The programs are being improved to automatically set the update rate in accordance with the BPM detector output bandwidth (which an automatic bandwidth control circuit scales with the beam current), and scale the sensitivity factor with the beam rigidity. These changes will make the system trivial to operate, and will be tested with beam in 1987.

In 1987 pick-ups will be installed for the Charge Symmetry Breaking Experiment. In addition, a specially-modified position detector with an ouput bandwidth of 250 Hz will be tested and used to measure the amount of high frequency and line-related beam position movement.

1) T. Ellison and O. Dermois, IUCF Scientific and Technical Report 1985 p. 140.

2) Timothy J.P. Ellison, C. Michael Fox, Steven W. Koch, and Liu Rui, Proc. of the 1986 Int. Cyclotron Conf., Tokyo, 13-17 October (1986).

3) Timothy J.P. Ellison, C. Michael Fox, Steven W. Koch, Proc. of the Ninth Conf. on the Appl. of Acc. in Res. and Ind., Denton, TX, 10-12 November (1986) (to be published in NIM).

4) D. L. Friesel, this report, p. 137.

EXPERIMENTAL FACILITIES DEVELOPMENT

Facilities in Operation - C. Foster

1. Existing Beamlines

Beamline 4 to the 64 inch scattering chamber was realigned to improve transmission of beam to the target in that chamber. A multiscattering foil was installed in beam line 4 upstream of the switching magnet for use in providing low-intensity-diffuse beams in the gamma-cave.

The shielding penetration block at the beginning of beam line 5 was removed to provide access to the beam corridor after installation of beam line 9 to the cooler ring. This activity required realignment of a downstream section of beam line 3 and removal and re-installation of the high energy polarimeter on the polarized neutron facility beam line.

Efforts to maintain beamlines continued to be significant. In particular, difficulties with compressed air leaks from electrically operated air valves for actuators and air operated vacuum gate valves consumed much time until a solution was found late in 1986.

Last components to allow beam splitting were installed in beamline 4 in the summer of 1986 and split beam achieved in July. The advent of split beam has provided access to the beam for detector tests, graduate student training and beam development while simultaneously providing beam for experiments. This is very beneficial to the laboratory but does result in increased workloads for the operations and research support groups.

2. New Beamlines

By the summer of 1986, installation of beamline 8 to the K600 spectrometer was complete. On July 7, 1987 first beam was delivered to the K600. It was learned, as a result of beam tests with the K600 and careful voltage measurements on all quadrupoles, that several quadrupole magnets were miss-wired. These were repaired. In addition, diagnostics were developed and installed in beamline 8 to allow proper set up of beamline optics and dispersion matching. These included installation of pop in slits, relocation of a steering magnet, installation of object defining slits before the old QDDM magnet and repositioning of a beamline viewer. While efforts will continue to improve ease and reliability of operation of beamline 8, it is effectively useful now.

Beamline 9 to the Cooler was about three quarters complete by the end of 1986. Installation of two magnetic elements and several beam diagnostic devices remain to be done. Beam tests for this beamline are scheduled for May, 1987.

3. Target Area Improvement

Considerable use was made of the low intensity (gamma) cave in 1986, particularly as a result of beam splitting and the development of a low intensity dispersed beam each of which became available in the last half of the year. No extensive hardware development has been required to exploit these new capabilities. However, nearly all existing target chambers and experimental set ups developed in the past have been used in this area.

No significant improvements were made in the pion spectrometer. A new sliding seal band for the spectrometer was ordered to replace the band which is severely damaged. A proton sweeping magnet was installed to support an experiment in which neutrons were detected in coincidence with pions.

Several experiments were performed in the 64 inch scattering chamber which demanded careful alignment and good reliable vacuum. Difficulties with alignment were solved by careful realignment of beamline 4. The cryopump on the scattering chamber is capable of producing vacuums in the chamber in the 10^{-7} torr range. However, it proved unable to maintain such vacuums reliably for runs of several days duration. In addition, when the cryopump fails, it suddenly causes a very poor vacuum which can cause damage to channel plate and solid state detectors. A liquid nitrogen cold trap was added to the chamber to help maintain good vacuums reliably and repairs were made to the cryopump/scattering chamber system. The scattering chamber was carefully leak checked and a significant leak repaired. A problem with contaminated helium which is used as the refrigerant in the cryopump was identified and solved. Finally a mechanically worn component in the cryopump itself was replaced. These steps have relieved the reliability problem. However, plans are underway to add a turbopump to the chamber to reduce dependence upon the cryopump for good reliable vacuum. In addition, an extension ring for this chamber is planned to add 17 1/2 inches of height in the vacuum chamber above the movable arms. This will expedite out-of-reaction-plane measurements.

After removal of the old QDDM spectrometer from its location on beamline 5, modifications were made to make this target station able to use target chambers designed for the gamma cave while allowing continued use of special purpose chambers already built for this target area. This involved the installation of controls for the existing pumps in the beam dump, new supports for downstream beam rails from above so that the spectrometer carriage could rotate from side to side freely, and plates to make the old spectrometer carriage flat. This area has become well used. It has supported detector tests for Cooler experiments for outside users (Illinois, Kentucky, and Pittsburgh) and inside users.

While the K600 spectrometer was successfully commissioned in the summer of 1986 and development begun, there were, naturally, bugs to be worked out and features to be implemented. The target chamber, which is the chamber used on the old QDDM spectrometer appropriately modified by inverting it, was found to require partial disassembly for addition of a new positioning stop to allow small angle operation of the spectrometer. The sliding band seal showed wear. A new one was ordered. Vacuum controls, which use a commercial industrial control computer and a personal computer, has bugs which are being eliminated. A lid hoist was installed above the target chamber. A separate mechanical pump for roughing the target chamber, aperture cassette and scattering chamber was installed. Plans are made for installation of small angle operation with beam stopped outside of the scattering chamber, but this capability does not exist as yet.

Holes were made in the shielding wall on the west side of the accelerator building into the Cooler addition near the beam swinger facility to allow measurements of neutron times-of-flight on two large angle flight lines. A new television mount and mirror was installed to view the target scintillator in the swinger and a ice target was developed and used. To support an (n,p) experiment a special exit window with an adjustable stripper foil was fabricated and installed.

In preparation for the installation of a superconducting solenoid to precess neutron spins on the zero degree flight path, a high ceiling metal building was designed and installed adjoining the building just north of the swinger and power installed near the swinger area.

Many miscellaneous tasks were performed to support the CSB experiment as well as experiments in the swinger, gamma cave, pion spectrometer, 64 inch scattering chamber and the beamline 5 target station. These efforts constitute the normal operational support of experiments at IUCF. In the 1986 operating year, 48 experimental setups were performed in 41 weeks of operations. The cyclotron did not operate for 6 weeks in the summer of 1986 to allow time for Cooler and spectrometer construction and for 5 weeks in December 1985 for sector D repairs in the mainstage cyclotron. Six of the seven experimental areas were used. The hot cell was not used. Table IV summarizes usage of experimental facilities in the 1985-1986 year.

Thirty different experimental groups participated in these experiments. About two thirds of these groups involved outside users of the facility.

The effects of beam splitting are not reflected in the number presented in Table IV. However, beam splitting increases the number of setups by 30 to 50%.

The level of activity indicated by the numbers of setups for the 1985-1986 year together with Cooler and spectrometer construction has been more than a comfortable load for the research support staff of the

Table IV

Experimental Facility Usage
Dec. 1, 1985 to Nov. 1, 1986

Experimental Facility	Number of Setups	Comments
64" Scattering Chamber	11	
Beam Swinger	11	2 (n,p), 1 large angles
Beam Line 5 (old QDDM location)	6	required development
Polarized Neutron Facility (CSB)	4	
QQSP (pion Spectrograph)	3	
Gamma Cave	2	
K600 Spectrograph	12	development runs

laboratory. This situation is likely to continue in the near future. Therefore, it is well for users to plan to put more effort into the performance of experiments at IUCF.

The K600 Magnetic Spectrometer System

G.P.A. Berg, L.C. Bland, B.M. Cox, D. DuPlantis, D.W. Miller, K. Murphy, P. Schwandt, K.A. Solberg, E.J. Stephenson, B. Flanders, and H. Seifert

Introduction. The final installation phases of the K600 spectrometer were brought to completion during the first half of 1986. These included completion of the service connections, vacuum pumping stations, and controls for the K600 magnet system and new beam line (BL8) to the K600 target station, modification and installation of the target chamber, and extensive field mapping and shimming of the K600 entrance quadrupole.

In July, following a scheduled 6-week suspension of cyclotron operation, the cyclotron beam was transported for the first time through the BL8 complex to the K600 target. After some initial development effort reasonable transmission of the beam to the target was achieved with beam line parameters and beam characteristics in fair agreement with the predictions of beam optics calculations.

There followed an intense period of activity in which the remaining subsystems of the K600 spectrometer were readied for testing with beam on target, including the spectrometer entrance quadrupole and hexapole magnets, acceptance-defining aperture cassette, dipole field NMR probes, focal plane detectors, and beam dump.

On August 29, we identified for the first time particles from nuclear reactions passing through the spectrometer magnets to the driftchamber/scintillation detector stack mounted on the medium-dispersion focal plane. In the several months following this initial test, a series of systematic and detailed development runs was undertaken to learn how to obtain the correct momentum dispersion on target, to study the properties of the spectrometer magnets and focal plane detectors, and to improve the energy resolution of the system. These efforts are detailed later in this report.

Much of this development work towards commissioning of the K600 spectrometer has been aided and guided by Georg Berg who joined IUCF in late August, bringing with him considerable spectrometer experience from the KFA Julich.

