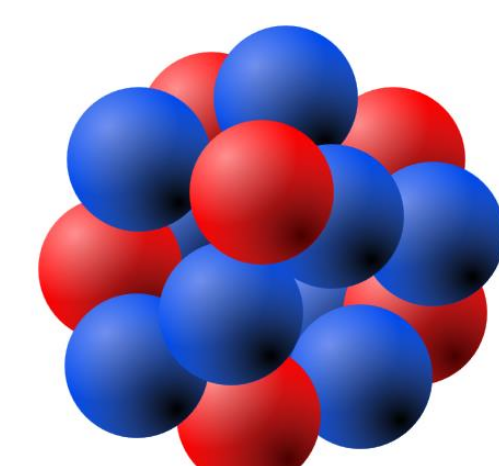


# Proton Charge Radius Experiment (PRad) in Hall B

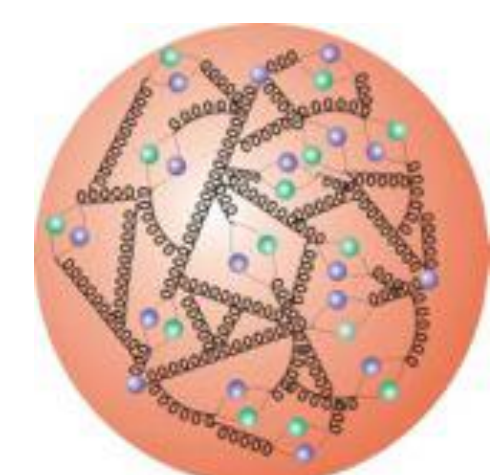
On behalf of PRad Collaboration (Spokespersons: A. Gasparian, M. Khandaker, H. Gao, D. Dutta)  
Chao Peng  
Duke University

## Proton Charge Radius

- Protons and neutrons are the building blocks of the atomic nucleus
- The root-mean-square proton charge radius is essential for understanding the structure of the proton
- It is also an important input to high precision tests of the QED calculation on hydrogen Lamb shift



A nucleus



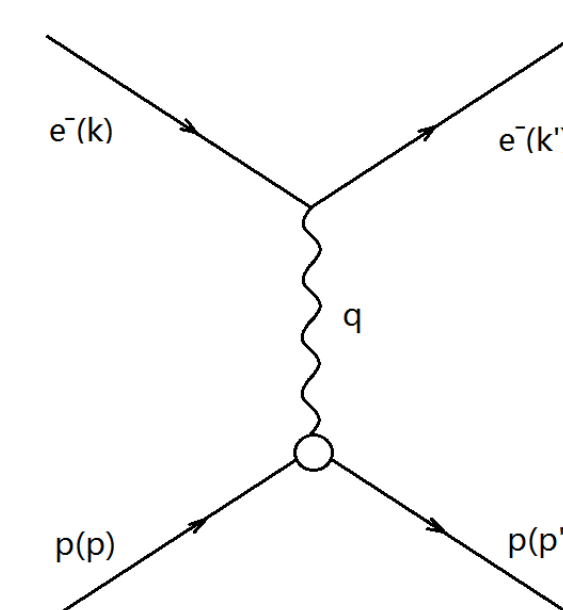
Nucleon  
Bag of quarks and gluons

$$r_p = \sqrt{\langle r_E^2 \rangle} = \left( \int_0^\infty r^2 \rho_E(r) 4\pi r^2 dr \right)^{\frac{1}{2}}$$

## Experimental Methods

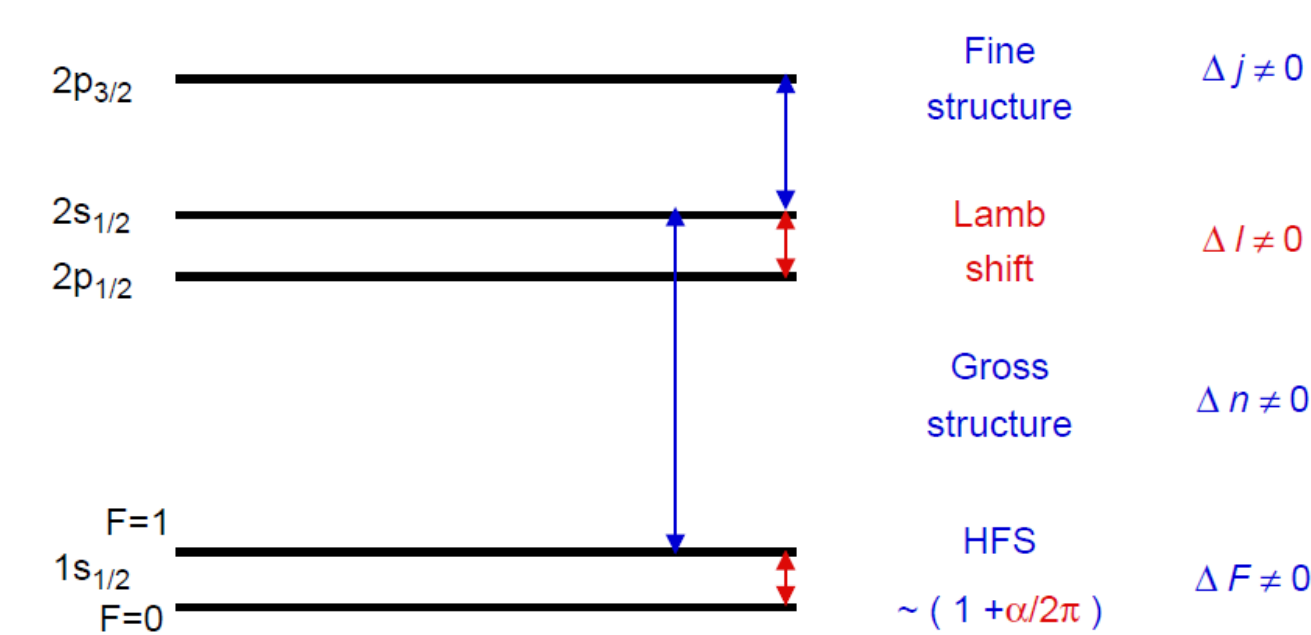
- Electron-proton elastic scattering measurements

$$\frac{\langle r \rangle^2}{6} = - \left. \frac{dG_E^p(Q^2)}{d(Q^2)} \right|_{Q^2=0}$$



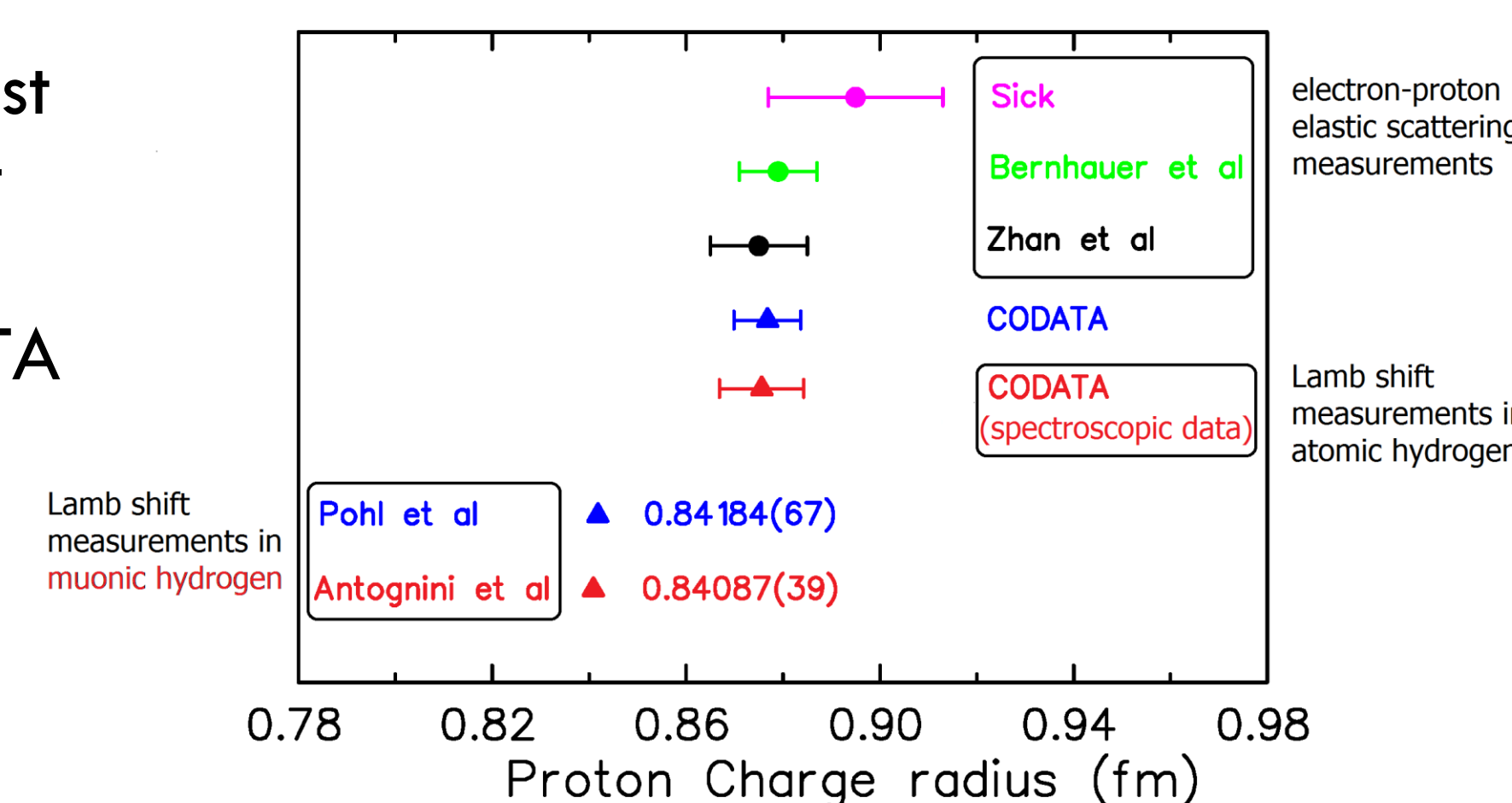
- Hydrogen Lamb shift measurements

proton charge radius can be determined by the combination of measured Lamb shift values and the QED calculations.



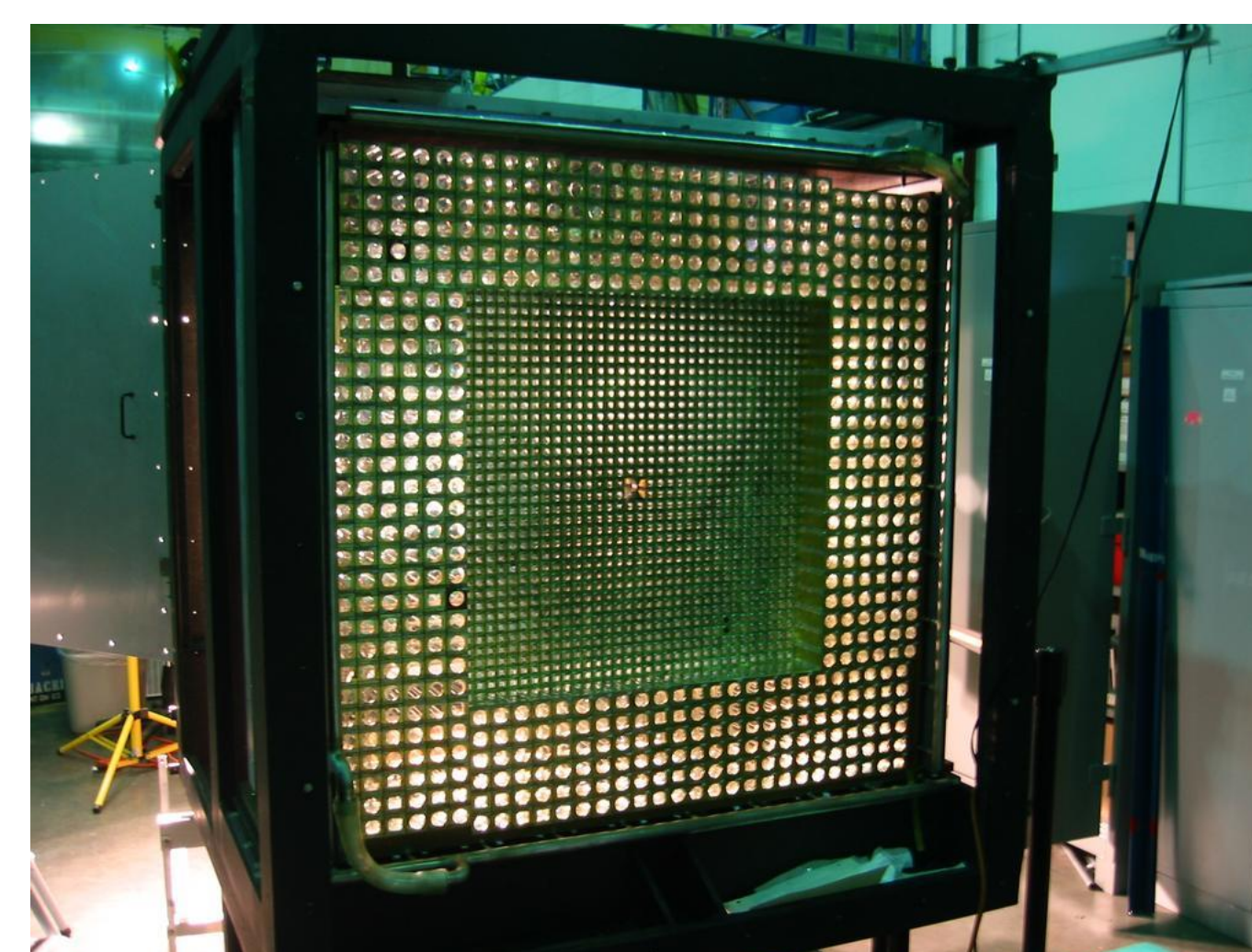
## Proton Radius Puzzle

- The proton radius puzzle was raised by the Lamb shift measurements of muonic hydrogen at PSI
- PSI value is the most precise one (about 0.05%), but is 7σ away from CODATA 2010 value

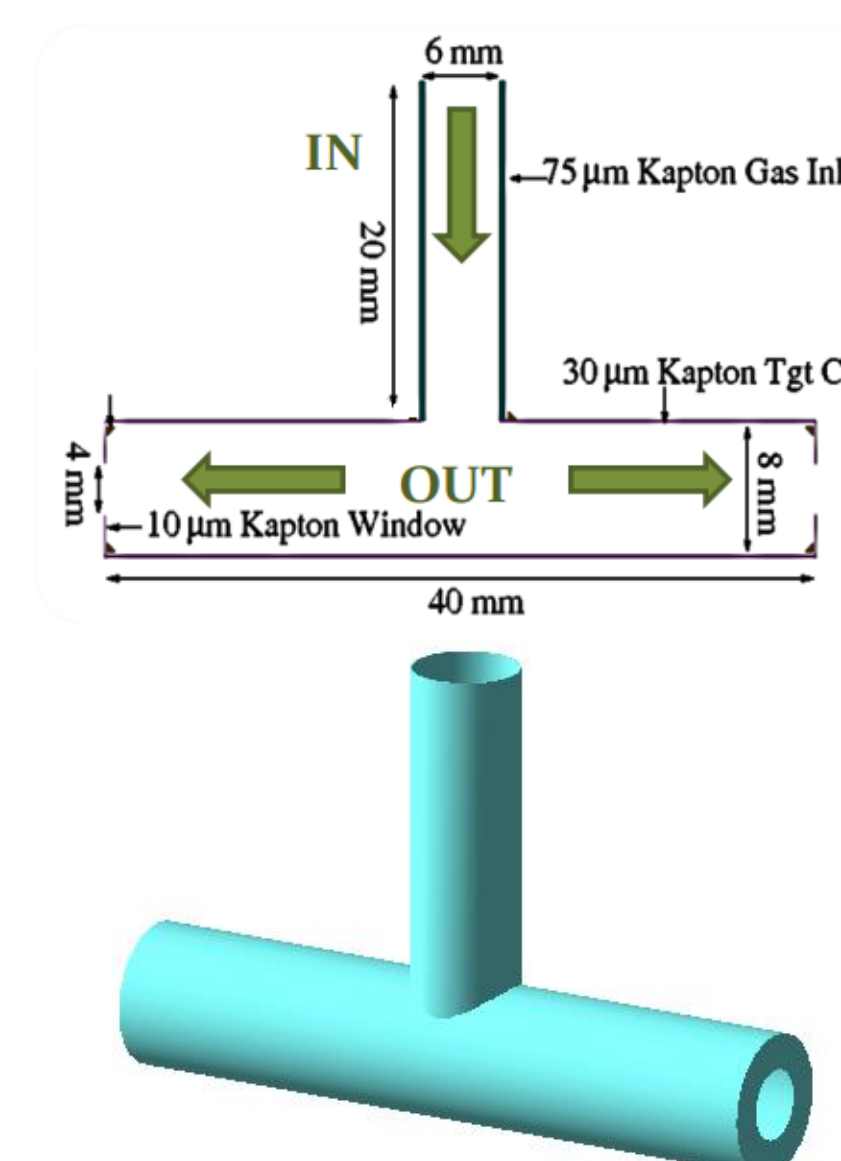


## PRad Experiment

- PRad experiment is a high precision measurement of proton charge radius based on electron-proton elastic scattering
- It will extract the proton charge radius at unprecedentedly low four momentum transfer ( $Q^2$ ) with a sub-percent uncertainty
- It is a non-magnetic and calorimetric experiment, the Hybrid Calorimeter (HyCal) and Gas Electron Multiplier (GEM) will be used as the detectors
- Background is suppressed by utilizing a window-less gas flow target, systematical uncertainties are controlled by measuring the Møller events simultaneously



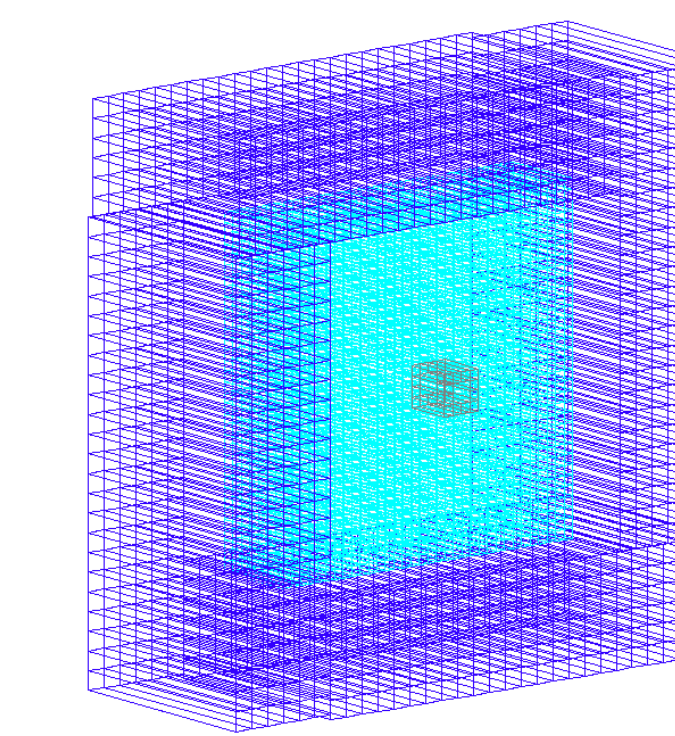
Hybrid Calorimeter (HyCal)



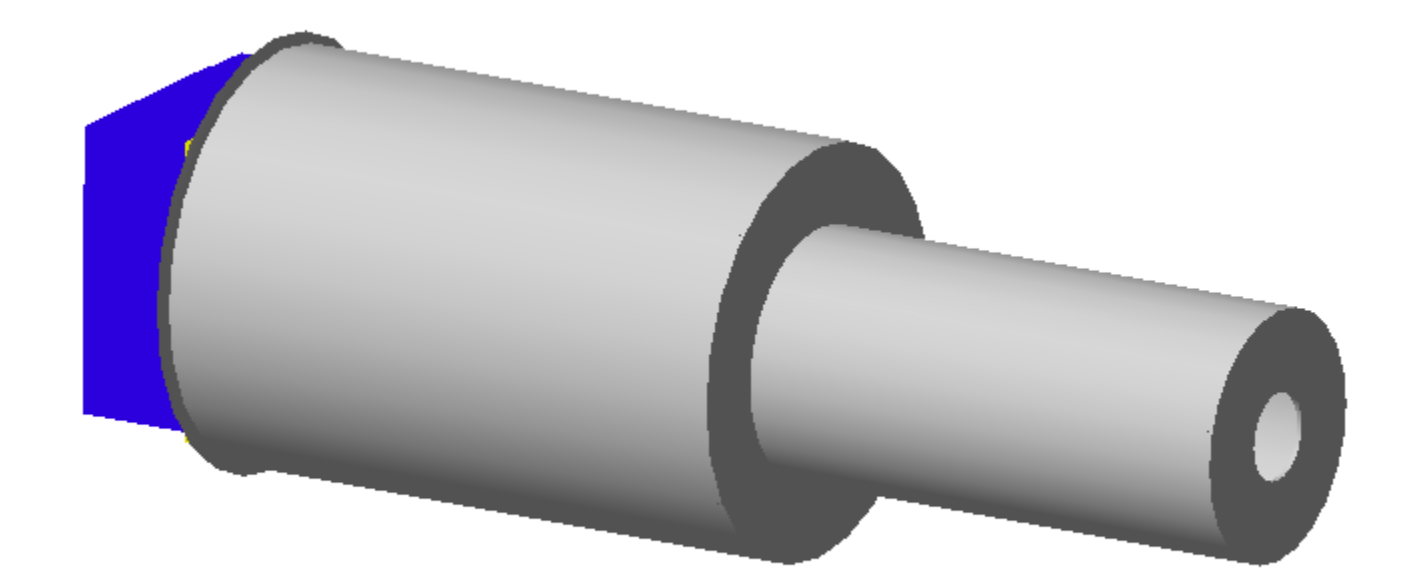
Windowless gas-flow target

## Simulation Study

- Simulation code was developed based on GEANT4

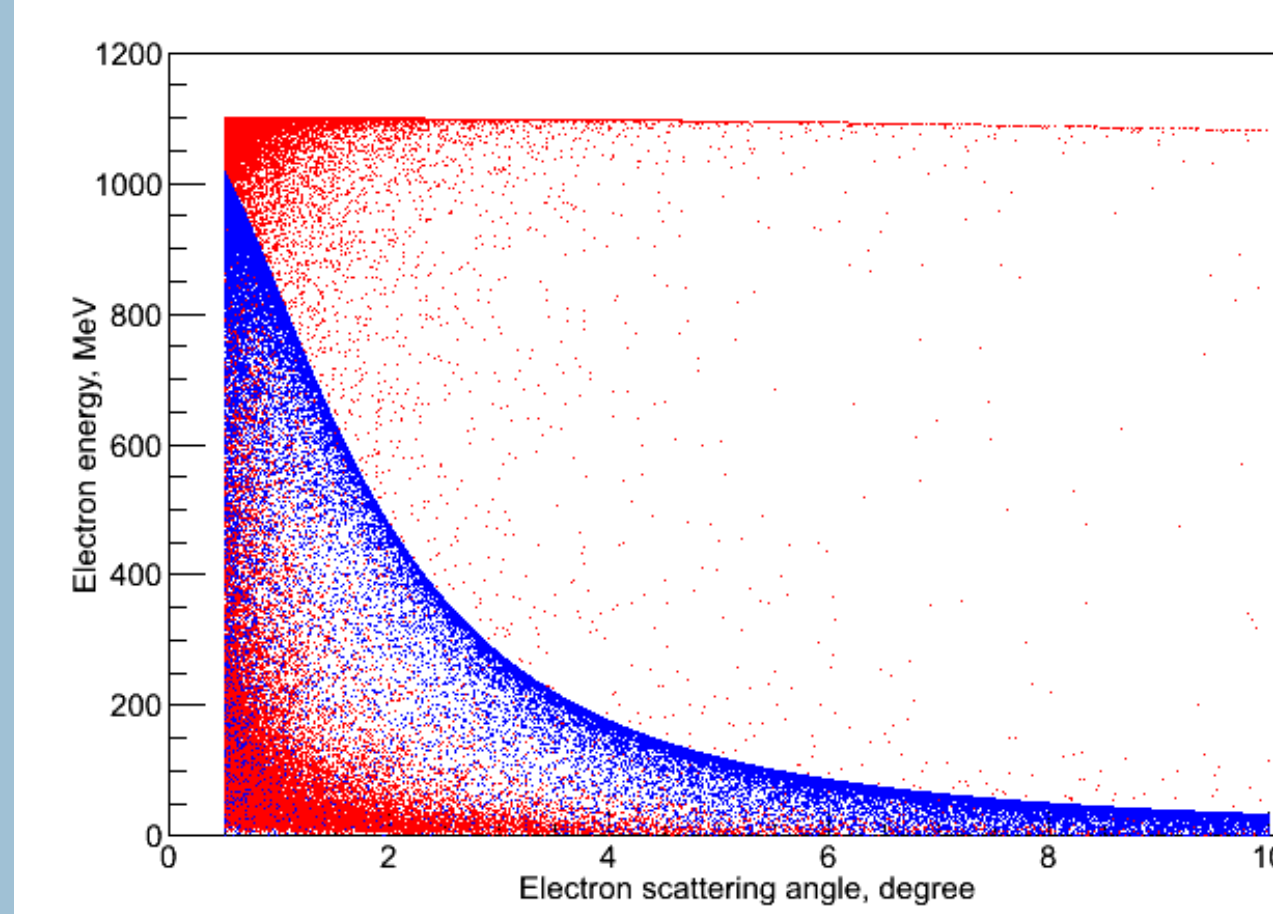


HyCal in the code

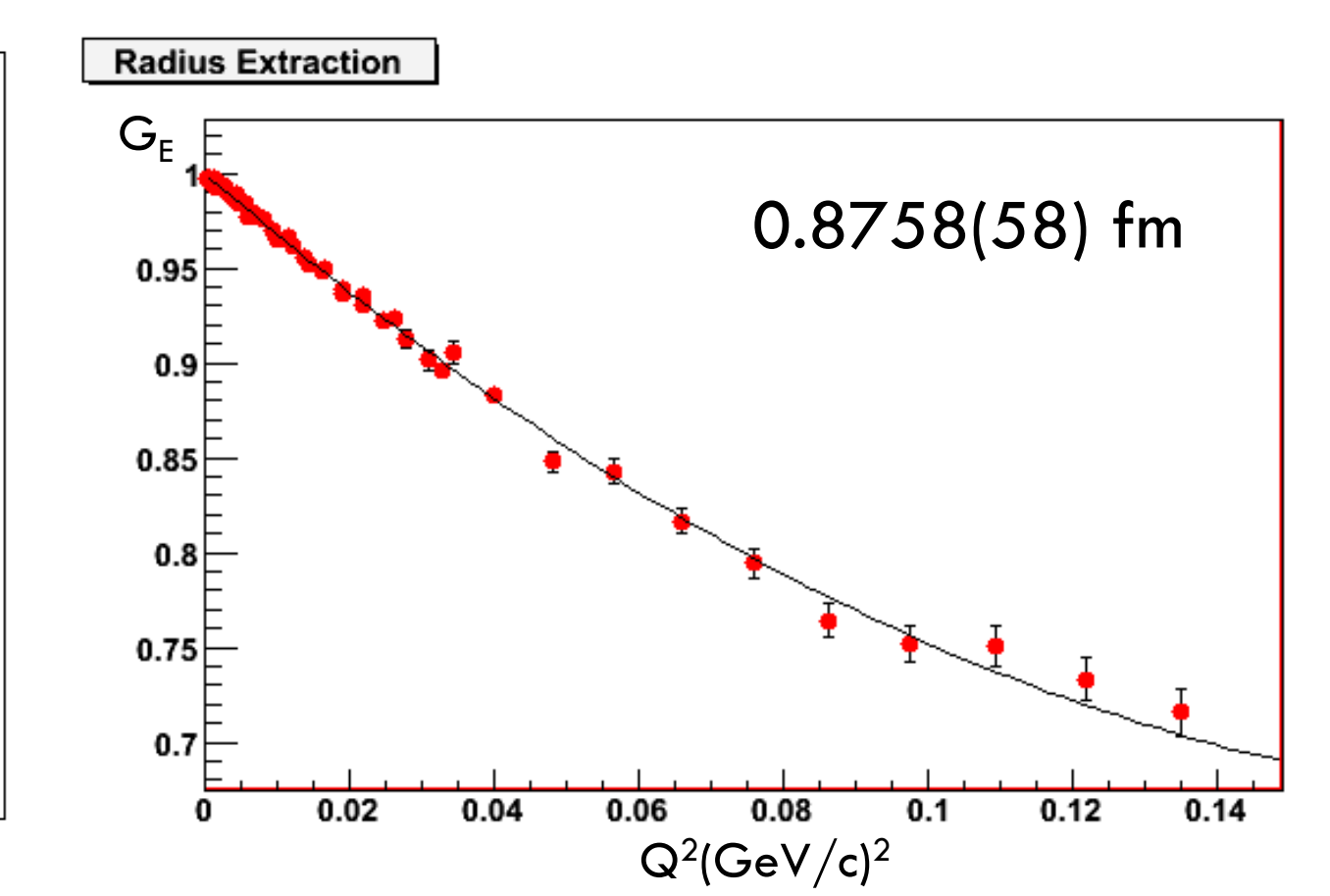


Geometries in the code

- The major background source is the electron-nuclei scattering of beam halo from the target structure
  - Size of the target cell is increased to reduce the background
  - Empty target run to do subtraction
- Two independent event generators with radiative corrections to ep and Møller process (one is developed by M. Meziane, I. Akushevich, and A. Afanasev; the other one is developed by A. Gramolin)

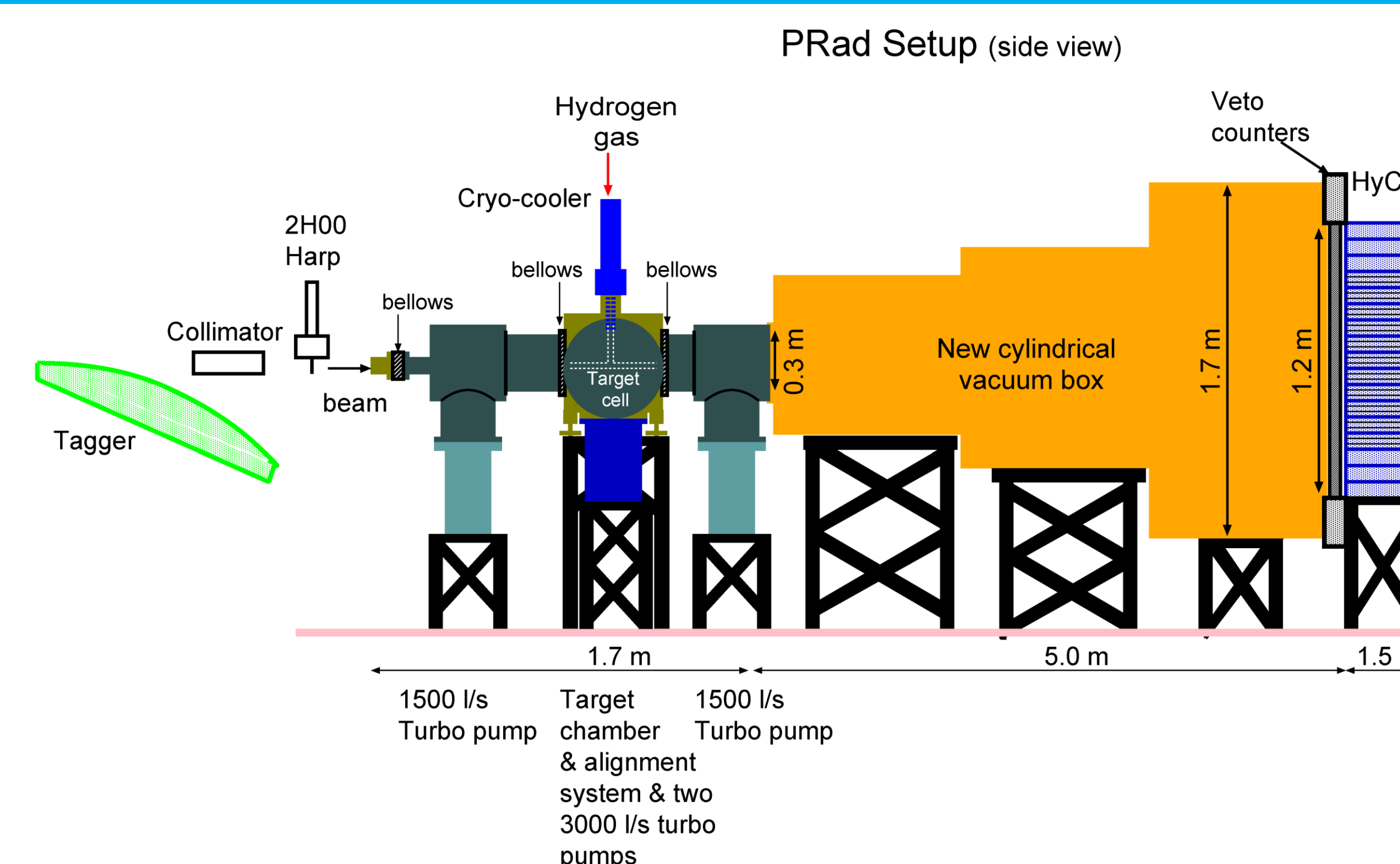


Events from A. Gramolin's generator

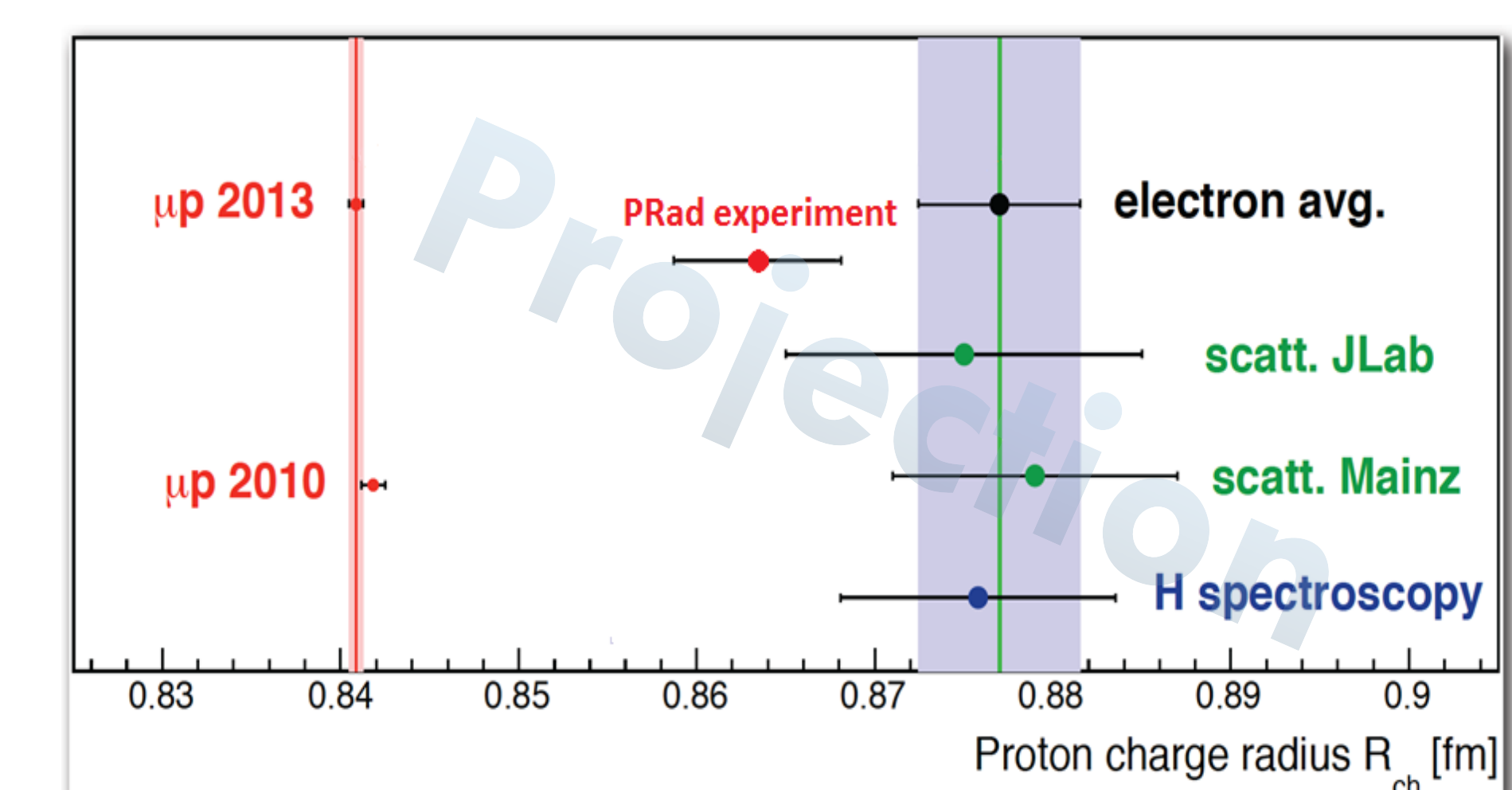


Radius extraction from simulated data

## Experiment Layout



## Projection



The expected precision of PRad experiment is better than 1 %