Proposal for TRIUMF Commitment (5YP 2015-2020)

Date:
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PROJECT/COMMITMENT TITLE: TRIUMF Neutral Atom Trap (TRINAT)

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PROJECT DESCRIPTION:

TRIUMF's neutral atom trap for beta decay (TRINAT) has measured beta-recoil coincidences to deduce the most accurate beta-neutrino correlation. EEC and NSERC-approved plans include improving that measurement, and also carrying out a full program of spin-polarized beta decay correlation measurements complementary to the decay of the neutron, utilizing in-situ atomic probes of the polarization of the decaying nuclei with part per thousand accuracy. Experimental accuracy at part per thousand is needed to provide meaningful constraints on particle physics models [e.g. Profumo PRD 75 (2007) 075017]. Further plans would include a time-reversal violation measurement in a decay correlation, and beta-delayed neutron emission measurements of utility for astrophysics and reactor science.

SCIENTIFIC JUSTIFICATION:

Spin-polarized experiments 2012-2014

We have published a measurement of the neutrino asymmetry Bnu in 37K decay at 3% accuracy [Melconian PL B649 370 (2007)]. The goals of our spin correlation program (TRIUMF experiment S1188) include a simultaneous measurement of beta singles asymmetry Abeta and recoil singles asymmetry Arecoil at part per thousand sensitivity, and eventually Bnu at 0.3%. E.g., from the detailed dependence of Arecoil on recoil momentum, a statistical sensitivity to 4-fermi tensor interactions Ct+Ct' of 0.002 can be reached in one week of counting. Other physics, including semileptonic right-handed V+A currents and 2nd-class currents, can be simultaneously constrained by the other observables. This program would provide similar but complementary sensitivity to the new physics probed by the community's measurement of neutron beta-decay [Bhattacharya PRD 85 (2012) 054512].

Beta-nu correlation in pure Fermi decay 2014-2016.

We also would improve our best limits on general scalar interactions coupling to the first generation of particles by measuring the beta-nu correlation in the pure Fermi decay of 38mK [Gorelov PRL 94 (2005) 142501]. The complete angular acceptance for recoils we have developed will minimize key systematic errors in our upgraded experiment, with a goal of reaching 0.1% accuracy in angular correlation parameter a and Fierz interference term b. We determine systematic errors for this experiment from statistics-limited kinematic observables that are independent of the angular correlation (see TRIUMF S1070 proposal). The results would constrain all possible chiralities and time-reversal properties of possible 4-fermi scalar interactions, complementary to the superallowed Ft value measurements of normal-chirality scalars and to indirect constraints on scalar interactions from the pi-> e nu/mu nu branching ration [Campbell NPB 709 419 (2005)]

Time-reversal violation 2016 +

Using our demonstrated abilities to polarize nuclei by optical pumping and measure beta and recoil momenta, we have a conceptual design for a detection trap geometry to efficiently measure the time and

