First results on A_y analyzing power measurements in $\overrightarrow{p}p$ elastic scattering experiment*

Z. Bagdasarian[a,b], S. Barsov[c], D. Chiladze[a,b], S. Dymov[a,d], A. Kacharava[a], G. Macharashvili[b,d], D. Mchedlishvili[a,b], S. Merzliakov[a,d], S. Mikirtychyants[a,c], N. Lomidze[b], M. Tabidze[b], S. Trusov[a], R. Schleichert[a], H. Ströher[a], and C. Wilkin[e] for the ANKE collaboration

The ANKE beam time in April 2013 was proposed to investigate nucleon-nucleon (NN) interactions [1]. The polarized beams and targets at COSY-ANKE facility allow a substantial contribution to the existing database by measuring various observables for both proton-proton (pp) and proton-neutron (pn) systems.

The experiment was carried out at ANKE using a transversely polarized proton beam incident on an unpolarized hydrogen (for pp investigations) or deuterium cluster-jet target (for pn studies). Six beam energies of T_p = 0.796, 1.6, 1.8, 1.965, 2.157 and 2.368 GeV were used. The aim of this contribution is to report on the preliminary results for the analyzing power A_y of the pp elastic scattering at the above mentioned kinetic energies in the 4°< θ_{cm} <29° scattering angle range. θ_{cm} will be referred to as just θ in the following.

The scattered protons were detected at the ANKE spectrometer using the **F**orward **D**etector (FD) and two **S**ilicon **T**racking **T**elescopes (STT) placed symmetrically around the cluster target. FD comprises one drift chamber, two multi-wire proportional chambers and three-plane scintillation hodoscopes, consisting of the vertically oriented counters (8 in the first plane, 9 in the second and 6 in the third one). Each STT consists of three layers of the double-sided micro-structured silicon strip detectors, that are placed close to the target inside the vacuum chamber. These layers (1^{st} layer: 70 μm thick, 2^{nd}- 300 μm and 3^{rd} - 5000 μm) were placed 2.8, 4.6 and 6.2 cm away from the target, covering laboratory angles 75°< θ_{lab} <140°. Data at ANKE was taken with the following triggers: STT alone and in coincidence with FD.

The criteria for pp elastic process identification were based on the missing mass and the scattering angle reconstruction. For the protons that passed the third layer of the STT system, the kinetic energy was reconstructed using the neural network method [3]. The proton scattering angle used in the analysis was calculated from its kinetic energy, because the geometrical angle is measured with larger uncertainties.

In order to make use of the so-called cross-ratio method [4], the beam polarization was reversed for every subsequent cycle. This technique allows to eliminate first-order systematic errors. Forming the geometrical means of the yields to the left $L = \sqrt{L_1 L_2}$ and to the right $R = \sqrt{R_1 R_2}$ with respect to the beam polarization direction, the asymmetry and its statistical uncertainty are estimated as

$$\varepsilon(\theta) = \frac{L(\theta) - R(\theta)}{L(\theta) + R(\theta)} = P\langle cos\phi\rangle A_y(\theta) \tag{1}$$

$$\sigma_\varepsilon(\theta) = \frac{LR}{(L+R)^2}\sqrt{\frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{R_1} + \frac{1}{R_2}} \tag{2}$$

in each θ scattering angle interval. P denotes the beam polarization. Hence, the analyzing power A_y is calculated as

$$A_y(\theta) = \frac{\varepsilon(\theta)}{P\langle cos\phi\rangle} \tag{3}$$

with the uncertainty

$$\sigma_{A_y} = \sqrt{\left(\frac{\sigma_\varepsilon}{\varepsilon}\right)^2 + \left(\frac{\sigma_P}{P}\right)^2} \tag{4}$$

The details on the estimate of the second-order systematic uncertainties are given in the ANKE report [3] and it is concluded that they are negligible for the final result.

As seen from Eq. 3 besides asymmetry calculation, one essential point for the analyzing power measurement was the determination of the absolute beam polarization. That was achieved by using the EDDA (**E**xcitation Function **D**ata Acquisition **D**esigned for **A**nalysis of Phase Shift) detector.

The EDDA experiment was conceived to provide high-precision elastic-scattering data in the COSY energy range (0.5-2.5 GeV) [6], but later has been modified to be used as the internal polarimeter. The thick carbon fiber target was inserted into the EDDA section for the last 20 seconds of each 3-minute COSY cycle. The EDDA detector is comprised of the long scintillator bars, that run parallel to the beam and the scintillator rings. Each of the ring-shaped scintillators of the EDDA detector cover a fixed polar angle range. Hence it is possible to compare count rates in the left and right semi-rings for each θ_{lab} range, while averaging over ϕ in every semi-ring. The details on the validity of that scaler method are given in [5].

The $p - {}^{12}C$-inclusive measurements let us obtain the beam polarization from the correlated trigger rates, without the full reconstruction of the events. The kinematic trigger makes a rough check whether the protons are elastically scattered ones. The triggers are generated for each semi-ring and counted in the so-called scalers. The time-marking system uses a clock to provide a precise time for each event trigger. The effective analyzing powers for the individual scintillator rings, measured earlier by the EDDA-collaboration were used in our analysis.