K600 Spectrometer Hardware. The most critical of the remaining K600 construction projects to be completed in 1986 was the assembly and mapping of the spectrometer entrance quadrupole magnet (actually a multipole magnet with significant hexapole and small octupole components). This project had been seriously delayed due to late deliveries by outside vendors of the pole tips and coils. After a number of iterations, a configuration of the pole tip ends and gap spacings was obtained that provided the correct quadrupole and octupole fields, with somewhat less hexapole strength than was desired. This shortfall was easily remedied with the separate, variable hexapole magnet mounted just ahead of the quadrupole. End shimming of the pole tips resulted in a quadrupole field whose effective length is uniform to 1% over the full aperture of the magnet (8 cm radius). The quadrupole magnet also contains a provision for operation at small scattering angles with reduced solid angle. Because of the lack of time, shimming of this part of the magnet was postponed until design of the small-angle mode with its septum magnet is complete. Following extensive mapping with both Hall probes and a rotating coil assembly, the quadrupole and hexapole magnets, along with the entrance aperture cassette, were installed on the K600 carriage and aligned. The aperture cassette provides six positions on a wheel for the insertion of fixed acceptance apertures of arbitrary shape for the spectrometer. The wheel position can be changed locally through a motorized Geneva drive assembly. This cassette wheel replaces the four-jawed rectangular slit system familiar to users of the old QDDM spectrometer. During this time the QDDM scattering chamber (modified for scattering to the left) was mounted on the spectrometer center pivot, and a number of unforseen mechanical interferences removed. Initial testing of the beam line was done with the beam stopping in one of the internal Faraday cups made for that scattering chamber. After initial beam tests, the external beam dump was installed, along with a vacuum pumping station and beam pipe connecting it to the scattering chamber. The beam stop in the external dump is divided into four quadrants to provide information on the direction of the beam leaving the target. At present, the beam pipe to the external dump limits the motion of the spectrometer to angles larger than 17° (to the left of the beam). With some modifications to the dump beam pipe, this angle could be reduced to 14.5°, the limit imposed by the sliding seal band on the scattering chamber. Scattering angles smaller than 17° (or 14.5°) require rotation of the scattering chamber and the use of an internal Faraday cup until the proper small-angle mode of operation with a septum magnet can be implemented, perhaps during the latter part of 1987.

The vacuum system for the beam line and external beam dump is operated from an IBM PC located inside the spectrometer vault. The PC provides a status map of the beam line vacuum and control access to all pumps and valves, the interlock logic and auto-pumpdown options. The K600 magnet vacuum is produced and monitored by two self-contained and locally controlled turbo-molecular pumping stations on the spectrometer carriage. The magnet system can be evacuated (from atmospheric pressure to 100 microtorr) in about 20 minutes using any one of these pumps, with the other one held in reserve (at full RPM and valved off) for final pumpdown to 5 microtorr operating vacuum in an additional 10 minutes. The scattering chamber is pumped by a valved cryopump. The aperture cassette can be valved off from both target chamber and spectrometer and evacuated independently, allowing rapid exchange of aperture plugs.

Moving the spectrometer to a specific angle (within the range of about 100° to the left to about 22° to the right of beam) is accomplished locally with a variable-speed motor drive (maximum rate 30°/min) operated either from the controls rack on the spectrometer carriage or from a hand-held controller on a long cable. The drive system incorporates a brake for immediate stopping (at slow speeds) at the desired angle. The angle setting is presently indicated by an optical encoder readout; an accurate, absolute mechanical angle scale with vernier for mounting along the 4.6 m radius track and associated TV camera for remote monitoring is ready for installation.

All power supplies for the K600 magnets (including the H and K correction coils) and beam line 8 magnetic elements are operating reliably and with the required stability (2 part in 10^5 for the main dipoles) with the exception of the supply (TRANSREX3) for the old QDDM dipole now used as a high-dispersion analyzing magnet in BL8 which, for 200 MeV protons, for example, runs close to its design limit. Supply failures causing considerable internal damage occurred several times over the past few months, forcing reduced-energy operation (up to 120 MeV protons) using an existing spare supply (ALPHA6).

Focal Plane Detectors. Initial operation of the detector system mounted on the central, medium-dispersion focal plane of the K600 spectrometer includes two x-position vertical-drift chambers (VDC) and two passing scintillators; the latter serve as the particle-identifying event trigger and start timing for the wire chambers. The two scintillation detectors presently in use were designed originally for pion detection with the QDDM and cover only slightly more than half of the available focal plane. Fabrication of full-length scintillation detectors of various thicknesses (1/8, 1/4, 1/2 inch) is in progress. Particles passing through the spectrometer magnets enter the detector stack through a 75 micron thick Kapton vacuum window. A 40 cm thick stack of concrete blocks is normally erected behind the scintillators to reduce the flux of background particles into the scintillators from localized sources along the incoming beam line. Scintillator coincidences arising from neutron-induced knock-on protons are further reduced by a 1.5 mm thick copper absorber inserted between the two scintillators.

The two x-position VDCs are similar to those specified in the focal plane detector proposal. Each wire plane consists of 160 sense wires separated by 6 mm. Two guard wires are placed between pairs of sense wires, so that the overall wire spacing is 2 mm. The wire and high-voltage planes are separated by 6.4 mm. The wire readout system includes individual preamplifier/discriminator channels for each plane. The data associated with an x-measurement consist of five words containing the encoded wire numbers from the multiplexers and five TDC values representing the drift times. These words are interfaced to the "HERA" VAX 11-750 for sorting and taping through an MBD-11. The acquisition system is presently capable of handling 400 events per second (each event contains 33 data words) at 10% dead time. Higher acquisition rates will be available with a parallel readout system within a year. In the range of the medium-dispersion focal plane, most good particle trajectories pass through three adjacent drift cells in each wire chamber. The efficiency of each wire chamber for detecting and correctly identifying such an event is typically 95±2% over the extent of the medium-dispersion focal plane for 100-200 MeV protons.

The counter gas used is a mixture of argon and ethane, with n-propyl alcohol vapor added to suppress sparking. The wire chambers are typically operated at 4300 to 4600 volts. While operation at these voltages produces the expected response with the present set of wire chambers, we observed earlier, for the initial set of wire planes used, that lower cathode potentials (below the VDC plateau voltage) resulted in an uneven drift time distribution within each wire chamber: under conditions in which each drift cell was uniformly illuminated with protons, several distinct peaks were observed in the distribution at large drift times. Operation at higher cathode potentials appeared unaffected. We now believe that uneven wire spacing (deviations of up to 100 microns from the nominal) in these early wire planes caused these problems. The wire planes presently in use were fabricated with greater precision and appear to be free from this problem.

Two sets of horizontal drift chambers are under development for measuring the y-position (perpendicular to the bend plane of the spectrometer) of rays in the focal plane. These chambers will have alternating sense and guard wires, with an 8 mm spacing between sense wires. The direction of the individual wires will be inclined at 11° to the horizontal to reduce the effects of multiple hits along the focal plane. Position will be interpolated on the basis of horizontal drift times recorded between the sense and guard wires. Each y-position measurement will require two wire planes with offset sense wire positions so that the ambiguity between the two sides of a single sense wire may be resolved. Altogether, four wire chambers will constitute a complete set of position-sensitive focal plane detectors.

Essentially all of the focal plane electronics, high voltage power supplies, and CAMAC computer interface are located on the K600 carriage next to the detectors. A number of signal lines have been installed to the HERA data acquisition area for inspection of output signals at various critical points in the circuit. Remote computer control is available for the wire chamber and photomultiplier tube high voltages. Overcurrent trips on the wire chambers are sensed by an IBM PC located in the data acquisition area, and the power supply is ramped to the programmed voltage under PC control after each trip (data acquisition is automatically suspended during this time). Start timing for the TDCs is adjustable through a remotely controlled delay line, and computer control of the wire chamber readout discriminator thresholds is also available.

A small carriage on a linear track runs parallel to the focal planes below the median plane just inside the focal plane vacuum box. An electron source for on-line checking of wire chamber operation in the absence of beam on target may be mounted on this carriage, or a shadow (stopping) block to absorb unwanted particle groups coming through the spectrometer magnets.

Data Acquisition Software. The data acquisition program in use with the K600 detector system is "Q", which was developed at Los Alamos and has been used extensively with the HRS and EPICS spectrometers there. The event processing routines have been adapted for use here by L. Bland. Additional routines have been added, e.g., to provide interpolated position based on the drift times recorded in neighboring cells of a drift chamber, and the angle of a ray passing through two drift chambers separated by about 10 cm along the ray direction. The plotting routines have been converted to make use of the Unified Graphics System. The use of this acquisition system permits easy modification of existing spectra and sorting conditions so that on-line checking of the quality of the data and the ion-optical setup of the spectrometer parameters are facilitated.

At present, the software requires that several conditions be met for a good event. The pulse heights of the two trigger scintillators must fall within the boundaries for the particle of interest. The wire chambers must not record multiple hits. The hit pattern in each chamber must contain at least three consecutive wires, with the center wire having the minimum drift time. The trajectory angles at the focal plane determined separately by each wire chamber must be consistent within tolerances. Of the events which pass the particle identification test at the beginning, about 88% also pass all the tests in the wire chambers. This number represents our present two-wire-plane efficiency.

The processing time required for calculating corrected wire chamber positions and sorting events into several on-line spectra is several times the data acquisition time in the MBD. For experiments where only occasional inspection of of the data is required to verify that everything is satisfactory, the acquisition program may be operated in the "may process" mode where events are sorted only when there is sufficient spare time in the CPU. All events are still written to tape.

The sorting program for both scalers and real events has recently been improved to include information about the polarization state of the beam. At present, the spin state is controlled from the cyclotron computer, and information is fed back to the VAX data acquisition system through a coincidence register. Eventually, programs will be added to the system to allow the spin state to be controlled directly from the VAX. Improvements are also being planned that will allow us to make corrections for the curvature of the focal plane, thus maintaining high resolution over the full momentum range.

Data Acquisition Area. The data acquisition area for the K600 spectrometer is located next to the HERA VAX 11-750 computer on the Cooler building balcony. At present, this area houses the VAX CAMAC interface, several controls and graphics terminals, and an IBM PC for the wire chamber HV control. In addition, the NMR controls and readouts for the two K600 dipoles and the high-dispersion bending magnet (old QDDM dipole) in BL8, as well as two beam current integrator units which can be read by the data acquisition and controls computers, are located at this station. We expect eventually to route all control and status information for the operation of the spectrometer and other status information to this area. In the near future we expect to install remote control of the aperture cassette and the drive for the spectrometer angle.

Operation at this remote site is facilitated by the use of new VAX software (program CYCLO) that gives the experimenter access to an appropriate subset of parameters in the IUCF controls computer. Adjustments may be made to any element in BL8 and the K600 spectrometer magnets from the HERA VAX. Operation from the IUCF control room is still possible using the standard software displays. Target values for setting the QDDM and K600 magnet systems may be obtained from a kinematics calculation and automatically loaded into the CYCLO program.

For polarized beam operation, spin status information and spin-flip control are available at the HERA station.

K600 Development. By the end of August all components of the K600 spectrometer required for testing with beam were installed and operational. In a series of development runs during the last four months of 1986 the spectrometer was tested with 100, 120 and 200 MeV protons for the medium-dispersion mode. These tests uniformly provided results in agreement with the design parameters of the magnet and detector systems. The first nuclear physics experiment (100 MeV inelastic proton scattering from calcium isotopes) which makes use of the established K600 properties has been successfully completed as of February 1987 (see Fig.12. for some representative results). Interspersed with the first physics uses of this new research instrument,

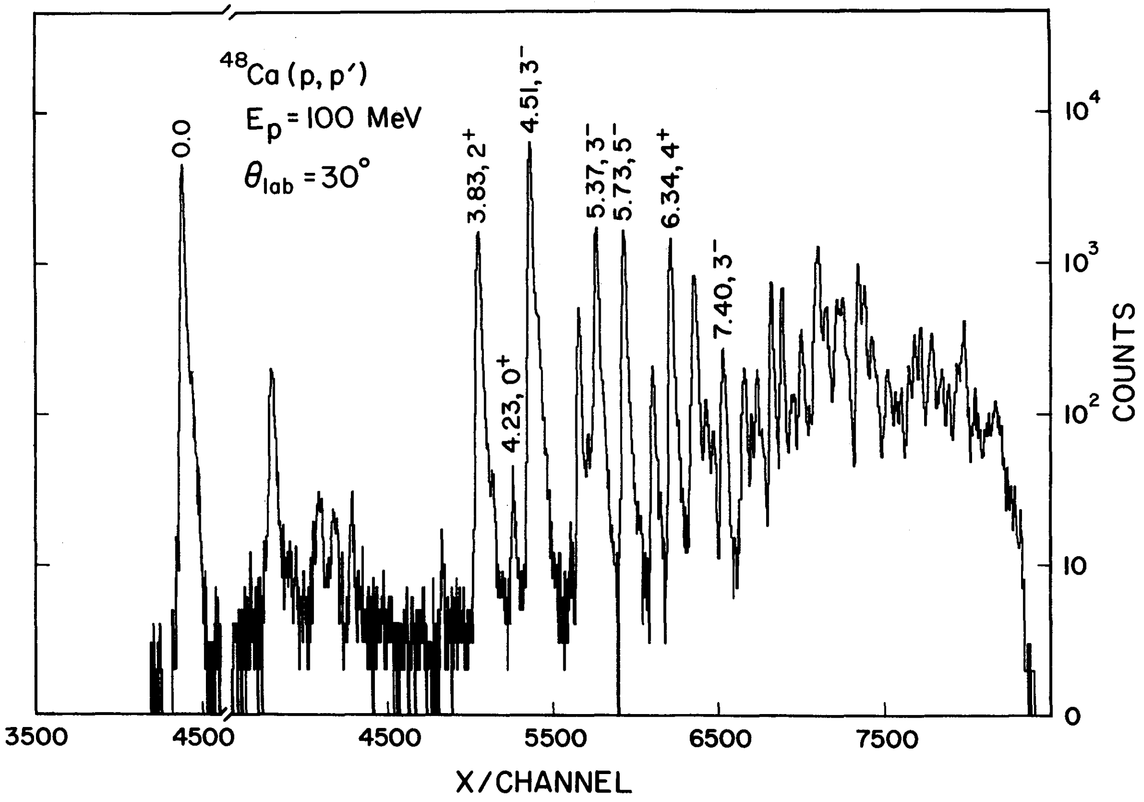

Figure 12. Typical spectrum measured for 100 MeV proton elastic and inelastic scattering from several Ca isotopes. The resolution of 37 keV resulted mainly from the target thickness of 15.2 mg/cm^2. The elastic peak was measured in a separate short run as indicated by the broken x-axis.

further development specific to other approved K600 experiments is in progress and will continue for some time to come.

In these early K600 development runs, the immediate availability of operational VDCs and "Q" data acquisition software was crucial to the rapid progress of the tests of the ion-optical properties of the K600 spectrometer and the beam line 8. The use of two VDCs enabled us to measure from the very beginning the horizontal position and angle of particles crossing the focal plane. This information was crucial to the successful diagnosis of the dispersion matching condition which allowed us to realize fairly quickly high energy resolution (within a factor of about two of the design goal of 60 parts per million). Figure 13 shows one such high-resolution spectrum.

The dispersion for the K600 spectrometer is generated by the 130° analyzing magnet system which previously constituted the QDDM spectrometer. For this scheme to operate correctly, the beam must be focussed to a very small spot at the object point of this magnet system. To achieve and maintain the required tight focus at this position within narrow tolerances, a slit with 0.55 mm horizontal width was used. The width of this slit corresponds to roughly the width of the image at the K600 focal plane and provides a lower bound of

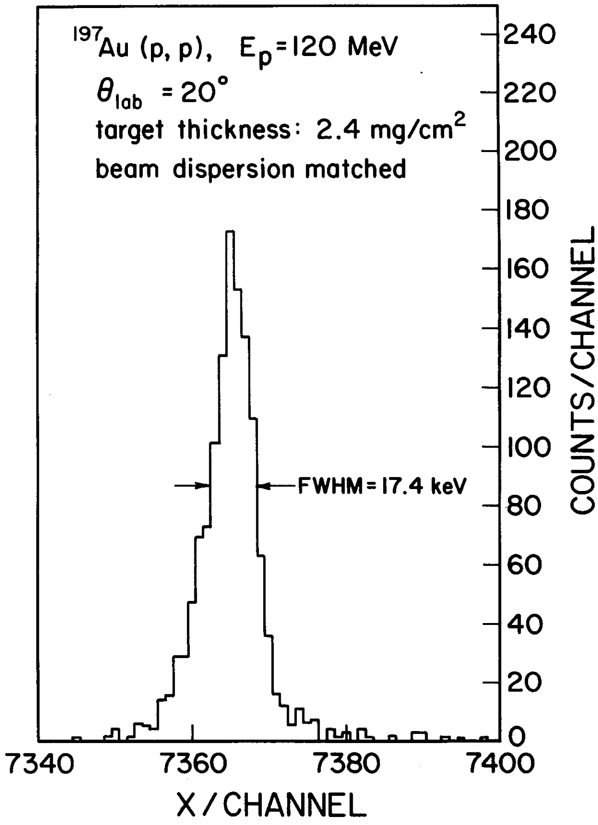

Figure 13. This spectrum shows the best resolution which was obtained for 120 MeV protons using a thin Au target, a well tuned beam and optimum dispersion matching condition.

about 10 keV FWHM at 100 MeV on the focal plane resolution. The value of the dispersion on target is adjusted by changing the balance between the two horizontally focussing quadrupoles in BL8 that transport the beam from the effective focal plane of the 130° analyzing magnet system to the target. In addition to providing the correct momentum dispersion, these quadrupoles must be adjusted to provide a monochromatic focus on the target (or just beyond it for the horizontal direction in the case of reactions with a significant kinematic factor), as well as the correct angular dispersion so that the scattering angle remains constant across the target.

target to the spectrometer, essential for good focal-plane resolution, can be easily checked using a diagnostic method we call the "passive hodoscope", consisting of a two-strip target, a three-slit aperture in the target chamber, and the measurement in the focal plane of position versus angle of rays defined by the passive hodoscope. The measured pattern provides immediate and independent information on the dispersion matching and focussing conditions for optimum resolution. Fig. 14 illustrates how a matched and properly focussed hodoscope image appears in the position vs. angle plot. Incorrect dispersion can be seen as horizontal misalignment of the rays (pencil beams) from the left and right target strips, while improper focussing results in horizontal broadening of the image spots.