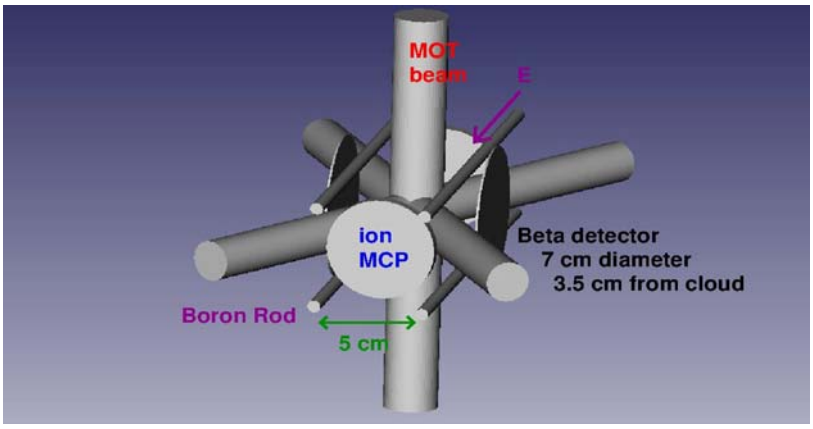

Illustration 1: compact efficient conceptual design for D coefficient

parity-reversal violating correlation D I . v_beta X v_nu of the lepton momenta and the nuclear spin. Since this correlation flips sign with time, it is zero if time-reversal is a good symmetry (with correction from `final state' effects of 2.0e-4 Precoil/Q predicted by electroweak and isospin symmetry from the small non-Dirac nuclear electromagnetic moments). Optical pumping light for polarization perpendicular to beta direction allows for a more compact geometry with 20% beta efficiency, so we could achieve 2e-4 statistical error/week. The best measurement in the decay of the neutron was recently published by emiT [Mumm PRL 107 102301 (2011)], a null result reaching 2.1e-4 sensitivity. A recent general effective field theory calculation [Ng and Tulin, Phys. Rev. D 85 033001 (2012)] concludes that all phenomenological terms producing nonzero D will also produce a nonzero neutron EDM, though not vice versa. A measurement of D can then help constrain contributions to EDM's if it can be done to better than 1e-4 accuracy, which would clearly require the increased total amounts of beamtime made possible by ARIEL.

Beta-delayed neutron branches and neutron energies, 2015+
A new technique has been pioneered by an ion trap at CARIBU at Argonne National Lab (See N. Scielzo talk http://www.ne.anl.gov/capabilities/nd/AFC-Apr11/program.shtml). Their elegant idea is that the recoiling nucleus momentum is greatly increased by the neutron emission, so the neutron momentum can be deduced from the recoil momentum without detecting the neutron, allowing more accurate measurements of the decay branch and the neutron energy spectrum. These are of use for many beta-delayed neutron emitters as a neutron source for times and places of the r-process at relatively low temperatures when photodisintegration no longer produces neutrons [see e.g. cold r-process work S. Wanajo, Astrophysical Journal, 666:L77 (2007)]. Knowledge of beta-delayed neutrons is needed for Generation IV reactors. An atom trap has some complementarity to an ion trap, in particular smaller perturbing fields enabling better momentum resolution and hence lower and higher neutron momentum thresholds. Some cases 92-96Rb could be done now, but cases of interest complementary to the CARIBU isotopes would become possible with the ARIEL photofission production. Rb and Cs isotopes could be done with the present TRINAT apparatus and lasers; if there were enough interest, Kr, Xe, Sr and Ba isotopes can be trapped with large changes in the collection trap and lasers.
**This would require from TRIUMF delivery of ARIEL beams to TRINAT, which would be possible during cyclotron maintenance times with the addition of two 3-way bender boxes, one at TRINAT level and the other at ISAC-I level.

RELATIONSHIP TO BROADER CANADIAN RESEARCH COMMUNITY: Physics complementarity to superallowed beta-decay Ft values and offshore (possibly future at TRIUMF UCN) work in neutron beta decay correlations pointed out above.
BROADER IMPACTS: HQP. Possibly reactor science.

MAJOR MILESTONES:

Description	Date
37K S1188 Spin correlations Abeta, Arecoil, Bnu	2012-2014
38mK S1075 Beta-nu correlation	2014-2016
37K D time-reversal correlation test	2016-2018
Beta-delayed neutron emission with ARIEL isotopes	2015-2018

RESOURCE REQUIRMENTS:

CASH FLOW REQUIREMENTS						
\YEAR SOURCE \	ONE	TWO	THREE	FOUR	FIVE	TOTAL
TRIUMF	$20K	$5K	$5K	$5K	$5K	$40K
EXTERNAL	$120K+	$120K+	$120K+	$120K+	$120K+	$600K+
TOTAL						
TRIUMF NON-CASH RESOURCES						
\YEAR RESOURCE\	ONE	TWO	THREE	FOUR	FIVE	TOTAL
Two 3-way benders, on ISAC-I floor and at TRINAT level						
Phys: Exp: Detectors	2 FTEW	Similar...				
Tech:Machinist	4 FTEW	Similar...				
Tech:Elect:Design	2 FTEW	Similar...				
IT:DAQ	3 FTEW	Similar...				

EXTERNAL FUNDING INFORMATION:
present NSERC TRINAT project grant $120K/year assumed. Students, support, and equipment from TAMU and Tel Aviv are NOT quantified here. A serious rebuilding of the front-end collection for Kr,Xe, and/or Sr, Ba would cost about $300K in capital.

ONGOING OPERATIONAL REQUIREMENTS:
$5K/year for TRINAT operation. Continued DAQ support. Continued detector facility support for electronics. Continued machine shop support. Possible SiPMT readout of scintillators for linearity, gain stability, and B-field insensitivity.

DECOMMISSIONING REQUIREMENT:
None, all isotopes short-lived.

Accepted: Date: