Coulomb Corrections in SIDIS

Part 1 of a new proposal (see next talk)

March 25, 2025

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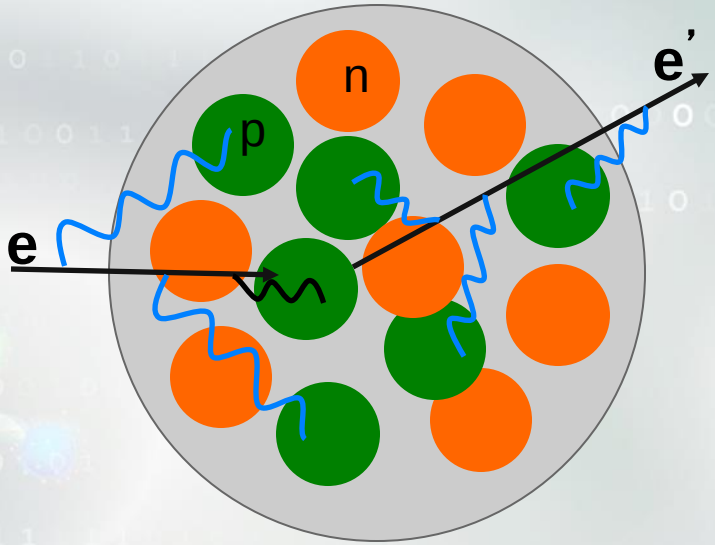
A new proposal for PAC53

- Physics topics:
  - Two photon exchange (TPE) in inclusive DIS
  - TPE in SIDIS
  - Coulomb Corrections (CC) in SIDIS
- Plan to run in Hall C
- Kinematics will largely mirror those of the upcoming E12-06-104 (R-SIDIS)
- Proton target will be used for TPE measurements ← *See next talk (M. Nycz)*
- Deuterium, Carbon, and Copper will be used for CC measurements

Coulomb Distortion in Heavy Nuclei



Electrons scattering from nuclei can be accelerated/decelerated in the Coulomb field of the nucleus

→ This effect is in general **NOT** included in most radiative corrections procedures

→ *Coulomb Corrections are perhaps more appropriately described in terms of multi-photon exchange, but Coulomb Corrections provide convenient shorthand*

- Well-known effect in QE scattering - relevant particularly for Coulomb sum rule
- Can be calculated in QE using DWBA → experimentalists use Effective Momentum Approximation (EMA) to apply corrections to data
- Comparisons of EMA with detailed DWBA calculations resulted in "improved EMA"

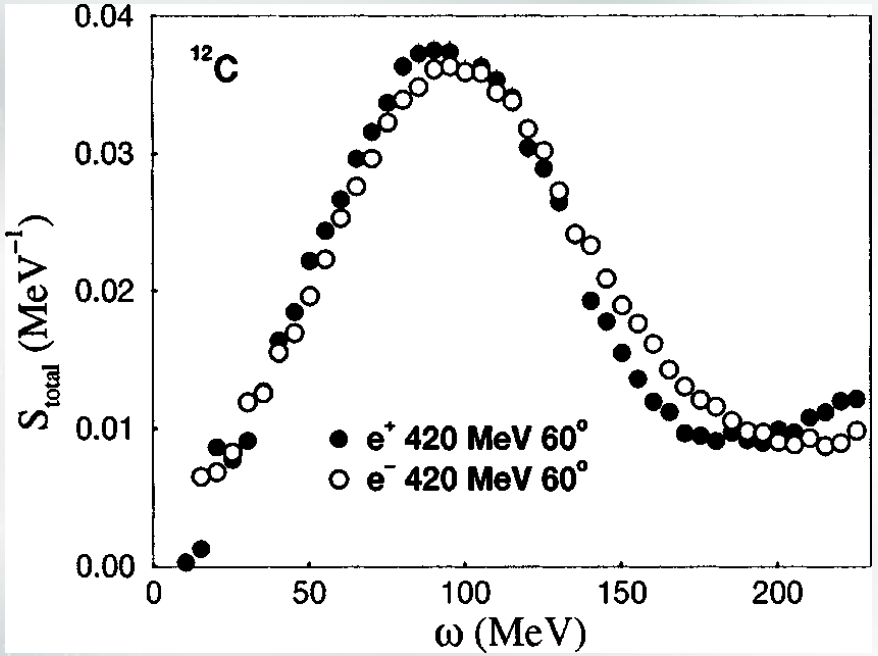
$$E_e \rightarrow E_e + V_0 \qquad E_e' \rightarrow E_e' + V_0 \quad \text{with "focusing factor"} \quad F^2 = (1+V_0/E_e)^2$$

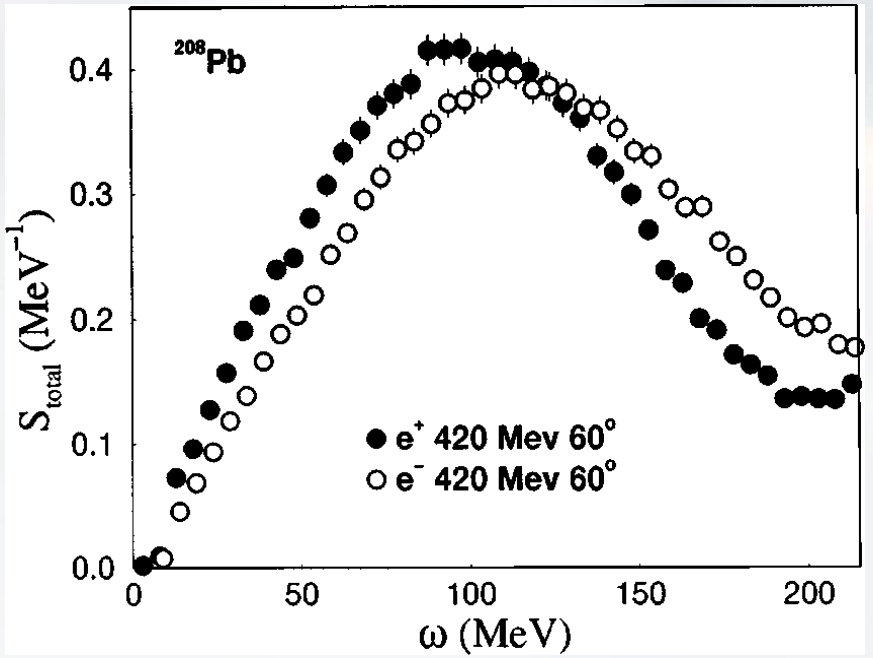
$$V_0 \rightarrow (0.7\text{-}0.8)V_0, \quad V_0 = 3a(Z-1)/2R$$

Slide from Dave Gaskell

[Aste et al, Nucl. Phys. A, 806:191-215 (2008) Eur.Phys.J.A26:167-178,2005, Europhys.Lett.67:753-759,2004]

Electron-Positron Comparisons in QE Scattering





Gueye *et al.*, PRC60, 044308 (1999)

- Comparisons of electron and positron scattering have been performed in QE scattering
- Were used to fit V_0 in context of EMA
- V_0 = 10 MeV for Fe, 20 MeV for Fe

Slide from Dave Gaskell

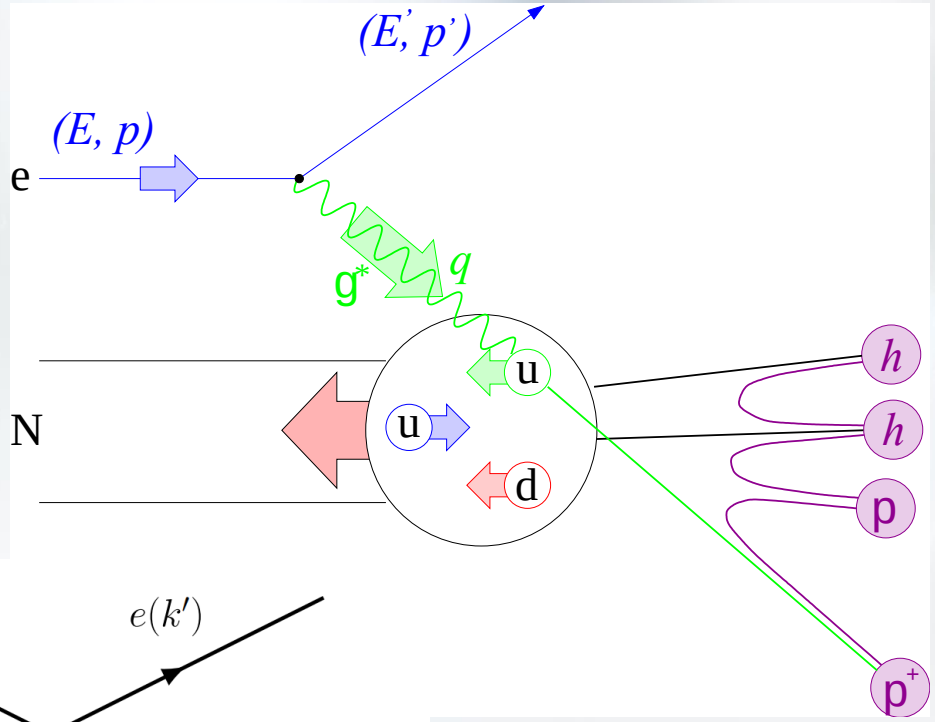
Coulomb Corrections in Inelastic Scattering

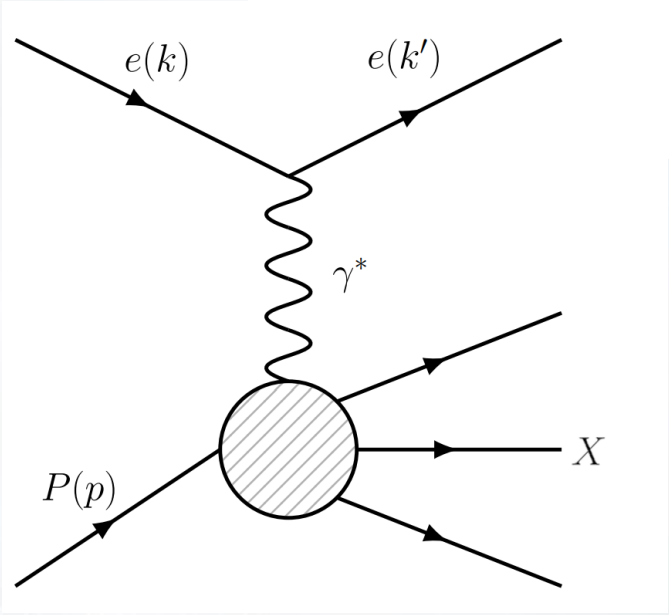
- E. Calva-Tellez and D.R. Yennie, Phys. Rev. D 20, 105 (1979)
  - Perturbative expansion in powers of strength of Coulomb field
  - Effect of order → $-\frac{Z\alpha}{12}\frac{(Q^2)^2}{\nu^2}\frac{(E_e+E'_e)}{E_eE'_e} < r >$
  - "For any reasonable kinematics, this is completely negligible" → plugging in JLab/SLAC kinematics, this is not true!
- B. Kopeliovich et al., Eur. Phys. J. A 11, 345 (2001)
  - Estimates non-zero effect using Eikonal approximation → applies estimates to vector meson production, not DIS
- O. Nachtmann, Nucl. Phys. B 18, 112 (1970)
  - Coulomb Corrections for neutrino reactions
  - DWBA calculation that results in modifications to structure functions → "at most 5%" effects for energies > 1 GeV
  - Final state particle only, not directly applicable to electron/positron scattering

Slide from Dave Gaskell

DIS and SIDIS

- It is unclear if the EMA is applicable at DIS kinematics
  - This will be tested by E12+23-003!
- A natural extension of this question is if CCs in SIDIS are the same as DIS
  - DIS integrates over all hadronic final states
  - SIDIS selects for a subset of these for specific kinematics of a *piece* of the final state
- Does this selection impact CCs to the process?





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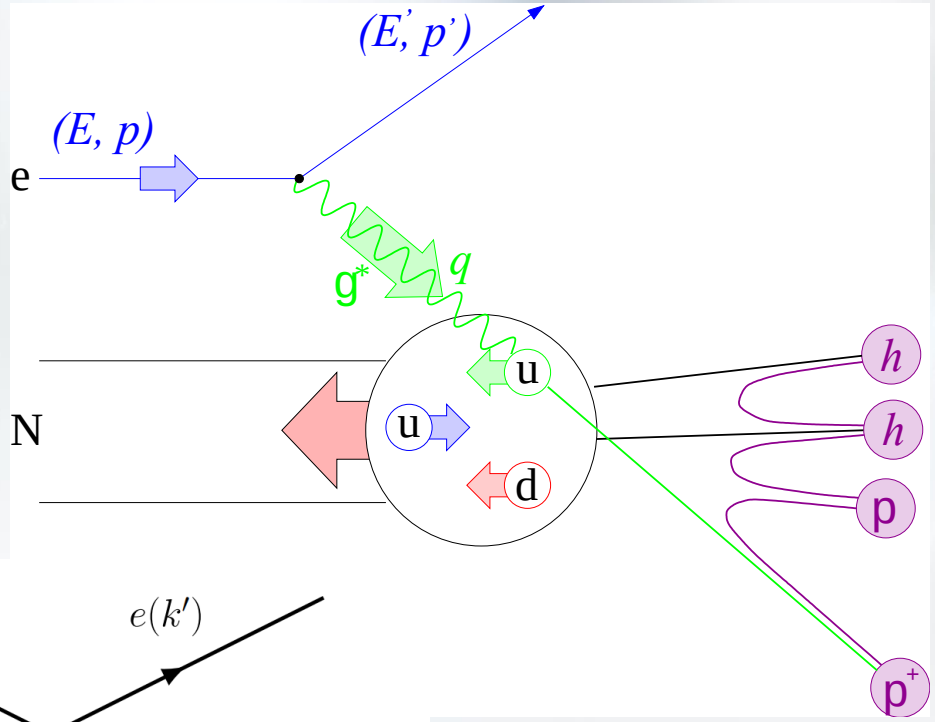
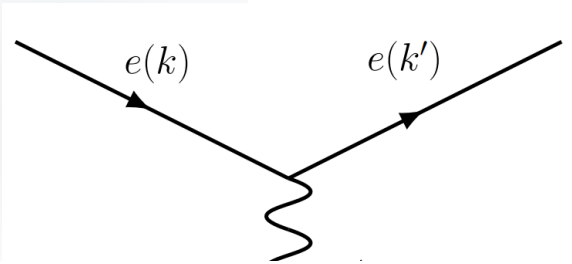
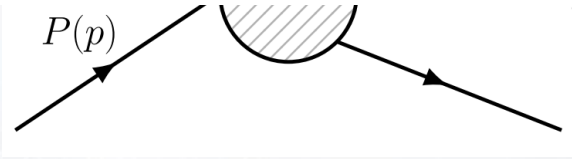


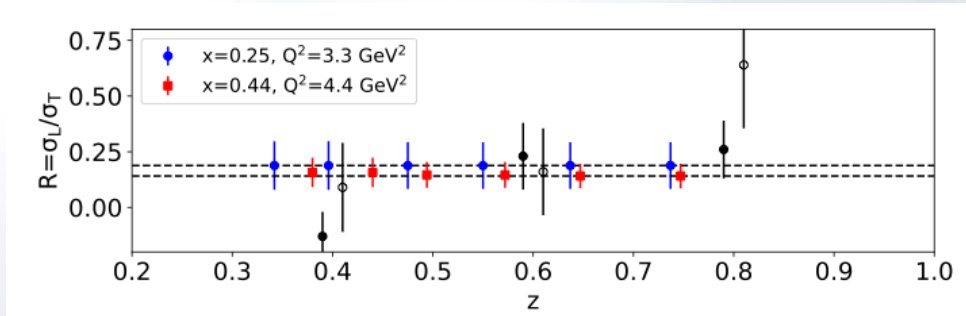


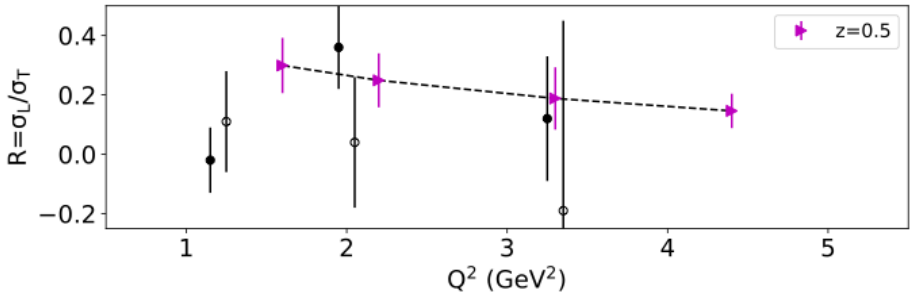


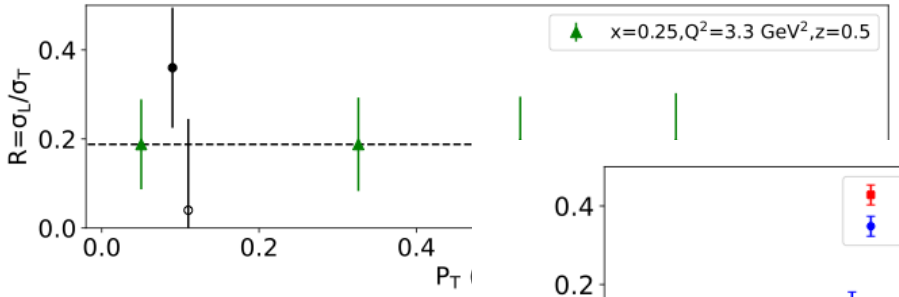
This is untested! The applicability of the EMA to SIDIS is an assumption that we can and should test!

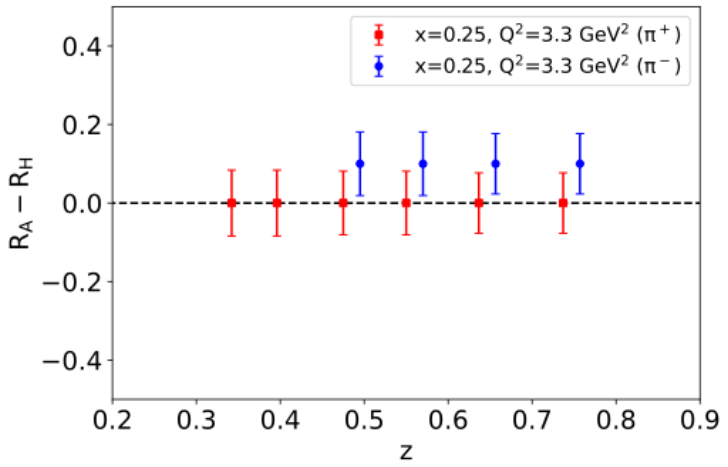
Impact on SIDIS Data

- E12-06-104 ***(this year!)*** will extract R_LT in SIDIS data!
  - Two-photon exchange, an ε-dependent effect, will clearly impact this
  - *See M. Nycz's talk immediately after this*
- E12-24-001 formed a run group to extract R_LT in *nuclear* SIDIS data
  - Exploratory study of if R_LT is the same in SIDIS as in DIS
  - Carbon and Copper targets
  - Unclear if Coulomb Corrections will be the same in DIS and SIDIS – *No Data!*
  - Coulomb Corrections are also an ε-dependent effect, will directly impact the results
- SIDIS is a key part of JLab program
  - Important to understand and constrain corrections







