Using MIPP data to reweight MINOS(+) beam MC

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MINOS+ collaboration meeting
& Numi-X meeting

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Conceptual overview

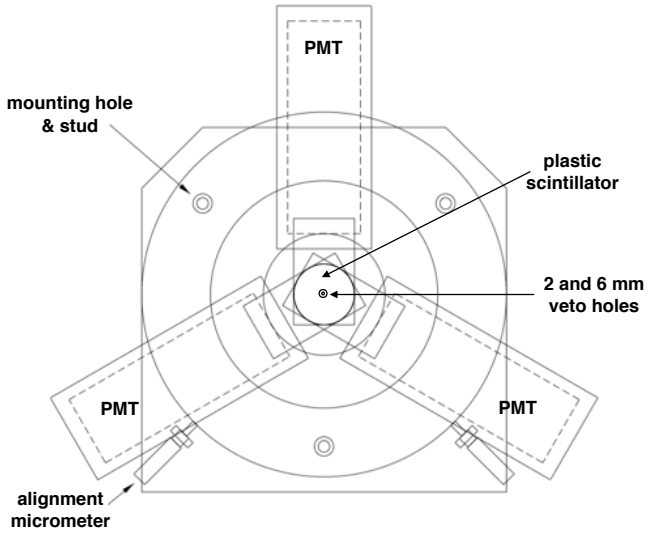
- There is disagreement between MINOS (and MINOS+) MC and data in Near Detector
- Most of it believed to come from inaccurate modelling of secondary hadron production in target
- MIPP experiment has measured pion yields from NuMI target in 120 GeV proton beam in bins of p_z and p_t
- MINOS beam MC stores kinematics of neutrino ancestors as they exit the target area
- Conclusion: use the MIPP data in MINOS(+) beamfits to constrain hadron production
- First step: try a naive reweighting procedure for horn-off configuration samples
  - No focusing effects
  - Expect MIPP weights to move MC prediction closer to data

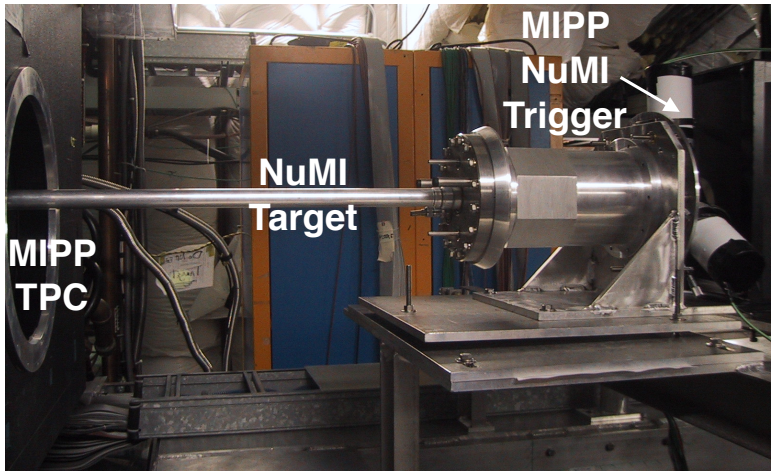
MIPP intro

- Main Injector Particle Production experiment
- Using Main Injector protons on different targets to study hadron production
  - One run with a spare NuMI target – $\sim$1.6 million events
- Suite of detectors (TPC, ToF, Cherenkov, RICH) to cover large range of products p_z
  - Only TPC and RICH used in the current analysis for NuMI pion yields – gap for p_z between 2 and 4 GeV

MIPP spot size

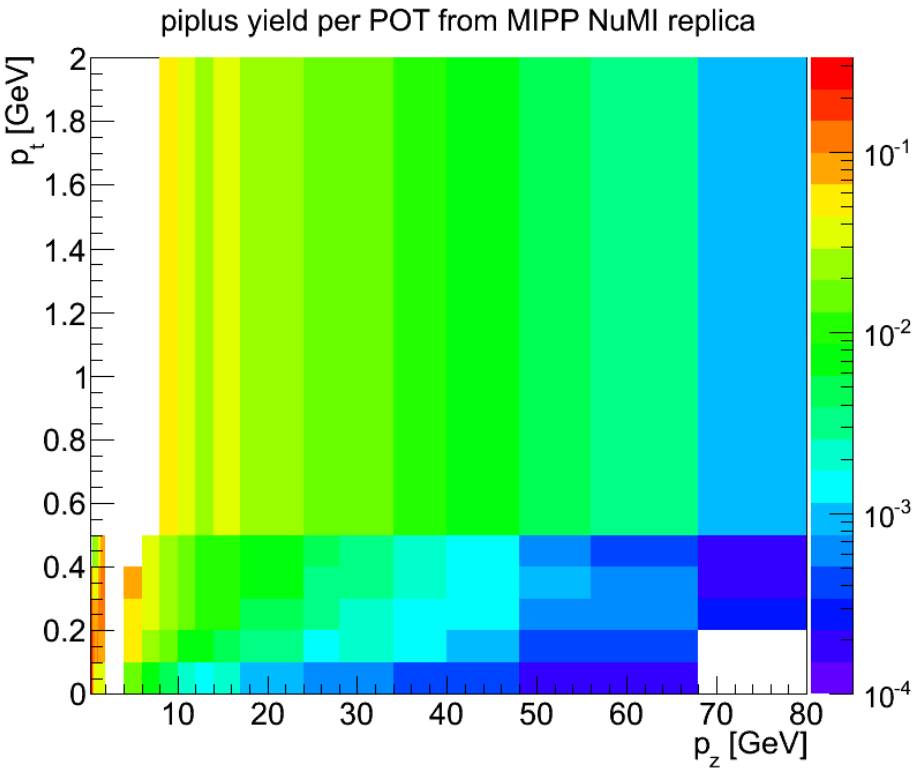
- Intensity decreased by 10^8 to reduce pileup
  - 16 μs TPC readout time
- Triggers used to center the beam and scale the spot size
  - Three thin scintillating plates placed before the target
  - Two with holes in the middle (2 mm and 6 mm)
  - (Anti-)coincidences used to scale the beam to the 1mm-σ gaussian profile

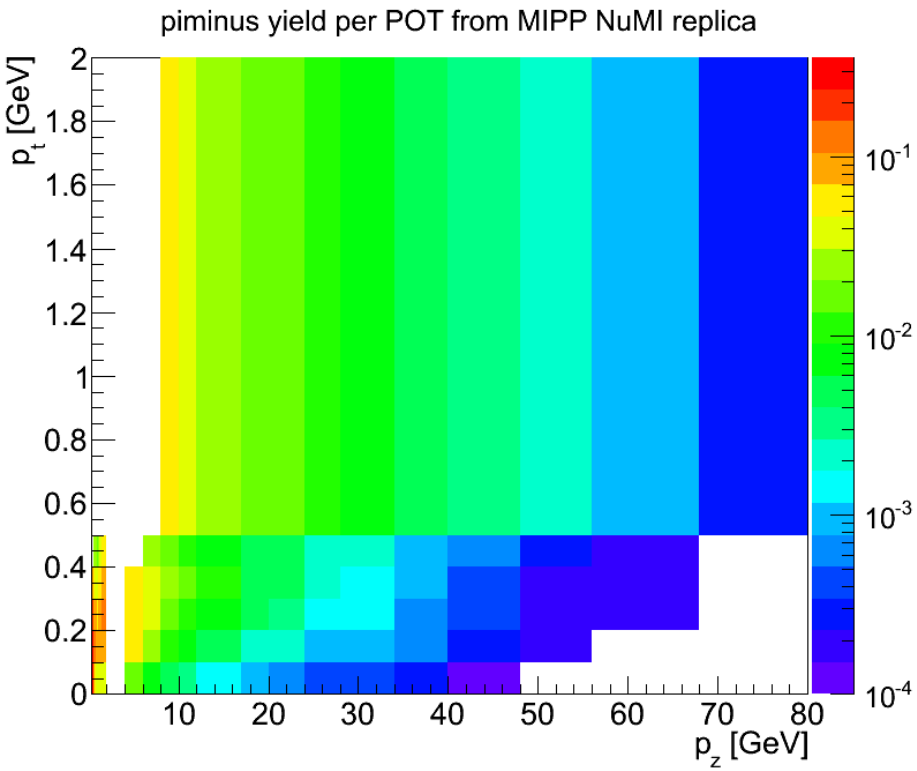




MIPP data

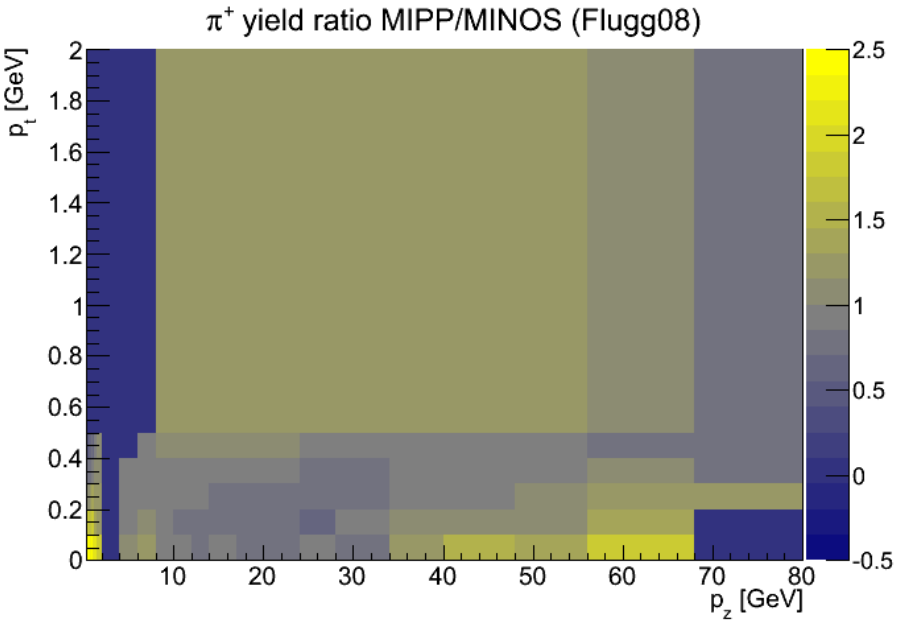
- π^+ and π^- yields normalised to 1 POT
- The binning is $\sim$linear in log p_z

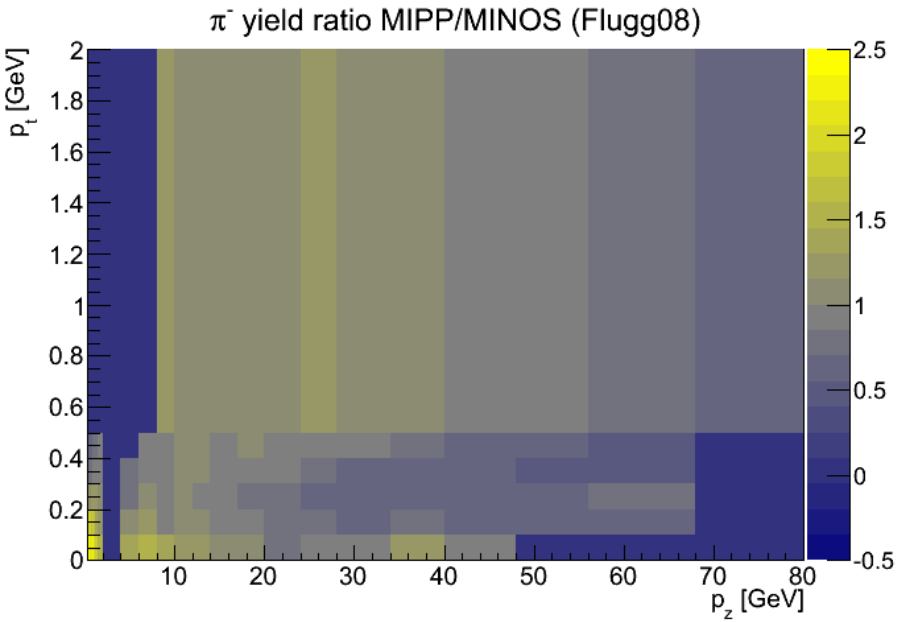




Weights from MIPP over Flugg08 ratio

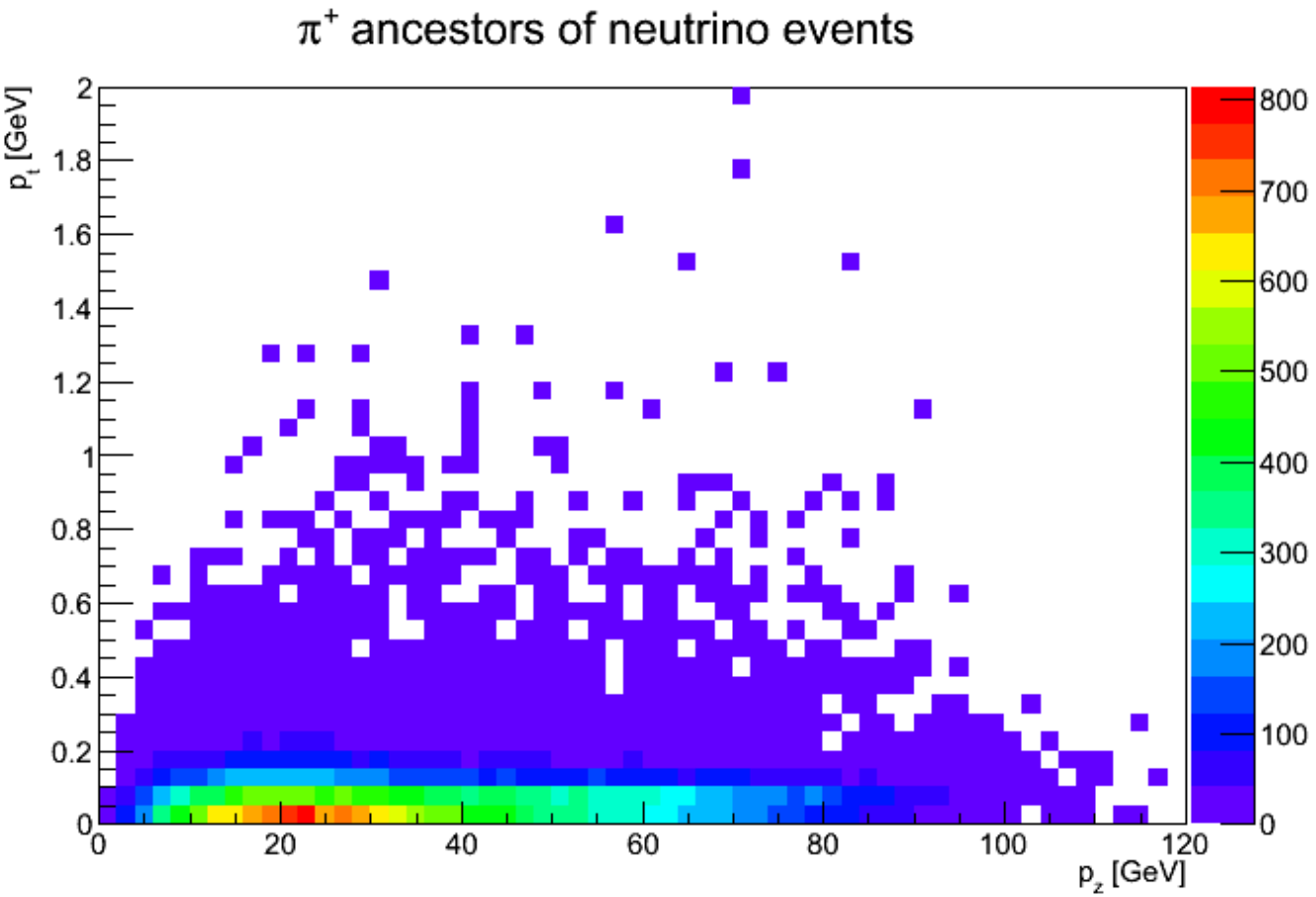
- I use MINOS target files generated with Flugg08 by Alex R.
- Fill $p_t p_z$ histograms with MIPP binning scheme
- Simple division to create a weight histogram
- Empty bins give a weight of 1





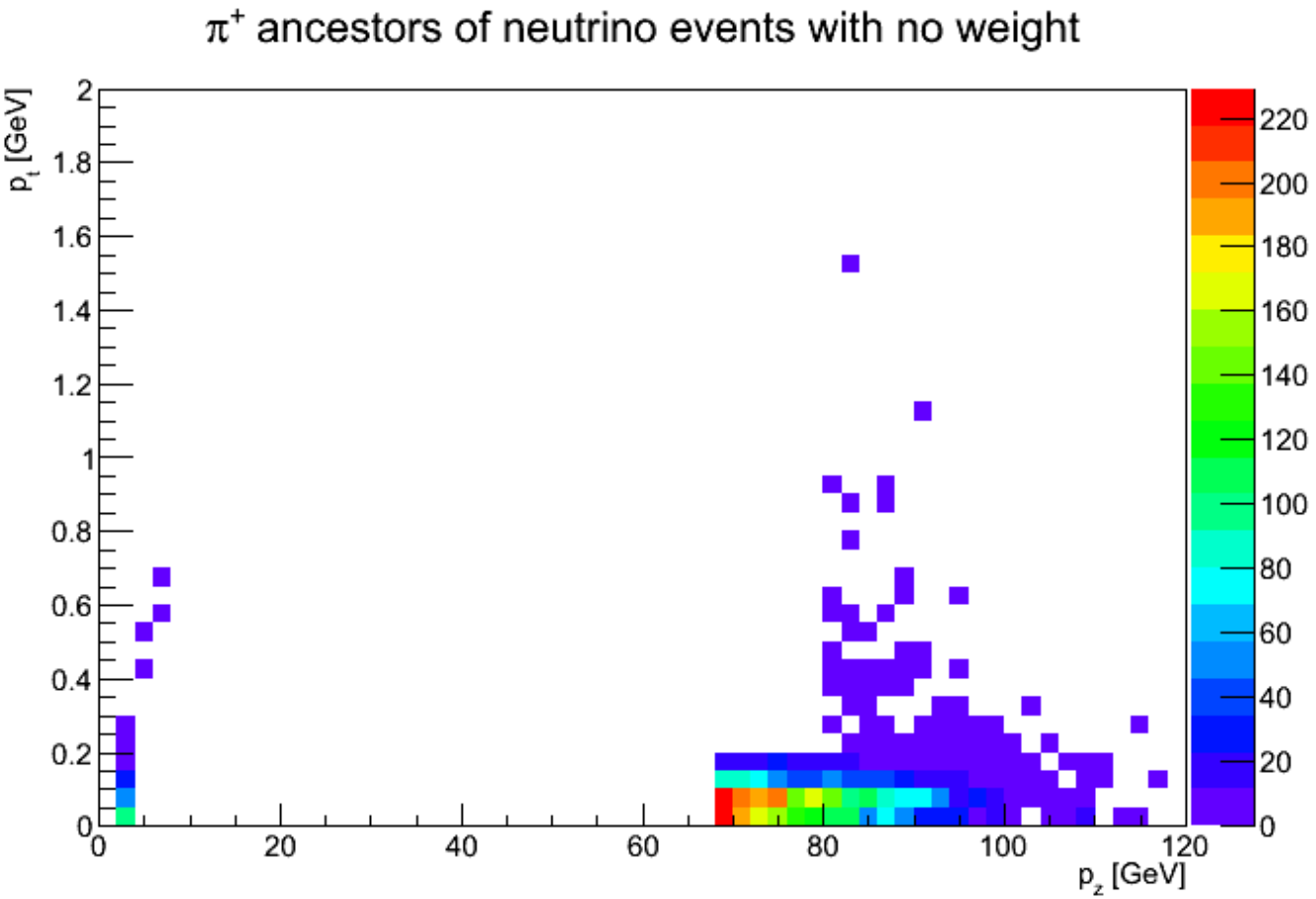
Where are the neutrino ancestors?

- Does the weight histogram cover the phase space of pions that decay to MINOS horn-off ND neutrinos?



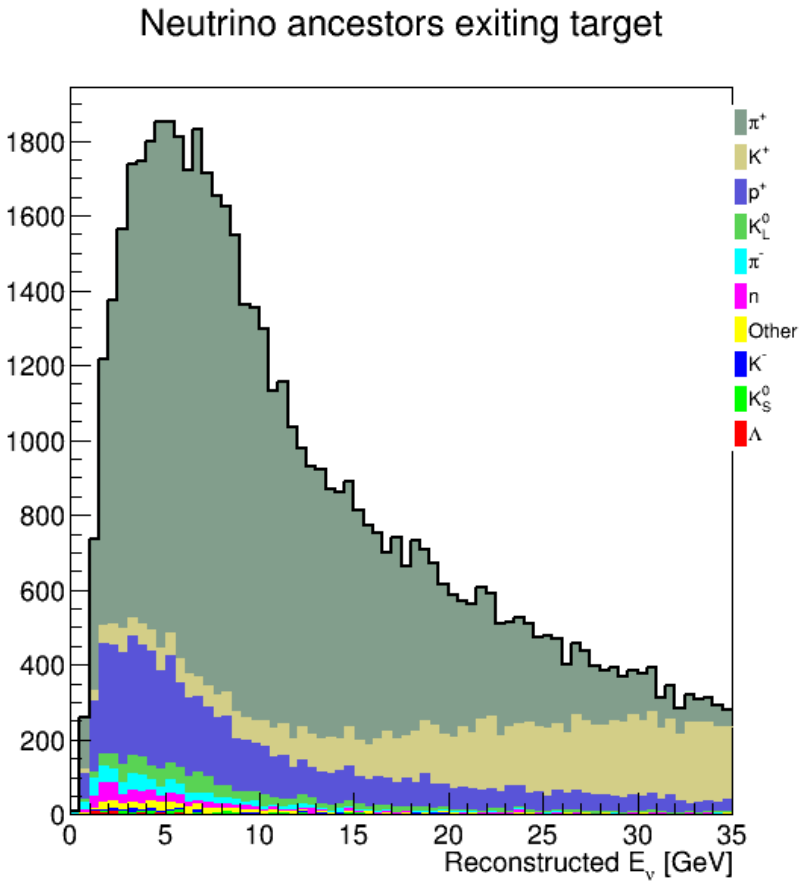
Where are the neutrino ancestors?

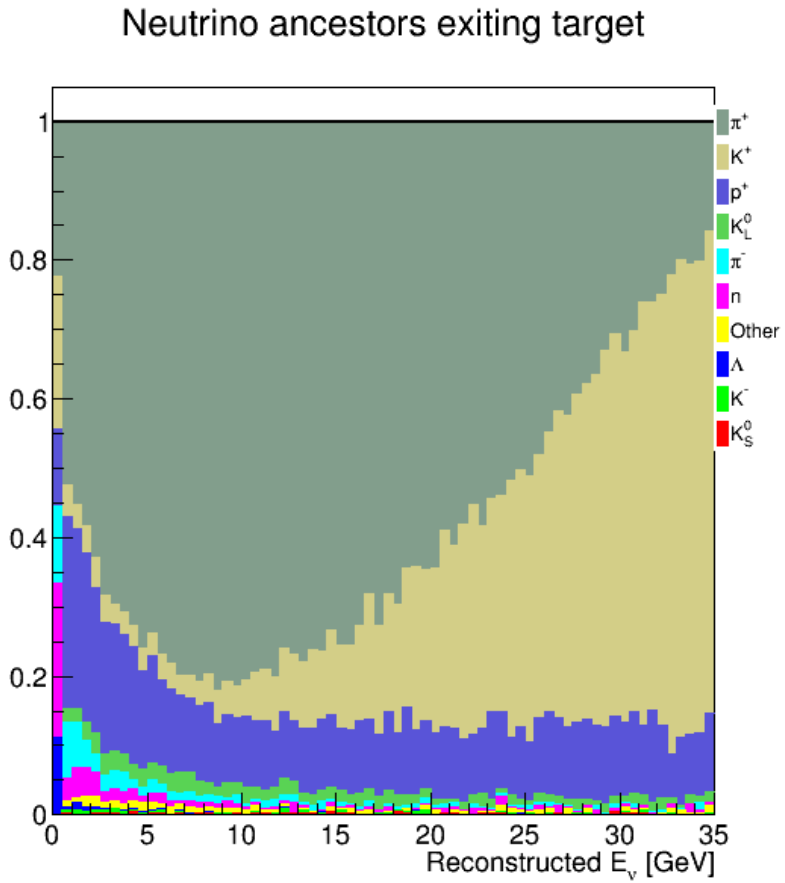
- Same plot for pions giving no weight to the neutrino events (11% of all pion ancestors)



What are the neutrino ancestors?

- Composition of MINOS horn-off ND neutrino ancestors
- Pions with weights are 50% of all neutrino events

