Nuclear Physics Working Group Report

M. H. Wood, Canisius College

March 31, 2017

Working Group Business

- 12 talks (1 conference and 11 invited) since last meeting
- 7 Analyses under review (same from Nov. 2016 meeting)
- Analysis review checklist or template (use https://www.jlab.org/Hall-B/secure/claschair/docs/AnalysisNoteOutline.docx as a starting point)
- CLAS12 Schedule
  - Announced to the group of future meeting of working group leaders, run group leaders, and Hall leader to discuss constraints of the schedule
  - Run group leaders asked to provide specifics about run conditions
  - Working group asked to consider ways to collect data sooner (beam energies compatible with other halls, shorter test runs for preliminary data, etc.)

14:00 **Nuclear Physics Working Group business** *10'*
Material: Slides

14:10 **Update on the pi+ and pi- Hadronization Analyses** *25'*
Speaker: Raphaël Dupré (IPN Orsay)
Material: Slides

14:35 **Analysis of the pi+ Hadronization** *25'*
Speaker: Hayk Hakobyan (UTFSM)
Material: Slides

15:00 **Break** *1h0'*
Mont Thank You Event
Coffee Break

16:00 **Neutrino Beam Energy Reconstruction Studies** *25'*
Speaker: Mariana Khachatryan (ODU)
Material: Slides

16:25 **Deeply Virtual Compton Scattering off He-4: New Results and Future Perspectives** *25'*
Speaker: Mohammad Hattawy (Argonne National Laboratory)
Material: Slides

16:50 **Update on the ALERT Run Group** *25'*
Speaker: Whitney Armstrong (Argonne National Laboratory)

17:15 **Electroproduction of the Neutral Pion off He-4** *25'*
Speaker: Bayram Torayev (Old Dominion University)
Material: Slides

17:40 **CLAS EG6: Particle ID, Event Selection, and Extracting Raw Asymmetries** *25'*
Speaker: Frank Cao (UConn)
Material: Slides

Study of the hadronization of charged pions

Raphaël Dupré
Institut de Physique Nucléaire, Orsay, France
Kawtar Hafidi
Physics Division, Argonne National Laboratory, Argonne, Illinois 60439, USA
Lamiaa El Fassi
Mississippi State University, Mississippi State, Mississippi 39762, USA
William Brooks, Ahmed El Alaoui, Hayk Hakobyan, Taisiya Mineeva
Universidad Técnica Federico Santa María, Valparaíso, Chile

March 1, 2017

Abstract

Hadronization is the process by which energetic quarks transform into colorless hadrons. The process is non-perturbative, therefore, only a qualitative understanding based on phenomenological models can be achieved. By comparing hadron production on different nuclei, one can measure the most sensitive variables to the hadronization phases, the transverse momentum broadening, that is believed to be tightly connected to the quark energy loss, and the multiplicity ratio, which is a measure of the hadron attenuation in the nuclear medium.

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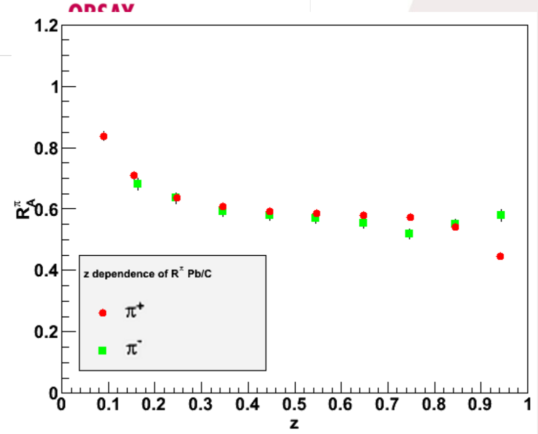
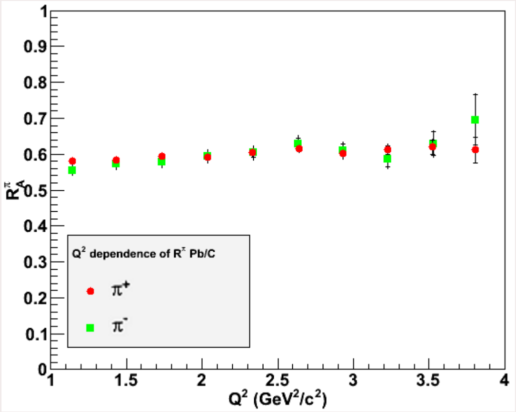
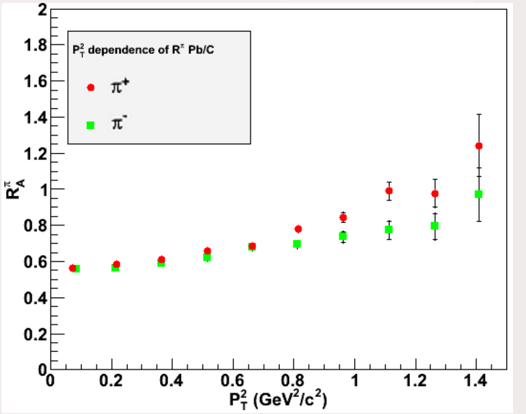
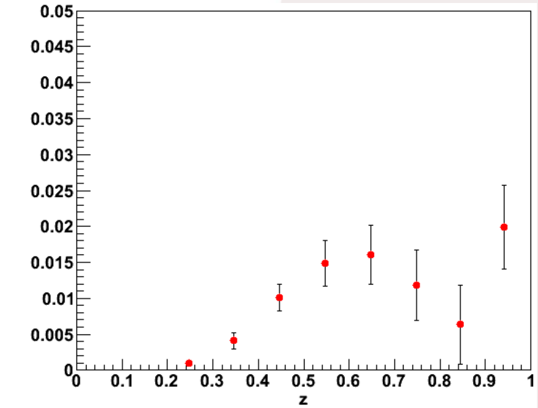
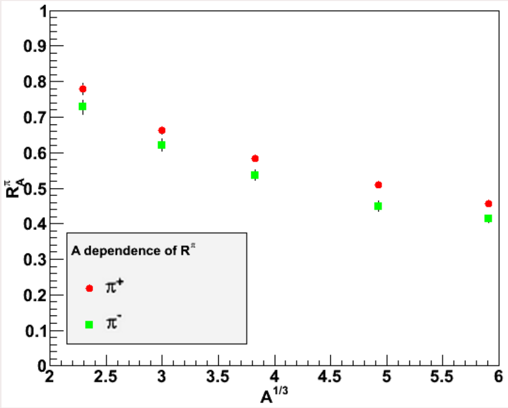
Many Results to Come (Soon)