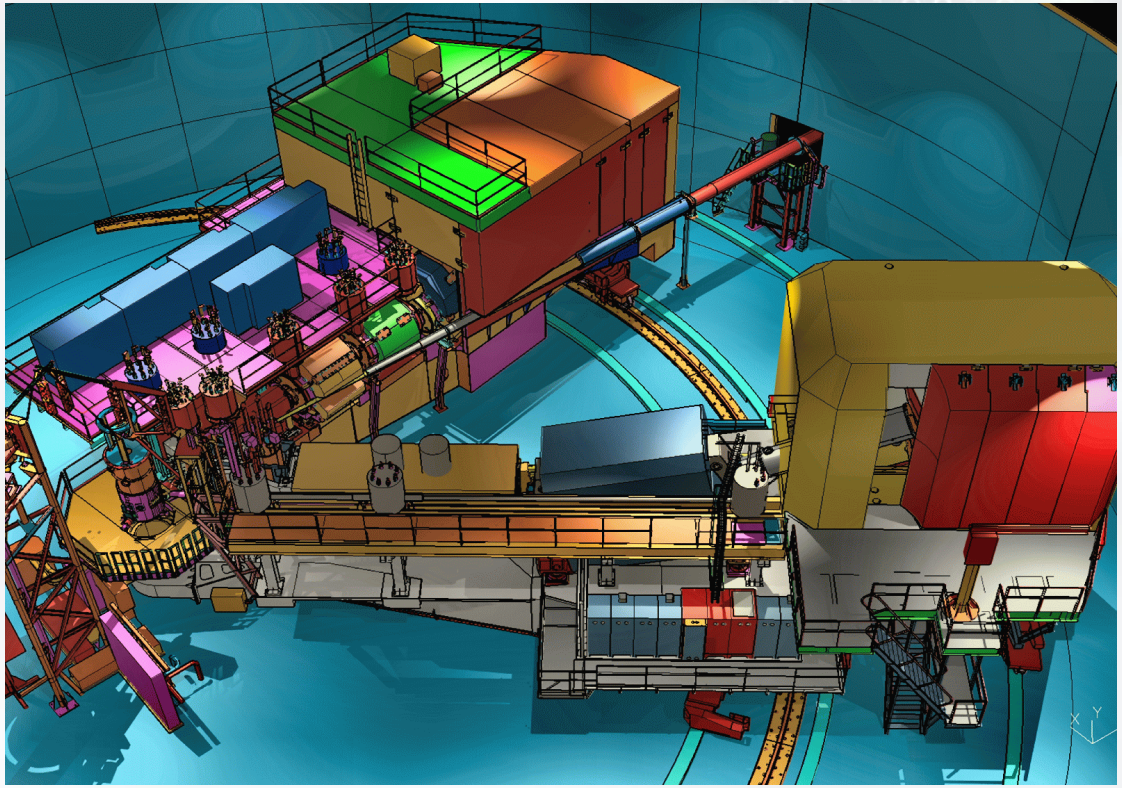


Accessing Coulomb Corrections

- Coulomb Corrections can be accessed in nuclei much like TPE by taking the ratio of electron and positron scattering
- In this case, nuclear instead of a proton target
- Ratios would be for positive
- Double ratios allow for heavily constraining time dependent systematics
- Carbon (Z=6) and Copper (Z=29) allow for constraining atomic number dependence
- As this is largely unconstrained, the kinematics include regions where the EMA predicts both large and small CCs to assess its validity

JLab Hall C

- High Momentum Spectrometer for electrons
- Super High Momentum Spectrometer for pions
- Well understood spectrometers with control of point-to-point systematics
- Proven success with ε-dependent measurements (LT-separations)



Coulomb Corrections in SIDIS

Estimated Coulomb correction for Copper target (ΔE=10.2 MeV)

x=0.44, Q^2=4.4 GeV^2, z=0.5

E_b (GeV)	E' (GeV)	e	CC	Time (hours)
6.5	1.20	0.28	2.63%	839.8
8.6	3.30	0.62	0.97%	68.2
10.7	5.40	0.77	0.62%	18.3

x=0.31, Q^2=3.1 GeV^2, z=0.5

E_b (GeV)	E' (GeV)	e	CC	Time (hours)
6.5	1.1	0.30	1.44%	252.6
8.6	3.30	0.63	0.48%	21.8
10.7	5.40	0.78	0.27%	5.8

x=0.25, Q^2=3.3 GeV^2, z=0.5

E_b (GeV)	E' (GeV)	e	CC	Time (hours)
8.6	1.60	0.33	0.81%	88.5
10.7	3.70	0.60	0.23%	11.5

Applying same prescription (EMA) for Coulomb Corrections yields similar effects as for measurements of R in inclusive DIS

→Does EMA make sense in this significantly more complicated reaction?

