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RESEARCH/ACCELERATORS

Bimonthly Status Report of Operations

Vol. 1 No. 5 September, October 1976

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CONTRIBUTING DIVISIONS

Accelerator

Biology and Medicine

Nuclear Science

Physics, Computer Science and Mathematics

COVER PHOTO: A 1.9-GeV iron nucleus fragments in a silver bromide emulsion in one of the early experiments with the first high-energy beam of iron particles. The record-setting beam was produced at LBL's Bevalac accelerator complex on 4 October 1976.

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THE FIRST IRON BEAM

A high-energy beam of iron particles was accelerated for the first time on October 4 at Lawrence Berkeley Laboratory's Bevalac accelerator complex. The iron particles were extracted at 1.9 GeV per nucleon (106 GeV total). The iron joins beams of carbon, nitrogen, oxygen, neon, and argon that have become available routinely to experimenters in the two years of Bevalac operation.

Since iron is the most abundant heavy element in cosmic rays, the ability to manipulate high-energy iron beams — which are essentially man-made cosmic rays — gives a special boost to astrophysics research. Understanding the fragmentation properties of iron is crucial to investigations that deal with the origin of the universe and the composition of interstellar space.

The successful high-energy iron run produced a beam of rather low intensity — about 3×10^3 particles per pulse — compared with a Bevalac carbon beam of 2×10^9 particles per pulse. Still there was enough iron during the 30 hours the beam was available to satisfy nearly a dozen eager experimenters. Their studies included fragmentation of iron on targets ranging from hydrogen to uranium, nuclear emulsion studies, and calibration of a lexan detector recently flown in a search for iron in cosmic rays.

Four days had been set aside from the research schedule to develop the iron beam. The victory was achieved in slightly less than three, due to intensive effort by both machine crews to overcome frustrating setbacks.

The first part of the attempt went smoothly enough. That involved accelerating a $^{15}N^{7+}$ beam through the Bevalac as a tracer for the eventual iron. Since the charge-to-mass ratio of $^{15}N^{7+}$ is .4666, exceedingly close to the $^{56}Fe^{26+}$ ratio of .4655, the former beam allowed operators to set preliminary steering values for the Bevalac transferline and determine how to recognize iron in the Bevatron.

Trouble started when the iron source was installed in ADAM, the 2.5-MV injector for the SuperHILAC. The source itself is a conventional Penning Ionization Gauge design with a stainless steel sputtering electrode. Stainless steel was chosen as the source material because it is nonmagnetic. Approximately 68% of the stainless steel introduced to the support gas is ^{56}Fe, the remainder being other isotopes and ingredients of stainless steel. After ionization, iron (3+) is separated from the other ion species. But unexpectedly short lifetimes of the first four sources, each averaging 7.8 hours before shorting out,* made the process of tuning the SuperHILAC frustrating indeed. By decreasing the pulse rate to 2 per sec, and adjusting the arc voltage, the fifth source lasted 38 hours.

With the installation of the final source, beam was readily accelerated at 17+ through the SuperHILAC, stripped of its remaining electrons at a foil at the exit of the linac, and delivered to the transferline. The nitrogen tuning served well, for some beam immediately made it to the Bevatron and was injected. The first iron beam was extracted from the Bevatron at 2:30 a.m.

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*No one could point with certainty to the cause of source failures. The hypothesis is that the plating process from the titanium cathode was disturbed by the addition of some 2% iron, which perhaps formed an alloy and caused improper adhesion of titanium to the normal plating surfaces. The source development group is currently investigating vanadium as a substitute for titanium to avoid this problem in the future.

After patiently awaiting the iron for three days, the experimenters were busy with other equipment when a voice over the intercom from the control room commanded them to "look!" Within 20 minutes they confirmed the huge pulse on their scintillator as iron 26+. Word travelled quickly even in the middle of the night, as more scientists, especially those from cosmic-ray groups, appeared in a steady stream. The experimenters themselves had plenty to do, since international colleagues had plied them with items to be exposed to iron 'cosmic rays' if they were ever produced.

More iron studies are planned in the future, probably in early 1977.

Bevalac Users Executive Committee Reports

The Bevatron/Bevalac Users Association Executive Committee has instituted periodic phone conferences with Bevalac program and operations management to streamline communications. The first of these conferences, arranged on fairly short notice, was held on September 29. Participants were executive committee members Frank George (USC), Doug Greiner (LBL), George Igo (UCLA), and M. Raju (LASL), along with Nuclear Science Division Director Bernard Harvey, Donner Lab Director Ed Alpen, and Acclerator Operations Group Leader Hermann Grunder. Eric Hall (Columbia U.), N. Porile (Purdue) and Ted Bowen (U. Arizona) were unable to participate.

The primary purpose of the conference was to consider plans for a joint SuperHILAC and Bevatron/Bevalac users meeting on February 17-19. The proposed joint meeting was approved, its schedule arranged, and speaker selection chairmen selected. Suggestions regarding speakers or agenda items on SuperHILAC subjects may be directed to Frank Stephens (FTS 451 + Lab Ext. 5724), or Frank Plasil (FTS 850 + Ext. 0187); on Bevatron/Bevalac nuclear science to George Igo (FTS 965 + Ext. 3440), or Doug Greiner (FTS 451 + Lab Ext. 5685); and to Edward Alpen (FTS 451 + Lab Ext. 5206), or Eric Hall (FTS 903-694-3551) for biomedical work.

Hermann Grunder reported that Bob Force is now head of operations for both the Bevatron and the SuperHILAC; he will be choosing a deputy at each. SuperHILAC source EVE will be rebuilt, and might be completed by March 1977. The computerized failure-analysis program is working quite well at the Bevatron, and will be extended to the SuperHILAC.

Grunder also gave a preview of the FY77 run schedule, with the warning that it is based on uncertain information about power rate increases:

October - March	Run full time
April 11 - May 16	Shut down
June - August	Run full time
September	Probable budgetary shutdown

Grunder's expectation is for at least 3,600 hours of running in FY77.

Bernard Harvey brought up the need for a low-energy (50 - 250 MeV/n) spectrometer facility at the Bevalac. Little work has been done in this interesting region. Such a facility has been proposed by Dave Hendrie (FTS 451 + Ext. 5088). There is a possibility of obtaining some of the necessary magnets from the University of Michigan. Harvey pointed out that funding of the project depends on its receiving wide support from experimenters within and outside of LBL.

Finally, the participants agreed to hold executive committee meetings once a year to coincide with the users meetings; the next executive committee

session will be on February 17, 1977. The phone conferences will be continued at about two-month intervals, with the next one in early December.

Nuclear Science Program Advisory Committee Meeting

The Nuclear Science Subcommittee of the Bevatron/Bevalac Program Advisory Committee met at LBL on October 28-29. It was the first time the group assembled apart from the Biomedical Subcommittee.

Among the morning's business was a report from Doug Greiner, representing George Igo, current chairman of the executive committee of the Bevatron/Bevalac Users Association. He mentioned the recently begun practice of bimonthly conference calls between the executive committee and LBL staff, announced the combined Bevatron/Bevalac and SuperHILAC users meeting on February 17, 18, and 19, and discussed the need for a low-energy spectrometer at the Bevatron. Later, wearing a different hat, Greiner presented the need for experimenters to secure agreement with the Electronics Equipment Pool so that their equipment needs can be met in advance of a proposal's final approval.

Speaking for Bernard Harvey and the Nuclear Science Division, Dick Diamond seconded the need for the low-energy spectrometer, nicknamed SOP (spectrometer of odd — or old — parts), as well as computer data-acquisition facilities for users. Finally he noted that long-term planning is essential to do justice to future directions and equipment needs at the SuperHILAC, 88-Inch, and Bevalac.

Hermann Grunder gave a review of accelerator operations, highlighting the successful acceleration of iron, the improvement in biomed running, the third ^{48}Ca run at the SuperHILAC to search for superheavies, and the development of low-energy (~ 100 MeV/nucleon) beams at the Bevatron. Projecting that the Bevatron/Bevalac will run 3600 hours during FY77, he is aiming to complete 1200 hours for nuclear science and 600 for biomed by the April 11 shutdown. As to future plans, Grunder noted that the K beam will probably be shipped to another laboratory next spring. Initial funding for the proposed heavy-ion spectrometer system (HISS) is expected in the amount of $600,000 in FY78, with more the following year. On the subject of heavy-ion fusion, Grunder reported that the Laboratory has become actively involved in a new national feasibility study. The problem areas are ion-ion charge exchange, ion-background charge exchange, accelerator systems studies, and final focusing of the beam on the pellet. Some initial studies can be done with the Bevalac.

Lee Schroeder summarized the status of current experiments and operating hours. For the six-month period, April through September 1976, 1612 hours were scheduled for nuclear science, with 1180, or 73%, run. If one includes the running time through November 1976, eight experiments, including five major ones, have been completed. Ten others are continuing.

During the remainder of the meeting, individual experimenters presented 20 proposals, two of which were extension requests, to the committee. Additional cosmic-ray calibration requests were presented as a group. It is worthwhile to note that the PAC had recommended these cosmic-ray requests at the previous meeting be turned down because of severe time limitations on the machine. During the interval between the two meetings, NASA had requested that ERDA provide approximately 300 hours of time at

the Bevalac, the only facility capable of delivering high-energy heavy ions, for calibrating cosmic-ray instruments.

George Rogosa, Assistant Director for Nuclear Science, Division of Physical Research at ERDA, was a special guest at most of the proposal presentations.

The approved nuclear science proposals, totaling approximately 1000 hours, are listed below. When added to the 2400 hours currently approved, the nuclear science portion of the Bevalac program is solidly committed for one-and-a-half to two years.

Exp. No.	Title	(Investigator, Institution)
313H	Cosmic-ray calibrations	(Hagen, CalTech)
337H	Cosmic-ray calibrations	(Israel, Washington U.)
338H	Cosmic-ray calibrations	(Greiner, UC Space Sciences)
342H	Cosmic-ray calibrations	(Mewaldt, CalTech)
354H	Cosmic-ray calibrations	(Teegarden, GSFC)
361H	Cosmic-ray calibrations	(Evenson, U. Chicago)
374H	Cosmic-ray calibrations	(Simpson, U. Chicago)
379H	Cosmic-ray calibrations	(von Rosenvinge, GSFC)
386H	Cosmic-ray calibrations	(Rio, Saclay)
284H	Large-momentum transfer in central collisions	(Poskanzer/Gutbrod, LBL/GSI)
339H	Neutron production by high-energy heavy ions	(Schimmerling, LBL)
352H	Medium-low-energy reactions and facility	(Hendrie, LBL)
362H	Nuclear reactions of silver with relativistic heavy ions	(Porile, Purdue)
371H	High-energy heavy ion interactions for wire-loaded nuclear emulsions	(Otterlund, U. Lund)
372H	Fragmentation of 3-GeV carbon on carbon	(Kidd, NRL)
373H	Low-energy pion production in high-energy nucleus-nucleus collisions	(Nakai/Rasmussen, TOSABE)
375H	Determination of half-life of ^{32}Si	(Lal, India/LBL)
377H	Relativistic heavy-ion induced fission	(Poskanzer/Gutbrod, LBL/GSI)
378H	Further tests of time projection chamber	(Wenzel, LBL)
381H	High-energy heavy fragments as tests of the coalescence model	(Price, UCB)
382H	Feasibility of plastic scintillators as iron anti-nucleus detector	(Price, UCB)

Biomed Program Advisory Committee Meeting

The Biomedical Subcommittee of the Bevatron/Bevalac Program Advisory Committee met November 1 at LBL. The format of the meeting was much the same as for the nuclear science subcommittee, except that the individual experimenters were not present to discuss the 21 research proposals (of which 6 were extension requests).

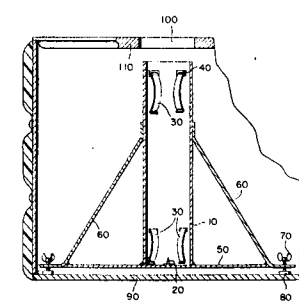
Hermann Grunder gave another rundown of current operations, devoting extra attention to the nuclear science aspects, about which several committee members were curious. Joseph Castro reported on the medical trials at the 184-Inch and Ed Alpen gave an overview of his activities to shape a coordinated biomed program from Donner Lab. Sometime next May or June, ERDA will review the Donner program; the favorable outcome of the review is crucial not only for Donner but also for the entire Bevalac biomed program. In light of this, the committee later decided to hold its next meeting in March somewhat earlier than usual.

Alpen suggested that the PAC must address the question of relative priority of various ion beams for the medical program. Since operating with argon is expensive and time consuming, decisions must soon be made on the appropriateness of continued experiments with this ion. The Committee decided to review all argon results at its next meeting.

Jerry Howard summarized the seven months of biomed running since the last PAC meeting. During this period there were 9 biomed runs, 8 experimental and 1 developmental. Of the 94 scheduled experiments, 83 were completed, 2 partially completed, and 9 not run. The total time was 723 hours scheduled, with the percentage of operating time to scheduled time, 61% (440/723). The percentage of data-taking time to operating time was 82% (362/440), which, Howard pointed out, is quite good considering the frequency of setups for the typically short, biomed experiments. The time split between local and outside users was approximately equal.

For an upbeat conclusion, Jerry informed the group that the biomed run then in progress, which was the first fractionation run ever attempted with the Bevalac, was averaging an astonishing 94% efficiency.

The titles of the proposals approved at the recent meeting are listed below. They represent 416 new hours, or approximately six months work. As of the end of October, there was a balance of 827 approved Biomed hours, so the Biomed program is now booked ahead slightly more than one year.



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COMBINATION HASSOCK AND CHRISTMAS TREE HOLDER

Exp. No.	Title	(Investigator, Institution)
355B	Trace-element analysis (x-ray fluorescence)	(A. Chatterjee, LBL)
356B	Beam implantation of positron-emitting tracers	(E. Alpen, LBL-Donner)
360B	Relative biological effectiveness for testicular atrophy of neon, argon, carbon, and helium ions	(A. Chatterjee, LBL)
363B	Radiation and the induction of Harderian gland tumors in the mouse	(E. Alpen, LBL-Donner)
364B	Relative biological effectiveness of heavy ions and He for crypt cell survival in LAF_1 mice	(E. Alpen, LBL-Donner)
366B	The induction of mammary carcinogenesis in female rats	(H. Vogel, U. Tennessee)
367B	Nuclear size and shape in synchronous cell responses	(P. Todd, Penn State)
369B	Yields of biologically relevant chemical species in water	(A. Chatterjee, LBL-Donner)
370B	Effects of heavy ions on superficial metastatic bodies	(J. Castro, LBL)
376B	Heavy ion radiation studies on blood vessels	(D. Philpott, Ames)
383B	Induction of dominant lethal mutations by high-LET radiations	(L. Goldstein, UCSF School of Medicine)
385B	Comparative studies on components of biostack irradiated with accelerated heavy ions	(H. Bücker, Frankfurt)
289B	OER determination for human and hamster cells with heavy-ion beams	(E. Blakely, LBL)
305B	Heavy-ion induced DNA damage and repair	(R. Roots, LBL)

Conference on Radiation Therapy, Part II

On September 14 through 17, Lawrence Berkeley Laboratory hosted *An International Conference on Particles and Radiation Therapy, Part II.* Approximately 400 therapists, physicians, and scientists attended. The degree of interest in this conference was evidenced by the fact that although the American College of Radiology was the chief sponsor, there were ten sponsoring societies ranging from the American Physical Society to the Radiological Society of North America. The National Cancer Institute and the Energy Research and Development Administration were among the supporting agencies. For the past several years, there has been intense interest in particle radiation therapy at the National Cancer Institute. The name of the conference, Part II, refers to the fact that there was only one previous general conference (Part I), held at Los Alamos in 1973. A smaller meeting, the International Particle Radiation Therapy Workshop (preparation for Part II), also sponsored by the American College of Radiology, took place in Florida in 1975.

Our laboratory was the logical host for Part II because of the recent developments at the Bevalac and the radiobiological and therapeutic studies in progress here in the Biomedical Division including the work of Drs. Cornelius Tobias, Edward Alpen, Joseph Castro, and others. A review was presented of each of the modes of particle therapy including neutrons, pi mesons, and heavy particles. Lawrence Berkeley Laboratory has played a major role in the development of each of these. John H. Lawrence, past Director of the Donner Laboratory and current Regent of the University of California, carried out the first experiments on the biological effects of neutrons beginning in 1934. These experiments led to the first therapy with fast neutrons, which was carried out here at the 37-Inch and 60-Inch Cyclotrons between 1937 and 1941 under the direction of the late Robert Stone. Biomedical research with energetic protons and helium ions commenced in 1947 under Cornelius Tobias and his group soon after the completion of the 184-Inch Synchrocyclotron. The first patient was exposed to protons in 1954. The first radiobiological work with pi mesons also took place here during the last ten years, and Chaim Richman, Mudundi Raju, Stan Curtis, and others have performed the first biological experiments pointing to the potential use of these particles. The meson work was transferred from here to the Los Alamos Scientific Laboratory when the proton linear accelerator was completed there.

The aim of the Conference was not only to review scientific progress but also to discuss therapeutic results and important aspects for future planning, including the state of accelerator art and eventual financing of particle therapy — topics presented by Hermann Grunder. Although design studies on neutron and particle accelerators indicate the great expense involved in constructing such facilities, Grunder's economic studies show that such therapy programs can be economical when large numbers of patients become involved.

In order to have the presentations as free of bias as possible, some speakers appeared as protagonists of the various forms of particle therapy while others were selected to critique and to review the progress of alternate modes. Key problems to be solved in radiation therapy for cancer are (1) the diagnosis and localization of tumors and, (2) the development of dose delivery systems that can provide adequate doses to stop the propagation of tumors at various depths in tissues while sparing normal sensitive parts

of the body. In this regard, Tobias spoke on particle radiography and autoactivation, John Lyman of LBL discussed dosimetry and instrumentation for helium and heavy ions, and Stan Curtis (LBL) continued on LET distribution of heavy ions. Other problems concern the special radiobiological action of highly ionizing particles, the elimination of the radiobiological oxygen effect, the variations of the effects in various states of cell division, and the elimination of repair. In addition, evaluation of both short- and long-term effects of heavy ions on normal tissues forms an integral part of radiation therapy studies. All of these studies are included in the pretherapeutic program at LBL under the direction of Tobias, Castro, and others. Tissue and tumor biology with regard to helium and heavy ions was discussed by Donald Chapman, John Leith, and Theodore Phillips, all of LBL, and Castro presented clinical experiences and expectations with these particles. The latest radiographs presented indicate that such radiography techniques are highly promising.

In the United States, neutron radiobiology and controlled studies of neutron radiation therapy were probably organized earlier than the other modes. Such work is done at three locations in the United States — at the Cyclotron of the Naval Research Laboratory in Washington, D.C., at the Cyclotron of Texas A & M University, and at the University of Washington in Seattle. Much of the current work with neutrons is being done at the Medical Research Council Cyclotron in London by the group at Hammersmith Hospital. They have shown striking results using neutrons on certain superficial tumors such as those of the head and neck. Accounts of results to date were presented by each of these laboratories.

With regard to pi mesons, much progress is expected in the near future. Recently, a lengthy shutdown of the LAMP accelerator occurred, during which certain problems with beam intensity and induced radioactivity were corrected. Work involving the irradiation of a few patients is continuing at Los Alamos under the leadership of Morton Kligerman.

The radiobiology of neutrons and pi mesons is fairly well known. The neutrons decrease the radiobiological oxygen effect coefficient from about 3 for x rays and gamma rays, to about 1.5 for fast neutrons. The various neutron programs differ in the energy of the beam. The higher-energy neutron beams penetrate deeper in the body and are less absorbed. Pi mesons have good depth-dose curves and can produce OER of 1.6 to 1.8 near the peak of their Bragg curves.

Most of the new information presented at the Conference on heavy-ion beams in radiation therapy came from work at the Bevalac. Donald Chapman, on sabbatical at LBL this past year from the Atomic Energy of Canada, Ltd. (Pinawa), reported on a comparative study of cellular radiobiology completed in the plateau and spread peak of beams of helium (230 MeV/amu), carbon (400 MeV/amu), neon (400 MeV/amu), and argon (500 MeV/amu). (See the description of the cancer radiotherapy program in Research/Accelerators, May/June 1976.) He demonstrated that the RBE (relative biological effectiveness) gain factor, that is, the ratio of RBE in the spread peak to RBE in the plateau, is maximum for carbon ions with the 4-cm, lead, ridged filter and that the decreases in the OER in the spread peaks of the heavier-ion beams are not quite as great as those in the unmoderated Bragg peak. However, hypoxic-cell sensitizers can be used in conjunction with heavy-ion beams to compensate for this OER reduction without affecting the RBE gain factor. More work must be done before the

particle beam most appropriate for therapy can be selected. Fractionation schemes, cell-cycle dependence on LET, and the design of ridge filters that will maximize the depth-dose advantage of accelerated heavy-ion beams must be investigated.

Eric Hall of Columbia University summarized the biological information presented at the Conference. Stating that "neutroneers are no longer pioneers," he highlighted the significant clinical progress made with neutron radiotherapy in England, as discussed by Mary Catterall; and elsewhere in Europe, as reported by Klaas Breur and Hans-Jurgen Eichhorn. The extensive but somewhat more conservative U.S. neutron clinical program has also been successful. Over 700 cancer patients have been treated with fast-neutron beams since 1972 in three U.S. programs — at the M.D. Anderson Hospital and Tumor Institute in Houston (TAMVEC), at the University of Washington in Seattle, and at the facilities of the Middle Atlantic Neutron Therapy Association (MANTA). Two other facilities, those of the Fermi Laboratory in Chicago and the Cleveland Clinic (NASA), are about to begin clinical programs.

Gross responses to neutron therapy have been encouraging, but some unusual responses have been noted in the cancer called "glioblastoma multiforme." Details of future neutron clinical trials were discussed by David Hussey and Charles Rogers of the M.D. Anderson and MANTA programs.

Studies of the responses of experimental-animal tumors to neutron therapy were reported by Janet Nelson (U. Washington), Rodney Withers (M.D. Anderson), Michael Fry (Argonne), Stanley Field (M.R.C. Cyclotron, England), and Eric Hall (Columbia U.). *In vivo* animal radiobiology with neutrons has raised some questions regarding fractionation schemes and combined neutron and megavoltage or telecobalt therapy.

Some basic cellular neutron radiobiology done at the Fermi Laboratory, at the Franklin McLean Research Institute (FMI), and at ANL's JANUS reactor were presented by Mort Elkind (Argonne). The mean energies of the Fermi, FMI, and JANUS beams were 25, 3.6, and 0.85 MeV, respectively. Although RBE values relative to 250-kVp x-rays decreased as the mean energy of the neutron beam increased, the OERs, measured with Fermi and JANUS neutrons, remained essentially constant. Additional cell studies of inter-fraction repair, growth delay and modification of neutron damage by hyperthermia or by hypo- and hypertonicity were reported. More work will be done in these areas to examine basic mechanisms of radiation damage and recovery.

Renewed interest in negative pi mesons for therapy has led to extensive evaluation of the current accelerator technology available for their production. In the past few years, high-intensity pion-beam facilities have been built at Los Alamos, and progress in the methodology of obtaining mesons from electrons has been made at Stanford. Significant progress in the dosimetry of negative-pion beams has been made, but new radiobiological and clinical studies are just beginning as these machines are completed.

Eric Hall concluded that heavy-ion radiobiology has provided some very promising evidence for its usefulness in therapy. Initial exposures of human patients may begin within a year after biological studies are concluded.

PEP Experimental Area Design

Since January several modifications and design improvements have

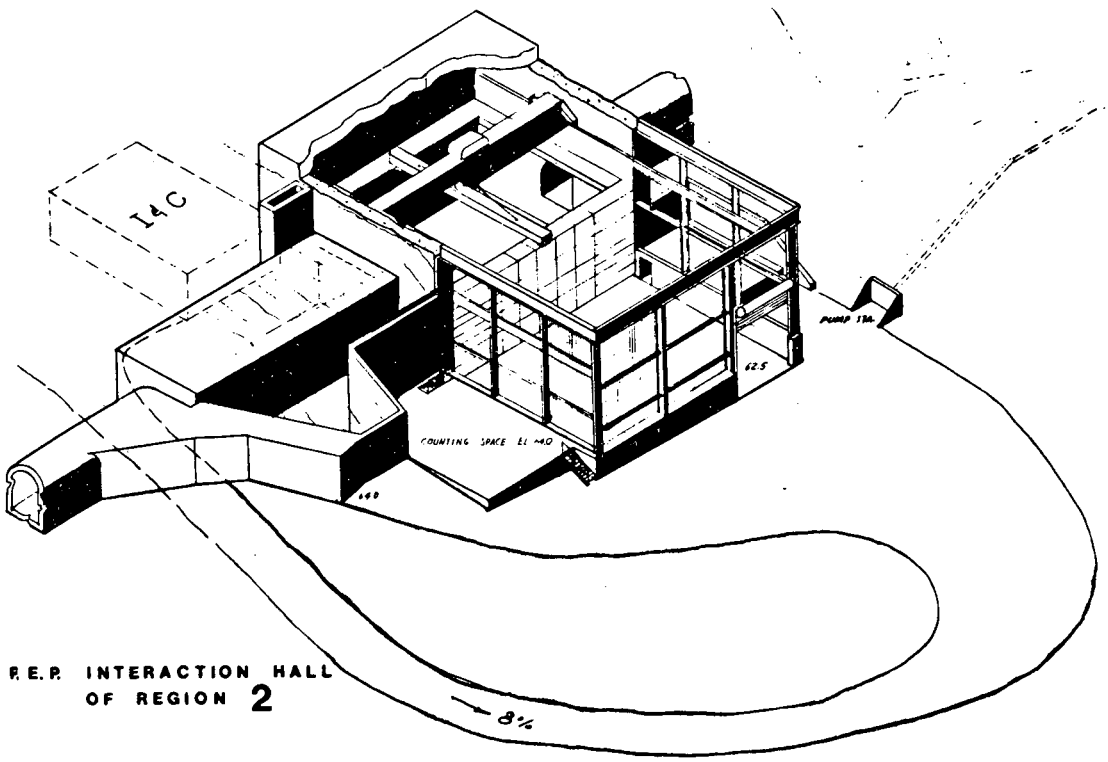


Fig. 1. Isometric view of experimental area in region 2 at PEP.

been made in the experimental areas.

We describe here the halls as they are now envisioned, emphasizing the differences from previous designs. These plans will be the starting point for the detailed engineering design to be carried out by the architect engineer.

Figure 1 shows an isometric view of the experimental area in region 2. This area also contains the basic concepts applied to areas 4, 8, and 12. The experimental hall shown is divided into two parts: (a) the beam area, constructed with concrete walls to provide radiation shielding and to support lateral earth pressures, and (b) the assembly area, built as a less expensive steel structure.

A single crane of approximately 30 tons capacity services both areas. A removable shielding wall separates the assembly area from the beam area. The beam area is capped by 'roof logs' to provide shielding from neutrons, which would otherwise scatter from the permanent roof of the building. A by-pass tunnel connects the assembly and beam areas, permitting fast access for personnel and small equipment.

The thickness of the removable shielding wall is set by structural considerations to be approximately 2 meters, and the thickness of the roof log is set by radiation protection requirements at about 70 cm. The local shielding provided by the wall and the roof logs allows experimenters to be present in the assembly area both when running a stored beam and during injection.

In previous designs the roof logs had been omitted to ease crane access to the detector. With a stored beam the total charge that can be dumped into an experimental hall is well determined, and the lateral wall alone is sufficient to protect the assembly area. Abnormal injection conditions, however, could lead to much higher integrated charge being dumped. Most of the radiation reaching the assembly

area would be coming over the wall. To protect against this possibility, the roof logs are necessary. Alternate schemes achieving personnel protection by electronic sensors and operational arrangements are less reliable.

In addition to accessibility to the assembly area under all operating conditions, the local shielding provides the further advantage of lighter walls. The construction of the assembly area is therefore cheaper and more flexible.

Two other improvements have been added: (a) The yards outside of the experimental halls are brought to the level of the floor of the halls. This has obvious advantages for transferring equipment, compared to the previous design which had a 4-meter step between the hall floor and yard, necessitating cumbersome loading platforms. (b) Two pads are provided on the sides of the experimental halls for counting houses. The convenience of having the electronics near the detector without a long flight of stairs is appreciated by all except a few body cultists.

Figure 2 shows an architectural view and a plan view of region 12, which has a building similar to that of region 2. Although areas 2, 4, 8, and 12 are similar in concept, they vary in size as shown in the table below.

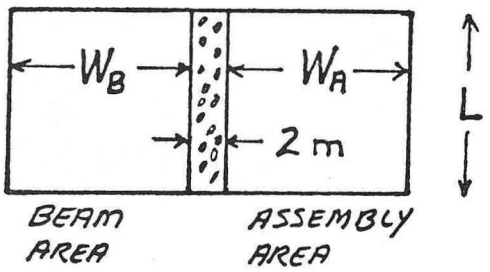
Area 4, which is in difficult terrain, is the smallest area and does not have an alcove. If a proton ring is added later, an extension in the proton direction may be needed.

Area 6 remains our 'open area.' At present it consists of a 40m × 40m pad. Portable buildings, shielding, and cranes will be used there.

With the above modifications, we feel that the areas are a better match to the goals set by the summer studies and working groups.

— P. Oddone

EXPERIMENTAL AREA SUMMARY



Area Name	Width of beam area W_B	Width of assembly area W_A	Depth below beam	Length (clockwise)	Exp. alcove 20m long 4m wide 5m high
2	± 7m	16m	4m	± 10	yes
4	± 6m	14m	4m	± 8	no
6*	± 20m	--	4m	± 25 - 15	--
8	± 10m	19m	4m	± 10	yes
12	± 7m	16m	4m	± 10	yes

* (open pad)

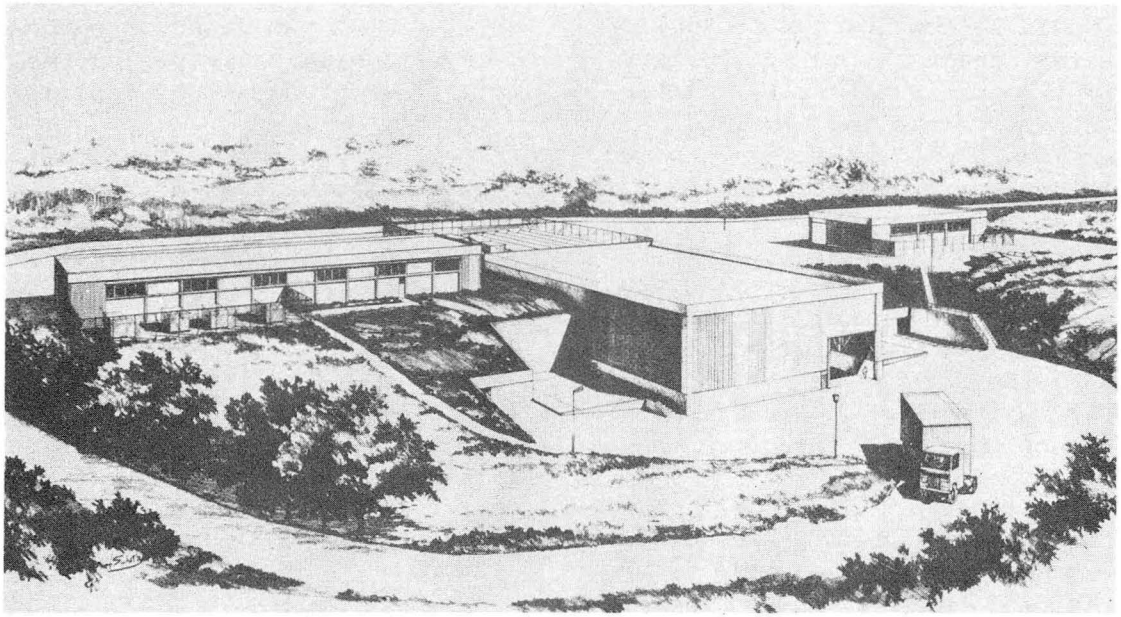


Fig. 2a. An architectural view of interaction region 12, whose structure resembles that of region 2 of the previous figure.

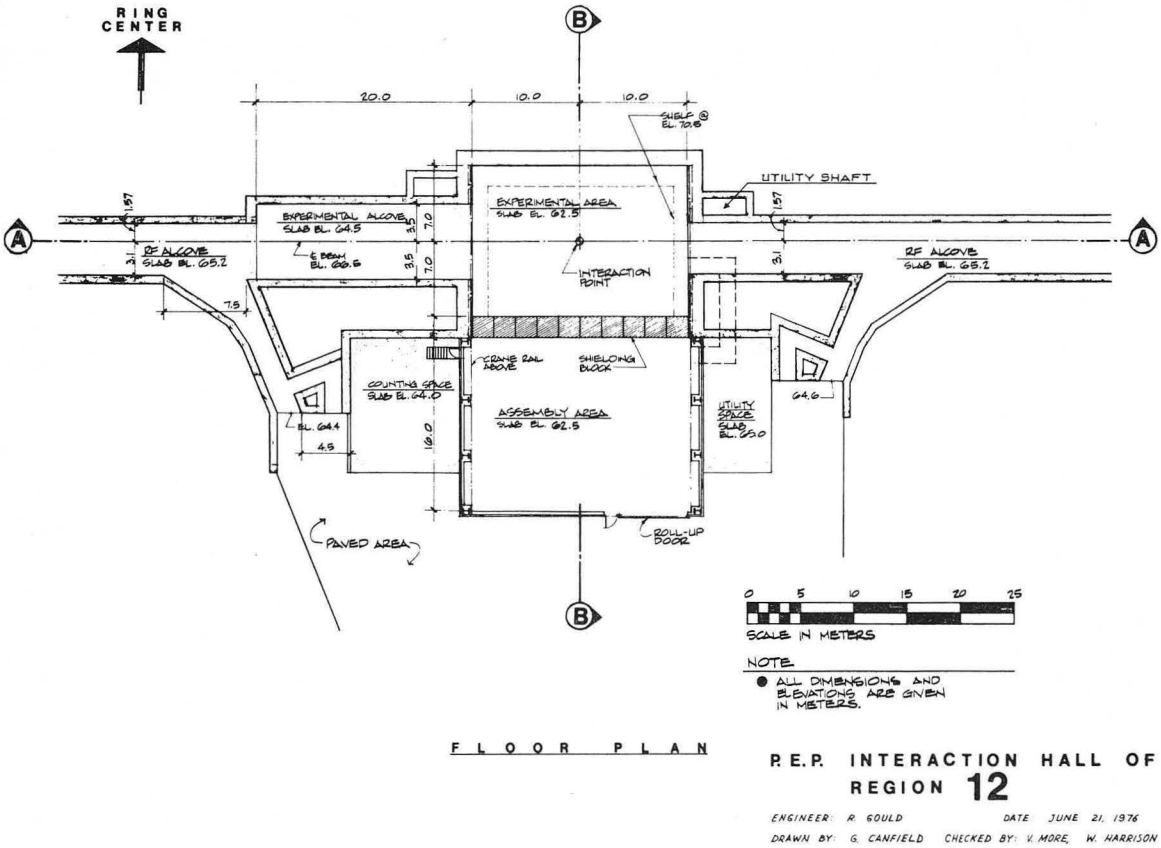


Fig. 2b. The plan view of region 12.

Cooperative Russian-American Efforts Regarding Element 104

In continuing the Russian-American exchange of scientists in transactinide research, J. Michael Nitschke recently returned from the Joint Institute for Nuclear Research (JINR) in Dubna, USSR. His visit was the counterpart to the May 1976 visit of I. Zvara reported earlier in Research/Accelerators (Vol. 1, p.3). This cooperative exchange of the JINR and LBL spectator-representatives is undertaken in the interest of resolving some questions associated with the discovery of element 104.

The experimental apparatus at JINR differs appreciably from that used at LBL, which was described in the earlier issue of Research/Accelerators. Instead of using a rotating drum, as does the Ghiorso group, Dubna researchers employ a nickel-tape system to transport the recoil nuclei past the phosphate-glass and Mylar detectors in which fission events are registered. Additional detectors are placed to monitor background and neutron-induced events. By bombarding a ^{249}Bk target with ^{15}N, scientists at Dubna produced a 100-msec activity and attributed it to ^{260}104.

Al Ghiorso has stated that although we see no reason to change the interpretation of our data, which does not show any such activity, the Russian observation has prompted the design of new experiments at Berkeley. The drum assembly used during the May 1976 bombardments of ^{249}Bk with ^{15}N will be modified to improve its signal-to-background characteristics — the background being caused by 2.63-h ^{256}Fm, which tends to obscure other activities. Efforts will be made to suppress this ^{256}Fm background in the drum experiments by reduction of the target area, change in the rotational frequency, and periodic renewal of the drum surface. Later experiments will achieve a large reduction of the background level by spreading the ^{256}Fm over both front and back surfaces of a 1000-m-long and 0.001-inch-thick stainless-steel tape.

Another important development is the observation in Dubna of the Berkeley-discovered 20-msec spontaneous fission activity. Dubna, however, attributes this activity to a combination of 13.7-msec ^{242m}Am and their 80-msec activity. Al Ghiorso states that our data does not support this interpretation, and he believes that the 20-msec fissions could even possibly be due to ^{260}104. He feels that if Dubna had discovered this activity in their original experiments they would certainly have claimed the discovery of element 104 on that basis since its abundance is several times that of their claimed 100-msec fissions. The new drum experiments should be able to decide without question whether the 20-msec activity is a single substance, or has dual components.

Nuclear Theory News

Two interesting developments have occurred recently in nuclear theory: a simple description of the giant dipole resonance (GDR) in nuclei, and the derivation of quantum-mechanical expressions for the nucleon one-body dissipation.

The first concerns the discovery by Bill Myers and Wladek Swiatecki of an unexpected simplicity in the description of the GDR in nuclei. While making some final checks after completing a paper that describes a coupled-mode approach (the Steinwedel-Jensen and Goldhaber-Teller modes) to the GDR, they found a completely new way of looking at the solutions.

In the coupled-mode description, the resonance is taken to consist of two parts. In the first, a rigid oscillation of the neutrons against the protons produces a neutron skin on one side and a proton skin on the other side which alternates back and forth during the vibration (GT mode). The second component of the vibration is viewed as a compressional vibration of the neutrons against the protons in such a way that a neutron excess appears on one side of the nucleus and a proton excess appears on the other and these alternate back and forth during the vibration (SJ mode).

When the GDR is described in this way, and Droplet Model restoring forces are used, it is possible to obtain excellent agreement with the measured values of the resonance energy. The new discovery consists of recognizing that the ratio of the neutron excess to the neutron skin thickness produced by the vibration at each point on the nuclear surface is nearly the same as the Droplet Model prediction for the static value of this ratio for neutron excess nuclei at their ground state. It turns out that an excellent approximation to the coupled-mode description can be obtained simply by fixing the ratio of the two components according to the Droplet Model rule. A greatly simplified treatment of the problem results which can probably be easily extended to isovector giant resonances of other multipolarities.

The second new development concerns the derivation (by Steven Koonin and Jørgen Randrup, summer visitors here from the Niels Bohr Institute, Copenhagen) of quantum-mechanical expressions for the nuclear one-body dissipation. In classical terms, the mechanism corresponds to the irreversible heating up of a gas of independent particles when the confining container is changing its shape in time. For such a system, the rate of energy loss is proportional to the surface integral of the local wall velocity squared. Using linear response theory, Koonin and Randrup have shown that the quantum-mechanical nature of the nucleons leads to a dissipation kernel connecting the local wall velocities at <u>different</u> points of the surface. The dissipation rate is therefore reduced (relative to the classical formula) if the wall velocity varies along the surface. When the associated wavelength is small compared to the nucleon Fermi wavelength, the classical result is retained. On the other hand, surface distortions of wavelength smaller than half of the Fermi wavelength do not produce any energy dissipation at all.

With their quantum-mechanical approach, Koonin and Randrup have furthermore studied the effects of the diffuse profile of the nuclear potential, the finite temperature of the Fermi gas of nucleons, and the curvature of the nuclear surface. These effects are important for the one-body dissipation in real nuclei and can be analyzed systematically with the approach taken.

Quasi-Fission Phenomena in Ar-Induced Reactions

At the 88-Inch Cyclotron the reaction Ag + Ar at 170- and 200-MeV bombarding energies has been studied. The fragments emitted have been resolved in Z, and the kinetic energy distributions and angular distributions have been determined as a function of Z. A similar experiment has been carried out at the SuperHILAC at higher energies (288 and 340 MeV) where the Z distributions are generally increasing with Z and the angular distributions are forward peaked, more so for particles close in Z to the projectile. At the lower energies of the 88-Inch-Cyclotron, the Z distribution shows two peaks, one close to Z = 18 and another at symmetry, while the angular distributions are side-peaked close

to Z = 18 and evolve into a forward peaking as one moves away from the projectile. For Z far removed from 18, the angular distributions become $1/\sin\theta$.

The change in the charge and angular distribution pattern appears to be due to a decrease in lifetime and in rotational period with decreasing energy of E/B ratio. These experiments show nicely how much the decreases in lifetime and rotational period promote a transition from the normal deep inelastic pattern to the quasi-fission pattern.

γ-Ray Multiplicities for the Deeply Inelastic Process

Heavy-ion beams from the Super-HILAC and the 88-Inch-Cyclotron have been used a great deal recently in studying a fairly new phenomenon in nuclear science — deeply inelastic or strongly damped collisions. Groups of experimenters from LBL and other labs have been measuring both kinetic energy angular and Z distributions of the projectile-like fragments emitted in such reactions. Even so, questions about this process remain unanswered. In particular, little is known about the mechanisms of mass and energy transfer between the light and heavy fragments.

Information on this problem can be obtained by determining the angular momentum of the fragments emitted in a strongly damped collision as a function of such things as the Z of the projectile-like fragment and the inelasticity (that is Q-value) of the reaction. The Moretto and Diamond/Stephens groups at LBL have joined together to examine the problem by using different experimental techniques. The experiment involves looking at γ-ray spectra in coincidence with outgoing fragments for the reactions Ag + ^{20}Ne at 175 MeV (at the 88-Inch) and Au, Ag + Kr at 620 MeV (at the SuperHILAC). This collaboration should be particularly fruitful in that it combines the many years of experience of the Diamond/Stephens group in measuring mean γ-ray energies and multiplicities with the expertise developed by the Moretto group in measuring (by means of gas ionization ΔE, solid-state E counter telescopes) the Z of fragments as heavy as Z = 65. The two groups have been able to obtain γ-ray multiplicities as a function of the Z of the fragment for both reactions.

In particular, the Ag + ^{20}Ne data have been analyzed in detail. Two extensive regions are observed in the data. For the highest degree of inelasticity, the fragment spins are consistent with a rigidly rotating intermediate complex. For lower degrees of inelasticity, as in the quasi-elastic peaks, the angular momentum appears to be transferred from the orbital motion to the fragment spin proportionally as the mass is transferred.

Projectile Fragmentation

The Heckman shack at the Bevalac was a scene of exuberance on October 19, as two NSD groups realized success in efforts to measure projectile-target correlations in peripheral reactions. A sodium target was bombarded with 4.8-GeV ^{12}C ions, with the projectile fragmentation pattern determined in a silicon detector stack in coincidence with discrete gammas from the target of its reaction products. The event-mode data tapes have yet to be analyzed in detail, but even partial analyses during the run showed excellent gamma spectra, far exceeding expectation, as gammas of ^{23}Na (target) ^{21,22}Ne, and ^{19}F stood sharply above background. It is

expected that the farther in mass from the target, the greater the degree of projectile breakup; and the preliminary analysis appears to confirm such correlation. Principal experimenters included: Harry Bowman, Junsei Chiba, Hank Crawford, Doug Greiner, John Ioannou, Peter Lindstrom, Chuck MacParlane, Kozi Nakai, Tokushi Shibata and John Rasmussen.

SHEIKS AT THE BEVALAC

According to recent theoretical models of high-energy nuclear reaction mechanisms, some nuclei with unusual shapes have been made in relativistic heavy-ion reactions carried out at the Bevalac. These nuclei are the spectator target residues left after the relativistic projectile has swept through the target. The nucleons in the region of overlap between projectile and target are swept away in a "nuclear fireball" leaving the target residue (pictured as having a gaping hole in it). (See previous issue.)

The de-excitation of a very heavy spectator target nucleus might be expected to give interesting and unusual mass distributions characteristic of various features of these nuclear reactions. The SHEIKS group has begun a radiochemical mass and angular distribution study of relativistic heavy ion reactions with gold, lead, bismuth, and uranium targets. As part of this study, thick targets of the above elements, along with recoil catchers and secondary reaction monitors, were bombarded last month with 2.1-GeV/n ^{12}C at the Bevalac. An additional experiment was carried out using recoil catchers and Lexan foils to measure the angular distribution of products from a thin Pb target irradiated with 2.1-GeV/n ^{12}C ions. Both x-ray and gamma-ray spectra were taken of all the target foils, recoil catchers and of a chemically separated gold fraction from the bismuth target.

A preliminary analysis of the x-ray spectra reveals a qualitative picture of some features of the mass distribution directly. In the gold target x-ray spectra there is a continuous range of $K_{\alpha 1}$ x-rays corresponding to elements with atomic numbers between the tin and gold regions. The lead and bismuth x-ray spectra show x-rays (corresponding to product atomic numbers) extending from the lead region down only into the lighter rare earth region. Probably the most interesting x-ray spectra are from the uranium targets. In these spectra we see $K_{\alpha 1}$ x-rays from elements in the vicinity of tin up to the lead region. The x-ray spectra from elements in the region of gold are unexpectedly similar to x-ray spectra of uranium targets irradiated with ^{85}Kr and ^{136}Xe projectiles at the SuperHILAC. (The mass distribution of these products from the ^{85}Kr and ^{136}Xe reactions has been dubbed the "goldfinger.") It will be interesting to see if these totally different energy realms of heavy-ion reactions have some similarities in the mass distribution region around gold.

NUCLEAR ORBITING IN THE SUPERHILAC'S SCATTERING CHAMBER

An experiment recently completed in the outside users 30-inch scattering chamber involved a continuation of a study of nuclear orbiting in the ^{139}La + ^{86}Kr system by the Vandenbosch group. It is now known that nuclear reactions produced in collisions between Kr and very heavy target nuclei such as ^{208}Pb are dominated by a direct reaction mechanism ("deeply inelastic scattering"), which exhibits almost complete damping of the incident kinetic energy. That is, the mechanism is

characterized by outgoing particle energies consistent with Coulomb repulsion of the two outgoing fragments. However, when a lighter system was investigated (Kr + La at 714 MeV), things looked differently since there are two components in the energy spectra of the reaction products. The higher-energy components (partially damped) exhibit behavior similar to that reported in heavier systems: a monotonic decrease in energy loss as a function of angle (but much more pronounced than that for heavier systems such as Kr + Pb). The lower peak remains at essentially a constant excitation energy, one which corresponds approximately to complete energy damping. While the partially-damped peak shows a bell-shaped angular distribution similar to those reported in heavier systems, the distribution for the fully-damped component is very forward-peaked (although not $1/\sin\theta$).

Qualitatively, what occurs is that the higher partial waves contribute to the partly damped events, while lower partial waves become increasingly damped until full damping is achieved. Near the onset of orbiting to negative angles, the collisions have already become sufficiently damped so that the outgoing kinetic energies for events corresponding to negative-angle scattering are essentially constant. Since orbiting would not be expected to dominate in an energy range where the Coulomb barrier is dominant, additional experiments have been carried out to look at the La + Kr system at the lower energies of 600 and 500 MeV. In agreement with the present picture, a preliminary examination of the new data shows that orbiting is clearly present at at 600 MeV but is less pronounced at 500 MeV.

Developmental work continues on the chamber. The last major piece of hardware has been obtained from Technolics, Inc. — a sliding-band chamber ring to be used for time-of-flight measurements. There are still vacuum problems associated with the motion of the band, which are understood, but unresolved. A replacement band is expected to arrive shortly and should alleviate the trouble.

Outside User Program at the 88-Inch Cyclotron

For almost two years scientists at the 88-Inch-Cyclotron have been encouraging and assisting non-LBL scientists in using the cyclotron for high quality experiments. The emphasis has been on the use of the unique beams and equipment that are unavailable elsewhere in the country and on high quality research that is not in the direct line of interest of any of the in-house users.

During the last year, about 850 hours of running time (more than 12% of the time available) was devoted to outside user research by scientists from 15 universities and laboratories throughout the country. The accepted experiments were evaluated by at least two Berkeley researchers and by Ed Flynn of Los Alamos, who has given program advice for almost a year.

The fruitfulness of the outside user program has been recognized by LBL's Director, who has allocated some discretionary funds to enhance the program. D. Hendrie, head of the 88-Inch, states that the first priority in use of these funds is to hire a capable young experimentalist to provide a continuing liasion between the visitors and the laboratory.

PEP Proposals

PEP proposals, due 31 December, will be considered in an open meet-

ing to be held February 24 and 25, 1977. Pier Oddone, Experimental Facilities Coordinator, asks that you let him know if you are planning to attend and he will send you the agenda and other information as it becomes available.

Guidelines on "What is Meant by a PEP Facility" were included with the announcement of the meeting so that anyone submitting a proposal could generate the required plans for operation and support of the facilities. Experimenters who initiate the large general detectors will have use of them for the first 12 to 18 months — the Priority Period. Following this period, the facility will be available for use by other physicists who can contribute new ideas, hardware, or analysis developments.

Whether a detector is characterized as an experiment or as a facility is determined by the originator (subject to review by the Experimental Program Committee) and depends upon how long-lived the detector might be, how general its application, and whether it requires a substantial fraction of the resources that are available for PEP detectors. If it is determined that the detector should be a facility, then the originator must devise a plan of operation so that other groups may readily use the detector, in particular dealing with the problem of the facility being operated by a group of experimenters who were not originally involved in its construction.

Addition at SuperHILAC

What is that yellow-girder construction on the Hill near the SuperHILAC? Well, we wondered too, and now have the answer. As a small part (0.5 million dollars) of a 2.8-million dollar improvement program for the SuperHILAC, which has included renovation of the SuperHILAC control room, this two-story building (4000 ft^2 usable space) is being constructed to provide office space for a dozen visiting scientists who use this national facility. They will occupy the second floor, while the first floor will be the new home for the machine shop presently located in the SuperHILAC building.

Unfortunately, this expansion will not alleviate the crowded conditions within the SuperHILAC building. The space vacated by the machine shop will be taken up by expansion of the computer room and a staging area for the experimenters.

The new building will comply with the latest seismic-code requirements for construction. The result is more reinforced steel in the concrete and heavier steel members in the building structure. Poor surface-soil conditions under the building necessitated the use of reinforced concrete friction piles (2½ - 3 ft diam), which were sunk an average of 30 ft below the surface. The piles act in conjunction with a heavy foundation slab and beam system to resist lateral forces that could be caused by active earth pressures, heavy research equipment, or earthquakes.

The basement entrance (Fig. 3) will become the main entrance to the SuperHILAC area, permitting access to the main building across the yard that separates the two buildings. A planned corridor would connect a future third floor of the new building with the SuperHILAC. The third floor, for which provision is included in the construction plans, hopefully will be added in several years. Meanwhile, the 50-ft space between the two buildings will be developed

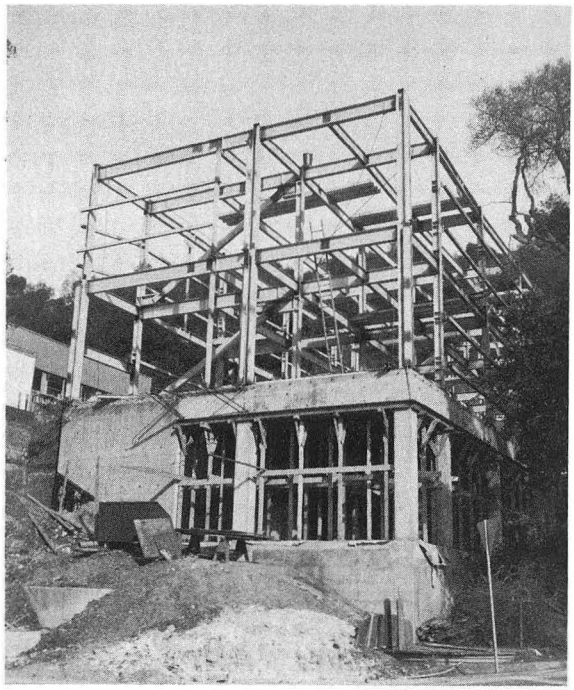


Fig. 3. The future main entrance to the SuperHILAC complex will be in the basement corner of this addition now taking shape there.

as an extension of the experimental area.

Note the oak tree to the right of the building. This and another 100-year-old tree were preserved during the building, as part of a continuing program to preserve and protect the environment.

The contract for construction was won by a local "small" construction contractor, T.L. Bake, who works on the job himself. LBL Engineering Staff, with Don Eagling - Plant Manager, Hugh Stoddard - Construction Engineer, and Tor Myhrer - Plant Architect, provides design and field guidance for the contractor. Occupancy is expected in February 1977.

New Space for Nuclear Science Division

A new office wing has been approved for the Nuclear Science Division. Costing $310,000, the wing will provide 22 offices and a small conference room and will be constructed on the grass area above the Cave Room in Bldg. 70; the cave will be removed. Plans are for the new space to be ready for occupancy in December, 1977, at which time members of the Division will move into the new wing and along the north side of Bldg. 70 on both floors. The space occupied in 70A will be vacated except for the Division Office and the Table of Isotopes. The vacated space in 70A will be used by groups associated with the Materials and Molecular Research Division. Creative ideas for the new wing are welcome at this stage.

Separated K-Beam (#34)

In the past year or so, demand for beam time in the separated K-beam (#34) located in the septum channel has decreased. One more run is scheduled for early 1977, and no new proposals have been received for use of this facility after that time.

Recently, there have been requests to relocate the K-beam outside LBL. Since the apparent demand for this facility at LBL has subsided, we are considering these outside requests. The ARC office invited comments from users by 1 December and hopes to determine whether users have any plans for using the facility.

San Francisco ACS Meeting

Glenn T. Seaborg, as President of the American Chemical Society, officiated at the ACS Meetings in San Francisco on August 29 to September 3 that were held to celebrate the Society's 100th anniversary as well as the 75th anniversary of the

California Section. Highlights of the meetings included speeches by Dr. Joel Hildebrand and Dr. Seaborg.

Dr. Hildebrand, former ACS President and Chemistry Professor Emeritus from UC Berkeley, presented his speech at a general meeting on Monday, August 30, following the President's Dinner, which was held on the UC Berkeley campus. Hildebrand whose life has spanned all but 5 years of the life of the ACS and half of the life of the United States gave his eyewitness view of the history of chemistry in the last 75 years and spoke from this perspective about the importance of science in the modern world.

Dr. Seaborg presented a speech at the ACS Centennial/California Section Diamond Banquet in San Francisco on August 31. Seaborg also spoke of the history of chemistry, outlining the many contributions made through chemistry in the last 75 years. He commented very optimistically on the future of chemistry and expressed his belief that it will be used as the tool to solve many of the world's problems (energy, food, mineral resources, etc.). He voiced concern about the consideration of ethical and human values in science and proposed the development of some broad codes of conduct and values that would insure scientific responsibility to society and also allow for necessary scientific freedom. [For the full text of both speeches see Chem. Eng. News 54, 25 (1976).]

The Division of Nuclear Science and Technology held several symposia in which many Nuclear Science Division members were involved. One symposium on Heavy-Ion Collisions included talks by Luciano Moretto and Mike Guidry. Joe Cerny organized a symposium on Exotic Nuclear Reactions at which Mike Zisman and Gordon Wozniak spoke. There was also a symposium on the Origin of the Elements, and there were many other contributed papers by Division members.

APS Meeting in East Lansing

On October 28-30 there was a meeting of the American Physical Society Division of Nuclear Physics (DNP) held at East Lansing, Michigan. Members of the Division who attended were Frank Stephens, Bernard Harvey, and David Hendrie. Talks were presented by Grant Mathews, Gordon Wozniak, Cathy Olmer, Joe Cerny, Bill Meyer, Reinhard Simon, and Lowell Charlton.

Bernard Harvey reported to the conference on the activities of the Committee on Funding of Nuclear Science. He emphasized that the Nuclear Science budget is a very small part of the national budget, so Congressmen cannot be expected to know about the adverse effect of budget cuts unless members of the nuclear science community explain them. The Committee is charged with the responsibility of informing the executive committee about federal budgets and of conveying information to Congress about their effects on Nuclear Science, when this is necessary.

European Heavy-Ion Conference

The European Conference on Nuclear Physics with Heavy Ions was held September 6-10 in Caen, France. Several members of the Division went to the Conference, most of them on non-LBL funds. Hans Gutbrod gave a paper on the recent Bevalac work of the Poskanzer/Gutbrod Group and David Scott spoke about new 88-Inch Cyclotron results in heavy-ion quasi-elastic reactions (fragmentation?) at 20 MeV/nucleon. Luciano Moretto

talked about his experimental and theoretical work on deep inelastic scattering. Glenn Seaborg reported on the failure to find superheavy elements by bombarding ^{248}Cm with ^{48}Ca beams at the SuperHILAC. B. G. Harvey's general impression is that the Conference was extremely well organized but that not much really new has happened within the last year except for the work presented by Gutbrod and Scott.

"Criteria" Paper

Three LBL scientists (B. G. Harvey, G. T. Seaborg, and E. K. Hyde), along with other internationally respected scientists (G. Hermann — GSI, R. Hoff — LLL, D. Hoffman — LASL, J. Katz — ANL, O. L. Keller, Jr. — ORNL, and M. Lefort — IPA, Orsay) have published a paper in the September 24 issue of Science entitled "Criteria for the Discovery of Chemical Elements." The paper outlines the minimal observations and experimental evidence that these experts deem necessary to substantiate a meaningful claim of the discovery of a new chemical element. It is being presented to establish an internationally conceived guideline that will hopefully prevent premature claims of element discovery in the future.

Poskanzer Assumes ACS Chairmanship

Art Poskanzer becomes chairman of the Division of Nuclear Chemistry and Technology of the American Chemical Society on January 1. He has served as chairman-elect during the past year and in this capacity has planned the programs for the Division meetings next year.

Appointments

Dr. A.M. Sessler, Director of LBL, has announced that he has appointed the following staff members: *Earl K. Hyde* as Deputy Director, *George L. Pappas* as Head of the Administration Division and Associate Director of the Laboratory, and *Walter D. Hartsough* as Head of the Engineering and Technical Services Division and Associate Director of the Laboratory.

Sessler states that "their dedicated service and more importantly, their significant contributions to the Laboratory's efficient and effective operation has been beyond my high expectations. It is, therefore, with considerable enthusiasm that I am pleased to announce that each has agreed to accept my invitation to remain in his respective post for a second three year term starting November 1, 1976.

User Handbooks at the Bevatron/Bevalac

A new Bevatron/Bevalac Users Handbook: Nuclear Science, has just been completed and is ready for distribution. The handbook was last revised in January 1973. Since then the research program has become oriented to heavy-ion work, and the biomedical program at the Bevalac has emerged: Two handbooks are thus required, one for nuclear science and one for biomedical research.

The just-finished edition covers general information about procedures for submitting and planning nuclear science experiments at this accelerator; a description of our major experimental facilities;

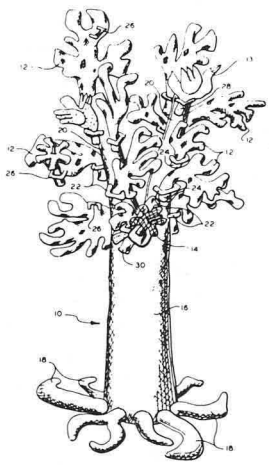
operational data on intensities, pulsing modes, extraction, etc.; individual beam-line diagrams and descriptions; and tables and graphs of magnet data.

Bevatron/Bevalac users may obtain a copy by request to the Accelerator Research Coordination Office (Bldg. 51, Rm. 208). Because the handbooks are expensive to produce, user groups are asked to share a copy where possible.

Change of "Street" Address

Effective 1 October 1976, the official street address for the Lawrence Berkeley Laboratory will be "1 Cyclotron Road." Previously the "street" address was "East End of Hearst Avenue."

In view of celebrating the 45th anniversary of the Laboratory's founding, it seems appropriate to incorporate the word "cyclotron" into our actual street location name. The Laboratory mailing address will remain unchanged.



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CONSTRUCTION TOY HAVING STUFFED PARTS OF SOFT MATERIALS

UPDATE ON CHARM

The discovery of a new, narrow subatomic particle was discussed in the May, June issue of Research/Accelerators. This particle was discovered by members of the SLAC-LBL collaboration by using data taken with the magnetic detector at the SPEAR e^+e^- colliding beam facility.[1] As discussed in that issue, the new particle was found to have a mass of 1865 ± 15 MeV/c^2 (about twice the mass of a proton) and a width of less than 40 MeV/c^2, an anomalously narrow width for such a massive particle. The particle was discovered by reconstructing its mass from its decay products, which consisted of neutral combinations of kaons and pions $K^{\mp}\pi^{\pm}$, $K^{\mp}\pi^{\pm}\pi^{\mp}\pi^{\pm}$). (See Figs. 4 and 5.) The presence of such a massive, narrow particle decaying into pions and kaons is predicted by the charm theory of Glashow and others, a theory that has gained prominence as a possible explanation for the existence of the psi/J particle.

In the five months since the discovery of the new particle, more data and new analyses by physicists from the Trilling-Goldhaber group and the Chamberlain group at LBL, and Groups C and E at SLAC, have cleared up several properties of the new particle and greatly strengthened the belief that the new state is charmed.

Shortly after the discovery of the original state in May 1976, a new narrow charged state was observed with a mass of 1876 ± 15 MeV/c^2 decaying into $K^{\mp}\pi^{\pm}\pi^{\pm}$. (See Fig. 6.) The discovery of this state was due in large part to the accumulation of new data concentrated at center-of-mass energies where new particle production was especially copious (E_{cm} = 4.03 GeV/c^2 and E_{cm} = 4.4 GeV/c^2). The natural interpretation for such a state is that it is in the

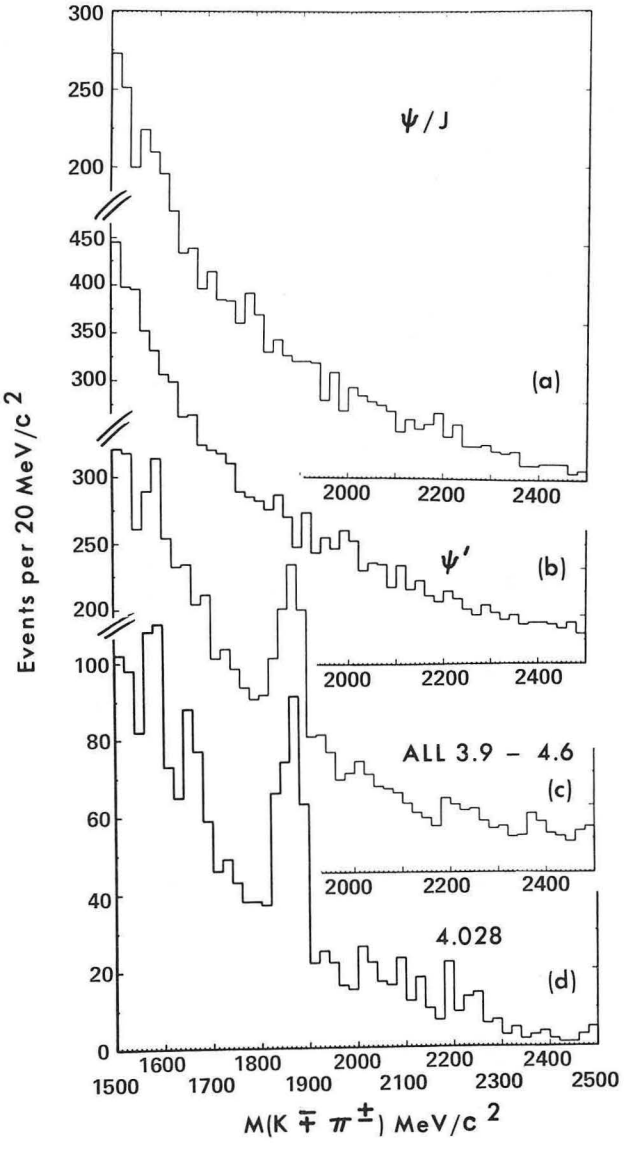

Fig. 4. Kπ mass spectrum at various center-of-mass energies. We note the signal appears after a definite threshold and is quite clean at 4.028 GeV. (XBL 7610-4862)

same isomultiplet as the neutral state at 1865 MeV/c^2. The observation of an apparent isodoublet of new mesons (two particles with nearly the same mass but different charges) is further evidence for the charm hypothesis, which organizes the lower-massed

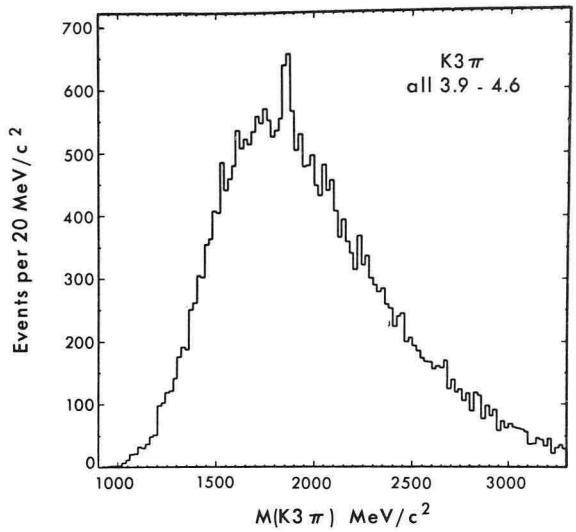

Fig. 5. $K^{\mp}\pi^{\pm}\pi^{+}\pi^{-}$ mass distribution. (XBL 7610-4867)

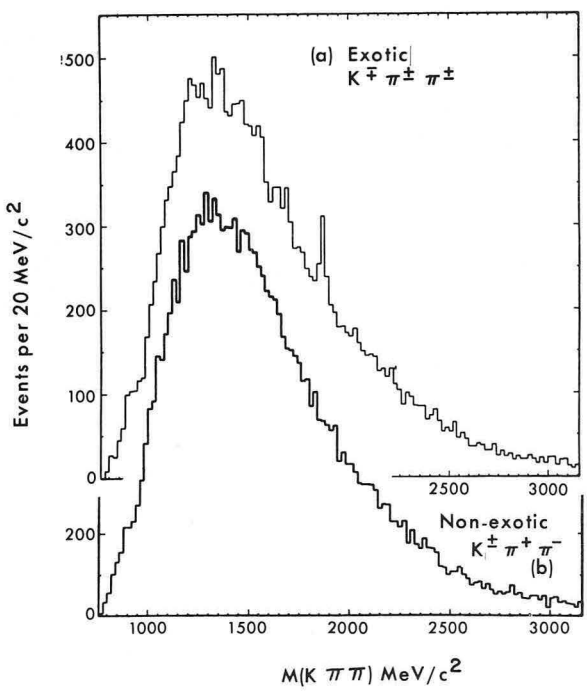

Fig. 6. Comparison of uncut K2π mass distribution for a) exotic charge combination, and b) non-exotic charge combination. (XBL 7610-4864)

charmed mesons into an isosinglet particle (the F^{+}) and an isodoublet (the D^{+}, D^{o}). The really telling evidence however is provided by the exotic nature of the charged particle decay.

