Title: Collaborative Research: Equipment for and Running of the PSI MUSE Experiment

Institution: Rutgers University New Brunswick

NSF Program: Hadrons and Light Nuclei

Principal Investigator: Gilman, Ronald

Rating: Good

Review:

In the context of the five review elements, please
evaluate the strengths and weaknesses of the proposal with respect to intellectual merit.

The recent experiment on the Lamb shift in muonic hydrogen has found a charge rms-radius of the proton which is many standard deviations away from the one measured via the traditional tool of electron-proton scattering. A similar disagreement is found with the radius that comes from transition energies in electronic hydrogen.

Many ideas have been advanced to explain this discrepancy, and the problem has generated a lot of interest and an extensive literature. No convincing idea has been found so far to resolve the puzzle. The perhaps most plausible proposal involves the polarizability of the proton which could be much larger than believed. The continued existence of this disagreement is highly unsatisfactory; a solution is urgently called for.

One of the ideas advanced as an explanation concerns a potential difference between the electron-proton and the muon-proton 'electromagnetic' interaction. Presence of such a difference would allow to simultaneously explain the difference of the muonic hydrogen result with the other two. In the past, electron/muon scattering experiments have been done to investigate this question and have found no difference. But these experiments had, by todays standards, very large uncertainties. Given todays experimental means, these could be improved by an order of magnitude, and the experiments envisaged in the proposal plan to do so.

In the context of the five review elements, please
evaluate the strengths and weaknesses of the proposal with respect to broader impacts.

One must add, however, that experiments involving heavier nuclei such as the comparison of Carbon rms-radii extracted from muonic Carbon and electron-Carbon scattering (or a similar comparison for a very heavy nucleus such as 208Pb) are much more precise and show no electron-muon difference.

It also is not clear to me whether an experiment on muon elastic scattering could indeed unambiguously identify a difference of the electron- and muon interaction with the proton. If, for instance, the problem is with the above-mentioned polarizability of the proton, then muon-proton scattering would presumably be affected similarly, in which case the true origin of the problem would still be unclear.

The authors plan to compare the electron and muon interaction via an experiment on elastic scattering on the proton to be performed at the Paul Scherrer Institute PSI in Switzerland. This experiment aims at measuring the form factor at low momentum transfer for both electrons and muons and for both charge states. PSI offers presently in the PiM1 experimental area the most suitable and intense beams for this purpose, and the PSI program advisory committee has welcomed the plan and positively evaluated the early test measurements that have been made.

Please evaluate the strengths and
weaknesses of the proposal with respect to any additional solicitation-specific review criteria, if applicable

The proposal gives little information on the set-up and the potential difficulties as found in the test measurements. I therefore cannot really judge whether the proposed experiment is likely to achieve the goals such as an rms-radius measurement with accuracy of order 1% for both electron- and muon beams which would be required to address a potential electron-muon radius difference for the proton. From the information given I also cannot evaluate whether it is possible to make a comparison of the electron- and muon cross sections at the fraction of a percent-level such as to allow for significant statements on a potential difference between electron and muon interactions.

In the absence of this information, I can only go by my own experience in measuring cross sections with mixed beams of large emittance such as available in PiM1. From my experience, I consider the stated goals as to be extremely ambitious. Among the goals, a precise e/mu comparison on the cross section level appears as a goal that is more straightforward to achieve; stitching together data from different beam energies to determine an accurate Q^2-dependence (needed for an rms-radius determination) requires very tight control over systematic errors. I think that this experiment has a fair chance to not reach the stated accuracies.

In order to carry out successfully the proposed experiment it seems imperative to me that the authors devote a major fraction of their own time to this experiment. From the proposal, I do not get the impression that this is

planned: The proposed activity at PSI seems to come as an add-on to the ongoing research program of the authors, a very substantial program as judged by its budget of a total of ~7M$ over 2-3 years. Adding on top of that the PSI program (~6.7M$) makes for an effort of an overall size which I estimate as being too ambitious. In order not to overreach, the authors should clearly specify which ongoing activities they plan to drop in order to devote a major fraction of their time at PSI to the MUSE experiment. Simply carrying out the MUSE experiment by the manpower of the postdocs + graduate students requested in the proposal appears to me to be not adequate given the difficulty of the experiment.

An extended presence of the authors at PSI is also advisable since, contrary to places like the experimental halls at e.g. Jlab, the PiM1 area to my knowledge does not have a local group running the facility. This complicates a lot a successful operation.

It also would seem desirable/necessary to me to include in the collaboration some researchers from PSI/ETH; this could greatly ease the logistics needed to carry out the experiment. In this respect a commitment of PSI to provide some manpower would appear appropriate to me.

Summary Statement

Overall, I recommend to fund the proposal. The team is qualified to carry out this challenging experiment, and the participants have adequate resources at their home institutions.