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Deuteron beam polarization measurement at 270 MeV at Nuclotron internal target

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Abstract. The current deuteron beam polarimetry at Nuclotron is provided by the Internal Target polarimeter based on the use of the asymmetry in dp-elastic scattering at large angles in the cms at 270 MeV. The upgraded deuteron beam polarimeter has been used to obtain the vector and tensor polarization during 2016 runs for the DSS experimental program. The polarimeter has been used also for tuning of the polarized ion source parameters for 6 different spin modes. The data analysis has been performed using developed software based on C++ language and ROOT5 library.

1 Introduction

The investigation the spin structure of two- and three-nucleon short-range correlations is main goal of the DSS project at Nuclotron [1, 2, 3]. The base tools for these studies are the measurements of the polarization observables in the deuteron induced reactions. The high precision deuteron and proton beams polarimetry is great of importance for DSS program and spin physics at NICA.

A method for deuteron beam polarization measurement in the Nuclotron ring based on measuring the asymmetry in dp-elastic scattering at 270 MeV internal target station (ITS) has been developed [4] and applied in 2016 year.

The goal of the present article is to report new results on the measurements of the vector and tensor beam polarizations using upgraded polarimeter. These measurements were performed during the DSS experiment on the study of the vector A_y, tensor A_{yy} and A_{xx} analyzing powers in dp-elastic scattering at large transverse momenta [5].

2 Deuteron polarimeter at ITS

The internal beam polarimeter with a very thin target may have approximately the same efficiency as the extracted beam polarimeters. It can be achieved even at relatively low beam intensity with using a thin solid target inside the inner ring of the accelerator and multiple beam passage through the interaction point.

The polarimeter is based on the dp-elastic scattering at large angles (θ cm ≥ 60º) at 270 MeV. Details of construction and performance are described in [4]. The polarimeter uses the high precision data on analyzing powers obtained at RIKEN [6]-[8]. The accuracy of the determination of the deuteron beam polarization achieved with this method is better than 2%.

Deuteron beam polarimeter [4] consists of a spherical scattering chamber and system change six different targets placed in the Nuclotron ring. A detector support with 39 mounted plastic scintillation counters coupled to the Hamamatsu H7416MOD photo-multiplier tubes is placed downstream the ITS spherical chamber. Eight proton detectors were installed for left, as well as for right and up, but due to space limitation – only four for down. The angular spin of one proton detector was 2º in the laboratory frame, which corresponds to ∼4º in the c.m.s. Three deuteron detectors are placed at scattering angles of deuterons coinciding kinematically with the protons. Only one deuteron detector can cover the solid angle corresponding to four proton detectors placed down. In addition, one pair of detectors is placed to register two protons from quasi-elastic p−p scattering at θ pp =90º in the c.m.s. in the horizontal plane. The scattered deuterons and recoil protons at 270 MeV were detected in kinematic coincidence over the c.m.s. angular range of 65–135º at eight different angles, defined by the positions of the proton detectors.

The VME (Versa Module Eurocard) based data acquisition system is used for the data taking from scintillation detectors [10]. The signals from the detectors are fed in 16-channel TQDC-16 charge-time-digital converters via commutator bar. TQDC-16 module allows to measure the amplitude and time appearance of the signal simultaneously. The hardware of the DSS VME system consists of 4 TQDC-16 modules, trigger module TTCM and VME controller. There is a possibility to tune the first-level trigger using logic of trigger and TQDC-16 modules. This system has been significantly upgraded recently [11].

Newly developed multichannel high-voltage power supply system (Wiener MPod) [12] is used to provide the power for about 70 scintillation detectors based on Hamamatsu photomultipliers.

3 Experiment at ITS

The internal target station (ITS) is highly effective tool in the investigation of dp-interactions in wide energy range. The CH^2-target of 10 μm thick has been used for these measurements. The measurements on carbon target is also carried out for evaluation of the carbon impurity in polyethylene data. Carbon target consist of several twisted 8 μm carbon wires. The measurements were performed using internal target station at Nuclotron [9] with new control and data acquisition system [13].

New polarized ions source (SPI) developed at VBLHEP at JINR[14] has been used to provide polarized deuteron beam. The spin modes with the optimal values of (Pz, Pzz) = (0, 0), (-1/3, -1) and (-1/3, +1) were used in the current experiment for the analyzing powers measurement at several energies. The deuteron beam polarization has been measured at 270 MeV energy [4].

The polarization observables data were collected on 2 parts: November 2016 and December 2016. The deuteron beam polarization measurements were performed at 270 MeV before and after each run of analyzing powers measurement in the energy range of

400-1800 MeV [5]. In addition, the polarimeter [4] has been used to tune other spin modes of SPI.

The software developed for the data analysis is based on the ROOT package in C++. The dp-elastic scattering events at 270 MeV were selected using correlation of the energy losses and time-of-flight difference for deuteron and proton detectors. The measurements were performed using CH^2 target only. The carbon contribution was estimated to be less than 0.5%.

