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Deuteron-breakup reaction studies at COSY

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Summary. — The possibility of identifying and reconstructing deuteron-breakup events by making use of the PAX detector has been investigated. The results are presented.

PACS 29.27.Hj – Polarized beams.
PACS 24.70.+s – Polarization phenomena in reactions.
PACS 25.40.Ep – Inelastic proton scattering.

1. – Introduction

The goal of the PAX Collaboration is the production of the first ever beam of polarized antiprotons [1]. To this aim the PAX Collaboration has defined a program to experimentally investigate spin-filtering, as a mechanism to polarized stored beam. Spin-filtering exploits the spin-dependence of the hadronic interaction by means of the repetead passage of the stored beam through a polarized internal target. The program foresees measurements at COSY with stored protons and subsequently at AD with antiprotons. The measurements at COSY include tests with polarized proton and deuterium targets. In order to measure the induced polarization in the beam, a dedicated detector is being developed aimed at the identification of azimuthal asymmetries in proton-proton and proton-deuteron elastic scattering. In the latter case, as a background reaction, also deuteron-breakup events will hit the detector. The present work is aimed at the identification and reconstruction of exactly these events. As in part of the kinematic range of interest for the spin-filtering studies at COSY no deuteron-breakup data exist, the study of this channel is of interest by itself. In particular, deuteron-breakup reaction data in the unexplored energy range 30–50 MeV represent a testing ground for the predictive power of the chiral perturbation theory and a tool to provide evidence for the three nucleon forces. In addition unknown polarization observables (such as vector and tensor analysing powers and spin-correlation coefficients) could be measured and evaluated over large kinematical areas in the three-nucleons final state [2].

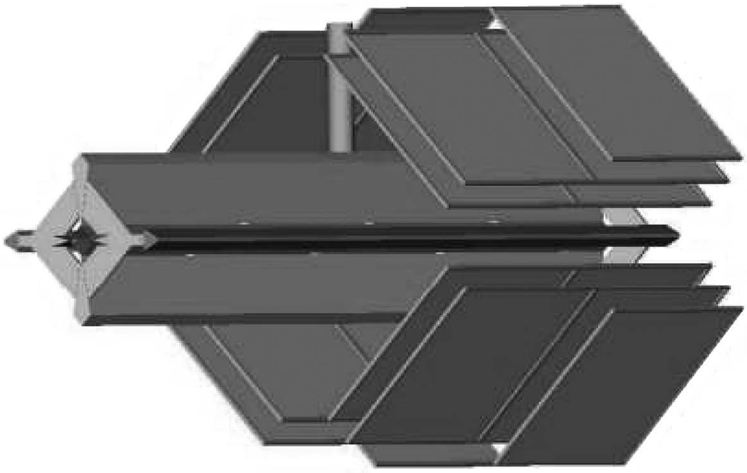

Fig. 1. – The target deuterium cell (in the middle) surrounded by the silicon detectors arranged in a barrel configuration. The beam direction is along the target cell. The system is equipped of a third layer in the forward part of the phase space, where the majority of the outgoing particles is concentrated.

2. – Detector configuration and simulation conditions

With a 30–50 MeV proton beam kinetical energy impinging on a deuteron target, only two channels are accessible: $pd \rightarrow pd$ elastic scattering and $pd \rightarrow ppn$ deuteron-breakup. The detector system is based on silicon microstrip sensors similar to the one developed at IKP for the ANKE experiment [3]. The PAX detector is composed by two layers of double-side strip silicon sensors of $97 \times 97\,\mathrm{mm}^2$ and thicknesses $300\,\mu\mathrm{m}$ and is able to detect charged particles. Since the neutron is invisible for this system, $pd \rightarrow ppn$ deuteron-breakup could be identified when the two outgoing protons stop inside the detector acceptance, then using the four-momentum conservation, the complete kinematic can be determined. In order to maximize the number of stopped protons, a third thicker silicon layer is implemented to provide the stopping power and allow energy reconstruction in breakup events in addition to the elastic events. This is a fixed target experiment so it is sufficient to equip the detector system with a third layer just in the forward part. The detector set-up is shown in fig. 1 surrounding the 40 cm long and 1 cm wide deuterium target cell. Two adiacent sensors along the beam axis cover the central and forward region of the target cell to maximize the acceptance for both channels.

