LOI to PAC 50:

Color Transparency in Dirty Kinematics

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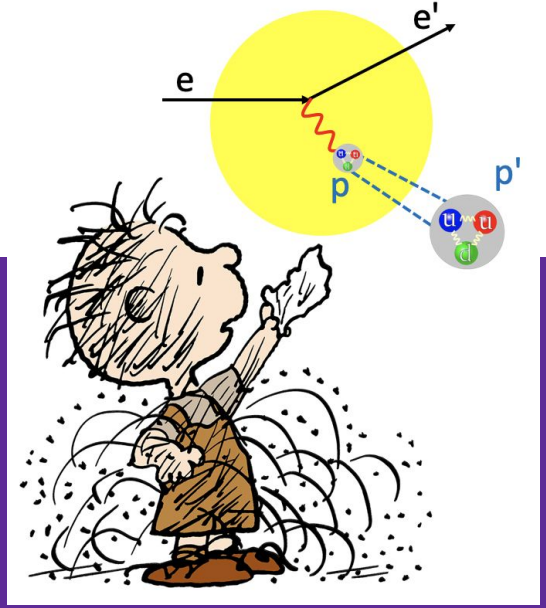
JLab Hall A/C Summer Meeting
06, 2022



Color Transparency

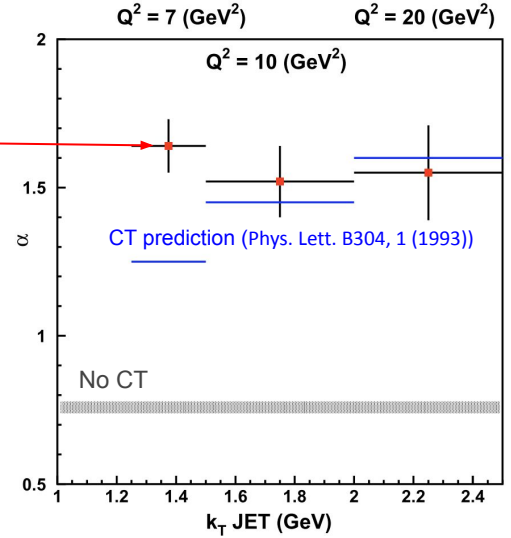
pQCD: small size color singlet (quarks and gluons) will have suppressed interaction with hadrons (color coherence) ⇒ suppression of initial/final state interaction in nuclear QE scattering (color transparency)

Observed in HEP:

- Pion dissociation
- Photoproduction of J/psi
- Vector meson production

FermiLab E791: π+A→ 2 jets + A (A=C, Pt)
Aitala et al., PRL 86, 4773 (2001)

Strong increase of cross section wrt A: $\sigma \propto A^{\alpha}$



CT at Intermediate Energy

- Search for Point-like configuration (PLC)
- **Nuclear transparency T(Q^2)** = measured xsection / PWIA

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

(σ_A: nuclear cross section; σ_N: free nucleon cross section)

- contraction/expansion v.s. CT
- **Coherence length l_c :** max longitudinal distance before completely losing coherence, determined by the minimal characteristic internal excitation energies of the hadron h.

$$l_c = \frac{2p_h}{\Delta M_h^2} \qquad \Delta M_h^2 = m_{inter}^2 - M_h^2$$

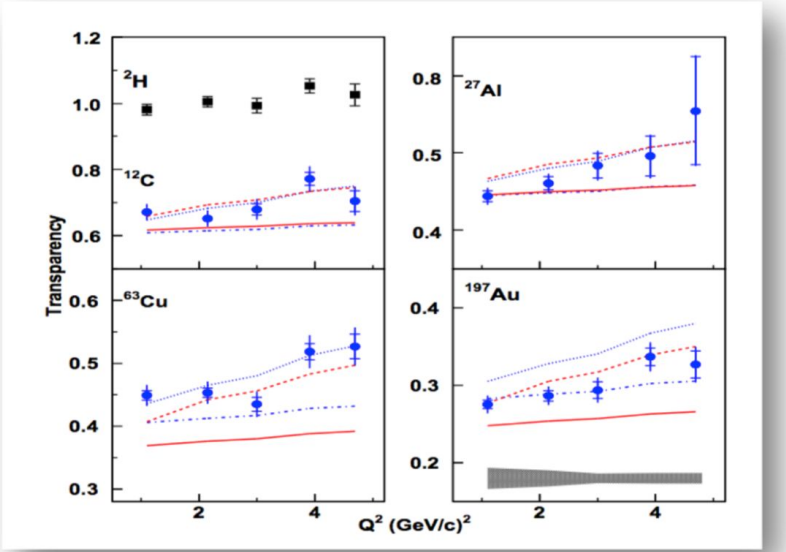
l_c increases with hadron momentum(Q2), and decreases with ΔM^2

CT at Intermediate Energy: mesons

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

Hall C E01-107 pion electro-production

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

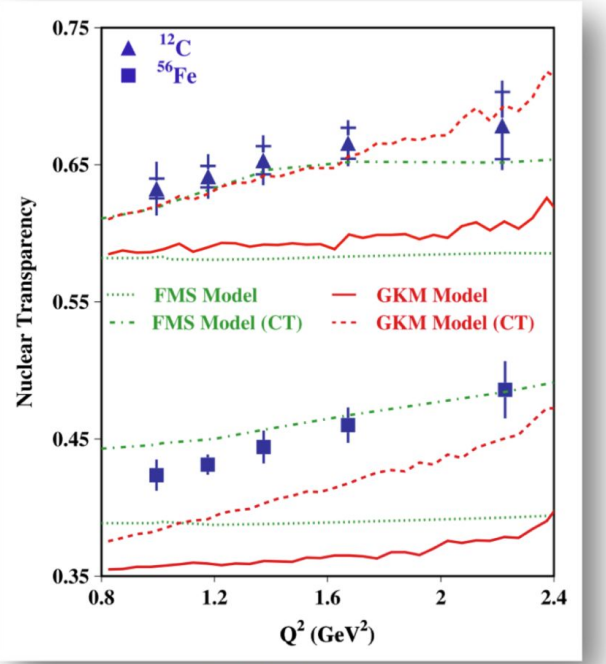


B.Clasie *et al.* PRL 99:242502 (2007)

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

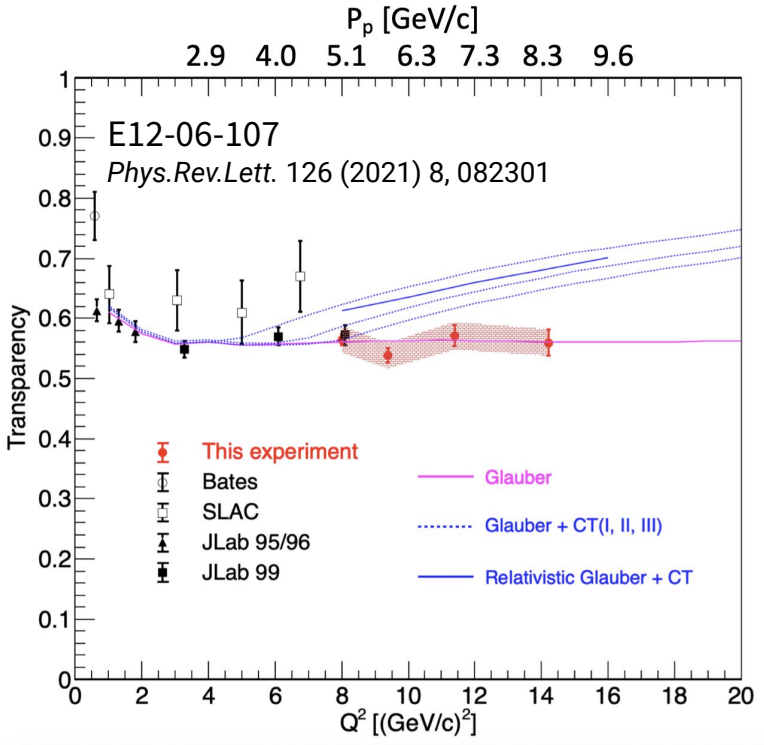
CLAS E02-110 rho electro-production

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



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

CT at Intermediate Energy: Baryons



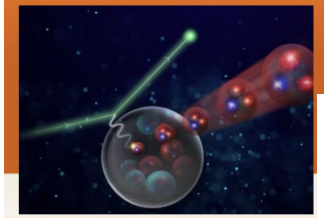
- NO sign of CT up to Q2 = 14.2 GeV2
- Updated ΔM^2 value:
  - Old prediction from theories and high energy data:

    0.7 - 1.1 GeV (CTI,II,III)
  - New fit to describe E12-06-107 results:

    $\Delta M^2 >= 2$ GeV

    (Calculation by Wim Cosyn and Misak Sargsian)

Next step:
higher Q2, larger signal

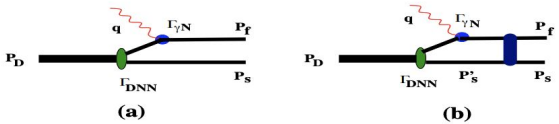


The Future of Color Transparency and Hadronization Studies at Jefferson Lab and Beyond

