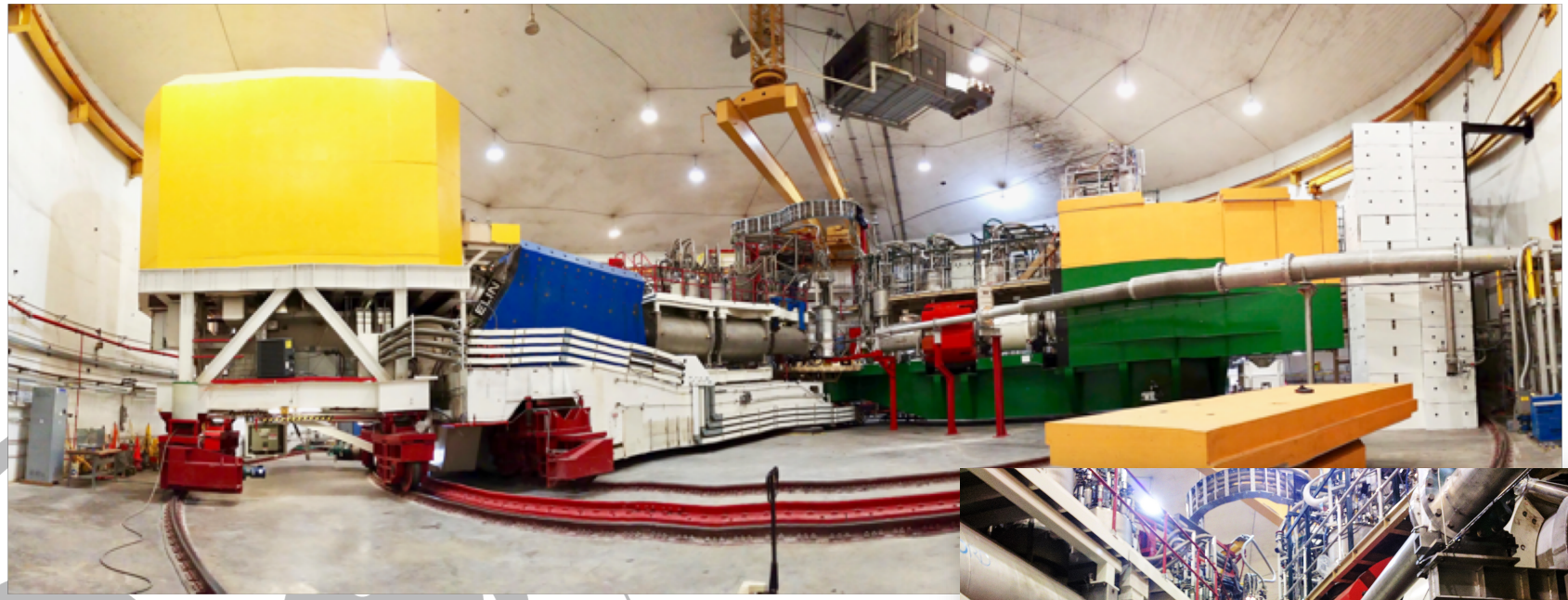
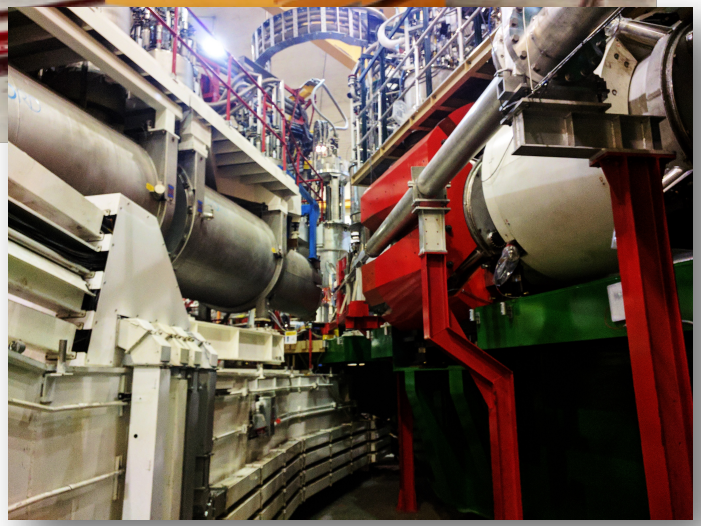
Searching for the onset of Color Transparency in Hall C





Holly Szumila-Vance

On behalf of the Hall C Collaboration

Wednesday, Apr 10 2019

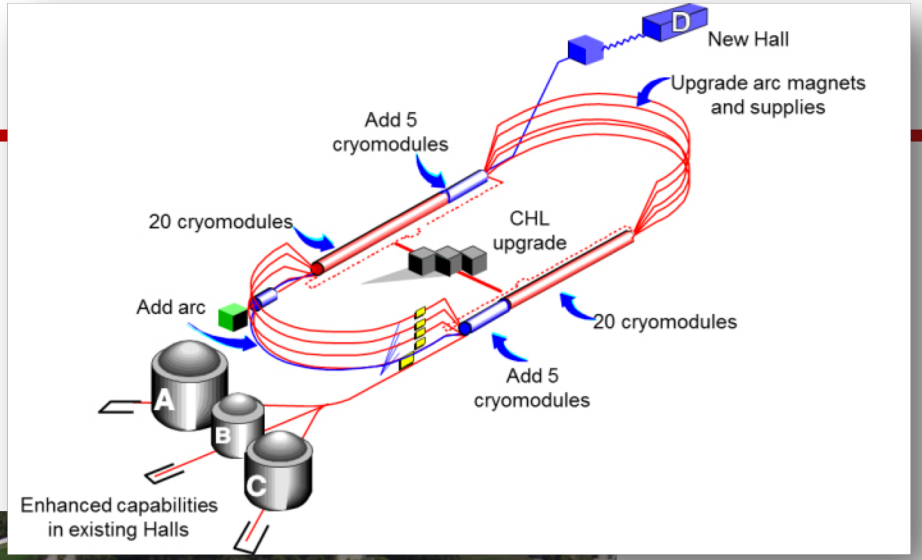
Jefferson Lab

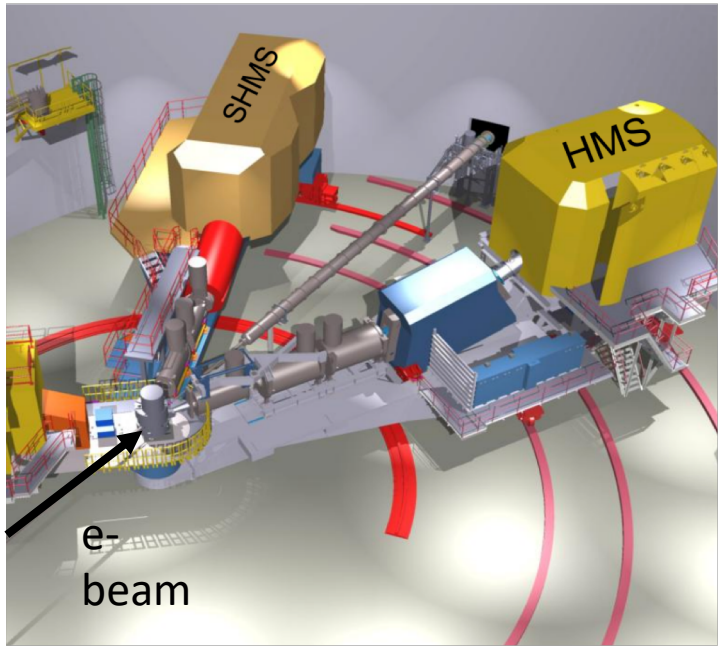
U.S. DEPARTMENT OF ENERGY | Office of Science

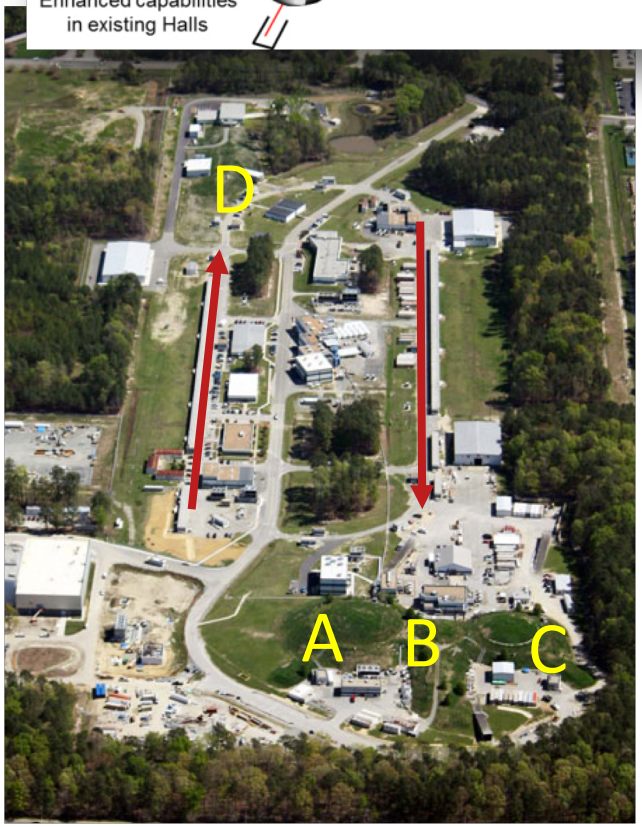
JSA

Overview

- Motivation
- Experiment
  - First commissioning experiment in Hall C!
  - Performance
  - Preliminary results
- Summary and Outlook







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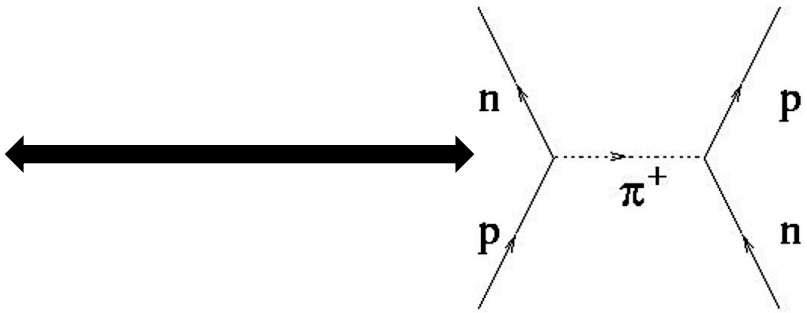
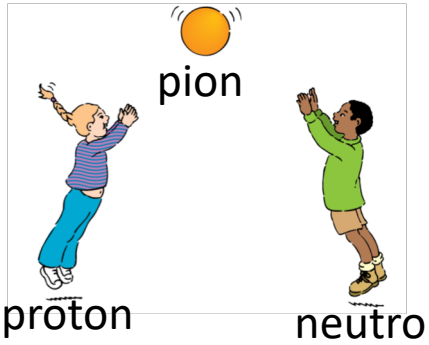
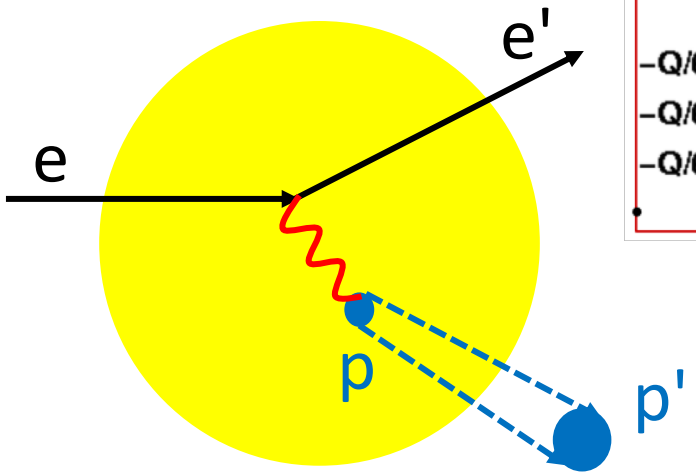
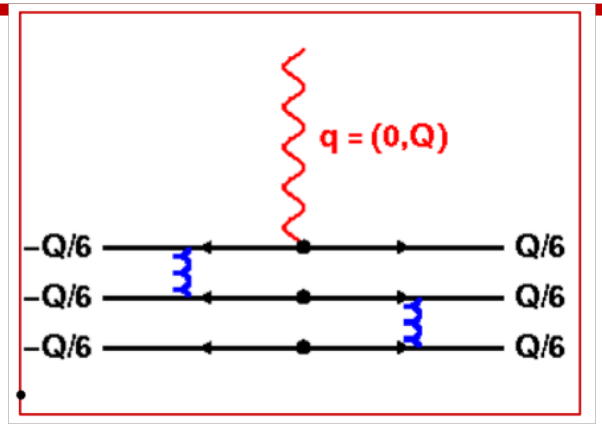
Exploring the strong interaction





