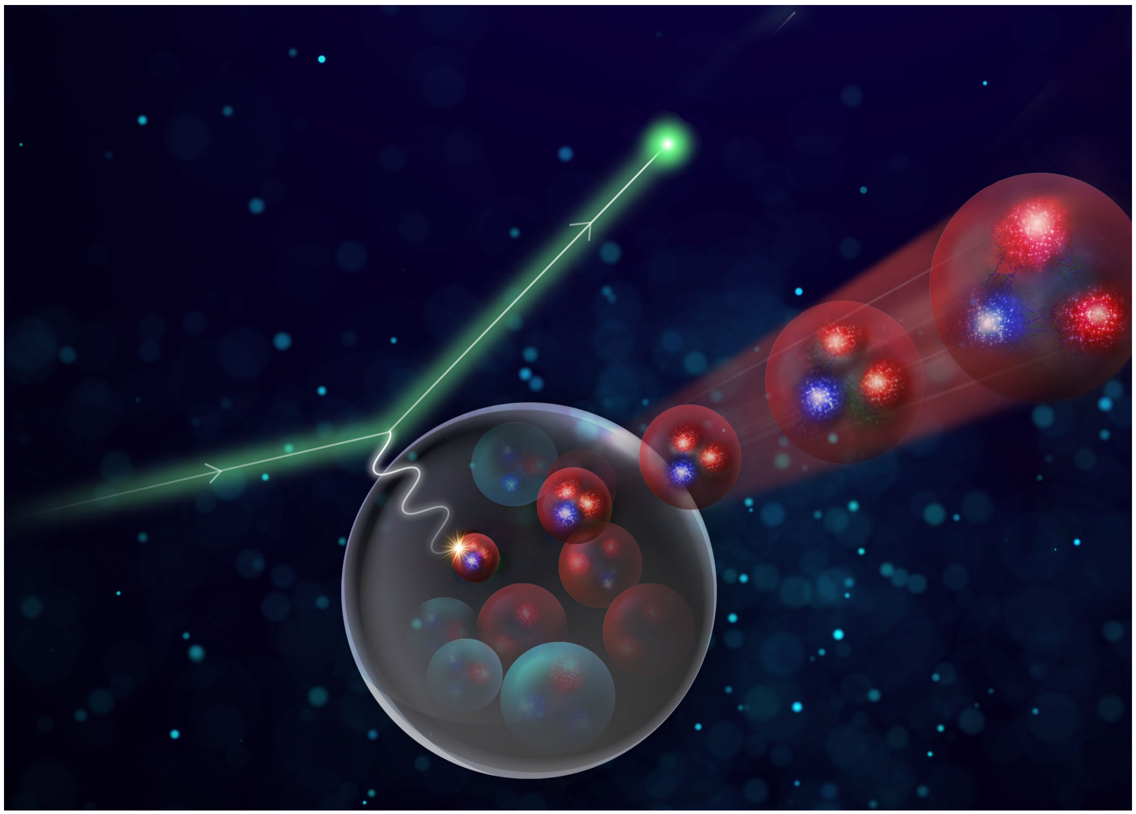
NEW RESULTS FROM E1206107 COLOR TRANSPARENCY (CT) EXPERIMENT IN PROTONS @ JLAB



Deepak Bhetuwal

Hall C Users Meeting

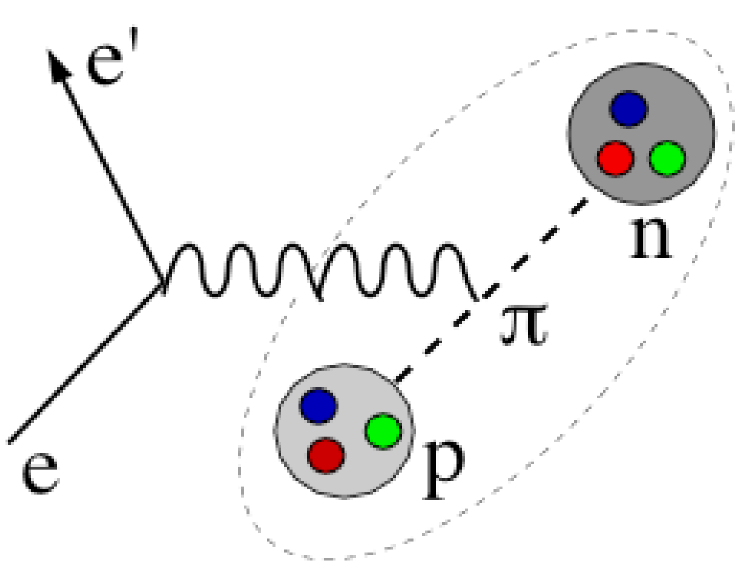
February 17, 2022

OUTLINE

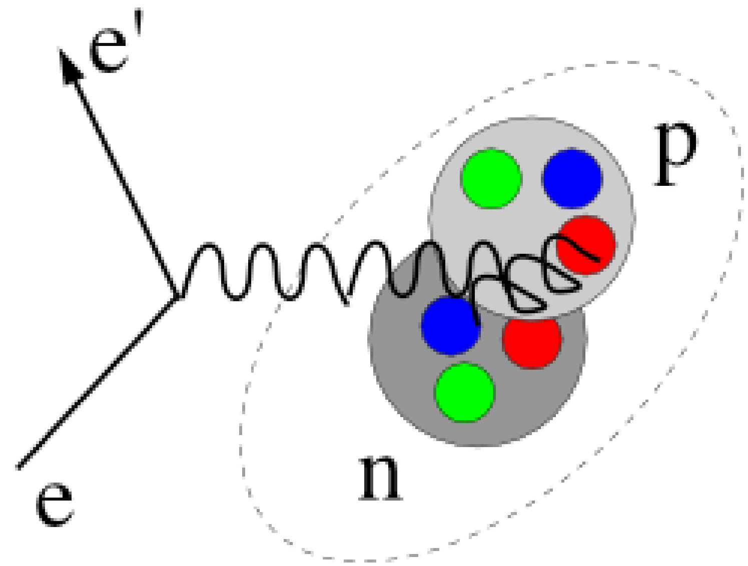
- Color Transparency (CT) : Background / Introduction
- Past Experiments Status
- Need of The Experiment E1206107
- Hydrogen Normalization Result
- Systematic Study
- Carbon Result
- What's Next?
- Summary

TRANSITION

Mapping the transition from the nucleon-meson degrees of freedom to the quark-gluon degrees of freedom of QCD.



Nucleon-meson degrees of freedom effective at low energies



Quark-gluon degrees of freedom at high energies

Exclusive processes (processes with completely determined initial and final states), are used to study the transition region.

NUCLEAR TRANSPARENCY

- **Nuclear Transparency T is a useful observable in studying CT.**
- **Ratio of cross-sections for exclusive processes from nuclei to nucleons is termed as Nuclear Transparency.**

$$T = \frac{(\sigma_A / A)}{\sigma_N}$$

σ_A - Nuclear cross section

σ_N - Free nucleon cross section

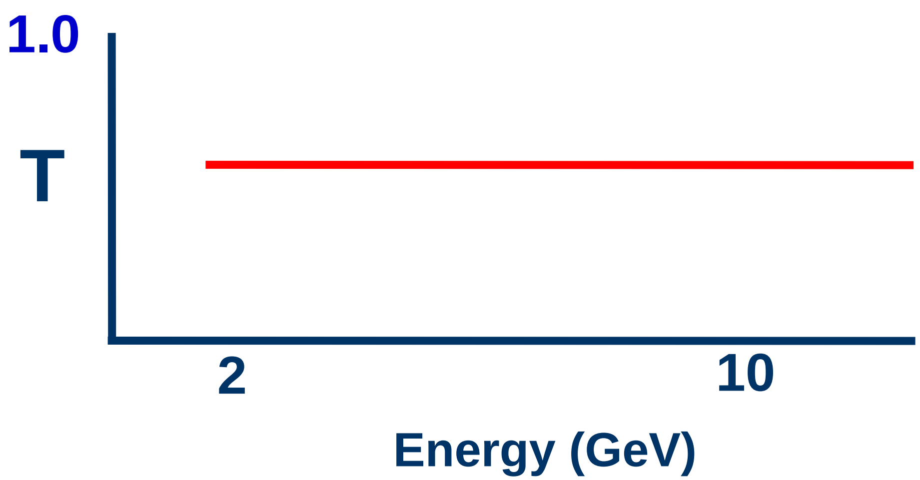
σ_A/A - Bound nucleon cross section

σ_A is parameterized as $= \sigma_N A^{\alpha}$

Experimentally: α = 0.72 – 0.78, for π, κ, p

GLAUBER NUCLEAR TRANSPARENCY

Traditional nuclear physics calculations (Glauber calculations) predict transparency to be energy independent .



Ingredients

- σ_{hN} (h-N cross-section)
- Glauber multiple scattering approximation
- Correlations and FSI effects

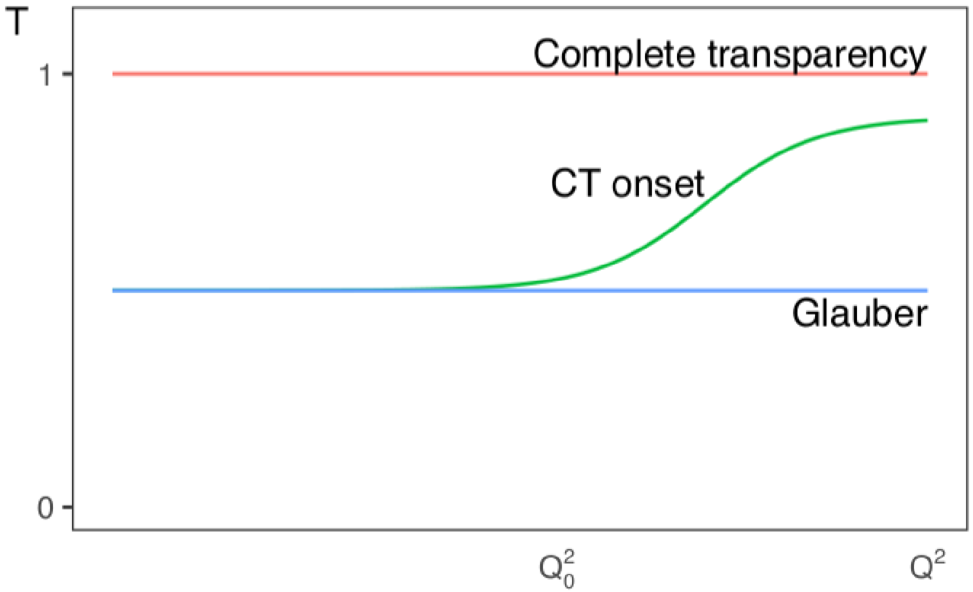
CT PHENOMENA

Color transparency (CT) refers to the disappearance of initial and final state interactions in exclusive scattering at large 4-momentum transfer squared Q^2.

Introduced by Mueller and Brodsky in 1982. It arises in picture of quark-gluon interactions only.

CT takes place in the following 3 steps:

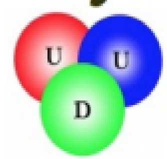
(1) Squeezing
The formation of a small-sized wavepacket PLC of quarks with small transverse size **(b)**.
(2) Reduced interactions
Reduced interaction between the PLC and the nuclear medium ($\sigma \sim b^2$).
(3) Freezing
The PLC escapes the nucleus while small, or reduced FSI.



CT PAST EXPERIMENTS

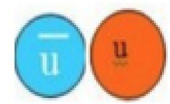
CT Experiments

Baryon



A(p,2p): BNL
A(e,e’p): SLAC, JLab

Meson



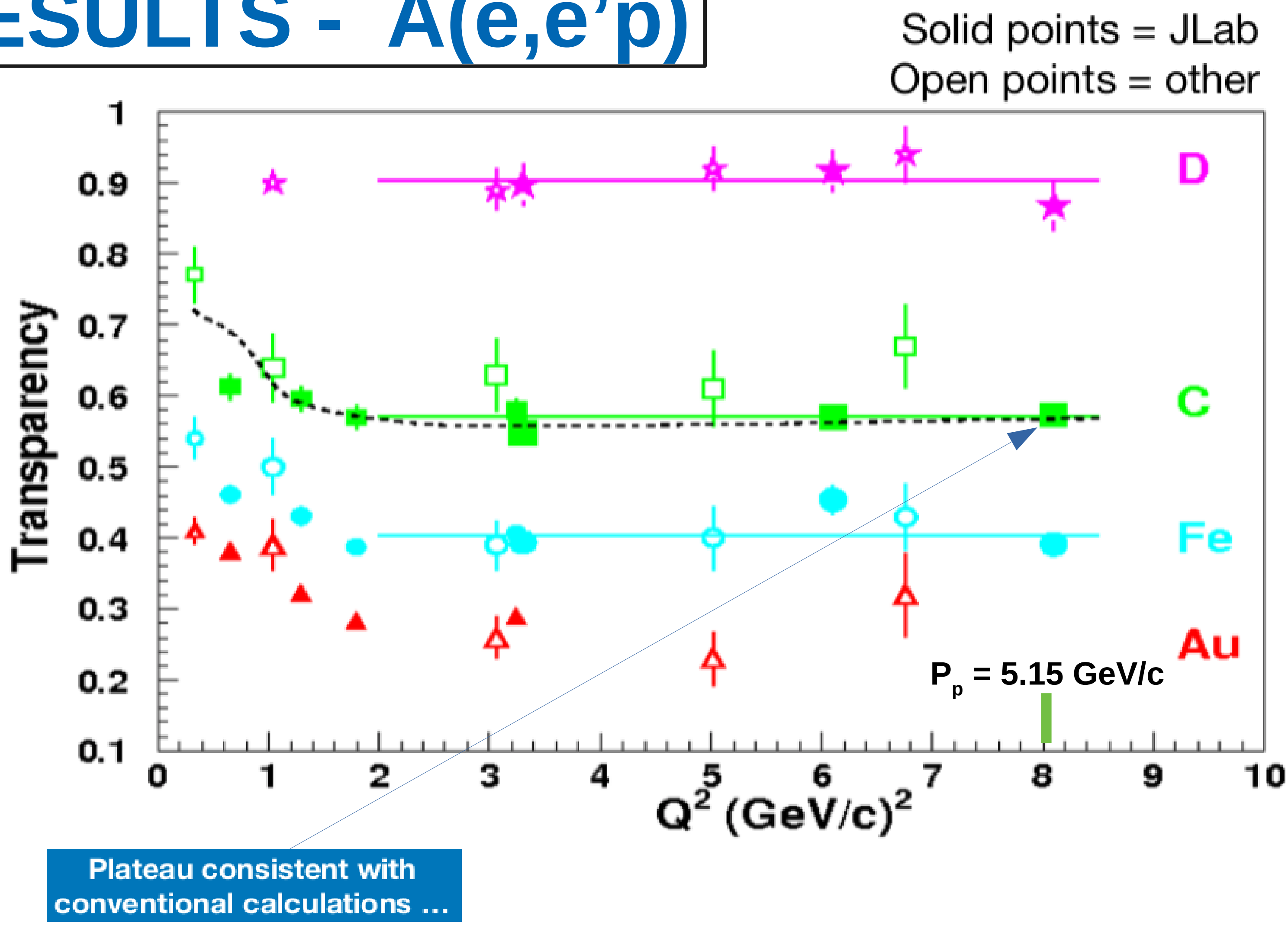
A(π,di-jet): FNAL
A(γ, π^- p): JLab
A(e, e’π^+): JLab
A(e, e’ρ^0): DESY & JLab

CT PAST RESULTS - A(e,e'p)

Electron beam incident on various nuclear targets

Previous measurements consistent with Glauber prediction up to 8.0 $(GeV/c)^2$.

Perhaps we haven't gone high enough in Q^2?