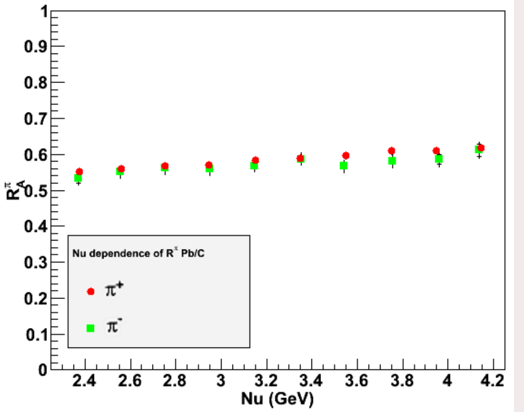


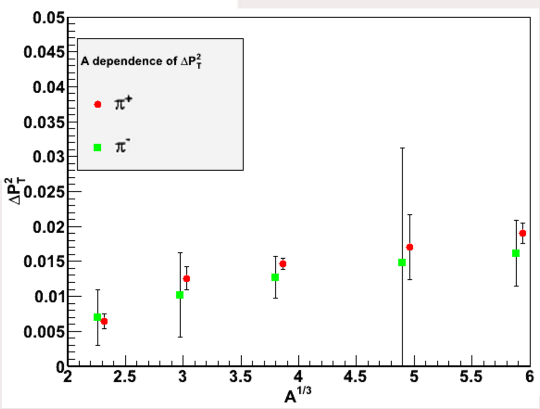


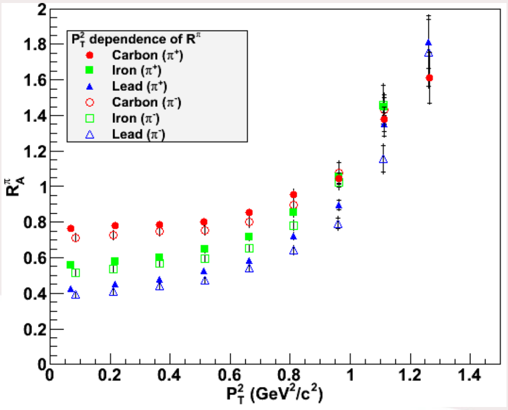


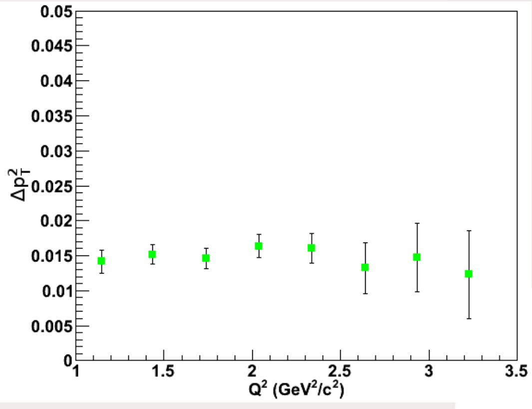












Summary

- **Analysis is complete and under review**
  - Review committee would like more details on radiative and acceptance corrections
  - We found a couple of minor bugs
    - Most importantly error bars got smaller
- **Parallel analysis of Hayk**
  - Several issues to be addressed (See next talk)
  - Comparison to Hall C is possible in a specific bin for aluminum
    - This analysis is 4% off, which is acceptable within our error bars (2% normalization and ~2% point to point in this bin)
    - This comparison will be added to the analysis note
- **End of round 1 in the coming month**

3 pions 1 dimensional Multiplicity Ratios distributions paper

Coordination – William Brooks

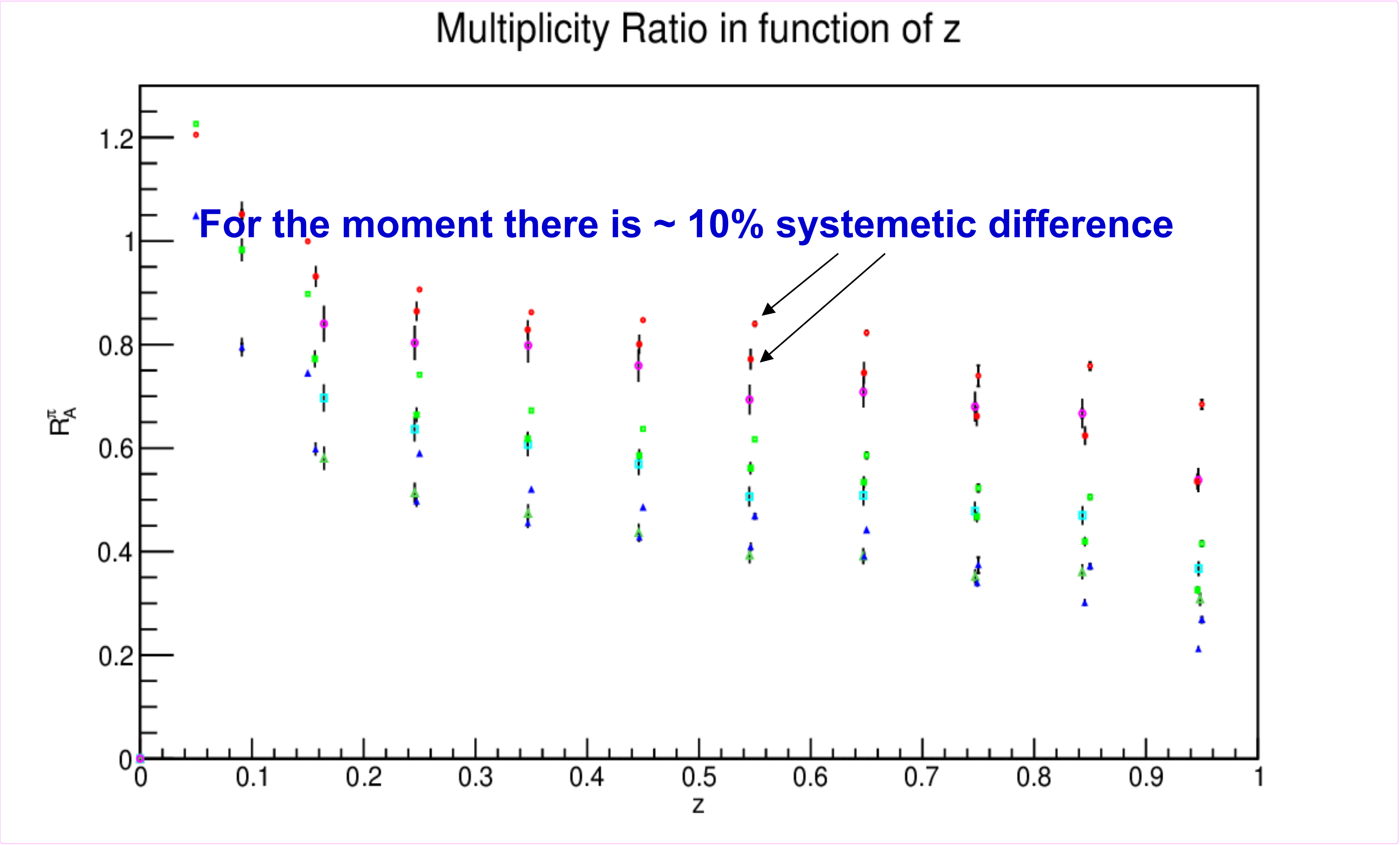
Positive Pions – Raphael Dupre, Hayk Hakobyan, Rodrigo Mendez

Negative Pions – Raphael Dupre, Ahmed El Alaoui

Neutral Pions – Taiysia Mineeva, Orlando Soto

Two analysis notes are under review

Integrated distribution comparison between Raphael and Hayk analysis



Possible sources for discrepancies

- Different dimensional binning in acceptance correction procedure (5 dim. - Hayk (up to 3% correction) & 4 dim. Raphael (10% correction))
- Tighter particle ID cuts in the case of Raphael's analysis for electrons and for pions.
- Different approaches in pion identification:

Δt – Hayk & $\Delta\beta$ – Raphael

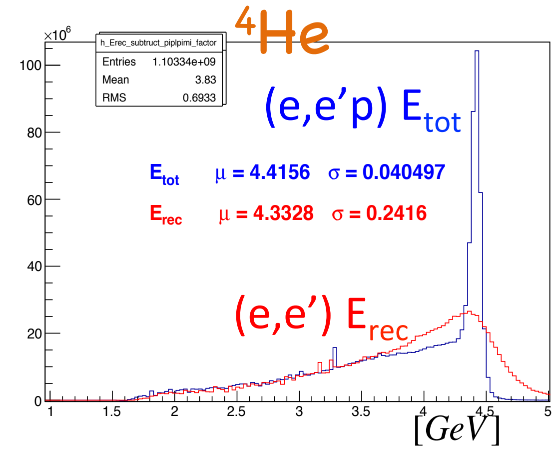
Mariana Khachatryan

Validation of neutrino energy estimation using electron scattering data

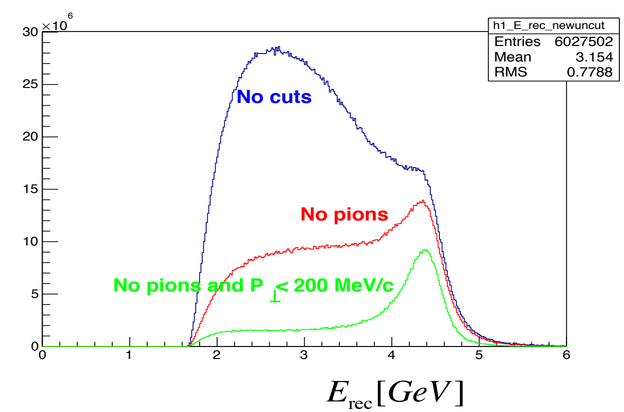
Conclusion slides

Conclusion

✧ Have obtained the beam energy using (e,e') and using (e,e'p).

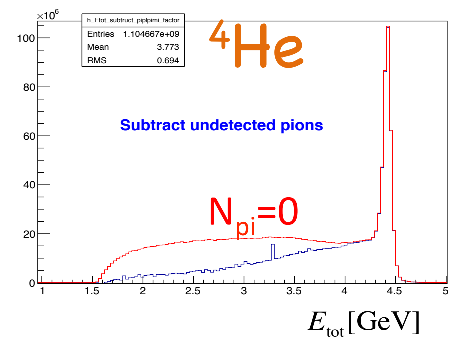


✧ Erec obtained using (e,e') isn't accurate as not all the events are quasi-elastic at these energies



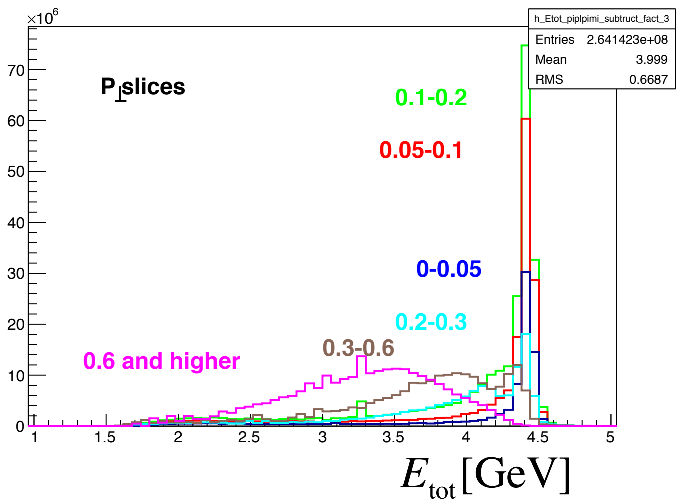
✧ E_{beam} is better reconstructed using

✧ (e,e'p)



Conclusion

✧ The reconstruction can be further improved with a transverse momentum cut



✧ It works better for light nuclei

Deeply Virtual Compton Scattering off ^{4}He:

New results and future perspectives

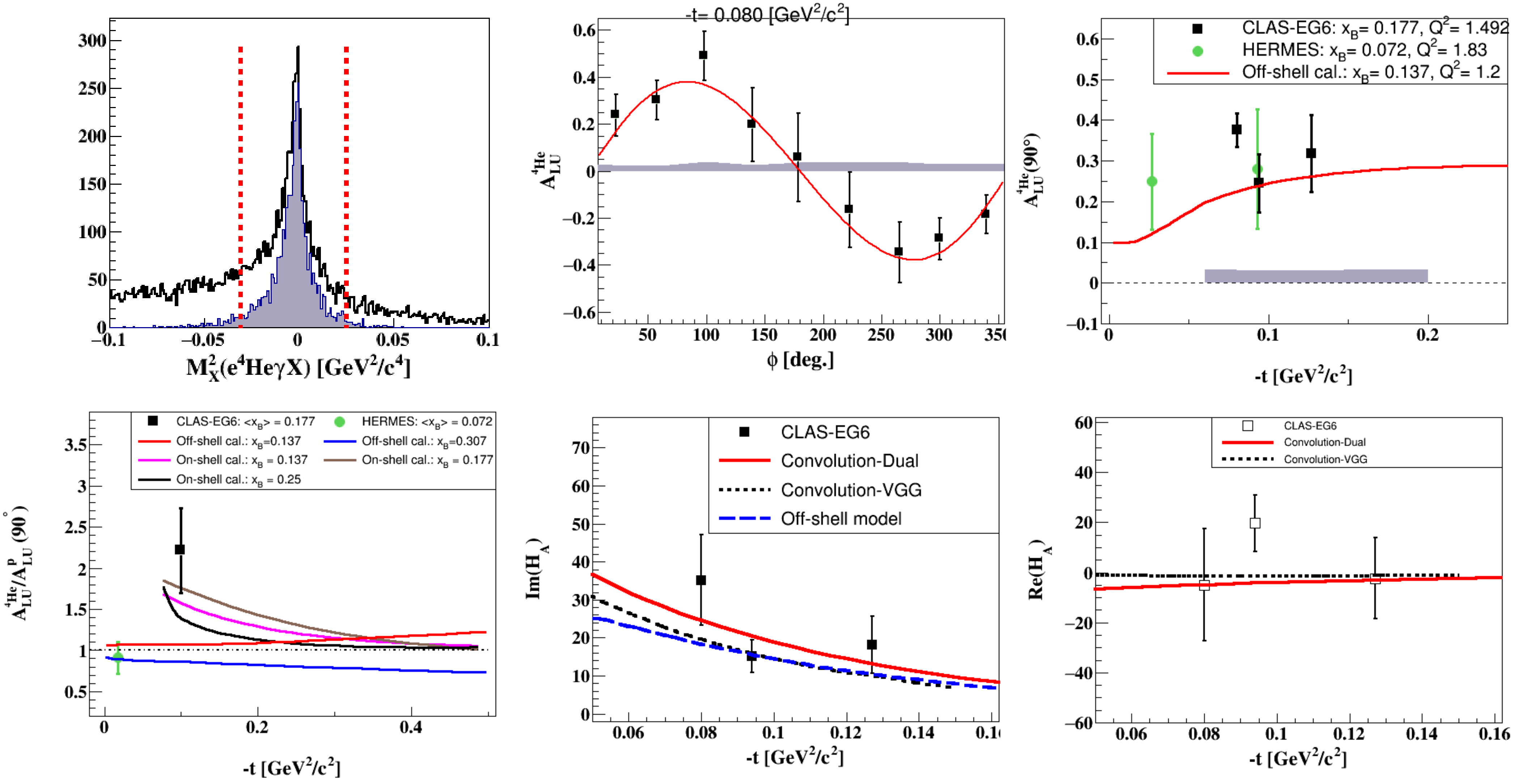
M. Hattawy

(On behalf of the CLAS collaboration)

NPWG - CLAS Collaboration Meeting (March 28-31, 2017)

Coherent DVCS events selection

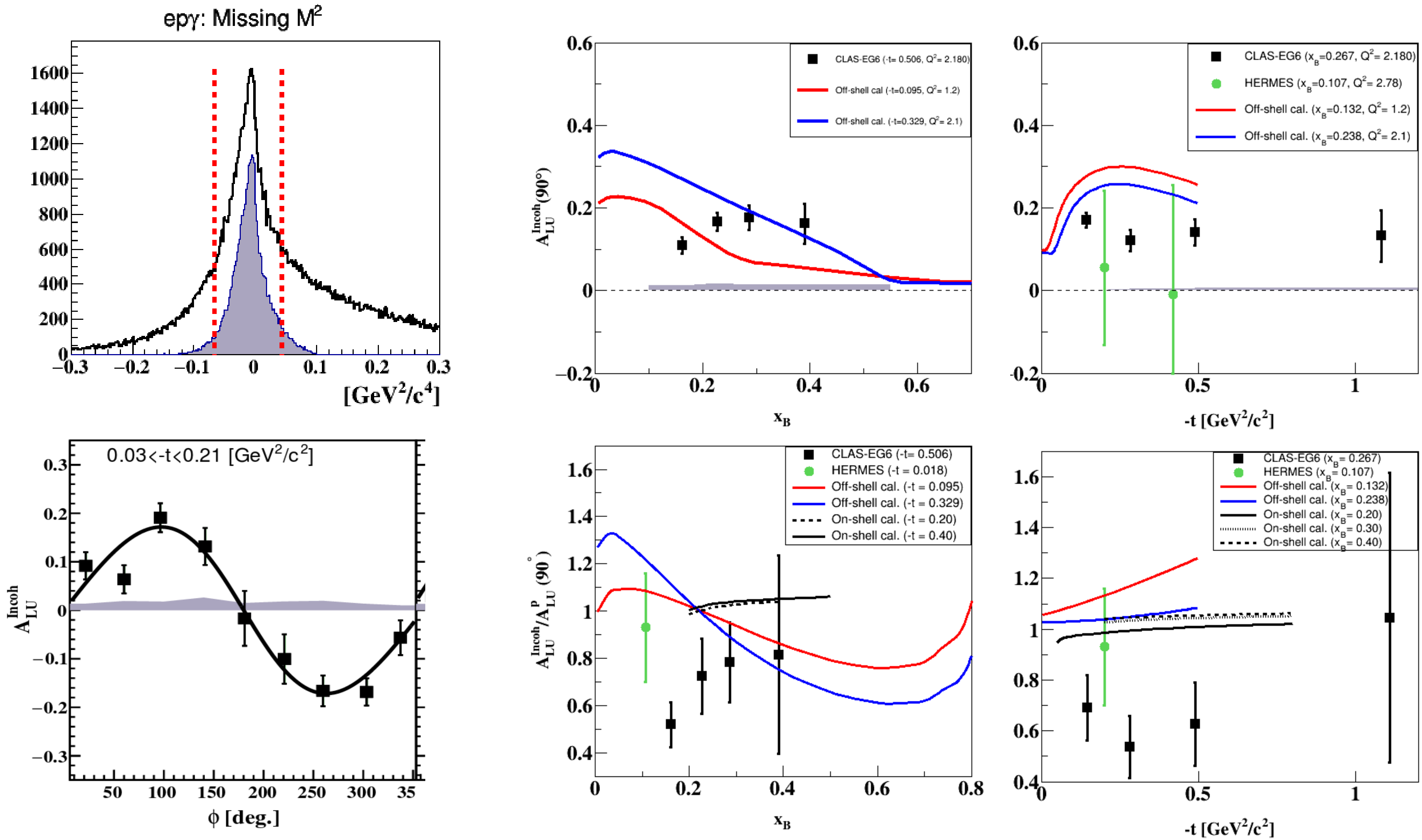
◊ One e-, at least one γ and only one ^4He. ◊ $E\gamma > 2$ GeV and $Q^2 > 1$ GeV^2. ◊ Exclusivity cuts (3 sigmas).



The coherent DVCS PRL is under review

Incoherent DVCS

◊ One e⁻. at least 1γ and one p. ◊ Eγ > 2 GeV, W > 2 GeV/c^2, Q^2 > 1 GeV². ◊ Exclusivity cuts (3 sigmas).



The incoherent DVCS PRL is in progress

Summary and outlook

◊ 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 performed the first ever experimental extraction of the real and imaginary parts of the He-4 CFF.

→ 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.

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

>> 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 ALERT Experiments

A comprehensive program to study nuclear effects

Coherent Processes on ^{4}He

- $^4\mathrm{He}(e, e'\ ^4\mathrm{He}\ \gamma)$
- $^4\mathrm{He}(e, e'\ ^4\mathrm{He}\ \phi)$

Explores the partonic structure of ^{4}He

Incoherent processes on ^{4}He and ^{2}H

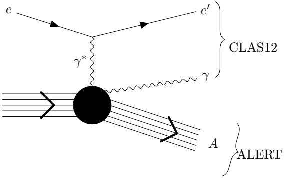
- $^4\mathrm{He}(e, e'\gamma\, p + {}^3\mathrm{H})$
- $^4\mathrm{He}(e, e'\gamma + {}^3\mathrm{He})n$
- $^2\mathrm{H}(e, e'\gamma\ + p)n$

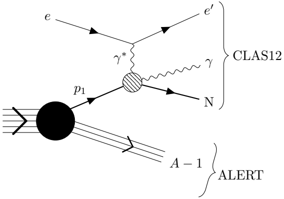
Identify medium modified nucleons

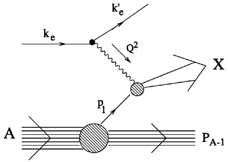
DIS on ^{4}He and ^{2}H : Tagged EMC Effect

- $^4\mathrm{He}(e, e' + {}^3\mathrm{H})X$ (proton DIS)
- $^4\mathrm{He}(e, e' + {}^3\mathrm{He})X$ (neutron DIS)
- $^2\mathrm{H}(e, e'\ + p)X$ (neutron DIS)

Test FSI and rescaling models

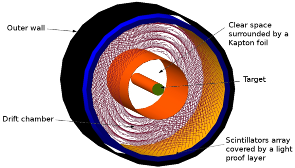


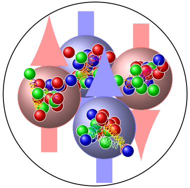


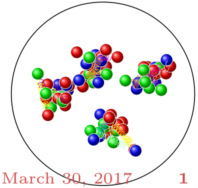


ALERT requirements

- Identify light ions: H, ^{2}H, ^{3}H, ^{3}He, and ^{4}He
- Detect the **lowest momentum** possible (close to beamline)
- Handle **high rates**
- Provide **independent trigger**
- Survive high radiation environment → **high luminosity**

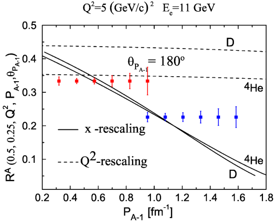




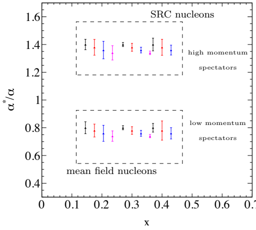


The ALERT Experiments

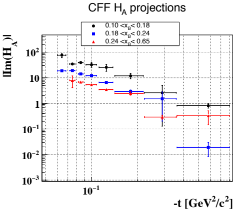
Tagged EMC



Tagged DVCS



Coherent DVCS and ϕ production



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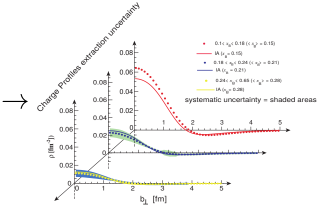

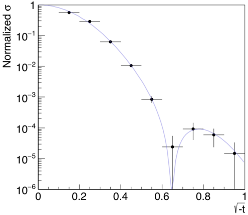

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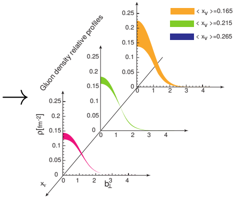


- Comprehensive program to study QCD in Nuclei
- Measure the transverse quark and gluon distributions in ^{4}He
- Answer: "What is the gluon radius in ^{4}He?"
- Pin down the origin of the EMC Effect

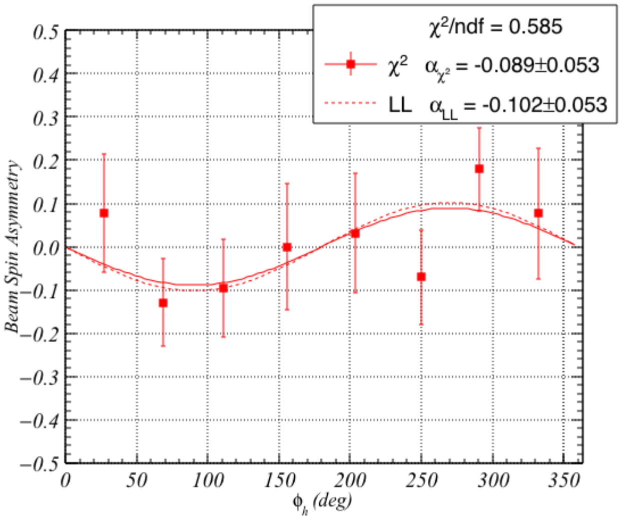
ALERT will provide important early insights for the EIC physics program

COHERENT AND INCOHERENT ELECTROPRODUCTION OF NEUTRAL PIONS OFF HELIUM-4

Bayram Torayev

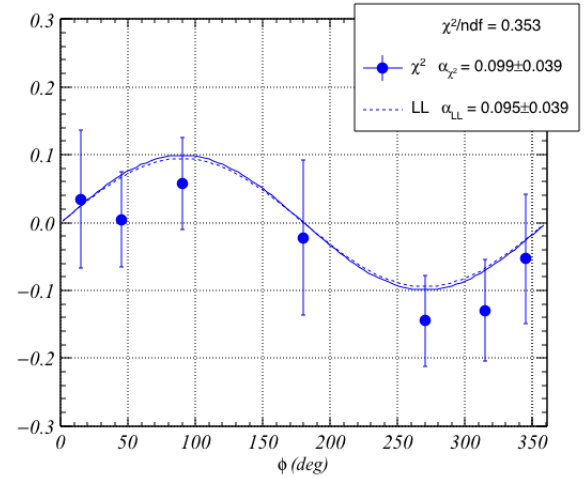
Beam Spin Asymmetry

Exclusive coherent production



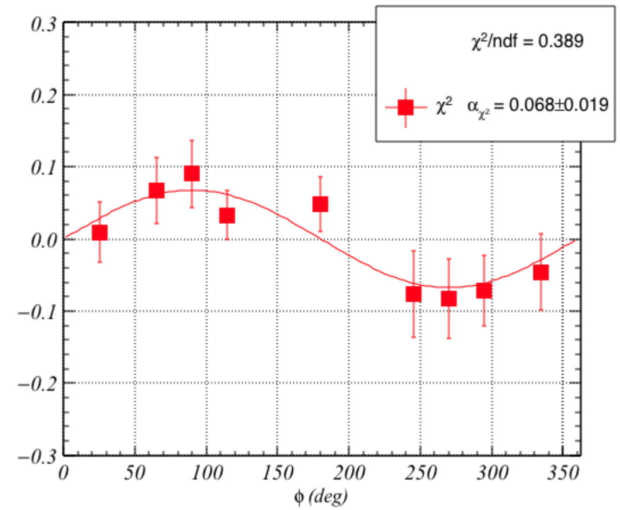
$$A_{LU}^{\sin(\varphi)}(LL) = -0.10 \pm 0.05(stat.)$$

Exclusive incoherent production



$$A_{LU}^{\sin(\varphi)} = 0.10 \pm 0.04(stat.)$$

Semi-exclusive incoherent production



$$A_{LU}^{\sin(\varphi)} = 0.07 \pm 0.02(stat.)$$

Summary

- ❖ For the first time, the beam spin asymmetry in the coherent neutral pion electroproduction on helium-4 has been measured using the CLAS detector, compact lead-tungsten calorimeter and a radial time projection chamber in Hall-B at JLAB
- ❖ The measure asymmetry has opposite sign compared to the sign of asymmetry measured in the pion electroproduction on the proton
- ❖ More theoretical support is needed to understand this result
- ❖ Work is in progress to extract cross section and try to estimate contributions of longitudinal and transverse photons (L/T separation)

Thanks for your attention

CLAS EG6:

Particle ID, Event Selection, and Raw Asymmetries for Coherent Processes

In this talk, I will outline relevant particle identification, selection of coherent DVCS and DVMP events, and details on extracting raw asymmetries.
A comparison to M. Hattawy's analysis will also be presented.

Frank Thanh Cao
UConn

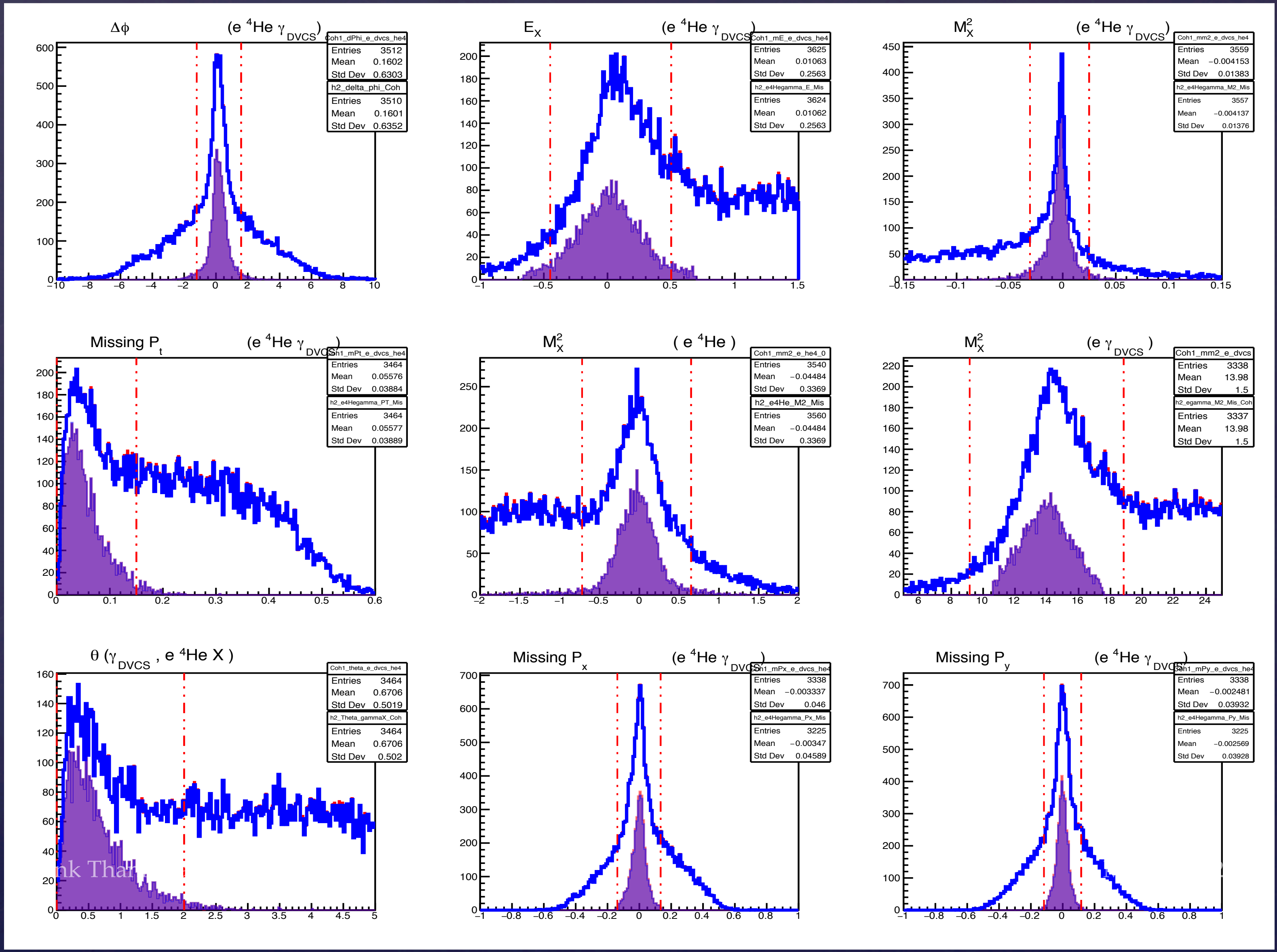
University of Connecticut

Argonne NATIONAL LABORATORY

Jefferson Lab
Thomas Jefferson National Accelerator Facility

Results

Coherent DVCS Exclusivity Cuts



Results

Coherent DVCS Raw Asymmetries