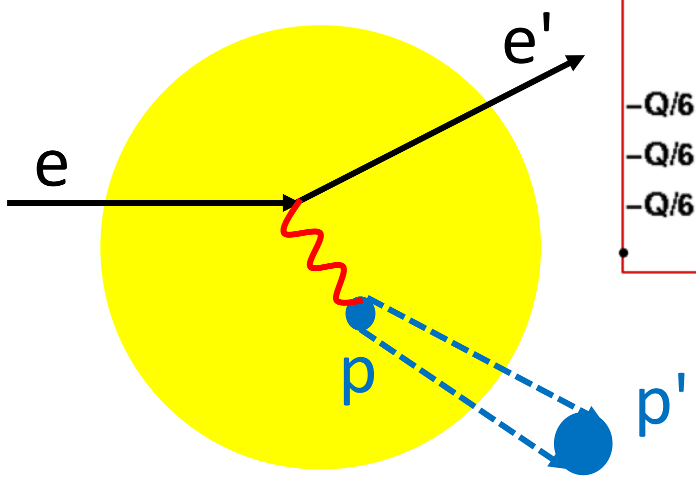
# Exploring Color Transparency with SBS

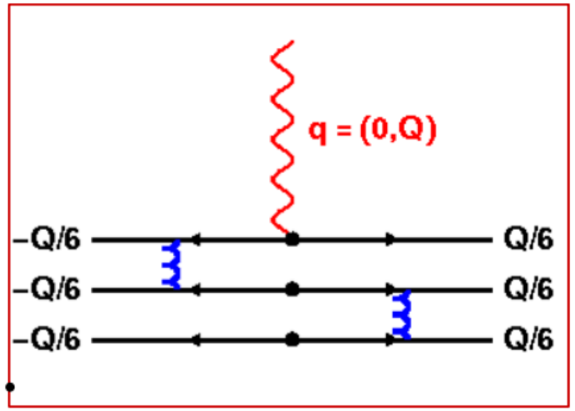
Holly Szumila-Vance

MIT/GWU

31 Jan. 2019

# Color transparency fundamental prediction of QCD

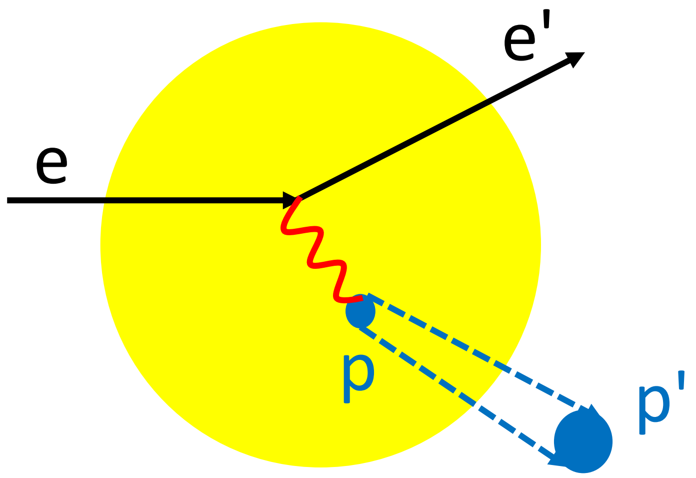


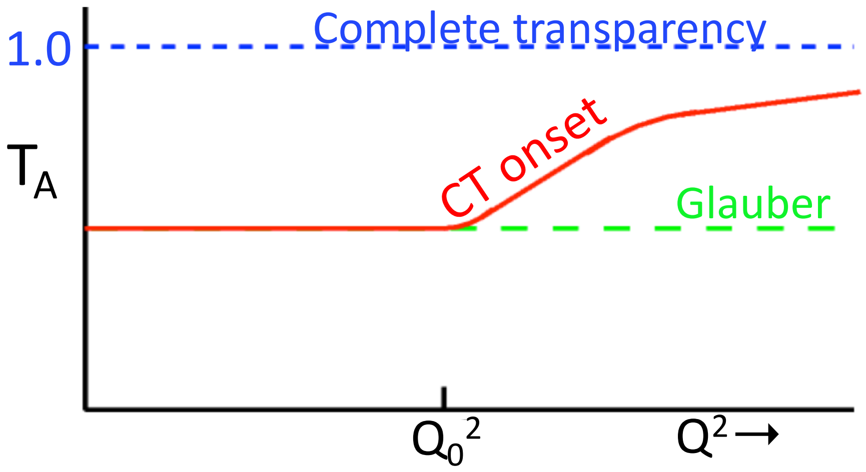




- Introduced by Mueller and Brodsky, 1982
- Vanishing of initial/final state interaction of hadrons with nuclear medium in exclusive processes at high momentum transfer

- 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, $Q^2$

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

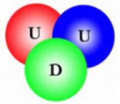
$\sigma_A$ (nuclear cross section)

$\sigma_N$ (free nucleon cross section)

