

## PP ELASTIC SCATTERING BETWEEN 200 AND 450 MeV

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The detector facility in the A-region of the Cooler is currently receiving an upgrade to meet the demands of several pending experiments. The upgrade consists of modifications to the scattering chamber, a replacement of the "45-degree" detectors and the first wire chamber, and the addition of a new, thick stopping detector.

The first experiment to make use of the improved setup (CE42 [Ref. 1]) is a study of the energy dependence of the spin correlation coefficients  $A_{xx}$ ,  $A_{yy}$  and  $A_{xz}$  in pp elastic scattering at angles up to  $\Theta_{cm}=90^\circ$ . The experiment makes use of the Wisconsin/IUCF polarized hydrogen target<sup>2</sup> that has been used by CE35 to measure the same observables at a fixed energy of 200 MeV at angles  $10^\circ \leq \Theta_{cm} \leq 35^\circ$ .<sup>3</sup> During the new experiment, the bombarding energy will be varied between 200 MeV and 450 MeV with particular emphasis on the region around 300 MeV where inelastic channels open up. Initially, CE42 was designed to take data only around  $\Theta_{cm}=90^\circ$ . However, the new detector system makes the simultaneous observation of smaller scattering angles possible. This is important because it allows a concurrent measurement of beam and target polarization using the known value of the analyzing power  $A_y$  (this would not be possible at  $\Theta_{cm}=90^\circ$  since  $A_y$  vanishes). The modifications and additions to the A-region setup are described in the following.

The exit cone of the CE35 scattering chamber was replaced by a new endcap that provides an unobstructed view of a larger range of scattering angles (between  $\Theta_{cm}=14^\circ$  and  $\Theta_{cm}=120^\circ$ ). The exiting protons now have to traverse a 0.34 mm thick stainless steel window of uniform thickness. The window is made from a spun, dome-shaped shell, welded to a support structure to prevent collapsing due to the pressure difference between the pumped chamber and the outside. The support structure consists of eight radial ribs spaced by  $\delta\phi=45^\circ$ , welded to a hub joined to the beam pipe that continues through the center of the detector arrangement. The azimuthal spacing of the ribs allows unobstructed detection of scattered protons within the  $\phi$  acceptance of the CE35 detectors. Fig. 1 shows an isometric view of the endcap and the target cell. The new endcap in conjunction with the target cell has already been used in two runs. During the first run the cell was filled with unpolarized hydrogen with a target thickness of  $5 \times 10^{14}$  atoms/cm<sup>2</sup>. This target is much thicker than the polarized atomic target contained in the same cell ( $3.5 \times 10^{13}$  atoms/cm<sup>2</sup>). Consequently, the gas flow rate is higher. Despite this, and despite the fact that the cell opening is much closer to the exit beam pipe than before (making pumping of the gas that emerges from the cell more difficult) good ring vacuum was maintained.

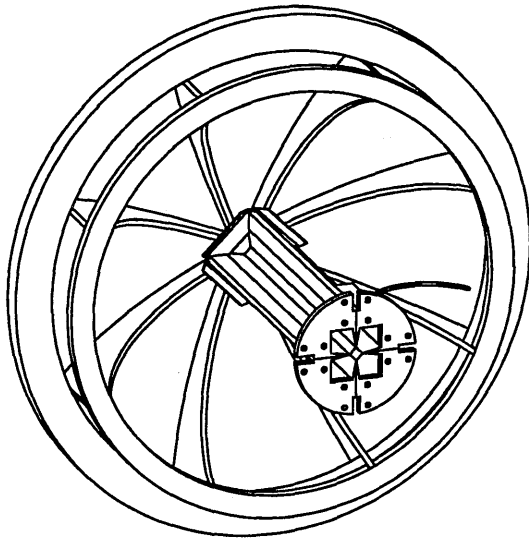


Figure 1. Endcap with target cell.

An early concern was that the welds of the stainless steel ribs of the endcap could be slightly ferromagnetic. Due to their proximity to the target cell it would be conceivable that the target polarization might be affected. During the second run the polarization of the target was measured without operating the medium field transition of the atomic beam source. Then, the target polarization is free from effects due to any inefficiencies in the transition or due to nearby stray magnetic fields. A value of  $0.421 \pm 0.029$  was found for the target polarization, compared to  $0.436 \pm 0.022$  during earlier runs. Thus, we conclude that the installation of the new endcap has had no effect on the operation of the polarized target as compared to its previous performance.

