EDDA AT COSY: SPIN-CORRELATION COEFFICIENTS OF ELASTIC PROTON-PROTON SCATTERING IN THE 0.8-2.5 GEV RANGE

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Abstract

The EDDA-experiment at the Cooler Synchrotron (COSY) in Juelich, Germany, has measured the differential cross section $\frac{d\sigma}{d\Omega}$ and spin observables of elastic proton-proton scattering, namely the analysing power A_N and the spin-correlation coefficients A_{NN}, A_{SL} and A_{SS}. With an atomic beam as a pure hydrogen target internal to the unpolarised (A_N) or the polarised (A_{NN}, A_{SL} and A_{SS}) COSY proton beam, angular distributions spanning the centre-of-mass scattering angles of $30^\circ \leq \theta_{c.m.} \leq 90^\circ$ have been obtained. The applied measurement technique provides for consistency and high statistics of the data taken.

With the data for A_N, a consistent normalisation standard over the whole COSY energy range has been established. New data on spin-correlation coefficients at several energies will be presented and their impact on phase-shift analyses and amplitude reconstruction will be discussed. Here, the data on A_{SS} – the first measurements between 0.8 and 2.5 GeV – will be shown to be of special importance.

Physics Motivation

Elastic nucleon-nucleon scattering plays a fundamental role in our understanding of the strong interaction. As the strong interaction is spin dependent, scattering of polarised particles has to be studied in order to investigate the degrees of freedom of the scattering processes. Theoretical calculations of various hadronic processes need experimental input, which ususally is parameterised by nucleon-nucleon (NN) phase-shifts. The validity of these phase-shifts depends on the density and quality of the available data. Different present phase-shift analyses (PSA) for elastic proton-proton scattering processes – e.g. those of the Saclay-Geneva [1, 2, 3] and the Virginia [4, 5] groups – show discrepancies at beam kinetic energies above about 1 GeV. This necessitates an unambiguous and consistent determination of phase-shifts in this energy range. On the one hand, the world data base – especially that on A_{SS} – was less dense at these energies, on the other hand the number of partial waves entering into the calculations increases. Another approach, the model independent reconstruction of the complex scattering amplitudes (in the case of elastic proton-proton scattering their number amounts to 5), can up to now not be carried out unambiguously [6]. Current models describe the data up to about 800 MeV. Above this energy the details of the short range interaction can be resolved, so that the models have to be adapted in this region. All these problems can be tackled only with new data of high quality.

Experimental Setup

The EDDA-experiment is an internal target experiment at the cooler synchrotron COSY. It has measured observables of unpolarised and polarised proton-proton elastic scattering in the beam kinetic energy range of 0.5-2.5 GeV. The experiment was carried out in three phases. The first phase consisted in the measurement of the p-p-elastic differential cross section $\frac{d\sigma}{d\Omega}$ [7], the second phase in the measurement of the analysing power A_N [8] excitation functions.

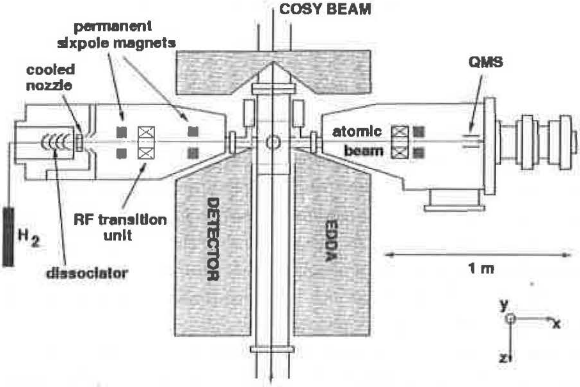

Figure 1: The atomic beam target

In the third and last phase of the experiment the spin-correlation coefficients A_{NN}, A_{SL} and A_{SS} have been measured [9]. These measurements – as well as those of A_N – were performed using a pure hydrogen atomic beam target. Earlier measurements using a similar device were done by the PINTEX collaboration at IUCF [10, 11] at lower energies. Our target provided a polarised hydrogen beam. The polarisation direction was aligned along a weak guiding field, which could be switched between x, y and z directions in the laboratory system. The measurements of the analysing power A_N were done with an unpolarised beam, those of the spin-correlation coefficients with a beam polarised along the y-axis (for axis directions see fig. 1). The duration of one COSY-cycle was about 10 s, and these cycles were repeated subsequently with changing target polarisation directions $(\pm x, \pm y, \pm z)$ and – when applied – alternating beam polarisation directions $(\pm y)$. This technique allowed to suppress false asymmetries. Measurements were performed during acceleration of the beam as well as during the flattop of constant energy. All in all, 9 different flattop energies distributed over the whole energy range were chosen. Data from the acceleration ramp generally have lower statistics than those from the flattop and thus fill the gaps with somewhat lower accuracy. Here we only present angular distributions reconstructed from the flattop data.

Events were detected by the EDDA-detector (fig. 2). It consists of two cylindrical double layers of scintillating material, which surround the the COSY-beampipe axially symmetric: the inner layer (H) made of helically wound scintillating fibres and the outer layer made of scintillator bars (B) and half-rings (F, R). Situated downstream behind the atomic beam target, the detector covers an angular range of $30° \leq \theta_{c.m.} \leq 90°$ for p-p-elastic scattering events. Target peak polarisations of 90% were reached. Due to the non-uniformly distributed unpolarised background over the considered reaction vertex, the effective polarisation was reduced to 70-80%. As the detector consists of two scintillator layers, the reaction vertex in the extended region of overlap between target and COSY-beam could be reconstructed to an accuracy of 1 mm. The angular resolutions are $\Delta\theta_{c.m.} \approx 1.5°$ for the polar and $\Delta\varphi \approx 1.8°$ for the azimuthal angles.