The K600 user has basically four adjustable magnetic correction elements available to him for controlling positions of horizontal and vertical focal planes and for minimizing $(x|\theta^2)$ and $(x|y^2)$ aberration terms. For operation in a given dispersion mode (focal plane location), the K600 entrance quad which provides most of the vertical focussing of the spectrometer should generally be adjusted such that the cross-over of vertical and horizontal focal planes (which are inclined steeply relative to each other) occurs near the central momentum ray; this insures that the vertical image size at the extreme ends of the focal plane is within the vertical acceptance of the detectors. At present, in the absence of y-information for rays crossing the focal plane, we rely on ion optics calculations (based on measured quad properties) to set the quad current. In order to check resolution readily on-line and to minimize x-position corrections during replay, it is desirable to have the horizontal

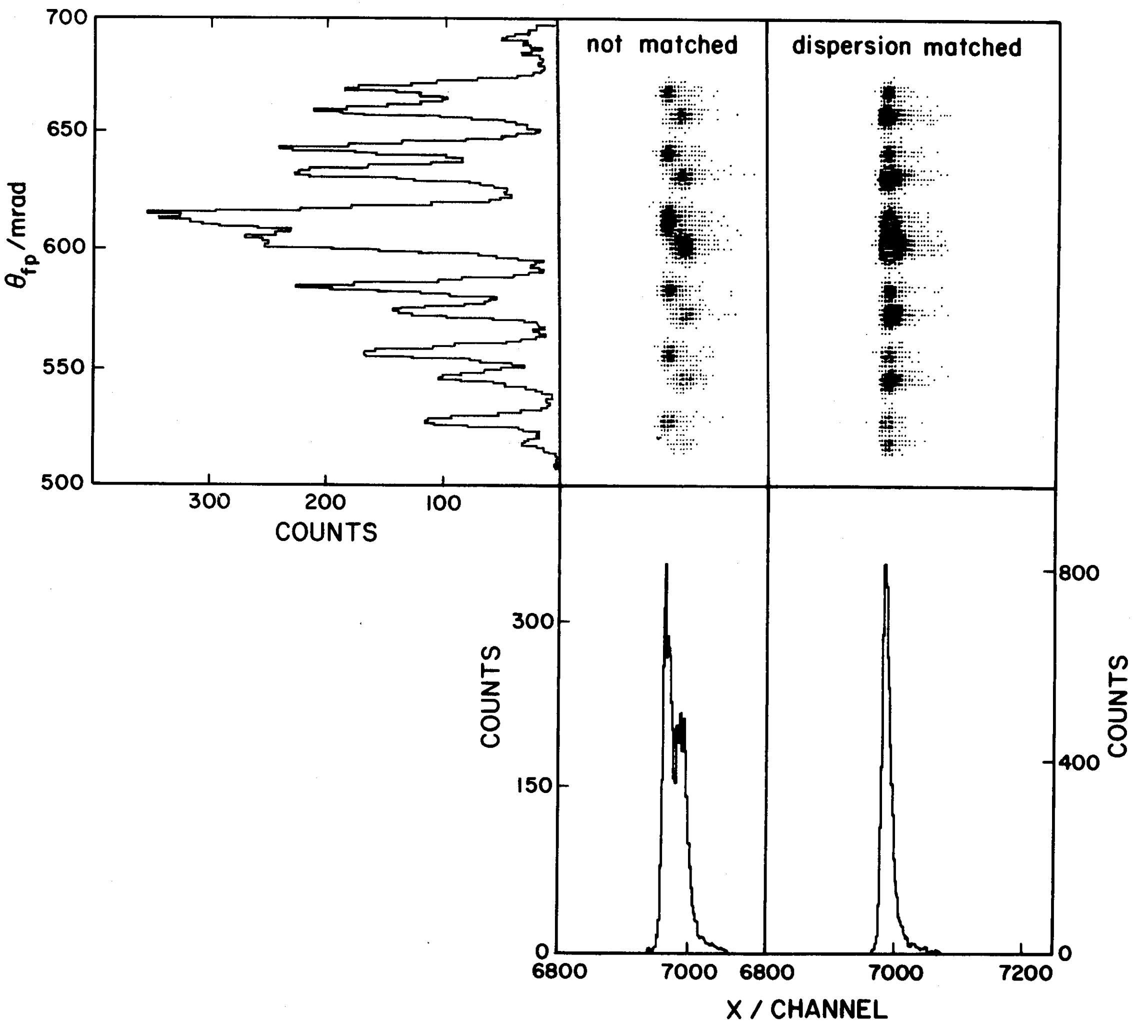

Figure 14. Position vs. angle plots using an early version of a passive hodoscope for a well-dispersion- matched beam and a beam with too large dispersion on target. The projection on the θ_{fp}-axis (focal plane angle) shows the doublets from 6 slits. The doublets result from the two target strips. For better separation a new strip and slit configuration is now available.

focal plane coincide with the front wire plane. This is achieved for a given reaction (with given kinematic factor (1/p)(dp/dθ)) by adjustment of the K-coil (a triangular poleface winding acting as a quadrupole lens in the second dipole) until all incident angles converge to the same position on the focal plane as evidenced by the absence of $(x|\theta)$ correlation in the x vs. θ plot. Curvature in this $(x|\theta)$ correlation line due to $(x|\theta^2)$ aberration is then removed by adjustment of the H-coil (a poleface winding providing a hexapole lens in the first dipole). For large vertical spectrometer acceptance a sharp line in the x-position (momentum) spectrum may exhibit noticable shape asymmetry due to $(x|y^2)$ aberration; in the absence of detailed y-position information this can be approximately corrected by adjustment of the K600 entrance hexapole magnet. First-order H-and K-coil adjustments are generally made prior to dispersion matching; once good momentum (x-position) resolution in the focal plane is achieved through dispersion hexapole may be fine-tuned. It should be noted that effects of these magnetic correction elements are coupled, and that the entrance quad and H, K coils have significant dipole components which affect x-positions of rays of given momenta in the focal plane.

Because of the large vertical magnification of the K600 (of order 4 to 12, depending on dispersion mode), correct vertical centering of the beam on target is critical for proper vertical centering of the image in the focal plane (important at extreme ends of the focal plane because of the potentially large vertical image size for large ϕ-acceptance). Vertical centering of the focal plane image can be checked at present by means of a pair of small, thin "top" and "bottom" diagnostic scintillators which overlap vertically by about ±5 mm centered about the K600 median plane. Measurements of the scintillator coincidence yield versus vertical position of beam on target (for a small entrance aperture) provide a sufficiently accurate indication of correct vertical centering. Eventually, addition of a y-position wire chamber covering the whole focal plane will automatically provide immediate and accurate information on y-centering and focussing (entrance quad setting) as well as $(x|y^2)$ aberration correction (entrance hexapole setting).

The best energy resolution figures (FWHM) obtained so far for the K600 in short test runs are 18 keV at 120 MeV and 25 keV at 200 MeV for protons scattered at 20° from a 2.4 mg/cm^2 thick Au target into an angular acceptance of 4°. To obtain such high resolution requires thin targets, good dispersion matching of the cyclotron beam on target, and use of the narrow object slit at the entrance to high-dispersion, 130° bending magnet in BL8 mentioned earlier. At present, that slit is sufficiently thick to permit monitoring of left and right slit currents for feedback to an automatic centering loop (the transmission through the slit is typically 40-50%). One very undesirable consequence of that thick slit is a substantial continuum of energy-degraded particles (from slit edge scattering and penetration) associated with the beam transmitted through the magnet. The large dispersion of this magnet results in sufficiently large horizontal displacement of the bulk of this momentum tail to eliminate most of it near the magnet image plane located on the other side of a thick shielding wall from the K600. A portion of this beam halo nevertheless gets transported to the K600 target region in the form of a fairly wide-spread horizontal tail to one side (the left, looking downstream) of the central, full-energy beam. We are presently removing the effect of this halo by the simple expedient of using open-sided target holders and frames. This expedient works well enough at sufficiently large scattering angles (>15°) and with an external beam dump. At small scattering angles and with an internal Faraday cup, geometric configurations can arise where halo-generated spray of charged particles can enter the K600 acceptance and be transmitted or scattered to the focal plane, causing significant unphysical background in detector spectra. Development work towards a proper solution which eliminates or drastically minimizes this particular beam halo is in progress.

<ins>K600 Completion and Future Improvements</ins>. The K600 system as it now exists is operational as a high-resolution spectrometer for standard experiments. Because of the lack of experience and systematic study of the optical properties of the beam line and the K600, setup is not yet routine and consumes considerable time. Data acquisition rates through the MBD are slow.

There are, in addition, a number of important K600 features and needs of general concern to the users that must be addressed and implemented before the K600 is a complete, general-purpose, high-quality and reasonably easy-to-use research instrument. These include correction of the beam halo problem (under consideration); a set of proper scintillation detectors (nearly completed) for full focal plane coverage and suitable for a variety of particles and energies; y-position wire chambers (under development) to provide vertical focal plane image information and permit correction of aberrations and rejection of pole face scattered events. Remote control and status indication of target chamber turntable, aperture cassette, carriage drive, and select vacuum components are needed for efficient spectrometer operation. To speed up front-end data processing, the present MBD will soon be replaced with a fast readout CAMAC controller incorporating a microprogrammed processor. Some of the more urgent HERA data station enhancements are terminal(s) with direct multiplexer connection, a hard-copy graphics device, at least one (eventually two) 6250 bpi tape drives, tape storage and additional relay racks, and more signal cables to the K600 cave and the cyclotron control room. Other near-term additions include precise magnetic field monitoring capability (using Hall probes) for the final BL8 quadrupole triplet used in dispersion matching, and improved, permanent focal plane detector radiation shielding on a proper support structure moving along with the K600 carriage.

Longer-range (more than 6 months) planned improvements which require considerable development effort include implementation of one or more of various possible small-angle modes as dictated by specific experimental requirements; spare focal plane wire chambers and (possibly segmented) scintillators; a acquisition computer (programmed to do simple, fast event pre-processing for bad event recognition and rejection), and a much faster data acquisition/replay software package (perhaps a more streamlined version of the "Q" program presently used with the K600). Also, a totally new or considerably modified scattering chamber compatible with various small- and large-angle modes and incorporating remotely-controlled target changing will eventually be needed. Finally, certain minimum quality-of-life improvements to the HERA data acquisition area, such as a dropped ceiling with good lighting, noise control, and adequate heating and cooling, must be provided to make long-term use of the K600 (and eventually the Cooler) by experimenters a less debilitating experience than it is now.

