Letter-of-Intent 00-002 for PAC 17

Study of the Parity NonConserving Force between nucleons through Deutron photodisintegration

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Introduction

The Parity NonConserving (PNC) effects were observed in a number of nucleon-nucleon and nucleon-nuclei interactions such as the radiative neutron capture, the gamma decay of $^{19}\overline{F}$, the elastic proton-proton, and the proton-alpha scattering [1]. These effects allow to study Parity NonConserving Nuclear Force. At low energy for NN processes we can use the heaviness of the W and Z, and consider a pointlike weak interaction between quarks. Because of strong repulsion between nucleons the probability of such interaction is very low. The size of the effect in the total cross section can be estimated as $G_F m_\pi^2 \sim 10^{-7}$. The effective PNC can be presented in terms of a sum of meson exchanges. It should work the same way as the ordinary low energy NN interaction can be discribed as exchanges of mesons. Resulting form of the parity violating Hamiltonian is:

$$\begin{aligned} H_{wk} &= \frac{f_\pi}{2}\overline{N}\,(\tau \times \pi)_3\,N \\ &+ \overline{N}\{h_\rho^0 \tau\cdot\rho^\mu + h_\rho^1 \rho_3^\mu + \frac{h_\rho^2}{2\sqrt{6}}(3\tau_3\rho_3^\mu - \tau\cdot\rho^\mu)\}\gamma_\mu\gamma_5 N \\ &+ \overline{N}\{h_\omega^0 \tau\cdot\omega^\mu + h_\omega^1 \tau_3\omega_3^\mu\}\gamma_\mu\gamma_5 N - \overline{N}h_\omega^{'1}(\tau\times\rho^\mu)_3\frac{\sigma_{\mu\nu}k^\nu}{2M}\gamma_5 N \end{aligned} \quad (1)$$

There are seven unknown weak coupling constants f_π, h_ρ^0, and other. A comprehensive calculation of these parameters was performed by Desplanques, Donoghue, and Holstein in 1980 [2]. Several experiments aiming to find values of coupling constants were done however experimental accuracy was not

sufficient to define f_π.
The calculations of the PNC asymmetry in the total cross section of $D(\overline{\gamma}, n)p$ reaction with DDH "best" coupling constants predicted $A_h \sim 2.5 \cdot 10^{-8}$ at $E_\gamma \sim 10\, MeV$, see [7].

The goal of the proposed experiment is determination of the pion-nucleon NPC coupling constant f_π . The purpose of this Letter-of-Intent is to solicit the evaluation by the PAC of a new line of research before investing the large effort required to development a full proposal. On stage of development of the proposal the detailed test of the feasibility need to be done which take little amount of beam time but considerable calendar time. This Letters-of-Intent involves in future a major new experimental apparatus. We are seeking for feedback at present early stage on the PAC's views on the scientific and technical merit of an idea that we intend to develop.

Previous results

Parity violating effect in Deutron photodisintegration near threshold was studied only one time in Chalk River experiment [3]. The experimental uncertainty was of 10^{-6} which is too big for the observation of the effect. However that experiment solved the problem of discrepancy between first result from inverse reaction [4] and theoretical expectation. Chalk River experiment put experimental upper limit on the value of NPC effect. The major contribution into the error budget was the fluctuation of the beam energy.

Experimental considerations

Development of the stable highly polarized electron beam at JLab presently reach the level when the systematics in NPC measurement is about 10^{-8} [5]. Stability of the beam energy on the level of few 10^{-6} become routine and ways for father improvement are under study. Beam polarization is twice higher than was used before [3]. Beam position jitter is about 100 nm. So, we have completely new situation for the second measurement of the NPC effect in the $D(\overline{\gamma}, n)p$ process. Below we outline the major parameters of the proposed apparatus. In Fig. 1 we present the schematic view of the setup.

- the beam polarization is $P_e \sim 80\%$.
- the beam current is of 1 mA.
- the beam energy is $3 \div 8$ MeV.

• the beam energy analyzed in the magnet with 50 cm radius.

• the beam position and direction measured by the cavity based BPM.

• the beam spot size is of 2 mm achieved by using passive diffuser.

• the photon production target is made of 0.75 mm gold plate.

• the 25-cm long liquid deuterium (LD_2) cell takes about 50 W of the heat power.

• the lead shielding will reduce intensity of the scattered photons on the neutron detectors.

• the heavy water moderator will be used to slowdown the neutrons.

• the main detector located on the distance of 1 meter from the (LD_2) target.

• the main detector has two types of components, one which is sensitive to slow neutrons and second which is sensitive to few MeV photons.

• the photon detectors located in the forward direction will be used to measure angular distribution in the photon beam.

• additional (Compton) detectors installed close to the target before the lead shield. They will be used to measure NPC effect in Compton scattering from electron which level is very small and can be calculated. Use of the aerogel radiator with refraction index n for example 1.01 allow avoid signals from the photons with energy below 3.5 MeV.

• the main detector has segmentation on the forward and the back parts to get sensitivity to the directional asymmetry in addition to NPC asymmetry in the total cross section.

Expected high counting rate of the neutron detectors ($\sim 10^{12}$ Hz) will help to study tiny systematics effects. Statistical accuracy will be ~ 6 *ppm* in 30 ms period. However the choice of spin flip frequency need to be optimize for minimum fluctuations of the beam energy and position. Coil pulsing technique developed [9] will be used for measurement of the rate variation with beam energy and position. Accuracy of these corrections expected to be a dominating factor of the error budget. Neutron statistics led to one day of data taking, so our best guess about total beam time for production run is of two weeks.

We anticipate that a proposal would include three energy points which allow to isolate the value of f_π from other contributions.

Conclusion

The NPC experiments at low energy got large attention in recent years [8].

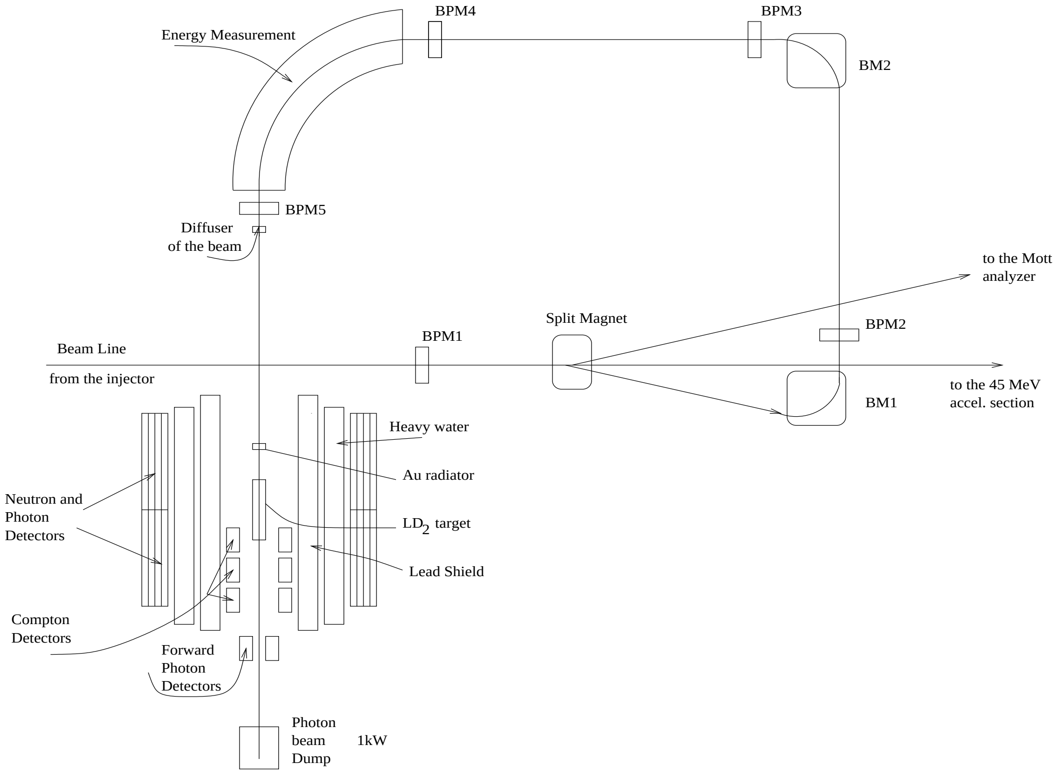

Figure 1: Proposed experimental setup for study $D(\overline{\gamma},n)p$. BM1-BPM5 are cavity based beam position monitors; BM1, BM2 are the bending magnets. Compton Detectors are used for monitoring of the helicity asymmetry in scattering of the photons from the atomic electrons.

Inverse reaction will be used in LANL experiment at threshold point [6]. Improvements of the polarized source and the experiment arrangement provide a gain of Figure-of-Merit by factor of **50** compare to the previous experiment. The level of beam quality was demonstrated during HAPPEX experiment. Monitoring of the helicity asymmetry of the Compton scattered photons allow to monitor the systematics of the experiment. We expecting that it should be possible with moderate beam time of data taking made the measurement of f_π on the level of accuracy of 30% of the "best" DDH value [2].

References

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