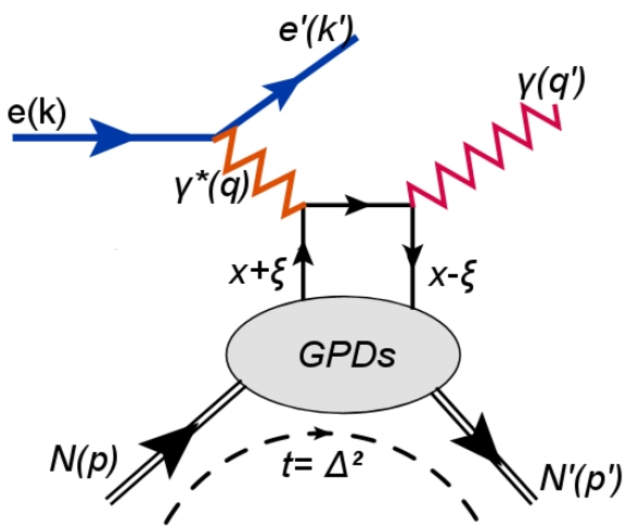
Deeply Virtual Compton Scattering off ^{4}He

CLAS-EG6 experiment

<u>M. Hattawy</u>, R. Dupré, M. Guidal



(i) Physics Motivations
(ii) Experimental Setup
(iii) Data Analysis
(iv) Results and Conclusions

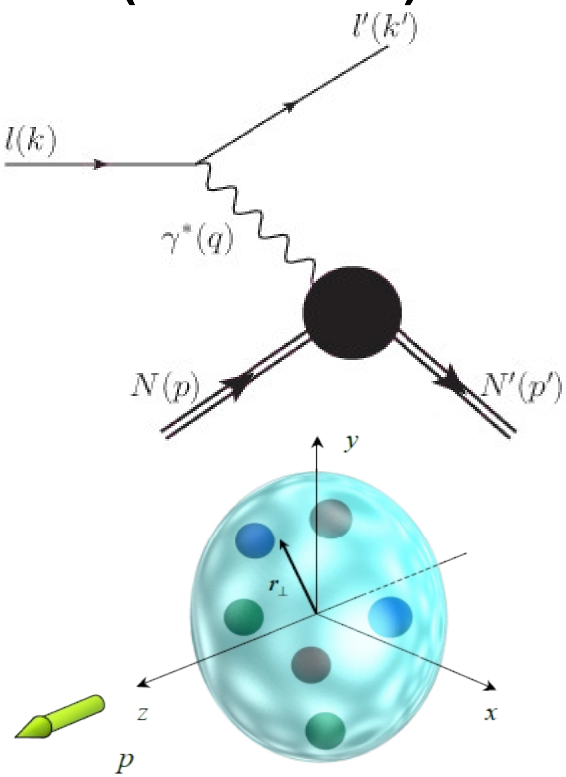
Physics Motivations

What is well studied about the nucleon parton structure?

What is missing?

Elastic Scattering

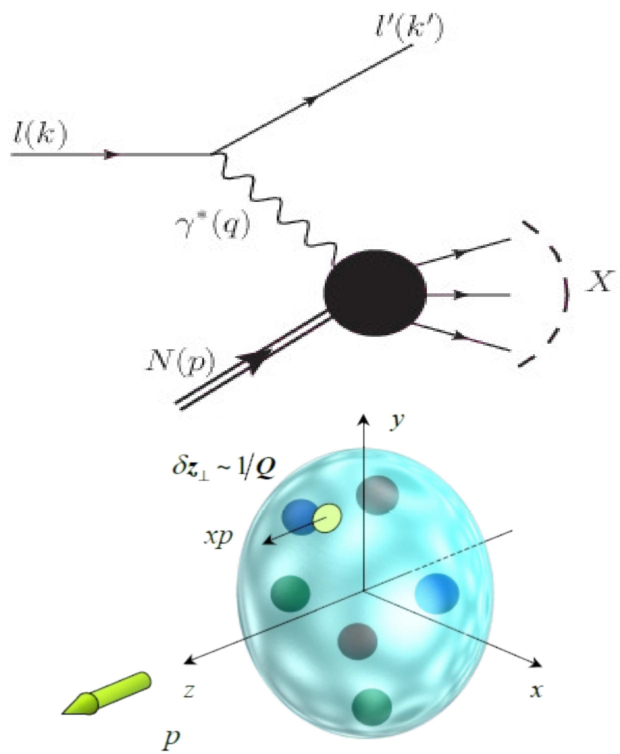
$(e^- N \rightarrow e^- N)$



Nucleon form factors, quark transverse spatial distributions.

Deep Inelastic Scattering

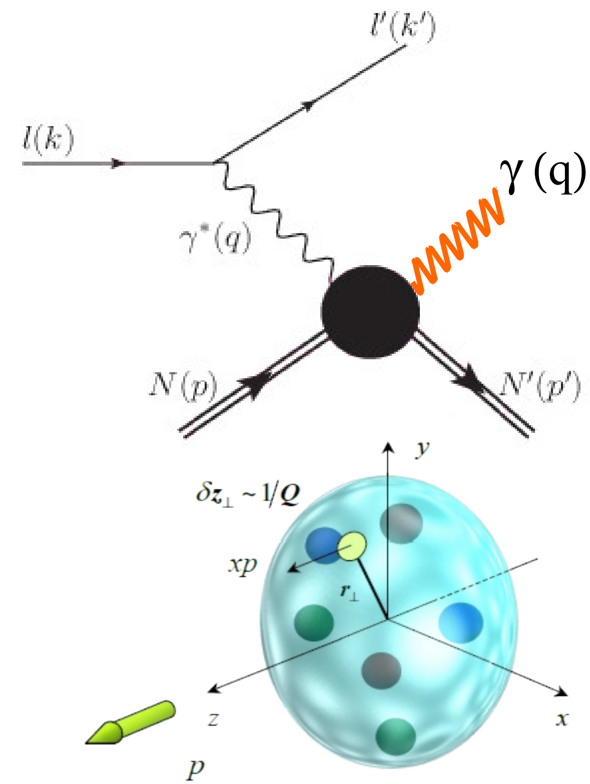
$(e^- N \rightarrow e^- X)$



Parton distribution functions, quark longitudinal momentum distributions.

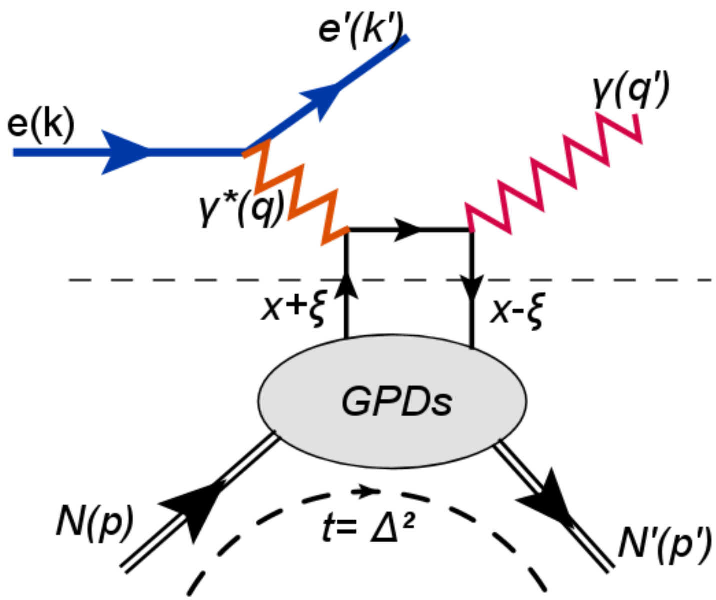
Deeply Virtual Compton Scattering

$(e^- N \rightarrow e^- \gamma N)$



Generalized parton distributions (GPDs), correlated quark longitudinal momentum in transverse space.

DVCS Reaction



Hard part (perturbative, calculable in PQCD)

Factorization

Soft part (Non-perturbative, parameterized in terms of GPDs)

t : transfer momentum
ξ : skewdness parameter
x : longitudinal parton momentum ($x \neq x_B$)
Q^2: photon's virtuality

$t=(p-p')^2=(q-q')^2$
$\xi=x_B/(2-x_B)$
$x_B=Q^2/2p.q$
$Q^2=-q^2=(k-k')^2$

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

EMC Effect

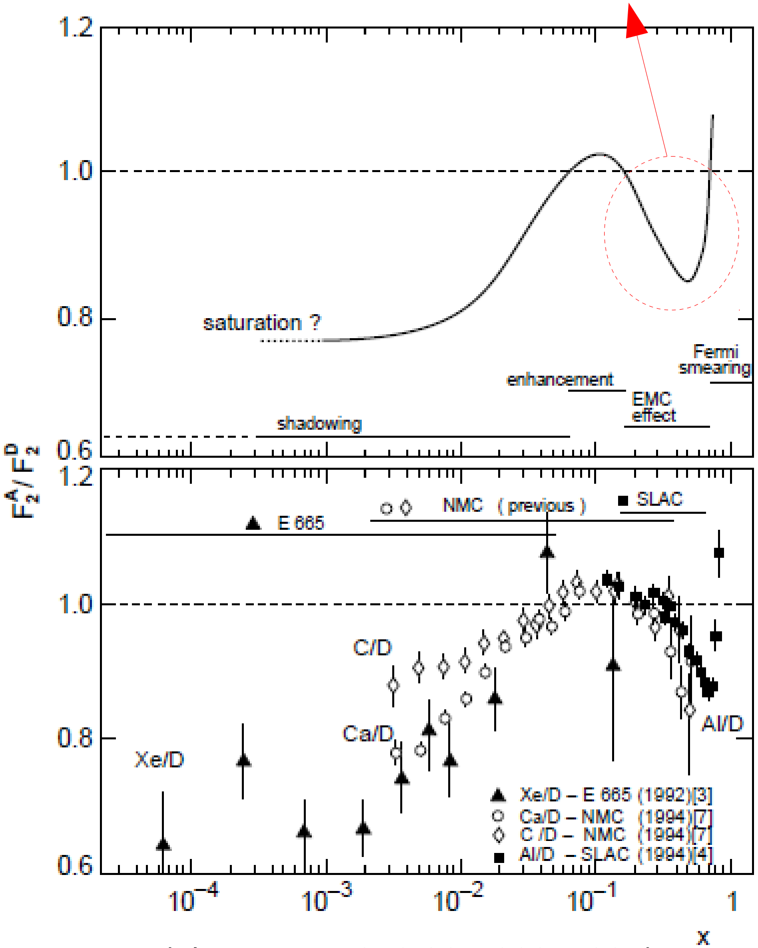
EMC (European Muon Collaboration) effect :

The structure function of the free nucleon ≠ the structure function of the nucleon inside a nucleus.

EMC effect region $0.2<x_B<0.7$

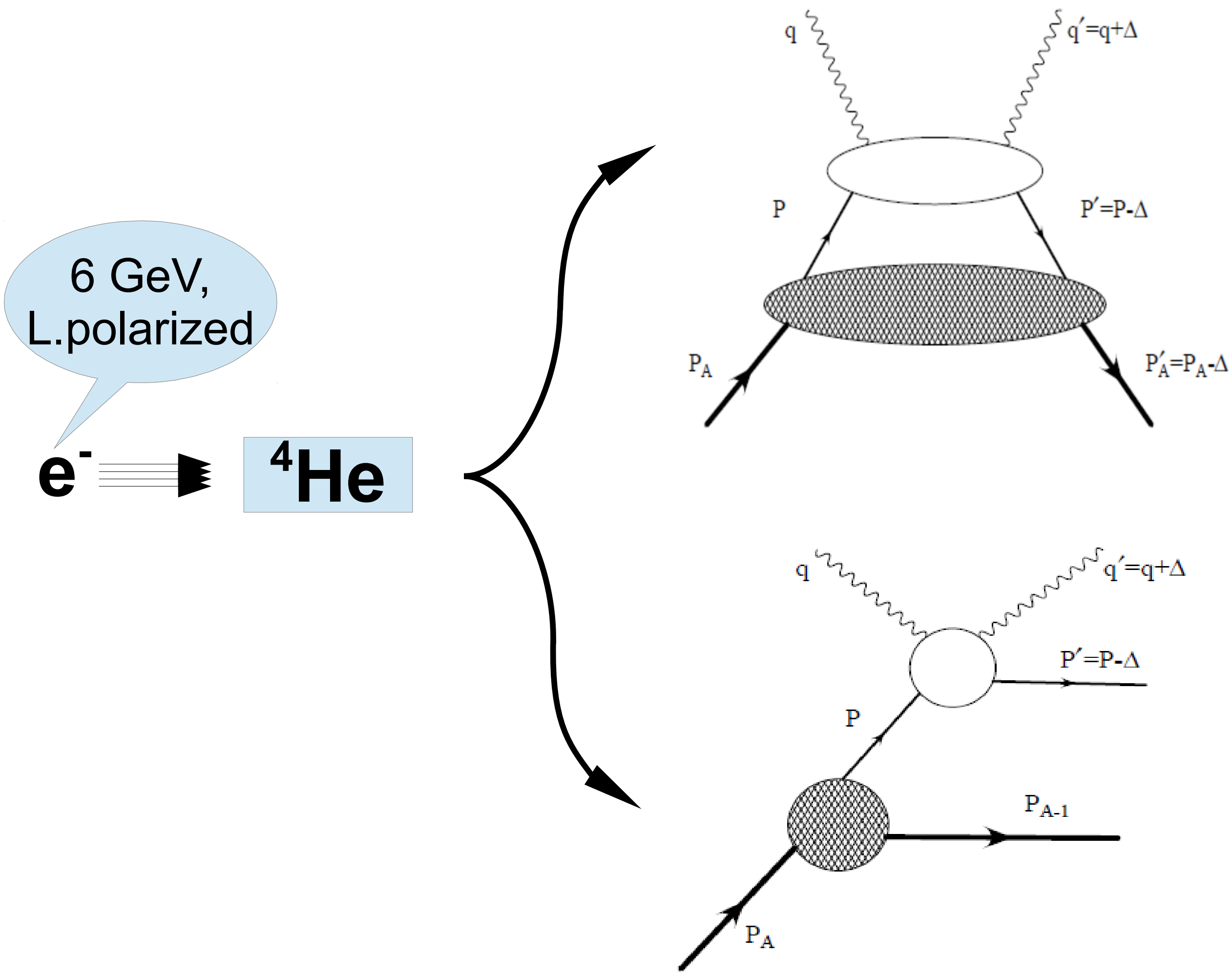
- Possible explanations:
  - → Modifications of the nucleons themselves in the nuclear medium
  - → Effect of non-nucleonic degrees of freedom, e.g, pion cloud

- We want to measure possible nuclear modifications of the GPDs with respect to the free ones.



(Phys. Rept., 240:301–393, 1994)

DVCS off ^{4}He



Coherent channel

→ ^{4}He(e,e'γ ^{4}He).
→ One GPD (spin = 0)
→ Study partonic structure of ^{4}He

Incoherent channel

→ ^{4}He(e,e' γ pX)
→ 4 GPDs needed (spin = 1/2)
→ Study medium modifications of the nucleon (EMC effect)

Our observable is the beam-spin asymmetry (A_{LU}) which is linearly sensitive to the GPDs.

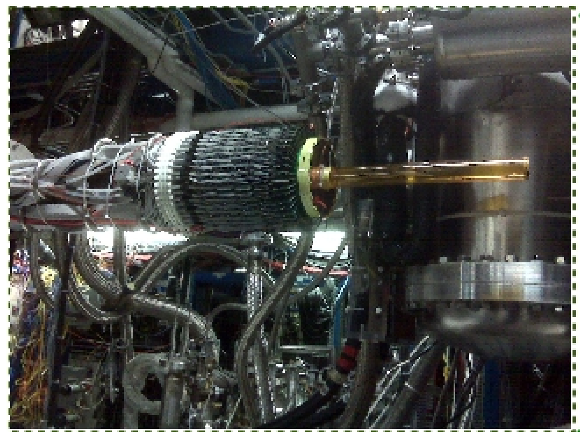
$$A_{LU} = \frac{\alpha_0(\phi)\Im_A}{\alpha_1(\phi) + \alpha_2(\phi)\Re_A + \alpha_3(\phi)(\Re_A^2 + \Im_A^2)}$$

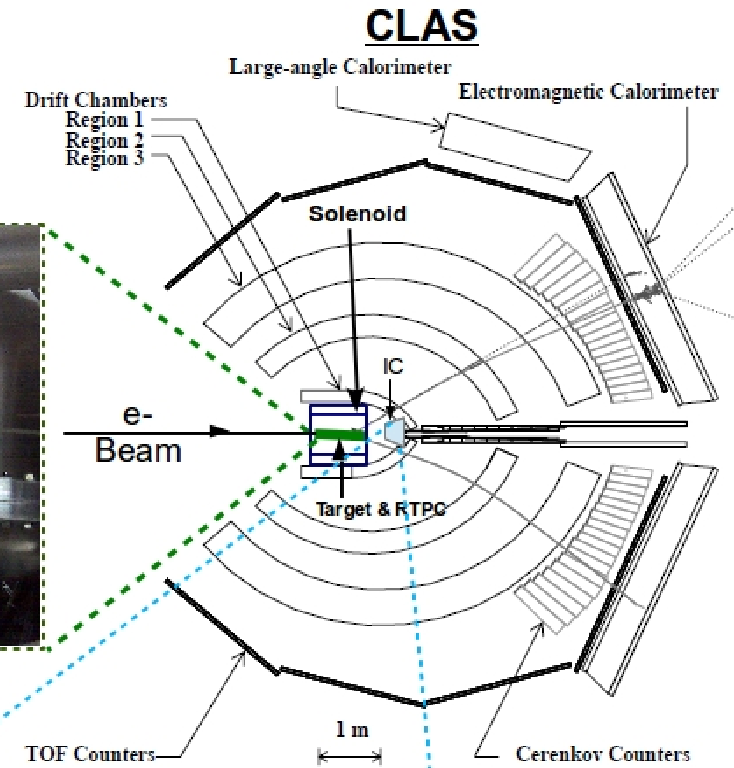
Experimental Setup

EG6 experiment, Hall B, JLab (Virginia, USA), 2009.

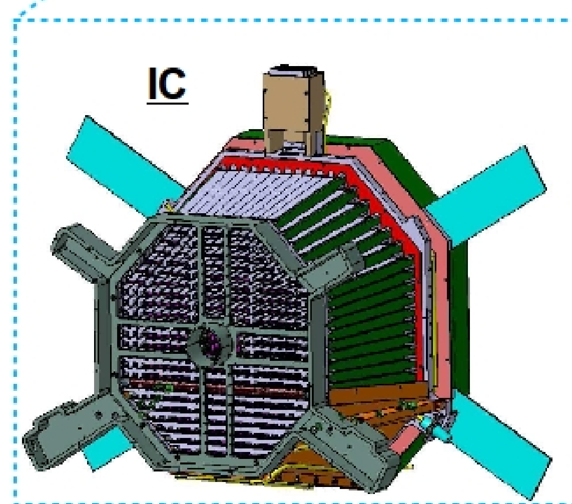
- CLAS:
→ Superconducting Torus magnet.
→ 6 independent sectors:
→ 3 DCs track charged particles.
→ CCs seperate e^-/π^-.
→ EC detect γ, e^- and n [8º,45º].
→ TOF identify hadrons.

RTPC





- RTPC:
→ Low pressure gasous detector.
→ Detect low energy nuclei.



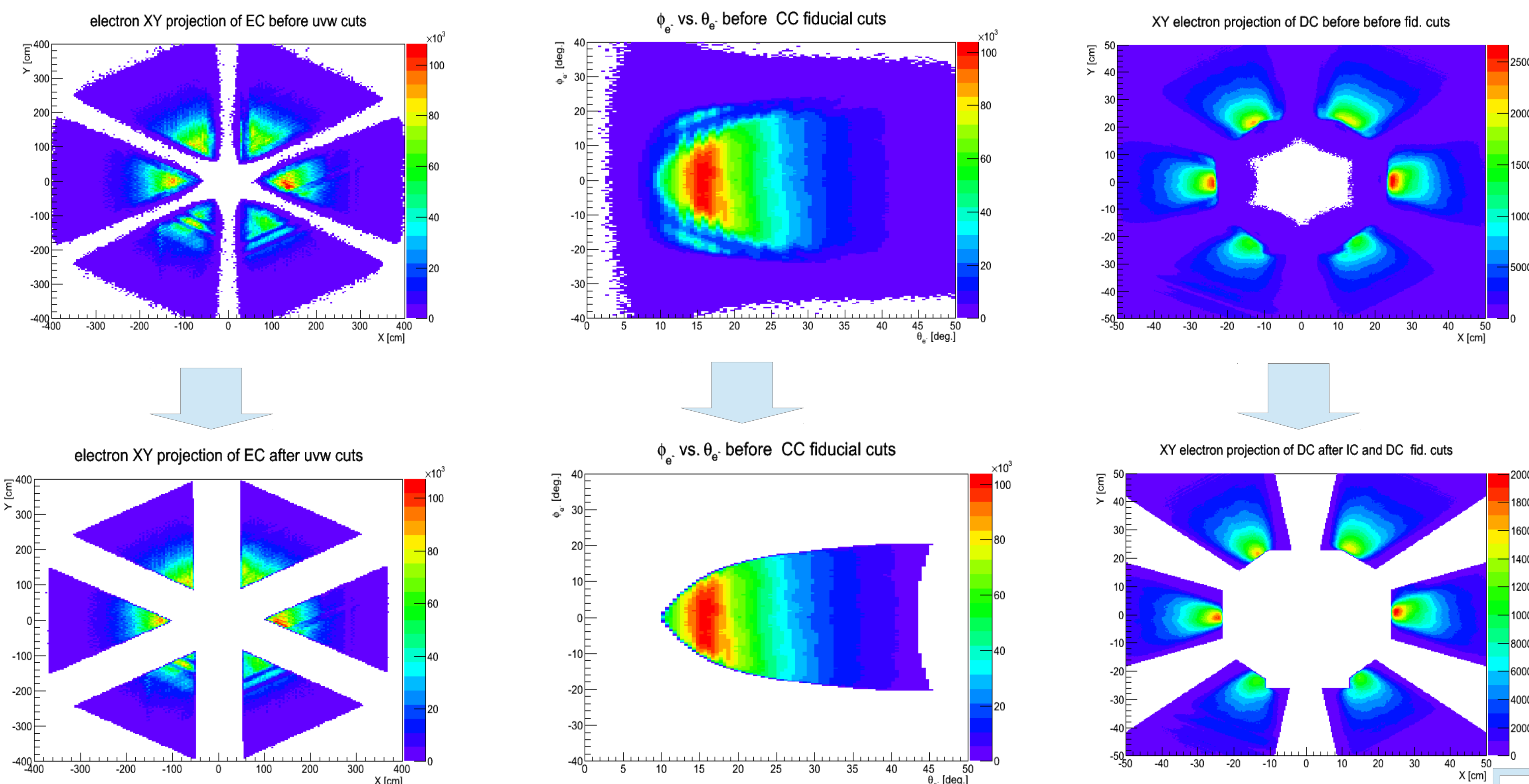
- IC: Improve γ detection acceptance [4º,14º].

- Solenoid: shield the detectors from Moller electrons.

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

Electron Selection ….. (1)

1) Negative charge.
2) Minimum momentum cut (p >500 MeV/c).
3) Geometrical cuts:
  → Electromagnetic Calorimeter (EC) cut.
  → Cherenkov Counters (CC) cut.
  → Inner Calorimeter(IC) cut and Drift Chambers (DC) cut.



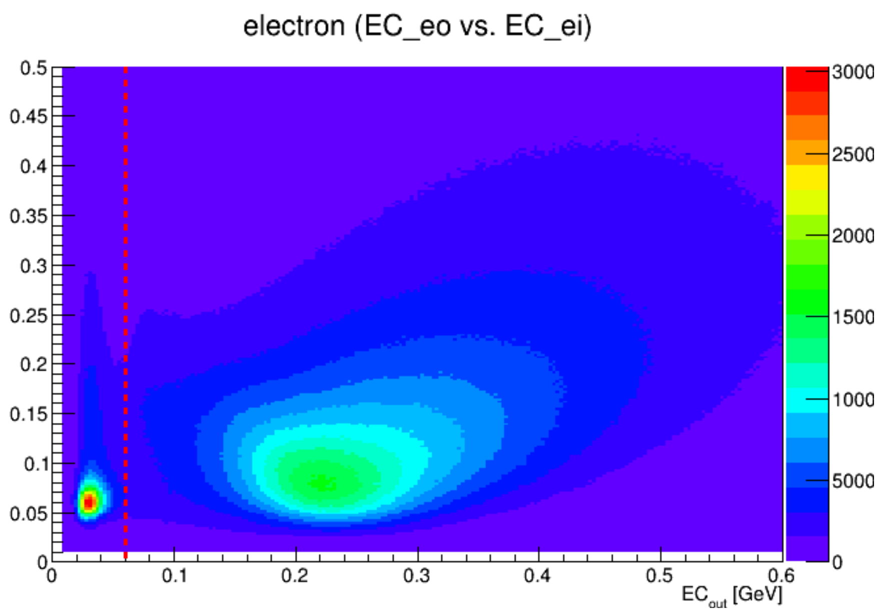
Electron Selection ….. (2)

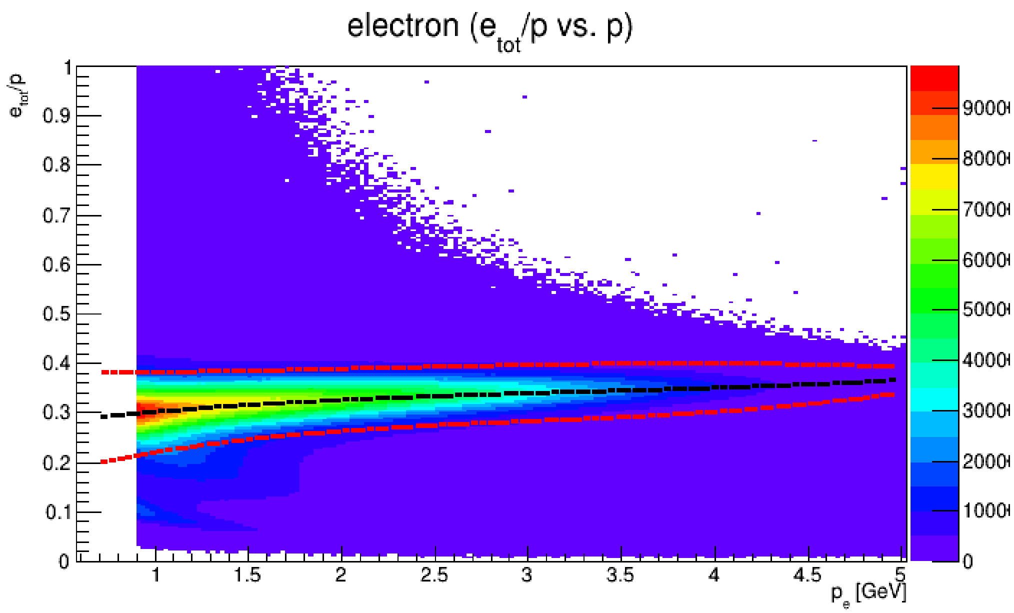
4) Energy cuts.

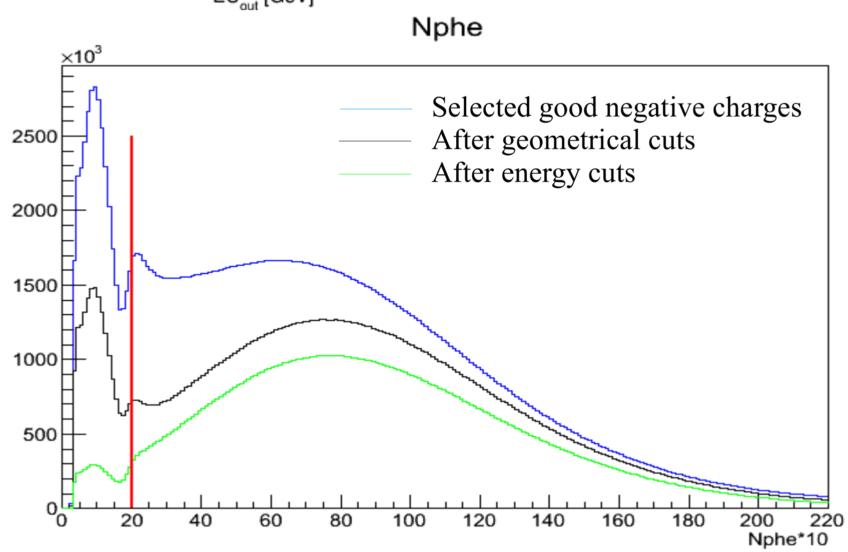
→ Minimum deposited energy in the inner side of the EC.

→ Deposited energy momentum fraction.

5) Number of photoelectrons detected in Cherenkov Counters.



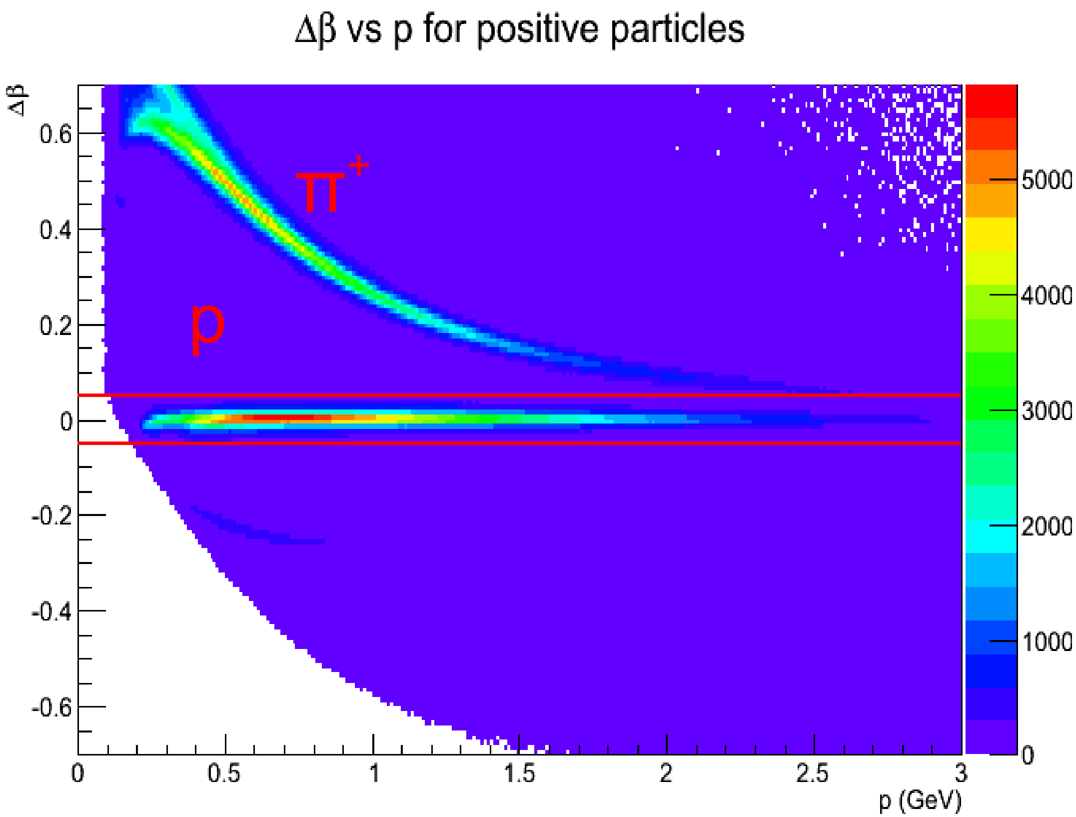




Proton Selection

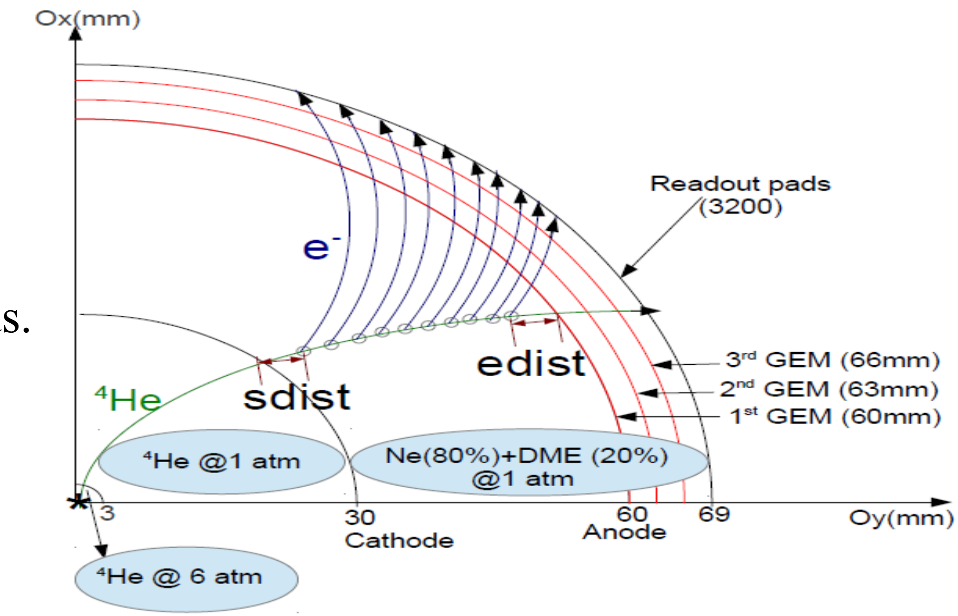
1) Positive charge.
2) Geometrical cuts:
   → Inner Calorimeter(IC) shadow cut
   → Drift Chambers (DC) cut.
3) $\Delta\beta$ cut:

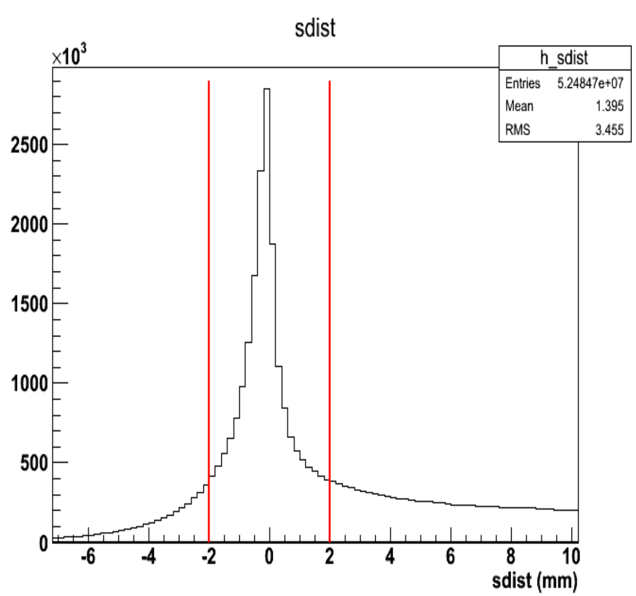
$$|\beta_{mes} - \frac{p}{\sqrt{(p^2+M^2)}}| < 0.05.$$

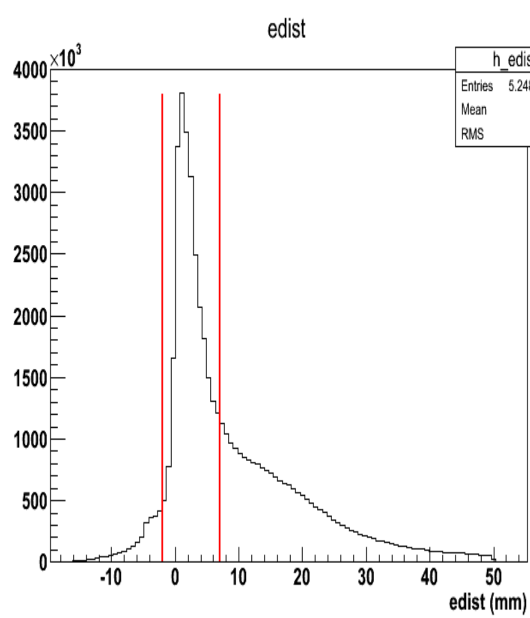


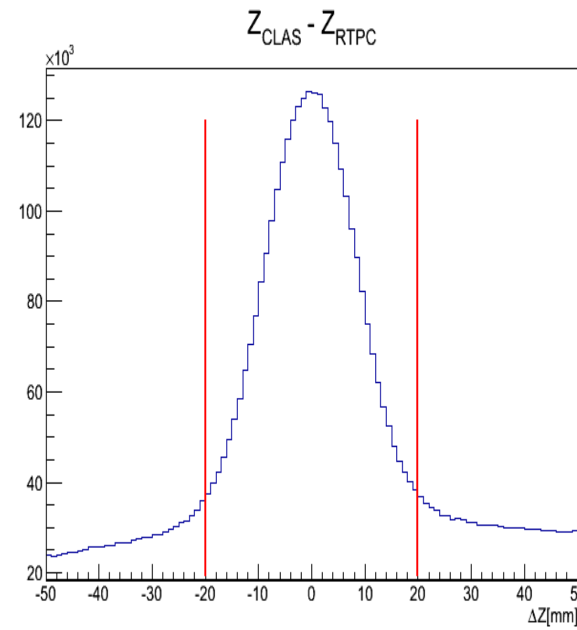
Helium Selection

1) One good electron is identified in CLAS.
2) Good track in RTPC.
   → Initiated close to the cathode (sdist).
   → Ended close to the anode (edist).
   → Positive curvature ($r_0 > 0$).
   → Readings from at least four different active pads.
   → $0.5 < X^2 < 3.5$
3) The correspondance between electron's vertex and RTPC track's vertex cut.









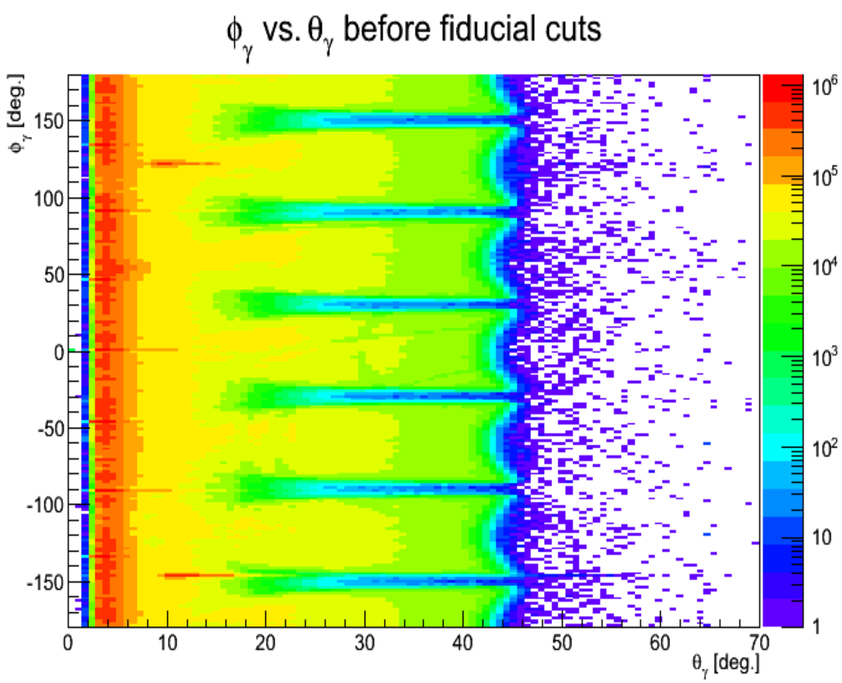
Photon selection

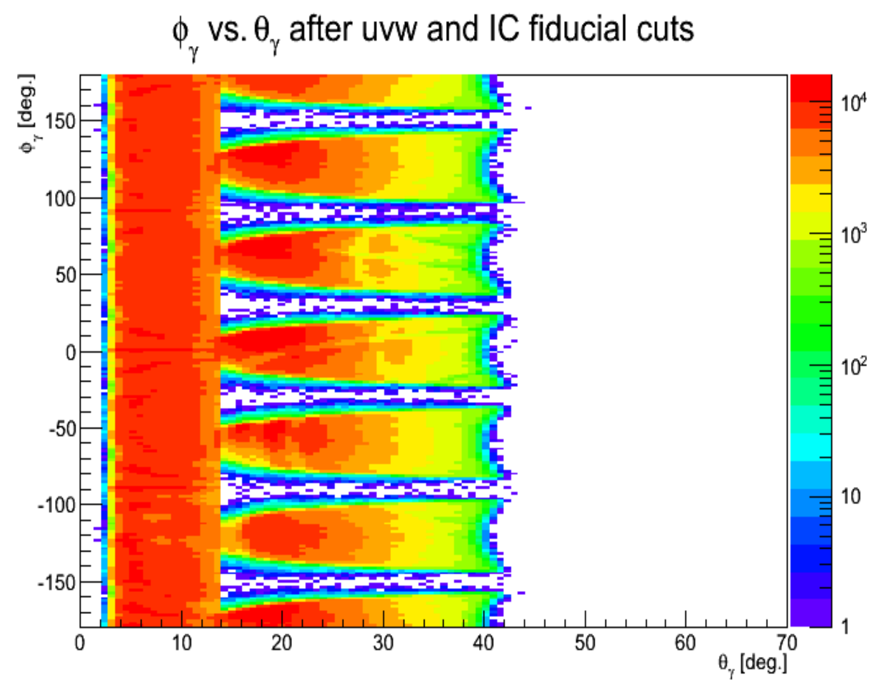
Electromagnetic Calorimeter θ[15, 45]

1) EC fiducial cut as the electron.
2) β cut [0,93, 1,07].

Inner Calorimeter θ[4, 14]

1) Clean hot channels.
2) Inner Calorimeter fiducial edges cut.





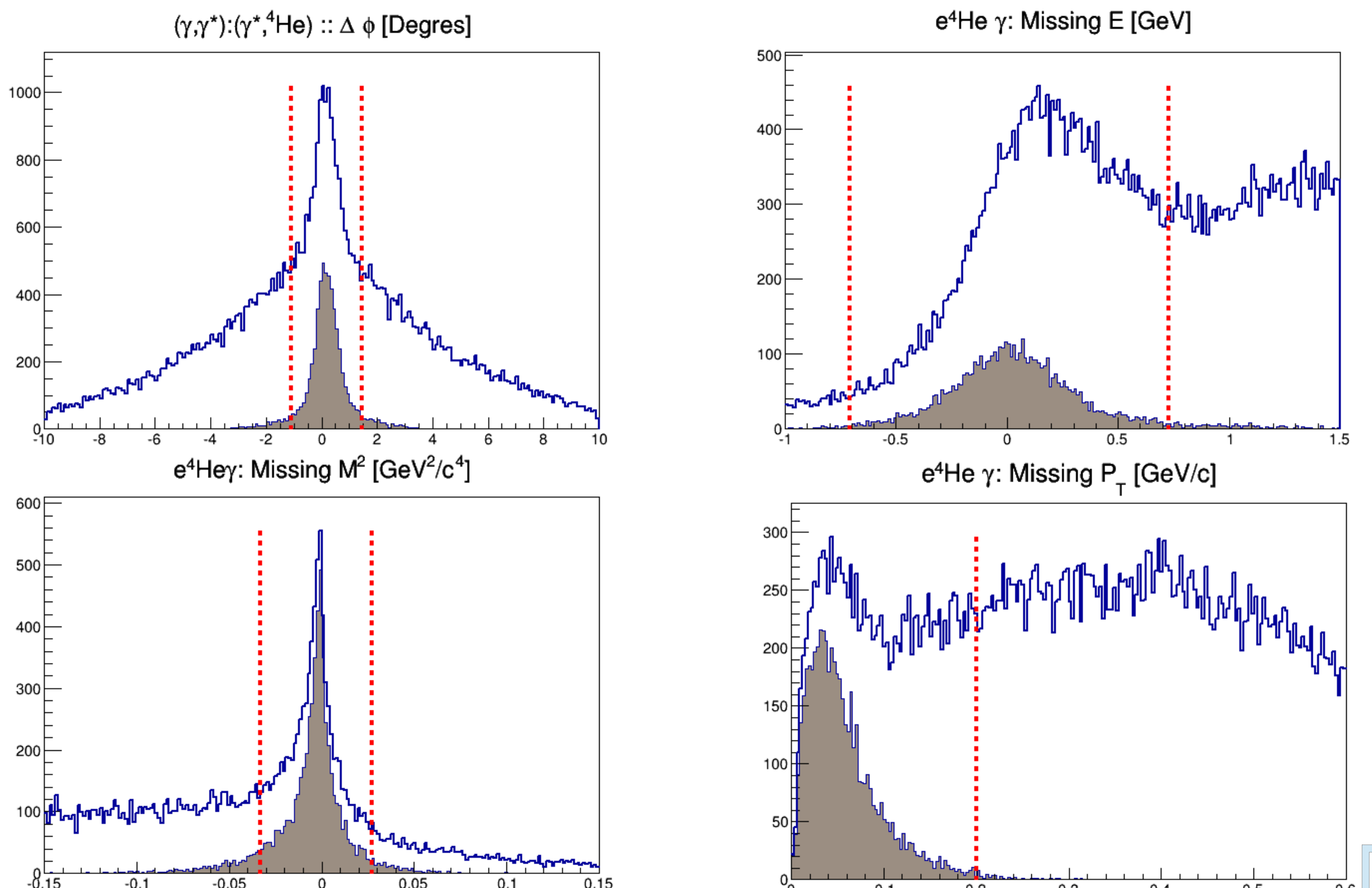
^{4}He Experimental DVCS Event Selection ….(1)

◊ One good electron in CLAS, one photon in the IC or the EC, and one good track in the RTPC.

◊ $E\gamma > 2$ GeV, $W > 2$ GeV/c , $(E_b\text{-}E_{e'})/E_b < 0.85$ and $Q^2 > 1$ GeV^2.

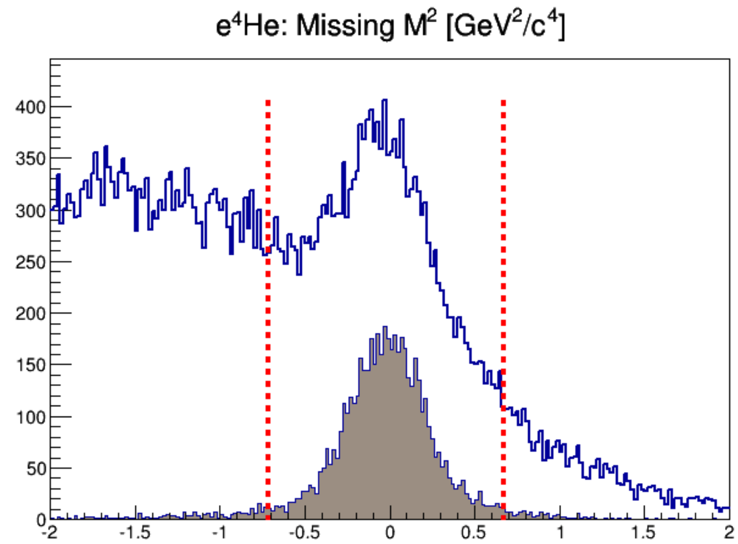
◊ Exclusivity cuts (3 sigma cuts):

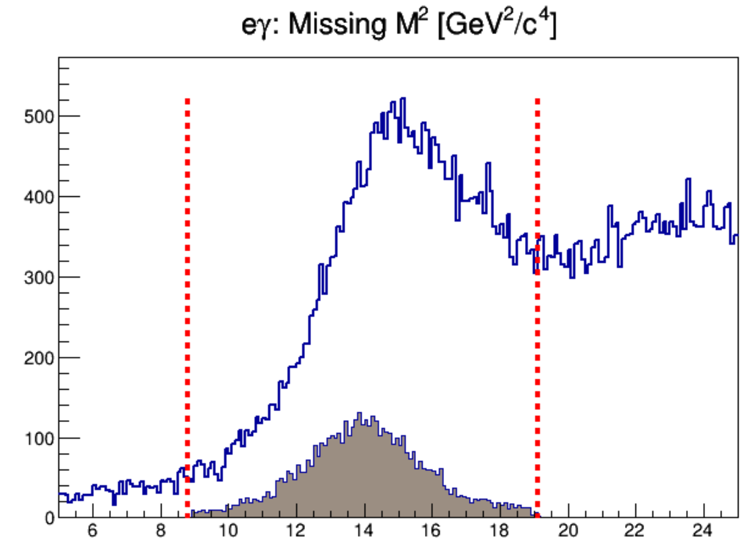
- In BLUE, DVCS events before all exclusivity cuts.
- In shadowed BROWN, DVCS events which pass all the other exclusivity cuts except the quantity itself.

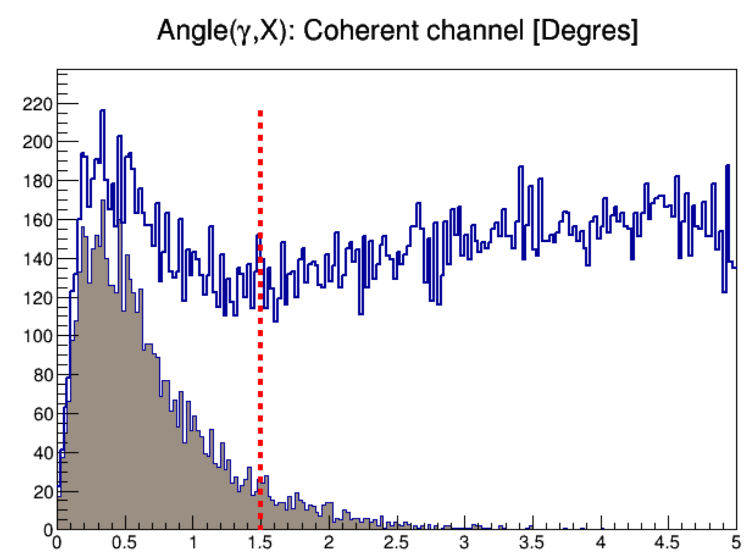


^{4}He Experimental DVCS Event Selection ….(2)

◊ One good electron in CLAS, one photon in the IC or the EC, and one good track in the RTPC.
◊ $E\gamma > 2$ GeV, W > 2 GeV/c , $(E_b - E_{e'})/E_b < 0.85$ and $Q^2 > 1$ GeV².
◊ Exclusivity cuts (3 sigma cuts):

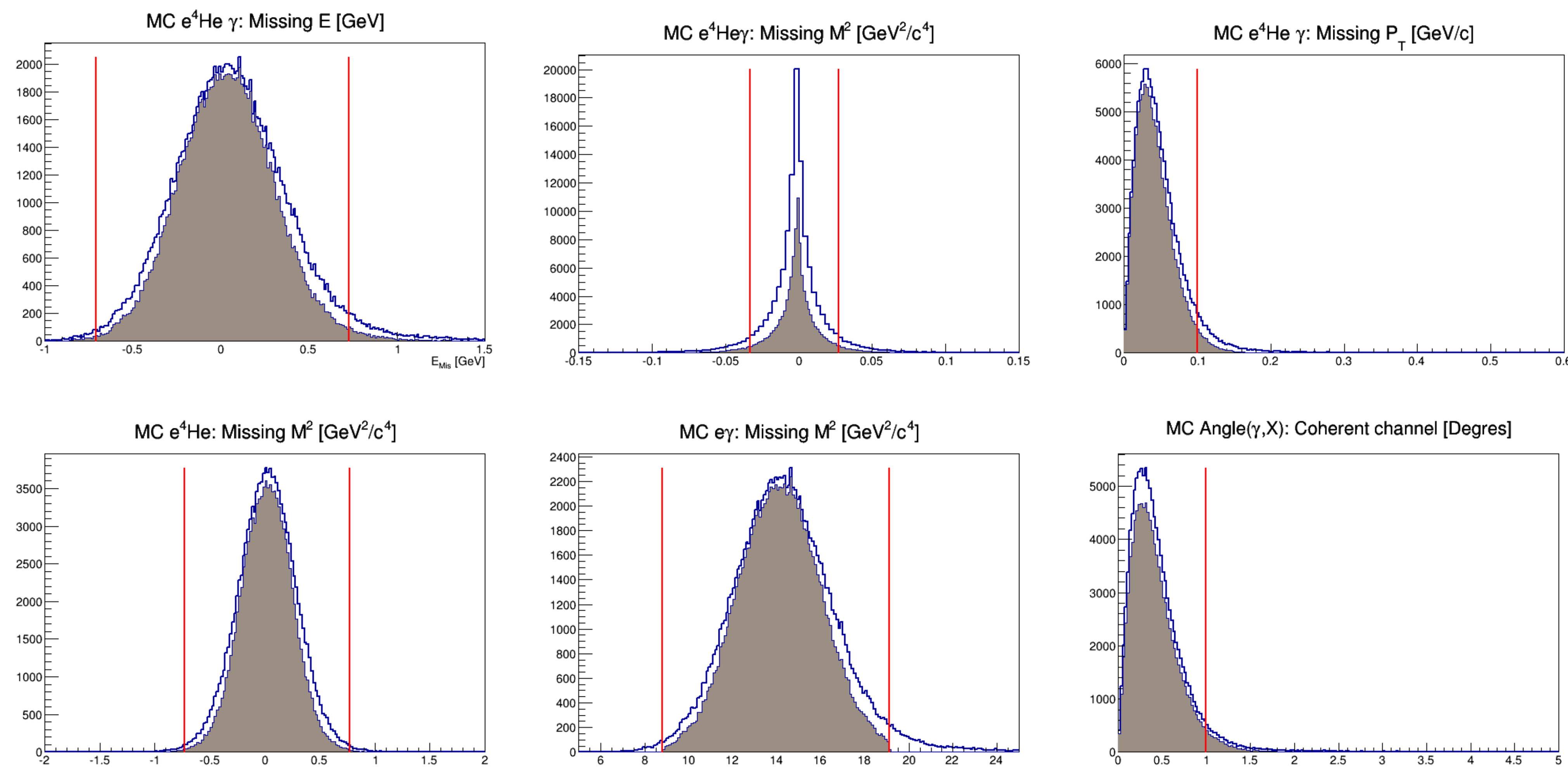






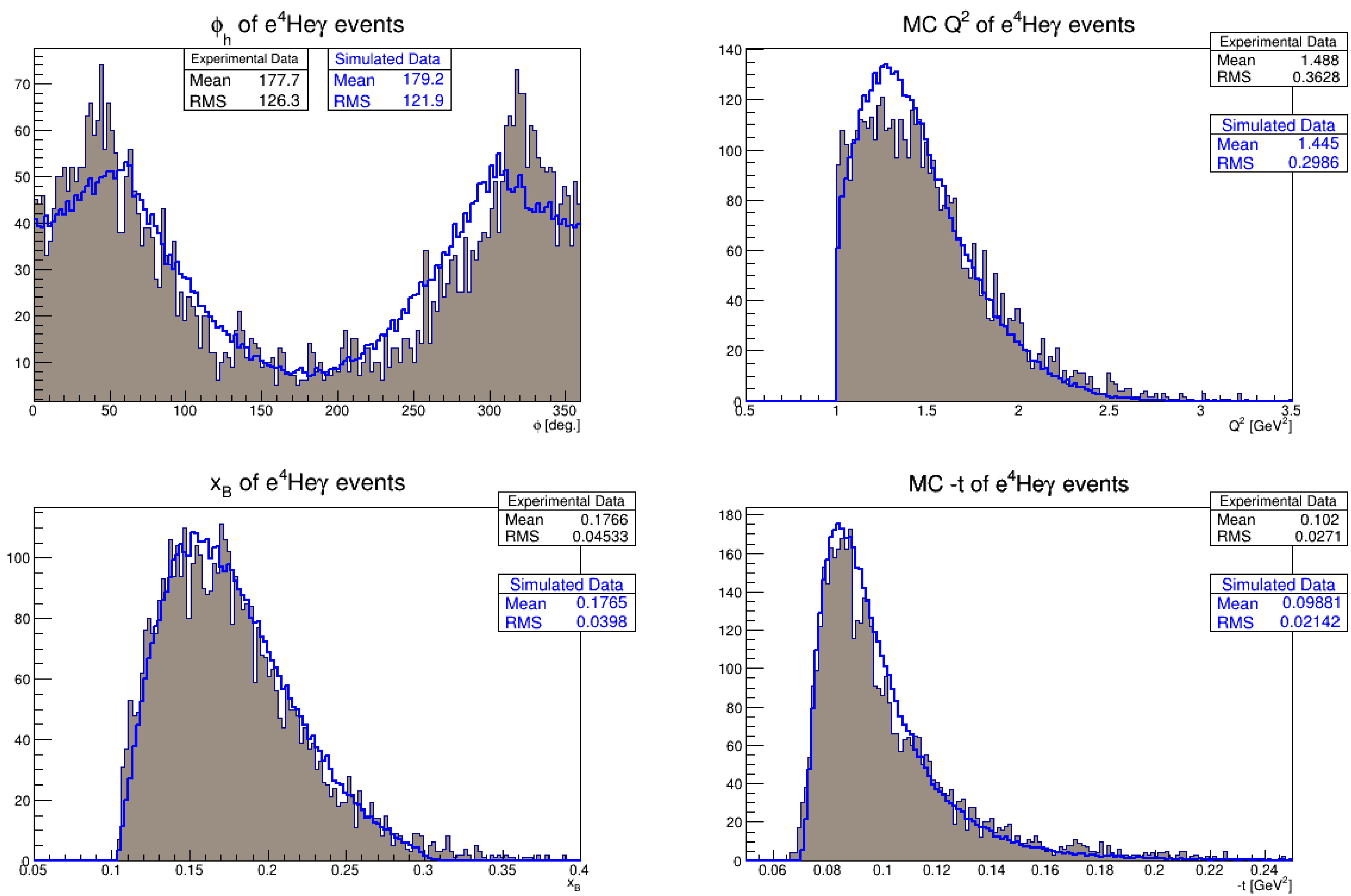
^{4}He Simulated DVCS Event Selection

◊ Apply the same experimental selection cuts.
◊ One good electron in CLAS, one photon in the IC or the EC, and one good track in the RTPC.
◊ $E\gamma > 2$ GeV, $W > 2$ GeV/c , $(E_b-E_{e'})/E_b < 0.85$ and $Q^2 > 1$ GeV².
◊ Exclusivity cuts (3 sigma cuts):



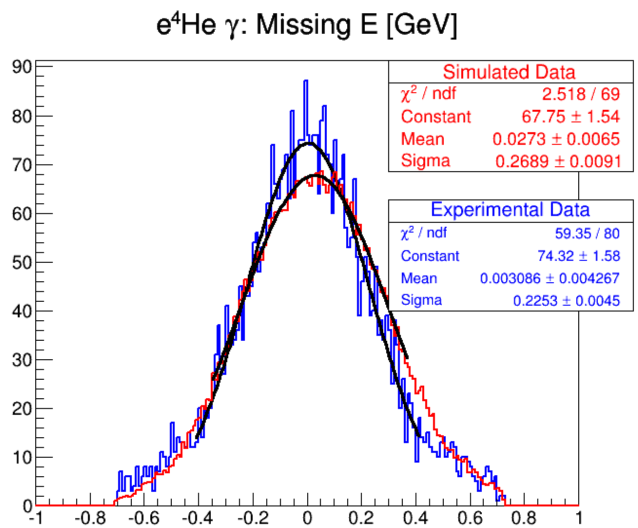
Comparison between Simulated and Experimental $e^4He\gamma$ ….(1)

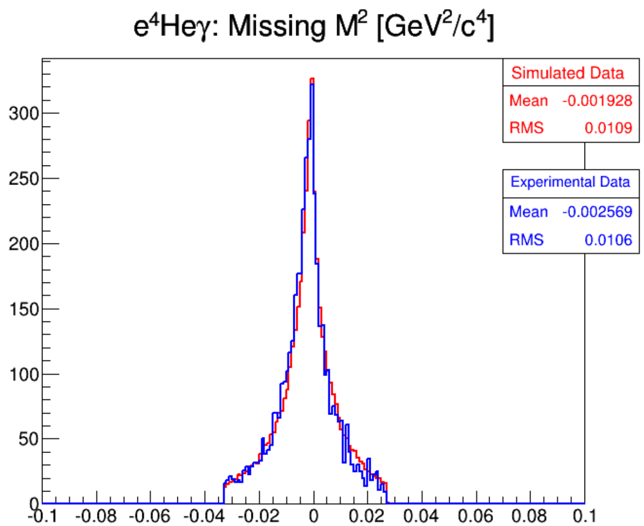
◊ Matching in terms of kinematics:

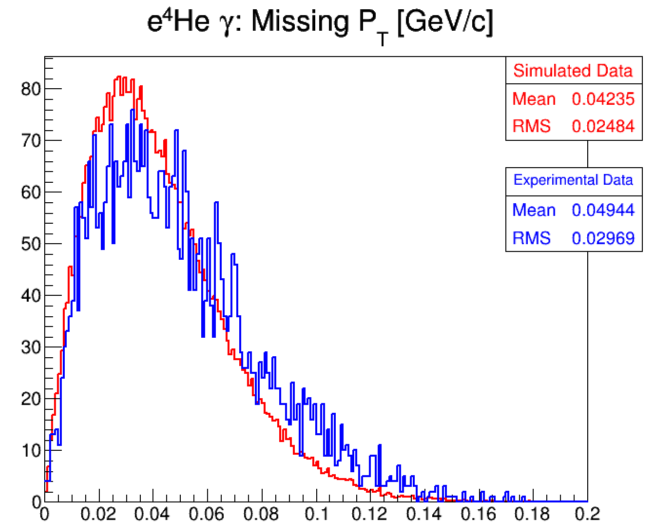


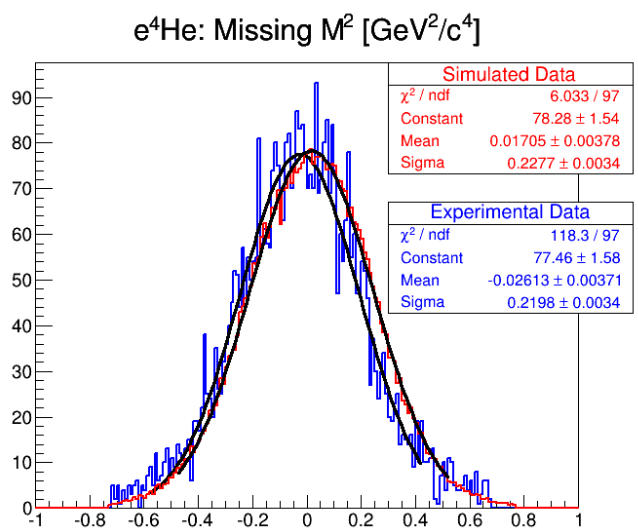
Comparison between Simulated and Experimental $e^4He\gamma$ ….(2)

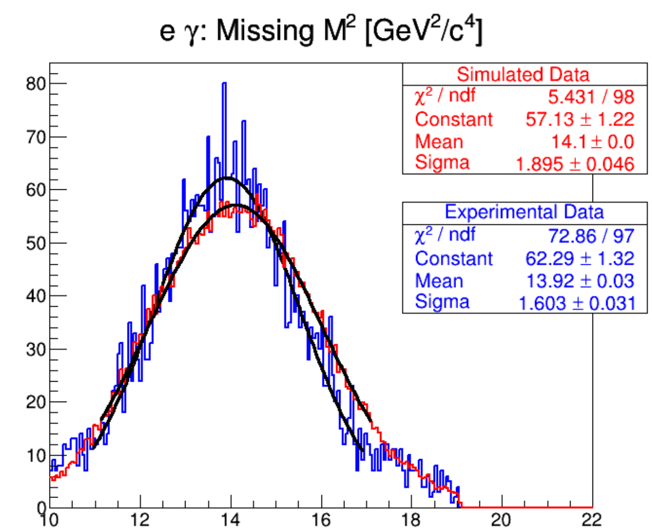
◊ In terms of the exclusive quantities:

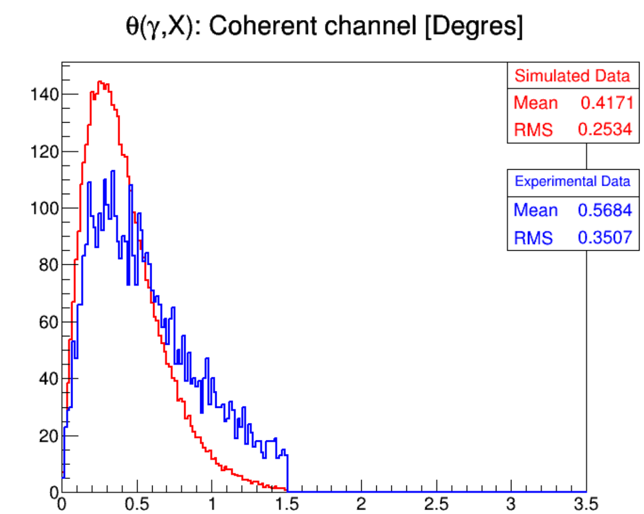












Background Subtraction

◊ With our kinematics, the main background comes from the exclusive π^0 channel ($e^4He\pi^0/ep\pi^0$) in which one photon of the π^0's photons is detected and passed the exclusivity cuts.

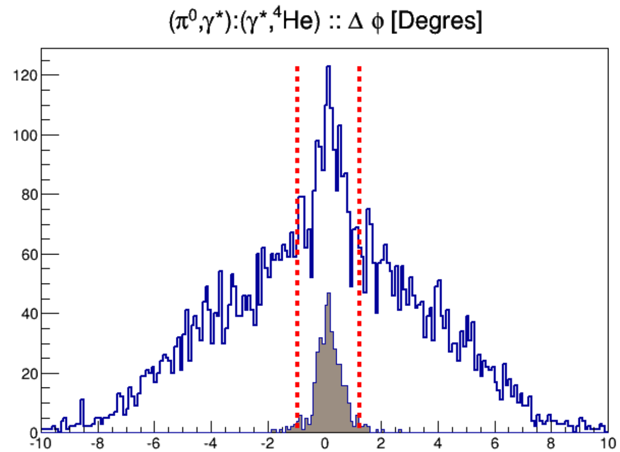
◊ We use the simulation to compute the contamination of π^0 to the DVCS channels.

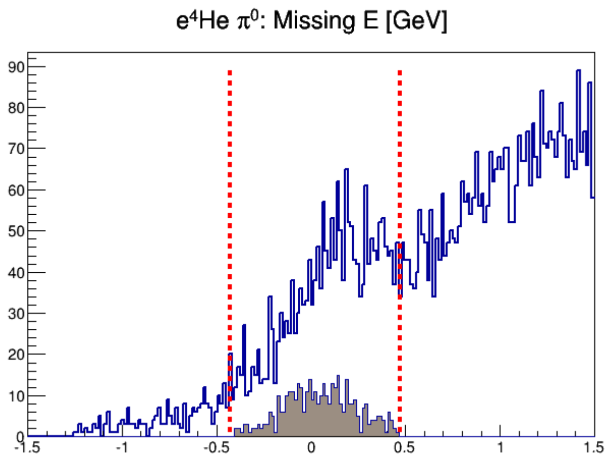
◊ The procedures:

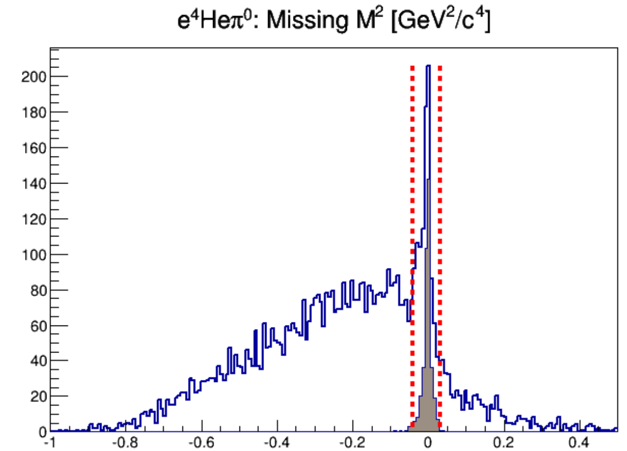
→ Select the experimental $e^4He\pi^0/ep\pi^0$ events.
→ Generate and simulate $e^4He\gamma/ep\gamma$ events to define the exclusivity cuts on the DVCS events.
→ Generate and simulate $e^4He\pi^0/ep\pi^0$ events.
→ Find the contamination ratio ($R = e^4He\pi^0(1\gamma)$ / $e^4He\pi^0(2\gamma)$). This is performed in Q2, x_B, t bins.
→ The number of experimental $e^4He\pi^0/ep\pi^0$ events in which one photon is detected is proportional to the ratio R.
→ Subtract this proportionality (function of phi, Q^2, x_B, t) from data.
→ Extract the corrected Beam Spin Asymmetries.

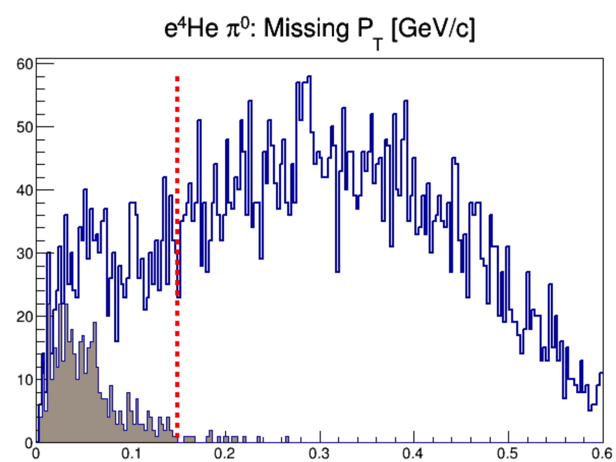
Experimental $e^4He\pi^0$ Event Selection

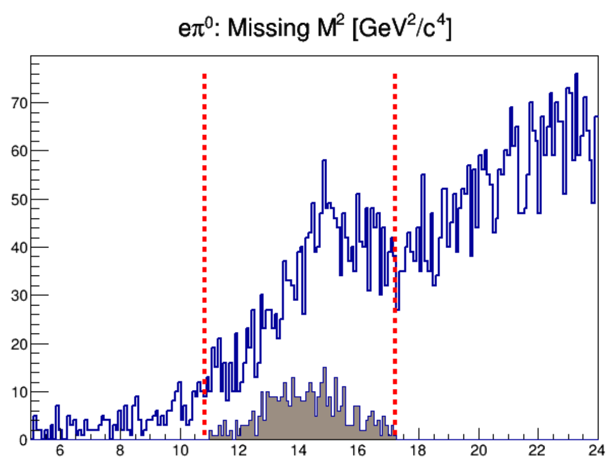
◊ Select events with one good e, ^{4}He and $\pi^0(\gamma\gamma)$ [ICIC, ICEC, ECEC] final state particles.
◊ Pass the cuts: $E_{\pi^0} > 2$ GeV, $W > 2$ GeV/c , $(E_b-E_{e'})/E_b < 0.85$ and $Q^2 > 1$ GeV^2.
◊ Pass these 3 sigmas exclusivity cuts.

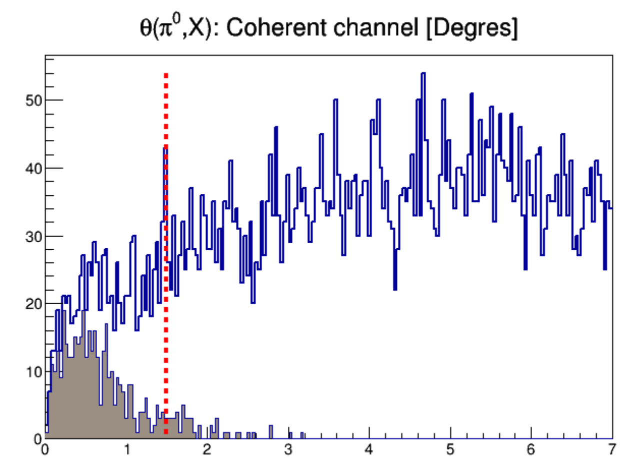










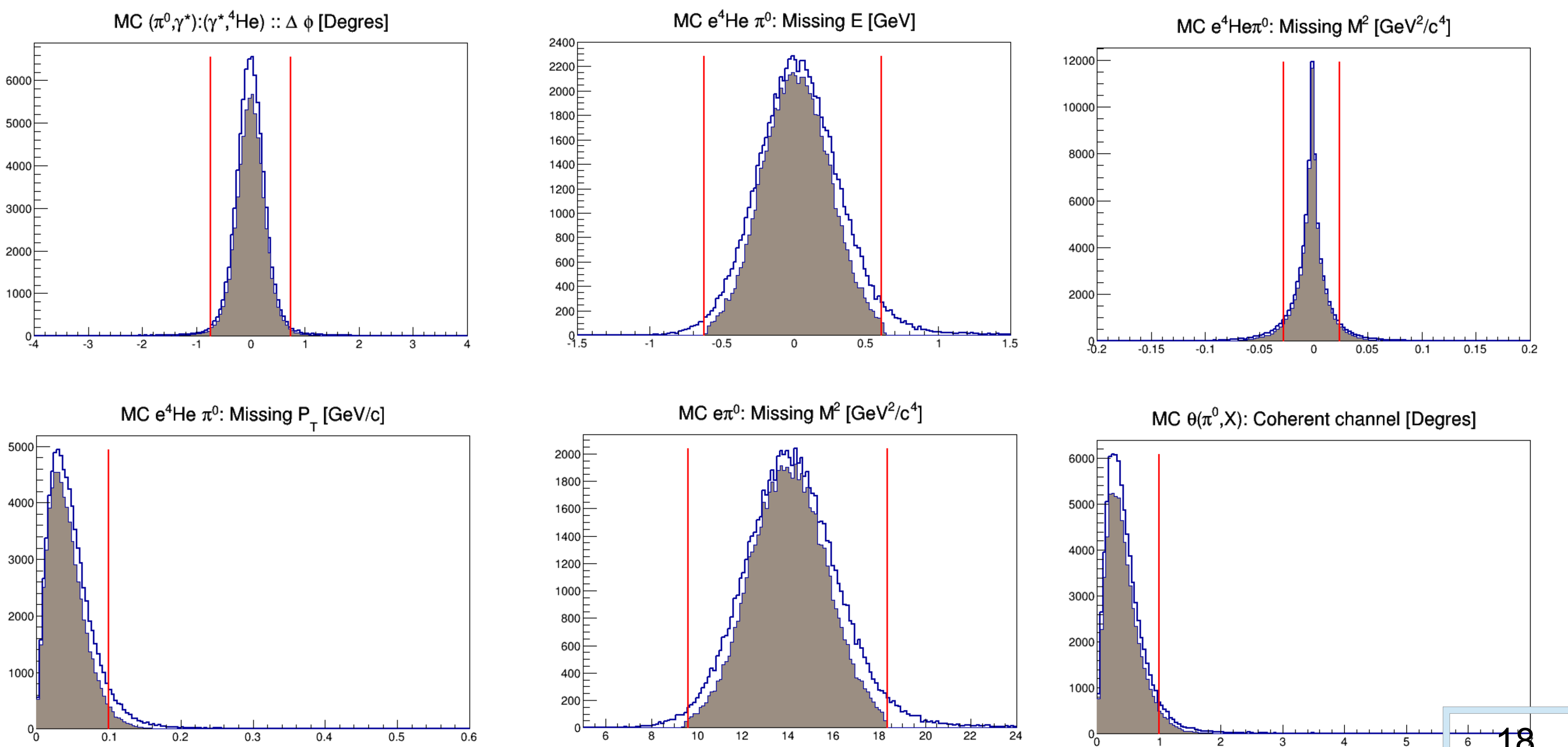


Simulated $e^4He\pi^0$ Event Selection

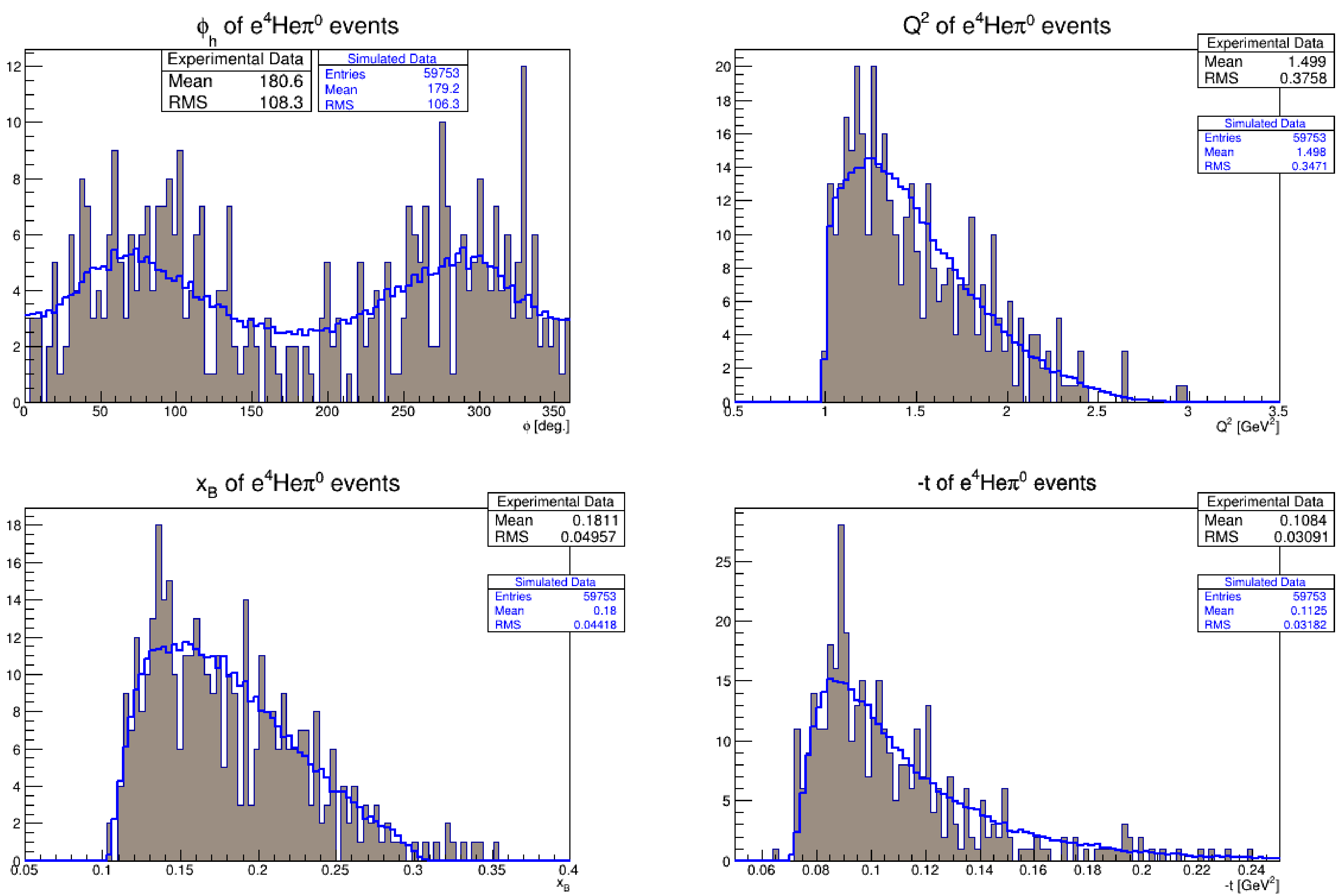
◊ Select events with one good e, ^{4}He and $\pi^0(\gamma\gamma)$ [ICIC, ICEC, ECEC] final state particles.

◊ Pass the cuts: $E_{\pi 0} > 2$ GeV, $W > 2$ GeV/c , $(E_b-E_{e'})/E_b < 0.85$ and $Q^2 > 1$ GeV².

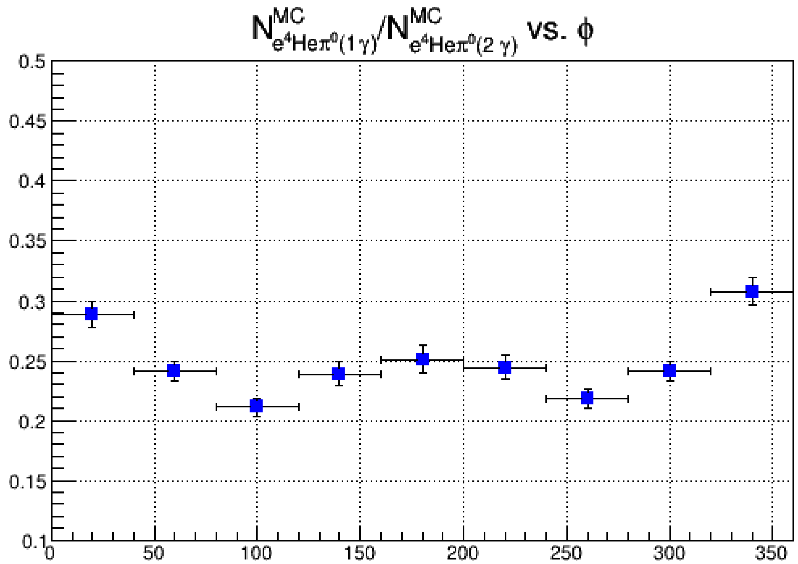
◊ Pass these 3 sigmas exclusivity cuts.

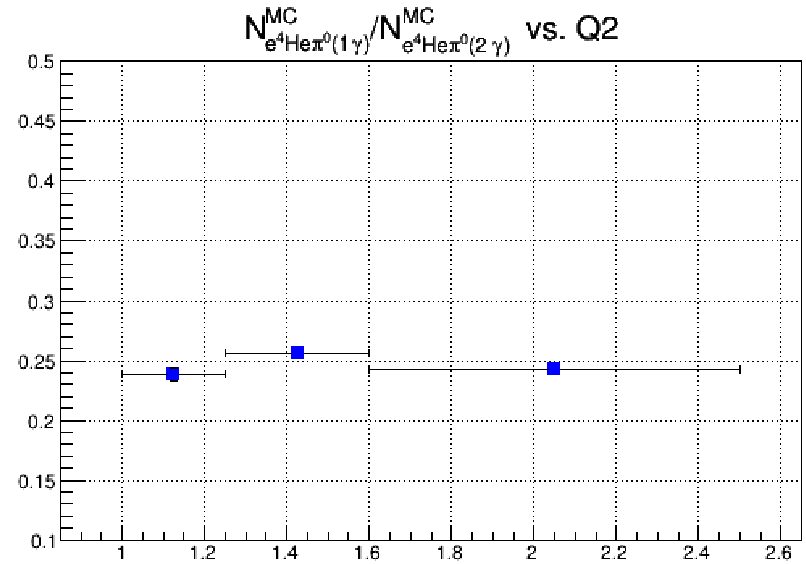


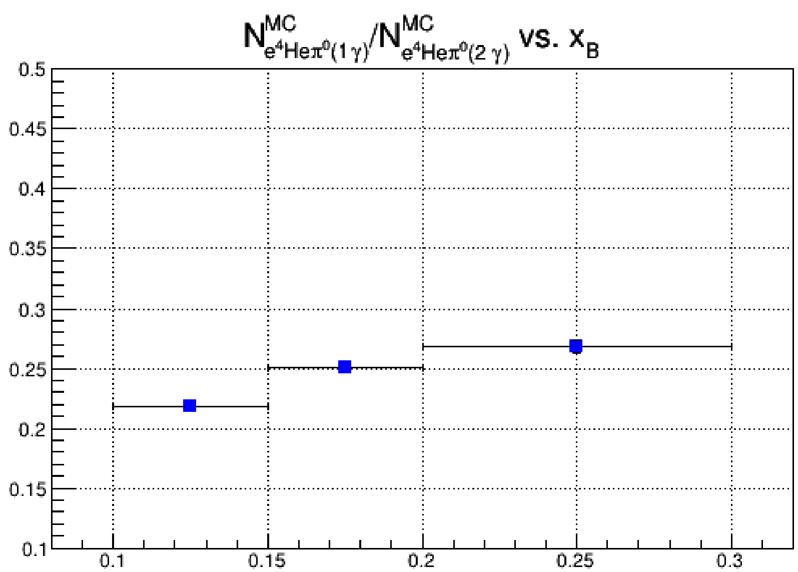
Comparison between Simulated and Experimental $e^4He\pi^0$

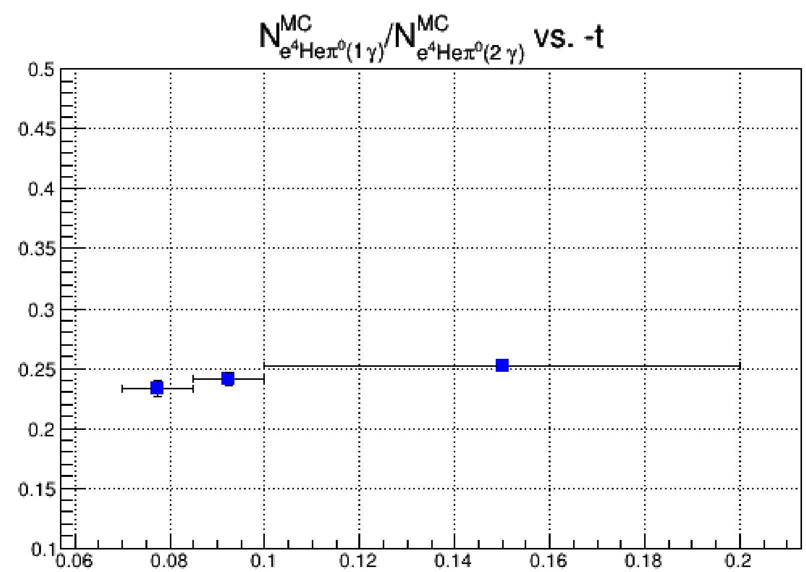


Coherent Contamination Ratio



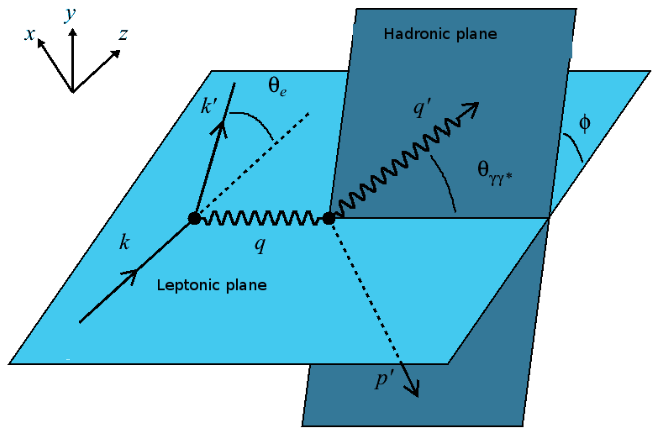




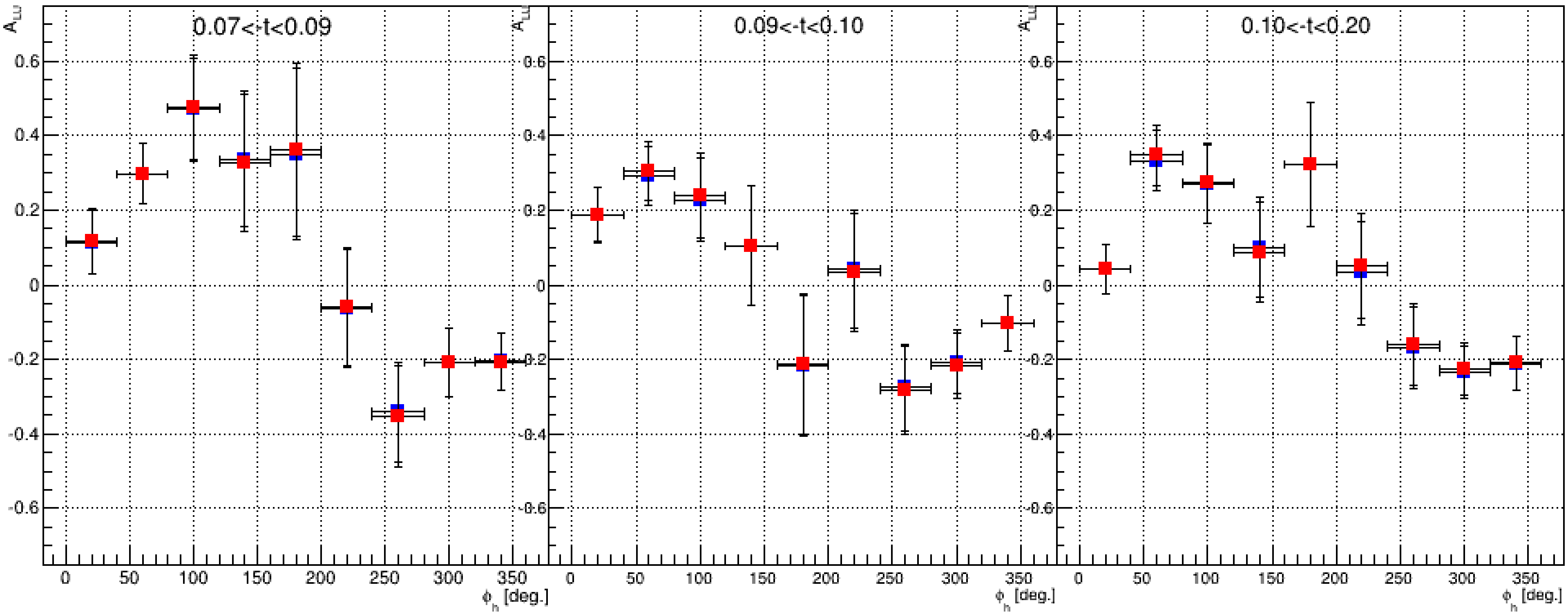


Coherent Beam-Spin Asymmetries

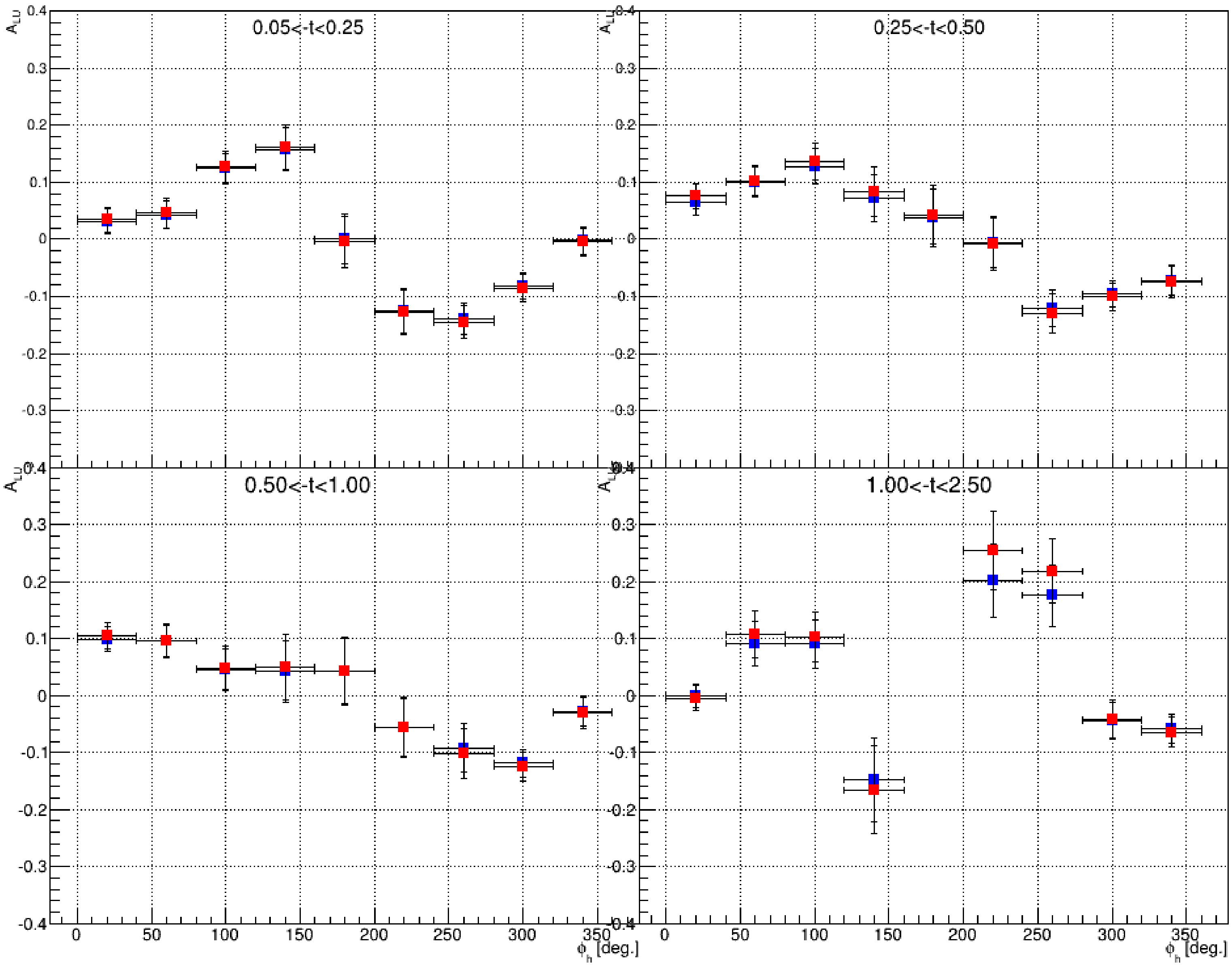
$$A_{LU} = \frac{1}{P_B}\frac{N^+ - N^-}{N^+ + N^-}$$



N^+/N^-: Number of events with +/- helicity of e^-.
Beam polarization (P_B) = 83%.
Φ_h : angle between the leptonic and the hadronic planes.
BLUE points: the raw asymmetries.
RED points: background subtracted asymmetries.



InCoherent Beam-Spin Asymmetries

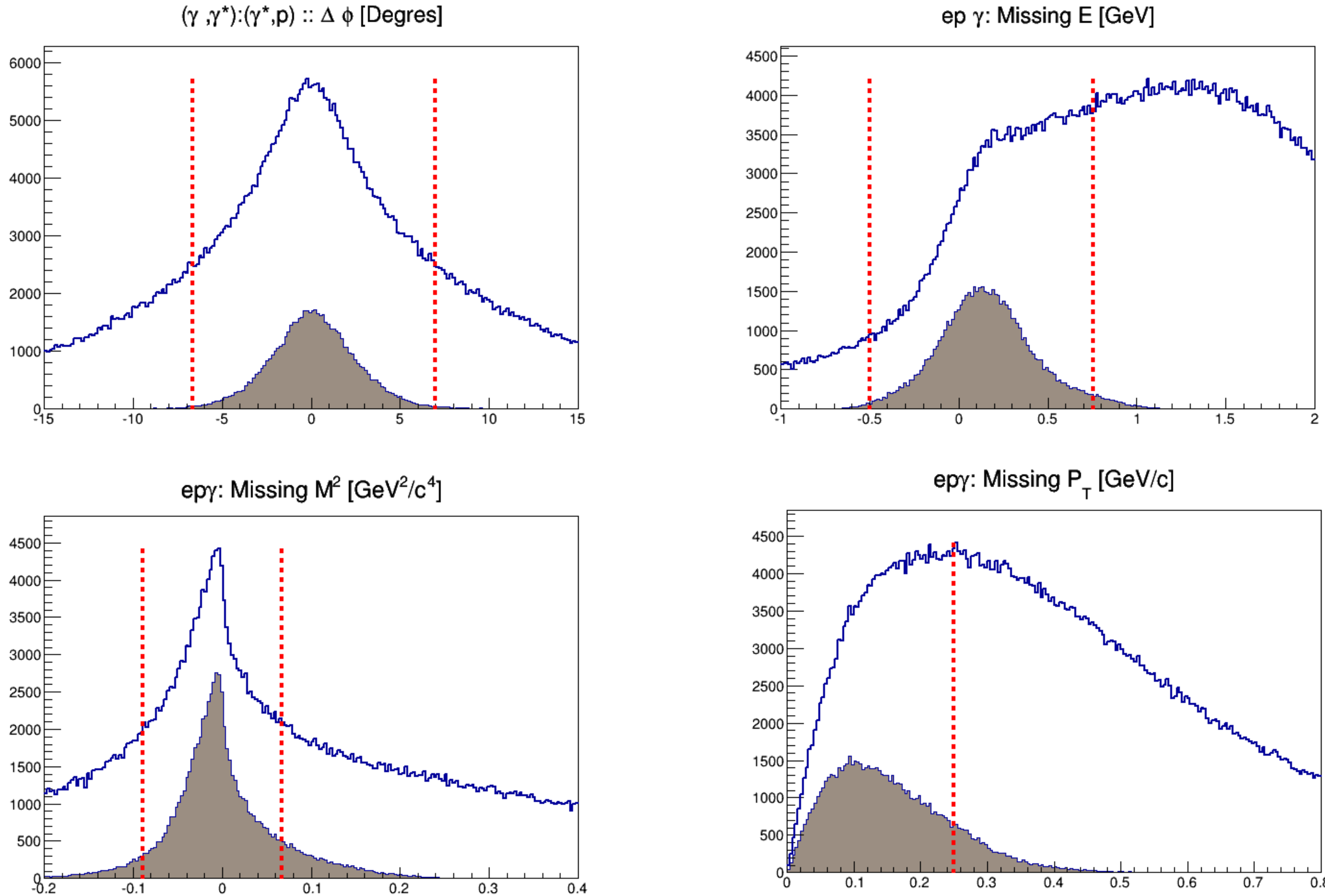


Conclusion

Proton DVCS Analysis

Experimental epγ Event Selection ….(1)

◊ One good electron in CLAS, one photon in the IC or the EC, and one good proton in CLAS.
◊ $E\gamma > 2$ GeV, $W > 2$ GeV/c , $(E_b - E_{e'})/E_b < 0.85$ and $Q^2 > 1$ GeV².
◊ Exclusivity cuts (3 sigma cuts):

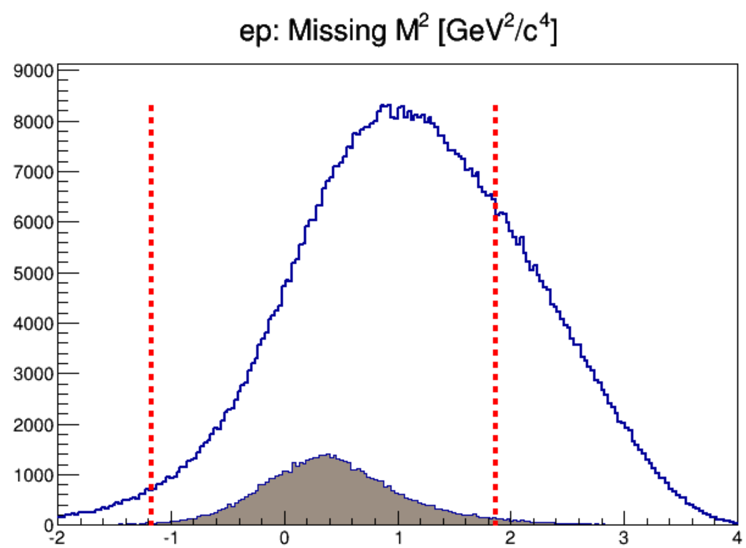


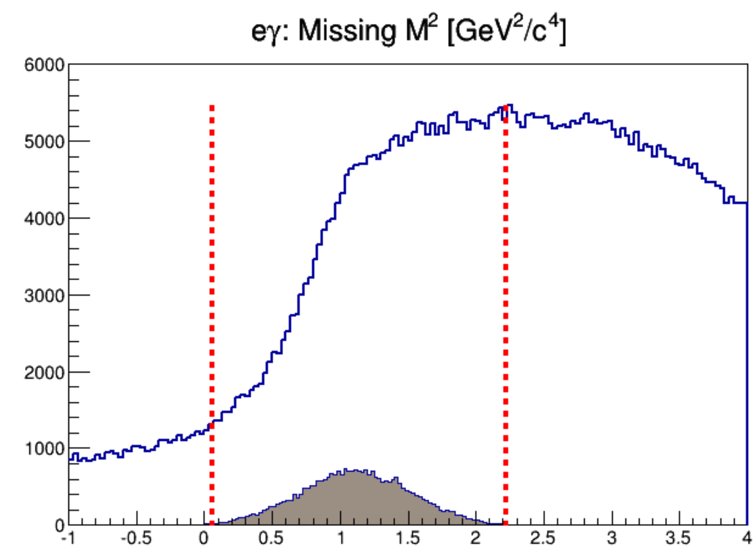
Experimental epγ Event Selection ….(2)

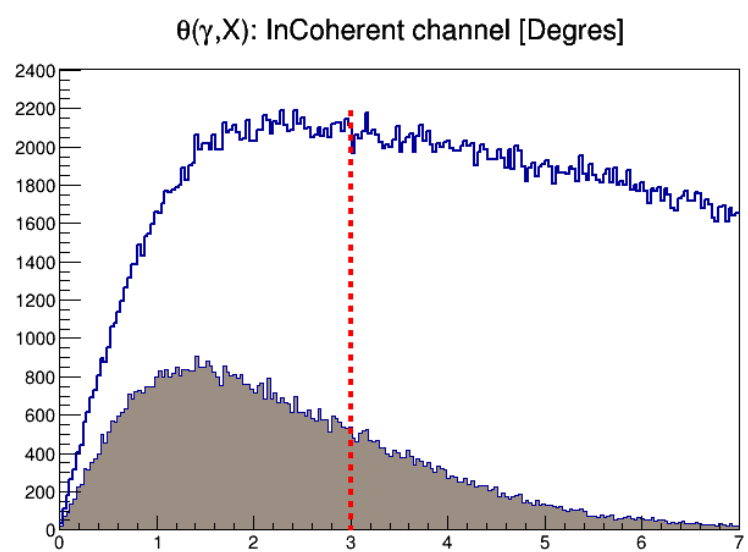
◊ One good electron in CLAS, one photon in the IC or the EC, and one good proton in CLAS.

◊ $E\gamma > 2$ GeV, $W > 2$ GeV/c , $(E_b-E_{e'})/E_b < 0.85$ and $Q^2 > 1$ GeV².

◊ Exclusivity cuts (3 sigma cuts):

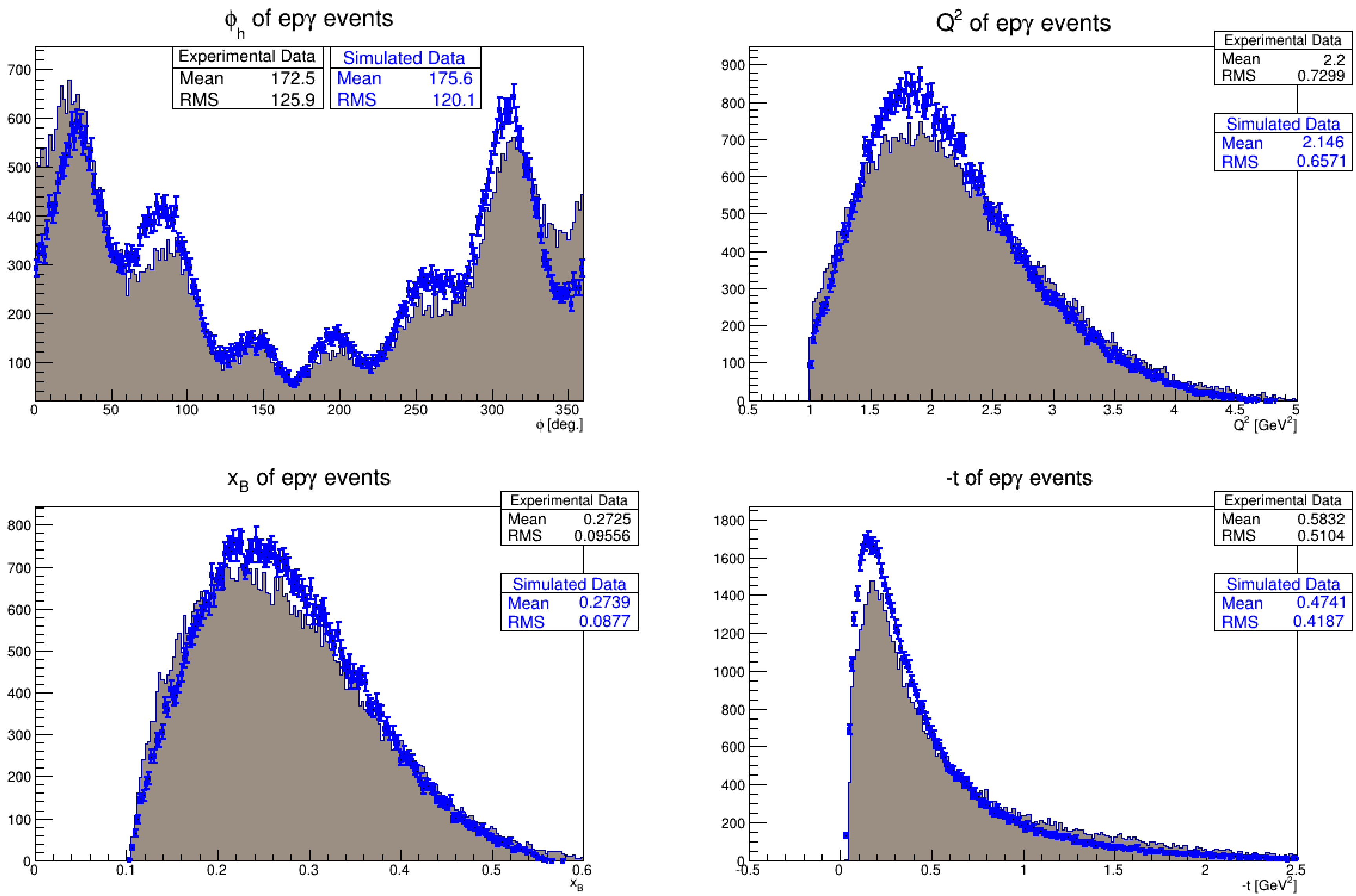






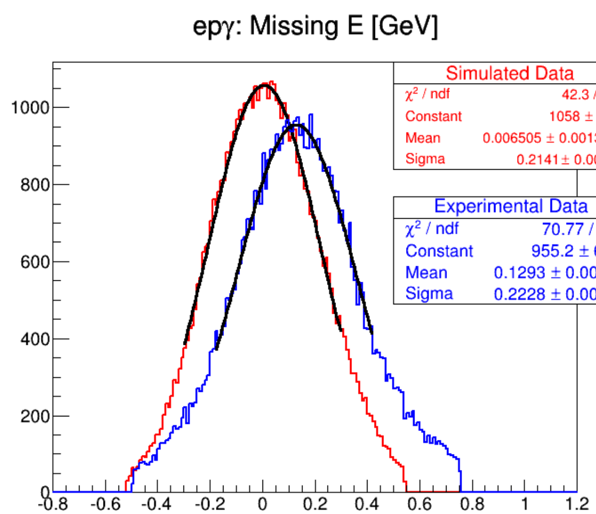
Comparison between Simulated and Experimental epγ … (1)

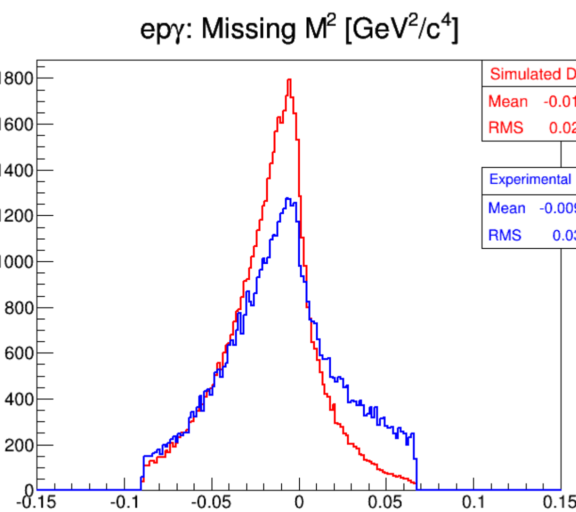
◊ Matching in terms of kinematics:

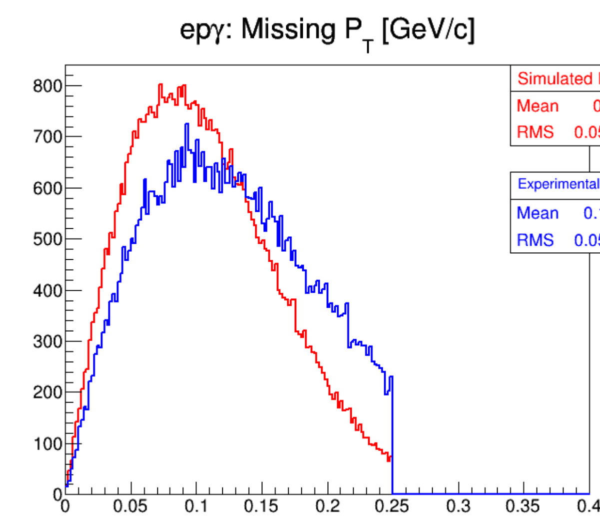


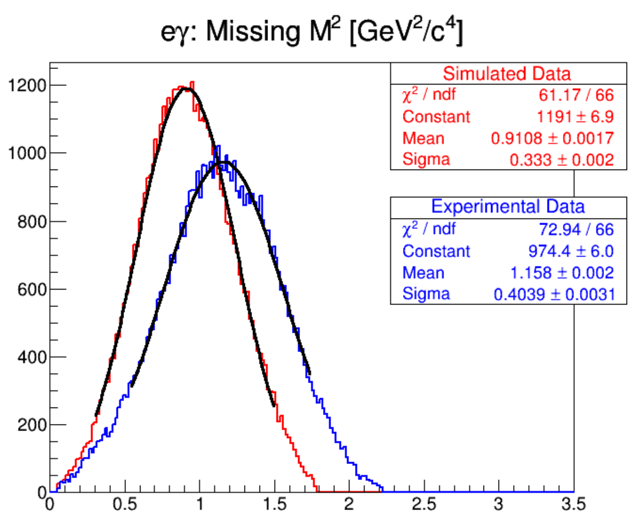
Comparison between Simulated and Experimental epγ ….(2)

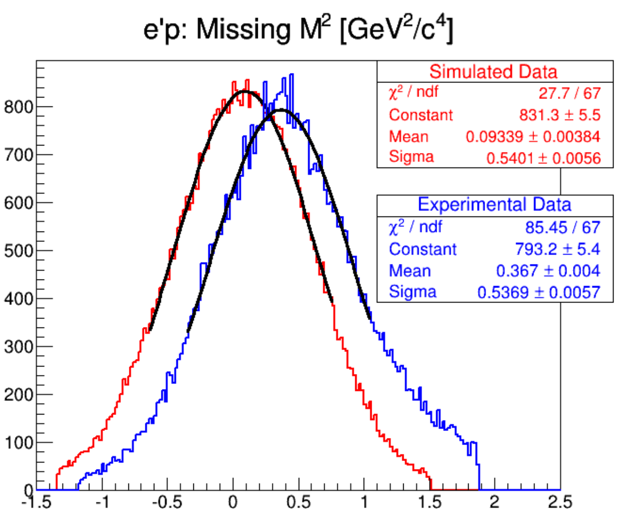
◊ In terms of the exclusive quantities:

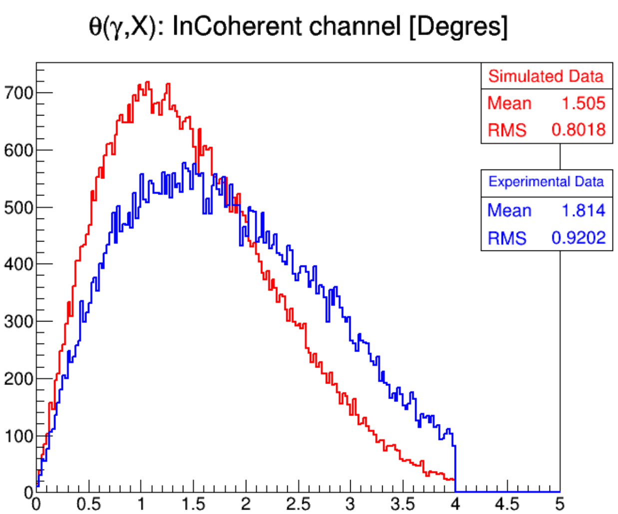










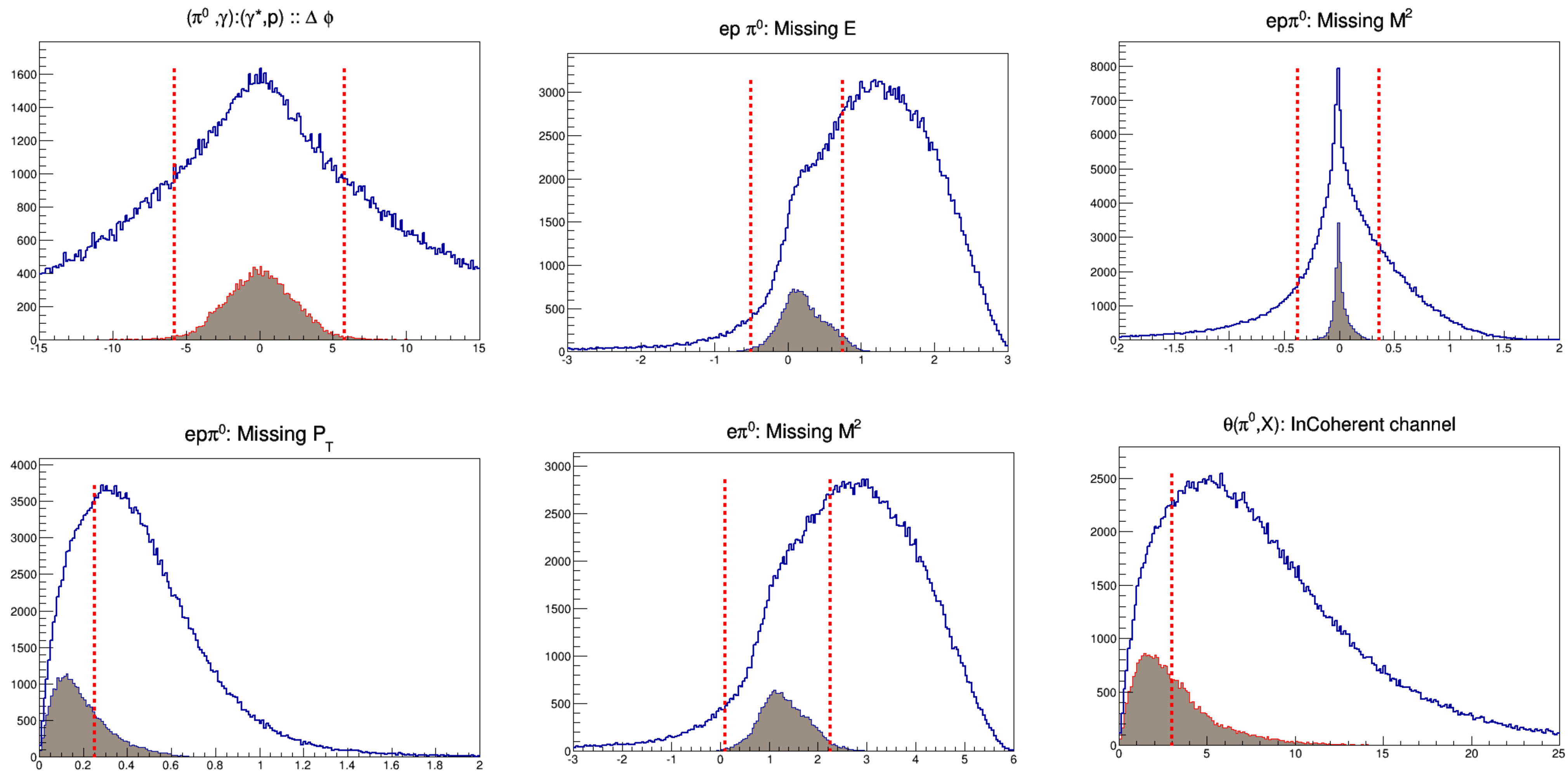


Experimental $ep\pi^0$ Event Selection

◊ Select events with one good e, p and $\pi^0(\gamma\gamma)$ [ICIC, ICEC, ECEC] final state particles.

◊ Pass the cuts: $E_{\pi 0} > 2$ GeV, $W > 2$ GeV/c , $(E_b - E_{e'})/E_b < 0.85$ and $Q^2 > 1$ GeV².

◊ Pass these 3 sigmas exclusivity cuts.

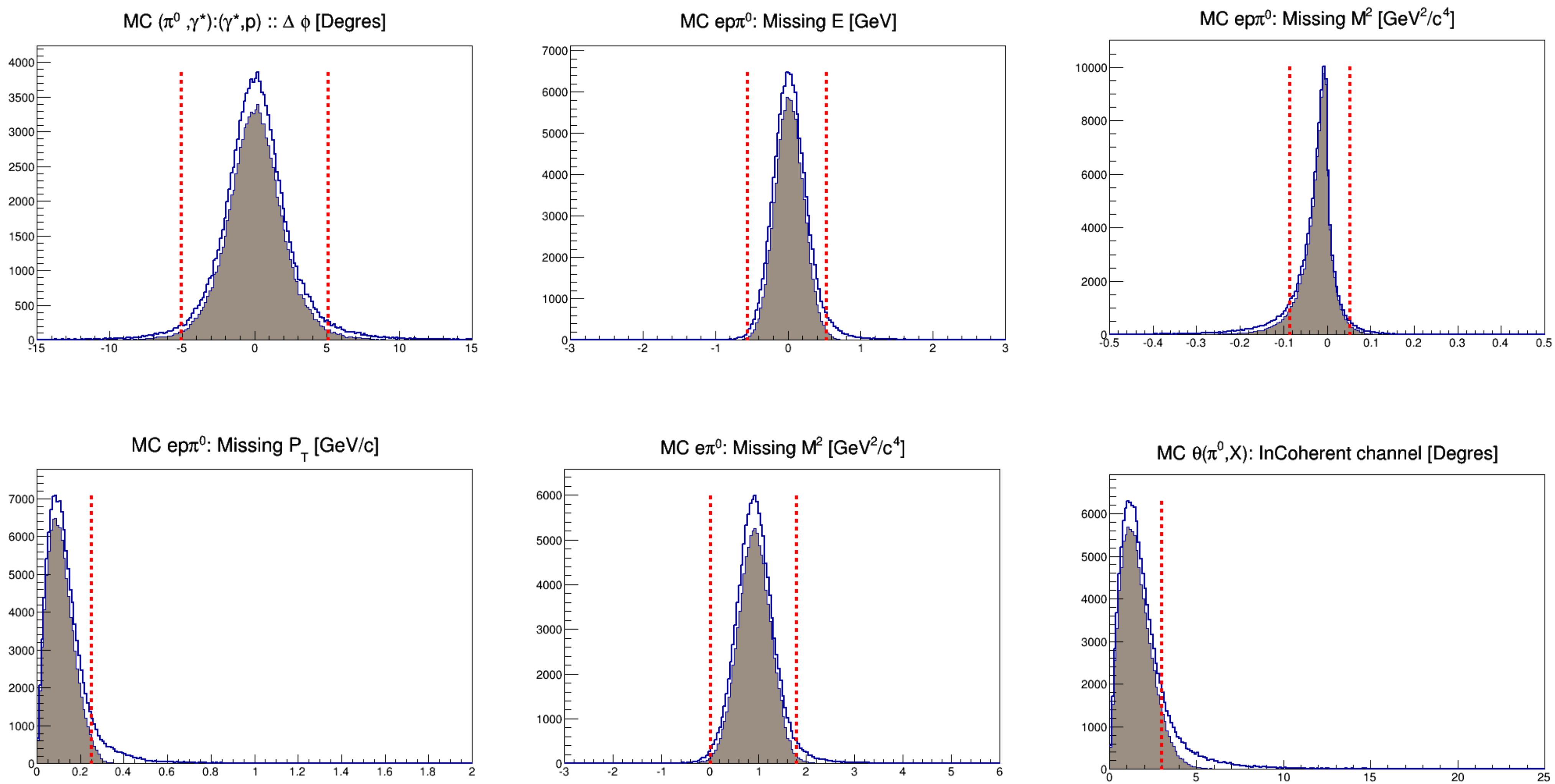


Simulated epπ^0 Event Selection

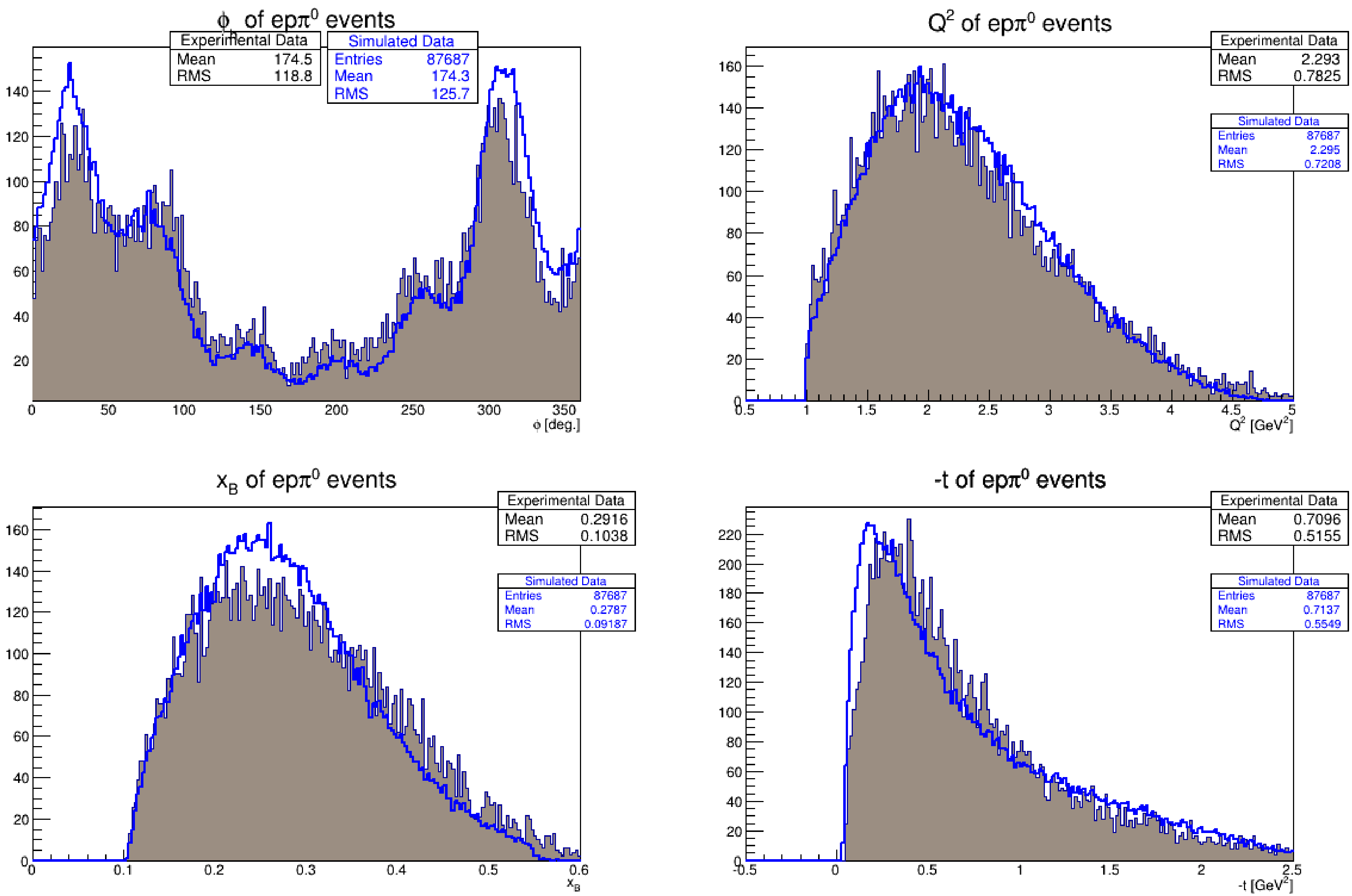
◊ Select events with one good e, p and $\pi^0(\gamma\gamma)$ [ICIC, ICEC, ECEC] final state particles.

◊ Pass the cuts: $E_{\pi 0} > 2$ GeV, $W > 2$ GeV/c , $(E_b - E_{e'})/E_b < 0.85$ and $Q^2 > 1$ GeV^2.

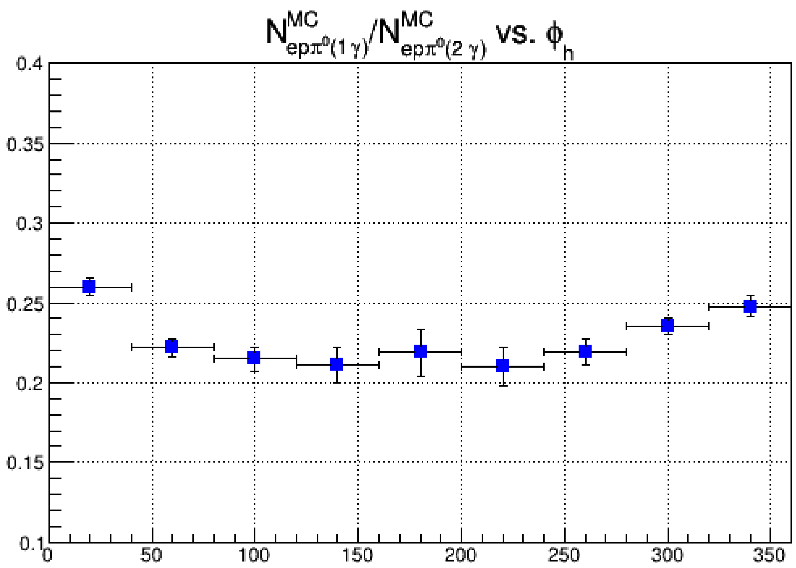
◊ Pass these 3 sigmas exclusivity cuts.

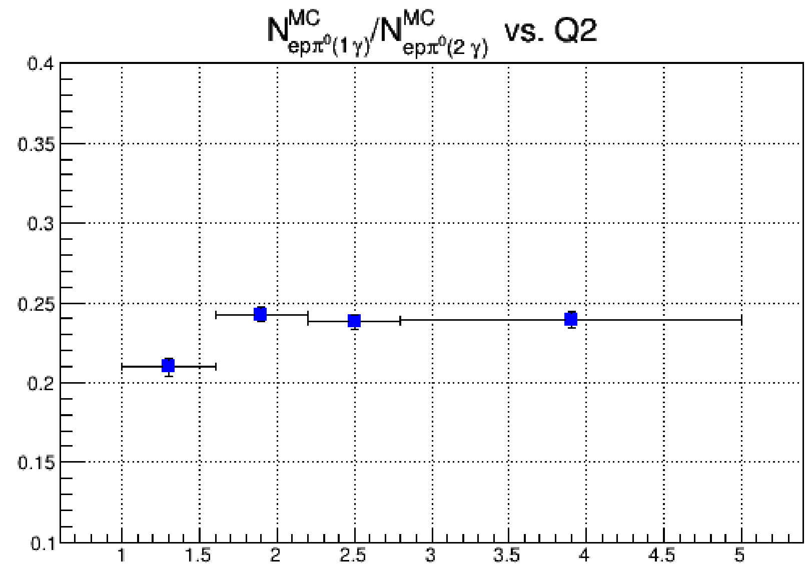


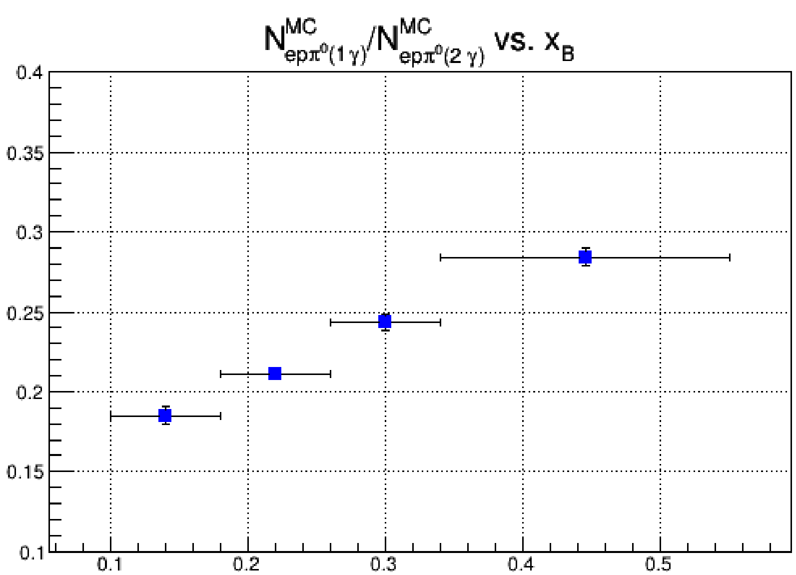
Comparison between Simulated and Experimental $ep\pi^0$

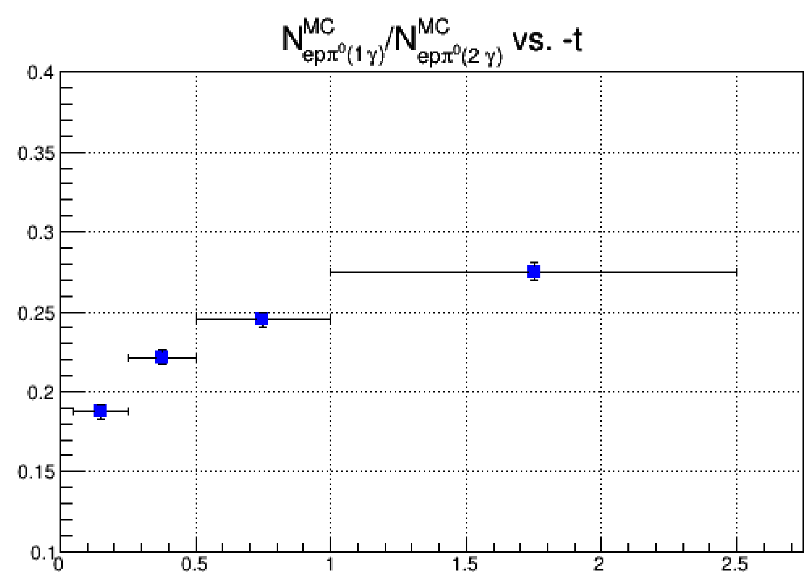


Contamination Ratio in the InCoherent Channel









InCoherent Contamination Ratio (t,Φ_h)