Proposal for TRIUMF Commitment (5YP 2015-2020)

Date:
September 15, 2012

PROJECT/COMMITMENT TITLE: Francium (electron) EDM

PROPONENT: H. Gould, LBL **TRIUMF CONTACT:** J. Behr, M. Pearson

PRINCIPAL COLLABORATORS: B. Feinberg, C. Munger

PROJECT DESCRIPTION:

Electron EDM measured with laser-cooled francium atoms optically prepared, tossed up and down in an atomic fountain about 1 meter high, and probed.
The LBL group has published a proof-in-principle experiment in Cs [Amini et al. PRA 75 063416 2007]. The francium atom has enhanced sensitivity to an electron EDM compared to Cs by 7.7x, while in this particular experimental method the very large hyperfine interactions in certain 209,211,213Fr [Dzuba PRA 82 062513 (2010) Table I] suppress key systematics by an additional factor of 25. This motivated their LOI.

SCIENTIFIC JUSTIFICATION:

Justification and Impact of ThC Target on S-1324: Electron EDM Experiment using Francium

An electron electric dipole moment (EDM) experiment using a fountain of laser-cooled francium-211 atoms has been proposed in S1324-LOI and endorsed with high priority by the Experimental Evaluation Committee. The goal of this experiment is to discover or rule out an electron EDM as small as 1.3x10^-50 C-m - a factor of 100 below the present limit. Discovering an electron EDM proves that there is a new source of CP violation, proves that there is new TeV-scale physics, and provides compelling motivation to construct a new large collider. And if particles heavier than the Higgs are discovered at the Large Hadron Collider, EDM experiments will be needed to inform us of their behavior under CP symmetry.

Observing no EDM after lowering the upper limit by two orders of magnitude will impose more stringent constraints on Standard Model extensions such as Supersymmetry (SUSY). It is already becoming difficult to have SUSY and not have EDMs, especially when constraints from the electron EDM limit are combined with constraints from the neutron EDM and diamagnetic atom EDM limits. Present electron EDM limits are about a factor of 100 below some SUSY calculations (see Illustration 1) that use super-partner masses of 100 GeV and CP-violating phases of unity and are not in complete agreement with models that use super-partner masses of one-TeV.

A proton beam intensity of 10 uA on a uranium carbide (UC) target of present thickness is expected to result in 5x10^8 211Fr ions/s. However based upon the difference in 211Fr yield at ISOLDE between a UC and a Thorium Carbide (ThC) target, an increase to over 2x10^9. 211Fr ions/s should be possible at TRIUMF by substituting, for the present UC target, a ThC target of the same thickness.

The increase in beam intensity directly translates into an improved limit for the electron EDM. Illustraion 2 shows how the EDM limit could be lowered by a factor of 2. Alternatively, the original result could be achieved using 1/4 of the counting time.

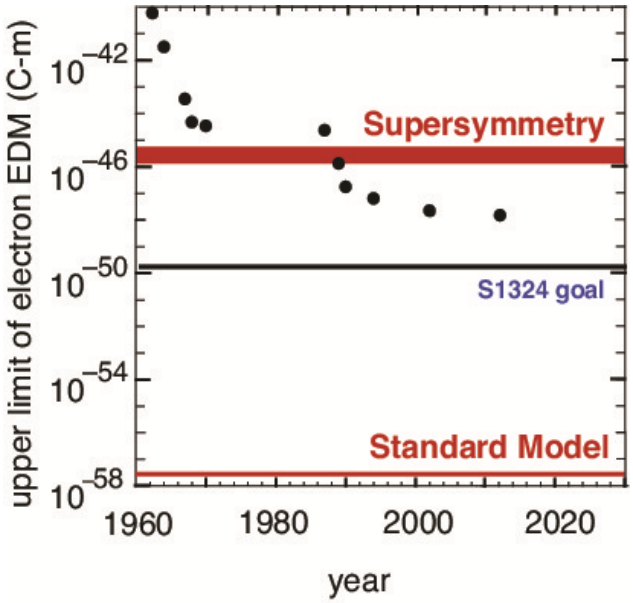

Illustration 1: Supersymmetry prediction (with $\mathcal{CP}$-violating phases of order one and superpartner masses of 100 GeV) and Standard Model prediction for the electron EDM, compared with successive best experimental upper bounds (black circles) and with a factor of one hundred reduction in the experimental limit (horizontal black line) from the proposed experiment.

