MEASUREMENT OF THE TENSOR ANALYZING POWER A_{yy} OF INELASTIC $p\,(dd')$ SCATTERING IN THE ENERGY REGION OF DELTA AND ROPER RESONANCES EXCITATION WITH **SPES4 – π** AT **SATURNE-II**

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1 Introduction

The excitation of broad hadronic resonances in nuclei by isoscalar projectiles has been studied intensively in recent years [1] – [5]. The inelastic interaction of isoscalar projectiles (as α or d) with a proton holds the prospect of isolating isobar excitations according to their isospin. The simplest process is the one where the target is excited to an isobar which then must have I=1/2. There is also the possibility that the excitation occurs in the projectile through exchange of an I=1 meson, in which case the Δ can also contribute. A guiding idea of this experiment was that by comparing single and double pion final states, one could distinguish the two reaction channels further. Indeed the free Δ does not decay into two pion final state channels, whereas the N* resonances do. Selecting 2-pion events would have the effect of eliminating I=3/2 projectile excitation contributions.

In this paper we present data for the tensor and vector analyzing powers in dp inelastic scattering very close ($\sim$ 30 MeV in the NN c.m.s.) to the $N^*(1440)$ excitation threshold. The experimental data contain information about the following channels of the inelastic deuteron scattering on protons: $dp \to dp\pi^0$; $dp \to dn\pi^+$ and $dp \to dN\pi\pi$.

The channels with one pion in the final state can occur both from the Δ and from the N^* resonance decays; therefore an interference between these channels can take place in the region of the resonance overlaps.
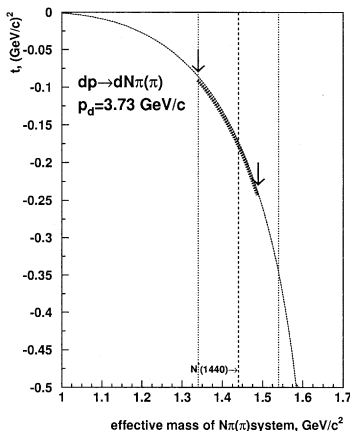

Figure 1: The missing mass M_x (the effective mass N $\pi(\pi)$) versus 4-momentum transfer $|t|$ at the deuteron beam momentum of 3.73 GeV/c. The dashed area represents the region covered in this experiment.

The tensor and vector analyzing powers for different channels of (d, d') reaction have been measured as functions of the squared deuteron 4-momentum transfer t, or the effective mass of the binary subsystem ($N\pi$) (see Fig. 1). The physical region for $d+p \to d+X$ reaction in the ($t - M_x$) plane studied in this experiment is shown in Fig. 1.
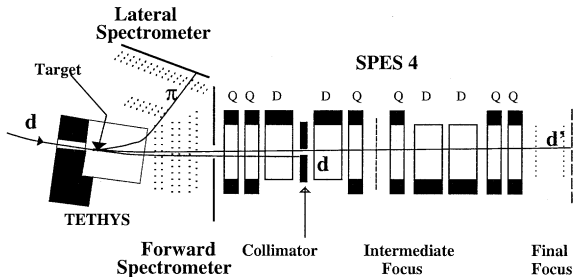
Figure 2: SPES4-π setup.

2 Measurements and data analysis

The SPES4-π setup which was used in a series of experiments at SATURNE-II is shown in Fig. 2. It consists of a large acceptance non-focusing magnetic spectrometer (the magnet Tethys and detectors: Forward (FS) [6]–[8] and Lateral (LS) spectrometers) in combination with the high resolution focusing magnetic spectrometer SPES4 [9]. The particles of high momenta (d') were detected in SPES4 while the secondary low momentum charged particles (protons and pions from the reactions listed above) were detected in the FS. The characteristics of the setup and the data taking are given in [6]–[8].

A polarized deuteron beam with momentum of 3.73 GeV/c produced by the SATURNE-II accelerator was used. The beam intensity was measured by ~ 0.5 cm thickness scintillation counter operating at lowered voltage, placed in the direct incoming beam just before the hole in the Tethys yoke.

The deuteron beam polarization was changed in the usual burst-to-burst mode; states 5, 6, 7, 8 (in SATURNE-II notations, see Table I), were used.

Table I. Maximum values of the beam vector and tensor polarization parameters for the used beam polarization states (taken from [10]) at Saturne-II.

Number of the beam polarization state	P_{ZZ}^{max}	P_Z^{max}
5	+1	+1/3
6	+1	−1/3
7	−1	+1/3
8	−1	−1/3

The vector polarization was normal to the plane containing the mean beam orbit of the accelerator. The beam polarization was measured periodically during the experiment with the SATURNE-II Low-Energy polarimeter. The average values were $P_{ZZ} = 0.902 \pm 0.015$ and $P_Z = 0.311 \pm 0.008$.

The tensor A_{yy} and vector A_y analyzing powers were calculated for each reaction by

the following way:

$$A_{yy}(t) = \frac{2}{P_{ZZ}} \cdot \frac{N_5 + N_6 - N_7 - N_8}{N_5 + N_6 + N_7 + N_8} \tag{10}$$

$$A_y(t) = \frac{2}{3P_Z} \cdot \frac{N_5 - N_6 + N_7 - N_8}{N_5 + N_6 + N_7 + N_8} \tag{11}$$

$$A_0(t) = \frac{N_5 + N_8 - N_6 - N_7}{N_5 + N_6 + N_7 + N_8} \tag{12}$$

Here $A_y(t)$ and $A_{yy}(t)$ are the vector and tensor analyzing powers of the reaction, N_5, N_6, N_7 and N_8 are the numbers of events detected in each polarization state normalized to the corresponding beam intensities. The last equation represents the false asymmetry. This asymmetry was checked for all reaction channels and is consistent to zero thus proving that the polarization observables were under full control.

The detected events originated mainly from the inelastic $p(d, d')N\pi(\pi)$ reaction and elastic backward $p(d, p)d$ scattering [11]. The elastic process was identified unambiguously by detecting the recoil proton in SPES4 ($p_p \simeq 2.93$ GeV/c) in coincidence with the scattered deuteron in the FS ($p_d \simeq 0.8$ GeV/c). It provided useful information for the calibration of the setup [7]. The data on the $p(d, p)d$ tensor analyzing power, obtained in the present experiment, are published in [11] and agree very well with the existing world data (see ref. in [11]). For the inelastic process $p(d, d')X$, $X = N\pi(\pi)$ the scattered deuterons were detected by SPES4, while the charged products of the decay of the intermediate system, X, were registered by the FS. The typical missing mass spectra for the reaction $dp \rightarrow dn\pi^+$ are shown in Fig. 3 for three bins in t at the central momentum of SPES4 equal to 2.94 GeV/c. Details of the data analysis are given in the paper [12].

3   Results

In Fig. 4 tensor analyzing power A_{yy} for the reaction $dp \rightarrow dn\pi^+$ and for the channel with two pions in the final state are presented and compared with the existing world data [13] from the inclusive $p(d, d')X$ scattering.

The difference between A_{yy} for one and two pions in the final state channels is not significant. They actually differ only at the point with the maximum $|t|$, t=-0.225 (GeV/c)^2.

The points corresponding to the exclusive channels are higher than the inclusive ones when taken at about the same beam momentum, while A_{yy} of the inclusive data demonstrate an approximate scaling in $|t|$.

Data on A_y and general discussion can be found in [12].

4   Conclusion

Tensor and vector analyzing powers for the reactions $dp \rightarrow dn\pi^+$, $dp \rightarrow dp\pi^0$, $dp \rightarrow dN\pi\pi$ were measured in the energy region of the Roper N(1440) resonance excitation as functions of the deuteron 4-momentum transfer squared in the t range, $-0.28 \leq t \leq -0.07$ (GeV/c)^2, of the effective mass of the subsystems $(N\pi)$, $(N\pi\pi)$, $1.33 \leq M_{eff} \leq 1.48$ GeV/c^2.

The results of this experiment show two interesting features:

• first, taken as a function of t one and two pions events have the same A_{yy} within statistical uncertainty;

• second, compared to the world data on inclusive p(d, d')X, the exclusive one and two pion A_{yy} data are systematically higher.

The simplest interpretation of the first point could be that the exclusive reaction in the kinematics of this experiment is fully dominated by the Roper. The second point can be explained by hypothesizing that the integration over the full phase space of the missing mass in (d, d') allows some other contribution which lowers A_{yy} somewhat. The Δ comes to mind because it is so overwhelming in this s-range.

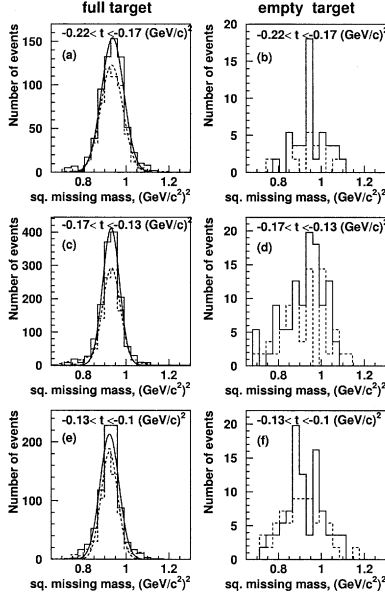Figure 3: Experimental missing mass squared distributions for $dp \to dn\pi^+$ channel when π^+ is detected by the FS. Empty target contribution is subtracted. The background from misidentification of the type of a charged particle (very small) is fitted by polynomial and subtracted. Solid line: the positive tensorial polarization of the beam; Dashed line: the negative tensorial polarization.
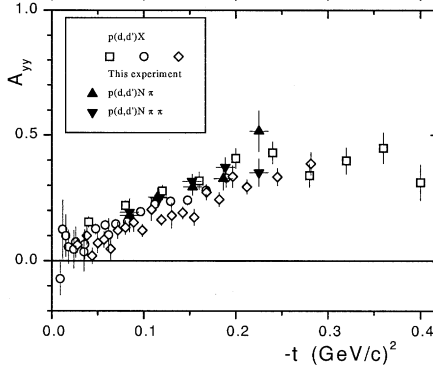

Figure 4: Comparison of the tensor analyzing power A_{yy} for p(d, d')X (world data [13] hollow symbols) with the results of this experiment (solid symbols) for the reactions $dp \to dn\pi^+$ and $dp \to dp\pi\pi$. Word data: squares $p_d = 9 \ GeV/c$, circles $p_d = 5.5 \ GeV/c$, diamonds $p_d = 4.5 \ GeV/c$.

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Измерение тензорной анализирующей способности A_{yy}
неупругого $p(dd')$-рассеяния в области энергий возбуждения
дельта-изобары и роперовского резонанса с использованием
спектрометра SPES4 –π на ускорителе SATURNE-II

Изучение неупругого рассеяния поляризованных дейтронов с импульсом 3,73 ГэВ/с на протонах в области энергий возбуждения роперовского резонанса N*(1440) и Δ(1232) было проведено в эксклюзивном эксперименте с использованием спектрометра SPES4 –π в Национальной лаборатории SATURNE (Сакле, Франция).

Тензорная и векторная анализирующие способности пионного рождения для реакций $d+p \to d+n+\pi^+$, $d+p \to d+p+\pi^0$, $d+p \to d+N+\pi\pi$ были измерены как функции квадрата переданного четырехимпульса t и эффективной массы подсистем $(N\pi)$, $(N\pi\pi)$.

Было обнаружено, что значения A_{yy} для рассматриваемых каналов реакции систематически больше ближайших по энергии пучка известных мировых данных для инклюзивной реакции $p(dd')X$.

Работа выполнена в Лаборатории высоких энергий ОИЯИ.

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Measurement of the Tensor Analyzing Power A_{yy}
of Inelastic $p(dd')$ Scattering in the Energy Region of Delta
and Roper Resonances Excitation with SPES4 –π at SATURNE-II

A study of inelastic scattering of polarized 3.73 GeV/c deuterons on protons in the energy region of the Roper N* (1440) and the Δ(1232) resonances excitation has been performed in an exclusive experiment at LNS (Laboratoire National SATURNE, Saclay, France) using the SPES4 –π setup.

Tensor and vector analyzing powers of pion production for the reactions: $d+p \to d+n+\pi^+$, $d+p \to d+p+\pi^0$, $d+p \to d+N+\pi\pi$ have been measured as functions of the squared deuteron 4-momentum transfer t and of the effective mass of the subsystems $(N\pi)$, $(N\pi\pi)$.

It is found that A_{yy} values for the considered reaction channels are systematically larger than the known world data from the inclusive $p(dd')X$ at the nearest beam energy.

The investigation has been performed at the Laboratory of High Energies, JINR.

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