

SECTION II

ABSTRACTS AND/OR TITLES OF TALKS AT  
AMERICAN PHYSICAL SOCIETY MEETINGS  
AND  
OTHER MEETINGS AND CONFERENCES

(JULY 1978-JUNE 1979)

Cross-Section Measurements for the  $\alpha + \alpha$  and  $p + {}^{16}\text{O}$  Reactions at Intermediate Energies.\*

B.G. GLAGOLA, G.J. MATHEWS, A. NADASEN, R.A. MOYLE, P.G. ROOS, H.F. BREUER and V.E. VIOLA, Univ. of Maryland, and S.M. AUSTIN, Mich. State Univ.--Recent cross-section measurements are reported for the production of: (1)  ${}^6\text{He}$ ,  ${}^6\text{Li}$ ,  ${}^7\text{Li}$  and  ${}^7\text{Be}$  in the  $\alpha + \alpha$  reaction at energies of 61.5-158.2 MeV and (2)  $A = 6-11$  isobars in the  $p + {}^{16}\text{O}$  reaction between 50-90 MeV. Measurements were performed at the University of Maryland Cyclotron. The  $\alpha + \alpha$  reaction was studied using a triple semiconductor counter telescope to measure the energy spectra and angular distributions of the heavy reaction product in the  $(\alpha, 2p)$ ,  $(\alpha, d)$ ,  $(\alpha, pn)$ ,  $(\alpha, n)$  and  $(\alpha, p)$  reactions, respectively. In the  $p + {}^{16}\text{O}$  studies a channel-plate fast-timing device was used with a semiconductor detector to perform time-of-flight mass, energy and angular distributions of the  $A = 6-11$  products. Comparison of the new data with previous cross section estimates for these systems will be presented.

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Giant Vibrations.\* GEORGE BERTSCH, Mich. State Univ.--In the last decade, a variety of experimental probes have firmly established the energy and width of the giant quadrupole vibration in nuclei, located at  $63/A^{1/3}$  MeV. Strong indications for a giant monopole vibration at  $80/A^{1/3}$  MeV have been found recently. The most favorable probes for studying the vibrations by inelastic scattering are those that have high velocity and do not interact too strongly with the target. Light ion probes excite the vibration together with background states that are more than twice as strongly excited. Intermediate energy machines offer the hope of a cleaner view of these vibrations. The theoretical interpretation of the vibrational energies is remarkably simple. The monopole energy is directly related to the compressibility of nuclear matter, with the empirical data implying a compressibility coefficient  $K \approx 190$ . This is larger than early theoretical estimates, but is smaller than given by the most recent theory. The quadrupole energy relates to the kinetic energy of the nucleons; the empirical data implies that  $\epsilon/A \approx 22$  MeV, in close agreement with the Fermi gas model. This bears on the question of the effective mass of nucleons in decay matter. The decay properties of the vibrations are of considerable interest. In light nuclei,  $\alpha$ -particle decays show structural features. The decay angular distribution, while in principle containing spectroscopic information, is strongly distorted by the coherent background of other multipoles excited by hadronic probes. The observed width of the vibrations is due to the decay of the vibration into the more complicated states of the compound nucleus. The spreading is smaller in magnitude than that of an equivalent single-particle excitation, in accordance with theory.

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Elastic Scattering of  ${}^{16}\text{O} + {}^{28}\text{Si}$  and  ${}^{12}\text{C} + {}^{32}\text{S}$  and the  ${}^{28}\text{Si}({}^{16}\text{O}, {}^{12}\text{C}){}^{32}\text{S}$  Transfer Reaction.\*

T.C. AWES, U.E.P. BERG and C.K. GELBKE, Mich. State Univ., J. BARRETTE and M.J. LEVINE, Brookhaven National Laboratory, and P. BRAUNMUNZINGER, SUNY at Stony Brook--Angular distributions and excitation functions are compared for the transfer reaction  ${}^{28}\text{Si}({}^{16}\text{O}, {}^{12}\text{C}){}^{32}\text{S}$  and the elastic scattering in entrance and exit channel. The resonance like structures observed in the backangle elastic excitation functions are uncorrelated and are dominated by different angular momenta for a fixed excitation energy in the compound nucleus, ruling out a common doorway state. The forward angle transfer data are dominated by partial waves different from the ones dominating the backangle elastic data. At forward angles, the transfer excitation function is rather smooth in contrast to the results of Paul et al.<sup>1</sup> for the  ${}^{28}\text{Mg}({}^{16}\text{O}, {}^{12}\text{C}){}^{28}\text{Si}$  reaction.

<sup>1</sup>M. Paul et al., Phys. Rev. Lett. **40**, 1310 (1978).  
\*This material is based upon work supported by the National Science Foundation under Grant No. Phy 78-01684.

Momentum Transfer in Peripheral Reactions of 20 MeV/A  ${}^{16}\text{O}$  with  ${}^{238}\text{U}$ .\*

B.B. BACK, A. MIGNEREY, and L.K. WOLF, Argonne National Laboratory, T.C. AWES, P. DYER, and C.K. GELBKE, Mich. State Univ., H. BREUER and V.E. VIOLA, Univ. of Maryland, and W.G. MEYER, Lawrence Berkeley Laboratory--The sequential fission in peripheral reactions of 20 MeV/A  ${}^{16}\text{O}$  with  ${}^{238}\text{U}$  has been studied. In coincidence with projectile like reaction products (Li, Be, ..., O) we have measured the energies and emission angles of the two fragments resulting from fission of the target residue. A kinematic analysis of the triple coincidence events allows an estimate of the average linear momentum transferred to the target nucleus. Our result indicates momentum transfers corresponding to a situation intermediate between the extremes of simple transfer and projectile break-up reactions.

\* This material is based upon work supported by the National Science Foundation under Grant No. Phy-01684.

Heavy Ion Source Operation in the MSU Superconducting Cyclotron Magnet.\* M.L. MALLORY, Mich. State Univ.--A cold cathode heavy ion source was successfully operated in the Michigan State University superconducting cyclotron magnet on June 22, and this represents the first time a heavy ion source has been operated in a magnetic field of  $\approx 5$  T. The arc parameters were of the same value as obtained in previous source operation at low magnetic field and no large difference of source operation was observed at high field. A mass analyzer system is presently being tested in the superconducting magnet and is designed to operate at 30 kV and will analyze m/q ratios greater than 5 at 5 T with unit resolution, e.g.  $^{40}\text{Ar}$  charge states up to  $8^+$ . This analyzer will then measure the charge distribution of the heavy ion source at high and low magnetic field levels.

\*Work supported by the National Science Foundation under Grant No. PHY 78-01684.

Cross Section Ratios for Elastic Scattering of 30.3 MeV Protons from  $^{40}\text{Ca}$ .\* SAM M.

AUSTIN, C.H. KING, E. KASHY, R. MARKHAM, I. REDMOUNT, and R. Ronningen, Mich. State Univ.--Ratios of cross sections for elastic scattering of protons from  $^{40}\text{Ca}$  have been measured using a new method. Protons scattered from a mixed metallic target with a thickness of  $100 \mu\text{g}/\text{cm}^2$  were detected by a position sensitive proportional counter in the focal plane of an Enge split pole spectrograph. Resolution of 8-10 keV permitted identification of the scatterer by the kinematic shift, for angles as small as  $30^\circ$ . The ratios should be free of most systematic uncertainties. Ratios of isotopes in the target were determined by Coulomb scattering of  $^{12}\text{C}$  in the Rutherford region.

\*This material is based upon work supported by the National Science Foundation under Grant No. Phy 78-01684.

AMERICAN PHYS. SOC. NEW YORK MEETING, January/February 1979

Design Considerations of a Recoil Mass Separator for MSU\* J.A. NOLEN, JR., L. HARWOOD, and E. KASHY, Mich. State Univ., and H.A. ENGE, MIT.--Design of a recoil mass separator for use with the superconducting heavy ion cyclotron at MSU is currently in progress. First order, second order, and ray tracing calculations are being carried out in order to compare the advantages and disadvantages of various types of devices. Currently under consideration are: a) A "beam trap" followed by a crossed-field velocity selector with horizontal dispersion and then by a magnetic dipole with horizontal momentum dispersion. This leads to an "m/q" focal plane as opposed to a two dimensional focal plane as in the MIT-BNL "EMS" spectrometer.<sup>1</sup> A design of a second generation "EMS system"<sup>2</sup> is currently being finalized for use at the super HILAC in Berkeley. b) A magnetic dipole followed by an electric dipole with dispersions adjusted to give an "m/q" focal plane. Some experiments for which such devices are advantageous will also be discussed.

\*National Science Foundation Grant No. Phy 78-01684.

<sup>1</sup>H.A. Enge and D. Horn, Nucl. Instr. Meth. 145 (1977)271.

<sup>2</sup>J.M. Nitschke and H.A. Enge, private communication.

Pion Production Near Threshold in Heavy Ion Collisions\* W. BENENSON, G. BERTSCH, G.M. CRAWLEY, E. KASHY, J.A. NOLEN, JR., Mich. State Univ. Cyclotron Laboratory; J.O. RASMUSSEN, H. BOWMAN, M. SASAO, J. IOANNOU, M.C. LEMAIRE, J. SULLIVAN, L. OLIVEIRA, Lawrence Berkeley Laboratory; M. KOIKE and J. CHIBA, Univ. of Tokyo--Measurements of pion production by 400 and 250 MeV/A Argon beams on KCl and Pb targets have been made at the LBL Bevalac. The pions which were emitted near  $0^\circ$  were detected in a  $180^\circ$  magnetic spectrograph. Three plastic scintillator telescopes were used on the focal plane to detect 30, 60, and 90 MeV pions. The results indicate a factor of three lower cross sections at the lower beam energy, which is below the free nucleon-nucleon threshold. Preliminary data analysis for  $\pi^+$  are consistent with the upper limits established by Lindstrom<sup>1</sup> et al. and by Kullberg<sup>2</sup> et al. but disagree with the high multiplicity found by McNulty<sup>3</sup> et al.

\*This material is based upon work supported by the National Science Foundation under Grant No. Phy 78-01684.

<sup>1</sup>P. Lindstrom et al., Phys. Rev. Lett. 40, 93 (1978).

<sup>2</sup>R. Kullberg et al., Phys. Rev. Lett. 40, 289 (1978).

<sup>3</sup>P.J. McNulty et al., Phys. Rev. Lett. 38, 1519 (1977).

Elastic and Inelastic Scattering of  $^6\text{Li}$ .\* A. GALONSKY, R. HUFFMAN, R. MARKHAM, and C. WILLIAMSON, Mich. State Univ.--Elastic scattering of 75-MeV  $^6\text{Li}$  ions has been measured on targets of  $^{58}\text{Ni}$ ,  $^{90}\text{Zr}$ ,  $^{124}\text{Sn}$ , and  $^{208}\text{Pb}$ . The data extend to  $\approx 55^\circ$  c.m. where  $\sigma/\sigma_R \approx 10^{-4}$ . Conventional optical-model analysis is in progress. Inelastic scattering to low-lying states of  $^{58}\text{Ni}$  has been measured. Using a preliminary set of optical-model parameters, a collective-model calculation of deformation lengths of the  $2^+$ ,  $4^+$ , and  $3^-$  states at 1.45, 4.75, and 4.47 MeV, respectively, gave values in agreement with those obtained from inelastic scattering of lighter ions.

\*This material is based upon work supported by the National Science Foundation under Grant No. Phy 78-01684.

Densely Measured  $(p,t_0)$  Angular Distributions and a Zero-Range DWBA Analysis.\* Y. IWASAKI, E. KASHY, and R.G. MARKHAM, Mich. State Univ.--The angular distributions for the  $^{56}\text{Fe}$ ,  $^{56}\text{Ti}(p,t_0)^{52}\text{Fe}$ ,  $^{88}\text{Ti}$  transitions were measured at  $E_p=40$  MeV with angular steps of  $1.0^\circ$  in general and of  $0.5^\circ$  around some deep minima. Measurement was made at five angles at the same time by use of a quintuplet of slits placed at the entrance to the Enge split-pole magnetic spectrograph and a position-sensitive proportional counter placed a little forward of the focal plane. Only the tritons corresponding to the  $(p,t_0)$  transition were selected by means of TOF and energy-loss signals. A series of zero-range DWBA calculations were performed for these angular distributions and the one for the  $^{40}\text{Ca}(p,t_0)^{36}\text{Ca}$  transition measured with a step of  $2.0^\circ$  at  $E_p=39$  MeV.<sup>1</sup> It has been shown that excellent fits to the angular distributions are obtained with almost one and the same set of potential parameters, if due attention is paid to the geometry of the potentials.

\*National Science Foundation Grant No. Phy 78-01684.

<sup>1</sup>Present address: Xerox Corporation, Webster, G.M. Crawley et al., Phys. Rev. C 8(1973)574.

The Masses of  $^{10}\text{C}$  and  $^{10}\text{O}$  and Superallowed Beta Decay.\* J.A. NOLEN, JR., P.H. BARKER,<sup>†</sup> and M.S. CURTIN, Mich. State Univ.--The masses of  $^{10}\text{C}$  and  $^{10}\text{O}$  have been measured, each with an uncertainty of 0.5 keV. The preliminary results<sup>1</sup> were both in disagreement with recent independent measurements<sup>2,3</sup> i.e. our value for  $^{10}\text{C}$  was 2.8 keV lower than that of Ref. 2, while our value for  $^{10}\text{O}$  was 2.5 keV higher than that of Ref. 3. The discrepancy is particularly important for  $^{10}\text{O}$  because this is the lightest superallowed beta decaying nucleus for which the ft-value is well known, and hence it has an important influence in determining the Z-dependence of these ft-values. Because of this importance a check on our preliminary results has been carried out. This check, consisting of a measurement of the difference between the  $^{12}\text{C}(p,t)$  and  $^{16}\text{O}(p,t)$  Q-values, is in excellent agreement with the preliminary separate measurements.<sup>1</sup> Hence, the discrepancies between these and the other recent measurements still exist.

\* National Science Foundation Grant No. Phy 78-01684.

<sup>†</sup> Permanent address: Univ. of Auckland, New Zealand.

<sup>1</sup> P.H. Barker and J.A. Nolen, Jr., Tokyo Conf., 1977.

<sup>2</sup> D.C. Robinson and P.H. Barker, Nucl. Phys. **A225** (1974) 109.

<sup>3</sup> H. Vonach et al., Nucl. Phys. **A278** (1977) 189.

AMERICAN PHYS. SOC. WASHINGTON MEETING, April 1979

Mass of  $^6\text{Li}$  in its ground and  $0^+$ , T=1 States.\* R.G.H. ROBERTSON and J.A. NOLEN, JR., Mich. State Univ.--Experiments searching for the parity-forbidden  $\alpha$  decay of the  $0^+$ , T=1 state at 3.56 MeV in  $^6\text{Li}$  by resonance techniques require an accurate knowledge of the mass of that state relative to the alpha particle and the deuteron. Our approach is to measure the excitation energy and the ground state mass in two separate experiments. We have used bremsstrahlung from the University of Illinois superconducting linac to excite the 3.56 MeV state and have compared the energy of the fluorescence radiation to accurately known lines from  $^{56}\text{Co}$  decay, finding  $E_x = 3562.9 \pm 0.1$  keV. To measure the ground state mass, we are attempting to make a precise comparison of the Q-value of the  $^6\text{Li}(p,\alpha)^3\text{He}$  reaction with that for  $^3\text{F}(p,\alpha)^1\text{O}$ . At  $E_p = 10.5$  MeV the  $^6\text{Li}$  line lies near lines from well-known states in  $^{16}\text{O}$ . An analysis of data taken on plates in the MSU split-pole spectrograph is in progress.

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<sup>†</sup> Alfred P. Sloan Foundation Fellow.

Broad cross section enhancements in (p,n) reactions.\* W.A. STERRENBURG, SAM M. AUSTIN, U.E.P. BERG, R. DEVITO, and A.I. GALONSKY, Mich. State Univ.--A structure in  $^{90}\text{Nb}$  with a width of about 4 MeV centered around 8 MeV excitation energy has been observed previously with the  $^{90}\text{Zr}(p,n)$  reaction.<sup>1</sup> With this reaction as well as with the ( $^3\text{He},t$ ) reaction the existence of a second broad peak some 10 MeV higher in excitation energy was found.<sup>2</sup> In the present work the study is extended to nearby nuclides ( $^{90,91,92,94}\text{Zr}$  and  $^{97,98,100}\text{Mo}$ ), for which similar features were observed, although the strength of the structures varied. Angular distributions of those cross section enhancements were measured at a bombarding energy of 45 MeV. The analysis is in progress.

\* National Science Foundation Grant Phy78-01684.

<sup>1</sup> R.R. Doering et al., Phys. Rev. Lett. **35**, 1691 (1975).

<sup>2</sup> Aaron Galonsky et al., Phys. Rev. Lett. **74B**, 176 (1978).

In-Beam  $\gamma$ -Ray Spectroscopy of Excited States in  $^{153}\text{Eu}$ .\* R. ARYAEINEJAD, R.B. FIRESTONE, W. BENTLEY, and Wm. C. MCHARRIS, Mich. State Univ.--The level structure of  $^{153}\text{Eu}$  has been investigated by the reaction,  $^{153}\text{Sm}(p,2n\gamma)^{153}\text{Eu}$ , using 30-MeV protons from the MSU cyclotron. We have assigned 37  $\gamma$  rays deexciting 32 states in  $^{153}\text{Eu}$ , placed on the basis of excitation functions and  $\gamma$ - $\gamma$  coincidence information. (These complement the extensive  $^{153}\text{Gd}$  decay data also obtained at this laboratory.<sup>1</sup> A  $\gamma$ -ray angular distribution experiment has recently been completed and data analysis is in progress. In addition, calculations are being performed to explain the resulting level structure in terms of a triaxial weak-coupling model.

\* Work supported in part by the U.S. National Science Foundation.

<sup>1</sup> R.B. Firestone, R.A. Warner, Wm. C. McHarris, and W.H. Kelly, Phys. Rev. **C17**, 718 (1978).

Status Report on 500 MeV Superconducting Cyclotron.\* H.G. BLOSSER, Mich. State Univ.--Construction work on the 500 MeV cyclotron is proceeding smoothly and approximately on schedule. Initial beam tests are now expected late this year with phasing into routine research use in early 1980. First high power tests of the prototype power amplifier have been completed with the amplifier driving a resistive load. Tests of the amplifier driving a prototype dee and dee stem assembly are expected to start in March. Substantial operating experience with the superconducting magnet has now been accumulated ( $\approx 20$  months total), the last eight months being devoted to an ion source testing program with charge state analysis via a biased electrostatic extraction electrode mounted in the magnet gap. A major disassembly of the magnet for installation of the extraction system and for upgrading of the liquid nitrogen shield is scheduled to begin in March.

\* National Science Foundation Grants Phy76-83254 and Phy78-22696.

The Masses of  $^{146}\text{Gd}$ ,  $^{147}\text{Gd}$ , and  $^{108}\text{Sn}$ .\* R.C. PARDO, S. GALES, R.M. RONNINGEN, and L.H. HARWOOD, Mich. State Univ.--We have used the  $^{144}\text{Sm}$ ,  $^{106}\text{Cd}(^{12}\text{C},^{10}\text{Be})$  and  $^{144}\text{Sm}(^{12}\text{C},^9\text{Be})$  reactions to measure the mass excesses of  $^{146}\text{Gd}$ ,  $^{147}\text{Gd}$ , and  $^{108}\text{Sn}$ . Products from the 75-MeV  $^{12}\text{C}^+$ -induced reactions were detected in the focal plane of an Enge split-pole spectrograph by a two-wire charge division detector backed by a plastic scintillator. The mass excess of  $^{146}\text{Gd}$  was determined to be  $-76.090 \pm 0.025$  MeV. The preliminary value for the mass excess of  $^{147}\text{Gd}$ ,  $-75.48 \pm 0.05$  MeV, is 280 keV lower than the currently accepted value. Both values indicate a weak shell effect at Z=64. The mass of  $^{108}\text{Sn}$  and information on excited states observed in this reaction will also be presented.

\* National Science Foundation Grant No. Phy78-01684.

<sup>†</sup> Permanent address: Institut de Physique Nucleaire, Orsay, France.

Isomeric Negative-parity Yrast Band in  $^{170}\text{Yb}$ .\* P.M. WALKER, S.R. FABER, W.H. BENTLEY, R.M. RONNINGEN, R.B. FIRESTONE, and F.M. BERNTHAL, Mich. State Univ.—Gamma-ray and electron conversion techniques have been used to identify a high-moment-of-inertia negative-parity sideband up to spin 17 in the well-deformed nucleus  $^{170}\text{Yb}$ , following  $(\alpha, 2n)$  and  $(\alpha, 4n)$  reactions. The 4 bandhead decays to the 4 ground band member with a half-life of 350 ns, yet the odd-spin members of the sideband have prompt E1 decays to the ground band, competing with the in-band transitions. The implication of low-K for the odd-spin states, yet high-K for the 4 bandhead, is consistent with Coriolis coupling effects and a probable two-quasi-neutron bandhead configuration of  $\{7/2^+ [633], 1/2^- [521] \}_4^-$ . The band is similar to the decoupled negative-parity sidebands already known in the isotopes  $^{172}\text{Hf}^1$  and  $^{174}\text{W}^2$ , although the isomeric bandhead in  $^{170}\text{Yb}$  is a distinctive feature.

\* National Science Foundation Grant No. Phy 78-01684.  
<sup>1</sup>P.M. Walker, G.D. Dracoulis, A. Johnston, and J.R. Leigh, Nucl. Phys. A293, 481 (1977).  
<sup>2</sup>G.D. Dracoulis, P.M. Walker, and A. Johnston, J. Phys. G4, 713(1978).

An Estimate of the Tensor Force and  $V_{\text{TT}}$  from the  $^7\text{Li}(p,n)^7\text{Be}$  Reaction.\* SAM M. AUSTIN, R. DEVITO, L.E. YOUNG, and R.R. DOERING, Mich. State Univ.—It has been difficult to obtain a reliable estimate of the tensor part of the effective interaction for inelastic scattering and charge exchange reactions. Its effects are dominant only in special cases and model uncertainties have not allowed an unambiguous determination. We have analyzed measurements<sup>1</sup> of the ratios of cross sections for the  $^7\text{Li}(p,n)$  Be reaction leading to the ground ( $\sigma_0$ ) and first excited states ( $\sigma_1$ ) of  $^7\text{Be}$  and have found that an observed peak in  $\sigma_1/\sigma_0$  near  $30^\circ$  can be reproduced only if a tensor force is introduced. A central force yields values of  $\sigma_1/\sigma_0$  nearly independent of angle between  $0^\circ$  and  $120^\circ$ . These conclusions were found to hold for a variety of different optical model potentials, wavefunctions, etc. Predicted individual cross sections changed by up to a factor of two, but most of the model dependence appeared to vanish in the ratio. The resulting estimate of the tensor force (and of  $V_{\text{TT}}$ ) is perhaps the most reliable available for this energy range. A comparison will be made with other measurements.

\*National Science Foundation Grant No. Phy78-01684.  
<sup>1</sup>R.R. Doering et al., B.A.P.S. 21, 978 (1976).

Proton Scattering at 35 MeV to Ground Band States in  $^{152}\text{Sm}$ ,  $^{176}\text{Yb}$ ,  $^{186}\text{W}$ ,  $^{232}\text{Th}$  and  $^{238}\text{U}$ .\* R.M. RONNINGEN, G.M. CRAWLEY, J.E. FINCK,† C.H. KING,\*\* R.C. MELIN, J.A. NOLEN, JR., P.T. DEASON, AND F.M. BERNTHAL, Mich. State Univ.—Angular distributions of elastically and inelastically scattered protons were measured over angular ranges of  $20^\circ$  to typically  $120^\circ$ , but to  $140^\circ$  for  $^{154}\text{Sm}$  and  $^{176}\text{Yb}$ , in step sizes of  $2.5^\circ$  and  $5^\circ$ . Angular distributions for states in the ground band, with  $I^\pi=0^+$  through  $8^+$ , are being analyzed within a coupled channels framework. Quadrupole, hexadecapole, and in some cases higher order mass moments, are being deduced. Particular attention is being paid to correlations and uncertainties in the optical model parameters and these moments. The results will be compared to moments from  $(e, e')$ ,  $(\alpha, \alpha')$ , and Coulomb excitation studies. A comparison will also be made between moments deduced with and without the employment of a spin-orbit interaction.

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Analysis of the  $^{194}\text{Pt}(p,t)$  and  $(p,p')$  Reactions in Terms of the  $O(6)$  Limit of the Interacting Boson Approximation Model.\* P.T. DEASON, R.M. RONNINGEN, C.H. KING,† J.A. NOLEN, JR., T.L. KHOO,† and F.M. BERNTHAL, Mich. State Univ.—The  $O(6)$  limit of the IBA model has been recently applied quite successfully in explaining the branching ratios and energy levels for several nuclei in the shape transitional region of Os-Pt. We will present results of further tests of the applicability of this model in the Pt nuclides by comparing calculated and experimental transition strengths in the six reactions. For the  $(p,t)$  reactions transition strengths for the  $L=0$  and  $L=2$  transitions will be discussed, while for  $(p,p')$ , results of coupled channel calculations using  $O(6)$  matrix elements will be presented.

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<sup>1</sup>R.F. Casten and J.A. Cizewski, NP A309, 477(1978).  
<sup>2</sup>Calculations for  $(p,t)$  strengths performed by Olaf Scholten, Yale University.

In-beam  $\gamma$ -Ray Spectroscopy in the Odd Mass N=80 Region.\* R. ARYAEINEJAD, R.B. FIRESTONE, W. BENTLEY, and WM. C. MCHARRIS, Mich. State Univ.—The level structure of  $^{143}\text{Eu}$ ,  $^{141}\text{Pm}$  and  $^{139}\text{Pr}$  are being investigated using the techniques of in-beam  $\gamma$  ray spectroscopy. Levels in  $^{143}\text{Eu}$  were populated by the  $(p, 2n\gamma)$  reaction whereas levels in  $^{141}\text{Pm}$  and  $^{139}\text{Pr}$  were populated by  $(p, 2n\gamma)$  and  $(\alpha, 4n\gamma)$  reactions. Data analysis in the cases of  $^{141}\text{Pm}$  and  $^{139}\text{Pr}$  are still in progress. Study of  $^{143}\text{Eu}$  has recently been completed. We have assigned 37  $\gamma$  rays deexciting 32 states in  $^{143}\text{Eu}$ , placed on the basis of excitation functions and  $\gamma$ - $\gamma$  coincidence information. These complement the extensive  $^{143}\text{Gd}$  decay states also obtained in this laboratory. In addition, calculations are being performed to explain the resulting level structure in terms of a triaxial model.

\*National Science Foundation Grant No. Phy78-01684.  
<sup>1</sup>R.B. Firestone, R.A. Warner, Wm. C. McHarris, and W.H. Kelly, Phys. Rev. C 17, 718(1978).

The  $^{48}\text{Ca}(d,n)^{49}\text{Sc}$  Reaction at  $E_d=20$  MeV.\* YOSEO IWASAKI, AARON GALONSKY, and DAVID J. WEBER, Mich. State Univ.—The  $^{48}\text{Ca}(d,n)^{49}\text{Sc}$  reaction was studied at  $E_d=20$  MeV. Differential cross sections were measured for transitions to states in  $^{49}\text{Sc}$  up to 7 MeV in excitation energy, in the angular range of  $7.5^\circ$  to  $50^\circ$  lab, using the neutron time-of-flight facility of the MSU cyclotron. The  $^{48}\text{Ca}$  target is a self-supporting metallic foil with a thickness of 1.1 mg/cm<sup>2</sup>. The length of the neutron flight path is 34 m, the time resolution 0.93 ns, and the FWHM of the neutron peaks about 120 keV. A DWBA analysis is being made of the experimental data. Derived spectroscopic factors will be compared with those obtained from the  $(^3\text{He}, d)$  reaction.

\*National Science Foundation Grant No. Phy78-01684.  
<sup>1</sup>R.M. Britton and D.L. Watson, Nucl. Phys. A272, 91 (1976).

Search for Light Tin Isotopes.\* D.C.

COYLE, R.B. FIRESTONE, and Wm. C. MCHARRIS, Michigan State University--Currently,  $^{106}\text{Sn}$  is the lightest isotope of tin to be characterized.<sup>1</sup> "ALICE" reaction cross-section calculations indicate large cross-sections for producing  $^{104-106}\text{Sn}$  by the  $^{106}\text{Cd}(^3\text{He}, \text{xn})$  reaction using up to 76 MeV  $^3\text{He}$  beams available from the Michigan State University Cyclotron. We have already observed the  $^{104-106}\text{In}$  daughter  $\beta^+$  decays as well as lighter nuclei in this region by  $\gamma$ - $\gamma$  coincidence, half-life, and  $\gamma$ -ray singles experiments. Short-lived activities were isolated and identified using He jet recoil transport techniques.<sup>2</sup> In the future,  $\gamma$ -mass and  $x$ - $\gamma$  coincidence experiments are planned to positively identify these new light tin isotopes.

\*National Science Foundation Grant No. Phy 78-01684.

<sup>1</sup>B.J. Varley, G.S. Foote, C. Garrett, and W. Gelletly, J. Phys. G: Nucl. Phys. 4, No. 10, 1643 (1978).

<sup>2</sup>M. Blann and F. Plasil, ALICE: A Nuclear Evaporation Code, U.S. Atomic Energy Commission Report No. COO-3494-10, 1973.

<sup>3</sup>K.L. Kosanke, M.D. Edmiston, R.A. Warner, R.B. Firestone, and Wm. C. McHarris, Nucl. Instr. Meth. 17, 78 (1975).

Mass of  $^{89}\text{Mo}$ .\* R. PARDO, L.W. ROBINSON,

E. KASHY, W. BENENSON, and R.M. RONNINGEN, Mich. State Univ.--The mass of  $^{89}\text{Mo}$  has been measured using the  $^{82}\text{Mo}(^3\text{He}, ^6\text{He})$  reaction. The reaction  $^{26}\text{Mg}(^3\text{He}, ^6\text{He})$  was used for calibration of the spectrograph. The experimental technique has been described in Ref. 1. A preliminary value for the mass excess of  $^{89}\text{Mo}$  is  $-74.957 \pm 0.020$  MeV. We will also report on the excited states observed in this study.

\*National Science Foundation Grant No. Phy78-01684.

<sup>1</sup>R.C. Pardo, E. Kashy, W. Benenson, and L.W. Robinson, Phys. Rev. C 18, 1249 (1978).

Determination of Nuclear Densities and Radii from the Elastic Electron Scattering.\*† J.R. BORYSOWICZ, Mich. State U.--The Fourier Series method<sup>1</sup> leads to the following exact expressions for the form factor and radius

$$F(q) = 4\pi \int_0^\infty \sin qr P(r) dr = 4\pi \Delta \sum_{r=1}^\infty \sin q r_n P(r_n) + F(2Q-q) + \dots$$

$$\langle r^2 \rangle = 4\pi \int_0^\infty r^3 \rho(r) dr = 4\pi \Delta \sum_{n=1}^\infty r_n^3 \rho(r_n) + 2F''(2Q) + \dots$$

where  $F(q) = qf(q)$ ,  $P(r) = r\rho(r)$ ,  $r_n = n\Delta$  and  $\Delta = \pi/Q$ .

The errors of  $P(r_n)$  and  $\langle r^2 \rangle$  determined from the above expressions are easy to estimate. The electric and magnetic radii of proton,  $^3\text{H}$ , and  $^3\text{He}$  have been determined. The relation to the method of finding  $\langle r^2 \rangle$  from  $f''(0)$  is explained.

\*Submitted by JERRY A. NOLEN, JR.

†Supported by NSF.

<sup>1</sup>J.R. Borysowicz and J.H. Hetherington, Nucl. Phys. A303, (1978) 425.

Experimental Resolution of the  $^{145}\text{Gd} \epsilon/\beta^+$

Decay Branching Ratio Anomalies.\* R.B. FIRESTONE, R.C. PARDO, and Wm. C. MCHARRIS, Michigan State Univ.--Previously, several large  $\epsilon/\beta^+$  decay branching ratio anomalies were measured in the decay of  $^{145}\text{Gd}$ .<sup>1</sup> These values could not be reconciled with beta decay theory. Recently, it was suggested that the apparent excess of electron capture decay could be explained by a lower decay energy and the large previously unobserved,  $\gamma$ -ray feeding intensity from a large density of electron capture fed levels in  $^{145}\text{Eu}$  deexciting through the anomalous states.<sup>2</sup> In this work we report a total decay energy,  $Q = 5.07 \pm 0.06$  MeV, measured by  $\gamma$ - $\gamma$  coincidence techniques which is 240 keV lower than the previously used value. We will also discuss a new, more complete decay scheme obtained with an order of magnitude more  $\gamma$ -ray coincidence and singles data. A total of 301  $\gamma$  rays deexciting 123 levels have been placed in  $^{145}\text{Eu}$  following the decay of  $^{145}\text{Gd}$ . This data is sufficient to remove the large anomalies previously reported.

\*National Science Foundation Grant No. Phy 78-01684.

<sup>1</sup>R.B. Firestone, R.A. Warner, Wm. C. McHarris, and W.H. Kelly, Phys. Rev. Letters 35, 401 (1975).

<sup>2</sup>P. Hornshøj, H.L. Nielsen, and N. Rud, Phys. Rev. Letters 39, 537 (1977).

Isobaric Mass Quartets for A=21, 29, and

37.\* L.W. ROBINSON, W. BENENSON, E. KASHY, and R. PARDO, Mich. State Univ.--A 70 MeV He beam was used to observe the reactions  $^{24}\text{Mg}(^3\text{He}, ^6\text{He})^{21}\text{Mg}$ ,  $^{32}\text{S}(^3\text{He}, ^6\text{He})^{29}\text{S}$ , and  $^{40}\text{Ca}(^3\text{He}, ^6\text{He})^{37}\text{Ca}$ . We have measured both ground state masses and excited states, with a resolution of 25-40 keV FWHM. We have also observed the corresponding  $T=3/2$  levels in  $^{21}\text{Na}$ ,  $^{21}\text{Ne}$ ,  $^{29}\text{P}$ ,  $^{29}\text{Si}$ ,  $^{37}\text{K}$ , and  $^{37}\text{Ar}$ . These states were observed using the (p,t) and (p, $^3\text{He}$ ) reactions on  $^{23}\text{Na}$ ,  $^{31}\text{P}$  and  $^{39}\text{K}$ , at  $E_p=45$  MeV. This data completes several new isobaric mass quartets.

\*National Science Foundation Grant No. Phy78-01684.

High-Spin Isomers in  $^{200,201,202}\text{Pb}$ .\* C.L.

DORS, J. WILSON, S.K. SAHA, H. HELPPI, P.J. DALY, Purdue Univ., S.R. FABER and F.M. BERNTHAL, Mich. State Univ.--The level structures of the neutron deficient lead isotopes  $^{200,201,202}\text{Pb}$  have been investigated using ( $\alpha, 4n\gamma$ ) and ( $^{13}\text{C}, 5n\gamma$ ) reactions, with the objective of locating and characterizing the high-spin states above the known  $9^-$  isomers in  $^{200,202}\text{Pb}$  and the  $29/2^-$  isomer in  $^{201}\text{Pb}$ . Comprehensive  $\gamma$ - $\gamma$ -t coincidence and  $t_{\gamma}$ -RF timing measurements have been performed, and  $\gamma$ -ray angular distributions have been determined. In contrast to  $^{204}\text{Pb}$ , which has no known high-spin isomers, several isomers with half-lives in the range 20 to 180 ns have been located in each of the even-A nuclei. The previously reported<sup>1</sup> 200 ns  $12^+$  isomer at 3103 keV in  $^{202}\text{Pb}$  could not be confirmed; instead, we identify a 21 ns isomer at 3238 keV as the  $12^+$  state of  $17/2^+$  character in this nucleus. In  $^{201}\text{Pb}$ , a new high-lying 49 ns isomeric state has been located. Detailed high-spin level schemes will be presented and probable isomeric configurations will be discussed.

\*Work supported by the USDOE and the NSF.

<sup>1</sup>Nuclear Data Sheets 25 (1978).

Pion Nucleus Scattering in the Resonance Region.\* K. STRICKER and H. McMANUS, Mich. State U.--It has been shown that the optical model approach used in pionic atom analysis may be applied to low energy pion-nucleus elastic scattering.<sup>1</sup> We generalize this model so that it applies for pion energies up to and above the resonance region, with parameters taken from pion-nucleon phase shifts and the two nucleon absorption model of Brack, Riska, and Weise.<sup>2</sup> Elastic and total cross sections are calculated and compared with the available data.

\*Work supported in part by the National Science Foundation.

<sup>1</sup>K. Stricker, H. McManus, and J.A. Carr, accepted for publication in Phys. Rev. C, February, 1979.

<sup>2</sup>M. Brack, D.O. Riska, and W. Weise, Nucl. Phys. A287, 425 (1977).

Inelastic Pion-Nucleus Scattering Calculations.\* J.A. CARR and H. McMANUS, Mich. State U.\*\*--Pion induced inelastic scattering calculations will be presented and compared to the data for a number of nuclei at energies between 50 and 180 MeV. The distorted waves have been calculated using the optical potential developed for low energy pion-nucleus elastic scattering and pionic atoms, with parameters extrapolated to higher energies by comparison to pion-nucleon phase shifts.<sup>1</sup> The impulse approximation has been used to calculate the inelastic scattering, with form factors determined using the collective model and electron scattering results.

\* Submitted by K. STRICKER.

\*\*Work supported in part by the National Science Foundation.

<sup>1</sup> K. Stricker, H. McManus, and J.A. Carr, Phys. Rev. C, to be published.

The  $^{14}\text{C}(p,n)^{14}\text{N}(g.s.)$  and  $^{14}\text{N}(p,n)^{14}\text{O}(g.s.)$  Reactions and the Tensor Force.\* T.N. TADDEUCCI, R.R. DOERING, and L.C. DENNIS, University of Virginia, and AARON GALONSKY and S.M. AUSTIN, Michigan State University.--The  $^{14}\text{C}(p,n)^{14}\text{N}(g.s.)$  and  $^{14}\text{N}(p,n)^{14}\text{O}(g.s.)$  reactions are sensitive to the strength of the isovector tensor component of the effective nucleon-nucleon interaction since the normally dominant  $L = 0$  central-force amplitudes are suppressed for these transitions. Differential cross sections have been measured at scattering angles from  $10^\circ$  to  $150^\circ$  and for a bombarding energy of 35 MeV. The results of antisymmetrized DWBA calculations will be presented. Preliminary analysis indicates that a tensor force of significant magnitude is required to account for the data.

\*Work supported by the NSF.

Cross-Section Measurements for  $^6\text{He}$ ,  $^6\text{Li}$  and  $^7\text{Be}$  in the  $\alpha+\alpha$  Reaction at 61.5-159 MeV.\* B.G. GLAGOLA, H.F. BREUER, G.J. MATHEWS,<sup>†</sup> A. NADASEN, P.G. ROOS and V.E. VIOLA, U. of Maryland, and SAM M. AUSTIN, Michigan State U.--Recent cross section measurements are reported for the production of  $^6\text{He}$ ,  $^6\text{Li}$ ,  $^7\text{Li}$  and  $^7\text{Be}$  in the  $\alpha+\alpha$  reaction at energies of 61.5, 80.8, 119, 139 and 158 MeV at the University of Maryland Cyclotron. A triple-semiconductor-detector counter telescope was used to measure the energy spectra and angular distributions of the heavy reaction products resulting from the  $(\alpha,2p)$ ,  $(\alpha,d)$ ,  $(\alpha,pn)$ ,  $(\alpha,p)$  and  $(\alpha,n)$  reactions. Comparison of these new data with previous cross section estimates for this system will be presented.

