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

Science and Engineering (Mathematical and Physical Sciences)

Title of Project : Precise determination of the proton charge radius by electron scattering off proton at ultra-low momentum transfer region

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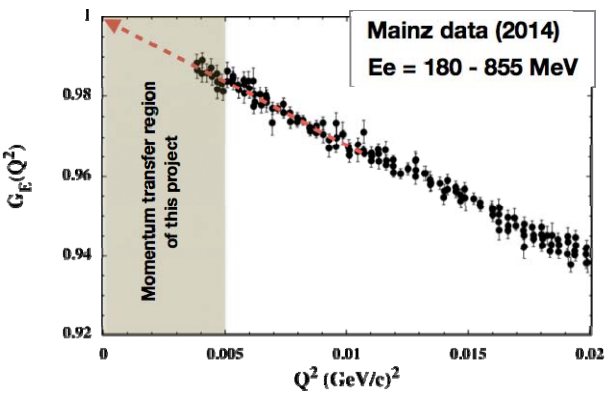
Research Project Number : 16H06340 Researcher Number : 30202138
Research Area : Nuclear Physics (Experiment)
Keyword : Elastic electron scattering, proton charge radius, ultra-low momentum transfer

【Purpose and Background of the Research】

The purpose of this research is a precise determination of the proton charge radius. The proton radius is under hot debates today known as "*Proton Charge Radius Puzzle*". We will determine the radius by elastic electron scattering at the smallest momentum transfer region ever accessed. Such measurements enable us to determine the radius in the least model dependent way.

The proton charge radius provided by elastic electron scattering and the Lamb shift measurement of atomic hydrogen has been 0.88 fm, whereas the radius extracted from the spectroscopy of muonic-hyodrogen atoms is found to be 0.84 fm. This is the puzzle. Since the proton size is one of the most fundamental physical quantities, much effort including careful re-analysis of the past data and reducing uncertainties in theoretical interpretation is underway. The puzzle, however, still remains, and the origin of this discrepancy is not yet clear.

This research aims at providing the most precise radius by means of electron scattering. We will conduct a series of measurements of elastic electron scattering off proton at an ultra-low momentum transfer region, $0.0003 \leq Q^2 \leq 0.005$ $(\mathrm{GeV/c})^2$) , where Q is the four-momentum transfer. As shown in the figure below, the minimum Q^2 accessed so far was 0.004 $(\mathrm{GeV/c})^2$ in the Mainz experiment. This project will reduce the minimum Q^2 further down to 0.0003 $(\mathrm{GeV/c})^2$. This allows us to extract the radius in a model independent way, since the radius is defined to be the derivative of the charge form factor, $G_E(Q^2)$, at $Q^2 = 0$.



【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 this low-energy and small accelerator, the charge and magnetic form factors are experimentally separated by so-called Rosenbluth separation method, which requires frequent changes of the beam energies.

The key for 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. We will be able to determine absolute elastic cross section off proton with high precision by the relative measurements to that of carbon.

【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 by means of the *Rosenbluth separation*, both of which are in sharp contrast to the Mainz experiments. The results of our project will, thus, provide the most reliable proton radius data for those determined by electron scattering.

【References Releveant to the Project】

・ R. Pohl et al., Nature **466** (2010) 213.
・ A. Antognini et al., Science **229** (2013) 417.

【Term of Project】 FY2016-2020

【Budget Allocation】 128,500 Thousand Yen

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