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New experimental upper limit of the electron–proton spin-flip cross-section

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ABSTRACT

In a previous publication, measurements of the depolarization of a stored proton beam by interaction with a co-propagating unpolarized electron beam at low relative energy have been presented and an upper limit of about 3×10^7 b for the electron–proton spin-flip cross-section was determined. A refined analysis presented in this paper reduces the previous upper limit by a factor of three by the introduction of a new procedure that also makes use of non-identified particles.

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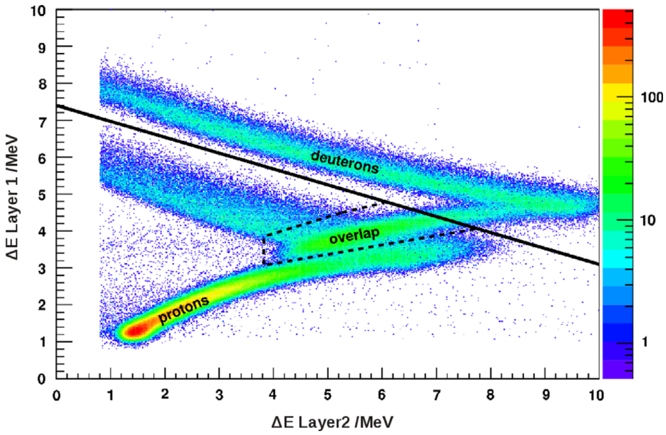

Fig. 1. Energy loss in the first vs second layer in one of the Silicon Tracking Telescopes. The minimum bias cuts used to reconstruct deuterons are indicated. In addition to the stopped deuterons, the new analysis made use of the additional events in the overlap region.

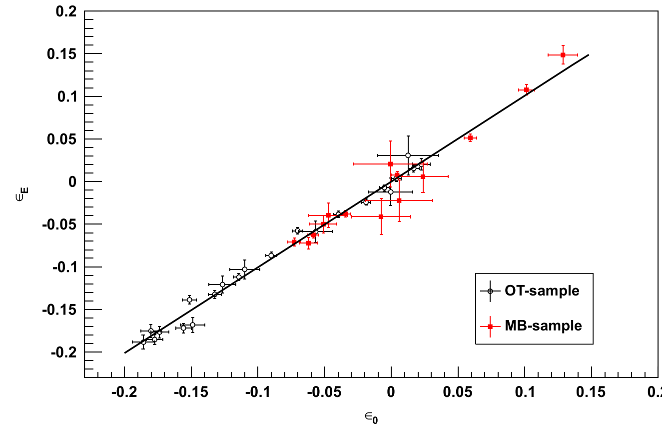

Fig. 2. Correlation plot ϵ_E vs. ϵ_0 for the asymmetries measured with and without electron beam interaction for a detune voltage of $\Delta U = 426$ V. The OT-sample is indicated by black-open circles, while the MB-sample by red-filled circles. The error bars indicate the statistical errors. The fit to the combined data set yields $R_{\mathrm{nn}} = \epsilon_E/\epsilon_0 = 1.004 \pm 0.016$ with $\chi^2/\mathrm{ndf} = 0.792$. (For interpretation of the references to color in this figure caption, the reader is referred to the web version of this paper.)

1. Introduction

In a recent paper, the PAX Collaboration has published the first experimental upper limit for the ep spin-flip cross-section at center-of-mass energies between 100 meV and 2 eV [1]. The measurement was motivated by the proposal to use the spin-flip mechanism in the interaction with a polarized positron beam to polarize a stored antiproton beam [2]. The experiment was performed by searching for the depolarization in the inverse reaction, i.e., the depolarization of a stored beam by spin-flip in ep scattering [1]. The test was carried out at the COSY storage ring of Jülich [3]. The experiment ruled out the use of spin-flip as a method to polarize a stored beam and led to a revised theoretical estimation of the ep spin-flip cross-section [5–7]. It allowed for the first experimental determination of an upper limit for the ep spin-flip cross-section in the region of interest.

In this paper we present a new analysis of the acquired data that allowed us to significantly increase the statistical accuracy of the measurement and thus to reduce the upper limit by a factor of three compared to our previous publication [1].

2. Experiment

The goal of the experimental test was to detect the possible depolarization of a polarized proton beam interacting with an unpolarized co-propagating electron beam [1]. The task was accomplished by injecting a polarized proton beam into COSY and by making dedicated use of the electron cooler beam. The electron cooler was employed to provide the usual phase-space cooling of the stored proton beam and, in addition, to serve as an electron target for the measurement of the low-energy ep spin-flip cross-section. The experimental cycle consisted of two parts. In the first part, a vertically polarized proton beam was injected into the ring and interacted with the electron cooler beam. During the second part, the residual polarization in the beam was measured. In order to identify the effect of the ep interaction on the polarization of the proton beam, two types of cycles were implemented, an E-cycle, where the electron target was present, and a 0-cycle without an electron target. Data were taken at six different relative proton–electron velocities in the range 0 and ± 0.003 c. The measured left–right asymmetry in pd elastic scattering at $T=49.3$ MeV was used to determine the beam polarization from the known analyzing power A_y [4]. The scattered particles from the interaction of the polarized beam impinging with a D_2-cluster target were detected by two telescopes symmetrically placed around the target, each consisting of three layers of double-sided silicon strip detectors. A complete description of the experimental setup can be found in Ref. [1].

3. Data analysis

In the previously published data, only clearly identified deuterons (D-sample) from elastic scattering were taken into account to determine the spin-flip cross-section σ_S, which is related to the ratio $R = P_E/P_0$ between the beam polarizations measured with (E) and without (0) interaction with the electron beam. The ep spin-flip cross-section is derived by integrating Eq. (4) of Ref. [1] over the duration t_E of the interaction

$$\sigma_S = \frac{-\ln R}{2 \cdot d_{\mathrm{t}} \cdot t_E \cdot f} \tag{1}$$

where d_{t} is the electron target density and f the beam revolution frequency. The beam polarization was determined by dividing the measured asymmetry ϵ of the reconstructed events by the known analyzing power A_y (from [4]). In the evaluation of the asymmetries use was made of the so-called *Cross-Ratio* method [8].

In the new analysis, the ratio R was evaluated directly from the measured asymmetries in each angle bin, without introducing the analyzing power and the beam polarization. This procedure allowed us to increase the statistics by including non-identified particles.[1] Two different event samples were utilized, a minimum-bias (MB) sample and a one-track (OT) sample. In addition to the D-sample, the MB-sample also contains events from the proton–deuteron overlapping region (see Fig. 1). Thus 4.4×10^6 events in the MB-sample were used in addition to the 3.2×10^6 events of the D-sample. The OT-sample contains all events with one track in the detection system and no identified deuteron using the MB cuts. These additional 10.9×10^6 events that exhibit asymmetries up to $|0.2|$ are primarily responsible for the gain in statistics.

The asymmetries ϵ_E and ϵ_0 for the E- and 0-cycles in each angular bin were separately evaluated for the six detune voltages. The angular binning of $\Delta\theta = 3^\circ$ is consistent with the precision of the track reconstruction. The data were fitted by a linear

[1] It should be noted that, although the beam polarization does not directly appear in Eq. (1), it clearly affects the statistical errors since $\epsilon \propto A_y P$.