

Calibration Study of PRad Experiment

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for PRad Collaboration

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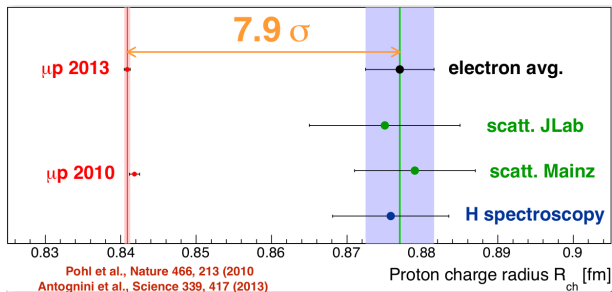


PRoton
radius

- 1 The PRad Experiment
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- 6 Summary

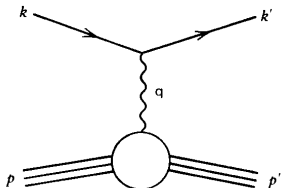
The Proton Radius Puzzle

- ▶ The proton radius r_p impacts all electromagnetic constants:
 $R_\infty, \alpha \dots$
 - ▶ Primordial in nuclear physics and atomic spectroscopy
- $\sim 8\sigma$ discrepancy with muonic hydrogen measurements



$$r_p(e^-) = 0.8770 \pm 0.0045 \text{ fm}$$

$$r_p(\mu^-) = 0.8409 \pm 0.0004 \text{ fm}$$

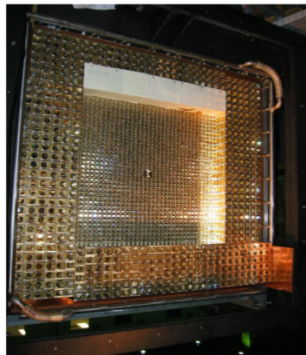


- ▶ Previous measurement from ep scattering suffer from large uncertainties
- Need new experiment with:
 - ▶ Controlled systematics (calibration/resolution/efficiency and radiative corrections)
 - ▶ Extraction over a large Q^2 domain ($2 \cdot 10^{-4}$ to $6 \cdot 10^{-2} \text{GeV}^2$)

- ▶ Electron beam or tagged photon beam at $\sim 1\text{GeV}$ or $\sim 2\text{GeV}$
- ▶ Windowless, high density H_2 gas flow target ($1.8 \cdot 10^{18} \text{ H atoms/cm}^2$)
- ▶ Vacuum box, one thin window at downstream
- ▶ Two Large area Gas Electron Multipliers (improve angular resolution)
- ▶ High resolution and high efficiency, Hybrid calorimeter (HyCal)



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



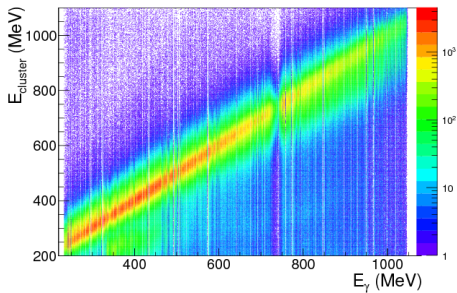
- ▶ Gains controlled by light monitoring system (*LMS*)
- ▶ Two different calibrations:
 - ▶ Before data taking:
Scan with 250-1050 MeV tagged photon beam moved in front of each module
→ study of resolution, efficiency and non linearity
 - ▶ During physics data taking:
With Møller and *ep* events

- ▶ Iterative method:

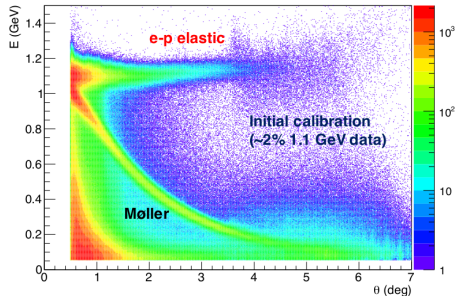
$$gain_{module}(n + 1) = gain_{module}(n) / \langle E_{measured} / E_{expected} \rangle$$

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

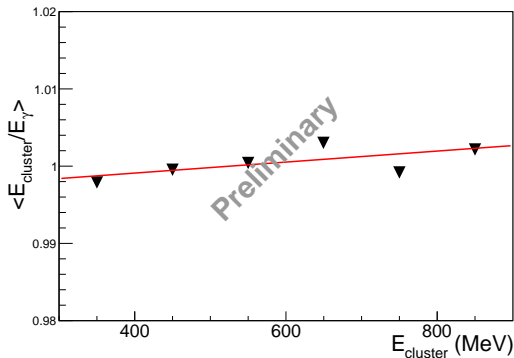
Calibration with tagged photon beam



Physics Calibration



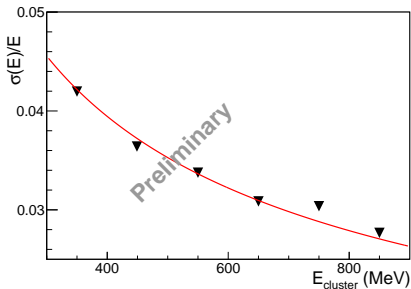
$$\left\langle \frac{E_{cluster}}{E_{\gamma}} \right\rangle = \alpha \cdot E_{cluster} + \beta$$



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

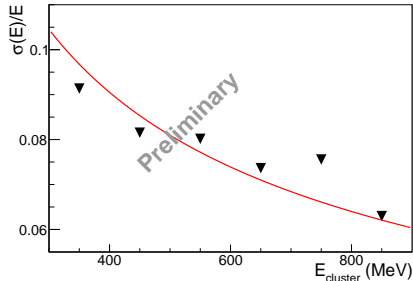
$$\frac{\sigma(E)}{E} = \frac{r}{\sqrt{E(\text{GeV})}}$$

PbWO₄



resolution at 1 GeV: 2.5%

Leadglass



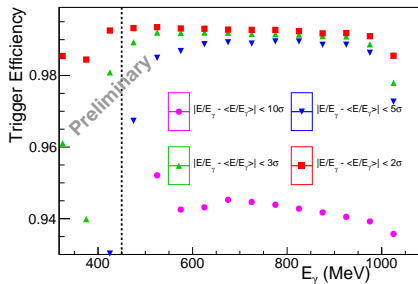
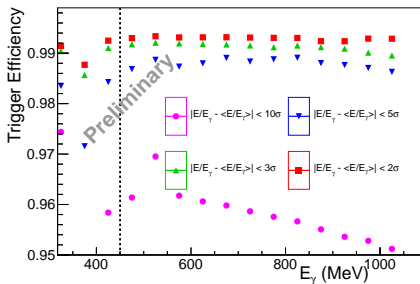
resolution at 1 GeV: 6.1%

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

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

Leadglass

PbWO₄



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

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

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