Measurement of the charge exchange np→pn reaction by means of the deuteron beam

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Annotation

The ratio of the differential cross section of the charge exchange reaction of the deuteron to that of the nucleon, at small transferred momenta, has been discussed in order to estimate the spin-dependent part of the np → pn charge exchange amplitude.

An estimation of the spin-dependent part of the np → pn charge exchange amplitude on the basis of dp → (pp)n data, taken at 1.75 GeV/c on the STRELA setup at the Nuclotron accelerator was made.The np → pn amplitude turned out to be predominantly spin-dependent.

The possibility to get additional information about the amplitude of the elementary charge exchange reaction by means of the charge exchange processes from the experiments with unpolarized deuteron was emphasized by A.B. Migdal and I.Y. Pomeranchuk in the early fifties. [A.B.Migdal ZhETF 28, 1955, p.3 I.Pomeranchuk DAN USSR, 1951, LXXVIII, N2, p.249]

Simplified versions of these two processes in the framework of the Impulse Approximation are shown in Fig. 1; a) the charge exchange process np $\rightarrow$ pn and b) the reaction dp $\rightarrow$ (pp)n, charge-exchange one on the simplest nucleus – the deuteron.

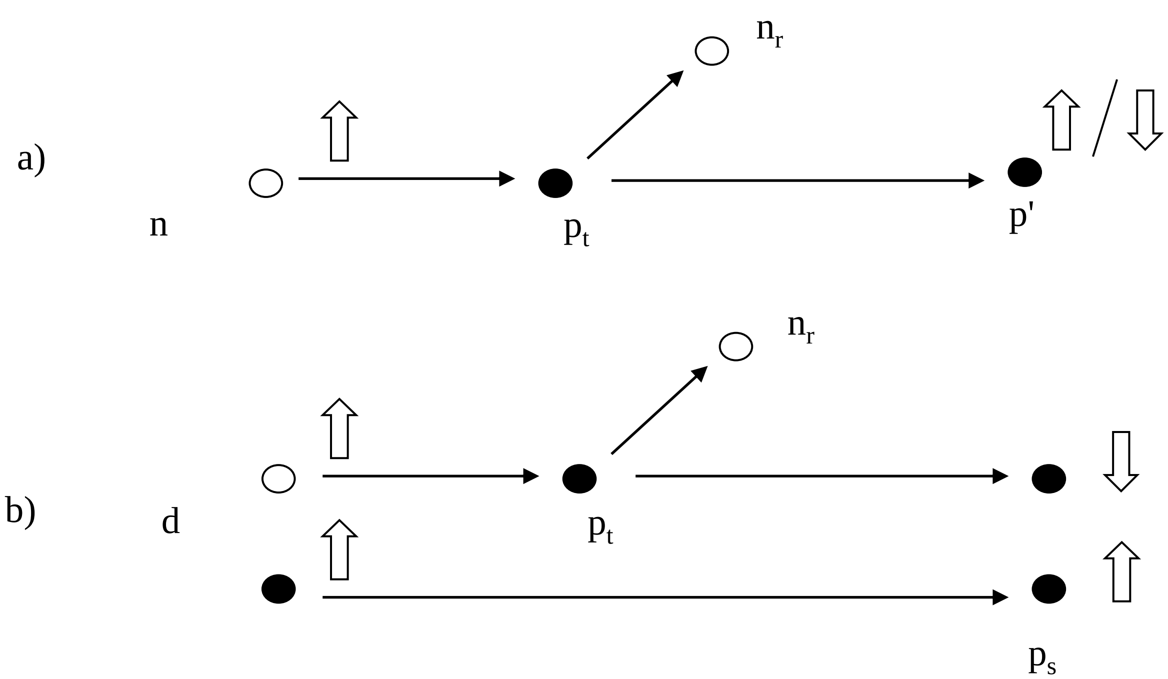


Figure 1 Elementary (a) and (b) charge exchange reactions.