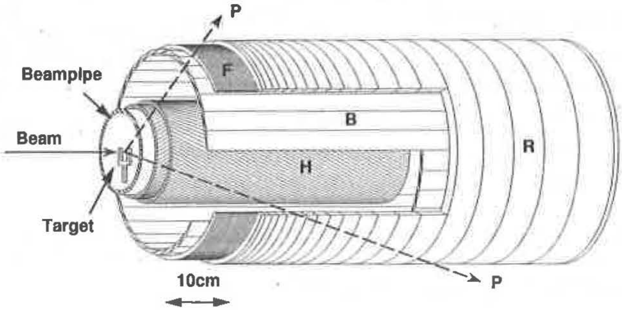

Figure 2: The EDDA detector

Analysis

In the first step of the data analysis the polar angle $\theta_{c.m.}$ and the azimuthal angle φ were reconstructed from the data. The chosen bin width in $\theta_{c.m.}$ was 5°. Elastic data were selected by their kinematical signature. Proper cuts were applied with respect to the overlap of target and COSY beams and the detector acceptance. This rendered event rates $N(\theta, \varphi)$ over the measured energy range. The anisotropy of polarised scattering processes with beam polarisation P and target polarisation Q for the case of only one beam polarisation axis is described by the relation

$$\begin{aligned}\frac{d\sigma}{d\Omega}/\frac{d\sigma_0}{d\Omega} = 1 \; &+ \; A_N(\theta)[(P_y + Q_y)\cos\varphi - Q_x \sin\varphi] \\ &+ \; A_{SS}(\theta)[P_y Q_y \sin^2\varphi + P_y Q_x \cos\varphi \sin\varphi] \\ &+ \; A_{NN}(\theta)[P_y Q_y \cos^2\varphi - P_y Q_x \cos\varphi \sin\varphi] \\ &+ \; A_{SL}(\theta)[P_y Q_z \sin\varphi]\end{aligned} \quad (1)$$

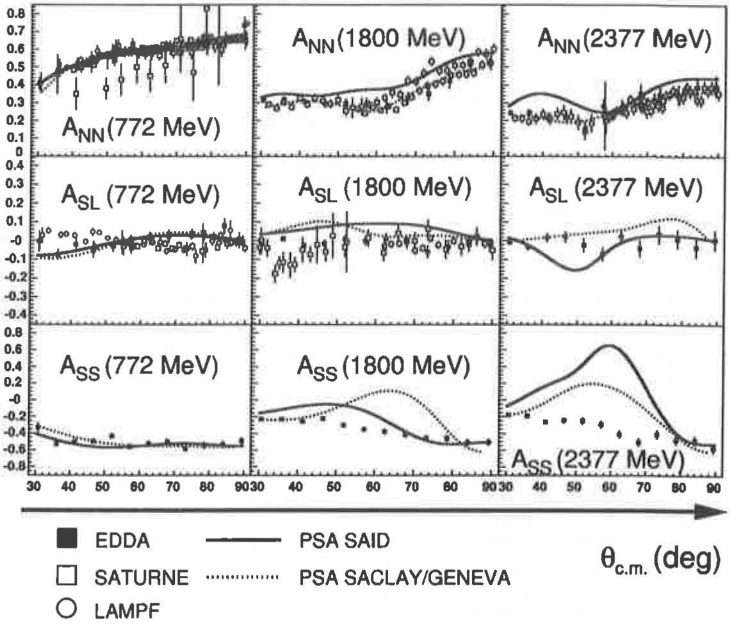

Figure 3: Preliminary EDDA results – angular distributions for spin-correlation coefficients, compared with other experimental data (SATURNE [14] and LAMPF [15, 16, 17]) and phase-shift analyses (SAID/SM00 [4, 5] and SACLAY-GENEVA [3])

This relation was exploited to extract the spin-correlation coefficients by two different procedures. Extending the method outlined in [12], one of these uses special asymmetries of the counting rates [13]. The other one is a χ^2-fit of the data to (1). The first method has the advantage of being first order independent of false asymmetries caused by non-uniform detector efficencies. The second method offers the possibility to study in detail these efficiency differences. Both methods yielded compatible results, which confirmed the validity of our data analysis. The data shown are derived by the asymmetry method. The polarisation scale has to be fixed by a set of values for A_N, which can be either results from PSA or those of our own measurements [8]. Data analysis is currently being finalised.

Results

Results for the spin-correlation coefficients A_{NN}, A_{SL} and A_{SS} have been determined in the center of mass angular range $30° \leq \theta_{c.m.} \leq 90°$ in $5°$ wide bins (fig. 3). Our measurements are compatible with previous ones, where the data base is sufficiently dense, e.g. [14, 15, 16, 17]. Energy dependent existing PSA [1, 2, 3, 4, 5] solutions are confirmed in regions with an already existing data base. Above 1 GeV the cited PSA on A_{SS} do neither agree with one another nor with our data. This shows, that the data on A_{SS} adds substantial information to these calculations.

As has been demonstrated in [9], the data also help to reduce ambiguities in the direct reconstruction of scattering amplitudes.

The data – especially those on A_{SS} – will have an important impact on future PSA.

Acknowledgements

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