Proposal for TRIUMF Commitment (5YP 2015-2020)

Date: 01.10.2012

PROJECT/COMMITMENT TITLE: Engineering and Technical Support for the MOLLER Experiment at Jefferson Laboratory

PROPONENT: **M. Gericke** **TRIUMF CONTACT:** **W.T.H. van Oers**

PRINCIPAL COLLABORATORS: J. Birchall, E. Korkmaz, J. Mammei, R. Mammei, J. Martin, M. Gericke, S. Page, W.T.H. van Oers

PROJECT DESCRIPTION:

The MOLLER collaboration proposes to measure the weak charge of the electron to 2.3%, attempting a determination of $\sin^2\theta_w$ with an uncertainty of $\pm 0.00026(\text{stat}) \pm 0.00013(\text{syst})$, at very low momentum transfer. At this precision, this measurement represents a search for new physics at the multi-TeV level, which is complementary to other measurements and on par in precision and sensitivity with similar searches at colliders. The experiment will use 11 GeV polarized electrons, scattered from a high power liquid hydrogen target. The weak charge will be extracted from the measured asymmetry in the number of electrons that are elastically scattered as a function of the electron polarization. The scattered electrons are steered into a set of quartz Cherenkov detectors, using a room-temperature spectrometer. Due to the measurement constraints and the high luminosity, the detector signal must be processed by high efficiency, low noise pre-amplifiers and integrating ADCs. **We intend to request support from TRIUMF, for engineering, technical, and shop support for the development and construction/procurement of the detector electronics as well as detector components (e.g. light guides).** The MOLLER focal plane and beam-line integrating detectors constitute about 500 channels of electronics, including pre-amplifiers and VME based integrating ADCs.

We expect to submit proposals to NSERC for MOLLER support after the experiment reaches CD0/CD1 on the DOE side, possibly for the 2014 – 2015 competition, and expect development and construction work to extend into the next TRIUMF 5-year plan period. **The proposed DOE budget for MOLLER includes $307k earmarked for electronics to be built at TRIUMF and we will apply for NSERC equipment funds to supplement this. It is envisioned that, together, these two funding sources will cover the costs associated with the requested support from TRIUMF.**

SCIENTIFIC JUSTIFICATION:

The measurement is sensitive to the interference of the electromagnetic amplitude with new neutral current amplitudes as weak as $1.5\times10^{-3}\cdot G_F$ from as yet undiscovered high energy dynamics, which corresponds to a sensitivity of $\Lambda/g = 7.5$ TeV. This would be the most sensitive probe of new flavor and CP-conserving neutral current interactions in the leptonic sector until the advent of a linear collider or a neutrino factory. Some examples of physics beyond the Standard Model to which our measurement extends sensitivity well beyond recent and ongoing low energy measurements include new Z′ bosons, electron compositeness, supersymmetry and doubly charged scalars. Within the Standard Model, weak neutral current amplitudes are

functions of the weak mixing angle $\sin^2\theta_w$. The two most precise independent determinations of $\sin^2\theta_w$ differ by 3 standard deviations. While the world average is consistent with other electroweak measurements and constraints on the Higgs boson mass, choosing one or the other central value ruins this consistency and implies very different new high-energy dynamics. The proposed measurement, which would achieve a sensitivity of $\delta(\sin^2\theta_w) = \pm 0.00029$, is the only method available in the next decade to directly address this issue at the same level of precision and interpretability.

RELATIONSHIP TO BROADER CANADIAN RESEARCH COMMUNITY:

The proposed research falls under the category of fundamental symmetries at the intensity frontier. This area of subatomic physics (SAP) research is prominently featured in the current Canadian SAP long range plan (LRP) and forms one of the cornerstones of the TRIUMF experimental program. The Jefferson Laboratory parity program itself is represented in the LRP as an important contribution to the overall Canadian research effort abroad. In the context of searches for physics beyond the Standard Model, the proposed experiment is perfectly in line with other current efforts in Canada and those outside of Canada that are supported by Canadian funding agencies, including many experiments at TRIUMF. Aside from mounting important SAP experiments on site, TRIUMF also has an excellent track record in supporting efforts at laboratories abroad, to which Canadian researchers make a significant contribution. Such efforts include those at CERN (most prominently ATLAS and ALPHA), in Japan (T2K), and in the US (BaBar and most recently Q-Weak). The proposed effort draws upon TRIUMF expertise in the development of particle detectors, the associated electronics, and spectrometer design. To date, the parity-violating electron scattering program at Jefferson Laboratory has been very successful. This was in no small part the result of the significant support the Canadian collaborators received from TRIUMF over the years. The recently completed Q-Weak experiment, for example, profited greatly from TRIUMF engineering and technical support in the development and construction of the spectrometer and detector electronics. As a result, it is internationally recognized that much of the credit for turning this high profile experiment into a success goes to the Canadian contributions made by our group and TRIUMF. At the intensity frontier, the PVES program at Jefferson Laboratory plays a very high profile role in the search for physics beyond the Standard Model; specifically the Q-Weak experiment and the proposed MOLLER experiment. Therefore, the scientific contributions TRIUMF has made to this program, and could make in the future, are in no way less significant than the contributions it has made to other searches for new physics, such as those at the LHC or in-house. Note that, since 2003, the Canadian team received funding for Q-Weak in excess of 2.4M for operations and 0.7M for instrumentation and that our requests for MOLLER will likely be at the same level or above.

BROADER IMPACTS:

The proposed experiment and the contributions the Canadian group proposes to make constitute excellent training ground for young scientists; for both students and post-doctoral research associates. As usual, in SAP projects of this type, the training combines many aspects of computational, theoretical, and hardware techniques. Such broad training is not often found in other programs. Based on the likely length and scale of the effort, we intend to recruit many students over the years and we have an excellent track record in doing so. For example, in the past 5 years alone, M. Gericke has recruited and supervised 5 graduate students and 3 post-doctoral research associates and there have been many more supervised by the other members of the team. Also, as mentioned above, the proposed research will contribute in a significant way to the knowledge base in subatomic physics.

MAJOR MILESTONES:

Description	Date
MOLLER CD0/CD1 on the DOE side (physicist level of simulation and design)	2013/2014
Engineering level design and prototype development / testing	2015
Pre-amplifier and VME intergrating ADC design completed	2016
Procurement / assembly of final Pre-amplifier and VME intergrating ADC modules	2016
Installation at Jefferson Laboratory	2017
Run I	2017

RESOURCE REQUIRMENTS:

CASH FLOW REQUIREMENTS						
\YEAR SOURCE \	ONE	TWO	THREE	FOUR	FIVE	TOTAL
TRIUMF	0	0	0	0	0	0
EXTERNAL	To be deter.	To be deter.	To be deter.	0	0	0
TOTAL	To be deter.	To be deter.	To be deter.	0	0	0
TRIUMF NON-CASH RESOURCES						
\YEAR RESOURCE\	ONE	TWO	THREE	FOUR	FIVE	TOTAL
Engineering	15 FTE-w	10 FTE-w	5 FTE-w	-	-	-
Technical/shop	5 FTE-w	20 FTE-w	5 FTE-w	-	-	-

EXTERNAL FUNDING INFORMATION:

NSERC request envisioned, at ~750k over a number of years, starting in 2014/2015.
DOE budget for MOLLER includes $307k earmarked for ADCs and Pre-amps from TRIUMF (proposed)

ONGOING OPERATIONAL REQUIREMENTS:

None

DECOMMISSIONING REQUIREMENT:

None

Accepted: Date: