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Vol. 1 No. 2

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RESEARCH/ACCELERATORS

Bimonthly Status Report of Operations

Vol. 1 No. 2 March, April 1976

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CONTRIBUTING DIVISIONS

Accelerator

Biology and Medicine

Nuclear Science

Physics, Computer Science, and Mathematics

COVER PHOTO: His Majesty the King of Sweden, Carl XVI Gustaf, visited LBL April 13 as guest of Glenn T. Seaborg, LBL Associate Director. While at the Laboratory the King was greeted by LBL Director Andrew Sessler and toured the Bevalac, the SuperHILAC, several experimental areas, and environmental displays. In the newly remodeled control room at the SuperHILAC Al Ghiorso describes the operation of the accelerator, illustrated by the model on the counter. Listening attentively are (from Ghiorso's right) Seaborg, Mr. Bjorn von der Esch, First Marshal of the Court in Sweden, the King, and a Protective Agent. (XBC-764-3438)

Research/Accelerators is published bimonthly and is a status report of operations of the contributing Divisions at the Lawrence Berkeley Laboratory, University of California, Berkeley. ** Contributions and comments concerning the report should be addressed to Mary Wildensten, Editor, Technical Information Department, LBL, Berkeley, CA 94720.
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RESEARCH NEWS

ELEMENT 104 CONFLICT BEING RESOLVED:

RUSSIAN PARTICIPATION IN NEW EXPERIMENTS AT LBL

In the continuing effort to clarify some of the uncertaintaies regarding element 104, Ivo Zvara, Russian chemist and member of the heaviest-element research team at Dubna, visited LBL to collaborate with the Ghiorso Group in experiments at the 88-Inch Cyclotron (Fig. 1). This Russian-American exchange of scientists in heaviest element research will continue with LBL's J. M. Nitschke's visit to Dubna in July of this year.

Collaborators

Scientists from three other laboratories were invited to join in collaborating on the new experiments to make sure that the results obtained would have the most careful scrutiny possible. Collaborating on this work were:

Oak Ridge National Laboratory,: R. J. Silva and C. E. Bemis- members of the Transuranium Research Laboratory.

Los Alamos Scientific Laboratory: M. Fowler- member of Radiochemistry Division, CNC-11.

Lawrence Livermore Laboratory: E. K. Hulet, Group Leader, Heavy Element Group; R. W. Lougheed, J. F. Wild, and J. H. Landrum - members of

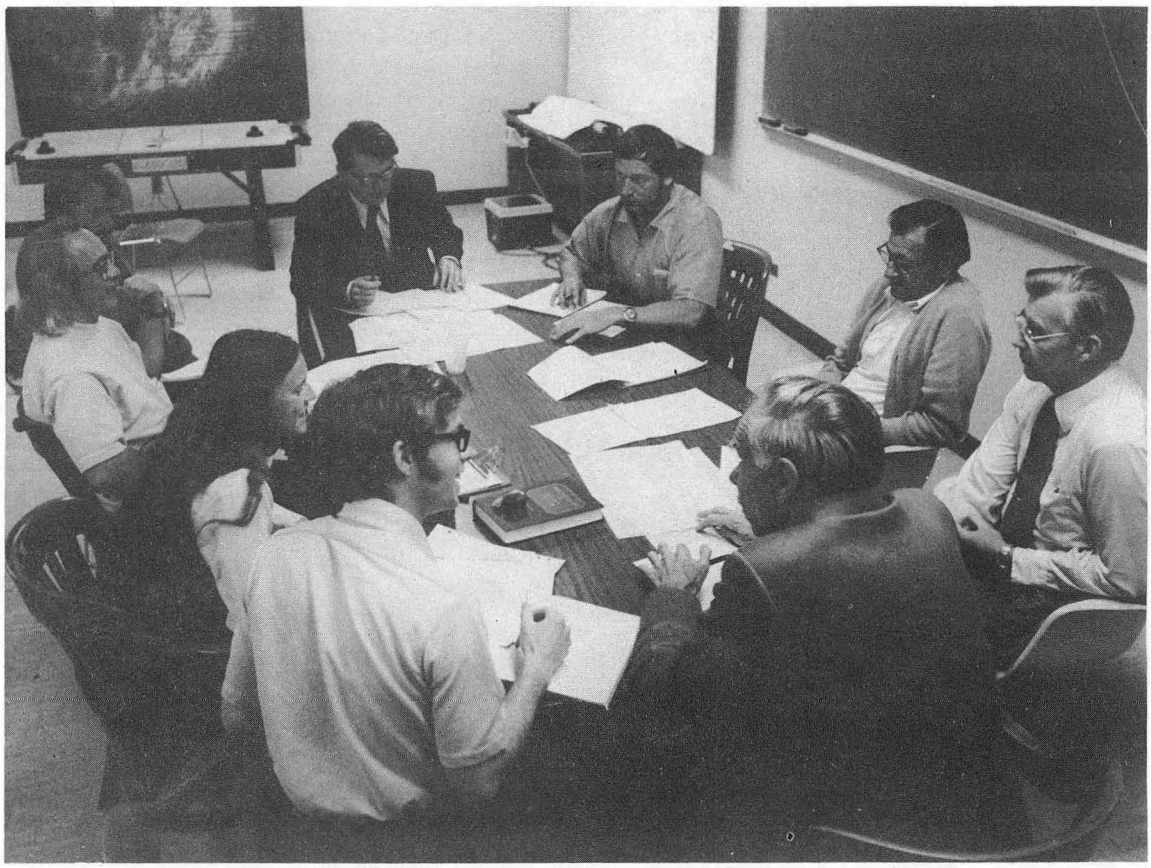


Fig. 1. Discussing the upcoming collaborative experiment to clarify uncertainties regarding element 104 are (clockwise from the top) Ivo Zvara from Dubna, Mike Nitschke, Al Ghiorso, Earl Hyde, Glenn Seaborg, Patrick Somerville, Kimberly Williams, Robert Silva from Oak Ridge and Eric Leber. (XBB-765-4125)

the Heavy Element Group.

Lawrence Berkeley Laboratory: A. Ghiorso, P. A. Baisden, I. Binder, R. E. Leber, D. M. Lee, D. J. Morrissey, J. M. Nitschke, M. J. Nurmia, R. J. Otto, L. P. Somerville, K. Thomas, and K. E. Williams.

G. N. Flerov et al. reported (1) in August of 1964 the synthesis (by way of a $^{22}Ne + ^{242}Pu$ reaction) of a spontaneous fission activity, which they attribute to the mass number 260 of element 104. Through spontaneous-fission fragment detection with phosphate glass plates, they found a half life of 0.3 ± 0.1 seconds for this nuclide; however, LBL researchers, A. Ghiorso, M. Nurmia, and J. Harris (2) were unable to confirm such an activity. In April of 1969 this LBL group published (with K. Eskola and P. Eskola) a report (3) on the alpha-emitting isotopes 257 and 259 of element 104. Produced in ^{249}Cf $(^{12,13}C,xn)^{257,259}104$ reactions, these alpha emitters were identified by the Berkeley team through direct alpha spectroscopy and genetic relationship (correlated decay) of the ^{253}No and ^{255}No daughters.

Description of present experiment

The current research at the 88-Inch Cyclotron attempts to reproduce the 1964 Dubna findings by bombarding ^{249}Bk and ^{246}Cm targets with ^{15}N and ^{18}O beams, respectively--reactions which are expected to yield the $^{260}140$ isotope in relatively higher production cross sections than the $^{22}Ne + ^{242}Pu$ process. (The targets were prepared by K. Hulet and co-workers at LLL.)

Because the transfer products ^{256}Md ($T_{1/2}$ = 1.3 h) and ^{256}Fm ($T_{1/2}$ = 2.63 h) contribute a significant spontaneous-fission background, in order to improve the detection limit for possible element 104 isotope(s) a sophisticated rotating-drum target assembly (shown in Fig. 2) has been

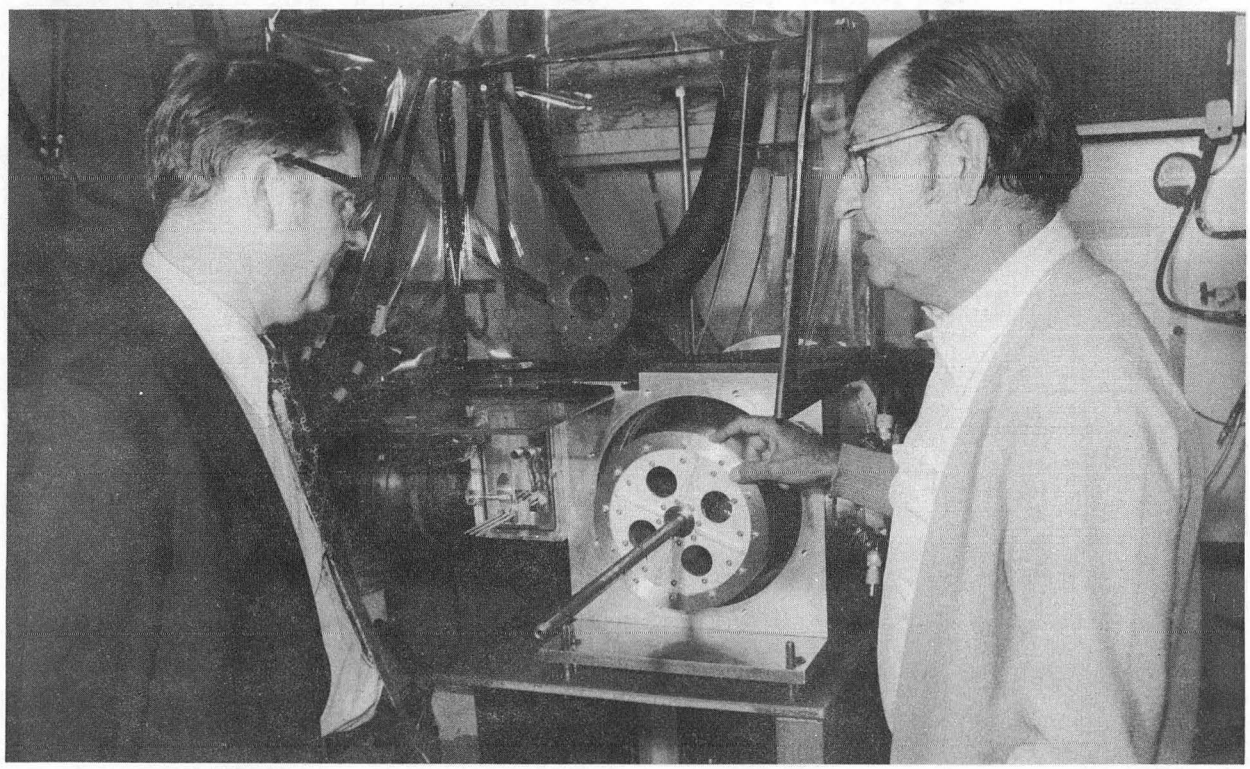


Fig. 2. Al Ghiorso discusses with Ivo Zvara from Dubna how spontaneous fission activitity will be detected for characterizing element 104. (XBB-765-4123)

constructed through the joint efforts of LBL and LLL. By "scanning" the drum (that is, moving it in a lateral direction, transverse to the beam) the longer-lived ^{256}Fe activity will be broadly distributed over the drum surface, thereby enhancing the shorter-lived ($T_{1/2} < 1$ second) spontaneous-fission component. The fission fragments are registered in 15 mica plates (5 cm x 3.1 cm) located in a ring about the drum. At the end of irradiation, the micas are removed from the target assembly, etched in hydrofluoric acid, and examined microscopically for fission tracks. From the spatial distribution (a function of time) of these tracks, the time dependence (half life) of the decay may be determined.

Results

Our recent experimental search for an 80-ms spontaneous-fission radioactivity (attributed by the scientists at the Dubna Laboratory to $^{260}104$) has been completed. Analysis of the data is continuing, but no evidence has been found for the 80-ms fission decay observed by the group at Dubna. The formation rate of such an activity, were it to exist, has been found to be at least ten times less than that reported by Dubna and the divergence from the theoretical value is even greater.

We hope these experiments will eventually resolve the disagreement arising from conflicting claims for the discovery of element 104.

1. G. N. Flerov, Yu. Ts. Oganesyan, Yu. V. Lobanov, V. I. Kuznetsov, V. A. Druin, V. P. Perlygin, K. A. Gavrilov, S. P. Tretiakova, and V. M. Plotko, At. Energy (USSR) 17, 310 (1964). [Translation: Sov. J. At. Energy 17, 1046 (1964) and Phys. Lett. 13, 73 (1964).]

2. A. Ghiorso, M. Nurmia, and J. Harris, UCRL-18714, 1969.

3. A. Ghiorso, M. Nurmia, J. Harris, K. Eskola, and P. Eskola, UCRL-18819 and Phys. Rev. Lett. 22, 1317 (1969).

Particles in the Spring

The office in Trilling-Goldhaber's Group is alive with talk of particles. Those of immediate interest are these biological particles that emerged with the help of their mother dove just in time for May Day. Talk of physical particles is being bandied about but so far not all are hatched.

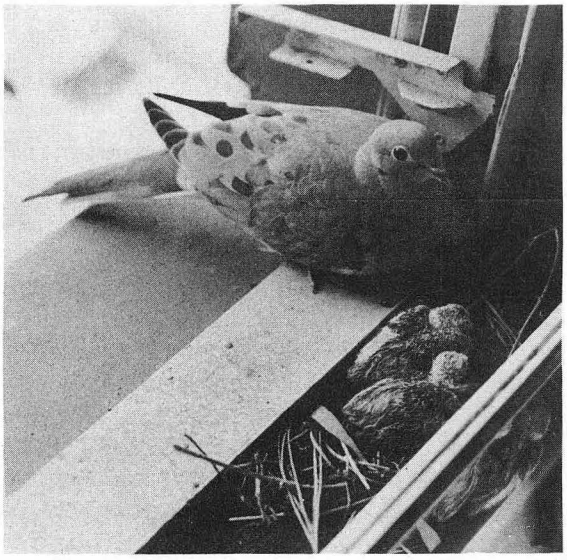


Fig. 3. Spring particles (XBB-765-4127)

New Particle States

The results discussed below are summarized from an invited talk, "Recent Results on the New Particle States Below 3.7 GeV Produced in e^+e^- Annihilations," at the International Conference on Production of Particles with New Quantum Numbers, University of Wisconsin, Madison, April 22-24, 1976. These findings

come from the SLAC-LBL magnetic detector experiment at SPEAR. The new features that give rise to what is "recent" in these results are the following:

(i) Additional running at SPEAR in Fall 1975 and Winter 1976 has increased the integrated luminosity at the Ψ and Ψ' each by about a factor of three. The total hadron sample studied here is approximately 150,000 events at the Ψ and 350,000 events at the Ψ'.

(ii) The new running was carried out with a "relaxed trigger requirement." This allowed triggering on lower momentum particles.

(iii) The magnetic detector was used as a γ-ray pair spectrometer. By inclusion of the proportional chambers in track reconstruction, the measurements were pushed to lower electron or positron momenta.

(iv) By improved geometrical correction and the application of bubble-chamber kinematical fitting programs, a higher mass resolution of the χ states, intermediate between the Ψ and Ψ', was obtained.

Three distinct χ states were identified: $\chi(3415)$, $\chi(3500)$, and $\chi(3550)$. For the $\chi(3415)$, which is the most prominent, the following decay channels were observed: $4\pi^{\pm}$, $3\pi^{\pm}$, $2K^{\pm}$, $6\pi^{\pm}$, $2\pi^{\pm}$, or $2K^{\pm}$, and $2\pi^{\pm}p\bar{p}$. The γ angular distribution is consistent with $1 + \cos^2\theta$. This distribution combined with the observed decay mode $\chi(3415) \rightarrow 2\pi^{\pm}$ or $2K^{\pm}$ indicates $J^{PC} = 0^{++}$. The other two χ particles (3500 and 3550) are resolved in the first two decay modes, but not in the $6\pi^{\pm}$ decay mode. There is some evidence that $\chi(3550)$ also decays into the $2\pi^{\pm}$ or $2K^{\pm}$ mode.

From a study of the e^+e^- pairs resulting from converted γ rays, the process $\Psi' \rightarrow \gamma + \chi(3415)$ was observed. The branching ratio for this reaction is 8.5±4%.

Finally, we have observed the reaction $\Psi' \rightarrow \gamma\gamma\Psi$ with the conversion of one of the γ's into an electron pair and the decay of the Ψ by either the $\mu^+\mu^-$ or e^+e^- mode. While in the earlier work[1] only the P_c was observed, we now find evidence for three distinct states at 3455 MeV, 3505 MeV, and 3545 MeV. The first of these does not show any measurable hadronic decay, while the last two can be associated with the χ's mentioned above. Taken all together, we thus have evidence for four distinct intermediate states between the Ψ' and Ψ. While we do not have spin parity assignments for all these states as yet, there is a resemblance with the qualitative features of the charmonium model. The latter predicts the following four states that can be reached by radiative transition from the Ψ' in this energy region: three P states $^3P_0$, $^3P_1$, and $^3P_2$, as well as a $^1S_0$ state.

- G. Goldhaber

1. W. Tanenbaum, J.S. Whitaker, et al., Phys. Rev. Lett. 35, 1323 (1975).

A Photon Target?

One of the most interesting discoveries that has come from the fragmentation experiments (EXP 162H) carried out by the Heckman group at the Bevalac is the observation that in certain types of nuclear collisions the target appears to the beam nucleus not as a bag of nucleons, but as a bag of photons. The consequence of this fact is that the beam nucleus, a 2.1-GeV/n ^{16}O for example, can be fragmented into smaller, secondary nuclei by the process of photodisintegration.

This mode of nuclear disintegration is in addition to the direct, catastrophic fragmentation by nuclear collision.

The photodisintegration of beam nuclei in heavy targets, such as Pb, comes about by a relativistic effect independently predicted by Mssrs. Weizsächer and Williams in 1934-35. Weizsächer and Williams showed that, in essence, the Coulomb field of a relativistic (high-energy) particle (i.e., the field associated with the electric charge) appears to an observer as a pulse of quasi-real photons. This pulse contains quasi-photons with a broad spectrum of energies, up to 100 MeV and above. Now, if you imagine yourself as riding on a 2.1-GeV/n heavy-ion beam from the Bevalac as it passes through a Pb target (we choose a Pb target since the number of the quasi-photons increases as Z^2 [=(charge)^2] of the Coulomb field), the Coulomb fields of the Pb nuclei, which seem to you to be moving at beam velocity, appear as pulses of electromagnetic radiation. Whenever a collision takes place, it is possible that the beam nucleus interacts with a quasiphoton, which thereby becomes a "real" photon, producing a photonuclear reaction. A consequence of this reaction is that the beam nucleus may be excited to such an extent that it emits a nucleon, i.e., a neutron or a photon, or, in some instances, two nucleons.

Although the phenomenon of "photon-targets" has only recently been observed, new experiments are being planned to verify further the effect and to extend the scope of the experimental measurements. Most intriguing is the possibility that the "photon-target" technique can be exploited to develop a new approach in the study of photonuclear physics. Even though these further experiments are only in their planning phases, the prospects for new contributions to a well established field of nuclear physics are good indeed. This is but one of the important scientific spin-offs that have, and surely will, come from Bevalac research.

- H. Heckman

Particle Transfer Between Heavy Ions

K. Pruess, G. Delic, L. A. Charlton, and N. K. Glendenning are investigating an effect which they believe may account for one of the two types of anomalies that are appearing in many experiments on particle transfer between heavy ions.

If two nuclei could be placed next to each other at a distance typical of grazing collisions, the single-particle states in each would adjust themselves to the presence of the other nucleus. They would develop an appreciable probability of being in the other nucleus, and the more weakly bound the state, the more strongly it would be polarized by the other nucleus. The solution to this situation has been realized in the two-center shell model. Whether such an adjustment can occur during a reaction depends on the ratio of the transit time to the nuclear periods of the more weakly bound nucleons. In typical low-energy experiments this ratio appears to allow for such a polarization. Clearly if it occurs, the form factor for a transfer reaction will be modified from those currently employed, which use the asymptotic single-particle states of the non-interacting separated nuclei. From the foregoing discussion we expect that (1) for stripping reactions to a sequence of excited states in

the target nucleus, the polarization effects will increase with increasing excitation (i.e., decreasing binding); (2) since transfer can take place for larger impact parameters if polarization occurs, the effect on the angular distribution will be a shift to smaller angles compared to normal DWBA; (3) the polarization effect will ultimately vanish at sufficiently high bombarding energy. We have found from calculations so far that the single-particle states of the heavier of the reaction partners suffer the greater polarization.

- N. Glendenning

Prototype Liquid Level for PEP

Richard Sah, LBL's Group Leader of the Survey and Alignment Group for PEP, checks the 200-foot prototype liquid level set up in Building 58 here at LBL. To gain this length, the line is doubled on itself, so that the two water wells side by side are the beginning and the end of the line. The line above the water wells is the vapor return system. The lower line carries water, which is the reference liquid used to establish the level. By rotating a micrometer, Sah drops a needle in the water well against the surface, and the ohmmeter shows when contact is made (Fig. 4).

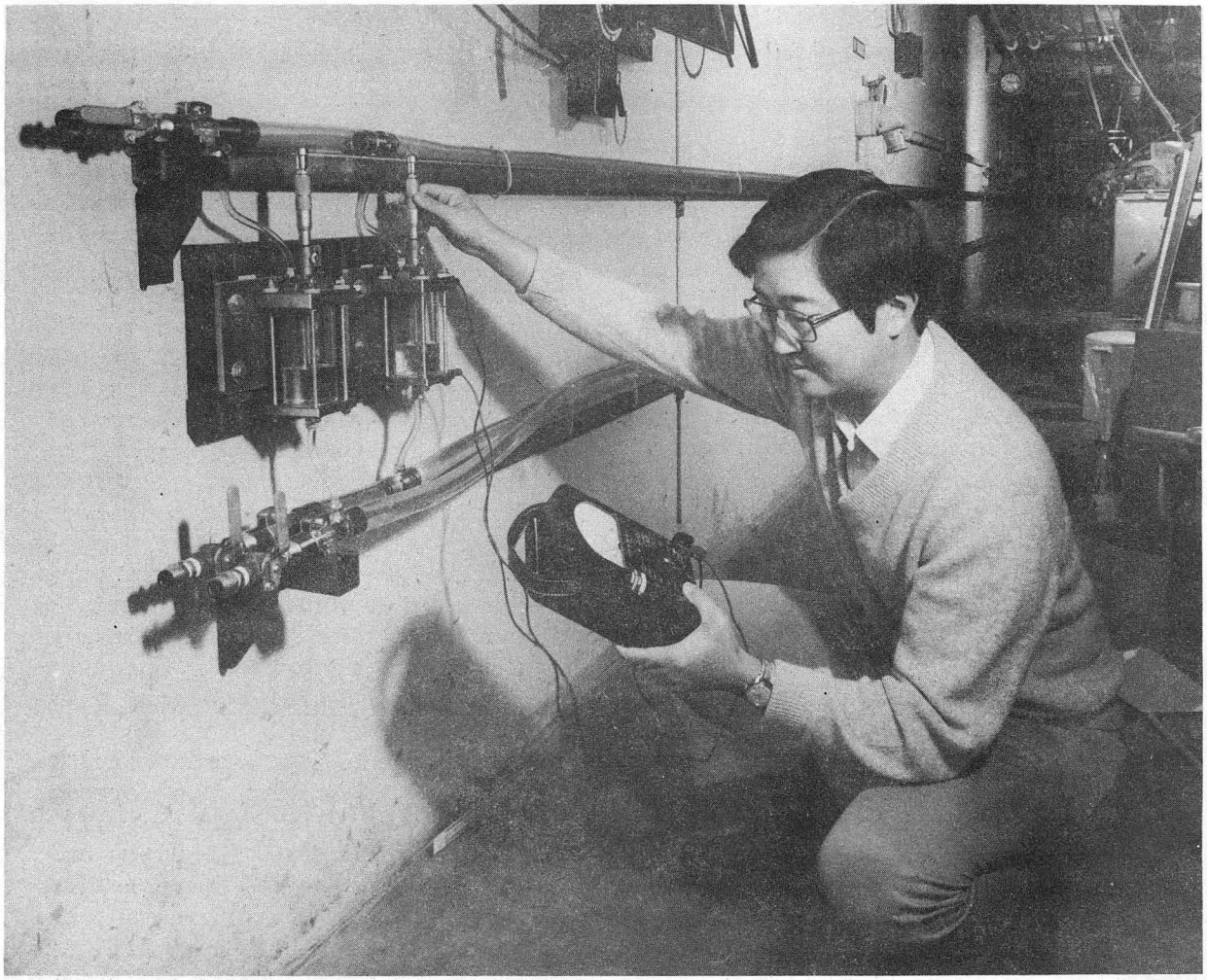


Fig. 4. Richard Sah and the prototype liquid level that will provide vertical alignment in the PEP ring. (XBB-764-3694)

This system, simple in concept, has not been used elsewhere because of the system's inherent susceptibility to errors caused by variation in temperature, air pressure, earth tides, and the surface tension of the water. Sah feels that the system as it presently exists has demonstrated that it is adequately insensitive to these sources of error.

As the tunnel advances around the PEP ring, so will this water-filled line. It will be used for vertical alignment and will have a tolerance of about 0.1 mm.

The attachment, seen on the floor in the ohmmeter's shadow fits atop the knurled knob Sah is holding and is used for conventional survey procedures.

Computer Codes for Magnet Evaluation

Two new computer codes for 2D magnet evaluation have been developed by a cooperative effort between LBL (K. Halbach) and LASL (R. F. Holsinger).

RIPPLE is a code for evaluation of ac eddy-current effects in solid-core magnets. It is derived from the magnet evaluation code POISSON by introducing and using appropriately complex vector potentials and boundary conditions. RIPPLE can be used to calculate magnetic fields caused by sinusoidal excitation of a solid-core magnet. These fields are an adequate representation of real fields if the excitation amplitude is small and the frequency is large enough so that the skin depth in the steel is small compared to the appropriate scaling length of the magnet. Computer runs confirm the theoretical prediction that ac power-supply ripple leads to ac fields that can be worse in a solid-core magnet than in a laminated magnet of the same dimensions.

DIRECT is a new 2D magnet evaluation code that is a modified version of the irregular triangular mesh code POISSON, which in turn is a descendant of Winslow's TRIM program. Following C. Iselin's (CERN) lead, the over-relaxation method for solving the field equations has been replaced by a direct, noniteration method, and the old description of the properties of the steel by H/B has been amended to use also dH/dB. It takes typically less than ten iterations on the nonlinear steel properties to obtain a solution. While this code saves little if any computer time on problems that converge rapidly with the over-relaxation code, it solves with equal ease problems that converge very poorly with the over-relaxation method, and can solve some problems that cannot be solved at all with POISSON. In the latter class are problems requiring a B-H curve that goes into the second quadrant, allowing now treatment of permanent magnets, remnant field distributions, etc. The code has not yet been coupled to the optimization code PISA, nor has a cylindrical version been written. A comparatively small modification of the program will allow evaluation of some small-amplitude, slow eddy-current effects in solid-core magnets.

PEP Policy Committee

It has been proposed by SLAC, LBL and SLUO representatives (including the SLAC and LBL Directors) that a PEP Policy Committee (PPC) be created. Its main roles would be to monitor the progress of PEP, to advise the Directors on policy questions and to report through the appropriate advisory committees to the Presidents of Stanford and

UC. (The closest analogy is the role of the SPC at SLAC). Official approval of the PPC by the University Presidents is expected in the very near future.

Some guidelines for the PPC as recommended by the SLAC, LBL and SLUO representatives are:

1. The PPC should advise the Directors of SLAC and LBL and should inform the Scientific Policy Committee (SPC - SLAC) and the Scientific and Educational Advisory Committee (SEAC - LBL) on all policy matters, users' relations and the developing and functioning of the PEP facility.

2. The PPC should be an active working committee.

3. The PPC should be national in character and its composition should be determined roughly as follows:
   2 members nominated by SEAC;
   2 members nominated by SPC;
   2 members nominated by SLUO;
   4 members nominated by the SLAC and LBL Directors.

The four nominations by the SLAC and LBL Directors were thought to be desirable as a means of balancing the composition of the PPC in regard to areas of special competence and appropriate regional representation.

SLUO has been actively advocating the creation of the PPC and feels that it will provide a valuable link to users to insure that the interests of the user community are served. It will be especially important in PEP's formative stage, as the administrative and programmatic structure is worked out. The PPC will, for example, likely advise the Directors on such topics as schedule deadlines for first-round facility and experiment proposals; how many interaction regions will contain facilities; how facility support groups will function; techniques to facilitate user involvement at PEP; how the Experimental Program Committee (which will recommend on specific facility and experiment proposals) will be structured; how Federal money for user activities at PEP should be handled, etc.

- PEP News

Cancer Myths Exposed

In the control room at the 184-Inch Synchrocyclotron, radiotherapist Joseph Castro observes the scope as he monitors simulated therapy of a patient in an adjacent treatment area. The technicians in the foreground are part of the camera crew from KGO-TV, San Francisco, who spent three days filming at LBL for a one-hour documentary on cancer treatment that will be shown in June. The film, entitled, "I used to have cancer," will expose to the light of present-day knowledge the myths that cancer cannot be treated and cannot be cured. The program will feature a number of cancer treatment studies underway at LBL: Castro will discuss how patients are treated at the 184-Inch for brain tumor conditions that require the use of large-field helium-ion irradiation. Films taken at the Bevalac will show pathologist Kay Woodruff discussing pretherapeutic studies of heavy-ion irradiation in which animals are used (Fig. 5).

Accelerator User Handbooks

Long awaited user's handbooks for researchers at the Bevatron/Bevalac and the SuperHILAC will be available in early summer. The Bevatron actually has two handbooks: "Bevatron/Bevalac User's Handbook: Nuclear Science" and one subtitled "Biology and Medicine."

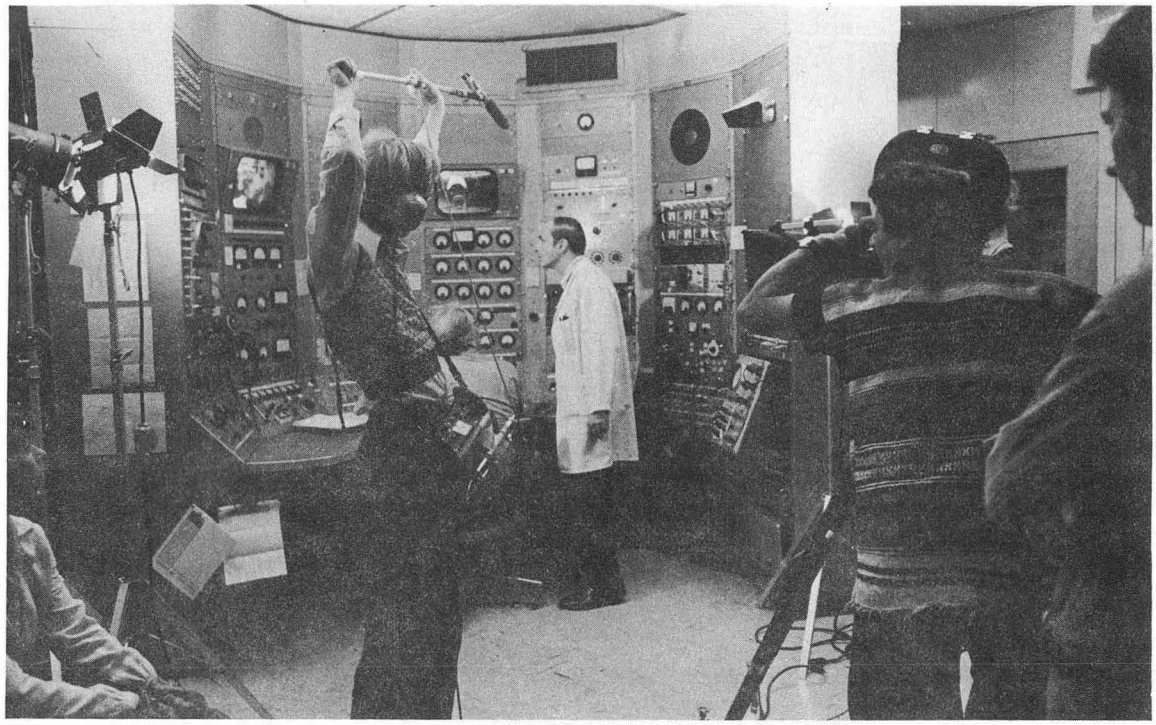


Fig. 5. The film crew from KGO-TV, San Francisco records the sights and sounds while radiotherapist Joseph Castro monitors the patient and operator James MacMullen monitors the accelerator. (XBB-764-3833)

Members of the Bevatron/Bevalac Users Association and the SuperHILAC Users Association will be sent postcards which must be completed and returned to receive a handbook. Where several members of a research group are involved in research at LBL accelerators, please request the fewest handbooks necessary to serve the group's needs.

Other requests for handbooks should be directed to the Accelerator Research Coordination Office, ext. 5185.

SuperHILAC and Bevatron July Shutdown

This year an unfortunate combination of circumstances has compelled us to schedule a shutdown of the SuperHILAC and the Bevatron in July. We are aware of the importance of the summer months to academically-based experimenters, and in the past have avoided summer shutdowns as much as possible.

The circumstances that have caught us this year are:

1. July through September are separately funded as an interim fiscal year at ~26% of FY76. This is not enough to run for 3 months, and the beginning of a new fiscal year in October precludes borrowing from the future.

2. Extensive modifications to the experimental facilities and the computer control system are presently being made. At the end of April we will bring the system back into operation. We plan to run an experimental program as soon as the machine and one beam-line are debugged, continuing debugging of other lines parasitically. For this program to function it is essential to achieve routine running soon after installation in order to more easily trace

assembly errors. Therefore, we planned an operating period in May and June.

3. Our staffing is now so slender that we do not have vacation backup; consequently, if vacations are spread over the three summer months, operation will probably be poor, as indeed it was last summer. Hence, to maximize good running time, we have asked all the crew to take vacation in the month when most of them traditionally have done so in the past, namely July.

In the future, we shall schedule as much operation as we can during the summer months. The first two of the three circumstances above will not apply next year. However, the third will unfortunately still be with us, restricting our range of choices, but not ruling out some improvement of schedule next year. We would appreciate hearing any of your ideas concerning the summer schedule for next year.

- E. Lofgren

LBL Nuclear Scientists at the ACS Centennial Meeting

Glenn Seaborg presided at the American Chemical Society Centennial Meeting held in New York City on April 4-9. He presented the keynote address on "Milestones in Nuclear Chemistry" at the Division of Nuclear Chemistry and Technology Symposium on Monday morning, April 5. His talk was followed by the Award Address "Breaking the Codes of Nuclear Rotational Patterns" by *John Rasmussen*, recipient of the 1976 ACS Award for Nuclear Application in Chemistry. That morning session was concluded with a talk by Vitalii Goldanskii, an ACS foreign fellow from the Soviet Union who last month spent a week in the Bay Area with his wife Mila.

On Tuesday, April 6 the Division of Nuclear Chemistry and Technology held a symposium on Nuclear Chemistry: Past, Present and Future. *Frank Stephens* spoke on the Development of Nuclear Structure, *Dave Shirley* on Looking Outward from the Nucleus, and *Art Poskanzer* on the Status of the NAS Panel on the Future of Nuclear Science.

An Award Symposium for *John Rasmussen* was held on Thursday, April 8. It was organized by former LBL nuclear chemist *Dave O'Kelley*. The symposium featured talks by present staff *Dick Diamond*, former Berkeley graduate students *Ken Toth* and *Dick Chasman* and former LBL research visitors *John Huizenga*, *Tom Sugihara* and *Ray Sheline*, among others. *Rasmussen's* award was presented at a banquet on April 6, the citation reading "...for his leading research on alpha decay and gamma spectroscopy, in particular the elucidation of the effect of pairing interaction on alpha emission, the generation of particle conserving paired wave functions, and his contribution to the understanding of decays and nuclear energy spectra in the region of collective excitations."

1976 PEP Conference

The Directors of LBL and SLAC have jointly announced the 1976 PEP Conference, which will be held at SLAC June 23-25. At this open meeting, users are invited to discuss and review the development of detectors and experiments for PEP. Among the topics which will be discussed are the status of the PEP machine; plans for the experimental areas; review of detector plans developed in the 1974 and 1975 Summer Studies; and policy

on proposals, funding of equipment, and development facilities. The conference is being sponsored by SLAC, LBL, and the SLAC/LBL Users Organization.

To facilitate the conference arrangements, those who wish to attend are asked to notify the PEP Conference Secretary, Bldg 47, Lawrence Berkeley Laboratory, University of California, Berkeley CA 94720.

The 1976 PEP Conference, which is being held instead of a Summer Study, as in past years, is only one of many opportunities users will have to discuss and be involved in PEP planning. Meetings and workshops on specialized areas will take place in the months following the conference as individuals and groups generate proposals, which will be called for in June, to be due in December. Some of these meetings will take place under the guidance of the PEP Experimental Program Committee soon to be formed. Others will be promoted by the users themselves. Offices and meeting rooms will be provided so that these working meetings can take place near PEP where the PEP staff can be of assistance.

Third Summer Study on High-Energy Heavy-Ion Physics

The Third Summer Study on High-Energy Heavy-Ion Physics will be held at the Lawrence Berkeley Laboratory July 12-16. The subject of the conference is the physics of collisions between nuclei, from the threshold of supersonic high-temperature nuclear physics through the onset of liberation of mesonic degrees of freedom to the relativistic regime.

The program provides time for a few talks and much discussion. The talks devoted to experiments will summarize the facts as they exist today and indicate expected directions of new experiments. The aim of the theory talks will be to make as explicit as possible what are the observable manifestations of new processes, what laws of physics can be tested, what theoretical approaches are promising and their range of applicability.

The preliminary program lists the following speakers addressing experimental findings:

W. Walker or J. Loos (Duke U.), High-energy hadron-nucleus collisions; R. Stock (Marburg, Germany), Central collisions; H. H. Heckman (LBL), Peripheral collisions; D. K. Scott (LBL), Nucleus-nucleus collisions at medium energy; B. Povh (Max-Planck-Institut, Heidelberg), Prospects for ultra-high-energy collisions between nuclei. The following scientists will present talks on theoretical aspects: M. Byualassy (Frankfurt), Critical scattering of heavy ions at the pion condensation threshold; A. S. Goldhaber (Stony Brook), Application of high-energy concepts to nucleus-nucleus collisions; J. Negele (MIT), Time-dependent Hartree-Fock theory of collisions between nuclei; J. R. Nix (LASL), Relativistic nuclear fluid dynamics; J. Hüfner (U. Heidelberg), Application of Glauber theory to high-energy heavy-ion collisions; and a Primer on Monte Carlo knock-on cascade calculations.

Any participants who have recent results are invited to communicate with these speakers.

No proceedings of the conference will be published nor will there be a registration fee. Suggestions concerning the organization or program of the conference may be sent to the organizers:

N. K. Glendenning and L.S. Schroeder
c/o Summer Study on Heavy Ions
Lawrence Berkeley Laboratory
Berkeley, California 94720

Anyone interested in attending should contact the organizers for information, as arrangements are being made on a first-come, first served basis. Included in the plans is a trip by bus on Wednesday afternoon to the Napa Valley, the premier wine-growing area of California. A winery tour, wine tasting, and evening banquet will cap off the day.

Fifth International Conference on Atomic Physics

The Fifth International Conference on Atomic Physics will be held on the campus of the University of California at Berkeley, July 26-30, 1976. The Department of Physics and the Lawrence Berkeley Laboratory will co-host the conference.

The scientific program will consist of invited papers selected by the program committee and contributed papers submitted by conference participants. These contributions will cover the most important developments in atomic physics since the Fourth International Conference at Heidelberg.

For information contact Richard Marrus, Chairman of the Conference, Department of Physics, University of California, Berkeley, California, 94720.

Particles and Radiation Therapy (Part II)

An international conference, Particles And Radiation Therapy (PART II), will be hosted by LBL and the University of California on September 14-17, 1976. The conference will be sponsored by the American College of Radiology with financial support from the National Cancer Institute. It will be concerned with evaluating research that uses charged-particle and neutron beams for treatment of cancer. Neutron beams are used throughout the world for this purpose, but charged-particle beams are still restricted to experimental applications. This conference is intended to inform the radiotherapeutic community as to the current level of knowledge and capability in the field of accelerator therapy.

The scientific program will consist of only invited papers on the therapeutic applications as well as the physics and radiobiology of this form of therapy. The papers will be presented in three sessions according to the particle beams being considered: heavy ions, neutrons, and pi mesons. There will be discussions on such topics as patient loads and the economic consequences of the use of these accelerators. In addition, on September 14, there will be a tour of the heavy-ion facilities at LBL and the pi meson facility at Stanford. Other less structured opportunities for convivial interaction will be scheduled during the conference period.

The registration fee of $100 will include the three days of meeting (Sept 15-17); a copy of the proceedings, which will be a publication of the *International Journal of Radiation, Oncology, Biology, and Physics;* and lunches and coffee breaks. Persons within a 75-mile radius of LBL may register for a special $50 fee with some differences in "fringe benefits."

Total registration is limited to 500 and will be on a first-come, first-served basis. The number of local registrants will be limited to 75.

For information or for those interested in applying, contact John J. Curry, American College of Radiology, 130 S. 9th Street, Philadelphia, PA 19107.

THE HIGH-ENERGY HEAVY-ION PROGRAM

The high-energy heavy-ion program at LBL has progressed substantially since its inception two years ago (CERN Courier, June 1974). The facility started in the summer of 1974 and has had its ups and downs. Since this early period, accelerator operations have settled down to a stable level, providing heavy-ion beams both for nuclear science and biomedical experiments. The routine running was brought about by innovations, dedication and hard work of the accelerator crews at both the SuperHILAC and the Bevatron.

The Bevalac Facility at LBL consists of the SuperHILAC acting as an injector of heavy-ions into the Bevatron at energies of about 8.5 MeV/nucleon. Once in the Bevatron, ions can be accelerated up to a maximum energy of 2.1 GeV/nucleon. At present, the heaviest ion to be accelerated in the Bevatron has been ^{40}Ar with average intensities of 1-2 x 10^8/pulse. The next heaviest has been ^{20}Ne with intensities of 1-2 x 10^9/pulse. In the next several months, either ^{56}Fe or ^{86}Kr should be available for experiments, with expected intensities in the range of 10^4-10^5/pulse.

Recently there has been an explosion in the experimental and theoretical interest in heavy-ion interactions at relativistic energies. The most exciting suggestions have involved the possibility of observing new phenomena associated with nuclear collisions at high energies. Possible new phenomena that may be observed are abnormal nuclei, pion condensates, and nuclear shock waves. A key element in these speculations is that these phenomena are associated with abnormally large nuclear densities. The exact nature of the potentially new phenomena is the subject of intense debate, both in experimental techniques and theoretical interpretation.

Some feel that relativistic heavy-ion central collisions may be the way to probe the behavior of nuclear matter at extreme conditions of density and excitation energy. The experimental techniques employed to look for central collisions are widely varied, from electronic to visual. A collaboration from LBL, GSI, and the University of Marburg has initiated a series of electronic experiments to look for events with large transverse momentum transfer by studying the emission of high-energy He fragments (30-300 MeV/nucleon) from the interaction of p, ^{4}He, ^{16}O, and ^{20}Ne on Al and U at bombarding energies of 250 MeV/nucleon to 2.1 GeV/nucleon. Recently, they have added an array of multiplicity counters. By selecting high-multiplicity events, they hope to enhance the central collision content of their data. Using visual techniques, a University of Frankfurt group has exposed their AgCl detectors to various heavy-ion beams at energies from 250 MeV/nucleon to 2.1 GeV/nucleon. Their early work, in which they observed peaks in the angular distributions of light fragments (most likely protons and He) that moved with beam energy in a manner suggestive of these particles arising from shock waves, caused considerable excitement in the nuclear science community. After being used for several high-energy experiments, the LBL streamer chamber has recently been adapted for use with heavy-ions. A collaboration from U.C. Riverside and LBL has recently demonstrated that the chamber can be used with heavy ions (see Fig. 6). The group has now begun a systematic survey of nucleus-nucleus collisions. In a recent run with 1.8-GeV/nucleon Ar on a lead oxide target, charged particle multiplicities of over 100 have been observed. It is clear

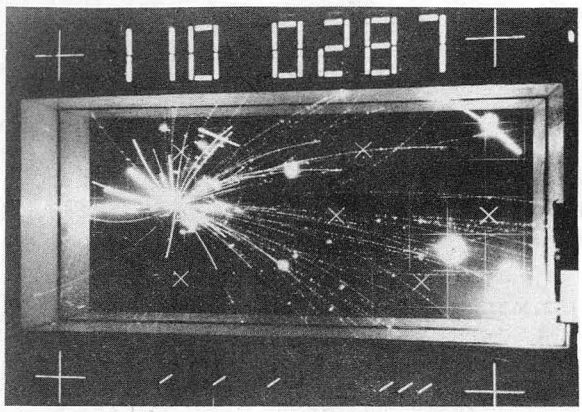


Fig. 6 Spectacular collision between 1.8 GeV/nucleon argon nucleus and lead oxide target. More than 70 charged tracks are visible. This photograph was taken from a UC Riverside/LBL streamer chamber experiment to study nucleus-nucleus collisions at relativistic energies. (XBB-7511-8445)

that the search for new phenomena will occupy a large part of the experimental program at the Bevalac.

In addition to work on central collisions, a wide variety of other experiments are in progress. There is continued widespread interest in projectile fragmentation studies, ranging from astrophysical applications to testing such high-energy physics concepts as scaling and limiting fragmentation. A spectrometer for this purpose has been developed by a group at LBL and the UC Space Science Laboratory, who also use it to calibrate cosmic-ray detectors before they are flown on balloons or satellites. An experimental program has developed on detecting γ-rays from heavy-ion collisions. These γ-rays, both from the deexcitation of nuclei after the collisions and from π° decay, may be used to study high nuclear-density effects. This same principle is also being applied in an experiment that extends to very large transverse momentum transfers in the projectile system. A spectrometer put together by a UCLA/LBL collaboration and originally used to study elastic scattering in the p- ^{4}He system has recently been augmented by a full azimuthal array of multiplicity detectors and is at present being used to study the multiplicity and momentum transfer distributions of projectile fragments produced in collisions of 1.05- to 2.1-GeV/n Ar and C beams with Be and Cu targets.

Basic research in the biomedical applications of heavy-ion beams is an important part of the LBL program, accounting for about one-third of the Bevalac operation and support. The primary emphasis is on pretherapeutic studies of the radiation effects on normal and cancerous tissue in animal subjects. Beams of neon and argon in the 300-600 MeV/nucleon range have been used to irradiate specimens of skin, lung, and spinal cord tissue as well as tumor tissue and cells in tissue culture. In another program the diagnostic potential of heavy-ion beams is being investigated by using the sensitivity of the ion range to local electron density changes as a means to pinpoint tumors. The basic studies involve radiological physics, chemistry, and biology on a cellular level.

Heavy-ion beams, by virtue of their extremely dense ionization known as linear energy transfer (LET), should offer significant advantages over traditional x-ray treatments. A heavy ion will deposit most of its energy just before stopping, and since heavy ions have a well-defined range, the energy of the beam can be chosen to make the ions stop at a tumor site. Thus one can deliver the radiation dosage exactly where it is needed with minimal damage to healthy surrounding tissue. X-rays show a simple exponential attenuation and

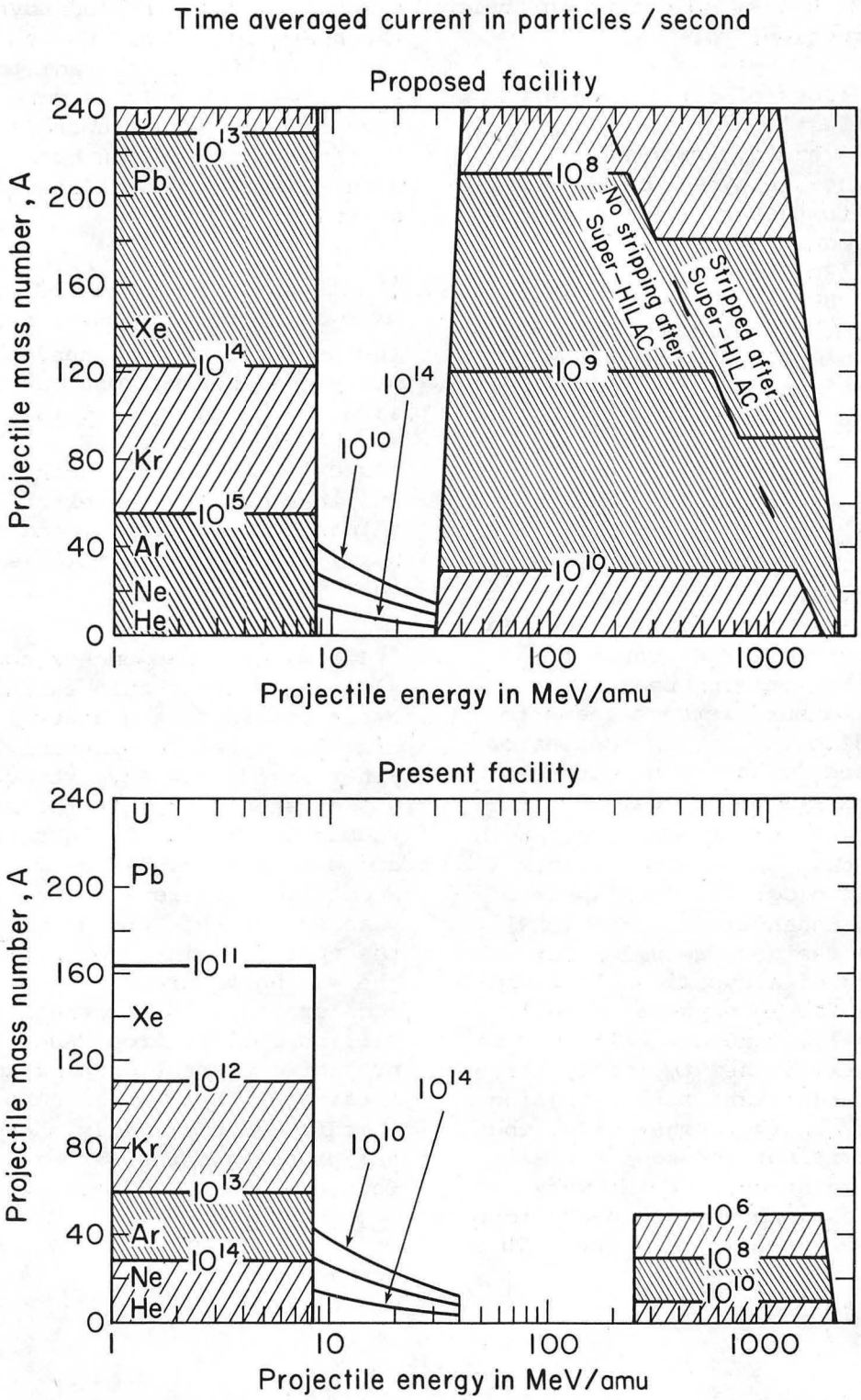


Fig. 7 Available heavy-ion beams from present and proposed Bevalac-SuperHILAC facility. The major improvements will come from a new Bevatron vacuum liner and a third injector for the SuperHILAC. (XBB-7511-8445)

are thus much less selective in their cell destruction.

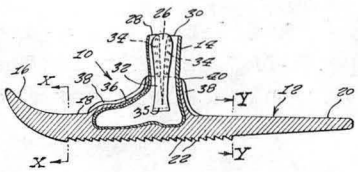
Not all types of ionization are equally effective in destroying cells for a given energy absorbed. The ratio of the energy absorbed (dose) by x-rays to that of the test radiation to produce the same effect is called the Relative Biological Effectiveness (RBE), a convenient figure of merit for radiological applications. The RBE for heavy-ion beams can be much greater than one, and the precise measurement of this factor for skin, lung, spinal cord, and tumor tissue is one of the major efforts of the Bevalac program.

The RBE is not the whole story in radiation therapy however. Various cells can show large differences in their recovery or resistance to destruction by ionizing beams. One cause for this resistance seems to be related to the oxygen content of the cell and it has been noted that cells which are low in oxygen (hypoxic) are much more resistant to radiation than oxygenated cells. Radiation biologists often speak of the Oxygen Enhancement Ratio (OER) defined as the dose required for destruction of a hypoxic cell divided by that for an oxygenated cell. Unfortunately, tumorous cells can be hypoxic, making them typically three times more resistant to x-radiation (OER - 3). On the bright side, the OER factor is not the same for all types of radiation; for the very large LET obtainable with heavy ions, the OER decreases to near one. This gives a double-barreled advantage to the heavy-ion beam. Not only can the ion deliver more radiation more selectively, but it is more effective in destroying tumorous cells. A cancerous tumor can be destroyed with much less total dosage to the patient.

Although the LBL biomedical program is concentrating on measuring the basic parameters needed for heavy-ion therapy, one can look forward to the day when this technique may be widely used. Special biomedical accelerators much smaller and less costly than existing machines are envisioned, and may make heavy-ion therapy available at future treatment centers.

Two major improvements now in the planning stage should extend the capabilities of the heavy-ion accelerator complex considerably. A new liner inside the Bevatron vacuum vessel should improve the machine vacuum to around 10^{-9} torr, thus allowing much higher beam currents. Secondly, a third injector is planned for the SuperHILAC. With the full facility, ion beams all the way up to uranium could be accelerated. LBL has requested six million dollars from ERDA for the project constructions and hopes for funding by FY 1978. Figure 7 compares schematically the present and proposed capabilities of the Bevalac-SuperHILAC complex.

- W. Carithers



3,269,037
FOAM LIGHT WEIGHT RUBBER SNOW SHOES

REAL-TIME COMPUTER SYSTEMS GROUP

Decomposition is a process that one usually thinks of as associated with something less than pleasant--not so in the Real Time Systems Group. Decomposition has been the key to their success! But let's begin at the beginning.

The first small computer was introduced at LBL in 1963. Its use in facilitating data acquisition and accelerator control was immediately recognized and LBL experienced a near population explosion of these inanimate members of the staff. Initially each small system was supported by computer scientists, engineers, and maintenance staff, who were assigned to a specific project as part of the research team. As the systems became less expensive, their numbers increased, and ever-larger computers were purchased for application to more complex problems.

Although the practice of each project having its own system had been effective when the systems and problems were small and the experiments autonomous, as the experiments became larger and more complex, the range of problems necessitated a range of skills broader than one person could supply. Furthermore, the amount of effort duplicated from project to project became substantial. At this point the few computer scientists involved in real-time systems began to communicate and to seek solutions that would have more general application.

For example, the first two projects that provided multi-use real-time computing were completely independent of one another: The PDP-15 system installed at the 184-Inch Synchrocyclotron supported five experiments belonging to three experimenters who shared the same system--hardware and software. The experimenters were pleasantly surprised to find that the shared operation was much less costly, and that the anticipated problems in management and pooled funding had not materialized. The other early multi-user system is ACQUIRE, the central computer-based data acquisition and analysis system at the Laboratory of Chemical Biodynamics. This system was designed to interface with a wide variety of instruments and has proved itself eminently satisfactory.

Other predecessors of the RTS Group were busy building a computer-based control system at the Bevatron. That system was started in 1966 and became operational over the next several years as it was installed in three functional parts, each a PDP-8 computer system. It is still functional. The first computer installed in 1968 controls the magnets that steer the external proton beam to the experiments; the second, installed about a year later, controls the motor generator sets that drive the Bevatron magnets. In another year control of the Bevatron master oscillator reached its final form. These minicomputers are now used to capacity. Plans call for converting them over the next two years to the new control system which is currently under construction.

In 1973 the RTS Group was formed from these isolated members in what was then the Mathematics and Computing Department of the Physics Division. The purpose of the RTS Group at that time was to provide software support to all computer systems that acquire and control data in real time.

The staff of this Group performed varied functions: They worked with project scientists and engineers to plan experiments and control systems that used computers. They provided dedicated project-oriented staff to work integrally with the research team during system development; and they provided routine systems support

as well as system-development expertise organized along general functional requirements that are common to instrumentation and control systems.

Prior to the formation of the original RTS Group, there was an increasing variety of small systems developing around the hill (minicomputers such as PDP-4, -5, -7, -8, -9, -11, -12, -15; Data General Nova; Sigma-2). Formalization of the Group brought initial attempts at standardization; the focus was on ModComp (Modular Computer Systems) and PDP-11 (Digital Equipment Corporation Computer Systems.

Hand-in-hand came organization in their philosophy of approach, so they began to decompose! That is, they applied the engineering technique of breaking down a problem into component parts, used specialists to solve the parts, and then reassembled the parts into a problem solved. The ability to untangle the Gordian knot of these complex control problems of data acquisition and to follow the single threads to the identified source of each, calls for a high level of expertise on the part of these specialists. The extent to which the Group has been successful, and has been

TABLE 1. COMMONALITY OF RESOURCES APPLIED BY THE RTS GROUP TO THEIR PROJECTS

Resources \ Projects	ACCELERATOR CONTROL			MASS TRANSIT	DATA ACQUISITION SYSTEMS			
	Bevalac	PEP	CTR	BART	Biomed.	Physics	LCB	LAIR
GENERAL SUPPORT FACILITIES								
Documentation system support	X	X	X	X	X	X	X	X
Development computer system & terminals	X	X	X	X	X	X		X
Computer system information library	X	X	X	X	X	X		X
ENGINEERING SUPPORT								
Process I/O instrumentation	X	X	X	X	X	X	X	X
Control consoles	X	X	X	X	X	X	X	X
General interfaces	X	X	X	X	X	X	X	X
TECHNICAL SUPPORT								
Preventative maintenance	X	X	X		X	X	X	X
System troubleshooting	X	X	X	X	X	X	X	X
Development support	X	X	X	X	X	X	X	X
SOFTWARE SUPPORT								
Operating systems	X	X	X	X	X	X	X	X
Networks	X	X	X	X	X	X		
Control console & graphics	X	X	X	X				
Process I/O	X	X	X	X	X	X	X	X
Data base	X	X	X	X			X	X
Languages	X	X	X	X	X	X		

able to apply standardized approaches is shown in Table 1. Obviously the Group would be a winner at tic-tac-toe.

Because of the rapidly increasing use of computers, and their importance to the control systems of the accelerators and other laboratory projects, Dr. Sessler, LBL's Director, issued a memo on April 12, 1976 that established the Real-Time Systems Group as part of the Electronics Engineering Department. It draws staff from the original Real-Time Systems Group of the Physics, Computer Science and Mathematics Division, and from the Electronics Engineering Department. Vic Elischer was appointed Group Leader with Don Rondeau as deputy. In Dr. Sessler's words, "This new group offers a complete package of support functions for Laboratory real-time computer systems including systems, software and hardware design and implementation, and technical support. This group will interface with and support scientific and electronic engineering groups associated with the research and accelerator programs to the extent that those programs require their services." You can get a feel for how these systems and their importance to the laboratory have grown when you consider that in December 1974 there were 12 people in the Real-Time Systems Group; today, nearly a year and a half later, there are a few more than 40, with 22 computer scientists and 10 engineers.

A survey of the projects in which the RTS Group is involved will give you an idea of the broad range of problems with which they deal.

Networks

Recent computer facilities have now become standardized essentially into two major networks: one consisting of ModComp systems and the other of DEC PDP-11 systems. The ModComp Network (Fig. 8) is set up primarily for control of the accelerators: the SuperHILAC Bevalac, the Controlled Thermonuclear Reaction (CTR) project in Bldg 5, and the Linac in Bldg 64. The PDP-11 Network (Fig. 9) provides data

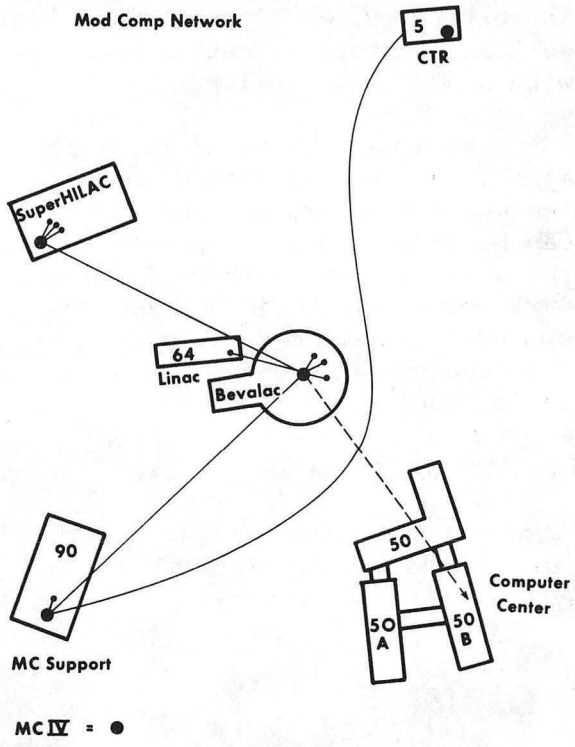


Fig. 8. Diagram of ModComp network. (XBL-765-2879)

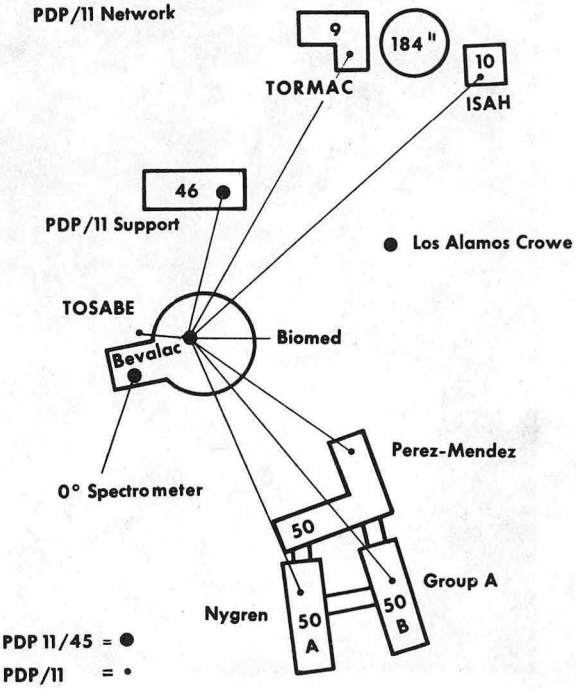


Fig. 9. Diagram of PDP-11 network. (XBL-765-2880)

acquisition and analysis systems for research projects. Networking has shown itself to be a most practical approach. There are overall savings in cost, time, and convenience, as well as permitting central computing with a powerful facility.

For each major network there is also a support and developmental system where new hardware and software can be developed for application to the other systems without interfering with operations. The ModComp developmental system is in Bldg 90 (Fig.10). The counterpart for the PDP-11 systems is in Bldg 46.

The ModComp Network

The Group's major effort at this time is the construction of control systems for the SuperHILAC and the Bevatron (when combined, the Bevalac). Design of generalized network control systems is structured on data bases so that as physical configurations of monitor and control points change, interactive editing of the data base will automatically and appropriately reconfigure the control system. Each accelerator control system consists of distributed real-time monitor and control processors that operate independently and asynchronously, but which are under the overall control of a larger central computer. This central computer will not only direct the activities of the secondary machines, but will manage all human-machine interactions through color displays and special function control panels.

The ModComp system to control the Bevalac is being installed in several stages. Phase Zero, the first stage,

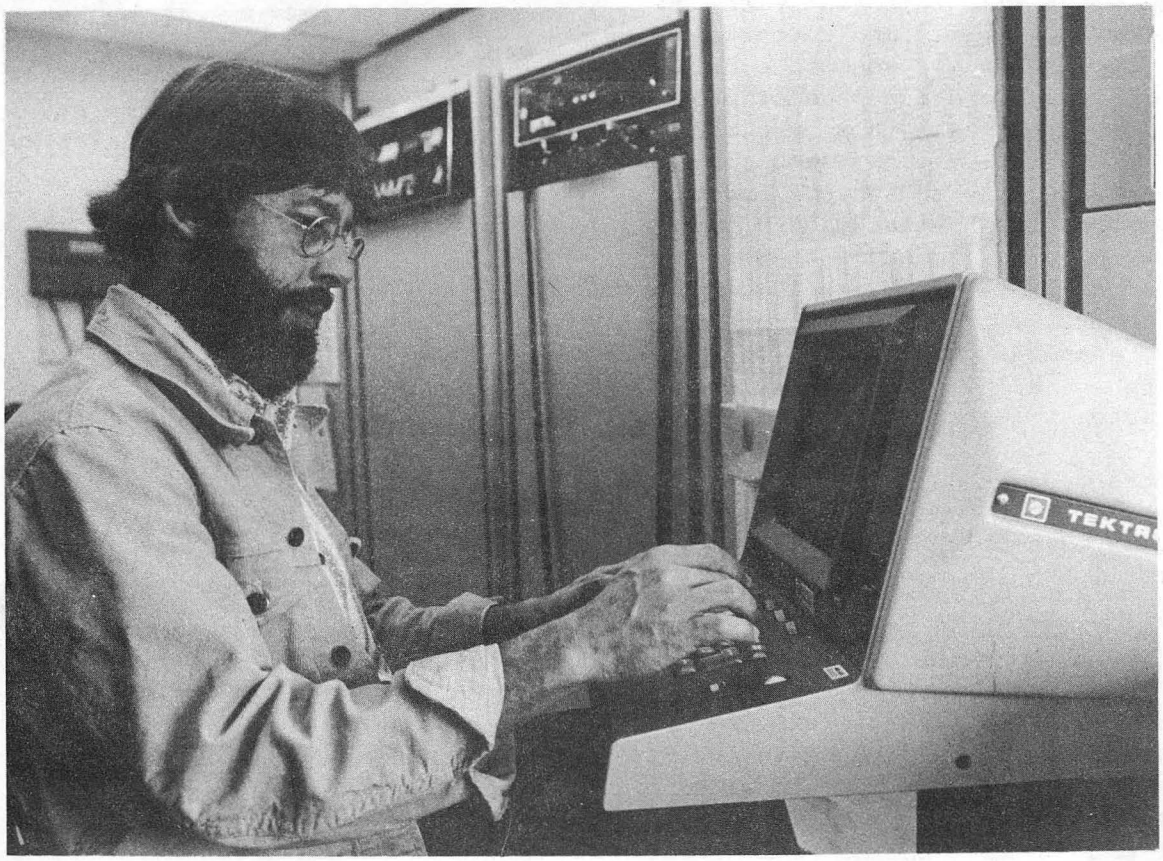


Fig. 10. Ken Wiley at the keyboard of the PDP/11 support system in Bldg. 90. (XBB-7511-8398)

became operational in April 1975 and consisted of only one computer system at the SuperHILAC and one at the Bevatron. Although only the first of four phases, Phase Zero enabled the SuperHILAC to operate in the timeshared mode. In timeshare, two injectors send pulses of different heavy ions interspersed in various combinations through the SuperHILAC at a maximum rate of 36 pulses per second. At the far end of the accelerator the pulses are separated: one pulse per second of the selected ion is sent through the transfer line to the Bevalac, the others are shunted into experimental areas at the SuperHILAC.

The two accelerators were brought up to Phase One in December 1975, with a two-computer network (MC IV and MC II) operating at each. Phase Two will come into action at the SuperHILAC after the current shutdown at the accelerators. At this time all the distributed real-time processors will be supported, and control will be extended to all machine parameters. When this system is proven, the Bevatron system will be changed to the Phase Two configuration. Figure 11 shows the ModComp room at the SuperHILAC in the Phase Two configuration. The control area at the Bevalac is comparable.

Fig. 11. The ModComp room at the SuperHILAC, at the windup of installing Phase Two configuration. In the foreground Bob Belshe, project leader for the accelerator control systems communicates with the CDC 6600, while (clockwise) computer scientists Mannie Clinnick and Loren Shalz study the ModComp printout. Stan Boyle, accelerator operator supervisor, checks the beam profile on the CRT as the profiles also print out on his left. Around the room periphery are the ModComp II and IV components. (CBB-765-4161)

Phase Three will come later. It will be an internal change, and will complete the system as originally conceived. At this point the PDP-8's will have been phased out of active control with all their functions having been moved to the ModComp II real-time processors under control of the central ModComp IV. Ultimately these two central computers at the accelerators, and the system support computer will be linked together and to the computer center to provide all the computer support capabilities available at the Laboratory to the accelerator staffs.

Another component in the ModComp network is the 50-MeV proton linac in Bldg 64. Originally designed for injection at the Bevatron, it is awaiting a complete new data acquisition system for adaptation to ESCAR.

The CTR Group presently has a ModComp II for data acquisition in two projects: the neutral beam test stand and the atomic physics experiments. The RTS Group designed the system to CTR requirements: They have had to provide a system that has the capacity to handle at least four remote experimental stations asynchronously and simultaneously that are up to 600 feet away and that can transfer data at a rate of at most 50,000 words per second between each experiment and the computer. By 1 July, Test Stand 3 should be up and running. A collaborative project with the Draper Laboratory of MIT will replace the ModComp II with a ModComp IV in the Fall.

In the more distant future is a medical accelerator designed and built for patient use which will have high reliability and can accelerate particles up through the "light" heavy ions (carbon, neon). Such a system will be highly computer controlled. The Group is presently doing a design and feasibility study on such a project, in particular, the beam delivery system for patient scanning, so that the accelerator will have a uniform dose distribution. This capability will require the handling of large amounts of data at a very fast rate and to a degree of accuracy never before attempted at an accelerator. This medical accelerator is of the type that could be installed at major hospitals through the country.

The PDP Network

The Biomed Division PDP-11/45 computer at the Bevalac is the control system of the other real-time computer network. It is also used to study the experimental biological effects of heavy-ion radiation on animals, directed toward the eventual goal of patient treatment.

This computer system provides for concurrent data acquisition from instrumentation specific to the particular irradiation in progress and has a large complement of memory, disc, and magnetic tape drives. On-line analysis and graphics routines, excluding system support, are written entirely in FORTRAN or BASIC. The system support and data acquisition routines accentuate the accessibility and usefulness of higher level languages for researchers.

In order for the PDP-11/45 to serve as the central host for this network, Biomed has established a working arrangement with the other divisions that their use shall be "transparent," that is, does not conflict with Biomed demands.

At present this network also serves the CTR TORMAC Group, and Nuclear Science, and Physics, CS&M Divisions. Currently six remote stations are connected, each consisting of a PDP-11/10 or similar machine with data acquisition and display devices. These small, inexpensive and remote computers in

the PDP-11 network serve a variety of research programs on the hill.

Dave Nygren's Group is using their PDP 11/20 system with the large-scale digitizer that has been developed here at LBL, for data acquisition at the Bevatron. Many samples are taken along the beam line to measure, particle by particle, the energy deposited in 2 mm of gas. They hope to develop a capability of separating particles of fixed momentum but with different mass, which will be incorporated in a time projection chamber to be used at PEP.

A networked PDP 11/10 is used by V. Perez-Mendez to analyze the parameters of multiwire proportional chambers (MWPC) and to manipulate and analyze the data from gamma distribution in tomographic imaging. In both projects the coordinates of events are stored in the computer.

Bernard Sadoulet in Group A uses the large scale digitizer to develop a high-accuracy cylingerical drift chamber for PEP. In this process he uses a small PDP 11 to reconstruct the cosmic-ray tracks for the chamber.

Presently, the PDP 11-10 used by the TOSABE (Tokyo-Osaka-Berkeley) Group for nuclear science studies at the Bevalac is servicing 8 scalers that make inclusive measurements of gamma rays emitted from carbon-ion collisions. According to John Rasmussen, in the Fall this computer will be used for multi-dimensional coincidence and time-of-flight spectra of particles and gamma rays from central collisions of high-energy heavy ions.

At the CTR TORMAC project in Bldg 9, a low-repetition rate experiment with a critical time period of 100 microseconds makes use of the network. During each pulse, time-result information from 32 channels is recorded. The information is stored in an analog memory, then digitized and stored in the PDP 11-10. Access to the PDP 11-45 central machine provides for disc and tape storage of large quantities of information.

At the 184-Inch Synchrocyclotron, Biomed is currently in the process of moving ISAH, the patient positioner, onto a networked PDP 11 computer so that both dosimetry and patient positioning are handled by the same computer. This change will be completed by next summer. In the meantime the PDP 11-10, which is used frequently, uses the network for downloading the BASIC system into its memory and so makes minimal impact on the system.

So much for the networks. The RTS Group does get involved in other things, such as computer systems that stand by themselves.

Other Projects

The 0° spectrometer at the Bevatron is designed to measure the fragmentation cross sections of heavy ions and provide a variety of variable energy and isotope beams for outside users. Recent acquisition of a PDP 11-15 for this facility gives it a stand-alone capability and provides the speed necessary to accommodate the high data rates involved in heavy-ion physics experiments. Here again the ability to use the high level programming language FORTRAN makes the experimenters more effective in their usage of the computer.

Ken Crowe and his group, using established techniques, will study the energy spectrum of high-energy photons resulting from the capture of stopped pions in tritium and neon with a high-resolution pair spectrometer at the meson factory (LAMPF) at Los Alamos in the Winter of 1976. The RTS Group is currently developing the computer

support system for the π^--capture experiment. Although the experiment and the PDP 11-45 computer are in New Mexico, the entire hardware/software development will take place at LBL on the local PDP-11 support system.

Members of the Group are also deeply involved in design of PEP's control system. This control system is extremely complex: The nature of the Positron-Electron Colliding Beam Storage-Ring Facility requires a control system to keep the beam in tune, and the control system must be subdivided to accommodate the real distances that would add excessive delay to the system's reaction time if it were controlled by only one central unit. Each of the six interaction regions will have its complete computer control system, which will in turn be connected by a high-speed serial link to two central computers in the main control room. These stand-alone units will permit local control, but during normal PEP operation the main control room operator will monitor and adjust beam parameters as needed. All work on PEP is in the system design stage, and final estimates of the complete control system have just been completed. Actual hardware design is to start in October 1976. Many of the techniques developed for the Bevalac project will have application here.

The RTS Group has designed and implemented a monitor and control system with interactive graphics analysis capability for human treadmills at the Letterman Army Institute of Research in San Francisco. Like the accelerator control systems, the Treadmill Automation System (TAS) is entirely data-base driven.

This same TAS hardware/software design will be used to implement, monitor, control, and operator interaction functions for LBL's Mobile Atmospheric Research Laboratory. The MARL will initially accommodate 48 monitors and 48 controls with the ability to run in an unattended mode for up to 48 hours.

All these projects involve quite a few computers, about 10 systems altogether, which have to be both routinely maintained and repaired in emergencies (Fig. 12). So an important function of the RTS Group is the operation of a 24-hour-a-day, 7-day a-week maintenance facility to keep the machinery running.

The RTS Group also serves as consultants to the Bay Area Rapid Transit District (BART) (Fig. 13). The District uses a Sigma-II-based computer system (Central Train Control Computer System) to provide system-wide train supervision. Failures of this system have been a major interruption to the operation of trains. The Group has investigated the problems of this system and has provided the District with recommendations to improve safety, reliability, and performance.

The BART District uses 13 different computer systems for a variety of applications. The cost of supporting these computer systems (operations, maintenance, and development) is substantial. This is a problem at BART, in part because of the adverse impact on District operations when adequate resources are not available to support these computer systems. The RTS Group has surveyed all these computer systems and is currently formulating recommendations for medium- and long-range computer system planning at BART.

As Dr. Sessler points out in his memo formalizing the Real-Time Computer Systems Group, "the application of the minicomputer has grown dramatically for both data acquisition and accelerator control. Now, nearly all research activities at

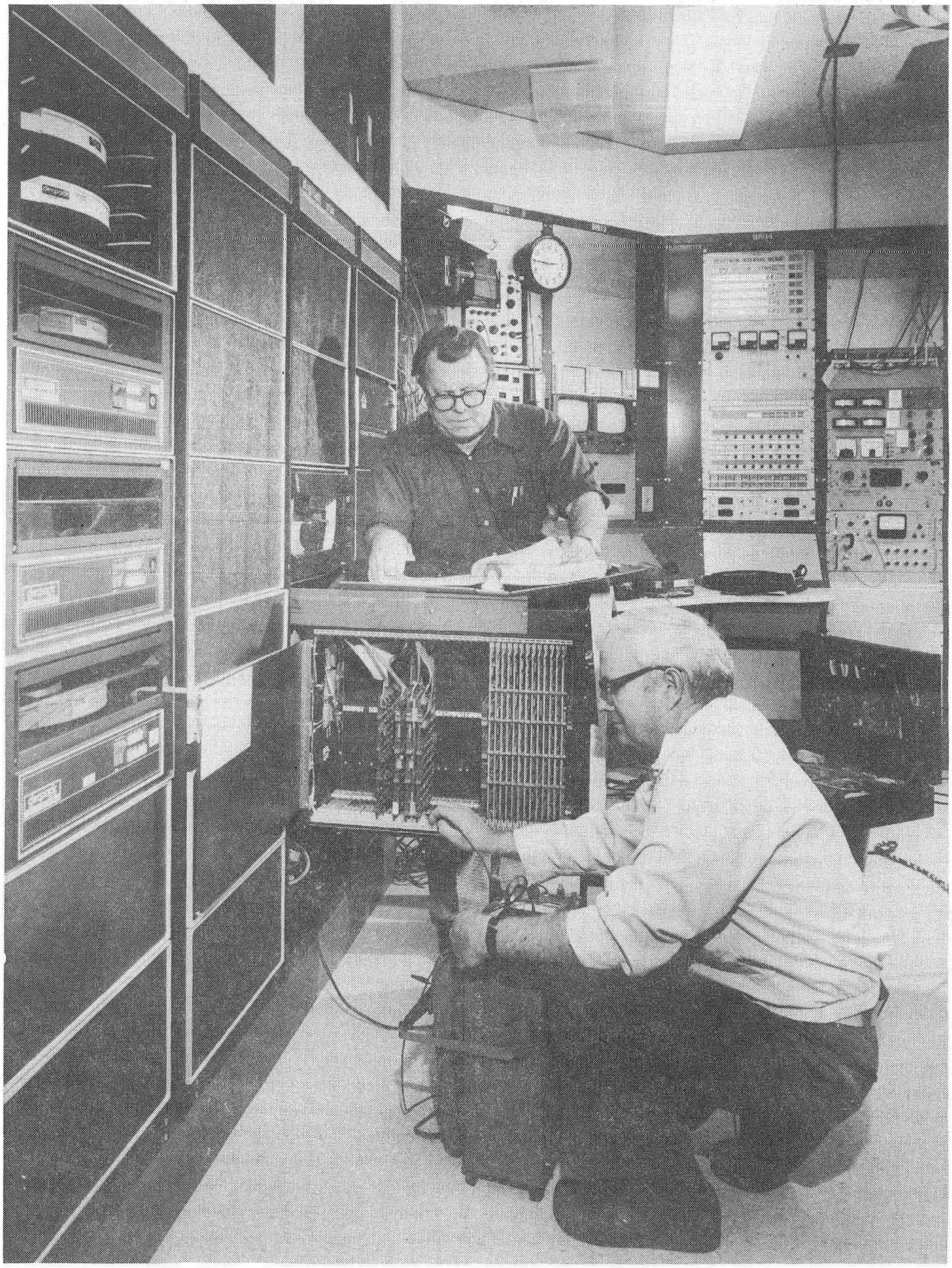


Fig. 12. Jim Harvill and Joe Lowe of the RTS Group Maintenance Section diagnose a problem in a PDP 11/45 system at the Bevatron. (XBB-765-4438)

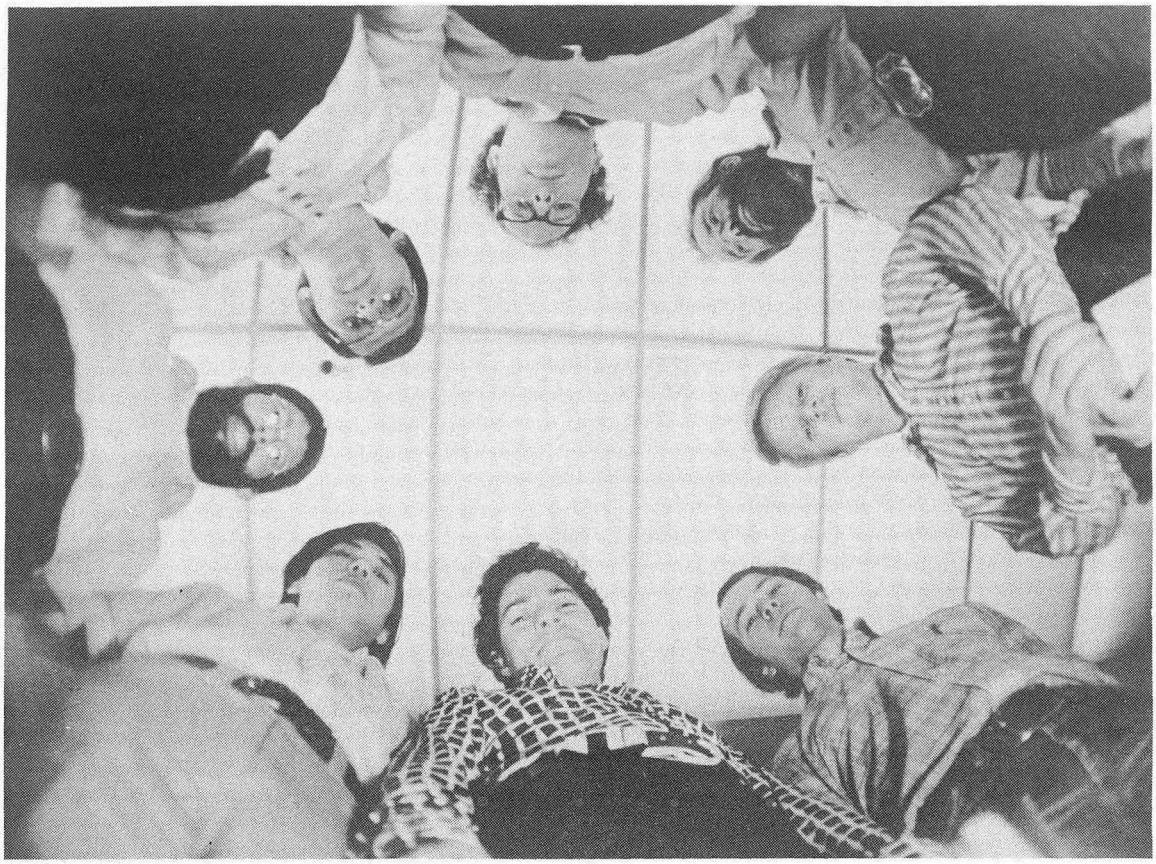


Fig. 13. Members of the RTS Group, the BART Engineering Computer Systems staff, and the California PUC have been putting their heads together to find ways to improve real-time computer systems at BART. (XBB-763-2738)

LBL are involved with small computers and are exploiting their capabilities in data gathering, control of accelerators and monitoring of experiment progress. It is clear that in the future the use of small computer systems will continue to increase, additional systems will be upgraded and systems will be called upon to perform more and more sophisticated operations. As this happens, the Laboratory will come to rely more heavily on effective design of computer hardware and software systems and their reliable operation."

It sounds like the Real-Time Computer Systems Group has got its future cut out for it.!

- M. Wildensten

(Ken Wiley's assistance is gratefully acknowledged.)

PROGRAM ADVISORY COMMITTEE MEETING

The Bevatron/Bevalac Program Advisory Committee (PAC) convened on April 23 for a two-day session to consider the experimental program to be carried out at that accelerator during the coming fiscal year. The Bevatron/Bevalac is a National Facility, as is the SuperHILAC, and each has a program advisory committee appointed by the Director of the Laboratory to advise him on the quality of the proposed research.

The PAC chaired by Arthur K. Kerman, MIT, consists of two panels, one for biology and medicine and one for nuclear science, which consider all proposals for experiments that are submitted by LBL and outside users. The Biomedical Panel consists of Ted Phillips, Chairman, UCSF; Max M.L. Boone, U. Arizona; Victor P. Bond, BNL; John L. Magee, Notre Dame U.; Harald H. Rossi, Columbia U.; and Mortimer M. Elkind, ANL. The Nuclear Science Panel consists of Arthur K. Kerman, Chairman, MIT; Alfred Goldhaber, Stony Brook; Arthur M. Poskanzer, LBL; Bruce B. Cork, LBL; C. J. Waddington, U. Minnesota; and Reinhard Stock, U. Marburg.

Deputy Director Earl Hyde in his opening remarks to the full committee stated that this meeting was "critically important." Now that reliability of the Bevalac has been established, the machine must have solid results in the next two years, for both nuclear science and biology and medicine. Two major changes have been made which will contribute to this success: the reorganization of the nuclear science program and the installation of Edward Alpen as head of Donner Laboratory, LBL's Biology and Medicine Division.

Bernard Harvey reviewed the organization of the Nuclear Science Division as it is now structured, and urged a concerted effort to get the Bevalac on a successful road for nuclear science. He briefly described the present status of heavy-ion induced fusion, and said that the preheat of the D-T fuel would come mainly from particle fragmentation. Some research is needed, although no formal proposal has been submitted to the PAC because the ideas are so recent and thinking is evolving rapidly.

Harvey also requested that there be judicious use of equipment in the coming years.

Hermann Grunder reported that the Bevalac is now routinely operating well, and support facilities have been improved: The newly established ARC (Accelerator Research Coordination) office is available to serve the experimenters. Ion-source lifetimes and intensities have been improved and the time required for changing the source has been shortened. Accomplishments in beam development include a continuous set of extraction energies with an increase in extraction efficiency to 60-70%. There will soon be enough MWPC detectors so that they will not need to be moved to accommodate various experiments. Computer control of the accelerators is ready to go into Phase II. Use of the transfer line has become routine and now requires only one-half hour tune-up time.

Grunder also reported that LBL is preparing a conceptual design report for the uranium capability at the Bevalac. Two developments will be required before uranium can be accelerated: a third, high-intensity, high-mass injector for the SuperHILAC that will inject particles of krypton and higher mass, and a vacuum system at the Bevalac that will go to 10^{-9} Torr to permit acceleration of

partially ionized ions. Such a capability will then produce ions of very high mass and low to medium energy.

It will also be necessary to update the rf system because the tubes in the existing system are obsolete and the supply of these tubes has been exhausted.

The proposed Presidential budget for FY 77 is a great disappointment. Although the dollar amount is essentially the same, we expect a 30-40% increase in the cost of electricity, and we will lose a number of employees funded by the Department of Commerce. In short, if we were to run the 1976 program in 1977, we lack two million dollars. We will have a total of only 2300 hours of running time as compared with 4000 in 1976. The time spent for beam development will be drastically curtailed, so any increase that may occur in the budget will mean a direct increase in running hours.

Grunder recommended that the Committee give preference to good experiments that run at low energy because of the lower running costs.

The Committee then separated into its two Panels to consider the proposals for the upcoming program.

At the Biomedical Panel, Hyde pointed out that the Bevalac was built originally because of its potential for biomedical applications, so there is a heavy responsibility to make the program work on three fronts: pretherapy, therapy, and diagnostics. July 1977 is the target date for the first patient program at the Bevalac. Alpen feels confident that this date can be met, but to do so he requested that the Committee reconsider the method of allocating time to the biomedical experiments.

A policy statement for animal use at LBL was introduced by Alpen, and is included *in toto*.

Operation of the experimental biomedical program during the past 6 months had 13 runs scheduled; of these, 9 were for program, 2 for development, and 2 for dosimetry. Local users used 219 hours, outside users 198. Some of the scheduled experiments with high priority did not run, usually because of uncertain beam, or because the experimentor was not prepared. It was difficult to obtain sufficient lead time for an experiment.

In the clinical program at the 184-Inch Synchrochyclotron, modifications have been completed to permit patient treatment with a large flat field from the helium-ion beam. Six patients with tumors were treated.

The nuclear science program conducted from October 1975 to March 1976 is summarized in Table 2. Those experiments typified as "general" are ones that remain on the Bevatron floor for several months or longer.

The proposals submitted by Biology and Medicine to be considered are grouped in seven categories:

Category	Objective
0	Fundamental dosimetry
I	Cancer therapy potential
II	Diagnostic and other medical applications
III	Fundamental radiological and chemical effects
IV	Fundamental biological effects
V	Exploratory studies
VI	Space biology

TABLE 2 NUCLEAR SCIENCE EXPERIMENTAL PROGRAM
OCT. '75 - MAR. '76

EXPERIMENT	TYPE	STATUS
162H Heckman (LBL/UCSSL)	General	Finished
203 Wiegand (LBL)	General	Continuing
205H Steiner (LBL)	General	Continuing
209H Kerth (LBL)	General	Continuing
211H Igo (UCLA/LBL)	General	Finished
212H Poskanzer (LBL/GSI/Marburg)	General	Continuing
228H Poe (UCR/LBL)	General	Continuing
248H Rasmussen (TOSABE)	General	Finished
284H Poskanzer (LBL/GSI/Marburg)	General	New and continuing
317H Igo (UCLA/LBL)	General	New and continuing
H32 Simpson (Chicago)	Cosmic ray calibrations	Continuing
246H Waddington (Minn.)	Cosmic ray calibrations	Finished
313H Cummings (Cal Tech)	Cosmic ray calibrations	Finished
225H Cumming (BNL)	Irradiation	Finished
261H Price (UC)	Irradiation	Finished
273H Cartwright (UC)	Irradiation	Finished
307H Schopper (Frankfurt)	Irradiation	Continuing

The following proposals were submitted. Copies are on file in the ARC office.

BIOLOGY AND MEDICINE

Category 0

Exp. 332B: (New Proposal)
RBE for Somatic Mutation Induction in Tradescantia, *J. Baum, BNL.*

Exp. 346B: (New Proposal)
Heavy-Ion Dose Quality at Depth, *G. Luxton, Stanford.*

Exp. 347B: (New Proposal)
Chronic Radiation Effects on the Spinal Cord of Rats, *K. Woodruff, LBL.*

Exp. 215B-1: (New Proposal)
Delayed Carcinogenesis and Pulmonary Fibrosis in Hamster Lungs, *K. Woodruff, LBL.*

Category I

Exp. 217B: (Renewal Request)
Survival of *in vivo* Brain Tumor Cells After Irradiation with Heavy Ions, *K. Wheeler, UCSF.*

Exp. 218B: (Renewal Request)
*In vivo*DNA Damage and Repair in Rat Normal Brain and Brain Tumor After Irradiation with Accelerated Neon Ions, *K. Wheeler, UCSF.*

Exp. 256B: (Renewal Request)
Measurement of RBE and OER for EMT6 Tumor Cells *in vitro, T. Phillips, UCSF.*

Exp. 269B: (Renewal Request)
Measurement of RBE for Pulmonary Lethality in the LAF1 Mouse, *T. Phillips, UCSF.*

Exp. 353B: (New Proposal)
Measurement of RBE for Intestinal Crypt Cells Following Fractionated Irradiation, *T. Phillips, UCSF.*

Exp. 289B: (Renewal Request)
OER Determinations for Human and Hamster Cells with Heavy-Ion Beams, *E. Blakely, LBL.*

Exp. 327B: (New Proposal)
The Influence of Heavy-Ion Irradiation on Wound Healing, *P. Baker, Mt. Zion, S.F.*

Exp. 343B: (New Proposal)
Minibeam Irradiation of Nondividing Mammalian Cells *in vitro, T. Yang, LBL.*

Exp. 344B: (New Proposal)
Response of Rat Rhabdomyosarcoma to Fractionated Treatments, *S. Curtis, LBL.*

Exp. 345B: (New Proposal)
Radiation Response Variations of Mouse Crypt Cells Through Cell Cycle, *R. Withers, U. Texas.*

Category II

Exp. 334B: (New Proposal)
Analog Film Technique of 3-D Reconstruction with Heavy Ions, *Z. Cho, UCLA.*

Category IV

Exp. 326B: (New Proposal)
Artemia Eggs Irradiation Research, *H. Planel, Toulouse, FR.*

Exp. 330B: (New Proposal)
Heavy-Ion Carcinogenic Potential, *C. Shellabarger.*

Exp. 331B: (New Proposal)
Mutations of Maize Gene by Accelerated Heavy Ions, *M. Freeling, UCB.*

Exp. 348B: (New Proposal)
Exploration of the Effects of Heavy Ions on Membranes, *M. Malachowski, LBL.*

Exp. 311B: (Extension Request)
Noncytokinetic Injury to Insect Tissue, *H. Ducoff, LBL - U. Illinois.*

Exp. 312B: (Extension Request)
Chemical Modifications of Inactivating Elements by Heavy Ions, *J. Chapman, LTD Canada.*

Category V

Exp. 336B: (New Proposal) Radiation Effects on Bacteria and Tissues of the Rabbit Eye, *P. Young, Mississippi State.*

Category VI

Exp. 288B-1: (New Proposal) Heavy-Ion Irradiation of Streptomyces, *T. Rogers, NASA-Houston.*

Exp. 292B: (Extension Request) Studies of the Mammlian Brain and Eye and Associated Head Structures, *W. Haymaker, NASA-Ames.*

NUCLEAR SCIENCE

Exp. 315H: (Resubmission) Elastic Differential Cross-Sections Near the Backward Direction in the pd and p^4He Systems, *J. Carroll, LBL/UCLA.*

Exp. 341H: (New Proposal) p^4He Polarization at 0.4, 0.72 and 1.0 GeV Equivalent Proton Kinetic Energies, *J. McClelland, UCLA/LBL.*

Exp. 168: (Extension Request) Elastic Scattering as a Test of Short Range Correlations in Mass-4, -2 Nuclei, *H. Spinka, UCLA/LBL.*

Exp. 317H: (Extension Request) Measurement of Light Fragment Spectra Produced in Nucleus-Nucleus Collisions, *M. Gazzaly, UCLA/LBL.*

Exp. 349H: (New Proposal) Target-Projectile Correlations Test, *J. Rasmussen, TOSABE/LBL/UCSSL.*

Exp. 248H: (300-301H) (Status Report and Request for Consolidation of Time Under 248H), Electromagnetic Radiation from Relativistic Heavy Ion Collisions, *J. Rasmussen, TOSABE.*

Exp. 340H: (New Proposal) Checkout of a Multiplicity Detector and Trigger Counters, *Johns Hopkins.*

Exp. 350H: (New Proposal) Coulomb Dissociation of Relativistic ^{16}O and ^{18}O, *B. Berman, LLL/LBL/UCSSL.*

Exp. 333H: (New Proposal) Nuclear Reactions from GeV Protons-Applications to Gamma-Ray Observations in Space, *A. Metzger, JPL.*

Exp. 351H: (New Proposal) Production of Light Particles Near 180^0 from Nucleus-Nucleus Collisions, *L. Schroeder, LBL.*

Exp. 352H: (New Proposal) Medium Low Energy Reactions and Facility, *D. Hendrie, LBL.*

Exp. 205H: (Status Report and Request for Remaining Time), Charged Particle Production from Collisions of Heavy Ions with Various Targets, *L. Anderson, LBL.*

Exp. 337H: (New Proposal) Calibration and Test of Heavy Nuclei Experiment for HEAO-C, *M. Israel, Washington U./Cal Tech/U. of Minnesota/McDonnell-Douglas.*

Exp. 342H: (New Proposal) Calibration of the ISEE-C Heavy Isotope Spectrometer Telescope, *R. Mewaldt, Cal Tech.*

Exp. 313H: (Extension Request) Calibration of the High Energy Isotope Spectrometer Telescope, *F. Hagen, Cal Tech.*

Exp. 335H: (New Proposal) Production of Heavy Fragments from the Interaction of Heavy Ions in a Gold Target, *Dublin Inst. Advanced Studies.*

Exp. 338H: (New Proposal) Calibration of ISEE-C Cosmic Ray Experiment, *D. Greiner, UCSSL/LBL.*

Exp. 354H: (New Proposal) Calibration of MJS Cosmic Ray Experiment, *A. Cummings, Goddard/ Cal Tech.*

Exp. H32: (Resubmission) Isotopic Resolution Studies of Satellite Cosmic Ray Instrumentation Using Heavy Ions, *J. Simpson, U. Chicago.*

POLICY FOR ANIMAL USE AT LBL

I. In order to maintain an efficient and properly functioning animal care facility, the following standards must be observed:

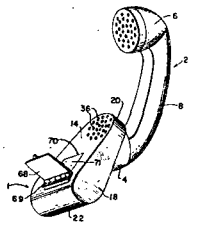
Investigators, both resident and visiting, whose proposals call for the use of laboratory animals, must arrange for procurement of the necessary animals from approved sources for delivery to LBL by consultation with the head of Animal Services. Animals will generally not be accepted from experimental facilities without special quarantine arrangements and advance approval by the Head of Animal Services and the LBL veterinarian. These special arrangements will be reviewed and approved by the LBL Animal Care Committee. The Head of Animal Services is Robert W. Springsteen, Building 74, Room 159A, LBL Ext. 5221. The LBL veterinarian is Hermann Bonasch, DVM, and may be contacted through Mr. Springsteen.

All proposals requiring laboratory animal usage must contain a statement of intent with respect to the type and amount of anesthetic, analgesic, and tranquilizing drugs used on animals during actual research or experimentation, which is appropriate to relieve all unnecessary pain and distress for the subject animals.

The above statement complies with Section 2.28 of the Federal Animal Welfare Regulations. Experiments involving necessary pain or distress without use of these drugs must be reported to the LBL Animal Welfare Committee, Bldg. 74, and a brief statement explaining the reasons.

II. LBL presently does not have approved biohazards facilities; therefore, infectious organisms, either free or in animal carriers, cannot be accepted at LBL, nor can such infectious agents be used in the Laboratory facilities.

III. If radioactive isotopes are to be used in the experimental protocol, the Safety Services Engineer responsible must be notified of such intent, and provisions made for disposal of radioactive residues and carcasses.



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TELEPHONE STERILIZING ATTACHMENT

PUBLICATIONS AND PRESENTATIONS

ON NUCLEAR SCIENCE

Reduced Transition Probabilities for High Spin States in ^{232}Th, *M. W. Guidry, P. A. Butler, P. Colombani, I. Y. Lee, D. Ward, R. M. Diamond, and F. S. Stephens (LBL); and E. Eichler, N. R. Johnson, and R. Sturm (ORNL)*

The lifetimes and reduced transition probabilities for spins 6^+ - 18^+ in the ground-state rotational band of ^{232}Th have been measured by recoil-distance, Doppler-broadened lineshape, and multiple Coulomb excitation methods, and have used ^{84}Kr and ^{136}Xe projectiles. Within the limits of experimental uncertainty, transition probabilities from all of the methods are consistent with those of a good rotor for spins 6^+ - 18^+. The discrepancy with the prediction of simple β-band mixing and centrifugal stretching models is discussed. *(LBL-4038) Submitted to Nucl. Phys. A.*

The Vector Analyzing Power in the ^{2}H($\vec{d}$,p)^{3}H Reaction Between 15 and 25 MeV, *H. E. Conzett, R. M. Larimer, F. N. Rad, R. Roy, and F. Seiler*

The entrance-channel particle identity in the ^{2}H(d,p)^{3}H reaction requires that $\sigma(\theta) = \sigma(\pi-\theta)$ and $p(\theta) = -p(\pi-\sigma)$ for the differential cross sections and nucleon polarizations, respectively. No comparable symmetry is imposed on the deuteron analyzing powers, and, indeed, no suggestion of symmetry is seen in the data at deuteron energies up to 11.5 MeV. Our recent measurements of the deuteron vector analyzing power at 30 MeV have shown that $A_Y(\Theta) = - A_Y(\pi-\Theta)$ is approximately fulfilled. We have also shown that this is an exact symmetry if the reaction should proceed entirely by way of the direct nucleon-transfer process. Thus, deviations from this symmetry provide clear evidence that the reaction proceeds (also) via the compound nucleus ^{4}He. We report our measurements of $A_Y(\Theta)$ at 15, 20, and 25 MeV, which were made in order to examine the transition from the complete lack of symmetry at 11.5 MeV to that of approximate symmetry at 30 MeV. Our results show the transition to be a gradual one, so the change from the compound-nucleus reaction mechanism to the predominantly direct nucleon-transfer mode is correspondingly gradual. At 30 MeV and above, analysis in terms of the direct-reaction process is clearly appropriate. *(LBL 4051)*

Alpha-Spectroscopic Factors for Light Nuclei, *T. Fliessbach (LBL), and P. Manakos (Stony Brook)*

In a recent paper it was shown that a consistent reaction theory requires a modification of the usual definition for α-spectroscopic factors. In the present paper a simple formula for the new spectroscopic factors is derived in the framework of the harmonic oscillator shell model. These factors are calculated for a number of light nuclei. *(LBL-4094) Submitted to Nucl. Phys. A.*

Evidence for Triaxial Shapes in Pt Nuclei, *T. L. Khoo, F. M. Bernthal, C. L. Dores (Michigan State U.); M. Piiparimen, S. Sahah, P. J. Daly (Purdue); and J. Meyer-ter-Vehn (LBL)*

Positive parity levels in ^{191}Pt obtained from (α,xnγ) reactions and β decay are presented as a first example of a rather complete $i_{13/2}$ level family. The spectrum confirms triaxial shapes found before from $h_{11/2}$ and $h_{9/2}$ proton structures in this mass region.
In addition to the usual decoupled yrast-band, a second ΔI = 2 band

within the $i_{13/2}$ family, built on a low-lying j-1 = 11/2 state, is observed in agreement with theory. *(LBL - 4349) Submitted to Phys. Rev. Lett.*

Symmetry Between Particle and Hole Level Systems in ^{189}Au, *J. L. Wood, R. W. Fink (Georgia Inst. Tech.); and J. Meyer-ter-Vehn (LBL)*

The $h_{11/2}$ and $h_{9/2}$ level systems have been studied experimentally and theoretically in ^{189}Au. If multiplied by a constant scaling factor, the two systems display identical relative energy spacings. This is in agreement with a particle-hole symmetry valid for triaxial odd-A rotors. *(LBL-4350) Submitted to Phys. Lett.*

Finite Range Evaluation of (p-d, d-t) With Momentum Space Techniques, *L. A. Charlton*

A momentum space methodology is presented for calculating second-order DWBA matrix elements without the use of the zero-range approximation. This methodology is applied to the sequential transfer term in (p,t) reactions. Examples are presented for ^{208}Pb(p,t) ^{206}Pb, which show that (1) finite-range effects can be large, (2) the shape of the calculated differential cross section can be strongly dependent on the contribution from a sequential transfer mechanism, and (3) the post-prior interchange usually used is probably the best realistic approximation. *(LBL-4356) Submitted to Phys. Rev. C.*

Radiative Ionization in Slow Ion-Atom Collisions, *R. Anholt (LBL) and T. K. Saylor (Stanford)*

Bremsstrahlung from the ionization of inner shell electrons in slow ion-atom collisions is considered. The yield predicted by the binary encounter approximation is small compared with experiment in 12- to 33-MeV O + Zr and O + Au collisions. *(LBL-4360) Submitted to Phys. Lett. A.*

Response of Pilot U Scintillator to Heavy Ions, *M. Buenerd, D. L. Hendrie, U. Jahnke, J. Mahoney, A. Menchaca-Rocha, C. Olmer, and D. K. Scott*

The light output response of Pilot U Scintillator for stopped charged particles has been measured for ^{4}He, ^{6}Li, ^{12}C, ^{16}O, ^{20}Ne, and ^{40}Ar ions incident at various energies up to 20 MeV/nucleon. From these we derived a systematic description of the variation of the scintillation parameters with the charge and energy of the projectile. The suitability of such a detector for the focal plane of a heavy-ion magnetic spectrometer is discussed. *(LBL-4372) Submitted to Nucl. Instrum. Methods.*

Heavy-Ion Potential Derived from a Velocity-Dependent Nucleonic Interaction, *J. Randrup*

A simple expression is derived for the elastic nuclear interaction between two colliding heavy ions. It is based on an effective velocity-dependent nucleon-nucleon interaction. An approximative treatment of the exclusion principle is indicated. Numerical results are presented. *(LBL-4376) Submitted to Phys. Lett.*

When Heavy Ions and Targets Get Heavier; or, the Effect of Shorter Interaction Times on the Spread of Charge Distributions, *L. G. Moretto*

Detailed measurements on the charge and angular distributions of the fragments emitted in reactions

induced by Ar and lighter projectiles have been performed. These studies support the existence of a short-lived intermediate complex retaining the shape of two touching nuclei and diffusing along the mass/charge asymmetry degree of freedom. The forward-peaked angular distributions and the broad charge distributions are consistent with a moderately long decay time (~ 10^{-21} seconds) during which a substantial diffusion along the mass/charge asymmetry coordinate occurs. Recent improvements on the Z resolution up to $Z \simeq 50$ have allowed us to study in detail the charge and angular distributions as well as the kinetic energy distributions in Kr-induced reactions on a variety of targets. The fragment angular distributions, peak sideways for Z's close to that of the projectile, flatten out and tend to $1/\sin\theta$ for much larger or smaller Z's. The Z distributions vary substantially with angle, from sharply peaked about the projectile to very broad. It appears that a shorter interaction time, probably due to the increased Coulomb repulsion, limits to a fair extent the diffusion along the mass/charge asymmetry coordinate. *(LBL-4377 Abs) Invited Paper for the Pasadena Meeting of the American Physical Society, 29-31 December 1975.*

The Reactions of ^{40}Ar with ^{160}Dy, ^{164}Dy and ^{176}Yb, *Y. LeBeyec (Orsay), R. L. Hahn and K. S. Toth (ORNL), and R. Eppley (LBL)*

Excitation functions for nuclear reactions induced by ^{40}Ar ions were measured for the reactions ^{164}Dy(^{40}Ar,xn)$^{204-x}$Po at the accelerator ALICE in Orsay, and for the reactions ^{160}Dy(^{40}Ar,xn)$^{200-x}$Po, ^{174}Yb(^{40}Ar,xn)$^{214-x}$Ra and ^{174}Yb(^{40}Ar,pxn)$^{213-x}$Fr at the Super-HILAC in Berkeley. For all of the systems studied, the (Ar,xn) reactions only make up a small part of the total reaction cross section of ~2 b; the largest cross sections encountered in each system were (at the peaks of the respective excitation functions) 30 mb for ^{164}Dy(Ar, 5n), 10 mb for ^{160}Dy(Ar,4n) and 5 mb for ^{174}Yb(Ar,4n-5n). The probabilities P_{xn} of neutron emission in the compound systems ^{204}Po and ^{200}Po were found to be very different, with respective maximum probabilities for the emission of 4, 5, and 6 neutrons of 0.064, 0.035, and 0.016 for ^{204}Po, and 0.010, 0.0025, and 0.0003 for ^{200}Po. Calculations performed with the statistical-model code ALICE, which includes angular-momentum effects and fission competition, are able to reproduce the shapes and magnitudes of the experimental excitation functions, although there is a systematic energy difference, ~10 MeV, between theory and the data. These model-dependent analyses describe in detail how the particle evaporation and fission de-excitation modes vary with angular momentum and excitation energy. The observed large differences in P_{xn} values for ^{204}Po and ^{200}Po are seen to arise from small difference, ~1.2 MeV, between the values of $\overline{S_n - B_f}$, the difference of neutron-separation and fission-barrier energies, in each compound system. *(LBL-4378) Submitted to Phys. Rev.C.*

Coulomb Dissociation of Relativistic ^{12}C and ^{16}O Nuclei, *H. H. Heckman and P. J. Lindstrom*

Cross sections for the dissociation of relativistic ^{12}C and ^{16}O nuclei by the Coulomb fields of target nuclei have been measured at the Bevatron. Coulomb contributions to the total fragmentation cross sections are interpreted by the Weizsäcker-Williams method. The minimum-impact parameters deduced from the

measured cross sections are characterized by radial overlap distances comparable to the charge-skin thicknesses of the interacting nuclei, compatible with the effects of nuclear absorption. *(LBL-4380) Submitted to Phys. Rev. Lett.*

^{142}Nd(^{18}O,^{16}O)^{144}Nd Reaction and Its Contrast to ^{144}Nd(^{12}C,^{14}C)^{142}Nd Reaction, *K. Yagi, D. L. Hendrie, U. Jahnke, C. F. Maguire, J. Mahoney, D. K. Scott (LBL); and D. H. Feng, T. Udagawa, K. S. Low, and T. Tamura, (U. Texas)*

An investigation is made of the ^{142}Nd(^{18}O,^{16}O)^{144}Nd reaction and compared with the inverse-type reaction ^{144}Nd(^{12}C,^{14}C)^{142}Nd. *(LBL-4382) Submitted to Phys. Rev. C.*

Diffusive Phenomena Reflected in the Charge and Angular Distributions of N, Ne, Ar, Kr Induced Reactions, *L. G. Moretto and J. S. Sventek*

The presence of diffusion processes in heavy-ion reactions is argued on a theoretical ground by pointing out the limitation of a Lagrangian approach to the time-dependent processes. The Master Equation is used to describe the diffusion of the probability distribution along the mass asymmetry coordinate. Calculations of the probability distributions as a function of time have been performed for many heavy-ion reactions. Experimental evidence of diffusion is shown to exist in the charge and angular distributions associated with a large number of heavy-ion reactions. It is shown that the deep inelastic processes occurring in lighter systems, and quasi fission observed for heavier systems can be interpreted in terms of the very same mechanism. A comparison between the theoretical calculations and the experimental data is shown. See Figs. 14 and 15. *Invited paper to the Symposium on Macroscopic Features of Heavy Ion Collision, ANL, Argonne, IL , April 1-3, 1976. (LBL-5006)*

Physical Basis for Large Forward Cross Sections in ^{60}Ni(^{18}O, ^{16}O) Reaction, *N. K. Glendenning and G. Wolschin*

Experiments on the reaction ^{60}Ni(^{18}O,^{16}O)^{62}Ni revealed an unexpectedly large forward cross section for production of the ground state, in contrast with an expected grazing peaked distribution. This has most recently been interpreted in terms of a surface transparent optical potential. In the inverse experiment, it is known that ^{18}O is produced in its 2^+ state with larger

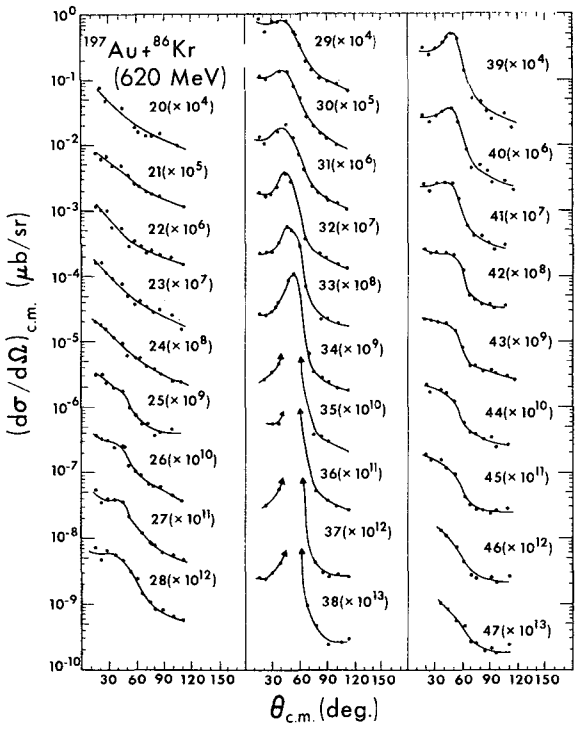


Fig. 14 Experimentally obtained center-of-mass angular distributions for the reaction Au + ^{86}Kr at 620 MeV. (XBL-7512-9891)

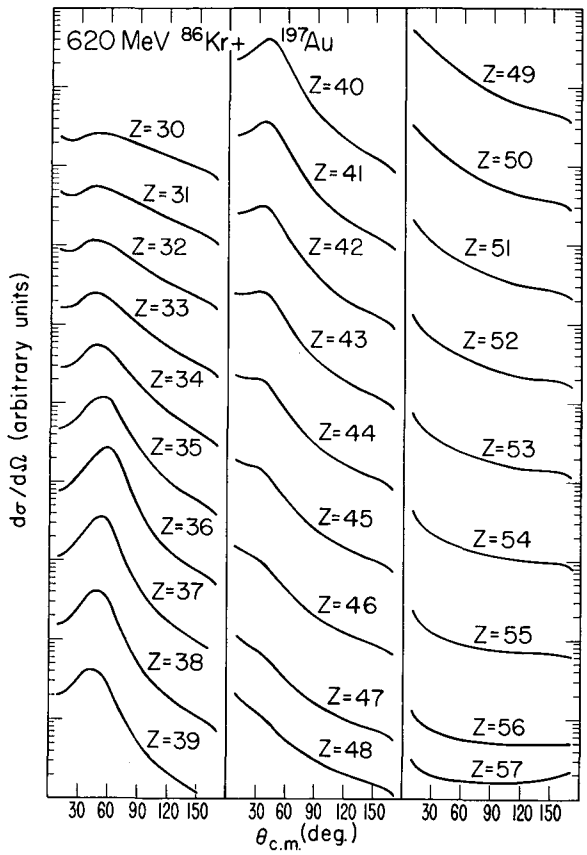


Fig. 15 Theoretical center-of-mass distributions for the reaction Au + ^{86}Kr at 620 MeV. (XBL-763-2504)

cross section than the ground state. This suggests that the above ground-state reaction can also be produced with appreciable probability through the excitation of ^{18}O in the incident channel, with a subsequent transfer of two neutrons to form the ground state of ^{62}Ni. We find that by including this process together with the direct transfer, we can account for the experimental data. The parameters of the optical potential employed are chosen so as to reproduce both the elastic and inelastic cross sections, and are of the normal strong absorbing type with no surface transparency. We conclude that the projectile excitation is the physical process involved in the large forward cross section. In addition, the interference of the direct and indirect processes can give rise to a minimum beyond the grazing peak followed by a secondary maximum, some indication of which can be found in the experiments on neighboring nuclei. The quantal deflection function is employed in a discussion of the S matrix and angular distribution emerging from this calculation and of the surface transparent potential parametrization of the effect. *(LBL-5007) Presented at the Symposium of Macroscopic Features of Heavy Ion Collisions, Argonne, IL, April 1-3, 1976.*

Polarization of Single-Particle States Involved in Heavy Ion Transfer Reactions, *K. Pruess, G. Delic, L. A. Charlton, and N. K. Glendenning*

If two nuclei could be placed next to each other at a distance typical of grazing collisions, the single-particle states in each would adjust themselves to the presence of the other nucleus. They would develop an appreciable probability of being in the other nucleus, and the more weakly bound the state, the more strongly it would be polarized by the other nucleus. The solution to this situation has been realized in the two-center shell model. Whether such an adjustment can occur during a reaction depends on the ratio of the transit time to the nuclear periods of the more weakly bound nucleons. In typical low-energy experiments this ratio appears to allow for such a polarization. Clearly if it occurs, the form factor for a transfer reaction will be modified from those currently employed, which use the asymptotic single-particle states of the non-interacting separated nuclei. From the foregoing discussion we expect that 1) for stripping reactions to

a sequence of excited states in the target nucleus, the polarization effects will increase with increasing excitation (i.e., decreasing binding), 2) since transfer can take place for larger impact parameters if polarization occurs, the effect on the angular distribution will be a shift to smaller angles compared to normal DWBA, 3) the polarization effect will ultimately vanish at sufficiently high bombarding energy. We have found from calculations so far that the single-particle states of the heavier of the reaction partners suffer the greater polarization. *(LBL-5008) Presented at the Symposium on Macroscopic Features of Heavy Ion Collisions, Argonne, IL, April 1-3, 1976.*

A New Recoil Effect in Nucleon Transfer Reactions Between Heavy Ions, *N. K. Glendenning, L. A. Charlton, G. Delic, and M. A. Nagarajan*

In the last few years it has become clear that the effect of the shifting centers of mass (recoil effect) have to be properly incorporated into the theory of single nucleon transfer between nuclei, especially at higher energies. A re-examination of the present theory reveals, however, that there remains a serious problem, which is associated with the so-called spurious center-of-mass motion in nuclear structure models. In principle, the present calculations that purport to treat recoil exactly, none the less ought to be corrected for the above defect in the nuclear wave functions that they employ. We have not obtained an exact resolution of the long outstanding problem of spurious center-of-mass motion in nuclear models, but we have formulated an approximate procedure for handling the correction to reaction calculations arising from this source. The correction has two components: There is a scalar one which corresponds merely to a scaling of the radial coordinate and applies to all reactions. There is also a vector correction which can be cast into a form in which a particle picked up or removed from a definite shell model state appears to occupy a distribution of states having the same parity but differing in angular momentum. This component of the correction applies only to certain reactions. Because of the dispersion in the apparent angular momentum of the transferred nucleon, the reaction can proceed through the transfer of larger units of angular momentum than the normal recoil calculations allow, and the correction therefore is expected to grow with increasing bombarding energy. The scheme we have developed for handling this effect, which might be referred to as bound state recoil, to distinguish it from the recoil effect that the current theories focus on, is presented, together with preliminary estimates of its importance. *(LBL-5009) Presented at the Symposium on Macroscopic Features of Heavy Ion Collisions, Argonne, IL. April 1-3, 1976.*

ON PHYSICS, MATHEMATICS AND COMPUTING

Total Muon Capture Rates in Actinide Nuclei, *O. Hashimoto, S. Nagamiya, K. Nagamine, and T. Yamazaki*

Lifetimes of negative muons bound to ^{232}Th, ^{235}U, ^{238}U and ^{239}Pu have been determined to be 80.4 ± 2.0 ns(^{232}Th), 78 ± 4 ns(^{235}U), 81.5 ± 2.0 ns(^{238}U), and 77.5 ± 2.0 ns(^{239}Pu) by observing decay electrons from muons. Systematics of

total muon capture rates are discussed. They are also compared with the lifetimes determined by fission fragments in view of possible fission-isomer excitation by muons. *(LBL-3850) Submitted to Phys. Lett.B*

An Adaptive Finite Difference Solver for Nonlinear Two-Point Boundary Problems with Mild Boundary Layers, *M. Lentini and V. Pereyra*

A variable-order variable-step finite-difference algorithm for approximately solving m-dimensional systems of the form

$$y' = f(t,y), \quad t \in [a,b]$$

subject to the nonlinear boundary conditions

$$g[y(a),y(b)] = 0$$

is presented.

A program, PASVAR, implementing these ideas has been written, and the results on several test runs are compared with those obtained by other methods. PASVAR's main features are that: a) Very precise global error estimates can be produced, which in turn allow a very fine control between desired tolerance and actual output precision. b) Non-uniform meshes allow an economical and accurate treatment of boundary layers and other sharp changes in the solutions. c) The combination of automatic variable order (via deferred corrections) and automatic (adaptive) mesh selection produces, as in the case of initial value problem solvers, a versatile, robust, and efficient algorithm. *(LBL-4226) Submitted to SIAM J. Num. Anal.*

Improved Techniques for the Analysis of Experiments with Polarized Targets, *E. Barrelet*

An experiment was performed at the Bevatron to measure the polarization in the reaction $\pi^- p \to \pi^0 n$ from a polarized target, at beam momenta between 1 and 2 GeV/c. As an adjunct to that experiment, proportional wire chambers were mounted to detect $\pi^- p$ elastic scattering from the same target.

This report concentrates on the geometrical reconstruction of the elastic events; the use of the high analyzing power of the reaction studied to probe the polarization of the target in magnitude and distribution; a study of the statistical estimation of the polarization parameter; and, a detailed study of the quasielastic background.

The initial objective has been fulfilled: we have drawn a map of the polarization inside the target with a resolution smaller than 1 cm. The hypothesis of uniformity of the target was tested successfully. The maximum possible error on the polarization parameter due to the target inhomogeneity has been computed and is negligible. *(LBL-4236)*

Measurement of Differential Cross Sections for Radiative Pion-Proton Capture in the Second Resonance Region, *A. J. Weiss, D. J. Blasberg, J. C. Comiso, R. P. Haddock, B.M.K. Nefkens, L. J. Verhey, M. B. Zeller (UCLA); and K. M. Crowe, A. Fainberg, P. Truoel (LBL)*

Differential cross section measurements for $\pi^- p \to \gamma n$, consisting of three angular distributions at 618, 676, and 718 MeV/c, and the energy dependence at $\tilde{\theta}_\gamma = 90°$ for seven incident pion momenta between

502 and 888 MeV/c, are presented. Our data qualitatively support recent multipole analysis. Good agreement with the Scheffler et al. results is obtained for the inverse reaction, $\gamma n \rightarrow \pi^- p$, when a ($\pi^-$-recoil p) coincidence technique is used, and excludes a large violation of time-reversal invariance. Only qualitative agreement with $\gamma n \rightarrow \pi^- p$ data is obtained when the $R(\pi^-/\pi^+)$ ratio technique or a deuterium bubble chamber is used. *(LBL-4241) Submitted to Nucl. Phys. B.*

Photon Spectrum in Pion Capture on Tritium, *J. A. Bistirlich, S. Cooper, K. M. Crowe, F. T. Shively (LBL); E. R. Grilly, J. P. Perroud, R. H. Sherman (LASL); H. W. Baer (Case Western Reserve); and P. Trüol, (Physic-Institut der Universität)*

The photon spectrum from the pion capture reaction $\pi^- + t \rightarrow 3n + \gamma$ was measured with a high-resolution pair-spectrometer. The measured branching ratio ($\pi^- t \rightarrow nnn\gamma$)/ $\pi^- t \rightarrow nnn\gamma$ or nnn) is 4.5 ± 0.8%. The shape of the photon spectrum is in satisfactory agreement with theoretical calculations (Fig. 16), which

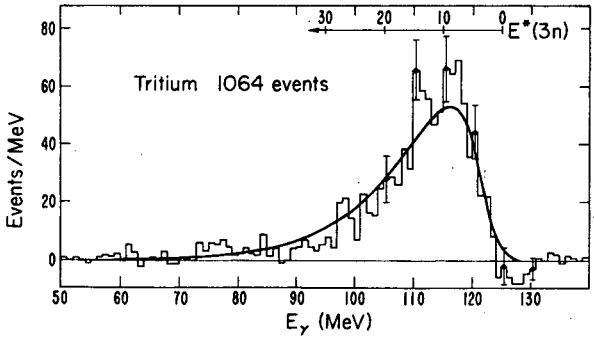


Fig. 16. Spectrum from reaction $\pi^- t \rightarrow nnn\gamma$ after subtraction of ^1H steel, and scintillator contribution. Solid curve is the theoretical spectrum folded with acceptance and instrumental line shape and normalized to the total number of photons. (XBL-761-2079)

include final state interactions among the three neutrons. No evidence for a bound trineutron is found. *(LBL-4268) Submitted to Phys. Rev. Lett.*

Observational Research in User-Computer Interaction, *D. F. Kane, Jr.*

An observational methodology is the best approach to research and development for user-computer interaction in information systems. This phenomenon is akin to interpersonal communication, very rich in complex interrelationships, and is not susceptible to controlled experimentation.

There are two primary aspects of the observational methodology as described. The intensive aspect involves the close teamwork among programmers and users in the development of the information system. The heuristic aspect involves the intentional evolution of the system from rudimentary to complex, primarily directed by the users' perceived needs, and harshly selected on the basis of observed ease of use.

Any research methodology must be directed by some measurements of success. In applied research, cost recovery is certainly an important measure. For information systems, the expansion of the user population is another measure, especially if new users come without solicitation, are able to get productive results quickly, and can use the system in different ways to suit their own needs. The most important measure of success for systems involving user-computer interaction, however, is that the users can concentrate on doing their job, undistracted by techniques alien to their own mental processing. *(LBL-4297) Presented at Workshop on Psychological Research on User On-Line Interaction, Boston, MA, October 26, 1975.*

Superconducting Detector Magnets Alternatives and Choices, *M. A. Green*

Detectors for colliding beam experiments will require magnetic fields in order to detect and analyze charged particles. Often it is best to use a superconducting magnet to generate this field. Potentially several kinds of superconducting magnets can be used in the charged particle detectors; the solenoid appears to be the best for this type of physics. Three kinds of superconducting solenoids can be used. The kind of solenoid magnet to be used in the experiment is dictated by the physics outside of the magnet coil. This report discusses a low-current-density conventional solenoid and two types of high-current-density magnet which permit physics to be performed outside the magnet. *Presented at the 1975 PEP Summer Study, LBL, July 28 - August 20, 1975. (LBL-4611).*

Strong Turbulence and the Anomalous Length of Stored Particle Beams, *P. J. Channell and A. M. Sessler*

A dispersion relation, including strong turbulence, is derived for short-wavelength longitudinal self-perturbations of bunched electron beams. The effects of radiation damping and quantum excitation are included. Assuming that turbulence stabilizes coherent oscillations allows the derivation of a formula for bunch length which gives excellent fits to the data from SPEAR. As a special case of the formalism, an integral equation which describes the longitudinal self-perturbations of proton beams is derived. *(LBL-4613) Submitted to Nucl. Instrum. Methods*

Complex Cubic Spline Approximation of Conjugate Harmonic Functions on Simple Polygonal Domains, *J. D. Young*

We present a method for approximating a harmonic function on and within a simple polygonal domain when values of the function are specified at seven or more points on the boundary. Function values must be specified at all the vertices of the polygon. Further, for any simple domain, the boundary may be approximated by a simple polygon, and the above process applied. Thus, we are able to approximate the solution to Laplace's equation with Dirichlet conditions on rather general simple domains. We are also able to approximate the harmonic conjugate of the original function to within an arbitrary constant. This constant may be determined if the value of the harmonic conjugate is specified at one point.

The original function and its harmonic conjugate are treated as, respectively, the real and imaginary parts of a complex function. The approximation of this latter function is by means of a complex cubic spline. *(LBL-4625) Submitted to Logistics and Transportation Review*

Exact Vlasov-Maxwell Equilibria with Sheared Magnetic Fields, *P. J. Channell*

We present a theoretical formalism which allows the generation of a large class of exact Vlasov-Maxwell equilibria with sheared magnetic fields. All quantities are assumed to vary only in one spatial direction, x, and the magnetic field has components only in the y and z directions. The Vlasov equations are solved by making the distribution functions depend only on constants of the motion. The Maxwell

equations are then reduced to finding the motion of a pseudo-particle in a two-dimensional potential. Three examples corresponding to sheet-like, sheath-like, and wave-like equilibria are presented. *(LBL-4640) Submitted to Phys. Fluids*

An Improved Shift Strategy for the QR-Algorithm for Real Hessenberg Matrices, *I. Karasalo*

We present some experimental results on the behavior of the QR-algorithm for real Hessenberg matrices, with shifts calculated from a $p \times p$ lower right-hand submatrix where p may be > 2. We show how one such shifting strategy may be conveniently implemented in a programming language thus permitting recursive procedure calls by modifying slightly the ALGOL procedure HQR by Martin, Peters, and Wilkinson (Numer. Math. 14, 219-231, (1970). In our comparison the modified procedure gives , in general, a 15 to 20% reduction of the total operations count for transforming the Hessenberg matrix to block triangular form (with diagonal blocks of order $\leqslant 2$) and for updating the product of the orthogonal transformation matrices. *(LBL-4648)*

The Shape of a Pendent Liquid Drop, *P. Concus (LBL) and R. Finn (Stanford)*

The most general form of the outer surface of a symmetric pendent liquid drop is characterized analytically, for arbitrary vertex height u_o. It is shown the surface exists throughout space as a nonsingular formal solution of the defining differential equations, even in situations for which instabilities are expected. We establish rigorously with quantitative estimates that if $u_o << 0$, then near the vertex the surface has the general form of a succession of spheres centered on the axis $r = 0$, joined to each other with short narrow necks, and asymptotically tangent to a certain hyperboloid of revolution. We prove a partial result to indicate that away from the vertex the surfaces converge in any fixed region, as $u_o \to -\infty$, to a singular solution that represents a spike of liquid extending downward like $-\frac{1}{r}$ to infinity. *(LBL-4649)*

Inverse Iteration on Defective Matrices, *N.-fu Chen*

Very often, inverse iterations are used with shifts to accelerate convergence to an eigenvector. In this paper, it is shown that if the eigenvalue belongs to a nonlinear elementary divisor, the vector sequences may diverge even when the shift sequences converge to the eigenvalue. The local behavior is further displayed through a 2 x 2 example. *(LBL-4653) Submitted to Mathematics of Computation*

A Numerical and Analytical Study of Anomalous Propagation of Electrical Impulses in Damaged Heart Fibers, *R. Miller*

This work presents a mathematical framework in which two sets of experimental data can be understood. Two models will be described. The first model is a set of ordinary differential equations whose solutions reproduce in detail the behavior of the plateau of the Purkinje fiber action potential as observed by Hauswirth, Nobel and Tsien, J. Physiol. 200, 205, 233, 255(1969). The second is a system of nonlinear

partial differential equations which is designed to reproduce qualitatively some of the anomalous impulse propagation effects observed by Cranefield, Hoffman and their coworkers [Circ. Res, 28, 199, 220 (1971); J. Gen. Physiol. 59, 227 (1972); Electrophysiology of the Heart, McGraw-Hill, N.Y. (1960)] in canine Purkinje fibers whose excitability had been chemically depressed within small portions of their lengths. *(LBL-4657) Ph.D. Thesis*

Strings with Dimension-Dependent Intercept, *W. Siegel*

When we change the boundary conditions of the relativistic string in extra dimensions, the intercept $\alpha(0)$ is lowered to $1-[(26 - D_0)/16]$ in the modified orbital model, where D_0 is the dimensionality of the Poincaré-invariant subspace of space-time. In the modified model of the spinning string, the boson intercept becomes $\frac{1}{2} - [(10 - D_0)/8]$, while the fermion intercept stays at zero. The projective invariance of the ground state is broken, giving the "photon" mass by a Higgs-like mechanism. Unfortunately, the strings have a negative "G-parity," so the usual unshifted strings appear as intermediate states in the scattering amplitudes. Also, some of the amplitudes are not dual. *(LBL-4661) Submitted to Nucl. Phys. B.*

Experimental Searches for Magnetic Monopoles, *R. R. Ross*

Analysis of the sensitivity of previous negative searches for magnetic monopoles shows that they constitute prior evidence against the monopole interpretation of the event reported as "evidence for detection of a moving magnetic monopole." The strength of the evidence varies with the unknown mass of the monopole. For $M \lesssim 10^5$ GeV, odds are greater than 10^6:1 against. For larger masses, the limits depend strongly on assumptions about the range of monopoles and the threshold for detection of monopole tracks in obsidian. In no case are the odds less than 8 : 1, and they may be no less than 8000 : 1 against. Since the reported event may also be due to an electrically charged heavy particle, it is probably not due to a monopole. *(LBL-4665) Invited talk presented at the ORBIS SCIENTIAE 1976, Center for Theoretical*

Observation of Dynamic E2 Mixing via Kaonic X-ray Intensities, *G. L. Godfrey, G. K. Lum, and C. E. Wiegand*

We have observed for the first time a nuclear resonance effect between a kaonic atom and a nuclear transition in ^{98}Mo. Our measurement gave ^{98}Mo(n=6→5)/^{92}Mo(n=6→5)= 0.16 ± 0.16 instead of the no-mixing value of 1. Dynamic E2 mixing caused kaons to be strongly absorbed from ^{98}Mo atomic state n=6, ℓ=5 in agreement with theoretical predictions. *(LBL-4673) Phys. Lett. 61B, 45 (1976). See Fig. 17.*

Temperature Independent Hyperfine Field on μ^+ in Nickel in the Temperature Range of 0.12 - 300 K,

K. Nagamine, S. Nagamiya, O. Hashimoto, N. Nishida, T. Yamazaki, and B. D. Patterson

The hyperfine field on a positive muon at interstitial site in a nickel single crystal has been measured by the muon spin rotation method in the temperature range from

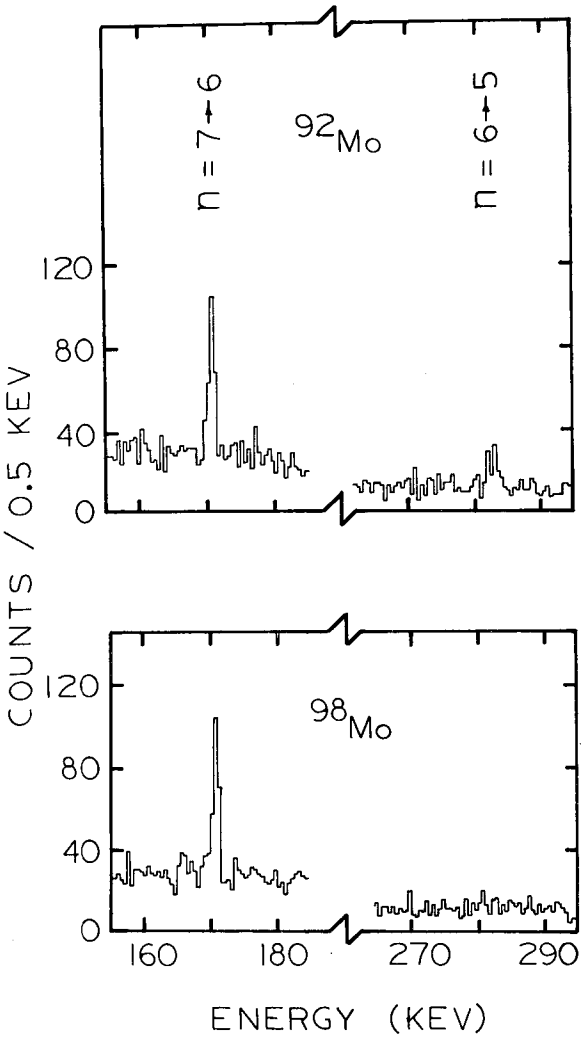


Fig. 17. Portions of the kaonic X-ray spectra of ^{92}Mo and ^{98}Mo showing the attenuation of the n=6→5 line in ^{98}Mo. (XBL-7512-9940)

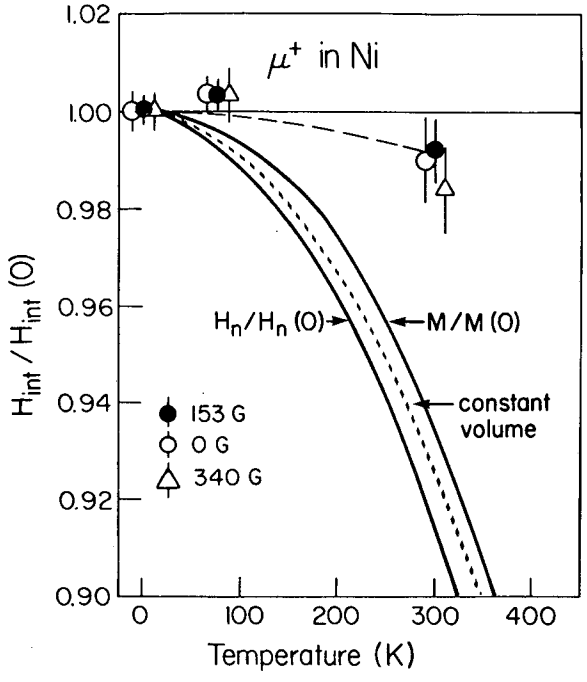


Fig. 18. Temperature dependence of the μ^+ hyperfine field with the external field of 0, 153, and 340 G, as well as the nuclear hyperfine field (H_n) and the magnetization of Ni (M)— all normalized at the lowest temperature. The values of magnetization and the hyperfine field are corrected to constant volume (both agree with each other to within 0.5%). The upper broken line shows the experimental tendency of the μ^+ hyperfine field. (XBL-764-1218)

0.12 K to 300 K. (Fig. 18) The hyperfine field in the low temperature limit was found to be -640.7 ± 2.2 gauss. While the saturation magnetization decreases by 7% as the temperature increases from 0.1 K to 300 K, the hyperfine field seen by the muon remains nearly constant. Possible mechanisms for explaining this result are considered. *(LBL-4694) Submitted to Hyperfine Interactions*

The Infinite Hard-Sphere System,

R. K. Alexander

We construct the time-evolution for the system of infinitely many particles in space interacting by the hard-sphere potential Φ:

$$\Phi(x) = \begin{cases} +\infty & |x| < a \\ 0 & |x| \geq a \end{cases}$$

Examples abound of configurations of the infinite system having

more than one solution to the Newtonian equations of motion. We impose a regularity condition on the solutions we seek, which limits the growth of velocities and of the length of chains of particles close together as $|x| \to \infty$; we prove that through any point of the phase space there passes at most one regular solution.

Every point in a subset $\overline{\mathfrak{X}}$ of the phase space $\mathfrak{X}$ is the initial point of a regular solution which is defined for all time. The subset $\overline{\mathfrak{X}}$ is of full measure for every Gibbs state and is invariant under the one-parameter group T^t of shifts along solution trajectories. Moreover, the flow T^t leaves every Gibbs state invariant.

The solutions we construct are limits, as $R \to \infty$, of motions in which particles inside the sphere of radius R are elastically reflected from its boundary while those outside remain fixed. For this reason, we also study the motion of finite systems.

For finitely many hard-sphere particles in a region of space with piecewise smooth boundary, the set of points of the phase space through which solutions exist for all time without triple or grazing collisions, is of full Lebesgue measure and is residual in the sense of Baire. Liouville's Theorem holds for the one-parameter group of shift-transformations T^t.

Finally, we give examples in which a single billiard moving in the plane is reflected infinitely often from a boundary curve in finite time, and we establish necessary conditions for such singularities to occur. *(LBL 4801) M. S. Thesis.*

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 (SLAC); W. R. Holley, R. P. Johnson (Fermi Lab); 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, the four-momentum 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 parametrizes the q^2 dependence of ξ by $\xi(q^2)=\xi(0)+\Lambda q^2/m_\pi^2$, then $\xi(0) = 0.178\pm0.105 - 3.80\Lambda$. 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 $\mathrm{Im}\xi(0) = 0.35\pm0.30 + 0.21\,\mathrm{Re}\xi(0)$. *(LBL - 4802) Submitted to Phys. Rev. D.*

Correction of Atmospheric Distortion with an Image-Sharpening Telescope, *A. Buffington, F. S. Crawford, R. A. Muller, A. J. Schwemin, and R. G. Smits (LBL and UC SSL)*

We have built and tested a 30 cm x 5 cm aperture telescope which uses six moveable mirrors to compensate for atmospherically-induced phase distortion. A feedback system adjusts the mirrors in real time to maximize the intensity of light passing through a narrow slit in the image plane. We have achieved essentially diffraction-limited performance when imaging both laser and white-light objects through 250 meters of turbulent atmosphere

(Fig. 19). The behavior of our telescope was accurately predicted by computer simulations. The system has yet to achieve its full potential, but has already operated successfully for objects as dim as 5th magnitude. *(LBL-4803) Submitted to Appl. Opt.*

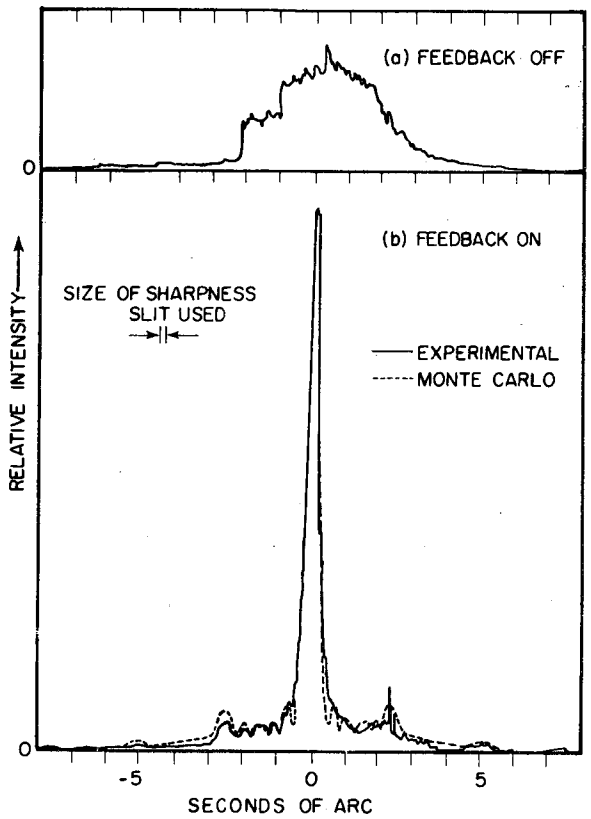


Fig. 19. Images of laser light viewed through 250 m of turbulent atmosphere. The agreement between corrected image and Monte Carlo calculation is good, and the corrected central diffraction peak is nearly a decade improved over the uncorrected image. The curves are normalized to the same area. (XBL-762-2228)

Eigenvalues and Eigenfunctions of the Hilbert Operator, *G. A. Sod*

The eigenvalues $\lambda_{r\ell}$ and the eigenfunctions $\phi_{r\ell}$ of the Hilbert operator have been evaluated as part of a technique for solving Boltzmann's equation for a gas model consisting of rigid spheres. The eigenfunctions are represented by the expansion

$$\phi_{r\ell} = p^{\ell} P_{\ell}(\cos\theta) \sum_{k=0}^{\infty} a_{r\ell k} \, L_k^{\ell+\frac{1}{2}}(p^2),$$

where L denotes the Laguerre polynomials and P the Legendre polynomials. The eigenvalues $\lambda_{r\ell}$ and the corresponding coefficients $a_{r\ell k}$ are given for $\ell = 0, 1, \ldots, 11$; $r=0, 1, \ldots, 56$; and $k = 0, 1, \ldots, 29$. *(LBL-4807) Submitted to Astrophys. J. (Suppl. Series)*

Discontinuity Formulas for Multiparticle Amplitudes, *H. P. Stapp*

In these lectures it is shown how discontinuity formulas are derived from unitarity and analyticity. The assumed analyticity property is the normal analytic structure, which follows from the macrocausality requirement on the S matrix. Both local and global discontinuity formulas are obtained. The local formulas give the discontinuities of the general multiparticle amplitude around arbitrary physical-region singularity surfaces. The global formulas give the global discontinuities across the normal threshold cuts in six-particle scattering functions. These latter formulas are the ones needed for the multiparticle generalization of the fixed-t dispersion relations that are described in subsequent lectures. These dispersion relations are the basis of an analytic formulation of multiparticle Regge theory that will be given by Alan White in later lectures. *(LBL-4811) Lectures delivered at the 1975 Les Houches Summer School on "Structural Analysis of Multiparticle Collision*

Amplitudes in Relativistic Quantum Theory," to be published by North-Holland.

APS MEETING IN WASHINGTON, D.C.

Scientists from the Nuclear Science Division and the Physics, Computer Science and Mathematics Division attended the Washington, D.C. meeting of the American Physical Society April 26-29, 1976 and made the following contributions:

Tensor Analyzing Powers in $^4He(\vec{d},d)$ ^4He Elastic Scattering from 20 to 40 MeV *(An invited talk), E. J. Stephenson, H. E. Conzett, R. M. Larimer, B. T. Leemann, and R. Roy.*

Measurements of $A_{yy}(\theta)$ in $^4He(\vec{d},d)$ ^4He elastic scattering have been made at c.m. angles from 30° to 160° and in energy steps of 5 MeV from 20 to 40 MeV. The beam polarization was monitored continuously by observing deuterons elastically scattered from ^4He at energies from 3 to 10 MeV below the beam energy. As the beam energy was increased during the experiment, the polarimeter deuteron energy and detector angle were chosen to correspond to previously measured values of $A_{yy}(\theta)$. The polarimeter was initially calibrated using the 17-MeV measurements of Ohlsen, et al.[1] The beam current was measured by observing deuterons elastically scattered at 23° into two monitor detectors. The tensor analyzing power at the monitor detector angle was measured separately and used to correct the monitor detector count rate. Regions of large tensor-analyzing power were observed at all the energies studied. Measurements of $A_{xx}(\theta)$ are in progress.

1. G. G. Ohlsen, et al. Phys. Rev. C8 1262 (1973) *(LBL-4365 Abs)*

An Investigation of the $(\alpha,^8Be)$ Reaction on 1p and 2s-1d Shell Targets, *(An invited talk), G. J. Wozniak, (LBL)*

The $(\alpha,^8Be)$ reaction was studied with a ^8Be identifier[1] on targets of ^9Be, $^{10,11}B$, $^{12,13}C$, $^{14,15}N$, ^{16}O, ^{24}Mg, ^{28}Si, and ^{40}Ca at bombarding energies between 55 and 72.5 MeV. For each target, cross sections were measured between 20 to 60° (θc.m.) at a single beam energy, while for ^{12}C and ^{16}O they were determined at several energies. Final states in 1p-shell nuclei were populated with strengths which correlated roughly with the magnitude of their theoretical α-spectroscopic factors.[2] In the 2s-1d shell, ground states were populated weakly as compared to excited states by the $(\alpha,^8Be)$ reaction. On the deformed target nuclei ^{24}Mg and ^{28}Si, this reaction strongly excited final states that correspond to rotational bands. A pronounced difference in the shape of the angular distributions was observed with the amount of structure decreasing as the orbital angular momentum transfer increased from 0 to 4. A reaction analysis was performed with zero-range and finite-range DWBA. Both relative and absolute α-spectroscopic factors were extracted from the data and are compared with theory.[2,3]

1. G. J. Wozniak, N. A. Jelley and Joseph Cerny, Nucl. Instrum. Meth. 120, 29 (1974).
2. D. Kurath, Phys. Rev. C 7, 1390 (1973).
3. J. P. Draayer, Nucl. Phys. A237, 157 (1975).

(LBL-4394 Abs)

Z and E Dependence of the Light Output Response of Pilot U Scintillator to Heavy Ions, *M. Beunerd, D. L. Hendrie, J. Mahoney, A. Menchaca-Rocha, C. Olmer, and D. K. Scott (LBL-4367 Abs.)*

Production of ^{11}Li in the (^{11}B, ^{11}Li) Reaction on ^{232}Th, *C. Olmer, M. Buenerd, D. L. Hendrie, G. Kekelis, J. Mahoney, A. Menchaca-Rocha, and D. K. Scott. (LBL-4370 Abs.)*

States at High Excitation in ^{16}O Observed in the Reaction ^{12}C(^{20}Ne ^{16}O)^{16}O, *A. Menchaca-Rocha, M. Buenerd, D. L. Hendrie, C. Olmer, and D. K. Scott. (LBL-4371 Abs.)*

The Classical S-Matrix and Quantum-Mechanical Corrections to Semiclassical Coulomb Excitation Theory, *R. Donangelo, M. W. Guidry, H. Massmann, and J. O. Rasmussen (LBL-4384 Abs.)*

Theory of Coulomb-Nuclear Interference for Heavy-Ion Rotational Scattering, *M. W. Guidry, H. Massmann, R. Donangelo, and J. O. Rasmussen, (LBL-4385 Abs.)*

Reduced Transition Probabilities for High Spin States in ^{232}Th, *P. A. Butler, M. W. Guidry, P. Colombani, I. Y. Lee, D. Ward, R. M. Diamond, and F. S. Stephens (LBL); and E. Eichler, N. R. Johnson and R. Sturm (ORNL) (LBL-4386 Abs.)*

Charge and Angular Distributions in Heavy Ion Reactions, *L. G. Moretto, B. Cauvin, P. Glässel, R. Jared, P. Russo, and G. Wozniak. (LBL-4391 Abs.)*

High-Spin States of ^{174,176}Yb Studies 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 (LBL-4396 Abs.)*

Determination of the $\pi^+p \to \pi^+p$ Zero Trajectories from 1.2 to 2.2 GeV Center-of-Mass Energy, *D. M. Chew, E. Barrelet, M. Urban (LBL-4644 Abs.)*

Elastic π^+p Partial Waves from Barrelet Zeros, *D. M. Chew, (LBL-4645 Abs.)*

Critique Via Barrelet Zeros of a Classical Partial-Wave Analysis, *D. M. Chew, E. Barrelet, M. Urban, (LBL-4646 Abs.)*

A Search for Backward A1 and A2 Production in 4 GeV/c π^-p Interactions, *D. Scharre, J. Chapman, R. Ely, G. Gidal, W. Michael, and P. Oddone. (LBL-4846 Abs.)*

The Reaction $\pi^-p \to p\pi^-\pi^0$ in the Baryon Exchange Domain, *J. Chapman, R. Ely, G. Gidal, W. Michael, P. Oddone, and D. Scharre. (LBL-4847 Abs.)*

Vector Meson Production by Baryon Exchange at 4 GeV/c, *G. Gidal, J. Chapman, R. Ely, W. Michael, P. Oddone, and D. Scharre (LBL-4848 Abs.)*

Forward Inclusive π^0 Production at Large Transverse Momentum from $\pi^{\pm}p$ and pp Interactions at 100 and 200 GeV/c, *G. Donaldson, H. Gordon, K.-W.Lai, I. Stumer (BNL); A. Barnes, J. Mellema, A. Tollestrup, R. Walker (CIT); O. Dahl, R. Johnson, A. Ogawa, M. Pripstein, S. Shannon (LBL). (LBL-4857 Abs.)*

Pion Nucleon Partial Wave Analysis from 0.8 to 2.0 GeV/c, *R. E. Hendrick, R. E. Cutkosky (Carnegie-Mellon U.); and R. L. Kelly (LBL). (LBL-4858 Abs.)*

Extraction of Average Multiplicity of Off-Mass-Shell $\pi\pi$ and $K\pi$ Scattering, *R. Kass, J. Erwin, J. H. Klems, W. Ko, R. L. Lander, D. E. Pellett, P. M. Yager (UC, Davis); and M. Alston-Garnjost (LBL). (LBL-4859 Abs.)*

Energy Dependence and Factorization in the Inclusive Pion Spectrum for π^+p and pp Interactions at 100 and 200 GeV/c. *J. H. Klems, J. Erwin, W. Ko, R. L. Lander, D. E. Pellett, P. M. Yager (UC, Davis); and M. Alston-Garnjost (LBL). (LBL-4860 Abs.)*

Leading Particles in π^-p Interactions at 205 GeV/c, *G. P. Yost, H. H. Bingham, D. M. Chew, B. Y. Daugeras, W. B. Fretter, W. R. Graves, A. D. Johnson, J. A. Kadyk, L. Stutte, and F. C. Winkelmann (UC, Berkeley); D. Bogert, R. Hanft, R. Harris, F. R. Huson, S. Kahn, D. Ljung, C. Pascaud, and W. M. Smart, (Fermilab). (LBL-4861 Abs.)*

Search for Rare Processes in Neutrino Interactions Using the Fermilab Neon-Hydrogen Bubble Chamber, *R. J. Loveless, J. Von Krogh, W. Fry, U. Camerini, D. Cline, J. Mapp, R. March, D. D. Reeder (U. Wisconsin); A. Barbaro-Galtieri, P. Bosetti, G. Lynch, J. Marriner, F. Solmitz, M. L. Stevenson (LBL); D. Haidt, G. Harigel, H. Wachsmuth, W. Hart, D. C. Cundy (CERN); R. Cence, F. Harris, S. Parker, M. Peters, V. Peterson, V. Stenger (U. Hawaii). (LBL-4862 Abs.)*

Search for Dimuon Production in High Energy Neutrino Interactions Using the Fermilab Ne-H_2 Bubble Chamber and External Muon Identifier. *R. Cence et al., U. Wisconsin, LBL, CERN, U. Hawaii as above. (LBL-4863 Abs.)*

Inclusive Neutral Current Production in Neutrino-Proton Interactions, *V. Z. Peterson, R. J. Cence, F. A. Harris, S. I. Parker, M. W. Peters, V. J. Stenger (U. Hawaii); J. P. Berge, D. V. Bogert, D. C. Cundy, F. A. Dibianca, V. Efremenko, P. Ermolov, R. Hanft, F. A. Nezrick, Y. Rjabov, W. G. Scott, W. Smart (Fermilab); A. Barbaro-Galtieri, G. R. Lynch, J. P. Marriner, F. T. Solmitz, M. L. Stevenson (LBL); C. T. Coffin, R. N. Diamond, H. T. French, W. Louis, B. P. Roe, J. Vander Velde (U. Michigan). (LBL-4865 Abs.)*

Search for Strange Particle Production by Neutral Current Interactions in High Energy Neutrino Proton Scattering, *F. A. Dibianca et al., Fermilab, U. Hawaii, LBL, U. Michigan as above. (LBL-4866 Abs.)*

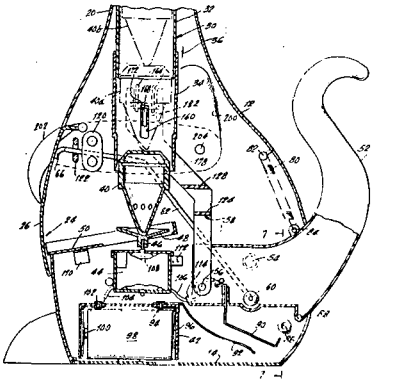
Search for Anomalous e^+e^- and $\mu^+\mu^-$ Events in e^+e^- Annihilation, *Frank B. Heile, SLAC-LBL Magnetic Detector Collaboration (LBL-4867 Abs.)*

Central Collisions of Relativistic Heavy Ions, *A. Sandoval, R. Stock (Marburg), H. H. Gutbrod (GSI), A. M. Poskanzer, J. Gosset, W. G. Meyer, G. D. Westfall (LBL). (LBL-5000 Abs.)*

Production of Fragments up to Z=18 from Irradiation of U and Ag by 4.9 GeV Protons, *G. D. Westfall, R. G. Sextro, A. M. Zebelman, and A. M. Poskanzer. (LBL 5001 Abs.)*

In-Beam Gamma Ray Spectroscopy with Relativistic Carbon Ion Beams. *T. Shibata, H. Ejiri (Osaka U.); R. Anholt, H. Bowman, J. G. Ioannou-Yannou, J. O. Rasmussen, E. Rauscher (LBL); and S. Nagamiya, K. Nakai (U.Tokyo). (LBL-5002 Abs.)*

Energy Dependence of the Distribution of Reaction Strength for ^{16}O + ^{40}Ca. *S. E. Vigdor, D. G. Kovar and P. Sperr (ANL); J. Mahoney, A. Menchaca-Rocha, C. Olmer and M. Zisman (LBL). (LBL-5004 Abs.)*



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ARTICULATED TOY FOR SPINNING TOPS

OPERATIONS

BEVATRON/BEVALAC

Shutdown efforts dominated the March-April period, including a large number of maintenance jobs inside and outside the vacuum tank. The magnet called Q2B, located just upstream of the EPB exit port of the Bevatron, was removed. This magnet is no longer needed now that the 50-MeV linac is not going to be used regularly for the Bevatron. Its removal has reduced the difficulty of changing energies, inasmuch as the radial position of the magnet had to be shifted when the particle energy was changed.

Installation of multiwire proportional chambers inside the vacuum system was completed this month when one was put in the M2 carriage in the South Straight Section. These chambers, used for monitoring the beam as it is extracted from the Bevatron, are now on the east and south extraction magnets, and will be extremely useful for beam intensities below scintillator-TV capability, which is about 10^{10} per pulse.

The accelerator was operated the first week in March, primarily for the program in Biology and Medicine, and the regular research program for Bevatron experiments is expected to resume early in May. The Bevalac should be functional again around the first of June, when the Super-HILAC returns to operation.

BEVATRON/BEVALAC OPERATING SCHEDULE, 26 April to 2 July, 1976

Bevatron operation for the research program is expected to resume on May 5, following a period of testing and tuning between April 26 and May 4. The current estimate for the resumption date of Bevalac operation is June 7. A tentative schedule for experiments to be performed is listed below.

Week of	Experiment	
4/26-5/2	Tests - tuneup - studies	
(5/3-5/4)		
5/5-5/9	Benton (Cruty)	(290B)
	Steiner-Anderson	(205H)
5/10-5/16	Kerth	(209H)
	Wiegand	(203)
5/17-5/23	Rasmussen	(248H)
	Steiner-Anderson	(205H)
5/24-5/30	Poskanzer-Gutbrod	(284H)
	Poe (Str. chbr)	(228H)
5/31-6/6	Carbon experiments Igo + Irradiations (Porile *et al.*) Bevalac if available, otherwise Bevatron)	
6/7-6/13	Biology and Medicine	
6/14-6/20	Poskanzer-Gutbrod	(284H)
	Porile	(236H)
	Caltech Argon Irradiations	
6/21-6/27	Biology and medicine	
	Heckman-Raisbeck	(239H)
6/28-7/2	Heckman-Raisbeck	(239H)
	Poe (Str. chbr)	(228H)
7/2-8/1	Summer shutdown	

BEVATRON/BEVALAC RESEARCH AND OPERATION

RESEARCH	Scheduled hours	Percent of program	Actual hours	Percent of program
Nuclear science	59.00	27.5	71.75	42.1
Biology and medicine	96.50	45.0	39.50	23.2
Machine studies	59.25	27.5	59.25	34.7
Total	214.75	100.0	170.50	100.0

OPERATION	Scheduled hours	Actual hours	Percent of hours scheduled
Research	214.75	170.50	76.6
Tune-up	8.00	26.75	12.0
Total operation	222.75	197.25	88.6
Failures and malfunctions		25.50	11.4
		222.75	100.0

TIME DISTRIBUTION	
Scheduled accelerator operation	222.75
Maintenance	321.25
Crew time off	200.00
Total (31 days of 24 h)	744.00

Summary of Bevatron/Bevalac Experimental Program

(Time in hours to the nearest quarter-hour)

	LBL groups			Other groups		
Exp. no.	Data-taking	Tune-up	Para-sitic	Data-taking	Tune-up	Para-sitic
NUCLEAR SCIENCE						
205H	2.25	8.25	31.75			
P87			50.50			
	2.25	8.25	82.25			
	92.75					
BIOLOGY AND MEDICINE						
215B	9.50					
218B	3.75	1.25		3.75	1.50	
256B				3.50		
269B				1.00		
289B	3.50					
293B	.25			.50		
294B	.75					
323B				1.00		
B73	5.00	.50				
B100	2.00					
	24.75	1.75	0	9.75	1.50	0
	26.50			11.25		

TOTAL EXPERIMENTAL PROGRAM

	Hours	No. of experiments
Nuclear science	92.75	2
Biology and medicine	37.75	10
	130.50	12

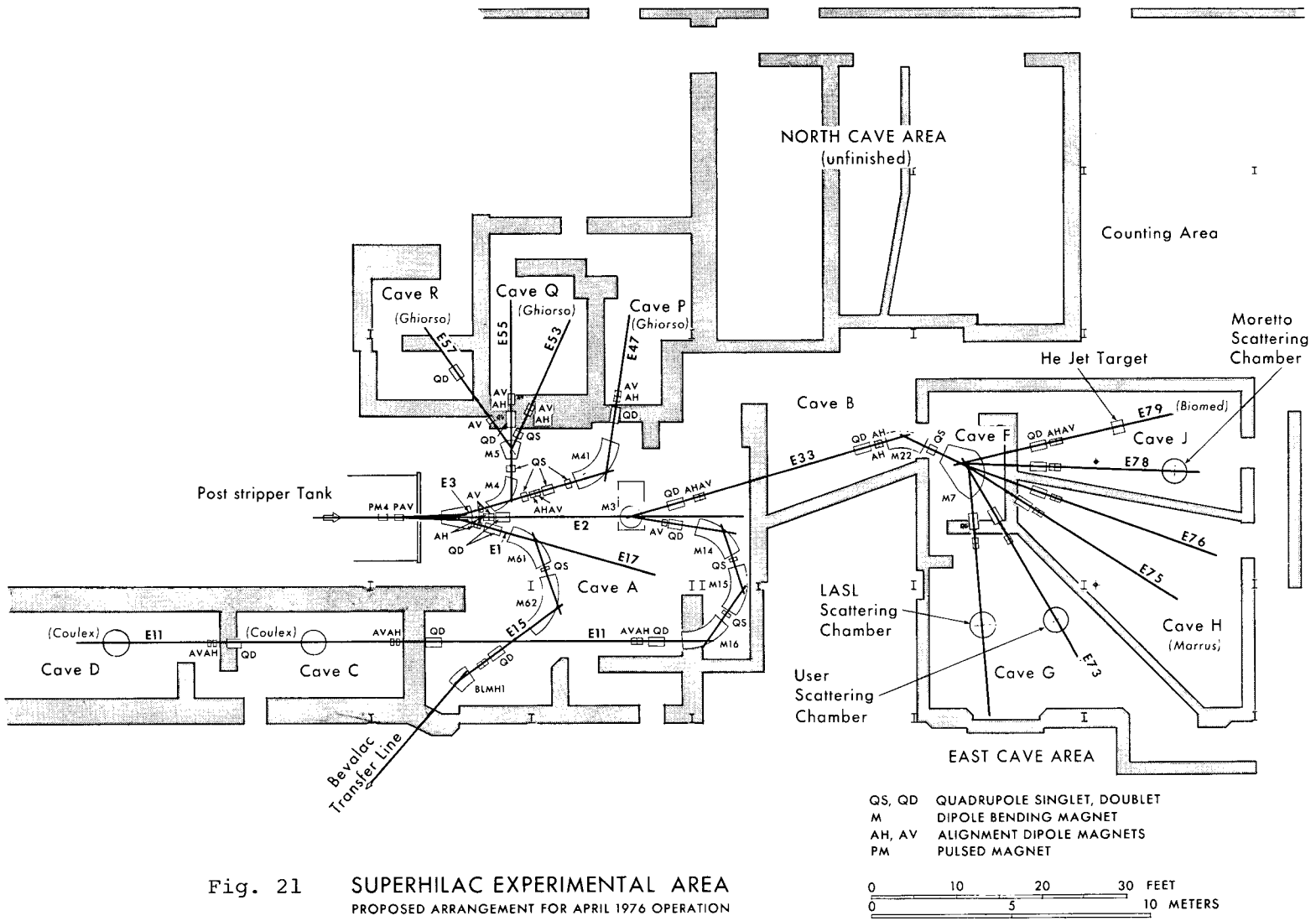

Fig. 21 SUPERHILAC EXPERIMENTAL AREA
PROPOSED ARRANGEMENT FOR APRIL 1976 OPERATION

XBL 764-1290

SuperHILAC

Beginning early in March, the SuperHILAC was shut down and an extensive rebuilding of the experimental area was begun. As shown in the accompanying Fig. 21, some old caves were rebuilt and some new caves were added. Beam lines E11 (Coulex) and E15(Bevalac), which formerly shared the same port in M1 and therefore could not be timeshared, now have different M1 ports, and can be timeshared. A new East Cave Area, with three caves and six beam lines has been added. A new North Cave Area with three caves was also added, with beam lines to be finished at a later date. All beam lines are now furnished with improved vacuum pumping and an increased number of steering magnets. In the experimental area, all control and monitoring of power supplies, vacuum valves, Faraday cups and other devices, will be done using the computer control system. This is supplemented by a local analog control capability where dictated by operational convenience-as in the vacuum valves. Where personnel safety requirements dictate, as in the cave gates, analog interlock capability is retained, and overrides any computer command.

The control room was enlarged and rebuilt, to provide increased console space as needed for three control stations. The cover photo was taken in the newly enlarged control room during the visit there by His Majesty the King of Sweden, Carl XVI Gustaf.

Limited operation of the accelerator for troubleshooting purposes will begin in May, with running for experiments planned for June.

Ion beams are distributed to beam lines in the new East Cave Area by a new bending magnet M7(Fig. 22). This magnet is able to bend the stiffest SuperHILAC beams through angles ranging from -60° to +38°. The asymmetric shape of the magnet results from the fact that the copper and iron were shaped to fit the geometry imposed by the beam lines, thereby saving considerable materials and expense compared with a symmetrical design.