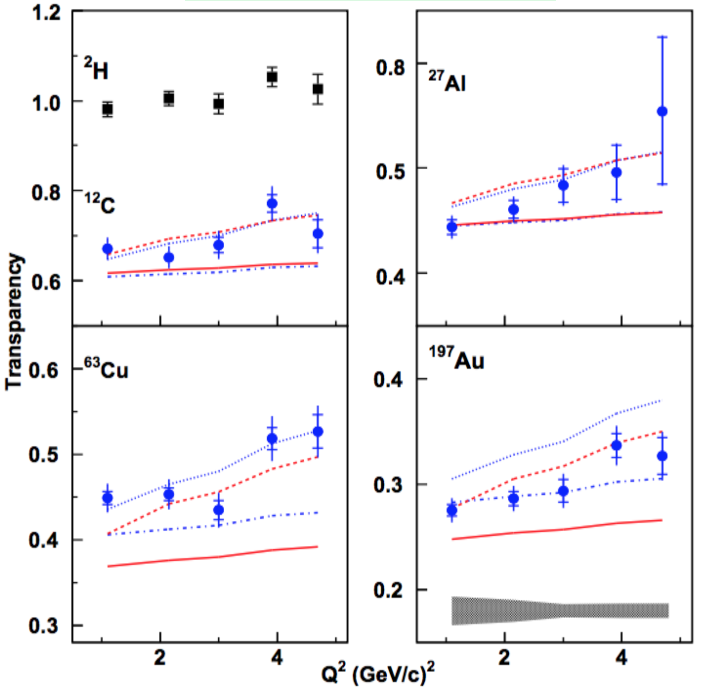
Makins, et al., Phys. Rev. Lett. 72, 1986 (1994)
O' Neill, et al., Phys. Lett. B 351, 87 (1995)
Abbott, et al., Phys. Rev. Lett. 80, 5072 (1998)
Garrow, et al., Phys. Rev. C 66, 044613 (2002)
Rohe, et al., Phys. Rev. C 72, 054602 (2005)
Garino, et al., Phys. Rev. C 45, 780 (1992)

CT PAST RESULTS - MESONS

CT is well established at high energies.
Onset of CT has been measured in Mesons but not in Baryons.

PION - A(e, e'π⁺)

Hall C E01-107 pion electroproduction

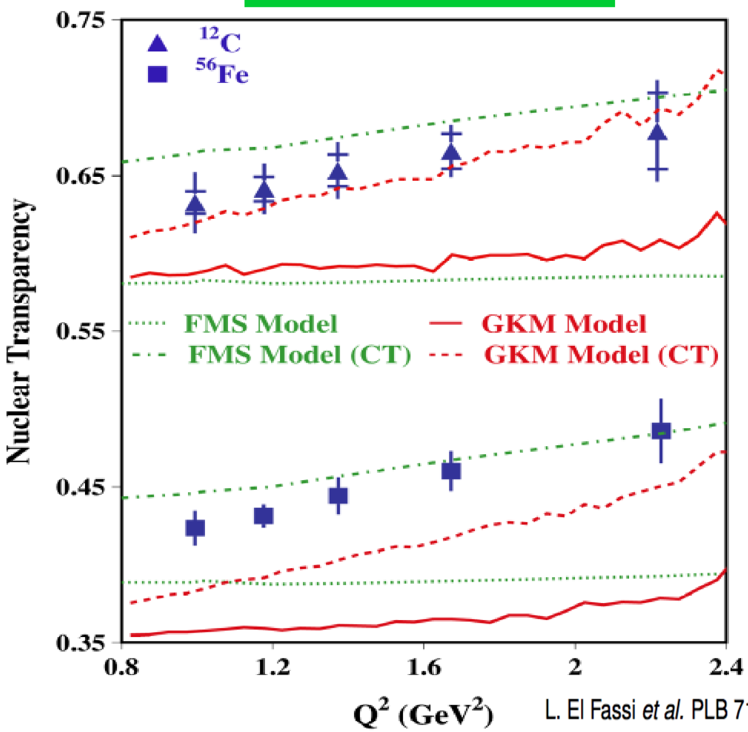


B.Clasie *et al.* PRL 99:242502 (2007)

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

RHO - A(e, e'ρ⁰)

CLAS E02-110 rho electroproduction



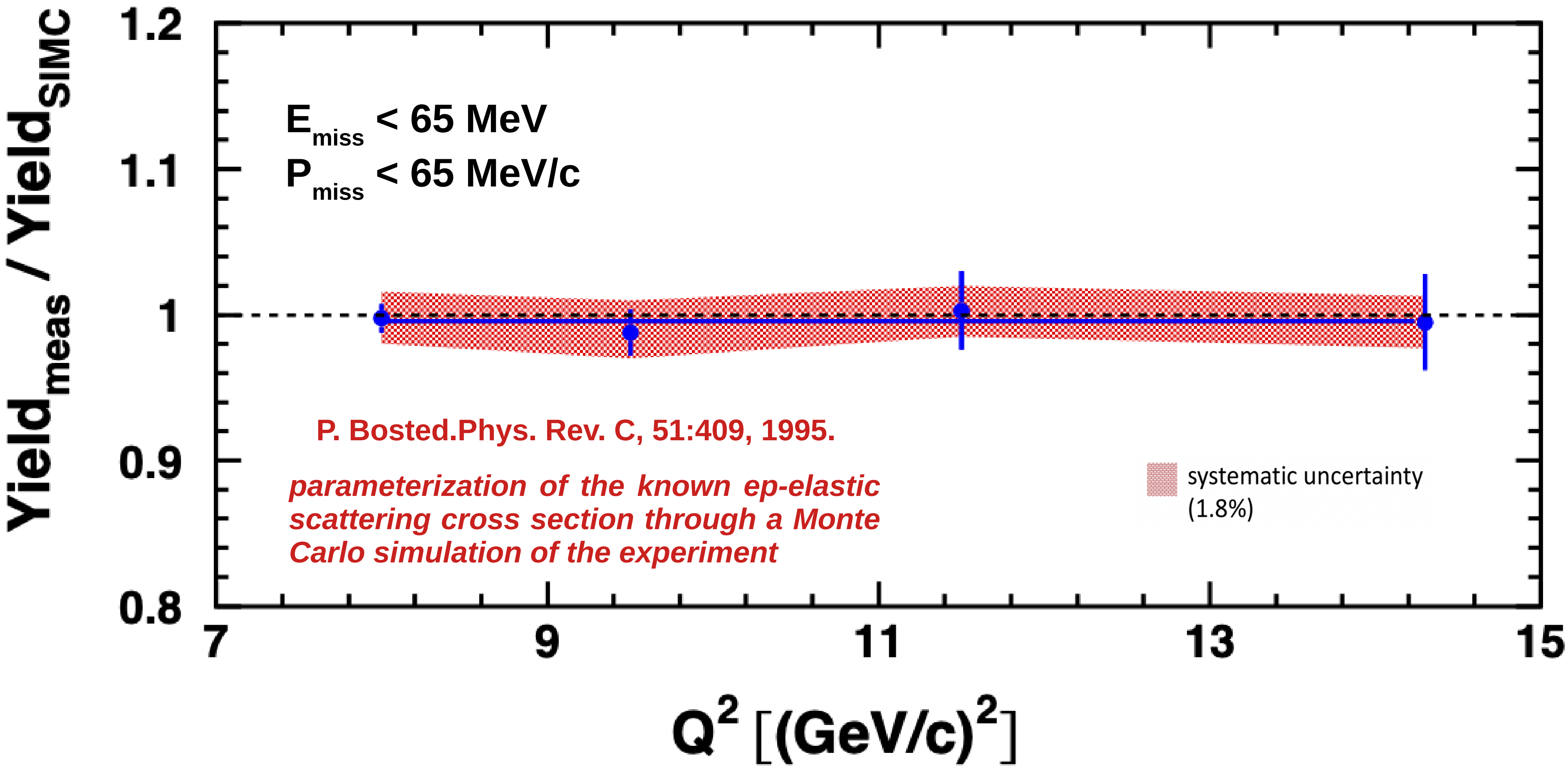
L. El Fassi *et al.* PLB 712,326 (2012)

CT This EXPERIMENT: E12-06-107

- E12-06-107 was the first experiment in the 12 GeV era
- Ran in Hall C at JLab in Spring 2018
- Coincidence trigger
- Targets: 10 cm LH_2, 6% rl ^{12}C, ^{27}Al
- ~20 days of data taking
- E_{beam} of 6.4 GeV and 10.6 GeV
- Beam current up to 65 μA

Beam	Q^2 [GeV^2]	SHMS angle [°]	SHMS central p [GeV]	HMS angle [°]	HMS central p [GeV]
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
	14.2	12.8	8.505	39.3	2.982

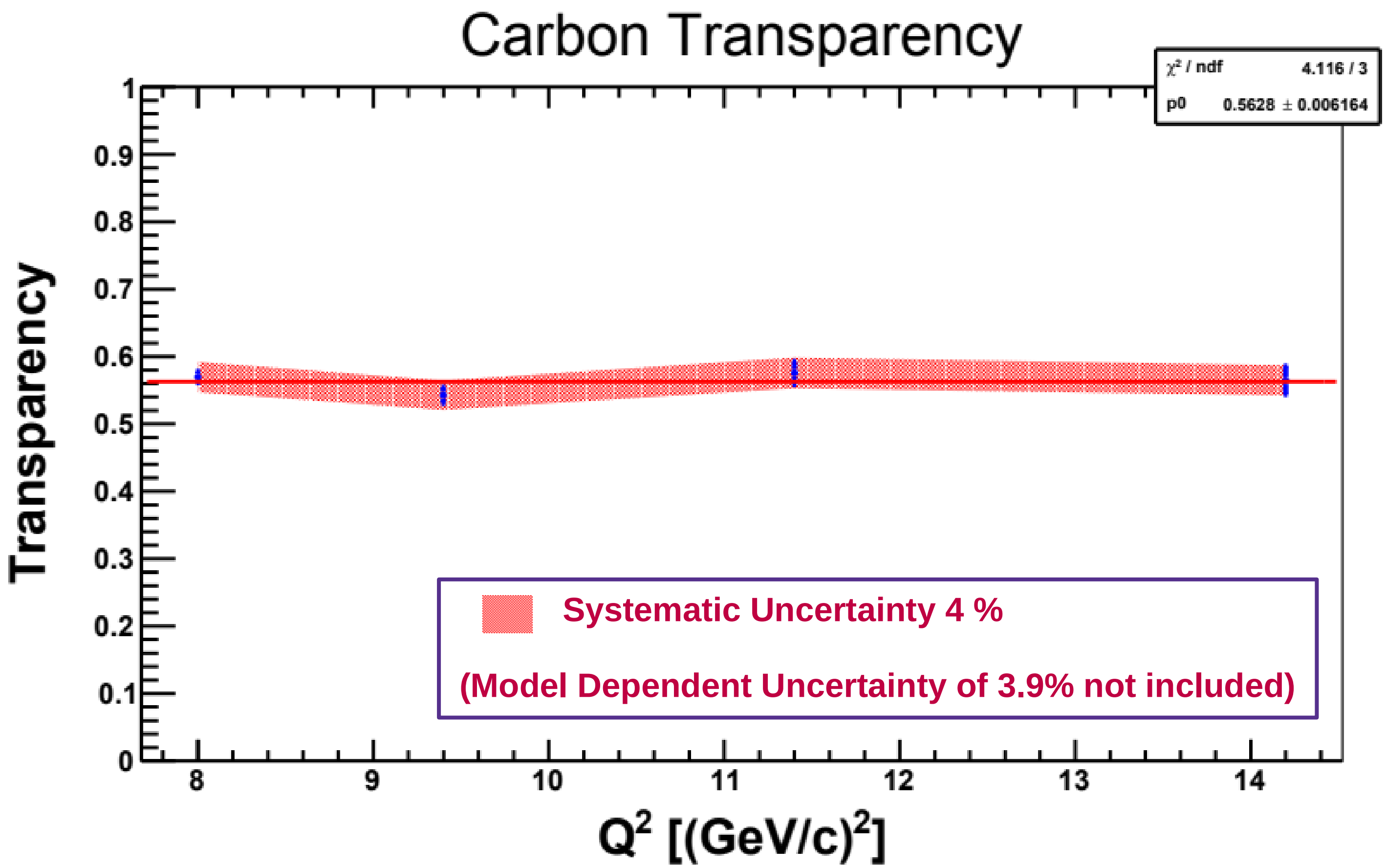
HYDROGEN NORMALIZATION



SYSTEMATIC UNCERTAINTY

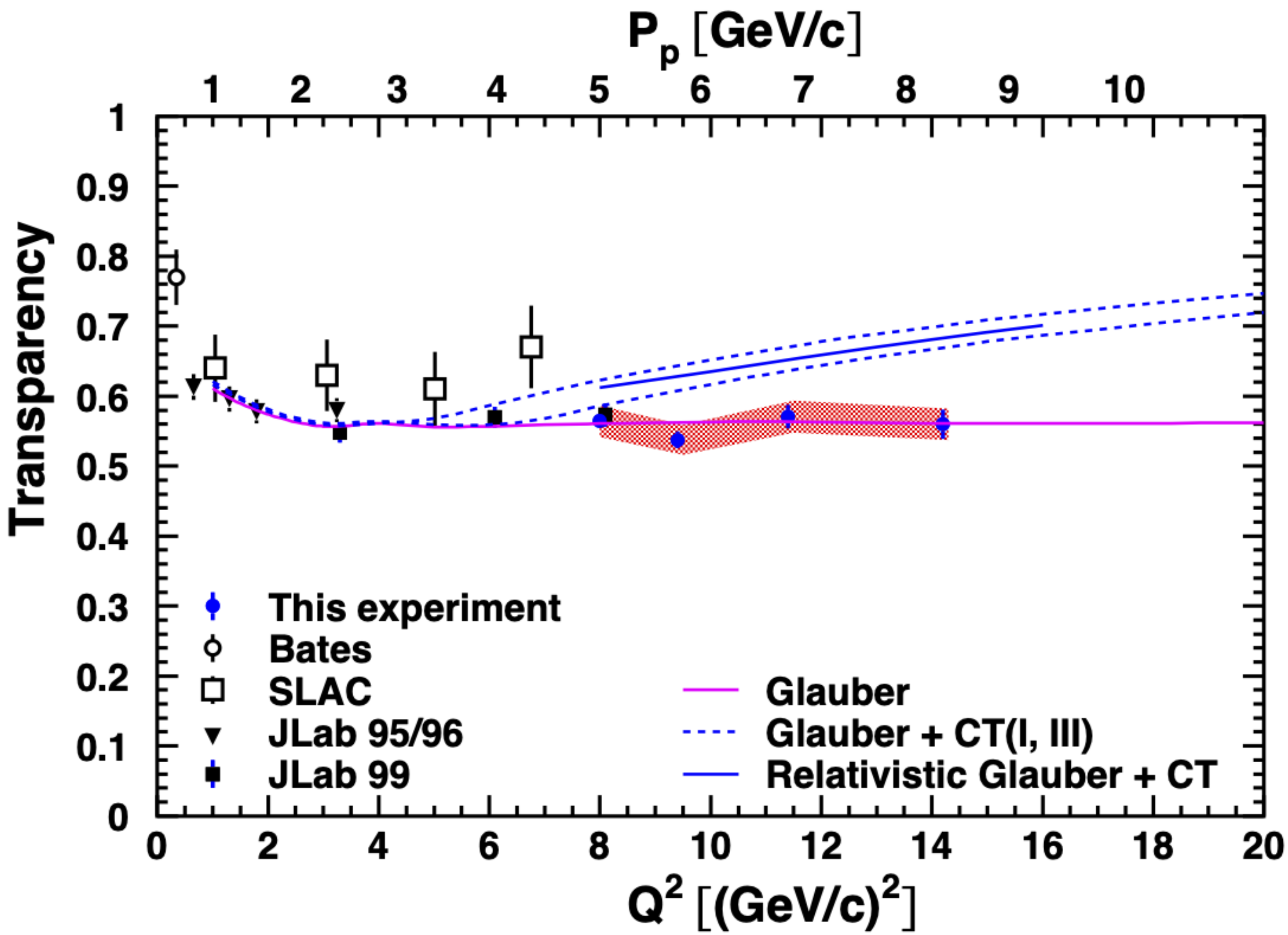
Source	Q^2 dependent uncertainty (%)
Spectrometer acceptance	2.6
Event selection	1.4
Tracking efficiency	0.5
Radiative corrections	1.0
Live time & Det. efficiency	0.5
Source	**Normalization uncertainty (%)**
Free cross section	1.8
Target thickness	0.5
Beam charge	1.0
Proton absorption	1.2
Total	4.0

TRANSPARENCY



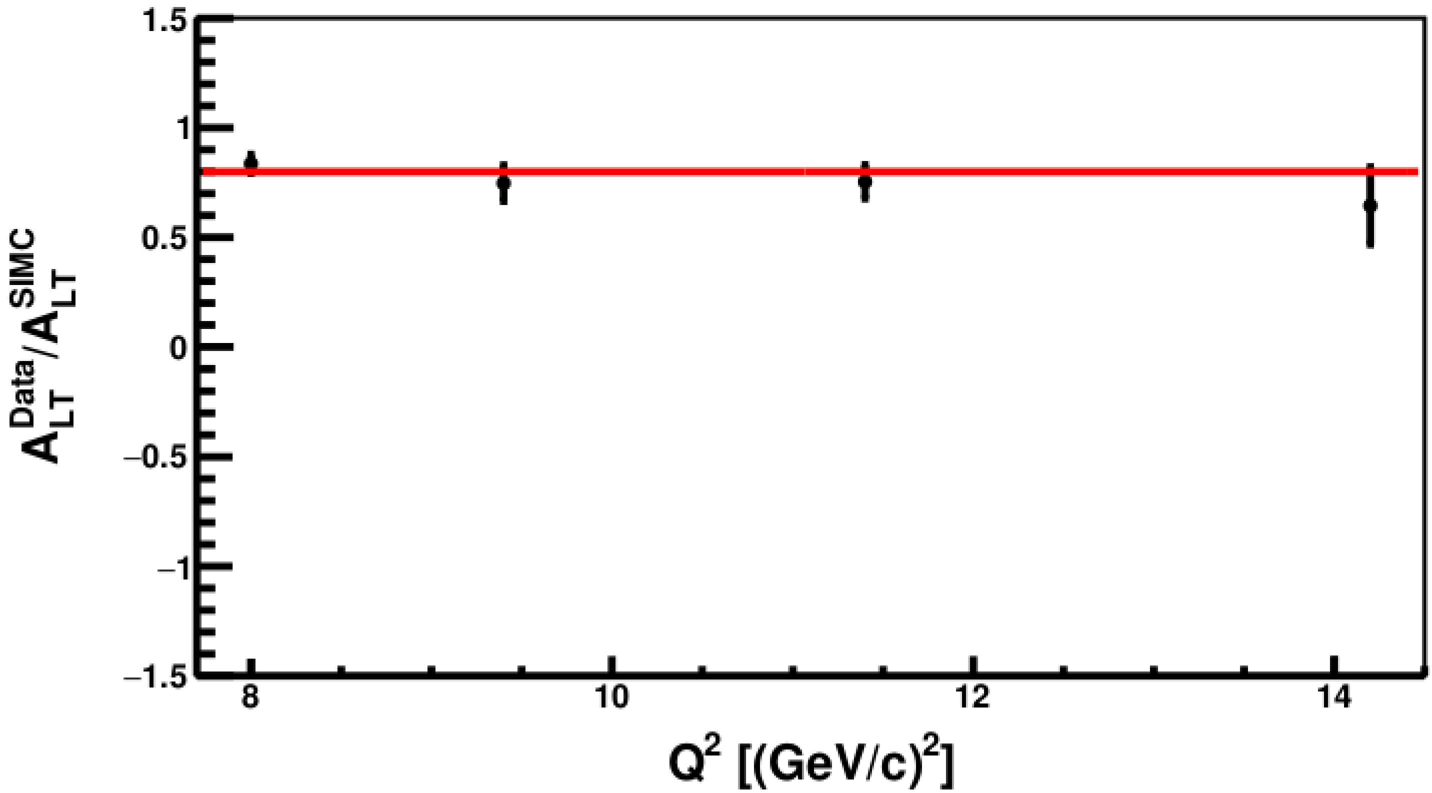
E_{miss} < 80 MeV
P_{miss} < 300 MeV/c

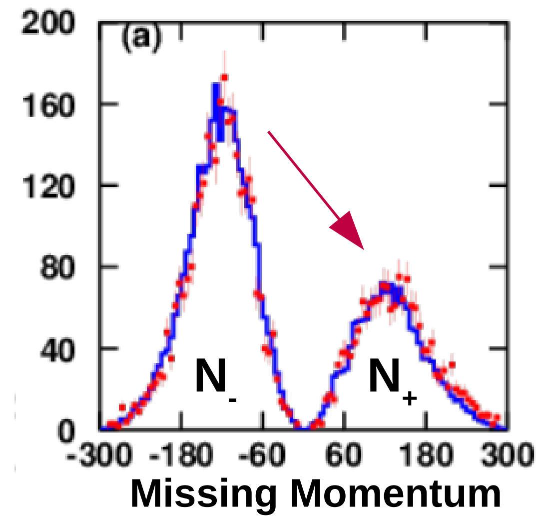
TRANSPARENCY – CONTD.



D. Bhetuwal et al.,
Phys. Rev. Lett., 126(8), 082301 (2021).

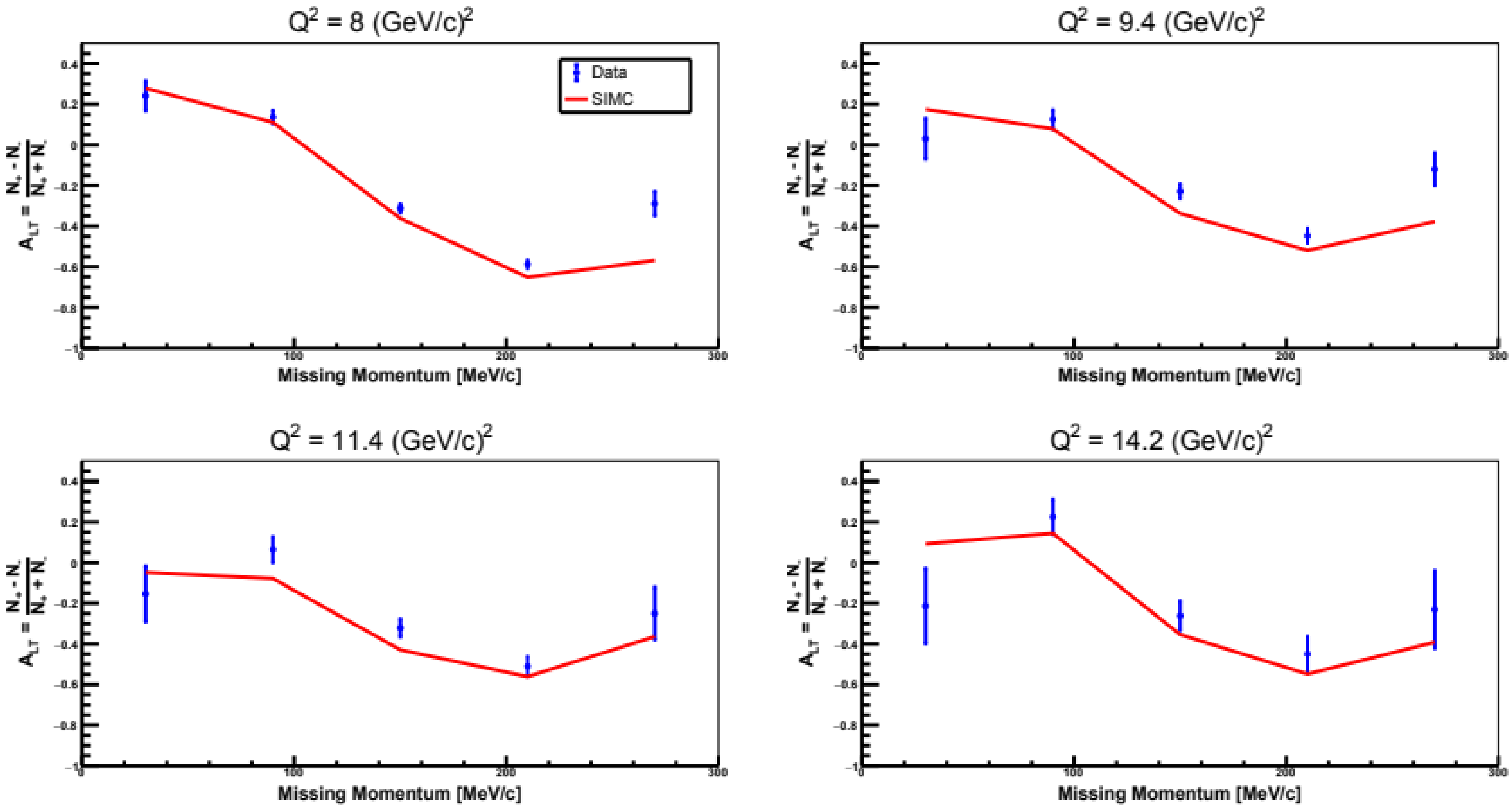
ASYMMETRY (A_{LT}) STUDY





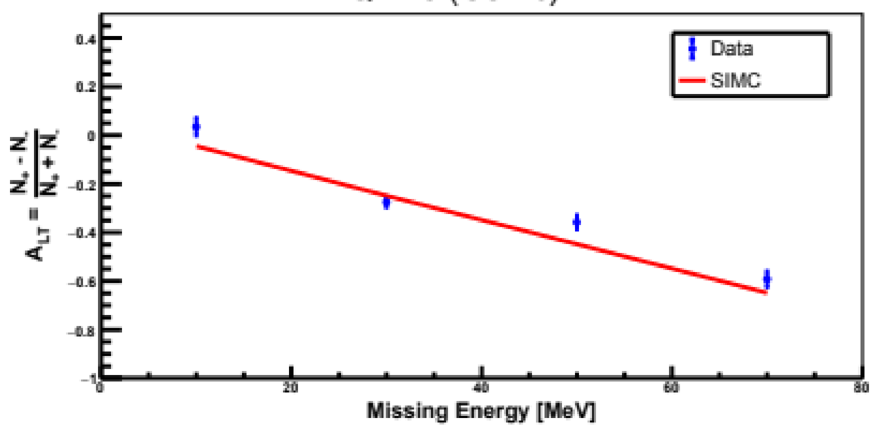
$$A_{LT} = \frac{N_+ - N_-}{N_+ + N_-}$$

ASYMMETRY VS MISSING MOMENTUM

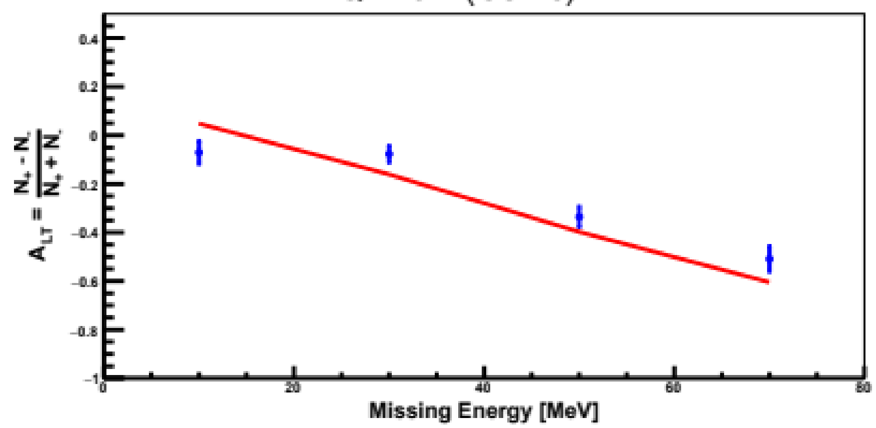


ASYMMETRY VS MISSING ENERGY

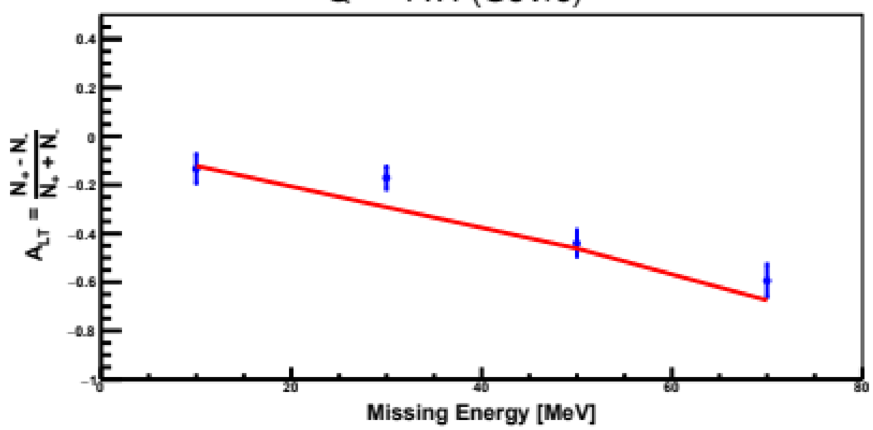
Q^2 = 8 (GeV/c)^2



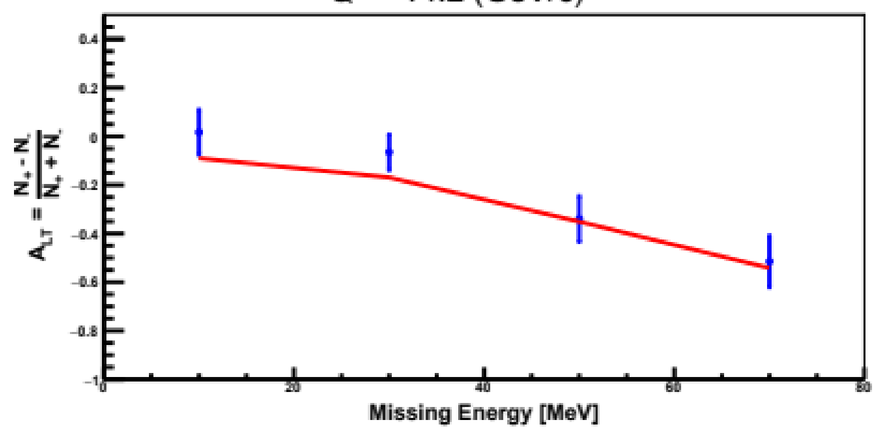
Q^2 = 9.4 (GeV/c)^2



Q^2 = 11.4 (GeV/c)^2

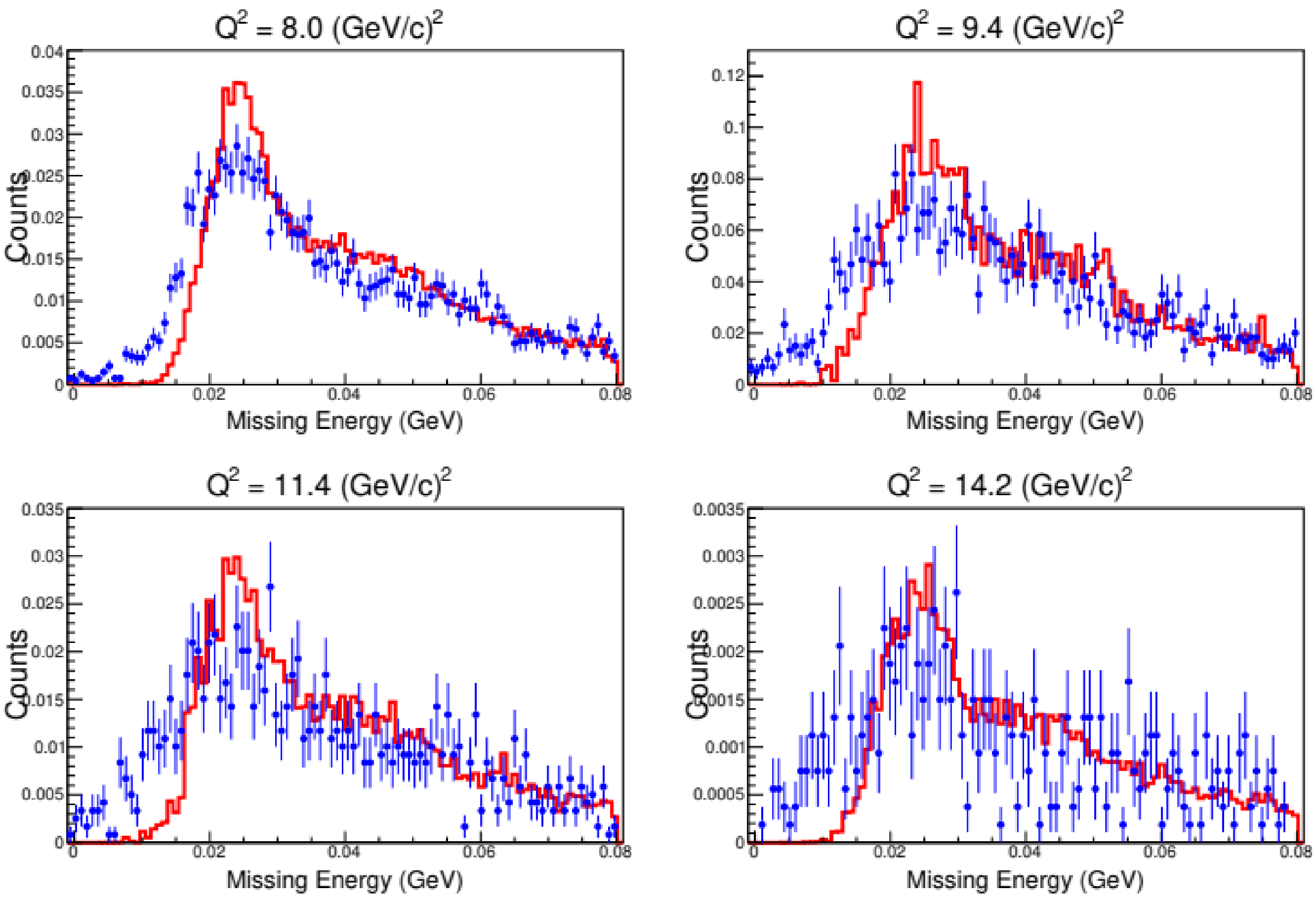


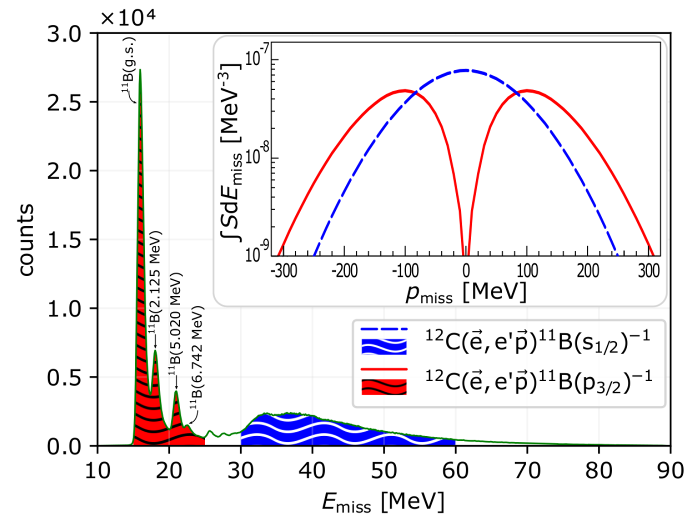
Q^2 = 14.2 (GeV/c)^2



SHELL STUDY

L. Frankfurt, M. Strikman, and M. Zhalov, Nuclear Physics A, vol. 515, no. 4, 1990, pp. 599–608.

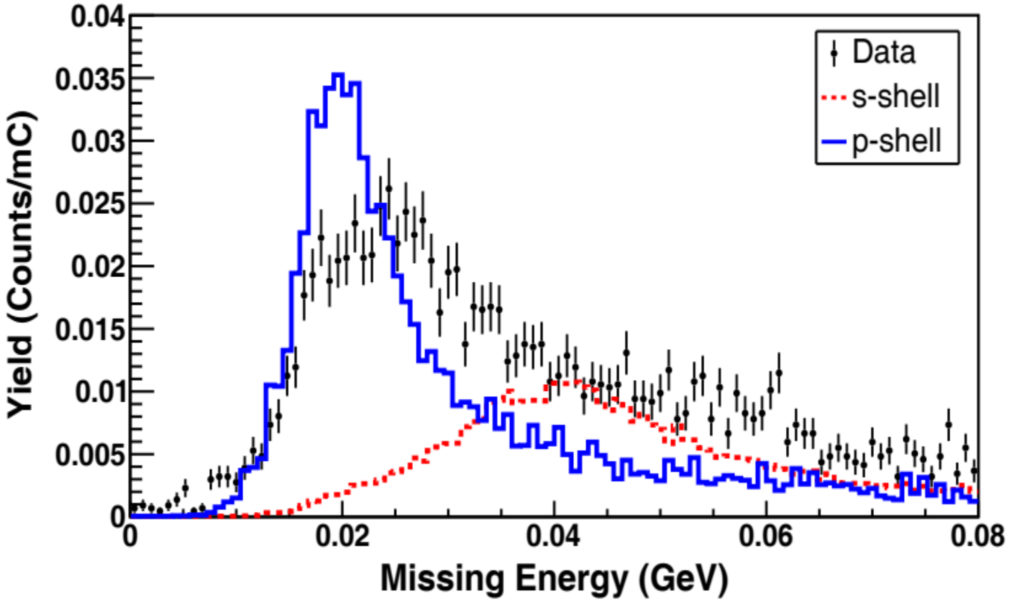


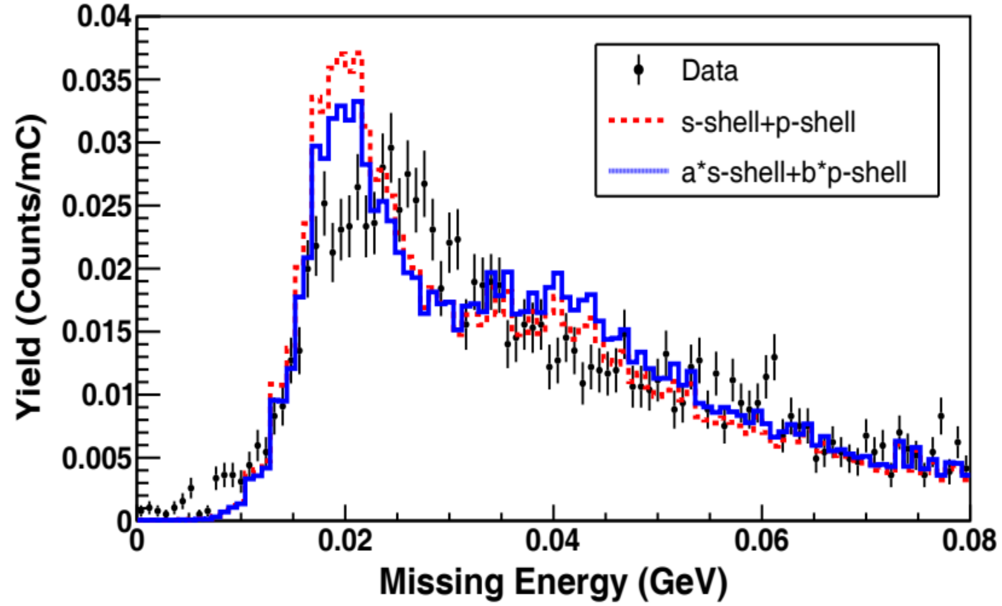


D. Izraeli et al.,Physics Letters B, vol. 781,Jun 2018, p. 95–98

Spectrometer resolution of ~0.1% ⟶ 2-5.5 MeV resolution

SHELL STUDY – CONTD.





