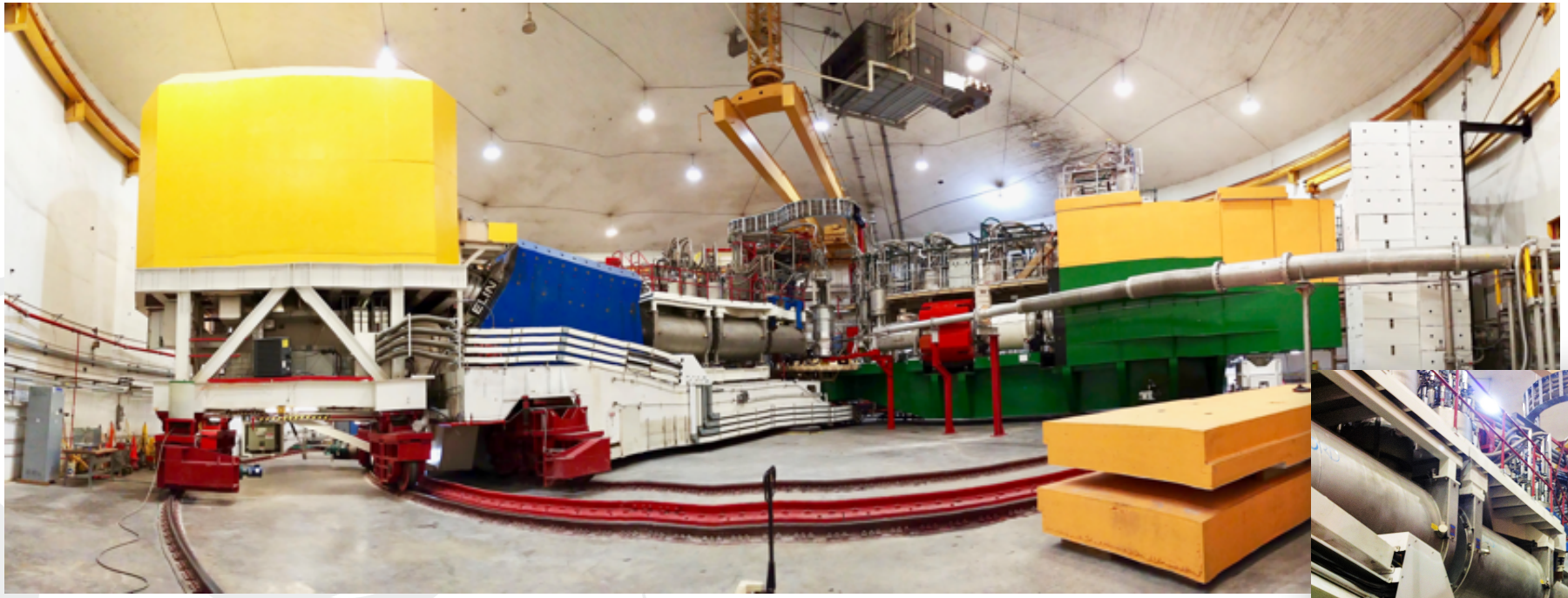
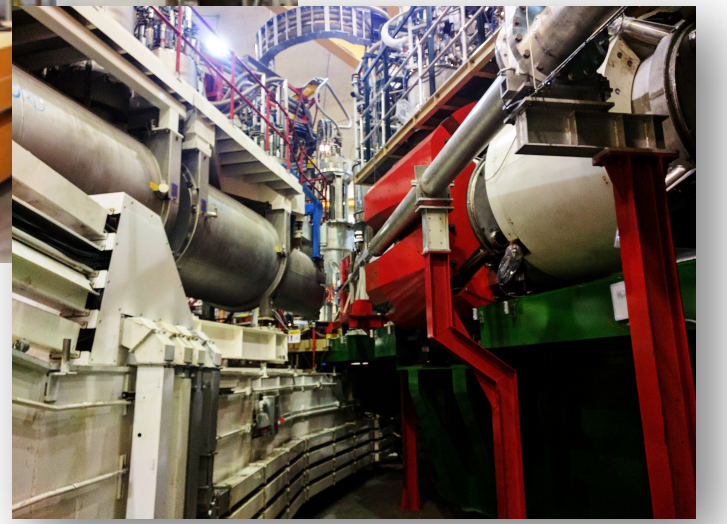
Searching for the Onset of Color Transparency in Jefferson Lab Hall C





Holly Szumila-Vance

On behalf of the Hall C Collaboration at Jefferson Lab

Wednesday, May 30 2018

Jefferson Lab

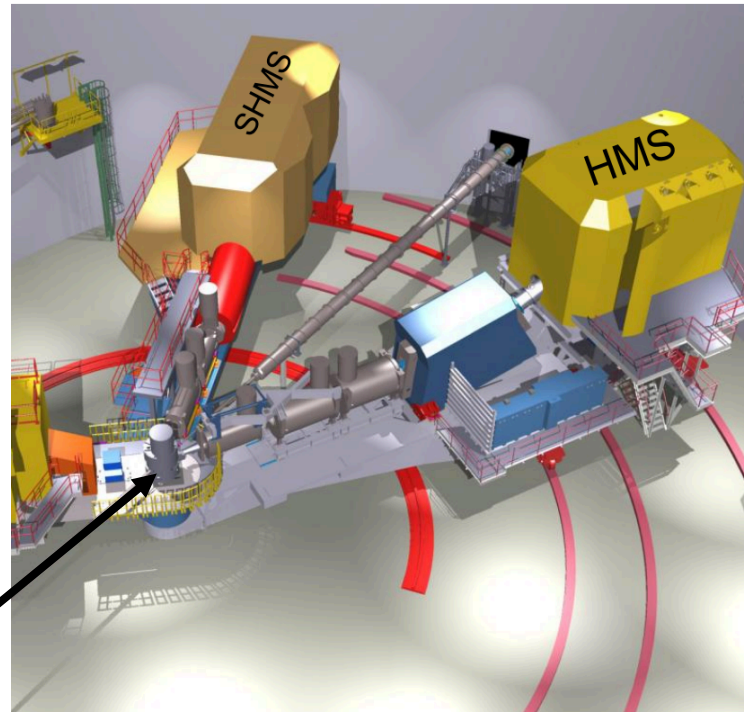
U.S. DEPARTMENT OF ENERGY | Office of Science

JSA

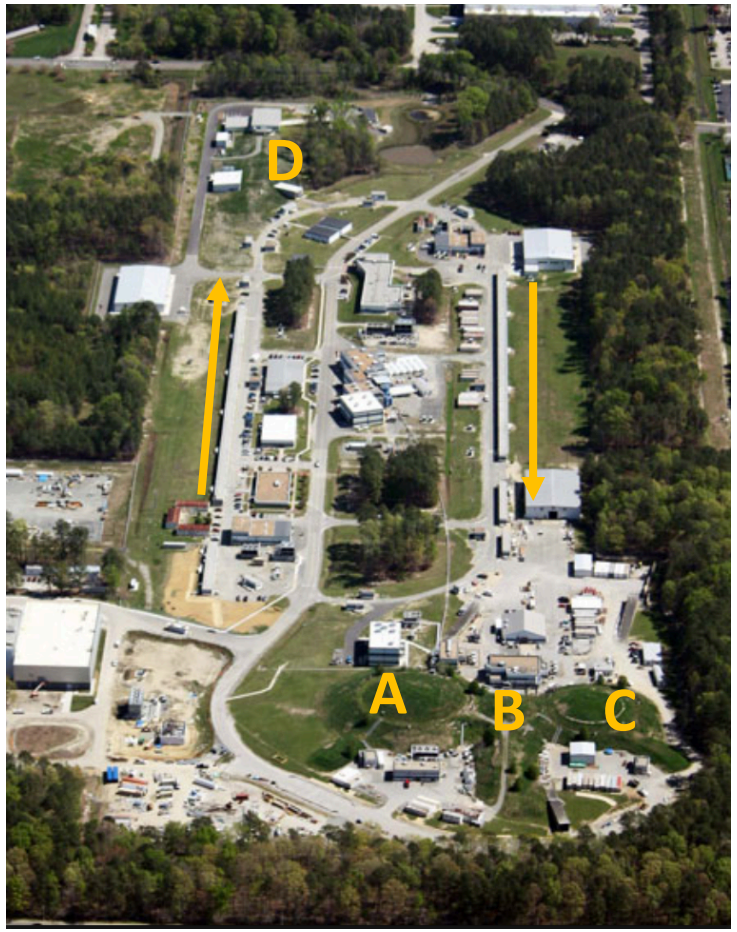
Overview

- Motivation
- Experiment
  - Jefferson Lab and Hall C
  - Commissioning the Super High Momentum Spectrometer (SHMS)
  - Performance
  - Current status
- Summary

Hall C

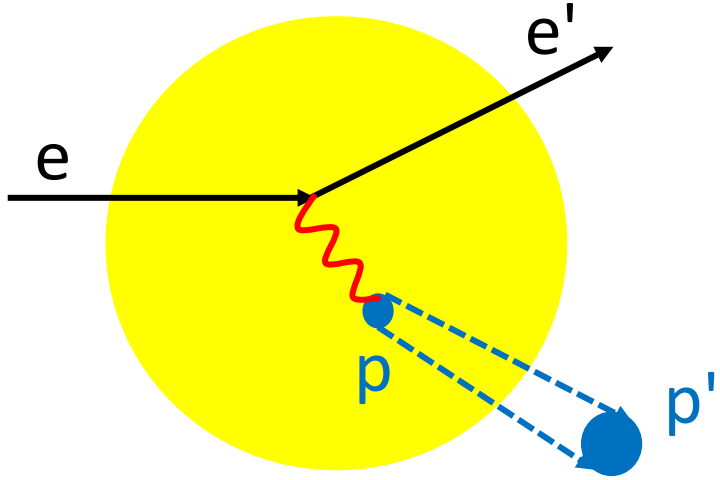


Jefferson Lab (Newport News, VA)
e- accelerator



Color Transparency (CT)

- CT: The disappearance of the final/initial state interaction of hadrons with the nuclear medium for exclusive processes at high momentum transfer

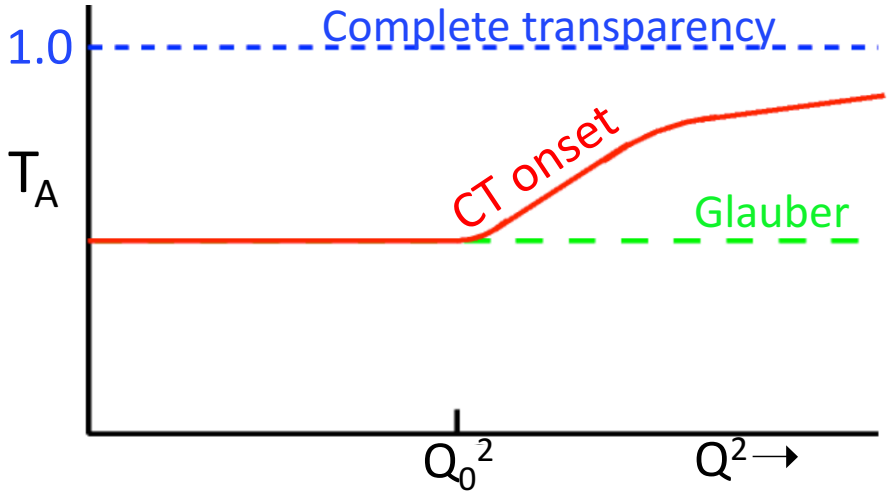


- Not predicted by strongly interacting hadronic picture → arises in picture of quark-gluon interactions
  - QCD: color field of singlet objects vanishes as size is reduced

- Signature for the onset of CT involves rise in nuclear transparency, T_A, as a function of the momentum transfer, Q^2

$$T_A = \frac{\sigma_A}{A\,\sigma_N}$$

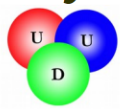
(σ_A: nuclear cross section; σ_N: free nucleon cross section)



Previous Measurements

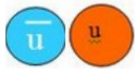
CT experiments

Baryon



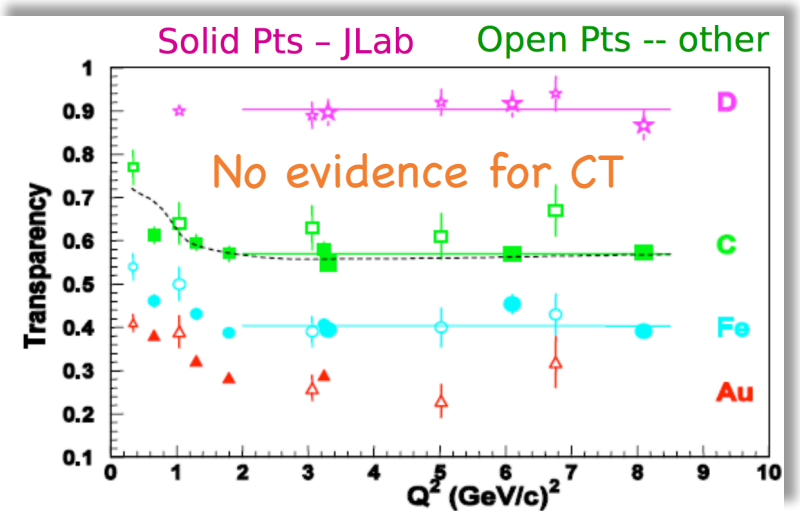
A(p,2p): BNL
A(e,e'p): SLAC, JLab

Meson

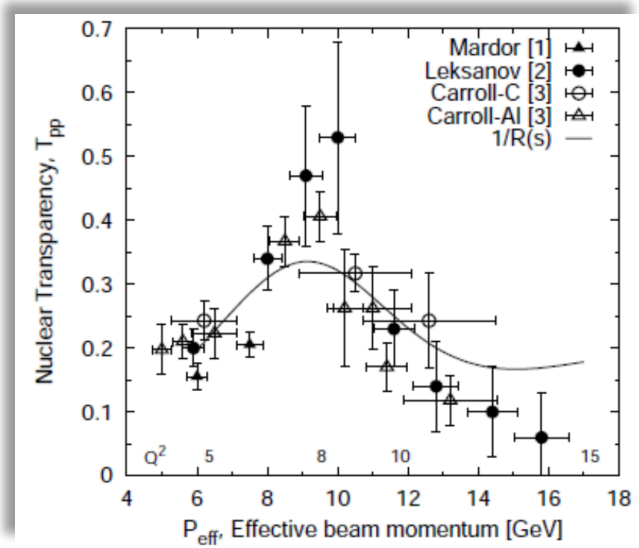


A(π,di-jet): FNAL
A(γ, π^- p): Jlab
A(e, e'π^+): JLab
A(e, e'ρ^0): DESY & JLab

- CT well established at high energies (essential for DIS)
- Onset of CT has been measured in mesons but not in baryons
- Onset is signature for QCD degrees of freedom in nuclei



