Upgrade of the polarimeter at the Internal Target Station at the Nuclotron

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Upgrade of the polarimeter at the Internal Target Station at the Nuclotron

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Abstract.
The results of the polarimeter upgrade at the Nuclotron internal target are presented. This polarimeter is intended for experiments to study of the spin structure of two-nucleon and three-nucleon short-range correlations. The measurements are performed in the frame of the DSS project. The simulation of the pd-elastic and pp-elastic scattering for 500 - 1000 MeV proton energy to optimization of the experimental setup is performed.

1. Introduction

The study of the spin structure of two-nucleon and three-nucleon short-range correlations via the measurements of the polarization observables in the deuteron induced reactions is one of the major scientific goals at Nuclotron. The high precision polarimetry of the deuteron and proton beams is important for these investigations.

A deuteron beam polarimeter based on the spin-asymmetry measurements in the dp-elastic scattering at large angles in center-of-mass system [1] has been constructed at the internal target station (ITS) [2] at the Nuclotron of JINR. This polarimeter is used for the measurements of the vector and tensor components of deuteron beam polarizations at the energies 270 - 2000 MeV simultaneously.

The results of the polarimeter upgrade for the measurements of the proton polarization at the Nuclotron internal target are presented. The study of the *pp*- and *pd*-elastic scattering at energies 100 - 1000 MeV are planned.

2. Polarimeter now

The measurements are performed in the frame of the DSS project [3]. The polarimeter based onthe use of *dp*-elastic scattering at large angles ($\theta_{cm} \geq 60^{\circ}$) at 270 MeV [1].The ITS setup

is well suited for study of the energy dependence of polarization observables for the deuteron-proton elastic scattering and deuteron breakup reaction with the detection of two protons at large scattering angles. Currently, the polarimeter consists from 39 scintillation detectors based on Hamamatsu H7416MOD photomultipliers. The VME (Versa Module Eurocard) based data acquisition system with new software [4] is used for the data taking from scintillation detectors.

The measurements were performed using ITS at Nuclotron in 2016-2017 years with new control and data acquisition system. New source of polarized ions [6] has been used to provide polarized deuteron beam. The measurements were performed at 500 and 650 MeV/nucleon to obtained the vector analyzing power and beam polarization. The CH_2- and C- targets were used in the experiment. Preliminary the selection of useful data was carried by using several criteria. Firstly, data are selected using the information on the internal target position monitor. The next step the analysis of the amplitude and time signal correlations in *pp*-quasi-elastic scattering in the *dp*-interaction for measurements on the CH_2- and C- targets. After this the $CH_2 - C$ procedure was performed.

The vector analyzing power data and deuteron polarization in the *pp*-quasielastic channel at 500 and 650 MeV/nucleon are shown in the Fig.1 - Fig.3, respectively.

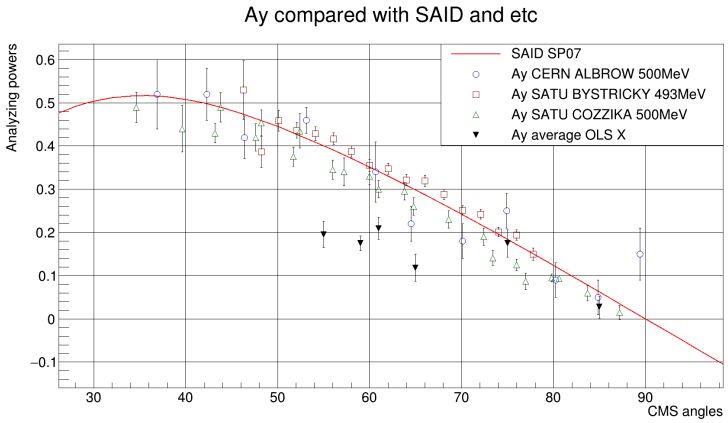

Figure 1. Angular dependence of the vector analyzing power A_y (full triangles) in *pp*-quasi-elastic scattering at 500 MeV/nucleon with compared with the world data and with the SP07 solution partical wave analyzis [5].

The all analyzing power data are in the reasonable agreemant at $\theta_{c.m.} = 70^\circ - 85^\circ$. At smaller angles the discrepancy is observed as at 500 well as at 650 MeV/nucleon.

The polarization calculated by the data of the reaction *dp*-interaction in the *pp*-quasi-elastic kinematic is corresponds to the polarization calculated at 270 MeV/nucleon. This indicates that the beam depolarization at other energies besides 270 MeV/nucleon is was not.

Also the measurements of the proton beam polarization using several pairs of the detectors placed in the kinematic coincidences corresponding to *pp*-elastic scattering in the horizontal plane (orbit plane of Nuclotron) have been proposed. The weighted average values of the proton beam polarization were found as 0.056±0.021 and -0.367±0.015 for unpolarized and polarized cases, respectively. There fore that the measurements of the proton polarization is possible using current polarimeter at ITS.

3. Polarimeter upgrade

The detectors set modernization is included in the polarimeter upgrade program. For this purpose it is necessary to calculate the detectors size, detectors number and distance to target.

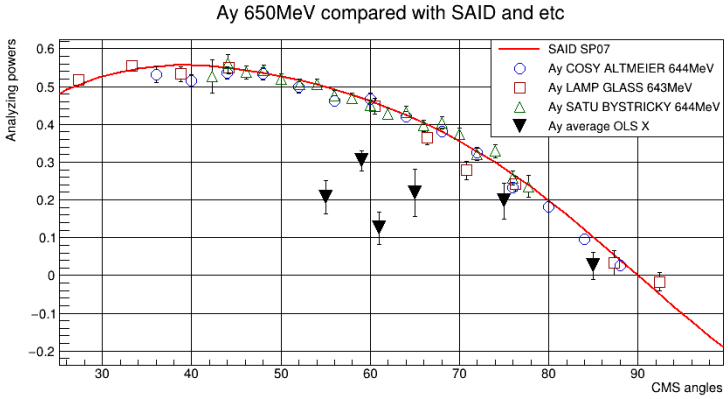

Figure 2. Angular dependence of the vector analyzing power A_y (full triangles) in pp-quasi-elastic scattering at 650 MeV/nucleon with compared with the world data and with the SP07 solution partical wave analyzis [5].

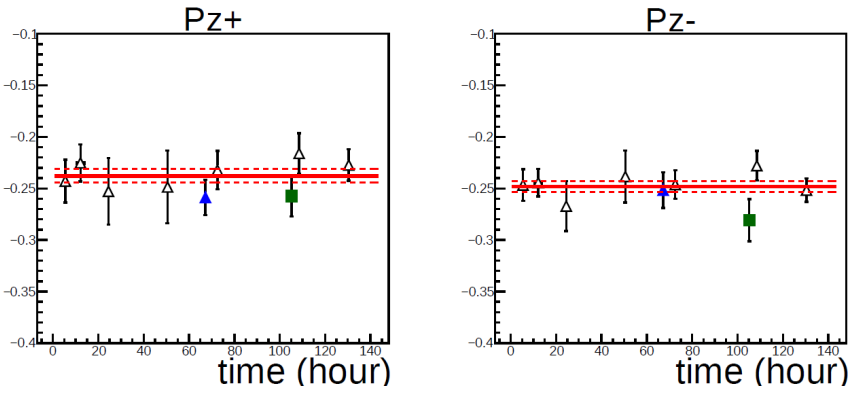

Figure 3. Deuteron polarization at 500 and 650 MeV/nucleon. Open triangles - data at 270 MeV/nucleon [7], full triangles - data at 500 MeV/nucleon, squares - data at 650 MeV/nucleon.

Here, the following factors play an important role. Firstly, the area of the detectors should be such that all falling events are recorded by the data acquisition system (no system overloads). Secondly, the area of the detectors should be such that the total number of events in all detectors will be not more $5 \cdot 10^9$ events/cycle using thin CH_2 target. Third, the effective area of the detectors (S_{eff}) should maximum equal to their geometrical sizes. Fourthly, if one detector is broken, it will be can easily to change to another detector. Fifth, the sizes of the detectors and the distance to the target should allow to place of a large number of counters. Here, the overlap between detectors should be is minimum because it can make the selection of the true events to more difficult.

The scheme which includes 42 detectors for pp-elastic scattering has been proposed. The counters will be placed every 5° in the c.m.s. and will coveres the range $40° < \theta_{c.m.} < 90°$. The calculation using the Pluto simulation [8] gives ratio of hight of the kinematical coincidence detectors shoud be equal 1/3. The detectors size were proposed as 2x2x2 cm and 2.3x6x2 cm.

