tron polarimeter, for which the long dimensions of the segmented detectors may be oriented at any angle between vertical and horizontal.

A liquid nitrogen cooled gas cell was built to go downstream of the usual swinger target location. This cell allows the use of gas targets of significantly increased density.

Considerable work was done on the maintenance and repair of the detector huts. Earth was removed on the west side of the zero degree flight line to improve access to detectors in huts positioned along that flight path. A vertical misalignment of a beamline quadrupole which had caused difficulties in tuning beam to the swinger was corrected.

K600 SMALL ANGLE DEVELOPMENT

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The small angle capability is the last major K600 development project. This report describes the status of the projects and the problems which have to be solved before nuclear reactions can be measured at very small scattering angles.

1) For angles $\Theta \leq 3°$ the beam transmission mode can be used for particular reactions. Calibration data are needed to determine scattering angles and solid angles. This mode was also used as a diagnostic tool to develop a clean and halo-free beam. This is necessary to reduce the background in the focal plane.

2) A septum magnet is necessary to make use of the "5°-port" provided in the K600 quadrupole as seen schematically in Fig. 1. Also needed are modifications to the scattering chamber and the construction of a support structure and vacuum chamber to house the magnet. Particular consideration must be given to the fact that the K600 can run in a variety of different modes which have to be interchanged quickly between experiments or even during the same experiment.

Considerable progress has been made in the past year towards the solution of these problems. This brings us closer to the scheduling of several approved experiments.

Transmission mode and halo-free beam:

The transmission mode was used to develop a reproducible beam line tuning procedure and to identify hardware improvements necessary to provide a halo-free beam. Fig. 2 shows

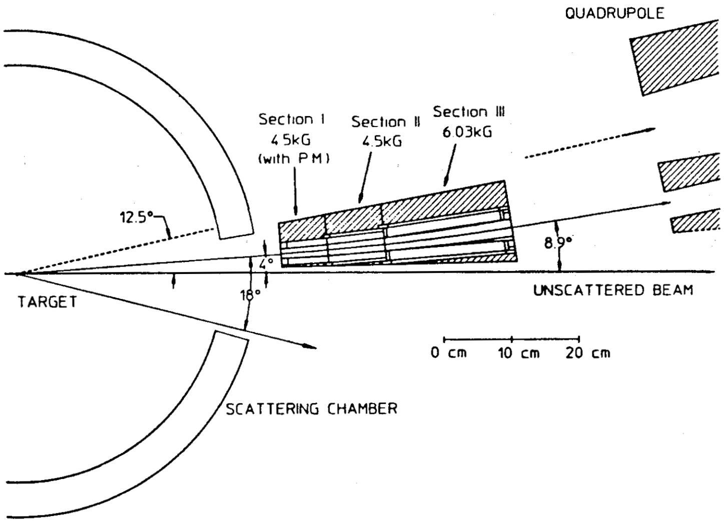

Figure 1. Hybrid septum magnet fitted between the existing scattering chamber and K600 quadrupole. Rays from the target are shown for the beam, a 12.5° ray into the normal quadrupole port and a 4° ray into the small angle port.

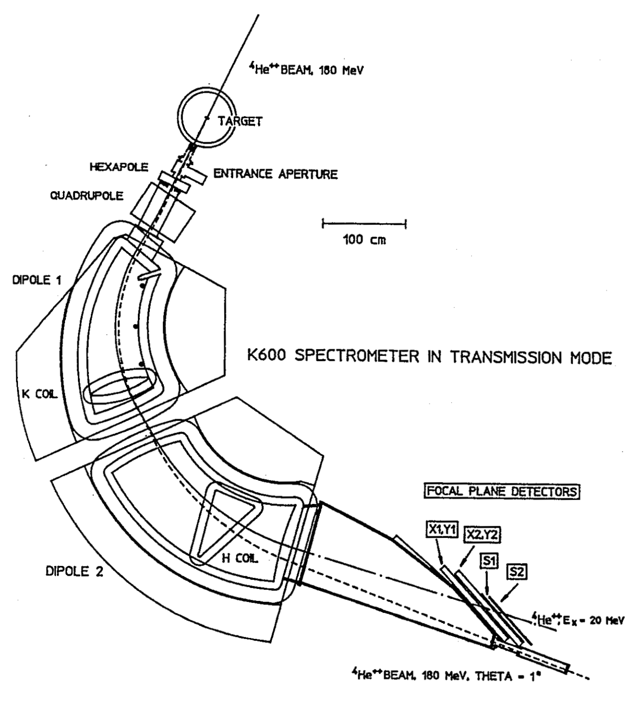

Figure 2. K600 spectrometer in beam transmission mode. The beam (dashed line) enters the spectrometer at $\Theta = -1°$ into the Faraday cup at the high momentum side of the focal plane while scattered alpha particles of 20 MeV excitation energy are shown entering the spectrometer at $\Theta = 0°$.

the K600 in this mode for 180 MeV alphas. A test run with this beam proved the feasibility of experiment E350 which proposes the study of $^{208}Pb(\alpha,\alpha')^{208}Pb$ at 0°. Fig. 3 shows a spectrum of $^{12}C(p,p')^{12}C$ measured in the transmission mode. The upper part shows a clean spectrum after setting a gate on the time of flight (TOF) spectrum. By using the TOF as diagnostic tool we have been able to eliminate "beam halo events" in subsequent test runs. This reduced the dead-time significantly and allowed the use of beam currents of several nA.

Important for a clean beam is a reproducible beam tuning procedure including careful beam centering, slit adjustments and magnet settings. A few hardware improvements were made to eliminate frequent sources of background. The standard object slit produces too much background. Setting of slit 1 in beam line 8 to $x_\circ = 1$ mm horizontal opening ensures the required high beam resolving power $R_p = D/(Mx_\circ)$ where D and M are the dispersion and magnification, respectively, of the QDDM beam analyzing system. Other beam line modifications are a new set of slits in front of the 45°-analyzing magnet in beam line 3 to reduce the vertical beam divergence and a larger entrance pipe to the scattering chamber.

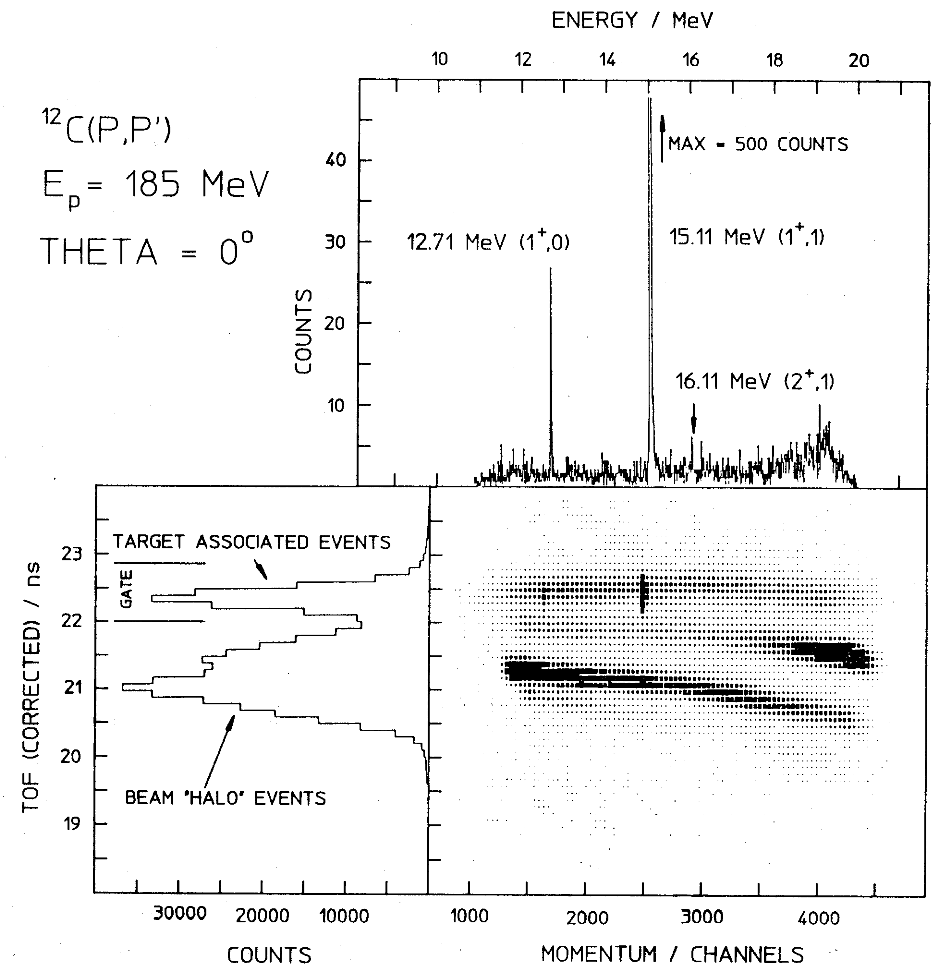

Figure 3. Measured two-dimensional corrected TOF vs. momentum spectra and projections in both axis. High resolution in TOF and energy of 350 ps and 25 keV makes possible to extract clean 0 °spectra.

In the case of (α, α') scattering a solid angle defining active collimator was used successfully to reduce slit scattering, which is particularly large for heavy targets.

The K600 magnetic dipole field ratio of D1/D2 = 1.49 provides a desirable high spectrometer dispersion to separate beam and low lying states and ensures that the beam passes into the transmission Faraday cup without creating background. The entrance of the Faraday cup was optimized for clear beam transmission and the smallest possible excitation energy (E_x). For 160 MeV protons with excitation energies E_x just below 8 MeV could be measured. While only small modifications of the standard wire chamber system were necessary to achieve this minimum excitation energy, a new set of $\Delta E/E$ plastic scintillators was built to cover the smallest energies and to cover the maximum momentum range of about 5%, which is limited by the exit window.

In order to determine scattering angles Θ_{tgt}, azimuthal angles Φ_{tgt}, and solid angles $d\Omega$, calibration data were taken to determine these quantities as functions of measured focal plane parameters, horizontal and vertical positions and angles (x, y, Θ_{fp}, Φ_{fp}).

Septum Magnet:

A modification of the original septum magnet design of R.E. Pollock was made by adding permanent magnet material (PM in Fig. 1) to the first section. This makes possible scattering angles as small as $\Theta = 4° \pm 1°$, as shown in Fig. 1, which displays the top view of all three sections.

In the septum magnet mode, the scattered particles enter the existing "5°-port" of the K600 quadrupole. To accommodate the septum magnet consisting of three sections and collimators (not shown) both mounted in a vacuum box behind the scattering chamber, the present hexapole magnet and aperture cassette have to be removed. The purpose of the hexapole is to minimize the (x,Φ^2) aberration when changing between low, medium and high dispersion modes. This flexibility is not needed in the transmission mode. The correct hexapole component has to be provided by shimming the quadrupole and septum magnet.

Calculations using the codes POISSON and PANDIRA were performed to design a prototype hybrid magnet including permanent magnet material.[1] The prototype was built and has been mapped. Fig. 4 shows the front view of the prototype. The required field of 0.45 T in the first section can be achieved with a current of 775 A. Fig. 5 shows the field B_y as a function of the x-direction. A strong hexapole component can be seen.

Before installation of the quadrupole, the fields were shimmed to specifications in the normal port only. We obtained the field components for the 5°-port from the original field maps (schematically shown in Fig. 6) by performing a least squares fit (through third order) to the mapping data. In order to obtain the correct quadrupole field the magnet current has to be reversed and adjusted. The resulting dipole field bends the particle towards the center of the main dipoles. The resulting hexapole component was found to be significantly larger in magnitude and of opposite sign than this same component in the central port, while the octopole component in the small angle port was of the same sign and also significantly larger than its counterpart in the central port.

In an attempt to avoid the disruptive task of removing and shimming the 5°-port of the K600 quadrupole we performed RAYTRACE calculations in order to determine if the

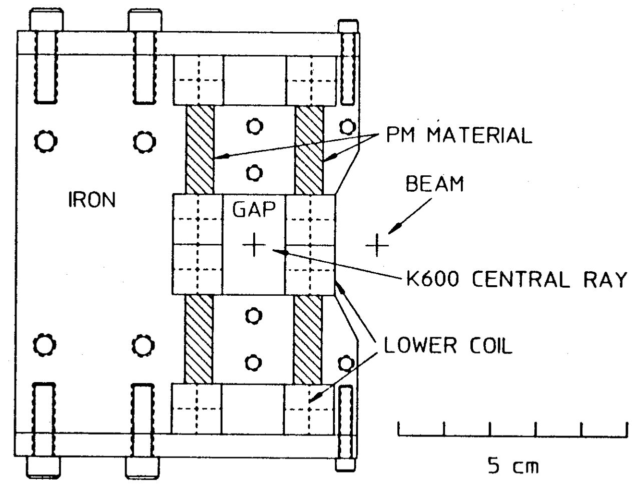

Figure 4. Front view of the prototype hybrid magnet. Two lower and upper coils provide the magnetic field enhanced by permanent magnet material. The clearance between the beam central ray and the coil is 1.2°. Top and bottom plates help to reduce the field at the location of the beam.

