UDC 539

Analyzing power of Inverse Diproton Photodisintegration at Intermediate Energies

Baimurzinova B.

Laboratory of Nuclear Problems, Joint Institute for Nuclear Research, RU-141980 Dubna, Russia
e-mail:baymurzinova@jinr.ru

The reaction $\gamma + \{pp\}_s \rightarrow p + p$, where diproton $\{pp\}_s$ is a proton pair in $^1S_0$ state, is a spin-isospin partner of the fundamental reaction of deuteron photodisintegration. The inverse reaction, the hard bremsstrahlung $p + p \rightarrow \gamma + \{pp\}_s$, has been observed with the ANKE spectometer at COSY-Jülich. In addition to differential cross section measured earlier, in this work it's analyzing power has been measured at forward angles at several energies in the region of Δ(1232) isobar exictation.

Key words: diproton, analyzing power, hard bremsstrahlung.
PACS number(s): 25.40.Ep, 13.60.-r, 25.20.Dc

1 Introduction

The formation of a so-called "diproton", i.e. a proton pair $\{pp\}$, in $^1S_0$ state, is being researched at ANKE collaboration in various processes: $pd \rightarrow \{pp\}_s\, n$, $pp \rightarrow \{pp\}_s\, \pi^0$, $pp \rightarrow \{pp\}_s\, \gamma$ [1-5]. Such reactions are of interest for several reasons. Firstly, they are the elementary inelastic processes in few-nucleon systems which could give valuable information on dynamics of nucleon-nucleon interaction. Secondly, restriction to only one partial wave (*S*-wave) in the final state considerably simplifies the reactions theoretical consideration in comparison to other reactions of this kind, for example deuteron photodisintegration $\gamma d \rightarrow pn$. The diproton photodisintegration $\gamma\{pp\}_s \rightarrow pp$ is kinematicly very similar to $\gamma d \rightarrow pn$, however dynamically they significantly differ from each other. The matter is that the quantum numbers of a diproton state ($I = 1$, $S = 0$, $L = 0$) differ from the corresponding quantum numbers of a deuteron ($I = 0$, $S = 1$, $L = 0.2$). As a result multipole contributions will also be significantly different. Therefore the data received for these two reactions mutually supplement each other, indicating that we should study such processes more carefully.

In absence of a free bound diproton, $\gamma\{pp\}_s \rightarrow pp$ is traditionally investigated for diproton which bound within a nucleus. At ANKE an alternative approach was applied for the first time – the study of the inverse reaction $pp \rightarrow \gamma\{pp\}_s$ [4], free from background created by the deuteron photoabsorption. Particulary, the goal of this work is to find analyzing power of this reaction.

2 Measurements and analysis

The experiment was carried out in Germany using ANKE facility of the synchroton storage ring COSY-Jülich (Fig. 0) [6]. A hydrogen cluster-jet target was positioned in the proton beam and secondary particles were detected with wire chambers and scintillation hodoscope. The proton beam was transversely polarized with it's polarization direction varying from up to down. The trajectories and three-momenta of the particles were reconstructed.

The first step in the identification of our reaction was the selection of two coincident protons among all the detected pairs of positively charged particles. The scintillation hodoscope allowed measurement of the difference between the times of flight from the target to detector for two recorded particles. If we assume the masses of the particles, we can also calculate this time of difference, using the measured momenta and trajectories. If our assumption was correct then these two values would coincide. With time resolution better than 2 ns, the comparison of this value with that calculated from the measured particle momenta and trajectories led to a very good identification of proton pairs. At low excitation energy $E_{pp} < 3$ MeV the diproton is predominantely in the $^1S_0$ state. The resolution of the ANKE setup $\sigma(E_{pp}) < 0.6$ MeV allowed reliable selection of $E_{pp} < 3$ MeV diprotons.

As the next step, histograms for missing mass squared were created at $T_p = 0.500, 0.550, 0.700$ GeV (Fig. 1). There is a clear visible γ peak that could be separated from the pion peak associated with the *pp*

$\to pp\pi^0$ reaction. The peak shapes were obtained by a detailed Monte Carlo simulation at each energy, which took into account all the known features of the setup. The free parameters of interest used to fit the missing-mass spectra were the number of events in the γ peak and the number of events in the pion peak. In order to compensate for the lack of knowledge of the beam spatial distribution, additional parameters were inserted into the fits: a shift of the pion peak position and correction factors for the γ and pion peak widths. The results of the fit can be seen in Fig. 1 as well.

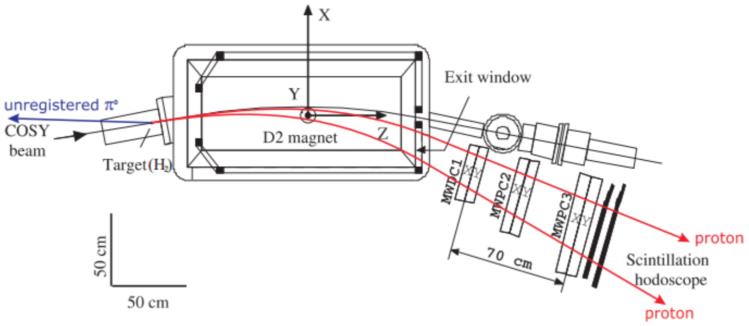

Figure 1 – Experimental setup

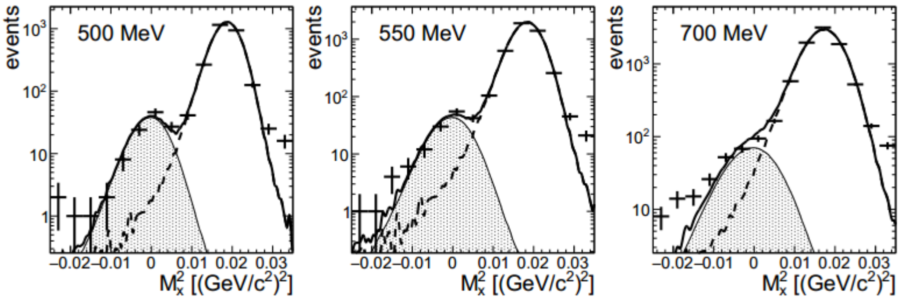

Figure 2 – Distribution of the missing mass squared in the $p + p \to \{pp\}_s + X$

To estimate the angular dependence of the analyzing power, the events were divided into two θ_{pp} intervals 5–13°, 13–30° and separate fits were made for each of these ranges. Firstly, we had to find polarization assymetry given by equation (1).

$$\varepsilon = \frac{N_\uparrow / L_\uparrow - N_\downarrow / L_\downarrow}{N_\uparrow / L_\uparrow + N_\downarrow / L_\downarrow}, \qquad (1)$$

where $N_\uparrow$ and $N_\downarrow$ are the numbers of events with beam proton spin up and down, and $L_\uparrow$ and $L_\downarrow$ are the corresponding luminosities. It is needed to calculate the analyzing power using equation (2).

$$A_y = \frac{\varepsilon}{P\langle\cos\phi_{pp}\rangle}, \qquad (2)$$

where P is the transverse polarisation of the beam and $\langle\cos\phi_{pp}\rangle$ the average over the diproton azimuthal angular distribution. Different approaches were applied to obtain the analyzing power. The numbers of events can be determined either by fitting separately $N_\uparrow$ and $N_\downarrow$, or directly $N_\uparrow - N_\downarrow$ and $N_\uparrow = N_\downarrow$ histograms. Concerning $\cos\phi_{pp}$ there are two possibilities, either to divide by the average value of $\cos\phi_{pp}$ distribution or to correct by $\cos\phi_{pp}$ event-by-event. Hence, four approaches were applied, each repeated for fine and gross histogram binning. These 8 values with errors were averaged. The dispersion of the values was considered as a systematic error. Polarization P was estimated using the known values of A_y for elastic pp and $pp \to d\pi^+$ reactions, registered in parallel with our reaction.

3 Results and outlook

In Fig. 2 and Table 0 the preliminary results are shown for analyzing power of the $pp \to \gamma\{pp\}_s$ reaction at $T_p = 0.500, 0.550, 0.700$ GeV.

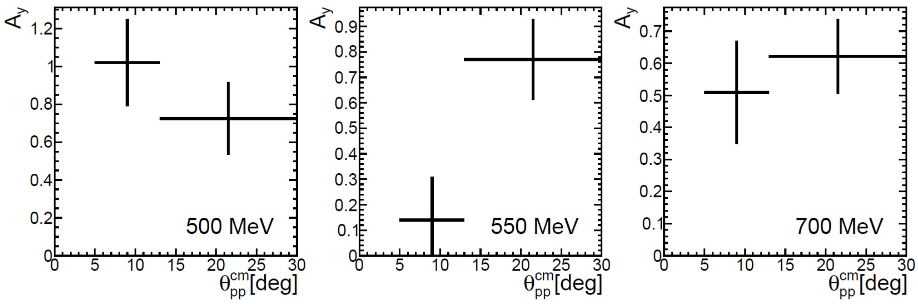

Figure 3 – Analyzing power for reaction $p + p \to \gamma + \{pp\}_s$, preliminary results.

Table 1 – Numerical values of analyzing power with systematical and statistical errors, preliminary results.

	500	550	700
$5-13^{\circ}$	$1.02 \pm 1.80 \pm 0.02$	$0.14 \pm 1.03 \pm 0.67$	$0.51 \pm 1.23 \pm 0.014$
$13-30^{\circ}$	$0.72 \pm 1.45 \pm 0.03$	$0.77 \pm 0.99 \pm 0.01$	$0.62 \pm 0.92 \pm 0.002$

Since multipole contributions *M*1 and non-spin-flip part of *E*1 are forbidden, it might be sufficient to retain only *E*2, *M*2 and spin-flip part of *E*1. The qualitative estimate of the results [7] suggests that there may be significant contribution of the *M*2 multipole contrary to the predictions of [8]. The numerical evaluation of *E*1, *E*2, *M*2 multipole contributions to the data is in progress.

Acknowledgements

The authors wish to think other members of the ANKE collaboration for their help and assistance in the running of the experiment and in the data analysis.

References

[1] S. Dymov et al.Deuteron breakup pd→{pp}sn with forward emission of a fast 1S0 diproton// Phys. Rev. C. – 2010. –Vol. 81. –P. 044001.

[2] V. Kurbatov et al.Energy dependence of forward 1S0 diproton production in the pp→ppπ0 reaction// Phys. Lett. B. – 2008. – Vol. 661. –P. 22.

[3] D. Tsirkov et al.Differential cross section and analysing power of the pp→{pp}sπ0 reaction at 353 MeV// Phys. Lett. B. – 2012. – Vol. 712. – P. 370.

[4] V. Komarov et al.Observation of Inverse Diproton Photodisintegration at Intermediate Energies// Phys. Rev. Lett. – 2008. – Vol. 101. – P. 102501.

[5] D. Tsirkov et al.Energy dependence of hard bremsstrahlung production in proton–proton collisions in the Δ(1232) region// J. Phys. G: Nucl. Part. Phys. – 2010. –Vol. 37. –P. 105005.

[6] S. Barsov et al.ANKE, a new facility for medium energy hadron physics at COSY-Jülich// Nucl. Instrum. Methods. Phys. Res. – 2001. –Vol. 462. –P. 364.

[7] P. Wilhelm et al. Signatures from polarization observables for photon absorption on a 1S0 proton pair // Nucl. Phys. A. – 1996. –Vol 597. – P. 613.

[8] P. Wilhelm et al. Photon absorption on a proton-proton pair in He3// Phys. Lett. C. – 1995. – Vol.51. – P. 2841.