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TRIUMF & Canadian Scientists Help Measure Proton's Weak Charge

(Newport News, VA, USA) --- An international team including Canadian researchers at TRIUMF has reported first results for the proton's weak charge in *Physical Review Letters* (to appear in the October 18, 2013 issue) based on precise new data from Jefferson Laboratory, the premier U.S. electron-beam facility for nuclear and particle physics in Newport News, Virginia.

The Q-weak experiment used a high-energy electron beam to measure the weak charge of the proton—a fundamental property that sets the scale of its interactions via the weak nuclear force. This is distinct from but analogous to its more familiar electric charge (Q), hence, the experiment's name: 'Q-weak.' Following a decade of design and construction, Q-weak had a successful experimental run in 2010–12 in Hall C at Jefferson Laboratory. Data analysis has been underway ever since.

"Nobody has ever attempted a measurement of the proton's weak charge before," says Roger Carlini, Q-weak's spokesperson at Jefferson Laboratory, "due to the extreme technical challenges to reach the required sensitivity. The first 4% of the data have now been fully analyzed and already have an important scientific impact, although the ultimate sensitivity awaits analysis of the complete experiment."

The first result, based on Q-weak's commissioning data set, is Q_W^p= 0.064 ± 0.012. This is in good agreement with the theoretical prediction of 0.0710 ± 0.0007 based on our current understanding of fundamental interactions, which physicists refer to as the Standard Model.

In order to measure the proton's weak charge, experimenters had to exploit the weak interaction's unique property of parity violation, closely related to mirror symmetry. The Q-weak collaboration built an apparatus to detect the scattered electrons with unprecedented sensitivity, allowing them to measure the tiny asymmetry in the electron scattering rate that depends on the longitudinal polarization of the electron beam. The success of the experiment relied on Jefferson Laboratory's world renowned 'parity quality' beam properties. When the spin of the beam particles is reversed with respect to their direction of motion, the changes to its other properties can be kept amazingly small -- for example, the beam moves less than the width of an atom, on average.

To achieve the required statistical precision for Q-weak, the CEBAF accelerator at Jefferson Laboratory was pushed to new limits of high intensity polarized beam delivery, and the liquid hydrogen (proton) target built for Q-weak was able to absorb 1.7 kW of beam power while maintaining uniform density at a temperature of only 20 degrees above absolute zero, making it the world's highest power liquid hydrogen target to date. The apparatus contained many interleaved diagnostic systems to monitor and diagnose beam conditions during data taking. All of these systems worked extremely well, as demonstrated by the first results reported here.

The Canadian group has played a leading role in the Q-weak experiment since its inception – a proposal submitted to Jefferson Laboratory's Program Advisory Committee 12 years ago. Dr. Shelley Page (U. Manitoba) is a co-spokesperson for Q-weak; Dr. Willem T.H van Oers led the construction of the large magnetic spectrometer for Q-Weak in collaboration with scientists and engineers from TRIUMF, the University of Manitoba, MIT-Bates Laboratory, and Jefferson Laboratory. In all, the Canadian group contributed about 15% of the Q-weak effort in terms of manpower and resources, focused on design and construction of the experimental apparatus, planning and execution of the measurements, and analysis of the data. Extending a successful design that was developed for the TRIUMF proton-proton parity violation experiment (TRIUMF E497), essentially all of the low noise integrating electronics used for Q-weak were built at TRIUMF, including readout of the novel diamond strip detector that was used in a new Compton polarimeter, provided by the University of Winnipeg group. Over the years, more than $3M of NSERC support has been provided through the subatomic physics Project Grant program to the Canadian group (which also includes scientists from the University of Winnipeg, University of Northern BC, and TRIUMF)

– funds were used to build equipment and support student and postdoctoral researchers' salaries and travel to carry out the measurements at Jefferson Laboratory.

The really great news is that Q-weak has about 25 times more data in hand, which is currently undergoing analysis. This will allow experimenters to further shrink the error bar, which will then be small enough to severely constrain possible physics beyond the Standard Model. The final result could reveal hints of new interaction-mediating particles, and would be complementary to searches at the highest energy scales such as at the Large Hadron Collider project in Geneva, Switzerland.

This first determination of the proton's weak charge was carried out by a team of 97 researchers from 23 institutions in the U.S., Canada, and Europe. It was made possible by funding from the US Department of Energy and the U.S. National Science Foundation, the Natural Sciences and Engineering Research Council of Canada, university matching contributions from The College of William and Mary, Virginia Tech, George Washington University, and Louisiana Tech University, and technical and engineering support from Jefferson Laboratory, TRIUMF, and MIT-Bates laboratories.

For more information, please visit http://www.jlab.org/qweak.

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About TRIUMF

TRIUMF is Canada's national laboratory for particle and nuclear physics. Together with its partner AAPS, Inc., TRIUMF also seeks to commercialize its technologies for the benefit of all Canadians. Located on the south campus of the University of British Columbia, TRIUMF receives operating support from the Government of Canada through a contribution agreement via National Research Council Canada; the Government of British Columbia provides capital for new buildings. TRIUMF is owned and operated as a joint venture by a consortium of the following Canadian universities: University of Alberta, University of British Columbia, University of Calgary, Carleton University, University of Guelph, University of Manitoba, McGill University, McMaster University, Université de Montréal, University of Northern British Columbia, Queen's University, University of Regina, Saint Mary's University, Simon Fraser University, University of Toronto, University of Victoria, University of Winnipeg, and York University. For more information, please visit us at http://www.triumf.ca.