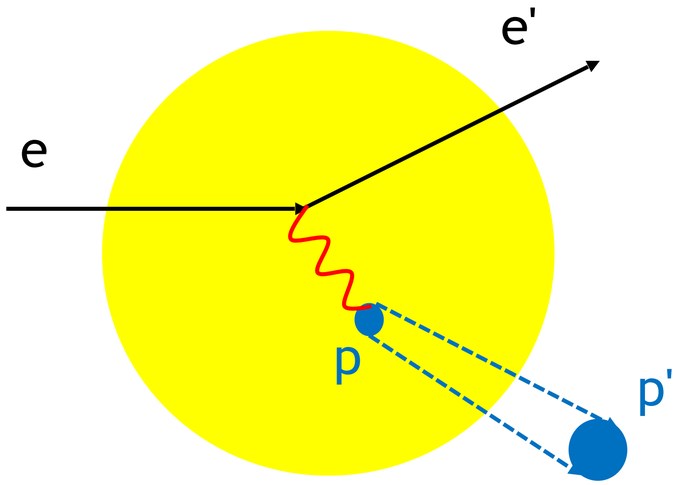
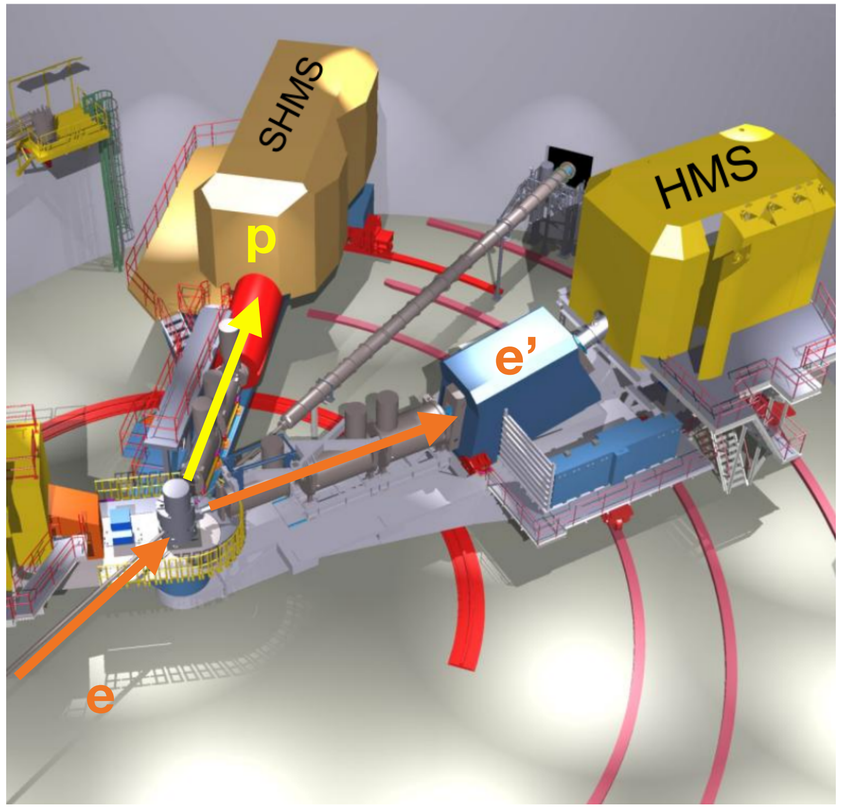
Update on the Color Transparency Experiment



16 July 2020

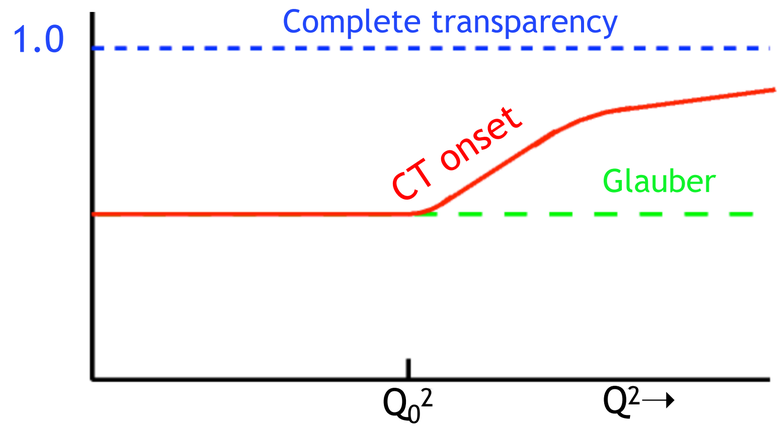
John Matter

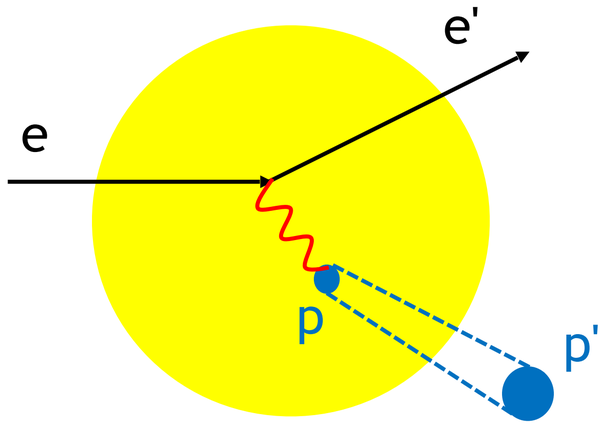


Summary

- CT definition
- Optics
- Target Boiling
- Proton Absorption
- PID efficiency
- Livetime
- Tracking
- Luminosity Scan (carbon "boiling")
- Systematic Uncertainty
- Results

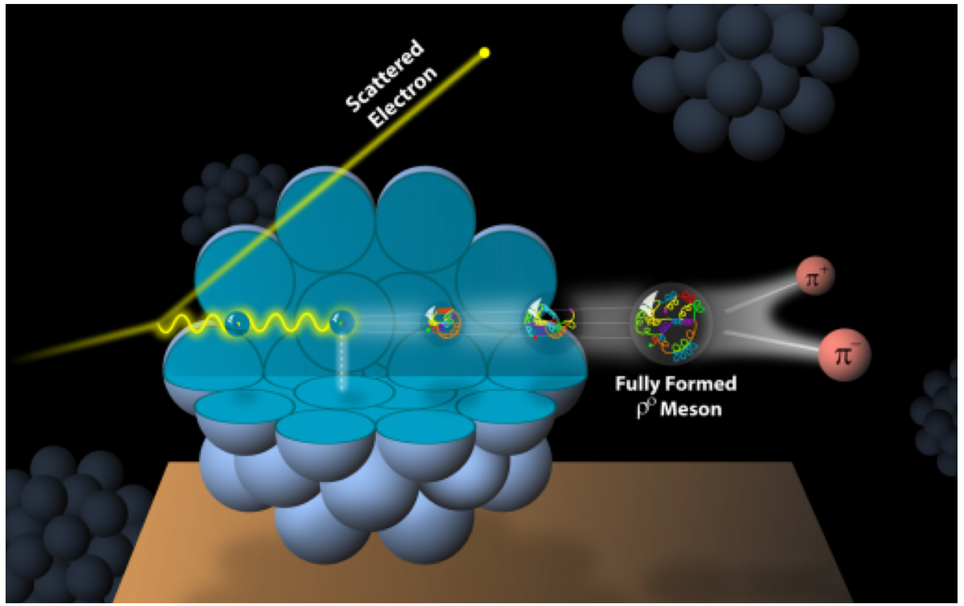
$$T = \frac{\sigma_N / A}{\sigma_0}$$





Color Transparency

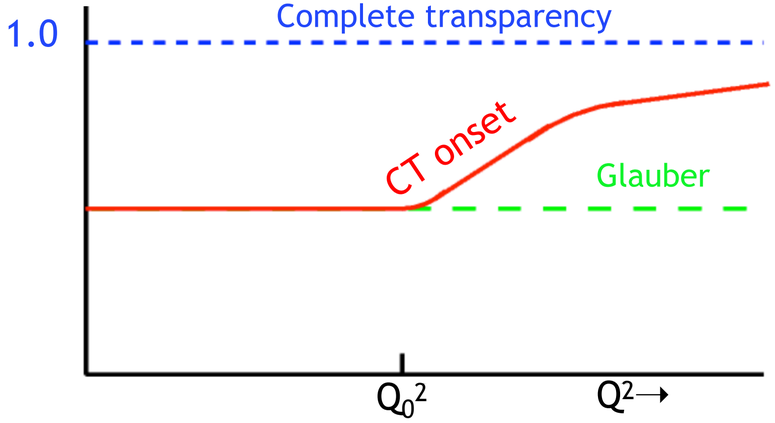
- Color Transparency
  - Vanishing of final/initial state interactions in exclusive processes at large momentum transfer
- Squeezing
  - Scattering of point-like configurations
  - Small transverse size ⇒ attenuated strong interaction; color-neutral singlet
- Freezing
  - Small size maintained as the hadron passes through nucleus



Color Transparency

- Define transparency T as the ratio of the cross section for a given process on a bound nucleon to the cross section for the same process on a free nucleon
- Glauber predicts **constant T**
- CT predicts a **rise in T**
- CT onset observed in meson production; baryon results are ambiguous.
- Where is the onset?

$$T = \frac{\sigma_N / A}{\sigma_0}$$



CT Experiments

Meson

u ū

A(π,di-jet): FNAL

A(γ, π^- p): Jlab

A(e, e'π^+): JLab

A(e, e'ρ^0): DESY & JLab

Baryon

u u d

A(p,2p): BNL

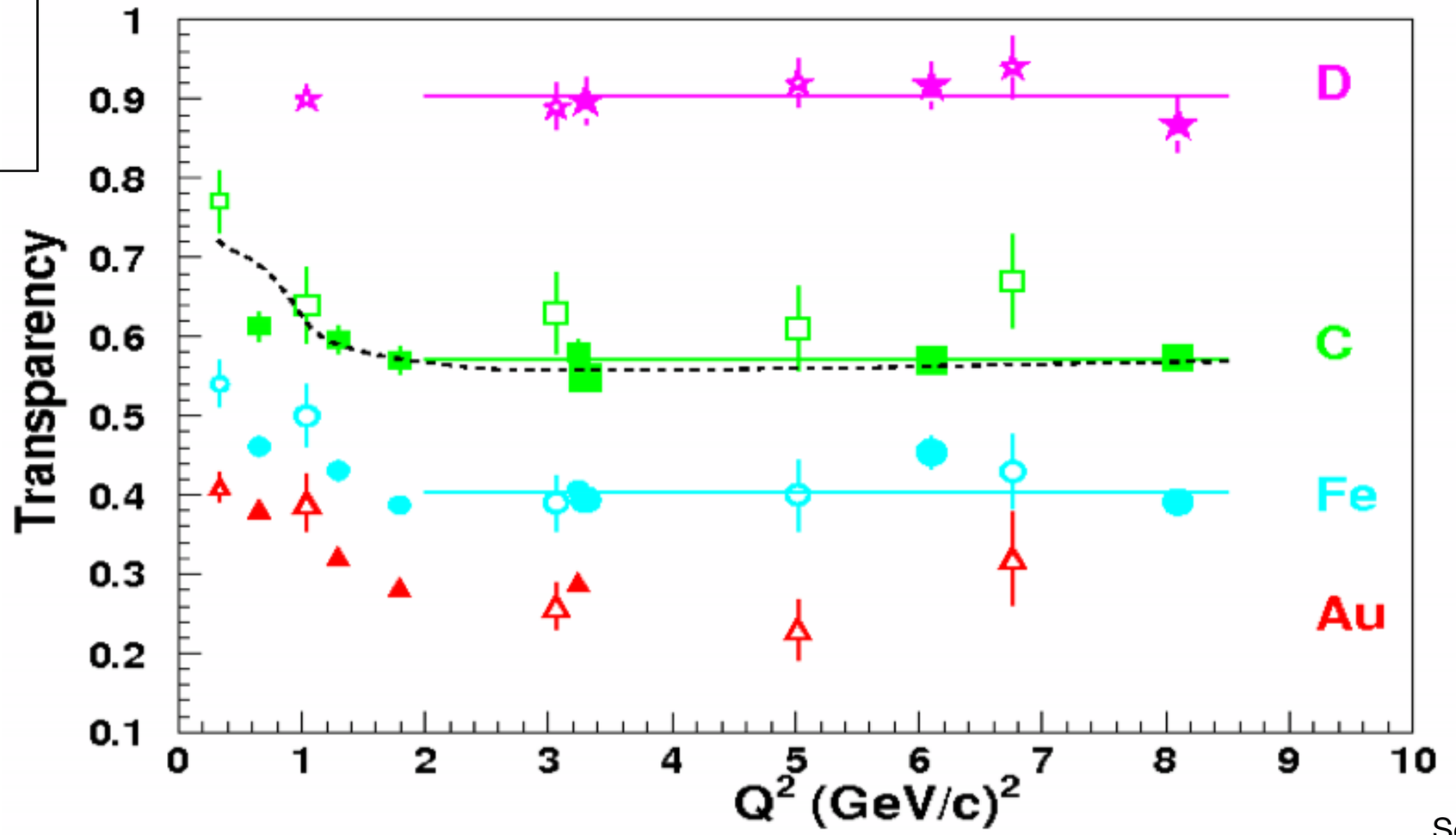
A(e,e'p): SLAC, JLab

Previous Measurements

A(e,e'p)

$$T = \frac{\sigma_N / A}{\sigma_0}$$

No onset… yet?

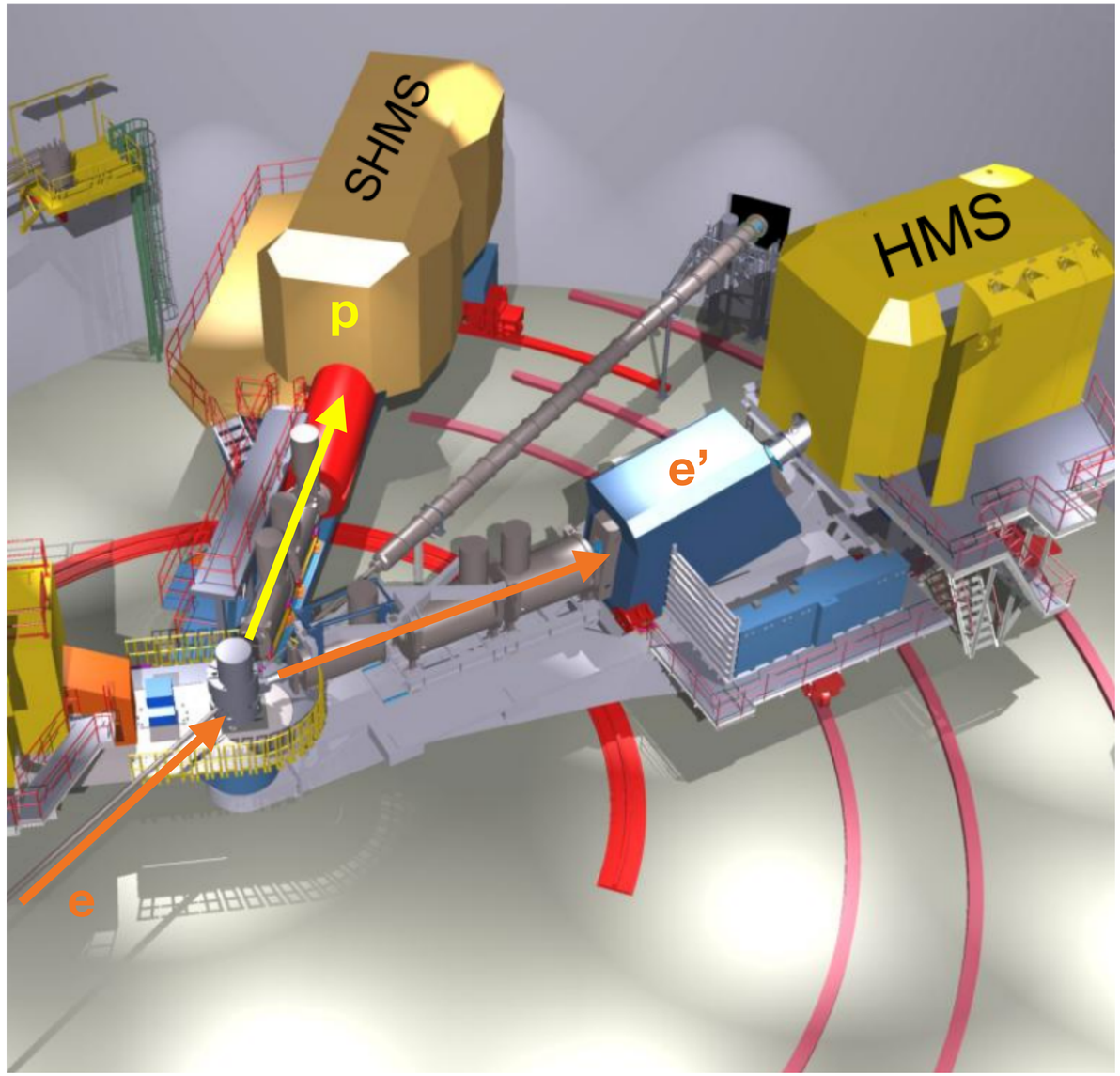


PRL 72, 1986 (1994)
PRB 351, 87 (1995)
PRL 80, 5072 (1998)
PRC 66, 044613 (2002)
PRC 72, 054602 (2005)
PRC 45, 780 (1992)

Solid points = JLab
Open points = other

E12-06-107

- First 12 GeV era Hall C experiment in early 2018
- Coincidence trigger
  - SHMS = proton
  - HMS = electron
- Targets
  - 10 cm LH_2 (Hee'p check)
  - 6% ^{12}C (production)
  - Al dummy (LH_2 background)



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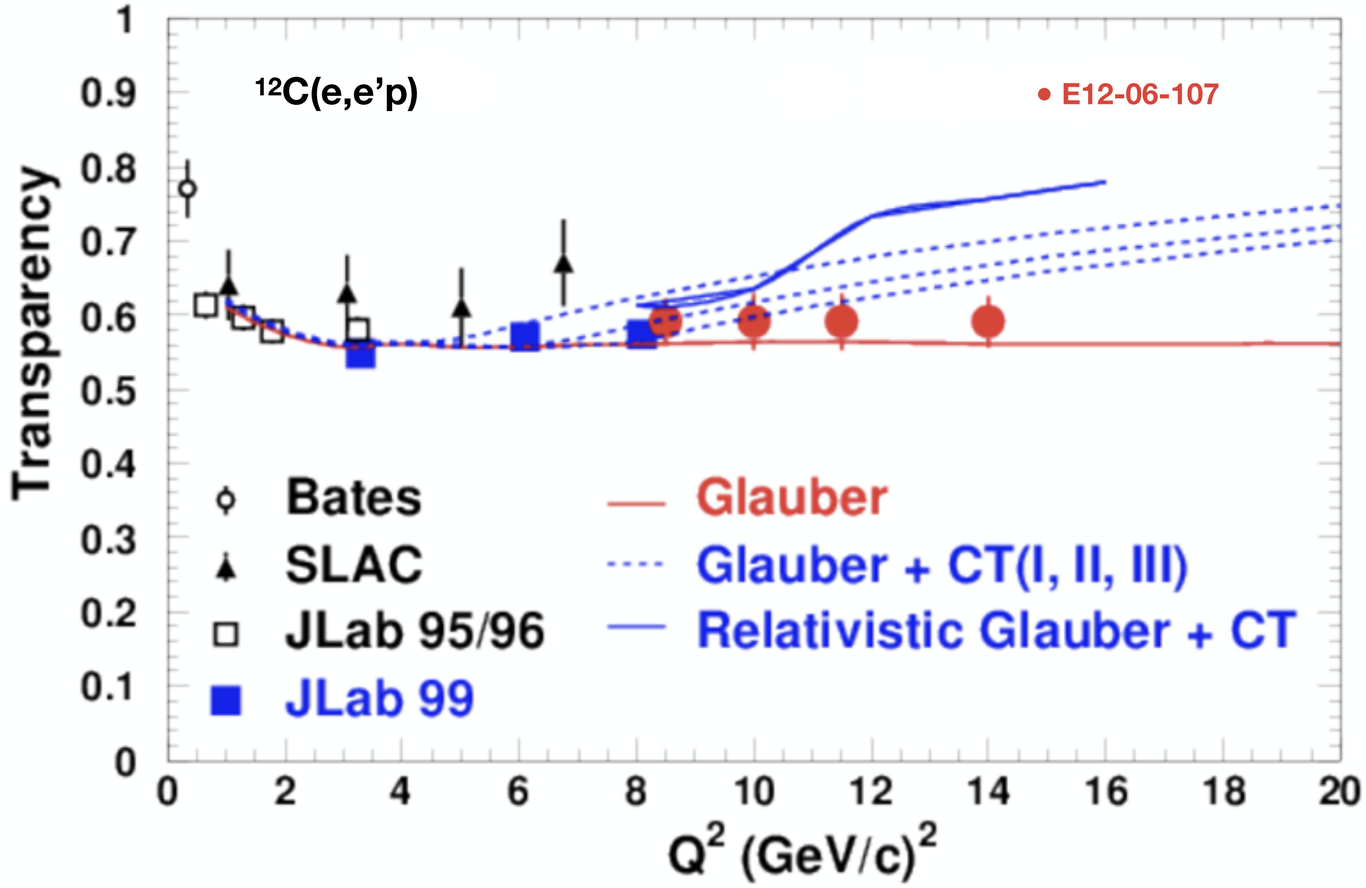
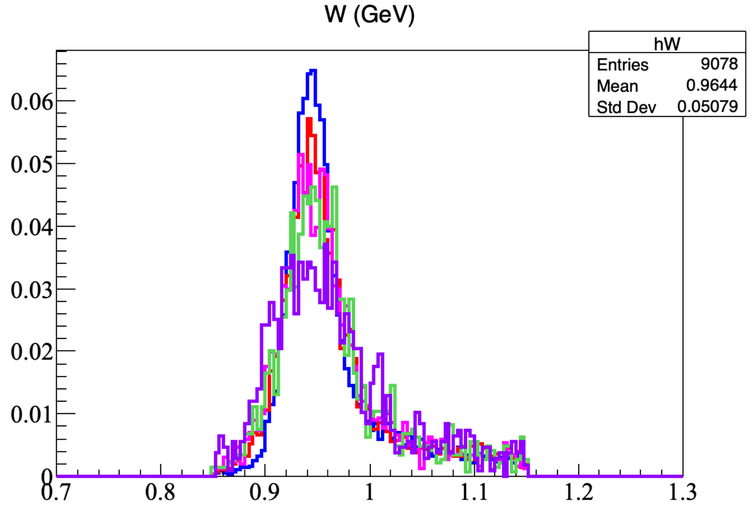
	Q^2 [GeV^2]	SHMS angle [deg]	SHMS central P [GeV/c]	HMS angle [deg]	HMS central P [GeV/c]
6.4 GeV beam	8.0	17.1	5.122	45.1	2.131
10.6 GeV beam	9.5	21.6	5.925	23.2	5.539
	11.5	17.8	7.001	28.5	4.478
	14.3	12.8	8.505	39.3	2.982



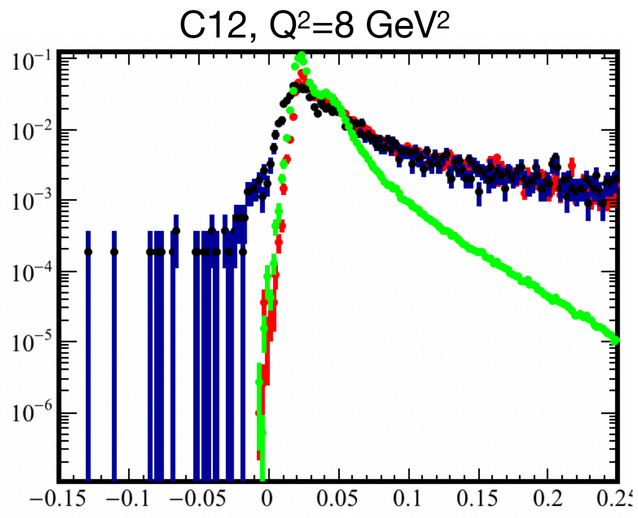
Optics (Holly Szumila-Vance)

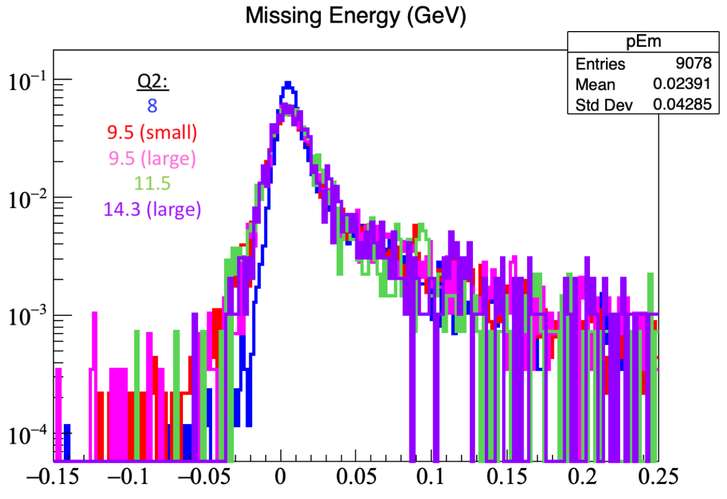
Blue = data
Green = MC w/o radiative effects
Red = MC w/ radiative effects

W

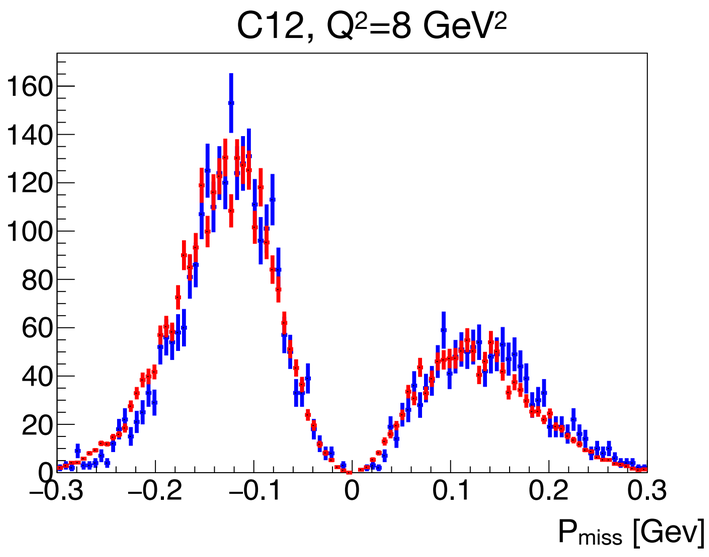


E_{miss}





P_{miss}



Optics (Holly Szumila-Vance & Deepak Bhetuwal)

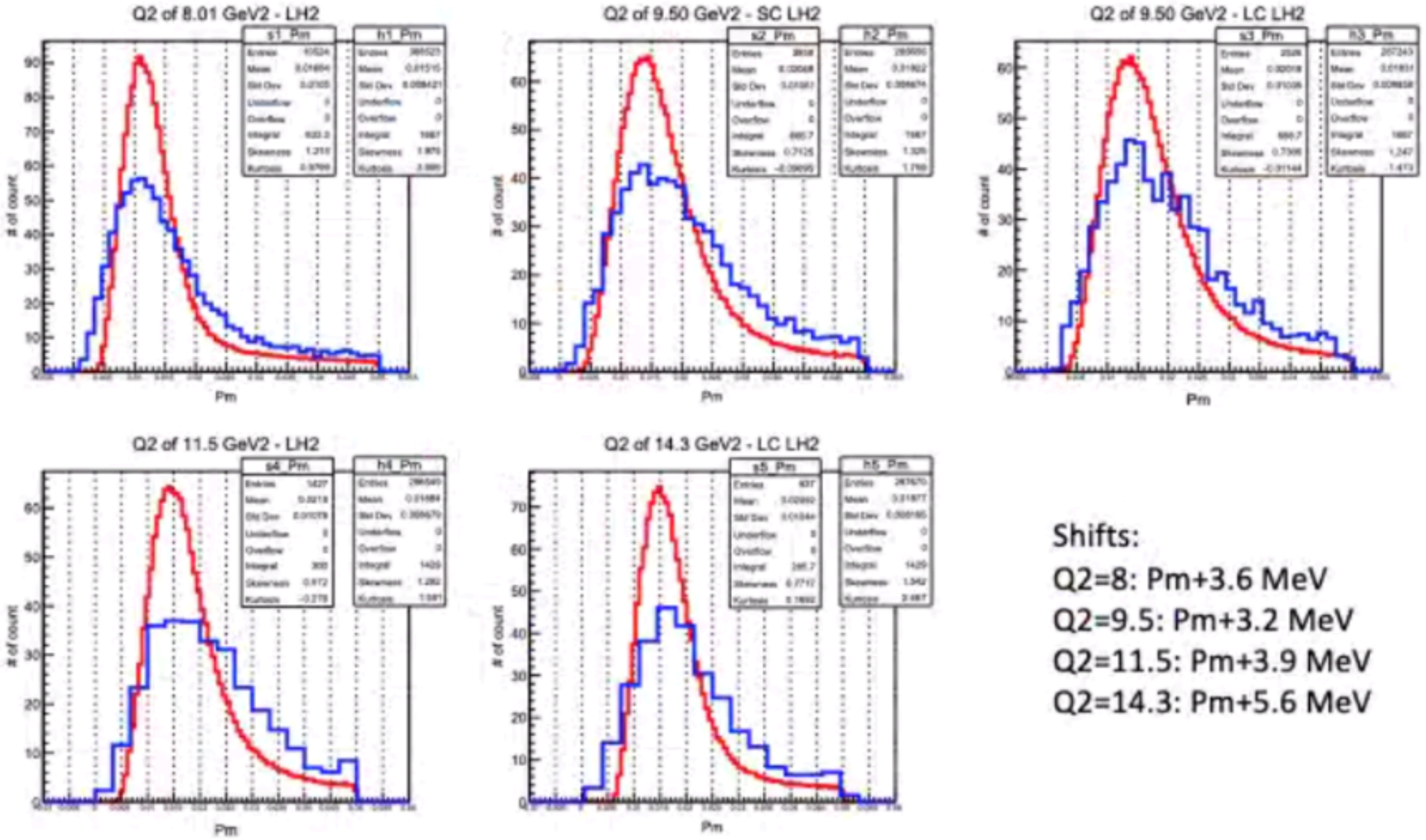
LH2 data

SIMC

data

Determine any missing momentum shifts between data and calculation

Missing momentum is one of our most sensitive parameters, as it depends on momentum and angle in both spectrometers



Shifts:

Q2=8: Pm+3.6 MeV

Q2=9.5: Pm+3.2 MeV

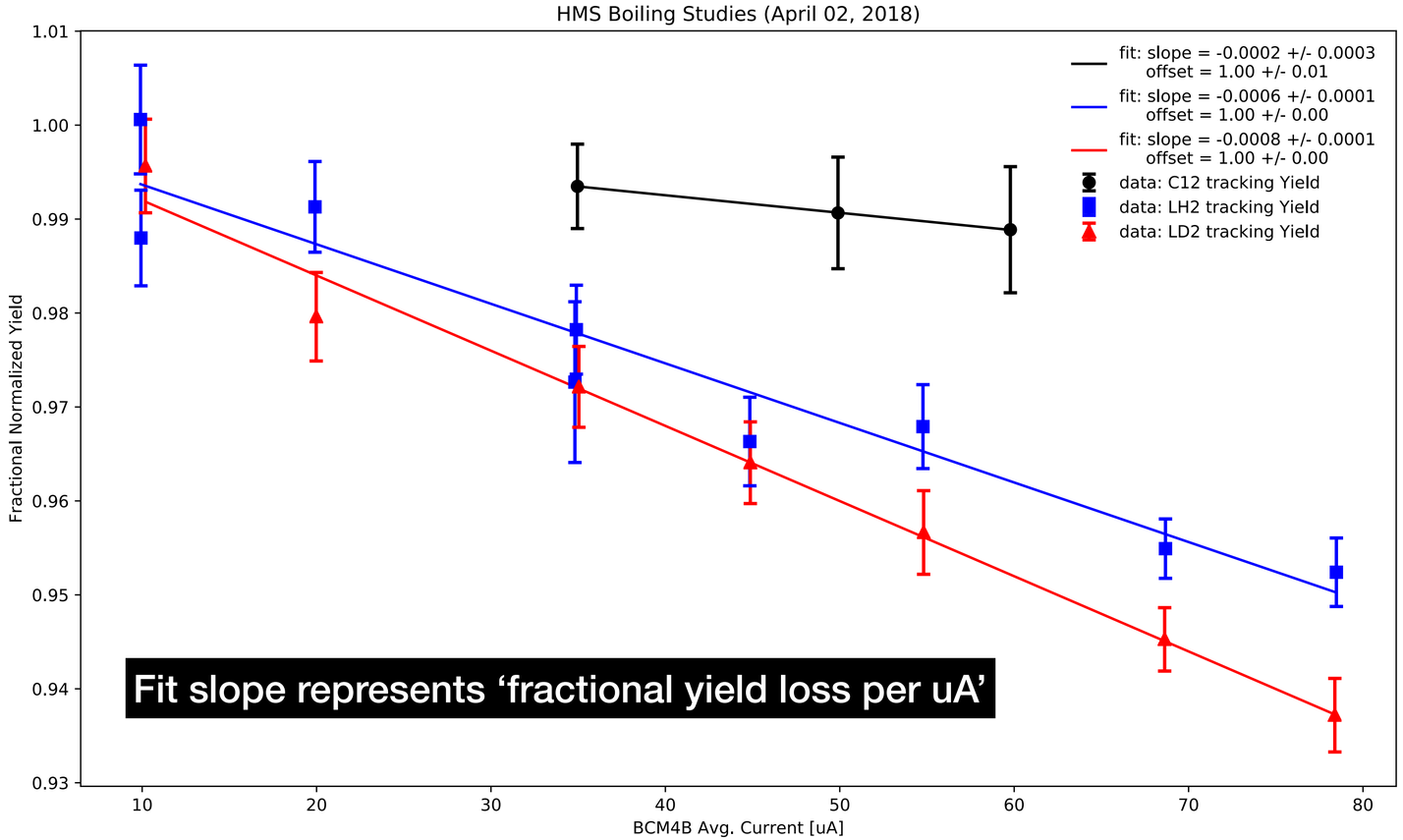
Q2=11.5: Pm+3.9 MeV

Q2=14.3: Pm+5.6 MeV

Target boiling (Carlos Yero)

Divide by the offset parameter to re-normalize data to unity

$$y = m * I_{beam} + b \Rightarrow \frac{y}{b} = \frac{m}{b} * I_{beam} + 1$$



https://hallcweb.jlab.org/DocDB/0010/001023/001/April2018_BoilingStudies.pdf

SHMS Proton Absorption

- Based on the materials in the proton's path, I estimate absorption to be 8.9%*
- From CT data, I estimate 8.5 ± 0.5%
    1. Place tight SHMS acceptance cuts on good ep coincidences
    2. Pick tight HMS-only cuts that produce the same distributions
    3. Calculate yields from ep coincidence and HMS singles data
- For comparison, Carlos estimates 4.66 ± 0.47% in the HMS
    - https://hallcweb.jlab.org/DocDB/0010/001020/002/ProtonAbsorption_slides.pdf

$$A = 1 - exp\left\{ -\sum \frac{x_i}{\lambda_i} \right\}$$

$$A = 1 - \frac{Y_{coin}}{Y_{singles}}$$

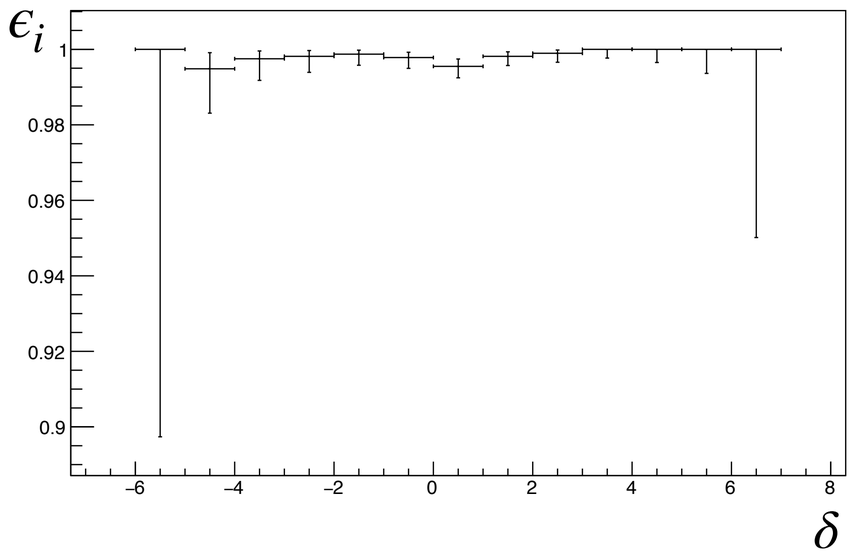
* https://docs.google.com/spreadsheets/d/1LeaFrQjKTuOeliKTEN8QAHqDkFCYzW18bMMjTKu1ejQ

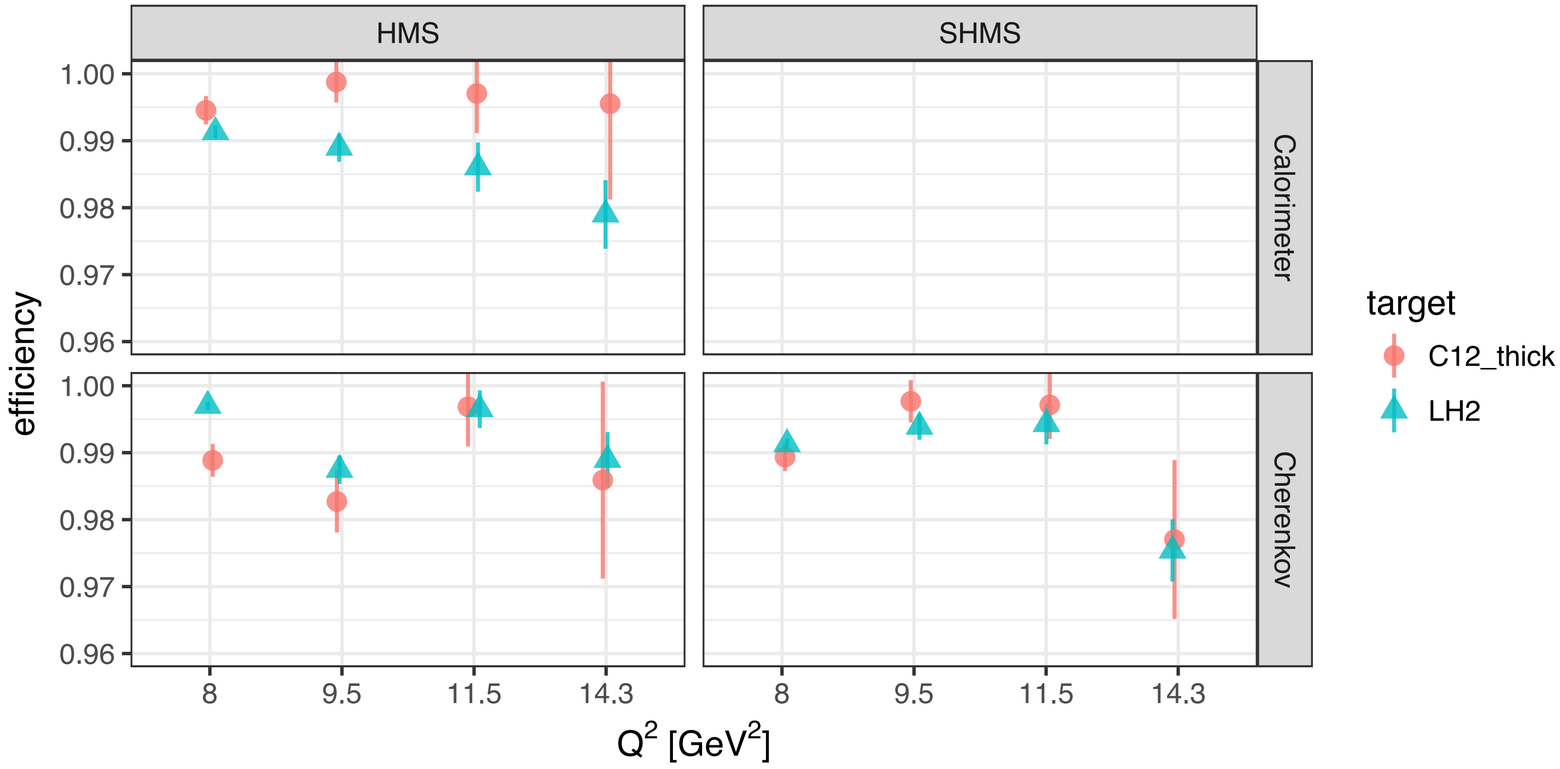
PID Efficiency

Calculated per delta bin, then weighted

$$\bar{\epsilon} = \frac{\sum_i w_i \epsilon_i}{\sum_j w_j}$$

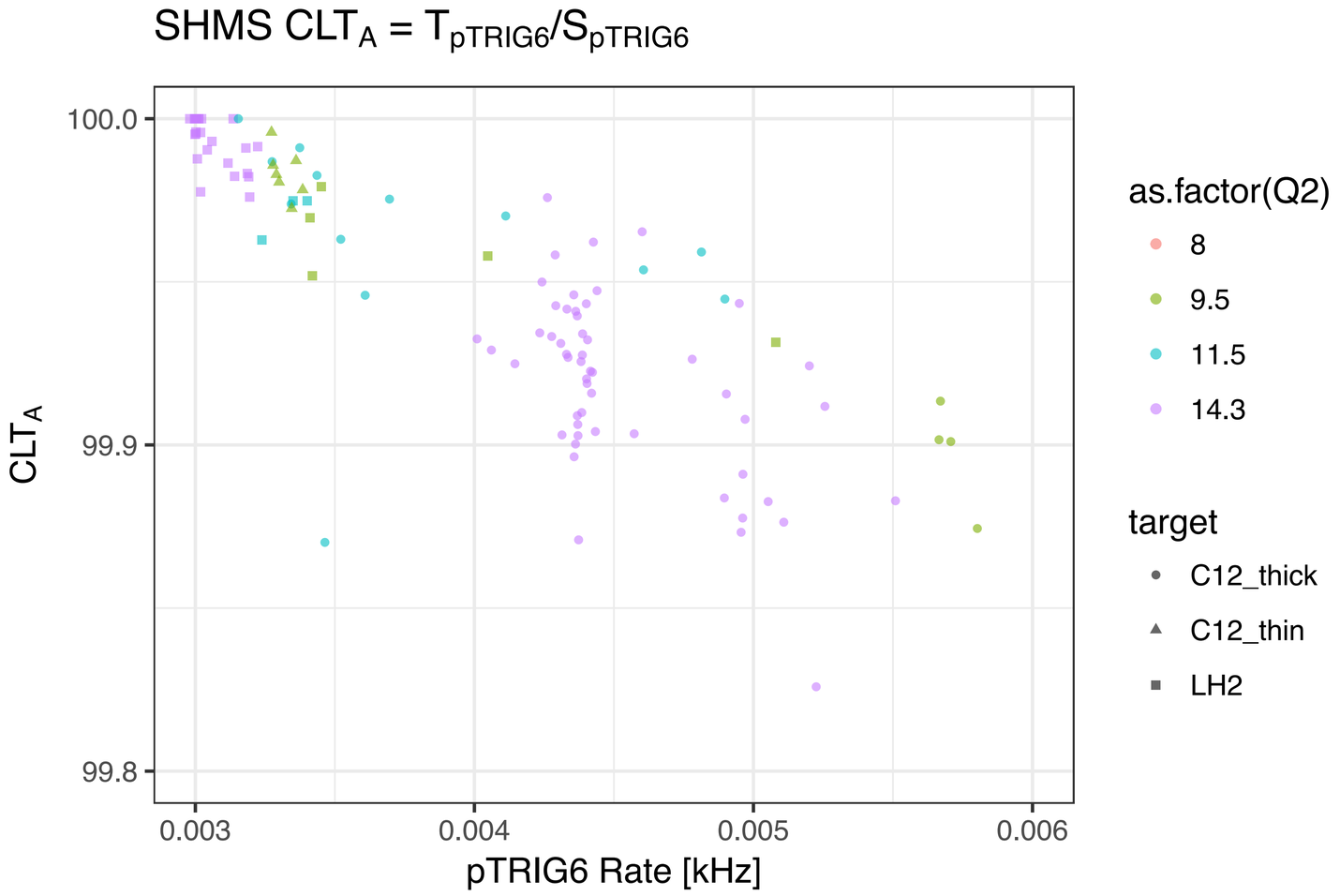
$$\epsilon_i = \frac{n_{i,did}}{n_{i,should}} \qquad w_i = 1/\sigma_i^2$$





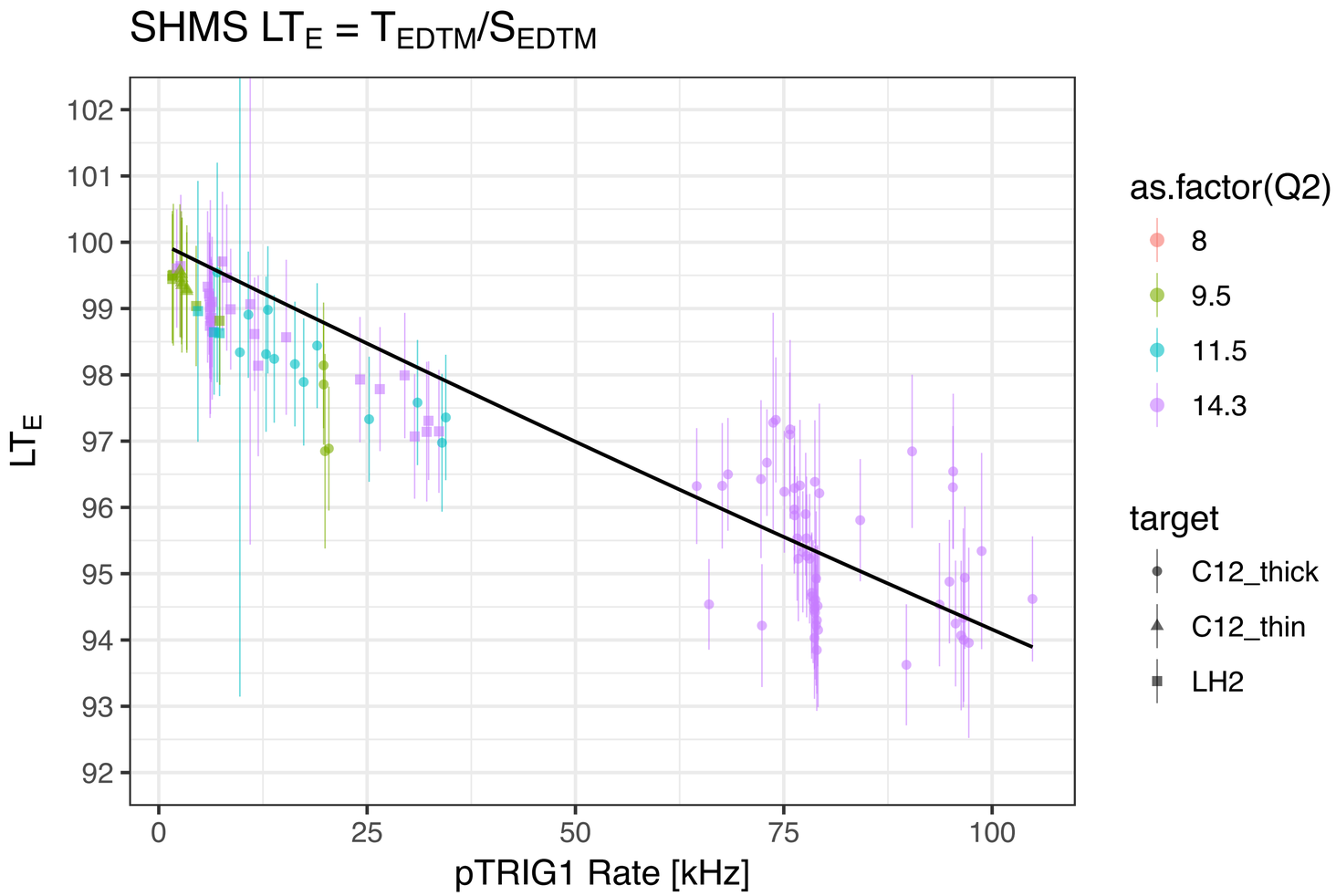
Livetime

- Place appropriate BCM cuts
- T = number of accepted triggers (T.shms.pTRIG1_tdcTimeRaw!=0)
- S = scaler counts (P.pTRIG1.scaler)
- Prescale factor P=1+2^(ps-1)
- CLT_A = P * T / S



Livetime

- Place appropriate BCM cuts
- T = number of accepted triggers (T.coin.pEDTM_tdcTimeRaw!=0)
- S = scaler counts (P.pEDTM.scaler)
- $LT_E = T / S$



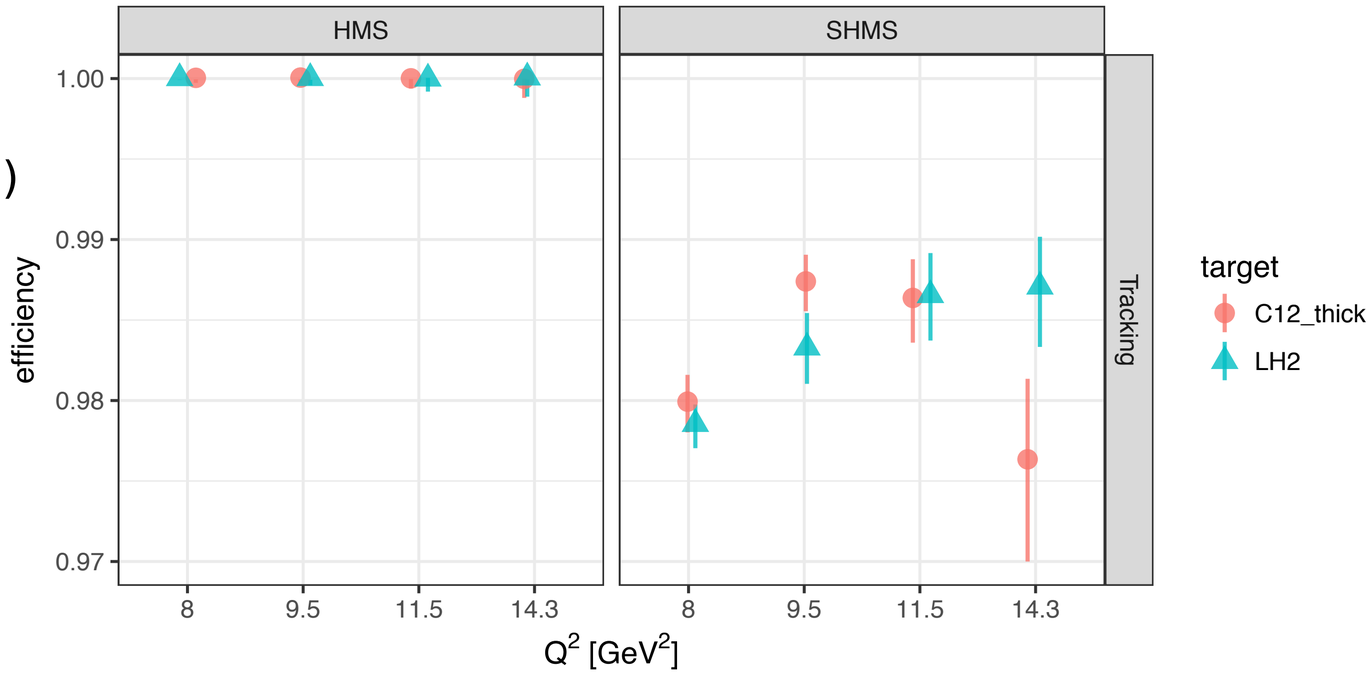
Tracking Efficiency

- Select events that should form a track

```
(PID cut) && P.hod.betanotrack < 1.2
          && (fewer than 21 hits per DC)
          && P.hod.goodscinhit==1
          && P.hod.goodstarttime==1
```

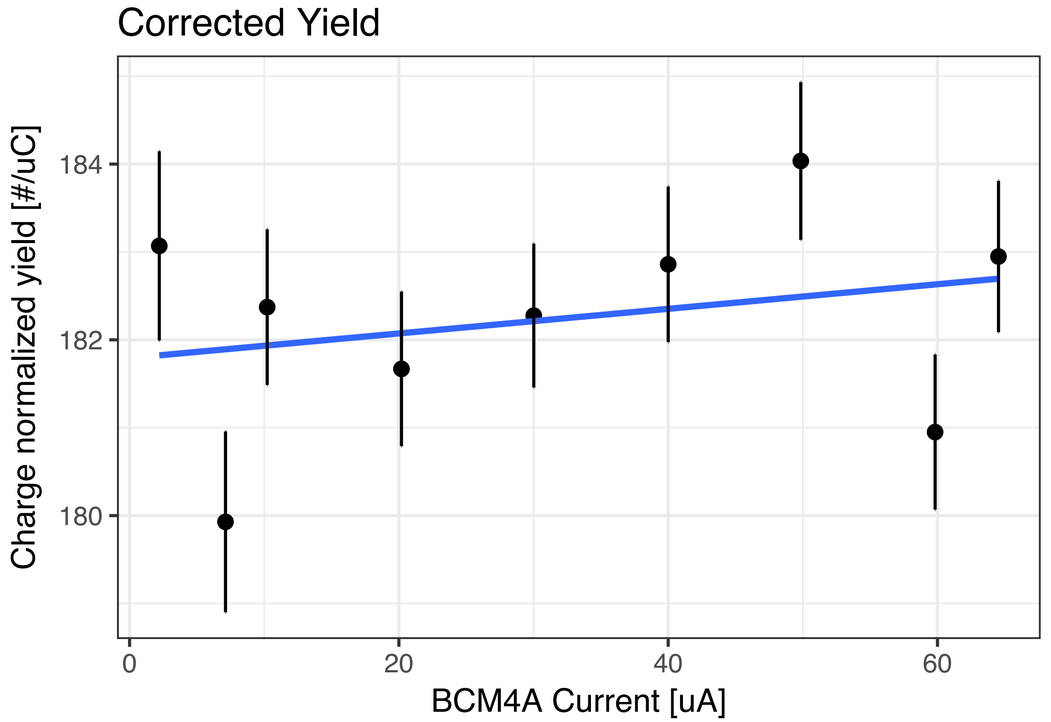
- How many did?

```
P.dc.ntrack==1 ||
(P.dc.ntrack>1 && abs(P.gtr.dp)<15
               && abs(P.gtr.y)<5
               && abs(P.gtr.th)<0.2
               && abs(P.gtr.ph)<0.2
               && -10 < P.hod.1x.fptime < 5
               && P.hod.1x.totNumGoodNegAdcHits<5
               && (same two cuts for 1y, 2x, 2y))
```



Luminosity Scan 1

- SHMS runs 1992–2000, each with different steady currents between 2 uA and 65 uA
- C12 0.5% target
- Calculate yields and correct for detector efficiency, livetime, and prescale factor
- Calculating precent change in yield per uA, we get 0.008 ± 0.010% which is consistent with zero
- Typical currents for CT data are 50 uA, or 0.4% per uA



$$Y = m * I + b$$
$$m = 0.014 \pm 0.019$$
$$b = 181.79 \pm 0.74$$

Luminosity Scan 2

- SHMS runs 3109–3114, each with different steady currents between 2.5 uA and 60 uA
- C12 1.5% target
- Calculate yields and correct for detector efficiency, livetime, and prescale factor
- I’m still working on this, but Deepak’s result is -0.1%/uA
- Can estimate systematic uncertainty for livetime, PID, and tracking from the difference between the results of these two luminosity scans
- Based on Deepak’s results, we expect 0.5% systematic uncertainty due to livetime and efficiency corrections

in progress

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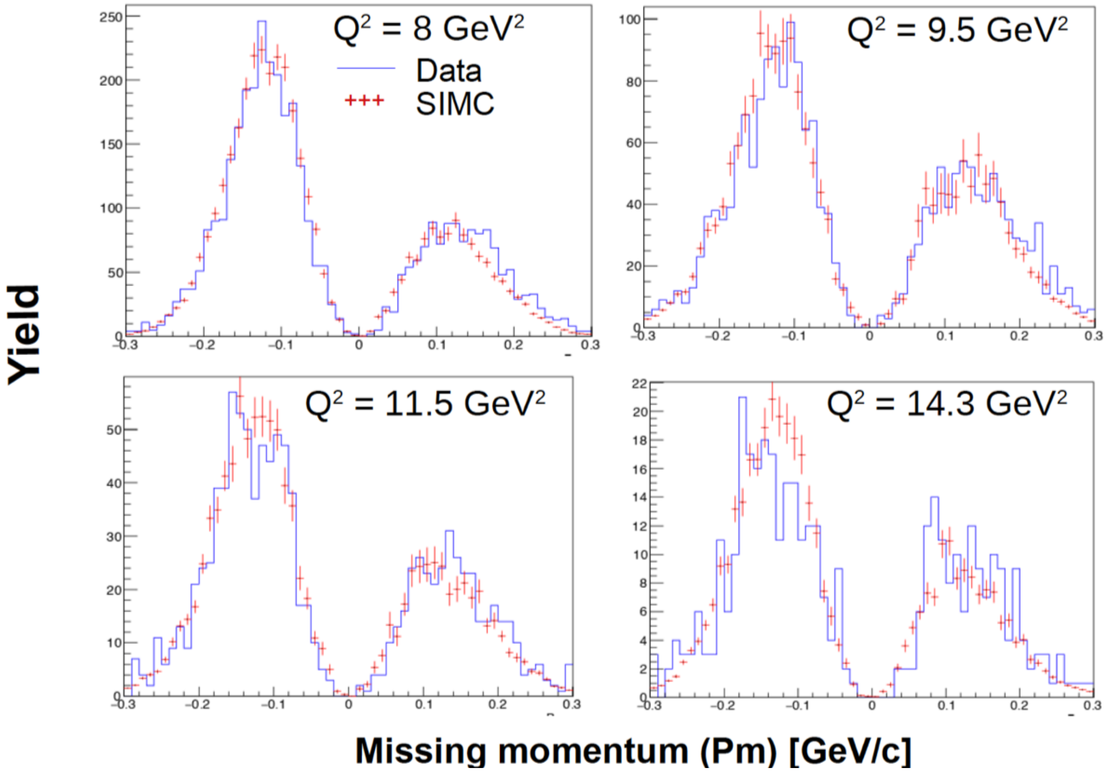
TABLE II. Systematic Uncertainties

Source	Q^2 dependent uncertainty (%)
Spectrometer acceptance[1]	3.0
Event selection[2]	1.5
Tracking efficiency	
Radiative corrections[3]	1.0
Live time correction	
Source	**Normalization uncertainty (%)**
Free cross section	2.0
Target thickness	0.5
Beam charge	1.0
Proton absorption	0.5
Total	



1. Preliminary number based on agreement between Pm spectra from simc and data
2. See cut study at https://hallcweb.jlab.org/elogs/Color+Transparency/48
3. Determined from variation in corrections for different model parameter choices

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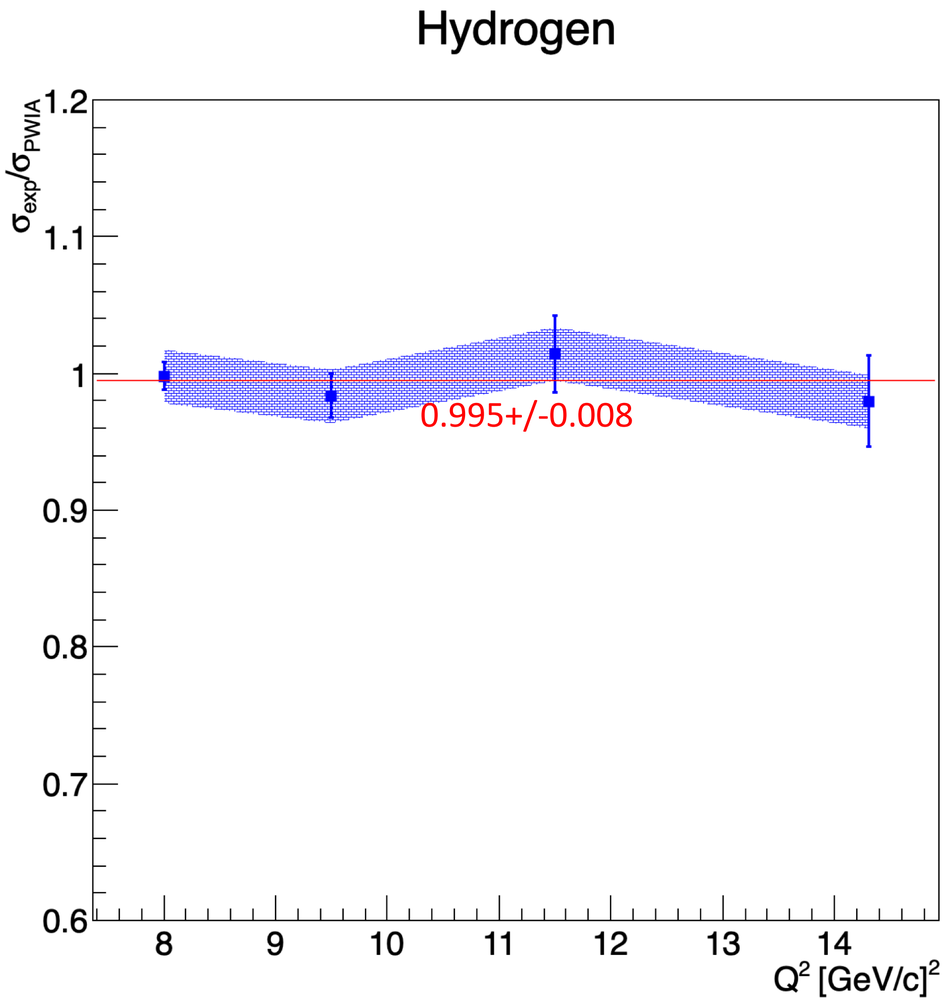
Final H(e,e'p) results

