Hadron multiplicities in GRAIN

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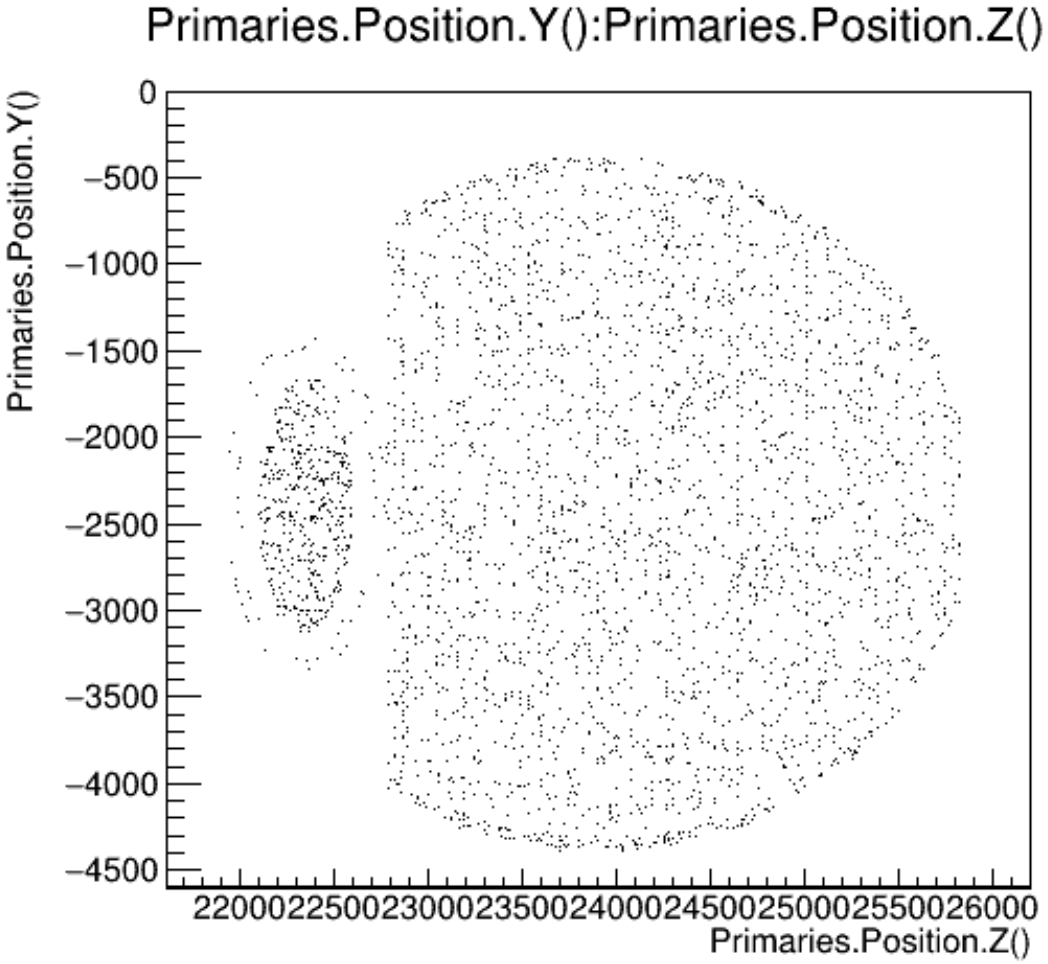
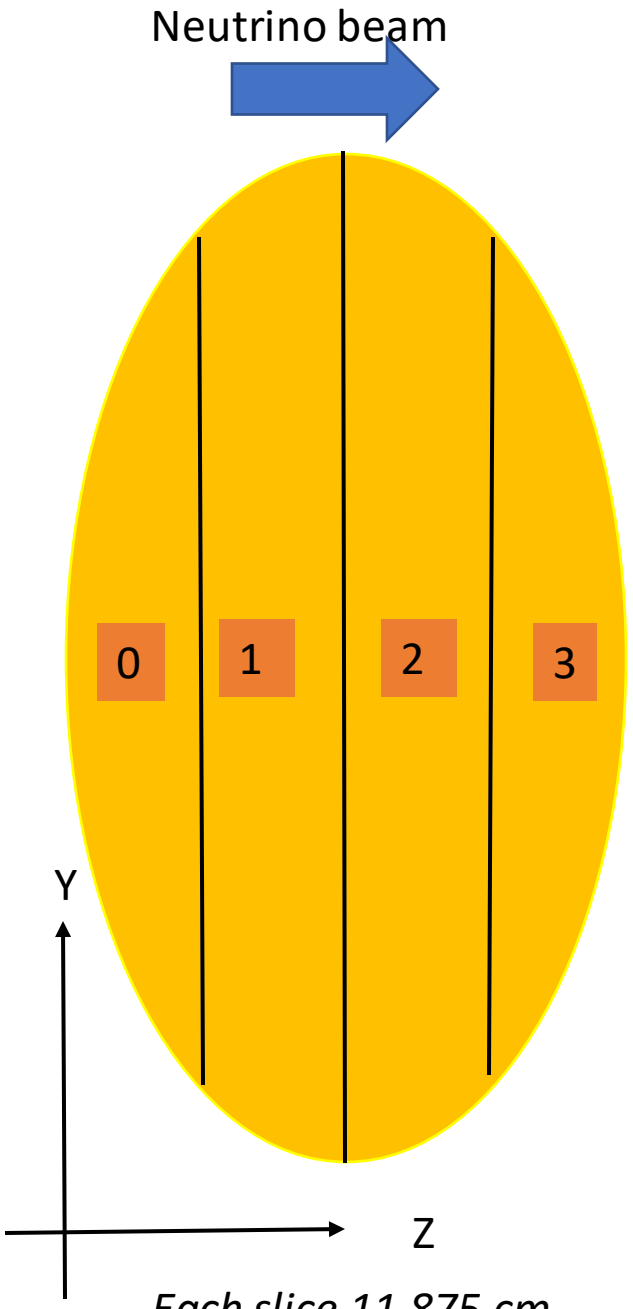
SAND Physics/Software meeting
14 January 2022

Simulations and Analysis

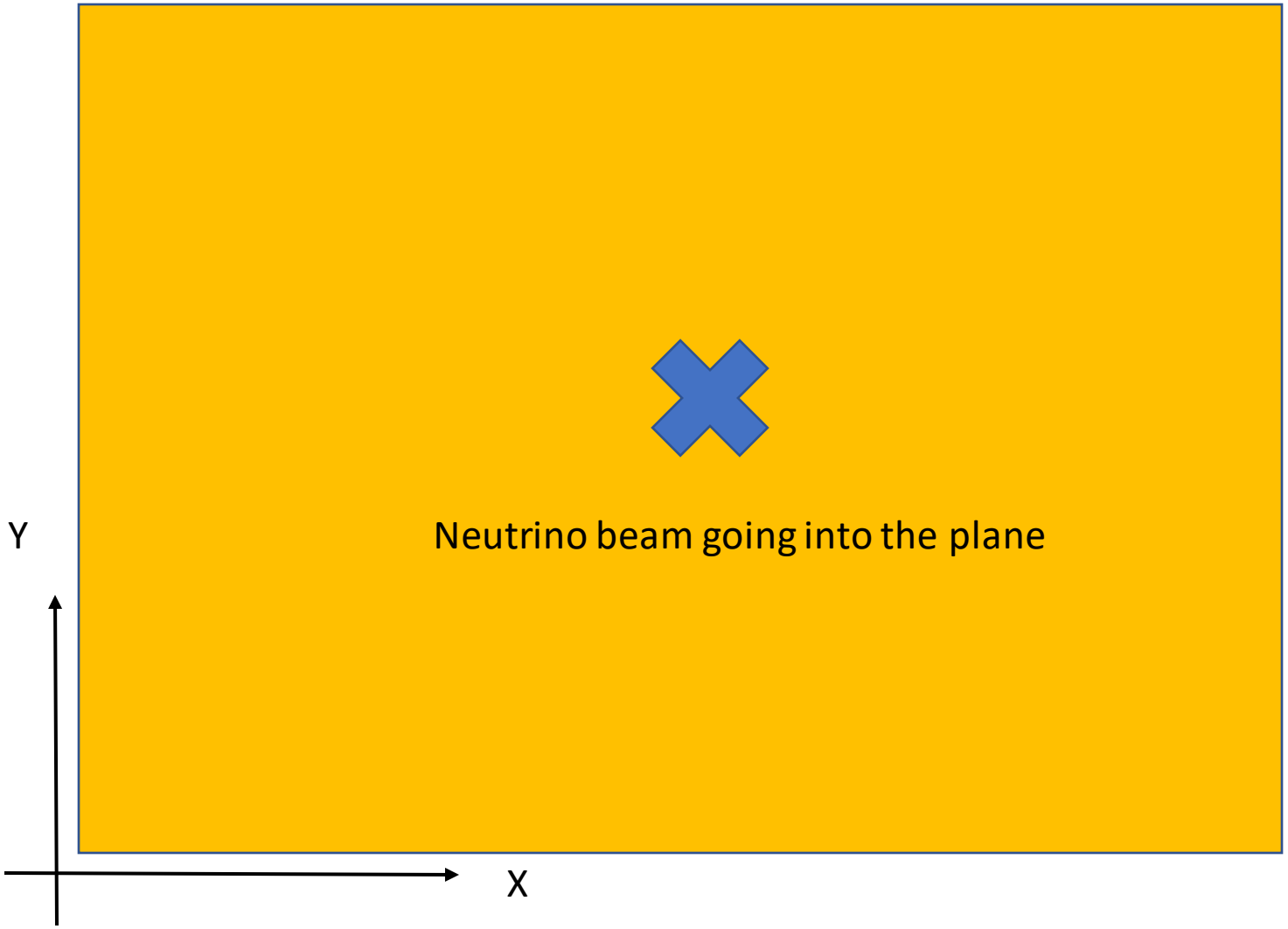
- FHC CC and RHC CC
- POT = 1.1*10^21 FHC && 1.1*10^21 RHC
- Events are generated with 1 yr statistics int GRAIN+STT:
  ~ 12 (6.29) * 10^6 FHC (RHC) events produced
- *used* genie v2_12_10d *with* DefaultPlusValenciaMEC *tuning*
- Used the new geometry



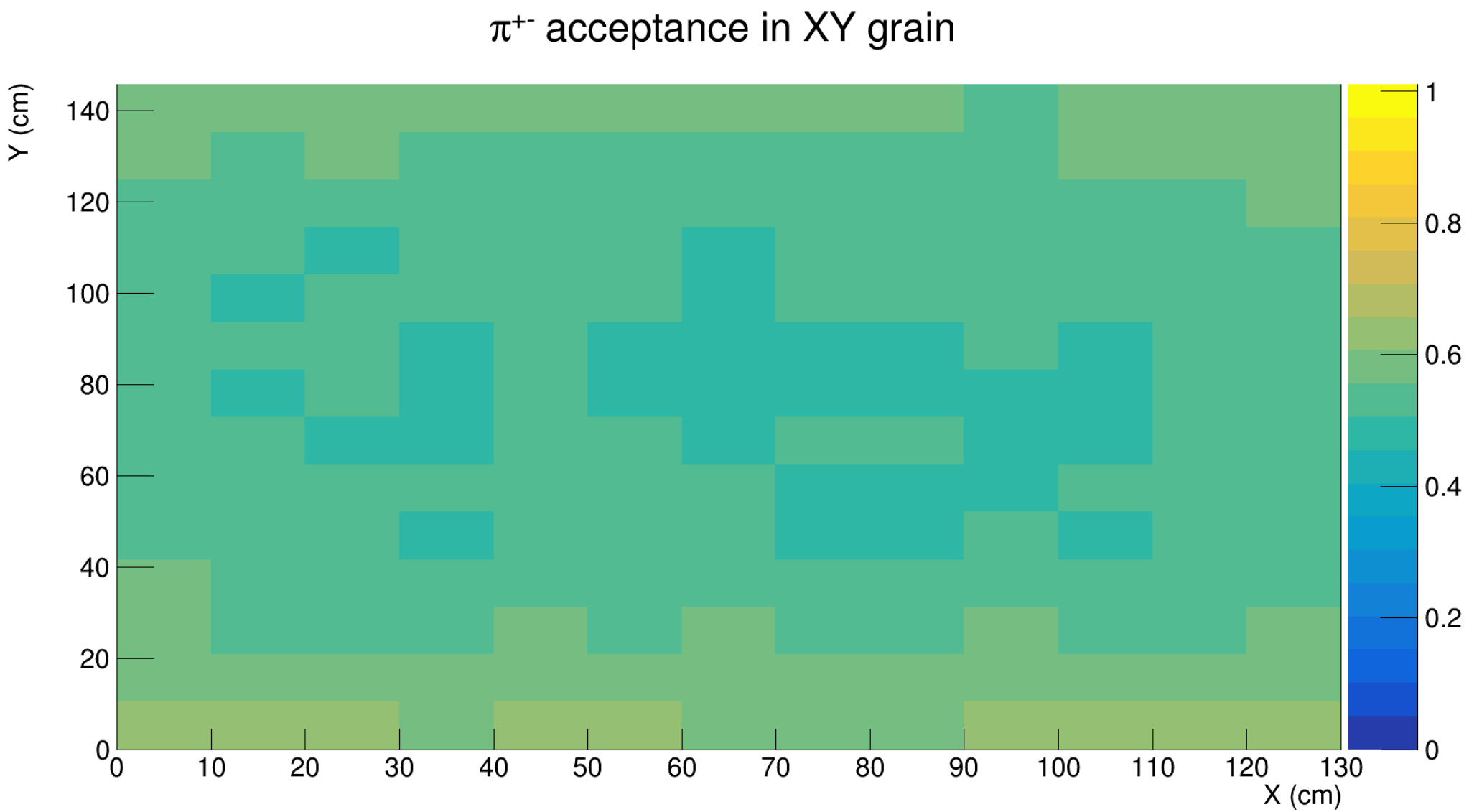
- *Require minimum of 6 Y hits to be able to reconstruct tracks in STT*
- *Smearing of simulated momenta/energy based of fast reconstruction*



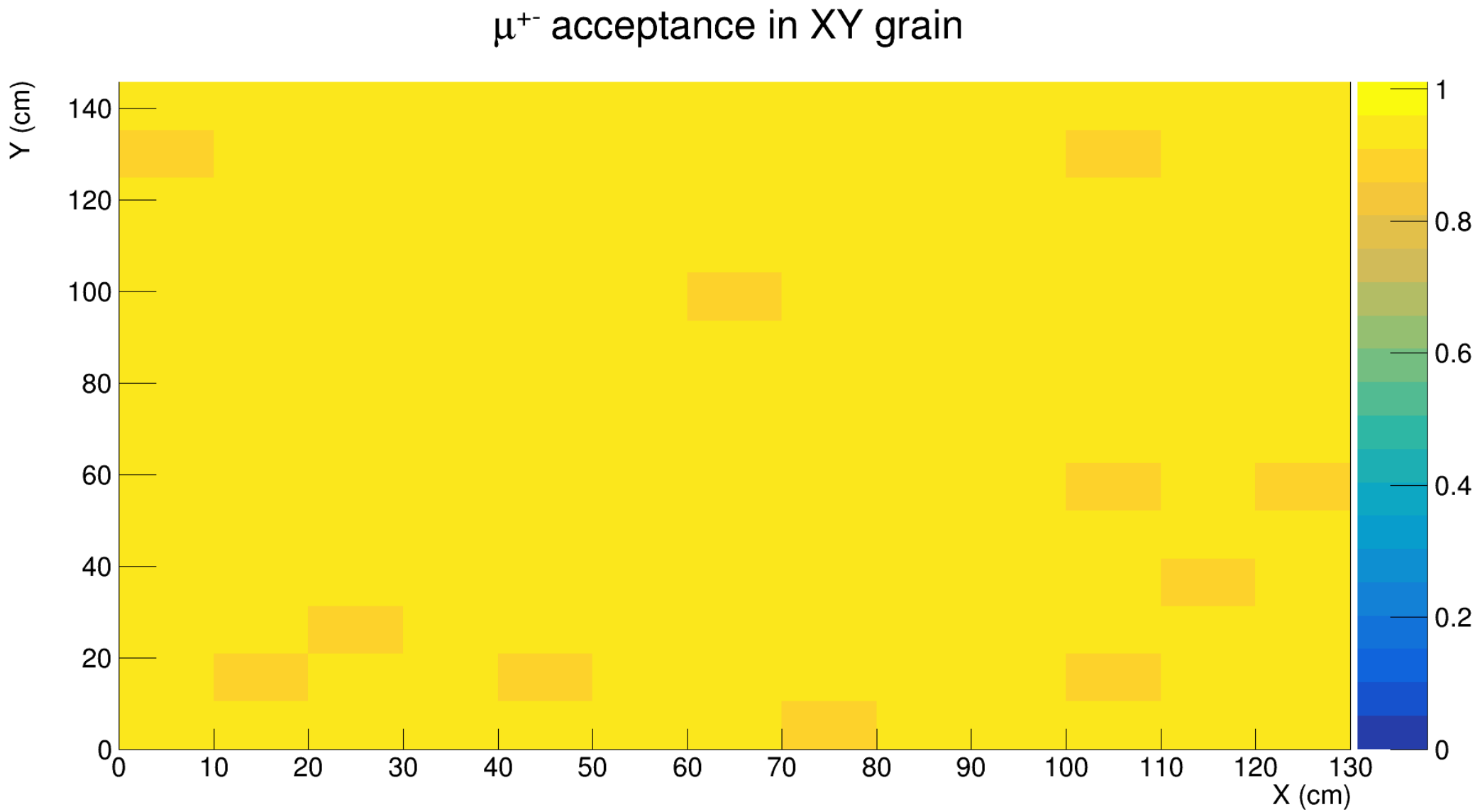
Each slice 11.875 cm



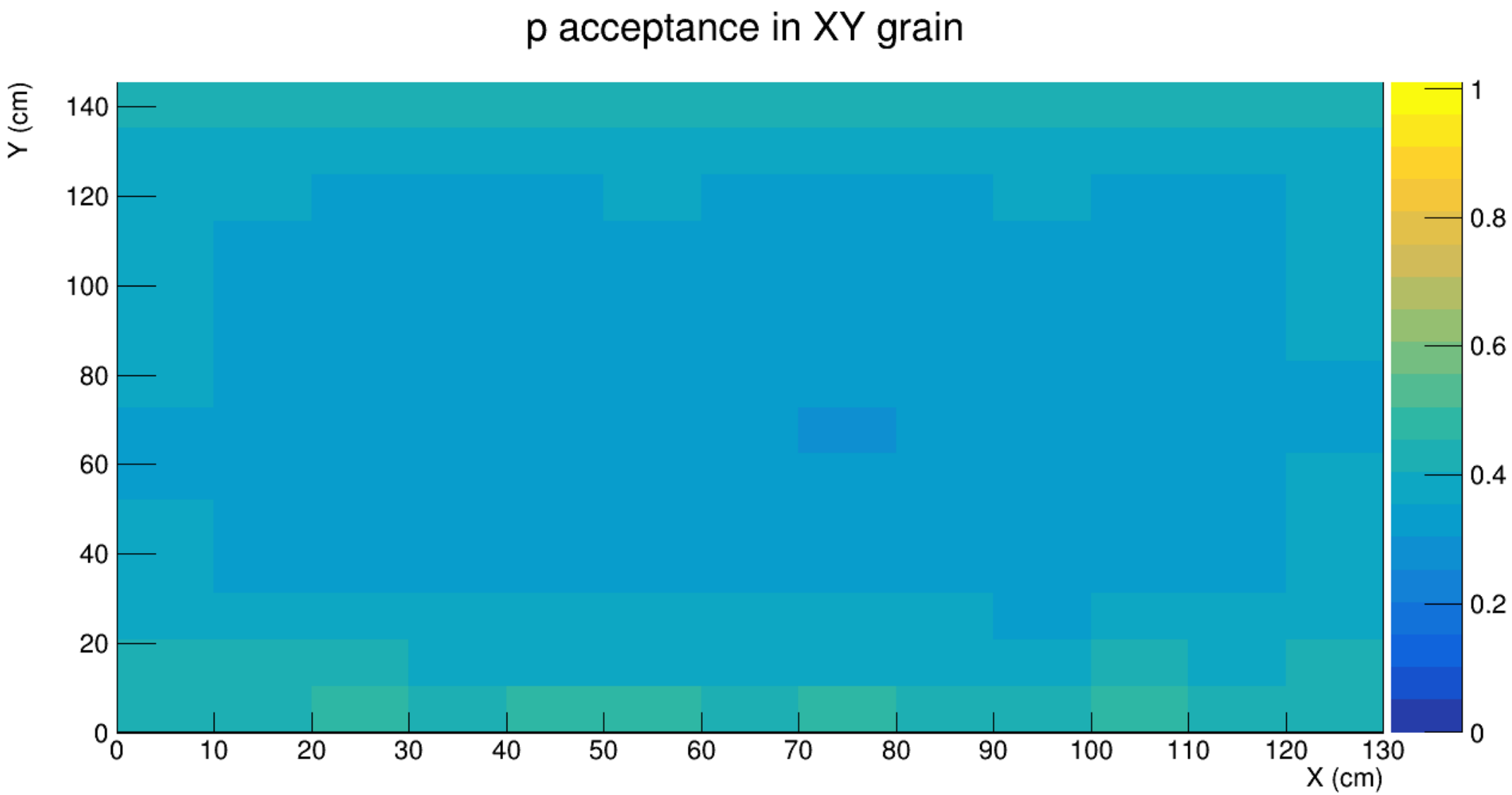
FHC



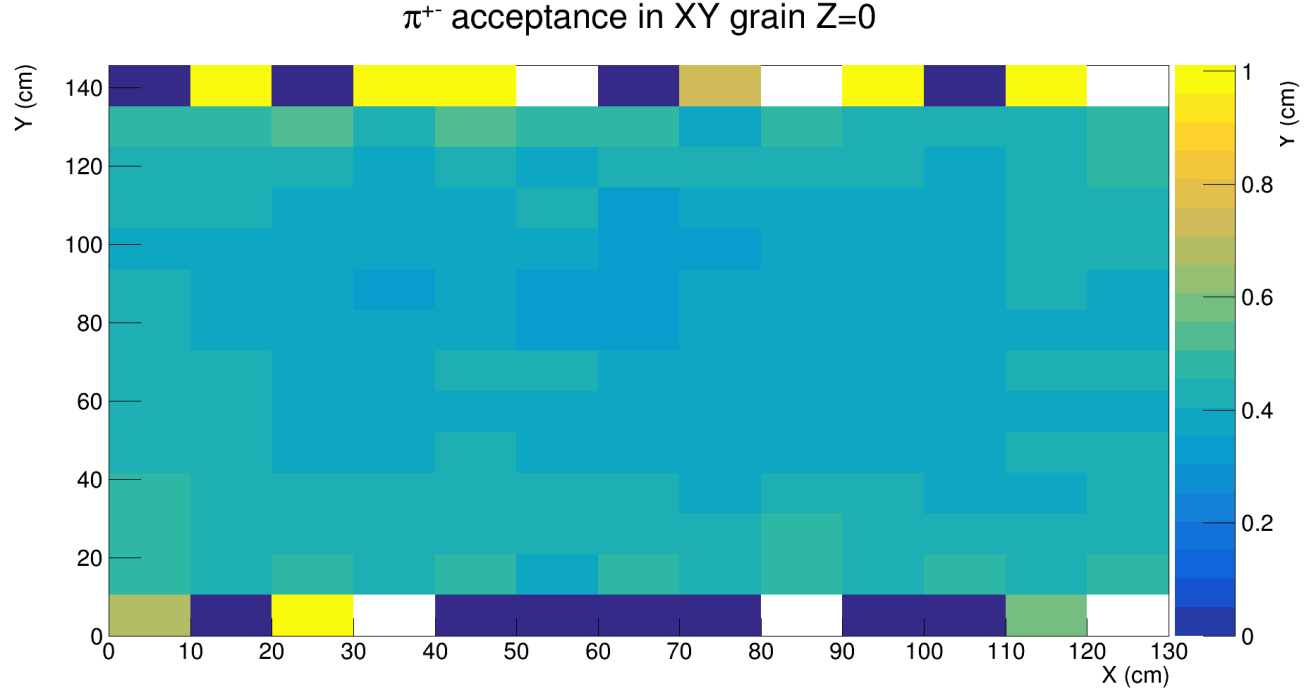
NOTE : require # Y hits >= 6 for reconstruction

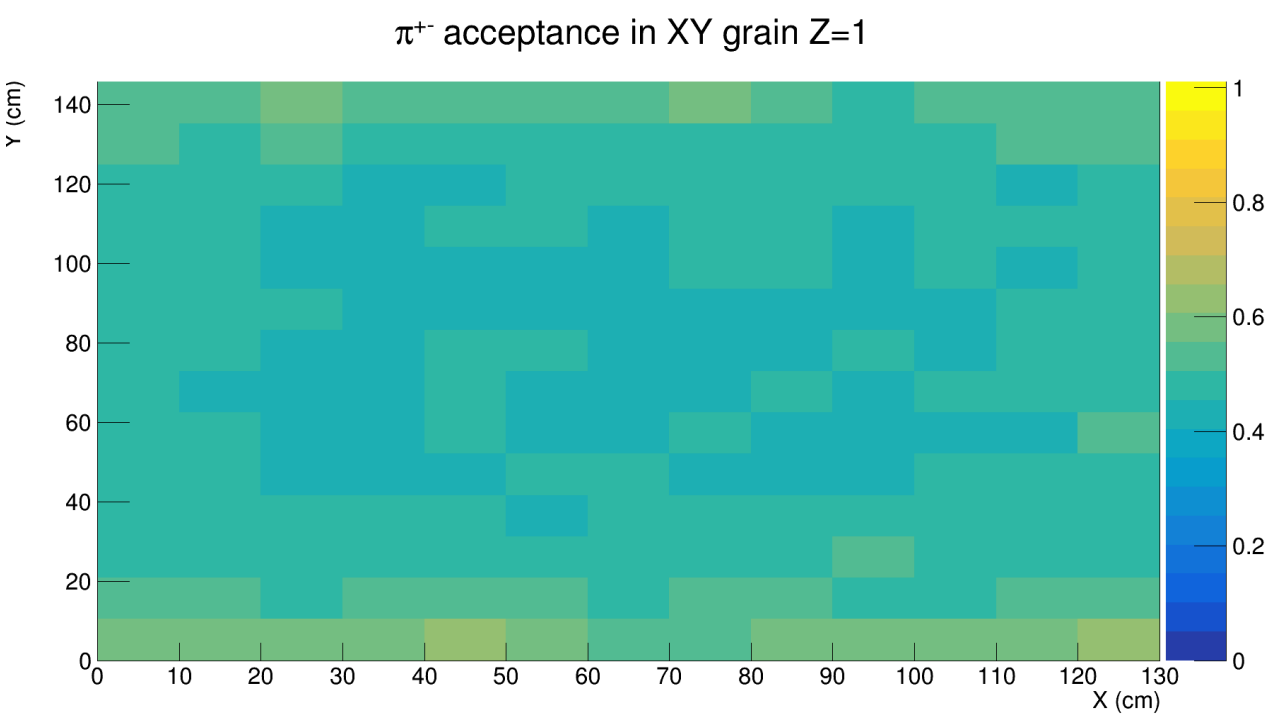


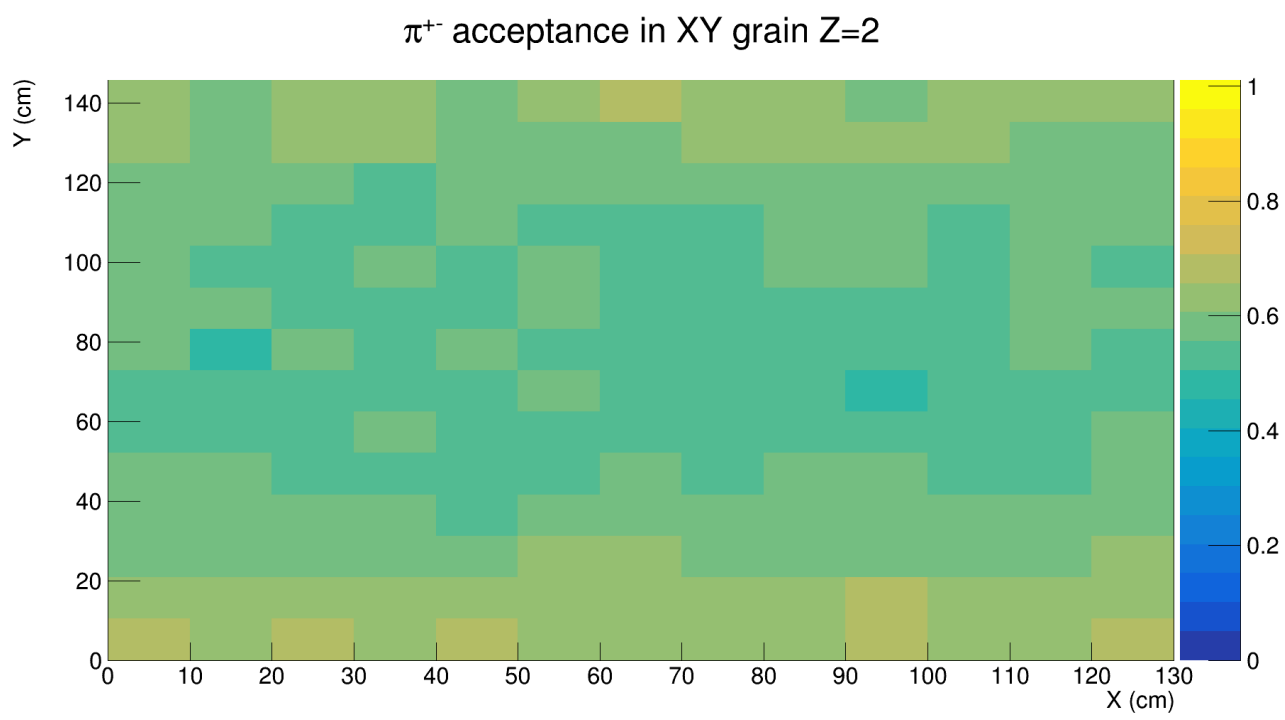
NOTE : require # Y hits >= 6 for reconstruction

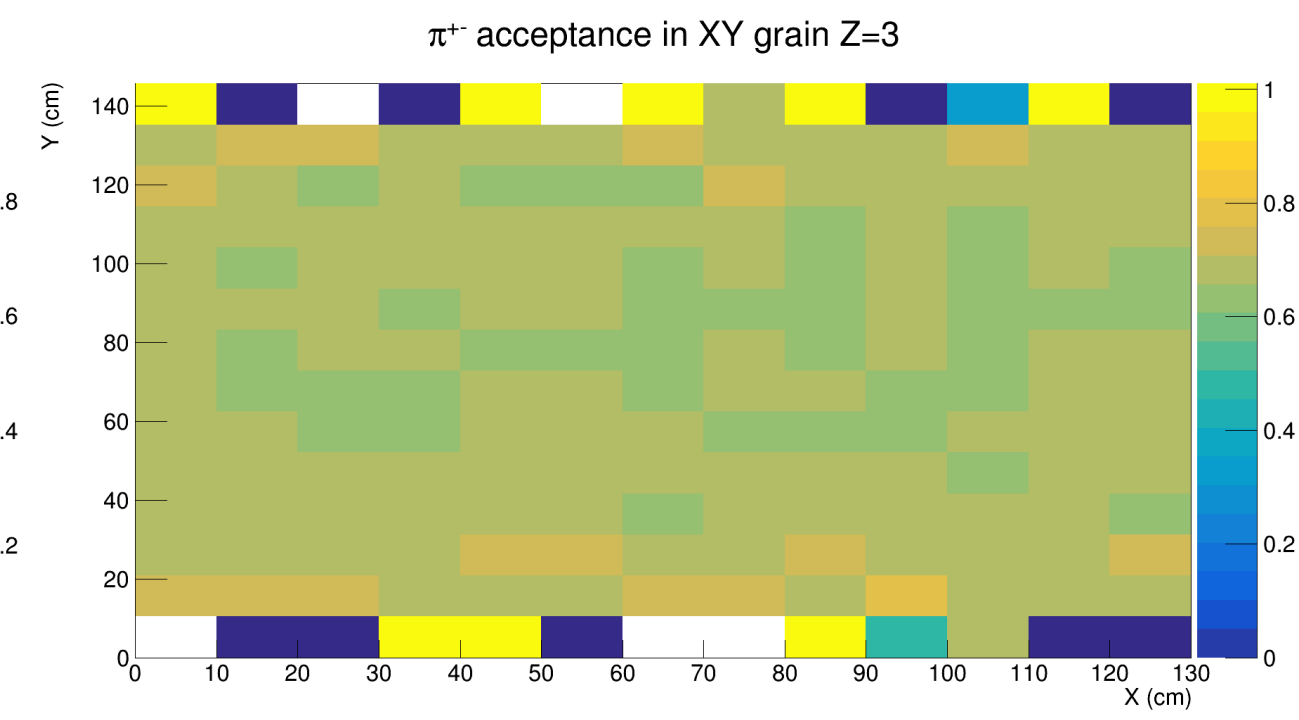


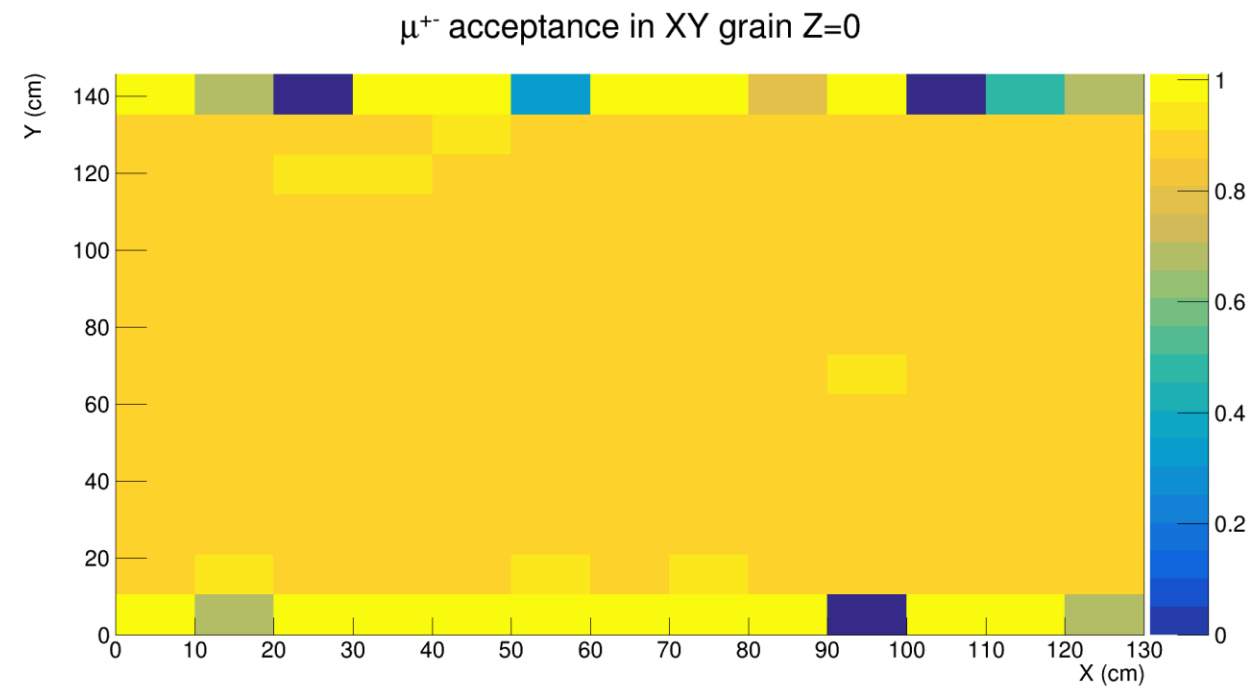
NOTE : require # Y hits >= 6 for reconstruction

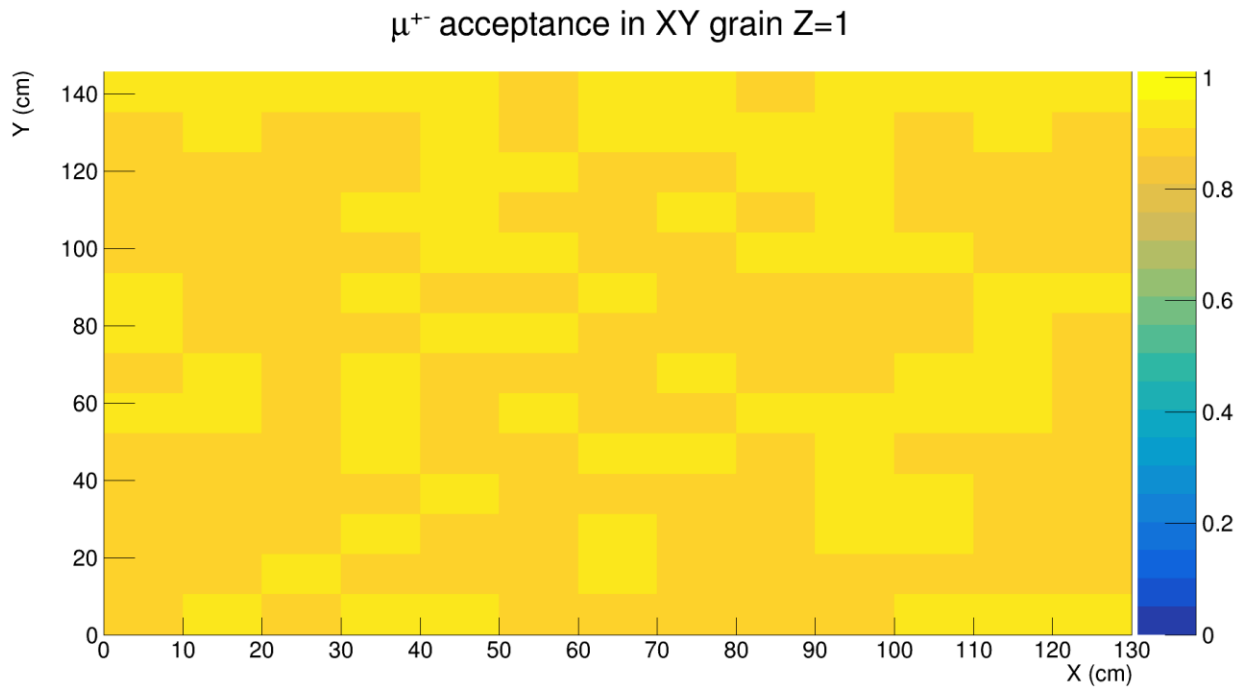

π+- acceptance in XY grain Z=0
Y (cm)
X (cm)

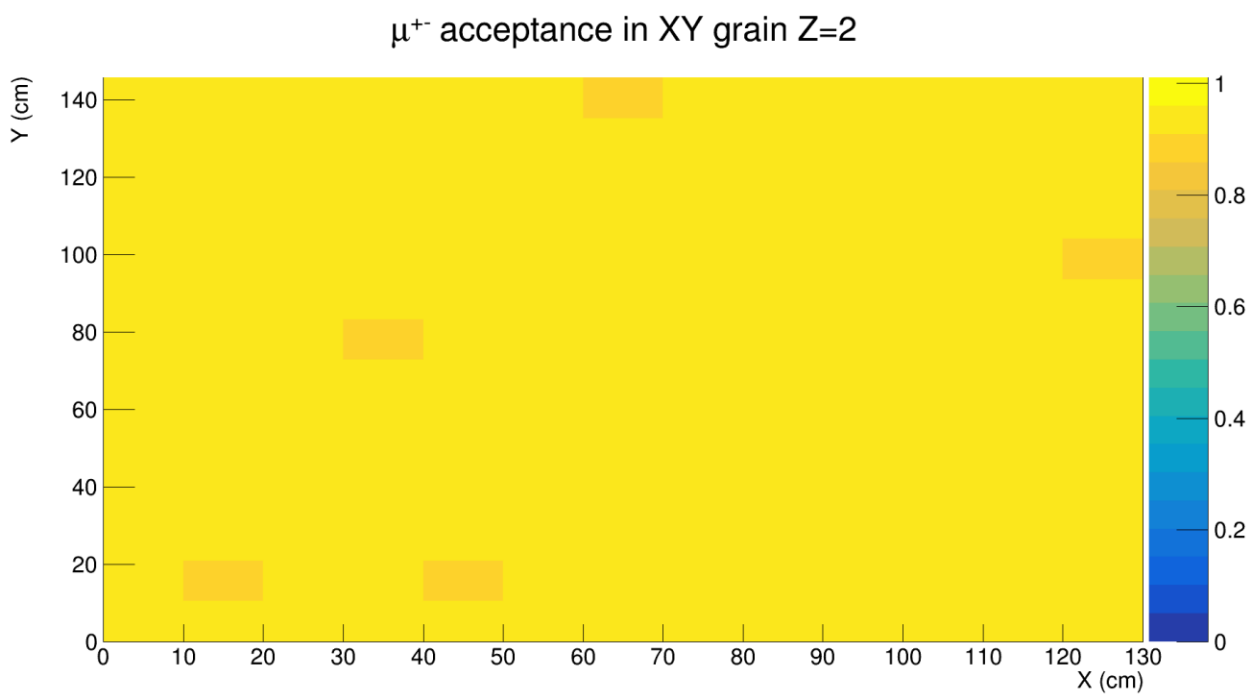

π+- acceptance in XY grain Z=1
Y (cm)
X (cm)

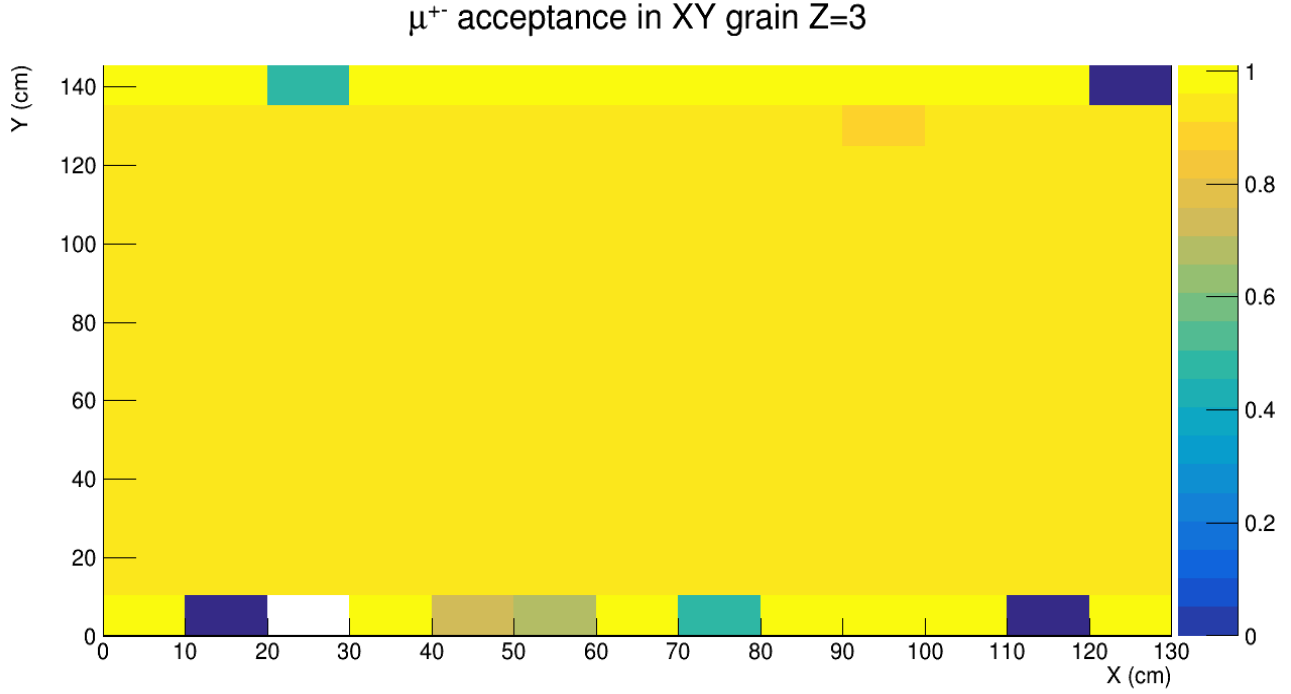

π+- acceptance in XY grain Z=2
Y (cm)
X (cm)


π+- acceptance in XY grain Z=3
Y (cm)
X (cm)

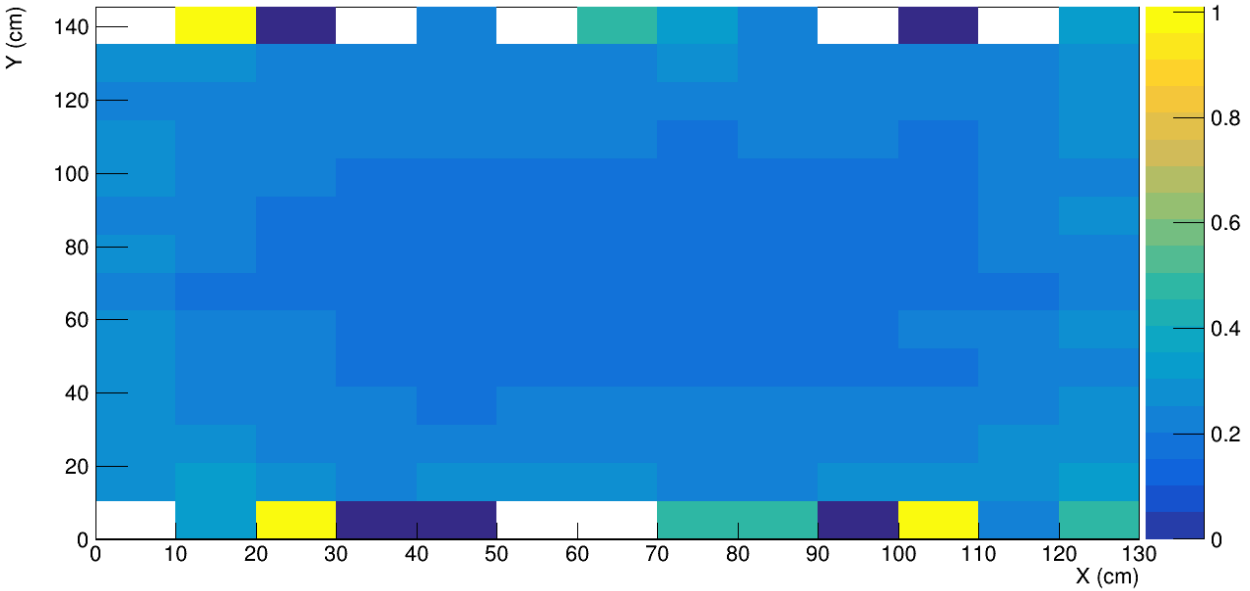

μ+- acceptance in XY grain Z=0
Y (cm)
X (cm)


μ+- acceptance in XY grain Z=1
Y (cm)
X (cm)

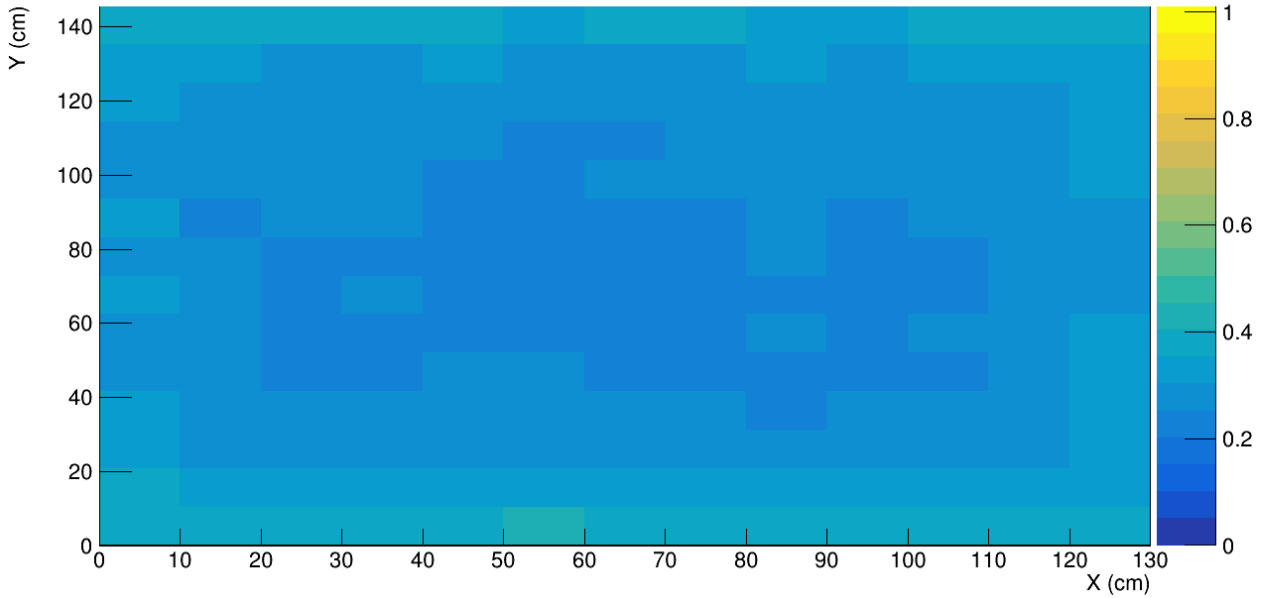

μ+- acceptance in XY grain Z=2
Y (cm)
X (cm)


μ+- acceptance in XY grain Z=3
Y (cm)
X (cm)

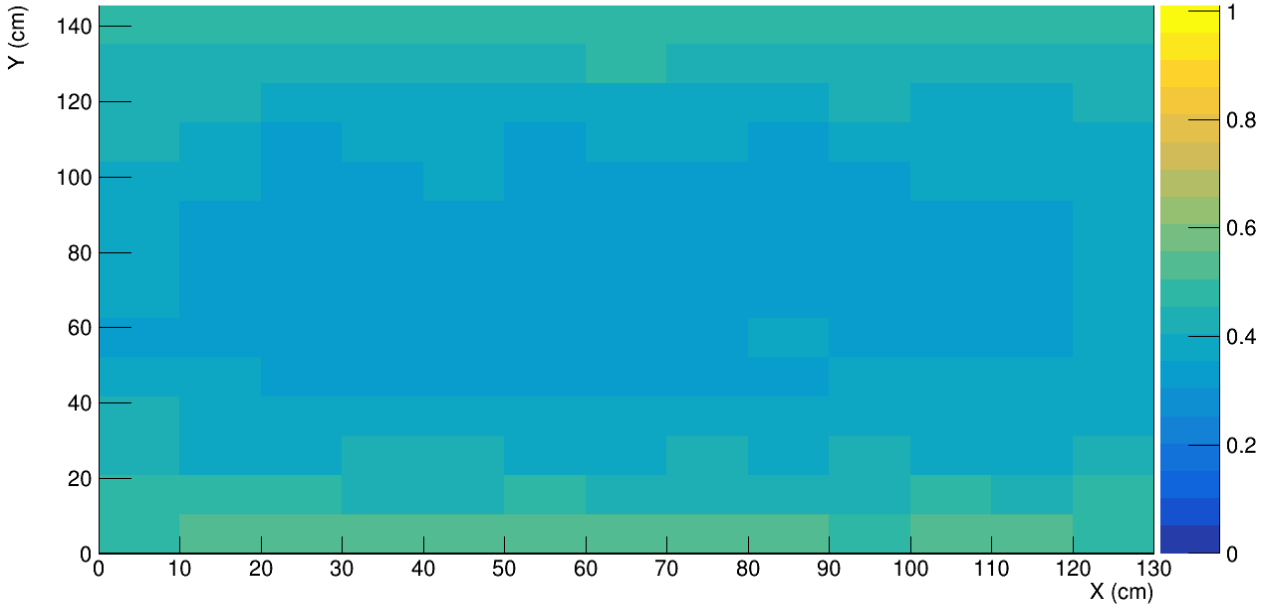
p acceptance in XY grain Z=0



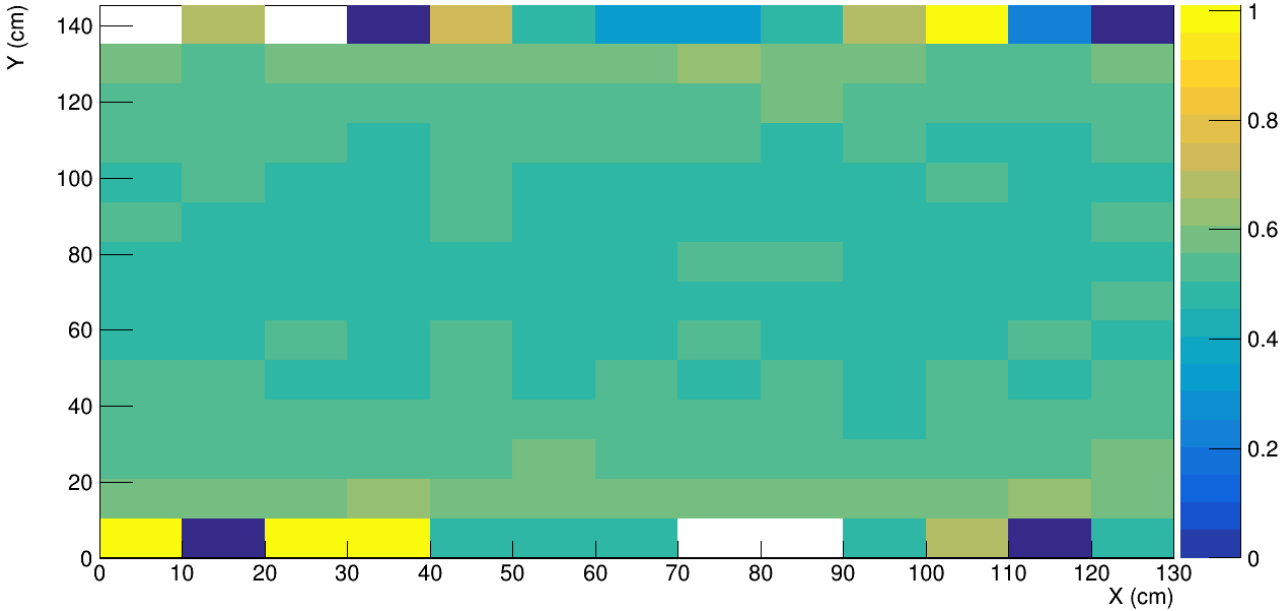
p acceptance in XY grain Z=1



p acceptance in XY grain Z=2



p acceptance in XY grain Z=3



FHC
c

Z slice	Pi+- Acceptance *Fraction of events (%)*	Pi+- Acceptance *Fraction of pions (%)*	mu+- Acceptance *Fraction of events (%)*	mu+- Acceptance *Fraction of muons(%)*	p Acceptance *Fraction of events (%)*	p Acceptance *Fraction of protons(%)*
0	39.99	32.62	89.47	89.46	21.23	8.03
1	48.07	40.89	90.67	90.67	28.66	11.08
2	57.28	50.68	92.00	92.00	38.82	15.63
3	66.65	61.02	93.31	93.30	50.94	21.81
Average	52.89	46.17	91.35	91.35	34.63	13.95

Center column: fraction of pion events with at least one reconstructed pion in STT
Right column: fraction of pion reconstructed in STT

Z slice	Interaction (%)	Stopping (%)
0	39.22	19.78
1	32.77	19.84
2	25.07	19.08
3	17.32	17.17
Average	28.69	19.08

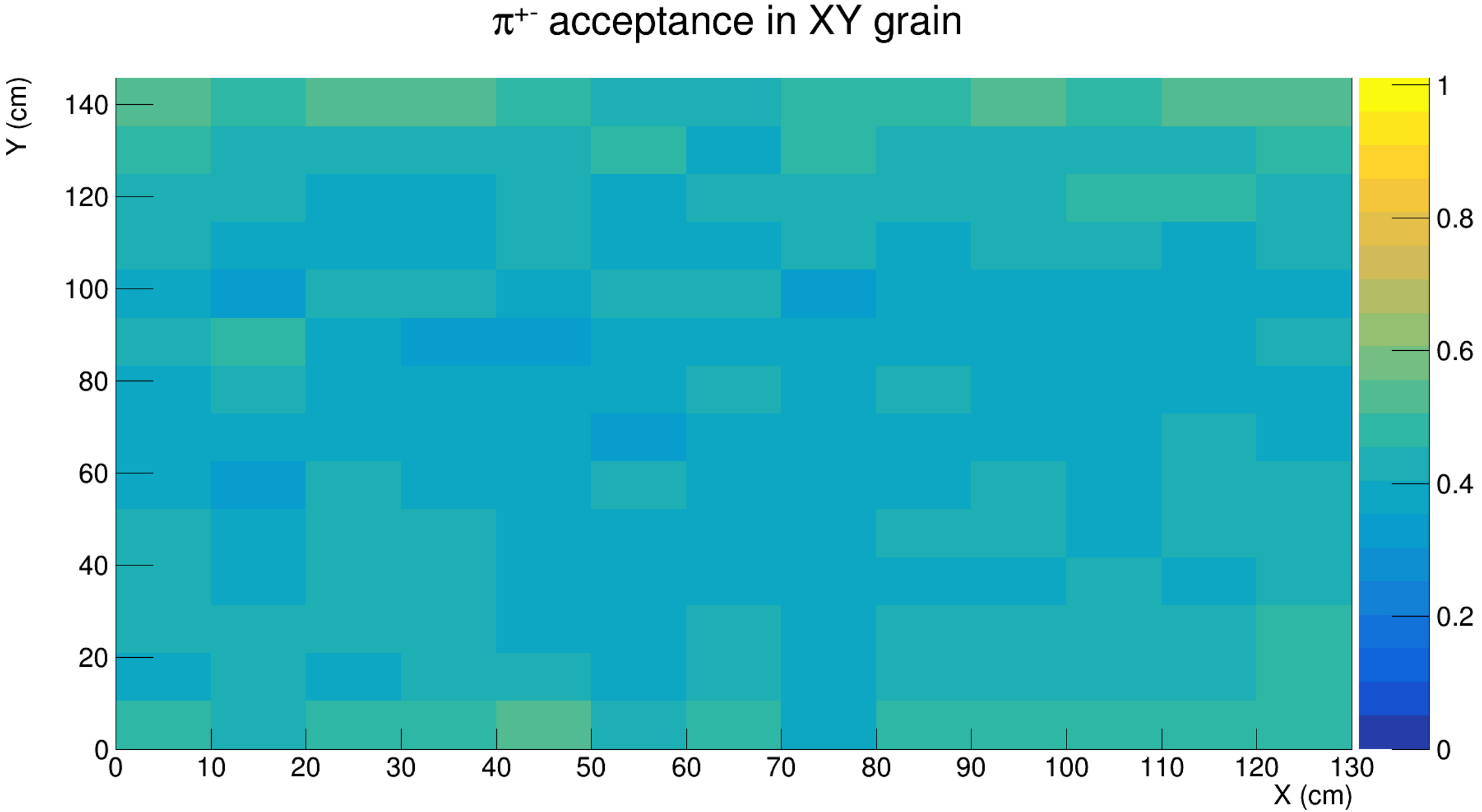
Fraction of pions interacting within GRAIN without reaching STT

FHC

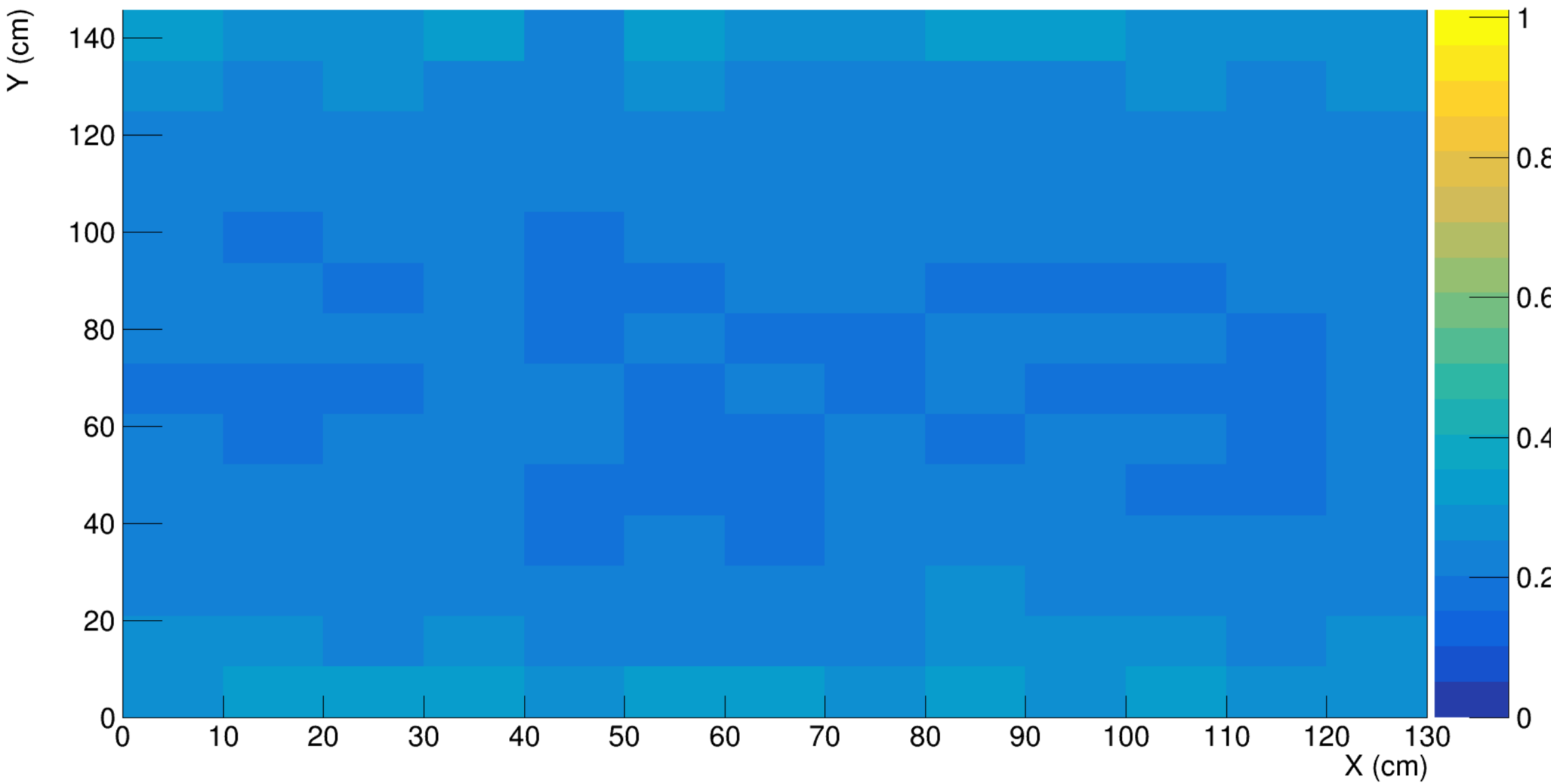
Slice	% photons (from pi0) converting in GRAIN	% pi0 with at least one photon converted in GRAIN	% pi0 with both photons converted in GRAIN
0	78.24	93.47	63.02
1	72.87	91.00	54.74
2	61.17	82.60	39.74
3	43.97	65.61	22.20
Average	64.72	83.99	45.46

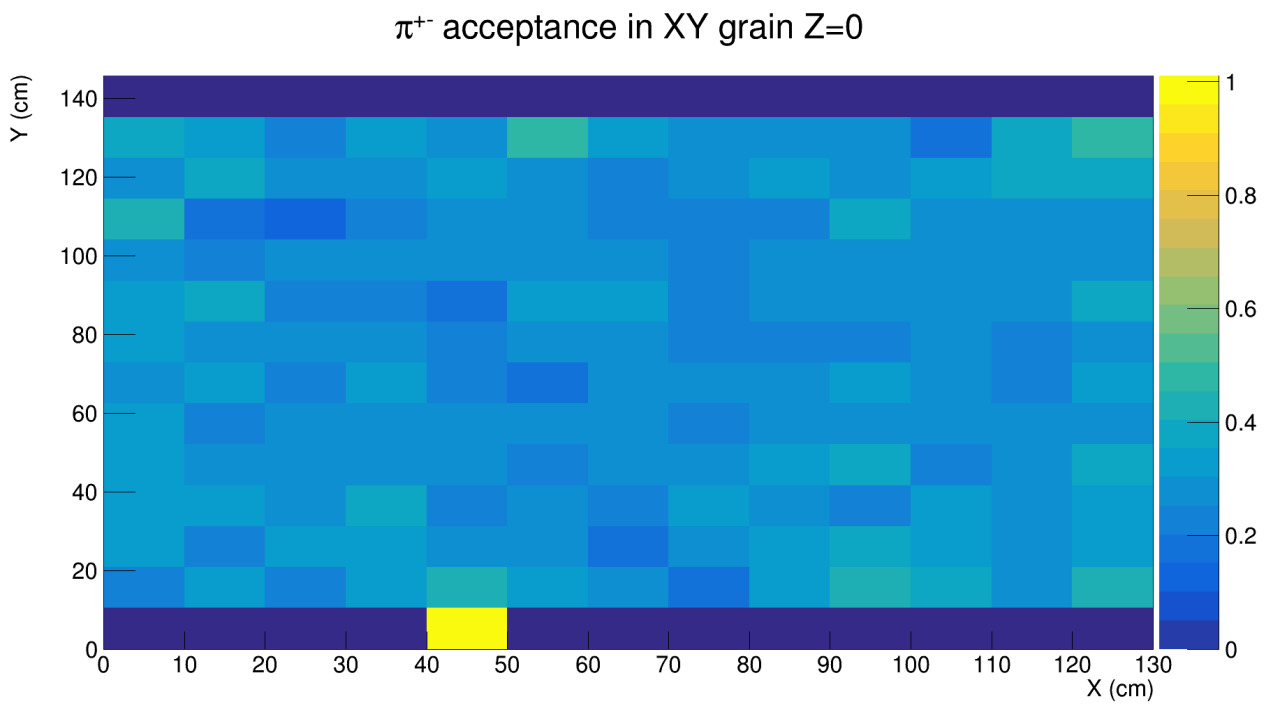
Fraction of photons and pi0 converting within GRAIN

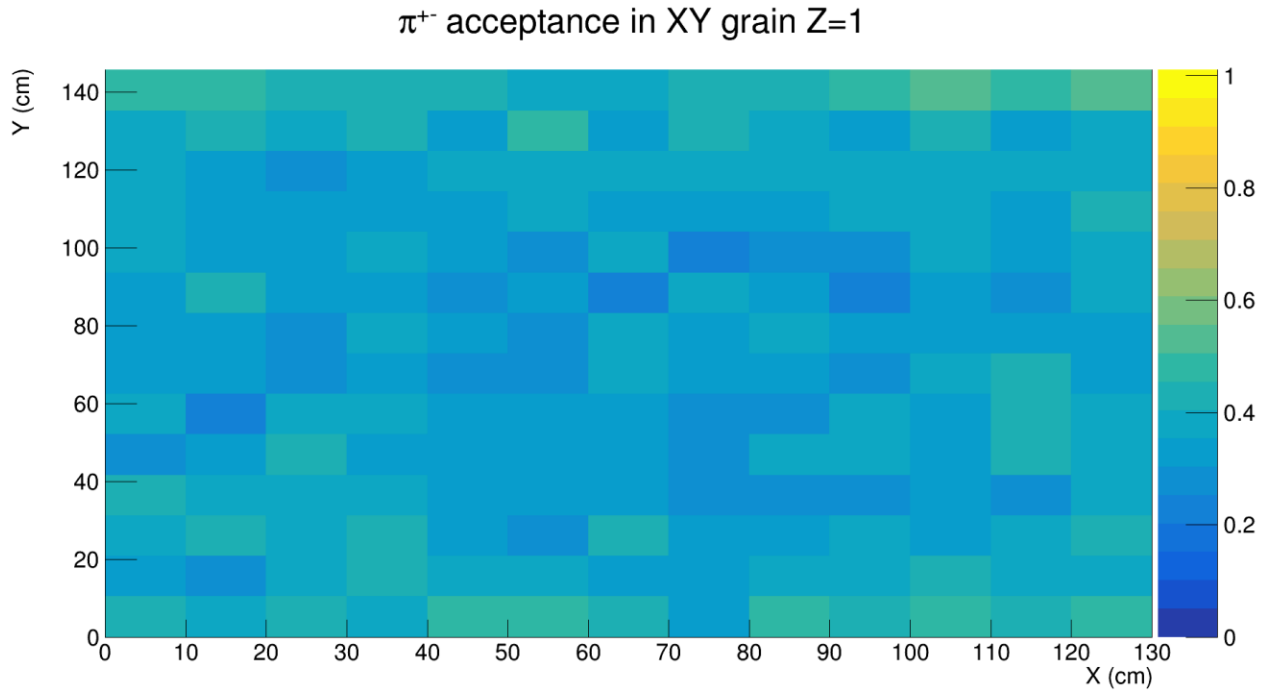
RHC

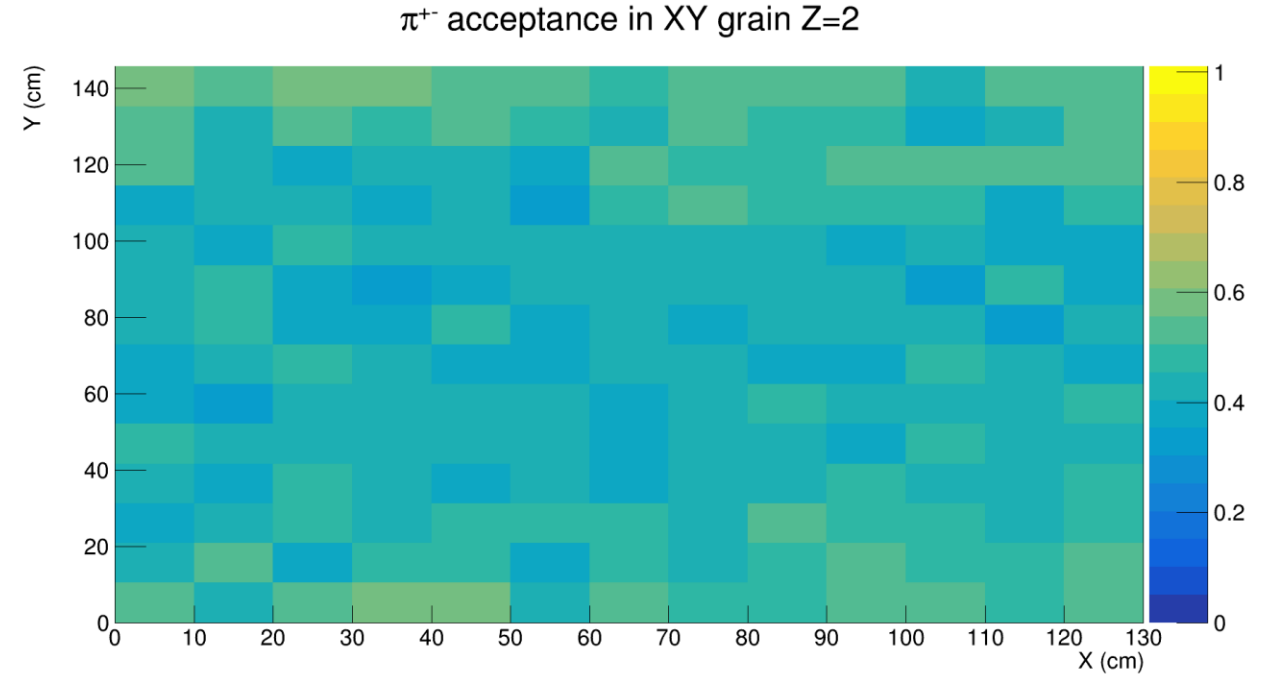

π+- acceptance in XY grain
Y (cm)
140
120
100
80
60
40
20
0
0
10
20
30
40
50
60
70
80
90
100
110
120
130
X (cm)
1
0.8
0.6
0.4
0.2
0

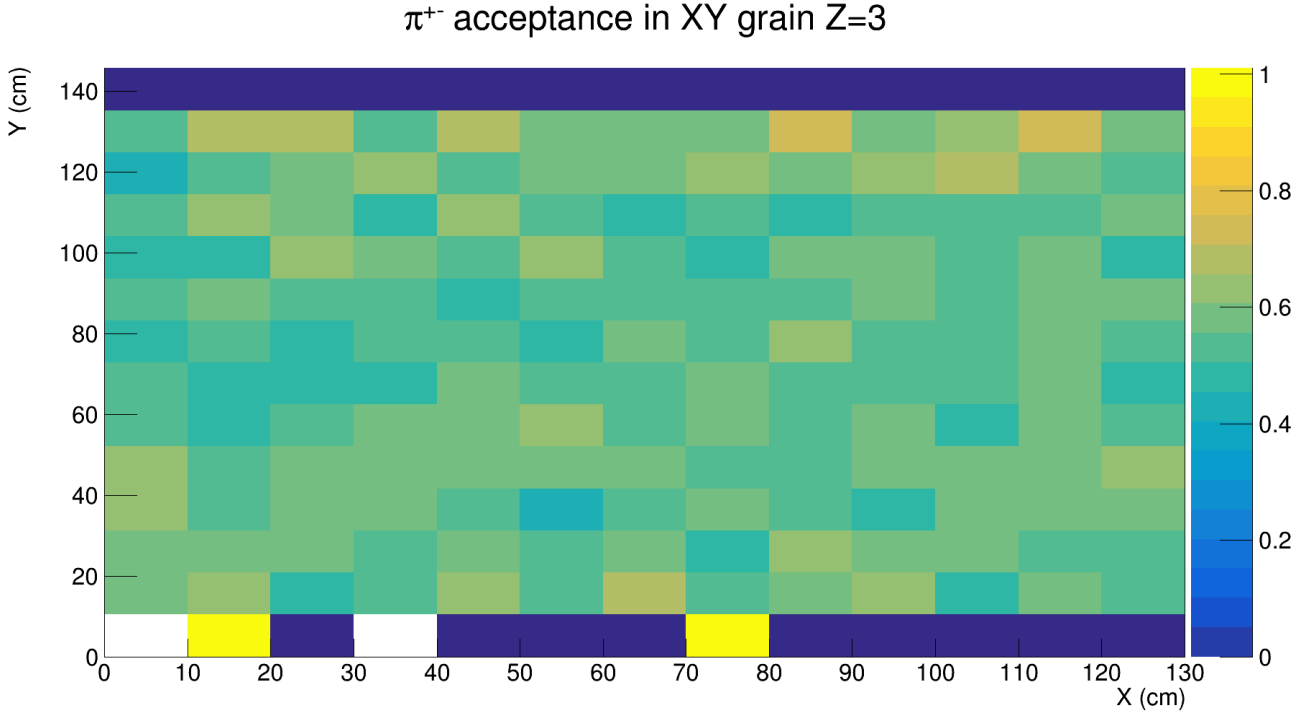

μ+- acceptance in XY grain
Y (cm)
140
120
100
80
60
40
20
0
0
10
20
30
40
50
60
70
80
90
100
110
120
130
X (cm)
1
0.8
0.6
0.4
0.2
0

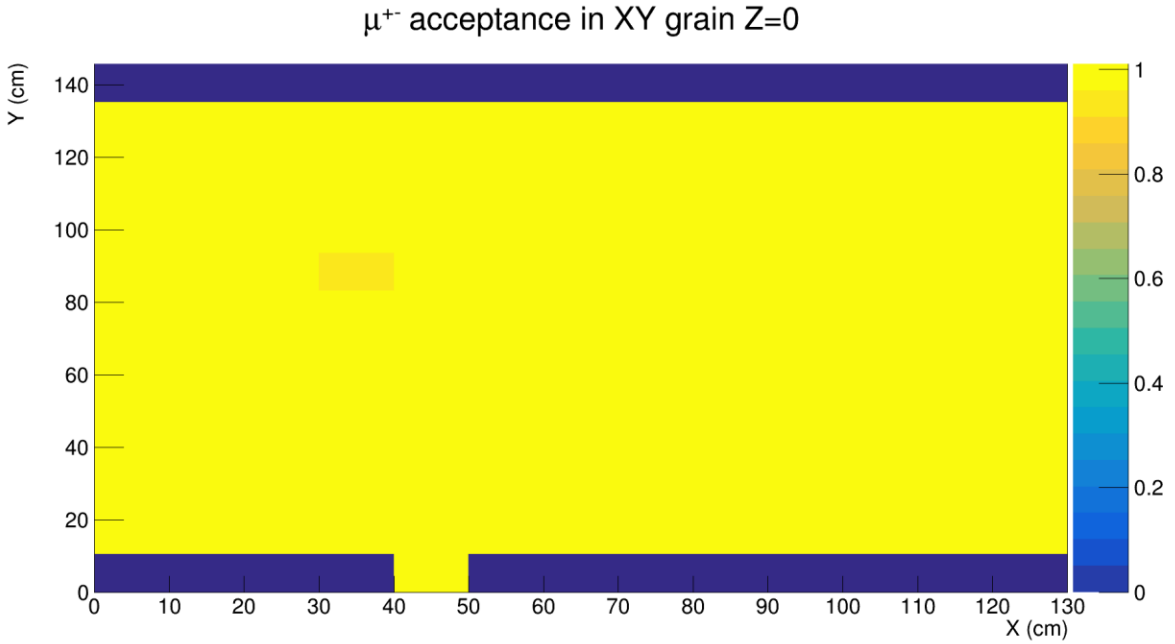

p acceptance in XY grain
Y (cm)
140
120
100
80
60
40
20
0
0
10
20
30
40
50
60
70
80
90
100
110
120
130
X (cm)
1
0.8
0.6
0.4
0.2
0

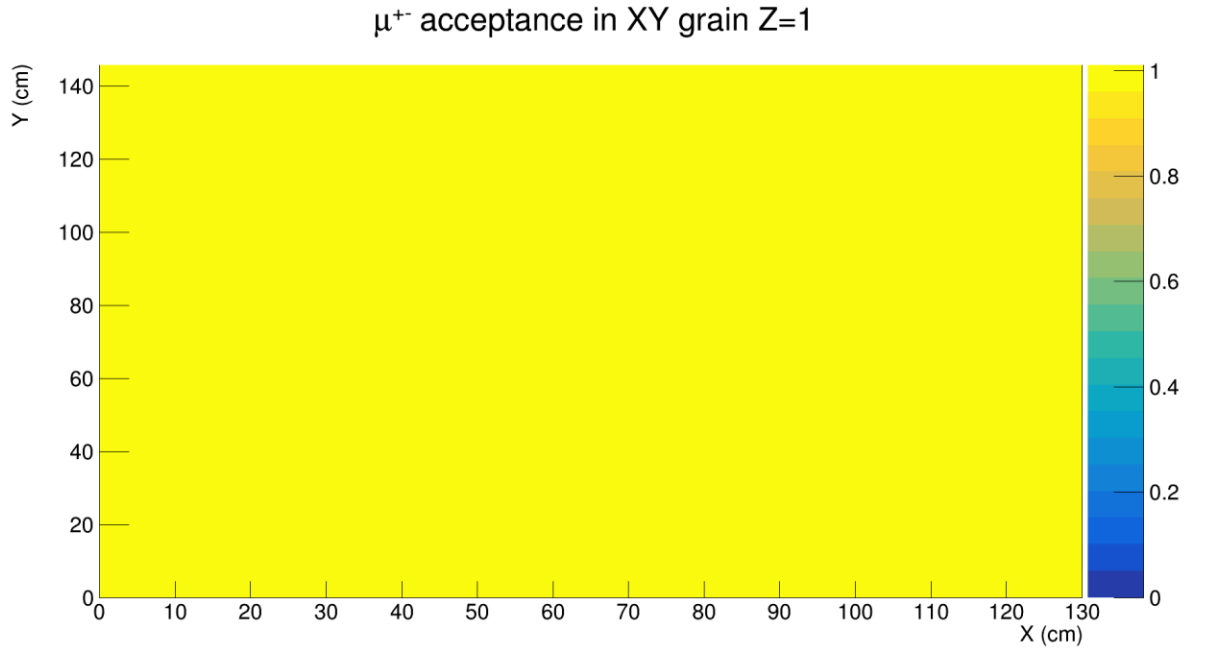

π+- acceptance in XY grain Z=0
Y (cm)
X (cm)

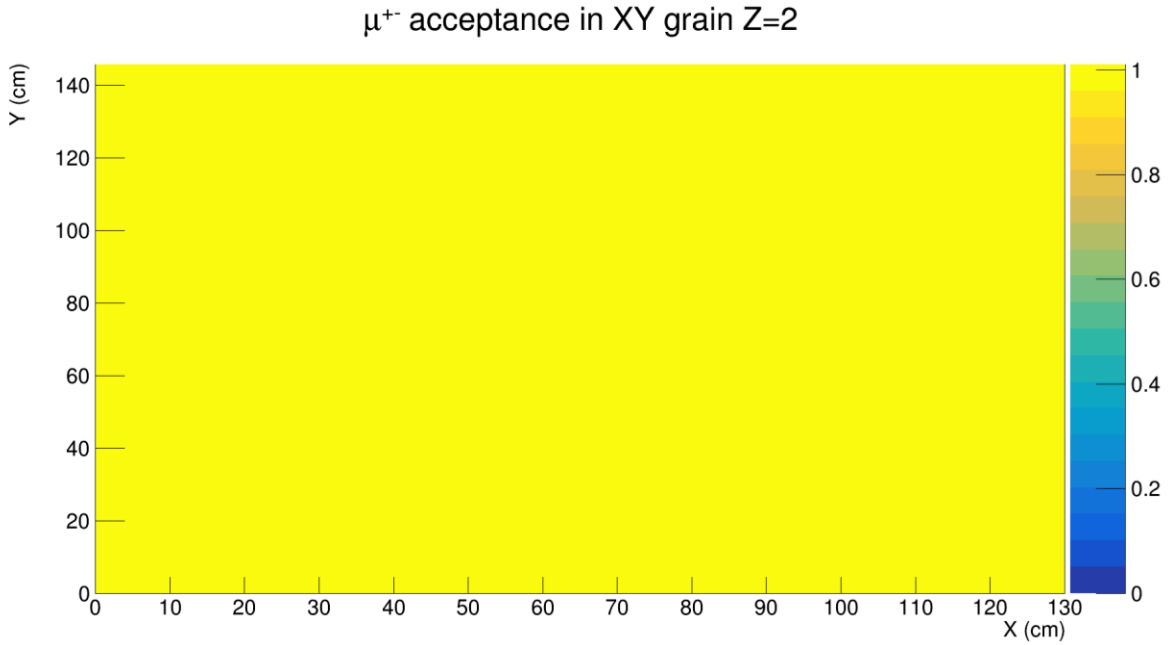

π+- acceptance in XY grain Z=1
Y (cm)
X (cm)

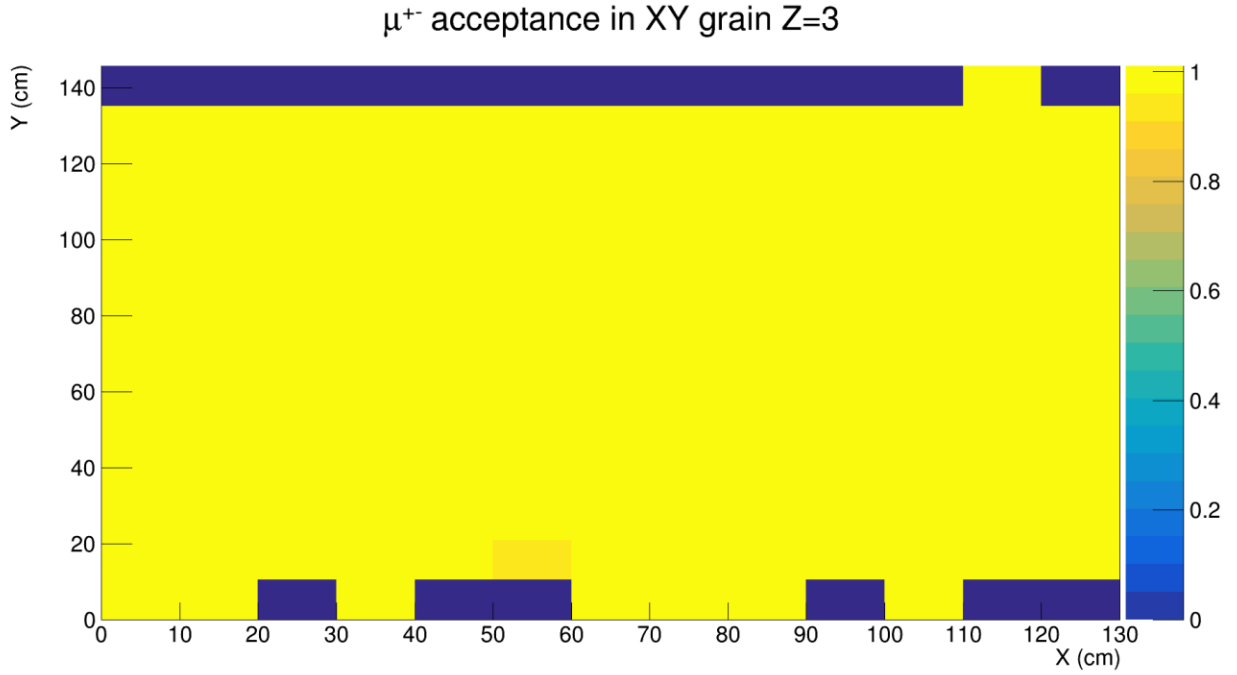

π+- acceptance in XY grain Z=2
Y (cm)
X (cm)


π+- acceptance in XY grain Z=3
Y (cm)
X (cm)

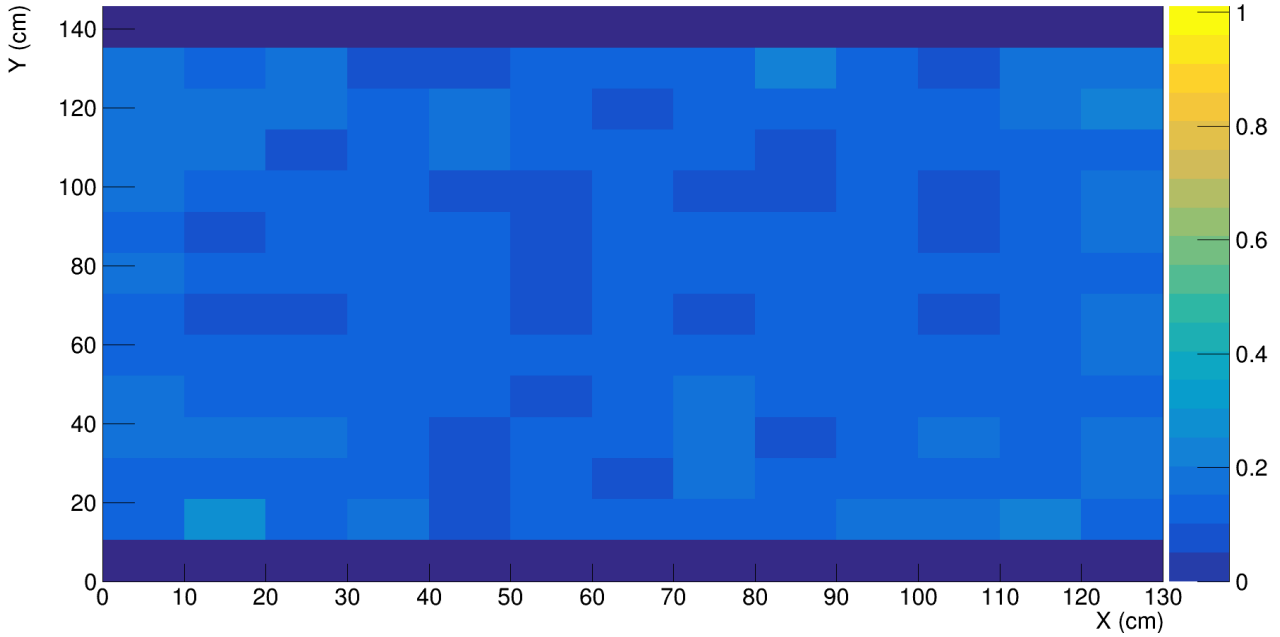

μ+- acceptance in XY grain Z=0
Y (cm)
X (cm)


μ+- acceptance in XY grain Z=1
Y (cm)
X (cm)

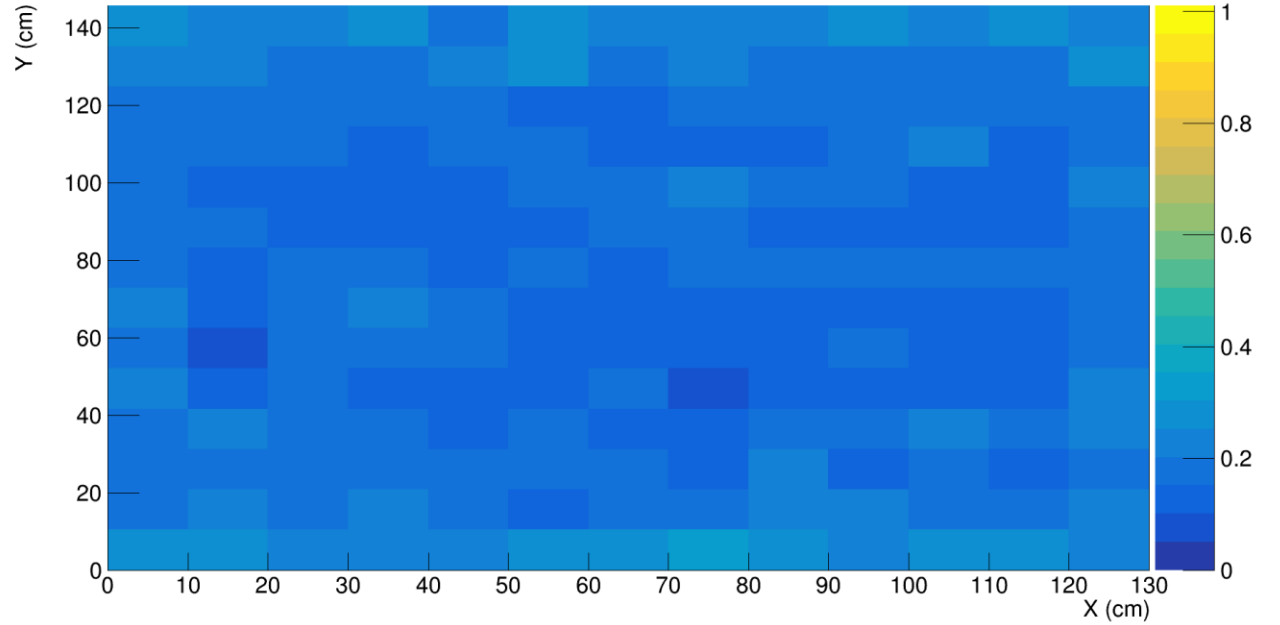

μ+- acceptance in XY grain Z=2
Y (cm)
X (cm)


μ+- acceptance in XY grain Z=3
Y (cm)
X (cm)

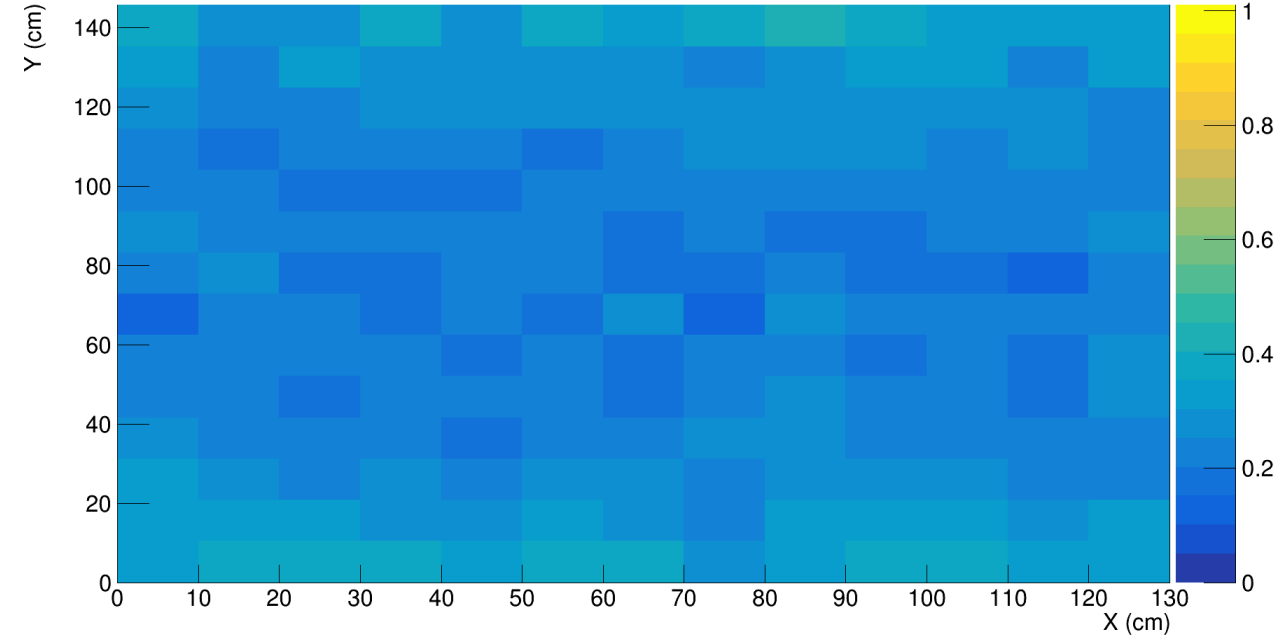
p acceptance in XY grain Z=0



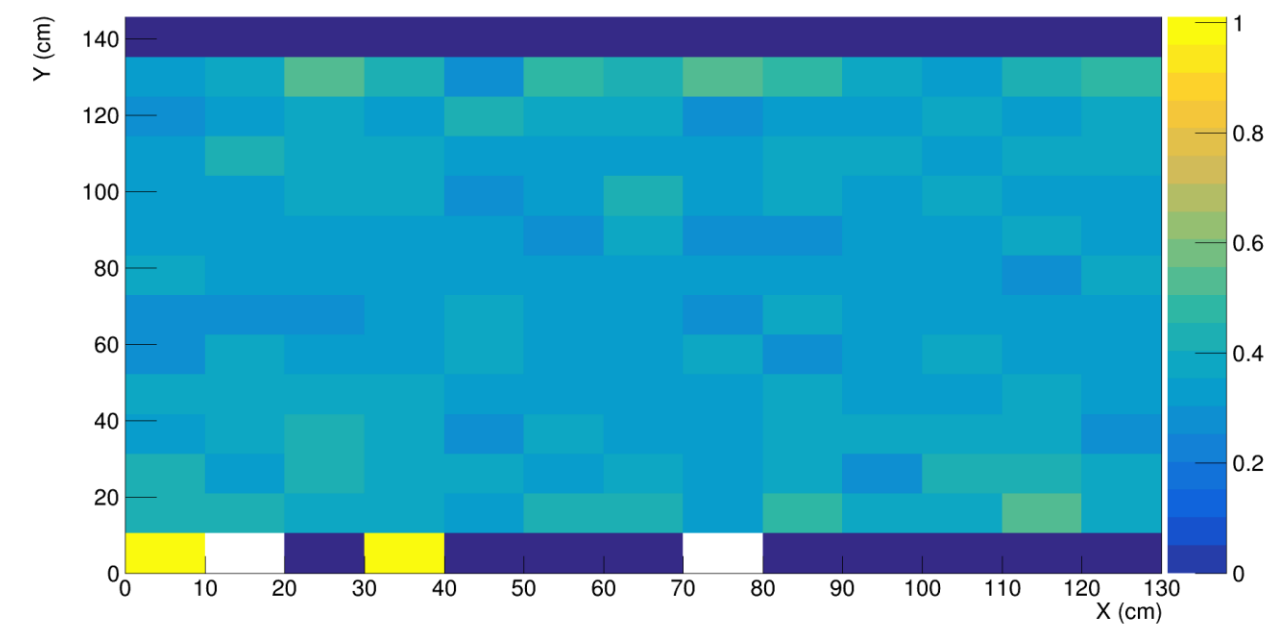
p acceptance in XY grain Z=1



p acceptance in XY grain Z=2



p acceptance in XY grain Z=3



RHC

Z slice	Pi+- Acceptance *Fraction of events (%)*	Pi+- Acceptance *Fraction of pions (%)*	mu+- Acceptance *Fraction of events (%)*	mu+- Acceptance *Fraction of muons(%)*	p Acceptance *Fraction of events (%)*	p Acceptance *Fraction of protons(%)*
0	28.00	37.47	98.27	98.27	12.53	4.49
1	35.72	32.16	98.66	98.66	17.43	6.37
2	44.53	41.40	98.89	98.89	25.18	9.45
3	55.14	52.14	99.24	99.24	34.80	13.77
Average	40.69	37.47	98.77	98.77	22.22	8.39

Center column: fraction of pion events with at least one reconstructed pion in STT
Right column: fraction of pion reconstructed in STT

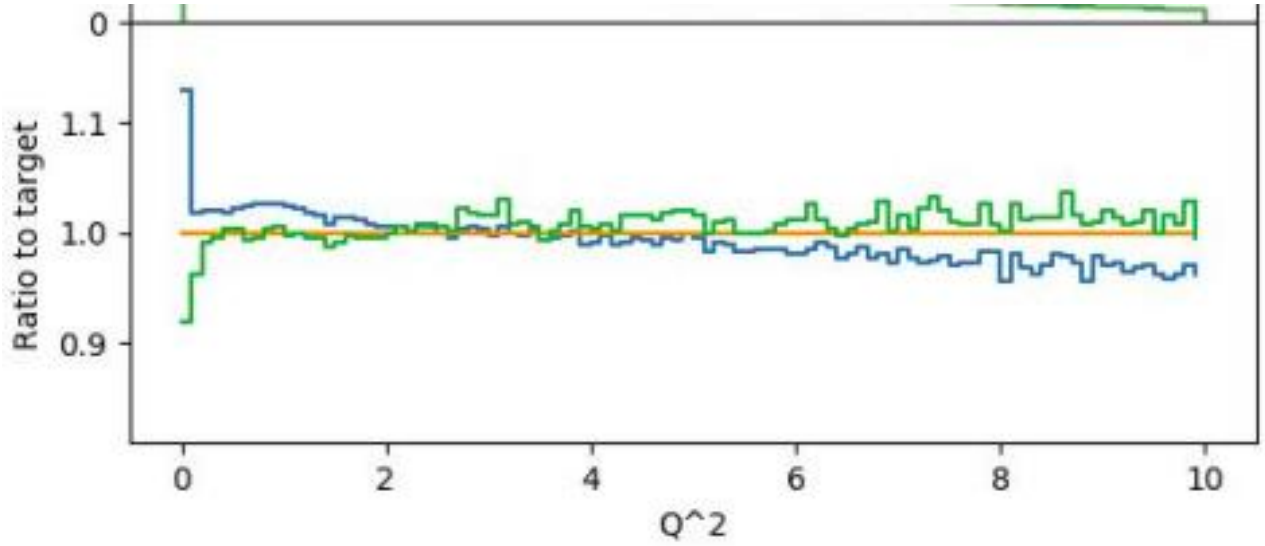
RHC

Slice	% photons (from pi0) converting in GRAIN	% pi0 with at least one photon converted in GRAIN	% pi0 with both photons converted in GRAIN
0	75.89	92.53	59.25
1	72.57	90.74	54.40
2	62.91	84.11	41.70
3	47.56	69.40	25.72
Average	65.33	84.86	45.81

Fraction of photons and pi0 converting within GRAIN

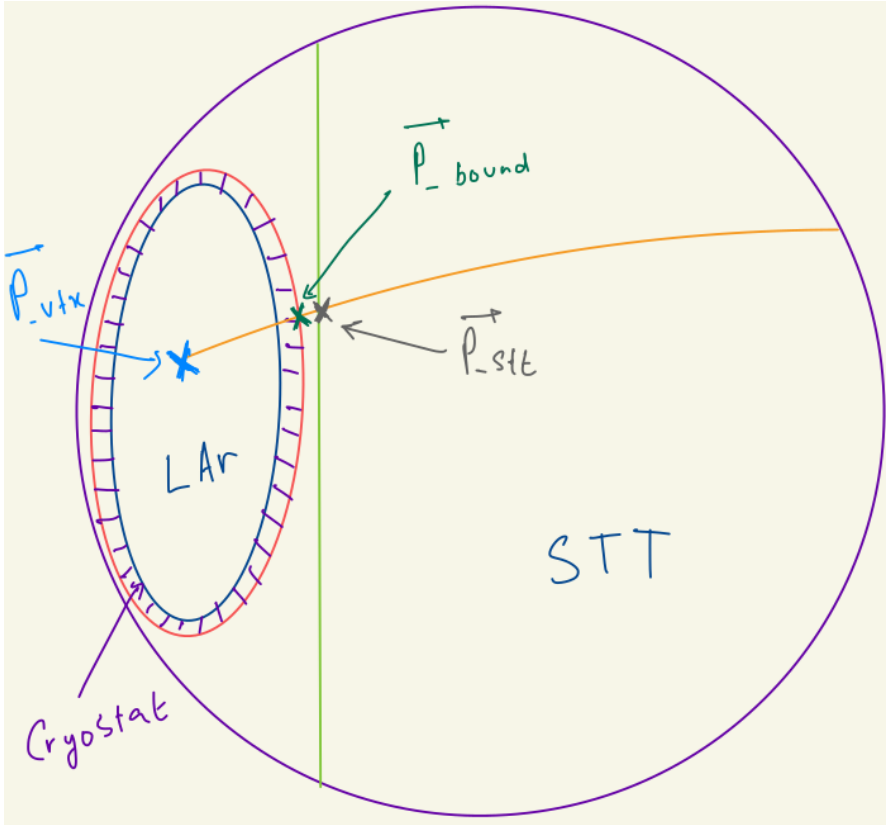
Re-weighting from GENIE to NuWro

- Used a BDT reweighting code by Cris Viela
- Reweighted GENIE v2.10.12 events to NuWro 19.02.2 events
- The code uses 23 MC variables to get the weights of the events



Origin = GENIE v2.10.12
Target = NuWro 19.02.2

Smearing of tracks with >= 6 Y STT hits



Angular smearing

- Multiple scattering in both STT and GRAIN at vertex

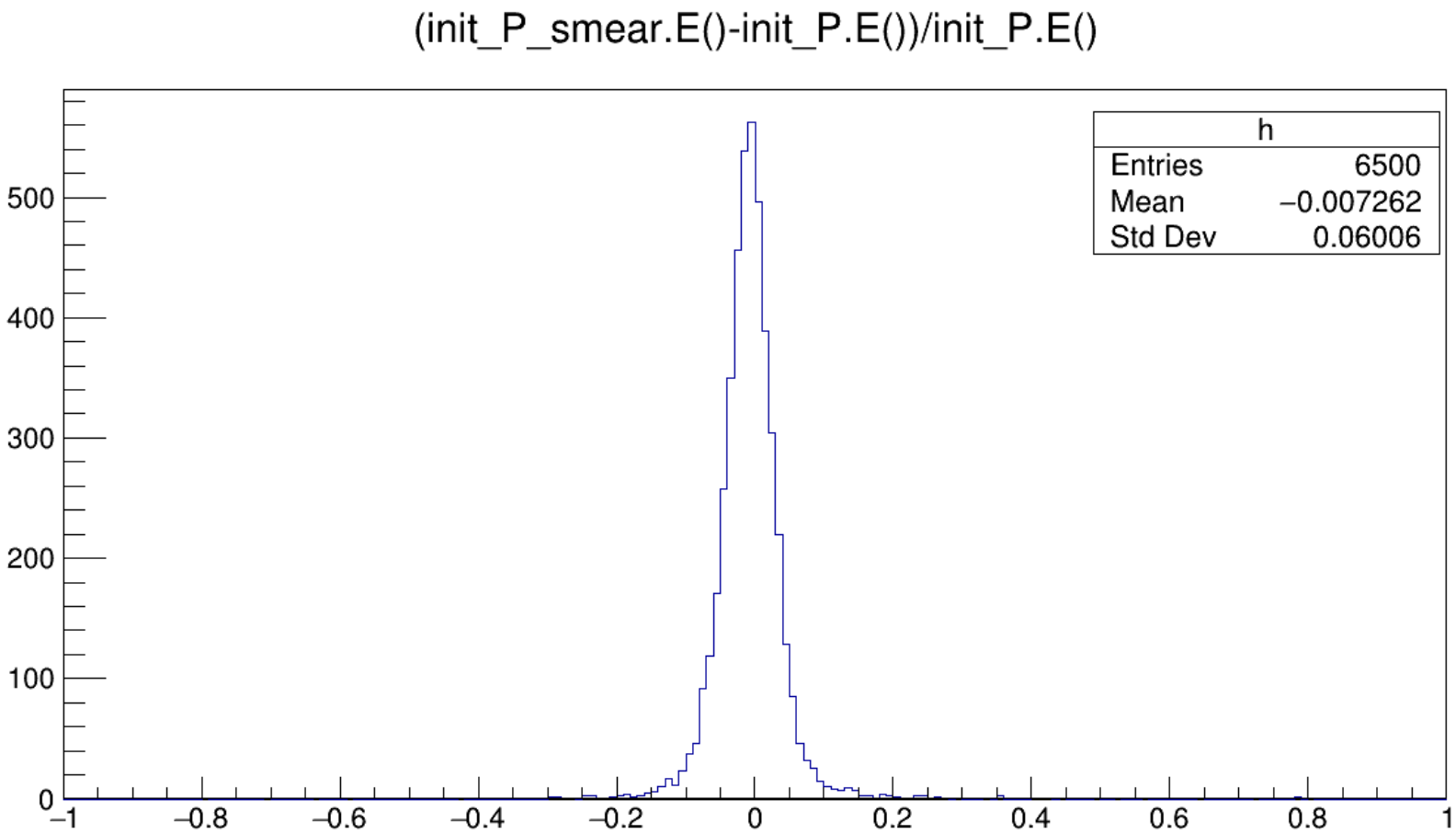
$$\sigma_{total} = \sqrt{\sigma^2_{STT} + \sigma^2_{LAr}}$$

$$\theta^{smear}_{dip,vtx} = \theta^{true}_{dip,vtx} + ran \rightarrow gaus(0, \sigma)$$

$$\theta^{smear}_{YZ,vtx} = \theta^{true}_{YZ,vtx} + ran \rightarrow gaus(0, \sigma)$$

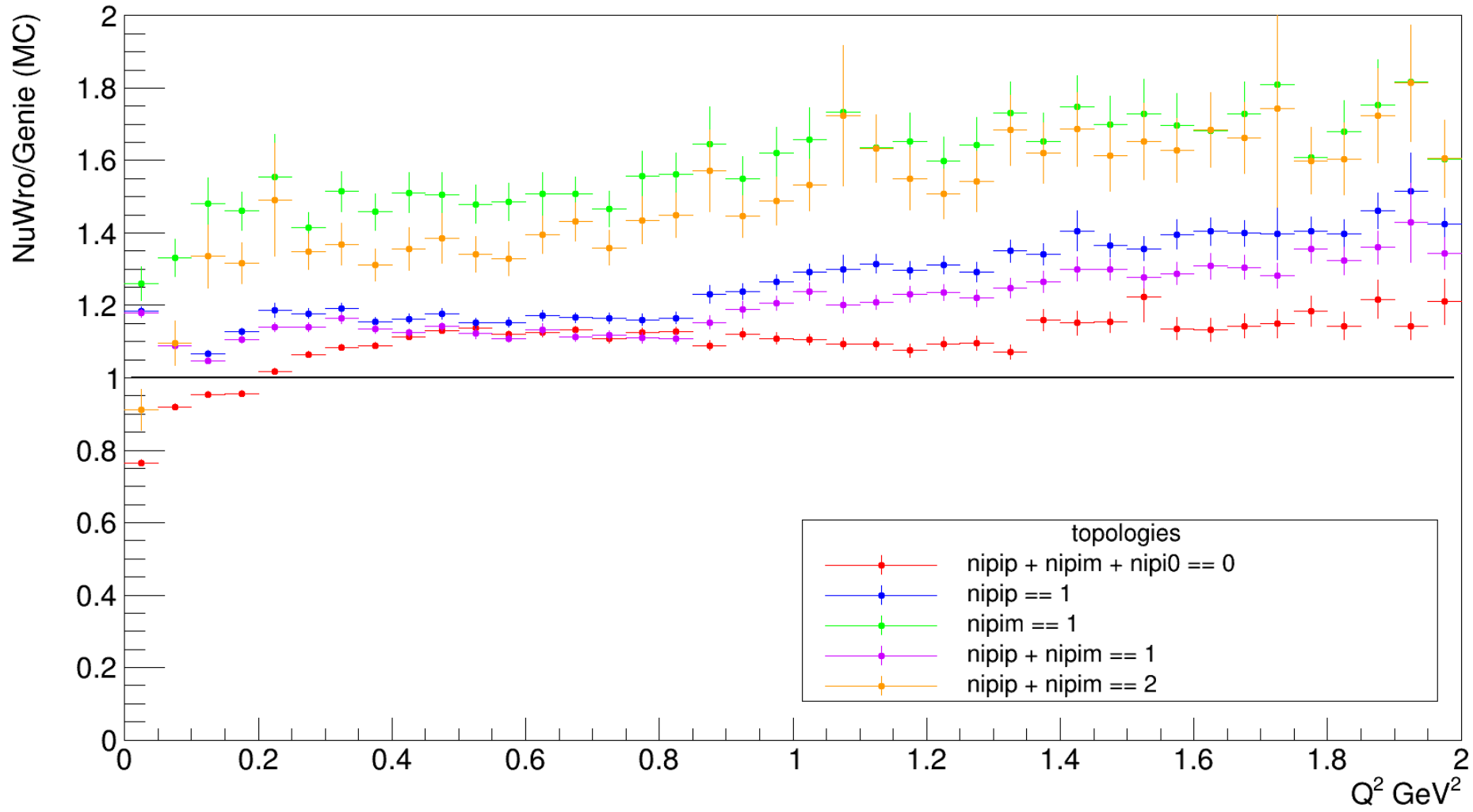
Momentum smearing

- Gluckstern + multiple scattering at first STT hit
- Add energy deposition in active LAr



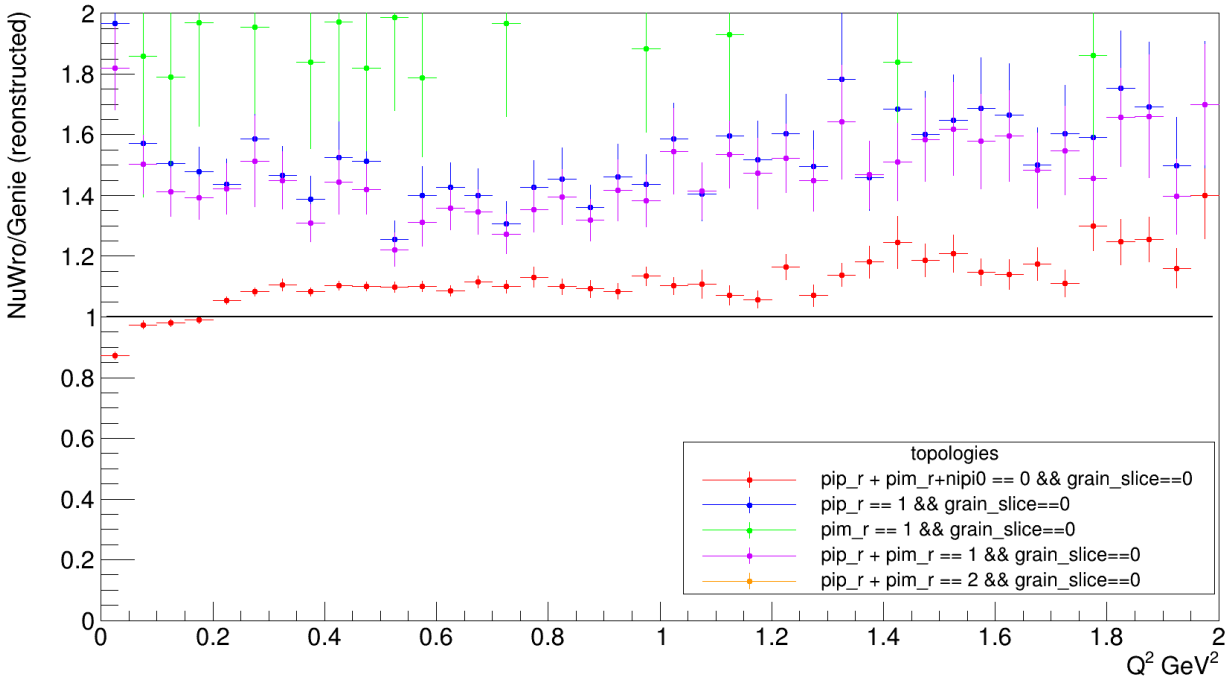
Energy resolution of the reconstructed charged tracks in GRAIN+STT

FHC 1.1×10^{21} pot (1 year)

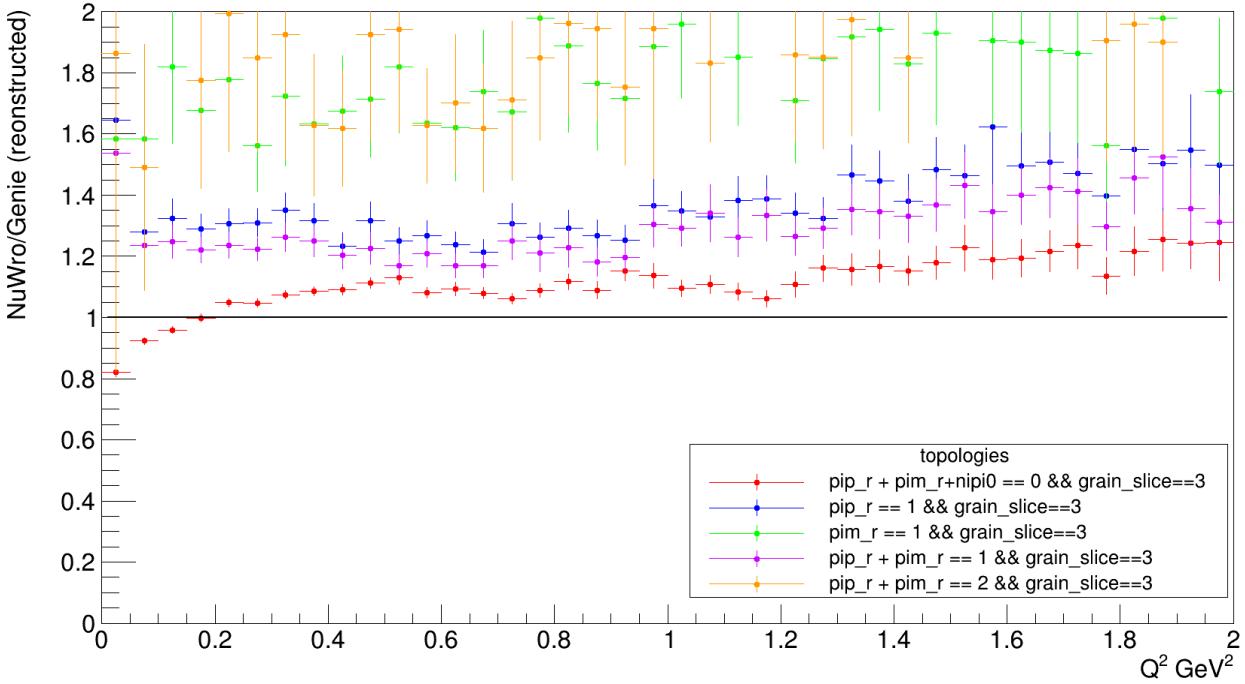


Simulated pions in all Z slices

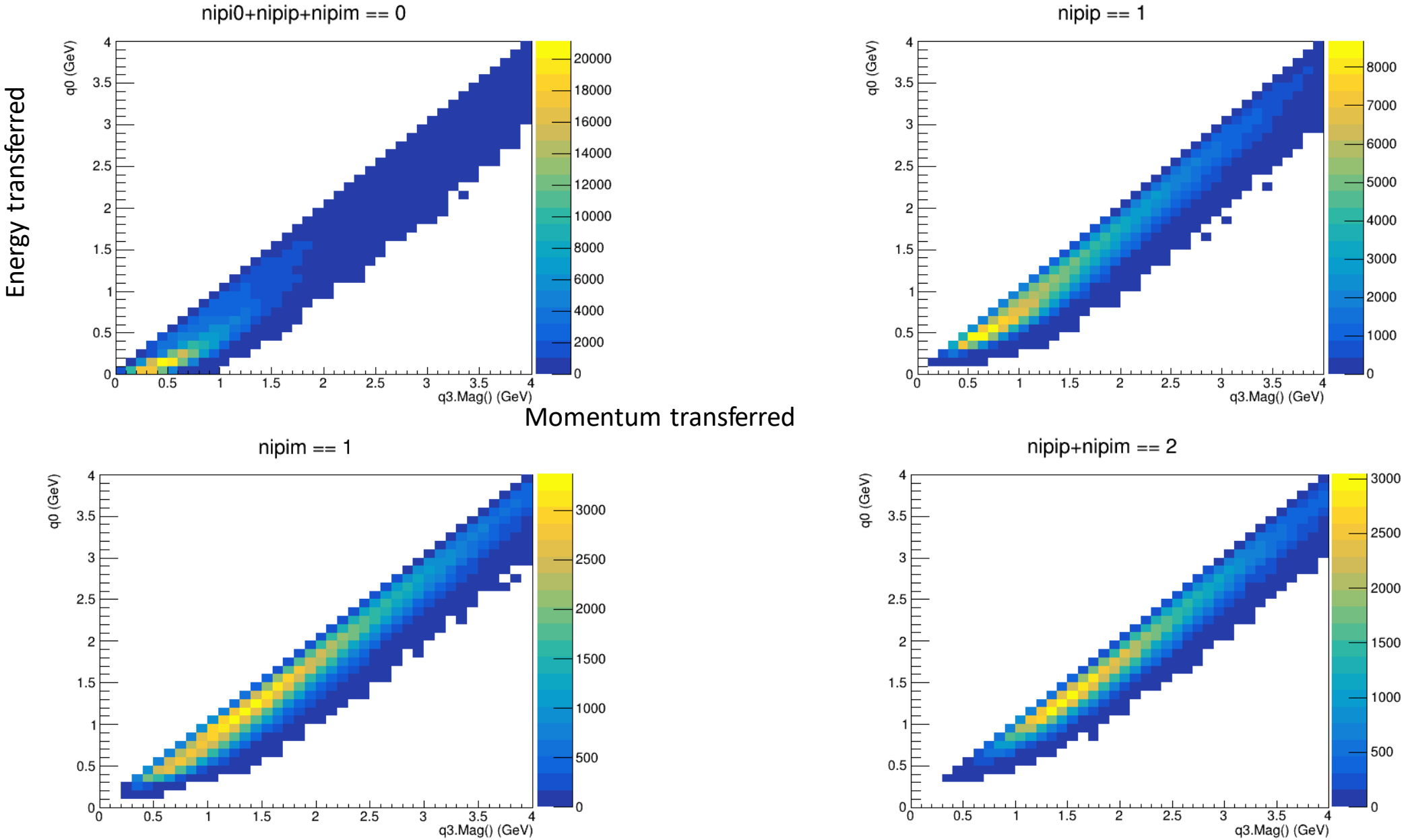
FHC 1.1×10^{21} pot (1 year)



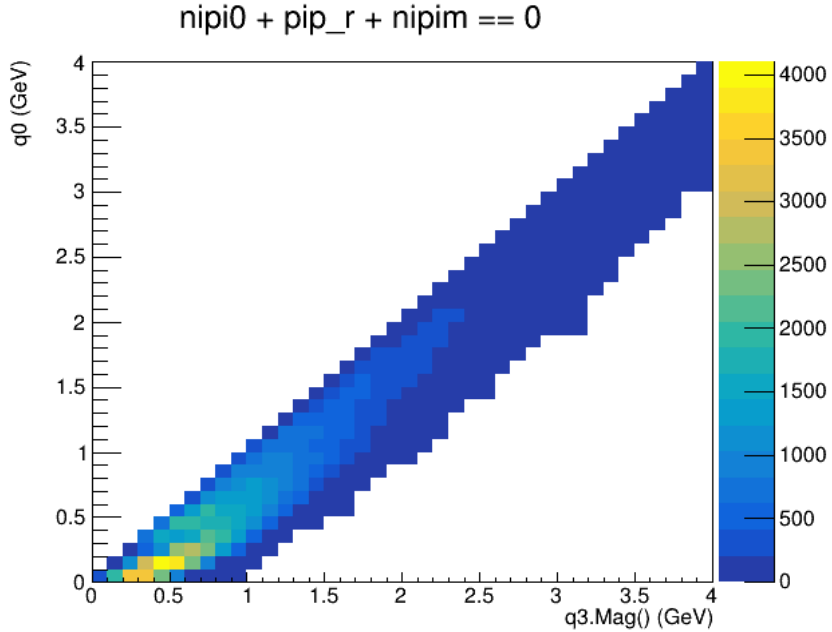
Reconstructed pions in Z slice 0 (upstream)

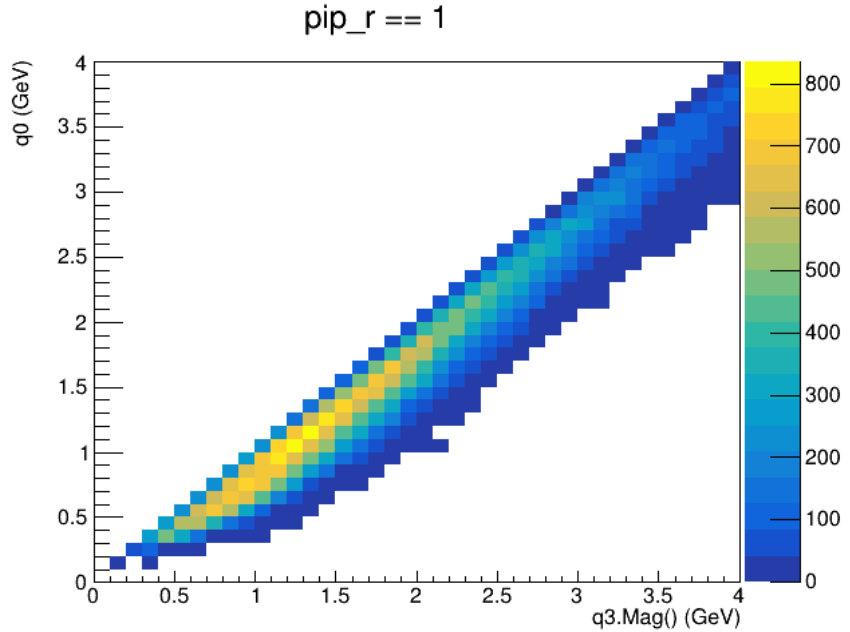


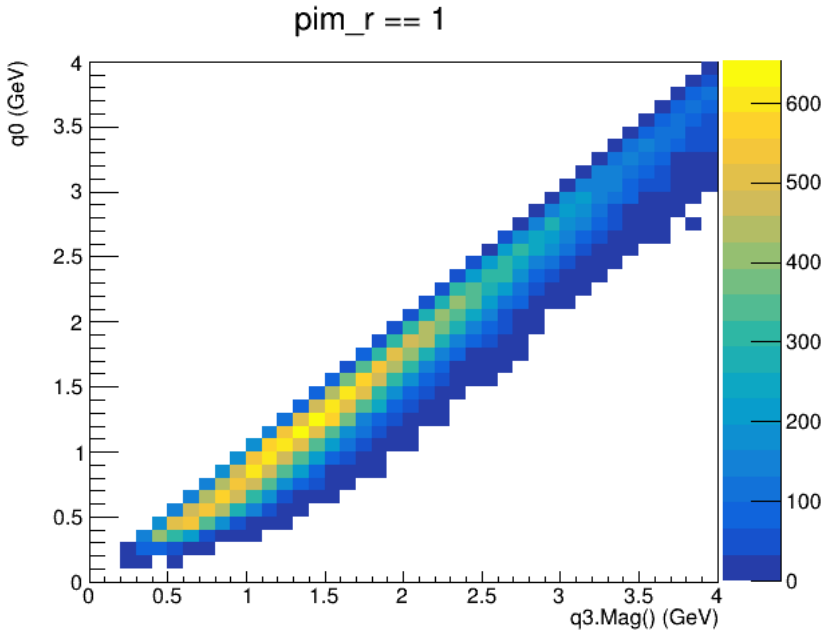
Reconstructed pions in Z slice 3 (downstream)

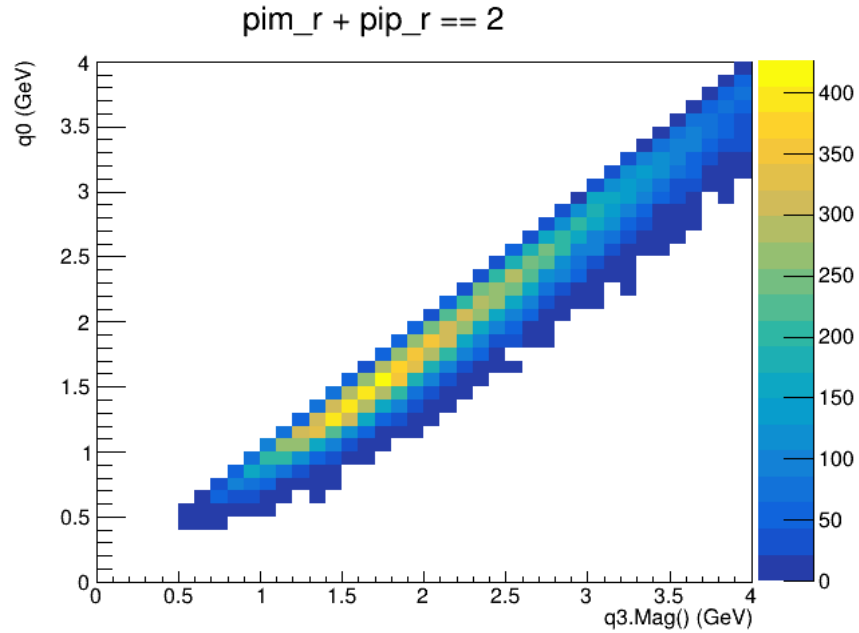


Simulated pions in all Z slices



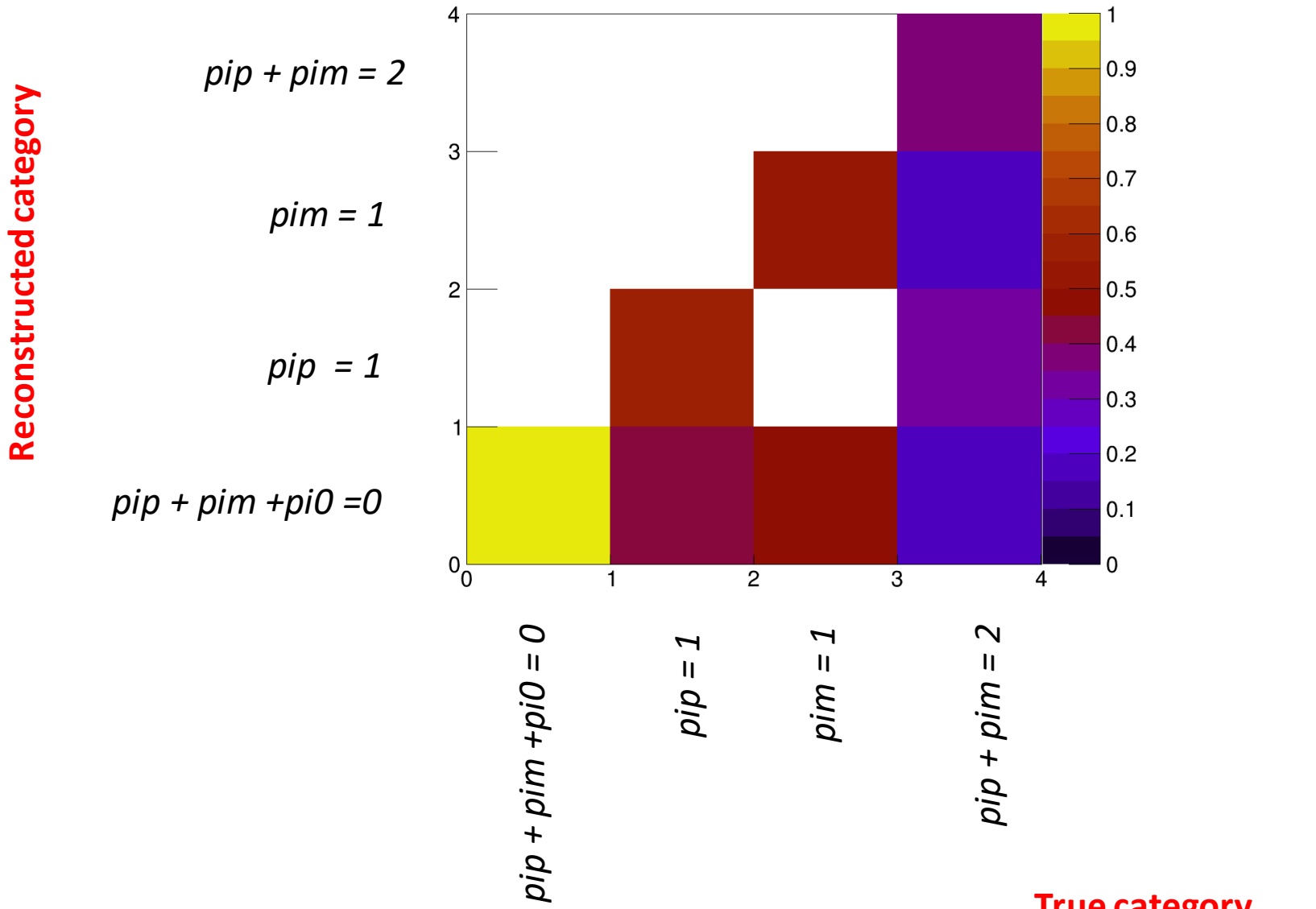




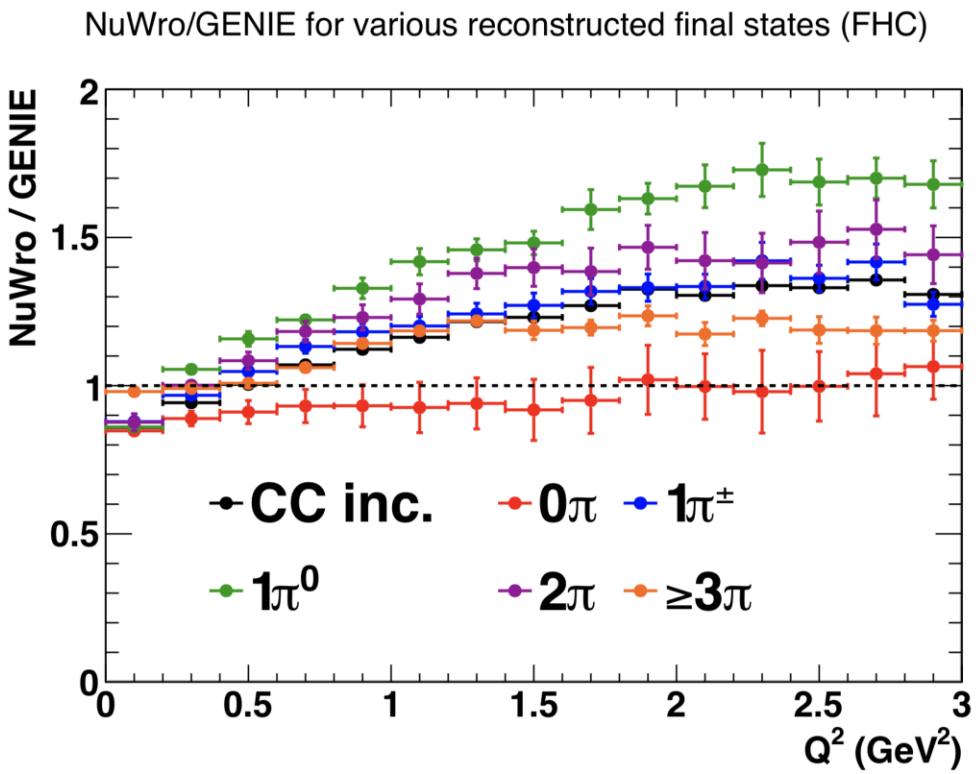


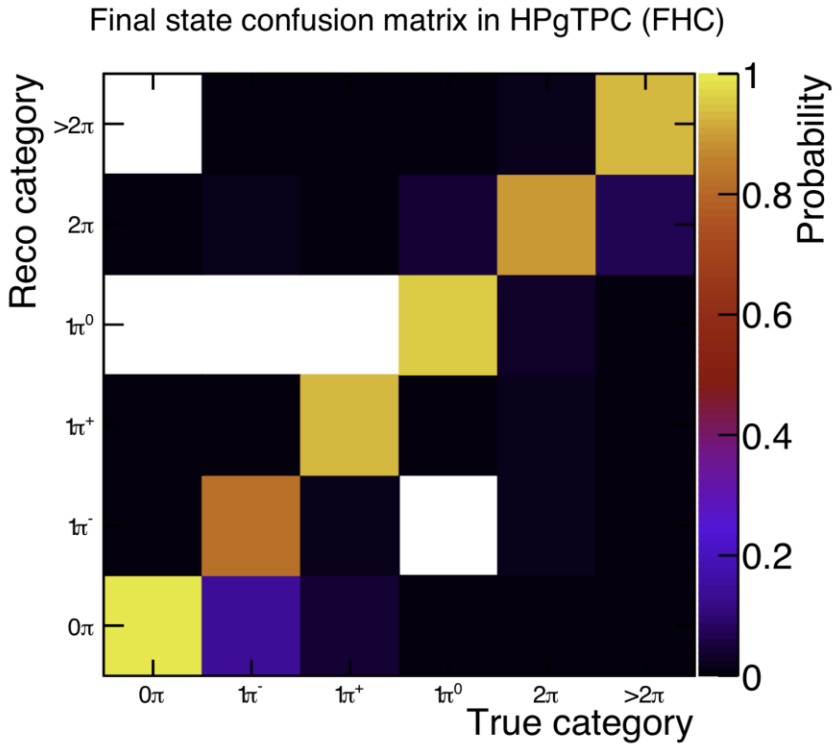
Reconstructed pions in Z slice 3 (downstream)

Preliminary Migration matrix for Z slice 3 (downstream)

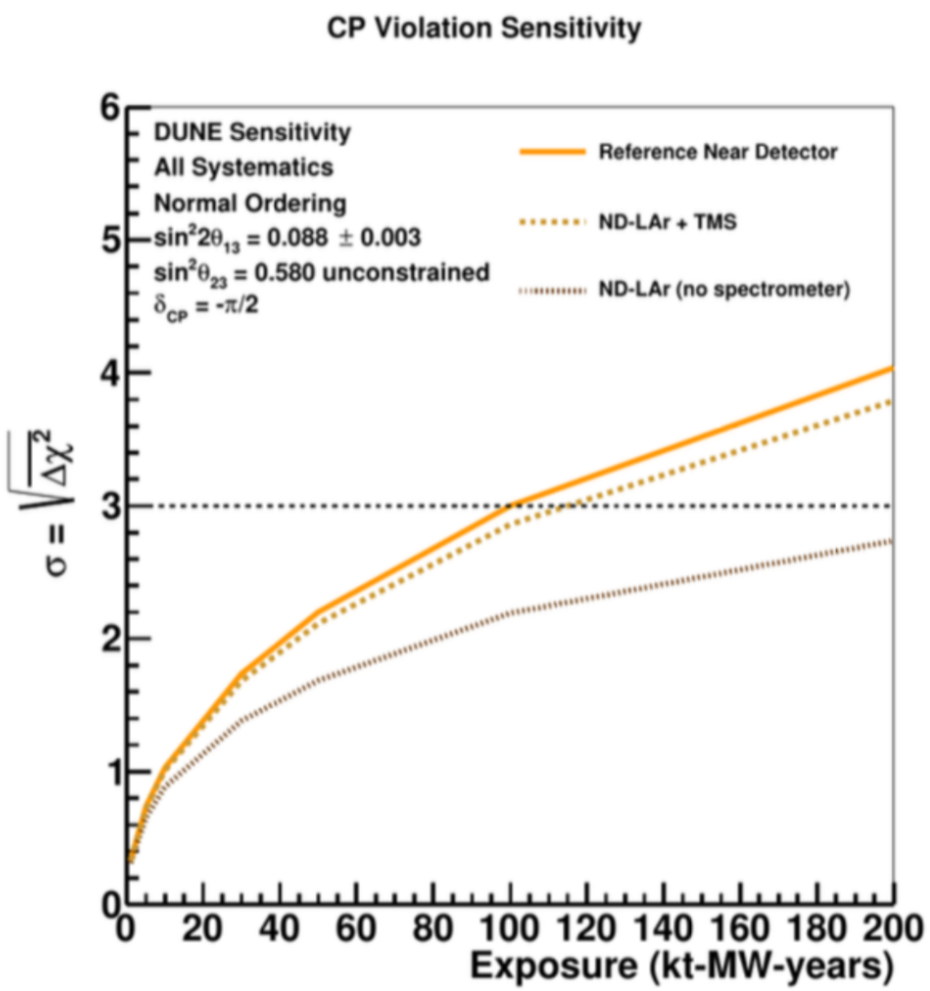


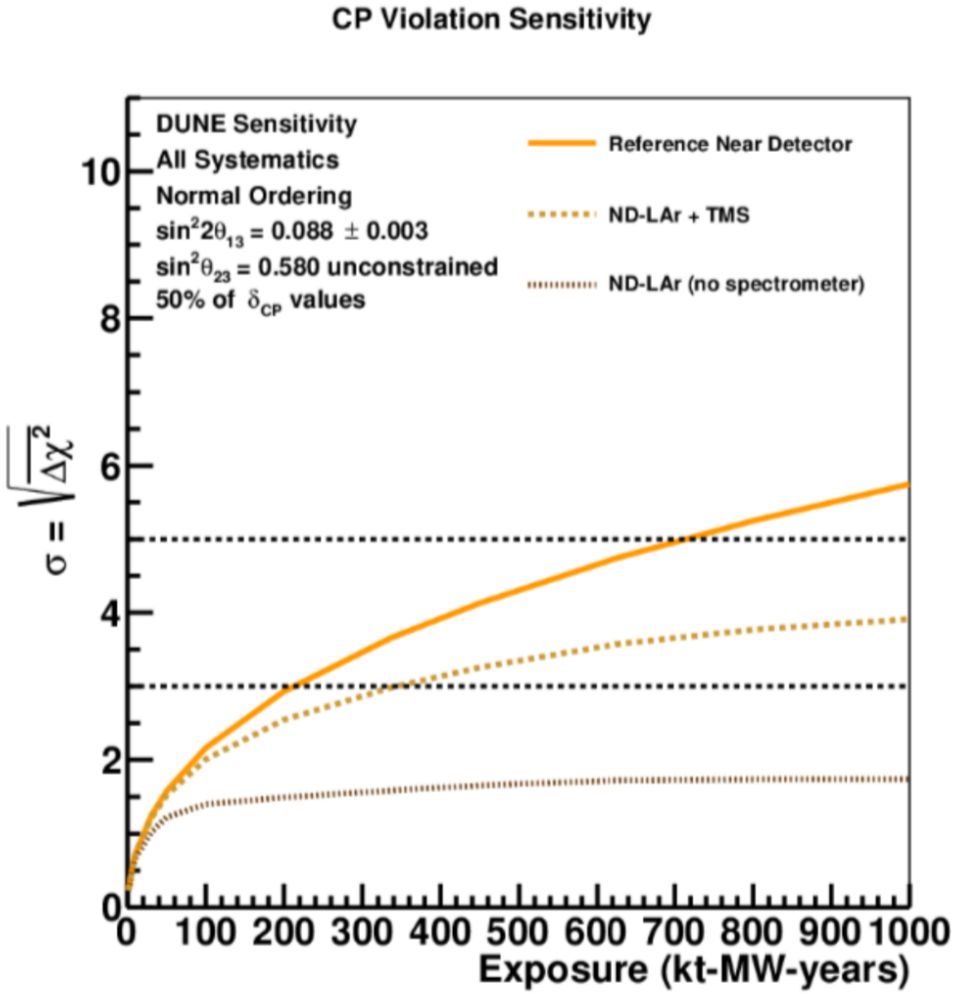
BACKUP



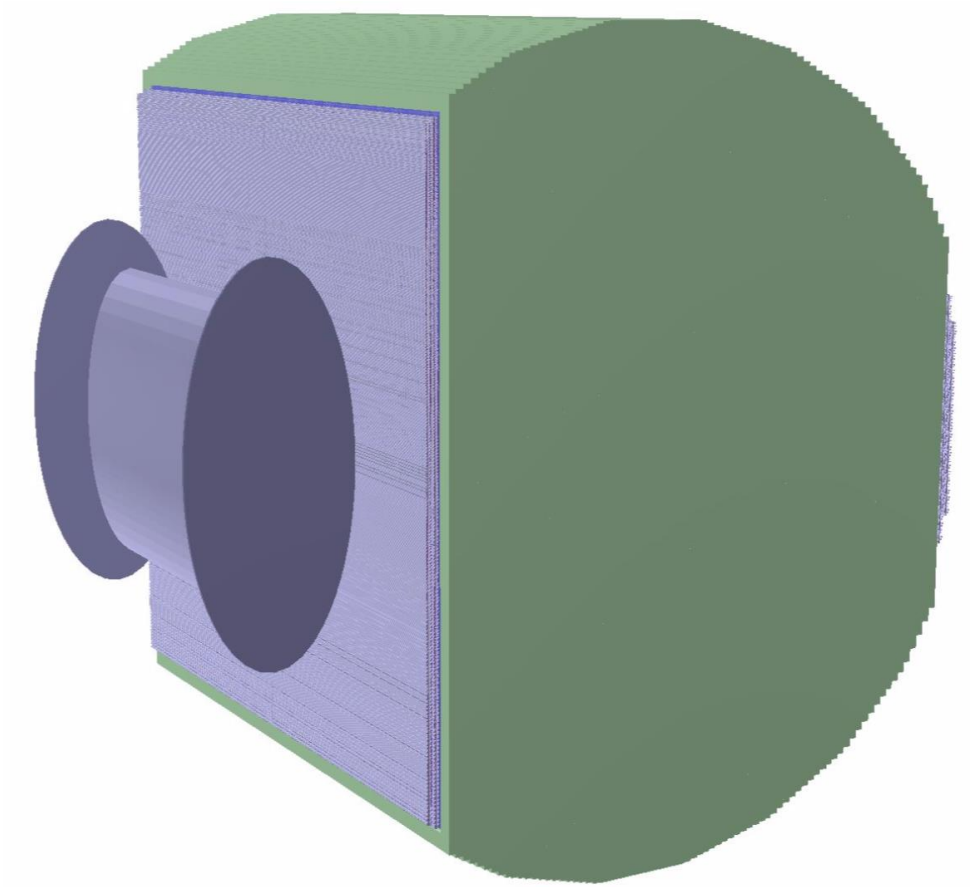


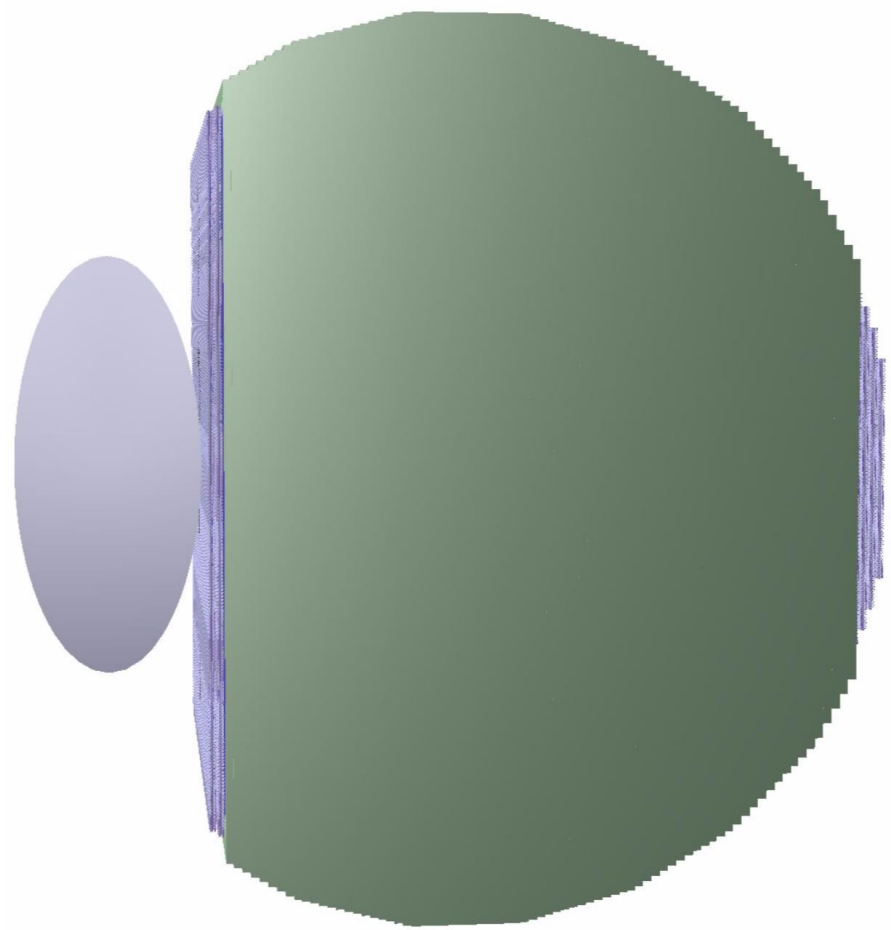
Hadron multiplicities in ND-GAr have been used to re-weight ND-LAr simulations in (q0,q3) plane





Impact of re-weighting from ND-GAr measurement of hadron multiplicities on oscillation sensitivity





Fast reconstruction

- Momentum smearing of tracks with >= 6 Y hits in STT:
  - Smear momentum at the first STT hit with Gluckstern parameterization + multiple scattering in STT;
  - Add energy deposited in active LAr.
- Angular smearing of tracks with >= 6 Y hits in STT:
  - Smear dip angle at primary vertex taking into account multiple scattering contributions from both STT and the GRAIN material crossed;
  - Smear angle in YZ plane including both STT and GRAIN contributions to MS.
- Add energy deposited in LAr by particles not reconstructed in STT
- Ongoing study to understand corrections for energy deposited in both thee active LAr and the cryostat walls