Deeply Virtual Compton Scattering off ^{4}He

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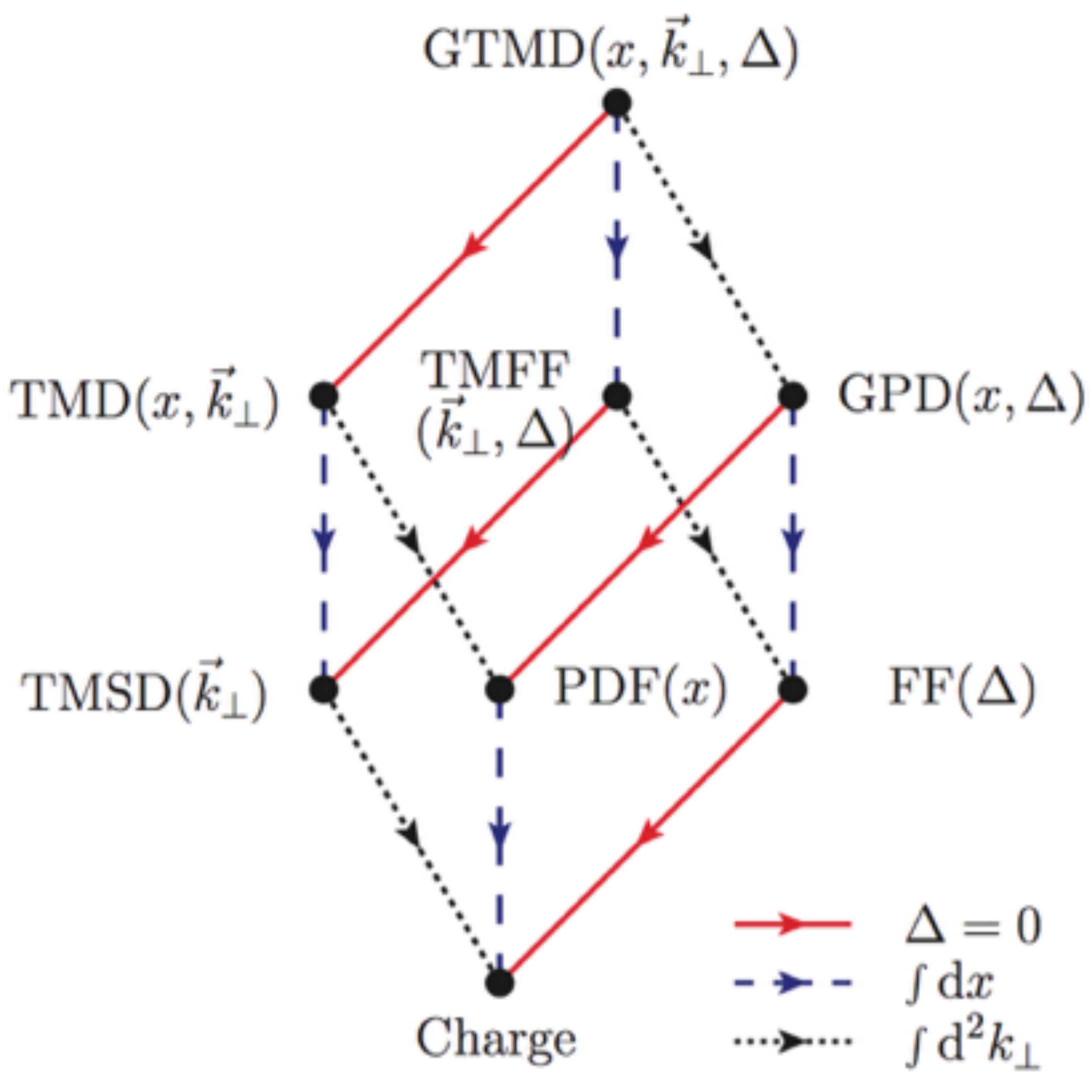
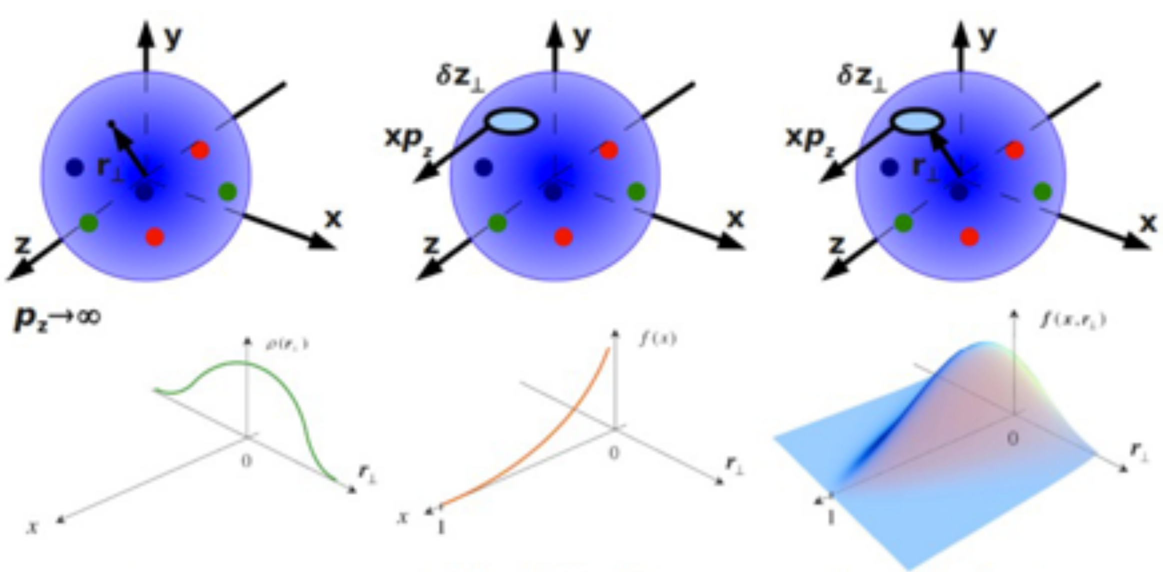
On behalf of the CLAS collaboration

APS DNP Meeting, October 2015, Santa Fe, NM

Nucleon Structure and GPDs





Form Factors (FFs)

- Transverse spatial structure
- Access through elastic scattering

PDFs and TMDs

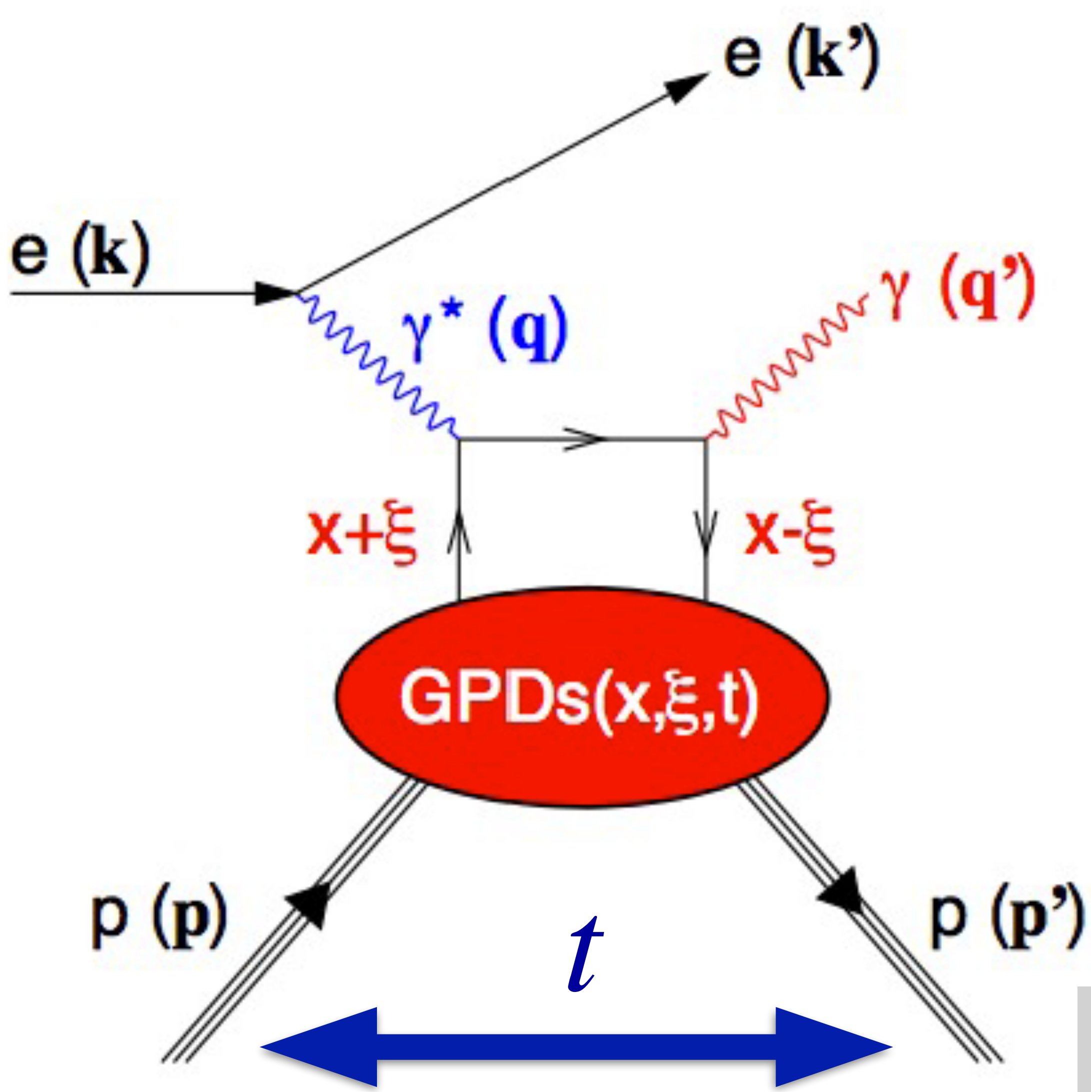
- Longitudinal and transverse momentum structure
- Access through DIS and SIDIS

Generalized Parton Distributions (GPDs)

- Encode the longitudinal momentum and transverse position of the partons
- Access through DVCS and DVMP

Deeply Virtual Compton Scattering

$$ep \rightarrow ep\gamma$$



Factorization in DVCS

- (Short-range): **hard scattering** reaction calculable in **pQCD**
- (Long-range): non-perturbative **proton structure** encoded in the **GPDs**

t Mandelstam variable (squared momentum transfer to nucleon).

x Average longitudinal momentum of the parton (NOT x_B)

ξ Skewness parameter

GPDs for nuclear DVCS

- Unpolarized H, E
- Polarized $\tilde{H}, \tilde{E}$

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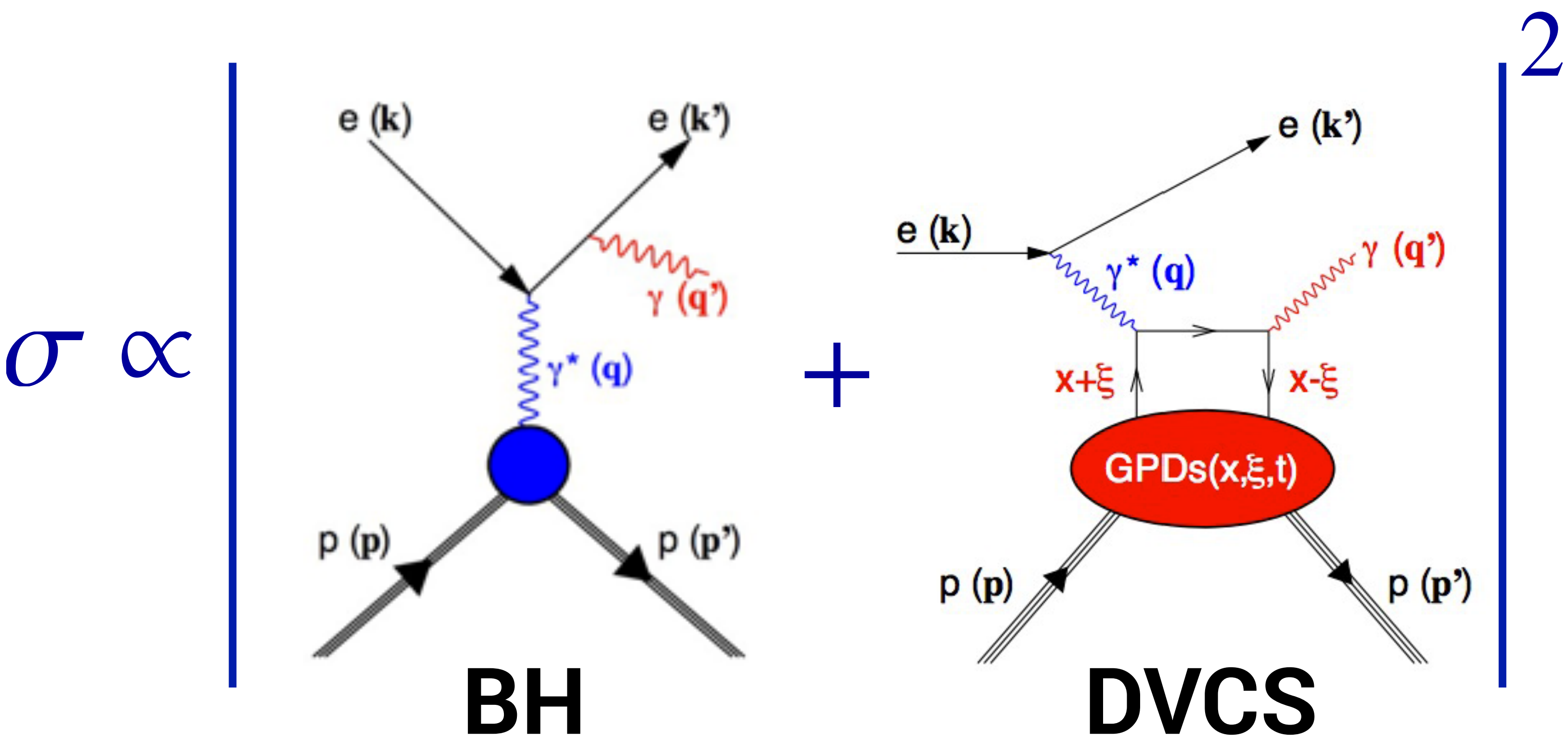
DVCS and Bethe-Heitler

- Bethe-Heitler (BH) and DVCS have the same final state



- The BH contribution to the cross section is dominant
- The DVCS contribution is enhanced through the interference term

- The GPDs are convoluted with the hard scattering kernel (Compton Form Factors)
- Experimental access through direct cross section measurements, or various azimuthal asymmetries

Beam Spin Asymmetry (BSA)

$$A_{LU}(\phi) = \frac{1}{\mathcal{P}_B} \frac{N^+ - N^-}{N^+ + N^-}$$

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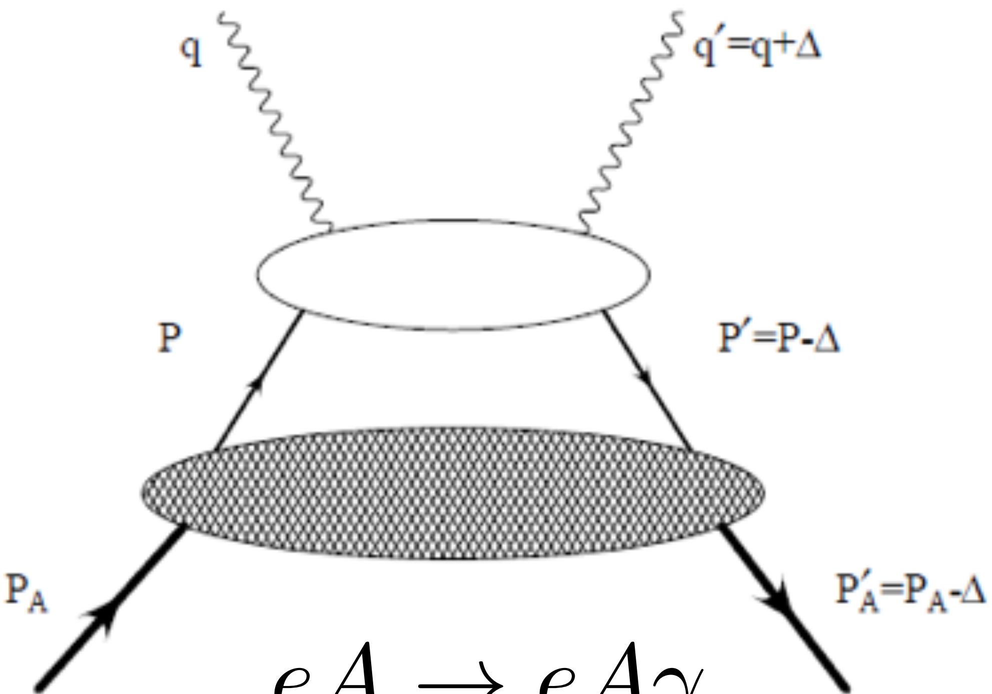
Nuclear DVCS

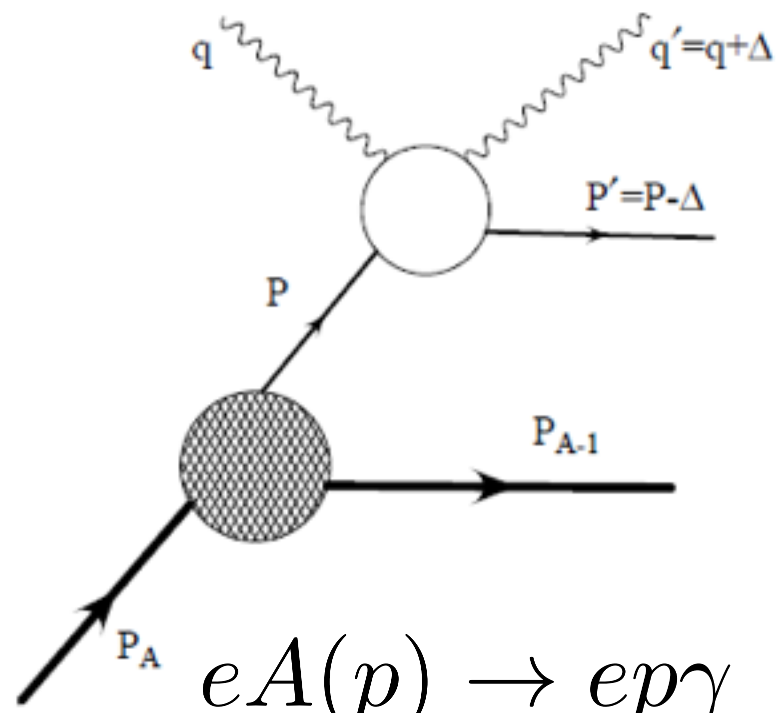
Coherent DVCS



$$eA \rightarrow eA\gamma$$

- Partonic structure of the nucleus
- Only GPD H needed for spin-0 nuclei (^{4}He, ^{12}C, ^{16}O, ...)