In order to study the reconstruction efficiency for deuteron-breakup events, a large sample of simulated breakup and elastic events (10^6) have been analysed in the framework of the pure phase-space (GENBOD) model with the proton beam kinetic energy of 30 MeV and 49 MeV. The Geant package [4] was used for the detector response. For each energy, two different thicknesses of the third layer have been considered: 1 mm and 1.5 mm.

3. – Deuteron-breakup identification

The deuteron-breakup identification requires the detection of two stopped protons in the final state since the silicon sensors can detect charged particles only [5]. The energy of stopped protons can be evaluated and used in the four-momentum conservation formula

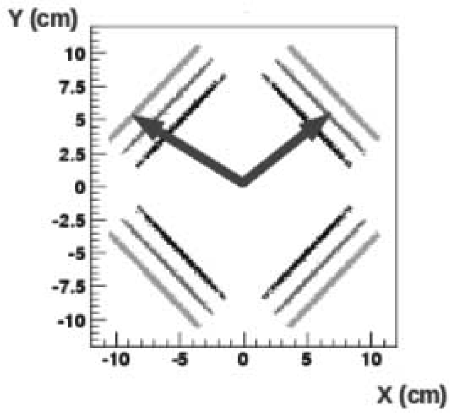

Fig. 2. – Front view of the detector system, in this case the 3-2 event sample is shown. This event is composed by a Long track and a Medium track.

to obtain the missing mass (for deuteron-breakup this should peak at the neutron mass) and have a complete kinematical knowledge of the process.

The event reconstruction is carried out in two steps. Firstly contiguous signals (within a radius of 1 mm) in the silicon strips are merged together into the so-called silicon hits. Only events with at least two hits in the first layers and one hit in the second layer of the detector are considered. Secondly the candidate tracks are reconstructed from one hit in the first and one hit in the second silicon layer, which are separated by less than 6 degrees in azimuthal angle when using radial coordinates.

A hit in the third silicon layer is linked to the reconstructed track if its distance from the extrapolated point of the track is less than 1 cm.

In events where two tracks are traced, the method of distance of closest approach is applied to reconstruct the interaction vertex. Whereas in events in which only one track is traced, the method of distance of closest approach is applied between the track and the beam line to localize the vertex point; after that the second track is traced connecting the vertex point to the coordinates of any untraced hit in the first layer.

Three track typologies are considered: S track, if the particle stops into the first layer, M and L track, if the particle stops into the second or the third layer, respectively. Consequently five event samples are investigated depending on the track type and these events samples are labelled 2-1, 2-2, 3-1, 3-2, see fig. 2, 3-3 referring to the number of hits in each track. These event samples are investigated separately as they, respectively, populate different zones of the phase space. Every sample is identified by means of specific energetic and geometrical selection criteria.

At this energy just two channels can be accessed: breakup and elastic. In data these two channels are combined together and it is necessary to separate them. The mutual request to suppress the elastic channel to negligible contribution is realized applying a coplanarity cut, shown in fig. 3. The coincidence between this selection and the request of having no deuterons in the final state provides the elastic and breakup channel separation.

Stopped particles in second and third layer are selected identifying a region of specific correlation between the deposited energies, $\Delta E/E$ method, see fig. 4.

Stopped particles in the first layer are selected by means of a geometrical cut in which the track is forward traced to check if it intercepts the second-layer acceptance but no associated silicon hit with it is found.

