Deeply Virtual Compton Scattering off ^{4}He:

Update on the analysis

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- Nuclear Physics Working Group -

CLAS Collaboration Meeting (23-26 February 2016)

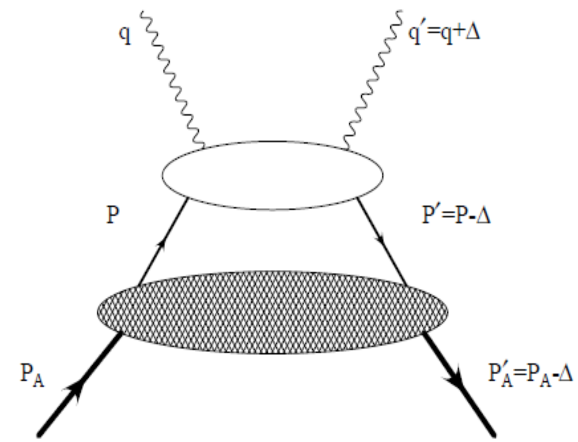
DVCS off nuclei

Two DVCS channels are accessible with nuclear targets:

◊ **Coherent DVCS: $e^- A \rightarrow e^- A \gamma$**

→ Study the partonic structure of the nucleus.

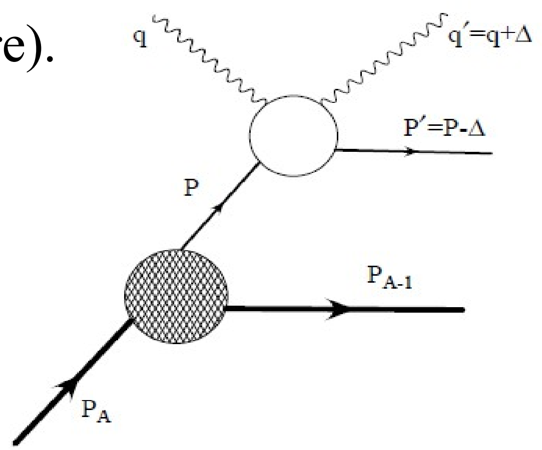
→ One chiral-even GPD (**$H_A(x,\xi,t)$**) is needed to parametrize the structure of the spinless nuclei (^{4}He, ^{12}C, ^{16}O, ...).



◊ **Incoherent DVCS: $e^- A \rightarrow e^- N \gamma X$**

→ The nucleus breaks and the DVCS takes place on a nucleon.

→ Study the partonic structure of the bound nucleons (4 chiral-even GPDs are needed to parametrize their structure).



conserve nucleon spin

unpolarized { **$H(x,\xi,t)$** , **$E(x,\xi,t)$** } — { **$\tilde{H}(x,\xi,t)$** , **$\tilde{E}(x,\xi,t)$** } **polarized**

flip nucleon spin

Nuclear spin-zero DVCS observables

The GPD H_A parametrizes the structure of the spinless nuclei (^{4}He, ^{12}C …)

$$\mathcal{H}_A(\xi,t) = Re(\mathcal{H}_A(\xi,t)) - i\pi Im(\mathcal{H}_A(\xi,t))$$

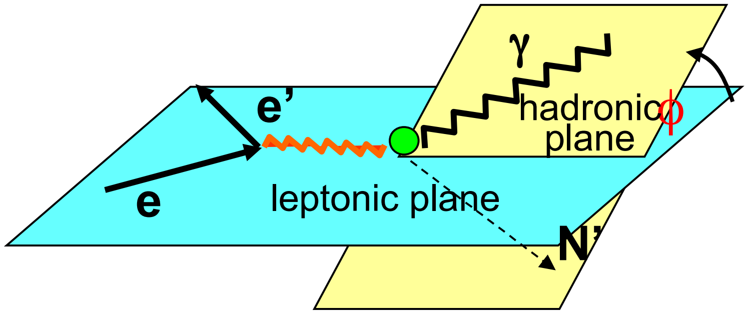
$$Im(\mathcal{H}_A(\xi,t)) = H_A(\xi,\xi,t) - H_A(-\xi,\xi,t)$$

$$Re(\mathcal{H}_A(\xi,t)) = \mathcal{P}\int_0^1 dx[H_A(x,\xi,t) - H_A(-x,\xi,t)]C^+(x,\xi)$$

Quark propagator

$$C^+(x,\xi) = \frac{1}{x-\xi} + \frac{1}{x+\xi}$$

→ Beam-spin asymmetry ($A_{LU}(\phi)$) : (+/- beam helicity)



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

$$= \frac{x_A(1+\epsilon^2)^2}{y} s_1^{INT}\sin(\phi) \Bigg/ \left[\sum_{n=0}^{n=2} c_n^{BH}\cos(n\phi) + \frac{x_A^2 t(1+\epsilon^2)^2}{Q^2} P_1(\phi)P_2(\phi)\, c_0^{DVCS} + \frac{x_A(1+\epsilon^2)^2}{y}\sum_{n=0}^{n=1} c_n^{INT}\cos(n\phi)\right]$$

CLAS - E08-024 experimental Setup

$$e^- \ {}^4He \rightarrow e^- \ ({}^4He/pX) \ \gamma$$

6 GeV,
L. polarized

Beam polarization (P_B) = 83%

- CLAS:
→ Superconducting Torus magnet.
→ 6 independent sectors:
→ DCs track charged particles.
→ CCs separate e^-/π^-.
→ TOF Counters identify hadrons.
→ ECs detect γ, e^- and n [8º,45º].

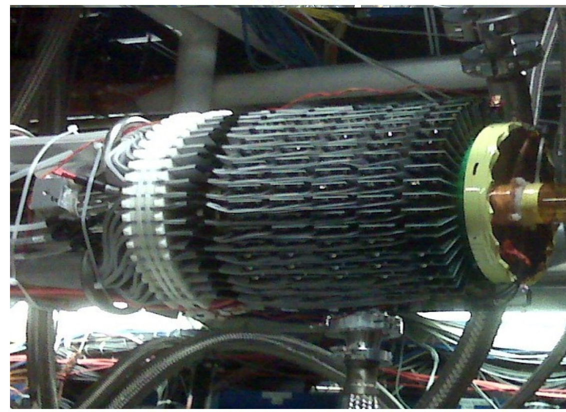
- IC: Improves γ detection acceptance [4º,14º].

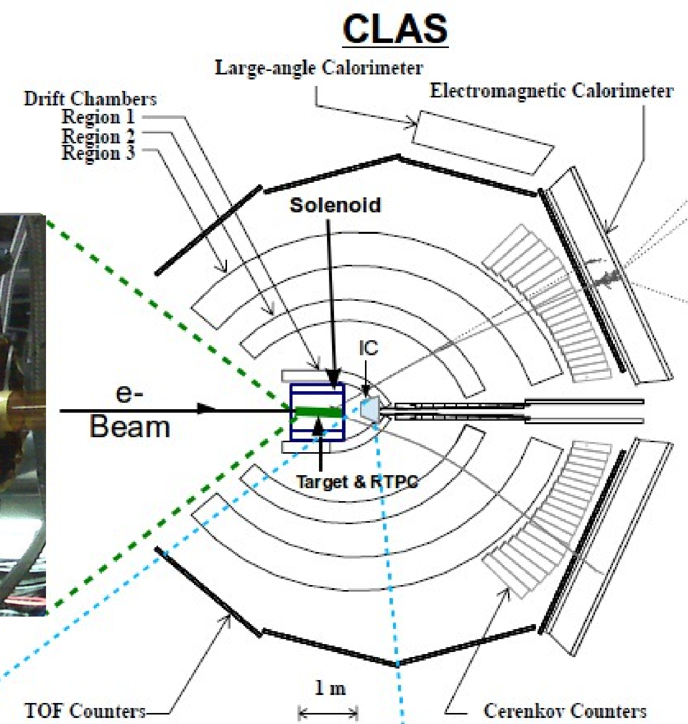
- RTPC: Detects low energy nuclear recoils.

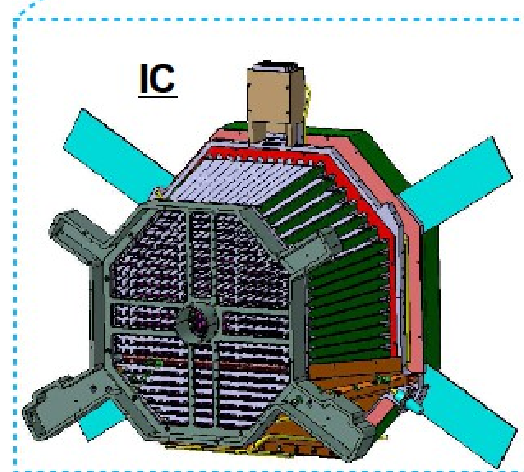
- Solenoid: - Shields the detectors from Møller electrons.
- Enables tracking in the RTPC.

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

RTPC





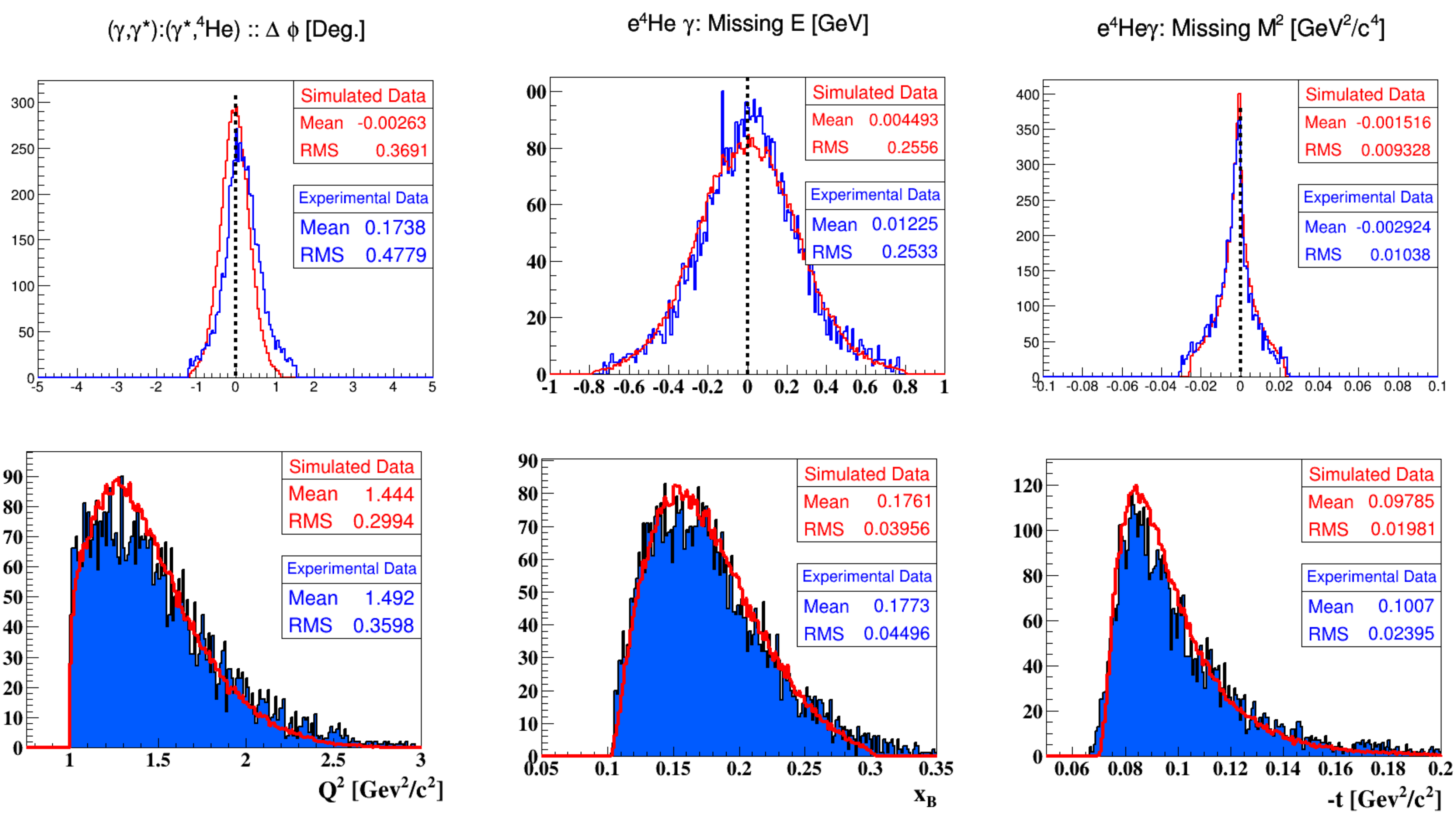


Coherent DVCS events selection

◊ Only one e⁻, at least 1γ and only one good ^{4}He.

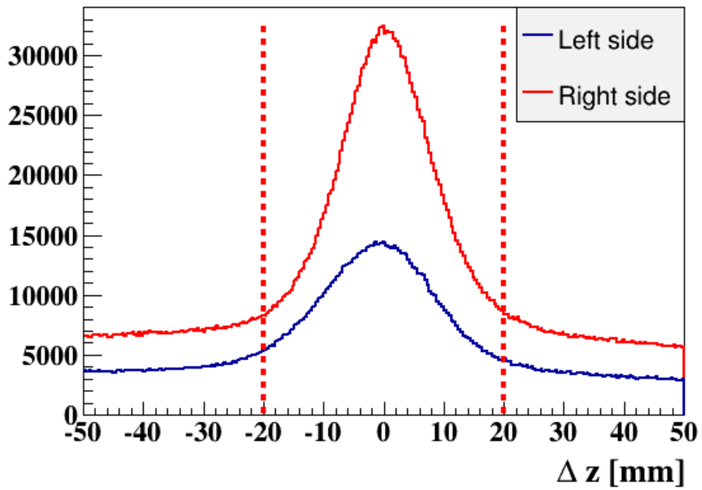
◊ Eγ > 2 GeV, W > 2 GeV/c^2 and Q^2 > 1 GeV^2.

◊ Exclusivity cuts (3 sigmas).

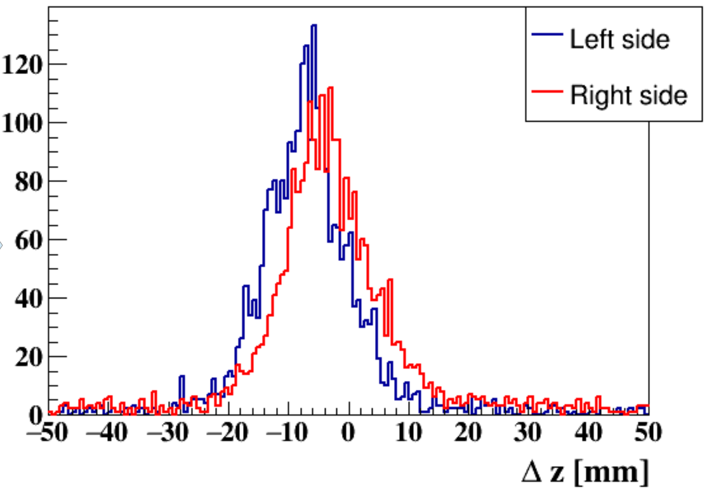


Coherent checking: accidental contaminations

Motivation: accidental contamination



Identifying the coherent DVCS events via the exclusivity cuts without any initial constrain on Δz