There are a number of tasks to be finished which require appreciable further investment in K600 operation/development time and effort: development of K600 operation in the low-and high-dispersion modes (after duplication of detector and shielding mounting hardware); systematic development of sets of optimum K600 operating parameters for various focal plane modes and kinematic conditions to speed up and automate the spectrometer setup process; and similarly, further improvements to BL8 diagnostics coupled with systematic investigation of beam transport parameters so that good-quality, dispersion-matched beams can be delivered to target routinely and reproducibly.

During 1987, construction will begin on the first phase of a polarimeter for the K600 focal plane. This polarimeter, which will first be operated at the medium-dispersion focal plane location, will consist of a thick carbon scattering target, two x-position wire chambers, and two scintillators used to trigger the electronics and identify protons elastically scattered in the thick carbon target. This polarimeter will provide measurements of the outgoing proton polarization and the $D_{NN'}$ polarization transfer coefficient. A second phase, which may begin as early as 1988, will augment the focal plane polarimeter with y-position readout, install spin precession solenoids in the high-energy beam line, and develop high-energy polarimeters to complement the new spin precession system. These enhancements will add horizontal-plane polarization transfer coefficients to the list of measurable quantities. This will then represent the first full polarization transfer capability at IUCF.

It is clear from the above that considerable additional effort and resources are needed to complete the K600 and realize its full potential as a generally useful and productive high-quality research tool. There will also clearly be a continuing need during the next year (or two) for K600 development time in the IUCF research schedule. In addition to the effort needed for the standard K600 development, there will be special projects undertaken to handle particular approved or planned experiments, such as special small-angle (including 0°) operation, special target or focal plane detector systems, and focal plane polarimetry.

Polarized Neutron Beam Facility - W.W. Jacobs, L.D. Knutson. S.E. Vigdor, R.C. Byrd, P.L. Jolivette, J.G. Sowinski, F. Sperisen, C.D. Whiddon, and S.W. Wissink

This facility is the site of continued preparation for an experimental search for charge symmetry breaking (CSB) in n-p scattering.[1] The emphasis of activities in this area during the past year was aimed at reducing possible systematic errors in the experiment and improving polarized target and detector performances before further production running for CSB begins in late spring of 1987. Some of these developments also have important implications for future experimental capabilities with this facility.

The CSB experiment requires making very precise measurements of the analyzing power difference $\Delta A(\Theta) = A_n(\Theta) - A_p(\Theta)$, where $A_{n(p)}$ is the analyzing power obtained when the beam (target) is polarized. During data acquisition, both neutron beam and proton target (PPT) are simultaneously polarized normal to the scattering plane. Small non-normal spin components are present in the neutron beam, arising from the polarization of the $^2H(p,n)$ production reaction and beam transport details of the PNF beam line. Similar components may be present in the PPT (e.g., if the holding field is not precisely perpendicular to the scattering plane), and may couple with the non-normal beam components through the spin correlation coefficients C_{LS} and C_{SL} to systematically mock up a CSB effect. Conceptually, the easiest way to get rid of such potential problems is to make the non-normal target components vanish through the addition of small correction fields to the normal target holding field. Such a capability was implemented for testing purposes by the first of last year. Subsequently, during a production run in March '86, a secondary proton beam with large sideways polarization[2] was scattered from the PPT in a first attempt at optimization of horizontal and longitudinal correcting field settings.[1] One outcome of this exercise was an appreciation of the difficulty of controlling systematic error effects in these measurements to the required level (i.e., corresponding to field corrections of order 10 Gauss or less). Furthermore, the lengthy running times with charged particles required to achieve the required accuracy were found to cause radiation damage to the target crystals, significantly reducing the spin relaxation times (factor of ~2.5) to an unacceptable level for production running.

A complementary approach to solving systematic error problems was thus launched during the summmer of '86. Design studies were initiated for a neutron spin precession magnet to fit in the meager space available immediately downstream of the production target (yet before the collimator wall). The result, a new room temperature, charged-particle dipole "sweeper" magnet is presently under construction and will be placed in the neutron beam-line before final CSB production running begins. Its integrated field strength (~1.7 kGm) will be more than sufficient to precess non-normal spin components of the PNF neutron beam by ± 90° (this is in contrast to the limit of ± 40° for the old sweeper magnet). By acquiring data alternately with both orientations of this precession field, interspersed with reversal of the PPT holding field (corrected with the supplemental fields as described above, but now without such high accuracy), effects due to the non-normal spin components can be cancelled to the degree essential for the CSB measurements. Several uncertainties, however, remain to be straightened out after magnet delivery this spring. The rather unconventional design involving large amounts of return and pole tip steel above the neutron beam line level, in conjunction with a thin lower plate (necessary to allow the vertically deflected charged particle beam exiting from the liquid deterium production target to pass closely below the magnet), will require shimming in order to ensure sufficient field uniformity in the gap (which also serves vertically as the neutron collimator). In addition, we are investigating the design of entrance field clamps to eliminate asymmetries in the integrated longitudinal fringe field, since the latter have the effect of producing small (additional) spin components in the spin polarized secondary neutron beam of precisely the type that we are trying to eliminate. Suitable clamps should reduce this type of systematic error to an insignificant level. We expect to have these problems solved soon after delivery of the magnet components and in time for a PNF test run with beam in the upcoming spring scheduling period. It should be noted, that in spite of these more detailed considerations, this new sweeper magnet will open the possibility of measuring spin correlation parameters for n-p scattering in the future using longitudinal and sideways neutron spin orientations (in conjunction with a longitudinal polarized target), provided a suitable production reaction can be found.

The polarized proton target (PPT) is of the spin refrigerator type[3,4] and is particularly suited for use in the CSB experiment at IUCF ($\langle E_n \rangle$ = 188 MeV) because of the small deflection of recoiling protons in the low magnetic holding field and non-critical requirements on polarizing field uniformity. This has allowed use of an open target geometry and broad angular acceptance of the detector arrays. The polarization is built up in such targets by physically rotating (30-60 Hz) the target crystals (e.g., ~0.005% Yb doped yttrium ethyl sulfate) in a strong field (>1.0 T) at low (~0.6°K) temperature. After spinning, the target is fixed in position and a holding field (~900 G) applied. Recent and ongoing PPT developments have been aimed at improving the polarizing field strength and the heat load encountered while spinning the large-area target (both of these of changes lead in principle to higher attainable target polarization). Attention has also been directed toward improving the spin relaxation times and the reliability of PPT performance for long running periods.

A major source of breakdown during target operation in the past several years has been due to the superconducting magnet assembly which produces both the polarizing and target holding fields. Since initial operation at IUCF, the saddle-shaped polarizing coil has been redesigned, and then rewound twice, in order to achieve higher fields and more reliable operation. However, our experience during the March '86 run made it clear that the new polarizing field coil, after initially showing somewhat better performance, would not run reliably at fields $\geqslant 1.0$ T without quenching. In order to expedite the solution to this matter (given the relatively small number of CSB collaborators and the time consuming nature and difficulty of the rebuilding job) we decided to appeal to commercial suppliers with regard to design philosophy, fabrication techniques, and delivery time. In the late summer of last year a contract was awarded to C.C.L. (London) to produce a new superconducting magnet assembly, within the geometrical limits of the present target dewar system, and with a guaranteed polarizing field of 1.25 T. We expect delivery of this system to IUCF for testing in the spring of 1987. In other developments, a great deal of work over the past year has gone on in parallel with the PPT microprocessor (in part because of the erratic behavior of the above-mentioned magnets), which controls and monitors target magnet operation. This controller should now be much more reliable in its operation (it is also now much more completely documented), after having undergone substantial revision both in terms of surge protection and the incorporation of more modern low-level logic circuitry.

Many of the difficulties associated with the target heat load arose in conjunction with deployment of the large (as opposed to the earlier small test samples) crystalline target array to be used in the CSB experiment. Solutions to these problems (some of which were mentioned in last year's report) have included: use of a smaller 5 cm x 7 cm (about neutron beam size) target, introduction of stringent shaft bearing cleaning procedures and elaborate target and target shaft balancing techniques, installation of additional baffles and cooling fans on the lower shaft bearings, and optimization of the liquid squirters ensure maximum cooling from the cold ^{3}He of the closed-cycle refrigerator. Other improvements over the past year of operation include the fixing of several persistant dewar leaks, increased pumping speed and additional radiation shielding around the target region, and revamping the ^{3}He plumbing and pumping system, including further improvements to a cryogenically cooled trap that enables long term operation without the system plugging. In order to improve the long term reliability of the target (particularly with respect to plugging from contaminant gases) a new hemetically sealed fore-pump has been purchased for the ^{3}He closed refrigerator system and will be installed soon. This pump has a somewhat larger pumping speed than the one presently being used, which should help reduce the target temperature.

Further target performance tests will focus on use of stiffer target shaft materials (to reduce heating effects arising from physical distortion of the lower target assembly upon cooling), room temperature maps of the non-normal field components (in order to understand more completely the size of possible systematic errors, as discussed above), and continued investigations aimed at decreasing the temperature attainable during polarization at increased target spinning rates. We hope that with the increased polarizing field from the new magnet system, and slightly lower operating temperatures at higher target spinning rates, to achieve a significant increase in target polarization over the average value (including relaxation effects during running) of 0.37 obtained with a polarizing field of 0.95T during the March run. In addition to these improvements, target crystal growing and Yb doping techniques have been made reliable. In off-line tests of a new target assembled from the latest batch of crystals properties very similar to the previous crystal batch were observed, including total polarizing times of ~3 hours and spin relaxation times of ~200 hours for a ~ 900 Gauss holding field. In fact holding times greater than ~100 hours do not gain us anything due to our 12 hour data acquisition cycle. We have in fact, recently observed holding times ≥100 hours with 600 Gauss fields, and it now seems quite likely that we will be able to run with such a reduced field (making accurate corrections for the defelection of recoiling protons in this field somewhat easier).

Considerable effort has also been expended on improving the performance and reliability of the multiwire proportional chambers (MWPC) and the multi-celled liquid scintillator neutron detectors used in the CSB experimental setup. The major advance in MWPC operation had to do with the small horizontal chambers, which during the long March run were very marginal in terms of holding voltage (tripping off repeatedly with beam when run at plateau voltage). The suspected cause of this problem was too small an anode wire to cathode plane distance, resulting in UV light generated during the avalanche reaching the anode wires and initiating the sparking.[5] Increasing this dimension (and thus more fully absorbing the light in the detector working gas) appears to have solved this problem. The large neutron detector arrays were drained of their liquid scintillator and front plates removed during a summer "work party" (many other nagging problems were also addressed). This allowed us to visually check (and improve) the phototube coupling on many cells as well as reposition the rear Alzac (thin highly polished aluminum) cell defining partitions, some of which had become dislodged, apparently through too virgorous bubbling of the scintillator liquid during routine maintenance of the detectors. All these efforts seem to have had a positive effect in terms of detector performance. Increasingly, the CSB/PNF detector arrays, and associated electronics and data acquisition hardware and software are becoming an extremely reliable, sophisticated, and flexible facility with which to carry out the production CSB running. It is apparent that it will see use in a number of post-CSB experiments as well.

1) See contribution to this report on pg. 1.
2) IUCF Scientific and Technical Report 1985, pg. 12.
3) G.P. Felcher et al., Phys. Rev. B <u>29</u>, 4843 (1984).
4) J.G. Sowinski and L.D. Knutson, in preparation.
5) K. Solberg, private communication.

<u>Computer Systems</u> - D. DuPlantis

The computer facilities have undergone modest changes in the last year. In fact, if it weren't for carry forward funding and purchases made through other grants, there would have been no significant equipment purchases this year.

A high speed data link to the central campus computing facility was established during the year. Operating at 57.6 kilobaud, it provides access to major world-wide communications networks. Future access to large laser printing systems and other sophisticated peripherals, beyond the scope of this laboratory, will be possible.

A small laser printing system was installed on node Venus. Providing support for daisy wheel printing, Tektronix emulation, and TeX output, it has proved to be a popular output device. Unfortunately, its reliability has been poor, and current plans call for the laser engine to be replaced this year.

We conducted a search for the next generation of graphic terminals for general use in the laboratory. After evaluating many devices, as well as making inquiries at other labs, we decided on the Graph-On GO-250 terminal. Centainly, not the least expensive terminal esamined, it was selected on the basis of matching most of our technical requirements. Because of its high video bandwidth, it does not support a direct hard copy unit.

Two microVAX II computers were purchased under separate grants. Their primary purpose is to support data replay, but they can be used for acquisition, if necessary. Each was purchased with 9 Mbytes of memory, TK50 console support, and an RA-81 disk. A Kennedy 6250 BPI tape drive, model 9401, was added to one system, while the other came with a DEC TSV)5 drive. A favorable campus purchasing aggrement made it possible to buy the large disks along with the systems. These computers were added to our laboratory Ethernet system during initial installation.

The laboratory will have to make a commitment to support the computer systems on a continuing annual basis. It will soon be prudent to upgrade the 8600 computer to an 8650, while that option still exists. disk space is about to become a serious problem on the analysis computer. Additional small acquisition systems will be needed to replace the Harris computers and support the expansion of the experimental areas in the laboratory.

Summary of IUCF Computer Systems

Node name:	Location	CPU	Memory:	Disks:	Tapes:	Comments:
VENUS	Main computer room	8600	12 MB	3 RA-81	2 TA-78	Analysis Computer
APOLLO	Main computer room	11-750	5 MB	1 RA-81	2 TU-78 2 TU-77	On line acquisition MBD in control room
ZEUS	Main computer room	11-750	3 MB	2 RM-80	1 TU-77	On line-acquisition MBD in control room
HERA	Cooler computer room	11-750	4 MB	1 RA-81	1 TU-77	On-line spectrometer MBD front-end
"SYSTEM B"	Control room	Harris	192 KB	1 28 MB	2 Lo den	Last generally available Harris computer
"SYSTEM C"	CSB Hut	Harris	288 KB	1 28 MB	2 lo den	PNF experiment use
PAN	Mail computer room	μVAXII	9 MB	1 RA-81	Kennedy 6250	Off-line replay
URANUS	Main computer room	μVaxII	9 MB	1 RA 81	TSV05 1600	Wire chamber lab, Off-line replay
PLUTO	Cooler control room	Micro 11	.5 MB	1RD-52	none	Cooler control room
DIANA	Main computer room	PDP11/44	1 MB	1 70 MB	Kennedy	Cyclotron control computer

Data-Acquisition Software Status - R.N. Yoder

The VAX computers are now used for data-acquisition on most experiments, the major exception being the CSB experiment (E80), although replay of the CSB data has been set up for the VAX computers. Two programs are currently installed for data acquisition and replay on the VAX computers: XSYS (an IUCF-modified version of the TUNL program) and Q (from LANL). Q has been used for all of the K600 development and K600 experiments.

A few significant improvements have been made to XSYS, as well as a number of miscellaneous additions. The ability to convert RAQUEL event tapes was extended to accept the CSB format, and provision was made for user-written event-conversion subroutines in Fortran to handle data from outside laboratories. Control of beam polarization has been incorporated into the data-acquisition program, so that automatic spin flip may be specified as part of the data-acquisition program parameter specification; the spin-state codes are automatically inserted into the event-data records.

Perhaps the most important addition to XSYS is the condition table, automatic condition testing routines and automatic histogramming routines. This set of routines permits one to specify the analysis in terms of a condition table and a histogram table, along with 1D and 2D gates which may be set using the display package. For applications where maximum speed of analysis is essential, the EVAL event-analysis language has been upgraded and user-written EVAL programs may interact with the condition-testing routines.

The Q system at IUCF is basically unchanged from LANL, except that the histogram display package has been revised to use the Unified Graphics System. A 2D window package which permits 2D windows to be drawn with arbitrary shape has been incorporated. The Unified Graphics System is also used by XSYS; it supports all of the graphics terminals and hardcopy devices, and is easily extended to new devices. Automatic beam-polarization control by Q is currently being implemented.

A separate program was developed to simulate a cyclotron control-system station on a VAX terminal, for remote control of K600-related magnetic elements (through DECNET to the PDP-11/44).

Both XSYS and Q are presently installed and operating on the VAX 8600, (3) VAX 750's, (2) MicroVAX's; acquisition is supported on the 750's, and will soon be working on at least one of the MicroVAX's.

Germanium Detector Development - D.L. Friesel and K. Komisarcik

The NASA funded IUCF-LBL collaboration to study the charged-particle radiation damage rate effects in high-purity germanium detectors, which was outlined in last year's report, is continuing. Preparations for the experiment (E267), which is expected to run in early 1987, are nearly complete. Three vertical dipstick cryostats, each capable of holding two high-purity germanium planar detectors, were constructed and tested at LBL. Each cryostat has two external FET charge-sensitive preamplifiers that have two gain settings. The high-gain setting is used when gamma rays are being counted, and the low-gain setting is used when protons or other charged particles are being counted. On one amplifier associated with each cryostat, the option of measuring the current instead of the individual charged-particle is available. This allows simultaneous, independent measurements of the charged-particle fluence (and flux). The cryostats, which must be capable of in situ annealing up to 150° C and low temperature annealing, were subjected to extensive temperature calibrations. All three cryostats are thermally identical.

The six 1 cm thick, 2 cm diameter high-purity Ge planar detectors were also fabricated. Two detectors made from n-type Ge are in one cryostat, two detectors made from p-type Ge are in a second cryostat, and the third cryostat holds one detector made from each type of Ge. A pulser resolution of 1.3 keV was measured for the completed cryostat systems.

While the six high-purity germanium detectors and their cryostats were being fabricated at LBL, the development work required to provide the diffuse, low intensity beams needed for the experiment was performed with the IUCF cyclotrons. The experiment called for a uniform proton flux variable from 1×10^2 to 1×10^6 protons/cm^2/sec over a diameter of about 3 cm. The initial plan was to deliver such a beam to the Hot Cell, which accepts beam from the cyclotrons without momentum analysis, and which had been used previously for experiments which required similar, but higher intensity beams. In this experiment, it is also important to maintain a constant particle flux for several 8 hour shifts at a time. The major problem to be overcome, then, was to deliver these low intensities (3×10^{-16} Ampere) from the cyclotrons while providing the operator with a reliable signal with which to tune.

During the year, several beam development runs were carried out at the discretion of the laboratory director. During the first run, two shifts were used to test a recently developed low intensity beam monitor and to try a new plan for delivering low intensity beam of uniform cross section to the "Gamma Cave" target room. A 160 MeV proton beam was delivered to the Gamma Cave via the momentum analysis system in beam line 3, which is followed by two 45° bends separated by about 15 meters in beam line 4. (These areas and beam line elements are illustrated in Fig. 5 in the report on accelerator performance.) A 1000 mg/cm^2 lead foil (approximately 0.75 mm thick) was placed on a target ladder in a cross located at a beam waist about midway between these 45° bends. A 160 MeV proton beam looses 2.6 MeV in the foil. In addition, the energy and angle straggling of the beam passing through the foil causes a significant defocussing of the beam. The 45° bend following the foil insures that only protons reach the target area.

