

# Hadron multiplicities in GRAIN

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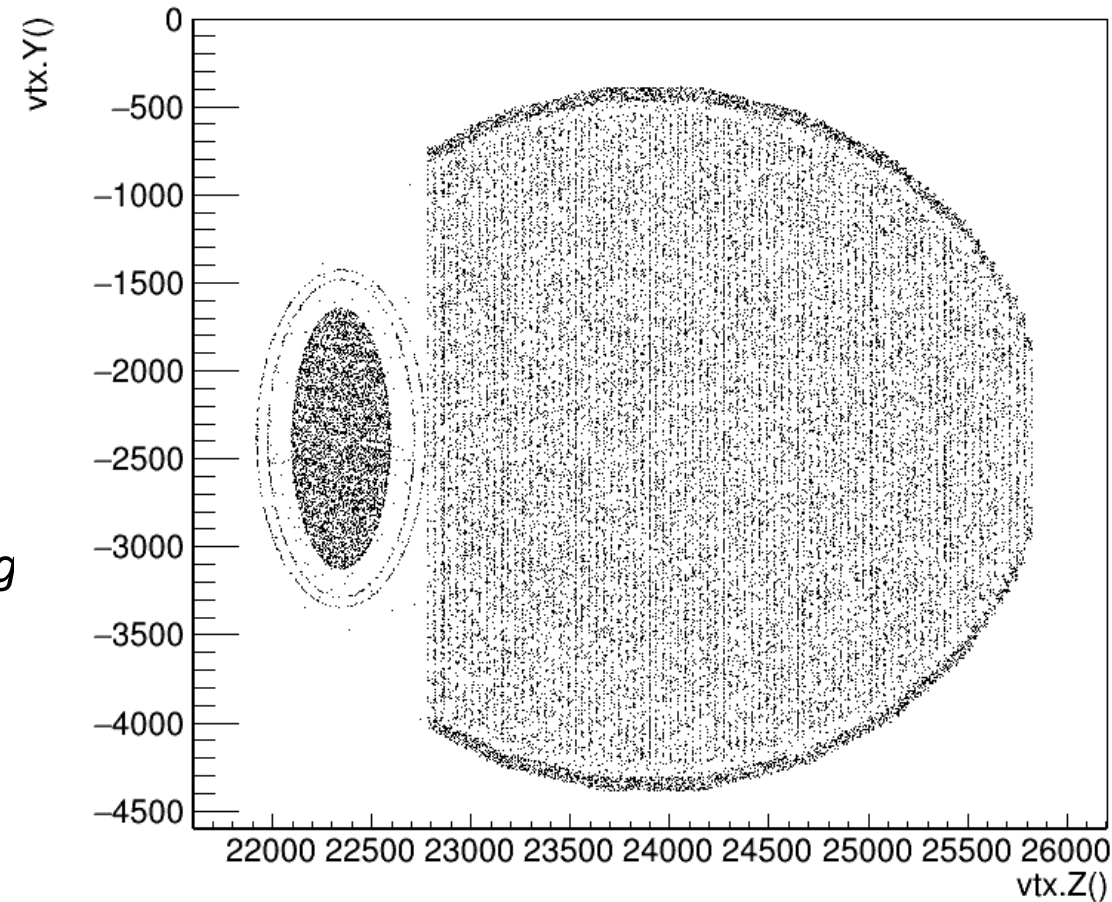
University of South Carolina, USA

SAND Physics/Software meeting

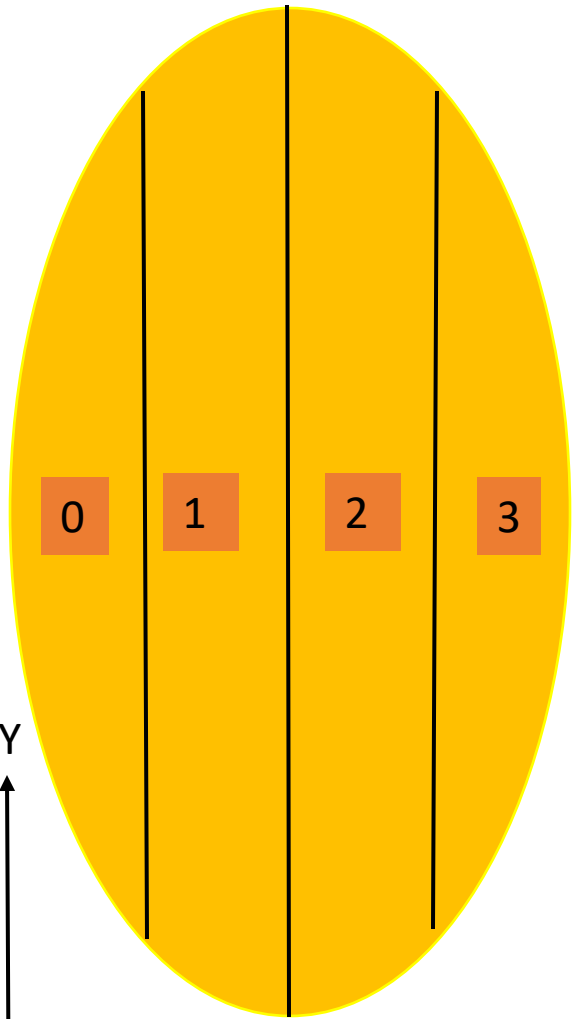
21 January 2022

# Simulations and Analysis

- FHC CC and RHC CC
- POT =  $1.1 \cdot 10^{21}$  FHC &  $1.1 \cdot 10^{21}$  RHC
- Events are generated with 1 yr statistics int GRAIN+STT:  
~ 12 (6) \*  $10^6$  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*



