# POLARIMETRY OF THE VECTOR POLARIZED DEUTERON BEAM AT THE JINR SYNCHROPHASOTRON

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## Introduction

The measurement of $(\Delta\sigma_L(\vec{n}\vec{p}))$, the difference between $np$ scattering cross sections for two pure longitudinal spin states, was carried out [1] on the polarized deuteron beam of the JINR synchrophasotron. A new beam polarimeter, based on the measurement of the $pp$ quasielastic scattering asymmetry, was installed on the extracted beam line to control the stability of the beam polarization and to measure the value of deuteron vector as well as proton polarizations. This method was used earlier on the SATURNE II polarized deuteron beam [2,3] in the energy region $T_d \leq 2.3$ GeV. It is based on the fact that the polarizations of protons and neutrons in the deuteron are equal. It is also assumed that in the kinematical and energy range of the experiment the asymmetry for quasielastic scattering on polarized nucleons in the deuteron is the same as on free polarized protons. This condition is trivially satisfied if there is no difference in analyzing power for scattering on free nucleons and on quasifree nucleons in deuteron. This is in fact found to be the case for $pp$ scattering in the region up to $\sim$ 1 GeV per nucleon. After dividing the asymmetry $\epsilon^d_{pp}$ measured in experiment by the analyzing power for scattering on free protons we can obtain a value of the polarization of protons in the deuteron which is expected to be close to the value of deuteron vector polarization [4]. The latter was independently checked in our experiment by means of measurement of the $\vec{d}p$ elastic scattering asymmetry [5].

The main equations which describe the process of elastic nucleon-nucleon scattering are presented below:

$$N^{\pm}(\theta) = N^0(\theta)[1 + (\vec{P}_T + \vec{P}_B)\vec{P}_{pp} + C_{NN}\vec{P}_B\vec{P}_T] \tag{1}$$

where $\vec{P}_T$ and $\vec{P}_B$ are the target and beam polarizations and $\vec{P}_{pp}$ is the $pp$ elastic scattering analyzing power (polarization).

If $\vec{P}_T = 0$, which is true in our case,

$$\epsilon_{pp}(\theta) = \frac{N^+(\theta) - N^-(\theta)}{N^+(\theta) + N^-(\theta)} = \vec{P}_B\vec{P}_{pp}(\theta) \tag{2}$$

and hence

$$\mid \vec{P}_B \mid = \frac{\epsilon_{pp}(\theta)}{\mid \vec{P}_{pp}(\theta) \mid} \tag{3}$$

The main advantages of the used method are:

1. The possibility of the on-line monitoring of the stability of the deuteron beam polarization during the whole run is ensured.
2. The calculation of the beam polarization needs the information on the values of $\vec{P}_{pp}$ only. The last one was carefully measured many times and can be extracted with a high precision

from results of these measurements as well as from a phase shift analysis calculation [6,7].
3. The measurement of the polarization of the quasielastic scattered protons allows to define directly the polarization of the proton inside the deuteron which has to be equal to the polarization of the neutron.

## Experimental Setup, Results and Discussion

The polarimeter was installed on the extracted polarized deuteron beam of the JINR synchrophasotron at F4 area. It consisted of eight scintillation counters $C_1 - C_8$ and detected the scattered and recoiled particles from a hydrogen containing target. The fourfold coincidences defined the right and left scattering events. The arms of the polarimeter were installed at the angles corresponding to the *pp* elastic scattering kinematics. $CH_2$ and carbon targets were used. The thickness of the $CH_2$ target along the beam was 5 mm; the thickness of the C target was chosen taking into account content of carbon in the $CH_2$ target. The experimental setup is presented in Fig.1. The main parameters of the polarimeter are listed below:

Polarimeter main parameters

| | | |
|---|---|---|
| Distance to the defining counters $C_{1,5}$ | $L$ | 188 cm |
| Size of the defining counters | $S_{C1,5}$ | $5 \times 5$ cm$^2$ |
| Angular resolution | $\Delta\theta$ | 1.5° |
| Solid angle | $\Omega$ | $7 \cdot 10^{-4}$ |

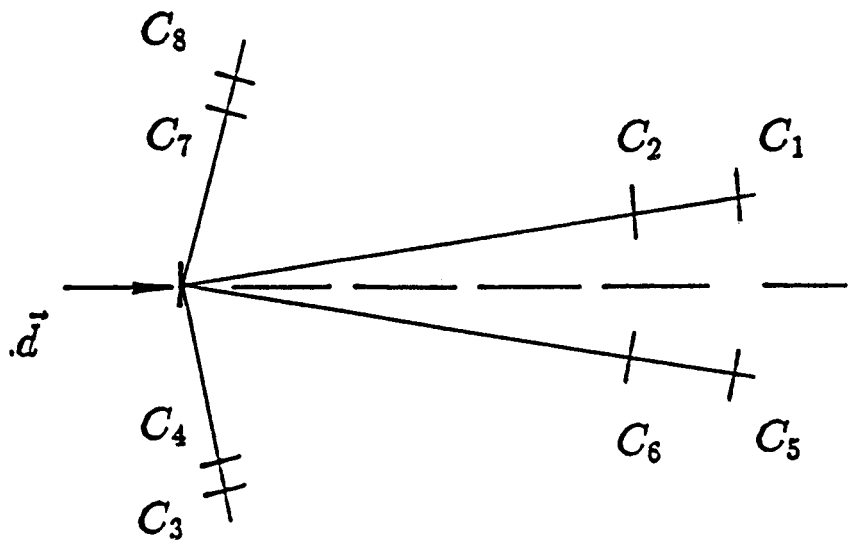


**Fig.1.** Schematic layout of the polarimeter

The measurements were carried out at four momenta of the polarized deuteron beam (3.0, 3.84, 6.64, and 9.00 GeV/c). The last of these momenta corresponds to the proton energy of 3.66 GeV which is considerably higher than the energy range where the *pp* quasielastic scattering was used before for polarization measurement. The forward arrays of the polarimeter were set at $\theta_{lab} = 8°$ for two higher momenta and at $\theta_{lab} = 14°$ for two

others. The chosen angles correspond to the maximum values of *pp* elastic scattering analyzing power [6,7]. The right-left and up-down asymmetries (the latter for both arms of the polarimeter) were measured on the transversely polarized deuteron beam with up– and down–oriented vector polarization. Obtained results are shown in Fig.2 where presented is the correlation of the normalized number of events per spill for left and right polarimeter arms for both orientations of the beam polarization. The events in the region close to the left corner belong to *pp* quasielastic scattering on protons of the carbon nuclei. The obtained left–right asymmetry for *pp* quasielastic scattering is shown in Fig.3. Both figures display data at $T_p = 2.5$ GeV.

Numerical results of our measurements are collected in Table. The good agreement of the results for left–right and up–down asymmetry was found and gives evidence of the low instrumental asymmetry of our measurement. The last column of the Table presents results of the beam polarization calculation. The results of $\vec{P}_B$ at $T_p = 0.83$, 1.20 GeV were corrected for asymmetry due to *pp* quasifree scattering on carbon using the results of Ref.[3]. Independent measurements on the C target were not carried out during the run.

*Table*

Asymmetry (left-right and up-down) for *pp* quasielastic scattering

| $p_d$(GeV/c) | $T_p$(GeV) | $\theta^o_{lab}$ | $\epsilon^{lr}$ | $\epsilon^{ud}$ | $\mid P_B \mid$ |
|---|---|---|---|---|---|
| 3.00 | 0.83 | 14 | 0.246±0.016 | | 0.58 |
| 3.84 | 1.20 | 14 | 0.2201±0.0015 | 0.2227±0.0015 | 0.60 |
| 6.64 | 2.51 | 8 | 0.1435±0.0015 | 0.1432±0.0015 | 0.58* |
| 9.00 | 3.66 | 8 | 0.0801±0.0022 | 0.0813±0.0020 | 0.50* |

* the asymmetry from scattering on carbon was not subtracted.

The independent estimation of the beam vector polarization was made at $p_d = 3.84$ GeV/c using the measurement of $\vec{d}p$ elastic scattering asymmetry. Obtained values are $0.53 \pm 0.03$ and $0.54 \pm 0.03$ for different signs of the beam vector polarization. The small discrepancy between these numbers and our data presented above is under discussion. As one of possible reasons for it, an unsufficient precision of used $\vec{d}p$–analyzing power data could be mentioned.

Measurements of the asymmetry of *pp* quasielastic scattering were being carried out during the whole $\Delta\sigma_L(\vec{n}\vec{p})$ experiment. The data on the stability of the deuteron beam polarization were obtained for three different beam momenta. As a result, the highest level of the *pp* scattering asymmetry instability could be estimated as $\Delta\epsilon \leq 0.01$. This estimation corresponds to the polarization instability less than 0.04 for the proton (or neutron) beam polarization at $T_p = 2.5$ GeV during the run. The results of $\Delta\sigma_L(\vec{n}\vec{p})$ measurements were published as a DAPNIA preprint [1] and submitted to Zs. fur Physik C.

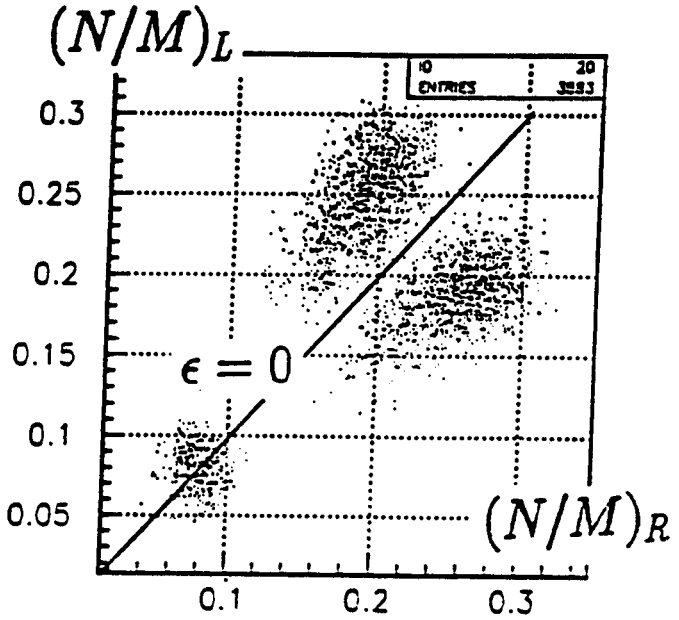


**Fig.2.** Correlation of the normalized event numbers for left and right polarimeter arms (data from measurement of *pp* quasielastic scattering on $CH_2$ target at $T_p = 2.5$ GeV for deuteron beam with up– and down–oriented vector polarization)

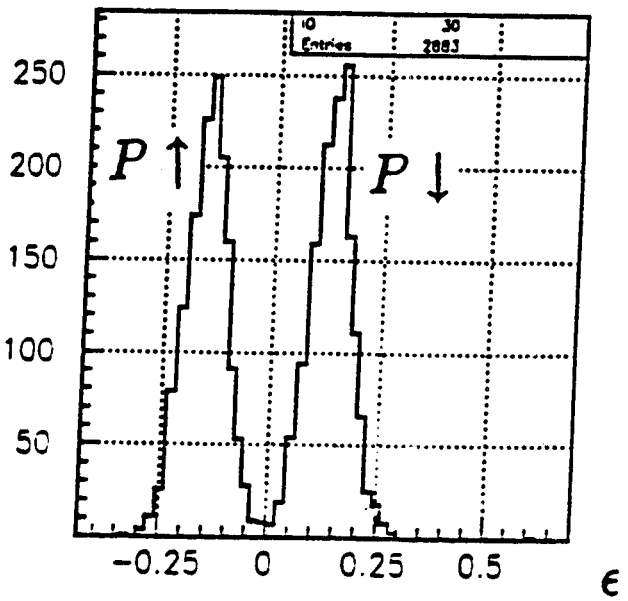


**Fig.3.** Left-right asymmetry from *pp* quasielastic scattering for deuteron beam with up- and down-oriented vector polarization

## Summary

The *on-line* polarimeter for monitoring and measuring the vector polarization of polarized deuteron beam was installed and tested at the JINR synhrophasotron. It was shown that the polarimeter based on the measurements of *pp* quasielastic scattering asymmetry can be successfully used in the momentum region up to $p_d = 9$ GeV/c.

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# NEW MEASUREMENTS OF THE ANTINEUTRINO–SPIN ASYMMETRY IN BETA–DECAY OF THE NEUTRON AND RESTRICTION FOR MASS OF $W_R$

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Precise measurements of neutron beta decay parameters allow one to test the Standard Model of weak interactions. Particularly, measurement of the antineutrino–spin asymmetry with an accuracy better than 1% gives a possibility to check the existing models of right W–bosons in the neutron decay [1–3].

This work has been carried out on the vertical channel of cold polarized neutrons at the WWR-M reactor.

Measurement of momentum and angle of escape of the undetected antineutrino is possible due to detection of the electron in coincidence with the recoil proton and due to determination of their momenta.

One can show that antineutrino–spin asymmetry $B$ can be expressed as

$$P \cdot B = \frac{[X(1 + a \cdot \frac{v}{c} \cdot (\cos\Theta_{e\tilde{\nu}})_{ik})] - A \cdot P \cdot \frac{v}{c} \cdot (\cos\Theta_{\sigma e})}{(\cos\Theta_{\sigma\tilde{\nu}})}, \qquad (1)$$

where $X$ is the experimental asymmetry, $a$, $A$ and $B$ are coefficients of electron–antineutino, electron–spin, and antineutrino–spin asymmetries, $P$ is the degree of neutron polarization. For determination of $B$ it is necessary to know the beam polarization and calculated values