

ANNUAL REPORT  
OF THE  
MICHIGAN STATE UNIVERSITY  
NATIONAL SUPERCONDUCTING CYCLOTRON LABORATORY  
FOR THE PERIOD  
JANUARY 1, 1987 TO DECEMBER 31, 1987

ACKNOWLEDGEMENTS

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JULY 1988  
EAST LANSING, MICHIGAN

## Preface

This Annual Report describes the activities of the National Superconducting Cyclotron Laboratory (NSCL) from January 1, 1987 to December 31, 1987. As for the past several years, the efforts of the laboratory during this period were focused on two principal activities: the operation of the K500 facility as a national users facility and the construction of the K800 cyclotron and other Phase II facilities. Considerable resources were also devoted to the development of Electron Cyclotron Resonance ion sources whose performance is central to the development of the NSCL. Finally, the laboratory continued its program of applying superconducting technology to oncology with design efforts on a superconducting synchrocyclotron for 250 MeV protons and construction of a compact 50 MeV deuteron machine for neutron therapy.

The K500 cyclotron operated smoothly, at or above its design specifications, throughout the year. Beams were routinely available up to 50 MeV/nucleon for ions through  $^{16}\text{O}$ , to 40 MeV/nucleon for Ar and to 20 MeV/nucleon for Kr. The new compact ECR source (CP-ECR) made possible 250 enA beams of  $^6\text{Li}$  at energies up to 40 MeV/nucleon, with less intense beams available to at least 50 MeV/nucleon. Test beams of deuterons (as a model for N=Z beams) have been run at 60 MeV/nucleon. In addition to the shutdown for installation of the CP-ECR, the K500 was off for most of September, November and December to concentrate manpower on completion of the K800 cyclotron. In spite of these extended scheduled shutdowns, the K500 operated for 4368 hours in 1987. Overall reliability was slightly lower than in 1987 because of the definitive failure of the Imsai computer which controlled the superconducting magnet's power supply; this necessitated a crash program to update the magnet control system.

First steps have been taken toward running very heavy ions of mass  $A \geq 180$  on the K500. Beam chamber vacuum is now about  $10^{-6}$  torr, adequate for acceleration of very heavy ions with acceptable attenuation. Development of metallic beams on the Room Temperature ECR (RT-ECR) has begun and  $\text{Ta}^{24+}$  beams (allowing accelerated beams of 8.5 MeV/nucleon) have been obtained in useful amounts. Acceleration tests for Ta beams will take place early in 1988 ( $\text{Ta}^{21+}$  has since been accelerated to 6 MeV/nucleon and extracted from the K500).

As in the past, K500 experiments this year were split relatively evenly between those aimed at a better understanding of reaction mechanisms in nucleus-nucleus collisions and those aimed at elucidating the structure of nuclei. A decision was made to install the large dynamic range  $4\pi$  detector in an area adjacent to the north vault where K500 beams will be available. It is anticipated that the  $4\pi$  will be finished and that first experiments will be run in the spring of 1988 (two experiments have now been completed). PAC 8 met 3-4 May 1987; it considered 26 proposals, requesting a total of 3221 hours of beam time. A total of 1654 hours of beam time were allotted; in addition 518 hours for 6 experiments were put on reserve because of uncertainty in the precise amount of K500 time that will be available as the K800 is brought on line. PAC 9 will be held after first beams have been extracted from the K800.

In the construction program, 1987 was a year of great progress on the K800 cyclotron. At the beginning of the year the cyclotron looked far from finished -- the magnet had been disassembled including removing the main coil from its cryostat for installation of extraction channels. The upper pole of the magnet had been moved to the east end of the building and inverted so that both upper and lower poles would be available for fitting of rf liners which were, at that point, in midstream in the fabrication process. Below the magnet, work was beginning on installation of the lower dee stems and sliding shorts (including the cryopumping system), but the upper cap of the magnet was still completely bare. By mid-year all this had changed greatly, the coil being back in its cryostat with

