Proton-Proton Elastic Scattering Excitation Functions at Intermediate Energies: Cross Sections and Analyzing Powers

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The EDDA experiment at the cooler synchrotron COSY measures proton–proton elastic scattering excitation functions in the momentum range 0.8 – 3.4 GeV/c. In phase 1 of the experiment, spin-averaged differential cross sections were measured continuously during acceleration with an internal polypropylene (CH_2) fiber target, taking particular care to monitor luminosity as a function of beam momentum. In phase 2, excitation functions of the analyzing power A_N and the polarization correlation parameters A_{NN}, A_{SS} and A_{SL} are measured using a polarized proton beam and a polarized atomic hydrogen beam target. The paper presents recent $d\sigma/d\Omega$ and A_N data. The results provide excitation functions and angular distributions of high precision and internal consistency. No evidence for narrow structures was found. The data are compared to recent phase shift solutions.

1. INTRODUCTION

The proton-proton elastic scattering [1] is fundamental to the understanding of the strong interaction. The long- and medium range parts of the NN interaction seem to be well understood. The meson exchange potential model provides an adequate description of the data at low energies (< 300 MeV). At smaller distances (< 0.8 fm), however, at which two nucleons overlap, genuinely new processes may occur involving the dynamics of the quark-gluon constituents. In order to reach such short distances essentially higher energies are needed because of the strong repulsive core. At 1-2 GeV bombarding energies proton-proton scattering provides an ideal focus on the short range part of the nucleon-nucleon interaction, especially on the role of the ω meson [2]. Another important problem is the question of existence or nonexistence of dibaryons [1]. Experimentally, there is a lack of data at higher energies and there are inconsistencies and normalization errors in the angular distributions measured at different discrete energies. In addition, energy dependent structures have been observed in certain spin observables [3]. Therefore, in order to provide consistent data and to scan the proton-proton interaction at short distances

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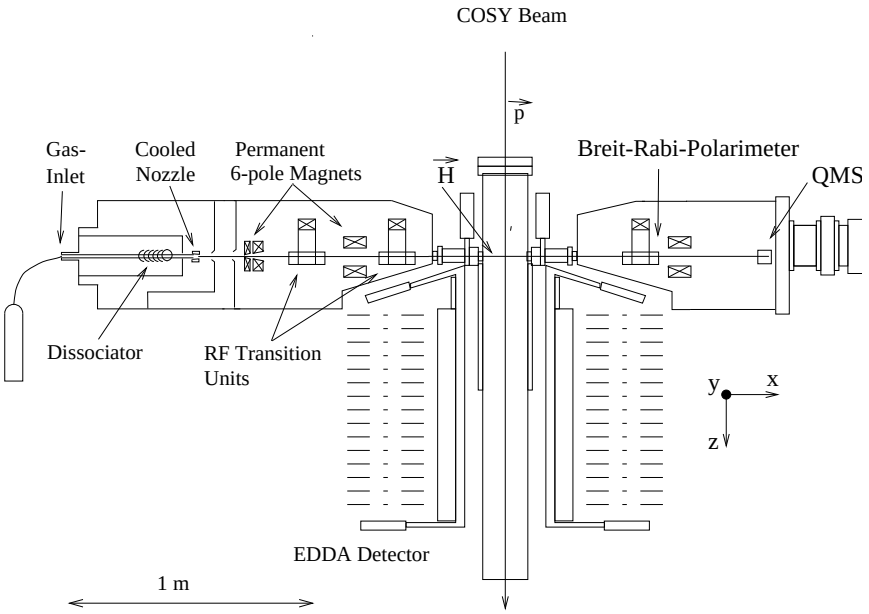

Figure 1. Scheme of the polarized atomic beam target and the EDDA detector.

excitation functions should be measured at intermediate energies in fine energy steps with a high relative accuracy. Precise data are also needed for the improvement and extension of potential models [2] and phase shift analyses [4] to higher energies.

2. EXPERIMENTAL TECHNIQUE

The EDDA experiment [5] is designed to measure excitation functions of spin-averaged and spin-dependent cross sections with a high relative accuracy over a wide momentum range during the proton beam acceleration in the cooler synchrotron COSY [6]. In phase 1, differential cross sections were measured in the momentum range 800-3400 MeV/c using 4 μm $\times$ 5 μm CH_2 fiber targets and 5 μm diameter C fiber targets for background subtraction [5]. Relative normalization was achieved by measuring δ electrons as well as the secondary electron current released from the fiber target. Absolute normalization was established by reference to Los Alamos data near 1500 MeV/c [7].

In phase 2 the analyzing power $A_{\rm N}$ and the polarization correlation parameters $A_{\rm NN}$, $A_{\rm SS}$ and $A_{\rm SL}$ will be measured as a function of momentum using a polarized atomic beam target and a polarized proton beam. The polarized atomic beam target [8] and the EDDA detector are shown schematically in Fig. 1. The polarized hydrogen atoms are prepared using an atomic beam source with dissociator, cooled nozzle, permanent sextupole magnets and rf-transition units. In the beam dump the polarization is continuously monitored using a Breit-Rabi polarimeter. Preparing a polarized atomic beam in the pure hyperfine state 1 yields a peak polarization of 85 %, and an effective target density of about $2{\cdot}10^{11}$ atoms/cm^2. The width at the target location is $\sim$12 mm (FWHM). The magnetic holding field (0.8 mT) can be switched between $\pm x$, $\pm y$ and $\pm z$.

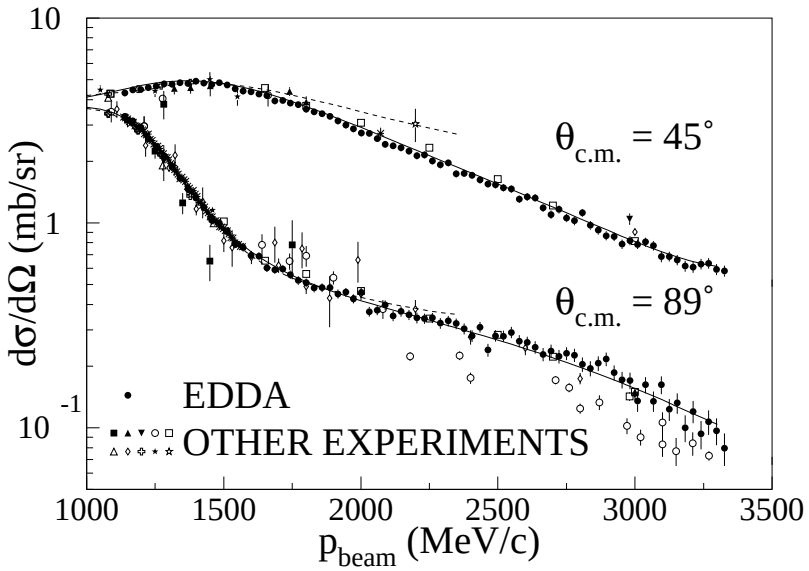

Figure 2. Differential cross section excitation functions for elastic pp scattering at $\Theta_{cm} = 45^\circ \pm 1^\circ$ and $89^\circ \pm 1^\circ$. The solid (dashed) curves are from the SM97 (SM94) phase shift analysis [4].

For the actual analyzing power measurements an unpolarized COSY beam was used. With $1.5 \cdot 10^6$ turns/s and $3 \cdot 10^{10}$ protons in the ring a luminosity of about $0.9 \cdot 10^{28}/\mathrm{cm}^2/\mathrm{s}$ was achieved. Data were taken during the acceleration and deceleration of the COSY beam. Since the target polarization is constant during acceleration/deceleration (time period $\sim$20 s) a high relative accuracy can be achieved. In two runs about $25 \cdot 10^6$ elastic scattering data were taken. The absolute calibration is established with reference to angular distributions measured at 1022 and 1458 MeV/c [9,10].

3. RESULTS

Two out of 28 differential cross section excitation functions [5] are shown in Fig. 2. On the basis of the new EDDA data Arndt and coworkers were able to extend their phase shift analysis up to 3300 MeV/c which is shown as solid curves [4]. The dashed curves are solutions from 1994. In a recent high statistics run the number of elastic events was increased from 15 to 45 million. All excitation functions show a smooth dependence on beam momentum. Assuming narrow (total width Γ=10 – 100 MeV) $^1S_0$ and $^1D_2$ resonances we deduce upper limits for the elasticity Γ_{el}/Γ of 0.05 – 0.18 and 0.02 – 0.08, respectively, in the momentum range 800 – 3400 MeV/c.

First preliminary results of analyzing power excitation functions in the momentum range 1000-3300 MeV/c are shown in Fig. 3 and compared to a recent phase shift solution SP98 [4]. The data are grouped in ($\Delta\Theta = 6^\circ$, Δp = 30 MeV/c) wide bins. The general

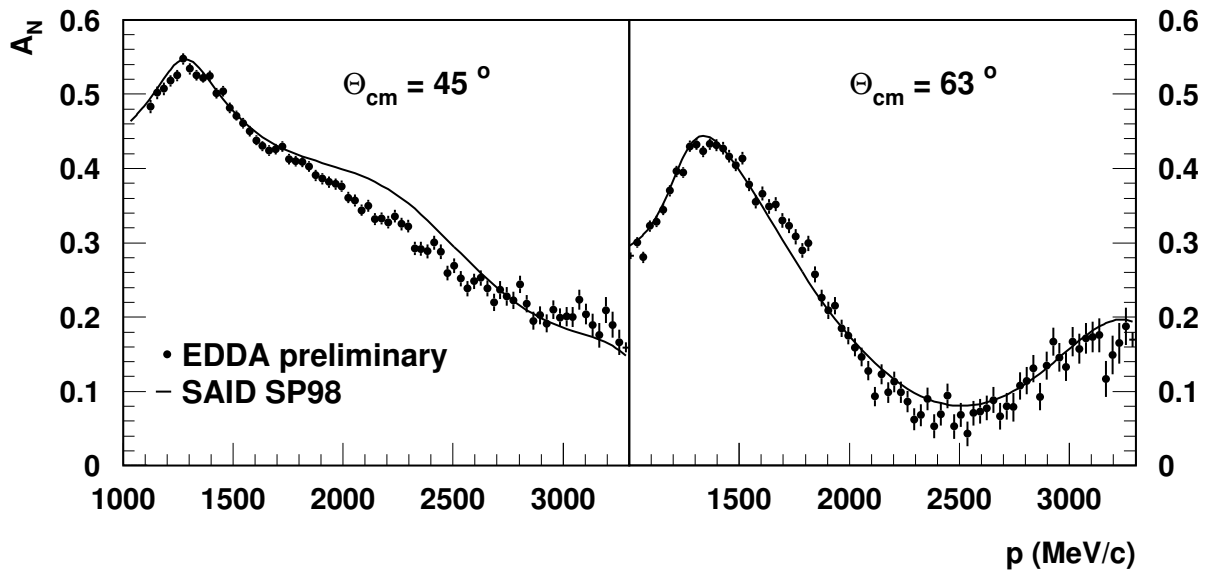

Figure 3. Preliminary results of analyzing power excitation functions for elastic pp scattering in the momentum range 1000 – 3300 MeV/c. The solid curves are recent phase shift solutions SAID SP98 [4].

trend of the excitations functions is reproduced by the phase shift solution SP98, but there are also marked discrepancies at higher momenta. The same holds true for the most recent phase shift solution SP99. It should be noted that the analyzing power data of this paper are not yet included in those phase shift analyses.

To summarize, the method of using the internal synchrotron beam during acceleration works well and can now be used to measure excitation functions of polarization correlation parameters. The EDDA collaboration gratefully acknowledges the great support received from the COSY accelerator group. This work was supported by BMBF and FZ Jülich.

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