Polarized Hydrogen-Deuteride (HD) target for future LEPS experiment at SPring-8

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Polarized HD target project [1] started in April 2005 and lasts five years. The first purpose of the project is to investigate the $s\bar{s}$-quark content of proton and neutron by measuring double polarization asymmetries for the ϕ meson photoproduction. In addition, the measurement of the double polarization asymmetries gives important informations to determine the spin-parity of Θ^+ particle. At the LEPS beam line of SPring-8, the circularly and linearly polarized photon beams with the maximum energy of 3.0 GeV are produced by backward Compton scattering. We are developing the polarized HD target for future LEPS experiment at SPring-8.

It is generally accepted that the low-energy properties of nucleon are well described in terms of three constituent u and d quarks. Therefore, recent experimental results are very surprising. Experiments from the lepton deep inelastic scattering indicate that there may be non-negligible strange quark content in the nucleon and that the strange quarks give 10-20% contributions to the nucleon spin [2, 3]. A similar conclusion has been drawn from the elastic νp scattering [4]. Analysis of the pion nucleon sigma term also suggests that the proton may contain an admixture of 20% strange quarks [5]. Experiments on annihilation reactions $p\bar{p} \to \phi X$ at rest show a strong violation of the OZI rule [6]. It has also been argued that such experimental results could be understood with little or no strangeness content in the nucleon. In this year, the G0 experiment shows non-negligible $s\bar{s}$-quark content of the proton by measuring parity-violating asymmetries in elastic electron-proton scattering [7]. This result draws strong interest and makes the controversy hotter. This controversy should be solved by providing new experimental information on the $s\bar{s}$-quark content of the nucleon.

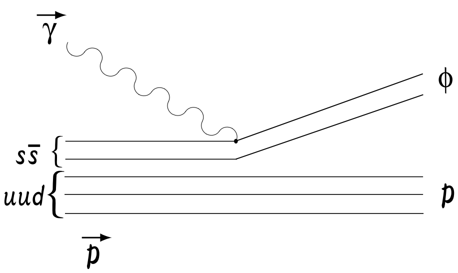

Figure 1: Direct knockout mechanism to the ϕ meson production.

Theoretical calculations by Titov *et al.* using the Pomeron-photon analogy and a relativistic harmonic oscillator quark model show that the beam-target asymmetry for the $s\bar{s}$ direct knockout ϕ meson photoproduction (Fig.1) is very sensitive to the $s\bar{s}$-quark content in the nucleon [8]. The interference of the vector-meson dominance model amplitude and the knockout amplitude gives distinct contributions to the asymmetry at small ϕ meson angles. Since the optimal photon beam energy range is expected to be 2-3 GeV, the LEPS facility is quite suitable for this purpose.

The frozen-spin molecular HD target was firstly proposed by Honig in 1967 [9]. With longstanding efforts by Syracuse, BNL and ORSAY groups, the polarized HD target system is now being used for the actual experiments at LEGS [10, 11] and GRAAL [12, 13]. Although there are still many technical problems to improve the performance of the HD system, the principal developments seem to finish in our preparation for the LEPS experiment. The HD molecule is an idealistic target for experiments to observe reactions with small cross sections. One of important advantages of using the polarized HD target is that the HD molecule does not include heavy nuclei which produce many background events. The only impurity in the HD target is thin aluminum wires which are necessary to insure the cooling. They represent at most 20% in weight of the HD target. The target size is 2.5 cm in diameter and 5 cm in thickness.

The HD molecule can be polarized and have interesting properties. The proton with spin 1/2 and the deuteron with spin 1 are independently polarized and are independently reversible. In order to achieve high polarizations of proton and deuteron targets, we employ the static method using “brute force” at low temperature (15 mK) and high magnetic field (17 Tesla). The polarization can exceed 90% for the proton after aging process for two months. The polarization of 60% for the deuteron can be obtained by transferring the proton polarization to the deuteron by using a method commonly known as “Adiabatic fast passage”. The relaxation (polarization) time of 30 days is achievable by keeping the HD target at low temperature below 300 mK with magnetic field of 1 Tesla during the experiment.

The polarization of the HD target is produced at RCNP and the target is transported to SPring-8, which is about 120 km distant from RCNP, by a truck. During the whole process, the magnetic field above 300 Gauss is provided to keep the polarization. Totally, five refrigerators are used to keep low temperature. Two large refrigerators are ^{3}He-^{4}He dilution refrigerators. One (DR) is to initially polarize the HD target at RCNP and the other (IBC) is to cool the target during the experiment at SPring-8. Remaining three refrigerators are used for transportation from RCNP to SPring-8.

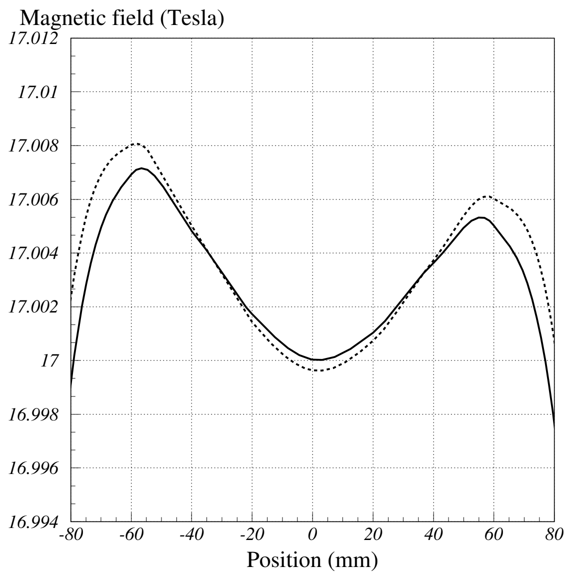

Figure 2: Magnetic field around the center of the super-conducting magnet. The solid and dashed curves are at R=0 cm and R=1.5 cm, respectively.

In this year, we constructed a system to initially polarize the HD target. We made a hole, where the DR and a dewar are installed, with a depth of 5.5 m and a diameter of 1.6 m in the building called "Ekika-shitsu" next to the main building of RCNP. A support frame for the DR and the dewar was constructed to remove vibrations which increase the temperature of the target. We installed the DR, fabricated by Leiden Cryogenics BV, with a cooling power of 3000 μW at 120 mK and a lowest temperature of below 5 mK. The consumption of liquid helium is estimated to be about 50 L/day. A super-conducting magnet was designed and the magnetic field profile estimated by the TOSCA simulation is shown in Fig.2. The magnet has a 7.1 cm bore and the maximum magnetic field at the target center is 17 Tesla (290 A) at 4.2 K. The homogeneity of the magnetic field is 5×10^{-4} at the target region. The target thickness can be extended up to 15 cm in the future. We are going to start cooling test of the DR and polarizing test using the super-conducting magnet in 2006.

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