Charged Pion Hadronization Update

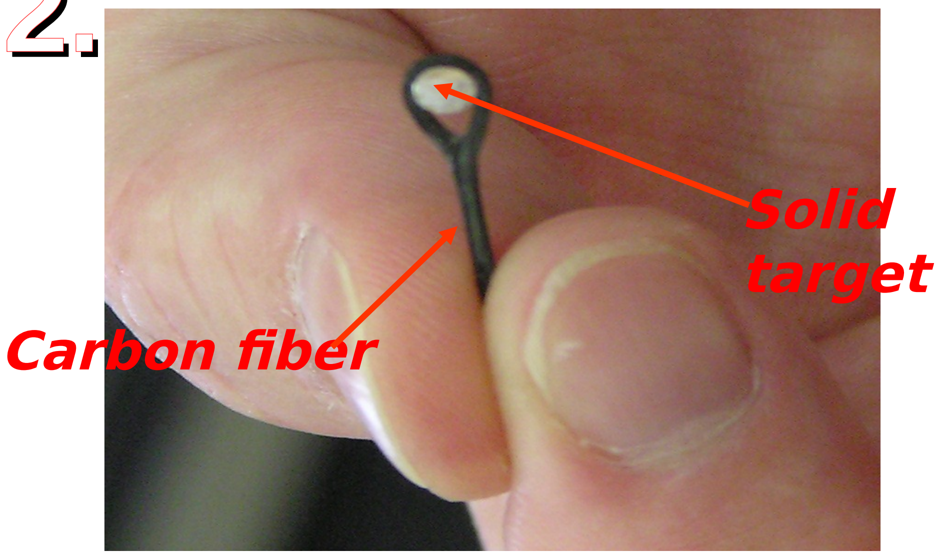
CLAS Collaboration Meeting

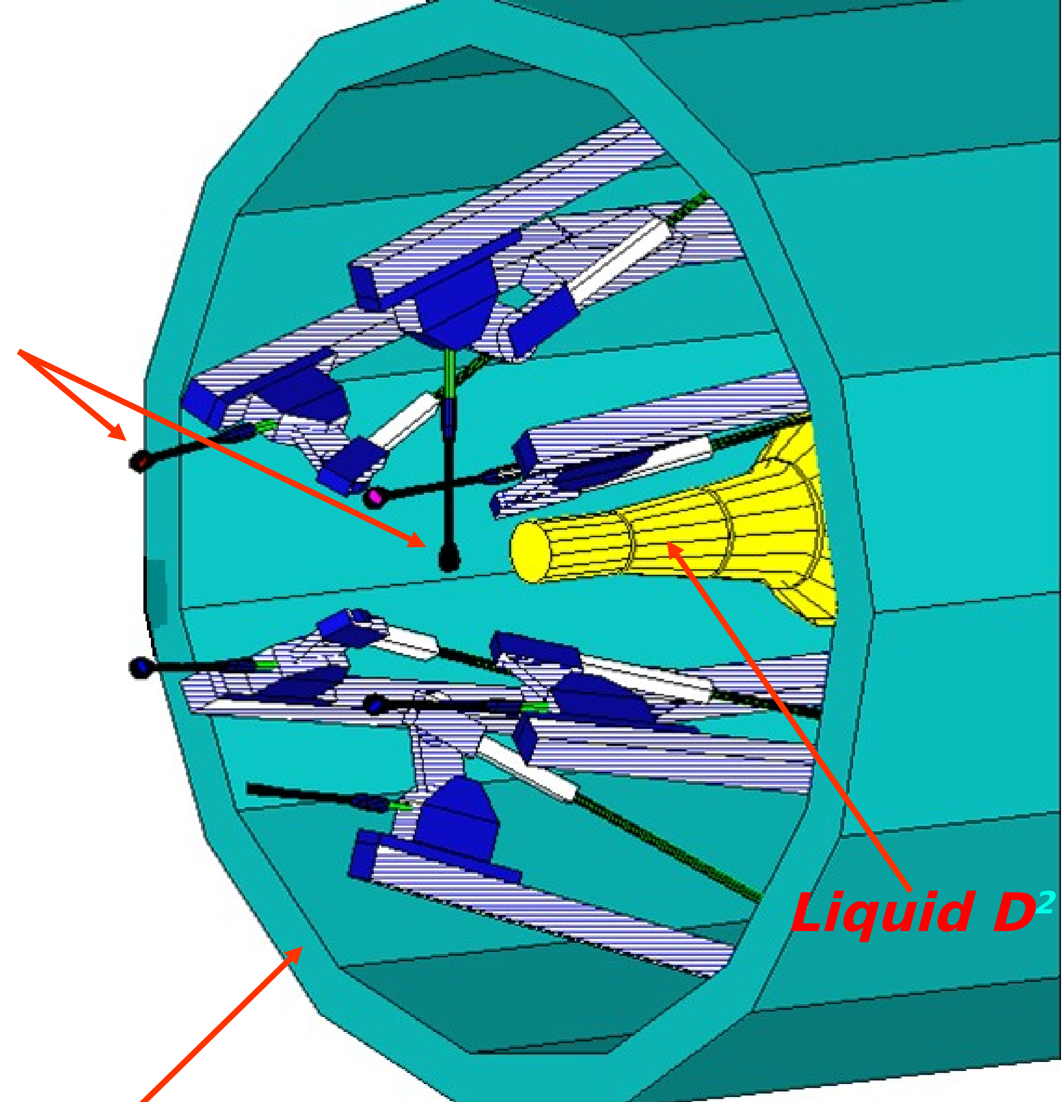
(results of CLAS EG2 experiment)

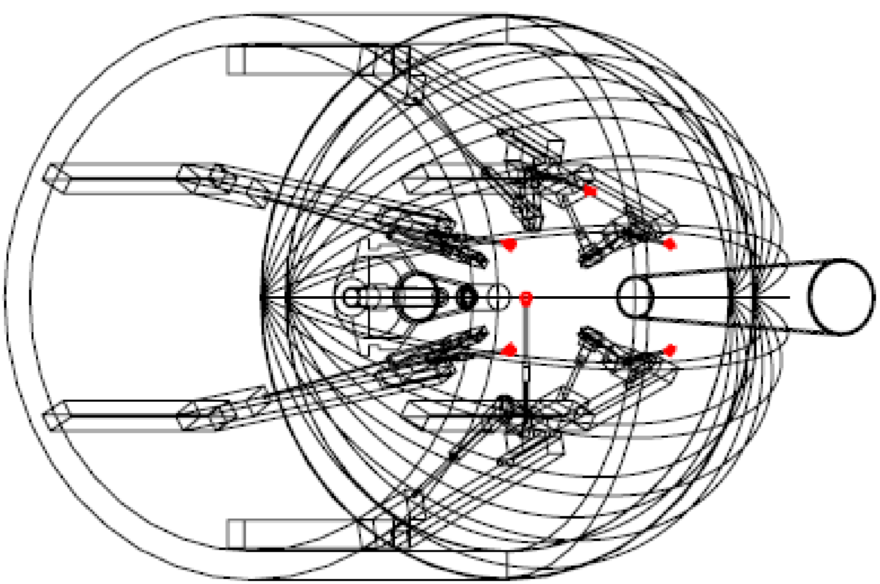
Sebastian Moran, Hayk Hakobyan and others

20th of June, 2019

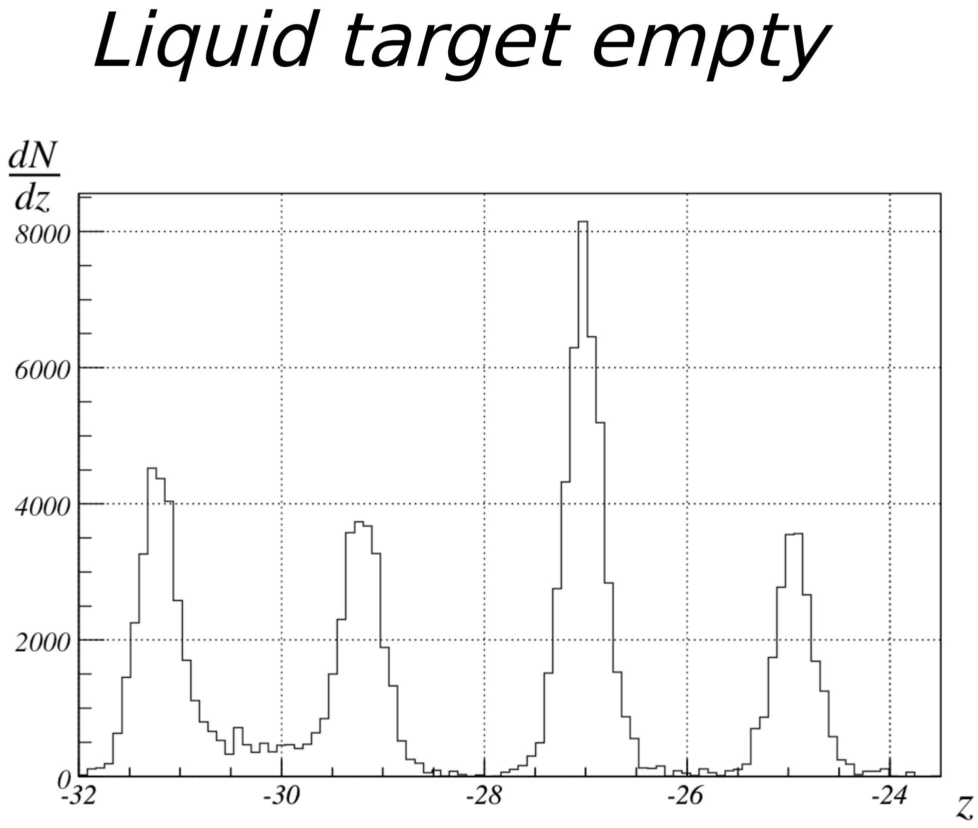
2. Experimental details

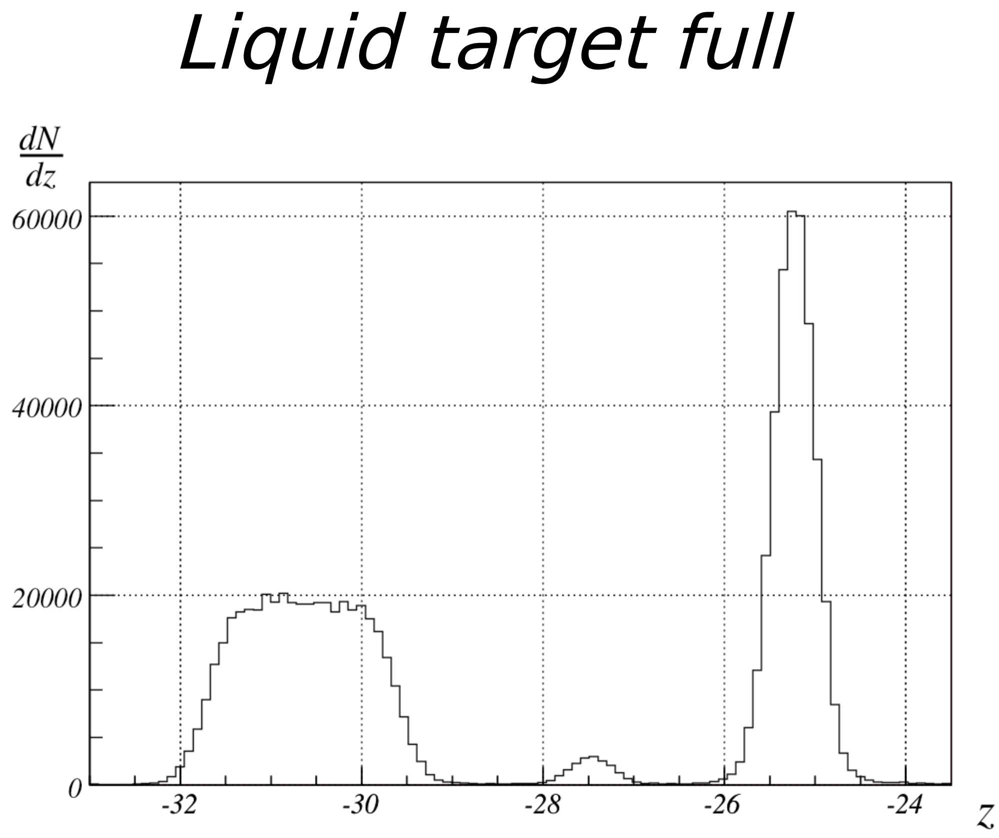






EG2 Experiment target in GEANT3
Solid (C, Al, Fe, Sn, Pb) target
simultaneously with deuterium target

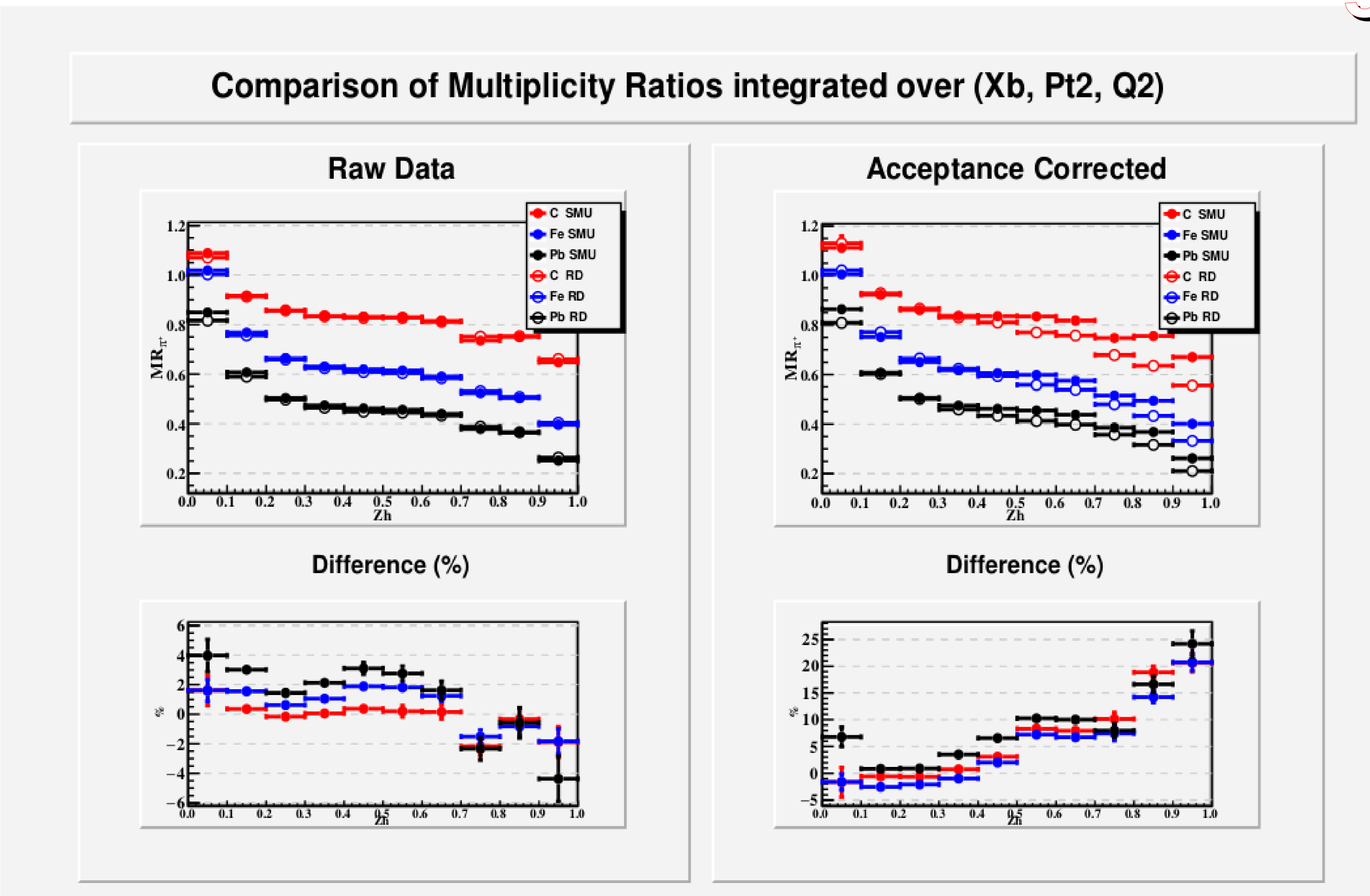

Liquid target empty
dN/dz
8000
6000
4000
2000
0
-32
-30
-28
-26
-24
z


Liquid target full
dN/dz
60000
40000
20000
0
-32
-30
-28
-26
-24
z

Hadronic multiplicity ratio

$$R_M^h(z,\nu,p_T^2,Q^2,\phi) = \frac{\left\{ \frac{N_h^{DIS}(z,\nu,p_T^2,Q^2,\phi)}{N_e^{DIS}(\nu,Q^2)} \right\}_A}{\left\{ \frac{N_h^{DIS}(z,\nu,p_T^2,Q^2,\phi)}{N_e^{DIS}(\nu,Q^2)} \right\}_D}$$

Disagreement between two independent analysis done Santa María University group (SMU) and by Raphael Dupré (RD).



- **<u>Xf definition:</u>** The difference in the MR using one definition or the other is **~0%.**

- **<u>Vertex Cuts:</u>** RD has tighter cuts in the Z coordinate for electron than SMU, but the difference in the MR using one set of vertex or the other one is **~0%.**

- **<u>Phi Implementation:</u>** The difference in the MR using one definition or the other is **~0%.**

- **<u>Run Numbers:</u>** Two set of Run Numbers, the difference in using one set or the other is less than **~0.5%.**

- **<u>Particles Identification:</u>** After some modification in SMU the agreement between both analysis is of order of **~1%.**

- **<u>Simulation Set:</u>** Apparently this is the most problematic, different simulation set gives very different results.

- **Acceptance Correction Implementation:** RD → event by event
  SMU → bin by bin
  Here is only compared the bin by bin case.

- **Number of dimension in the acceptance:**

  SMU → 5D (Xb, Pt2, Q2, Pt2, Phi)
  RD → 4D (Xb, Pt2, Q2, Pt2)
  In **SMU** analysis the difference between 4D and 5D in MR is for the most part within **~1%.**
  In **RD** the difference between 4D and 5D goes up to **~10%.** and beyond that at high Zh.

- **Requirement of the electron as the first and only particle in the event:**
  No studied here, but should not make any important difference.

List of observations/suggestions from the committee

- Apply the same vertex cuts in the simulations. Study the absence of the Y-vertex offset in part of SMU simulations.

- In SMU analysis use tighter timing cuts in TOF PID for pions with P < 2.7 GeV

- In the PID for high momentum pions (P > 2.7 GeV) understand the difference between Chereckov counter method (SMU) versus TOF (RD).

- Find the differences in the overall acceptance. Make a comparison of the generated events between the two analyses. Compare the different parameters in the Pythia input.

- Study the number of simulation bins dependence on final analysis.

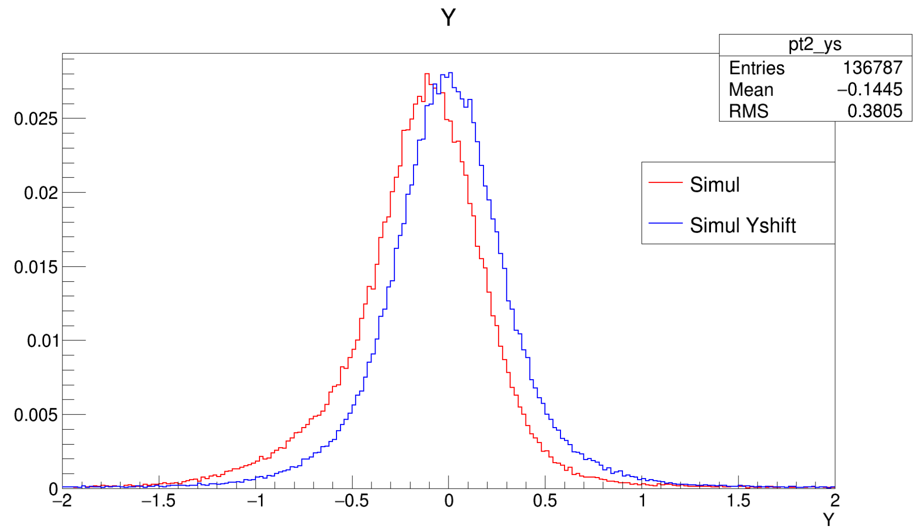
- At **data level** the discrepancy goes up to **~4%**, mainly for lead.
- At **Acceptance Corrected level** the discrepancy is **~10%** for most of the range, and for high Zh it goes up to **~25%**.

To see the source of this discrepancy, the following points were studied:

1. Y offset in SMU simulations.
2. Cerenkov Counter efficiency.
3. Comparison between generated events for both analysis.
4. Parameters in the Pythia input.
5. Comparison between Data and Reconstruction.
6. Z shift in RD analysis.
7. Change in the binning choice.

1. Y offset in SMU simulations

$Y_{BEAM} = 0$ vs $Y_{BEAM} = 2$ [mm] in simulations (40% vs 60% of whole available data)

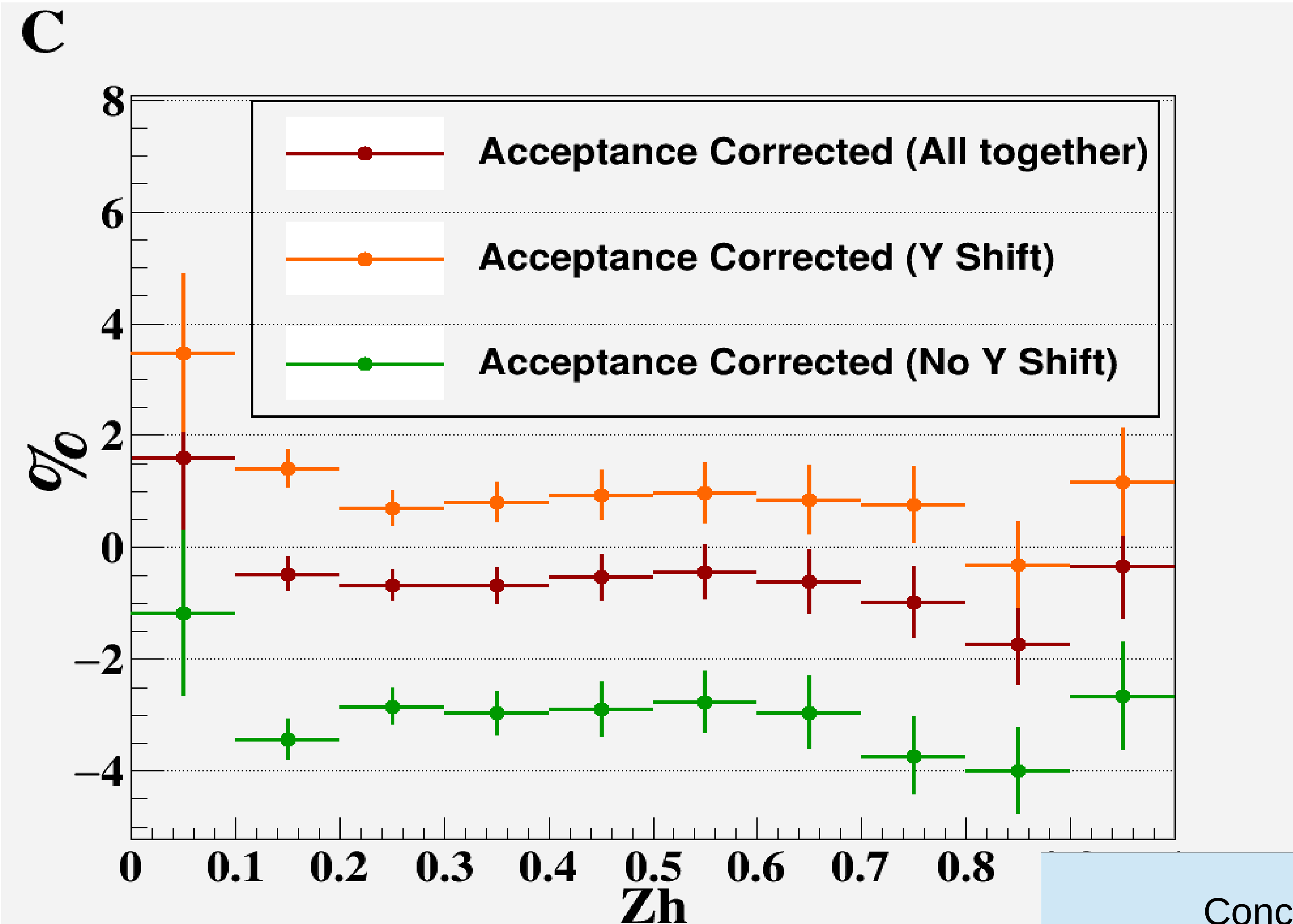


To study this the whole simulation files were divided into three categories:

- **No Y shift** → Only the set of simulations with no Y shift.
- **Y shift** → Only the set of simulations files with Y shift.
- **Together** → Both cases together, files with and without the Y shift.

Multiplicity Ratio was plotted for all this 3 distinct cases.

