

ANNUAL REPORT  
OF THE  
MICHIGAN STATE UNIVERSITY  
CYCLOTRON LABORATORY  
FOR THE PERIOD  
JULY 1, 1980 TO JUNE 30, 1981

BY  
PROJECT STAFF

DECEMBER 1981  
EAST LANSING, MICHIGAN

## Preface

This issue of our annual report covers activities during the period of July 1, 1980 to June 30, 1981 except for one exciting postdeadline item - the first beam of the K500 cyclotron. The announcement of this event, reproduced below, gives status information on the K500 project through Nov. 1981.

The experimental work described in this report used accelerator facilities at a number of laboratories including Argonne, Berlin, Chalk River, Indiana, LBL, Los Alamos, Oak Ridge, Orsay, and Saclay. We thank these institutions for their hospitality and cooperation. The experiments cover a wide range of topics and, like the theory contributions, are nicely split between heavy-ion and nuclear structure physics. An important highlight of this year was the discovery of the M1 giant resonance in  $^{90}\text{Zr}$  by an MSU-Orsay group using (p,p') at 200 MeV.

The experimental techniques section gives status descriptions for several of the main pieces of equipment for Phase I operation as of last August. At the time of this writing (Dec. 1981) it seems clear that all of the major components of the experimental equipment will come into operation during the first four month scheduling period, which will begin around March 1982. Also the new building addition, which is described in the previous annual report, is coming along nicely and should be completed on schedule next spring.

In September 1982 the laboratory will host an International Conference on Nucleus-Nucleus Collisions, and a formal inaugural session for the National Superconducting Cyclotron Laboratory will be held then also. Additional information on this conference is available from P. Pirnie, conference secretary. We hope that many of you will be able to attend this conference and visit the laboratory.

Walter Benenson

### Beam Test Report - November 81 MSU K500 Superconducting Cyclotron

A series of internal beam tests were conducted on the K500 superconducting cyclotron in the month of November, internal beam being achieved for the first time on November 13th, nuclear reactions being observed for the first time on November 21st, and first beam to full radius occurring on November 24th. The objective of these tests was confirmation of fundamental design features of the cyclotron system, i.e. that the superconducting magnet would indeed produce stable orbits with properties corresponding to calculations, that the RF system would accelerate particles in these orbits, that the ion source would produce ions in the presence of the RF and magnetic field, that these ions would clear the intricate central region structures, that all the above would happen simultaneously, etc. In view of the crucial importance of these fundamental tests and the concomitant desire to conduct the tests on the earliest possible date, the cyclotron was pushed into operation with several major subsystems in an incomplete or interim status. This led to a number of operating difficulties as described in more detail in following paragraphs, but pressing through these difficulties, the basic beam tests were able to proceed and the results were beautifully successful on all fundamental issues. These tests then mark the first time a beam has actually been accelerated in a superconducting cyclotron and correspondingly constitute the first experimental verification of operating characteristics of this new accelerator system.

The tests were not without difficulty, the first efforts to operate the complete cyclotron on November 6, 7, and 8 revealing an unexpected problem in achieving balanced voltages with  $120^\circ$  phasing on the 3 dee accelerating system. This difficulty has since been traced to a small asymmetry in the dee to dee coupling capacitance as discussed further below. By November 13, the RF problem was partially circumvented and a  $\text{C}^{2+}$  beam was successfully accelerated in a 34 kilogauss magnetic field, although dee phasing errors (often as large as  $20^\circ$ ) gave a badly off center beam. By November 16 the phasing errors had been brought down to the  $2^\circ$  range through a technique of introducing compensating asymmetries in the operating parameters of the three RF amplifiers and  $\text{C}^{2+}$  was again accelerated in the 34 kilogauss field, but attenuation in the relatively poor ( $2 \times 10^{-5}$  Torr) vacuum prevented taking the beam to full radius. Since the vacuum was expected to remain in the  $10^{-5}$  range until installation of the final pumping system in late December, the tests were shifted to a less vacuum sensitive ion, namely deuterium. Running on November 21 with the vacuum in a very marginal condition, a few brief bursts of beam were achieved and the all important first neutrons were observed. By November 23, the vacuum had improved significantly and with the RF running smoothly, the beam current reached 20 microamps and a large area of the building had to be cleared as a consequence of the limitations

of the interim shielding arrangement which was in use. In later runs the beam current was reduced by diluting the source gas and in a series of runs on November 24, tuning studies verified that beam phase and turn number were in good agreement with design calculations and as the probe was withdrawn to full radius, beam behavior at the  $\nu_r = 2\nu_z$  resonance, namely vertical loss of radially off centered beam, further confirmed that the basic operating conditions of the cyclotron were just as calculations predicted. Looking ahead, the focus of project effort in coming weeks will be on bringing various partially completed subsystems to full design status and introducing a modification in the RF system to more effectively circumvent the difficulty caused by the unbalanced central region coupling capacitance.

Discussing the RF problem in somewhat more detail, the asymmetry in the coupling capacitances is a consequence of details of the central region geometry, namely that the ion source location required to achieve well centered orbits puts the source in a location which blocks the coupling capacitance between two of the three dees. The missing capacity is extremely small, namely 0.2 picofarads and in view of this was thought to be unimportant and was neglected in the original design. Subsequent computer calculations have, however, shown the important error in this assumption and in an RF test run on December 3rd, with the source replaced by a 0.2 picofarad coupling capacitance, the RF system operated in complete accord with design expectations, namely balanced voltages and phases on both dees and amplifiers.

Introducing a comparable coupling which is compatible with the ion source is unfortunately a much larger job, constraints of the geometry forcing the coupling to be made outside the vacuum in an inductive region of the resonator structure. The design, manufacturing and installation of the required mechanisms is expected to require four to six weeks.

In the same time interval the cryopumping system is expected to be completed and installed after which operating pressure should drop to the  $10^{-7}$  Torr range, a vastly more effective diagnostic probe will be installed, and electrostatic deflectors should be completed and installed so that beam extraction studies can begin. Also in the same period, shield walls will be brought to their final configuration so that beam runs can proceed simultaneously with normal occupancy of the building.

When the various items described above are complete, the cyclotron is expected to be in a condition which will allow beam studies over the full operating range of the machine including extraction studies. In view of these events, a call for proposals has been issued to the members of the NSCL User group with proposals due on January 20, 1982, after which the Program Advisory Committee will meet and by early spring the first experimental operating period on the K500 is expected to begin. (Persons interested in submitting proposals who are not in the User's group should immediately contact W. Benenson to receive necessary information.)

Henry Blosser

Table I. Scientific staff of the MSU Cyclotron Laboratory for the period July 1, 1980-June 30, 1981 and their principal sources of support.

Faculty	supported by	present address	Faculty (continued)	supported by	present address
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Joseph Purcell	NSF-exp,MSU				

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