Facilities in Operation

Scattering Chambers

The electronic control/readout system for remote angular positioning of the detector platforms in the general-purpose 64" scattering chamber failed several times during the past year and has become generally unreliable. Repair and maintenance of the system is hampered by its age and use of non-standard components. A new motor control/digital encoder readout system was, therefore, designed around standard interface modules employed generally throughout the accelerator controls system. A dedicated microprocessor will handle all logic functions and positioning/monitoring/interlocking tasks and permit convenient interfacing with the experimenter's data acquisition computers in the future. New stepping motors, absolute optical shaft-angle encoders and other hardware items have been acquired or ordered. Assembly and installation of the new system is expected to proceed during the summer of 1979.

The oil-free vacuum roughing system for the 64" chamber described in the 1976 IUCF Technical and Scientific Report also was plagued with sufficiently frequent and serious problems to require replacement. The new roughing system, similar in concept to the original one, is a Varian "Megasorb" roughing module purchased in the fall of 1978 and scheduled for installation in early 1979. This system, which includes a 14.5 cfm carbon vane pump and a 2-stage sorption pump with 42 lbs. of molecular sieve (1.7 million torr-liters capacity) with automatic valving and bakeout controls, should allow faster cycling of the chamber and more reliable and accident-proof operation by experimenters.

In the In-Beam γ-ray Area two different aluminum target chambers are in use. The first chamber, relatively heavy-walled, accommodates up to five targets mounted on a vertically movable target ladder whose height and angle with respect to the beam axis can be controlled remotely. The second chamber is thin-walled (0.8 mm wall thickness): two targets and a scintillator viewer can be positioned manually inside the chamber. The detector support table facilitates placement of large Ge (Li) detectors at angles ranging from 20° to 160° with respect to the beam direction. Such a set-up is illustrated in Fig. 8. Adequate space for the necessary shielding is provided.

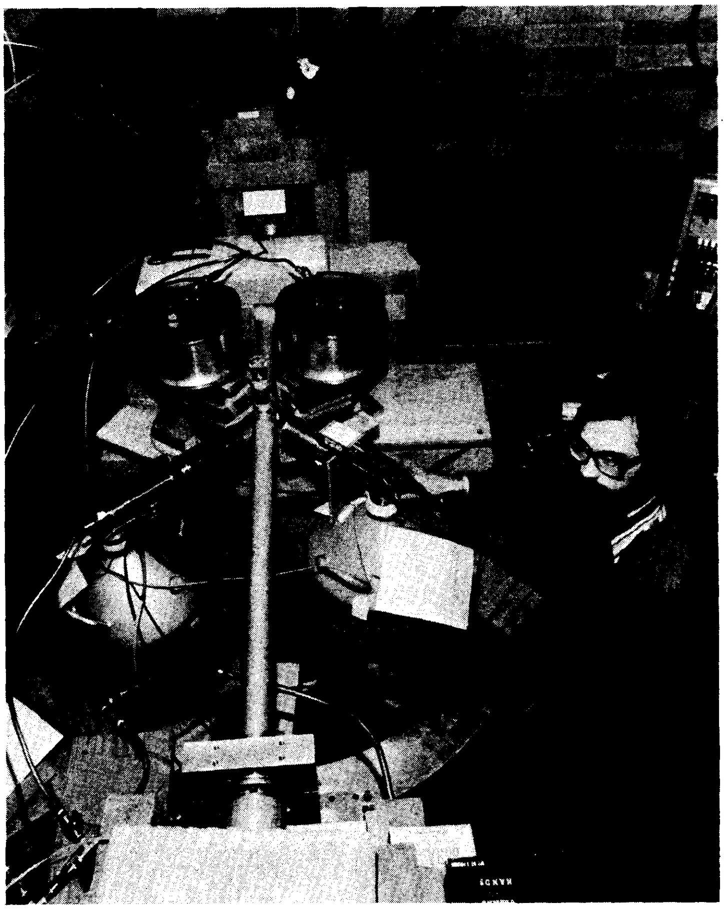

Figure 8. Set-up for in-beam γ-ray measurements showing low-mass beam tube and target assembly, a pair of intrinsic-Ge detector cryostats (rear) and two Ge(Li) systems (front).