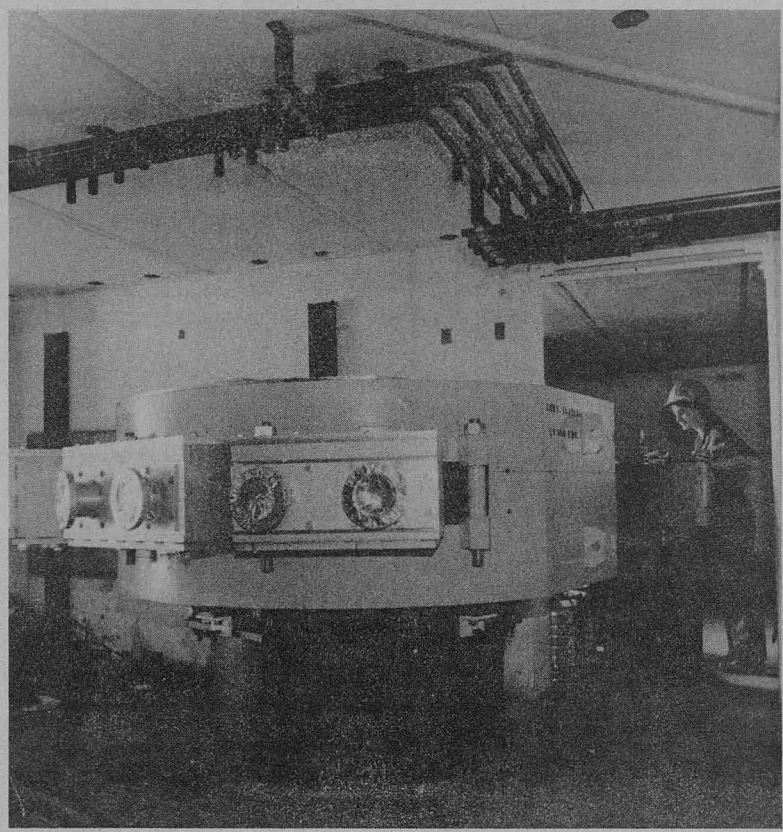

Fig. 22 Magnet M7 in the newly developed East Cave Area of the Super-HILAC. Mechanical Technician Ann Siri leans on the connecting beam line coming from the accelerator as she studies plans for completing the experimental area. (XBB-764-3719)

SuperHILAC Experimental Log to 8 March

Exp. no.	Experimenter	Beam line	Time share mode*	Ion	Sched. hours	Target hours	Total research hours	Charge states	Beam stop current	Energy MeV/u
122	Coulex II	E11.2	2B	^{86}Kr	40	26.50	28.50	6,23	30 nA dc	5.89
122	Coulex II	E11.2	2C,D	^{40}Ar		9.50	13.25	3,13	8 nA dc	5.89
124	Ghiorso	E53	4E,F	^{40}Ar	56	54.25	62.25	3,13	1 μA dc	5.89
	Bevalac	E15	1F,G,H	^{20}Ne	86	52.25	58.25	3,7,10	55 μA pK	8.5
100-1	Seaborg(Otto)	M1-0°	2H	^{136}Xe	22	20.00	20.00	8,29	220 nA dc	8.5
			TOTAL		204	162.50	182.25			
124	Ghiorso 1/20P	E53	4B	^{40}Ar	40	14.50	26.75	6,13	20 nA dc	5.89
124	Ghiorso 1/20P	E53	4D	^{40}Ar		8.75	9.50	3,13	-	5.89
					40	23.25	36.25			
		COMBINED TOTAL			244	185.75	218.50			
	TUNE-UP	E11.2	2A	^{86}Kr	16	0	5.00	6,23	30 nA dc	5.89
		E53	4A	^{40}Ar	16	0	11.25	6,13		5.89
		E15	1E	^{20}Ne	16	0	13.25	3,7,10	20 μA pK	8.5
		E53	4C	^{40}Ar	16	0	1.50	3,13		5.89
		M1-0°	2G	^{136}Xe	8	0	2.75	8,29	210 nA dc	8.5
			TOTAL		72		33.75			

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

SuperHILAC Research and Operation

	Hours	Percent
SCHEDULED TIME TO SHUTDOWN 8 MARCH		
Research hours 204		
Parasitic 40		
Machine studies 0		
Machine operation for research	126	75.00
Machine tune	32	19.00
Maintenance	10	6.00
Total scheduled crew time	168	100.0 %
ACTUAL TIME		
Setup	11.75	7.0
Tune-up	21.00	12.5
Target time	185.75	110.6
Total actual research	218.50	130.1 %
Machine tune	33.75	20.1
Machine studies	0	0
Maintenance	60.50	36.0
Total support time	94.25	56.1 %

88-Inch Cyclotron

During March and April the 88-Inch Cyclotron ran 1328 scheduled hours for experiments, most of which are tabulated; 64 hours were devoted to beam development and 72 hours to routine maintenance. We also had 64 hours of unscheduled maintenance and repair. The rf amplifier tube failed and was replaced with a new 4648. A transient failure in the screen voltage power supply made trouble shooting the new tube more time-consuming than usual. At present the maximum usable frequency is 15 MHz at a maximum rf voltage of 70 kV.

New cyclotron solutions were developed for 105-MeV $^{15}N^{4+}$ and 112-MeV $^{18}O^{4+}$ for use in the $^{260}104$ experiment by the Ghiorso Group. External beams in excess of 5 μA were produced.

Studies to develop beams of $^{28}Si^{5+}$ and $^{28}Si^{6+}$ were completed, and the development of Si^{7+} is planned.

Effort is continuing in the high harmonic acceleration of low charge/mass beams.

88-INCH CYCLOTRON EXPERIMENTAL LOG

Experimenter	Cave	Scheduled hours	Energy (MeV)	Ion	Charge state	Beam stop current (μA)
Jahn	2	24	65	^{4}He	+2	0.720
Nurmia/Williams	0	8	70	^{3}He	+2	13.
		8	50	^{14}N	+3	0.450
		8	77.6	^{14}N	+3	
		8	200	^{40}Ar	+8	0.800
		8	155	^{28}Si	+6	
Harvey/ Mahoney	4C	24	104	^{16}O	+4	
Conzett	5A	72	17	$\vec{d}$	+1	
		72	45	$\vec{d}$	+1	0.470
Moretto	1B	104	170	^{40}Ar	+7	0.400
		8	170	^{20}Ne	+6	
Ghiorso		38	106	^{16}O	+4	3.
		64	104	^{16}O	+4	12.
		56	91	^{15}N	+4	10.
Yano	HLC	14	65	^{4}He	+2	16.
		4	30	^{1}H	+1	8.
Meyer	HLC	8	78	^{12}C	+3	6.
		8	132	^{12}C	+4	10.
		8	42	^{4}He	+2	12.
Diamond/ Stephens	1A	24	185	^{40}Ar	+8	0.075
		32	161	^{40}Ar	+8	0.182
		32	78	^{12}C	+3	
Scott/Hendrie	4C	8	50	^{16}O	+3	
		8	104	^{16}O	+4	
		48	315	^{16}O	+4	0.260
		8	91	^{15}N	+4	0.800
		96	315	^{16}O	+6	0.650
Selove	4C	96	114	^{11}B	+3	0.250
Welch	2B	2	315	^{16}O	+6	0.250
		12	252	^{20}Ne	+6	0.075
		8	132	^{12}C	+4	0.002
Muller	5B	8	9	^{2}H	+1	
		8	7.6	$^{2}H_3$	+1	
Cerny	2	35	55	^{4}He	+2	0.200
		54	50	^{7}Li	+2	1.
		16	55	^{2}H	+1	
Vieira	4A	16	104	^{16}O	+4	5.4
Ruhter	HLC	8	38	^{4}He	+2	12.
Zisman	4A	16	160	^{14}N	+4	0.200
		48	250	^{14}N	+5	0.275
		24	170	^{14}N	+5	0.200
Clemenson	HLC	2	21	^{1}H	+1	1.
Beam dev.	vault	8	250	^{14}N	+5	0.600
		8	104	^{16}O	+4	5.6
		8	103	^{28}Si	+5	0.600
		8	155	^{28}Si	+6	0.500
		16	112	^{18}O	+4	4.0
		16	9th Harmonic studies			

184 Inch Synchrocyclotron

During March and April the 184 Inch Synchrocyclotron was operated for about 148 hours for a variety of physics and biomedical studies, as well as for the therapeutic treatment of two patients.

A female patient with maxillary sinus carcinoma, whose treatment regime began in February, was continued through March for a total of 21 fractionated exposures to helium ions. Since it was not feasible to provide true multiple-port entry, we attempted to spare the skin and subcutaneous tissue by the use of several different collimators and a wax bolus in conjunction with a variation of the residual range of the treatment particles.

A young male patient with brain-tumor (pinealoma) received 16 irradiation treatments over a period of about three weeks. A multi-port technique was used that allowed five different entries. Although somewhat unusual at this facility, the patient was treated in a sitting position with the necessary immobilizations accomplished by means of a "bite-block" arrangement. Our Stereotaxic Positioner ISAH and computer-adjusted water column degrader are invaluable tools in patient treatment.

Approximately 13 hours of running time with 740-MeV protons were devoted to completing the Crowe-Johnson muon depolarization Exp 05. As reported in the Research Section of this publication, the target material was crystalline silicon at reduced temperature.

A relatively large number of biomedical studies were performed in which cell cultures and live animals were exposed to helium ions both in plateau and in the extended Bragg Peak. Many of these experiments are related to similar exposures to x-rays, various gamma sources and the heavier ions available from the Bevalac, and are concerned with determining RBE (radiobiological effectiveness), OER (oxygen enhancement ratio) and any possible advantage of a particular LET (linear-energy-transfer).

Although the emergent helium-ion beam from the 184 Inch has a diameter of 5 to 7 cm and a range (in water) of about 31.3 cm, the greater part of our operation uses the extended or "spread-out" Bragg Peak and a large area beam of somewhat lesser range. These features are accomplished by means of scattering foils and a rotating spiral-cut ridge filter placed several meters upstream of the usual treatment plane. (See LBL-4235 Aug. 75.)

In order to provide a 5-cm extended Bragg Peak (in addition to the one of 8 cm that has been commonly available), we have designed, fabricated, and placed in service a new ridge filter Fig 23a,b characterized in Fig. 24. These filters are precisely machined from a brass disc with the use of a specially made tool, the shape of which must comform to computer-generated curves. The expertise of a number of people was required for successful production of this deceivingly single-appearing filter, John Lyman, Rollin Armer, Sylvester Clark, and Ted DeBonis.

The ridge filter is incorporated with a scattering foil and two-"occluding rings" (as shown in the photographs). Two sets of scatterers are available to provide beams of approximately 20- and 30-cm diameter. Fig. 25 shows an X-Y plot across the 30-cm diameter beam indicating an intensity uniformity of better than ±2% over 90% of the diameter.

0 0 0 0 4 5 0 2 4 0 1

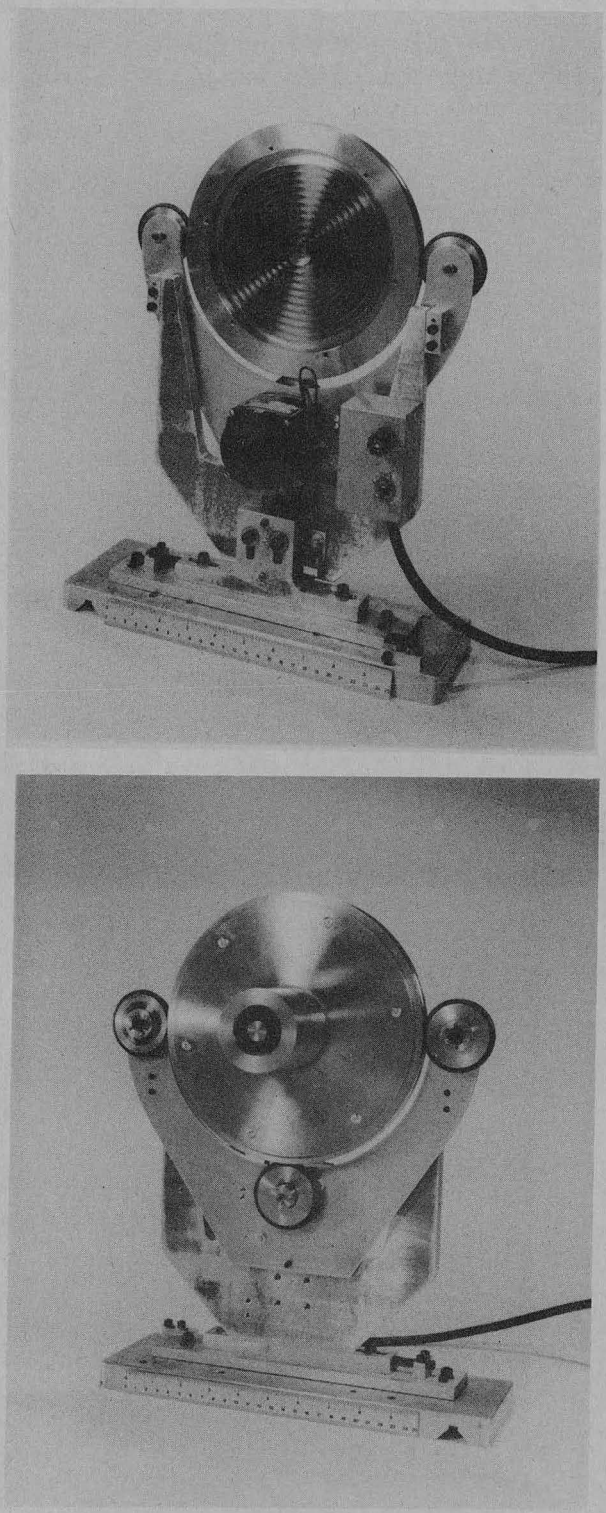

Fig. 23 a,b a) Ridge filter exposed. b) Ridge filter with cover plate. Beam from the 184-Inch comes from behind the filter, passing through and existing to the front. (BBC-759-6501, BBC-759-6499)

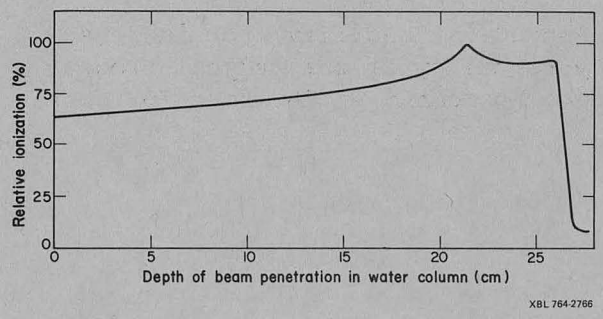

Fig. 24 Dose versus depth of beam penetration when a 5-cm ridge filter is used.

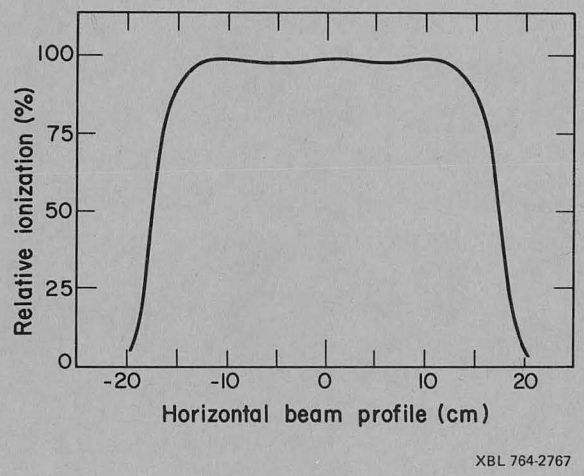

Fig. 25 Horizontal beam profile with 5-cm ridge filter at 5.3 cm residual range.

As a means of insuring uniform spatial distribution of all discrete energy components of the "filtered" beam, the ridge filter is rotated at about 15 rpm in the apparatus shown in the photographs.

Depending upon the ridge filter and scatterer combination used, the beam intensity may vary from approximately 165 to 265 rads/min (large-area beam) or from 2000 to 4200 rads/min for the primary, or non-scattered beam.

We have recently added a PDP-11/10 computer (tied by telephone line to the PDP-11/45 housed at the Bevalac

Biomedical Facility) for increased versatility of our medical program. At the moment it is about 70% operational. The remaining 30% is seemingly devoted to grief and operator headaches.

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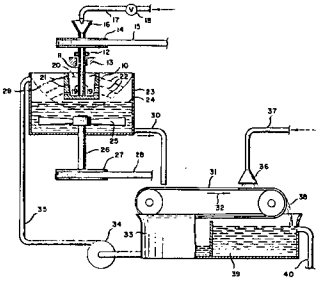
METHOD FOR THE PRODUCTION OF FLUID PEARLS



RESEARCH PROGRAM SUMMARY

BEVATRON/BEVALAC

Exp. 205H: Positive and Negative Particle Production from Heavy-Ion Bombardment of Various Nuclei, *H. Steiner, L. Schroeder, and L. Anderson, LBL.* Measurements of the helium phase have been virtually completed to determine the yield of light positive and negative particles as a function of angle and momentum. A variety of nuclear targets will be bombarded by protons, deuterons, alphas, and carbon nuclei at kinetic energies ranging from 0.5 to 2.1 GeV/nucleon. The components of the positive beam are separated by momentum, dE/dx, and time of flight over a 65-foot flight path.

Exp. P-87: Tests of Proton Shielding Material, *H. Kruger, LLL.* First tests of shielding materials for energetic protons and their associated secondaries were tested in Beam 36.

Exp. 215B: Effects of Heavy-Ion Irradiation on the Lungs of Hamsters. *H. K. Woodruff, LBL.* To study the acute and chronic effects of radiation on the lung, the whole thorax of hamsters was irradiated in the neon beam with single heavy doses of 500 to 2000 rads. At monthly intervals up to one year post irradiation, the lungs will be examined histologically and evaluated by morphometric analysis. In addition, sections of myocardium and thymus will be evaluated histologically. After establishing single-dose response, we hope to investigate the effects of dose fractionation on the lung. Later investigations will include analysis of the effects of radiation on the cell populations of the lungs.

Exp. 218B: *In Vivo* Damage and Repair in Rat Normal Brain and Brain Tumor After Irradiation with Bevalac-Accelerated Neon Ions. *K. Wheeler, UCSF.* Initial exposures of rats were made in the Bevalac neon beam in this experiment that is designed to clarify DNA damage and repair in rat cerebellum and intracerebral rat brain tumor. From the findings the investigator expects to be able to 1) assess the effects of charged particles of varying LET (linear energy transfer) on normal brain neutrons, 2) determine if a critical repair period does exist after charged-particle irradiation, and if so to 3) determine if the critical period occurs in both normal brain and brain tumor tissue.

Exp. 256B: Measurement of RBE and OER for EMT6 Tumor Cells *in Vitro, T. L. Phillips, UCSF.* Hypoxic and oxygen-rich mouse tumor cells were exposed to the Bevalac's neon beam. A control group of tumor cells was exposed to ^{137}Cs irradiation. The cell suspensions then were diluted and dispensed in flasks, and the colonies counted after 9 days. The survival curves will be calculated and the RBE (relative biological effectiveness) and OER (oxygen enhancement ratio) values derived with respect to those of ^{137}Cs.

Exp. 269B: Measurement of RBE for Pulmonary Lethality in LAF_1 Mice, *T. L. Phillips, UCSF.* A set of LAF_1 mice were irradiated in the thoracic region with the neon beam. A six-month follow-up study will be done to determine the RBE of heavy ions as compared with x-rays.

Exp. 289B: OER Determinations in Human and Hamster Cells with Heavy-Ion Beams, *E. Blakely, LBL.* Data-gathering continued with irradiation

of human kidney T-1 cells in the neon beam. The cells were attached to glass in a chamber designed for gas flushing. After exposure, the cells were trypsinized, counted, and dispersed for assessing their colony-forming ability. Survival curves were obtained and the RBE and OER were determined for various particle velocities at various times along the curve.

Exp. 293B: Time-Lapse Cinematographic Studies of the Mitotic Delay and Division Probability of EMT6 Tumor Cells, *in Vitro*, After Heavy-Ion Irradiation, *S. Curtis, LBL; R. Gilet, Inst. Gustav Roussy.* EMT6 tumor cells were irradiated in the Bevalac neon beam in March and a series of pictures were taken. Changes in the intermitotic time caused by different doses are being followed by time-lapse cinematography and will be compared with results obtained with a 645-MeV helium beam at Saturne, Saclay.

Exp. 294B: Cell Transformation as a Function of LET of Heavy Ions, *T. C. Yang, LBL.* Cultured mouse fibroblasts showing contact inhibition as normal differentiated cells and *Arabidopsis* seeds containing embryonic cells were exposed to the Bevalac neon beam at various positions on the Bragg curve. The frequency of transformation in fibroblast cells and the tumor formation in *Arabidopsis* will be correlated to the LET of HZE (heavy-ion) particles.

Exp. 323B: Determination of RBE and TCD_{50} for the EMT6 Tumor Irradiated *in Vivo* with Oxygen, Neon, and Argon Ions, *T. L. Phillips, UCSF.* Tumors were irradiated *in vivo* with neon beams under various conditions. The relative biological effectiveness will be determined by growing single-cell suspension colonies and measuring the survival of irradiated and control tumors. The TCD_{50} will be determined by observing tumor regression of irradiated mice, and the dose for 50% cure of the tumors will be estimated, based on probit analysis.

Exp. B-73: Acute Effects of Accelerated Oxygen Ions on the Skin of Mice, *J. Leith, LBL.* The epilated skin of the legs of mice were irradiated in the modified Bragg-peak region of the neon beam. The acute effects of the irradiation will be studied as a function of dose.

Exp. B-100: Dosimetry for Biomedical Applications, *J. Lyman, LBL.* Dosimetry was established under this number for the other experiments in the Bevalac Biomedical Program.

88-Inch Cyclotron

The $^{24}Mg(^{11}B,^{11}Li)\ ^{21}Si$ Reaction, *F. Ajzenberg-Selove, M. Buenerd, J. Cerny, D. L. Hendrie, G. KeKelis, A. Menchaca-Rocha, C. Olmer, D. K. Scott, and M. Zisman.* Our previous studies of the production of ^{11}Li in the $(^{11}B,\ ^{11}Li)$ reaction on ^{232}Th showed that ^{11}Li could be clearly identified with low yield in the magnetic spectrometer. We have now attempted to use the $^{24}Mg(^{11}B,\ ^{11}Li)\ ^{24}Si$ reaction to measure the mass-excess of the $T_z = -2$ nucleus ^{24}Si, at an incident energy of 114 MeV. Spectra were accumulated at 5° and 6.5° for a total charge of 15,000 microCoulombs. The ground state could not be positively identified in the spectra. An upper limit of approximately 3 nb/sr was placed on the cross section.

The Continuum in Heavy-Ion Reactions at Incident Energies of 20 MeV/u, *M. Buenerd, D. L. Hendrie, J. Mahoney, A. Menchaca-Rocha, C. Olmer, and D. K. Scott.* We have begun experiments aimed at the study of the quasi-elastic continuum in reactions with ^{16}O beams of 320 MeV on targets of ^{232}Th, ^{208}Pb, and ^{197}Au. The overall features of the spectra for transfer reactions were measured with solid-state counter telescopes, while simultaneously the magnetic spectrometer was used to search for structure in the continuum. Structure was observed in single nuclear transfers up to 15-MeV excitation, the cross sections for which increase rapidly, relative to simple low-lying direct transitions, as a function of the bombarding energy. The nature of this structure is under investigation. The systematics of the quasi-elastic continuum as a function of angle and of Z and M transfer are also being investigated.

Heavy-Ion Central Collisions at 20 MeV/u, *M. Buenerd, D L. Hendrie, J. Mahoney, A. Menchaca-Rocha, C. Olmer, and D. K. Scott.* We have extended to asymmetric geometry our previous experiments on the angular distribution of light particles (protons to alphas) emitted symmetrically about the beam axis in the reaction $^{16}O + ^{232}Th$ at 20 MeV/u. Two fixed angles of 15° and 45° were chosen for one detector telescope, and in each case the distribution of light particles in coincidence on the opposite side of the beam was measured: For 15°, the distribution was strongly forward-peaked (as in our previous symmetric geometry), whereas for 45° the distribution was symmetric about 90°. These results suggest the presence of two reaction mechanisms: a predominantly direct, or break-up process at forward angles and a compound nuclear reaction mechanism at more backward angles. These mechanisms are also evident in the distribution of alpha singles spectra, which display a strong high-energy component at forward angles and an evaporative shape peaked at the Coulomb barrier at wider angles, with a temperature considerably higher than predicted by a degenerate Fermi gas model. Although our results do not provide any simple evidence for nuclear shock-wave effects in the form of emission of fragments at preferential angles, the data are being analyzed to yield information on reaction mechanisms in the transitional region between low temperature nuclear physics (<20 MeV/nucleon) and the high-energy GeV/u physics at the Bevalac.

Study of Highly-Neutron-Rich Nuclei via the (^{7}Li, ^{2}He) Reaction, *J. Cerny, R. Jahn, G. Kekelis, D. Moltz, and D. Stahel.* We tested the feasibility of the (^{7}Li,^{2}He) reaction on ^{12}C at $E_{^7Li}$ = 50 MeV. Transitions to the ground state and several excited states of ^{17}N have been observed with cross sections of about 0.5 μb. The (^{7}Li,^{2}He) reaction seems to be a good spectroscopic tool to investigate highly-neutron-rich nuclei and further experiments on neutron-rich targets are planned.

A Study of Relaxation Phenomena in the Ne + Cu System, *L. G. Moretto, R. Jared, G. Wozniak, B. Cauvin, P. Glässel, P. Russo, R. Schmitt, J. Moulton and M. Neuman.* A natural Cu target has been bombarded with 170-MeV ^{20}Ne. The fragments have been identified in Z by means of a gas ΔE, solid-state E telescope. The kinetic energy spectra associated with each Z show the usual relaxed components at energies close to the Coulomb energies of two touching fragments. For Z's close to that of the projectile, a quasi-elastic component is also seen close to the grazing angle. The Z distributions

are very broad with large cross sections at low Z's. The angular distributions appear to be forward peaked in excess of 1/sin θ, especially for Z's close to the projectile.

Tensor-Analyzing Powers in the $\vec{d}$-p Breakup Reaction, *R. Roy, H. E. Conzett, F. N. Rad, R. M. Larimer, B. T. Leemann, and E. J. Stephenson.* Exact three-body calculations that have been successful in fitting p-d breakup cross sections had been limited to S-wave nucleon-nucleon input interactions, and could provide no polarization. A very recent calculation has included the tensor force, and the calculated tensor-analyzing powers in the $\vec{d}$-p breakup reaction at 45 MeV show very substantial values. We have made measurements of the analyzing-power components $A_{yy}(\theta)$ and $A_{xx}(\theta)$ at 45 MeV for comparison with these theoretical predictions.

Tensor-Analyzing Powers in $\vec{d}$-^{4}He Elastic Scattering, *E. J. Stephenson, H. E. Conzett, R. M. Larimer, B. T. Leemann, and R. Roy.* We had previously measured the deuteron tensor-analyzing power component $A_{YY}(\theta)$ in $\vec{d}$-^{4}He scattering between 17 and 45 MeV in our program to establish a deuteron tensor-polarization analyzer above 17 MeV. We now have completed measurements of the A_{xx} (θ) component at 17 and 20 MeV.

Fusion of ^{14}N + ^{12}C at 250 MeV, *R. G. Stokstad, R. Dayras, P. H. Stelson, ORNL; C. Olmer and M. S. Zisman, LBL.* In a continuation of measurements begun at Oak Ridge, we have looked at the fusion cross sections for ^{14}N + ^{12}C by using the 250-MeV $^{14}N^{5+}$ beam of the LBL 88-Inch Cyclotron. Data were taken in a pair of 3-counter telescopes, placed on opposite sides of the beam axis, over the angular range from 3° to 40° (lab). The Z-resolution of the system was sufficient to resolve all elements produced with Z $\gtrsim$ 2. Of particular interest is the fact that at this bombarding energy, the compound system should be formed with an angular momentum exceeding the limit for a rotating liquid drop.

184-Inch Synchrocyclotron

Exp. 05: Muonium Precession in Cooled Silicon, *R. Johnson, LBL.* This set of runs was made to improve the statistics in the observation of muonium precession in Si at 120 and 140 K. Approximately 750,000 events were obtained for each temperature. There is evidence of a temperature dependence of the precession frequencies, which indicates that the muon forms a virtual state in the valence band. Because of the covalent admixture of the muonium state with the electron states of the band, the localized spin density at the muon will become temperature dependent, implying that the muonium precession frequencies will have a temperature dependence. This model consistently explains the lack of muonium precession in N-type silicon and a signal in P-type.

Response of the Mouse Intestinal Crypt Cells to Helium-Ion Irradiation, *E. Alpen, LBL.* LAF_1 mice, 12-15 weeks old, were given whole-body irradiation with the 184-Inch helium-ion beam, by using plateau and spread-out Bragg peak regions of ionization. Four days later the mice were sacrificed. Sections of the small intestine were removed and examined histologically to count the number of

regenerated crypts. Other groups of mice received 230-kV x-rays. Attempts are being made to establish a model system for recovery and fractionation to be used in the heavy-ion therapy program.

Cell Sensitization by Certain Chemical Agents, *J. Chapman, R. Urtasun, AEC, Canada; C. A. Tobias, LBL; and J. Castro, Mt. Zion Hospital, S.F.* Chinese hamster lung (V79) cells were exposed *in vitro* to helium ions in the extended Bragg peak. Cell inactivation was measured under both air-saturated and hypoxic conditions in the presence and absence of certain chemical sensitizers of hypoxic cells. Preliminary results indicate that the OER (at the 10% survival level) for hamster cells in the extended Bragg peak of the ions is about 2.2. In the presence of 5mM Ro-7-0582, the OER is reduced to 1.44 by the selective radio-sensitization of only the hypoxic cells. This study is part of an ongoing experiment to assess the potential usefulness of hypoxic cell sensitizers in future clinical trials with heavy particles. The sensitizers tested to date are metronidazole and the Hoffman-LaRoche drugs designated as Ro-7-0582 and Ro-7-0741.

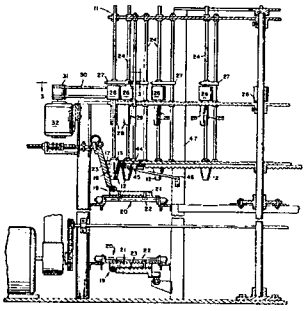
Ferric Yields and Chemical Isotope Effects, *A. Appleby, Rutgers U.; M. Jayko, LBL.* Ferrous sulfate solutions were irradiated at various concentrations, in the presence and absence of dissolved oxygen. Ferric yields were determined as a function of penetration of the beam. Hydrogen peroxide yields were also determined from dilute bromide solutions. These studies relate to the fundamental chemical processes following energy deposition of these beams. (Refer to Bevalac Exp. 245B.)

Measurement of RBE/OER for Mouse Intestinal Crypt Cells, *T. L. Phillips, K. Fu, UCSF.* The EMT6 tumor *in vivo* and *in vitro* and the bone marrow, colony forming unit (CFU) systems were used to calibrate the large-field helium-ion beam against 230 kVp x-rays and gamma rays from ^{137}Cs for both RBE and OER. The systems were exposed to the helium-ion beam on the plateau and distal portion of the spread Bragg peak. This particular run on the 184-Inch Syndrocyclotron will reconfirm and add to data already obtained. (Refer to Bevalac Exp. 266B.)

Measurement of RBE and Mortality of Esophageal and Thoracic Irradiation in LAF_1 Mice, *T. L. Phillips, K. Fu, UCSF.* The thoracic region of LAF_1 mice was exposed to the helium-ion beam on the plateau and distal portion of the spread Bragg peak in order to determine the RBE for the esophagus and the lungs as compared with 300 kVp x-rays and the 4-MeV linac beam used for patient therapy at UCSF. The LD_{50} for the esophagus will be computed from the survival data at 4 to 6 weeks post irradiation exposure. The LD_{50} for the lung is generated from survival data at 160 days post irradiation. The RBE's are computed from the relative LD_{50}'s for each beam type. (Refer to Bevalac Exps. 267B, 269B.)

OER and RBE Determinations in Human Cells Irradiated with Helium Beam, *E. Blakely, LBL.* OER/RBE determinations for human kidney (T-1) cells were continued by using both the "submarine" culture system and the gas-flushed chambers, in which the cells are attached to the glass cover plate. After exposure to the helium-ion beam, the cells are trypsinized, counted, and appropriate dilutions are made for later scoring of their colony-forming ability. (Refer to Bevalac Exp. 289B).

Time-Lapse Cinematographic Studies of the Mitotic Delay and Division Probability of EMT6 Tumor Cells, *in vitro*, After Helium-Ion Irradiation, *S. Curtis, LBL; R. Gilet, Inst. Gustav Roussy*. Suspended EMT6 tumor cells *in vitro* were irradiated with both plateau and extended Bragg-peak helium ions. Subsequent changes in the intermitotic times and division probabilities are studied through the use of time-lapse photography. The results are compared with those obtained from exposures of gamma rays and the heavier ions available from the Bevalac as well as with previous work done at Saclay. (Refer to Bevalac Exp. 293B).



3,269,335
MACHINE FOR FORMING FLAT TOP ROLLED ICE CREAM CONTAINERS

ADVANCED ACCELERATOR STUDIES

ESCAR

General

On March 9, members of the ERDA staff were briefed on the expected accelerator research and development program to be pursued at LBL in the near future. Both existing work and proposals were reviewed.

Several ESCAR staff members visited SLAC and the LASS (large aperture superconducting solenoid) device for familiarization and discussion of mutual concerns.

Shielding design, with radiation safety gates and barriers, has been completed.

The frame and shell of Building 56, the Plant Cryogenic Facility, has been erected at the north end of the Bevatron EPB hall. Facilities in the surrounding area have been laid out, to be installed when the strengthened slab for ESCAR is installed. (See Fig. 20)

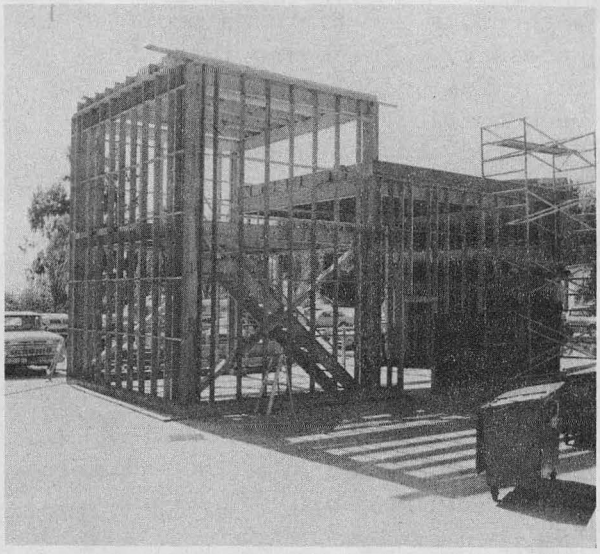


Fig. 20. The building to house ESCAR takes shape alongside the Bevatron. The right wing will house two helium compressors of 1000 HP total. The helium cold box in the two-story wing will liquify helium gas from the compressors and will supply the ESCAR superconducting magnet and cryopumping system, as well as other Laboratory requestors. (XBB-764-3554)

Physics

A review of aperture requirements throughout the ESCAR ring was made. It was decided to reduce the quadrupole aperture to a 7-cm radius, the same as the dipoles. This lessens the longitudinal interaction between beam and bore tube due to varying sizes of bore and reduces the cost and size of the quadrupole assemblies.

The probable excursions of beam-focusing parameters were examined, and a maximum quadrupole gradient of 18 tesla/meter was fixed as adequate. A limited range of operating modes was found which permits the use of just two independent circuits instead of four for the quadrupoles. Initial operation will use this mode, and will preserve the more flexible option for later.

Ring Magnets

The cryostat design for production ring dipoles is complete. The helium flow space has been increased by a factor of three, and the liquid helium inventory reduced over the previous design. The entire cryogenic system, as well as the magnet cryostat design, was reviewed by Peter Van der Arend, a professional cryogenic consultant; no major changes were indicated.

A practice winding of the production dipole has been completed,

with tools and fixtures modified as necessary. Following that, the first full dipole coil winding has been completed. Each quarter coil required about one week for parts checkout, cable preparation, winding, and baking. Occasional delays were involved for work on tools, production of finished parts, and adjustments to the taping and winding machines. This coil will be assembled with its bore tube and structural rings early in May.

Over 4000 feet of a 7000-ft reel of conductor cable received in April has been cleaned, repaired, and spooled. The coil for the second dipole was started on April 29th.

The dipole bore-tube material has been changed to type 316 stainless steel because of the change in magnetic properties of other types under thermal cycling to liquid helium temperatures. The design has been modified to eliminate contamination of the end weld by hot epoxy residues.

Sufficient iron lamination punchings have been received to assemble the yokes for six dipoles.

The arrangement of multipole trim coils has been determined for control of various beam conditions in ESCAR. Detailed designs are in progress.

Air pads and lifting jigs for shifting and hoisting dipole girder assemblies have been received and are being tested.

Cryogenics and Refrigeration

The 1500-watt helium refrigerator is delayed again pending review of a vendor-proposed modification, which would use one turbo-expander rather than two. A large surplus refrigerator from NASA-Langley Field is being procured to enable ESCAR tests to proceed if necessary at a reasonably early date.

The oil-removal equipment and starters for the compressors have been ordered.

Following the conclusion of D3B tests, the performance of the CTi 1400 helium refrigerator liquefier was measured with a low-loss Sulfrian Dewar being used as a calorimeter cryostat. Nominal ratings of this system were measured as approximately 20 liters/hr maximum liquefaction rate and 50 W maximum refrigeration rate. Performance as a function of engine speed, heat load, and gas withdrawal rate was also measured. These data can now be used to choose operating conditions and to diagnose any malfunctions in the magnet test program.

SUPERCONDUCTIVITY

The bulk of our laboratory experiments were directed to ESCAR-related problems, with implications ranging beyond that specific program. A retest of the Physics, CS & M Division Group A's large solenoid was done in March.

Group A - PEP Detector Development

A 1-meter-diam. solenoid has been built and previously tested by Group A in their PEP detector development program. The cryostat and liquid helium transfer line were rebuilt, and the magnet was retested in the Building 64 Superconducting Laboratory in March.

Short-Sample Tests for ESCAR

New superconducting cable for the ESCAR dipoles has been purchased through Fermi NAL. Several samples from the first 7700-foot-long supply spool have been tested, and the second ESCAR dipole is being wound from this material. A similar cable from Furakawa has also been tested.

Damaged-Cable Solenoid Test for ESCAR

A cable was prepared with several flaws introduced. Some of these flaws were nicked wires, some improperly crossed-over wires, and the worst were broken wires that were soldered together as a repair. Normally one doesn't wind this type of cable into a magnet designed to operate near the conductor short-sample limit.

We built one of our standard solenoids with the above-described damaged ESCAR cable. The solenoid performed as well as similar solenoids without any such flaws. One or two such flaws will be built into the outer winding of an ESCAR dipole as a more stringent test of this finding. Since each winding is of the order of 1000 feet, and minor flaws occur with a comparable frequency, the savings in cable through the allowance of such defects would be many thousands of feet.

Insulation Studies and Solenoid Tests for ESCAR

The influence of insulation and adhesives on magnet performance, or training, was studied through tests of three similar solenoids. The same ESCAR cable was used, but with different insulation-adhesive schemes. The first solenoid has the cable spirally wrapped, with B-stage epoxy-impregnated glass tape; the coverage being about 60%. This has been our standard technique for two to three years. The second system has a complete (100% coverage) wrap of 1-mil-thick Mylar between the cable and the glass tape. The third system is similar to the second that uses Mylar, but the B-stage epoxy adhesive is replaced with a urethane resin. The second and third systems performed substantially the same, and both had considerably less training than did the system without the Mylar wrap. The Mylar film adds additional voltage protection and is now incorporated into the ESCAR design.

Temperature Sensors: Development and Evaluation

A calibration and development effort has been started in the field of low-temperature measurement and liquid helium level sensing. The object is to evaluate several commercial vendor's products as to reproducibility and reliability from a systems standpoint as compared with a selection process of very low price carbon resistors and various material diodes. Fourteen detectors of various types were measured from room temperature down to 4.2 K.

Third-NBS-ARPA Workshop

Two staff members, W. S. Gilbert and R. B. Meuser, attended the third NBS-ARPA Workshop in April. The workshop consisted of two consecutive meetings; the first being a Symposium on Stress Effects in Superconductors, and the second being on Materials Research for Superconducting Machinery.

HEAVY-ION SOURCE DEVELOPMENT

A lithium beam of 5 MeV/nucleon was accelerated recently at the Bevatron 20-MeV linac. A $^{6}Li^{2+}$ beam, generated in the PIG source, was accelerated by the linac operating in the $2\beta\lambda$ mode, and was then passed through a 50 μgram/cm^2 aluminum foil stripper into a Faraday cup immediately downstream. The total pulsed beam measured 0.3 μA ($^{6}Li^{3+}$).

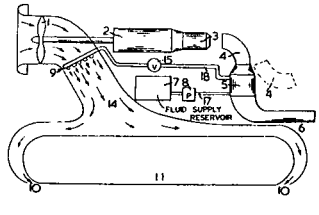
The PIG source cathodes used in this particular case were filled with a mixture of ^{6}LiF and tantalum powder and then compressed at approximately 30,000 psi. The mixture was composed of 40% lithium fluoride, the balance was tantalum.

Because of the low duty cycle (0.1%), a bake-in time of about 3 hours was required before a stable operating level could be achieved. Some pertinent data parameters are shown below, the most sensitive ones are the gas pressure and arc voltage.

Source magnet field	4096 gauss
Extractor voltage	20.1 kV
Arc voltage	1.0 kV
Arc current	0.5 A
Column pressure	2.2 μTorr

An additional test was made using titanium cathodes in place of the tantalum cathodes with the same lithium-fluoride mix ratio as before. The resulting beam dropped to about one-third of the previous value. Neon was used as the support gas in both cases. In the near future tantalum cathodes will be used again but with greater percentages of lithium-fluoride in an effort to achieve greater intensities of lithium beam.

3,269,476
METHOD TO ENABLE A GROUND EFFECT MACHINE TO LEAP OVER OBSTACLES



COMPUTER SCIENCE AND MATHEMATICS

COMPUTER CENTER

SYSTEMS PERFORMANCE

		Turnaround time		
	January	20 min	2 h	4 h
7600 availability	89.10%			
Jobs processed	72,539			
Percent of rush jobs returned		57.84	87.73	94.16
Percent of all jobs returned		62.08	84.57	91.29
Percent returned, CU limit	≤100	65.13	89.05	95.23
	≤500	37.74	64.74	83.34
	≥1000	20.11	41.86	57.55

	February	20 min	2 h	4 h
7600 availability	93.86%			
Jobs processed	71,610			
Percent of rush jobs returned		70.54	92.00	96.27
Percent of all jobs returned		70.10	87.42	92.77
Percent returned, CO limit	≤100	77.62	94.31	97.72
	≤500	43.55	70.22	82.73
	≥1000	20.11	41.92	55.09

There was a significant improvement in 7600 availability. We had half as many hardware failures in February as in January.

	March	20 min	2 h	4 h
7600 availability	91.31%			
Jobs processed	87,266			
Percent of rush jobs returned		66.04	91.39	96.28
Percent of all jobs returned		67.73	85.88	91.37
Percent returned, CU limit	≤100	72.46	92.71	96.62
	≤500	31.73	60.18	77.73
	≥1000	15.50	35.24	47.04

The 7600's No. 2 disk, "Chippewa", broke several times this month, causing periods of user, operator, and engineer anxiety. It is fixed now, though, and seems to be as good as it ever was.

	April	20 min	2 h	4 h
7600 availability	93.34%			
Jobs processed	80,262			
Percent of rush jobs returned		68.35	92.71	96.65
Percent of all jobs returned		69.10	87.99	92.74
Percent returned, CU limit	≤100	74.74	93.48	96.40
	≤500	43.39	74.52	86.68
	≥1000	21.45	45.06	55.91

FORTRAN Progress: The mills are now grinding out an interface package to permit MNF-compiled programs to use the FTN4 library. Also, a 6600 FTN4 compiler and I/O library are in the works.

Research Program Spotlights

Computational Plasma Physics Group
C-F. Chen, A. Paul, L. Soroka

Several computer programs have been devised to aid in the design of different plasma devices and to simulate their behavior under varying operating conditions. Design studies of 120-kV neutral beam source for injection into the Princeton Tokamac Fusion Testing Reactor and of a 40-kV source for injection into the LLL 2X11B mirror machine were undertaken in order to optimize the electrode potentials and shape (with W. Cooper of LBL CTR Group). The computer code WOLF has been applied to the electrode design for an isotope separator, where the spacecharge limited extraction current was determined for several different conditions of operation (UCID-3826 with M. Lutz of LLL). The computer code EGUN was used to determine the electrostatic focusing electrode configuration and potential necessary to maximize the collection of charge-exchanged ions in an atomic beam apparatus. Points of possible electric field breakdown in the dielectric supporting structures of the neutral beam sources were examined by computer simulation that used the program JASON.

Detailed knowledge of the power density profiles of a neutral beam line operating in the many mega-watt power region is necessary to determine practical aperture sizes and beam dump locations. A program was developed for evaluation of the power deposition of these high-intensity neutral beam lines consisting of many converging sources (UCID-3827). Either elliptical or rectangular modules may be used in a multi-array source structure.

Experimental data from the LBL TORMAC plasma device is transferred to the 6600/7600 computer system weekly and stored on the mass storage system. The data is maintained in PDP-11 format as backup and converted to CDC format for analysis. A program was written to extract the plasma temperature from the spectral line shape and to display this temperature as a function of time (with M. Levine, I. Brown of LBL CTR Group).

A complete theoretical model involving the solution of a modified Tonk-Langmuir equation with specific boundary conditions is being developed to study the steady-state plasma-sheath formation process initiated by electron neutral gas kinetics within the ion generating chamber of a neutral beam source device (with W. Cooper, F. Burrel and J. Carry of LBL CTR Group).

Interlaboratory Working Group for Data Exchange, *D. Austin.*

The broadened ERDA mission in energy policy analysis and environmental impact assessment requires the utilization and exchange of large amounts of computerized descriptive information and numeric data among the national laboratories. These large data bases form the basis of regional and national studies in support of ERDA's energy and environmental policy formulation. Resource sharing and standardization of computer readable files and modeling programs for interlaboratory exchange will lead to significant efficiencies in carrying out those studies. To comply with these demands in a timely and cost effective manner, the Interlaboratory Working Group for Data Exchange was formed with the following mission:

1. To share expertise in computer-based systems for handling large data bases;

2. To establish both short-term and long-term objectives for resource sharing and data management;
3. To establish, test, and implement practical data exchange standards;
4. To examine the laboratories' present data management systems and data bases, and develop mechanisms for interfacing among these systems;

5. To make long-term recommendations for a common ERDA data-management system; and
6. To recommend administrative guidelines for exchange of data and programs.

The Joint Program 189 form for this effort was submitted simultaneously by the seven major multiprogram ERDA laboratories: ANL, BNL, LASL, LBL, LLL, ORNL, and PNL. The Interlaboratory Working Group for Data Exchange (IWGDE) was organized at the November, 1975 meeting at LBL. Don Austin/LBL was elected chairman and Carmen Benkovitz/BNL was elected secretary; Paul Dionne/PNL was named chairman of the Geocoding Subcommittee. Representation in the Group was expanded to include at least one computer scientist and one representative familiar with energy- and environment-related activities at each of the seven laboratories. The steering committee for Regional Studies Programs was added to the IWGDE distribution list to ensure that the RSP directors would be kept informed of the Group's progress.

The first task undertaken by the IWGDE was to collect summaries of existing data bases, modeling programs, and computer equipment at the seven laboratories. These summaries will provide a directory of resources and facilities for ERDA researchers.

The second task was to develop a data-exchange standard for ERDA. Al Brooks, ORNL, proposed an extension to the ANSI Standard Interchange Format to provide for exchange of structural numerical data bases as well as bibliographic files. Subsequent modifications were suggested by Joe Nardi, BNL, and Dave Richards, LBL. Wendell Haynes, LBL has implemented the Level 0 ERDA Interchange Standard at LBL, and Jim Miller, LBL, is currently implementing a QwickQwery-to-ERDA Standard interface for providing selected socio-economic data bases to ANL, BNL, LASL, and ORNL. This work should obviate the task of writing one-time conversion programs at each laboratory for each data base exchanged.

Work is proceeding on the development of transportable data management systems which can run identically on the various operating systems at the laboratories. Dave Richards, LBL, plans to implement the Berkeley Data Management System (BDMS) at BNL and Rutherford High Energy Laboratory in England.

Automated Counting of Cell Clones, *H. White.*

The computer programs developed to count tissue clones were operational at the beginning of this period. These were designed on the basis of two typical petri-dish images supplied by the Tobias group last summer. A 90-dish sample of two tissue strains was digitized in February. Because this sample was photographed by using the new high-volume techniques, colonies had substantially different appearance than the initial data indicated. Three digitizings of the film were made at two levels of FSD threshold, in order to study reproducibility of counting.

The counts obtained from the three runs and visual counts made by members of the Tobias group during this

reporting period, were compared. Measurement diameter was the principal criterion for clone selection. Dish-by-dish counts were compared, as were total counts for the 24-dish sets of the T1 strain experiment. Reproducibility of individual colony diameters for constant digitizing threshold, as measured by differences from the mean of both runs, was excellent (standard deviation, 10 microns = 5% of diameter). Diameters were well correlated for different thresholds. Clone counts for the total sets obtained by visual and automated procedures were brought into excellent agreement. About 10% of the individual dish counts showed significant differences between visual and automated counts, although the automated counts of all thresholds agreed well among themselves, as did the visual counts. This suggests that visual counts may be based on some additional criteria.

Results were presented at a Biomedical Seminar on 8 April.

A study of the images that yielded significantly different counts was begun. Program modifications reflecting criteria more subtle than clone diameter alone are expected to improve agreement of individual dish counts to a satisfactory level.

Further Aids for Interactive Users, *B. Healey.*

INTERAC is a system designed to allow LBL interactive programmers a standard and high-level method of reliable access to their files (where "access" implies storage as well as retrieval). INTERAC is in no way concerned with the type or content of files. When used in its most general sense, INTERAC will store a file on all LBL storage devices (disk, PSS, MSS, and tape) and will retrieve it the logically fastest way possible (from the fastest device which is operational). This relieves nonprogrammer interactive users from needing to have specific knowledge of LBL storage devices e.g., (is MSS up?). They may be assured that the "LBL access system" will "fetch the stored data" through a taxation of the entire storage resource, even if it means waiting for a tape to be hung (in September 1975 the average tape mount time from all vaults was 6.5 minutes.)

INTERAC is composed of the modules STORE, INDEX, CACHE, and FETCH. They are designed for both batch and interactive use in that they are available as both object code programs and subroutines with identical argument lists.

INTERAC initially stores a file on tape. (This assumes that all interactive programmers want to backup their online files both in the traditional sense and for actual user retrieval if necessary). That file may then be "cached" to any combination of the online devices. This allows interactive programmers complete freedom in the use of LBL storage devices depending on the quantity of data involved, the amount of space available on each device, user retrieval patterns, etc. It also decreases the problem of having to choose which data to eliminate from the user's grasp because of space limitations.

INTERAC updates the index to the files each time they are accessed, and on demand will provide a standard report of the contents of the index, both in detailed and/or summary form.

INTERAC addresses the problem of elimination of data from a continually growing data base which must eventually be limited. It does this by first allowing the programmer to

associate subsets of the files in the data base with particular tapes and MSS "special sets" (particular MSS boxes). Secondly, the index may be purged of all files associated with these tapes and MSS special sets when they are physically removed. And thirdly, a particular file may be purged from the index and PSS cache even though the entire set of tapes and MSS boxes associated with it are not eliminated.

INTERAC is not designed with any level of "exportability" in mind because it involves accessing the unique hardware configuration of LBL.

INTERAC was originally designed in December, 1975, for use with LBL's Regional Management Information System interactive retrieval program (RGNLMIS). The modules are being generalized so that other interactive systems may easily use them; the complete system should be up and running by June 1, 1976.

Socio-Economic Environmental Demographic Information System (SEEDIS), *D. Merrill, E. Schroeder.*

Significant improvements were made to SEEDIS during March and April, with the addition of new data and programs, and with the provision of additional on-line documentation for more convenient user access. Existing data found new applications. Remote users' use of SEEDIS and interlaboratory communication in general both increased markedly.

Many LBL data bases and programs have had either little on-line documentation or documentation whose existence and storage location were not widely publicized. Supplementary summary documentation has now been written for later inclusion into an on-line reference catalog to be known as LBLIRI (Interactive Resource Index).

Preliminary guidelines and priorities were established for LBLIRI in consultation with members of the Computer Science and Applied Mathematics Department, the Energy and Environment Division, and the Technical Information Division. An up-to-date on-line status report is being maintained by D. Merrill, and S. Buckman.

An extensive library of information on storage locations, formats, etc. of data, programs, and documents relevant to SEEDIS is being assembled. Trial data-base formats are being tested in runs with BDMS and TBLD. The collected information, appropriately formatted and keyworded, is being incorporated into a BDMS data base and associated thesaurus by D. Merrill.

Recent applications of SEEDIS:

1. Selected Summary of 1970 Census Employment data by sex, race, and occupation; for all SMSA's and states; for U.S. HEW's Office of Civil Rights (E. Schroeder).

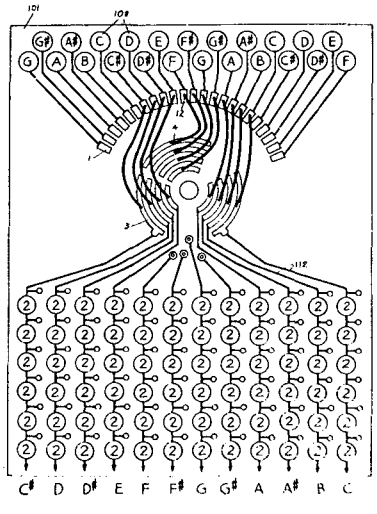
2. Input-Output Analysis of economic impacts of water curtailment in the Central Lohonton Region of Nevada (including Pyramid Lake and Reno); for the state of Nevada (E. Schroeder).

3. Aggregation of First Quarter 1975 California ES202 Employment Data for detailed industries at the county level; for a project being performed by the Regional Studies Group for CERCDC (California Energy Resources Conservation and Development Commission) (E. Schroeder).

Selected SEEDIS data and documentation were provided upon request to

users at UC Berkeley, Stanford University, Brookhaven National Laboratory, University of Illinois, University of Hawaii, and elsewhere. Active communication via an ad hoc "computer mailbox" has been established with the Center for Advanced Communication, University of Illinois.

Limited-use guest account numbers and passwords were exchanged with members of other ERDA installations at a meeting of the Interlaboratory Working Group for Data Exchange. From a terminal in Berkeley, over FTS telephone lines, selected data were located, inspected, and retrieved from major SEEDIS-related data bases at Livermore, Oak Ridge, Argonne, Los Alamos, and Brookhaven. More ambitious data-exchange projects await completion of ARPANET links at those installations. (Data bases at Pacific Northwest Laboratory cannot be accessed via remote terminal at this time.)



3,949,638
ELECTRONIC MUSICAL INSTRUMENT

DATES TO REMEMBER

May	7	SuperHILAC Program Advisory Committee meets.
	17	Bevalac operation resumes.
	24	Full SuperHILAC operation resumes.
	25,26	Berkeley Workshop on Distributed Data Management and Computer Networks, hosted by LBL's Computer Science and Mathematics Department.
	31	Memorial Day, an LBL holiday.
June	23-25	1976 PEP Conference: Call for proposals for experiments and facilities requiring long lead time for PEP.
July 3 - August 1		Summer shutdown of SuperHILAC and Bevatron/Bevalac operations.
July	5,6	Independence Day and LBL holiday.
	12-16	The Third High-Energy Heavy-Ion Summer Study at LBL.
	26-30	Fifth International Conference on Atomic Physics, LBL and Physics Department, UC Berkeley co-host.
September	6	Labor Day, an LBL holiday.
	14-17	Particle Accelerators in Radiation Therapy (Part II). An international conference sponsored by the American College of Radiology, to be held at LBL. Registration fee, $100.
November	25,26	Thanksgiving, an LBL holiday.
December		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.
	24	Christmas, an LBL holiday.
	31	New Year's, an LBL holiday.

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

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