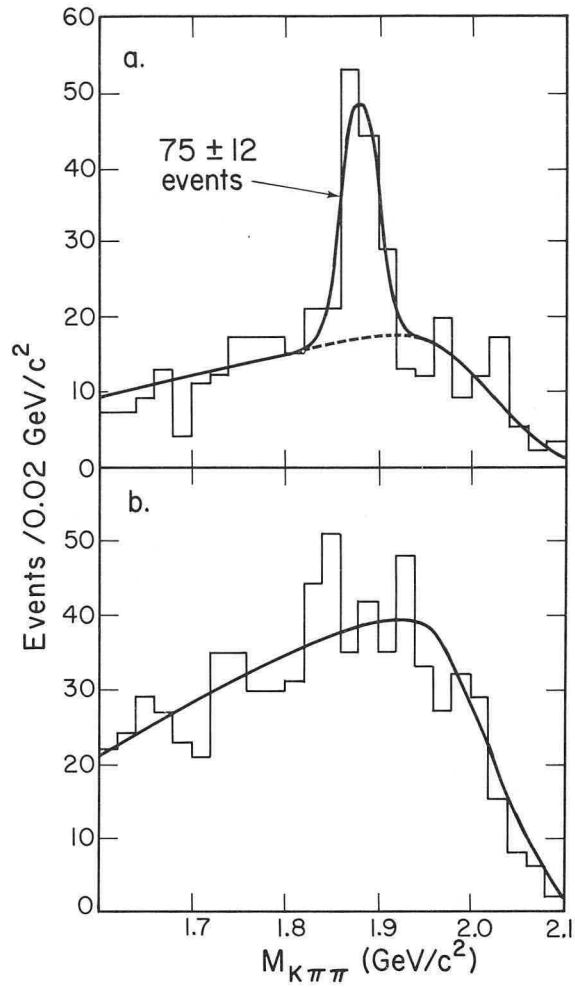

Fig. 7. K2π exotic a) and non-exotic b) mass distributions with recoil cut explained in text. (XBL 7610-4115)

The invariant mass distribution of $K^{\mp}\pi^{\pm}\pi^{\pm}$ combinations for data taken at a center-of-mass energy of 4.03 GeV can be seen in Fig. 7a. In order to obtain the particularly clean signal near 1.9 GeV/c^2, a cut was placed on the effective mass of particles recoiling off the $K^{\mp}\pi^{\pm}\pi^{\pm}$ combination (more about recoils later). Figure 7b contrasts the situation for $K^{\pm}\pi^{\pm}\pi^{\mp}$ combinations that satisfy the identical energy and recoil mass requirement as Fig. 7a. Clearly the charged state prefers to decay into $K^{\mp}\pi^{\pm}\pi^{\pm}$ rather than $K^{\pm}\pi^{\pm}\pi^{\mp}$. This is an unusual choice indeed for an ordinary, strongly decaying particle.

The $K^{\mp}\pi^{\pm}\pi^{\pm}$ state has positive charge and negative strangeness and hence cannot be constructed from 2 quarks as in the conventional quark theory. Such states are labeled exotic, and have thus far escaped detection in numerous searches among the ordinary, strongly decaying particles. This observation suggests that the new charged-particle state at 1876 MeV/c^2 is not a strongly decaying particle at all but rather a weakly decaying particle. The failure of a massive state to decay strongly suggests the presence of a new quantum number (such as charm), which inhibits the decay. The charm interpretation explains the presence of the exotic decay. The particular structure of the theory of charm also predicts the suppression of the $K^{\mp}\pi^{\pm}\pi^{\pm}$ mode.

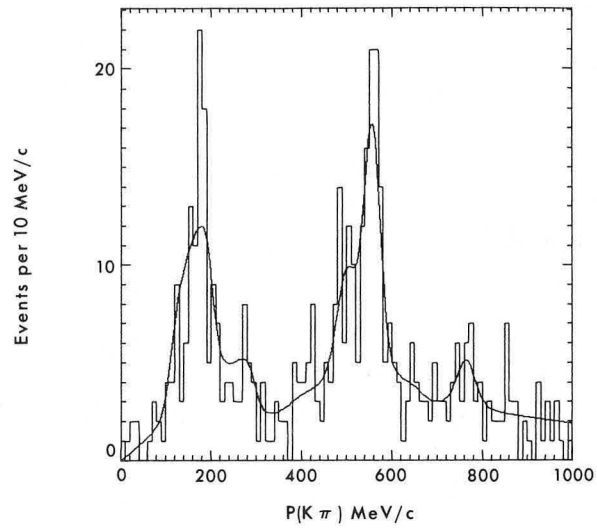

Fig. 8. $K\pi$ (1865) momentum spectrum at $\sqrt{s}$ = 4.028 GeV. Solid curve is a fit to model of De Rujula, Georgi, and Glashow.

Investigation of the recoil spectrum against the new particles has provided interesting results since the time of their discovery.[4] (The recoil spectrum against a given particle is the distribution of effective mass of all particles other than the given particle.) In a colliding-beam experiment one can readily deduce the recoil mass against a given particle from a measurement of its momentum and the initial energy of the e^+e^- colliding system. The very early work on the new particles indicated that they were formed in association with systems of particles of comparable or greater mass. This result is to be expected for charmed particles, which must be created in pairs by electromagnetic or strong processes in order to conserve charm.

Investigation of the data taken near threshold at a center-of-mass energy of 4.03 GeV, where new particle production is maximal, reveals the presence of sharp recoil peaks. Figure 8 shows the momentum spectrum for the new neutral particle at 4.03 GeV center-of-mass energy. The structure in the particle momentum spectrum at fixed center-of-mass energy is equivalent to the structure in the recoil mass spectrum. (Also see Fig. 9.) Identification of the peaks is made in accordance with a recently published model of De Rujula, Georgi, and Glashow (DGG), which attributes threshold D^o production primarily to the presence of the three processes: $e^+ e^- \rightarrow D^o \overline{D^o}$, $D^o \overline{D^{o*}}$, $D^{o*} \overline{D^{o*}}$.[5] Here we identify the new particle with the D^o, and hypothesize the existence of an excited state of the D^o, the D^{o*}, which can decay into the D^o via pion or gamma emission. The solid curve of Fig. 9 represents a fit of the experimental $K\pi$ decay momentum spectrum to the DGG model. From fits such as this, one hopes to derive accurate measures of the mass of the D^o and D^{o*} as well as the relative importance of D^{o*} gamma decay vs pion decay.

As previously mentioned, the observation of the new charged particle decaying in an exotic final state provides evidence that the new particles decay by weak interaction, as expected for low-lying charmed

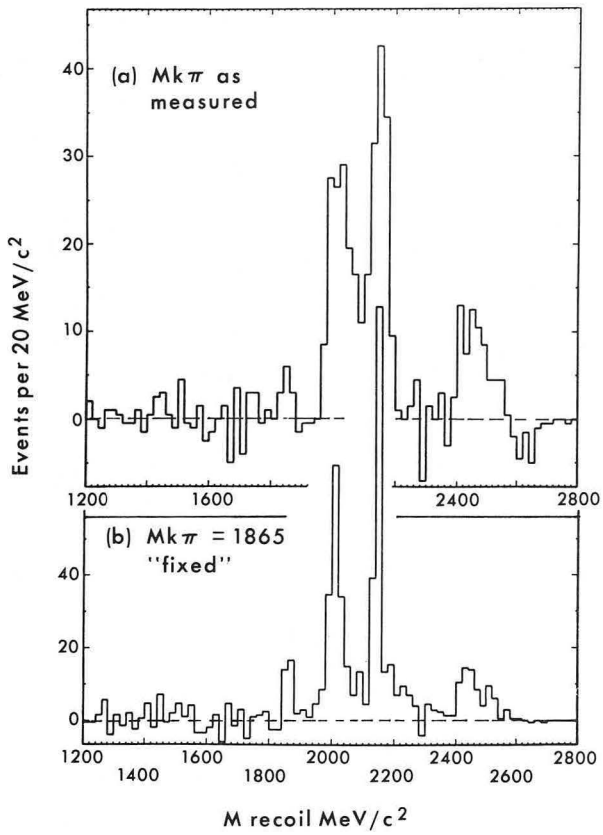

Fig. 9. Background-subtracted, recoil mass spectra against the Kπ (1865). In Fig. 6b one uses the known mass of the Kπ (1865) to improve resolution on recoil mass.
(XBL 7610-4865)

states. This evidence, however compelling, is rather indirect, for it rests upon an as-yet-unexplained rule forbidding the production of exotic states by strong interaction.

Further work has provided direct evidence that the new states decay weakly by demonstrating parity violation in their decay. Parity conservation, or the inability of the observer to distinguish right from left in a particle-scattering experiment, is a well-known property of the strong interaction. The so-called τ, θ puzzle of the early 50's led Lee and Yang to conjecture parity violation in the weak interaction, a conjecture whose verification led to their receiving the Nobel prize in 1963. The argument for parity violation in the decays of the new particles, just published in Phys. Rev. Lett., is remarkably similar to the original τ, θ argument of the 50's.[3]

For experts the argument is as follows: If one assumes that the neutral state decaying into Kπ and the charged state decaying into Kππ are members of the same isodoublet, a demonstration that the Kππ final state is incompatible with natural spin parity provides a demonstration of parity violation since the Kπ final state must have natural spin-parity. This incompatibility can be demonstrated by a study of the Kππ Dalitz plot. General symmetry arguments first formulated by Dalitz and Gell-Mann show that: Kππ final states of natural spin parity must exhibit regions of strong depopulation that depend on the spin of the final state. Figures 10a and 10c show the depopulation regions expected for spin 1 and 2. Comparison of Figs. 10a to 10b and Figs. 10c to 10d shows that approximately equal signal population resides in the regions of depopulation and their complement. One expects a 1:8 and 1:6 depopulation ratio for spin 1 and 2, respectively, if the final state is of natural spin parity. Since three pseudoscalars cannot be in a natural spin-parity state of spin 0, Fig. 10 serves to demonstrate parity violation for spins less than 3.

In summary, work at LBL and SLAC on the new particles in the five months since their discovery, has greatly strengthened the belief that they are charmed. Work on the recoil spectrum against the particles has provided evidence for the existence of new excited charmed mesons. Recent important work at Fermilab has provided

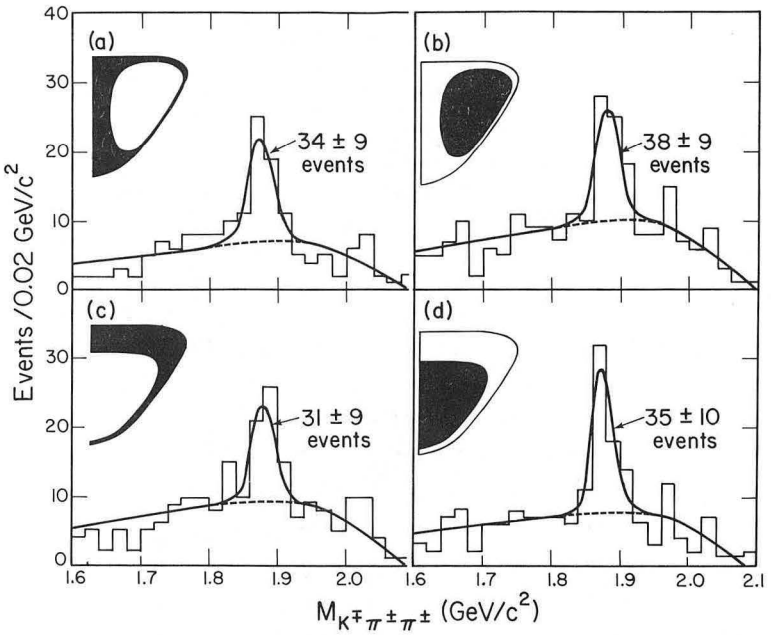

Fig. 10. Dalitz plot discrimination regions for parity violation argument in text. (XBL 7610-4114)

strong evidence for the presence of charmed baryons as well. One looks forward to the discovery of a rich spectrum of new particles as SU(3) expands to SU(4).

— J. Wiss

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4. G. Goldhaber, Study of Charmed Mesons at SPEAR, Summer Institute on Particle Physics, SLAC, Stanford, Calif., August 2-13, 1976, LBL-5534.

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The Time Projection Chamber

The time projection chamber (TPC)[1] is an exciting new concept for charged-particle detection and track reconstruction over large solid angles for high multiplicity events (Fig. 11). The TPC can provide high spatial resolution (50 to 200 microns) in a large volume, nearly 100% pattern recognition and reconstruction efficiency over 95% of 4π, good time resolution, fast recovery time, digital data output, compatibility with high magnetic fields, as well as particle identification in a compact package.

Such a detector is well-suited to be the central element of a larger general purpose detector for high-energy e^+-e^- machines like PEP. At PEP, jet structure is expected to dominate interactions in which hadrons are produced. Jets are directional clusters of high-energy particles observed in recent colliding-beam experiments. The high resolution, good efficiency for high-multiplicity track reconstruction, and particle identification abilities make the TPC a good choice for PEP.

At Berkeley, the TPC could be a useful detector in nuclear science experiments, especially for heavy-ion research. It is nondestructive, has good momentum and spatial resolution, and could be used to resolve nuclear jets. It could be used to study

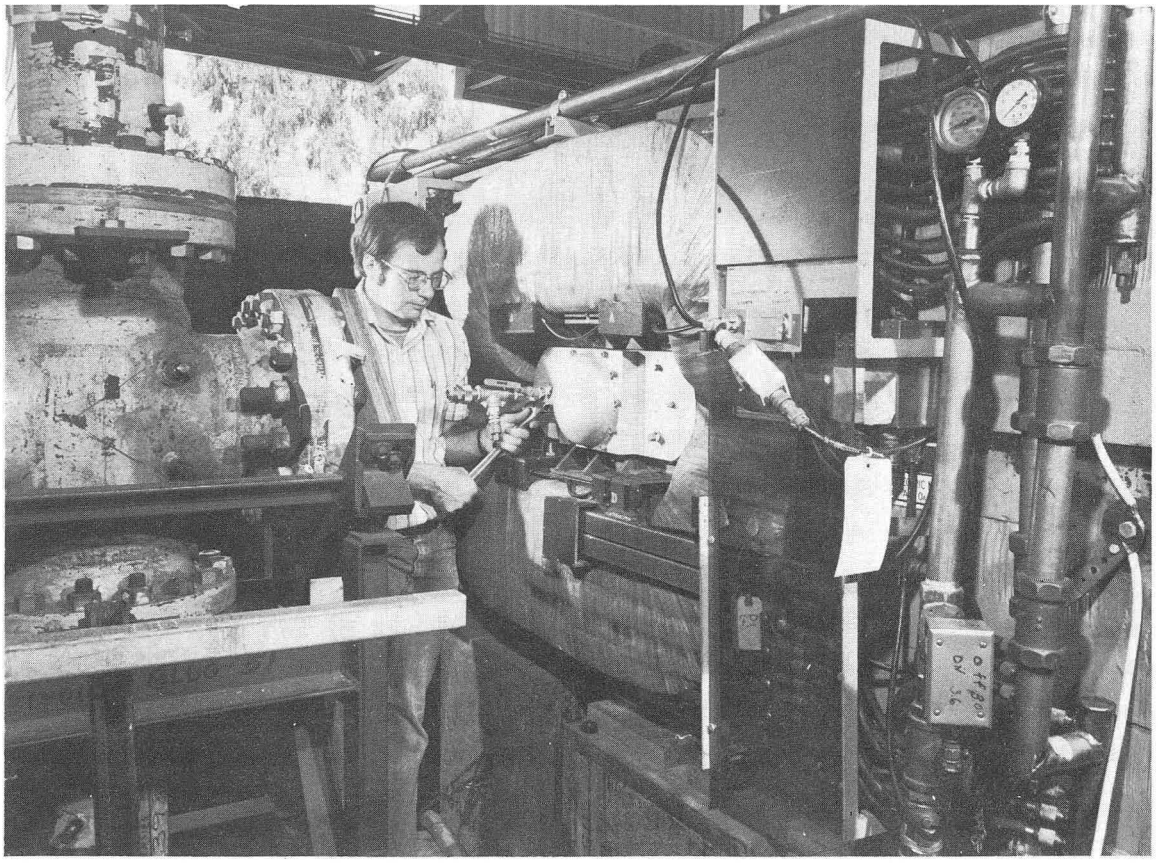

Fig. 11. Dave Fancher makes an adjustment on the pressure vessel of the prototype time projection chamber. (CBB 760-10482)

the fragmentation or diffractive dissociation of nuclei, particularly correlation between like fragments.

The basic concept of the TPC is that of a large drift chamber with proportional amplification placed in a strong magnetic field — the magnetic field being parallel to the drift electric field. The chamber is filled with an argon-methane gas mixture pressurized to ten times atmospheric pressure. Charged particles traverse the chamber and create ionization electrons along their trajectories. These ionization electrons drift in the direction of the electric field towards the sense wires (the Z wires in Fig. 12). The parallel magnetic field suppresses transverse diffusion of the electrons, helps contain delta rays, and provides the bend in the particle trajectories for momentum measurement. The signals picked up by the sense wires induce signals on pads located in the ground plane beneath the wires (see Fig. 12).

These induced signals are used to compute the X coordinate of the particle crossing. An algorithm can be used to find the centroid of the signals induced on several adjacent pads. This technique gives an X resolution much better than the size of the pad. The drift time of the electrons from the particle trajectory to the sense wires is also determined (see Fig. 12) by measuring the time delay between a trigger pulse and the signal on the wire (time t in Fig. 12). The time delay is proportional to the distance Y between the crossing particle and the wire. The proportionality constant is computed from the known mean drift velocity of the ionization electrons. Thus, all spatial coordinates of a charged particle trajectory are read out at many places along the trajectory.

The momentum is calculated from the curvature of the tracks as measured by the X pads and a knowledge of the strength of the magnetic field. The particle's mass (and hence its identity) is obtained from a measurement of the dE/dx (for Fig. 12, dE/dz)

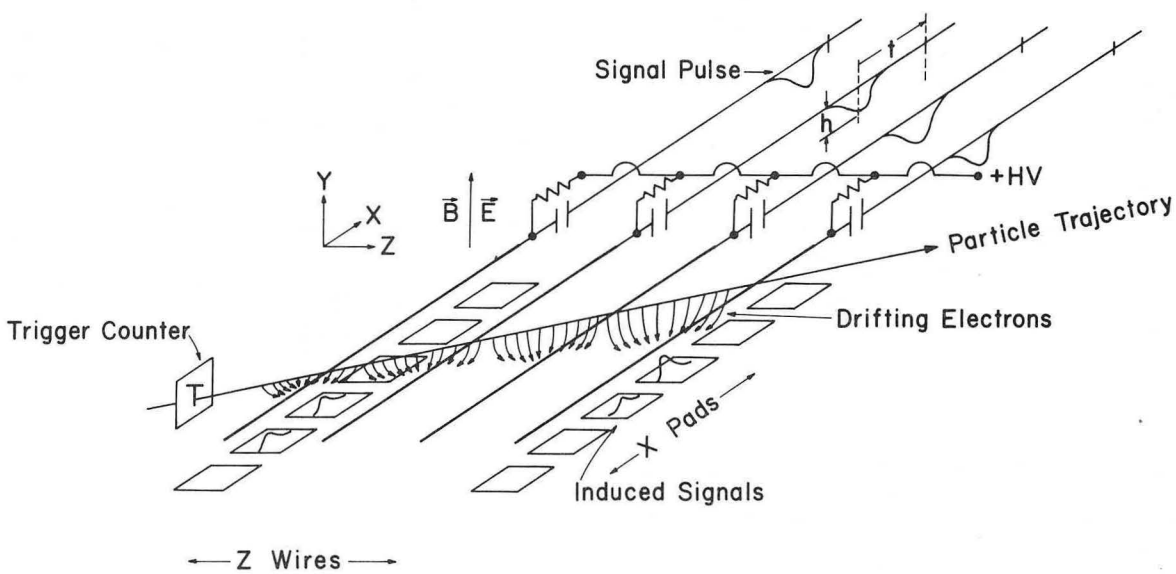

Fig. 12. The principle of operation of the Time Projection Chamber.
(XBL 7611-9879)

energy loss along the particle trajectory. The amount of track ionization per sense wire is preserved through proportional amplification at the wires, and the analog signals of the Z wires can be digitized to give the ionization energy lost for each wire. By studying the distribution of the energy lost for a large number of samples (wires) one can separate particles by their mean energy loss.[2] Figure 13 shows the most probable energy loss for electrons (e), pions (π), kaons (K), and protons (p) as a function of particle momentum. Figure 14 shows a Monte Carlo simulation of the mean energy loss for 2-GeV e, π, K, and p, obtained by using 200 samples of dE/dx information and an algorithm described in Ref. 2 to compute the mean energy loss. At higher energies the separation is better (see Fig. 13); at lower energies the separation is also better since dE/dx is proportional to $1/\beta^2$, where $\beta = v/c$, velocity of particle. At intermediate energies (about 1 GeV), where ambiguities exist (see Fig. 13), other techniques can be used to extract the particle identity.[2]

To test the feasibility of a detector like the TPC, we are constructing a prototype to be tested at the Bevatron at LBL. This prototype will have the geometry of Fig. 15 and will

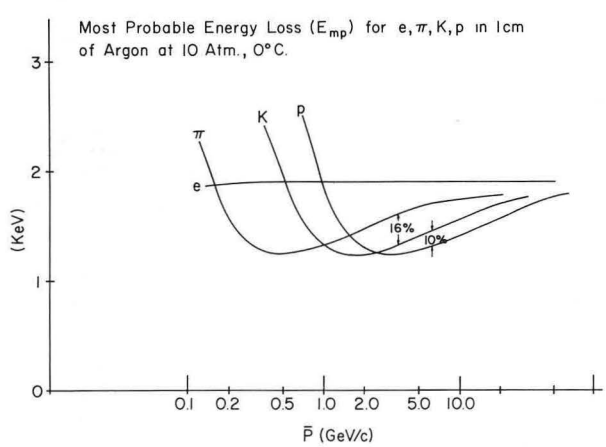

Fig. 13. The most probable energy loss (E_{mp}) for electrons, pions, kaons, and protons in 1 cm of argon at 10 atm., 0°C. (XBL 7611-9880)

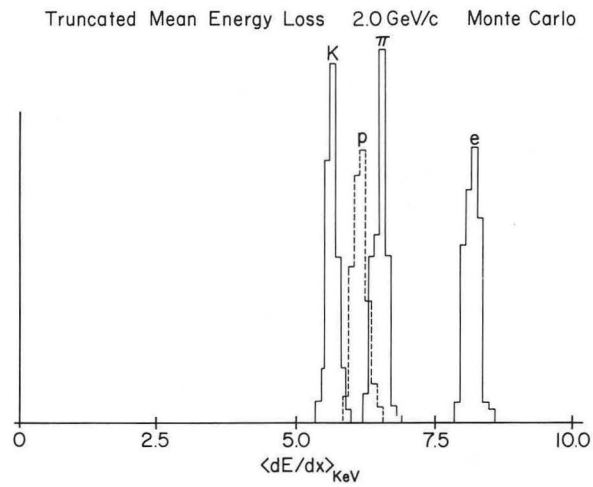

Fig. 14. A Monte Carlo simulation of the truncated mean energy loss for 2 GeV electrons, pions, kaons, or protons. (XBL 7611-9881)

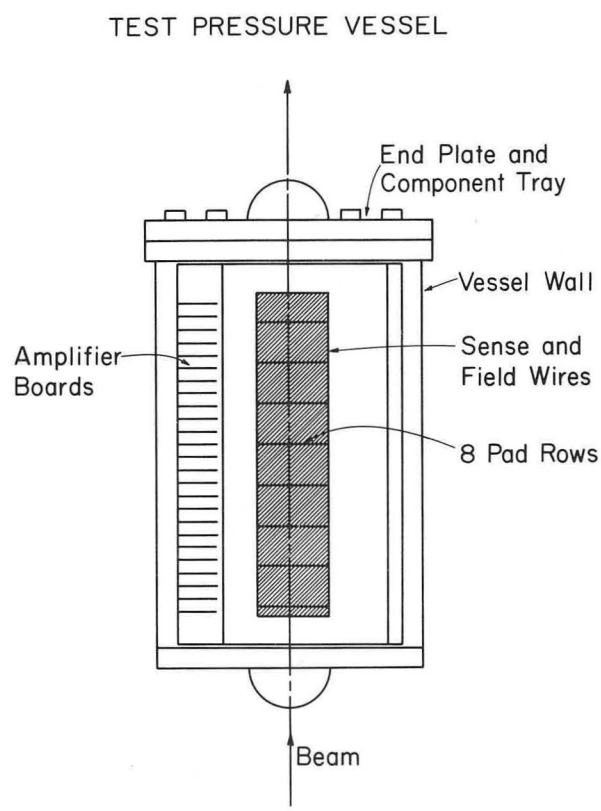

Fig. 15. Test pressure vessel and prototype TPC. (XBL 7611-9883)

consist of 200 sense wires spaced 4 mm apart and 8 rows of 16 pads — the pads being 8 mm by 8 mm square, 0.5 mm apart, and the rows being 100 mm apart. The drift region is about 100 mm and the entire detector is inside a pressure vessel containing an argon-methane mixture at 150 psia. The pressure vessel in turn is inside a large magnet ("Ulysses"). Figure 15 shows the pressure vessel and prototype TPC. The direction of the E and B fields is perpendicular to the plane of the paper.

The prototype will allow us to study techniques of track reconstruction and particle identification for various types of particles and different momenta.

The TPC envisioned for PEP has a different geometry (Fig. 16). The drift region is cylindrical: two meters long and two meters in diameter. A membrane at a large negative potential, across the center of the cylinder, separates the cylinder into two drift regions causing electrons to drift towards the two endcaps. The cylinder is surrounded by a solenoidal magnet producing a B field parallel (or anti-parallel) to the E field. The electrons drift to the endcaps where the sense wires measure R and the pads under wires determine ϕ. Z, the distance along the beam direction is measured by the drift time of the electrons to the wires. Analog signals from the wires are used to extract dE/dx information for particle identification.

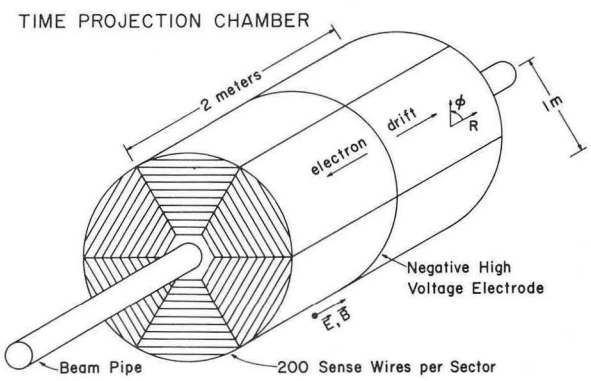

Fig. 16. The Time Projection Chamber proposed for PEP. (XBL 7611-9882)

A chamber of this design would be used as the heart of a TPC facility being proposed for PEP by a collaboration of several groups[3] including an LBL group. Such a facility might look like Fig. 17. The TPC is surrounded by a thin cylindrical solenoidal superconducting magnet, a design pioneered at LBL. Outside of the magnet are cylindrical wire chambers to measure the particles' exit trajectories and then a cylindrical calorimeter, which is designed to measure the energy and location of electrons, positrons, and photons, and is useful for the detection of neutral pions that decay to two photons. The calorimeter could be made of alternate layers of liquid argon and lead sheets. Outside the calorimeter is the iron return yoke of the magnet. Outside of the magnet (not shown in Fig. 17) would be layers of iron and drift chambers for muon identification.

In conclusion, the TPC shows promise of proving to be an ideal general purpose charged-particle detector in the current and future physics environment of such acceler-

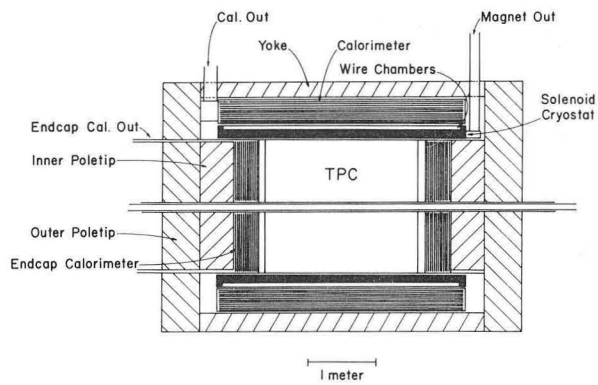

Fig. 17. The TPC Facility proposed for PEP, which includes ancillary counters and supporting equipment. (XBL 7611-9884)

ators as PEP. Its features, which include compact size, high resolution, particle separation, close to 4π detection efficiency, good momentum resolution, and high efficiencies for reconstruction of large multiplicity events, make it ideal for studying jet structure and hadron physics at PEP.

— D. Fancher

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3. The collaborators and their affiliations are: B. Barnett, C. Y. Chien, L. Madansky, J. Matthews, and A. Pevsner (John Hopkins University); A. Clark, O. Dahl, D. Fancher, P. Eberhard, R. Kenney, L. Kerth, S. Loken, D. Nygren, P. Oddone, M. Pripstein, P. Robrish, G. Shaprio, M. Strovink, M. Urban, and W. Wenzel (Lawrence Berkeley Laboratory); C. Buchanan, W. Slater, D. Stork, and H. Ticho (UCLA); W. Gorn, A. Kernan, J. Layter, and B. Shen (UCR); J. Marx, P. Nemethy, and M. Zeller (Yale).

Similarities Between Cross Sections for Peripheral Collisions at 20 MeV/nucleon and 2.1 GeV/nucleon

Until recently, no one thought there was much connection between the experiments performed at the 88-Inch Cyclotron, where the particle energies are in the range of 5 to 10 MeV/n, and those at the Bevalac, where energies reach several GeV/n — some 100 to 1000 times higher. Now the Heavy-Ion Group at the Cyclotron has begun the task of building an experimental and conceptual bridge between these two apparently quite different worlds. Their work adds another piece to the intriguing puzzle of how two heavy ions interact. Members of the Heavy-Ion Group are M. Buenerd (Grenoble), C. K. Gelbke, B. G. Harvey, D. L. Hendrie, J. L. Laville (Caen), J. Mahoney, A. Menchaca-Rocha (U. of Mexico), M. C. Mermaz (Saclay), C. Olmer and D. K. Scott (Fig. 18).