The target cell and the detector system are shown in Fig. 2. The four new "45-degree" detectors (S1-S4) are  $25 \text{ cm} \times 25 \text{ cm} \times 5 \text{ cm}$  blocks of plastic scintillator. Scattered protons in the angle range  $60^\circ \leq \Theta_{cm} \leq 120^\circ$  are detected as coincidences between two opposite elements of this detector array. The hit position on the face of the detectors is determined by a new xy wire chamber with a wire spacing of 3.2 mm. The new wire chamber replaces one of the two CE35 wire chambers (the one closer to the target). The new chamber is half as large as the old one and has half the wire spacing. It provides better resolution and a better match to the active solid angle of the experiment. As before, in the center of the chamber the wires are suspended from a hub structure that forms a hole that accommodates the beam pipe. The central hole of the new chamber has an inner diameter of 2.54 cm, compared to 7.62 cm for the old chamber. The new chamber has been operated without problems during two runs; its efficiency was found to be uniform, including the wires closest to the hole.

From the wire chamber information the difference  $\delta\phi$  between the azimuthal angles of the two outgoing protons is determined for each event. For elastic scattering events, the condition  $\delta\phi = \pi$  has to be fulfilled. Fig. 3 shows the  $\delta\phi$  distribution measured at a bombarding energy of 450 MeV, with a polarized hydrogen target of thickness  $3.5 \times 10^{13} \text{ atoms/cm}^2$ . It can be seen that the peak from pp scattering is superimposed on a broad distribution due to a background from (p,2p) reactions in materials other than the

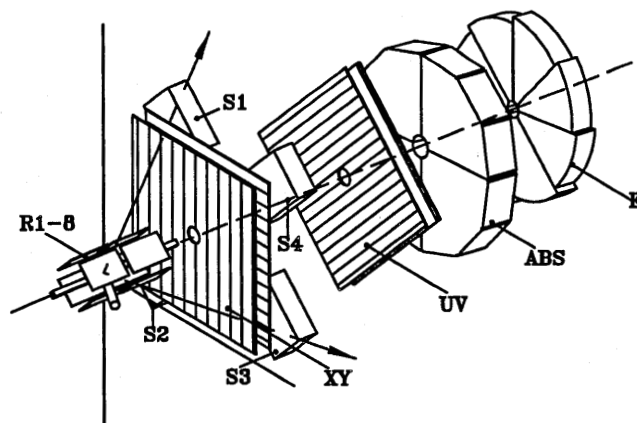


Figure 2. CE42 detector setup in the A-region of the Cooler.

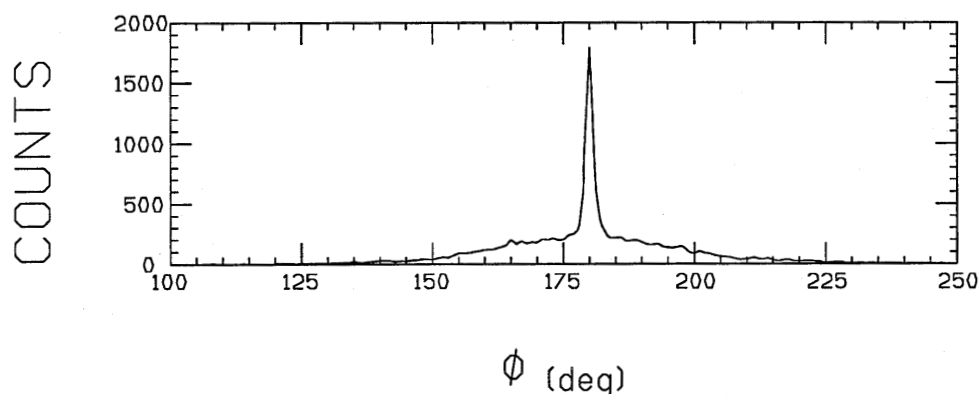


Figure 3. Opening angle between two protons. Proton-proton elastic scattering events are distinguished by an opening angle of  $\pi$ .

target gas, most likely the teflon walls near the upstream end of the target cell. It is clear that the admixture of background events is sensitive to the centering of the beam in the target cell.

