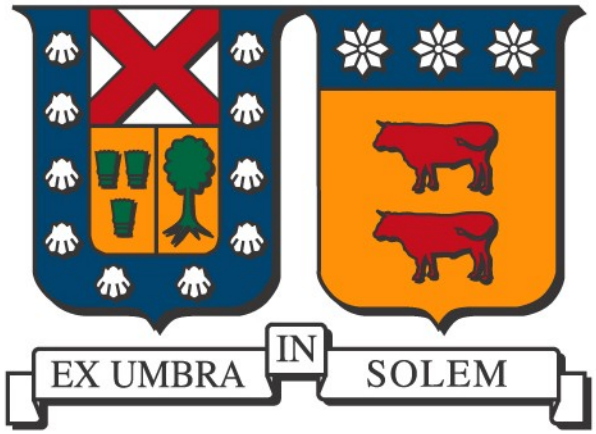
Updates in Color Propagation analysis for Positive Pions



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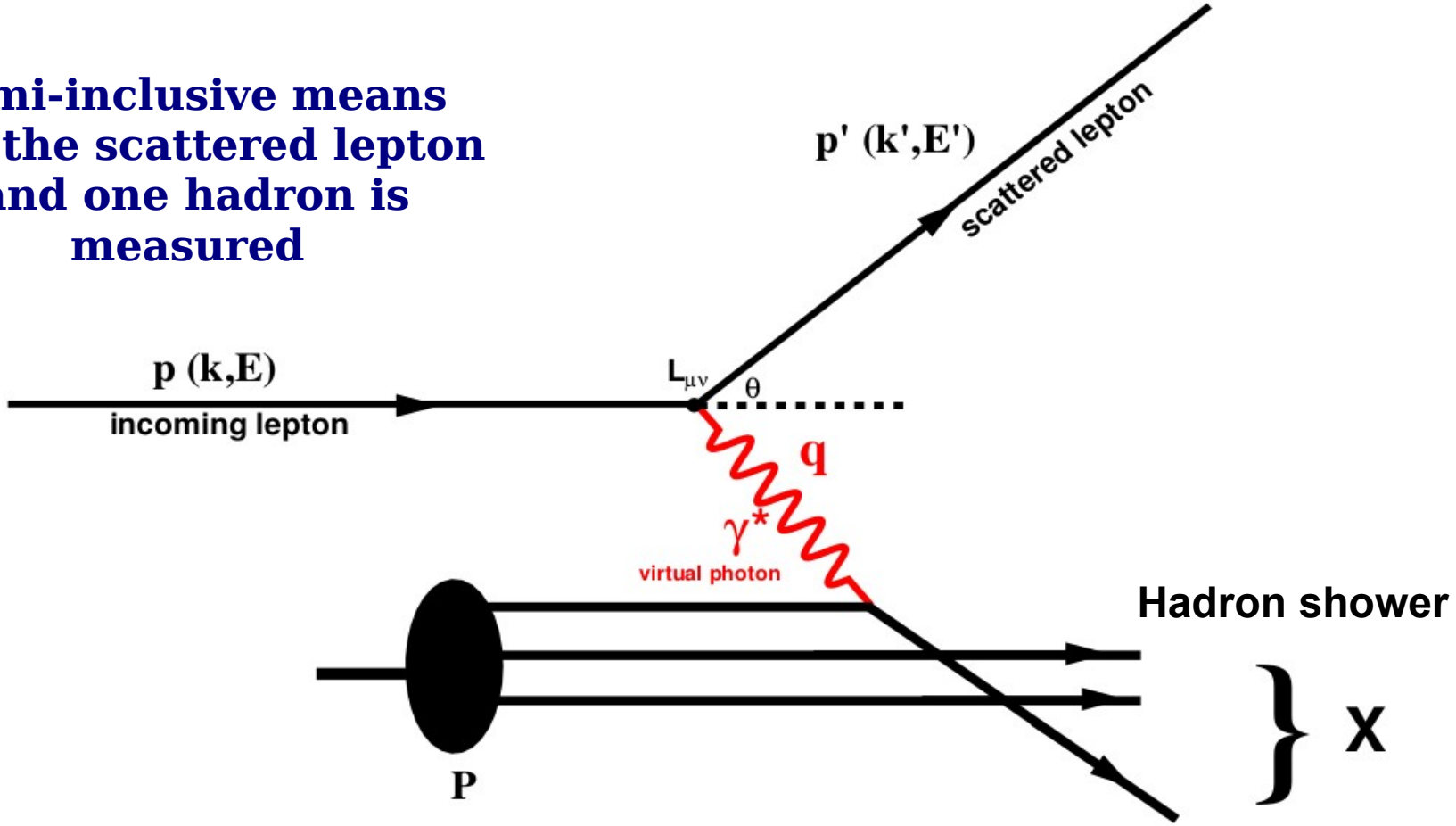
Outline

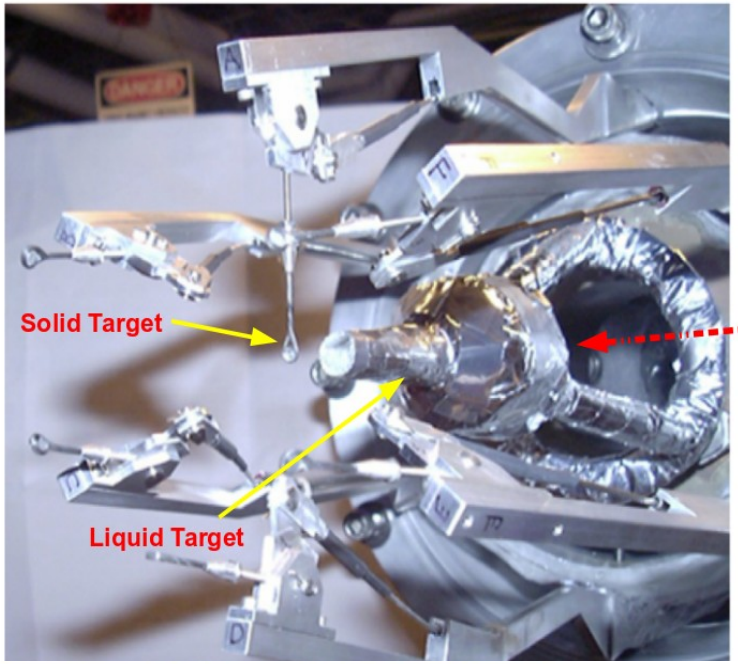
- **Introduction**:
  - SIDIS
  - EG2 CLAS Experiment
  - Experimental Variables
  - Particle identification scheme
- **EMC effect:**
  - Corrections, CC and RC.
- **Hadronic Multiplicity ratio:**
  - Vertex cuts dependency
  - Azimuthal angle problem
  - Multidimensional studies
- **Conclusions**

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

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



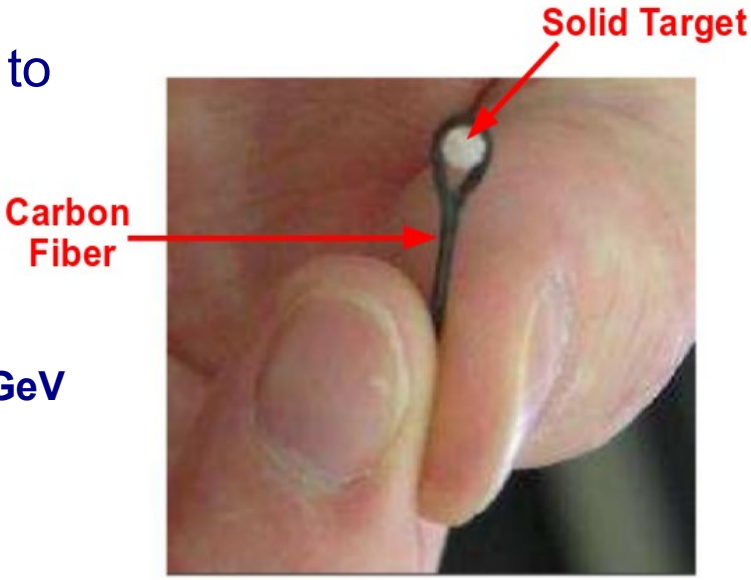
The CLAS EG2 Experiment

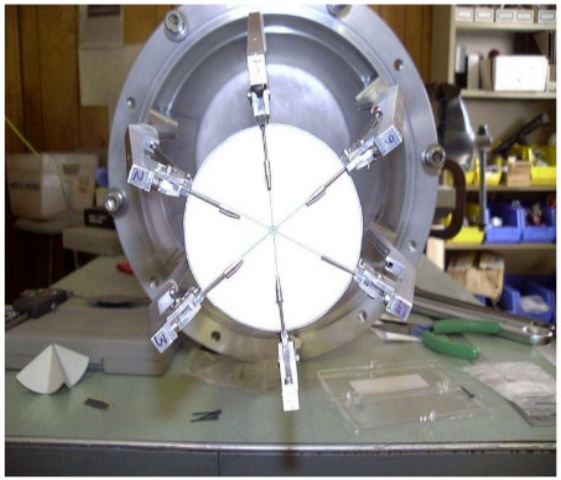


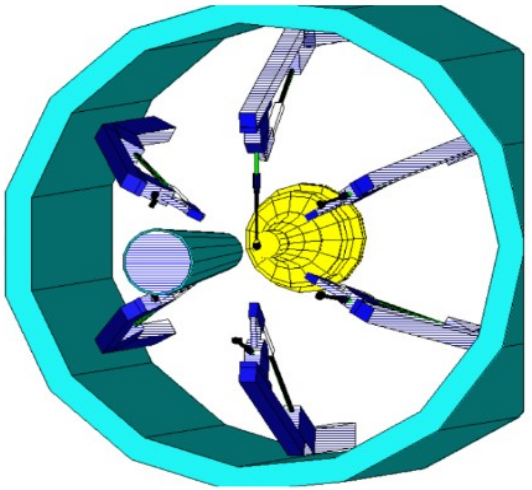
Two targets exposed to the beam **simultaneously**

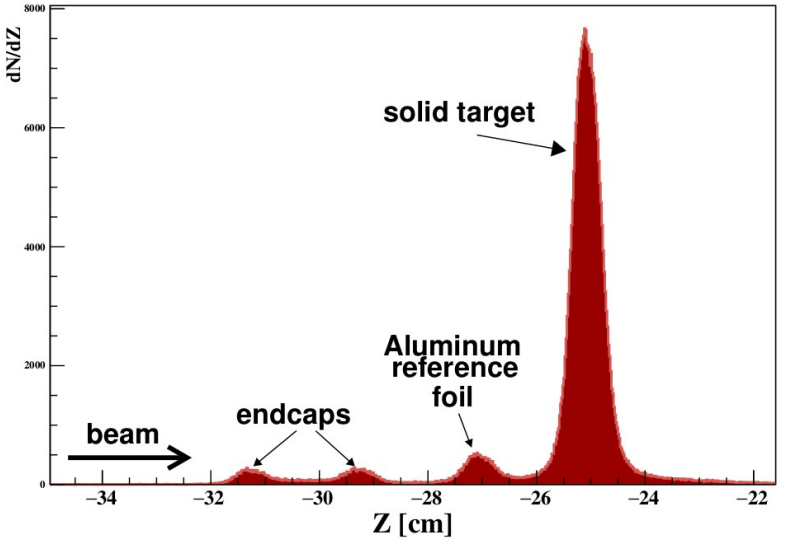
Energy beam = 5.014 GeV

The run Eg2c took place during March 2004

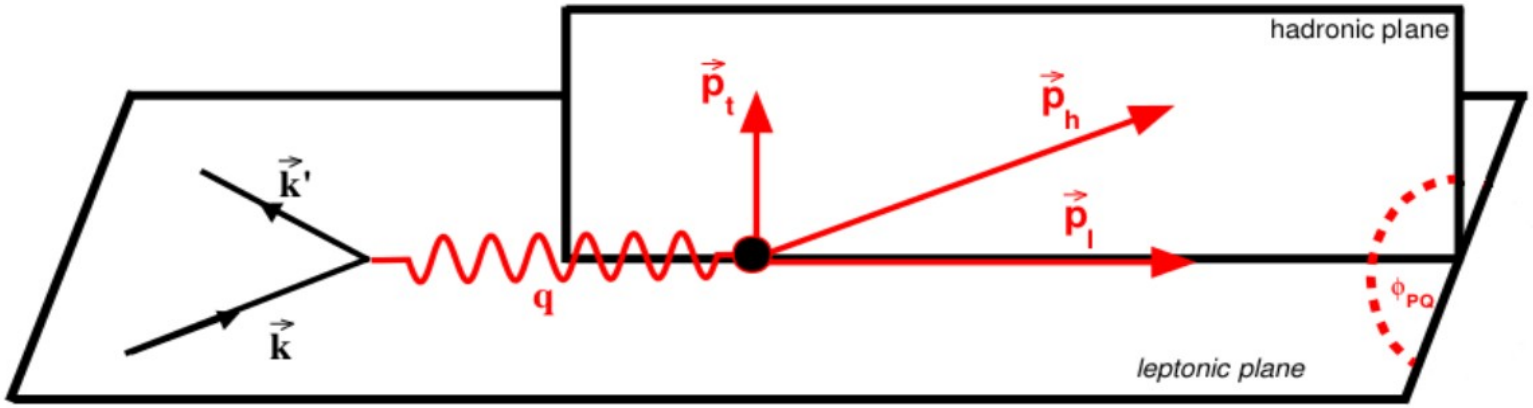








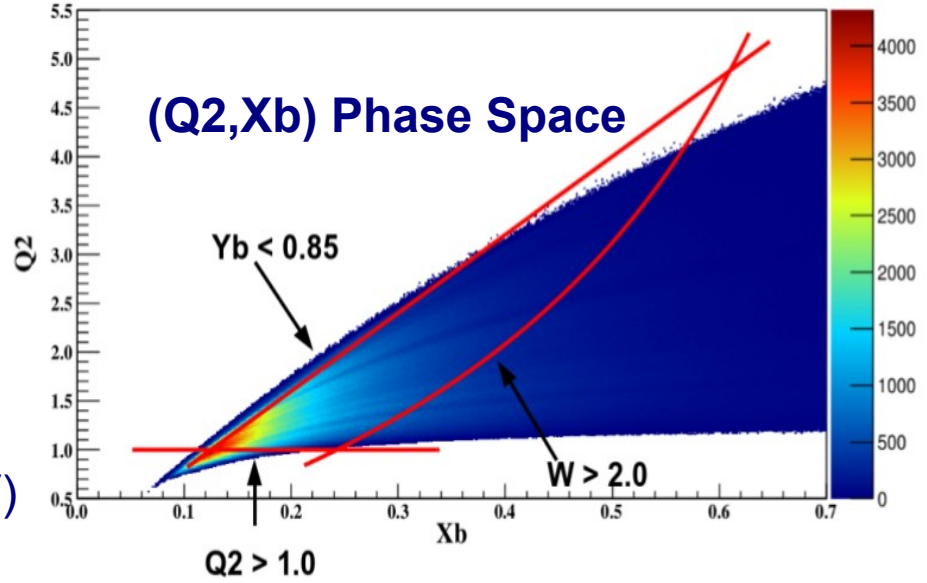
Experimental variables used in the analysis:



- **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].

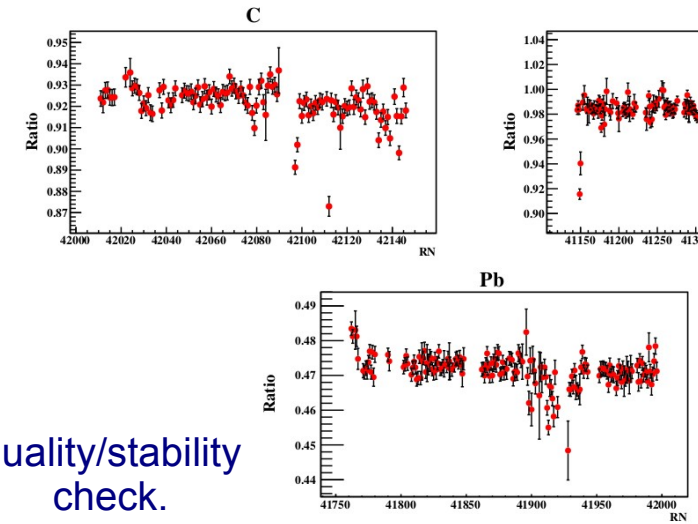
DIS kinematics

- **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 where radiative corrections are large (equivalent to P>0.75GeV)



Data files

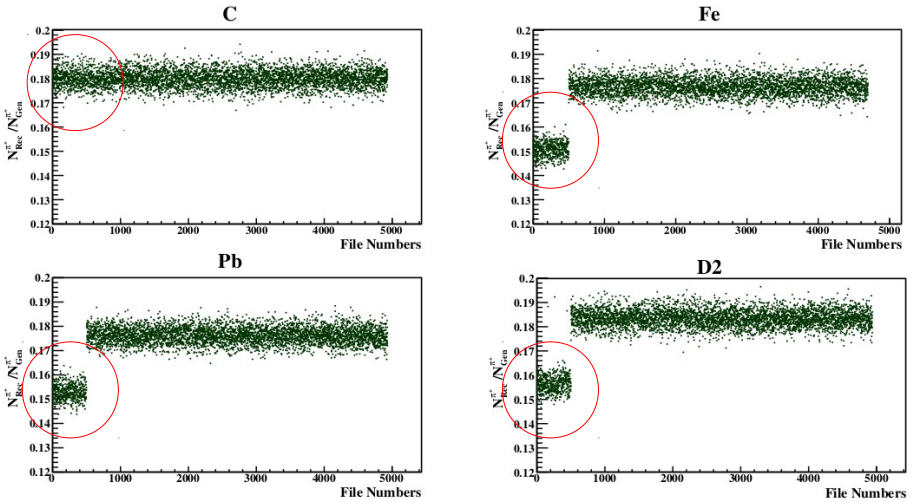
Ratio of the scattered electron yield from the solid and liquid target for each run number



quality/stability check.

Simulation files

Ratio of reconstructed and generated events for each file of the simulation set.



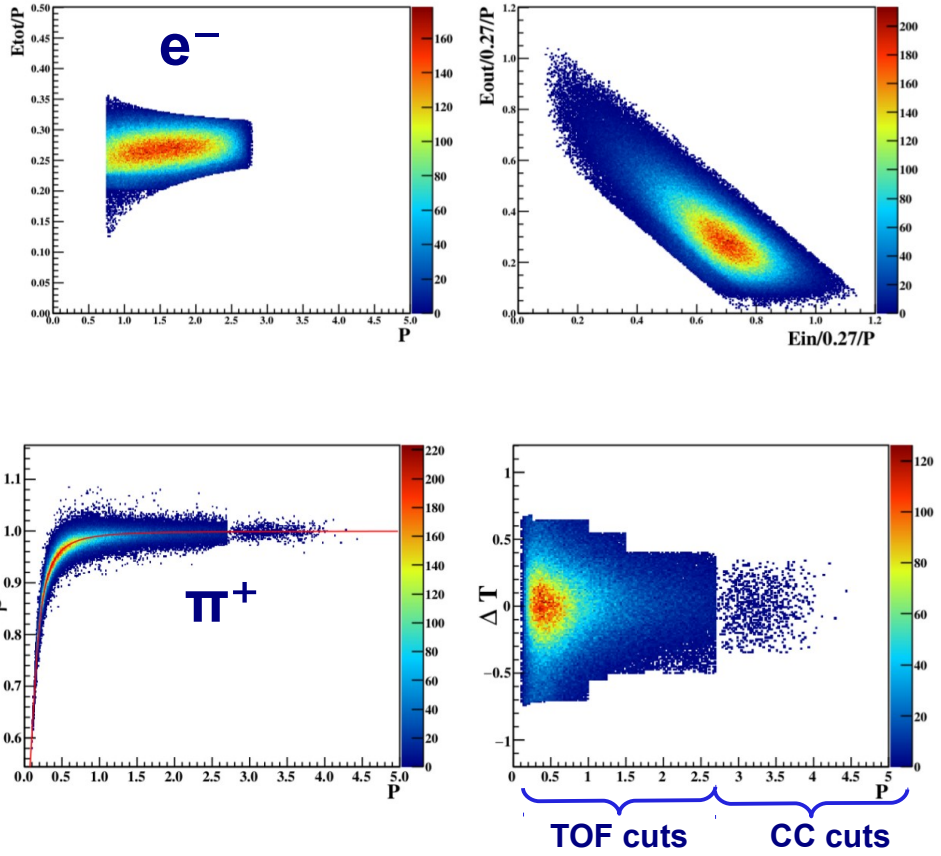
Sudden drop in the ratio for some files, for consistency those were removed from the sample for all targets

Particle Identification cuts

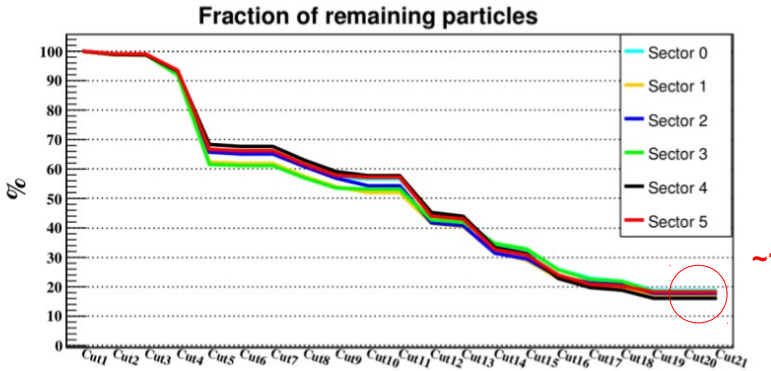
Main features :

- **All cuts are sector dependent.**
- **Recalculation of all fit parameters for Sampling Fraction cuts.**
- **Separate treatment for the simulation set (tuned cuts when it's appropriate).**

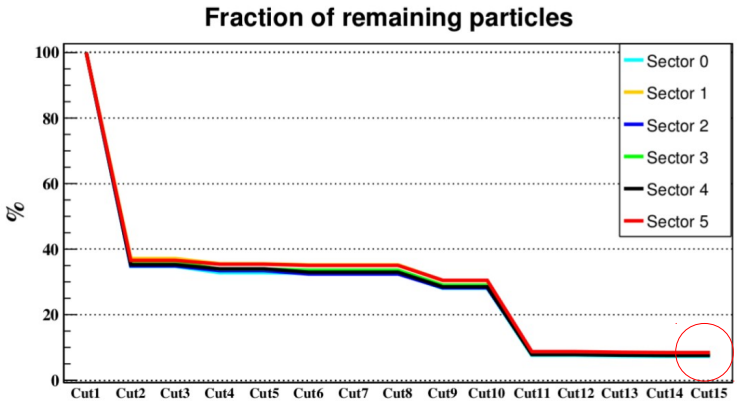
Final distributions



Fraction of remaining events in the electron/pion selection as the different cuts are imposed in an incremental way



~17% of total electron candidates are considered proper electrons



~8% of total pion candidates are considered proper pions

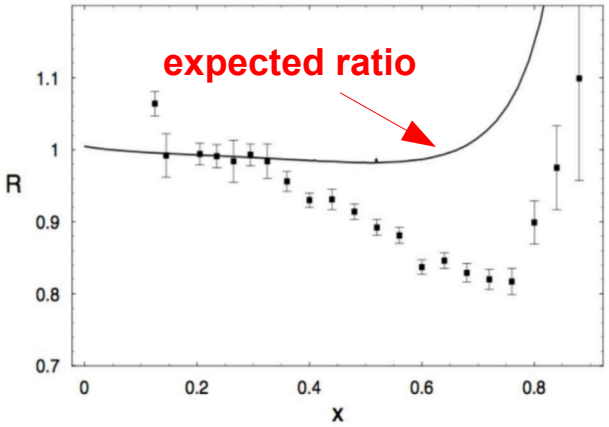
- **EMC Effect**

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

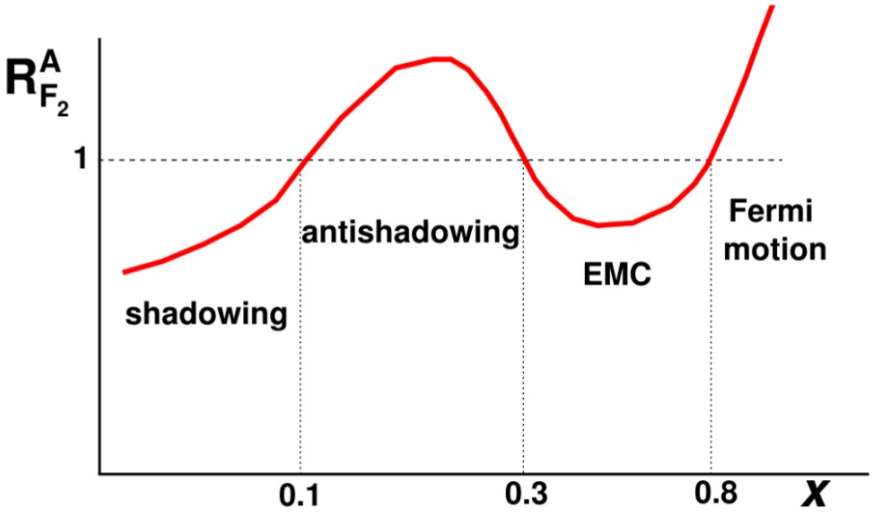
$$\mathrm{EMC} \equiv \frac{\left(\mathrm{N}_{el^-}^{\mathrm{DIS}}\right)_A}{\left(\mathrm{N}_{el^-}^{\mathrm{DIS}}\right)_D}$$

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



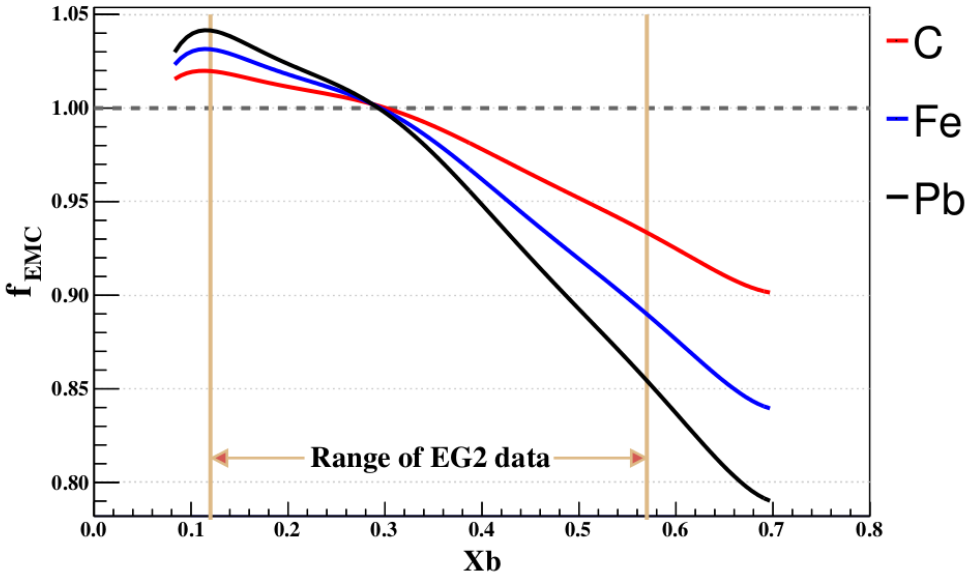
Nuclear ratio as a function of Xb



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

fixed Q2

Empirical fit function



Based on world data

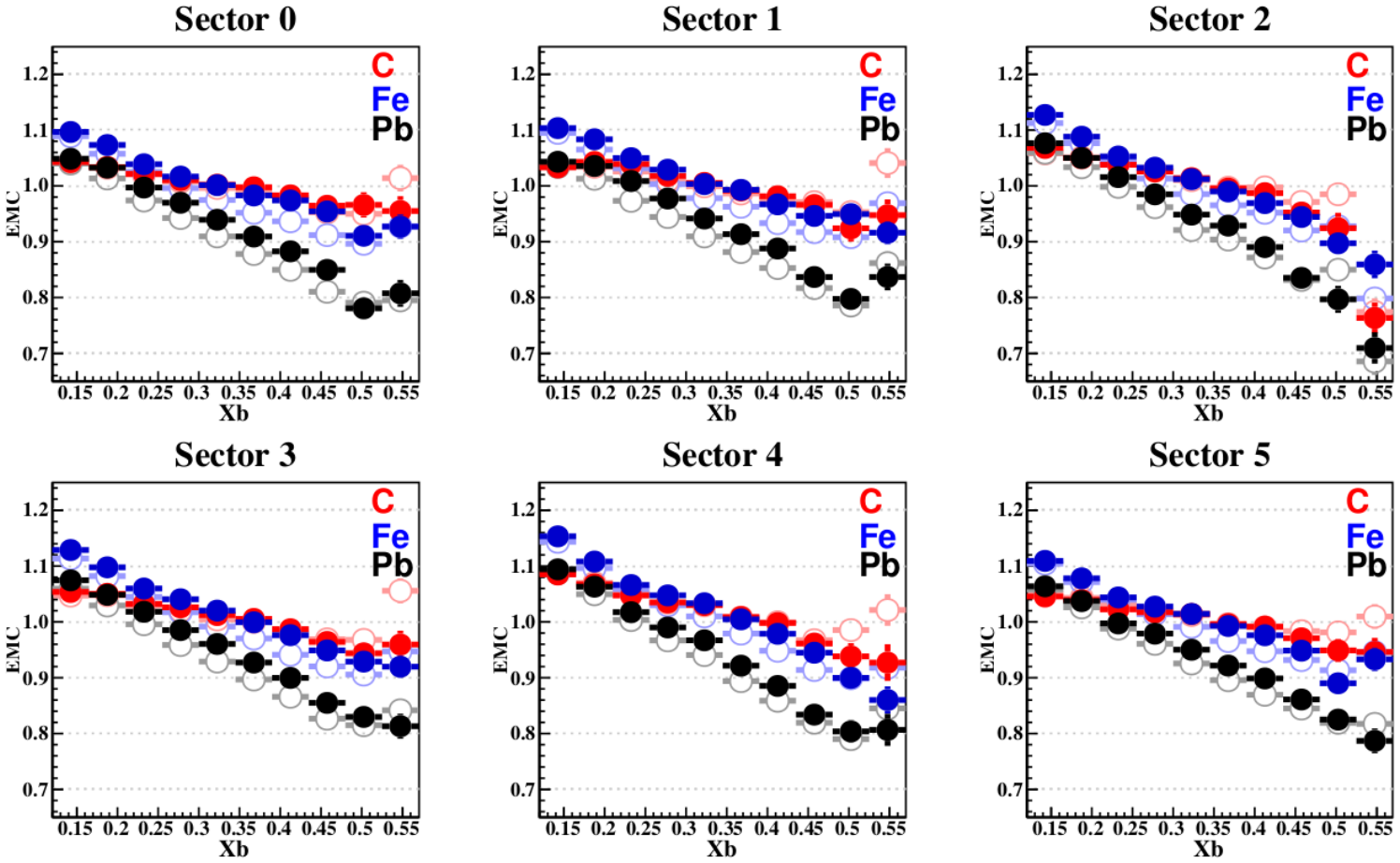
EMC ratios v/s CLAS sectors

The EMC effect is a strong function of the local nuclear density

Hollow symbols: no acceptance correction

On average the acceptance is a few percent effect

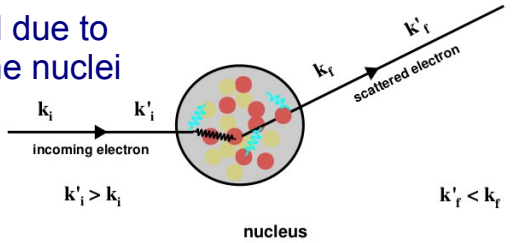
Integration over Q2 in a 10X10 grid



In addition to the acceptance two additional corrections are implemented, Coulomb Corrections (CC) and Radiative Corrections (RC), based on Mo and Tsai work.

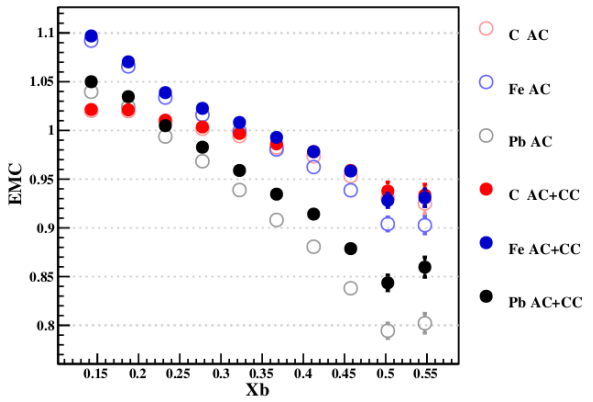
Coulomb Corrections (CC)

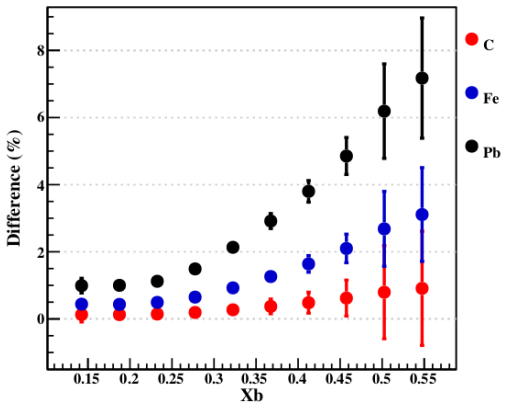
The electron's wave function is distorted due to the effect of the electrostatic field V of the nuclei

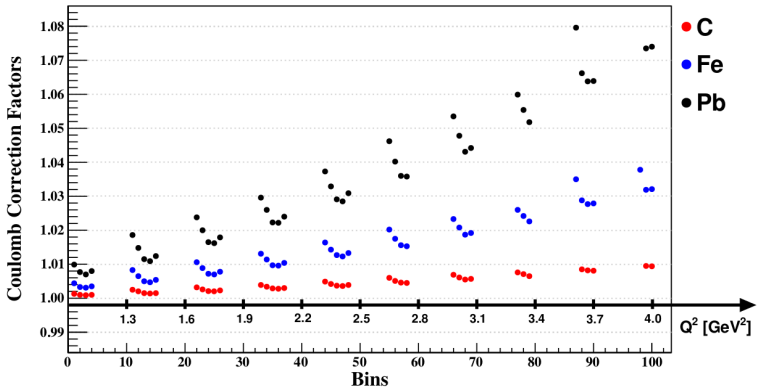


CC is a ratio of the cross section model with experimental kinematics to the cross section model with shifted kinematics multiplied by a focusing factor

Comparison EMC for C, Fe and Pb



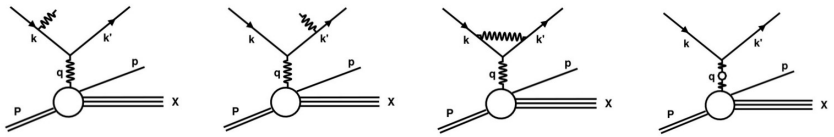




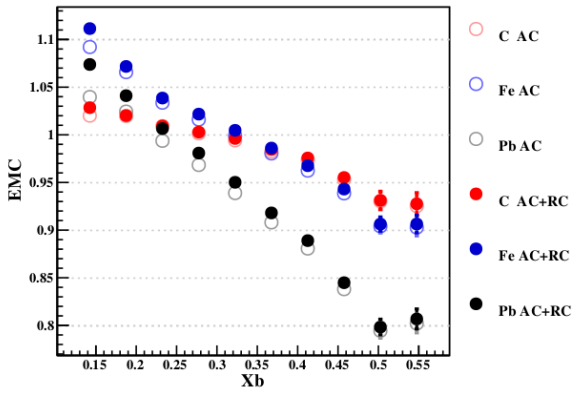
At our energies CC are relevant

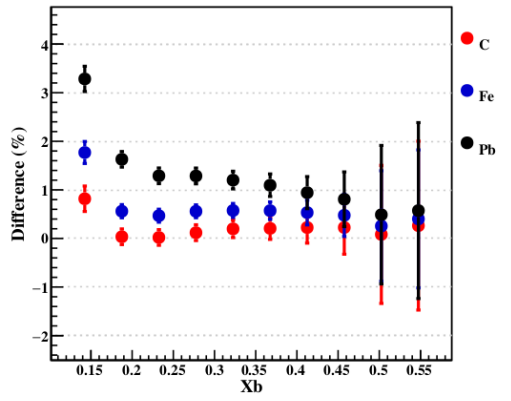
Radiative Corrections (RC)

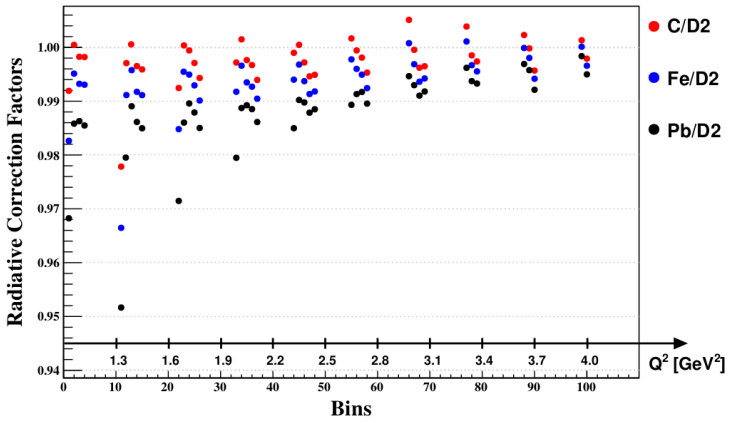
Higher order internal radiative corrections



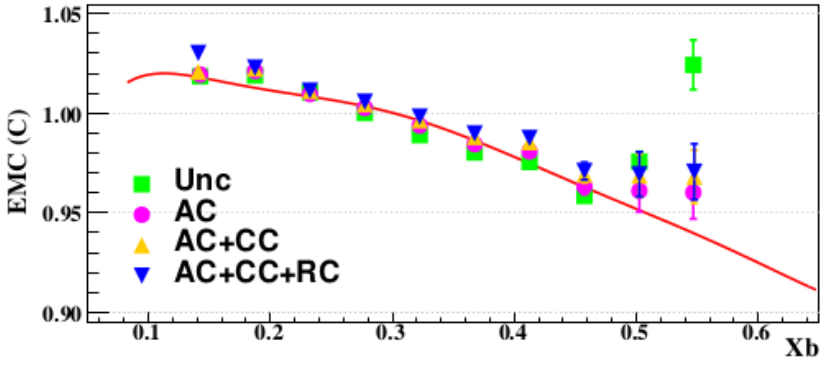
Comparison EMC for C, Fe and Pb

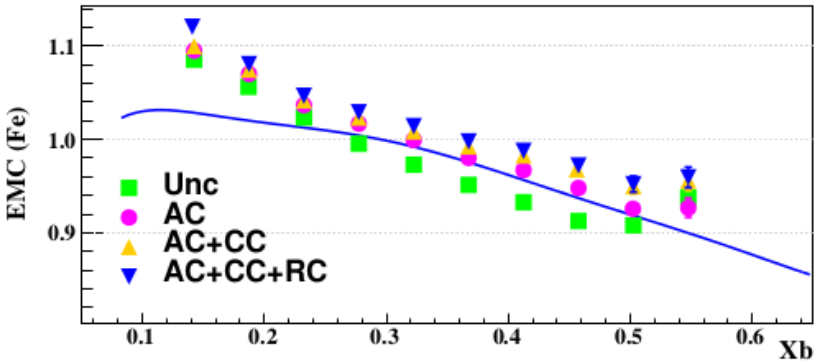


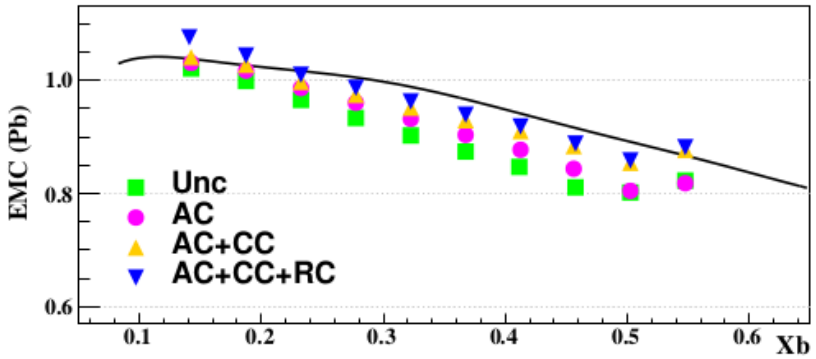




EMC ratios comparison

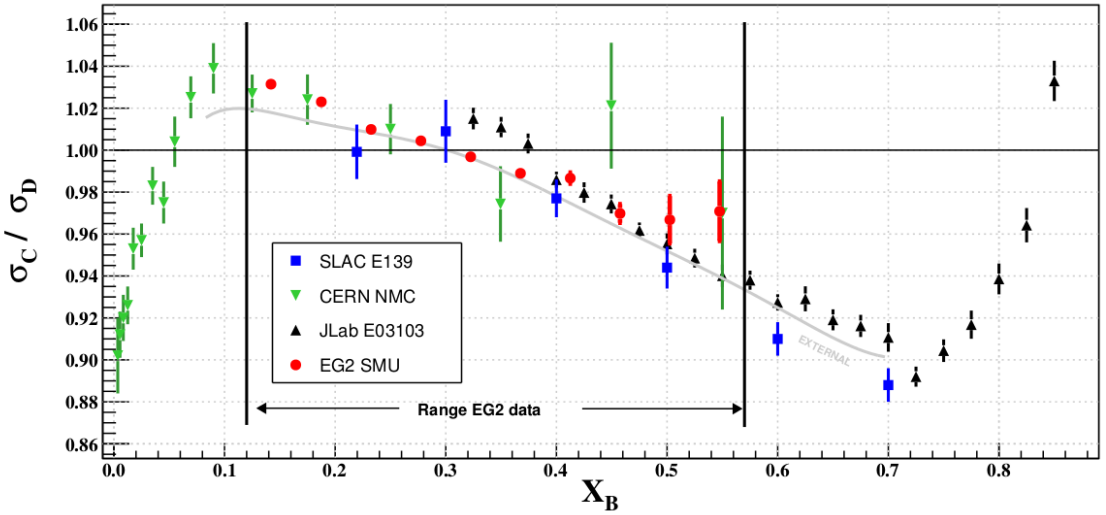






AC = Acceptance Correction
CC = Coulomb Correction
RC = Radiative Correction

Comparison with some other groups

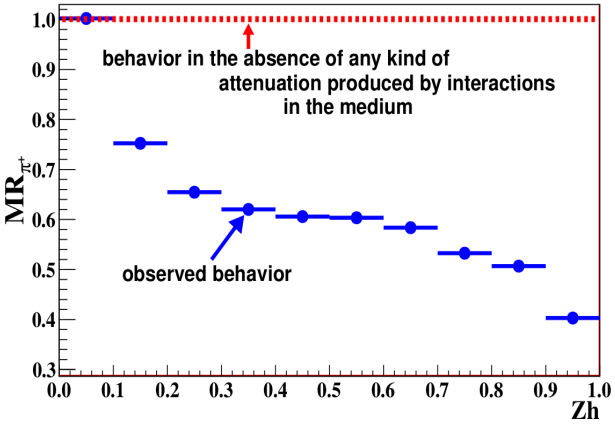


Iron is consistently above the parametrization function which is expected since previous analysis observed some strange features for the iron case in the multiplicity ratios. This suggest that the origin of that could be at the electron level at low Xb

• Hadronic Multiplicity ratio (MR)

Double ratio

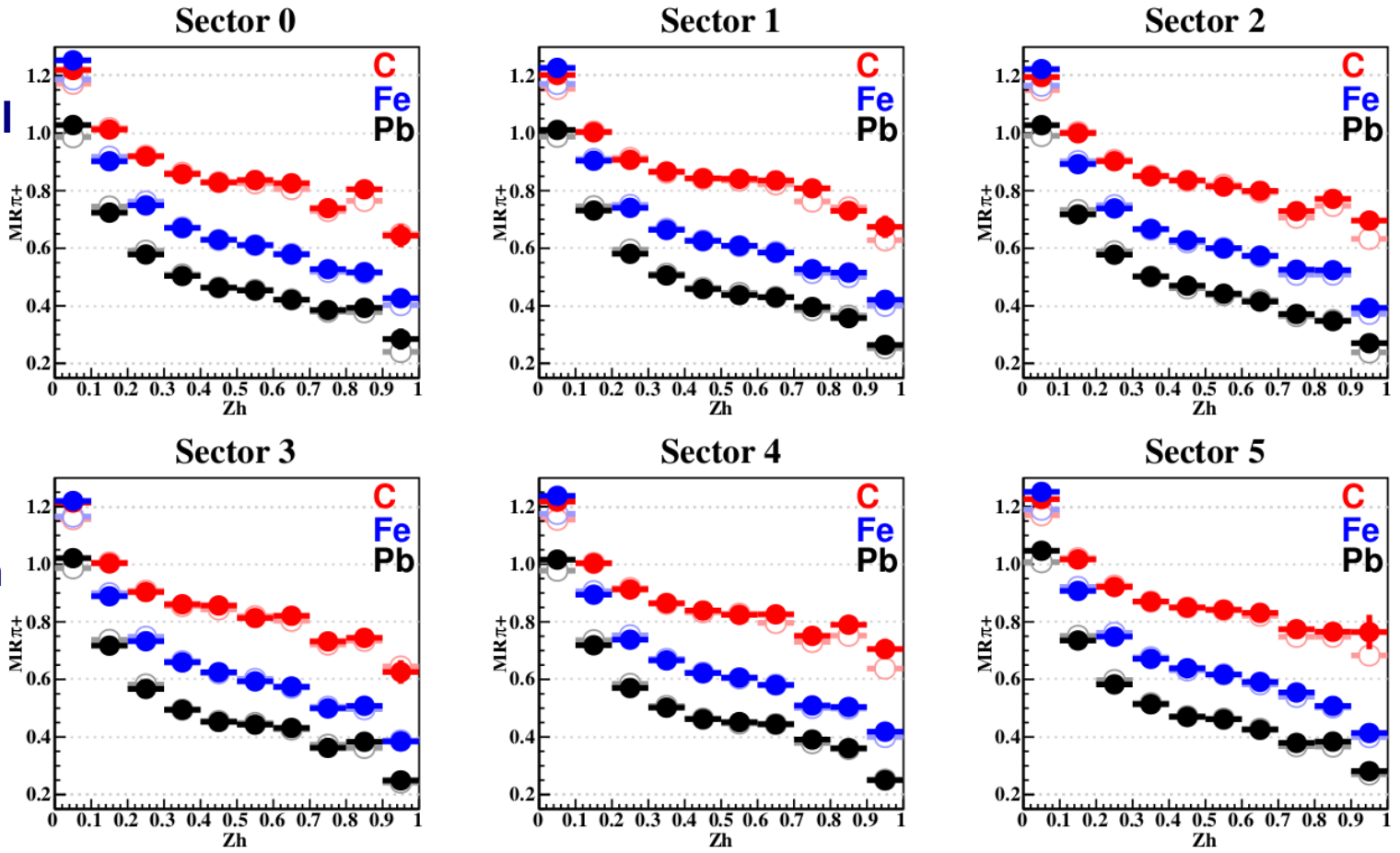
$$\mathrm{MR} \equiv \frac{\left(\frac{\mathrm{N}_{\pi^+}^{\mathrm{DIS}}}{\mathrm{N}_{el^-}^{\mathrm{DIS}}}\right)_A}{\left(\frac{\mathrm{N}_{\pi^+}^{\mathrm{DIS}}}{\mathrm{N}_{el^-}^{\mathrm{DIS}}}\right)_D}$$



π^+ 1D MR v/s CLAS sectors

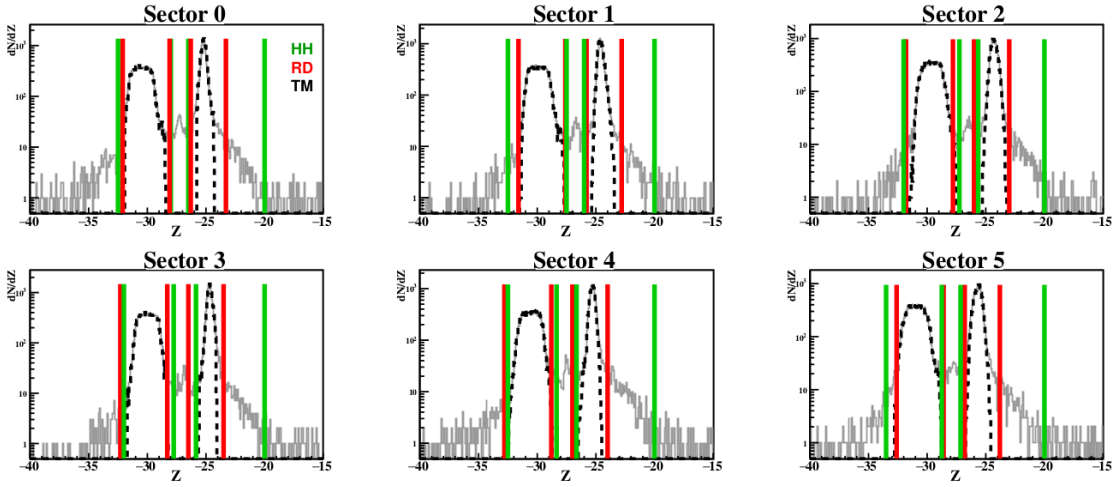
5-fold differential acceptance corrected MR

Hollow symbols: no acceptance correction



Vertex cuts for electrons dependence

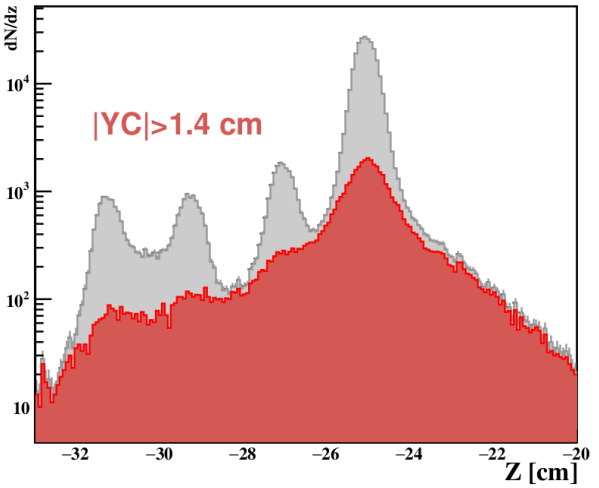
3 different set of vertex cuts compared

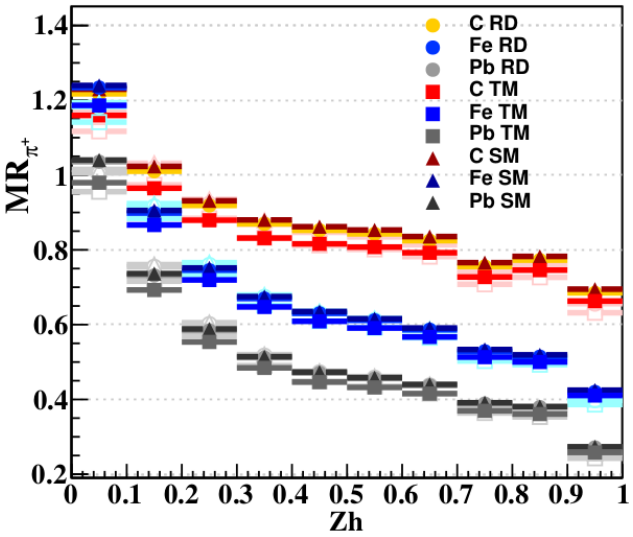


HH = Hayk Hakobyan
RD = Raphael Dupre
TM = Taisiya Mineeva

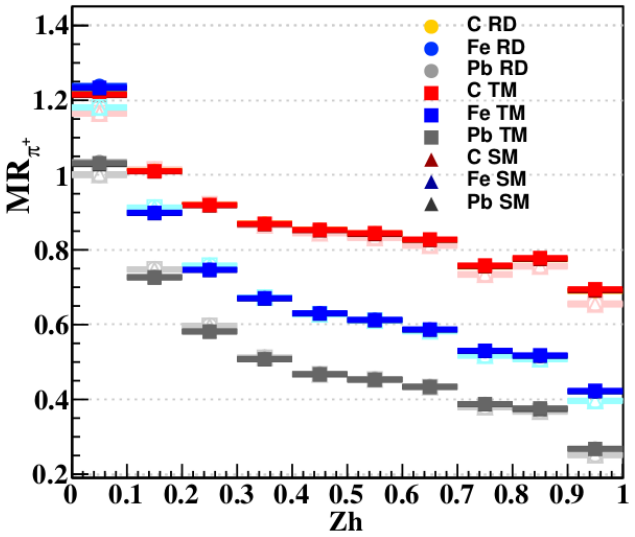
Background subtraction

Corrected Y coordinate (YC), in cm
(considering the beam misalignment)





Without YC cut

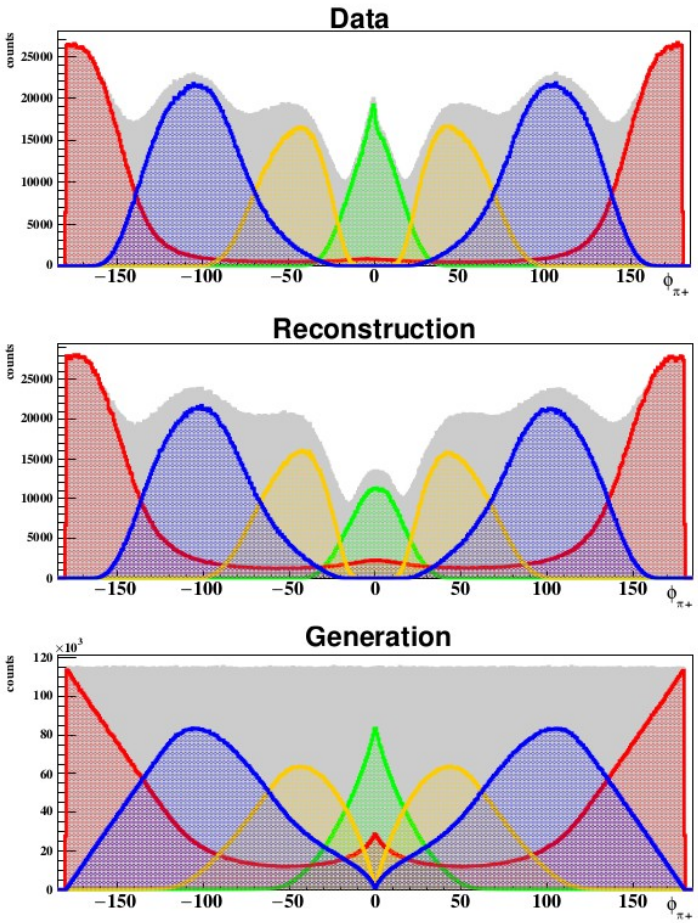


With YC cut

With the implementation of the YC cut all 3 sets of vertex cuts agree within less than 1% difference

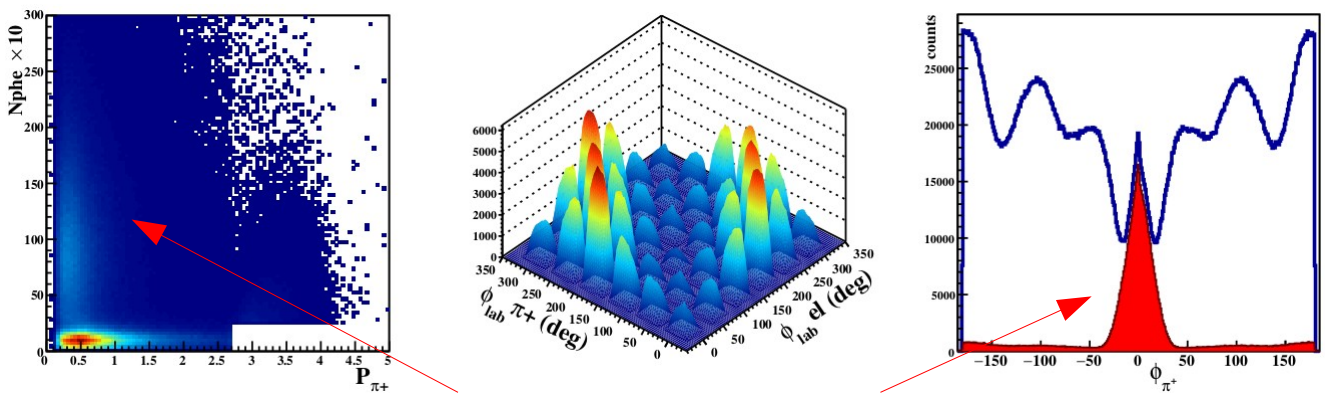
Azimuthal angle between leptonic and hadronic production planes

$$\phi_h = cos^{-1}\left(\frac{(\vec{q}\times\vec{p})\cdot(\vec{q}\times\vec{p}_h)}{|\vec{q}\times\vec{p}||\vec{q}\times\vec{p}_h|}\right)$$



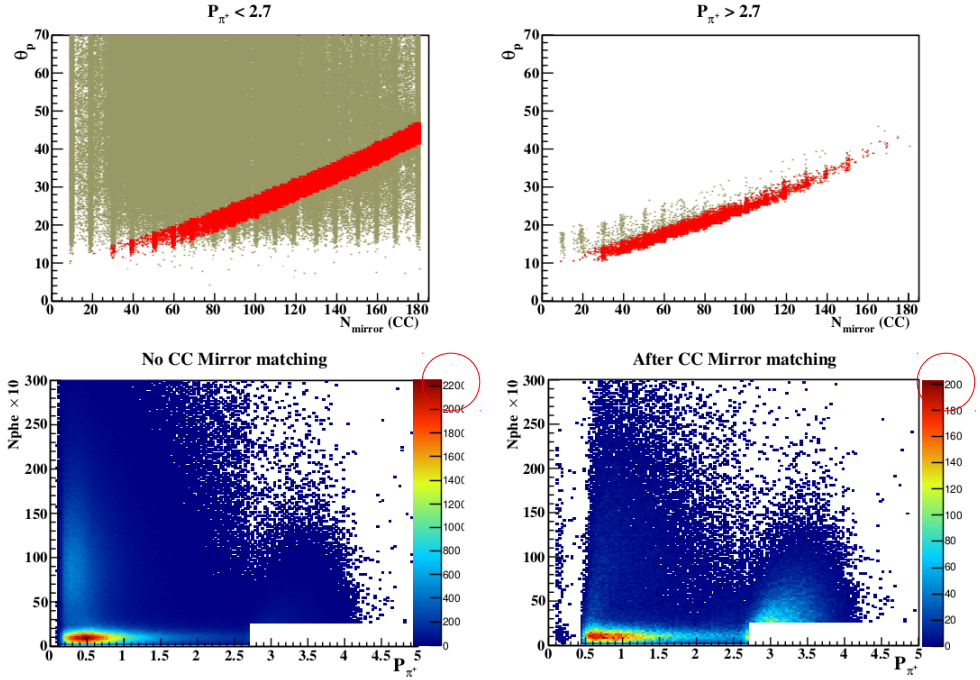
Different peaks highlighted following the definition (comparing sector of the electron and pion)

Lab angles for the pion and electron track

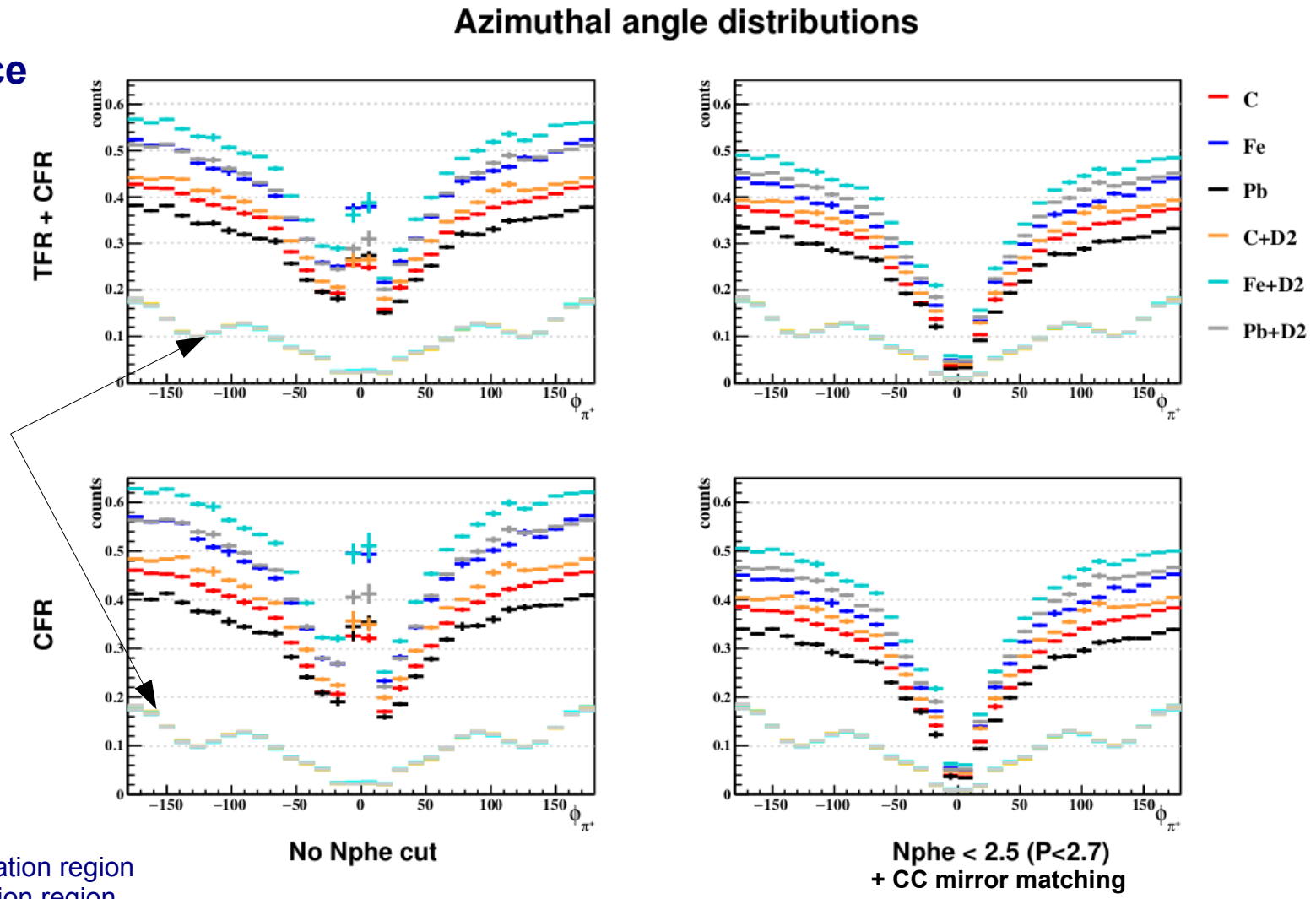


Low P pions with big CC signal

Applying CC mirror matching to the pion track



5-fold acceptance corrected distributions



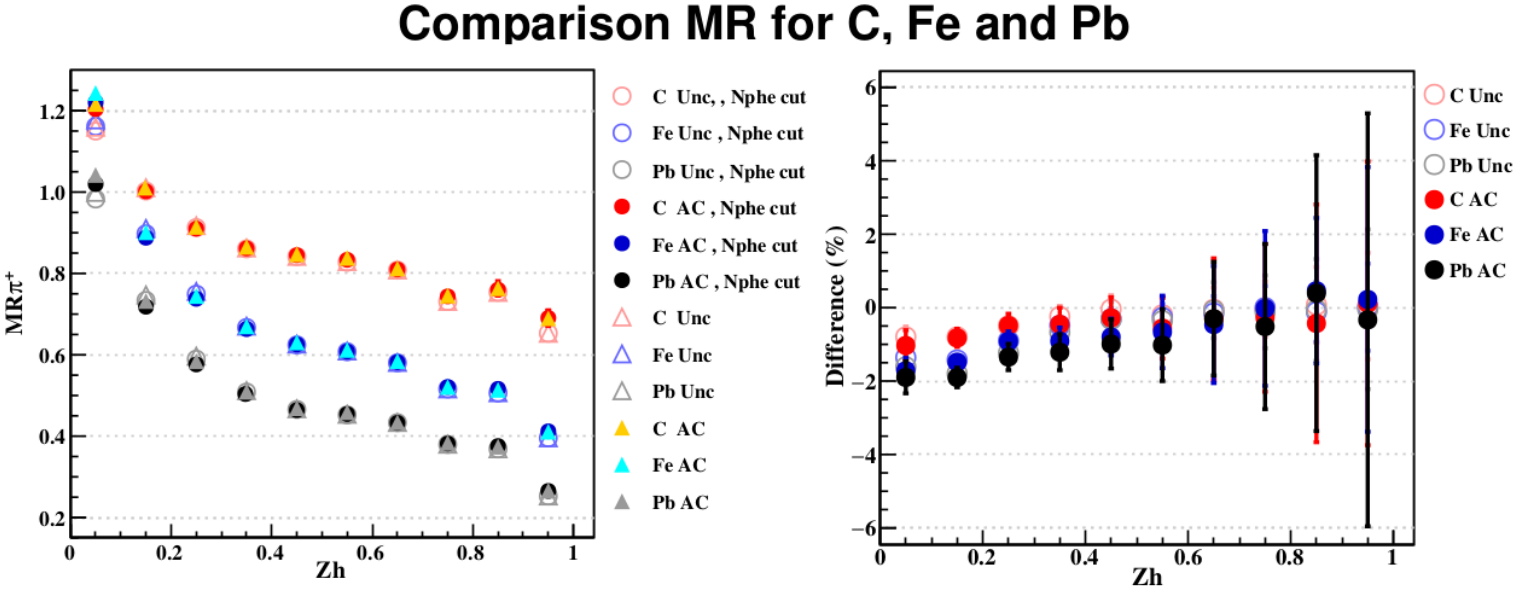
Uncorrected case enhanced for visual purpose

CFR = Current fragmentation region
TFR = Target fragmentation region

Using the conventional fitting function: A + B cos(Φ) + C cos(2Φ) with the 'new' distribution presents some challenges, further studies are needed.

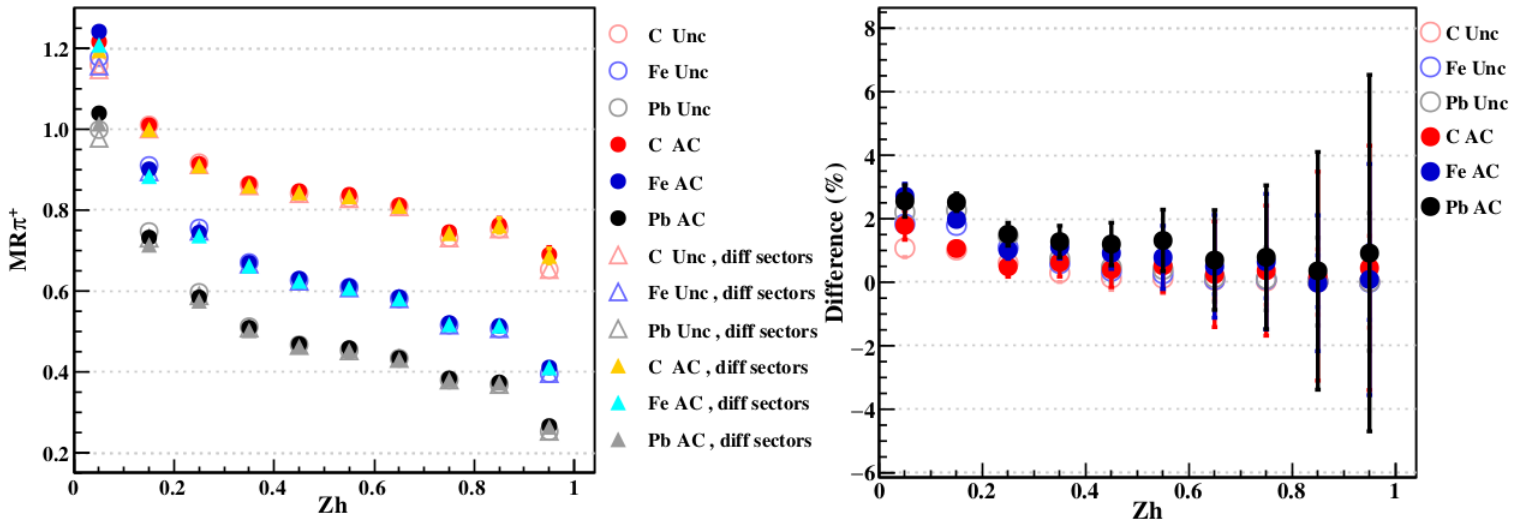
Impact on the final MR result

As expected, the difference with the previous case is mainly in the lower region of Zh and it is an small change



A more radical approach would be to consider only pions that were measured in different sectors than the observed electron.

This cut will completely remove the central peak



Probing multidimensionality

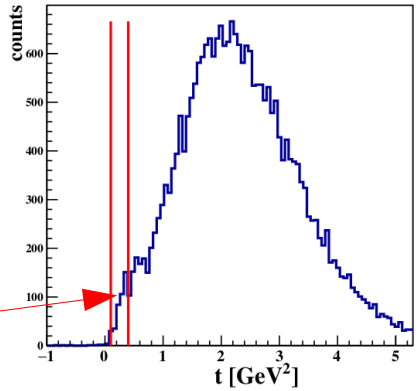
One of the key points of EG2 data

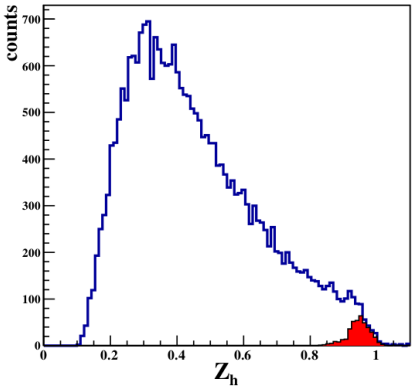
The highest statistic information is for π^+ → **Multidimensional studies, in principle up to 4-fold differential**

Some considerations to take into account:

Diffractive Processes

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

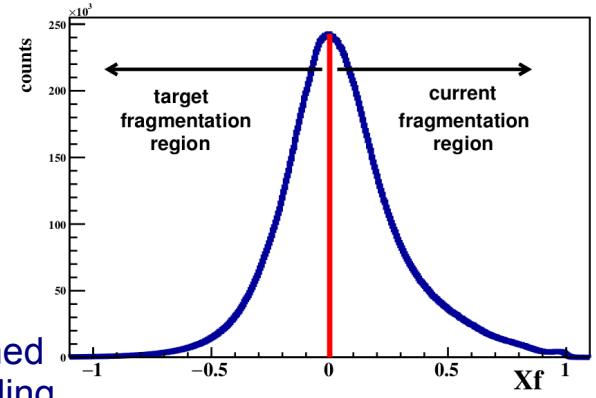


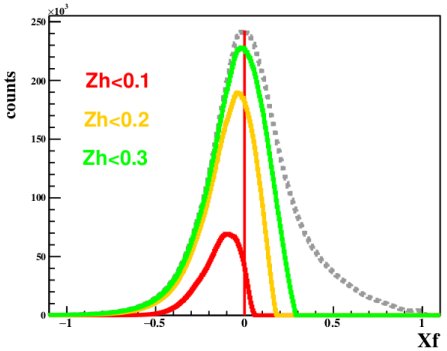


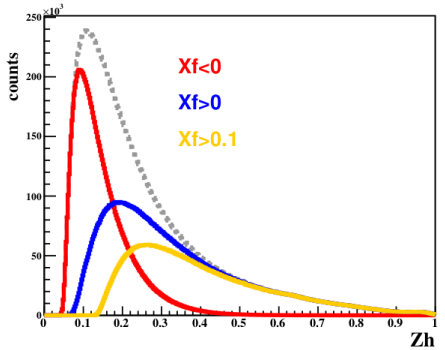
Contamination at high Zh

Target fragmentation contribution

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



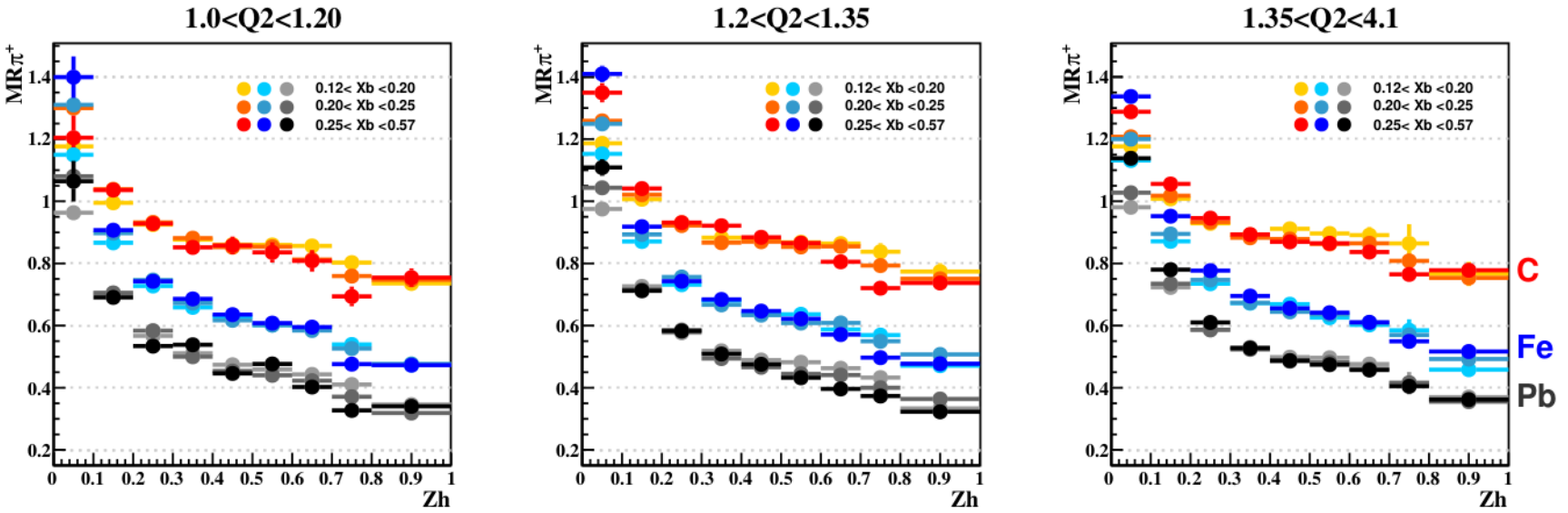




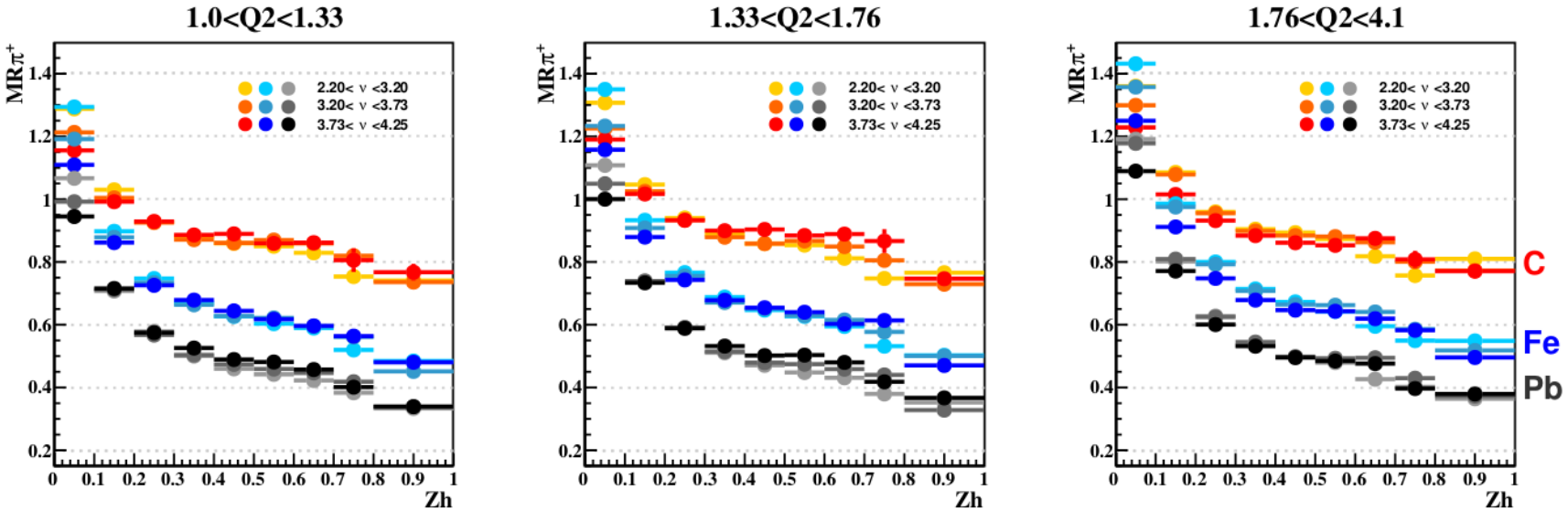
Contamination at low Zh

π^+ 3D Multiplicity Ratios dependence on Zh

Different (Xb,Q2) bins



Different (ν,Q2) bins



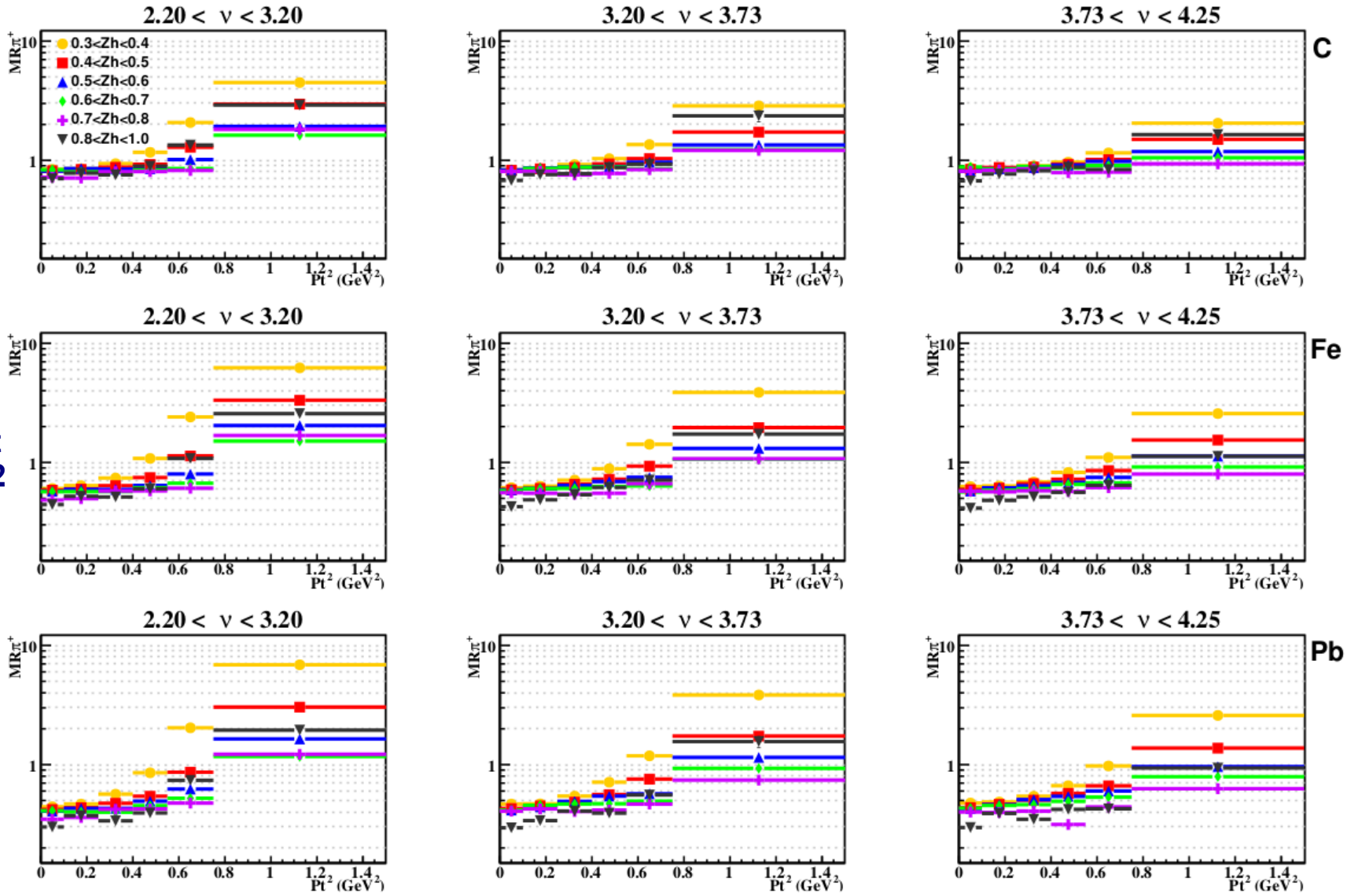
Weak dependence on the electron kinematics

*Acceptance corrected applied. Integration over Pt2. Only statistical errors are shown

π^+ 3D Multiplicity Ratios dependence on Pt2

Different (v,Zh) bins

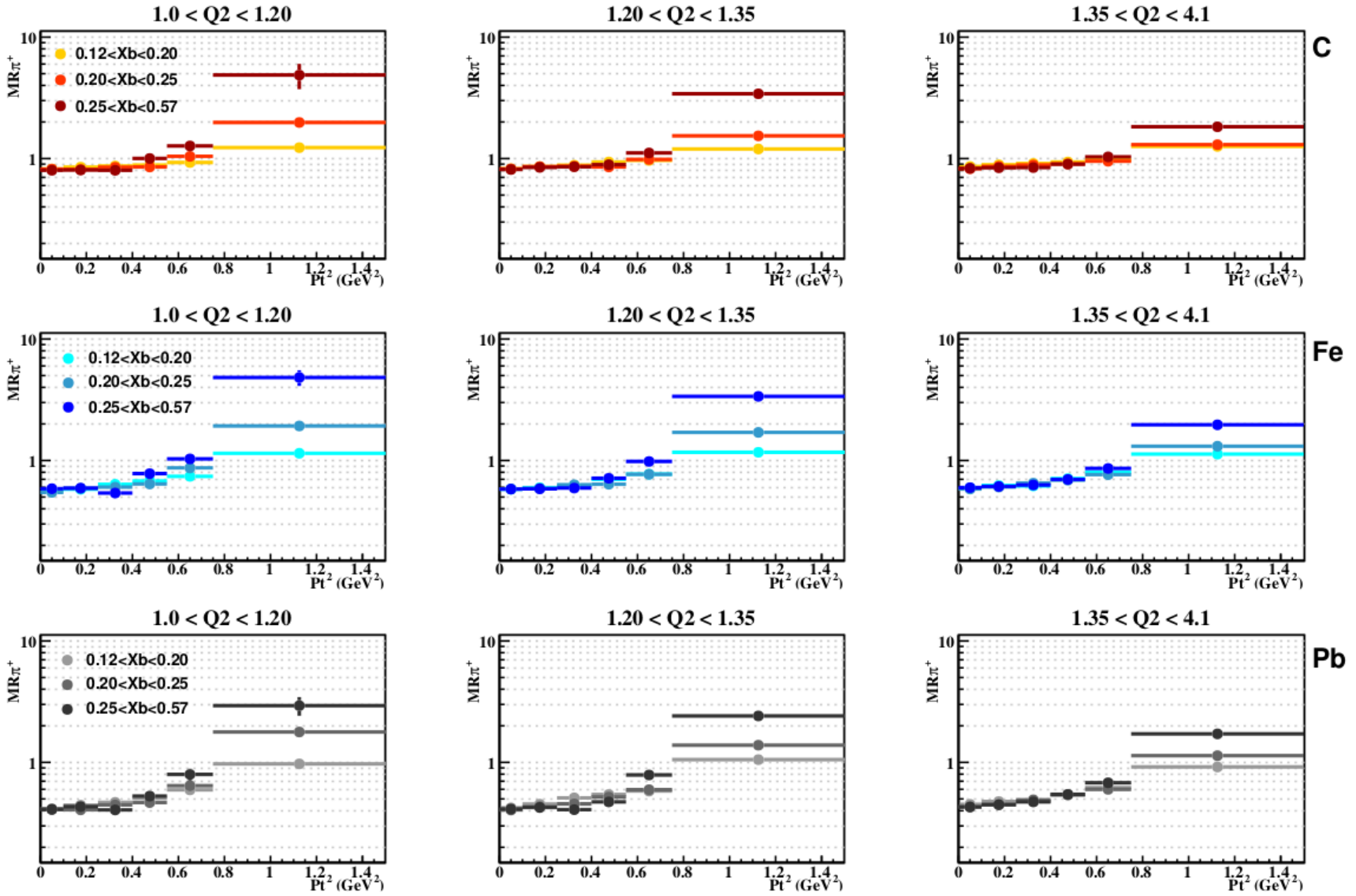
Large increase at high values of Pt2 ("Cronin effect")



*Acceptance corrected applied. Integration over Q2. Only statistical errors are shown

π^+ 3D Multiplicity Ratios dependence on Pt2

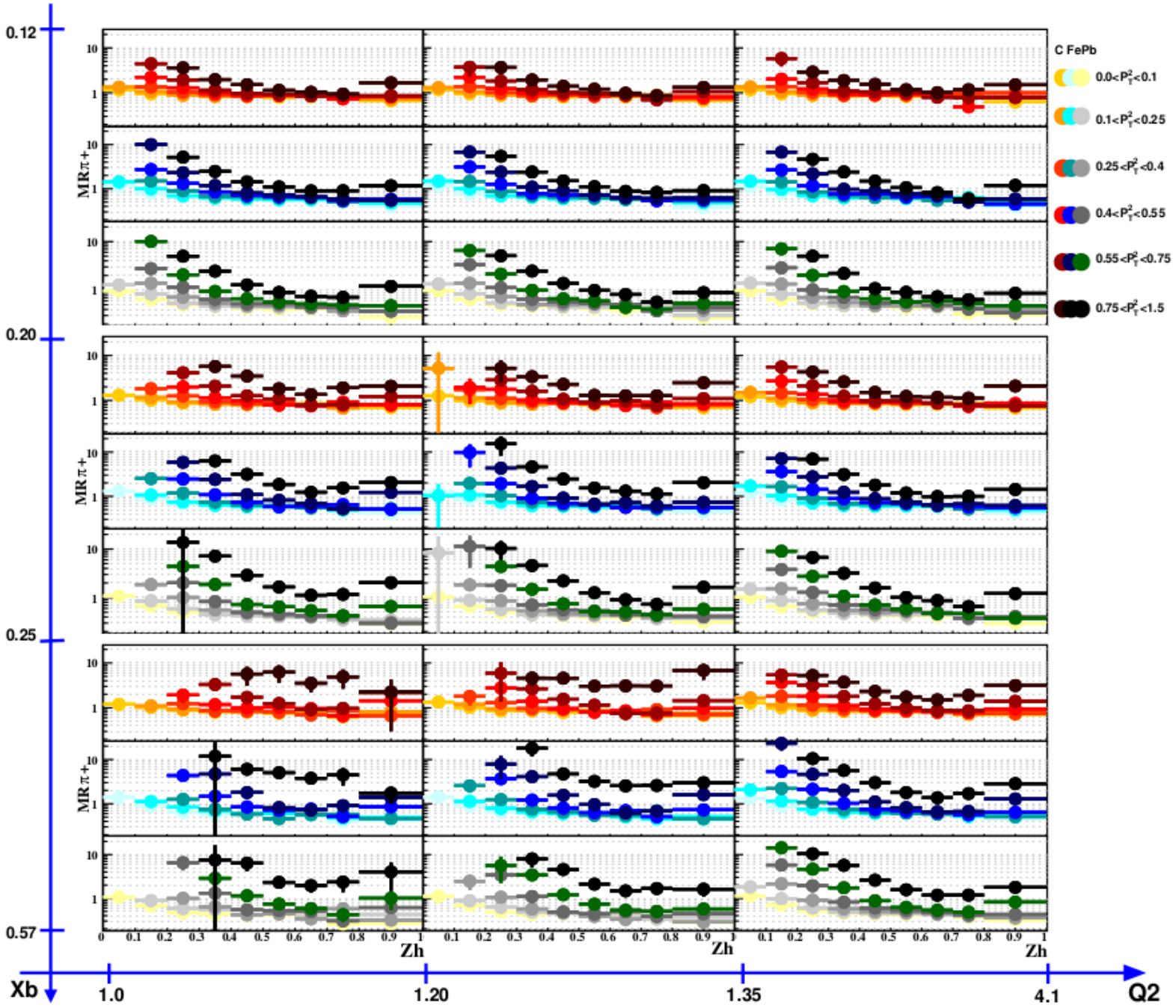
Different (Xb,Q2) bins



*Acceptance corrected applied. Integration over Zh. Only statistical errors are shown

π^+ 4D Multiplicity Ratios dependence on Zh

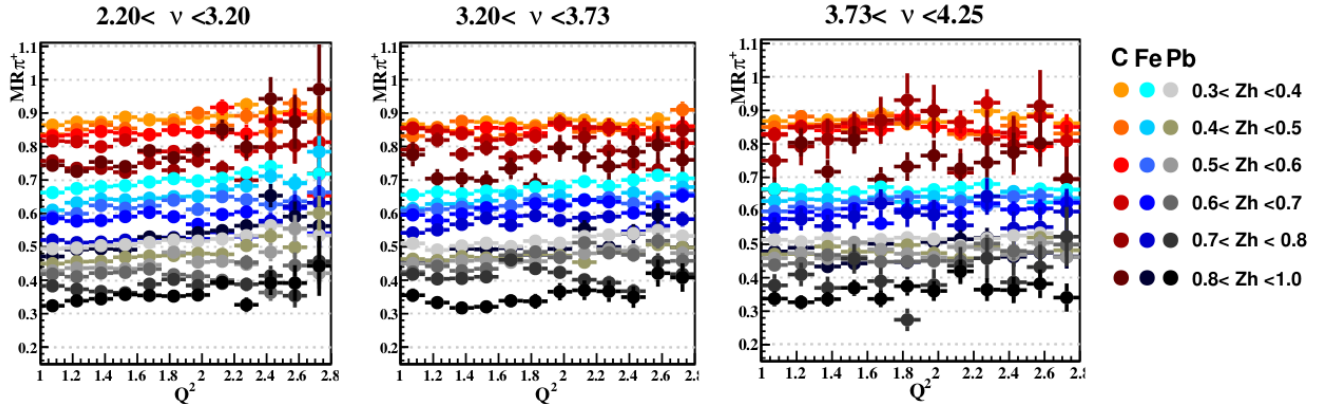
Different (Xb,Q2,Pt2) bins



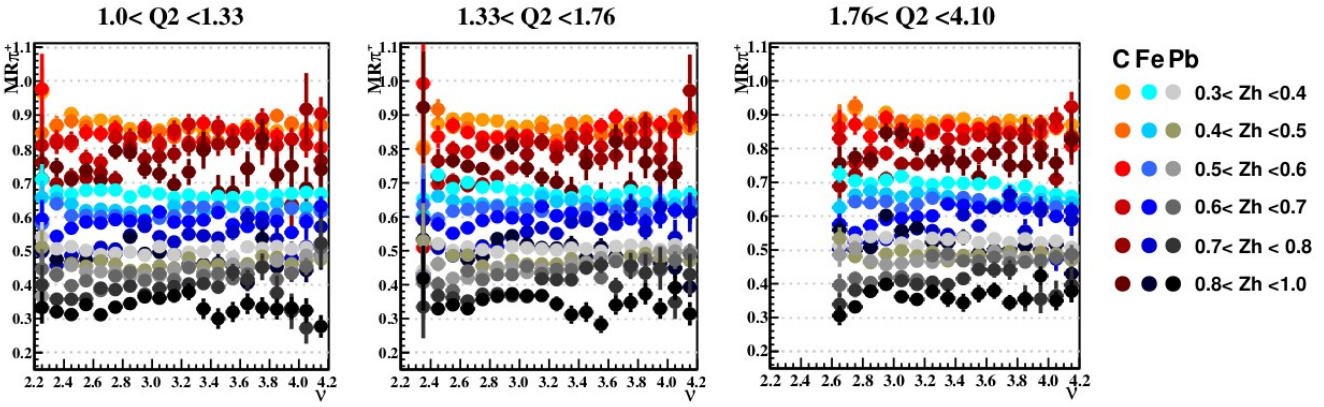
*Acceptance corrected applied. Only statistical errors are shown

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

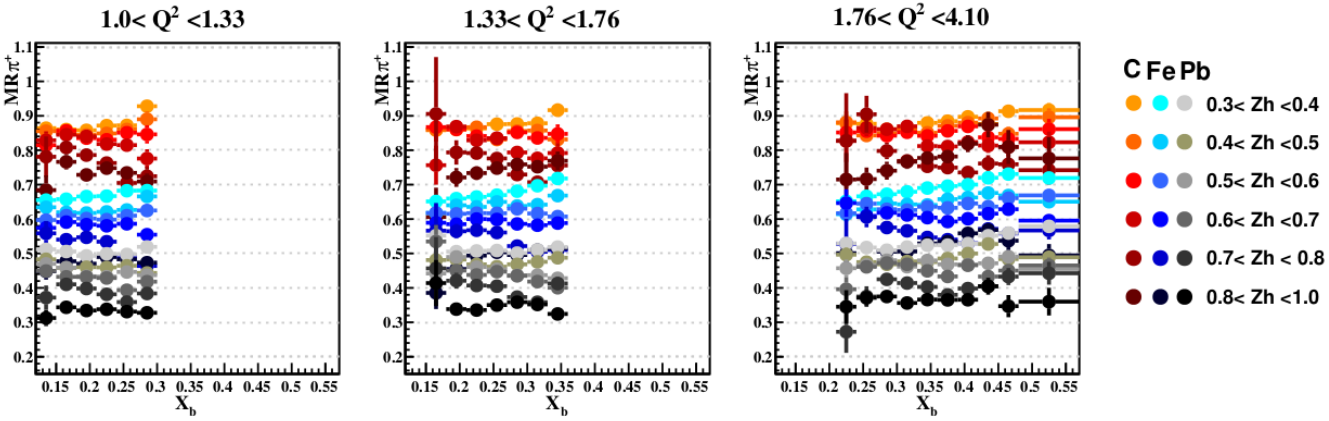
Q2 dependence for different (ν,Zh) bins



ν dependence for different (Q2,Zh) bins



Xb dependence for different (Q2,Zh) bins



*Acceptance corrected applied. Only statistical errors are shown

Conclusions

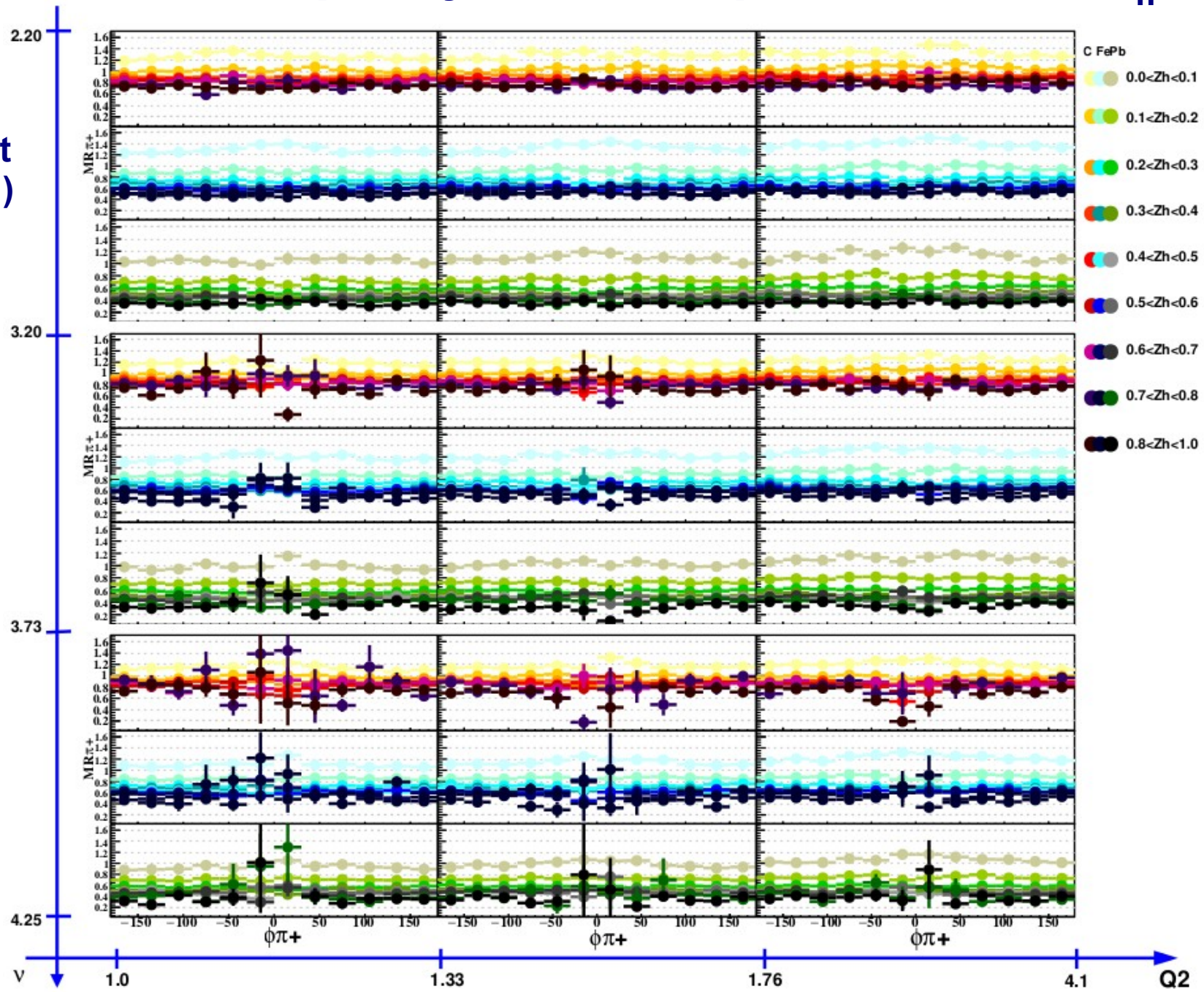
- **EMC ratio for C problem solved. Now the result is in agreement with world data.**
- **Vertex cuts dependency of the MR problem solved. Now all the results agree.**
- **Important advances in the understanding of the azimuthal angle between hadronic and leptonic plane shape. Further studies are necessary, but the source of the problem seems to be identified.**
- **The multidimensional studies for positive pions have qualitative similar features than neutral pions (Taisiya Mineeva's work). A more detailed comparison is the next step.**

Thanks

BACKUP SLIDES

π^+ 4D Multiplicity Ratios dependence on Φ_{π^+}

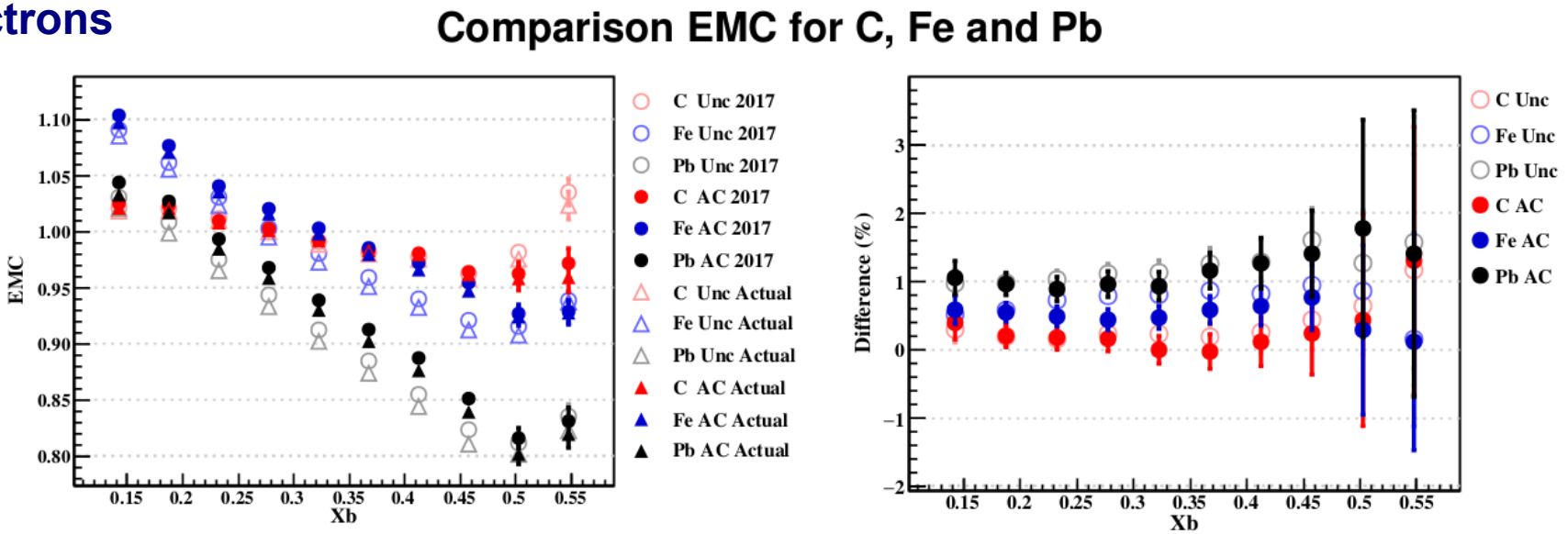
Different (v,Q2,Zh) bins



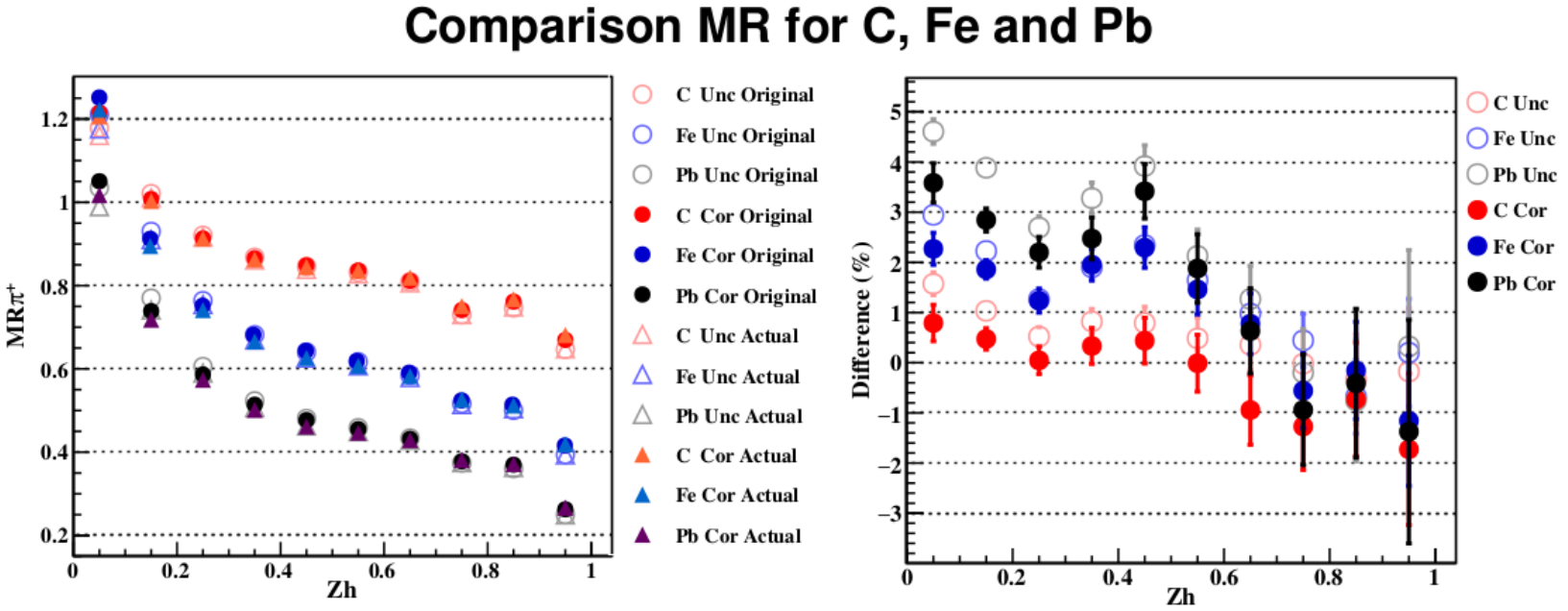
*Acceptance corrected applied. Integration over Pt2. Only statistical errors are shown

Difference with the previous state of the analysis

electrons



pions



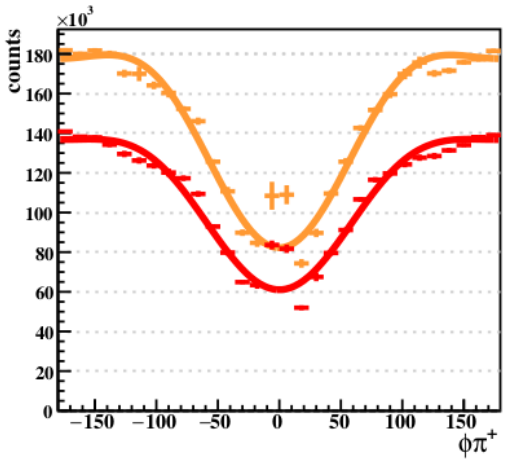
Fitting the Φ_{π^+} distributions

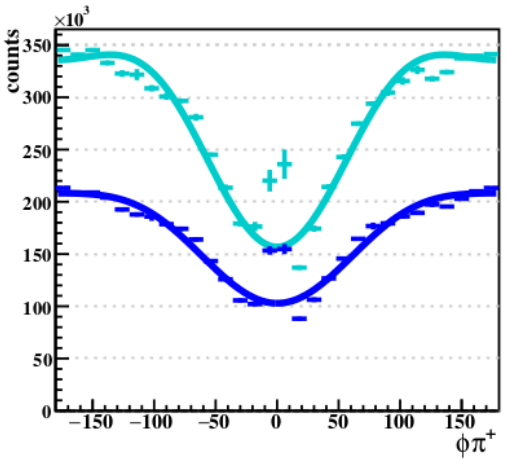
C

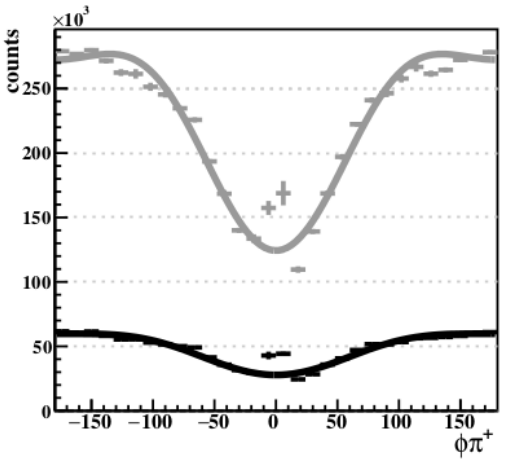
Fe

Pb

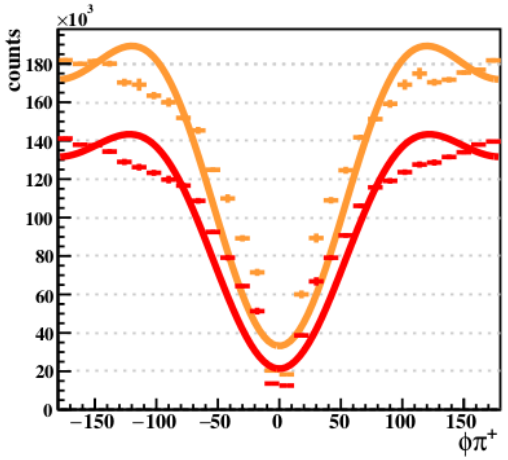
With peak at ~0

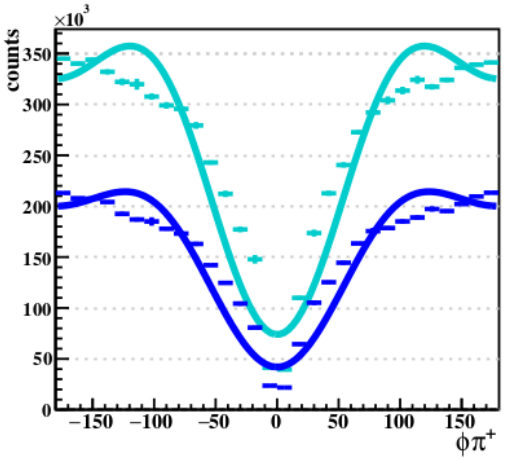


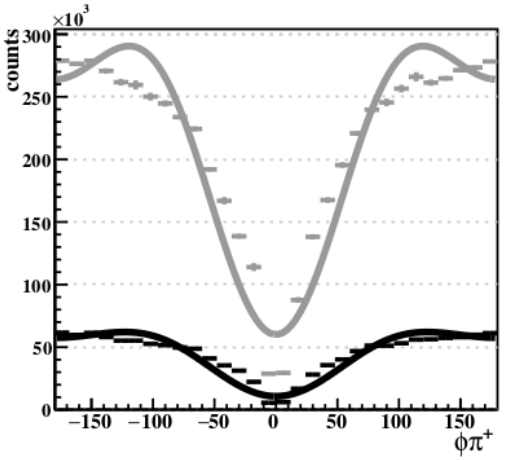




No peak at ~0







Fitting function: A + B cos(Φ) + C cos(2Φ)

Light color is the deuterium case

MR comparison between 4-fold and 5-fold acceptance correction