Updates in Measurement of charged pion production in deep-inelastic scattering off nuclei with CLAS detector

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Outline

- **Introduction**:
  - SIDIS
  - EG2 CLAS experiment
  - Experimental variables
  - DIS kinematics + particle identification scheme

- **EMC effect:**
  - Corrections, CC and RC, results.

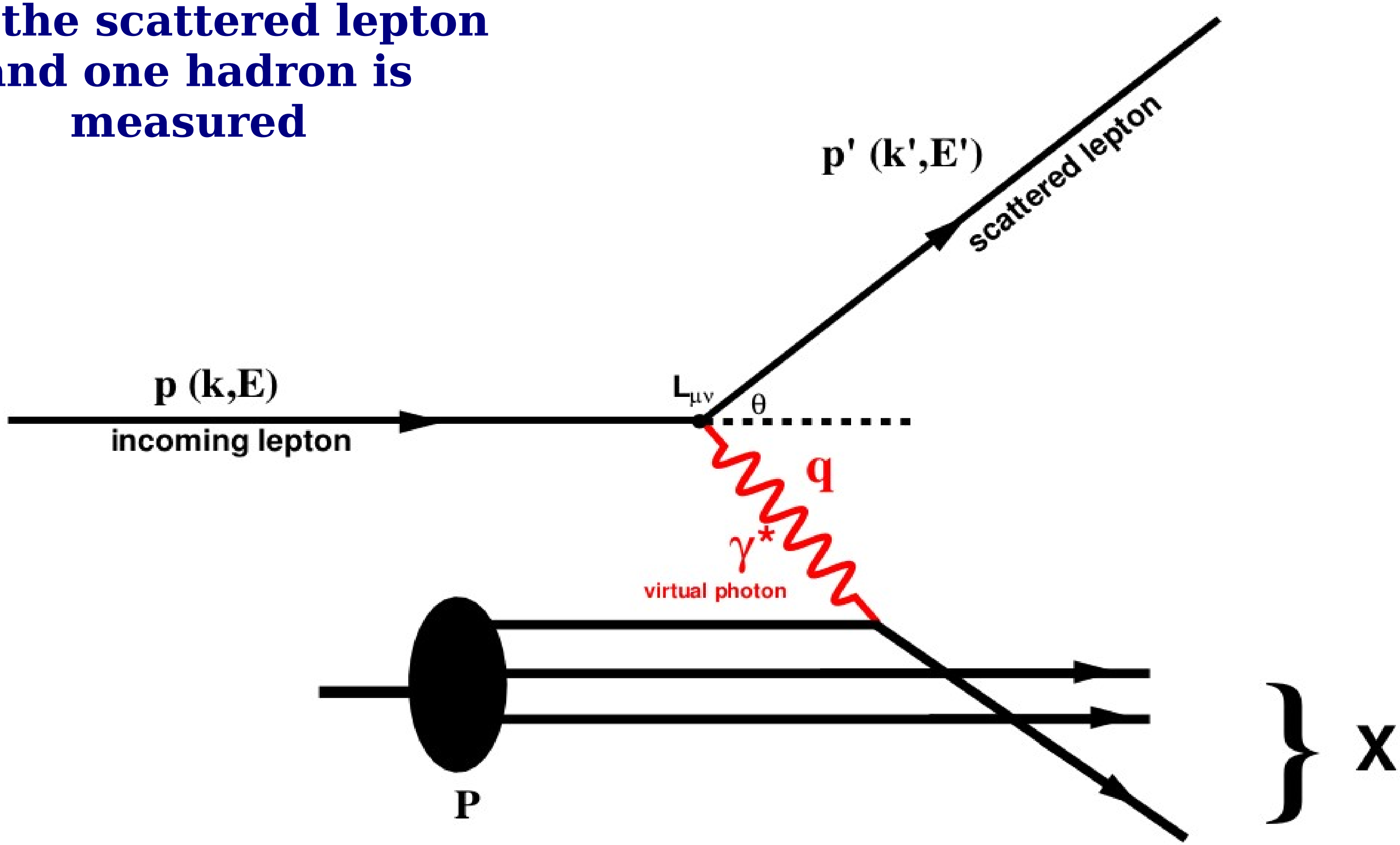
- **Hadronic Multiplicity ratio for charged pions:**
  - Zh dependence
  - Zh dependence in different (ν,Q2) bins
  - Pt2 dependence for different ranges of Zh

- **Conclusions**

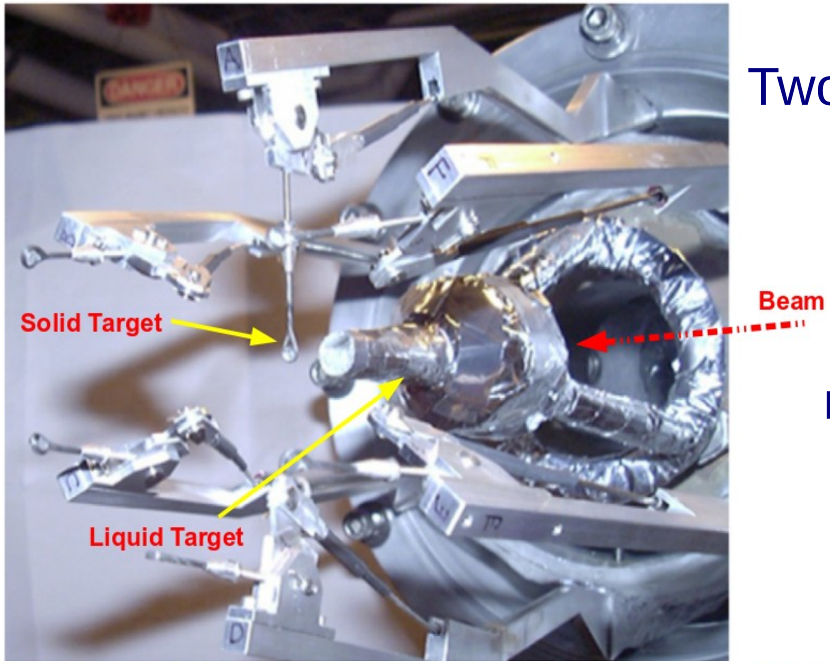
Semi-inclusive Deep Inelastic Scattering (SIDIS) of a lepton off a nucleon

Semi-inclusive means that the scattered lepton and one hadron is measured

$$e + A \rightarrow e' + \pi^{\pm} + X$$



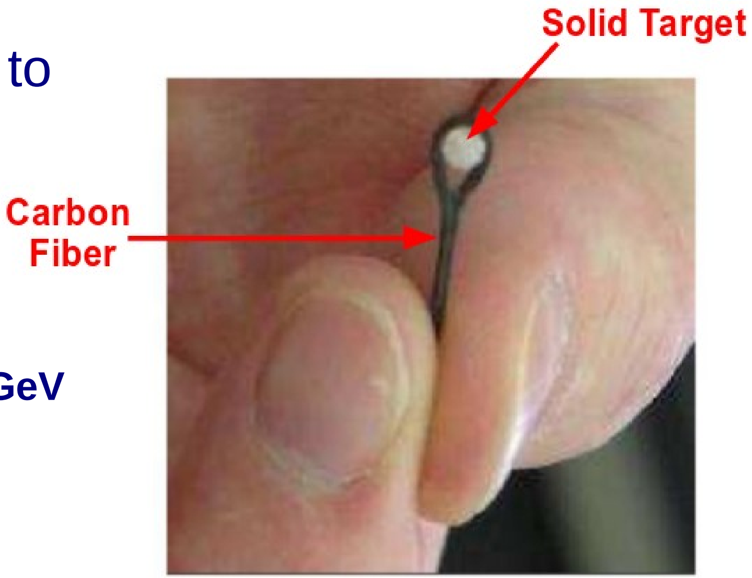
The CLAS EG2 experiment

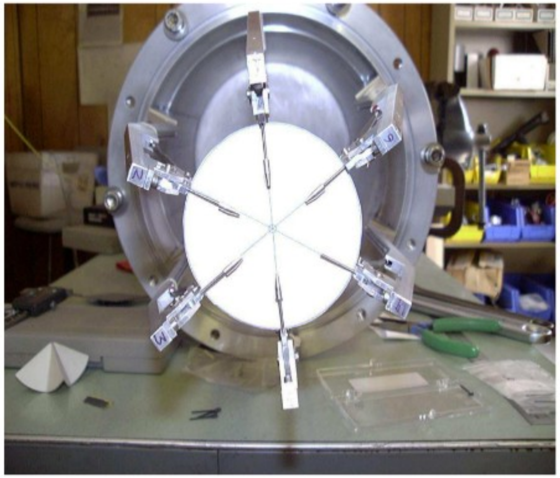


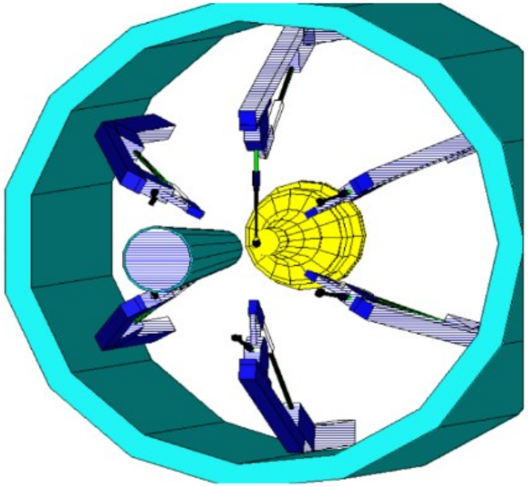
Two targets exposed to the beam **simultaneously**

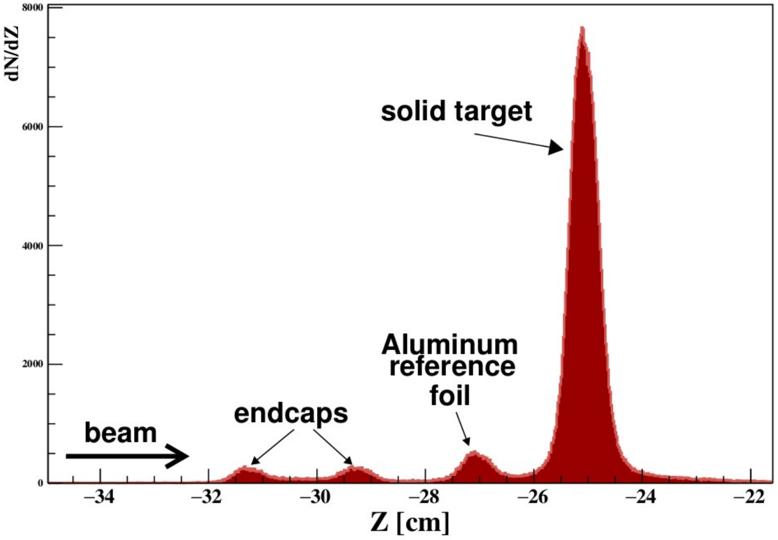
Energy beam = 5.014 GeV

The run Eg2c took place during March 2004

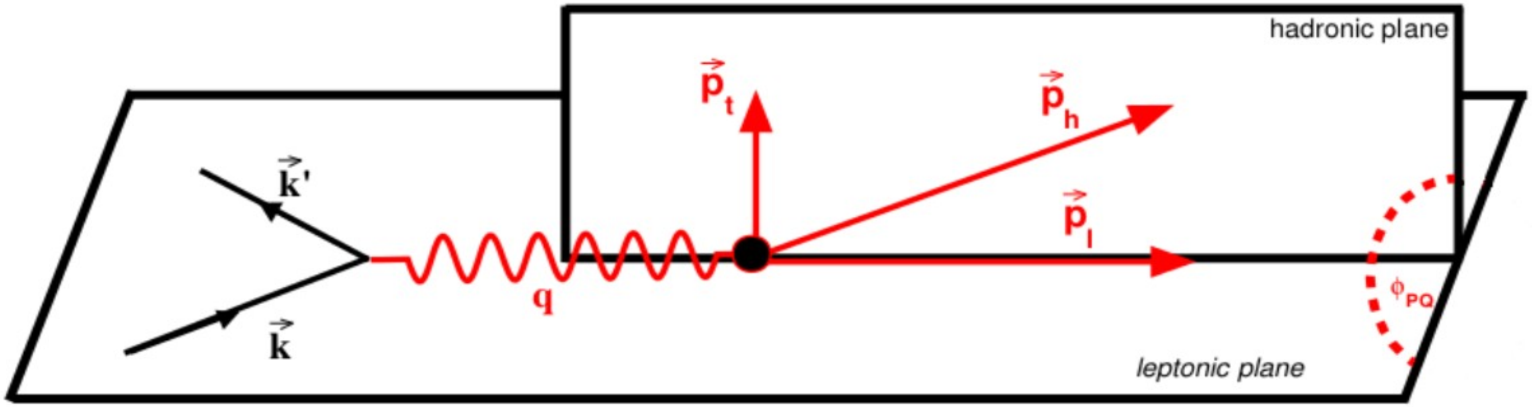








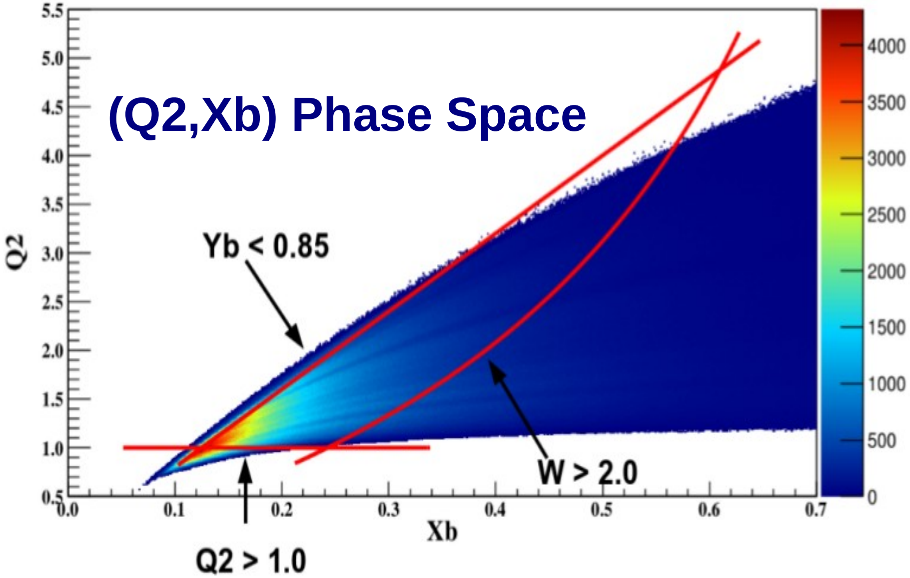
Experimental variables used in the analysis:



- **Q2** = four momentum transferred by the electron [GeV^2].
- **Nu** = energy transferred by the incoming electron [GeV].
- **Zh** = fraction of the initial quark energy carried by the hadron.
- **Pt2** = hadron transverse momentum, w.r.t. virtual photon [GeV^2].
- **PhiPQ** = angle between leptonic and hadronic production planes (deg).
- **Xb** = proton momentum fraction carried by the struck quark.
- **Ebeam** = 5.014 [GeV].

DIS kinematics

- **Q2 > 1.0** [GeV²], range of virtualities to resolve the parton.
- **W > 2.0** [GeV] to avoid resonance region
- **Yb < 0.85** to avoid regions with large radiative corrections

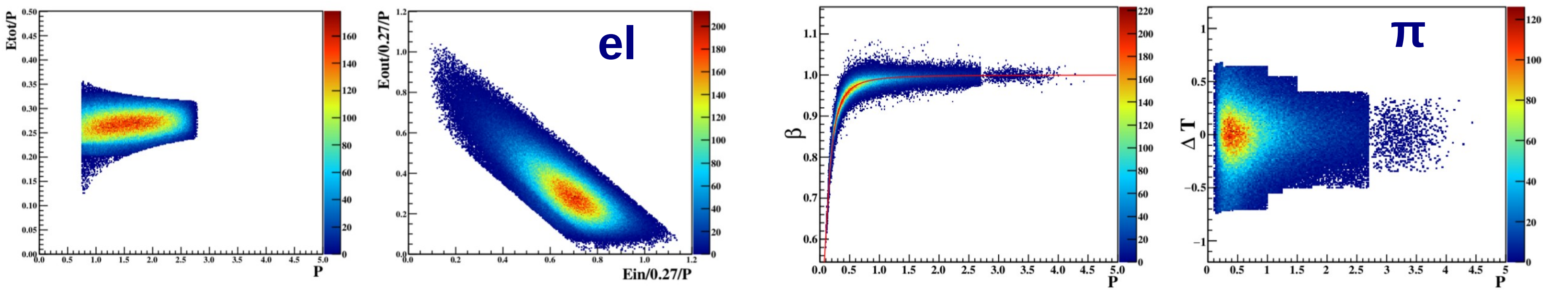


Particle Identification scheme

Main features :

- **All cuts implemented are sector dependent.**
- **TOF+CC based cuts to select pions**
- **Separate treatment for the simulation set (tuned cuts when it's appropriate).**

Some final distributions



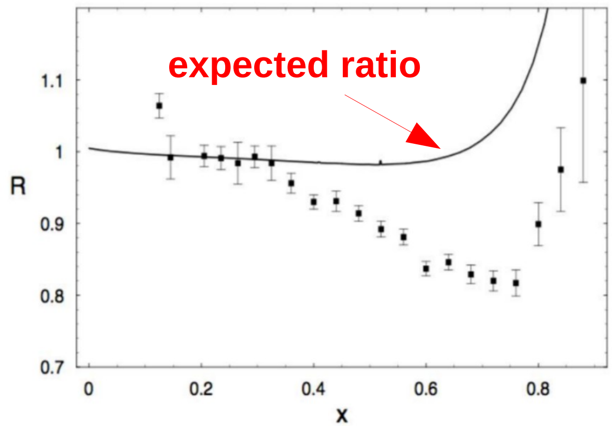
- **EMC ratio**

"Protons and neutrons act differently when they're inside an atom, versus floating freely through space"

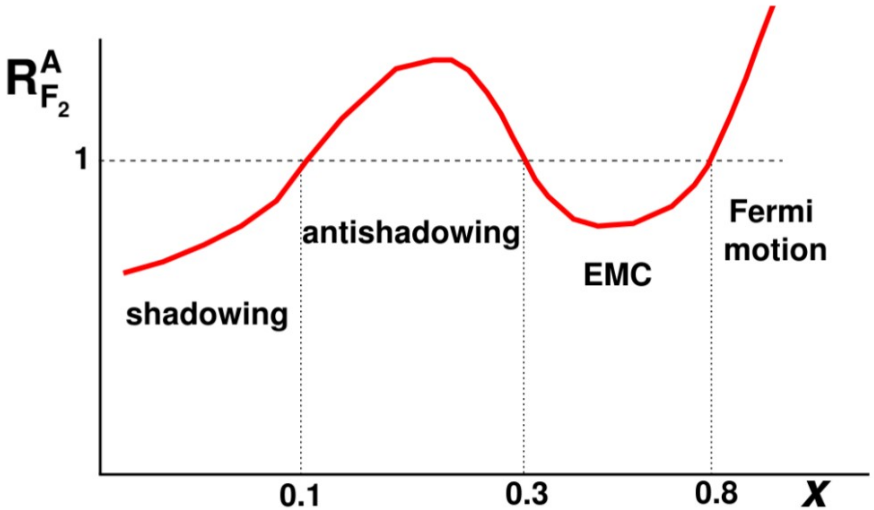
$$\mathrm{EMC} \equiv \frac{\left(\mathrm{N}_{el^-}^{\mathrm{DIS}}\right)_A}{\left(\mathrm{N}_{el^-}^{\mathrm{DIS}}\right)_D}$$

This ratio must be normalized by a factor related to the target thickness.

DIS cross section ratio of gold relative to deuterium as a function of Xb, from SLAC



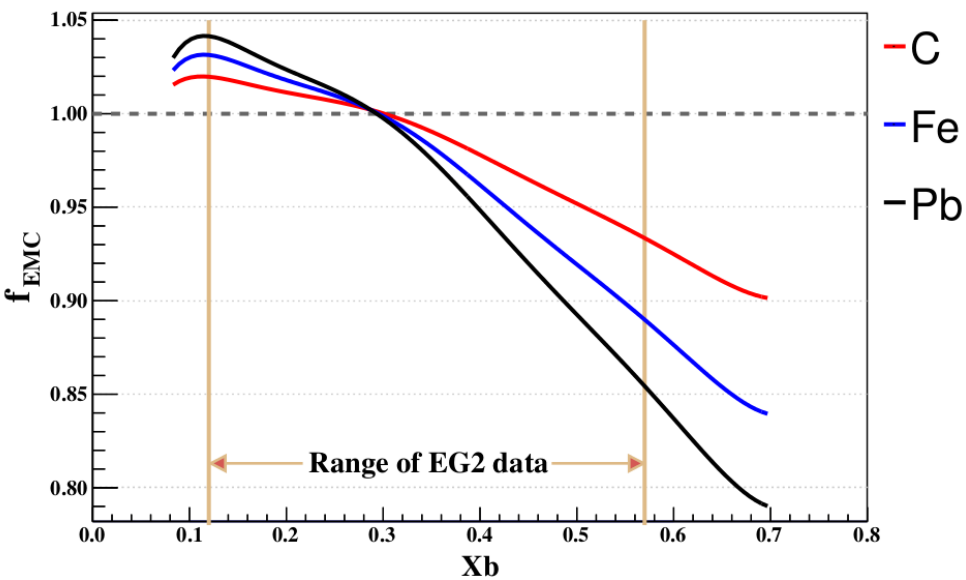
Nuclear ratio as a function of Xb



$$R^A_{F_2}(x,Q^2) = \left(\frac{F_2^A(x,Q^2)/A}{F_2^{nucleon}(x,Q^2)}\right)$$

fixed Q2

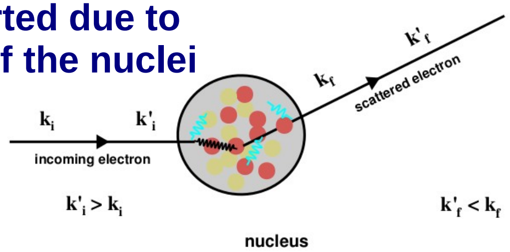
Empirical fit function



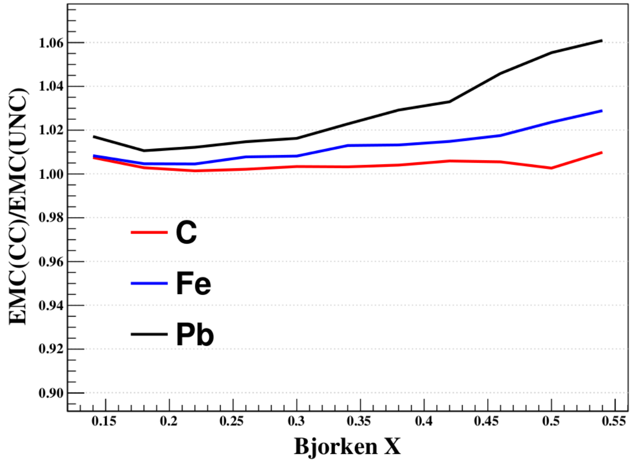
Based on world data

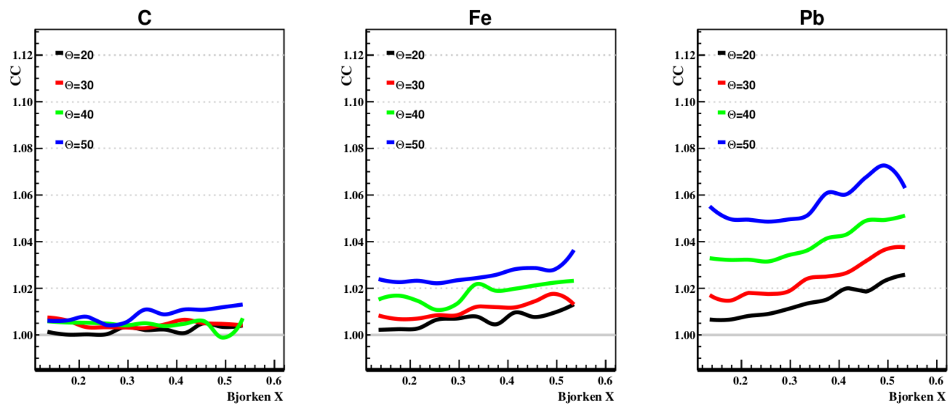
Coulomb Corrections (CC)

The electron's wave function is distorted due to the effect of the electrostatic field V of the nuclei



CC is a ratio of the cross section model with experimental kinematics to the cross section model with shifted kinematics multiplied by a focusing factor

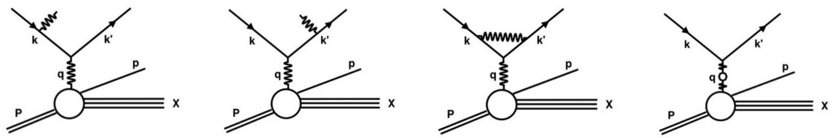


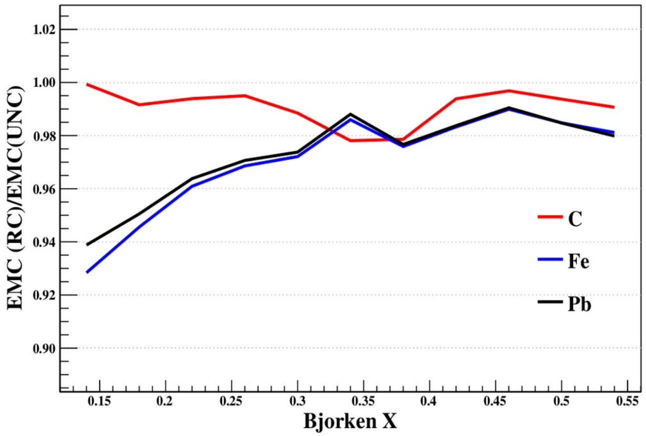


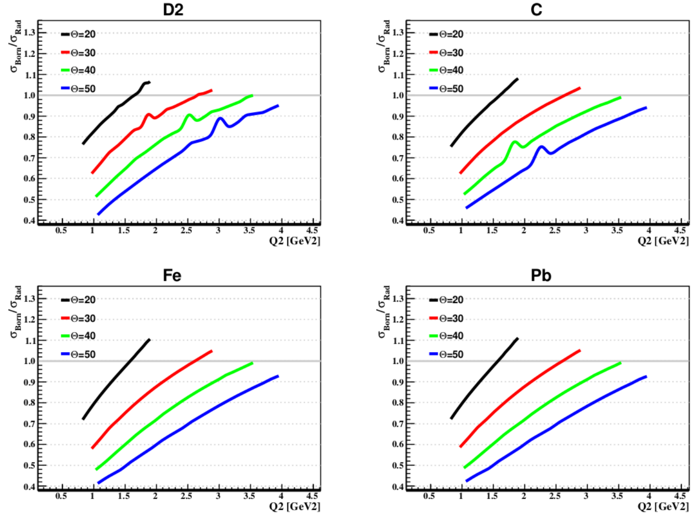
At our energies CCs are relevant

Radiative Corrections (RC)

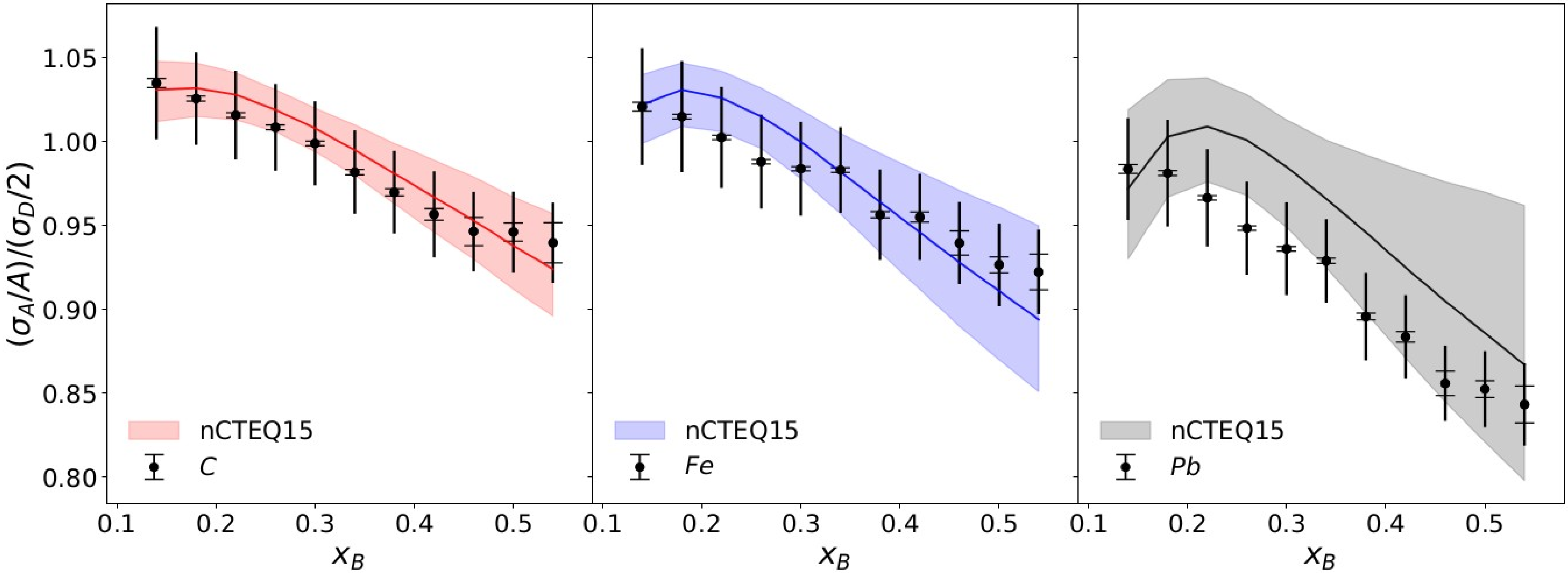
Higher order internal radiative corrections







EMC ratio for carbon, iron and lead targets



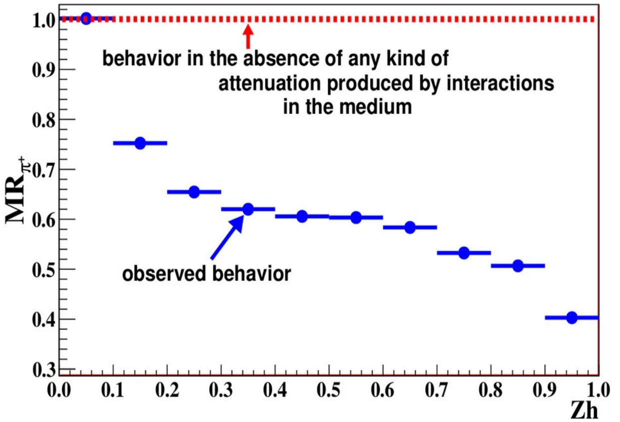
Inner error bars represents statistical uncertainties only.
Outer error bars represent systematic uncertainties.
Shaded bands represent the 68% confidence interval from nCTEQ15 PDF.

No 'isoscalar' corrections applied

Hadronic Multiplicity ratio (Rh)

Double ratio

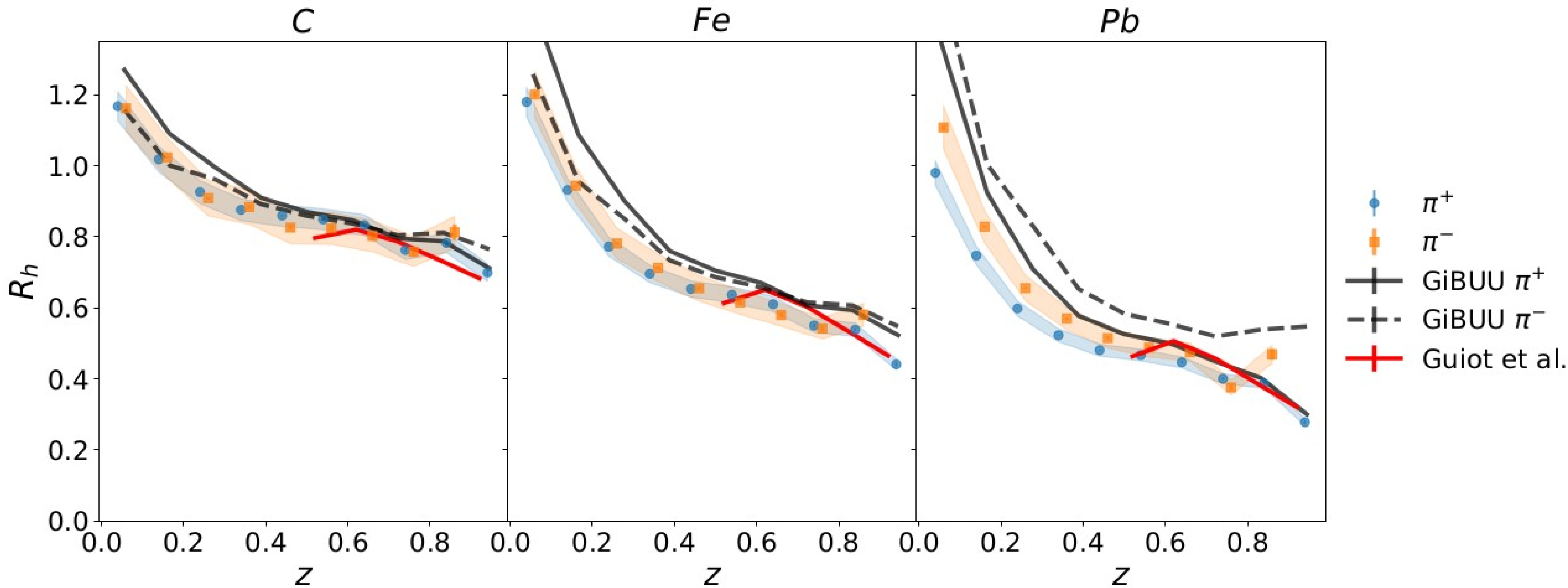
$$R_h(z, p_T^2, \nu, Q^2) = \frac{N_h^A(z, p_T^2, \nu, Q^2)/N_e^A(\nu, Q^2)}{N_h^D(z, p_T^2, \nu, Q^2)/N_e^D(\nu, Q^2)}$$



Multidimensional Rh for charged pions

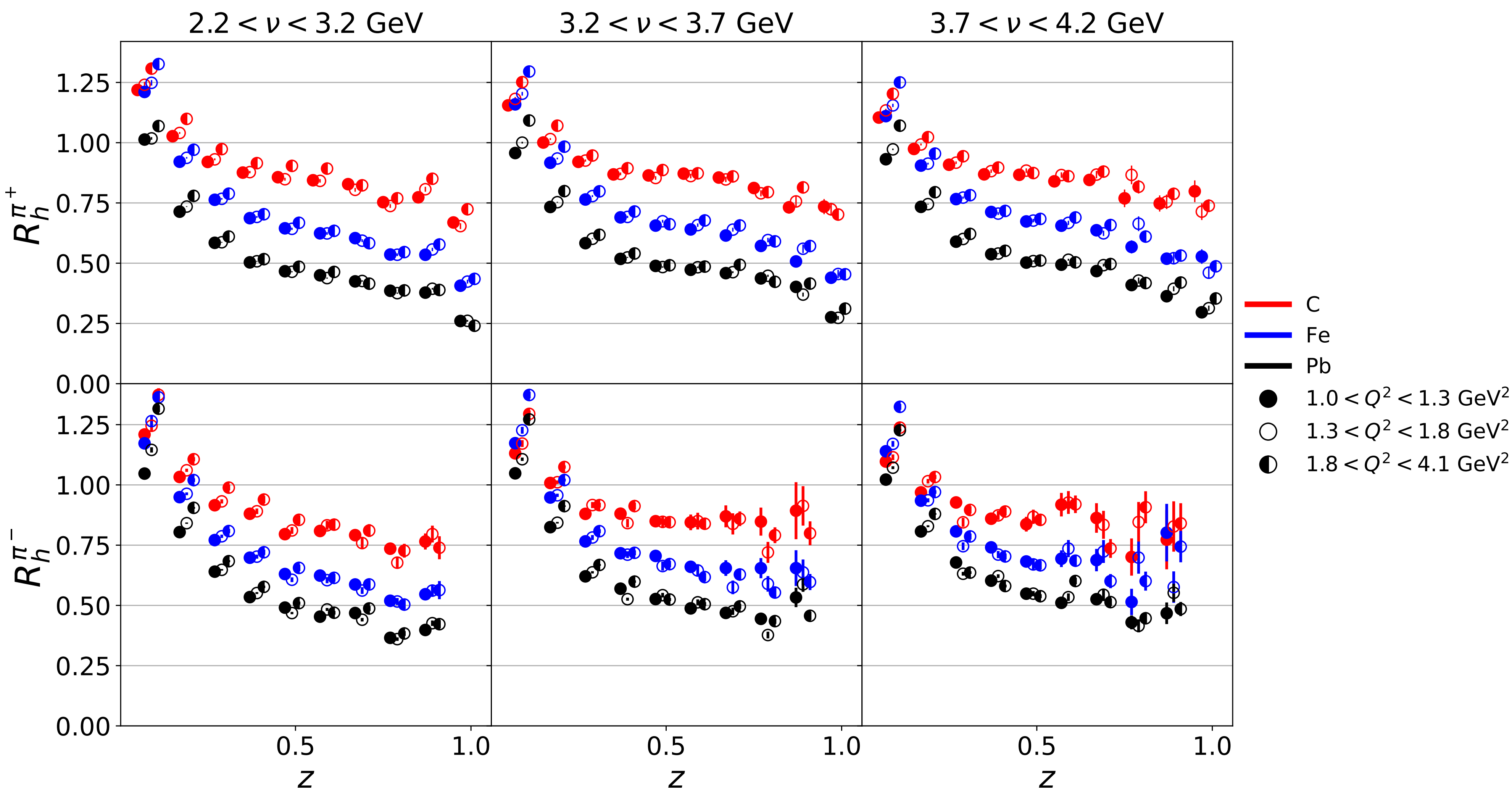
- Integrated Rh as a function of Zh.
- 3D Rh as a function of Zh for different bins in ν and Q2.
- 2D Rh as a function of Pt2, for different bins in Zh ('Cronin Effect').

Multiplicity ratio for carbon, iron and lead as a function of Zh for π^+ and π^-



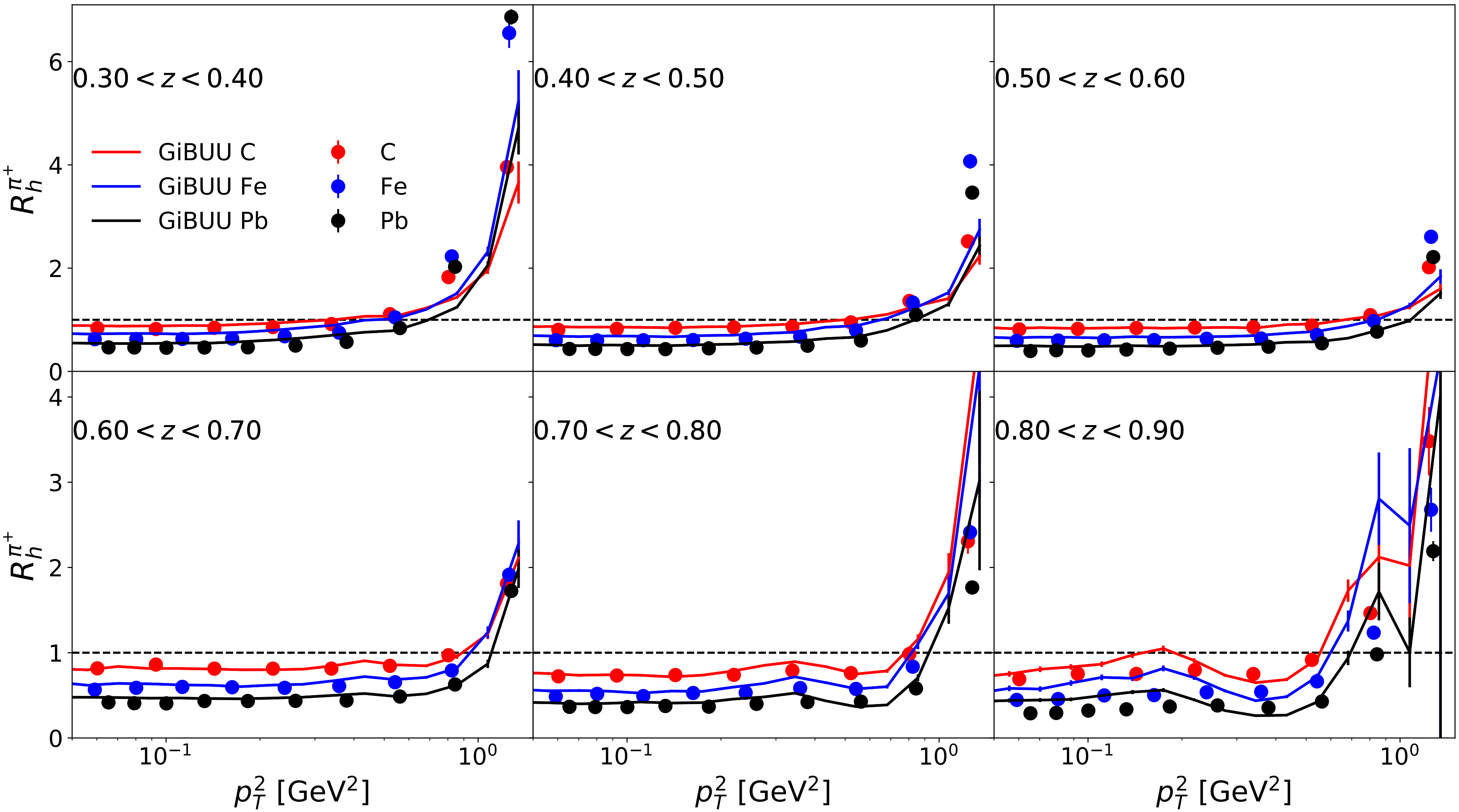
Error bars represents statistical uncertainties only (typically smaller than the marker size).
The bands represent systematic uncertainties (largely correlated bin to bin).
Lines correspond to model calculations from GIBUU and Guiot et al.

Multiplicity ratio for C, Fe and Pb as a function of Zh for π⁺ and π⁻ and for different intervals of ν and Q2

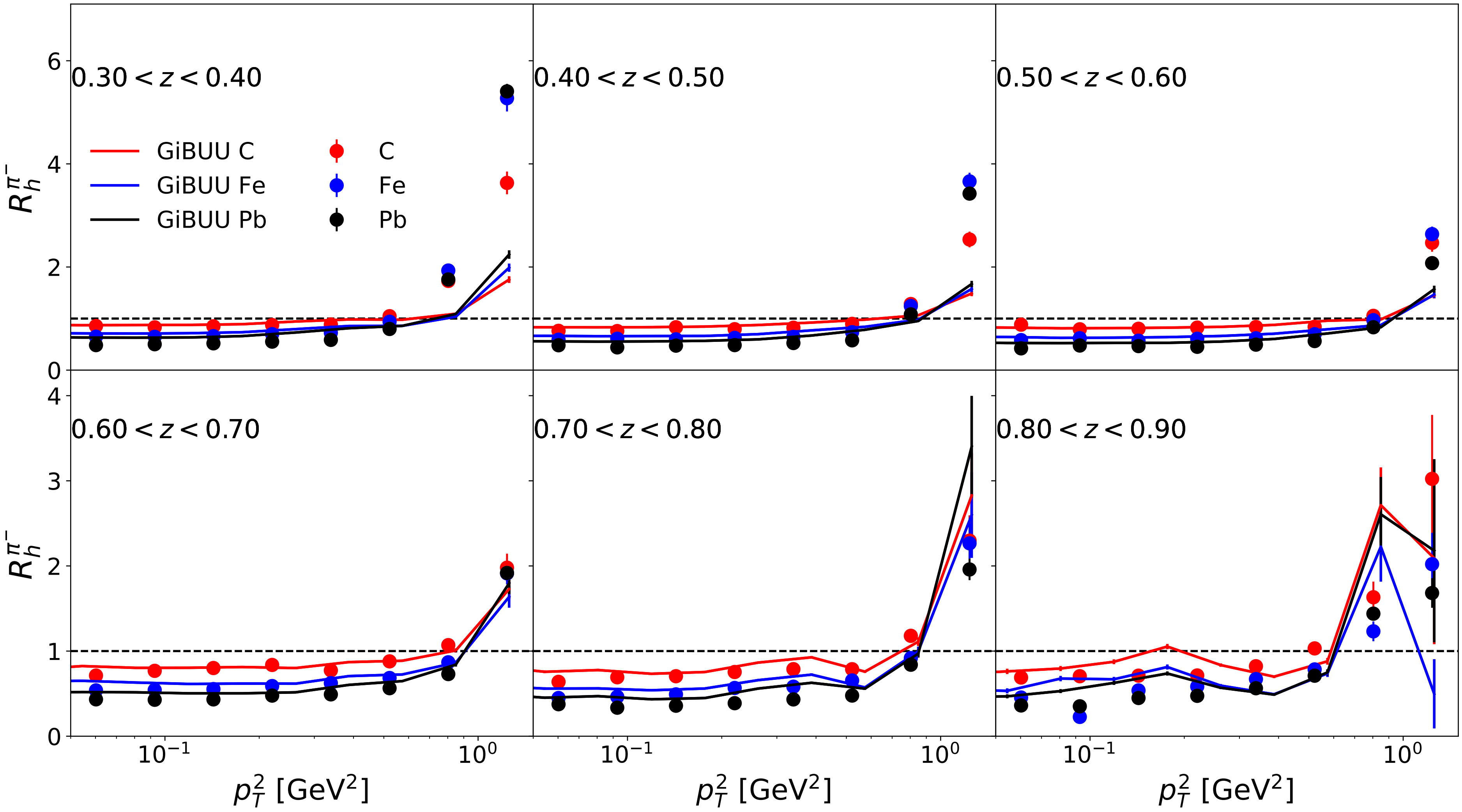


Error bars represents statistical uncertainties only.
Small horizontal shift for visual purpose.

Multiplicity ratio for C, Fe and Pb as a function of Pt2 for π^+ and for different intervals of Zh



Multiplicity ratio for C, Fe and Pb as a function of Pt2 for π^- and for different intervals of Zh



Conclusions

- The measured EMC ratios are consistent within uncertainties with a previous CLAS measurement that used a slightly different electron-selection methods and world data, as encoded in recent re-weighted versions of the CTEQ nuclear parton density functions nCTEQ15.

- The results on π^+ and π^- have similar qualitative features. The precision of the data reveal small but significant differences between the two, which are at the level of 10% for the Pb target data. This difference between π^+ and π^- can be attributed to the large neutron proton asymmetry, and is consistent with the expectations from the GiBUU model.

- The data for π^+ and π^- show the same qualitative features for the multiplicity ratio as a function of Pt2 and are consistent within 10% over most of the kinematic range.

- **Next steps:** Add π^0 (Taisiya Mineeva's work) in the comparison.
  Work on proper documentation of the analysis for a review.

Thanks!

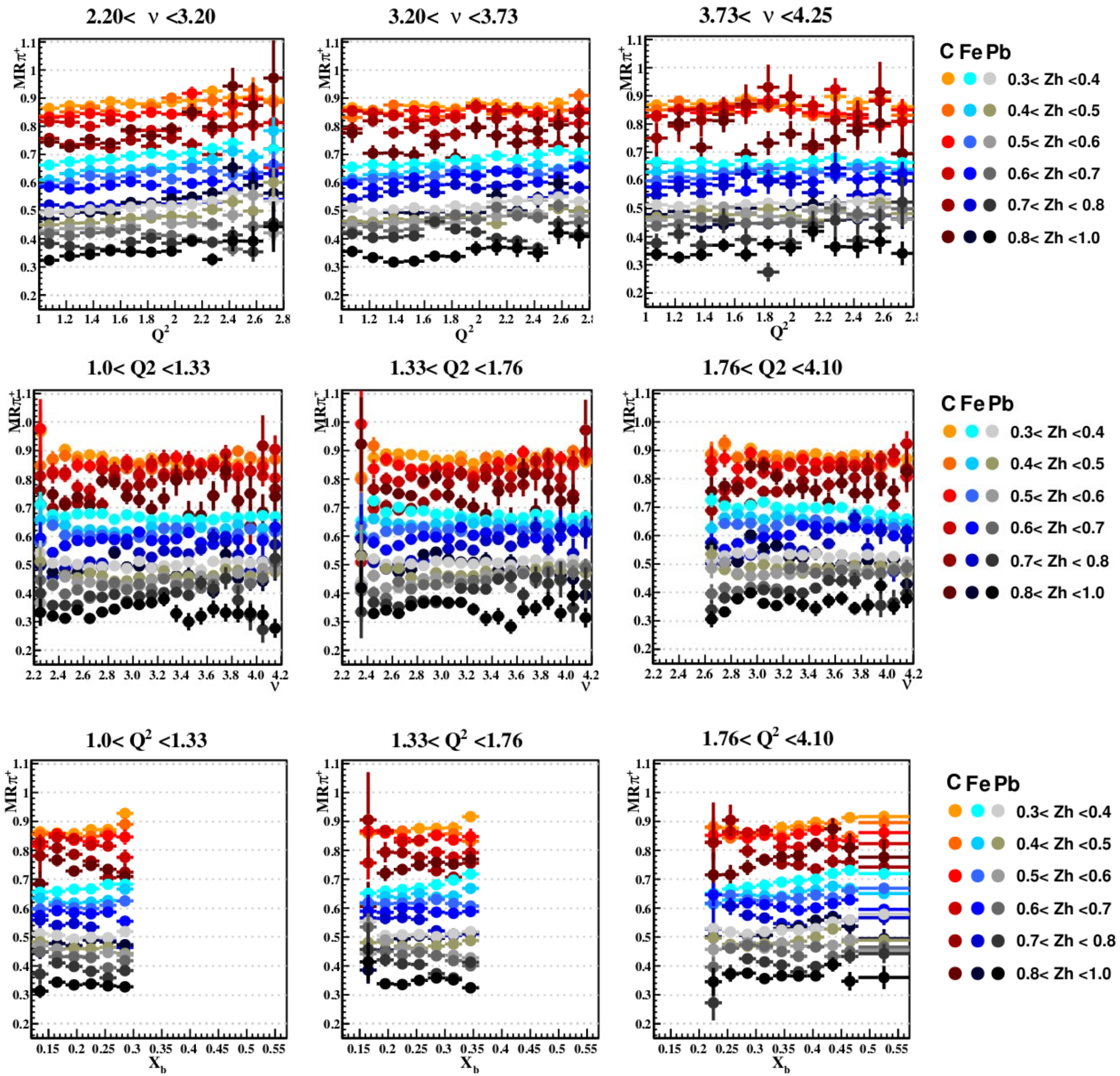
Backup Slides

π^+ 3D Multiplicity Ratios dependence on Q2, ν and Xb

Q2 dependence for different (ν,Zh) bins

ν dependence for different (Q2,Zh) bins

Xb dependence for different (Q2,Zh) bins



*Acceptance corrected applied. Only statistical errors are shown

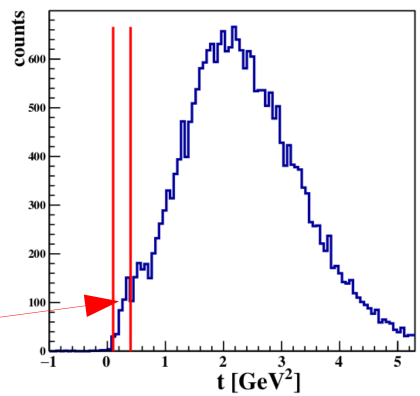
Probing multidimensionality

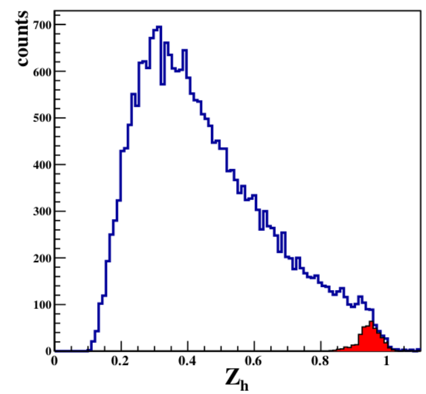
One of the key points of EG2 data

The highest statistic information is for π^+ → **Multidimensional studies, in principle up to 4-fold differential**

Some considerations to take into account:

Diffractive Processes

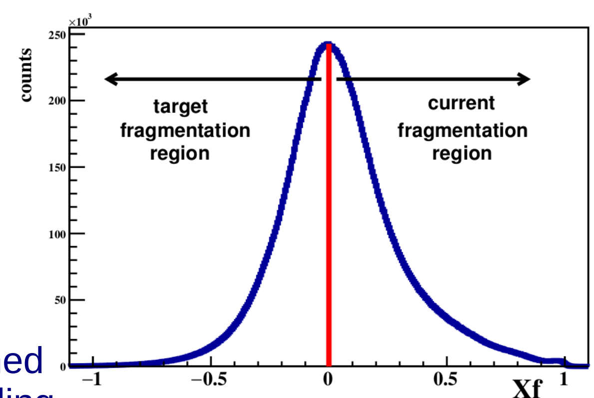


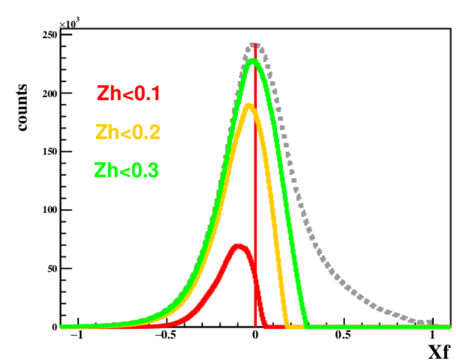


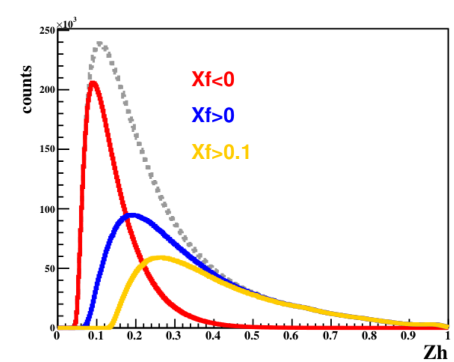
Contamination at high Zh

Diffractive region based on t variable. ($t = (q-P_h)^2$)

Target fragmentation contribution



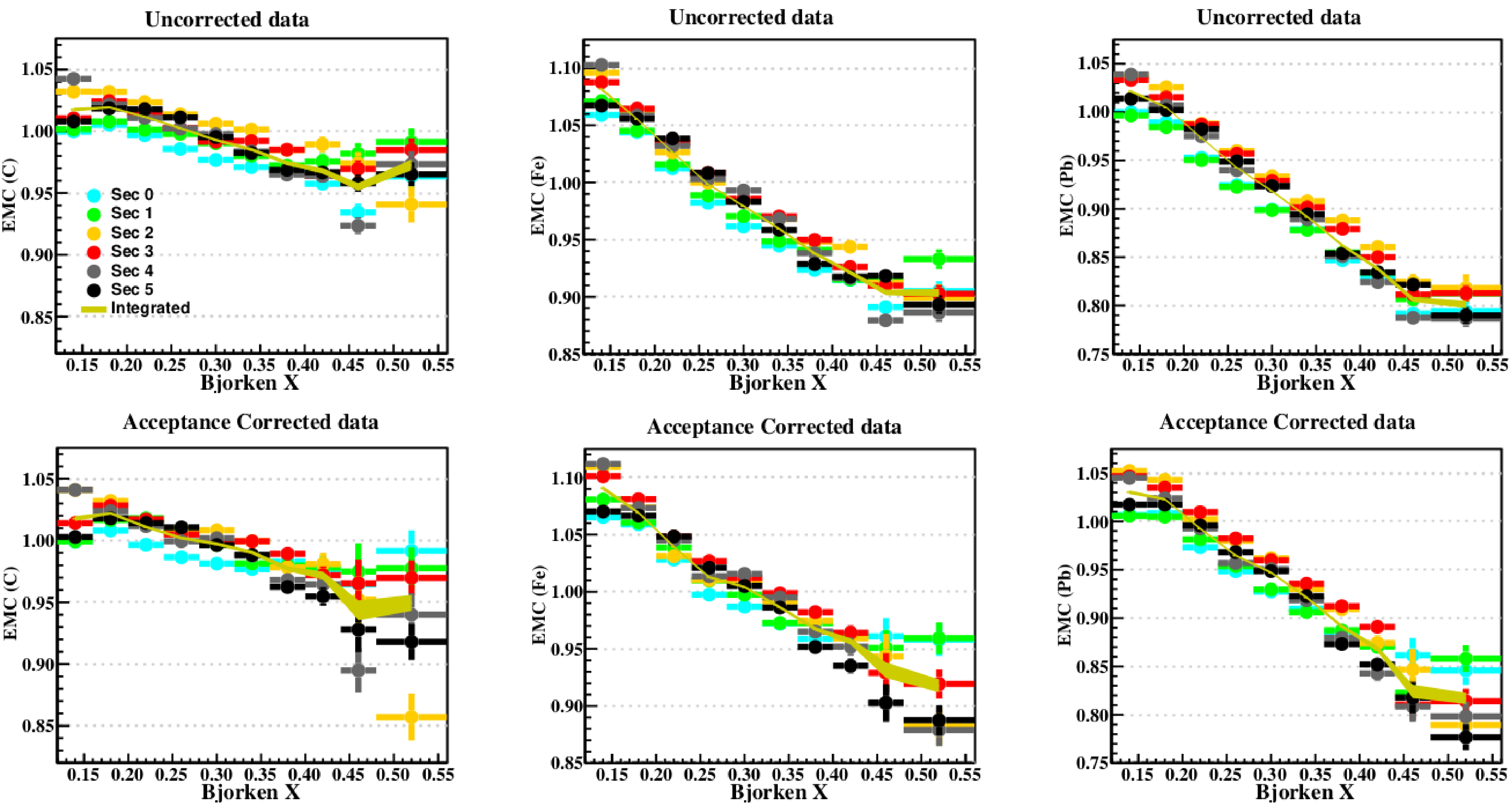




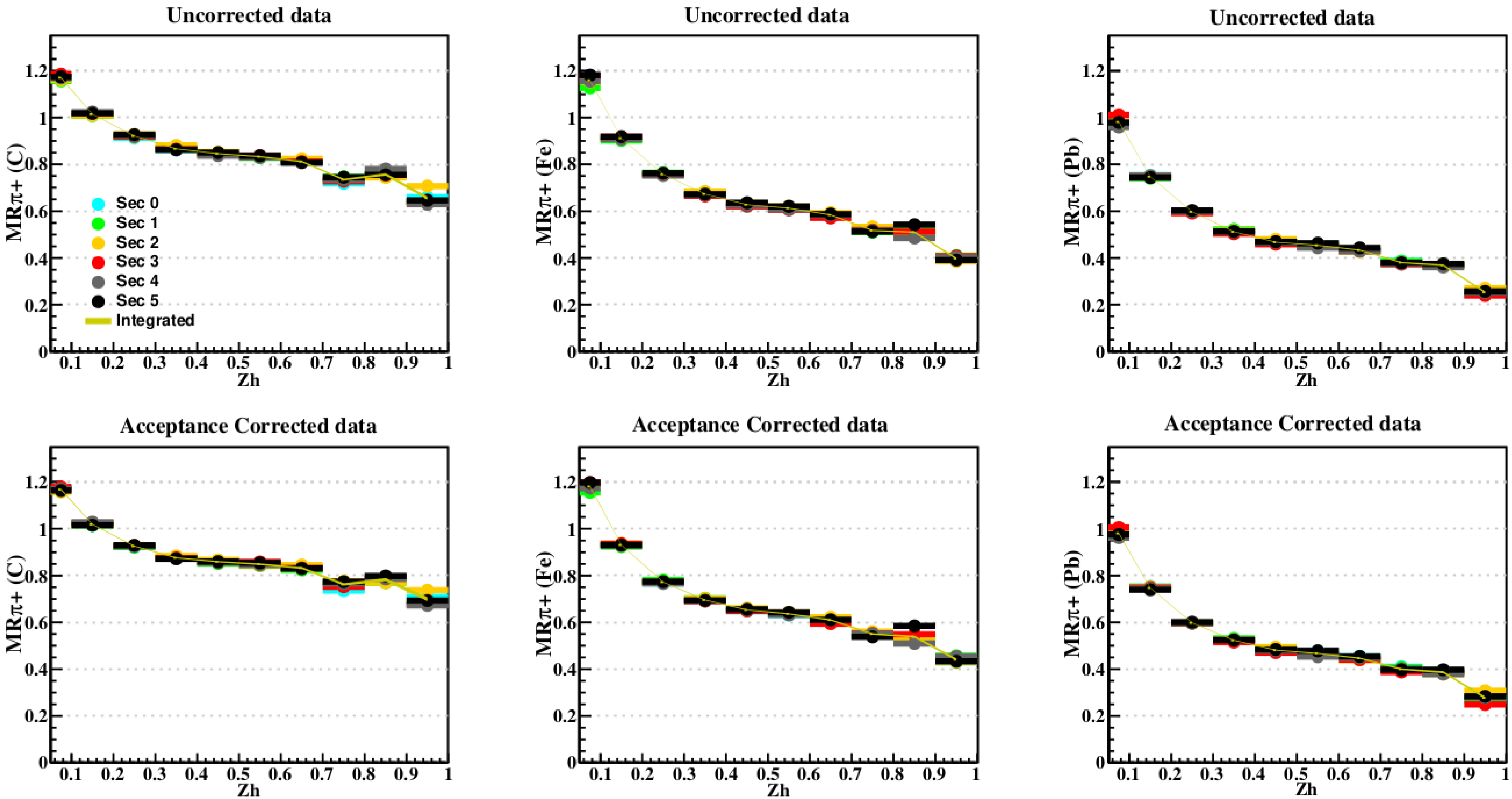
Current and Target fragmentation regions defined based on the sign of the scaling variable Feynman X

Contamination at low Zh

EMC ratio v/s CLAS sectors



Rh for π^+ v/s CLAS sectors



Rh for π^- v/s CLAS sectors