Below  $\Theta_{cm}=70^\circ$ , pp scattering is measured in a similar manner to the CE35 experiment by observing coincidences between the forward, segmented E detector (E) and one of the eight position-sensitive silicon detectors (R1-8) mounted alongside the target cell. At extremely small angles (less than  $14^\circ$  in the center of mass) the forward scattered protons travel inside the hub of the endcap, missing both wire chambers. However, since the recoiling protons are stopped in the silicon detectors, the scattering angle can still be determined from the measured recoil energy. In order to obtain an absolute value for the recoil energy, the silicon detectors are continuously calibrated by observing alpha particles from  $^{241}\text{Am}$  sources permanently mounted in front of each detector. Recoils associated with forward scattering angles up to  $\Theta_{cm}=18^\circ$  are stopped in the silicon detectors even at the highest bombarding energy (450 MeV). Also shown in Fig. 2 is a new stopping detector (the K detector, for details see elsewhere in this report) that has been added to the setup.

Coincidences between one of the four segments of the new K detector and one of the silicon detectors R1-8 subtend an angular range between  $14^\circ$  and  $70^\circ$ . Since the K detector has a larger outer diameter, the largest detectable angle is considerably increased compared to CE35. Since  $A_y=0$  at  $\Theta_{cm}=90^\circ$ , the beam and target polarizations are measured using events at smaller angles with the trigger signatures E-R1-8 and K-R1-8. Data for both ranges of scattering angles are acquired concurrently.

Another upgrade of the setup in the A-region concerns the data-acquisition hardware which was upgraded from the older MBD system with a new VME-based system. This change has increased the rate capability by roughly a factor of two.

All components of the new detector setup have been commissioned except for the recently added K detector. So far, the first  $A_{ik}$  data have been taken at 450 MeV. The data are shown in Fig. 4. This measurement sets the record for the highest energy polarized beam at IUCF. It was shown that it is possible to accelerate the beam in the presence of the narrow,  $8 \times 8 \text{ mm}^2$  target cell. In an earlier experiment, CE25, polarized beam had been accelerated to 420 MeV in the presence of a polarized  $^3\text{He}$  target cell of much larger, and thus less critical, dimensions.

In this first run, the beam and target polarizations were measured using a calculated analyzing power based on the SAID C450 solution. During future CE42 runs, we will measure the polarization of the beam at 200 MeV, accelerate the beam, measure the asymmetry in pp elastic scattering, decelerate the beam, and measure the polarization again at 200 MeV, where an absolute polarization standard is available.<sup>4</sup> If the beam polarizations before the upramp and after the downramp are the same, the polarization at the higher energy must also be the same, and the analyzing power at the higher energy can be calibrated, allowing an absolute measurement of the  $A_{ik}$ . This method represents a novel technique for transporting a polarization standard in energy that is unique for storage rings. Around the pion production threshold (300 MeV), one other approved experiment (CE44) also depends on a precise calibration of the analyzing power in pp elastic scattering.

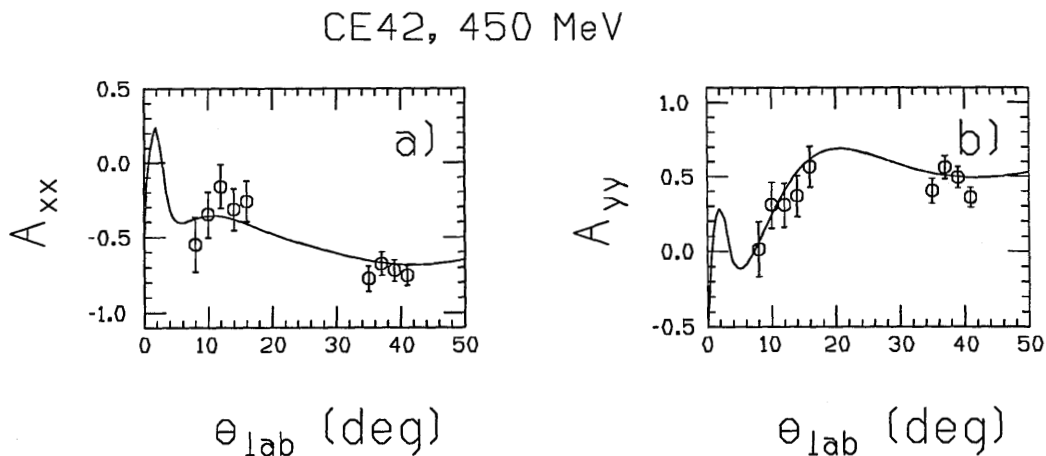


Figure 4. Spin correlation coefficients measured during a recent CE42 run. The errors are statistical only. The curve is the SAID C450 solution. a) Spin-correlation coefficient  $A_{xx}$  at 450 MeV. b) Spin-correlation coefficient  $A_{yy}$  at 450 MeV.

Decelerated beam has been developed during the past year. For a detailed description of the downramp development see elsewhere in this report.

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