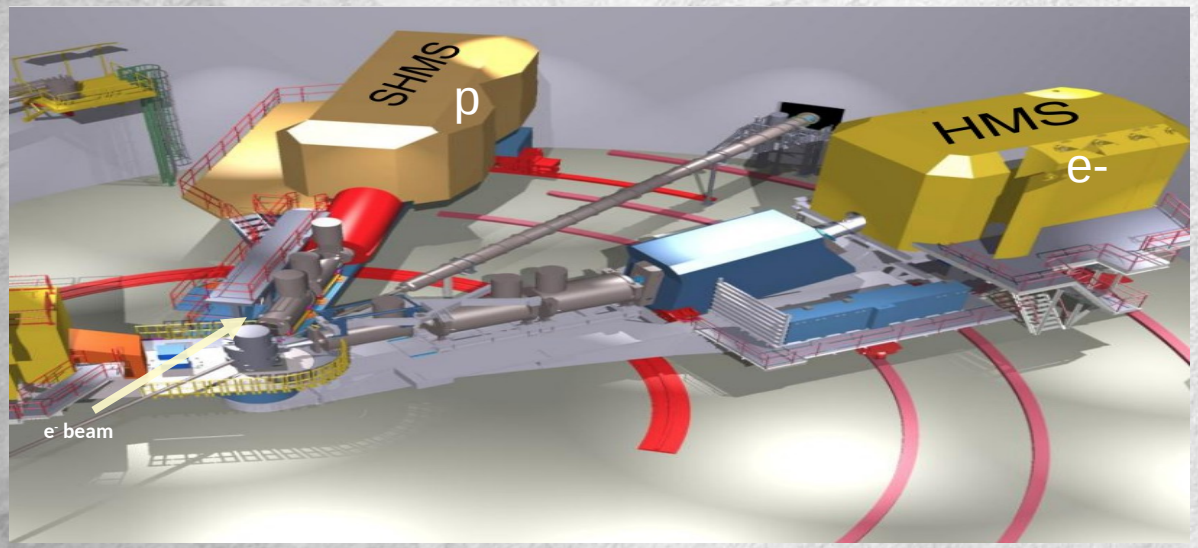
THE SEARCH FOR COLOR TRANSPARENCY OF PROTONS @ 12 GeV

In

HALL C, JEFFERSON LAB



Deepak Bhetuwal

June 28, 2019

OUTLINE

- Introduction
- Color Transparency (CT)
- JLab Experiment E12-06-107
- Experimental Setup
- Data VS Simulation (SIMC)
- Detector Calibration
- Efficiency Study
- Preliminary Yield and Transparency
- Work Status
- Summary

INTRODUCTION

Color transparency (CT) is a a unique prediction of Quantum Chromo Dynamics (QCD) where the final (and/or initial) state interactions of hadrons with the nuclear medium are suppressed for **exclusive processes** at high momentum transfers (Q^2).

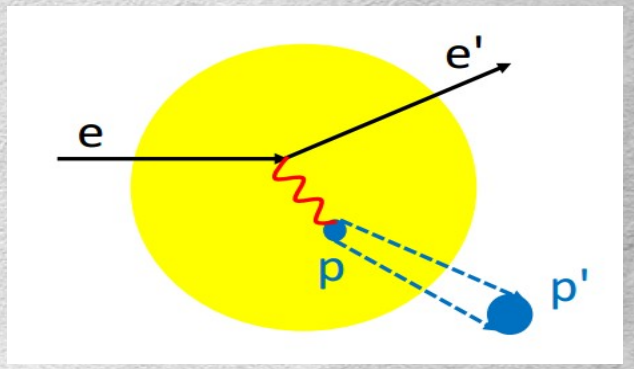
A clear signal for the onset of CT for baryons would show the transition from the nucleon-meson picture to quark-gluon degrees of freedom → **Onset is signature for QCD degrees of freedom in nuclei.**

COLOR TRANSPARENCY (CT)

- Introduced by Mueller and Brodsky, 1982.

→ arises in picture of quark-gluon interactions only.

- Scattering takes place via selection of point-like configurations (PLC) with small transverse size — **squeezing (QM)**.
- PLC's compact size is maintained while traversing through the nuclear medium — **freezing (relativity)**.
- Color field of singlet objects vanishes as size is reduced. PLC is **color-neutral**, passing through the nuclear medium undisturbed **(nature of the Strong force as described by QCD)**.



A(e, e'p)

CT ONSET

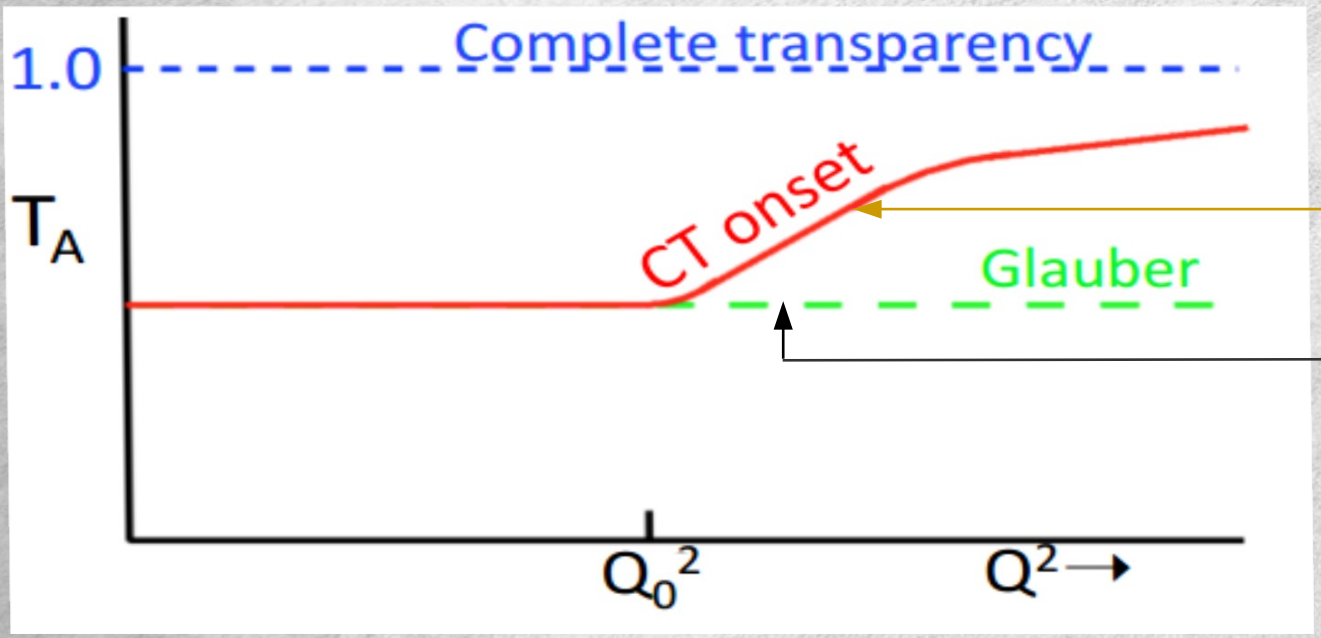
Signature for the onset of CT involves a rise in nuclear transparency (T_A), as a function of the momentum transfer (Q^2).

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

σ_A (nuclear cross section)

σ_N (free nucleon cross section)

$\sigma_A/A \rightarrow$ bound nucleon cross section



QCD prediction

Traditional nuclear physics prediction

OR

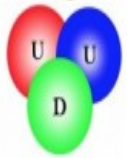
Conventional Glauber calculations predict constant T with increasing Q^2 (Energy independent).

Clear signature of CT would be dramatic rise in T around Q_0^2.

CT PAST EXPERIMENTS

CT Experiments

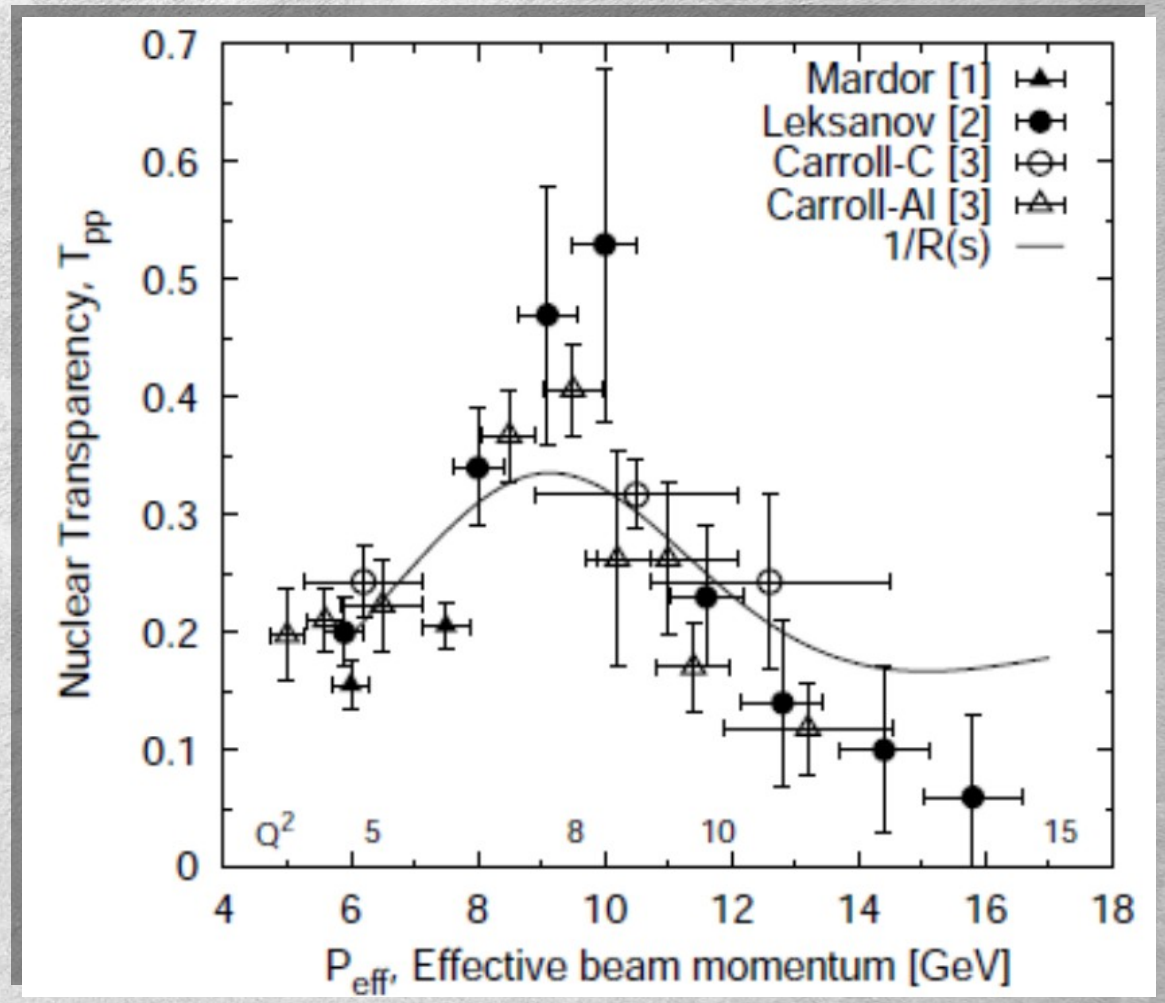
Baryon



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

Meson

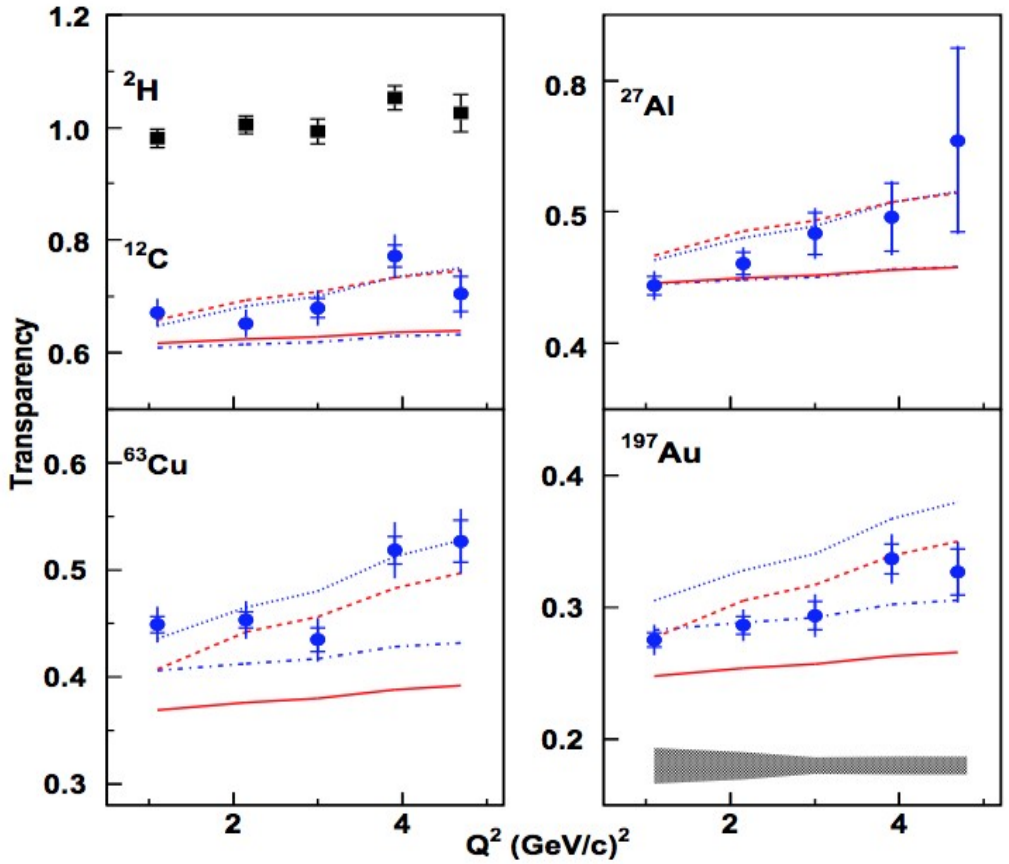
A(π,di-jet): FNAL
A(γ, π^- p): JLab
A(e, e'π^+): JLab
A(e, e'ρ^0): DESY & JLab



CT RESULTS UNTIL NOW

PION

Hall C E01-107 pion electroproduction



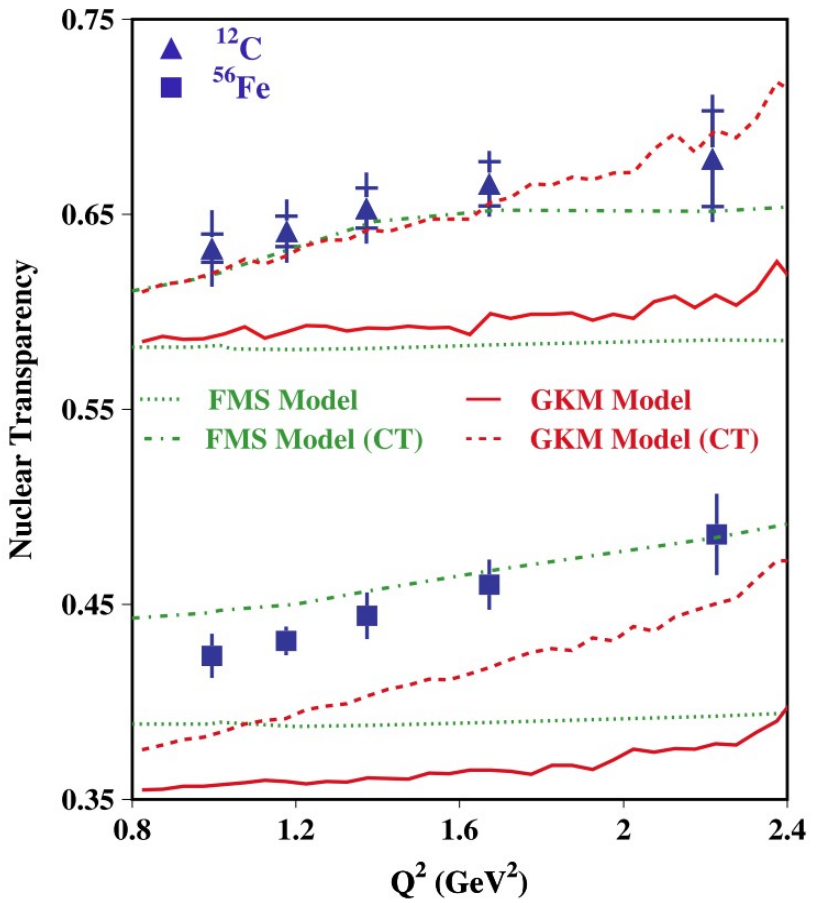
B.Clasie *et al.* PRL 99:242502 (2007)

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

CT is well established at high energies [essential for x – scaling in Deep Inelastic Scattering (DIS)].

Onset of CT has been measured in Mesons but not in Baryons.

RHO



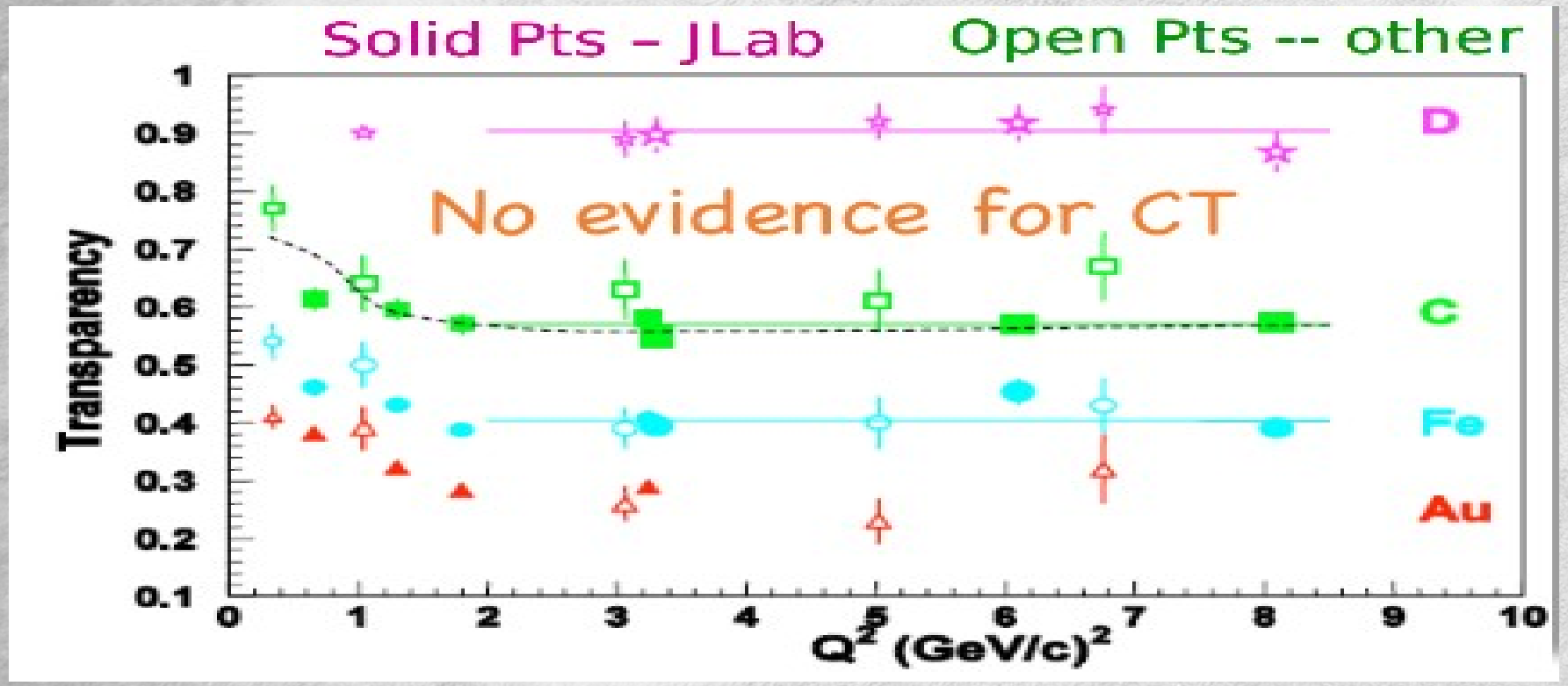
L. El Fassi *et al.* PLB 712,326 (2012)

CLAS E02-110 rho electroproduction

CT RESULTS UNTIL NOW

PROTONS

Plateau consistent with conventional calculations …



Onset of CT has been measured in Mesons but not in Baryons.

CT EXPERIMENT: E12-06-107

First experiment to run in Hall C in the 12 GeV era to take data using the new magnetic spectrometer SHMS (Super High Momentum Spectrometer) along with HMS (High Momentum Spectrometer)!

The experiment E12-06-107, to search for color transparency (CT) in protons, ran in Hall C at JLab in Spring 2018.

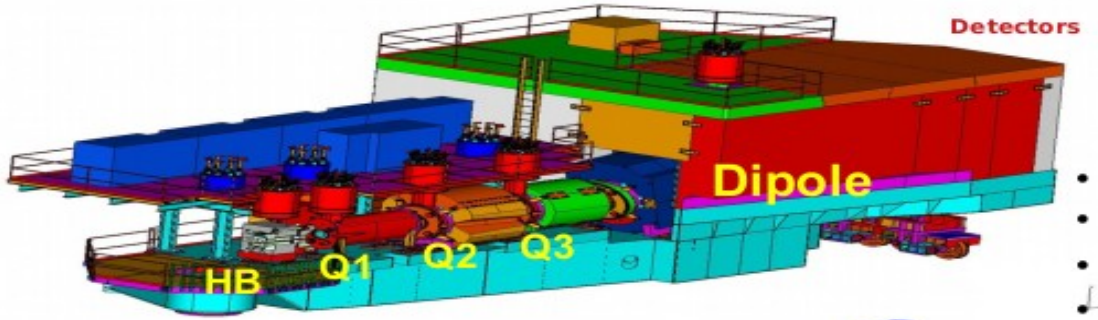
~20 days of data taking with E_{beam} of 6.4 GeV and 10.6 GeV and up to 60 uA of beam current.

Data collected over a wide range of 4 Q^2 points covering the region where a previous A(p,2p) experiment at BNL had observed an enhancement.

	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

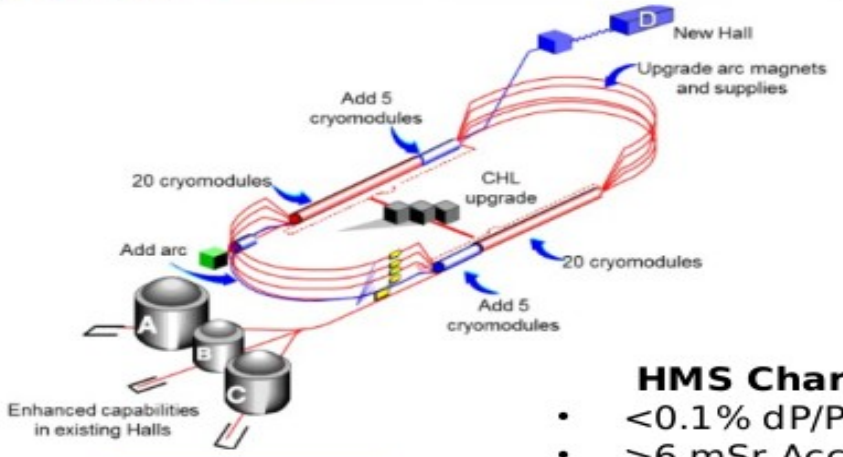
EXPERIMENTAL SETUP

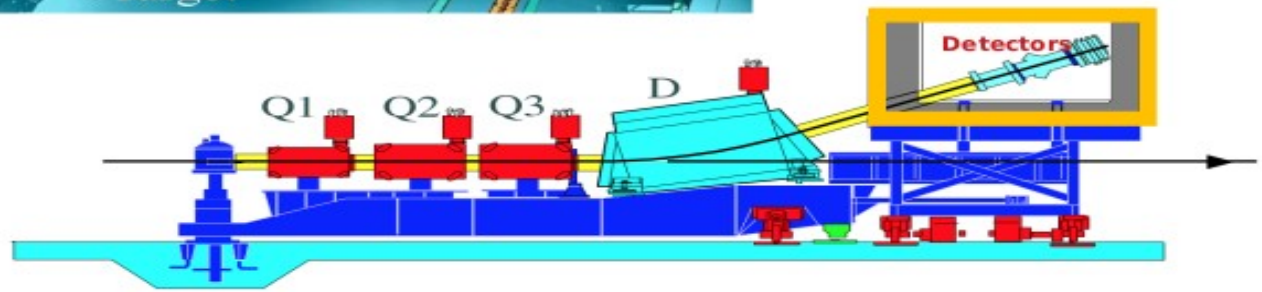
- Coincidence trigger: SHMS measures protons, HMS measures electrons
- Targets: 10 cm LH_2 (Elementary process, Hee'p check), 6% ^{12}C (production), Al dummy (background)



SHMS Characteristics:

- 5 x 10^{-4} dP/P resolution
- 4 mSr Acceptance
- P_0 = 1 to 11 GeV/c
- Scattering Angle = 5.5 deg to 40 deg
- 18.4 degree vertical bend (dipole)





HMS Characteristics:

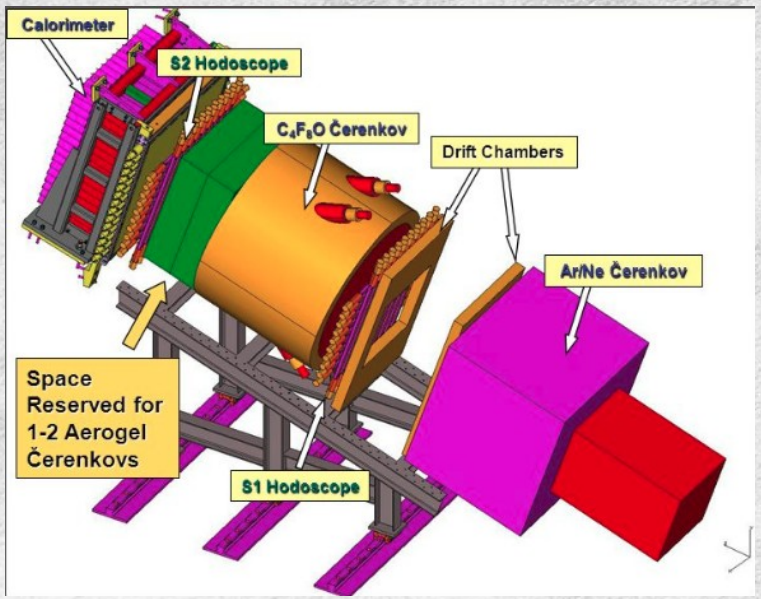
- <0.1% dP/P resolution
- >6 mSr Acceptance
- P_0 = 0.5 to 7.5 GeV/c
- Scattering angle = 12.5 deg to 90 deg

Well shielded detector huts

DETECTOR HUT

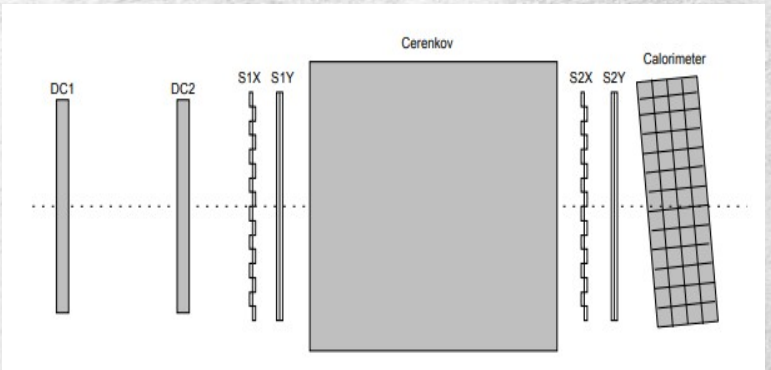
SHMS HUT

Drift Chambers (DC)
Hodoscopes (HODO)
Cerenkovs (HGC,NGC & Aerogel)
Calorimeter (CAL)



HMS HUT

Drift Chambers (DC)
Hodoscopes (HODO)
Cerenkovs (Gas, Aerogel)
Calorimeter (CAL)



E12-06-107 DETECTORS

SHMS / HMS

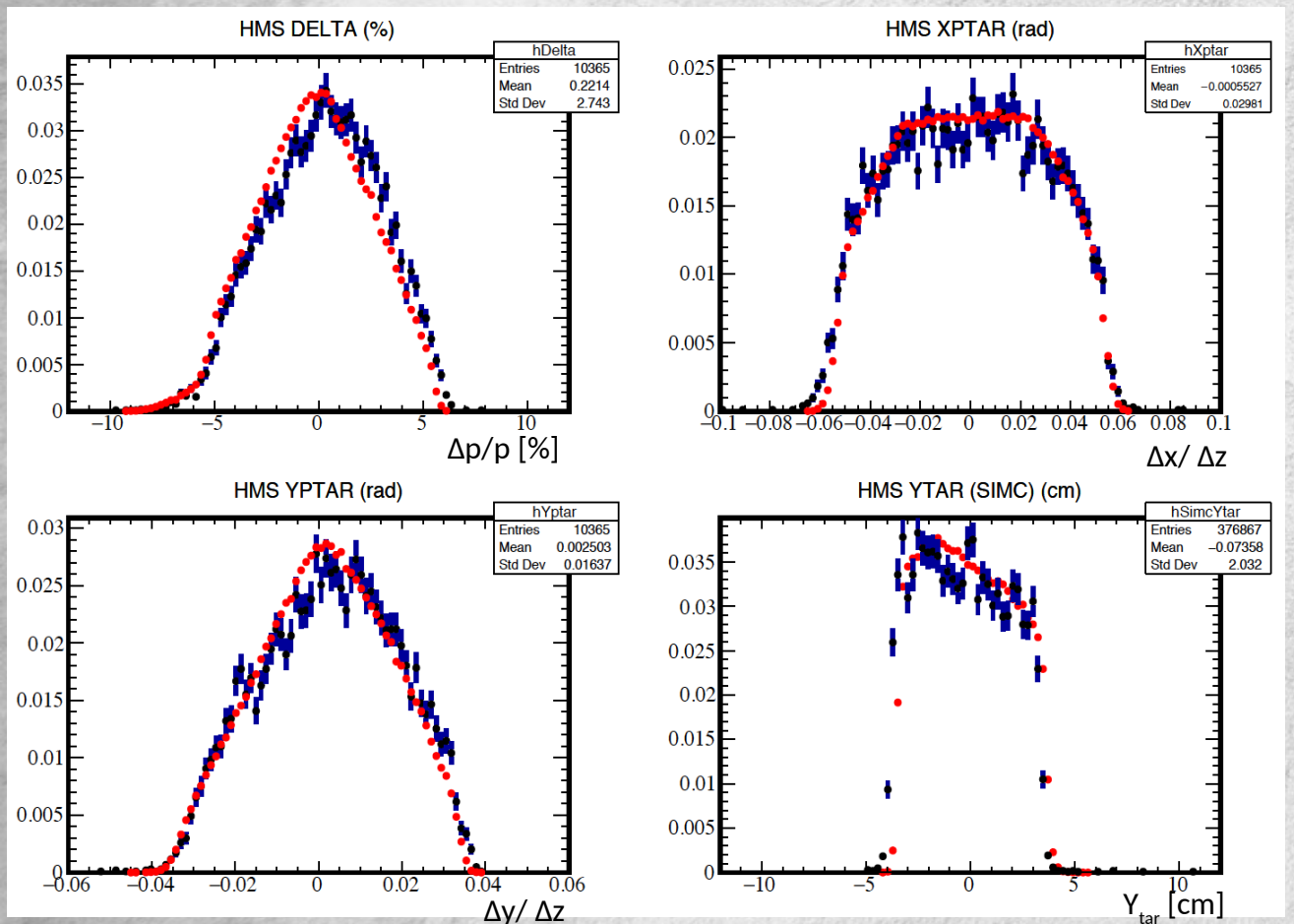
Drift Chambers (DC)
Hodoscopes (HODO)
Cerenkovs (Gas, Aerogel)
Calorimeter (CAL)

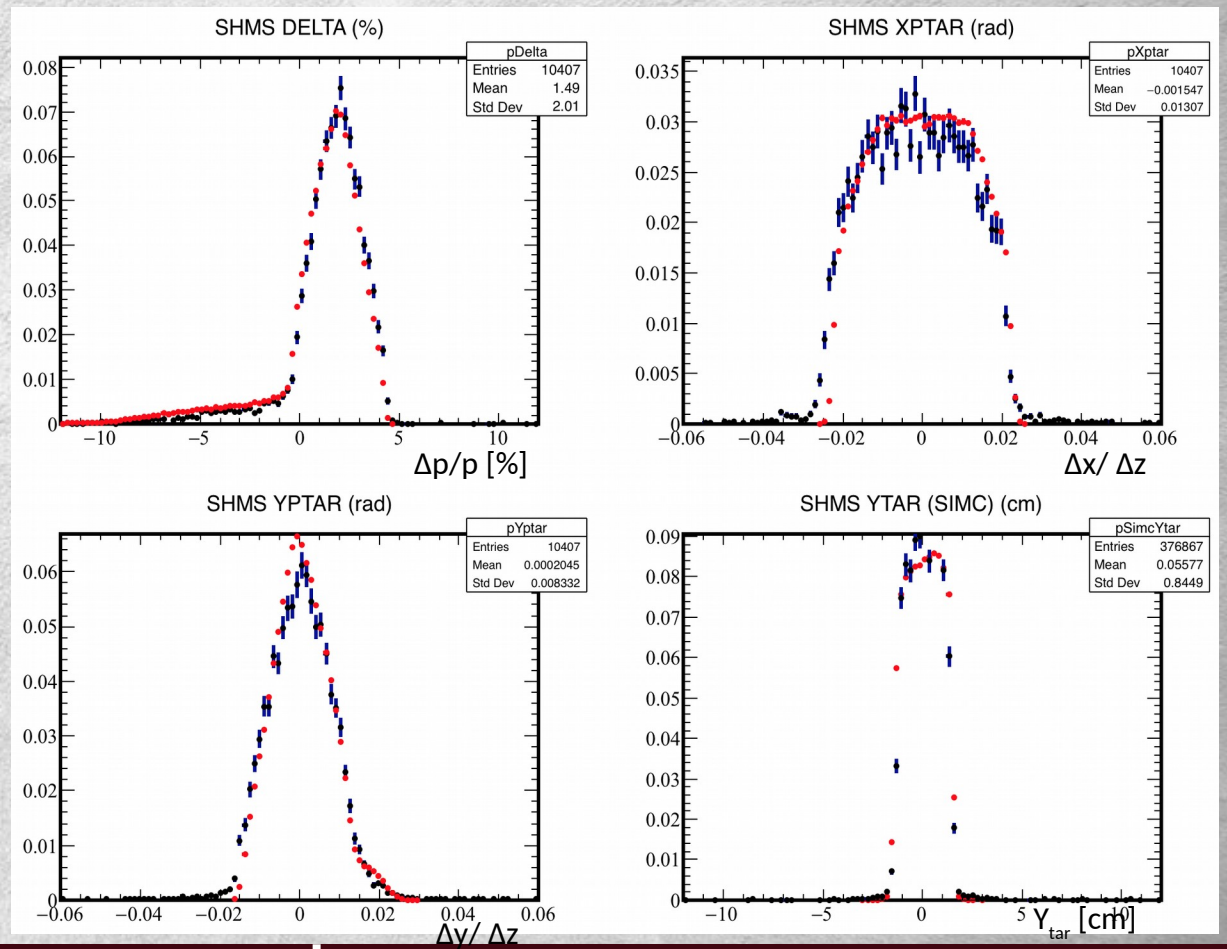
SIMC AND DATA

Plots from Holly S. Vance

SPECTROMETER QUANTITIES

Hydrogen: $Q^2 = 8\ GeV^2$

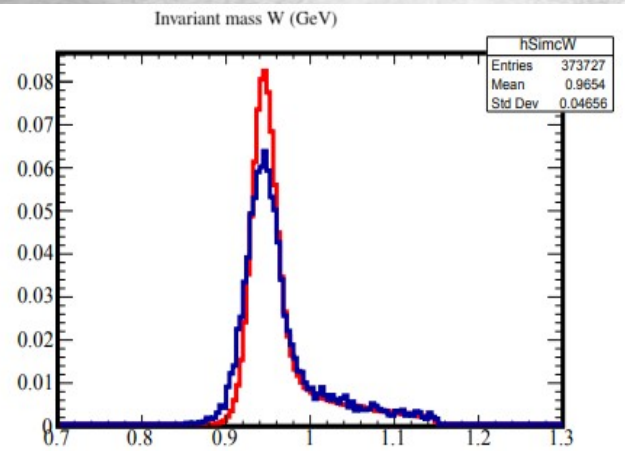


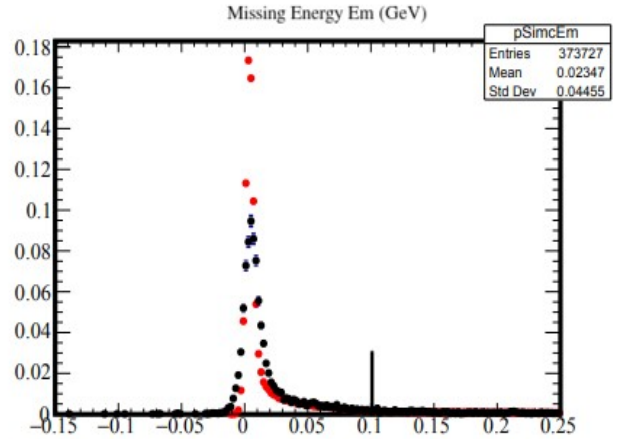


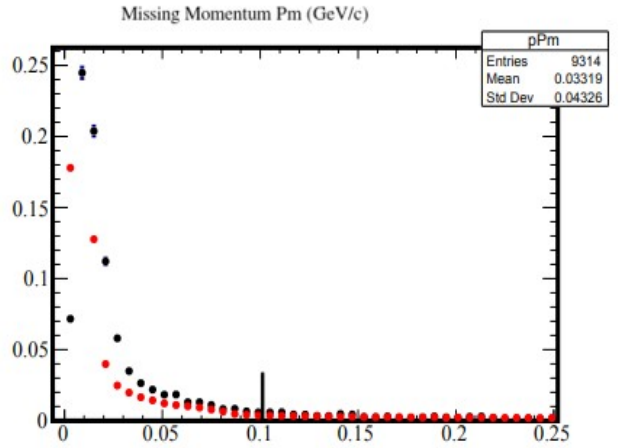
SIMC AND DATA

Plots from Holly S. Vance

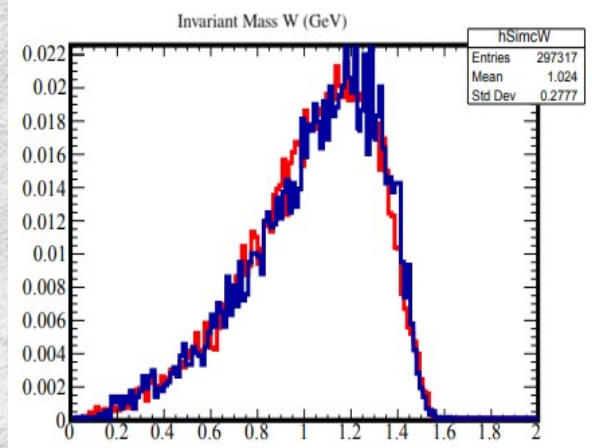
PHYSICS QUANTITIES

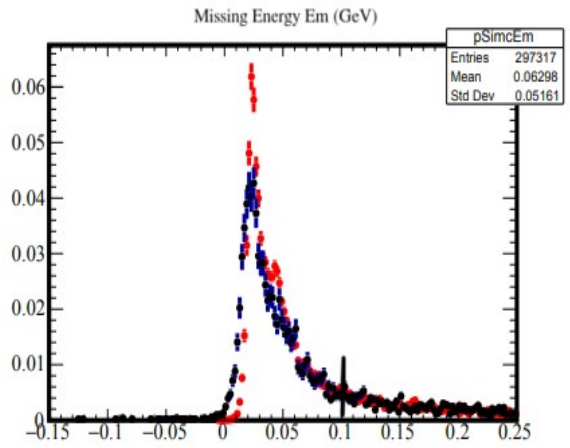


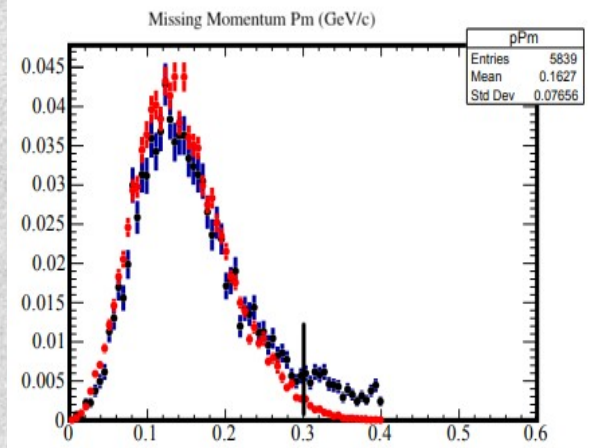




Hydrogen: Q^2 = 8 GeV²







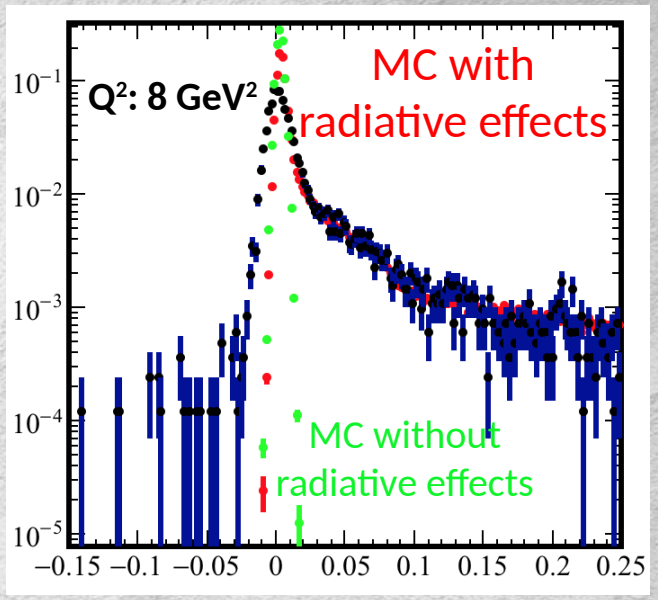
Carbon: Q^2 = 8 GeV²

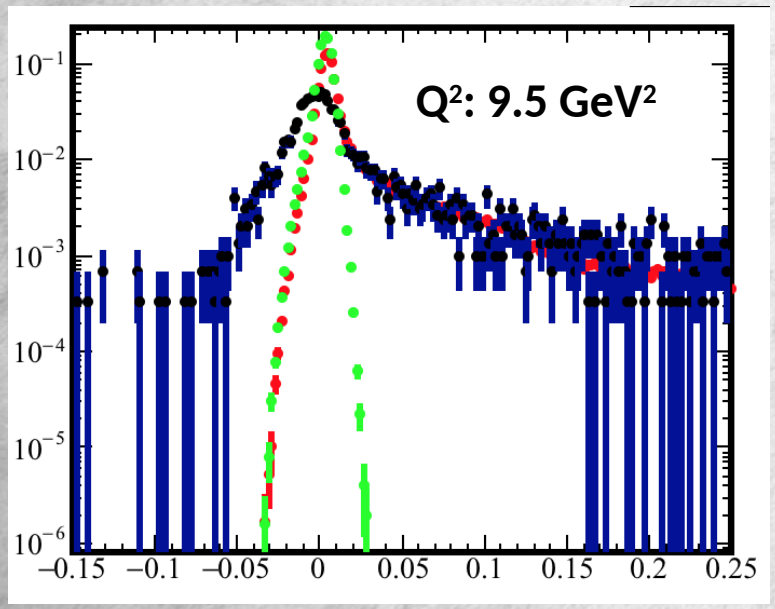
SIMC AND DATA

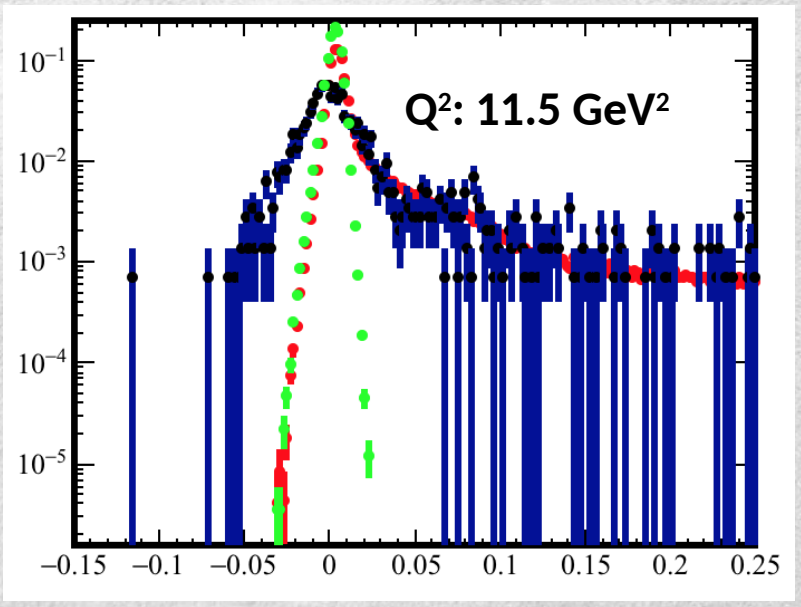
Plots from Holly S. Vance

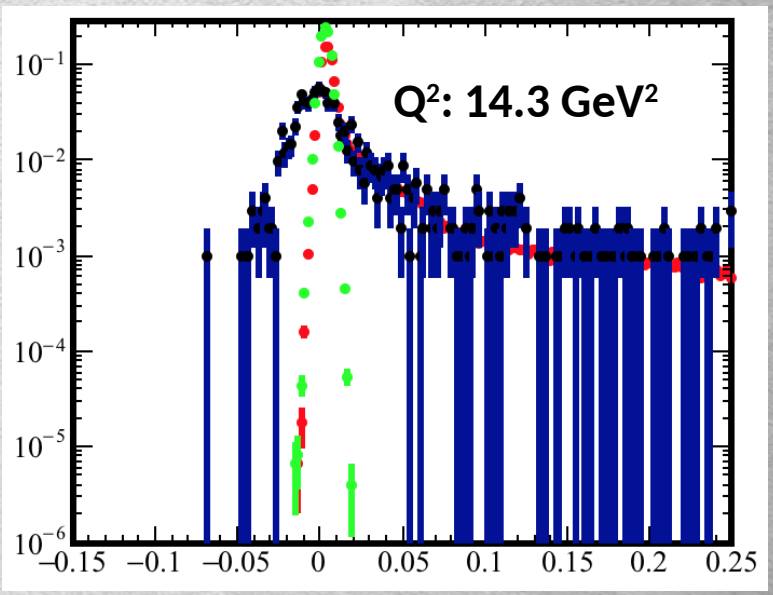
Hydrogen radiative tails: Emiss spectra

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







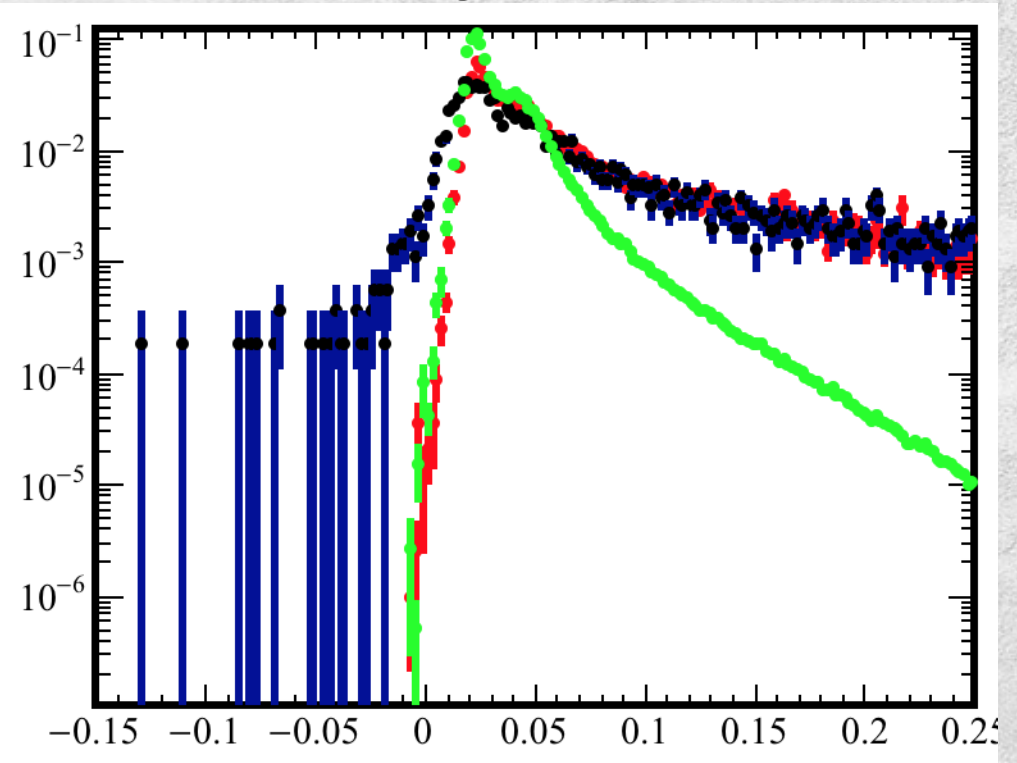


SIMC AND DATA

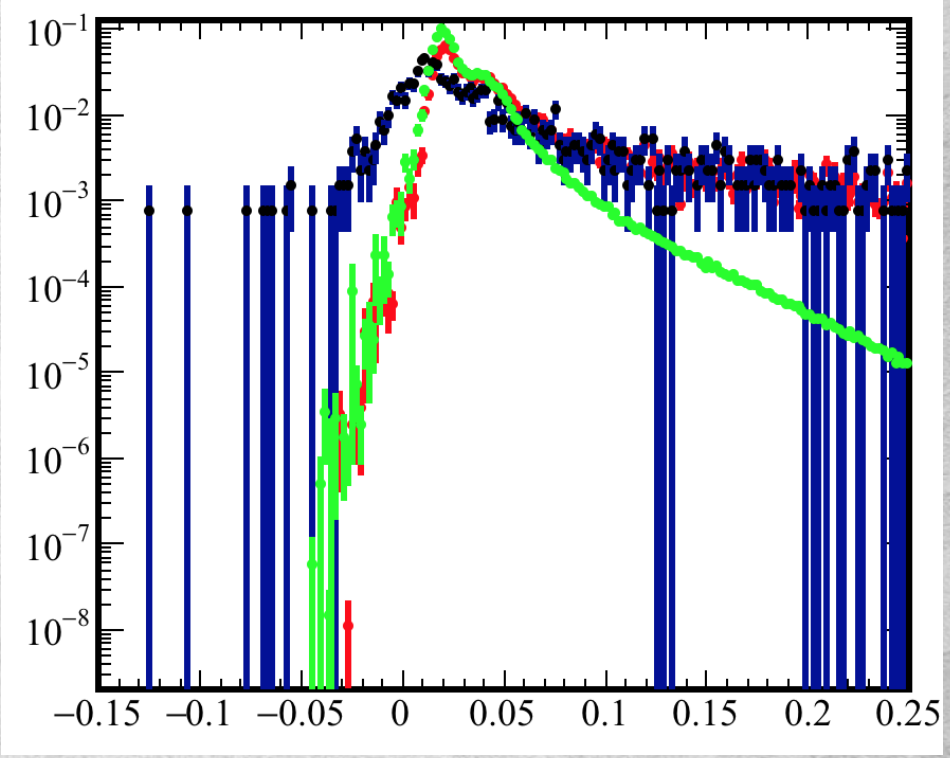
Plots from Holly S. Vance

Carbon radiative tails: Emiss spectra

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



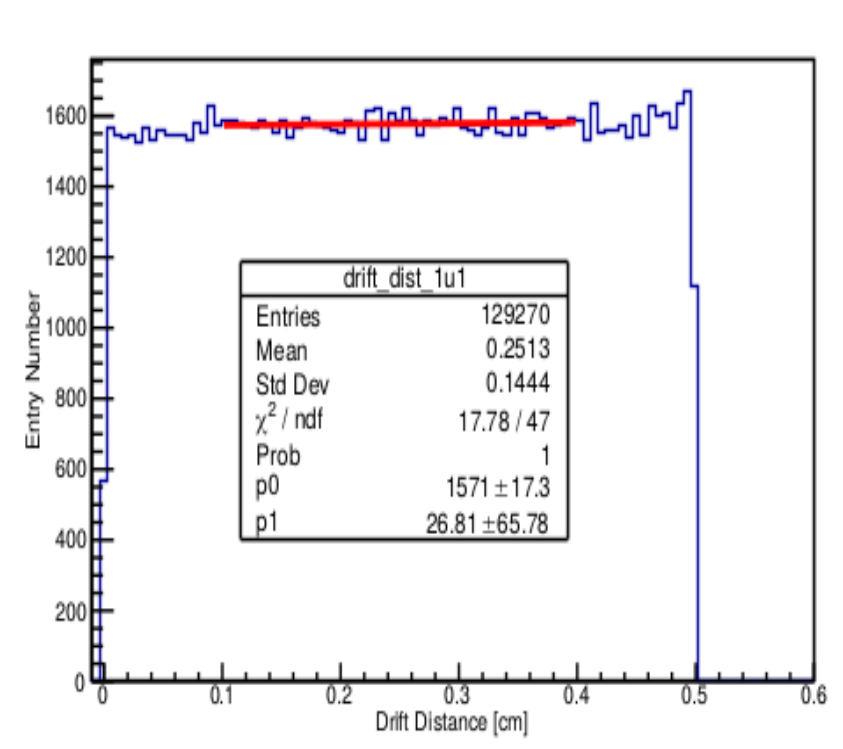
1.5% ^{12}C target, Q2 = 9.5 GeV^2

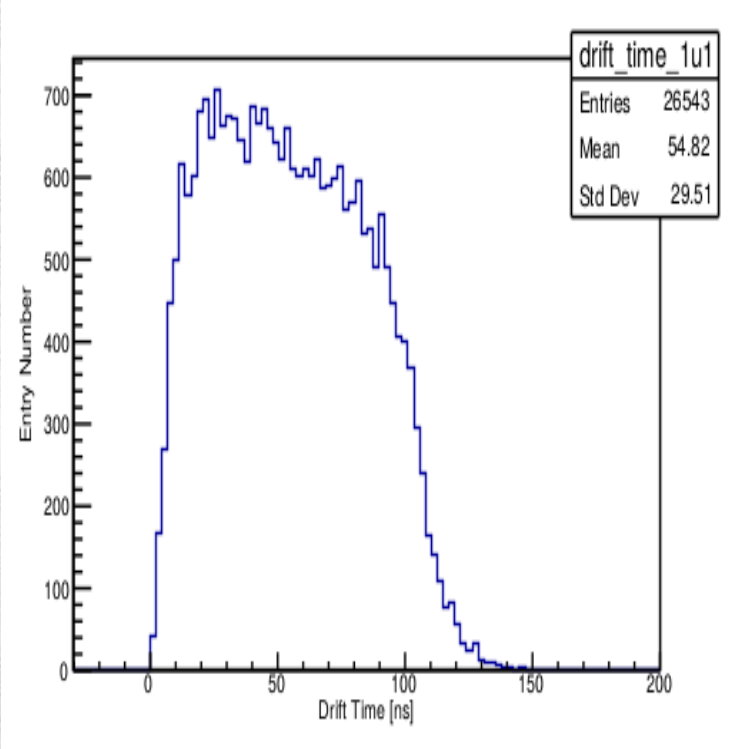


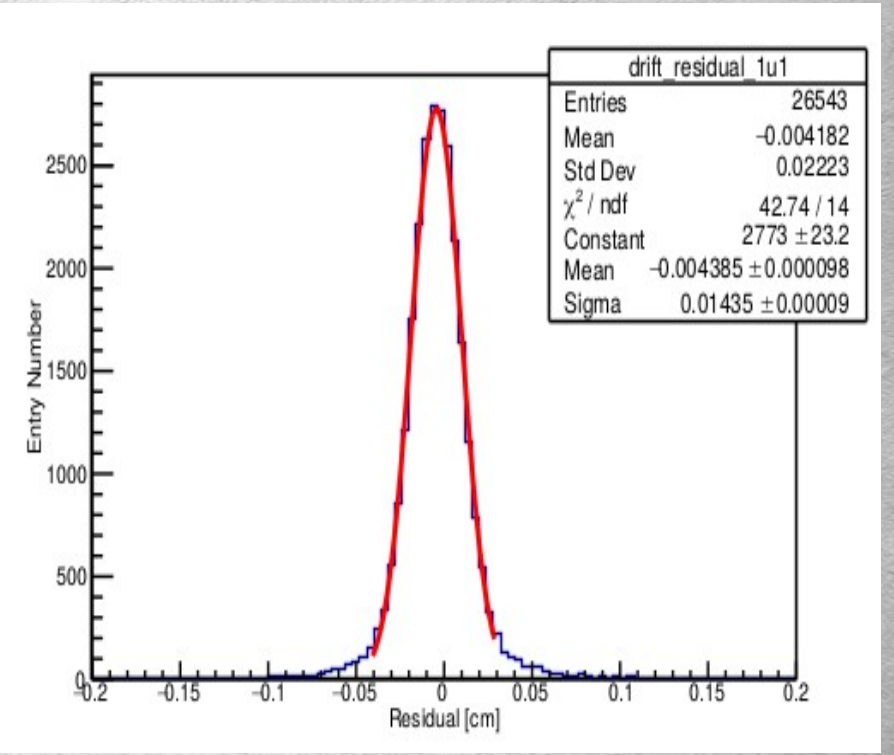
Radiative effects agree with simulation in the tails

CALIBRATION PLOTS

DRIFT CHAMBER CALIBRATION

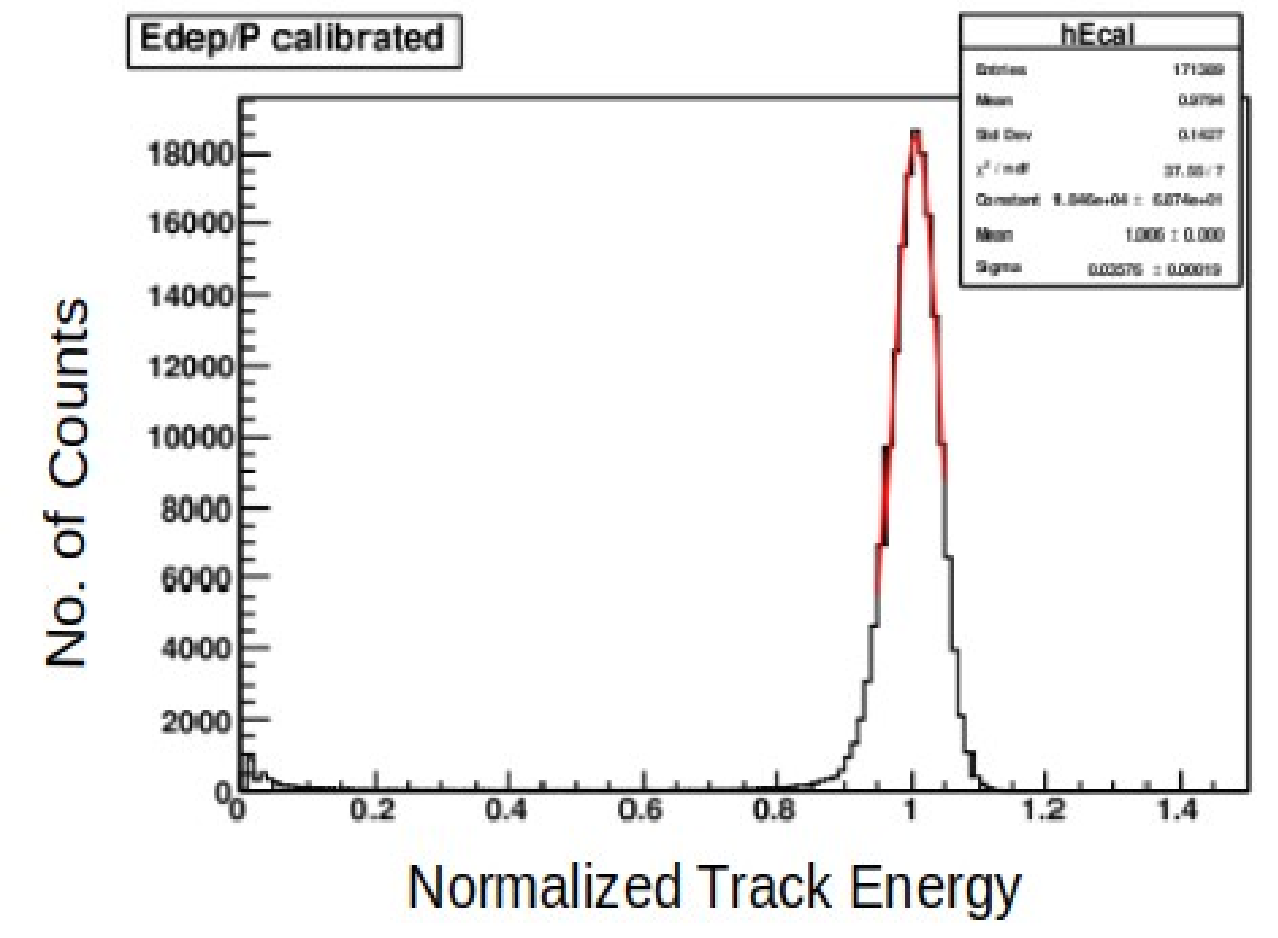


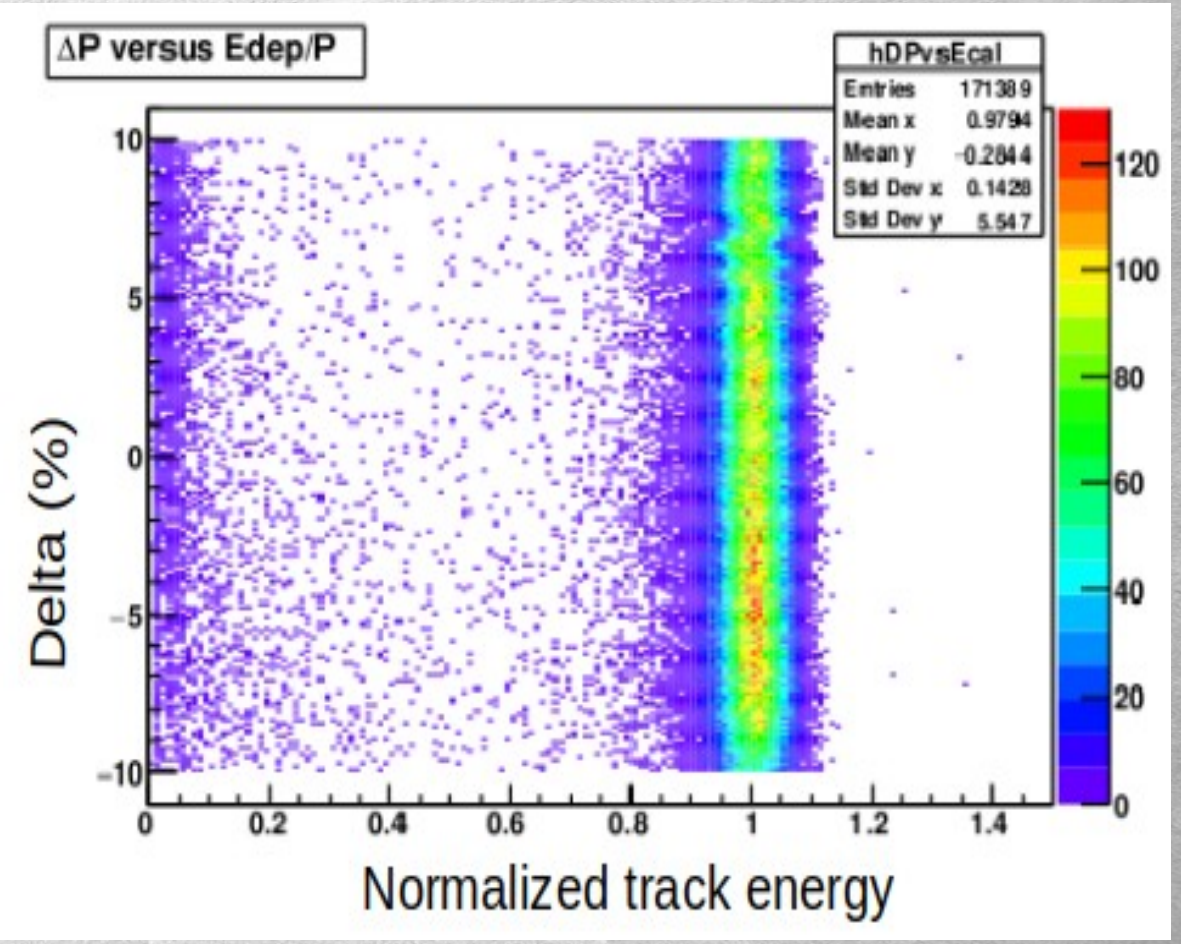




CALIBRATION PLOTS

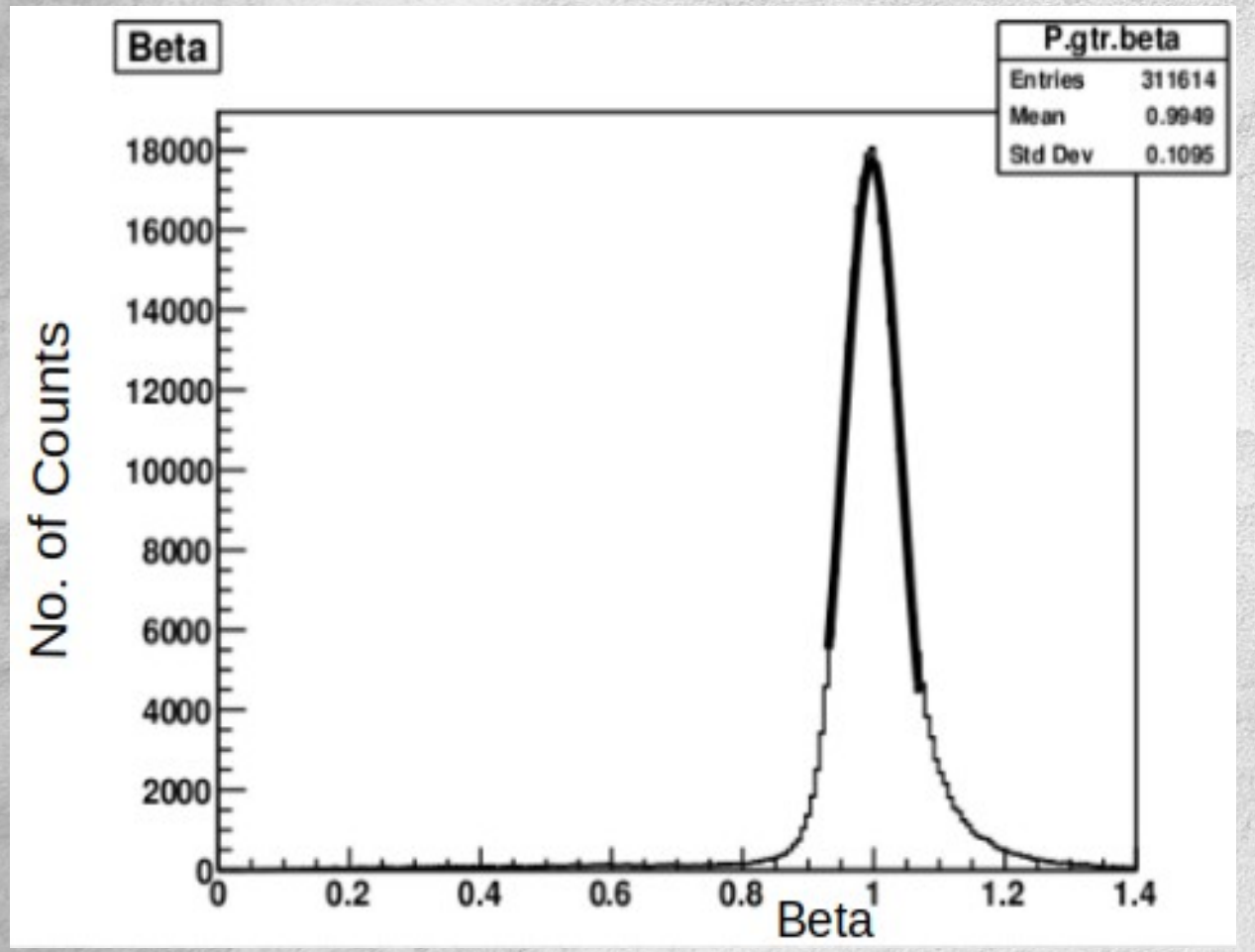
CALORIMETER CALIBRATION

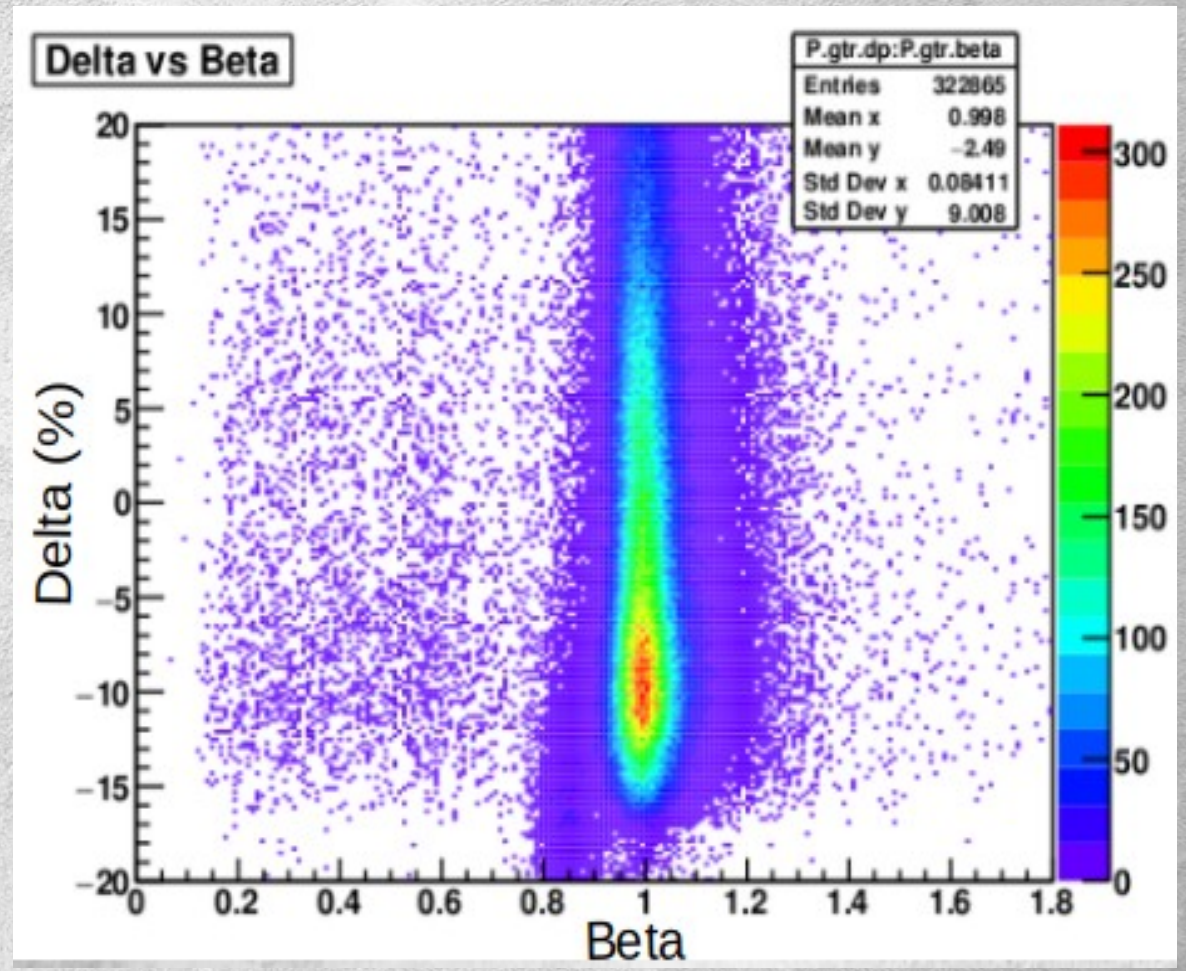




CALIBRATION PLOTS

HODOSCOPE CALIBRATION





COINCIDENCE TIME

Plots from Holly S. Vance

relative time difference between e- and p at the target

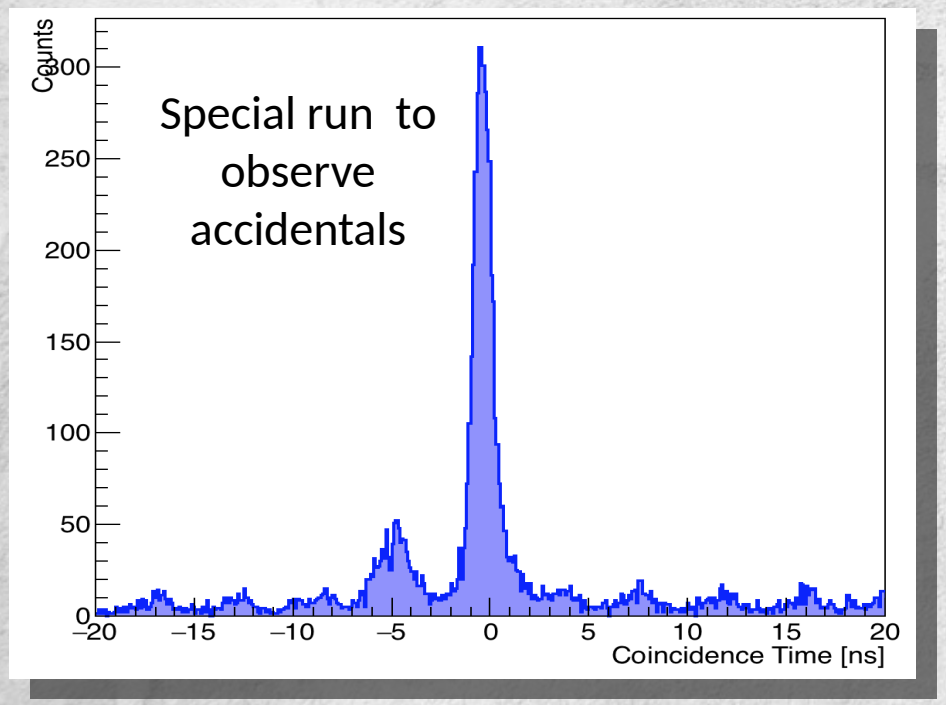
General coincidence time: $t_{coin} = t_e^{tar} - t_p^{tar}$

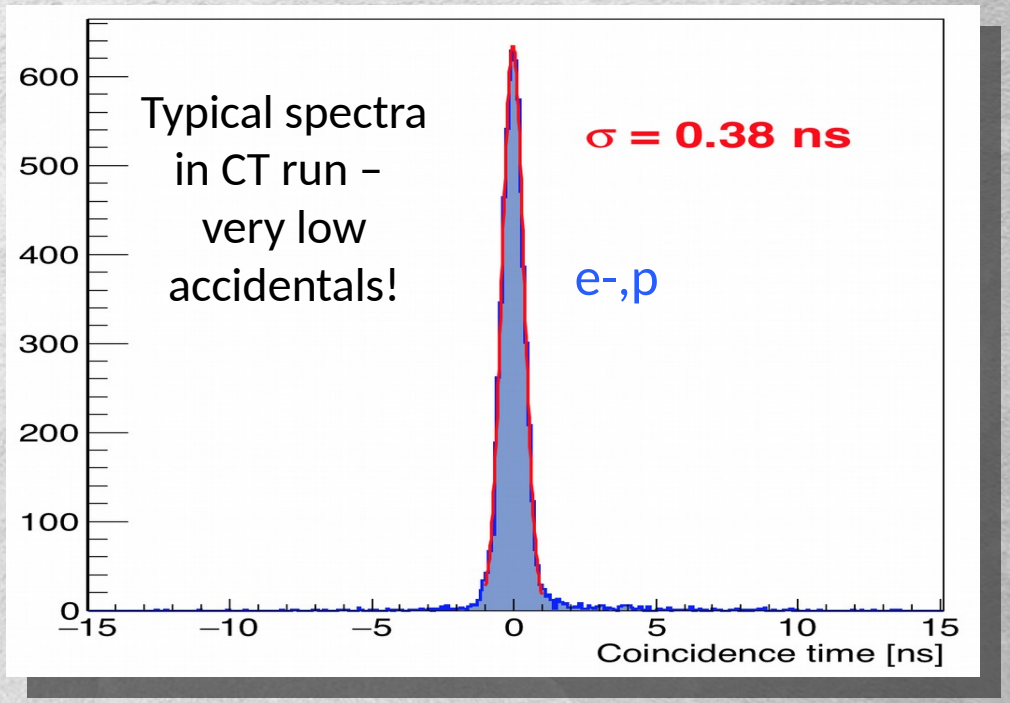
The time of each particle: $t_{e,p}^{tar} = (t_{e,p}^{trigger} - \Delta t_{e,p}^{corr})$

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:

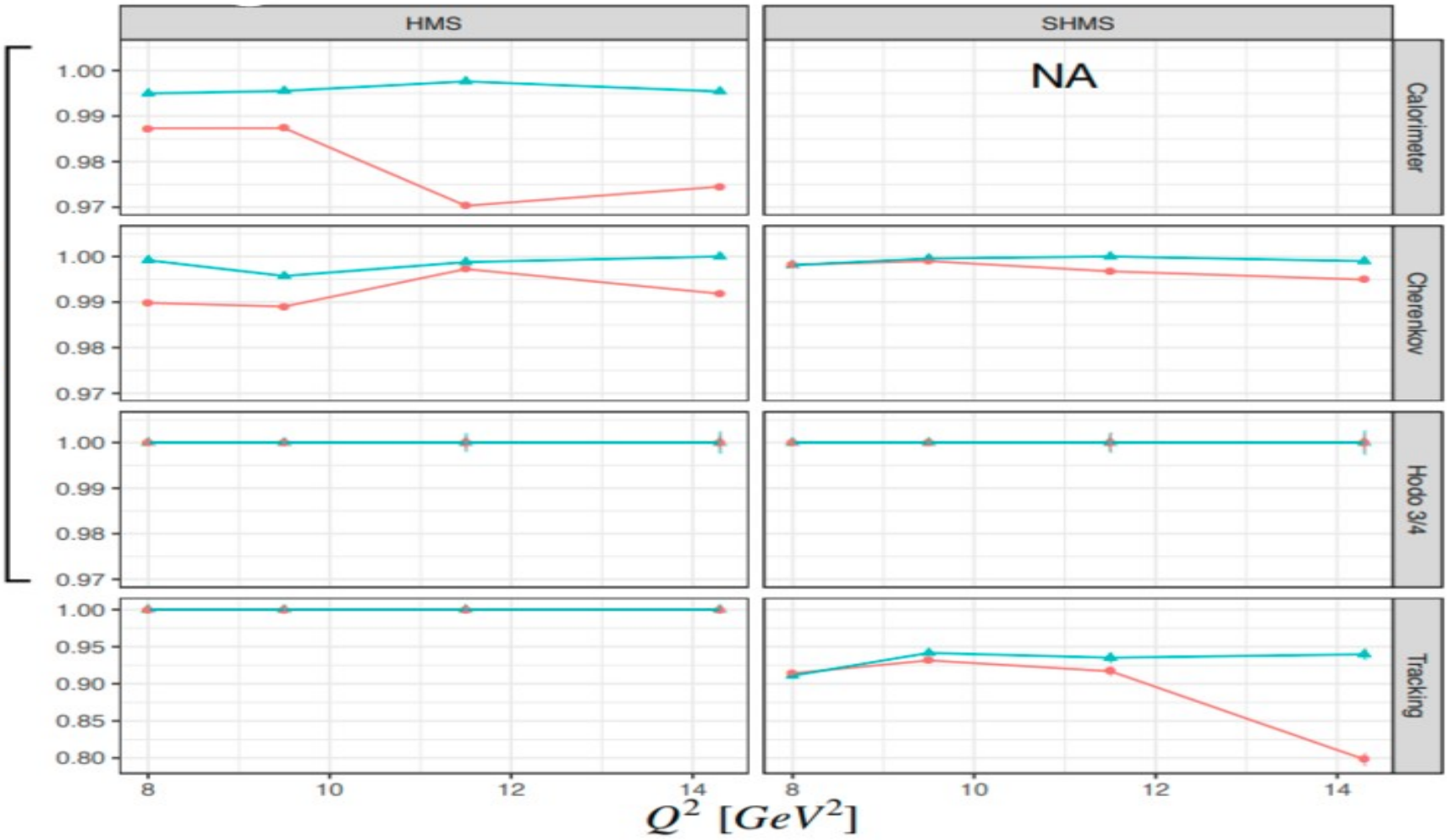




DETECTOR EFFICIENCIES

Calorimeter, Cherenkov, hodo 3/4 mostly ~99%

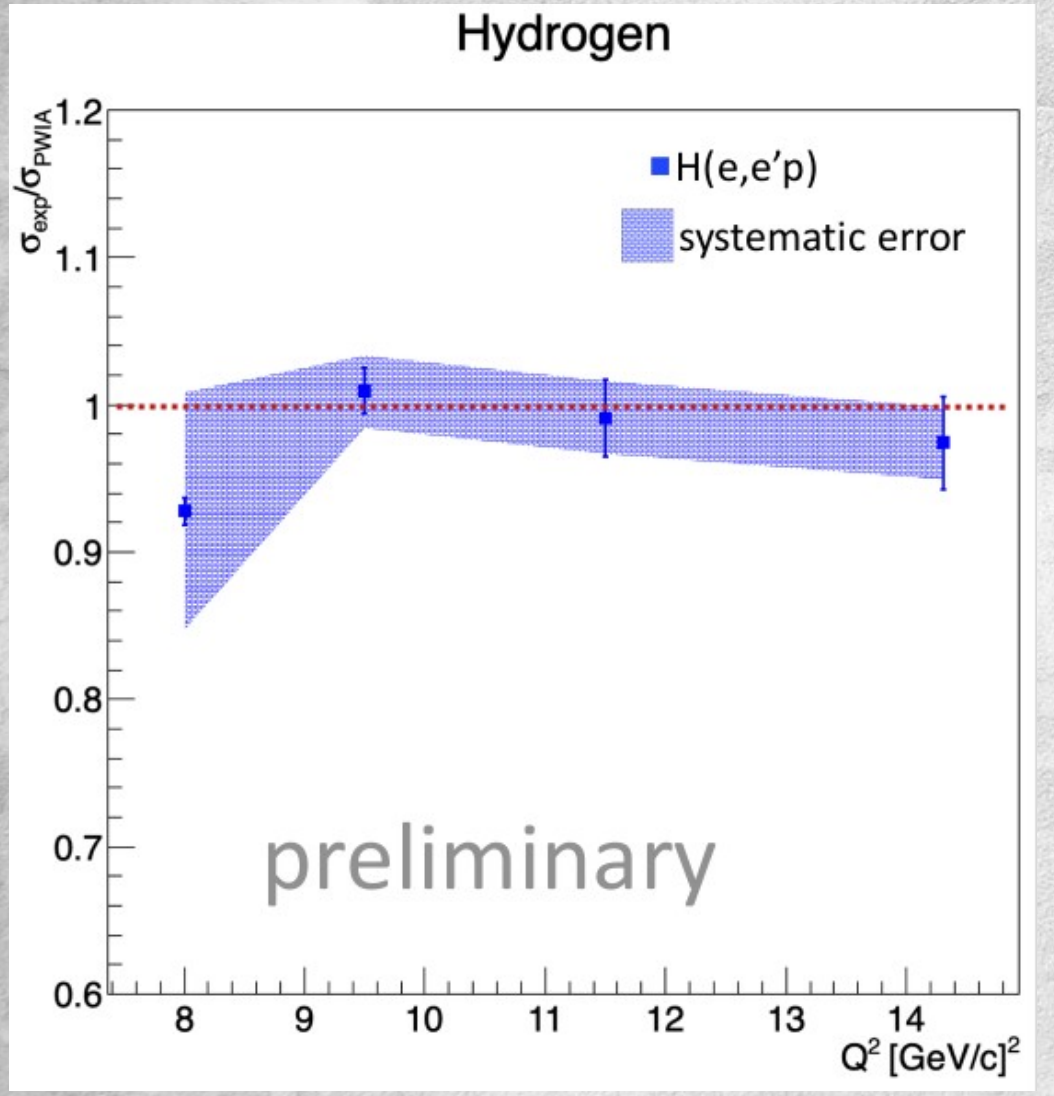
SHMS tracking efficiency is 80—95%

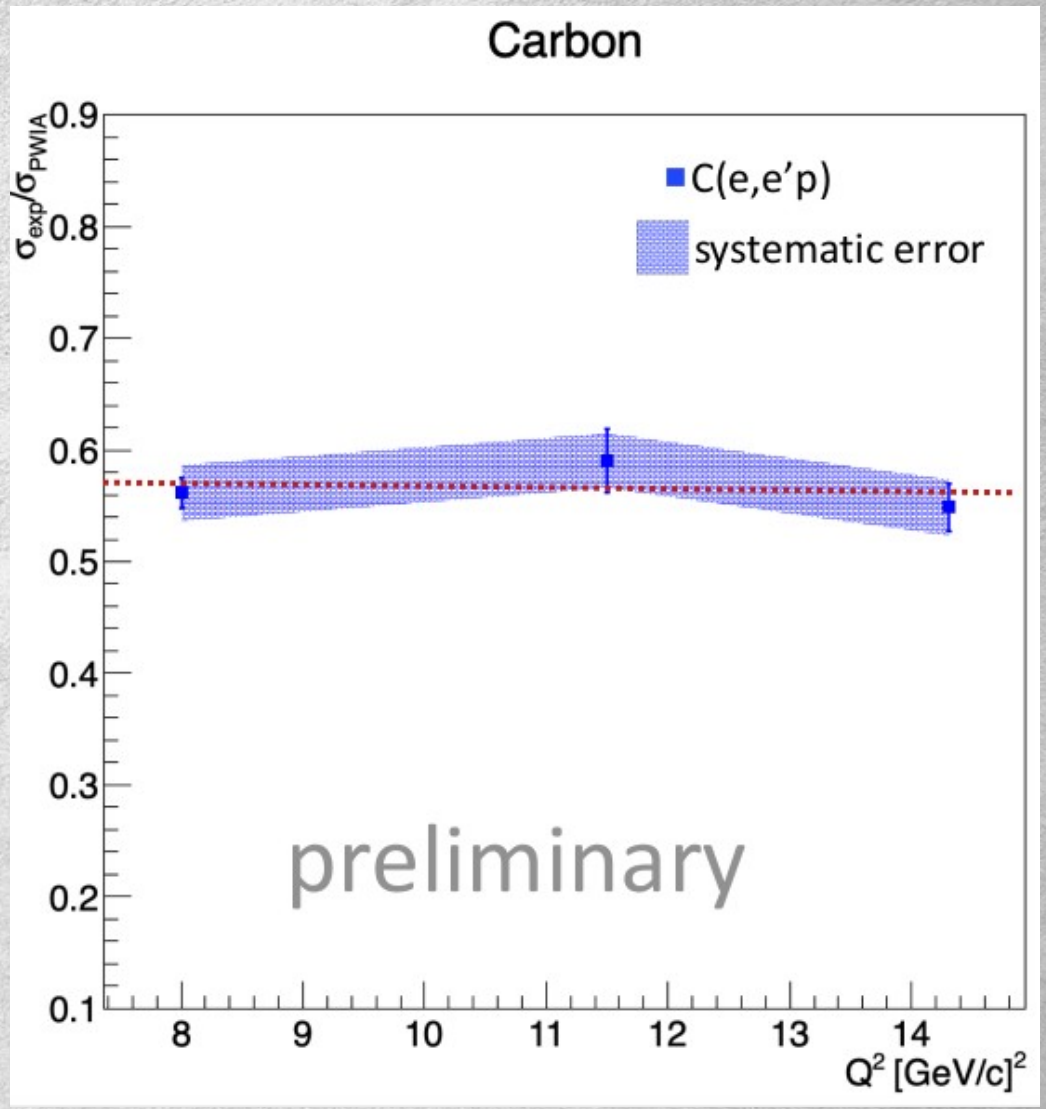


Plots from John Matter, UVA

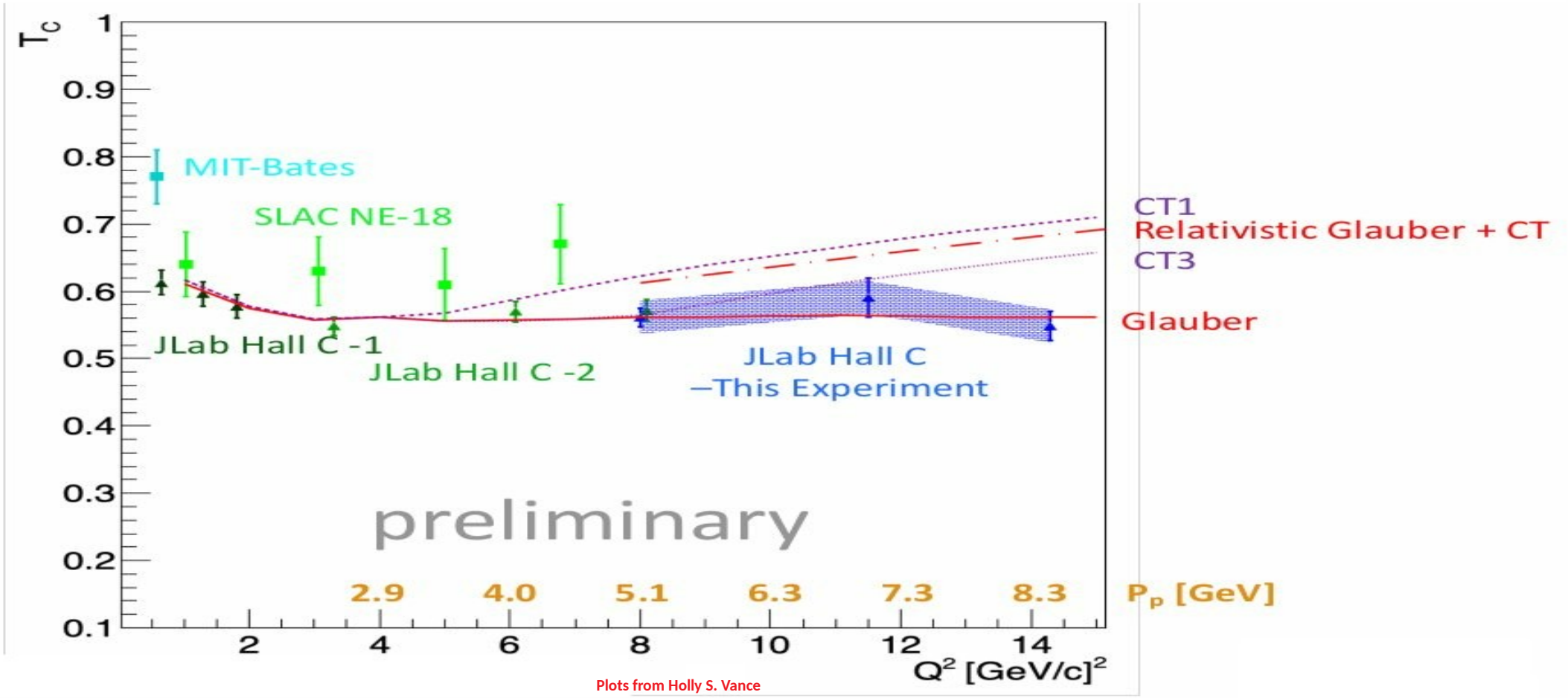
YIELD – PRELIMINARY

Plots from Holly S. Vance





TRANSPARENCY – PRELIMINARY



Plots from Holly S. Vance

STATUS OF THE WORK

Done with calibration of the detectors.

Improved HMS and SHMS efficiencies calculation.

We have improved HMS and SHMS optics now.

Analysis to understand systematics is ongoing → full results expected by the end of the year!

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 $(GeV/c)^2$, region overlaps with Brookhaven data.

First experiment to run in the 12 GeV era in Hall C and to take data using both the SHMS and HMS.

Preliminary results do not show the onset of Color transparency in protons.

U.S. DEPARTMENT OF ENERGY | Office of Science

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(US DOE Grant Number: DE-FG02-07ER41528)

Thanks to the Hall C Collaborators!