all extraction elements in place and again cooled to 4K, and the magnet cap was once more in place so that installation of the upper dee stems could begin. Final magnet mapping proceeded intermittently for a period of five months from July to November, unraveling perplexing problems in the measuring apparatus itself and studying an unusual first harmonic, which appeared at high field and which we now think is due to non-symmetric aspects of the yoke and of structures outside the yoke (although this interpretation is in no sense conclusive). At Thanksgiving a decision was made to interrupt the mapping and proceed with final assembly and preparations for beam tests. The possibility was held open of returning to a fourth mapping cycle at a later date if computer studies indicated the unexpected first harmonic to be beyond the range of the cyclotron's correction coil system or if experimental beam studies indicated the presence of undetected errors in the field maps; these would manifest themselves as discrepancies between computer beam properties and experimentally observed properties. A great deal of work then happened in December and, by the end of the year, the acceleration chamber was under vacuum, dees were installed and low power rf tests were beginning. The cyclotron at this point was about 95% complete, the major missing components being the electrostatic deflectors and the electric motor gear drives for the 25 position adjustments in the extraction system. (In 1988, progress on the cyclotron proceeded smoothly with first internal beam in February and first external beam in June, as will be described in the 1988 Annual Report.)

Several advances were made on ECR sources during 1987. A second source, the "compact ECR" came into operation in the late winter and was soon in use on the K500. With two sources, the option of running ions which would "poison" the source and require extensive after-cleaning became feasible. In addition, time was released for study of the source itself, an important advantage since the complexity of ECR's is still very high compared to overall understanding of their operation. Work on ECR's also included planning studies for a high field superconducting ECR source with the goal of exploring and exploiting much higher rf frequencies than have thus far been used in ECR's. The superconducting source will include a coil-produced sextupole field which can be adjusted (the sextupole field is fixed in the customary permanent magnet design). The coil-based sextupole also allows rescaling of the operating field if rf transmitters with higher frequency become available; the coils are designed to work up to 30 GHz, while our existing transmitters operate at 6.4 GHz. In April 1987, a grant from the NSF provided funds to proceed with construction of the superconducting coils for this source and by the end of the year this work was proceeding rapidly. At this time work was also proceeding on the injection beam line which will ultimately connect any of the ECR's to the K800 cyclotron; the first configuration of this beam line is less versatile with the compact source connected to the K800 and the more powerful room temperature source remaining on the K500 until the experimental program with the K800 begins.

Beams from the K800 will first be available in an interim experimental area located near the cyclotron and containing a 92" diameter by 120" long scattering chamber and the  $4\pi$  detector. Limited space for other apparatus will also be available. Details about this area and the available experimental apparatus are given elsewhere in this report. To the extent it is consistent with K800 operation, K500 operation in the S320 spectrograph and RPMS areas will continue while the final vaults and the beam analysis line are being completed. Operation in the interim vault should begin at the end of summer, 1988. Layout of the Phase II experimental vaults and their equipment was discussed in a workshop involving the user community in August 1987. The final Phase II experimental areas are scheduled for completion in Summer 1989.

Several developments of the NSCL computer system should make its use more convenient and powerful for NSCL users. The aging VAX780 was replaced with a VAX8530; this has greatly relieved the slow

response of the system to interactive users. In addition, discs and tapes have been clustered via a Hierarchical Storage Controllers (HSC 50) so that all storage media are now accessible to all VAX computers. Another important development was the arrival on the MSU campus of a parallel processor modeled on the Fermilab Advanced Computer Project; this device consists of 16 parallel processors, each with approximately the power of a VAX 780, and will be available to the laboratory via DECNET. Trial use of this device for data analysis will indicate whether the lab should purchase such a device for dedicated use.

During 1987 the NSCL sponsored two conferences. The Fourth Gull Lake Nuclear Physics Conference on "Energetic Products of Heavy Ion Reactions", organized by Walter Benenson, George Bertsch and Alex Brown, was held on 17-20 May 1987; approximately 100 scientists attended. An "International Conference on ECR Ion Sources and their Applications" was held at MSU, 16-18 November, 1987 and was attended by 90 scientists. Proceedings will be published as an MSU report edited by the Conference Chair, Tim Antaya of MSU. The Fifth Gull Lake Conference, on Phase Transitions in Nuclear Collisions, will be held 23-27 May 1988; the conference organizers are Laszlo Csernai and Gary Westfall. In addition, Gary Crawley chaired the Nuclear Structure Gordon Conference in 1987, Konrad Gelbke chaired the ACS Symposium on Central Collisions and Fragmentation in Denver, April 7-10 1987, and Gary Westfall will chair the Sun Valley Meeting on 23-27 February 1988.

