ANKE Internal Report

Optimization of the ANKE setup for Measurement of the Vector Analyzing Power in the $\vec{p}d \to (pp)_s + n$ process.

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Jülich, September 2001

1. Measurement of the vector analyzing power $A_y{}^p$ of the proton pair emission in the $\vec{p}d \to (pp)_s + n$ reaction has been recently proposed for ANKE [1]. The experiment is based on results of ref.[2], where the quantity $A_y{}^p$ was calculated as a function of the neuteron scattering angle $\theta^n{}_{cm}$ (Fig.1). Because of conservation of the angular momentum and parity this quantity is strictly zero at zero degree scattering and therefore is small at small angles. In the 0.5 GeV - 0.65 GeV energy region it is expected to increase with the scattering angle rather fast, so that reaches value of about 0.2 at the proton pair c.m. emission angle $\theta^{pp}{}_{cm} = 10^0$. The ANKE setup has the angular acceptance located at small forward angles ($\theta \leq 10^0$) around zero value ('zero degree facility') and in this respect it is not favour for the vector analyzing power measurements. Nevertheless, the expected angular dependence of $A_y{}^p$ and the setup acceptance leave place for such measurements.

Our aim here was to estimate an expected value of the observable spin-up/spin-down asymmetry and to choose the setup parameters for the measurement.

Here we present results for the 0.5 GeV energy only, since the first measurements have been oriented at this energy value.

2. The expected value of the observable asymmetry can be found taking the predicted theoretical values of the asymmetry for the pairs emitted at polar and azymuthal angles (θ, ϕ) and passing the pairs through the setup acceptance.

The theoretical value of the asymmetry A^{th} (at 100% beam polarization) according results of ref.[2] can be approximated by a simple expression:

$$A^{th} \simeq (180^0 - \theta^n{}_{cm}) \cdot 1.8 \cdot 10^{-2} \cdot cos\phi,$$

where $\theta^n{}_{cm}$ is the neuteron emission angle. Then the expected value for the observable asymmetry may be calculated in the form:

$$A^{obs} = \frac{1}{N_3} \sum_{i=1}^{N_3} \cdot (180^0 - \theta^n{}_{cm,i}) \cdot 1.8 \cdot 10^{-2} \cdot cos\phi_i \cdot n_i,$$

where number n_i of events at θ_i, ϕ_i angles may be taken from the real event distribution obtained in the experiment, or from the simulated distributions found for the phase space distributions for the process and the setup acceptance. (N_3 denote the number of events with $T_{pp} < 3$ MeV).

An example of such calculation is shown in Fig.2. Here the event distribution over θ_i, ϕ_i angles was taken from the Feb.2001 experiment at 0.6 GeV ($\alpha = 7.4^0, x = -79.6mm$). The average value of the observable asymmetry is expected equal to 0.105 ± 0.07 for this case.

Further we calculate this quantity at different parameters of the setup with better statistics using the mentioned above event simulation.

3. The main factor significant for the experiment optimization is a maximal value of the xz-projection θ_{xz} of the pair emission angle θ acheavable at the setup. The larger is this angle the higher can be the observable asymmetry.

Position of the COSY beam in the beam pipe between the D2 and D3 magnets is also important since if influences the background level in the Forward Detector recording the pairs and arranged right near the tube.

Momentum resolution for the recorded protons is also an important factor to be taken into account.

The obvious parameters of the setup determining the mentioned factors are the angle α of the COSY beam deflection in D1 and the target position x relative the D2 magnet.

Calculation of the setup acceptance has been done at four pairs of the α, x parameters seen in **Table 1**. The corresponding acceptances at the (θ_{xz}, P) plot are shown in Fig. 3–6. Change of the parameters in the considered range does not disturb significantly a form of the acceptance area but shifts it slightly at the (θ_{xz}, P) plot. These shifts are reflected in some variation of the momentum acceptance at 0^0 and the θ_{xz} interval at momenta of interest (momenta of protons in the forward emitted proton pair $(\mathrm{pp})_0$ with zero relative energy.)

It is seen that:

- increase of α shifts the acceptance area to higher momenta and up in the positive θ_{xz} direction;
-increase of x shifts the acceptance area to lower momenta and down in the negative θ_{xz} direction.

Therefore, the maximal values of $\mid \theta_{xz} \mid$ are achieved at $\alpha = 7.4^0$ and $x = -55$ mm.

Figs. 7–10 show event distribution for $pd \to (pp)_s + n$ reaction over values $\theta^{pp}{}_{xz,lab}$, $\theta^n{}_{lab}$, $\theta^n{}_{cm}$ and $\phi^n{}_{cm}$.

The angles correspond to vector of the summed momentum of the $(pp)_s$ -pair. It is seen that for the $7.4^0; -55$ mm set one really gets the maximal value of the $\theta_{cm}{}^{pp}$ angle: $\theta^{pp}{}_{cm} = 180^0 - \theta^n{}_{cm} = 17^0$.

Distribution of the events over the asymm values, given in Fig.11 for the same sets of the α, x parameters, reveals a significant variation of the observable asymmetry. (See **Table 2** also).

Table 1. Momentum acceptance at 0^0 angle and the θ_{xz} interval at $pd \to (pp)_s + n$ momenta

α^0	$x \Longrightarrow$	-55 mm	-79.6 mm
7.4^0	$P_{min} \div P_{max}$	$0.41 - 0.73$	$0.43 - 0.79$
	ΔP	0.32 GeV/c	0.36 GeV/c
	$\theta_{xz}{}^{left} \div \theta_{xz}{}^{right}$	$0.5^0 \div (-7^0)$	$1.4^0 \div (-6.4^0)$
10.6^0	$P_{min} \div P_{max}$	$0.51 - 0.78$	$0.52 - 0.83$
	ΔP	0.27 GeV/c	0.31 GeV/c
	$\theta_{xz}{}^{left} \div \theta_{xz}{}^{right}$	$1.4^0 \div (-5.7^0)$	$2.3^0 \div (-5.0^0)$

Table 2. Average values of the observable asymmetry.

$\alpha^0 \setminus x$	-55 mm	-79.6 mm
7.4^0	0.137	0.100
10.6^0	0.083	0.050

From this point of view the $(7.4^0; -55$ mm) set is the best among the considered values.

Certainly the momentum resolution may be obtained higher at larger values of α. However, we know from the previous measurements (Feb.2001) that the resolution achieved at

7.4^0 is already quite sufficient for the aim of $(\mathrm{pp})_s$ pairs separation from the all pp-pairs accepted by the forward detector.

For the other hand, change of the target coordinate from the 'Kaon mode' value -79.6 mm to -55 mm locates the internal proton beam right in the center of the exit flanch of the D2 vacuum chamber. It should result in minimizing of the background produced by the beam halo in the exit flanch and the ring vacuum tube between D2 and D3 magnets.

Summary.

- A change of the angular-momentum acceptance area at change of the beam deflection angle α and the target position x was qualitively studied;
- The optimal set of the D2 parameters was choosen;
- The expected values of the observed asymmetry were calculated at four sets of the D2 parameters.

References

1. ANKE Collaboration, 'Supplement to the COSY Beam request (20.5) for the pd-Breakup Study at ANKE (March 19, 2001).'

2. Yu.Uzikov, 'Deuteron Breakup $pd \to ppn$ in Specific Kinematics and Short-Range NN-Interaction'. Arxiv: nucl-th/0006067, v2, 30 Oct.2000.

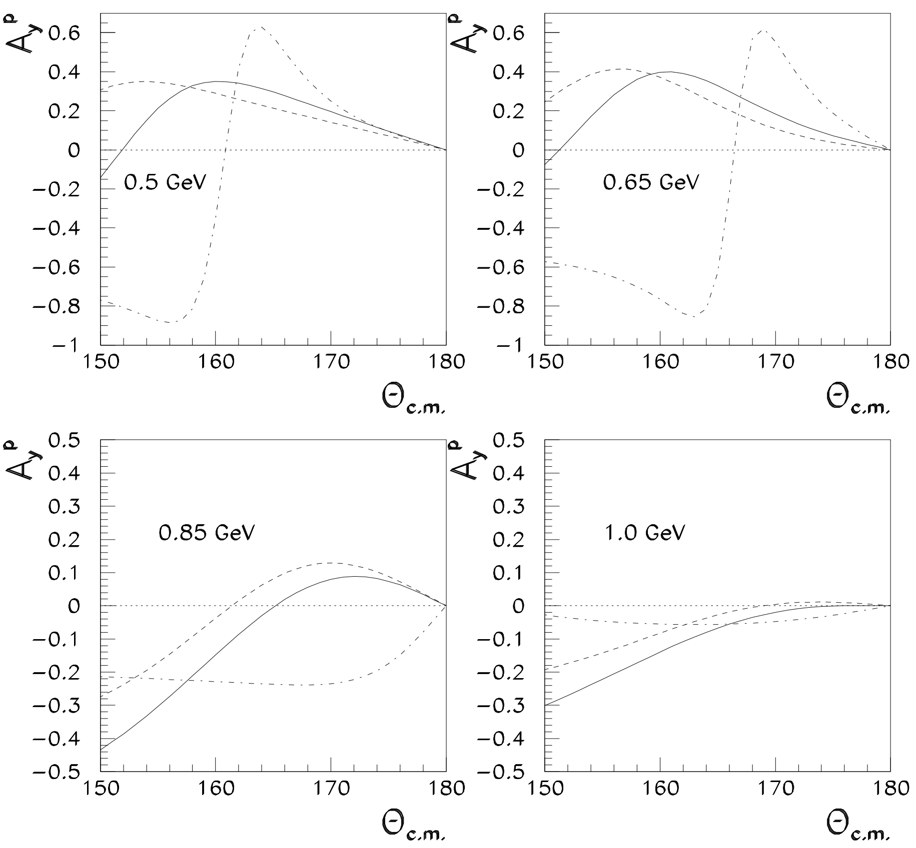


Fig.1 Vector analyzing power of the proton $A_y{}^p$ in the $\vec{p} + d \to (pp)_s + n$ reaction at E_{pp} = 3 MeV for the different mechanisms at kinetic energies T_{pp} = 0.5, 0.65, 0.85 and 1 GeV: ONE(DWBA) (dashed-dotted); Δ (dotted); ONE+Δ+SS (dashed); ONE(DWBA)+Δ+SS (full).

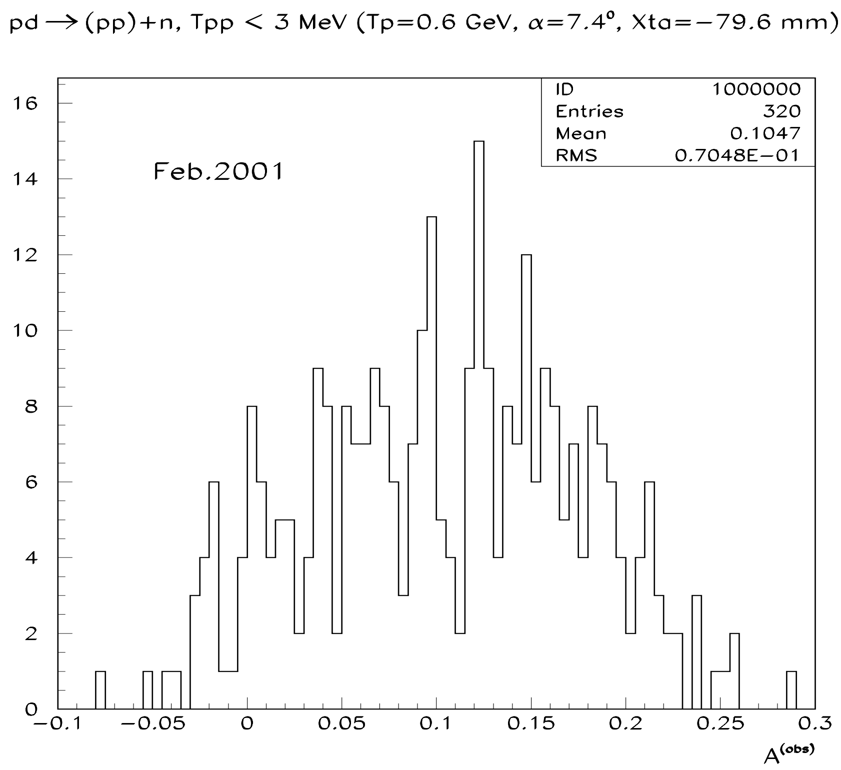
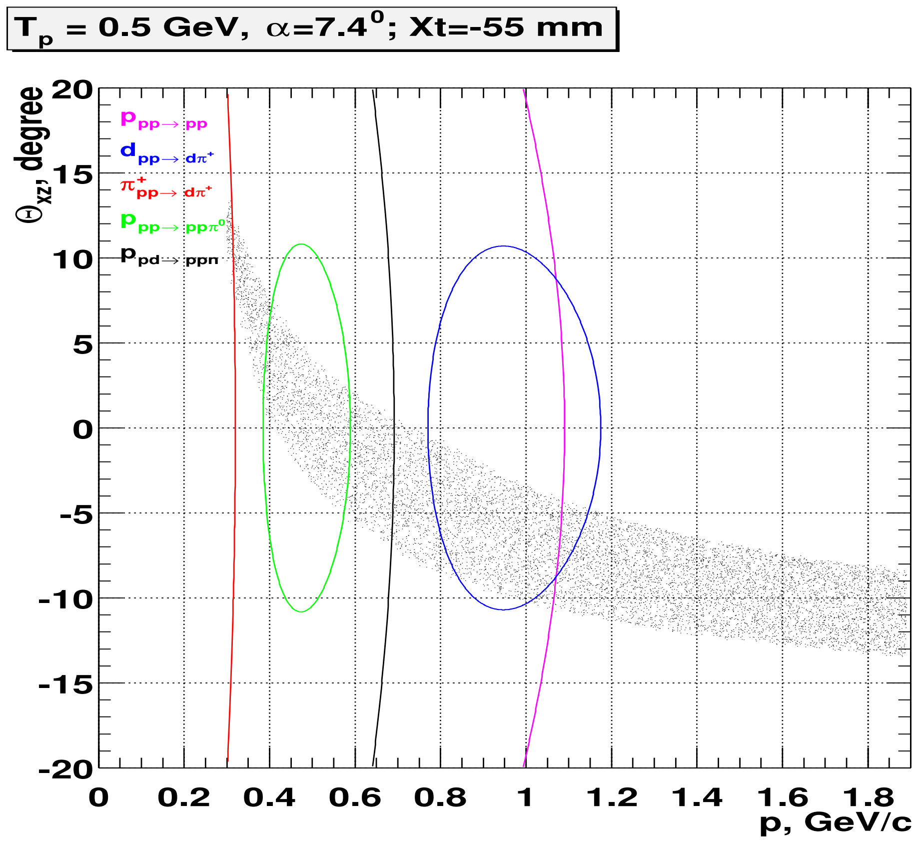
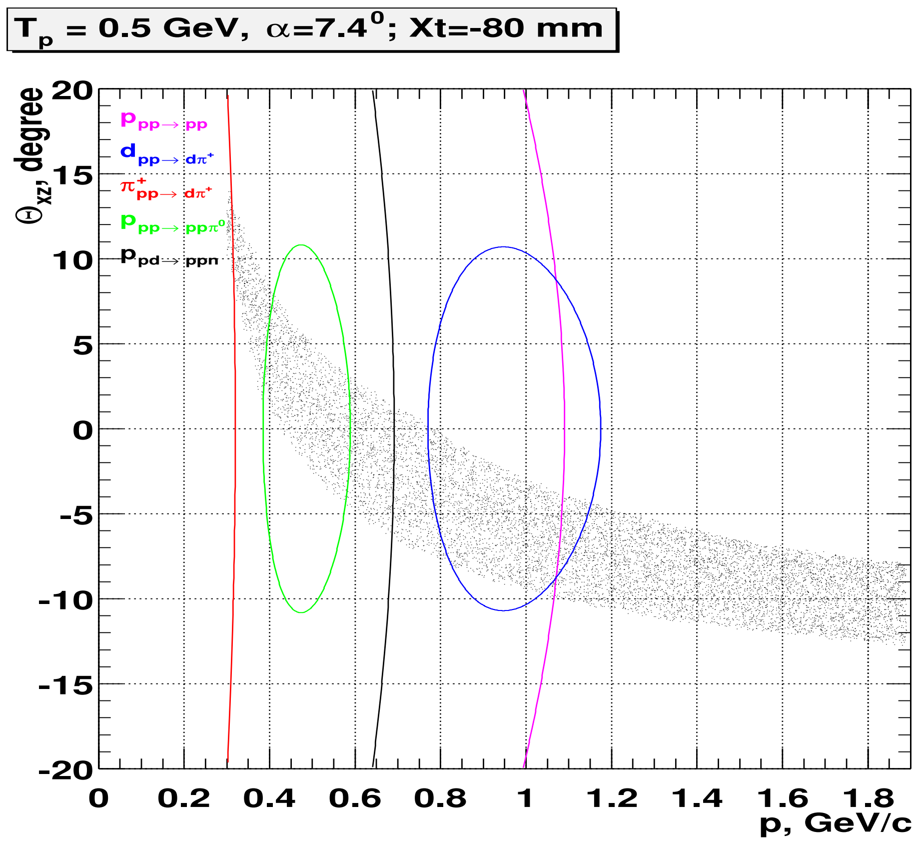