Color transparency fundamental prediction of QCD

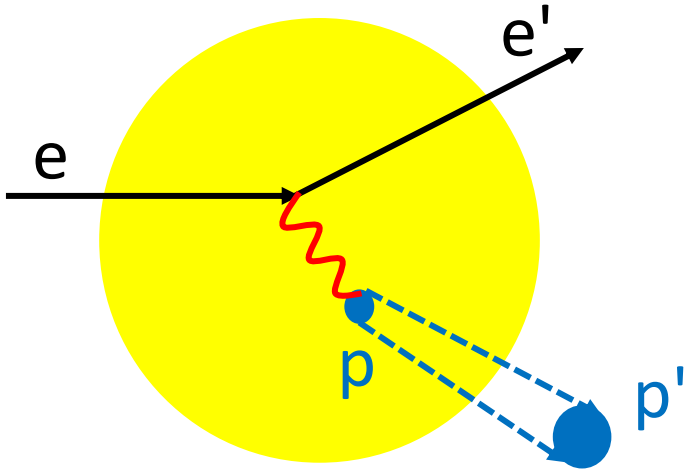




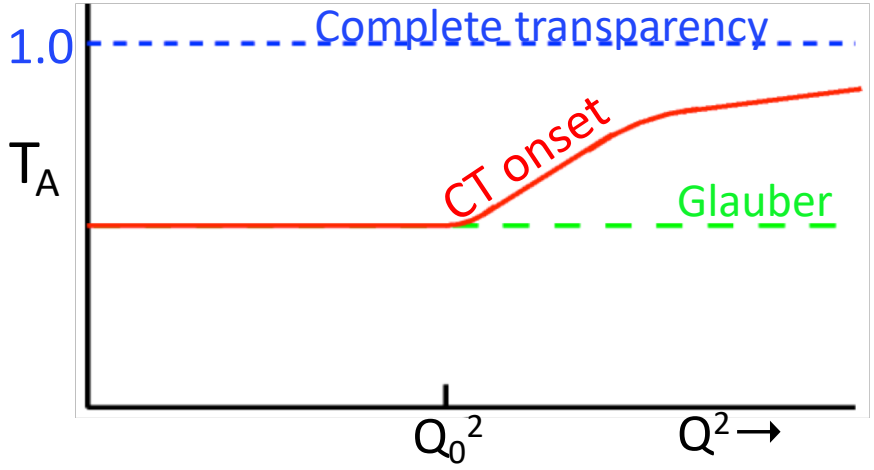
- Introduced by Mueller and Brodsky, 1982
- Vanishing of initial/final state interaction of hadrons with nuclear medium in exclusive processes at high momentum transfer

- Hadron fluctuates to small transverse size (quantum mechanics)
- Maintains this small size as it propagates out of the nucleus (relativity)
- Experiences reduced attenuation in nucleus, color screened (strong force)

Color transparency fundamental prediction of QCD



- 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 is a rise in nuclear transparency, T_A, as a function of the momentum transfer, Q^2



$$T_A = \frac{\sigma_A}{A\,\sigma_N}$$ (nuclear cross section) / (free nucleon cross section)

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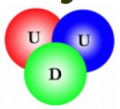
CT experiments

CT experiments

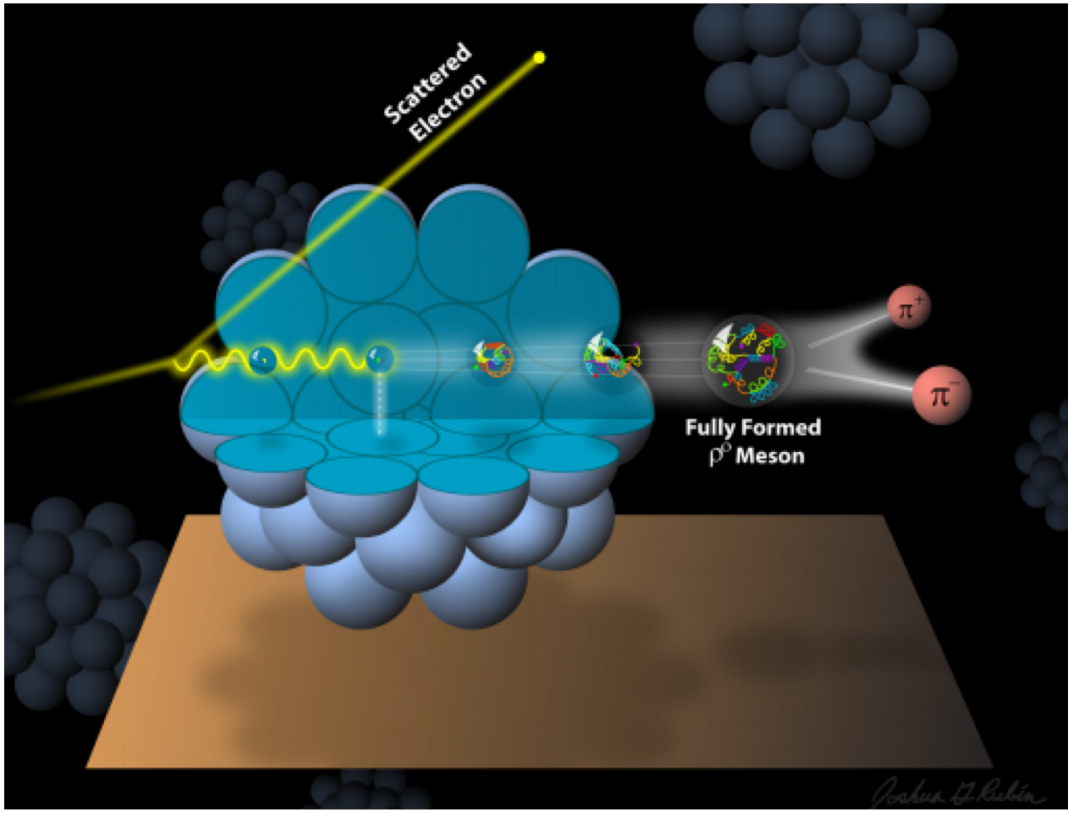
Baryon



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



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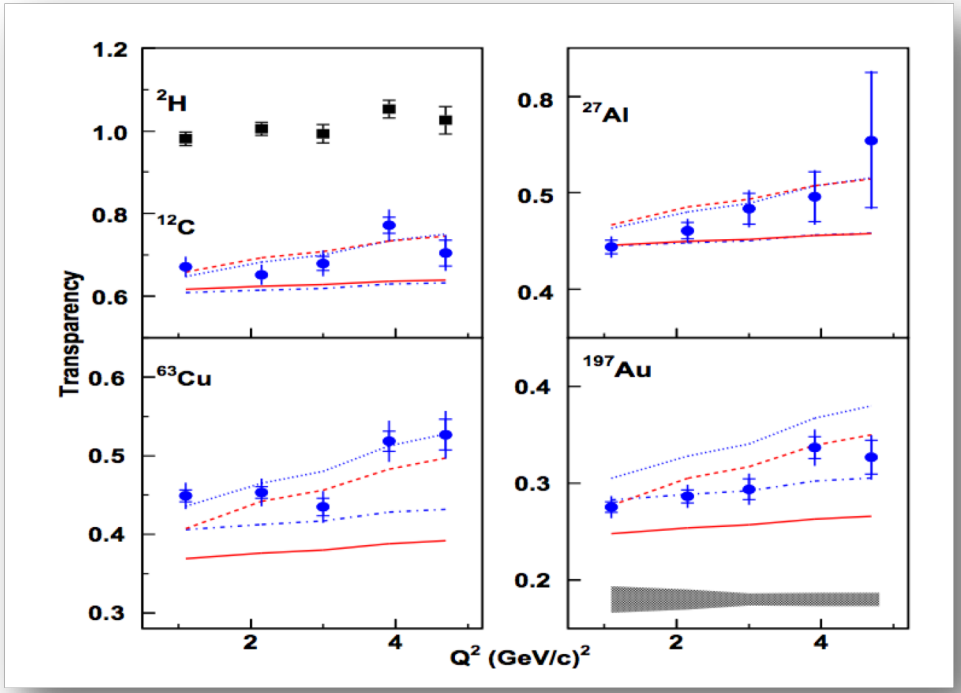
Previous Measurements: Mesons

Enhancements consistent with CT (increasing with Q^2 and A) observed

Hall C E01-107 pion electro-production

$A(e,e'\pi^+)$

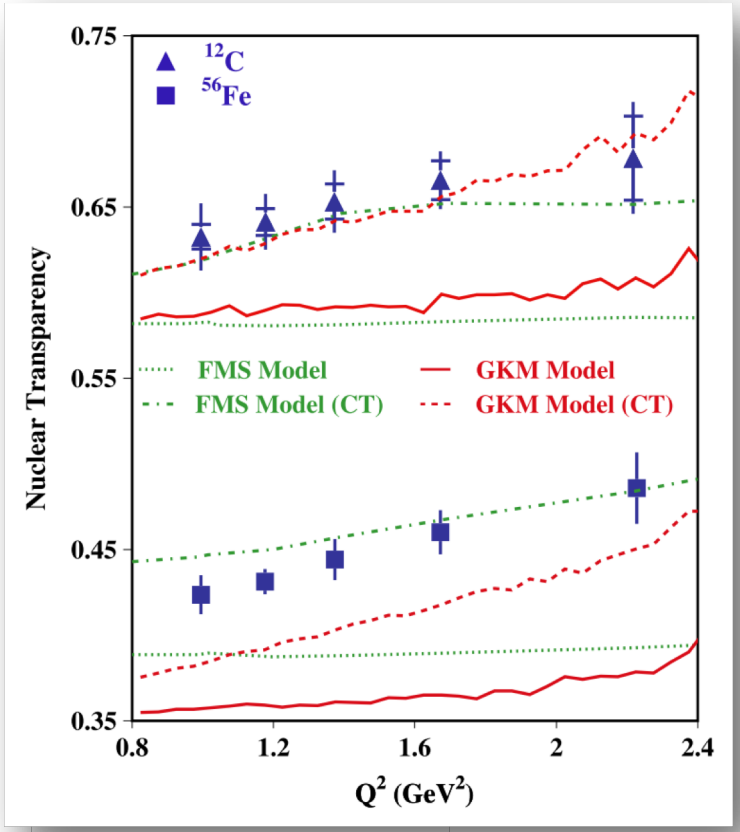


B.Clasie *et al.* PRL 99:242502 (2007)

X. Qian *et al.* PRC81:055209 (2010)

CLAS E02-110 rho electro-production

$A(e,e'\rho^0)$



L. El Fassi *et al.* PLB 712,326 (2012)

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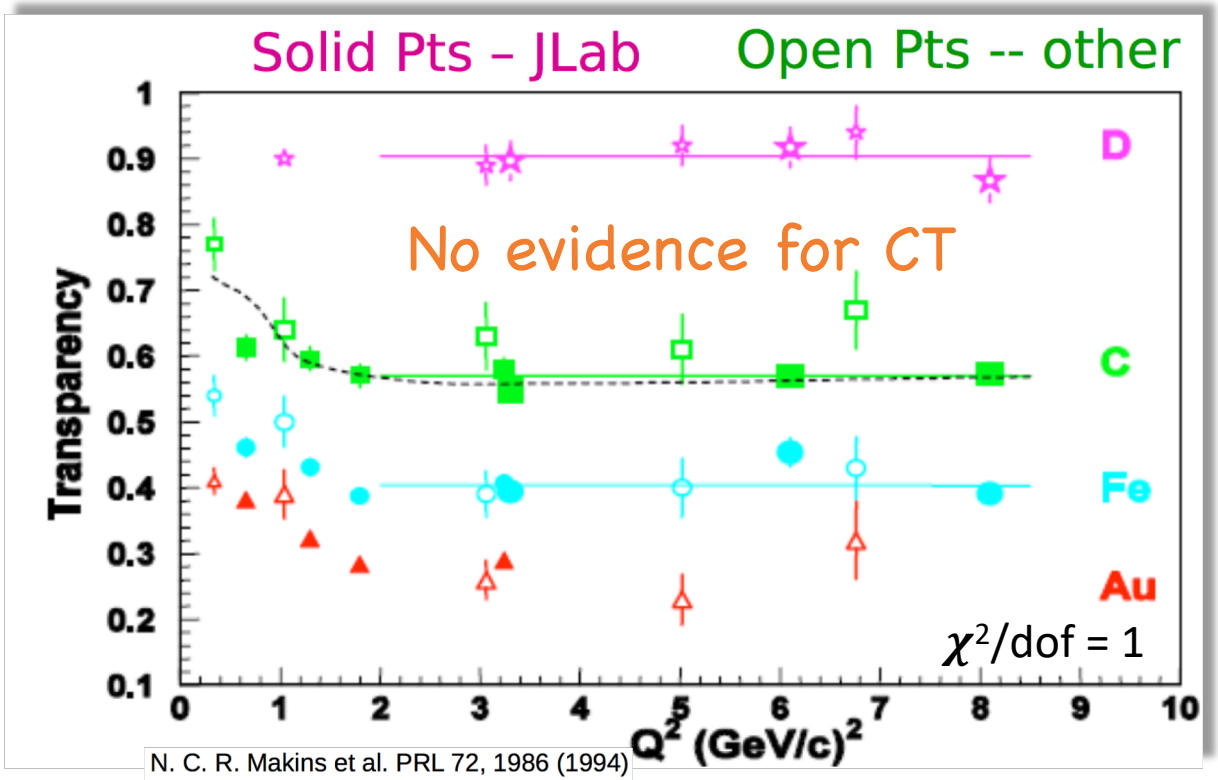
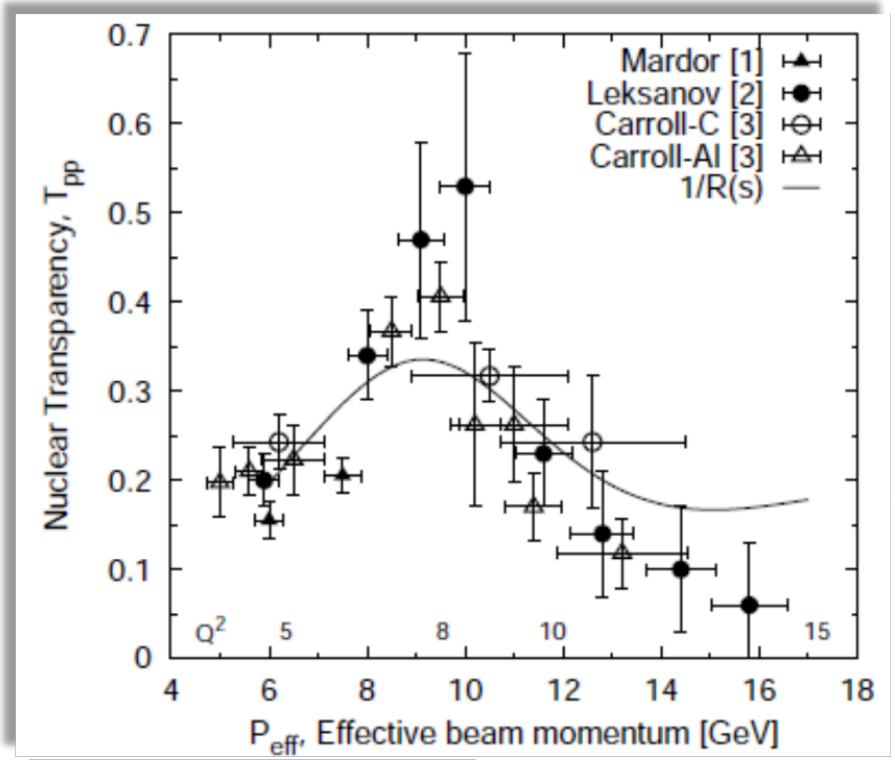
Previous Measurements: Baryons

A(e,e'p) results consistent with standard nuclear physics



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)

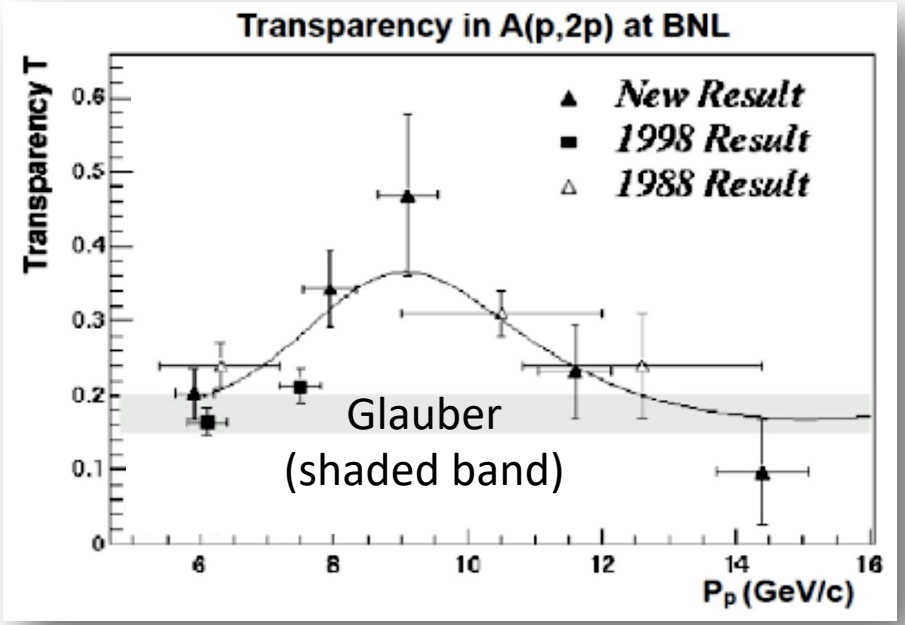
Previous Measurements: Baryons



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

Transparency in A(p,2p) experiment at Brookhaven:

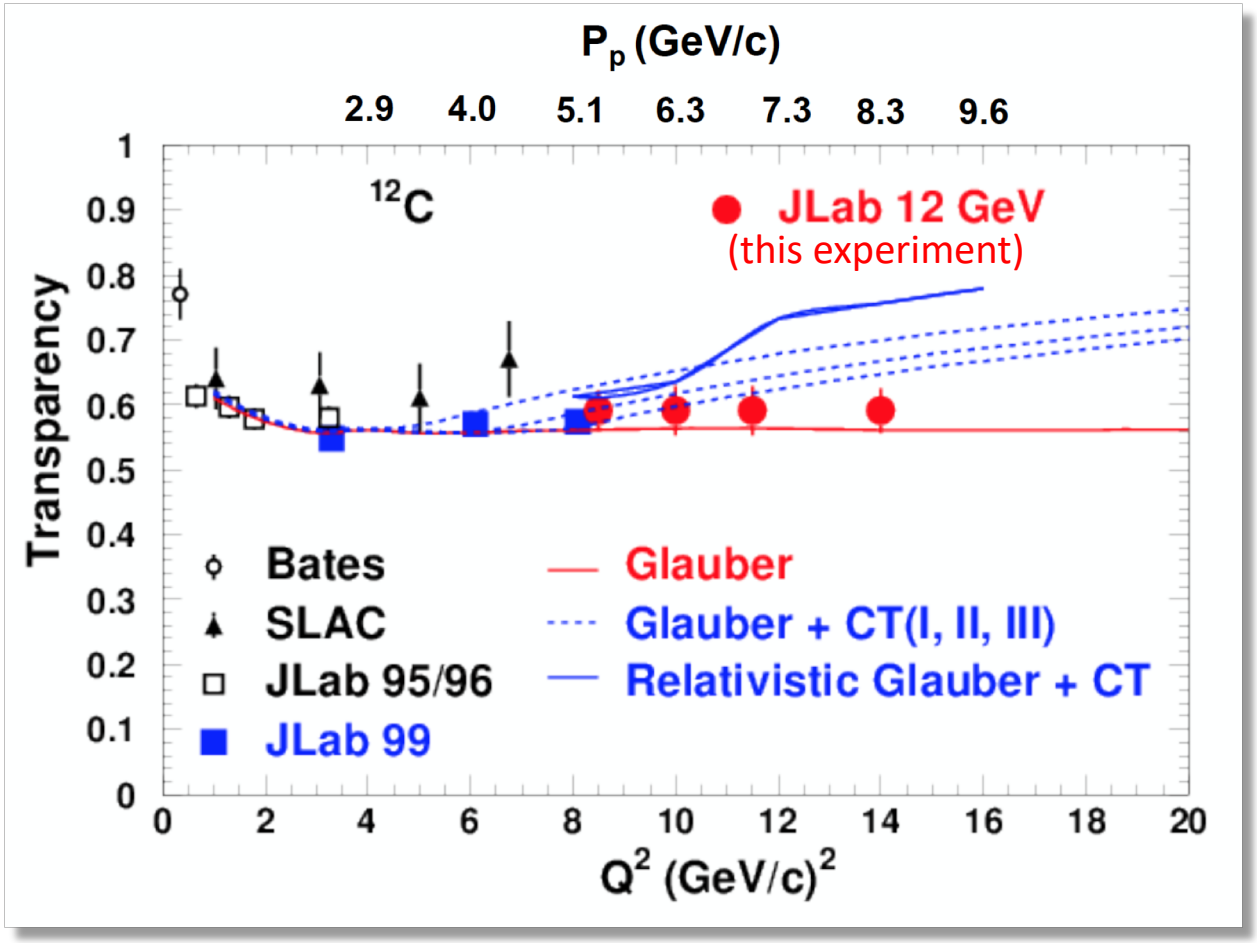
- observed enhancement in transparency
- inconsistent with CT only
- could be explained by including nuclear filtering or charm resonance



PRL 87, 212301 (2001)
PRL 81, 5085 (1998)
PRL 61, 1698 (1988)

Measuring the onset in the 12 GeV era!

A(e,e'p) experiment can reach higher proton momenta in 12 GeV upgrade



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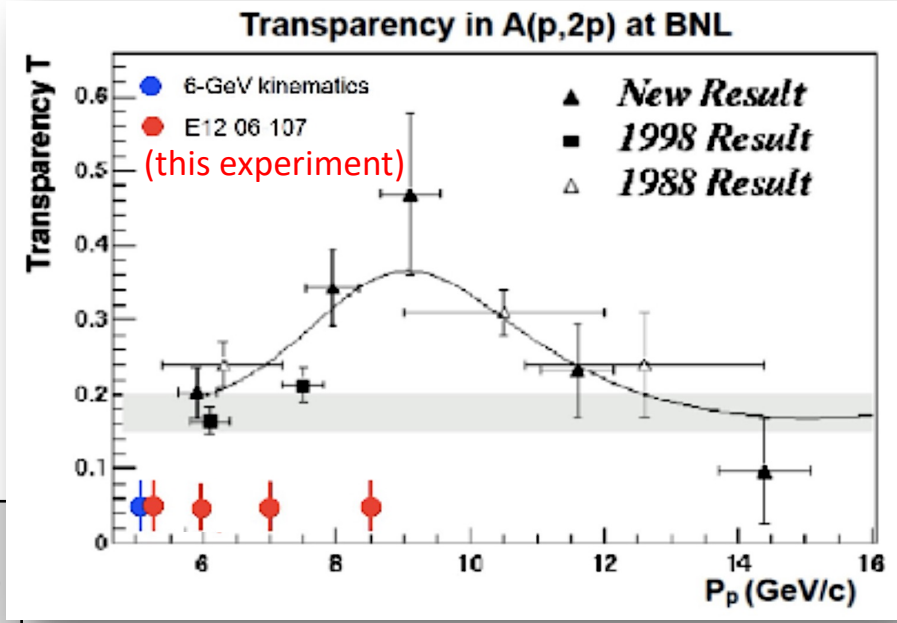
Experiment overview: First experiment to run in Hall C in the 12 GeV era!

- Coincidence trigger: SHMS measures protons, HMS measures electrons
- Targets: 10 cm LH_2 (H(e,e'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]	
8.0	17.1	5.122	45.1	2.131	6.4 GeV beam
9.5	21.6	5.925	23.2	5.539	10.6 GeV beam
11.5	17.8	7.001	28.5	4.478	
14.3	12.8	8.505	39.3	2.982	

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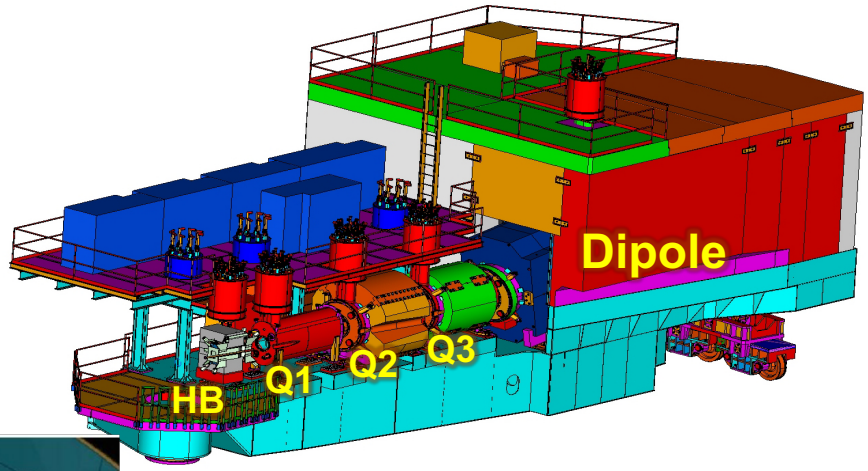
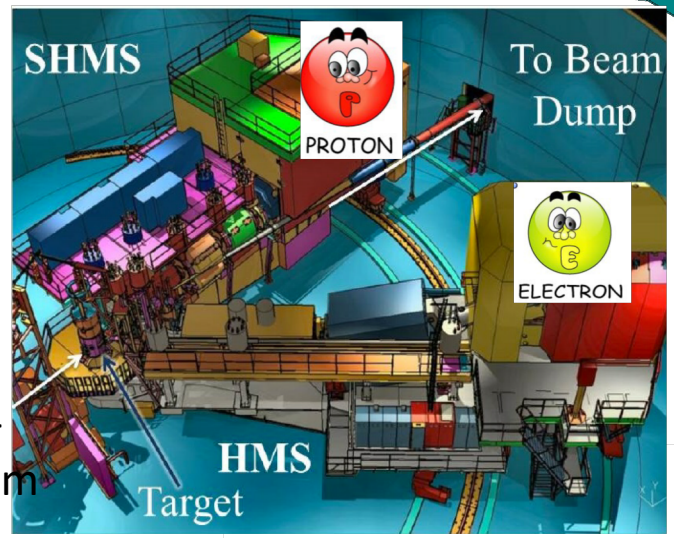
Experiment overview: First experiment to run in Hall C in the 12 GeV era!

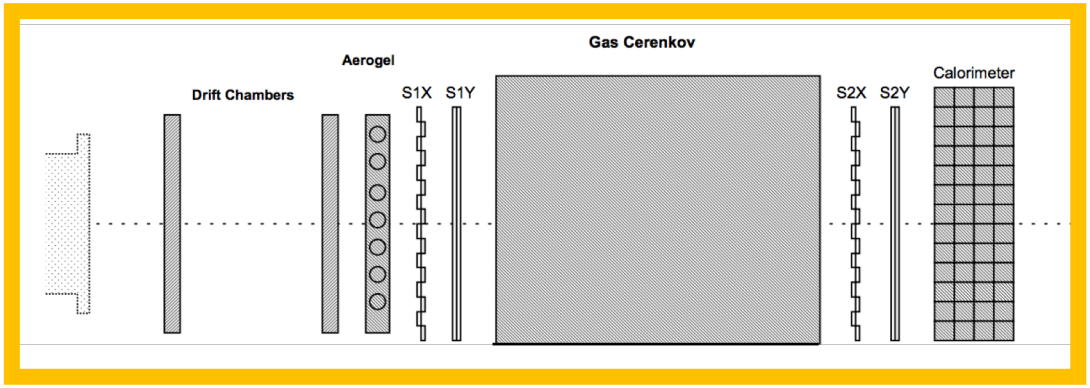
- Coincidence trigger
- Targets: 10 cm LH_2 for H(e,e'p) check, 6% ^{12}C (production), Al dummy (background)

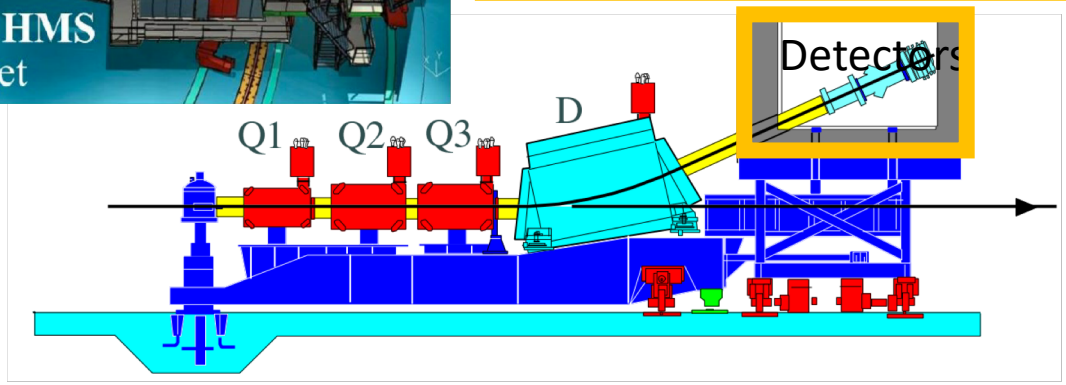


SHMS Characteristics:

- 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)







HMS Characteristics:

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

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

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

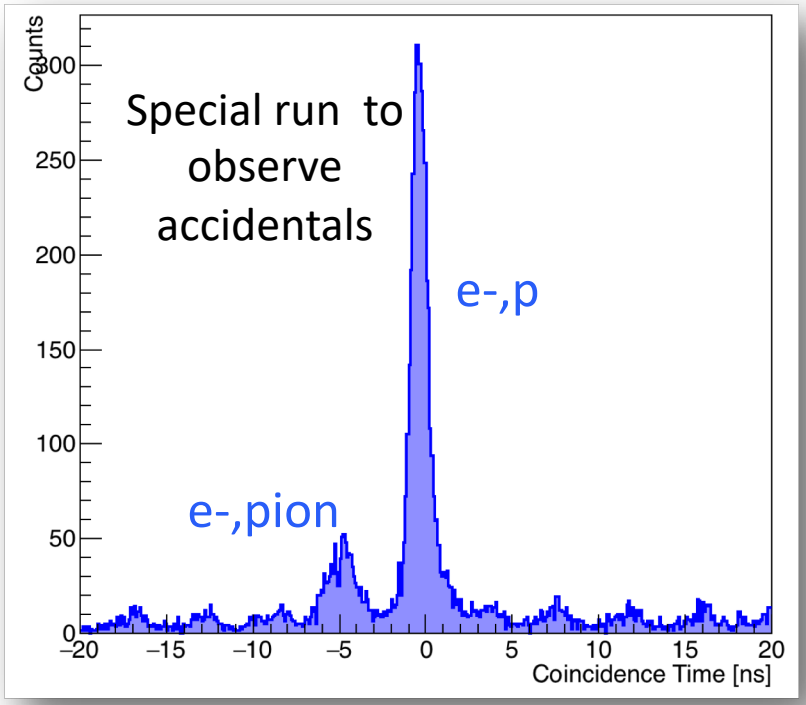
The time of each particle:

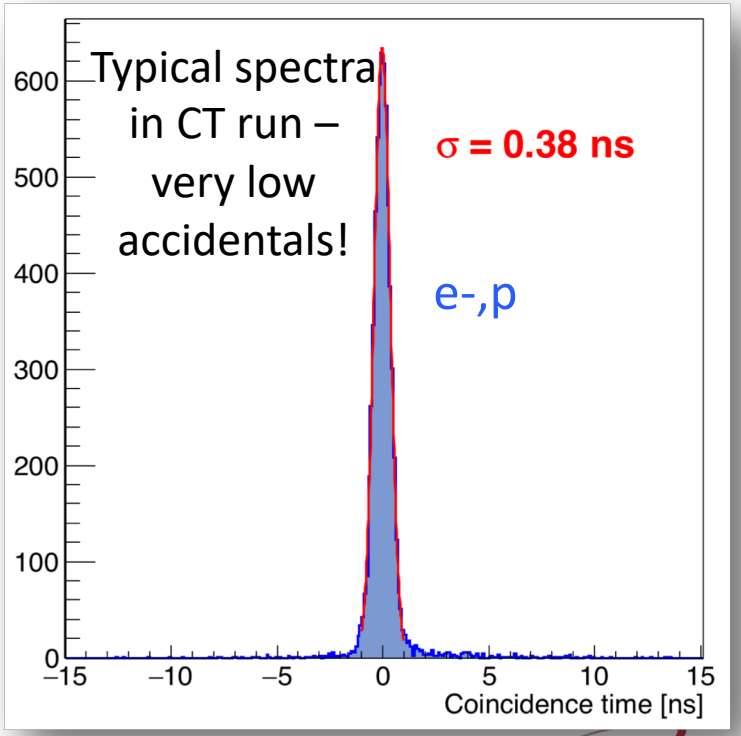
$$t_{e,p}^{tar} = (t_{e,p}^{trigger} - \Delta t_{e,p}^{corr})$$

Each particle time corrected for:

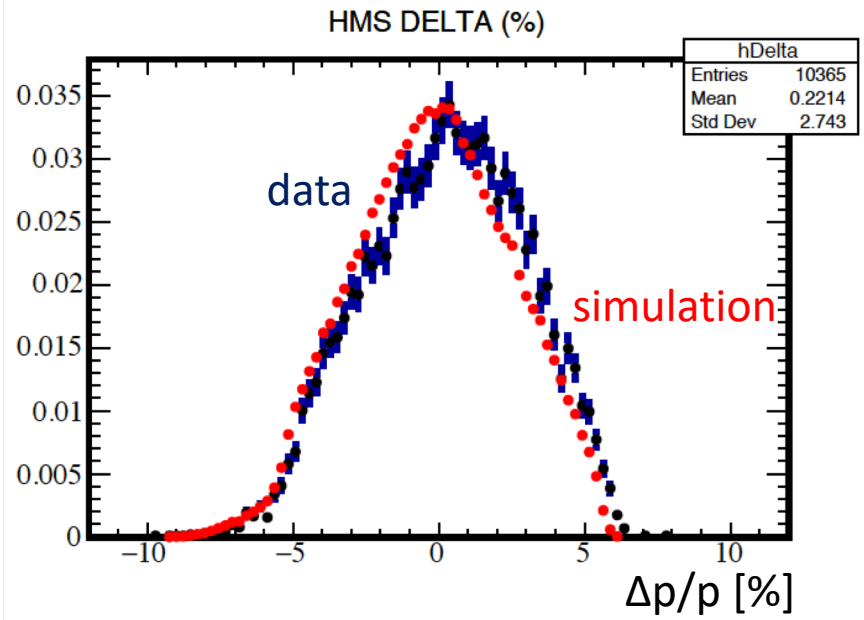
- Particle traveling along central ray to focal plane
- Path length variations
- Difference in time between hodoscope start and focal plane time

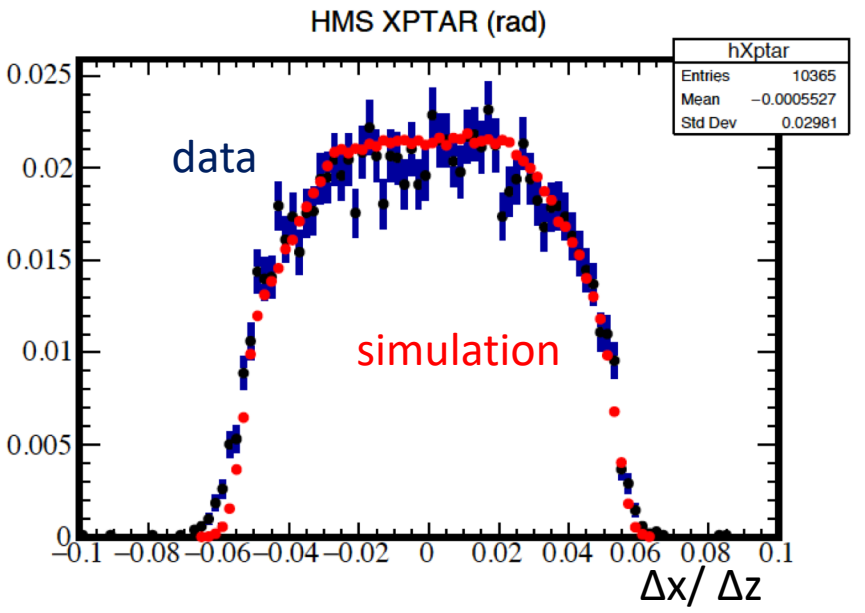
Coincidence time spectra:

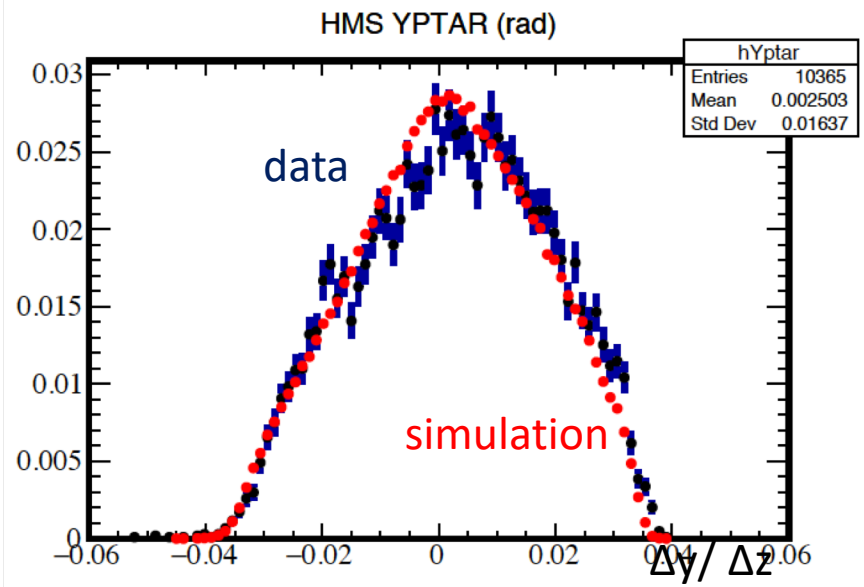


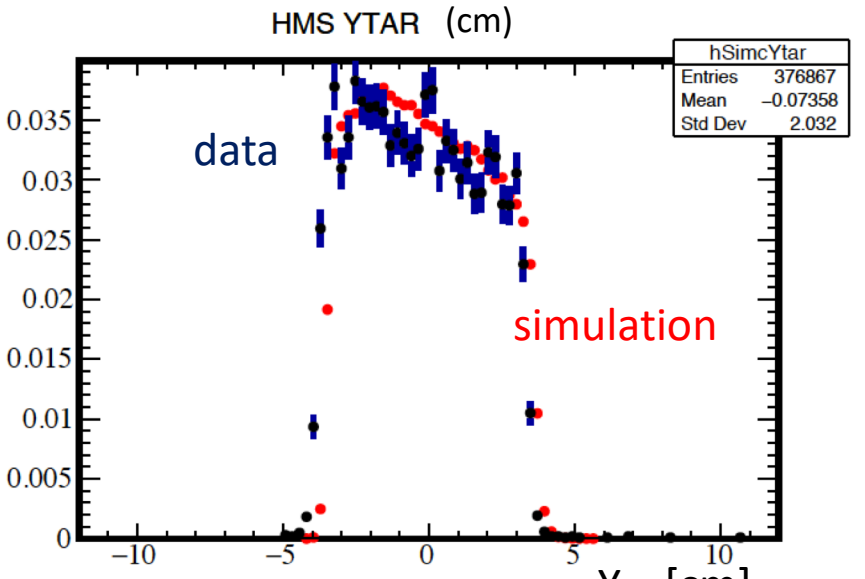


Hydrogen HMS data: Q^2 = 8 GeV^2

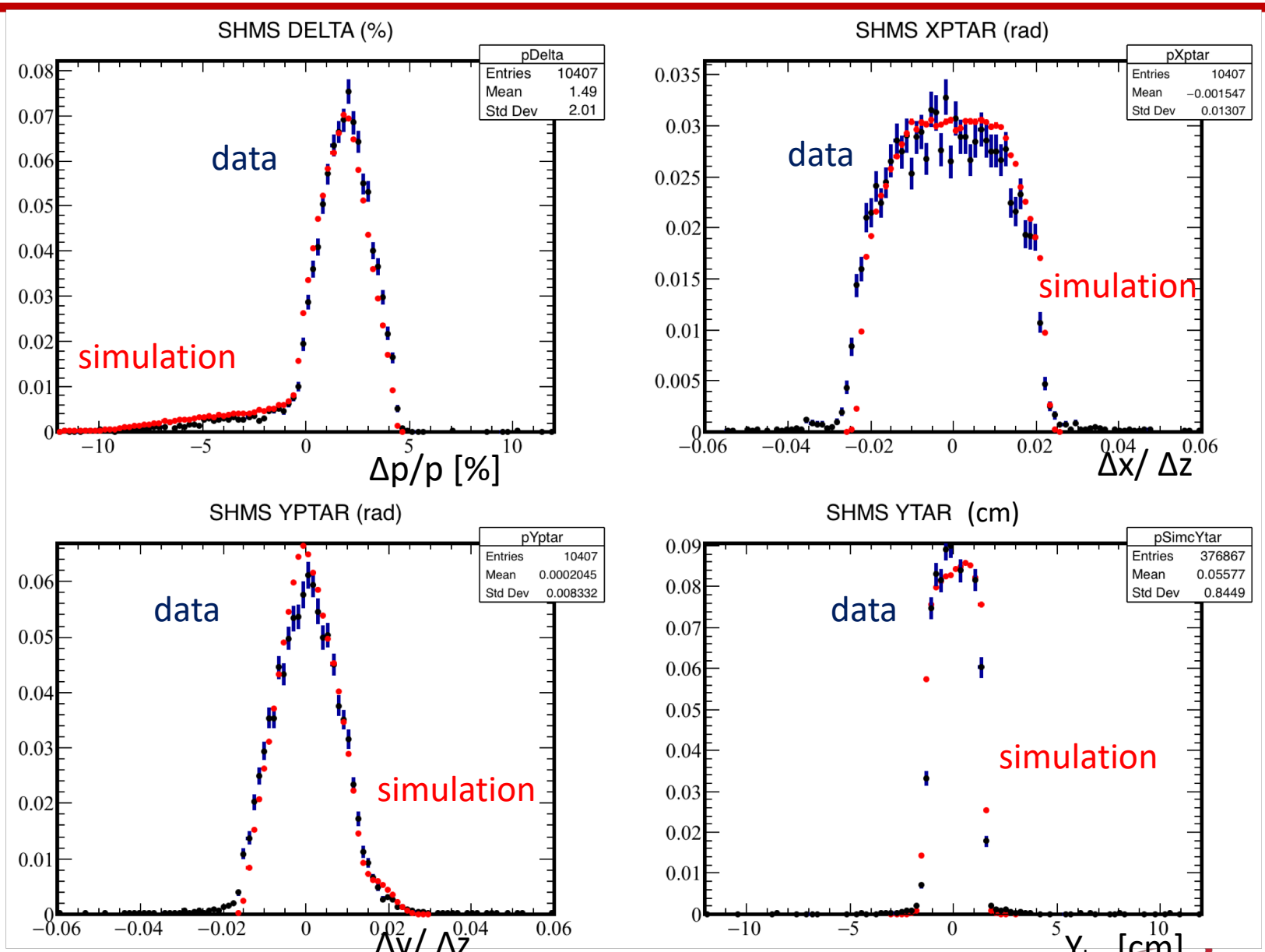






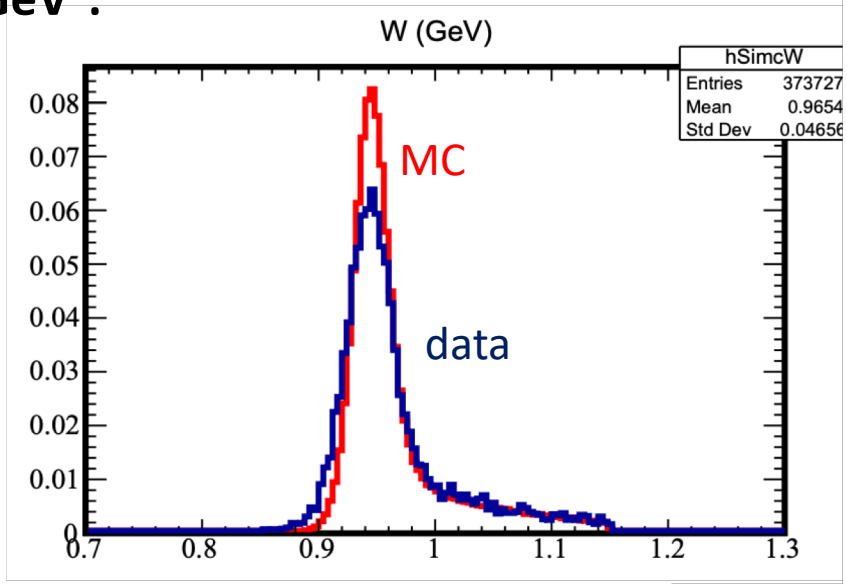


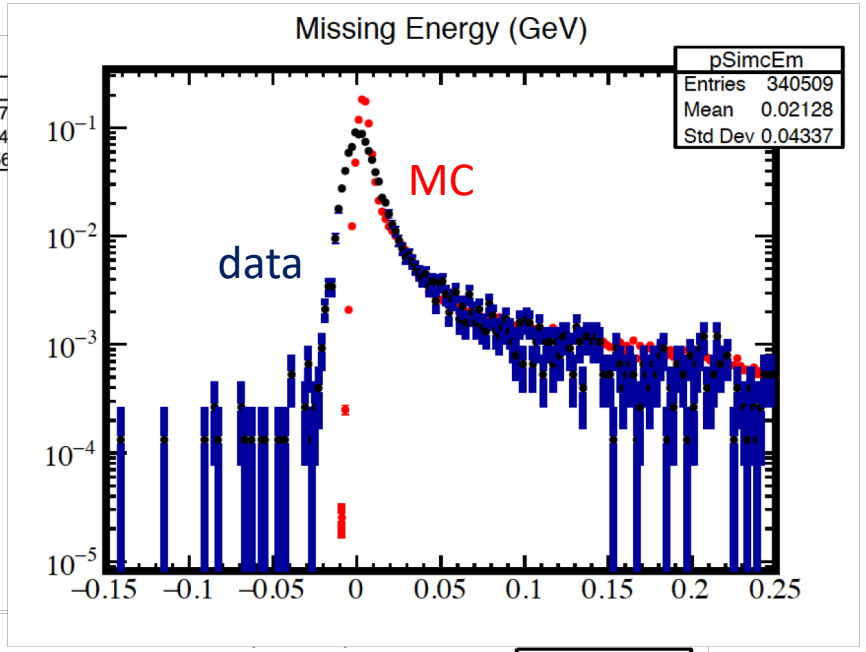
Hydrogen SHMS data: Q^2 = 8 GeV^2

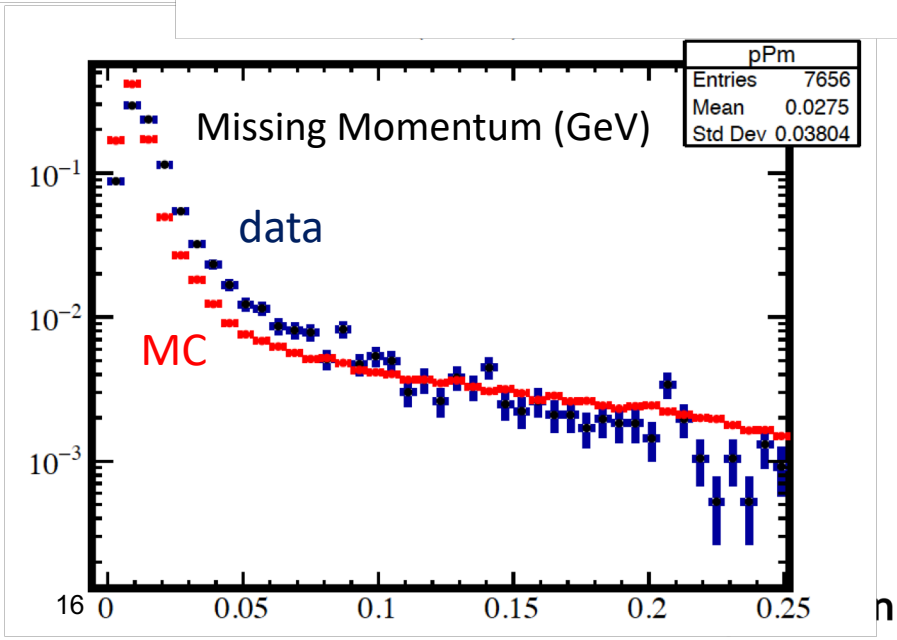


Hydrogen: W, Emiss and Pmiss

Q^2: 8 GeV^2:



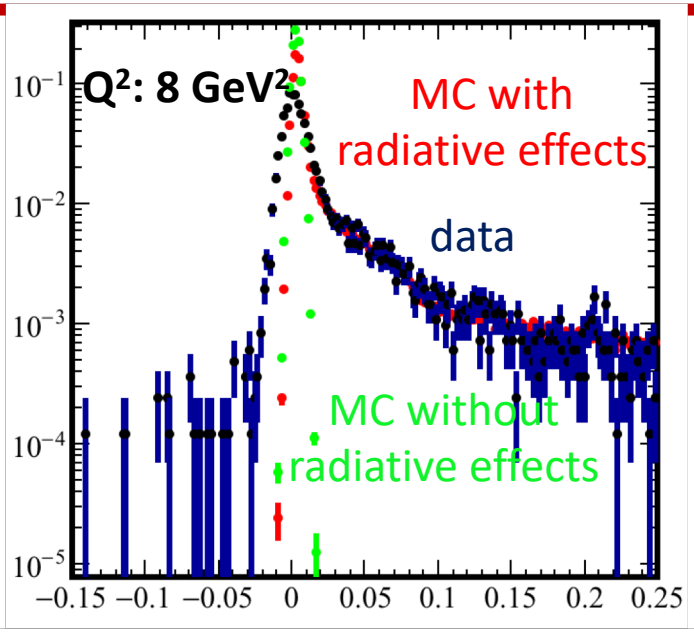


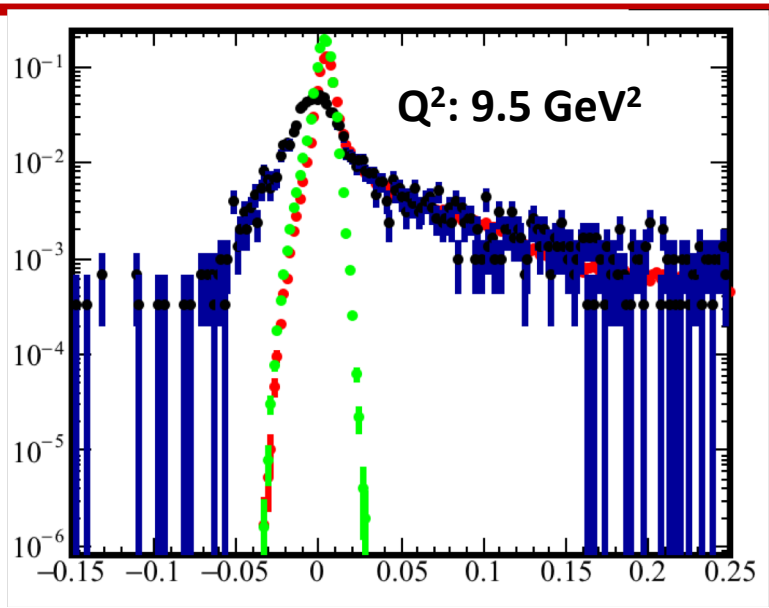


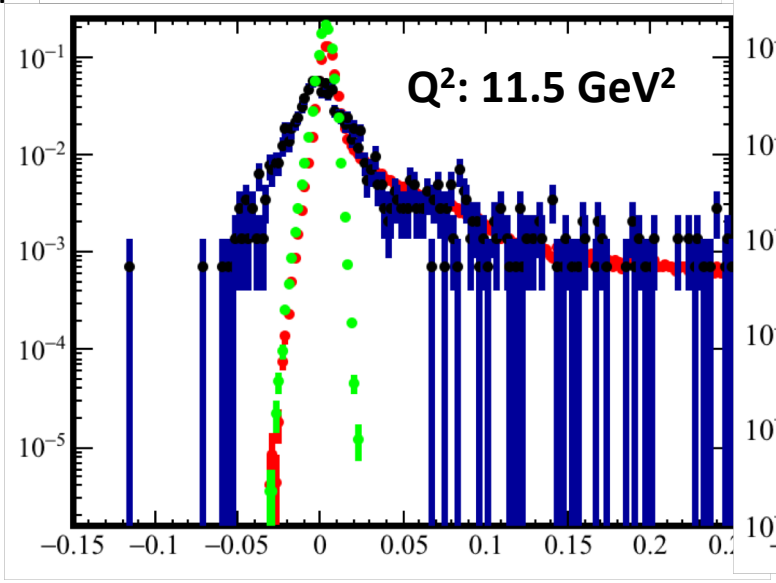
Hydrogen data used to fine tune the optics settings

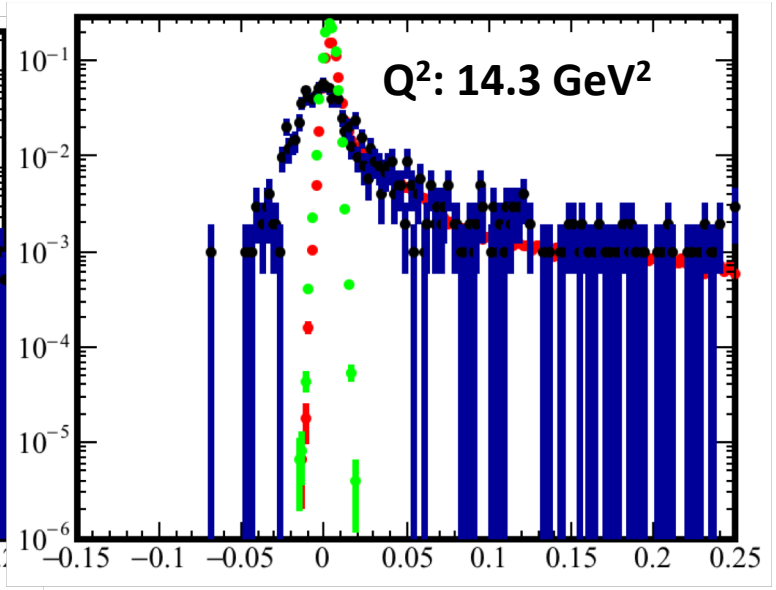
Hydrogen radiative tails: Emiss spectra

Radiative effects in agreement with PWIA model in MC (SIMC)







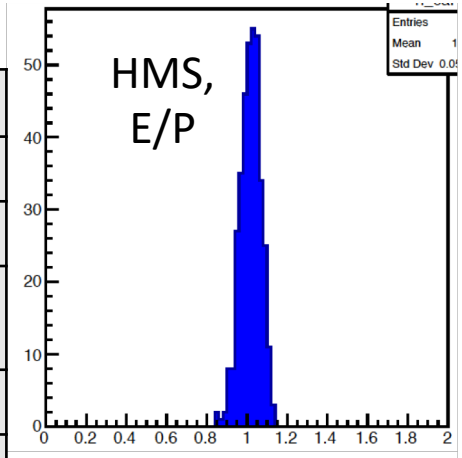


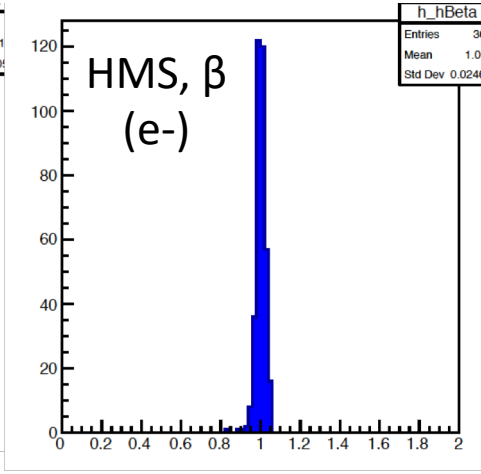
Cuts: Particle identification selection

Calibrations by Deepak Bhetuwal, MSU

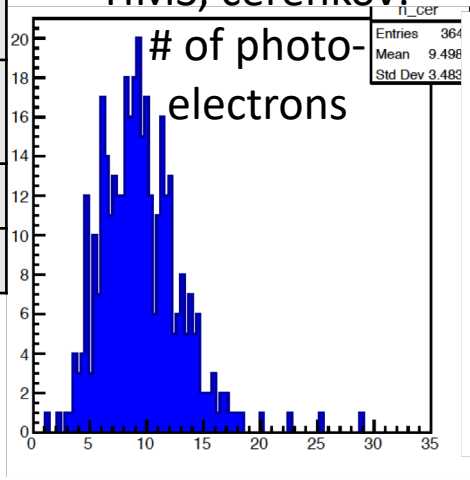
Cuts for hydrogen data:

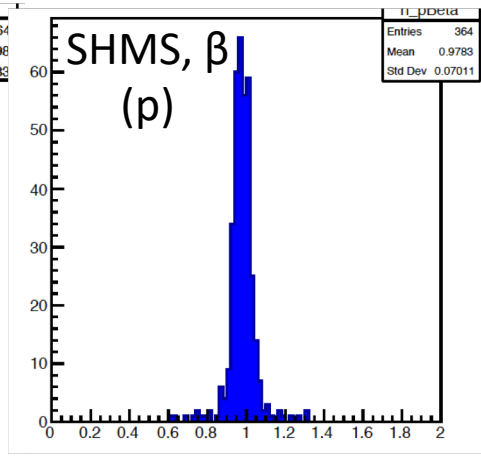
Cut	Value
HMS delta	-10%<delta<10%
SHMS delta	-10%<delta<12%
SHMS cerenkov	<0.1 photoelectrons
SHMS beta	0.6<beta<1.4
HMS beta	0.8<beta<1.2
HMS cerenkov	>0.1 photoelectrons
HMS calorimeter	0.85<E/P<1.15
Emiss	<0.1 GeV
Pmiss	<0.1 GeV





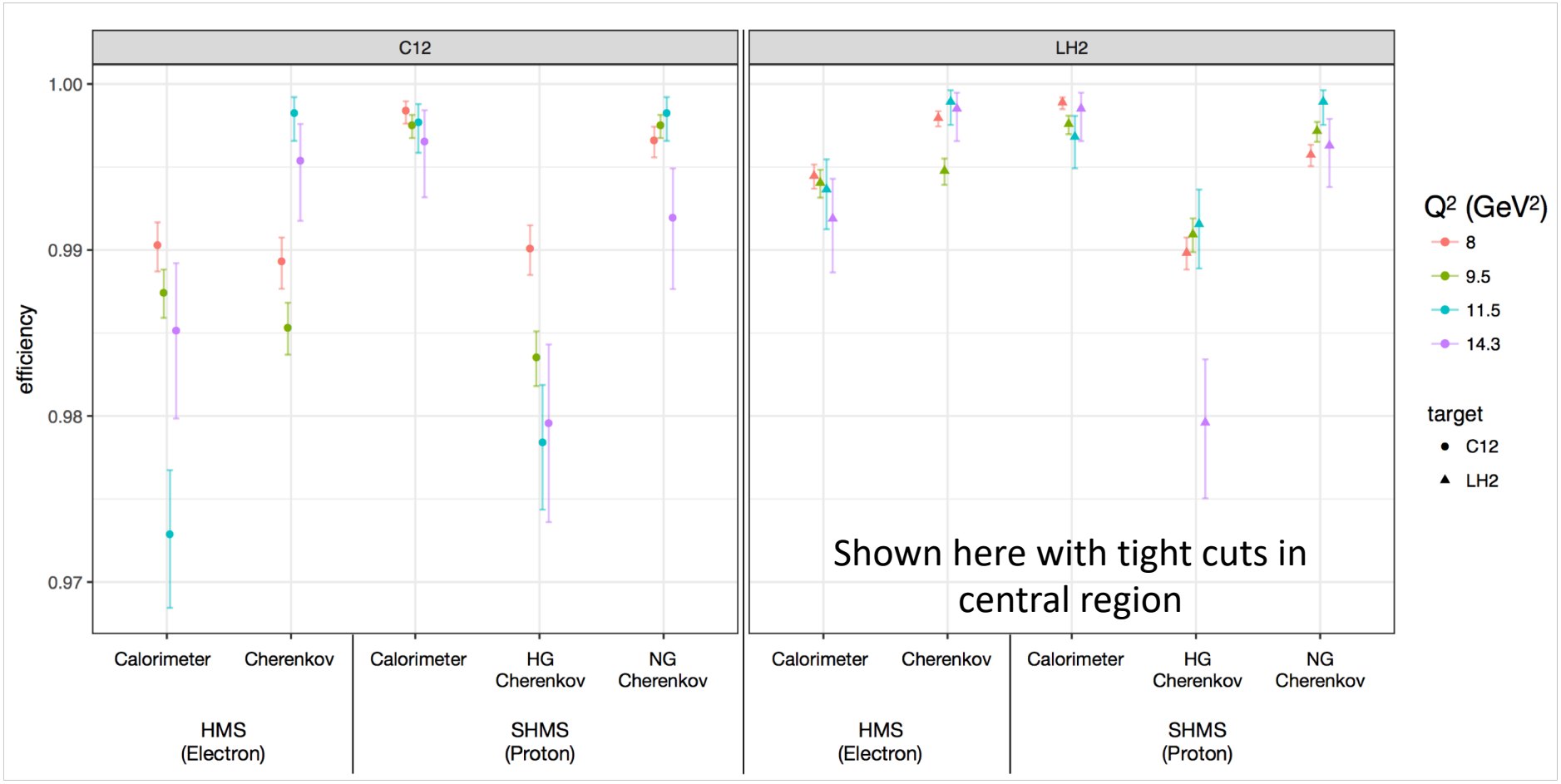
HMS, cerenkov:





Detector efficiencies

Plots from John Matter, UVa



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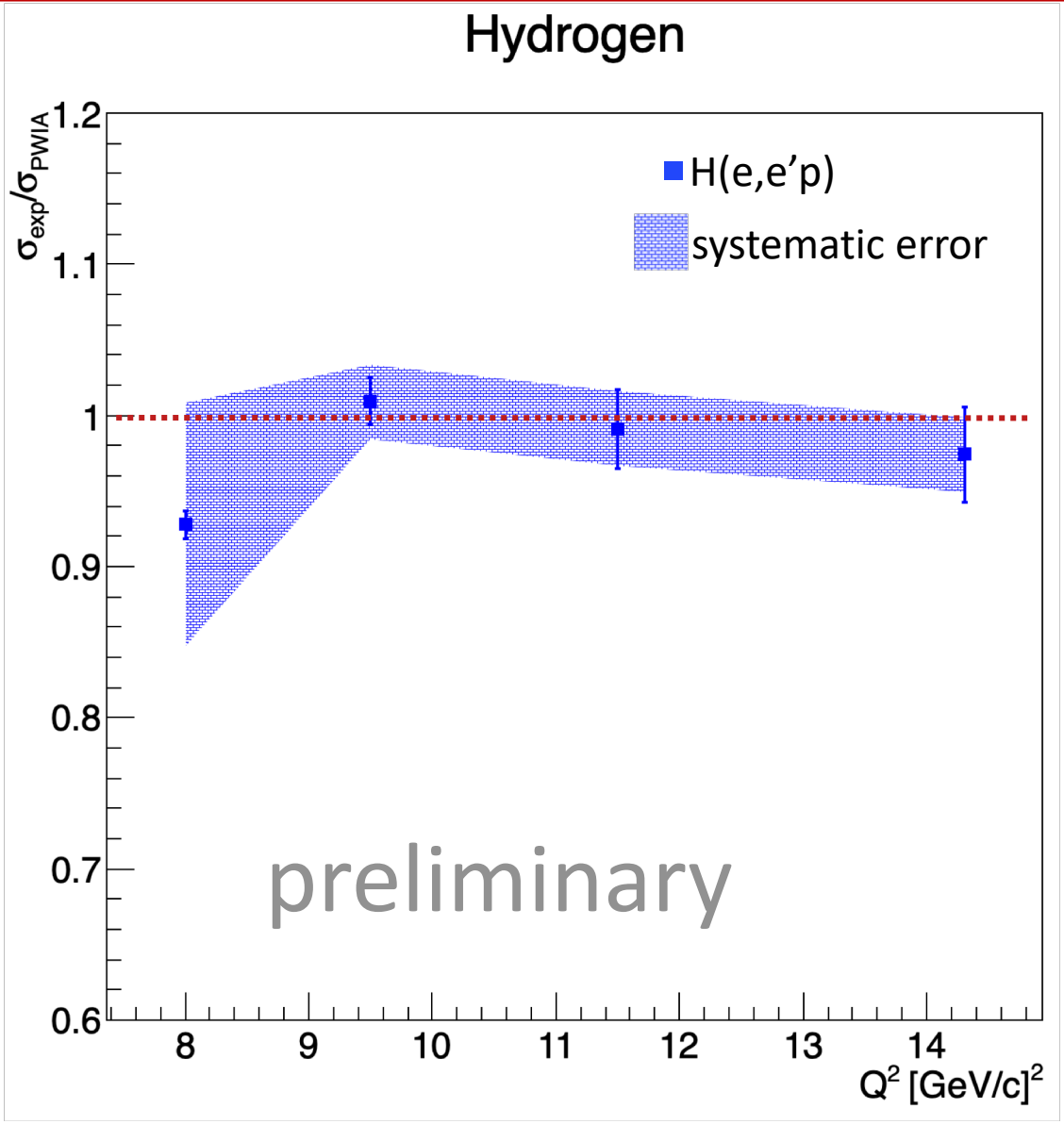
Hydrogen yield-preliminary



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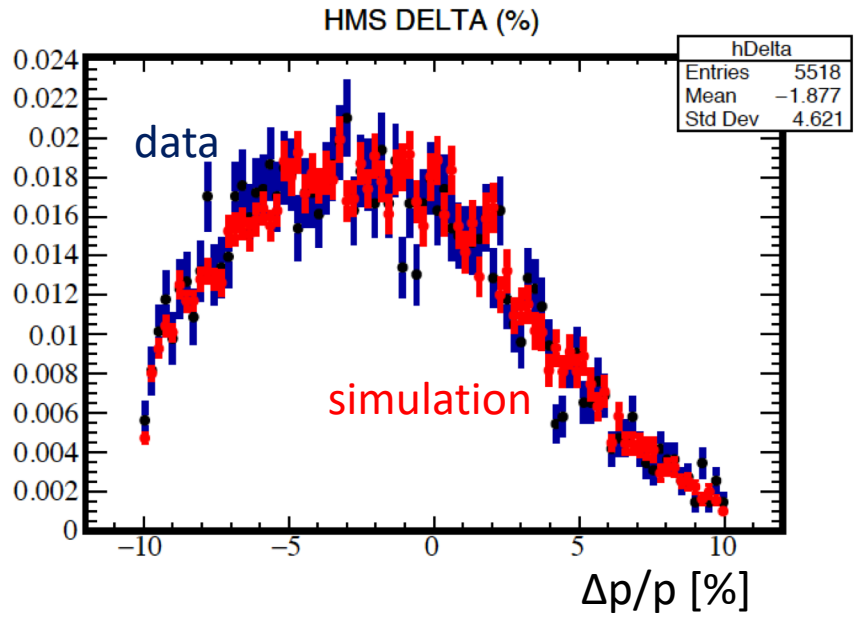
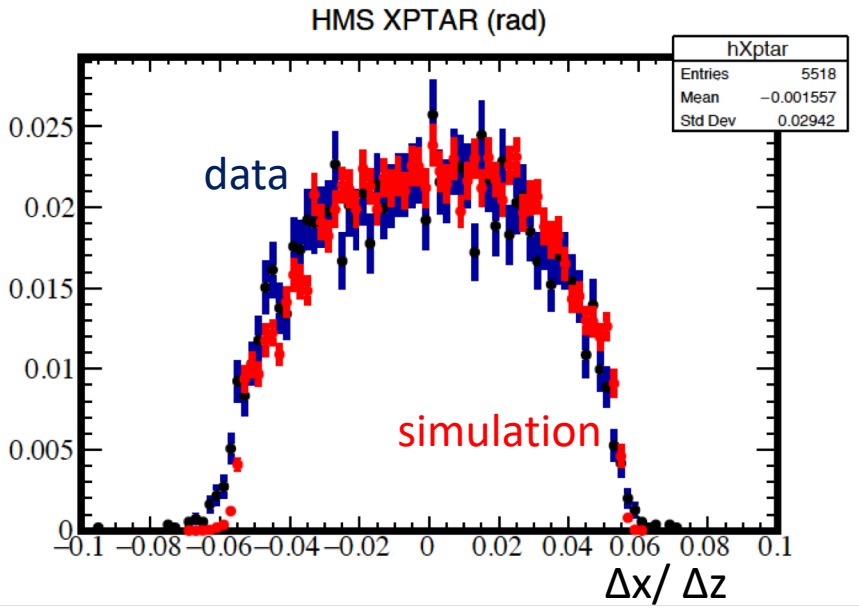
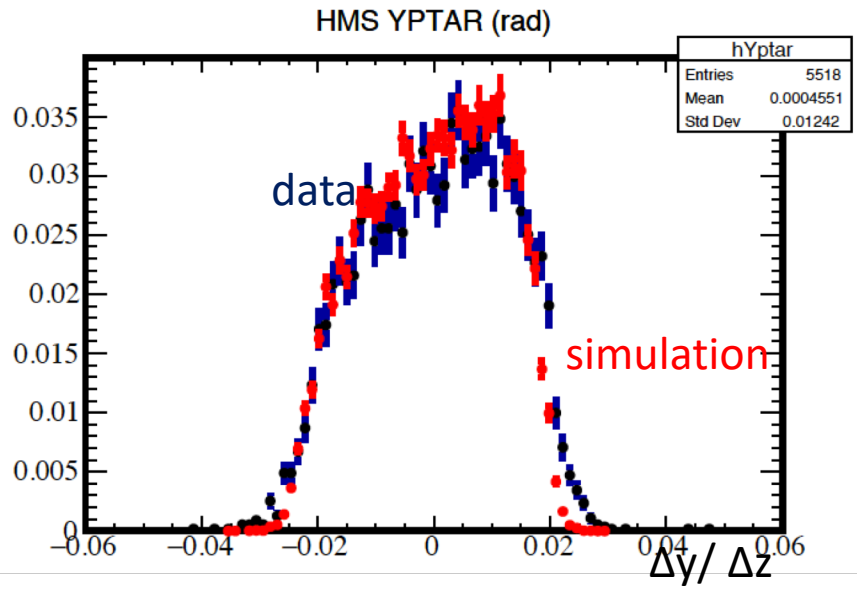
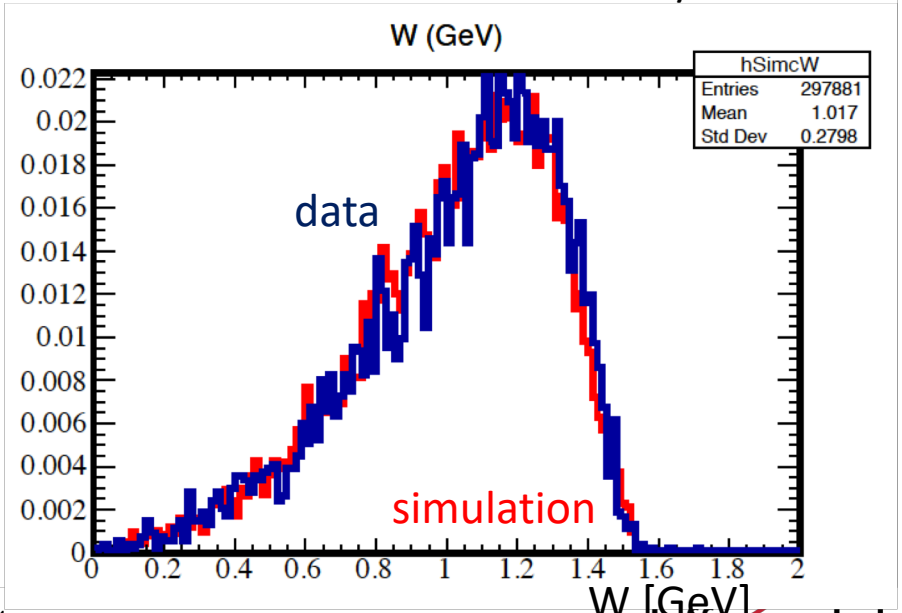
Carbon HMS data: Q^2 = 8 GeV^2









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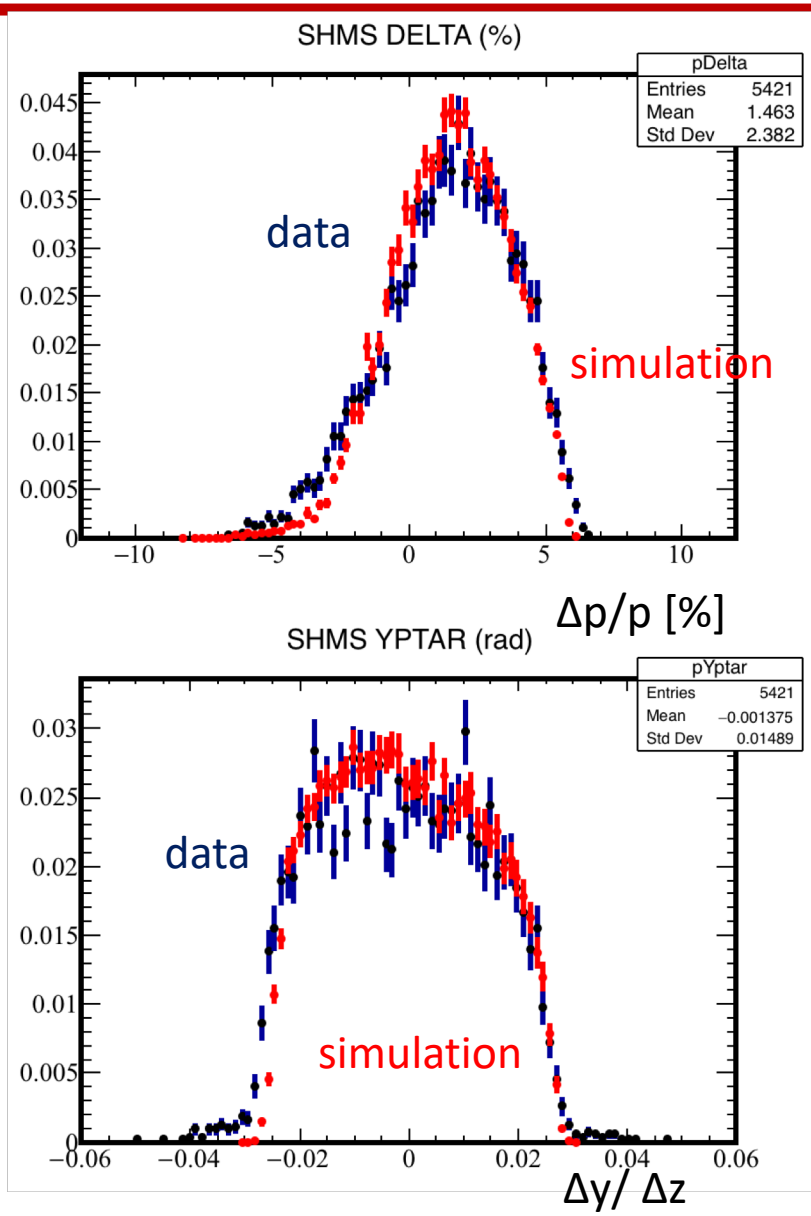

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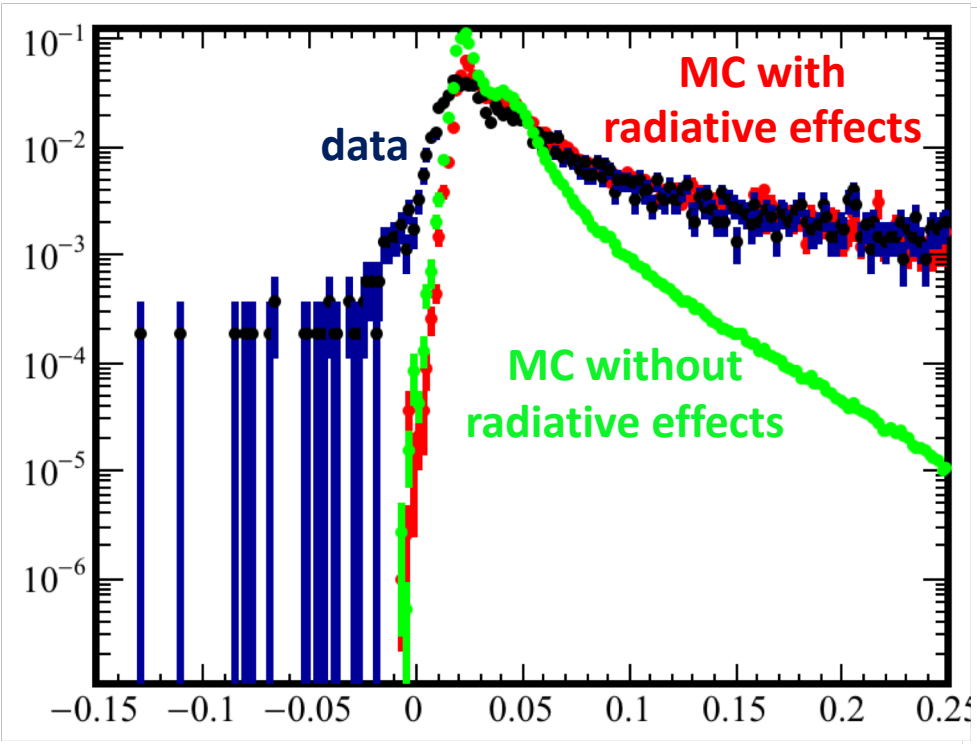
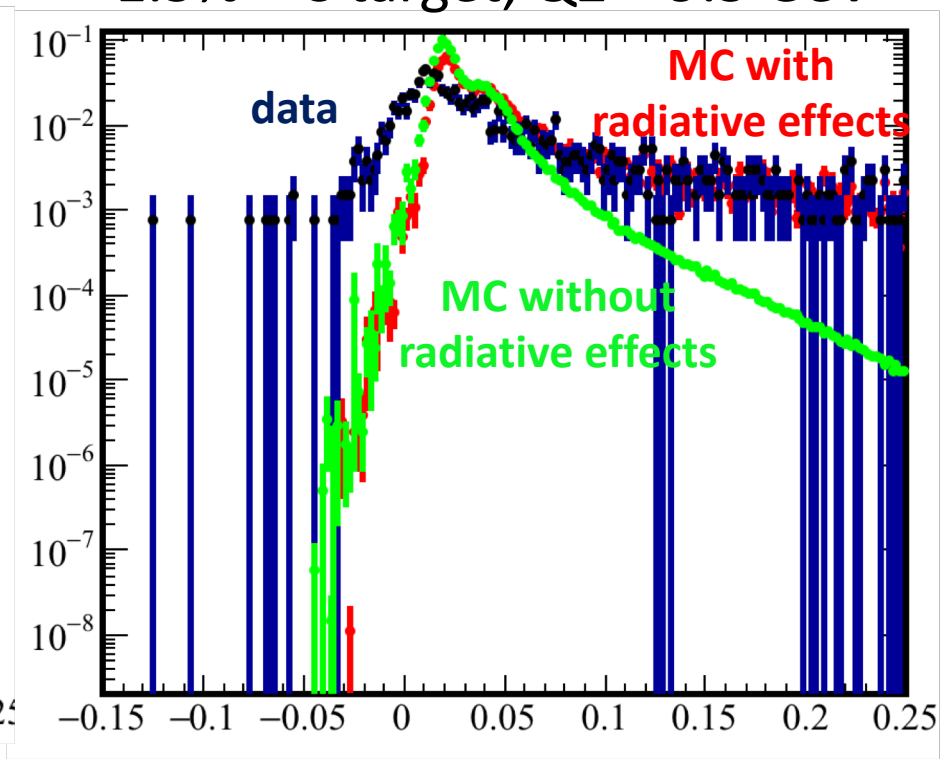
Carbon radiative tails

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



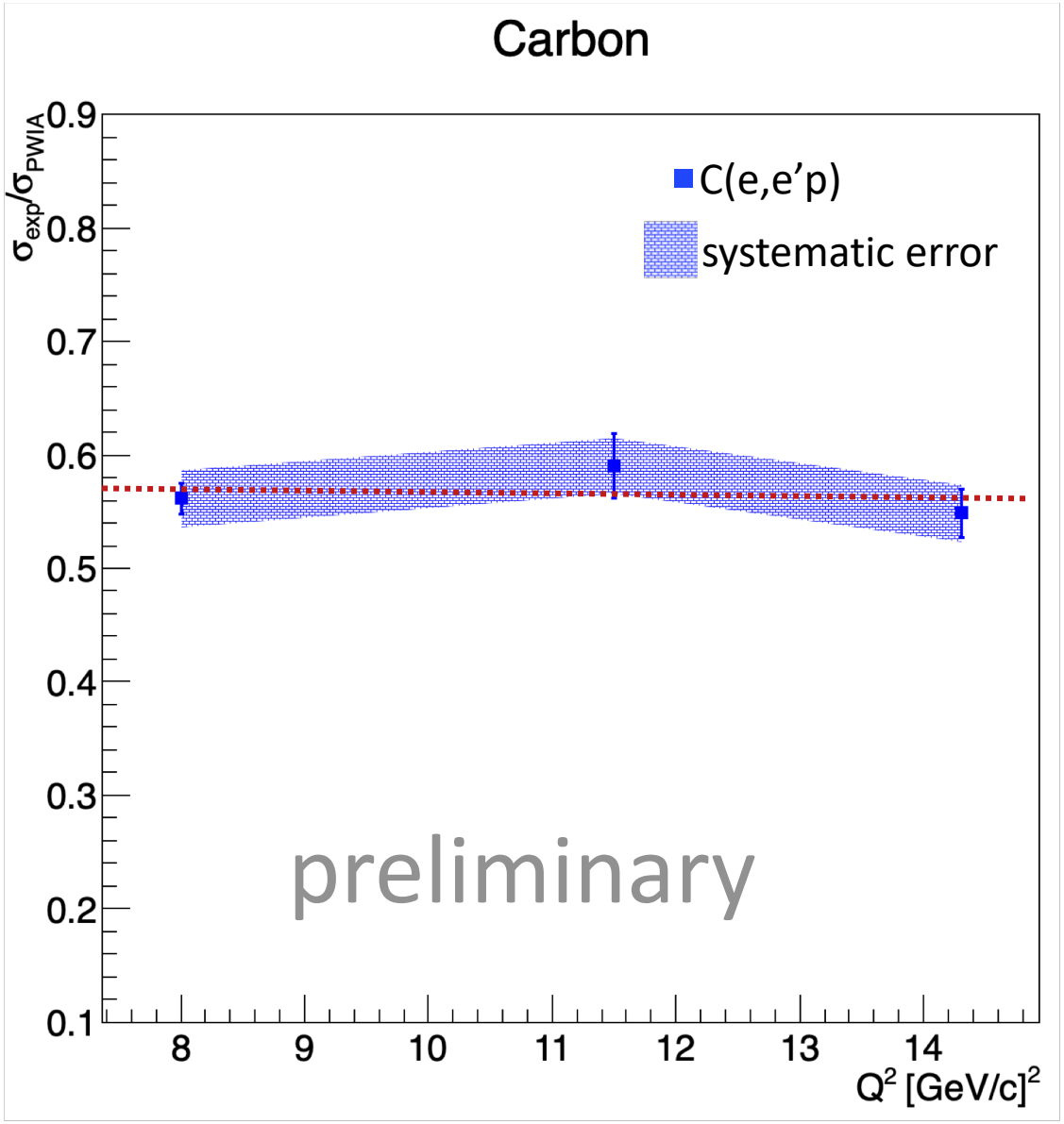
1.5% ^{12}C target, Q2 = 9.5 GeV^2



- Radiative effects agree with simulation in the tails.

Carbon yield-preliminary

Emiss < 80 MeV
Pmiss < 300 MeV



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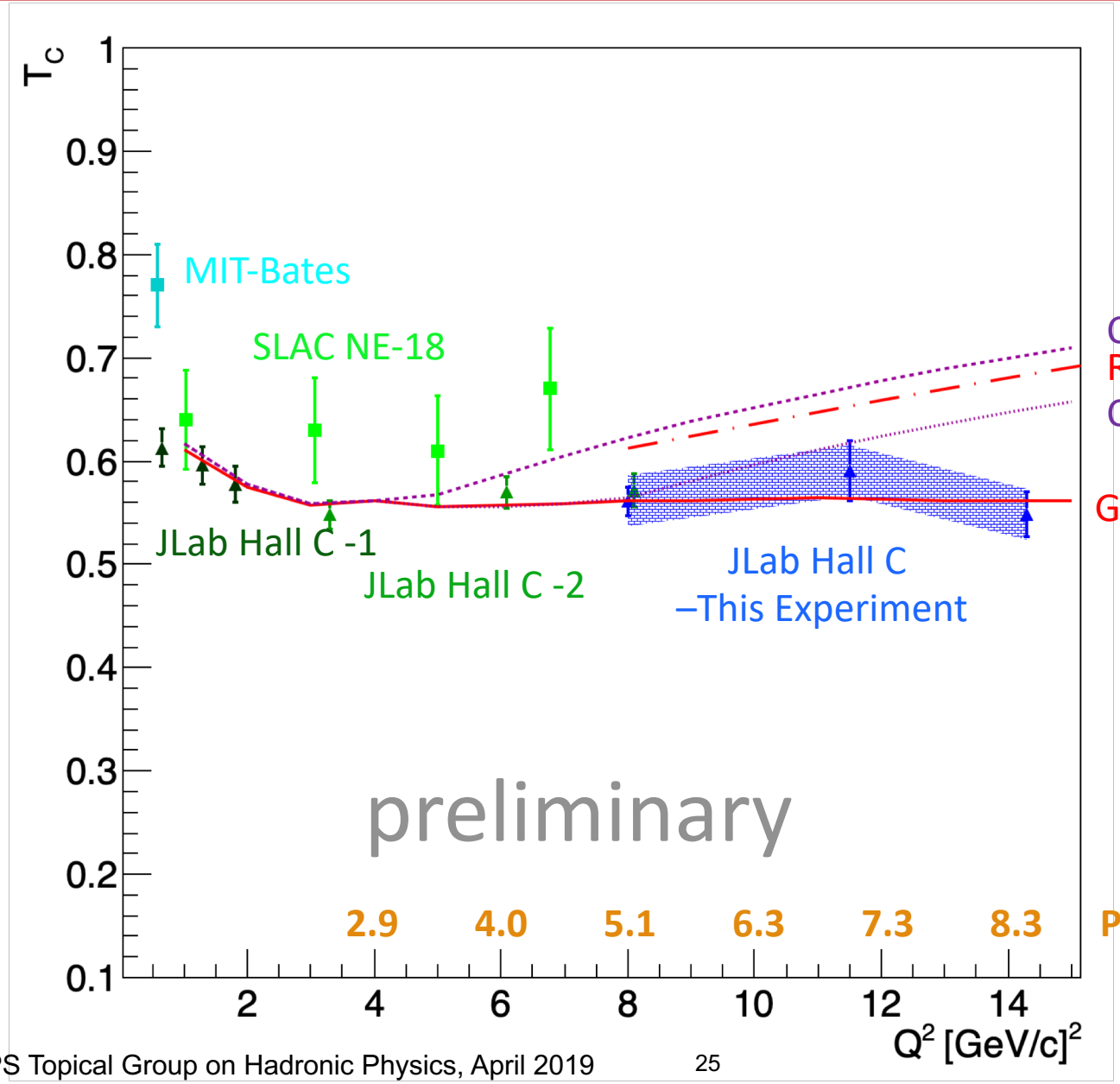
Transparencies-preliminary



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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
- Preliminary results for nuclear transparencies
- Analysis to understand systematics is ongoing

Thank you to the Hall C Collaborators!

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