# CT experiments

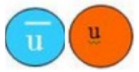
## CT experiments

**Baryon**

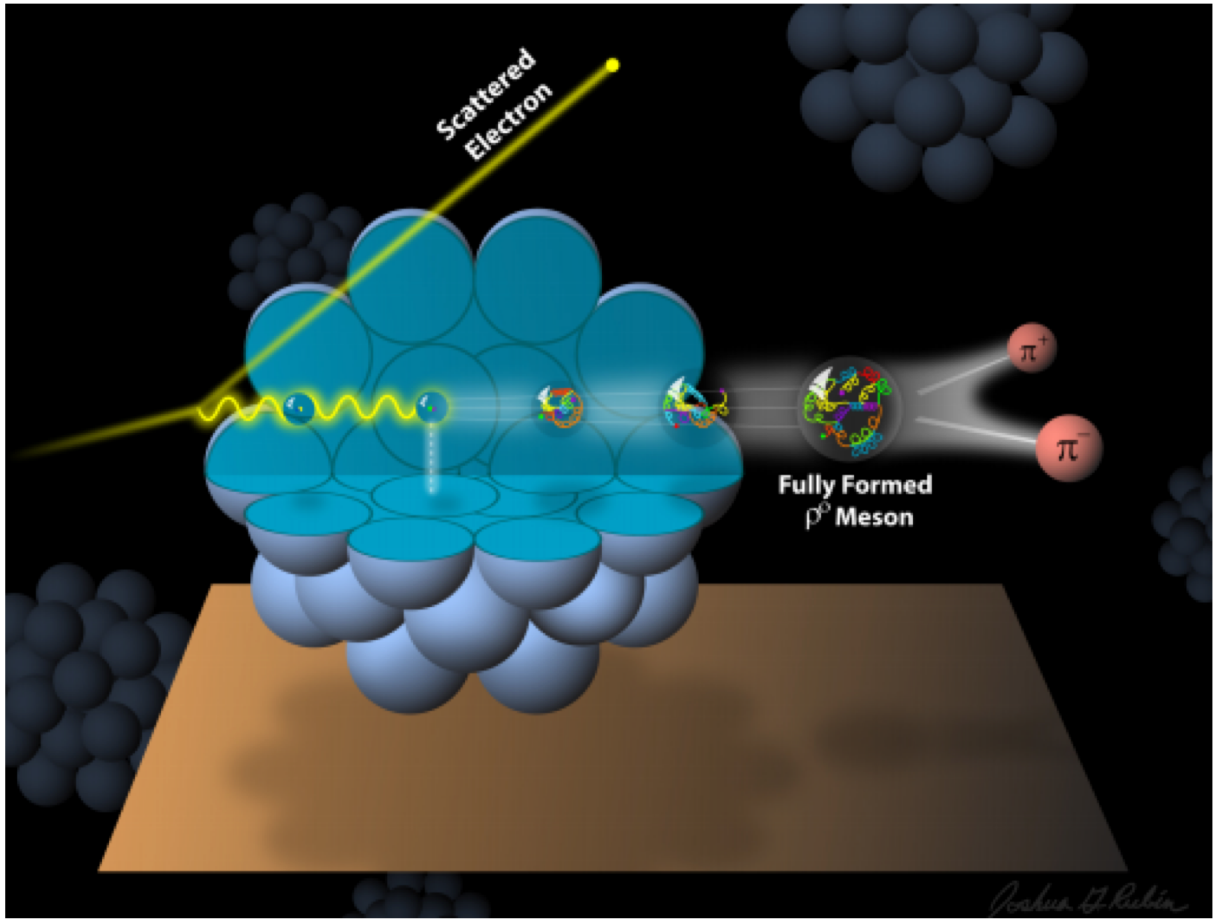



A(p,2p): BNL
A(e,e'p): SLAC, JLab

**Meson**




A($\pi$,di-jet): FNAL
A($\gamma$, $\pi^-$ p): JLab
A(e, e'$\pi^+$): JLab
A(e, e'$\rho^0$): DESY & JLab

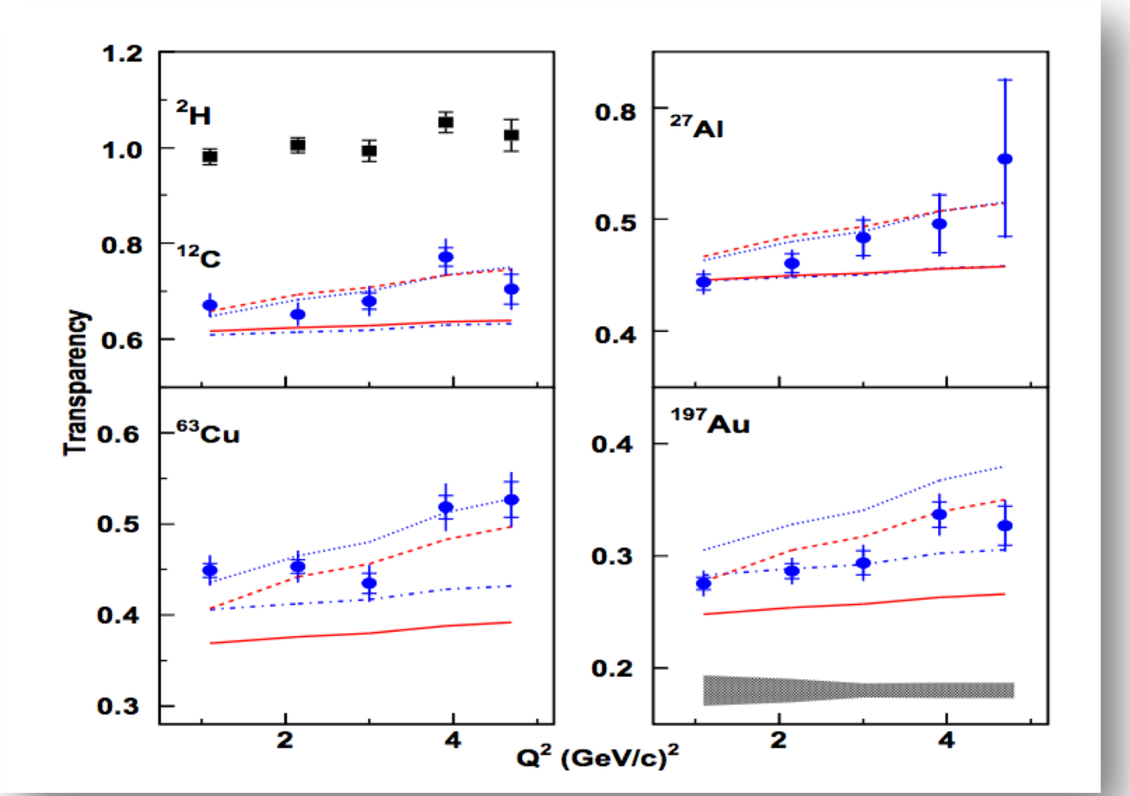


# Previous Measurements: Mesons

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

Hall C E01-107 pion electro-production

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

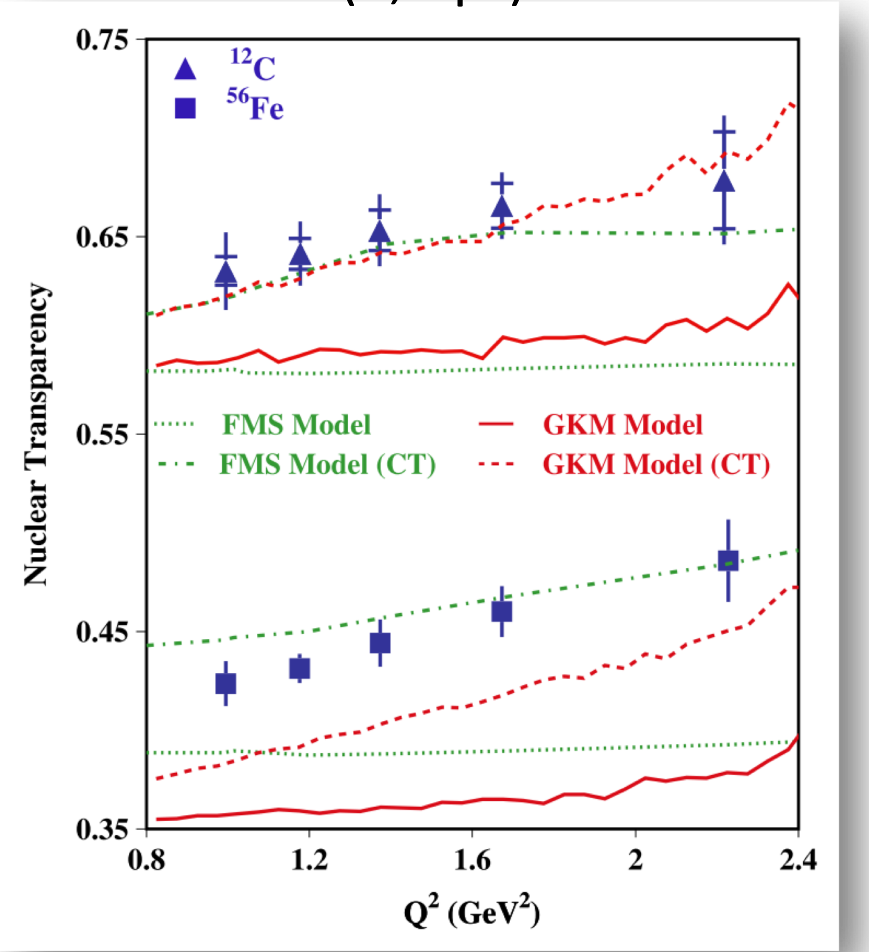



B.Clasie *et al.* PRL 99:242502 (2007)

