Calibration Study of PRad Experiment

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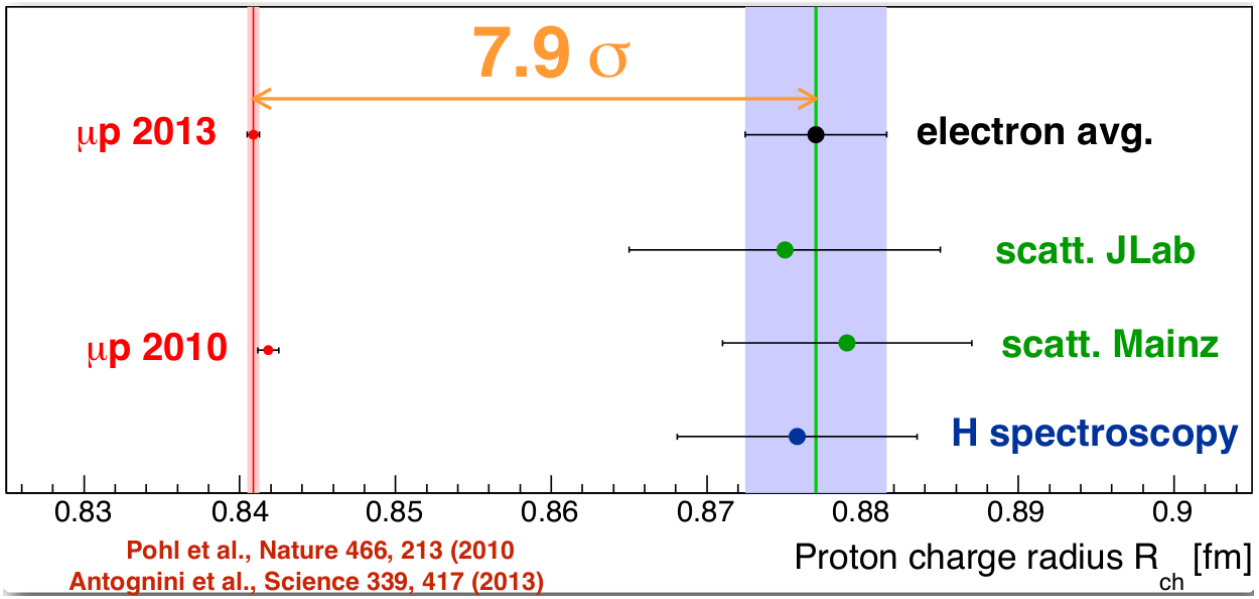
PRadius

Outline

The Proton Radius Puzzle

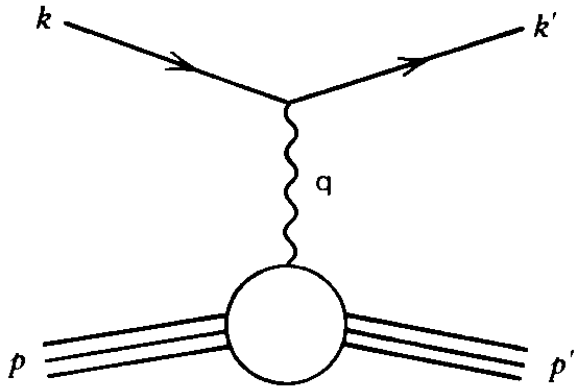
- The proton radius r_p impacts all electromagnetic constants: R_∞, α...
- Primordial in nuclear physics and atomic spectroscopy

$\rightarrow$ $\sim 8\sigma$ discrepancy with muonic hydrogen measurements



$r_p(e^-) = 0.8770 \pm 0.0045 fm$ $\quad$ $r_p(\mu^-) = 0.8409 \pm 0.0004 fm$

Extraction from *ep* Scattering



- Previous measurement from *ep* scattering suffer from large uncertainties

→ Need new experiment with:

- Controlled systematics (calibration/resolution/efficiency and radiative corrections)
- Extraction over a large Q^2 domain ($2 \cdot 10^{-4}$ to $6 \cdot 10^{-2}\text{GeV}^2$)

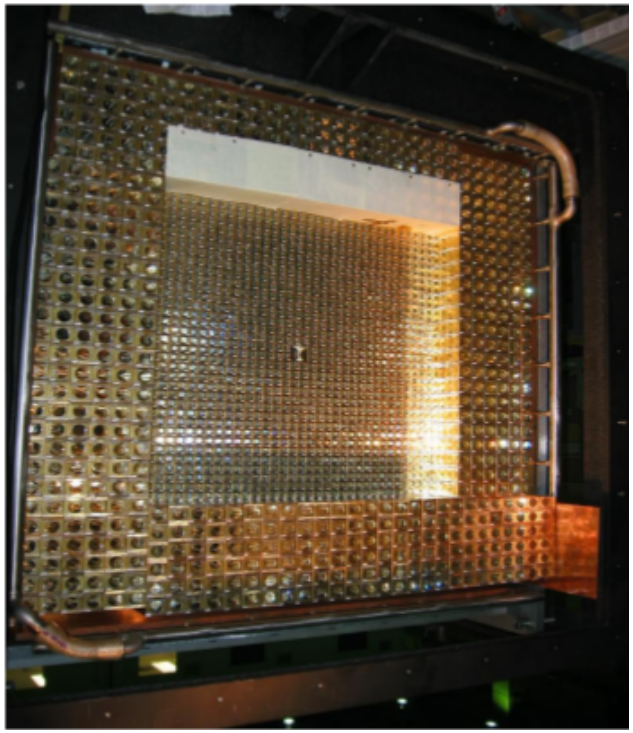
PRad Setup

- Electron beam or tagged photon beam at $\sim$ 1GeV or $\sim$ 2GeV

- Windowless, high density H_2 gas flow target ($1.8 \cdot 10^{18}\ H\ atoms/cm^2$)
- Vacuum box, one thin window at downstream
- Two Large area Gas Electron Multipliers (improve angular resolution)
- High resolution and high efficiency, Hybrid calorimeter (HyCal)

Hybrid Calorimeter - HyCal

- Central part:
  - 34 x 34 matrix of $PbWO_4$ detectors
  - dimension of block: 2.077 x 2.075 x 18 cm^3
  - 2 x 2 blocks removed from the middle
- Peripheral part:
  - 576 Leadglass detectors
  - dimension of block: 3.815 x 3.815 x 45 cm^3



Calorimeter Calibration Method

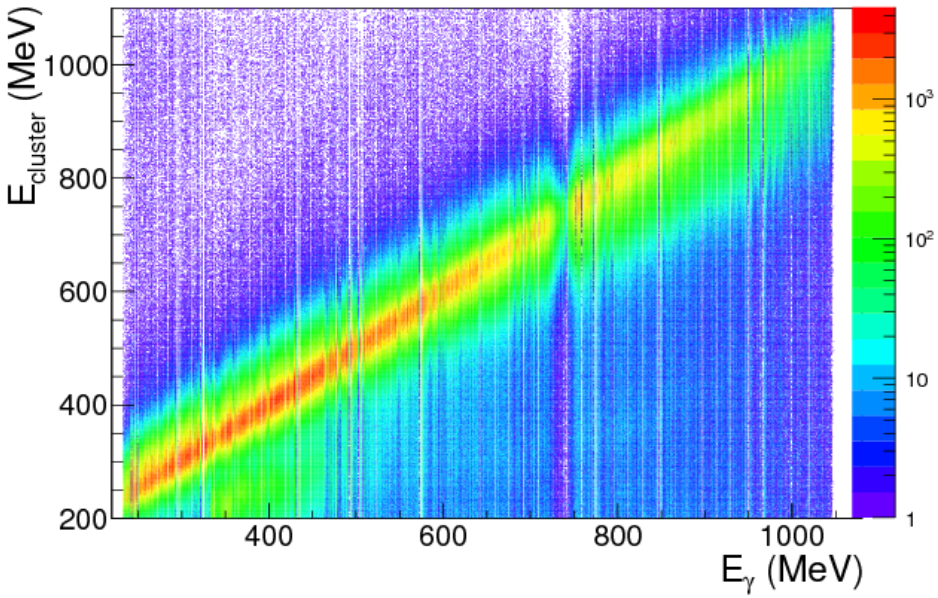
- Gains controlled by light monitoring system (*LMS*)
- Two different calibrations:
  - Before data taking:
    Scan with 250-1050 MeV tagged photon beam moved in front of each module
    $\rightarrow$ study of resolution, efficiency and non linearity
  - During physics data taking:
    With Møller and *ep* events
- Iterative method:

$$gain_{module}(n+1) = gain_{module}(n) / < E_{measured}/E_{expected} >$$

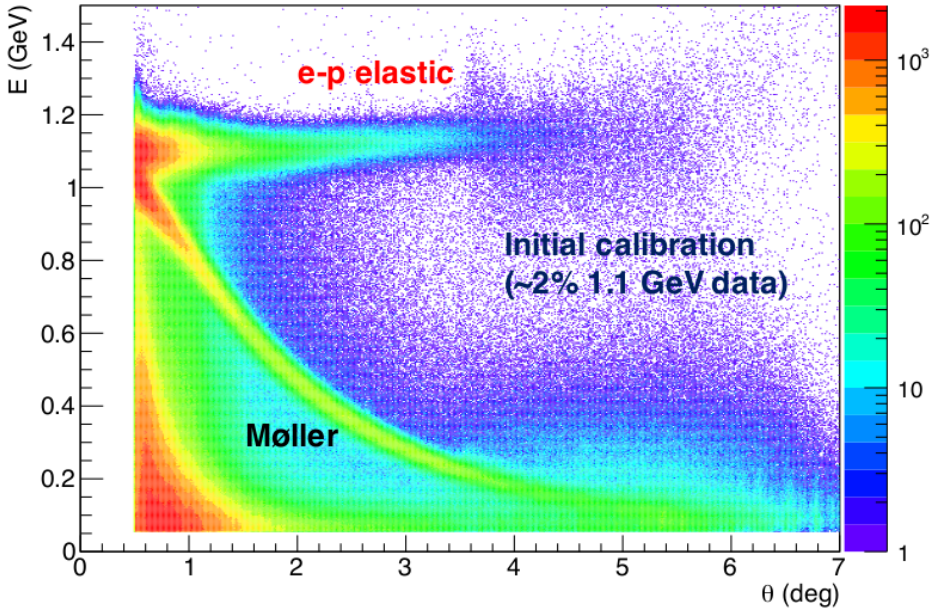
- Different clustering *Island* algorithms used for cross-check

Energy Identification

Calibration with tagged photon beam

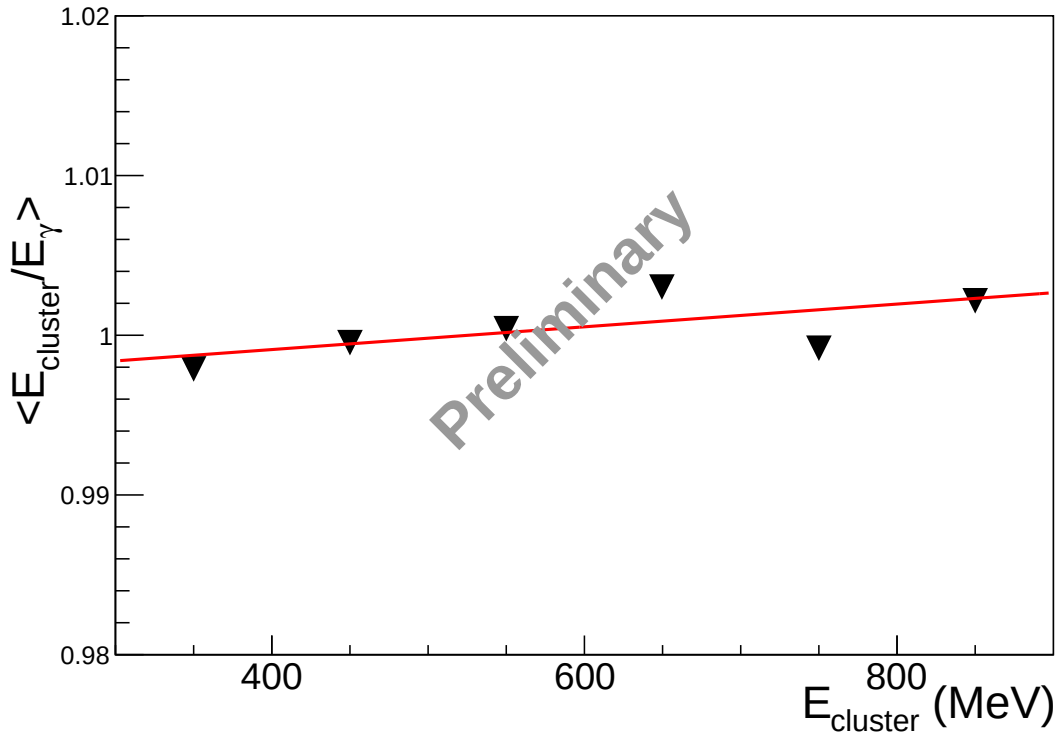


Physics Calibration



Non-Linearity of modules w.r.t. $E_{cluster}$

$$< \frac{E_{cluster}}{E_\gamma} >= \alpha \cdot E_{cluster} + \beta$$

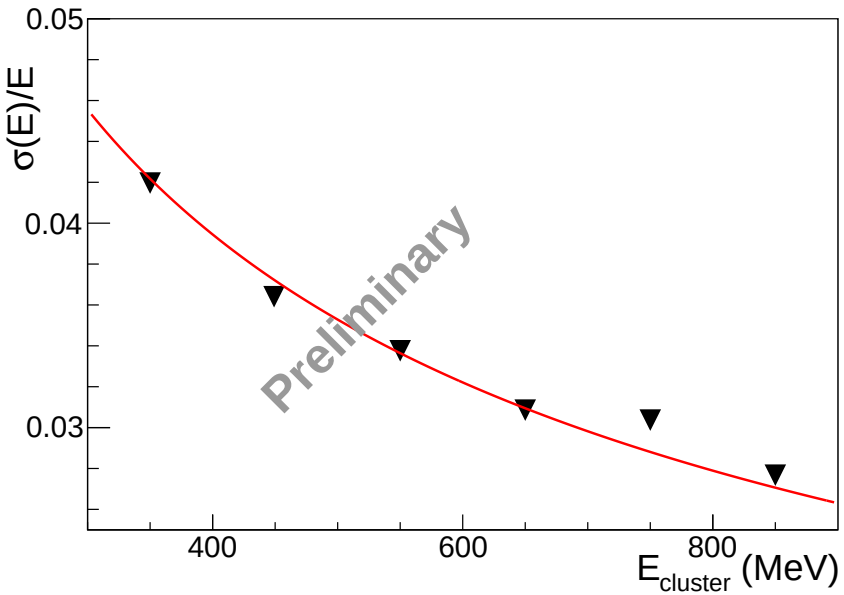


→ Non-Linearity of 0.01 GeV^{-1} for $PbWO_4$ part

Energy Resolution

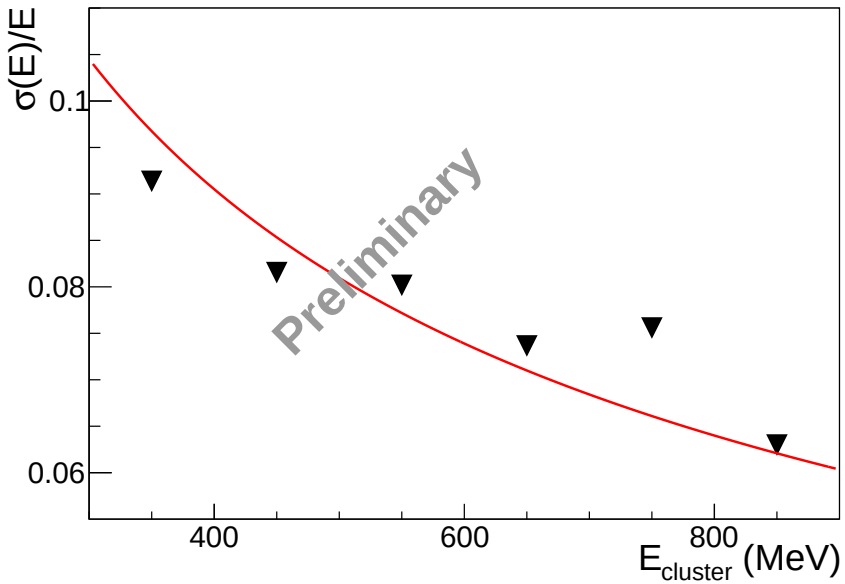
$$\frac{\sigma(E)}{E} = \frac{r}{\sqrt{E\,(GeV)}}$$

$PbWO_4$



resolution at 1 GeV: 2.5%

Leadglass



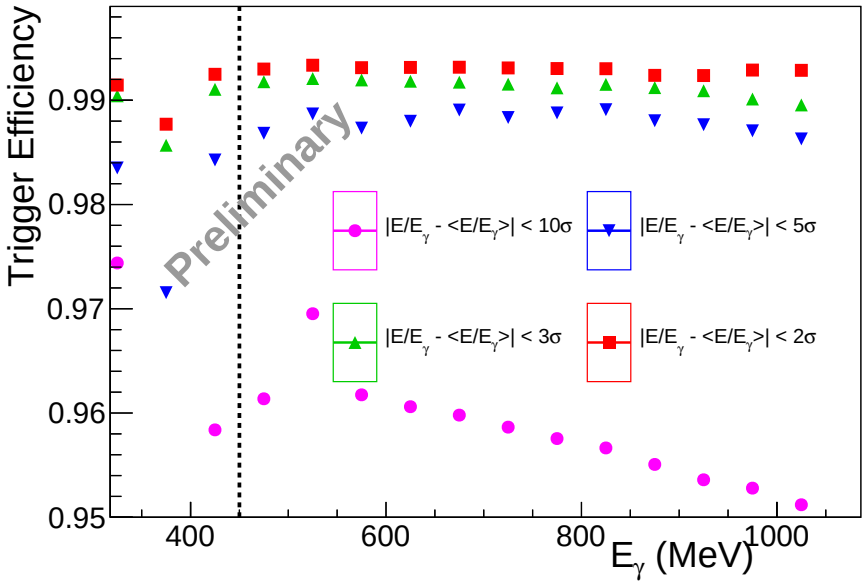
resolution at 1 GeV: 6.1%

Trigger Efficiency Study

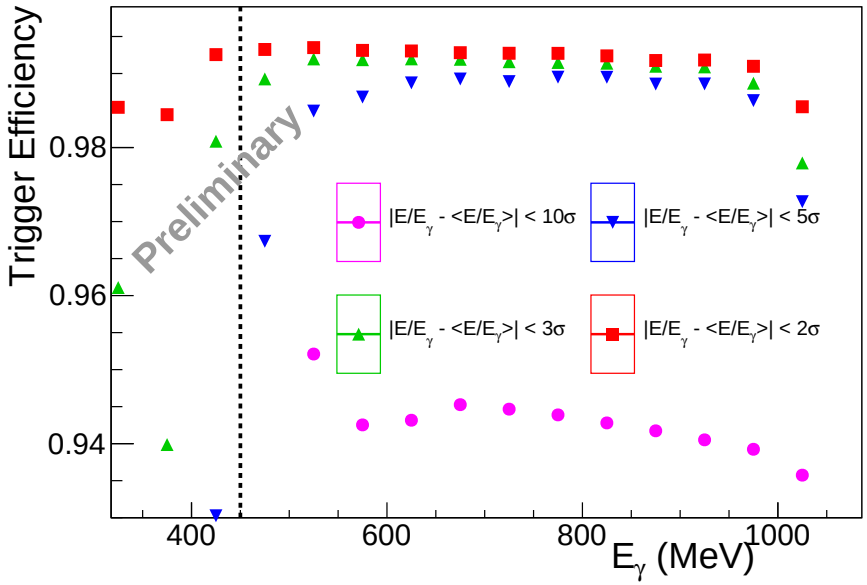
- 3 triggers:
  (2: TotalSum) > (1: LeadGlassSum) > (5: Tagger)

$$\epsilon = \frac{N_1 + N_2}{N_1 + N_2 + N_5}$$

Leadglass



$PbWO_4$



- Plateau from 450 MeV with an efficiency of 0.994
- Good uniformity

Summary

- The PRad collaboration developed a unique experiment to address the *Proton Radius Puzzle* in hadronic physics
- The experiment succesfully took data during May - June 2016
- Calibration with tagged photon beam performed:
  - Expected resolution achieved
  - High and uniform efficiency
- Physics Calibration on progress

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