【Grant-in-Aid for Scientific Research (S)】

Broad Section B

Title of Project： Electron-proton scattering using the lowest-ever energy beam for precise determination of proton charge radius.

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Keyword：Elastic electron scattering, proton charge radius, lowest-ever beam energy

【Purpose and Background of the Research】

This research aims to determine the proton charge radius by electron scattering in the least model-dependent way. We will conduct electron-proton elastic scattering using low-energy electron beam, Ee = 20 – 60 MeV, the *lowest-ever electron beam energy* used for proton-radius studies. Note that the radius is defined as the derivative of the charge form factor at $Q^2 = 0$, where Q is the momentum transfer.

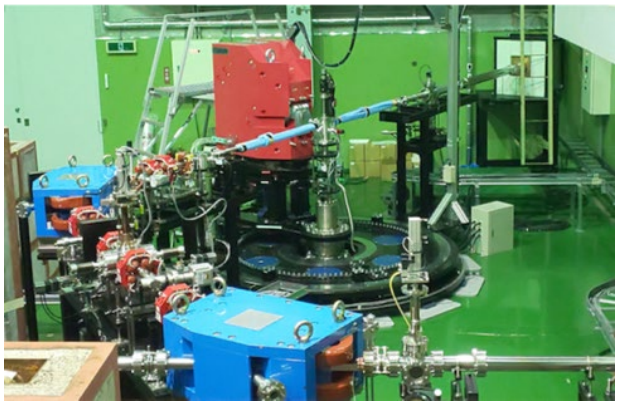
The proton radius is under debate since 2010, known today as the "*Proton Charge Radius Puzzle*". The proton charge radius provided by elastic electron scattering and the Lamb shift measurements of atomic hydrogen has been 0.88 fm, whereas the radius extracted from the spectroscopy of muonic-hydrogen atoms is found to be 0.84 fm. Since this uncertainty of the proton radius directly corresponds to the Rydberg constant in addition to obvious importance as one of the fundamental physics quantities of the proton for nuclear physics. This radius difference by electron and muon also introduces speculation for possible new physics beyond the Standard Model.

【Research Methods】

The experiments will be performed using the 60 MeV electron linear accelerator of Research Center for Electron Photon Science (ELPH), Tohoku University. Making full use of the advantages of the low-energy and small accelerator, it becomes possible to determine the charge and magnetic form factors experimentally separated by the so-called Rosenbluth separation method, which requires frequent changes of the beam energies.

The key to the success of this research is to control systematical uncertainties to be an order of 10^{-3}, since the change of $G_E(Q^2)$ in the momentum transfer range is only a few %. The CH_2 target will be employed for this purpose since the charge radius of carbon is precisely known in the 10^{-3} level. The absolute cross section for proton is determined relative to that of the known cross section for carbon. We will, thus, be able to determine absolute elastic cross section off proton with high precision by the relative measurements to that of carbon.

Installing the 2nd spectrometer for monitoring C/H ratio of the CH_2 target, which is known to change its ratio by beam irradiation, a series of elastic cross section measurements will be performed at the new beamline shown in the photo above.



【Expected Research Achievements and Scientific Significance】

Our measurements will cover the lowest momentum transfer region so that the proton charge radius is determined in the least model-dependent way. We will measure the ***absolute*** cross section, and extract the charge form factor from the cross section using the ***Rosenbluth separation***, both of which are in sharp contrast to previous electron scattering experiments. Thus, the results of our project will provide the most reliable proton radius data for those determined by electron scattering.

【Publications Relevant to the Project】

- R. Pohl et al., Nature 466 (2010) 213.
- A. Antognini et al., Science 229 (2013) 417.
- T. Suda et al., Journal of Part. Acc. Soc. Japan, 15(2018)52-59.
- T. Suda and K. Tsukada, Genshikaku Kenkyuu 61(2017) 87-98.

【Term of Project】 FY2020-2024

【Budget Allocation】 132,500 Thousand Yen

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