- Vertical arrows stand for the nucleon spins with respect to an arbitrary axis of quantization. In the first case (a) both spin orientations are allowed while in the second one (b) at small angle scattering (spatial symmetry) due to the produced charged symmetry (two protons move in the very forward direction with small relative momentum) the reaction can proceed only if the scattered proton spin flips (caused by the Pauli exclusive principle). So, the deuteron behaves itself as a spin filter.

- The mathematical formalism for exchange scattering was developed, for example by L.I. Lapidus, N.W. Dean [L.I.Lapidus ZhETF 32, 1957, p.1437. N.W.Dean,

Phys.Rev. D5, 1972, p. 2832] and others. The differential cross section for the charge exchange process on the deuteron

- can be written as:

$$\left(\frac{d\sigma}{dt}\right)_{dp\to(pp)n} = [1-F_d]\left(\frac{d\sigma_{nf}}{dt}\right)_{np\to pn} + \left[1-\frac{1}{3}F_d\right]\left(\frac{d\sigma_f}{dt}\right)_{np\to pn}$$

,

$$\left(\frac{d\sigma_f}{dt}\right)_{np\to pn} \qquad \left(\frac{d\sigma_{nf}}{dt}\right)_{np\to pn}$$

where *Fd* denotes the deuteron form factor,

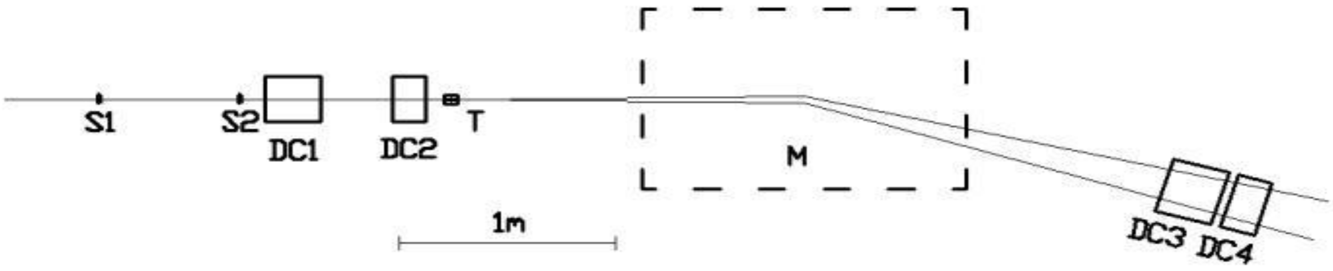
the spin flip and no spin flip parts of the differential cross section,. At zero momentumtransfers (|t| ~ 0) when Fd=1 this expression becomes

$$\left(\frac{d\sigma}{dt}\right)_{dp\to(pp)n} = \frac{2}{3}\left(\frac{d\sigma_f}{dt}\right)_{np\to pn}$$

,

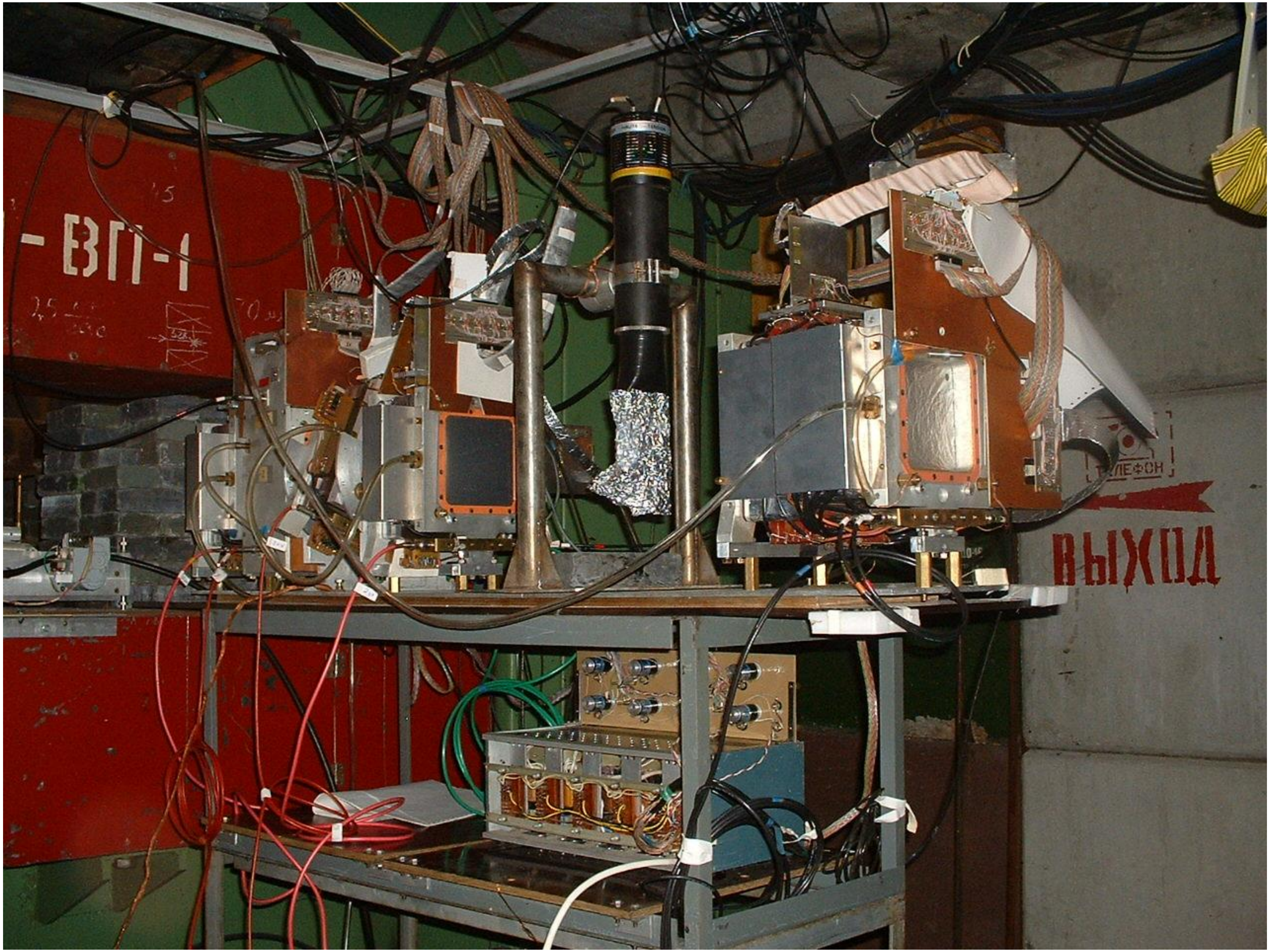
- i.e. the differential cross section is determined by the spin flip part of the charge exchange process.

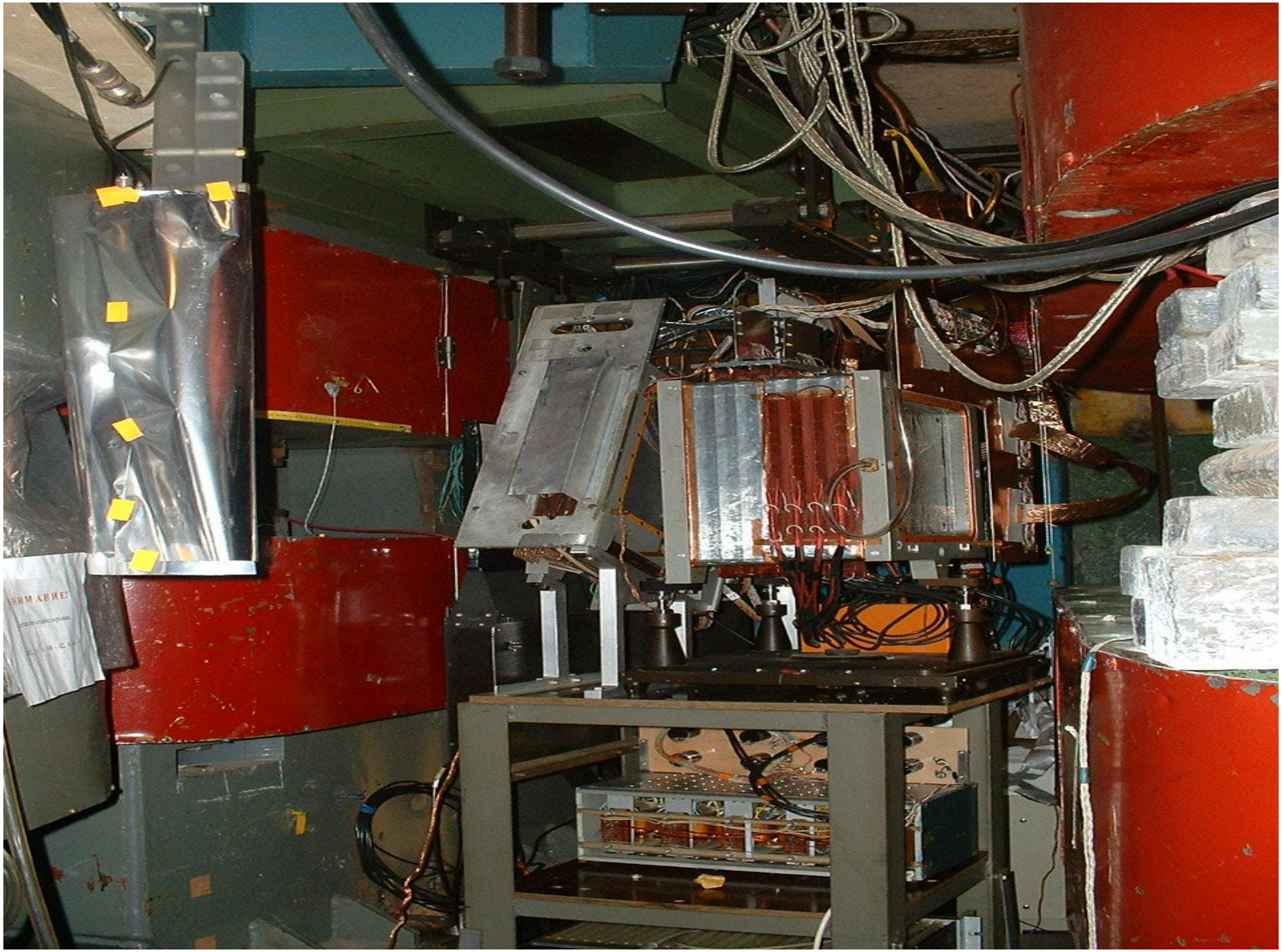
- Due to the high complexity of obtaining and processing data with hydrogen bubble chamber there is a need of transition to electronic methods . For observation narrow pairs of protons from the reaction dp(pp)n ,suggested several variants of installation with the name Strela. The last scheme of setup (March 2014) and the photos are presented in.



Scintillator counters – S1, S2
Drift chambers – DC1-DC4
Sensitive areas - 125 x 125 mm2 (DC1,DC2)
250 x 250 mm2 (DC3,DC4)
Sensitive planes- DC1, DC3 – 8 (4y, 4x)
DC2 - 4 (4x)
DC4 - 4 (2y, 2x)
Total drift time - ~ 450 ns
Drift length (all chambers) – r = 21 cm
M – analyzing magnet
Magnetic field – B = 0,85 T

