Updates in Color Propagation Analysis for Positive Pions

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Outline

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- Particle Identification Scheme:
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    - Positive pions
- Results:
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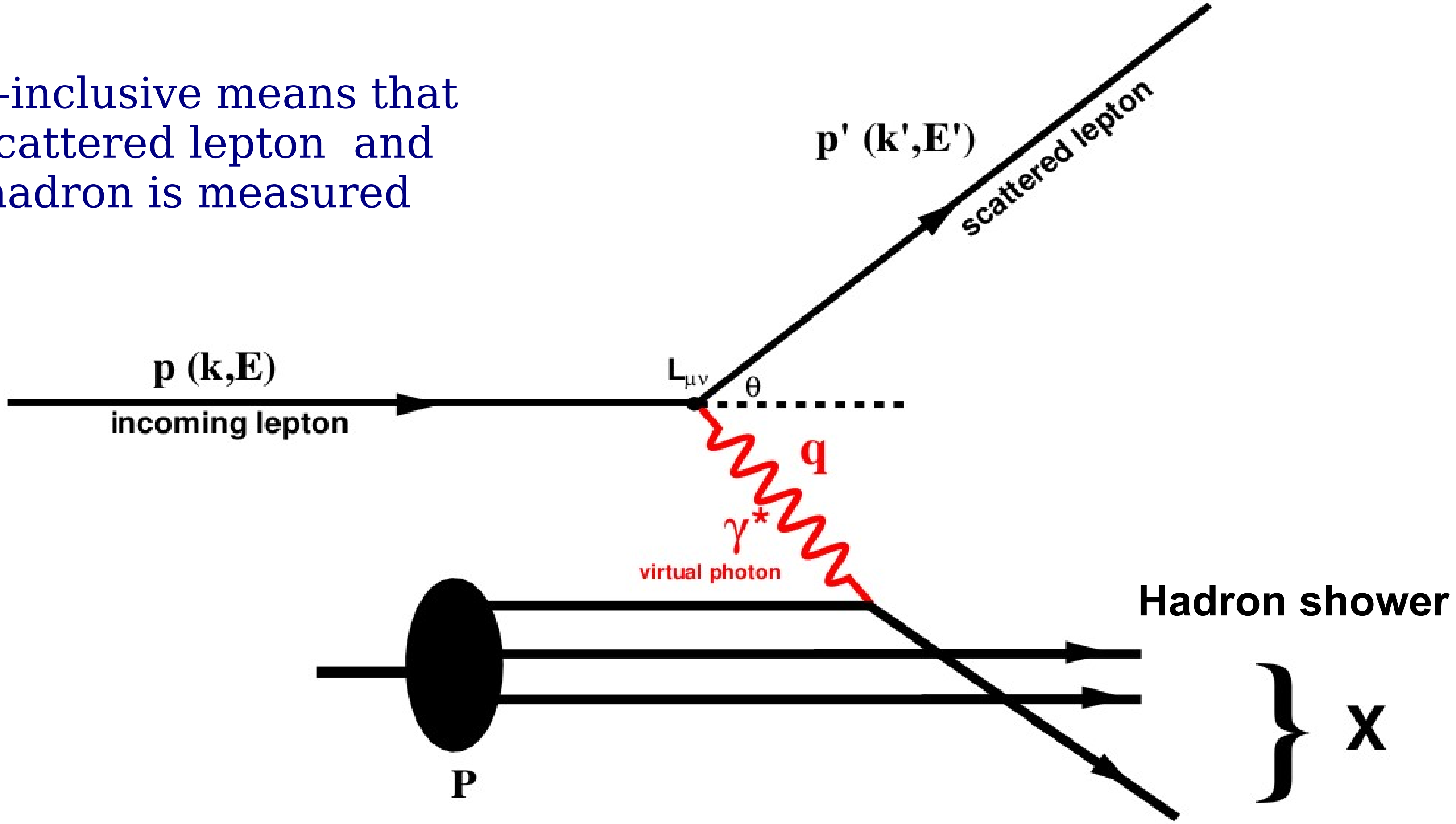
- Conclusion:
    - Final comments on the comparisons
    - Further studies

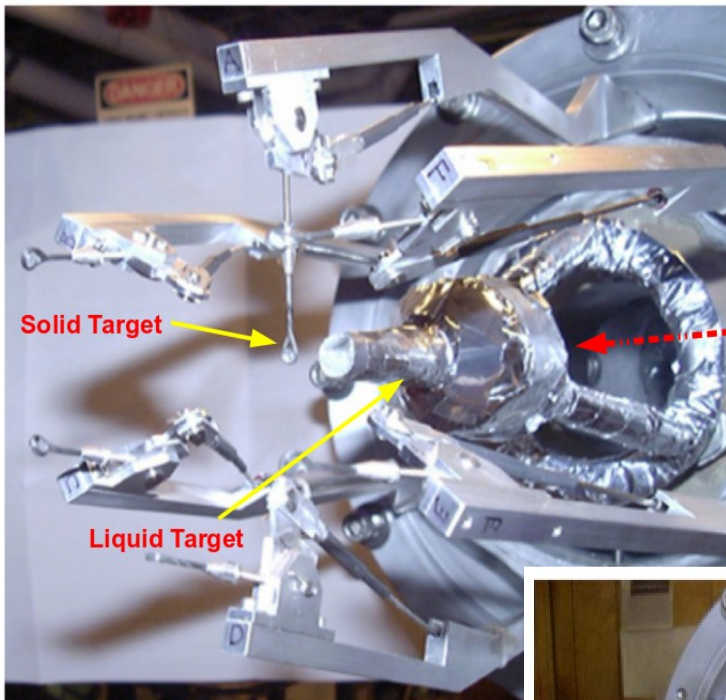
Semi-inclusive Deep Inelastic Scattering (SIDIS) of a lepton off a nucleon

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



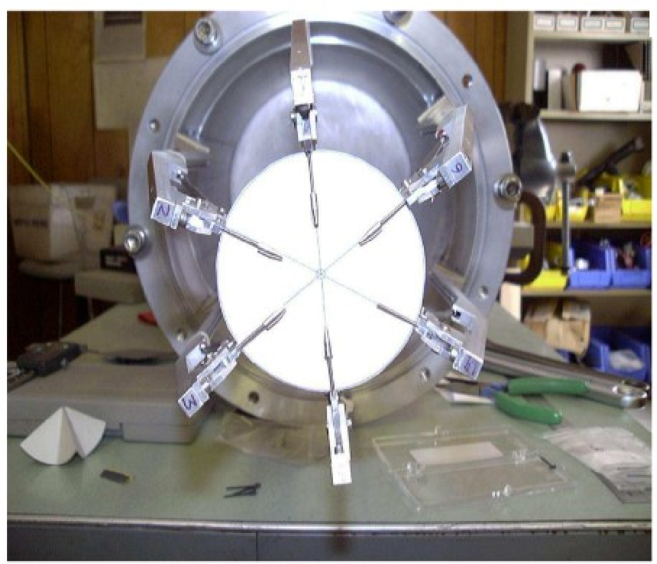
The CLAS Eg2 Experiment

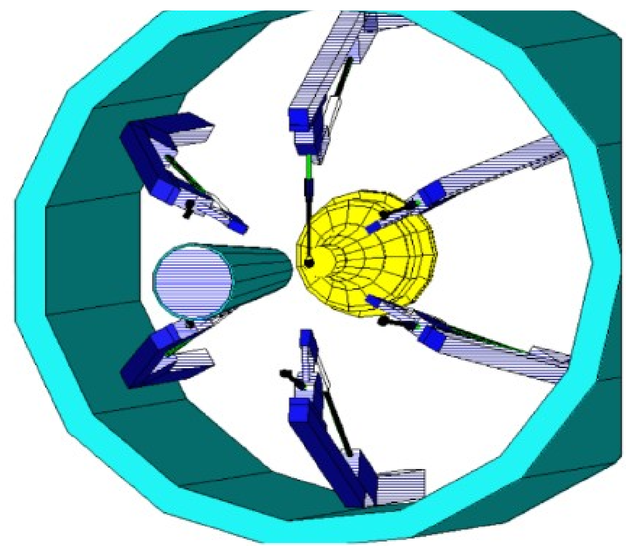
Two targets exposed to the beam **simultaneously**



Energy beam = 5.014 GeV

The run Eg2c took place during March 2004





Problem to address:

In our group we have two independent analysis, in this presentation are called:

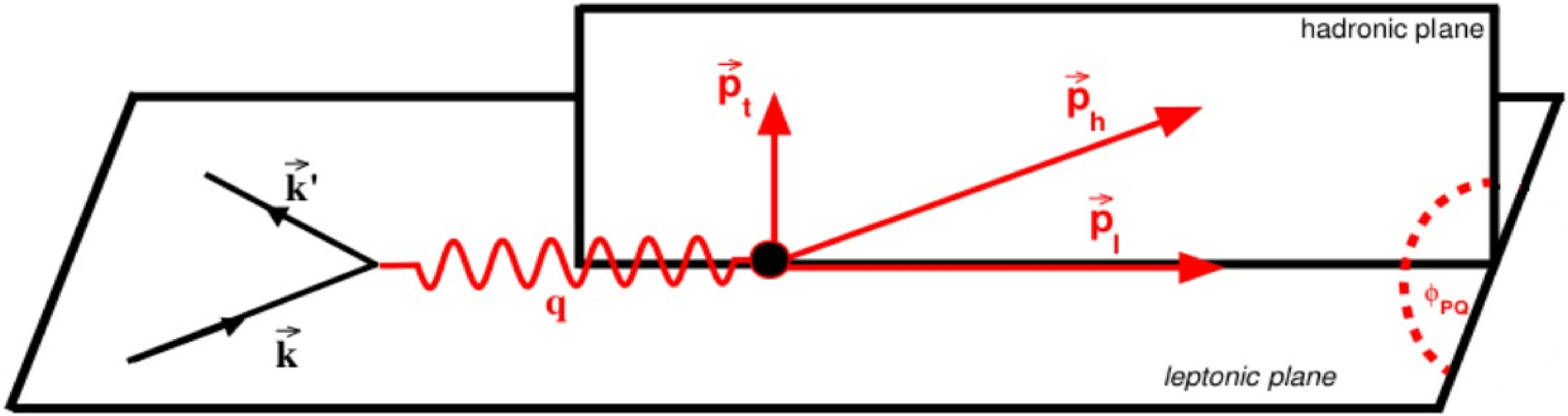
- Santa Maria University Analysis (**SMU**)
- Raphael Dupre Analysis (**RD**)

which gives different final results.

- Differences:
    - Particle Identification Criteria. (Different set of cuts)
    - Different choice of electron Vertex Cuts
    - Different Set of Simulations
    - Number of variables consider in the Acceptance Correction

The goal of this presentation is to explore the possible sources of this discrepancy, for that purpose two observables are consider, EMC ratio, and hadronic Multiplicty Ratio.

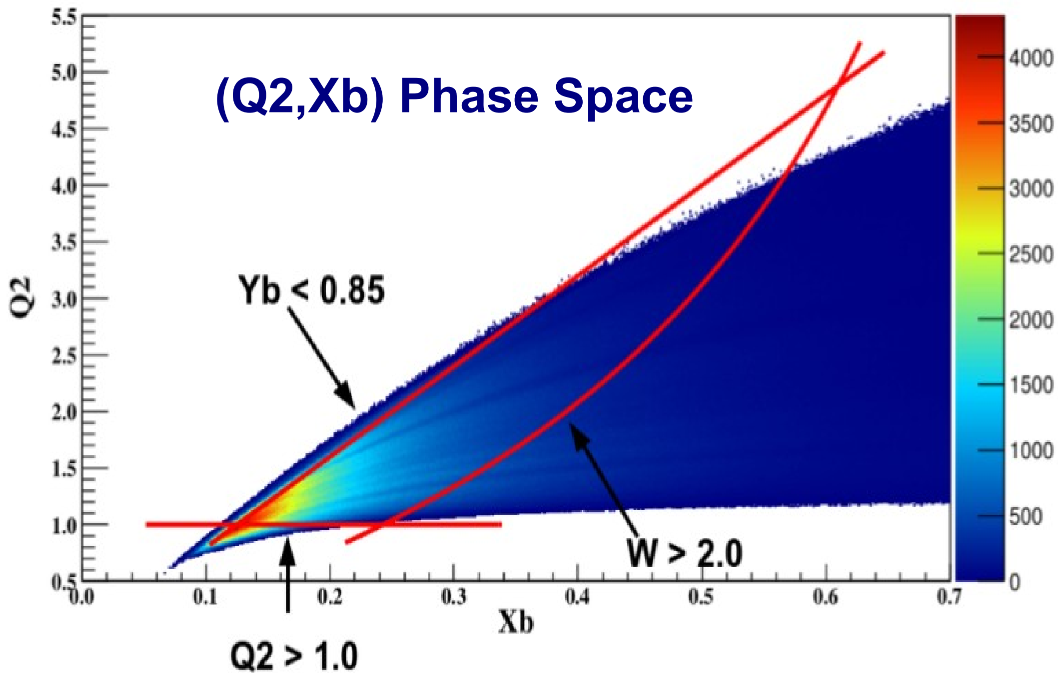
Experimental variables used in the Analysis:



- **Q2** = four momentum transferred by the electron [GeV^2].
- **Nu** = energy transferred by the incoming electron.
- **Zh** = fraction of the initial quark energy carried by the hadron.
- **Pt2** = hadron transverse momentum , to the virtual photon direction.
- **PhiPQ** = angle between the leptonic and hadronic plane.
- **Xb** = proton momentum fraction carried by the struck quark.
- **Ebeam** = 5.014 [GeV]

DIS kinematics

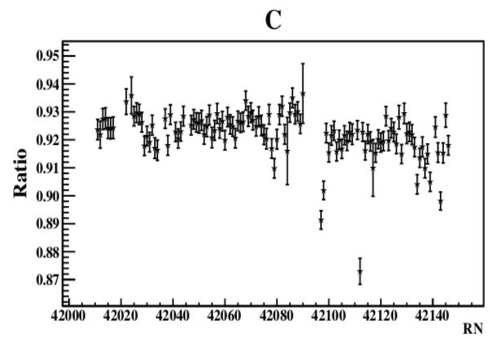
- **Q2 > 1.0** [GeV²], high energy, to get inside the proton
- **W > 2.0** [GeV] to avoid resonance region
- **Yb < 0.85**, to avoid regions where radiative corrections are large

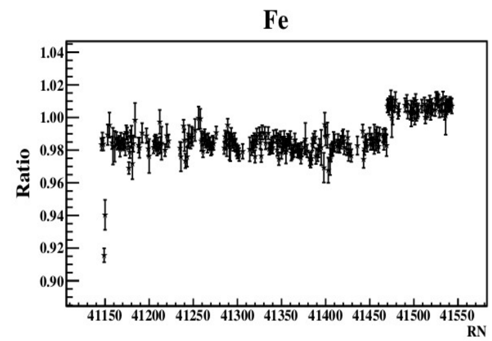


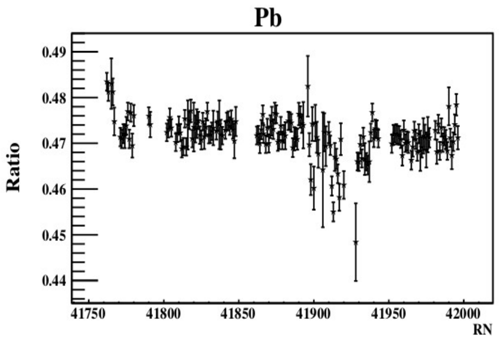
Run Numbers Set

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

The same run numbers are used in both analysis



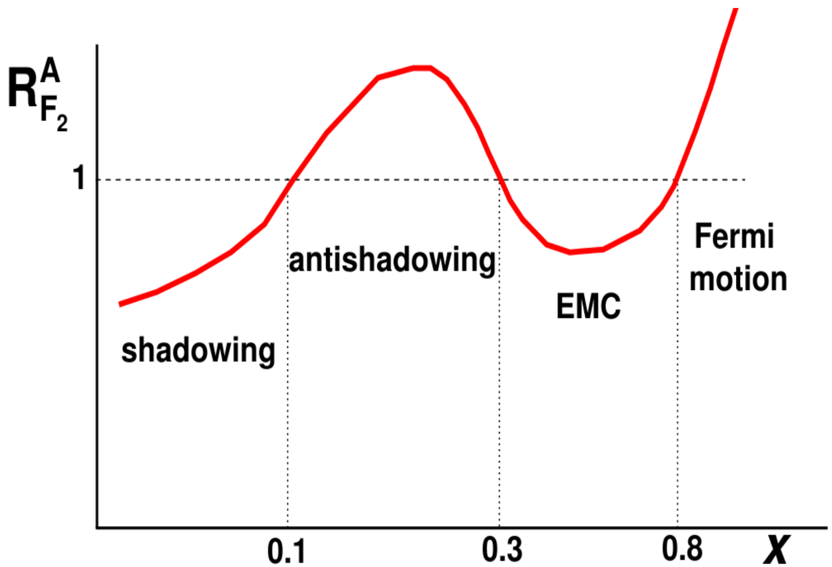




In order to compare the analysis, two observables are considered:

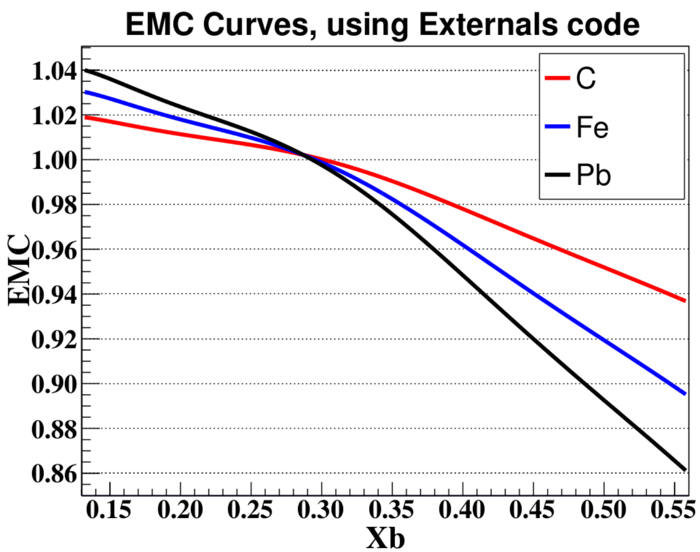
- **EMC Effect**

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



Only electrons

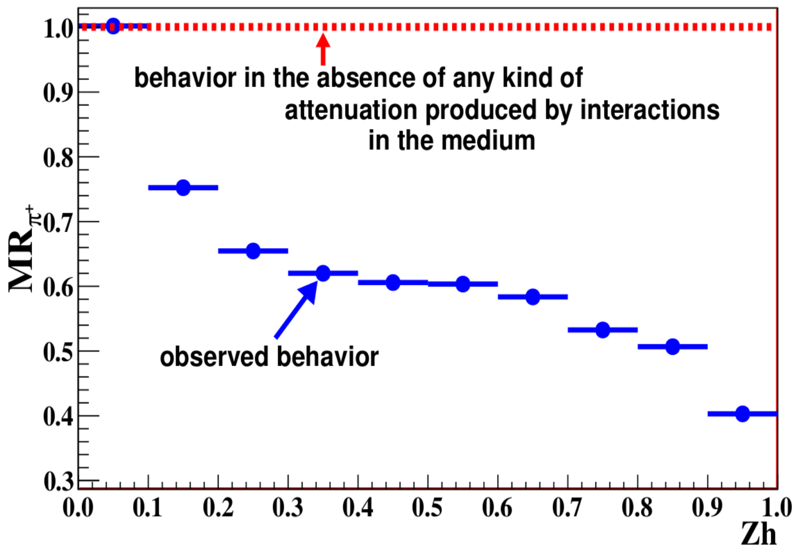
This ratio must be normalized by a factor related to the target thickness



, using the "Externals" code (by Dave Gaskell)

- **Hadronic Multiplicity Ratio**

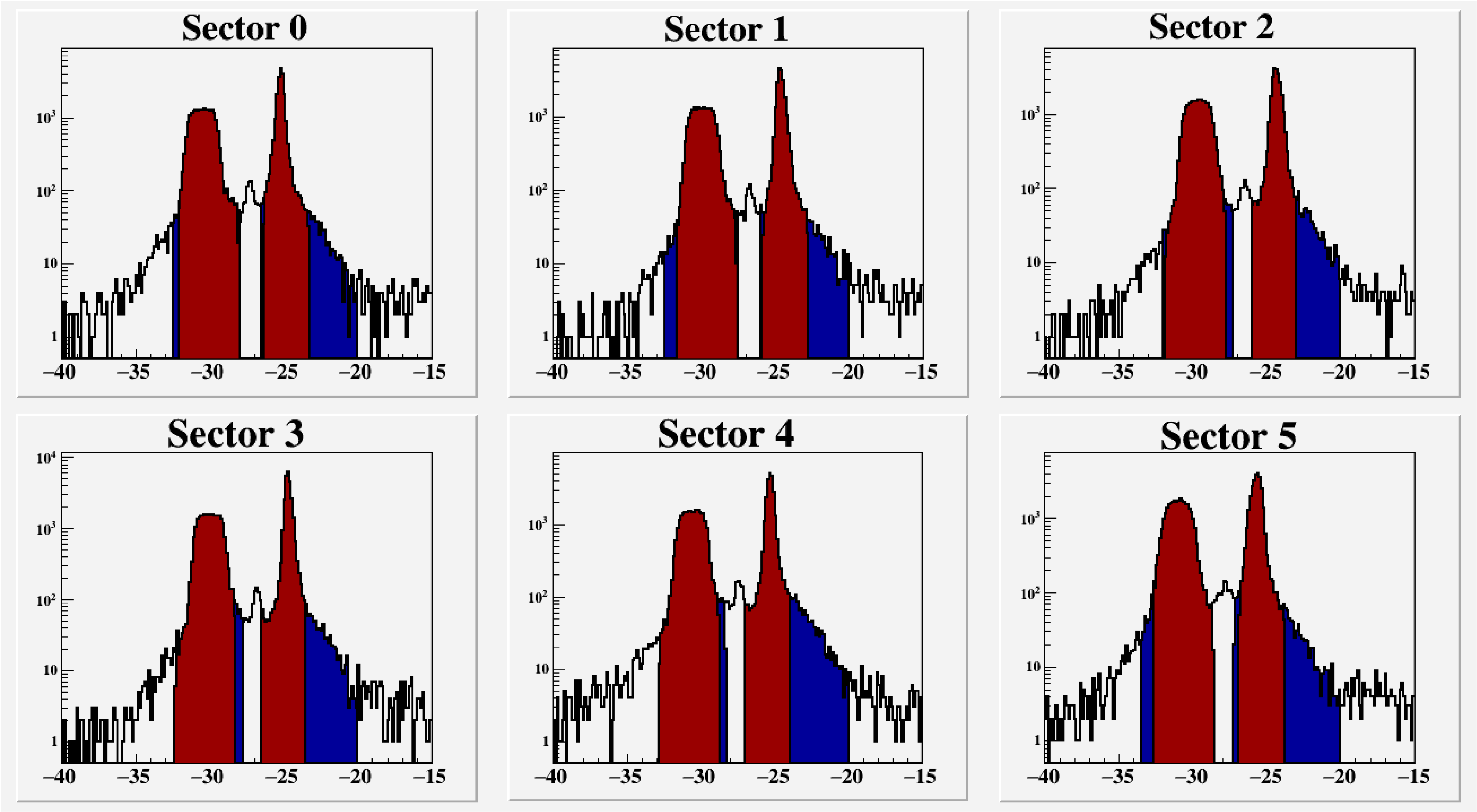
$$\mathrm{MR} \equiv \frac{\left(\dfrac{\mathrm{N}^{\mathrm{DIS}}_{\pi^+}}{\mathrm{N}^{\mathrm{DIS}}_{el-}}\right)_A}{\left(\dfrac{\mathrm{N}^{\mathrm{DIS}}_{\pi^+}}{\mathrm{N}^{\mathrm{DIS}}_{el-}}\right)_D}$$



Vertex cuts, for electrons

Z distributions, in cm, for all the six CLAS sectors

RD
SMU



SMU vertex are wider and target independent, meanwhile RD is narrower and target dependent

Particle Identification Scheme for electrons

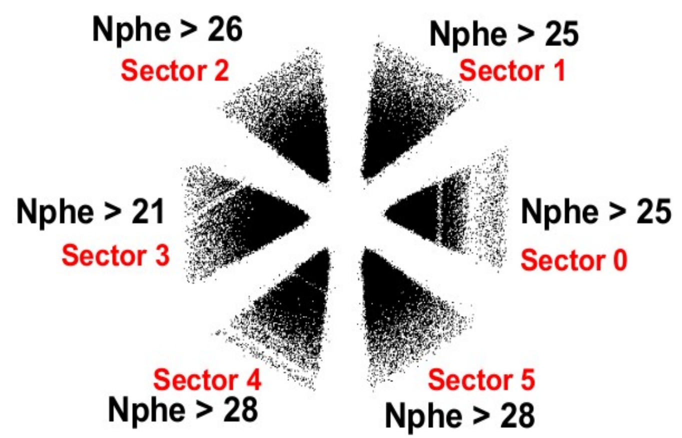
Both analysis agree on:

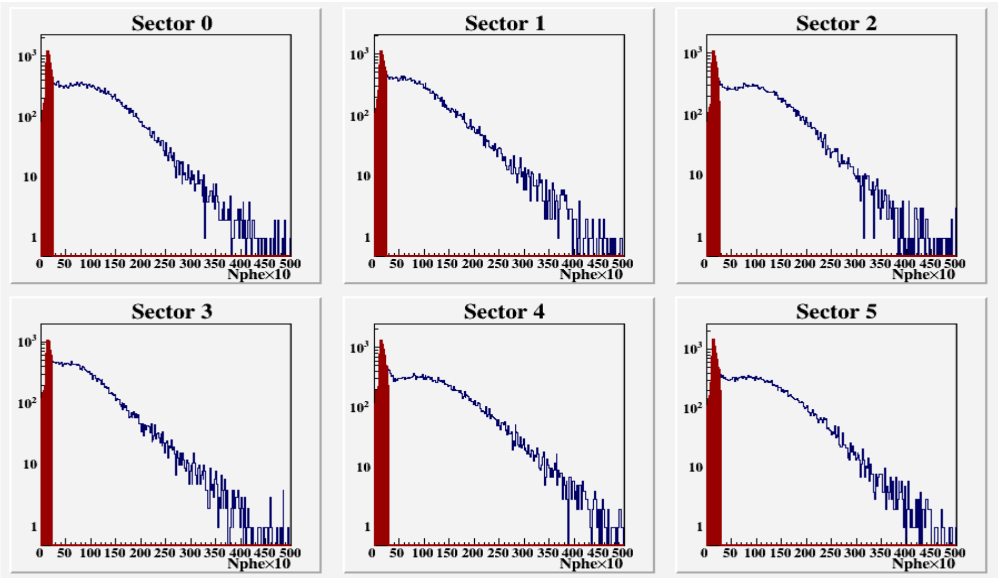
- The "good" electron cuts in the Banks (DC, SC,CC and EC)
- Negatively charged tracks
- Energy deposited in the inner part of the EC > 60 [MeV]

Both analysis are different in:

- Application of cuts in the energy deposited in the EC (Etot, Ein and Eout)
- Fiducial cuts in DC (SMU only)
- Number of photo-electron cut.
- Fiducial cuts in EC (RD only)
- Sampling Fraction Cut (SMU only)
- Coincidence time cut, Elapsed time between SC and EC (SMU only)

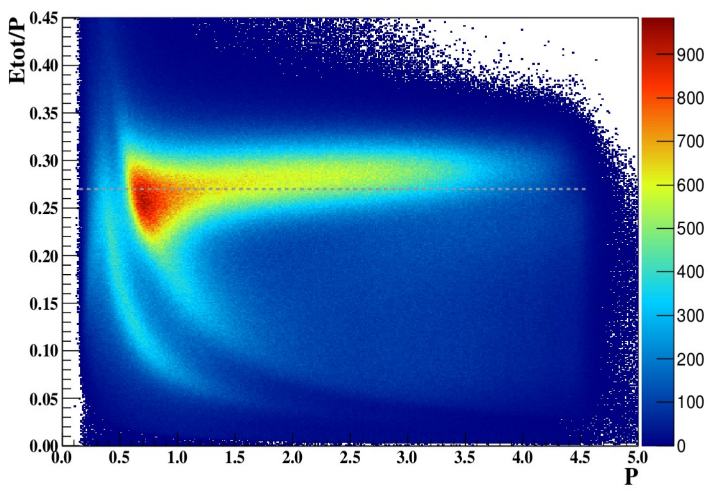
Number of Photo-electrons cut

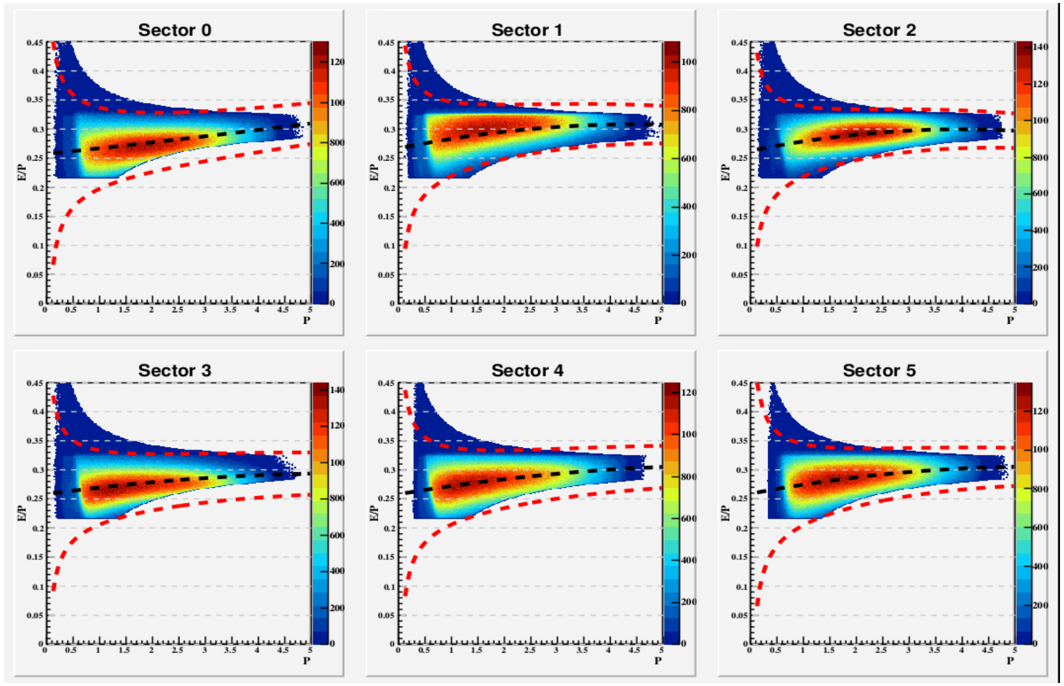




For RD analysis this cut is > 25 for all sectors, for SMU is sector dependent

Sampling Fraction cut (SMU only)

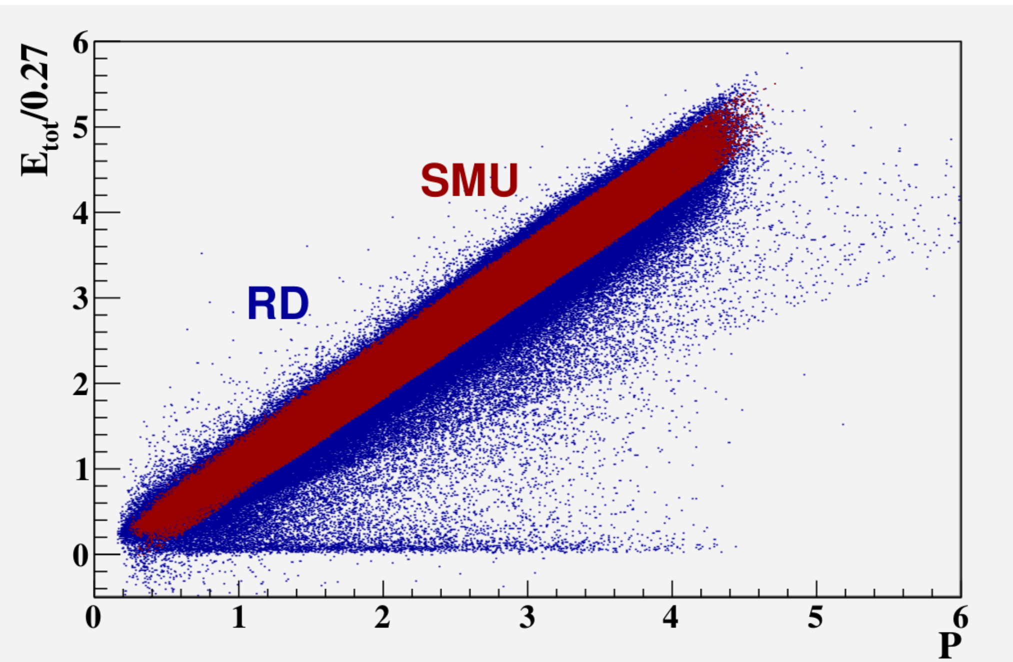


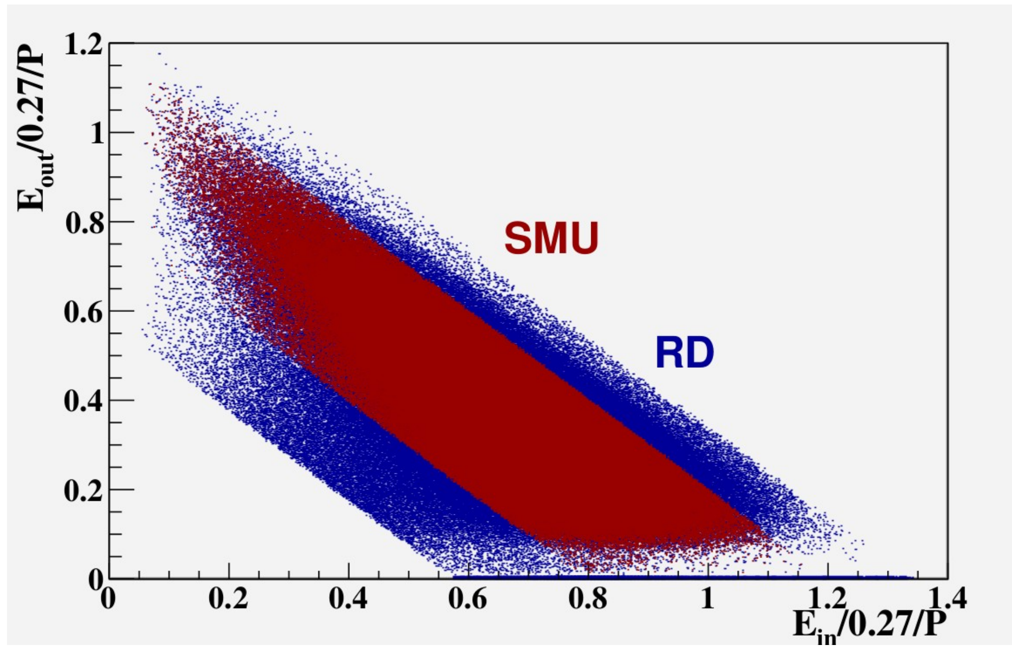


Energy deposited in the EC based cut

Energy deposited in the 13 layers of the EC = Energy deposited in the 5 innermost layers + Energy deposited in the 8 outermost layers

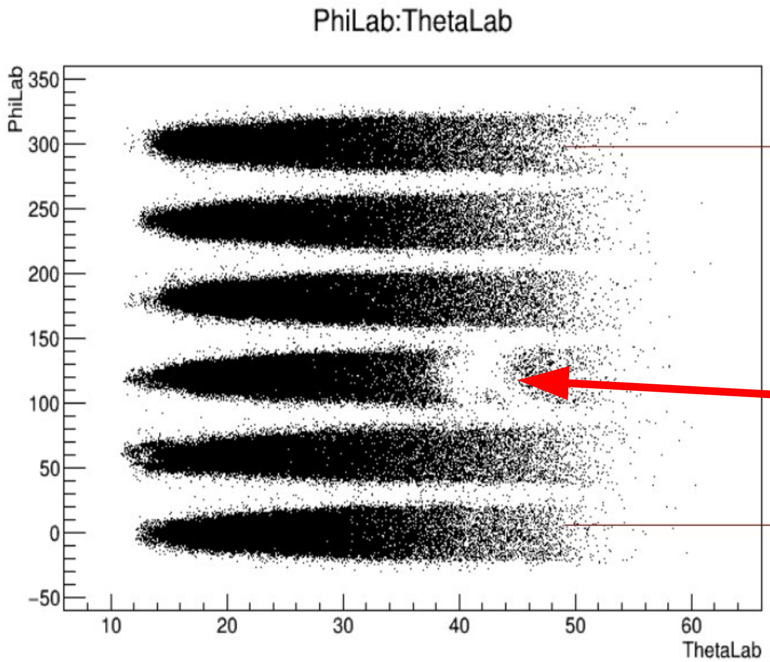
$$\underbrace{\text{Energy deposited in the 13 layers of the EC}}_{\text{Etot}} = \underbrace{\text{Energy deposited in the 5 innermost layers}}_{\text{Ein}} + \underbrace{\text{Energy deposited in the 8 outermost layers}}_{\text{Eout}}$$





Fiducial Cuts on DC (SMU only)

By Lorenzo Zana



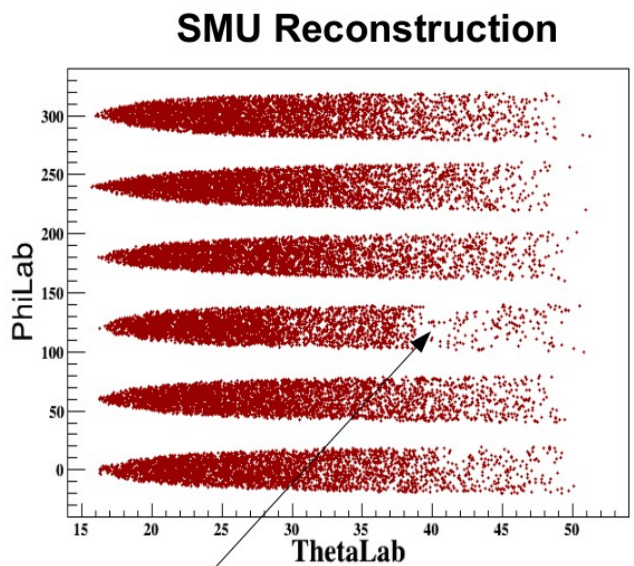
Sector 5
(between 270° and 330°)

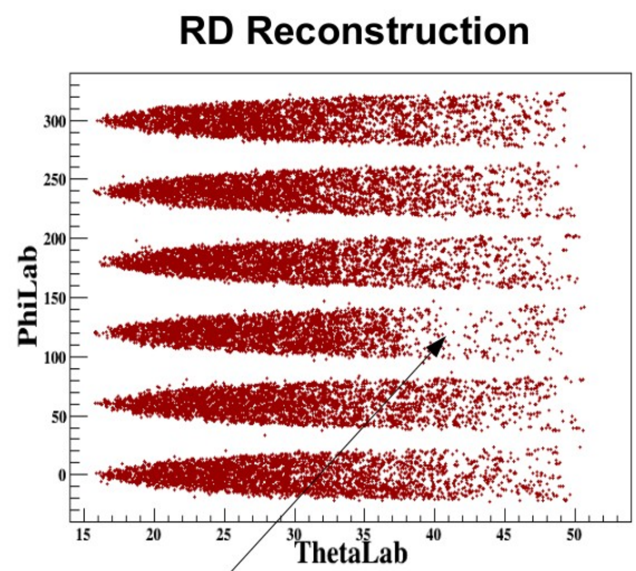
•
•
•

a “hole” in sector 2,
a dead channel

Sector 0
(between -30° and 30°)

Is observed in both simulations as well

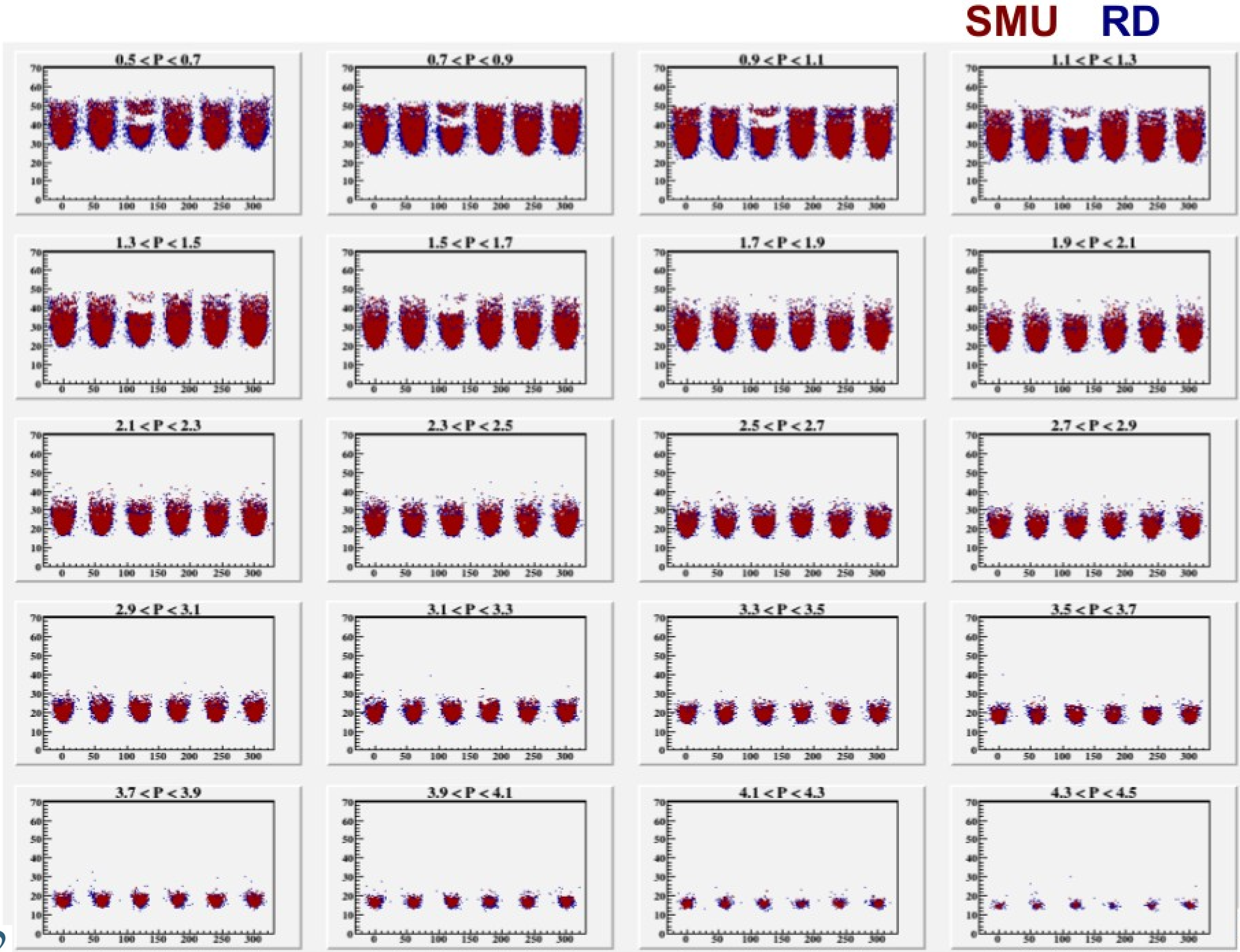




“hole”

“hole”

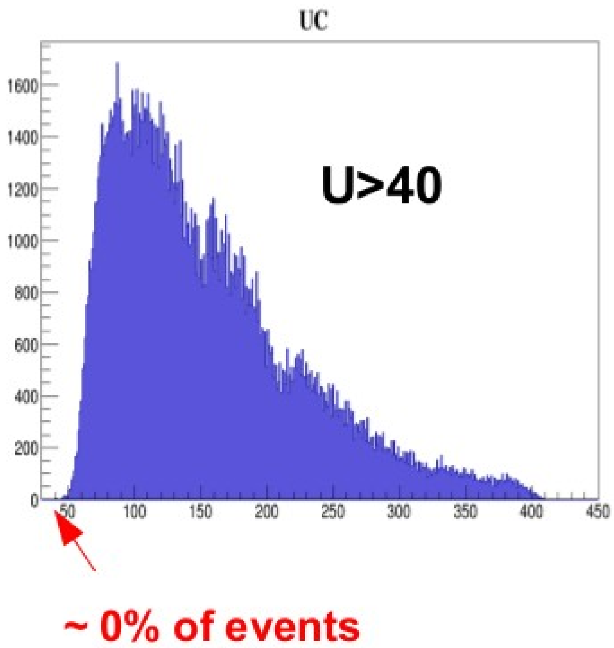
PhiLab (Y axis) v/s ThetaLab (X axis), for different momentum ranges.

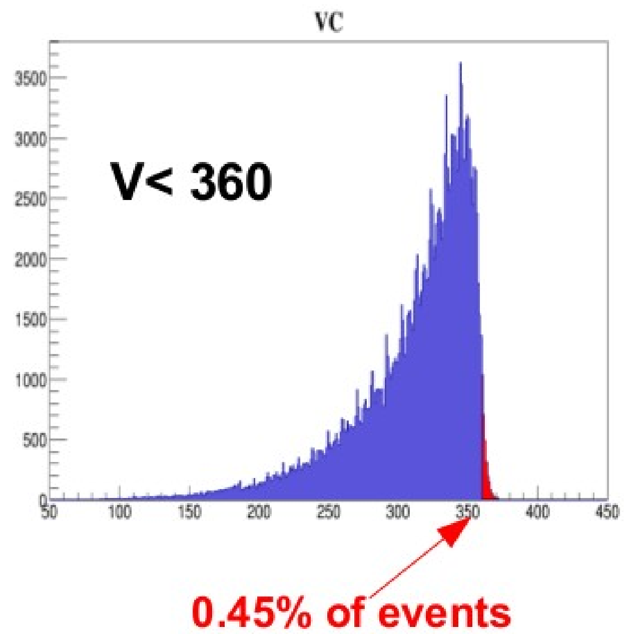


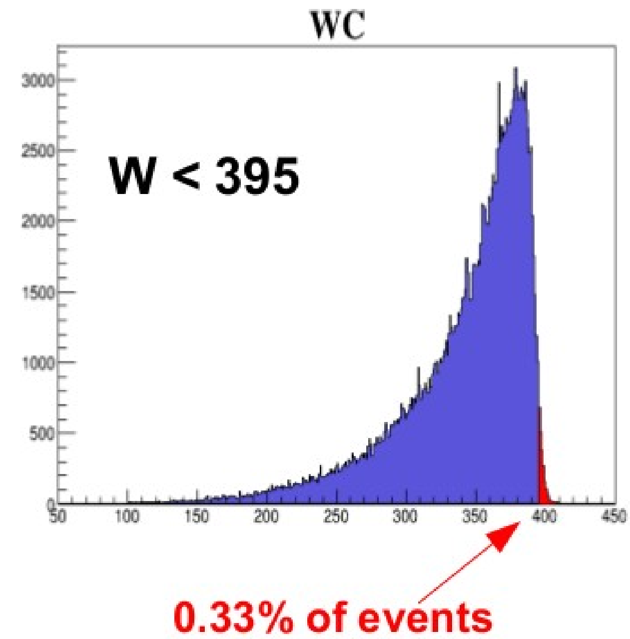
Fiducial Cuts on EC (RD only)

U, V and W are the “views” in the forward Electromagnetic Calorimeter

After all the cuts:





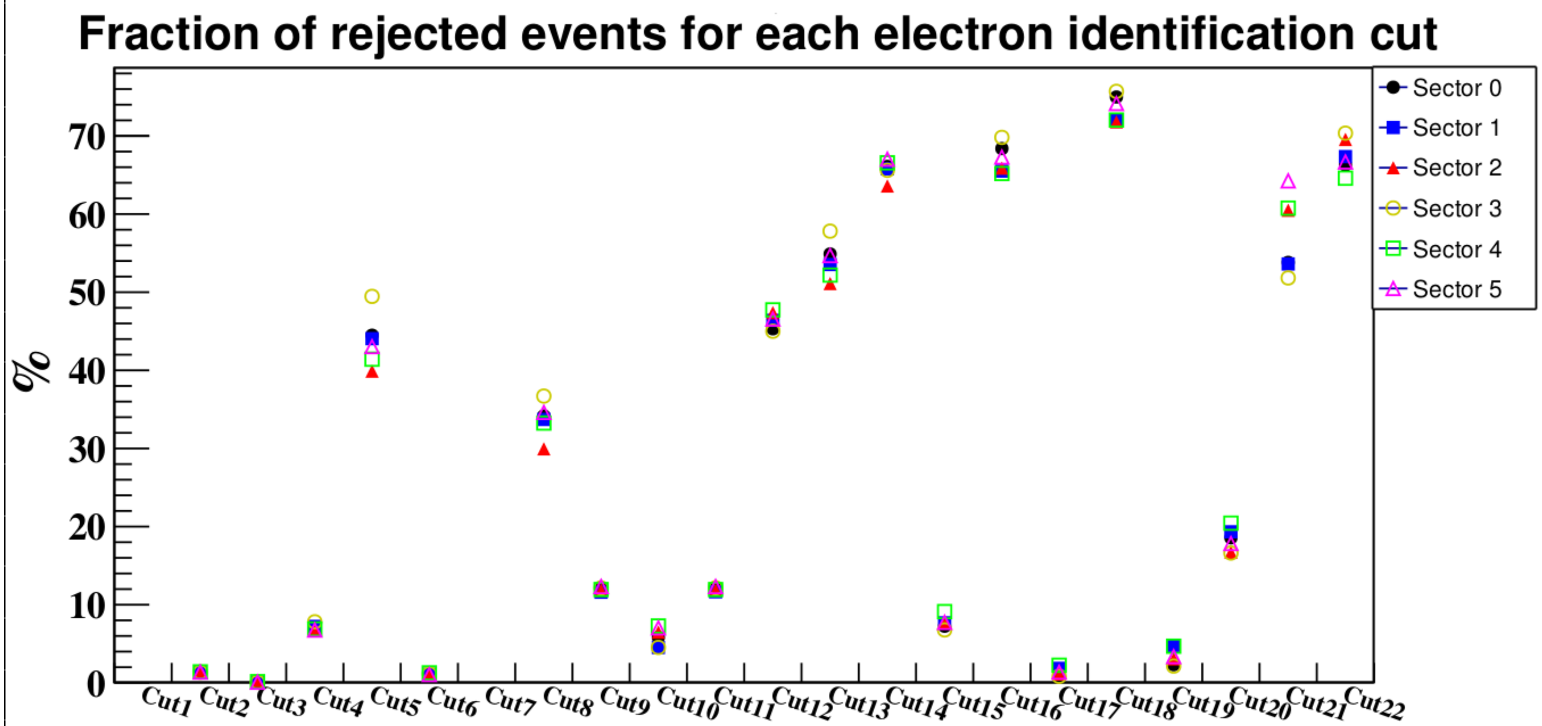


Good electrons after all the cuts are:

- **SMU** : **~28%** of all candidates are truly electrons
- **RD** : **~46%** of all candidates are truly electrons

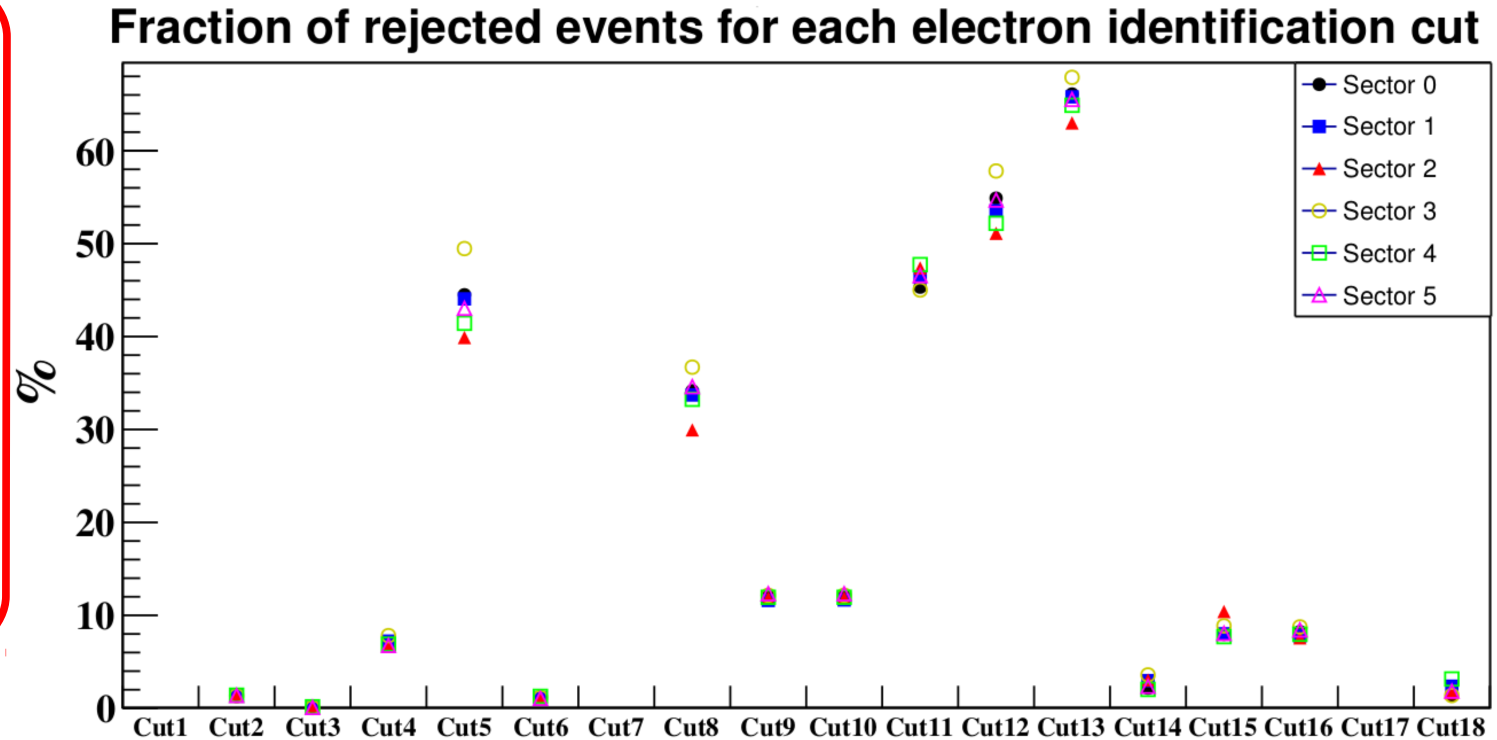
SMU case

Cut1	numberDC != 0
Cut2	numberEC != 0
Cut3	numberSC != 0
Cut4	numberCC != 0
Cut5	StatCC > 0
Cut6	StatSC > 0
Cut7	StatDC > 0
Cut8	StatEC > 0
Cut9	DCStatus > 0
Cut10	SCStatus =33
Cut11	0 < Status <100
Cut12	Charge=-1
Cut13	Ein> 0.06
Cut14	Nphe cut
Cut15	DeltaT < 5×0.35
Cut16	Etot/1,15 + 0,4 > P
Cut17	Etot/1,15 − 0,2 < P
Cut18	Ein+Eout> 0,8 × P
Cut19	Ein+Eout< 1,2 × P
Cut20	Eout ! =0
Cut21	Fiducial Cut
Cut22	Sampling Fraction



RD case

Cut1	numberDC != 0
Cut2	numberEC != 0
Cut3	numberSC != 0
Cut4	numberCC != 0
Cut5	StatCC > 0
Cut6	StatSC > 0
Cut7	StatDC > 0
Cut8	StatEC > 0
Cut9	DCStatus > 0
Cut10	0 < Status <100
Cut11	Charge=-1
Cut12	Ein> 0.06
Cut13	Nphe > 25
Cut14	U(EC)>40
Cut15	V(EC)<360
Cut16	W(EC)<395
Cut17	$E_{in}+E_{out} > 0{,}15P$
Cut18	$E_{in}+E_{out} <$ term2



Same as **SMU**

Results

Binning information:

- 10 bins in Xb, between 0.12 and 0.57, equal width.
- 10 bins in Q2, between 1.0 and 4.0, equal width.

Acceptance Correction Method: Bin by Bin application.

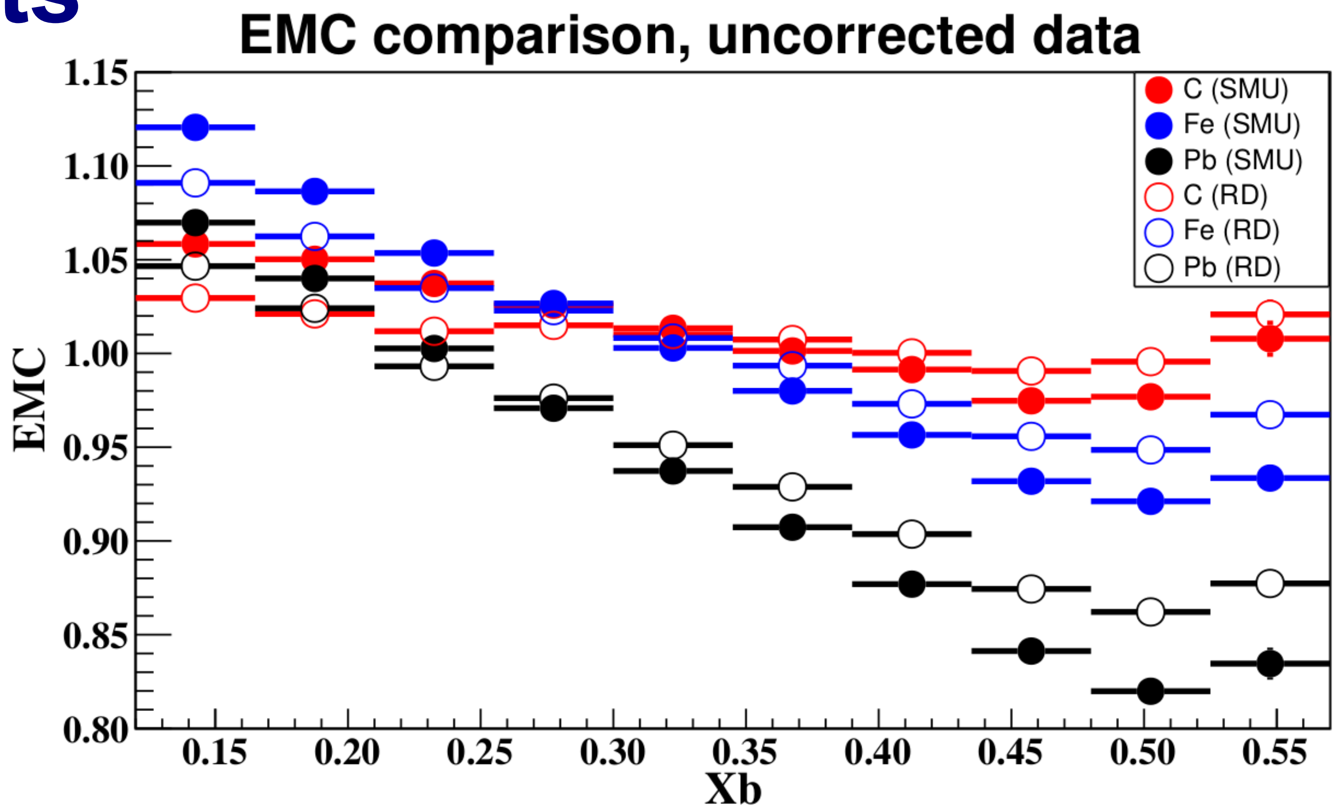
For Hadronic Multiplicity Ratio, the set of variables used in the acceptance correction are:

- Zh, 10 bins between 0. and 1.0
- Pt2, 5 bins between 0 and 1.0
- Q2, 6 bins between 1.0 and 4.0
- Xb, 5 bins between 0.12 and 0.57

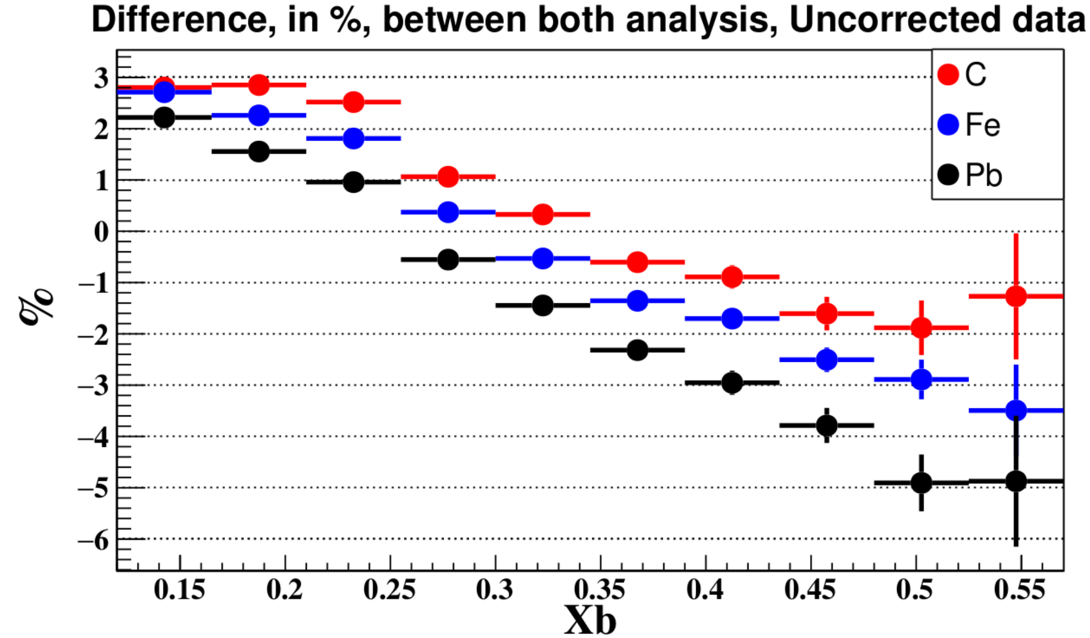
This is called “4D”, the “5D” case is taking into account Phi as well.

It was found that the vertex cuts choice make a big impact in the final result, so, for simplicity the results are with the same vertex cuts (SMU's)

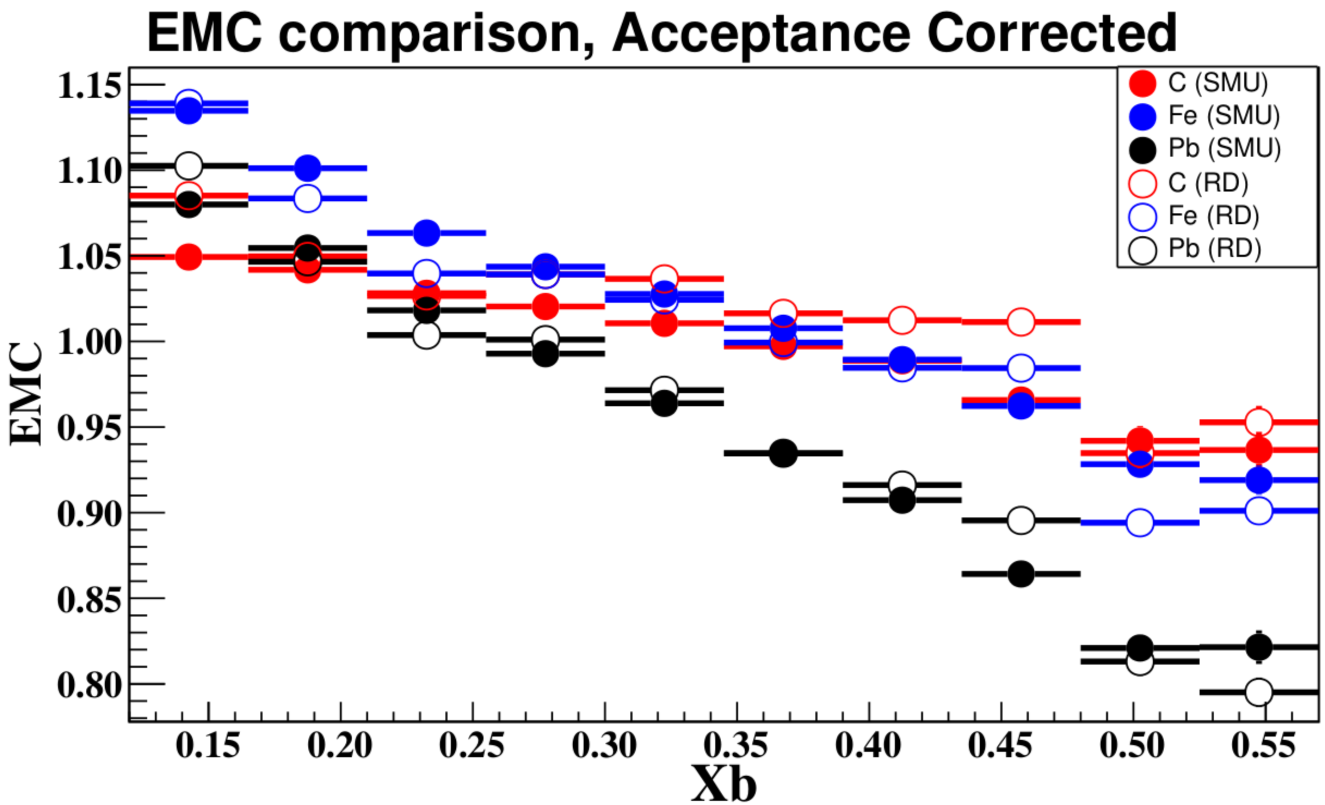
Results

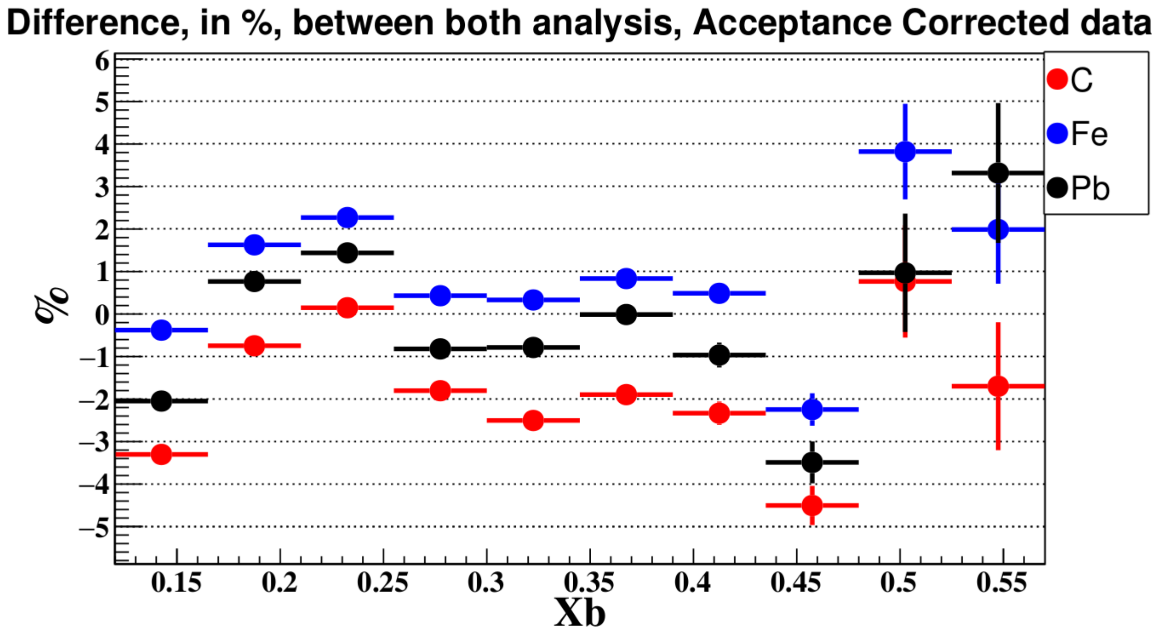


EMC comparison, uncorrected data
C (SMU)
Fe (SMU)
Pb (SMU)
C (RD)
Fe (RD)
Pb (RD)
EMC
Xb
1.15
1.10
1.05
1.00
0.95
0.90
0.85
0.80
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
0.55



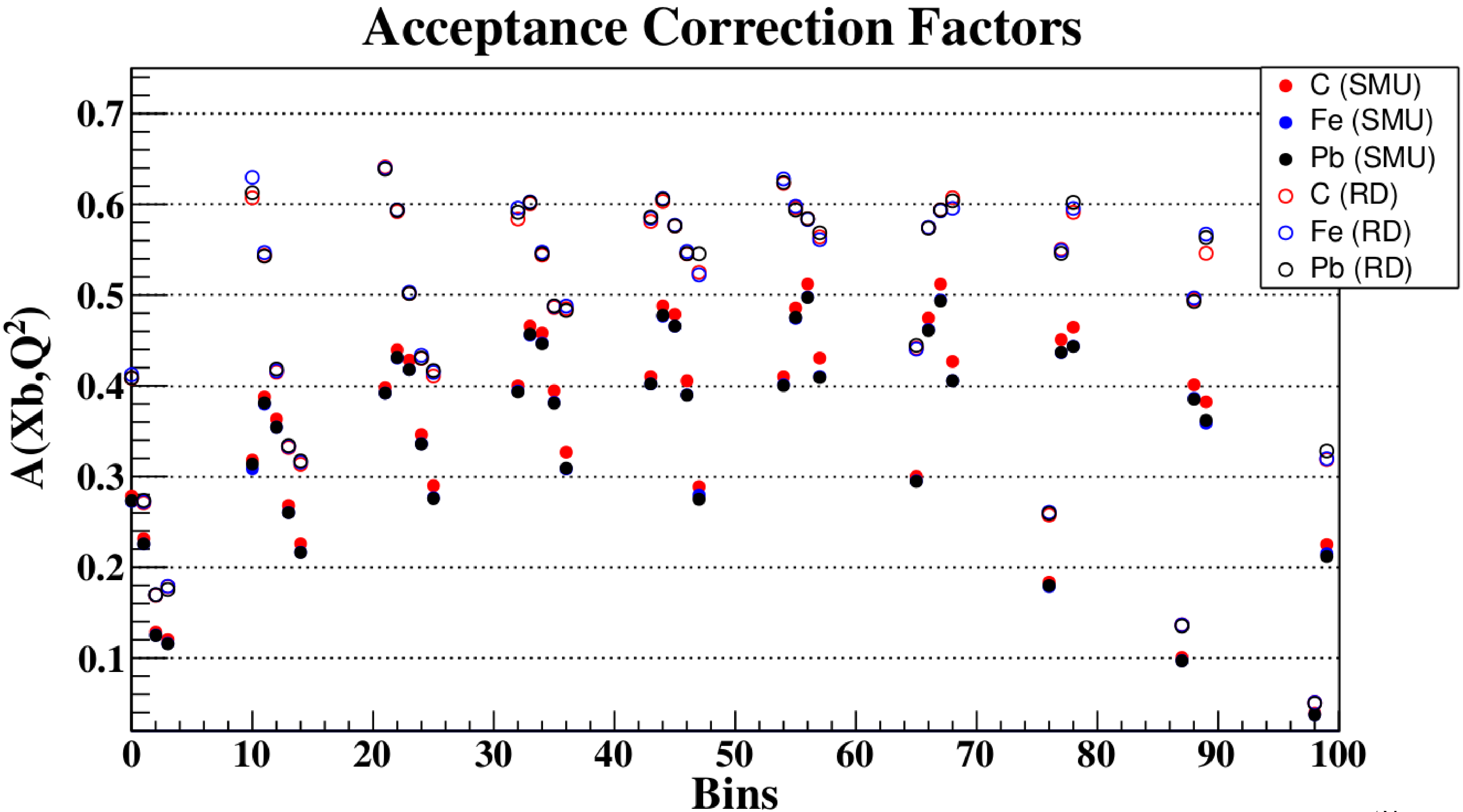
Difference, in %, between both analysis, Uncorrected data
C
Fe
Pb
%
Xb
3
2
1
0
−1
−2
−3
−4
−5
−6
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
0.55


EMC comparison, Acceptance Corrected
C (SMU)
Fe (SMU)
Pb (SMU)
C (RD)
Fe (RD)
Pb (RD)
EMC
Xb

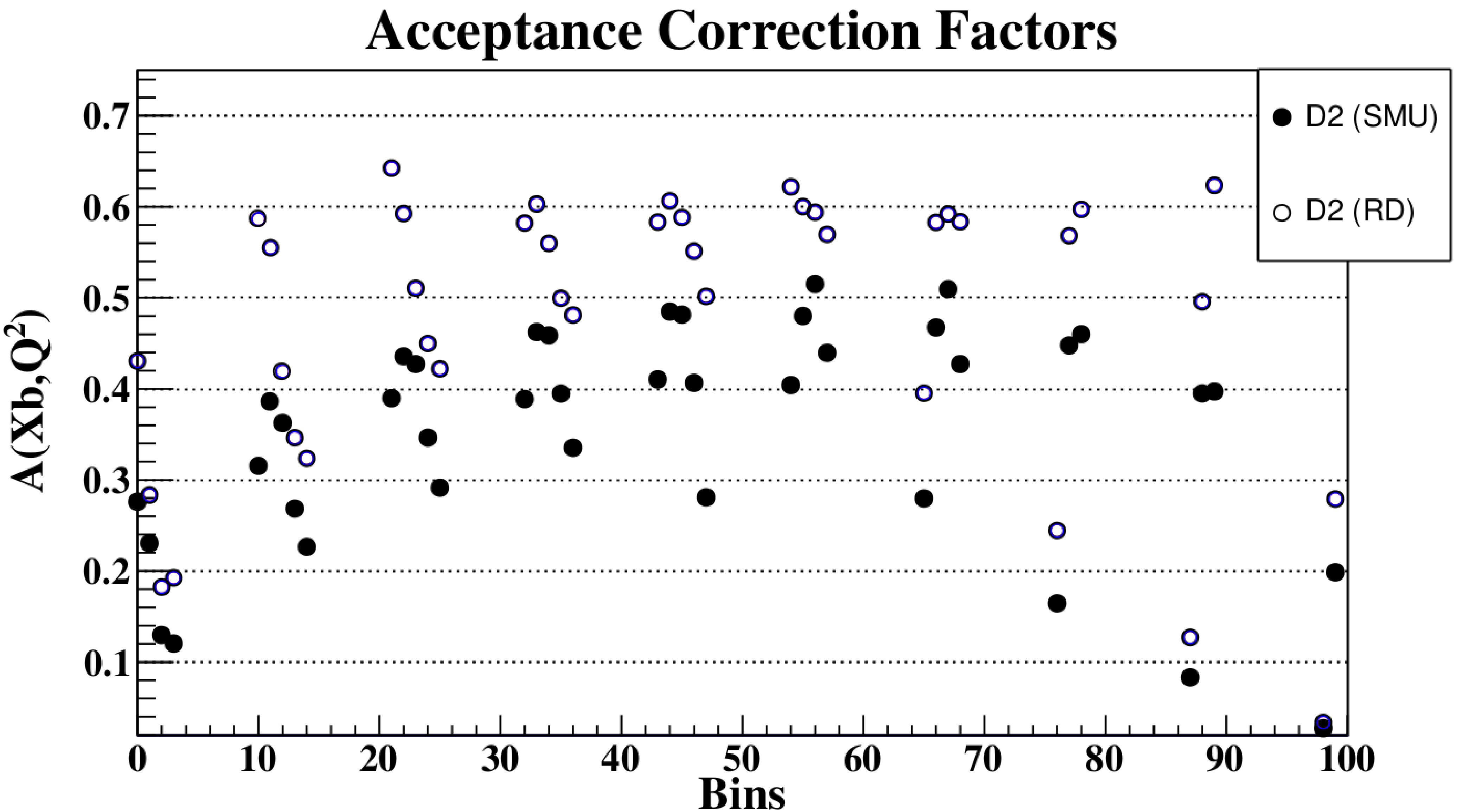

Difference, in %, between both analysis, Acceptance Corrected data
C
Fe
Pb
%
Xb

Acceptance Correction applied

10 bins in Q2, 10 bins in Xb = 100 bins → 100 Acceptance Factors (a lot of them are zero)



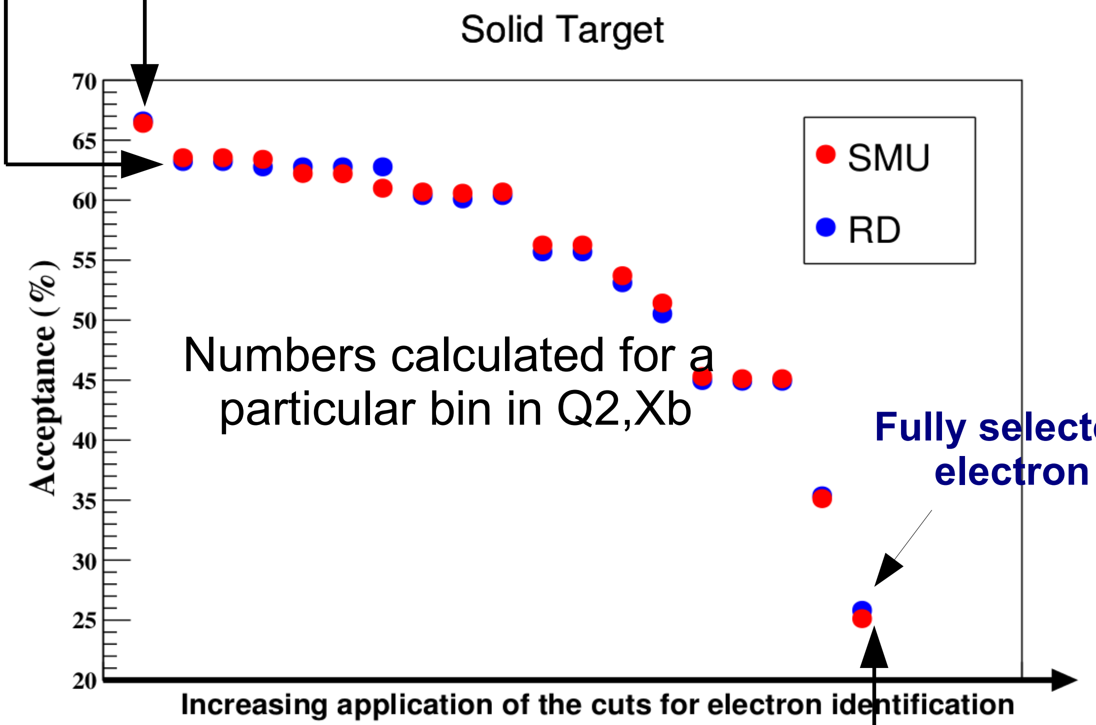
For deuterium

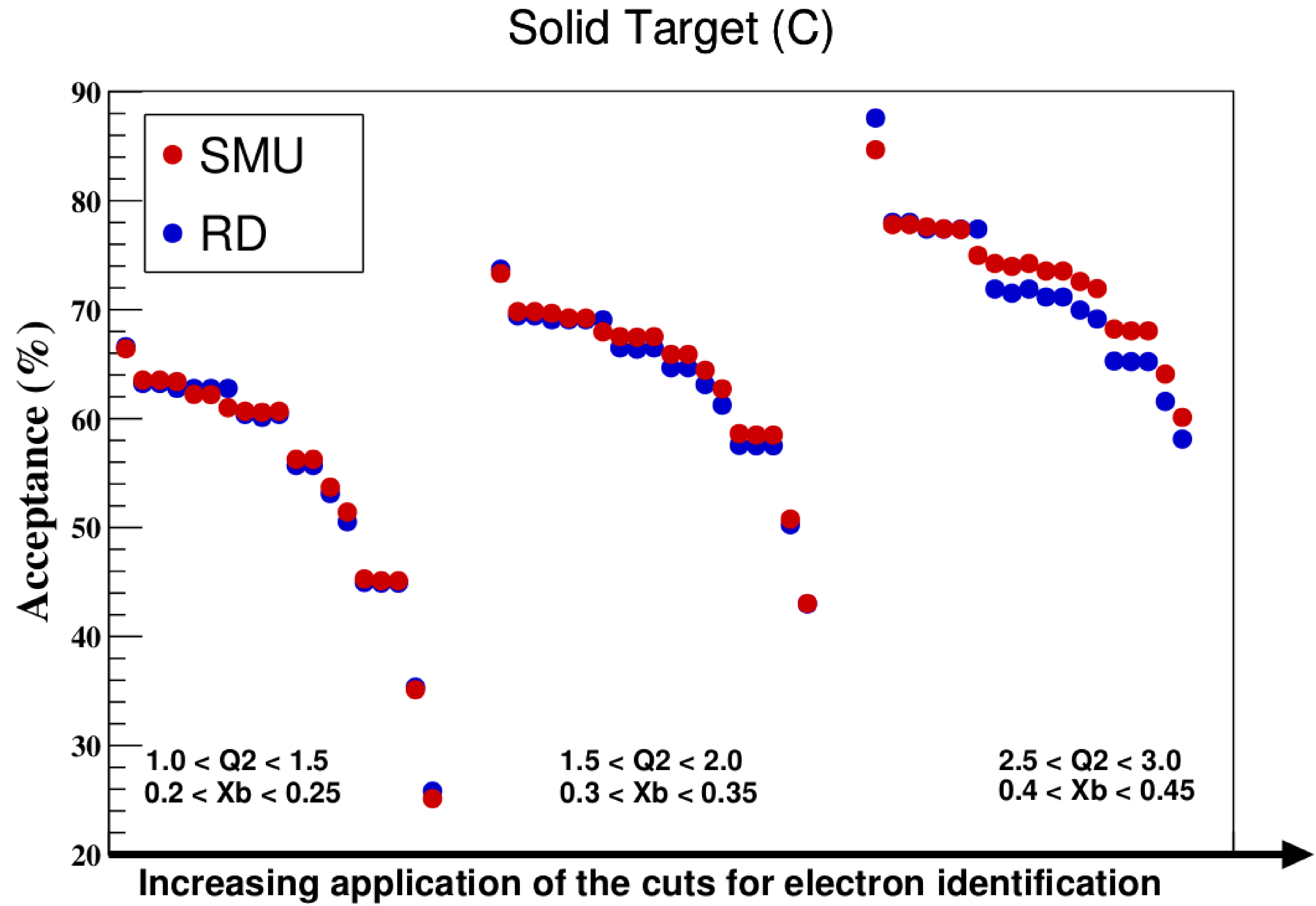


Comparison between both simulations in the acceptance (in %), for each cut in the electron selection.
In the table is shown all the cuts to select electrons according to **RD** analysis.
The cuts here are **accumulative**.

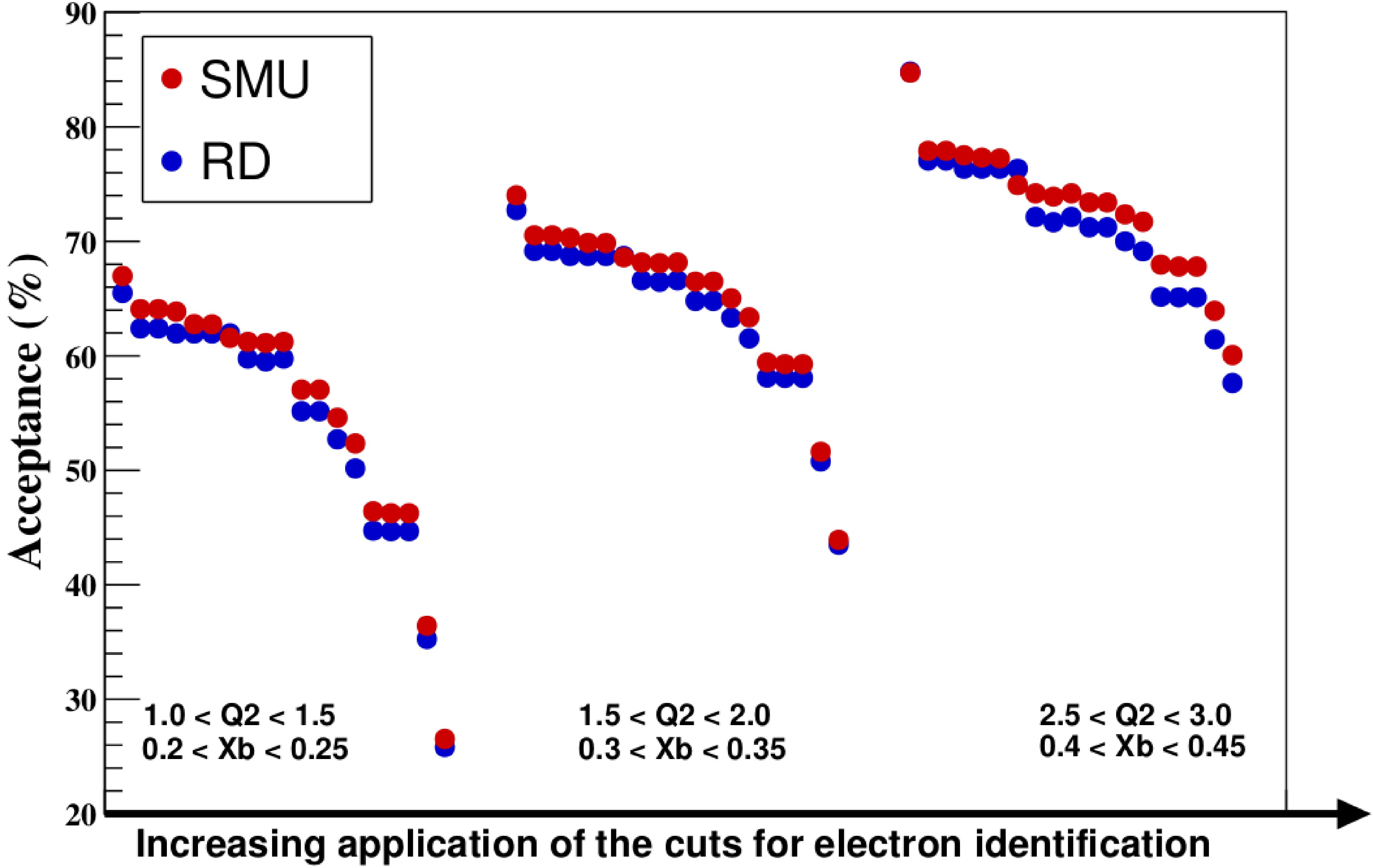
	Cut
Cut 1	Bin selected + DIS
Cut 2	+ Charge == -1
Cut 3	+ $number_{dc}$ $! = 0$
Cut 4	+ $Status > 0$
Cut 5	+ $number_{ec}$ $! = 0$
Cut 6	+ $number_{sc}$ $! = 0$
Cut 7	+ $number_{cc}$ $! = 0$
Cut 8	+ $StatCC > 0$
Cut 9	+ $StatSC > 0$
Cut 10	+ $StatDC > 0$
Cut 11	+ $StatEC > 0$
Cut 12	+ $DCStatus > 0$
Cut 13	+ $Ein > 0{,}06$
Cut 14	+ $Nphe > 25$
Cut 15	+ $term1 >= constTerm$
Cut 16	+ $term1 <= term2$
Cut 17	+ $U_{EC} > 40$
Cut 18	+ $V_{EC} < 360$
Cut 19	+ $W_{EC} < 395$