Fig.2



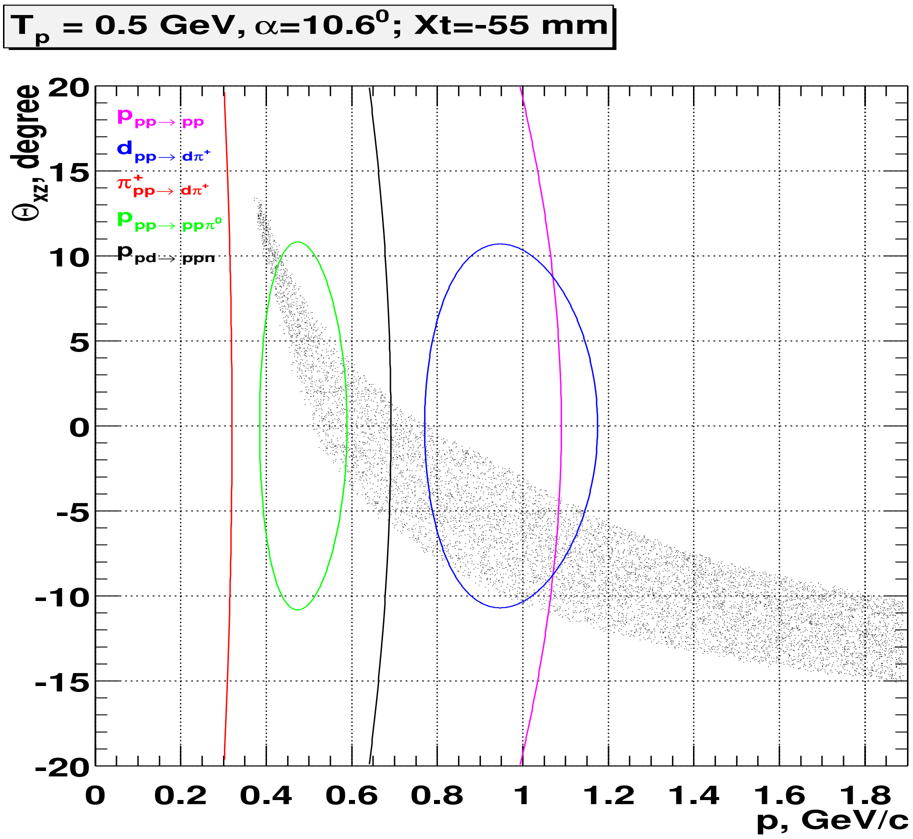
T_p = 0.5 GeV, α=7.4^0; Xt=-55 mm
Θ_{xz}, degree
p, GeV/c
$p_{pp\to pp}$
$d_{pp\to d\pi^+}$
$\pi^+_{pp\to d\pi^+}$
$p_{pp\to pp\pi^0}$
$p_{pd\to ppn}$

Fig.3



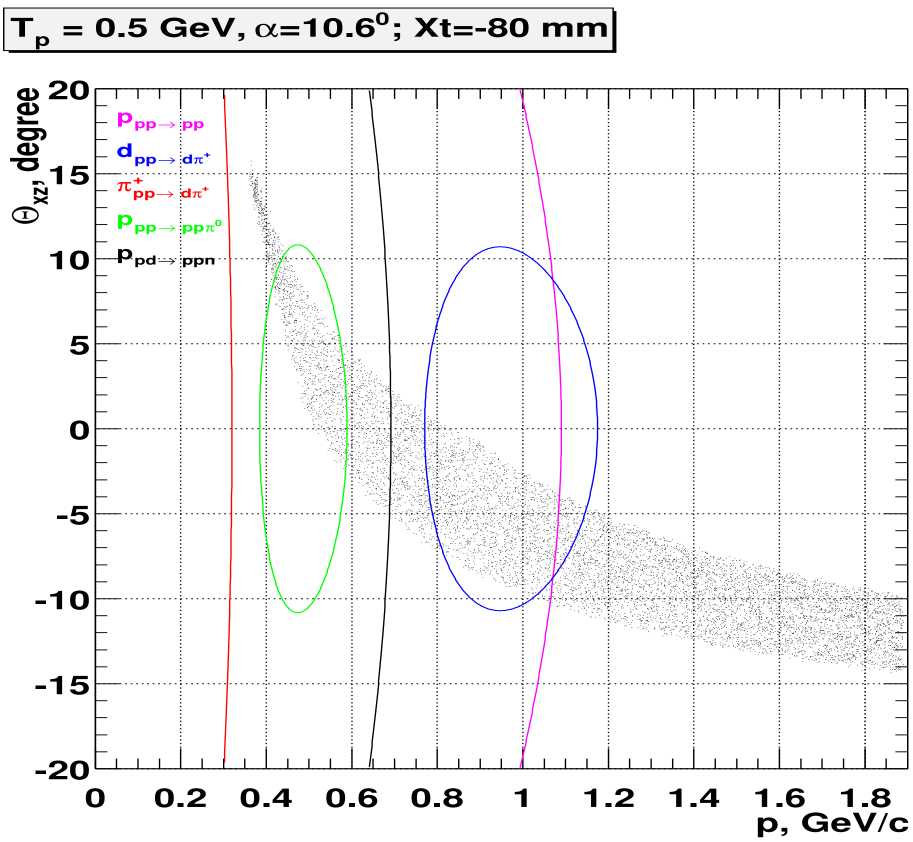
T_p = 0.5 GeV, α=7.4^0; Xt=-80 mm
Θ_{xz}, degree
p, GeV/c
$p_{pp\to pp}$
$d_{pp\to d\pi^+}$
$\pi^+_{pp\to d\pi^+}$
$p_{pp\to pp\pi^0}$
$p_{pd\to ppn}$

Fig.4



T_p = 0.5 GeV, α=10.6°; Xt=-55 mm
Θ_{xz}, degree
p, GeV/c
$p_{pp\to pp}$
$d_{pp\to d\pi^+}$
$\pi^+_{pp\to d\pi^+}$
$p_{pp\to pp\pi^0}$
$p_{pd\to ppn}$

Fig.5



T_p = 0.5 GeV, α=10.6°; Xt=-80 mm
Θ_{xz}, degree
p, GeV/c
$p_{pp\to pp}$
$d_{pp\to d\pi^+}$
$\pi^+_{pp\to d\pi^+}$
$p_{pp\to pp\pi^0}$
$p_{pd\to ppn}$

Fig.6

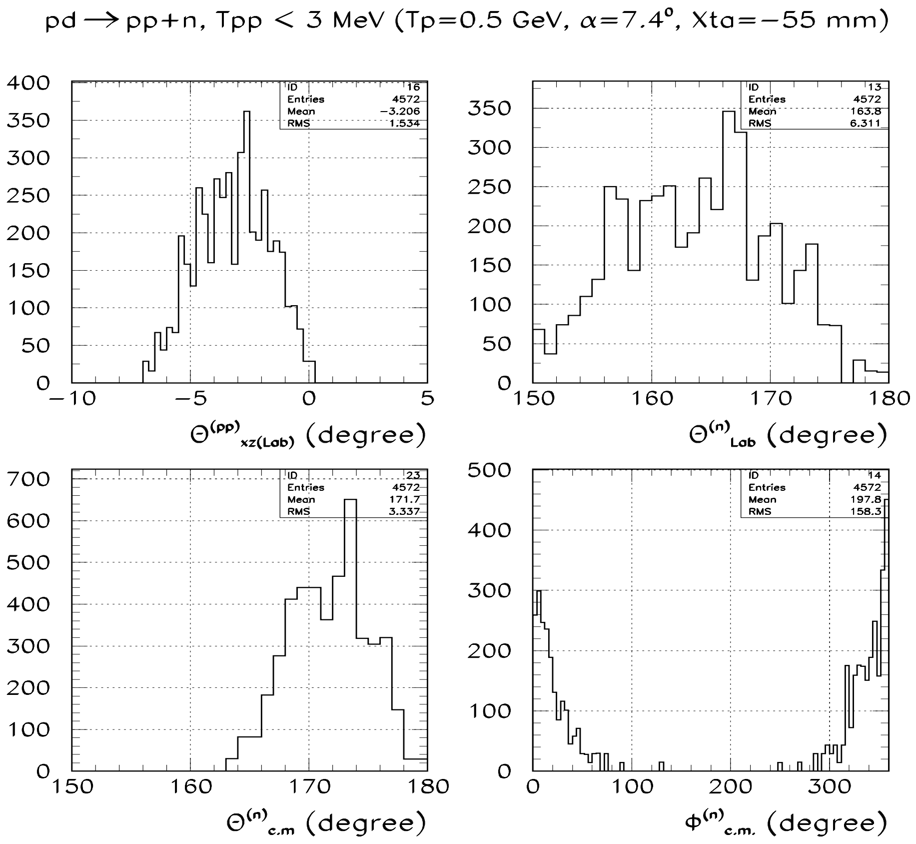

pd → pp+n, Tpp < 3 MeV (Tp=0.5 GeV, α=7.4°, Xta=−55 mm)
ID 16 Entries 4572 Mean −3.206 RMS 1.534
Θ(pp)xz(Lab) (degree)
ID 13 Entries 4572 Mean 163.8 RMS 6.311
Θ(n)Lab (degree)
ID 23 Entries 4572 Mean 171.7 RMS 3.337
Θ(n)c.m (degree)
ID 14 Entries 4572 Mean 197.8 RMS 158.3
Φ(n)c.m. (degree)

Fig.7

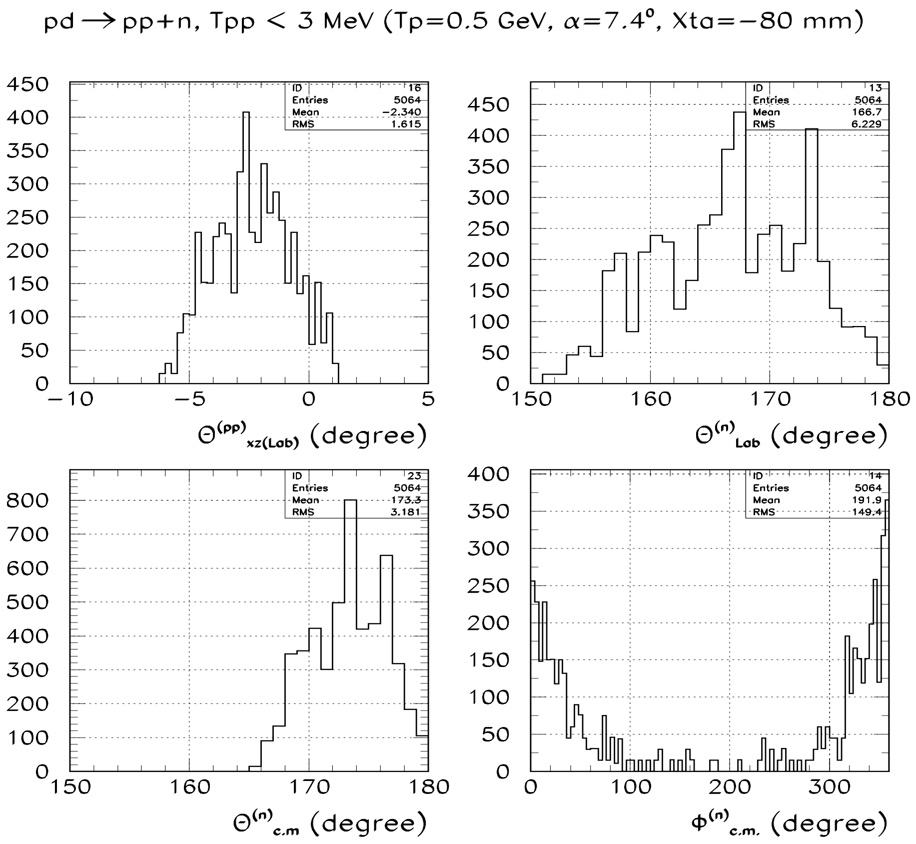

pd → pp+n, Tpp < 3 MeV (Tp=0.5 GeV, α=7.4°, Xta=−80 mm)
ID 16 Entries 5064 Mean −2.340 RMS 1.615
Θ(pp)xz(Lab) (degree)
ID 13 Entries 5064 Mean 166.7 RMS 6.229
Θ(n)Lab (degree)
ID 23 Entries 5064 Mean 173.3 RMS 3.181
Θ(n)c.m (degree)
ID 14 Entries 5064 Mean 191.9 RMS 149.4
Φ(n)c.m. (degree)

Fig.8

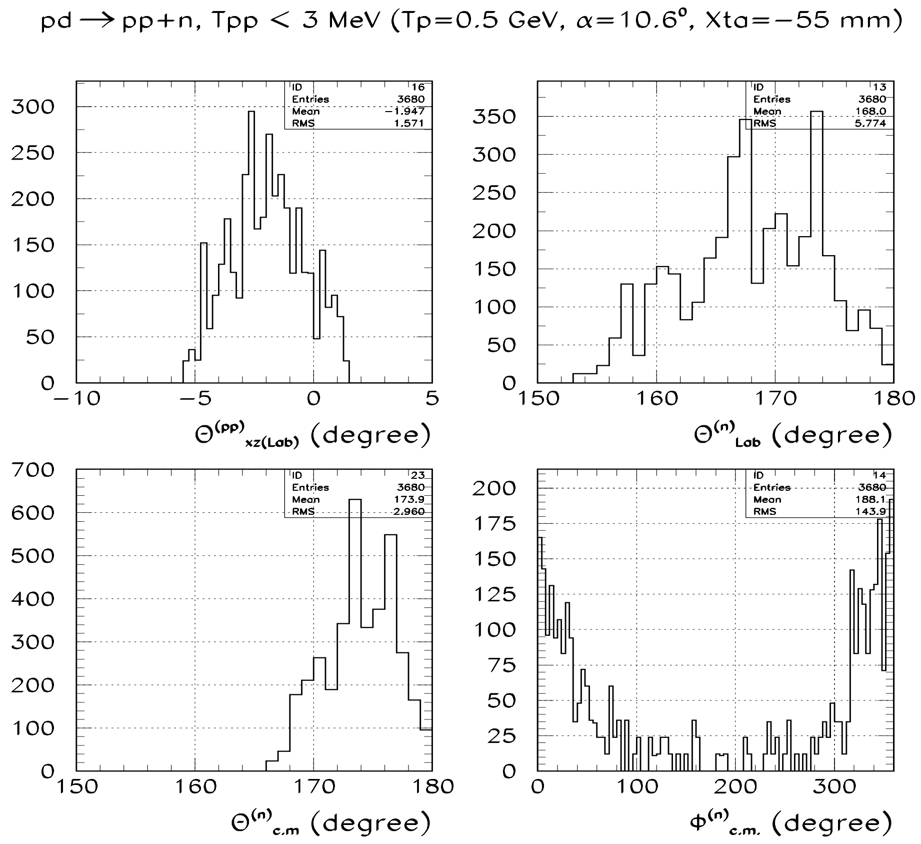

pd → pp+n, Tpp < 3 MeV (Tp=0.5 GeV, α=10.6°, Xta=−55 mm)
ID 16 Entries 3680 Mean −1.947 RMS 1.571
Θ(pp)xz(Lab) (degree)
ID 13 Entries 3680 Mean 168.0 RMS 5.774
Θ(n)Lab (degree)
ID 23 Entries 3680 Mean 173.9 RMS 2.960
Θ(n)c.m (degree)
ID 14 Entries 3680 Mean 188.1 RMS 143.9
Φ(n)c.m. (degree)

Fig.9

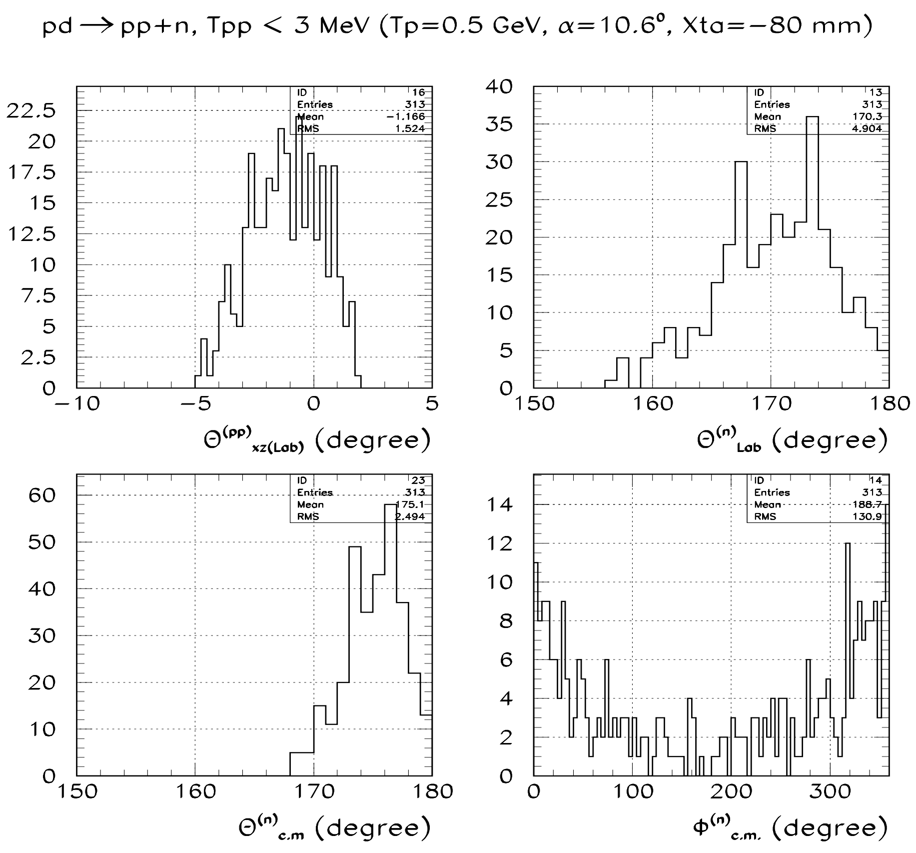

pd → pp+n, Tpp < 3 MeV (Tp=0.5 GeV, α=10.6°, Xta=−80 mm)
ID 16 Entries 313 Mean −1.166 RMS 1.524
Θ(pp)xz(Lab) (degree)
ID 13 Entries 313 Mean 170.3 RMS 4.904
Θ(n)Lab (degree)
ID 23 Entries 313 Mean 175.1 RMS 2.494
Θ(n)c.m (degree)
ID 14 Entries 313 Mean 188.7 RMS 130.9
Φ(n)c.m. (degree)

Fig.10

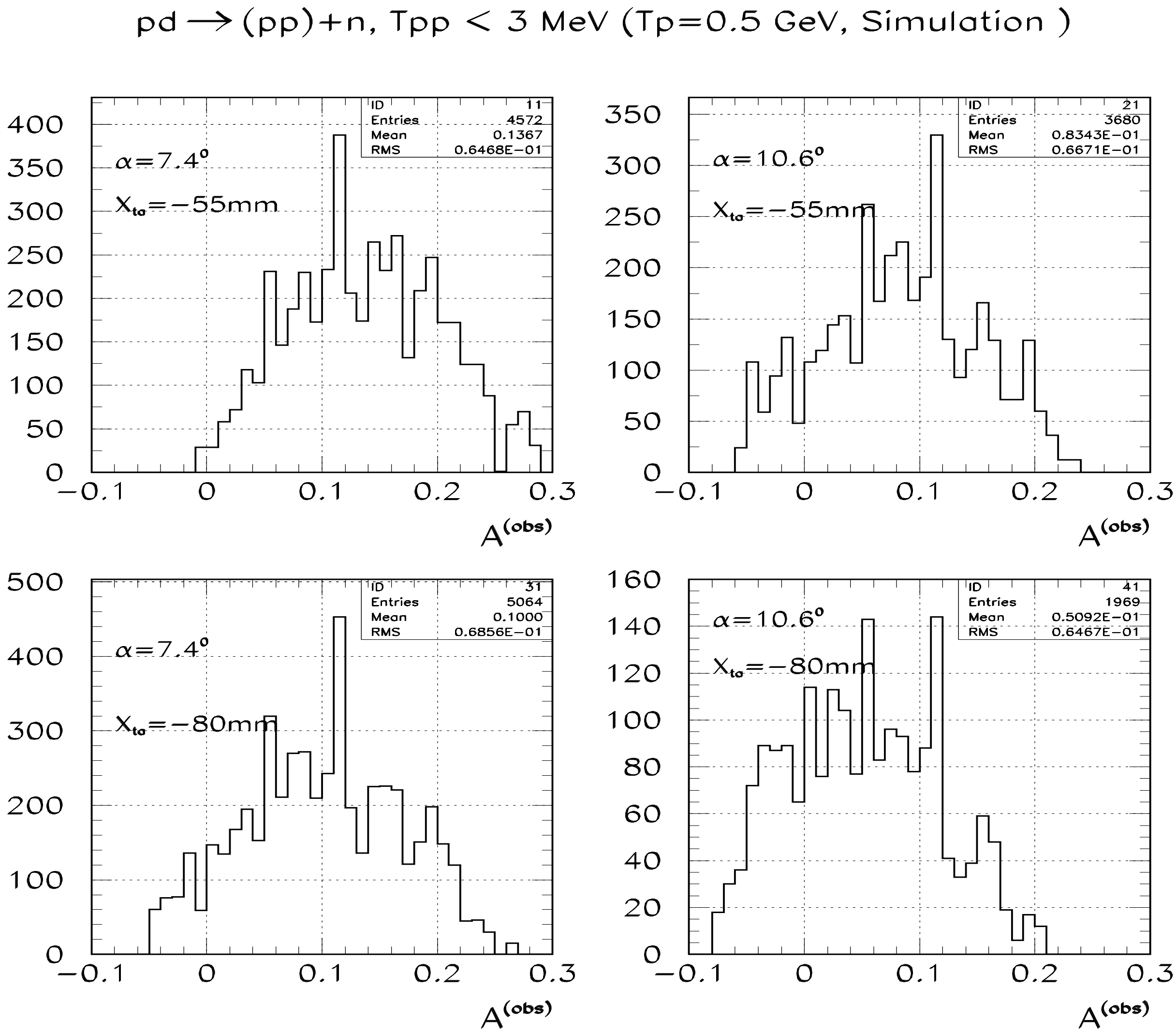

pd → (pp)+n, Tpp < 3 MeV (Tp=0.5 GeV, Simulation)
ID 11
Entries 4572
Mean 0.1367
RMS 0.6468E-01
α=7.4°
Xto=−55mm
ID 21
Entries 3680
Mean 0.8343E-01
RMS 0.6671E-01
α=10.6°
Xto=−55mm
ID 31
Entries 5064
Mean 0.1000
RMS 0.6856E-01
α=7.4°
Xto=−80mm
ID 41
Entries 1969
Mean 0.5092E-01
RMS 0.6467E-01
α=10.6°
Xto=−80mm
A(obs)

Fig.11