# Supplement to the COSY Beam Request (20.5) for the *pd*-Breakup Study at ANKE (March 19, 2001)

Data Analysis Results from the first run (Feb. 12-19, 2001)

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# 1 Introduction

The first dedicated beamtime for the deuteron break-up experiment at ANKE has been carried out earlier this year (Feb 12-19, 2001). The goals were *a)* the identification of the process that in *pd* collisions a proton pair with a small relative energy $T_{pp}$ is emitted in the forward direction (predominantly in the $^1S_0$-state) and *b)* a first measurement of the differential cross sections at several proton beam energies ($T_0$ = 0.6, 0.7, 0.8, 0.95, 1.35 and 1.9 GeV). These energies have been chosen such as to determine the energy dependence of the cross section, for which a theoretical prediction [1] is shown in Fig. 1. Unpolarized beam and a deuterium cluster jet

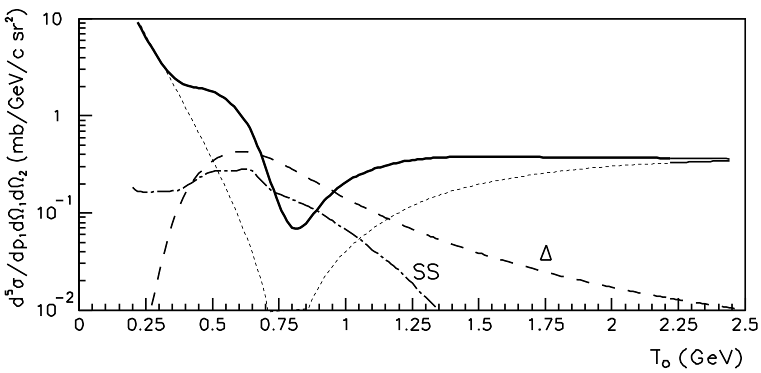


Figure 1: Theoretical calculation of the differential cross section of the deuteron breakup reaction with two forward protons (0°) of relative energy $T_{pp} = 3$ MeV [1].

target were used during these measurements.

In the following some preliminary results obtained are presented to the extent that they concern the measurement of the vector analyzing power $A_y^p$ for the break-up of unpolarized deuterons by bombarding them with polarized protons. The physics motivation of the deuteron breakup programme at ANKE is given elsewhere [2, 3].

# 2 Results

## 2.1 Identification of the process

The total flux of charged particles recorded by the Forward Detector (FD) at ANKE exceeds the flux of proton pairs with a small relative energy ($T_{pp} < 3$ MeV) by factors between $0.2 \cdot 10^6$ and $5.3 \cdot 10^6$ for the range of beam energies given above. In order to separate the process under consideration from other processes a subset of events with two tracks in the FD multiwire proportional chambers was selected. For these events it was verified that the tracks cross the corresponding hodoscope counters, and that the measured energy losses and time-of-flight differences correspond to what is expected for protons. The reconstruction of the momentum of the individual tracks enables to calculate the missing mass $M_x$ for the process

$$p + d \to p_1 + p_2 + X \,,$$

where $p_1$ and $p_2$ are the protons with measured momenta $\vec{P}_1$ and $\vec{P}_2$, respectively. The missing-mass distributions obtained at all beam energies exhibit the expected peak at missing mass values near the neutron mass, as indicated in the left panel of Fig. 2. These events must stem from the process $p + d \rightarrow p_1 + p_2 + n$. The