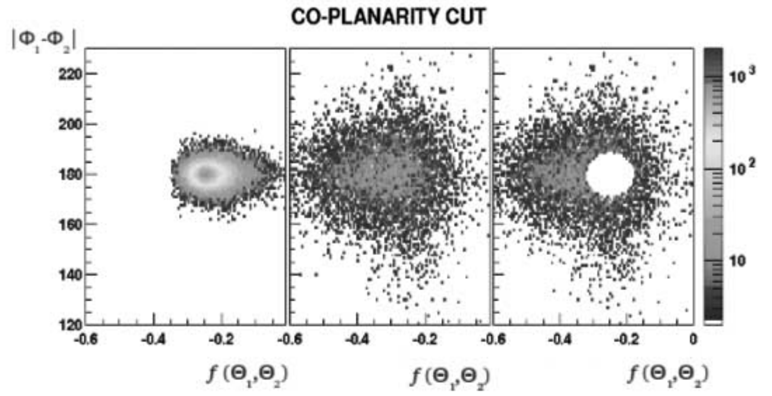

Fig. 3. – The co-planarity cut: the left panel shows the phase space of the elastic channel, the middle panel shows the phase space of the breakup channel, the right panel displays the phase space of the breakup channel in which the area of the main concentration of elastics has been eliminated.

The benefit of the selection criteria for stopped particles is ensured by the behaviour of the Missing-Mass spectrum, which peaks at the neutron mass with a narrow width when they are applied, see fig. 5.

This study has been performed for two different proton beam kinetic energies: 30 and 49 MeV, for each energy two different thicknesses of the third layer of the detector system have been considered: 1 mm and 1.5 mm. In all of these cases the reconstruction efficiency is 5%, the stopping efficiency at 30 MeV (1 mm and 1.5 mm third-layer thicknesses) is 4%, whereas the stopping efficiency at 49 MeV (1 mm and 1.5 mm) is 2%. At 30 MeV, the third layers of 1 mm and 1.5 mm have the same stopping efficiency; the layer of 1 mm thickness is preferable to the 1.5 mm one, since it is already available in the market.

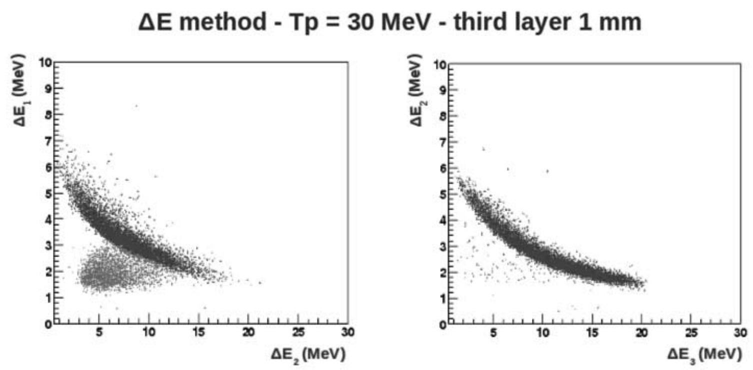

Fig. 4. – The left panel displays the correlation between the deposited energy in the first layer (y) and the second layer (x); the upper band represents events stopped inside the second layer. The right panel shows the correlation between the deposited energy in the second layer (y) and third layer (x), in this case particles in the upper band are particles stopped inside the third layer.

