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88-Inch Cyclotron Newsletter

February 1987

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NUCLEAR SCIENCE DIVISION

PUB-458 c.1

Prepared for the U.S. Department of Energy under Contract DE-AC03-76SF00098

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88-Inch Cyclotron Newsletter

88-Inch Cyclotron Users Association
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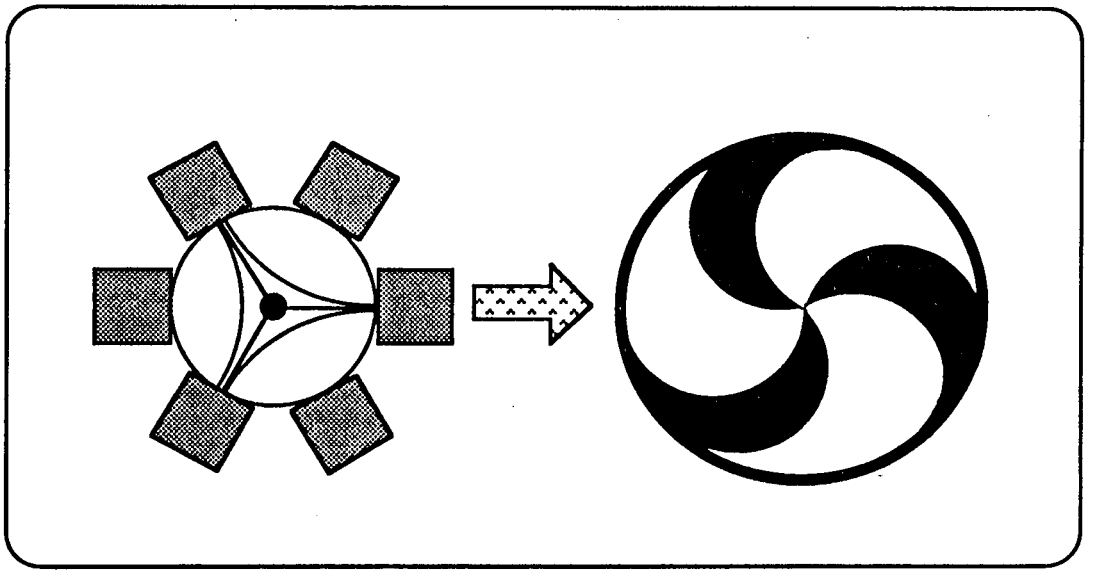

This work was supported by the Director, Office of Energy Research, Division of Nuclear Physics of the Office of High Energy and Nuclear Physics of the U.S. Department of Energy under Contract DE-AC03-76SF00098.

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1. Scientific Director's note

The most significant change at the 88-Inch Cyclotron in the last year and a half is the increased demand for beam time. The number of shifts requested for nuclear science is now twice the number available. This increased interest on the part of users is attributable to the new beams and reliability of the ECR source and cyclotron, and to new instrumentation such as HERA and the large NaI spectrometer system. Other improvements and additions are described in the following sections prepared by Gordon Wozniak and the Users Executive Committee (K. Hulet, M. A. Deleplanque, and E. Norman).

In spite of reduced budgets for operations, the addition of the ECR source has increased the vitality and momentum of this Facility. In effect a major upgrade of the 88-Inch Cyclotron has occurred with a substantial increase in both the energy and number of the beams available. Because ECR technology is a relatively young technology, we expect further performance improvements. In particular, we hope to construct an advanced ECR source, utilizing higher RF frequencies, which would enable the 88-Inch Cyclotron to accelerate elements up to bismuth to energies above the Coulomb barrier.

R. Stokstad

2. ECR update

The operating experience with the Cyclotron + ECR has been highly successful in terms of reliability, stability, production of high charge state currents, and in the range of ions which can be produced. Many new beams have been developed which have enabled physicists to do experiments previously impossible at the 88-Inch Cyclotron. For example: a beam of 32.5 MeV/u $^{16}O^{8+}$ was used in a nuclear structure experiment, a $^{36}Ar^{18+}$ beam with a total energy of **1.08 GeV** was used to test the response of scintillator materials to intermediate energy heavy ions, and ^{48}Ca beams between 200 and 400 MeV were used in fission cross section measurements with gold and lead targets.