With existing accelerators, heavy-ion reactions have largely been studied in two energy regimes: below 10 MeV/n, which is the well-trodden territory of nuclear structure laboratories all over the world, and a few

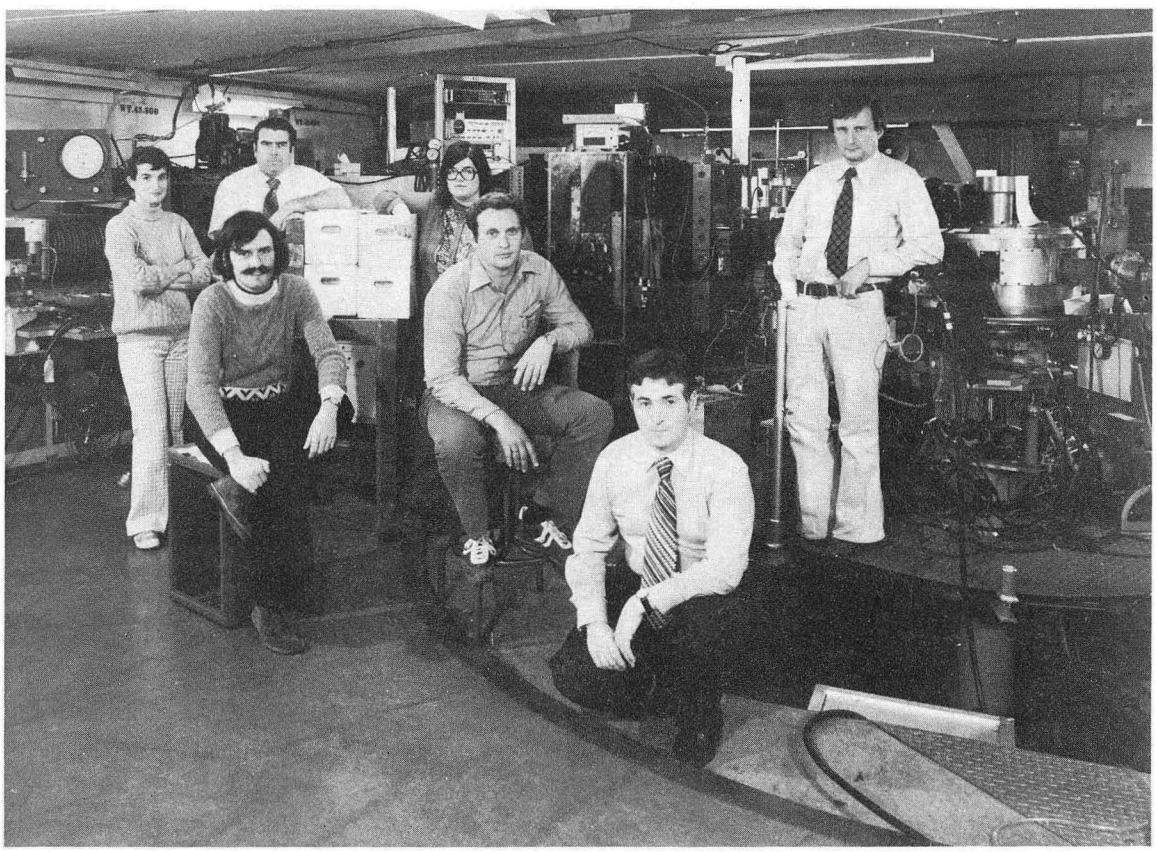


Fig. 18. The magnetic spectrometer at the 88-Inch Cyclotron poses for a formal portrait with the Heavy-Ion Group. From left, clockwise, Jeanette Mahoney, David Hendrie, Catherine Olmer, David Scott, Michel Mermaz (kneeling), Konrad Gelbke, and Jean-Louis Laville. (XBB 760-10486)

GeV/n, the scientific wonderland of the Bevalac. Between the two regions there exists a gap, the significance of which is illustrated in Fig. 19. This diagram shows the collision time for the passing of two heavy ions as a function of their mass and energy. The first region, up to 10 MeV/n, has collision times of the order of 10^{-21} sec to 10^{-22} sec, corresponding to velocities of about one-tenth of the speed of light. These times are long, compared to the characteristic nuclear time, τ_n, taken by a nucleon in the Fermi sea to make a trip across the nucleus. During the collision, nucleons can pass back and forth between the nuclei, converting the energy of motion into internal excitation energy. It is widely believed that the two nuclei merge into a short-lived double nuclear system, leading to "deeply inelastic" and equilibration phenomena. Close to the vertical axis of the figure is the other region of study, labeled "relativistic fragmentation." Here the relative velocities are > 0.30c. The collision time is so short that the nuclei are gone before much exchange of nucleons can take place, and the dominant peripheral process is fragmentation of the projectile. The incident energy of 20 MeV/n (marked on the figure with a bold line) may be a transition region because this energy matches the characteristic nuclear time, τ_n. Measurements here might be expected to yield results bridging the two explored regions.

At the 88-Inch Cyclotron, ^{16}O beams of 20 MeV/n have been developed by the persistent efforts of the experimentalists and the machine physics groups. The initial experiments by the Heavy-Ion Group indeed already show a remarkable similarity between the yields of high-energy fragments produced by ^{16}O beams of either 20 MeV/n or 2.1 GeV/n on ^{208}Pb. (The data at 2.1 GeV/n were measured by the Heckman/Greiner Group.) As

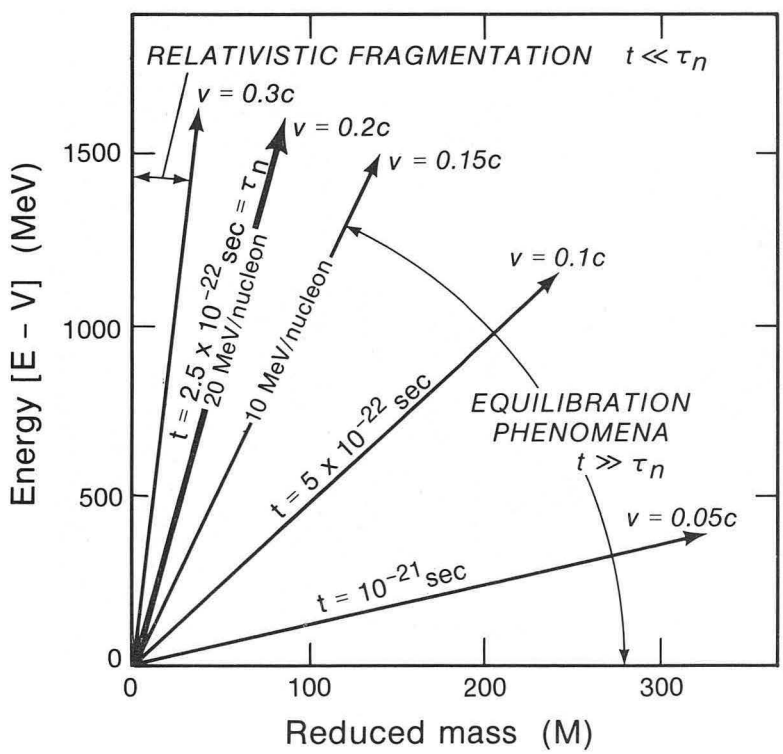


Fig. 19. Collision times of nuclear reactions as a function of energy above the barrier (E-V) and reduced mass (M) of the colliding ions. Some lines of constant collision time are drawn, together with the corresponding velocities and energies in MeV/n. The bold line for 20 MeV/n is close to the average energy of a nucleon in the nuclear surface and divides the map into two regions. Until now only the regions of energy less than 10 MeV/n and greater than 300 MeV/n have been extensively explored. (XBL 7610-4154)

Fig. 20 illustrates, the relative yields of elements are almost identical, with systematic differences in the isotope yields. At both energies the cross sections can be related systematically to the Q-values for fragmentation of the projectile. These cross sections do not agree well with the systematics of deeply inelastic equilibrating reactions (the first region discussed), although some aspects of these phenomena are still present in the 20 MeV/n data. So, although the experimenters have caught a glimpse of the new world, they have not totally lost sight of the old.

This Group also finds that the difference between the total geometrical cross section and the summed cross section for the production of all the fragments in Fig. 19 remains roughly constant at the two energies. This remaining cross section can be attributed to collisions of a more central nature, which lead to complicated processes, but which appear to be determined by the bulk overlap of nuclear matter over a wide energy range.

All of the above results are concerned with the average gross properties of heavy-ion collisions, and are almost devoid of any nuclear structure information. Because the 88-Inch Cyclotron is equipped with a high-resolution magnetic spectrometer, the experimenters have been able to look with a finer microscope at the energy spectra, as shown in Fig. 21. Here for the single nucleon transfer reaction $^{208}Pb(^{16}O,^{15}N)^{209}Bi$, fine structure appears, in addition to the continuum, corresponding to the excitation of well-defined states in the residual nucleus. These states are the bread and butter subjects of nuclear structure studies, and sophisticated theoretical techniques exist for handling them in the form of that old work-horse of nuclear spectroscopy, the Distorted Wave Born Approximation (DWBA). In collaboration with M. H. MacFarlane and S. Pieper of Argonne National Laboratory, the Group finds that this model predicts most aspects of the transfer (i.e. angular distributions and relative yields), but when used to predict the total cross sections, it suffers a catastrophic failure for the wide range of incident

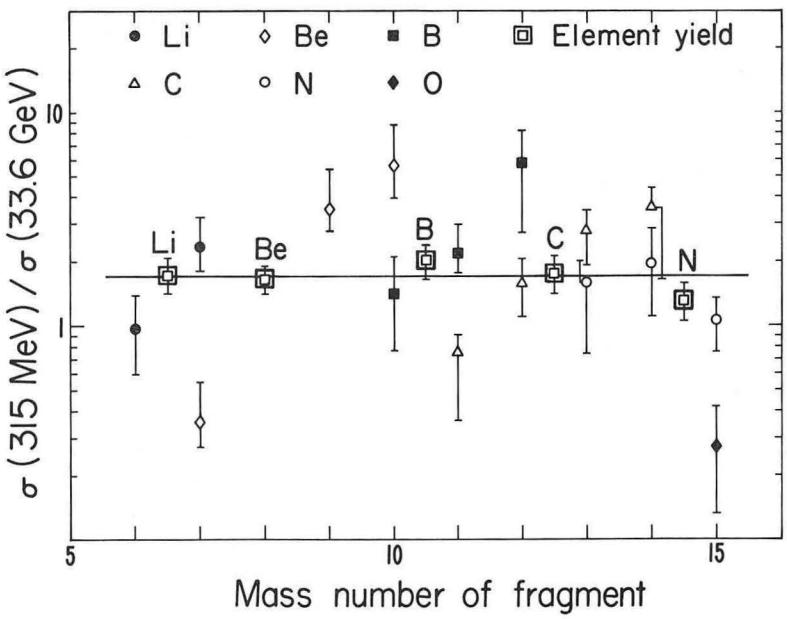


Fig. 20. Ratios of cross sections for peripheral processes induced by ^{16}O on ^{208}Pb at laboratory energies of 315 MeV and 33.6 GeV. (XBL 768-3340)

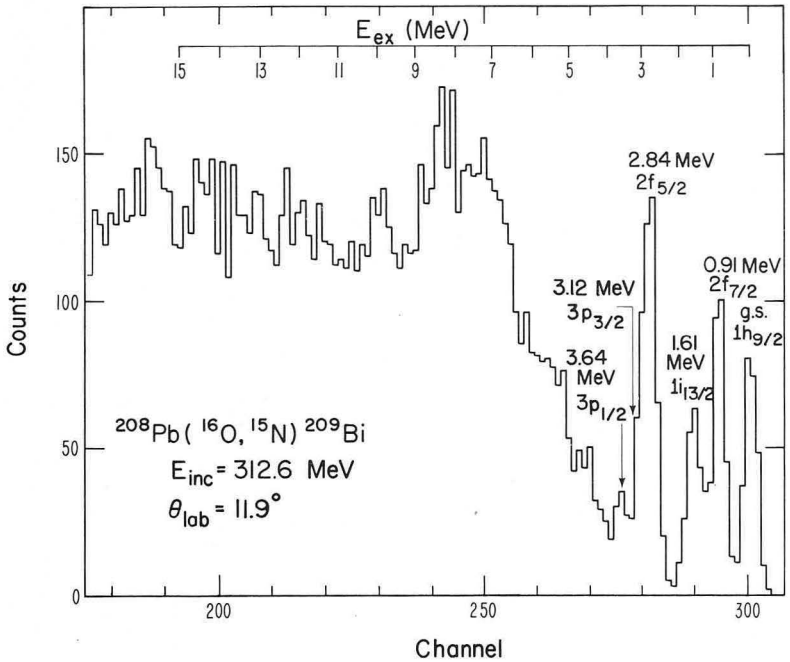


Fig. 21. A portion of the spectrum of ^{15}N observed from the bombardment of ^{208}Pb with ^{16}O at 315 MeV. At the right we see the sharp low-lying excited states of ^{209}Bi and to the left the large "quasi-elastic" cross section, which we compare with the Bevalac results. (XBL 7610-4290)

energy encompassed by their experiments and by others measured previously at lower bombarding energies. The correlation of this picture with the increase in the intensity of the continuum, which resembles Bevalac fragmentation, is an intriguing aspect of these heavy-ion collisions and suggests that the failure of DWBA may be intimately linked to the onset of fragmentation. The experimenters are optimistic that there is a real hope of unifying the various theoretical approaches to heavy-ion reactions.

— The 88-Inch Heavy-Ion Group

Relevant Publications

1. M. Buenerd, C. K. Gelbke, B. G. Harvey, D. L. Hendrie, J. Mahoney, A. Menchaca-Rocha, C. Olmer, and D. K. Scott, Phys. Rev. Lett. 37, 1191 (1976).

2. C. K. Gelbke, M. Buenerd, D. L. Hendrie, J. Mahoney, M. C. Mermaz, C. Olmer, and D. K. Scott. LBL-5094, to be published in Phys. Lett. B.

3. D. K. Scott, talk given at 3rd Bevalac Heavy-Ion Summer Study, July 1976.

PUBLICATIONS AND PRESENTATIONS

ON ACCELERATORS

ESCAR Midterm Report, *T. Elioff, R. A. Byrns, W. S. Gilbert, G. R. Lambertson, R. B. Meuser*

The LBL Advanced Accelerator Group is now well into the design and fabrication of a small pilot-project accelerator and storage ring using superconducting magnets. This project has the acronym ESCAR, which stands for Experimental Superconducting Accelerator Ring. One refrigeration building has been completed, and detailed drawings are being prepared for other conventional facilities. The accelerator layout is firm, and machine components are in fabrication.

The bulk of our efforts has been directed to the new and more uncertain superconducting magnet systems and their associated cryogenic and refrigeration interfaces. The construction and operation of ESCAR goes beyond a test of laboratory-proven magnets. It is a test of the engineering and economic impact of converting to primarily cryogenic components in a large distributed system. The presence of the low-temperature magnets is so pervasive that it is a design criterion that

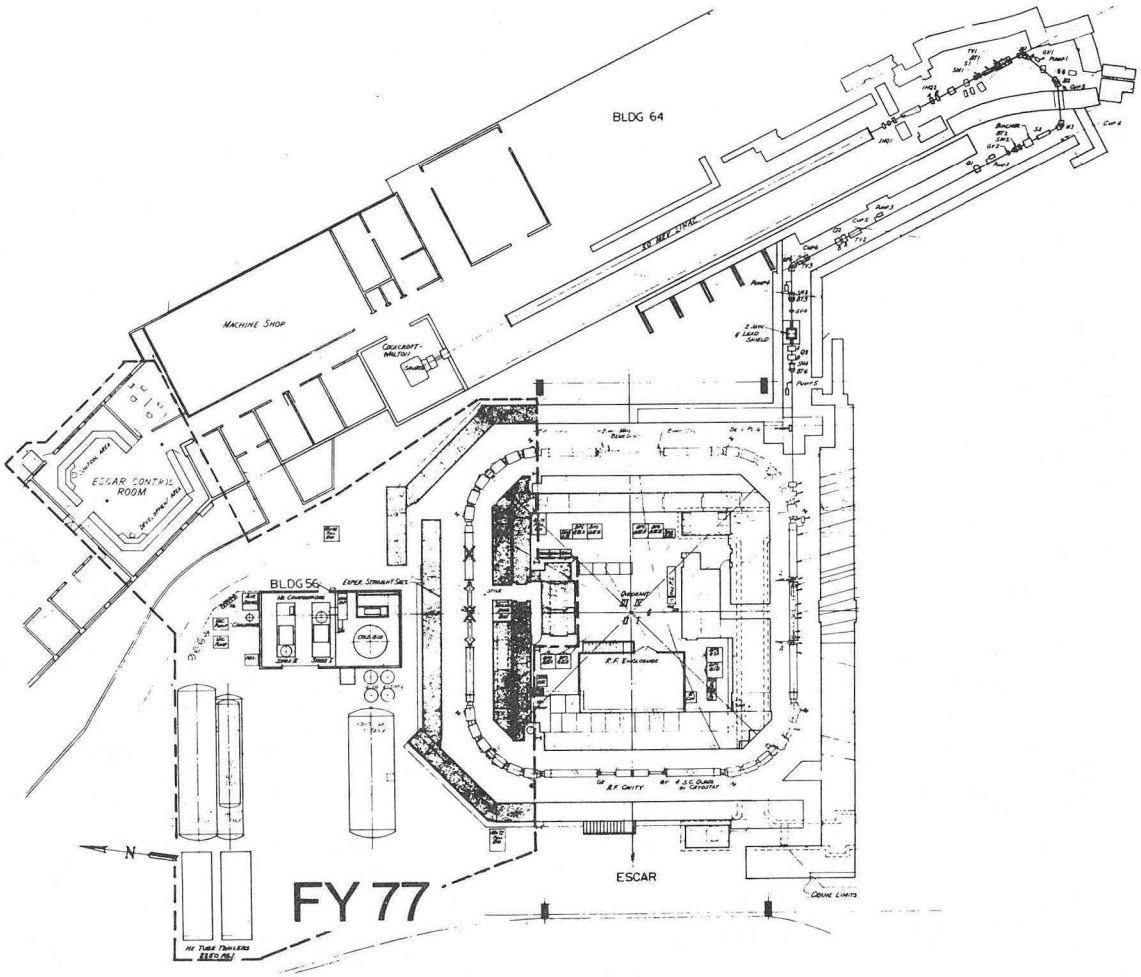


Fig. 22. ESCAR plan view. Portion to be constructed during FY 1977 is outlined by dashed line.

all components in the accelerator ring shall be at liquid helium temperature unless technically impractical.

Main ring dipoles (24 required) are now in serial production at the rate of one per month. Our 1500-watt helium refrigerator is scheduled for delivery in Spring 1977. We plan to test a "stripped-down" one-half ESCAR in Summer 1977 (Fig. 22). Complete accelerator operation with beam will follow in about two years. *(LBL-4818) Presented at the 1976 Applied Superconductivity Conference, Stanford, CA, August 17-20, 1976*

The Status of the SuperHILAC,
H. A. Grunder and F. B. Selph

The SuperHILAC is an Alvarez linear accelerator designed to accelerate all ions to a maximum energy of 8.5 MeV/u. It functions as an essential part of two research programs of national importance — first, as a supplier of beams for research at less than 10 MeV/u, secondly as an injector for the Bevalac facility, for nuclear physics and medical research at energies greater than 200 MeV/u. This duplication of effort from a single accelerator is made possible by the utilization of a technique known as time-share — two different ion beams are accelerated independently through the same linac structure. Recent operation has been in the mass range $12 \leqslant A \leqslant 136$. Usually, a heavy ion ($A > 40$) is delivered to the SuperHILAC experimental area for nuclear physics experiments while concurrently a lighter ion ($A \leqslant 40$) is delivered to the Bevatron for further acceleration (max. 2.5 GeV/u) to be used in experiments exploring the physics of very-high-energy heavy ions, in investigations of radiation biology, and in preclinical tests as a tool for cancer treatment.

Recent operating experience is reviewed. Also discussed are recent major improvements which have been made to the accelerator, and a proposed improvement which will increase reliability and beam intensity for the very heavy ions ($A \gtrsim 84$) by adding a third injector of improved design. *(LBL-5390) Presented at the 1976 Proton Linear Accelerator Conference, Chalk River, Ontario, Canada, September 14-17, 1976*

ON BIOLOGY AND MEDICINE

Kidney Compartment Model,
G. T. Gullberg

A multiparameter kidney compartment model which quantitates the amount of iodohippurate concentration as a function of time in the blood, tissue, kidneys, and bladder is developed from a system of differential equations, which represents first-order kinetics. The kinetic data are obtained by using a gamma camera and an HP5407 computer system that allows one to delineate areas of interest for the blood and tissue, kidneys, and bladder, thus separating the data into four data sets. The estimated tubular transit times have a high ratio of the signal to the variance, whereas the estimates of the amount of iodohippurate in the blood, tissue, and kidneys have a low ratio of the signal to variance. Application of this model to patient data requires better statistics than available with conventional ^{131}I-hippurate doses; thus a true test of the efficacy awaits availability of ^{123}I-hippurate. *(LBL-2896)*

Development of Positron-Emitting Radionuclides for Imaging with Improved Positron Detectors, *Y. Yano*

Recent advances in positron cameras and positron ring detectors for transverse section reconstruction have created renewed interest in positron emitting radionuclides. This paper reports on: 1) generator-produced ^{82}Rb; 2) cyclotron-produced ^{62}Zn; and 3) reactor-produced ^{64}Cu.

Investigation of the ^{82}Sr (25 d)-^{82}Rb (75 s) generator determined the elution characteristics for Bio-Rex 70, a weakly acidic carboxylic cation exchanger, using 2% NaCl as the eluent. The yield of ^{82}Rb and the breakthrough of ^{82}Sr were determined for newly prepared columns and for long-term elution conditions. Spallation-produced ^{82}Sr was used to charge a compact ^{82}Rb generator to obtain multi-millicurie amounts of ^{82}Rb for myocardial imaging. See Fig. 23.

Zinc accumulates in the islet cells of the pancreas and in the prostate. Zinc-62 was produced by protons on Cu foil and separated by column chromatography. Zinc-62 was administered as the amino acid chelates and as the $ZnCl_2$ to tumor and normal animals. Tissue distribution was determined for various times after intravenous injection. Pancreas and liver images of ^{62}Zn-histidine uptake were obtained in animals with the gamma camera, and the liver uptake of ^{99m}Tc sulfur colloid was computer-subtracted to image the pancreas alone. The positron camera imaged uptake of ^{62}Zn-histidine in the prostate of a dog at 20 h.

^{64}Cu was chelated to asparagine, a requirement of leukemic cells, and administered to lymphoma mice.

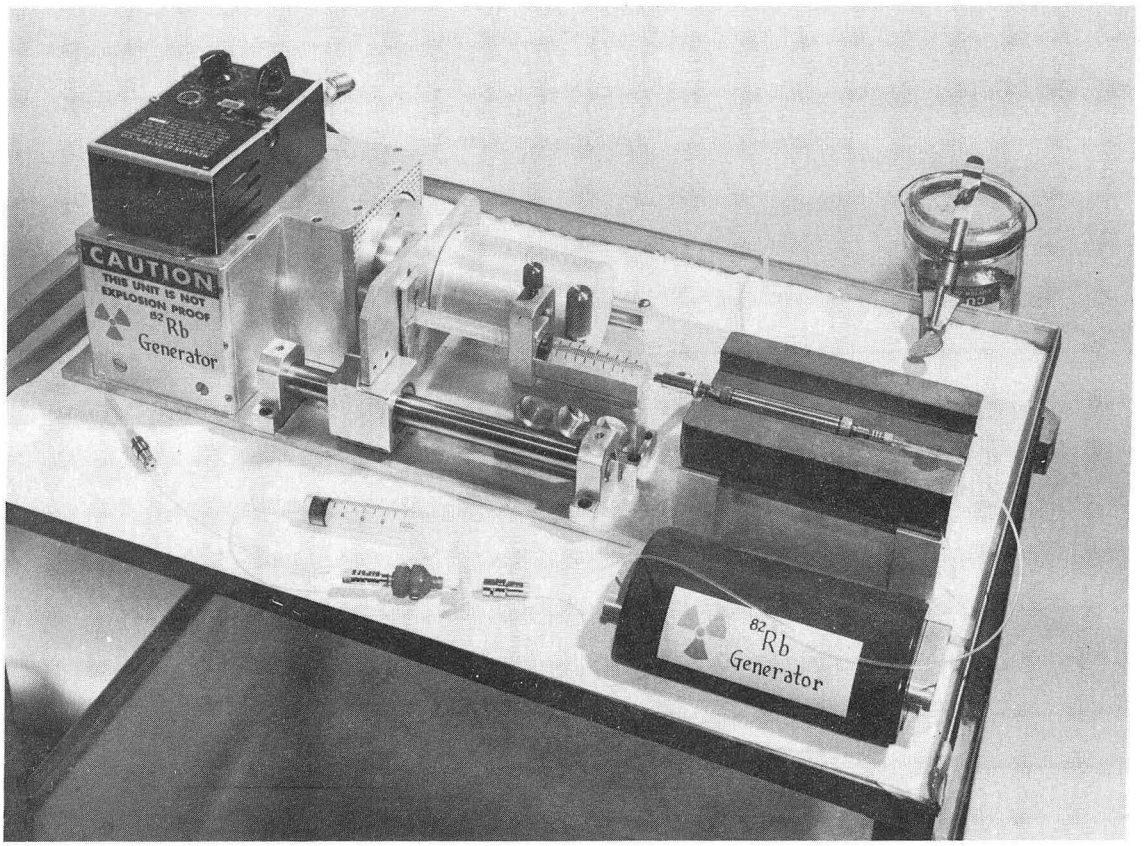


Fig. 23. Compact generator for obtaining multimillicurie amounts of ^{82}Rb with 2% NaCl. (CBB 748-5258)

Uptake in tumor and various tissues was determined and compared with the uptake of ^{67}Ga citrate under the same conditions. ^{64}Cu-asparagine had better tumor-to-soft tissue ratios than ^{67}Ga-citrate. *(LBL-4785; IAEA-SM-210/123) Presented at the IAEA Symposium on Medical Radionuclide Imaging, Los Angeles, CA, October 25-29, 1976*

Emission Computed Axial Tomography

T. F. Budinger, S. E. Derenzo, G. T. Gullberg, W. L. Greenberg, and R. H. Huesman

Computed transverse section emission tomography using ^{99m}Tc with the Anger camera is compared to positron annihilation coincident detection using a ring of crystals and ^{68}Ga. The single photon system has a line spread function (LSF) of 9 mm FWHM at the collimator and gives a transverse section reconstruction LSF of 11 mm FWHM with 144 views. The positron ring has a LSF of 6 mm at the center with a transverse section reconstruction LSF of 7.5 mm FWHM. Correction for uniformity of detector response and accurate center of rotation determination is essential in both techniques. The signal-to-noise in a reconstruction is diminished by a factor of 1.2 times (number of resolution elements)$^{1/4}$ over that expected from the average number of events per resolution element. Attenuation compensation causes more noise to appear in the center than the edge for both modes and an average increase in uncertainty of 30%. The effects of attenuation result in more loss of data for positron coincidence imaging than for single photon imaging even at energies of 80 keV. For a 20 cm cylinder imaged in transverse section, only 20% of the positron annihilation events are not scattered; however, at 140 keV 40% of the photons are not scattered. The relative crystal efficiency gives single photon imaging an advantage of 5. On the other hand, the solid angle advantage of positron photon coincidence imaging is about 100 for the comparisons of this paper. Taking these factors into account, we find positron-computed section imaging has a tenfold increase in sensitivity over multiple-view imaging with the gamma camera which gives multiple sections but requires rotation of the camera or patient. *(LBL-4794) Presented at the International Atomic Energy Agency Symposium on Medical Radionuclide Imaging, Los Angeles, CA, October 25-29, 1976*

ON INSTRUMENTATION

Automated Counting of Cell Clones: A Progress Report, *H. S. White, E. A. Blakely, and T. C. Yang*

This report summarizes progress made in adapting the Flying Spot Digitizer, designed for bubble chamber data measurement, for use in enumerating human cell colonies grown *in vitro*. A description is given of the digitizing hardware and the general pattern recognition programs that are available in the FSD system. The development of the computer program called PETRI is also described. This new software provides the basis for analysis of the digitized information from the FSD.

As with particle track studies from the bubble chamber, experimental data are photographed and the film strip is processed through the FSD for digitizing. Tests of the FSD-PETRI analysis system have been made with film strips of the cell colonies grown on plastic petri dishes. Further work is necessary, but preliminary results presented here demonstrate that the system can be used to enumerate cell colonies with a

precision near that of counts made by eye. This precision was made possible by the machine's ability to distinguish overlapping colonies as more than a single large colony. In addition, the FSD-PETRI system provides information that is virtually impossible to obtain by eye; namely, a measurement of the distribution of colony sizes including those of very small colonies. These data potentially will enable the biologist to understand more clearly the cellular mechanisms of damage and repair, and will facilitate his ability to measure cell survival rapidly and objectively. (Fig. 24) *(LBL-4674)*

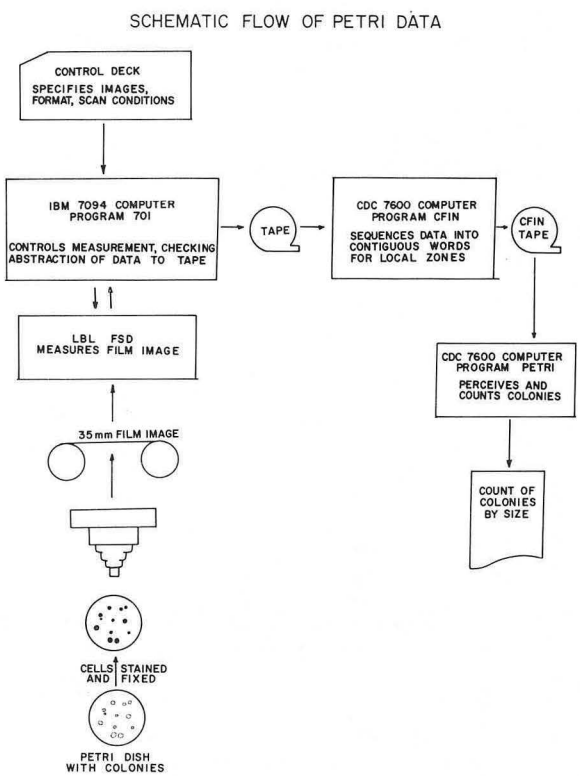


Fig. 24. Data flow schematic. (XBL 766-8491)

First Observatory Results with an Image-Sharpening Telescope,

A. Buffington, F. S. Crawford, R. A. Muller, and C. D. Orth

The image-sharpening telescope described in LBL-4803 was installed and operated on equatorial mounts at Leuschner Observatory in Lafayette, California and Lick Observatory at Mount Hamilton, California. We present measurements of the characteristic speckle change times for stars observed at these locations. We also present sharpened images of Sirius and Arcturus (Fig. 25). *(LBL-5503) Submitted to J. Opt. Soc. Am.*

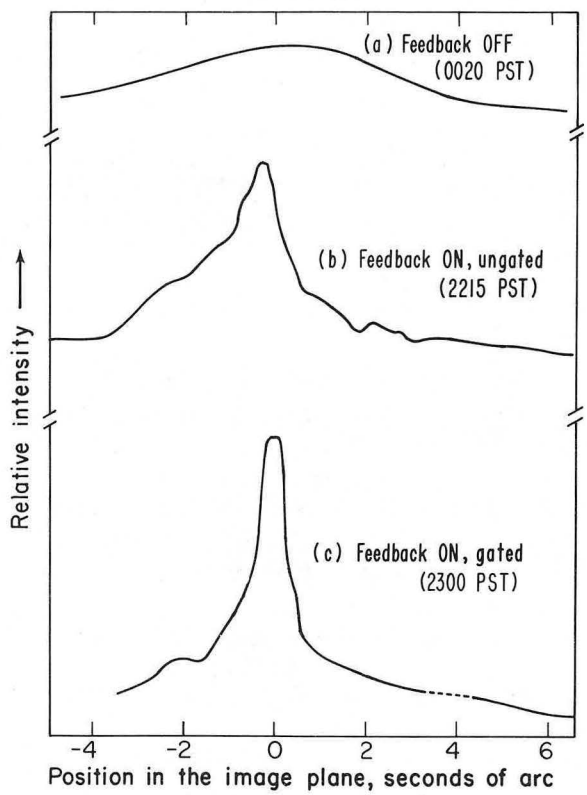


Fig. 25. Images of Arcturus recorded at Lick Observatory on the night of 13-14 July 1976. The typical value of $\tau_{1/2}$ was 10 msec. In (c) the gate threshold was set at twice the average feedback-ON sharpness and allowed data recording during the best 5 to 10% of the time. (XBL 768-3251)

Three Dimensional Imaging with Large Area Positron Cameras, *V. Perez-Mendez (LBL-5509) Contributed paper at the First Asia and Oceania Congress of Nuclear Medicine, Sydney, Australia, September 5-9, 1976*

New Instrumentation in Nuclear Medicine, *V. Perez-Mendez, Invited talk presented at the First Asia and Oceania Congress of Nuclear Medicine, Sydney, Australia, September 5-9, 1976.*

Application of High Energy Physics to Gamma Imaging and Three Dimensional Reconstructions, *V. Perez-Mendez, talk presented to the Electrical Engineering Department, University of Christchurch, New Zealand, September 1976*

High Efficiency Gamma Converters and Their Application in a MWPC Positron Camera, *D. Chu, K. C. Tam, V. Perez-Mendez, S. N. Kaplan (LBL), C. B. Lim, R. Hattner, L. Kaufman, D. Price, and S. Swann (UCSF)*

Honeycomb structured lead γ-ray converters have been developed and coupled with multiwire proportional chambers to produce a position-sensitive hybrid detector for spatial localization of MeV-range γ rays. Two such detectors operate in time-coincidence mode function as a large-area, large-solid-angle, positron camera. The sensitivity of the camera system is measured to be 1600 counts/min-μCi, corresponding to a detection efficiency of 5.5% per detector. Images of phantoms and clinical objects are obtained by using the back-projection reconstruction method, and the results demonstrate the tomographic capability of such a positron camera system.

A design analysis of the γ converter is presented; the detection efficiencies of converters of various dimensions are measured, and the results agree quite well with calculation. Further improvements in converter efficiency can be expected with modifications in the converter designs based on the concepts of enhanced surface area and uniformity of electron extraction field. The new converters under consideration are made of small-diameter high-lead-content lead glass tubing made conductive by hydrogen reduction treatment (Fig. 26,27) *(LBL-5516) (IAEA-SM-210/63), presented at the Symposium on Medical Radionuclide Imaging, Los Angeles, CA, October 25-29, 1976.*

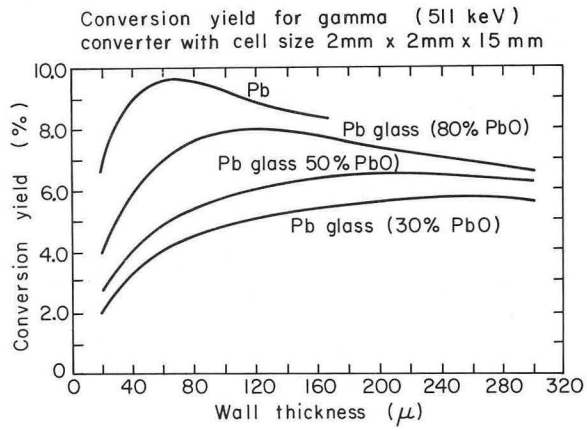


Fig. 26. Comparison of conversion yield of lead glass converter and lead converter. (XBL 7511-9524)

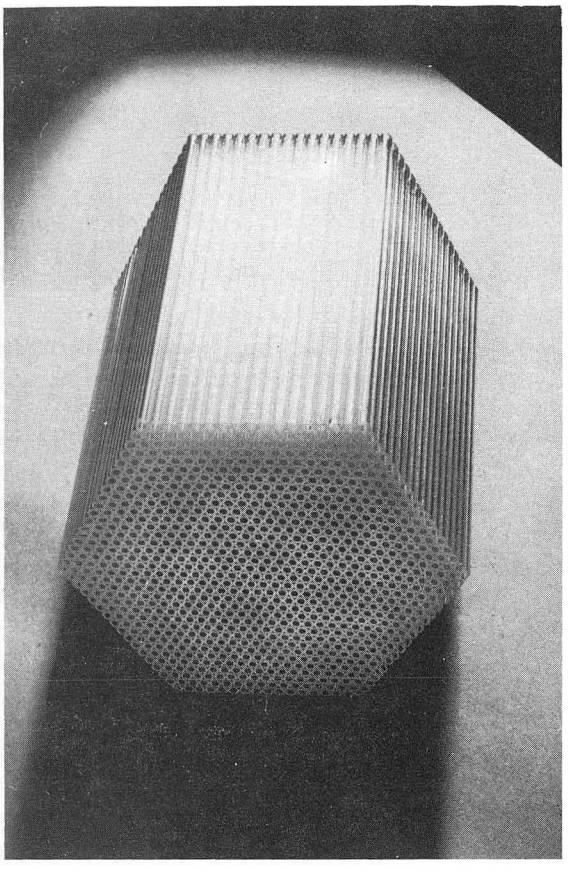


Fig. 27. Hexagonal array of lead glass tubing used in drift chamber for detecting gamma rays by showers produced in the lead glass. This type of lead glass converter can be used both for high-energy gamma rays (50 MeV to 10 GeV) as well as for low-energy gamma rays (0.1 to 2 MeV) by changing the hole and wall dimensions. (CBB 765-4207)

MISCELLANEOUS

Reducing Patient Exposure to Ionizing Radiation — Is It Really Necessary?,

R. H. Thomas (LBL) and D. D. Busick (SLAC)

The thesis that medical radiation exposures to the general population in the United States are excessive and that urgent steps need to be taken to reduce them is examined. At the present time, no evidence is found that deleterious effects result from radiation exposures at the level of a few rads or less. Nevertheless it is prudent that we assume the possibility of harmful effects of radiation exposure. However, because medical radiology is clearly so beneficial, and the harmful effects are problematical, it is doubtful whether the public should be alarmed by the suggestion of any crisis. A balancing of risks and benefits in the medical uses of radiology supports this latter contention. (Fig. 28). *(LBL-4868) Submitted to Am. Ind. Hyg. Assoc. J.*

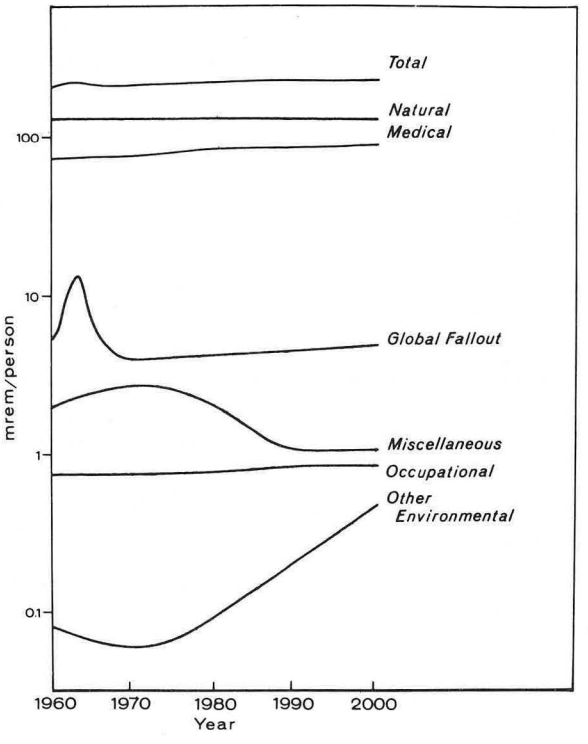


Fig. 28. A summary of the major sources of human radiation exposure predicted by the Environmental Protection Agency until 2000 A.D. (XBL 746-974)

ON NUCLEAR SCIENCE

Vector-Analyzing Power in the $^3He(\vec{d},{}^3He)np$ Reaction, *R. Roy, F. N. Rad, H. E. Conzett, and F. Seiler*

The polarization in nucleon-deuteron elastic scattering has received the major recent experimental and theoretical study, while similar effects in the breakup reaction have received little attention. The exact three-body calculations have shown very good agreement with the proton- and deuteron-analyzing powers in p-d elastic scattering; however, the breakup-channel calculations have been restricted to s-wave nucleon-nucleon forces and, thus, predict no polarizations. Recent investigations of both the $^1H(\vec{d},p)np$ and $^2H(\vec{p},p)np$ reactions show significant values of the vector-analyzing powers and, also, an unexpected and unexplained similarity in angular distributions to those in the elastic scattering. Since the spin structure of the deuteron breakup on ^3He and ^1H is the same, the non-dynamical properties of the two reactions are identical, and it is of interest to look for similar polarization effects in the $^3He(\vec{d},{}^3He)np$ reaction. We report on measurements of the vector-analyzing power A_y in this reaction at 30, 35, and 45 MeV. We find that A_y reaches substantial values and, again, it follows that of the elastic channel at angles beyond 90° c.m. *(LBL-4041)*

C. F. A. Schaeffer (editor) Alasia (I) Mission Archéologique d'Alasia, Vol. IV, Paris, 1971, 573 p., 37 plates, *M. Artzy*

A review of the book. *(LBL-5024) Submitted to J. Am. Oriental Soc.*

Final Resolution of the Element 104 Question, *A. Ghiorso*

A history of the long controversy between Dubna and Berkeley concerning the discovery of the element 104 is given. In particular we review the difficulties associated with the use of spontaneous fission in detecting new elements and contrast this method with the use of alpha particle activities to define the atomic number. Recent experiments at Dubna and Berkeley concerned with bombardments of ^{246}Cm with ^{18}O, ^{248}Cm with ^{16}O, and ^{249}Bk with ^{15}N are compared in detail. The categorical conclusion is drawn that the Dubna claim that the isotope $^{260}104$ decays by spontaneous fission with a half life of 0.1 second is not valid. *(LBL-5037) Presented at the 3rd International Conference on Nuclei Far From Stability, Cargese, Corsica, France, May 19-26, 1976*

Deformation Effects and Secondary Fission in the Deep Inelastic Reaction Au + 979-MeV Xe, *P. Russo, B. Cauvin, P. Glässel, R. C. Jared, R. P. Schmitt, G. J. Wozniak, and L. G. Moretto*

The reaction between Au and 979-MeV Xe projectiles has been studied with a $\Delta E - E$ counter telescope. Kinetic energy spectra, differential cross sections and angular distributions are presented for individual elements resolved up to and above $Z = 60$. The kinetic energy spectra show two distinct components. One of these is the binary deep inelastic product. The other is a contribution from secondary fission of the binary target-like product. The experimental evidence from the deep inelastic events indicates large fragment deformations. *(LBL-5050) Submitted to Phys. Rev. Lett.*

Indirect Transitions in Two-Nucleon Transfer Reactions Between Heavy Ions, *N. K. Glendenning and G. Wolschin*

Two-nucleon transfer reactions between heavy ions are investigated in the coupled channel framework. Indirect transitions through the collective $^{18}O(2^+)$ state in (^{16}O, ^{18}O) reactions, or their inverse, can modify considerably the direct ground-state transfer cross sections. Characteristic features of the direct process, the indirect process, and their interference are discussed. Special emphasis is put on the consistency of the parameters with the experimental elastic and inelastic scattering data for the channels involved in the reaction calculations. For the targets nickel and tin, a comparison with the data of various experimental groups is presented (Fig. 29). *(LBL-5052) Submitted to Nucl. Phys. A.*

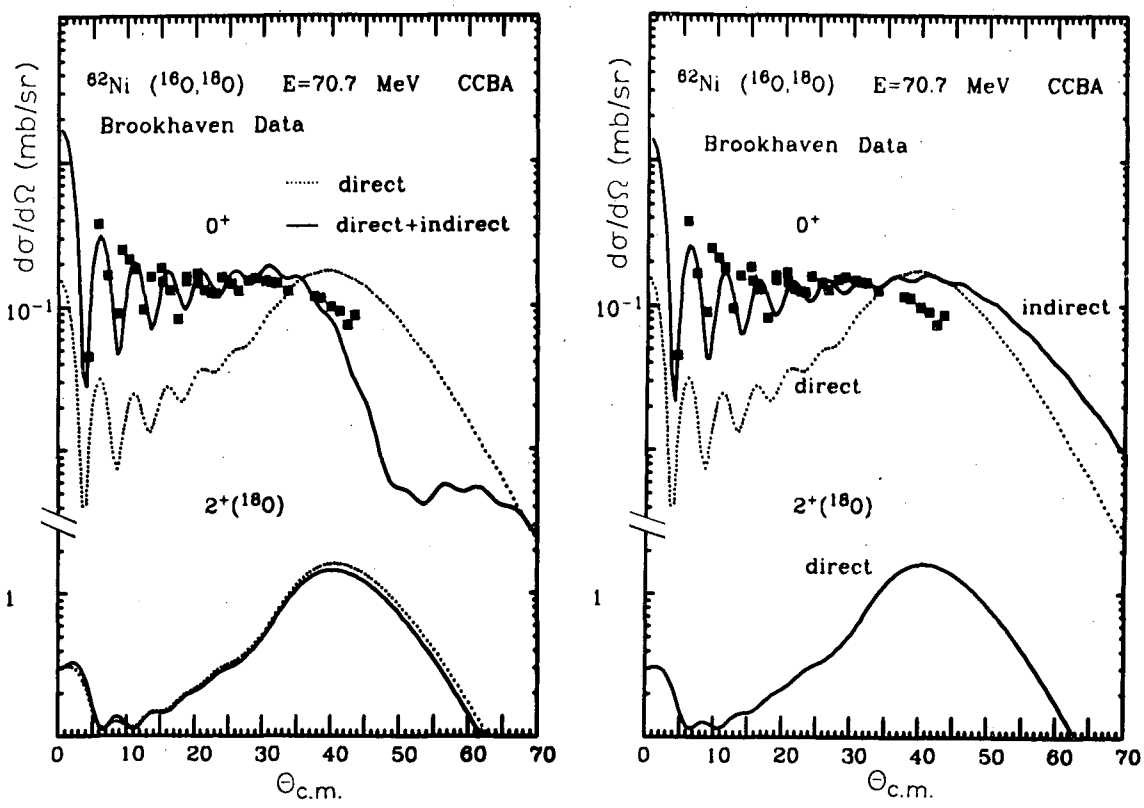


Fig. 29. (a) Solid lines are differential cross sections from a coupled calculation where both 0^+ and 2^+ states of oxygen are fed, via direct and indirect transfer, through the other state. Dotted curves represent direct transfer, with the inelastic coupling included. A common normalizing factor 1.6 is used. The ground-state data are for the time-reversed reaction at the energy of E_L = 65 MeV. (b) The bell-shaped direct transition (dotted curve) leading to the ground state of oxygen and nickel is compared with the forward-peaked indirect transition through the collective $^{18}O(2+)$ state (solid curve). The forward-angle cross section is dominated by the second-order process. (XBL 7512-9887)

Experimental Evidence and Physical Implications of the Time Evolution Along the Mass Asymmetry Mode in Heavy-Ion Reactions, *L. G. Moretto and R. Schmitt*

The complex experimental features associated with the mass or charge distributions, and with the angular distributions as a function of fragment mass or charge, are interpreted as evidence of an intermediate structure, or intermediate complex, evolving in time along the mass asymmetry mode. Strong circumstantial evidence suggests that this time evolution is diffusive in nature and can be described in terms of the Master Equation or the Fokker-Planck Equation. The experimental evidence of broad mass distributions for large ratios E/B, where E is the center of mass energy and B is the interaction barrier, and narrow mass distributions peaked at the projectile and target mass for small ratios E/B, is interpreted as due to an increasing lifetime of the complex with energy. For short lifetimes, the system has little time to evolve in mass asymmetry and gives rise to rather narrow distributions centered about the target and projectile mass. For long lifetimes the system undergoes extensive relaxation in mass asymmetry and gives rise to very broad mass distributions. Similarly the angular distributions seem to evolve from side-peaked to forward-peaked with increasing E/B. This is interpreted as due to a transition from a short lifetime-slow angular velocity regime, which does not allow for orbiting beyond 0°, to a long lifetime-large angular velocity regime, which produces orbiting past 0°. The evolution from side peaking to forward peaking in the same reaction as one moves away in Z from the projectile is interpreted as due to the time lag introduced by diffusion in the population of fragments farther removed in Z from the projectile. The variation of charge and angular distribution with the fragment kinetic energy allows one to connect the energy relaxation to the mass asymmetry relaxation. Theoretical calculations based on diffusion models allow one to fit mass and angular distributions as well as to extract transition probabilities and Fokker-Planck coefficients. The reliability of various methods of analysis is discussed. *(LBL-5057) Invited paper to the European Conference on Nuclear Physics with Heavy Ions, Caen, France, September 6-10, 1976*

Polarization of Single-Particle States in Heavy-Ion-Induced Nuclear Reactions Within the Two-Center Shell Model, *K. Pruess*

In "slow" nucleus-nucleus collisions the single particle states will adjust continuously to an instantaneous two-center potential. Transfer reactions will occur between polarized rather than between asymptotic states.

In order to employ two-center states in reaction calculations, an expansion in terms of asymptotic states with good angular momentum is required. This expansion is formulated, and equations for the expansion coefficients are derived. Model calculations for the system $^{40}Ca + ^{16}O$ indicate that the polarization of unoccupied proton states in ^{40}Ca is strong, while it is very weak for the tightly bound $1p_{1/2}^-$ proton in ^{16}O. The dependence of the polarization effect on several relevant parameters is discussed. *(LBL-5066) Submitted to Nucl. Phys.*

Similarity of Cross Sections for Peripheral Collisions at 20 MeV/A and 2.1 GeV/A, *M. Buenerd, C. K. Gelbke, B. G. Harvey, D. L. Hendrie, J. Mahoney, A. Menchaca-Rocha, C. Olmer, and D. K. Scott*

Peripheral collisions between ^{16}O and ^{208}Pb are investigated at a laboratory energy of 315 MeV. The relative cross sections are remarkably similar to published cross sections measured at 33.6 GeV laboratory energy. They are compared with statistical models involving di-nuclear systems and projectile fragmentation. *(LBL-5067) Phys. Rev. Lett. 37, 1191 (1976)*

Threshold Pion Production in Heavy-Ion Collisions, *G. F. Bertsch*

Pion production from heavy-ion collisions is calculated in the independent-particle model, by using nucleon-nucleon cross section data as input information. The assumption is made that only the first collision of a nucleon pair can create a pion; also all collective effects are neglected. For the representative case of ^{16}O bombardment of ^{238}U at 250 MeV/nucleon, one out of seven inelastic collisions should produce a pion. One-third of these pions should be able to escape to the outside. The pion spectrum peaks at 20 MeV with an average energy of 50 MeV, viewed in the nucleon-nucleon center-of-mass frame (Fig. 30). *(LBL-5070) Submitted to Phys. Rev. C.*

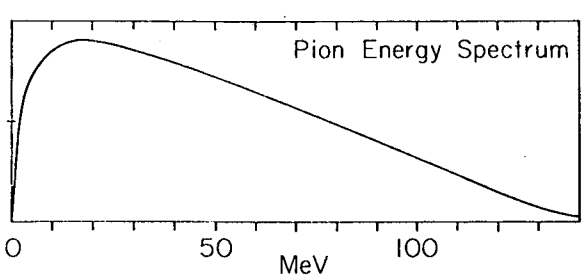


Fig. 30. The energy spectrum of pions produced by nucleon-nucleon collisions in the double Fermi sphere with $p = 2.55p_F$. The reference frame is moving with velocity = 0.34c.

Comparison of the Coupled Reaction Channels and DWBA Series Approaches to Sequential Transfer Processes, *L. A. Charlton*

The coupled reaction-channels and DWBA-series approaches to sequential transfer reactions are formally compared. It is found that coupled-reaction-channels calculations effectively over-predict higher order terms relative to the DWBA series. *(LBL-5073) Submitted to Phys. Rev. Lett.*

Generalized Particle-Core Coupling, *G. J. Mathews (U. of Maryland and LBL) and J. D. Immele (LLL)*

A general particle-core coupling scheme is proposed for the description of simultaneous shape and pairing correlations in odd-A nuclei of arbitrary deformation. This coupling scheme, which is similar to intermediate coupling in spherical vibrators, exactly reproduces the Coriolis decoupled bands and triaxial-rotor-plus-particle structure of deformed nuclei. *(LBL-5076) Submitted to Phys. Lett.*

Monopole Excitation of ^4He in α-Particle Scattering from ^{12}C, ^{13}C, and ^{16}O, *R. Jahn, D. P. Stahel, G. J. Wozniak, J. Cerny (LBL); and H. P. Morsch (Michigan State U.)*

The excitation of the 0^+ state in ^4He at 20.1 MeV has been studied in α-scattering from ^{12}C, ^{13}C, and ^{16}O at E_α = 65 MeV by measuring the decay $\alpha^* \rightarrow p + t$ with a coincidence method. DWBA calculations of this monopole transition that use both microscopic and collective model

transition densities are presented. *(LBL-5079) Submitted to Phys. Lett.*

Central Collisions of Relativistic Heavy Ions, *H. H. Gutbrod*

Data are presented for double differential cross sections which have been measured for high energy p, d, t, ^{3}He, and ^{4}He particles emitted from uranium targets irradiated with ^{20}Ne ions at 250, 400, and 2100 MeV/nucleon and ^{4}He ions at 400 MeV/nucleon. In the analysis, by using the shape and yield of the proton energy spectra we can deduce the shape and yield of the d, t, ^{3}He, and ^{4}He energy spectra at all measured angles for all incident projectile energies, assuming that they are formed by coalescence of cascade nucleons. This is based on a model analogous to that of Butler and Pearson, and Schwarzschild and Zupančič. Finally and most important, we find that the overall features of the proton inclusive spectra are fit without any adjustable parameter by a proposed nuclear fireball model. In this model the nucleons that are mutually swept out from the target and projectile form a hot quasi-equilibrated fireball, which decays as an ideal gas. *(LBL-5081) Presented at the European Conference on Nuclear Physics with Heavy Ions, Caen, France, September 6-10, 1976*

Trends of Isotope Yields Observed in Reactions Induced by ^{16}O Ions of 140, 315, and 33 600 MeV, *C. K. Gelbke, M. Buenerd, D. L. Hendrie, J. Mahoney, M. C. Mermaz, C. Olmer, and D. K. Scott*

Isotope yields from reactions induced by ^{16}O ions of 140 and 315 MeV on ^{94}Zr, ^{197}Au, ^{208}Pb, and ^{232}Th targets are measured and compared with published data at 33.6 GeV. The previously reported similarity of cross sections at 315 MeV and 33.6 GeV is augmented by the fact that the relative isotope yields are essentially target-independent at 315 MeV (as has been established at 33.6 GeV). Significant differences are observed between cross sections at 140 and 315 MeV. *(LBL-5094) To be published in Phys. Lett. B.*

ON PHYSICS, COMPUTER SCIENCE AND MATHEMATICS

High-Order Fast Laplace Solvers for the Dirichlet Problem on General Regions, *V. Pereyra (CalTech and LBL), W. Proskurowski (Royal Inst. Technol., Stockholm), and O. Widlund (New York U.)*

Highly accurate finite difference schemes are developed for Laplace's equation with the Dirichlet boundary condition on general bounded regions in R^n. A second-order accurate scheme is combined with a deferred correction or Richardson extrapolation method to increase the accuracy. The Dirichlet condition is approximated by a method suggested by Heinz-Otto Kreiss. A convergence proof of his (previously not published) is given, which shows that, for the interval size h, one of the methods has an accuracy of at least $O(h^{5.5})$ in L_2. The linear systems of algebraic equations are solved by a capacitance matrix method. The results of our numerical experiments show that highly accurate solutions are obtained with only a slight additional use of computer time when compared to the results obtained by second-order accurate methods. *(LBL-4244)*

More on the Pendent Water Drop, *P. Concus and R. Finn (LBL-4649 Supp.)*

Determination of the $K_L^0 \to \pi^- \mu^+ \nu_\mu$ Form Factor $\xi(q^2)$ by Muon Polarization Measurements, *A. R. Clark, R. C. Field, W. R. Holley, R. P. Johnson, L. T. Kerth, R. C. Sah, and G. Shen*

The polarization of the muon in the decay $K_L^0 \to \pi^- \mu^+ \nu_\mu$ ($K_{\mu 3}$) was measured as a function of q^2, and the four-momentum was transferred to the lepton pair by using a precession polarimeter with a double-armed spectrometer at the Bevatron. A sample of 207,260 events collected with a vertical precession field was used to determine the $K_{\mu 3}$ form factor $\xi(q^2)$, assuming $\mathrm{Im}\xi(q^2) = 0.0$. If one parameterizes the q^2 dependence of of ξ by $\xi(q^2) = \xi(0) + \Lambda q^2/m_\pi^2$, then $\xi(0) = 0.178 \pm 0.105 - 3.80\Lambda$. A sample of 55,604 events collected with a horizontal precession field was used to determine $\mathrm{Im}\xi(q^2)$. If one assumes that $\mathrm{Im}\xi(q^2)$ has no dependence on q^2, then $\mathrm{Im}\xi(0) = 0.35 \pm 0.30 + 0.21\ \mathrm{Re}\xi(0)$. (Fig. 31). *(LBL-4802 Rev.) Submitted to Phys. Rev. D.*

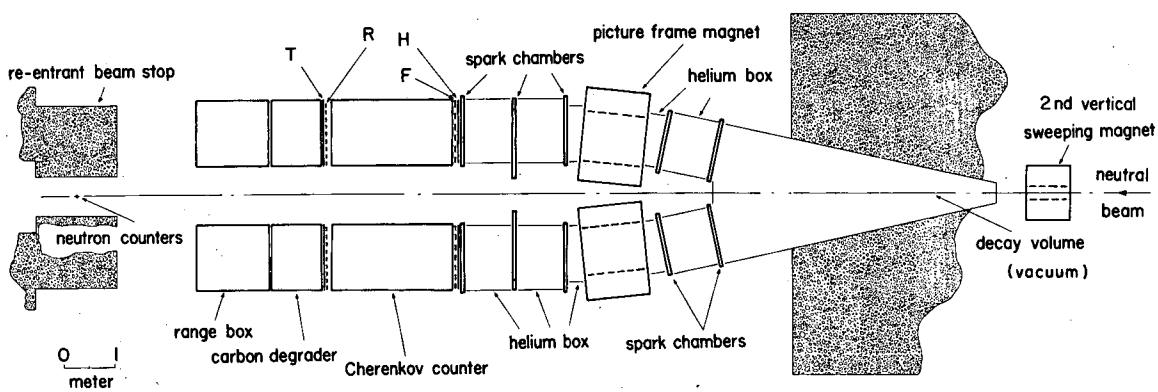


Fig. 31. Plan view of the apparatus. T are the timing counters, H are the horizontal hodoscopes, F and R are the front and rear vertical hodoscopes. (XBL 702-315)

The Pomeron-f Identity and Hadronic Total Cross Sections at Moderate Energy, *P. R. Stevens (CalTech), G. F. Chew (LBL), and C. Rosenzweig (U. of Pittsburgh)*

The topological expansion of the S-matrix implies that the Pomeron and f are the same Regge trajectory. We confront this hypothesis with data by successfully fitting σ_{tot} at moderate energies in a Regge model containing only one prominent vacuum trajectory, plus the ρ and ω (Fig. 32). Couplings and intercepts obey the constraints imposed by the topological expansion. The cylinder coupling is found to be 0.16. Existing data on $\pi\pi$ total cross sections are studied by using finite energy sum rules.

Table of Parameters

(Asterisk denotes a fitted parameter.)

(a) Intercepts

α_0	α_3	α_f	α_ω	$\alpha_{f'}$	α_ϕ
0.58*	0.23*	0.96	0.41	0.31	-0.06

(b) Coupling constants

g	γ_N^f	γ_N^ω	γ_N^ρ	k
1.49*	4.94*	5.89*	0.785*	0.152*

(c) Mixing angles

θ^+	θ^-
20.3°	-33.7°

(d) Scale factor

$s_0 = 0.376\ \mathrm{GeV}^2$ *

The Pomeron-f identity is consistent with the analysis. The conventional picture is not (see Fig. 33). *(LBL-4825; CALT-68-541) Submitted to Nucl. Phys.*

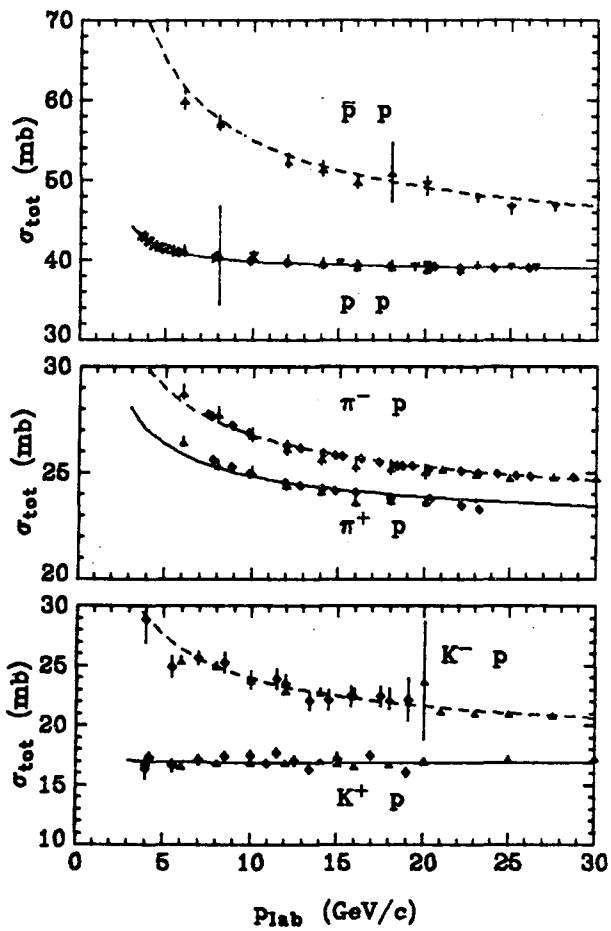


Fig. 32. The model fit, with the parameters in the Table to moderate energy pp, πp, and Kp total cross sections. The data are from reference 10.

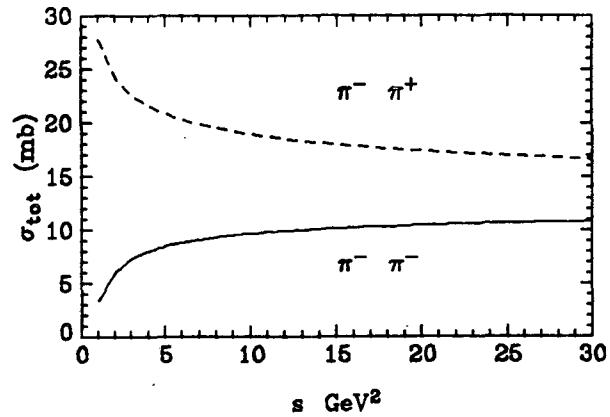


Fig. 33. A prediction, based on the model of reference 1 and the parameters of the Table, for the $\pi\pi$ total cross section.

Proceedings of the Berkeley Workshop on Distributed Data Management and Computer Networks, Lawrence Berkeley Laboratory, 25-26 May 1976

The Berkeley Workshop was organized by members of the Computer Science and Applied Mathematics Department of LBL under the sponsorship of the Energy Research and Development Administration (ERDA). Workshop participants included representatives from ERDA, the national research laboratories, universities, research institutes, and industry. There were approximately 150 registered participants, 44 of whom were speakers. These proceedings contain short position or idea papers presented by the invited speakers. In some cases only abstracts are available because the presented papers are to be or have been published elsewhere. *(LBL-5315)*

Neutrino Interactions with $e^+\mu^-$ and Multiple K^0's, *Berkeley (LBL), CERN, Hawaii, Wisconsin collaboration*

A scan for directly produced positrons in 5,000 neutrino interactions in the neon (21%)-hydrogen-filled bubble chamber at Fermilab has yielded 15 events, 9 of which have μ^-'s identified in the external muon identifer. On correcting for detection efficiency one obtains $\sigma(e^+\mu^-)/\sigma(\mu^-) \sim 1 \times 10^{-2}$ for $E_{e+} > 0.8$ GeV and $E_\nu > 5$ GeV. The kaon multiplicity is unexpectedly high. Eleven of the events have one or more Vees and three have two or more. Among the 11 events are two clear Λ's and two ambiguous K^0/Λ. There are four events with identifiable charged kaons. A sixteenth e^+ event ((9)) is a definite $\bar{\nu}_e$. From this information one concludes that the kaon multiplicity is 2 ± 0.6 K^0's and 2 ± 1 $K^\pm$'s per interaction. From the observation $\langle p_{\mu^-}\rangle/\langle p_{e^+}\rangle = 6.6$, one concludes that the e^+'s are probably not uniquely from heavy lepton decay. From a variety of analyses involving the e^+ and/or K^0's one learns that the mass of the hadron (C) that produces the e^+'s is greater than 1.6 GeV. By determining the fraction of normal charged current (CC) events that have $K_S^0 \to \pi^+\pi^-$, we are able to compare this fraction with the fraction of CC events that have $e^+\mu^-$ ($K_S^0 \to \pi^+\pi^-$) to establish a conservative lower limit to the semileptonic branching ratio,

$$\frac{C \to (e^+ \text{ and } \mu^+)\nu}{C \to \text{all}} > 0.33\ (1 \pm .42),$$

provided that the same number of K_S^0 exists in the nonleptonic decays as in the semileptonic ones, and that the phase space for μ^+ and e^+ are nearly equal. There is no compelling evidence for an energy threshold, and there is a hint of some neutral current events among the e^+ events. *(LBL-5319) Presented at the XVIII International Conference on High Energy Physics, Tbilisi (USSR) 15-21 July 1976 by M. L. Stevenson*

ERDA Interlaboratory Working Group for Data Exchange (IWGDE); Annual Report for 1976 Fiscal Year 1976, *D. Merrill and D. Austin, Editors*

In this report the activities of the ERDA IWGDE (Interlaboratory Working Group for Data Exchange) during fiscal year 1976 are discussed. The IWGDE was created in response to an evident need for increased sharing of resources among ERDA installations. During fiscal year 1976 it was supported through funds allocated to the Energy Analysis and Assessment programs of seven multipurpose ERDA national laboratories. Principal accomplishments included the interlaboratory exchange of socioeconomic, environmental, demographic, and energy-related data bases; liaison development through interlaboratory meetings; creation of a national index of energy-related models and data bases; and definition and partial implementation of a computer-independent standard for exchange of data via magnetic tape. *(LBL-5329)*

Correlation Experiments and the Nonvalidity of Ordinary Ideas About the Physical World, *H. P. Stapp*

It is shown that the predictions of quantum theory in certain correlation experiments are incompatible with ordinary ideas about the physical world. In particular the following theorem is proved: Consider situations involving two experimenters, one working in each of two space-like separated regions. Suppose each is apparently free to choose to perform in his region one of two alternative experiments. Assume that the results that would be obtained in each of the alternative cases conform to the statistical predictions of quantum theory. Then the experimental

results in one region must, in some cases, depend on which experiment is performed in the space-like separated region. This theorem is akin to a theorem of J. S. Bell. However, Bell's theorem refers to hidden-variables, which may not exist in nature, whereas the present theorem deals directly with connections between the (macroscopic) results of possible measurements and physical variables subject to the control of experimenters. *(LBL-5333)*

Rising Total Cross Sections and the Flavoring of the Pomeron, *J. W. Dash (LBL) and S. T. Jones (U. of Alabama)*

The relationship of the non-diffractive renormalization of the bare Pomeron via $K\bar{K}$ and $B\bar{B}$ production — or its "flavoring" by λ quark loops and di-quark loops — and the shape of the NN total cross section are studied in some detail. The "unflavored" bare Pomeron $\hat{P}$ generated by nonstrange quark loops with intercept $\hat{\alpha} = 0.85$ is nondiffractively renormalized into the "flavored" (Gribov) bare Pomeron P with intercept α above one ($\alpha = 1.06$ here). We utilize inclusive data on $K\bar{K}$ and $B\bar{B}$ production as well as inelastic diffraction to constrain parameters, and we fit the combination $1/2(\sigma_{pp} + \sigma_{p\bar{p}})$ from $s = 10$ GeV^2 through ISR energies, including the new Fermilab data, to high accuracy. No pronounced long wavelength oscillations are observed. We suggest that these data favor the Chew-Rosenzweig realization of the topological expansion over that of Harari-Freund. We show that our scheme is consistent with the rising behavior of $2\sigma_{KN} - \sigma_{\pi N}$. *(LBL-5337) Submitted to Phys. Lett. B.*

Topological Expansion and Cutkosky Rules, *F. J. Capra*

An unambiguous way of cutting duality diagrams according to the Cutkosky rules is established which permits a topological classification of the terms appearing on the right-hand side of the unitarity equation. *(LBL-5338)*

Observed Isotropy in Pionic Argon X-Ray Angular Distribution, *G. K. Lum, C. E. Wiegand (LBL); and G. L. Godfrey (SLAC)*

A measurement of the angular distribution of x rays from pionic Ar indicated that the emission was isotropic. Our results show $\alpha = 0.007 \pm 0.089$ where α is defined by $P(\theta) = 1 + (\alpha/2)\sin^2\theta$ and θ is the polar angle with respect to the incident pion beam (see Fig. 34). *(LBL-5345) Submitted to Phys. Lett.*

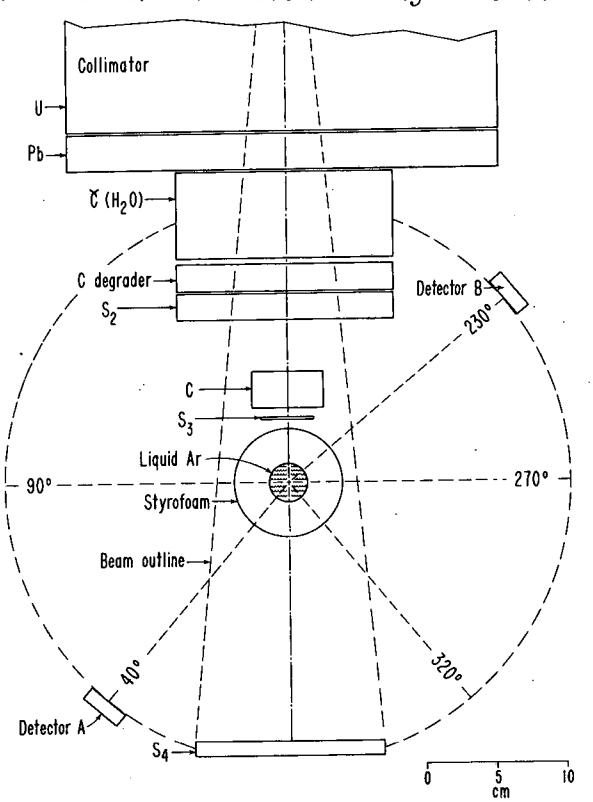


Fig. 34. Schematic plan view of the apparatus. Scintillation counter S_1 was 4.9 m upstream at the first mass separation slit. S_1, S_2 were used in a time-of-flight circuit. S_3 was 0.16 cm thick and defined the beam incident on the target. $\check{C}$ and S_4 were operated in anticoincidence. (XBL 768-3244)

μe Events in Electron-Positron Annihilation with Longitudinally Polarized Beams, *R. Simard and M. Suzuki*

Muon-electron production processes are examined in the case where one of electron-positron beams is longitudinally polarized. A special emphasis is put on the asymmetry in the angular distribution of muon (or electron) emission to reveal the structure of weak interactions of possible heavy leptons. The angular asymmetry will easily distinguish between V - A and V + A for the weak current of heavy leptons. *(LBL-5356) Submitted to Phys. Rev. D.*

$\bar{p}p$ Charge Exchange Scattering Below 1.1 GeV/c, *R. D. Tripp*

Some possible experiments are discussed by which the quantum numbers of the S(1932) meson could be clarified by using the reaction $\bar{p}p \rightarrow \bar{n}n$. *(LBL-5361) Presented at the 3rd European Symposium on Antinucleon-Nucleon Interactions, Stockholm, Sweden, July 9-13, 1976*

Tests on Large Diameter Superconducting Solenoids Designed for Colliding Beam Accelerators, *P. H. Eberhard, M. A. Green, W. B. Michael, J. D. Taylor, and W. A. Wenzel*

Two, prototype, large-diameter, thin-coil solenoids, which use the mechanical structure to moderate quenches, have been built and systematically tested. The solenoids are cooled by two-phase helium flowing in tubes that form a part of the coil structure (Fig. 35). The coils have been tested by inducing a series of quenches at various currents. The results of these tests showed that

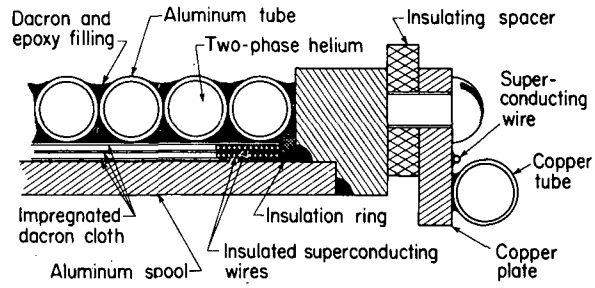


Fig. 35. A cross section of the thin solenoid.

superconducting magnets can be cooled by using a two-phase helium tubular cooling system connected to a refrigerator. Electrically the two magnets behaved as expected. The current was shifted from the coil to the bore tube during a quench. Thus, the magnets can be safely quenched even when the superconductor matrix current density is greater than 10^9 Am^{-2} and the magnet stored energy is in excess of 300 kJ. *(LBL-5364) Presented at the Applied Superconductivity Conference, Stanford University, Stanford, CA, August 17-20, 1976*

Use of Dipole Sum Rules to Estimate Upper and Lower Bounds for Radiative and Total Widths of χ(3414), χ(3508), and χ(3552), *J. D. Jackson*

Upper and lower bounds on the widths for $\chi_J \rightarrow \gamma\psi(3095)$ can be estimated by assuming E-1 transitions and approximate Russell-Saunders coupling for the $c\bar{c}$ system. Experimental widths for $\psi(3684) \rightarrow \gamma\chi_J$ make the lower bound more restrictive and give radiative widths of 160 → 240, 230 → 400, 280 → 480 KeV for 3414-, 3508-, and 3552-MeV states, respectively. Cascade branching ratio data permit estimating the total widths to be > 1.6, 0.3 - 1.5, 0.6 - 4 MeV, respectively (Fig. 36). *(LBL-5369) Submitted to Phys. Rev. Lett.*

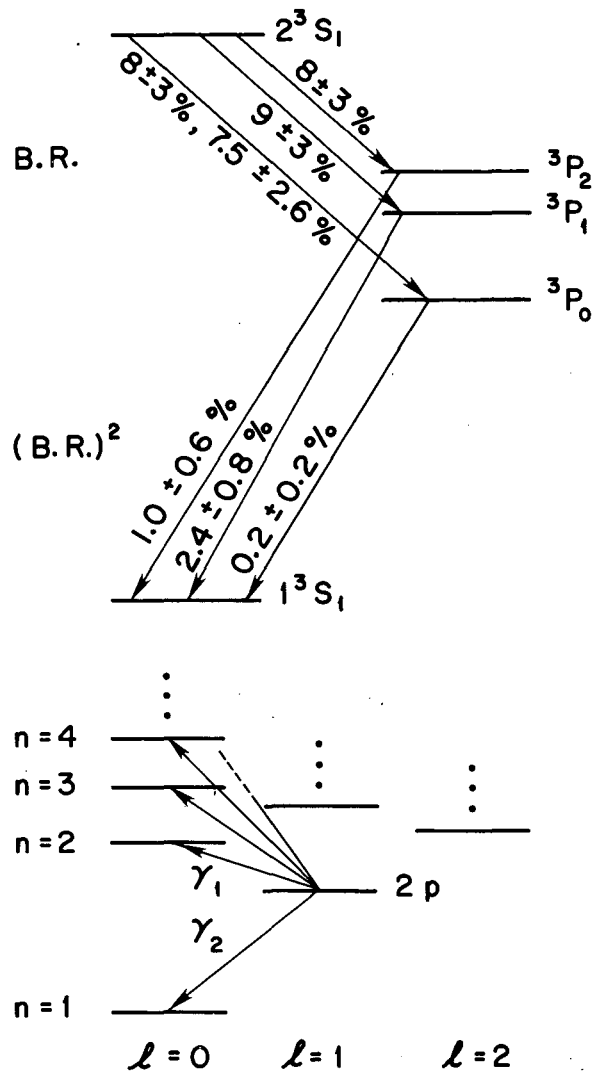


Fig. 36 (top) Observed radiative transitions through the X states. For the first transitions the numbers are branching ratios (ref. 7; for the J = 0 final state the second number is from ref. 8). For the second step the numbers are the products of the branching ratios (refs. 8,10).

(bottom) Schematic diagram showing the transitions involved in the second sum rule, used to set lower limits on the radiative widths. (XBL 768-3339)

X Spectroscopy and Newer Particles, *F. Pierre*

Two recent results from the SPEAR Magnetic detector are covered. First a study of $\Psi' \to \gamma + X$, $\gamma\gamma\Psi$, γ^+ hadrons is presented; four intermediate states are seen, branching fractions and production angular distribution are given, which agree with the predictions of the charm quark model.

In the second part, evidence is presented for two narrow new states (charges 0 and 1) decaying to a kaon and pions. Structures are now seen in the recoil mass spectra. The production and decay characteristics support the assignment of those states as the low-lying non-strange charmed mesons. *(LBL-5372) Presented as the invited talk at the XVIIIth International Conference on High Energy Physics, Tbilisi, USSR, July 15-21, 1976*

The Sign of the Unnatural-Parity Cylinder, *J. Millan*

We explain the sign difference between the natural-parity and the unnatural-parity cylinder by using a Reggeon-loop model proposed previously by Chew and Rosenzweig. *(LBL-5374) Submitted to Phys. Rev. D. (Comments and Addenda)*

Production of Charmed Meson Pairs in Electron-Positron Annihilation, *M. Suzuki (LBL) and W. W. Wada (Ohio State U.)*

Production of charmed meson pairs of $J^P = 0^-$ and 1^- is examined near the threshold. Production cross sections are parametrized by a quark model of a broken SU(8) symmetry. The charmed hadron production is dominated by

$(0^-,1^-)$ pairs, and $D^* D^*$ production comes out to be much too small to reproduce the higher peak in the recoil mass spectrum against $D^\circ(\bar{D}^\circ)$ through reflection. We point out a few experimental measurements that will clarify the origin of the higher peak of the recoil mass spectrum. *(LBL-5377) Submitted to Phys. Rev. D.*

Polarization in π^-p Elastic Scattering at 1180, 1250 and 1360 MeV/c,

E. Barrelet, O. Chamberlain, W. Gorn, S. Shannon, G. Shapiro, and H. Steiner

We have measured the polarization parameter in π^-p elastic scattering at laboratory momenta of 1180, 1250, and 1360 MeV/c in the angular interval $65° < \theta_{cm} < 115°$. The results were used to show that the polarized target used in these (and other similar) experiments was uniformly polarized. These measurements were also used to resolve preexisting experimental discrepancies in the determination of the polarization parameter, and to clarify the behavior of scattering amplitudes in this energy range. We show that local measurements of this type are important in resolving discrete ambiguities affecting the energy continuation of the amplitudes. An important by-product of this experiment is the development of a fast method of reconstructing particle trajectories and fitting the elastic events, which could have a significant impact for future high statistics experiments. (Fig. 37). *(LBL-5386) Submitted to Phys. Rev. D.*

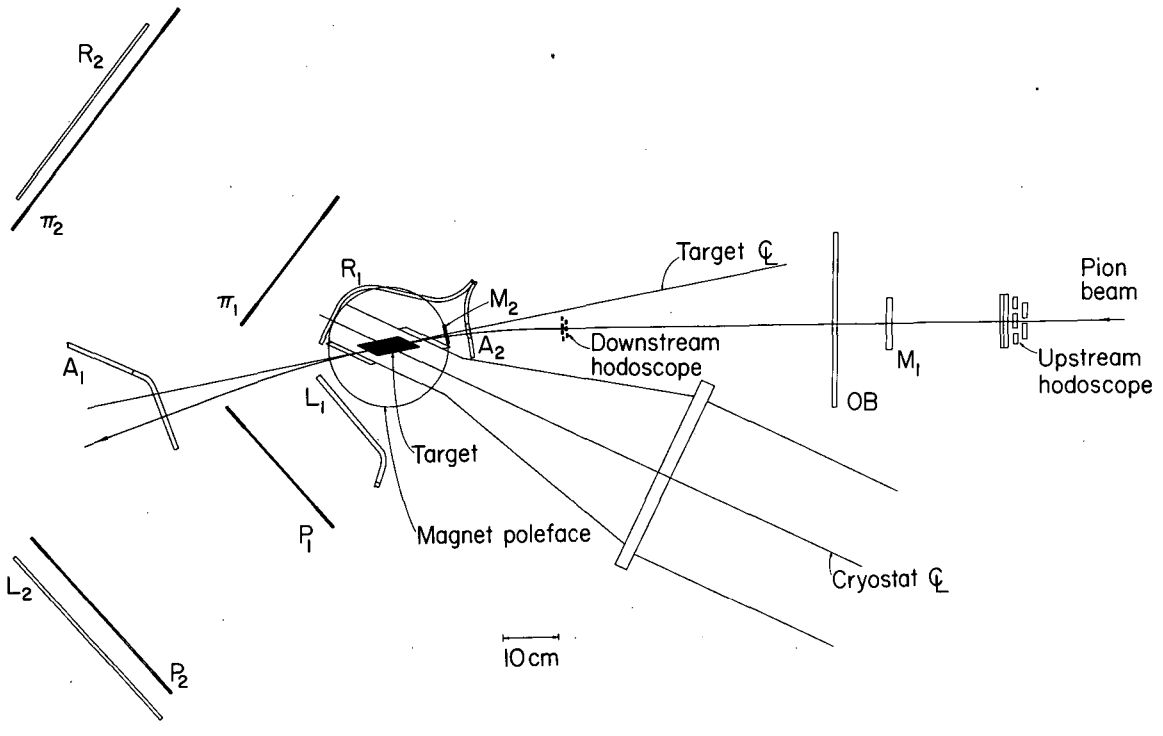


Fig. 37. Plan view of experimental arrangement showing the polarized target and the detectors. π_1, π_2, P_1, and P_2 are multiwire proportional chambers; all other detectors are scintillation counters. (XBL 758-1900)

Lectures on the New Particles, *J. D. Jackson*

As a result of the phenomenal success of the magnetic detector at SPEAR, a rich spectrum of states is being unfolded, which implies a rich and complicated spectroscopy — the main subject of these lectures. The lecture notes represent an attempt to discuss the systematics of the new particles and their spectroscopy in a simple way, understandable to relative beginners in the field and to the experimenters who are so busy making discoveries that they have no time to digest the indigestible theoretical papers that are triggered by each new revelation. The coverage is uneven and incomplete because of the division of subject matter among the lecturers. *(LBL-5500) To be published in the Proceedings of the Summer Institute on Particle Physics, SLAC, Stanford, CA, August 2-13, 1976*

New Data on $K^-p \to \bar{K}^0n$ and a $\bar{K}N$ Partial Wave Analysis Below 1.2 GeV/c, *R. D. Tripp*

Results are reported on a high precision measurement in 10 MeV/c steps of the total cross section for the reaction $K^-p \to \bar{K}^0n$ between 515 and 1065 MeV/c. These results are incorporated with other experiments to make a partial wave analysis of the $\bar{K}N$ channel from 365 to 1200 MeV/c. Good evidence for the P01 $\Lambda(1677)$ with a width of 25 MeV is found in this channel. *(LBL-5502) Presented at the Topical Conference on Baryon Resonances, Oxford, England, July 6-9, 1976*

The Outlook for Baryon Spectroscopy, *R. D. Tripp*

New generation experiments, with their greatly enhanced statistics are recalled and the direction these experiments are taking in the immediate future is explored. Some problems and deficiencies that can be resolved with contemporary techniques are outlined. *(LBL-5508) Presented at the Oxford Conference on Baryon Resonances, Oxford, England, July 6-9, 1976*

Radioisotope Dating with a Cyclotron, *R. A. Muller*

The sensitivity of radioisotope dating is improved by counting atoms rather than decays. By considering radioisotope dating as a problem in trace-element detection, and by using the cyclotron as a high-energy mass-spectrometer for this purpose, we show that one can greatly increase the maximum age that can be dated while simultaneously reducing the size of the sample required. The cyclotron can be used to detect atoms or molecules which are present at the 10^{-18} level or greater. For ^{10}Be dating one can go back 34 million years with a sample of rock 10 cm^3 in volume; for ^{14}C dating: 88 thousand years with a 25 mg carbon sample; for ^{53}Mn dating: 35 million years with a 10 cm^3 rock sample; for tritium dating: 153 years with a half-liter water sample. The feasibility of the technique has been demonstrated experimentally by measuring the tritium/deuterium ratio in a sample 24 years old. For samples many half-lives old, the fractional error $\delta t/t$ in the age is small even if there are large uncertainties in the rates of production or of deposition of the isotopes. *(LBL-5510) Submitted to Science.*

An IBM 360/370 Channel for CDC Computers, *R. L. Fink*

The Lawrence Berkeley Laboratory has developed hardware and software subsystems to allow the use of IBM plug-compatible peripherals on the CDC 6400, 6600, and 7600 systems installed at the LBL Computer Center.

This has given the ability to replace unreliable CDC tape drives and controllers and overpriced CDC disk drives and controllers with their IBM plug-compatible versions.

Most important of all, LBL is now able to procure peripherals in an open and competitive marketplace, taking advantage of the best cost and performance benefits available in the computer industry today. *(LBL-5514) Invited talk presented at the Technical Session of the AESOP XV Conference, Denver, Colorado, September 28-30, 1976*

Radiative Decays of $\psi(3684)$, *J. S. Whitaker*

Results of studies of radiative decays of $\psi(3684)$ are presented. The data for this work were obtained with the Magnetic Detector at the electron-positron storage ring SPEAR. These results indicate the existence of three states χ, with masses 3415, 3500, and 3550 MeV, produced in radiative decays of ψ'. There is evidence for a fourth state with mass either 3340 or 3455 MeV. From study of the $\psi(3684)$ inclusive photon spectrum, the branching fraction for $\psi(3684) \rightarrow \gamma\chi(3415)$ has been determined to be $7.5 \pm 2.6\%$. Branching fraction upper limits of 1 - 4% at the 90% confidence level have been obtained for monochromatic photon production above 250 MeV by ψ or ψ'. *(LBL-5518) Ph.D. Thesis*

μSR Newsletter No. 10, 13 September 1976, *edited by K. M. Crowe (LBL), A. M. Portis (UC Berkeley), and T. Yamazaki (U. Tokyo)*

Contents: The Depolarization and Diffusion of μ^+ in Chromium, and The Muon Depolarization Rate in β-Palladium Hydride. *(UCID-3857)*

On the Rise Height of a Capillary Surface, *P. Concus (LBL) and R. Finn (Stanford)*

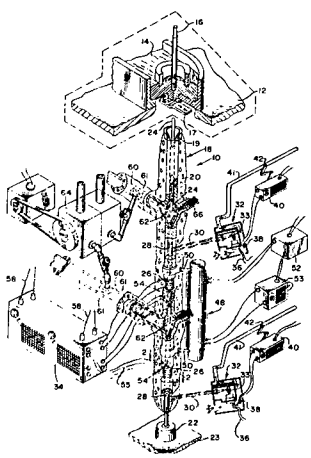
We address the question: does the rise height of liquid in a small capillary tube, when dipped vertically into an infinite reservoir, always exceed that in a larger one? We consider a wetting liquid (contact angle γ between 0 and $\pi/2$), and we prove that if a circular tube T_o is replaced by a tube T_i of arbitrary cross section lying interior to that of T_o, then the liquid-vapor free interface in T_i is at all points higher than was the (original) surface in T_o.

The situation can be very different when T_c is not circular. We prove by example that there exist configurations, even with convex and smooth cross sections for both T_o and T_i, for which the volume (and hence the average rise height) of fluid lifted by T_o over the section of T_i exceeds that lifted by T_i. *Presented at the 14th International Union of Theoretical and Applied Mechanics Congress, Delft, The Netherlands, August 30-September 4, 1976*

A Generalized Conjugate Gradient Method for Certain Large Structured Problems, *P. Concus (LBL), G. H. Golub (Stanford), D. P. O'Leary (U. of Michigan)*

We consider a generalized conjugate gradient method for finding the minimum of a nonquadratic function in finite dimensions that has a positive definite symmetric Hessian. The method is based on splitting off from the equivalent system of nonlinear equations for the vanishing of the gradient an approximating positive-definite system that is easily solvable, and then accelerat-

ing the associated iteration by using (nonlinear) conjugate gradients. The method, which is an extension of our earlier one for the quadratic case, finds application in the solution of problems arising from the discretization of nonlinear elliptic partial differential equations. Its behavior is illustrated for the minimal surface equation, with splittings corresponding to symmetric, extrapolated block, Gauss-Seidel-Newton iteration and to separable elliptic operators amenable to fast direct methods. *Invited talk for the IX International Symposium on Mathematical Programming, Budapest, Hungary, August 23-27, 1976*



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APPARATUS FOR AUTOMATICALLY CONTROLLING THE TEMPERATURE OF A FREE-FALLING GLASS GOB

ACCELERATOR OPERATIONS

BEVATRON/BEVALAC

Bevatron/Bevalac operation in September accented the biology and medicine program to offset losses due to accelerator problems earlier this year. Of the 626 hours scheduled for research, 318 were committed to the biomedical program, and 208 hours were actually run. The ions used included carbon, neon, and argon in the Bevalac mode, and carbon in the Bevatron mode. Operating efficiency with the SuperHILAC as injector was very good.

The nuclear science program did not fare as well. A failure of the SuperHILAC's heavy-ion ($z \geqslant 18$) injector, ADAM, to deliver argon to the streamer chamber and beam 33, resulted in a substantial loss of operating hours to nuclear science research.

On the whole, however, accelerator operation reliability is improving. One recent change in the weekly operating schedule has increased available research time. Instead of taking one day every week for maintenance, we have begun taking two days, Tuesday and Wednesday, every other week for maintenance, and operating continuously for 12 days. There is now only one startup every two weeks, resulting in an additional two or three shifts available to the research program.

Several momentous achievements fill the October Bevatron/Bevalac log. On October 4, three days of intensive work culminated in the acceleration and extraction of a 1.9 GeV/n iron beam. This is the highest energy beam ever produced in the world. Although the intensity was low—only several thousand particles per pulse—several experiments were performed in the Heckman-Greiner Beam 33 area during the 30 hours the beam was available. More iron running is expected next spring.

Biology and medicine researchers carried out their first fractionation runs in October and enjoyed exceptionally trouble-free operation. There is substantial importance attached to fractionation. It is the means by which a biological sample receives a large cumulative total dose of irradiation that is administered in several equally-spaced small doses. Biological repair mechanisms, which are at work between doses, permit a higher total dose with fractionation than would be tolerated by the sample if it were given in a single irradiation.

The Bevalac carbon beam was used for a steady six-day run, at 94% run time/scheduled time.

Erratum: The July/August issue of Research/Accelerators stated that a new RF system had been installed and was operational on the 20-MeV injector. The report should have said that engineering design and modeling continued very successfully these two months, and that installation of the operational unit is eagerly anticipated.

BEVATRON/BEVALAC RESEARCH AND OPERATION

RESEARCH	Scheduled hours	Percent of program	Actual hours	Percent of program	Run percent of scheduled
			SEPTEMBER		
Nuclear Science	270.75	43	127.25	35	47
Biology & Medicine	318.25	51	208.50	57	65
Studies	37.25	6	30.00	8	80
Total research	626.25	100	365.76	100	58.4
			OCTOBER		
Nuclear Science	249.50	38.3	201.25	42	80.7
Biology & Medicine	237.75	36.5	197.00	41	82.8
Studies	163.50	25.2	79.75	17	48.7
Total research	650.75	100.0	478.00	100	73.5
OPERATION					
			SEPTEMBER		
Research	626.25	97	365.75		58
Tune-up	18.00	3	36.50		
			402.25	63	63
Failures			242.50	37	
Total operation	644.25	100	644.25	100	
			OCTOBER		
Research	650.75	96.2	478.00		73.5
Tune-up	25.75	3.8	47.50		
			525.50		77.7
Failures			151.00		22.3
Total operation	676.50	100.0	676.50		100.0

TIME DISTRIBUTION	SEPTEMBER	OCTOBER
Scheduled Operation	644.25	675.50
Maintenance	51.75	68.50
Holiday	24.00	0.00
Crew time off	0.00	0.00
Total	720.00	745.00
	(30 days of 24h)	(30 days of 24h) (1 day of 25h)

Summary of Bevatron/Bevalac Experimental Program

(Time in hours to the nearest quarter-hour)

Exp. No.	LBL GROUPS Data-taking	LBL GROUPS Tune-up	OTHER GROUPS Data-taking	OTHER GROUPS Tune-up
NUCLEAR SCIENCE	SEPTEMBER			
239H	45.25	13.75	45.50	14.00
	60.00		59.50	
Total Nuclear Science	119.50			
BIOLOGY AND MEDICINE				
215B	8.50			
217B	1.50		1.50	
221B	1.00			
245B	4.50		4.25	
266B			3.25	
274B	3.00		3.00	
275B	.25		.25	
276B	3.00		3.00	
278B	2.50			
289B	18.25			
305B	4.00			
312B	4.50		4.25	
323B			5.00	
331B	3.50			
360B	37.50			
B45	7.50	4.75		
B79	2.50	2.25		
B94	3.25	.75	3.50	1.00
B100	44.50			
B101	4.50			
	154.25	7.75	28.00	1.00
		162.00		29.00
Total Biology and Medicine			191.00	
Total research hours combined			310.50	

Exp. No.	LBL GROUPS Data-taking	LBL GROUPS Tune-up	OTHER GROUPS Data-taking	OTHER GROUPS Tune-up
NUCLEAR SCIENCE	OCTOBER			
178H				68.50
205H	38.75	23.75		
228H	15.75	9.00	15.75	9.25
237H	4.25			
239H	45.25	18.45	45.50	19.00
317H	0.75	12.25	0.50	12.00
349H	12.50	8.25	12.25	8.25
	117.25	72.00	74.00	109.00
	189.25		183.00	
Total Nuclear Science	372.25			
BIOLOGY AND MEDICINE				
215B	11.50	3.00		
245B	4.25	.25	4.50	.25
266B			16.25	
280B			3.75	
289B	22.50	1.00		
290B	3.00	.25	3.25	.50
292B			7.00	4.25
304B			9.50	
312B	3.00		2.75	
344B	20.25	1.75		
346B			8.00	.75
360B	25.50	1.50		
B45	7.50	4.75		
B100		18.25		
	97.50	30.75	55.00	5.75
	128.25		60.75	
Total Biology and Medicine	189.00			
Total research hours combined	561.25			

BEVATRON/BEVALAC SCHEDULE, JANUARY - FEBRUARY 1977

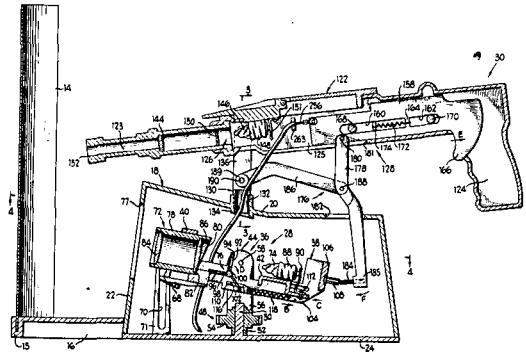
Period	Exp. no.	Group	Sched. hours	Ion	Beam line
1/9-1/18*	340H	Walker	6	^{12}C	-
		Biomed	19	Ar,Ne	Bio 2
1/23-1/31	317H	Igo	2	α	36
	284H	Poskanzer/ Gutbrod	2	α	Septum
	299H	Nagamiya	8	^{12}C	30-2
		Biomed	14	^{20}Ne	Bio 2
2/3-2/14	284H	Poskanzer/ Gutbrod	11	^{20}Ne	Septum
		Biomed	13	^{12}C	Bio 2
	178H	Kirk	8	^{6}Li	38
2/17-2/28		NASA Calib.	11	^{40}Ar	33
	284H	Poskanzer/ Gutbrod	8	^{40}Ar	Septum

*Scheduling for period 1/19-1/22 will be done after startup of experimental program at Bevatron/Bevalac.

SuperHILAC

The most noteworthy event of this period was the delivery of a fully stripped ^{56}Fe beam to the Bevalac line on October 3 which was then accelerated to full energy by the Bevatron. The amount of ^{56}Fe accelerated to 8.5 MeV/μ was 25μA, pk, after stripping. Of this, about 3% was 26+. The thickness of carbon stripper was 330 μg/cm^2. There is reason to believe that a thicker foil would yield a higher proportion of fully stripped beam. The lifetime of the iron sources was disappointing — only 5 to 10 hours when run at the 36 Hz rate. Two failure mechanisms were evident: one was caused by iron chips shorting cathode to anode, another the gradual closing up of the source slit by iron apparently sputtered over from the iron electrode. This is a special problem of ^{56}Fe, since neither of these effects occurs with the ^{48}Ca sources. Tests are being conducted on the ion source test bench to try to improve performance of the source for ^{56}Fe.

September was a very successful month in which 1082 research hours (including parasitic beams) were scheduled, 1115 were performed. In October the corresponding figures were 912 scheduled, 810 performed. The lost time in October was due primarily to injector failures, particularly Eve. Many Eve components are being overstressed, making this injector prone to breakdown. This problem has long been recognized, but limited manpower and the presence of more urgent problems have delayed work on Eve. High priority has now been given to rebuilding the Eve high voltage power supply and other critical components.