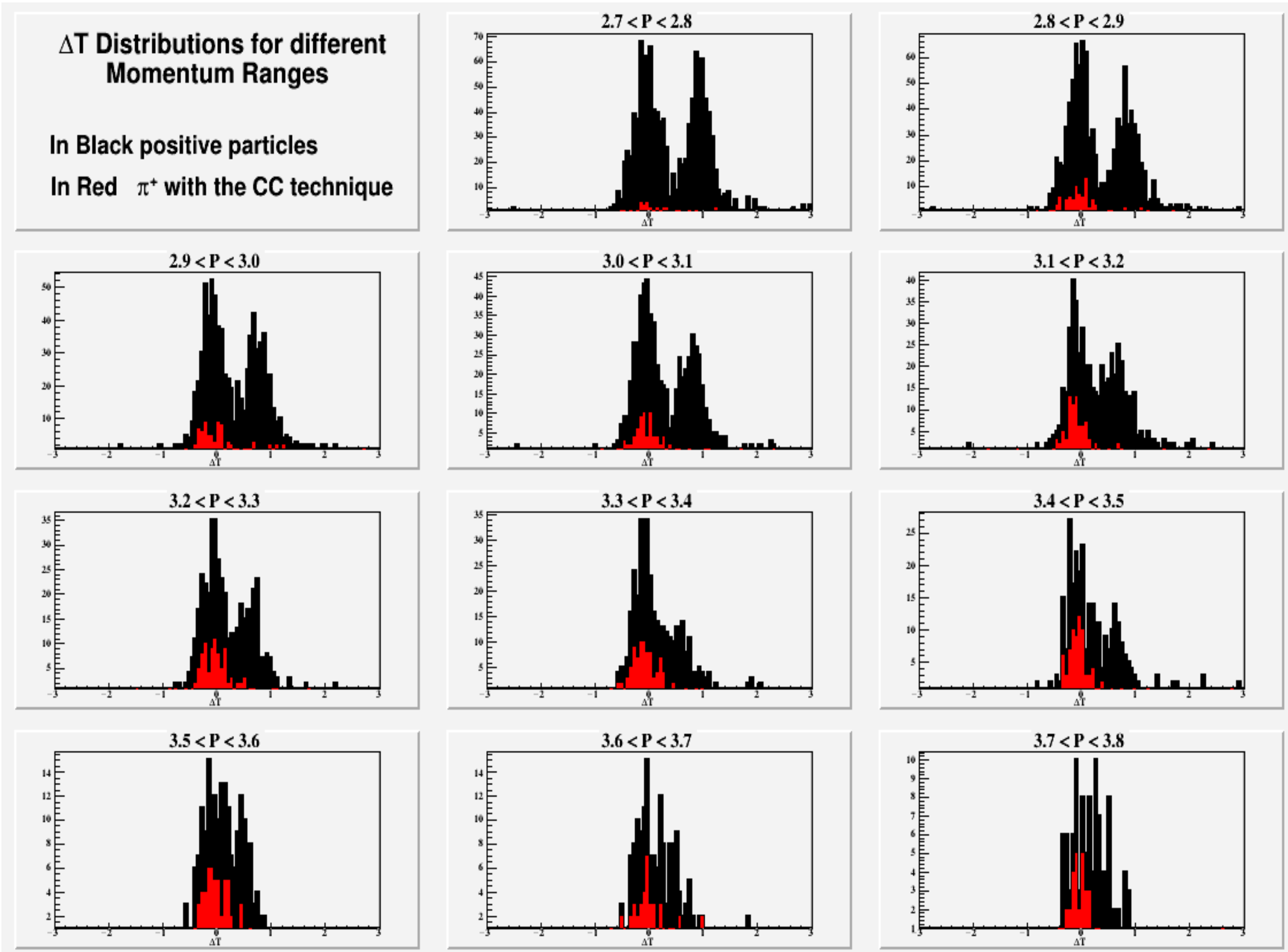
Effects of the acceptance, for **SMU** only, in the Multiplicity Ratio, for the Acceptance done with the three set of simulations, for each target separately:



Conclusion...
this changes the results,
but is not the main source of the
discrepancy observed

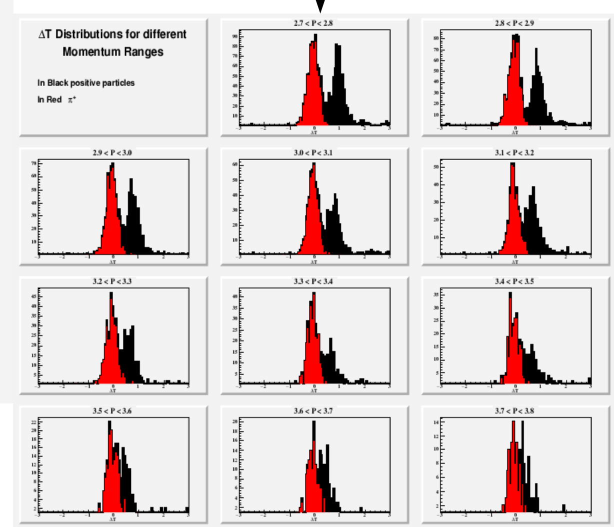
2. Cerenkov Counter efficiency

For the positive pion identification, in SMU analysis, there is a threshold value in the momentum at P=2.7(GeV/c), above this, the CC technique is used, before that it is T.O.F technique.



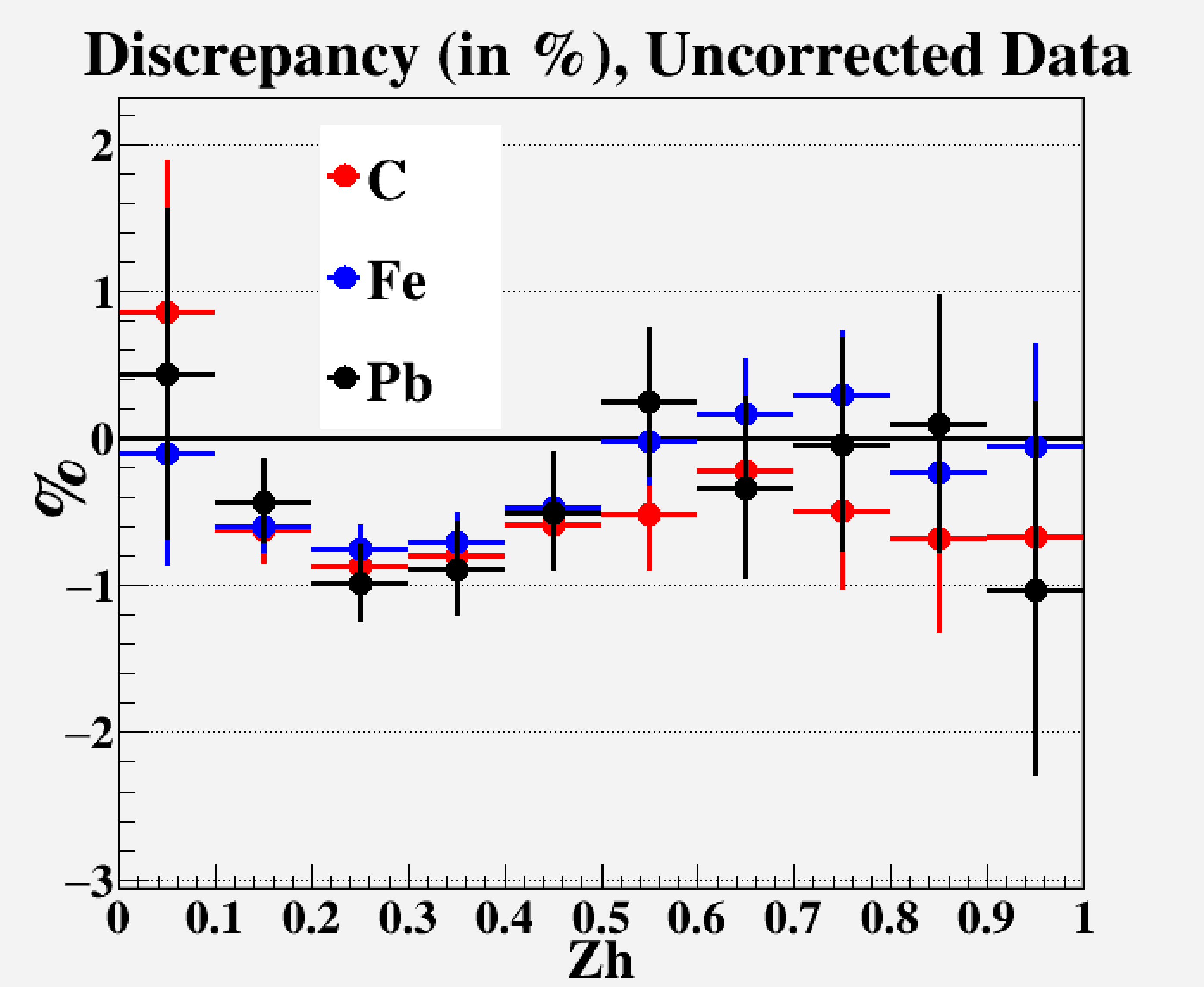
ΔT distributions for P > 2.7, in Red **Positive Pions**, in black **positives particles**, for SMU.

Same plot for **RD** case, it takes the full peak



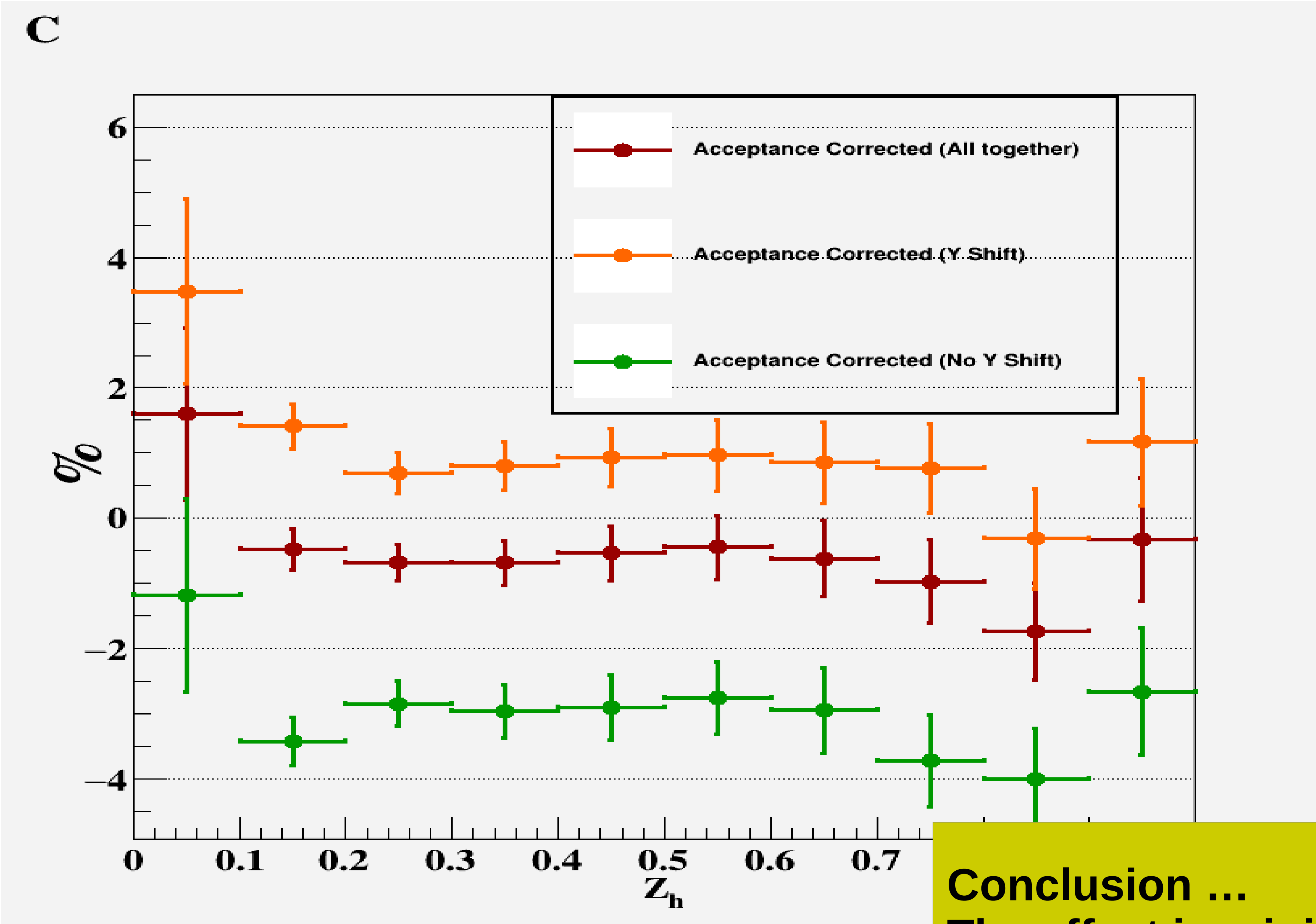
This is a big difference between the two analysis, ...

Now, if in **SMU** analysis used the T.O.F method for all P, without making the distinction at P=2.7, and also the cuts in ΔT for P < 2.7 are tighter, so it takes only the peak, the discrepancy between both analysis decreases:



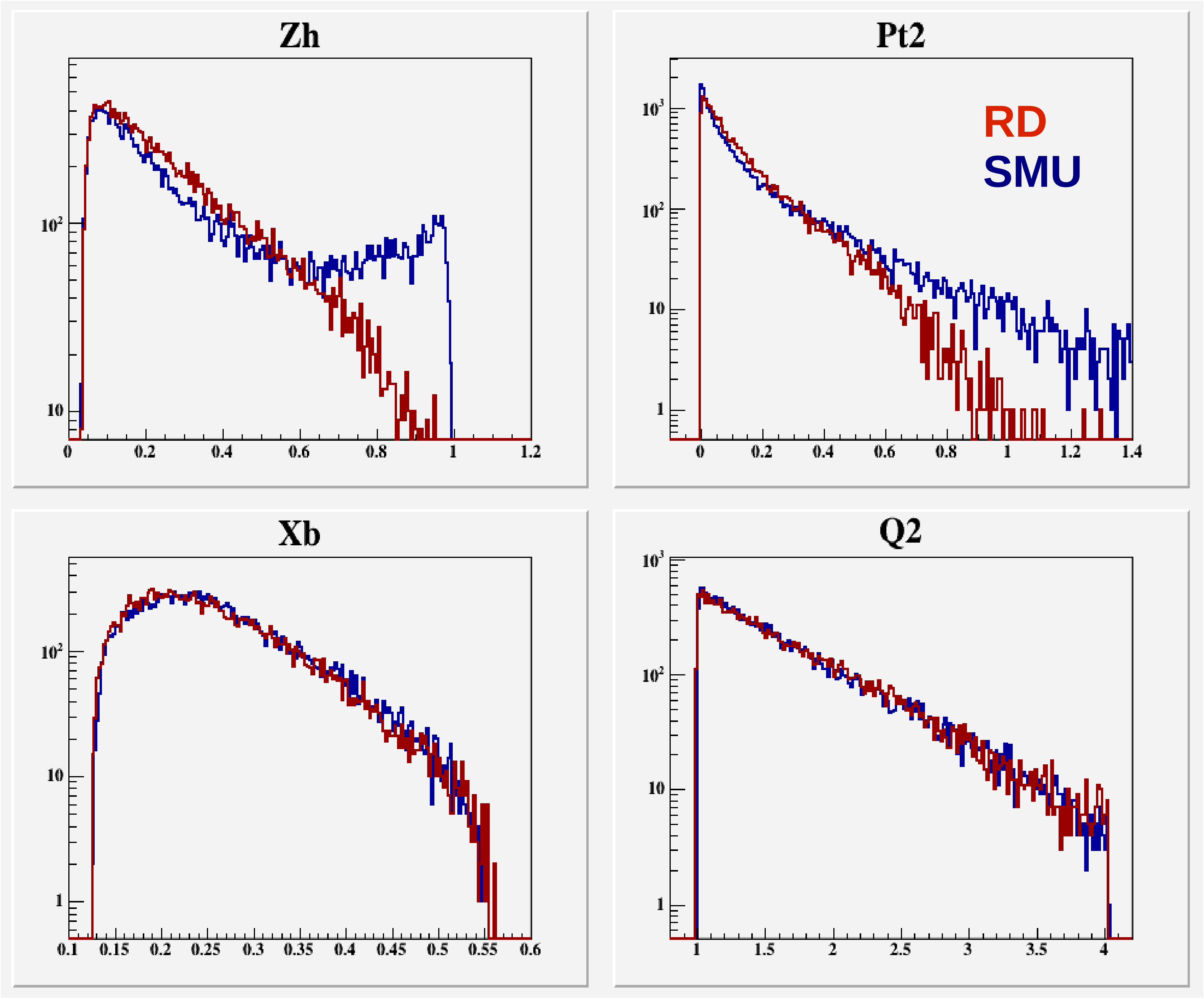
Both Analysis agreed within ~1% difference at data level

Effect of this new cuts for positive pions in the Acceptance for **SMU** analysis:



Conclusion …
The effect is minimal

3. Comparison between Generated events for both analysis.



*this is for Carbon, the behavior is the same for the other targets.

4. Parameters in the Pythia input (SMU)

In the following is the list of parameters (with their value and short explanation) which are different from the default value in Pythia 6.319:

MSTP(1)=2: defines the maximum number of generations equal to two;

MSTP(2)=1: strong coupling constant $\alpha_s = 0.20$ is fixed (including also for parton showers);

MSTP(13)=2: to set the range of Q^2 over which electrons are assumed to radiate photons by the user-determined $Q^2_{\max}$, given in PARP(13) (see below in the list);

MSTP(20)=0: do not suppress resolved (VMD or GVMD) cross sections, introduced to compensate for an overlap with DIS processes in the region of intermediate Q^2 and rather small W^2;

MSTP(38)=4: to use the massless approximation throughout for $gg \to \gamma\gamma$ and $gg \to g\gamma$, assuming the presence of four effectively massless quark species (at the most, eight) to satisfy the CLAS kinematics;

MSTP(41)=1: to put master switch for all resonance decays on;

MSTP(58)=4: to put maximum number of quark flavors used in parton distributions equal to four, and thus also for initial-state space-like showers;

MSTP(61)=0: to put master switch for initial-state QCD and QED radiation off;

MSTP(81)=0: to put master switch for multiple interactions off;

MSTP(82)=1: to assume the same probability for multiple interaction in all events, with an abrupt $p_{\perp\min}$ cut-off at 1.9 GeV;

MSTP(92)=4: to set energy partitioning hadron or resolved photon remnant proportional to $(1-\chi)^k / \sqrt{\chi^2 + c_{\min}^2}$, where χ is the energy fraction taken by one of the two objects, k=1 when a meson or resolved photon remnant is split into two fragments and k=3 when nucleon remnant is split into a diquark and a quark fragment, with χ giving the energy fraction taken by the quark jet and $c_{\min} = 0.6\ GeV / E_{cm} \approx 2 < m_q > / E_{cm}$ for both cases;

MSTP(101)=1: to set the structure of diffractive system as forward moving diquark plus interacting quark.

PARP(2)=3: to set the lowest center of mass energy for the event as a whole equal to 3 GeV;

PARP(18)=0.17: to scale k_ρ by 0.17 to set the cross section of a GVMD state of scale $k_\perp$ is suppressed by a factor $k_\rho^2 / k_\perp^2$ relative to those of a VMD state;

PARP(62)=0.5: to set effective cut-off Q or $k_\perp$ value equal to 0.5 GeV/c, below which space-like parton showers are not evolved. Primarily intended for QCD showers in incoming hadrons, but also applied to $q \to q\gamma$ branching;

PARP(65)=0.5: to set effective minimum energy (in c.m. frame) of time-like or on-shell parton emitted in space-like shower equal to 0.5 GeV;

PARP(91)=0.44: to set the width of Gaussian primordial $k_\perp$ distribution inside hadron equal to 0.44 GeV/c, i.e. $\exp(-k_\perp^2/\sigma^2)k_\perp dk_\perp$ with $\sigma = 0.44$ and $< k_\perp^2 >= 0.44^2$;

PARP(93)=2: to set the upper cut-off for primordial $k_\perp$ distribution inside hadron equal to 2 GeV/c;

PARP(99)=0.44: to set the width parameter of primordial $k_\perp$ distribution inside photon equal to 0.44 GeV/c;

PARP(100)=2: to set the upper cut-off for primordial $k_\perp$ distribution inside photon equal to 2 GeV/c;

PARP(102)=0.5: the mass spectrum of diffractive states (in single and double diffractive scattering) is assumed to start 0.5 GeV above the mass of the particle that is diffractively excited. In this connection, an incoming γ is taken to have the selected VMD meson mass, i.e. m_ρ, m_ω or m_ϕ;

PARP(103)=0.5: to assume that if the mass of a diffractive state is less than 0.5 GeV above the mass of the particle that is diffractively excited, the state is forced to decay isotropically into the two-body channel. In this connection, an incoming γ is taken to have the selected VMD meson mass, i.e. m_ρ, m_ω or m_ϕ. If the mass is higher than the threshold, the standard string machinery is used;

PARP(104)=0.3: to set the minimum energy above threshold for which hadron-hadron total, elastic and diffractive cross sections are defined, equal to 0.3 GeV;

PART(111)=0: do not put lower limit to the invariant mass of the remnant hadronic system (i.e. when interacting partons have been taken away), together with original parton masses and extra parton masses.

PARP(161)=2.69: to set the coupling $f_V^2/4\pi$ of the photon to the ρ^0 equal to 2.69;

PARP(162)=24.6: to set the coupling $f_V^2/4\pi$ of the photon to the ω equal to 2.69;

PARP(163)=18.8: to set the coupling $f_V^2/4\pi$ of the photon to the ϕ equal to 2.69;

PARP(165)=0.33: to apply multiplicative factor equal to 0.33 to the cross section for the transverse resolved photons to take into account the effects of longitudinal resolved photons;

PARJ(1)=0.025: to set the suppression of diquark-antidiquark pair production in the color field $\mathrm{P}(qq)/\mathrm{P}(q)$ =0.025, compared with quark-antiquark production;

PARJ(2)=0.120: to set the suppression of **s** quark pair production in the field compared with **u** or **d** pair production;

PARJ(3)=0.25: to set the extra suppression of strange diquark production compared with the normal suppression of strange quark (P(us)/P(ud))(P(s)/P(d))=0.25;

PARJ(11)=0.25: to set the probability that a light meson (containing **u** and **d** quarks only) has spin 1 equal to 0.25 (with correspondingly probability 0.75 for spin 0);

PARJ(3)=0.25: to set the extra suppression of strange diquark production compared with the normal suppression of strange quark (P(us)/P(ud))(P(s)/P(d))=0.25;

PARJ(11)=0.25: to set the probability that a light meson (containing **u** and **d** quarks only) has spin 1 equal to 0.25 (with correspondingly probability 0.75 for spin 0);

PARJ(12)=0.3: to set the probability that a strange meson has spin 1, equal to 0.3;

PARJ(21)=0.63: to set the width $\sigma = 0.63$ in the Gaussian p_x and p_y transverse momentum distributions of for primary hadrons;

PARJ(23)=0.3, PARJ(24)=5: to set a fraction 0.3 of the Gaussian transverse momentum distribution is taken to be a factor 5 larger than input in PARJ(21). This gives a simple parameterization of non-Gaussian tails to the Gaussian shape assumed above.