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

CLAS E02-110 rho electro-production

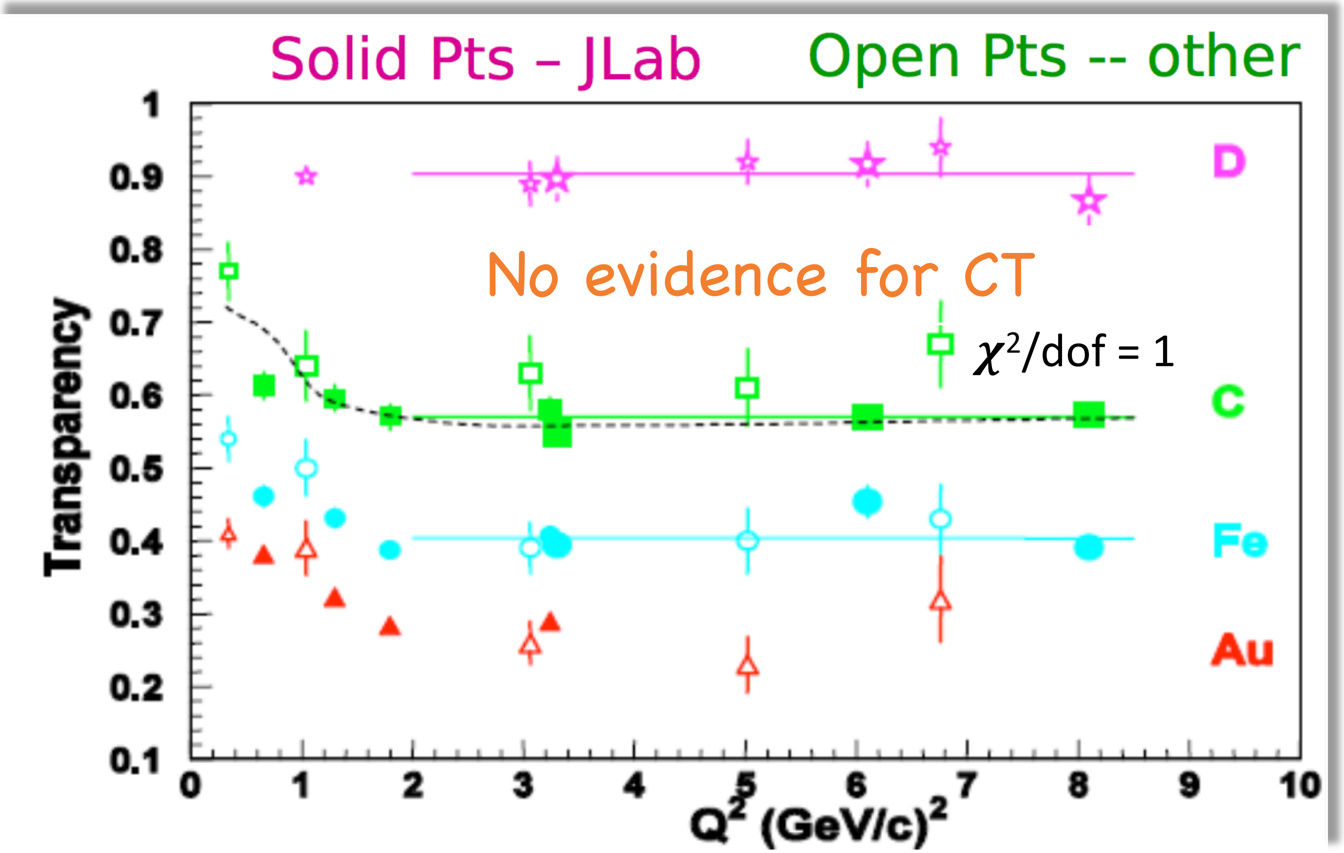
$A(e,e'\rho^0)$




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

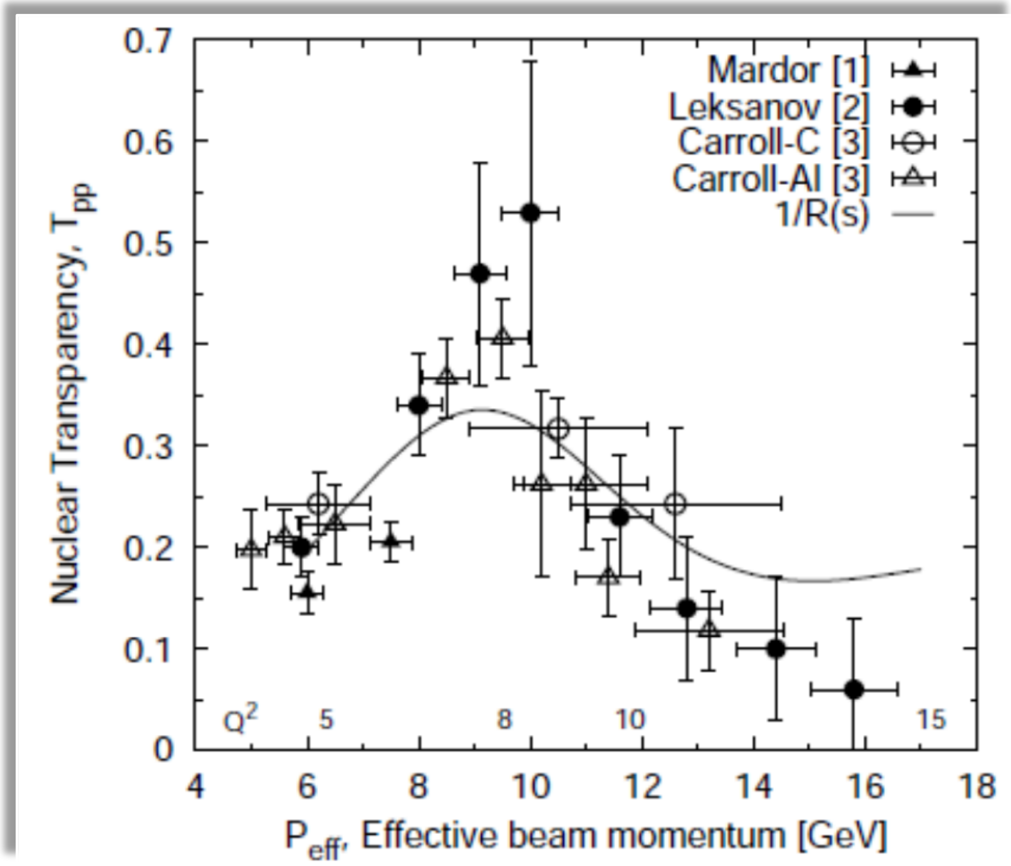
# Previous Measurements: Baryons

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)

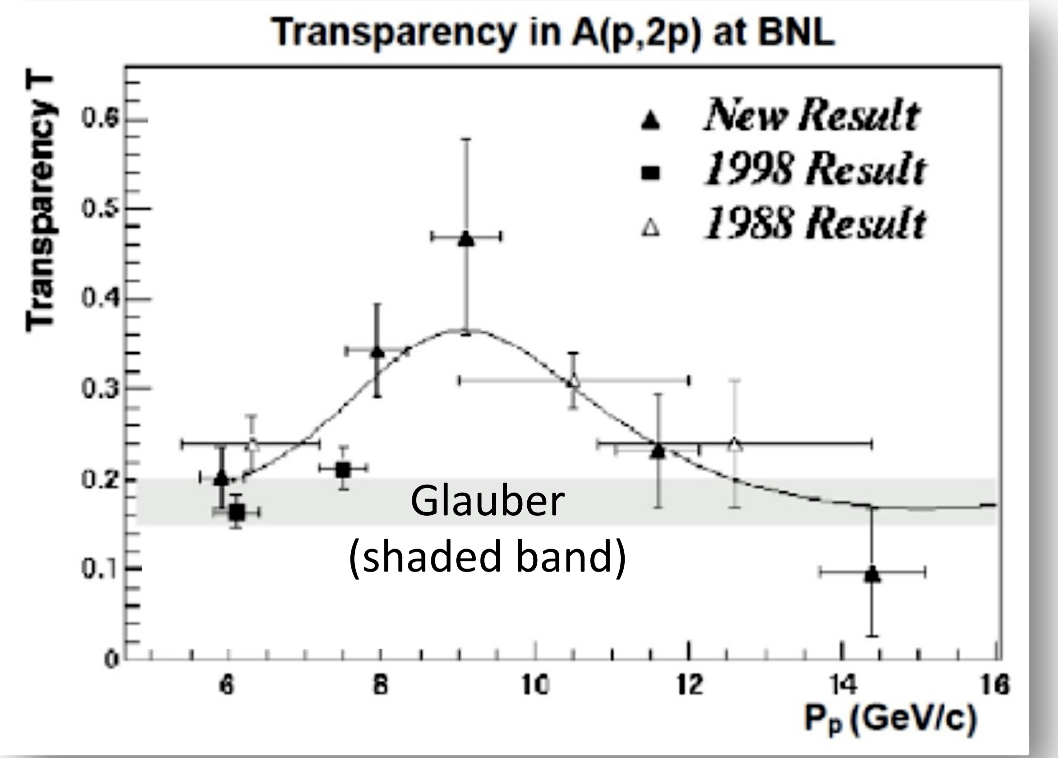
# Previous Measurements: Baryons




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

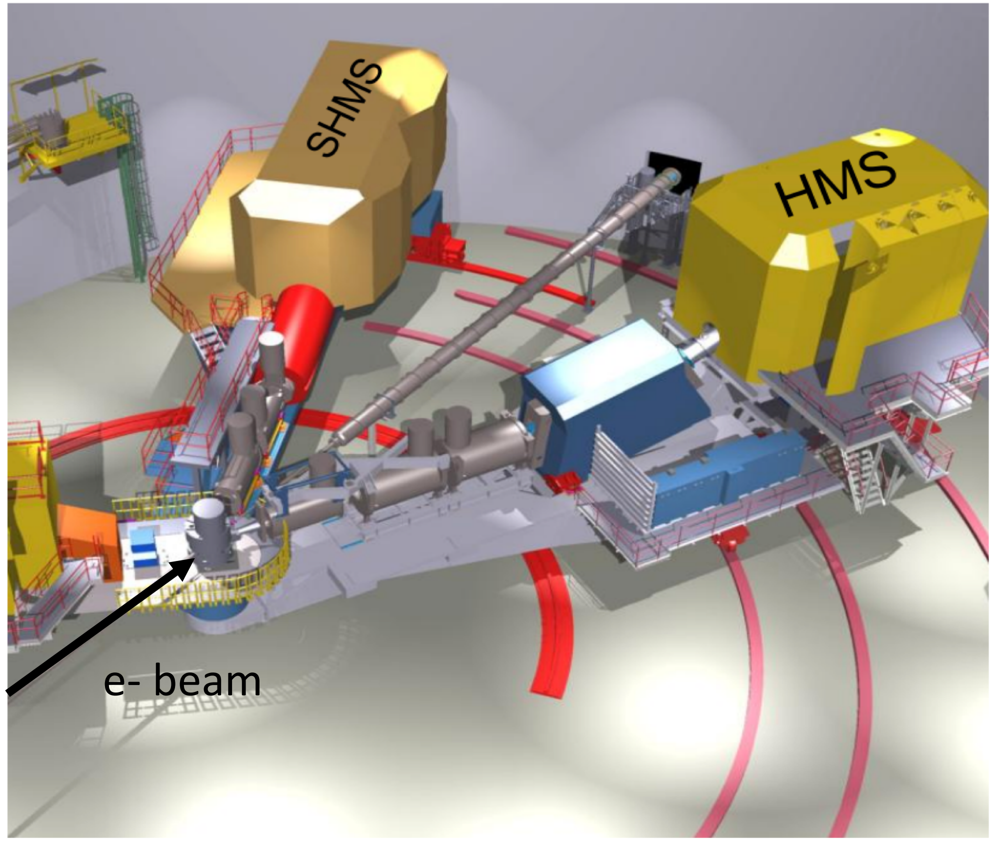


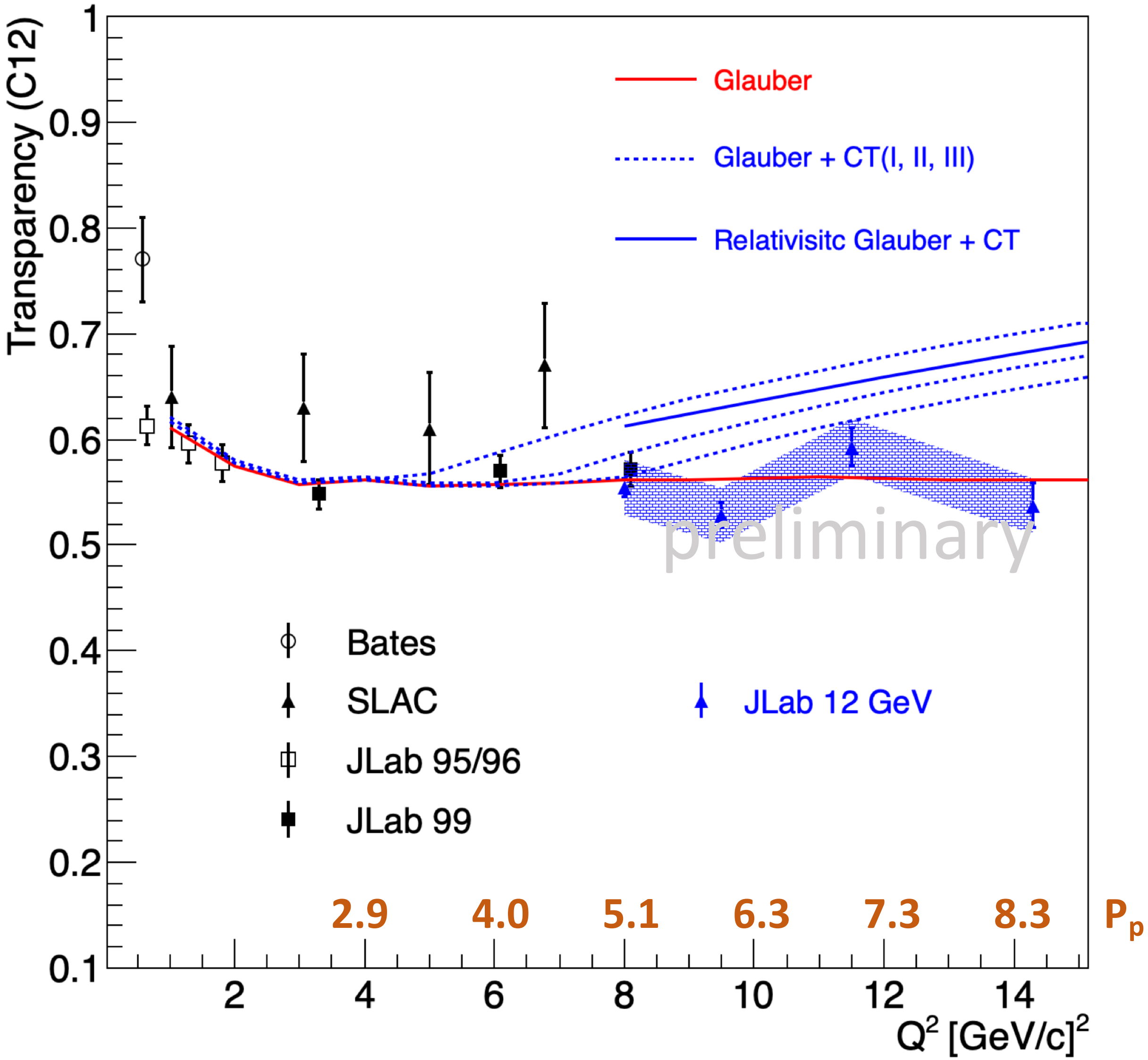

PRL 87, 212301 (2001)
PRL 81, 5085 (1998)
PRL 61, 1698 (1988)