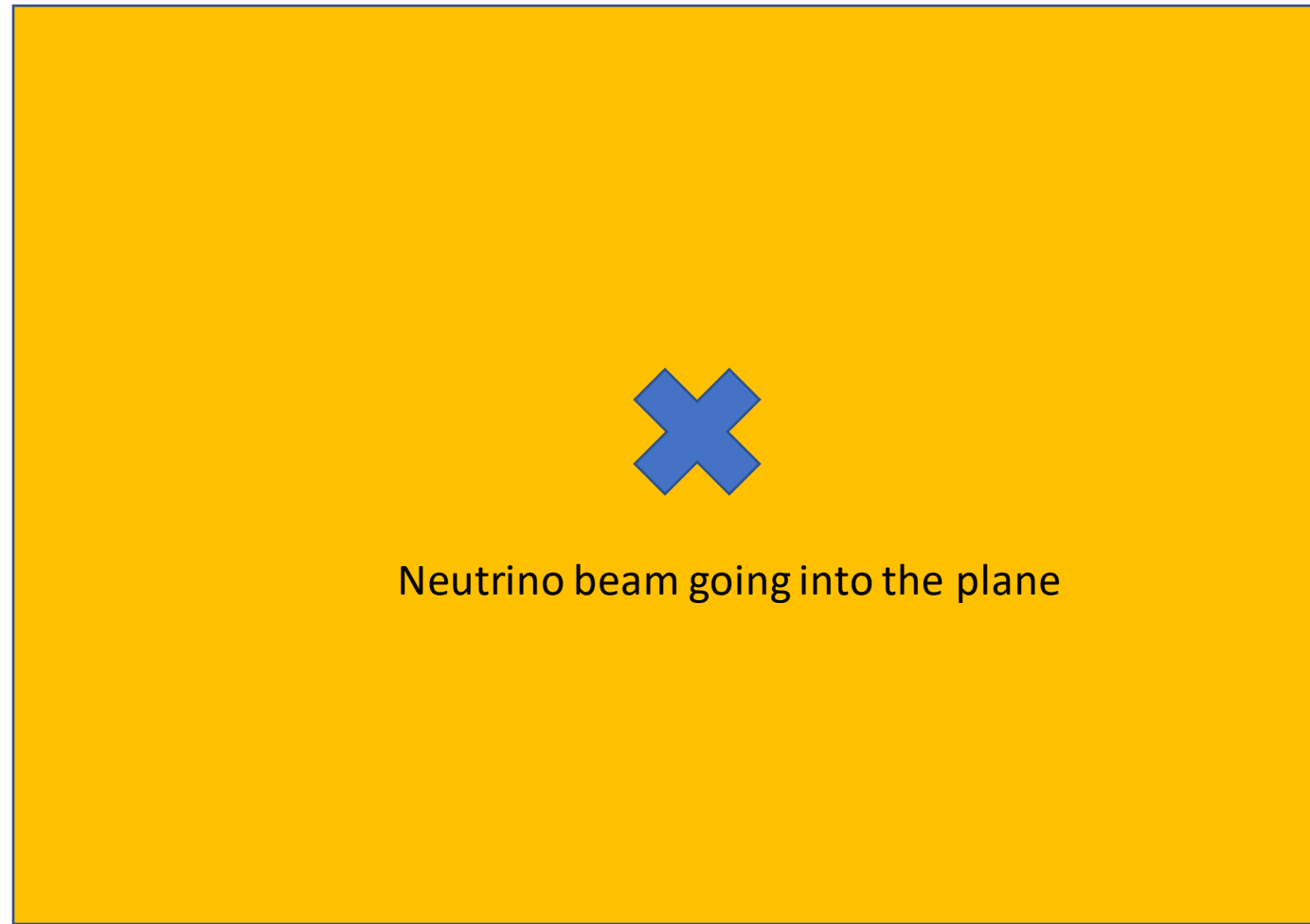
Neutrino beam



0 1 2 3

Z

*Each slice 11.875 cm*



Neutrino beam going into the plane

Y

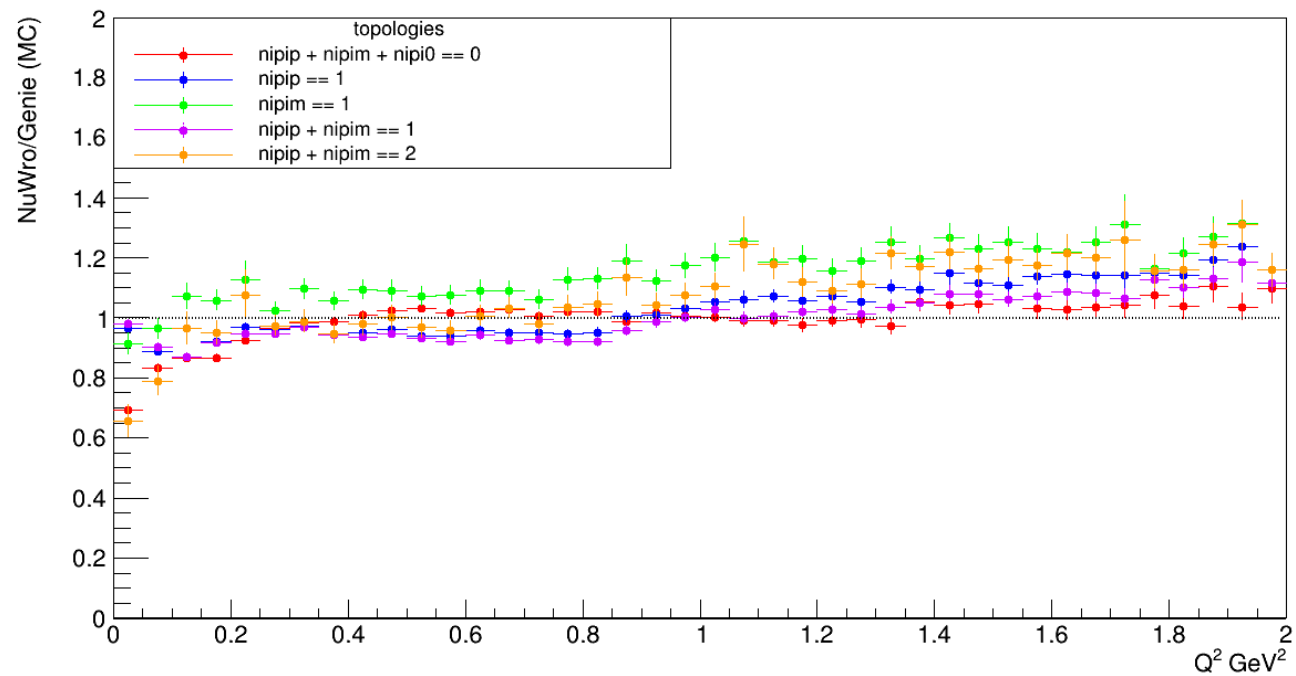
X

## FHC

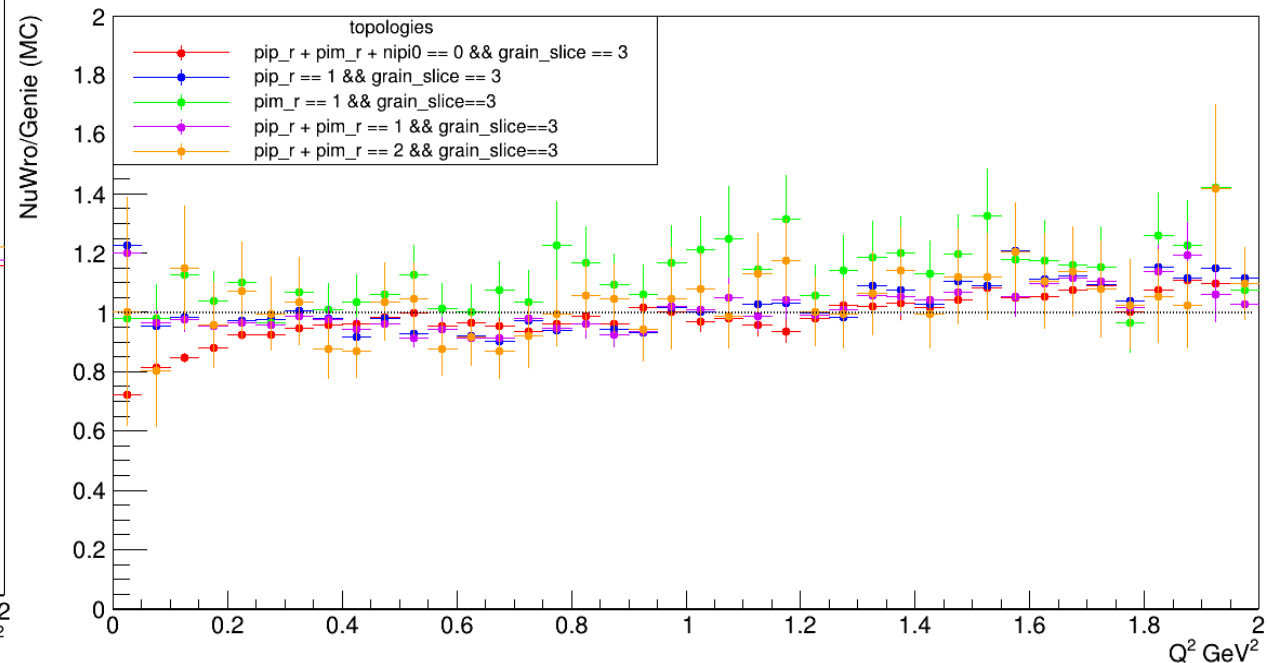
Z slice	Reconstructed (%)	Interaction (%)	Stopping (%)	Sum(%)
0	32.6	39.2	19.8	91.6
1	40.9	32.8	19.8	93.5
2	50.7	25.0	19.0	94.8
3	61.0	17.3	17.2	95.5
Average	46.2	28.7	19.0	94.0

Fraction of pions interacting within GRAIN without reaching STT

## Q<sup>2</sup> distribution NuWro/Genie using reweighting



Simulated pions in all Z slices

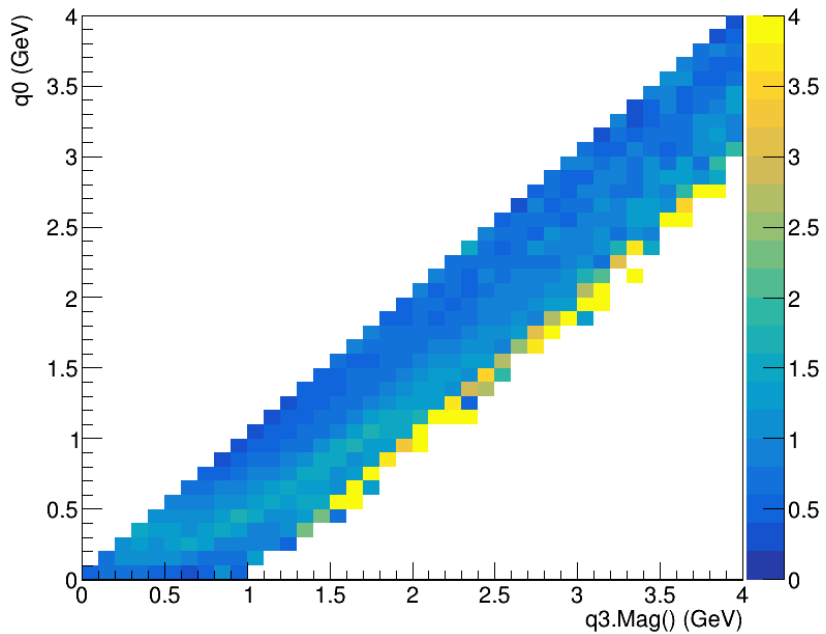


Reconstructed pions in Z slice 3 (downstream)

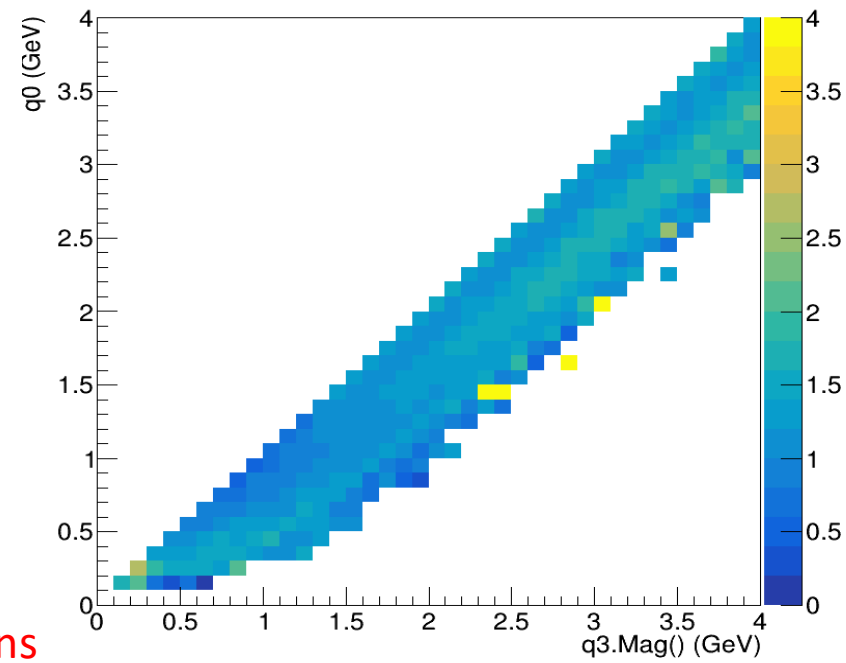
FHC  $1.1 \times 10^{21}$  pot (1 year)

NuWro/Genie (MC)

nipip + nipim + nipi0 == 0

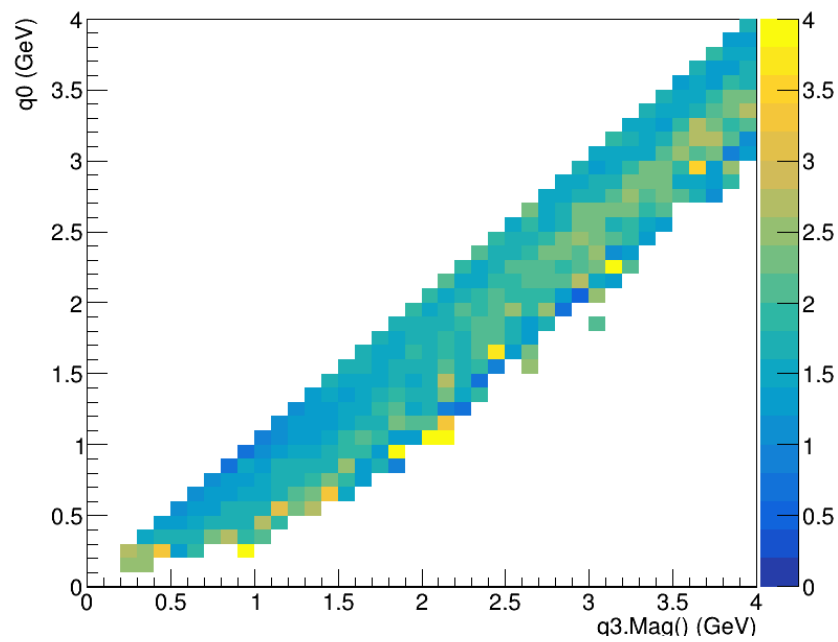


nipip == 1

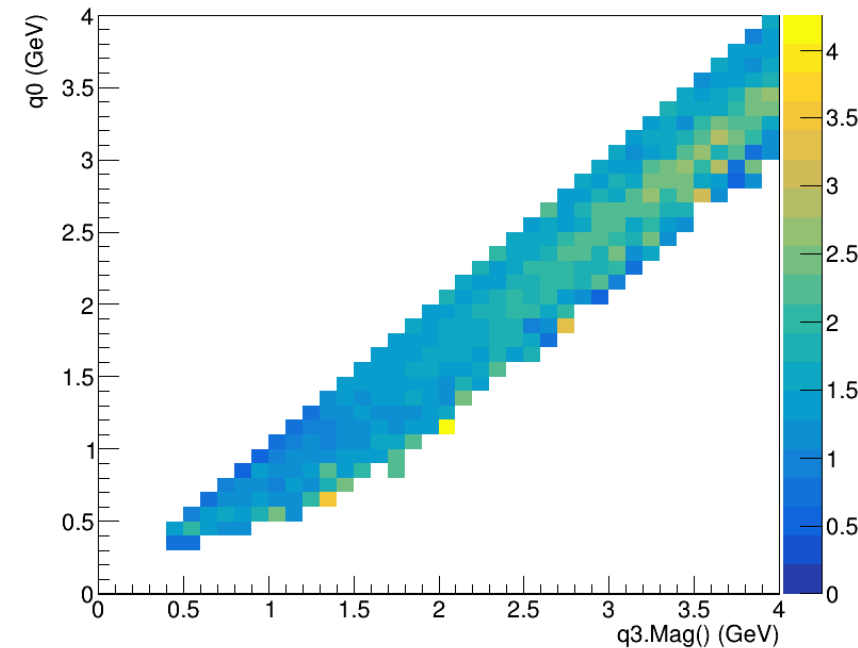


Simulated pions  
in all Z slices

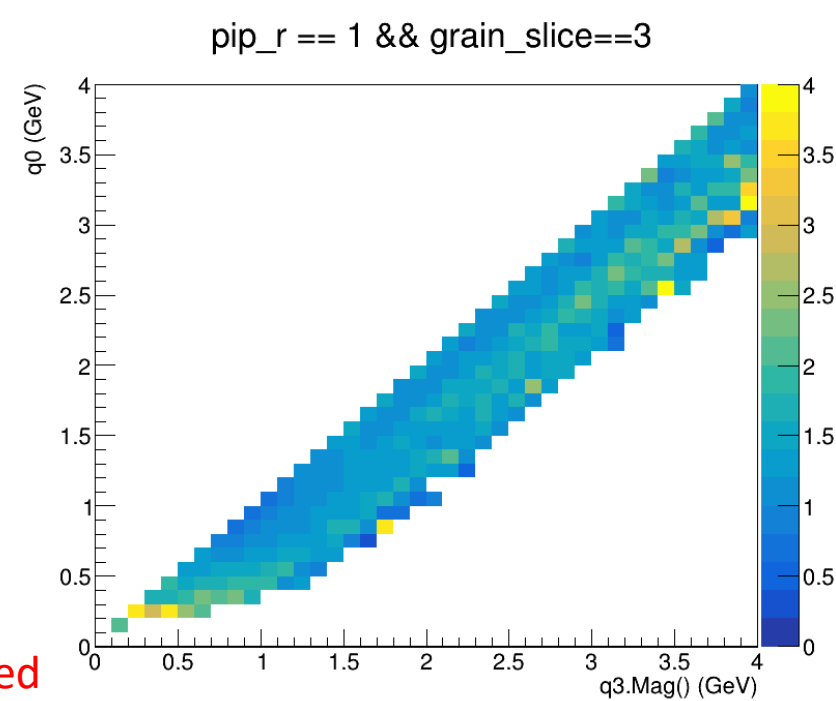
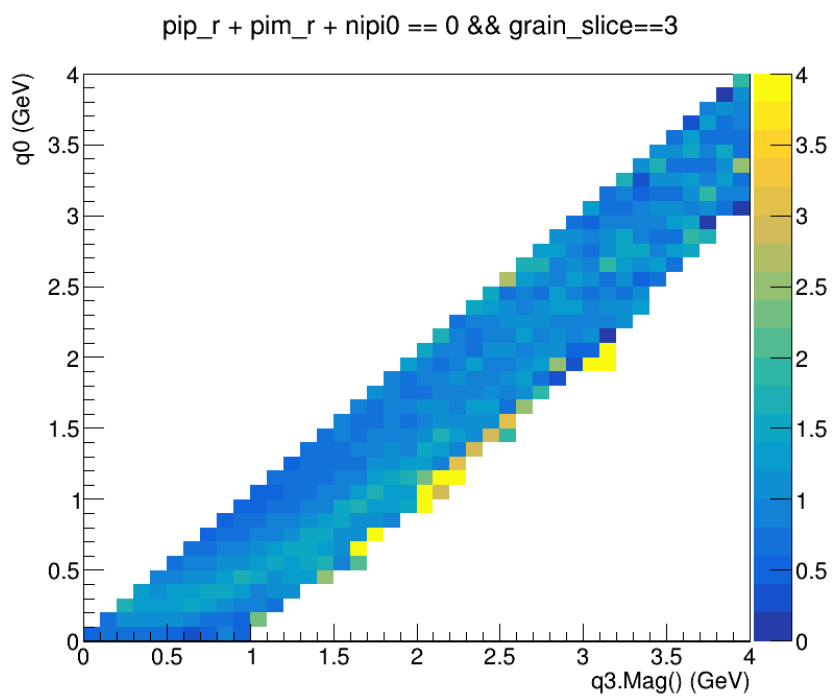
nipim == 1



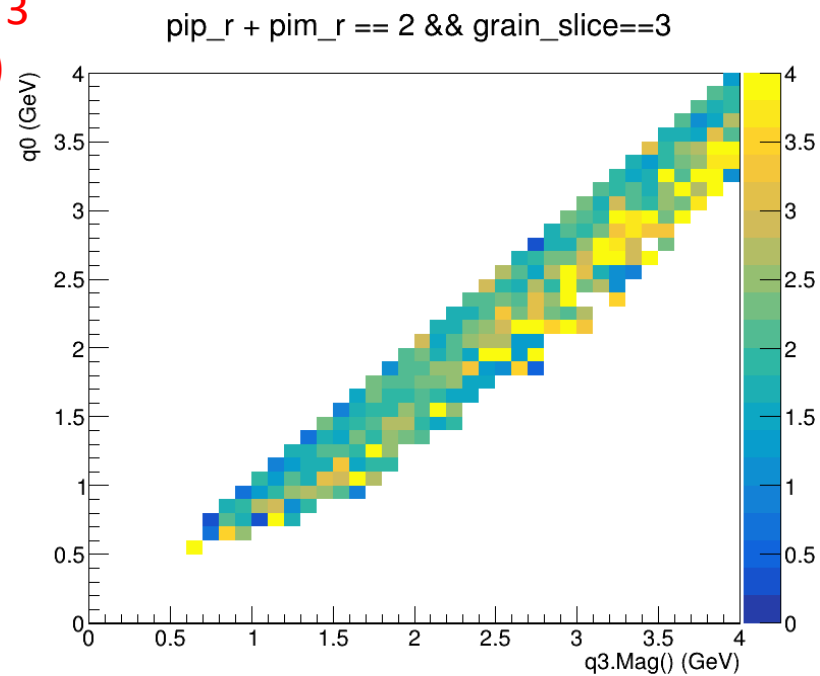
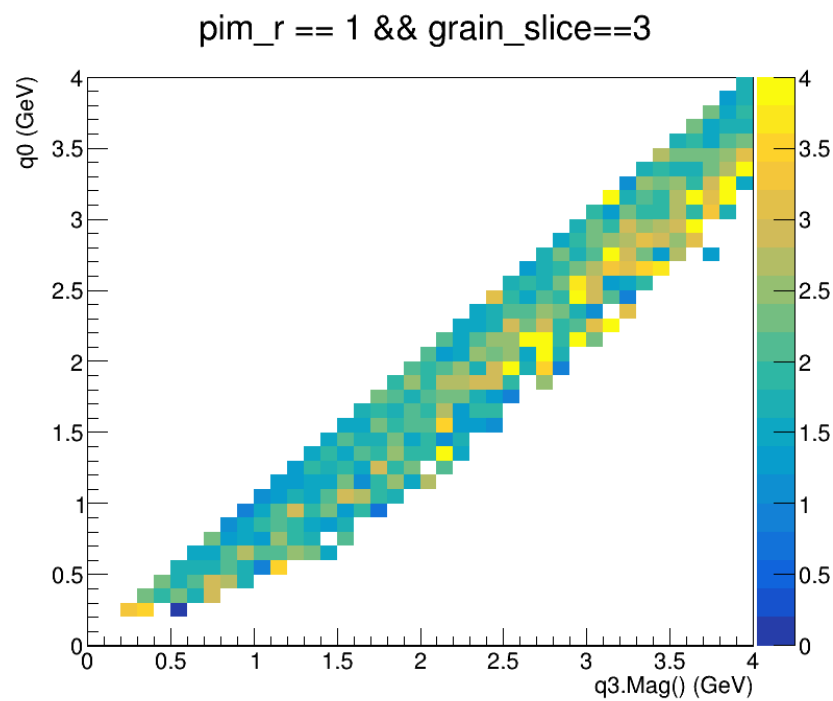
nipip + nipim == 2



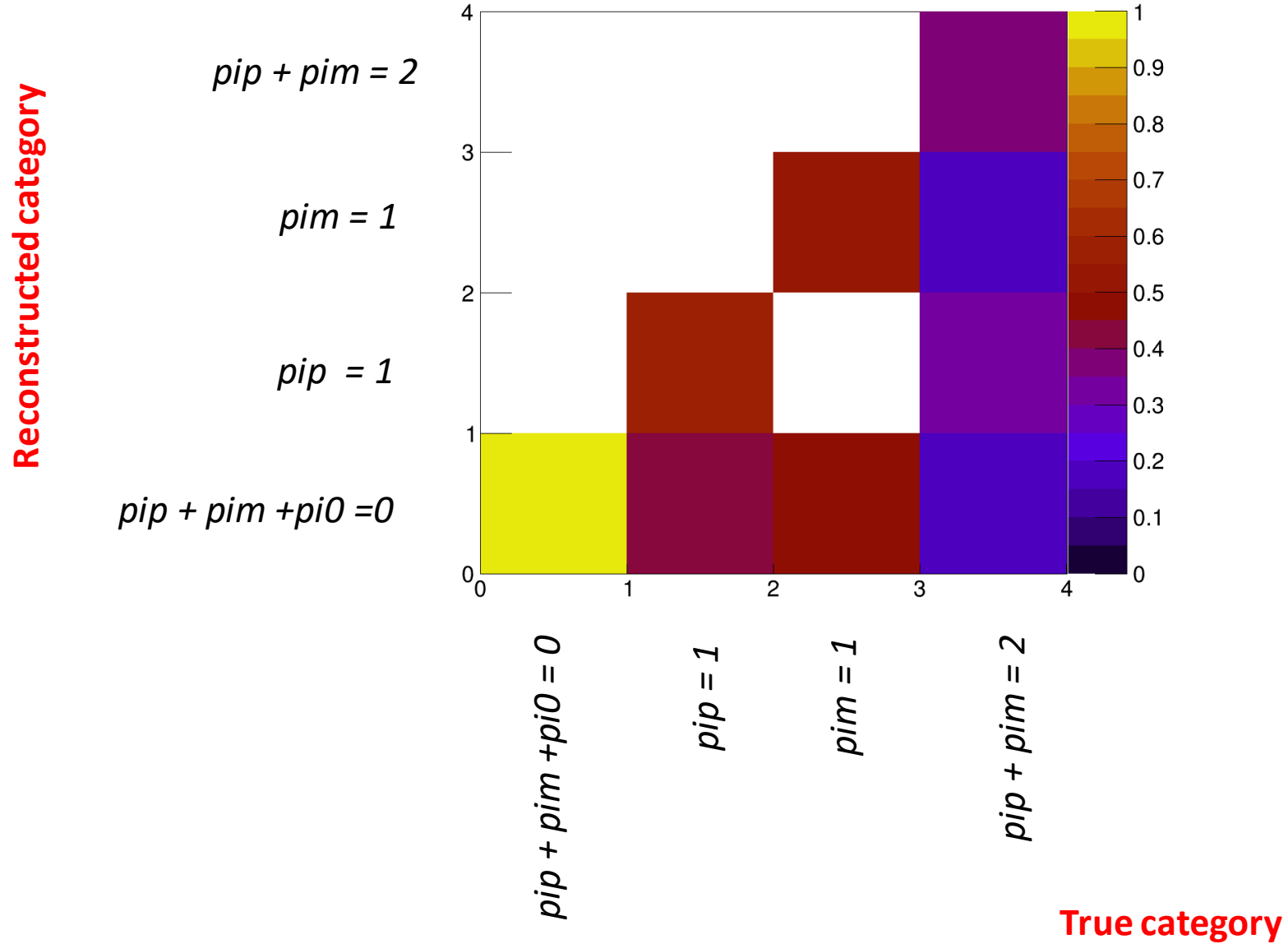
NuWro/Genie (MC)  
reconstructed topologies



Reconstructed  
pions in Z slice 3  
(downstream)

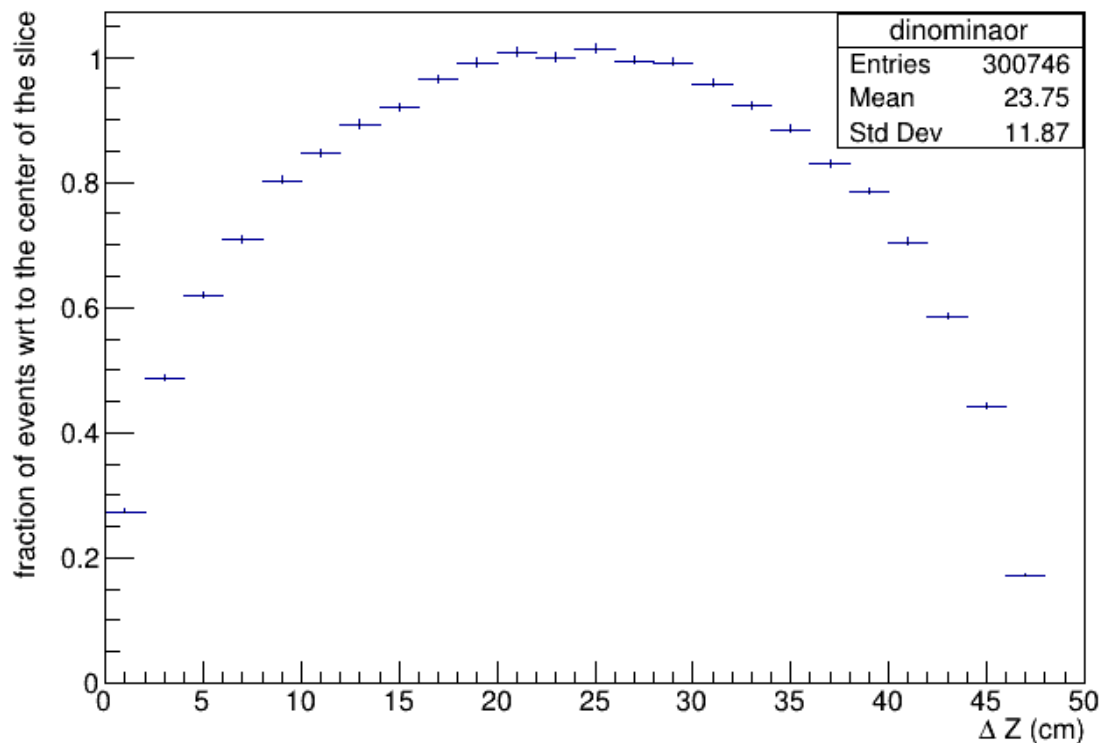


# Preliminary Migration matrix for Z slice 3 (downstream)

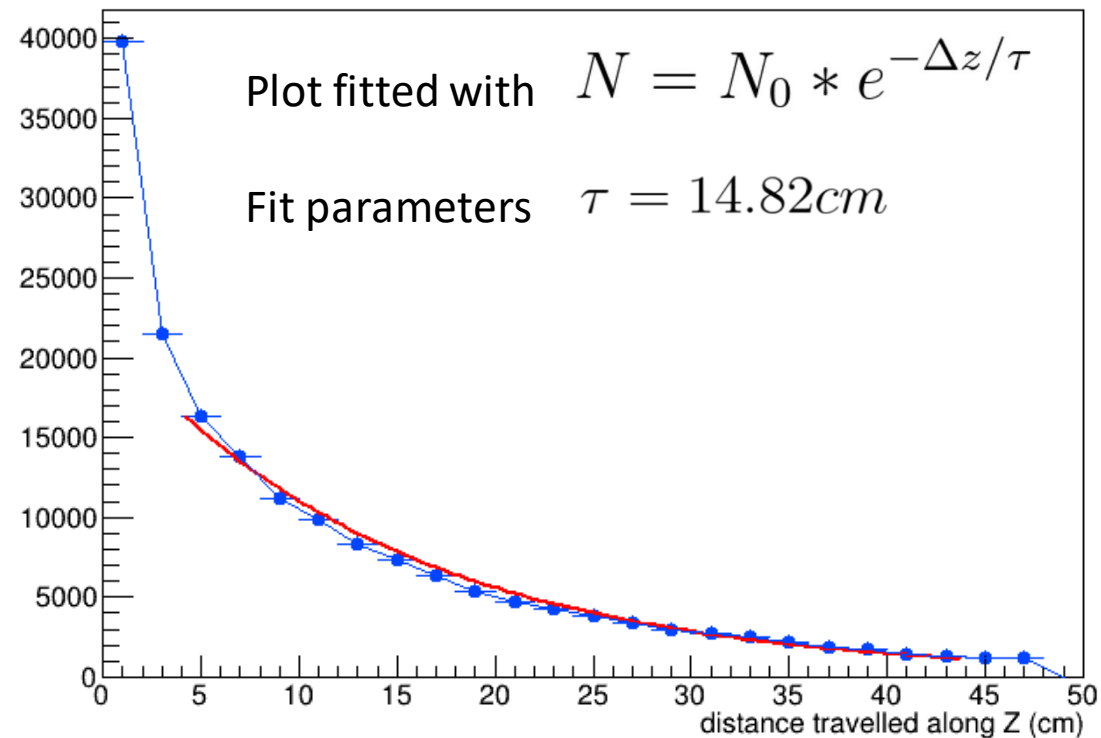




# Correction to the 2 pion case (pip+pim=2) due to the interaction of primary pions

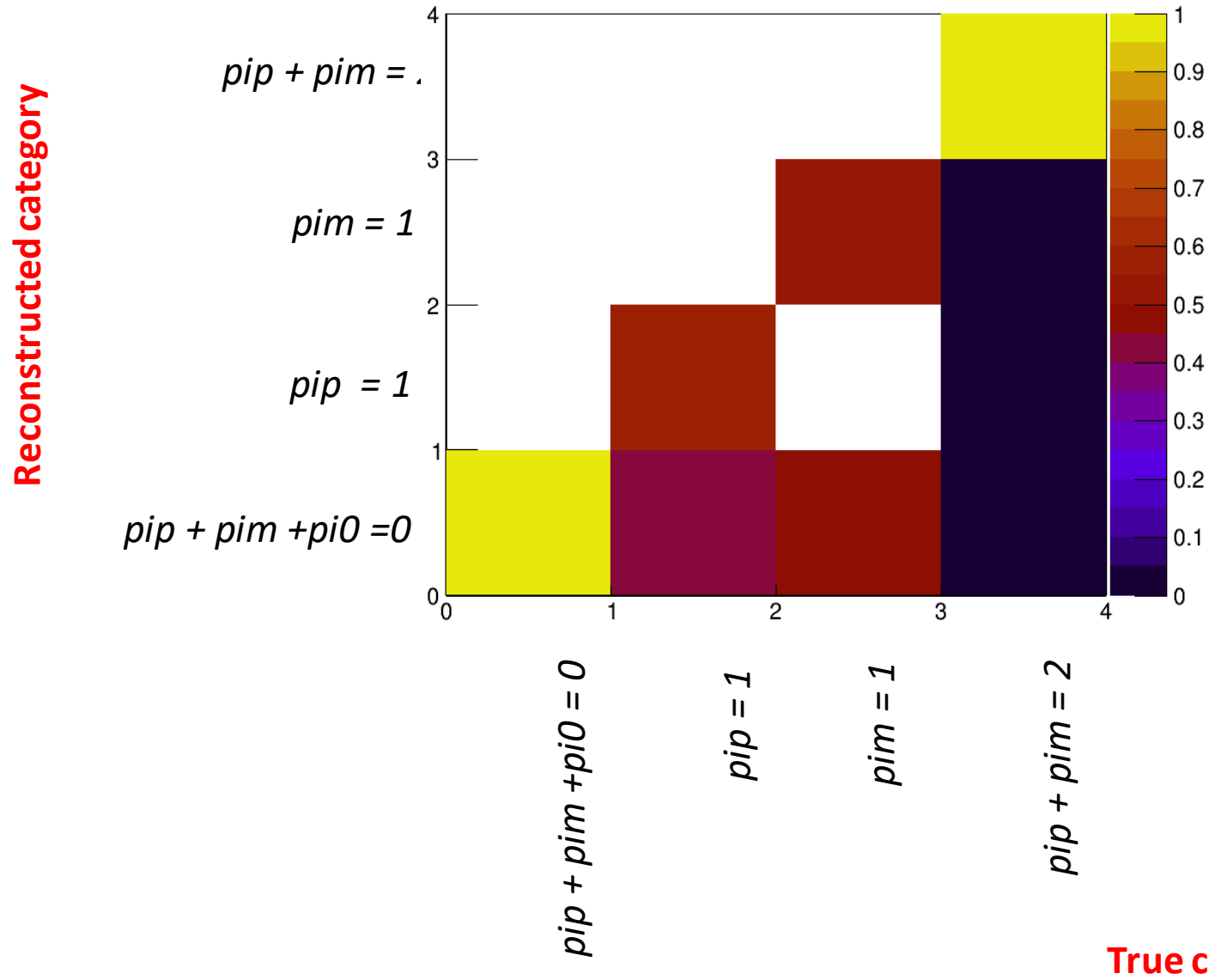


Events normalized wrt to the CC events in the center



Delta z of pion after geometrical correction

Preliminary Migration matrix for Z slice 3 (downstream)  
Correction to the case (pip+pim=2)



$$N_{2\pi}^0 = N_{2\pi} \exp(2\Delta z/\tau)$$

Before correction :  
 Migration (pip+pim=2) = 0.374

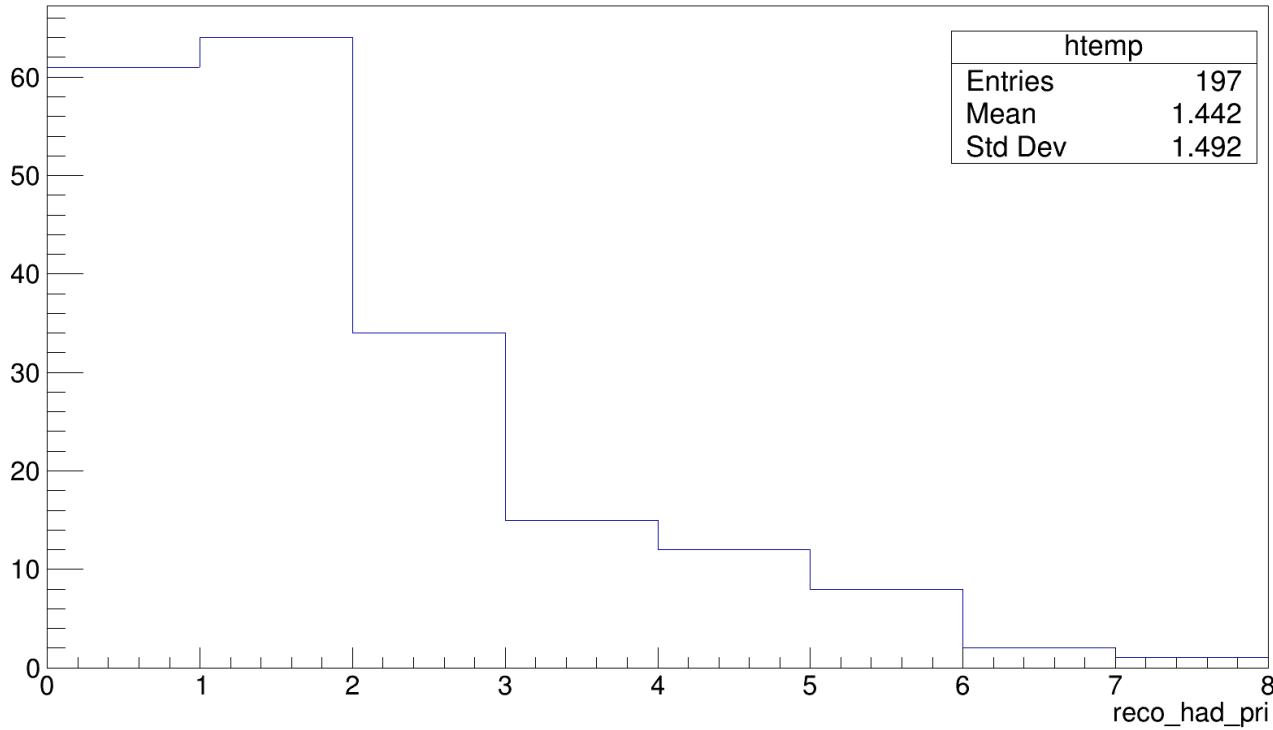
After correction :  
 Migration (pip+pim=2) = 0.964

*Correction yet to be applied to the other topologies*

Slice	%events with $\geq 1$ reconstructable secondary pion
0	26.6
1	20.0
2	16.1
3	10.6
Average	17.8

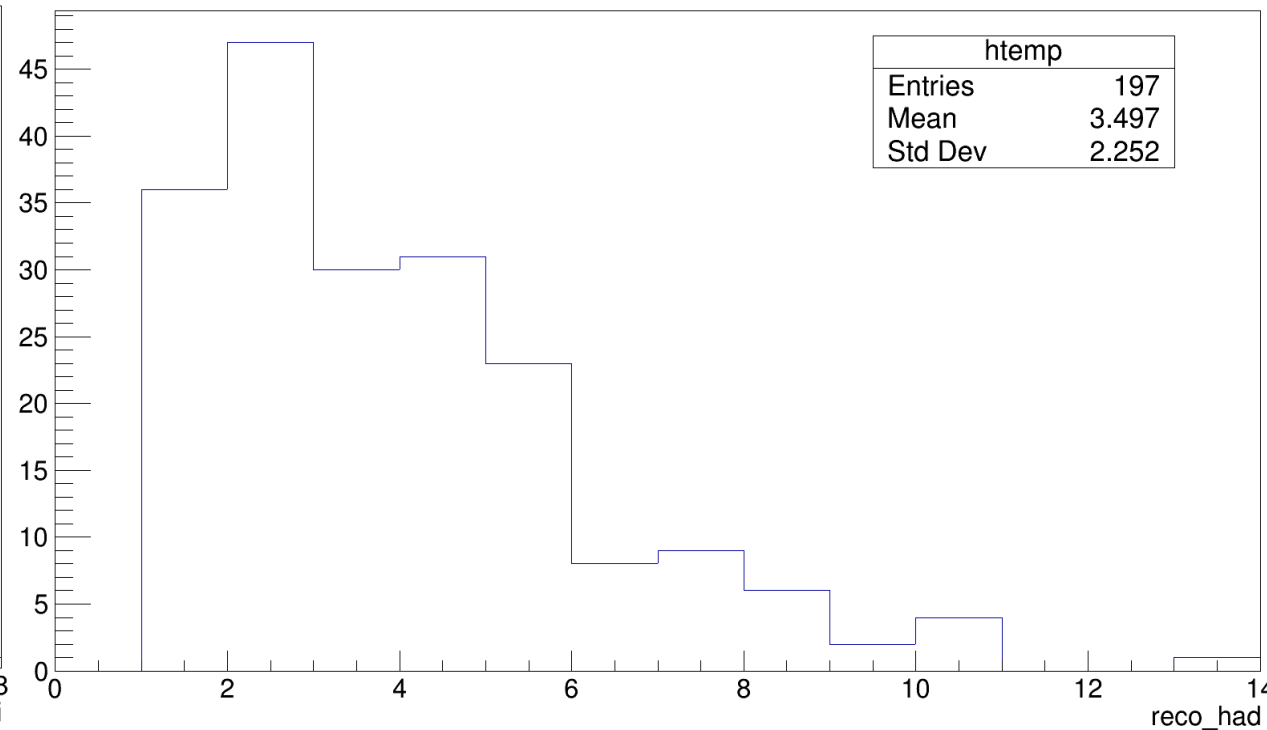
Fraction of events with secondary pions reconstructed in STT

reco\_had\_pri {reco\_seco\_pi\_nw>0 && grain\_slice==3}



# reconstructable **primary** hadron

reco\_had {reco\_seco\_pi\_nw>0 && grain\_slice==3}



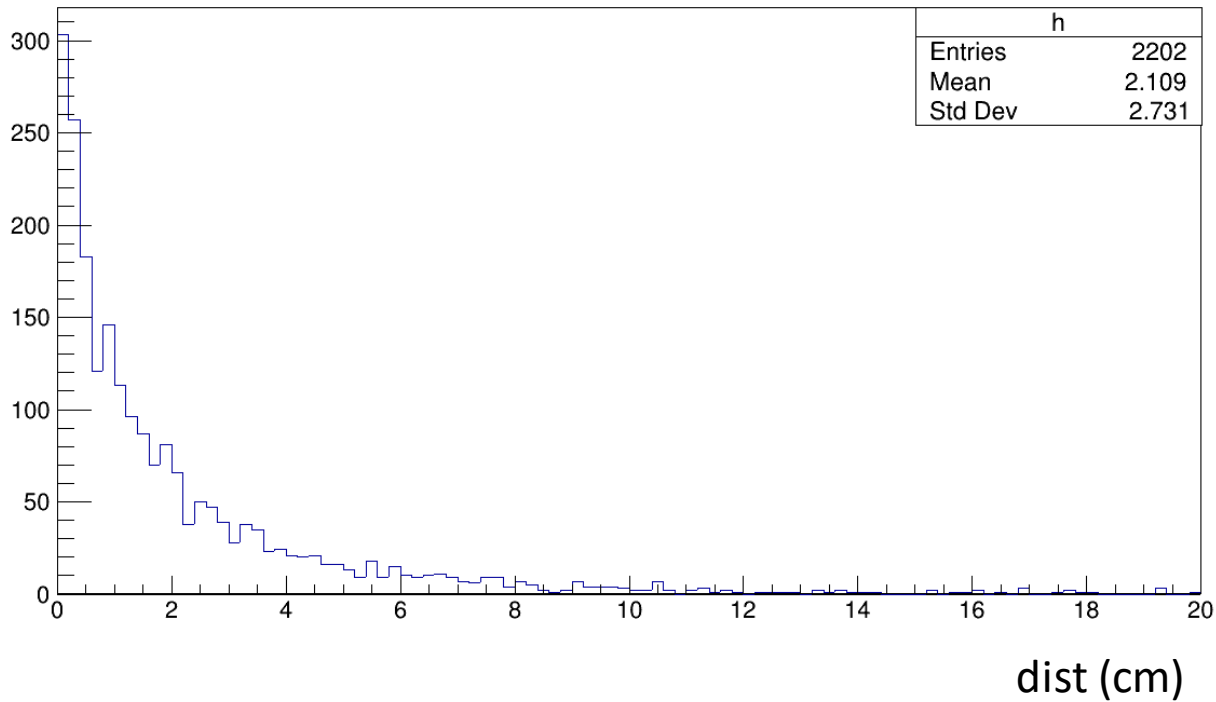
# reconstructable hadron

*Events with reconstructable secondary pion  $\geq 1$  in slice =3 (downstream)*

~70% of events have at least one primary pion reconstructed

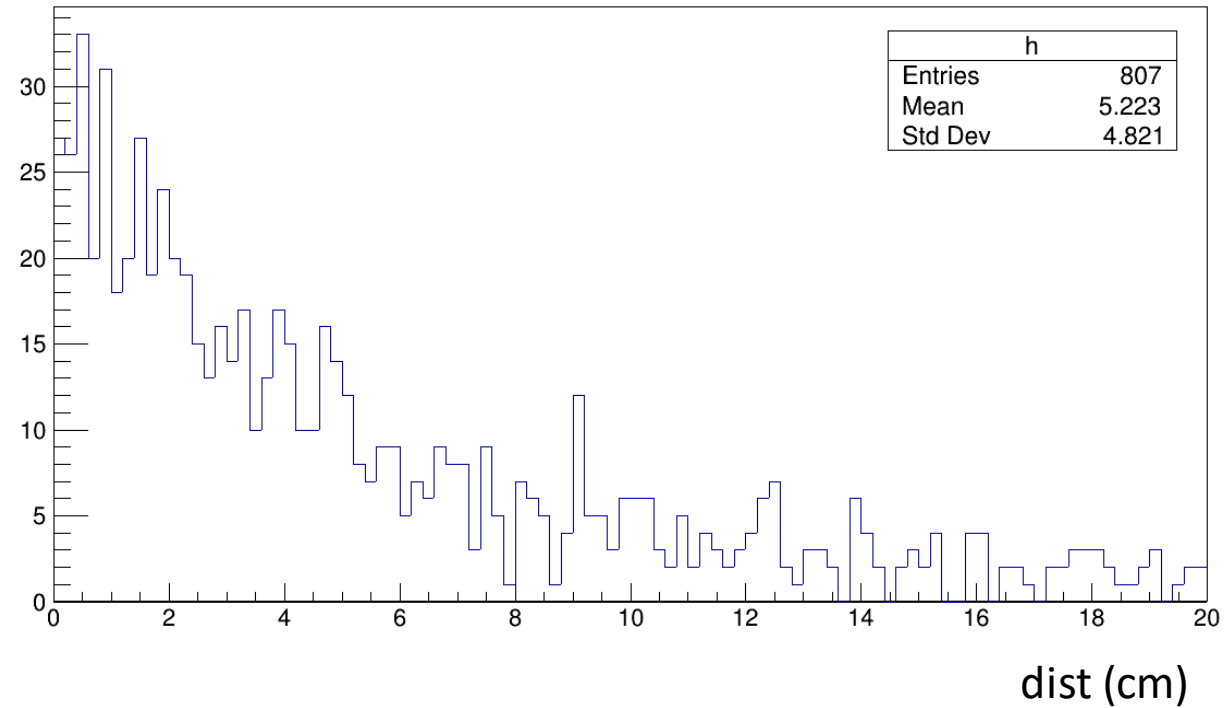
*Minimum distance between extrapolated reconstructable pion track (slice 3) and muon track*

dist {parentID==-1 && grain\_slice==3}



Primary pions

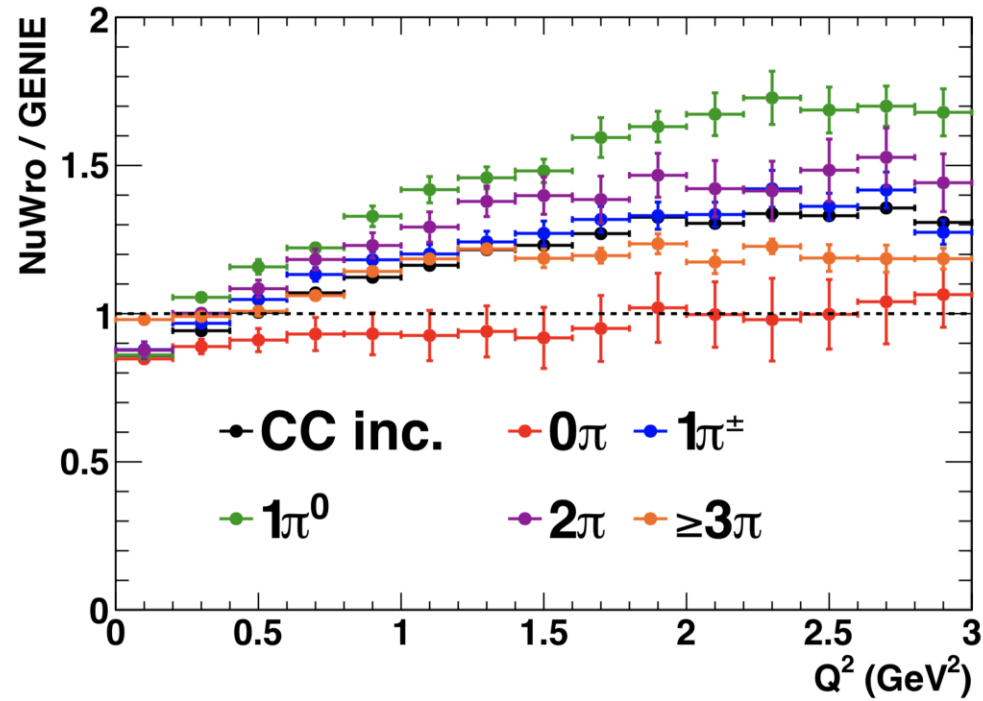
dist {is\_sec\_int==1 && grain\_slice==3}



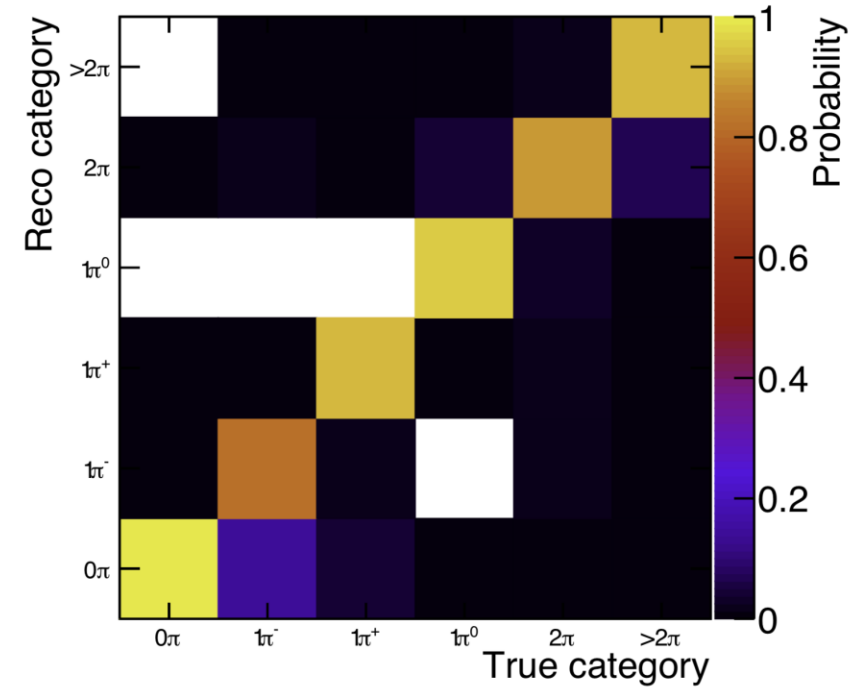
Secondary pions

**BACKUP**

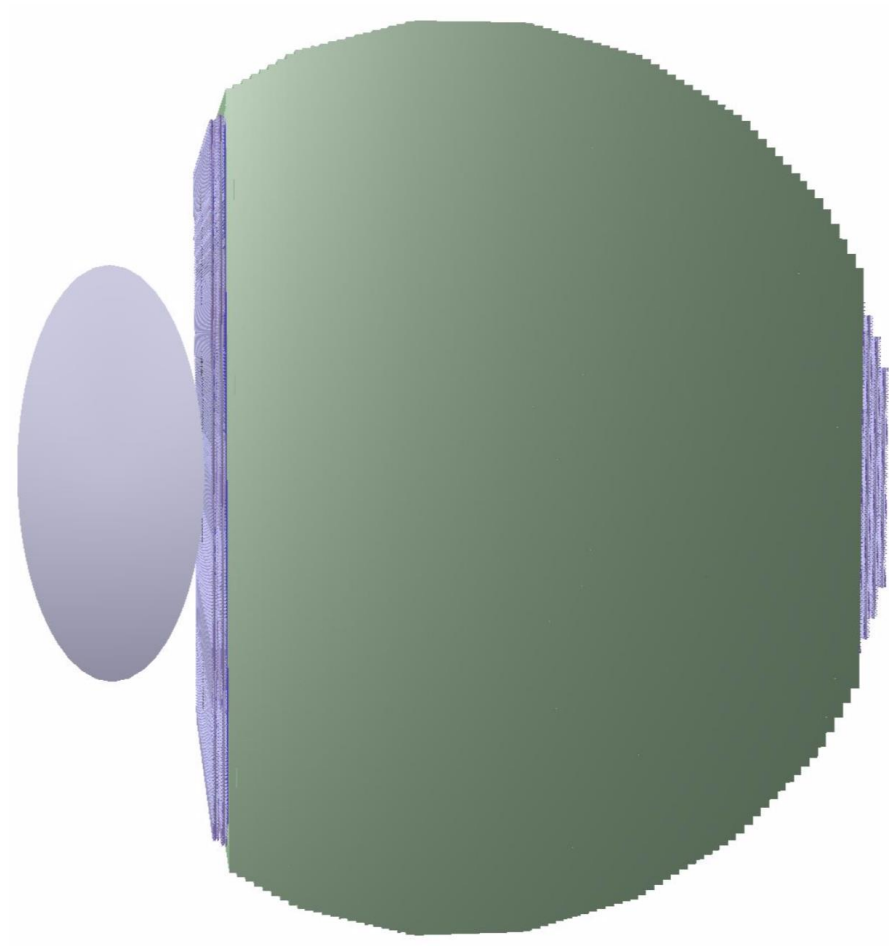
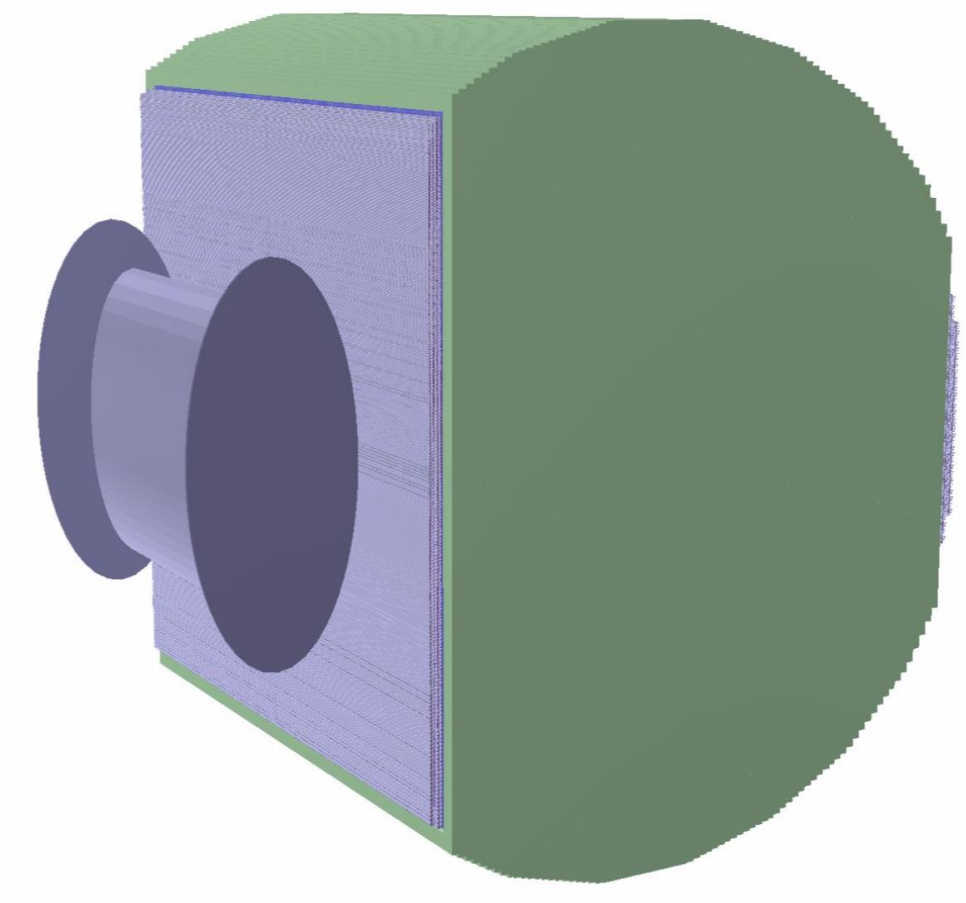
NuWro/GENIE for various reconstructed final states (FHC)



Final state confusion matrix in HPgTPC (FHC)

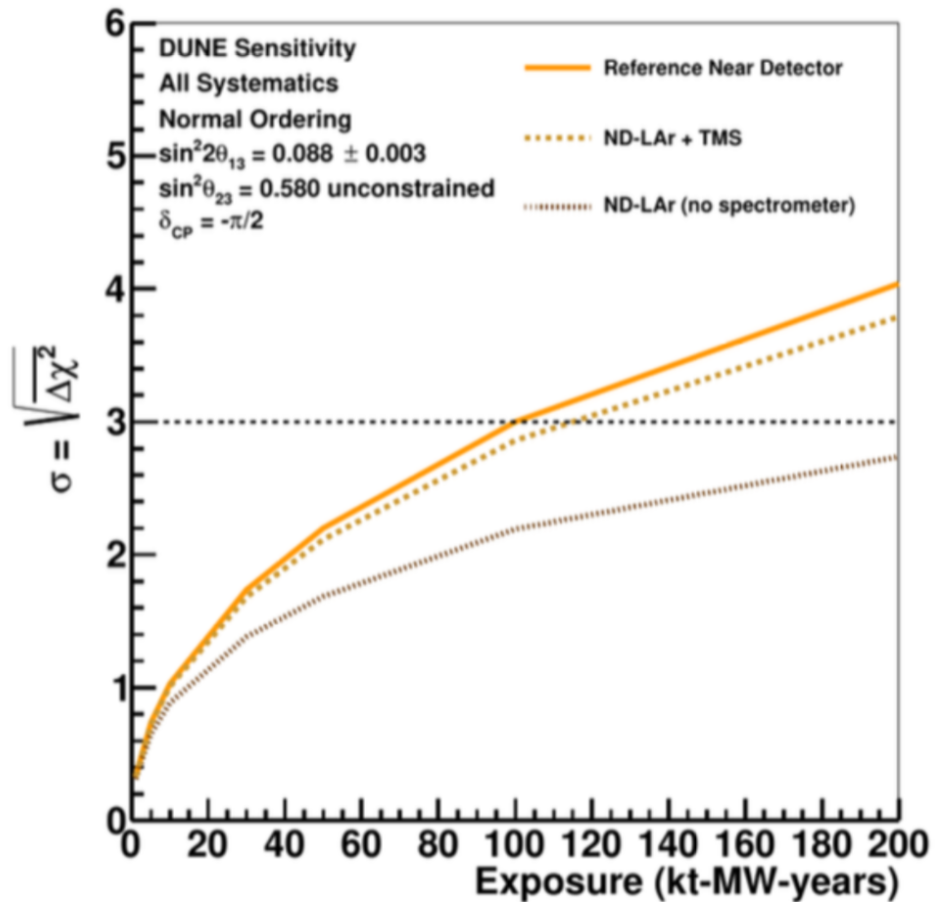


Hadron multiplicities in ND-GAr have been used to re-weight ND-LAr simulations in  $(q_0, q_3)$  plane

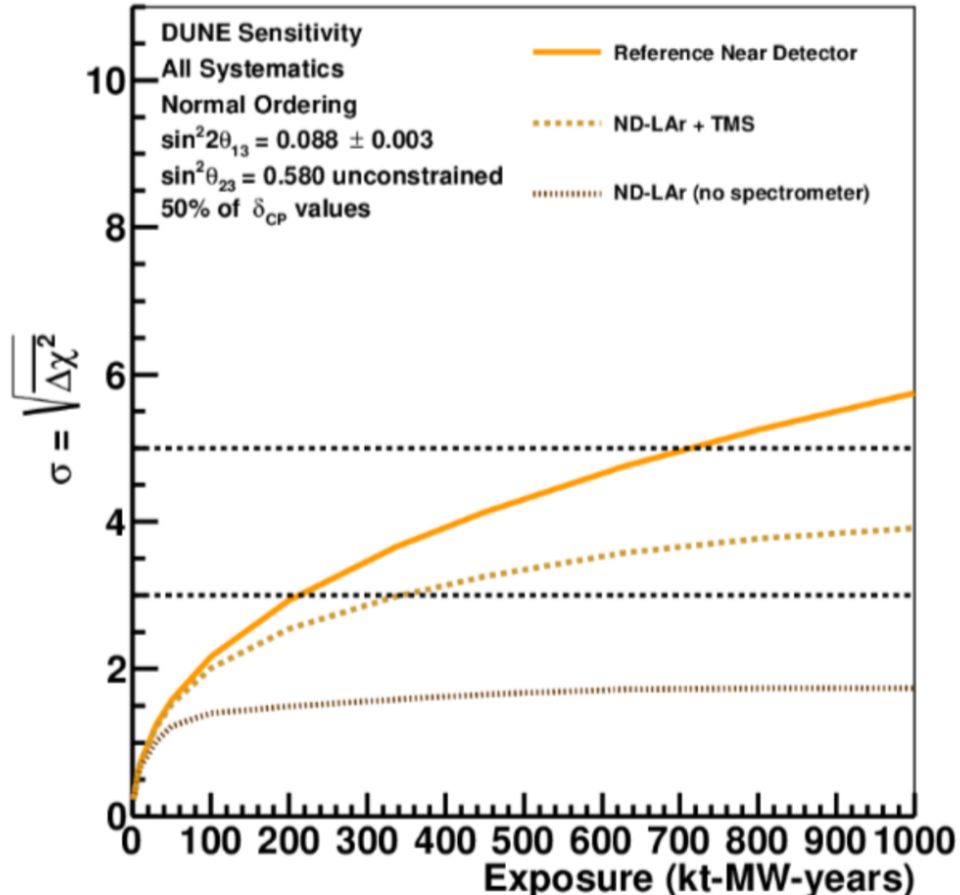




CP Violation Sensitivity



CP Violation Sensitivity



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