Charge Item 8: Software, reconstruction; Collaboration documented track record

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James Madison University
on behalf of the
E12-13-010, E12-13-007, E12-14-003, E12-14-005
collaborations

May 1, 2019

Charge (Reminder)...

Questions:

- **What** is the simulation and data analysis software status?
- **Has** readiness for expedient analysis of the data been demonstrated?
- **What** is the projected timeline for the first publication?
- **Provide** a documented track record from prev. exp.

E12-13-010, E12-13-007, E12-14-003, E12-14-005 will...

- Use the HMS-NPS to detect charged and neutral particles.
- Analyze small aperture spectrometer data.
- Track neutral particle(s) in the NPS.
- Analyze HMS-NPS coincidence data.

Hall C Analysis software framework

hcana

- **hcana:** Hall C's version of the common (A/C) ROOT/C++ based analysis framework.
- completely OO
- adding new spectrometers (NPS) very easy (if C++ gnostic!)
- ...especially since no magnetic fields are involved.

GN $0.02:

- is this done?
- who is in charge of it?
- timeline?
- i/o routines for new/specialized electronics ?

Commissioning experiments lessons

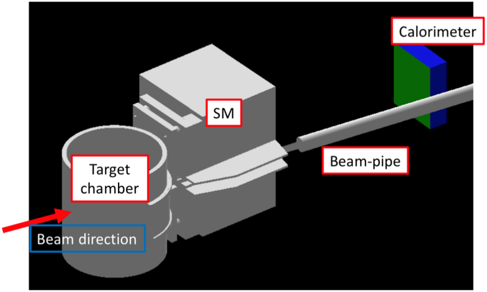
2018-2019

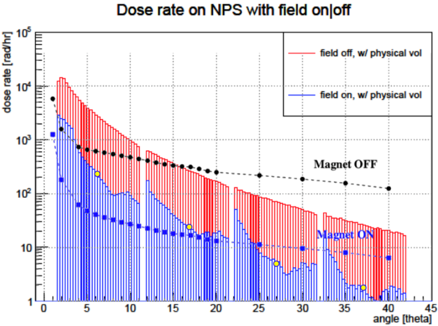
- first Hall C exp. in the 12 GeV era.
- single arm & coincidence
- substantial experience gained*:
  - calibration, optics
  - FADC readout
  - improving/streamlining analysis workflow

GN $0.02:

- do I mention ppl and exp. by name here?

DVCS Simulation & Analysis:

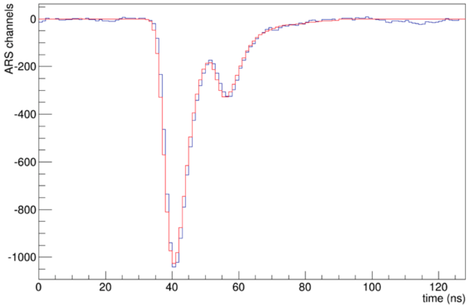




Notes:

- DVCS/NPS in Geant4
- Validation against JLab dose standards.

DVCS Analysis:



			0.2		
			3.0	1.0	0.2
0.3	0.2	0.4	7.0	2.0	0.2
2.0	8.0	1.0	0.4		
0.2	0.6	0.3	0.2		

			3.0		
			7.0	7.0	2.0
8.0	8.0	8.0	7.0	7.0	2.0
8.0	8.0	8.0	7.0		
8.0	8.0	8.0	1.0		

			7.0		
			7.0	7.0	7.0
8.0	8.0	8.0	7.0	7.0	7.0
8.0	8.0	8.0	7.0		
8.0	8.0	8.0	8.0		

Notes:

- pulse fitting (l)
- cellular automaton algorithm (r)

DVCS Simulation and Analysis:

DVCS Simulation

- HS Ko (IPN Orsay) has updated the Geant 4 DVCS simulation to the NPS case.
- Event generator for DIS, π^0 production & DVCS NPS geometry.
- Radiation background, magnetic configuration and dose rate validated against JLab standards.

DVCS Simulation and Analysis (II):

DVCS Analysis

- Will use the existing DVCS libraries linked to hcana.
  - fADC/ARS and trigger decoding
  - Multi-pulse fitting
  - Clustering (Cellular automaton)
  - Output: hit position, energy, time
- HS Ko (IPN Orsay) has modified the existing DVCS libraries to accommodate the NPS calorimeter (208 to 1116 blocks)
- Available on github

To do:

- Write the FADC decoding (JLab personnel?)
- Implement DVCS libraries into hcana

DVCS-SIDIS analysis needs:

DVCS-SIDIS analysis needs

- Based on the Hall A DVCS scheme
- Online analysis (on shift): minimal calorimeter analysis
- Almost-online analysis (expert within a day): Full fledged pulse fitting and clustering.
- Estimation of the total amount of data produced $\sim$50 TB
- Use DIS rates and beam time request
- Assume 75 fADC signals saved by events (26 sample per fADC)

Julie:

- So far nothing to take into account HMS events – question out to A. Camsonne

DVCS track record

DVCS Hall A collaboration...

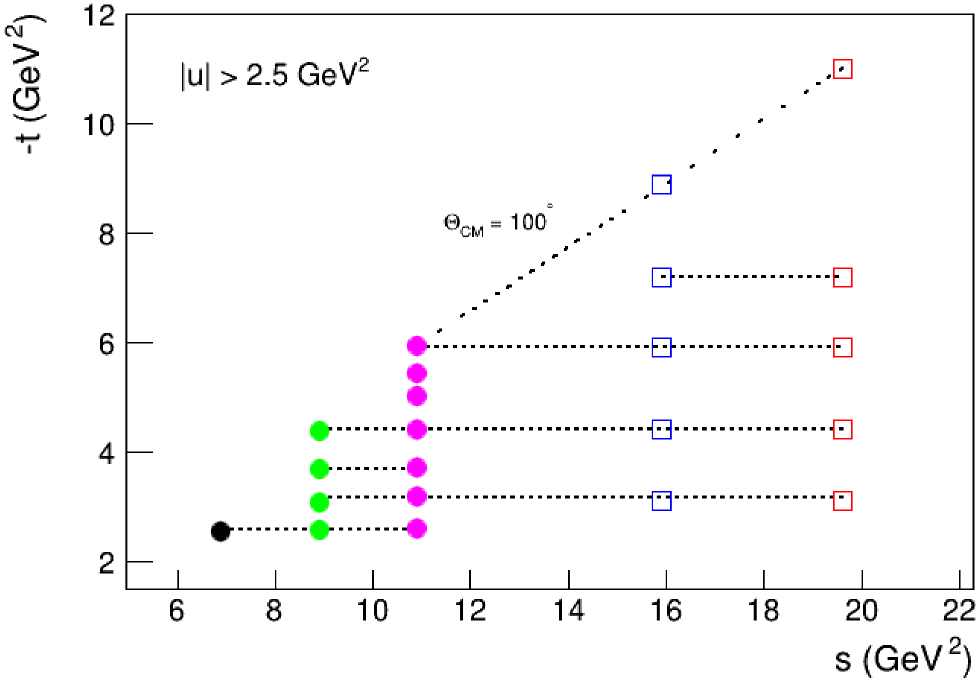
- E07-007 & E08-025:
  - 4 Ph. D. thesis
  - 2 PRL, 1 Nature Comm, 1 article under review
- E12-06-114
  - 50% of the data taking completed in Dec 2016. Q1-HRS
  - 2 Ph. D. thesis completed, 4 in preparation
  - Preliminary DVCS and p0 cross-sections presented in conferences.

???

- Julie: Not sure what to put here for the SIDIS group??
- GN: no timeline on the above...

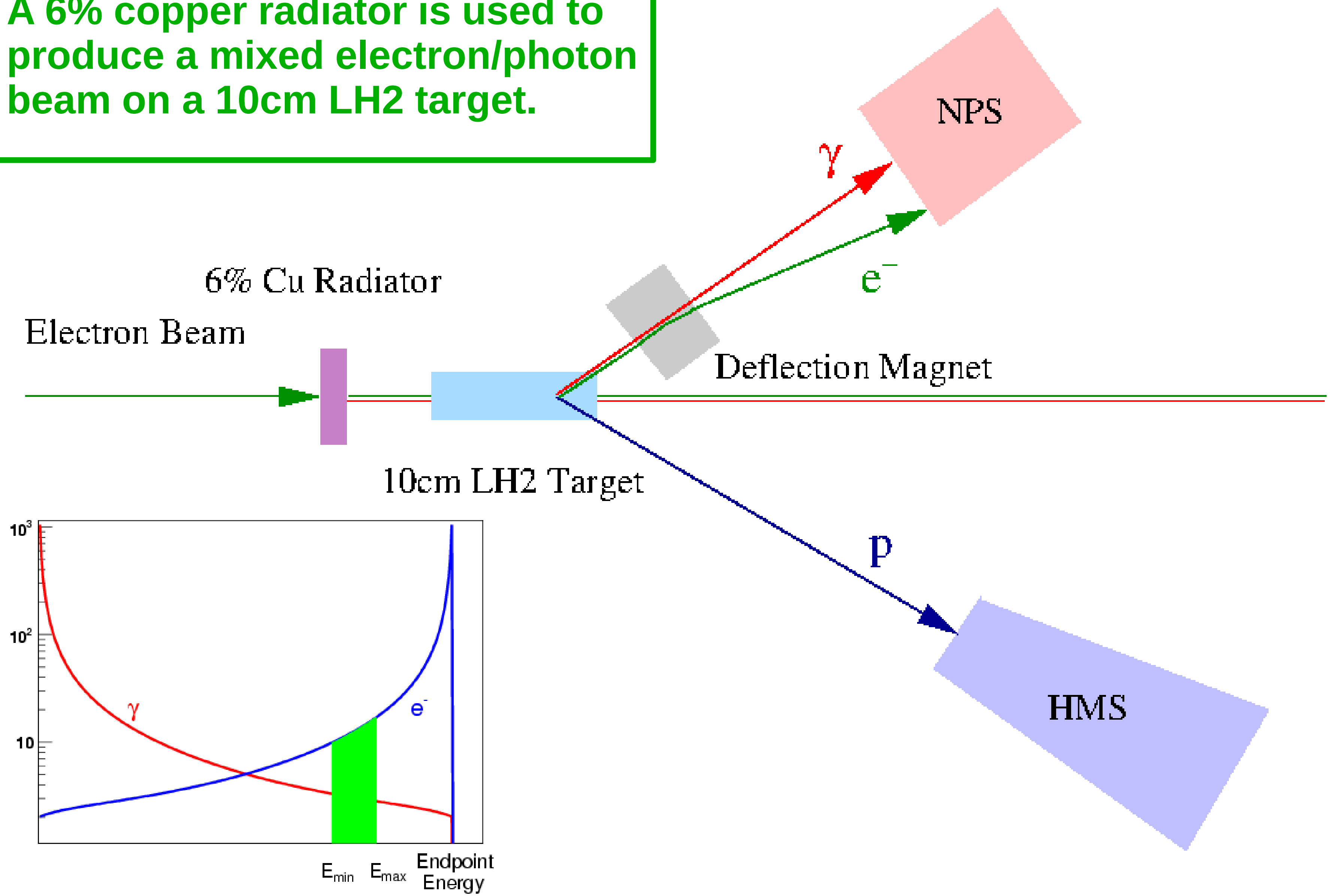
WACS at Jlab: 12 GeV Kinematic Settings

	Θ_{CM} (deg)	s (GeV^2)	-t (GeV^2)	-u (GeV^2)
4A	55.8	15.89	3.10	11.03
4B	67.6	15.89	4.39	9.75
4C	80.4	15.89	5.91	8.22
4D	90.9	15.89	7.20	6.93
4E	104.8	15.89	8.90	5.23
5A	48.9	19.65	3.07	14.81
5B	59.5	19.65	4.41	13.47
5C	70.1	19.65	5.91	11.97
5D	78.7	19.64	7.21	10.68
5E	103.2	19.65	11.01	6.88



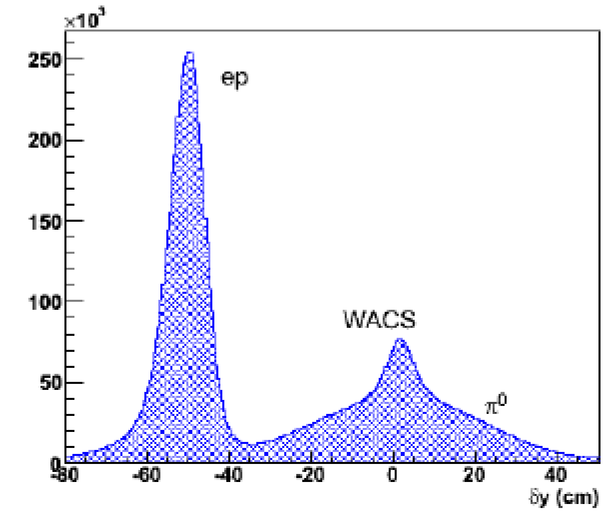
Experimental Technique

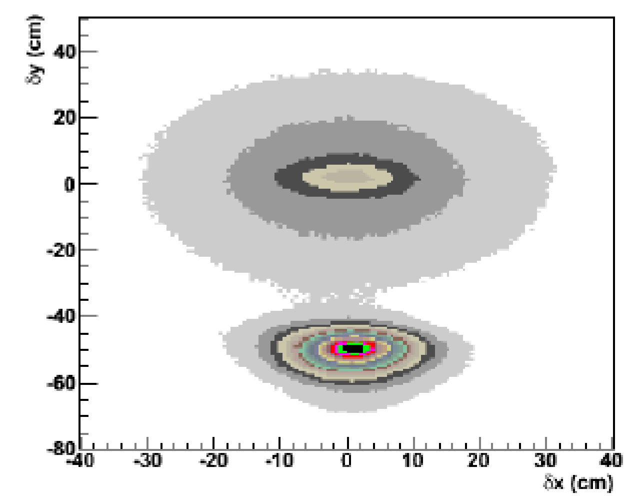
A 6% copper radiator is used to produce a mixed electron/photon beam on a 10cm LH2 target.



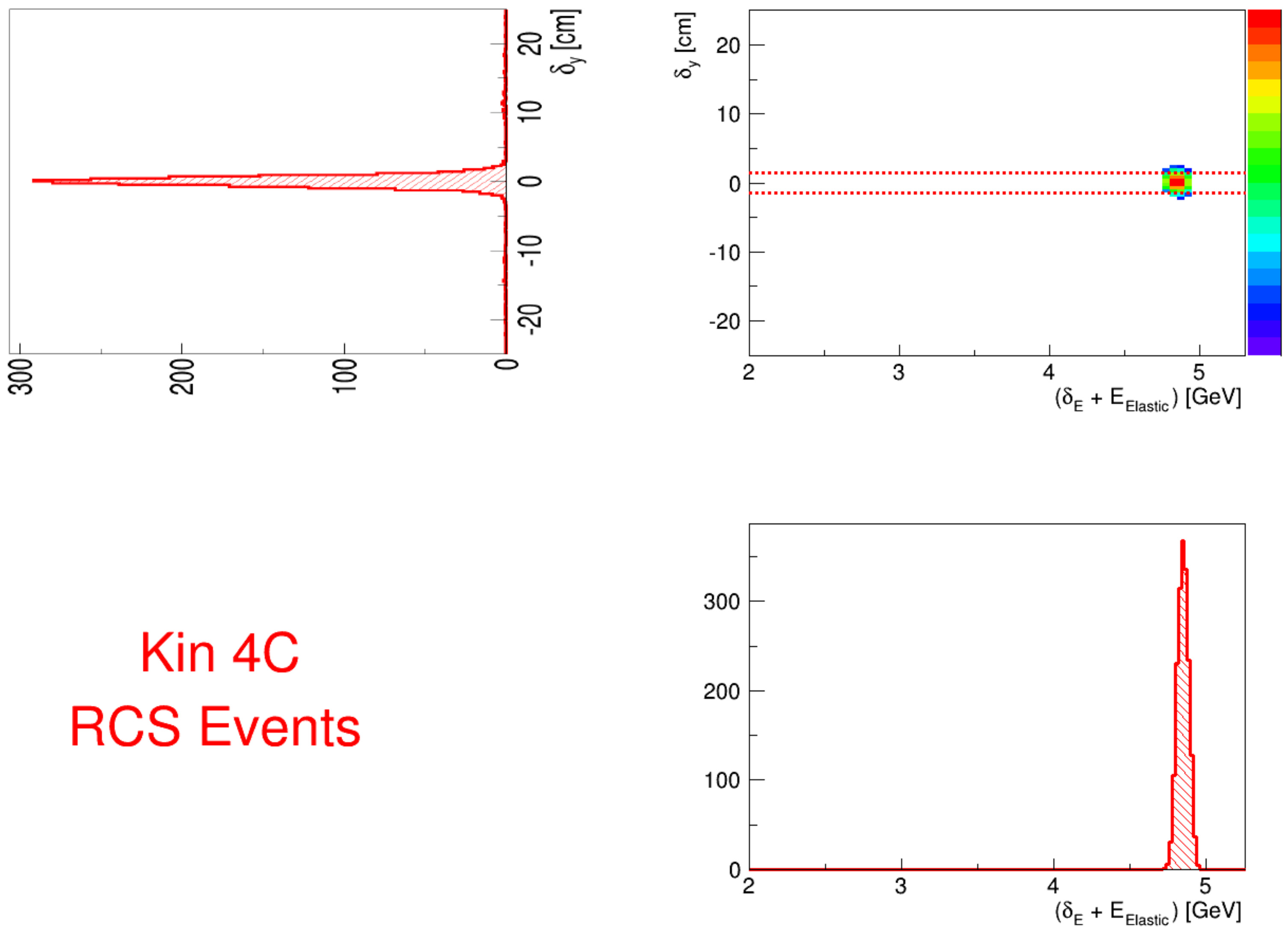
Analysis Technique and Background Reactions

- The analysis technique relies on utilization of the two-body kinematic correlation between the scattered photon/electron and the recoil proton.
- The three dominant reaction channels are:
  - $\gamma + p \rightarrow \gamma + p$
  - $\gamma + p \rightarrow \pi^0 + p \rightarrow \gamma + \gamma + p$
  - $e + p \rightarrow e + p$ (and $ep\gamma$)
- The Compton peak sits on top of a background from both neutral pion and $ep\gamma$ reactions.



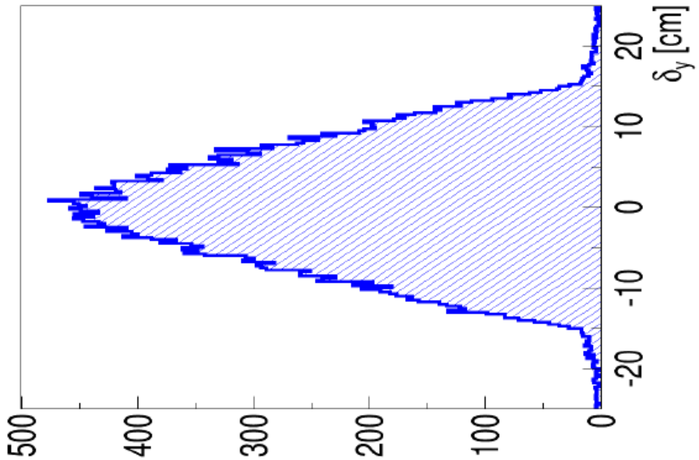


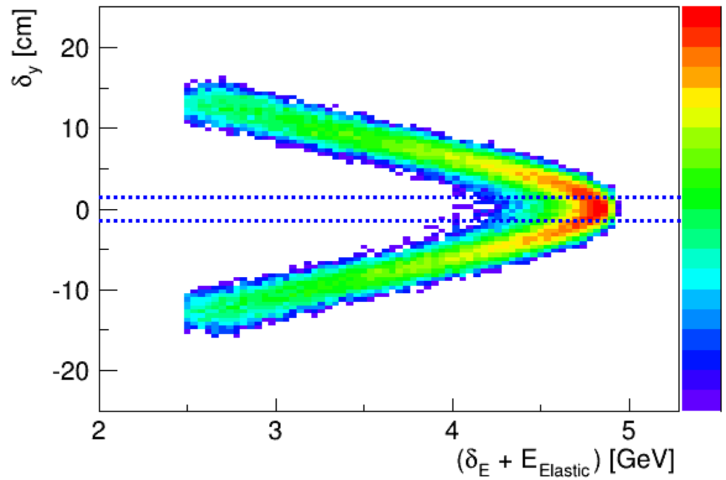
Analysis Technique:
Simulated Data for Compton Events



Kin 4C
RCS Events

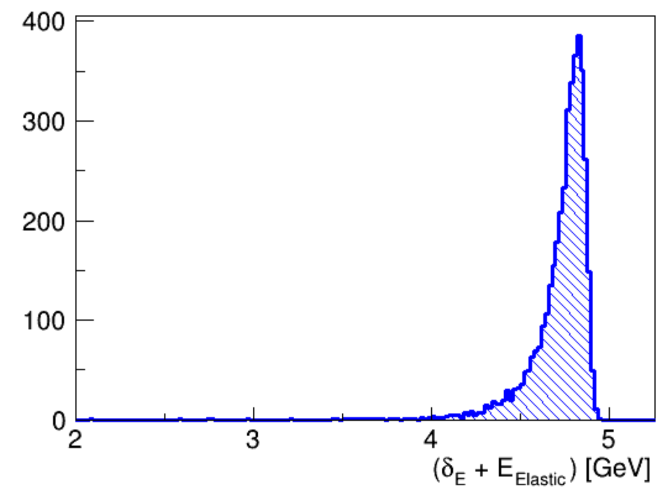
Analysis Technique:
Simulated Data for Pion Events



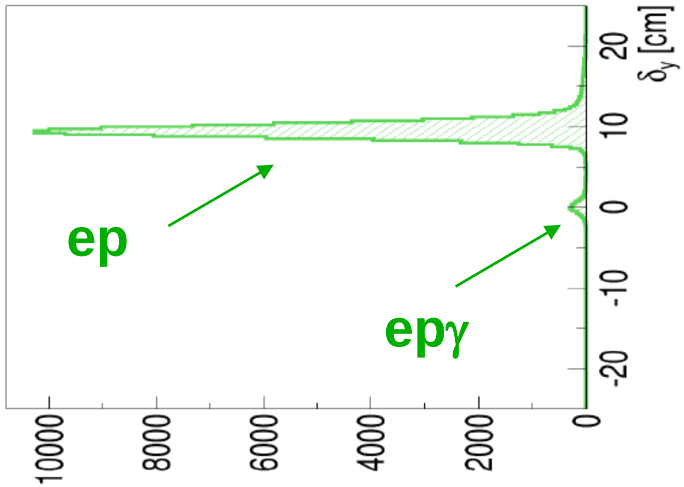


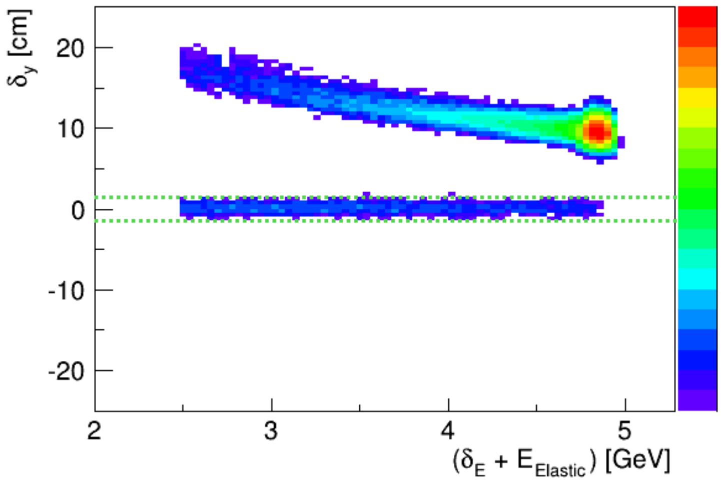
Kin 4C

π^0 Events

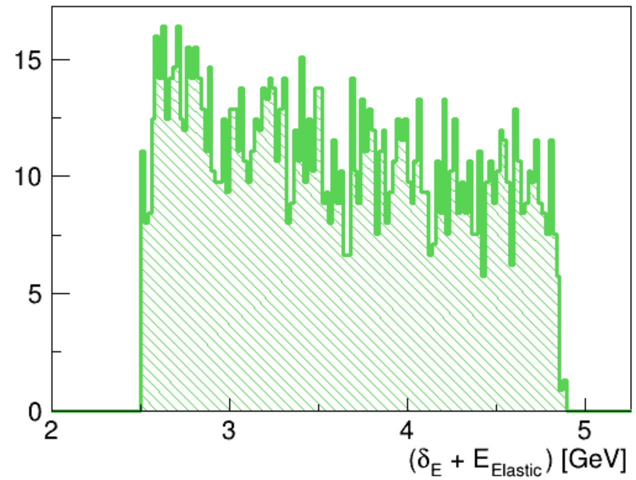


Analysis Technique:
Simulated Data for ep Events



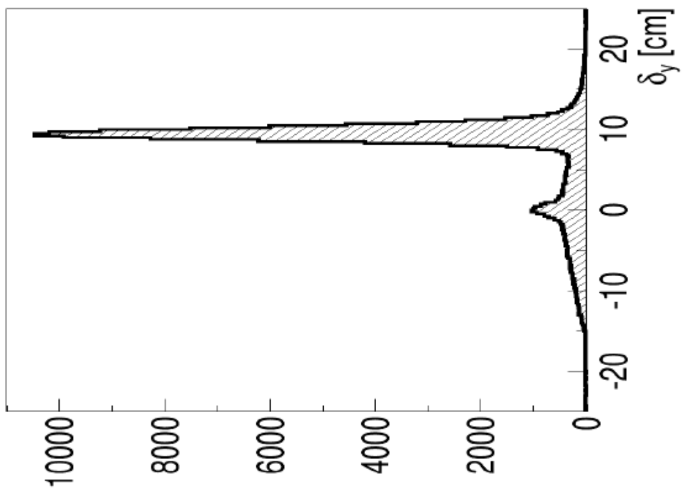


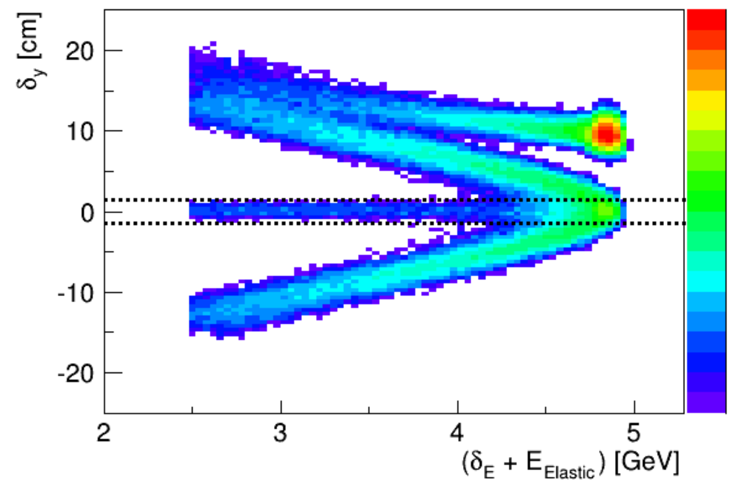
epγ Spectrum



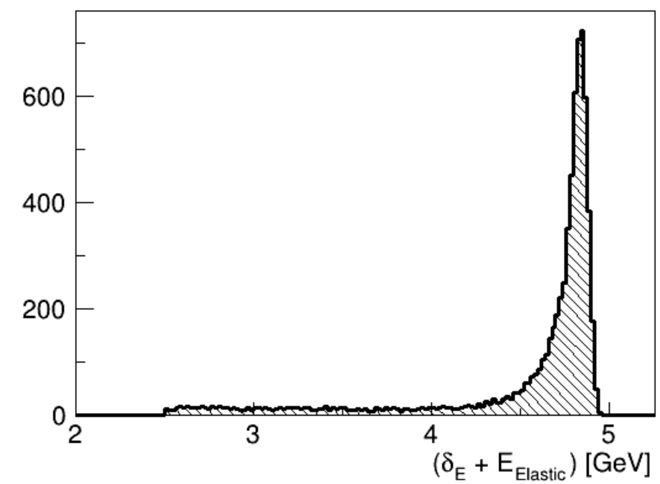
Kin 4C
ep (epγ) Events

Analysis Technique:
Simulated Data for All Events

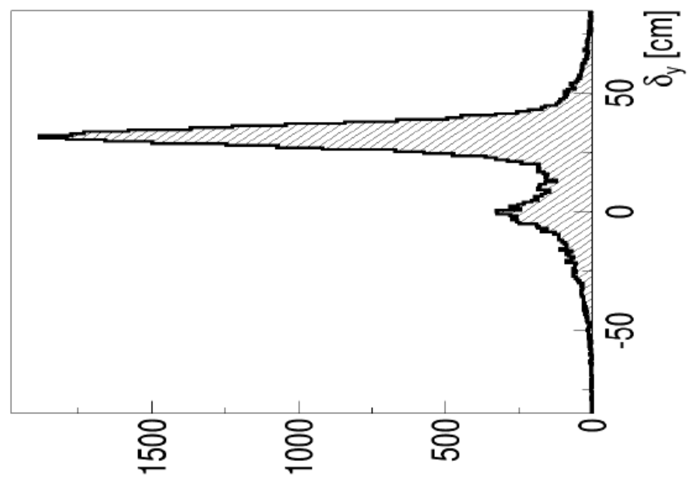


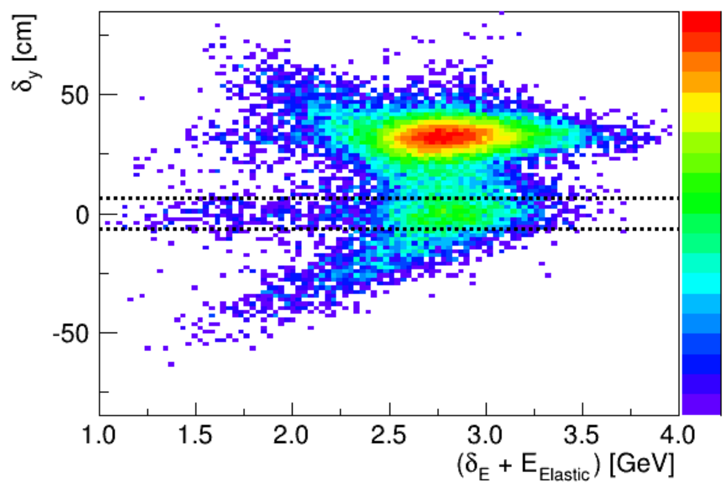


Kin 4C
All Events



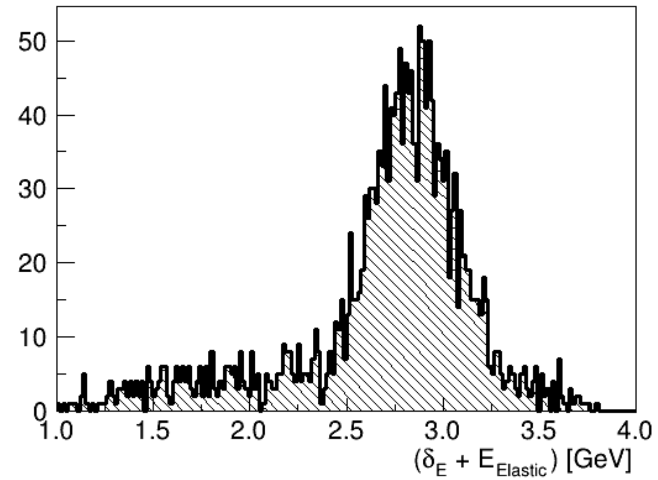
Analysis Technique:
JLab 6 GeV Data from Hall A (2002)



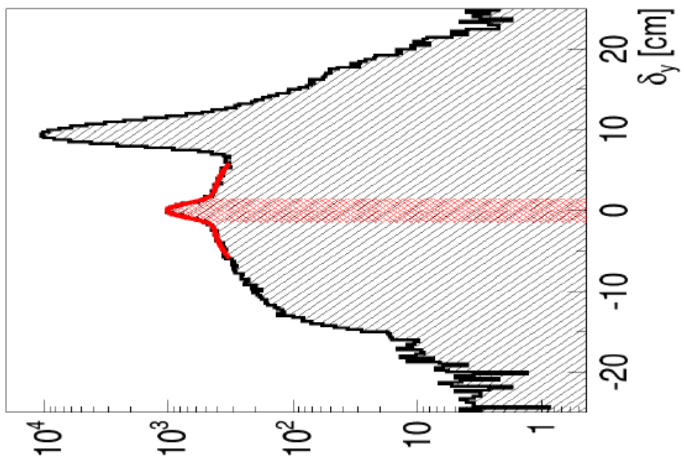


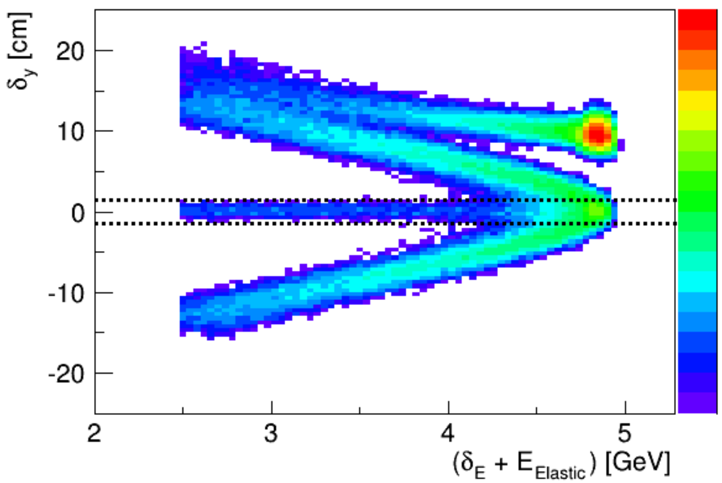
E99-114 Kin 4C

All Events



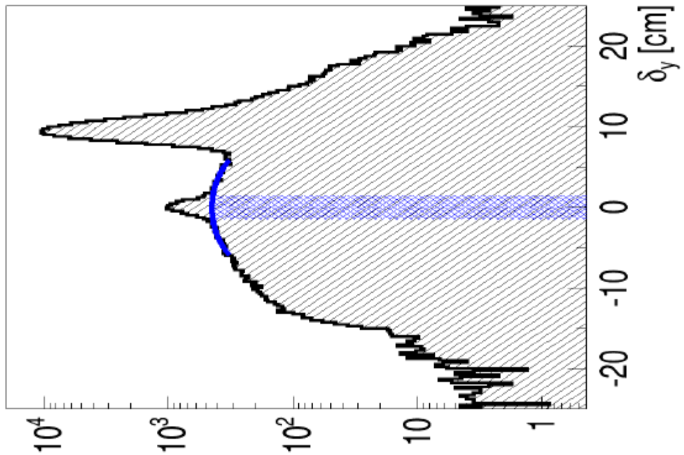
Analysis Technique:
Extract Total Yield

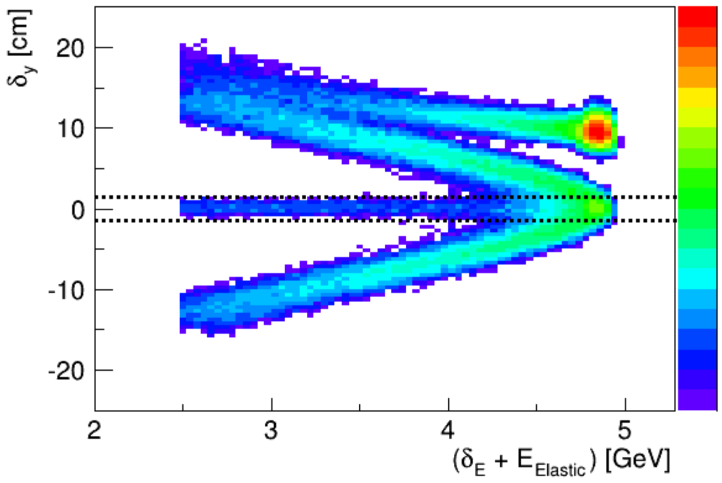




(1) Extract N_{tot} = 9267 ± 96

Analysis Technique: Extract Pion Yield

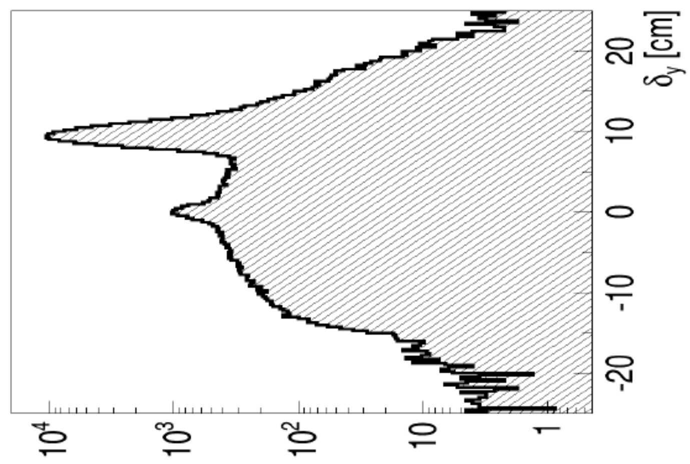


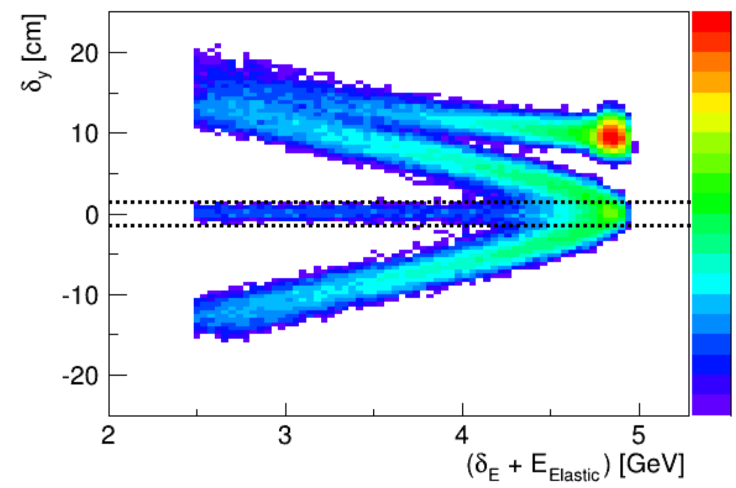


(1) Extract $N_{tot} = 9267 \pm 96$

(2) Extract $R_{\pi^0} = 0.576 \pm 0.010$

Analysis Technique:
Extract epγ Yield

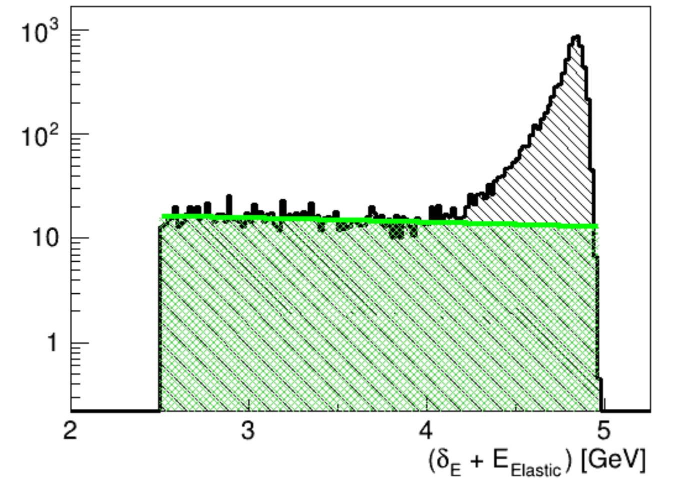




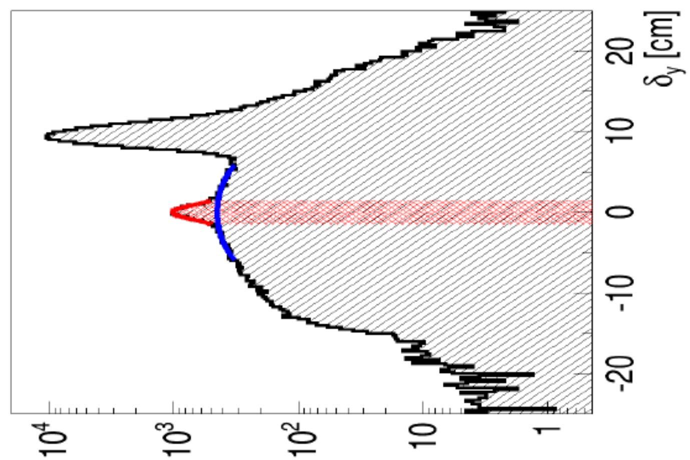
(1) Extract $N_{tot} = 9267 \pm 96$

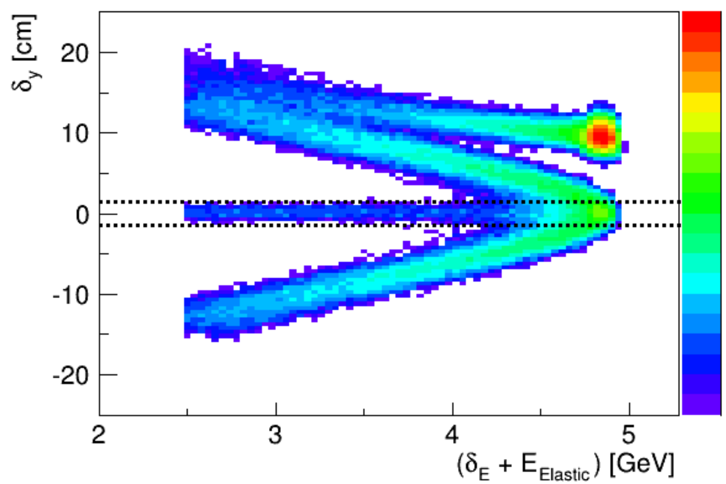
(2) Extract $R_{\pi^0} = 0.576 \pm 0.010$

(3) Extract $R_{ep\gamma} = 0.236 \pm 0.006$



Analysis Technique: Determine Compton Yield





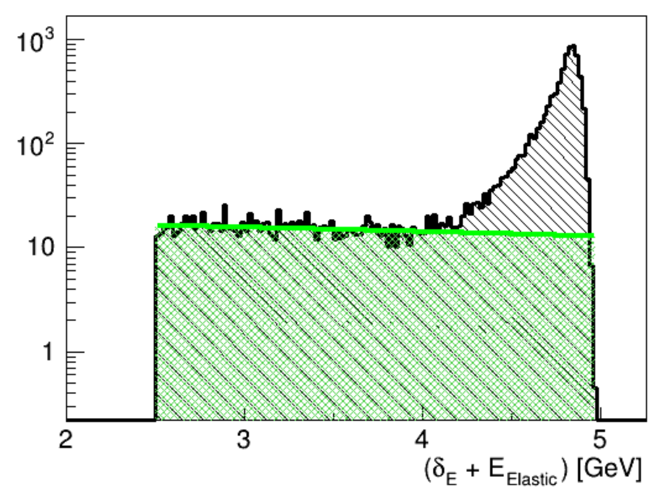
(1) Extract $N_{tot} = 9267 \pm 96$

(2) Extract $R_{\pi^0} = 0.576 \pm 0.010$

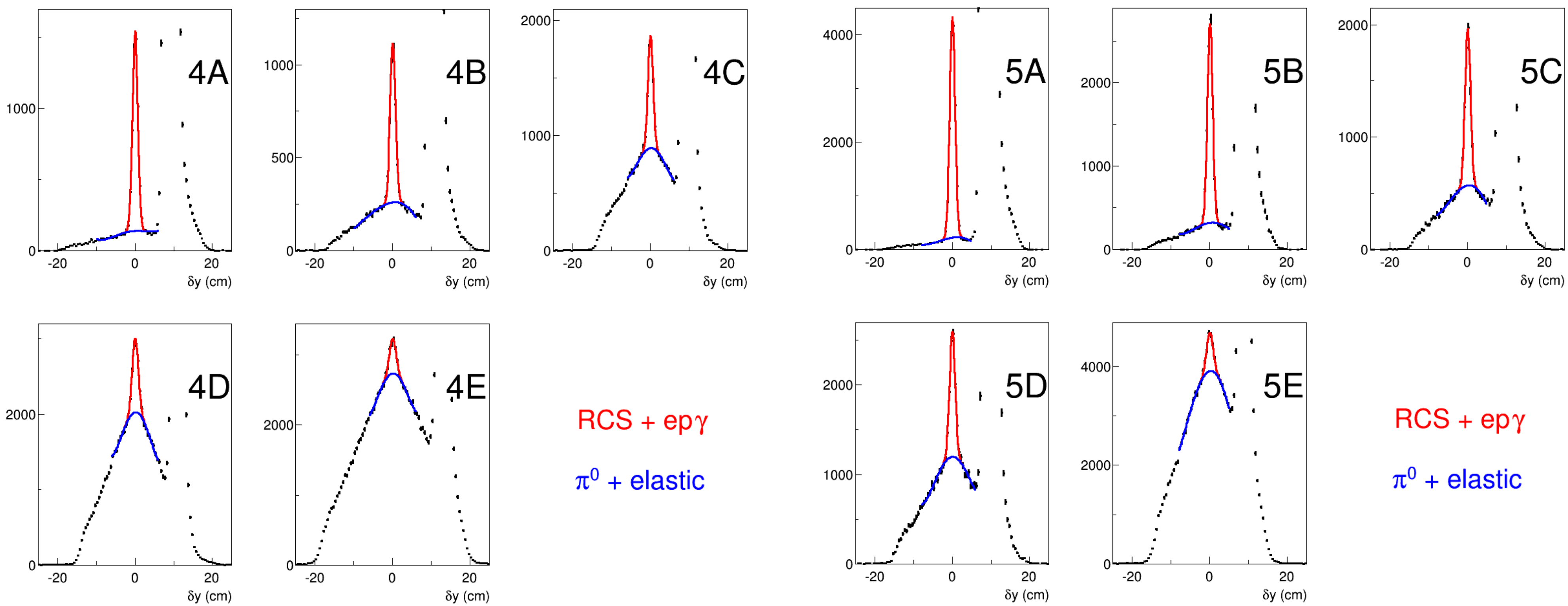
(3) Extract $R_{ep\gamma} = 0.236 \pm 0.006$

(4) $N_{RCS} = N_{tot}(1 - R_{\pi^0} - R_{ep\gamma})$

$N_{RCS} = 1742 \pm 113$ (1800)



Analysis Technique:
All Kinematic Settings



Projected Rates and Uncertainties

- Compton rate projected from MC and extrapolation from data.
- 7 hours per setting for spectrometer move and calibration runs.

cross section solid angle photon flux

$$N_{RCS} = \frac{d\sigma}{dt}_{RCS}\left(\frac{(E_\gamma^f)^2}{\pi}\Delta\Omega_p\frac{d\Omega_\gamma}{d\Omega_p}\right)f_{\gamma p}\left(\frac{\Delta E_\gamma^f}{E_\gamma^f}\frac{t_{rad}}{X_o}\right)\mathcal{L}_{e\vec{p}}$$

	N_{RCS} (/h)	I (μA)	δ_{NRCS}/N_{RCS}	Time (h)
4A	15.0	5	0.05	20+7
4B	6.0	15	0.05	20+7
4C	3.0	30	0.05	20+7
4D	1.5	60	0.05	30+7
4E	0.7	60	0.08	50+7
5A	9.0	20	0.05	15+7
5B	3.0	30	0.05	20+7
5C	1.6	60	0.05	20+7
5D	1.0	60	0.05	40+7
5E	0.3	60	0.08	120+7
Total				**425**

Projected Rates and Uncertainties

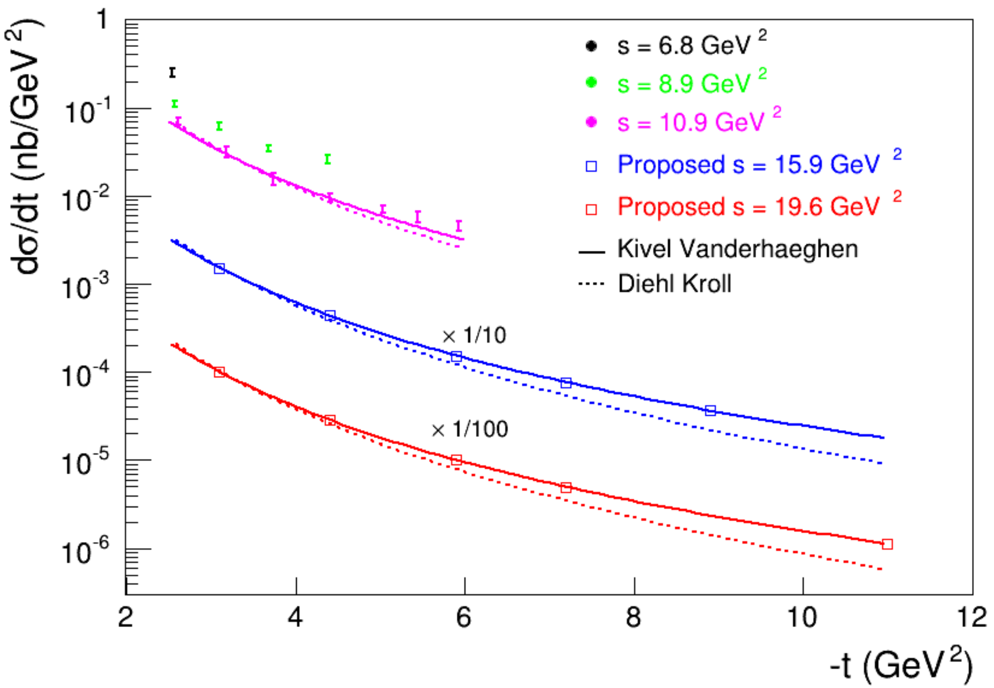
- Compton rate projected from MC and extrapolation from data.
- 7 hours per setting for spectrometer move and calibration runs.
- Total systematic uncertainty is dominated by contributions from incident photon flux determination and background subtractions.

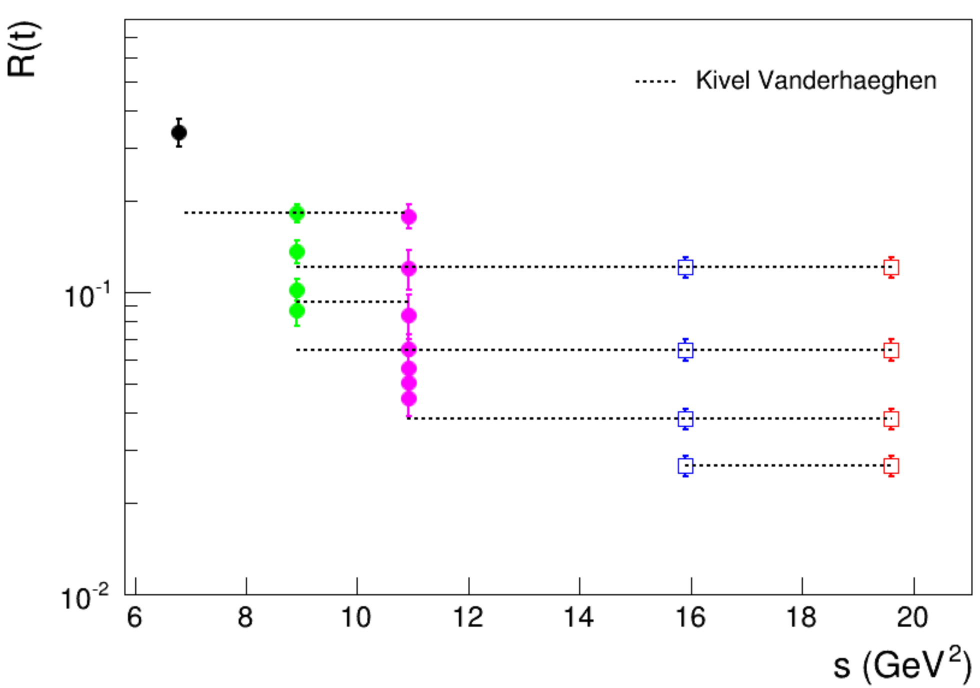
cross section solid angle photon flux

$$N_{RCS} = \frac{d\sigma}{dt}_{RCS}\left(\frac{(E_\gamma^f)^2}{\pi}\Delta\Omega_p\frac{d\Omega_\gamma}{d\Omega_p}\right)f_{\gamma p}\left(\frac{\Delta E_\gamma^f}{E_\gamma^f}\frac{t_{rad}}{X_o}\right)\mathcal{L}_{e\vec{p}}$$

Source	Uncertainty (%)
Beam Charge	1.0
Target Thickness	1.0
Photon Flux	3.0
NPS Detection Efficiency	1.5
HMS Acceptance	1.5
HMS Tracking Efficiency	1.5
Pion Background Subtraction	3.0
epγ Background Subtraction	3.0
Total	**6.0**

Expected Results





All kinematic settings unambiguously satisfy the wide-angle condition that $s, -t, -u \gg m_p^2$

Four fixed -t scans, three of which overlap with 6 GeV data, will allow for a rigorous test of factorization.