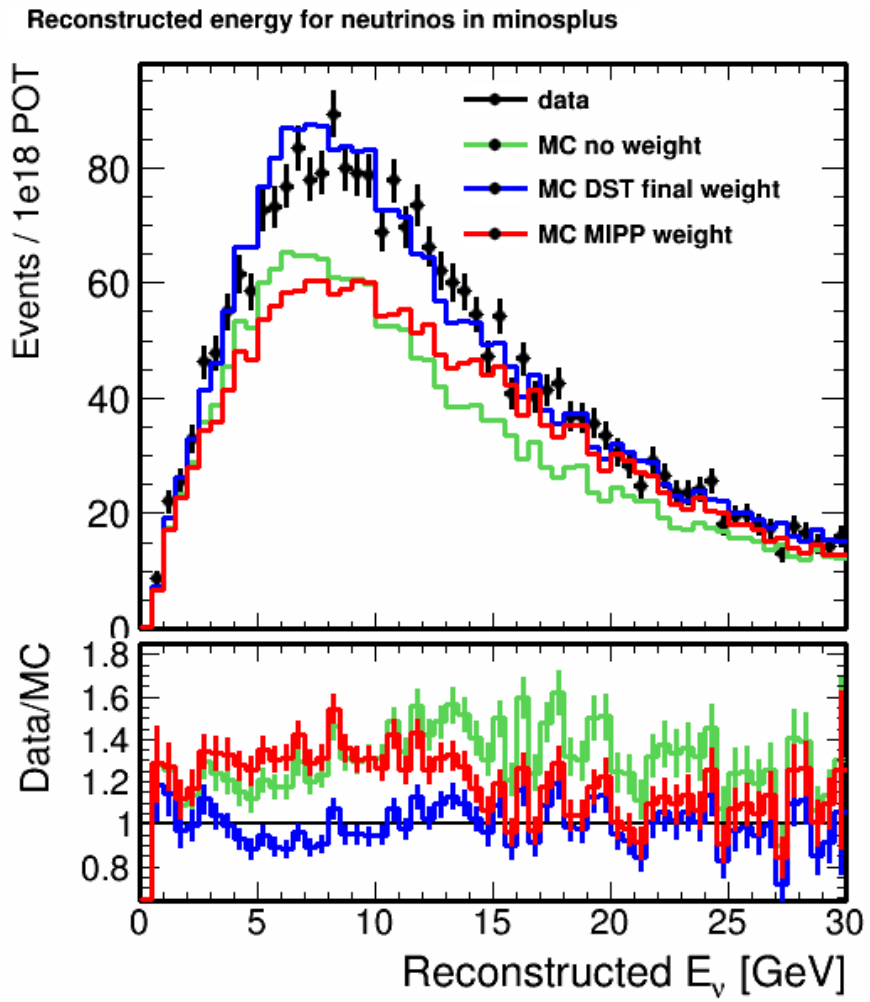


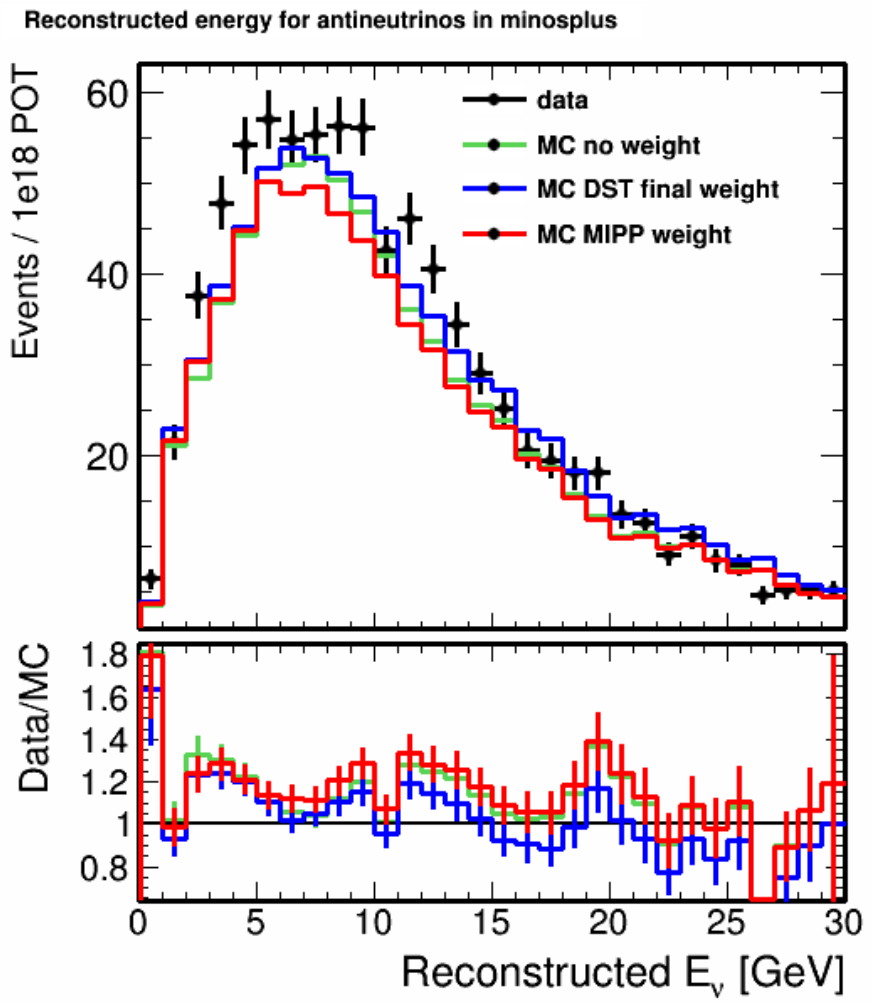


Reweighting procedure

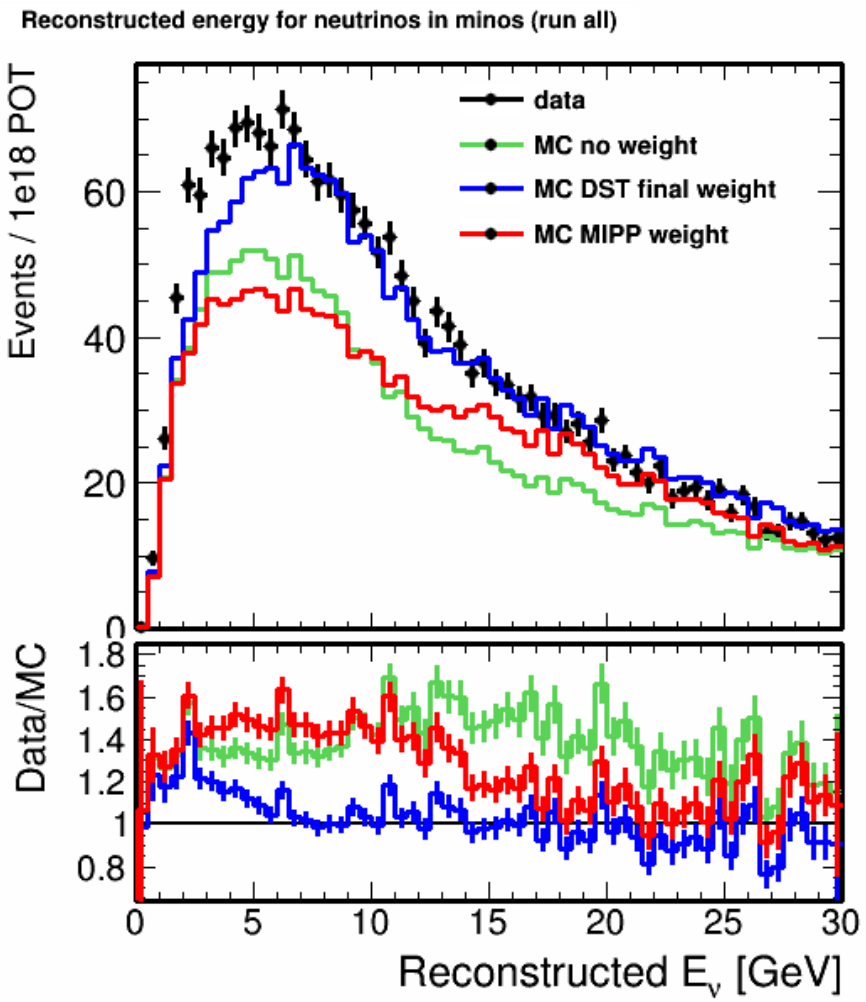
- Presenting results for MINOS+ and MINOS horn-off samples
- The weights are from MIPP/MINOS, whether I reweight MINOS+ or MINOS spectra
- Apply CC selection cuts to data and MC
- Neutrino vs. antineutrinos samples determined by track charge sign
  - Reweighting is applied based on true parent PID anyway
- Compare MC with data on plots with reconstructed energy spectra of ND CC events
  - Data in black points, MC as coloured lines
  - Green for pure MC, no reweighting
  - Red for MC reweighted with the MIPP/MINOS weigths
  - Blue for the official beamfit result for comparison

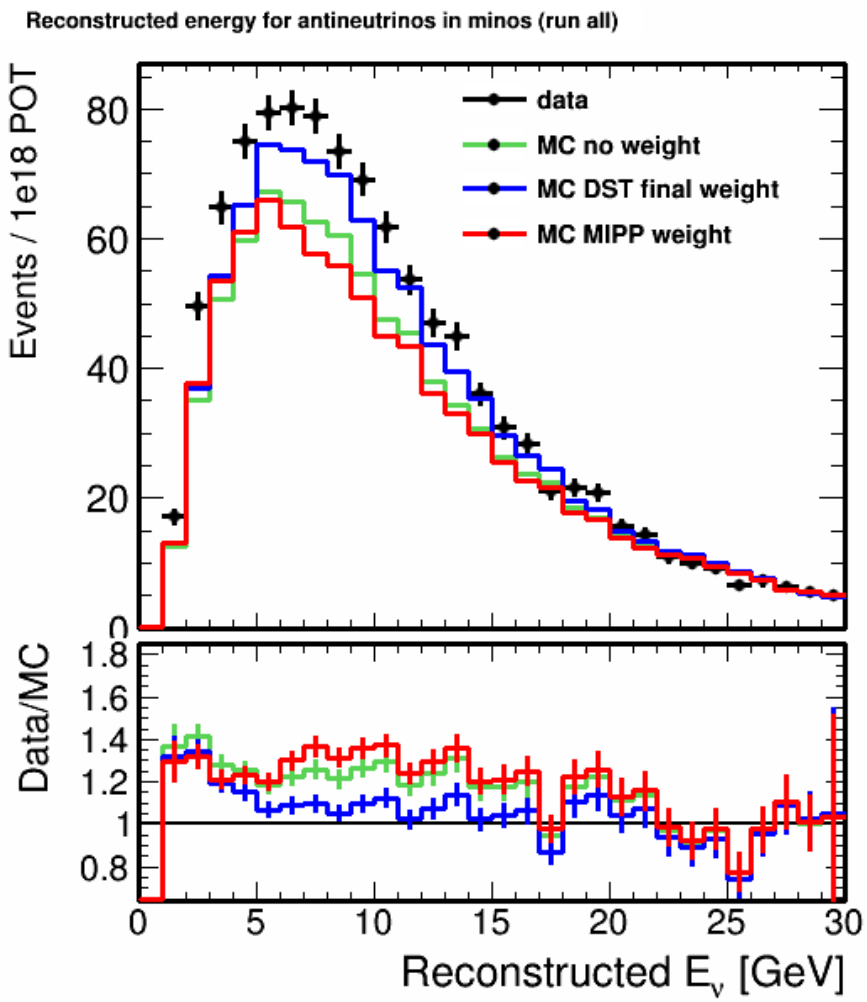
Data vs MC – MINOS+ horn off





Data vs MC – MINOS horn off



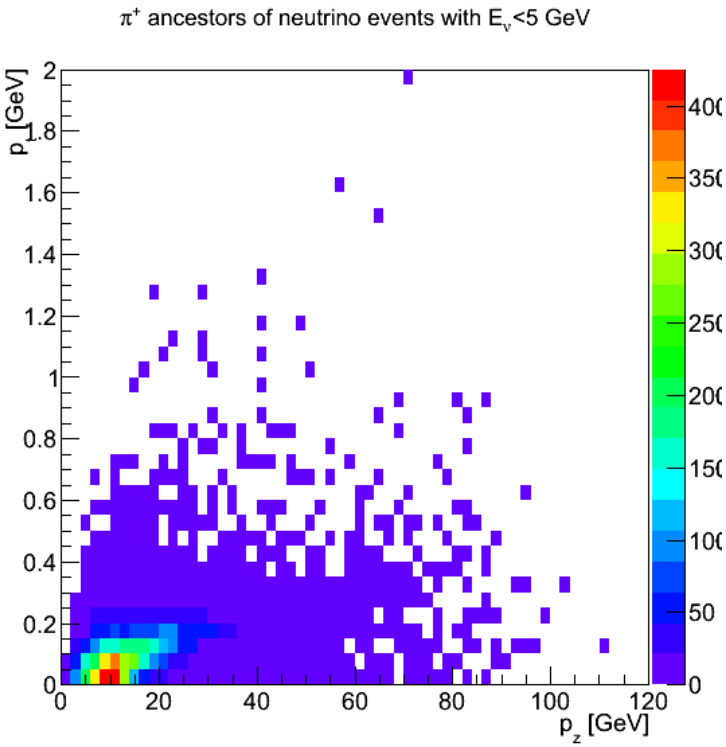


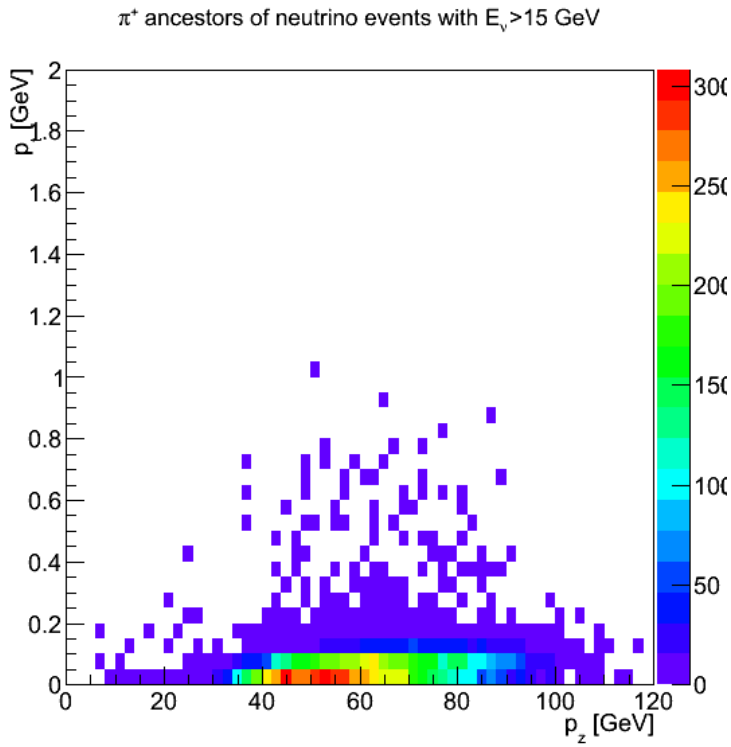
Observations

- MIPP weights make it worse for neutrinos in 5 GeV region!
- Sign of effect seems to switch around 10 GeV, good agreement in the tail
  - Switch occurs as kaons start to dominate in ancestor composition – indication of a bug?
- Overall effect of reweighting is very small!
  - But remember small weights applied only to 50% of events
- Almost no effect for antineutrinos

Bug checks

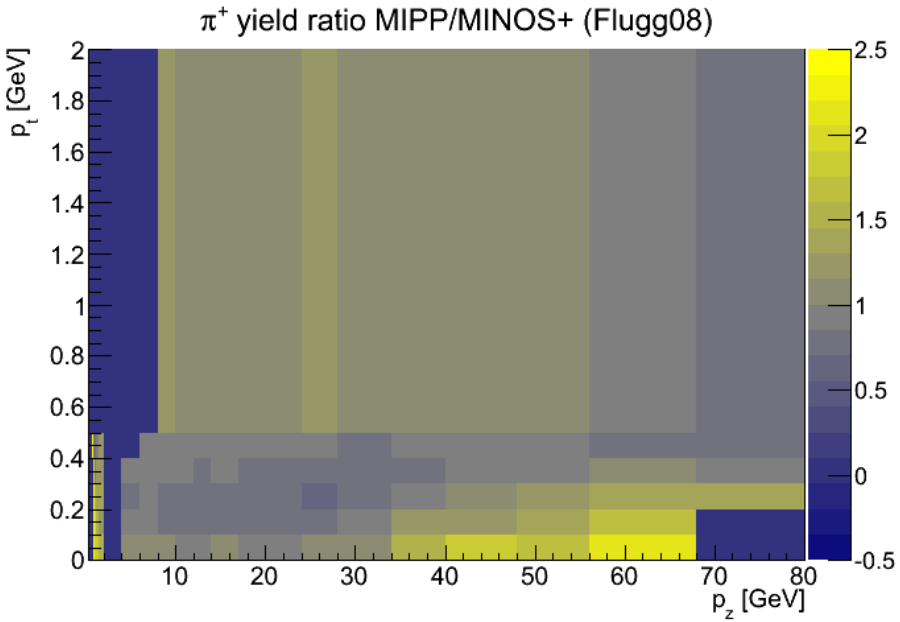
- Made sure that weights are applied correctly, and only for pions
- Low energy neutrinos come from regions with weights < 1 and vice versa – sign of reweighting is correct

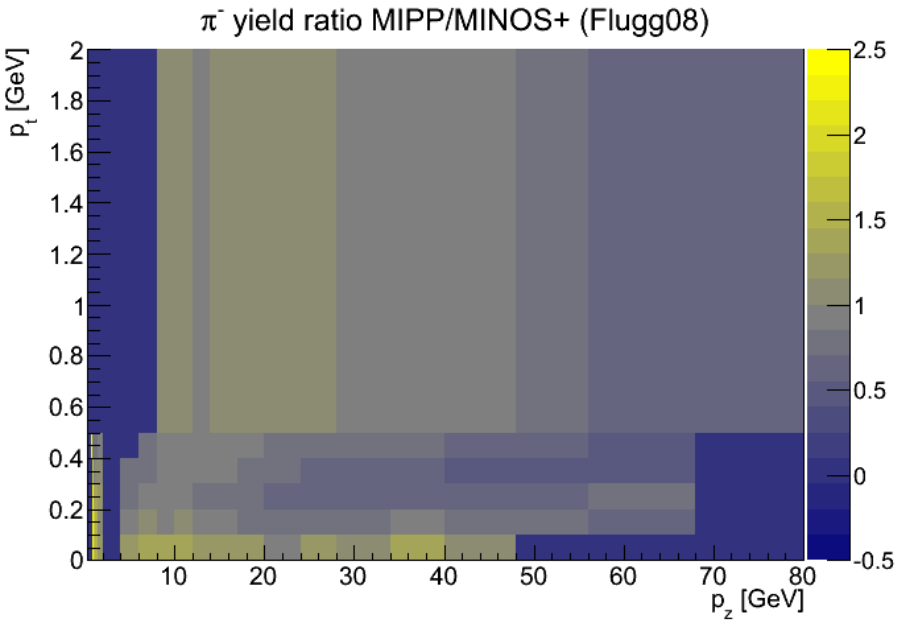




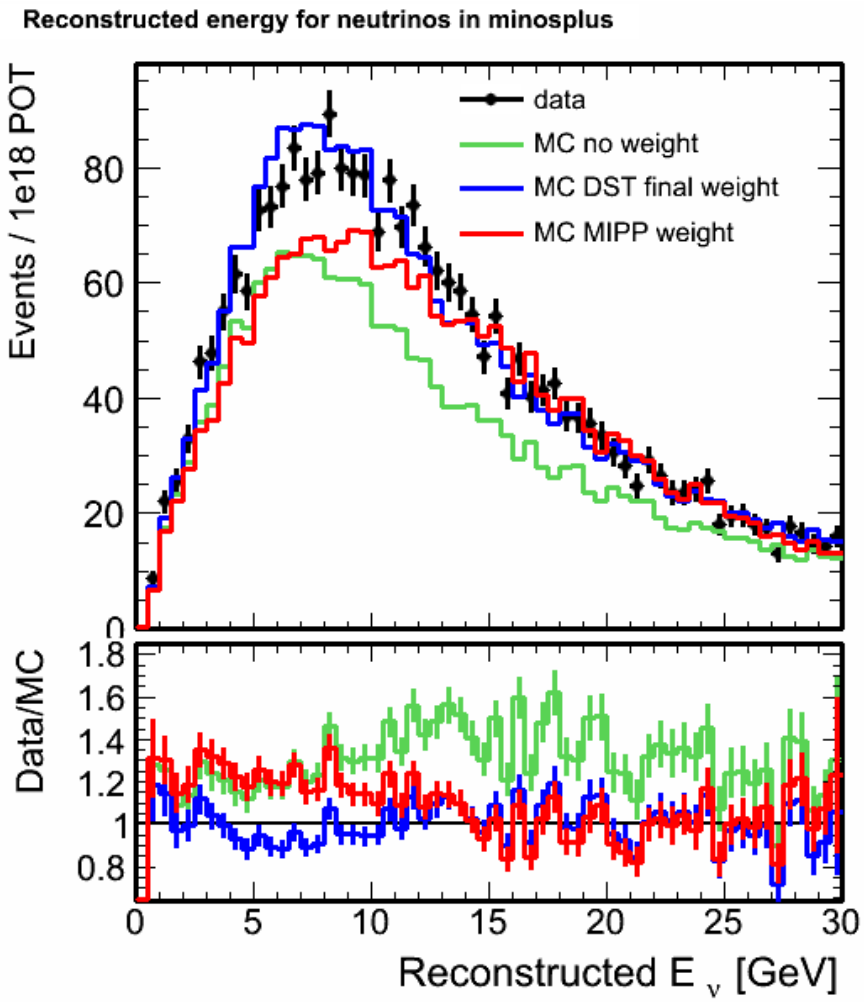
MIPP/MINOS+ reweighting check

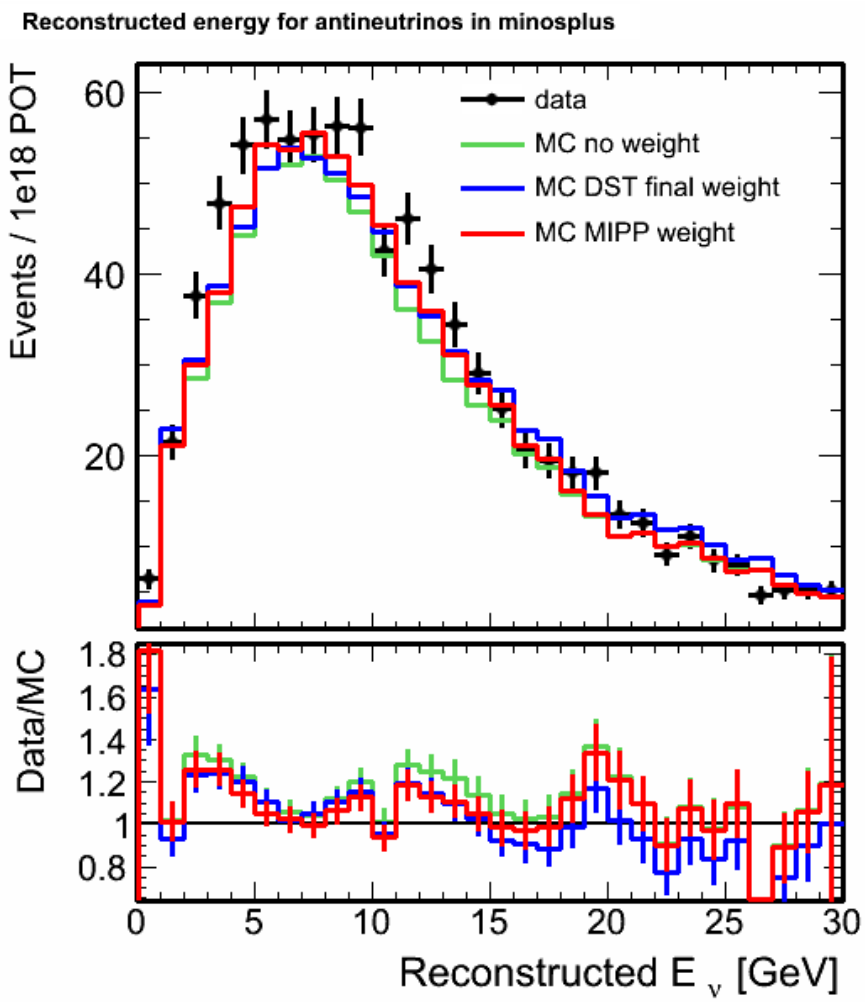
- There were some issues with beam MC (eg. importance weight bug); MINOS target files are from before fixes
- Do the 'wrong thing', use (newer?) MINOS+ Flugg08 target files to get weights
- Very similar to MIPP/MINOS histograms



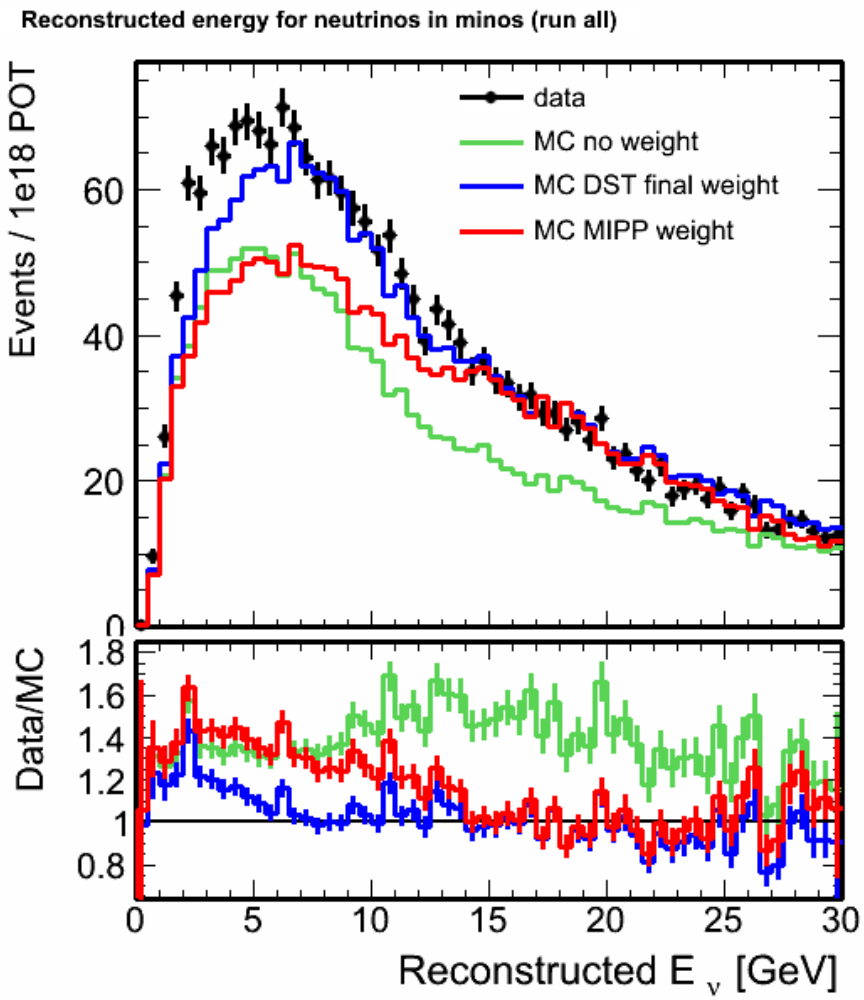


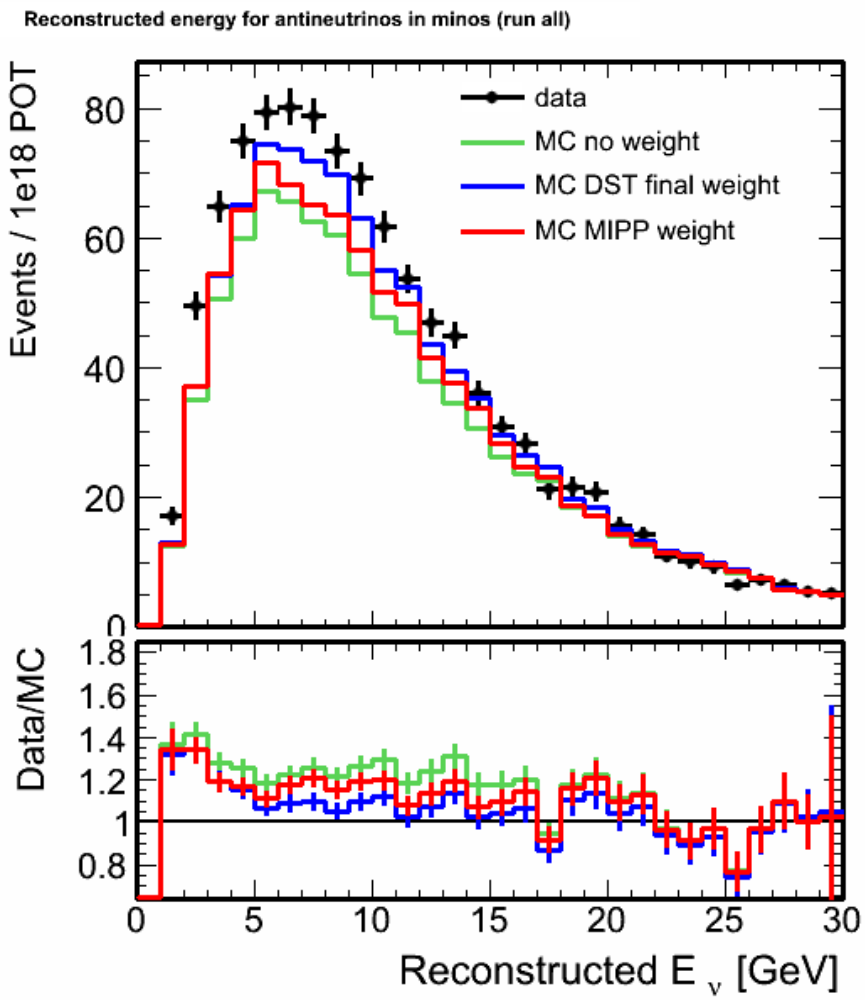
MIPP/MINOS+ reweight – MINOS+ horn off





MIPP/MINOS+ reweight – MINOS horn off





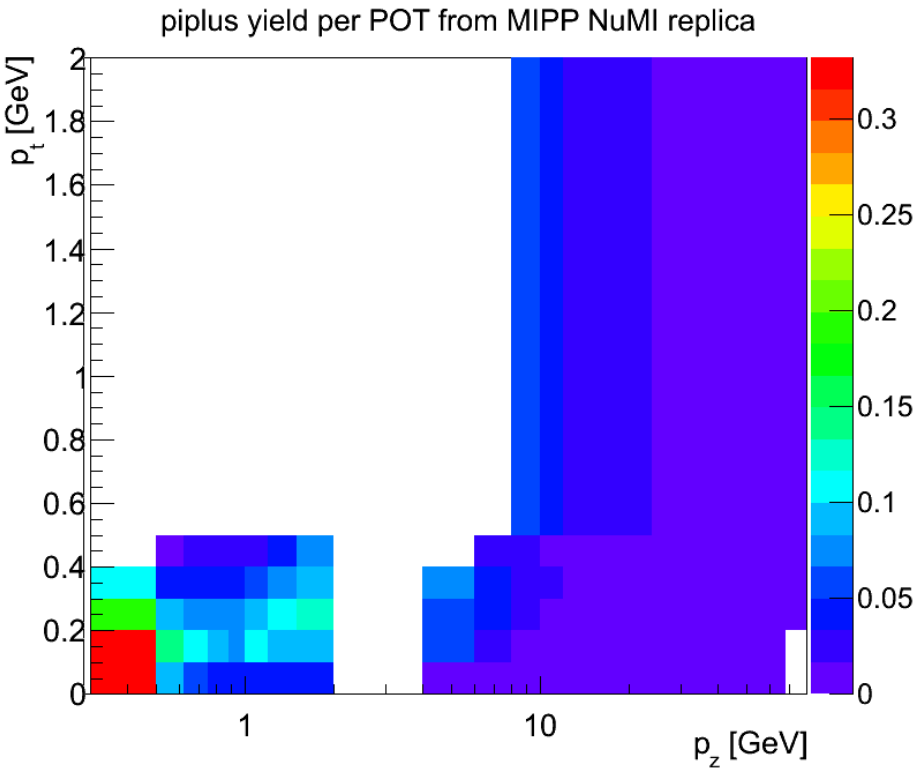
Conclusions

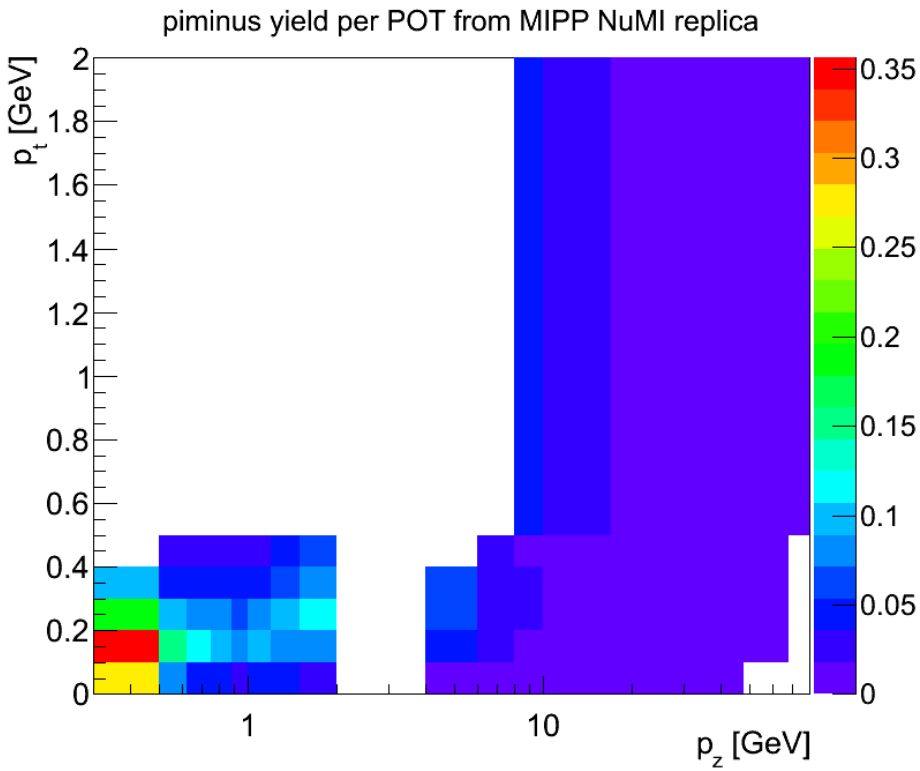
- Naive MIPP reweighting does not seem to work well for horn-off samples
- The expected effect may be small, but should be in the right direction
- I couldn't find any bugs in my code
- There may be an issue with the MINOS Flugg08 target files
  - Will generate them with newest version of Flugg for comparison
- Using MINOS+ target files to get weights gives better results, but there is not enough understanding why
- Is there any good reason why MIPP data would not be applicable to MINOS?

Backup

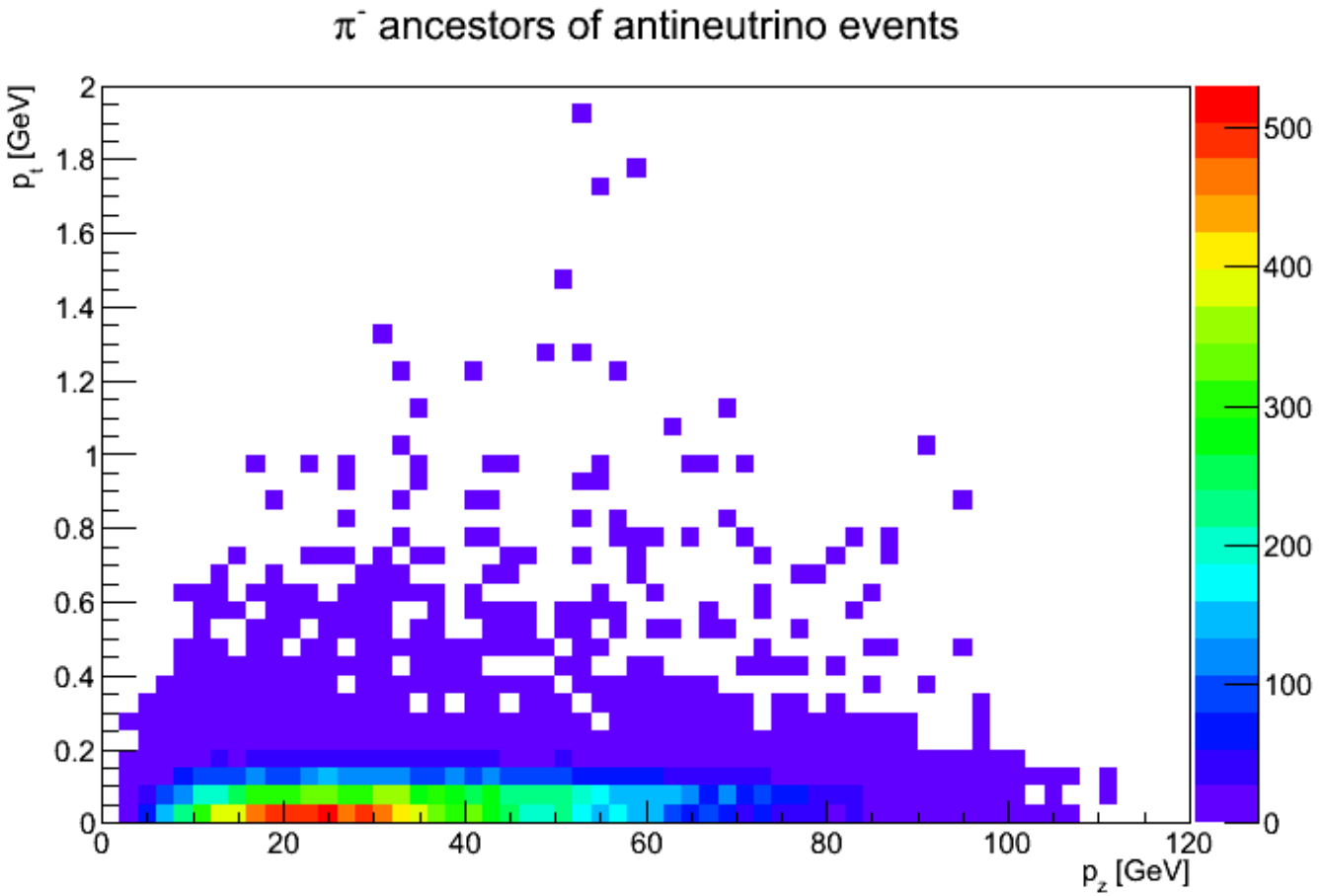
MIPP data

- π^+ and π^- yields normalised to 1 POT
- The binning is $\sim$linear in log p_z



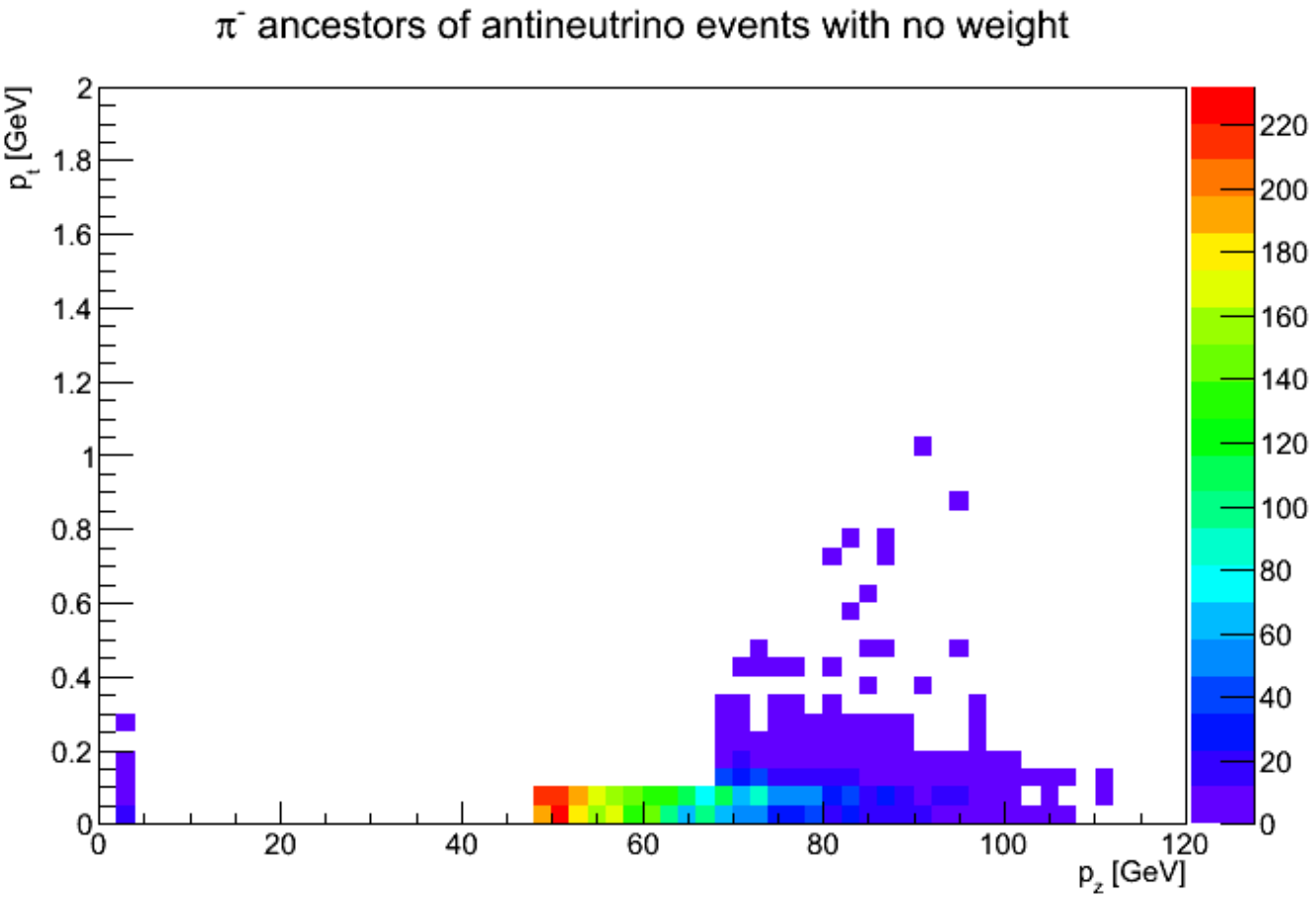


Antineutrino ancestor kinematics



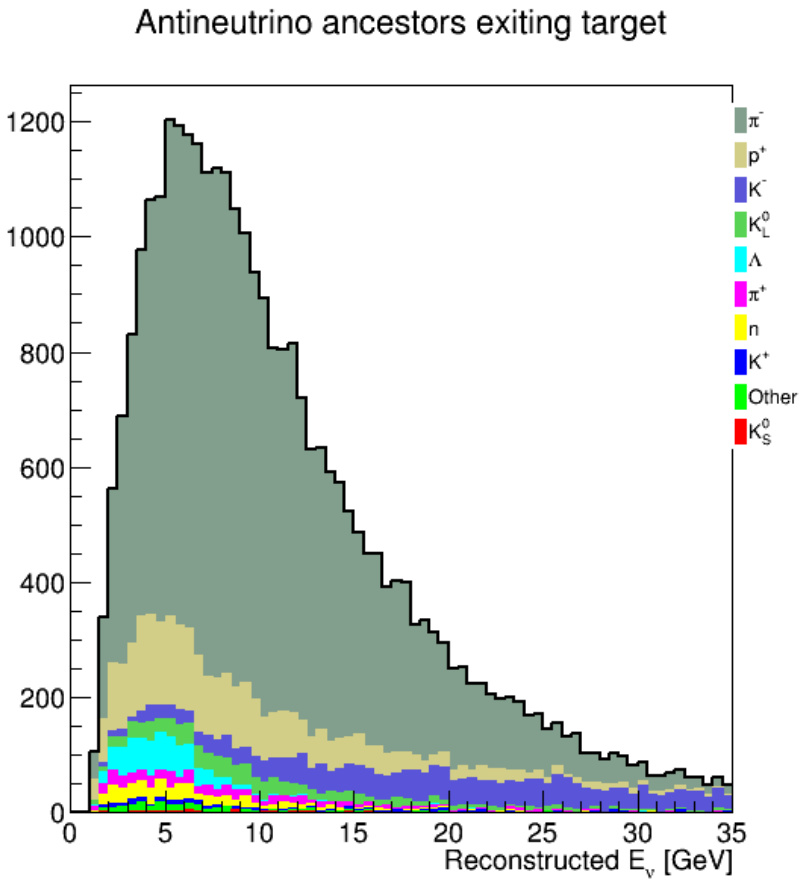
Antineutrino ancestor kinematics

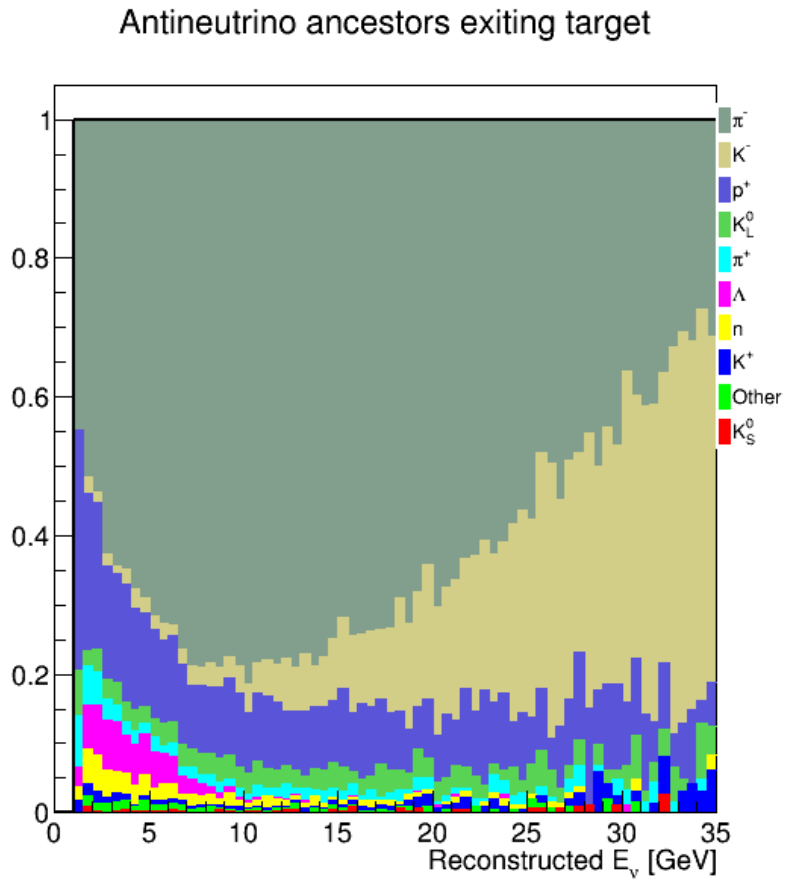
- Same plot for negative pions giving no weight to the antineutrino events (24% of all pion ancestors)



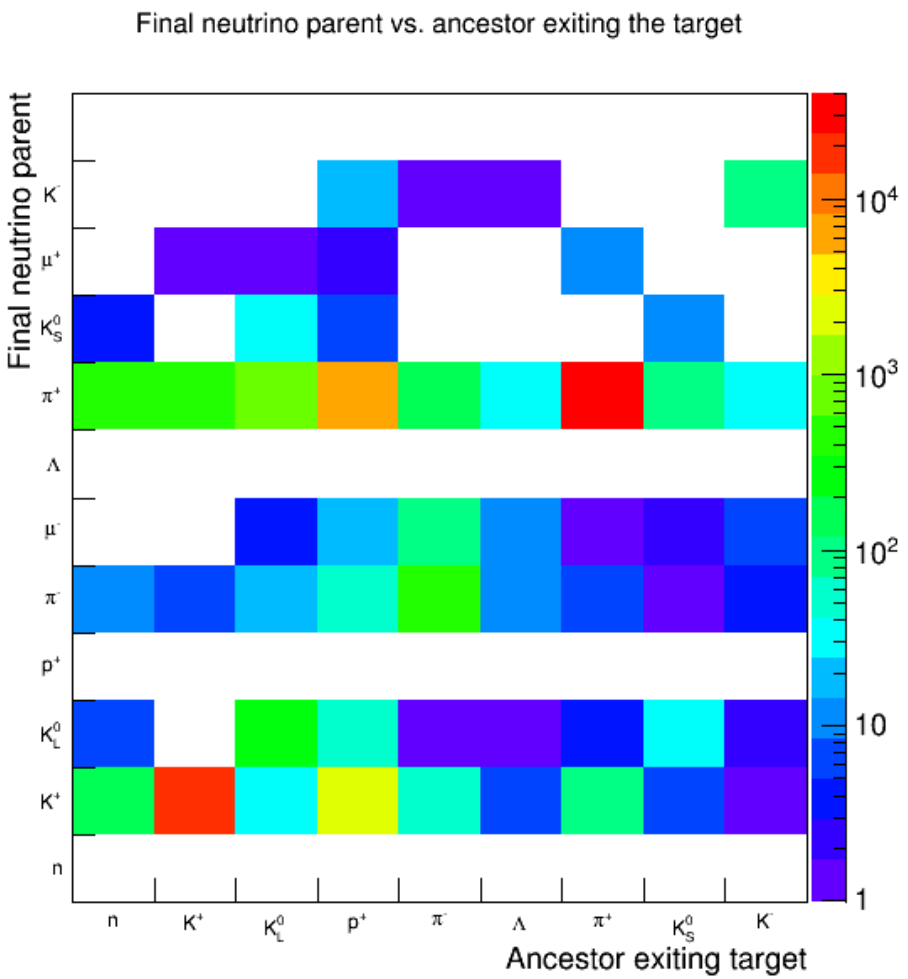
Antineutrino ancestor composition

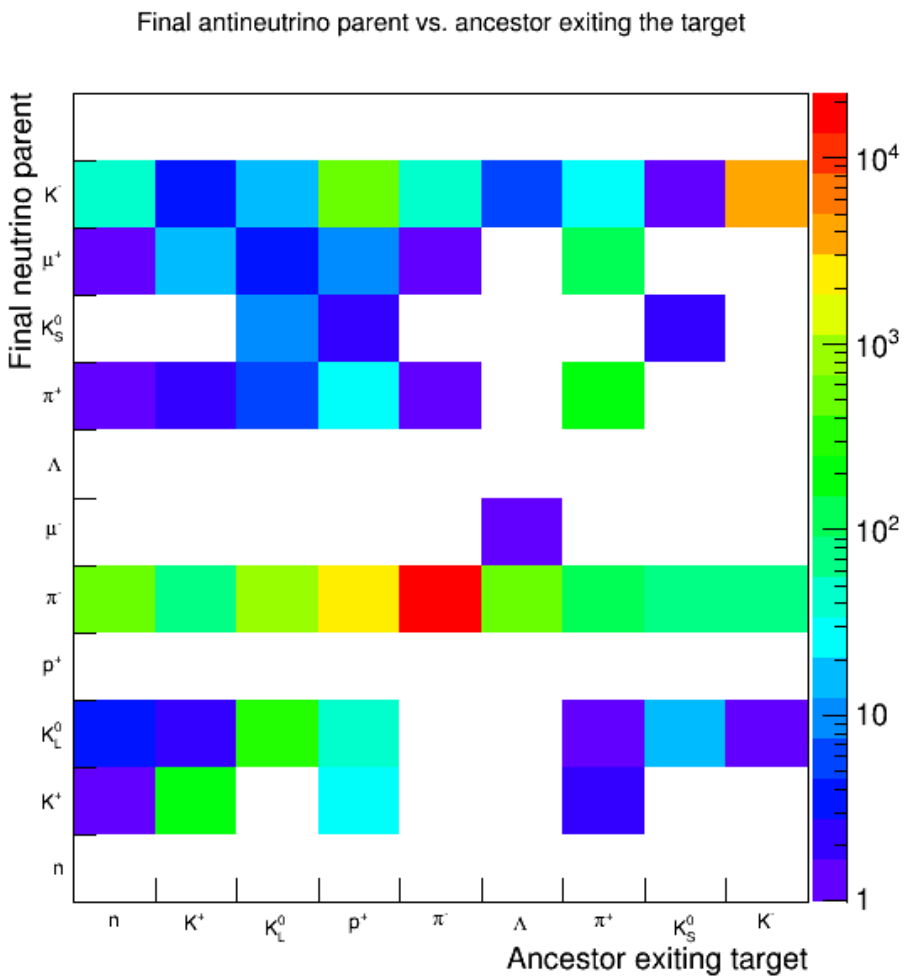
- Composition of MINOS horn-off ND antineutrino ancestors
- Negative pions with weights are 43% of all antineutrino events





Actual parents vs. ancestors exiting the target





Parent generation of ancestors exiting the target