Other important developments for 1987 were several new additions and changes in laboratory faculty. On September 1, 1987, Gary Westfall moved from an appointment in the NSCL to an Associate Professorship in the Department of Physics and Astronomy. On September 1, 1988, Associate Professor Pawel Danielewicz, of the Institute of Theoretical Physics, Warsaw University, Assistant Professor Wolfgang Bauer, of Cal Tech, and Assistant Professor Aurel Bulgac of the University of Pennsylvania will join the Physics Department working in nuclear theory. During 1987, Alex Brown was awarded Fellowship in the APS, Bill Lynch held a Presidential Young Investigator Award and Sam Austin was appointed Editor of Physical Review C.

Closing, we solicit advice and suggestions from all readers as to any ways in which the contents of this Annual Report could be made more useful, and things we could do to make the NSCL a more supportive and convenient place to do research.

Sam Austin

Henry Blosser

Members of the Users' Executive Committee serve three-year terms, beginning November 1 (formerly two-year terms, beginning October 1). Members are elected each year from the general membership of the Users' Group, and a non-voting liaison representative from MSU is appointed by the Director of the NSCL. Committees to date are:

## October 1, 1982 - September 30, 1983

F. Becchetti	University of Michigan, Chair
A. Galonksy	MSU, Liaison
J. Kolata	Notre Dame University
V. Viola	Indiana University
D. Youngblood	Texas A&M University

## October 1, 1983 - September 30, 1984

A. Galonsky	MSU, Liaison
J. Kolata	Notre Dame University, Chair
F. Prosser	University of Kansas
R. Tickle	University of Michigan
D. Youngblood	Texas A&M University

## October 1, 1984 - October 31, 1985

A. Galonsky	MSU, Liaison
J. Kolata	Notre Dame University
L. Lee	SUNY, Stony Brook
F. Prosser	University of Kansas
R. Tickle	University of Michigan Chair

## November 1, 1985 - October 31, 1986

A. Galonsky	MSU, Liaison
D. Kovar	Argonne National Laboratory
L. Lee	SUNY, Stony Brook
F. Prosser	University of Kansas Chair
R. Tickle	University of Michigan

## November 1, 1986 - October 31, 1987

A. Galonsky	MSU, Liaison
D. Kovar	Argonne Nat'l Laboratory Chair
K. Kwiatkowski	IUCF
L. Lee	SUNY, Stony Brook
J.X. Saladin	University of Pittsburgh

## November 1, 1987 - October 31, 1988

A. Galonsky	MSU, Liaison
D. Kovar	Argonne Nat'l Lab Chair
K. Kwiatkowski	IUCF
J.X. Saladin	University of Pittsburgh
L.G. Sobotka	Washington University St. Louis

At present the Program Advisory Committee of the NSCL meets about every six months to review proposals for beam time; the possibility of more frequent meetings is under consideration. There are no oral presentations.

Meetings to date:

PAC-1	February 1982
PAC-2	September 30, 1983
PAC-3	July 2, 1984
PAC-4	January 13-14, 1985
PAC-5	July 28-29, 1985
PAC-6	April 6-7, 1986
PAC-7	October 26-27, 1986
PAC-8	May 3-4, 1987

PAC Members:

H.C. Britt (LANL)	1,2
D. Cline (Rochester)	1,2,3,4,5
S.E. Koonin (CalTech)	1,2,3,4,5,6
P. Paul (Stony Brook)	1,2
D.K. Scott (MSU)	1,2,3
J. Cramer (Washington)	3,4,5,6,7
V. Viola (Indiana)	3,4,5,6,7,8
W. Benenson (MSU Non-voting Chair)	4,5,6,7,8 1,2,3
P. Siemens (Texas A&M)	5,6,7,8
F. Stephens (LBL)	6,7,8
J. Vary (Iowa State)	7,8
G. Young (ORNL)	8

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