## Starting point: recent Hall C experiment (E12-06-107)

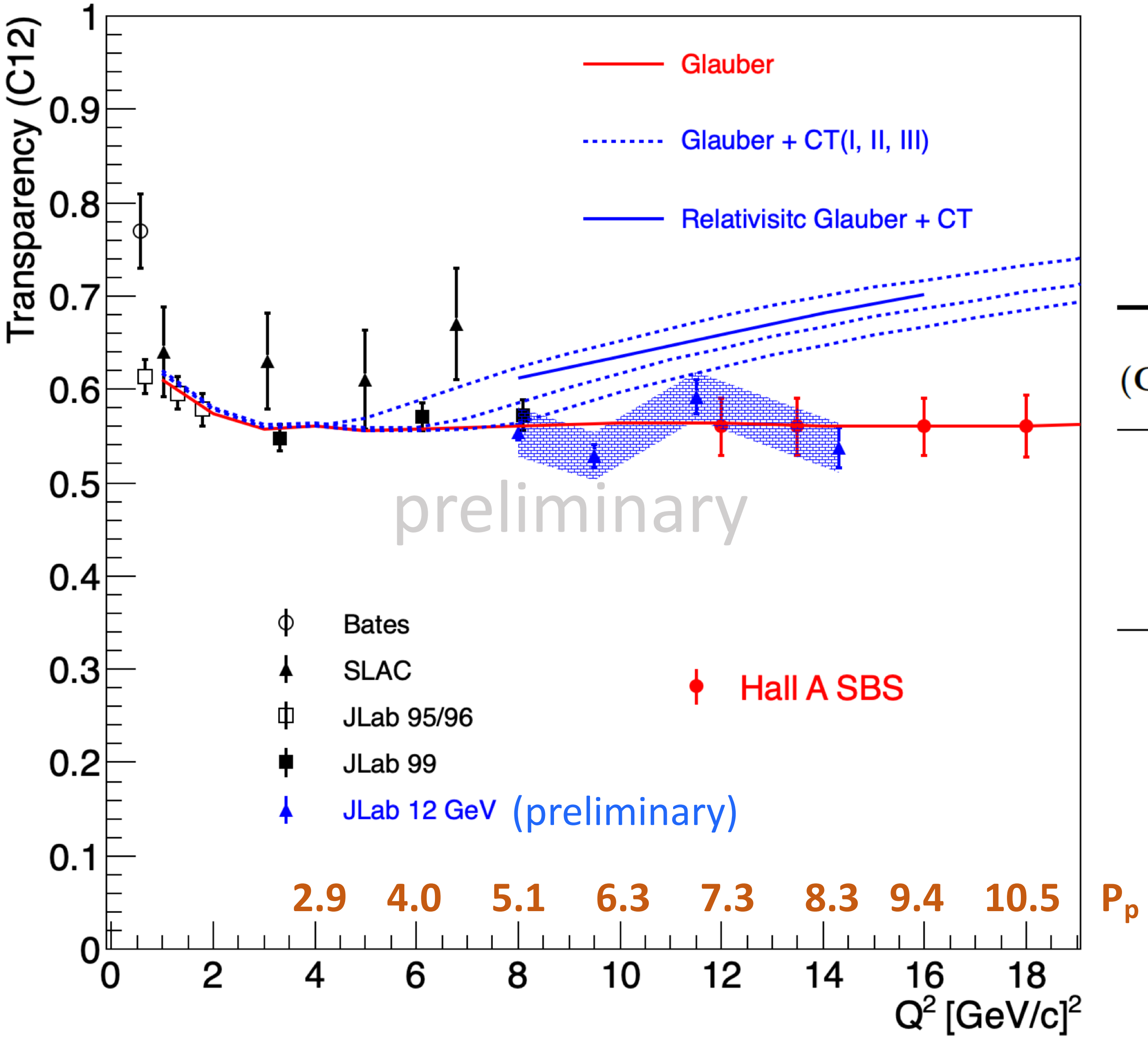
CT on $^{12}C(e,e'p)$ in Hall C:

- T = data/PWIA simulation (SIMC, deForest prescription)
- LH2 data for normalization (4%)
- Parallel kinematics (w/r/t q-vector)
- Prelim results show no rise up to $Q^2$=14.3 $[GeV/c]^2$