The result of this run was that a proton beam variable in intensity from about 50 to 1×10^6 cm^{-2}sec^{-1} was delivered to the Gamma Cave target over an area of 25 cm^2. The beam spot size at the target was a 5 cm square with a uniform particle flux over all but the outer few mm, where the flux appeared to fall off rapidly. The flux reduction in the vertical direction appeared to be worse than in the horizontal direction, although the central 20 cm^2 was uniform in flux to better than 20%. Intensity measurements on target were made with a plastic scintillator monitor detector and with a high-purity germanium detector (#280 - 1.0) which had been used previously for several radiation damage studies by our collaborators at LBL. A count rate meter from the germanium detector was provided to the cyclotron operator for tuning purposes. Particle flux (beam intensity) was controlled by the use of the vertical chopper slits in the transfer beam line to the injector cyclotron. The low particle fluxes achieved on target are also helped by the fact that the beam intensity reaching the target is 40 times less than that extracted from the cyclotron because of the energy and angle straggling from the lead foil in the beam line. Using the count rate meter, the operator was able to maintain any particle flux requested during the run using a vertical steerer upstream of the chopper slits in beam line 1 and the count rate meter. Stability was good.

A second development run was made to reproduce the above results, test the long term stability of the system, and to investigate the possibility of using beam splitting to continue these radiation damage studies after the proposed experiment is completed. This second run lasted 6.6 shifts, during which time the above results were precisely duplicated. Detector #280 - 1.0 was then placed in the particle beam and subjected to a fluence of 3.8 × 10^8 particles/cm^2 at a flux of 5 × 10^3 particles/cm^2/sec. The gamma ray resolution degradation with fluence was monitored during the run, and is shown in Fig. 15. Also shown in this figure are similar data taken for this detector at 74 MeV with a flux of 2.1 × 10^4 particles/cm^2/sec. A comparison of these data shows little difference in the rate of resolution change with particle fluence for these two particle flux rates. This is a preliminary result, and data will be taken over a much wider range of particle fluxes.

The last beam development work for this experiment was made to test the affects of beam splitting on the low intensity beam properties. During this run, the proton beam was pulsed at 1 kHz using the beam splitting system recently developed at IUCF,[1] which causes a 1 kHz pulse structure to be superimposed on the natural cyclotron beam pulse structure. An average particle flux at the detector similar to the previous test runs was achieved. However, the variation of the flux with cyclotron tune was larger than desired, and further development is needed to use the low intensity beam with beam splitting. If this development is eventually successful, then several radiation damage and anneal experiments can be carried out using a small amount of beam split from another user doing experiments at IUCF. This ability, of course, is also important to several applications related radiation damage studies of interest to other users. The details of how to adjust the particle flux at the germanium detector target independently from the other user, who will necessarily require beams of much higher intensity (<200 nA), also needs to be explored.

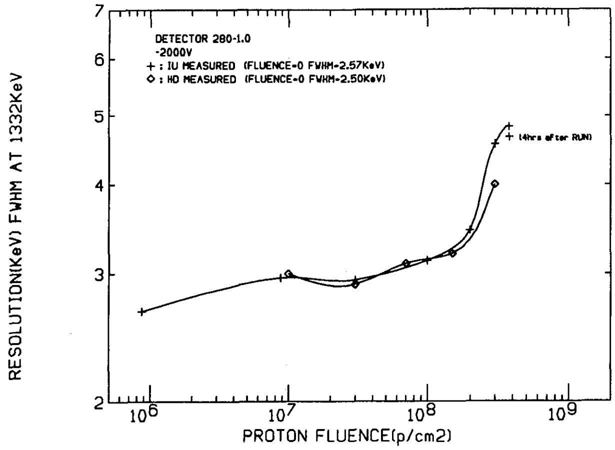

Figure 15. Gamma ray resolution as a function of proton fluence for 160 MeV protons and 74 MeV protons.

The use of high-purity germanium detectors for experiments continued at IUCF this year at about the same pace experienced in previous years. Nine detectors were exposed to 480 hours of beam for 5 experiments in 7 cyclotron runs. Two detectors experienced failures of the boron ion implanted contact and were returned to Berkeley for repair. One of these detectors, #172-3.1, has been in service since 1976 without a single problem. Both detectors have been repaired. There are 14 high-purity planar detectors with thicknesses ranging from 5 to 20 mm and 4 detector cryostats available here for experiment. These detectors and their properties are listed in Table V.

Table V. IUCF Germanium Detector List

Detector No.	Ge Type	Thickness (mm)	Impurity Concent. ($X10^{10}cm^{-3}$)	Depl. Bias (-V)	Total Hrs Beam Time	Li Layer Depth mm
			TRANSMISSION DETECTORS			
501- 9.3	n	~ 2.0	4.4	100	352	NA
501- 9.6	n	~ 2.0	4.4	100	488	NA
551-11.8	n	5.18	7.5	1100	200	NA
475-10.7	n	9.07	3.3	1700	1404	NA
477- 6.1	n	9.52	2.0	1000	928	NA
501- 6.7	n	10.77	2.7	1800	2155	NA
474- 5.8	n	~12.0	1.6	1600	469	NA
550-10.0	n	~13.0	2.4	2200	1210	NA
517- 9.7	n	~15.0	1.2	1500	2120	NA
			STOPPING DETECTORS			
172- 3.1	p	10.6	0.98	350	721	1.23
514- 7.0	p	~15.21	1.86	1600	2482	3.90
514- 8.6	p	14.94	1.10	1200	2549	3.60
525- 8.6	p	~12.0	1.10	1000	56	1.06
602- 6.1	n	~20.0	0.75	1700	289	2.80

Wire Chambers - K. Solberg

i) Multiwire Proportional Chambers (MWPC)

The small x-chambers for the CSB experiment developed persistant sparking problems. The problems were solved by increasing the cathode to anode spacing. The original cathode to anode spacing was 3.18 mm. the spacing was increased to 4.76 mm.

Dan Low has designed and built three MWPC's. Each MWPC has both an x and a y plane. The wire spacing for each planed is 4 mm. One plane has 60 active wires and the other has 80 active wires. This gives an active area of 240 mm by 320 mm. The chambers have delay line readout. The delay line is solid state delay line chips witha two nano-second delay between each wire. The chamber was constructed so that the delay line can be segmented into any combination of ten wires per delay line. These detectors will be available for general lab use when E-274 is completed. E-274 is scheduled to be completed this summer.

11) Wire Winding Machine

There are still some flaws in the wire winding machine. These flaws lead to wire placement errors which caused unusual spectra mentioned in the K-600 report. The flaws will be fixed shortly.

iii) Gas Handling system

All of the parts for the gas pressure control system are in house and construction is underway.

iv) Gas Mixing System

Flow controllers for a gas mixing system are in house. These controllers control the flow rate to within + 2% of the reading for up to four separate gases. This will allow us to test different gas mixtures easily.

Scintillation Lab - K. Komisarik

During the past year, 57 scintillation detectors were built or repaired. Included in this total were two sets of large ΔE-E detectors for the d+p study, two prototype, 4 inch thick, wedge shaped detectors for the first Cooler experiment, and eight 5 inch diameter by 5 inch long liquid scintillators for E291, (p,π^+). A set of 1/8", 1/4" and 1/2" detectors have been constructed for the K600 focal plane. These have an active area of 4" × 48" and are constructed such that they may be used in any of the three dispersion modes.

Early in the year a Monte Carlo program which simulates the light transmission through a variety of shapes of scintillators and lightpipes was written. This program also allows the use of five different reflective coatings. Photons are randomly started throughout the scintillator. The intensity and pathlength of those photons collected by the PMT are stored and then histogramed in various ways. From these results, information on timing, energy and position resolution can be obtained. Most importantly, time response or light collection efficiency can be quickly maximized by changing the shape or reflective coatings of the detector. Figure 16 shows a simple detector with a cylindrical scintillator mounted to a conic lightpipe, which in turn is mounted to a PMT. Figure 17 shows the light output versus pathlength of the photons when the detector is wrapped in aluminum foil. Figure 18 shows the same detector covered with white paint. Two thousand photons were traced through each detector. Very different results arise from the two wrappings. More light is collected by the PMT in the case of the painted detector. However, most of the light arrives sooner at the PMT when the detector is wrapped in aluminum foil.

The output of this program has been compared to the actual response of many detectors and the two agree very well to the ten percent level.

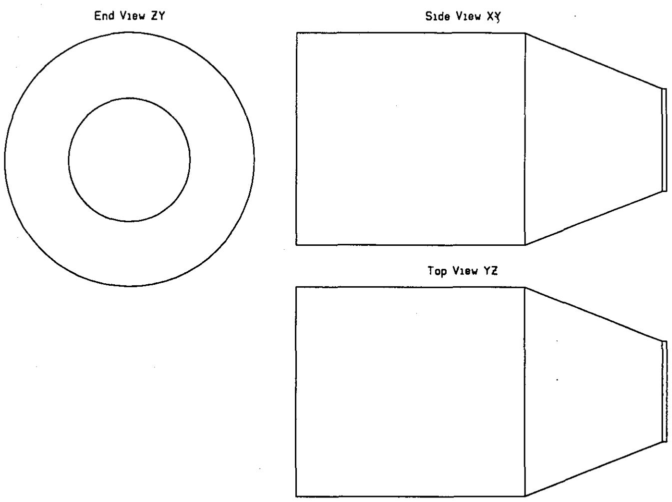

Figure 16. X, Y, Z view of a detector with a cylindrical scintilator, a conic lightpipe and a PMT.