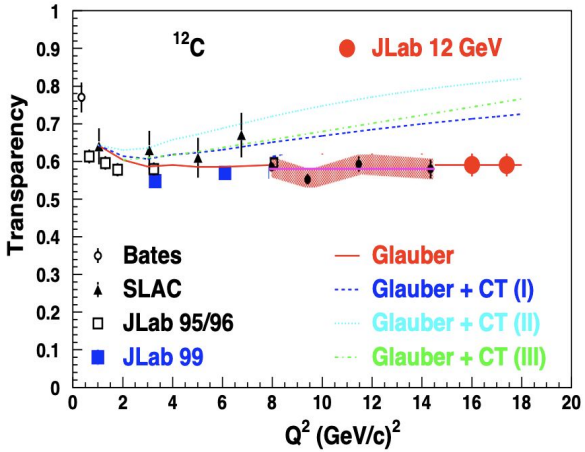
7-8 June 2021
Online
US/Eastern timezone

https://indico.jlab.org/event/437/contributions/8508/

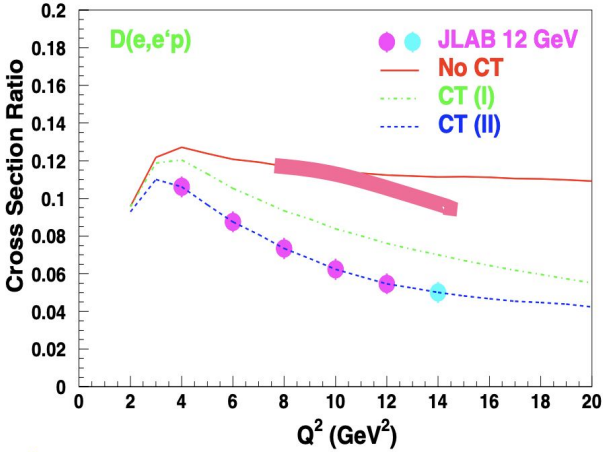
$e + d \rightarrow e' + p + n$ CT in Double Scattering



MS et al, Hadrons in the Nuclear Medium, J.Phys. G 2003



$$R = \frac{\sigma(p_r = 400\,MeV/c)}{\sigma(p_r = 200\,MeV/c)}$$



$$\sigma_{tot}(l, Q^2) = \sigma_{tot}\left\{\left[\left(\frac{l}{l_h}\right)^n + \frac{\langle r_t(Q^2)^2\rangle}{\langle r_t^2\rangle}\left(1 - \left(\frac{l}{l_h}\right)^n\right)\right]\Theta(l_h - l) + \Theta(l - l_h)\right\},$$

$$n = \frac{1}{2}$$

$$l_h = 2p_f/\Delta\,M^2 \qquad \Delta\,M^2 = 1.1\ GeV^2$$

D(e,e'p)