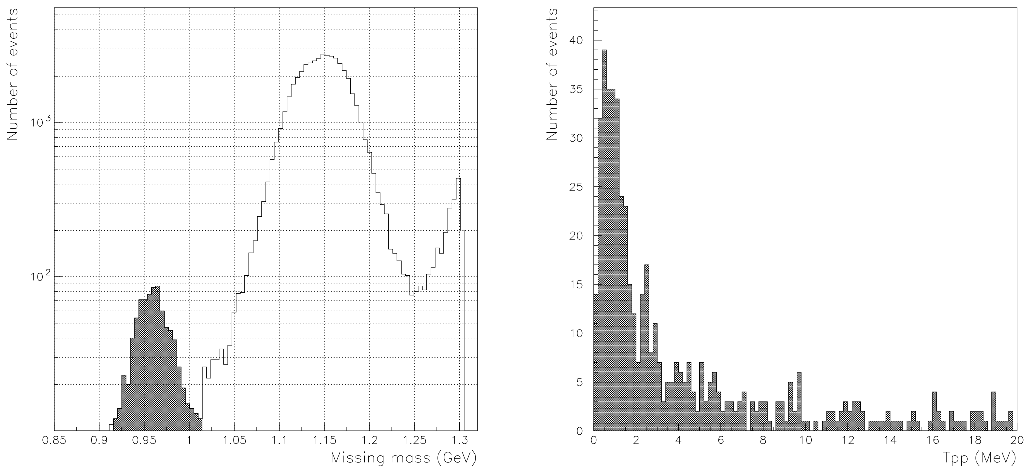


Figure 2: **Left:** Missing mass distribution of the deuteron breakup reaction with two forward protons at a beam energy of 0.6 GeV. **Right:** Distribution of relative energies $T_{pp}$ for the events in the neutron missing mass peak of the figure on the left. (For clarity events above $T_{pp} = 20$ MeV have been omitted. The full observed range of $T_{pp}$ is shown in Fig. 3, right panel.)

relative energy distribution ($T_{pp}$) of the events in the neutron missing mass peak is shown in the right panel of Fig. 2. The enhancement for events with $T_{pp} < 3$ MeV is pronounced.

In the left panel of Fig. 3 the momenta of both forward protons are plotted versus each other, the momenta are strongly correlated. Due to the quasibinary character of the process the protons from the reconstructed two-particle events with $T_{pp} <$ 3 MeV possess nearly the same momenta. It should be noted, that an independent identification of protons of small relative energy is possible by determination of the time-of-flight difference of the particles, as shown on the right of Fig. 3.

## 2.2 Measured counting rates

In Table 1 the results of the beam time are summarized. $N$ denotes the total number of events in the neutron missing-mass peak, $N_{<10}$ and $N_{<3}$ denote the number of events with $T_{pp} < 10$ MeV and $T_{pp} < 3$ MeV, respectively. Also given is the total measuring time $t$ used to obtain these events. The quantities $n$, $n_{<10}$ and $n_{<3}$ denote the corresponding counting rates.

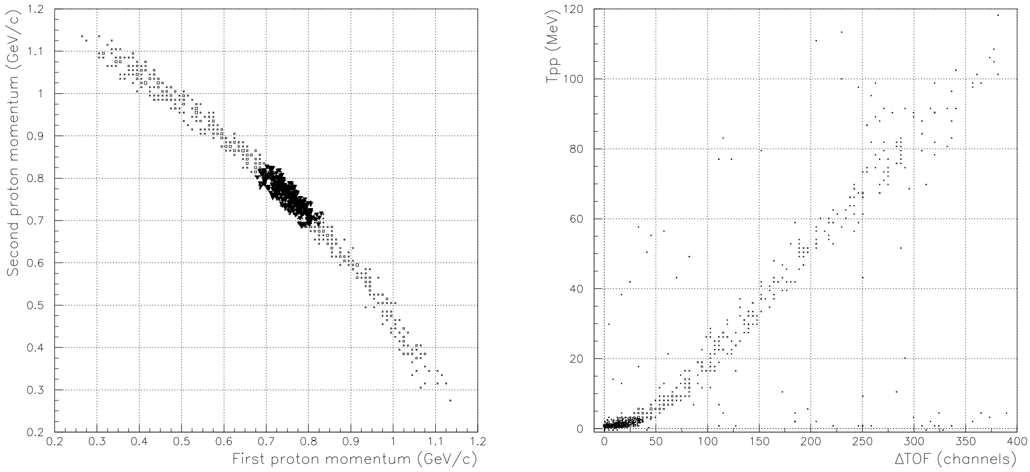


Figure 3: **Left:** Distribution of the momenta of one proton versus the other from $pd$ breakup for $M_x = m_n$. Events with $T_{pp} < 3$ MeV are emphasized. **Right:** Independently, protons of small relative energy can be also identified from the measured time-of-flight difference in the forward hodoscope counters (emphasized dots). (One $\Delta$TOF channel corresponds to 40 ps.)

| $T_0$ [GeV] | $N$ | $N_{<10}$ | $N_{<3}$ | t [h] | $n$ [$10^{-3}$s$^{-1}$] | $n_{<10}$ [$10^{-3}$s$^{-1}$] | $n_{<3}$ [$10^{-3}$s$^{-1}$] |
|---|---|---|---|---|---|---|---|
| 0.6 | 700 | 463 | 328 | 10.82 | 18 | 12 | 8.4 |
| 0.7 | 585 | 379 | 212 | 26.88 | 6 | 3.9 | 2.2 |
| 0.8 | 1200 | 433 | 256 | 30.7 | 11 | 3.9 | 2.3 |
| 0.95 | 531 | 148 | 80 | 19.6 | 7.5 | 2.1 | 1.1 |
| 1.35 | 206 | 18 | 15 | 9.02 | 6.3 | 0.6 | 0.5 |
| 1.90 | 159 | 31 | 13 | 8.15 | 5.4 | 1.1 | 0.4 |

Table 1: Count rates during the first breakup run Feb. 2001.

# 3 Request for the next Beamtime

## 3.1 Count rate estimate

In order to obtain a realistic count rate estimate for the present request, several factors have to be taken into account.

*i)* The rates listed in Table 1 were obtained with a deuterium cluster target operating at a target density about 9 times lower than one would normally expect. This was caused by a technical failure in the target gas supply system just before our measurements, from which we could not recover during the run.

*ii)* The rates were obtained with a track reconstruction algorithm that at present uses only data from two packages of the FD MWPCs, while all tree packages have been operated during the measurements. For that reason the efficiency of the two-track event reconstruction procedure is at most 50%, even when the average efficiency per wire plane exceeds 90%. When all three packages are processed, this loss of events can be eliminated to a large extent.

*iii)* For measurements with polarized beam one has to take into account that the polarized beam intensity is about half of the unpolarized beam intensity.

The expected counting rates, listed in Table 2, are therefore about a factor 9 higher than the ones shown in Table 1. The higher rates will present no limitation to the ANKE data-acquisition system, since a more sophisticated trigger will be used in the future. The values for 0.5 GeV beam energy have been obtained by extrapolation from the observed energy dependence.

| $T_0$ [GeV] | $n_{<10}$ [s$^{-1}$] | $n_{<3}$ [s$^{-1}$] | $\sigma(\overline{A_y^p})$ | $T$ [h] |
|---|---|---|---|---|
| 0.5 | $\sim 0.14$ | $\sim 0.11$ | 0.02 | **13** |
| 0.6 | 0.11 | 0.080 | 0.02 | **18** |
| 0.7 | 0.035 | 0.02 | 0.02 | **71** |
| 0.8 | 0.035 | 0.02 | 0.02 | **71** |
| 0.95 | 0.019 | 0.01 | 0.02 | **142** |
| 1.35 | 0.005 | 0.005 | 0.02 | 283 |
| 1.90 | 0.010 | 0.004 | 0.02 | 354 |

Table 2: Expected count rates $n_{<10}, n_{<3}$ and measuring time $T$ needed to determine the angle average of the analyzing power $\overline{A_y^p}$ with an uncertainty $\sigma(\overline{A_y^p}) = 0.02$ for an assumed beam polarization $\mathcal{P} = 0.7$ [Eq. (1)].

## 3.2 Measurement of the vector analyzing power

We request for the first time polarized beam for ANKE. COSY has never stored a polarized beam with ANKE not in 0° position and we are aware that there might be unexpected difficulties to be encountered, but we believe that this request is the next logical step in the chain of actions in order to carry out the deuteron breakup study with polarized beam and target.

