telescopes (2 mm silicon ΔE detector and a 15 mm germanium E detector) to determine the factors limiting the charged-particle energy resolution. 60 MeV protons incident on thin carbon and gold (2.3 mg/cm^2) targets were used to measure the detector calibrations and energy resolution, respectively. The observed spectrum resolution of 58 keV FWHM for elastically scattering protons from gold detected in a single germanium detector corresponds to a detector resolution of less than 10 keV. However, the best spectrum resolution for the same target and beam for the two-element telescope was about 81 keV FWHM, which corresponds to a detector telescope resolution of about 40 keV. The reason for this unexpectedly worse resolution for the telescopes is not known. With this telescope arrangement we also found that the energy calibration was different for different reaction products from the source target and in a direction opposite to that which would be caused by a dead layer in either detector. Speculation for the cause of this effect is a possible energy or penetration-depth dependent charge collection efficiency of the silicon or germanium detectors resulting from crystal impurities. This effect was observed and reported[1] for silicon detector telescopes at lower energies, and will be the subject of continuing study here. In general, the energy resolution of germanium telescopes at IUCF is about 0.1% of the beam energy.

The current inventory of intrinsic Ge detectors at IUCF now consists of one 1 mm, two 10 mm and two 15 mm deep transmission detectors, and one 10 mm and two 15 mm deep lithium-backed detectors. These detectors are available for use by any IUCF user group. However, advance notification of their intended use must be given before they will be released to the user(s).

1) Comparative Pulse-height Anomaly for Protons and Alpha-particles in Silicon Surface Barrier Detectors, K.W. Kemper and J.D. Fox, NIM 105, 333 (1972).

Future Facilities

Pion Spectrograph System

Engineering design work on the QQSP pion spectrograph[1] and its support system was completed during 1979, and significant progress was made on the fabrication of these components. The support system will be delivered to IUCF in early February 1980 and factory acceptance tests of the spectrograph magnet system are scheduled for mid-March 1980.

It was necessary to rework the original mechanical design of the entrance quadrupole magnet extensively to permit the use of an external beam dump at relatively forward angles. In the latest design the beam can be transported to an external dump for scattering angles greater than 22°. The system has been designed to permit extraction of the beam through an aperture in the yoke of the dipole with the system positioned to allow measurements between 0° and 10°. It is also possible to make measurements at scattering angles between 170° and 180°.

Substantial progress has been made in constructing the beam line branch and beam dump for the spectrograph. It is anticipated that the entire system will be ready for initial use in experiments in early summer, 1980.

1) IUCF Techn. and Scient. Report 1977, p. 23 and 1978, p. 158.

Drift and Multiwire Proportional Chamber Development

As described in the 1978 IUCF Techn. and Scient. Report, the development of vertical wire drift chambers (VWDC) began in late 1977. Design and construction of the VWDC were completed in 1978. Initial high-voltage breakdown problems with the chamber were overcome and in-beam tests have begun.

The first beam tests were carried out in the focal plane of the QDDM spectrograph and confirmed the intrinsic resolution of the chamber to be adequate for our application. However, no definite figure for the operating resolution is available at this time since software and hardware configurations have not been finalized.

Tests are currently being conducted in a parasitic mode in the spectrograph vault, looking at protons scattering out of the beam line at a momentum-analysis slit. The tests are being conducted with prototype electronics which reads out only 1/6 of the detector area. The chamber electronics is interfaced to a data acquisition computer via CAMAC. The goals of the parasitic tests are:

1) to observe operating characteristics of the chamber and associated electronics,

2) to determine optimum chamber operating voltage and electronic threshold settings,

3) to evaluate the counting efficiency of the chamber at various data rates, and

4) to accumulate real-time, unprocessed data on magnetic tape for later software development.

The software now in use calculates a particle's position and angle of incidence with a processing time of $\sim$ 1 millisecond/event. Even though streamlining of the software can decrease processing time by up to a factor of two, a number of program enhancements to be added to the final version will very likely offset this gain.

A prototype of the multiwire proportional chamber (MWPC) to replace the present helical wire chamber used on the QDDM spectrograph was designed and tested in 1979. The first MWPC constructed did not operate properly because of various fabrication faults and the chamber design is being modified to eliminate these problems. Bench test on a new MWPC should begin in May of 1980.

Polarized Neutron Beam Facility

Planning, design and component procurement for the polarized neutron production facility[1] progressed during 1979. The ion optics of the beam transport system for the incoming and outgoing polarized proton beams (to the LD_2 target and to the beam dump) was calculated. All special dipole and quadrupole magnets for the system were designed and placed on order in August. The He refrigerator with hydrogen condenser for the LD_2 target was received late in 1979. The target cell system and associated vacuum enclosure, mechanical supports (with target motion capability), D_2 gas handling system and target safety and failure recovery systems are being designed. Construction of the proton beam line up to the LD_2 target is planned to commence in early fall of 1980, following installation of the QQSP pion spectrograph.

1) IUCF Techn. and Scient. Report 1978, p. 159

Proposal for a New Spectrograph for IUCF

Research began at IUCF in 1976 with a spectrograph (the QDDM) assembled at modest cost by converting an older magnet from the University of Chicago cyclotron to higher resolving power over a limited momentum bite. Although this instrument has been rather successful in exploring numerous scattering and reaction phenomena in the IUCF energy range, and has achieved resolution close to the design limit (e.g., 35 keV at 100 MeV, 50 keV at 135 MeV, 70 keV at 160 MeV have been reported), it can be recognized as the limiting

Table III. IUCF Spectrograph Specifications

	QDDM (1975)	QQSP (1979)	Proposal (1983)
Maximum Rigidity (Tesla-meters)	2.25	0.76	3.42
Energy Factor ($K = AE/Q^2$ MeV)	240	29	600
P_{max}/P_{min}	1.03	1.6	1.15 @ 80 MeV 1.06 @ 200 MeV
Resolving Power $p/\Delta p$	6,000	1,000	35,000 @ 200 MeV 14,000 @ 80 MeV
Solid Angle (millisterad.)	3	30	5(10 at lower resolution)
Dipole Mass (tons)	40	20	(est. 150)
Circle Radius (meters)	4	2.4	7(5 for second magnet, on opposite side)
Dispersion Match?	Yes	No	Yes
Angular Range; External Beam Stop	$24-90^o$, $90-154^o$	0,180, $40-140^o$	$5-120^o$
Internal Cup	-20^o to $+60^o$	-20^o to $+70^o$	-15^o to $+15^o$
Detector: Length (cm)	50	60	60
# of Position Parameters	1	2	3
Required Spectral Resolution (mm)	1.5	1.0	0.25

factor in many experiments. A part of the planning for IUCF has included the installation of a state-of-the-art spectrograph better matched to the accelerator performance characteristics and the research characteristics and the research needs of the IUCF user community. A poll of our users conducted two years ago identified a high-performance spectrograph as the highest-priority need for future IUCF research instrumentation. Our attention in the past 18 months has been diverted by the procurement and startup of a much smaller magnet (the QQSP) for threshold pion studies; however, we have now assembled a local working party which has produced a tentative design specification shown in Table III below. A design which comes close to meeting these specifications is under active consideration.

The working party will be seeking advice on design parameters and would also welcome indications of interest in active participation in the spectrograph project. A number of elements of the instrument might well best be proposed by and funded to user groups as a home-based instrumentation project to be brought to IUCF and incorporated into the final device. We intend to prepare a funding request for submission by about April 1980.

Note that the proposed spectrograph aims for 10 keV resolving power over a 20 MeV energy bite for energies from 80 to 200 MeV and can bend all reaction products in the IUCF range except tritons from the (^{3}He,t) reaction at full energy. A 200 cm radius, 16 kilogauss field magnet can just meet both these requirements. Anything smaller compromises both resolution and rigidity; anything larger cannot be accommodated within the existing experimental area. An important element in the design is to allow space opposite to the high resolution magnet for a future second magnet of larger solid angle and momentum bite, but smaller resolution and rigidity for particle-particle correlation studies.