Storage Ring Proton EDM
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Precision electric dipole moment (EDM) experiments of fundamental particles are the most sensitive probes of CP-violation beyond the standard model (SM). They can help solve such crucial mysteries as the baryon-antibaryon asymmetry of our universe and the nature of dark matter. Hadronic EDM experiments can also help to shed light on the strong CP-problem, completing the standard model (SM).

Storage ring EDM experiments can advance the EDM sensitivity by means of a great increase in statistical accuracy: 10^{11} of highly polarized proton and deuteron beams are readily available. The storage time is entirely defined by the horizontal spin coherence time (hSCT) of the stored beam, i.e., the spread of its horizontal spin precession rate, and not by particle lifetime (as in the case of neutrons), which acts as a natural upper limit.

The storage ring EDM collaboration has submitted a proposal to DOE NP for a proton EDM experiment sensitive to 10^{-29} e·cm [1]. The method utilizes polarized protons at the so-called "magic" momentum of 0.7 GeV/c in an all-electric storage ring. At this momentum, the proton spin and momentum vectors precess at the same rate in any transverse electric field, letting the radial E-field act on the proton EDM and precess its spin out of the horizontal plane for the duration of the storage time. The magic momentum concept was first used in the last muon g-2 experiment at CERN [2] and in the muon g-2 experiment at BNL [3]. The spin direction is inferred by continuously monitoring it with a precision internal polarimeter located in a straight section of the ring. The ring radius is 40 m for an electric field strength of 10 MV/m. Tracking simulations have estimated an hSCT consistent with 1,000 s storage time, which would provide the required statistics in one to two years. Using stochastic cooling, it may be possible to reach another order of magnitude in sensitivity down to 10^{-30} e·cm. The collaboration has developed more sophisticated methods of "freezing" the spin vector along the momentum direction by applying a combination of magnetic and electric fields [1, 4] applicable to particles like the muon, deuteron and proton. The collaboration believes the proton EDM method at the magic momentum is the simplest one to implement at this point.

This method is an extrapolation of the muon g-2 experimental techniques combining experience from polarized beams accelerator physics. The collaboration has:

1. Studied the systematic errors, efficiency and analyzing power of the polarimeter [5] with stored polarized deuteron beams at COSY, Institute of Nuclear Physics, Juelich/Germany.

2. Developed a tracking program that can accurately simulate the spin and beam dynamics of the stored particles in the all-electric ring. As noted above, the tracking program indicates the hSCT is adequate for a storage time of 1,000 s for the particles within the admittance of the ring.

3. Made E-field measurements at BNL using the technology developed as part of the international linear collider (ILC) and energy recovery linacs (ERL) R&D efforts [6]. We should be able to achieve more than 10 MV/m for 3 cm plate separation. Tests of a prototype consisting of large surface area electric field plates is part of the R&D request included in the proposal submitted to DOE.

4. Developed a plan to build a SQUID-based, beam position monitor (BPM) system, capable of detecting a possible vertical split between the counter-rotating beams. Such a split, produced by a net radial B-field around the ring, would be the main source of systematic error in the experiment. We aim to test the proposed, state-of-the-art BPM system in the accelerator environment of RHIC, again as part of the R&D request included in the proposal.

5. Shown that geometric phases (GP) can be reduced to a level below the EDM signal by using position tolerances of (commonly achievable) 1 mil ($\sim 25\mu$m) in the relative positioning of the E-field plates around the ring together witih beam-based alignment techniques. A second polarimeter or beam-based alignment reduces the GP effect to well below our statistical sensitivity.

References

[1] The proposal is available at http://www.bnl.gov/edm

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