A new alignment support for the entrance quadrupole and aperture cassette has been fabricated to improve ease and reproducibility of alignment of these devices. A new mounting arrangement for the internal Faraday cup was devised. The cup now mounts to the wall of the scattering chamber rather than the rotatable table. This frees the table for use with diagnostic slits or other purposes. Television readout of the spectrometer angle markings on the track has been installed and angle scales attached to the track from 0° to 30°. Scales to cover the entire angular range of operation of the spectrometer are fabricated and awaiting installation.

A crane and hoist assembly was designed, fabricated and installed to ease handling of the external Faraday cup beam pipe when changing from internal to external cup configurations or vice versa. Rearrangement of the beam dump and room shielding to better accommodate spin measurements with the K-600 spectrometer is being actively considered.

7. Beam Swinger Facility (Neutron Time-of-Flight Facility)

Several (p,n) experiments are performed with the beam swinger facility each year. Completion of the Cooler ring has limited measurements at very large angles (greater than 75°) to flight paths of about 10 m. The zero degree flight path has been paved with asphalt and a wheeled carriage installed on the zero degree detector hut.

Five telephone poles have been installed along the side of the zero degree flight line to transport additional AC power to the hut, which may be used at any distance up to 200 m from the target. These improvements were made to eliminate a problem with marginal power and allow placement of a MICROVAX computer in the zero degree hut for better data acquisition. A telephone line has been provided along the zero degree flight path so that a standard telephone may be used in the hut. A pad for a house trailer was built near the 40 m distance of the zero degree line and a trailer temporarily used for an experiment. Installation, near the north wall of the accelerator building, of a superconducting solenoid between the swinger magnets and the detectors on the zero degree line for precession of neutron spins is planned for late 1988.

THE HIGH RESOLUTION K600 SPECTROMETER

G.P.A. Berg, L.C. Bland, D. DuPlantis, C.C. Foster, D.W. Miller,
P. Schwandt, R. Sawafta, K. Solberg, and E. Stephenson

A. Introduction.

Early last year the commissioning of the K600 Spectrometer was completed and the first nuclear physics experiments started. Development of the spectrometer continued in parallel with the performance of approved experiments.

A considerable part of the development time was dedicated to the testing of equipment and procedures necessary for scheduled experiments, e.g. coincidence detectors in the scattering chamber, small angle proton scattering and 0° (^{3}He,t) reactions.

Development beam time (partly during scheduled experiments) was also used for establishing a faster procedure for dispersion matching and focussing and for studies of those focal-plane aberrations which can be corrected in software. These runs were part of a program to reduce spectrometer and detector setup time.

During the last year, 6 approved K600 experiments were completed. These experiments are presented in separate contributions to this report. Four additional experiments were started or received time to test feasibility. Twelve approved experiments were not scheduled, partly because of beam time priorities, and partly because additional development is needed.

B. K600 Development

Highlights in K600 development include the following: 1) Successful dispersion matching and focussing on target for kinematical k-factors up to 0.09 was accomplished. 2) Feasibility of coincidence experiments between the K600 and surface barrier detectors in the scattering chamber was demonstrated by L. Bland and his group. 3) Feasibility of (^{3}He,t) reactions at 0° and 200 MeV incident energy, combining the unique capability of high resolution and energy for this charge transfer reaction was shown. 4) Time saving procedures for dispersion matching, resulting in about 2 hours per k-factor were developed. 5) Resolution of 17 keV at 200 MeV, reaching the design limit of the spectrometer was achieved.

The installation and beginning of commissioning of the Focal Plane Polarimeter is described in an independant contribution to this report.

C. K600 Spectrometer Operation.

The K-coil in dipole 2 is operational up to 200 A. This will correct a kinematic factor of k=0.082 at a field of 9.2 kG. Higher currents cannot be permitted due to design limitations. It is possible to correct larger k-factors and other aberrations of higher order in focal plane angle by software which is available online in the Q and XSYS data aquisition systems. These corrections depend on accurate angle measurements and may result in some loss in resolution for large corrections.

Cycling of the K600 dipole field has been studied. Analysis of the data shows that, with a simple polynomial calibration, the field may be predicted to better than 50 G, for all fields above 3.6 kG, if the field is first set to the maximum values of 17.4 kG for dipole 1 and 17.6 kG for dipole 2 for 20 min and then decreased to the desired value. The "target" currents are provided by CYCLO, a program that allows adjustments of Beam Line 8 (BL8) and K600 parameters.

D. K600 Spectrometer Hardware Development.

With the redesign of the temporary external beam dump line, it is now possible to set spectrometer angles as far forward as 14° in the external beam dump mode. This design makes full use of the cutouts in dipole 1 and the quadrupole and hexapole magnets. The new pipe imposes tighter constraints on the direction and size of the beam. A setup procedure has been defined to ensure that the acceptance requirements of the K600 and BL8 are met simultaneously. With an internal cup in the scattering chamber, angles down to somewhat below 6° are feasible if special efforts are made.

Installation of a new sliding seal at the scattering chamber eliminated the leak problem during angle changes. A new fixture allows lifting of the chamber lid without removing the target ladder from the air lock chamber. The angle of the K600 relative to a zero mark has been calibrated optically and can be measured with a precision better than 0.01° by a mechanical readout and an angle encoder. The scattering angle uncertainty is therefore dominated by beam direction, which can vary a few tenths of a degree depending on the tune.

A sturdier lead shielding cart between the focal plane and beam line has been constructed. This shielding is attached to and travels along with the K600 carriage. It can be oriented to shield the focal-plane polarimeter detectors, which are mounted on an addition to the K600 support frame behind the medium dispersion focal plane.

The Geneva drive of the six K600 entrance apertures can now be controlled locally and remotely from the K600 control station, allowing aperture change without entry into the K600 area.

For the (^{3}He,t) experiment at 0° a removable beam stop was mounted inside dipole 1. This device allowed the ^{3}He beam to be stopped and its current read out without activating the dipole walls. For future experiments a more permanent externally movable beam stop will be available to allow adjustments of the K600 spectrometer near 0° without losing the beam on this stop.

Remote control of the target ladder position and angle has been designed and fabricated. A new aperture cassette mounting platform which will permit more controlled alignment and a flexible vacuum coupling to the K600 entrance quadrupole have been fabricated.

E. Beam Line 8 Improvements.

Considerable development effort of the BL8 beam transport system is dictated by the fact that the beam properties are crucial parameters in the high resolution performance of the spectrometer.

The resolving power of $p/dp > 3\times10^4$ of the system is ensured by a 0.55 mm wide horizonal slit in the object position of the beam-line analyzing system, which is the old QDDM spectrometer system. This object slit is mounted on a remotely controlled drive allowing quick change to one of three mounted slits. About 60% of the beam can be focussed through the 0.55 mm wide slit. A 1.1 mm wide slit with better than 90% transmission can be used when more beam current is needed, at the sacrifice of highest resolution. The thickness of the brass object slits is chosen to degrade the beam in the slit jaws by 1.0% in dp/p, corresponding to a deviation of 3 inches close to the focal plane of the analyzing system. The degraded beam is stopped in a flange ahead of quadrupole 7 while the main beam continues to the target.

The original QDDM quadrupole (Q6) developed a water leak and was replaced by a standard beam line quadrupole. The reduced acceptance of the new quadrupole is tolerable for the beam emittance. Also quadrupole 9 in BL8 was replaced to allow the higher field gradients needed for 200 MeV protons.

All quadrupoles in BL8 from Q4 to Q10 and the K600 quadrupole have been equipped with Hall probes to set fields without special procedures to avoid hysteresis. This allows fast and reproducible field settings to a precision of about 1/1000, and has been helpful in the dispersion-matching procedure. The Hall probes, mounted on the pole tips of the quadrupoles, operate with a common stabilized current source, and the Hall voltages are amplified and sent to the controls computer. The outdated NMR system for bending magnet 3 (QDDM dipole) failed and was replaced by a new system.

Development beam time was devoted to the empirical study of BL8. Rules were established that allow more accurate and rapid setting of the focus and dispersion on target which is necessary for the resolution performance. It was found that matching is obtained more quickly when the correct focus is established first. In the diagnostic method for matching, a full target is now used instead of the double-strip target used initially. The full-target method gives the same information (the correct focus and dispersion on target) and leads to a good setting more rapidly. Two positions on target are defined by two software windows in the target angle space. The advantages of this procedure include the higher count rates allowed by the window technique and the insensitivity to beam position on target.

We also investigated the angular dispersion of the beam, with the objective of tuning it so that for different beam rays across the target, the incident angle changes in such a way that the scattering angle remains the same. This is important because large beam spots on target, consistent with a dispersion matched beam, may lead to a large spread in scattering angle. To diagnose this effect, we moved the beam with the QDDM dipole and looked for changes in the measured cross-section and analyzing power. At 100 MeV this angular-matching condition is met with 40 A of current in quadrupole 7. This choice did not scale to 200 MeV, however, and further investigations are necessary.

Since space limitations prevent quadrupole 7 in BL8 from being mounted at the focal plane of the energy analysis system (old QDDM), and decoupled adjustments of spatial and angular dispersion at the target cannot be made. Independent tuning is desirable since spatial dispersion matching provides the high resolution of the K600 spectrometer, and a correct angular dispersion will insure that cross sections will be stable against small fluctuations in the cyclotron beam energy, conditions that often require separate adjustment. (These conditions have been met so far only for 100 MeV protons.) Transport calculations have shown that it is possible to decouple these adjustments by moving the image of the object slit of the analysis magnet using the kinematic coils of the QDDM spectrometer. (An upstream shift of 17.4 cm is needed.) If tests with beam show that this approach is effective, new sets of dispersion matching values will be needed.

F. Focal Plane Detectors and Electronics.

Drift-time irregularities initially observed in the vertical drift chambers (VDC) at lower voltages were traced to irregularities in sense wire spacings. New wire planes have been made with smaller tolerances on wire spacing, and the problem has not recurred.

The detector efficiencies were measured in small steps across the focal plane and found to be constant. For 200 MeV protons an efficiency of 89% was measured. This includes all events where both wire chambers measured n-wire hit events ($n>2$) in coincidence. With this value, good agreement was obtained with measured cross sections for p + p and p + ^{12}C elastic scattering.

The sparking problem with the ethane-argon gas mixture initially used in the vertical drift chambers made disassembly and cleaning of the wire chamber necessary after one year of operation. This problem has been solved by using a mixture of equal parts of isobutane and argon, bubbled through refrigerated n-propanol. The new gas mixture results in spreading of the short drift times. In order to avoid errors in the position determination resulting from the assumption that drift distance and time are proportional, drift distance to time calibrations can be measured to allow better position measurements.

To replace the prototype short focal plane plastic scintillation detectors initially used, a set of 4 long detectors was constructed which cover the full focal plane. The light output of these detectors is collected at both ends by photomultipliers, and the timing signal (obtained by a mean-timer circuit) is independent of the position of the particle hit. The timing information is needed for the VDC drift time measurements and to provide particle identification information from the energy loss signals in both detectors. The scintillator thicknesses available are 1/16″ 1/8″, 1/4″, and 1/2″ and the ability for sliding thin absorber sheets between successive detectors gives flexibility for particle identification and background reduction.

The electronics of the focal plane detector system was reorganized and improved. A second level of coincidence was added that may be used for experiments that involve a slow coincident or veto signal. If this coincidence is not triggered, focal plane event processing is halted, the modules cleared, and the event trigger to the CAMAC crate suppressed. The CAMAC modules were rearranged to allow a fast clear of the wire chamber multiplexers via the CAMAC crate. As a permanent addition to this system, the hit multiplicity of the front and rear wire chambers may be used as a part of this second coincidence level. This prevents the processing of unwanted events that do not trigger the wire chambers. Additional signal cables between the K600 and the HERA station give needed flexibility for special electronics setups.

G. Data Aquisition Software.

A second data acquisition package has been constructed for the K600 using the XSYS system. Because the analyzer program has been written in EVAL (simplified machine language), it runs a factor of 5-10 times faster than a similar Q system setup. The drift time to distance calibration mentioned above makes the recovery of 2-hit events in the VDCs possible and improves the chamber efficiency by several percent. Polynomial fits are included to correct spectrometer aberrations and to reconstruct the target angle from the measured position and angle in the focal plane.

The original Q data aquisition system has been modified to the particular needs of spectrometer experiments. This includes identification and sorting of data according to spin state and handling of coincidence detector information.