→What about outgoing pion? (not addressed here)

Slide from Dave Gaskell

Testing Coulomb Corrections in SIDIS with Positrons

Can test the impact of CC in SIDIS in the same way as for inclusive DIS

→ Match kinematics with E12-24-001 (Nuclear Dependence of R-SIDIS)

→ Measure epsilon-dependence of A/H ratios

→ can compare to earlier electron data with (minimal) normalization concerns

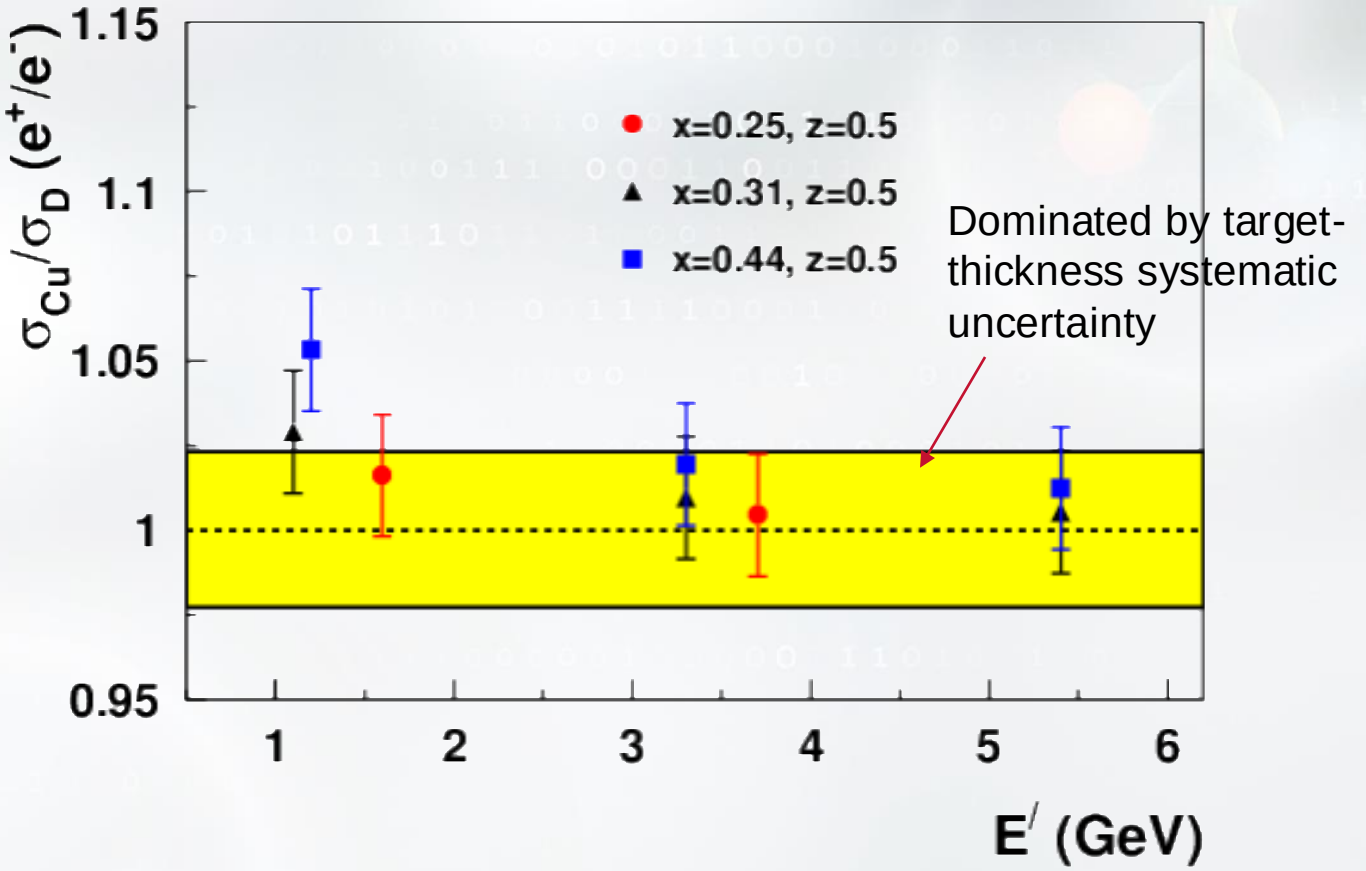
→ Should be able to achieve similar precision as inclusive measurements – but run times will be longer

Preliminary study indicates some sensitivity at low E' for x=0.2 (assuming validity of EMA)