The performance of the LBL ECR is summarized in Tables 1 & 2. The tabulated currents represent the best results taken from many tests. (These are the currents injected into the cyclotron. The currents extracted from the cyclotron are typically 5% of those injected.) To a large extent the ion beam development has been dictated by the needs of the cyclotron users. For elements such as nitrogen, oxygen, and argon that have been frequently used, the values in the tables are well optimized. Other beams such as fluorine, sulfur, and titanium have been infrequently used and the performance will probably improve with further development. The ^{84}Kr and ^{129}Xe currents were produced using natural krypton and xenon, respectively, so higher currents could be obtained with isotopically enriched gases.

Table 1.

Currents (eμA) for the LBL ECR: hydrogen through silicon. The asterisks denote charge to mass ratios for which more than one beam may emerge from the ECR source. This makes an accurate measurement of the current difficult. In the case of $^{16}O^{8+}$, a measurement was made using $^{18}O^{8+}$.

Charge state	^{1}H	^{3}He	^{12}C	^{14}N	^{16}O	^{19}F	^{20}Ne	^{24}Mg	^{28}Si
1^+	300	300	27	82	118				
2^+		200	37	117	143	43	51	32	20
3^+			*	106	152	55	63	34	33
4^+			31	110	*	53	78	28	69
5^+			6.5	93	96	37	58	44	72
6^+				19	82	17	45	34	47
7^+					14	11	21	18	30
8^+					.95	1	11	8	17
9^+						.05	1.1	6.3	7
10^+							.04	2.2	2.7
11^+								.1	.5
12^+									.2

Table 2

Currents (eμA) for the LBL ECR: sulfur through xenon

Charge state	^{32}S	^{39}K	^{40}Ar	^{40}Ca	^{48}Ti	^{84}Kr	^{127}I	^{129}Xe
3^+	10	4	38	23				
4^+	*	4.5	82	24				
5^+	20	5	*	*				
6^+	*	8.5	60	37		9		
7^+	63	11	66	38	2.4	12		
8^+	*	18	106	36	*	22		
9^+	36	37	72	31	12	25		4.1
10^+	*	22	*	*	10	22	4.2	4.7
11^+	5	12	18	22	8	19	4.9	5.1
12^+	*	2.4	13	11	*	*	5.7	5.2
13^+	.4		5	3.2	1	21	7.5	5.2
14^+	*		1.4	1.1		*	8.5	5
15^+	.001		*	*		16	11	4.3
16^+			.03	.03		8	*	4.6
17^+						7	12	4.3
18^+						*	15	4.4
19^+						2	15	4.8
20^+						.9	14	4.8
21^+						*	*	*
22^+						.1	11	3.5
23^+							10	3.1
24^+							8.3	2.7
25^+							5.6	2
26^+							2.1	1.1
27^+							.83	.34
28^+							.2	
29^+							.05	
30^+							.009	

Several different techniques are used to produce beams from the LBL ECR source. Elements that exist in gaseous form are fed into the ECR source via a flexible gas manifold system, which allows up to three gases to be used simultaneously. The gases can be injected into either the first or second stage of the source. The best proton and alpha beams are produced by feeding the gas directly into the second stage and turning off the first stage. For elements heavier than oxygen, gas mixing with a lighter gas such as oxygen is used to enhance the high charge state performance of the source. Beams from elements such as carbon, sulfur and silicon can be produced using gaseous compounds such as CH_4, SO_2, and SiH_4, respectively.

A variety of metallic ion beams can now be produced from the LBL ECR using a simple resistance-heated oven. The oven is inserted radially into the second stage so that vaporized metal atoms stream through the ECR plasma and are ionized by electron impact. With the oven in use, the plasma is maintained by running either oxygen or nitrogen as a support gas in the first stage. A number of cyclotron runs lasting several days have used the metal ion beams from the ECR source. During some of these runs no adjustment of the ECR source or oven was required.

A list of beams available from the cyclotron + ECR is contained in Table 3 at the end of the newsletter.

3. Cyclotron update

The 88-Inch Cyclotron has 17 trim coil power supplies, 10 Mag-Amp power supplies and 7 Silicon Controlled Rectifiers (SCR) power supplies. Recently, one of the old Mag-Amp supplies was replaced by a new prototype SCR supply utilizing an advanced triggering circuit and new SCR's. The prototype, which was built to test the new power supply design, is now in regular operation with the cyclotron and has demonstrated a stability of better than 1×10^{-3}. In FY87 four more of the new supplies will be built and installed. In FY88 the remaining Mag-Amp supplies will be replaced with the new SCR power supplies. This should eliminate the major source of instability in the present operation of the cyclotron and improve both the operating efficiency and the beam quality.

4. Experimental facility improvements

a. HERA

A major improvement to HERA, the 21-element High Energy Resolution Array, is scheduled for this year. The capability to measure the total γ-ray energy and multiplicity will be added in the form of a 40 element BGO 4π ball, which will fit inside the array of 21 Compton-suppressed Ge detectors. The central ball has been designed to preserve the high efficiency of HERA, allowing the Ge detectors to be as close as 15 cm from the target. The first BGO prototype will be received in January of 1987 and the ball elements will be constructed shortly thereafter. The space available inside the BGO ball is 3" in diameter by 3" high and could be increased by removing some of the inner ball elements. Also, a mini-orange electron detector has been designed and constructed to fit inside the outer bottom ring of the BGO ball. This device will be tested soon.

During the last year, the response function of the germanium detectors was improved by fitting a NaI "nose cone" in front of each BGO anti-Compton shield to suppress the pulses associated with the backscattered γ rays from the Ge detector. These pulses at (E_γ <250 keV) were almost completely suppressed and the peak to total ratio was improved from 50% to 55%. The cross talk between the detectors was also somewhat reduced. However, to fit in the "nose cones", the detectors were moved back slightly, lowering the detection efficiency by ~25%.

Typically, because of counting rate limitations in the data acquisition system, only triple coincidences are written on magnetic tape. Recently, to improve the statistics for double coincidences, a 4 Mw external memory was added to the acquisition system to directly increment the double coincidences. On-line gain adjustments are made to each Ge detector. Up to 16 Mw of memory can be handled by this system and the memory can be segmented into several smaller matrices if desired.

To minimize neutron damage effects arising from the heavy use of the germanium detectors, they are always kept at liquid nitrogen temperature. Even so, each year the resolution of 2 or 3 Ge detectors degrades sufficiently to require annealling with the ORTEC-designed heating system.

b. RAMA upgrade

To improve the effiency of the recoil atom mass analyzer, RAMA, for detecting short-lived nuclei ($t_{1/2} < 100$ ms), the ion source, which is currently fed by a long capillary from the He jet to the roof above the cave, will be moved into the cave adjacent to the bombardment area. This will significantly shorten the capillary transport time from >200 ms to <5 ms. An integrated target-to-ion source system is being constructed. The ionized radioactive species will be transported from the cave up to the mass analysis and counting station on the roof via a series of electrostatic and magnetic lenses. With this improvement, nuclei far from beta stability with very short half-lives can be studied.

c. Capture Beamline (Cave 4C2)

Two 10-inch x 10-inch NaI detectors have been acquired on long term loans from Lawrence Livermore National Laboratory and the National Bureau of Standards. The central crystal of each detector is surrounded by an active plastic scintillator shield and by passive lithium and lead shielding. This system makes possible studies of high-energy γ-ray emission from both light- and heavy-ion induced reactions at beam energies of 5 - 25 MeV/u.

A new beamline has been constructed in Cave 4C at the 88-Inch Cyclotron to accommodate these large detector systems. A 25-degree bending magnet was obtained from the SuperHILAC. An 18-inch scattering chamber was constructed at TUNL and has recently been installed at the cyclotron. At present, one detector is mounted on a movable cart that rotates from 20 to 150 degrees about the target position. The other detector is situated at 135 degrees on the opposite side of the beamline. In order to minimize the neutron levels at the detector positions, an eight-foot deep hole has been dug into the hillside behind the cave wall. The beamline extends from the scattering chamber to the end of this hole where a Faraday cup stops the beam.

This system is now fully operational and has been used in experiments by a group from Duke University and the National Bureau of Standards which has used the $\vec{d} + d \rightarrow {}^4He + \gamma$ reaction to determine the D-state admixture in the ^{4}He wave function, and by a group from the University of Washington which has used beams of ^{12}C and ^{19}F on a variety of targets to study nuclear shapes at high temperatures.

d. Low background counting facility

In many experiments in nuclear astrophysics and tests of fundamental symmetries, one is searching for small ß- or γ-decay branches in the presence of a large background. The experimental sensitivity is ultimately limited by events produced by cosmic rays and/or unwanted sources of radiation within the sample under study. To significantly enhance the sensitivity to such small effects, a low-background counting system is being developed. The centerpiece of this

system will be a 4π NaI detector that will surround primary α, ß, or γ detectors. For most applications, the NaI shield would be operated in anti-coincidence with the main detector. This would provide high rejection efficiency for cosmic-ray induced events, since a cosmic ray would have to traverse a large amount of NaI to reach the central detector. In the case of γ-ray counting, the NaI shield would also significantly reduce the background observed in a central Ge(Li) detector caused by γ rays which Compton scatter and deposit only a fraction of their total energy in the Ge(Li) detector.

The NaI system will be composed of a 25-cm long x 30-cm diameter annular detector and two existing 7.6-cm long x 7.6-cm diameter removable endcap detectors. The annulus will be segmented into two halves to allow the possibility of using it in coincidence with the central detector for experiments such as electron-positron pair spectroscopy. To make effective use of this detector array, a dedicated, self-contained data acquisition system will also be assembled. The components are now being ordered and the complete system should be operational by the summer of 1987.

5. General facility improvements

Early in 1986, a used VAX 11/780 (88VAX) was acquired for data analysis and acquisition at the 88-Inch Cyclotron. The 88VAX has 900 Mb of disk, 8 Mb of memory, and two 6250 BPI magnetic tape drives. An additional 4 Mb of memory and 456 Mb of disk will be added in FY87. The 88VAX is linked via ethernet with the Computer Cluster of five VAX 8650s and the Nuclear Science Division's three VAX 11/780s at the Bevalac. The Low Energy Computer Software group has been working on connecting the front-end Starburst CAMAC preprocessor with a microVAX. When this new Starburst-VAX based data acquisition system is operational, the 88VAX will be used as a taping station and for online monitoring and analysis.

A program of upgrading the electronics pool at the 88-Inch Cyclotron is currently underway. Two Tektronics 2465 oscilloscopes have been purchased over the last two years. A new fast (channel-plate based) Tektronics 2467 oscilloscope has been ordered for FY87 for fast timing work. Approximately, $20K/year is being spent on NIM & CAMAC modules to modernize the pool.

6. PAC III update

All PAC III experiments were completed during the 1986 Fall running period. A brief highlight of some of the PAC III approved heavy nuclei research is given below.

A large number of heavy ion bombardments of a new ^{254}Es target were performed during the Fall running period. The new target was prepared from fresh einsteinium from the transplutonium facilities at ORNL. The over **25** collaborators came from LLNL, LBL, GSI, University of Mainz, and Marburg University. In these experiments two new isotopes of lawrencium (Lr) were discovered, the number of neutrons accompanying the unusual modes of spontaneous fission decay of ^{260}Md was determined, and the chemical properties of Lr were investigated extensively. The new isotopes of Lr are believed to be ^{261}Lr and ^{262}Lr, which decay by spontaneous fission with half-lives of 40 and 216 minutes, respectively. Searches were undertaken for two nuclides within a mini island of stability, predicted to lie in the region of N = 162 to 164.

7. PAC IV

The fourth meeting of the 88-Inch Cyclotron Program Advisory Committee (PACIV) was held Jan. 14, 1987 to consider proposals for the second trimester of FY87 (Feb. 16 - May 30, 1987). The Committee consisted of:

1. C. Goodman, IUCF, Chairman
2. J. Randrup, LBL
3. J. Rasmussen, LBL
4. L. Riedinger, Univ. of Tennessee
5. R. Vandenbosch, Univ. of Washington

The Committee considered **22** proposals for **239** shifts from **106** individual scientists from **15** institutions and **4** countries. 130 shifts of beam time were available for Nuclear Science experiments and were allocated by the Scientific Director based on the recommendations of the PAC. A list of the approved experiments and the spokesperson is given below:

8. PAC IV Approved Proposals

A. Nuclear Reactions

1. Characterization of heavy mass fragments from intermediate energy ^{32}S-nucleus collisions. W. Loveland, Univ. of Oregon.
2. Multifragmentation of ^{12}C, ^{14}N, ^{16}O and ^{20}Ne. R. Stokstad, LBL.
3. Measurement of "Heavy Fragment" emission from excited medium mass nuclei. L. Vinet, LBL.

B. Nuclear Structure

4. Measurement of $\sigma(\theta)$, $A_y(\theta)$ for the reaction ^{2}H(d,γ)^{4}He at E_d = 30 MeV and 20 MeV. H. Weller, Duke University.
5. Half-life determination of ^{10}Be. K. Lesko, LBL.
6. Branching ratio for ^{10}C superallowed Fermi decay. K. Lesko, LBL.
7. ß-decay asymmetry of polarized ^{35}Ar. E. Commins, UCB.
8. Investigation of ^{182}Tl. K. Toth, ORNL.
9. The ß-delayed two-proton decay of ^{31}Ar. J. Cerny, LBL.
10. The ground state proton decay of ^{65}As. J. Cerny, LBL.
11. Lifetimes in a region of constant moment of inertia. R. Diamond, LBL.
12. Superdeformed band in ^{134}Nd. M. Deleplanque, LBL.
13. Studies on continuum γ-ray spectra. F. Stephens, LBL.

C. Heavy Nuclei

14. Non-aqueous reduction of lawrencium, radiochemical search for ^{263}105 and ^{252}Bk. D. Hoffman, LBL.
15. Search for ^{272}109 and ^{272}108. K. Hulet, LLNL.

D. Development

16. Development and testing of phoswich detectors. Y. Chan/C. Britt, LBL/LLNL

Table 3. Updated 88-Inch Cyclotron beam list.

Ion	Charge State	External Beam (eμA)	E/A Range/Max (MeV/u)
p	1	100-10	.2-55
p (pol.)	1	.7-.4	6-50
d	1	100-10	.5-65
d (pol.)	1	.7-.4	10-65
^{3}He	2	100-10	4-140
^{4}He	2	100-10	3-130
^{12}C	4	2.0	16
	5	.06	24
	6	.001	32
^{14}N	5	3.0	18
	6	.15	26
	7	.005	32
^{16}O	6	3.0	20
	7	.1	27
	8	.03	32
^{19}F	7	.6	20
^{20}Ne	6	2.0	13
	7	.4	17
	8	.1	22
	9	.015	28
^{24}Mg	6	1.5	9
	7	.7	12
	8	.2	16
	9	.1	20
	10	.03	24
	11	.001	29
^{28}Si	6	2.0	6
	7	1.0	9
	8	.6	11
	9	.1	14
	10	.04	18
	11	.007	22
	12	.002	26
^{32}S	7	3.5	7
	8	2.0	9
	9	1.0	11
	10	.4	14
	11	.1	17
	12	.02	20
	13	.003	23
	14	.001	27
^{35}Cl	9	.4	9
	10	.1	11
	11	.02	14
	12	.005	16
^{39}K	9	4	7
	10	2	9
	11	1	11
	12	.02	13
^{40}Ar	9	3.0	7
	10	1.5	9
	11	.6	11
	12	.4	13
	13	.09	15
	14	.015	17
	15	.002	20
^{40}Ca	9	1.5	7
	10	1.0	9
	11	.8	11
	12	.4	13
	13	.06	15
	14	.006	17
	15	.002	20
^{44}Ca	12	.6	8.9
^{48}Ca	13	.05	8.6
^{84}Kr	17	.2	6
	19	.08	7
	20	.04	8
^{129}Xe	23	.01	4
	27	.01	6

The listed currents are based on natural isotopic source feed, except for ^{3}He, ^{44}Ca, and ^{48}Ca, and represent either achieved values or extrapolations based on measured source performance. Beam intensity on target will vary according to beam line optics, collimation, and energy resolution requirements. For most ions, higher intensities can be obtained at charge states lower than those shown.

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

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