# What we can do with SBS




Errors shown include statistical ++ 5% systematic

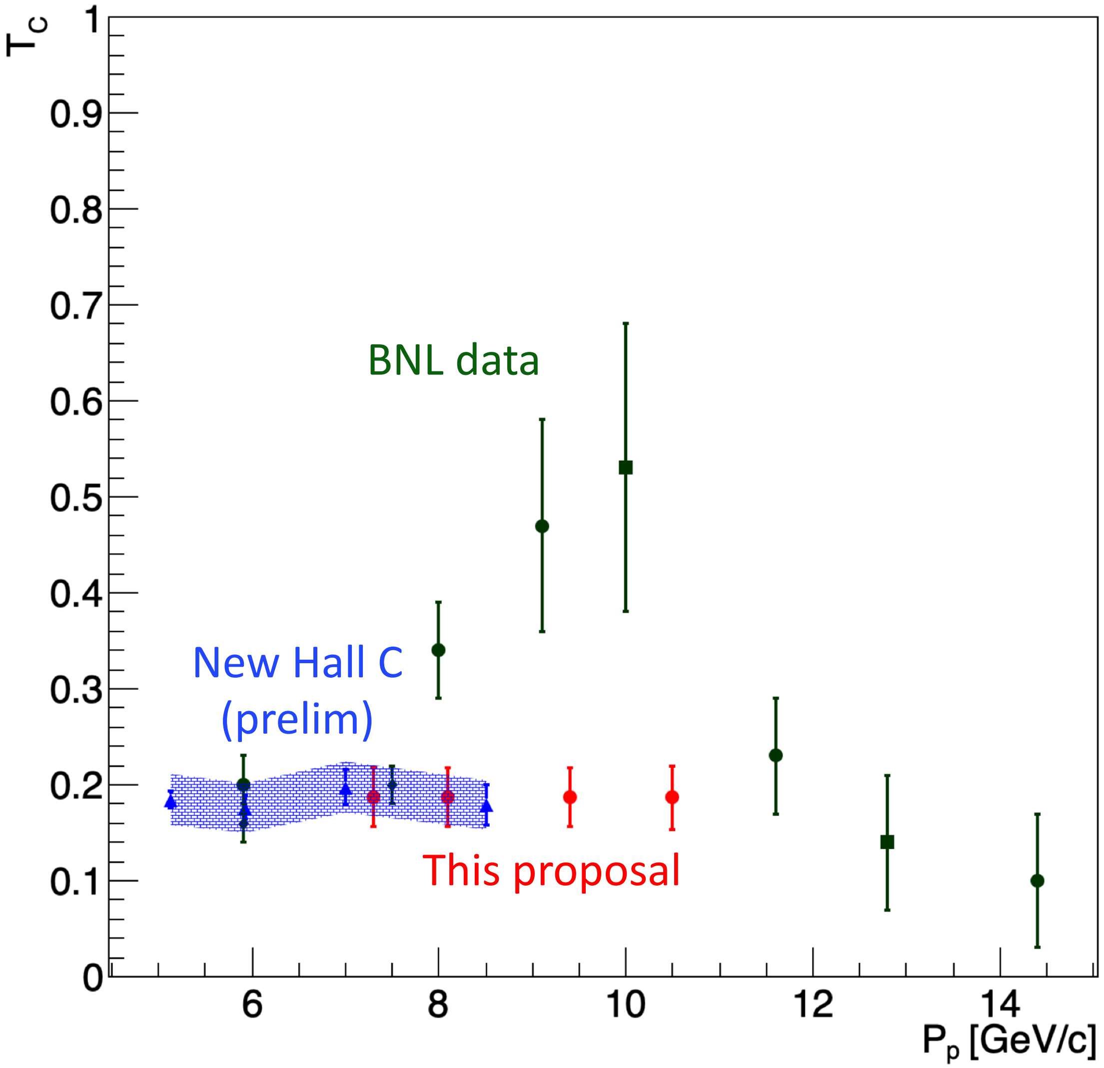
Proposed kinematics

| $Q^2$ $(GeV/c^2)$ | $E_{beam}$ (GeV) | $\theta_{e'}^{lab}$ (deg) | $p_{e'}$ (GeV/c) | $\theta_p^{lab}$ (deg) | $p_p$ (GeV/c) |
|---|---|---|---|---|---|
| 12. | 8.8 | 44.2 | 2.4 | 13.3 | 7.3 |
| 13.5 | 11. | 33. | 3.8 | 14.8 | 8.1 |
| 16. | 11. | 45.1 | 2.5 | 10.7 | 9.4 |
| 18. | 11. | 65.2 | 1.4 | 7.0 | 10.5 |

Explore two avenues simultaneously:

- Onset at higher $Q^2$
- Full pT?