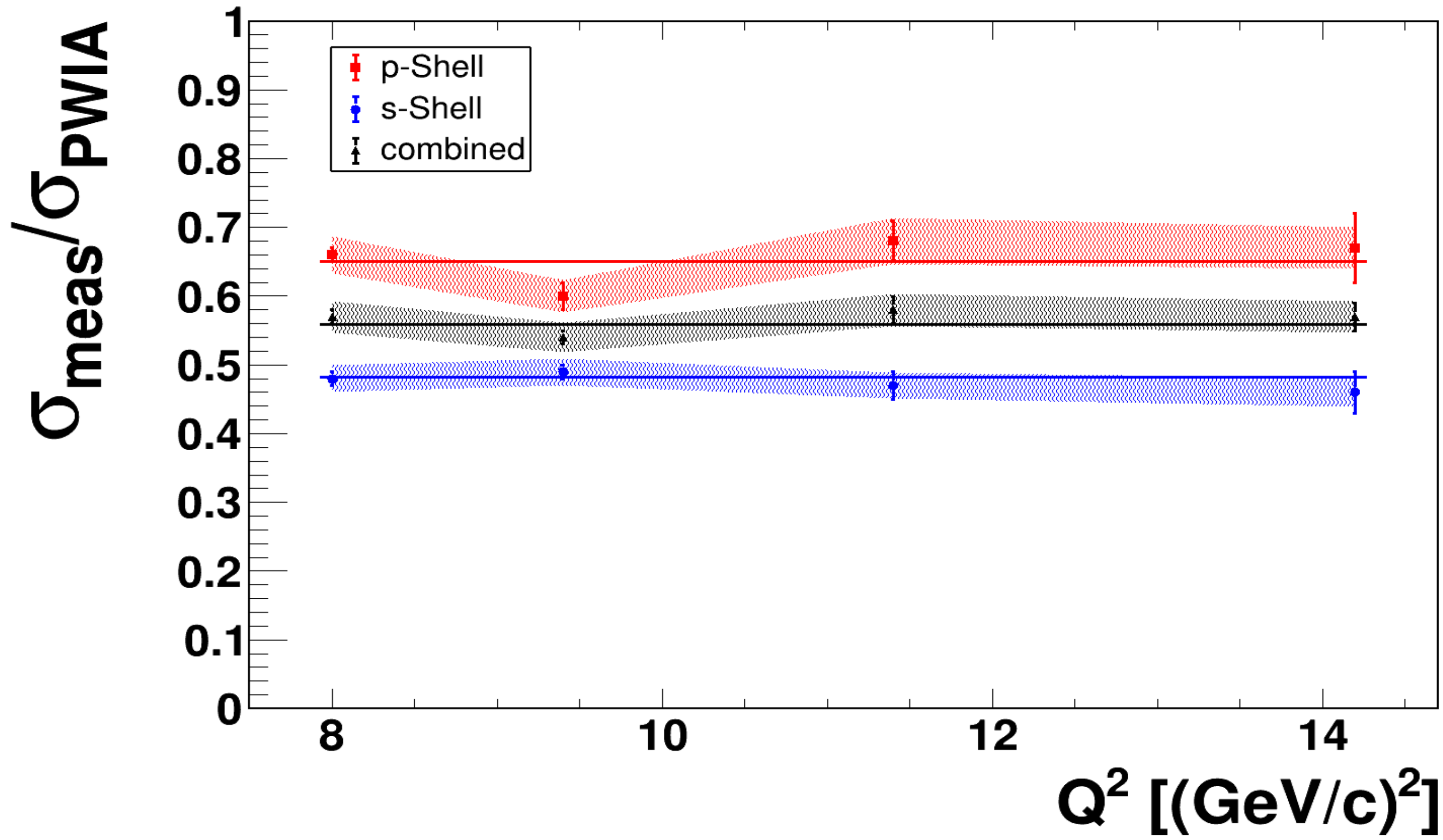
SIMC S-shell when P-shell is turned off

SIMC P-shell when S-shell is turned off

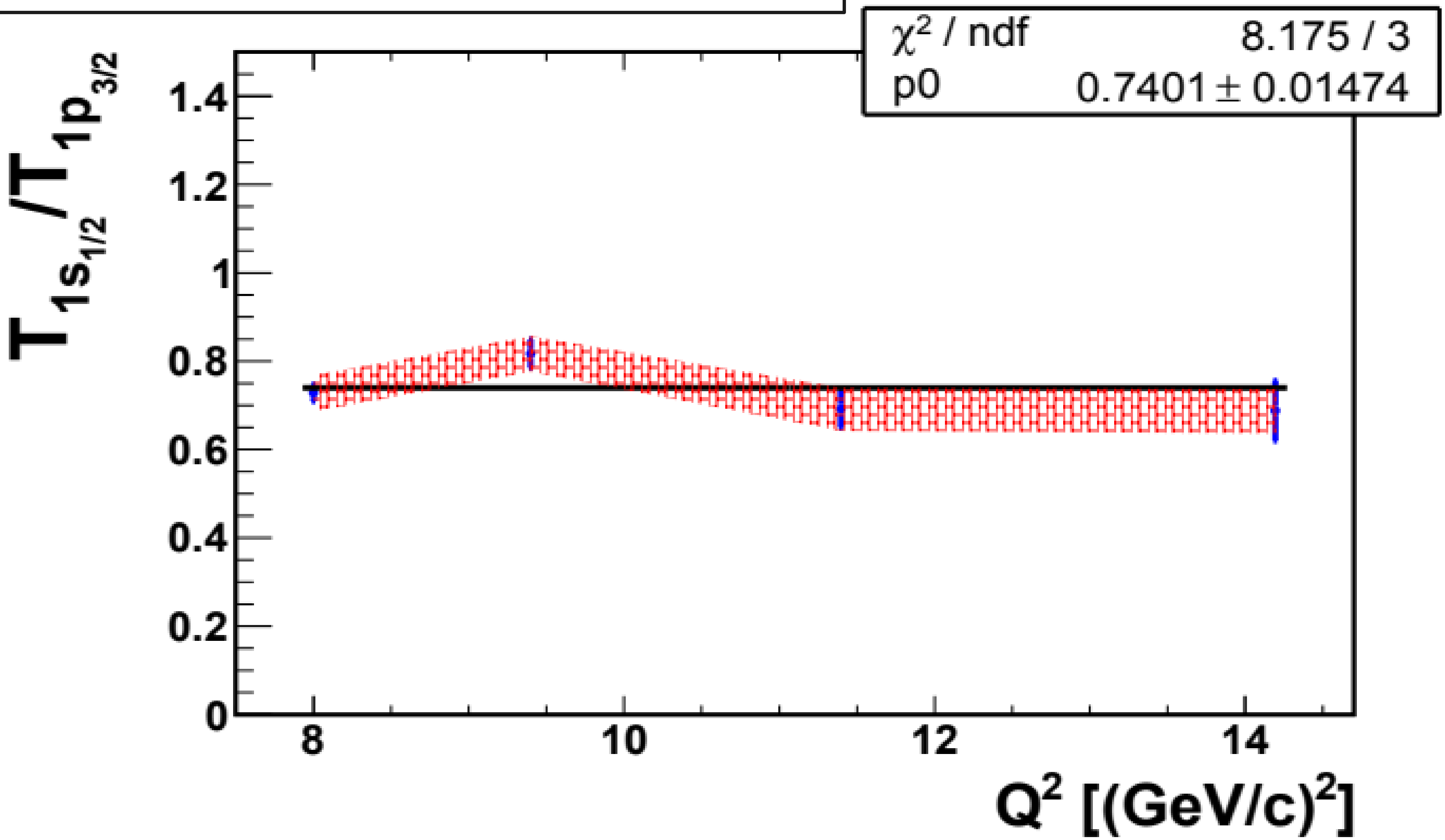
aS+bP = data, 2a+4b=6

SIMC S+P

SHELL STUDY – CONTD.



SHELL STUDY – CONTD.



SUMMARY

- **First experiment to take data using High Momentum Spectrometer and new Super High Momentum Spectrometer in 12 GeV era in Jefferson Lab.**
- **Hydrogen normalization result agrees with world's ep elastic scattering data confirming that Hall C apparatuses are well-understood and well calibrated, and Monte Carlo Simulation is a good simulation of elastic scattering.**
- **Our results DO NOT SHOW the onset of Color transparency in protons up to 14.2 $(GeV/c)^2$, covering all kinematics of previous BNL results (proton momentum, Q^2).**
- **An article has been published in Physical Review Letters (D. Bhetuwal et al., Phys. Rev. Lett., 126(8), 082301 (2021).).**
- **A long paper is being finalized to send to Collaboration for review and then to Physical Review C.**
- **Future experiments will measure CT effects with different reaction mechanisms and precision.**

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Thanks to the Hall-C Collaborators!

U.S. DEPARTMENT OF ENERGY | Office of Science

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