Proton-3He Scattering at 70 MeV with Polarized 3He Target

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I. 1. Proton-^{3}He Scattering at 70 MeV with Polarized ^{3}He Target

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One of the main interests in nuclear physics is understanding the forces acting between nuclear constituents. A hot topic in the study of nuclear forces is to clarify the roles of three-nucleon forces (3NFs) in nuclei, and to describe various phenomena of nuclei by explicitly taking into account nucleon-nucleon (NN) interactions combined with 3NFs. The 3NFs arise naturally in the standard meson exchange picture[1)] as well as in the framework of chiral effective field theory which has a link to QCD[2)]. Few-nucleon scattering offers good opportunities to investigate dynamical aspects of these forces, such as momentum, spin, and iso-spin dependencies. First indication of the 3NFs in the scattering system was pointed out in the cross section minimum for nucleon-deuteron elastic scattering at intermediate energies (E/A> about 60 MeV). Since then nucleon-deuteron elastic scattering at incident energies of up to around 300 MeV have been extensively performed both experimentally and theoretically[3)]. The nucleon-deuteron scattering has provided an solid basis to nail down detailed properties of 3NFs, 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[4)]. 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 are planning the measurements of ^{3}He analyzing powers at 70 MeV. We started construction of polarized ^{3}He target as well as the detection system in 2013[5)].

Schematic view of the polarized ^{3}He target is shown in Fig. 1. Spin-exchange optical pumping method is adopted for polarizing ^{3}He nucleus[6], where Rb atoms are polarized by optical pumping and their polarizations are transferred to ^{3}He nucleus by hyper-fine interactions. 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 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 vapor. During operation the pumping chamber is heated to about 430 K to provide a high Rb vapor density and maintain the polarization of ^{3}He nucleus. Circularly polarized photons with power of 30 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 10% now[7].

Experiments with 70 MeV proton beams in conjunction with the newly developed 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 5 nA during the experiment. Scattered protons at 55 and 70 degrees in the laboratory system were detected by the *dE-E* scintillation counters. They consisted of a plastic scintillator with thickness of 1mm and a NaI(Tl) scintillator with thickness of 55 mm. In the measurement we successfully obtained asymmetry of the events from proton-^{3}He scattering.

Further developments of the polarized target, e.g. to increase laser power, to reduce spin relaxation time, are now in progress to obtain high polarization. This is necessary to obtain high precision analyzing power data.

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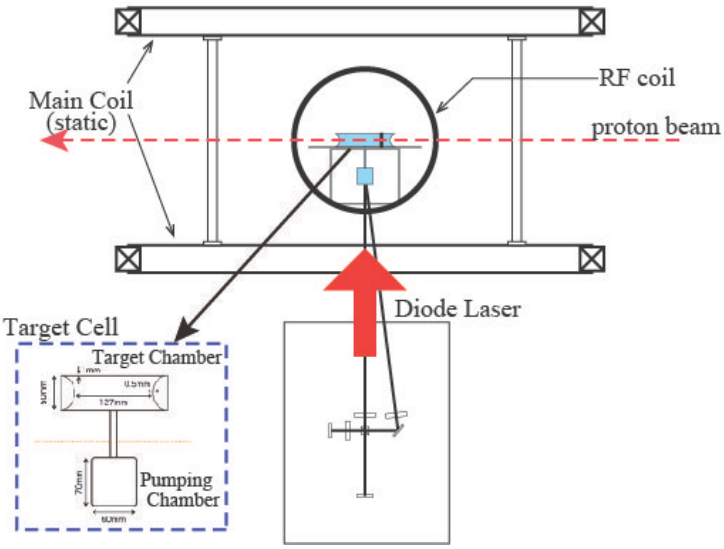

Figure 1. Schematic view of the polarized ^{3}He target.