PARJ(33)=0.6: to define the remaining energy below which the fragmentation of a parton system is stopped and two final hadrons formed, equal to 0.6 GeV;

PARJ(41)=1.13, PARJ(42)=0.37: to set the a=1.13 and b=0.37 GeV^{-2} parameters of the symmetric Lund fragmentation function;

PARJ(45)=0.8: to set the effective **a** parameter in the Lund flavor dependent symmetric fragmentation function to be by 0.8 larger than the normal **a** when diquarks is produced. More specifically, referring to equation 4.10 $a_\alpha = PARJ(41)$ when considering the fragmentation of a quark and equal to PARJ(41)+PARJ(45) for the fragmentation of a diquark, with corresponding expression for a_β depending on whether the newly created object is a quark or diquark;

MSTJ(12)=1: to assume that in baryon production model diquark-antidiquark pair production allowed; diquark treated as a unit;

MSTJ(45)=4: to set the maximum flavor that can be produced in shower by $g \rightarrow q\overline{q}$ equal to 4;

MSTU(112)=4: to set the nominal number of flavors assumed in the α_s expression equal to 4, with respect to which Λ is defined;

MSTU(113)=4: to set the minimum number of flavors that may be assumed in the α_s expression equal to 4;

MSTU(114)=4: to set the maximum number of flavors that may be assumed in the α_s expression equal to 4;

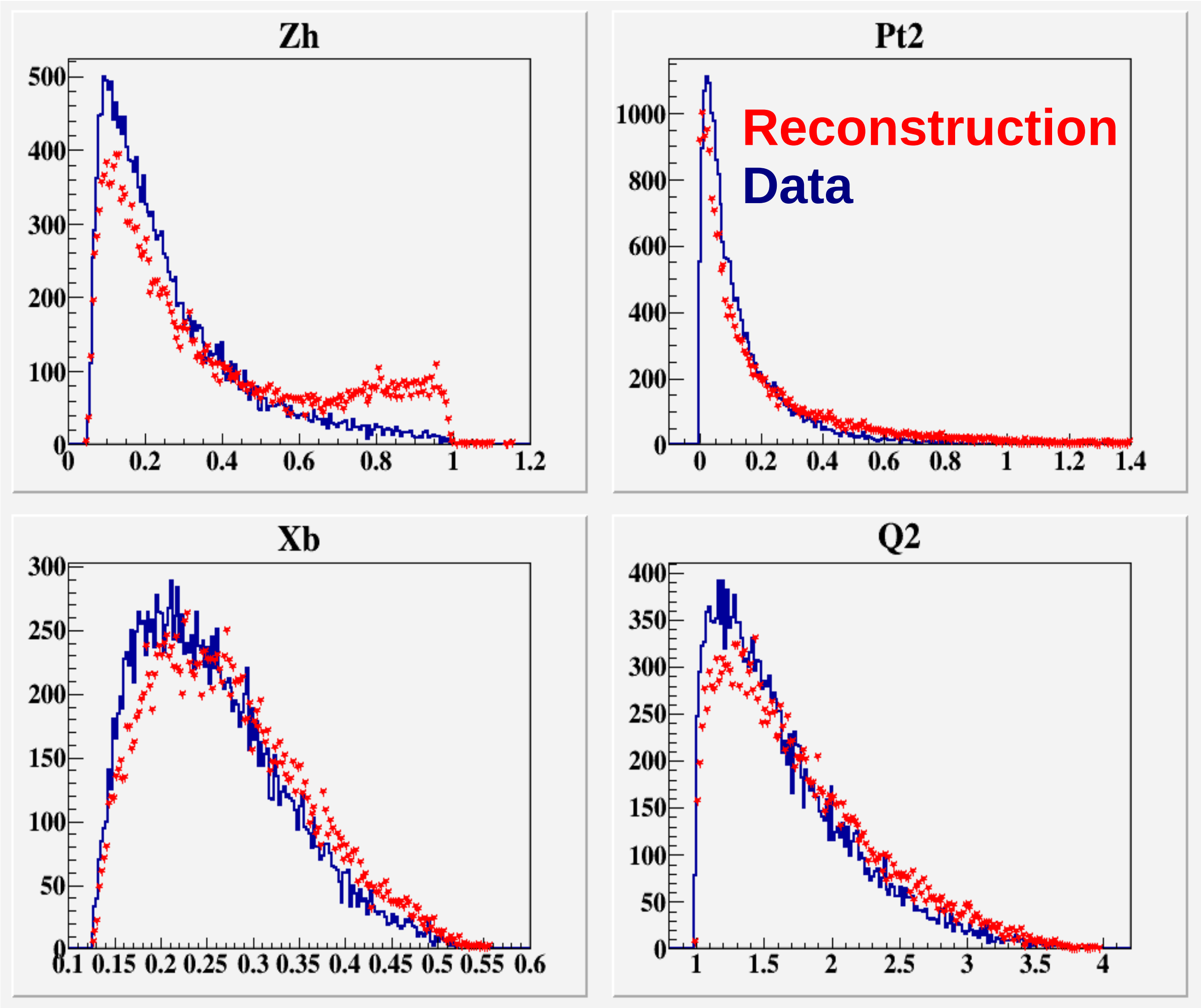
CKIN(1)=1, CKIN(2)=-1: to set the range of allowed $\hat{m} = \sqrt{\hat{s}}$ greater than 2 GeV;

CKIN(3)=0, CKIN(4)=2: to set the range of allowed $0 < \hat{p}_{\perp} < 2GeV$ for hard $2 \rightarrow 2$ processes, with transverse momentum $\hat{p}_{\perp}$ defined in the rest frame of the hard interaction. These limits can also be used in $2 \rightarrow 1 \rightarrow 2$ processes. Here, however, the product masses are not known and hence are assumed to be vanishing in the event selection. The actual $p_{\perp}$ range for massive products thus shifted downwards with respect to the nominal one;

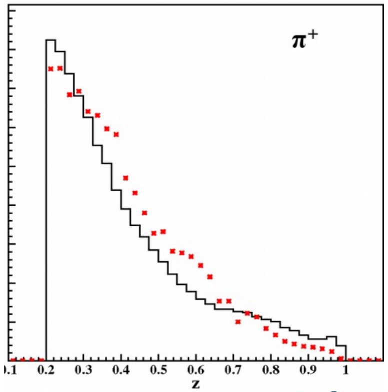
CKIN(65)=1, CKIN(66)=4: to set the range of for the spacelike virtuality of the photon $1 < Q^2 < 4GeV^2$;

CKIN(77)=2, CKIN(78)=-1: to set the range for invariant mass $W > 2\ GeV$.

5. Comparison between Data and Reconstruction, for SMU analysis.



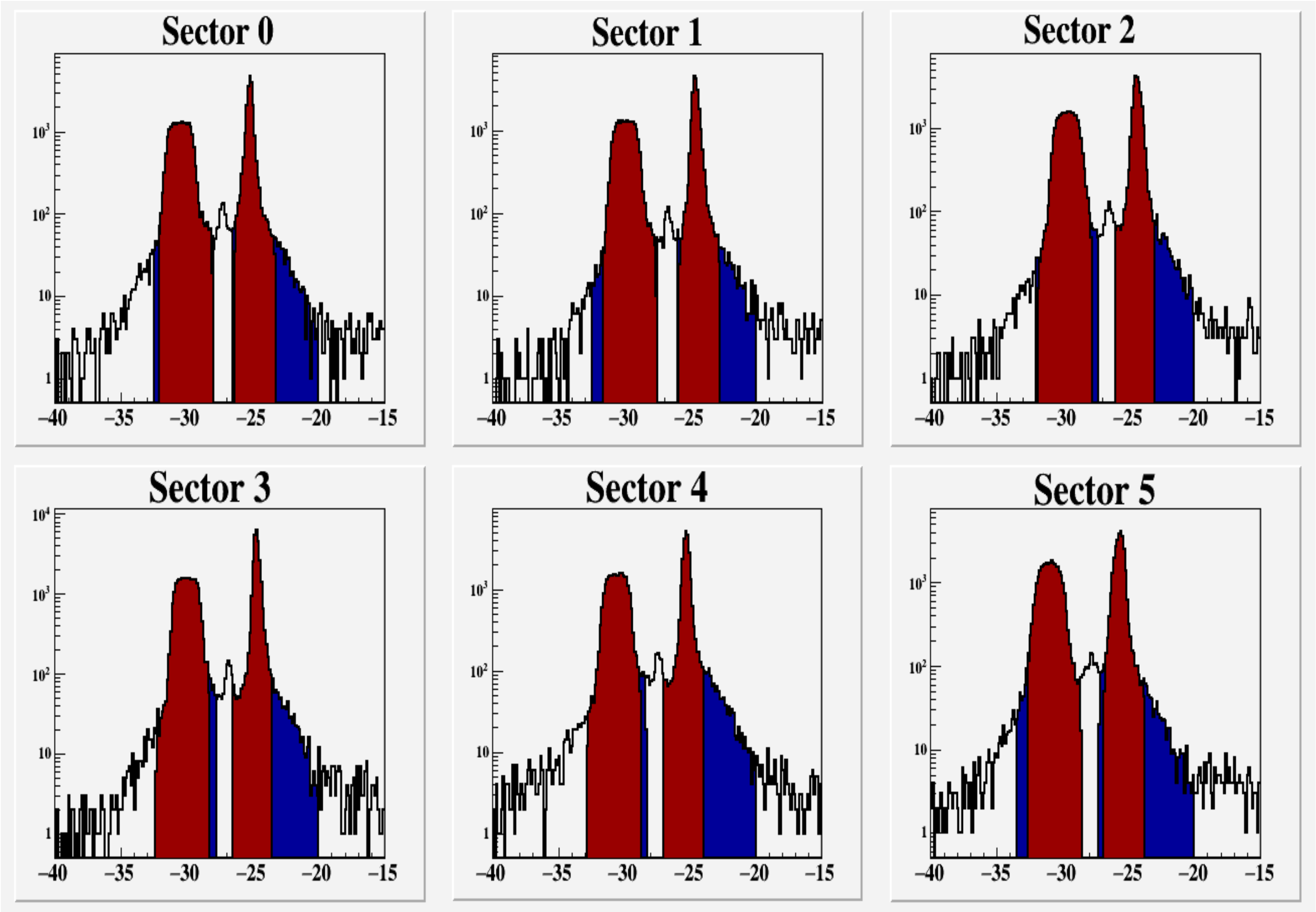
Zh, RD case



The mayor difference with RD is at high Zh

6. Z shift in RD analysis.

The two analysis have two independent set of vertex cuts:

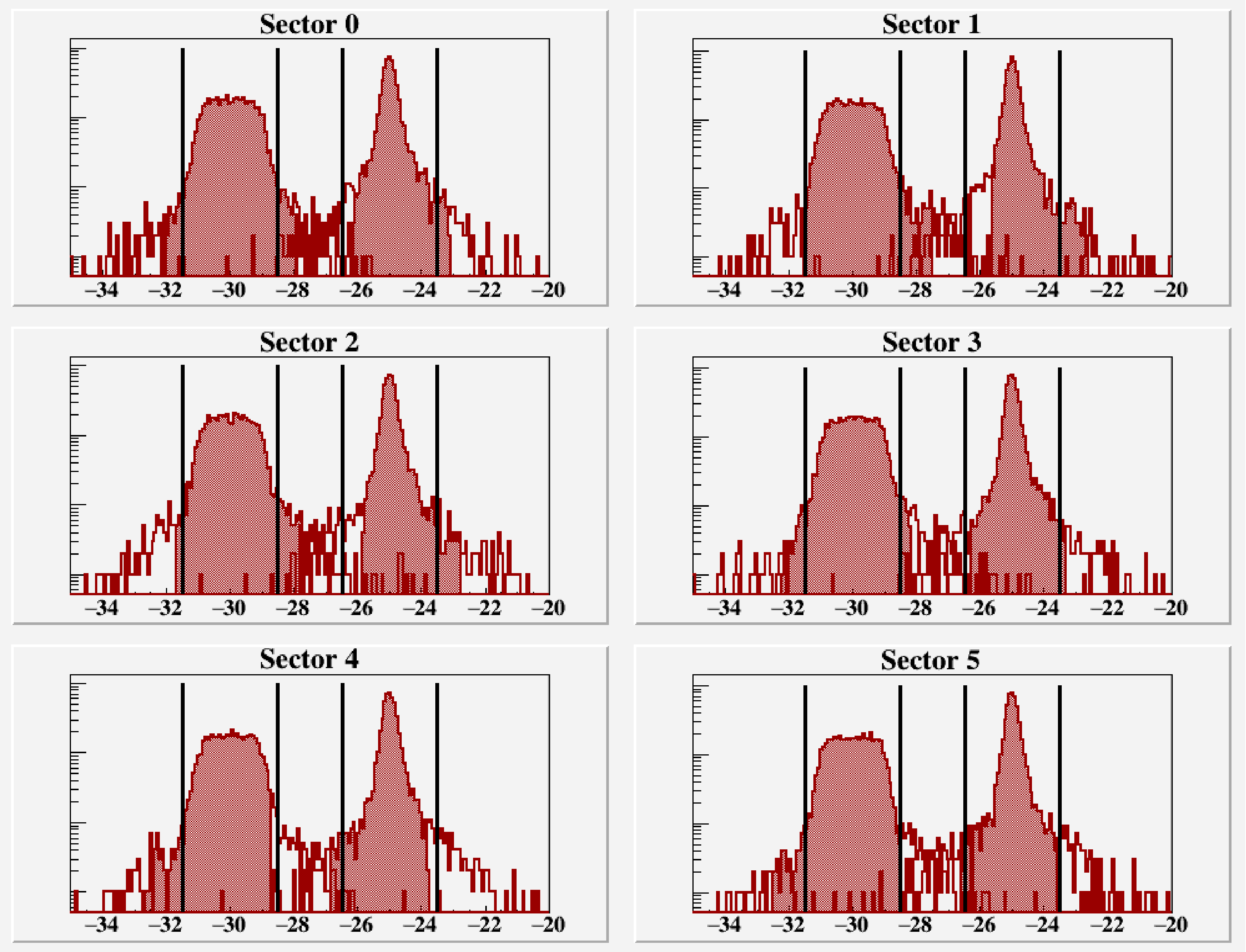


SMU
RD

RD has a tighter cut than SMU.

In **SMU** analysis the vertex cuts is the same for data than for Simulations, and is the same for all targets, but for **RD** is different, is one set for data and another for simulations, for data a sector dependent shift in Z is applied

Z distribution for the electron in the Reconstruction, the **shadow** region is the vertex cuts using the shift (the same vertex as in data) and the **black** lines are the vertex without any shift



To see the effect of this Z shift in simulations, **for RD case**, the MR is calculated for both cases:

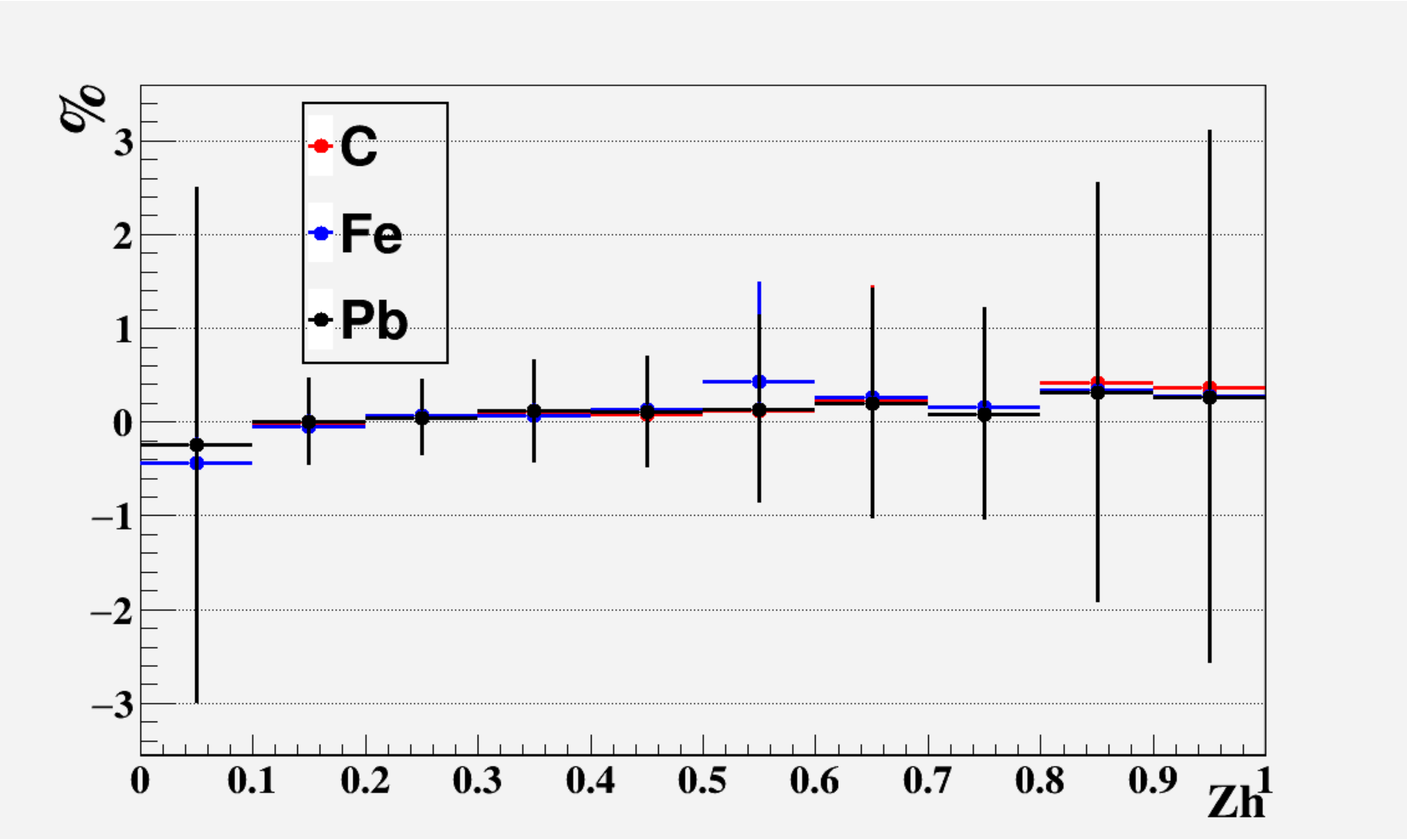
	Normalization Factors for MR, for RD case.		
	Uncorrected Data	Acceptance Corrected (No Shift in Z)	Acceptance Corrected (Shift in Z)
Carbon	1.13723	1.12225 (-1.33457 %)	1.10149 (-3.24461 %)
Iron	1.04534	1.03522 (-0.976857 %)	1.01893 (-2.59202 %)
Lead	2.18093	2.15142 (-1.37177 %)	2.11308 (-3.21097 %)

In **Red** is the effect of the correction in the number, in percentage.

Applying the same cuts in data and in simulations leads to an increment in the acceptance effect in the normalization factor.

The difference between the MR with the acceptance performed With the Z shift and without it is plotted here:

Difference in the Multiplicity Ratio, when the Z shift is applied or not in the simulation



(No_shift – Shift) / Shift *100

For RD case it doesn't matter if the Z shift is applied or not in the simulation

7. Change in the binning choice

Up to this point we have been using the same binning, with equidistant width for all

Variable	# of Bins	Low Limit	Up Limit	Width
Q^2	6	1.0	4.0	0.5
Z_h	10	0.0	1.0	0.1
Nu	10	2.2	4.2	0.2
X_b	5	0.12	0.7	0.09
P_T^2	5	0.0	1.0	0.2
Φ	12	-180°	180°	30°

*Q2 and Pt2 are in GeV2, Zh and Xb are dimensionless by definition and Nu is in GeV.

The new binning is shown here, the same number of bins are used, but the width is **variable** for all, except for Zh:

Variable	Number of Bins	Width
Q2	6	Variable
Xb	5	Variable
Pt2	5	Variable
Zh	10	Fixed

Q^2	X_b	P_t^2	Z_h
1.00	0.12	0.00	0.0
1.17	0.19	0.03	0.1
1.33	0.23	0.06	0.2
1.51	0.27	0.10	0.3
1.75	0.33	0.18	0.4
2.12	0.57	1.00	0.5
4.00			0.6
			0.7
			0.8
			0.9
			1.0

This new binning was chosen to have in each bin approximately the same percentage of events, the idea now is to explore the impact of this choice in the Multiplicity Ratio.

New Normalization factors, for electrons, with the variable width bins:

	Normalization Factors for MR, for SMU case.			
	Uncorrected Data	Acceptance Corrected (Y Shift)	Acceptance Corrected (No Y Shift)	Acceptance Corrected (Together)
Carbon	1.08474	1.08327 (-0.1356 %)	1.10308 (1.66278 %)	1.09111 (0.5843 %)
Iron	1.01093	0.991979 (-1.9092 %)	0.992977 (-1.8068 %)	0.992021 (-1.905 %)
Lead	2.11932	2.06534 (-2.6125 %)	2.07549 (-2.111 %)	2.06939 (-2.4119 %)

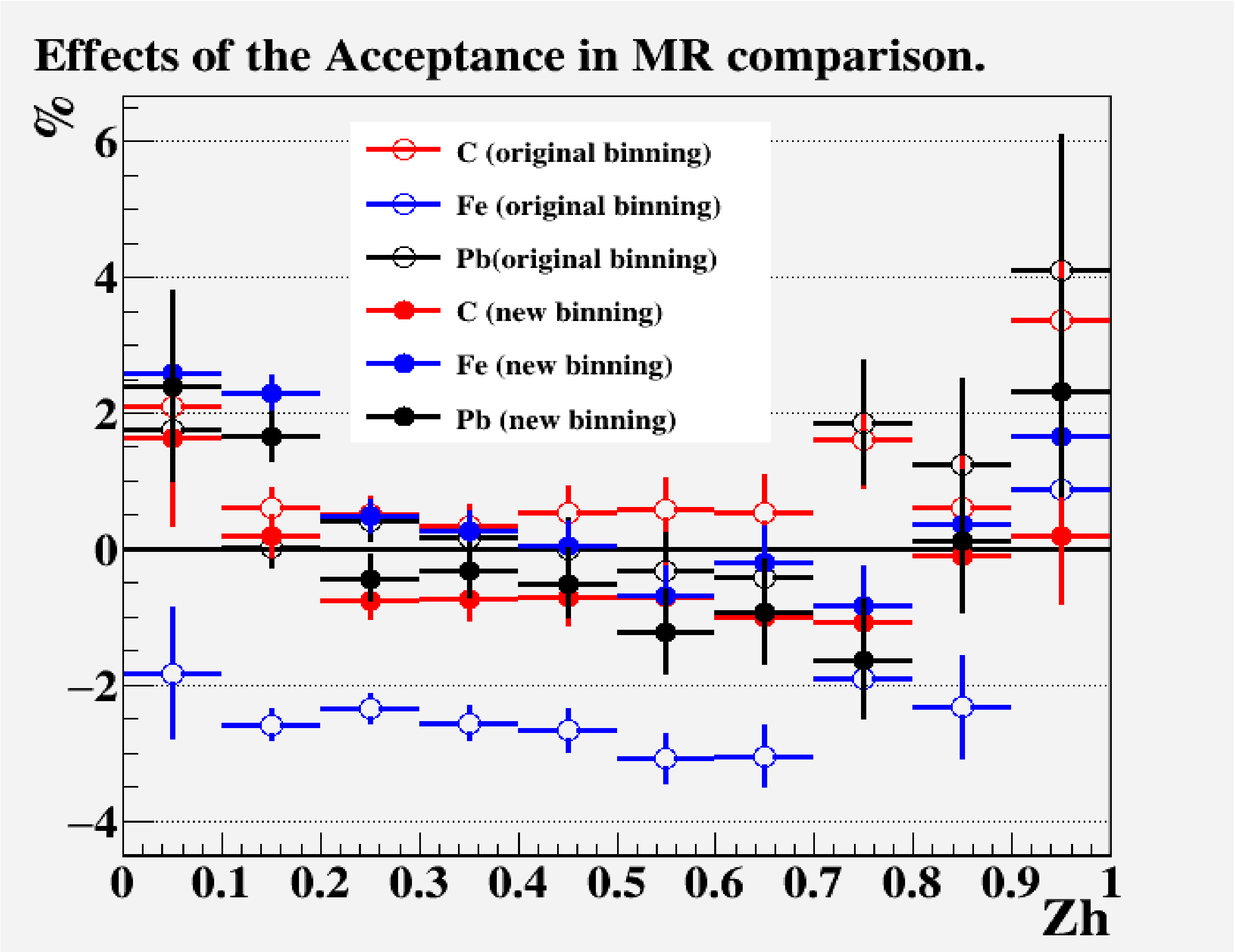
In **Red** is the effect of the correction in the number, in percentage

Comparison with the previous case, for the case of all the set of simulations together

	Acceptance Corrected (Old Binning)	Acceptance Corrected (New Binning)
Carbon	0.4001 %	0.5834 %
Iron	-5.2117 %	-1.9057 %
Lead	-2.4532 %	-2.4119 %

The new binning makes the effect of acceptance in Fe smaller, now is ~2% instead of ~5%.
Now for the three targets the effects of acceptance is less than 2.5%

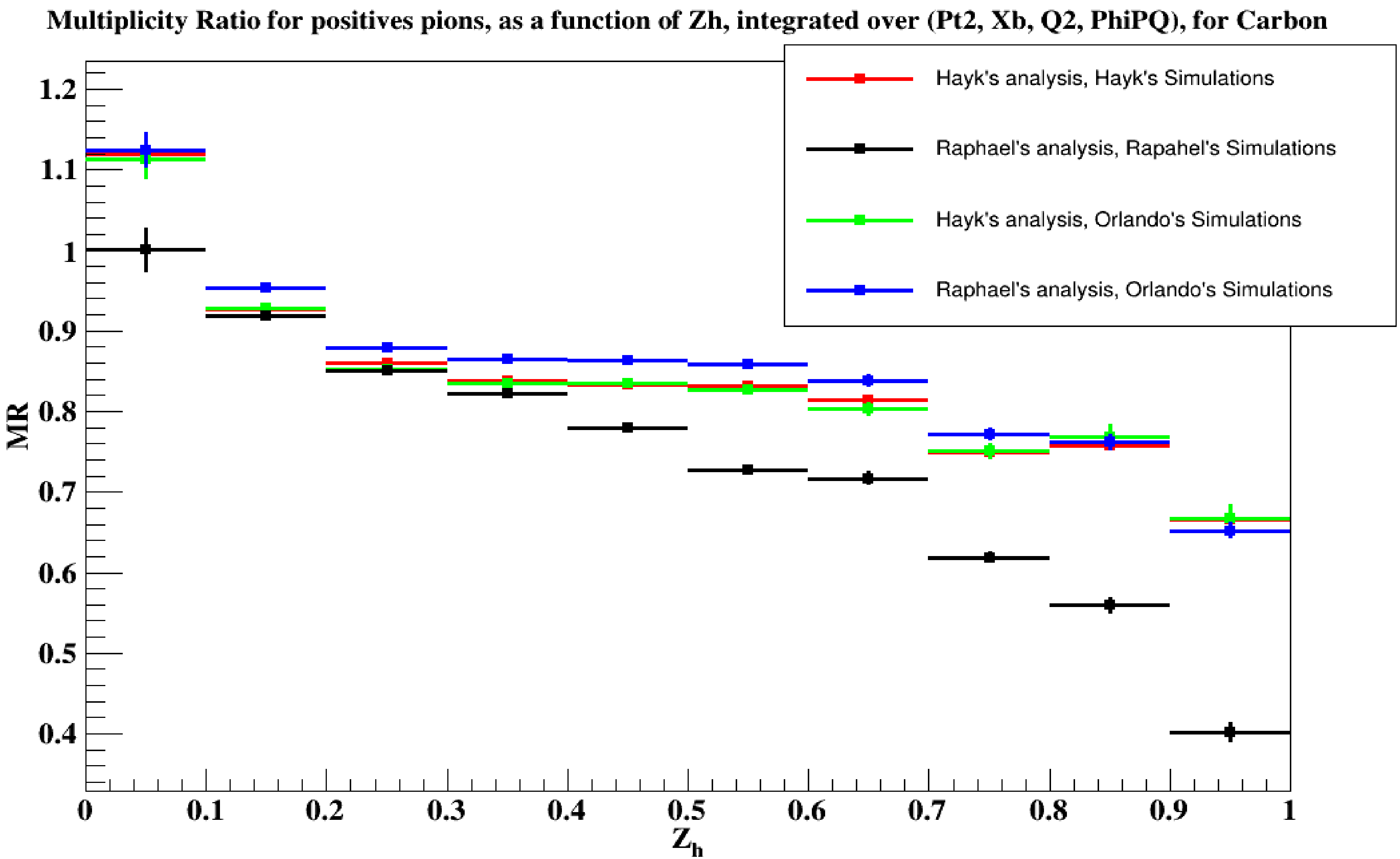
The comparison between both cases, old binning (equal width) and this new binning (variable width), **<u>just for SMU case</u>**:



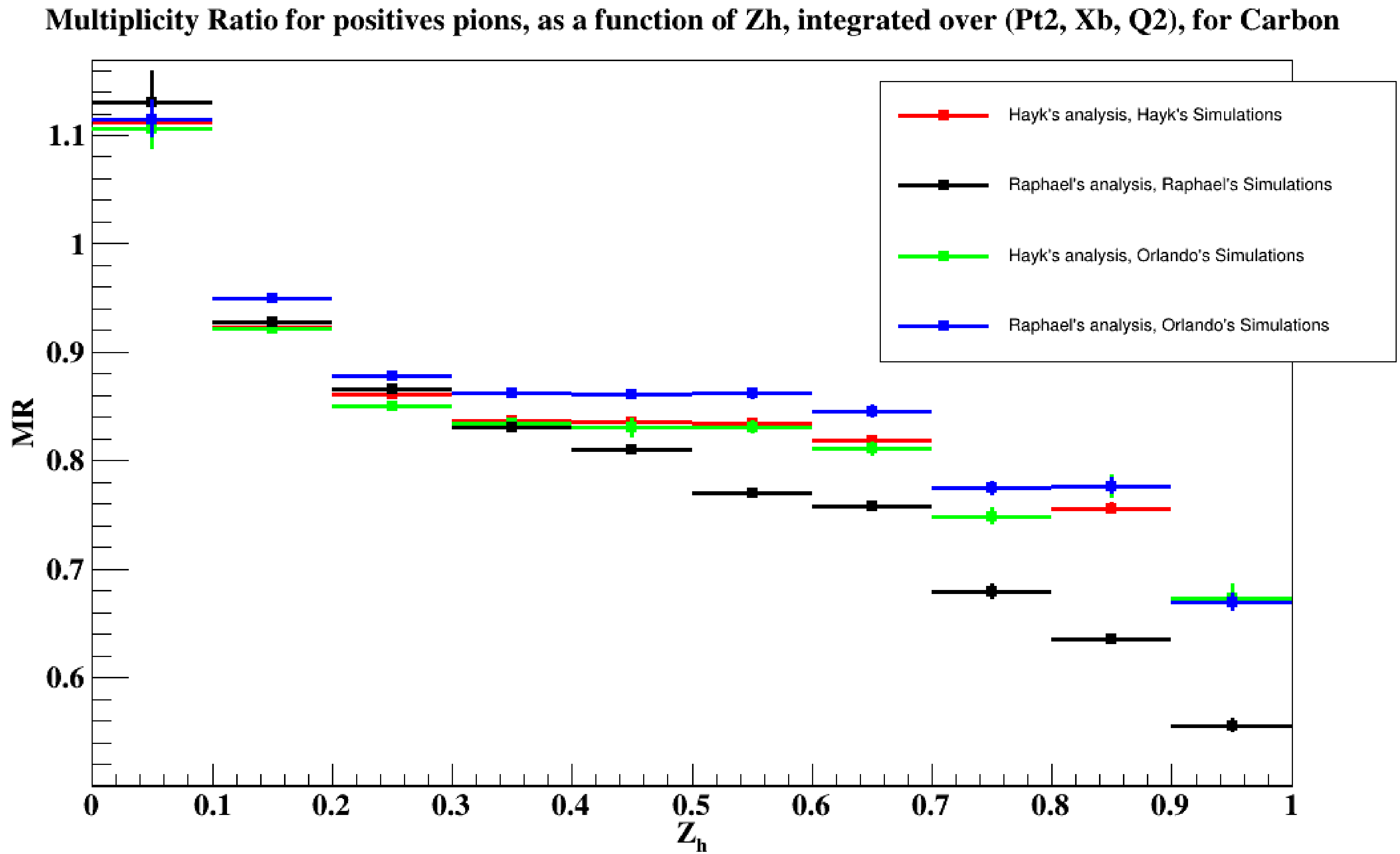
The new choice of binning mainly put the acceptance effect down, but the most clear effect is in Iron, now behaves like the other targets.

None of this modifications in the analysis has change the MR curve so significantly
that could lead to an explanation about the original discrepancy between the analysis,
at Uncorrected Data Level, both analysis are in reasonable agreement (~1%),
but with acceptance Correction there is still a mayor difference

5-D acceptance correction comparison for Carbon, including LEPTO based simulations made by Orlando Soto



4-D acceptance correction comparison for Carbon, including LEPTO based simulations made by Orlando Soto



Backup slides

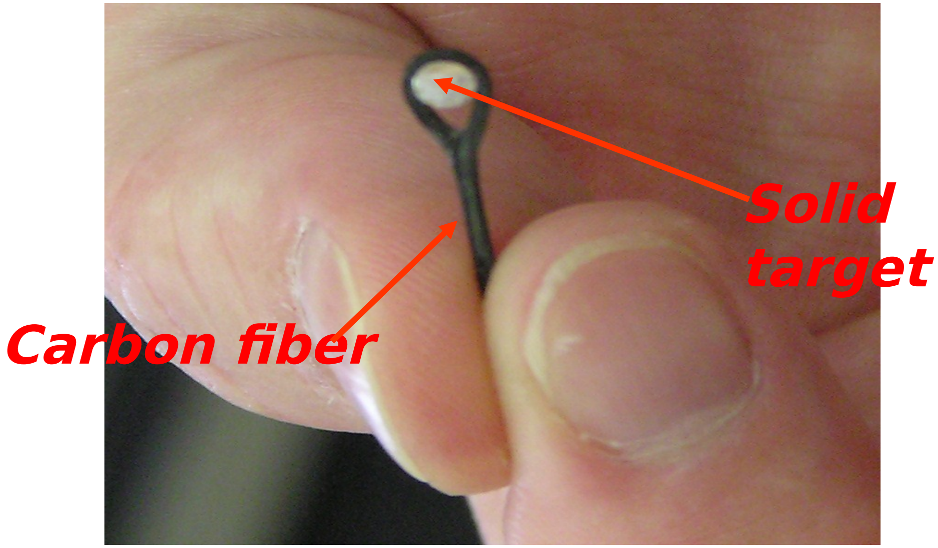
Positive pions analysis

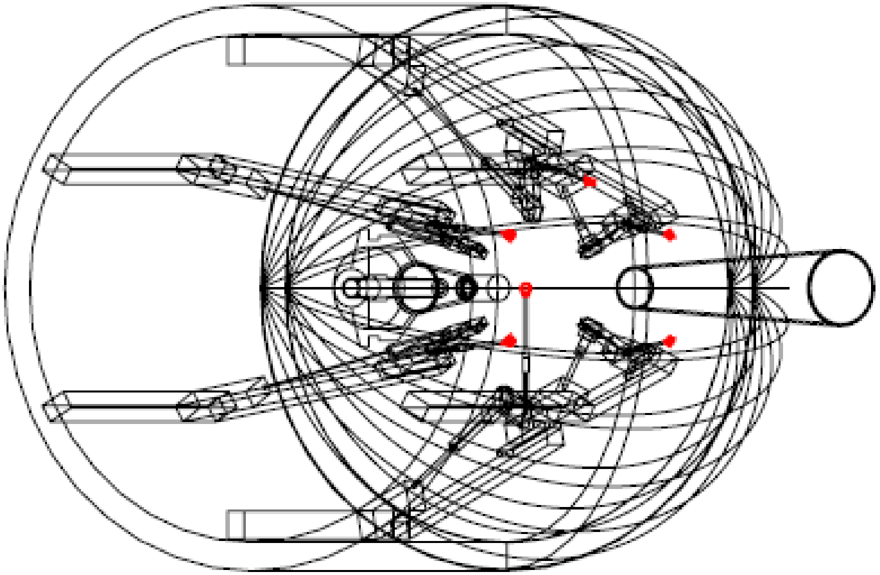
(results of CLAS EG2 experiment)

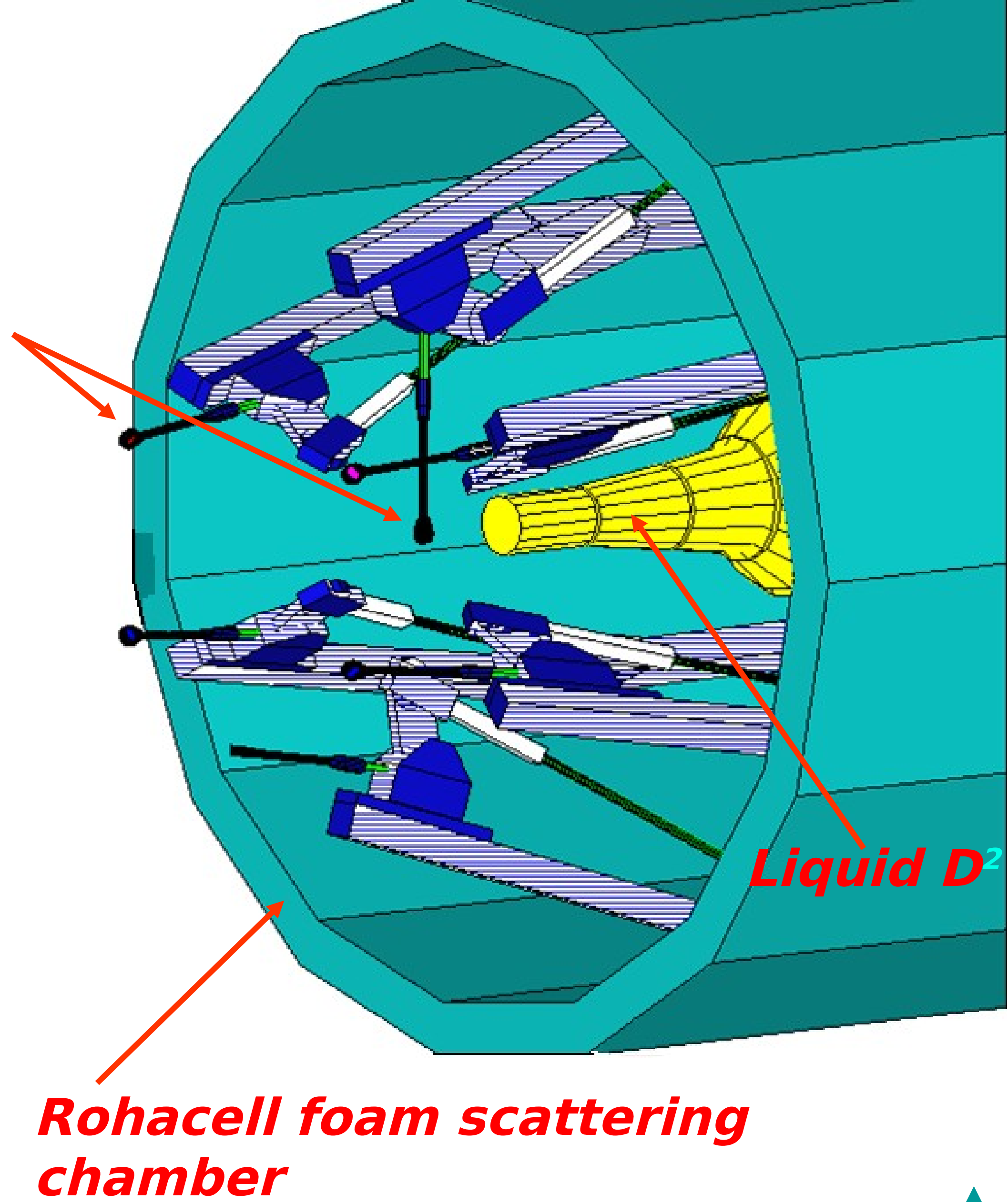
Hayk Hakobyan and co.

18th of April, 2019

Experimental details

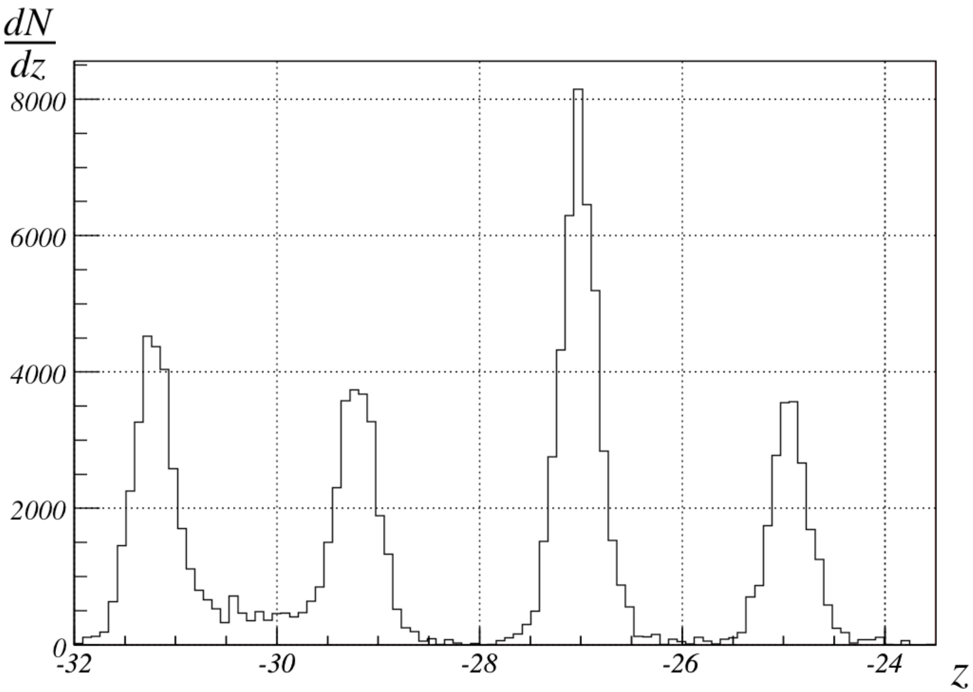




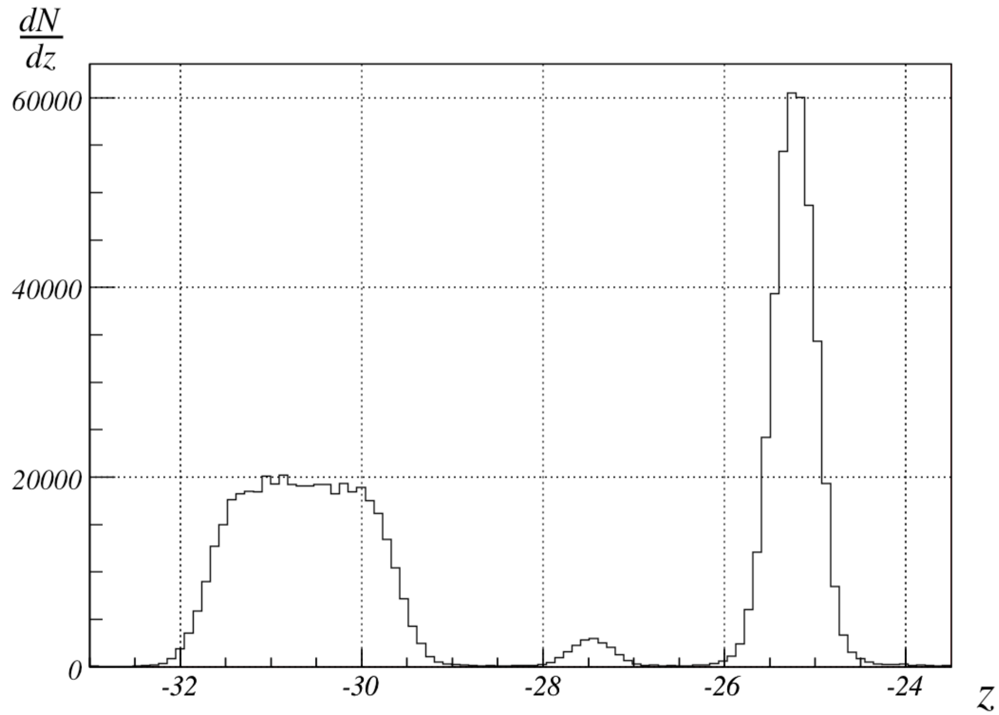


EG2 Experiment target in GEANT3
Solid (C, Al, Fe, Sn, Pb) target
simultaneously with deuterium target

Liquid target empty



Liquid target full



Experimental Variables

ν – energy transferred by the electron, = initial energy of struck quark, (2 ~ 4.5) GeV here

**Q – ** probe, (1 ~ 4) GeV^2 here

z_h – Energy fraction carried by hadron; $0<z_h<1$

p_T – hadron momentum transverse to virtual photon direction

Φ – hadron azimuthal angle to virtual photon direction

E_{BEAM}=5.014 GeV

Hadronic multiplicity ratio

$$R_M^h(z,\nu,p_T^2,Q^2,\phi) = \frac{\left\{\dfrac{N_h^{DIS}(z,\nu,p_T^2,Q^2,\phi)}{N_e^{DIS}(\nu,Q^2)}\right\}_A}{\left\{\dfrac{N_h^{DIS}(z,\nu,p_T^2,Q^2,\phi)}{N_e^{DIS}(\nu,Q^2)}\right\}_D}$$

Data analysis procedure

- Data Taking, Calibration and Processing During EG2 Experiment .
- Development of Particle Identification Scheme for electrons and pions.
- PYTHIA 6.319 Adaptation to the EG2 Experiment.
- EG2 Target implementation in the GSIM.
- Simulation and Reconstruction with GPP included
- Acceptance Calculation and Simulation Results analysis.
- Electronic and Hadronic radiative corrections.
- Fiducial Cuts and the analysis of Their Effect on the Final Results.

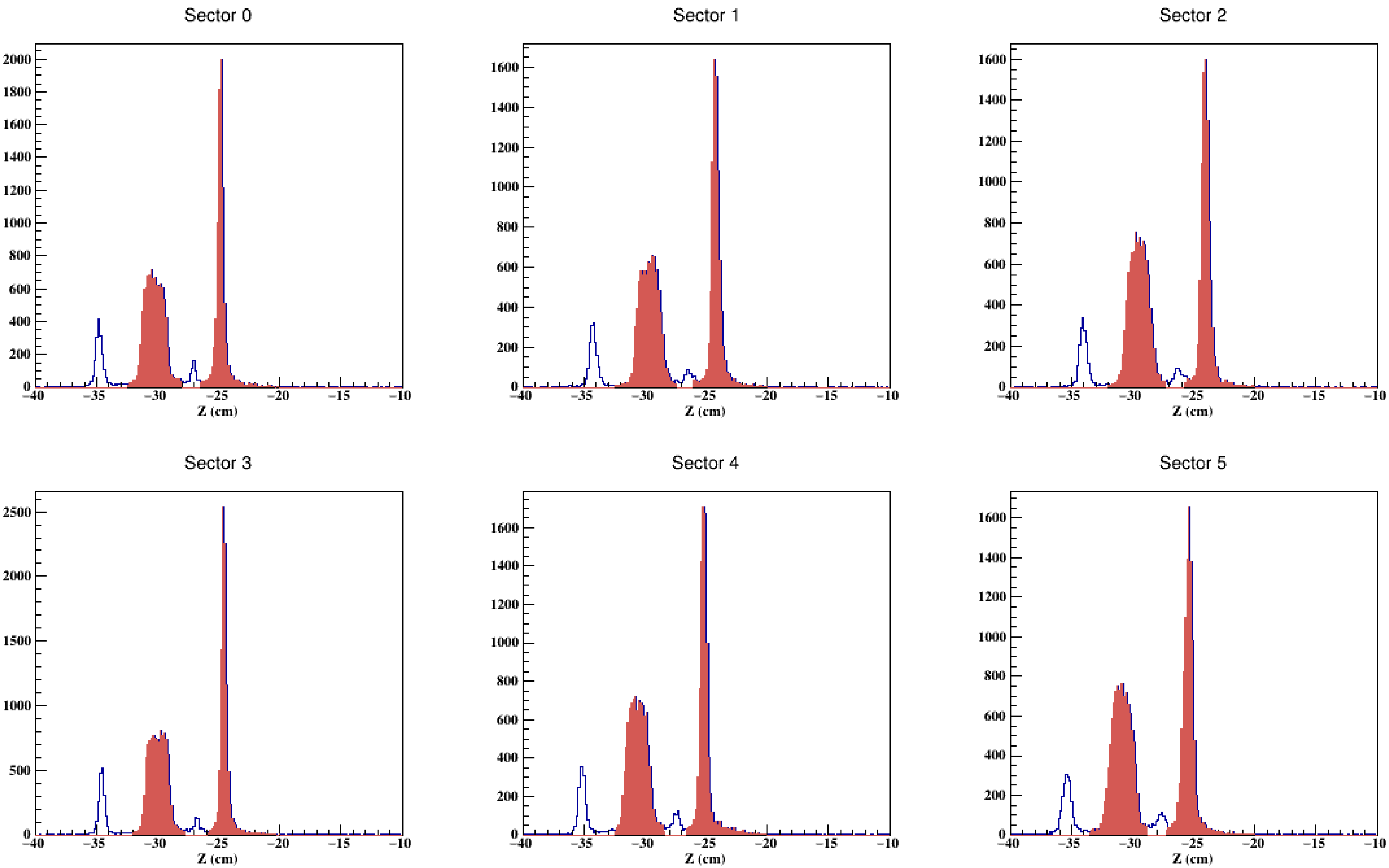
Electron cuts

- Signals in all detectors"DCPB", "CCPB", "SCPB", “ECPB"
- 0 < Status < 100
- Charge = -1
- StatCC > 0, StatSC > 0, StatDC > 0, StatEC > 0, DCStatus > 0, SCStatus = 33
- Nphe > 25 (S0 and S1); 26 (S2); 21 (S3); 28 (S4 and S5)
- Momentum > 0.75
- Ein > 0.06
- Time(EC) – Time(SC) – (Path(EC) – Path(SC))/30.
- Etot / 0.27/1.15 - 0.2 < Momentum < Etot / 0.27/1.15 + 0.4
- 0.8 * 0.27 * Momentum < Ein + Eout < 1.2 * 0.27 * Momentum
- Eout is different of zero
- Fiducial Cut (made by Lorenzo Zana and approved in several analysis)
- Vertex cut (sector by sector)

Additional cuts on electrons

- $Q^2 > 1$
- $W > 2$
- $Y = Nu/E_{BEAM} < 0.85$ (to remove the region where Rad Corr.s are large)

Electron vertex cuts



Positive pions cuts

- 0 < Status < 100
- Charge = 1
- StatDC > 0

Momentum < 2.7 (low energy)

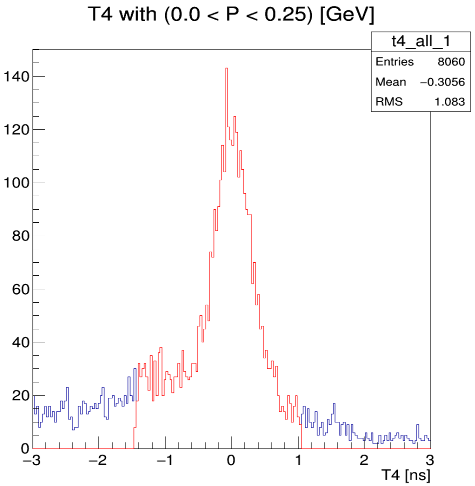
- StatSC > 0
- Momentum dependent ΔT cut

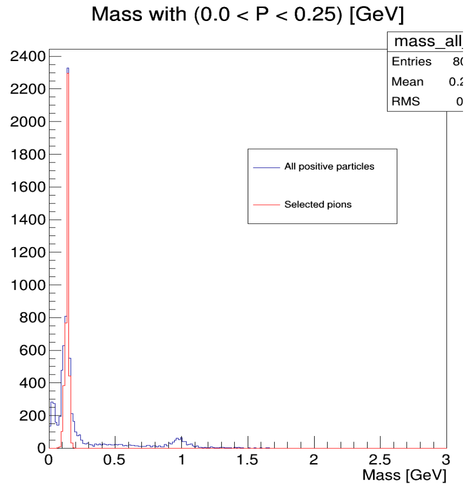
Momentum > 2.7 (high energy)

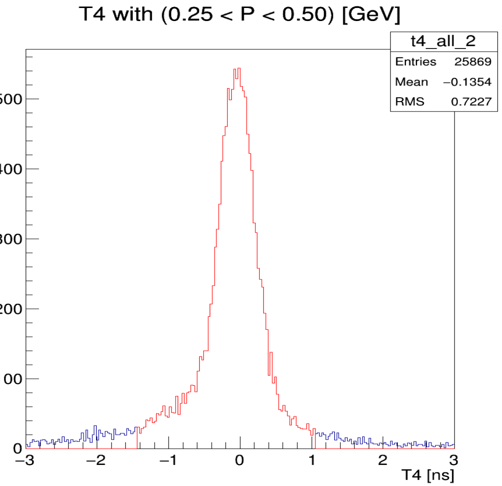
- Nphe > 25
- Chi2CC < 5 / 57.3

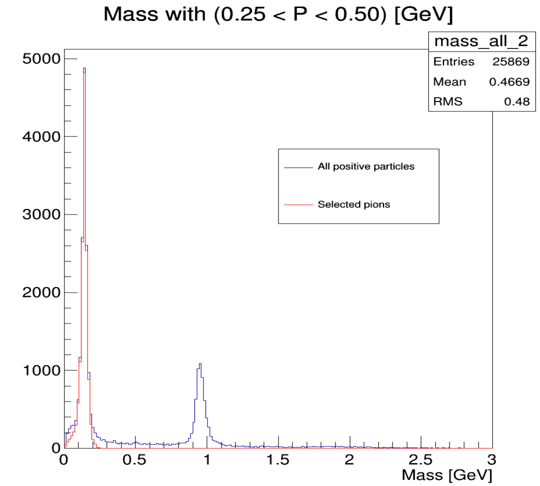
$\Delta T = Path_e(SC)/30. - Time_e(SC) – Time_{Pi}(SC) – 0.08 - -Path_{Pi}(SC)/30. * Sqrt((0.139570/Momentum)\char`^2 + 1)$

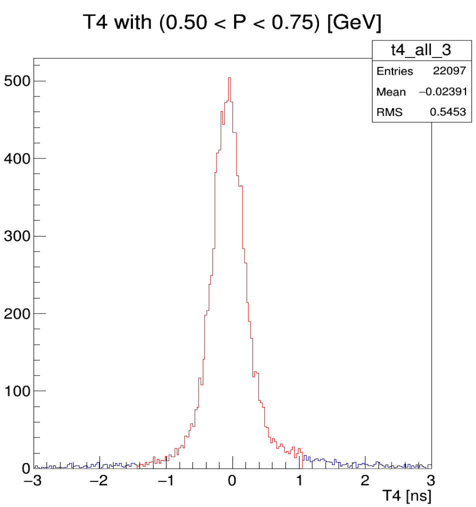
ΔT cut and its impact on mass dist.