- Ratio of yields from data to simc should be 1
- Ingredients:
  - Livetime
  - Tracking, hodo, PID efficiency
  - Target boiling
  - Em, Pm < 50 MeV
- simc form factor is Peter's fit* from 1995



*P. E. Bosted, Phys. Rev. C 51, 409 (1995)

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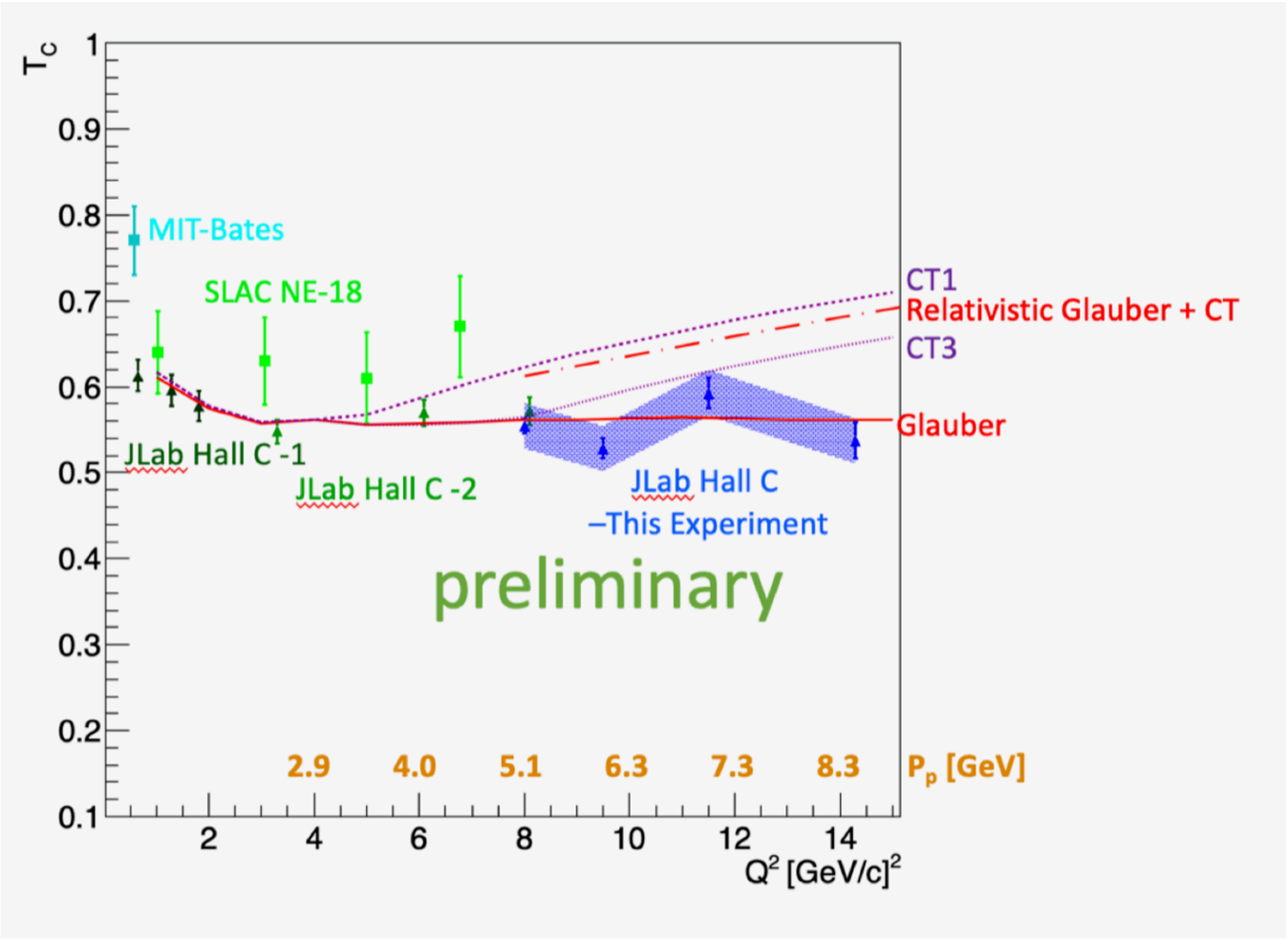
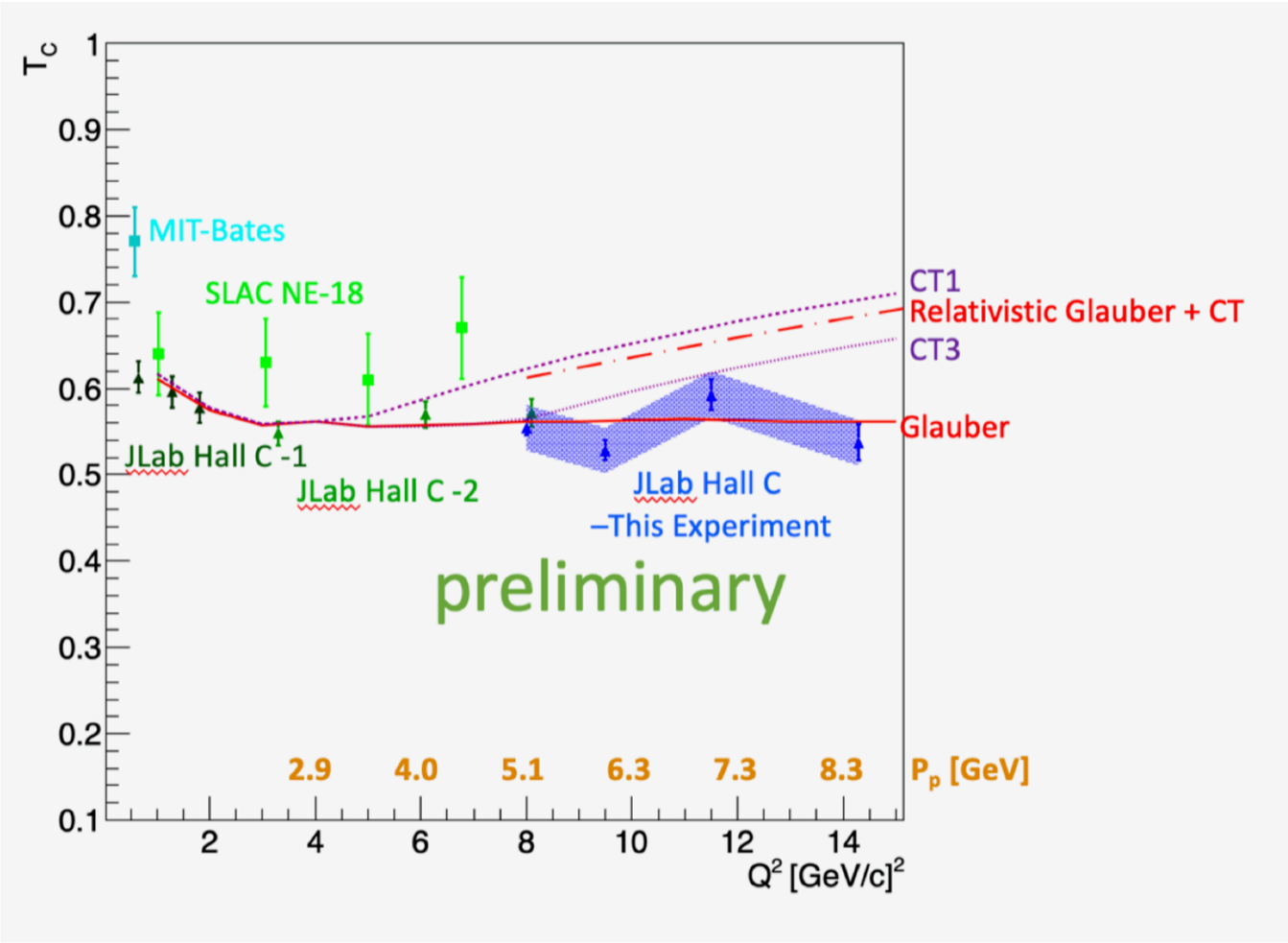
C12 transparency

- Preliminary results consistent with no increase in transparency
- H(e,e'p) analysis finished
- Final C12 transparency soon
- Still need:
    - Final luminosity scan (to determine systematic uncertainty from efficiency and livetime corrections)
    - Convergence of my work and Deepak's
    - A publication of these CT results will be ready to circulate once we complete these cross checks



Thank you!



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