Isotope Production Area and Off-Line Radiochemistry and Decay Spectroscopy Laboratory

The isotope production area is presently used for a variety of experiments with high-intensity beams using both charged particles and high-energy secondary neutrons. The target stations located along the beam line can accommodate a number of experiments, often parasitically. They are: (a) a He-jet terminal, (b) a solid-target charged-particle irradiation facility, (c) an automatic beam degrader, (d) a general-purpose station, and (e) a stopped beam, high-energy neutron facility. The charged particle and neutron targets are transported from the isotope production room to the chemistry trailer using a pneumatic rapid transport system.

Typical activation studies making use of these facilities are the pion production experiments, excitation functions of several isotopes of medical interest, sources for Mössbauer studies, ^{7}Li(p,n)^{7}Bi activation and (^{6}Li,xnyp) reaction studies. In addition, a special radioiodine (123) isotope production facility which attaches conveniently to the beam line has been in use.

The radiochemistry trailer is complete with fume hood, water, sink, vacuum and chemical supplies for use in experiments. The spectroscopy trailer will soon be used for all off-line α-β- or γ-ray counting. At present a Canberra 8180 analyzer and various Ge (Li) detectors, a KEVEX x-ray detector and other experimental configurations are being used.

Target Laboratory

During 1978, the target lab supplied about 90% of the targets used at IUCF. Among the targets prepared were: Li, LiOH, ^{10}B, ^{12}C, ^{13}C, ^{24}Mg, ^{Nat}Si, ^{40}Ca, ^{64}Zn, ^{94}Mo, ^{154}Sm, ^{159}Tb, ^{172}Yb, ^{175}Lu, ^{178}Hf, ^{208}Pb with very low oxygen content, and depleted U. The most notable improvements in the lab were those which increased its ability to handle air-sensitive materials. The glove box has been entirely resealed; the airlock is now routinely vacuum evacuated; and the argon used to provide the positive-pressure atmosphere within is now 0.5 ppm O_2 level. In addition, an oil-driven rotary actuator has been coupled to the rolling mill within the glove box. A second glove box with a closed-loop argon purification system will be purchased for the lab in 1979.

Multiwire Proportional Chamber Development

As the beam intensity has increased at IUCF, the present helical detector on the QDDM spectrograph$^{1)}$ has become awkward to use. The long delay in the helix (approximately 2 μs) can cause accidental position measurement errors at high rates, and the detector cannot tolerate the increased particle rate of incidence. The beam intensity which the helical detector can tolerate varies widely with target composition and thickness, spectrograph position, and with the Faraday cup used (i.e., internal or external to the target chamber); general estimates are 50 nA with the internal cup, 200 nA with the external cup.

The plan to overcome this problem calls for construction of position-sensitive detectors which can tolerate the higher background rates. Two such detection chambers are presently in development.

The first is a "vertical drift chamber,"$^{2)}$ a detector now in use at the MIT/Bates laboratory. Several features recommend it: (a) This detector should tolerate background rates up to six times higher than those the present helical detectors can tolerate. (b) Its position resolution equals or exceeds that of the helical detector. (c) Since a vertical drift chamber measures the angle at which the particle crosses the detector, it is an ideal ray tracer, which the QQSP pion spectrograph[3] requires. (d) It has been reported[4] that a vertical drift chamber has operated for 30,000 hrs. without a major breakdown. Other types of position-sensitive wire detectors are less durable. Two or three of these would be necessary as backup units in case of breakdown. These advantages make the vertical drift chamber the preferred detector for the QQSP spectrograph.

One drawback of the vertical drift chamber is, however, the computer time required to analyze each data point.[2] It is for use in experiments where both high data rates and high background rates are encountered that the second detection chamber, a multiwire proportional counter, is being developed. This second chamber will have 2 mm wire spacing and individual wire readout. The expected resolution of 2 mm (set by the wire spacing) is adequate for most experiments presently being run. The background rate capabilities of this detector are more than adequate for any anticipated background radiation at IUCF.

Either of the above detectors can easily be adjusted to see only a portion of the focal plane. Hence, experiments which produce low data rates on one portion of the focal plane and high background rates on another unused portion will be much simpler to run.