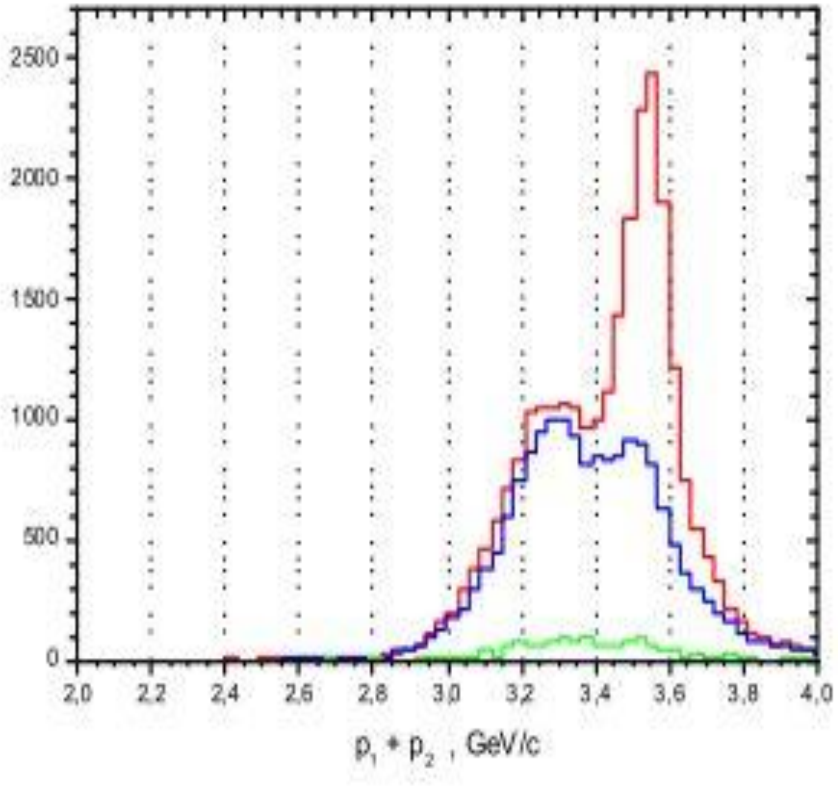
More technical detail in: V.V. Glagolev et al.: PTE, 2013,No4,pp.20-31


ВП-1
ТЕЛЕФОН
ВЫХОД

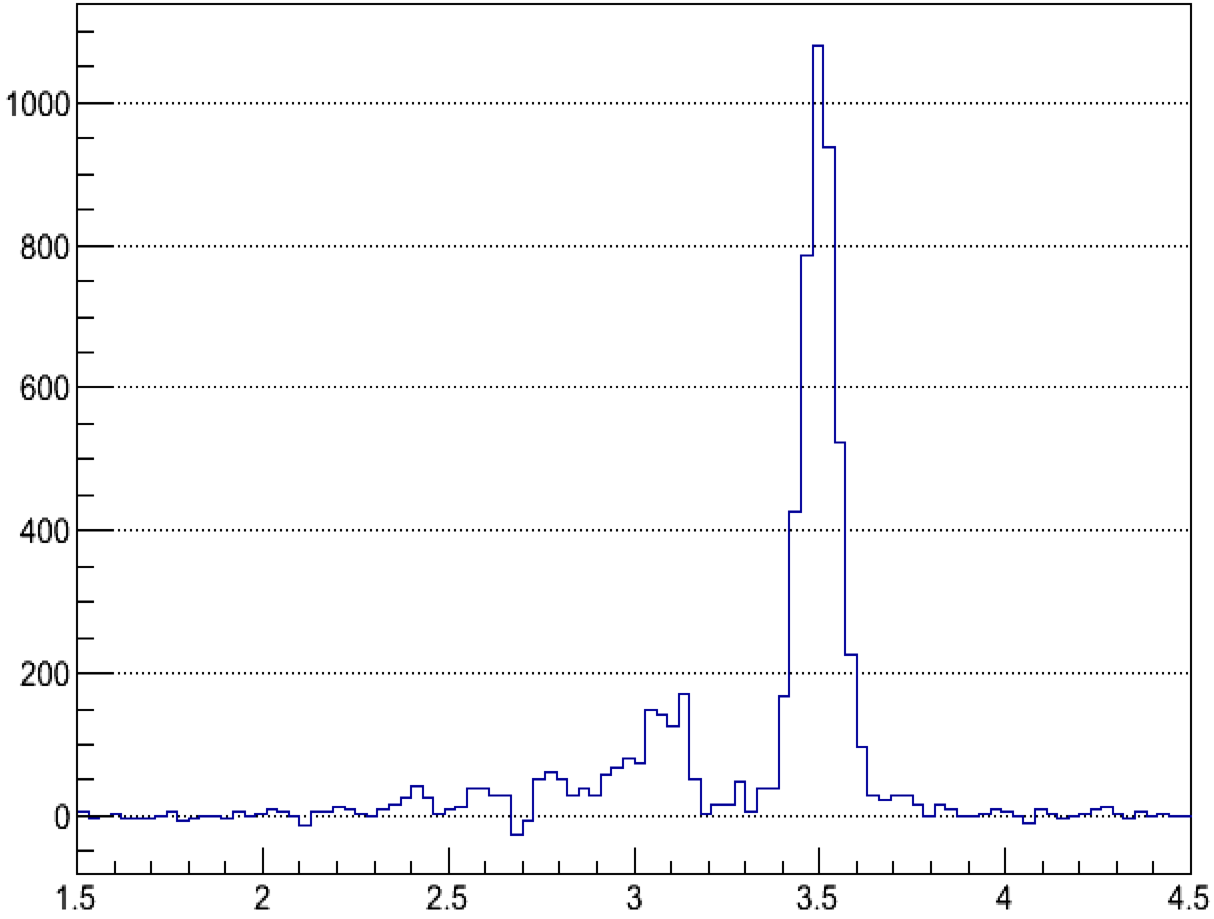


- In the run of March 2014 at the Nuclotron was received about a billion triggers. Without going into the details here are two plots of the results. The first plot is the distribution of the sum of the momenta of two protons.

- The experiment was carried out using polyethylene and carbon targets, equivalent in content of carbon nuclei. Results are given for the differential effect of the interactions on hydrogen.
- Conveniently show data representation as the sum momenta of two protons.



Red for CH_2 – target,
Blue for carbon target
Green - without target

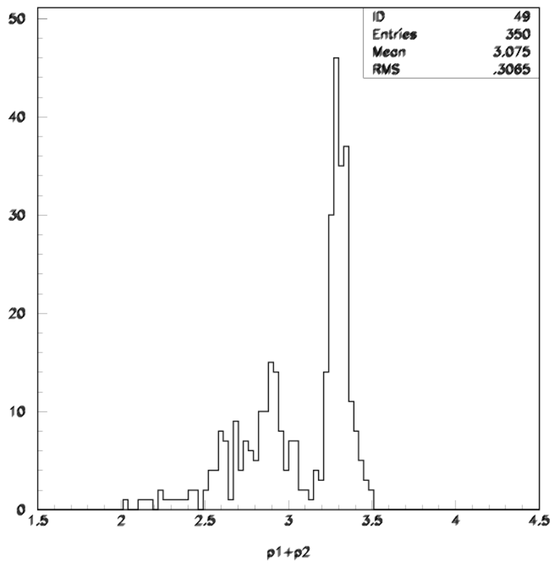


$P_1 + P_2$; CH_2 - C

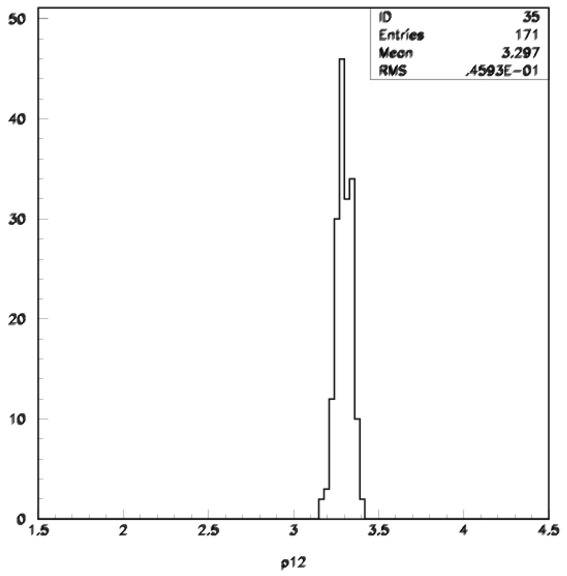
- To understand the structure of the obtained distribution was Monte Carlo generation was done. The real tracks from bubble chamber dp events were used as input data to MC.

The two distributions were obtained. One is for the sum of the momenta of two particles and other for pairs of protons from the reaction dp-ppn.