Incoherent DVCS



$$eA(p) \rightarrow ep\gamma$$

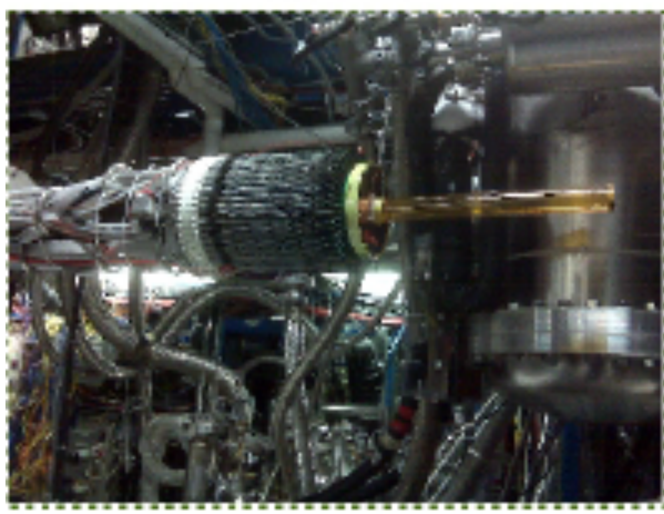
- DVCS off a nucleon inside a nucleus
- Partonic structure of a bound nucleon
- Ideal laboratory to study medium modifications of the nucleons (EMC effect) in the GPD framework!

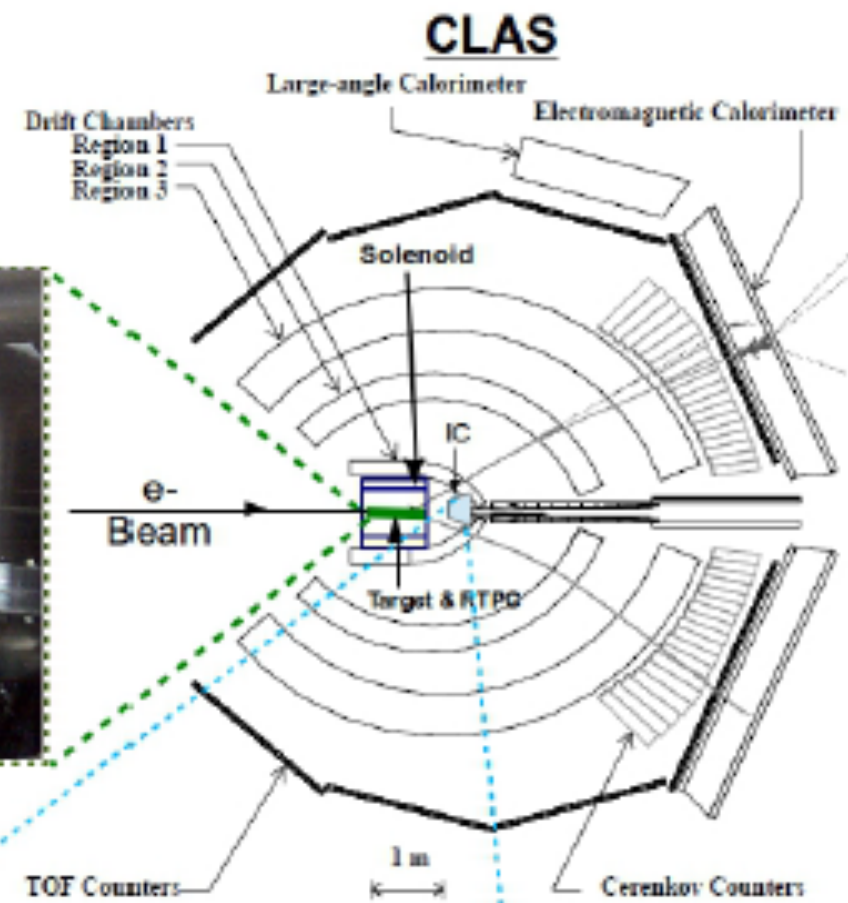
EG6 experiment

E08-024 experiment, Hall B, JLab, 2009

Beam
- 6 GeV CEBAF
- Longitudinally polarized

RTPC

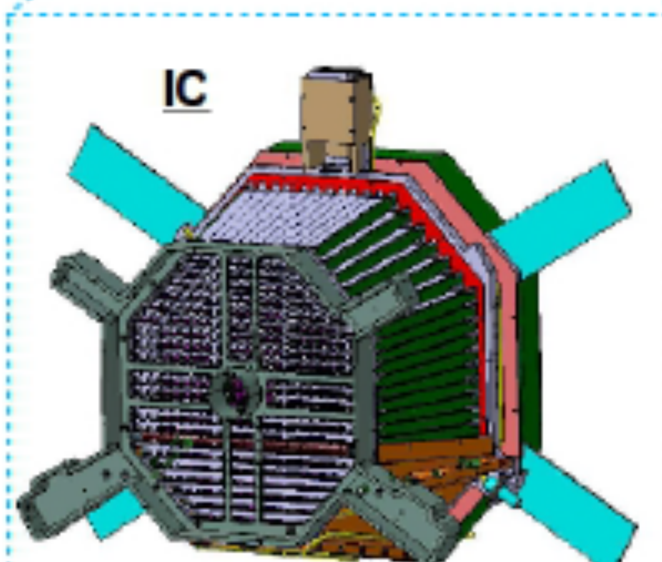




CLAS
- Superconducting torus magnet
- 6 independent sectors
  - DC for tracking
  - CC for e/π separation
  - EC for γ, e- and n
  - TOF Counters for hadron PID

Target
- ^{4}He gas
- 6 atm, 293K

RTPC
- Detection of low energy recoil nuclei



Inner Calorimeter (IC)
- γ-detection in the forward region

Exclusive Event Selection

Event Selection

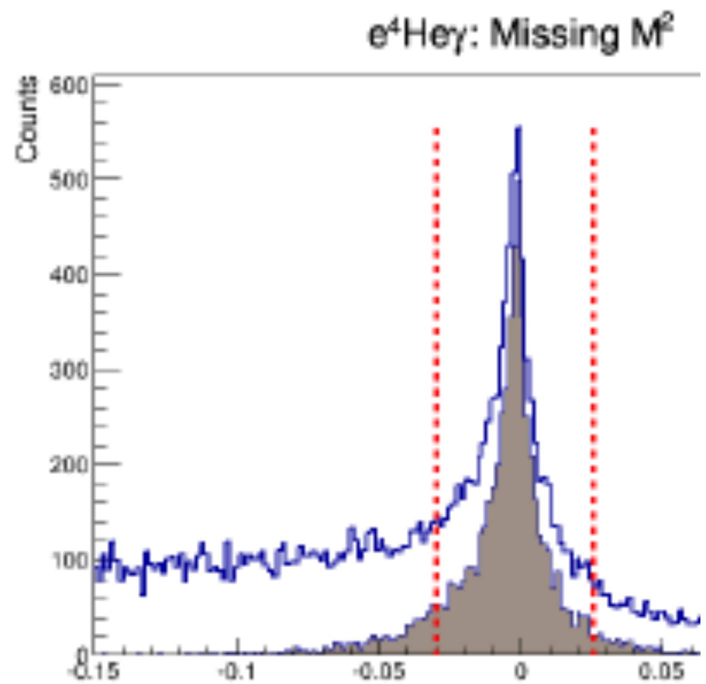
- Exactly one good electron
- Exactly one good recoil candidate
  - ^{4}He in RTPC (coherent)
  - p in CLAS (incoherent)
- At least one photon

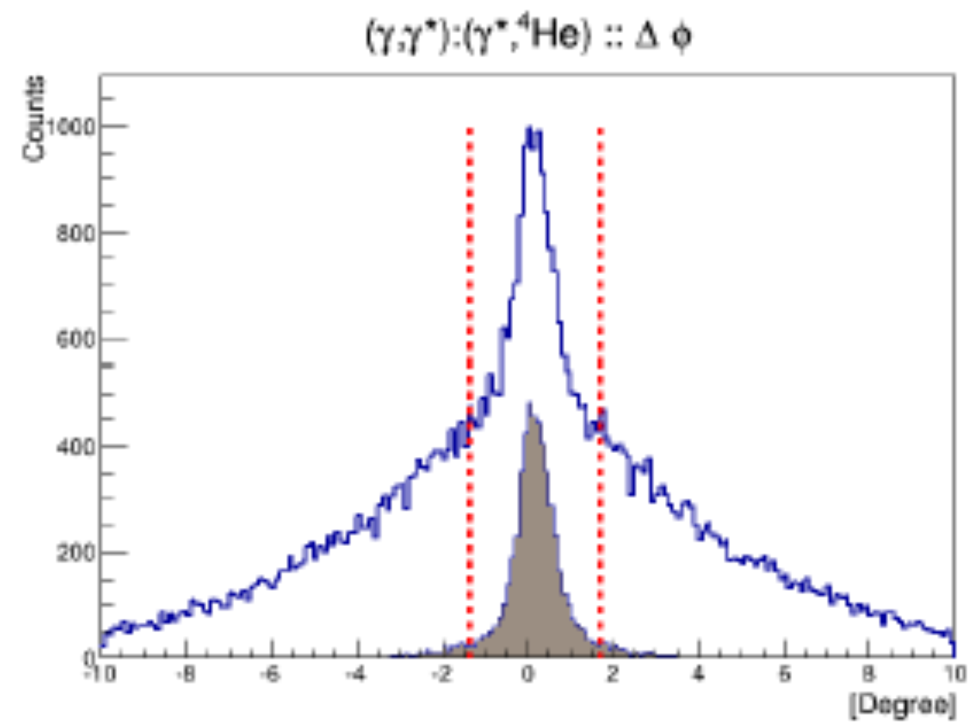
Exclusivity Cuts

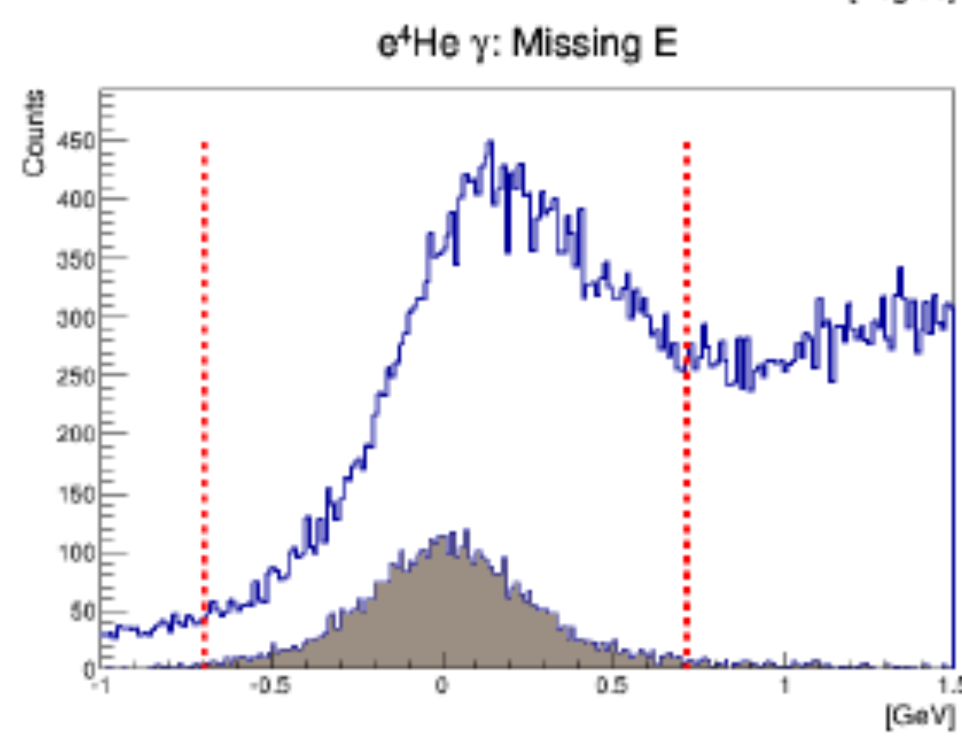
- 3 sigma cuts:
  - Missing mass and energy
  - Missing transverse momentum
  - Coplanarity between γ, γ* and recoil

Hard Cuts

- $E_\gamma > 2$ GeV
- $W > 2$ GeV
- $y < 0.85$
- $Q^2 > 1$ GeV^2







Background Subtraction

Exclusive π⁰ channel

$$eA \to eA\pi^0 \to eA\gamma\gamma$$

(one photon detected)

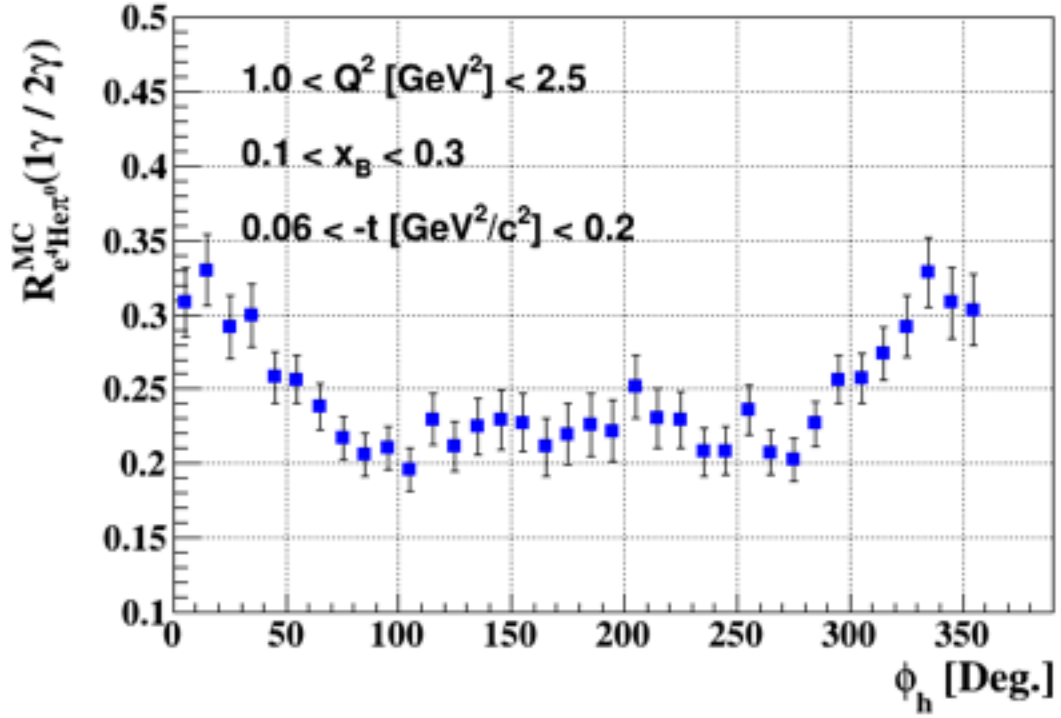
- Contamination can be calculated by normalizing the number of detected exclusive π^0 events with the acceptance ratio R(1γ/2γ) from the MC

$$N^{\mathrm{true}}_{eA\gamma} = N^{\mathrm{meas}}_{eA\gamma} - N^{\mathrm{corr}}_{eA\pi^0(1\gamma)}$$

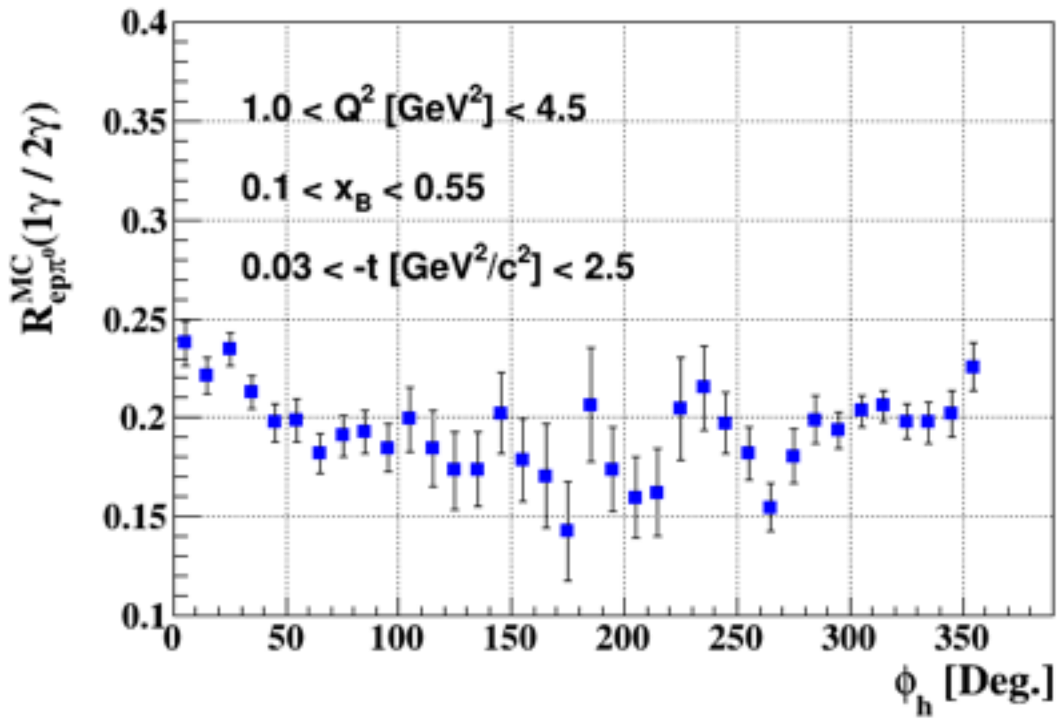
$$N^{\mathrm{corr}}_{eA\pi^0(1\gamma)} = R^{\mathrm{MC}}_{eA\pi^0}(1\gamma/2\gamma) \times N^{\mathrm{meas}}_{eA\pi^0(2\gamma)}$$

$$R^{\mathrm{MC}}_{eA\pi^0}(1\gamma/2\gamma) = \frac{N^{\mathrm{MC}}_{eA\pi^0(1\gamma)}}{N^{\mathrm{MC}}_{eA\pi_0(2\gamma)}}$$

contamination for coherent: 2-4%



contamination for incoherent: 8-11%

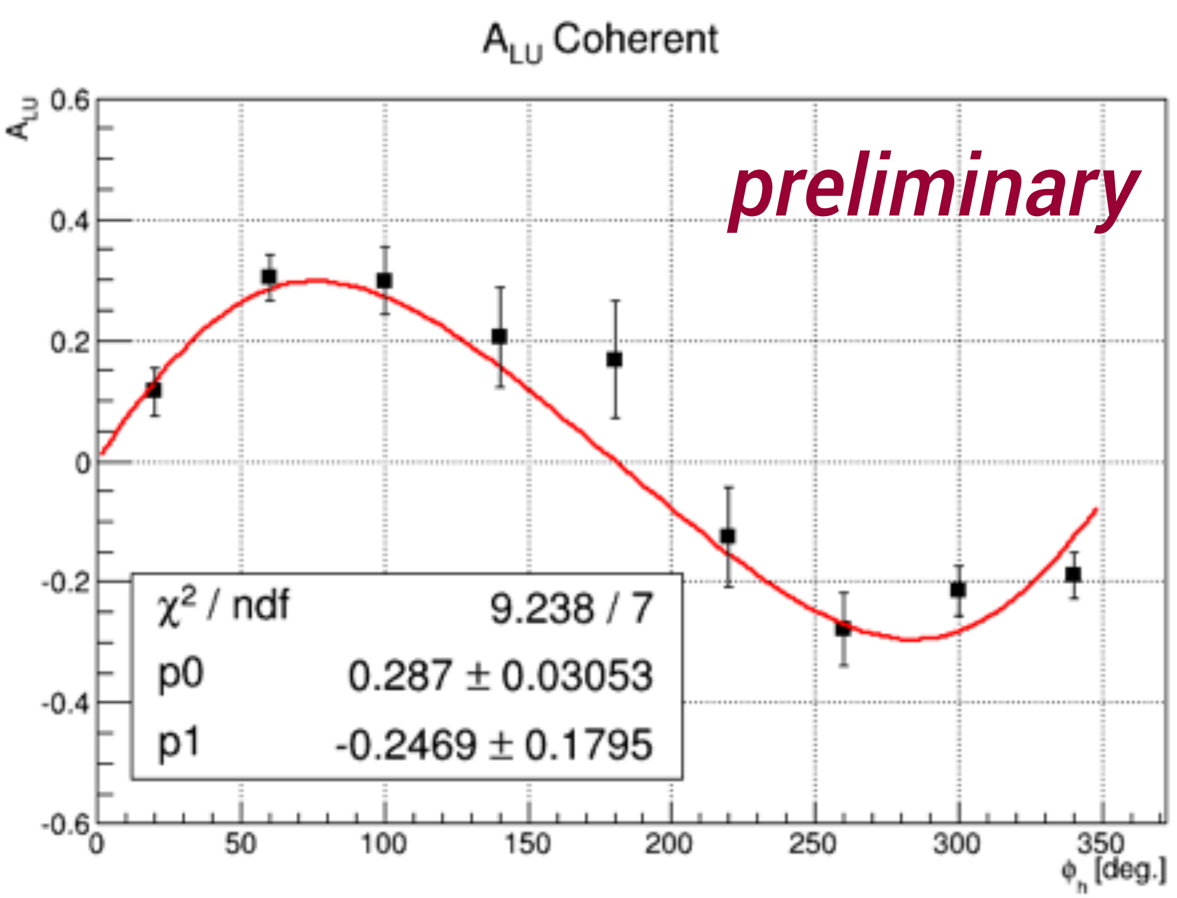


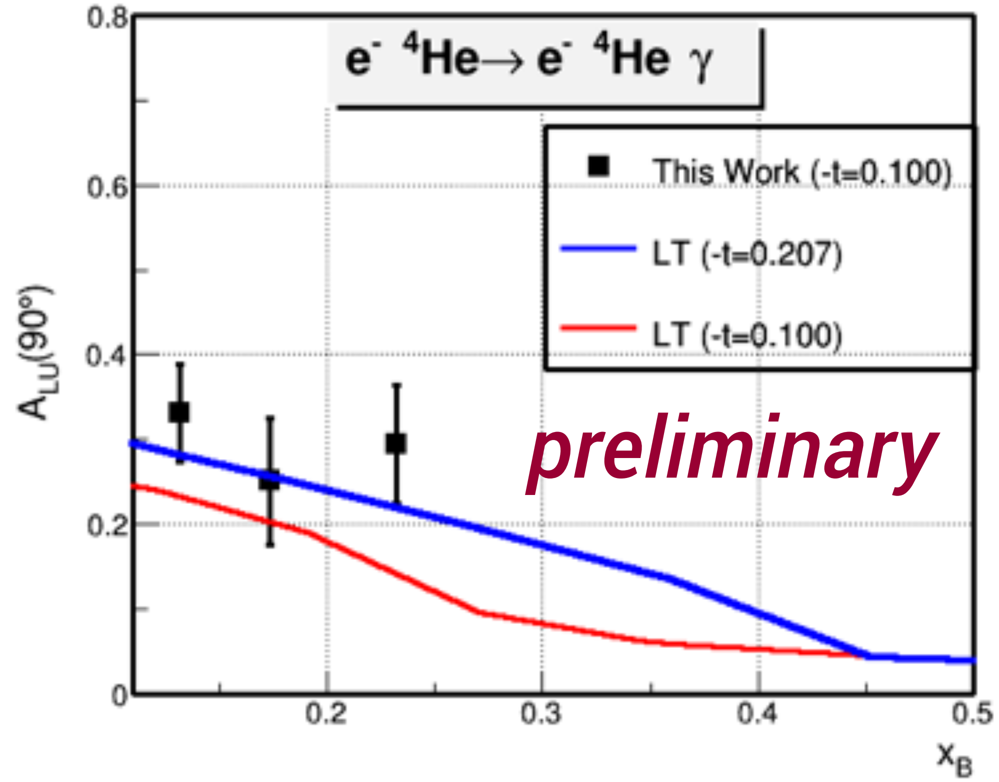
Coherent BSA (preliminary)

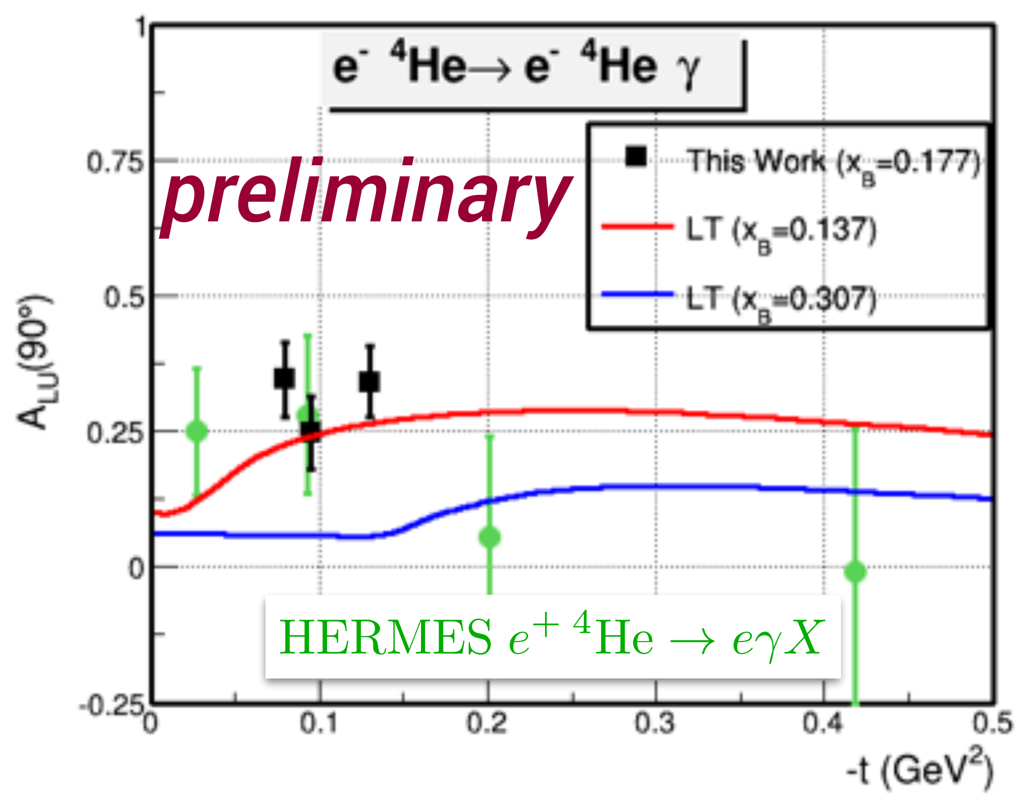
Kinematic Reach

$$0.06 < -t < 0.2 \rightarrow \langle -t \rangle = 0.10 \text{ GeV}^2$$
$$1.0 < Q^2 < 2.5 \rightarrow \langle Q^2 \rangle = 1.49 \text{ GeV}^2$$
$$0.1 < x_B < 0.3 \rightarrow \langle x_B \rangle = 0.18$$

- Data extracted in 2D bins versus φ and either -t, x_B or Q^2
- A_{LU} fit with: $p_0 \sin\phi/(1 + p_1 \cos\phi)$



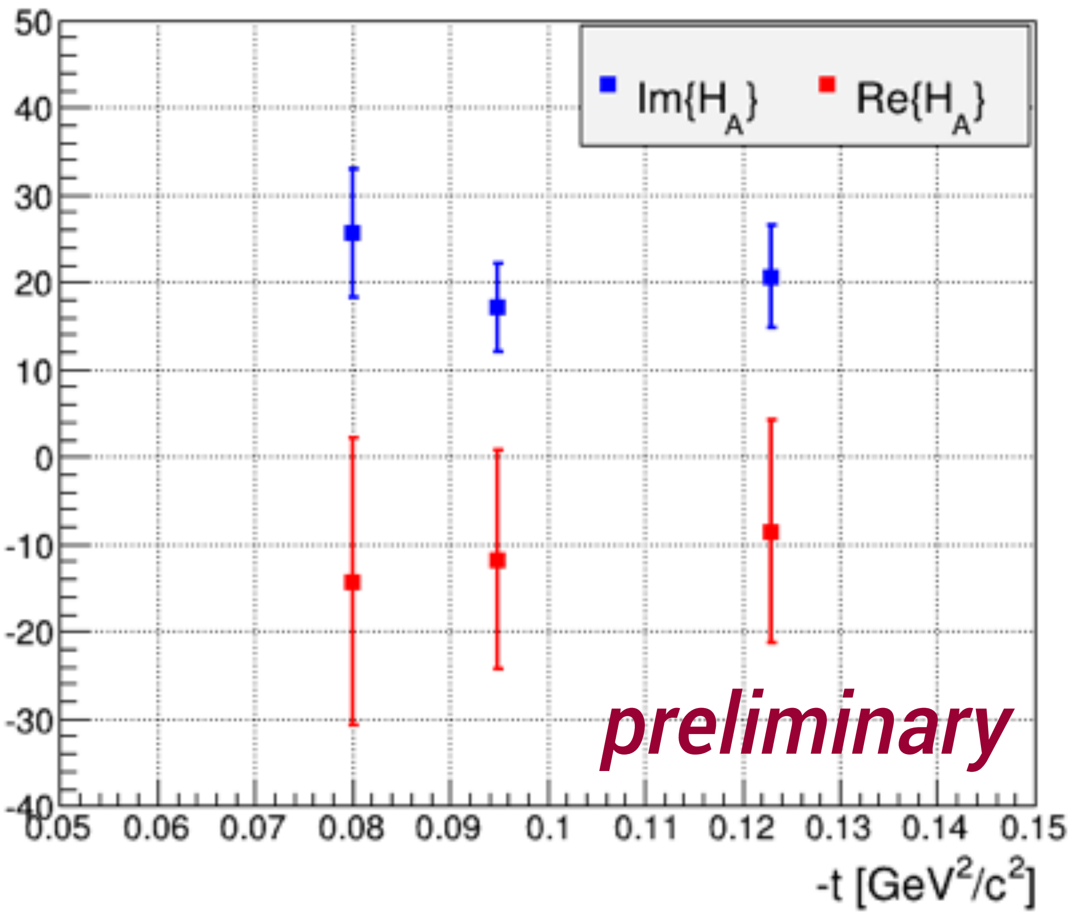


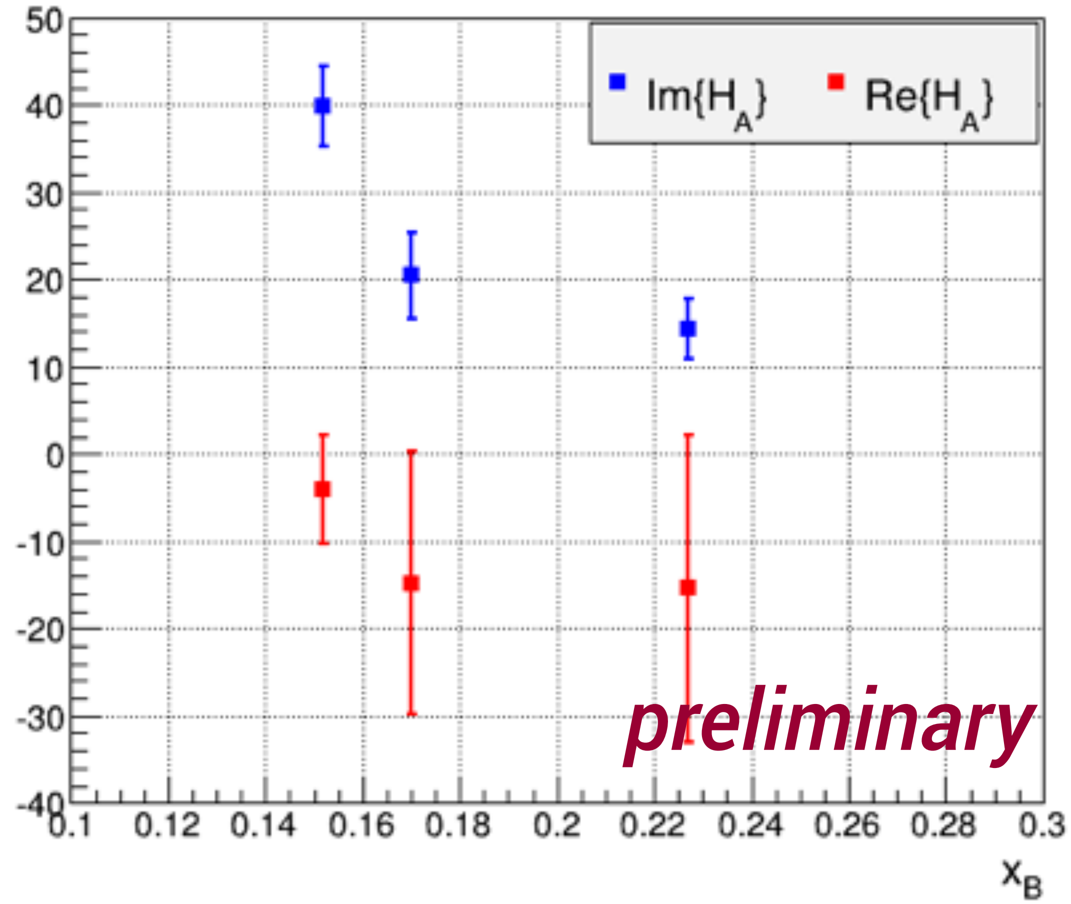


LT: S. Liuti and S. K. Taneja.Phys. Rev., C72:032201, 2005.
HERMES: A. Airapetian, et al., Phys Rev. C 81, 035202 (2010).

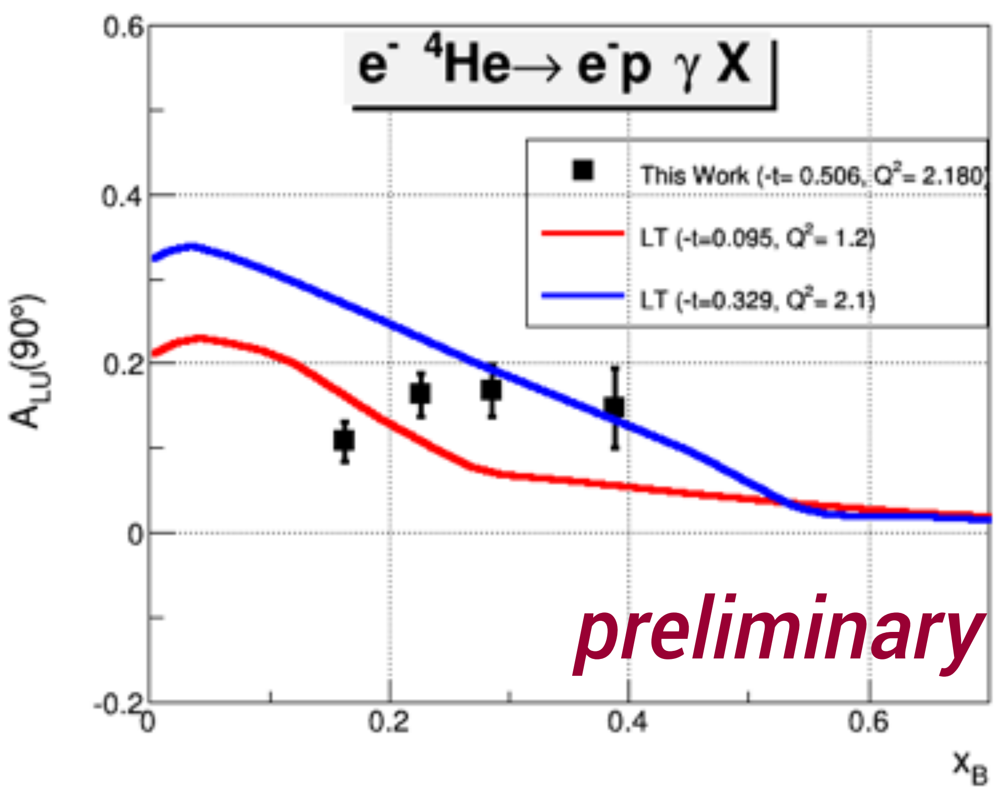
Compton Form Factors for ^{4}He (preliminary)

$$A_{LU} = \frac{\alpha_0(\phi)\mathcal{H}_{\rm Im}}{\alpha_1(\phi) + \alpha_2(\phi)\mathcal{H}_{\rm Re} + \alpha_3(\phi)(\mathcal{H}^2_{\rm Im} + \mathcal{H}^2_{\rm Re})}$$
$$\approx \frac{p_0 \sin\phi}{1 + p_1 \cos\phi}$$





Incoherent BSA (preliminary)



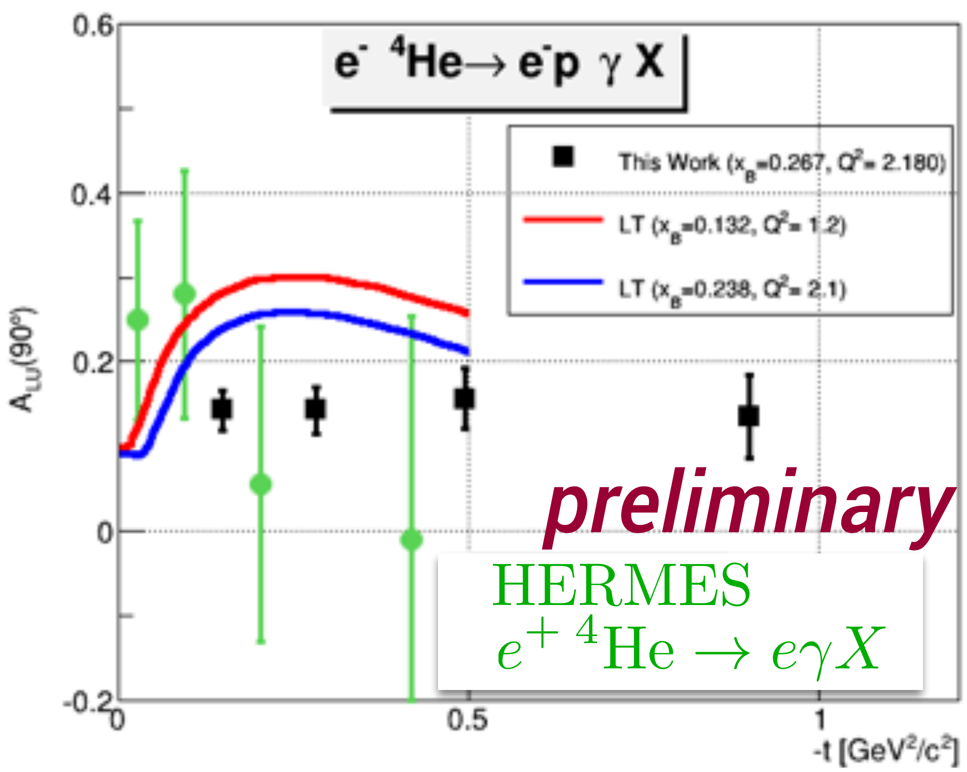
Kinematic Reach

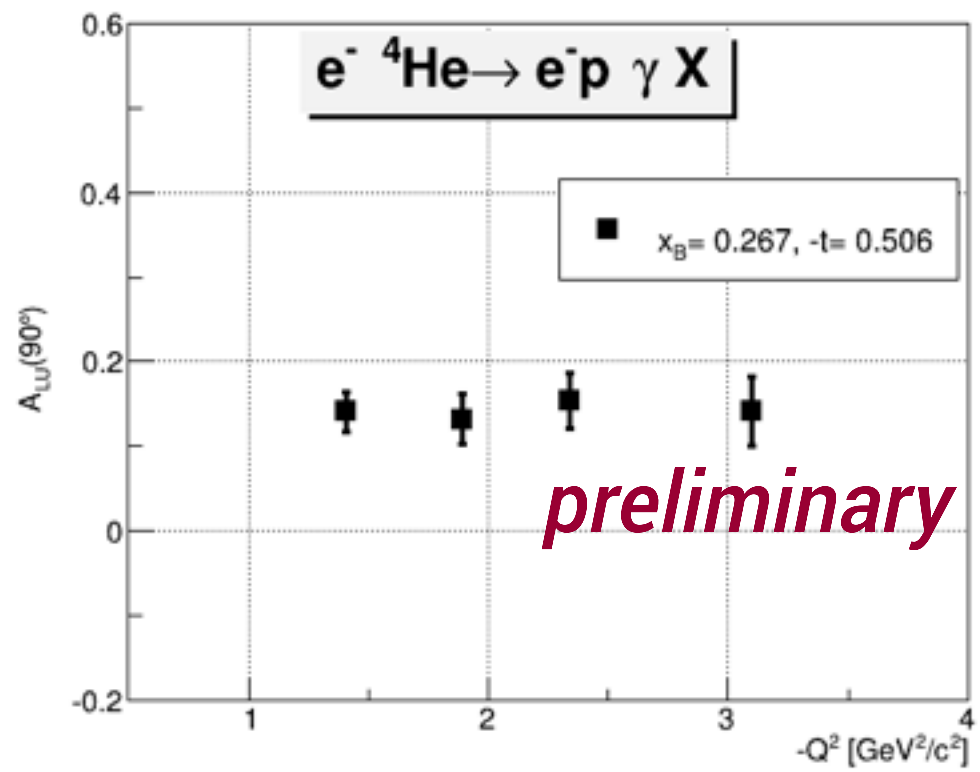
$$0.05 < -t < 2.5 \rightarrow \langle -t \rangle = 0.53\ \mathrm{GeV}^2$$

$$1.0 < Q^2 < 4.5 \rightarrow \langle Q^2 \rangle = 2.20\ \mathrm{GeV}^2$$

$$0.1 < x_{\mathrm{B}} < 0.55 \rightarrow \langle x_{\mathrm{B}} \rangle = 0.26$$

- Data extracted in 2D bins versus φ and either -t, x_B or Q^2





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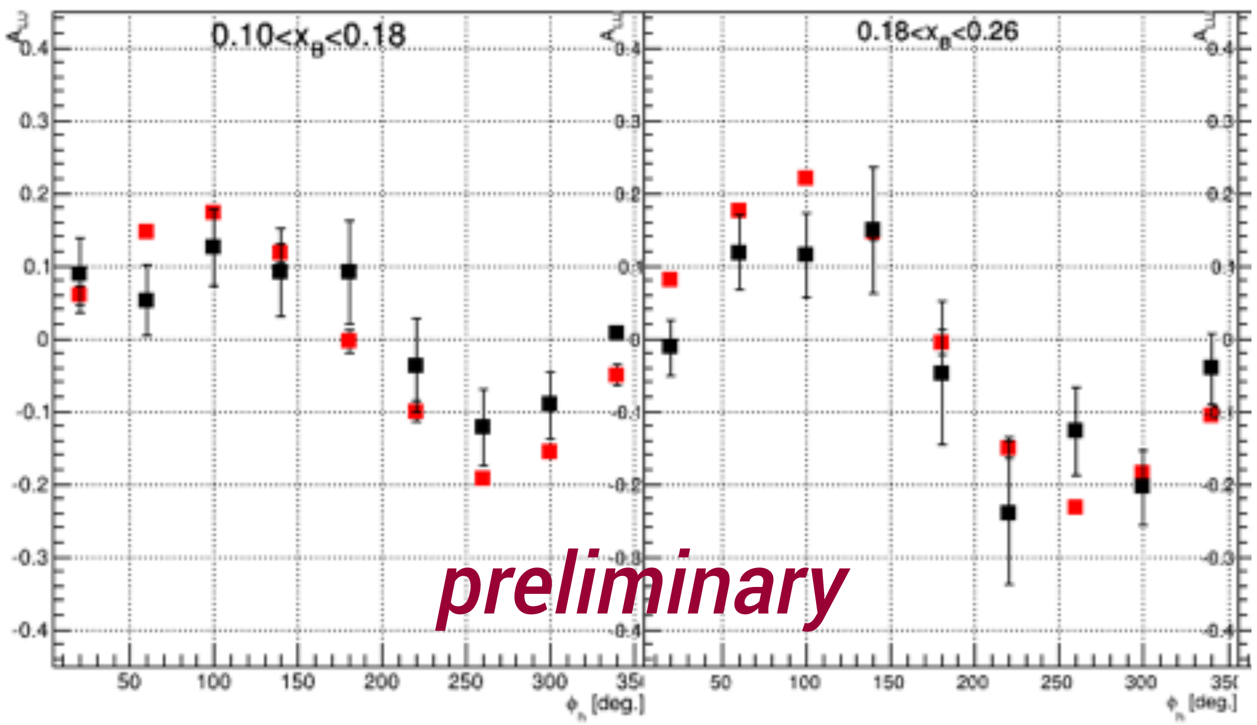
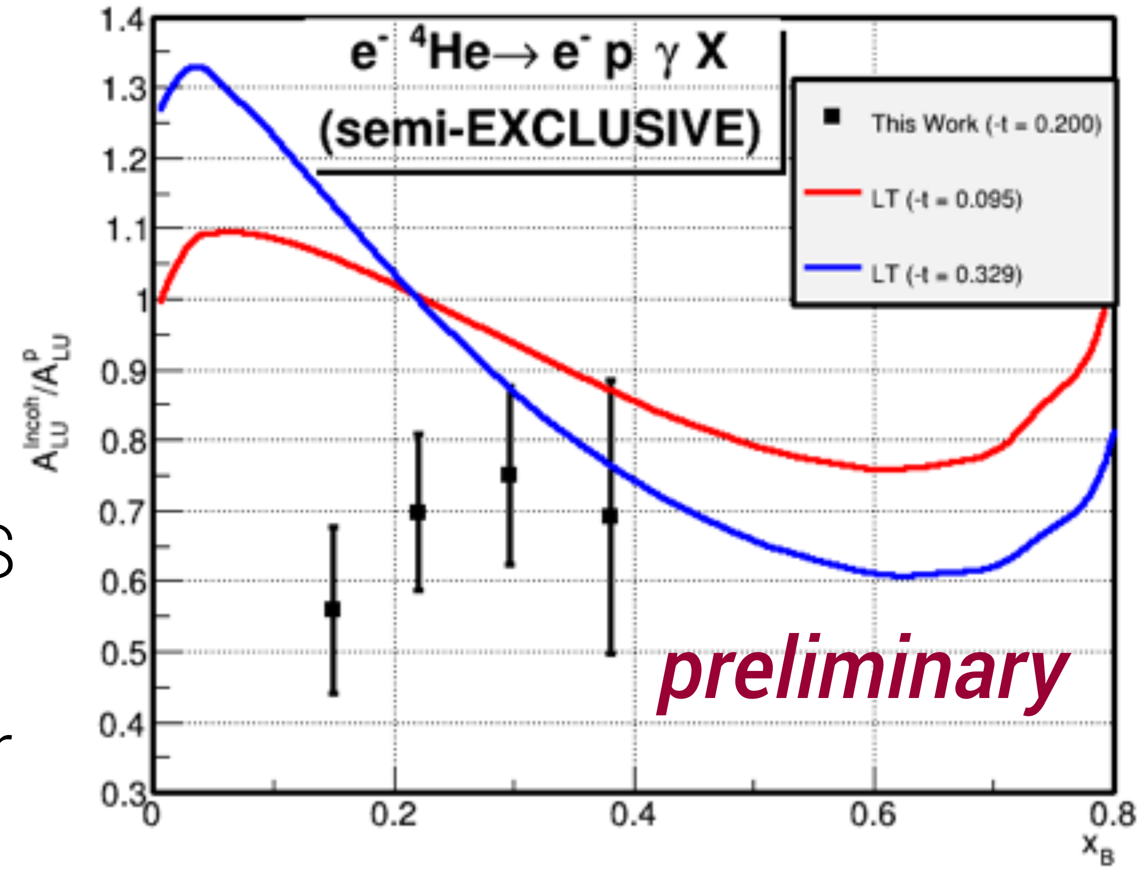
Generalized EMC Ratio vs x_B (preliminary)



- Measured **incoherent asymmetries** compared to the published CLAS DVCS results off the **proton**.
- The bound proton results show a lower asymmetry relative to the free proton across all bins in x_B.



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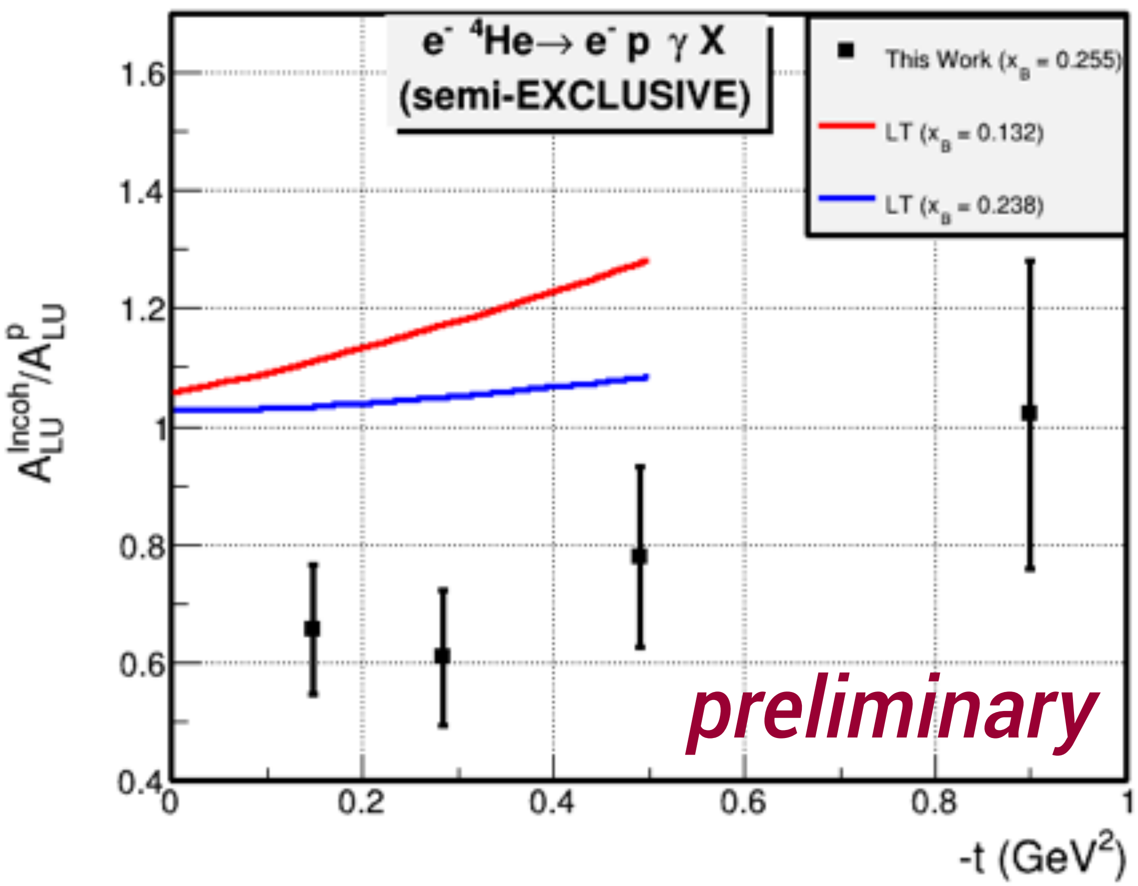
Generalized EMC Ratio vs t (preliminary)



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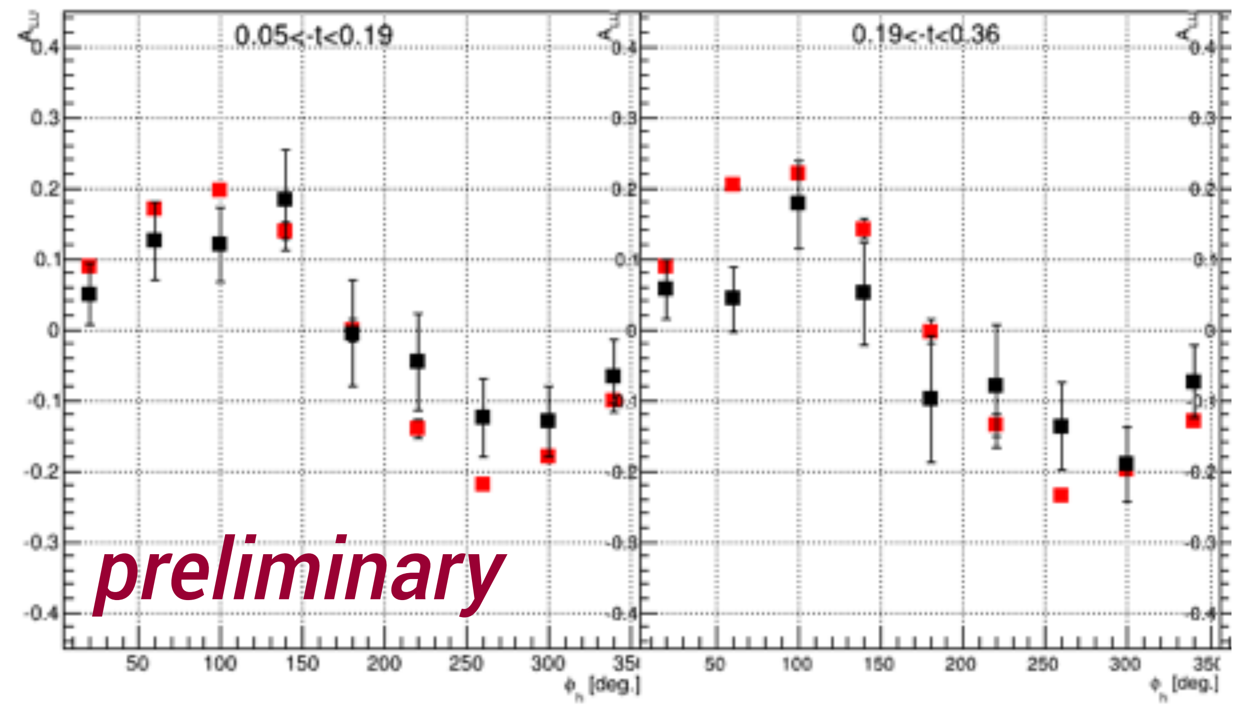

- Measured **incoherent asymmetries** compared to the published CLAS DVCS results off the **proton**.
- The results show a lower asymmetry at small values of -t, while both values are compatible at high -t.

Conclusions

- These results constitute the first fully exclusive measurement of DVCS off ^{4}He
- Preliminary results for the BSA have been extracted and compared with theoretical predictions
- The results from the incoherent channel display a suppression of the BSA for small values of t
- **Final results coming soon!**