\*Work supported by the National Science Foundation and the Department of Energy.

<sup>†</sup> Present address: LBL, Berkeley, CA 94720.

The Two-Nucleon Components of the Pion-Nucleus Optical Potential. D.O. RISKA and J. CHAI, Mich. State U.--The absorptive and dispersive parts of the two-nucleon component of the pion-nucleus optical potential have been computed using a two nucleon model for the pion absorption mechanism involving pion and  $\rho$ -meson rescattering. The absorptive part of the S-wave interaction parameter  $B_0$  is somewhat smaller than the value obtained from pion atom level widths at threshold and it increases smoothly with energy. The dispersive part of  $B_0$  is very small and sensitive to the wavefunction correlations. The absorptive part of the P-wave potential parameter  $C_0$  is in reasonable agreement with the predictions from pion atom level widths at threshold, and very strongly energy dependent. The dispersive part of  $C_0$  is of the same magnitude as  $\text{Im}C_0$ .

ESCUELA LATIN AMERICANA DE FISICA, MAYAGUEZ, P.R., July 1978

Three Lectures on Heavy Ion Theory, G. Bertsch.

GORDON CONFERENCE ON NUCLEAR STRUCTURE, TILTON, NEW HAMPSHIRE, July 1978

Inelastic Scattering and Charge Exchange Reactions, Effective Interactions and Analogs to Electromagnetic Transitions, S.M. AUSTIN

Mass Measurements with Exotic Heavy Ion Reactions, J. NOLEN

Pion Production Near Threshold in Heavy Ion Collisions.\* G.M. CRAWLEY, W. BENENSON, G. BERTSCH, E. KASHY, and J.A. NOLEN, JR., Mich. State Univ., J.O. RASMUSSEN, H. BOWMAN, M. SASAO, J. IONANNOU, M.C. LEMAIRE, J. SULLIVAN, and L. OLIVEIRA, Lawrence Berkeley Laboratory, and M. KOIKE and J. CHIBA, Univ. of Tokyo--The production of pions in heavy ion collisions near threshold is an extremely interesting problem both theoretically and experimentally. According to current theoretical ideas on pion-nucleon interactions, nuclear matter is not far from a phase transition involving the pion field. Models for the behavior of the pion in nuclear matter show peculiarities such as a near-zero or negative effective mass for the pion. Under such conditions, pions can be produced in the interactions of nucleons with the potential field, in addition to production in the collisions of nucleons with each other. The rate of pion production is thus increased by the potential field mechanism, and a characteristic angular distribution is predicted for the pions. On the experimental side, the information on the pion production cross section at energies near threshold, obtained using emulsions, is conflicting. In one case a very high pion multiplicity per collisions is reported, but in the other cases a much lower upper limit for pion production is given. A theoretical prediction has been made for this cross section, based on production by nucleon-nucleon collisions alone. In the present experiment, measurements were made with 400 MeV/A and 250 MeV/A Argon beams from the Berkeley Bevelac incident on KCl and Pb targets. Pions were detected near  $0^\circ$  using plastic scintillator telescopes in a  $180^\circ$  magnetic spectrograph set up specifically for these measurements. A preliminary analysis of the data from the first run shows that the  $\pi^+$  yield at 250 MeV/A is about a factor of three lower than at 400 MeV/A for the KCl target. The present data are consistent with the lower limit established by Lindstrom et al. and Kullberg et al. and disagree with the earlier measurements. A comparison of the results with theoretical predictions will be presented.

\*National Science Foundation Grant. No. Phy-7801684 and the Department of Energy.

HAMBURG TOPICAL WORKSHOP ON NUCLEAR PHYSICS, HAMBURG, GERMANY, September 1978

A New Technique for Measuring Ratios of Elastic Scattering Cross Sections: An Application to the Calcium Isotopes.\* SAM M. AUSTIN, Mich. State Univ.--A technique has been developed which allows one to measure ratios of elastic scattering cross sections for nearby nuclei and which should be free of most systematic uncertainties. Protons scattered from a mixed target are momentum-analyzed in a high resolution spectrograph and the scatterer is identified by the kinematic shift. The result of an application to scattering from the calcium isotopes  $^{40,44,48}\text{Ca}$  is discussed.

\*National Science Foundation Grant No. Phy-7801684.

OAK RIDGE USERS GROUP MEETING, OAK RIDGE, TENNESSEE, September 1978

Future Trends in Heavy Ion Physics, G. BERTSCH



Design Characteristics of the K=800 Superconducting Cyclotron Project at MSU.\* F. RESMINI, G. BELLOMO, E. FABRICI, H.G. BLOSSER, and D. JOHNSON, Mich. State Univ.--Design work on the proposed K=800 superconducting cyclotron at MSU has progressed to the point where overall machine characteristics are to a large extent established. When coupled to the K=500 cyclotron the machine will accelerate fully stripped light ions to 200 MeV/n and uranium ions to 25-30 MeV/n, the main harmonics coupling modes between the two cyclotrons being 3:1, 2:1, and 4:1 (for the very heaviest ions). A pole radius of 41" has been chosen with three spiral sectors, having a spiral constant of 1/13", and a minimum hill gap of 2.5". For 200 MeV/n beams a minimum  $v_z$  value of  $\approx 0.1$  is thus obtained. Careful main coil design allows overall trim coil power requirements to be confined within 40-50 Kw. Beam extraction has to take place before the unexpected onset of the  $v_z=1.5$  stopband, at  $v_z \approx .82$ . This unusual feature is due to the simultaneous fast fall-off of the fringing field and a large alternating gradient effect due to the tight sector spirals. Extraction is, however, accomplished in about 330°, by using three deflectors, 50° long, with electric fields in the range of 140=150 Kv/cm.

\*National Science Foundation Grant No. Phy-7801684.

Injection Studies for the K = 800 Superconducting Cyclotron Project at MSU.\* G. BELLOMO, E. FABRICI, and F. RESMINI, Mich. State Univ.--Beam injection from the K = 500 cyclotron into the proposed K = 800 machine has been the subject of a detailed study, where injection both along and against the spiral has been investigated. Due to the tight spiralling of the K = 800 sectors, injection through a valley, which is a most favorable option, leads typically to stripping in a valley, i.e. in a dee. The latter is to some extent undesirable from a construction point of view. An unusual pole tip geometry has therefore been devised where the sectors run clockwise up to the farthest out stripping radius and counterclockwise thereafter, thus effectively substituting hills to valleys, in the useful range of stripping radii. Although some decrease of axial focusing is experienced in the transition region between the two spirals, this scheme seems to work, and constitutes a viable alternative to the conventional approach. A comparison between the two options, including phase space tracking of the injected beams, will be presented.

National Science Foundation Grant No. Phy-7801684.

The Michigan State University Superconducting Cyclotron Program.\* H.G. BLOSSER, Mich. State Univ.--The prototype superconducting magnet described at the previous cyclotron conference was brought into operation in May 1977; the performance is excellent. A program to construct a K = 500 MeV cyclotron using this magnet was funded in August 1977, and work on major components of this cyclotron is in progress. First accelerated beam is expected in September 1979, and use of the cyclotron for experimental programs is expected in early 1980. Design studies for a second K = 800 superconducting cyclotron are in progress, and funding of this cyclotron has been recommended for FY 1980. Operation of the two-cyclotron system is expected in 1984. Design details of 500 MeV cyclotron subsystems and of the 800 MeV cyclotron are described in other papers. This paper reviews project status as of September 1978, and expected performance from the K = 500 and from the 500 + 800 coupled system.

\*National Science Foundation Grant No. Phy-7801684.

Central Region Studies on the MSU 500 MeV Superconducting Cyclotron.\* E. LIUKKONEN\*\* and J. BISHOP, Mich. State Univ.--Different central regions for the MSU superconducting cyclotron are designed and extensively studied in order to find central regions which would yield desired beam qualities for a wide variety of ions and energies planned to accelerate, including the coupled operation of the 500 and 800 MeV cyclotrons. The basic central region was designed for the third harmonic operation. This same geometry can also be used in the second and fourth harmonic modes. When the 500 MeV cyclotron is operating as a stand-alone accelerator, the light heavy ions would run in N = 1 mode, or on N = 2 with an alternate high frequency rf resonators depending on whether voltage clearance for N = 1 proves adequate. Very low turn numbers needed in some coupled cyclotron operations require the placement of the ion source at unwanted large radii (1.5"-1.8"). This can be handled either by debalancing the dee voltages or by using a de-extracted ion source.

\* National Science Foundation Grant No. Phy-7801684.  
\*\*Work supported by the Academy of Science, Finland.

A Method for Minimizing Trim Coil Power Requirements in Superconducting Cyclotrons.\* G. BELLOMO and F. RESMINI, Mich. State Univ.--A key issue in the design of superconducting cyclotrons is often the trim coil power needed to isochronize the magnetic field over the whole range of desired particle energies. In this connection we have developed a least squares fitting procedure which allows us to find out very precisely the requirements for minimum trim coil power, while determining at the same time the optimum shape of the magnetic field which should be produced by the saturated pole tips. Use of this procedure in the case of the K = 800 machine shows indeed that proper design of the main coils and of the iron generated field can reduce drastically the needed trim coil power, down to levels of a few tens of kilowatts. A systematic study of this problem, yielding results of general validity, is presented and the implications for superconducting cyclotron design discussed.

\*National Science Foundation Grant No. Phy-7801684.

Design Calculations for the Beam Extraction System of the MSU Superconducting Cyclotron.\* E.M. FABRICI and M.M. GORDON, Mich. State Univ.--Our extraction system consists of three fixed electrostatic deflectors plus several sets of magnetic "focusing bars" which transport the beam out through the sharply falling edge region of the magnetic field. The effects of these elements under different operating conditions have been calculated, and results are presented for the central ray trajectories together with the radial and axial beam envelopes. In order to induce turn separation at the entrance to the first electrostatic deflector, we plan to use the precessional extraction method which has proved so successful in our present machine and in many other cyclotrons. A multitude of accelerated orbits have been calculated through the region preceding extraction in order to clarify the many phenomena which affect turn separation and beam quality. These results are summarized in a series of phase space diagrams which characterize the behavior of the radial and axial motion of the beam.

\*National Science Foundation Grant No. Phy-7801684.

Computer Control of the MSU 50 MeV Cyclotron.\* J.F.P. MARCHAND, Mich. State Univ.--The MSU cyclotron control system employs a novel concept of operator-machine interface. An Intel 8080 front end microprocessor to a DEC PDP 11/20 minicomputer is dedicated to the control of the trim coils and centering coils and the beamline quadrupole magnets. The operator has control of these elements through dedicated control modules. Each module has a digital readout, a thumbwheel switch, and a rotary knob for control of the setpoint. Standard CAMAC hardware is used in the interface. The RF system tuning elements can also be set with the computer. Radial beam current traces can be taken and displayed on a graphics terminal. A link to the laboratory  $\Sigma$ -7 computer allows access to its mass storage devices and peripherals.

\*National Science Foundation Grant No. Phy-7801684.

Charge Exchange Losses During Cyclotron Acceleration: Experiment and Theory. R.A. GOUGH, Lawrence Berkeley Laboratory, and M.L. MALLORY, Mich. State Univ.--Quantitative estimates of charge exchange (CE) losses during acceleration are very important in the design and operation of heavy ion cyclotrons. Such estimates have been made using a vacuum model computer code for cyclotrons which was developed to establish vacuum requirements for the MSU superconducting heavy ion cyclotron. This code uses pressure and cross-section data to calculate the radial loss of beam due to charge exchange. Since CE cross sections and radial pressure profiles are not always well known, certain specific measurements have been made using the LBL 88-Inch Cyclotron to provide experimental data needed to test the code. These include measurements of pressure versus radius under vacuum conditions closely approximating those existing during acceleration of  $^{14}\text{N}^{8+}$  and  $^{40}\text{Ar}^{8+}$  beams. Beam intensity versus radius data demonstrating transmission losses for several beams will be presented. Comparisons with theoretical predictions will be given. These predictions are also useful in providing estimates of transmission losses during acceleration of proposed or very low intensity beams.

Magnetic Field Measurements in the MSU 500 MeV Superconducting Cyclotron.\* P. MILLER, H. BLOSSER, D. GOSSMAN, D. JOHNSON, and P. MARCHAND, Mich. State Univ.--The mid-plane field of the superconducting magnet has been mapped at excitations of 200, 400, 500, 600, and 700 A, the latter being the design maximum. The main coils are divided into two sections for coarse trimming of the radial field profile. The smaller coil, containing about 1/3 of the total turns, is closer to the midplane than the large coil. Maps were measured with different currents in the two coil sections as follows (small/large): 400/200, 400/600, 600/400, 600/700, 700/200, 700/400, and 700/600. Fourier analysis of the fields has been performed to facilitate comparison with calculations of the field distribution. The agreement between measurements and the calculated field is within .2% at full excitation and 1% at an excitation of 200 A. The computer controlled measuring bar contains 55 flip coils, giving a precision of approximately 1 gauss rms at an average field of 48 kgauss.

\*National Science Foundation Grant No. Phy-7801684.

Beam Emittance Measurements with a Dispersion Matched Magnetic Spectrograph.\* P.S. MILLER, E. KASHY, and J.A. NOLEN, JR., Mich. State Univ.--For these measurements, the split-pole magnetic spectrograph at MSU is dispersion-matched to the cyclotron beam entering it at zero degrees with no target present. A thin scintillator is placed in the focal plane and viewed by a high magnification TV camera. The line width representing the incoherent beam emittance is measured directly from this display. The divergence angle is measured by a movable current-measuring wire probe. Typical emittances measured are  $0.35 \pi$  mm-mrad for a 0.6  $\mu\text{A}$ , 35 MeV proton beam and  $1.5 \pi$  mm-mrad for a 15 pA, 77 MeV  $^{12}\text{C}^{6+}$  beam. The emittance measured is an upper limit because the angular divergence contains a component due to coherent energy spread.

\*National Science Foundation Grant No. Phy-7801684.

Operating Experience with the Michigan State University Superconducting Cyclotron Cryogenic System.\* M.L. MALLORY, Mich. State Univ.--The MSU superconducting cyclotron cryogenic system has been operating for about one year and we have measured many cryogenic parameters. Data for cryostat cooldown, liquid helium consumption, liquid nitrogen consumption, cryostat warmup, and vacuum jacket pressure as a function of temperature have been taken. In addition, methods have been developed for handling of contaminants in the helium system (air), for filling liquid helium in the cryostat, and for various cryogenic failure modes. Finally, we have developed a leak-detection method that is applicable at liquid helium temperatures and has been used to find ultra-small leaks in the cryostat. This method utilizes the density, and viscosity variations of cold helium gas as a function of temperature and may ultimately provide three orders of magnitude sensitivity improvement beyond presently achieved room temperature leak rates.

\*National Science Foundation Grant No. Phy-7801684.

Particle Optics Due to an Ion Source D.C. Extraction Grid.\* S. MOTZNY, Mich. State Univ.-- In order to reach the puller electrode, many interesting ions necessitate the use of a biased D.C. extraction grid to give them an initial boost of energy before crossing the first acceleration gap. This paper is concerned with the optics associated with such grids. The effects of several different gridded source geometries on the trajectories of particle rays is studied here.

\*National Science Foundation Grant No. Phy-7801684.

WORKSHOP ON CONTINUOUS SPECTRA, BAD HONNEFF, GERMANY, November 1978

Inclusive Cross Sections, G. BERTSCH

XVII INTERNATIONAL WINTER MEETING ON NUCLEAR PHYSICS, BORMIO, ITALY, January 1979

A = 9 Isobaric Quartet, EDWIN KASHY

PARTICLE ACCELERATOR CONFERENCE, SAN FRANCISCO, March 1979

Progress Report on the 500 MeV Superconducting Cyclotron, HENRY BLOSSER

Lifetime Improvements of Heavy Ion Source Cathodes.\* P.S. MILLER, H. LAUMER, M.L. MALLORY, and J.A. NOLEN, JR., Mich. State Univ.--The cathode lifetime for a cold cathode Penning heavy ion source has been increased to  $\approx 24$  hrs. (a factor of 7 increase) by the use of hafnium cathodes when accelerating a carbon beam on the Michigan State University cyclotron. Compared to tantalum, the hafnium cathodes are operated at reduced power ( $\approx 1$  kW) to avoid melting them. Thus, while the carbon beam intensity achieved with Ta cathodes is 3 to 10 times higher than that from the Hf cathodes, this is no advantage for experiments which need low beam currents (e.g. due to count rate limitations). For injection into a  $K = 800$  cyclotron the higher intensity for lower charge states from a lower power source is expected to favor Hf cathodes. Lowering the arc power for Ta cathodes, thus reducing beam intensity, does not substantially lengthen cathode lifetime. Source feed gas composition strongly influences Hf cathode performance. Extended lifetimes were achieved with CO and O<sub>2</sub> while Ne gas resulted in very short lifetimes, suggesting the difference may be due to an oxide layer formed on the Hf cathodes.

\*National Science Foundation Grant No. Phy-7801684.

CONFERENCE ON THE USE OF MAGNET SPECTROMETERS IN NUCLEAR PHYSICS, DARESBURY, ENGLAND, March 1979

Tuning Techniques for High Resolution, EDWIN KASHY

CONFERENCE ON THE (p,n) REACTION AND THE NUCLEON-NUCLEON FORCE, TELLURIDE, COLORADO, March 1979

Empirical Extraction of the Effective Interaction, S.M. AUSTIN

Excitation of Spin-flip, Isospin-flip States in (p,n), (e,e') and ( $\gamma$ , $\gamma'$ ): A Comparative Study on <sup>24,25,26</sup>Mg, U.E.P. BERG

Giant Gamow-Teller Transitions in (p,n) Reactions, A.I. GALONSKY

Foundations of the Microscopic Relation Between Gamow-Teller Beta Decay, Magnetic Dipole Radiation, and Hadronic Charge Exchange Processes, B.H. WILDENTHAL

INTERNATIONAL SCHOOL OF NUCLEAR PHYSICS, ERICE, SICILY, March and April 1979

Three Lectures on Heavy Ion Theory, G. BERTSCH

AMERICAN CHEMICAL SOCIETY HONOLULU MEETING, April 1979

Group Theoretical Description of Deformed Nuclear States, WM. C. MCHARRIS

SECOND INTERNATIONAL CONFERENCE ON MESON-NUCLEAR PHYSICS, HOUSTON, TEXAS, March 1979

Interpretation of  $\pi$ -Nucleus Scattering, H. MCMANUS

AMERICAN SOCIETY FOR MICROBIOLOGY LOS ANGELES MEETING, May 1979

Influence of Sulfide on NO and N<sub>2</sub>O Reduction by Denitrifiers. J. SØRENSEN and J.M. TIEDJE, Mich. State Univ.--A previous study on denitrification in a marine sediment indicated that accumulations of nitric oxide (NO) and nitrous oxide (N<sub>2</sub>O) were associated with low redox potentials or the presence of sulfide. The apparent inhibition of NO and N<sub>2</sub>O reduction by one or both of these parameters was studied with pure cultures of four denitrifiers, Alcaligenes faecalis, Flavobacterium sp., Pseudomonas aeruginosa, and P. fluorescens. Stationary phase, nitrate-grown cells were incubated anaerobically in 20 mM phosphate buffer (pH 7.0) and 0.2% glucose. Hydrogen sulfide (p.5 mM) and Titanium (III) oxalate (10 mM) were added in two separate series with a redox potential of about -200 mV. A control series without reductant had a redox potential of about +200 mV. The production of NO, N<sub>2</sub>O, and N<sub>2</sub> from <sup>15</sup>N<sub>3</sub><sup>-</sup> was followed. In the presence of sulfide, the NO accounted for 2% and N<sub>2</sub>O for about 90% of the total gas production during maximum activity of denitrification after 3-5 min. In the Ti (III)-containing series and the control, the NO was about 0.5% and the N<sub>2</sub>O was less than 30% of the gas production after 3-5 min. The total rate of gas production was similar in the three series. Parallel series with autoclaved cells showed that the production of NO was biological. The results indicate that sulfide inhibits NO and N<sub>2</sub>O reduction by denitrifiers.

Fate of Nitrate in Methanogenic Environments, H.F. KASPAR, A.J. SEXSTONE, and J.M. TIEDJE, Mich. State Univ.--<sup>15</sup>N- and GC/ECD-techniques were applied to investigate methanogenic environments for their denitrification capacity. Digested sludge and sediments of various eutrophic lakes and rivers showed the ability to denitrify without any lag-phase and at rates comparable to those in soils. Time course experiments revealed three different phases in sediments: 1) concomitant production of N<sub>2</sub>O and N<sub>2</sub>; 2) no further N-gas production; 3) consumption of N<sub>2</sub>O and simultaneous production of N<sub>2</sub>. N<sub>2</sub>O/(N<sub>2</sub>O + N<sub>2</sub>) ratios were generally dependent on total denitrification capacity, concentration of nitrate and time after NO<sub>3</sub><sup>-</sup> addition. Incubated with 10<sup>-6</sup>M NO<sub>3</sub><sup>-</sup> a sample of digested sludge showed N<sub>2</sub>O/(N<sub>2</sub>O + N<sub>2</sub>) ratios of 0.83 after 3 minutes and 0.03 after 15 minutes. Autoclaved samples did not show any denitrification. Pasteurized samples exclusively produced N<sub>2</sub>O in amounts similar to the total N-gas production by untreated samples. Methanogenic enrichment cultures with propionate or butyrate as sole carbon- and energy-source lost their ability to denitrify after the second transfer. Rumen fluid converted NO<sub>3</sub><sup>-</sup> to NH<sub>4</sub><sup>+</sup> with an appreciable amount of N<sub>2</sub>O but not N<sub>2</sub> as other products. In sediments and digested sludge no ammonia was produced from NO<sub>3</sub><sup>-</sup>.

Assimilatory Nitrate Uptake in Pseudomonas fluorescens. M.R. BETLACH and J.M. TIEDJE, Mich. State Univ.--Lack of a suitably long-lived radioisotope of nitrogen has hindered investigations of uptake mechanisms for inorganic nitrogen ions. We have used  $^{13}\text{N-NO}_3^-$  generated at the MSU Cyclotron Laboratory to study nitrate transport in aerobically grown Pseudomonas fluorescens. We grew cells in a glucose mineral salts medium with 10 mM  $\text{KNO}_3$ ,  $\text{NH}_4\text{NO}_3$ , or  $(\text{NH}_4)_2\text{SO}_4$  as the nitrogen source. We harvested exponentially growing cultures, washed them twice and resuspended the cells in phosphate buffer, pH 7.0, containing 200  $\mu\text{g}$  chloramphenicol per ml. At various times after addition of  $^{13}\text{N-NO}_3^-$  and carrier to stirred suspensions, we filtered samples, washed the filters, then counted  $^{13}\text{N}$  positron decay (10 min. half-life) in a liquid scintillation spectrometer. Nitrate-grown cells readily took up  $^{13}\text{N-NO}_3^-$ . Both 1 mM azide and 1 mM cyanide inhibited label accumulation in nitrate-grown cells, as did 5 mM ammonium. The internal form of  $^{13}\text{N}$  was ammonium or a cochromatographing substance, e.g. an amino acid, as determined by high pressure liquid chromatography on an anion exchange column. Cells grown on ammonium sulfate or ammonium nitrate did not take up labeled nitrate. A growth lag observed when cells growing aerobically on ammonium were transferred to nitrate-containing medium indicated that ammonium represses synthesis of the enzymes for nitrate assimilation.

INTERNATIONAL CONFERENCE ON THE STRUCTURE OF MEDIUM-HEAVY NUCLEI, RHODES, GREECE, May 1979

Systematics of Deep Hole States Observed in One and Two Particle Transfer Reactions, G.M. CRAWLEY

TOPICAL CONFERENCE ON LARGE AMPLITUDE COLLECTIVE NUCLEAR MOTIONS, LAKE BALATON, HUNGARY, June 1979

Isvector Giant Resonances, AARON GALONSKY