Proposal for TRIUMF Commitment (5YP 2015-2020)

Date: September 14, 2012

PROJECT/COMMITMENT TITLE: **Searches for New Physics at the Intensity Frontier**

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PROJECT DESCRIPTION:

We propose to participate in one new flavor physics experiment among three possibilities under active development: ORKA ($K^+ \to \pi^+ \nu \bar{\nu}$ at Fermilab), DeeMe or COMET ($\mu - e$ Conversion at JPARC), listed in priority order. All three have scientific approval at their respective labs and are attempting to arrange funding.

ORKA will use the Fermilab Main Injector to produce a 600-MeV/c separated K^+ beam provided to an upgraded detector assembly similar in concept to BNL E949. Pions arising from the decays $K^+ \to \pi^+ \nu \bar{\nu}$ will be tracked in a uniform 1.25T magnetic field (CDF solenoid) and identified using the $\pi \to \mu \to e$ decay sequence and measurements of their range, momentum, and energy. The Canadian group proposes to construct the ORKA central tracking chamber based on the TRIUMF/E949 "Ultra-Thin Chamber". It will have four thin spiral cathode-strip foils supported by differential pressure located between three super-layers of axial drift cells. This is a relatively small scale device with outer radius of 50 cm, length 75 cm and approximately 1000 sense wires and 1000 cathode strips. The principal physicists, engineer, and technologist who participated in the BNL UCT project are currently at TRIUMF.

DeeMe, aiming for sensitivity $<10^{-14}$ employs a new method for observing $\mu - e$ Conversion in which an intense pulsed source of negative muons is produced in a specially designed production target. This project is comparable in scale to the TRIUMF PIENU experiment and may be completed in about 4 years. The conversion electrons are to be observed using a new beam line at the 3 GeV JPARC synchrotron which will contain a kicker magnet and an electron spectrometer. We would propose to construct the wire chamber system for the spectrometer consisting of four chambers each with three planes of proportional drift cells. The system would be similar to those chambers constructed at TRIUMF for the PIENU experiment and would have comparable in numbers of wires and channels to the UTC describe above.

COMET is based on the Loboshev proposal to use a high field solenoidal collector of low energy muons in the neighborhood of the pion production target to produce an intense source for $\mu - e$ Conversion aiming for a sensitivity of 10^{-16}. This is an ambitious project of the $125M class which will take more than a decade to realize. For this project we would expect to participate in the construction of the straw tube tracker or the electromagnetic calorimeter.

SCIENTIFIC JUSTIFICATION:

Despite the recent momentous discovery of the Higgs boson at the LHC many aspects of particle physics remain to be explored. Flavor physics studies in the era of the LHC continue to be effective for searching for physics beyond the Standard Model (SM). If non-SM discoveries are made at the LHC, then precision, high sensitivity flavor physics experiments will be important for sorting out the flavor- and CP-violating couplings of the new particles. If new physics is not found at the LHC, then such experiments are

needed to access higher mass scales (up to 1000 TeV) through virtual effects. A short list of "superstar" flavor experiments would include B decays (B_s mixing, $B_{s/d} \to \mu\mu, B_s \to X_s \mu\mu(\nu\bar{\nu})$), K decays ($K^+ \to \pi^+\nu\bar{\nu}, K_L^0 \to \pi^0\nu\bar{\nu}$), lepton flavor violating decays ($\mu \to e\gamma, \mu - e$ Conversion, $\tau \to \mathrm{e}\gamma$ (+others)), EDM measurements (n, atoms) and muon g-2. These special measurements can all be cleanly interpreted as indications of new physics by their very observation as for the LFV decays or through observed deviations from solid SM predictions as in $B \to \mu\mu$ and $K \to \pi\nu\bar{\nu}$ decays and the interplay of such measurements will be necessary to establish the underlying theory. Here we propose to concentrate efforts on either the "golden" $K^+ \to \pi^+\nu\bar{\nu}$ decay or $\mu - e$ Conversion .