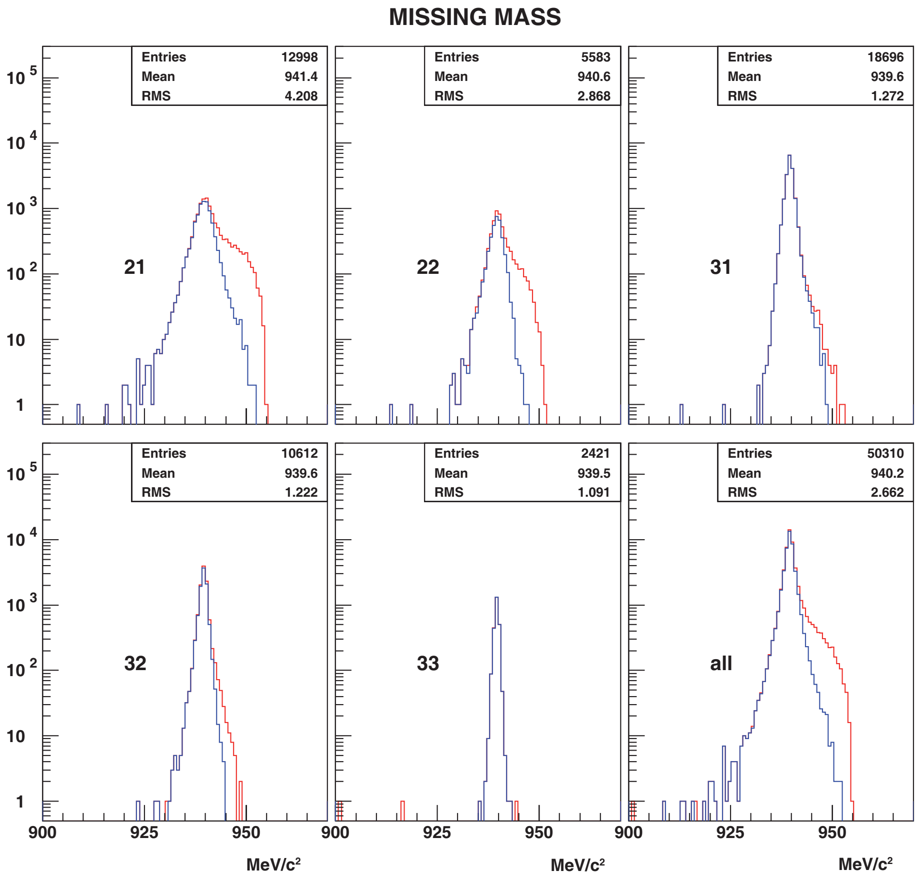

Fig. 5. – Missing Mass at 30 MeV, third layer of 1 mm thickness. The Missing Mass distribution is shown for all events samples separately and together (lower-left panel). The larger distibutions display reconstructed events (all the protons that enter the detector acceptance) while inner distributions represent stopped events. In particular in the 3-3 case, reconstructed and stopped distributions overlap since the majority of the protons that enter the third layer are stopped inside its acceptance. In all these plots, once the selection criteria of stopped particles are applied, the width of the Missing Mass distribution is reduced.

4. – Conclusions

The deuteron-breakup reaction with the PAX detector has been simulated in the framework of the GENBOD model at 30 and 49 MeV proton beam energies. The acceptance in both cases is around 5% and the stopping efficiency is 4% at 30 MeV, whereas it is around 2% at 49 MeV. According to this Monte Carlo study, the best configuration of a run dedicated to the deuteron-breakup reaction studies at COSY using the PAX detector is: a proton beam kinetic energy of 30 MeV and a third-layer thicknesses of 1 mm.

REFERENCES

[1] Proposal submitted to the COSY Program advisory Committee by the PAX Collaboration *Spin Filtering Studies at COSY*, available from: www.fz-juelich.de/ikp/pax, Spokespersons of the proposal Nekipelov M. and Weidemann C., July 2009.

[2] Letter of Intent submitted to the COSY Program advisory Committee by the PAX Collaboration *Measurement of Spin Observables in the pd Breakup reaction*, available from: www.fz-juelich.de/ikp/pax, Spokespersons of the proposal Thorngren Engblom P., September 2009.

[3] Mussgiller A., *Identification and tracking of low energy spectator protons*, Ph.D. thesis University of Cologne.

[4] wwwads.web.cern.ch/wwwasd/geant/index.html.

[5] Bertelli S. *et al.*, *A measurement of deuteron-breakup at* 49 MeV *using Silicon Tracking Telescope* IKP Annual Report 2008 available from: http://www.fz-juelich.de/ikp/publications/AR2008/en/contents.shtml, pp. 11-12.