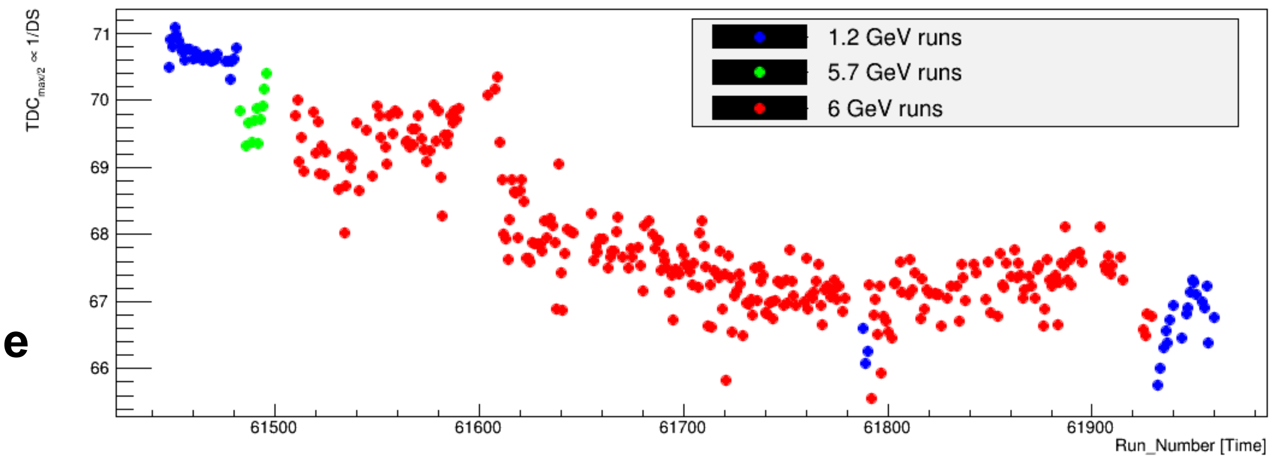
Number of coherent DVCS events		
Δz [mm]	Left module	Right module
[-50:-30]	42	77
[-20:20]	2741	2856
[30:50]	34	78
Contamination percentage	2.7%	5.4%

- A global contamination of 4.1%
- Correct the reconstructed asymmetries:

$$A_{LU}\ \ corr. = \frac{1}{1-contamination} A_{LU}$$

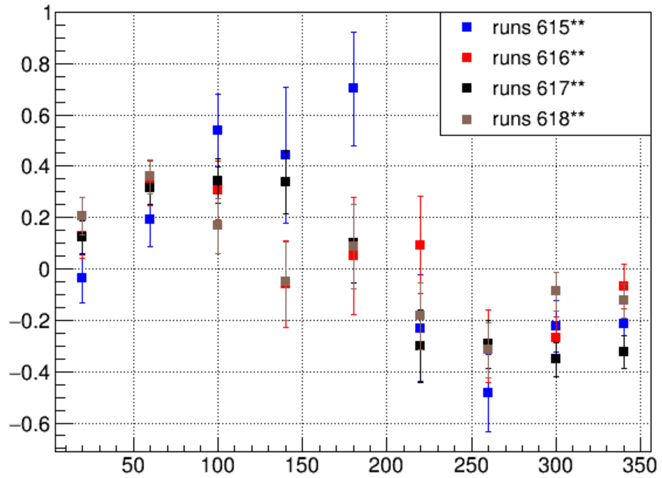
Coherent checking: Time dependence

Motivation: some aspects of the RTPC calibration, such as the drift speed, have shown a time dependence.



Checking: we carried out the DVCS analysis for different groups of runs that exhibit similar trends in the drift speed.

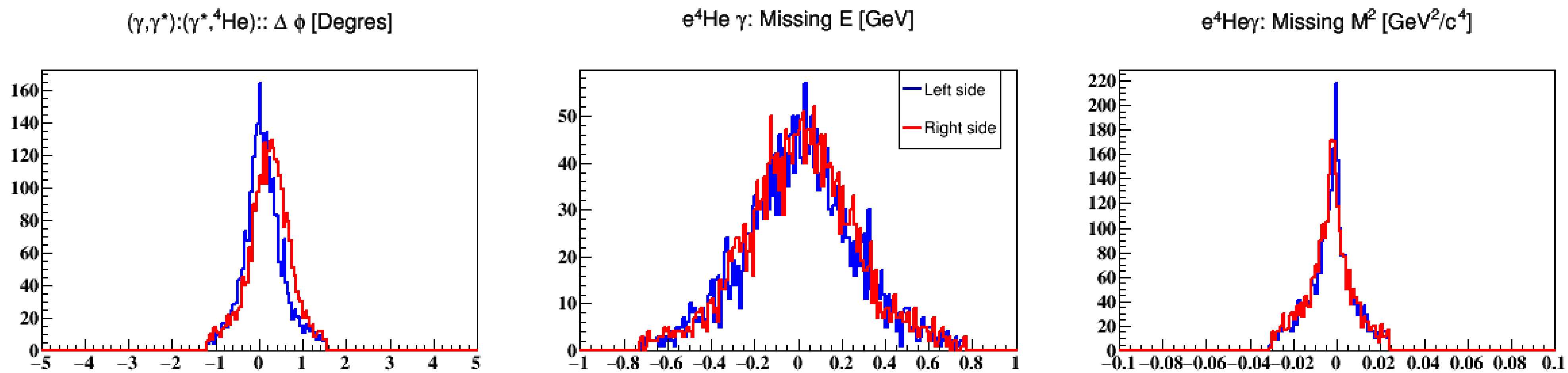
Coherent channel: A_{LU} vs. ϕ

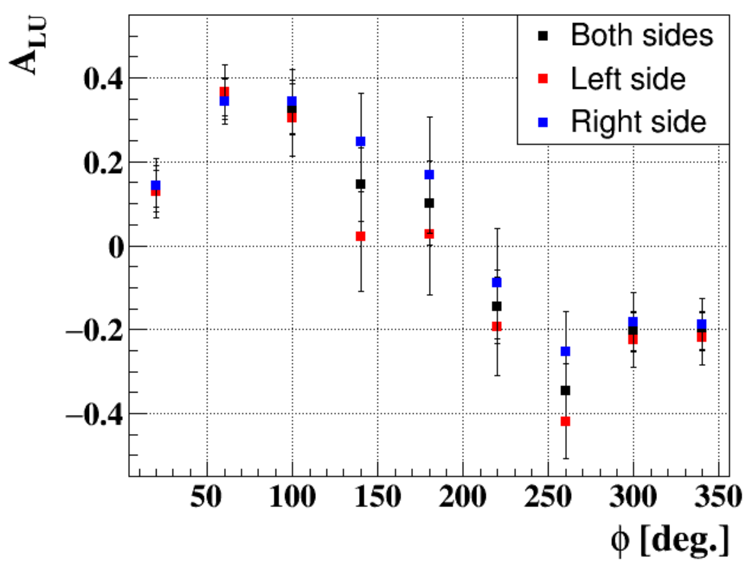


<u>Within the given statistics:</u>
- Compatible reconstructed asymmetries.
- No time-dependence

Coherent checking: Left/Right Modules of the RTPC

Motivation: the two modules of the RTPC has shown slightly different yields in terms of the initial reconstructed tracks, that should not affect the reconstructed beam-spin asymmetries.