Positron run time at x=0.25: 4.2 days

x=0.31: 11.7 days

x=0.44: 38.6 days ← dominated by low epsilon running



Assumes combining data from 2 different run periods

Slide from Dave Gaskell

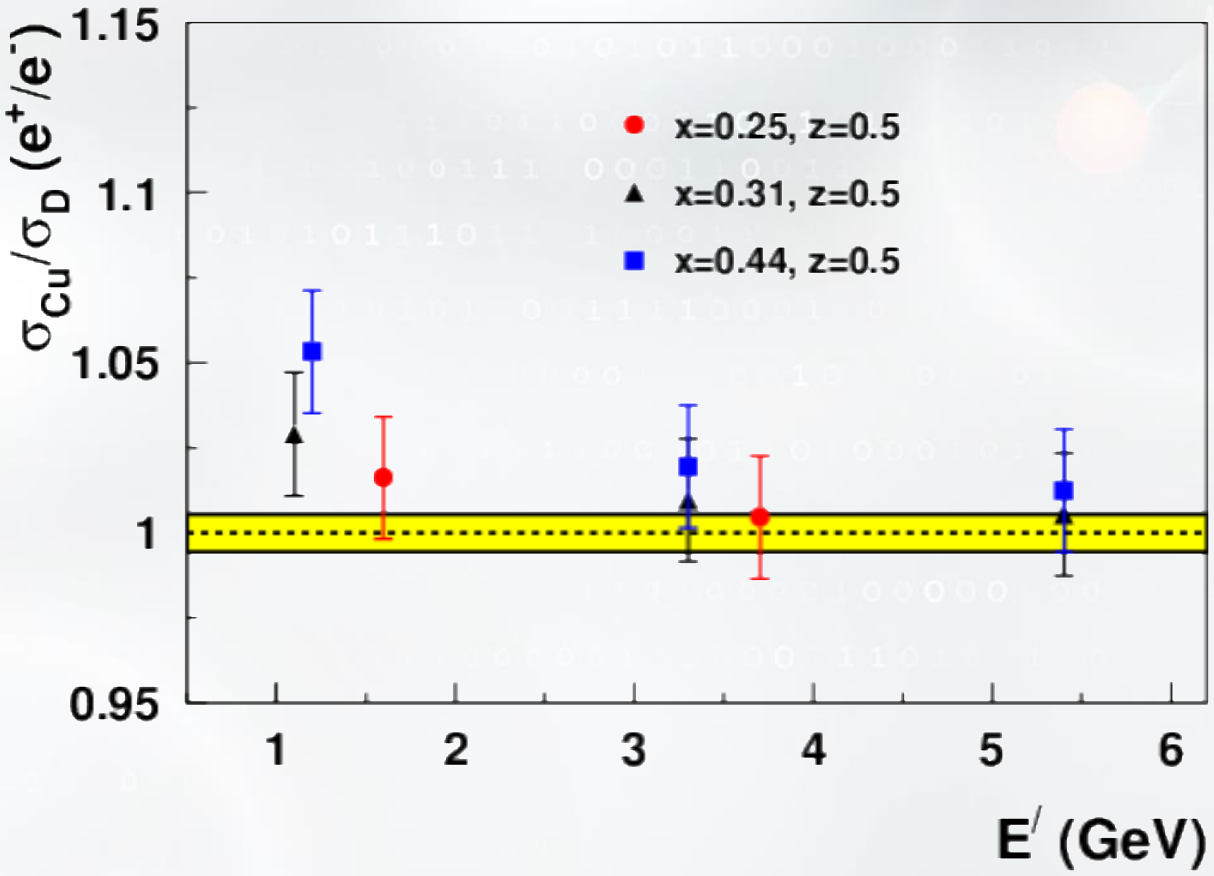
Testing Coulomb Corrections in SIDIS with Positrons

Sensitivity can be improved if positron and electron data taken during same run period
→ Target thickness uncertainties cancel in double ratio when using same targets

Running with low current (degraded?) electron beam would ***double*** required run time

Running higher current electrons (possible?) would result in minimal time increase

If available, this would be preferential



Positron and electron data taken during same run period

Slide from Dave Gaskell

Summary

- There are many assumptions regarding Coulomb Corrections in SIDIS
- There is *no* data to constrain it
- This measurement is critical to the correct interpretation of existing, imminent, and future SIDIS data – *A key piece of the JLab program!*
- This is an exploratory measurement to assess the validity of the Effective Momentum Approximation in SIDIS

QUESTIONS?