3,990,704
TARGET IMAGE PROJECTOR WITH SIMULATED GUN ASSEMBLY

SuperHILAC Research and Operation

Time	September Hours	September Percent	October Hours	October Percent
SCHEDULED TIME				
Research Hours	922		840	
Parasitic research hours	160		72	
Machine studies	32		54	
Machine operation for research	560	80.5	606	81.4
Machine tune	92	13.2	96	12.9
Maintenance	44	6.3	42	5.7
Total scheduled crew time	696	100.	744	100
ACTUAL TIME				
Setup	46.50	6.7	39.50	5.3
Tune-up	200.25	28.7	68.75	9.2
Target time	868.75	124.8	701.75	94.3
Total actual research time	1115.50	160.2	810.00	108.8
Machine tune	7.75	1.1	145.00	19.5
Machine studies	27.75	4.0	28.25	3.8
Source changes	9.75	1.4	14.25	1.9
Maintenance	219.95	31.5	218.75	29.4
Total support time	265.20	38.0	406.25	54.6

SuperHILAC Experimental Log: September

Exp. no.	Experimenter	Beam line	Timeshare mode*	Ion	Scheduled hours	Target hours	Total research hours	Charge states	Beam stop current	Energy (MeV/μ)
	Bevalac	E15	1A,B,G	^{20}Ne	170	142.50	164.25	3,7,10	180μA pk	8.5
	Kaplan	E53	4A	^{20}Ne	4	11.50	11.50	3,7	30μA pk	8.5
127	Guidry	E11.2	4B	^{86}Kr	48	39.00	44.25	6,22	30nA dc	5.58
	Bevalac	E15	1C,H,J	^{12}C	144	106.75	143.75	2,5,6	80μA pk	8.5
161	Coulex	E11.2	2G	^{136}Xe	78	67.50	83.50	8,29	28nA dc	4.58
	Bevalac	E15	1D,E,F	^{40}Ar	96	66.75	97.00	3,13,18	110μA pk	8.5
	Bevalac	E15	1K,L,M	^{40}Ar	184	59.00	84.25	6,13,18	8μA pk	8.5
155	Groll	E71	2L	^{86}Kr	116	46.25	74.25	6,21	50μA dc	8.5
162	Moretto/Diamond	E11.1	2M	^{86}Kr	82	23.00	39.25	6,21	25nA dc	4.58
	Total Run				922	562.25	742.00			
Parasitic										
131	Marrus/Gould	E76	2D	^{40}Ar	64	12.75	21.50	6,13	4nA dc	8.5
131	Marrus/Gould	E75	2F	^{40}Ar		10.25	19.75	6,13	7.5μA pk	8.5
	SHEIKS	E53	2E	^{40}Ar	24	7.50	18.25	6,13	1.5μA pk	8.5
161	Coulex	E11.2	2J	^{136}Xe	72	62.25	67.25	8,29	15μA dc	4.58
	Total Parasitic				160	92.75	126.75			
	Total for September				1082	655.00	868.75			
Beam Studies										
		E11.2	2H	^{136}Xe	8	12.75	14.50	8,29	—	4.58
		E75	4C	^{86}Kr	24	—	13.25	6,22	400nA dc	8.50
				Total	32	12.75	27.75			
Machine Tune										
		E71	2K	^{86}Kr	16	—	7.75	6,21	25nA dc	8.5
	Other scheduled tune-up				108	included in Exp. time				
				Total	124					

SuperHILAC Experimental Log: October

Exp. no.	Experimenter	Beam line	Timeshare mode*	Ion	Scheduled hours	Target hours	Total research hours	Charge states	Beam stop current	Energy (MeV/μ)
162	Coulex	E11.1	2A	^{86}Kr	8	7.00	7.25	6,21	Trace	4.58
	Bevalac	E15	1A,B	^{15}N	7	17.00	22.00	3,5,7	40μA pk	8.5
	Bevalac	E15	2	^{56}Fe	32	28.00	29.25	3,17,26	0.6μA pk	8.5
	Bevalac	E15	1C,D,E	^{40}Ar	80	64.00	67.75	3,13,18	80μA pk	8.5
	Bevalac	E15	1	^{40}Ar		13.75	13.75	3,13,18	140μA pk	8.5
154	Miller/Alexander	E73	—	^{40}Ar	24	0	0	—	—	—
	Bevalac	E15	1H,J	^{12}C	160	141.75	143.50	2,5,6	75μA pk	8.5
154	Miller/Alexander	E73	2G	^{12}C	0	5.00	9.50	2,5	—	8.5
161	Coulex	E11.1	2H	^{86}Kr	64	7.25	10.50	6,21	Trace	3.02
161	Coulex	E11.1	2H	^{86}Kr		30.25	38.00	6,21	Trace	3.88
154	Miller/Alexander	E73	2J	^{86}Kr	88	77.75	87.75	6,21	100nA av.	8.5
131	Marrus/Gould	E76	2	^{40}Ar	24	0.75	5.75	3,13	350nA av.	8.5
131	Marrus/Gould	E76	2	^{40}Ar		0.00	12.00	6,13	300nA av.	8.5
	Ghiorso	E53	4	^{48}Ca	104	63.50	79.50	3,14	550nA av.	6.25
	SHEIKS	M10°	4	^{48}Ca		2.75	3.00	3,14	1μA av.	6.25
	Bevalac	E15	1K,L	^{12}C	136	133.25	133.50	2,5,6	100μA pk	8.5
164	Moretto	E78	2K	^{86}Kr	80	27.00	29.75	6,21	80nA av.	8.5
164	Moretto	E78	2K	^{86}Kr		34.50	38.75	6,21	40nA av.	5.89
161	Coulex	E11.2	2L	^{86}Kr	40	36.25	41.75	6,21	65nA av.	5.89
				Total Run	840	689.75	773.25			
Parasitic										
131	Marrus/Gould	E76	2D	^{40}Ar	16	7.25	12.50	3,13	600nA av.	8.5
131	Marrus/Gould	E76	2D	^{40}Ar	40	0.00	21.00	6,13	15nA av.	8.5
125	Griffith	E71	2E	^{40}Ar	16	4.75	10.25	6,13	1.3nA av.	7.2
	Total Parasitic				72	12.00	43.75			
	Total for October				912	701.75	817.00			
Beam Studies										
		E15	2B	$^{56}Fe(+^{15}N)$	48	0	24.25	3,17,26	0.6μA pk	8.5
		E33/15	1,2	^{12}C	6	4.00	4.00	2,5		8.5
				Total	54	4.00	28.25			
Machine Tune										
		E15	1AB	^{15}N	16	0	15.00	3,5,7	40μA pk	8.5
		E15	1C,D,E	^{40}Ar	24	9.75	19.50	3,13,18	70μA pk	8.5
		E76	2C	^{40}Ar	8	0	7.00	3,13	—	8.5
		E15	1G	^{12}C	32		33.25	2,5,6	20μA pk	8.5
		E73	2G	^{12}C		3.00	7.25	2,5	—	8.5
		E11.1	2H	^{86}Kr	32	0	18.50	6,21	40nA av.	3.02
		E73	2J	^{86}Kr	8	0	3.00	6,21	—	8.5
		E76	2	^{40}Ar	8	0	8.50	3,13	300nA av.	8.5
		E53	4	^{48}Ca	16	0	11.00	3,14	550nA av.	6.25
		E15	1	^{12}C	8	1.75	8.50	2,5,6	—	8.5
		E78	2K	^{86}Kr	16	0	10.00	6,21	—	8.5
		E11.2	2L	^{86}Kr	8	0	3.50	6,21	—	5.89
				Total	176	14.50	145.00			

*Modes are numbered 1,2, etc. Letters A,B, etc. indicate modes that were timeshared together

88-Inch Cyclotron

Time on the cyclotron for September and October was distributed as follows:

	Hours
Scheduled running	1072
Routine maintenance	56
Scheduled shutdown	224
Unscheduled shutdown	24
Beam development	88
Total	1464

Part of the unscheduled shutdown was due to time needed to repair damage to the cross connects between trim coils 16 and 17 and their power supplies. It seems that water from a warming liquid-nitrogen trap located 10 feet above the cross connects had slowly saturated the benelex insulation and finally shorted the cross connects to ground, and/or a flow switch on the water line failed, causing the lines to overheat. The rest of the time was spent hunting for leaks in the resonator tank.

There are currently three visitors at the 88. Dr. Nripendra K. Ganguly is here for three months from the Bhabha Atomic Research Center in Bombay. Dr. J. L. Laville is here for a year from Centre National de la Recherche Scientifique in Paris working with the Hendrie-Scott group. Dr. M. Mermaz, here for one year from Centre d'Etudes Nuclaires, Saclay, is also working with the Hendrie-Scott group.

BEAM DEVELOPMENT

During the summer shutdown, non-focusing electrodes were installed on the exit deflector elements of the 88-Inch Cyclotron. Over the past several years a two-element deflector channel has been used, which is entirely adequate for most heavy-ion beams and for the reduced demand for the higher-energy, light-ion beams, which are difficult to extract from the acceleration chamber. Currently, there is considerable interest in very-high-charge-state heavy-ions (e.g. $^{16}O^{6+}$ and $^{16}O^{7+}$) and in high-energy deuteron and $^{4}He^{2+}$ beams (26-33 MeV/nucleon). These all require that very high electric fields be maintained on the first two elements of the deflector. By using all three deflector elements, the beam deflection occurs over a longer distance, thereby reducing the required electric fields. The exit deflector is also a handle for good alignment of the beam with the beam transport system, which is often difficult for beams requiring a near-maximum main magnet field. Recently, $^{4}He^{2+}$ beams at energies of 110, 118, and 128 MeV have been successfully run with the exit deflector.

Another set of tests was recently completed of the modified center region for high-harmonic acceleration of low-energy beams. The beam intensity was found to be very sensitive to small radial displacements of the modified upper dee insert. External beam intensity was increased tenfold by proper tuning to the dee insert position. The radial positioning of the insert used for normal operation does not exhibit this sensitivity.

88-Inch Cyclotron Experimental Log

Experimenter	Cave	Scheduled hours	Energy (MeV)	Ion	Charge state(+)
Conzett	5A	136	15,20,25	d	1
Ghiorso	0	16	104	^{16}O	4
KeKelis/Cerny	4C	16	104	^{16}O	4
		96	120	^{4}He	2
Hendrie	4C	16	104	^{16}O	4
Moretto	1B	88	200	^{40}A	8
Jahn/Cerny	2	168	55-60	^{3}He	2
Yano	HLC	6	50	^{1}H	1
Clemenson/Markowitz	0	2	16	^{1}H	1
Diamond/Stephens	1A	120	130-174	^{40}Ar	7
Scott/Olmer	4C	144	312	^{16}O	6
Baisden/Seaborg	0	16	170-175	^{20}Ne	5
Sommerville/Seaborg	0	8	85	^{26}Mg	5
		40	115	^{22}Ne	5
Muller/Alvarez	5B	20	quarks		
Selove	4C	112	80	^{3}He	1
Nurmia	0	12	90	^{14}N	3
Moltz/Cerny	2	40	40	^{1}H	1
Stephenson/Holly/ Clark/Gough	vault	16	14	^{40}Ar	
	Total	1072			

184-Inch Synchrocyclotron

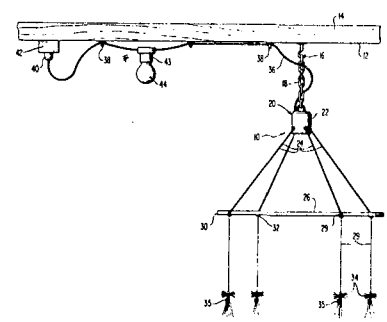
During September and October the 184-Inch was operated for approximately 66 h of patient therapy and biomedical studies.

A group of 16 patients received individual pituitary suppression treatments of four fractions each. Of these, 11 were patients with acromegaly, 3 with Cushing's disease, and 2 with prolactin-secreting tumors.

One patient with pancreatic carcinoma was started on a regime of 10 treatments.

One run for biological experimentation was carried out for Alpen and Smith, and approximately 13 h were used by the Health Physics Group in association with W. Schimmerling and the crew of the 184-Inch to determine the neutron flux and energy spectrum in the medical treatment area during patient therapy. This study is incomplete at this time.

A 4.25-h run was made for Michael Goitien of Harvard for calibrating his ionization chambers.



3,990,173
BAT TRAP

RESEARCH PROGRAM SUMMARY

BEVATRON/BEVALAC

Exp. 178H: A Study of Two-Body Fragmentation Modes of Light Nuclei, *P. Kirk, R. Huggett, W. V. Jones, and E. F. Zganjar (Louisiana State).* The tendency of nuclei of light ions to coalesce into sub-nuclei, or "cluster," will be examined in this experiment. Data will be collected from projectiles of protons, helium-3 and helium-4, lithium-6, boron, carbon, nitrogen, and neon impinging on carbon, polyethylene, and some heavier target materials. The fragmentation products will be examined with scintillator hodoscopes and spark chambers at the entrance and exit ends of a magnetic spectrometer. A new beam, Beam 38, has been established for this purpose. During October, set-up was finished. The group is now ready for its first data-taking run in December.

Exp. 205H: Positive and Negative Particle Production from Heavy-Ion Bombardment of Various Nuclei, *H. Steiner, O. Chamberlain, G. Shapiro, D. Nygren, L. Anderson, S. Nissen-Meyer, S. Nagamiya, and L. Schroeder (LBL).* This experiment to measure the yield of light positive and negative particles as a function of angle and momentum is now finished. The last run was completed in October with the first measurements of very-high-energy pion production by carbon projectiles.

Exp. 228H: Studies of Particle Fragmentation in the LBL Streamer Chamber, *S-Y Pung, W. Gorn, G. Kiernan, R. Poe, B. Shen (UC Riverside); L. Schroeder, and H. Steiner (LBL).* Particle production and fragmentation of helium, carbon, neon, and argon ions interacting with nuclear targets inside the LBL streamer chamber are being studied. A very efficient run with 400-MeV and 2.1-GeV/n carbon was accomplished in October. The experiment should finish up with a low-energy argon run in November. Streamer chamber film is being analyzed at Riverside.

Exp. 237H: Mass-Yield Measurements from Bombardment of Au and U Targets with Very-High-Energy ^{12}C and ^{16}O Ions, *G. Seaborg, R. Otto, M. Fowler, D. Lee, and I. Binder (LBL).* Gold and uranium targets are bombarded with carbon and oxygen beams of 0.25 GeV/n and 2.1 GeV/n. Radiochemical separations are then performed so that the many products are divided into chemistry groups for identifying the radioactive species and obtaining spectral data. With high-intensity carbon running in October, this experiment is nearing completion.

Exp. 239H: Atomic Charge-Exchange Cross Sections for High-Energy Heavy Ions, *H. Heckman, B. Cork, P. Lindstrom (LBL); D. Greiner, F. Bieser, H. Crawford (UCSSL); and G. Raisbeck (Orsay).* Atomic electron capture and loss cross sections of high-energy heavy ions are of fundamental importance for understanding the basic mechanism of electron transfer reactions at relativistic energies. This experiment, designed to measure these cross sections, was completed with heavy carbon and neon running in September and an argon run in October. Data has been collected at high and low energy with all three projectiles. The results will be relevant for predicting the behavior of certain isotopes in cosmic rays.

Exp. 317H: Measurements of Light Fragment Spectra Produced in Nucleus-Nucleus Collisions, *G. Igo (UCLA); J. Carroll, V. Perez-Mendez (LBL).* The spectra of light fragments (all Z = 1,2 isotopes) produced in nucleus-

nucleus collisions in the laboratory angular range of 3° - 16° are being studied in the momentum range, p/Z, from 1 to 6 GeV/c. The data collected will overlap the small transverse momentum transfer of data of Heckman et al., and will extend to the large momentum transfer region not heretofore covered. In October the running at 2.1 GeV/n carbon was completed by filling in some missing points. With a final argon run scheduled for December, this experiment will be done.

Exp. 215B: Effects of Heavy-Ion Irradiation on the Lungs of Hamsters, *K. Woodruff, J. Leith, and W. Schilling (LBL).* The lungs of healthy hamsters receive high-LET radiation for studies of tolerance of the lung to acute and long-term effects of the radiation. Hamsters are free of the chronic respiratory diseases typically found in colonies of normal aging rats and mice. Groups of hamsters receive single doses of 500 to 2000 rads to each thorax. At monthly intervals, up to one year postirradiation, the lungs are removed, and histologically processed. A two-week split-dose experiment with neon ions was performed in September, and the first 5-day fractionation run with carbon was carried out in October.

Exp. 217B: Survival of *in vivo* Brain Tumor Cells After Irradiation with Heavy Particles of Various LET, *K. Wheeler (UCSF), J. Leith (U. Arizona), G. Ross, and P. Smith (LBL).* Brain tumors in humans show a very poor prognosis after either radio- or chemotherapy. To date there are no available data on the actual cell survival characteristics, hypoxic fraction, repair of sublethal damage, or reoxygenation of brain tumors after irradiation. We have developed a model system that uses intracerebral tumors in rat brain. We have already determined the survival characteristics of this model tumor *in vivo* in terms of the actual number of clonogenic cells surviving after x-irradiation in both oxygenated and hypoxic states. We propose to investigate the effects of high-LET radiations in our brain tumor system, with regard to determinations of RBE, OER, and reoxygenation of brain tumors. First irradiations were done in September in the Bevalac neon beam.

Exp. 221B: Bone Marrow Stem Cell Survival After Heavy-Ion Irradiation, *J. Schooley, L. Kelly, and R. Thomas (LBL).* Survival of bone marrow stem cells is being studied after their irradiation with a 400-MeV/n neon beam. The cells are exposed to various doses of radiation *in vitro,* and then appropriate dilutions are injected into lethally-irradiated mice to determine the percentage survival by the spleen coloy assay. Survival curves will be compared to cobalt gamma-irradiated cells to determine the RBE. Argon was used in this initial irradiation.

Exp. 245B: Hydrogen Yields and Chemical Isotope Effects, *A. Appleby, E. Christman (Rutgers U.); M. Jayko, and A. Chatterjee (LBL).* The radiation chemical yields of hydrogen from various dilute aqueous solutions as a function of the penetration depth of heavy ions are being measured. This experiment has completed its alloted time, with carbon, neon, and argon running in these months. These measurements of free radical production in chemical solutions complement studies of radiosensitizers that scavenge free radicals (Exp. 312B).

Exp. 266B: Measurement of RBE for Mouse Intestinal Crypt Cells and Mouse Clonogenic Bone Marrow Cells Irradiated *in Situ* with ^{137}Cs, ^{12}C, ^{20}Ne, and ^{40}Ar, *T. Phillips, K. Fu, and L. Kane (UCSF).* This experiment

involves whole-body irradiation of 12-week-old LAF_1 mice. At 3½ days after irradiation the small intestine is examined for the number of regenerating crypts as a function of radiation dose. Response curves are being calculated with these data. A second aspect of the experiment is the extraction of the mouse femur bone marrow immediately following irradiation. This is then diluted and injected into previously irradiated whole-body recipients. Spleen colonies are counted 8 days after injection. The results of the spleen colony count allow calculation of RBE. During September and October several runs with carbon, argon and neon were completed.

Exp. 274B: Aerobic and Hypoxic Cell Survival at the Plateau and Peak of Extended Bragg Peaks of Helium, Neon, and Argon Ions, *M. R. Raju (LASL); E. Blakely, C. Tobias, and J. Lyman (LBL).* Cultured cells (T1) in small capsules, at a concentration of 3×10^4 per ml for oxygenated conditions and at a concentration of 3×10^6 per ml for hypoxic conditions, will be exposed at the plateau and peak of extended Bragg curves of helium, neon, and argon ions. After exposure, the cells are plated into petri dishes at the proper concentrations to determine cell survival by colony formation. Further data were taken this month. Exposures were to carbon and neon ions.

Exp. 275B: Cell Survival as a Function of Depth for Extended Bragg Peaks of Helium, Neon, and Argon for Single and Two-Fraction Exposures, *M. R. Raju (LASL); E. Blakely, C. Tobias, and J. Lyman (LBL).* Cultured mammalian cells (T1) are suspended in a cylinder containing gelatinous substrate and exposed to beams of helium, neon, and argon. The gelatin is sliced and cultured post-irradiation to determine survival as a function of depth. The first data were taken this month with argon as the bombarding ion species.

Exp. 276B: Early and Late Effects of Extended Bragg Peaks of Helium, Neon, and Argon at the Plateau and Peak Positions on Mice Feet, *M. R. Raju (LASL).* The mouse-foot system will be used to measure the acute and late response to radiation. The left hind feet of each of six mice/group will be exposed to each dose point at the plateau and at the peak (14 dose points, total) of the extended Bragg curve of helium, neon, and argon ions. Visual observations based on an arbitrary scale will be made daily for about 50 days for scoring acute effects. Late effects will be scored about 6 months after exposure. Exposures were made in September with the Bevalac neon and carbon beams.

Exp. 278B: RBE of Heavy Ions for Bone Marrow "Stem" Cell Survival, *L. Kelly, J. Schooley, and R. Thomas (LBL).* The RBE of several heavy-ion beams for mouse bone-marrow colony-forming units are measured by using the spleen colony assay technique. Irradiation is carried out *in vitro* and both the plateau and Bragg peak region of the beam are studied. Neon was the first bombarding ion, the higher Z particles are used as they become available. Argon was used in September.

Exp. 280B: Calibration of and Experimentation with Silver Chloride Trace Detectors, *E. Schopper (U. Frankfurt) and E. Benton (USF).* This long-range experiment is designed to test the applicability of silver chloride detectors for recording high-energy, heavy-ion particles in space dosimetry and space biology and deals with the following: (a) calibration of track parameters in AgCl detectors

with different response to charge and LET, and (b) measurement of the decay time of nonstabilized, nondeveloped tracks of different ions. In October AgCl crystals were exposed to argon.

Exp. 289B: OER Determinations in Human and Hamster Cells with Heavy-Ion Beams, *C. Tobias, T. Yang, and E. Blakely (LBL)*. The purpose of this set of experiments is: (1) To determine the RBE, OER, and shape of the survival curve for human kidney T-1 cells as a function of atomic number and particle velocity. (2) To study the OER for human kidney cells at several oxygen concentrations in the peak of the Bragg curve. (3) To examine the extent of dose-fractionation recovery in air for human kidney cells in the plateau and in the peak. (4) To determine the RBE, OER, and the shape of the survival curve for asynchronous and synchronous Chinese hamster lung (V-79) cells in both plateau and peak. Cells are irradiated while attached to glass in a chamber designed for gas flushing. After exposure, the cells are trypsinized, counted, and titrated for determining clone-forming ability. Five dishes are plated per dose point. During these two months, eight good runs were made with carbon, argon, and neon beams.

Exp. 290B: Heavy Particle Radiography, *E. Benton, R. Henke (USF); W. Holley, and C. Tobias (LBL)*. Using plastics as particle detector, we are developing a technique for heavy-particle radiography for imaging of soft tissue abnormalities and tumors often not detectable by x-rays or other conventional techniques. During September and October there were three carbon runs, one with patients, the others with specimens.

Exp. 292B: Heavy-Ion Studies of the Mammalian Brain and Eye and Associated Head Structures, *W. Haymaker, (NASA, Ames*. Pocket mice, C57Bl mice, and gerbils will be exposed to the Bevalac heavy-ion beams. At intervals thereafter the head structures will be examined in an effort to assay the nature and extent of radiation damage to be expected in space flights. This experiment ran with carbon in October.

Exp. 304B: Tumor Induction in Rat Skin with High-LET Radiation, *F. Burns, R. Albert (NYU Medical Center)* The skins of 100 rats were irradiated with argon at various doses in order to determine the general shape of the dose response curve for tumor induction. The positioning apparatues held 20 rats at a time, shielded from the beam, with a portion of skin exposed through a slot. The experiment is completed.

Exp. 305B: Heavy-Ion—Induced DNA Damage and Repair, *R. Roots (LBL)*, In this experiment radiation effects previously observed at SuperHILAC energies will be looked for at Bevalac energies. It has been noted that heavy-ion radiation produces more non-rejoining DNA strand breaks than does x-radiation. In this Bevalac experiment a series of tests will be done in which DNA strand breakage and its rejoining will be investigated as a function of ion species, ion velocity, LET, oxygen tension, and temperature. Cell survival data will also be obtained as a function of these same variables, so that the extent of correlation between cell killing and DNA damage and repair can be determined in detail. Cells were irradiated in the Bevalac neon beam in September.

Exp. 312B: Chemical Modifications of the Inactivating Events Produced in Mammalian Cells by Heavy Ions, *D. Chapman (AEC Canada), E. Blakely, J. Lyman, C. Tobias, S. Curtis, and T. Yang (LBL).* Survival curves with aerated mammalian cells are being generated with beams of 10 to 300 KeV/u LET in the presence of various concentrations of OH scavenger as well as -SH protector. The purpose is to estimate the direct and indirect chemical effects on the cell resulting from heavy ion beams. Carbon and argon runs were completed in September and October. Argon data were collected with the 10-cm special ridge filter to allow comparisons with earlier work with the 4-cm lead ridge filter. Carbon data are also available now with both filters.

Exp. 323B: Determination of RBE and TCD_{50} for the EMT6 Tumor Irradiated in Vivo with Oxygen, Neon, and Argon Ions, *T. Phillips, K. Fu, and L. Kane (UCSF).* Tumors *in vivo* are irradiated with heavy-ion beams under various conditions. RBE are determined by growing single-cell suspension colonies and measuring the survival of irradiated and control tumors. The TCD_{50} is determined by observing tumor regression of irradiated mice, and the dose for 50% cure of the tumors will be estimated, based on probit analysis. Irradiations continued this month with the Bevalac carbon beams.

Exp. 331B: Mutation of Alcohol Dehydrogenase -1 Gene of Maize by Accelerated Heavy Ions = Gene Structure and Nature of Damage, *M. Freeling (UCB); T. Yang, C. Tobias (LBL).* The effect of irradiation on corn pollen will be studied with special emphasis on the alcohol-dehydrogenase - 1 (ADH) gene. Some of the pollen grains will be mutant, independent of irradiation, and will not contain ADH. The two strains will be separated chemically after maturation and then compared with each other for overall mutation rate and other specific reactions. This experiment began its irradiation in the Bevalac neon beam in September.

Exp. 344B: Response of Rat Rhabdomyosarcoma Tumors to Fractionated Treatments of Heavy Ions, *S. Curtis, T. Tenforde (LBL).* Spherical solid tumors transplanted in the WAG/Rij rat are irradiated in the peak and/or plateau regions of various heavy-ion beams on a fractionated schedule. A six-day fractionation run with carbon was completed in October. Tumor volumes will be measured after irradiation, and the regression and regrowth characteristics obtained. Comparison will be made with equivalent x-ray fractionated treatments.

Exp. 346B: Determination of Heavy-Ion Dose Quality at Depth, *G. Luxton, P. Fessenden, and W. Hoffmann (Stanford).* In this experiment we will measure the spectrum of energy deposited in a tissue-equivalent counter that simulates a sphere of tissue 2 microns in diameter. The measurement is made at several depths in a water phantom with both Bevatron C^{6+} and Bevalac Ne^{10+} ions. The same technique is in use at the Stanford Medical Pion Concentrator, and a comparison of the results obtained from the several types of heavy particles will be made.

Exp. 360B: Relative Biological Effectiveness of Carbon and Argon Ions for Testicular Atrophy, Relative to ^{60}Co, *E. Alpen (LBL).* Carbon, neon and argon ions are being used to determine RBE by irradiating normal mouse testes and intestines, since both contain radiation sensitive tissue. Testicular weight loss is measured as a function of dose. The

RBE of the heavy ions will then be determined. The small intestines are removed and examined histologically, and the number of regenerated crypts counted. Excellent running with carbon, neon, and argon was accomplished in September. One of the runs was a series of neon split doses with three fractions delivered in 24 hours to test sublethal repair of radiation damage to the crypts. In October, testes were irradiated with carbon plateau and peak, both in single doses and three fractions over five days, to test for dose recovery between fractions. This experiment ran eight times in September and October. The bulk of the running was with carbon and argon at different positions on the Bragg curve. Both monolayer and suspension cultures of human kidney and hamster cells were exposed to permit comparisons.

Exp. B45: Heavy-Ion Irradiation of Rhabdomyosarcoma in Rats, *S. Curtis (LBL)*. Rhabdomyosarcomas, solid transplantable tumors in rats, are irradiated at various doses to measure the extent of tumor volume regression due to plateau and/or peak heavy-ion beams, the latter spread out by a "ridge filter." The tumors are then excised, and the cells dissociated and plated, to permit measuring the fraction of cells capable of proliferation at various times postirradiation. With a good carbon run in September and argon run in October, this experiment was completed.

Exp. B79: Effects of Heavy Ion Irradiation of the Retina, *D. Philpott and L. Kraft (NASA)*. Controlled exposures of the left retinas of pocket mice are being made to obtain data for comparison with that obtained from satellite and balloon flights. Initial exposures were made in September in the Bevalac argon beam at the Bragg peak.

Exp. B94: Skin Tumor Incidence in Rats After Exposure to Heavily Ionizing Particles, *J. Leith (U. Arizona) and K. Woodruff (LBL)*. Bevalac heavy ions are being used to induce skin tumors in susceptible rats, the CD albinos. The RBE for such irradiations will be determined, as an assessment of the possible carcinogenic potential for humans exposed to high-LET radiation. First exposures were made in September in the Bevalac carbon beam.

Exp. B100: Dosimetry for Biomedical Applications, *J. Lyman (LBL)*. September saw the first delivery of Bevalac carbon to the Biomed area. Complete Bragg curves were run, along with beam scans using the E66 probe to generate the beam profile. These scans will be compared with film scans and calculated data.

Exp. B101: Miscellaneous Investigations with the Bevalac Heavy-Ion Beam, *C. Tobias (LBL)*. In September a number of brief biomedical studies were done under this number in the Bevalac neon beam.

SuperHILAC

Exp. 146: SHEIKS; Mass Yield Distribution Studies of the Reaction of ^{48}Ca with ^{238}U, ^{208}Pb, and Natural Silver Targets, *D. J. Morrissey, W. D. Loveland, P. A. Baisden, D. Lee, K. E. Thomas, I. Binder, R. J. Otto, G. T. Seaborg (LBL)*. A combination of radiochemistry, gamma-ray analysis, and x-ray analysis was used to begin a study of the mass distribution from the reaction of ^{48}Ca with thick targets of uranium, lead-208, and natural silver. Although the data are still being analyzed, evidence for a quasi-fission (multinucleon transfer reaction) component can be seen in the ^{208}Pb + ^{48}Ca x-ray spectra, as

well as evidence for the fusion-fission reaction. Radiochemical separation of scandium was done for the $^{48}Ca + ^{238}U$ and ^{48}Ca + Ag reactions, and the $^{44m}Sc/^{44g}Sc$ production cross-section ratios were sought. These isomer ratio measurements are part of a larger program recently begun at the SuperHILAC to study these ratios in heavy-ion reactions.

Exp. 154: Miller/Alexander; Emission of Light Charged Particles in the Reaction 740-MeV $^{86}Kr + ^{197}Au$, *J. Miller, D. Logan, G. Catchen (Columbia U.); J. Alexander, M. Rajagopalan (SUNY).* Other workers have established that deep inelastic reactions predominate in interactions of ^{86}Kr with ^{197}Au at energies well over the barrier. In earlier experiments we have measured cross sections and angular distributions for single fragments of ^{1}H, ^{2}H, ^{3}H, and ^{4}He. The interpretation of these data as probes of the reaction mechanism requires identification of which particles are emitted from fragments (light or heavy) after separation and which on impact. To elucidate this point we have completed an experimental study of H and He emitted in coincidence with one of the heavy reaction products.
We used a Jared gas telescope to identify the heavy product in coincidence with a solid-state telescope for H and He. The gas telescope was placed at 41° (outside the grazing angle) and H and He were detected in coincidence from 60° to 300° (lab). This series was repeated with the gas telescope at 35° (near grazing). Coincidence data were recorded event-by-event with the new ModComp computer, and they are presently being analyzed. The Kr beam was steady and reliable throughout the 80-hour run.

Exp. 155: GROL: Fusion and Other Strongly Damped Collisions, *H. C. Britt, B. H. Erkkila, P. D. Goldstone, R. H. Stokes (LASL); R. L. Ferguson, F. Plasil (ORNL); M. Blann (U. of Rochester); and H. H. Gutbrod (LBL/GSI).* We have finished a study of mass and charge distributions of evaporation residue products obtained in ^{86}Kr-bombardments of targets ranging from ^{65}Cu to ^{109}Ag. A time-of-flight system was used to measure masses, and a gas telescope to measure charges of products. The same apparatus was used to initiate a study of the mass, energy, and charge distributions of various reaction products from the collisions between ^{86}Kr and ^{124}Sn at about 700 MeV. We plan to study this reaction at a lower energy as well as the reactions between ^{86}Kr and ^{116}Sn.

Exp. 161: High-Spin States of $^{174,176}Yb$ Studied in Coulomb Excitation with Kr and Xe Beams, *D. Ward, P. Colombani, I. Y. Lee, P. A. Butler, R. S. Simon, R. M. Diamond and F. S. Stephens.* Rotational states up to spin 20^+ (18^+) in ^{174}Yb (^{176}Yb) have been Coulomb excited by using beams of ^{136}Xe. Lifetimes up to and including the 14^+ state have been measured by using Doppler-broadened lineshape techniques with ^{136}Xe and ^{86}Kr beams. An annular gas-scintillation counter has been developed to perform particle-γ coincidence studies. Moments-of-inertia in $^{174,176}Yb$ behave very regularly, showing no signs of backbending effects. The measured lifetimes are in agreement with the rotational model predictions, and the measured cross sections for Coulomb excitation of the high-spin states are in agreement with the semiclassical Winther-deBoer calculation.

Exp. 162: Gamma-Ray Spectra of Au, Ag + Kr at 620 MeV, *L. G. Moretto, R. Diamond, F. Stephens.* In collaboration with the Diamond-Stephens group, we have measured the γ-ray spectra in coincidence with fragments identified in Z for the reactions Au, Ag + Kr at 620-MeV bombarding energy. While the data have not been analyzed yet, we expect to be able to obtain the γ multiplicities as a function of the Z of the fragment. These data will provide us with information regarding the transfer of the orbital angular momentum to the intrinsic spin of the fragments. This will represent an important step in the understanding of the dynamics of interactions of two large nuclei.

Exp. 163: Bombardment of Au, Tb, Ag, and Xe at 980 MeV, *L. G. Moretto, R. Jared, J. Hunter, J. Moulten, P. Russo, and P. Glassel.* We have completed the study of the reactions Au, Tb, Ag, and Xe at 980-MeV bombarding energy. Detailed angular distributions for particles identified in atomic number up to $Z \simeq 65$ have been obtained. The observed patterns are consistent with an increasing lifetime of the intermediate complex with decreasing target Z.

