THE HIGH RESOLUTION K600 SPECTROMETER

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• Introduction

The past year of K600 operation has again included routine operation of the spectrometer for approved nuclear physics experiments and also developments to enable the running of proposed experiments.

A considerable part of the development time (partly during scheduled experiments or with split beam) was dedicated to develop the spin precession capability, the focal plane polarimeter and the small angle modes of the spectrometer. Development beam time was also used to establish the proposed angular dispersion matching for an improved definition of the scattering angle.

During the last year eight 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 are not yet scheduled, partly because of beam time priorities, and partly because additional development is needed.

Highlights of K600 development include the following:

1) Installation and successful test of two superconducting solenoids in the high energy beam lines to allow all spin directions at the K600.
2) First normal spin transfer $D_{NN'}$ and $P$ experiment completed.
3) Successful ($^3$He,t) experiment including coincident neutron and gamma decay from the IAS and giant resonances at 0°.
4) Feasibility to measure inelastic proton scattering down to 4.5° using time of flight and an active slit system. All major background components were identified and efficiently eliminated.
5) Angular dispersion matching was established.

• Completed Experiments

Several experiments at the K600 have been completed. Measurements on high spin states in $^{208}$Pb and $0^-$ states in $^{16}$O made use of the high resolution of the spectrometer for determining the cross sections and analyzing powers of inelastically scattered protons. The neutron decay from the isobaric analog state excited in the $^{117,120}$Sn($^3$He,t)$^{117,120}$Sb reactions at 0° was measured using coincidence and time of flight techniques. The $^{205}$Tl($\vec{d}$,$^3$He)$^{204}$Hg and $^{204}$Hg($\vec{d}$,$^3$He)$^{203}$Au reactions were studied at 80 MeV. Most notably, phase I of the focal plane polarimeter project was completed with a calibration run in November and measurements of the spin observables $D_{NN'}$ and $P$ in proton inelastic scattering on $^{12}$C and $^{16}$O. Details of these and other K600 experiments may be found in other contributions to this newsletter.

• K600 Spectrometer Operation.

The sometimes large spread of the dispersed beam on target leads to significant uncertainties in the scattering angle, especially if the illumination changes with operator tuning.

These may be eliminated if the angular dispersion of the beam is properly adjusted. In order to decouple the spatial and angular dispersions on target it was necessary to shift the focus of the analyzing magnet BM3-8 system into the middle of quadrupole Q7-8. This was accomplished using the kinematic coils of BM3-8 which are ideally suited for this purpose. These coils were used when BM3-8 was the old QDDM spectrometer system. It was demonstrated that with appropriate kinematic coil settings (an effective k=0.225) the angular dispersion could be varied using Q7-8 until the scattering angle into the spectrometer was nearly independent of the beam ray on target. The dispersion on target and, therefore, the dispersion matching and resolution were not affected by the procedure.

Previously established dispersion matching procedures remain essentially valid. The general experience is that about 2-3 hours are required to obtain a match for one kinematic factor $k=(dp/d\theta)/p$, with a final resolution typically 20 keV for 200 MeV protons. A problem seen in February where resolutions below 30 keV were not possible and the BM3-8 system focus appeared to have moved upstream has been attributed to a partial short of the multipole of that system. After this short was removed matching procedures again worked successfully.

With the spin capability of beam lines and the K600 well in progress, interest in the development of the small angle modes of the K600 has increased considerably. In a very successful collaborative run involving Chaden Djalali, Aaron Galonsky, and Gwang Ho Yoo from Michigan State University, it was shown that most of the background can be reduced by replacing the spectrometer's entrance aperture with an active slit system to eliminate scattering from the slit edges. Another fraction of the background could be separated by measuring the time of flight as a function of both focal plane angle and position. The latter background may originate from the region of the BL8 analyzing magnet and can be reduced by closing object slits S3-3 and image slits S7-3 of the 45° analyzing magnet in BL3. This reduces the beam intensity by about 50%, but this is usually not a limitation for small angle experiments.

Split beam of 100 and 45 MeV protons was used to study the beam transmission mode for 0° (p,p′) scattering. In this mode a halo-free proton beam is directed through the spectrometer to exit through a port at the high momentum side of the standard focal planes and focal plane polarimeter detectors. For this purpose the end flange of the K600 detector chamber was modified to accomodate the exit pipe for the beam in the zero degree transmission mode. A beam stop is available to be mounted at the end of this pipe behind the focal plane. This mode allows the investigation of beam halos in the momentum space and might be a mode to measure 0° to 3°. With 100 MeV elastic scattering, it was shown that particles can be guided through the existing exit end flange beyond the high dispersion mode. The dispersion of 10.1 cm/% allows us to measure exitation energies larger than about 6 MeV. This mode is actually the design high dispersion plane but with a field setting reduced by 1.1% to shift the beam onto the end flange. With 45 MeV protons and the K600 set at $-1°$, the beam was transmitted into the cup. With a total horizontal spectrometer acceptance of 4° this leaves the angles range of $0°-3°$ open for scattered particles. While the ion optics for this setup has been proven to be feasible, it still has to be demonstrated in an upcoming development beam time that it is possible to handle the expected high count rate in the detector system and that measured background can be reduced efficiently using the above mentioned techniques.

- K600 Spectrometer Hardware Development.

The new target ladder mechanism is now operational including the remote control. This reduces running time losses due to cave entries and personnel exposure to radiation, especially during experiments that use an internal Faraday cup. Simple beam spot checks required 10 minutes. This procedure is frequently necessary when the beam is unstable or temporarily lost due to RF or other problems. Also the lower turn table in the 24 inch scattering chamber can now be controlled remotely from the K600 control station at HERA.

The new sliding seal support for the scattering chamber has reduced band friction significantly. Due to lateral forces, however, excessive band wear is observed. A modification is necessary and in progress.

The new movable carbon Faraday Cup for the ($^3$He,t) experiment at 0° was mounted inside dipole 1. This device allowed the $^3$He beam to be stopped and its current read without activating the dipole walls. It is now possible to exchange the stop without removing the complete drive mechanism. This proved very useful when it was discovered during the experiment that a modification was necessary because the new design for a larger solid angle produced unacceptable background.

After the installation of both superconducting solenoids upstream and downstream of the 45° analyzing magnet in BL3, several shifts were used to establish the new beam line setup. TRANSPORT calculations had shown that the mixing of horizontal and vertical beam components could be handled with the present beam line elements if a skewed quadrupole was installed adjacent to the first solenoid. These predictions were verified.

Hall probes are now installed in all quadrupoles from the cyclotron to the K600 spectrometer and are ready for use for more reproducible beam line settings and computer controlled checks of magnetic field problems. Presently we are waiting for the read-out system which is under design. A reference Hall probe has been installed at the location of the NMR probe in the K600 dipole 2 in order to verify the accuracy of the Hall probe system and possible dependence on temperature or other factors.

The external beam dump line can now be mounted and removed by a hoist designed for this purpose. With this hoist the beam pipe can be stored completely assembled on a shelf at the south wall.

It is now possible to move the K600 to 14° when the external dump line is installed. An experiment with 150 MeV protons showed that there is a significant effect of the fringe field of the first K600 dipole at this angle. The field varies between 1–2 kG across the beam pipe. It was possible to refocus the beam using BL8 quadrupoles to obtain a full beam current reading. This is of course not feasible when dispersion matching dictates fixed quadrupole settings. This sets a practical limit to the smallest K600 angle with an external dump of about 15° when high resolution or correct current readings are required.

The original rigid support of the K600 entrance elements (aperture cassette and hexapole) made proper alignment of these elements very difficult without straining the vacuum seals. This alignment and leakage problem was solved by installing another bellow and an adjustable support.

Another alignment problem was solved by reinforcing the Q10-8 support with sturdier braces. This important element of the beam line is now less vulnerable to mechanical shocks.

The lid of the K600 scattering chamber was designed to rotate so that additional experimental equipment could be mounted in a flexible way on it. This feature was recently made workable again with the replacement of the lid ball bearing. A hand driven crank is installed for rotation. A system for remote control is under construction.

We replaced the cryogenic pump at the scattering chamber by a 500 $l/s$ turbo molecular pump. Because of the lack of helium pressure the cryopump previously installed there did not render consistent service.

For the beam transmission mode a new Faraday cup at the high dispersion end has been installed and tested. Also a mounting fixture to install the focal plane detectors in the high dispersion focal plane was built.

- Focal Plane Detectors and Electronics.

The gas handling system has been reorganized in order to incorporate the gas supply for the focal plane polarimeter. Check of alcohol level, refills and monitoring can now be done from a convenient location behind the focal plane.

The argon gas pressure is monitored by a transducer and the isobutane is weighed with an electronic scale. If either gas runs low an interrupt is sent to the trigger circuit and an audible alarm sounds in both the data taking area and the K600 control room.

All 4 focal plane scintillators with thicknesses of 1/16", 1/8", 1/4", and 1/2" are now mounted on separate frames for easy exchange when particle identification requires a different scintillator.

The electronics for the readout of the focal plane was modified to allow greater flexibility and compatibility with a variety of experiments. A second level of triggering was added. This provides an opportunity to include additional restrictions in the definition of the trigger. At present this is routinely used to verify that there is at least one wire of each focal plane wire chamber hit before any event is accepted. This trigger can accept other slow coincidence information, including coincident detectors in the scattering chamber or triggers from the focal plane polarimeter. The second level also generates a system-wide clear if the event is not valid. This scheme was tested with a development run to look for coincident protons in the focal plane from $(d,{}^2He)$ events. It has also been used to look for coincident protons in the focal plane with up to 8 solid state detectors or neutron detectors in the scattering chamber. In the latter case, a second type of trigger was also used based on prescaled single events from the focal plane. K600 experiments needing coincidence capabilities can now be set up routinely.

- Development in progress.

After installation and successful testing of the superconducting solenoids all transverse and longitudinal spin orientations at the K600 target and for the Cooler are possible.

Testing of the y axis wire chambers is under way and installation in the K600 focal plane is expected soon.

During the June/July shut-down final modifications will be made to allow K600 operation at angles at the right side of the beam up to about 45°. This is the last major requirement of the focal plane polarimeter project and enables measurements of all sideways spin transfer components. These modifications include the moving of the south wall, shortening the fixed end and lengthening of the movable part of the external beam dump line, relocation of the dump shielding and several auxiliary components and supply line.

The ion optics for the beam transmission mode for the K600 at 0° is established. In this mode the beam is transmitted through the spectrometer end exits into a special port into a dump. Mounting fixtures are presently installed in order to mount the existing focal plane detector in the high dispersion mode. A crucial test will be conducted in August in order to test if the detectors can be operated so close to the transmission dump and if beam halo and background sources can be eliminated.

## THE K600 FOCAL PLANE POLARIMETER

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During 1988, we completed the construction and calibration of a high–efficiency polarimeter for detection of intermediate–energy charged particles, currently mounted downstream from the medium–dispersion focal plane of the K600 spectrometer system. All components of the dedicated electronics are installed and tested, acquisition and preliminary analysis software exists, and two extended running periods of approximately ten days each (for initial calibration of the polarimeter[1] and for experiment E306[2]) have resulted in detailed measurements of the polarimeter's efficiency, momentum bite, effective analyzing power, and count rate capabilities which have met or exceeded all design goals.

As shown schematically in Fig. 1, the focal plane polarimeter (FPP) consists of a thick carbon block, followed by two sets of paired $x$–$y$ multiwire proportional chambers, and two planes of plastic scintillator. The high–density (1.78 g/cm$^3$) graphite target serves as the polarization analyzer; thicknesses of 1.27 cm, 3.81 cm, or 5.08 cm are currently available. For incident proton energies between 120 and 200 MeV, the p–$^{12}$C analyzing powers are large in magnitude, and have been carefully studied for both elastic and inelastic scattering processes.[3] The graphite block is carefully counterbalanced, and can be moved vertically in or out of the reaction plane in a matter of seconds. The entire analyzer mounting system can also be completely removed with relative ease if need be for calibration or alignment studies.

After extensive bench testing, the two sets of $x$–$y$ chambers were installed in their final location in July 1988. A complete set of spare chambers has also been built and tested. The smaller $x$ and $y$ chambers have active areas that measure approximately 70 cm horizontally and 30 cm vertically, while the corresponding numbers for the larger chambers are 100 cm and 50 cm, respectively. Readout of the wire chamber information occurs via the LeCroy PCOS III system, which offers several advantages over either direct coincidence register readout or highly multiplexed configurations. A feature crucial for our application is the rapid ($<$ 500 ns) encoding of the first wire hit in real–time, with presentation of the encoded output at an ECLport. This information is used as input to a second–level trigger processor for on–line rejection of events in which the detected