The scheme which includes 80 detectors for pd-elastic scattering has been proposed. The counters will be placed every 5° in the c.m.s. and will cover the range $30° < \theta_{c.m.} < 125°$. The detectors size were proposed as 2x2x2 cm and 2.3x6x2 cm. The distance to the target was

estimated as 56 – 65 cm.

The calculation of the effective area of the detectors by the Pluto generator was performed at energies from 100 to 1000 MeV for *pp*- and *pd*- elastic scattering (Fig.4 - Fig.5). The S_{eff} increases with the $\theta_{c.m.}$ increasing for *pp*-elastic scattering. The minimum of S_{eff} equal the 80% from the detector geometrical sizes. The S_{eff} decreases with the $\theta_{c.m.} > 60^{\circ}$ for *pd*-elastic scattering. At $\theta_{c.m.} \approx 110^{\circ}$ S_{eff} equal the 65% from the detector geometrical sizes. In this domain the additional detectors set was proposed with the size of proton detectors 3.5x6x2 cm. It allows to increase of the S_{eff} up to 95%.

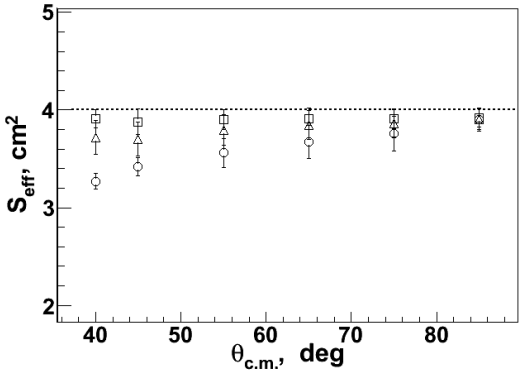

Figure 4. The effective area of the detectors S_{eff} for *pp*-elastic scattering. Squares - data at 100 MeV, triangles - data at 500 MeV, circles - data at 1000 MeV. Dashed line - the geometrical area of the detectors.

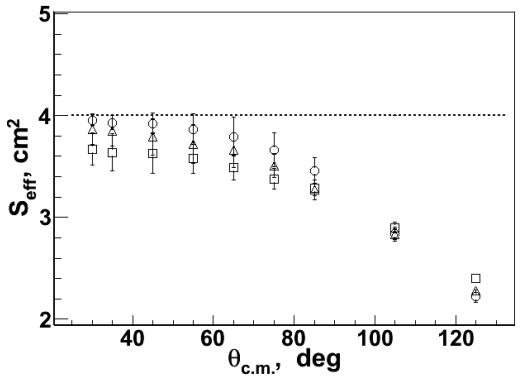

Figure 5. The effective area of the detectors S_{eff} for *pd*-elastic scattering. Squares - data at 100 MeV, triangles - data at 500 MeV, circles - data at 1000 MeV. Dashed line - the geometrical area of the detectors.

Also, the calculation of the total number of *pp*- and *pd*- elastic events in all detectors was performed. The results is shown that the sizes of the detectors and their number are satisfy to other requirements related to the VME system download and CH_2-target capabilities.

4. Conclusion

The experiments at Nuclotron with deuteron and proton beams demonstrated that the measurements of the proton polarization is possible at ITS.

The modernization of the polarimeter at Nuclotron was proposed to study *pp*- and *pd*- elastic scattering at energies 100 – 1000 MeV.

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References

[1] P.K. Kurilkin et al., Nucl.Instr.Meth. in Phys.Res.A642(2011) 45.
[2] A.I. Malakhov et al., Phys.Res.A 440 (2000) 320.
[3] V.P. Ladygin et al., Few Body Syst. 55(2014) 709.
[4] A.Yu. Isupov, J.Phys.Conf.Ser.938(2017) 01201.
[5] http://gwdac.phys.gwu.edu/analysis/nn-analysis;
[6] V.V. Fimushkin et al., J.Phys.Conf.Ser. 678 (2016) 012058.
[7] Ya.T. Skhomenko et al., EPJ Web of Conferences 201 (2019) 04005.
[8] I. Froehlich et al. Eur. Phys. J. A45 (2010) 401.