The first prototype of the vertical drift chamber is under construction. It will mount on the QDDM in the exact location presently occupied by the helical detector. After bench tests and tests on the QDDM, a second, refined version will be designed for mounting on the QQSP. Construction of the second version should be completed by the time the QQSP is ready for use.

The multiwire proportional counter is in an early stage of design; it should be ready for tests in fall 1979.

1) IUCF Techn. and Scient. Report 1976, p. 22.

2) W. Bertozzi, M.V. Hynes, C.P. Sargent, C. Creswell, P.C. Dunn, A. Hirch, M. Leitch, B. Norum, F.N. Rad, and T. Sasanuma, Nucl. Instr. and Meth. <u>141</u>, 457 (1977).

3) IUCF Techn. and Scient. Report 1977, p. 23; see also present report, p. 158

4) M.V. Hynes, Dept. of Physics and Lab. for Nucl. Sci., MIT, Cambridge, Mass., private communication.

Hyper-Pure Germanium Detector Telescope System

Development of the hyper-pure germanium detectors for use in medium-energy particle detector telescopes was pursued in 1978 in several directions. This program is a collaborative effort between Dr. Richard Pehl of the Lawrence Berkeley Laboratory and IUCF, and has resulted in the successful use of these detectors in several experimental programs. The development efforts were directed towards improving both the versatility of the cryostats to meet varying experimental demands, and the reliability of the detectors themselves when used in our environment. The philosophy is to use these detectors in a manner similar to silicon surface barrier detectors, with all the versatility and convenience this implies, both in storage and in use.

The detector telescope cryostats, described previously in the 1977 IUCF Techn. and Scient. Report, were constructed for use in the general-purpose 64" scattering chamber. They were designed, however, with support systems which provide vacuum pumping and cooling to LN temperatures independently of the 64" scattering chamber, thus allowing them to be used outside the chamber if desired (see Fig. 8 for example of such application). Modifications to the cryostats were made to allow placement of two telescopes at smaller angles relative to one another and to allow their placement closer to the target when used in the scattering chamber. This was done by extending the cold finger and vacuum housing to the edge of the cryostat LN dewar and providing for either axial or transverse mounting of the detectors on the cold fingers, as shown in panels 1A and 1B of Fig. 9. In the transverse mode, a telescope can be mounted on each arm of the 64" scattering chamber on either side of the incident beam center line with a minimum separation angle of 10°. Hence, both telescopes can simultaneously be placed at a minimum scattering angle of 5°. This setup, shown in panel 2A of Fig. 9, is desirable especially for making polarized beam asymmetry measurements. In the axial mode, shown in panel 2B of Fig. 9, the minimum separation angle between telescopes is about 30°, although the minimum usable scattering angle for any one telescope is still 5°. In either mode, the use of silicon surface barrier ΔE detectors, mounted externally on the telescope housings, is a built-in option. A mount for placing silicon surface barrier ΔE detectors in front of the germanium detectors inside the cryostats is currently being designed.

Development work on the hyper-pure germanium detectors themselves has been aimed towards providing a larger variety of detectors, understanding their operating limitations and improving their reliability when used as we require. At our request, Pehl's group has successfully fabricated, in addition to the standard 10 mm deep detectors, both 15 mm and 1 mm deep intrinsic germanium detectors with ion implanted electrical contacts on both surfaces. The phosphorous ion-implanted negative contact, which replaces the relatively thick ($\sim$ 10 μm) lithium contact, has proven to be generally as rugged as the usual boron ion implanted surface under our conditions of temperature and vacuum cycling. The thicker detectors are needed to stop higher-energy particles with fewer detectors, while the thin ones are required to replace the silicon ΔE detectors to give a large energy range to the telescope without sacrificing solid angle (the largest area available for silicon surface barriers detectors is 150 mm^2, whereas all of the intrinsic germanium detectors have a 450 mm^2 usable area). For example, a telescope consisting of a 1 mm Ge detector followed by 40 mm of thicker Ge detectors will stop and identify protons from 16 to 138 MeV. Our experience with the 10 and 15 mm deep detectors is discussed later. The 1 mm detectors have been fabricated but not yet used in the telescope.

Improvement in detector reliability, i.e., increasing detector life time, has been a difficult problem. We do not always understand the causes of detector failure.* Storage in a clean dessicant jar has been successful for some detectors, but not for others. The failure rates vary considerably. One detector has never failed to hold bias since its delivery two years ago, even after having undergone many radiation and annealing cycles, while another never really worked well for more than two or three temperature or vacuum cycles. On the average, detectors last for many runs before a failure occurs which requires repair by the Berkeley group. A common failure mode is characterized by very high detector leakage current when bias is applied. The usual solution is to warm the detector to room temperature under

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*Detector damage caused by obvious mistreatment such as overheating, vacuum accidents, or running the detector into the path of the primary beam is not included in this discussion.

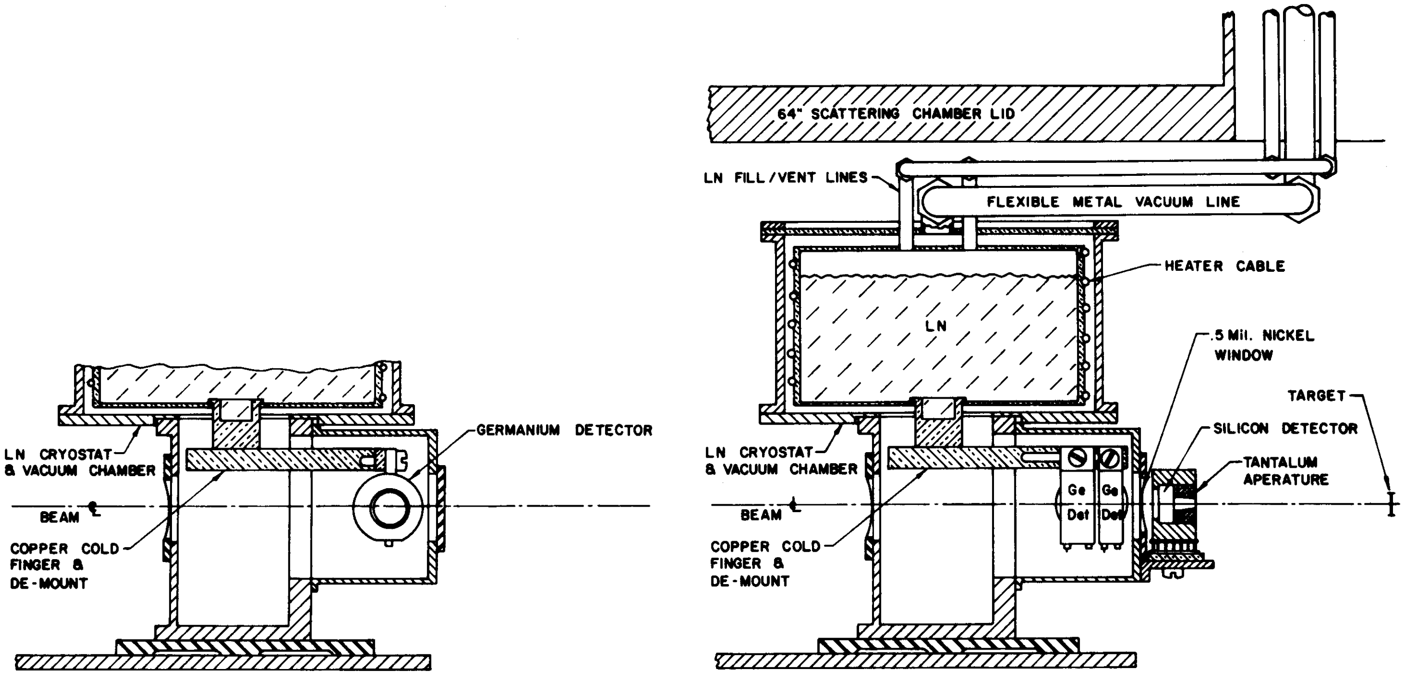

FIGURE 1A
TRANSVERSE MOUNT
CONFIGURATION

FIGURE 1B
AXIAL MOUNT
CONFIGURATION

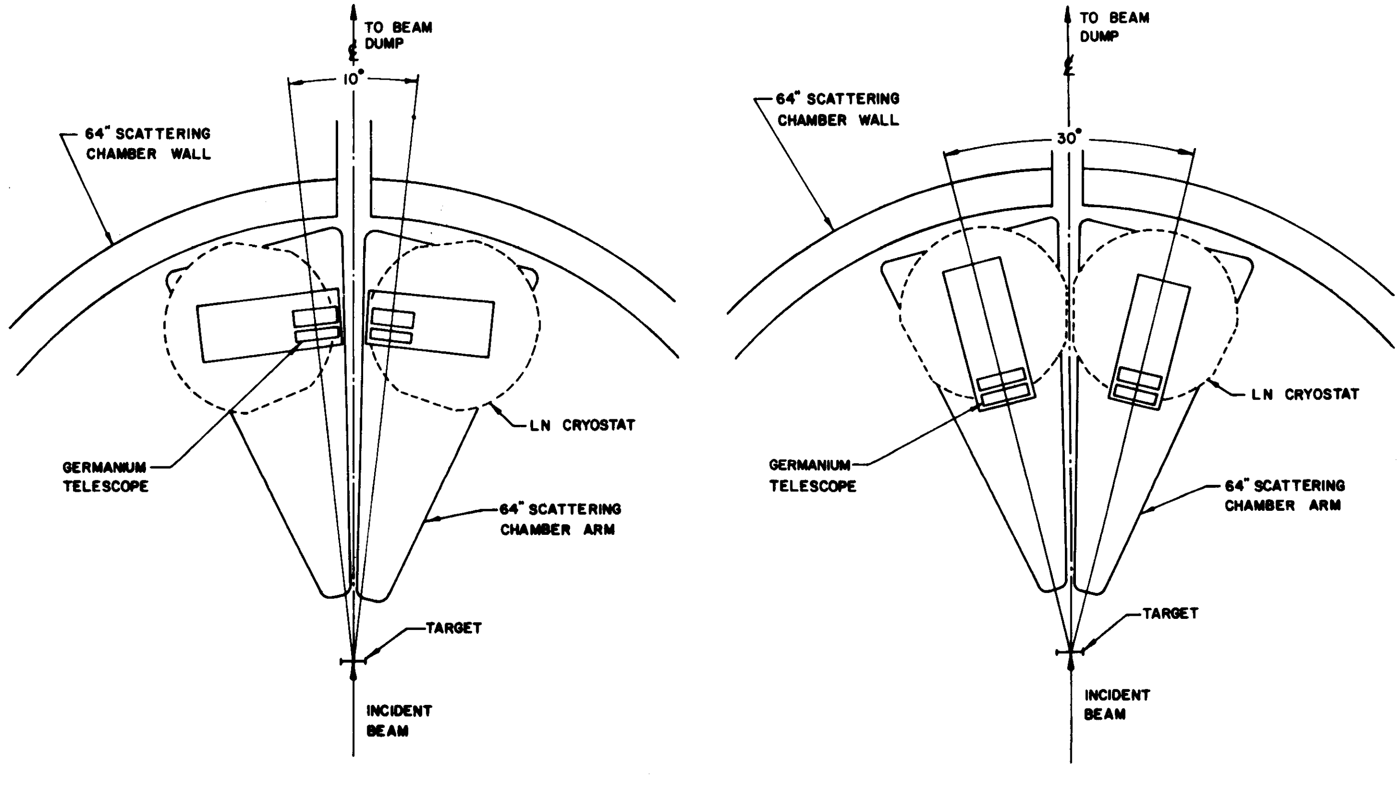

FIGURE 2A

TOP VIEW OF TRANSVERSE
MOUNTED EXPERIMENTAL CONFIGURATION

FIGURE 2B

TOP VIEW OF AXIAL MOUNTED
EXPERIMENTAL CONFIGURATION

Figure 9. Top panel: sections through the intrinsic-Ge detector telescope cryostat assemblies for transverse and axial detector mounting. Bottom panel: plan view of cryostat arrangement in the scattering chamber for transverse and axial configurations.

vacuum to clean off the edge surfaces of the detector. When this procedure proves unsuccessful, the detector is returned to Dr. Pehl, where the usual repair procedure has been to replace the boron contact. Whether the boron surface deterioration is, in fact, the cause of the failure or the result of some other effect of our use is not yet known.

Much experience has been gained in the last year in the use of these detectors. They have been employed in the detection of x-rays, protons, deuterons, tritons and lithium ions in several experiments. Charged particles are the primary cause of radiation damage: a charged particle dose of 10^9 at IUCF energies suffices to destroy the resolution of a germanium telescope. Usually, the front detector in the telescope stack will show the first and most severe sign of radiation damage. If the source of the damage were neutrons, all detectors in the stack would be equally damaged. The average useful life of a telescope with a 50 nA beam of 140 MeV protons incident on a thin (of order 10 mg/cm^2) target is about three days, the time it takes to complete a typical inelastic scattering experiment. Recovery of the resolution of these detectors by annealing at 140°C for 20 hours has repaired the damage in all cases where this procedure has been attempted. The detector cryostats are equipped with heating elements and temperature readouts and controls so that annealing can be done in place inside the 64" scattering chamber.

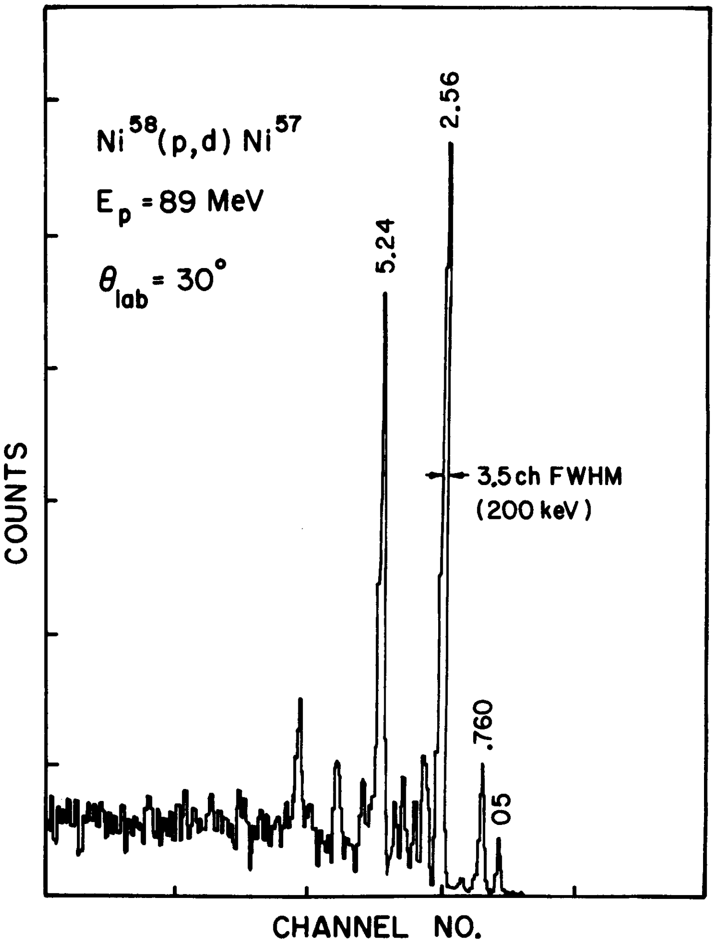

Figure 10. Deuteron spectrum for the $^{58}Ni(p,d)$ reaction at 89 MeV obtained with the intrinsic-Ge detector telescope (200 keV FWHM resolution).

Many experiments use the intrinsic germanium detectors as a stopping detector in a telescope employing silicon surface barrier ΔE detectors. A good example of this is an experiment by G.M. Crawley and collaborators$^{1)}$ where the (p,d) and (p,t) reactions on several nuclei were studied using 90 MeV incident protons. The telescope consisted of a 2 mm silicon ΔE detector followed by a 10 mm thick germanium E detector. The spectrum shown in Figure 10 is for the $^{58}Ni(p,d)^{57}Ni$ reactions at 30°. The observed experimental resolution (190 keV) was larger than the minimum expected resolution (140 keV) due to kinematics, target thickness and beam energy resolution effects; the poorer resolution in this case was traced to preamplifier saturation at high count rates.

Perhaps the experiment which best demonstrates the utility of these detectors at IUCF energies is the inelastic scattering experiment of P.P. Singh et al.,$^{2)}$ in which a telescope consisting of two 15 mm deep germanium detectors was used to stop up to 115 MeV protons. This was the first attempt to use one of the new phosphorous-backed, transmission-mounted germanium detectors as a ΔE detector in our laboratory. A typical spectrum for the scattering of 115 MeV protons from ^{28}Si at a 34° lab angle is in Figure 11. Preamplifier gains were reduced to eliminate the saturation problem previously mentioned. The observed spectral resolution of 180 keV was very near the minimum expected experimental resolution of 150 keV.

The versatility as well as the difficulties of using these detectors have been demonstrated during the past year. Work is continuing to improve and simplify their use in this laboratory. The problem of reliability will be partially solved by having a larger number of these detectors on hand, so that the failure of any one detector will not prevent an experiment from continuing. Our present stock consists of two 15 mm and two 10 mm thick detectors. We expect during 1979 to increase that number to four 15 mm, four 10 mm, two 5 mm and two 1 mm thick detectors. These detectors will be available to any user of the facility, although prior notification of their intended use is recommended.

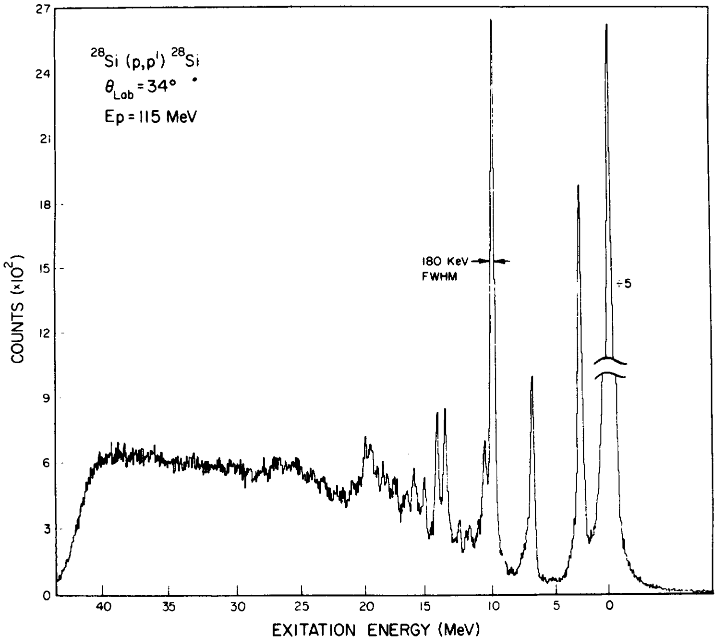

Figure 11. Excitation spectrum for inelastic proton scattering from ^{28}Si at 115 MeV measured with the intrinsic-Ge detector system (180 keV FWHM resolution).

1) G. M. Crawley et al., this report, p.71

2) P.P. Singh et al., this report, p.39

Future Facilities

Beam Swinger Facility

Work on the beam swinger facility$^{1)}$ for neutron time-of-flight measurements has progressed to the stage in which all three magnets are in position at the northwest end of the high-bay area (Fig. 12) and mechanical installation of beam line components is being completed. Remaining to be done to complete installation with one hut on the 0° to 26° line at 30 to 70 meters is completion of the beam dump, fabrication and installation of the Faraday cup, installation of beam line controls, extension of the radiation interlock system, and installation of power and signal cables to the hut stations. This work is expected to be finished in mid-February 1979, with beam tests and first data runs on the facility to be carried out in late February. In preparation for use of the swinger system, the floating wire technique was used to determine proper operating conditions for the entrance (magnet 1) and swinger (magnet 2) magnets. These conditions can be parametrized in terms of the radii of curvature, ρ_1 and ρ_2, of the two magnets as function of the scattering angle θ. Thus, to set the system for a given angle for particles of a given $B\rho$