【Grant-in-Aid for Scientific Research(S)】
Science and Engineering (Mathematical and physical sciences)

Title of Project : Time reversal symmetry violation test with new generation ultracold neutrons

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Research Area : Particle and nuclear physics

Keyword : time reversal symmetry, ultracold neutron

【Purpose and Background of the Research】

Many theories beyond the standard model are proposed, since the standard model can't explain the baryon asymmetry in the universe, can't resolve the hierarchy problem and can't include gravity. The neutron electric dipole moment (n EDM) places a strict constraint on these theories. The early stage of SUSY was already excluded by the n EDM measurement. Recent SUSY predicts a n EDM of 10^{-25} to 10^{-28} e·cm. The most precise measurement was carried out at ILL, which showed the upper limit of 3×10^{-26} e·cm. The precision was limited by UCN counting statistics, namely UCN density in the EDM cell. We have been developing a new generation ultracold neutron (UCN) source for n EDM measurement.[1] We will increase the UCN density higher than 1×10^{3} UCN/cm^{3}, for the precision n EDM measurement.

【Research Methods】

For the n EDM measurement, we will use the Ramsey resonance in a UCN bottle, [2] which is placed in an electric field and a small magnetic field. The systematic error in the previous experiment is limited by a geometric effect, which arises from magnetic field inhomogeneity [3]. The geometric effect can be decreased from 10^{-27} to 10^{-28} e·cm in a $10^{1/2}$ times smaller diameter UCN bottle, by using a higher UCN density. The systematic error is also limited by magnetic stability and homogeneity. We will use a superconducting magnetic shield and the magnetic moment of ^{129}Xe, in addition to ^{199}Hg, as a magnetometer, which is more preferable to reduce the geometric effect. We will use a spherical coil to produce a homogenous magnetic field. This magnetic field has cylindrical symmetry, which is more preferable to control the geometric effect.

Our new UCN source breaks through the limitation of UCN density in the previous UCN source, which is imposed by Liouville's theorem. We have produced UCN by means of phonon excitation in superfluid helium (He-II) placed in a spallation neutron source [1] and then transported them to an experimental volume. The UCN density is proportional to a cold neutron flux f_n in the He-II and a UCN storage lifetime t_s. Our present UCN density is the world's highest. Moreover, we will increase f_n by means of an improved He-II cryostat and a higher proton beam current for the cold neutron production. We will increase the storage lifetime by means of the new He-II cryostat.

【Expected Research Achievements and Scientific Significance】

We will improve the precision of n EDM measurement to the region of 10^{-27} e·cm, which is in the center of the SUSY prediction. Other new theories also predict the n EDM in this region. The n EDM is complimentary to LHC, which is aiming to discover SUSY particles, since the n EDM gives us phase information.

Our new UCN source is also very useful for the studies of neutron *b* decay, gravity and N-Nbar oscillation. Many institutes, which have reactor based and accelerator based neutron sources, are developing new generation UCN sources, since the UCN density is the key parameter to developing this field. ILL and Oakridge are using He-II in cold neutron beamlines. Los Alamos, PSI, North Carolina and Munich are using solid deuterium in cold neutron sources. Among them our new UCN source will produce the highest UCN density, and then greatly contribute to this field.

【Publications Relevant to the Project】

[1] Y. Masuda et al., Phys. Rev. Lett. 89 (2002) 284801.
[2] Y. Masuda et al., Phys. Lett. A364 (2007) 87~92.
[3] J.M. Pendlebury et al., Phys. Rev. A70 (2004) 032102.

【Term of Project】 FY2009-2013

【Budget Allocation】 158,500 Thousand Yen

【 Homepage Address and Other Contact Information】
http://fnp.kek.jp/