Why DOE High Energy Physics (HEP) Should Support Electron Electric Dipole Moment Experiments to Search for CP-Violation in the Lepton Sector

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I. Introduction: I have submitted a proposal to DOE HEP to search for CP-violation (T-violation) in the charged lepton sector in the form of an electron electric dipole moment (EDM) experiment. The proposed experiment will improve the best present limit by a factor of 250 (Fig. 1) or find CP-violation in the lepton sector. The proposal cost is $1.8 M, and results will be obtained in three years.

II. What an Electron EDM Experiment Contributes to High Energy Physics:

• Finding an EDM proves there is physics beyond the Standard Model (SM). Because the SM predicts an unobservably small electron EDM ($< 10^{-57}$ C-m), mere observation of an electron EDM is proof that the SM must be extended: there is no SM effect to first be subtracted out.

• Finding an electron EDM is a realistic possibility because SM extensions contain CP-violating phases that couple directly to leptons and from which a large electron electric dipole moment (EDM) can be generated [Bernreuther and Suzuki, 1991; Abel et al., 2001]. The Minimal Supersymmetric Standard Model (MSSM) has 41 CP violating phases, at least three of which couple directly to charged leptons and therefore so do all theories that reduce to the MSSM, such as SUSY, super gravity, string theory, and SUSY GUTs. And *these theories predict electron EDM's within the range of our proposed experiment.*

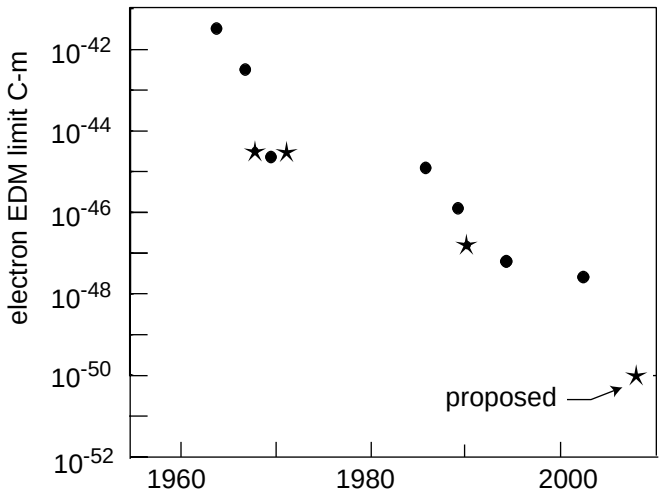

Fig. 1. Improvement in the measured upper limit to the electron EDM in S. I. units (1 C-m = 1.6 x 10^{-21} e-cm). Results that I co-authored are shown as stars.

• Improving the limit to the electron EDM provides information useful in limiting all theories that reduce to the MSSM.

• The experiment is unique: there is no accelerator-based experiment that provides similar information. The electron EDM is the most sensitive test of CP conservation (T conservation) in the lepton sector (See Review of Particle Properties).

• The research is timely because there is a standing disagreement between theory and experiment in the form of the baryon asymmetry which is not accounted for in the SM. As Sakharov (Sakharov, 1967) pointed out, this asymmetry requires a large CP violation in an as yet undiscovered massive particle.

• The experiment directly contributes to DOE Office of Science High Energy Physics Strategic Plan -2004 (see below) and the HEP long range plan.

• Finding or further constraining an EDM in the lepton sector can be done in time to optimize quark sector experiments to which HEP will commit substantial resources over the next decade.

• The research can be accomplished within the framework of limited budgets

DOE OFFICE OF SCIENCE STRATEGIC PLAN - 2004 HIGH ENERGY PHYSICS

Electron EDM Experiment's Contribution to (six) "Key Indicators of Success"

Direct Contribution

"Progress in confirming the existence of new supersymmetric (SUSY) particles or ruling out the minimal SUSY Standard Model..."

Indirect Contributions

"Progress in discovering or ruling out the Standard Model Higgs particle..."

"Progress in measuring the matter-antimatter asymmetry in many particle decay modes with high precision"

Electron EDM Contribution's to "Strategic Timeline for High Energy Physics"

Direct Contributions

"Using Super Neutrino Beam, begin measurements of matter/antimatter asymmetry in lepton sector (2021)"

"Discover supersymmetric particles or rule out minimal supersymmetric Standard Model of new physics (2020)

Indirect Contributions

"Discover or rule out Standard Model Higgs boson ...(2014)"

"Measure matter/antimatter asymmetry in quark sector with high precision (2013)"

"Use results from Tevatron Run 2 at energy frontier to discover or set better limits for Higgs boson, supersymmetric particles, and extra dimensions (2008)"

III Examples: of how the electron EDM limit constrains specific models, compliments other high energy physics experiments, and makes it easier to interpret any new CP violation observed in other systems.

B decay - The electron EDM experimental limit (and neutron EDM limit) constrains CP odd decays B -> $X_s g$ [Bailin and Khalil, 2001, Baek and Ko, 1999] and B^0 - B^0bar mixing [Baek and Ko, 1999], while other models require EDMs to be suppressed to allow new CP violation in B physics [Cohen et al., 1997].

Higgs - The electron EDM experimental limit constrains new sources of CP violation in Higgs decay [Choi et al., 2001; Hinchliffe and Kersting, 2000] and adjustment of various models' masses and couplings to cancel electron (and neutron and ^{199}Hg) EDMs can significantly affect the Higgs production cross sections [Dedes and Moretii, 2000a; Dedes and Moretii, 2000b]. Production of other heavy particles at future (linear) colliders are also constrained buy the upper limit to the electron EDM [Barger et al., 2001].

SUSY - SUSY contributions to the observed baryon asymmetry in the universe are constrained by the electron EDM experimental upper limit [Chang et al., 2002], as are T-odd, P-even interactions [Kurylov et al., 2001]. The electron EDM limit might also constrain the range of masses of several SUSY particles [Brhlik et al., 1999; Choi et al., 2000].

Muons - The electron EDM experimental limit constrains SUSY contributions to the anomalous magnetic moment of the muon [Ibrahim et al., 2001; Arnowitt et al., 2001]. The electron EDM experimental limit may also constrain the muon EDM [Babu et al., 2000; Ibrahim and Nath, 2001] and provides information about the mass scaling of the EDMs of heavier leptons [Babu et al., 2001a; Godbole et al., 2000].

Neutron EDM - the ratio of possible electron and neutron EDMs vary widely with the mechanism generating the EDM's [Barr and Segrè, 1993; Bramon and Shabalin, 1997] allowing the observation or the non-observation of an electron EDM to constrain the possible origin of a neutron EDM.

IV Timeliness: Lastly, some may ask if, in a time of tight budgets, HEP should be considering new experiments such as the one I have proposed? What better time is there to consider a project that can be executed for one-tenth the cost of the average accelerator based experiment, delivers results in half the time, and, independent of which model you prefer, yields useful information?

V. References

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