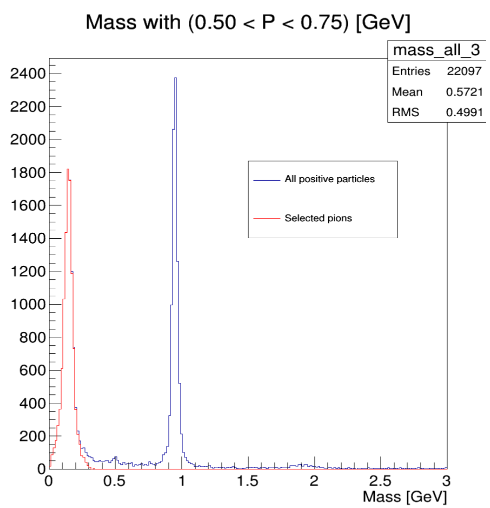


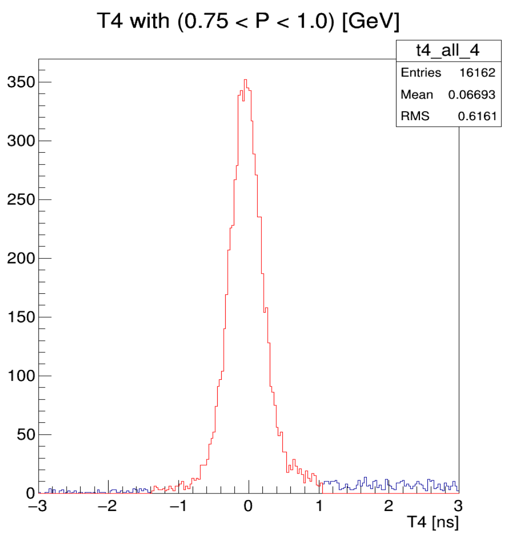


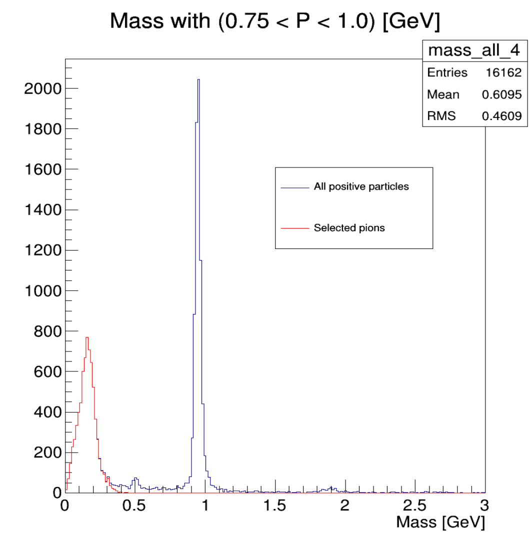




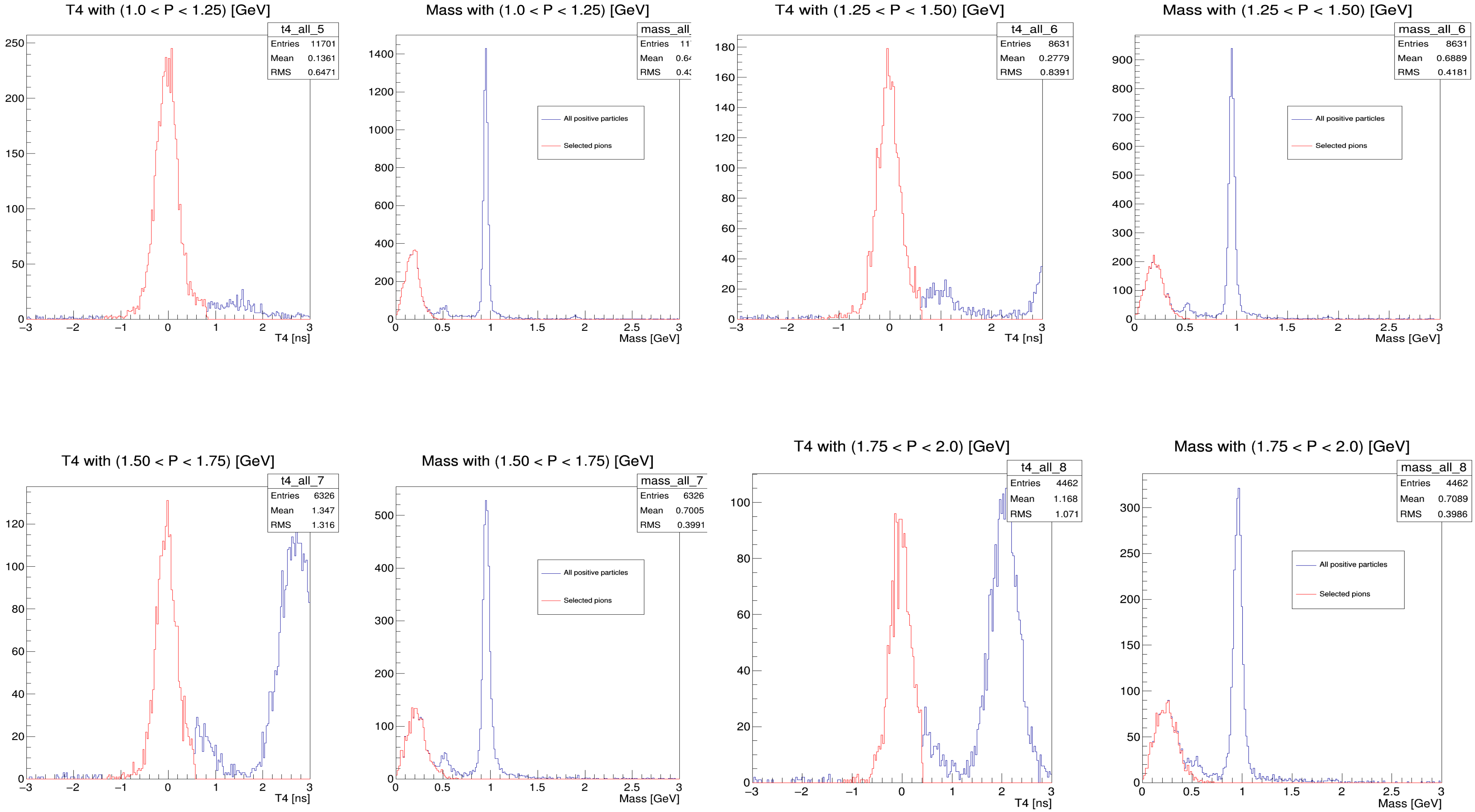




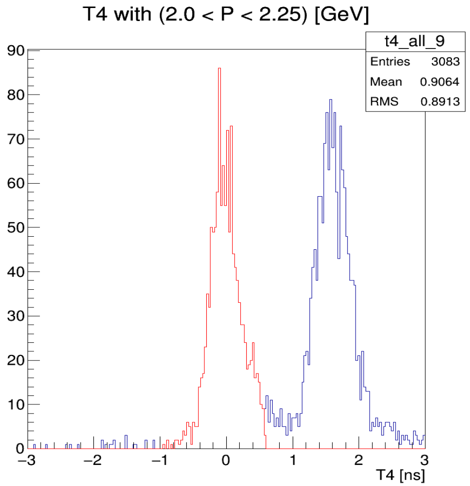


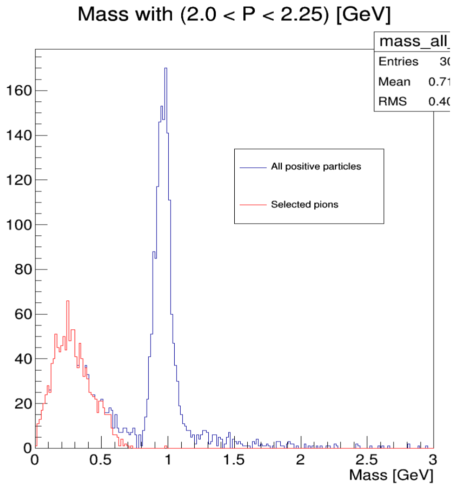


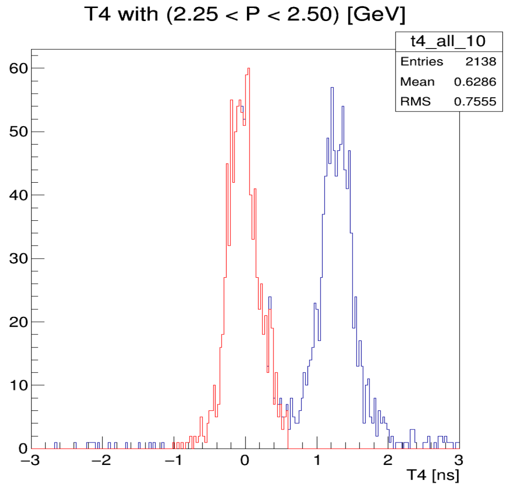
ΔT cut and its impact on mass dist.

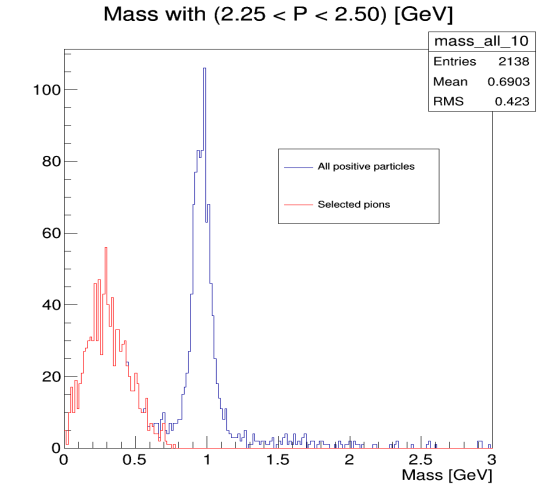


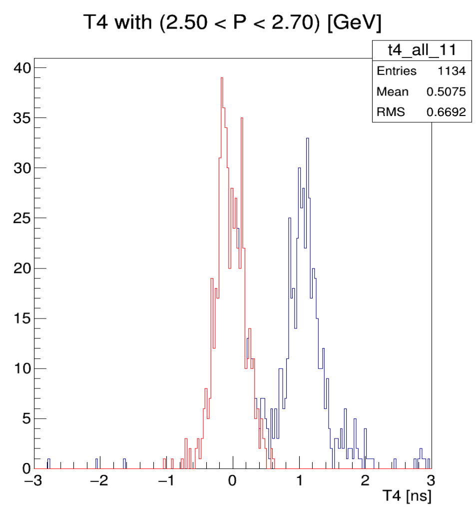
ΔT cut and its impact on mass dist.

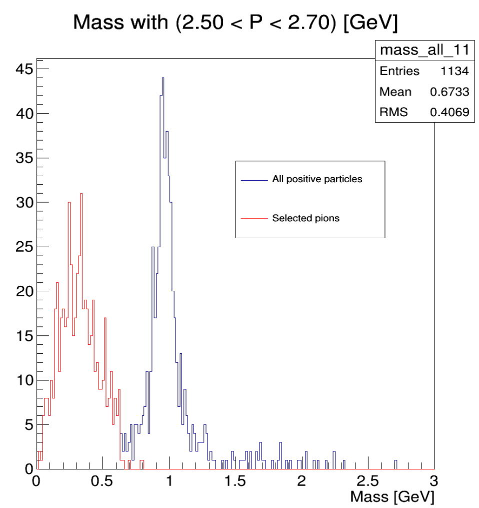




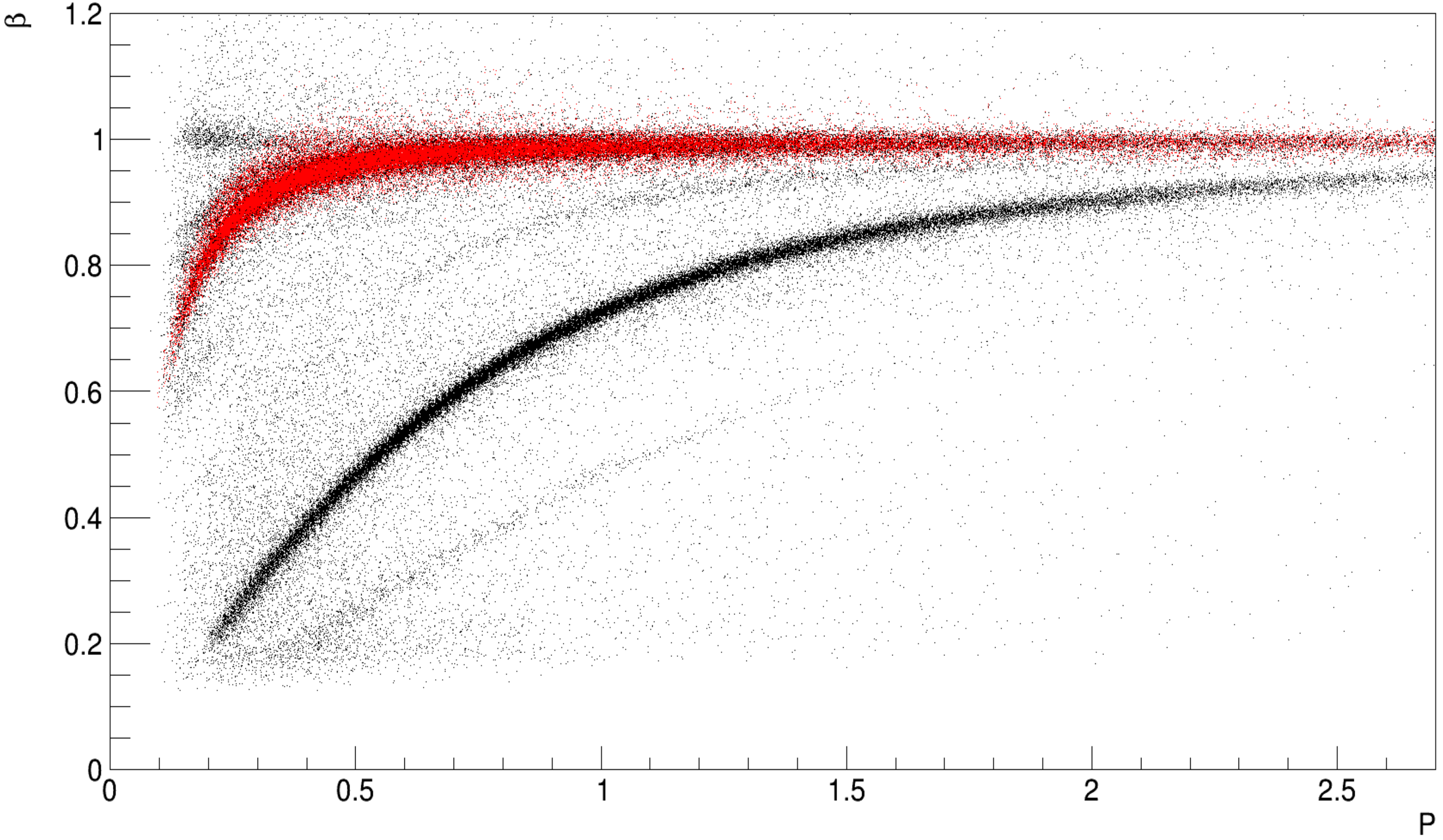








Beta vs Momentum for positive particles



P

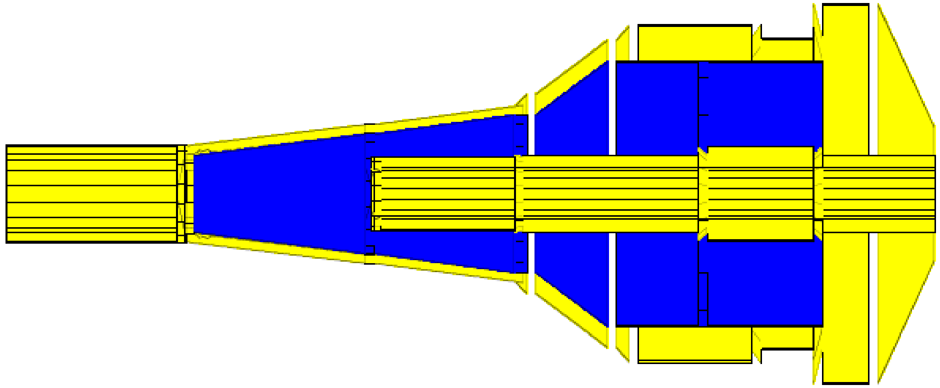
Acceptance correction

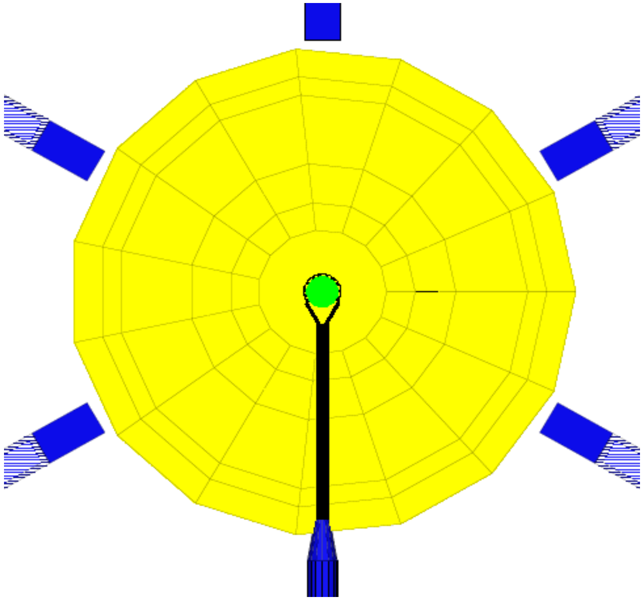
PYTHIA 6.319 parameterized for CLAS energy.

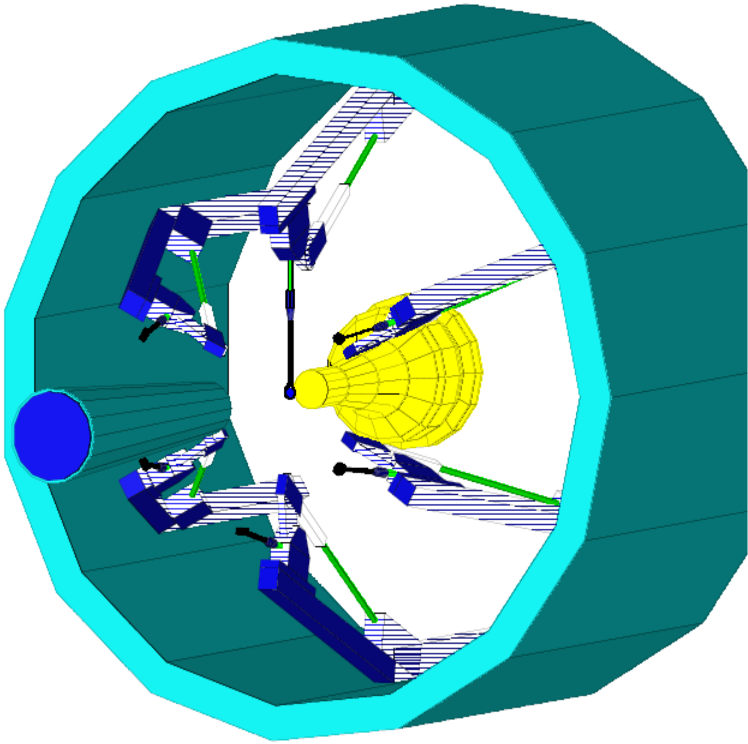
400,000,000 simulated events; 100,000,000 each for carbon, iron, lead and deuterium targets.

For semi-inclusive pion electro-production at a fixed beam energy one needs to specify six independent kinematical variables. One of the variables can be chosen to be the electron polar angle in the laboratory frame. In the absence of any transverse polarization of the target or the beam, polar angle can be averaged.

