

INSTALLATION, COMMISSIONING, AND APPLICATIONS OF THE K600 SMALL ANGLE SEPTUM MAGNET

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Through the use of the K600 high resolution spectrometer and associated focal plane polarimeter (FPP), cross section and spin-observable data have been taken for a wide variety of nuclear states. These data-taking capabilities have been limited at small laboratory scattering angles due to the physical constraints of the spectrometer system which required the use of a local Faraday cup for angles smaller than 14° . Scattering angles smaller than about 6° were not possible at all. The septum magnet mode of the K600 spectrometer has been developed to permit data to be taken at smaller laboratory scattering angles while allowing the unscattered beam to be deposited in a well-shielded beam dump downstream of the target. The scattering angle range accessible in the septum magnet mode ranges from 18° to as small as 3.5° . In this mode the reaction products are bent by the septum magnet into the spectrometer system. The unscattered beam drifts past the septum magnet and the specially designed quadrupole and first dipole magnets on the K600, and is deposited in a beam dump shielded by a layer of iron and several feet of concrete, thereby avoiding the large background generated by Faraday cups mounted inside the 24" scattering chamber. Minimizing room background is also a prerequisite for coincidence experiments in which charged particle or gamma detectors are placed near the target.

The development of the septum magnet was finished in early 1992. Details of the K600 Septum Mode and the development of the magnet were described in previous reports.¹ Several modifications to the existing system were necessary to accommodate the septum magnet in the limited space between the scattering chamber and the K600 entrance quadrupole. The scattering chamber was modified to allow the required rotation and to accept the flange of the septum vacuum chamber. The support for the aperture cassette and the sextupole magnet was redesigned to accommodate these two devices during normal operation and to support the vacuum chamber in septum mode. The original quadrupole vacuum chamber was designed to accommodate both modes, but warping during fabrication caused serious misalignment. At present a different chamber is used for each mode requiring the disassembly of the quadrupole during mode changes. A single chamber suitable for both modes is planned to facilitate mode changes in the future. The beam dump pipe had to be modified to allow the beam to pass from the movable septum vacuum chamber to the fixed beam dump pipe. The beam now exits the septum chamber through a thin Kapton foil, passes through a several centimeters of air and enters the beam dump pipe, which is under vacuum, through another foil. This solution was chosen to avoid an expensive mechanical coupling device and possibly jeopardizing the access to the smallest scattering angles.

Two other modes are frequently used at the K600. The normal mode allows measurements at angles of 14° and backward. The transmission mode can be used if angles between 0° and 3° are to be measured. Mode changes during an experiment have to be well planned because they take an eight hour shift with three trained technicians. All ele-

ments are carefully pinned to ensure correct alignment without repeating a lengthy optical alignment procedure.

At angles smaller than about 6° , the beam in the dump pipe passes through the fringe field of the K600 dipole 1. At maximum dipole excitation, this field varies between 0.1 T and 0.3 T across the beam pipe. This will defocus and bend the unscattered beam significantly towards dipole 1, causing unwanted background and preventing proper beam current integration. A magnetic shielding pipe of soft iron was designed to reduce the field within the beam pipe to less than 3 mT. This is small enough to eliminate beam steering problems.

The power supply and a shunt specially designed by the power supply group allows the septum magnet current to be run up to a maximum of 900 A while reducing the current in the second section by 70 A. Two calibrated Hall probes installed in the first and second sections of the septum magnet give measurements of the magnetic field in both sections.

After the installation and checking of all components and supplies, the K600 septum magnet was commissioned in several test runs. These were conducted to verify proper operation under experimental conditions and to check the ion-optical design parameters. At present with 200-MeV protons, a resolution of about 35 keV has been obtained for the full solid angle defined by a circular entrance aperture of $\pm 0.9^\circ$. The setting for best transmission was established by adjusting the currents of the septum and the entrance quadrupole, both of which provide a significant dipole component.

The K600 septum magnet is designed to bend protons of 200 MeV (corresponding to a magnetic rigidity of 2.15 T·m). While this limitation is less than the bending power of the K600 spectrometer, it was chosen to accommodate the smallest possible angle for a series of approved experiments all using protons of 200 MeV (the highest available proton energy). The active ($^3\text{He}, t$) program at the K600, in which 180-MeV tritons must be analyzed, has its own transmission mode, covering an angular range from 0° to 3° .

Since the successful commissioning of the septum magnet mode of the K600, several experiments, which could not run earlier because they required the septum mode, were started or completed. During experiment E350 (ISGDR in $^{208}\text{Pb}(\alpha, \alpha')^{208}\text{Pb}$), use was made of both the septum magnet mode and the transmission mode of the K600. Experiment E269, in which incident protons were scattered at small laboratory scattering angles from ^{48}Ca in an attempt to determine the M1 strength for this reaction, also made use of the septum magnet mode.

Because use of the septum magnet mode allows the unscattered beam to be deposited in a beam dump far downstream from the target, coincidence measurements at small proton scattering angles can now be performed with the K600 spectrometer. In particular, with the use of a large photon detection system, measurements of the type $(\vec{p}, p'\gamma)$ are possible at small angles. Measurements of this type were performed for experiments E354 ($^{12}\text{C}(\vec{p}, p'\gamma)^{12}\text{C}$ investigating the two dominant 1^+ states: $T = 0$ at 12.71 MeV and $T = 1$ at 15.11 MeV) and E360 ($^{208}\text{Pb}(\vec{p}, p'\gamma)^{208}\text{Pb}$ isolating the dipole piece of the giant resonance region). Of the many types of γ detectors available, we felt that the best choice for coincident γ detection in the K600 cave environment was BaF_2 . These crystals have the dual advantage of both excellent timing characteristics (due to a fast response component, with $\lambda \sim 220$ nm) and the ability to maintain an energy resolution (this from a slow

component, with $\lambda \sim 310$ nm) comparable to more conventional γ detectors such as NaI, which have much poorer timing characteristics. Shown in Fig. 1 is one of four close-packed 19-detector bundles, or 19-packs, of BaF₂ (supplied by the ORNL collaborators) which we used as our photon detection system in the K600 cave. Each of the 19 BaF₂ crystals in each pack is hexagonal in shape, 6.5 cm across and 20 cm long, which is sufficiently thick to stop a 200-MeV γ -ray with a conversion efficiency of nearly 100%. Associated with these crystals are individually-matched photomultiplier tubes with quartz photocathodes and highly stabilized bases. The detector hardware and signal-processing electronics has been designed for optimum time and energy resolution, while the logic and event readout schemes have been tailored for maximum efficiency in identifying and processing potential events.

Charged particle coincidence measurements at small proton scattering angles have also been proven feasible. In a test run for experiment E367 ($D_{NN'}$ measurement for p+p elastic scattering), both protons emitted from a p+p elastic scattering event were detected. The forward-going protons were detected in the K600 focal plane while the recoil protons were detected in a Si/CsI recoil telescope positioned in the scattering plane on beam right at a distance of ~ 20 cm from a 1.2 mg/cm² CH₂ target. The Si detector was 500 μ m in thickness and measured 6 cm vertically and 4 cm horizontally. This detector was mounted in an aluminum box with a conducting front face composed of ~ 1.5 μ m thick, two-sided aluminized mylar. The CsI crystal, also in vacuum, was mounted directly behind the Si and read out via a photomultiplier tube. The recoil detector telescope was read out for every event in which a valid K600 focal plane trigger was produced. Coincident recoil protons with energies as low as 1.2 MeV, associated with protons scattered at $\theta_{lab} = 5^\circ$ from a 200 MeV incident beam, were cleanly detected.

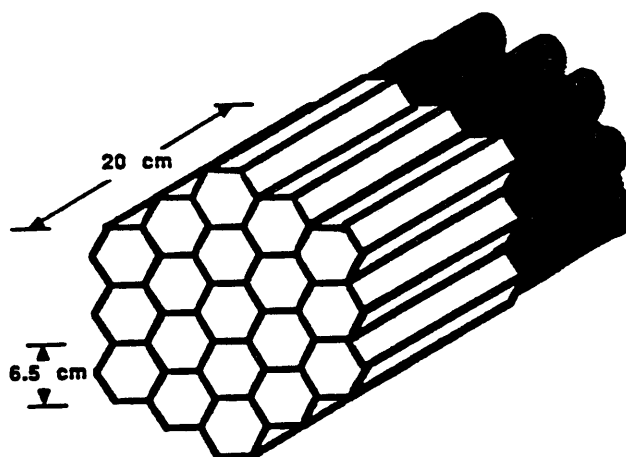


Figure 1. A close-packed 19-detector bundle of BaF₂ detectors, showing the dimensions of the individual crystals. The shaded cylinders represent phototubes and base assemblies.

Results from these studies, as well as schematic diagrams of the septum magnet mode hardware, can be found in other contributions to this report. Several other approved K600 experiments requiring very small angles only accessible with the septum magnet have been scheduled in the upcoming beam time period.

1. G.P.A. Berg, S. Wells, P. Craw, J. Doskow, W. Franklin, P.Schwandt, E.J. Stephenson, and V. Willcut, IUCF Sci. and Tech. Rep., May 1991 – April 1992, p. 232.