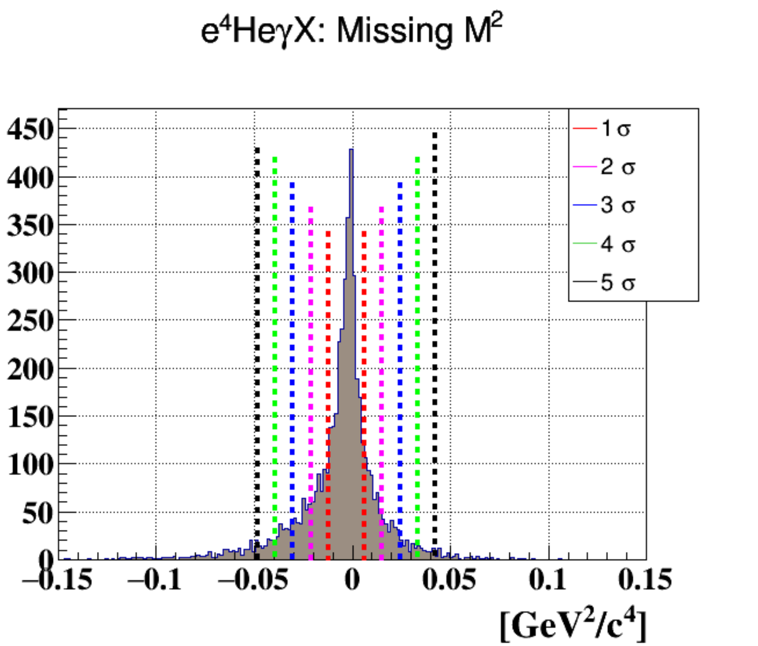


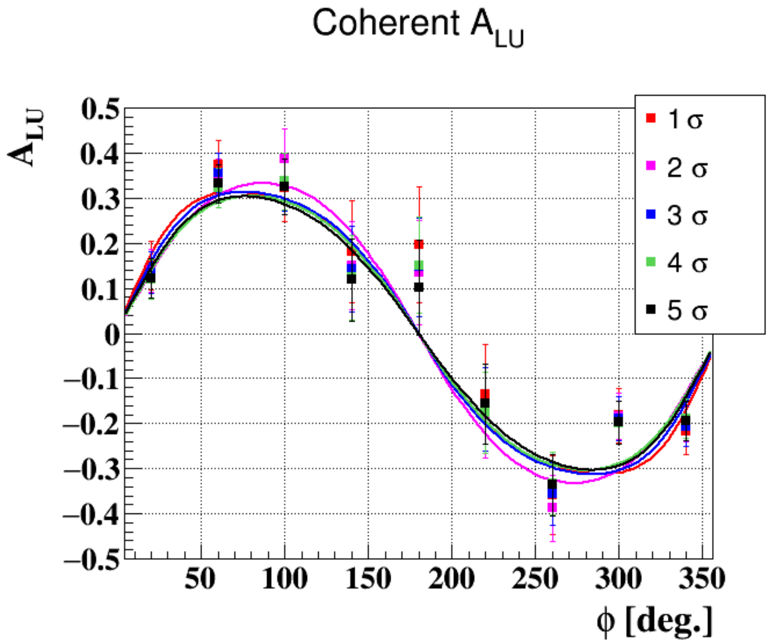
Left/Right modules have:
- Similar performances in terms of the DVCS.
- Compatible reconstructed asymmetries

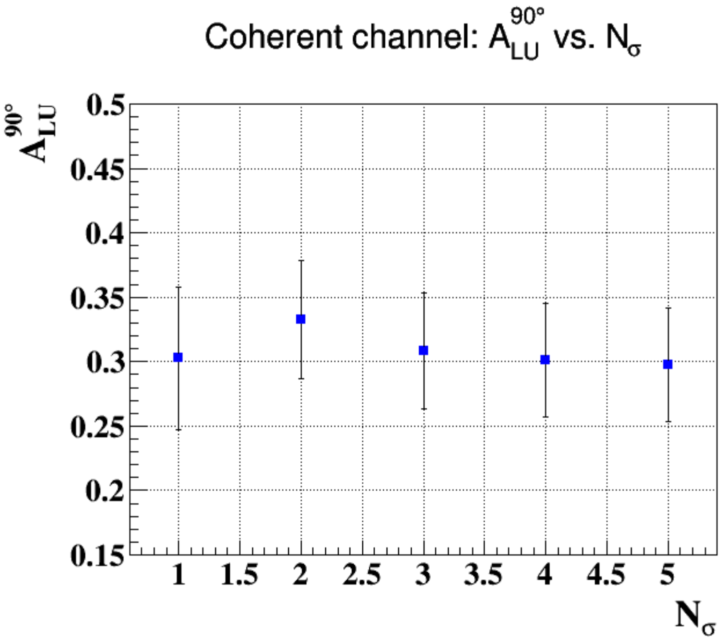
Coherent checking: DVCS cuts

Motivation: **Systematic uncertainty stemming from the DVCS selection cuts.**

Check: **Fix 3σ cuts on all the exclusivity cuts and changing the width of eHeγ missing mass squared.**





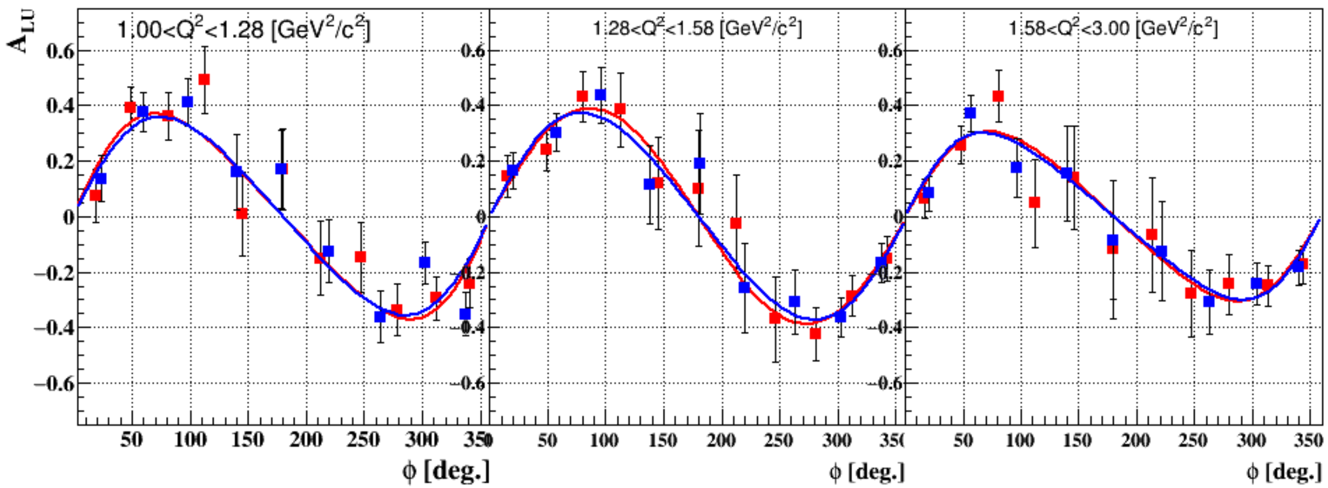


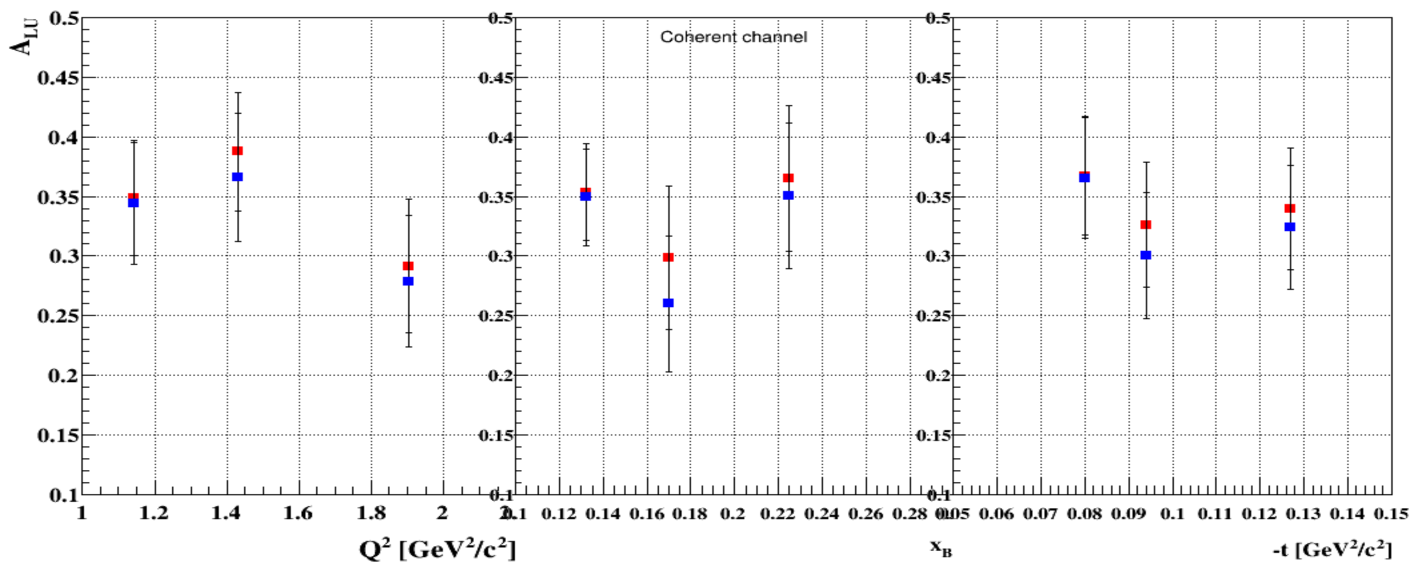
8% global systematic uncertainties

Coherent checking: Binning DVCS data

Motivation: **systematic uncertainty stemming from the DVCS events in φ.**

Check: **perform two sets of binning in ϕ ->> watch the reconstructed asymmetries.**

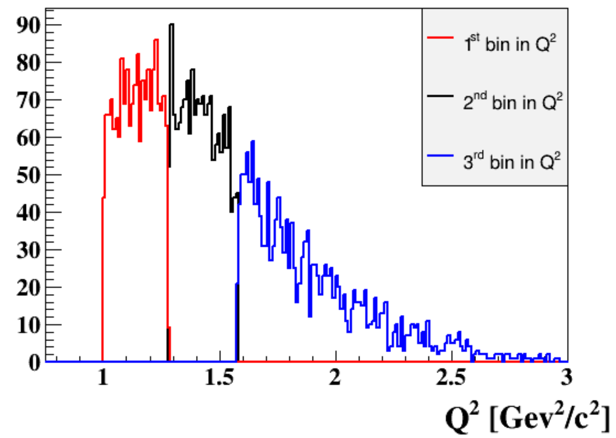


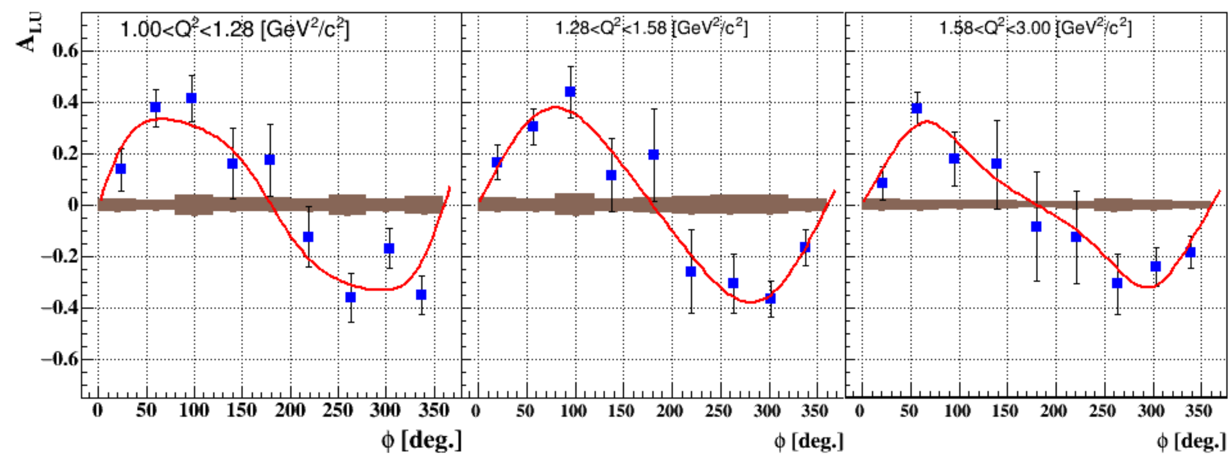


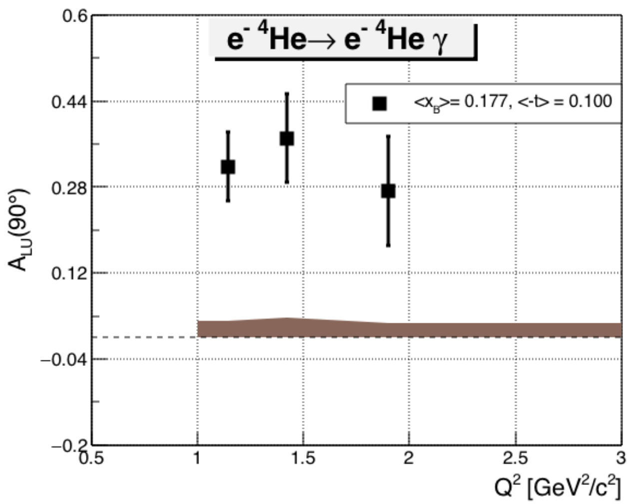
5.1% global systematic uncertainties

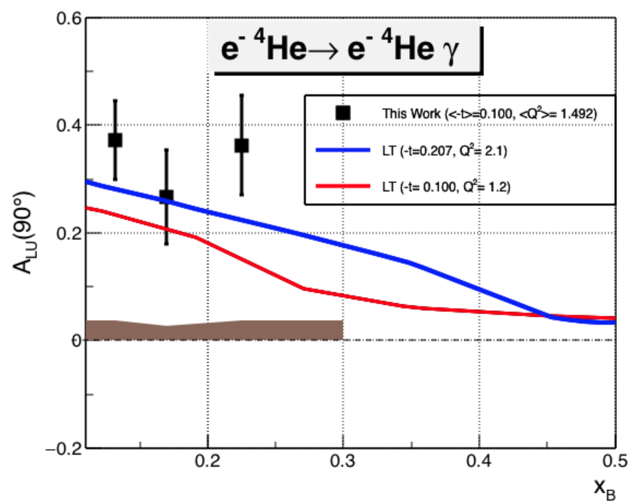
Coherent beam-spin asymmetries

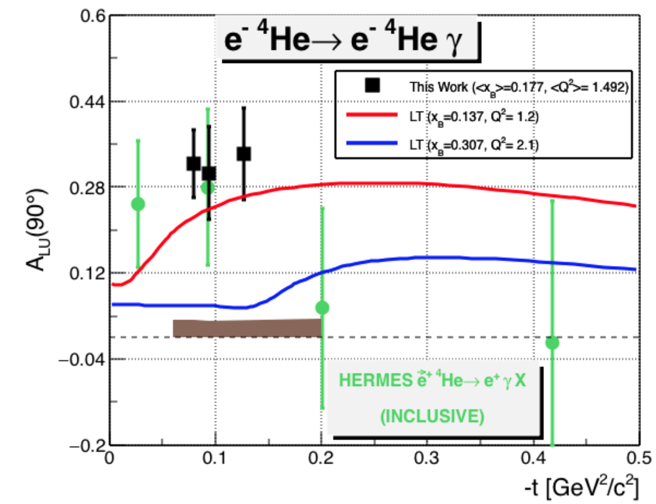
- Due to statistical constraints, we construct 2D bins -t or x_B or Q^2 versus φ
- Fit A_{LU} signals: $\alpha * \sin(\phi)/(1+\beta * \cos(\phi)+\eta * \cos(2\phi))$











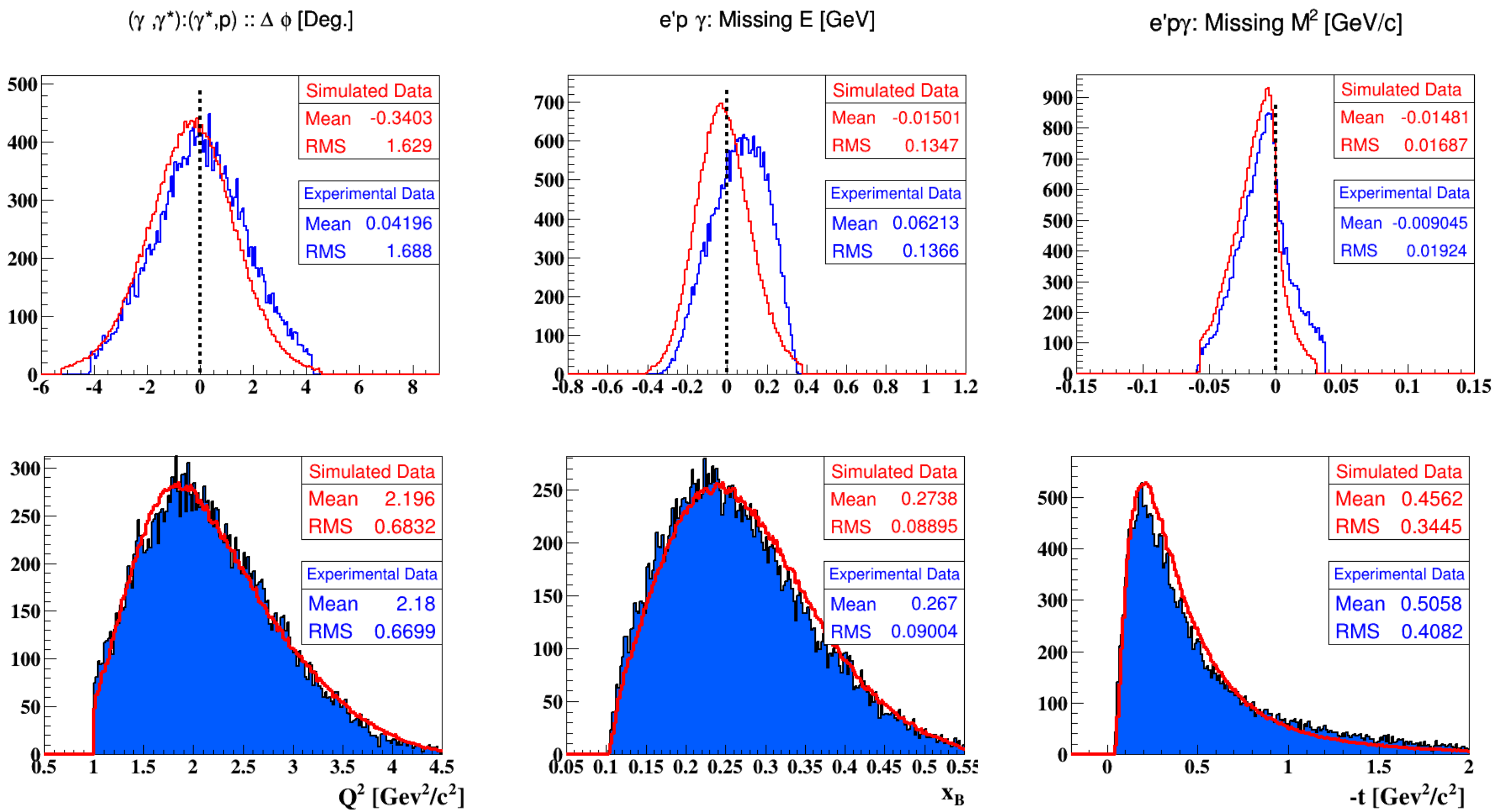
LT: S. Liuti and S. K. Taneja, PRC 72 (2005) 034902.
HERMES: A. Airapetian, et al., Phys. Rev. C 81, 035202 (2010).

Incoherent DVCS events selection

◊ Only one e⁻, at least 1γ and only one good p.

◊ Eγ > 2 GeV, W > 2 GeV/c^2 and Q^2 > 1 GeV².

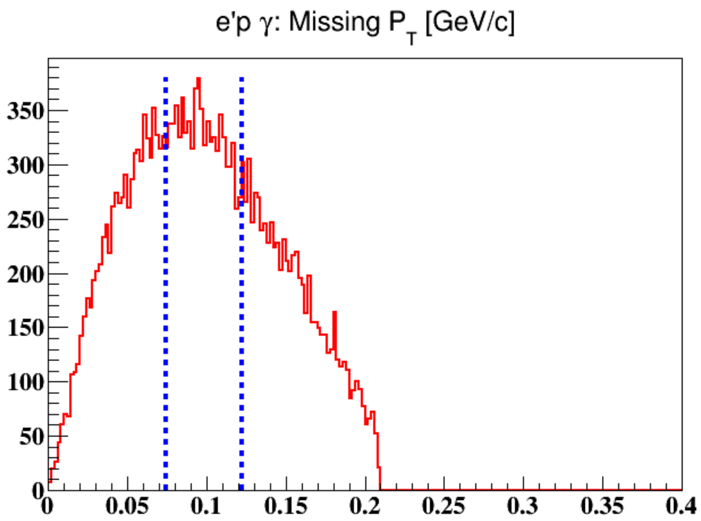
◊ Exclusivity cuts (3 sigmas).

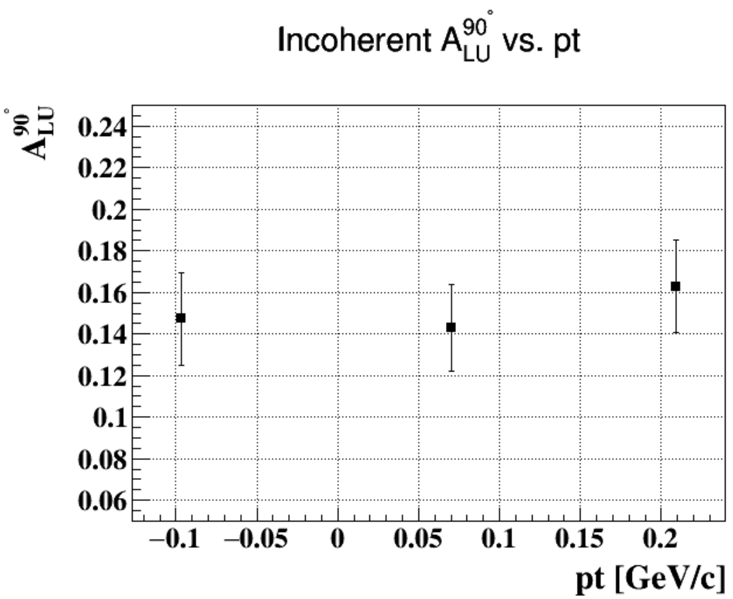


Incoherent checking: FSI

- The previously presented checks for the coherent DVCS were performed on the incoherent channel with similar conclusions. Additional effects may affect the incoherent rather than the coherent, such as the final state interactions.

Check: construct bins in the missing p_T ->> watch the reconstructed asymmetries.

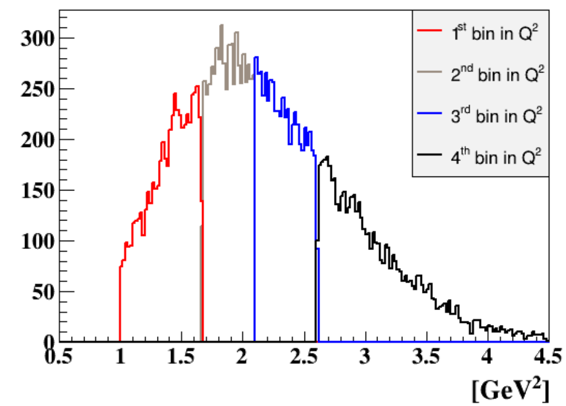


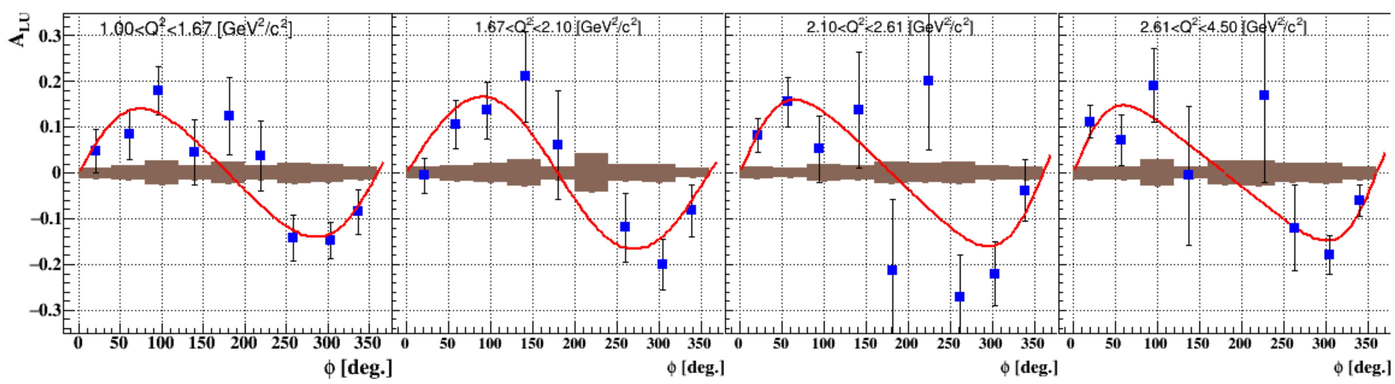


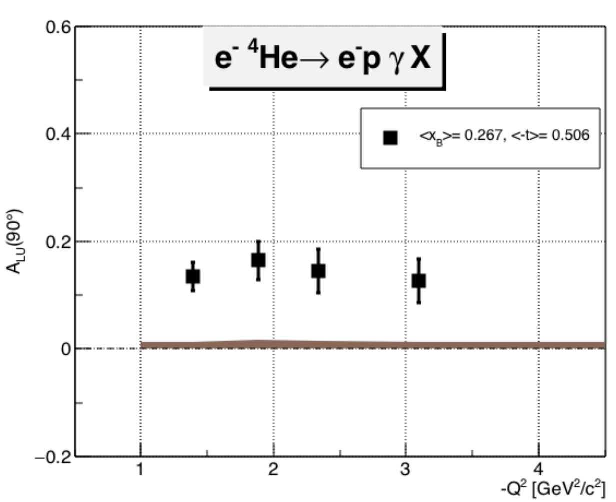
The incoherent asymmetries are consistent and so the FSI seem to have no big effects on the measured asymmetries

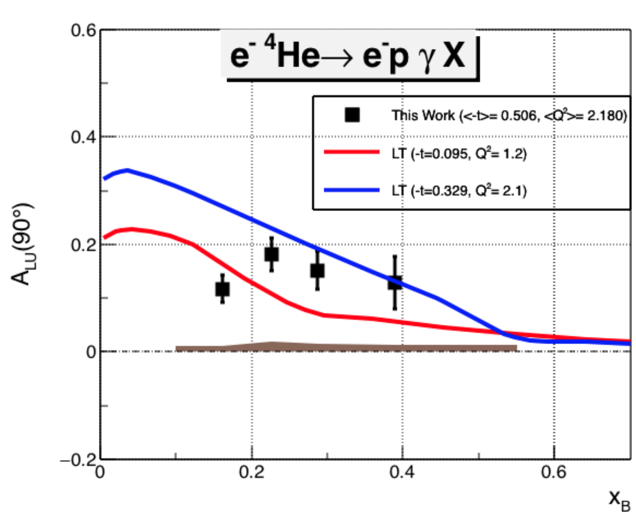
Incoherent beam-spin asymmetries

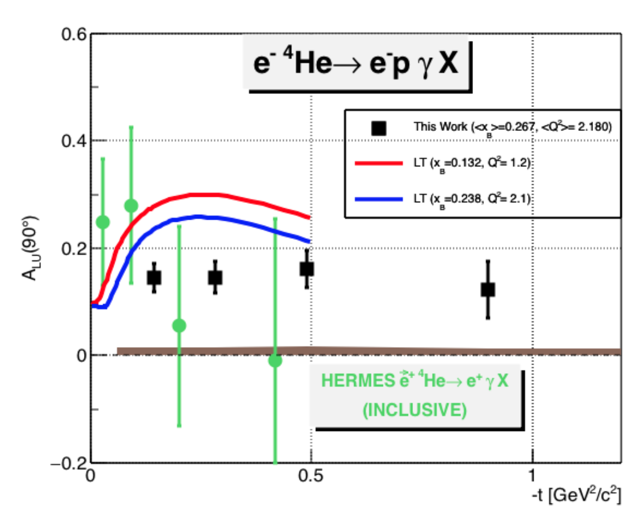
Q² of epγ events







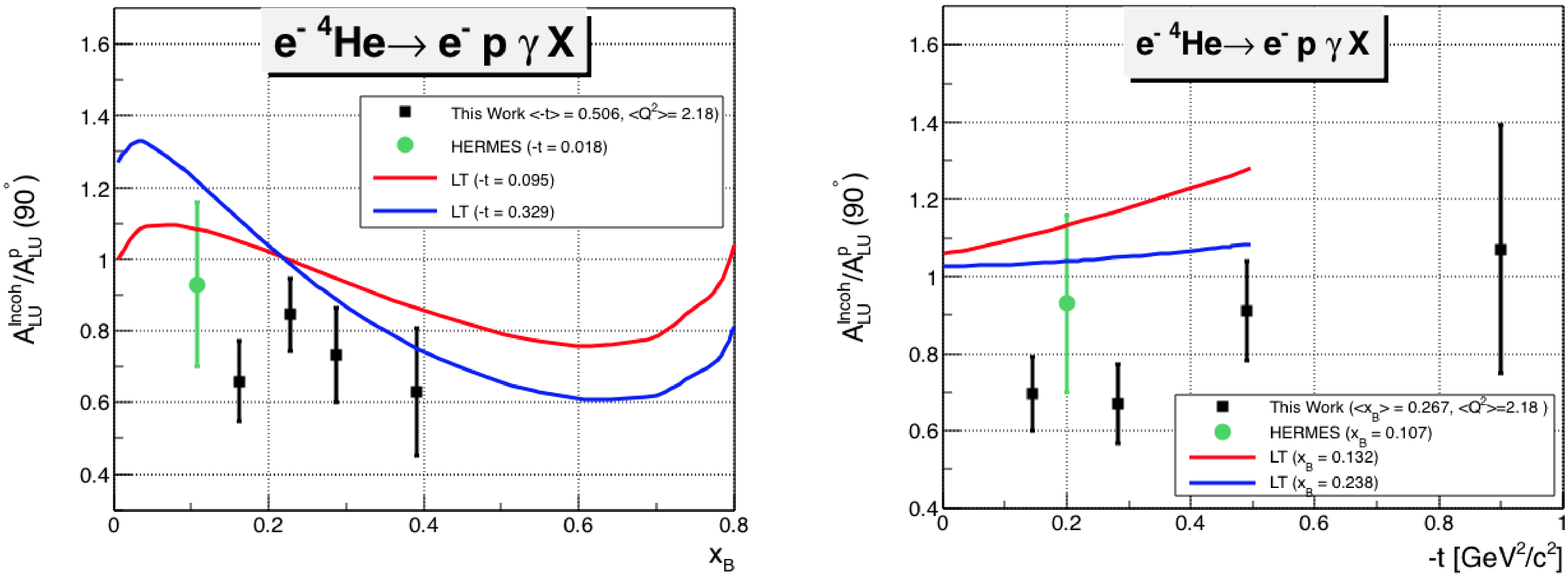




[1] LT: S. Liuti and S. K. Taneja.Phys. Rev., C72:032201, 2005.
[2] A. Airapetian, et al., Phys Rev. C 81, 035202 (2010).

EMC ratio (1/2)

◊ Comparing our measured incoherent asymmetries with the asymmetries measured in CLAS DVCS experiment on the proton.



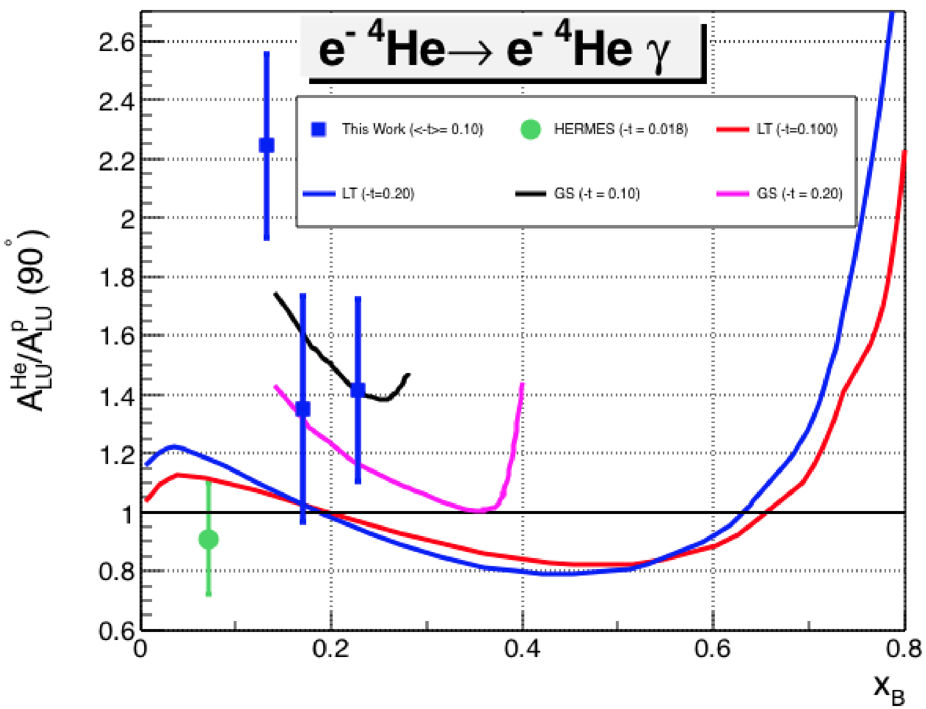
◊ The bound proton shows a lower asymmetry relative to the free one in the different bins in x_B.

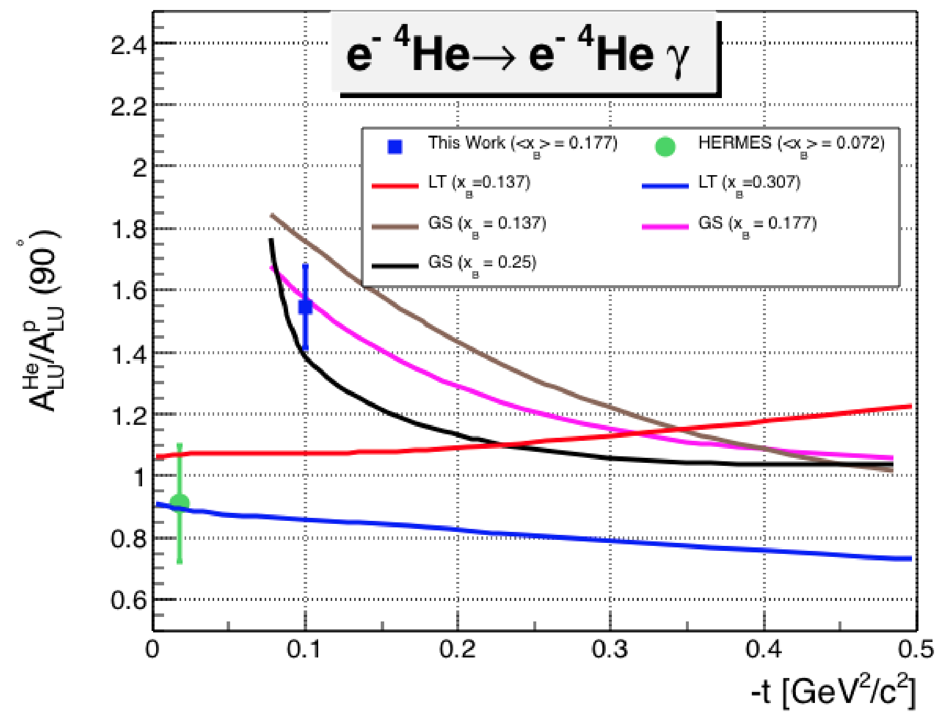
◊ At small -t, the bound proton shows lower asymmetry than the free one.

◊ At high -t, the two asymmetries are compatible.

EMC ratio (2/2)

◊ Comparing the coherent asymmetries to the free proton ones:





→ Consistent with the enhancement predicted by the Impulse approximation model [V. Guezy et al., PRC 78 (2008) 025211]

→ Does not match the inclusive measurement of HERMES.

→ Additional nuclear effects have to be taken into account in the nuclear spectral function calculations. [S. Liuti and K. Taneja. PRC 72 (2005) 032201]

Conclusions

◊ CLAS – E08-024 experiment:

→ The first exclusive measurement of DVCS off ^{4}He.

→ The coherent DVCS shows a stronger asymmetry than the free proton as was expected from theory.

→ We extracted EMC ratios and compared them with theoretical predictions.

→ The bound proton has shown a different trend compared to the free one indicating the medium modifications of the GPDs.

◊ Perspectives:

→ Final results soon

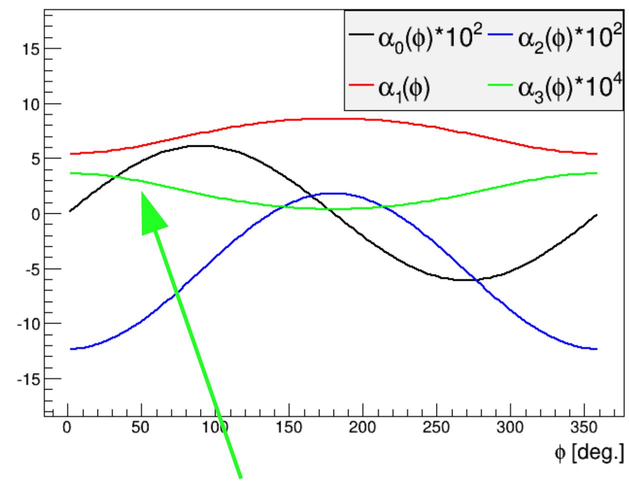
→ We will need 12 GeV Jlab to obtain better statistics and wider kinematic coverage.

He-4 CFF extraction

$$A_{LU}(\phi) = \frac{\alpha_0(\phi) * Im(\mathcal{H}_A)}{\alpha_1(\phi) + \alpha_2(\phi) Re(\mathcal{H}_A) + \alpha_3(\phi)(Im(\mathcal{H}_A)^2 + Re(\mathcal{H}_A)^2)}$$

$$\begin{aligned} \alpha_0(\phi) &= a \sin(\phi) \\ \alpha_1(\phi) &= b + c\cos(\phi) + d\cos(2\phi) \\ \alpha_2(\phi) &= h + f\cos(\phi) \end{aligned}$$

Expected to be small magnitude



Suppressed by 2 orders of magnitude

- Using the kinematical calculable factors (a, b, c, h and f) and the fitted coherent

$$p_0 * \sin(\phi) / (1 + p_1 * \cos(\phi))$$

→ Extracted the real and the imaginary parts of the Compton form factor from ALU @ 90° vs. <-t>

- We have "significant" trends with t and xB