Argonne NATIONAL LABORATORY

Jefferson Lab PAC 44

Nuclear Exclusive and Semi-inclusive Measurements with a New CLAS12 Low Energy Recoil Tracker

Partonic Structure of Light Nuclei

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NPWG - CLAS Collaboration Meeting - Friday, 17 June 2016

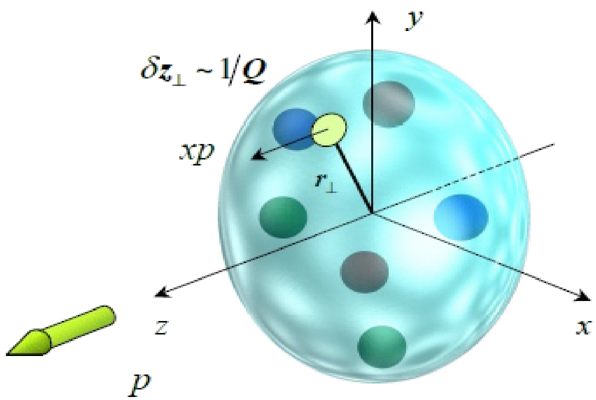
U.S. DEPARTMENT OF ENERGY

Physics motivations

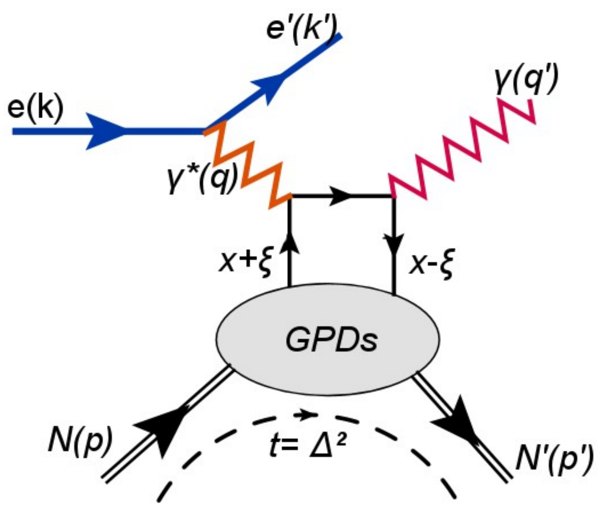
- **Generalized Parton Distributions (GPDs)**

  - Contain information on:

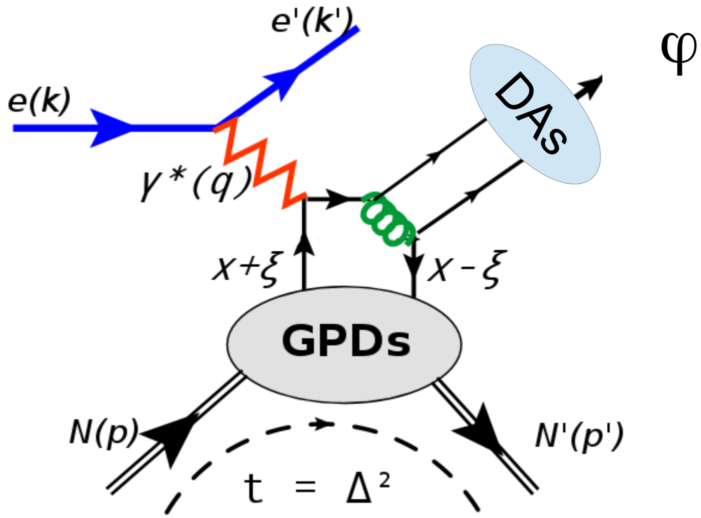
  → Correlation between quarks and anti-quarks
  → Correlation between longitudinal momentum and transverse spatial position of partons



  - Can be accessed via exclusive processes:



Deeply Virtual Compton Scattering



Deeply Virtual Meson Production

Access charge profiles

Access gluon profiles

Nuclear spin-zero DVCS observables

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

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

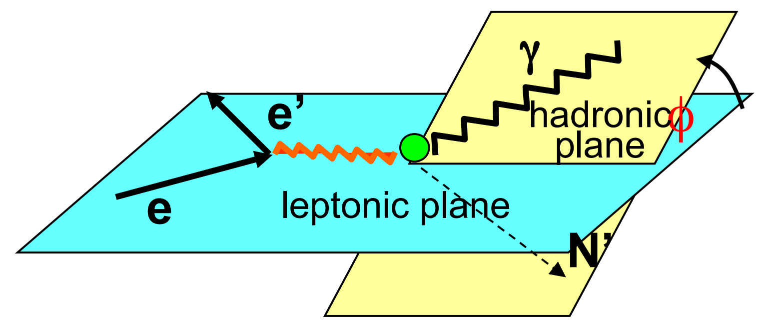
$$Im(\mathcal{H}_A(\xi,t)) = H_A(\xi,\xi,t) - H_A(-\xi,\xi,t)$$

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

Quark propagator

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

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



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

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

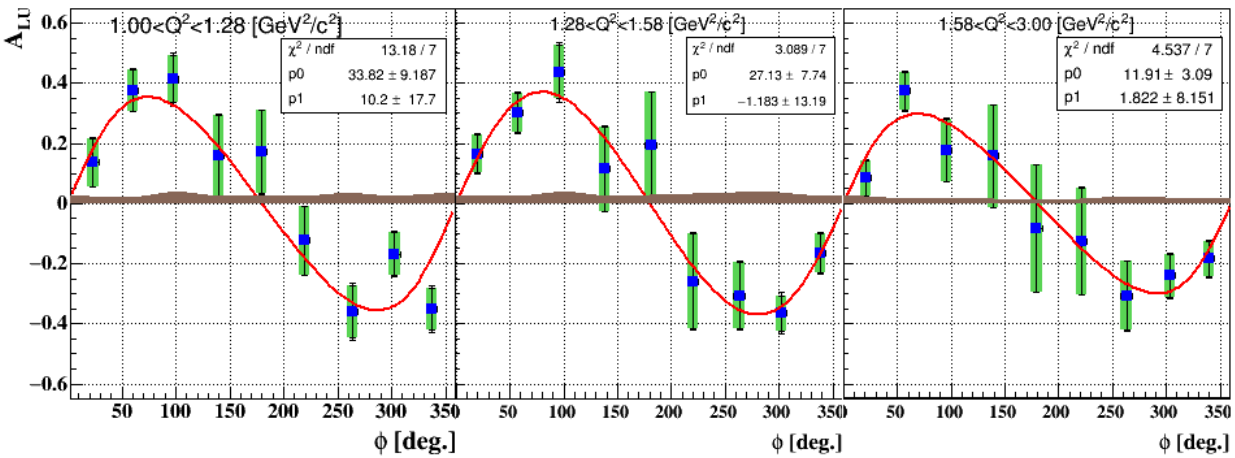
CLAS-E08-024 coherent A_{LU}

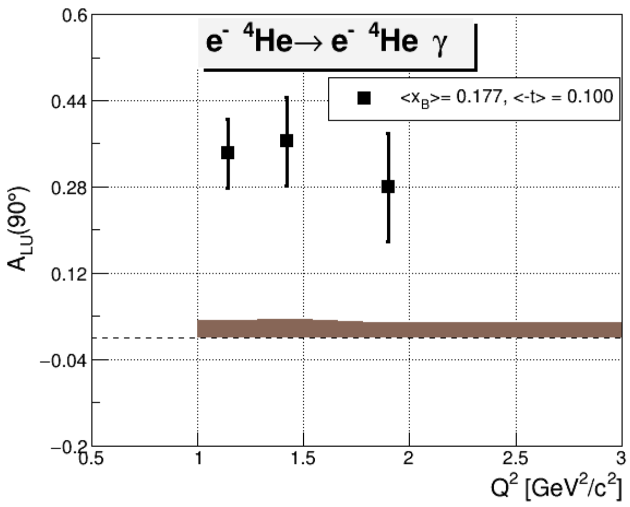
$e^- \, {}^4He \rightarrow e^- \, {}^4He \, \gamma$

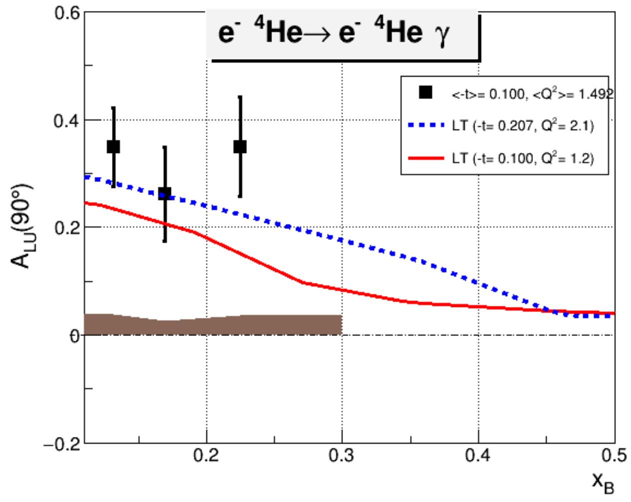
6 GeV, L. polarized

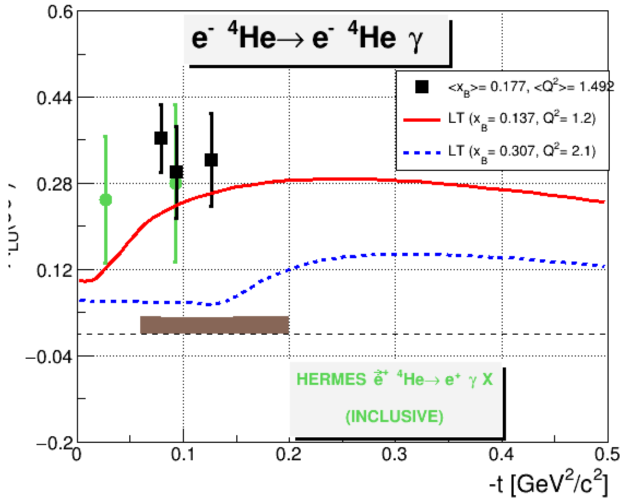
Beam polarization (P_B) = 83%

- Due to statistical constraints, we construct 2D bins -t or x_B or Q^2 versus φ.







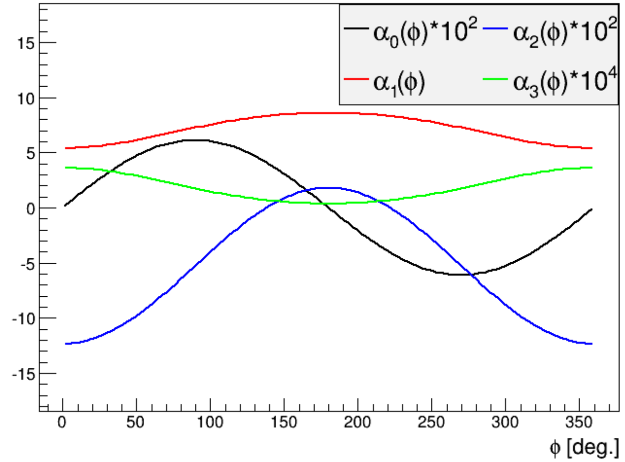


LT: S. Liuti and S. K. Taneja, PRC 72 (2005) 034902.
HERMES: A. Airapetian, et al., Phys. Rev. C 81, 035202 (2010).

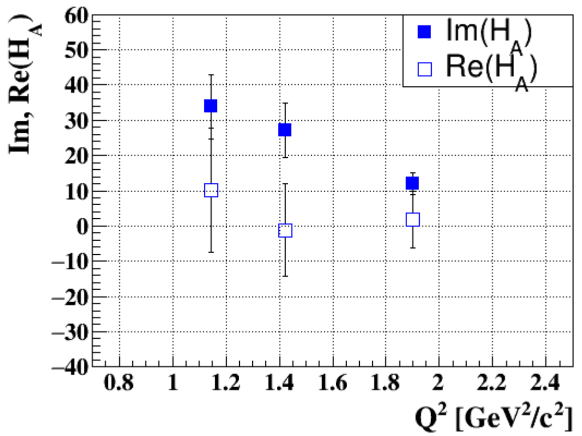
He-4 CFF extraction

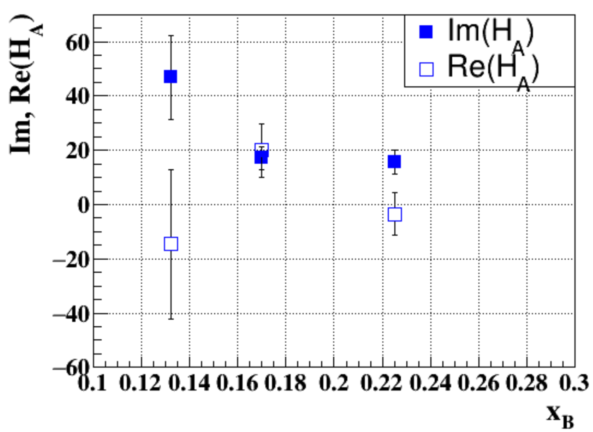
$$A_{LU}(\phi) = \frac{\alpha_0(\phi)\,\Im m(\mathcal{H}_A)}{\alpha_1(\phi) + \alpha_2(\phi)\,\Re e(\mathcal{H}_A) + \alpha_3(\phi)\left(\Re e(\mathcal{H}_A)^2 + \Im m(\mathcal{H}_A)^2\right)}$$

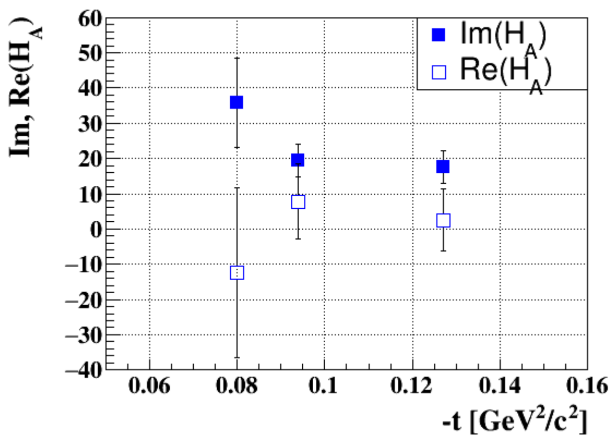
$$\begin{aligned}
\alpha_0(\phi) &= \frac{x_A(1+\varepsilon^2)^2}{y} S_{++}(1)\sin(\phi) \\
\alpha_1(\phi) &= c_0^{BH} + c_1^{BH}\cos(\phi) + c_2^{BH}\cos(2\phi) \\
\alpha_2(\phi) &= \frac{x_A(1+\varepsilon^2)^2}{y}\left(C_{++}(0) + C_{++}(1)cos(\phi)\right) \\
\alpha_3(\phi) &= \frac{x_A^2 t(1+\varepsilon^2)^2}{y}\mathcal{P}_1(\phi)\mathcal{P}_2(\phi)\cdot 2\frac{2-2y+y^2+\frac{\varepsilon^2}{2}y^2}{1+\varepsilon^2}
\end{aligned}$$



→ The first ever experimental extraction of the real and the imaginary parts of the He-4 CFF:







→ Difference between the precision of the extracted real and imaginary parts; A_{LU} is mostly sensitive to the imaginary part of the CFF HA.

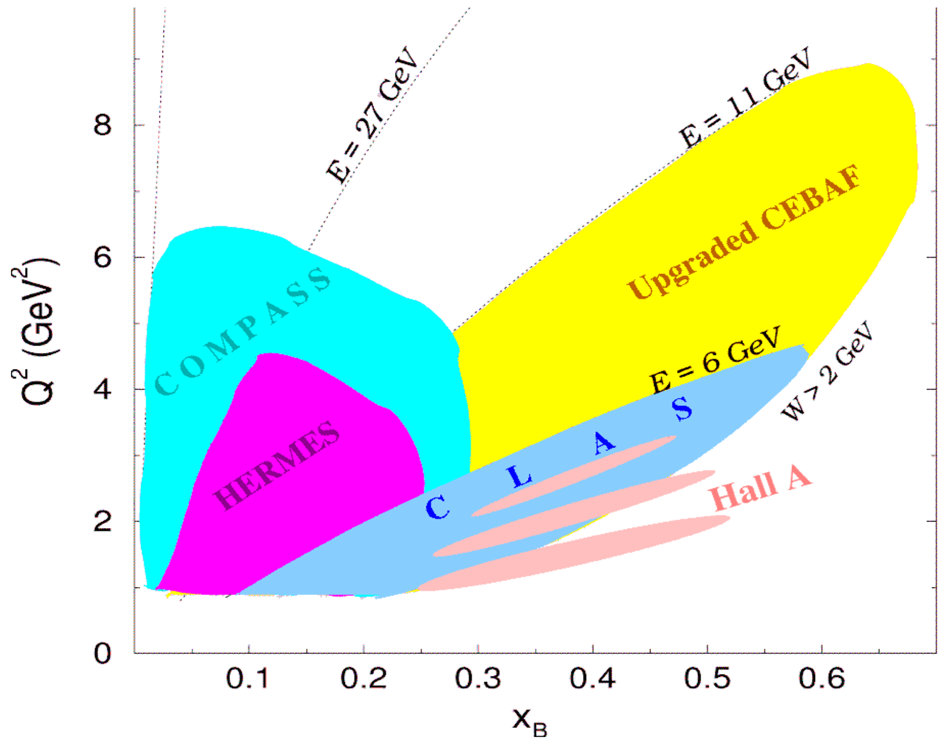
CLAS12-ALERT proposed 11 GeV measurements:

◊ CLAS–E08-024 experiment:
→ 2D binning due to limited statistics and limited phase-space.

◊ We propose to measure:

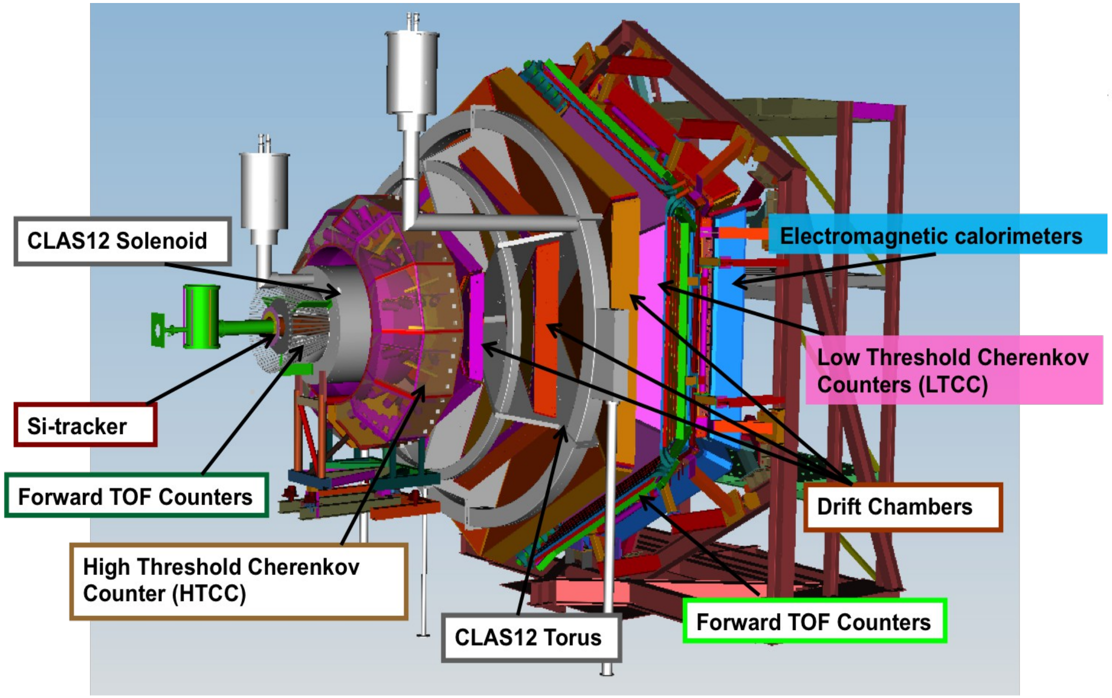
- Partonic Structure of Light Nuclei: Quarks and gluon GPDs
- Tagged DVCS Off Light Nuclei
- Tagged EMC on Light Nuclei

→ CLAS12-ALERT setup will allow higher statistics and wider kinematical coverage
→ 3D binning
→ More precise CFF extractions.

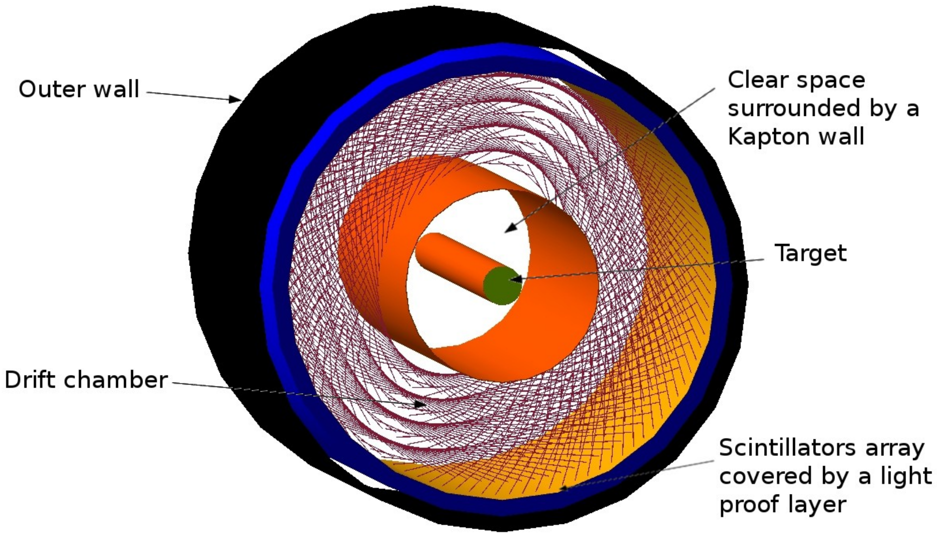


Proposed experimental setup:

CLAS12 detector



ALERT detector



- 300 mm long
- 90 mm diameter

- High luminosity & large acceptance.

- Measurement of deeply virtual exclusive, semi-inclusive, and inclusive processes

→ Can be included in the trigger.

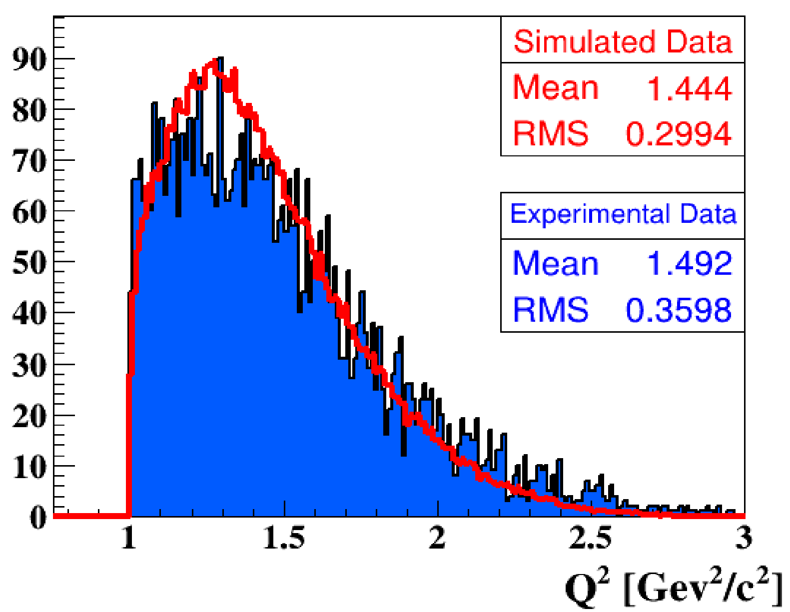
→ Separate protons, deuterium, tritium, alpha, helium-3.

→ Can be used for BoNuS12, tagged EMC and DVCS on He4 ...

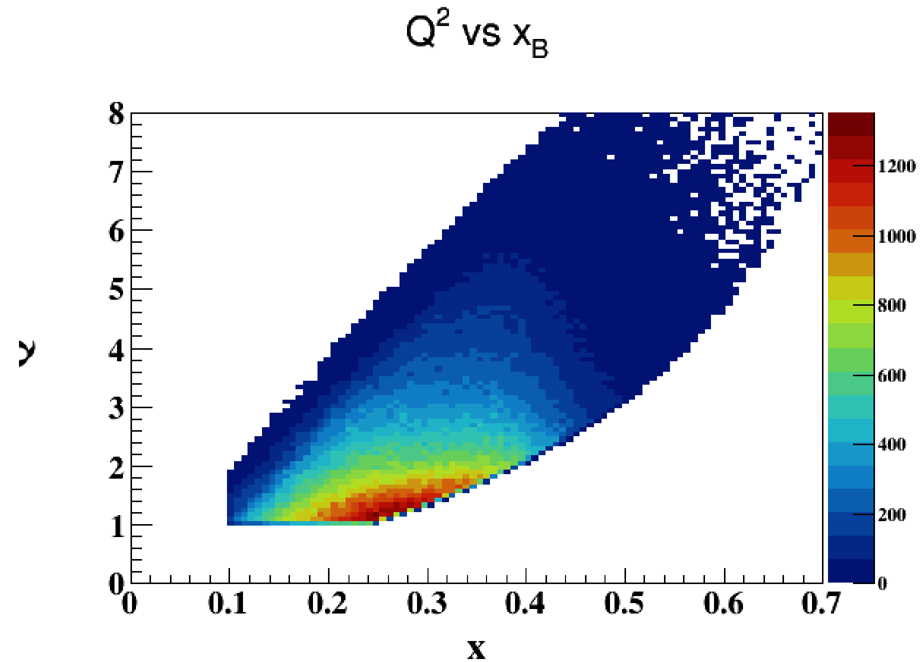
DVCS off He-4: Event generator

we have usCd a parametrization of the cross section which parameters were calibrated to reproduce CLAS-E08-024 data.

$$\frac{d^4\sigma}{dQ^2 dx_B dt d\phi} \propto \left(\frac{Q_0^2}{Q^2}\right)^{\alpha} \frac{1}{1+(\frac{x_B-x_c}{c})^2} \frac{1}{(1+bt)^{\beta}} (1-d(1-cos(\phi)))$$



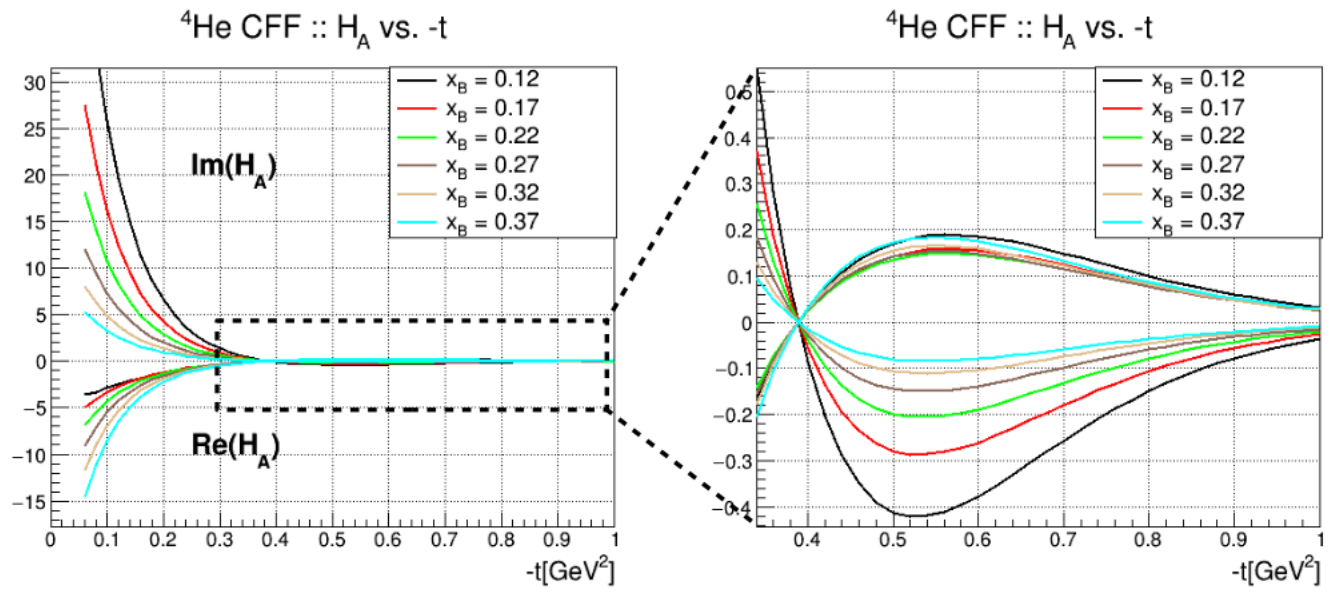
6 GeV comparison



Projected 11 GeV phase-space

DVCS off He-4: CFFs and proposed binning

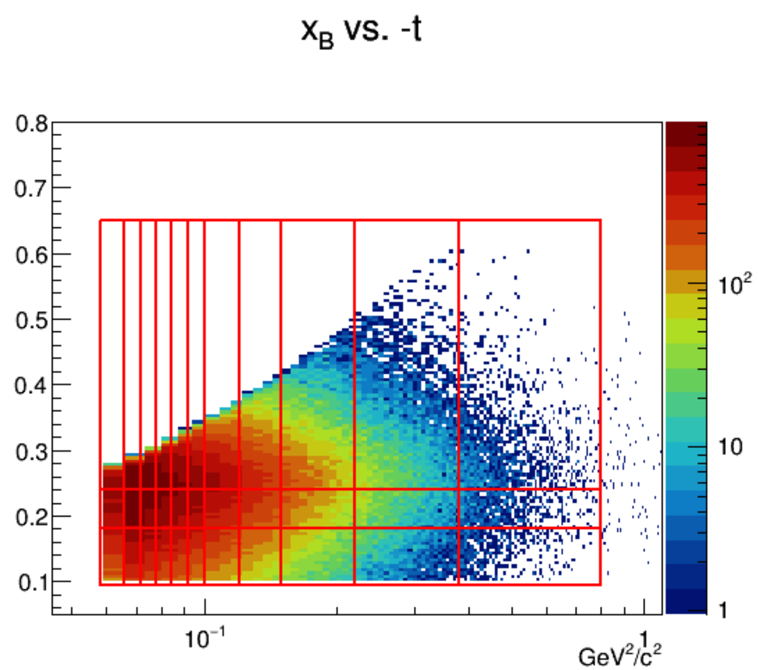
Fed CFFs from IA calculations



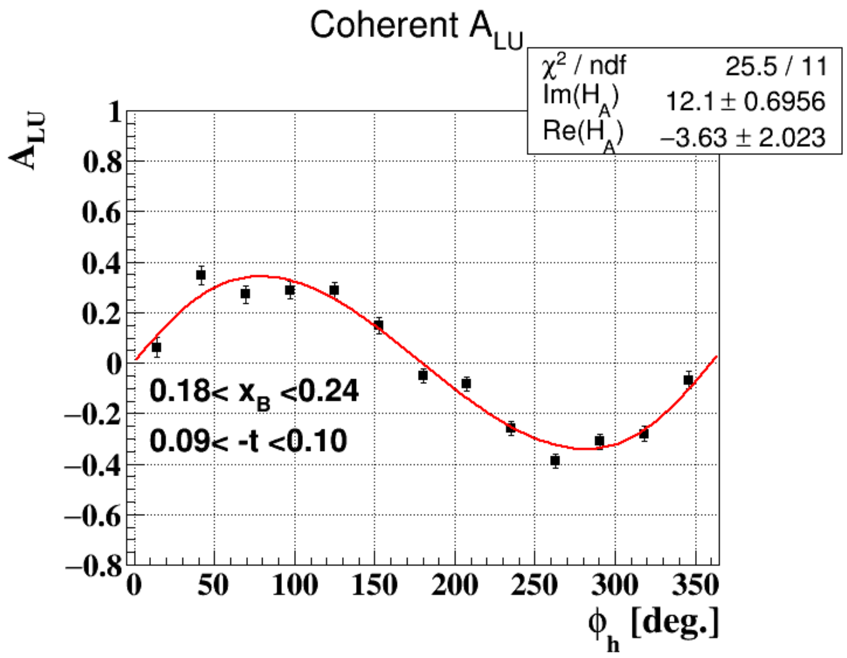
Binning data

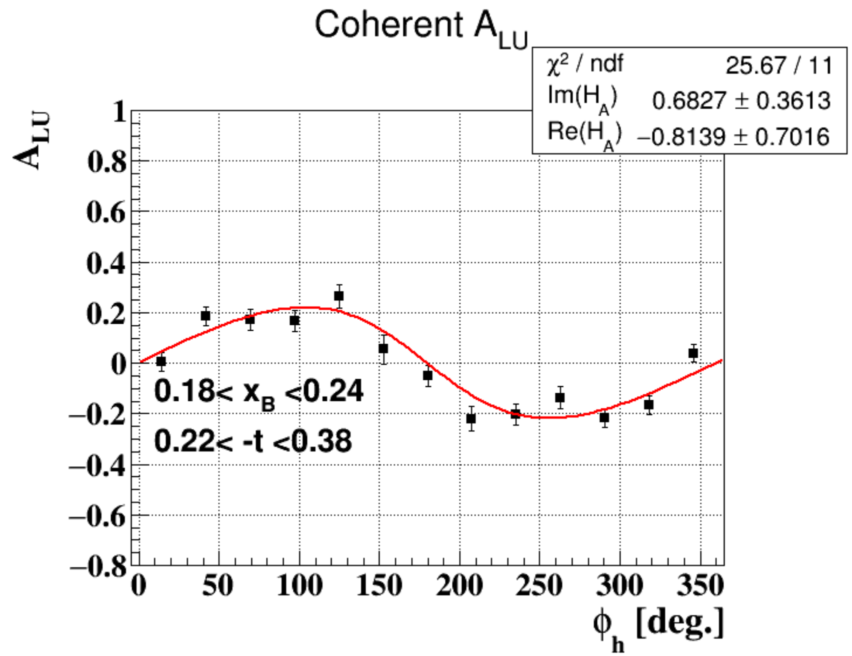
The statistical error bars are calculated for:

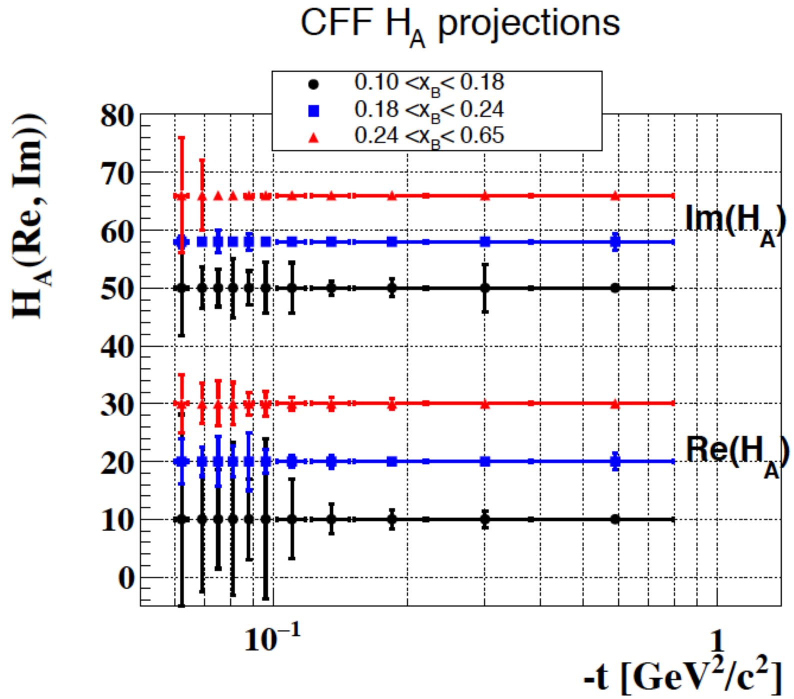
- 20 days at a luminosity of 3.0×10^{34} cm^{-2}s^{-1}.
- 10 days at a luminosity of 6×10^{34} cm^{-2}s^{-1}.

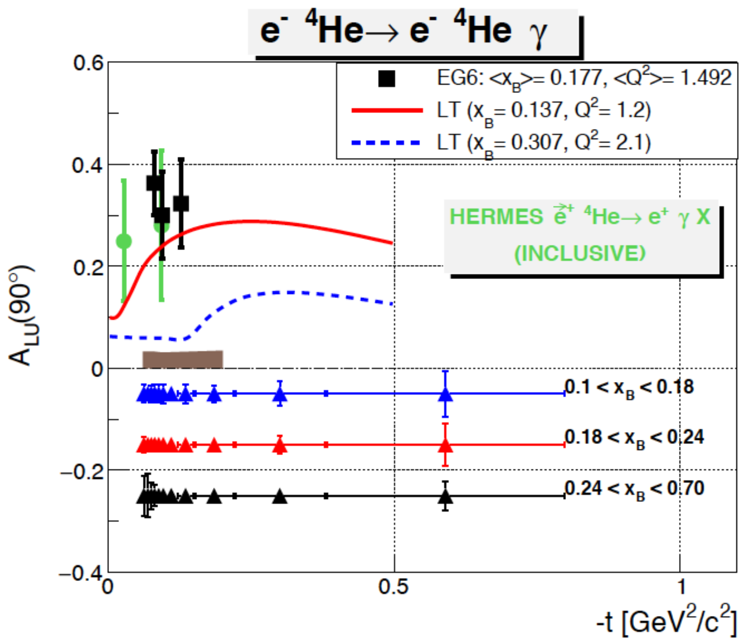


DVCS off He-4: Projected precisions





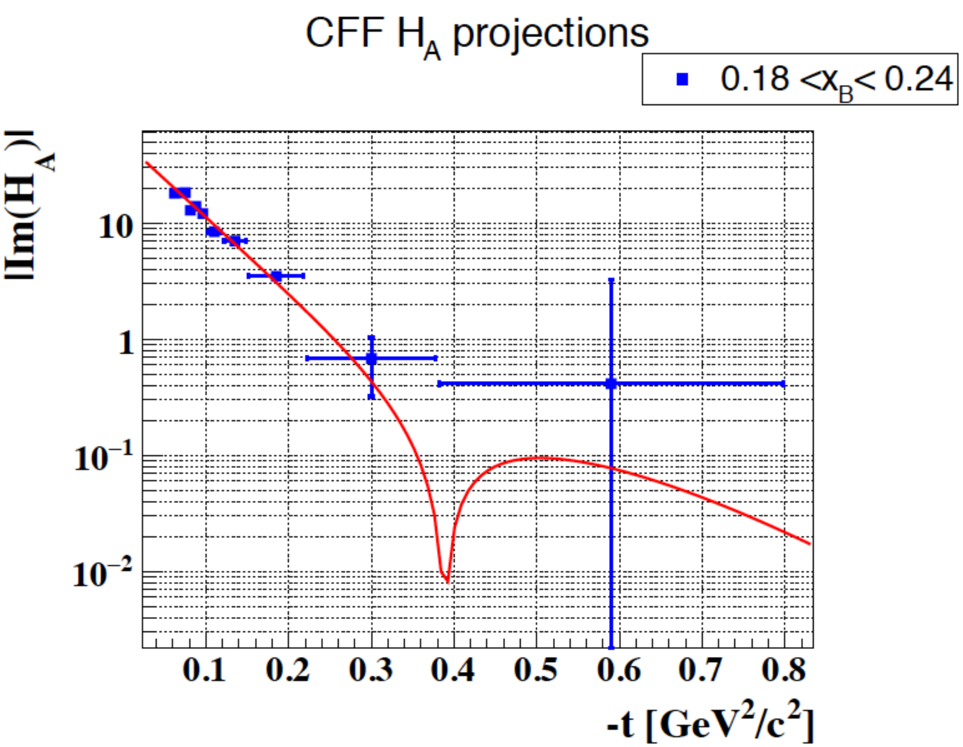


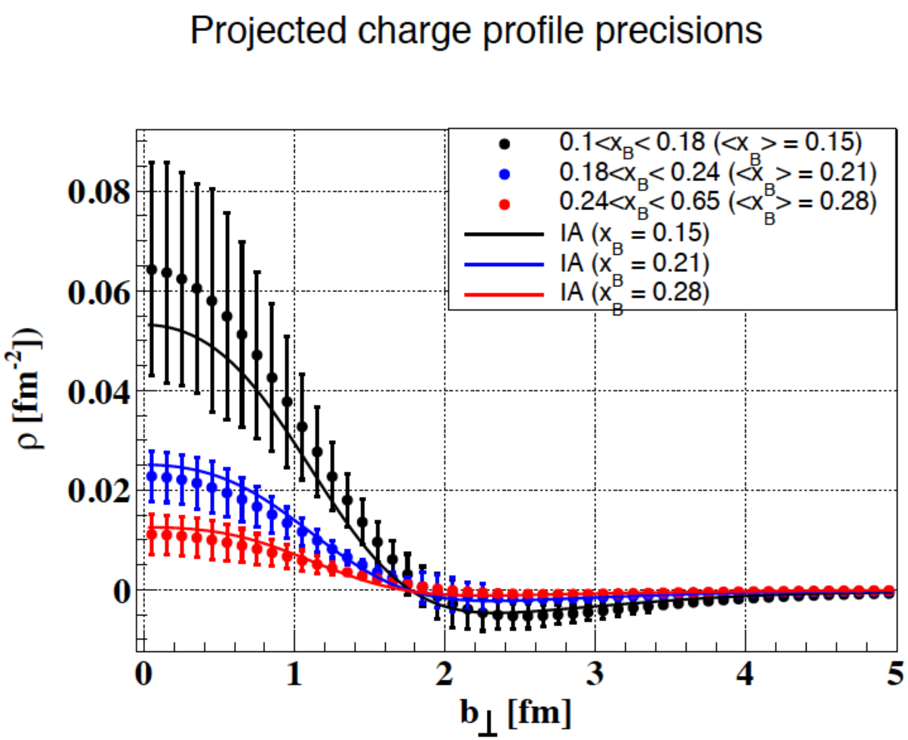


DVCS off He-4: Charge profile extraction

$$\rho(x,0,b_\perp) = \int_0^\infty J_0(b\sqrt{t})H^A(x,0,t)\frac{\sqrt{t}}{2\pi}d\sqrt{t}$$

J_0 is the first order cylindrical Bessel function.



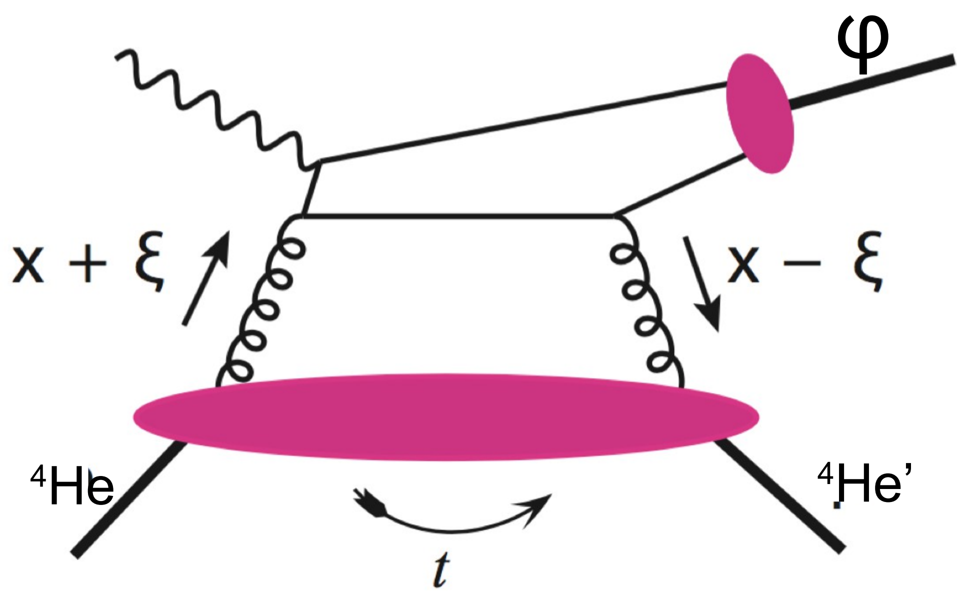


φ production off He-4: Gluon profiles

Φ production FF → (Hankel transform) → Gluon density

$$\rho_g(x,0,b_\perp) = \int_0^\infty J_0(b\sqrt{t}) H_g(x,0,t) \frac{\sqrt{t}}{2\pi} d\sqrt{t}$$

J_0 is the first order cylindrical Bessel function.



Production of mostly strange phi-meson off a mostly up-down nucleus favors a gluon exchange mechanism.

$$e + {}^4He \rightarrow e' + {}^4He + \phi$$
$$\hookrightarrow K^+ + K^-$$

Detect recoil ^{4}He', e', and K^+ (missing K^-)

φ production off He-4: Gluon profiles

Φ production FF —Hankel transform→ Gluon density

$$\rho_g(x,0,b_\perp) = \int_0^\infty J_0(b\sqrt{t})H_g(x,0,t)\frac{\sqrt{t}}{2\pi}d\sqrt{t}$$

J_0 is the first order cylindrical Bessel function.

$$\frac{d\sigma_L}{dt}(\text{proton}) = \frac{\alpha_{em}}{Q^2}\frac{x_B^2}{1-x_B}[(1-\xi^2)|\langle H_g\rangle|^2 + \text{terms in}\langle E_g\rangle]$$

Proton case (See CLAS12 approved PR12-12-007)

φ production off He-4: Gluon profiles

Φ production FF → Hankel transform → Gluon density

$$\rho_g(x,0,b_\perp) = \int_0^\infty J_0(b\sqrt{t})H_g(x,0,t)\frac{\sqrt{t}}{2\pi}d\sqrt{t}$$

J_0 is the first order cylindrical Bessel function.

$$\frac{d\sigma_L}{dt}(\text{proton}) = \frac{\alpha_{em}}{Q^2}\frac{x_B^2}{1-x_B}[(1-\xi^2)|\langle H_g\rangle|^2 + \text{terms in}\langle E_g\rangle] \longrightarrow \frac{d\sigma_L}{dt}(^4\text{He}) \propto |\langle H_g\rangle|^2$$

Proton case (See CLAS12 approved PR12-12-007)

4He case (this proposal)

Gluon density calculation:

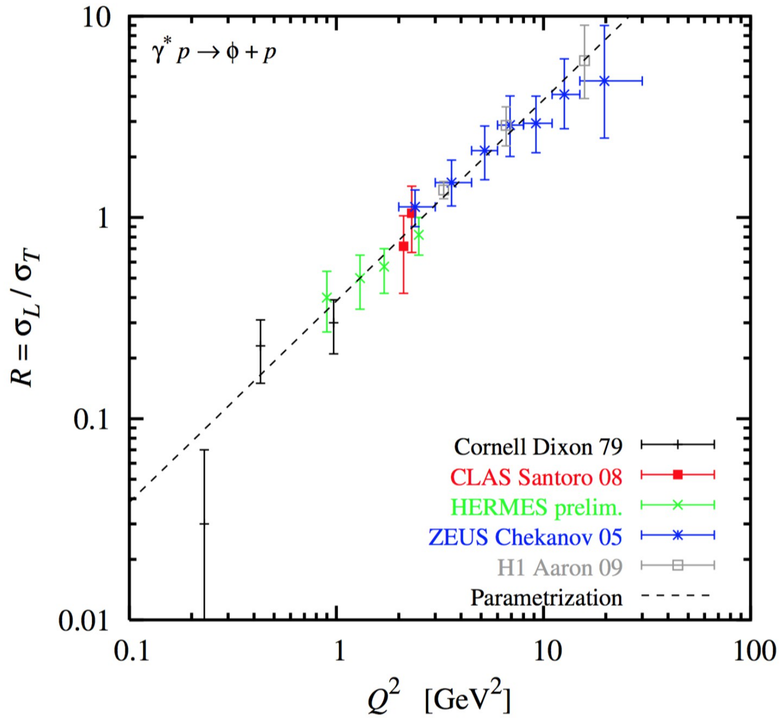
$$\rho_g(x,0,b_\perp) \to \int_0^\infty J_0(b\sqrt{t})\sqrt{\frac{d\sigma_L}{dt}}\frac{\sqrt{t}}{2\pi}d\sqrt{t}$$

Need longitudinal differential cross-section

φ off He-4: Longitudinal cross-section calculation

Total cross-section for phi production:

$$\frac{d^3\sigma}{dx_B\,dQ^2\,dt} = \Gamma(x_B, Q^2, E)\left(\frac{d\sigma_T}{dt}(W, Q^2, t) + \varepsilon\frac{d\sigma_L}{dt}(W, Q^2, t)\right)$$



Phi production data (proton)

Plot from PR12-12-007

$$R = \frac{\sigma_L}{\sigma_T} \longrightarrow \frac{d\sigma_L}{dt} = R\frac{d\sigma_T}{dt}$$

Once you calculate R, you can extract the longitudinal cross-section:

$$\frac{d\sigma_L}{dt} = \frac{1}{(\varepsilon + 1/R)\Gamma(Q^2, x_B, E)}\frac{d^3\sigma}{dQ^2 dx_B dt}$$

φ off He-4: Calculating R

R can be extracted from the angular distribution of the kaon decay
In the phi helicity frame, assuming s-channel helicity conservation:

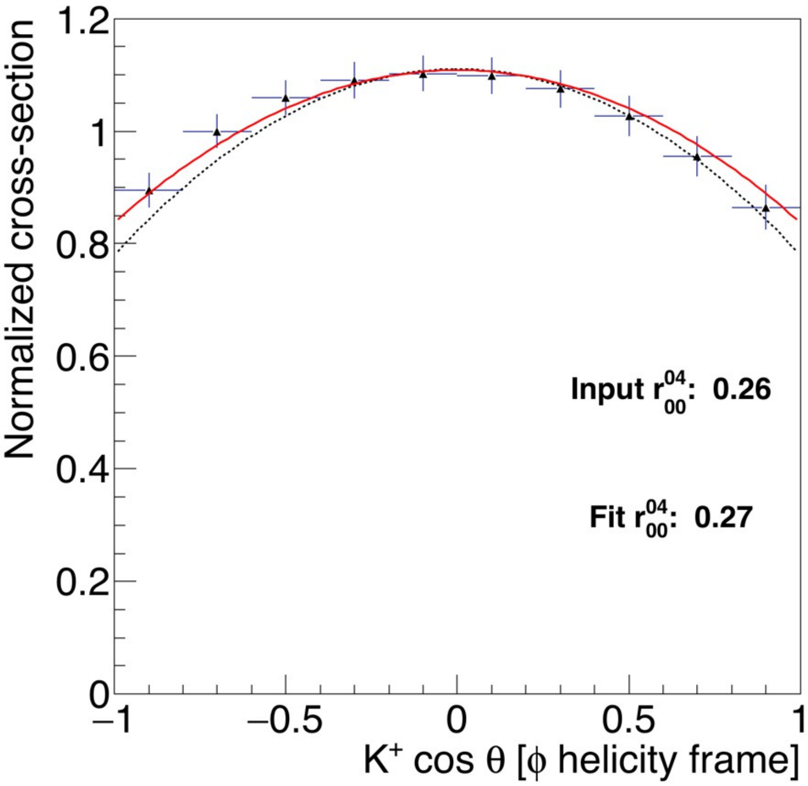
$$W(\cos\theta_H) = \frac{3}{4}\left[(1 - r^{04}_{00}) + (3r^{04}_{00} - 1)\cos^2\theta_H\right]$$

Angular distribution amplitude

Spin-density matrix coefficient:

$$r^{04}_{00} = \frac{\epsilon R}{1 + \epsilon R}$$

Angle of kaon decay In phi helicity frame

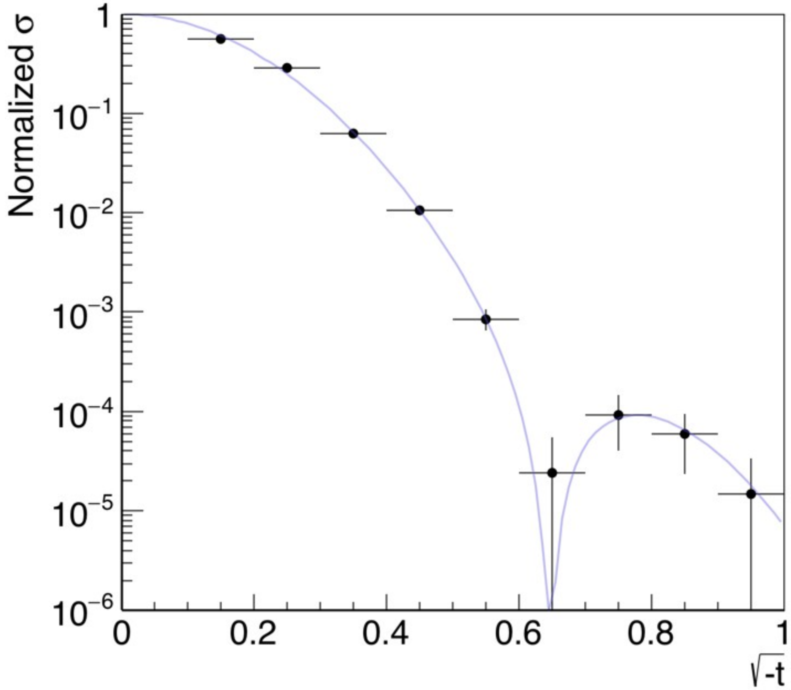


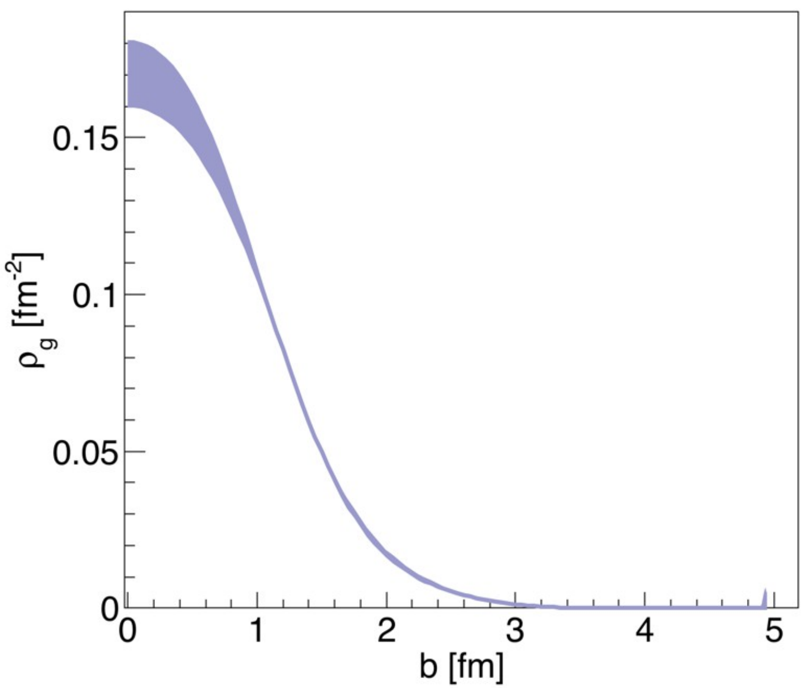
Example fit to angular distribution
To extract R

φ off He-4: Calculating the gluon density

The longitudinal cross-section can be normalized to t' = 0 and the Hankel transformation can be applied.

$$\rho_g(x,0,b_\perp) \to \int_0^\infty J_0(b\sqrt{t})\sqrt{\frac{d\sigma_L}{dt}}\frac{\sqrt{t}}{2\pi}d\sqrt{t}$$

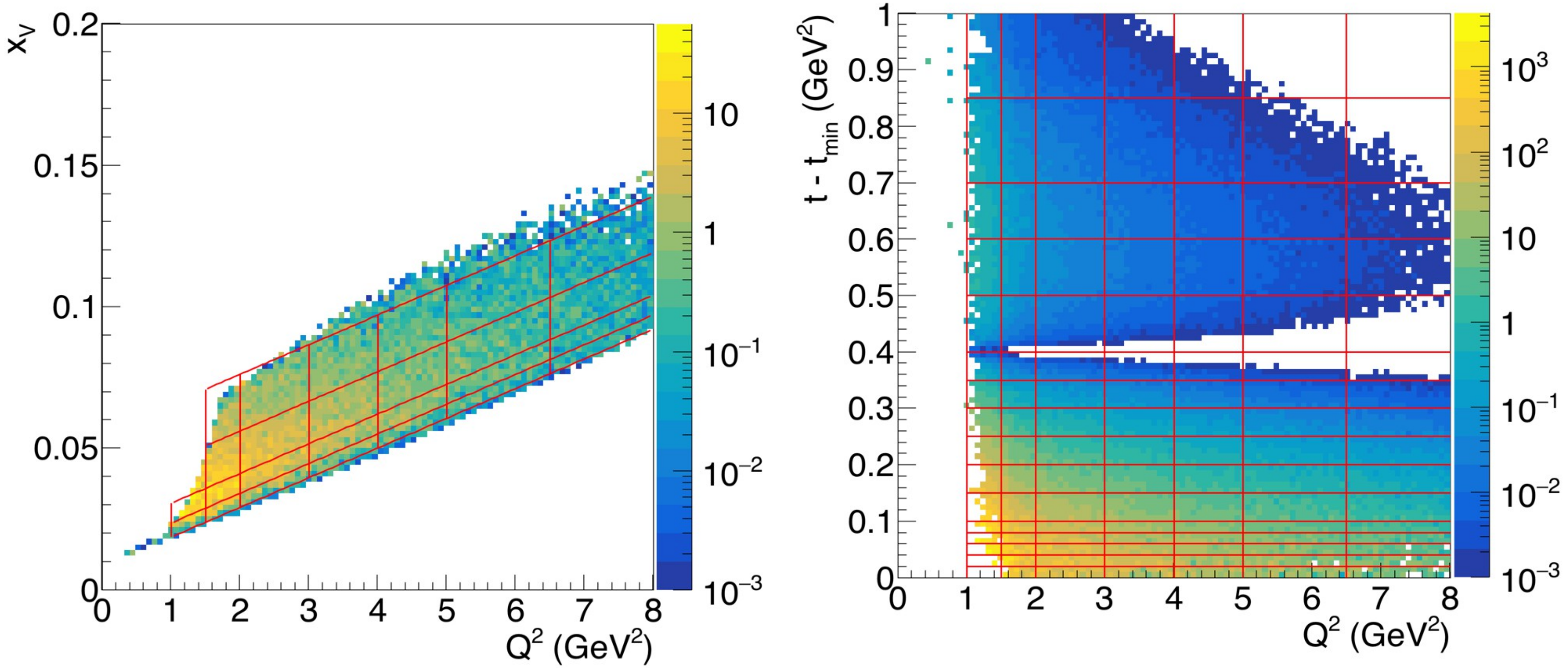




High statistics bin: $0.18 < x_{Vp} < 0.25$, $2.0 < Q^2 < 3.0$ GeV^2

φ off He-4: Proposed binning

Density will be extracted over a number of bins in x, and Q2.



A possible binning in the kinematic phase-space. Z-axis is simulated cross-section

Conclusions

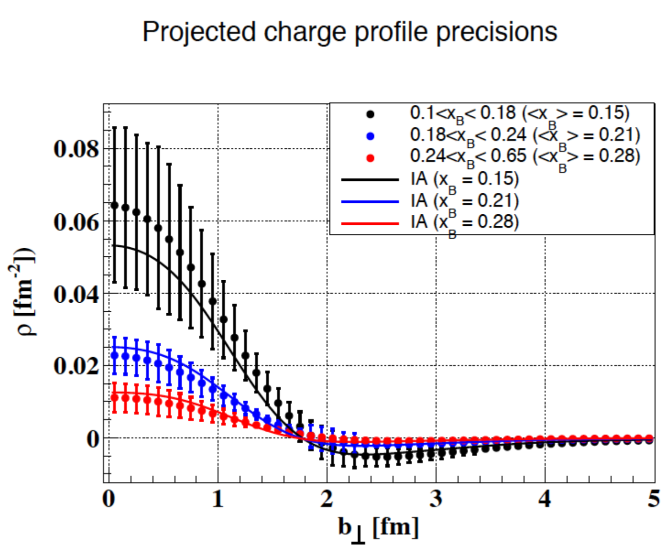
◊ We propose new generation nuclear physics experiments to extract quarks' and gluons' GPDs of He-4 using CLAS12 detector that will be upgraded with a low energy recoil tracker.

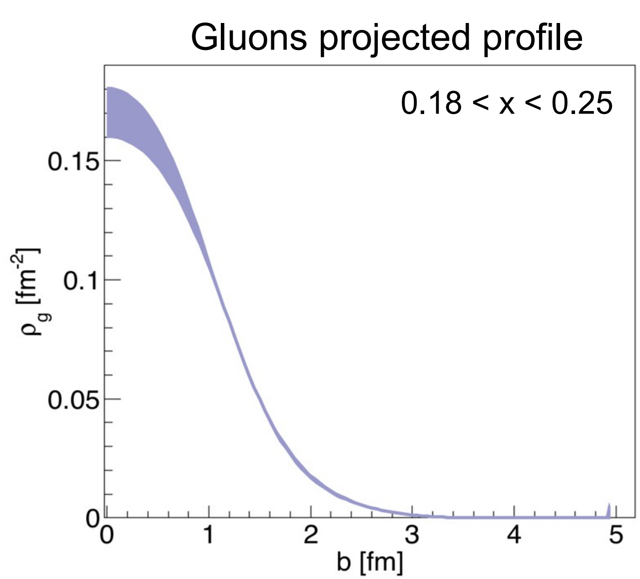
◊ We request 20 days of running at a luminosity of 3.0 X 10^{34} $cm^{-2}s^{-1}$ and 10 days at a luminosity of 6 X 10^{34} $cm^{-2}s^{-1}$.

◊ Wider kinematical coverage and better statistics that will allow 3D binnings for both the DVCS and DVMP channels

> Will allow model independent extractions of the charge and the gluon densities of He-4.

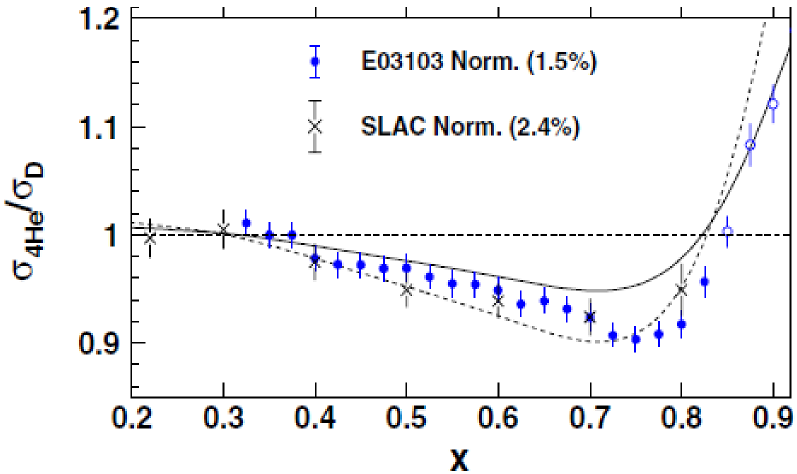
> The profiles of quarks and gluons will be compared at similar x values.





EMC effect in He-4

EMC effect: the modification of the PDF f_2 as a function of the longitudinal momentum carried by the struck parton.



[J. Seely, A. Daniel, D. Gaskell, J. Arrington et al., Phys. Rev. Let.: PRL 103, 202301 (2009)]

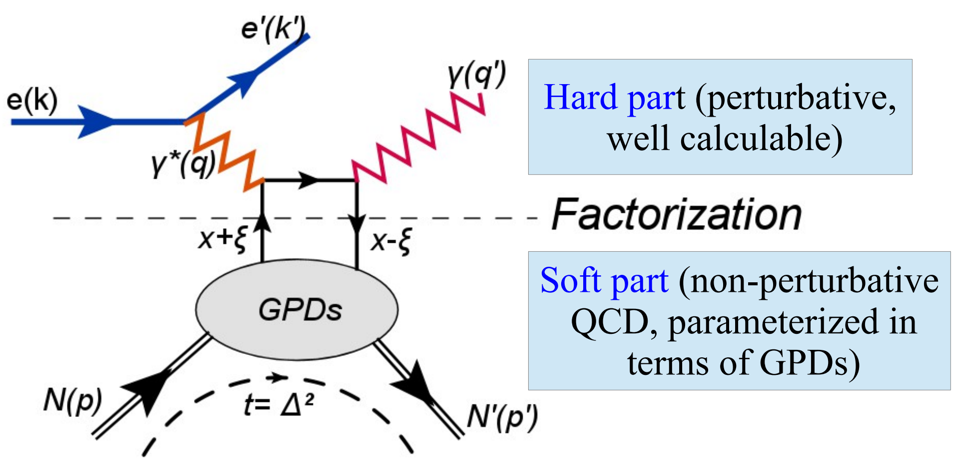
- Nuclear modifications of the DIS cross section measured by CERN, SLAC and JLab
  → Variations with the nuclear properties, i.e. mass & density

- The origin of the EMC effect is still not fully understood, but possible explanations:
  → Modifications of the nucleons themselves
  → Effect of non-nucleonic degrees of freedom, e.g. pions exchange
  → Modifications from multi-nucleon effects (binding, N-N correlations, etc...)

- Clear explanations may arise from measuring the nuclear modifications via measuring the Generalized Parton Distributions.

DVCS reaction

The DVCS can be described, at leading order in $1/Q^2$ (twist-2) and in the coupling constant of QCD (α_s) as:



$$\xi \simeq x_B/(2-x_B),\ x_B = Q^2/2p.q$$

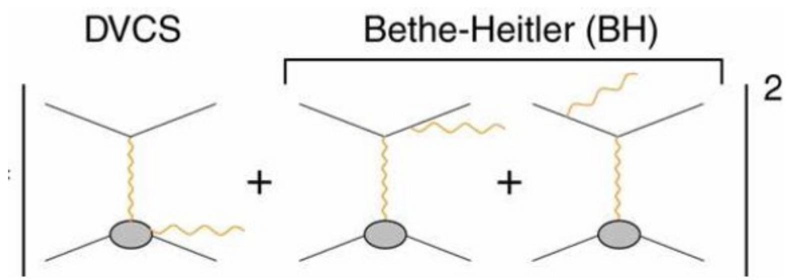
$$t = (p-p')^2 = (q-q')^2$$

GPD(x,ξ,t): The probability amplitude of picking up a parton with momentum x+ξ and putting it back with a momentum x-ξ without breaking the nucleon with a momentum transfer squared t.

Experimentally, the DVCS is indistinguishable from the Bethe-Heitler (BH) process.

The measured photon-electroproduction cross section (ep → epγ) is:

$$d\sigma \propto |\tau_{BH}|^2 + \underbrace{(\tau^*_{DVCS}\tau_{BH} + \tau^*_{BH}\tau_{DVCS})}_{\mathcal{I}} + |\tau_{DVCS}|^2$$



- The cross section is dominated by BH, which is calculable using the elastic FFs on most of the phase space.
- The DVCS signal is enhanced by the interference with BH.

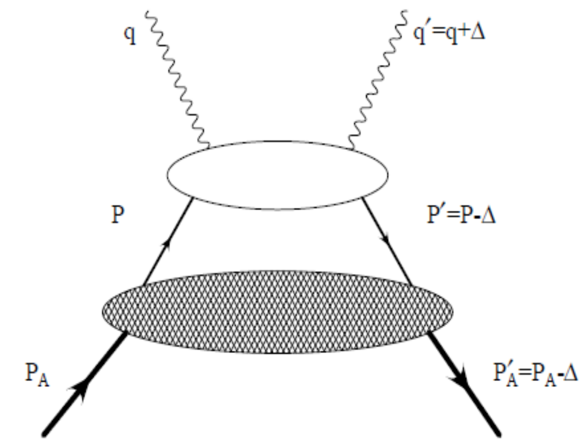
DVCS off nuclei

Two DVCS channels are accessible with nuclear targets:

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

→ Study the partonic structure of the nucleus.

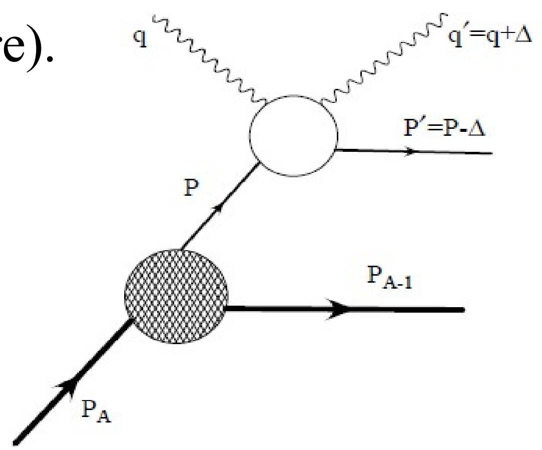
→ One chiral-even GPD ($H_A(x,\xi,t)$) is needed to parametrize the structure of the spinless nuclei (^{4}He, ^{12}C, ^{16}O, ...).



◊ **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

Theoretical predictions of the EMC in 4He

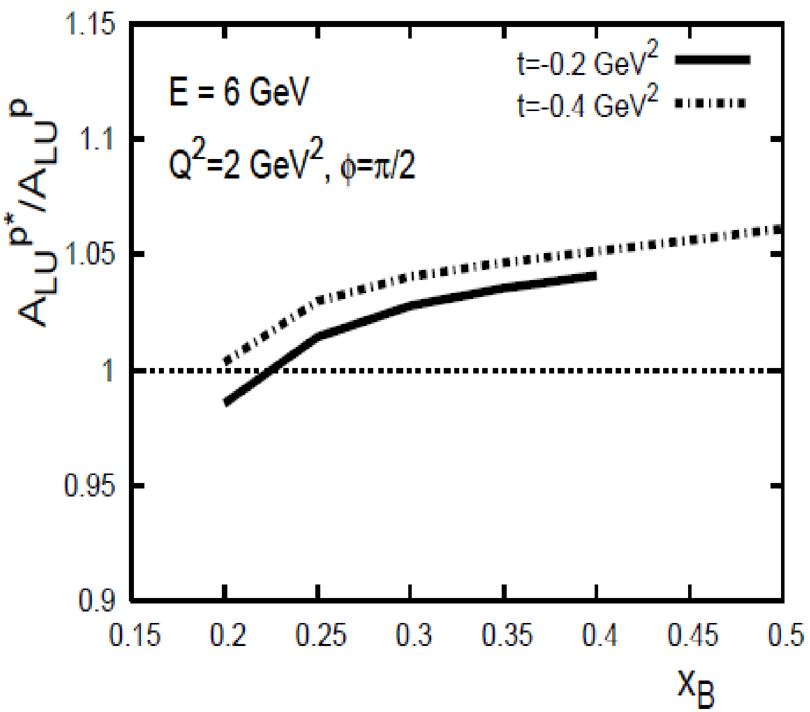
On-shell calculations:

(1) Impulse approximation

GPD^{4He}(x,ξ,t) = Σ (free p and n GPDs)*F_{4He}(t)

(2) Medium modifications:

$$H^{q/p^*}(x,\xi,t,Q^2) = \frac{F_1^{p^*}(t)}{F_1^p(t)} H^q(x,\xi,t,Q^2),$$



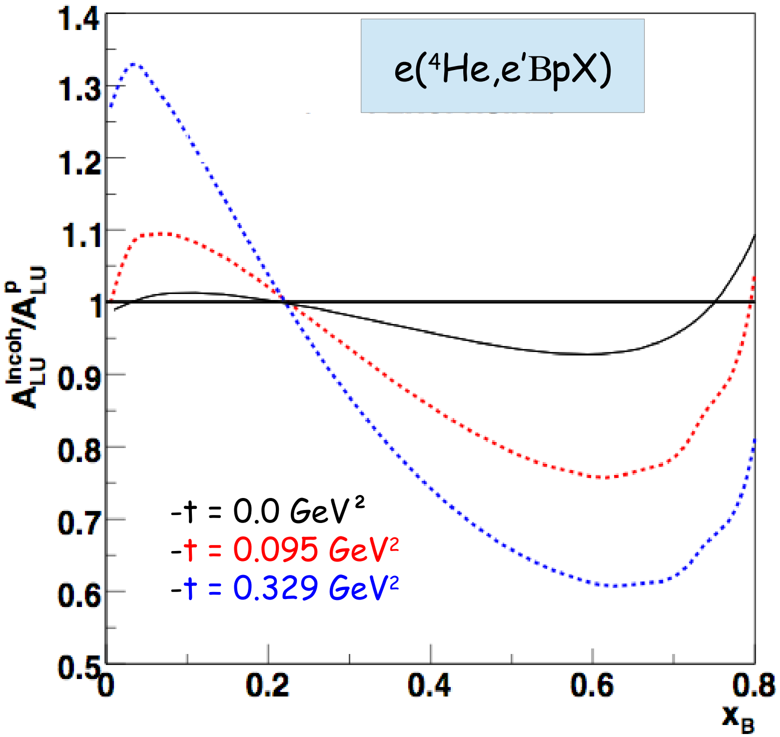
[V. Guzey, A. W. Thomas, K. Tsushima, PRC 79 (2009) 055205]

Off-shell calculations:

Nucleus = bound nucleons + nuclear binding effects

$$H^A(x,\xi,t) = \sum_N \int \frac{d^2P_\perp dY}{2(2\pi)^3} \frac{1}{A-Y} A \rho^A(P^2,P'^2) \times \sqrt{\frac{Y-\xi}{Y}} \left[H^N_{OFF}\left(\frac{x}{Y},\frac{\xi}{Y},P^2,t\right) - \frac{1}{4}\frac{(\xi/Y)^2}{1-\xi/Y} E^N_{OFF}\left(\frac{x}{Y},\frac{\xi}{Y},P^2,t\right) \right]$$

Nuclear spectral function



[S. Liuti, K.Taneja, PRC 72 (2005) 034902]

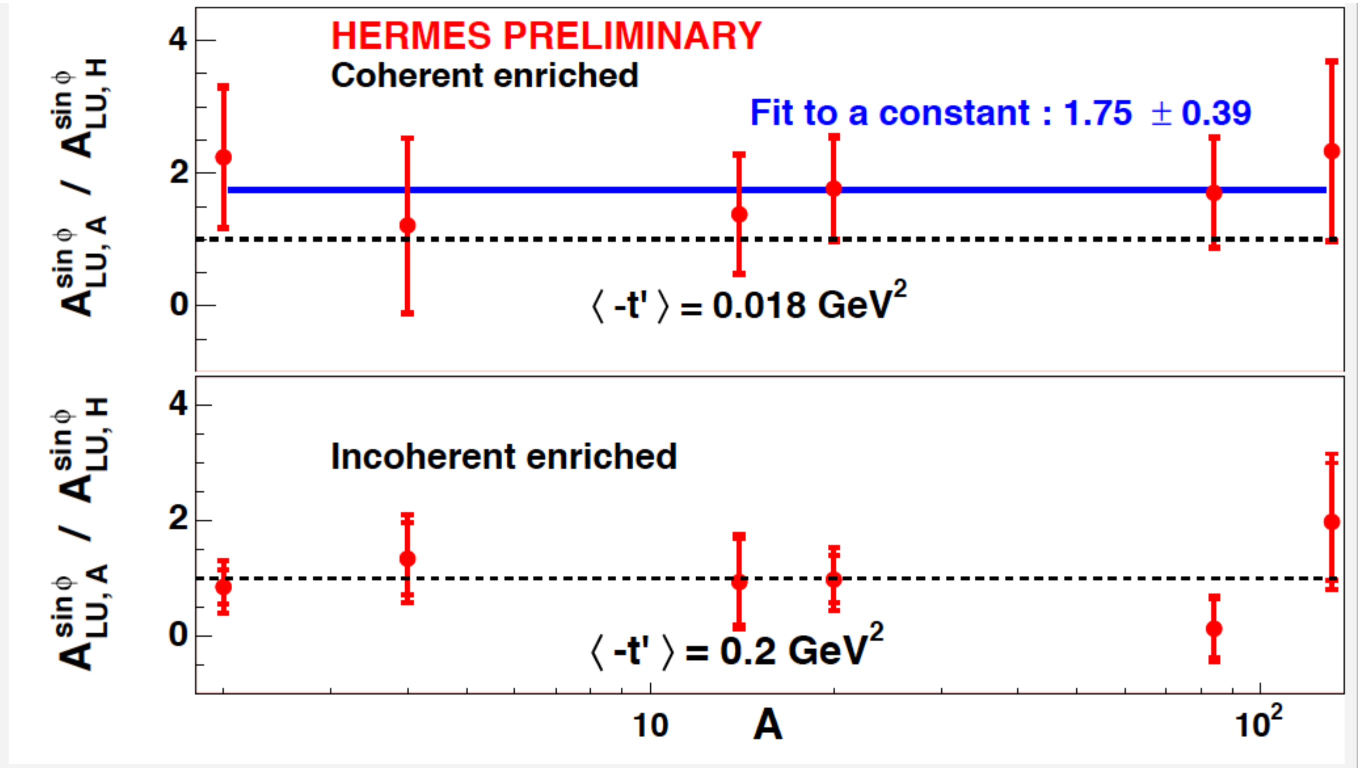
Nuclear DVCS measurements: HERMES

- The exclusivity is ensured via a cut on the missing mass of eγX final state.

- Coherent and incoherent separation depending on -t, i.e. coherent rich at small -t.

$$A_{LU}^{sin} = \frac{1}{\pi}\int_0^{2\pi} d\phi \, \sin\phi \, A_{LU}(\phi)$$

[A. Airapetian, et al.,
Phys Rev. C 81 (2010) 035202]



- Conclusions:
  - → No obvious A-dependence of the A_{LU} is observed. The coherent enriched ratio exhibits 2σ deviations from unity.
  - → The incoherent enriched ratio is compatible with unity.

CLAS - E08-024 experiment

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

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].

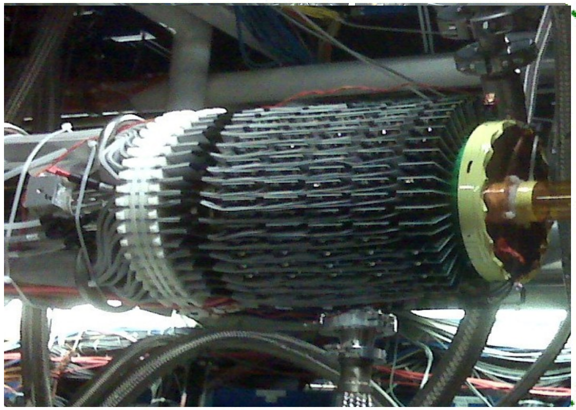
- **IC:** Improves γ detection acceptance [4º,14º].

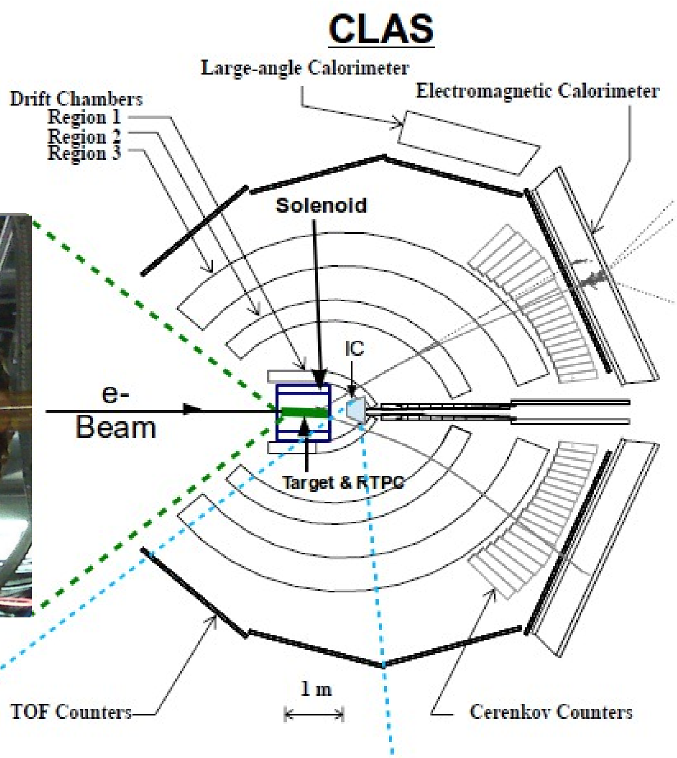
- **RTPC:** Detects low energy nuclear recoils.

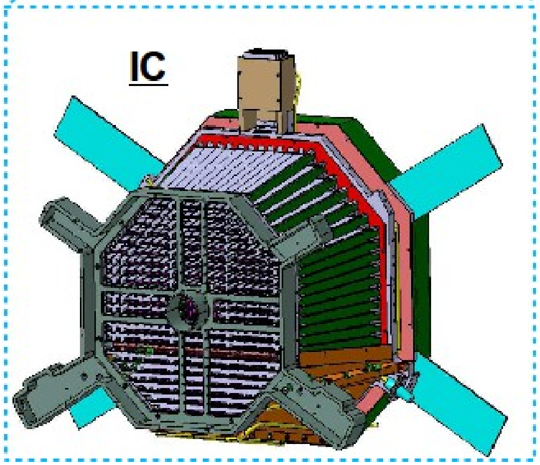
- **Solenoid:** - Shields the detectors from Møller electrons.
  - Enables tracking in the RTPC.

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

RTPC







DVCS events selection

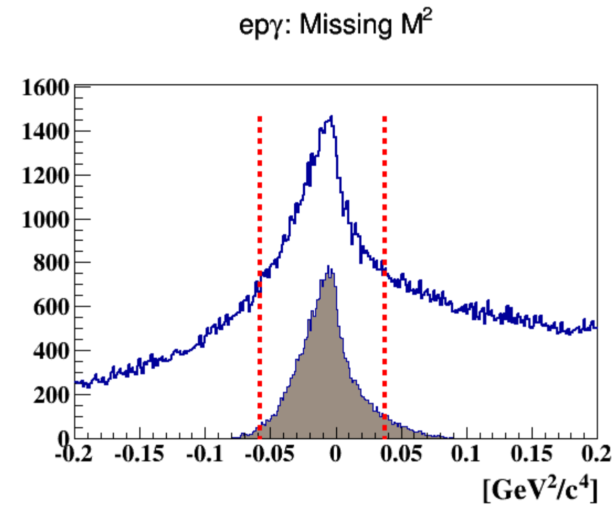
We select INCOHERENT events which have:

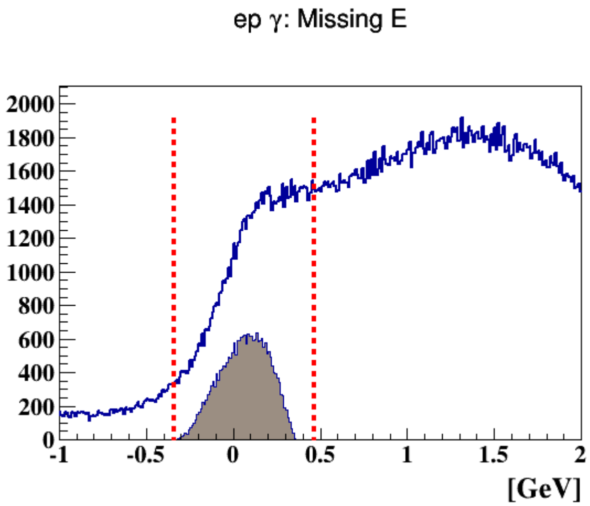
◊ Only one good electron, at least one photon and only one good p.

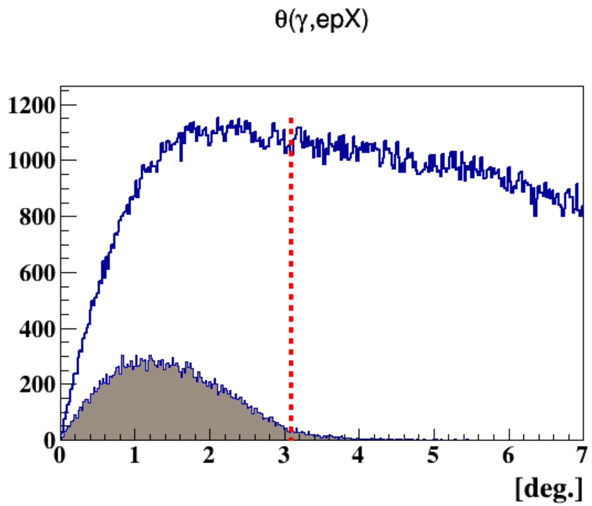
◊ $E\gamma > 2$ GeV, $W > 2$ GeV/c^2 and $Q^2 > 1$ GeV².

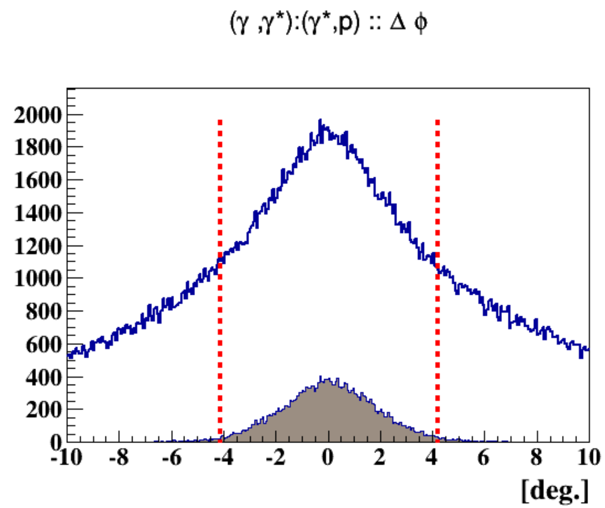
◊ Exclusivity cuts (3 sigmas).

- In BLUE, incoherent events before all exclusivity cuts.
- In shaded BROWN, incoherent DVCS events which pass all the other exclusivity cuts except the one on the quantity itself.

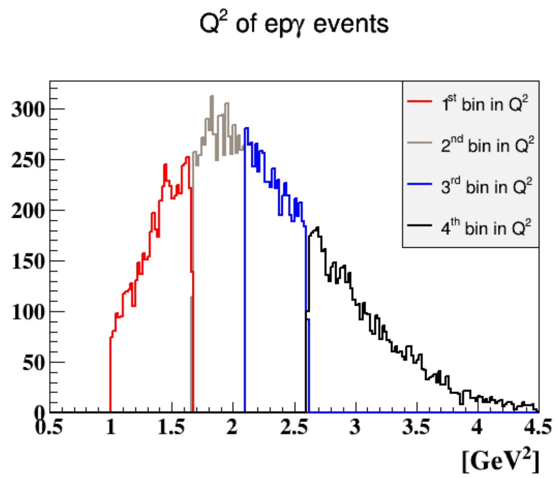


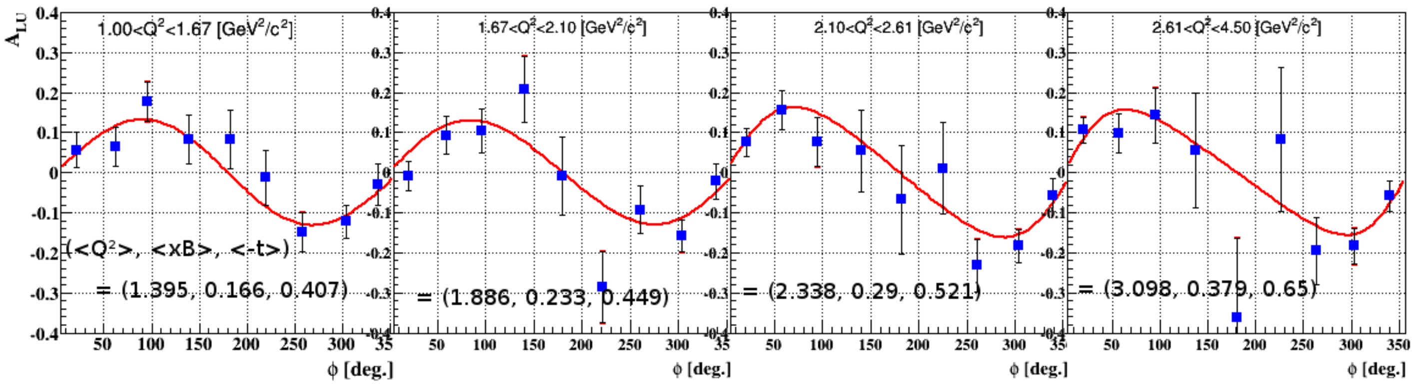


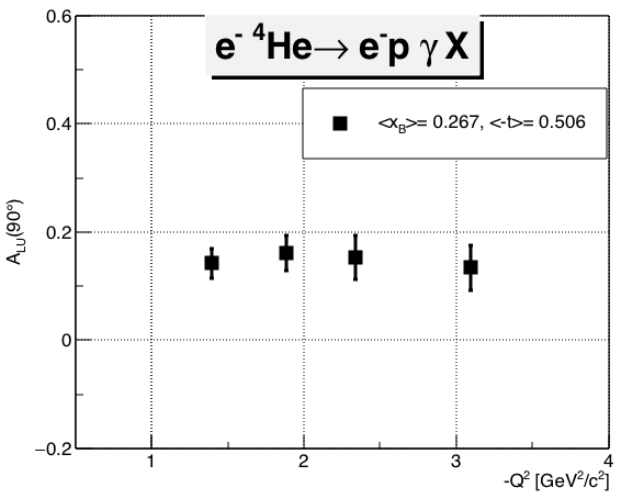


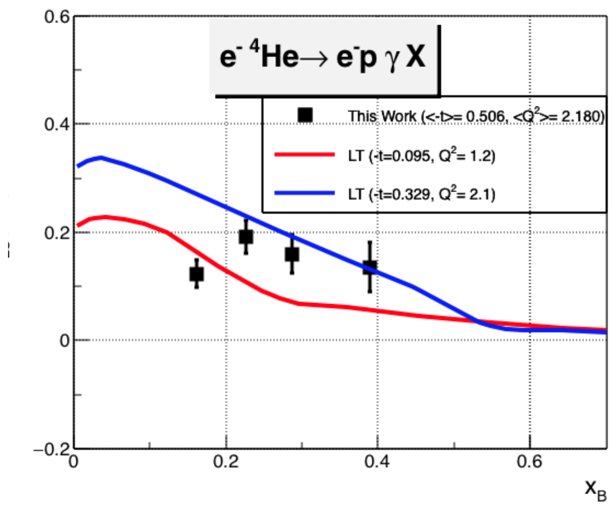


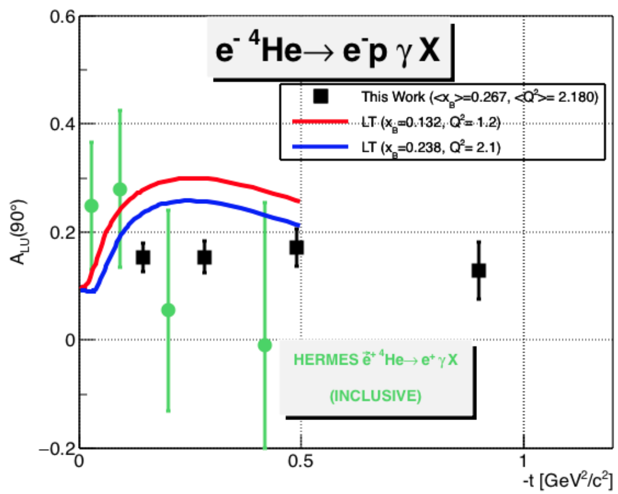
CLAS – E08-024 Incoherent beam-spin asymmetries







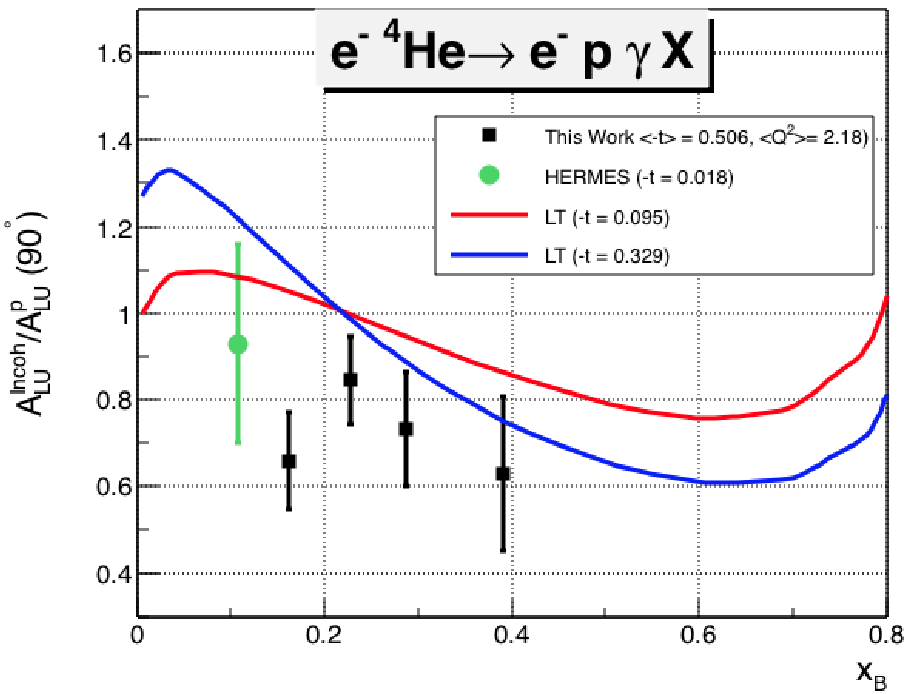


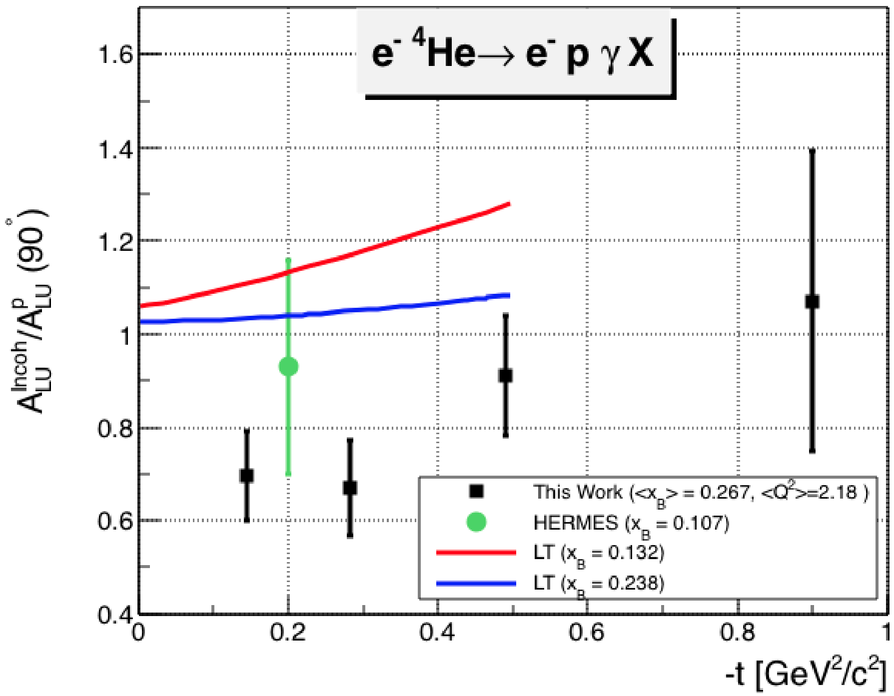


[1] LT: S. Liuti and S. K. Taneja.Phys. Rev., C72:032201, 2005.
[2] A. Airapetian, et al., Phys Rev. C 81, 035202 (2010).

EMC ratio

◊ 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.

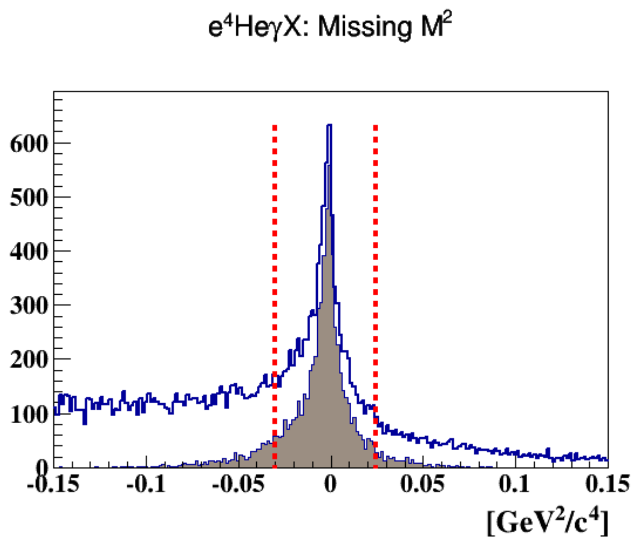
◊ At small -t, the bound proton shows lower asymmetry than the free one.

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

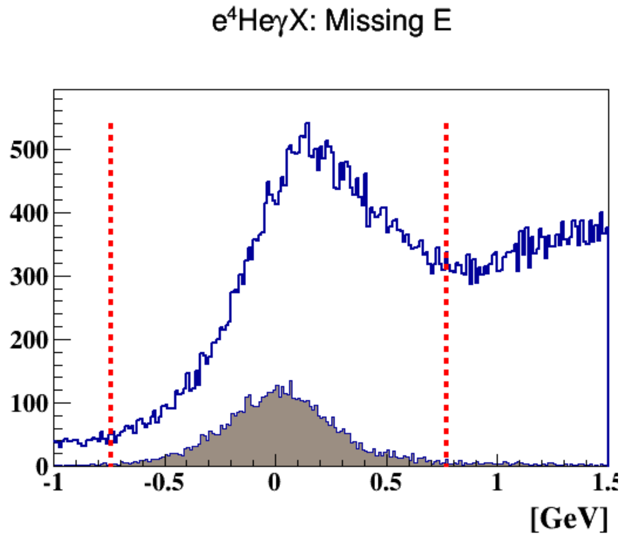
CLAS – E08-024: DVCS events selection

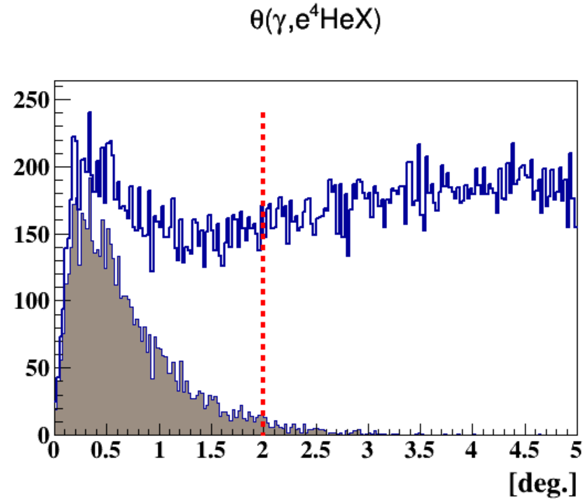
We select COHERENT events which have:

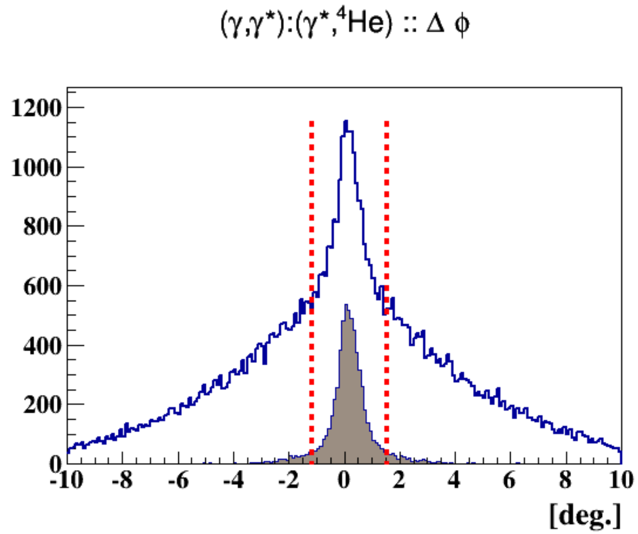
◊ Only one good electron, at least one photon and only one good ^{4}He.
◊ $E\gamma$ > 2 GeV, W > 2 GeV/c^2 and Q^2 > 1 GeV².
◊ Exclusivity cuts (3 sigmas).



- In BLUE, coherent events before all exclusivity cuts.
- In shaded BROWN, coherent DVCS events which pass all the other exclusivity cuts except the one on the quantity itself.

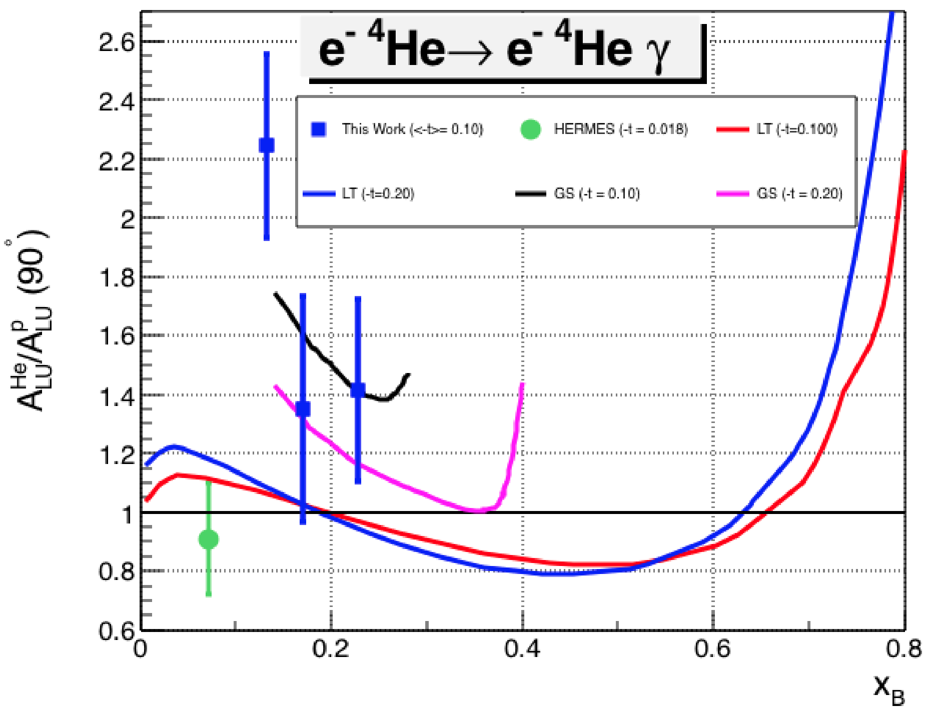


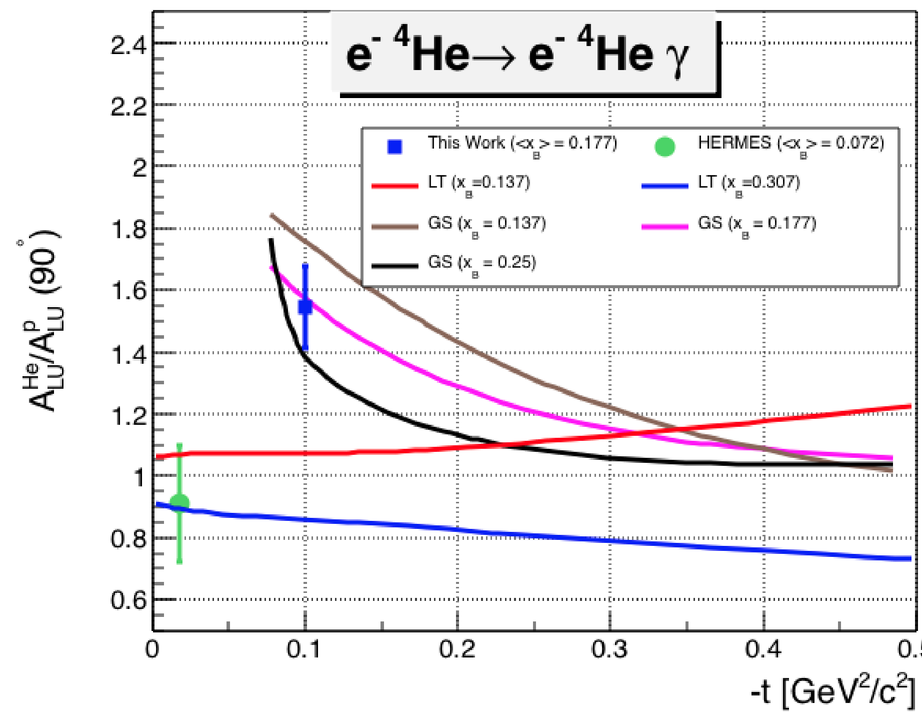




CLAS – E08-024: EMC ratio

◊ 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]

Monte Carlo simulation

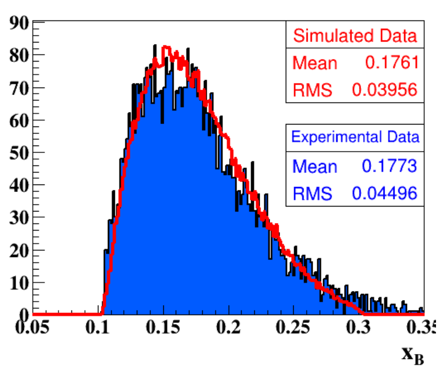
◊ **We use Monte Carlo for two goals:**

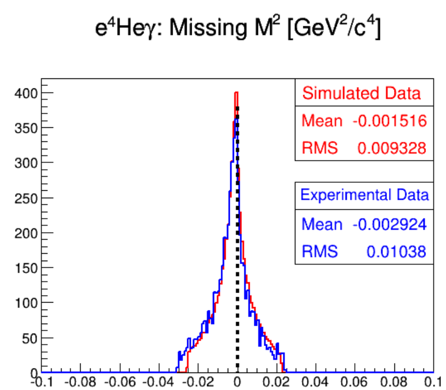
- Understanding the behavior of each particle type in our detectors
- Calculate the acceptance ratio for the purpose of the π^0 background subtraction

◊ **Simulation stages:**

- **Event generator:** e ^{4}Heγ, e ^{4}Heπ^0, epγ and epπ^0 events are generated in their measured phase space (Q^2, x_B, -t, ϕ_h) following this parametrization of the cross section.
- **Simulation:** GEANT4, describes the detectors' response to the different particles.
- **Smearing:** Makes the simulation more realistic by smearing the positions, energies and times.

Coherent DVCS





Adequate agreement between data and simulation

Background Subtraction

◊ With our kinematics, the main background comes from the exclusive π^0 channel,

$$e^4He \rightarrow e^4He\pi^0 \rightarrow e^4He\gamma\gamma \qquad\qquad ep \rightarrow ep\pi^0 \rightarrow ep\gamma\gamma$$

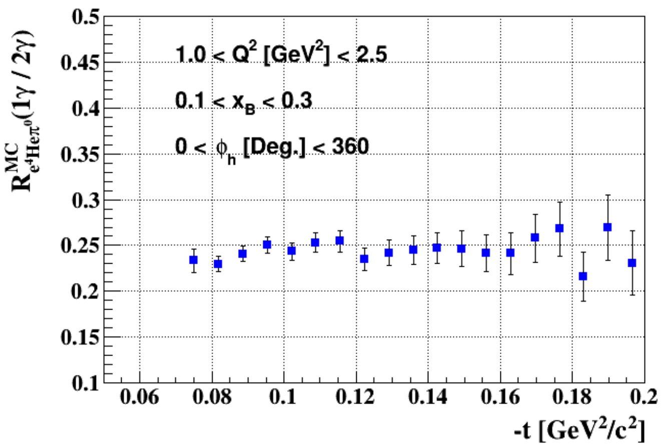
in which one photon from π^0 decay is detected and passes the DVCS selection.

◊ We combine real data with simulation to compute the contamination of π^0 to DVCS.

$$\overleftrightarrow{N}_{DVCS/BH} = \overleftrightarrow{N}^{Exp.}_{eHe\gamma} - \overleftrightarrow{N}^{Exp.}_{eHe\pi^0(1\gamma)} = \overleftrightarrow{N}^{Exp.}_{eHe\gamma} - \left(\frac{N^{MC}_{eHe\pi^0(1\gamma)}}{N^{MC}_{eHe\pi^0(2\gamma)}}\right) * \overleftrightarrow{N}^{Exp.}_{eHe\pi^0(2\gamma)}$$

Acceptance ratio (R (1γ/2γ))

→ In -t bins (integrated over φ_h, Q^2, x_B):



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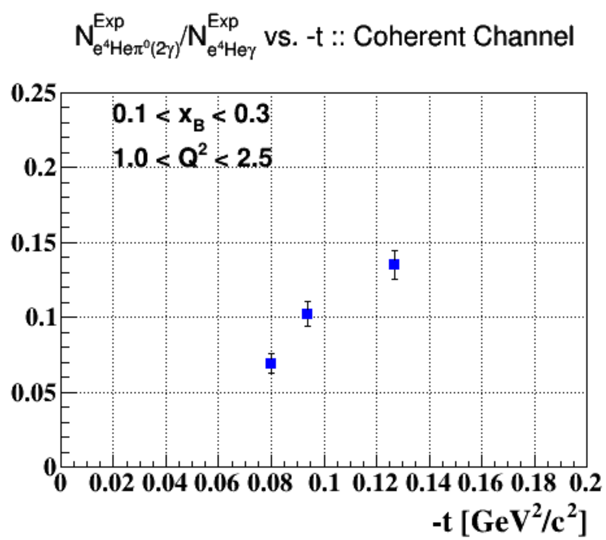

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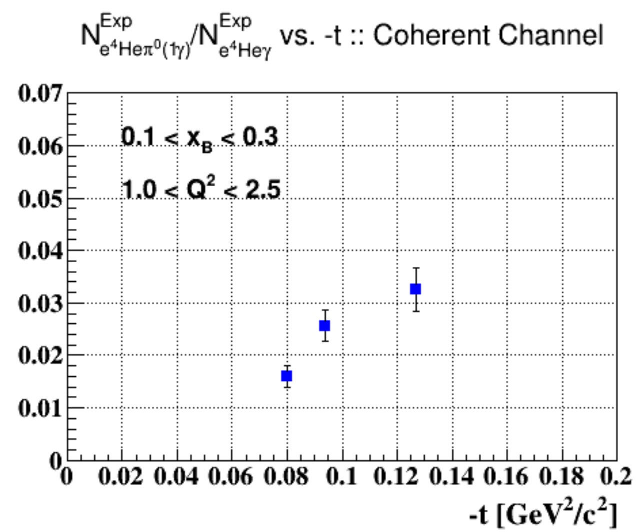


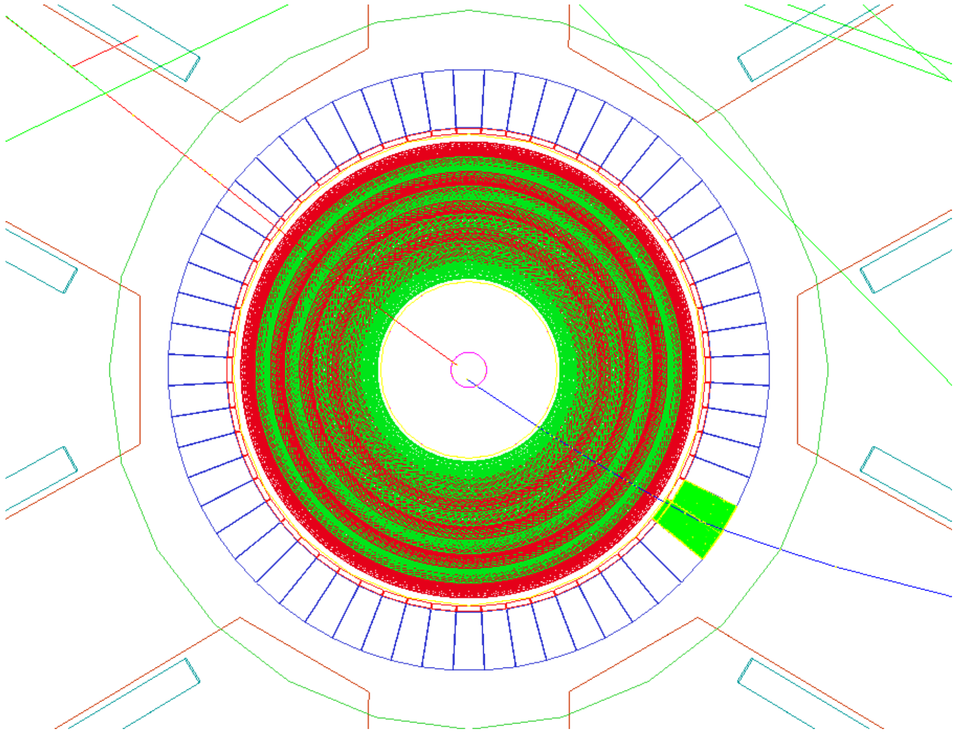
◊ Background yield ($N^{Exp}_{e^4He\pi(1\gamma)}$ / $N^{Exp}_{e^4He\gamma}$) ratio ~ 2-4% (8-11%) in $e^4He\gamma$ ($ep\gamma$) channel.

CLAS12-ALERT proposed experiment: ALERT detector

- The threshold of the CLAS12 inner tracker is too high to be used for our measurements.

- The recoil detector planned for BoNuS12 is not suitable due to its inability to distinguish all kind of particles we need to measure and cannot be efficiently included in the trigger.

→ we propose to use A Low Energy Recoil Tracker (ALERT) that will be installed inside the solenoid magnet instead of the CLAS12 Silicon Vertex Tracker.

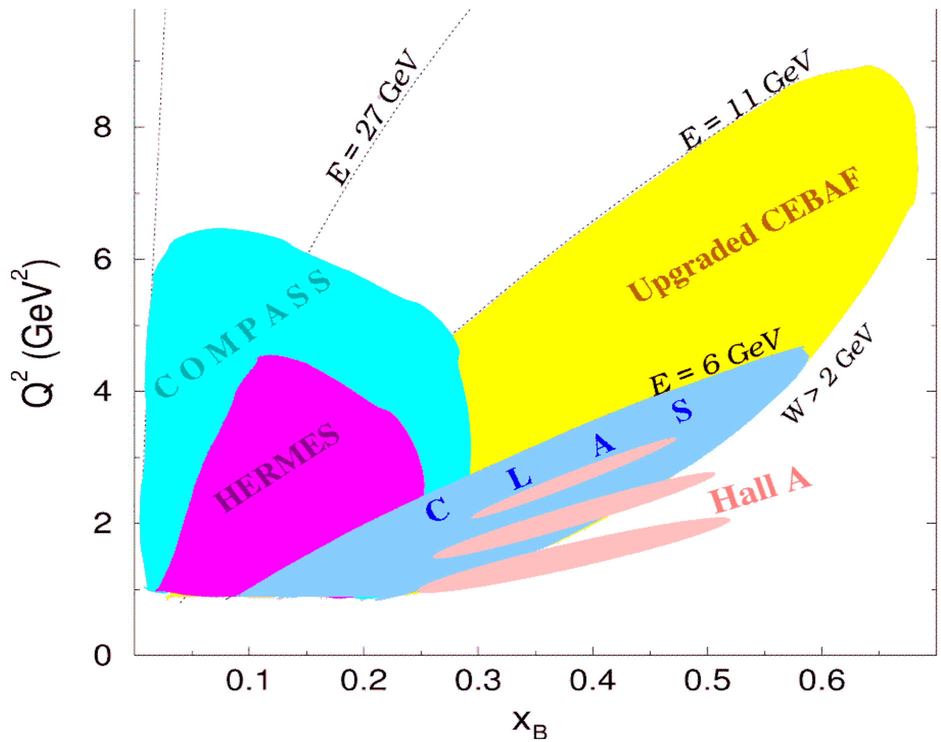


→ The drift time is short.
→ Can be included in the trigger.
→ Separate protons, deuterium, tritium, alpha, helium-3.
→ Can be used for BoNuS12, tagged EMC and DVCS on He4 ...

Design parameters of CLAS12

	Forward detector	Central detector
Angular range		
Tracks	$5 - 40^{\circ}$	$35 - 125^{\circ}$
Photons	$2.5 - 40^{\circ}$	n.a.
Resolution		
$\delta p/p$	$< 1\%$ @ 5 GeV/c	5% @ 1.5 GeV/c
$\delta\theta$	< 1 mr	$<$ 10-20 mr
$\delta\phi$	< 3 mr	< 5 mr
Photon detection		
Energy	> 0.15 GeV	n.a.
$\delta\theta$	4 mr @ 1 GeV	n.a.
Neutron detection		
Efficiency	< 0.7	under dev.
Particle ID		
e/π	Full range	n.a.
π/p	Full range	< 1.25 GeV/c
π/K	Full range	< 0.65 GeV/c
K/p	< 4 GeV/c	< 1 GeV/c
$\pi \to \gamma\gamma$	Full range	n.a.
$\eta \to \gamma\gamma$	Full range	n.a.

DVCS worldwide effort



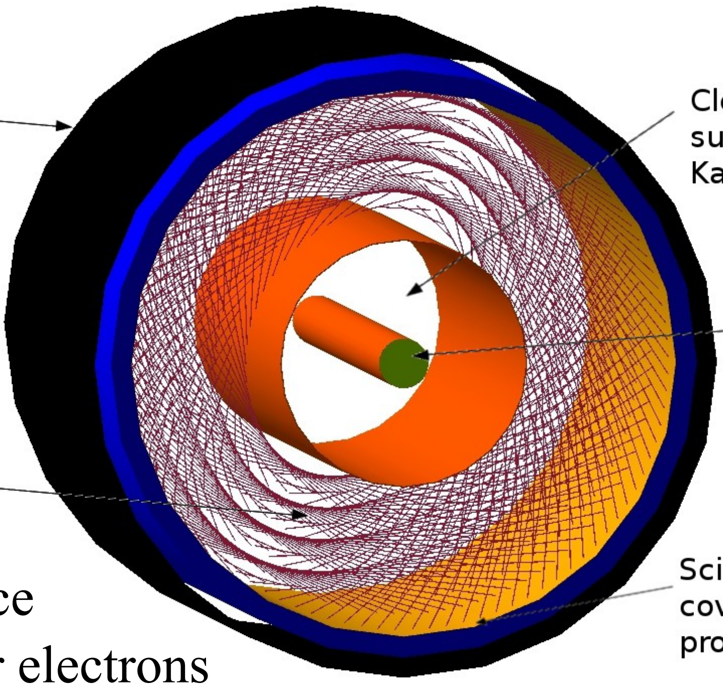
CERN
COMPASS
p-DVCS: X-sec,BSA,BCA, tTSA,lTSA,DSA

DESY	
HERMES	***H1/ZEUS***
p-DVCS BSA,BCA, TTSA, LTSA,DSA	p-DVCS X-sec,BCA

JLAB	
Hall A	***Hall B***
p,n,d -DVCS: X-sec	p-DVCS: BSA,LTSA, DSA, X-sec Helium-4: BSA

Promising future experiments with JLab upgrade and COMPASSII

CLAS12-ALERT proposed experiment: ALERT detector



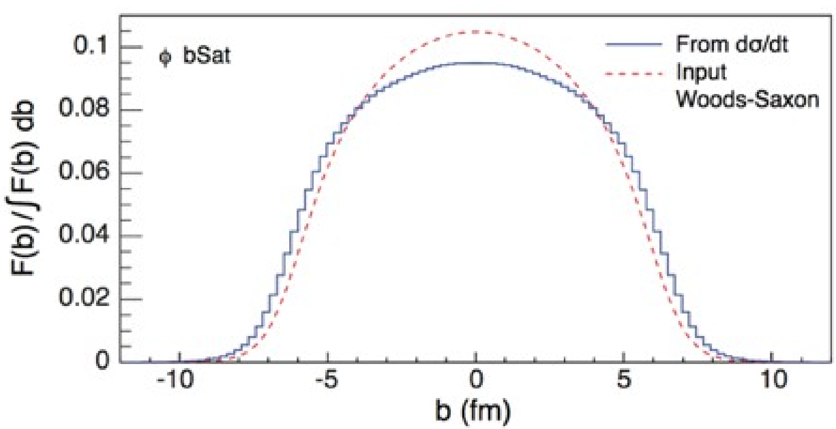
- Cylindrical target:
  - 30 cm long
  - 6 mm outer radius.
  - operating at 3 atm pressure.
  - 25μm target wall (Kapton).
- A clear space filled with helium to reduce secondary scattering from the high rate Moller electrons (outer radius is 30 mm).
- The drift chamber, its inner radius is 32 mm and its outer radius is 85 mm. It will detect the trajectory of the low energy nuclear recoils.
- Two rings of plastic scintillators placed inside the gaseous chamber, with total thickness of roughly 20 mm.

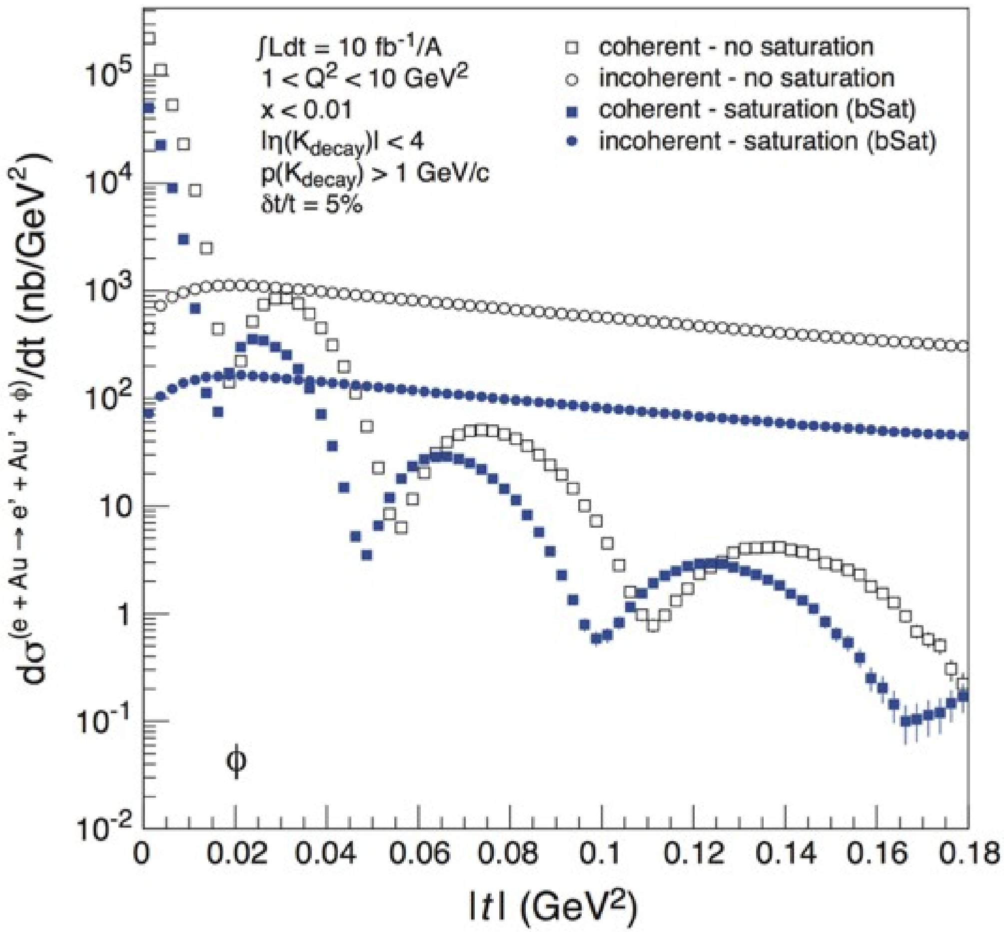
Coherent electroproduction of ϕ off heavy nuclei at EIC

- **EIC White Paper**: Tull and Ullrich[1,2]: Measurements of Diffractive Events (p.83)

- Uses convention of Munier, Stasto, and Mueller[3]:
  - Fourier transform of cross section can give information on gluon distribution in impact parameter (b) space!

$$F(b) = \int_0^\infty \frac{dq\, q}{2\pi} J_0(q\, b) \sqrt{\frac{d\sigma_{coherent}}{dt}}$$





[1]EIC white paper (arXiv:1212.1701)
[2]Phys. Rev. C 87, 024913 (2013) (arXiv:1211.3048)
[3]Nucl.Phys. B603 (2001) 427-445 (arXiv:hep-ph/0102291)

Estimating the coherent ϕ electroproduction cross-section off ^{4}He

- Phenomenological approach to production off proton:

$$\frac{d\sigma}{dx_B dQ^2 dt} = \Gamma(Q^2, x_B, E)\left(\frac{d\sigma_T}{dt}(Q^2, x_B, t) + \epsilon\frac{d\sigma_L}{dt}(Q^2, x_B, t)\right)$$

  - Longitudinal and transverse response functions
  - Exponential t-dependance of ϕ
  - W, Q^2 dependence parameterized to world data.
- Kinematics are restricted to e + ^{4}He → e' + ^{4}He + ϕ.
  - Cross-section is calculated with (naively) modified "t" and "W":
    - "target nucleon" has random isotropically distributed fermi-momentum
    - "recoil nucleon" has (^{4}He momentum)/4 + random fermi-momentum
- Helium charge form factor $F_{c,4He}$ is calculated with both a Fourier-Bessel transform and DQSM for large Q^2.
  - $Q^2 \rightarrow |t - t_{min}| = t'$, for calculation of all form-factors.
- Cross-section goes like:

$$\frac{d\sigma_{^4He}}{dx_B dQ^2 dt} = \frac{d\sigma_p}{dx_B dQ^2 dt}\left|\frac{A\,F_C(t')_{^4He}}{F_C(t')_p}\right|^2$$

Identical parametrization as CLAS12 proposal for ϕ production off p