88-Inch Cyclotron

Completion of a Recoil Atom Mass Analyzer (RAMA), *D. Moltz, M. Zisman, R. Gough, D. Vieira, and J. Cerny.* The completion of the RAMA (Recoil Atom Mass Analyzer) system was finally realized with the detection of the β-delayed α-emitter ^{20}Na produced by the ^{24}Mg(p,αn) reaction upon the mass-dispersed focal plane (Fig. 38). A subsequent test experiment with ^{20}Na was used to optimize several RAMA

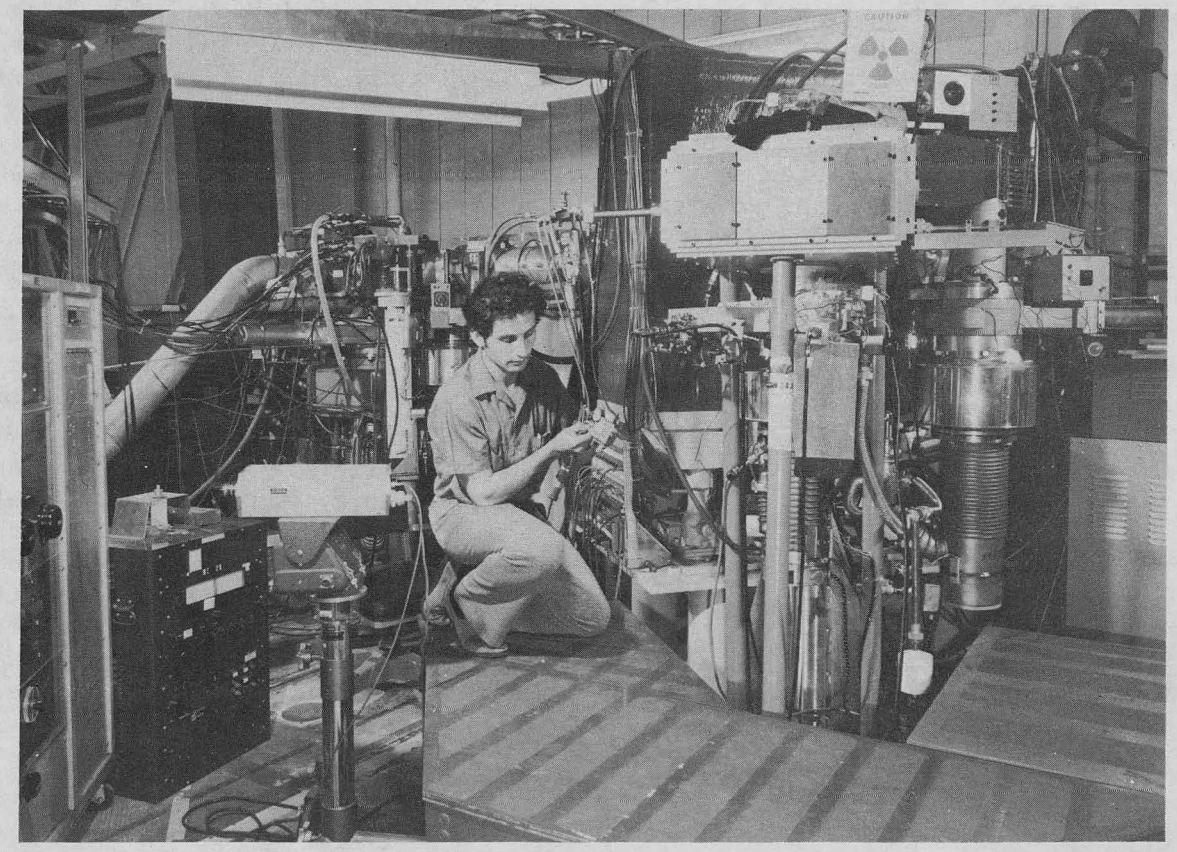


Fig. 38. Graduate student Dennis Moltz makes adjustments on the Recoil Atom Mass Analyzer prior to testing at the 88-Inch Cyclotron. (CBB 760 10478)

parameters. The present overall efficiency is approximately 0.01%, the ion source accounting for most of the loss with an efficiency of 0.1%. Several test runs are also scheduled that involve the $^{142}Nd(^{12}C,xn)^{154-x}Dy$ (x = 3,4,5) reaction before planned initial experiments are undertaken.

The RAMA project permits on-line mass analysis of radioactive nuclear reaction products with half-lives down to 0.1 sec. A He-gas jet is used to transport the activity away from the target area and to inject it into an ion source located outside the target cave. The activity is extracted from the ion source at 10 kV as an ion beam, which is then directed through a magnet/slit system capable of resolving adjacent mass numbers throughout the periodic table. This mass identification can be of enormous value in α-decay studies or in work with exotic nuclear decay modes frequently found in nuclei far from β-stability. Present techniques often cannot positively identify the nucleus undergoing decay.

In this particular test, 40-MeV protons from the 88-Inch Cyclotron were used to bombard a ^{24}Mg target to produce the β-delayed α-emitter ^{20}Na. The ion optics had been pre-tuned off-line by feeding ^{20}Ne gas into the RAMA ion source and setting the analysis system for mass 20. After some preliminary optimization of the ^{20}Na yield at the end of the He jet, the activity was then fed into the ion source, and an α detector in the focal plane of the analysis magnet began to register the familiar α spectrum of ^{20}Na. It is hoped that the overall efficiency of the system will be 0.1% or higher.

Tensor Analyzing Powers in $^3He(\vec{d},p)^4He$ Reaction, *F. Seiler, B. T. Leemann, H. E. Conzett, R. M. Larimer, and E. J. Stephenson.*

Measurements were made of the tensor-analyzing powers $A_{yy}(\theta)$ and $A_{xx}(\theta)$ in the $^3He(\vec{d},p)^4He$ reaction at 15 MeV. These results, along with the previously measured cross section and vector analyzing power, will provide information on the question of broad states in ^5Li at rather high excitation energies.

A One-Minute Spontaneous Fission Activity in the Reaction $^{22}Ne + ^{209}Bi$, *L. P. Somerville, M. J. Nurmia, A. Ghiorso, and G. T. Seaborg.*

In 1966-1967 Dubna experimenters Kuznetsov *et al.*[1] observed several spontaneous fission activities with half lives in the minute range. For example, in the bombardment $^{22}Ne + ^{209}Bi$ they observed a spontaneous fission decay with a half life of 60 ± 5 sec. They explained the spontaneous fissions by assuming that ^{228}Np was made in the reaction and decayed by electron capture with a small branching ratio to a short-lived fission isomer of ^{228}U. This hypothesis was termed "delayed fission." Later other spontaneous fission decays with half lives in the minute range were observed in the reactions ^{27}Al + Pb, $^{10,11}B + ^{233}U$, and $^{10,11}B + ^{230}Th$. These spontaneous fission activities were presumed to be due to neutron-deficient isotopes of americium. Since the hypothesis of delayed fission was first conceived, it has remained untested and unchallenged.

At the 88-Inch Cyclotron, we have bombarded 115-MeV ^{22}Ne ions on a thick ^{209}Bi target and observed, with fixed mica track detectors, a spontaneous fission decay with a half life of ~ 51 ± 15 sec and a cross section of roughly one-half a nanobarn. And more recently, we have tested a new drum system in which the recoils can be rotated to fixed mica detectors every 15 sec. With our fission events now concentrated in small spots on the mica detectors, instead of continuously spread out over a large area of

mica, we are able to reduce our background events for future experiments. With this system in operation we were able to observe ~ 100 spontaneous fission events and obtain a half life of ~ 52 ± 8 sec from the reaction $^{22}Ne + ^{209}Bi$. Further experiments are being planned to test the delayed fission hypothesis.

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[1] V. I. Kuznetsov *et al.*, J. Nucl. Phys. (USSR) 4, 279-281 (August 1966).

Search for T = 2 States in ^{16}F and the $^{20}Ne(^{3}He,^{6}He)^{17}Ne$ Reaction, *F. Ajzenberg-Selove, G. KeKelis, D. Scott, D. Hendrie, M. Zisman, J. Mahoney, and J. Cerny.* The The ($^{3}He,^{6}He$) reaction was used to search for the T = 2 states in ^{16}F, which are expected to be at about 10-MeV excitation energy. The ^{3}He beam with energy of 80 MeV was obtained from the 88-Inch Cyclotron, and the magnetic spectrometer was used to detect the ^{6}He particles at $\theta = 10°$. After bombarding a 250-μg/cm^2 CaF_2 target with 9000 μC of charge, a continuum of states was observed in the region of interest, but no T = 2 states could be unambiguously identified.

Next, isotopically pure ^{20}Ne gas was bombarded, and the same reaction was used to obtain an excellent spectrum of ^{17}Ne. The experimental resolution was about 150 keV and should be sufficient to resolve many of the expected close-lying states in ^{17}Ne. The data of both of the above experiments are currently under analysis.

The $^{26}Mg(^{18}O,^{18}Ne)^{26}Ne$ Reaction as a Tool for Measuring Nuclear Masses, *G. KeKelis, M. Zisman, D. Scott, D. Vieira, and J. Cerny.* Another attempt was made to measure the mass of ^{26}Ne via the $^{26}Mg(^{18}O,^{18}Ne)^{26}Ne$ reaction. The 124-MeV $^{18}O^{4+}$ beam was obtained from the 88-Inch Cyclotron in sufficient quantity to allow 200 to 300 nA of beam to be maintained on target. This is adequate beam intensity to allow cross sections down to about 5 nb/sr to be measured with the sophisticated detection system employed in the magnetic spectrometer at the 88-Inch. A number of experimental difficulties were encountered, but data of high quality were finally obtained, which allowed ^{18}Ne particles to be unambiguously detected at the level necessary for measuring cross sections in the nanobarn region. The data are currently under analysis.

Heavy Ion - Light Particle Coincidence Experiments Induced by ^{16}O Ions of 315 MeV on Heavy Targets, *C. K. Gelbke, D. L. Hendrie, J. L. Laville, J. Mahoney, M. Mermaz, C. Olmer, and D. K. Scott.* Following our studies of the energy dependence of isotope cross sections produced in peripheral collisions of 140- and 315-MeV ^{16}O ions on various targets, we have begun experiments to detect light particle - heavy ion coincidences. The aim of these experiments is to clarify the roles of light particle emission and/or projectile fragmentation in peripheral collisions of heavy ions on heavy target nuclei. The experiments used two counter telescopes in fast coincidence, detecting light fragments from hydrogen to lithium in one telescope and heavy fragments from lithium to oxygen in the other. Analysis of the multiparameter coincidence data is in progress.

Study of Analog States in Neutron-Deficient Nuclei with the $(d,^{2}He)$ Reaction, *R. Jahn, D. P. Stahel, G. J. Wozniak, and J. Cerny.* The $(d,^{2}He)$ reaction has been investigated at E_d = 55 MeV on targets of ^{7}Li, ^{10}B, and ^{12}C. Strong transitions to analog states in the final nuclei have been observed, which establish the usefulness of this reaction for

studying analog states in neutron-deficient nuclei. This reaction is more feasible than the comparable charge-exchange reactions (n,p) and (t,^{3}He), since n and t beams are rarely available and are confined to relatively low energies.

Single-Nucleon Transfer Reactions Induced by 20-MeV/n ^{16}O on ^{208}Pb,

C. K. Gelbke, D. L. Hendrie, J. Mahoney, M. Mermaz, C. Olmer, D. K. Scott (LBL); M. H. Macfarlane and S. C. Pieper (ANL). Multinucleon transfer reactions induced by 20-MeV/n ^{16}O on a variety of targets are currently being investigated at the 88-Inch Cyclotron, in order to study the nature of the reaction mechanism at this incident energy where a link between low- and high-energy phenomena might be encountered. One phase of this study has involved high-resolution experiments in which the QSD magnetic spectrometer is used to measure the one-proton and one-neutron stripping reactions ^{209}Pb(^{16}O,^{15}N)^{209}Bi and ^{208}Pb(^{16}O,^{15}O)^{209}Pb, which have been thoroughly studied at lower incident energies.

The spectra that are obtained show narrow transitions to low-lying single-particle states as well as broader structures at higher excitation (8 to 25 MeV). The angular distributions for all these structures are narrow and bell-shaped, and are peaked at a grazing angle determined from elastic-scattering measurements. Other qualitative features of the spectra are observed to be different from those seen at lower incident energies, e.g. (1) the strong excitation of high-spin fragments, which are only weakly populated at low-bombarding energies, and (2) the preferential population of $j = \ell - 1/2$ rather than $j = \ell + 1/2$ states in the residual nuclei, whereas the opposite is observed at lower incident energies.

All of these effects are basically dynamical (rather than structural) in origin, and can be accounted for with a DWBA or semiclassical analysis. In particular, application of the DWBA to the (^{16}O,^{15}N) and (^{16}O,^{15}O) angular distributions at 315 MeV results in relative spectroscopic factors in excellent agreement with those obtained at lower incident energies and also with light-ion-induced single-nucleon-transfer reactions.

However, a serious discrepancy in the DWBA is found when the DWBA is applied to these reactions measured over a wide range of incident energies, with an energy-dependent optical potential for ^{16}O + ^{208}Pb elastic scattering from 104- to 315-MeV incident energy. When the resulting DWBA predictions, together with light-ion spectroscopic factors, are compared to the data, the DWBA is seen to overestimate the transfer cross sections by a factor of 5 to 10. A possible explanation of the DWBA failure is that the basic premise of the DWBA — that each transfer process is a minor perturbation on the dominant elastic channel — may be violated at these high incident energies. This possibility is suggested by our earlier observation that in the interaction of 315-MeV ^{16}O with ^{208}Pb, about 30% of the total-reaction cross section goes into quasi-elastic processes. Specifically, the quasi-elastic peak in the 1-nucleon transfer cases has grown by about two orders of magnitude with respect to the single-particle states as the beam energy is increased from 104 to 315 MeV.

Nuclear Reactions for Analysis of Low-Z Elements in Aerosols,

S. S. Markowitz and M. Clemenson. Experiments have started on the development of the ^{14}N(p,α)^{11}C reaction for a sensitive, nondestructive means to determine by activation the total nitrogen in microgram to

milligram samples of atmospheric aerosols. The ^{11}C, a 20.4-min positron emitter, is measured with Ge(Li) detectors by its 0.51-MeV annihilation radiation. At low proton energy (6 MeV), few elements can interfere, and the potential interference of boron is negligible because of the extremely low amount of boron present in aerosol samples. This nitrogen determination is important, as existing methods of "wet chemistry" depend upon extraction of N-containing species, and such extraction may be incomplete. Combustion methods require milligrams of material and are destructive. Due to the low Z, methods based upon x-ray fluorescence are not applicable. Recent runs, in which melamine and $(NH_4)_4SO_4$ have been used as nitrogen standards, have shown excellent agreement at the level of 70 $\mu gN/cm^2$. The method looks quite promising.

184-Inch Synchrocyclotron

Absorbed Dose Rate Due to Neutrons in the Patient Treatment Area of the 184-Inch Synchrocyclotron, *R. Thomas, A. Smith, W. Schimmerling, and L. Kanstein.* Clinical trials are underway in which the 910-MeV alpha particle beam is used for tumor therapy. Although the staff at LBL's 184-Inch has considerable experience with small radiation fields as in the irradiation of the pituitary gland,[1] the present trials require uniform radiation fields as large as 30-cm diam. The production of such large, uniform radiation fields, with the desired depth-dose characteristics from charged-particle beams, requires the use of collimators, scatterers, and energy degraders. Neutrons produced at the edge of the collimators and in the energy degrader itself may be a source of patient exposure outside the treatment area, as may the scattering of neutrons produced within the tumor itself. Thus it is important, for example, to be able to estimate the neutron dose that might result to the lens of the eye of a patient receiving treatment of a brain tumor so that the probability of cataract induction might be estimated. Again, an estimate of neutron dose to the blood-forming organs would be helpful in assessing the risk of leukemia induction.

Rough calculations suggest that the patient dose outside the immediate treatment area is small.[2] Measurements made about a year ago confirmed these calculations and showed that the absorbed dose rate due to stray neutrons, just in the shadow of the collimator, was ~ 0.7% of the dose rate in the treatment field. The neutron-absorbed dose rate falls with distance from the treatment area: the dose rate at 0.5 meter from the treatment field is ~ 0.2% of the absorbed dose rate. Kanstein *et al.*[3] concluded that, "in a typical treatment to a brain tumor, the absorbed dose might total 2000 rads and the dose at the edge of the treatment area (e.g. lens of the eye) would be 14 rads. The corresponding whole-body dose would be about 4 rads."

A series of measurements are underway to refine these measurements of Kanstein *et al.* in the following respects:

- Measurements that will enable the stray neutron spectrum to be determined are being made. In particular, measurements are being made of the neutron component with energy above 50 MeV by using a bismuth fission counter.

- The sources of scattered neutrons have been identified and their relative magnitude measured. This knowledge will facilitate beam design and permit the efficient use of patient shielding should it be required by the radiotherapist.

- Measurements of the neutron production in tissue (water) will be made to determine the absorbed dose due to neutrons very close to the edge of the treatment area.

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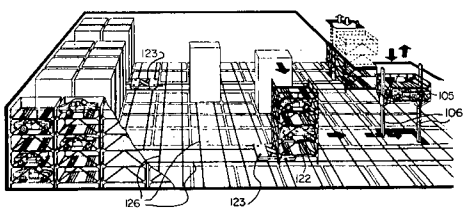
[1] J. Lawrence and C. Tobias, Ann. Int. Med. 62, (2) February 1965.

[2] R. H. Thomas, Some Preliminary Thoughts Concerning the Dose to the Lens of the Eye During Tumor Therapy, Health Physics Dept. Note, HPN #42, July 22, 1975.

[3] L. L. Kanstein, A. R. Smith, and R. H. Thomas, The Absorbed Dose Due to Neutron Contamination Around the Periphery of the Alpha-Particle Beam of the 184-Inch Synchrocyclotron, Health Physics Dept. Note, HPN #37, September 5, 1975.

Irradiation Effects on Mouse Testes, *E. Alpen.* Young adult male mice were exposed to several doses of the helium-ion beam on the plateau and midpeak of the extended Bragg curve. Four weeks later the testes of the irradiated mice were removed and weighed. Testicular atrophy was determined in terms of testes weight decrease as a function of dose.



3,987,912
MOVABLE VEHICLE PARKING TOWERS

Advanced Accelerator Studies

ESCAR

General and Plant

Additional office space in Building 46 has been completed. Most personnel for PEP and ESCAR have now been consolidated in the area of Buildings 58-47-46, with central offices and services in Building 47, as before.

Work is in progress on the installation of the heavy floor slab extension at the north end of the Bevatron external beam hall. Under-slab and around-slab piping, ducting, and conduit work is also in progress. The ESCAR control room complex in Building 64 has been cleared, cleaned up, and framed for space partitions.

A preliminary proposal covering this Laboratory's possible contributions to studies of inertial fusion (pellet fusion) with heavy ions has been submitted to ERDA. As part of this proposal, the contributions that could be made by ESCAR were outlined, with a recommendation that the schedule for ESCAR's completion be advanced to make it more timely for the inertial fusion work.

A layout of the ESCAR site area, with all known tanks, auxiliary equipment, piping runs, access, etc. is being drawn up. The area will be fully and densely utilized.

Ring Magnets

Design. The design for a complete quadrupole magnet and cryostat is now being correlated and firmed up in a series of weekly meetings of those involved. Vendors are still working on a satisfactory superconducting "Rutherford" Cable.

Dipole Tests. The first production dipole ESD-1, complete with production cryostat and iron shield, has undergone a series of tests in the Building 58 test facility. As reported earlier, the cryostat has heat leakage that is satisfactorily low. Ramped current losses were also low. However, this magnet exhibits a large amount of training and an associated training-and-field — dependent sextupole field component. There is evidence that the coil structure is moving slightly under magnetic forces, which may cause both the normal transitions of the superconducting windings and the field-dependent sextupole component.*

Between test series on this complete magnet, another production coil designated ESD-2, was trained with its compression rings in a vertical test cryostat. No measurements were made. ESD-2 reached essentially "short-sample" current of 2040 A in 21 transitions. It was then warmed to room temperature, re-cooled, and tested again. A current of 2130 A was reached in 8 transitions, showing that most of the training persisted through warm-up. An additional warm-up to liquid nitrogen temperature and back to 4.2°K did not cause any need for retraining. This coil assembly has also displayed evidence of conductor movement. The maximum central dipole field, without iron, is 41 kG.

At the present time it is believed that:

- Present production procedures and techniques can produce magnets with the required integrity and accuracy of conductor placement. Cryostats, supports, alignment

*We stopped the training program of ESD-1 at a central dipole field of 35 kG and a sextupole component of about 1.5×10^{-3} of the dipole field.

procedures, etc. are all satisfactory. At moderate fields, field strength and quality are as calculated.

- Present compressional constraint forces on coils are probable not high enough to prevent inelastic coil movement.

- Present coil assemblies are too compliant, resulting in elastic deformation under high field forces.

The following measures are being taken:

- To devise a more rigid structure, tests are being conducted on alternate materials and assembly procedures that are used in the coil restraint and insulation systems.

- The next coil to receive its compression rings, ESD-3, will have considerably more compression built into it by assembling a hot 150°C aluminum ring stack over a cold 77°K coil with small clearance. (Formerly the coil was at room temperature.) A novel, room-temperature, assembly technique based on the principle of a circular wedge, or inclined plane, may be used on ESD-3.

- The first two assemblies may be modified, depending upon the results of tests on ESD-3.

- ESD-4 windings have been completed but not assembled into a complete magnet.

Cryogenics and Refrigeration

The two screw compressors for the helium liquefier-refrigerator in Building 56 have been installed, as well as most of the heavy duty gas piping associated with them. Utilities to the building are being run in conjunction with the floor slab and conduit work.

The cold box is being assembled at Cryogenics Technology, Inc., Waltham, Massachusetts. Close liaison is resolving problems as they come up. Delivery is scheduled for April or May 1977.

Design detailing of the cryogenic distribution systems and the whole facility is progressing.

Vacuum Systems

A design note has been written describing the requirements of a high-vacuum beam-line valve with low beam impedance. Such valves will be needed for sector isolation in ISABELLE and PEP as well as in the ESCAR ring. Possible manufacturers are being sought.

PEP

General

We have further explored and defined the range of flexibility required for PEP beam dynamics, and the quadrupole power supplies and cabling have been sized accordingly. Within the present design, we can increase the tunes of the machine up to about 25, permitting PEP operation up to 18 GeV. The beam dynamics also allow a variation of the eta function at the interaction point so that the strength of synchrobetatron resonances can be minimized. We also want to keep the values of the betatron functions at the interaction point flexible. Low beta values maximize the luminosity as well as the sensitivity of the beam to magnetic field and alignment errors. It is because of this sensitivity that a large betatron function will be used at the interaction point during initial operation of the machine. As our

understanding of the beam behavior improves, the betatron functions can be lowered to the design values.

A decision has been reached on how best to separate the beams at the interaction point during injection. Although rf magnetic separators are preferable in that they reduce higher-order-mode losses, technical problems inherent in the design outweigh the advantages; so instead, we will use electrostatic fields, generated by a voltage of ± 120 kV on a pair of 5-m-long plates on either side of the interaction region.

Magnets

The main-ring dipole lamination die is complete and sample laminations have been accepted, but punching of the laminations for the engineering model is delayed until the steel arrives in early December. Laminations will be punched from steel presently on hand so that a shortened model can be available by the end of November for mechanical evaluation of the present dipole design.

Construction of the stacking fixture for the main ring quadrupoles is being done outside due to the high work load in our shops. Everson Electric in Allentown, Pennsylvania was the successful bidder for the quadrupole coil bid package, with a unit coil cost of $750 compared to our estimate of $749. Deliver is scheduled for 1 March 1977.

Design of the equipment for quadrupole magnetic measurement is under way. The computer that will operate the system has arrived, and the software is being developed.

Support stands will consist of a box beam girder supporting two bends, a quadrupole and a sextupole — a design favored over the open frame concept for its greater torsional rigidity. An engineering model will begin construction in November.

Orders have been placed for fabricating the precision die-set and for punching the laminations for the Mark II insertion quadrupole engineering model. The POISSON computer program predicts a theoretical field quality for the final pole contour of considerably better than 10^{-4} ($\Delta B/B$) over the required field region. Coil-winding fixtures are being fabricated, and completed drawings for the Mark II coils and potting molds will be released for fabrication shortly.

Beam Transport and Injection

Both PEP and PETRA have the problem of removing heat produced by eddy currents in the thin conducting liner of the kicker magnets. PETRA's solution is to form the conducting liner by firing a metallic layer at high temperature onto the inner surface of the ceramic vacuum chamber. A local supplier is providing sample metallized pieces for resistivity tests at PEP so that we can evaluate this solution.

TRANSPORT computations have shown that positioning three of the pulsed quadrupoles in the last three 6-inch gaps between the 40-foot linac sections and the fourth between the linac and the pulsed switch magnet will be suitable for matching the nominal linac beam into the PEP beam-transport line. Engineering calculations on the 5.4-m bend magnet are complete and final layout has begun. Coil construction for the engineering model of the injection quadrupole is in progress, and the core is out to bid.

Magnet Power Supplies

Because the integrated circuit chips for the pulse-width modulator have so far proven to be unreliable, we are designing a version with

discrete components to be tested. With the quadrupole and bend magnet requirements firmly established, the final layout of the power supplies in their buildings is under way. The mechanical layout of the ± 100 A trim supplies has been completed. Each chassis will occupy 10.5 inches of rack space, and will contain two separate bipolar units.

Vacuum

The cleaning tank bid package for the Chemical Cleaning Facility has been completed and is in the bid process, and the piping drawings and specifications should be complete and at Purchasing by November 5. Procedures for cleaning, leak checking, and assembling rf cavity sections are being written, as are detailed schedules concerning vacuum processing.

The desorption diode for electron bombardment of surfaces has been fabricated and is being assembled. Tests will be conducted to evaluate the effects of argon discharge on reducing the gas desorption.

Preliminary designs to reduce higher-order-mode losses in flanges and valves are complete with prototype fabrication scheduled to begin in November. Tapered sections that join rectangular to circular cross sections have been designed and await fabrication.

The 14-m extrusions produced by Kaiser are scheduled for production on November 8 and delivery at the end of November. A 7-m chamber for the evaluation of discharge modes has been fabricated and is currently being assembled. Tests to determine the ion current intensity per square centimeter will be conducted in November.

Radiofrequency System

The first research model of the PEP klystron used with the SPEAR collector developed a leak, and further tests on the two-cell cavity will be run with the spare SPEAR klystron, currently being rebuilt. Tuners are being cycled continuously to life-test the mechanical performance of the finger stock.

Detailed design and drawing packages have been completed for the shell, divider, and end-closure subassemblies of the five-cell engineering model cavity. Specifications are being written, and orders for materials and some subcontracted fabrication have been placed.

The experimental full-sized klystron has been baked out and is being prepared for testing.

A new method for phase-locking low-level drive and control is under development and will be tested on SPEAR.

Instrumentation and Control

The control computer RFP has been completed, and will be submitted to Business Services during the first week of November. Methods of establishing a remote-control link between the ion gauge heads and their control chassis are being evaluated so that the control chassis can be installed in the I & C huts.

The design of a digital delay unit is under way. This unit will be a fundamental building block in the PEP trigger system, and will provide delayed triggers synchronous to the PEP beam.

Survey and Alignment

Preliminary results of the PEP site survey have been received from the National Geodetic Survey, translated into the local PEP coordinate system, and transmitted informally to the architect engineer. This

trilateration network will form the basis for all ring location work for construction. Final results are expected within a few weeks.

Site, Building, and Utilities

General requirements for seismic design of structures are being prepared by PBQ & D/Kaiser (P/K) for a second review meeting on November 16th. Architectural studies of PEP structures are being prepared for review by Stanford University's Committee on Land and Building Development in November.

On October 14th, nine bids ranging from $440,707 to $471,000 were received for construction of the Vacuum Assembly Building and the Cleaning Facility. SLAC's estimate was $438,000. Low bid was submitted by M & H Construction, and contract award is scheduled for the first week in November.

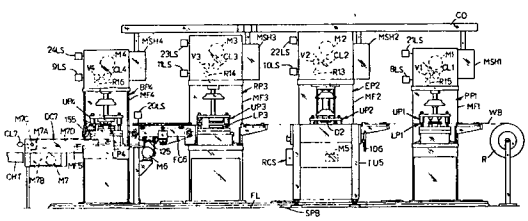
Experimental Facilities

The first meeting of the PEP Experimental Program Committee, held in September, dealt only with procedural and organizational problems since just one proposal has been received so far. Other proposals are not expected until the deadline, December 31, 1976.

The basic design of the experimental halls with a beam area and an assembly area has been well developed. A series of calculations and experiments is being carried out to determine the minimum shielding required. We should be able to choose from among the several designs already developed when the experiments are finished in early November.

We are continuing efforts to understand the fluxes of backgrounds for experiments at PEP. Several tools have been developed for studying both primary and rescattered synchrotron radiation fluxes and the flux of high-energy electrons so we can optimize the design of masks.

The first design for the Region 10 luminosity monitor has been developed. Further work on polarization continues with a proposed monitor at SPEAR to compare theoretical models with actual machine operation, which will allow us to extrapolate the polarization predictions to the PEP regime.



3,987,721
APPARATUS FOR MANUFACTURING AUTOMOBILE LICENSE PLATES

COMPUTER CENTER OPERATIONS

SYSTEM PERFORMANCE

September

7600 Availability 91.13%
Jobs processed 86,672

Turnaround time	20 min	2 h	4 h
Percent of Rush jobs returned	64.33	88.98	94.82
Percent of all jobs returned	66.45	85.22	90.94
Percent returned, CU limt ⩽ 100	68.51	89.91	94.00
⩽ 500	35.66	58.69	73.61
⩾ 1000	19.52	44.13	59.43

October

7600 Availability 83.53%
Median service interval*.... 3.70 h
Jobs processed 86,706

Turnaround time	20 min	2 h	4 h
Percent of Rush jobs returned	73.88	93.76	97.14
Percent of all jobs returned	72.91	88.75	93.17
Percent returned, CU limit ⩽ 100	75.96	91.26	94.53
⩽ 500	43.70	69.23	79.78
⩾ 1000	24.77	51.83	66.12

*A new line has been added to the above numbers (Median Service Interval). A service interval is the length of time the system is available for use between deadstarts, recoveries, or other interruptions of service. Median Service Interval is a more user-oriented measure than MTBI (the standard computer center measure in this area); it is also uniformly less flattering than MTBI. (Our MTBI for October, for instance, was a respectable 12.72 hours.) We do not consider the present number representative of acceptable service.

Once again the disks are the principal generators of interrupted service. During the past few months we have had cause to replace most of the mechanical portions of the disks. As a consequence, our outlook for the future is cautiously optimistic.

You will also note that "7600 Availability" took a sharp drop in October. This does not represent hardware difficulties, but reflects our provision of block-time to ERDA's high-priority MFE (magnetic fusion energy) program. (Inasmuch as block-time is not available to the general use, we have elected to consider it "not available" for the purpose of this report as well.)

Conference Activities

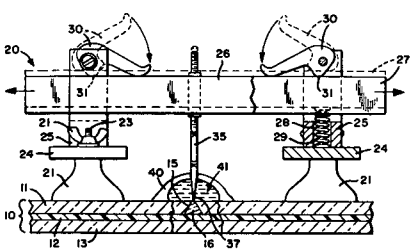
A number of Computer Center staff members attended the Fall AESOP/SCIE and VIM conferences. VIM is the international users group for large-scale Control Data computers, while AESOP/SCIE is an information exchange among computing folk from ERDA Headquarters, field offices, and contractor installations. Bob Harvey of LBL, a member of AESOP's Executive Committee, served as program chairman for the AESOP conference. Bob Fink also described his CDC/IBM Channel Adaptor (see below) at this conference. (His talk is available as LBL-5514.)

We also did our semiannual turn at RUM-V, the fifth Remote User's Meeting for users of the LBL computing facility. A dozen sites were represented, and more bouquets than brickbats were thrown.

CDC/IBM Channel Adaptor

LBL has developed hardware and software subsystems to allow the use of IBM plug-compatible peripherals on the CDC 6000/7600 systems installed at the Computer Center. This will provide LBL with the ability to replace our present unsatisfactory tape drives and controllers with more reliable IBM plug-compatible counterparts. It will also open up to LBL the intensely price-competitive market for plug-compatible disk drives and controllers and for new mass-storage devices.

The first step of this development (operational in November 1976) will provide a 6250 BPI tape facility to support the LBL experimentors at SLAC. (They currently have to transcribe a 6250 BPI reel at SLAC onto as many as five 1600 BPI reels for transport to LBL.) This 6250 capability should help to smooth the path towards effective LBL/SLAC collaboration on the PEP project.



3,988,400
METHOD OF REPAIRING CRACKED WINDSHIELDS

DATES TO REMEMBER

November	1	Biomedical Section of the Bevatron/Bevalac Program Advisory Committee meets.
	19	SPAC meeting to consider proposals for experiments at SuperHILAC.
	25,26	Thanksgiving, an LBL holiday.
		Accelerator holidays. Operations resume November 29.
December 11 - January 2		Christmas shutdown (3 weeks).
December	24-27	Christmas, an LBL holiday.
	31	New Year's, an LBL holiday.
	31	Deadline for submission of proposals for experiments and facilities requiring long lead time for PEP. Those proposals received before December will be made public, and Studies and Workshops on the proposals will be held.

1977

January	21	PEP Experimental Program Committee meeting.
February	17-19	Combined Bevatron/Bevalac and SuperHILAC Users meeting.
	21	President's Holiday, an LBL holiday.
	24,25	Open presentation of PEP proposals.
May	30	Memorial Day, an LBL holiday.

Inset drawings from Official Gazette of the United States Patent and Trademark Office.

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This report was done with support from the United States Energy Research and Development Administration. Any conclusions or opinions expressed in this report represent solely those of the author(s) and not necessarily those of The Regents of the University of California, the Lawrence Berkeley Laboratory or the United States Energy Research and Development Administration.

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