Measurement of 3He Analyzing Power for Proton-3He Scattering at70 MeV with Polarized 3He Target

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I. 1. Measurement of ^{3}He Analyzing Power for Proton-^{3}He Scattering at 70 MeV with Polarized ^{3}He Target

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Study of three-nucleon forces (3NFs) is essentially important in clarifying nuclear phenomena, e.g. discrete states of nuclei and equation of state of nuclear matter. Few-nucleon scattering offers good opportunities to investigate dynamical aspects of these forces, such as momentum, spin, and iso-spin dependencies. The nucleon-deuteron scattering has provided a solid basis to nail down detailed properties of 3NFs[1)], however, the total isospin channel of the 3NFs is limited to T=1/2. Recently importance of the iso-spin dependence study of 3NFs have been pronounced for understanding of nuclear system with larger-isospin asymmetry, e.g. neutron-rich nuclei, neutron matter, and neutron stars[2)]. The p+^{3}He scattering is an attractive probe since this system is the simplest one where the 3NFs in the channels of total isospin T=3/2 can be studied. In order to explore the properties of three-nucleon forces via proton-^{3}He scattering we have performed the measurements of ^{3}He analyzing powers at 70 MeV by using the newly developed polarized ^{3}He target.

In the polarized ^{3}He target system alkali-hybrid spin-exchange optical pumping method is adopted for polarizing ^{3}He nucleus[3)]. The Rb atoms are optically pumped and polarized and they in turn transfer their polarization to the K atoms. Spin exchange collisions among Rb, K, and ^{3}He atoms transfer the polarization to ^{3}He through hyper-fine interactions[4)]. The target cell consists of double chamber which includes the target chamber and the optical pumping one. Both are connected by a thin transfer tube. This is designed to separate the

target chamber from the optical pumping one which needs external oven to produce Rb/K vapor. The target cell contains the ^{3}He gas with pressure of 3 atm at room temperature together with a small amount of N_2 gas and Rb/K vapor. The pumping chamber is heated to about 493 K to provide high Rb/K vapor density and maintain the polarization of ^{3}He nucleus. Circularly polarized photons with power of 50 W are used to optically pump Rb atoms. Polarized ^{3}He nuclei are allowed to diffuse into the target chamber. The target cell is made of GE180 glass which is known to have a very long relaxation time for the polarization of ^{3}He. The polarizations are monitored by the adiabatic fast passage (AFP) NMR method. The NMR signals give relative values of the polarization. The absolute values of the target polarization are calibrated by using frequency shift of the electron spin resonance of Rb atoms. Typical values of polarizations are 50%.

Experiments with 70 MeV proton beams in conjunction with the polarized ^{3}He target were performed at the room TR4. Proton beams bombarded the polarized ^{3}He target and they were stopped in the faraday cup. Beam intensities were about 10 nA during the experiment. Scattered protons were detected by the *dE-E* scintillation counters. They consisted of a plastic scintillator with thickness of 0.2-1 mm and a NaI(Tl) scintillator with thickness of 55 mm. The measured angles were 35-125 degrees in the laboratory system which are equivalent to 46-141 degrees in the center of mass system. In the measurement we successfully obtained asymmetry of the events from proton-^{3}He scattering.

The preliminary results of the ^{3}He analyzing power for p-^{3}He scattering at 70 MeV are shown in Fig. 1. The statistical errors together with the systematic ones are also shown. The data are compared with the rigorous numerical calculation of the four-nucleon scattering based on the modern nucleon-nucleon potentials[5]. Here the INOY[6] and CDBonn[7] potentials are taken into account. Clear differences are found at the angles 70-100 degrees and 130-140 degrees in the center of mass system. The results of comparison indicate that 3NFs are needed in the calculations in order to describe the experimental data.

References

1) Sekiguchi K, et al., *Phys Rev.* C **65** (2002) 034003; *ibid*, **89** (2014) 064007.
2) For example, Pieper SC, et al., *Phys Rev* C **64** (2001) 014001; Demorest PB, et al., *Nature* **467** (2010) 1081; Gandolfi S, et al., *Phys Rev* C **85** (2012) 032801.
3) E. Babcock, et al., *Phys Rev. Lett.* **91** (2003) 123003.
4) Happer W, et al., *Rev. Mod. Phys.* **44** (1972) 169.

5) Deltuva, A., private communications.
6) Doleschall, P., *Phys Rev.* C **69** (2004) 054001.
7) Machleidt, R., *Phys Rev.* C **63** (2001) 024001.

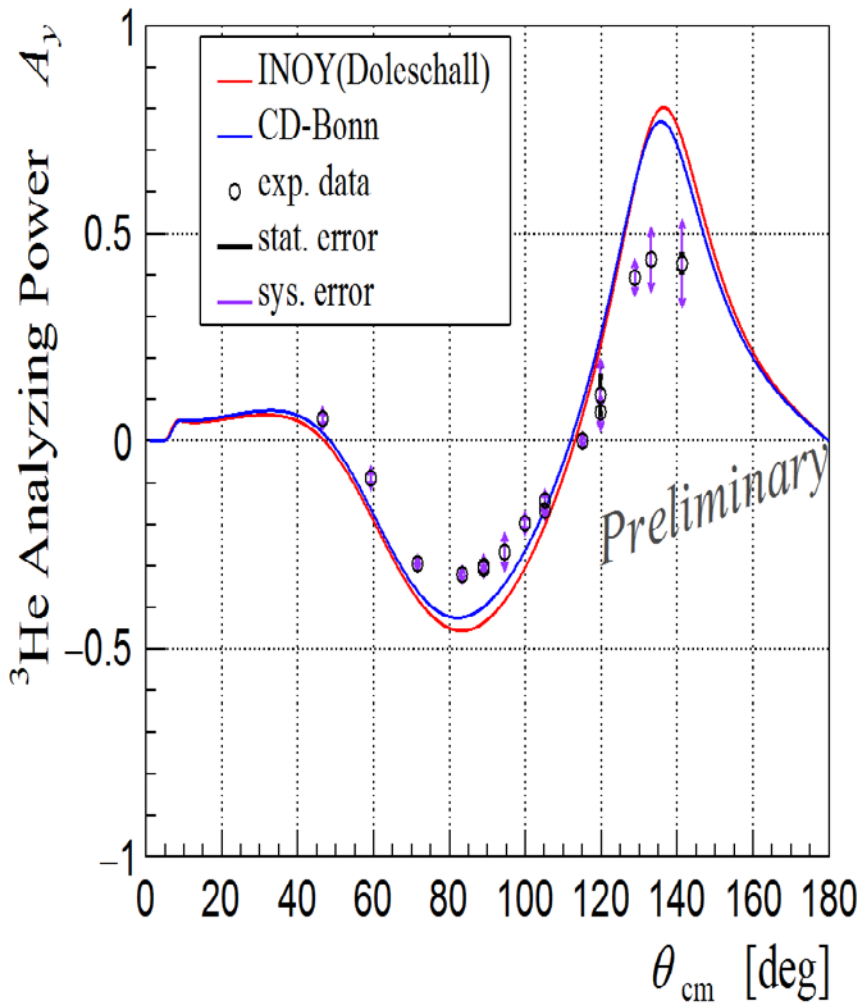

Figure 1. Preliminary results of ^{3}He analyzing power for p-^{3}He elastic scattering at 70 MeV. The rigorous numerical four-body calculations based on the INOY (CDBonn) potentials are shown in the red (blue) curve.