Status of the PRad Experiment (E12-11-106)

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for the PRad collaboration

Outline

- PRad Physics goals
- Experimental setup
- Current status
- Summary

CLAS col. meeting, June. 2016
The Proton Charge Radius Puzzle

Existing data:

1) e-p elastic scattering
2) Ordinary hydrogen spectroscopy;
3) Muonic hydrogen spectroscopy

- Muonic hydrogen Lamb shift experiment at PSI (2010,2013)
  - \( r_p = 0.84184(67) \text{ fm} \) \( \rightarrow \) Unprecedented less than 0.1% precision
- 7σ discrepancy from most of previous experimental results and analyses
The PRad Experiment (E12-11-106)

- **Experimental goals:**
  - reach very low $Q^2$ range (~ 10 times less than the Mainz experiment)
  - reach sub-percent precision in $r_p$ extraction

- **Suggested solutions:**
  1) **Non-magnetic-spectrometer method:**
     - use high resolution high acceptance calorimeter and high position resolution GEM detector
     - reach smaller scattering angles: $(\theta = 0.8^0 - 7.0^0 )$ 
     - $(Q^2 = 2x10^{-4} - 1x10^{-1} )$ GeV/c$^2$
     - essentially, model independent $r_p$ extraction
  2) **Simultaneous detection of $ee \rightarrow ee$ Moller scattering**
     - (best known control of systematics)
  3) **Use high density windowless H2 gas flow target:**
     - beam background fully under control with high quality CEBAF beam
     - minimize experimental background

- **Two beam energies:** $E_0 = 1.1$ GeV and 2.2 GeV to increase $Q^2$ range: $(2x10^{-4} - 1x10^{-1} )$ GeV/c$^2$
- Will reach sub-percent precision in $r_p$ extraction
- Approved by PAC39 (June, 2012) with high “A” scientific rating
PRad Experimental Setup (schematics)

- Main detectors and elements:
  - windowless H$_2$ gas flow target
  - PrimEx HyCal calorimeter
  - vacuum box with one thin window at HyCal end
  - X,Y – GEM detector in front of HyCal

- Beam line equipment:
  - standard beam line elements (0.1 – 10 nA)
  - photon tagger for HyCal calibration
  - collimator box (6.4 mm collimator for photon beam, 12.7 mm for e$^-$ beam halo “clean-up”)
  - Harp 2H00
  - pipe connecting Vacuum Window through HyCal

PRad Setup (Side View)

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Windowless H₂ Gas Flow Target

- Target chamber is differentially pumped with four high speed turbos.
- Kapton orifices up- and downstream from the cell reduce the beam line vacuum.
- A four-axis motion mechanism positions the target cell, with approximately ±10 μm accuracy.

Target specs:

Cell: 30 μm thick Kapton, length 4 cm
- diameter 8 cm with 2 mm diameter holes for the beam to pass through
- Cell pressure 0.5 torr

Target: H₂ input gas temp. 19.5 K
- thickness 2×10^{18} (atoms) / cm²
- density 2.75×10^{17} (molecules) / cm³
- Vacuum in target chamber ~5×10^{-3} torr

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Vacuum Box

- Engineering design is done by Duke/Jlab
- Construction is done (March 2015)
- Tested with window by vendor (March 2015)
- Delivered to JLab (March 2015)
- Preassembled at JLab
- Installed: May, 2016
PRad GEMs: Design & Specifications

- Largest GEM detector ever built in the world
  - Each module (123 cm x 55 cm) is twice the size of SBS Back Tracker GEMs
  - The two modules overlap in the central part for the alignment of the beam pipe hole
- COMPASS-like strip readout (1.3 m long strips in the vertical direction \(\Rightarrow\) capacitance noise still OK)
Electromagnetic Calorimeter (PrimEx HyCal)

- Combination of PbWO$_4$ and Pb-glass detectors (118x118 cm$^2$)
- 34 x 34 matrix of 2.05 x 2.05 x 18 cm$^3$ PbWO$_4$ shower detectors
- 576 Pb-glass shower detectors (3.82x3.82x45.0 cm$^3$)
- 2 x 2 PbWO$_4$ modules removed in middle for beam passage
- 5.5 m from H$_2$ target (~0.5 sr acceptance)

- Moved back to Hall B in June, 2014:
  - (thanks to Technical Group (D. Tilles and All))
  - Cabling system with infrastructure reassembled
  - Trigger, analog and HV electronics are reinstalled
  - Cooling system is operational
  - LMS checked and repaired
  - All individual detectors checked and repaired
  - DAQ is operational (HyCal readout part)
  - Transporter is reinstalled/repaired and operational

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PRad Installation in Hall B Beam Line

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Gain Equalizing and Calibration

a) Gain equalizing and calibration data taking completed (May 25 - May 31)

b) 1.1GeV production completed (June 04 - June 12)
Event Matching Between GEM and HyCal Hits
(an e-p elastic scattering event candidate)
Event Matching Between GEM and HyCal
(an e-e Moller event candidate)
Data taking status

By June 12th
ran with 10 nA beam current @ events rate 1.8KHz and 65% live-time for 5 days (busy signal issue)
ran with 15 nA beam current @ events rate 4.0KHz and 87% live-time (data rate 400MB/sec) for 3 days

Reached production goal for 1.1GeV beam on Hydrogen
(600M events collected)
(50M events collected with empty target)
Preliminary Gain Calibrations

\[ \text{~3.5 \% energy resolution on ep} \]

\[ \text{~3.0 \% energy resolution on ee} \]
HyCal Hit Position for Double Cluster Events
Q2 distribution of single cluster events

With better calibration, background subtraction and GEM hits reconstruction, will reach lower Q2

preliminary matching of GEM hits with HyCal clusters
total cluster energy > 700MeV

Q^2 \sim 1.5 \times 10^{-4}
Summary

• PRad was designed to address the “Proton Radius Puzzle”

• PRad installation completed (May 08 - May 11)

• Physics data taking in progress (started from May 25, 2016)
  a) Gain equalizing and calibration completed;
  b) 1.1 GeV production data taking completed;
  c) 2.2 GeV production data taking in progress;
  d) Largest GEM detectors tested in beam with high trigger rate;
  e) DAQ with highest data rate in Hall B achieved (400 MB/sec);
  f) Lowest $Q^2$ in e-p scattering process recorded ($\sim 10^{-4}$ GeV/c$^2$);

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Thank you!

- Hall B Engineering and Physics staff
- Target group
- Data acquisition and Fast Electronics groups
- Physics Division
- Accelerator Division
- JLab Administration
- All funding agencies
Proton Charge Radius puzzle?