

**ANNUAL REPORT**  
**OF THE**  
**MICHIGAN STATE UNIVERSITY**  
**NATIONAL SUPERCONDUCTING CYCLOTRON LABORATORY**  
**FOR THE PERIOD**  
**JANUARY 1, 1993 TO DECEMBER 31, 1993**

## Preface

This Annual Report describes the activities of the National Superconducting Cyclotron Laboratory (NSCL) from January 1, 1993, to December 31, 1993. Major efforts of the laboratory were focused towards:

- operating the NSCL as a national user facility and carrying out a research program in nuclear science, accelerator physics and related instrumentation R&D,
- continuing vigorously with the construction of the S800 magnetic spectrograph,
- implementing accelerator improvements to allow extraction of full energy beams ( $E/A = 200$  MeV for  $q/A = 0.5$ ) from the K1200 cyclotron and studying options for a cost-effective facility upgrade to meet the increasing physics need for radioactive beams of substantially higher intensities.

Construction of the superconducting S800 magnetic spectrograph continued with high priority, and significant progress has been made. Technical problems (formation of cracks during flame-hardening) were encountered by the commercial manufacturer of the track on which the spectrograph moves, causing delayed delivery in January 1994. Assembly of the first dipole was completed, and work on the second is under way. Winding has been completed on more than half of the beam line quadrupoles. Steel for the spectrograph quads Q1 and Q2 has been procured, and machining is under way at an outside shop. Construction of the power supplies for the S800 beam line and for Q1 and Q2 is in progress.

Considerable resources were also devoted to completing the S2 vault and its beamline and to installing and commissioning the new Superball neutron multiplicity meter built by the University of Rochester group.

During 1993, reliability of the K1200 remained high (90.8%). The K1200 was scheduled to operate for 7031 hours, and it was operational for 6386 hours. Significant R&D was devoted to the improvement of the performances of the ECR ion sources and of the rf and extraction systems with the goal of extracting a 200 MeV/nucleon beam. A high magnetic field, low frequency mode of operation of the SCECR ion source was developed and found to yield outstanding results. One by one, the problems encountered in the development of the 200 MeV/nucleon beam were solved. The last technical hurdle was a slight readjustment of the vertical position of the main superconducting coils by 0.025 inch. On February 2, 1994, a beam of fully-stripped oxygen ions of 200 MeV/nucleon (3.2 GeV total) energy was extracted from the K1200.

Pressure for beam time remains high, and the NSCL continues to be oversubscribed; PAC 15 (May 1993) and PAC 16 (November 1993) received requests for 7243 hours of beam time and approved 4766 hours for research. Roughly 3/4 of the approved experiments were collaborations between outside groups and NSCL staff. As in the previous year, about one-half of the approved experiments involve the use of the NSCL's radioactive beam capabilities. As a result, there is now considerable pressure to improve the intensities of these beams. As a short-term, low-cost improvement, the target area of the A1200 was redesigned to allow the addition of a short-focal-length

quadrupole to increase the brightness of the beam spot on the production target by an order of magnitude. Fabrication of the necessary hardware was nearing completion by the end of the year, and installation was started in February 1994.

In 1993, the NSCL hosted an unusually large number of meetings: the Third International Conference on Radioactive Nuclear Beams (May 24 - 27); a Symposium on Weak Interactions, Nuclear Astrophysics and Cosmology (June 4-5); the Gull Lake Nuclear Physics Conference on Giant Resonances (August 17-21); and a workshop to discuss anticipated physics needs of the US intermediate-energy heavy-ion reactions program for the next decade (November 12-13). At these meetings, emerging needs for higher intensity radioactive beams and for higher energy, heavy ( $A \approx 200$ ) beams were brought into focus, and various options for the NSCL to meet these needs were discussed.

Additional discussions with NSCL users, the NSCL Users' Executive Committee, and also with the National Science Foundation led to a number of conceptual design studies of options for upgrading the NSCL facility. By mid 1993, it was decided that the option of refurbishing the K500 cyclotron and coupling it to the K1200 cyclotron provided the most cost-effective way to achieve the goal of large intensity gains for radioactive beams, with the secondary benefit of providing heavy beams ( $A \approx 200$ ) with energies above 100 MeV/nucleon to meet the most pressing needs for the reaction physics community. These plans are now being finalized, and technical feasibility studies have been initiated. A detailed report on these upgrade plans is expected to be completed by mid 1994.

During 1993, the research productivity of the NSCL remained high, and a large number of exciting new results were published in Physical Review Letters. In reaction dynamics, progress was made in establishing the systematic energy dependence of multifragmentation, the dependence of the balance energy on the mass of projectile and target, and the effect of impact parameter selection in intensity interferometry. Considerable advances were made in the understanding of nuclei far from stability, with major focus on the halo nucleus  $^{11}\text{Li}$ . Much of this research and of the ongoing technical work is summarized in this annual report.

During 1993, the NSCL suffered a significant and unexpected reduction in federal operating funds which forced the laboratory to reduce its technical and scientific staff and initiate a new operating schedule with less beam time available for experiments. I would like to express my appreciation to all NSCL staff and users for coping with the new fiscal reality. Personally, I am proud of the extraordinary performance of the NSCL technical and scientific staff during this difficult year.

We welcome advice and suggestions from all readers on how the contents of this Annual Report could be made more useful or what could be done to make the NSCL a more supportive place to do research within the existing severe financial constraints.

C. Konrad Gelbke

## NSCL USERS EXECUTIVE COMMITTEE

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:

July 1, 1982 - September, 1982

F. Becchetti -- University of Michigan  
A. Galonsky -- Michigan State University  
J. Huizenga -- University of Rochester  
Vic Viola -- Indiana University  
G.M. Crawley -- MSU, Liaison

October 1, 1982 - September 30, 1983

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

October 1, 1983 - September 30, 1984

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

October 1, 1984 - October 31, 1985

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

November 1, 1985 - October 31, 1986

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

November 1, 1986 - October 31, 1987

D. Kovar -- Argonne National Lab, Chair  
K. Kwiatkowski -- Indiana University  
L. Lee -- SUNY, Stony Brook  
J. Saladin -- University of Pittsburgh  
A. Galonsky -- MSU, Liaison

November 1, 1987 - October 31, 1988

D. Kovar -- Argonne National Laboratory  
K. Kwiatkowski -- Indiana University  
J. Saladin -- University of Pittsburgh  
L. Sobotka -- Washington Univ. at St. Louis  
A. Galonsky -- MSU, Liaison

November 1, 1988 - October 31, 1989

T. Awes -- Oak Ridge National Laboratory  
K. Kwiatkowski -- Indiana University  
J. Saladin -- University of Pittsburgh  
L. Sobotka -- Washington Univ. at St. Louis  
A. Galonsky -- MSU, Liaison

November 1, 1989 - October 31, 1990

T. Awes -- Oak Ridge National Laboratory  
A. Nadasen -- University of Michigan  
L. Sobotka -- Washington Univ. at St. Louis  
G. Wozniak -- Lawrence Berkeley Lab  
A. Galonsky -- MSU, Liaison

November 1, 1990 - October 31, 1991

T. Awes -- Oak Ridge National Laboratory  
J. Kolata -- Notre Dame  
A. Nadasen -- University of Michigan  
G. Wozniak -- Lawrence Berkeley Lab  
A. Galonsky -- MSU, Liaison

November 1, 1991 - October 31, 1992

J. Kolata -- Notre Dame  
A. Nadasen -- University of Michigan  
U. Schroeder -- Univ. of Rochester  
G. Wozniak -- Lawrence Berkeley Lab  
A. Galonsky -- MSU, Liaison

November 1, 1992 - October 31, 1993

F. Bertrand - Oak Ridge National Laboratory  
J. Kolata -- Notre Dame  
U. Schroeder -- Univ. of Rochester  
R. Vandenbosch - University of Washington  
N. Anantaraman - MSU, Liaison

November 1, 1993 - October 31, 1994

F. Bertrand - Oak Ridge National Laboratory  
U. Schroeder -- Univ. of Rochester  
R. Vandenbosch - University of Washington  
M. Wiescher - Univ. of Notre Dame  
N. Anantaraman - MSU, Liaison

## Meetings and Members of the NSCL Program Advisory Committee

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-9	September 18-20, 1988
PAC-10	April 29-May 1, 1990
PAC-11	March 3-5, 1991
PAC-12	October 27-29, 1991
PAC-13	May 3-5, 1992
PAC-14	November 8-10, 1992
PAC-15	May 2-4, 1993
PAC-16	December 5-7, 1993
PAC-17	June 26-28, 1994

### PAC Members

Members serve for about six PAC Meetings with one member leaving the PAC after each meeting. The Director of the NSCL is Convenor of the Committee. PAC Members to date and the meetings at which they have served are:

Britt, H.C.	LANL	1,2
Cline, D.	Rochester	1,2,3,4,5
Koonin, S.E.	Caltech	1,2,3,4,5,6
Paul, P.	Stony Brook	1,2
Scott, D.K.	MSU/NSCL	1,2,3
Cramer, J.	Washington	3,4,5,6,7
Viola, V.	Indiana	3,4,5,6,7,8
Benenson, W.	MSU/NSCL	4,5,6,7,8,9
Siemens, P.	Texas A&M	5,6,7,8,9,10,13
Stephens, F.	LBL	6,7,8,9,
Vary, J.	Iowa State	7,8,9,10,11,12
Young, G.	ORNL	8,9,10,11,12,13
Natowitz, J.	Texas A&M	9,10,11,12,13,14
Hardy, J.	Chalk River	10,11,12,13,14,15
Kashy, E.	MSU/NSCL	10,11,12,13,14,15,16
Randrup, J.	LBL	11,12,14,15,16,17
Haxton, W.	Univ. of Washington	13,14,15,16
Henning, W.	Argonne	14,15,16,17
Datz, S.	ORNL	14,15,16,17
Wozniak, G.	LBL	15, 16,17
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