The polarization was measured individually in each pair of the semi-rings, and then using the independence of the

polarization on the polar angle, the weighted average is presented as the final result for P.

$$P = \sum_{i=1}^{n} \frac{P_i}{\sigma_i^2} / \sum_{i=1}^{n} \frac{1}{\sigma_i^2} \tag{5}$$

with the statistical uncertainty

$$\sigma_P^2 = 1 / \sum_{i=1}^{n} \frac{1}{\sigma_i^2} \tag{6}$$

where i is the ring number. The beam polarization systematic uncertainties, estimated up to 5% [5] dominate the analyzing power result uncertainties.

Preliminary results for the analyzing power at all the six energies are shown in Fig. 1 along with the existing experimental data and the SAID (**S**cattering **A**nalysis **I**nteractive **D**ial-in) predictions [2]. The error bars of our data points show the statistical uncertainties only. The analysis of the data from Forward Detector is still in progress. The good agreement between the data from previous experiments and our results at 796 MeV serves as an additional confirmation of the validity of our measurements. Moreover, such a close coincidence to the data of the other experiments indicates that actually the systematic uncertainty in P measurement by EDDA is probably less than 5%. Our results greatly extend the existing experimental data: analyzing power for pp elastic scattering has been measured for the first time in the $T_p = 1.6 \div 2.4$ GeV beam kinetic energy and $4^\circ < \theta < 24^\circ$ angular range.

References:

[1] Z. Bagdasarian et al, *COSY Proposal* #212 (2012); available from http://collaborations.fz-juelich.de/ikp/anke/proposal/prop2012_v4.pdf

[2] *SAID data base* available from http://gwdac.phys.gwu.edu

[3] G. Macharashvili, *ANKE internal report* #24, 2013; available from http://collaborations.fz-juelich.de/ikp/anke/internal_notes/TechNote24.pdf

[4] G.G. Ohlsen and Jr.P.W. Keaton, *Nuclear Instruments and Methods* 109(8):41-59, 1973

[5] E. Weise, *EDDA internal report* #00=01, 2000

[6] M. Altmeier, *Phys. Rev. Lett.* 85: 1819-1822, 2000

[a] IKP FZJ, Jülich, Germany
[b] HEPI TSU, Tbilisi, Georgia
[c] PNPI, Gatchina, Russia
[d] LNP JINR, Dubna, Russia
[e] University College London, U.K.

* supported by Shota Rustaveli National Science Foundation of the Republic of Georgia

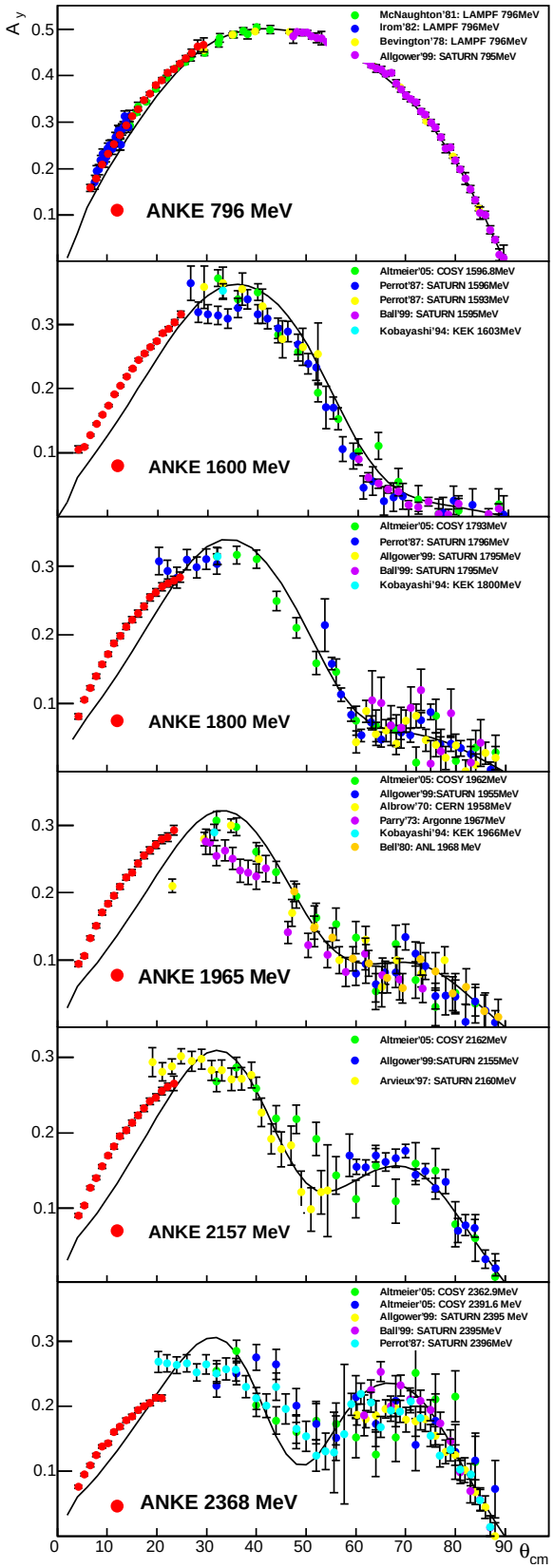

Fig. 1: The preliminary values of the analysing powers for elastic pp scattering measured with the ANKE STT at several energies (red circles) are compared to published data. Also shown are curves corresponding to the SAID 2007 partial wave solution.