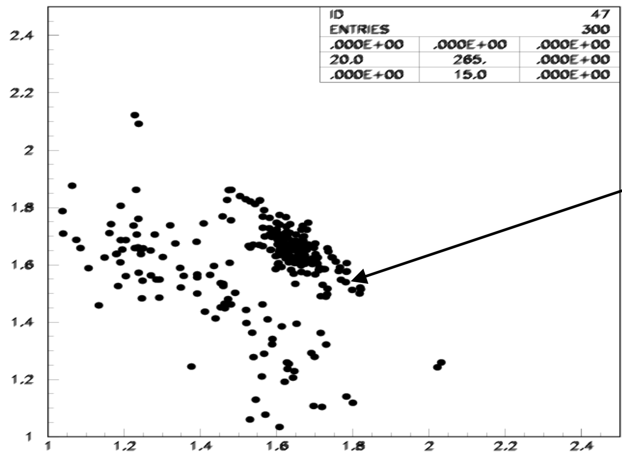
We see the good selection of charge exchange from the background of inelastic events.


ID 49
Entries 350
Mean 3.075
RMS .3065
p1+p2

all

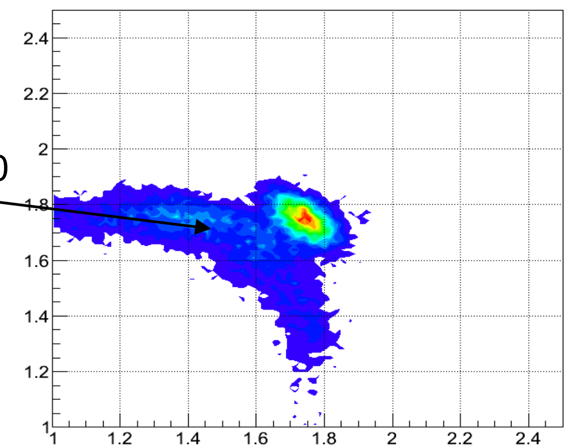

ID 35
Entries 171
Mean 3.297
RMS .4593E-01
p12

dp→ppn

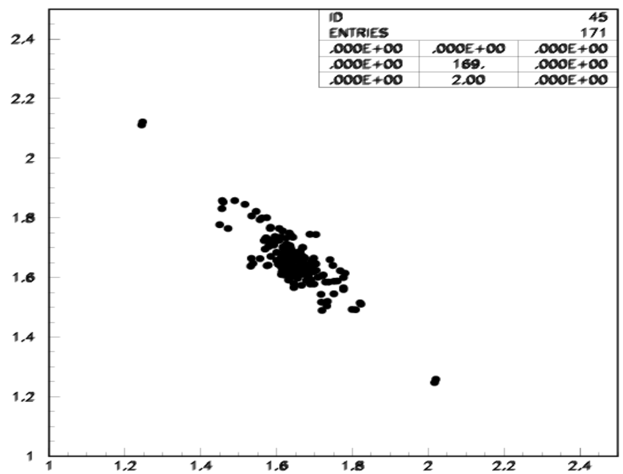


171

10 000

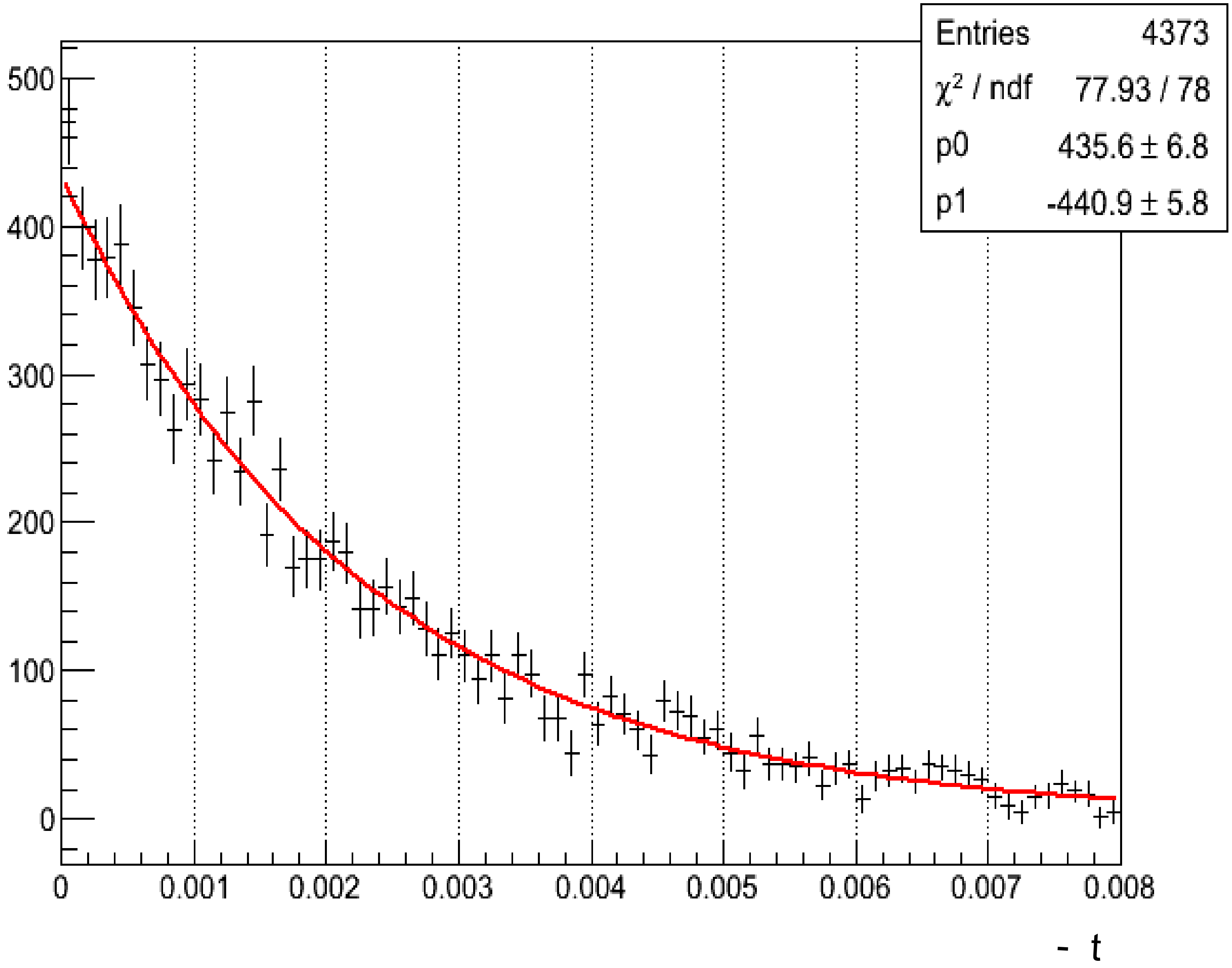


p1 vs p2, ГэВ/c
STRELA, p_d= 3,5 ГэВ/c



p1 vs p2, ГэВ/c
GEANT+ HBC, p_d= 3,3 ГэВ/c

Differential cross section for charge-exchange dp-ppn reaction



The cross section was calculated using the relation

$$\sigma = \frac{1}{nl\Delta} \ln\left(\frac{1}{1 - \frac{N_{\text{int}}}{N_0}} \right) \quad \text{, where}$$

l - length of target

n- density of H nuclei /cm^{-3}

N_0 - number of triggers

N_{int} - number of interactions

Δ - step histograms

Number of triggers was corrected for:

- admixture of beam
- efficiency of streamer chambers

One can introduce ratio of the differential cross section at t=0 for the forward scattering (charge exchange) on the deuteron and proton

Under the assumption stated above it can be related to

$$R = \frac{(d\sigma / dt)_{dp}}{(d\sigma / dt)_{np}} = 0,637 \pm 0.010$$

and accordingly value of the spin- independent part of the elastic np $\rightarrow$ pn charge exchange cross section has been obtained.

$$R_{np}^{ID} = \frac{(d\sigma / dt)_{np}^{SI}}{(d\sigma / dt)_{np}^{SD}} = \frac{2}{3xR} - 1 = 0,047 \pm 0,017$$

CONCLUSION

We can conclude that the above amplitude is almost completely spin dependent.

THANK YOU FOR YOUR ATTENTION