# Comparing the kinematics with the BNL results

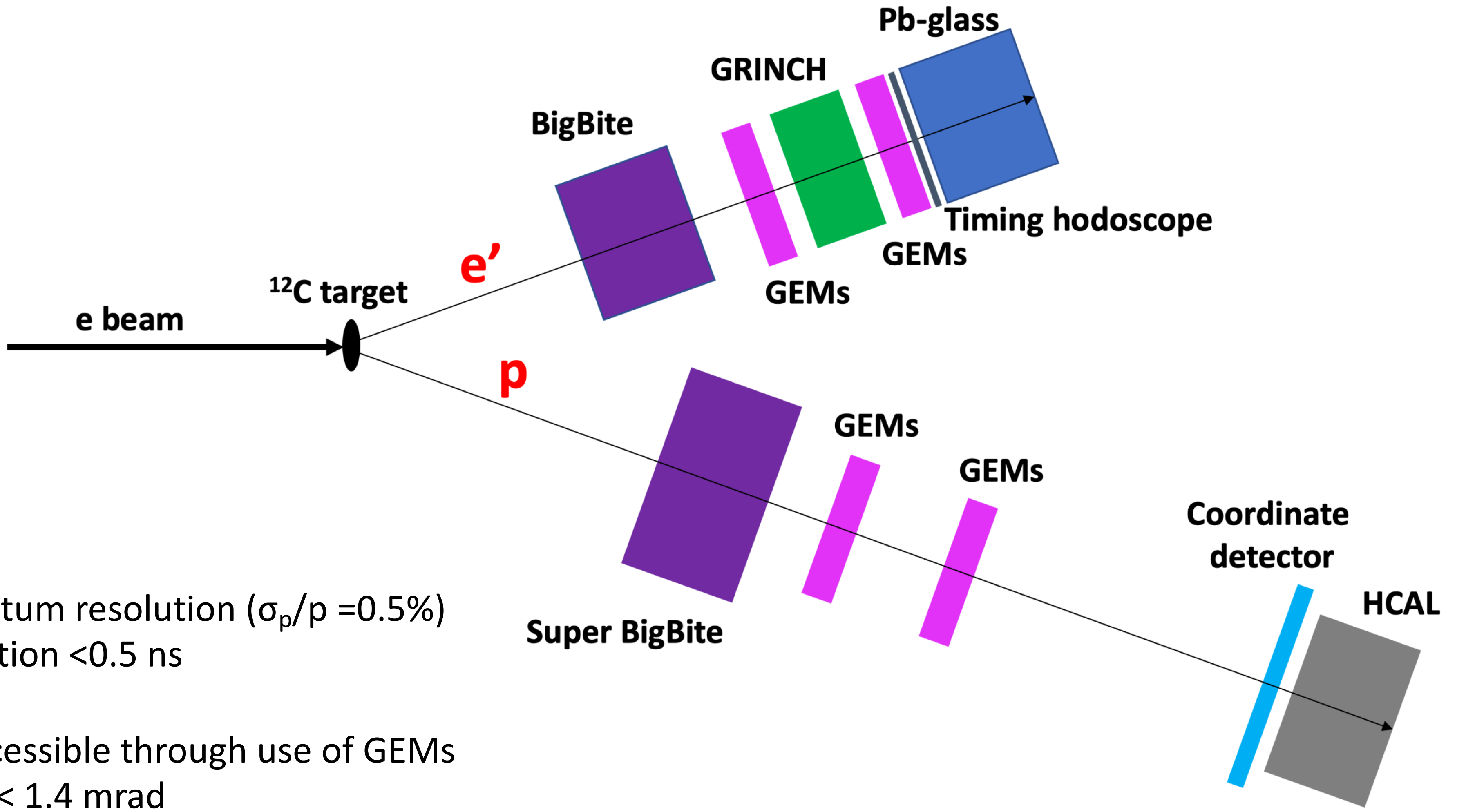



(Arbitrary scaling of the JLab experiments)

Proposed kinematics

| $Q^2$ ($GeV/c^2$) | $E_{beam}$ (GeV) | $\theta^{lab}_{e'}$ (deg) | $p_{e'}$ (GeV/c) | $\theta^{lab}_{p}$ (deg) | $p_p$ (GeV/c) |
|---|---|---|---|---|---|
| 12. | 8.8 | 44.2 | 2.4 | 13.3 | 7.3 |
| 13.5 | 11. | 33. | 3.8 | 14.8 | 8.1 |
| 16. | 11. | 45.1 | 2.5 | 10.7 | 9.4 |
| 18. | 11. | 65.2 | 1.4 | 7.0 | 10.5 |

GEp-RP setup with GEM tracking on both arms:




- Good momentum resolution ($\sigma_p/p = 0.5\%$)
- Timing resolution <0.5 ns
- Particle ID
- High rates accessible through use of GEMs
- $\theta_e$ resolution < 1.4 mrad

Targets:
- 5% $^{12}C$ production target
- 15 cm hydrogen for normalization
- Al dummy for background subtraction

Requesting:
- 70 uA on hydrogen
- 40 uA on $^{12}C$

| $Q^2$ ($GeV/c^2$) | $^1H$ counts/hour | $^{12}C$ counts/hour | $^1H$ time days (2k counts) | $^{12}C$ time days (2k counts) |
|---|---|---|---|---|
| 12. | 3570 | 149 | 0.02 | 0.6 |
| 13.5 | 840 | 35 | 0.1 | 2.4 |
| 16. | 735 | 31 | 0.1 | 2.7 |
| 18. | 126 | 5 | 0.7 | 8* |
| **Total:** | | | 1.1 | 16 |

*1k counts

Particle ID

- Electrons:
    - GRINCH detector for pi- rejection
    - Timing hodoscope to reduce accidentals
- Protons:
    - Clean proton tracks: GEM tracking + coordinate detector + HCAL

Physics analysis:

- $^{12}C$ $P_{miss}$ using spectral function (exploring this)

Synergy with other SBS experiments:

- Same setup as GEp-RP
- First two kinematic points overlap with GMn
- LH2 target for calibrations
- 1 beam energy change

Systematics

- Biggest systematic from hydrogen normalization: 2.5%
- Simulation to determine contamination from inelastics (certainly <5% from GMn proposal at highest $Q^2$)
- Determine $P_{miss}$ spectra and compare with spectral function

## Summary

- Measuring the onset of CT is a signature for the onset of QCD degrees of freedom in nuclei
- SBS optimized for high Q2 running- extends previous CT measurements to higher Q2
- SBS large acceptance can measure large pT spectrum

## Going forward:

- Simulations! carbon QE width and inelastics
- Pmiss spectra, estimate cuts to reduce fringe field effects
- Stay tuned for update at SBS collaboration meeting!

Many thanks for the helpful discussions:
Jerry Miller, Mark Strikman, Bogdan, Thia, and Dipangkar