TEST OF CHARGE SYMMETRY IN n-p ELASTIC SCATTERING AT 480 MeV⁺

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Résumé - L'expérience en cours à TRIUMF vise à mesurer la différence ΔA entre les puissances d'analyse des neutrons et des protons, A_n et A_p , en diffusion élastique n-p à 480 MeV.

Abstract - The experiment in progress at TRIUMF measures the difference ΔA between the neutron and proton analyzing powers A_n and A_p in n-p elastic scattering at 480 MeV.

Designed as a null-measurement, requiring no accurately known polarization standards, the experiment determines the difference in angle at which A_n and A_p cross through zero ($\sim 71^\circ$ c.m. or 32° lab). The two interleaved phases of the experiment consist of scattering polarized (unpolarized) neutrons from an unpolarized (polarized) target of the frozen spin type. The experiment is to provide an unambiguous test of class IV charge-symmetry breaking effects to the level of $\Delta A = 0.001$, corresponding to a laboratory angle difference at the zero-crossing of $\sim 0.04^\circ$.

A 480 MeV polarized neutron beam is produced via transverse polarization transfer in the $D(p,n)2p$ reaction at 9° lab using a 20 cm long liquid deuterium (LD_2) target. A superconducting solenoid rotates the transverse polarization direction of the 500 MeV proton beam by 90° clockwise into the horizontal reaction plane. Polarization direction reversals are implemented at the polarized ion source. The neutron beam passes through a 3.37 m long lead collimator. In the neutron scattering area the horizontal component of the neutron polarization is precessed into the vertical plane by two dipole magnets (see Fig. 1). The component of polarization perpendicular to the reaction plane is precessed simultaneously along the direction of travel of the neutron beam. A proton beam polarization with typical values in the range 0.65 to 0.70 produces a neutron beam polarization of ~ 0.50 . In the interleaved second phase of the experiment a neutron beam with zero transverse polarization components is produced as above, but with an unpolarized proton beam incident on the LD_2 target.

The proton beam polarization is monitored continuously by a polarimeter observing p-p scattering at 17° lab using a left-right symmetric detector telescope arrangement complete with recoil counters. The proton beam energy is monitored using six element range counters following the forward angle (17° lab) polarimeter detector telescopes. Two sets of split-plate secondary electron emission monitors (SEM's) coupled via a feedback system to two sets of steering elements located upstream in the beam line allow the centroids of the proton beam to be locked into position to within ± 0.15 mm. After traversing the LD_2 target the proton beam is deflected away from the neutron beam and transported to a beam dump.

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Fig. 1. Experimental layout of the test of charge symmetry in n-p elastic scattering.

The collimated neutron beam is incident on a frozen spin polarized hydrogen target (FST) with a target cell 40 mm in height and a diameter of 40 mm containing 1.2 mm in diameter butanol beads. In the first major data-taking run operational temperatures were 75 mK. The average positive polarization was +0.66 while the average negative polarization was -0.72. In the second data-taking run operational temperatures were about 60 mK with average positive and negative polarizations of +0.81 and -0.87 respectively. The strength of the holding field is 0.257 T at the FST causing an average deflection of 1.2° for the recoil protons. A complete measurement cycle lasts four days and consists of holding field directions up and down each with positive and negative target polarizations for incident unpolarized neutrons, interleaved with the target depolarized for incident polarized neutrons. The FST holding field strength is both stable and reproducible to better than ± 0.25 mT.

After traversing the FST the neutron beam passes a profile monitor. The neutron beam profile exhibits an intensity distribution which is flat topped over a rectangular area and is reproducible in position to within ± 0.5 mm from run to run. The area of uniform intensity at the position of the FST is 56 mm wide by 40 mm high encompassing the target cell.

The profile monitor is immediately followed by a polarimeter determining left-right and up-down asymmetries. The effective analyzing powers of the neutron polarimeter were derived from the amplitudes of the precession curves. The zero crossings of the precession curves provided the calibration of the spin precession magnets.

The neutron energy spectrum consists of a relatively narrow peak (calculated FWHM = 11 MeV) around 480 MeV and a smooth flat background /1/. Approximately one-half of the neutrons are contained in the peak corresponding to an intensity of $9 \times 10^3 \text{ s}^{-1} \text{ cm}^{-2}$ per 100 nA of proton beam. The polarized proton beam has intensities greater than 300 nA for each of the three spin states and reached intensities of 650 nA during one week of running in late 1983. A detailed description of the neutron beam facility is presented elsewhere /2/.

Scattered neutrons and recoil protons originating in the FST are detected in coincidence in two left-right symmetric detection systems allowing cancellation of many of the systematic errors to first order. Each neutron detection system placed at an angle of 32° consists of four elements: A neutron scintillator array, a plane

of charged particle veto scintillators covering the forward side of the neutron scintillator array, a set of small scintillators ("button" counters) used for monitoring on line the gain of the photomultipliers of the neutron scintillator array by triggering on fast protons, and a charged particle time-of-flight (TOF) scintillator.

Each proton detection system is supported by a boom placed at the complementary angle of 52° . The boom carries three functionally distinct systems: a TOF system for determining proton velocity consisting of a TOF start scintillator close to the target and an energy scintillator E which serves as the stop, a set of four 0.58 m by 0.58 m delay line chambers for track reconstruction, and a range counter telescope for removal of high energy and low energy background. A detailed description of the detection equipment is presented elsewhere /3/.

With the detection system one measures the neutron TOF and position, and the proton TOF, trajectory and energy. Measurements of the opening angle and coplanarity of the coincident neutron-proton pair discriminates against quasi-free n-p scattering from heavier nuclei, e.g. ^3He , ^4He , ^{12}C and ^{16}O , present in the FST. Further constraints on the data are cuts on the reconstructed target image, the summed neutron-proton energy, and the neutron-proton transverse momentum. Two major data taking runs have resulted in ~40% of the required number of events. A preliminary analysis of the data gave a difference in the cross over angle for A_n and A_p with a statistical accuracy of $\pm 0.11^\circ$. The value obtained for ΔA lies within the range established by existing theoretical predictions.

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