Double target in GSIM

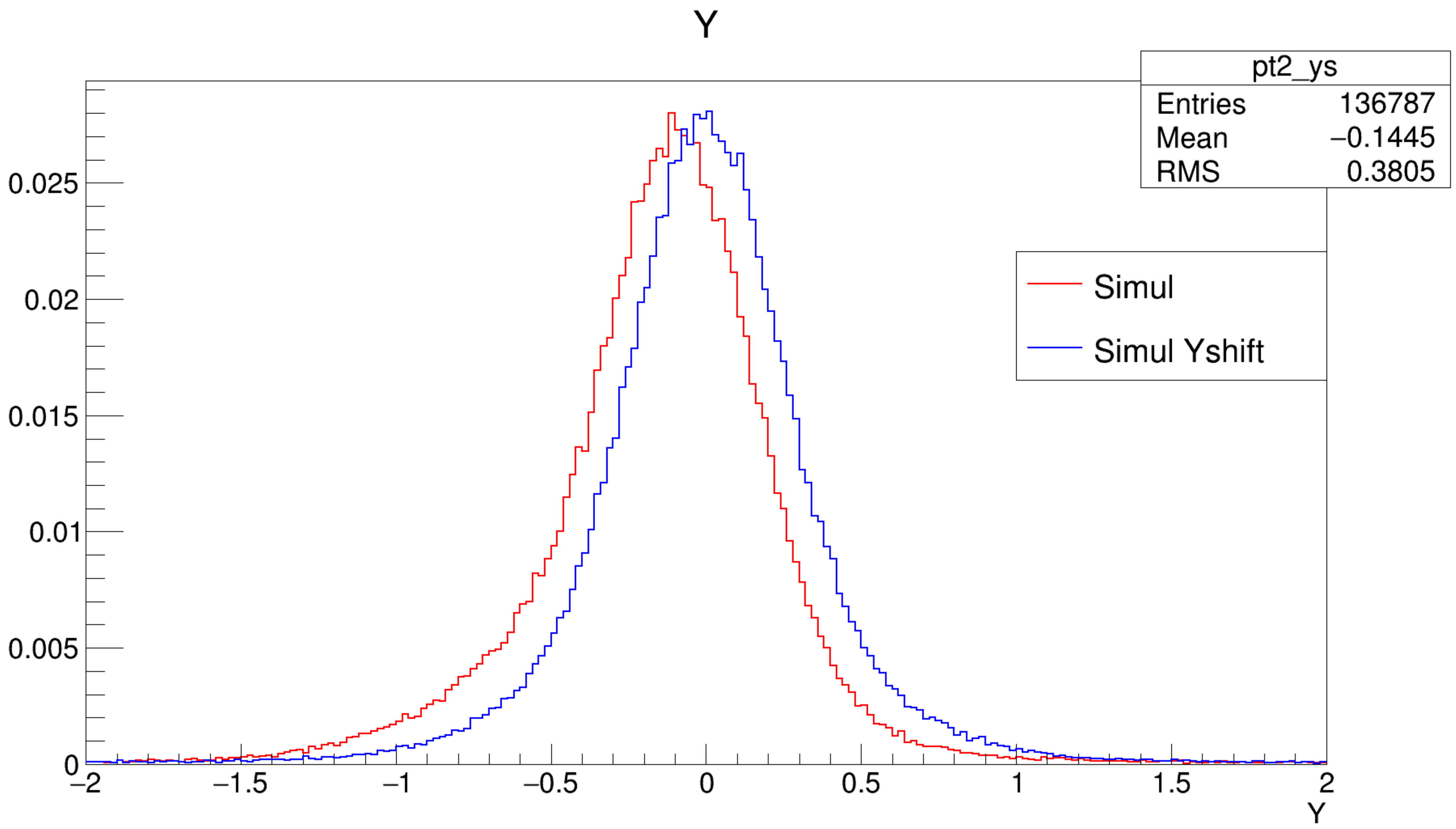




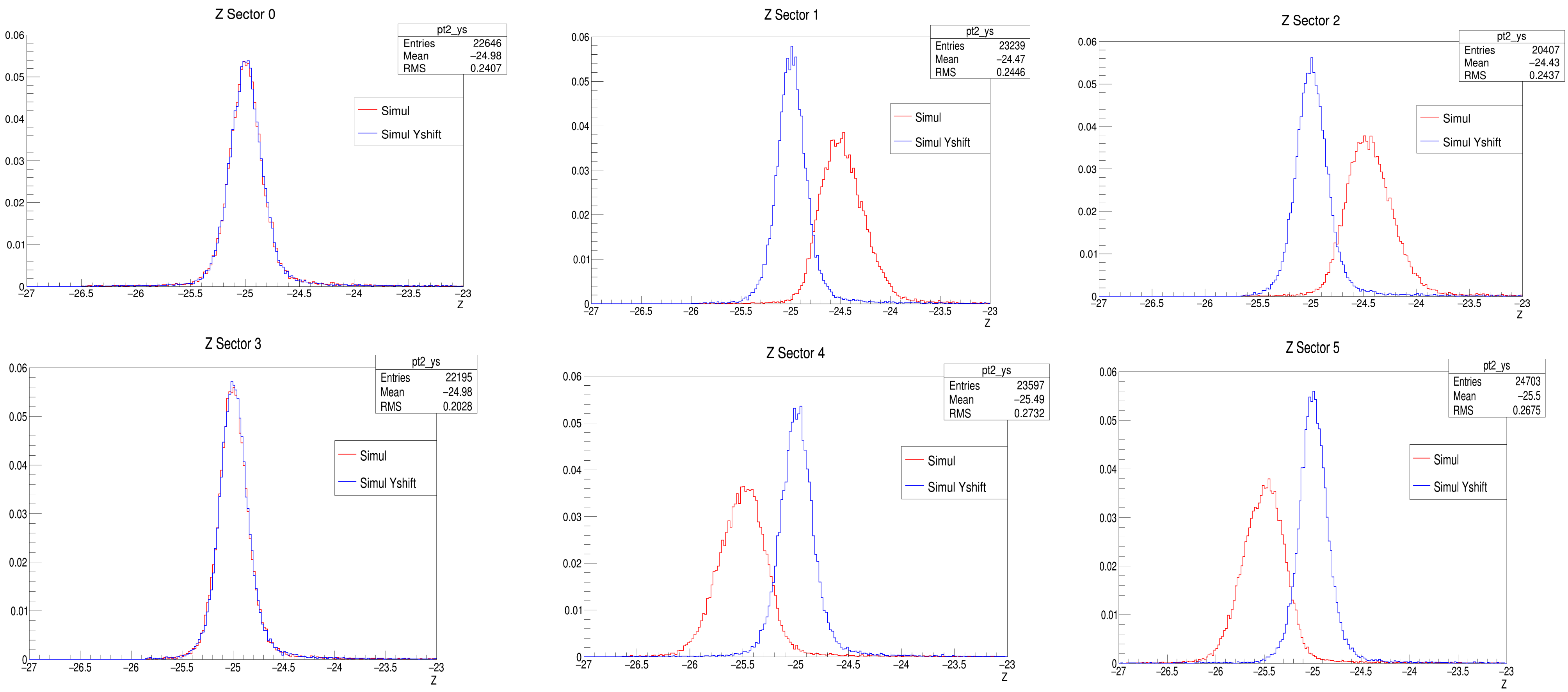


Events generated by Pythia inside GSIM are distributed homogeneously along the targets

$Y_{BEAM} = 0$ vs $Y_{BEAM} = 2$ [mm] in simulations (40% vs 60% of whole available data)



Simulated Z vertex dist.s in all sectors with and without 2 mm shift



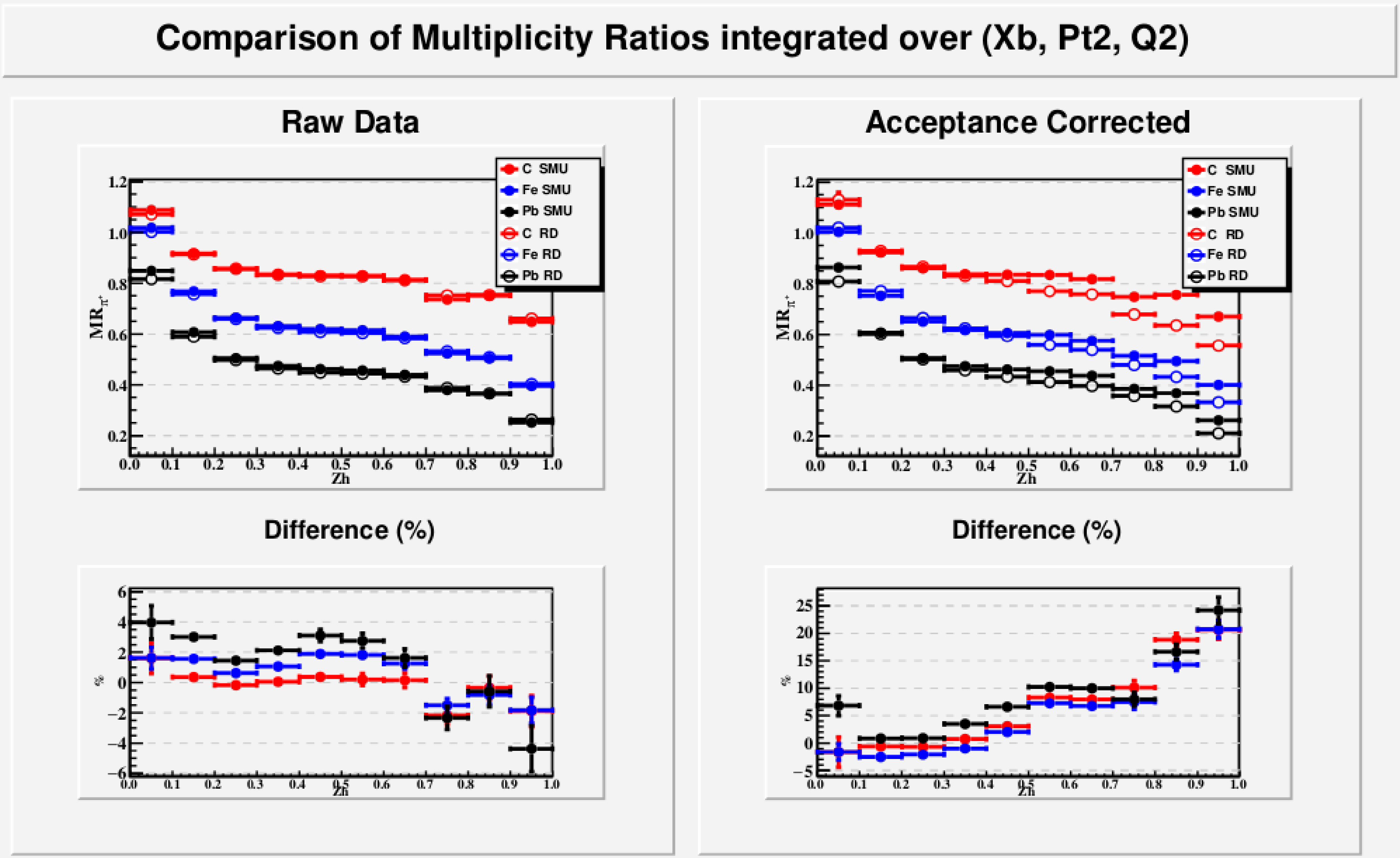
Still should be studied if the shift on the Y position of the target may have an effect on acceptance correction.

Variable	# of bins	Lower limit	Upper limit	Bin width
Q^2	6	1.0	4.0	0.5
x_B	5	0.12	0.57	0.09
z_h	10	0.	1.	0.1
p^2_T	5	0.	1.	0.2

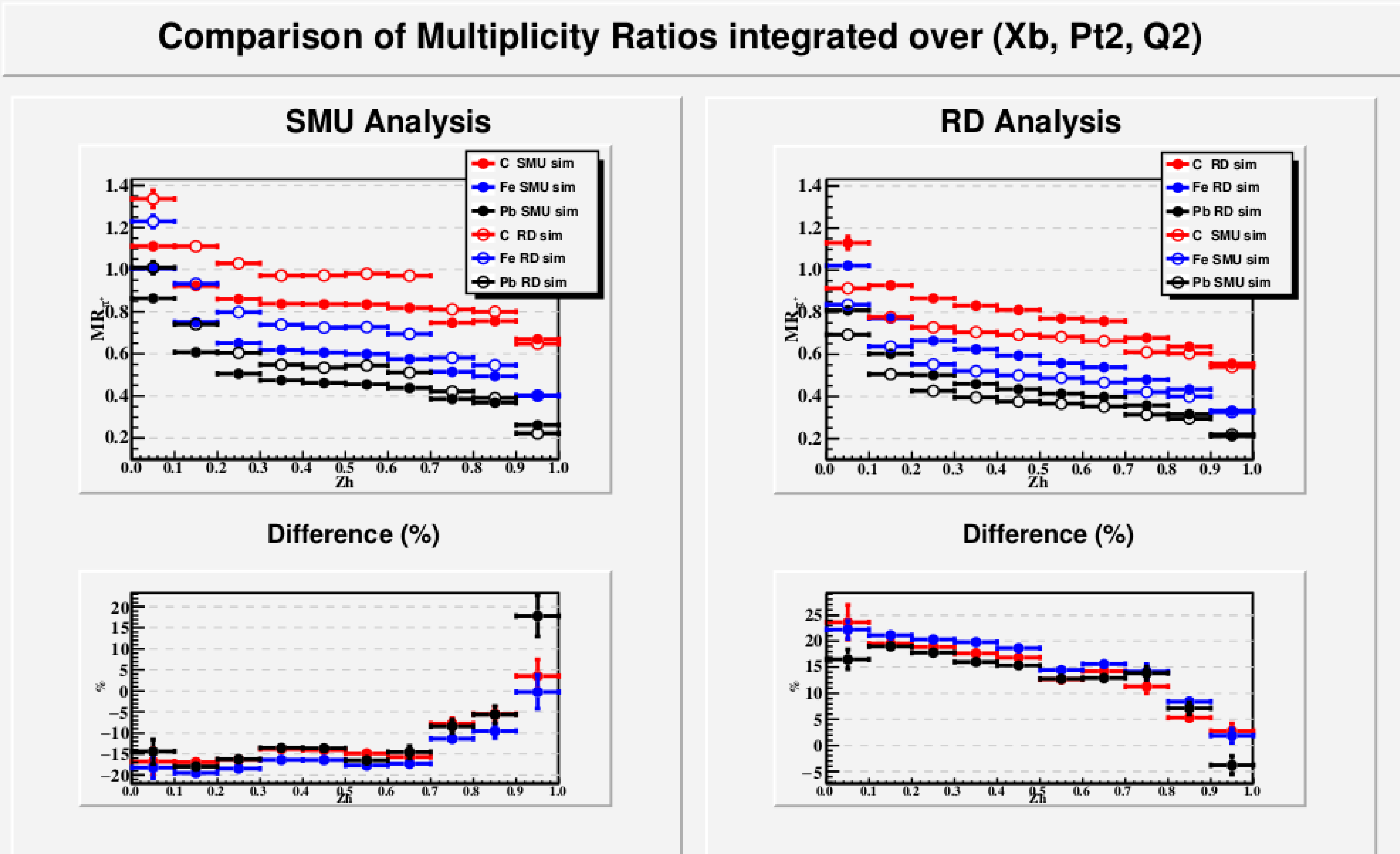
Some comparisons between the analysis of Raphael Dupré (RD) and the SMU analysis performed by Sebastian Moran

Different components of two analysis to be discussed:
- PID
- Vertex cut
- Acceptance correction method
- Acceptance correction dimension
- Simulated data set

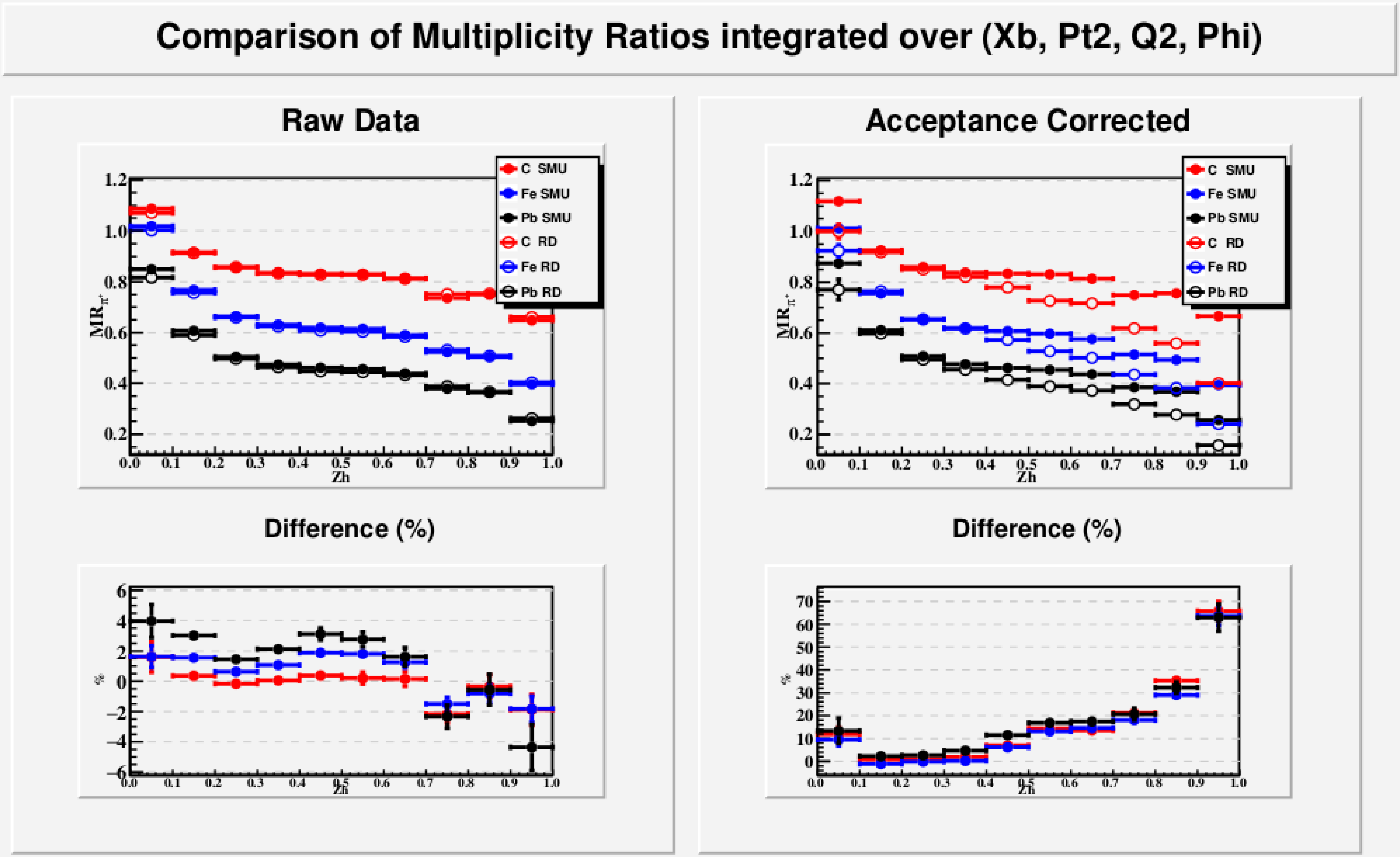
4-D acceptance correction comparison between RD and SMU analysis



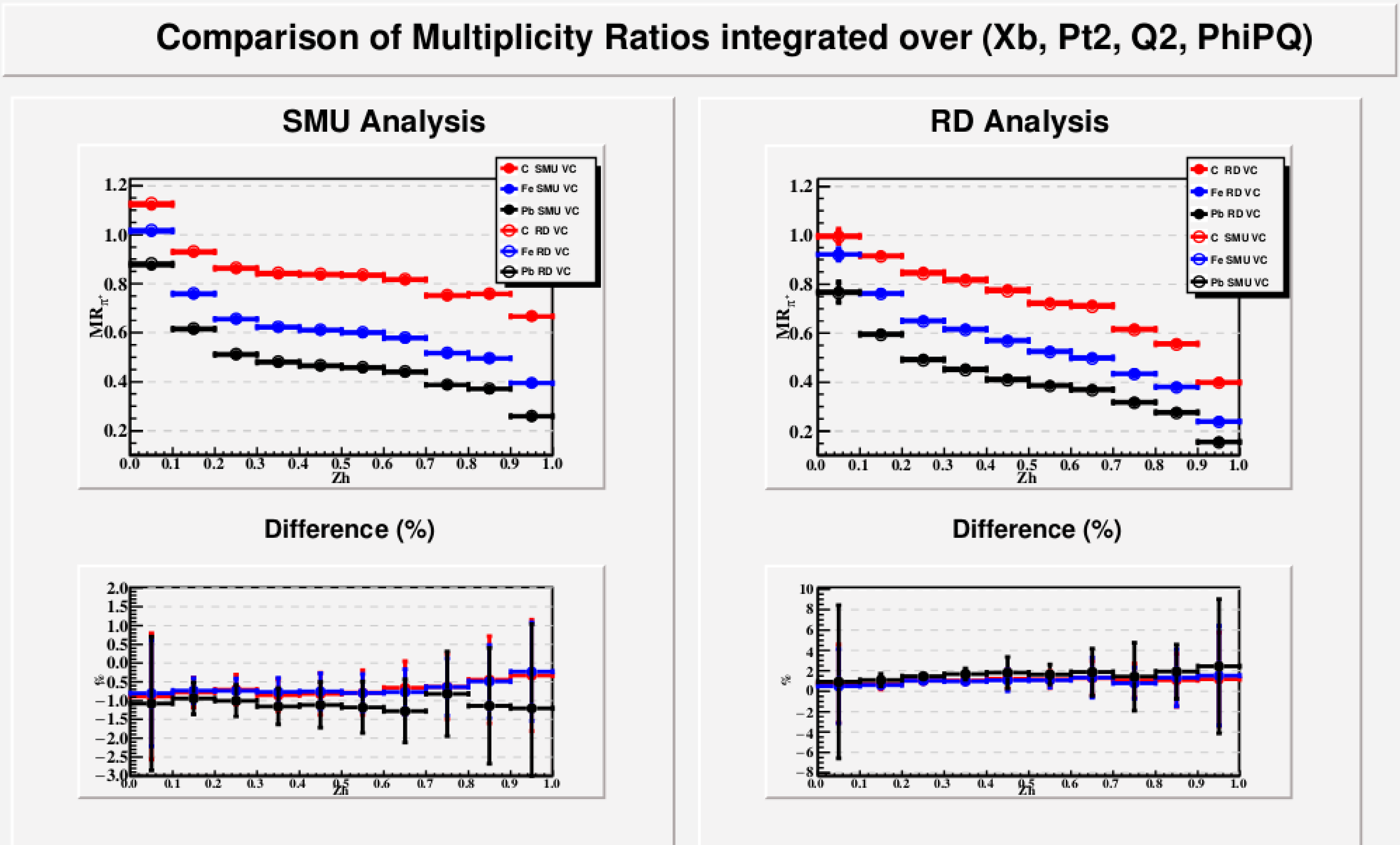
4-D acceptance correction comparison (only simulation set is different)



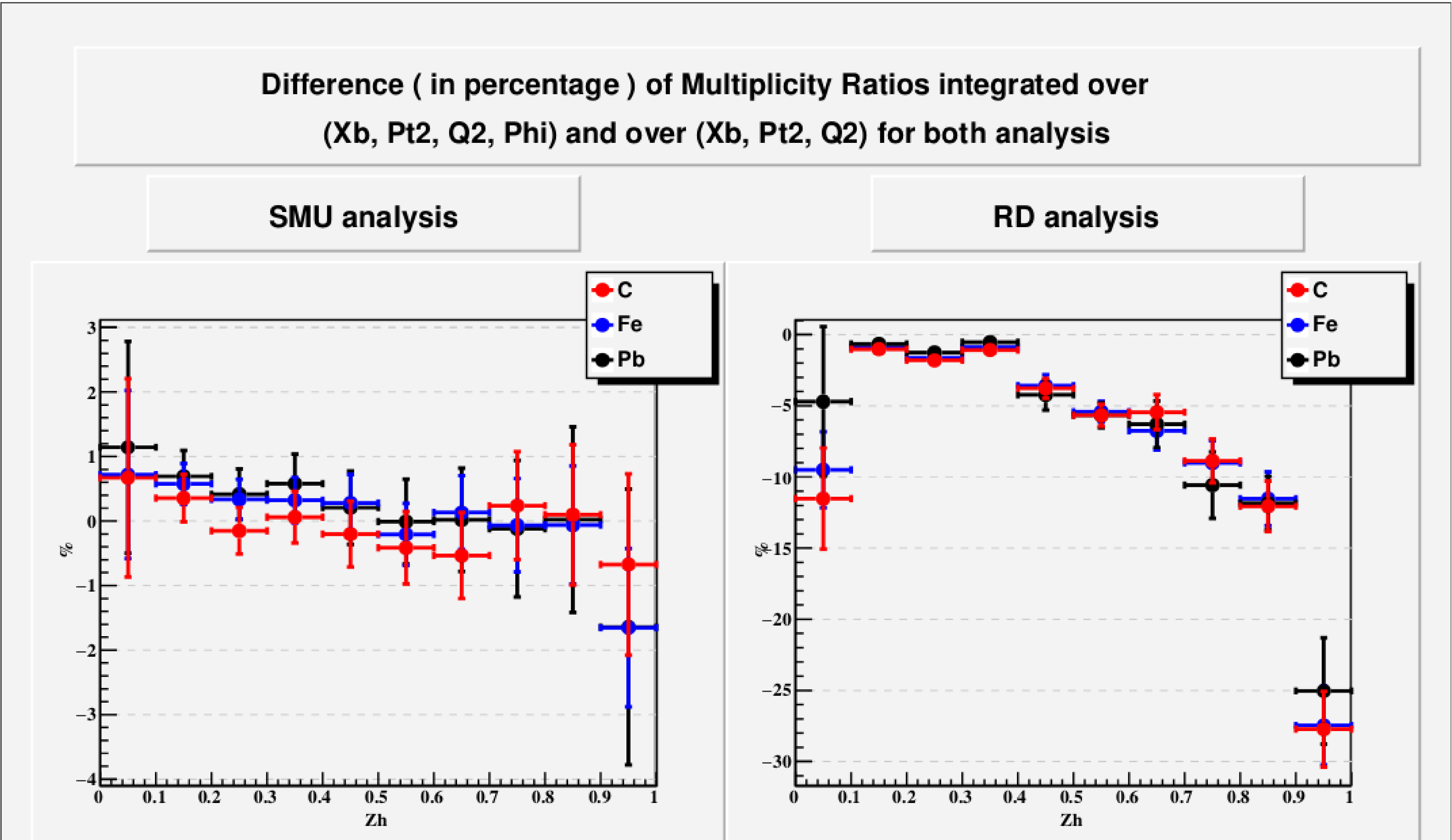
5-D acceptance correction comparison between RD and SMU analysis



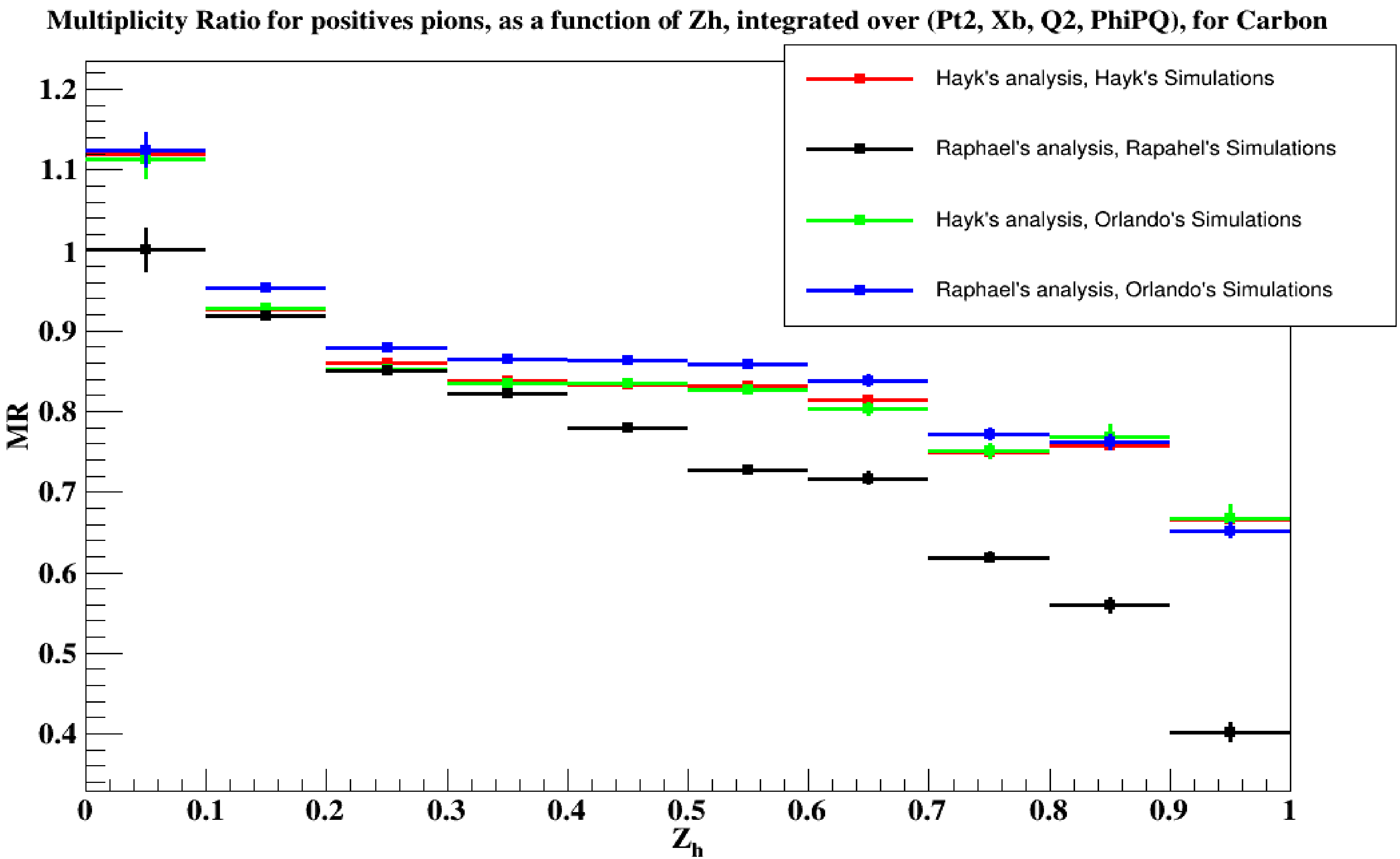
Vertex cut comparison between two analysis



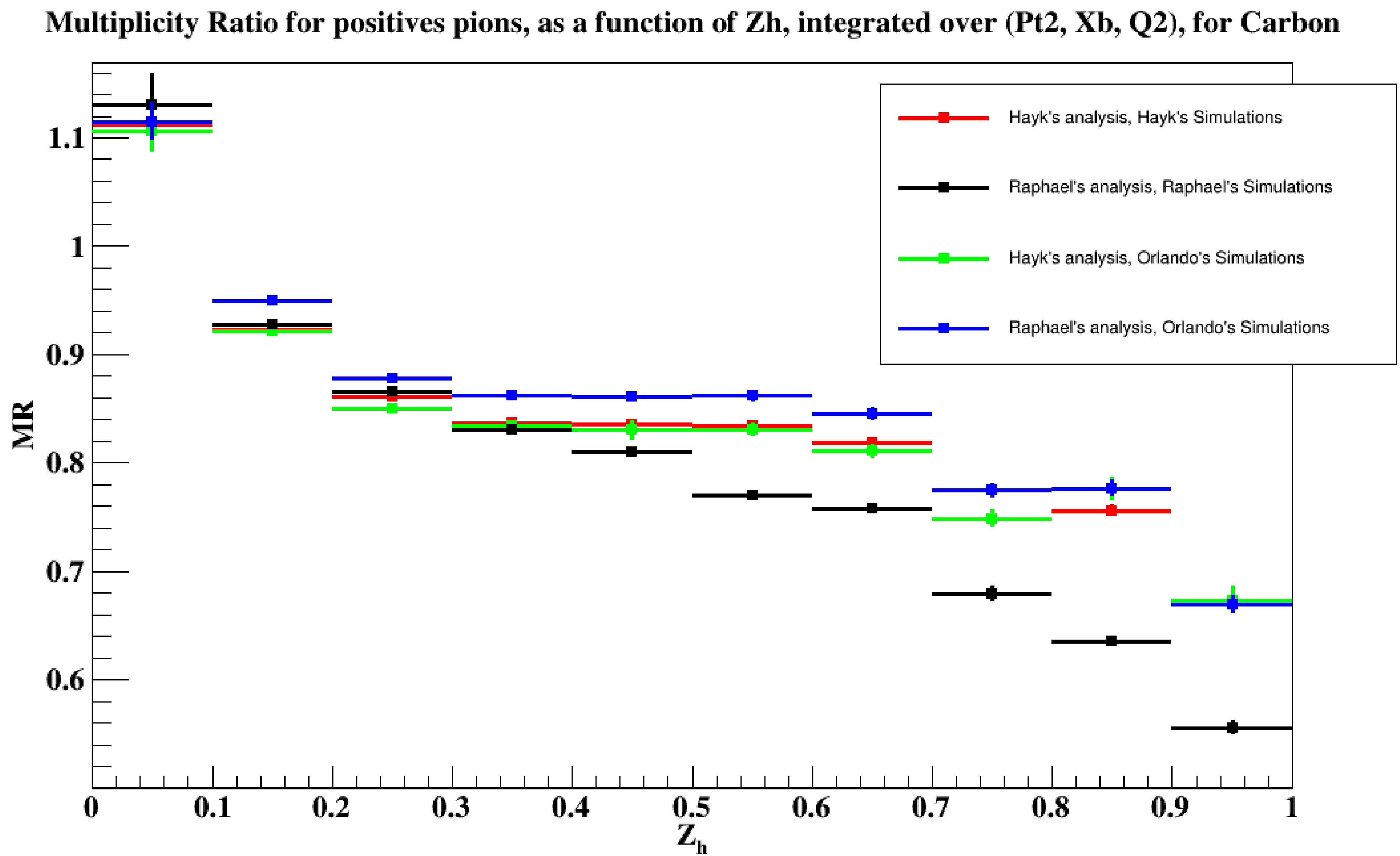
4-D vs. 5-D in each of analysis separately



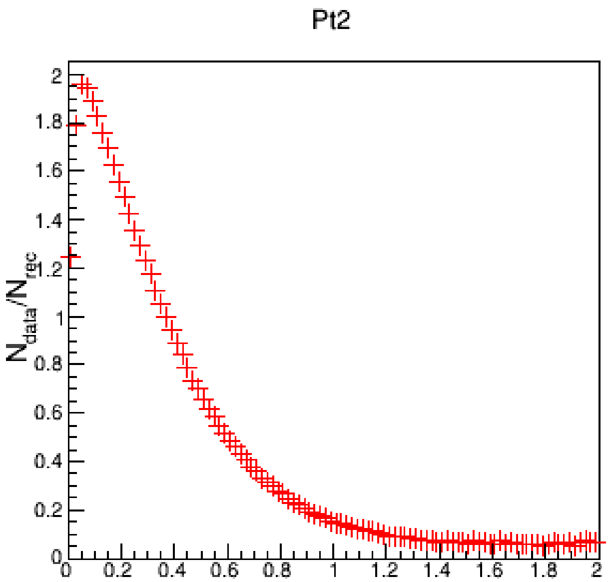
5-D acceptance correction comparison for Carbon, including LEPTO based simulations made by Orlando Soto

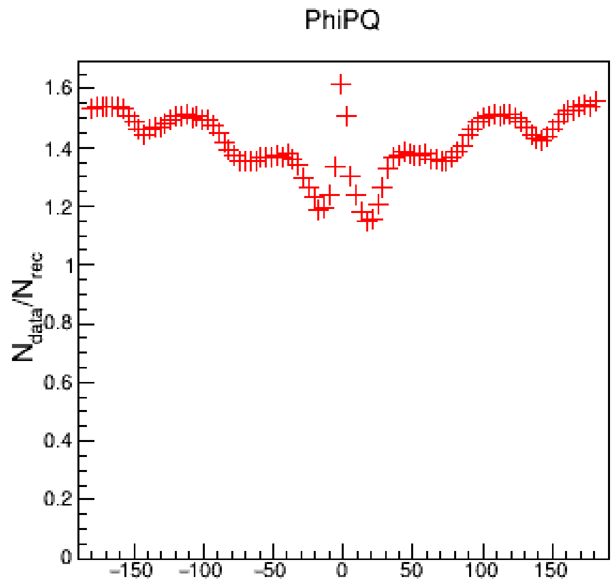


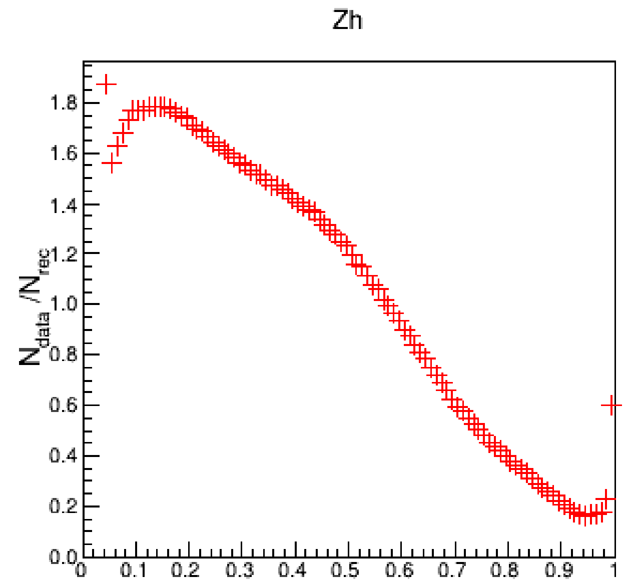
4-D acceptance correction comparison for Carbon, including LEPTO based simulations made by Orlando Soto

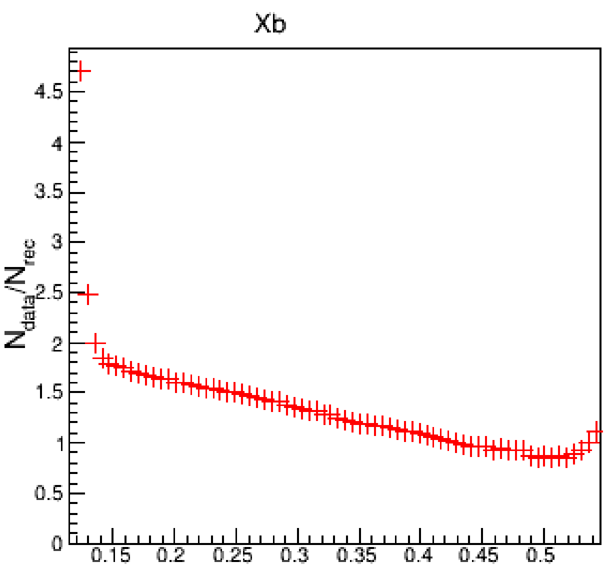


Discussion on SMU acceptance corrections

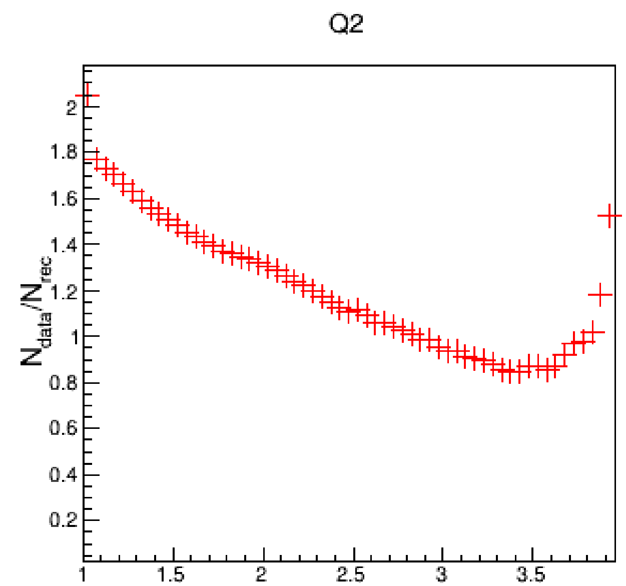








Ratios of experimental data distributions to the reconstructed distributions



Since in our analysis 4-D vs. 5-D acceptance render the same result then for simplicity we will discuss 4-D case

For 4-D acceptance correction the number of bins in the grid is:
$6 \times 10 \times 5 \times 5 = 1500$ bins.

The number of bins with data either in the real data or reconstructed simulation is:

Carbon: 587 bins (solid target)
Iron: 588 bins (solid target)
Lead: 587 bins (solid target)

Carbon: 587 (liquid target)
Iron: 586 (liquid target)
Lead: 586 (liquid target)

Bin statistics

Empty Data Bins	Carbon			
	Solid Target		Liquid Target	
	Empty Gen.	Non Empty Gen.	Empty Gen.	Non Empty Gen.
Empty Rec.	0 %	0 %	0 %	0 %
Non Empty Rec.	0.17762 %	8.88099 %	0 %	13.8596 %

Empty Data Bins	Iron			
	Solid Target		Liquid Target	
	Empty Gen.	Non Empty Gen.	Empty Gen.	Non Empty Gen.
Empty Rec.	0 %	0 %	0 %	0 %
Non Empty Rec.	0.177305 %	5.85106 %	0 %	12.0419 %

Empty Data Bins	Lead			
	Solid Target		Liquid Target	
	Empty Gen.	Non Empty Gen.	Empty Gen.	Non Empty Gen.
Empty Rec.	0 %	0 %	0 %	0 %
Non Empty Rec.	0 %	13.6525 %	0 %	12.1053 %

Bin statistics

Non Empty Data Bins	Carbon			
	Solid Target		Liquid Target	
	Empty Gen.	Non Empty Gen.	Empty Gen.	Non Empty Gen.
Empty Rec.	0 %	0.53286 %	0.175439 %	1.05263 %
Non Empty Rec.	0 %	90.4085 %	0 %	84.9123 %

Non Empty Data Bins	Iron			
	Solid Target		Liquid Target	
	Empty Gen.	Non Empty Gen.	Empty Gen.	Non Empty Gen.
Empty Rec.	0.177305 %	0.886525 %	0 %	1.7452 %
Non Empty Rec.	0 %	92.9078 %	0 %	86.2129 %

Non Empty Data Bins	Lead			
	Solid Target		Liquid Target	
	Empty Gen.	Non Empty Gen.	Empty Gen.	Non Empty Gen.
Empty Rec.	0.177305 %	0 %	0 %	1.22807 %
Non Empty Rec.	0 %	86.1702 %	0 %	86.6667 %

Bin statistics

Carbon	[0]	]0 - 5]	]5 - 10]	]10 - 15]	]15 - ... [
Data	9.05861 %	15.0977 %	4.4405 %	3.73002 %	67.6732 %
Rec.	0.53286 %	5.86146 %	4.4405 %	2.6643 %	86.5009 %
Gen.	0.17762 %	1.59858 %	0 %	0.53286 %	97.6909 %
Data(D2)	13.8596 %	15.9649 %	4.21053 %	2.63158 %	63.3333 %
Rec.(D2)	1.22807 %	8.07018 %	4.03509 %	2.10526 %	84.5614 %
Gen.(D2)	0.175439 %	1.75439 %	0.526316 %	0.526316 %	97.0175 %

Iron	[0]	]0 - 5]	]5 - 10]	]10 - 15]	]15 - ... [
Data	6.02837 %	14.1844 %	4.96454 %	2.65957 %	72.1631 %
Rec.	1.06383 %	5.49645 %	4.43262 %	1.41844 %	87.5887 %
Gen.	0.35461 %	1.95035 %	0 %	0.531915 %	97.1631 %
Data(D2)	12.0419 %	14.3106 %	4.18848 %	3.4904 %	65.9686 %
Rec.(D2)	1.7452 %	8.02792 %	4.01396 %	2.09424 %	84.1187 %
Gen.(D2)	0 %	2.26876 %	0.52356 %	0.52356 %	96.5096 %

Lead	[0]	]0 - 5]	]5 - 10]	]10 - 15]	]15 - ... [
Data	13.6525 %	14.8936 %	6.20567 %	4.25532 %	60.9929 %
Rec.	0.177305 %	6.91489 %	3.5461 %	2.12766 %	87.234 %
Gen.	0.177305 %	1.59574 %	0 %	0.531915 %	97.695 %
Data(D2)	12.1053 %	15.0877 %	4.38596 %	2.2807 %	66.1404 %
Rec.(D2)	1.22807 %	8.07018 %	4.03509 %	2.10526 %	84.5614 %
Gen.(D2)	0 %	1.92982 %	0.526316 %	0.526316 %	97.0175 %

Radiative Corrections

The radiative corrections are performed by HAPRAD-CPP code based on the paper: I. Akushevich, N. Shumeiko, A. Soroko, Eur. Phys. J. C 10, (1999) 681–687.

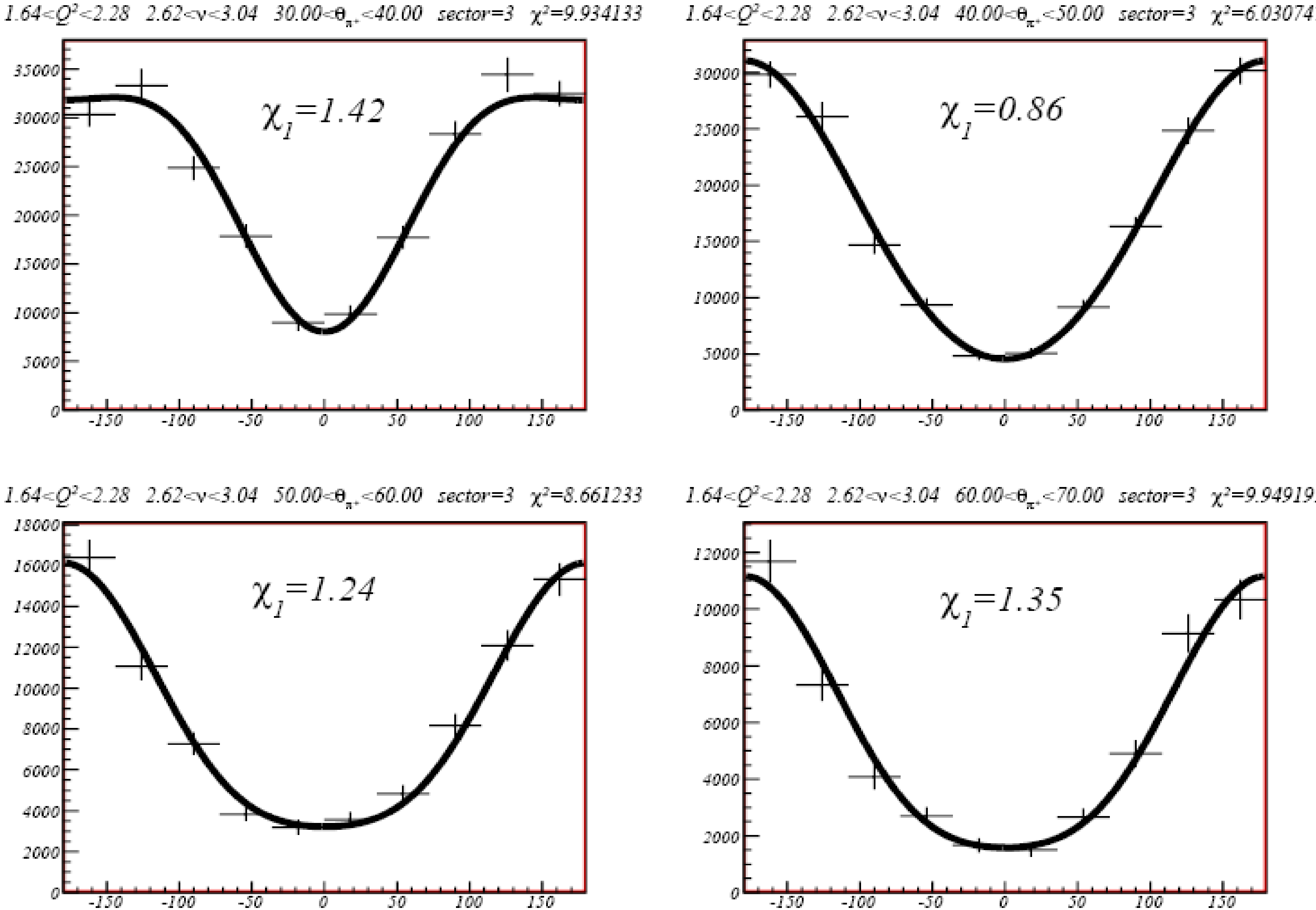
By contracting leptonic and hadronic tensors we get:

$$L^{\mu\nu} H_{\mu\nu} = \frac{2}{y}\left(A + B\cos\phi_h + C\cos 2\phi_h\right)$$

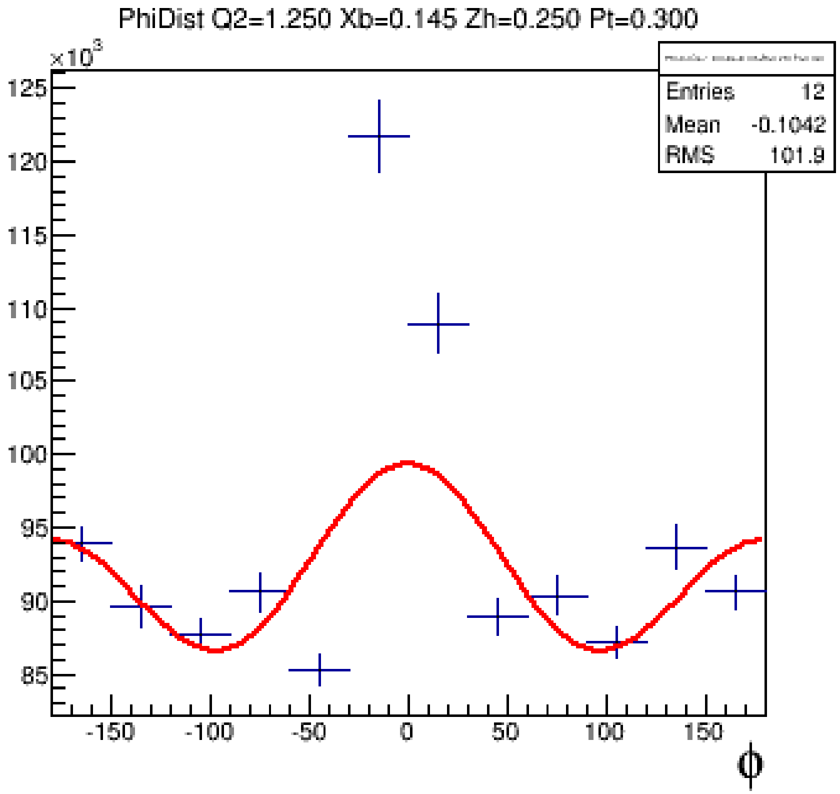
A, B, C constants are extracted as 5-D functions through fitting of whole data set for all targets separately

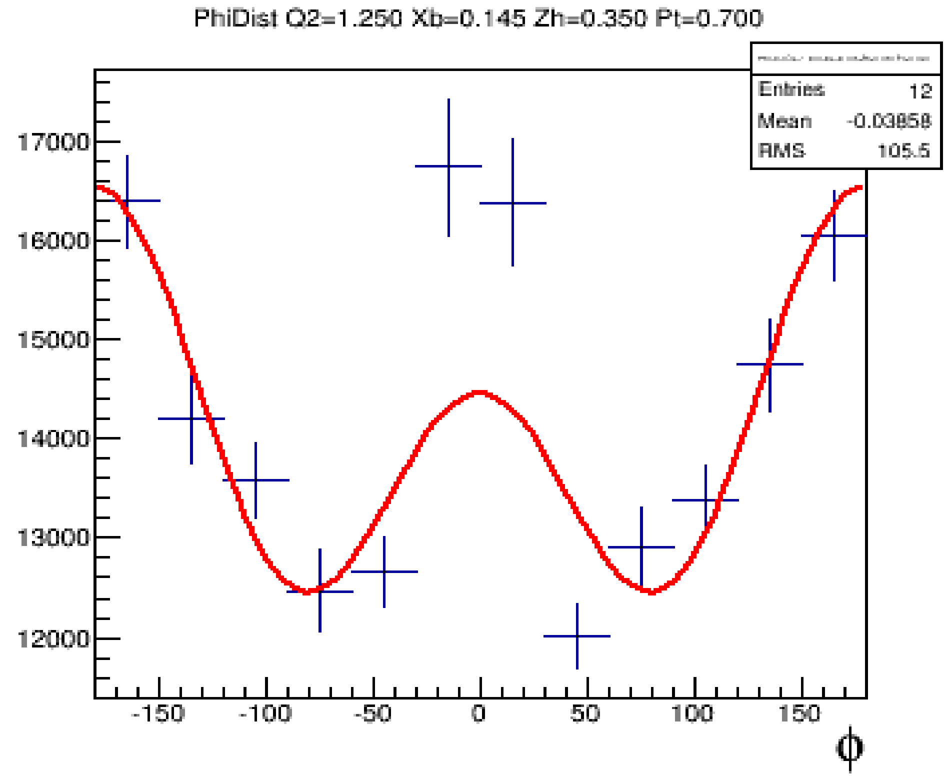
H1, H2, H3 and H4 Structure function, required to run the code, are derived from A, B, C constants.

Fitting function is $f\left(\varphi_{q\pi^+}\right)=A+B\cos\left(\varphi_{q\pi^+}\right)+C\cos\left(2\cdot\varphi_{q\pi^+}\right)$

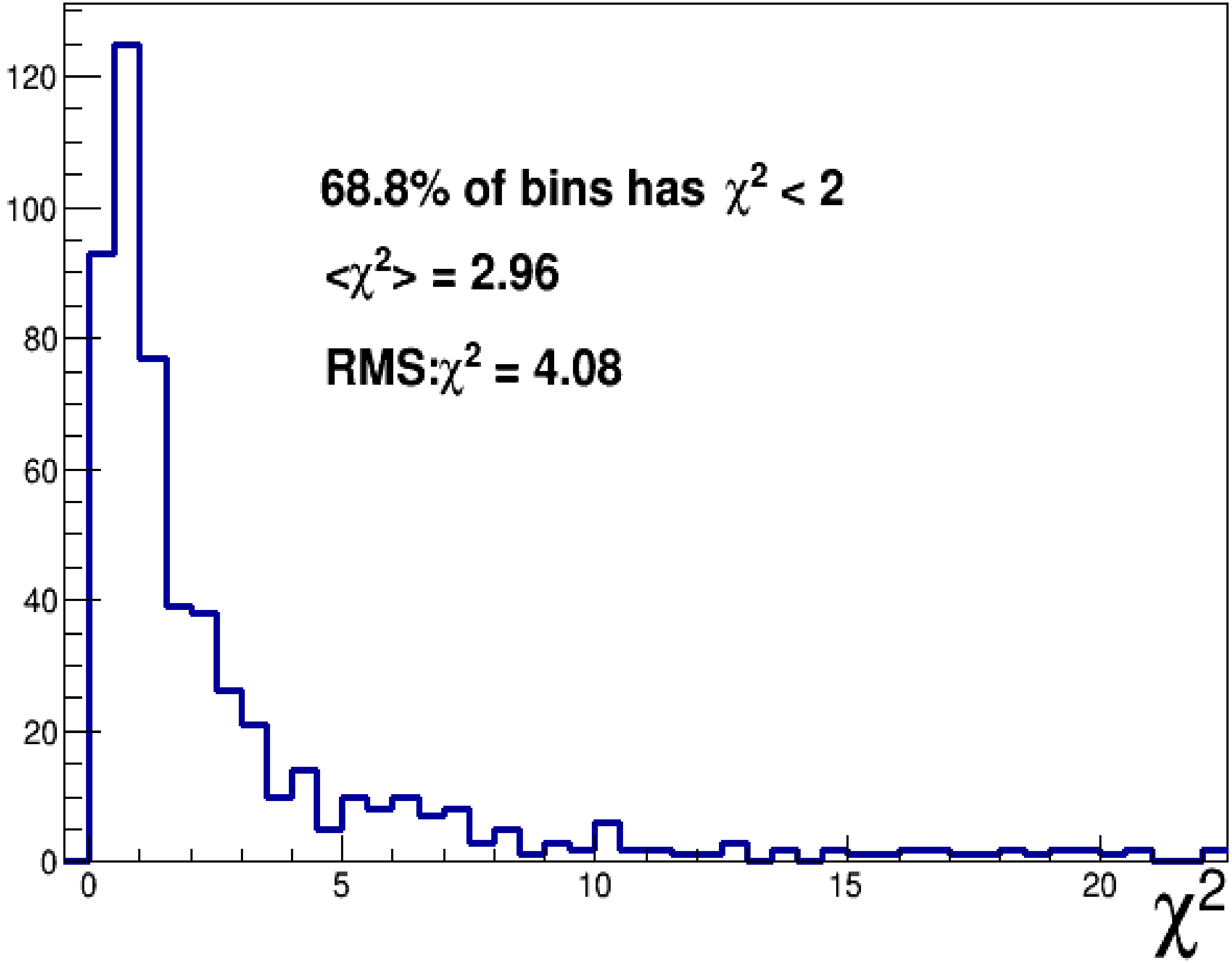


Phi Problem (exp. of failed fits)

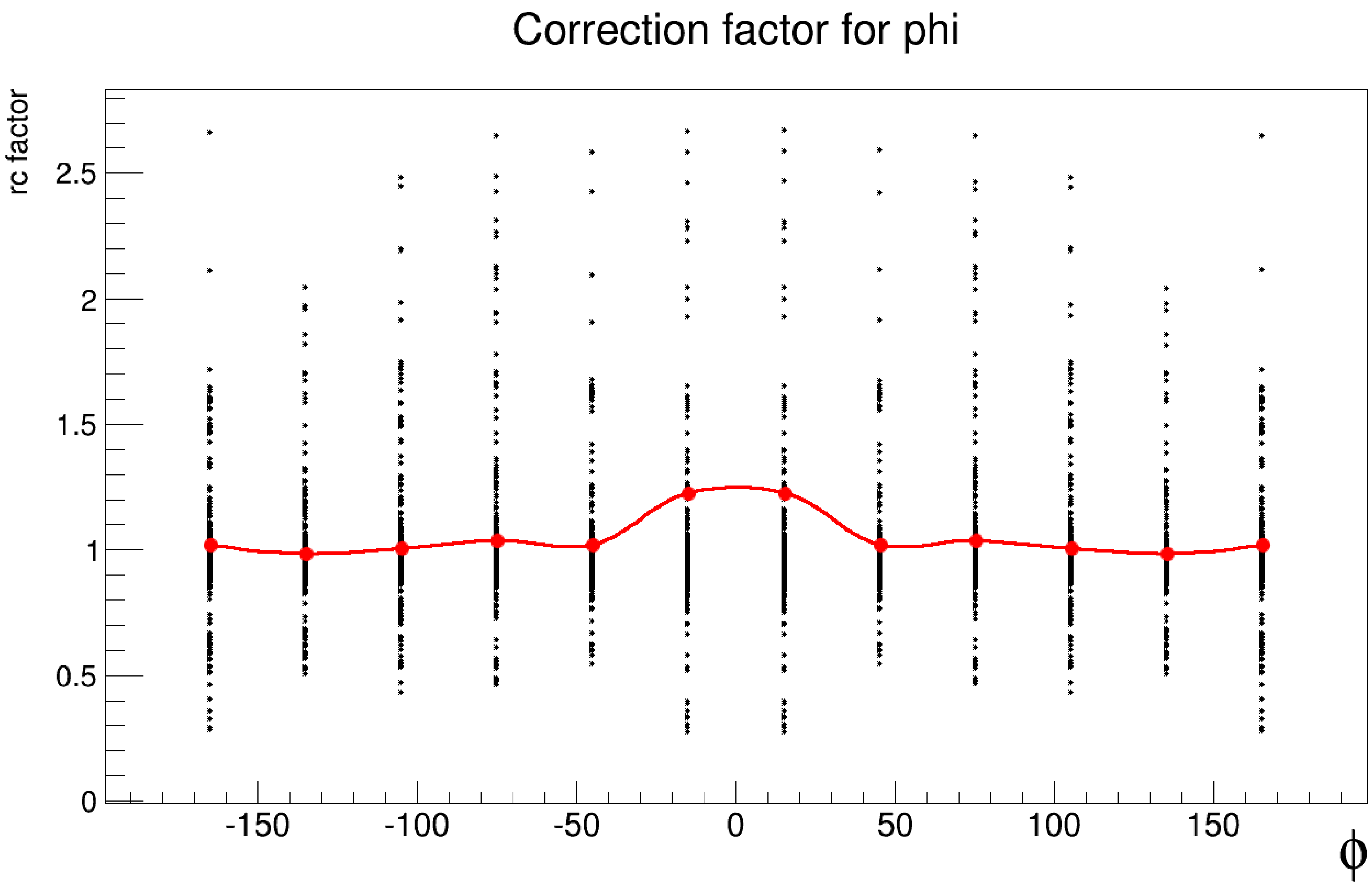




Phi Problem (Chi2 dist. for all bins)

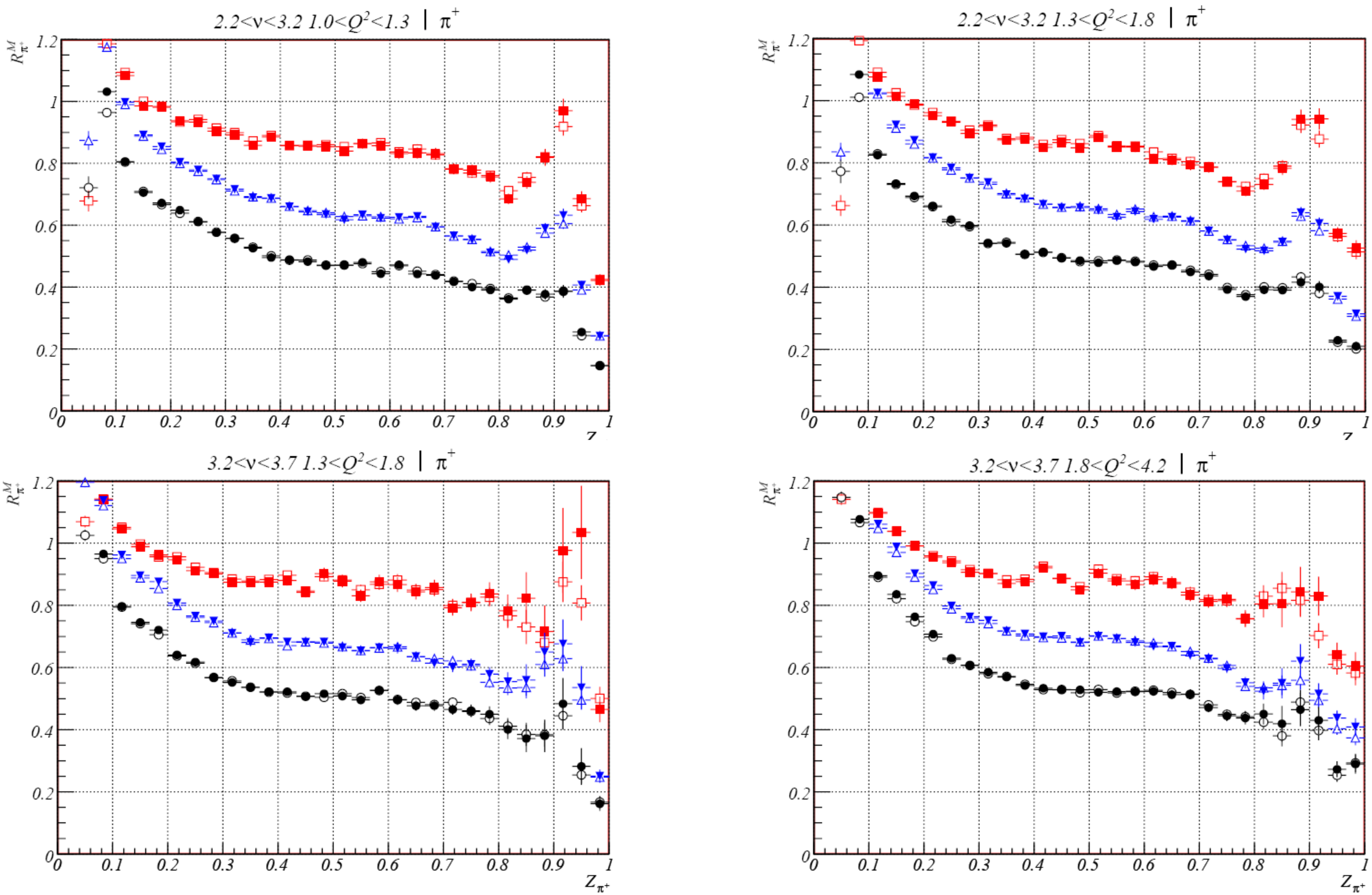


RC factors per phi bin, red points correspond to the average correction using HAPRAD-CPP:

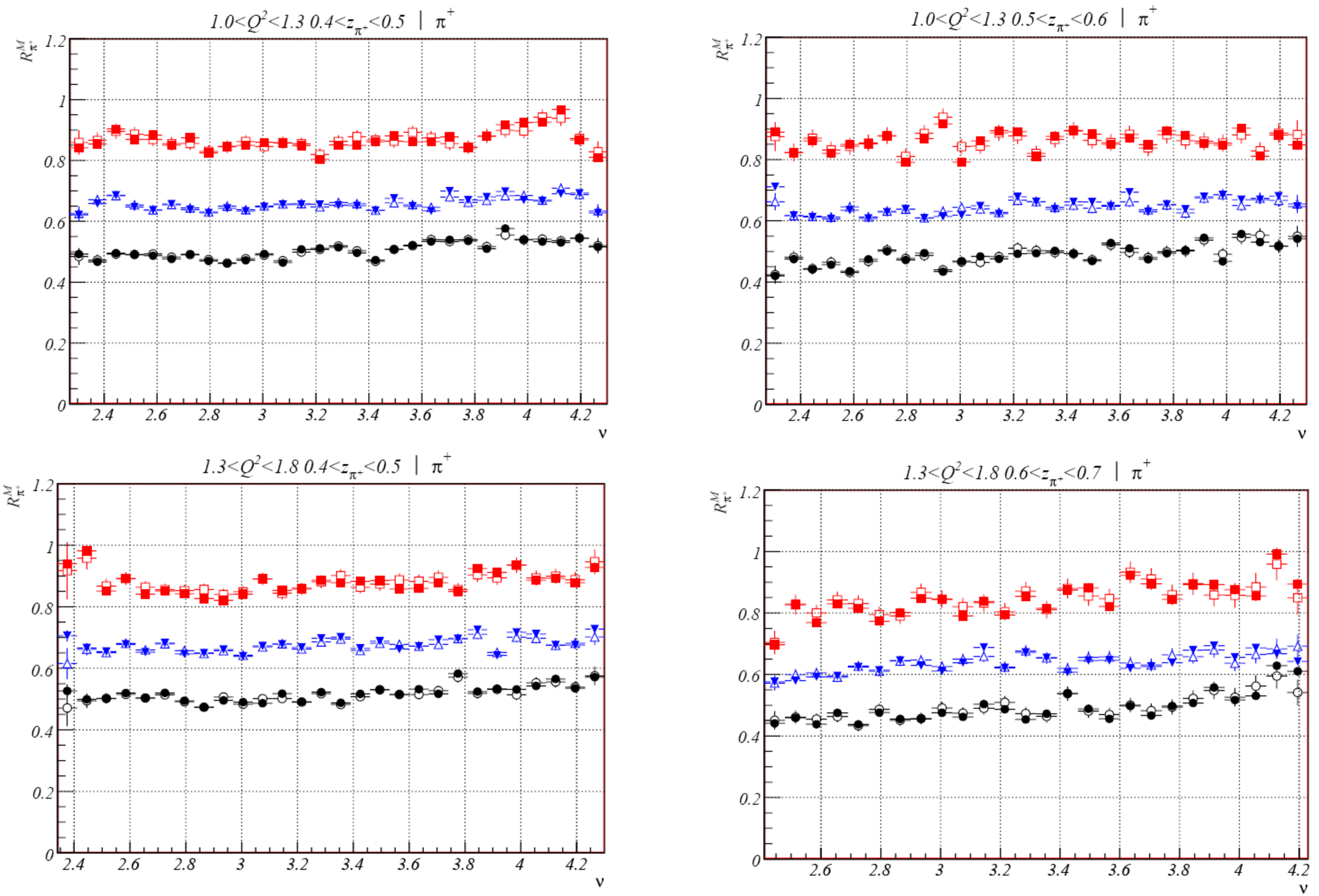


Backup slides

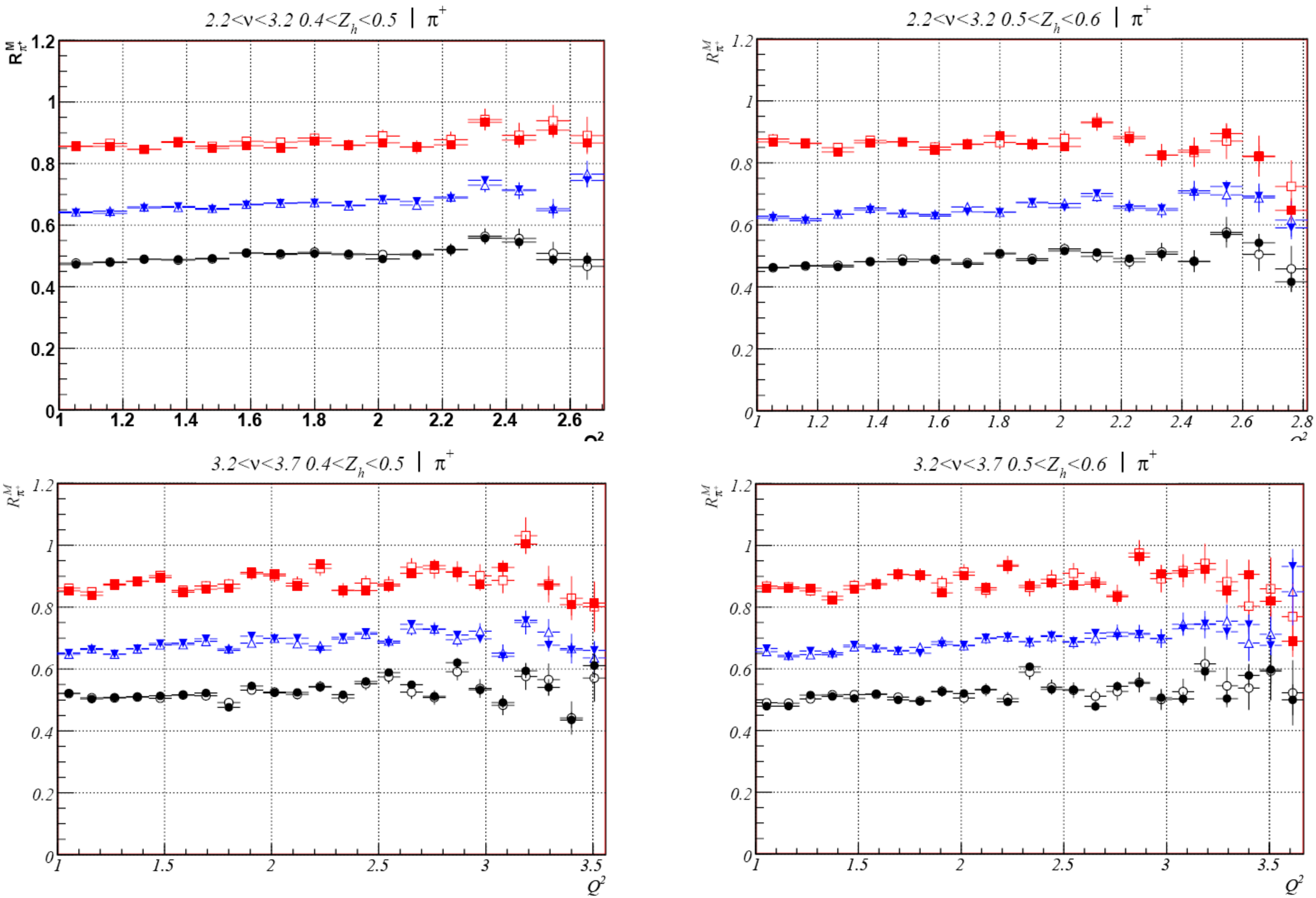
Multiplicity Ratio Dependence on Z_h in different Q^2 and ν bins

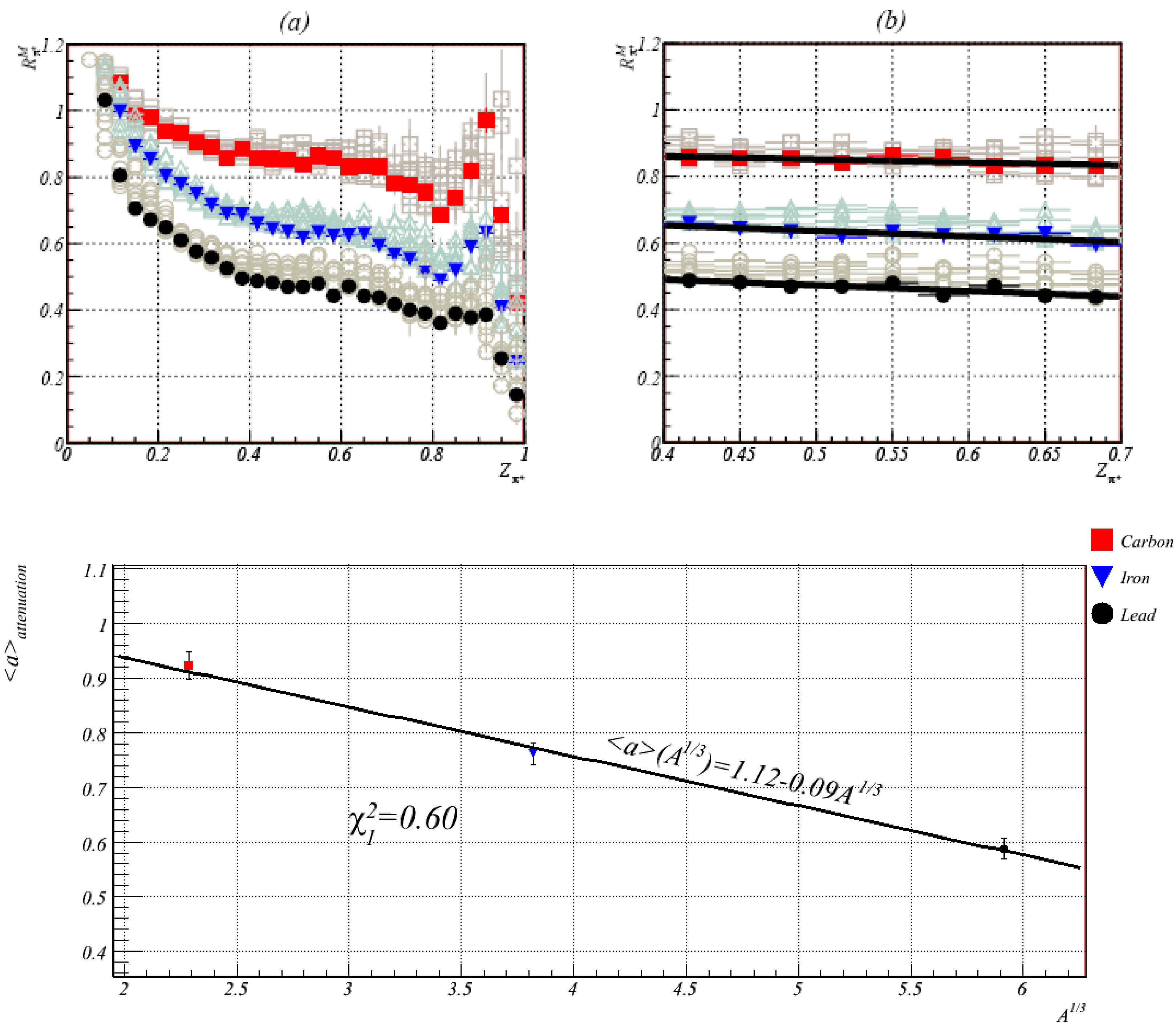


Multiplicity Ratio Dependence on ν in different Q^2 and Z_h bins



Multiplicity Ratio Dependence on Q^2 in different Z_h and ν bins





(a)
(b)
$R^M_{\pi^+}$
Z_{π^+}
Carbon
Iron
Lead
$<a>_{attenuation}$
$<a>(A^{1/3})=1.12-0.09A^{1/3}$
$\chi^2_1=0.60$
$A^{1/3}$