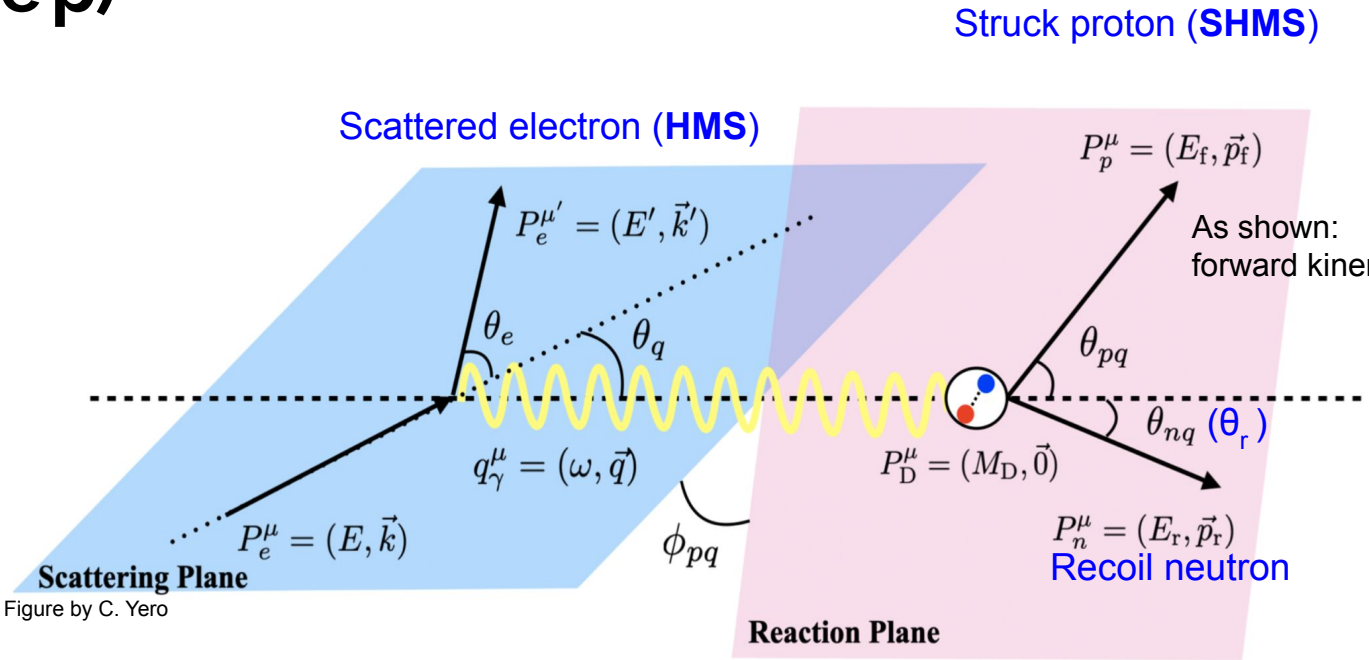


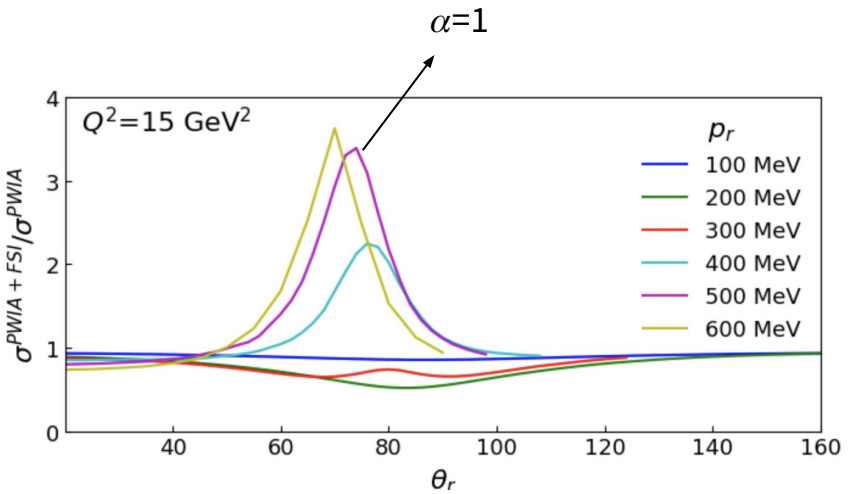
Figure by C. Yero

As shown:
forward kinematics, positive Pmiss

FSI v.s. CT

Choose perpendicular kinematics to maximize FSI:

$$\alpha = (E_n - p_n \cos\theta_{\gamma n})/m_n \rightarrow 1$$



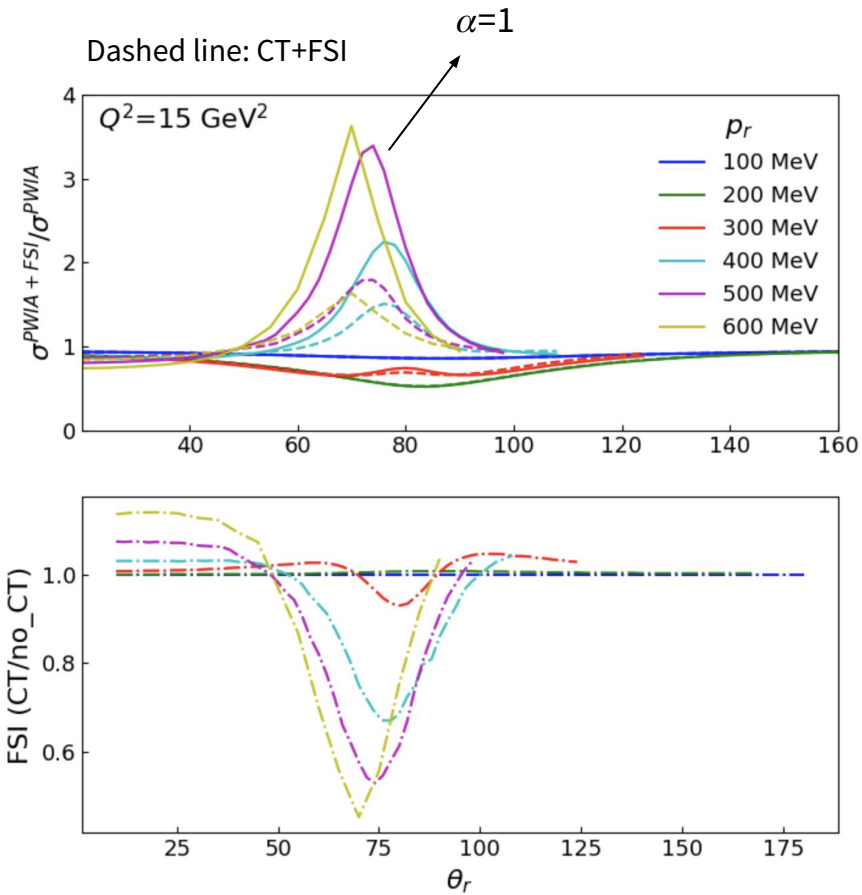
FSI v.s. CT

Choose perpendicular kinematics to maximize FSI:

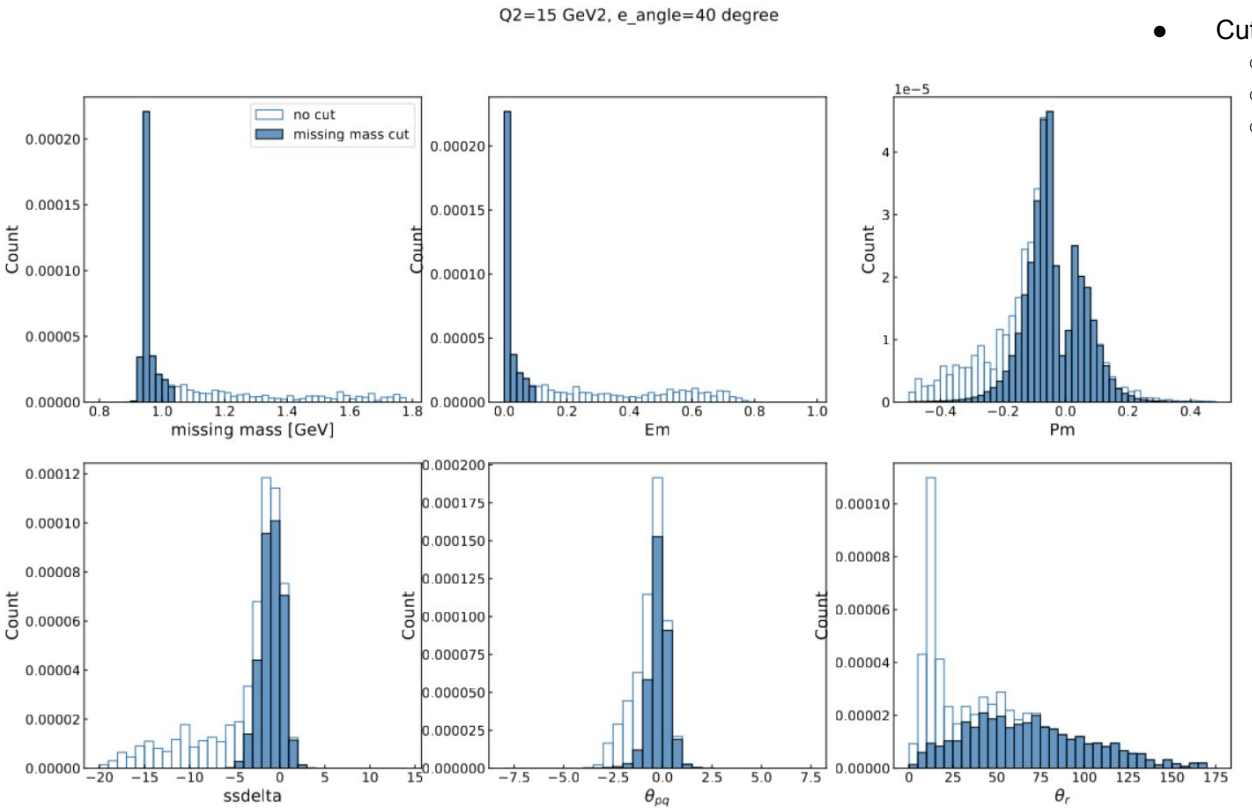
$$\alpha = (E_n - p_n \cos\theta_{\gamma n})/m_n \rightarrow 1$$

Double ratio:

$$R(Q^2) = \frac{\sigma(p_{miss} large; Q^2)\downarrow}{\sigma(p_{miss} small; Q^2)\uparrow}$$



SIMC with radiative effect



- Simulation weighted by
  - xsection (Av18, PWIA)
  - FSI factor (from Misak's code)
- Cuts:
  - -10<hsdelta<10
  - theta_rq > 40 degree
  - (missing mass - 0.9383)<0.1

Rate Estimation

Kinematics	Q^2	P_e (GeV/c)	θ_e (deg)	P_p (GeV/c)	θ_p (deg)
1	8.046	6.713	19.000	5.121	27.380
2	9.958	5.694	23.000	6.154	22.972
3	11.941	4.637	28.000	7.222	19.073
4	14.026	3.525	35.000	8.341	15.363
5	15.127	2.939	40.000	8.931	13.461

Kinematics		P_m	θ_r	Q^2	Rate/hour	PAC days
1	a	0.08	79.06	7.49	5690.81	1.5
	b	0.41	73.33	7.88	149.04	
2	a	0.08	77.15	9.52	1536.20	3.0
	b	0.41	74.44	9.77	36.47	
3	a	0.08	77.40	11.62	413.28	5.7
	b	0.41	75.46	11.70	9.16	
4	a	0.09	77.28	13.76	93.63	25.1
	b	0.40	75.95	13.74	2.07	
5	a	0.09	78.73	14.94	36.63	55.9
	b	0.40	75.72	14.83	0.93	

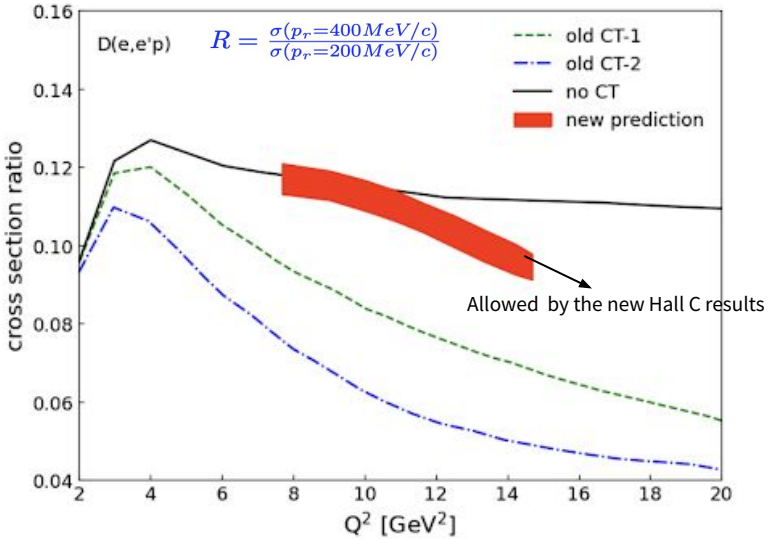
- Each kinematics setting can cover BOTH high and low Pmiss.
  - Kin a: 0.05<Pm<0.15
  - Kin b: 0.30<Pm<0.60
- Goal: 1000 events at large Q2 setting
- Cut on missing mass rejected most of radiative tails and significantly reduced high Pmiss event counts.
- 11 GeV beam
- Assumed luminosity = 80uA * 25cm cell * 0.8 efficiency factor

  ⇒ high beam power ONLY possible after ESR upgrade (according to D. Meekins)

95 PAC days 😱

Improvements: sensitivity check

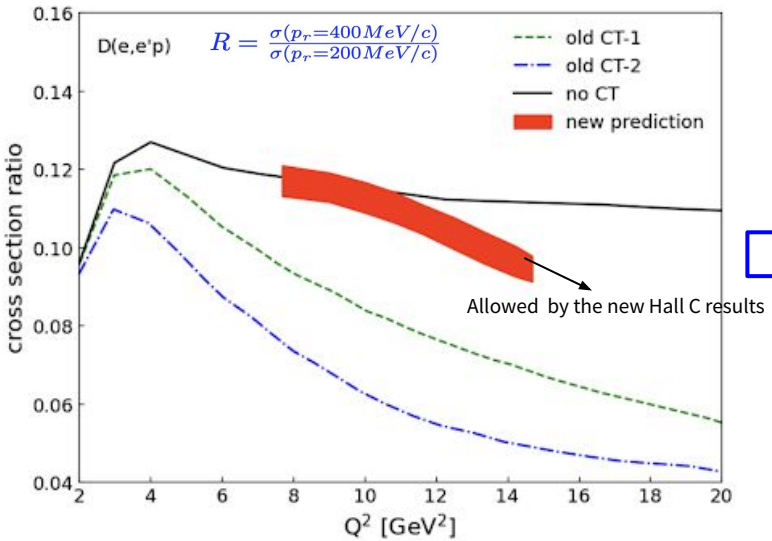
Cross section model with
factorization assumption



Calculations by W. Cosyn and M. Sargsian

Improvements: sensitivity check

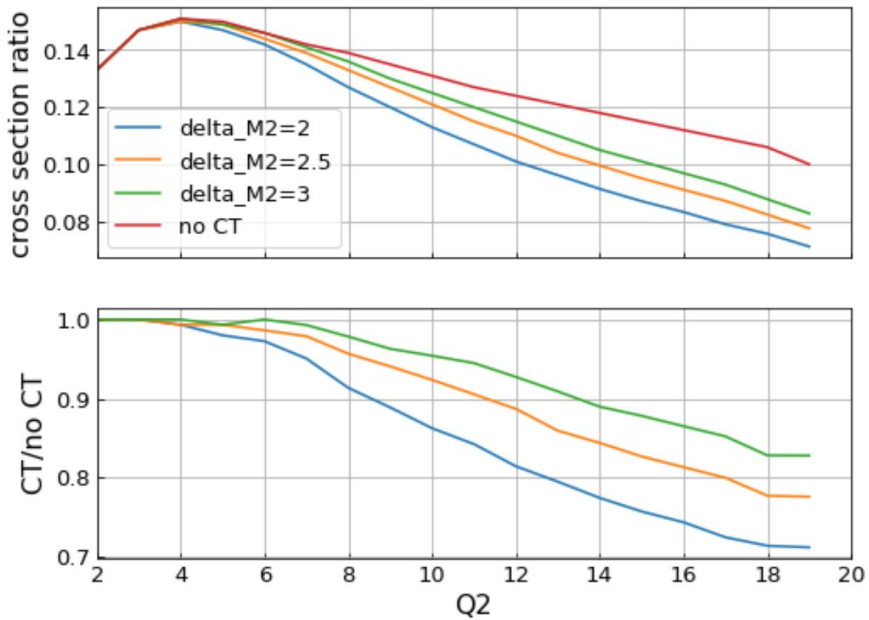
Cross section model with factorization assumption



Calculations by W. Cosyn and M. Sargsian

With new Hall C D2 data at large Pmiss

Phys.Rev.Lett. 125 (2020) 26, 262501



Improvements: sensitivity check

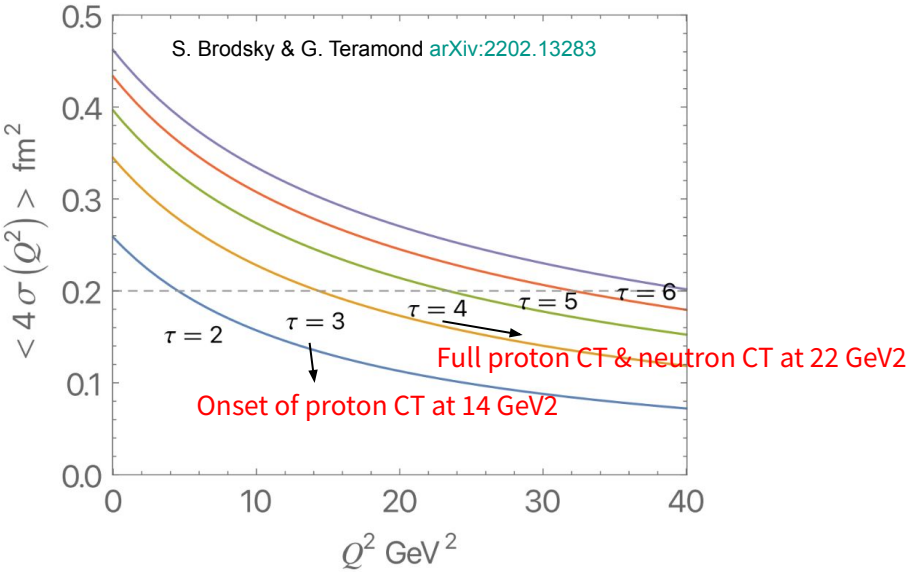


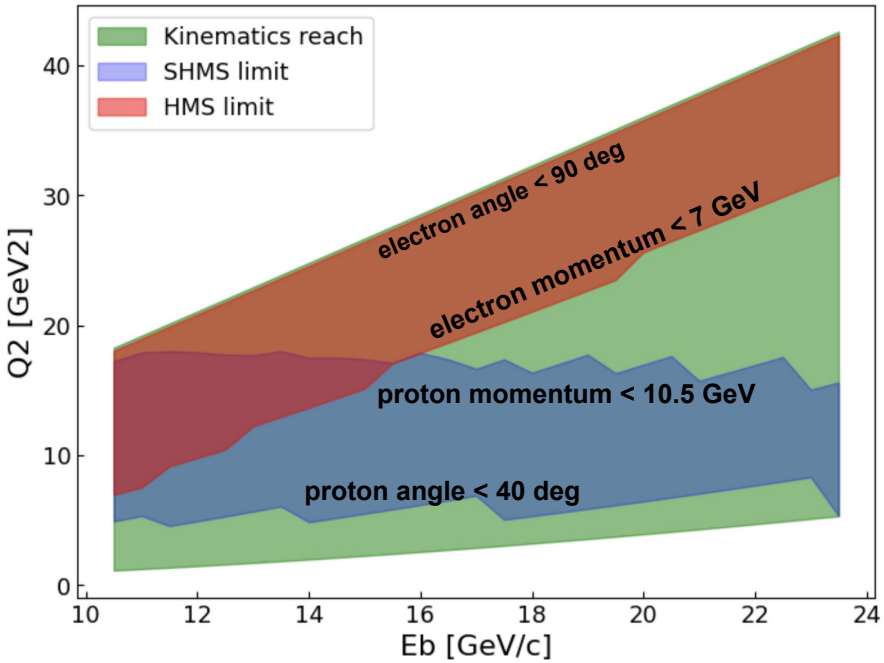
FIG. 2. The transverse impact area $\langle 4\,\sigma\,(t)\rangle$ as a function of $Q^2 = -t$ and the number of constituents τ implies a significant delay in the onset of color transparency at intermediate energies for $\tau > 2$. The dashed line indicates the characteristic transverse size required for the onset of color transparency.

Improvements: kinematics optimization

- Higher beam energy ?
  - 30% higher rates with 11.5 GeV beam
  - Q2 range will not get better with higher Ebeam due to spectrometer limits

- Use detectors with larger acceptance?

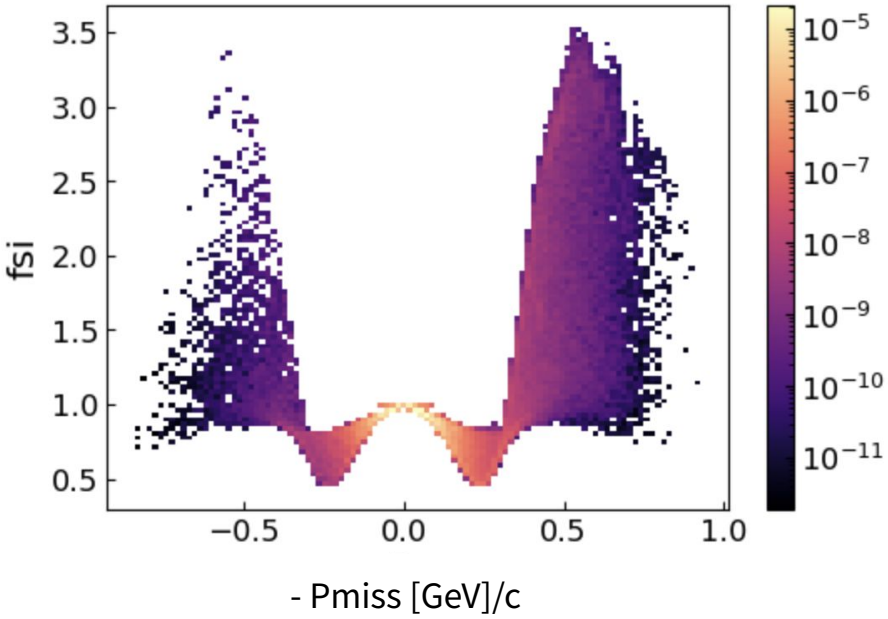
More suggestions are welcome!



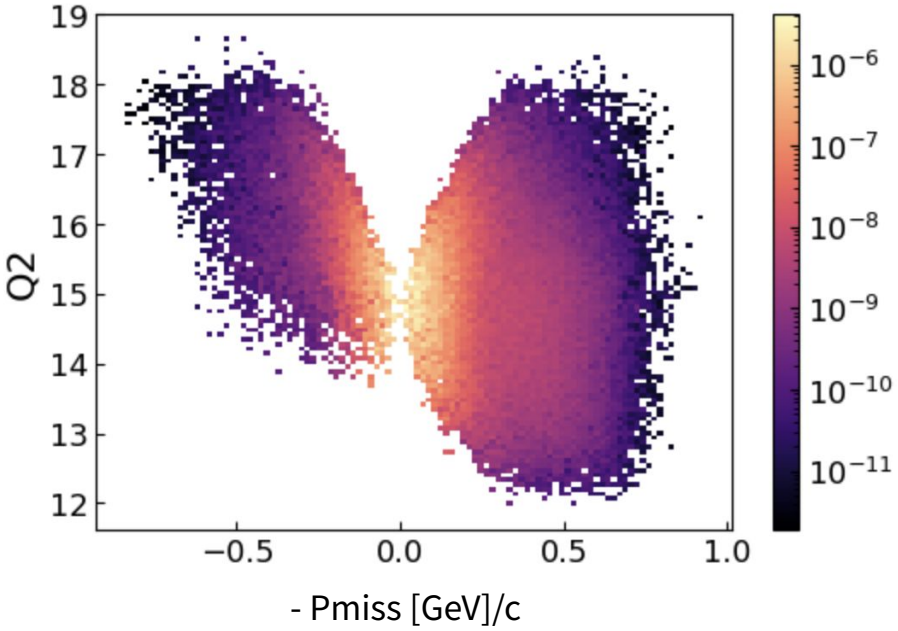
THANK YOU!

Phase Space

Q2=15, e_angle=40. Histogram weighted by xsection and FSI ratio from Misak's calculation

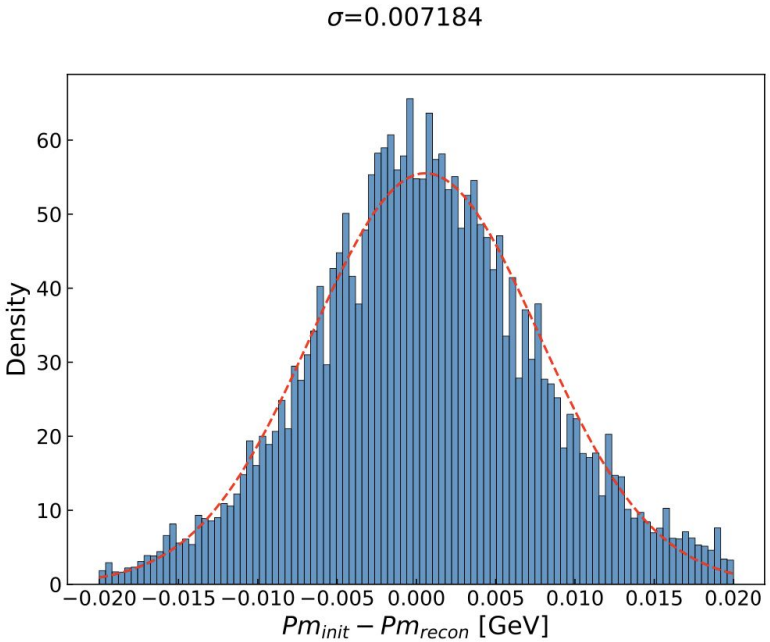


- Pmiss [GeV]/c



- Pmiss [GeV]/c

1.


σ=0.007184
Density
0
10
20
30
40
50
60
−0.020
−0.015
−0.010
−0.005
0.000
0.005
0.010
0.015
0.020
$Pm_{init} - Pm_{recon}$ [GeV]