Nuclear Physics Working Group Summary Report

M. H. Wood, Canisius College

March 8, 2019

Conferences

Since November 2018 meeting, there were 5 presentations.

Contributed 1 (not notified)

General – 4 (2 notified)

Active Reviews

- **Neutral pion electroproduction ratios off C, Fe, and Pb to D**,
  T. Mineeva et al. (analysis review)
- **Validation of neutrino energy estimation using electron scattering data**,
  L. Weinstein et al. (analysis review)
- **Coherent DVπ^0P with CLAS EG6**, F. Cao et al. (analysis review)
- **Ratio of A(e, e'pp) to A(e, e'p) events in SRC kinematics**,
  A. Schmidt et al. (analysis review)

08:30 - 10:00 **Nuclear Physics Working Group - I**

Convener: Dr. Michael Wood (Canisius College)

Location: A110 - https://bluejeans.com/7168882426

08:30 **NPWG Business** *10'*
Speaker: Dr. Michael Wood (Canisius College)
Material: Slides

08:40 **3He/4He (e,e'p) and (e,e'n)** *20'*
Speaker: Peninah Levine (MIT)
Material: Slides

09:00 **A(e,e'pn) detecting the n in the TOF** *20'*
Speaker: Dr. Igor Korover (NRCN)
Material: Slides

09:20 **(e,e'pp)/(e,e'p) ratios and the GCF** *20'*
Speaker: Axel Schmidt (MIT)
Material: Slides

09:40 **Analysis Updates on the EG2 Lambda Study** *20'*
Speaker: Dr. Taya Chetry (Mississippi State University)
Material: Slides

10:30 - 12:00 **Nuclear Physics Working Group - II**

Convener: Dr. Michael Wood (Canisius College)

Location: A110 - https://bluejeans.com/7168882426

10:30 **BSA of Coherent π^0 DVMP on Helium-4** *20'*
Speaker: Mr. Frank Cao (UConn)
Material: Slides

10:50 **Validation of neutrino energy estimation using electron scattering data** *20'*
Speaker: Mariana Khachatryan (ODU)
Material: Slides

11:10 **Electrons for Neutrinos - Simulations** *20'*
Speakers: Afroditi Papadopoulou (MIT), Adi Ashkenazi (MIT)
Material: Slides

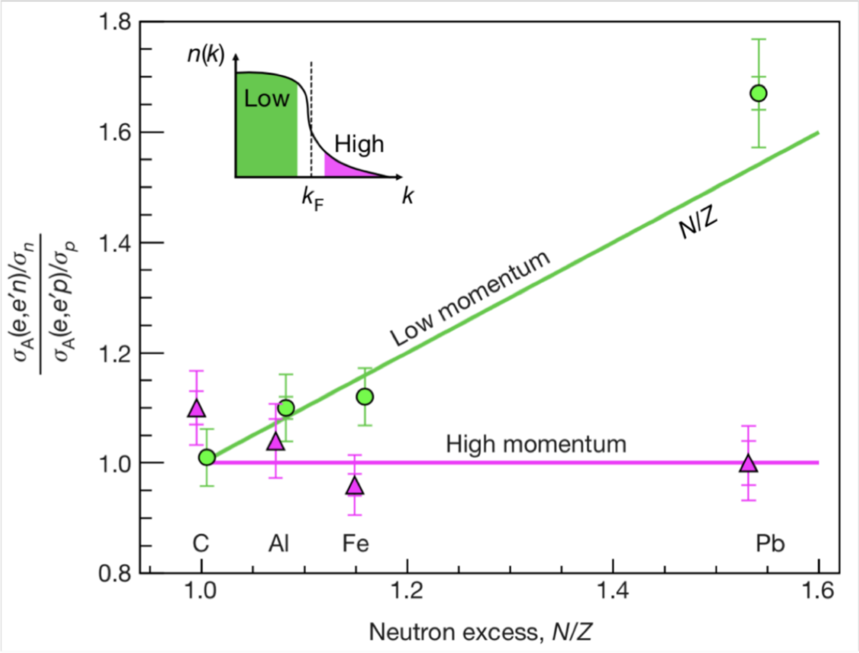
11:30 **Update on the Analysis of Color Propagation of pi+** *20'*
Speaker: Sebastian Moran (UTFSM)
Material: Slides

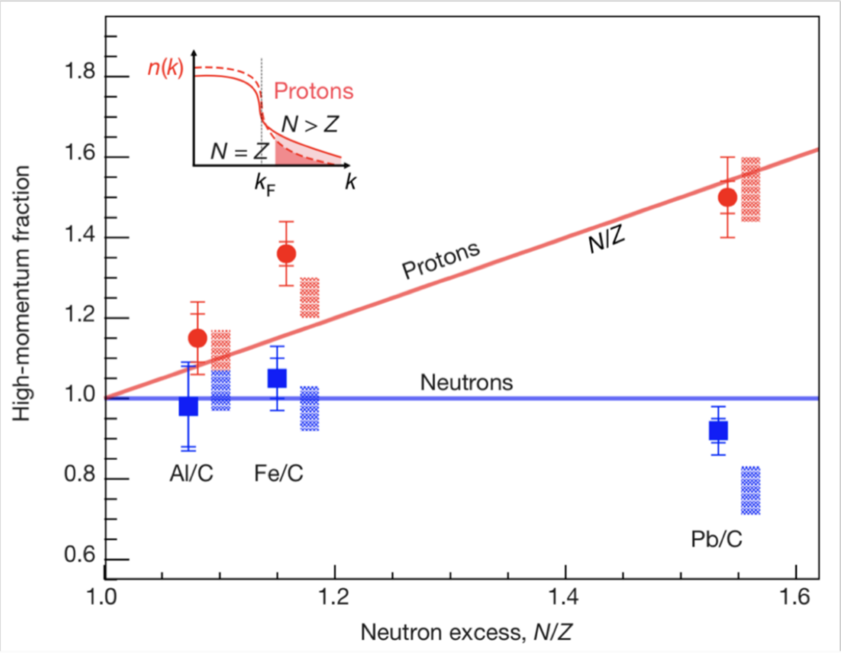
Probing 2N-SRC via (e,e'N) reactions off $^{3,4}He$ (^{12}C)

Using e2a data

Peninah Levine
March 7, 2019

SRC in n. Rich systems





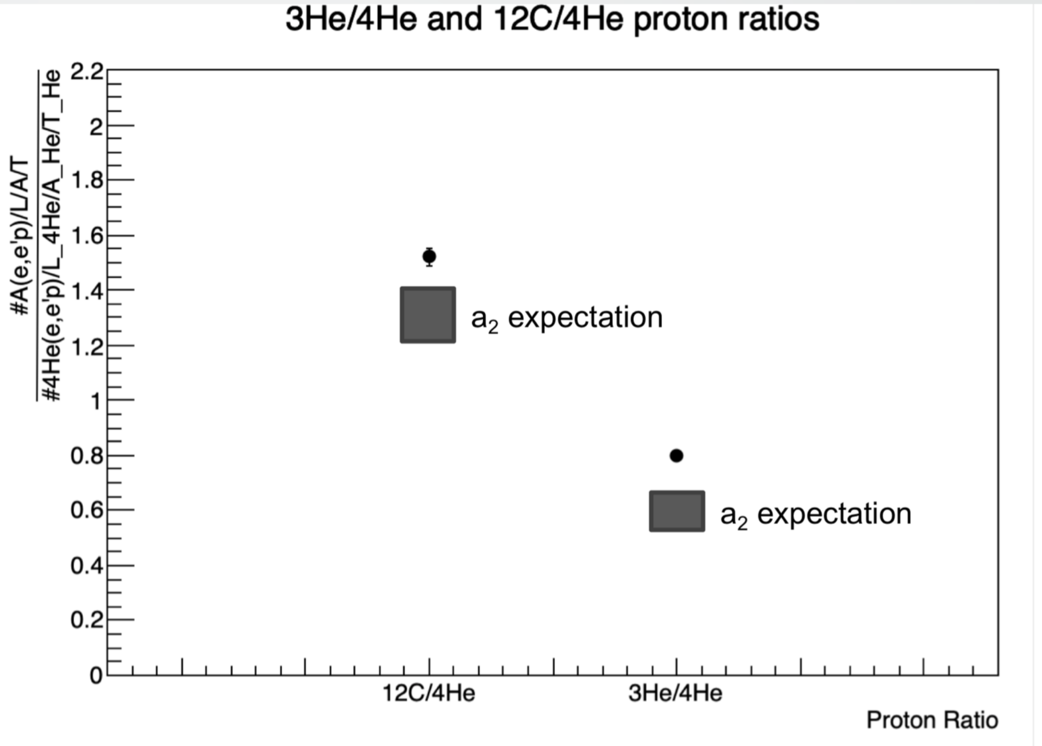
^{12}C / ^{4}He (e,e'p)

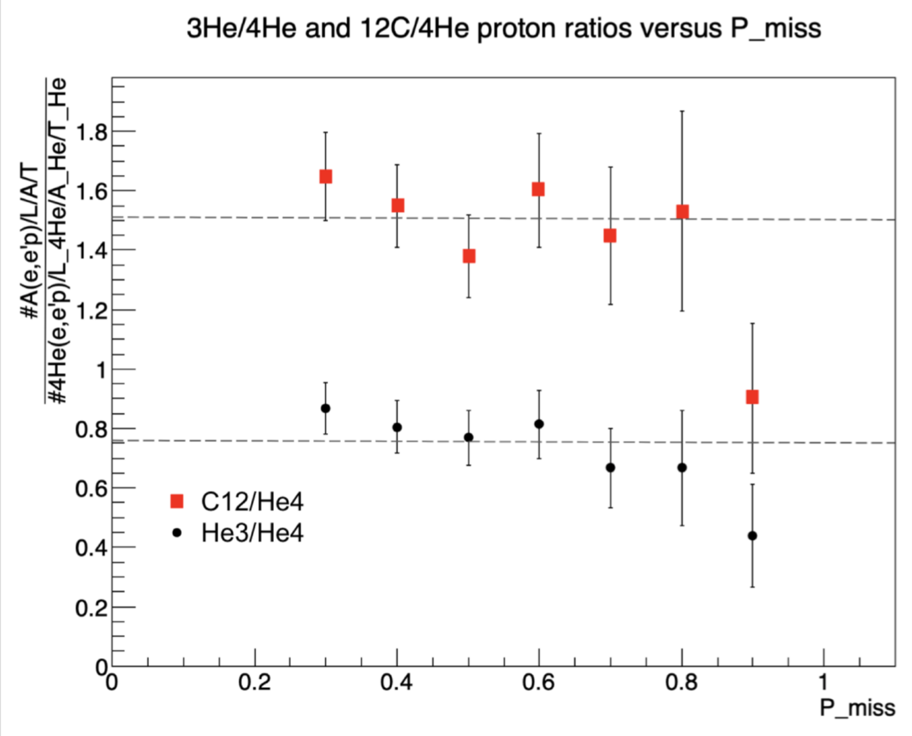
^{3}He / ^{4}He (e,e'p)

A / ^{4}He (e,e'p)

Stat. uncertainties only

Sys. Uncertainties:
- luminosity (~2%)
- Transparency
- Cut sensitivity
- P_{miss} (in)dependence





A(e,e’p)/A(e,e’n) ratios

Nucleus	$(\#(e,e'p)/Z/sigma_{ep}) / (\#(e,e'n)/N/sigma_{en})$
^{4}He	1.05 ± 0.2
^{12}C	1.00 ± 0.2

A(e,e'pn) detecting Neutrons in TOF counters

Igor Korover
NRCN & Tel Aviv University

Motivation

Search for Short Range Correlation using A(e,e'pn) reaction

Complimentary analysis to A(e,e'pp)

Advantages over A(e,e'np) (*knocked out neutron detected in EC*)

Better missing momentum resolution (same as A(e,e'pp) analysis)

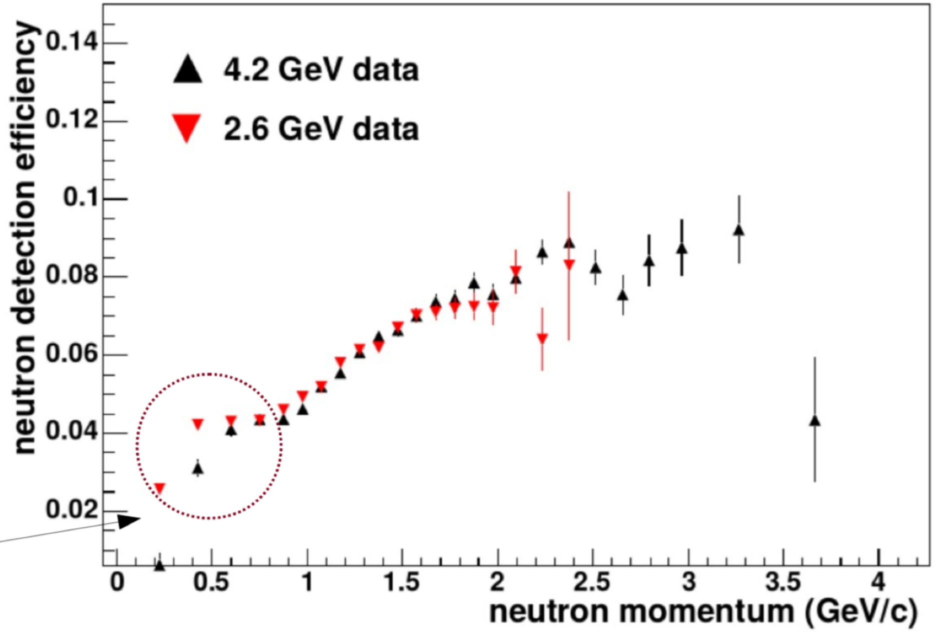
Larger acceptance compared to A(e,e'np)

A(e,e'pn)/A(e,e'p) as function of missing momentum

A(e,e'pp) and A(e,e'pn) Allows better comparison to NN-interaction calculations (using the generator)

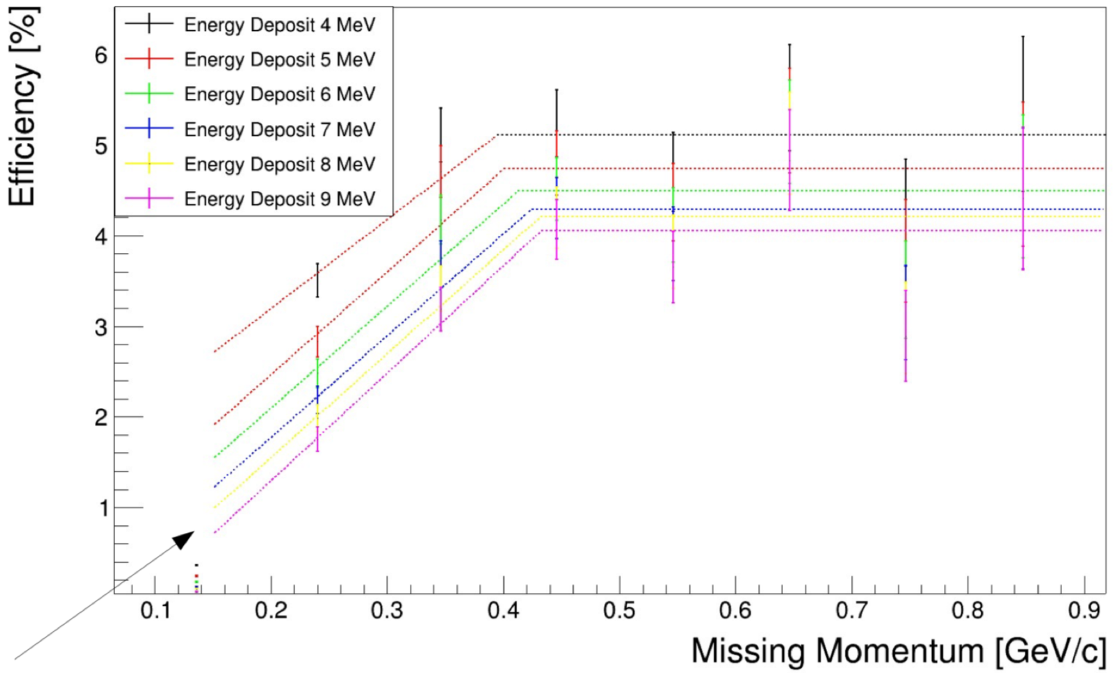
Previous analysis

CLAS Analysis Note 2008-103



Relevant region

Absolute neutron detection efficiency



Efficiency measurement below 0.25 GeV/c is not reliable

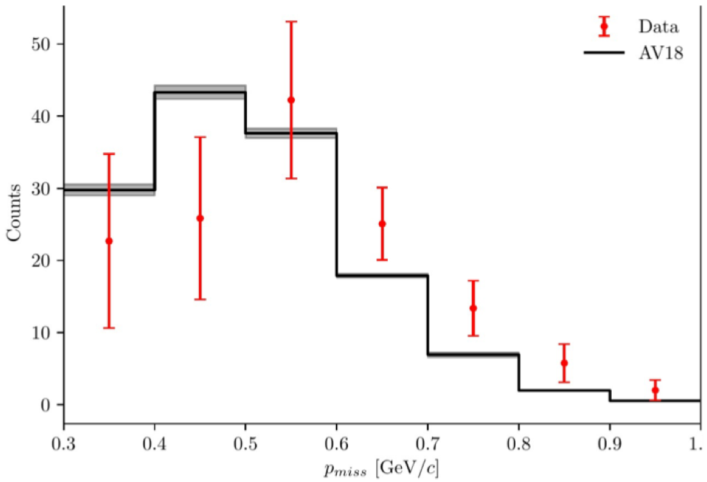
C(e,e'pn)/C(e,e'p) Result

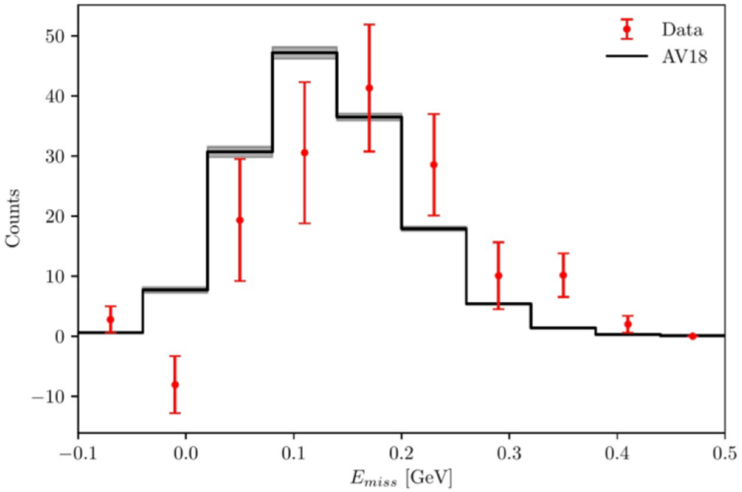
Kinematic variable comparison to the generator prediction

E_p - Energy of knocked out proton

Comparison between missing energy $E_{miss} = \sqrt{(\omega + m_{Carbon} - E_p)^2 - p_{miss}^2} + m_n - m_{Carbon}$

Missing Momentum





$(e, e'pp)/(e, e'p)$ ratios and the Generalized Contact Formalism

CLAS Nuclear Physics Working Group Meeting

Axel Schmidt

MIT

March 7, 2019

New EG2 Data Mining Analysis Note

1. Previous EG2 analyses selected SRC break-up events.
2. We have a new formalism, event generator to simulate SRC break-up events.
   - Key input: 2-body wave function from NN-interaction
3. By comparing data to our generator, we can test short-distance NN-interaction.

Generalized Contact Formalism

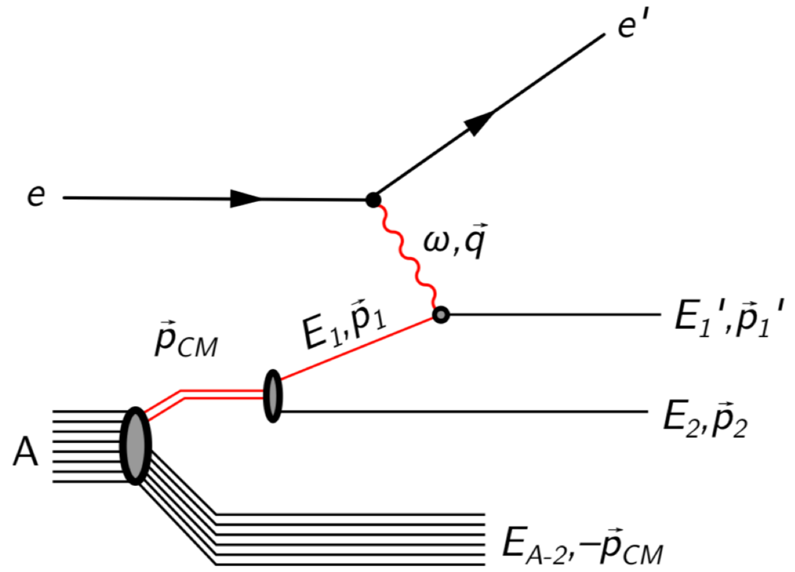
$$\Psi(k_{ij} \gg k_F) \longrightarrow \tilde{\varphi}(k_{ij}) \times A(K_{ij}, \vec{k}_{m\neq i\neq j})$$

For large k : $$\rho_2(k) = \sum_\alpha C_\alpha |\tilde{\varphi}_\alpha(k)|^2$$

$\tilde{\varphi}(k)$ is a 2-body solution to the Schrödinger eq. for an NN interaction.

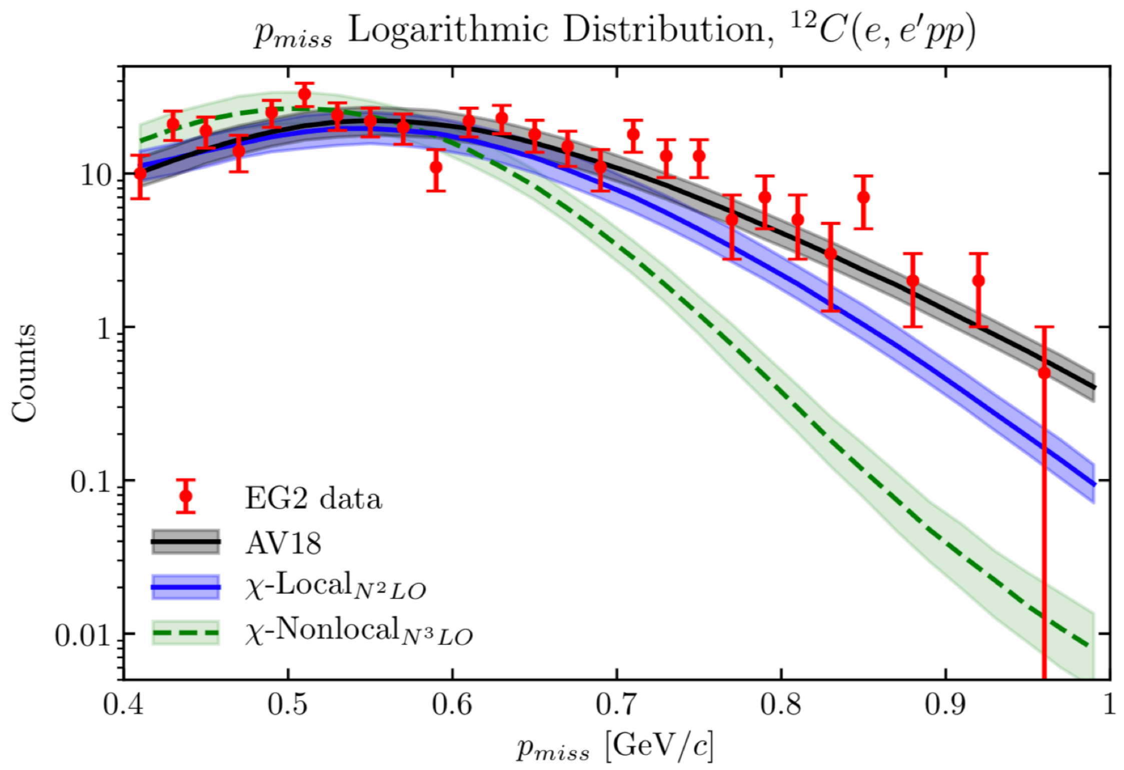
See: R. Weiss et al., PLB 780 (2018) 211–215 and R. Weiss et al., arXiv:1806.10217

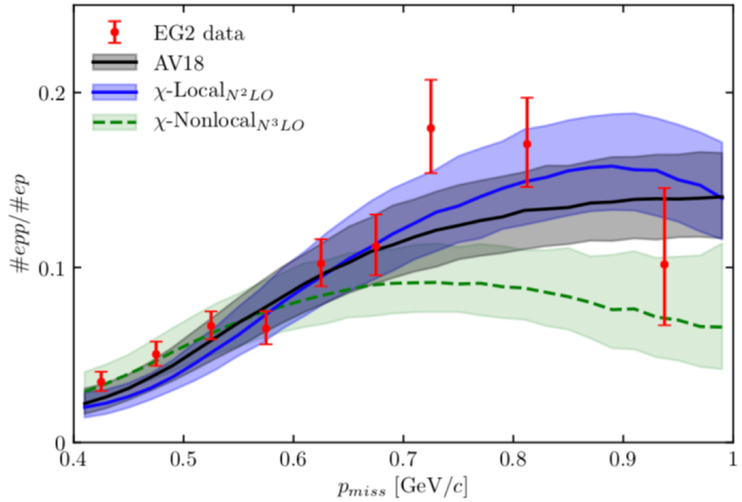
GCF Event Generator



$$d\sigma \sim \sigma_{eN} \cdot n(\vec{p}_{CM}) \cdot \sum_\alpha C_\alpha |\tilde{\varphi}_\alpha(k)|^2$$

Missing Momentum Distributions





- GCF agrees with EG2 data.
- AV18 works well, even up to 1 GeV/c.
- New constraints on *NN* interaction at high-momentum

Study of neutrino energy reconstruction using electron scattering data

Mariana Khachatryan - ODU

Neutrino Energy Reconstruction for QE reactions

Cherenkov detectors:
- Detect: e–, muons & pions.
- Miss: protons and neutrons.

Tracking detectors:
- Detect: Charged particles $+\pi^0$.
- Miss: Neutrons and charge particles below threshold.

Lepton kinematics:
[(e,e′) or (ν, l)]

$$E_{\mathrm{QE}} = \frac{2M\varepsilon + 2ME_1 - m_l^2}{2(M - E_1 + |k_1|\cos\theta)}$$

$\varepsilon \approx 20$ MeV single nucleon separation energy

M -nucleon mass

m_1 outgoing lepton mass

k_1 – lepton three momentum

θ – lepton scattering angle

Final state Calorimetry
$[(e,e'pX)$ or $(\nu,lX)]$

$$E_{\mathrm{Cal}} = E_e' + \sum T_p + E_{\mathrm{Binding}} + \sum E_\pi$$

E_{Binding} – Binding energy

T_p – kinetic energy of knock out proton

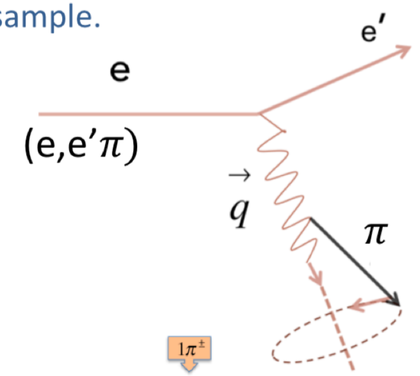
E_e' – energy of scattered electron

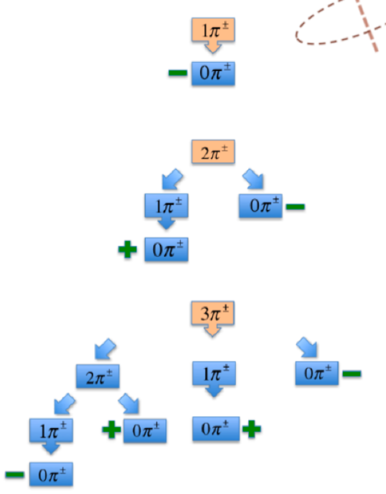
E_π – energy of produced meson

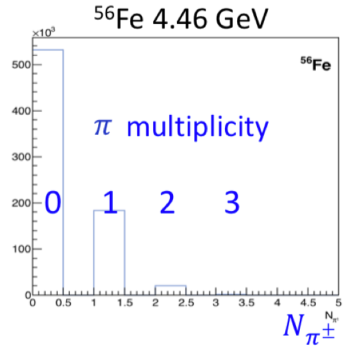
Background Subtraction in (e,e’) analysis

Neutrino analysis select 0 π events to maximize QE sample.

Data Driven Correction:
1. Use measured (e,e’π) events,
2. Rotate π around q to determine its acceptance,
3. Subtract undetected (e,e’π) contributions,
4. New: Do the same for 2π, 3π.



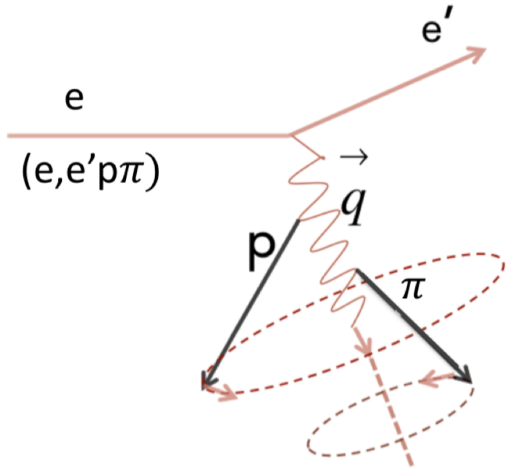


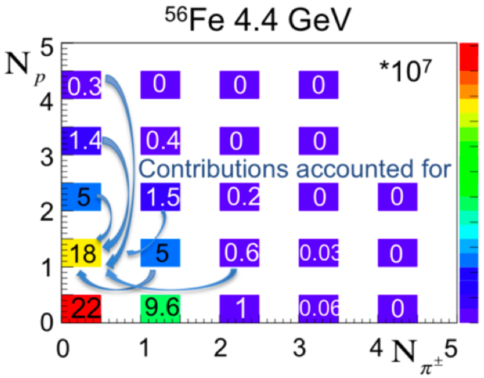


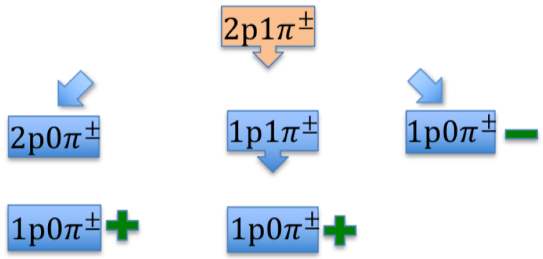
Background Subtraction in (e,e’p) analysis

Subtract for undetected π and multiple p.

Data Driven Correction:
1. Use measured (e,e’pπ) events,
2. Rotate π around q to determine its acceptance,
3. Subtract (e,e’pπ) contributions
4. New: do the same for 2p, 3p 2p+ π etc



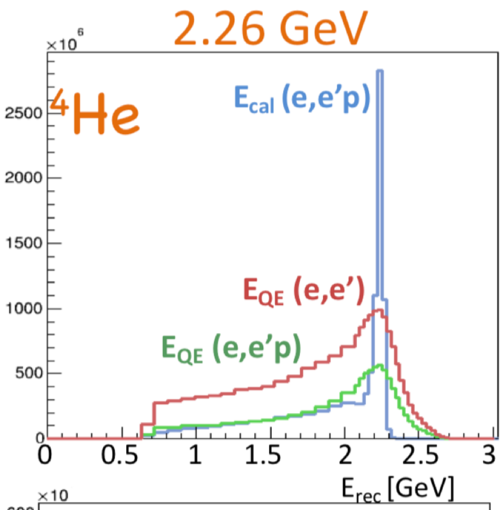


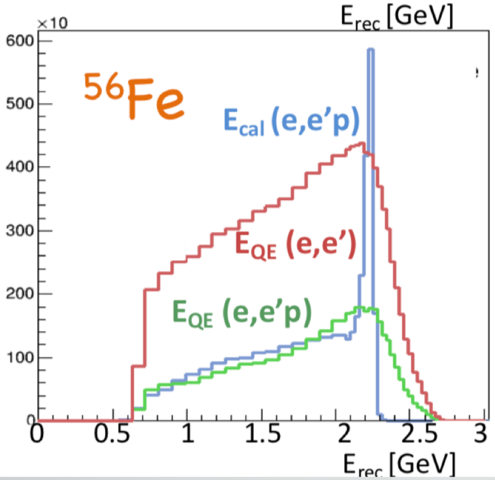


Large A dependence

$$E_{\text{Cal}} = E'_e + T_p + E_{\text{Binding}}$$

$$E_{QE} = \frac{2M\varepsilon + 2ME_l - m_l^2}{2(M - E_l + |k_l|\cos\theta)}$$

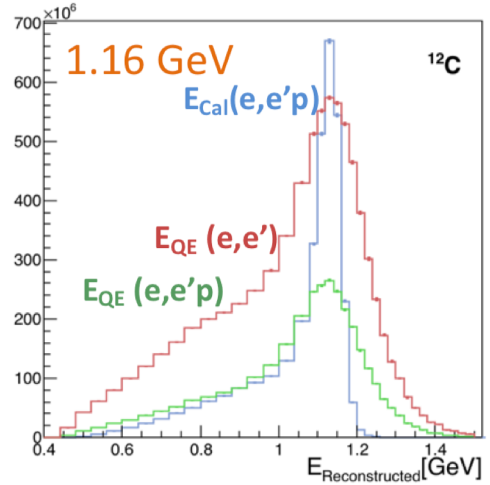


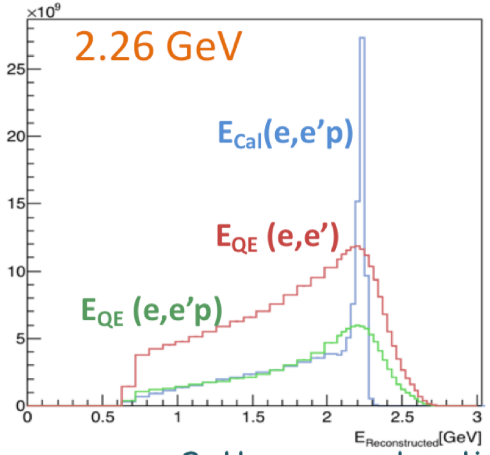


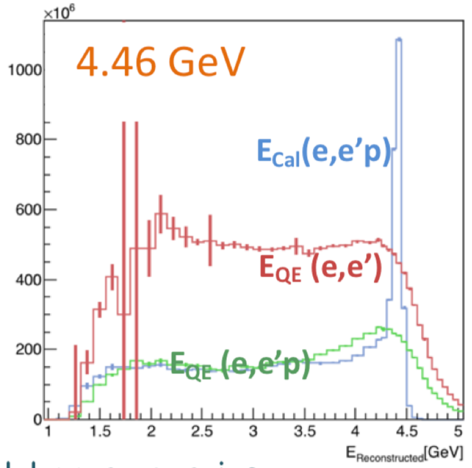
1. E_{QE} has worse peak resolution than $E_{Cal.}$
2. Same tail for E_{QE}+$E_{Cal.}$
3. ^{56}Fe is predominantly tail.
4. ^{56}Fe is much worse than ^{4}He.

Large E dependence

^{12}C







Better reconstruction at lower energies.

Electrons for Neutrinos Simulation

e4ν

03/07/2019
CLAS Collaboration Meeting

Afroditi Papadopoulou, Adi Ashkenazi (MIT)

νA Interaction Modelling

Neutrino event generators are used to simulate a νA interaction

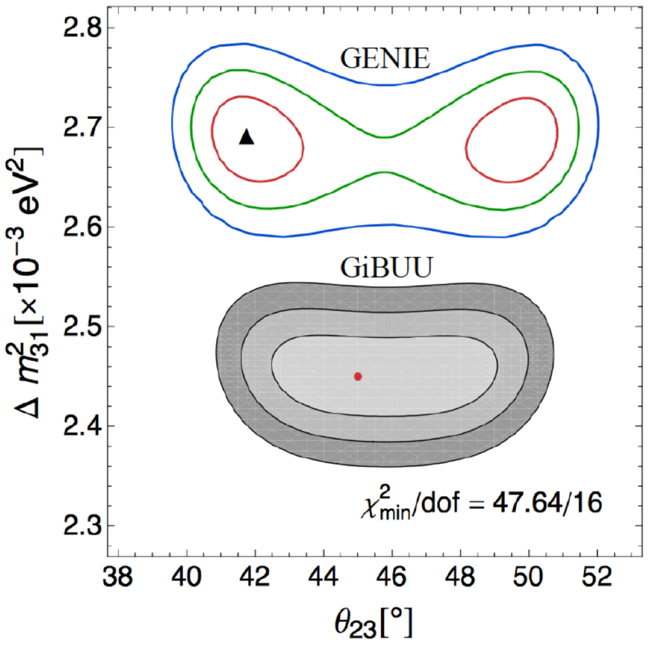
Among those:

Genie

GiBUU
The Giessen Boltzmann-Uehling-Uhlenbeck Project

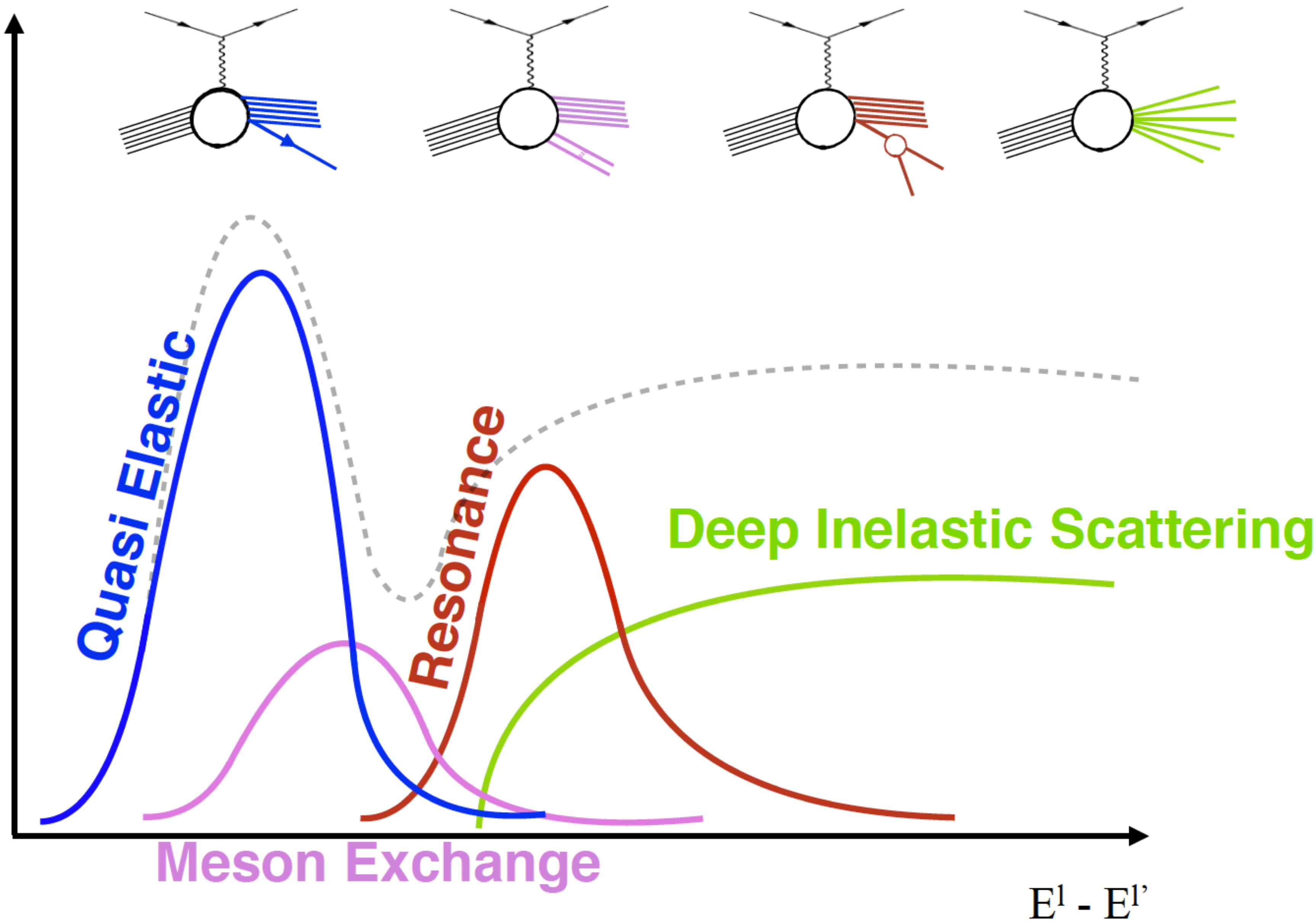
and many more

Nuclear uncertainties are significant

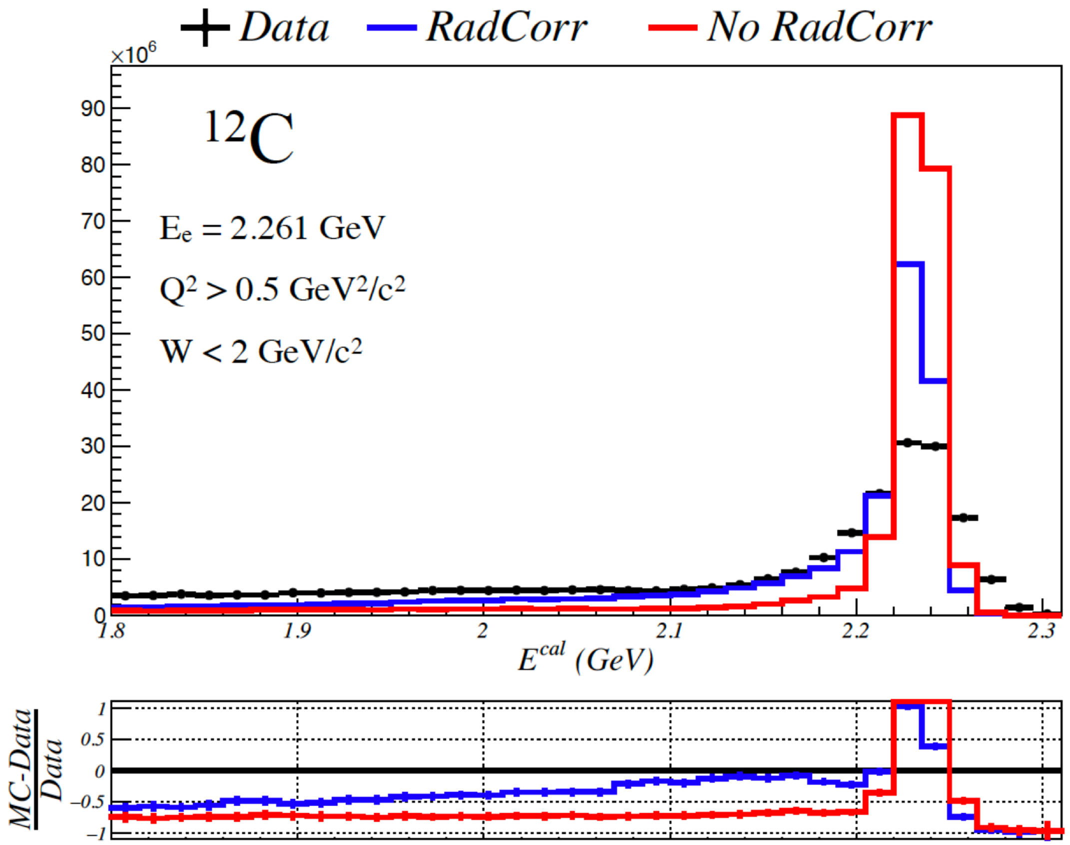


Phys. Rev. D 89, 073015 (2014)

E_ν Reco Requires Interaction Modeling



Data to Simulation Comparison



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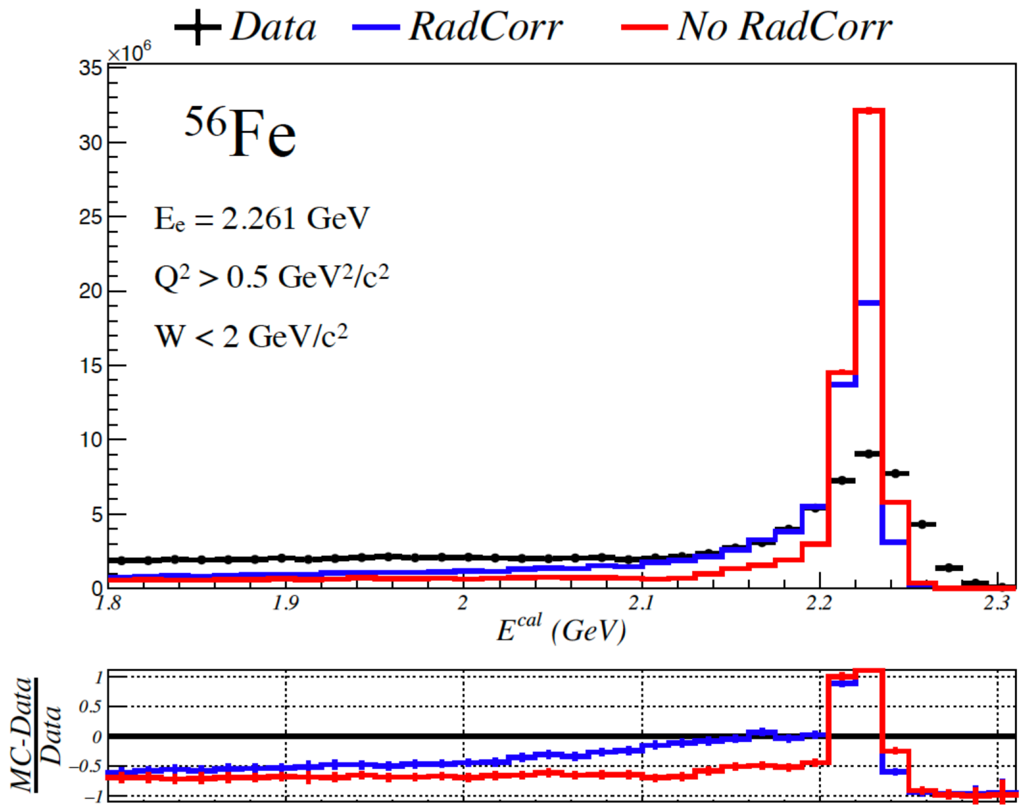
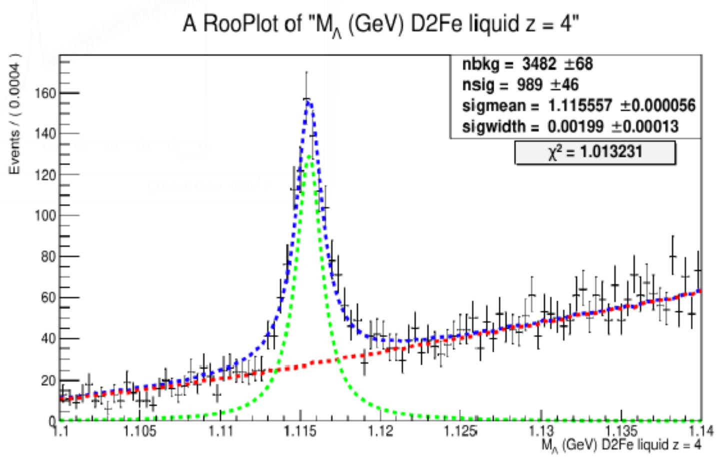


Analysis Updates on the EG2 Λ Study

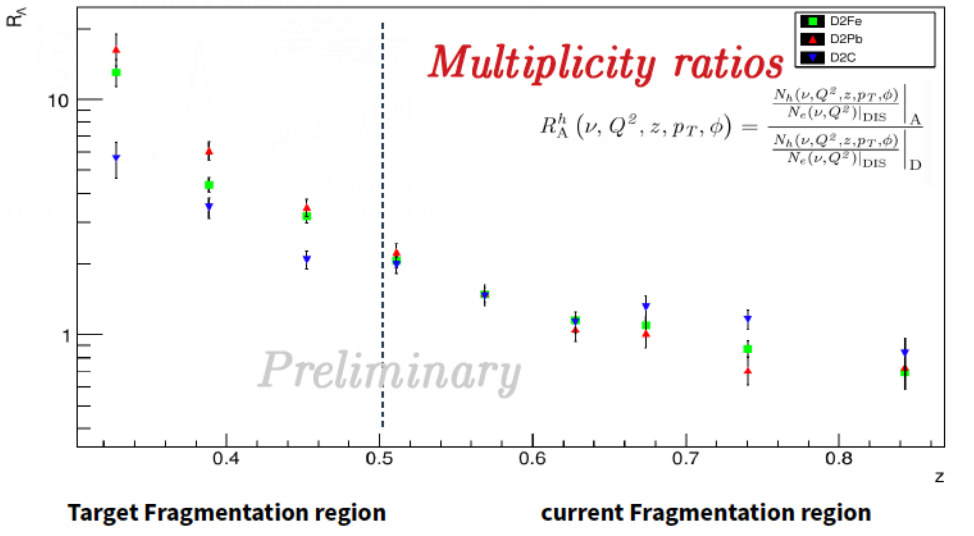
Taya Chetry
Lamiaa El Fassi
Mississippi State University

CLAS Collaboration Meeting
03/07/2019

Λ Hadronization study using CLAS eg2 — Summary

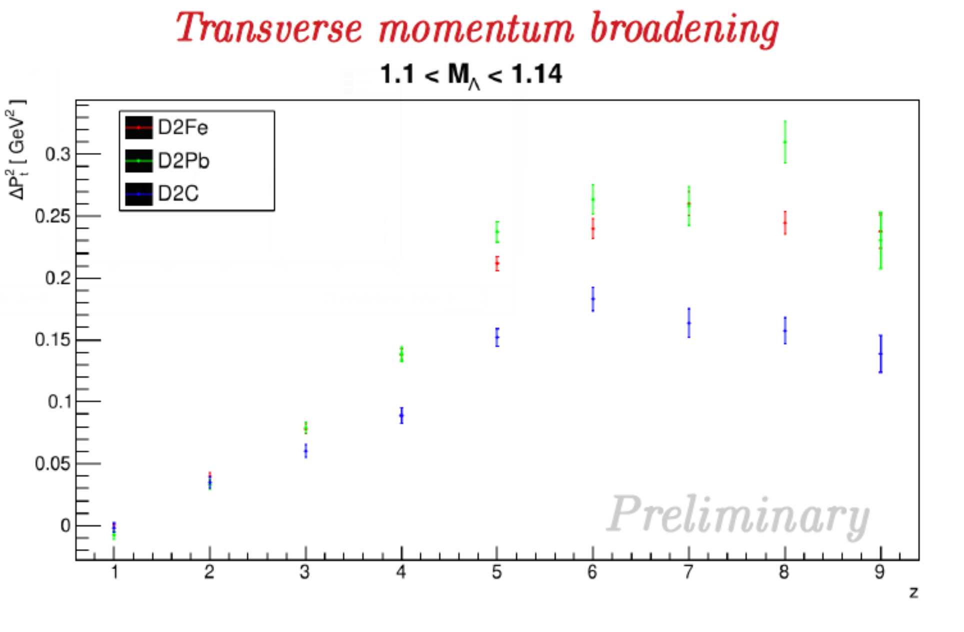


Λ yield extraction:
Event mixing/combinatorial background and Breit-Wigner combined using χ^2 minimization (RooFit).



Ongoing and Future directions:

- Validation of PYTHIA event generator: Nice looking Λ invariant mass peaks for different targets.
- Acceptance corrections: GSIM+GPP+RECSIS. Compare simulated to exptl. data
- Radiative corrections.
- Systematic Studies: such as PID, etc.
- Study other dependencies of R_Λ, P_T^2, Cronin effect, etc.



Color Propagation Analysis Updates for Pi Plus

Sebastián Morán Vásquez

Universidad Técnica Federico Santa María
Physics Department
Casa Central, Valparaíso

7 de marzo de 2019

Situation:

We have two independent analysis , here we call them:

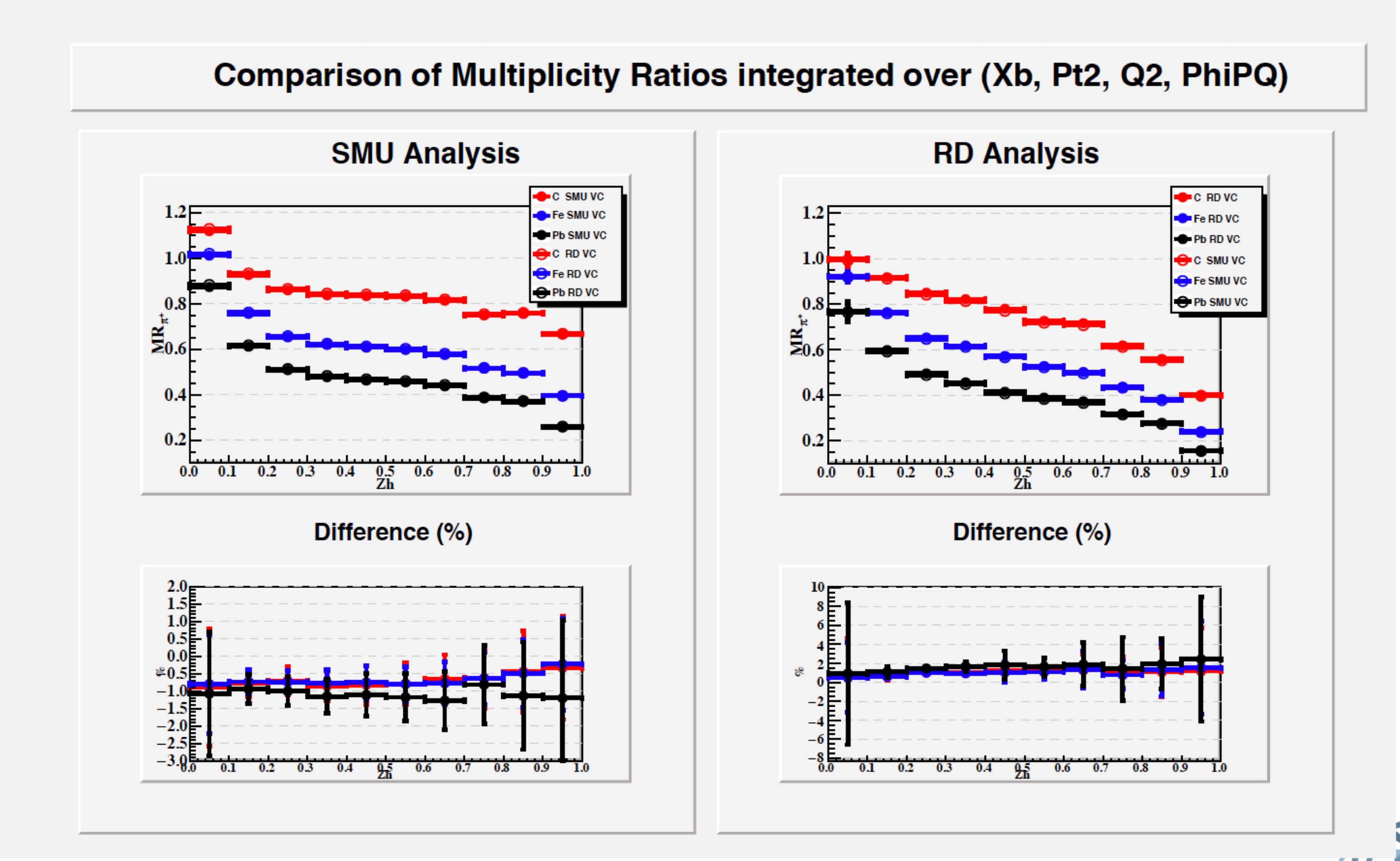
- Santa Maria University analysis (SMU).
- Raphael Dupre Analysis (RD).

which give different final results.

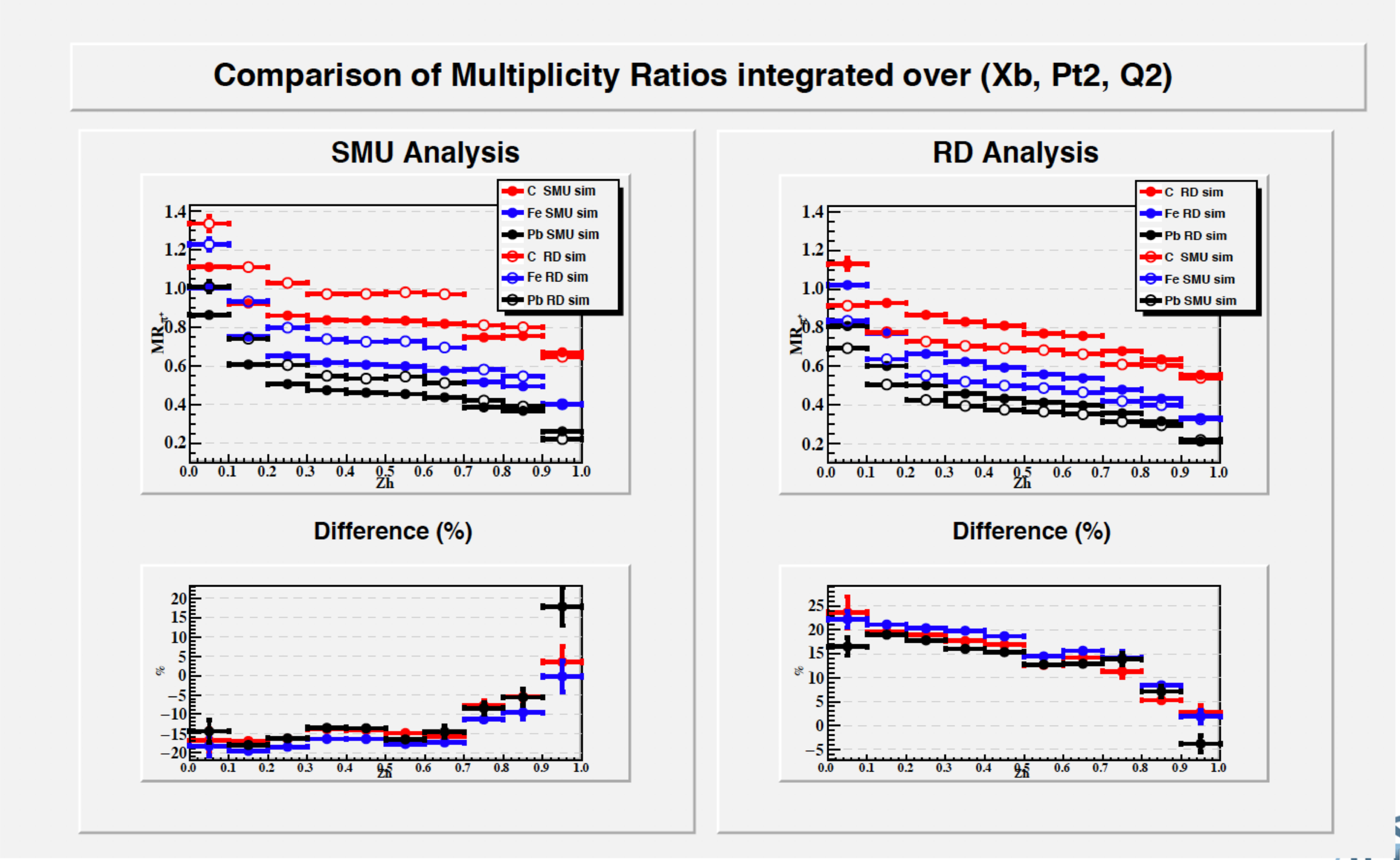
What are the differences between the analysis?

- The selection criteria (Particle Identification).
- The Vertex cuts, for electrons.
- The Set of Simulations.
- The Method of doing the Acceptance Correction.
  - USM $\rightarrow$ Bin by Bin base Correction.
  - RD $\rightarrow$ Event by Event base Correction.
- Number of variables consider in the Acceptance Correction:
  - USM $\rightarrow$ Zh , Q2, P_t^2, Xb and PhiPQ bins (this is called 5D case).
  - RD $\rightarrow$ Zh , Q2, P_t^2 and Xb bins (this is called 4D case).

There are two sets of vertex cuts. If we mixed them



If we only mixed the set of simulations.



BSA of Coherent π^0 DVMP on Helium-4

Frank Thanh Cao
Advisor: K. Joo
Co-Advisor: K. Hafidi

University of Connecticut

March 2019

When embedded in the nucleus,

- What about proton changes?
- What remains the same?

Accessing the nuclear generalized parton distributions (GPDs) and form factors (FFs) are a way to approach and answer these questions.

Measuring beam-spin asymmetries (BSA) from DVCS and DVMP processes help to uncover these intricate math. objects.

Nuclear targets offer two distinct channels:

- Coherent (Nucleus stays intact)
- Incoherent (Nucleon breaks off and traverses nuclear medium)

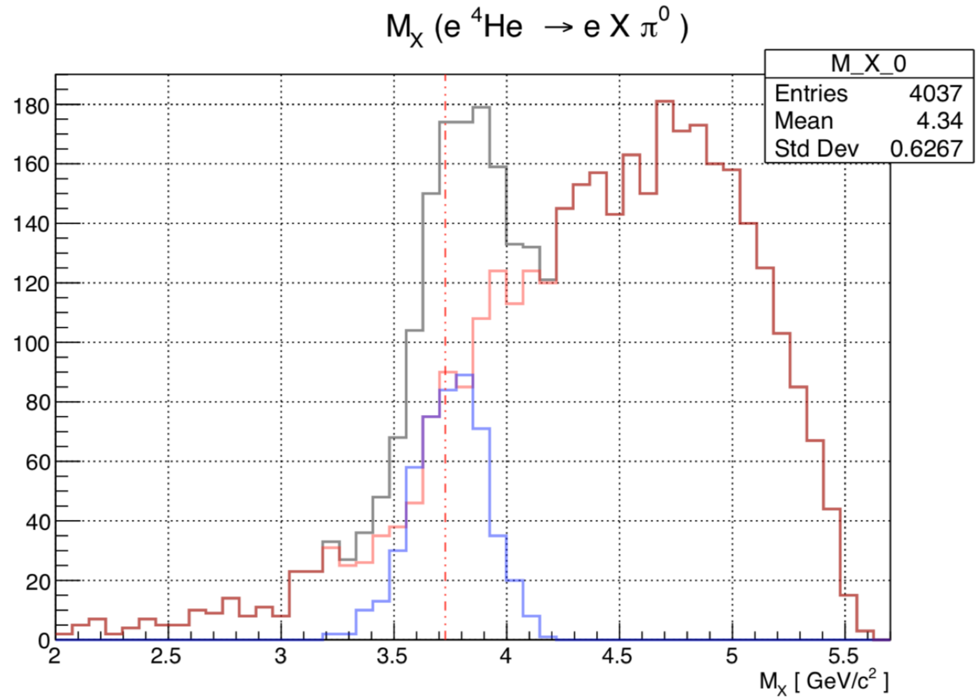
Enter the CLAS EG6 Experiment

Start with the simplest dense stable nucleus: $^{4}\mathrm{He}$.

Measure the BSA for exclusive processes to get at nuclear and modified nucleonic FFs and GPDs.

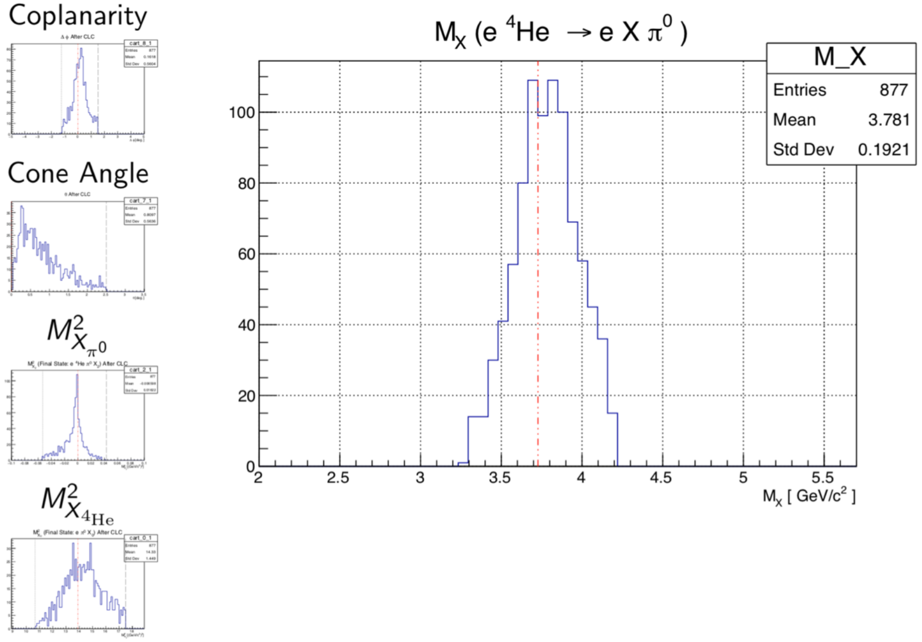
Channel	Process		BSA
Coherent	DVCS:	$\left(e\ ^{4}\mathrm{He}, e\ ^{4}\mathrm{He}\ \gamma\right)$	Published[1]
	DVMP:	$\left(e\ ^{4}\mathrm{He}, e\ ^{4}\mathrm{He}\ \pi^{0}\right)$	This talk
		$\left(e\ ^{4}\mathrm{He}, e\ ^{4}\mathrm{He}\ \eta\right)$	Stats. too low
Incoherent	DVCS :	$^{4}\mathrm{He}\,(e, e\ p\ \gamma)\,X$	Under review
	DVMP:	$^{4}\mathrm{He}\left(e, e\ p\ \pi^{0}\right)X$	Work in prog.[2]
		$^{4}\mathrm{He}\,(e, e\ p\ \eta)\,X$	Work in prog.[2]

Kin. Fit Applied

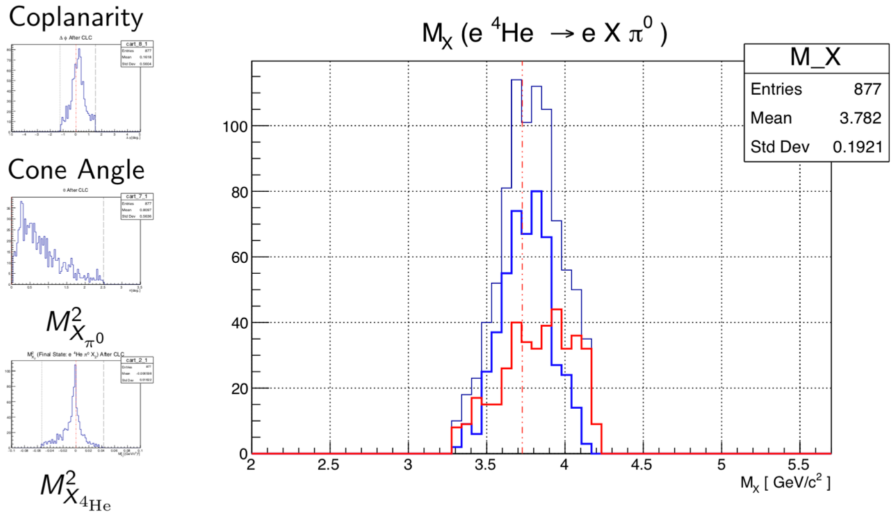


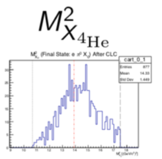
Red : Events failing CLC
Blue : Events passing CLC

Sequential Exclusivity Cuts Applied



Sequential Exclusivity Cuts Applied





Red : Events failing CLC
Blue : Events passing CLC

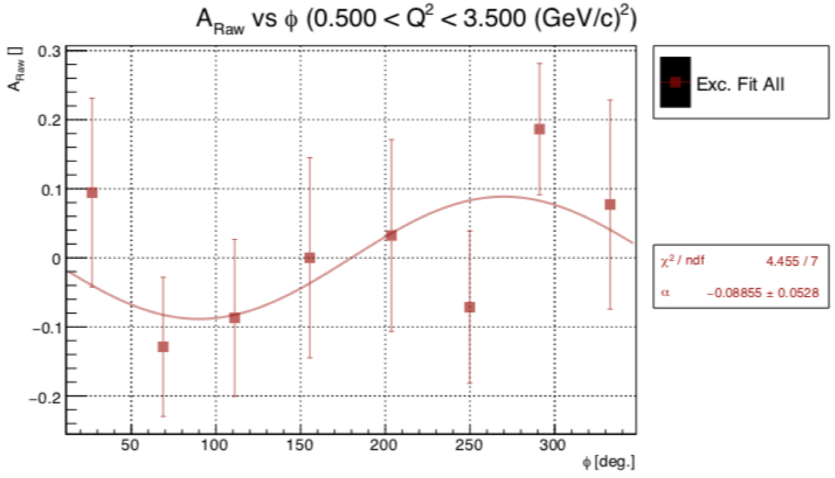
Beam-Spin Asymmetry Comparison

For

$$e\ ^4\mathrm{He} \rightarrow e\ ^4\mathrm{He}\ \pi^0 \quad , \tag{1}$$

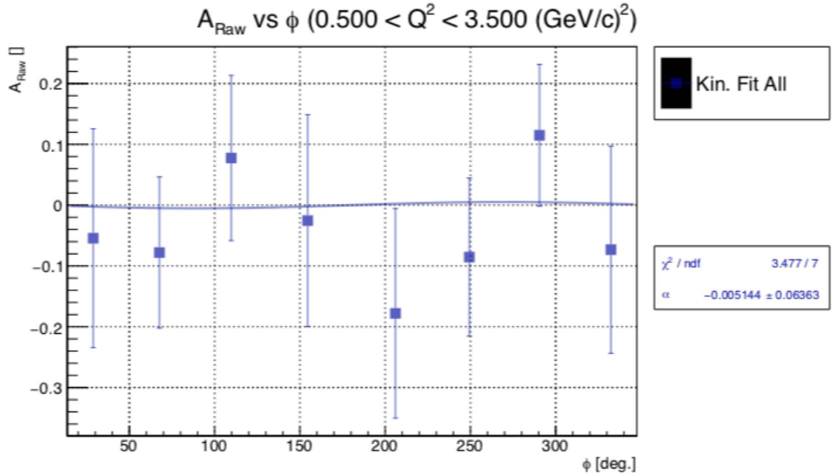
the BSA is obtained from two different event selection methods:

Exclusivity Cuts



BSA = -8.9±5.3 %
(800 events)

Kinematic Fit



BSA = -0.5±6.3 %
(537 events)

Summary

- The BSA of coherent π^0 electroproduction off $^4\mathrm{He}$ is consistent with 0 (-1.08±3.22%)
  - Benchmark measurement for Ji's formulation
- Event selection plays a *crucial* role
- Exclusivity cuts require some cleverness
  - Intimate knowledge of the dataset and reaction needed to remove background and to clean the dataset
- Kin. fitting does not
  - It uses both detector resolutions and conservation law constraints to do a fantastic job in rejecting background
  - Some of these events cannot be rejected by any obvious series of cuts
- Kinematic fitting should be used in more analyses![3]

[3] The repo contains the library, FCKinFitter, with a wiki and working examples to help install, set up, and use kinematic fitting in (hopefully) an intuitive way.