The ultra-rare decay $K^+ \to \pi^+\nu\bar{\nu}$ provides an excellent opportunity to test a firm SM prediction and to search for new physics. This highly suppressed decay has been calculated to an unusual degree of precision in the SM and the techniques for measuring it have been firmly established, opening the door for discovery. The measured branching ratio is $Br^{Ex}(K^+ \to \pi^+\nu\bar{\nu}) = \left(1.73^{+1.15}_{-1.05}\right) x10^{-10}$ based on seven events from BNL E787/E949 experiments. The predicted SM branching ratio is $Br^{Th}(K^+ \to \pi^+\nu\bar{\nu}) = \left(7.81 \pm 0.72 \pm 0.62\right) x10^{-11}$ where the first uncertainty arises from the CKM matrix and the second is a combination of other theory uncertainties. Thus, a deviation as small as 30% of the measured decay rate from the SM prediction (expected to reduce to 5%) could be detected with 5σ significance by the proposed ORKA experiment which will have measurement accuracy of <5% with sensitivity to obtain 1000 events at the SM level; this level is 100 x the sensitivity of the BNL experiments and 10 x the proposed level of NA62 at CERN. $K^+ \to \pi^+\nu\bar{\nu}$ decay is sensitive to most non-SM models of interest such as minimum flavor violation, Littlest Higgs with T parity, Randall-Sundrum with custodial protection, and those postulating 4-generations .

$\mu - e$ Conversion , the reaction of a muon converting to an electron in the field of a nucleus, occurs coherently resulting in a mono-energetic electron near the muon rest energy. This distinctive signature has experimental advantages including the near-absence of background from accidentals (which are severe in the case of $\mu \to e\gamma$) and the extreme suppression of background electrons from muon decay in orbit. Current limits on $\mu - e$ Conversion are at the 10^{-12} level ($B(\mu Au \to eAu) < 7x10^{-13}$ from PSI (2006) and $B(\mu Ti \to eTi) < 4.6x10^{-12}$ from TRIUMF (1987)) whereas the proposed experiments at JPARC (DeeMe and COMET) and Fermilab (mu2e) aim for 100-10000 times higher sensitivity. These experiments will be the most sensitive LFV searches with potential mass scale reach for new physics of 3-10 beyond present results. Most theories of new physics naturally incorporate Charged LVF interactions.

RELATIONSHIP TO BROADER CANADIAN RESEARCH COMMUNITY:

The flavor physics experiments discussed here complement other major activities of the community by searching for new physics at high mass scales using the most incisive indirect methods. CLFV interactions have a close relationship with neutrino oscillations, EDM, and double beta decay studies.

BROADER IMPACTS:

The proposed experiments represent opportunities for Canadian leadership in prominent international science endeavors. Forefront, modest scale flavor physics experiments are prime training grounds for graduate students, undergraduates (e.g. seniors honors thesis), and other HQP who get unusually broad and intimate exposure to state-of-the-art instrumentation and innovative techniques enabling them to contribute effectively to future projects ranging from colliders to industry. The experimental projects make use of and help expand facilities and capabilities for producing state-of-the-art detector instrumentation which has long been a feature of leading TRIUMF projects. The TRIUMF rare decay group has a history of pursuing applications of particle physics technology for solving practical problems such as in medical and geophysical imaging; this type of activity has the potential to make particle physics research more relevant to the broader society.

MAJOR MILESTONES:

Description	Date
Project Decision	2013-14
Funding Proposal	2014
Detector Construction	2017
First Data	2018
Initial Results	2020

RESOURCE REQUIRMENTS:

CASH FLOW REQUIREMENTS						
\YEAR SOURCE \	ONE	TWO	THREE	FOUR	FIVE	TOTAL
TRIUMF						
EXTERNAL	100K	450K	300K	75K		
TOTAL	**100K**	**450K**	**300K**	**75K**		
TRIUMF NON-CASH RESOURCES						
\YEAR RESOURCE\	ONE	TWO	THREE	FOUR	FIVE	TOTAL
Physicists	1	1.5	1	1		
Engineer	0.5	0.5	0.5			
Technologist	0.25	1	1	0.25		

EXTERNAL FUNDING INFORMATION:
The capital requirements would be sought from the CFI and/or from international collaboration sources. Funding for TRIUMF technical personnel would be included in the grant requests.

ONGOING OPERATIONAL REQUIREMENTS:
Operational expenses for the instruments (e.g. gases, maintenance items, etc.) and for the physics group (students, post-docs) would be sought from NSERC.

DECOMMISSIONING REQUIREMENT:
Minimal

Accepted: Date: