# Study of Tagged Processes with $^{4}$He and ALERT at 22 GeV

Mathieu Ouillon
Mississippi State University

Science at the Luminosity Frontier: Jefferson Lab at 22 GeV
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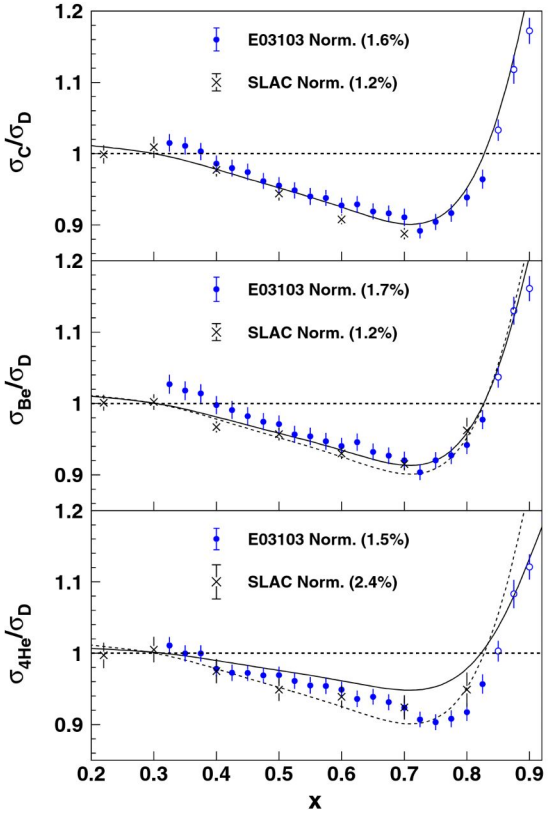
# In-medium Structure and Effects



- Modifications of bound nucleons properties and dynamics:
  - EMC effects at moderate Bjorken *x*, and shadowing at small *x*
  - Many models for the EMC effect
  - Significant even for $^4$He
  - The origin of the effect remains unclear
- Nuclear modifications of DIS cross sections were probed by CERN, SLAC, and JLab experiments
- Clear explanations may arise from studying the nuclear modifications via other reactions, such as Deeply Virtual Compton Scattering and Deeply Virtual Meson Production…
- What is the partonic structure of nuclei?

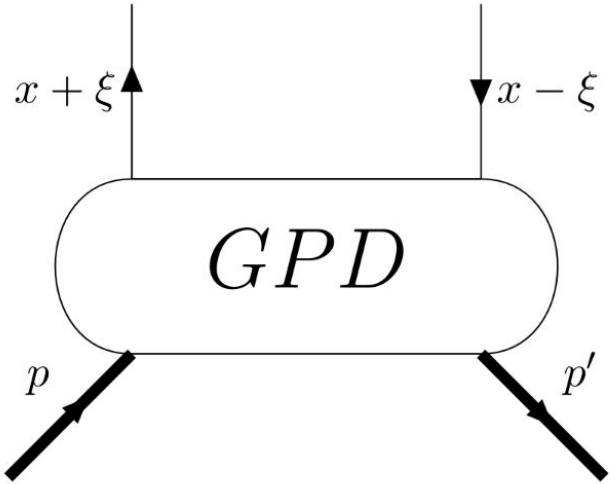
J. Seely et al. Phys.Rev.Lett. 103 (2009) 202301



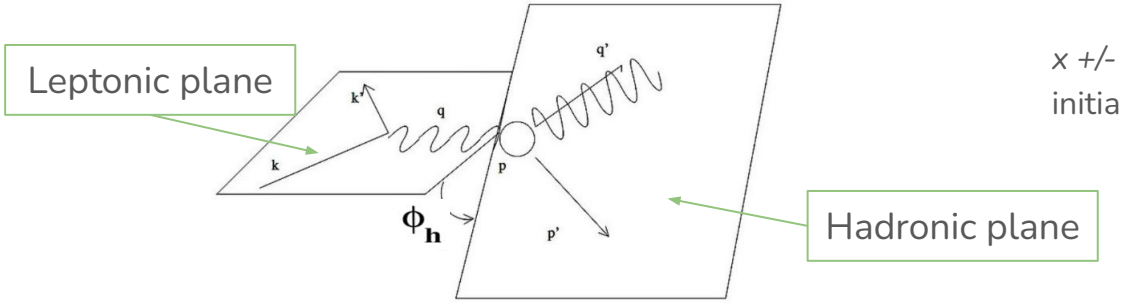
# Generalized Parton Distributions



- GPDs describe the nucleon structure in terms of longitudinal momentum and transverse position:
  - Three dimensions: *x*, $\xi$ and *t*
  - Spin-0 → 2 GPDs, Spin-1/2 → 8 GPDs, Spin-1 → 18 GPDs
  - Accessible through exclusive processes such as DVCS, DVMP, Time-like Compton Scattering, Double DVCS...
- Experimental efforts (JLab, HERA, CERN) mainly focused on proton, which triggered the need for neutron studies



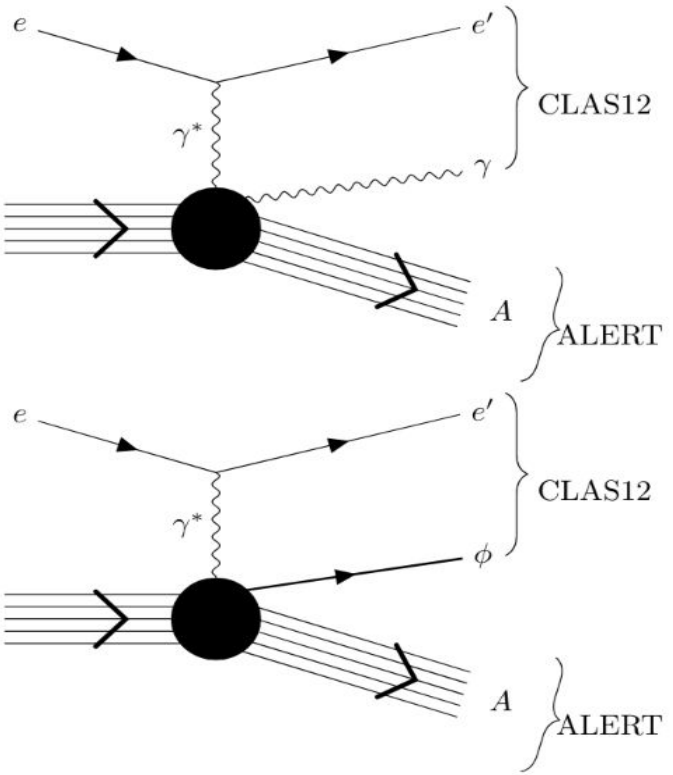

*x +/- ξ* is the momentum fraction of the initial/final quark.



# DVCS on $^4$He



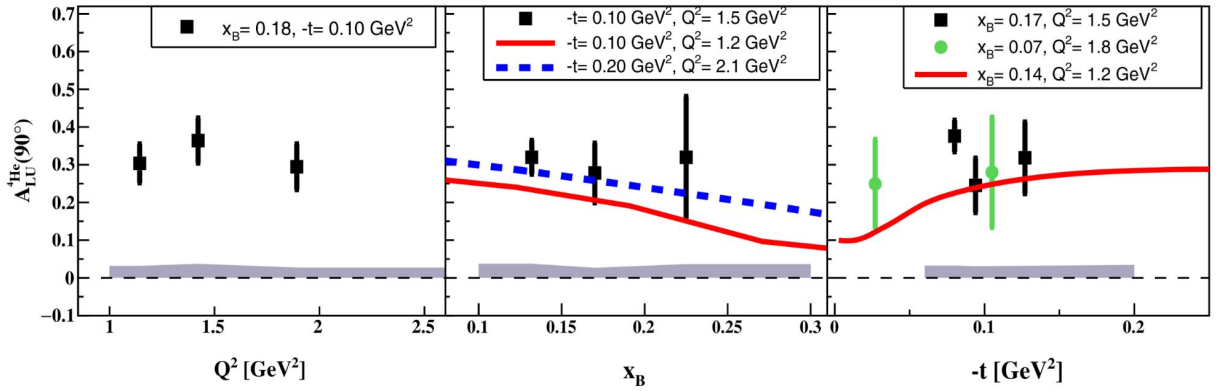
- Provides a straightforward access to GPDs
- Advantages of using such a probe on $^4$He:
  - Only two GPDs for $^4$He: H (chiral-even) and $H_T$ (chiral-odd)
  - Ensure model independent extraction for the coherent DVCS Beam Spin Asymmetries
  - A few body system that is theoretically well known
  - Realistic calculations are difficult, but possible
- Ability to explore two tagged processes:
  - Coherent DVCS: access to non-nucleonic degrees of freedom
  - Incoherent DVCS: access to nucleonic modifications in the cold nuclear environment
- But, would it be studied regardless of its
  - small cross section?
  - large energy gap between recoiled target fragments and outgoing forward particles (electron and photon)?



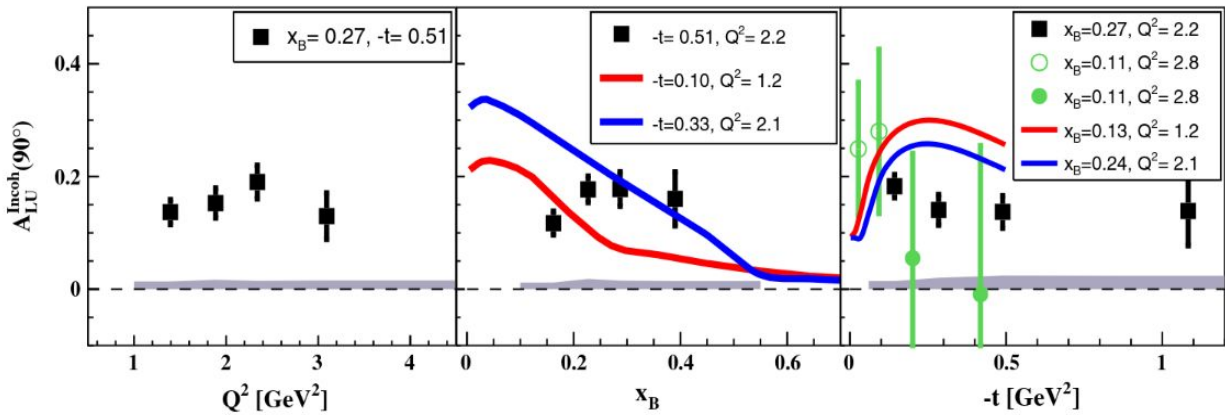
# Previous 6 GeV Experiment with CLAS (EG-6 Experiment)



- Results extracted for
  - First exclusive coherent DVCS on tagged $^4$He
  - Incoherent DVCS on $^4$He via spectator tagging of target fragments
- Detected $^4$He using a Radial Time Projection Chamber for which
  - the response was slow
  - identified only $^4$He
  - rates were limited, and could not be part of the CLAS6 trigger




Coherent/Incoherent DVCS (top/bottom)

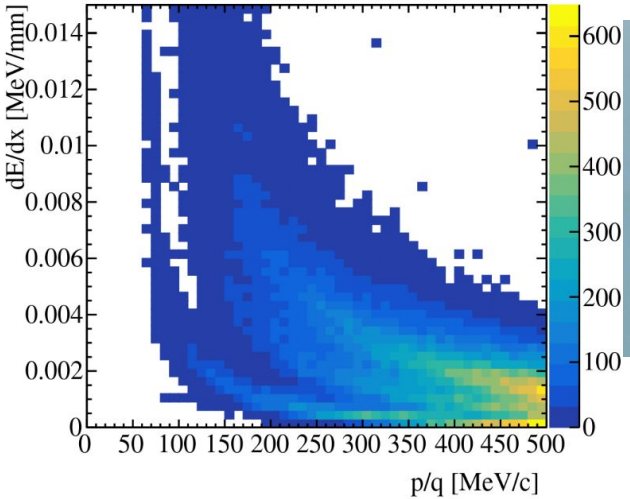


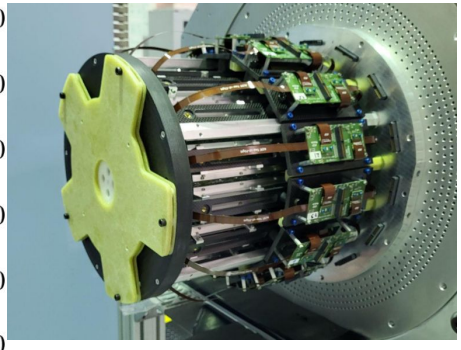

M. Hattawy *et al.*, Phys. Rev. Lett. 119, (2017) 202004
M. Hattawy *et al.*, Phys. Rev. Lett. 123, (2019) 032502

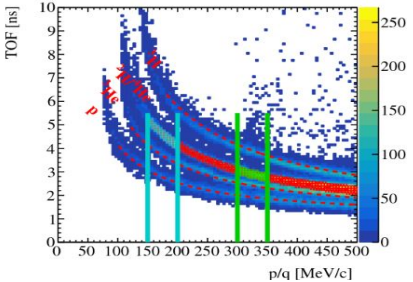
# CLAS12 ALERT Experiment

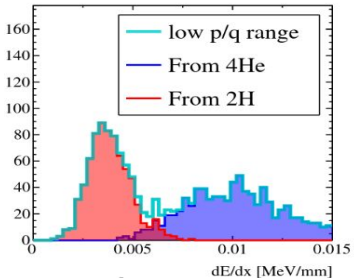


- Aim to identify light ions: H, $^{2}$H, $^{3}$H, $^{3}$He, and $^{4}$He
- Detect the lowest momentum possible, down to 70 MeV/c
- Handle high CLAS12 rates and luminosities
- ALERT is composed of a hyperbolic drift chamber (AHDC) and a time of flight (ATOF);
  - The TOF measurement is degenerate for $^{2}$H and $^{4}$He, but *dE/dx* can distinguish the two nuclei bands



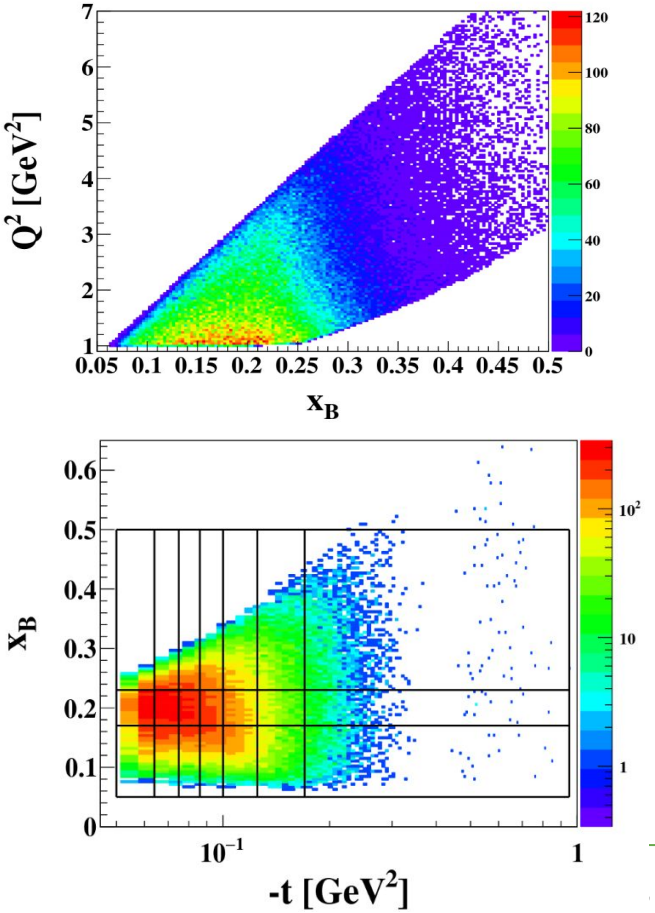


# Coherent DVCS with CLAS12 ALERT



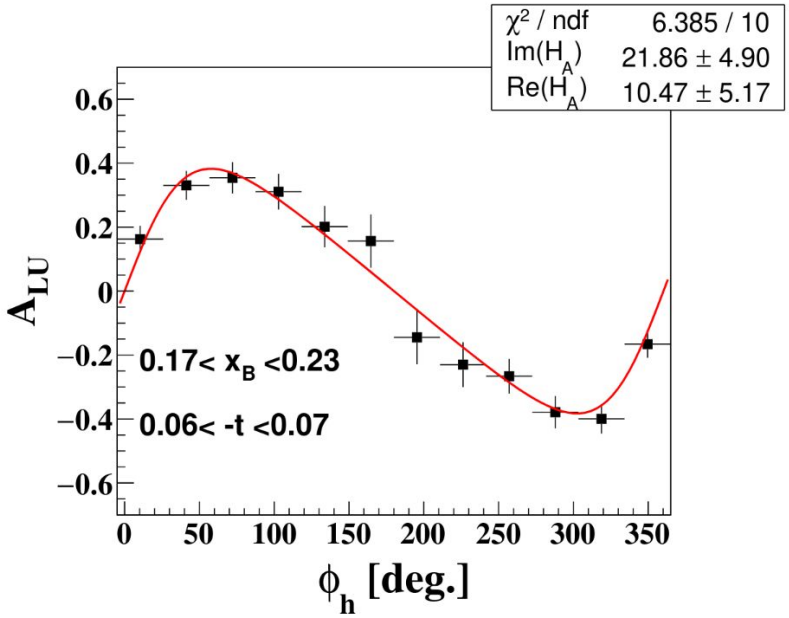
- Proposed measurements of coherent DVCS on $^4$He aim to
  - extract BSA, $A_{LU}$
  - use a high luminosity: 20 PAC days at $1.5 \times 10^{34} cm^{-2} s^{-1}$, and 10 PAC days at $0.75 \times 10^{34} cm^{-2} s^{-1}$
  - utilize a 55-cm-long gaseous target
  - run with approximately 80% beam polarization
  - cover a phase space consisting of 7 bins in $-t$, 3 bins in $x_B$, and 12 bins in $\phi_h$
  - detect scattered electron and a real photon with CLAS12, and $^4$He with ALERT
  - identify $^4$He with momenta in the range of $230 < p < 400$ MeV/c

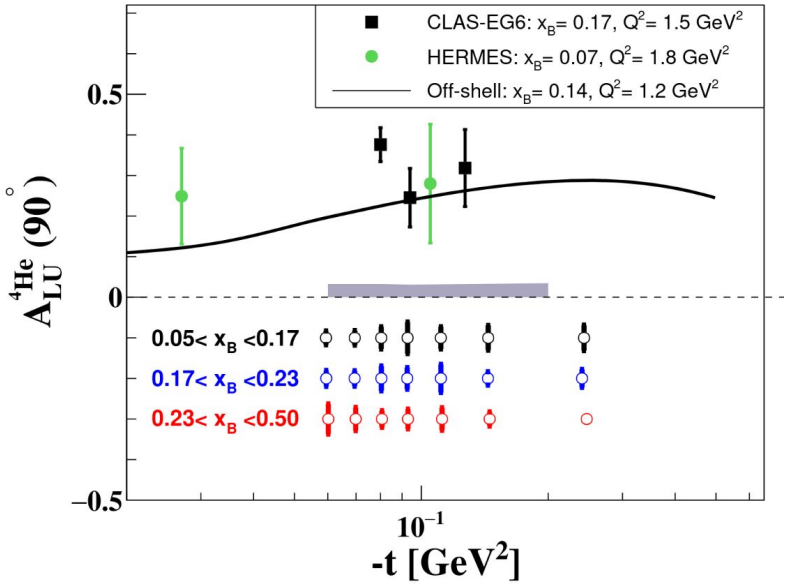


# Coherent DVCS with CLAS12 ALERT



- Get an estimation of projected precision for $A_{LU}(90°)$
- Extract real and imaginary part of the Compton Form Factor, $H_A$

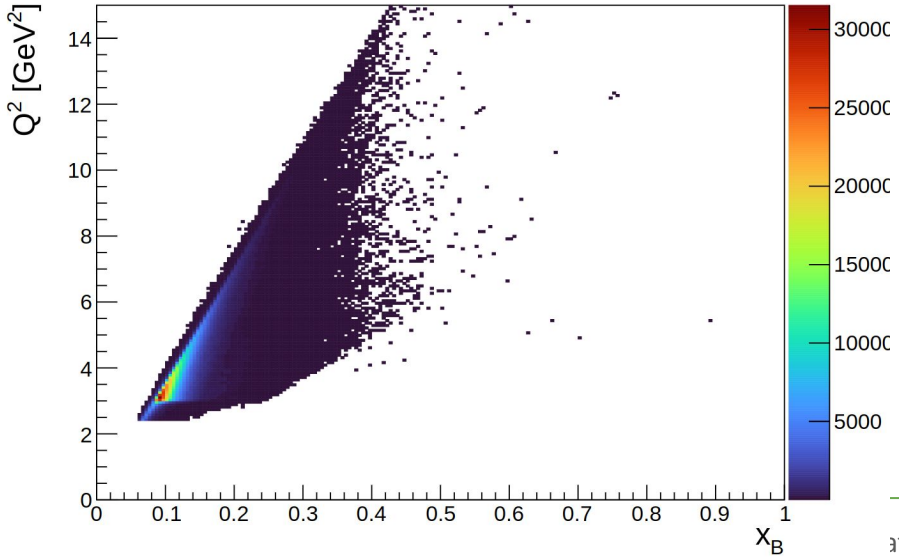


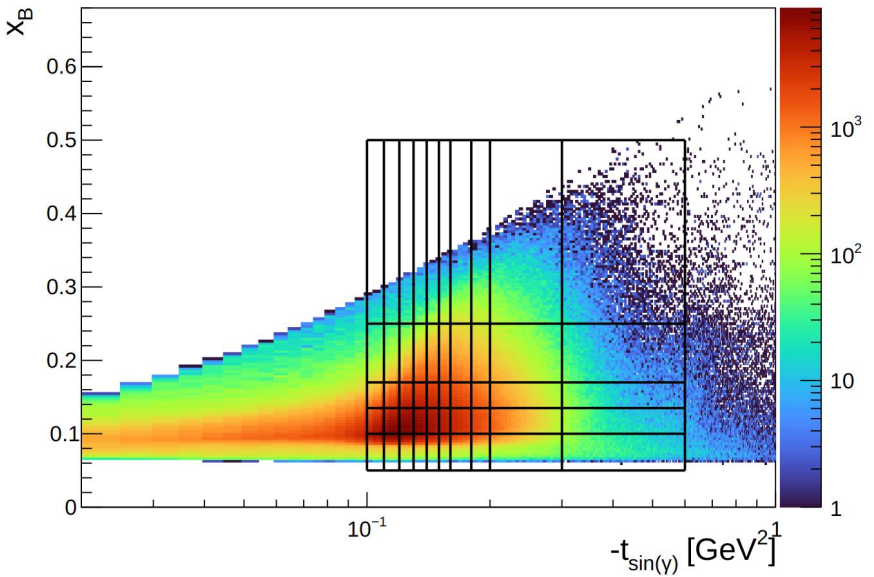



# Coherent DVCS with ALERT @ 22 GeV



- Performed the 22 GeV simulation of coherent DVCS on $^4$He using
  - TOPEG, The Orsay-Perugia Event Generator,
  - CLAS12 and ALERT GEant4 Monte-Carlo packages as well as their up-to-date event reconstruction chains
  - 10 bins in -$t$, 5 bins in $x_B$, and 12 bins in $\phi_h$

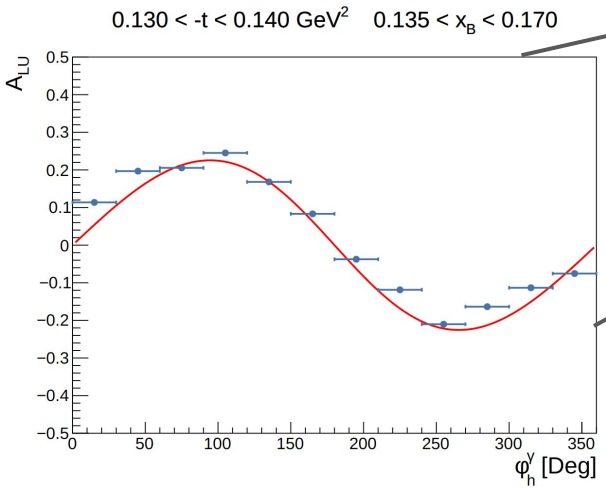


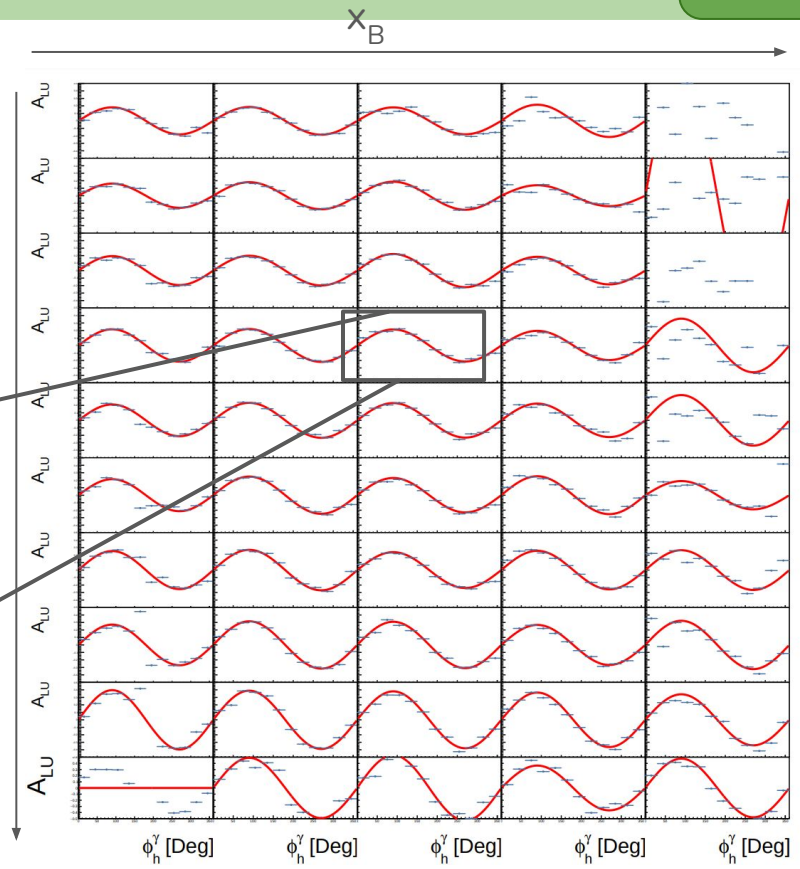



# Coherent DVCS with ALERT @ 22 GeV



- Projections for the ALERT BSA @ 22 GeV:
  - Beam time: 20 PAC days
  - Luminosity: $2 \cdot 10^{35}$ cm$^2$ s$^{-1}$, but just $1 \cdot 10^{35}$ cm$^2$ s$^{-1}$ is considered in this extraction since only half of the target is contained within the ALERT detector
  - Beam polarization: 80%



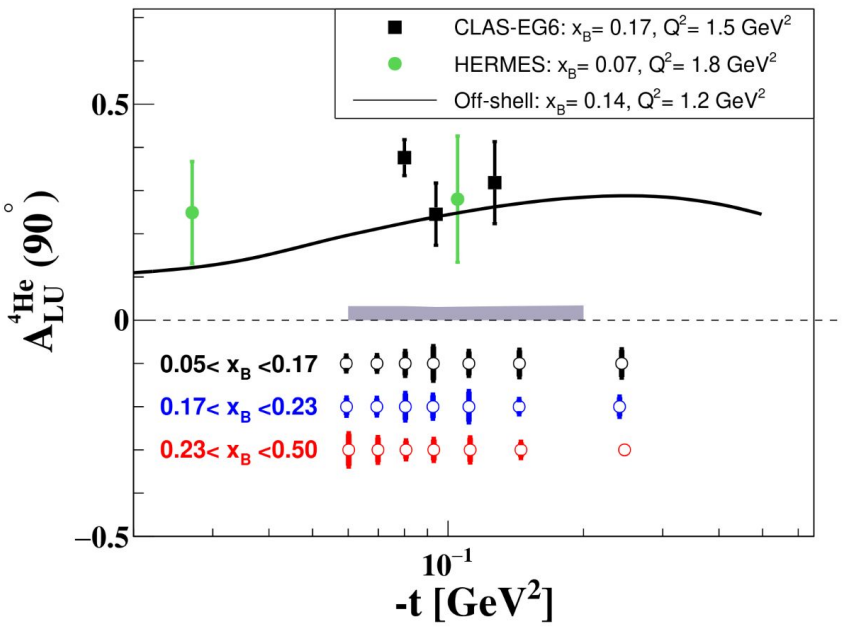



# Coherent DVCS with ALERT @ 22 GeV

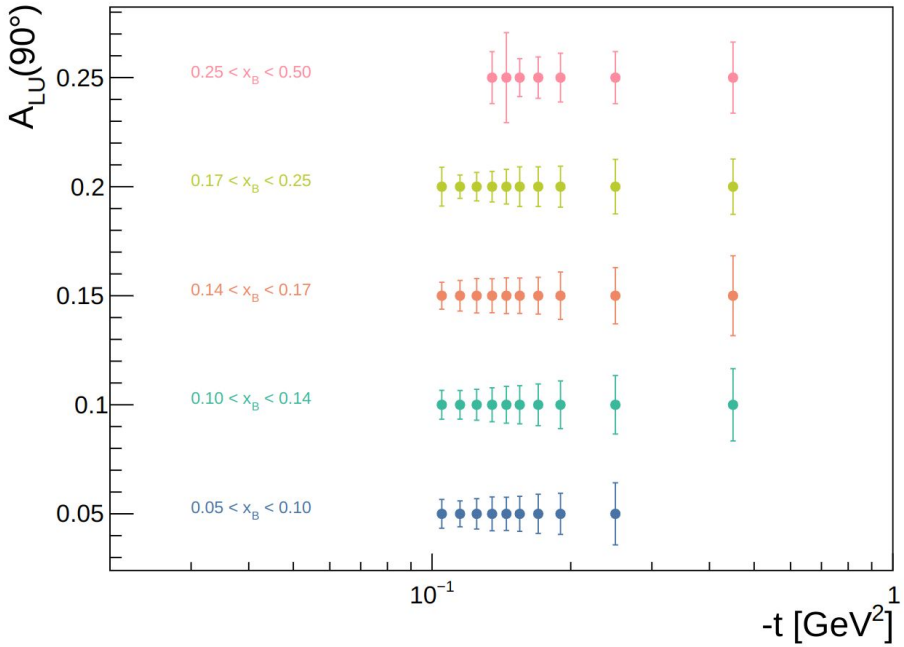


- Projections for the ALERT BSA @ 90°, $A_{LU}(90^\circ)$

ALERT at 12 GeV




ALERT at 22 GeV



# Summary and Outlook



- Study coherent DVCS on $^4$He to explore the partonic structure of nuclei
- The performed 22 GeV studies deployed the up-to-date CLAS12 and ALERT simulation and reconstruction chains
- Extract BSA for the entire angular coverage as well as at 90°
- The 22 GeV upgrade will allow
  - access to smaller $x_B$, larger $Q^2$, and finer kinematical binning in both $-t$ and $x_B$
  - extract CFF and GPDs for a broader kinematical coverage compared to forthcoming CLAS12 ALERT measurements
- Could explore other tagged processes such as incoherent DVCS

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Thank you; Questions?

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