The precise data on the deuteron analyzing powers at 270 MeV [6]-[8] were used to obtain the polarization values at several angles [4]. The vector P_z and tensor P_{zz} components of polarization were calculated using the normalized dp-elastic scattering events and analyzing powers known [4]. The values of the beam polarization for different spin have been obtained as weighted averages for 8 scattering angles for dp-elastic scattering in the horizontal plane only. The typical values of the beam polarization were ~65-75% from the ideal values.

4 The results of the polarization measurements

The vector and tensor polarizations of deuteron beam were measured seven and six times in November 2016 and in December 2016 experimental runs, respectively. The values have small statistical and systematics errors. The values show the stability within each part of the experiment, except the December 2016 part, when the physics program was separated on two parts by the tuning of the SPI for pure tensor modes (P_z, P_{zz}) = (0,-2) and (0,+1) during 8 hours.

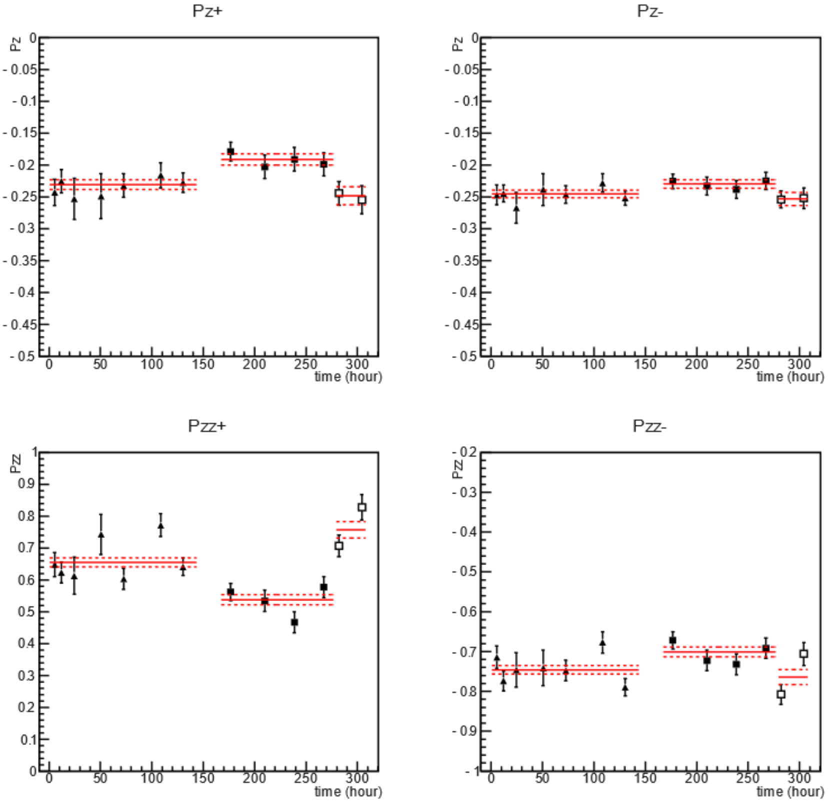

Fig. 1. Polarizations values P_z and P_{zz} for spin modes (P_z, P_{zz})= (-1/3,-1) and (-1/3, +1) during the runs in 2016.

The experimental results are presented in Fig. 1. Open triangles, squares and circles correspond to the one November and two December run steps, respectively. Red lines show the mean value for each step. All the results are within two standard deviations from mean values obtained for corresponding experimental runs. One can see that the beam polarization values are quite stable within more than 200 hours of the SPI operation. On the other hand, SPI demonstrates good reproducibility of the polarization values for different sets of the data after long interruptions. The typical values of the vector and tensor components of the beam polarization for the spin modes (-1/3, -1) and (-1/3, +1) are given in the table 1.

Table 1. The vector and tensor polarization for different spin modes of SPI

Spin mode(P_z, P_{zz})	P_z	dP_z	P_{zz}	dP_{zz}
(-1/3, 1)	-0.272	0.019	0.733	0.035
(-1/3, -1)	-0.272	0.014	-0.793	0.026
(+2/3, 0)	0.427	0.021	0.061	0.037
(-2/3, +1)	-0.489	0.026	0.631	0.045
(0, +1)	0.040	0.023	0.725	0.042
(0, -2)	0.042	0.013	-1.478	0.030

The polarimeter [4] has been used also to tune the SPI [14] operation for pure tensor spin modes (0, -2) and (0, +1), for pure vector spin mode (+2/3, 0) and for the spin mode (-2/3, +1) with both vector and tensor components. The preliminary results are presented in table 1. One can see, that the typical values of the beam polarization were ~65-75% from the ideal values for all 6 spin modes of SPI.

5 CONCLUSION

The upgraded version of the 270 MeV deuteron beam polarimeter has been used to obtain the vector and tensor polarization during 2016 runs.

The long-term stability of the vector and tensor components of the beam polarization has been demonstrated for the spin modes (-1/3, +1) and (-1/3, -1) of SPI.

The polarimeter has been used for tuning of the polarized ion source parameters for 6 different spin modes.

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