Cut Flow Plot



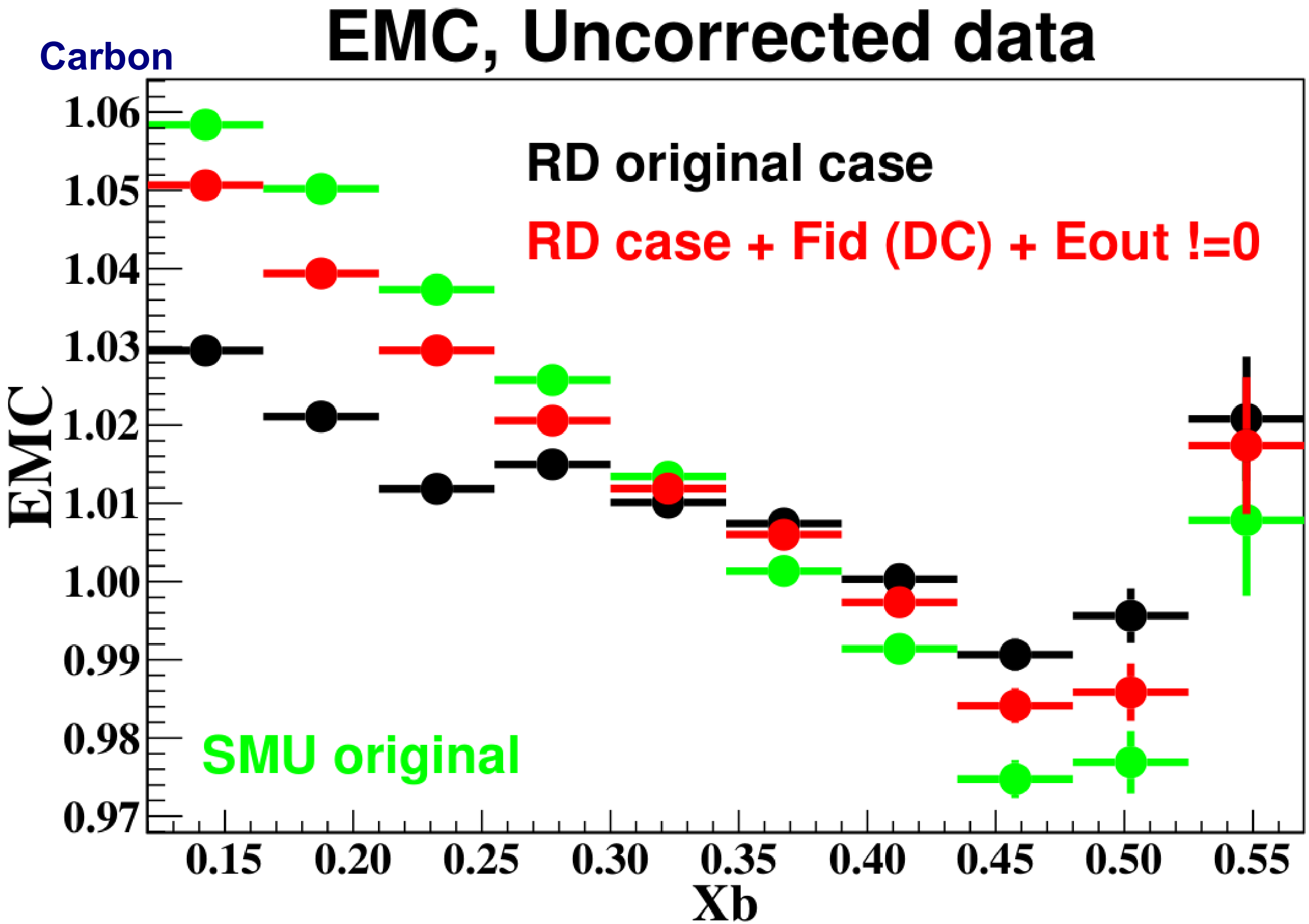

Solid Target (C)
SMU
RD
Acceptance (%)
90
80
70
60
50
40
30
20
1.0 < Q2 < 1.5
0.2 < Xb < 0.25
1.5 < Q2 < 2.0
0.3 < Xb < 0.35
2.5 < Q2 < 3.0
0.4 < Xb < 0.45
Increasing application of the cuts for electron identification

Liquid Target (D2)



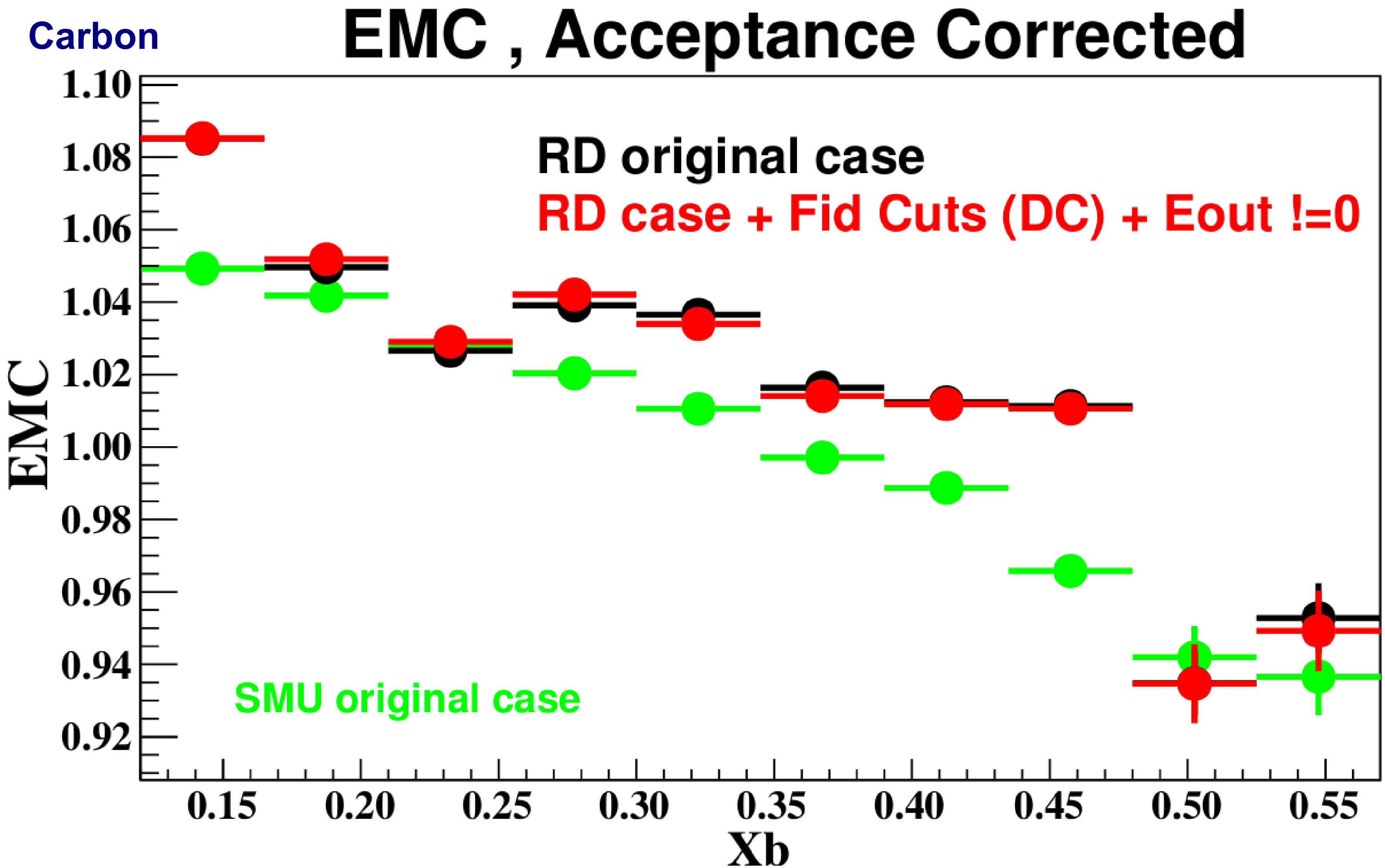
Imposing two additional cuts in RD case:

- Fiducial cuts on DC.
- Not null energy deposited in the outer part of the calorimeter.

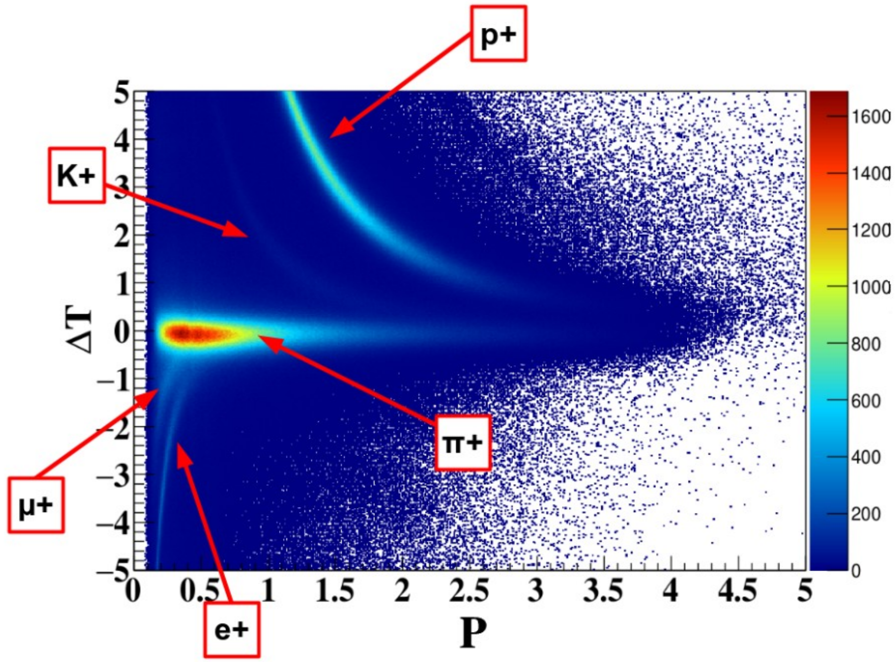


The discrepancy between both analysis **decrease**, at an uncorrected level.

For the acceptance corrected curve, the two additional cuts basically **makes no difference**, the discrepancy between both analysis remains.



Positive Pion Identification Scheme



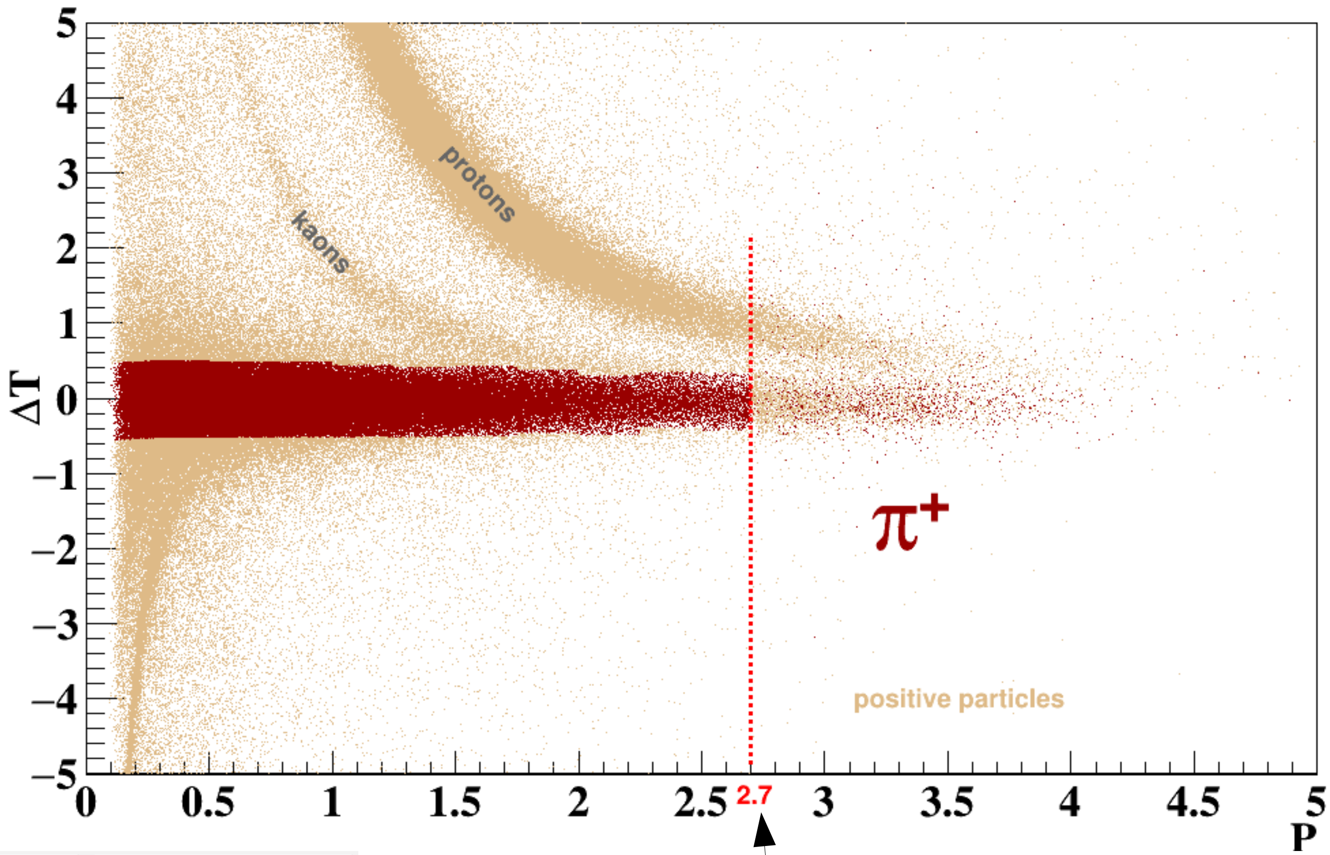
SMU case:

- Positive particles divided into two groups:
  - P<2.7 → **T.O.F** technique
  - P>2.7 → **CC** technique

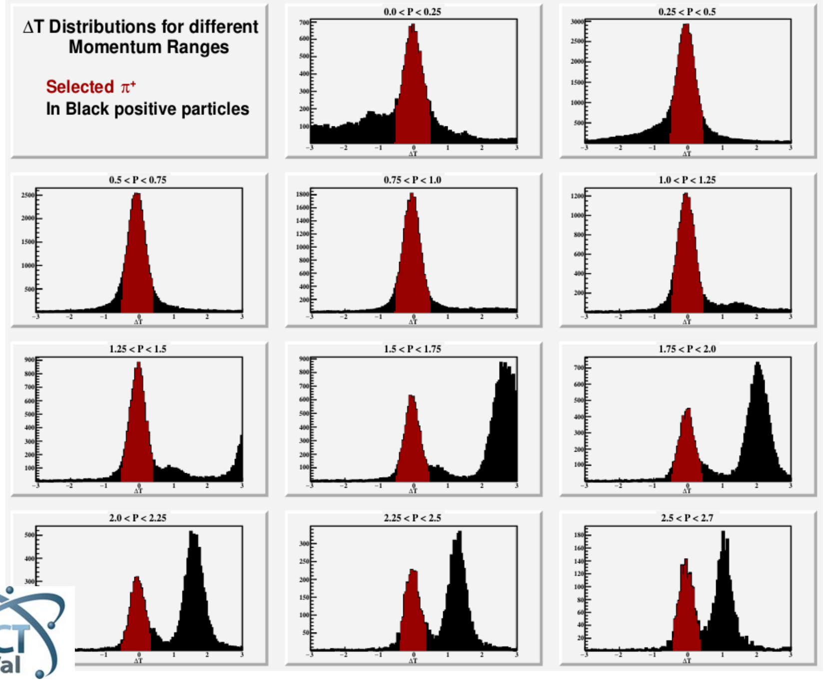
RD case:

- Cuts in Δβ, for different momentum ranges

Positive pions, according to **SMU**

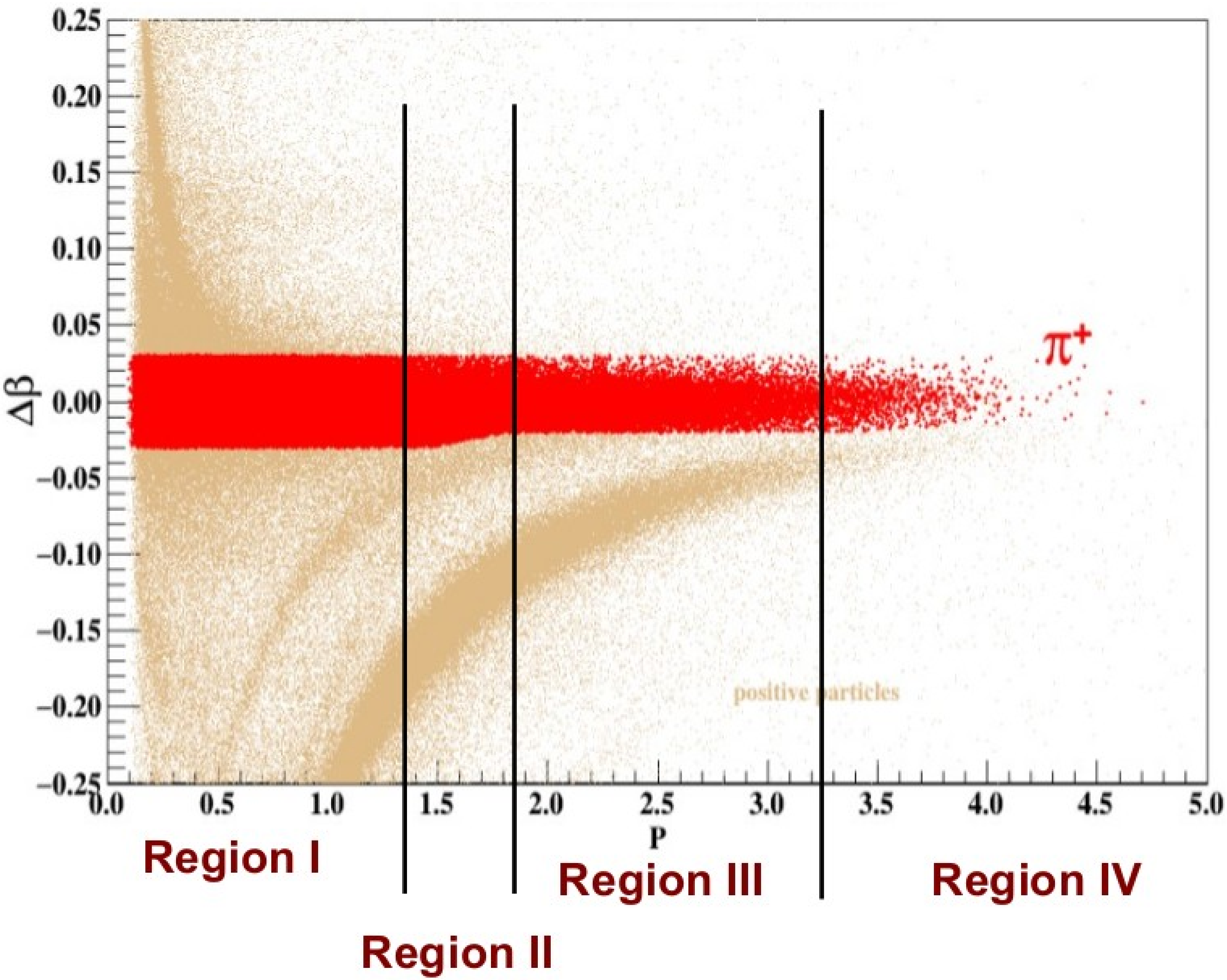


Threshold value



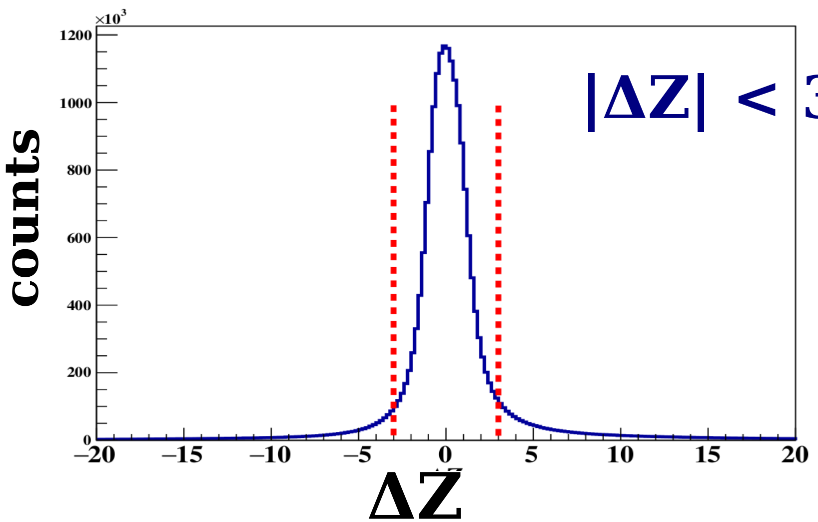
Cuts in ΔT for different momentum ranges up to 2.7, in red the positive pions, **narrower since the last presentation (avoiding kaons)**

Positive Pions Selection (RD)

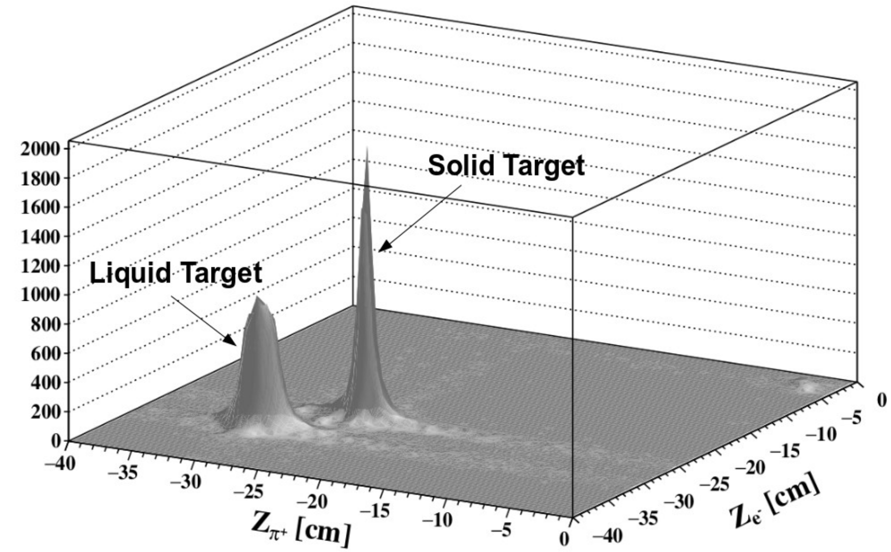


Additional Cuts used in the analysis

- $\Delta Z = Z_{\pi+} - Z_{el}$



$|\Delta Z| < 3[cm]$

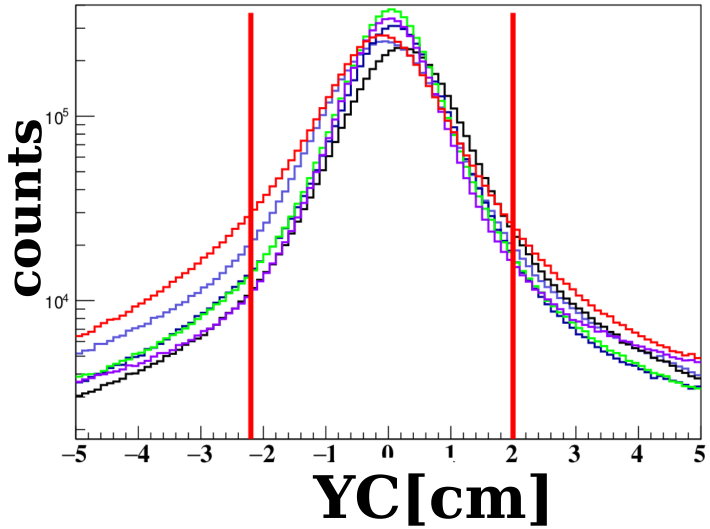


- **Y Corrected (YC)**

The real beam position is not (x, y) = (0, 0), there is an **offset** and it was determined (by Taisiya Mineeva) to be:
(x, y) = (−0.043, 0.33)

-2.2 [cm]< YC < 2.0[cm]

YC distribution for all different sectors

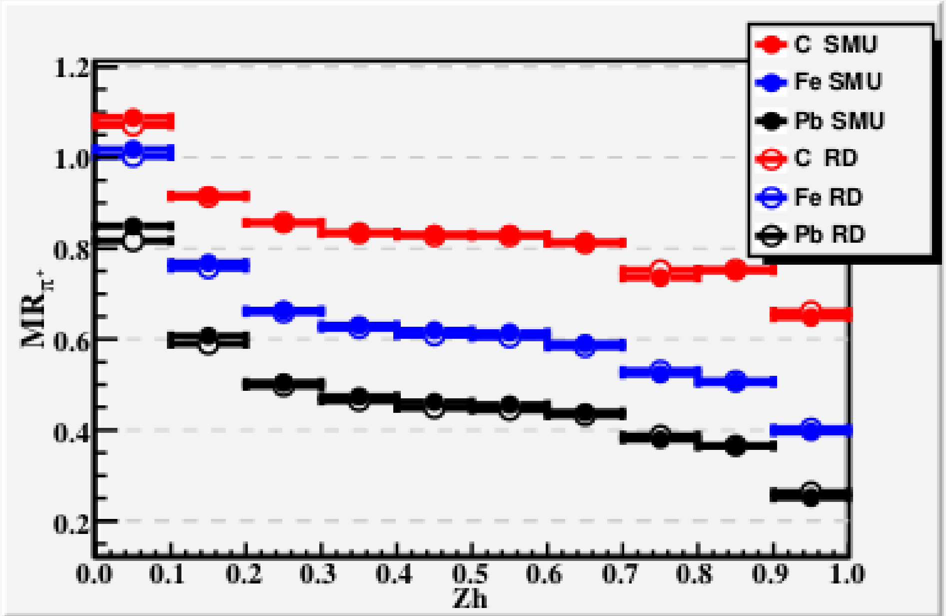


Results

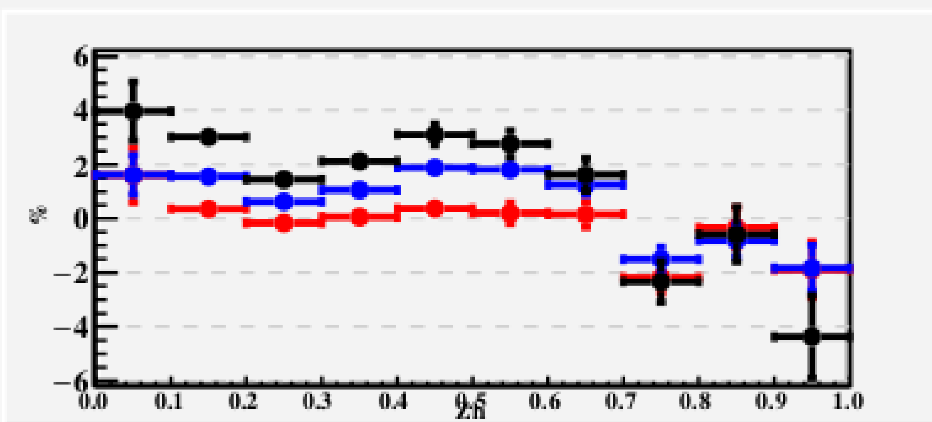
Previously:

(4D case)

Uncorrected data



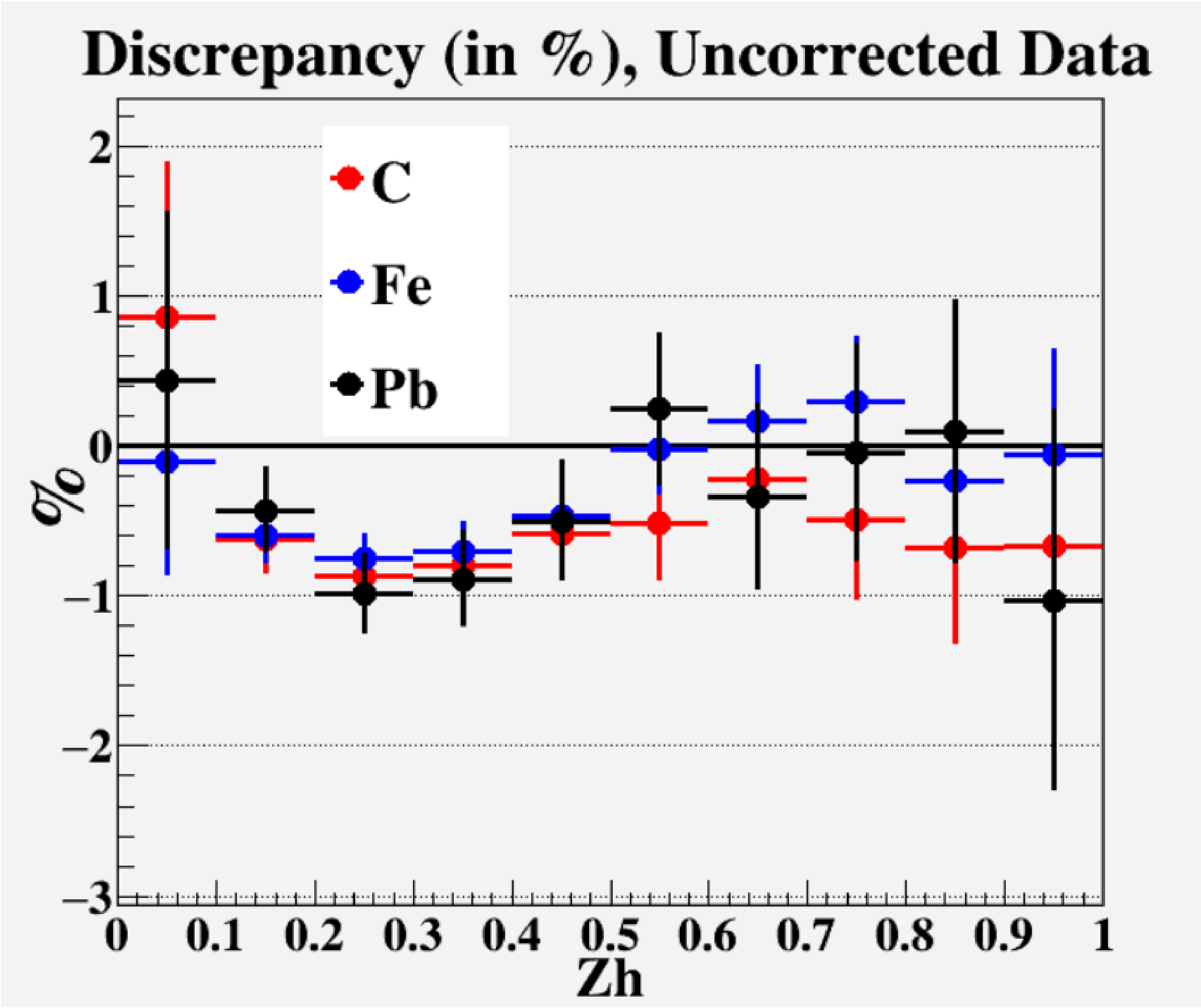
Difference (%)



Some modifications, since the last time:

- Narrower cuts in ΔT, to avoid kaon contamination.
- Not use of CC for positive pions, T.O.F for all momenta.

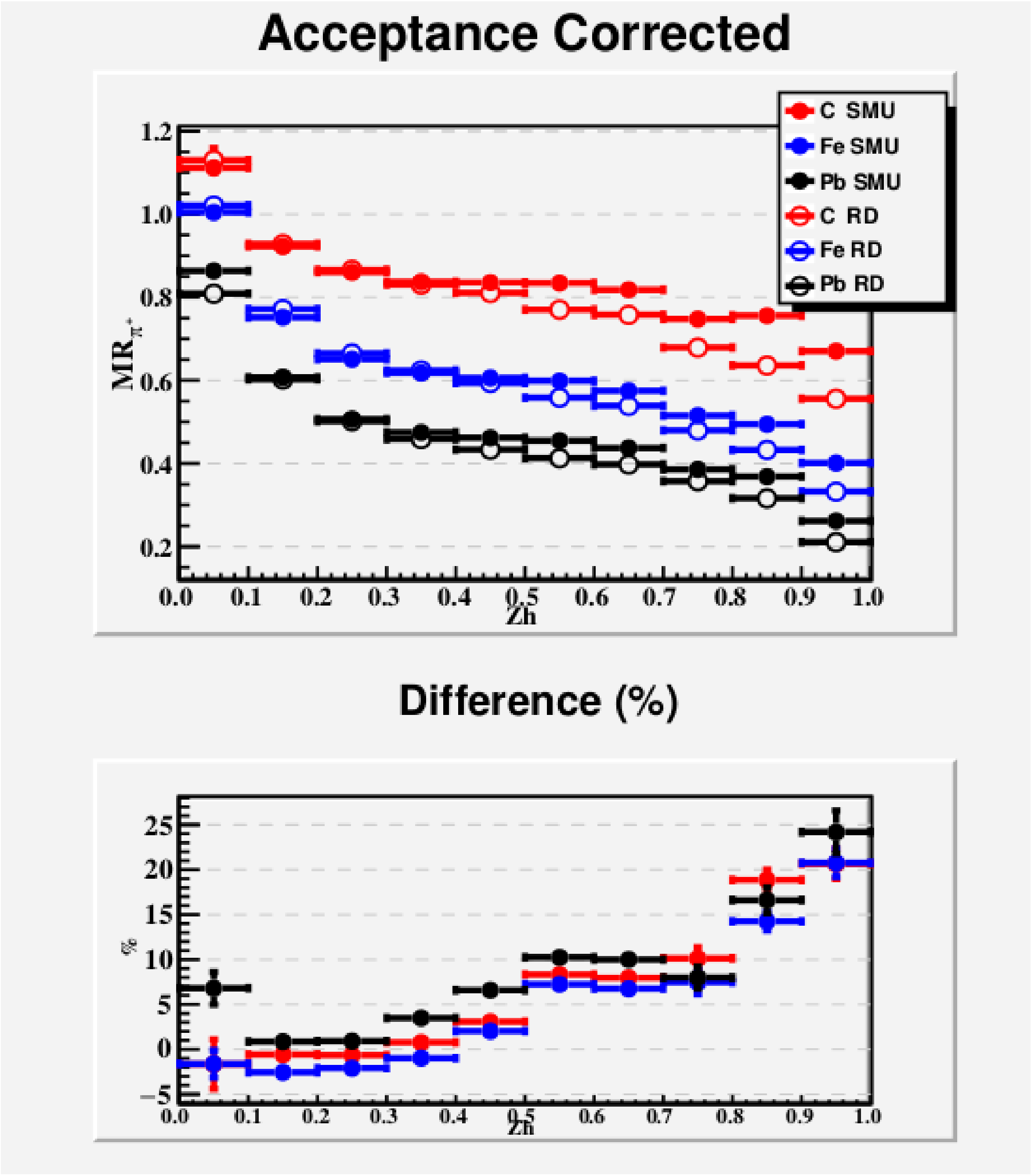
The new comparison between both analysis, after this modifications in **SMU** analysis, is:



Both analysis agreed within ~1% difference, at uncorrected level

Acceptance Correction case.

Previously:



We need a closer look at the simulations

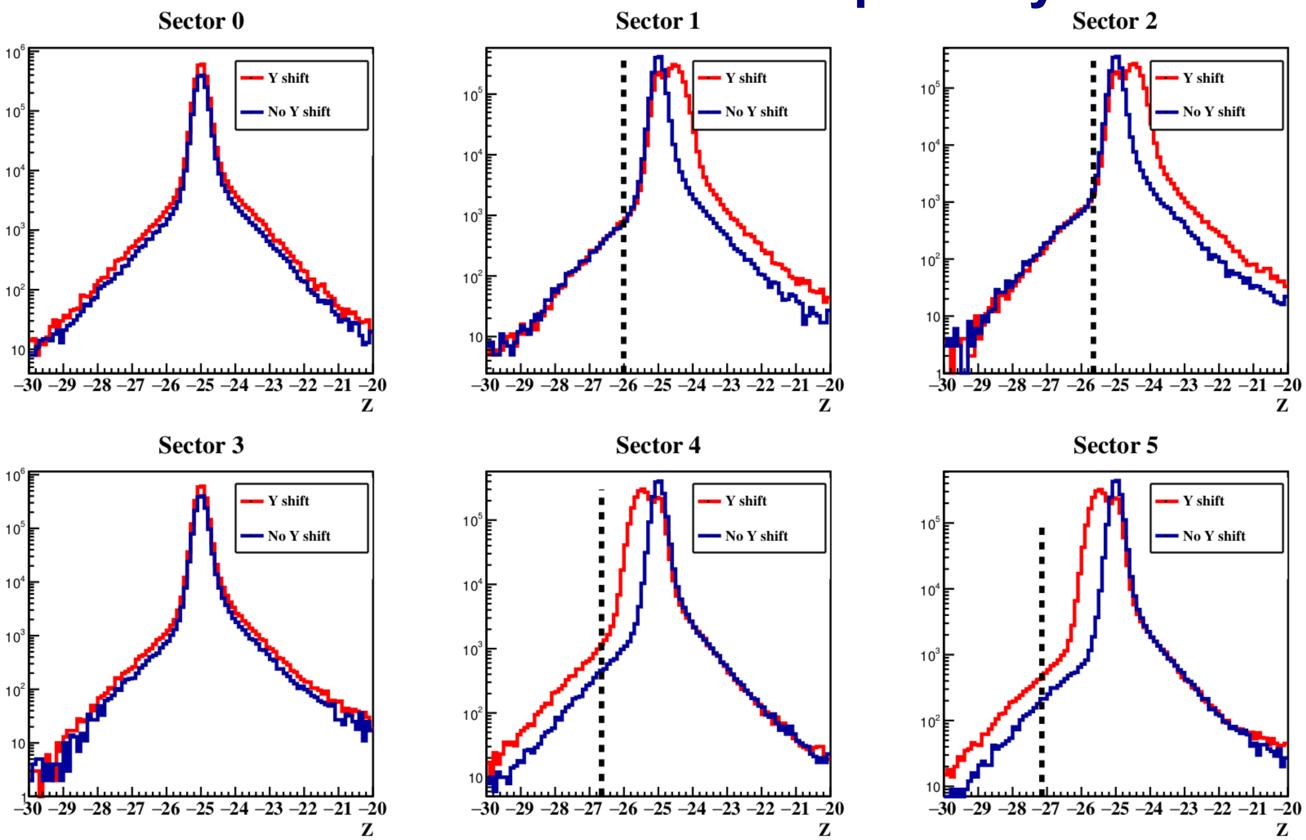
Simulation Sets

For **SMU** case, the simulation set was implemented by Hayk Hakobyan.

An implementation of a shift in the Y position divided the simulation into two groups:

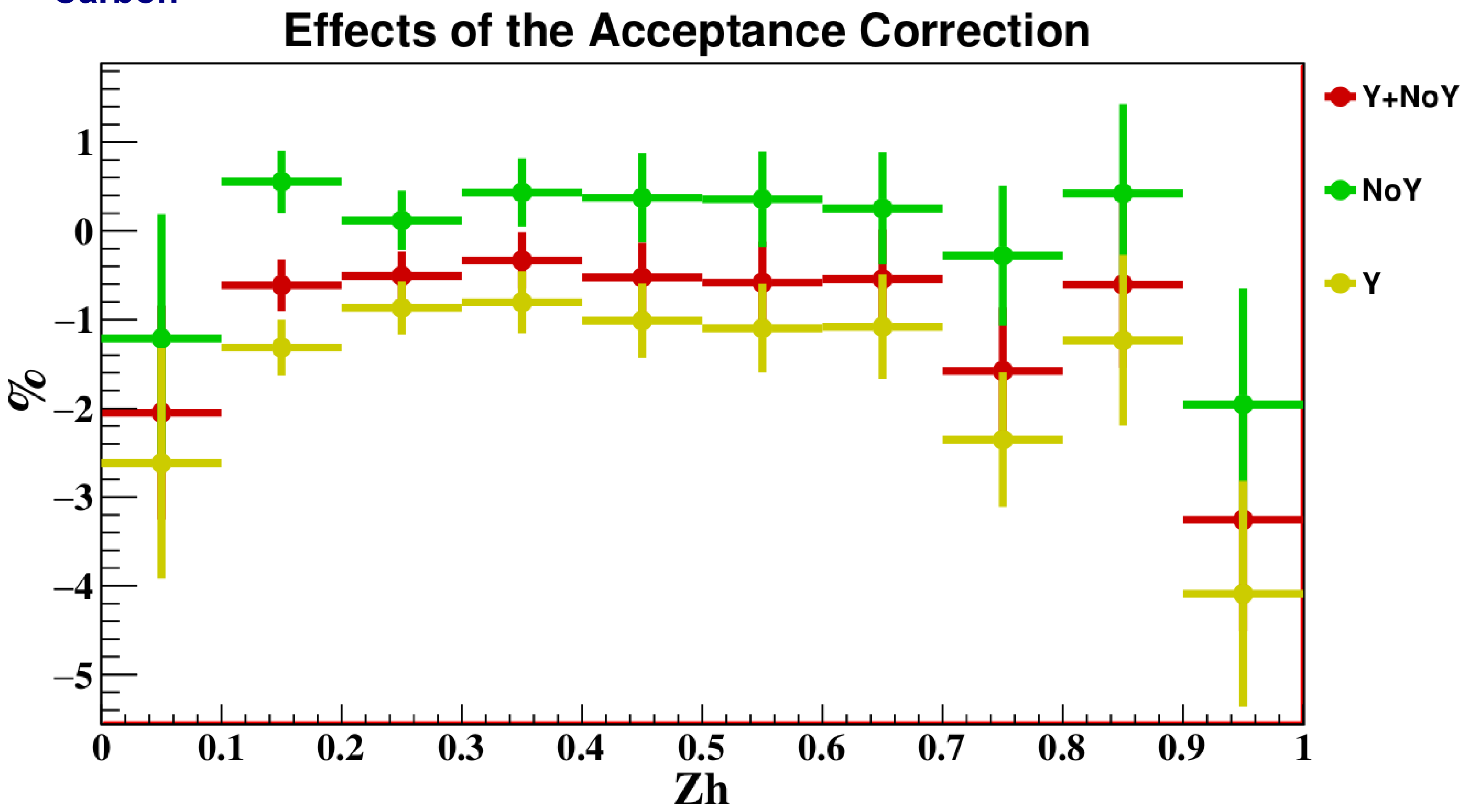
Simulation Set		
Target	With Y shift	Without Y shift
C	63.93%	37.07%
Fe	56.31%	43.69%
Pb	60.08%	39.92%
D2	59.56%	40.44%

Z distributions for the electron, for each set of simulations separately

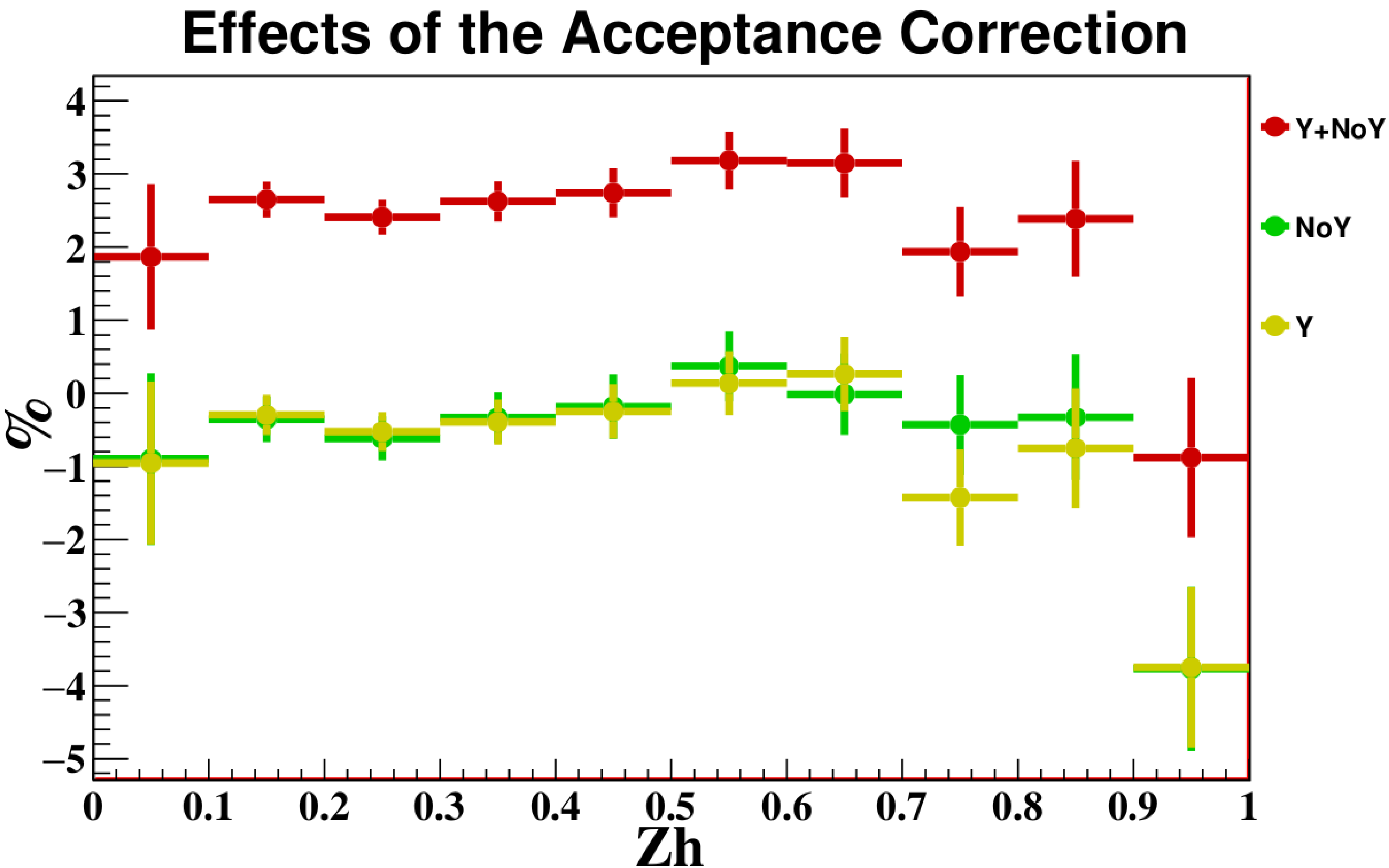


The Acceptance correction effect in the uncorrected Multiplicity Ratio (in %) for the use of the three set of simulations, with the Y shift implementation (**Y**), without it (**No Y**) and all the set of simulations together (**Y+NoY**)

Carbon

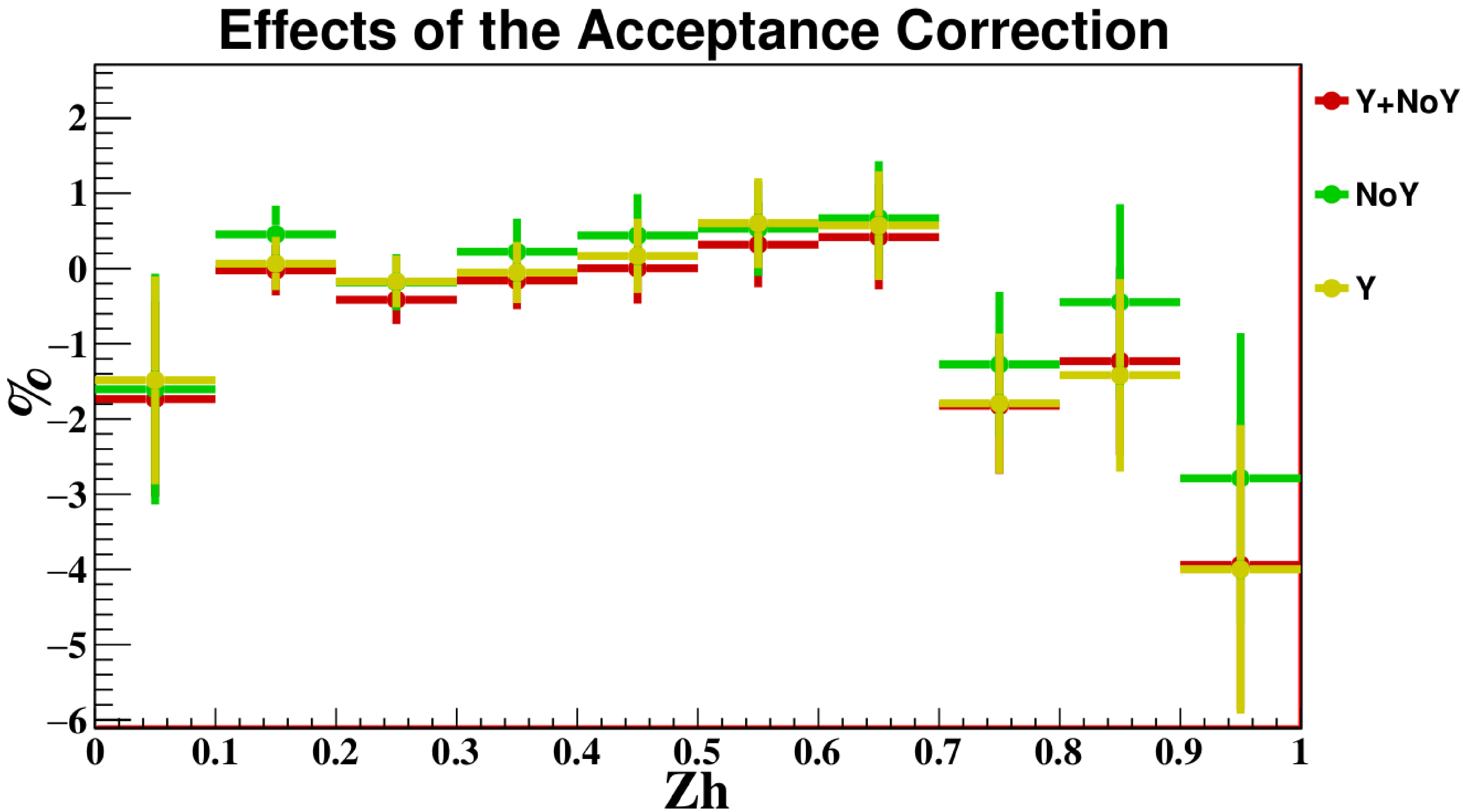


Iron



Effects of the Acceptance Correction
%
Zh
4
3
2
1
0
−1
−2
−3
−4
−5
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Y+NoY
NoY
Y

Lead



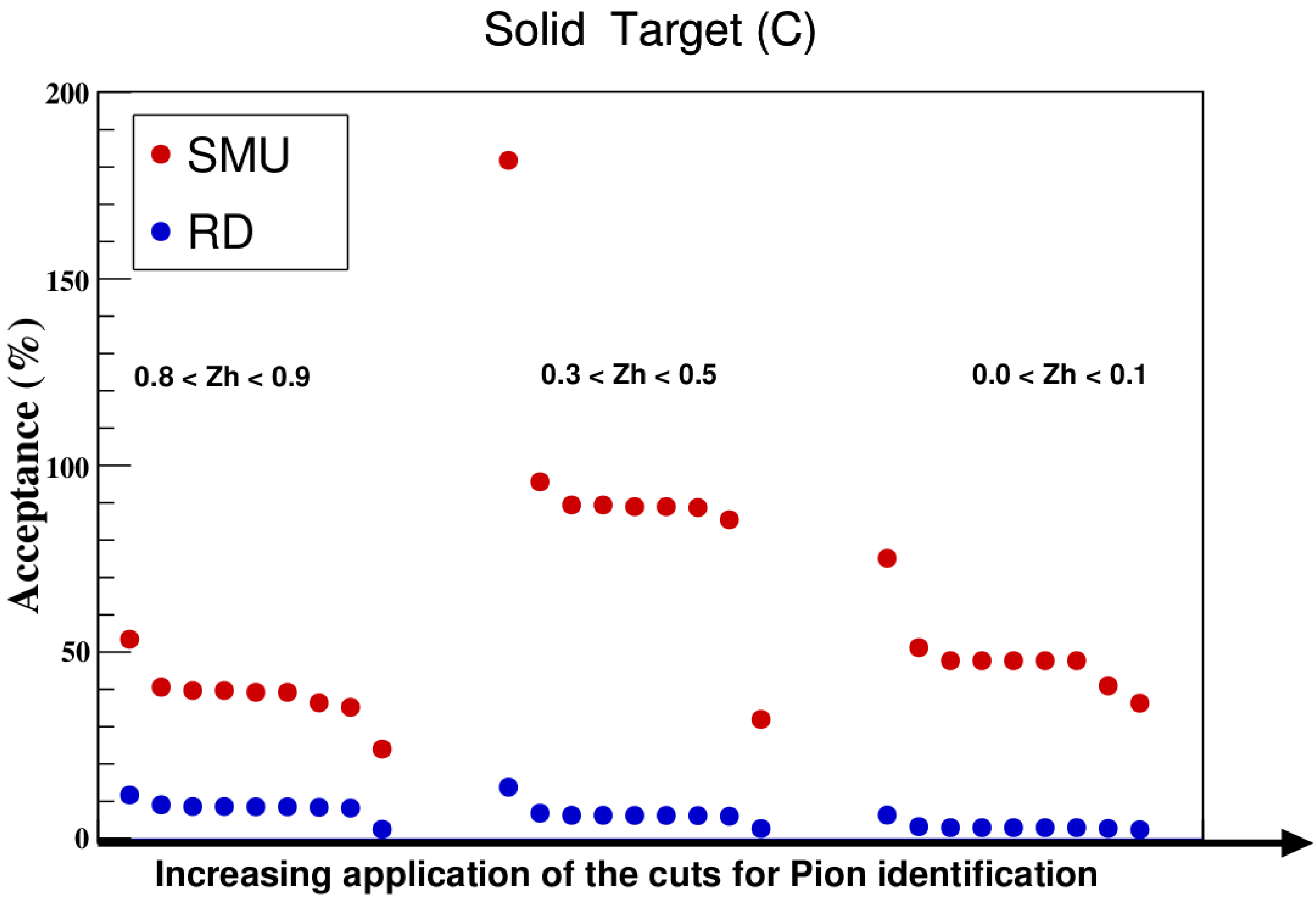
Effects of the Acceptance Correction
Y+NoY
NoY
Y
%
Zh
2
1
0
−1
−2
−3
−4
−5
−6
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

RD cuts for pions and electrons, the same "Cut Flow" plot as in the electron case

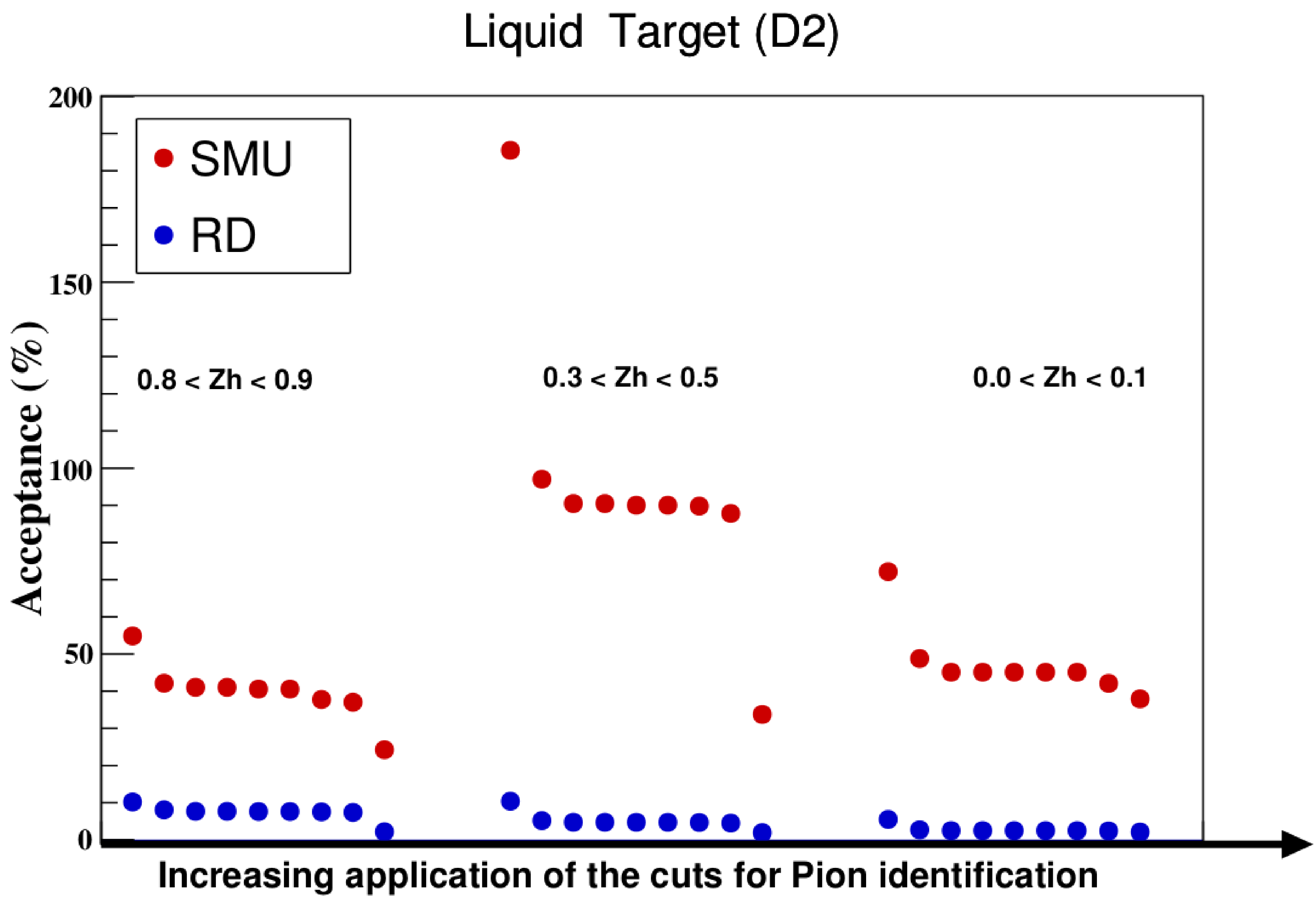
	Cut
Cut 1	Bin selected + DIS
Cut 2	+ Charge == +1
Cut 3	$+ \ Status > 0$
Cut 4	$+ \ Stat_{DC} > 0$
Cut 5	$+ \ Stat_{SC} > 0$
Cut 6	$+ \ DCStatus > 0$
Cut 7	+ No Positron
Cut 8	$+ \ \Delta\beta < 0{,}03$
Cut 9	$+ \ \Delta\beta > \alpha$

$$\alpha = \begin{cases} -0{,}03 & , \quad P \leq 1{,}487 \\ \frac{P}{\sqrt{P^2+0{,}4^2}} - \frac{P}{\sqrt{P^2+m_\pi^2}} & , \quad 1{,}487 < P \leq 1{,}838 \\ -0{,}02 & , \quad 1{,}838 < P \leq 3{,}375 \\ \frac{P}{\sqrt{P^2+0{,}7^2}} - \frac{P}{\sqrt{P^2+m_\pi^2}} & , \quad 3{,}375 < P \leq 6 \end{cases}$$

Kinematics:
1.75 < Q2 < 2.12
0.10 < Pt2 < 0.18
.027 < Xb < 0.33



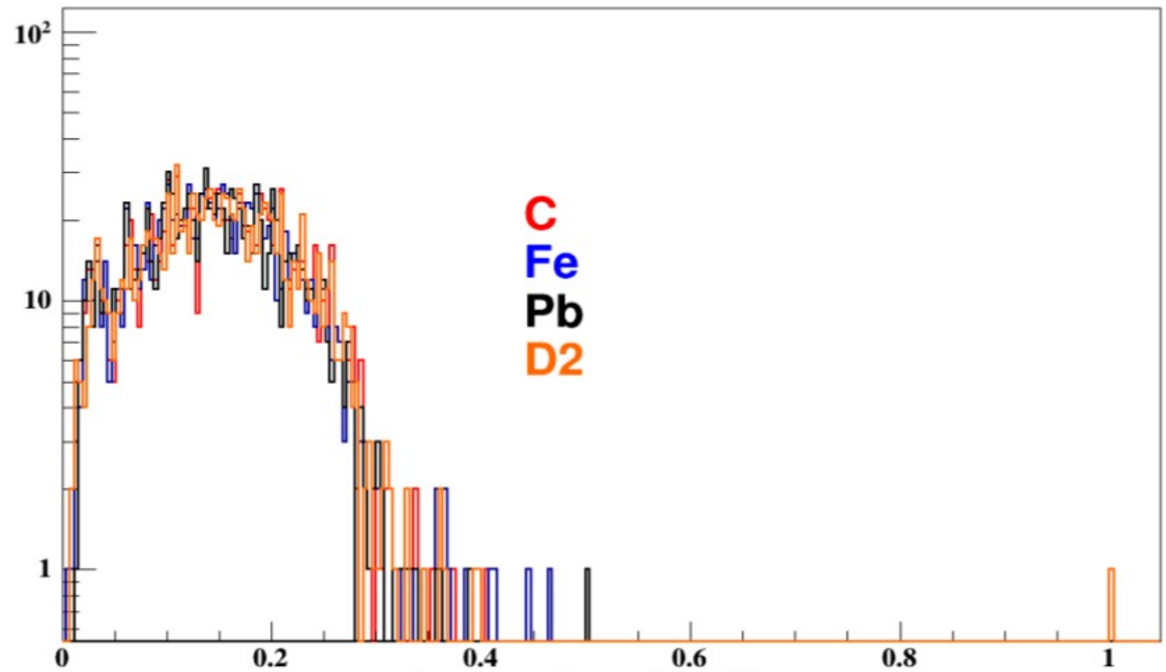
An important difference since the beginning



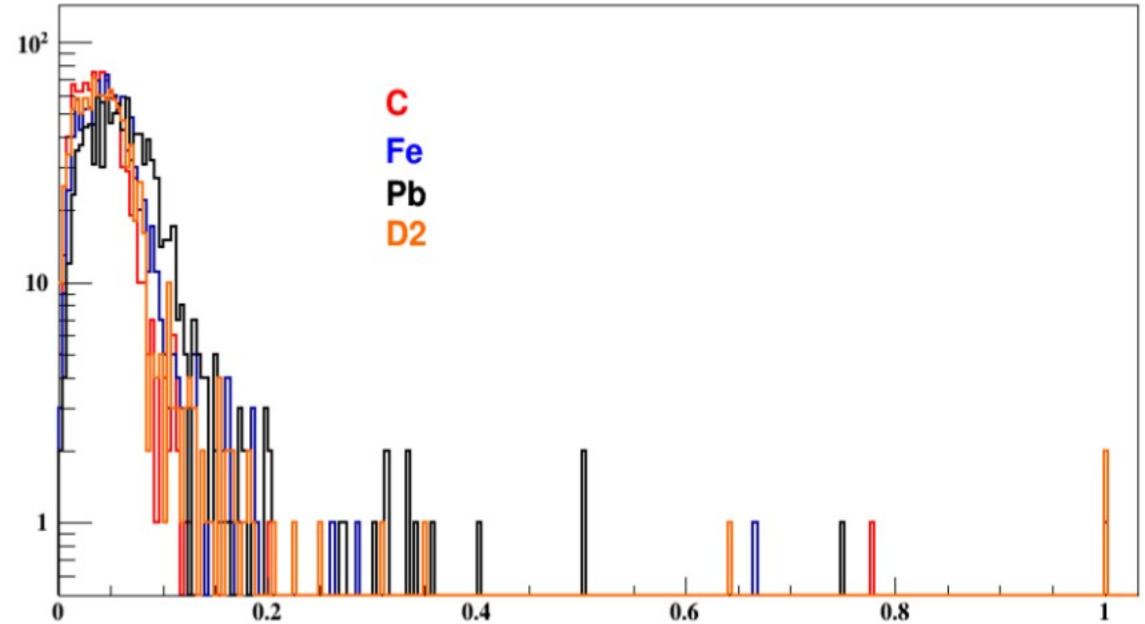
Liquid Target (D2)
SMU
RD
Acceptance (%)
200
150
100
50
0
0.8 < Zh < 0.9
0.3 < Zh < 0.5
0.0 < Zh < 0.1
Increasing application of the cuts for Pion identification

Acceptance Factors

SMU



RD



Conclusions:

- At an uncorrected level, the disagreement between the two analysis regarding electrons are fully explained by vertex cuts, fiducial cuts and energy deposited in the outer part of the EC.

- At an acceptance corrected level, regarding electrons, the discrepancy remains even if the cuts are modified, the source of the discrepancy are the simulation set.

- For positive pions, the narrower cuts in ΔT and the fact that CC is not used, but TOF technique for all momenta, explain the difference at uncorrected level.

- For positive pions, at acceptance corrected level, the difference is important, the simulations do not agreed and is not a problem of the particle identification cuts.

- Currently a new set of simulations is running, that could give us new insights to explain this discrepancies.

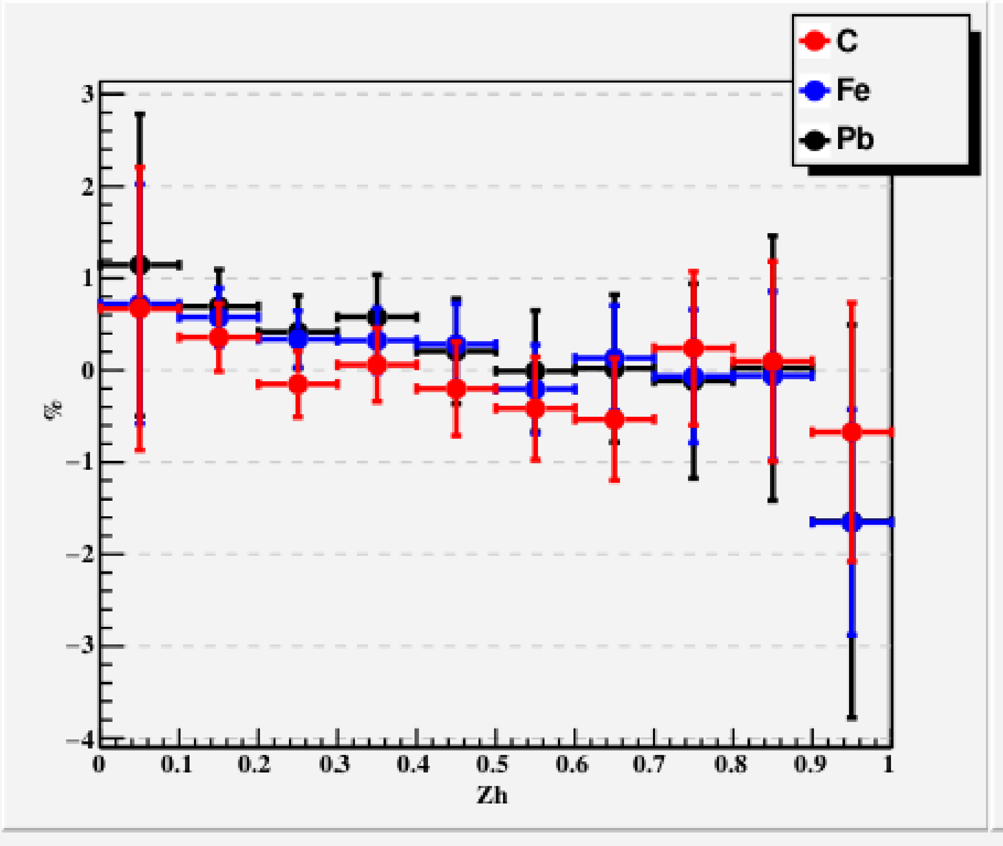
Thanks!

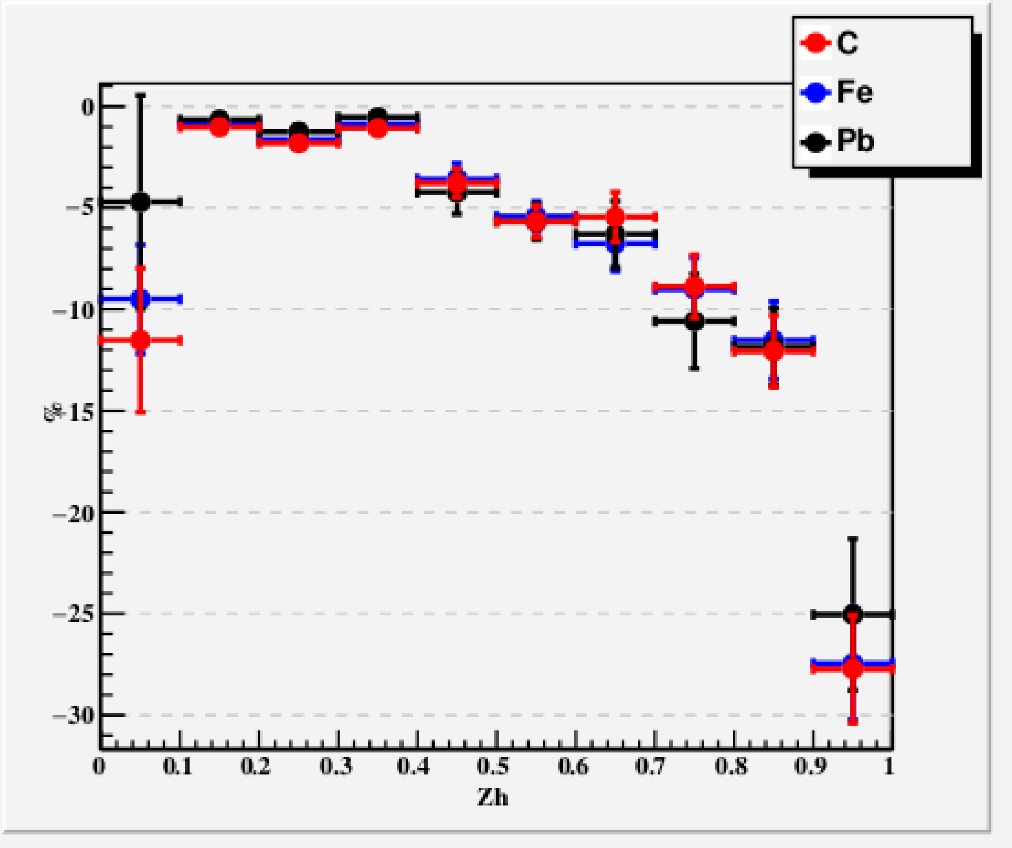
Backup Slides

Difference (in percentage) of Multiplicity Ratios integrated over (Xb, Pt2, Q2, Phi) and over (Xb, Pt2, Q2) for both analysis

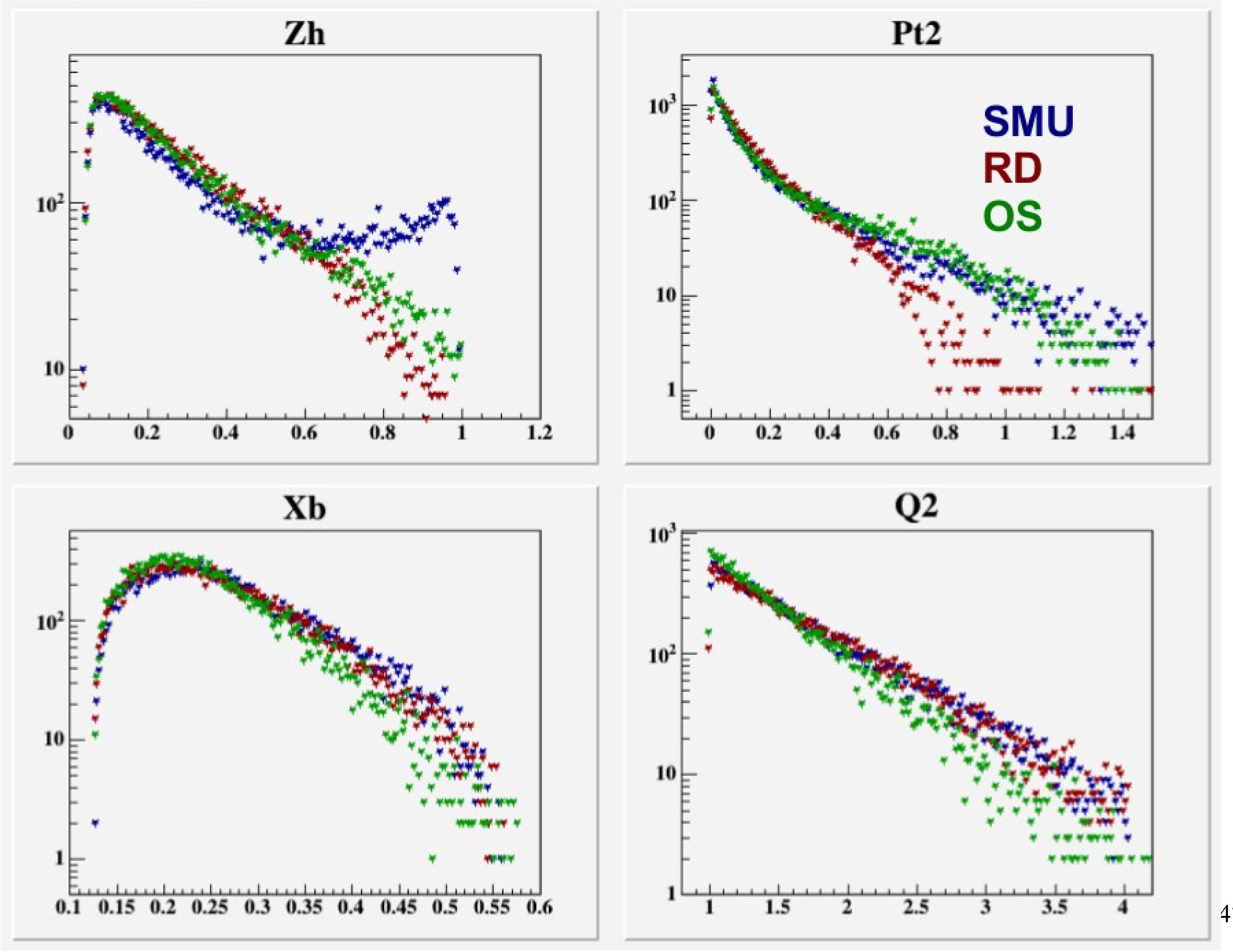
SMU analysis

RD analysis





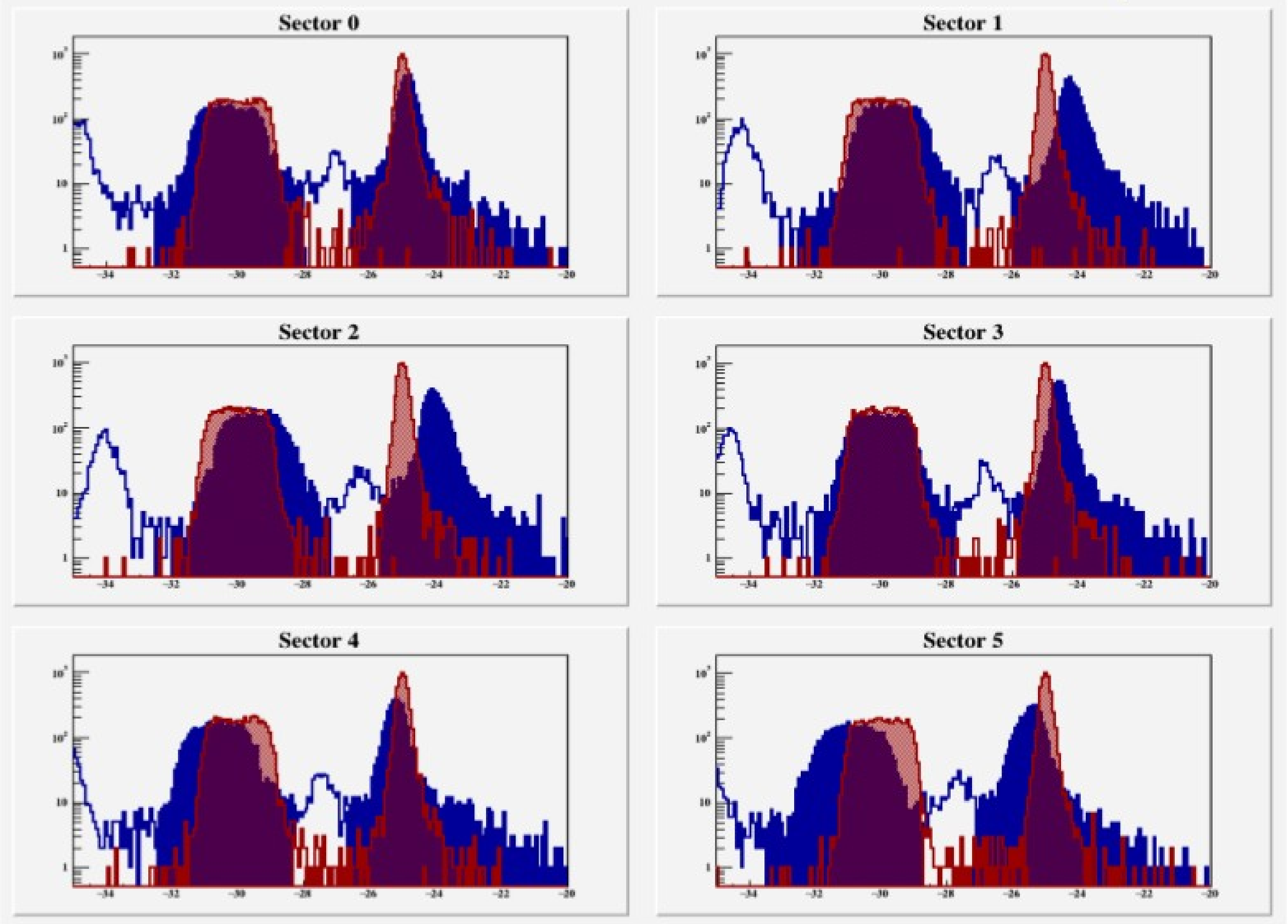
Generated events comparison, for the three set of simulations available:



Comparison of Z coordinate in each sector for Data and Reconstruction, for SMU analysis.

Carbon:

Reconstructed electrons
Electrons, from data



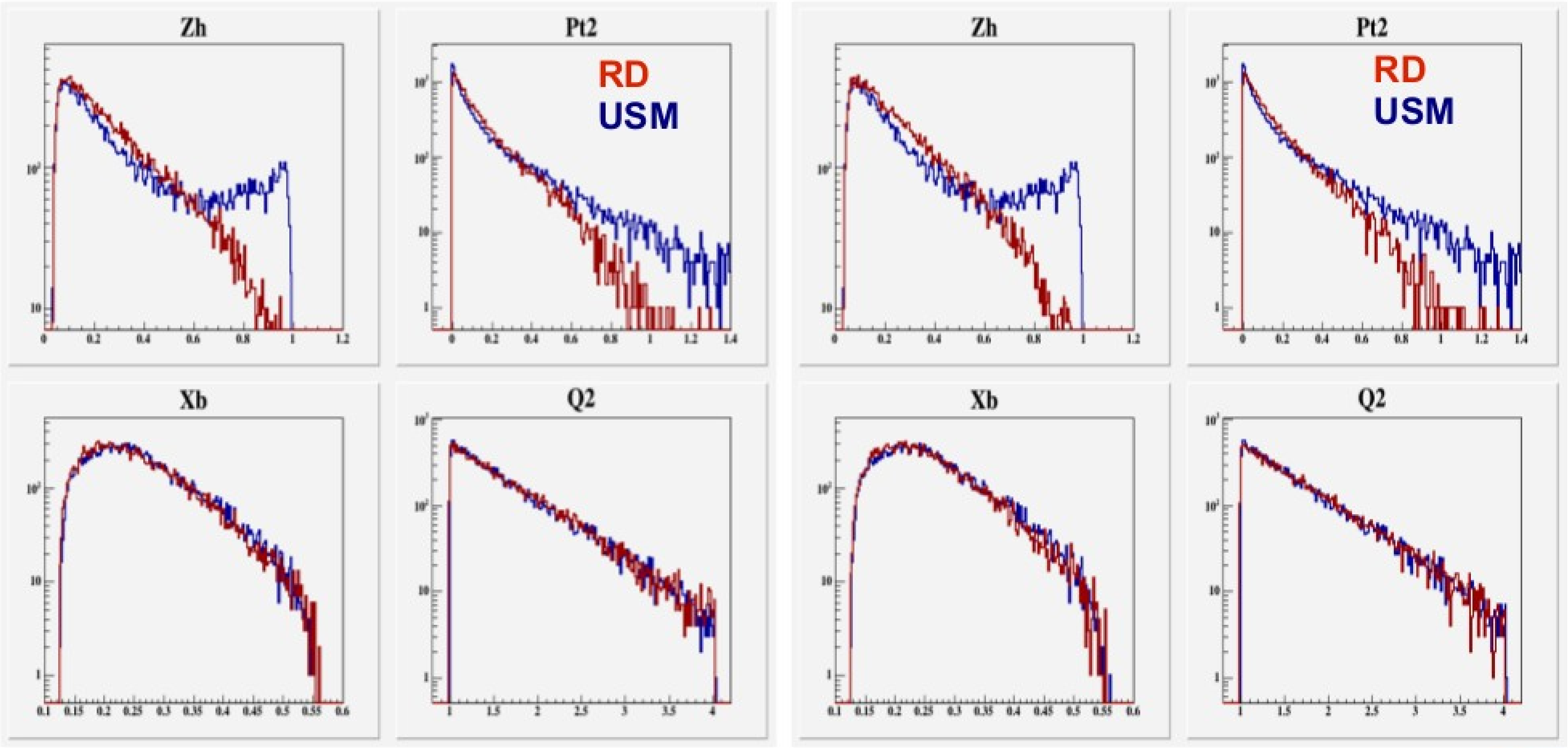
*This comparisons are with all the simulations together (with and without the Y shift). Later each case alone.

*The shadow region correspond to the vertex cuts selection.

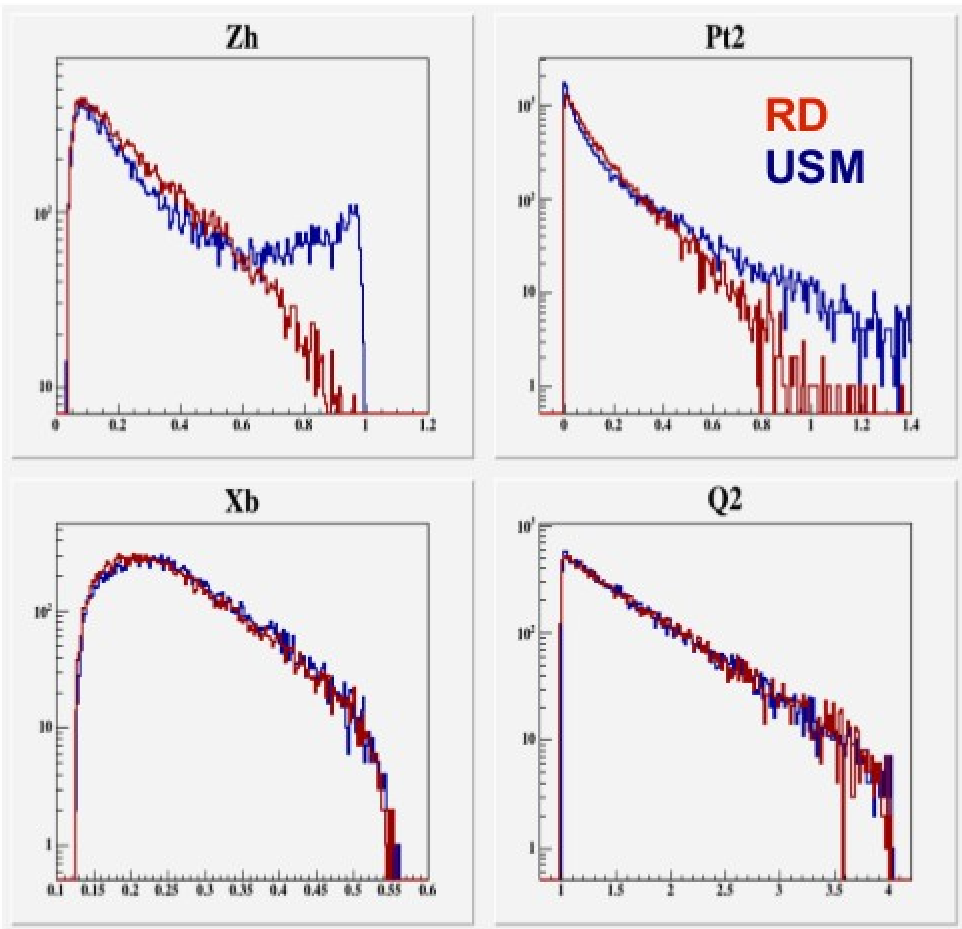
Comparison between the Generated events for both analysis.

The number of positive pions in both cases is 20.000, and the comparison was made for the 4 targets separately.

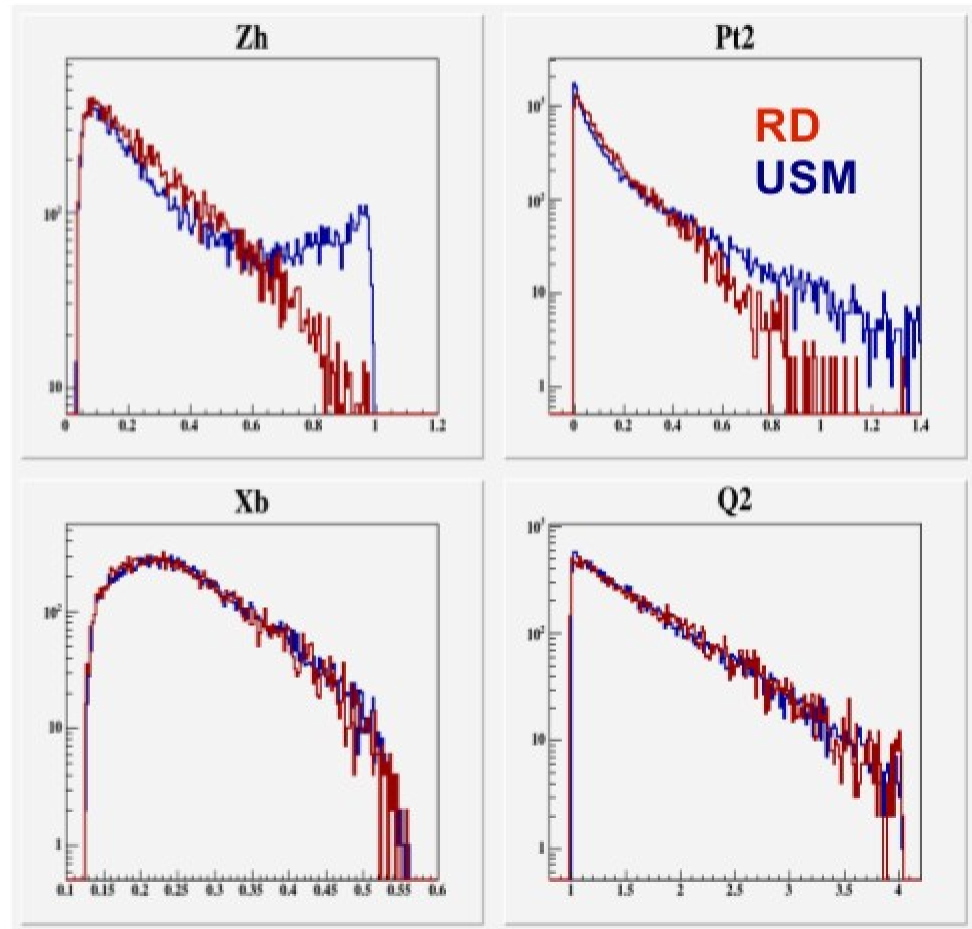
Carbon **Iron**



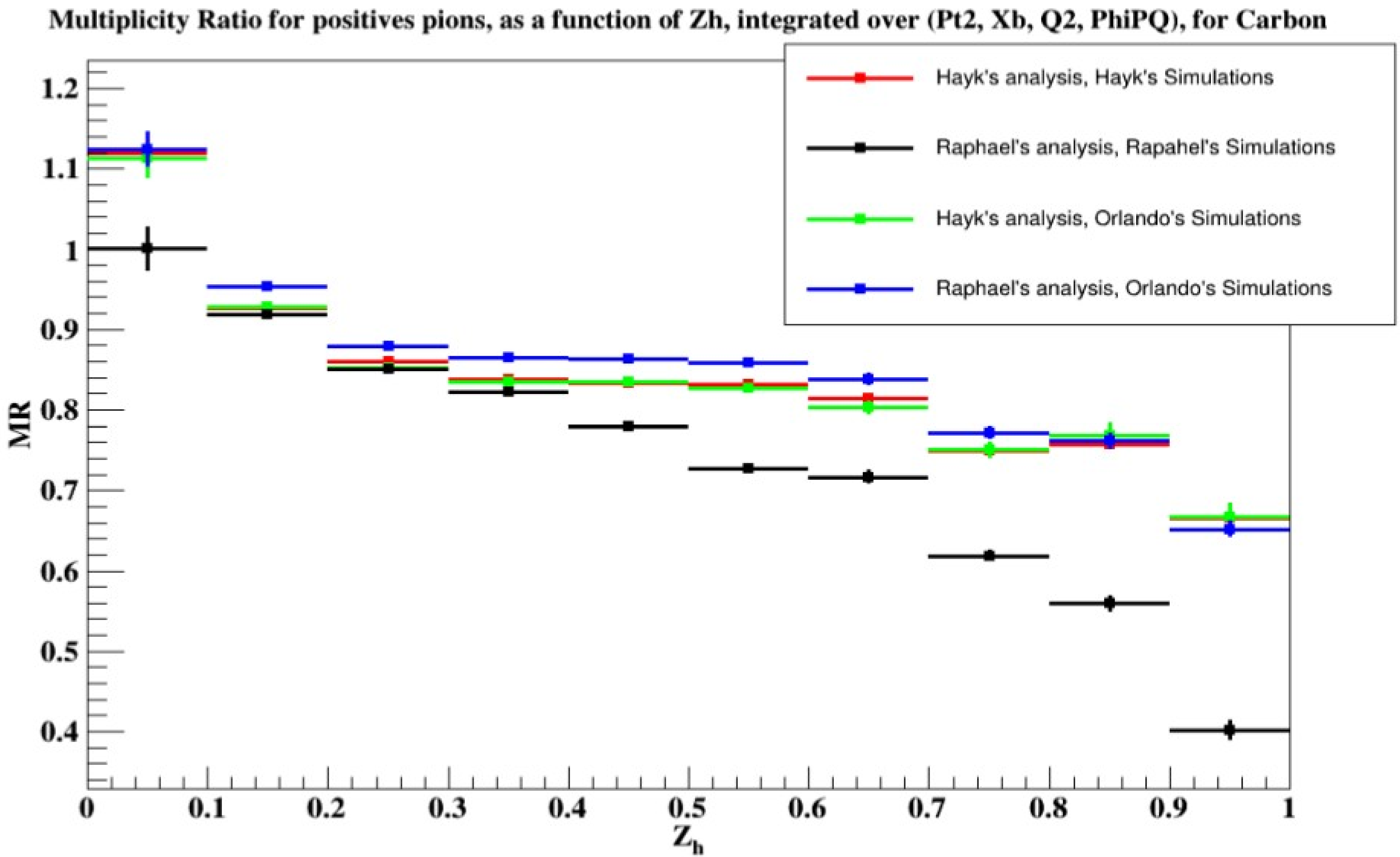
Lead



Deuterium



New set of simulations involved



New set of simulations involved