Electrons for Neutrinos

08/03/2018

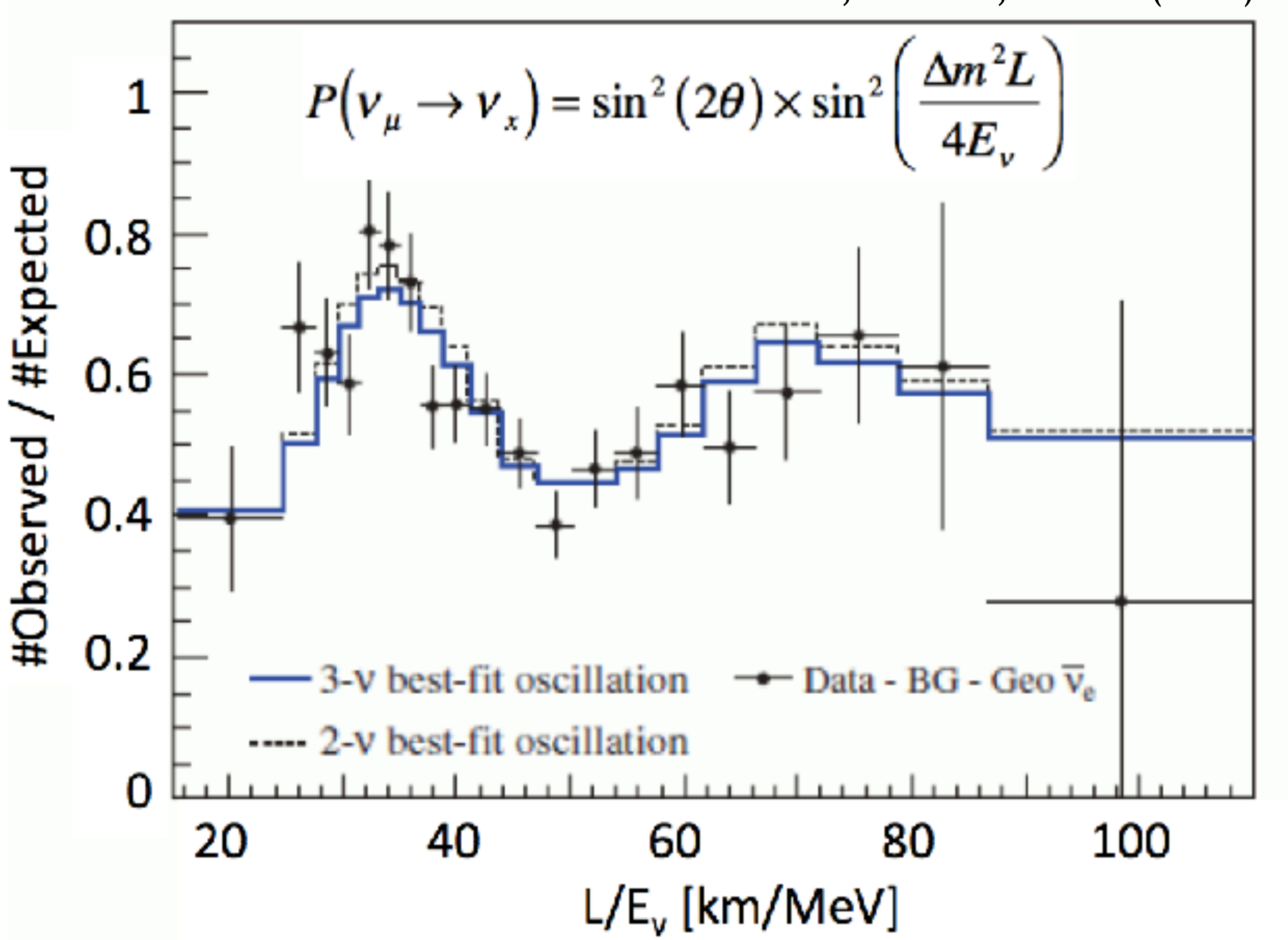
INT Workshop INT-18-1a - Nuclear ab initio Theories and Neutrino Physics

Or Hen, Larry Weinstein, Afroditi Papadopoulou ,Mariana Khachatryan, Luke Pickering, Adrian Silva, Axel Schmidt, Reynier Cruz Torres, Barak Schmookler, Erez Cohen, Adi Ashkenazi

Introduction

Neutrino Oscillation Measurements are based on the incoming neutrino energy

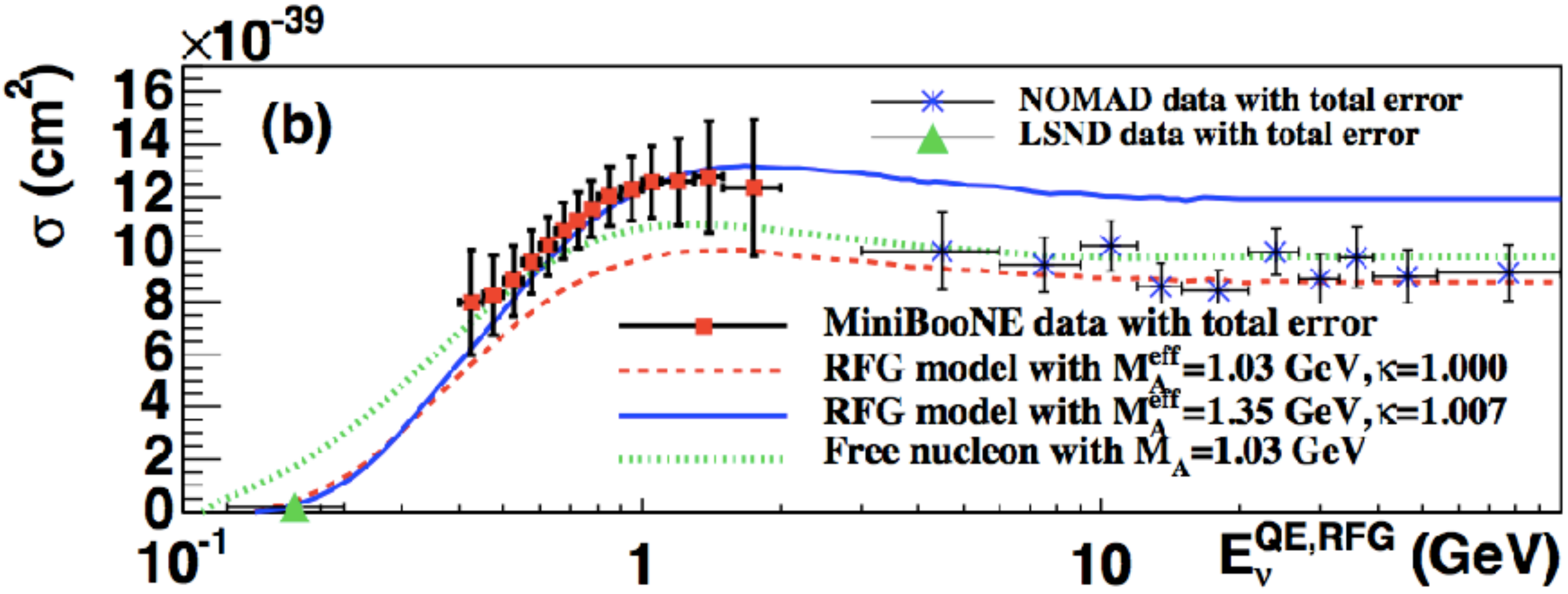
KamLAND, PRL 100, 221803 (2008)



Introduction

Neutrino side

The incoming energy is reconstructed from the final state
Highly dependent on the nuclear model



Introduction
Neutrino side

This problem can be addressed by:

- Improving the theories
- Use near detector
  - Where we wish to probe nuclear physics and no oscillation effects
  - But the flux model and the nuclear model are convoluted
- **External constraints on nuclear model**

Introduction

Nuclear physics input

We suggest looking at wide phase space ELECTRON DATA:

- In the semi classical regime the final state is similar.
- We know the incoming energy and can test its reconstruction.

Keeping in mind:

EM and not weak interaction is the dominant.

Different radiative effects.

CLAS

Incoming Electron beam 1 - 5 GeV

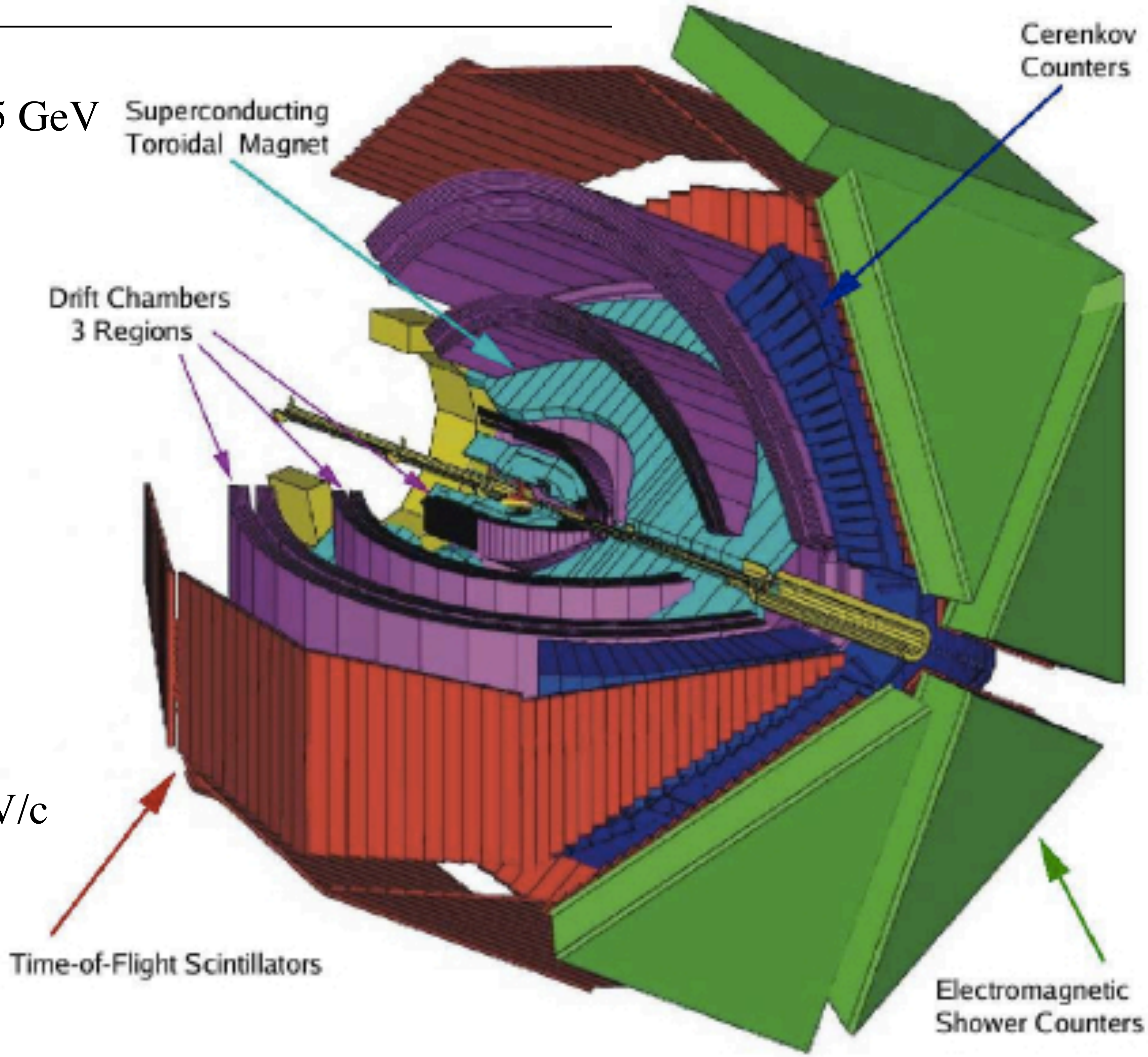
Large acceptance

Sub detectors:

- Tracking in a toroidal field
- TOF scintillators
- Cherenkov detector
- EM calorimeter

Detection threshold: 300 MeV/c

Open Trigger



CLAS Data

E2 experiment:

Beam energies : 2.2, 4.4 GeV

Targets: ^{3}He, ^{4}He, ^{12}C, ^{56}Fe

E2G experiment (less statistics):

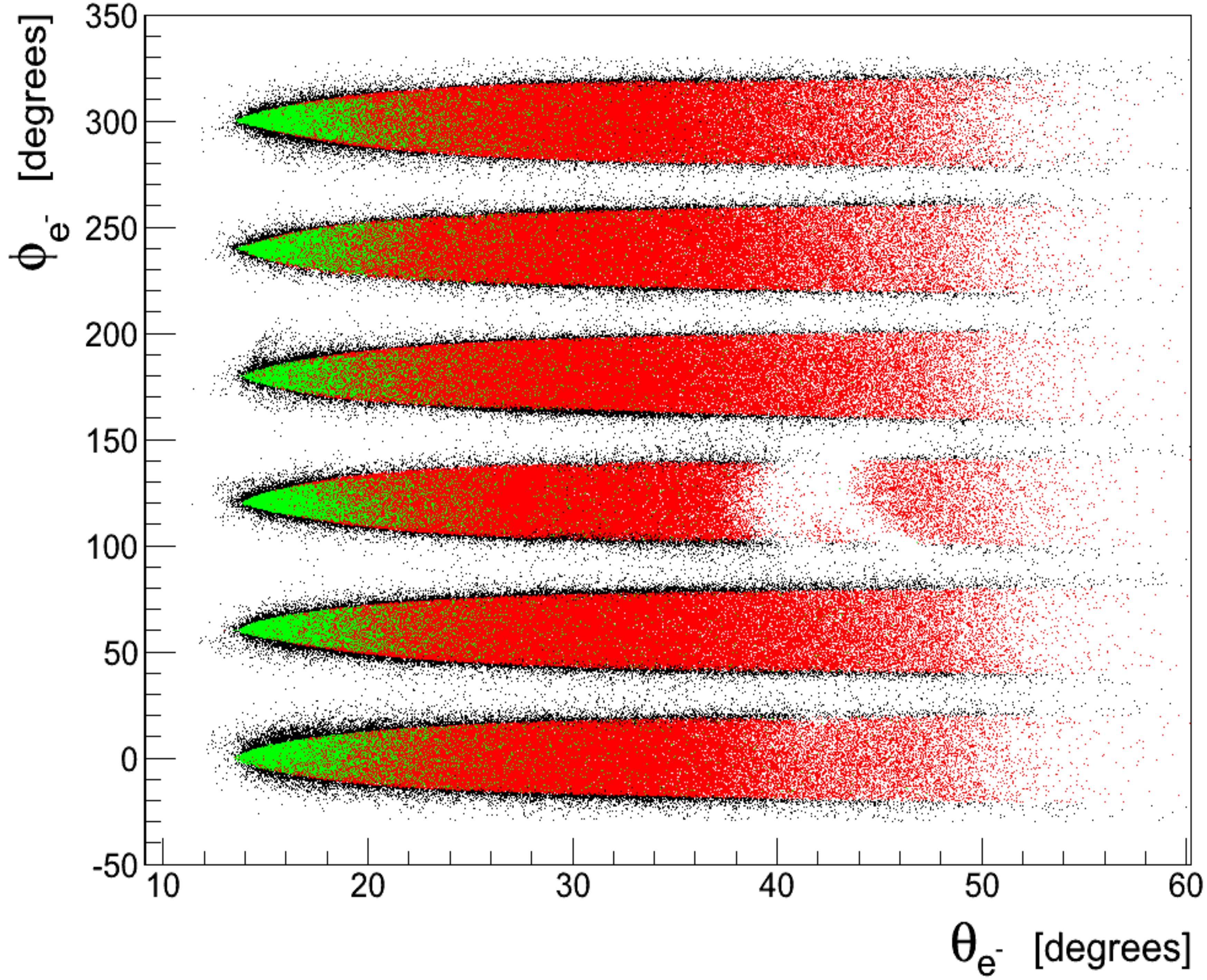
Beam energy: 5 GeV

Elements: ^{2}D, ^{12}C, ^{27}Al, ^{56}Fe, ^{208}Pb

CLAS Data

Acceptance

CLAS acceptance is large but not complete



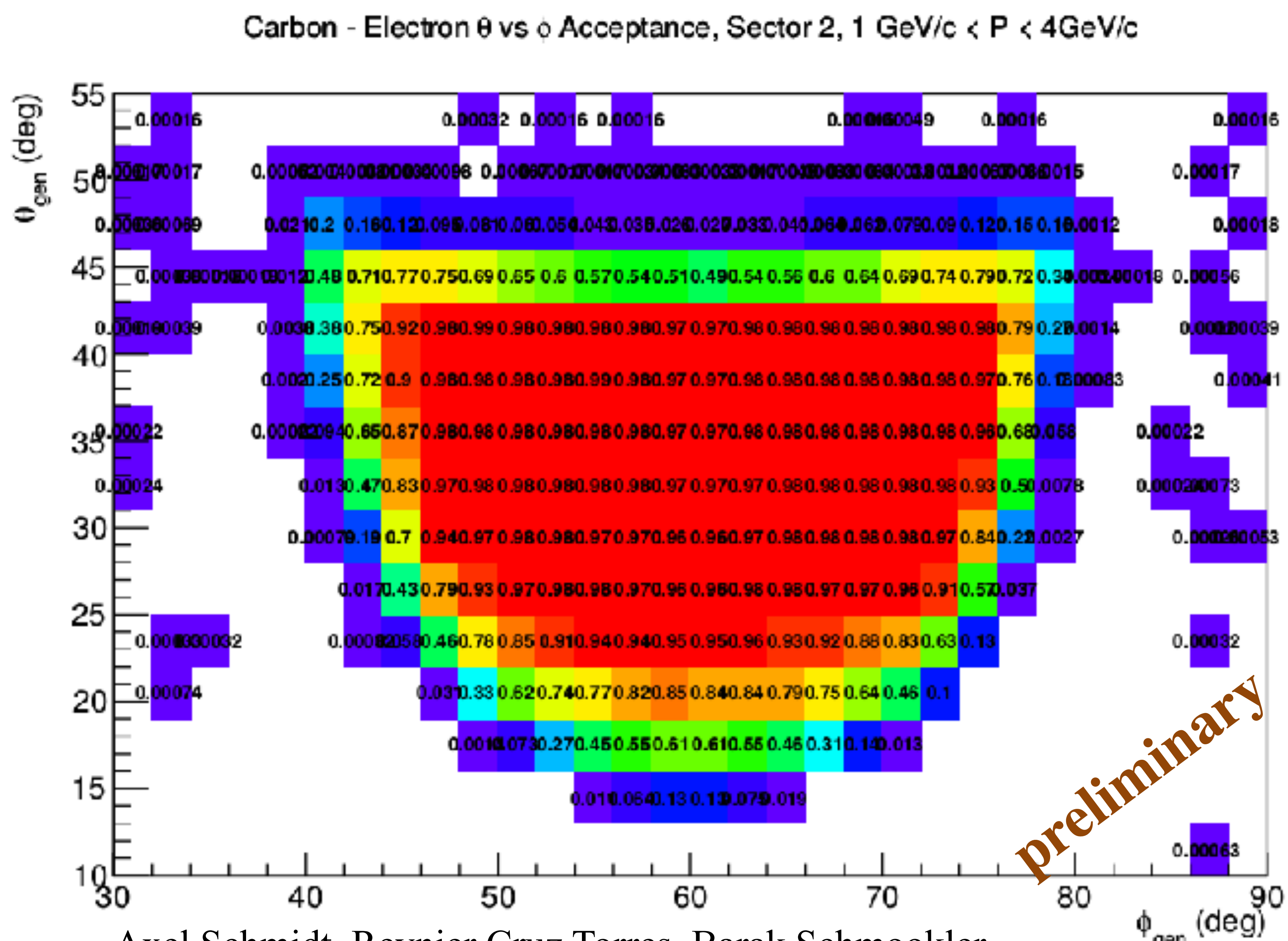
CLAS Data

Acceptance - Available for all

For each:

- target width
- target location
- outgoing particle type
- outgoing particle direction

The CLAS detector has a different efficiency, which we wish to publish as acceptance maps for public use.



Axel Schmidt, Reynier Cruz Torres, Barak Schmookler

CLAS Data

Event Selection

To focus on QE events:

1 proton with momentum larger than 300 MeV/c

no additional charged hadrons

CLAS Fiducial cuts for proton and electron

CLAS Data

Scaling

Due to the difference between the neutrino vs. electron differential cross section

We're applying an event by event weight:

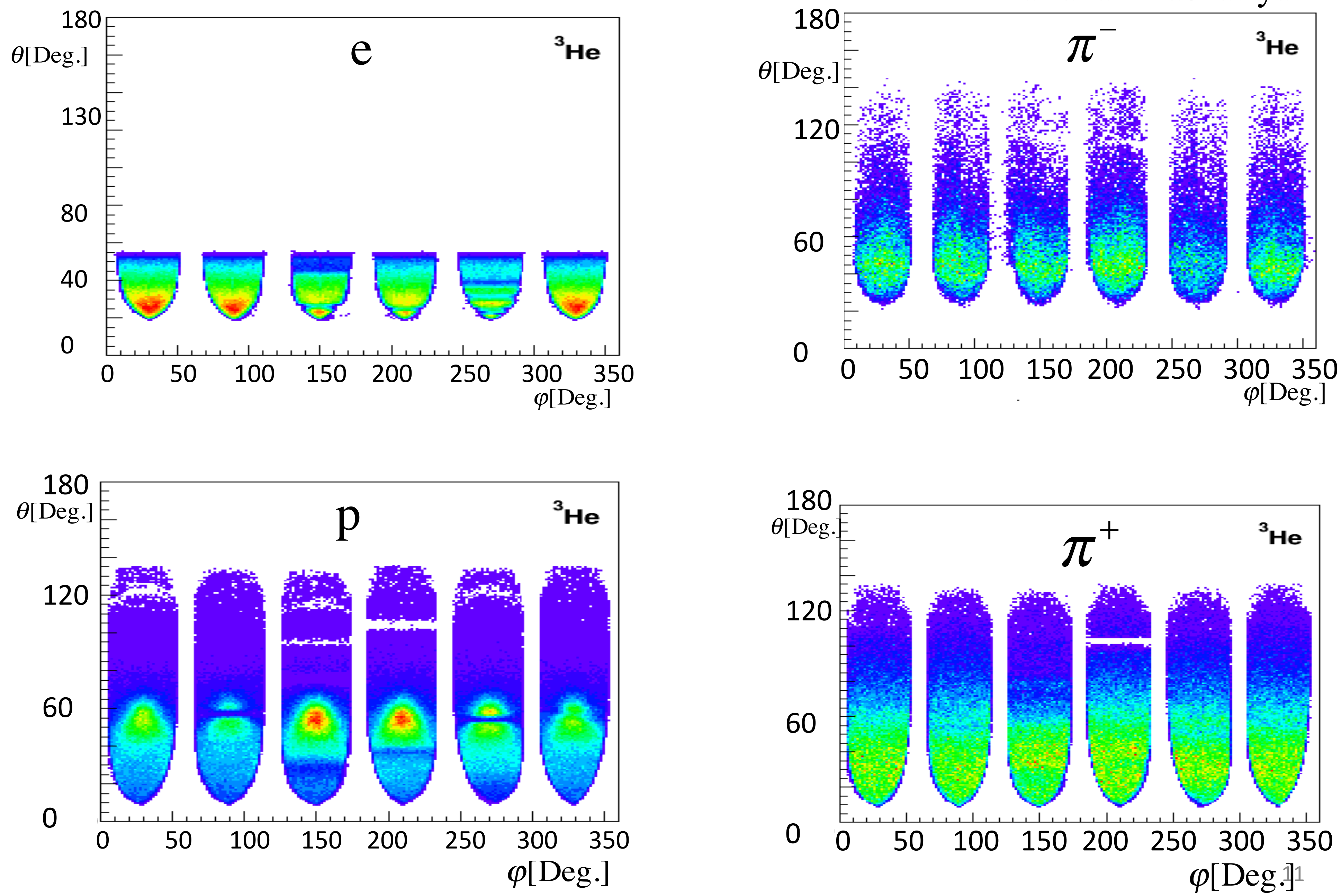
$$1/\sigma_{\mathrm{Mott}}$$

To make sure we're looking at the kinematically interesting regions

CLAS Data

2.2 GeV on ^{3}He

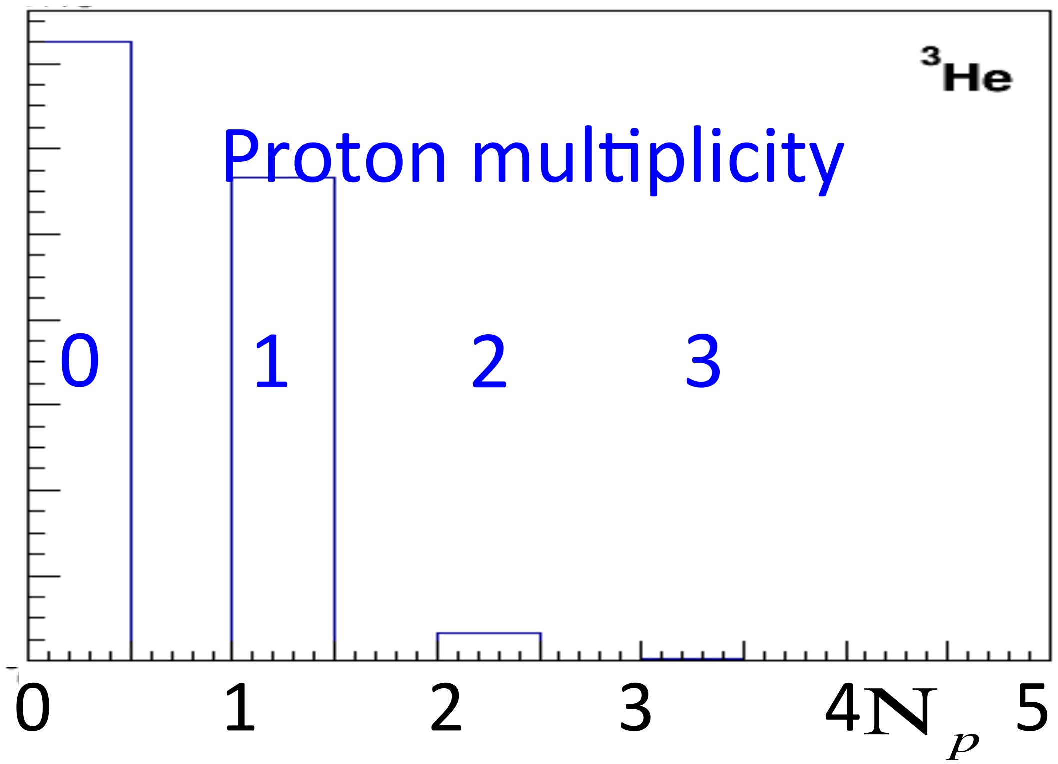
Mariana Khachatryan

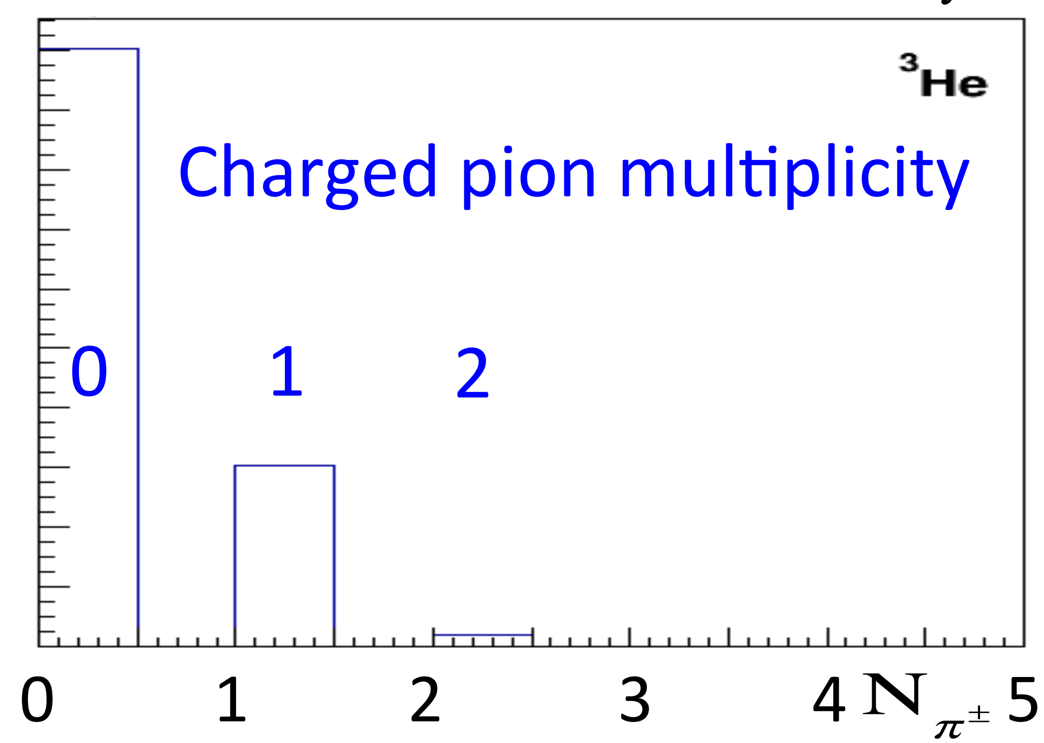


CLAS Data

2.2 GeV on ^{3}He

Mariana Khachatryan





CLAS Data

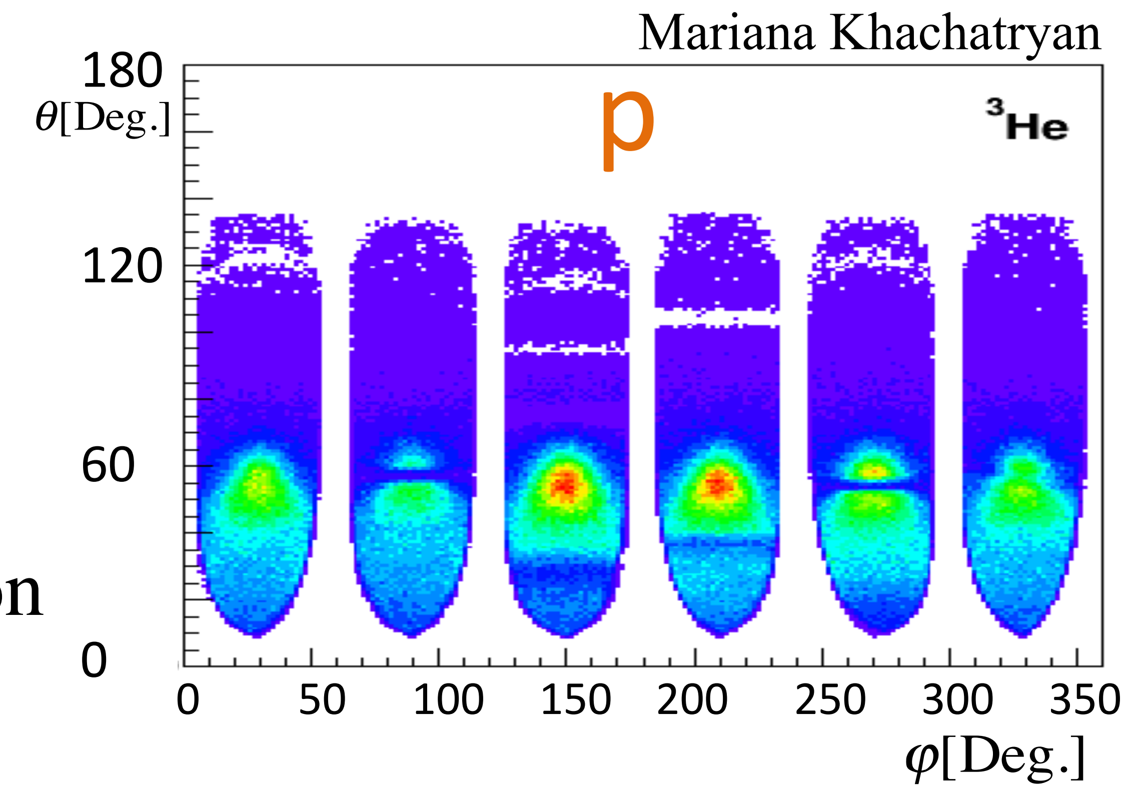
Event Selection

To focus on QE events:

1 proton above 300 MeV/c

no additional charged hadrons

CLAS Fiducial cuts for proton and electron



Given the detector acceptance map,

Any event with an additional hadron, implies more events of its kind where one of the hadron was not detected.

CLAS Data

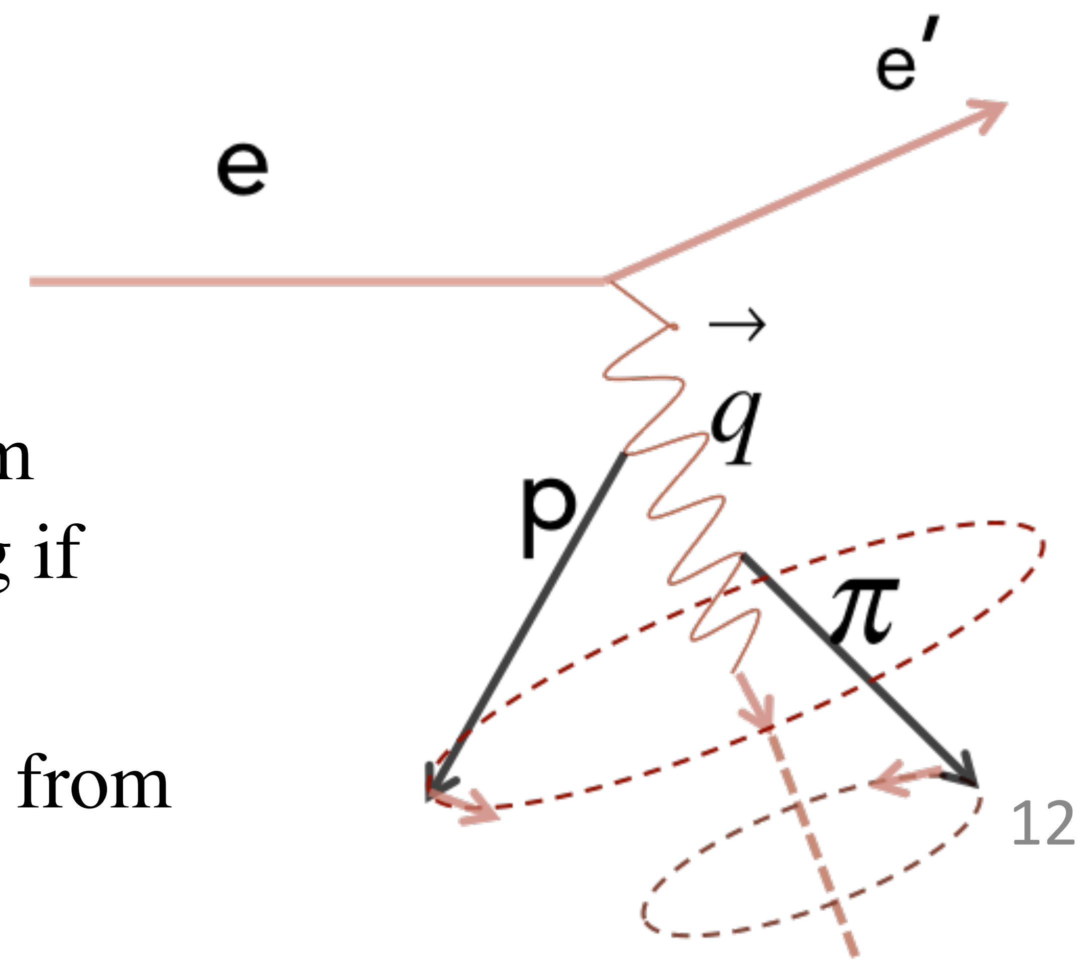
Background subtraction

Two proton / pion subtraction method:

Using events with two hadrons,

rotating the two outgoing hadron system around the q vector, each time checking if only the proton was detected

Subtract contribution to QE-like events from the final distributions



CLAS Data

Incoming Energy Reconstruction

Two methods for calculating the incoming energy:

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

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

M-nucleon mass

m_1 outgoing lepton mass

k_1 – lepton three momentum

θ – lepton scattering angle

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

E_{Binding} – Binding energy

T_p – kinetic energy of knock out proton

$E_e^{'}$ – energy of scattered electron

E_π – energy of produced meson

In use in Cherenkov detectors

Assuming QE interaction

In use in Tracking detectors

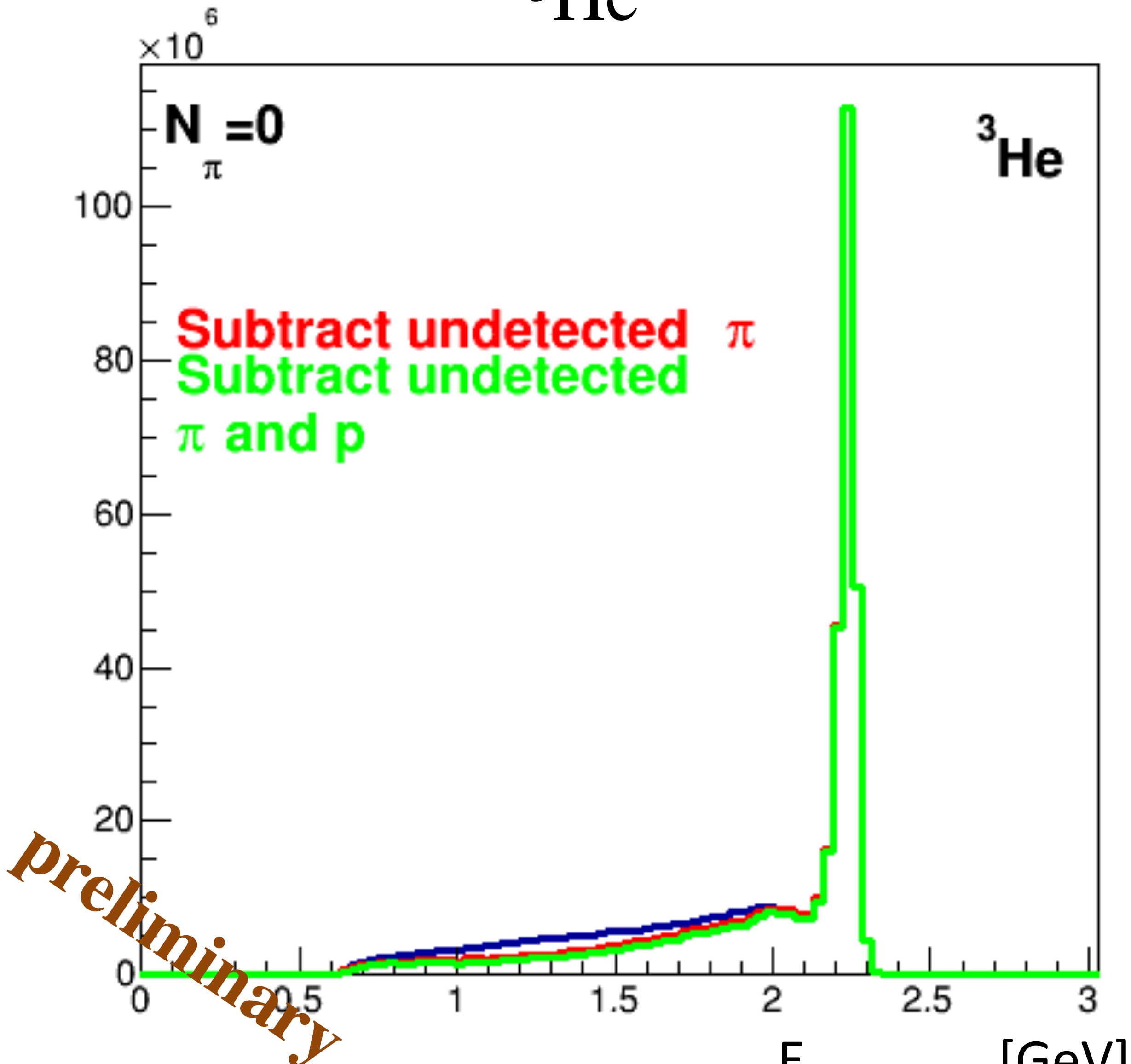
Need good hadronic reconstruction

CLAS Data

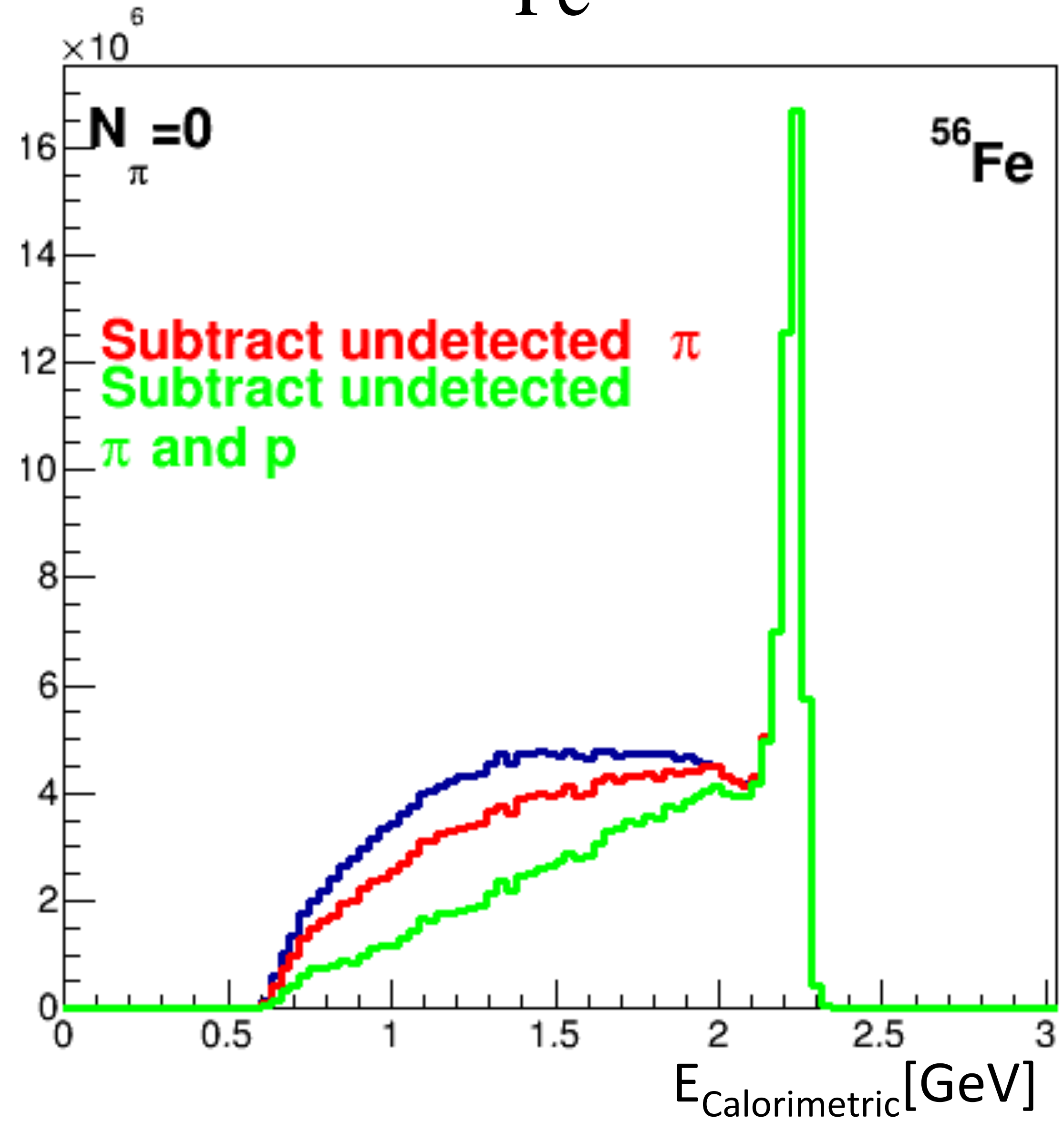
Results

Mariana Khachatryan

^{3}He



^{56}Fe

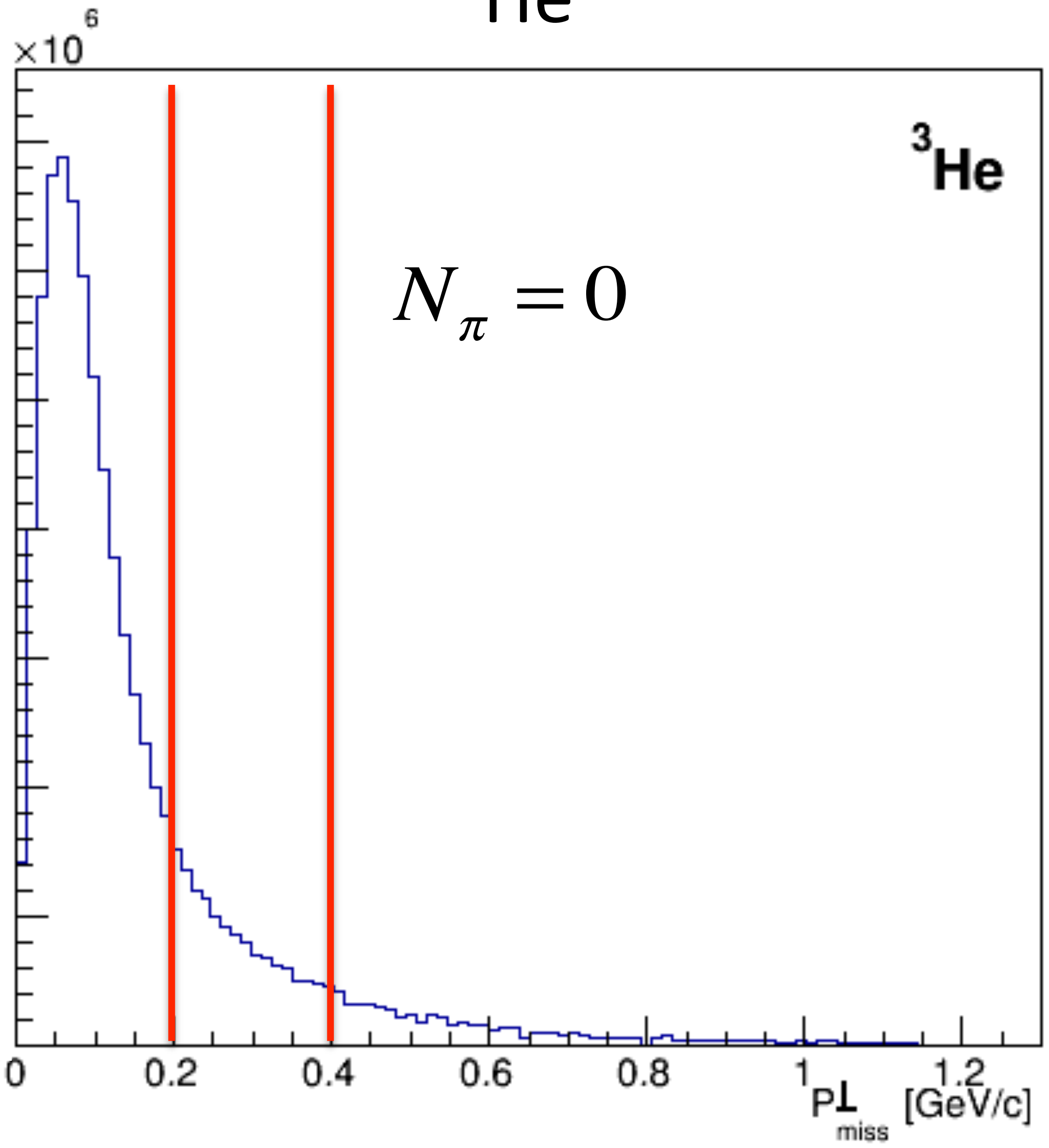


CLAS Data

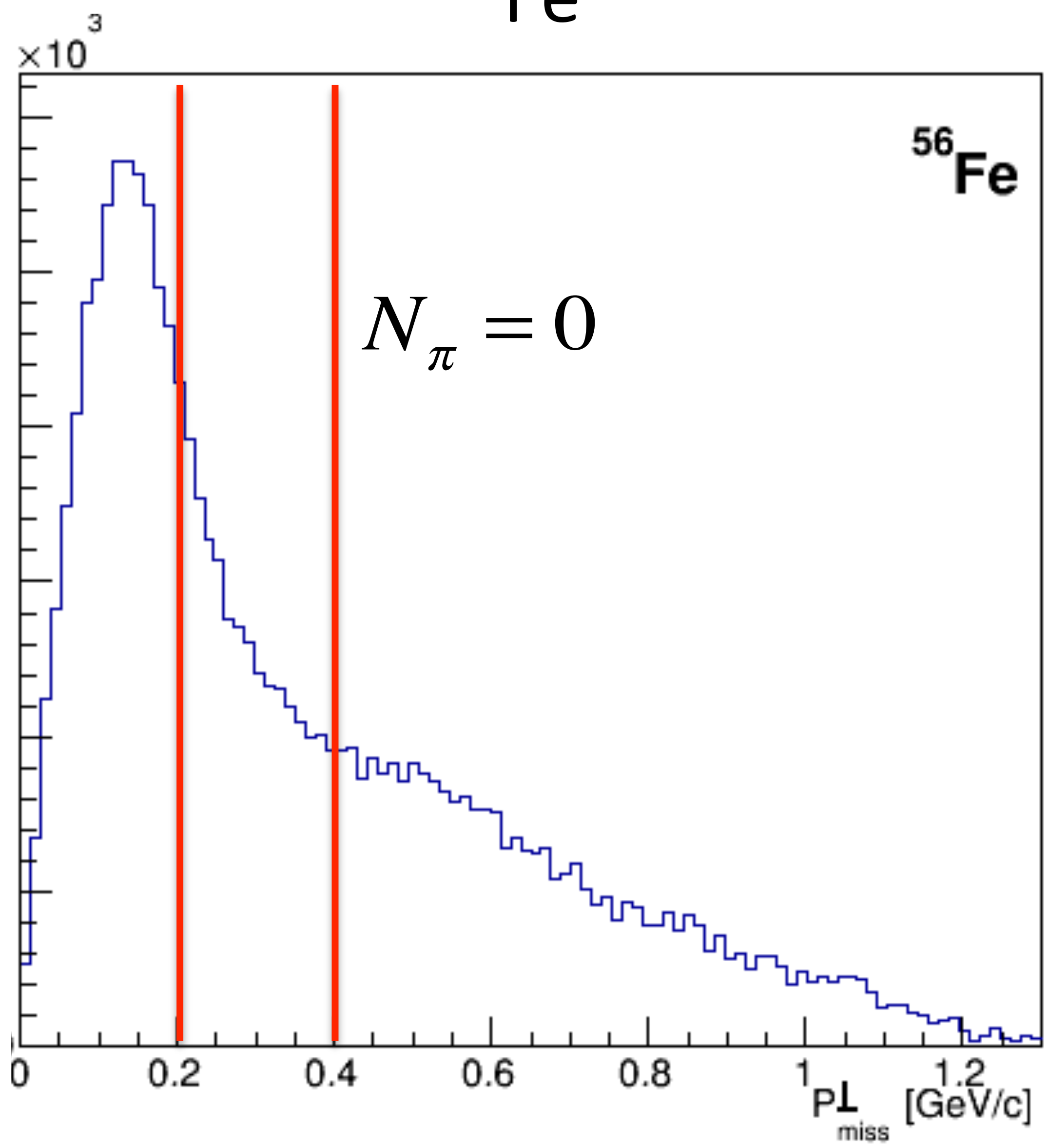
Results

$$\vec{P}_{\perp}^{miss} = \vec{P}_{\perp}^{e'} + \vec{P}_{\perp}^{p}$$

^{3}He



^{56}Fe



Mariana Khachatryan

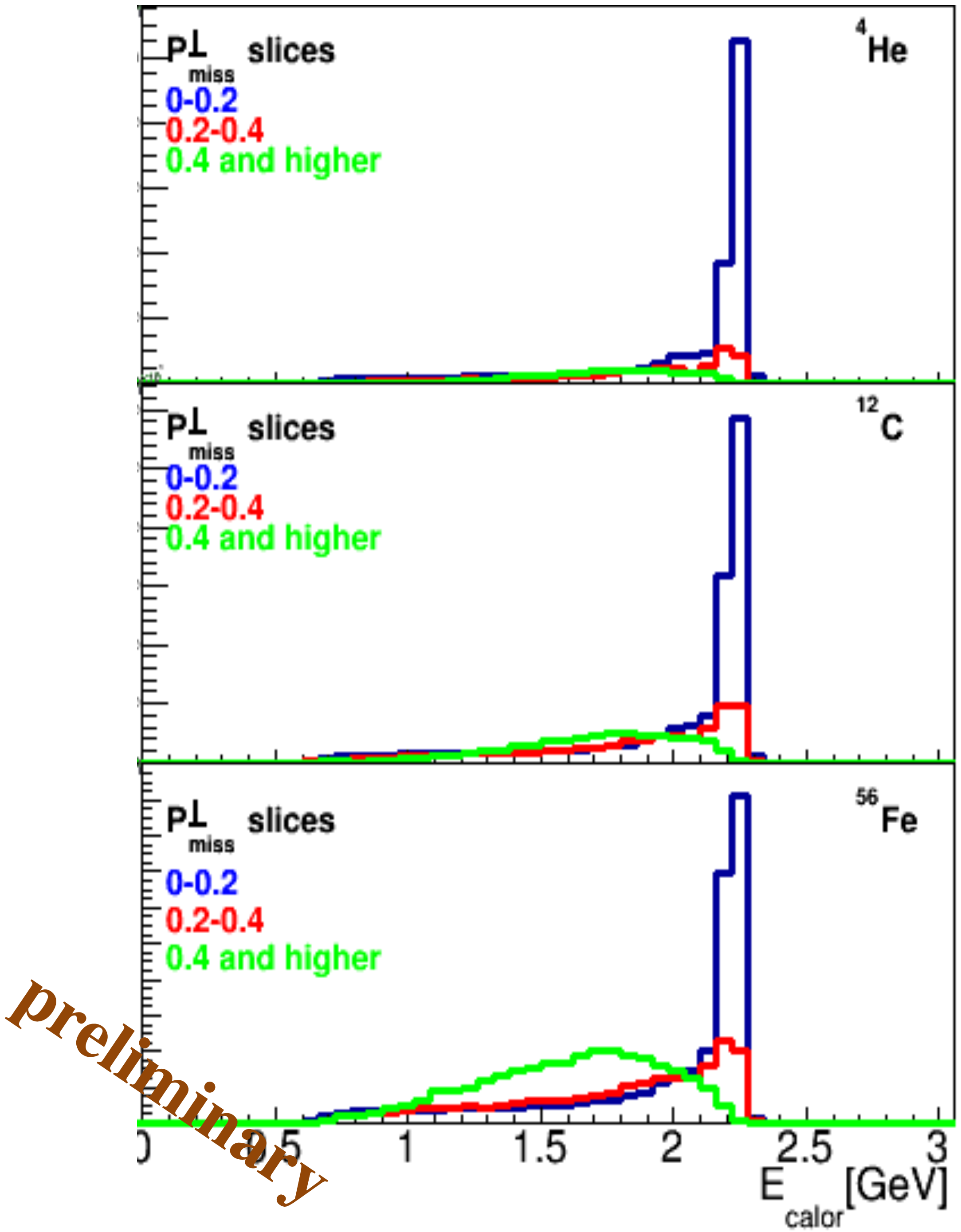
CLAS Data

Results 2.2 GeV - Calorimetric Energy

Mariana Khachatryan

Increased tail for heavier nucleis.

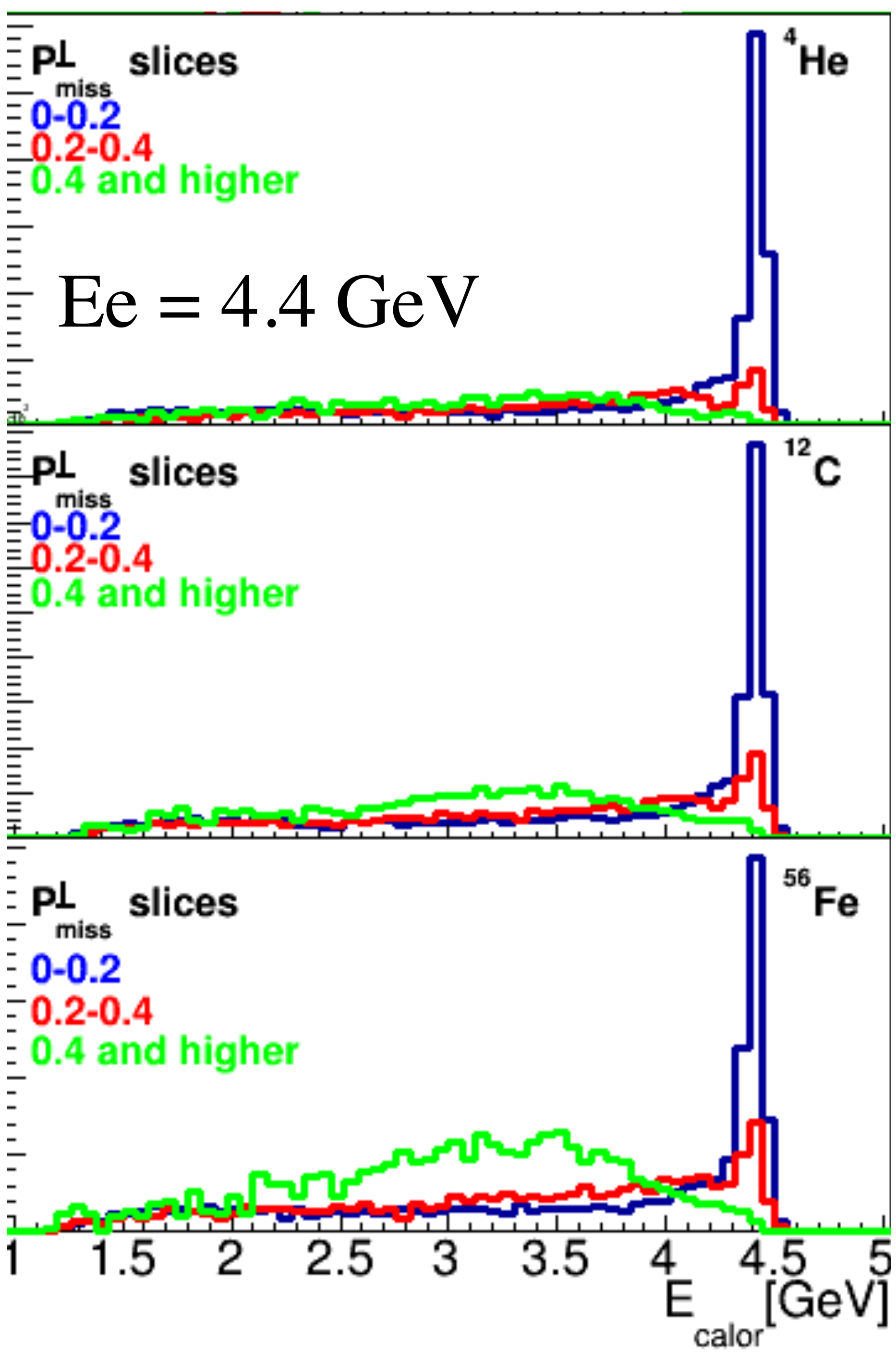
Increased non QE background for higher values of missing transverse momentum.

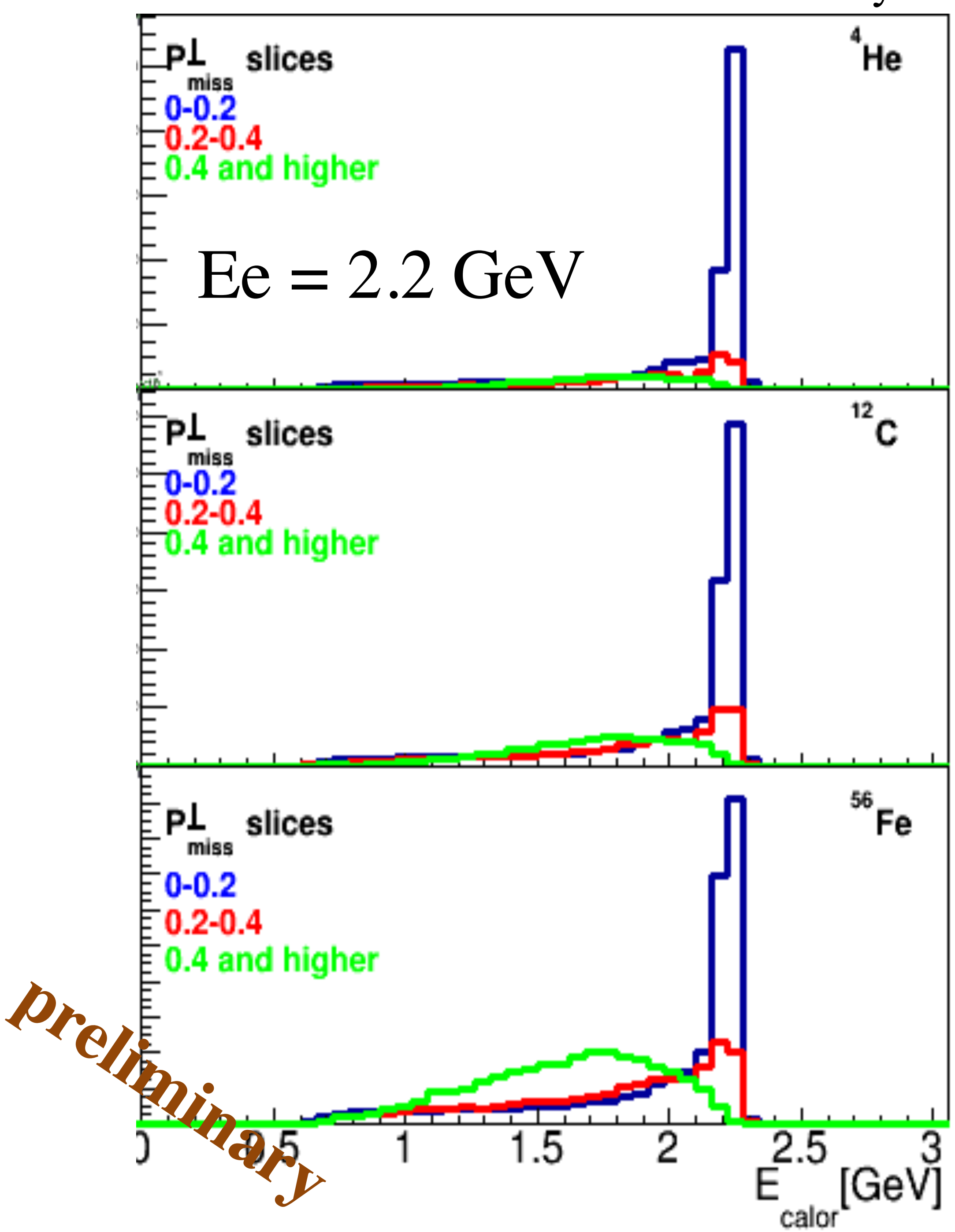


CLAS Data

Results - Calorimetric Energy - different energies

Mariana Khachatryan





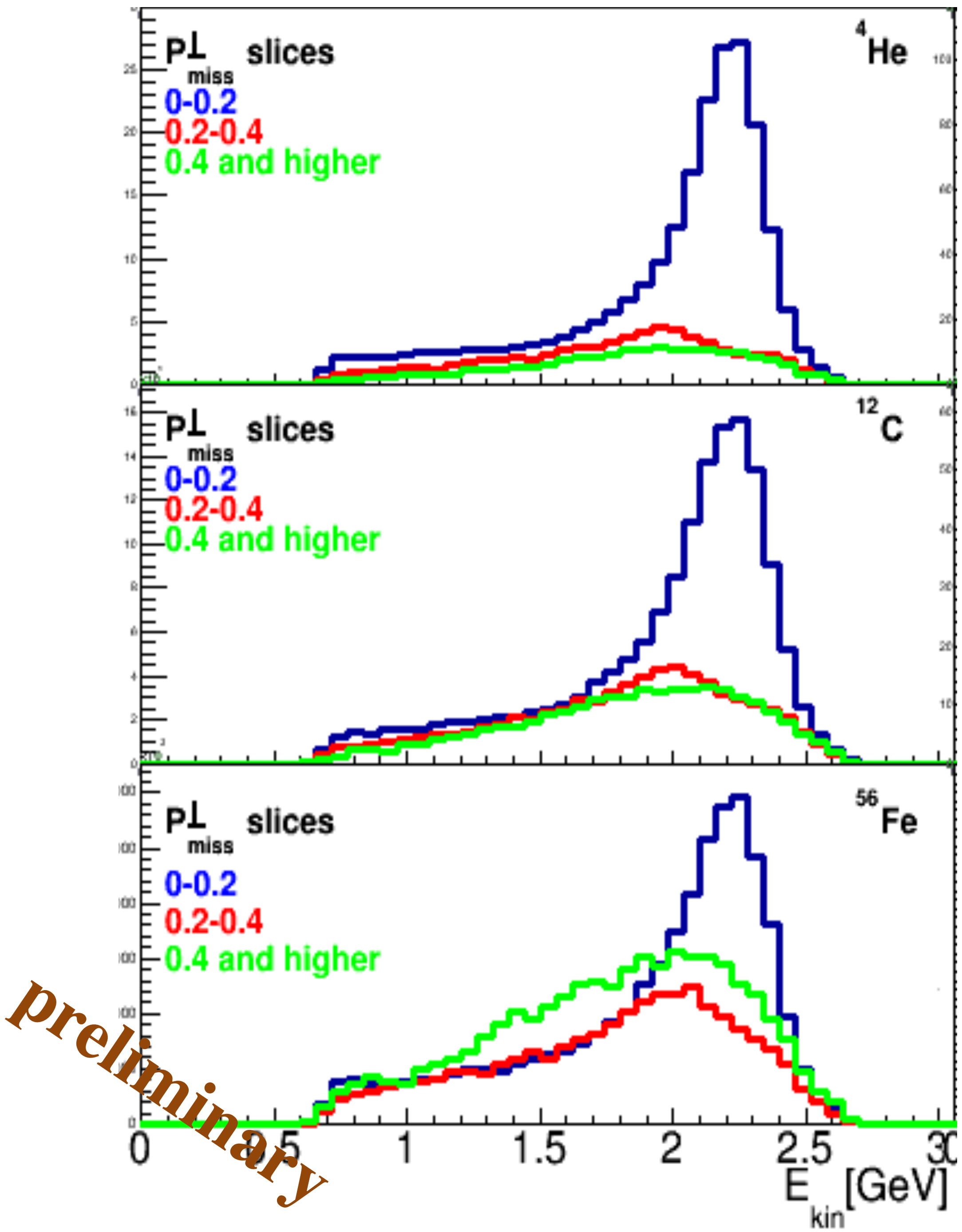
CLAS Data

Mariana Khachatryan

Results 2.2 GeV - Leptonic Energy

Worse resolution for leptonic energy.

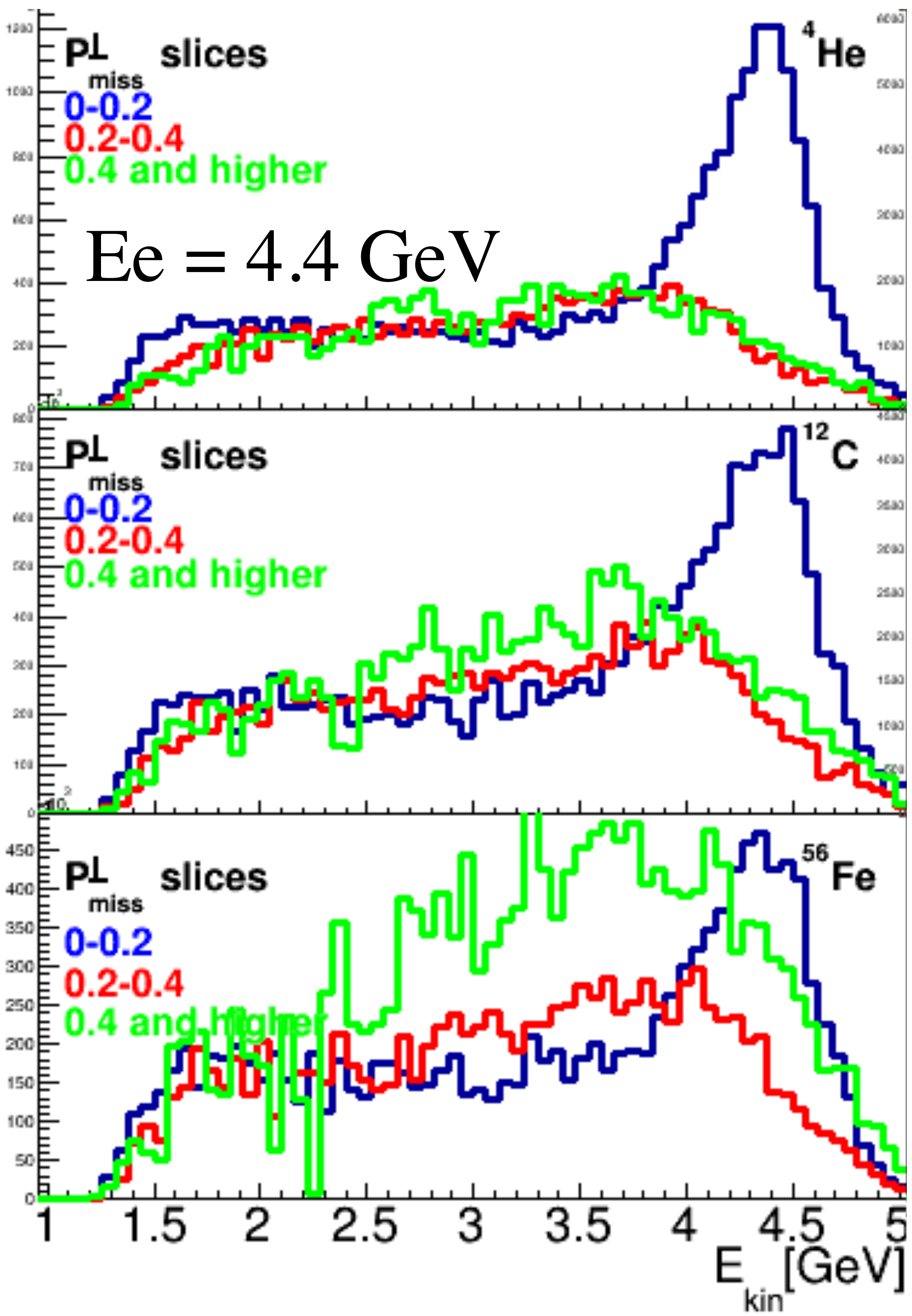
Increased tail for heavier nucleis.

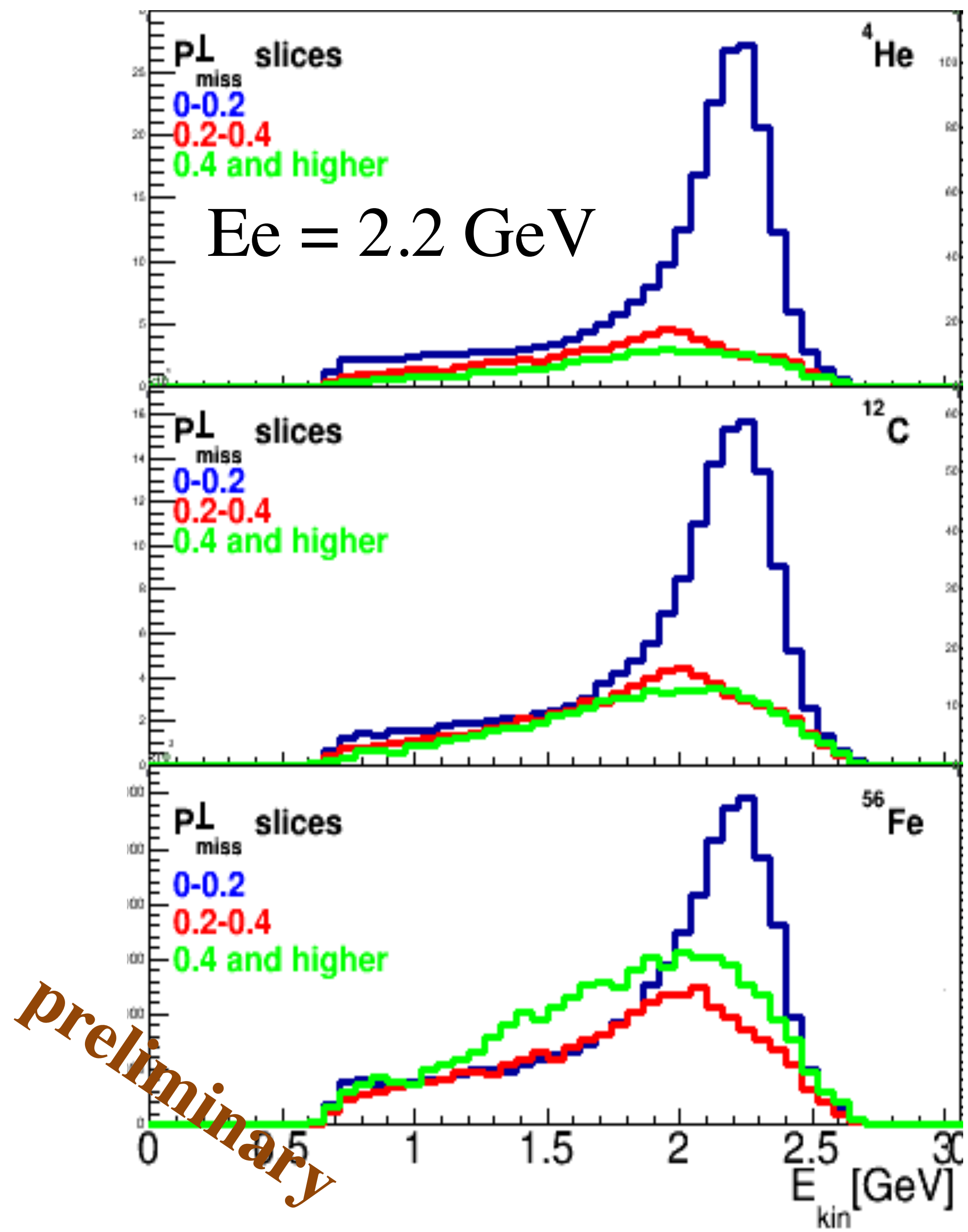


CLAS Data

Mariana Khachatryan

Results 4.4 GeV - Leptonic Energy





Simulation

GENIE

Nuclear model	Correlated fermi gas model
QE	Lewellyn Smith for neutrino
	Rosenbluth CS for electrons
MEC	Empirical Dytman model
Resonances	Rein Sehgal
FSI	data driven

Currently 1M events with **EM QE and MEC only**

Event Selection

Reminder:

1 proton above 300 MeV/c

no additional charged hadrons

CLAS Fiducial cuts for proton and electron

Additional Kinematics:

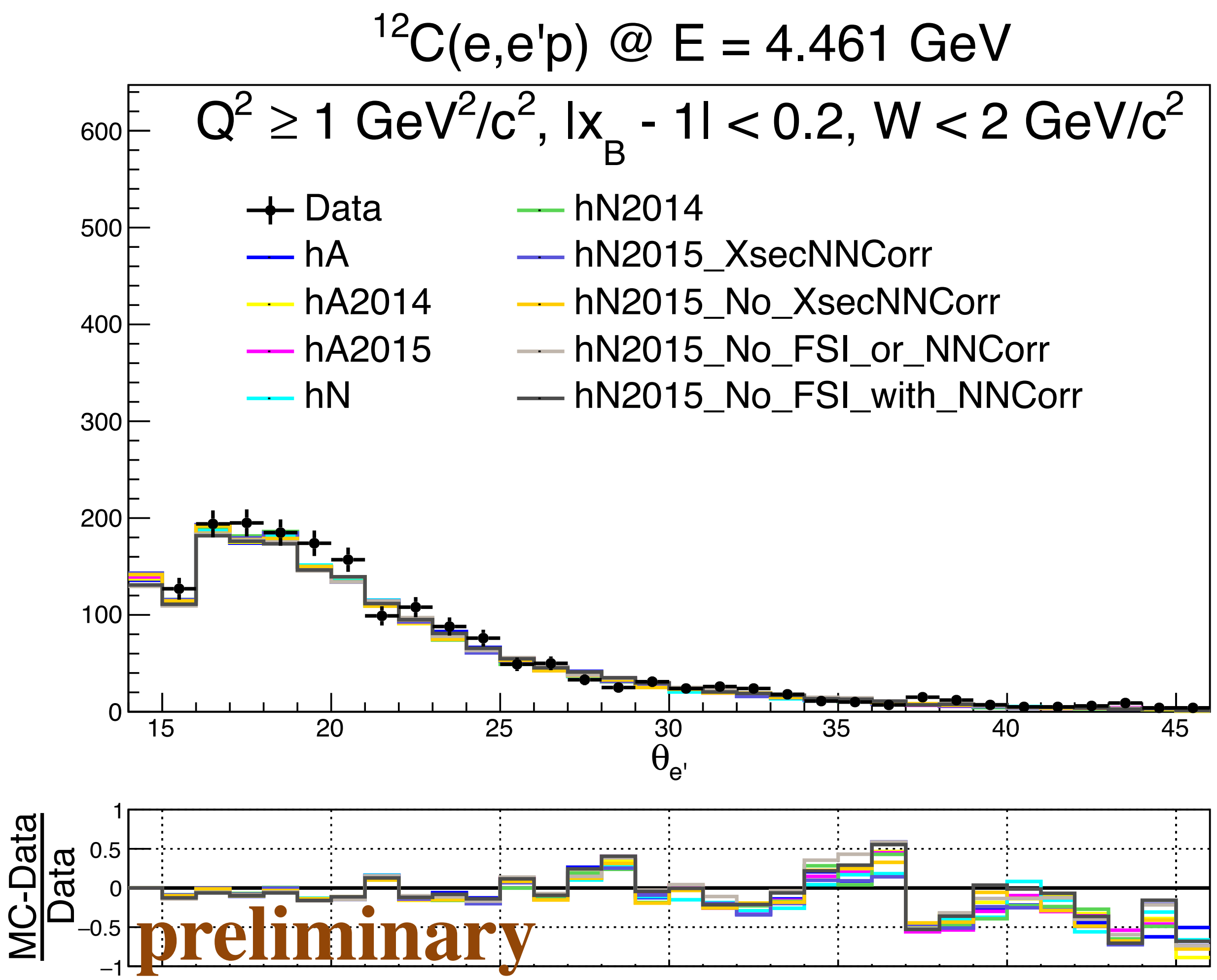
$Q^2 > 0.5$ GeV^2/c^2

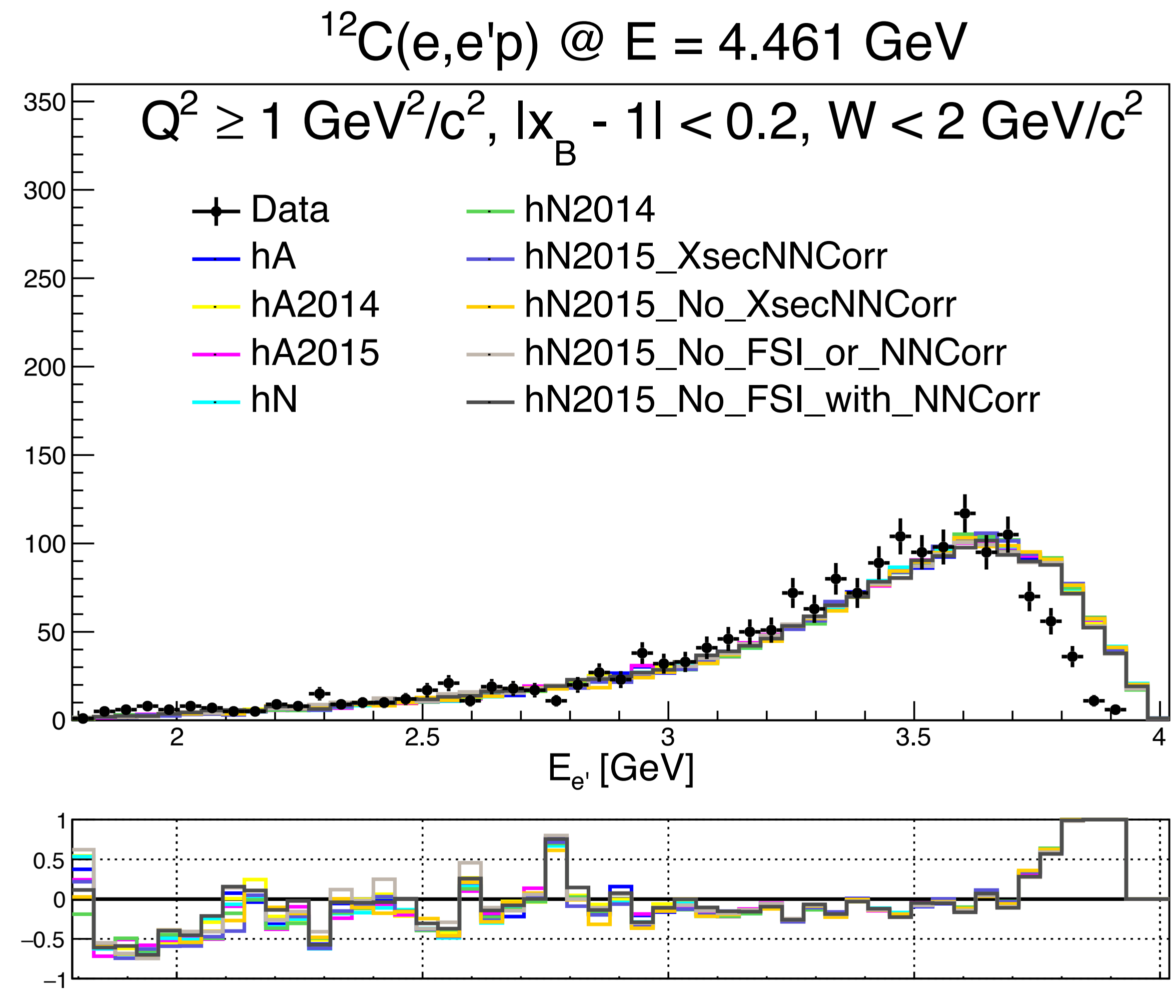
$W < 2$ GeV/c^2

$|X_B - 1| < 0.2$

Data vs. GENIE MC comparison

Electron Kinematic Variables

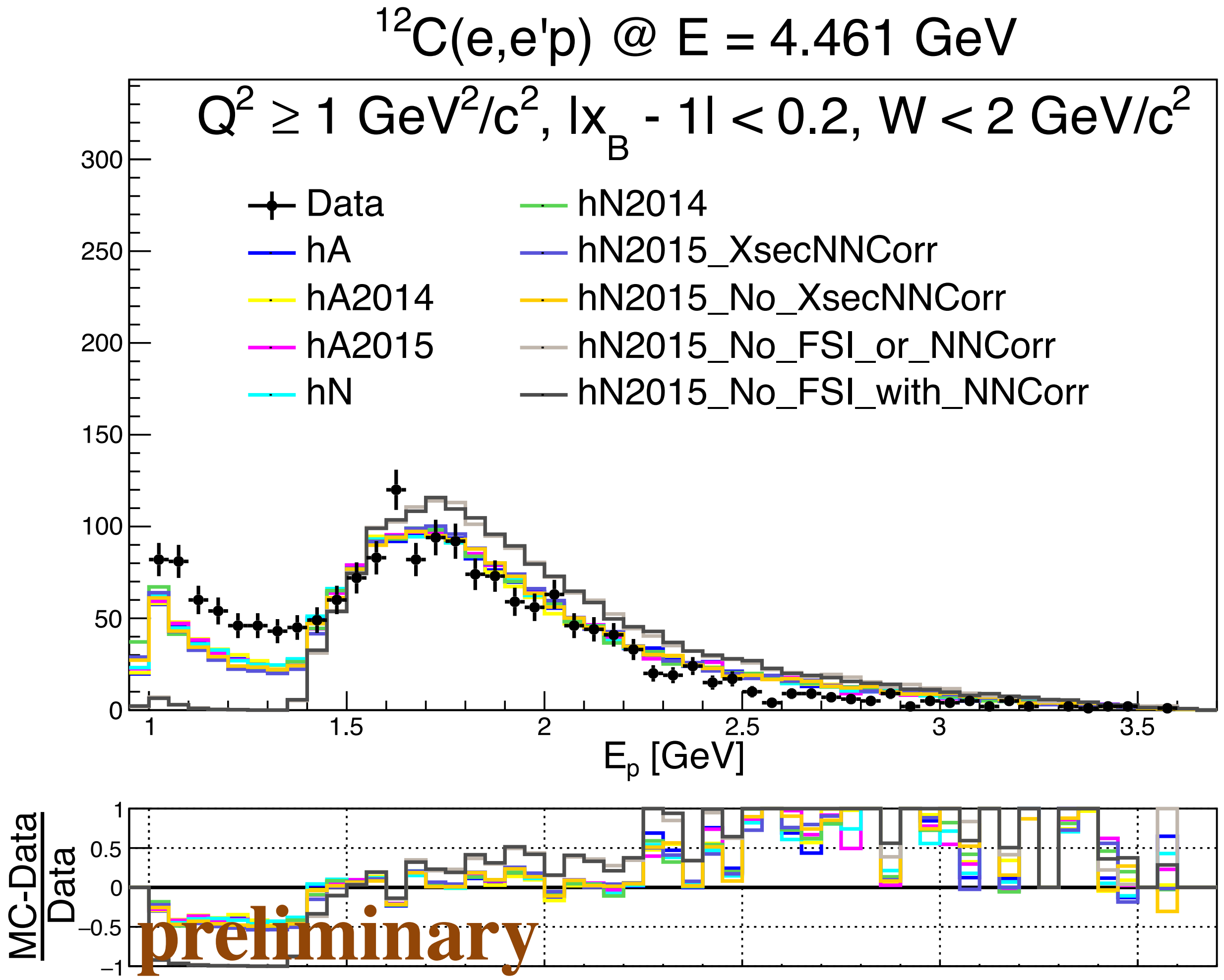


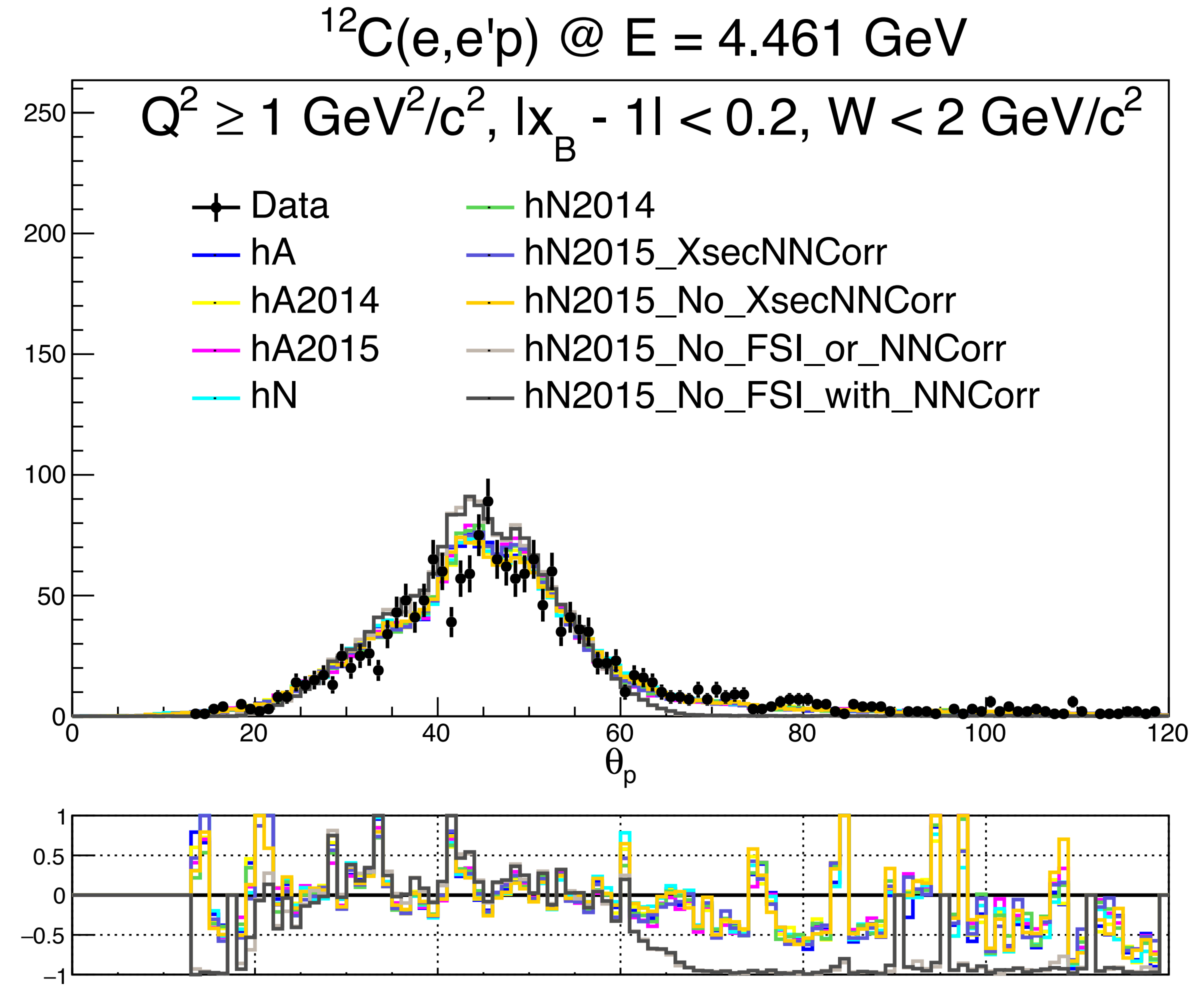


Afroditi Papadopoulou

Data vs. GENIE MC comparison

Electron Kinematic Variables



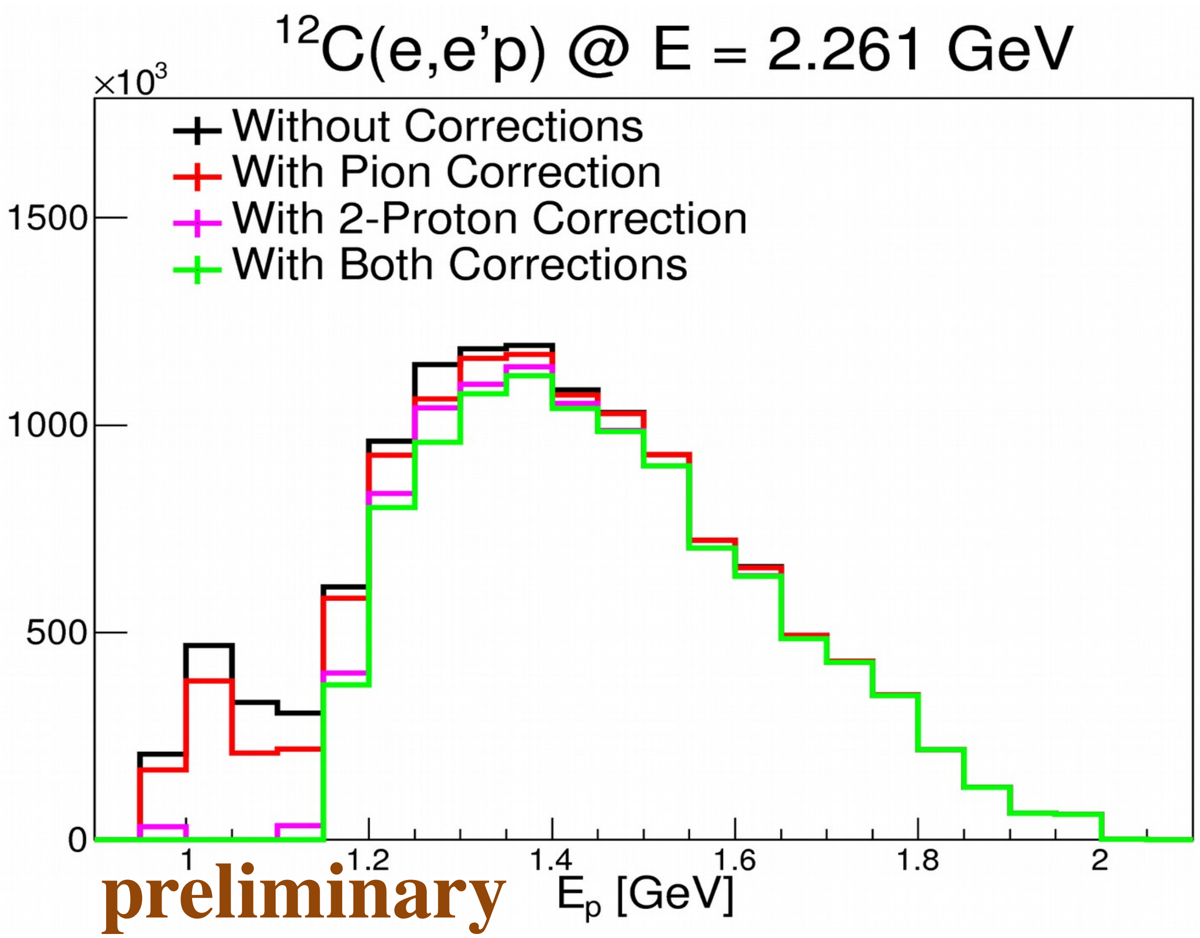


Afroditi Papadopoulou

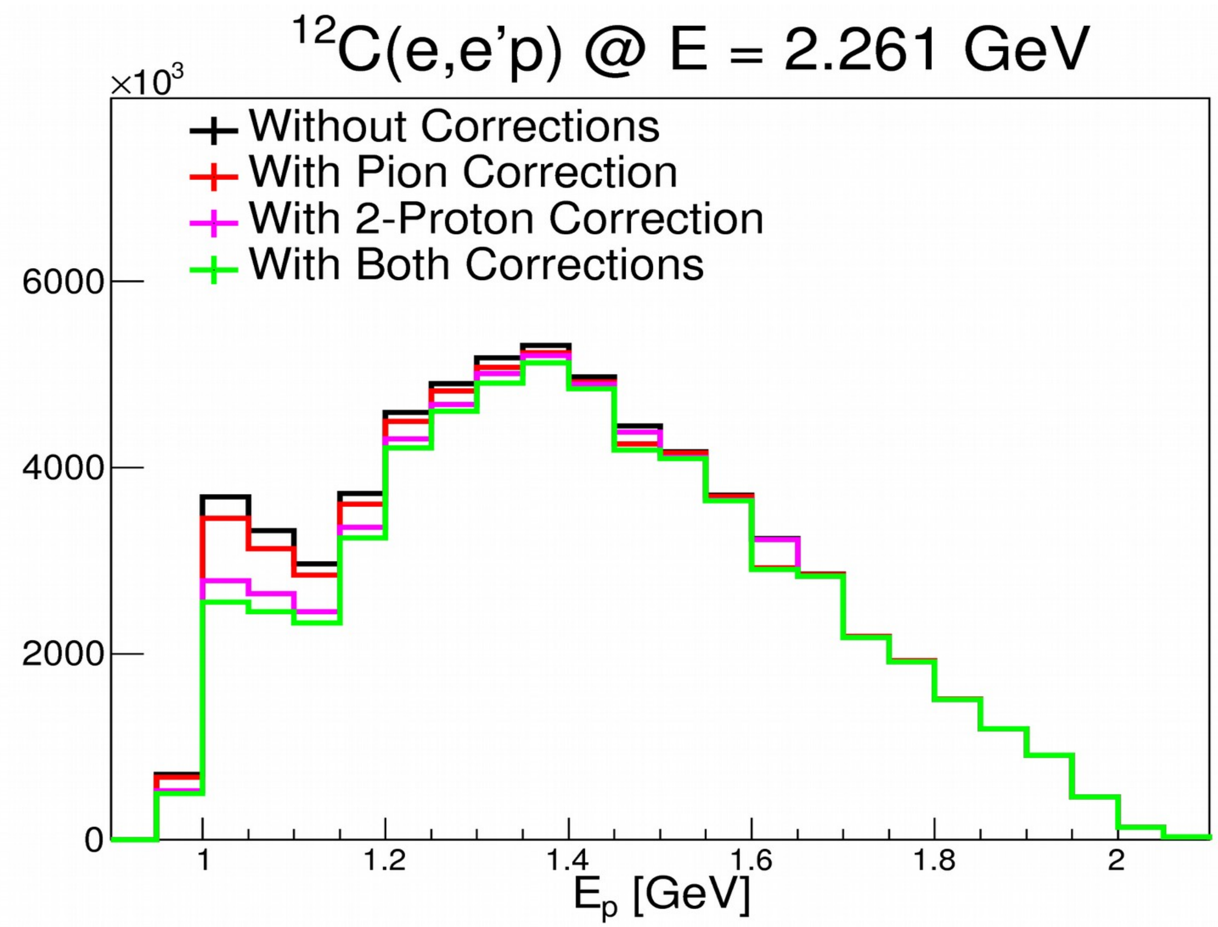
Data vs. GENIE MC comparison

Background subtraction effect

Simulation



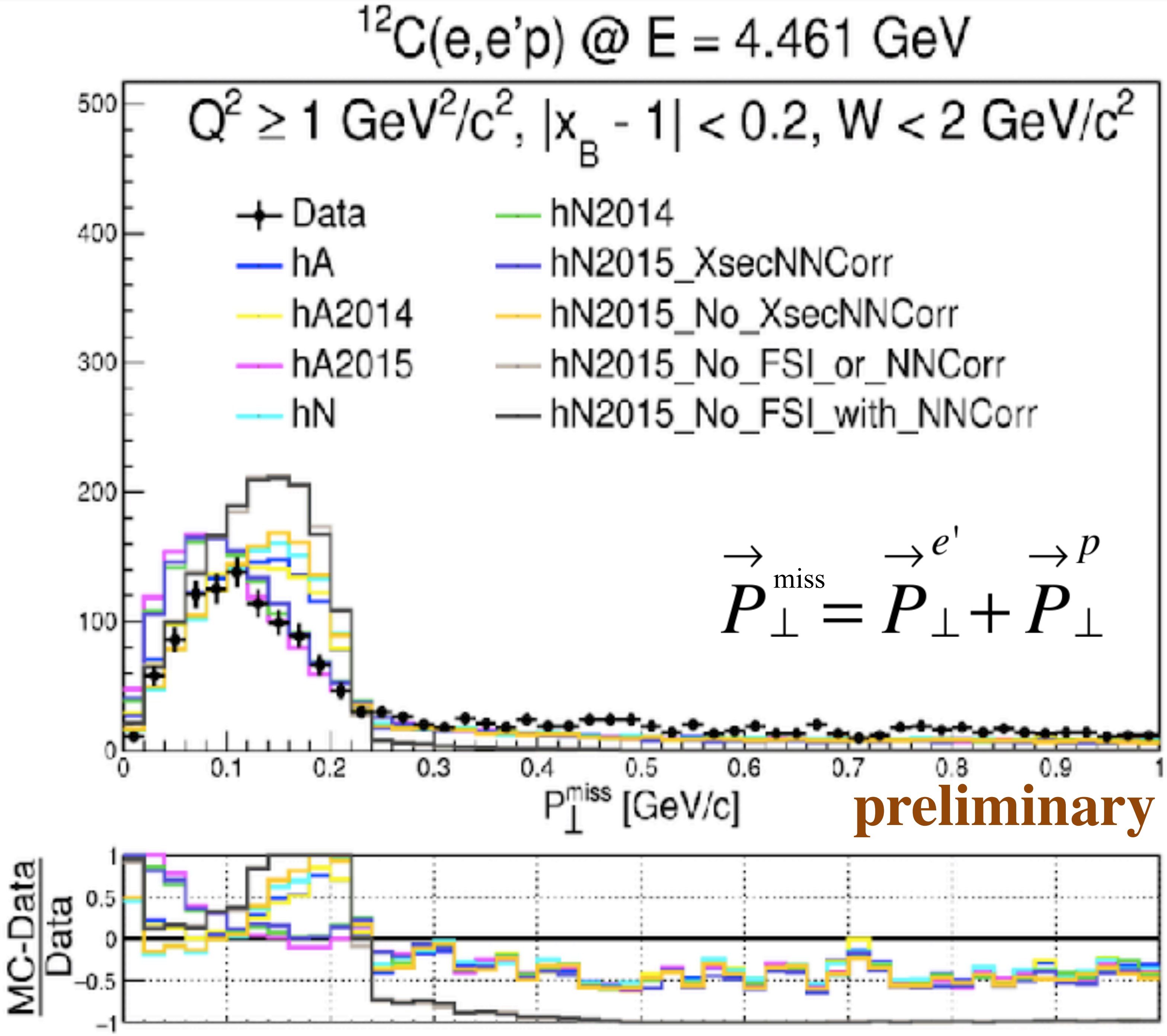
Data



Afroditi Papadopoulou

Data vs. GENIE MC comparison

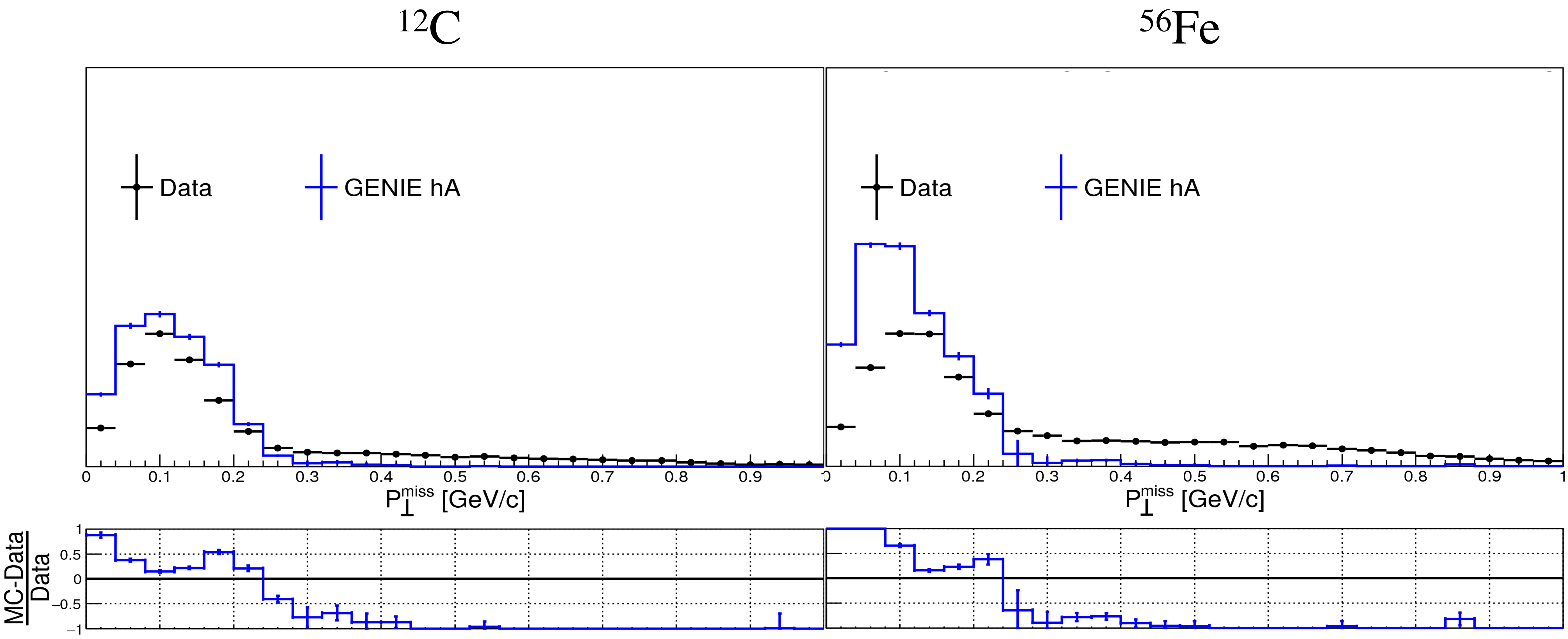
Missing transverse momentum



Afroditi Papadopoulou

Data vs. GENIE MC comparison

Missing transverse momentum C and Fe



preliminary

Afroditi Papadopoulou

Summary

Presenting electron data to test the reconstruction energy method for neutrino experiments.

For QE-like events both leptonic and hadronic have bad resolution

- for heavier nuclei

- for high missing transverse momentum

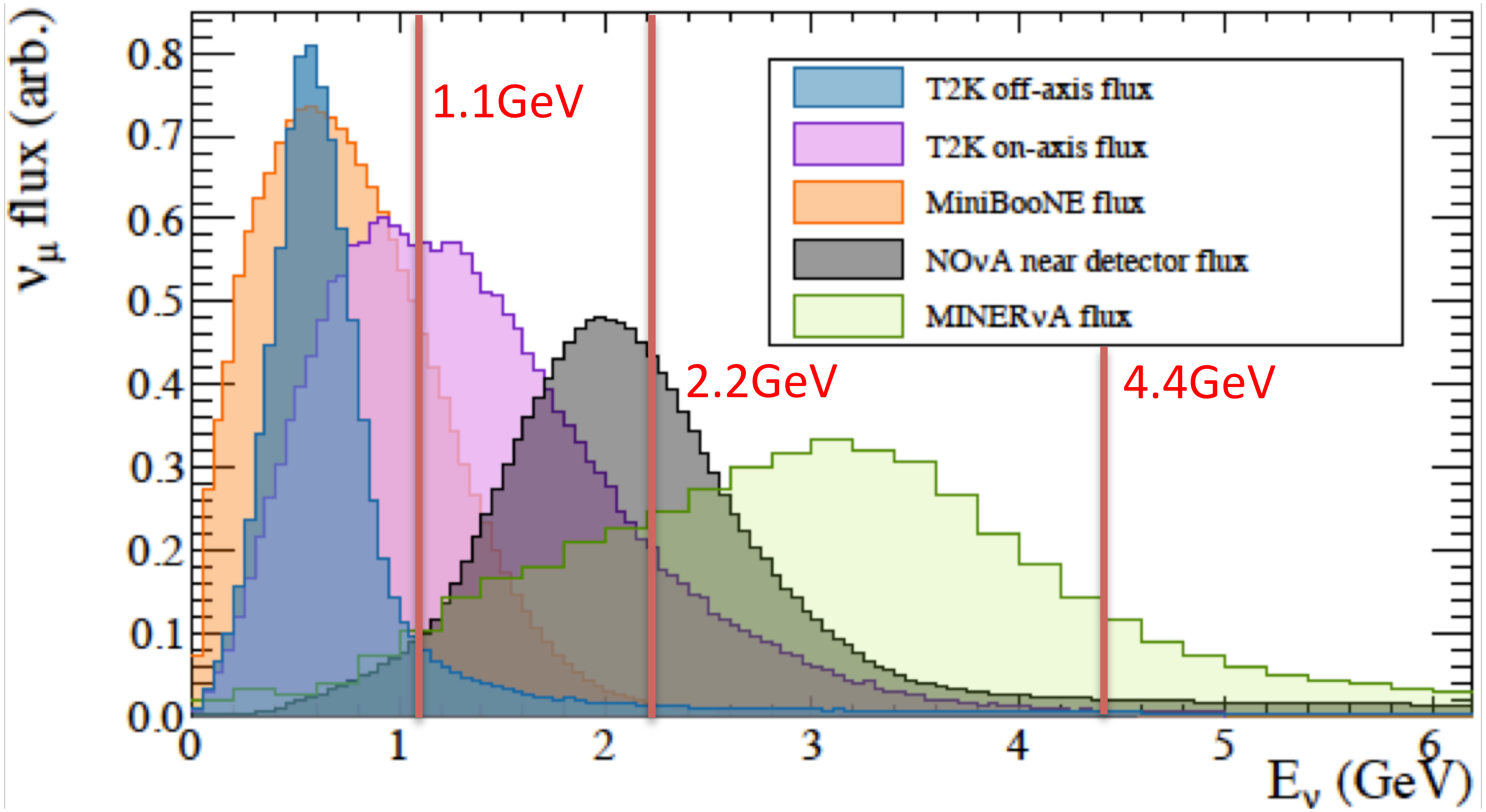
We wish to compare the data to MC to obtain constraints on the nuclei models and show implication on oscillation measurements.

In addition we would like to make this data available for everyone by publishing CLAS acceptance maps.

Summary

Current available data: ^{3}He, ^{4}He, ^{12}C, ^{56}Fe

with incoming 2.2 GeV and 4.4 GeV



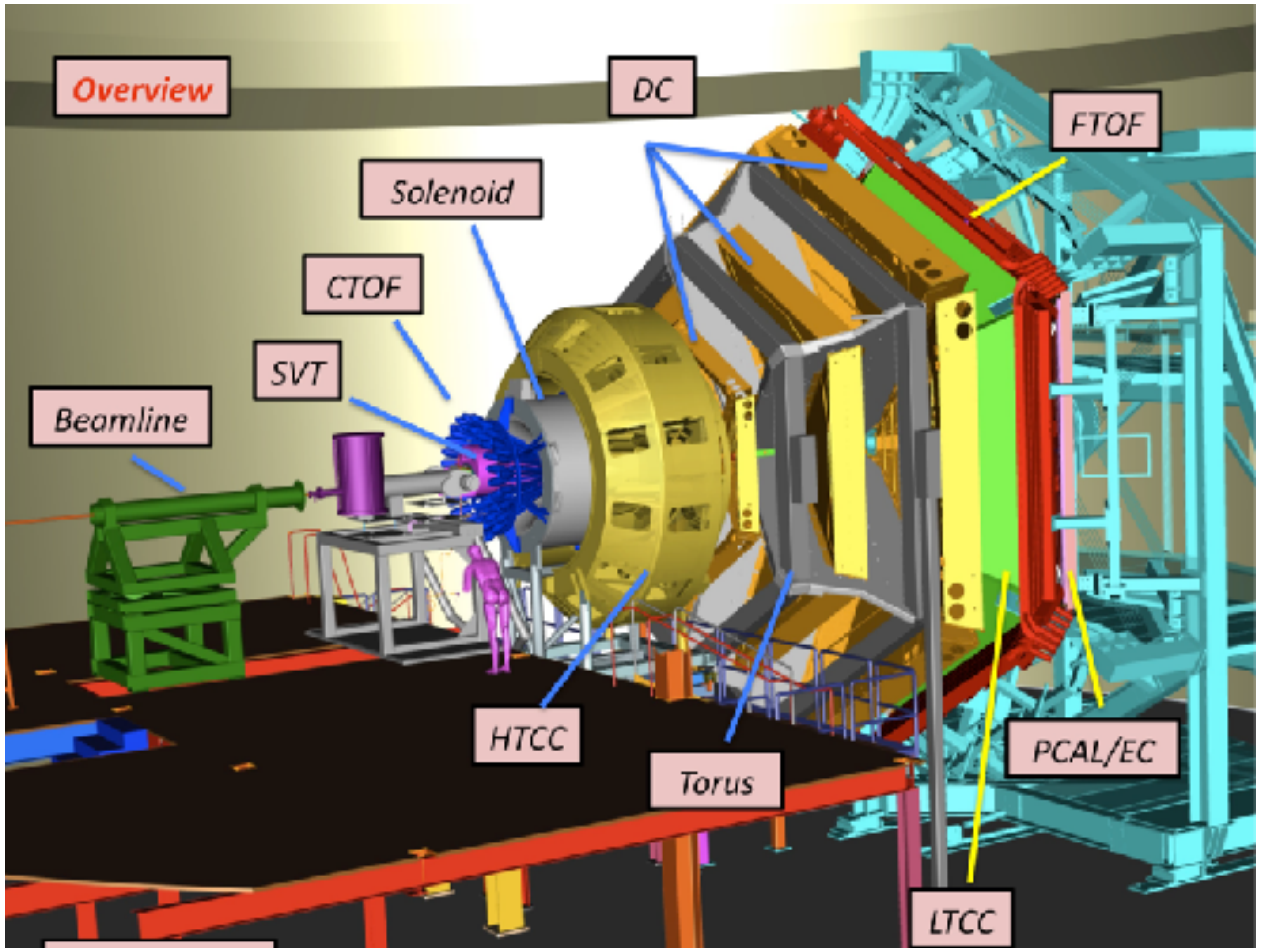
Future Plans

With CLAS12

Ten times more luminosity

Keeping the low threshold

300 MeV/c



Targets: ^{4}He, ^{12}C, ^{16}O, ^{40}Ar, ^{56}Fe

with incoming electron energies 1.1, 2.2, (3.3), 4.4, 6.6 GeV

Thank you for your attention