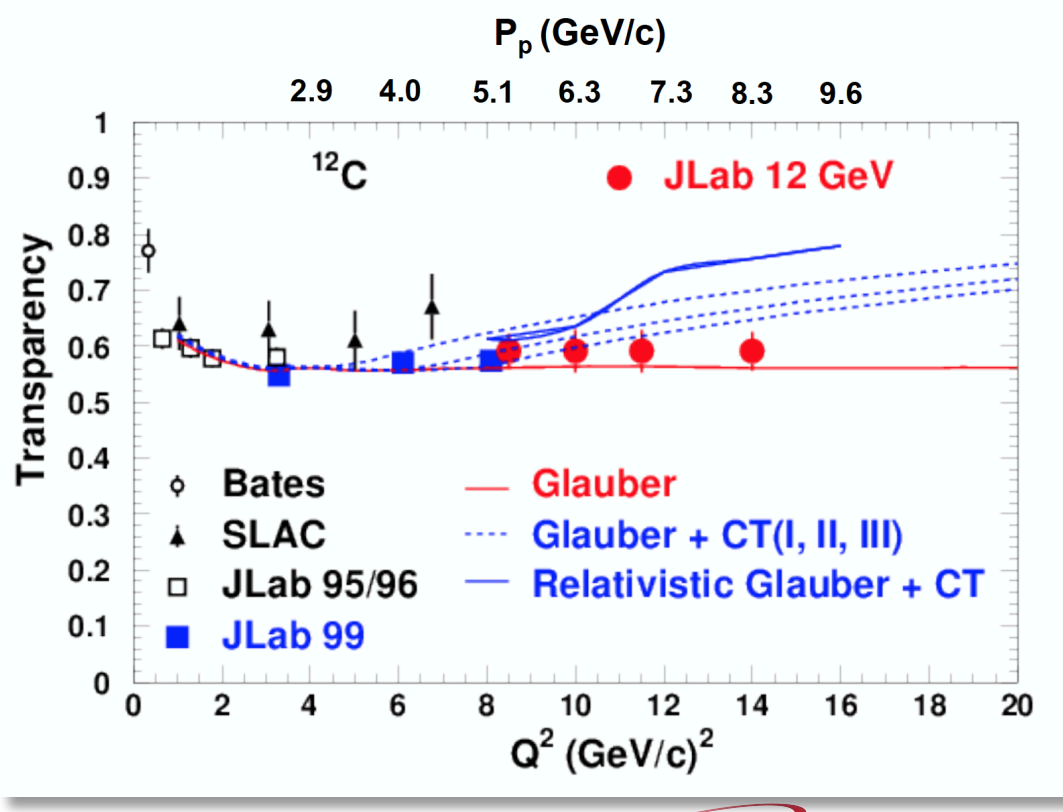
N. C. R. Makins et al. PRL 72, 1986 (1994)
G. Garino et al. PRC 45, 780 (1992)
D. Abbott et al. PRL 80, 5072 (1998)
K. Garrow et al. PRC 66, 044613 (2002)



A. Leksanov et al. PRL 87 (2001)
J. L. S. Aclander et al., PRC 70 (2004)

Found enhancement in transparency
->Inconsistent with CT only

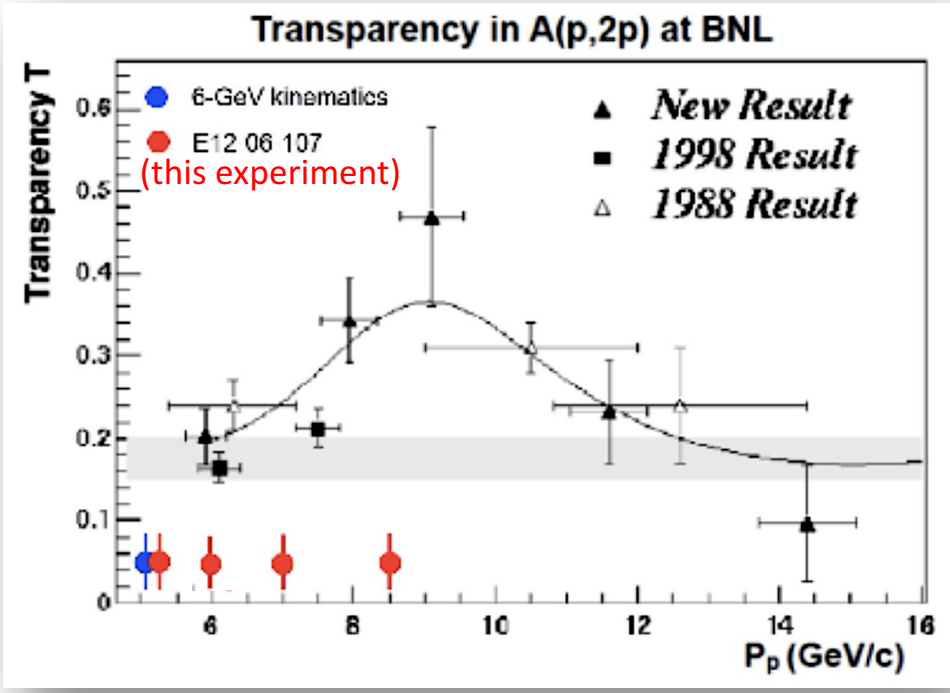
Measuring the onset in 12 GeV era:



Experiment overview: First experiment to run in Hall C in the 12 GeV era!

- Coincidence trigger: SHMS measures protons, HMS measures electrons
- Targets: 10 cm LH_2 (Hee'p check), 6% ^{12}C (production), Al dummy (background)

	Q^2 [GeV^2]	SHMS angle [deg]	SHMS central P [GeV/c]	HMS angle [deg]	HMS central P [GeV/c]
6.4 GeV beam	8.0	17.1	5.122	45.1	2.131
10.6 GeV beam	9.5	21.6	5.925	23.2	5.539
	11.5	17.8	7.001	28.5	4.478
	14.3	12.8	8.505	39.3	2.982



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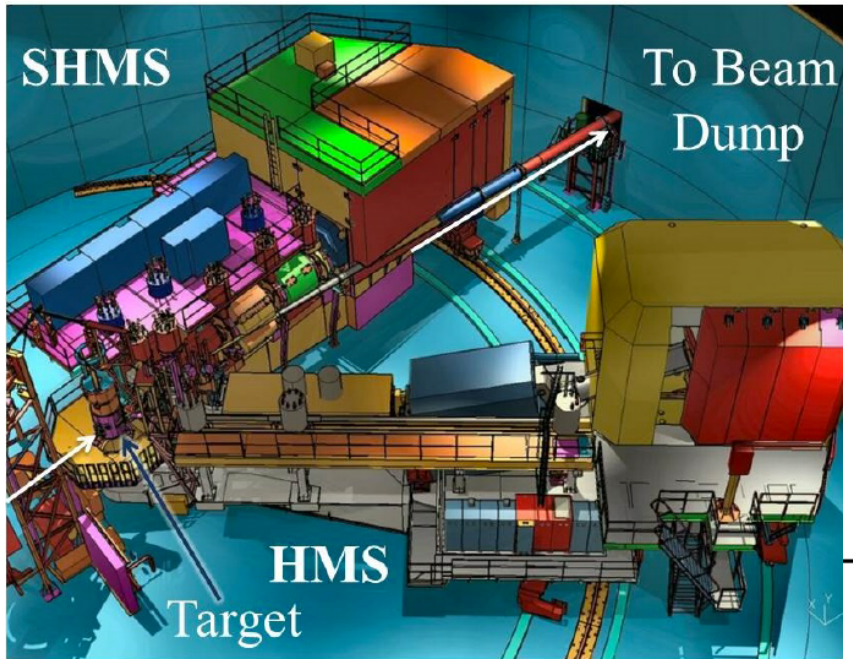
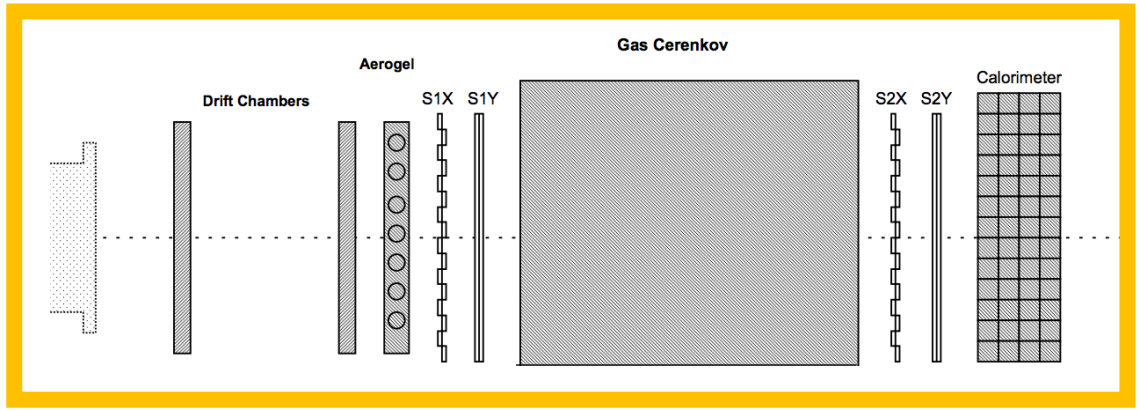
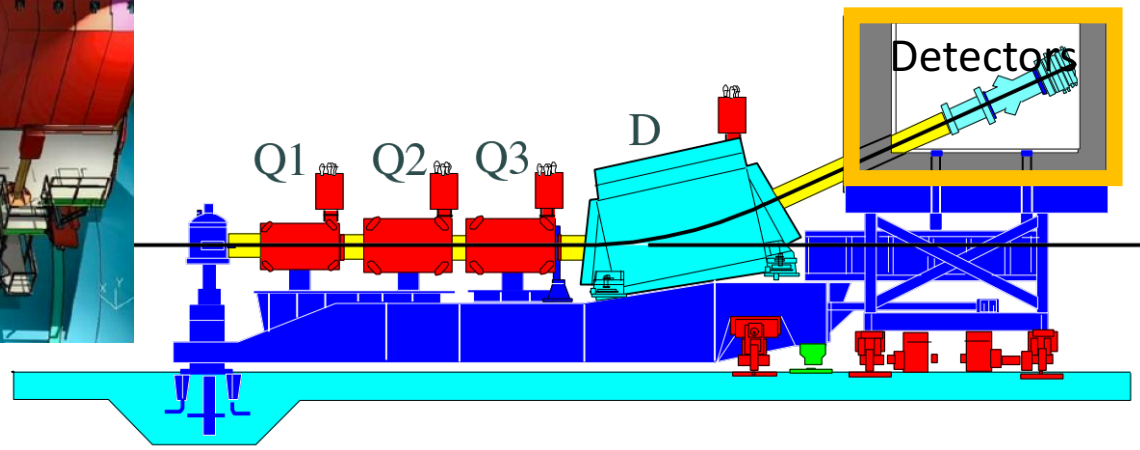
Hall C (viewed from above)







HMS Characteristics:

- <0.1% dP/P resolution
- >6 mSr Acceptance
- 0.5 to 7.5 GeV/c
- 12.5 deg to 90 deg

SHMS Overview

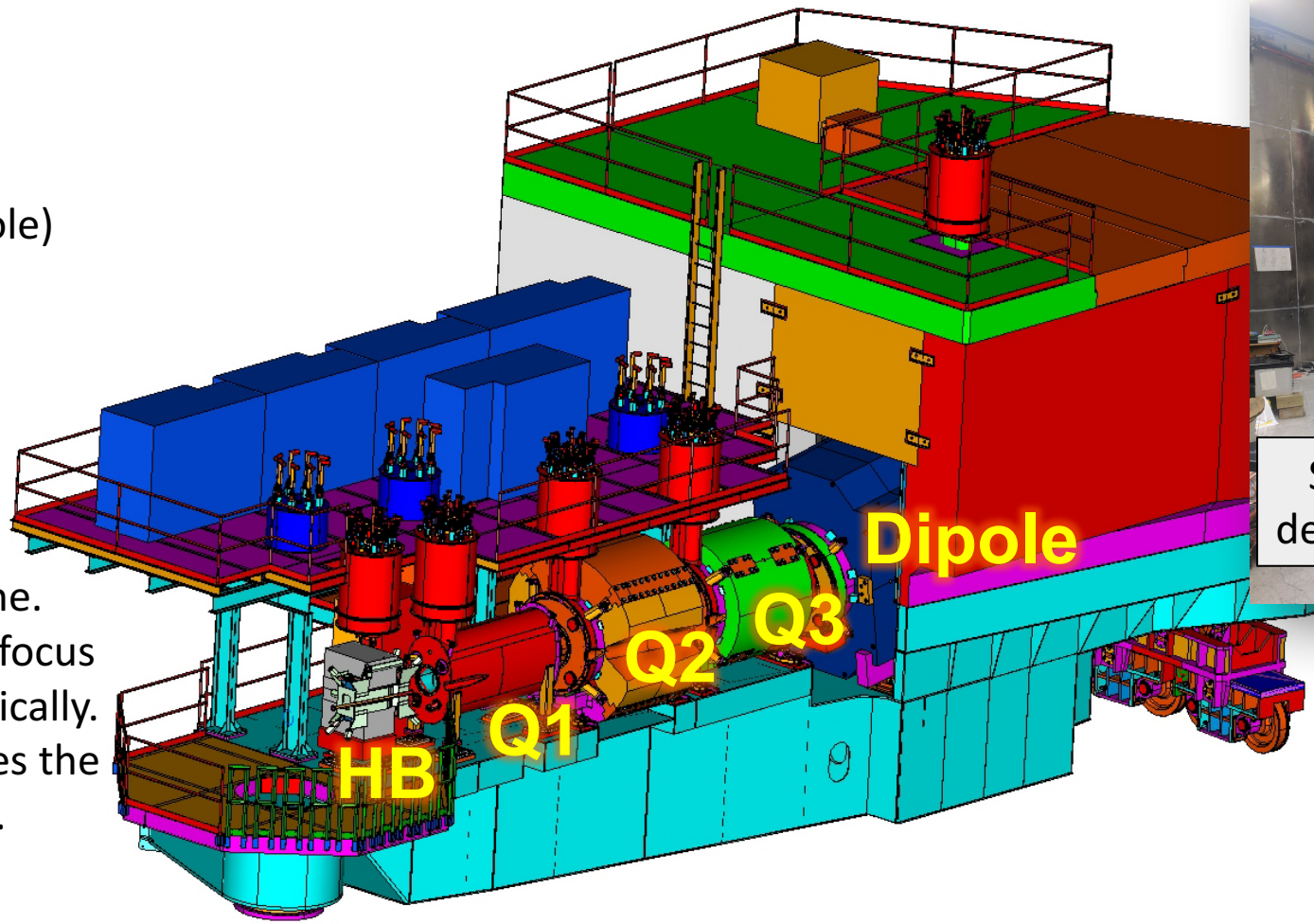
General Characteristics:

- 5 x 10^{-4} dP/P resolution
- 4 mSr Acceptance
- 1 to 11 GeV/c
- 5.5 deg to 40 deg
- 18.4 degree vertical bend (dipole)

Components:

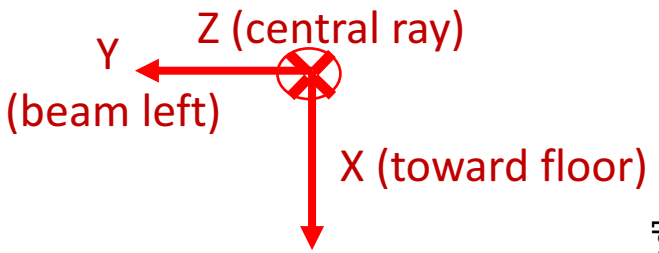
- **Horizontal Bender** (HB, dipole) steers the beam 3 degrees horizontally into SHMS beamline.
- **Q1, Q2**, and **Q3** (quadrupoles) focus the beam horizontally and vertically.
- **Spectrometer** (dipole) separates the beam vertically by momentum.

Super High Momentum Spectrometer (SHMS)



Tuning the SHMS

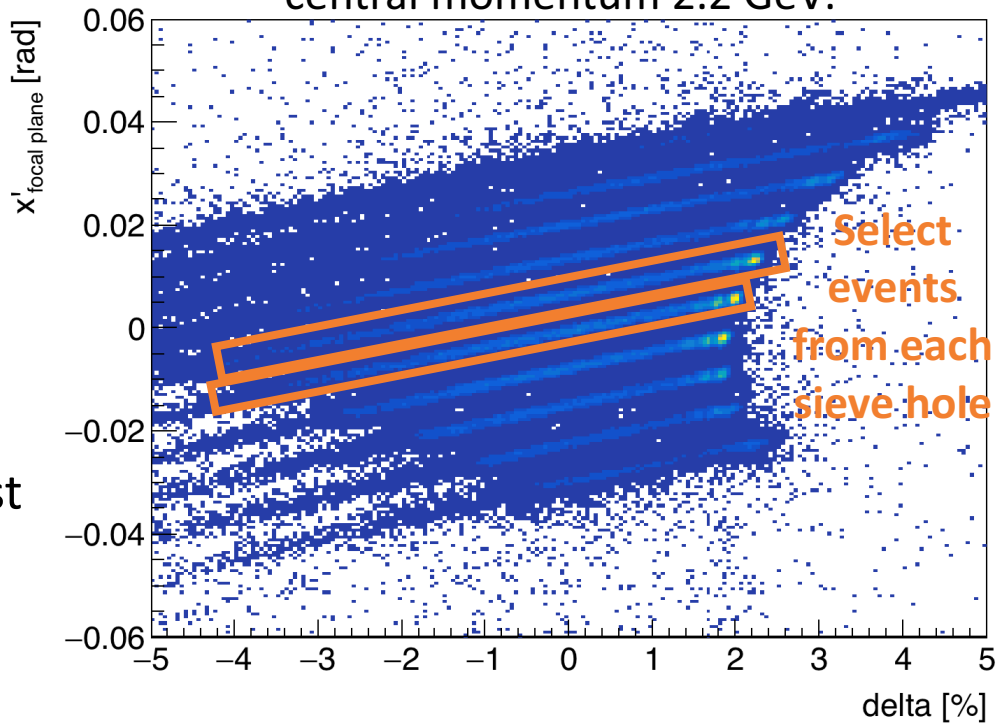
Spectrometer coordinate system:

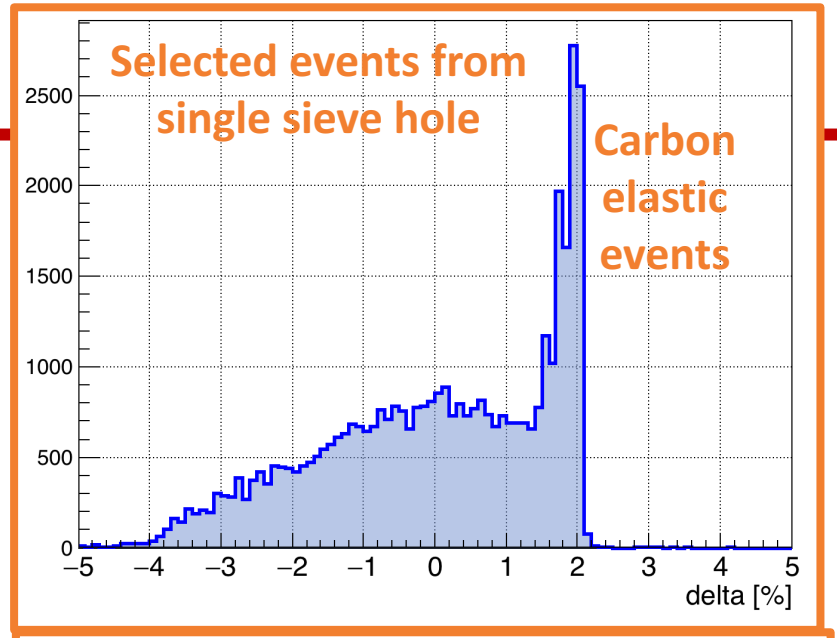


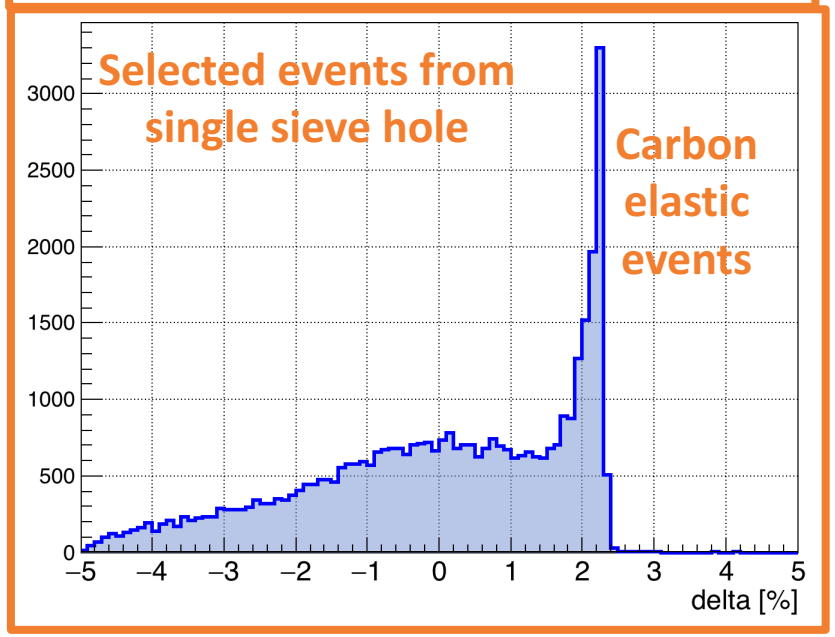
Goal: Adjust strengths of quads to find best focus

Events: Select carbon ground and excited states for cleanest focal plane distributions

SHMS at 7.5 degrees
central momentum 2.2 GeV:

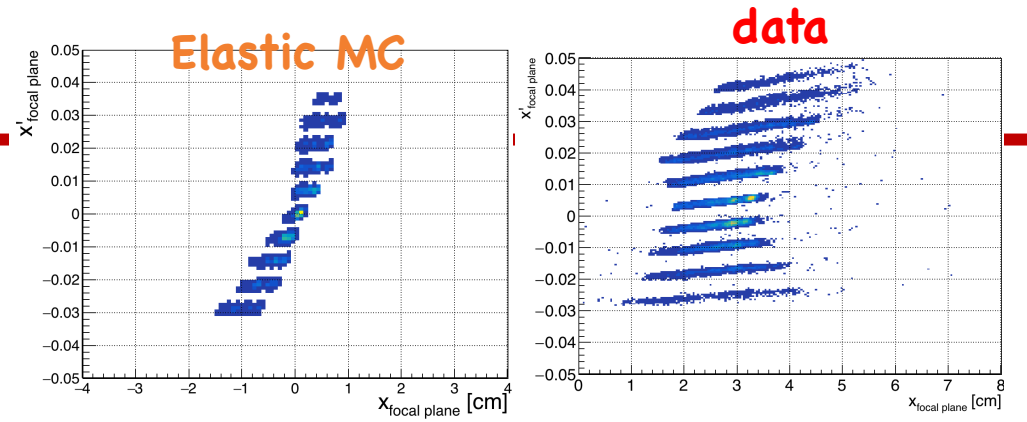


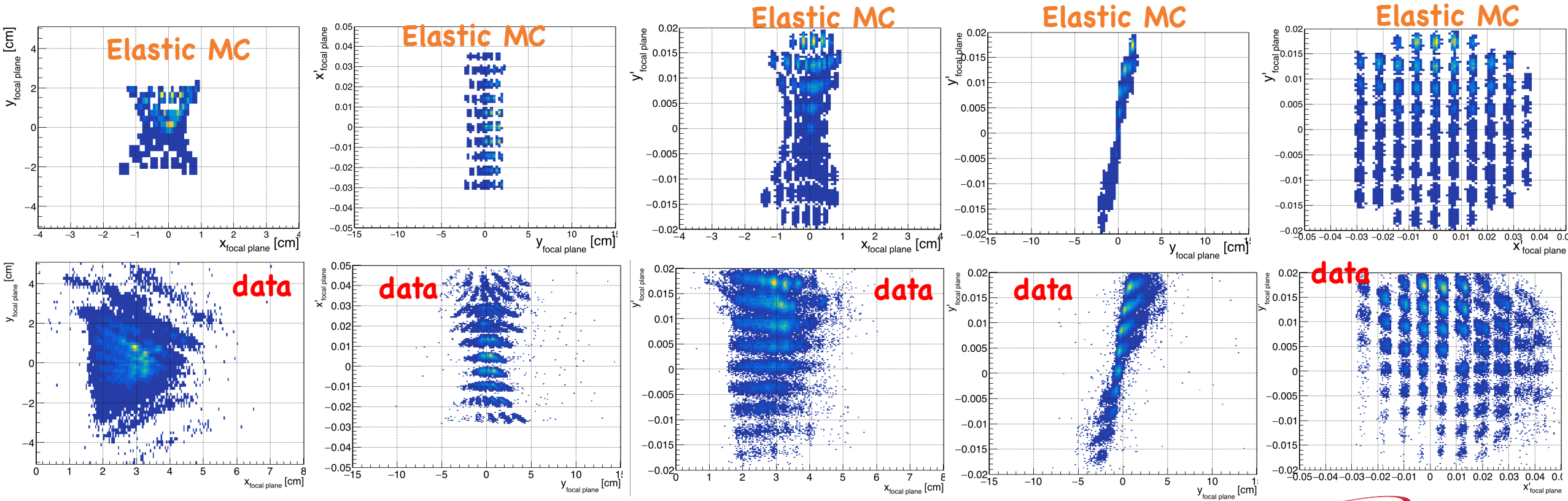




Tuning the SHMS

- Simulate all possible quad strength permutations
- Interpret the focal plane distributions
- Adjust until setting is closest to MC
- Shown here is for final setting of Q1 3% high, Q2 4% high, Q3 3% high

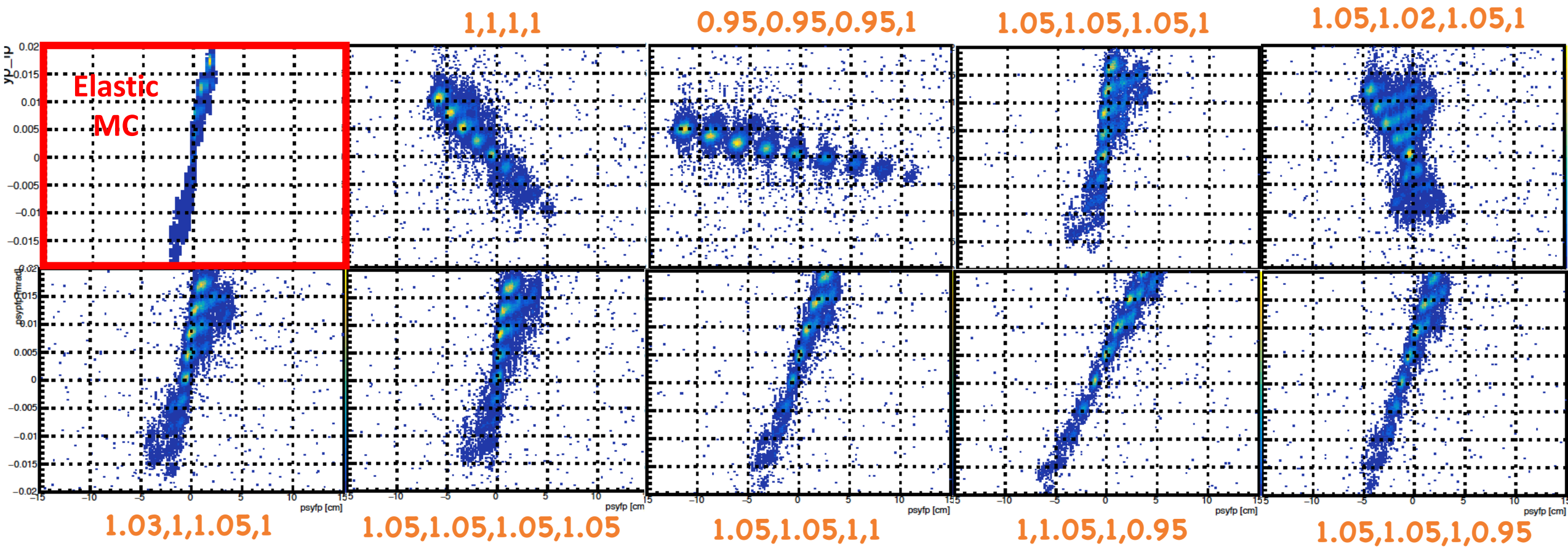




Tuning the SHMS

Scaling key:
Q1,Q2,Q3,HB

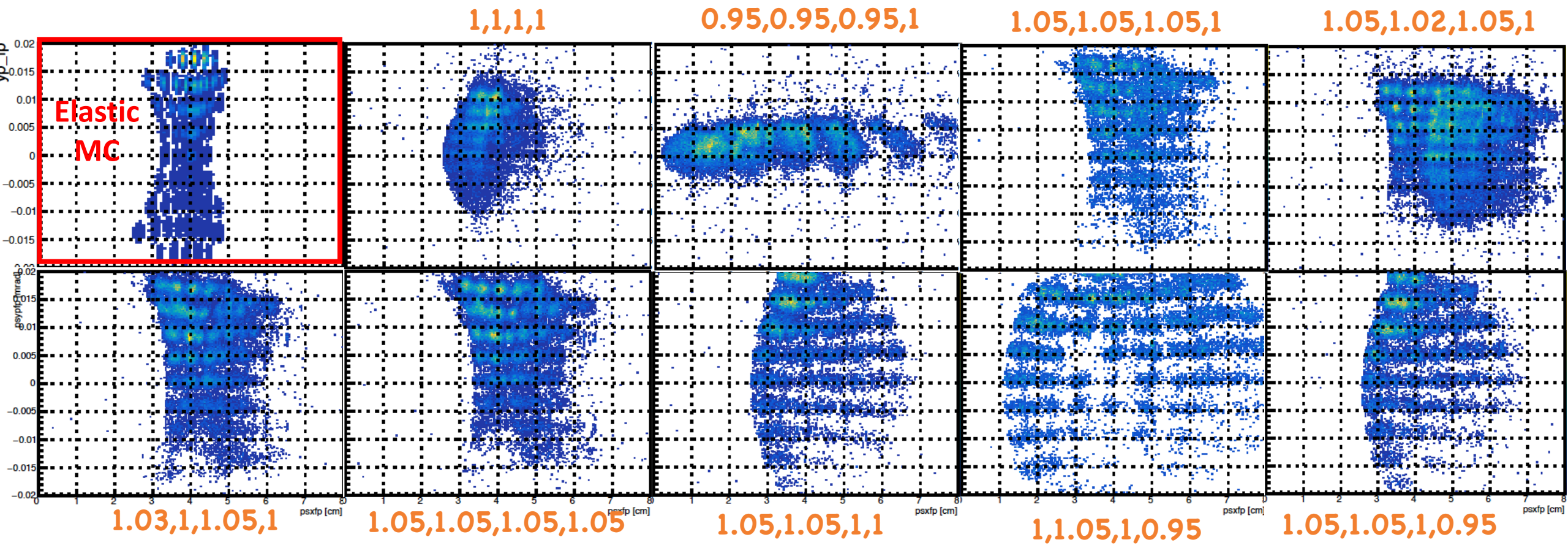
Shown here is just **y' vs y** (focal plane) for runs taken with SHMS at 10 deg:



Tuning the SHMS

Scaling key:
Q1,Q2,Q3,HB

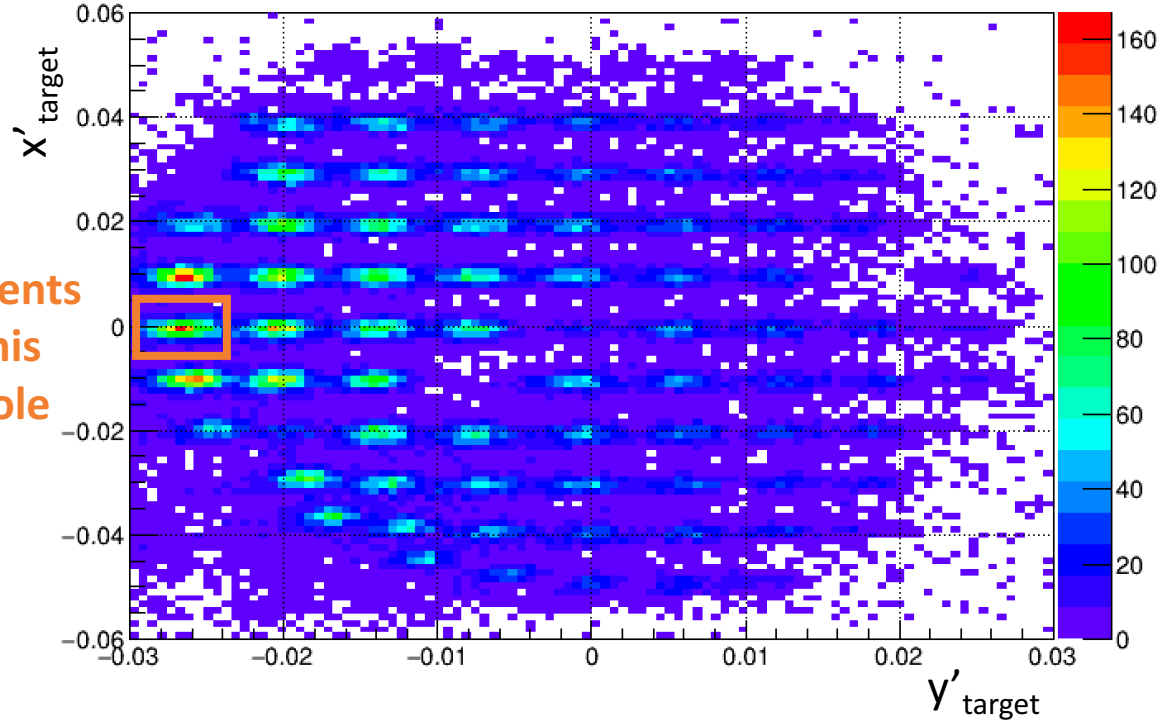
Shown here is just **y' vs x** (focal plane) for runs taken with SHMS at 10 deg:

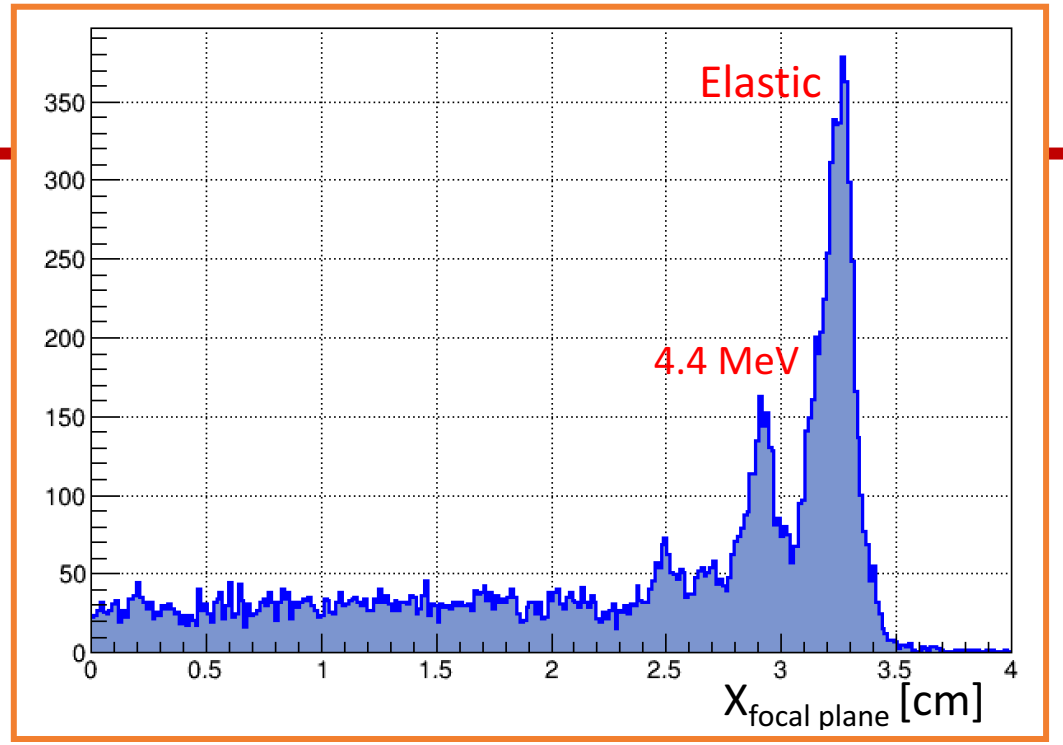


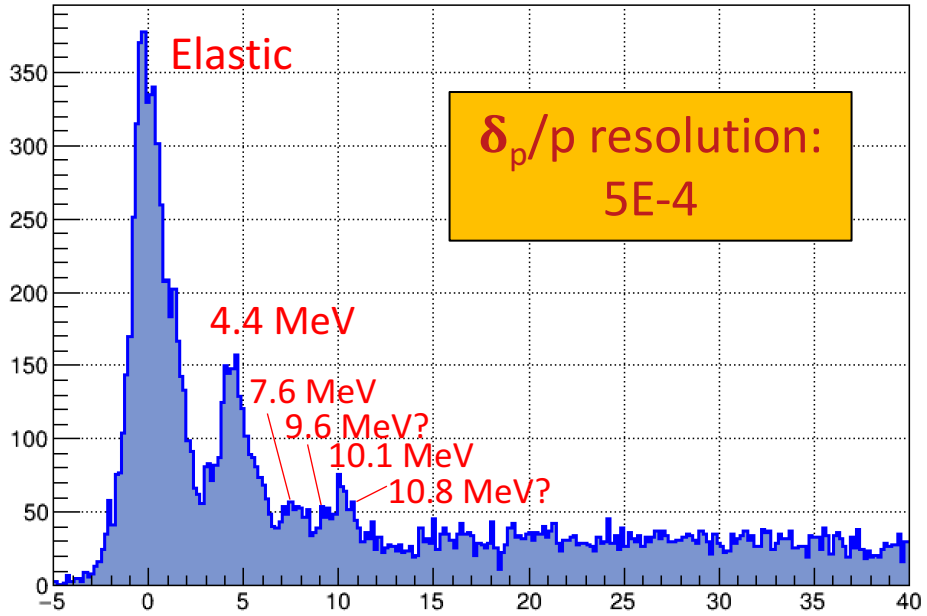
Carbon elastics

SHMS at 7.5 degrees, central momentum 2.214 GeV

Select events from this sieve hole







From the focal plane and target quantities, we know delta according to the first order optics matrix elements:

$$
\begin{aligned}
xfp(mm) &= -1.38 * xtar(mm) - 0.004 * xptar(mr) + 16.5 * delta \\
xpfp(mr) &= -.0602 * xtar(mm) - .72 * xptar(mr) + 3.2 * delta \\
yfp(mm) &= -1.6 * ytar(mm) - 0.03 * yptar(mr) - 1.5 * delta \\
ypfp(mr) &= -.268 * ytar(mm) - 0.61 * yptar(mr) + 0.074 * delta
\end{aligned}
$$

Jefferson Lab

Coincidence timing: relative time difference between e- and p at the target

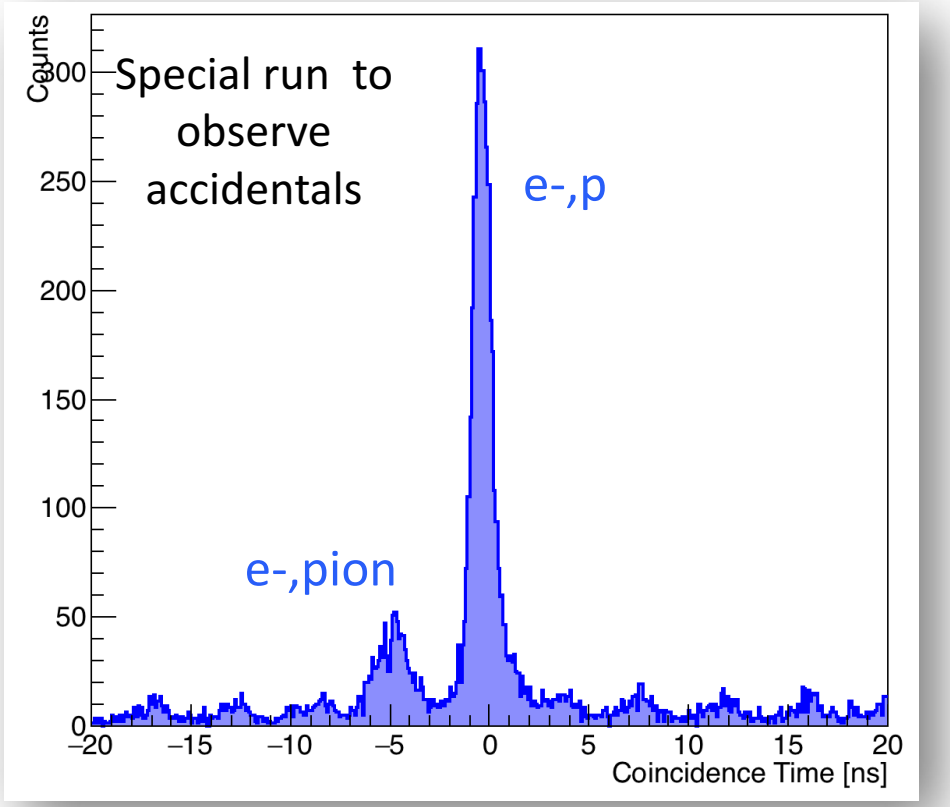
General coincidence time: $t_{coin} = t_e^{tar} - t_p^{tar}$

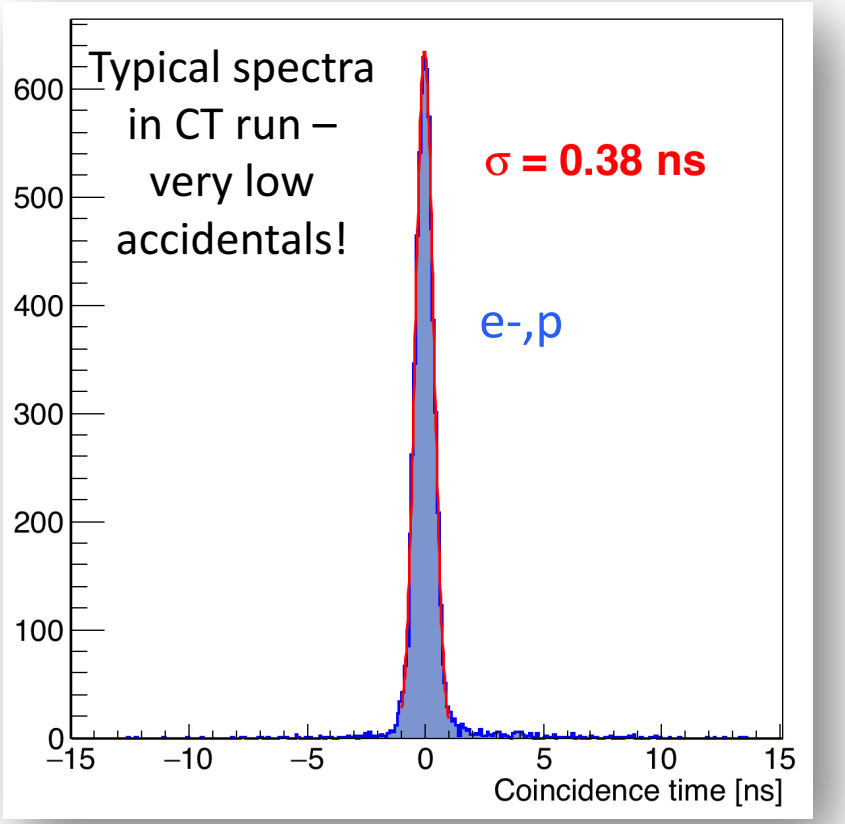
The time of each particle: $t_{e,p}^{tar} = (t_{e,p}^{trigger} - \Delta t_{e,p}^{corr})$

Each particle time corrected for:

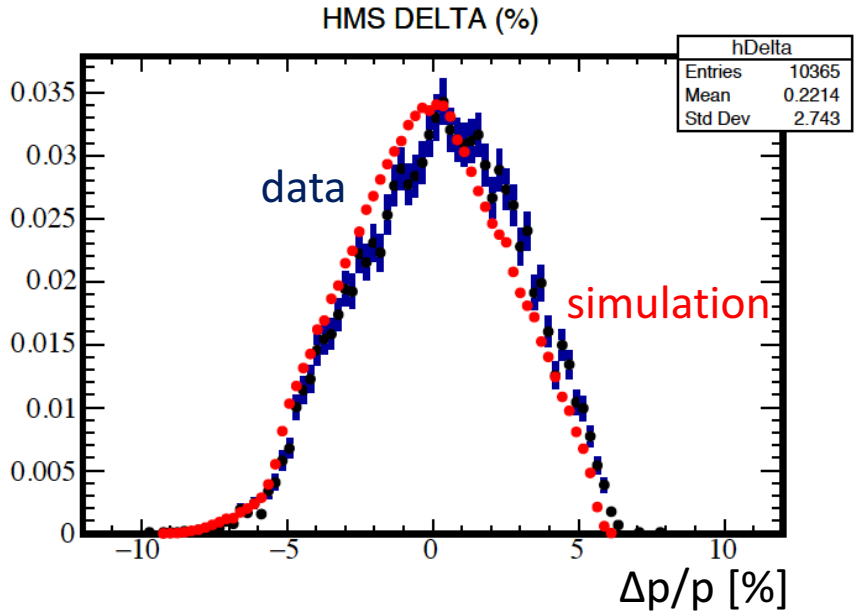
- Particle traveling along central ray to focal plane
- Path length variations
- Difference in time between hodoscope start and focal plane time

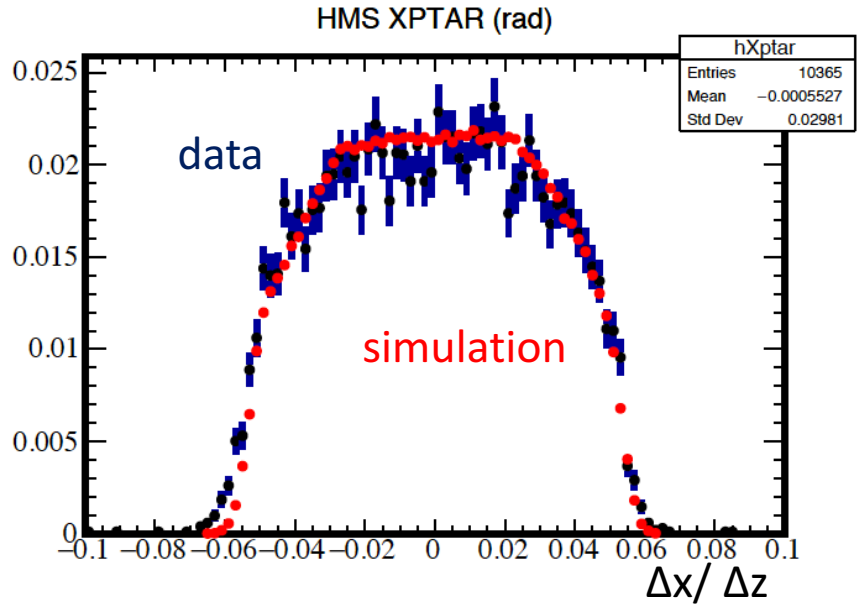
Coincidence time spectra:

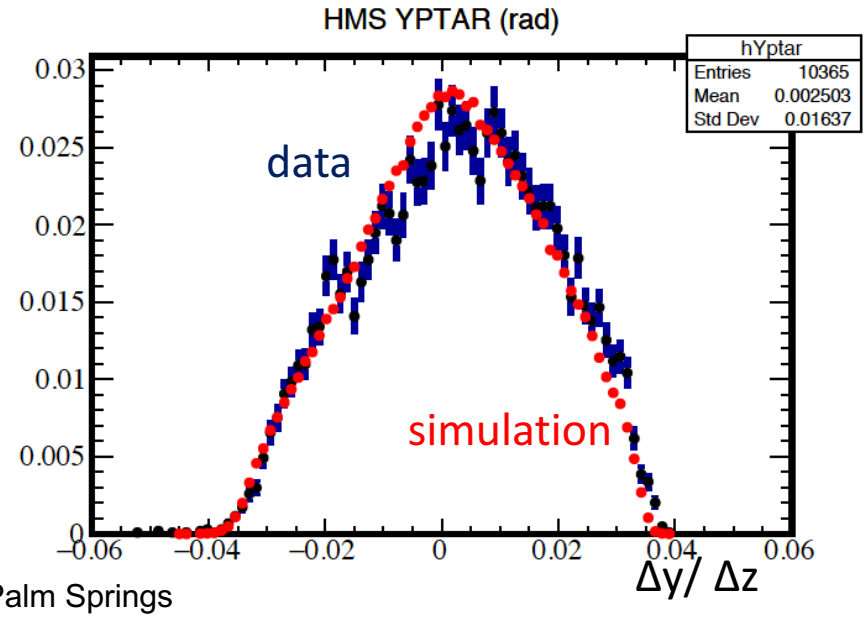


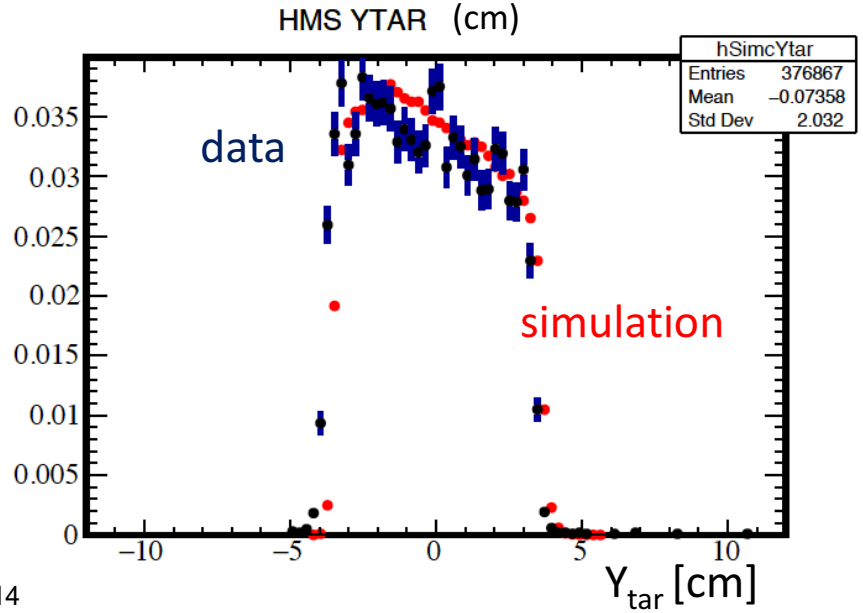


Hydrogen HMS data: Q^2 = 8 GeV^2









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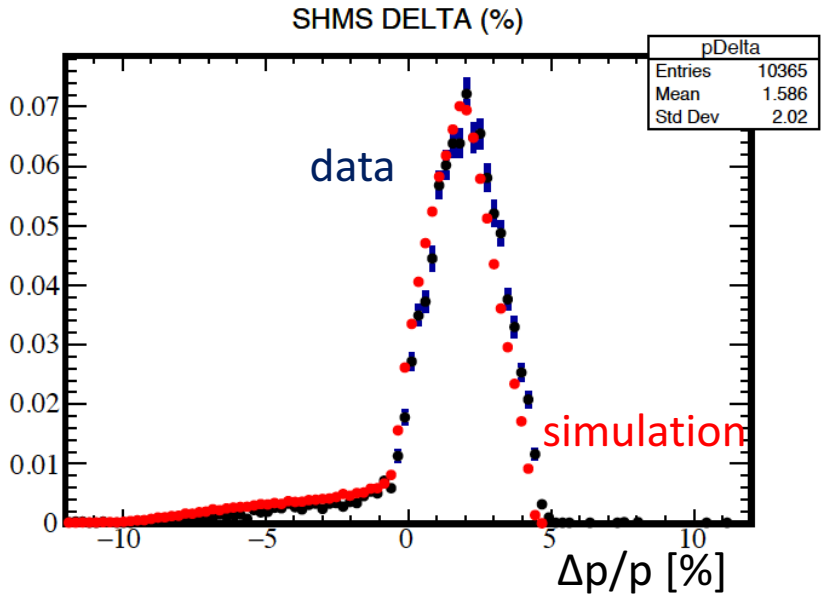
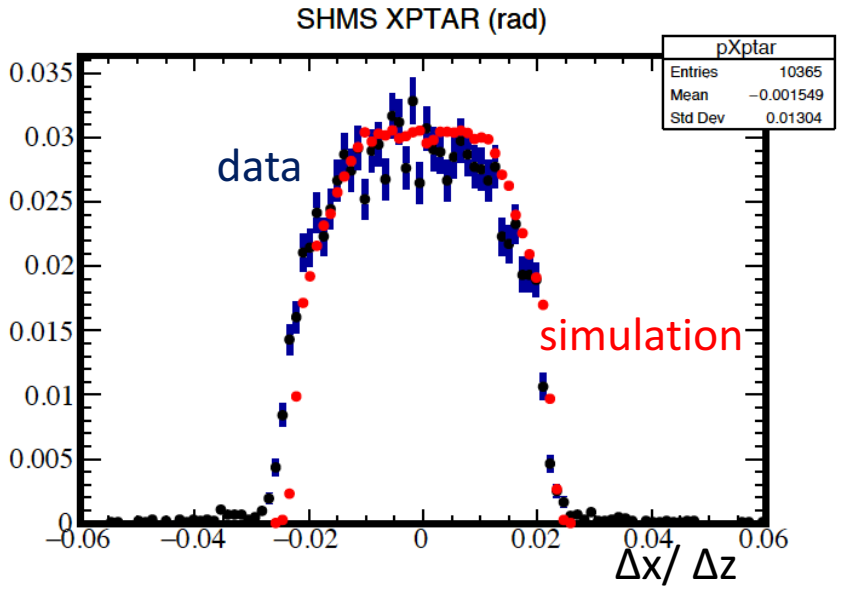
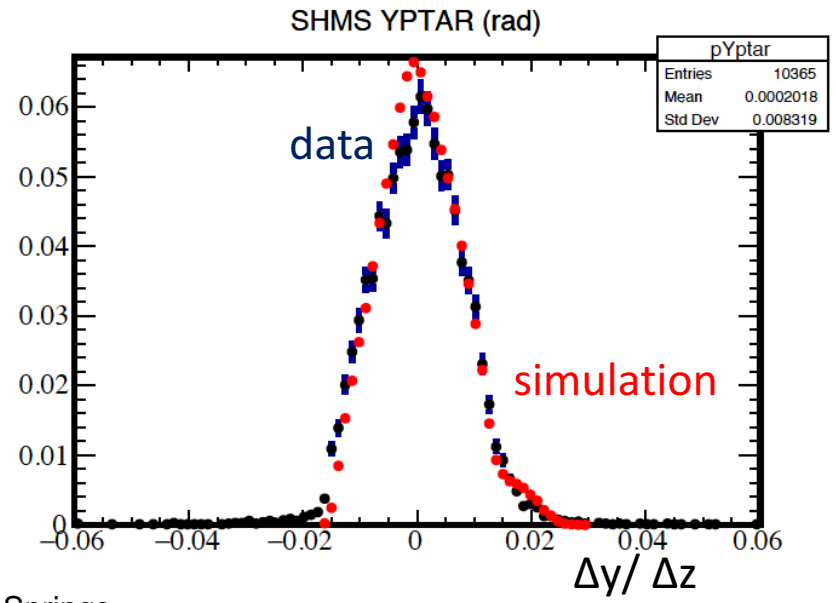
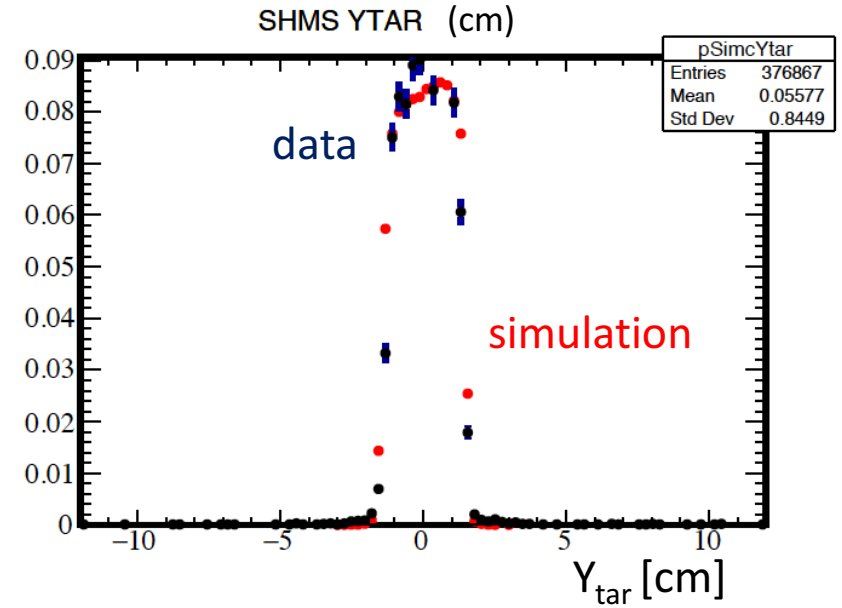


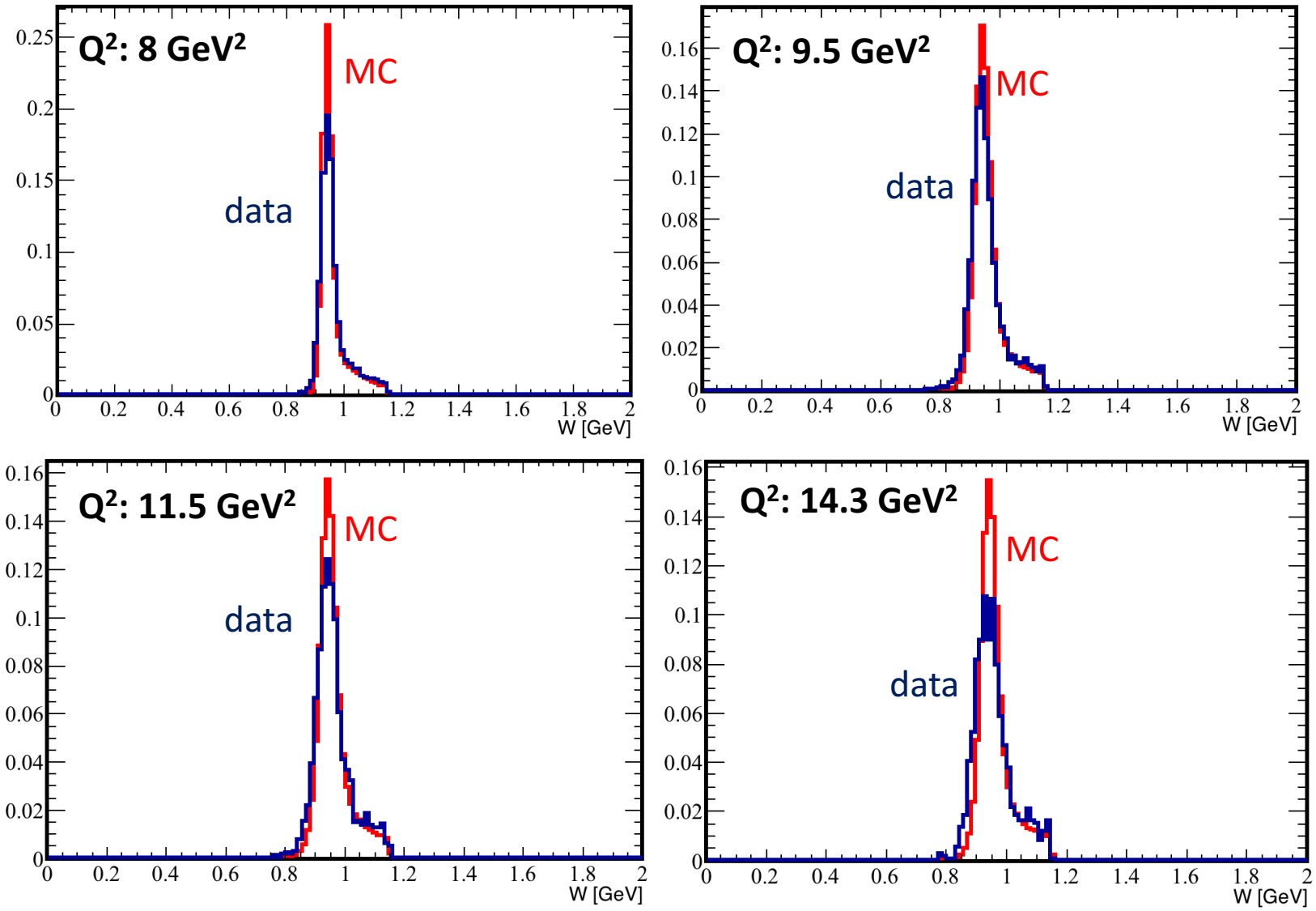






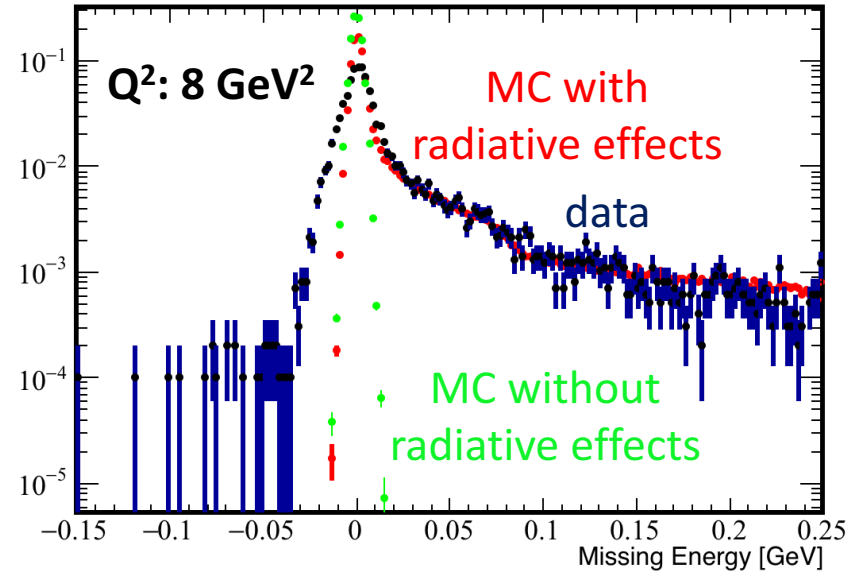
Hydrogen: W [GeV]

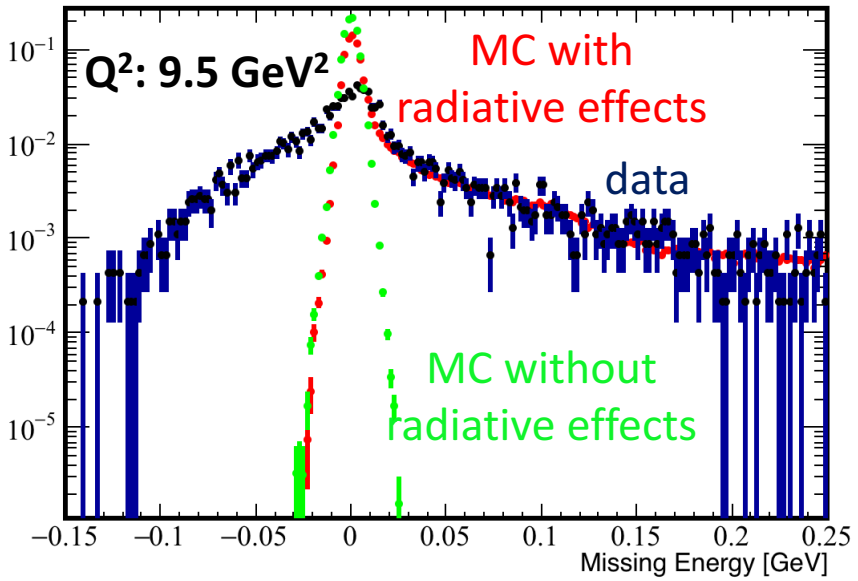
- Hydrogen data used to fine tune the optics settings
- HMS is well-understood even when pushed to higher central momenta

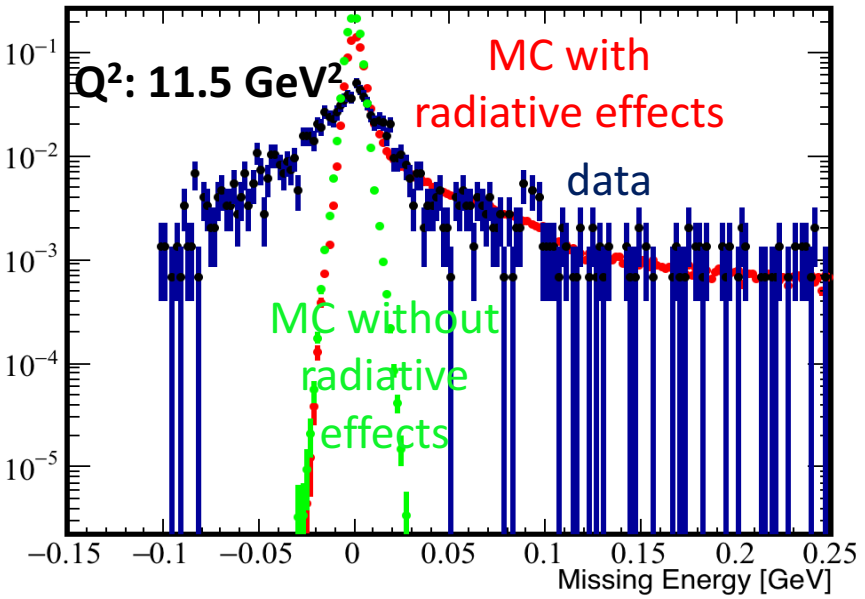


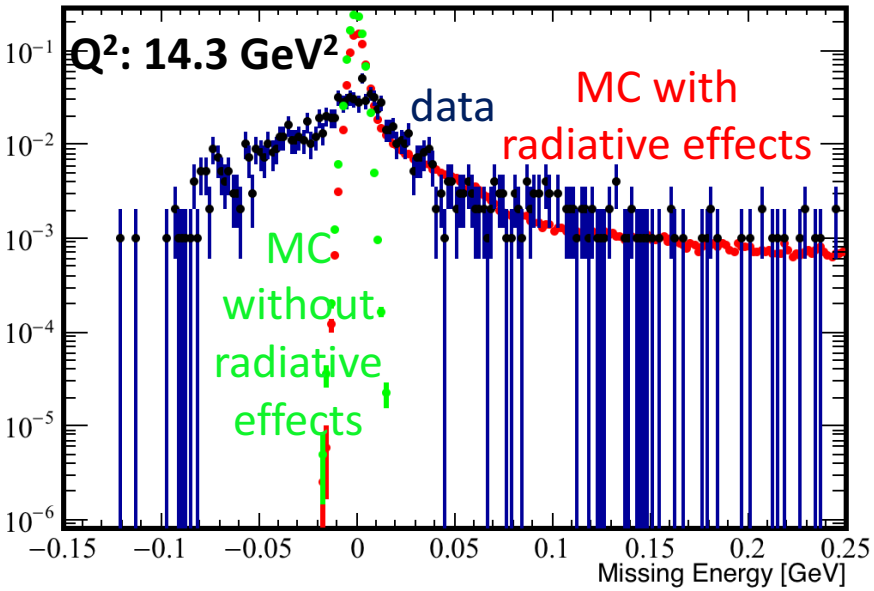
Hydrogen radiative tails

- Radiative effects in agreement with PWIA model in MC (SIMC)
- SHMS optics effects still being improved at higher momentum

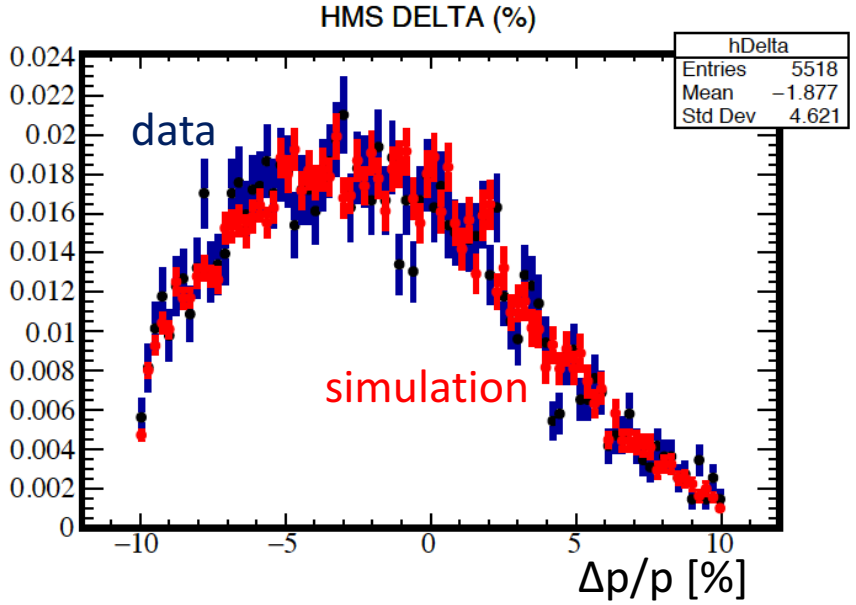


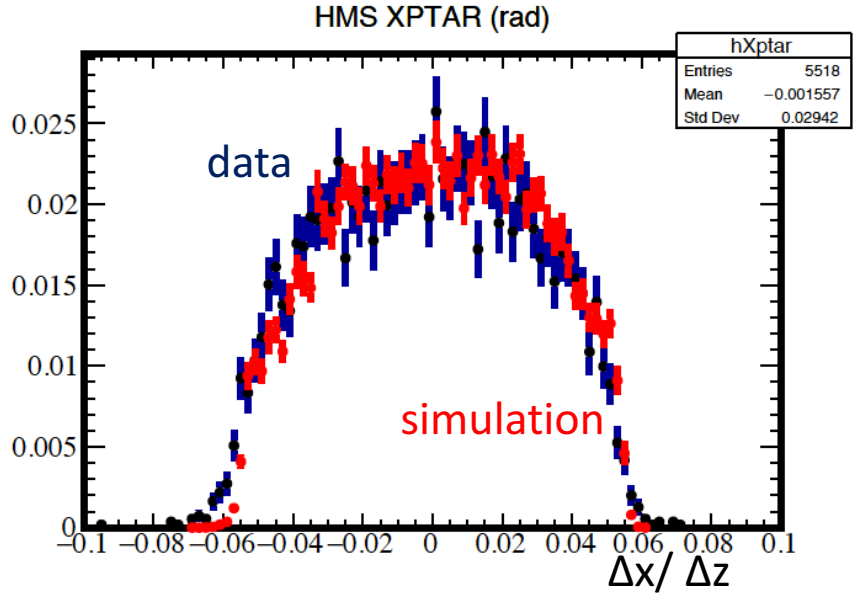


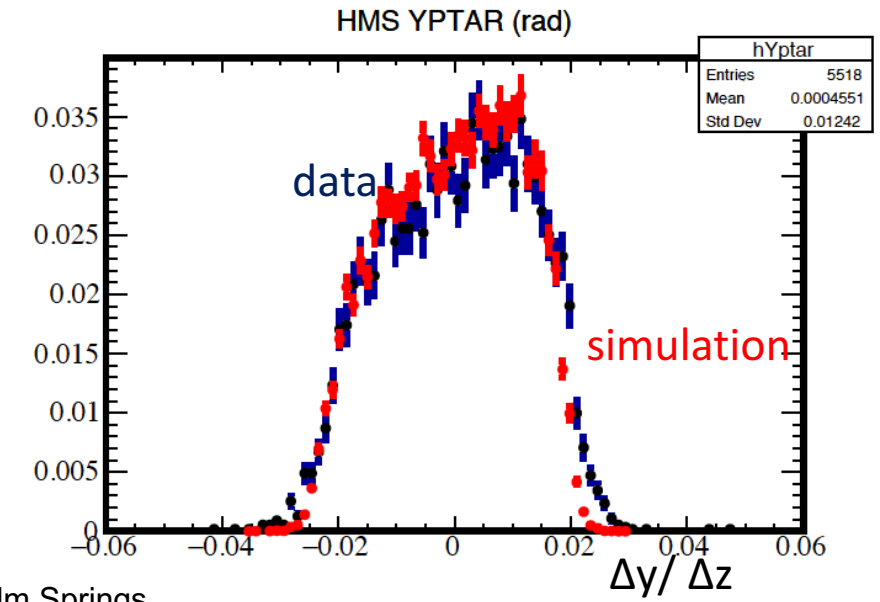


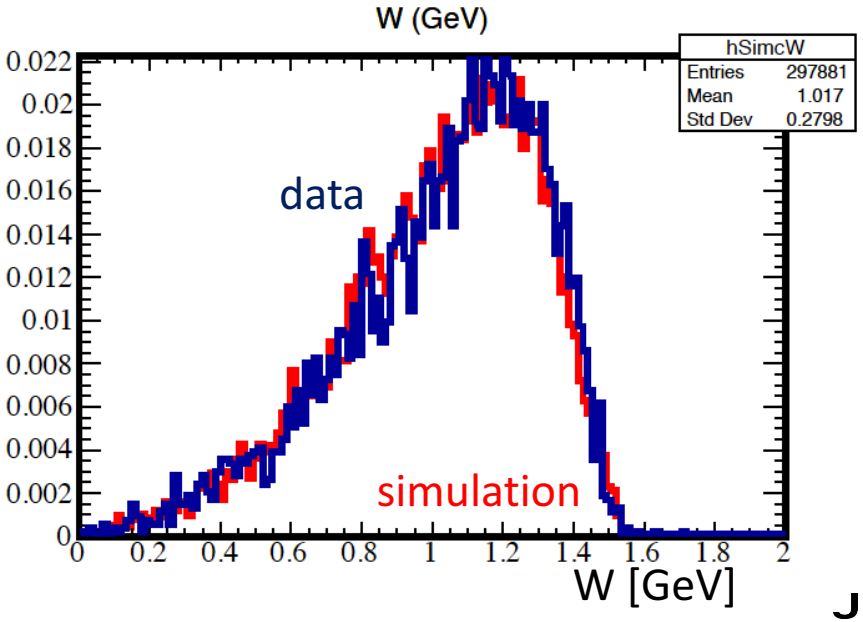


Carbon HMS data: $Q^2 = 8$ GeV^2









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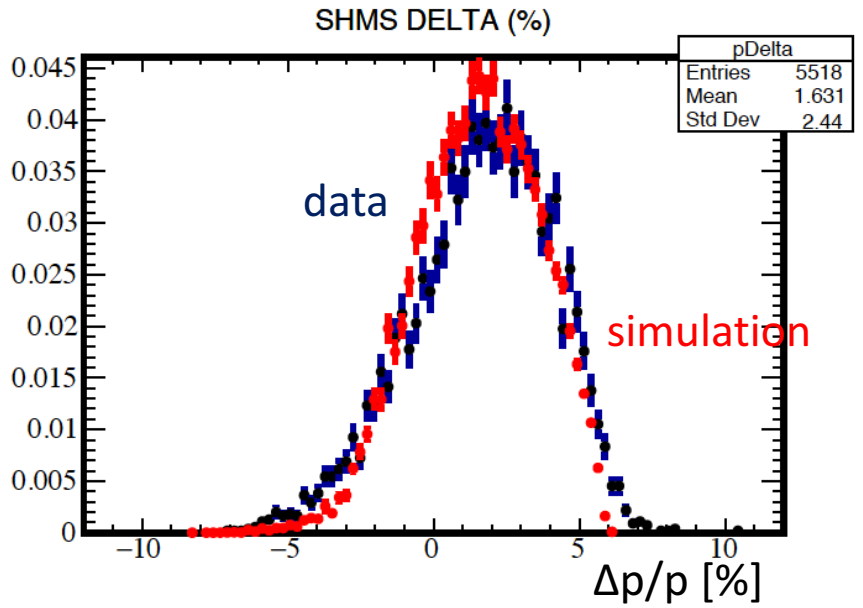
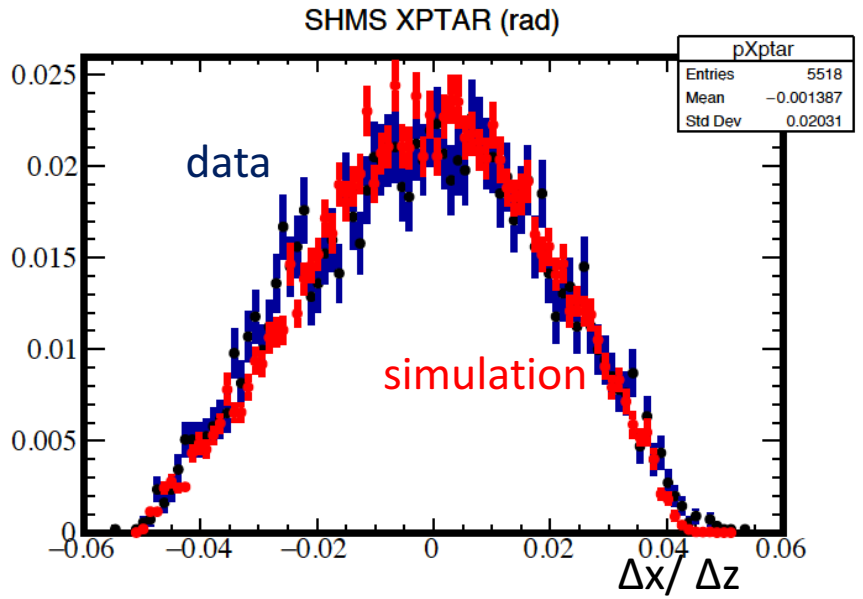
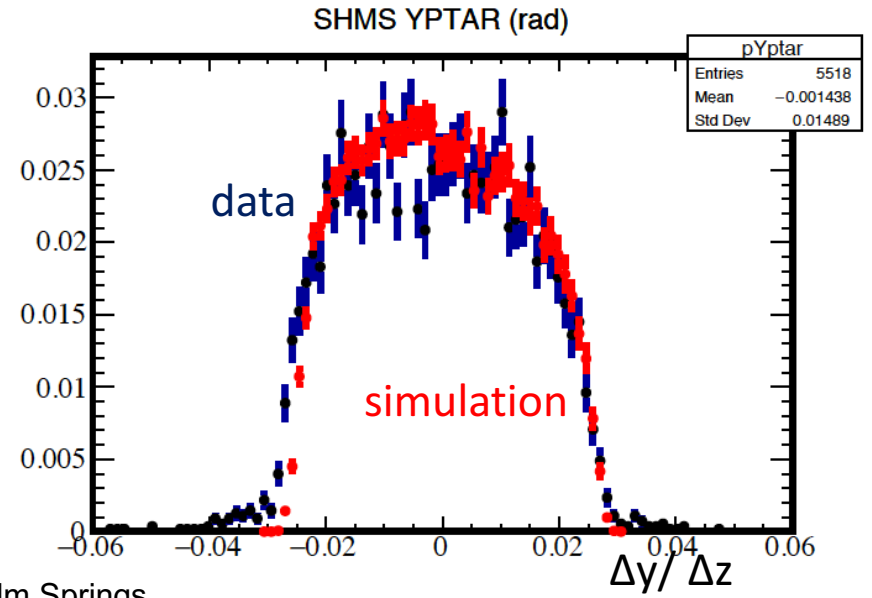
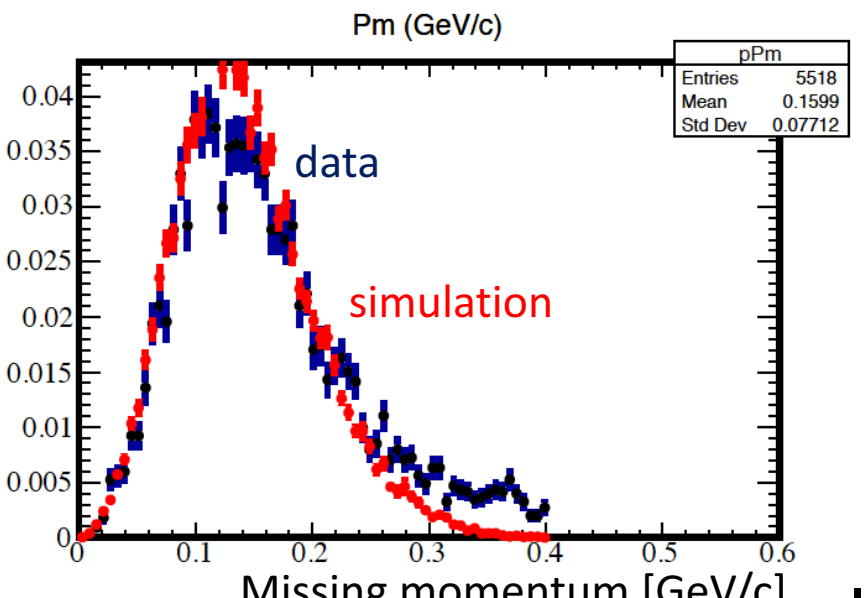


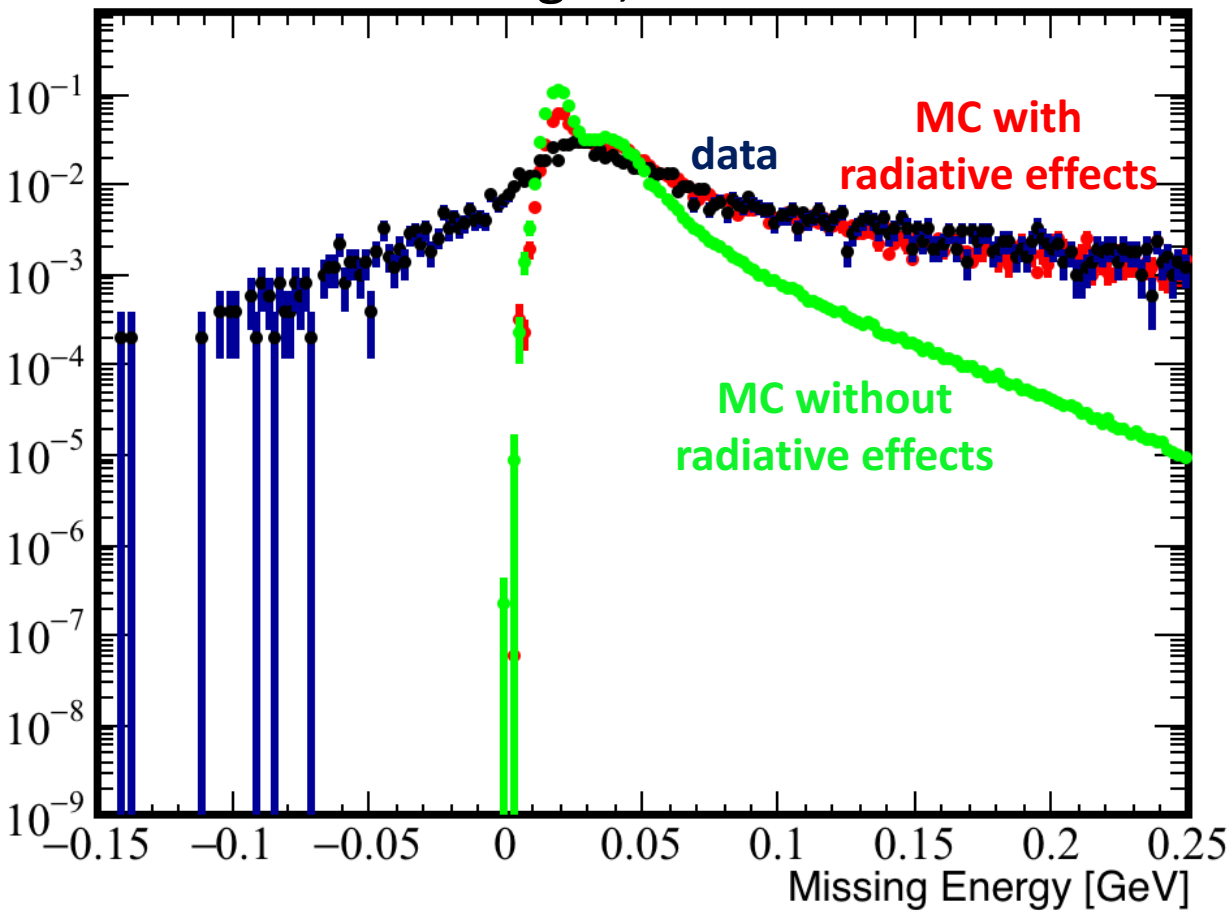




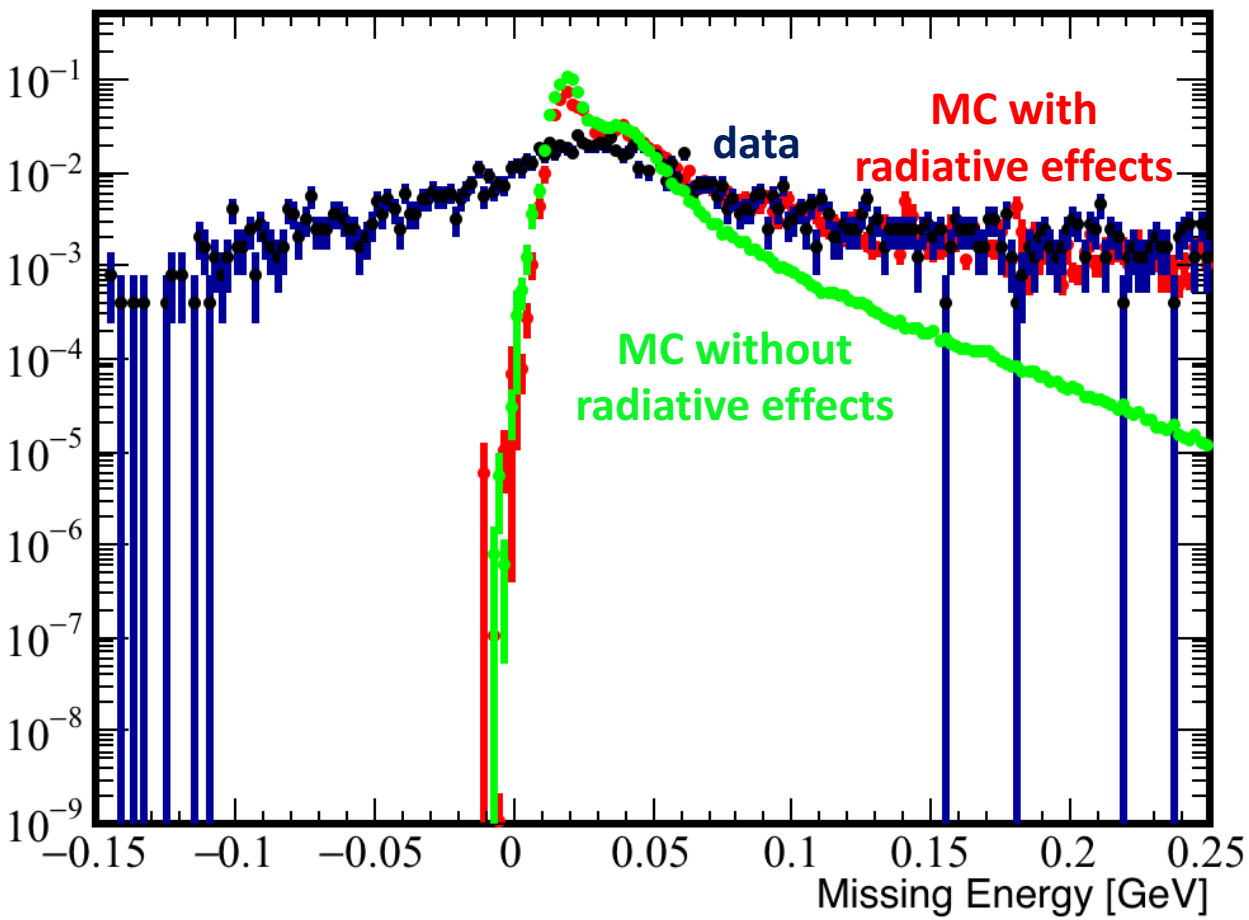


Carbon radiative tails

6% ^{12}C target, Q2 = 8 GeV^2



1.5% ^{12}C target, Q2 = 9.5 GeV^2



- Radiative effects agree with simulation in the tails.
- Still optimizing optics in the peak

Efficiencies

- Efficiencies vary by rates, configuration
- Initial data comparisons show good quality, consistency
- Full understanding of efficiencies critical to the extraction of the normalized cross section

Consideration	General Efficiency
Proton track (SHMS)	>90%
Electron track (HMS)	>90%
HMS Trigger (3/4)	>99%
SHMS Trigger (3/4)	>99%
HMS Cerenkov	Approx 95%
SHMS Cerenkov	Approx 95%
HMS calorimeter	Approx 95%
Proton absorption	Approx 92%

Thank you to the Hall C Collaborators!

U.S. DEPARTMENT OF ENERGY | Office of Science

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100+ Institutions

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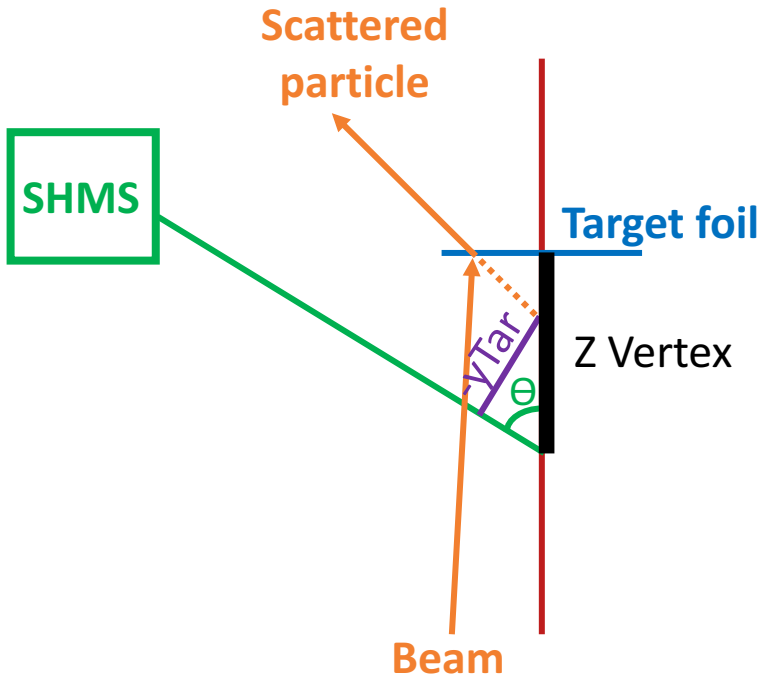
21 Countries

Armenia, Belgium, Brazil, Canada, Chile, China, Croatia, France, Germany, Israel, Italy, Russia, Saudi Arabia, Slovenia, South Korea, Spain, Switzerland, Turkey, Ukraine, United Kingdom, and United States

Summary

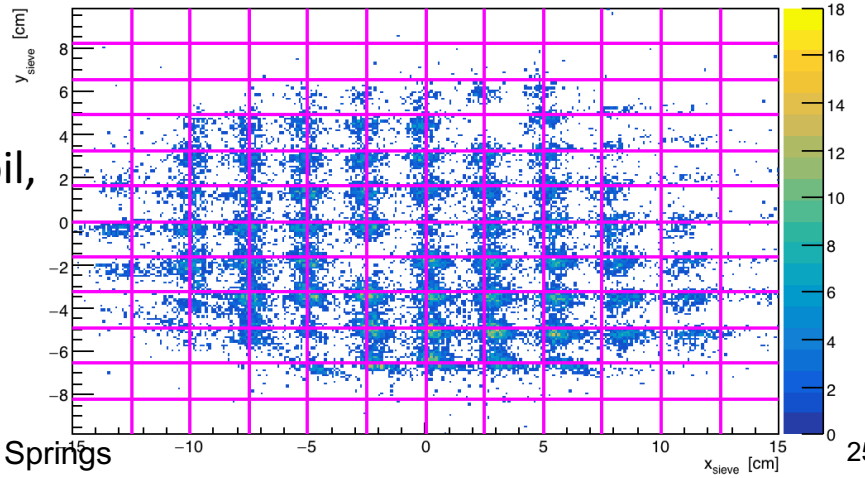
- Measuring the onset of CT is a signature for the onset of QCD degrees of freedom in nuclei
- Experiment took 4 data points in Q^2 regime 8-14.3 GeV^2, ideal region to measure the onset of CT
- First experiment to run in the 12 GeV era in Hall C and to take data using the SHMS
- Analysis to extract the transparency is ongoing → full results expected by the end of the year!

Optimization

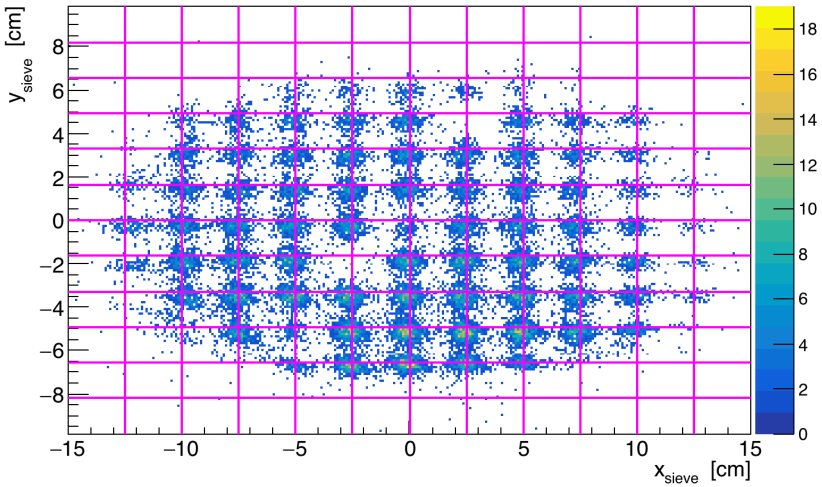


- Begin with focal plane quantities from drift chambers: x_{fp}, y_{fp}, x'_{fp}, y'_{fp}
- Ultimately want to reconstruct events at the interaction point
- Optimize reconstruction matrix elements x'_{target}, y_{target}, and y'_{target} to describe the interaction point.
- General procedure:
  1. Initial reconstruction of events using generated maps from expected.
  2. Determine the true physical values using the position of events passing through the sieve.
  3. Minimize the difference between reconstructed and true, find better matrix elements.

15 deg, central C foil, pre-optimization:



15 deg, central C foil, post-optimization:



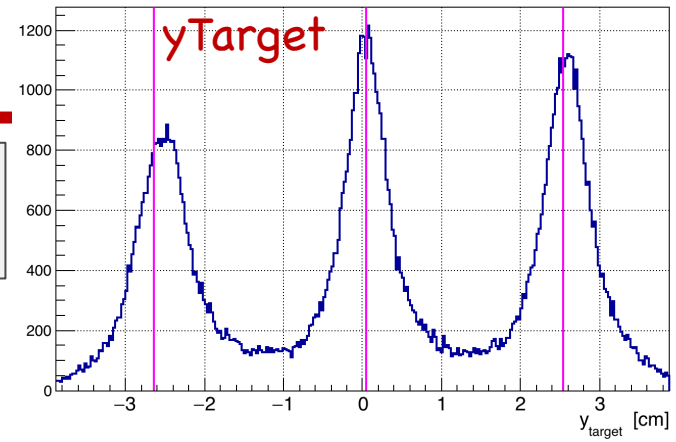
Jefferson Lab

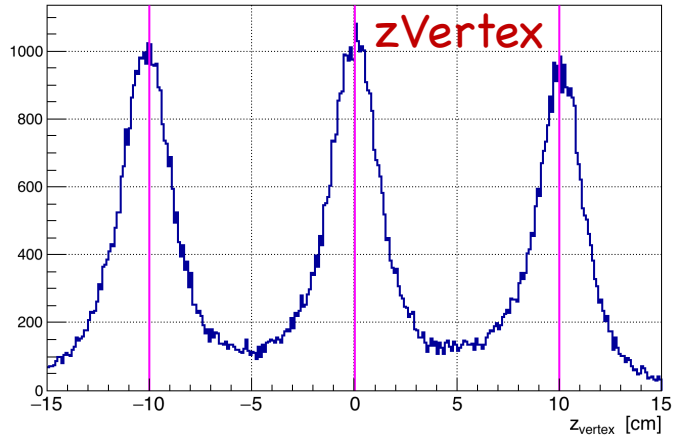
Optimization

Special runs:

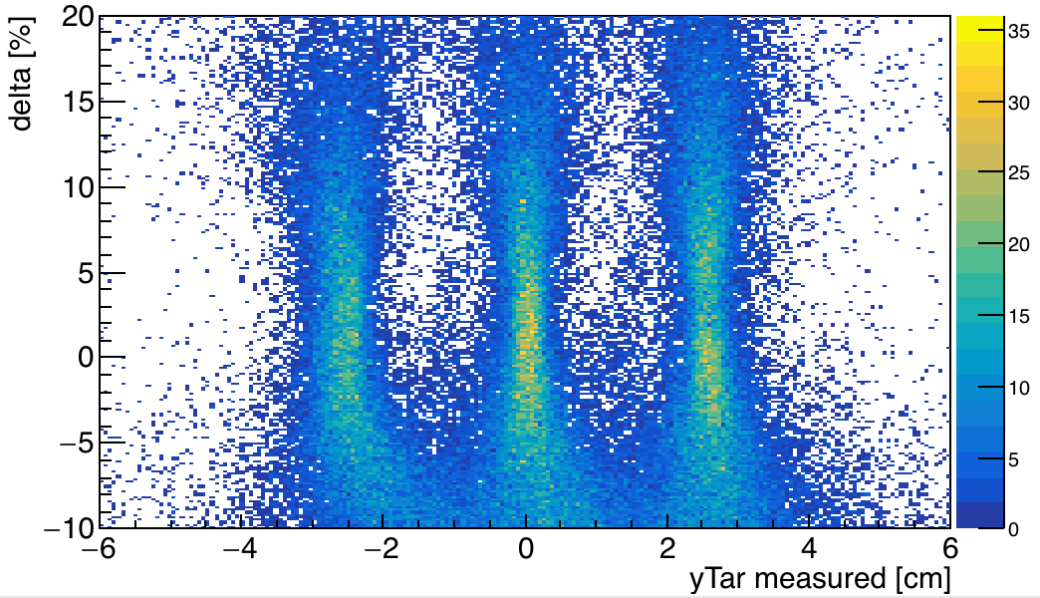
- Various SHMS angles
- Extended foil targets
- Sieve

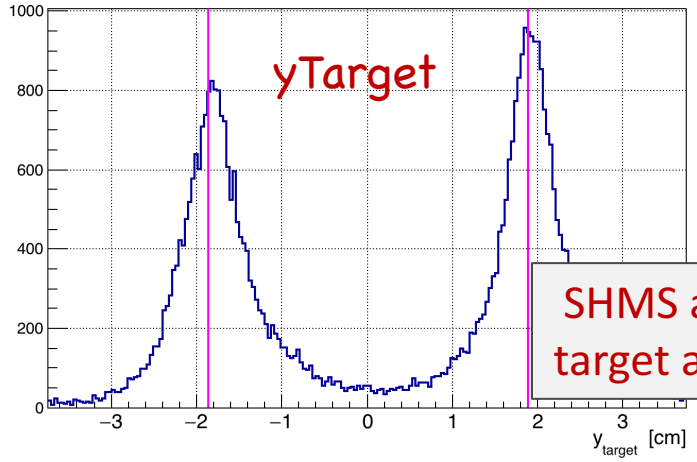
SHMS at 15 deg, target at +/- 10, 0 cm

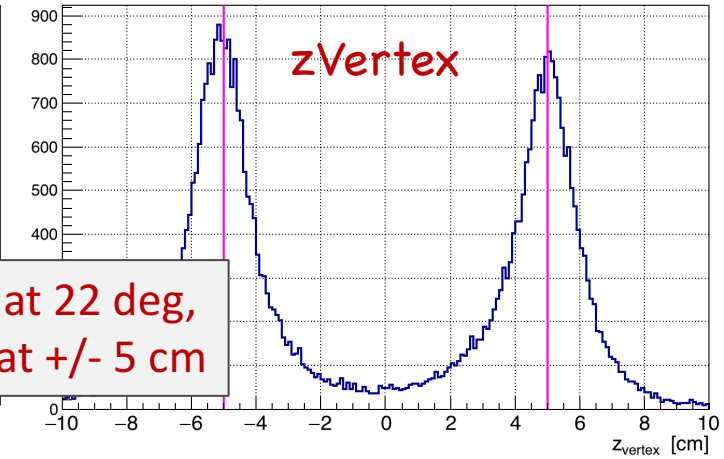




Optimize yTarget for all delta, delta not optimized… yet!







SHMS at 22 deg, target at +/- 5 cm

Optimized matrix elements have nearly the same first order matrix elements as from initial calculation!

SHMS at 30 deg, target at +/- 10, 0 cm