ECAL Studies in ND-GAr:

Analysis of Exclusive Event Categories using Truth Information

Kelly Nagel
Advisor: Vivek Jain
University at Albany
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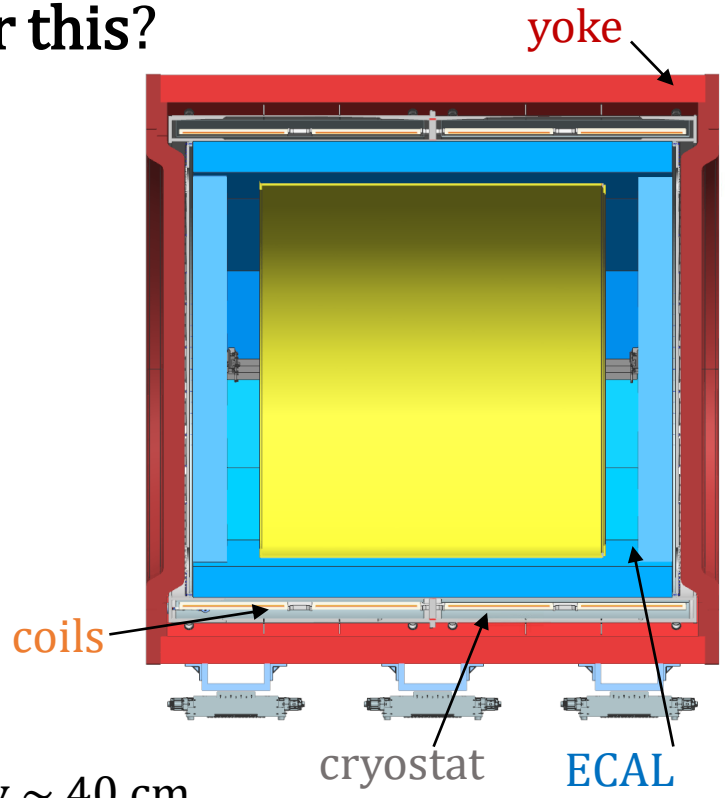
Introduction

Which parts of the ECAL are necessary? **How should we answer this?**



New ECAL geometry (Eldwan Brianne)

- ECal12sides_42l_SPY_v3_wMuID
- 42 layers of Pb-Scintillator sandwich (~ 10.5 X_0)
  - Scintillator: 8 layers, each 0.5 cm thick, and 34 layers, each 1 cm thick
  - Pb – 8 layers, each 0.7 mm thick, 34 layers, each 1.4 mm thick
- Barrel has 12 fold symmetry
- Newly optimized SPY magnet and cryostat as the pressure vessel
  - No extra material between the ECAL and TPC - Endcaps are pulled in by ~ 40 cm

Studying the effect of removing different parts of the ECAL, done by ignoring neutrons and photons in those different parts

Looking at specific event types, depending on whether CC/NC events, ν type, and number of pions

Using (FHC) ParamSim ntuples: /pnfs/dune/persistent/users /ebrianne/ProductionSamples/ND-GAr/nd_hall_mpd_only_ECal12sides_42l_SPY_v3_wMuID/

Eldwan put flags in the ntuple that tell you where the particle stopped e.g., in the ECAL, TPC, or went through the ECAL

Using only truth information

Using the ΔP metric:

$$\Delta P = |\text{Vector sum of } p \text{ of all particles from the primary vertex}| - |p_{inc\ \nu}|$$

Also comparing the modes and number of n and γ in different categories

Just looking at particles emerging from the neutrino vertex i.e., throwing out events with strange/charm baryons and anti-baryons

These metrics get messed up because I don't follow the decay chain

In resonance events, the decay products of the resonance particles are listed as primaries, not the resonance particles themselves

Only using daughter γ from primary π^0 in the ΔP calculation, not π^0 themselves

Event categories

Charged current ν_μ events (152722)

- with no pions (55213)
- with one $\pi^\pm$ and no π^0 (39451)
- with one π^0 and no $\pi^\pm$ (15984)
- others (42074)

Charged current $\bar{\nu}_\mu$ events (6496)

- with no pions (2014)
- with one $\pi^\pm$ and no π^0 (1666)
- with one π^0 and no $\pi^\pm$ (561)
- others (2255)

Neutral current ν_μ & $\bar{\nu}_\mu$ events (50512)

- with no pions (16280)
- with one $\pi^\pm$ and no π^0 (9629)
- with one π^0 and no $\pi^\pm$ (9672)
- others (14931)

Average number of n (and γ) in different categories

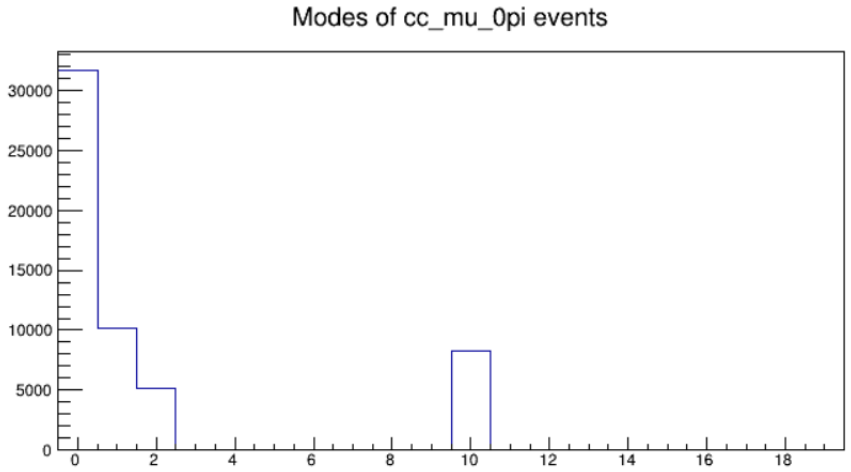
	CC ν_μ	CC $\bar{\nu}_\mu$	NC ν_μ	NC $\bar{\nu}_\mu$
No pions	2.1 n (0.18 γ)	3.3 n (0.20 γ)	2.5 n (0.20 γ)	2.6 n (0.23 γ)
1 $\pi^\pm$ and no π^0	1.9 n (0.55 γ)	2.0 n (0.78 γ)	2.0 n (0.65 γ)	2.1 n (0.67 γ)
1 π^0 and no $\pi^\pm$	1.6 n (2.3 γ)	2.8 n (2.4 γ)	2.0 n (2.2 γ)	2.1 n (2.3 γ)
Others	2.1 n (4.1 γ)	2.6 n (4.7 γ)	2.3 n (4.0 γ)	2.6 n (4.5 γ)

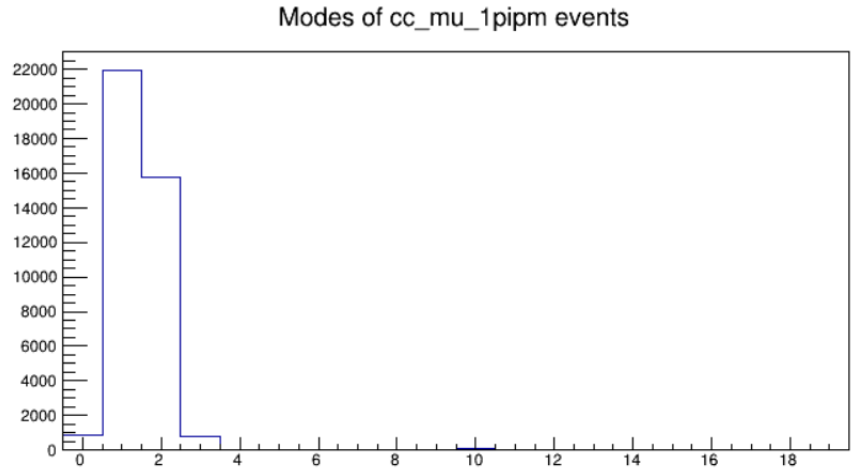
Error for CC ν_μ with 0 pions:
0.01 (n) $<$ 0.01 (γ)

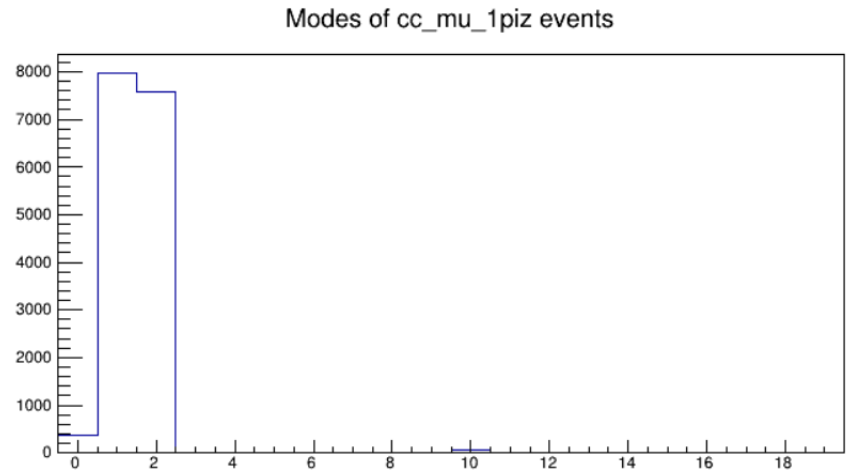
Error for NC ν_μ with 0 pions:
0.03 (n) $<$ 0.01 (γ)

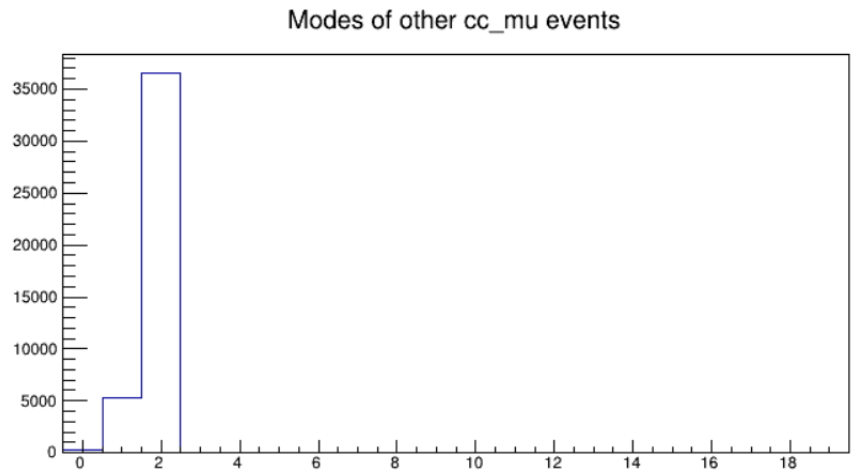
Charged Current ν_μ Events

Modes for CC ν_μ events



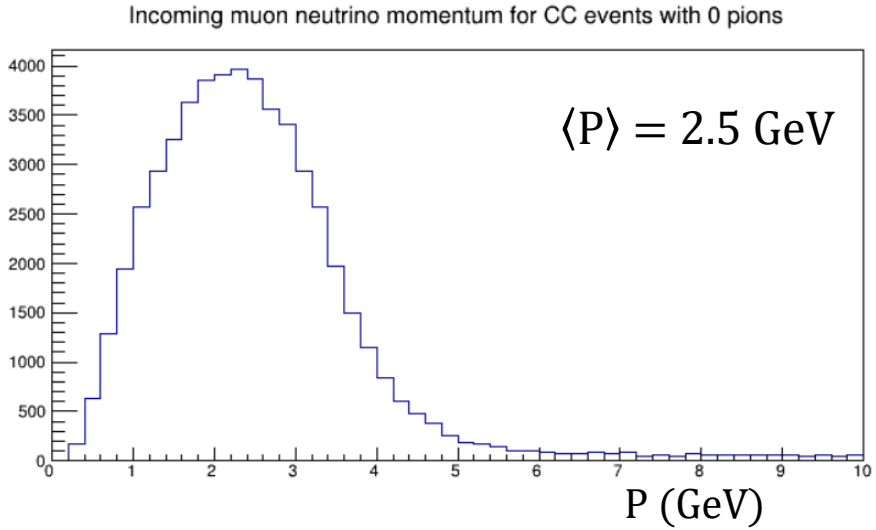


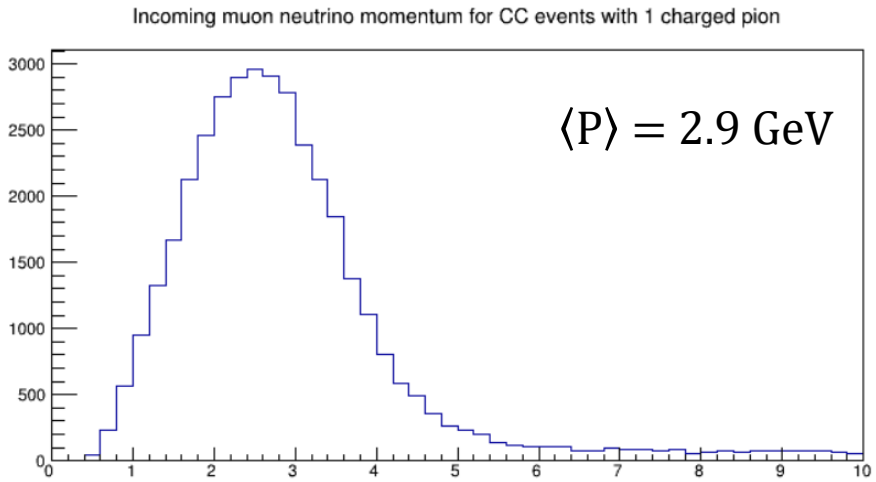


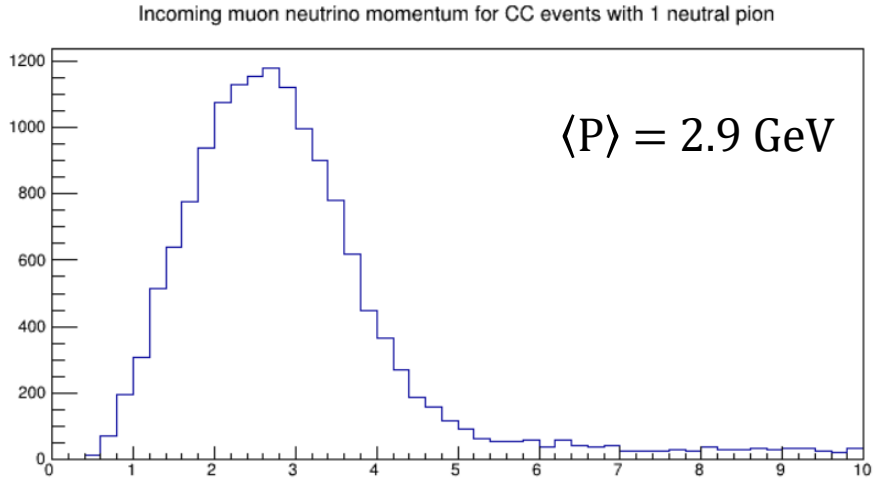


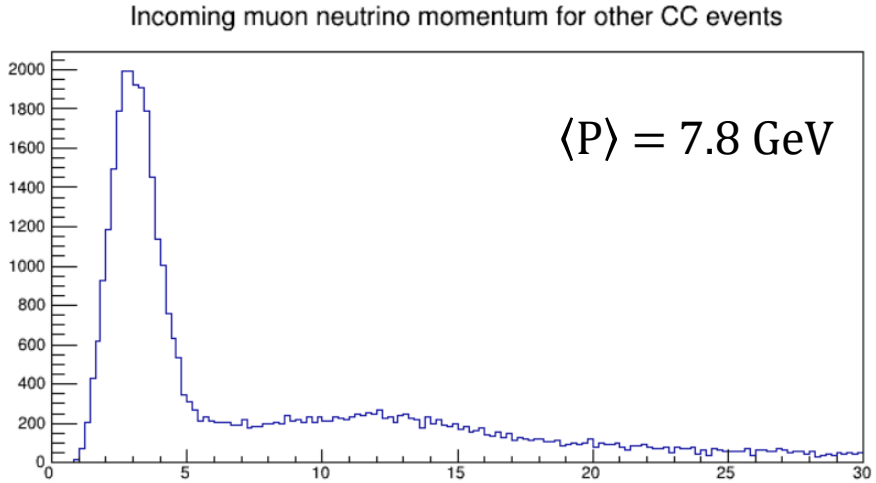
Modes: 0 – QE; 1 – RES; 2 – DIS; 3 – COH; 10 - MEC

Incident ν_μ momentum



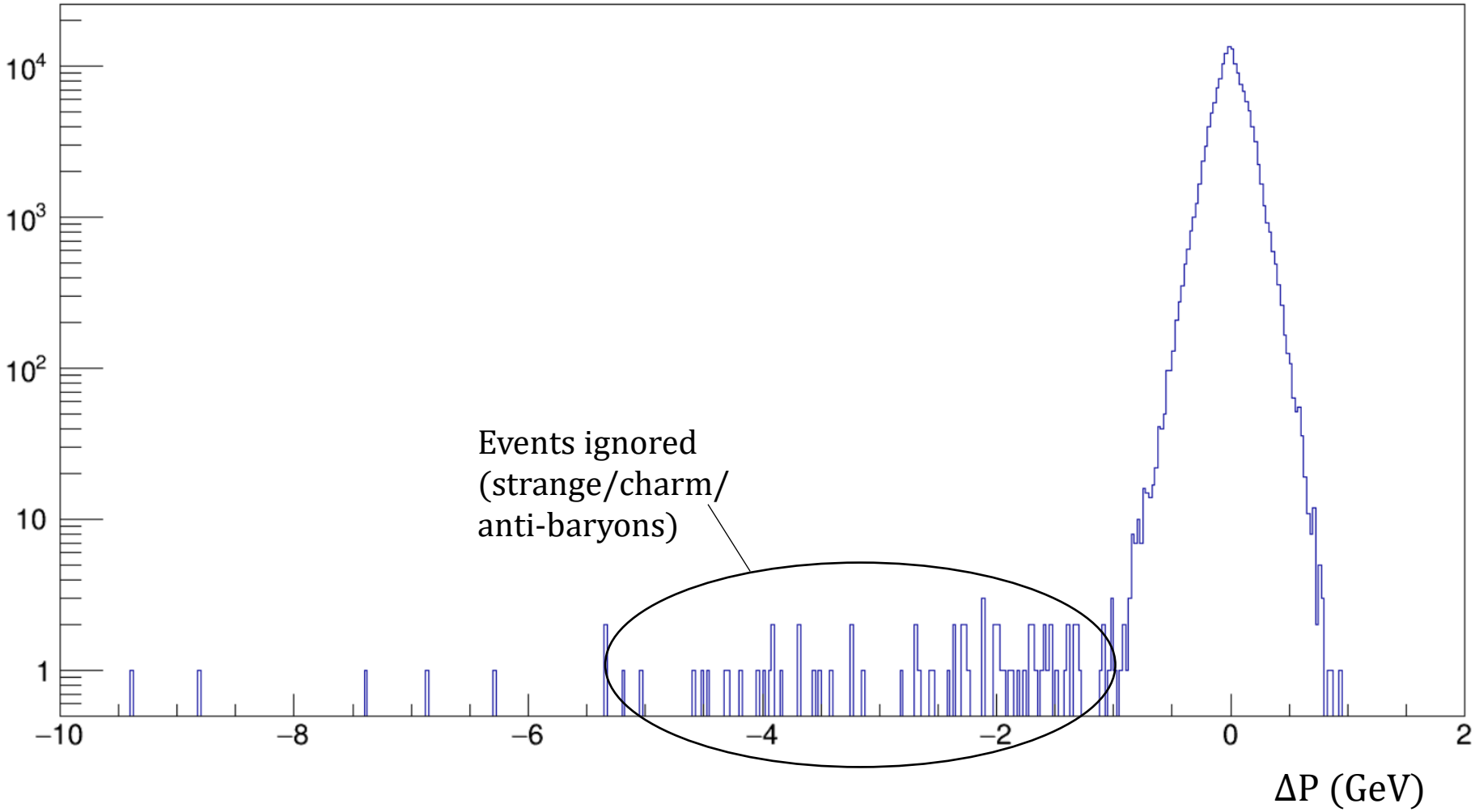




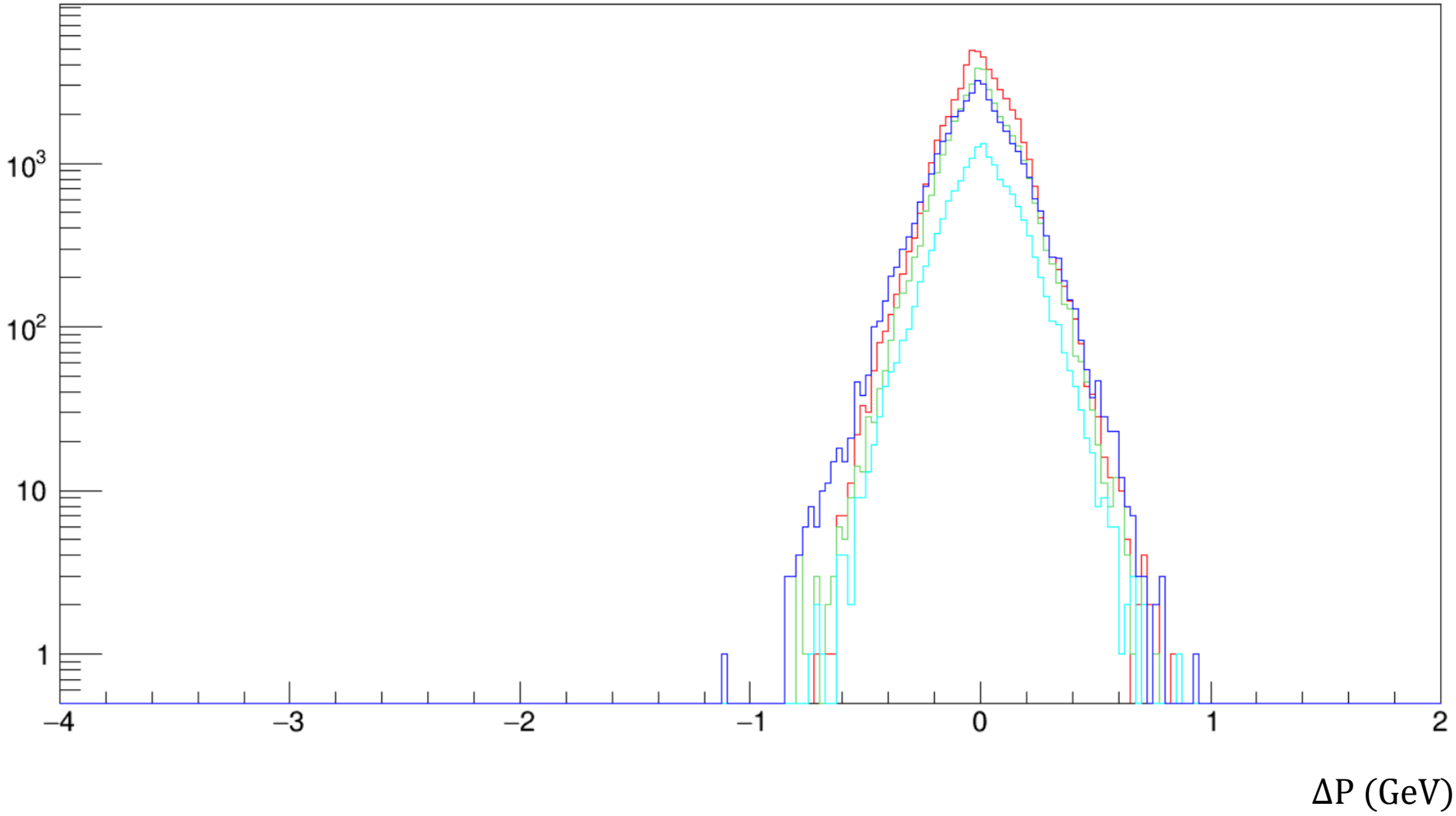


ΔP for all CC ν_μ events – full CALO

All plots use truth information



ΔP for CC ν_μ events – full CALO (no n nor γ ignored)



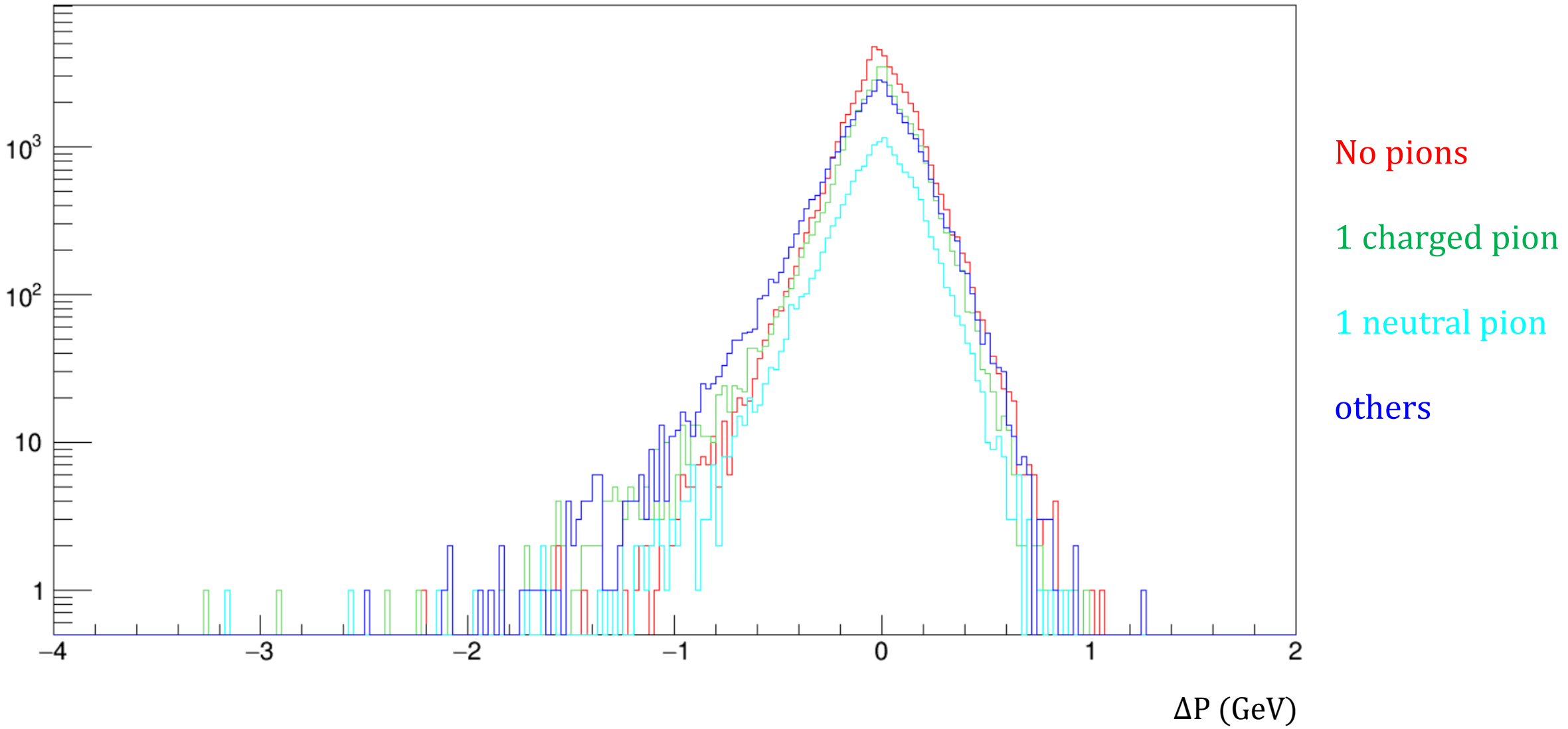
No pions

1 charged pion

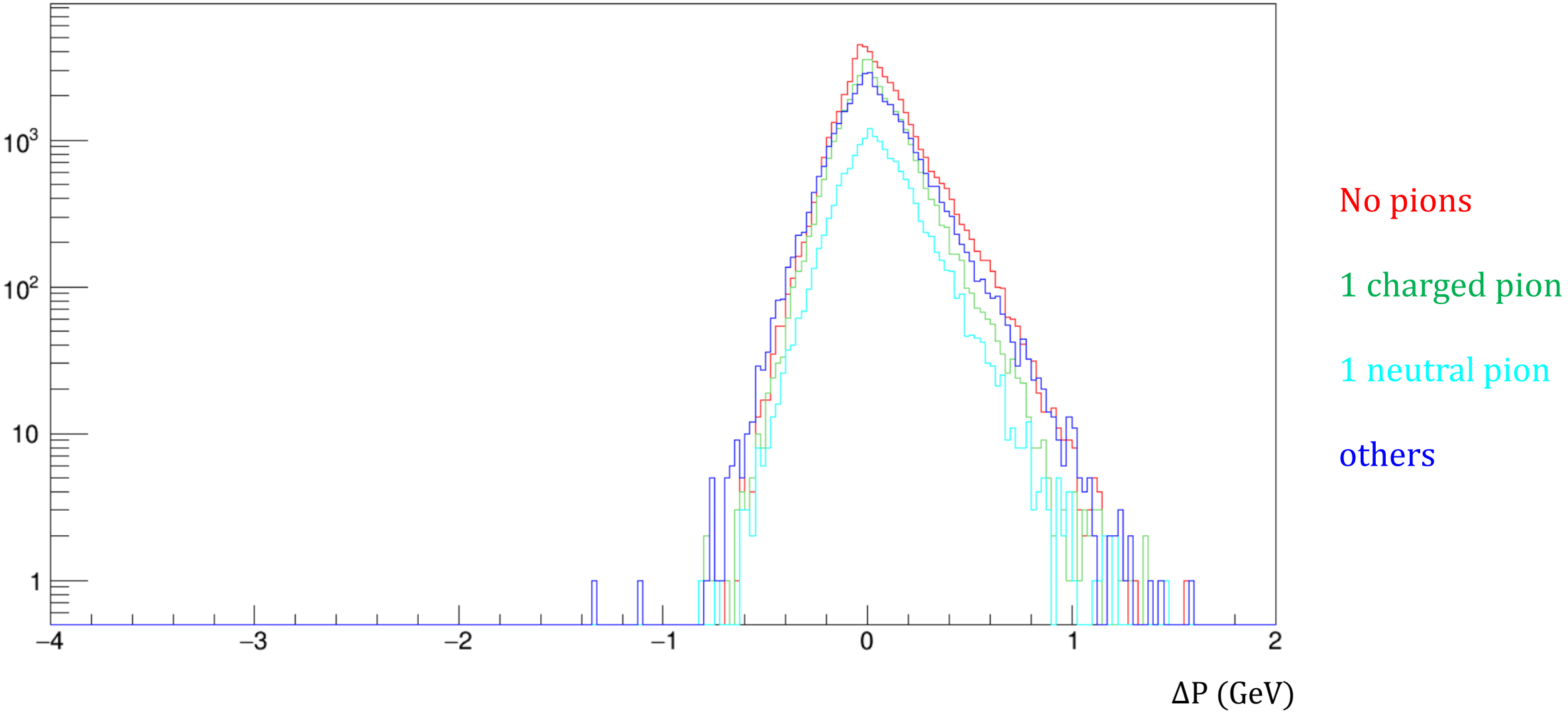
1 neutral pion

others

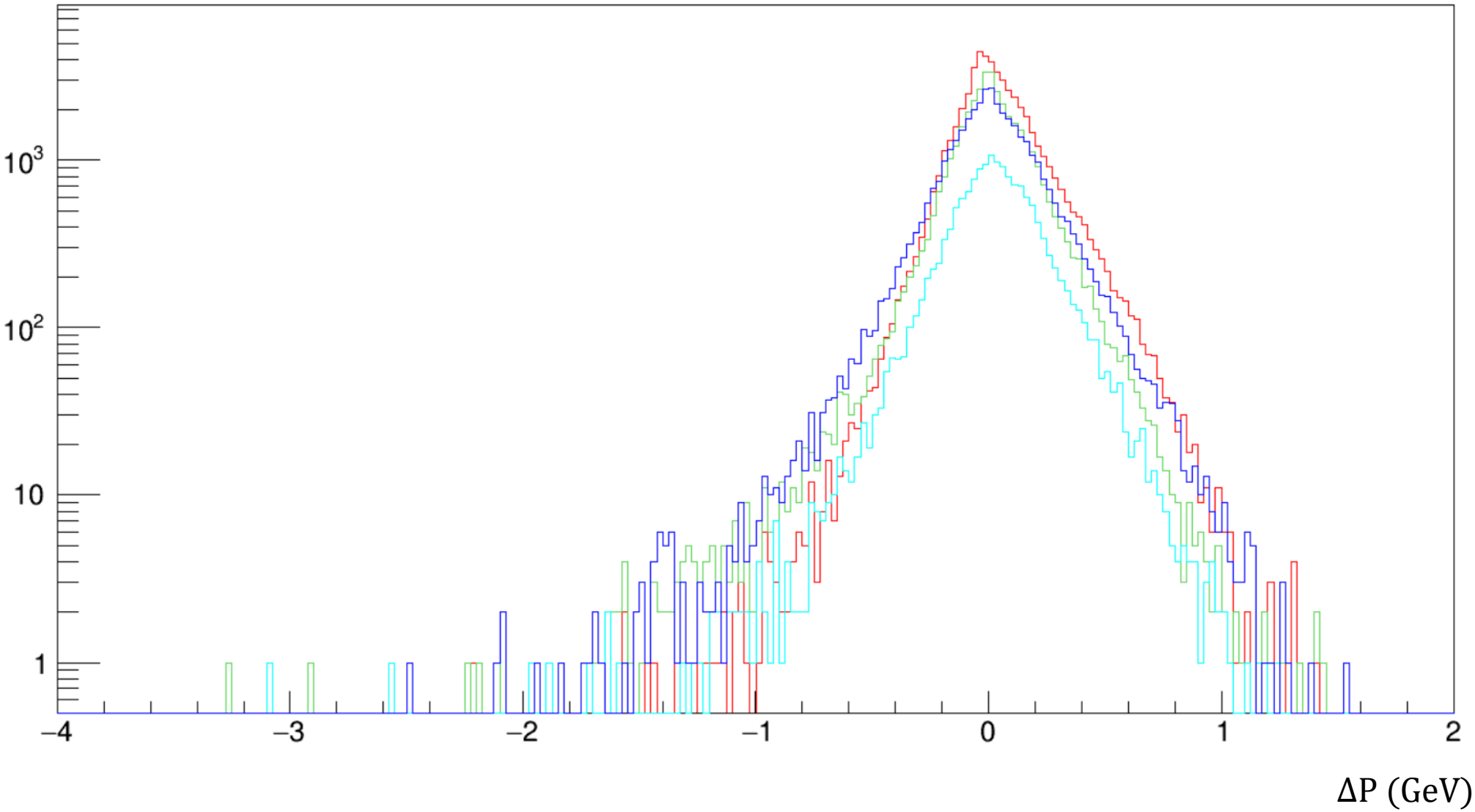
ΔP for CC ν_μ events – ignoring n and γ in the endcap



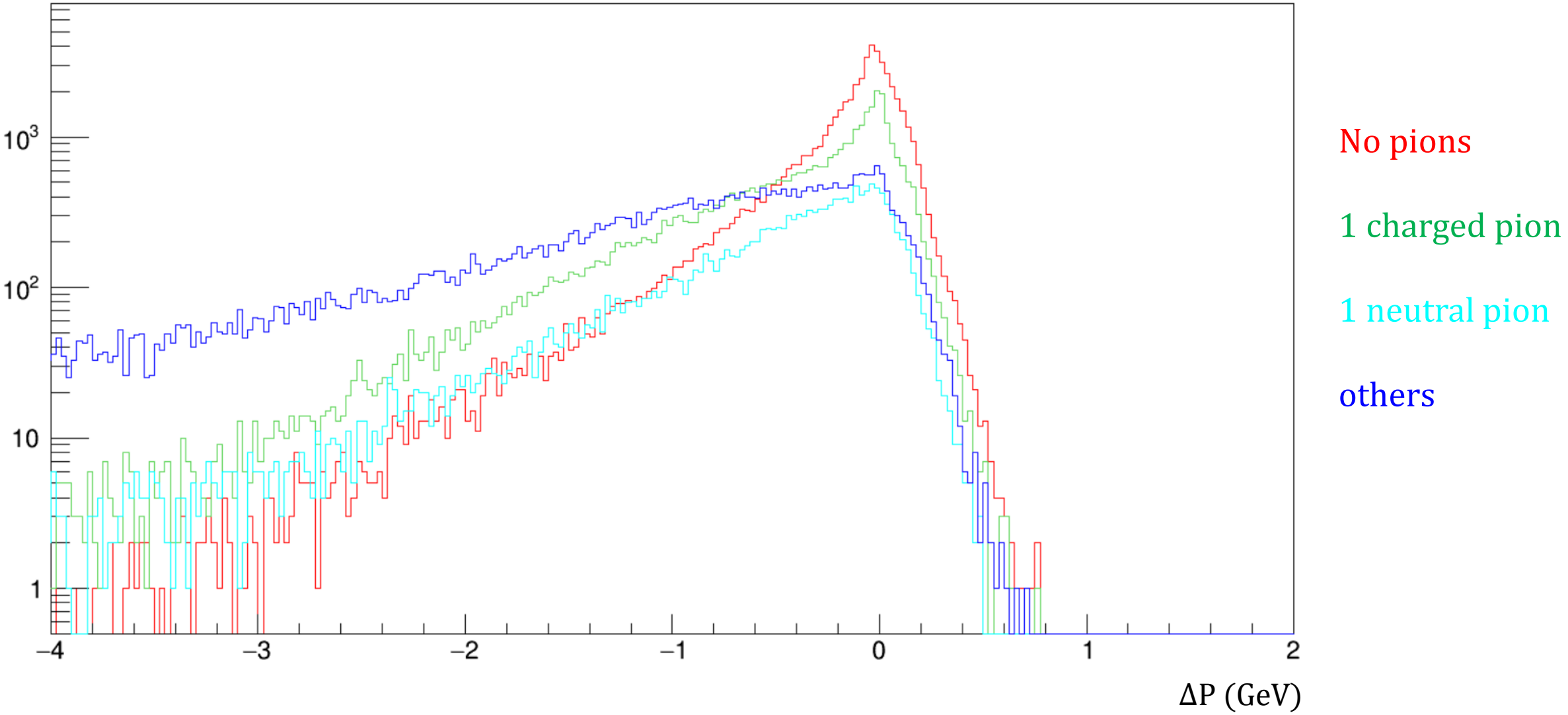
ΔP for CC ν_μ events – ignoring n and γ in the upstream barrel



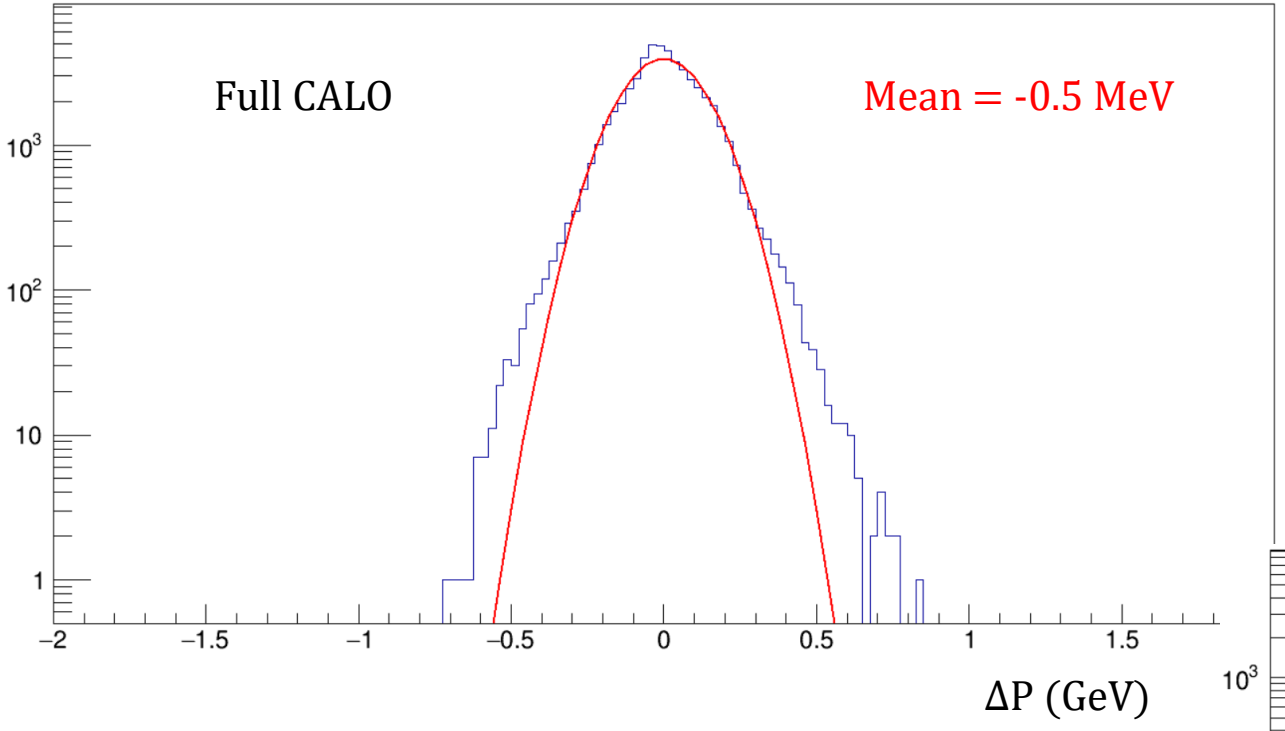
ΔP for CC ν_μ events – ignoring n and γ in endcap and upstream barrel



ΔP for CC ν_μ events – ignoring n and γ in the downstream barrel

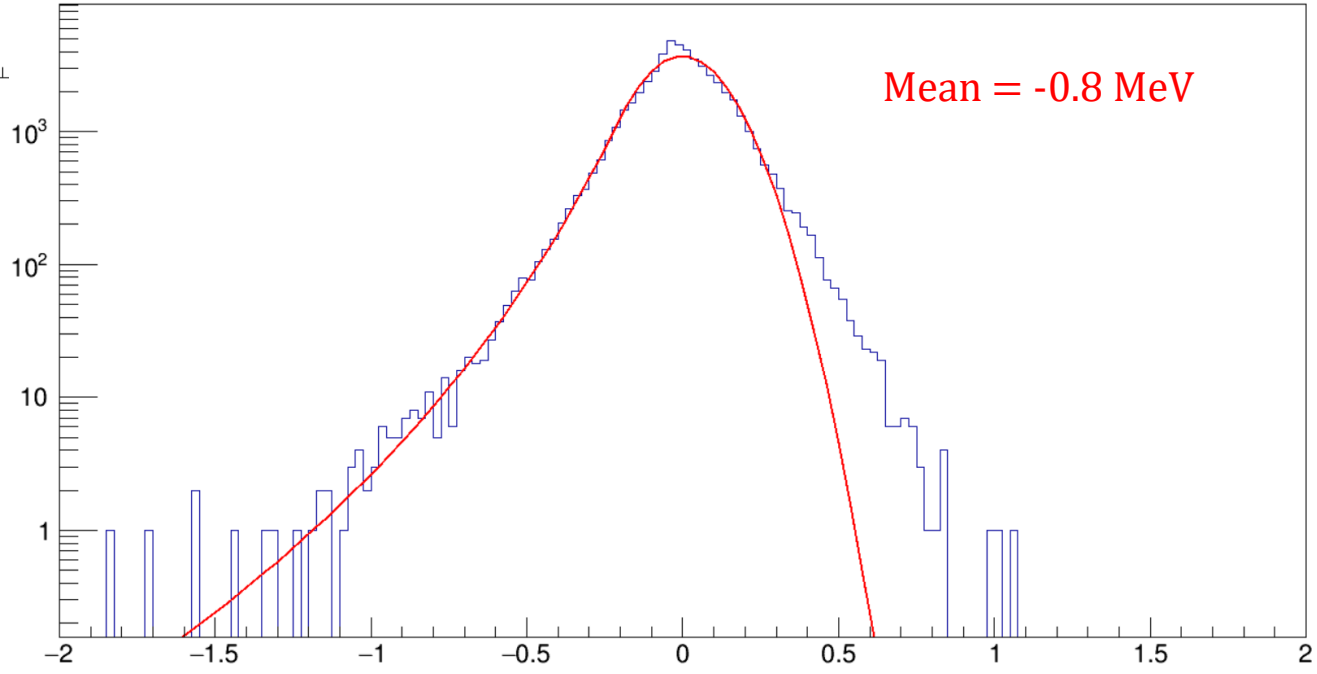


Fit attempts – CC events with no pions



Fitting with CrystalBall function – misses the upper tail and peak

Ignoring n and γ in the endcap



Conclusions

The selected categories are all affected similarly by removal of different CALO pieces (except downstream barrel case)

Comparing the energy of the n and γ in the different categories could provide insight into the behavior of the ΔP plots

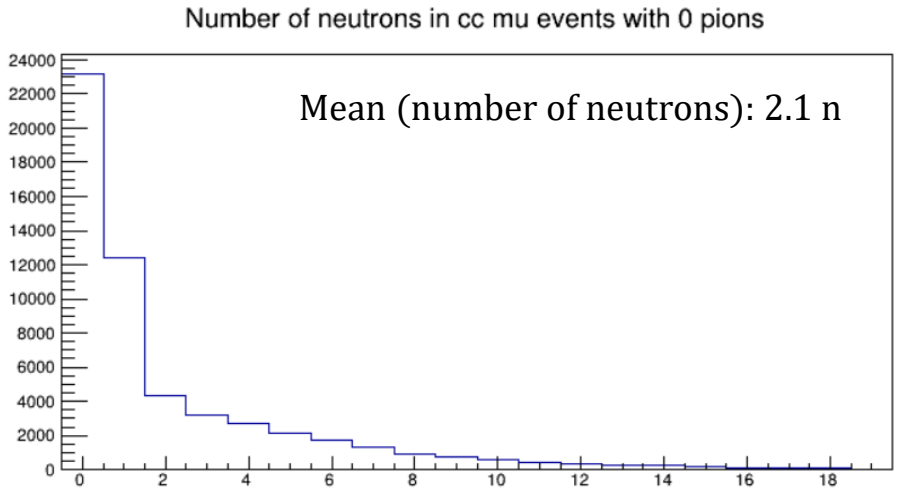
Future work:

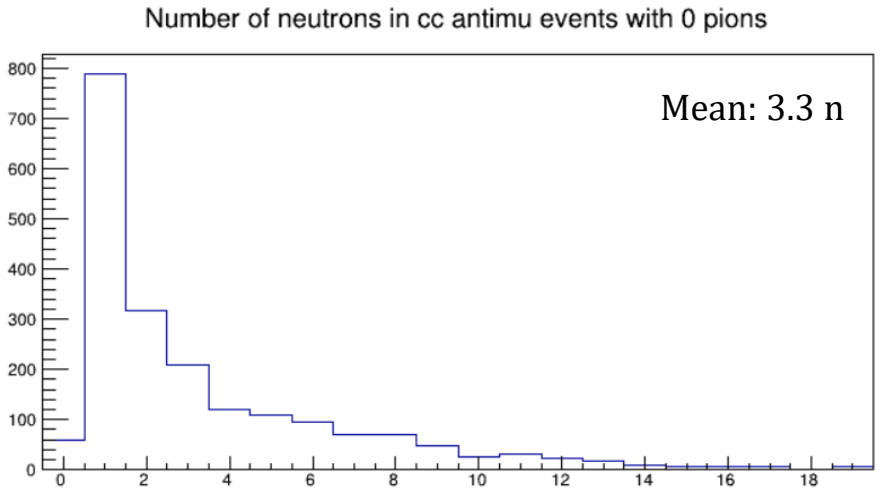
Finding the optimal fit for the ΔP plots

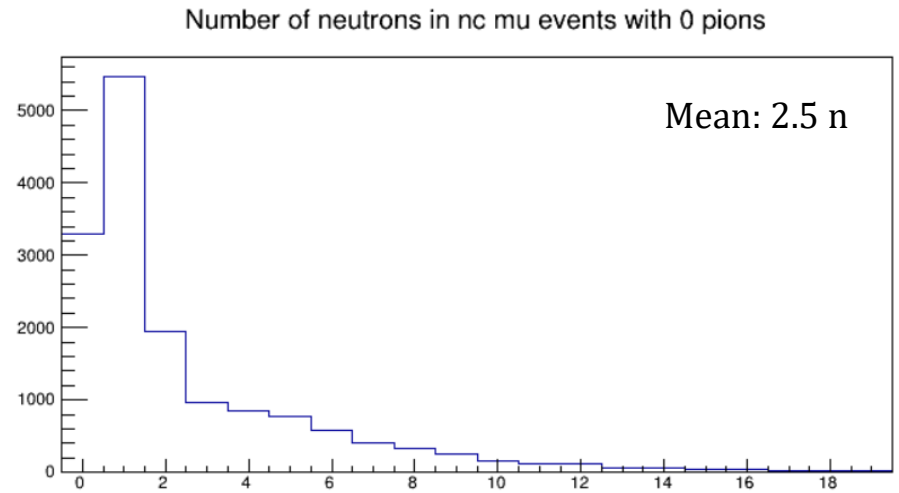
Already tried CrystalBall function – try a modified version e.g., CrystalBall and an exponential function

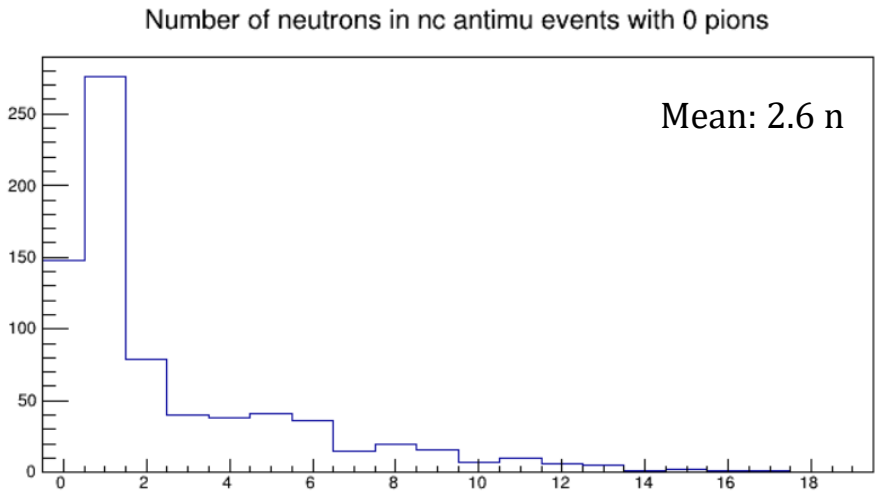
Extras

Number of neutrons for 0 pion events

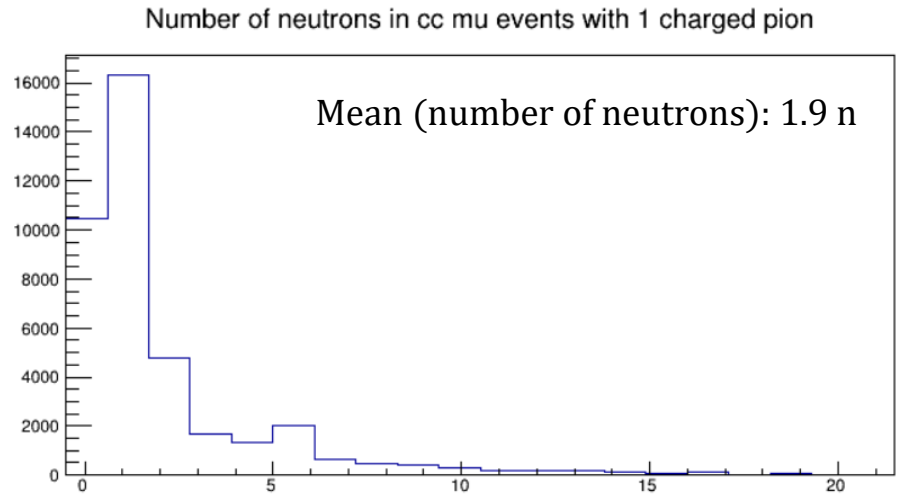


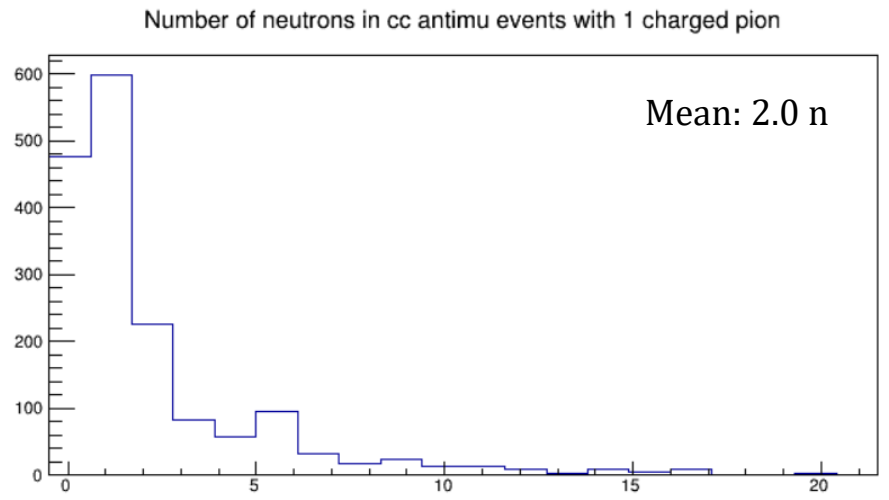


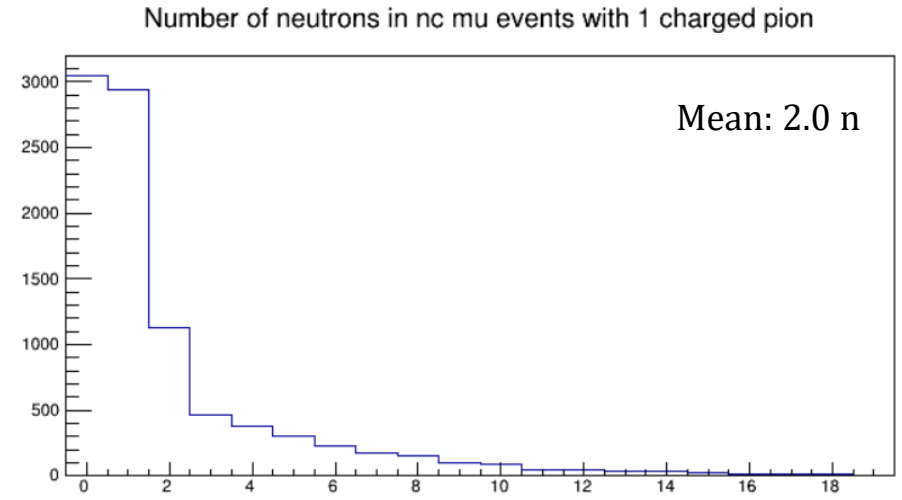


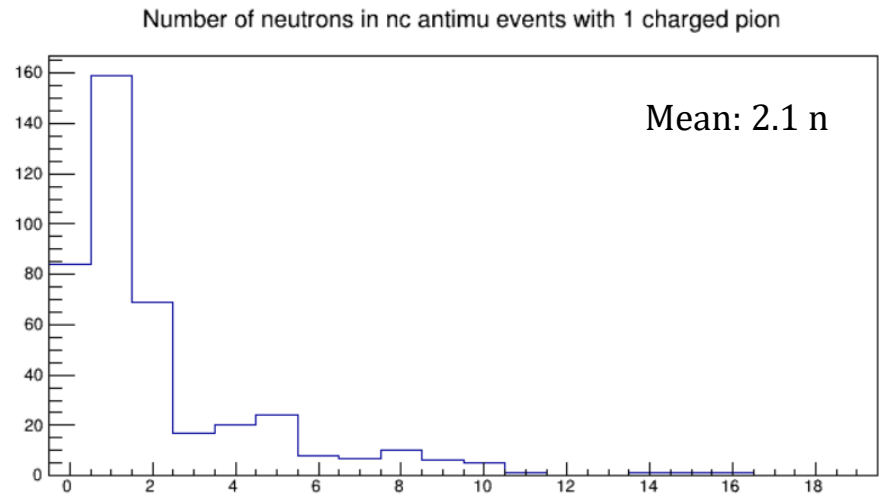


Number of neutrons for 1 $\pi^{\pm}$ events

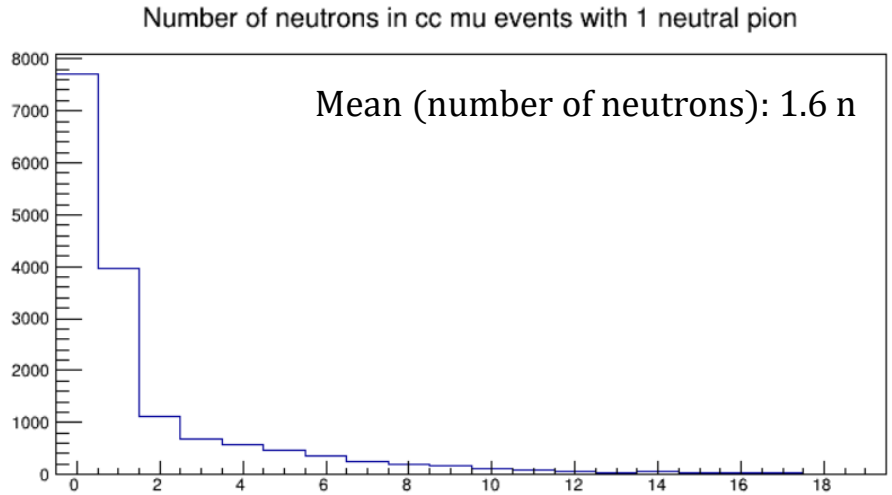


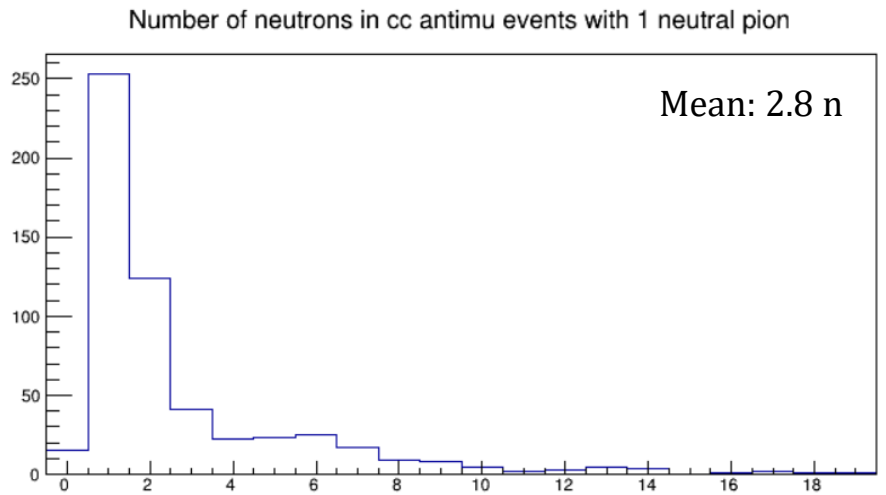


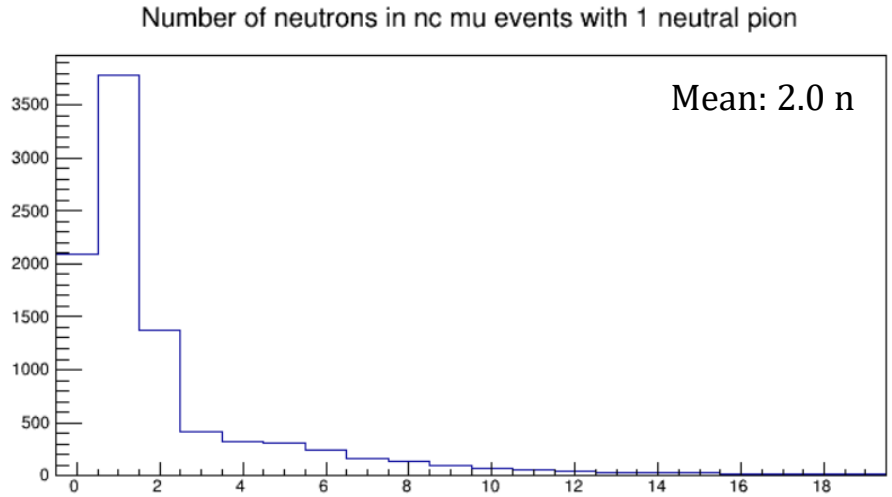


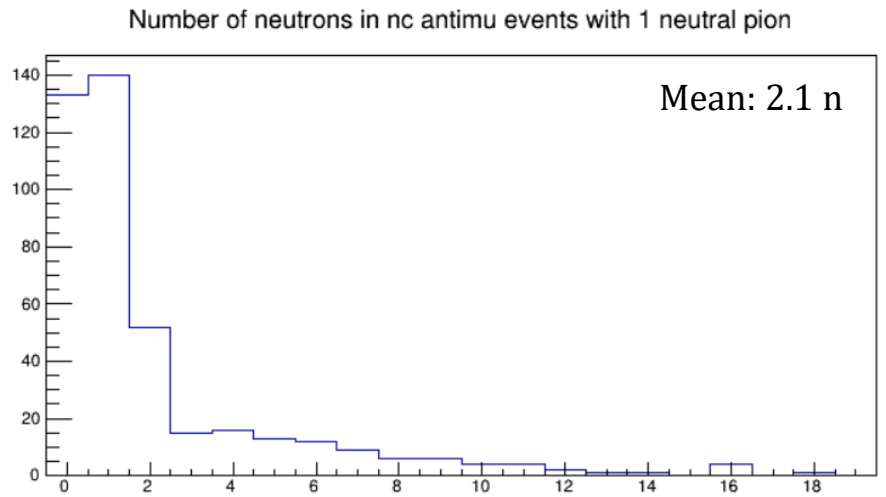


Number of neutrons for 1 π^0 events

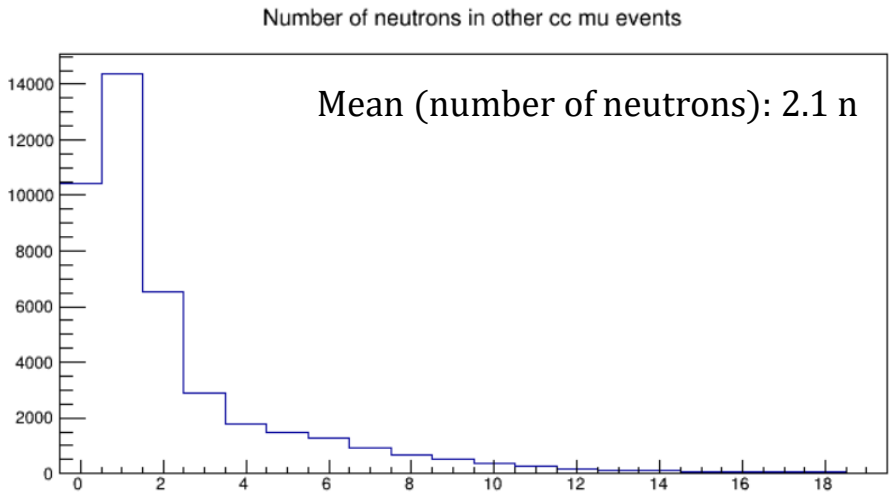


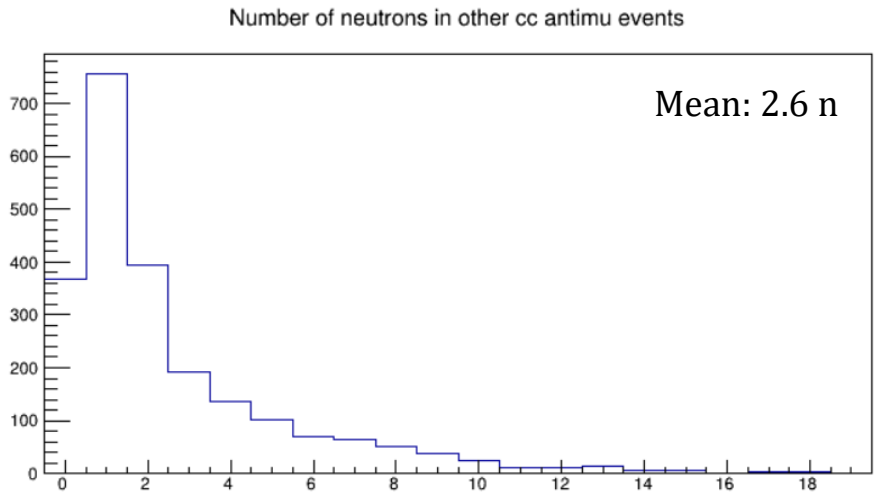


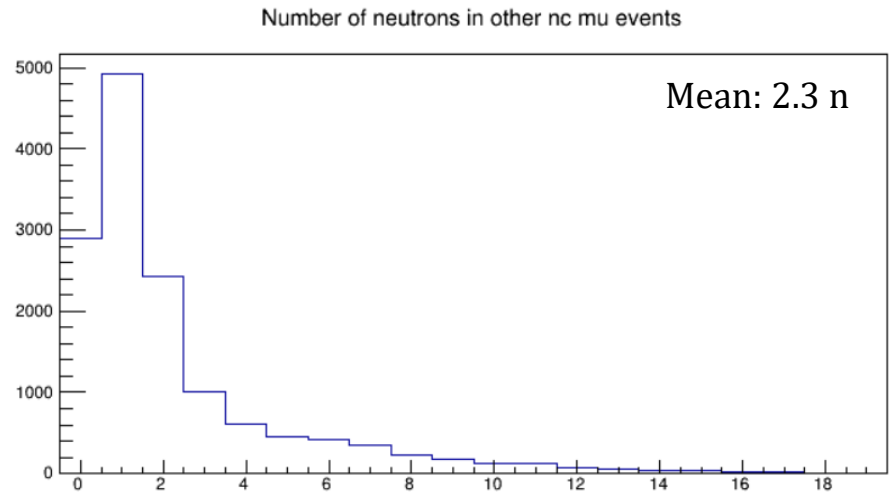


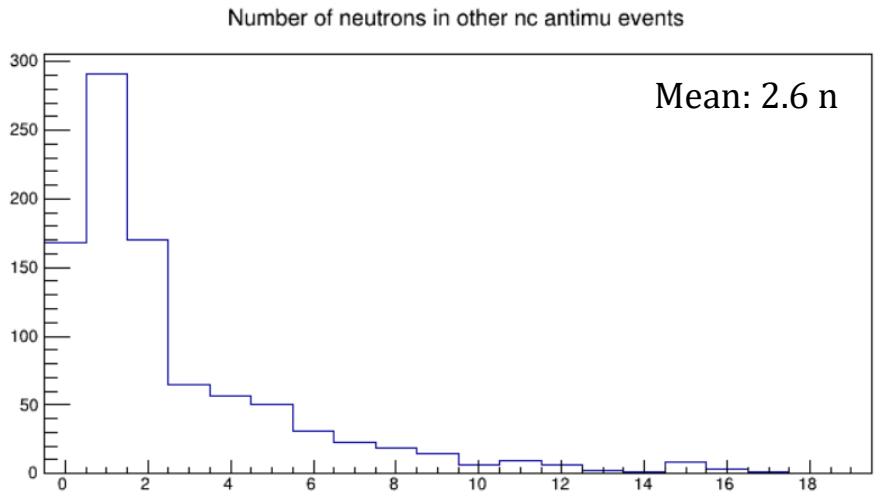


Number of neutrons for other events

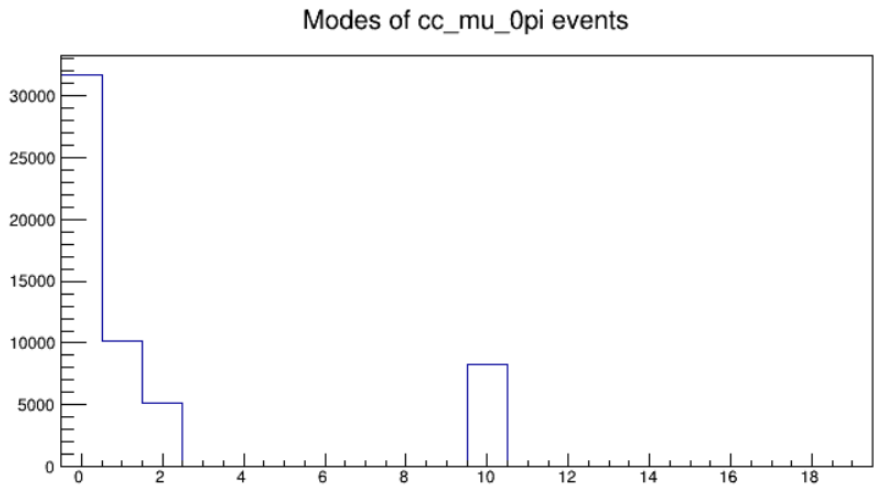


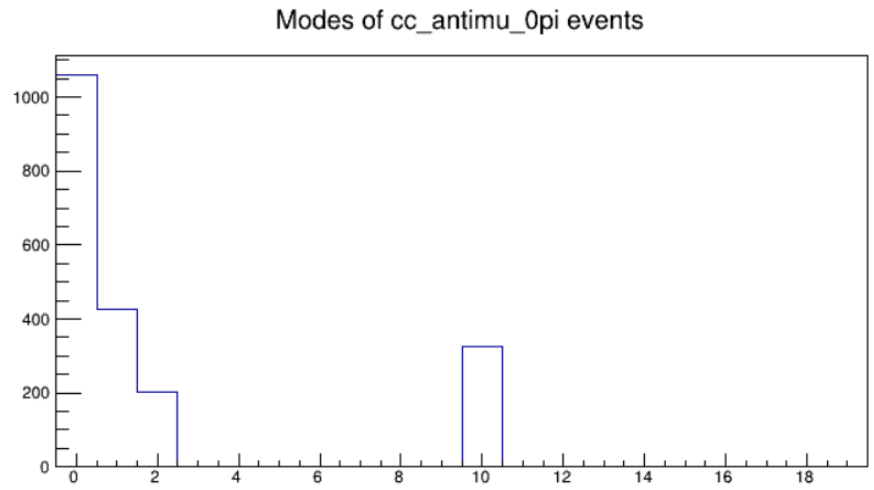


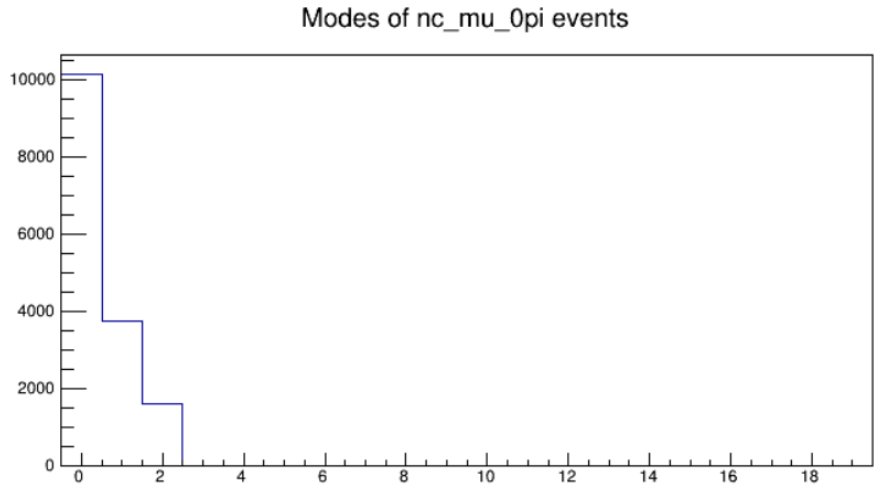


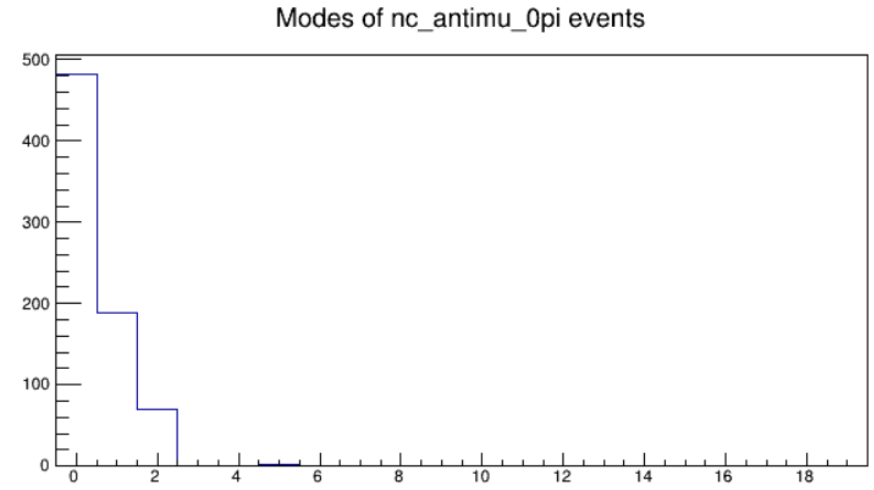


Modes for events with no pions



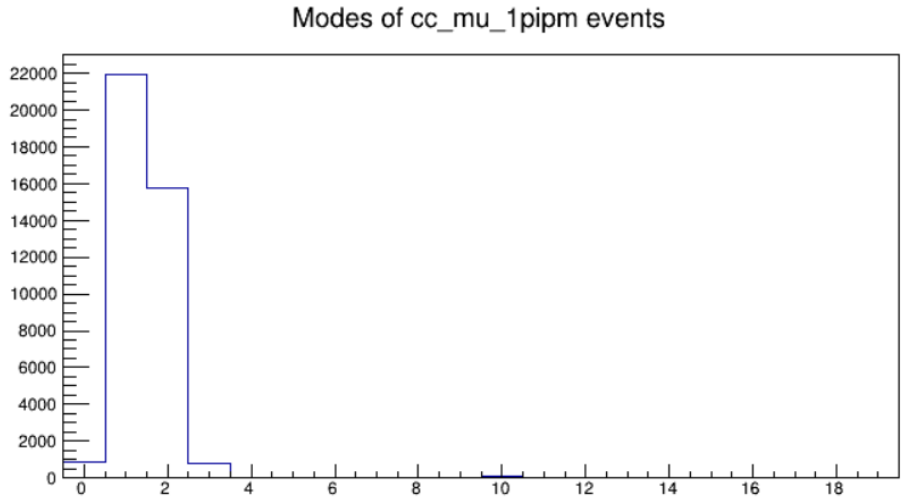


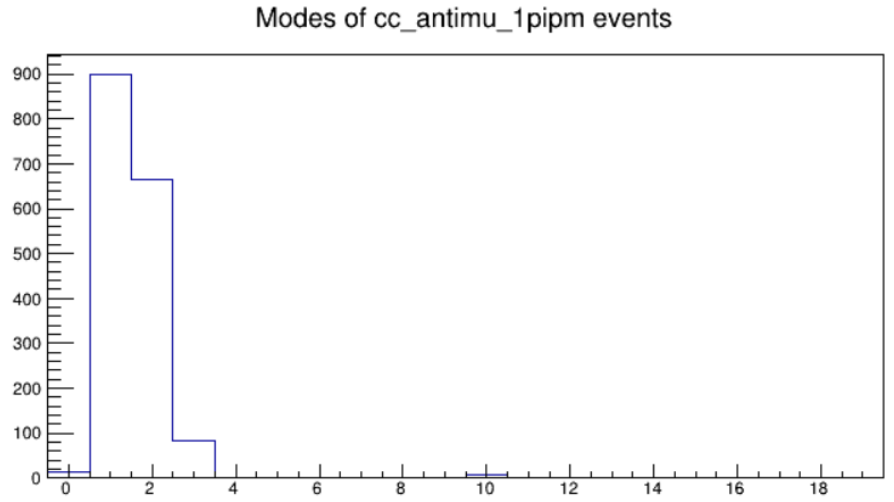


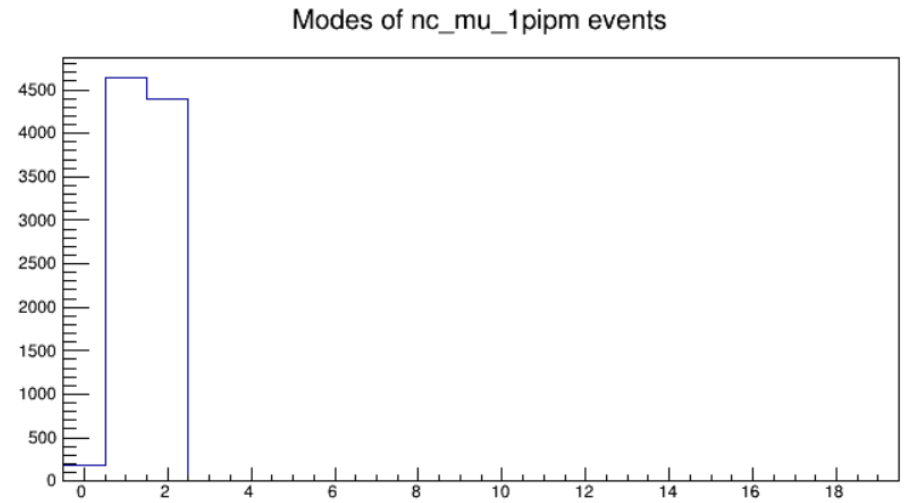


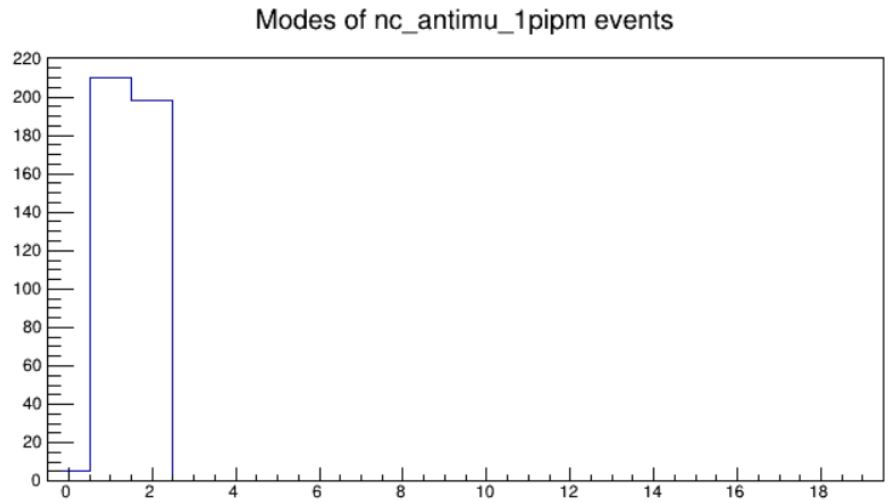
Modes: 0 – QE; 1 – RES; 2 – DIS; 3 – COH; 10 - MEC

Modes for events with 1 $\pi^{\pm}$



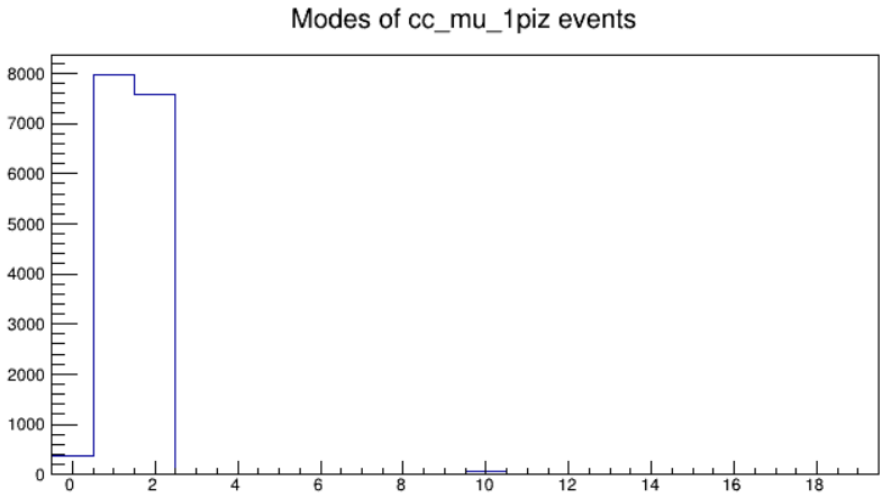


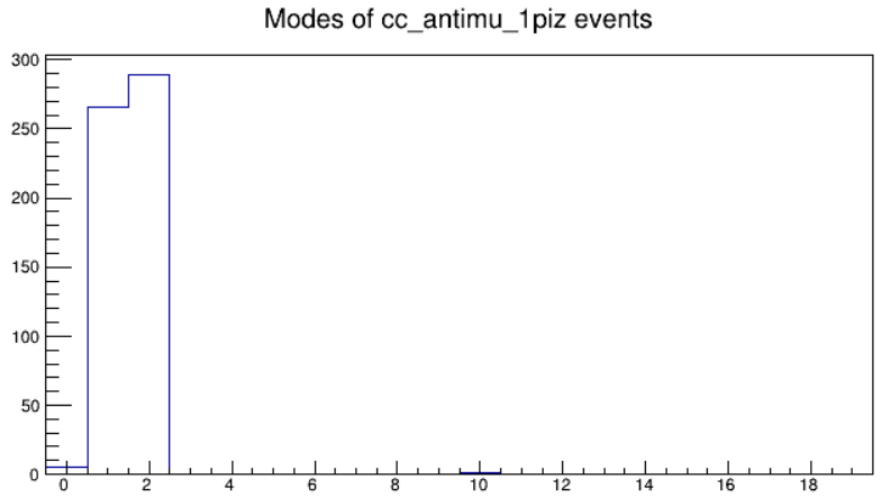


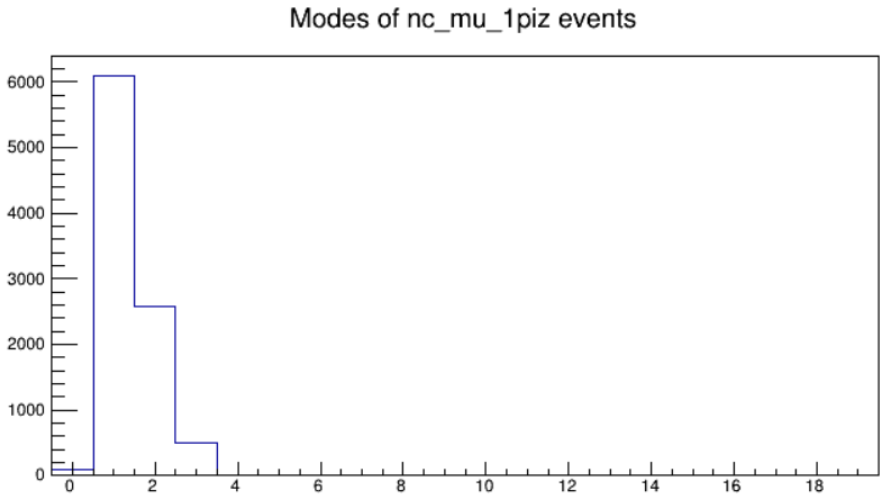


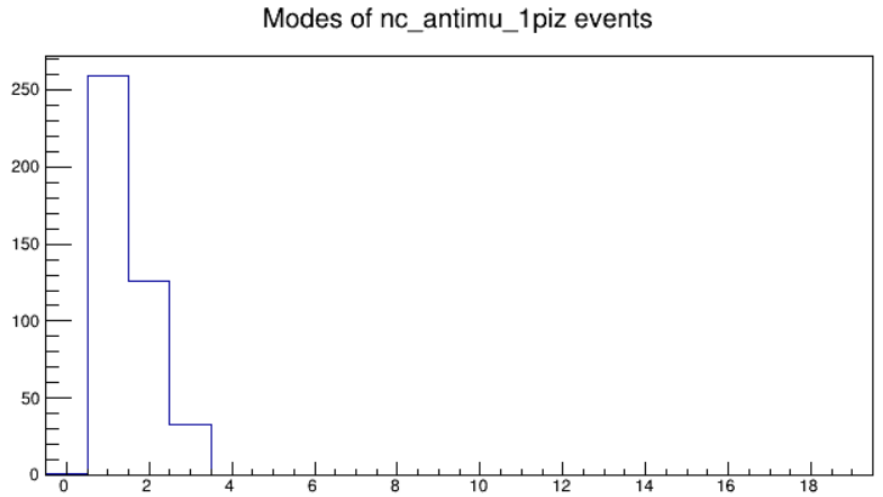
Modes: 0 – QE; 1 – RES; 2 – DIS; 3 – COH; 10 - MEC

Modes for events with 1 π^0



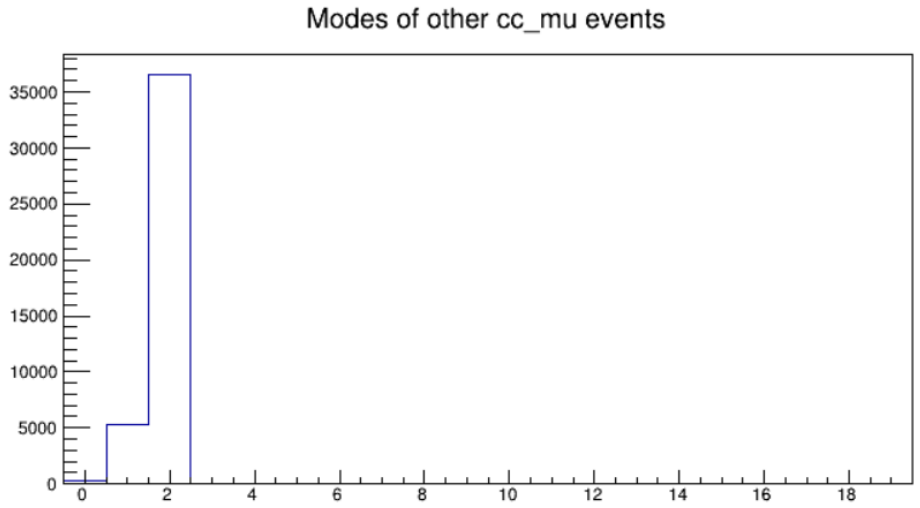


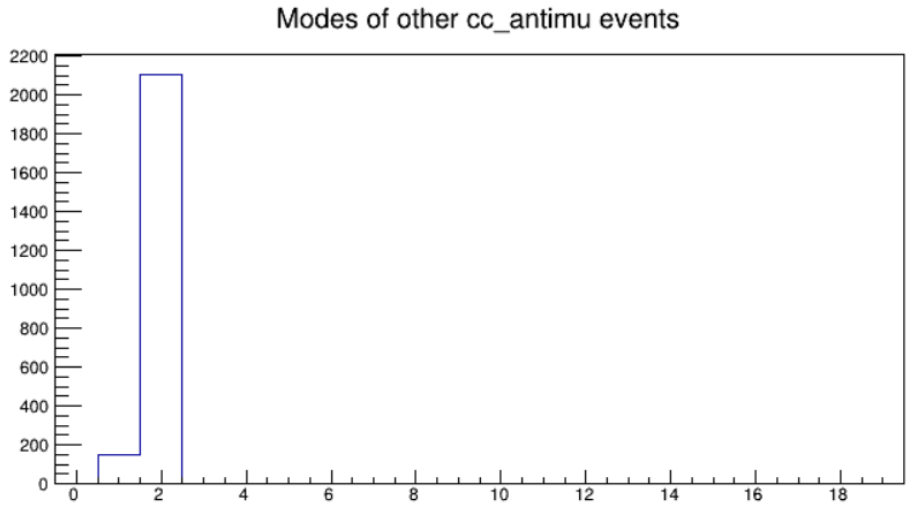


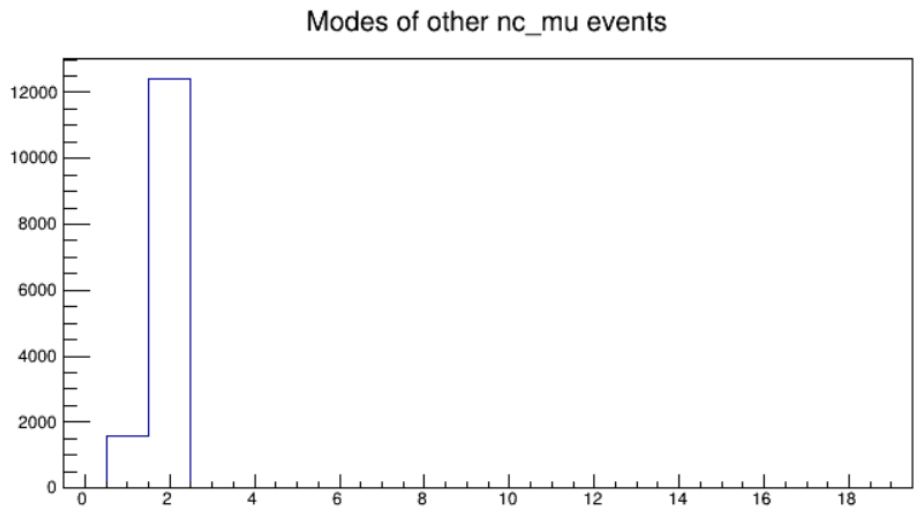


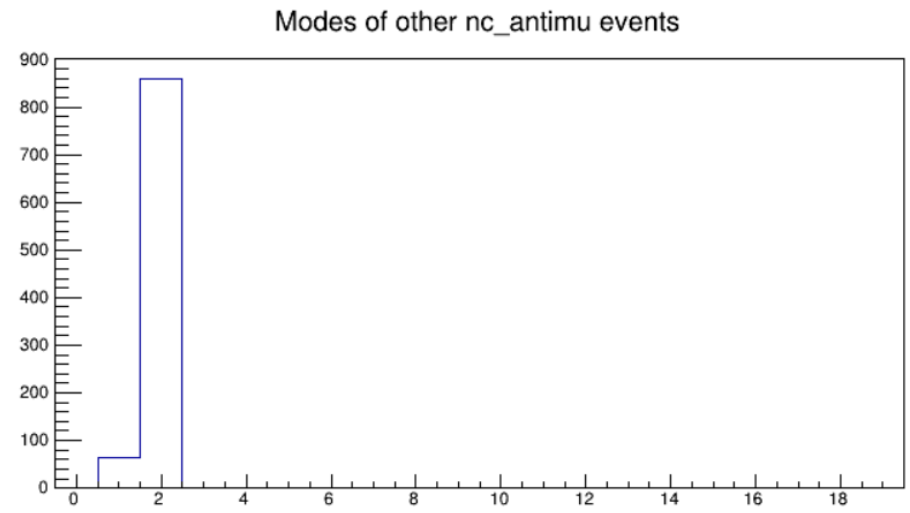
Modes: 0 – QE; 1 – RES; 2 – DIS; 3 – COH; 10 - MEC

Modes for other events



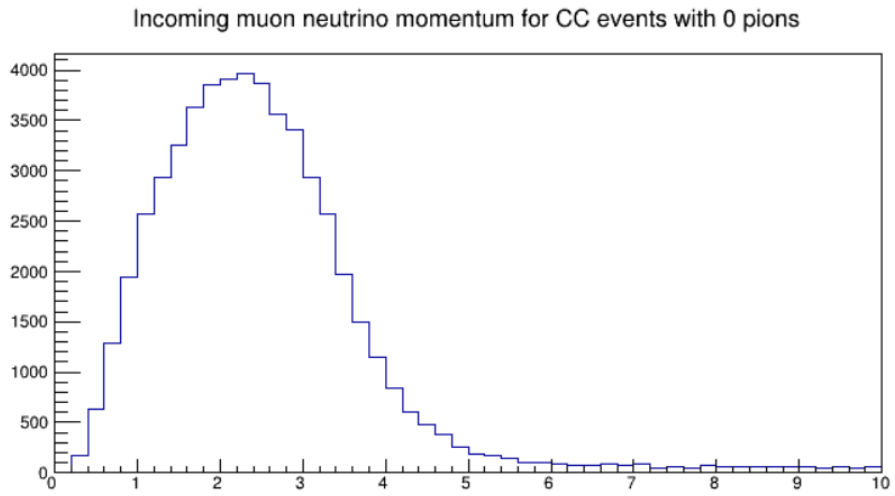


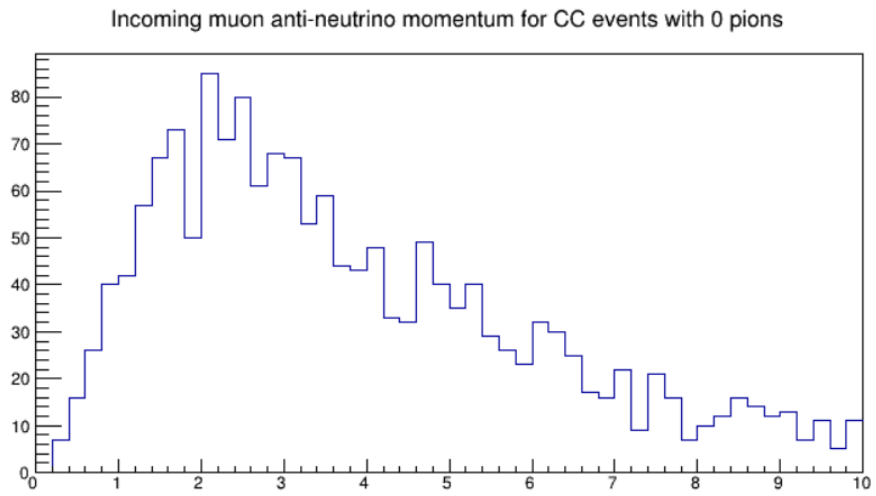


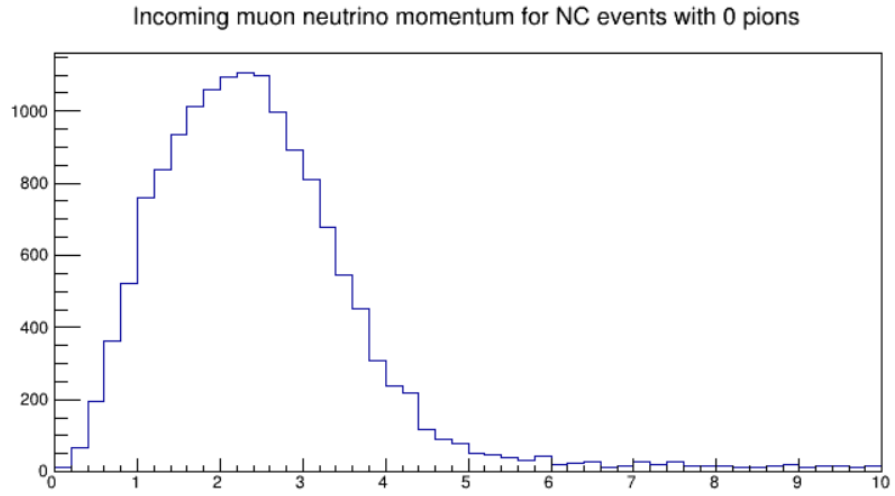


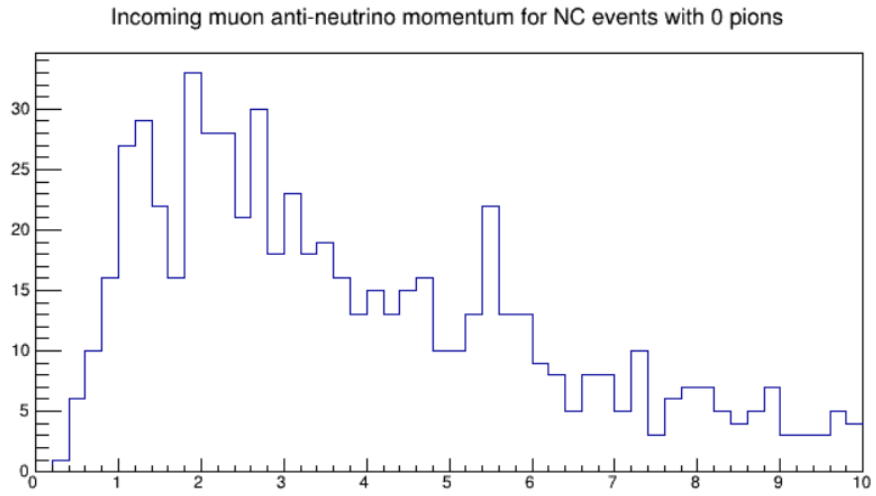
Modes: 0 – QE; 1 – RES; 2 – DIS; 3 – COH; 10 - MEC

Incident ν_μ momentum – 0 pions

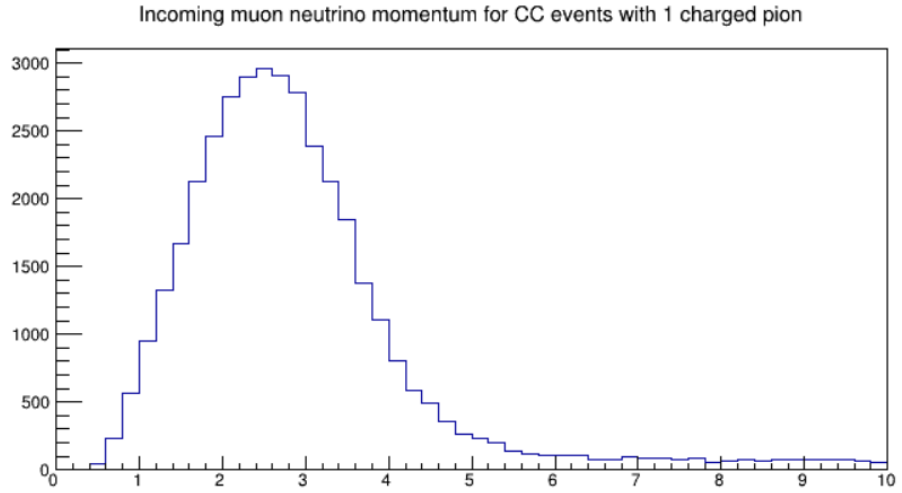


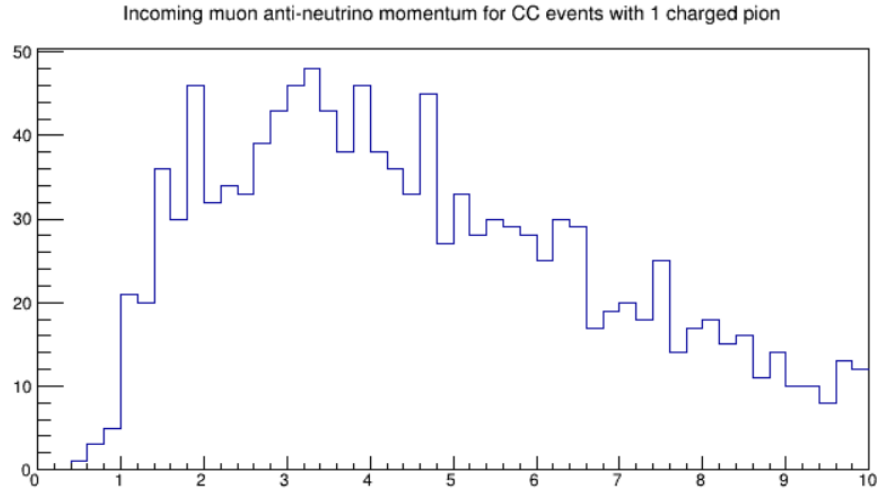


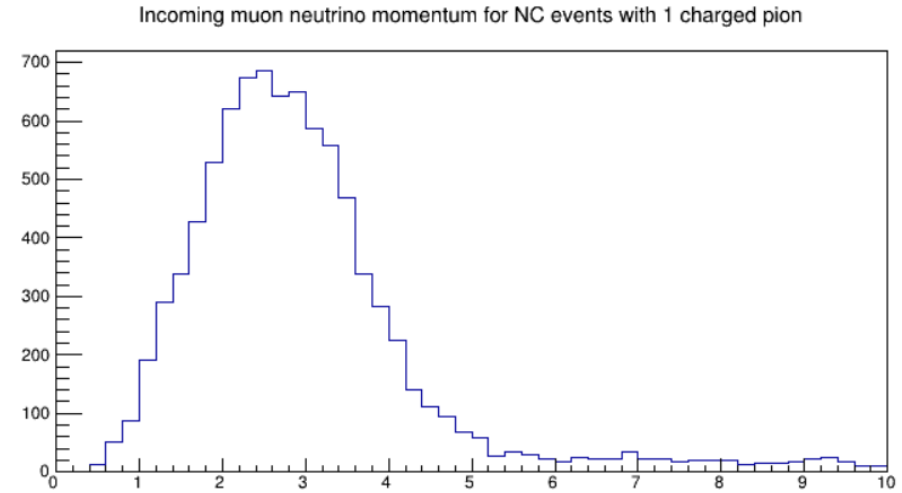


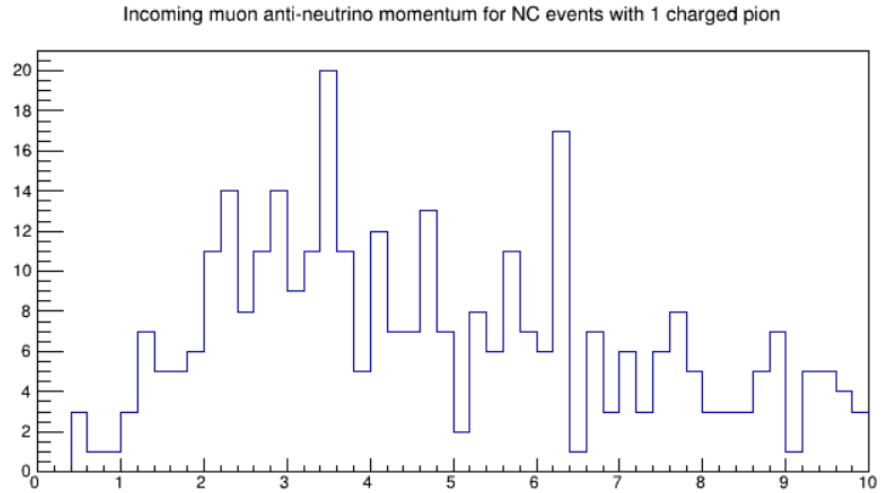


Incident ν_μ momentum – 1 $\pi^{\pm}$ (no π^0)

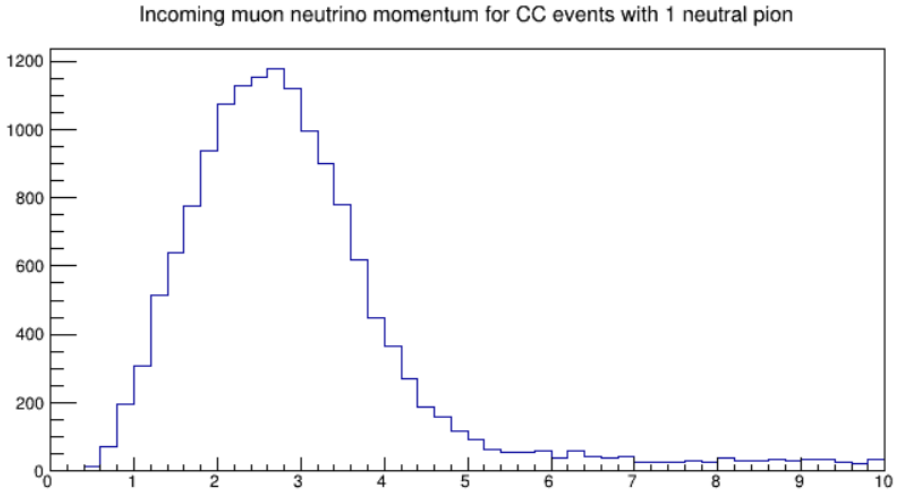


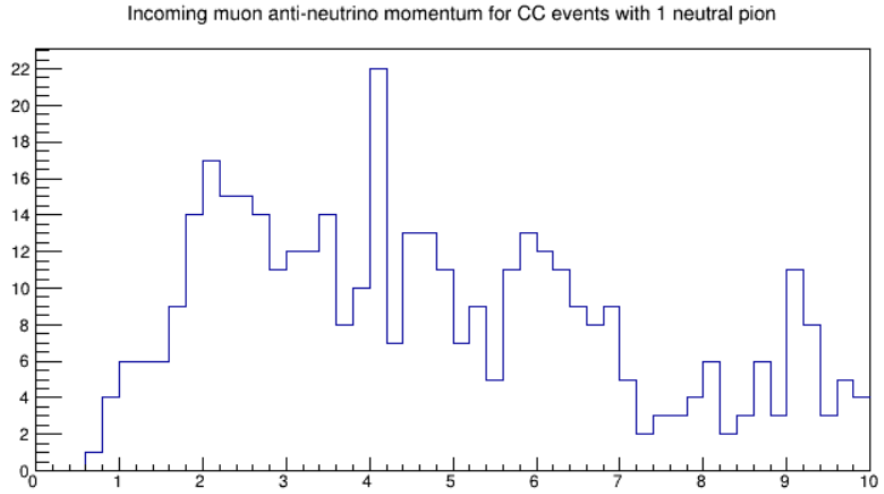


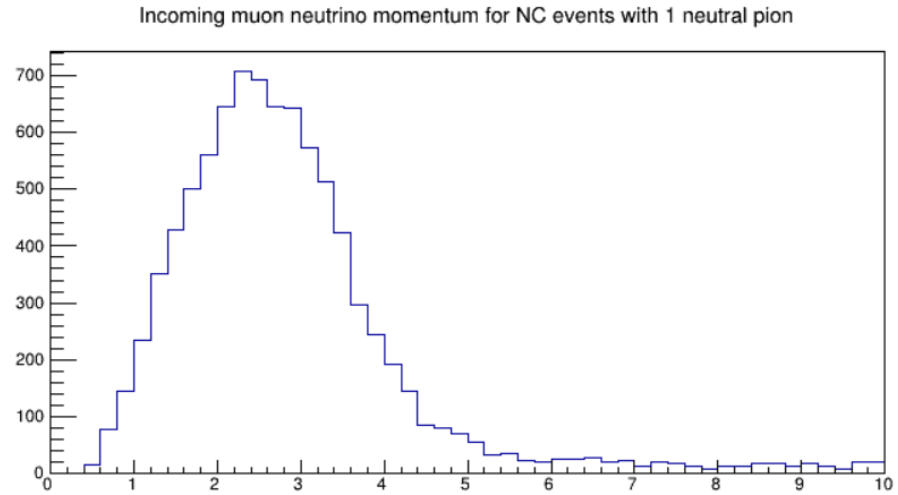


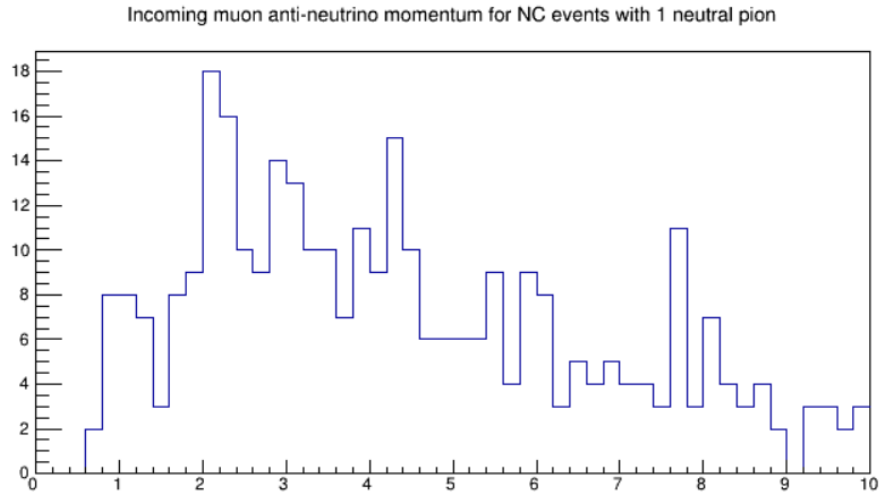


Incident ν_μ momentum – 1 π^0 (no $\pi^\pm$)

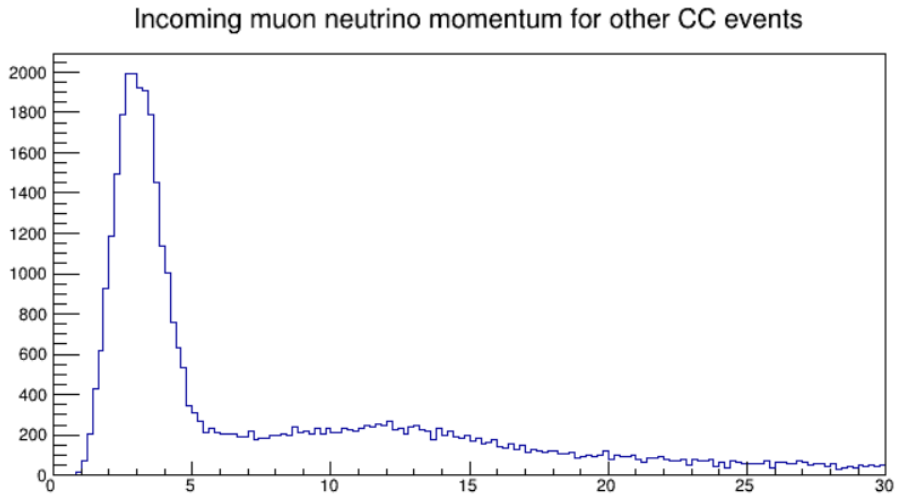


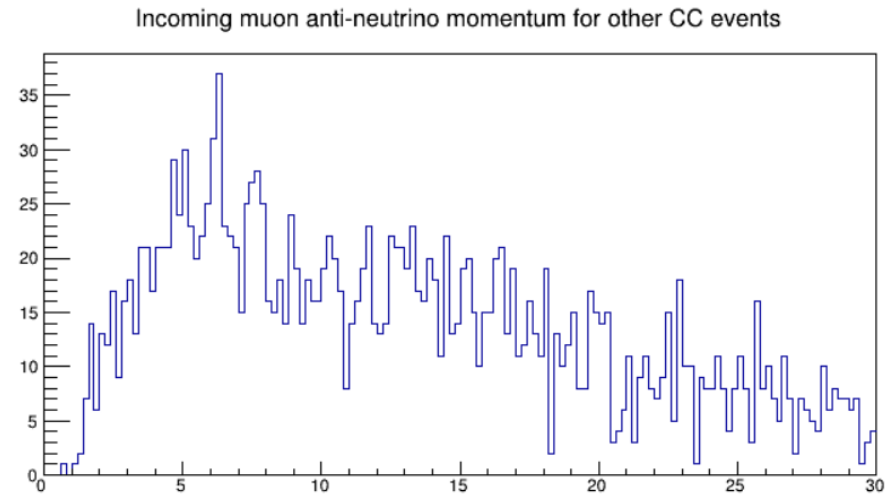


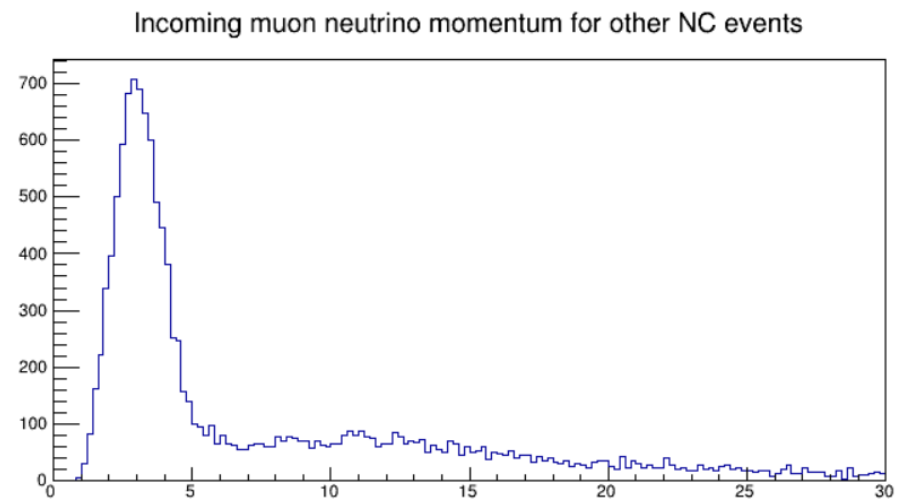


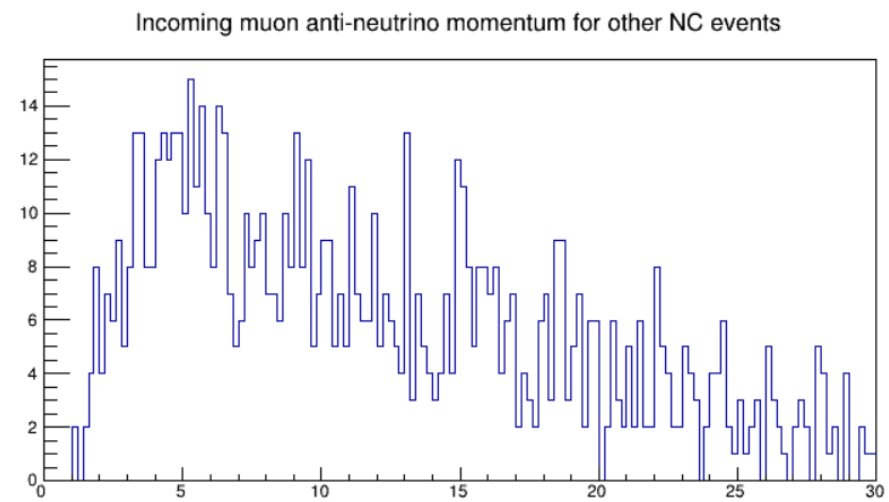


Incident ν_μ momentum – others



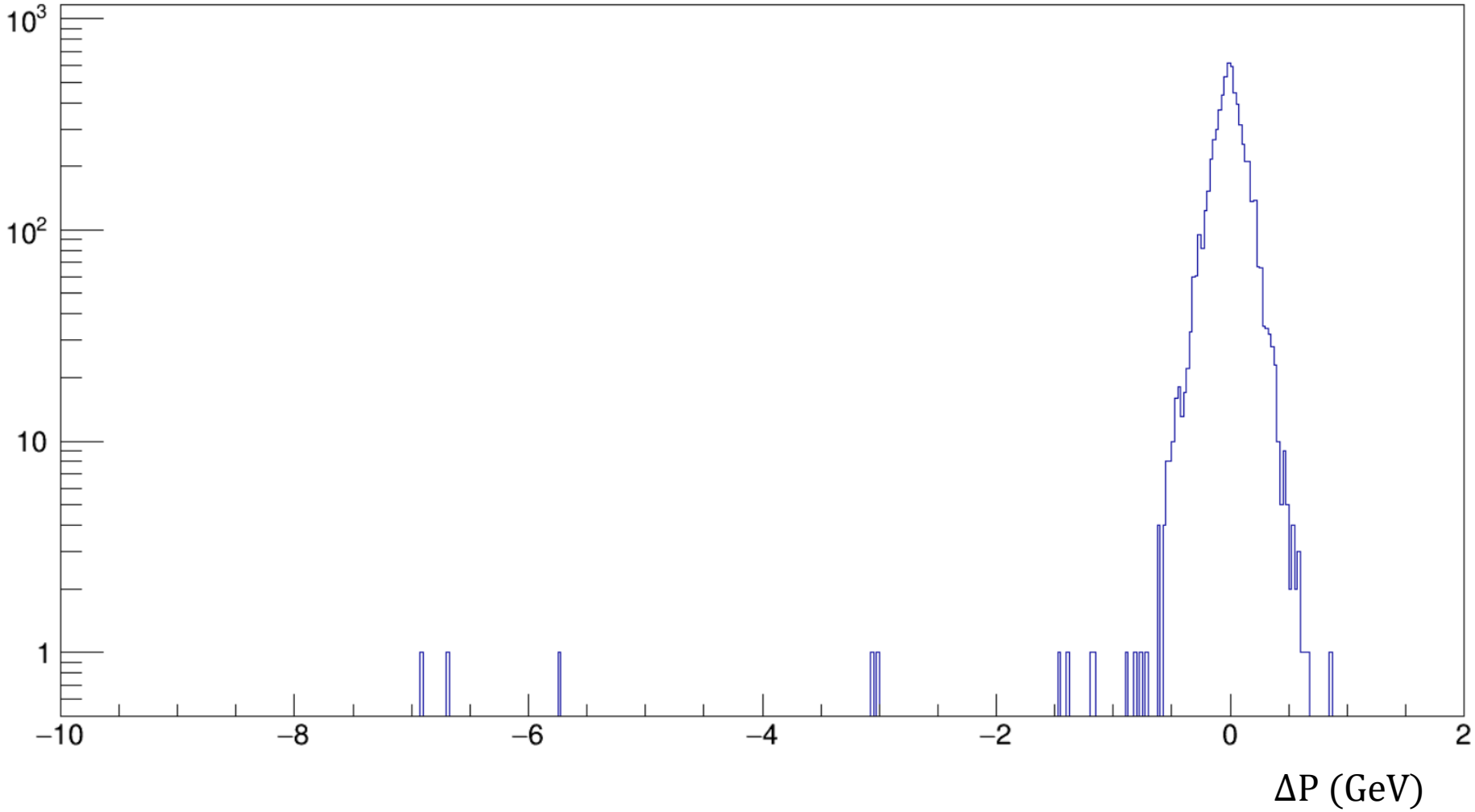






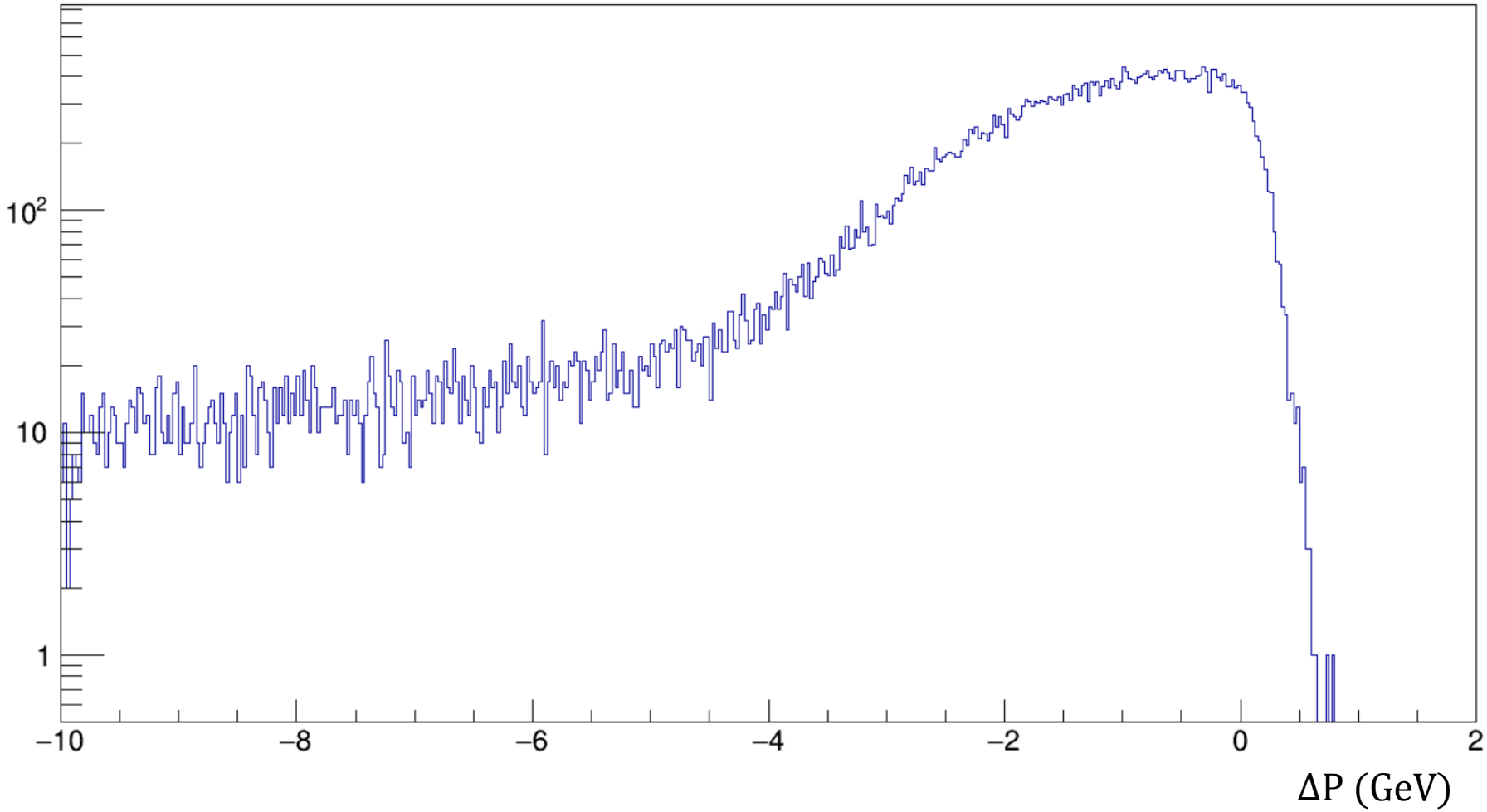
DeltaP for all CC $\bar{\nu}_\mu$ events

All plots use truth information



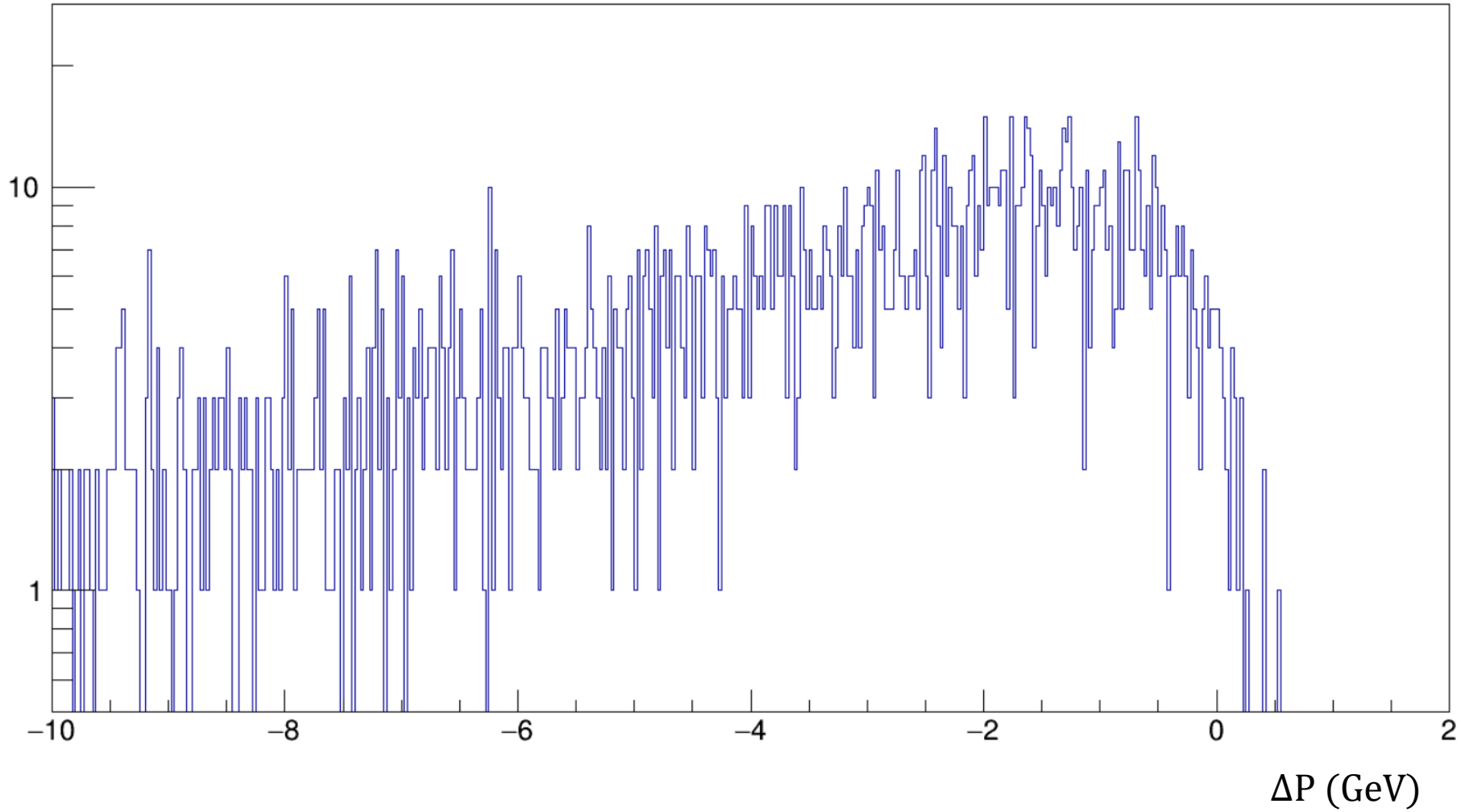
DeltaP for all NC ν_μ events

All plots use truth information



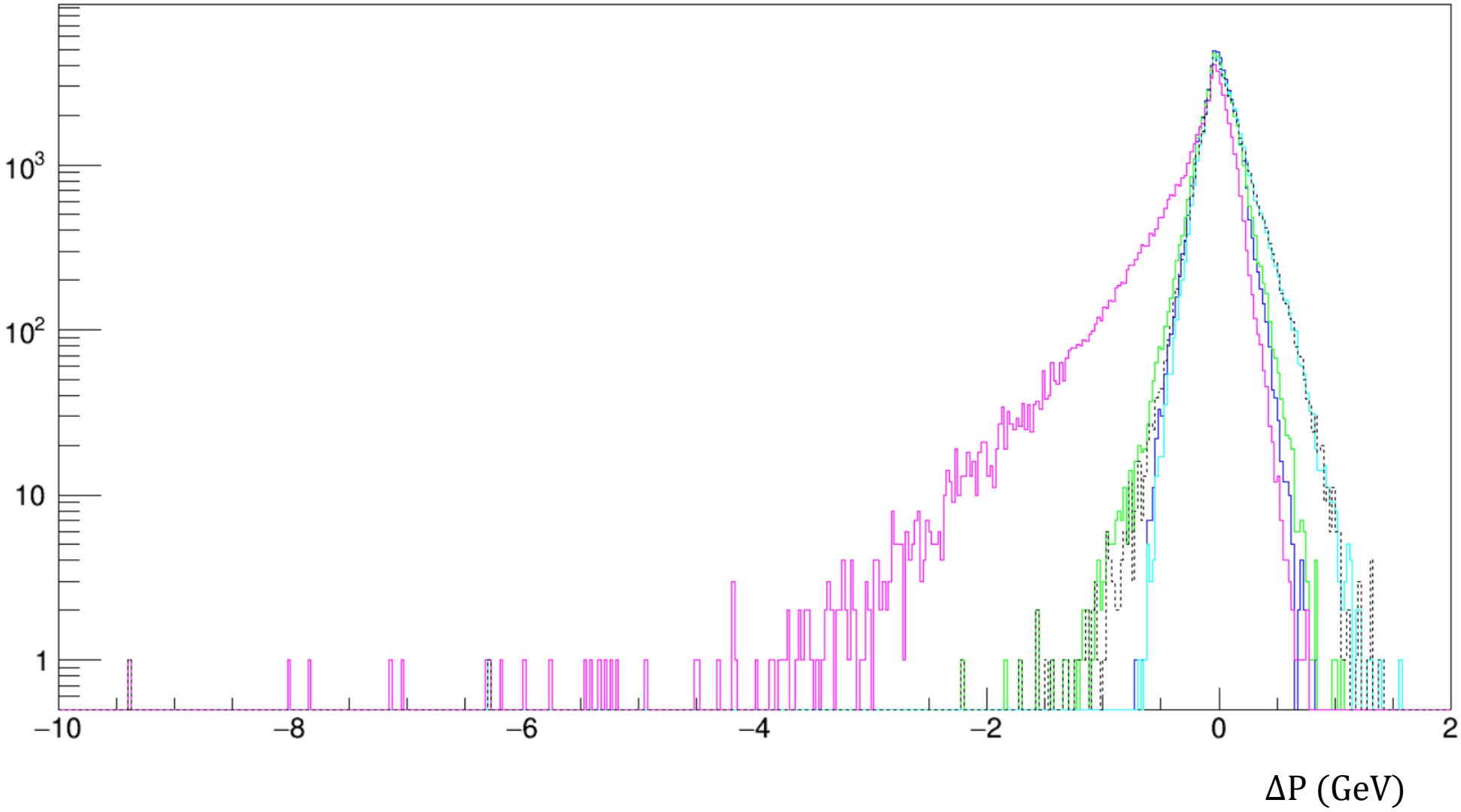
DeltaP for all NC $\bar{\nu}_\mu$ events

All plots use truth information



Charged Current ν_μ Events

Charged current ν_μ events – no pions



All particles

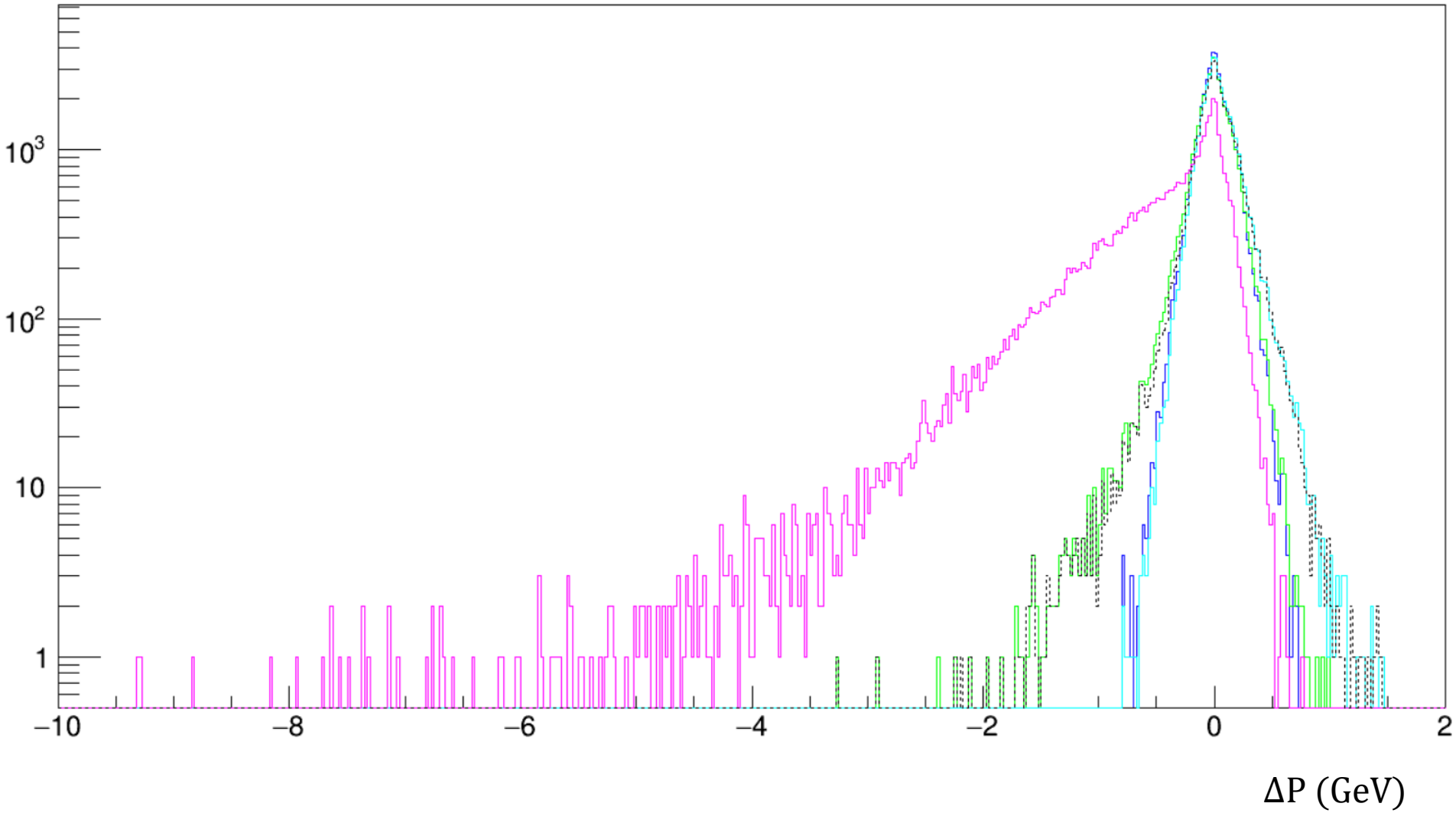
No (γ or n in) endcap

No (γ or n in) upstream barrel

No (γ or n in) downstream barrel

No (γ or n in) upstream barrel nor endcap (dashed)

Charged current ν_μ events – 1 $\pi^\pm$ (no π^0)



All particles

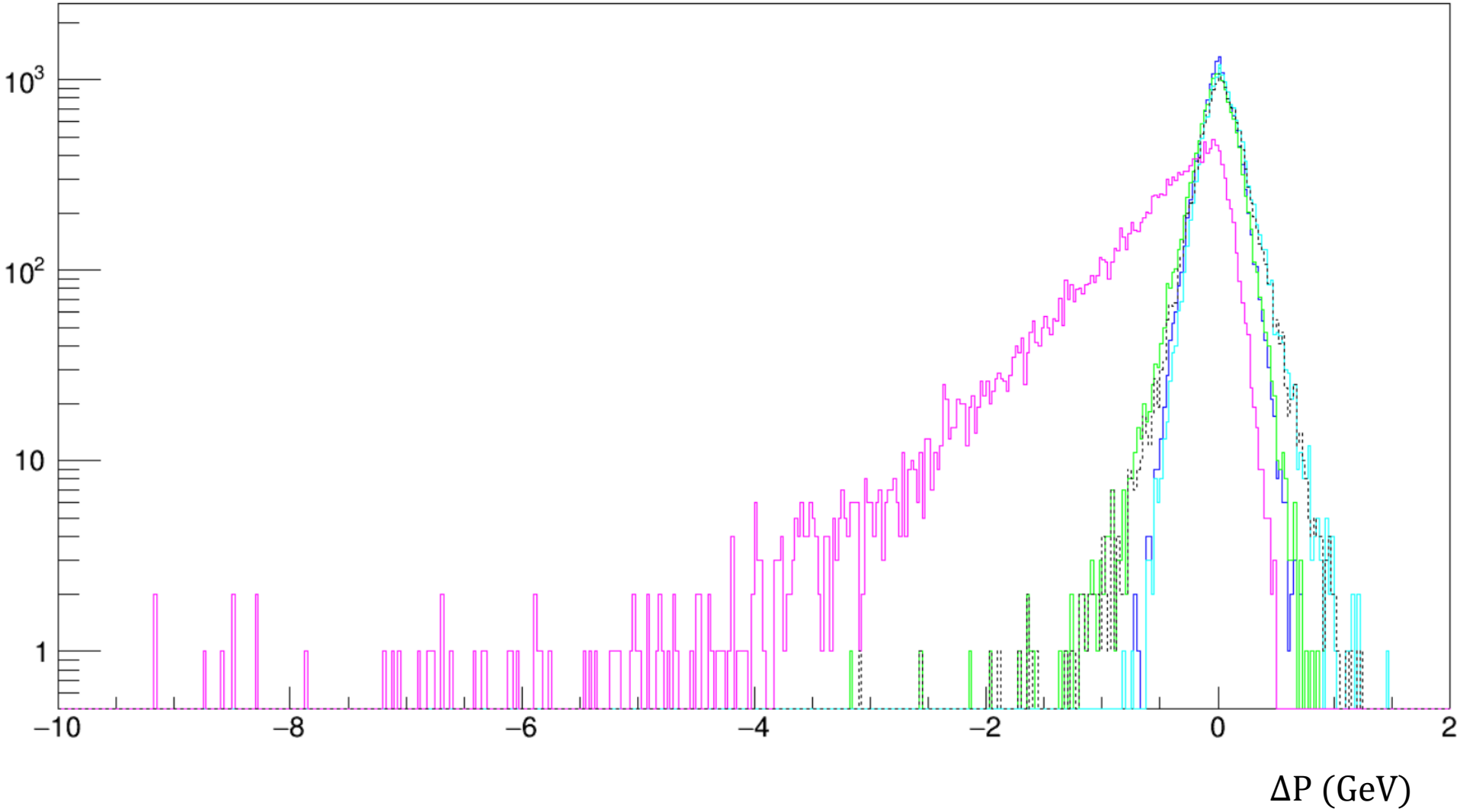
No endcap

No upstream barrel

No downstream barrel

No upstream barrel nor endcap (dashed)

Charged current ν_μ events – 1 π^0 (no $\pi^\pm$)



All particles

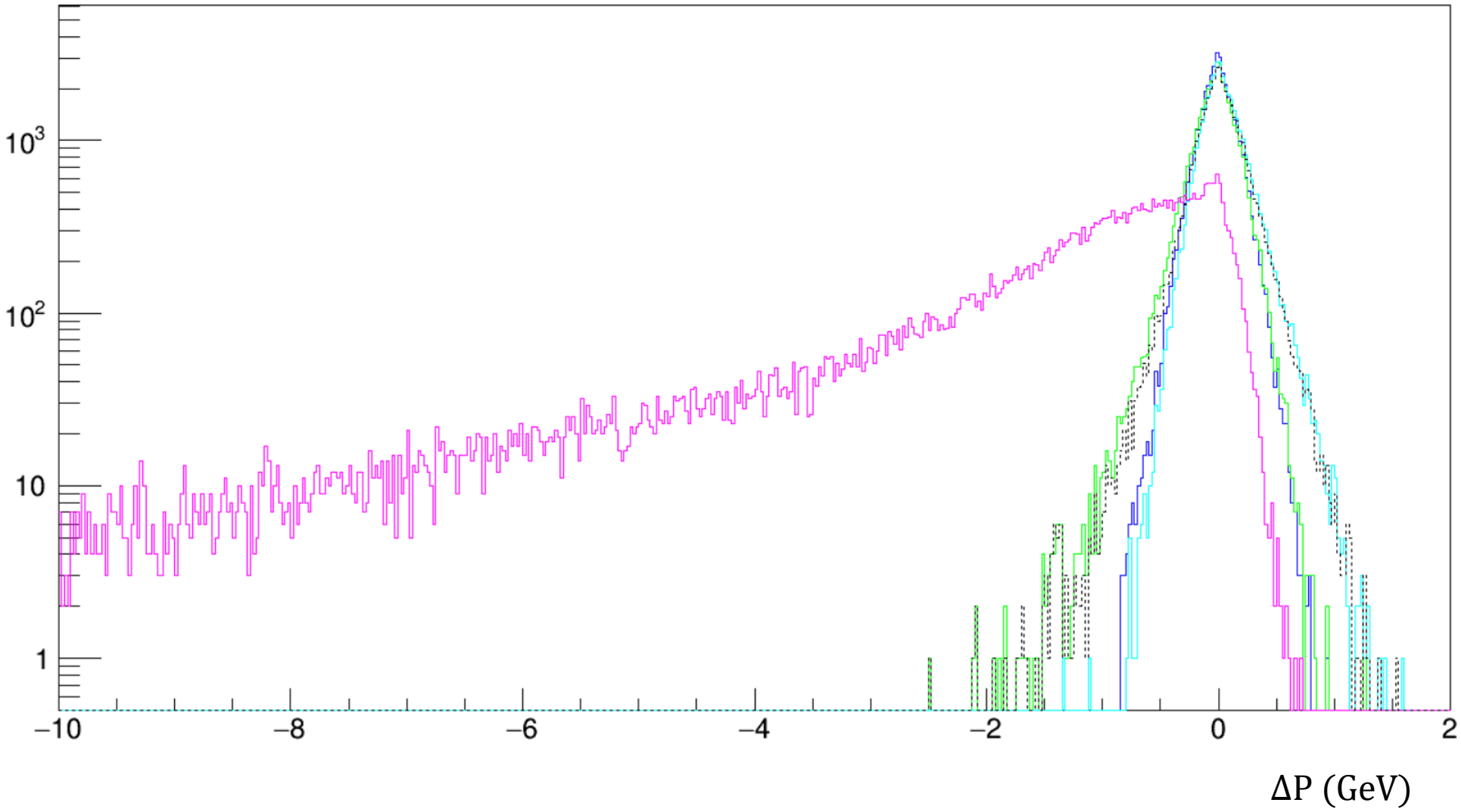
No endcap

No upstream barrel

No downstream barrel

No upstream barrel nor endcap (dashed)

Charged current ν_μ events – others



All particles

No endcap

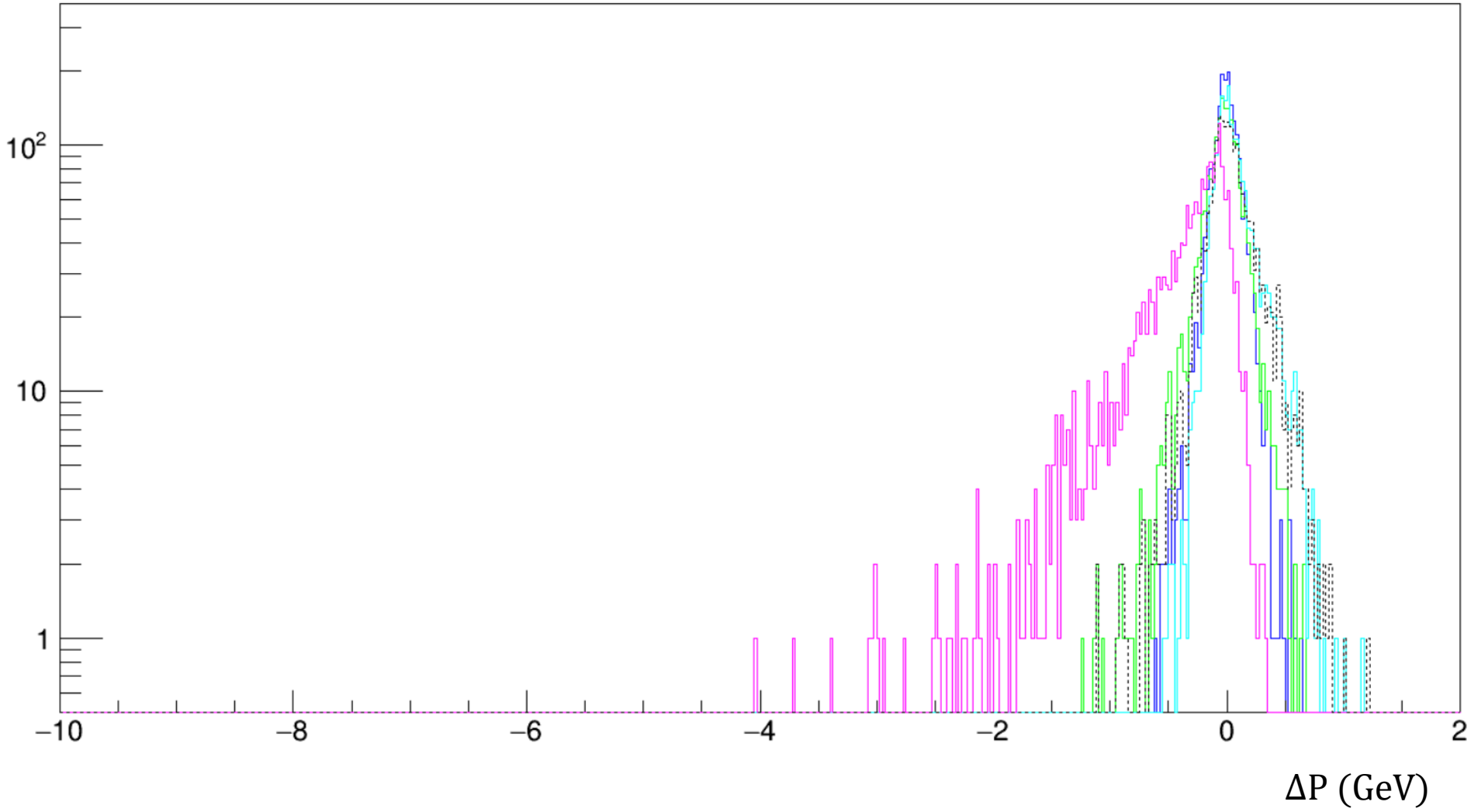
No upstream barrel

No downstream barrel

No upstream barrel nor endcap (dashed)

Charged Current $\bar{\nu}_\mu$ Events

Charged current $\bar{\nu}_\mu$ events – no pions



All particles

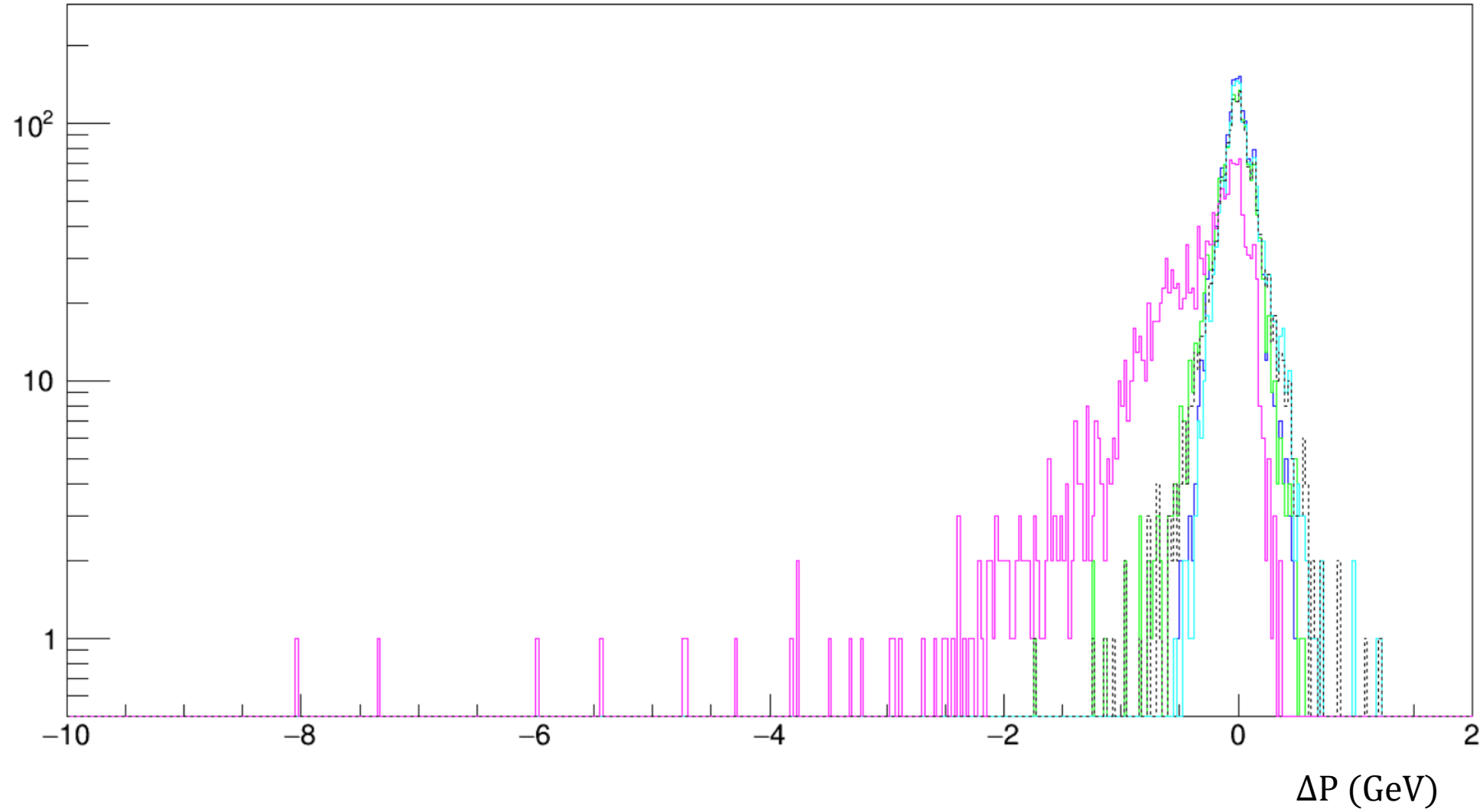
No endcap

No upstream barrel

No downstream barrel

No upstream barrel nor endcap (dashed)

Charged current $\bar{\nu}_\mu$ events – 1 $\pi^\pm$ (no π^0)



All particles

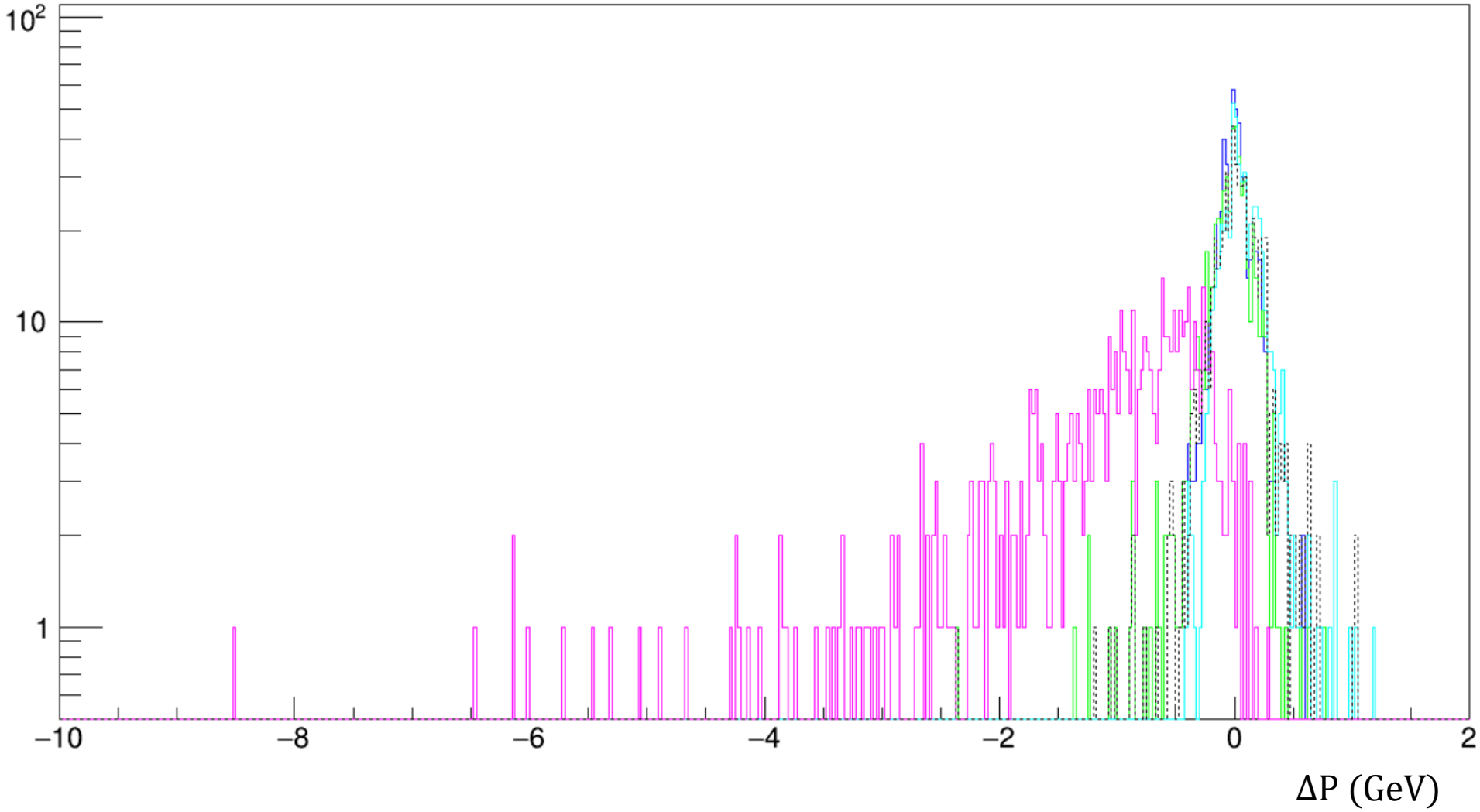
No endcap

No upstream barrel

No downstream barrel

No upstream barrel nor endcap (dashed)

Charged current $\bar{\nu}_\mu$ events – 1 π^0 (no $\pi^\pm$)



All particles

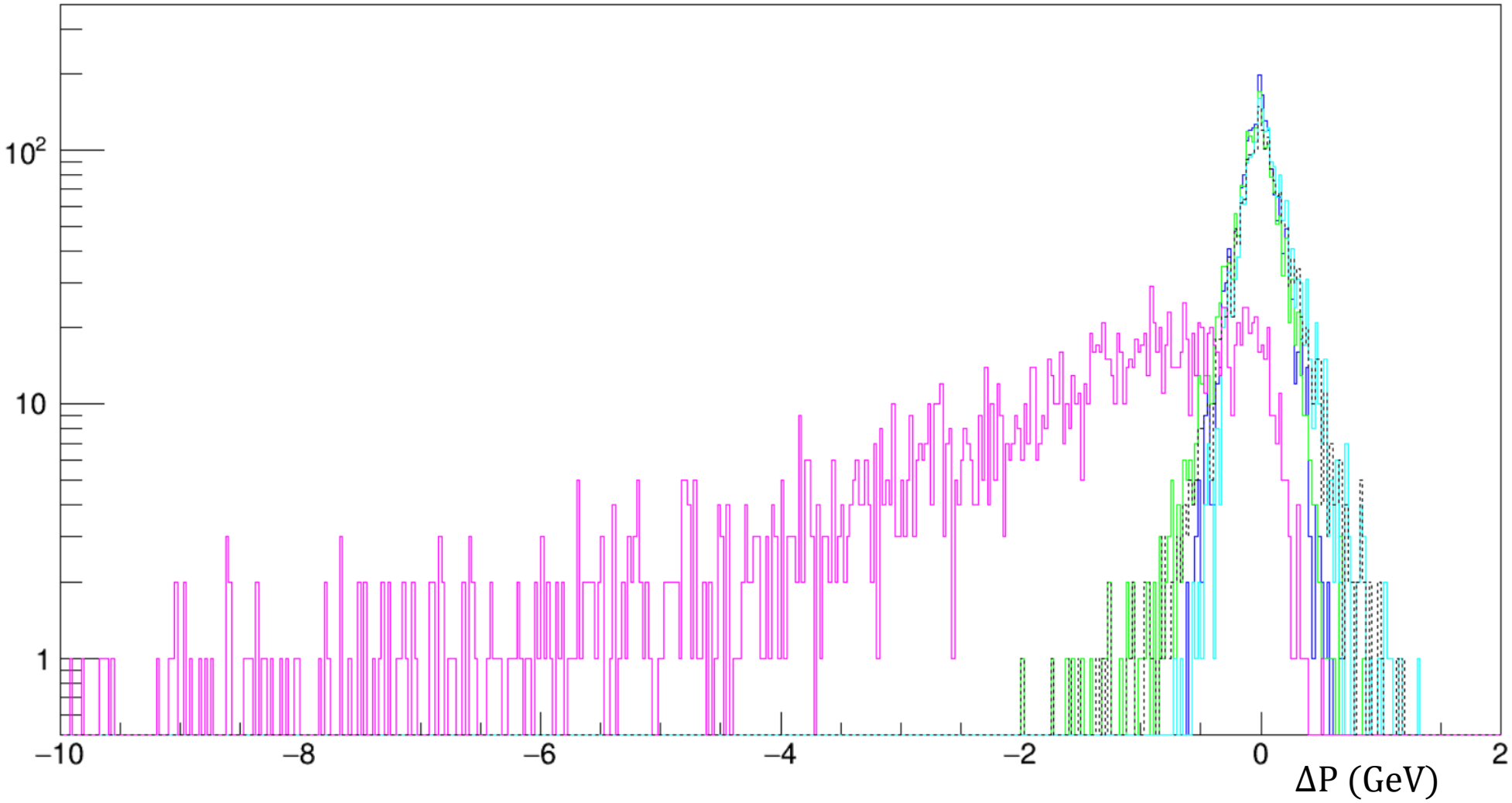
No endcap

No upstream barrel

No downstream barrel

No upstream barrel nor endcap (dashed)

Charged current $\bar{\nu}_\mu$ events – others



All particles

No endcap

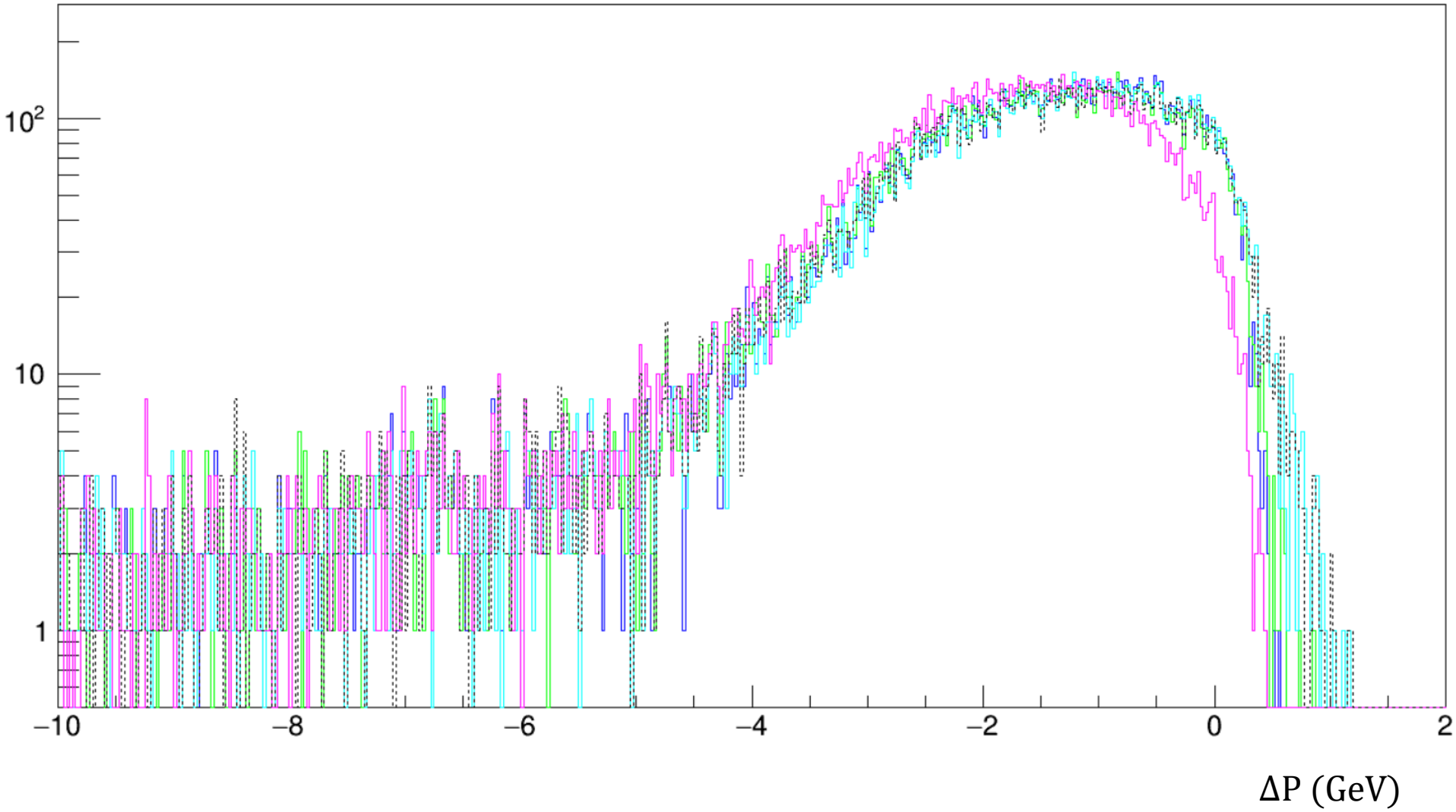
No upstream barrel

No downstream barrel

No upstream barrel nor endcap (dashed)

Neutral Current ν_μ & $\bar{\nu}_\mu$ Events

Neutral current ν_μ & $\bar{\nu}_\mu$ events – no pions



All particles

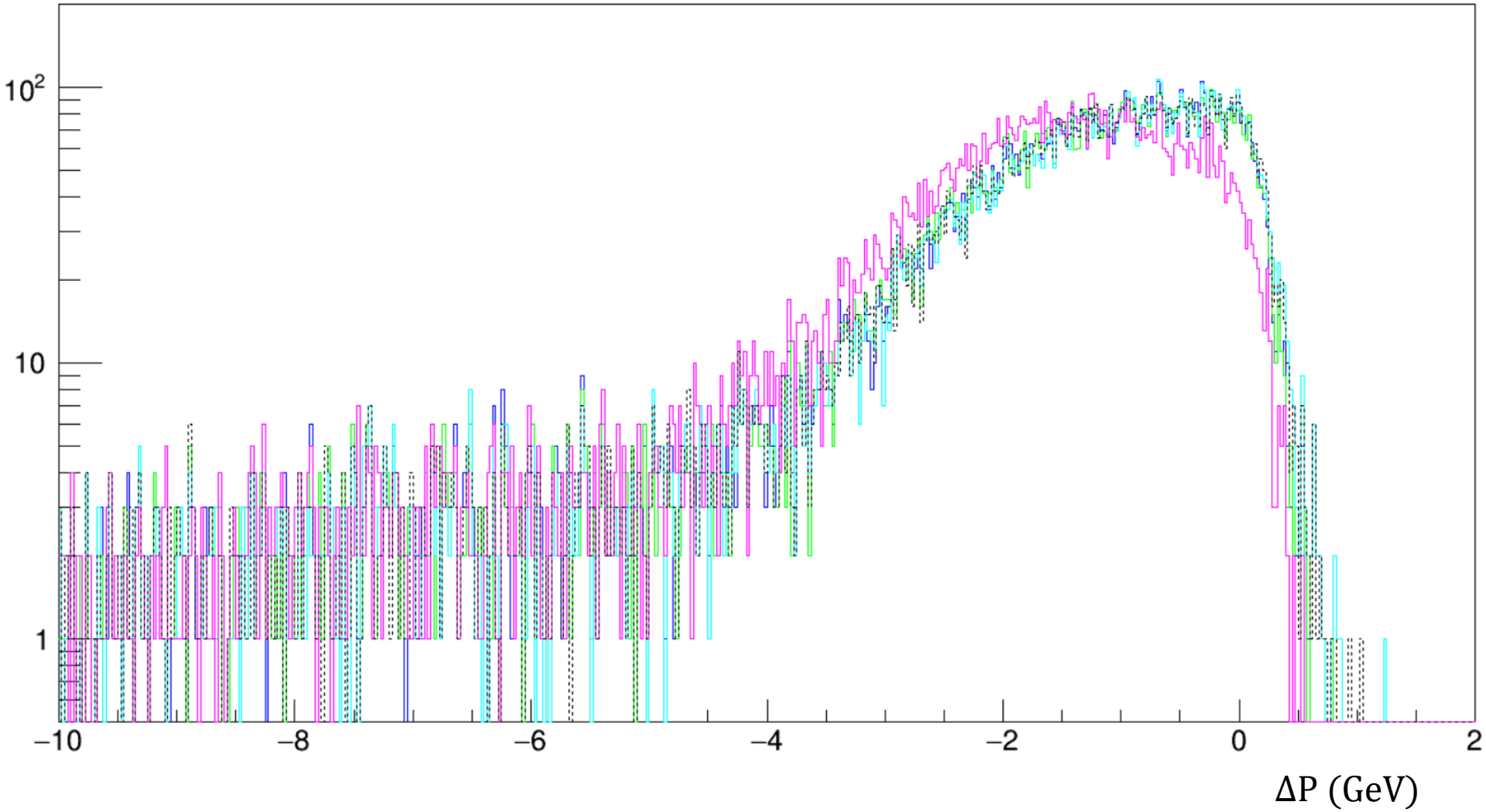
No endcap

No upstream barrel

No downstream barrel

No upstream barrel nor endcap (dashed)

Neutral current ν_μ & $\bar{\nu}_\mu$ events – 1 $\pi^\pm$ (no π^0)



All particles

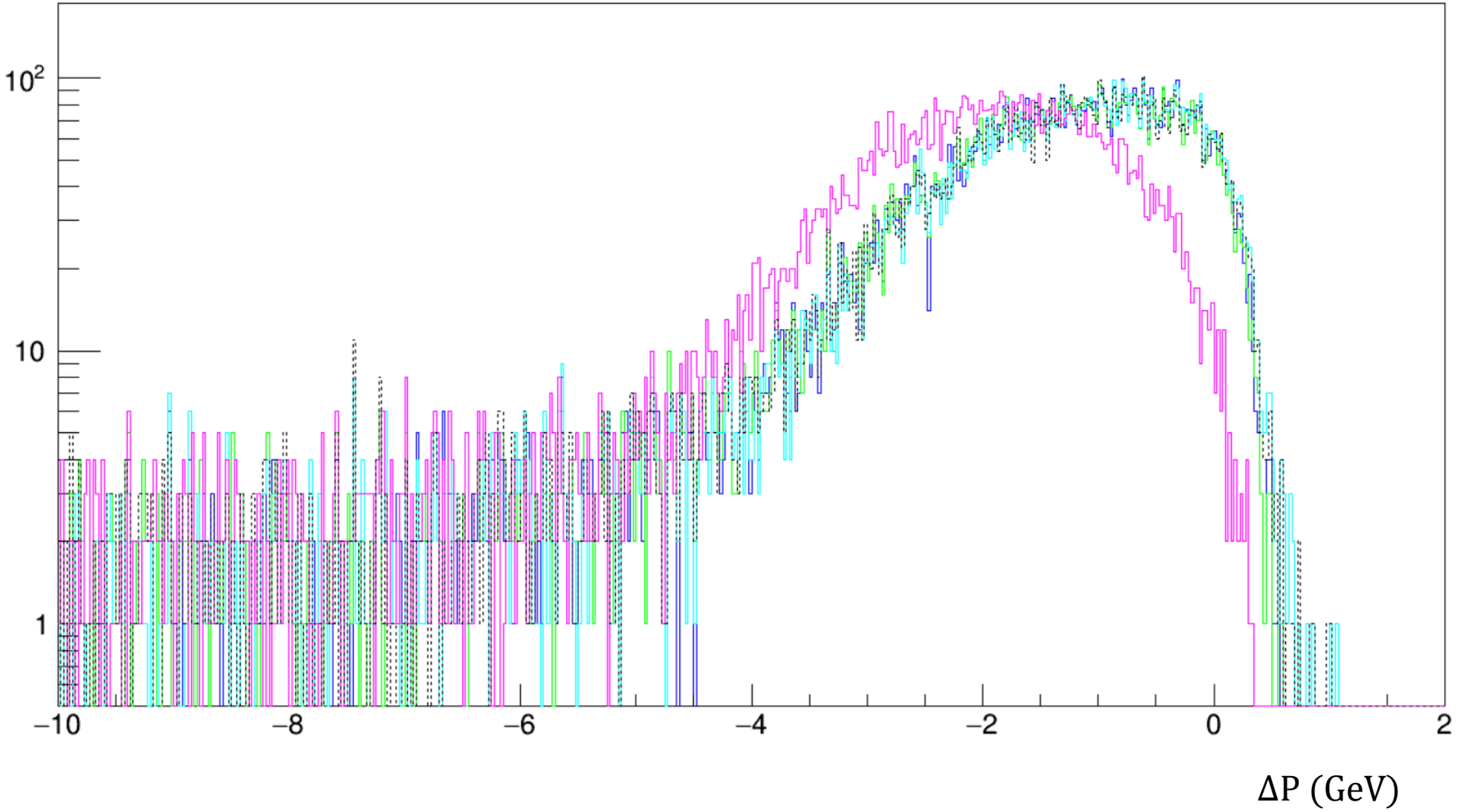
No endcap

No upstream barrel

No downstream barrel

No upstream barrel nor endcap (dashed)

Neutral current ν_μ & $\bar{\nu}_\mu$ events – 1 π^0 (no $\pi^\pm$)



All particles

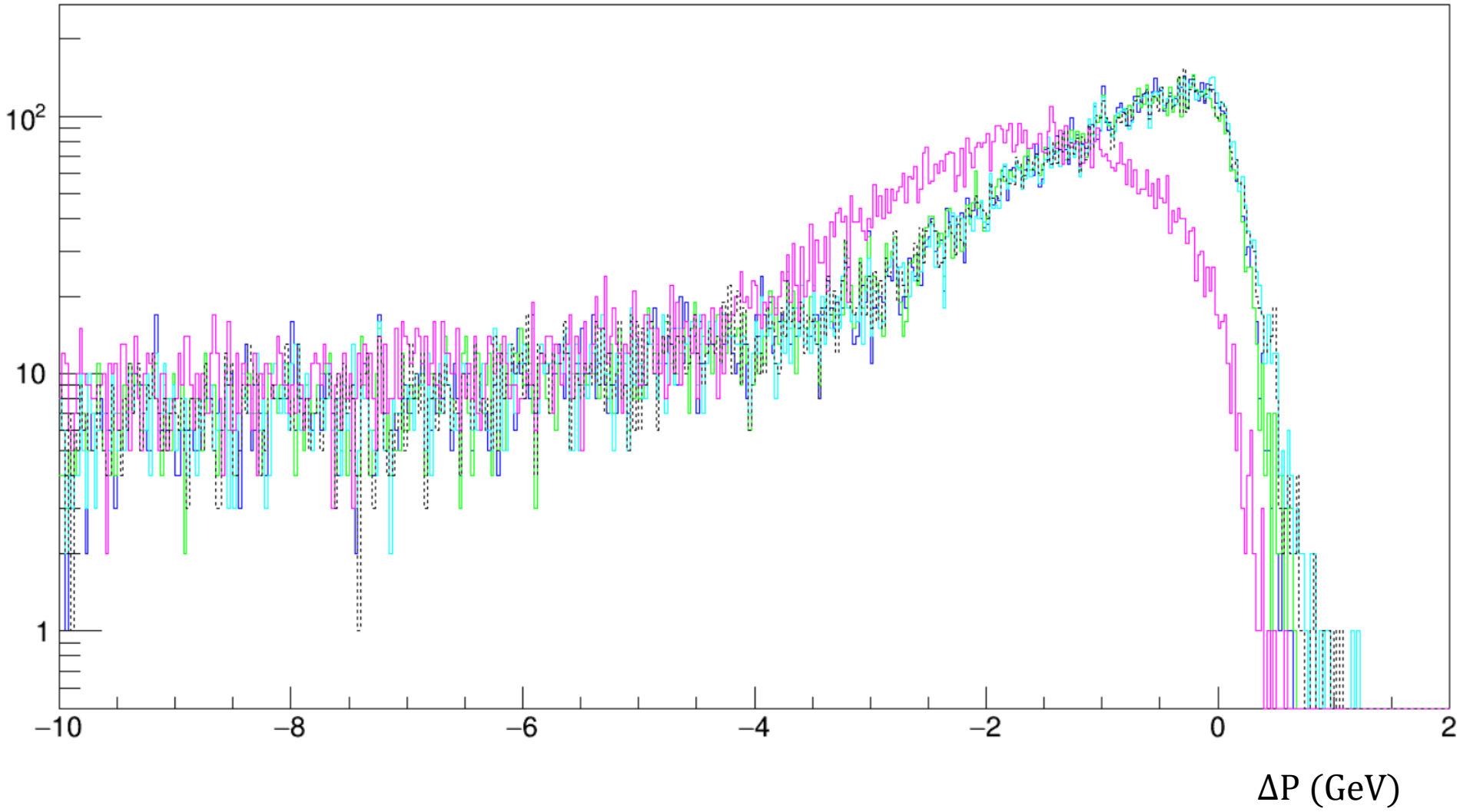
No endcap

No upstream barrel

No downstream barrel

No upstream barrel nor endcap (dashed)

Neutral current ν_μ & $\bar{\nu}_\mu$ events – others



All particles

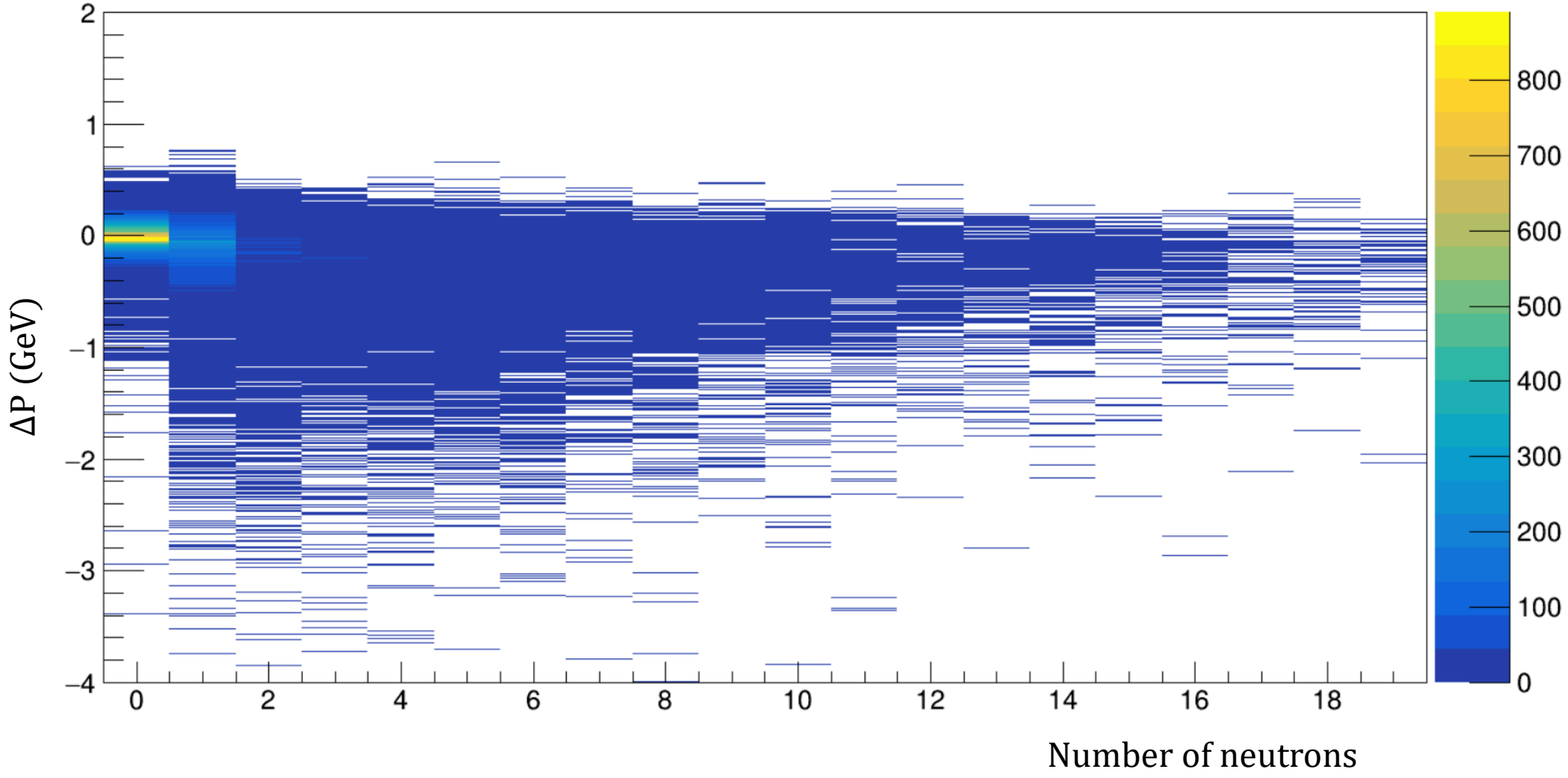
No endcap

No upstream barrel

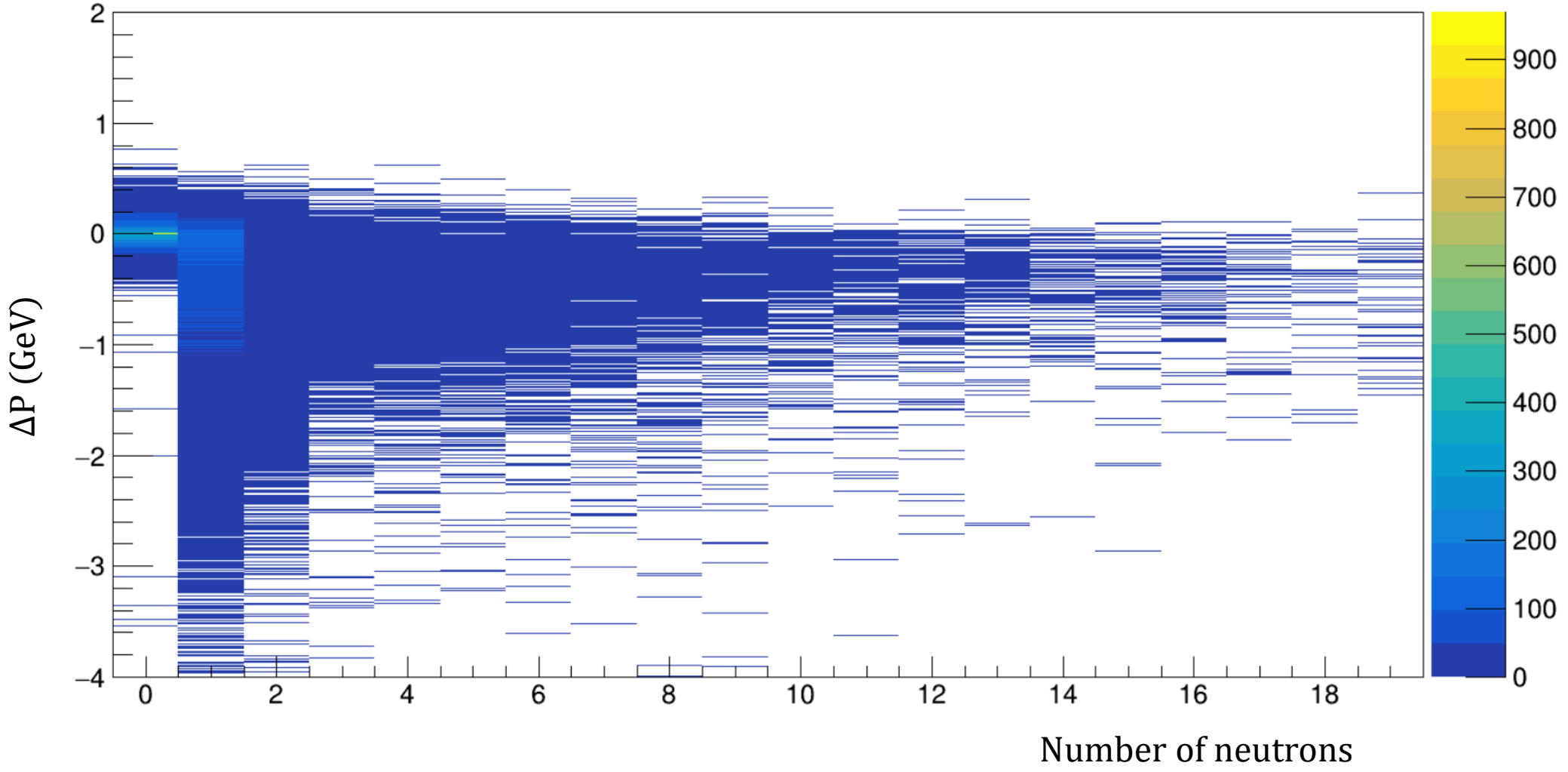
No downstream barrel

No upstream barrel nor endcap (dashed)

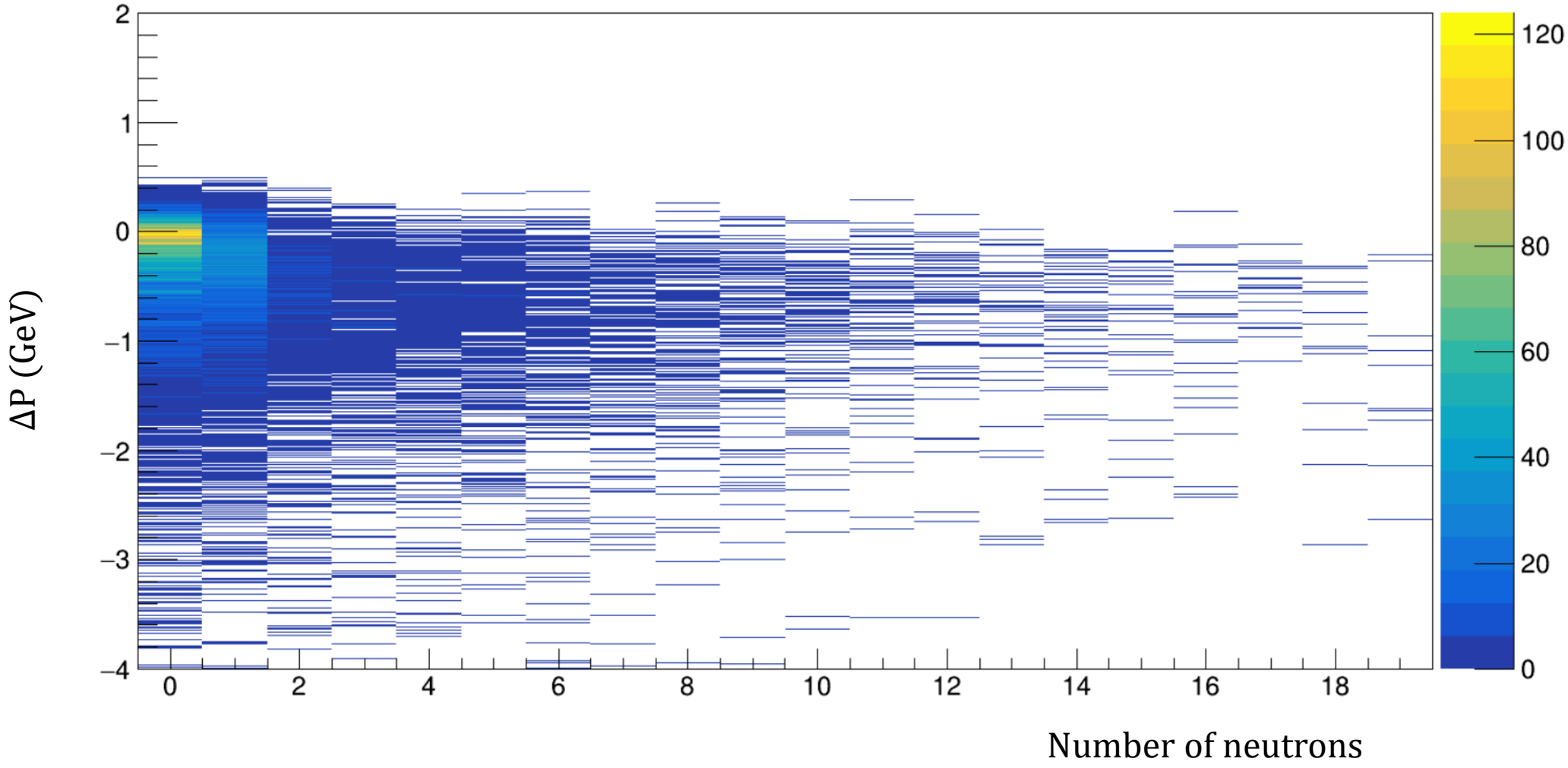
DeltaP_noBRF v number of neutrons– no pions



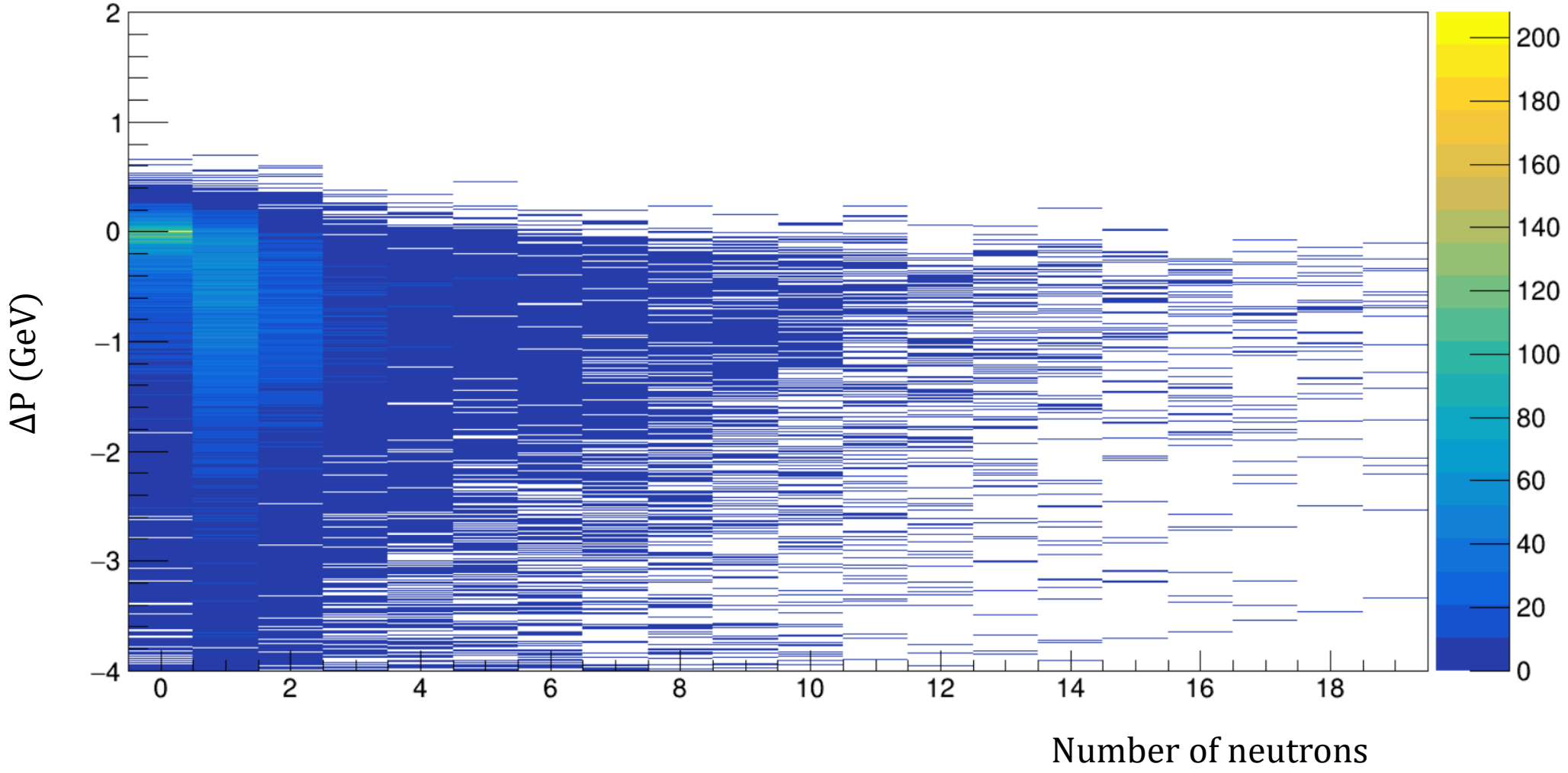
DeltaP_noBRF v number of neutrons – 1 charged pion



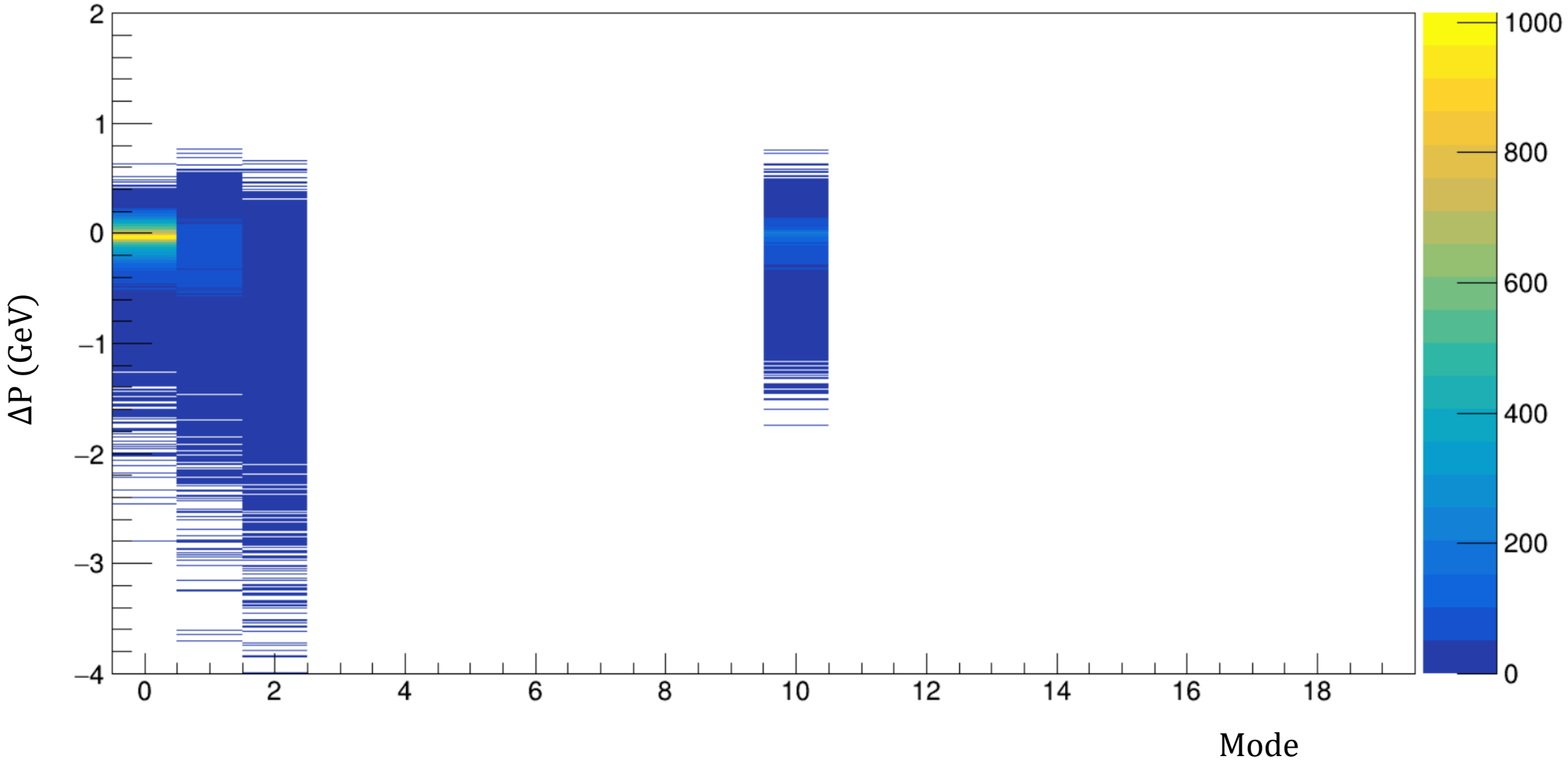
DeltaP_noBRF v number of neutrons – 1 neutral pion



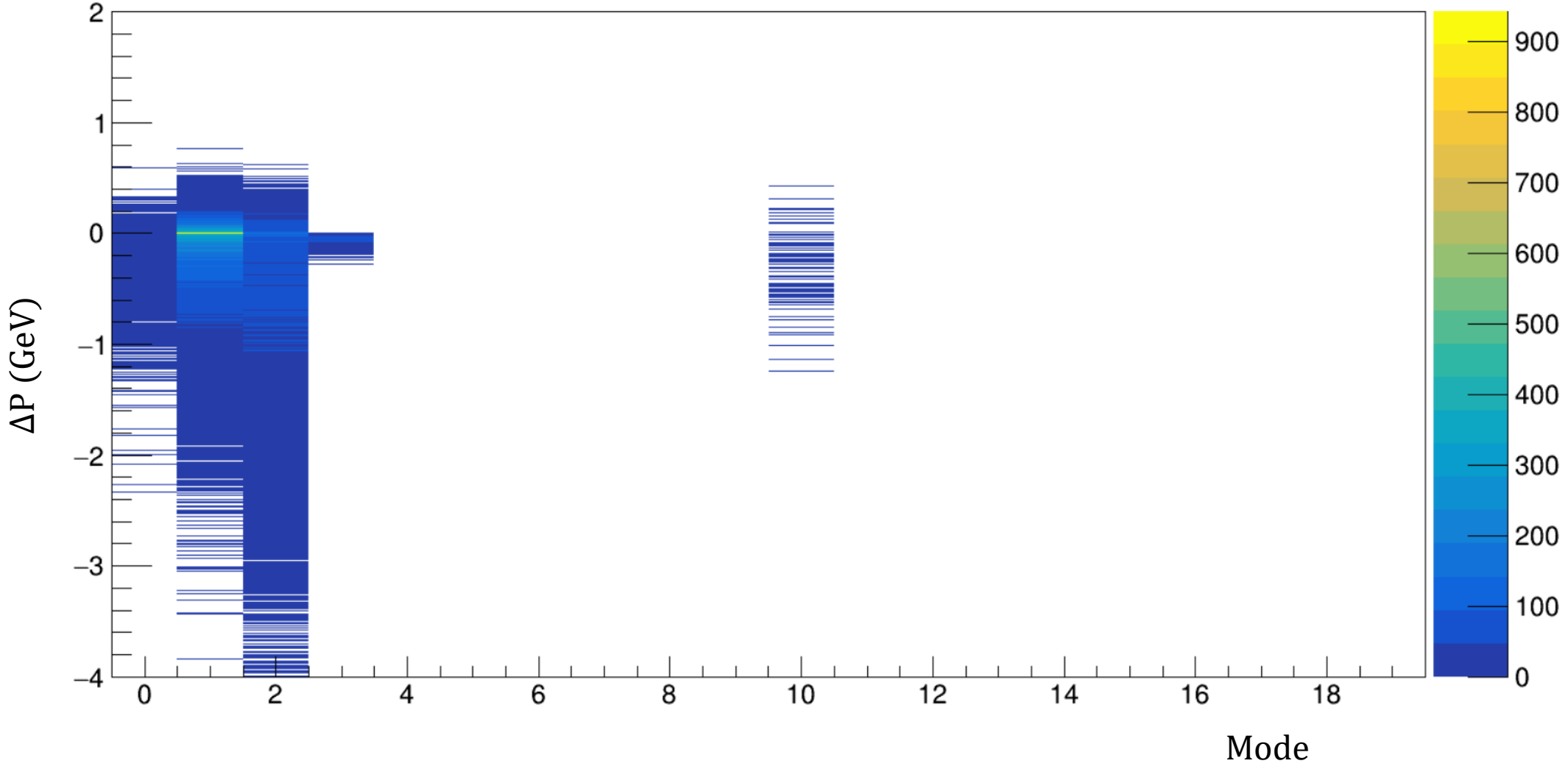
DeltaP_noBRF v number of neutrons – others



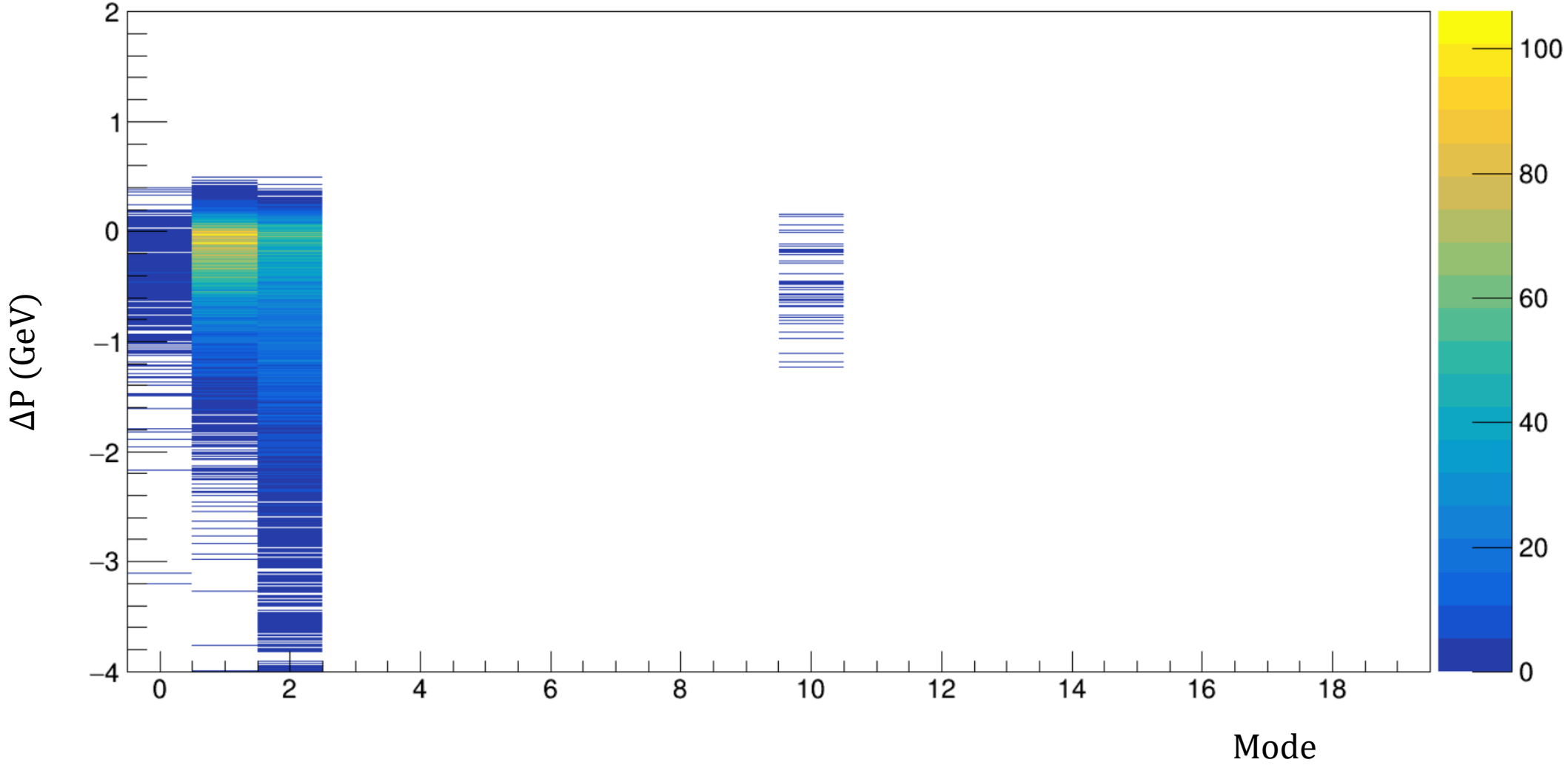
DeltaP_noBRF vs mode – no pions



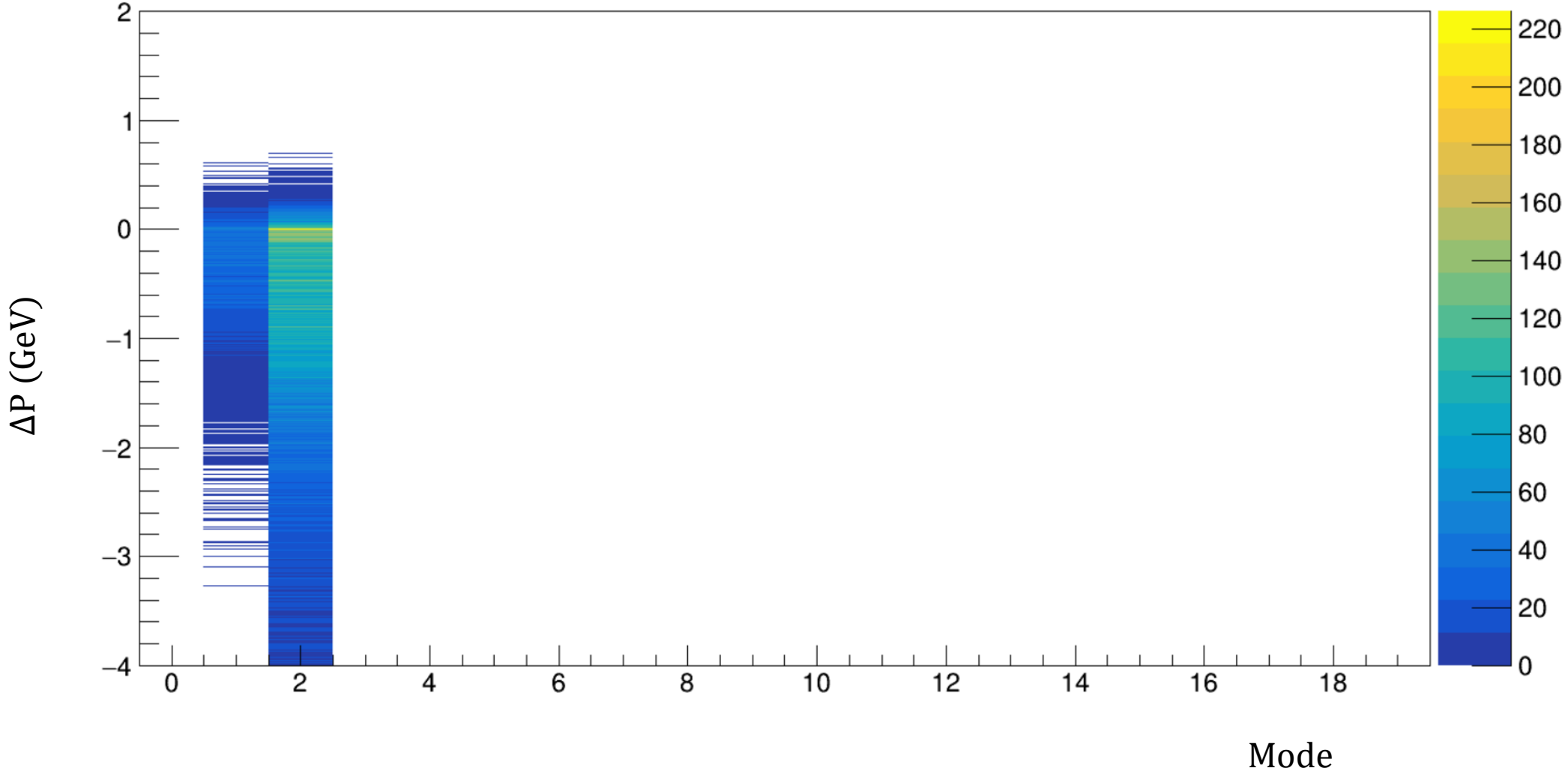
DeltaP_noBRF v mode – 1 charged pion



DeltaP_noBRF v mode – 1 neutral pion



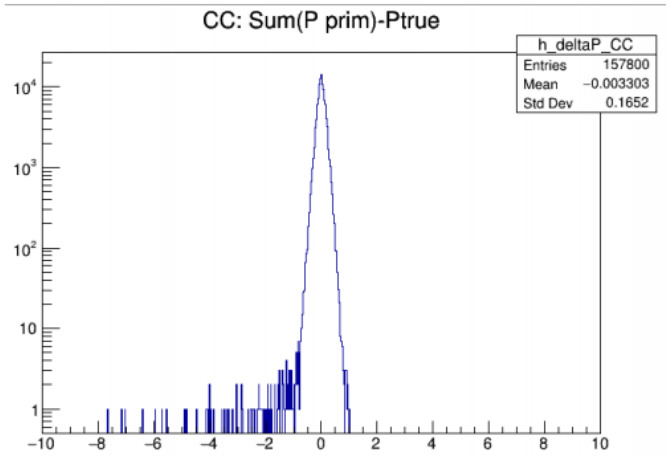
DeltaP_noBRF v mode – others

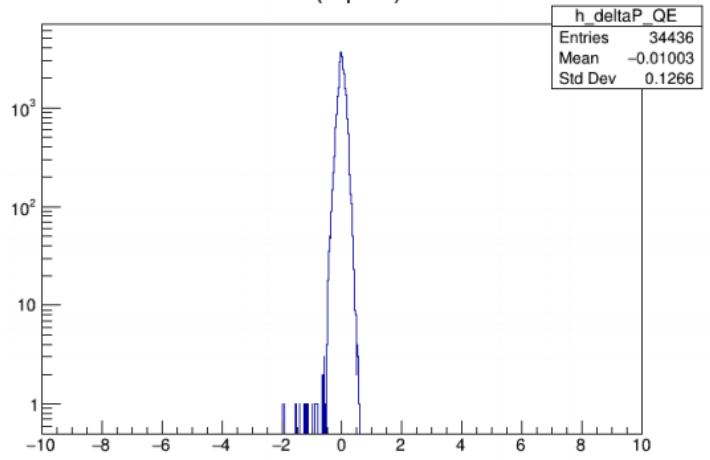


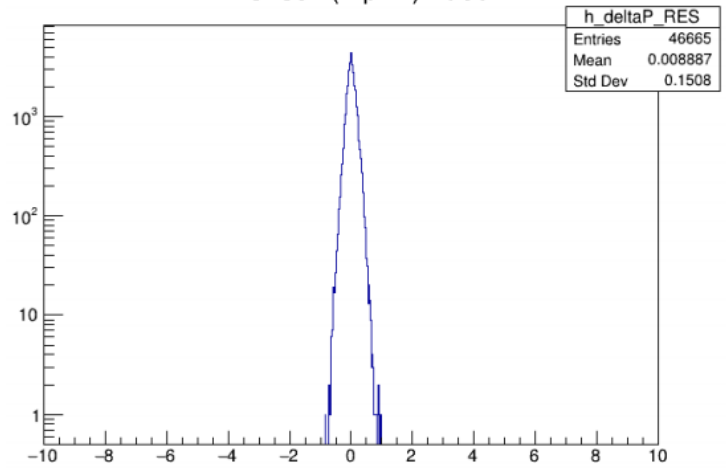
Why does the all primary case have a large width for ΔP?

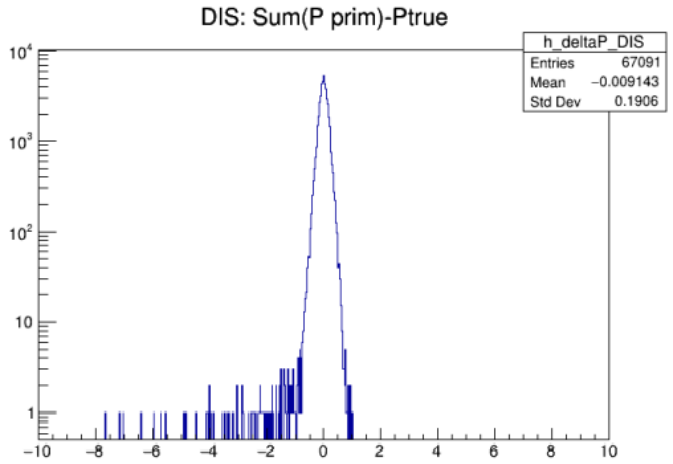
These plots have bin width = 25 MeV

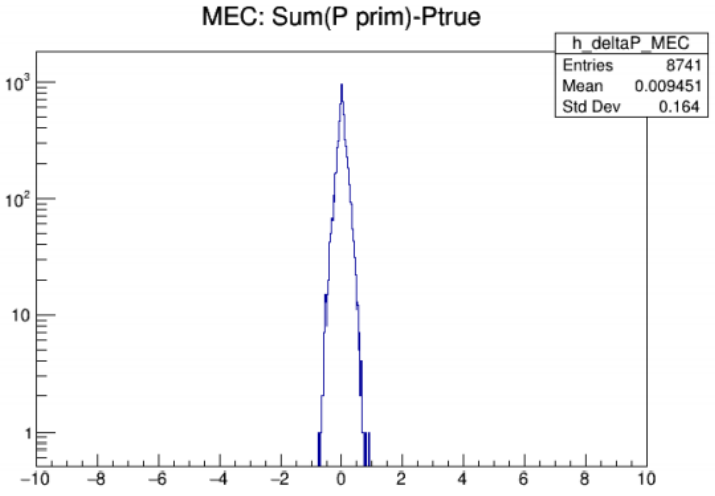
Could it be due to Fermi Motion?

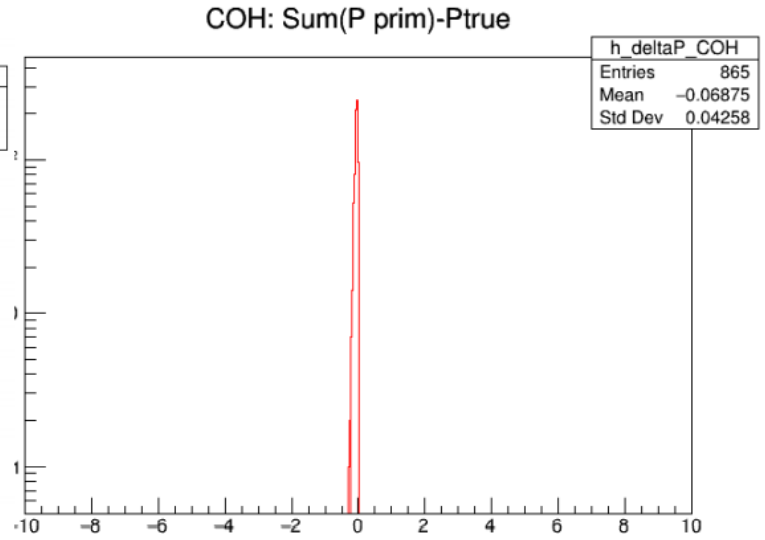












Vivek Jain