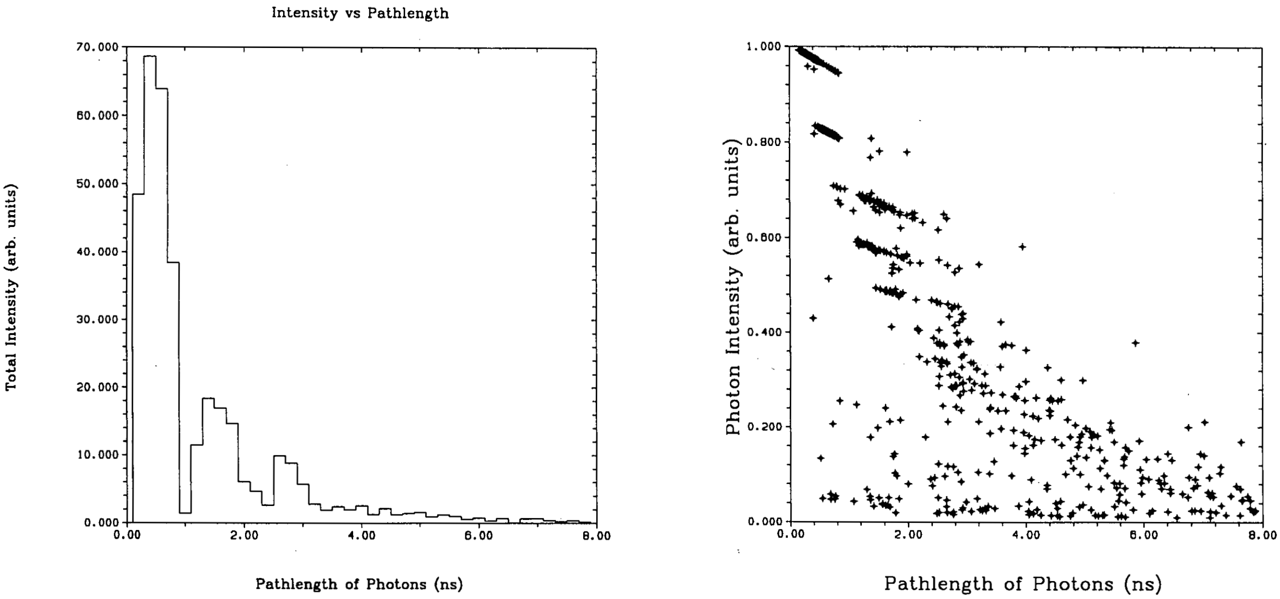

Figure 17. Dot plot and histogram of the intensity versus the time it takes to reach the PMT when the detector is wrapped in Al foil.

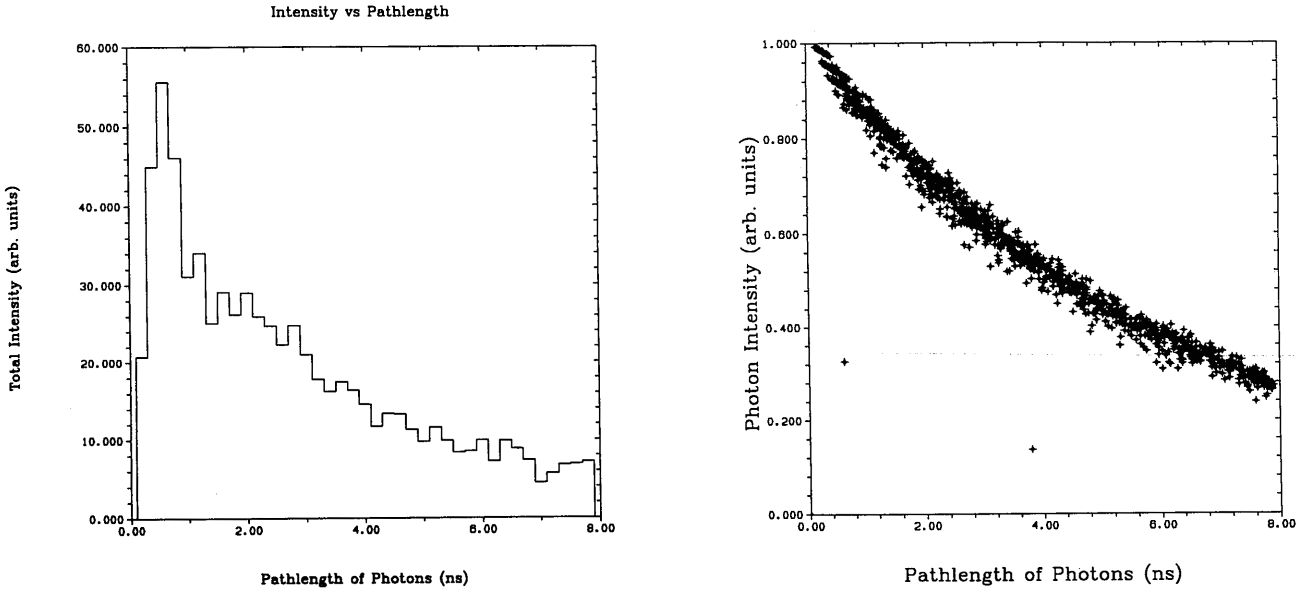

Figure 18. Dot plot and histogram of the intensity versus the time it takes to reach the PMT when the detector is coated with white paint.

Target Lab Technical Status - W. Lozowski

Target preparations for 1986 included: ^{6,7}Li, ^{7}Li$_2$O, ^{7}LiOH, ^{11}B, CH$_2$, CD$_2$, ^{12,13}C, V^{14,15}N, C$_3$H$_6$^{15}N$_6$, V$_2$O$_5$, Al$_2$O$_3$, Si ^{18}O$_2$, ^{23}Na, ^{24,26}Mg, Al, ^{28,30}Si, ^{31}P, ^{40}Ca ^{35}Cl$_2$, ^{34}S, ^{40,41}CaCO$_3$, ^{45}Sc, ^{50}Cr$_2$O$_3$, ^{59}Co, ^{71}Ga, ^{24}Mg, Ag, ^{141}Pr, ^{156}Gd, Ta, Au, ^{206,208}Pb.

Target development highlights for 1986 were:

1) A self-supporting target of ^{71}Ga ^{24}Mg (12 mg/cm^2 ^{71}Ga, 3 mg/cm^2 ^{24}Mg) was produced by a novel method. With many necessary steps omitted for brevity: the ^{71}Ga was chilled with LN, ground with a special mortar and pestle and distributed in a 1/2" dia. circular area imprinted on the surface of a rolled ^{24}Mg foil. The alloy formation took place on a graphite support, under argon in a quartz tube furnace at 400° C. Although the target was thin and fragile, it was supported at the edge by the Mg foil and was ready for the experiment when it came from the furnace. The target was reported to have worked very well for (p,n) measurements.

2) Material for a 180 mg/cm^2 ^{40}Ca^{35}Cl$_2$ pressed powder target was produced from Na^{35}Cl and ^{40}CaCO$_3$. To begin, a water solution of the Na^{35}Cl was passed through a "strong acid type" ion exchange resin to produce H^{35}Cl. Careful attention to the resin bed volume, backwashing, concentration of the Na^{35}Cl solution, and flow rate resulted in an efficiency of 96% for the exchange (as determined by titration with NaOH). The H^{35}Cl was reacted directly with the ^{40}CaCO$_3$ to produce ^{40}Ca^{35}Cl$_2$ • 6 H$_2$O (after evaporation of the solution).

Complete drying of this compound cannot be achieved with heat and/or vacuum without risking a significant loss of ^{35}Cl$_2$. Fortunately, a reference in the chemical literature suggested the use of 2, 2- dimethoxypropane for the dehydration of hydrated halides. This reagent was effective and left no residue. The pressed powder target was reported to be free of water and other contaminates.

3) V^{15}N targets were produced both as nitrated vanadium foil (19 and 40 mg/cm^2) and vanadium nitride pressed powder (32 mg/cm^2) targets. A first attempt during the summer resulted in targets with a high oxygen content; however, late in the year, a second effort produced foils with vastly improved (p,π^+) spectra.

The lab crucible furnace was turned on its side and modified to accept either one-open-end or both-opened-end alumina tubes for the 1200°C reaction with ^{15}N$_2$. Because vanadium proved to be an excellent oxygen getter at temperatures as low as 400°C (preferentially to nitrogen), the critical design problem was to produce a 1200°C high vacuum tube furnace which did not outgas or leak appreciably when valved off for four hours. A baked viton o-ring was used to seal a water-cooled aluminum end cap. A water cooled brass ring was clamped directly to the furnace tube as further insurance against overheating the o-ring. The furnace was positioned as close as possible (~ 20 cm) to the high vacuum port of the vacuum evaporator and the minimum number of valves and connections were used.

Before loading the tube with vanadium, it was baked at 600°C and 1.2×10^{-7} Torr for 17 hours. After cooling the furnace to 150°C and loading it, 1.2×10^{-7} Torr was maintained in the system until 1000°C was attained. A flow meter was used to admit the amount of ^{15}N$_2$ which if unreacted, would result in a positive pressure of 10 psi within the tube at 1200°C. After the four hour reaction time, the tube was allowed to cool overnight. Before-and-after weighings of the foils and powder indicated >95% conversion efficiencies. This procedure was a high risk venture (i.e., insufficient time for methodical development), but early in-beam results indicate that it worked.

4) Self-supporting e-gun evaporated ^{11}B targets were attempted for the first time in the lab and successfully produced. Of several parting agents, we found $BaCl_2$ to be the best. The metal is brittle and while none of the substrates used (Ni, Al, stainless steel) yielded good foils consistently, targets of 150 $\mu g/cm^2$ to 1 mg/cm^2 were mounted.

5) An efficient technique for producing 300 $\mu g/cm^2$ $^{206,208}Pb$ targets with very low oxygen content and excellent physical properties (high reflectively, very few pinholes, 2 cm dia.) was developed. Only 13.5 mg of metal was required to produce each uniform target. The Pb was vacuum evaporated onto 1.1 mg/cm^2 styrene film positioned 3.5 cm over the hearth of the Varian e-gun. The styrene was dissolved off in dry chloroform to yield self-supporting Pb foils.

The key to achieving a close evaporation distance was the cooling of the back side of the styrene with ultra-pure helium. A small package with a controlled flow rate was fabricated for this purpose. Although a detectable amount of carbon was present in the targets, the experimentalist was pleased with them.