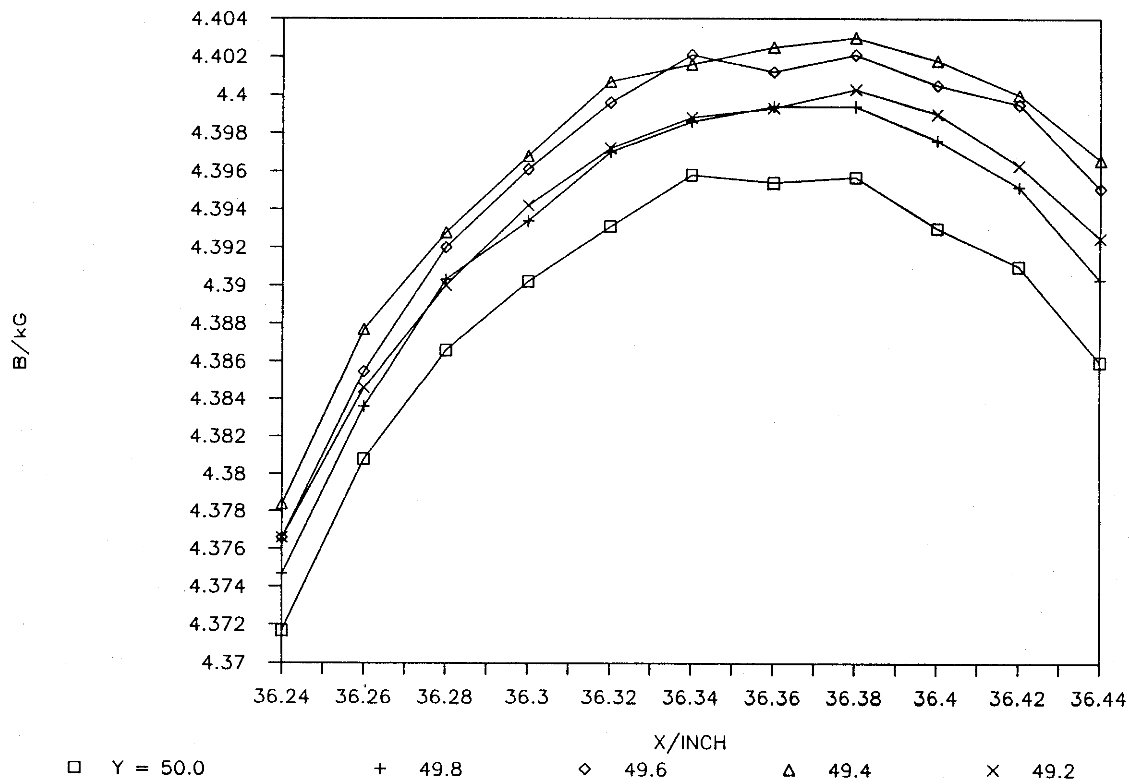

Figure 5. Measured magnetic field B in the hybrid septum magnet in x-direction at a current of 760 A.

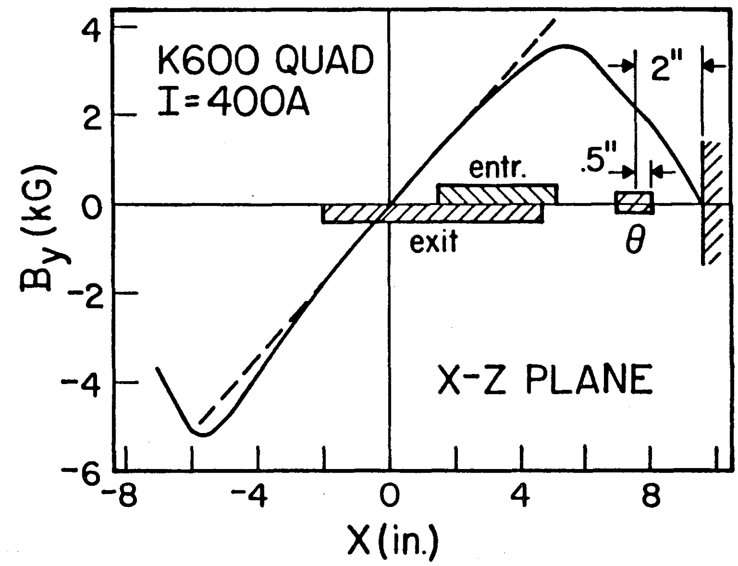

Figure 6. K600 field map in x-direction. Shown are the entrance and exit of the normal port and the entrance of the small angle port Θ.

septum magnet could be designed to compensate the incorrect higher order components of the quadrupole. The study has shown that it is possible to eliminate the horizontal or the vertical aberrations but not both at the same time. This comes from the fact that horizontal and vertical strength functions for the corresponding aberrations are different.[2] Using the higher order coefficient from RAYTRACE calculations and assuming a constant ray distribution in a given solid angle, a program was written to calculate the familiar one and two dimensional focal plane spectra, x, x-Θ, and x-Φ. The resulting resolutions in the K600 focal plane were unacceptable and at best ~ 120 keV.

Shimming of the 5°-port guided by POISSON calculations is necessary to provide the correct field components. The "natural" hexapole component of the hybrid magnet has to offset by concave effective field boundaries to provide a pure dipole except for the hexapole component needed to replace the removed hexapole magnet. It should be mentioned that the hexapole generated by the permanent magnet is constant. A hexapole component in the electromagnet is generated by the gap in the iron created by the permanent magnet and scales with the field. The system is therefore only optimized for a particular energy. Preliminary calculations indicate that the aberrations can be kept small to ensure high resolution in the range between 150 and 200 MeV.

The scattering chamber has been modified to allow the previous internal and external modes as well as the new septum magnet mode and the right-hand side operation. A section of the external beam dump line has been replaced by a special iron section mounted to the floor. This eliminates field effects on the beam when passing through the fringe field of dipole one. The immediate result is that measurements at the scattering angle of 14° are now possible. A crane has been installed at the scattering chamber to facilitate installation of equipment and mode changes, which will become more and more frequent.

1. R. D. Hartman, Composite Septum Magnet Prototype Test, REU Report IUCF 1990, unpublished.
2. S. A. Martin, A. Hardt, J. Meissburger, G. P. A. Berg, U. Hacker, W. Hürlimann, J. G. M. Römer, T. Sagefka, A. Retz, O. W. B. Schult, K. L. Brown, K. Halbach, Nucl. Instr. Meth. **214**, 281 (1983).

TARGET LAB TECHNICAL STATUS

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Projects on which we worked since the last report are summarized below.

•For carbon micro-ribbons and stripper foils, both the width and thickness of usable ribbons were reduced substantially when etched-metal substrates (new to our technique) were used with a new parting agent. The ribbons, yet to be tested in beam, have a much less corrugated surface than our previous ones. Production of thinner Cooler stripper foils was also made possible with these changes. Details may be found in the Proceedings of the 15th World Conference of the INTDS to be published in a special edition of NIM, vol. A, dated September, 1991.

•A spacing guide for the wire grills used to produce the micro-ribbons was developed. The guide allows precise widths of evaporated ribbons to be made when desired. Details of its construction may be found in the forthcoming publication cited above.

•Precision electro-chemical machining of stainless steel foil was undertaken as a possible construction technique for a proposed beam-position monitor consisting of stacked micro-channel plates (Frank Dohrmann). The results of this effort were less impressive than those we achieved by mechanically machining and grinding the desired features into the foil.

•A vacuum vise for machining graphite skimmer targets to a thickness of less than 100 μm was produced. The aluminum block from which it was made was machined with a step of comparable height to assist the vacuum in holding the graphite at an edge. The surface of the block was drilled with 0.76 mm diameter holes staggered 3.5 mm apart o.c., to produce targets with thinned sections of 25 mm length $\times$ 11 mm width.