The vector analyzing power $A_y^p$ is related to the measured count rate asymmetry by $\varepsilon = \mathcal{P} \cdot A_y^p = (N^\uparrow - N^\downarrow)/(N^\uparrow + N^\downarrow)$, where $\mathcal{P}$ is the beam polarization and $N^\uparrow$, $N^\downarrow$ are the number of events measured for each spin state of the beam, up ($\uparrow$) and down ($\downarrow$), respectively. A theoretical prediction for the analyzing power of the process as a function of the neutron scattering angle is shown in Fig. 4. The statistical uncertainty of the angle averaged analyzing power $\sigma(\overline{A_y^p}) = \frac{1}{\mathcal{P}} \frac{1}{\sqrt{N_{tot}}}$, where $N_{tot} = N^\uparrow + N^\downarrow = n_{<3} \cdot T$. Thus the time needed to determine $\overline{A_y^p}$ to a statistical uncertainty of $\sigma(\overline{A_y^p})$ is given by

$$T = \frac{1}{[\sigma(\overline{A_y^p}) \cdot \mathcal{P}]^2 \cdot n_{<3}} \,. \tag{1}$$

Values for $T(\mathcal{P} = 0.7, \sigma(\overline{A_y^p}) = 0.02)$ are listed in Table 2.

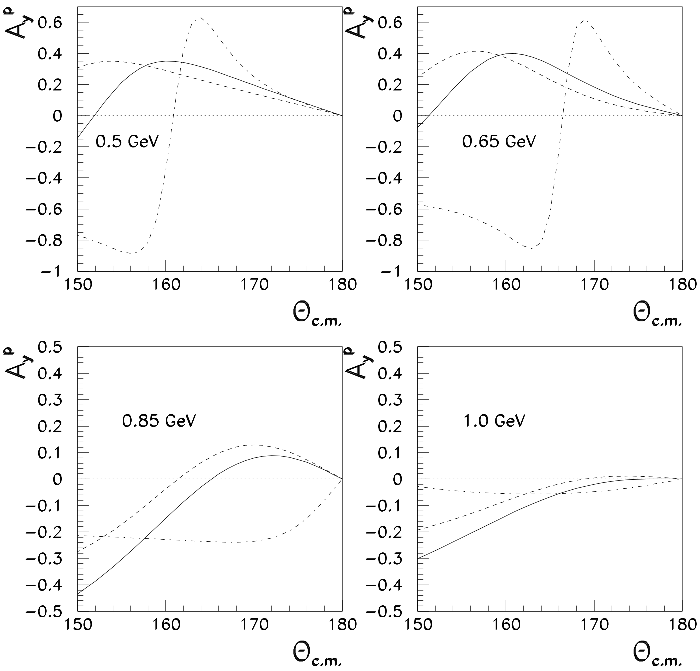


Figure 4: Vector analyzing power $A_y^p$ of the proton versus the neutron scattering angle $\theta_{cm}$ in the $\vec{p} + d \to (pp)_s + n$ reaction at $T_{pp} = 3$ MeV for the different mechanisms at kinetic energies $T = 0.5$, 0.65, 0.85, and 1 GeV: ONE (DWBA) (dashed-dotted), $\Delta$ (dotted), ONE $+\Delta+$ SS (dashed) and ONE (DWBA) $+\Delta+$ SS (full) [1]. The acceptance of ANKE covers scattering angles above $\theta_{cm} \approx 166°$.

## 3.3 Requested Beamtime

We request two weeks of beamtime to carry out a measurement of the proton vector analyzing power between 0.5 GeV and 1 GeV at ANKE. We would like to stress that the beamtime will also improve significantly the accuracy of the cross section measurement of the process under consideration.

# References


[1] Yu. N. Uzikov, JINR E2-2000-149, Dubna, (2000), preprint: `nucl-th/0006067`.

[2] V. Abazov *et al.*, *Exclusive deuteron break-up study with polarized protons and deuterons at COSY (Extension)*, COSY Experiment #20.2, (presented to PAC #19, Fall 1999), Spokesperson: V.I. Komarov.

[3] S. Dymov *et al.*, *Beam Time Request for Machine Studies and First Measurements of the $\vec{p}d$ break-up reaction*, COSY Experiment #20.4, (presented to PAC #21, Fall 2000), Spokesperson: V.I. Komarov.