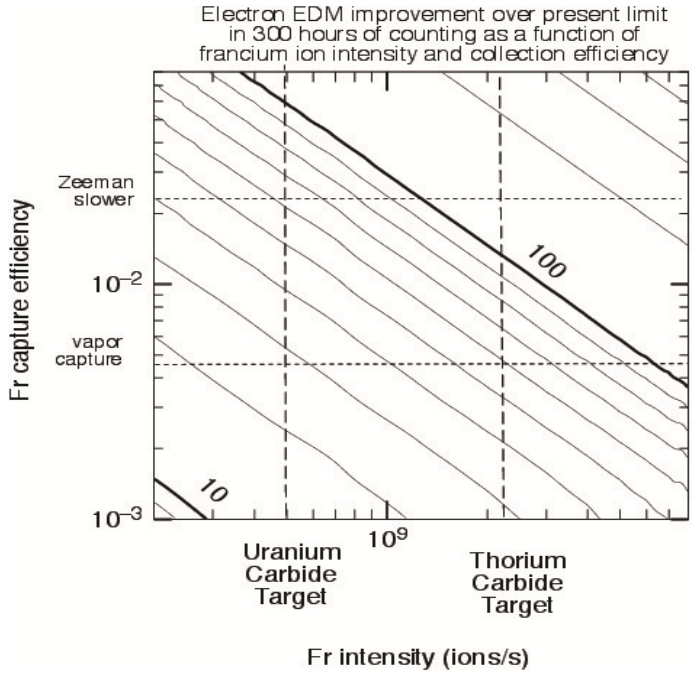

Illustration 2: Improvement in the electron EDM upper limit based upon counting for 300 hours at TRIUMF using a beam produced from a UC target and a ThC target. The results are shown as a function of efficiency in capturing the atoms into the atom trap that forms the fountain

RELATIONSHIP TO BROADER CANADIAN RESEARCH COMMUNITY:

Electron EDM is complementary to nucleon and to nuclear EDM's.
TRIUMF's UCN project shared a workshop on mu-metal shielding with this group in August 2012, and the LBL progress is very instructive.
There is synergy in laser trapping and cooling techniques with TRINAT and with FrPNC, and in atomic spin manipulation techniques with TRINAT. Some laser resources can be shared with TRINAT.

BROADER IMPACTS:

HQP. (Source of baryon asymmetry is pretty broad, but that's not what you want.)

MAJOR MILESTONES:

Description	Date
Null tests with rubidium atoms in LBL	2012 - 2015
LEBT UHV beamline at TRIUMF and experiment infrastructure	2015
ThC target development at TRIUMF	2015
Experiment at TRIUMF commences	2016

RESOURCE REQUIRMENTS:

CASH FLOW REQUIREMENTS						
\YEAR SOURCE \	ONE	TWO	THREE	FOUR	FIVE	TOTAL
TRIUMF						
EXTERNAL	To be determined					
TOTAL						
TRIUMF NON-CASH RESOURCES						
\YEAR RESOURCE\	ONE	TWO	THREE	FOUR	FIVE	TOTAL
LEBT BEAMLINE	$150K					
Electrical	$25K					
Plumbing	$5K					
Thorium Carbide target, 4x yield	unknown					

EXTERNAL FUNDING INFORMATION:
To be determined.

ONGOING OPERATIONAL REQUIREMENTS:
it's a new project

DECOMMISSIONING REQUIREMENT:
Essentially none. There would be 5 microCuries of 207Bi (beta-gamma, no alpha) from 211Fr, or 500 Bq of 102-year 209Po from 209Fr decay, per 10 days of running.

Accepted:	Date: