NUMUCC4PIMULTIPI SELECTION STATUS

IFAE Neutrino Group Meeting

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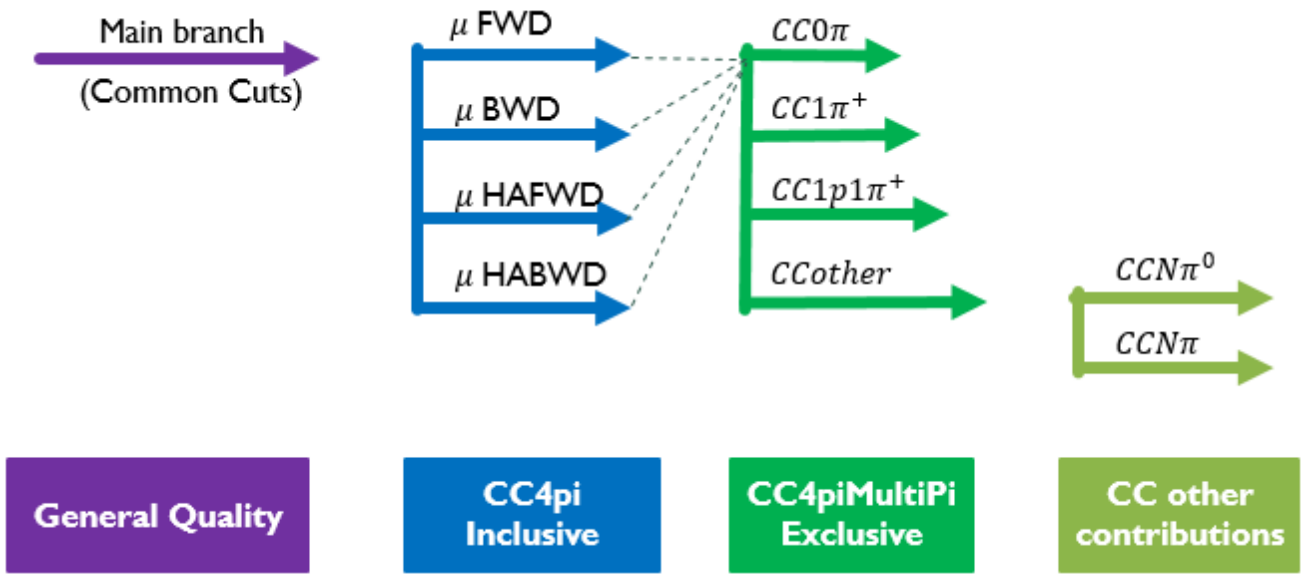
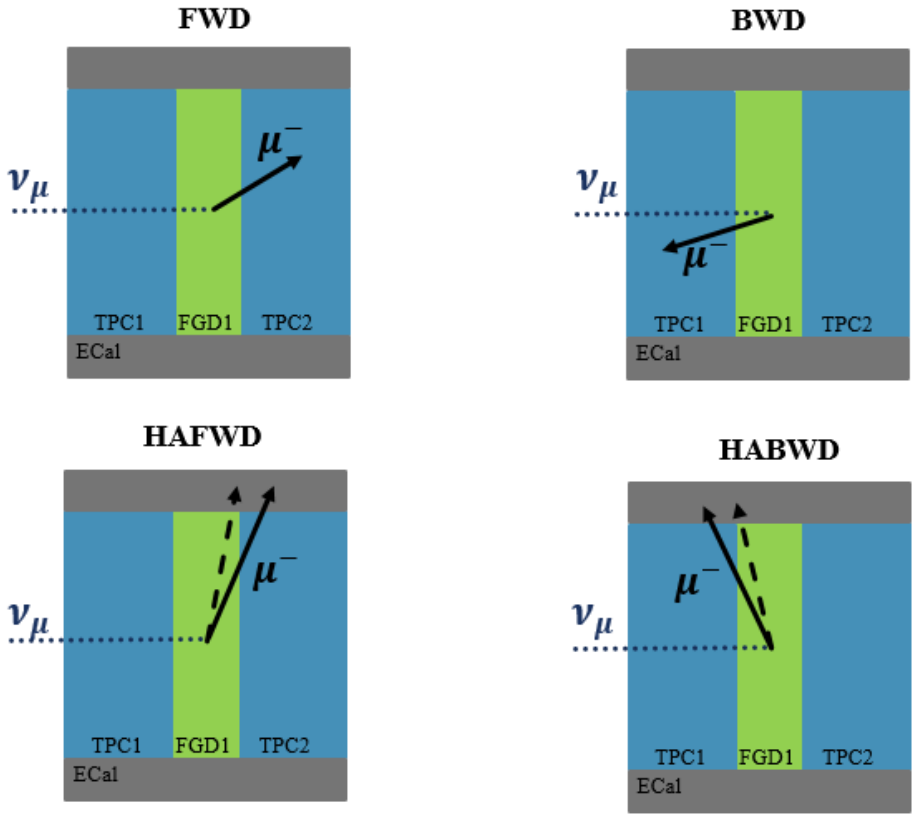
Selection steps

- The selection is implemented following the scheme below, where FWD mean forward, BWD backward and HA high angle.



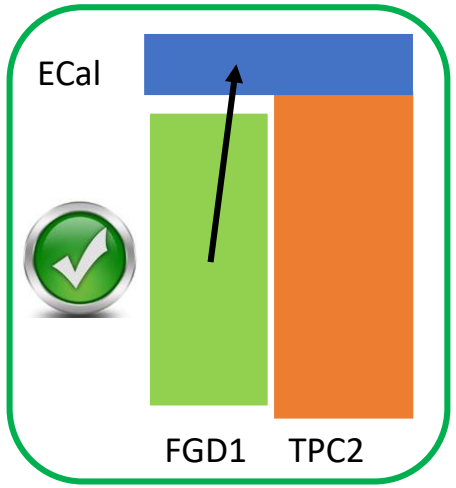


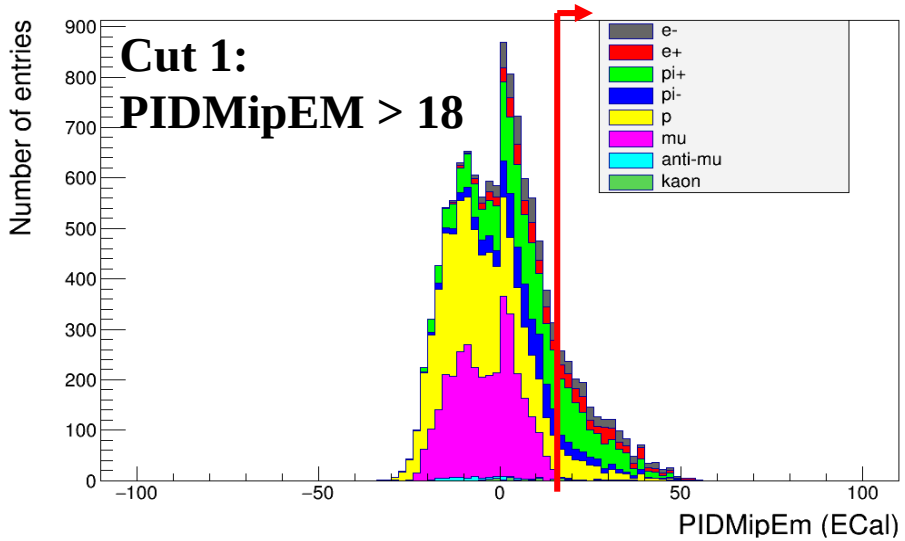
- **Note: all of these directions are defined by the muon candidate.**

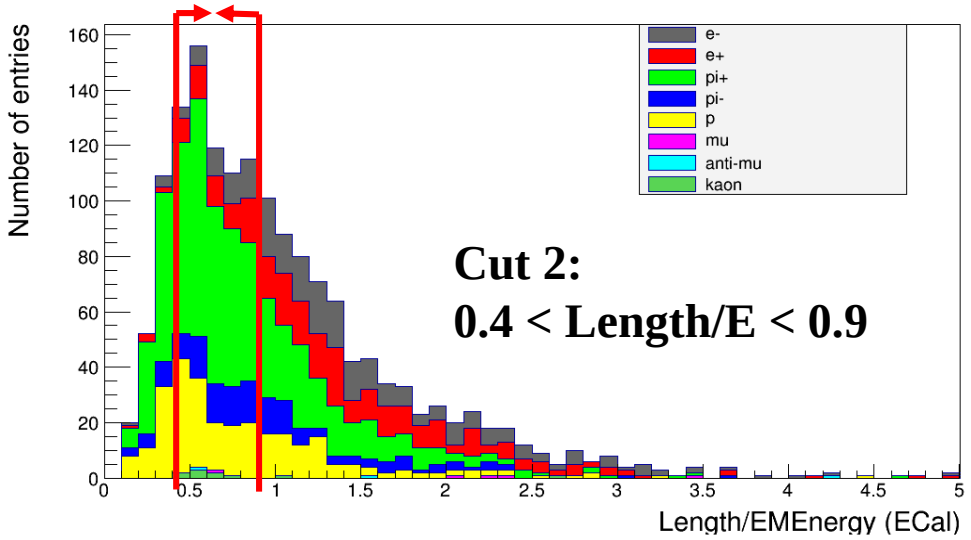
Find Pions Action: ECal Pions

ECal Pions

- Track needs to start in FGD1 and stop in the Barrel ECal,
- Track should not be a muon,
- Track should not be a TPC pion,
- PIDMipEm > 18,
- 0.4 < Length/EMEnergy < 0.9.

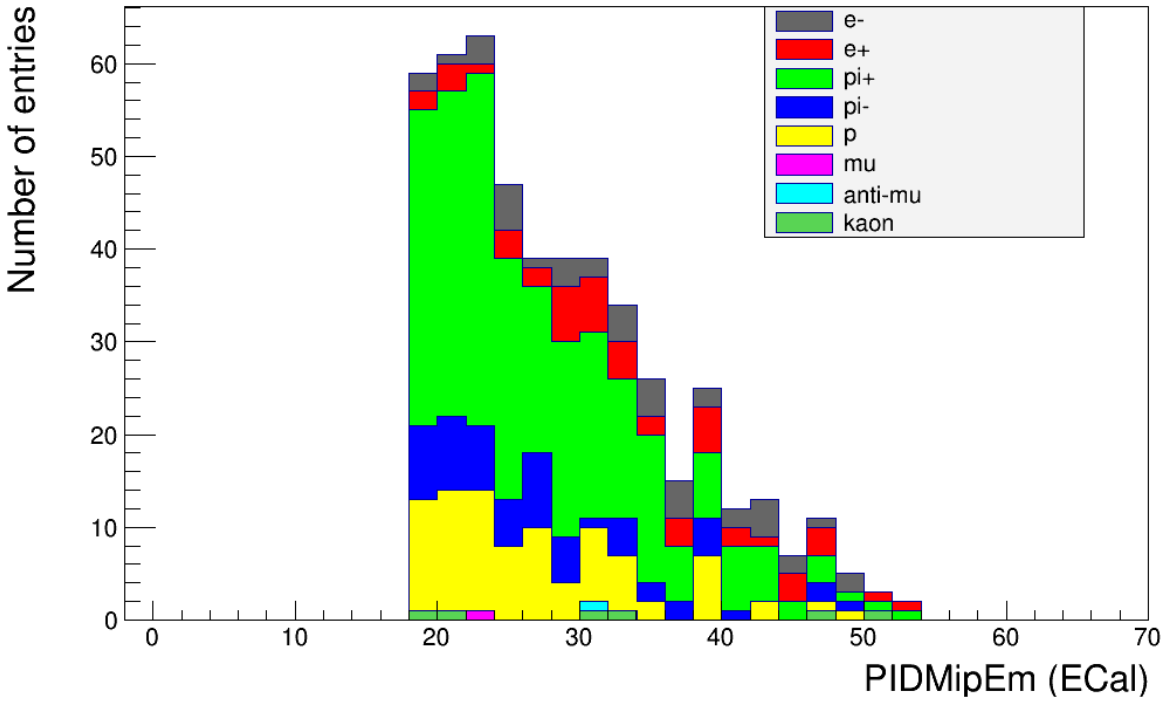


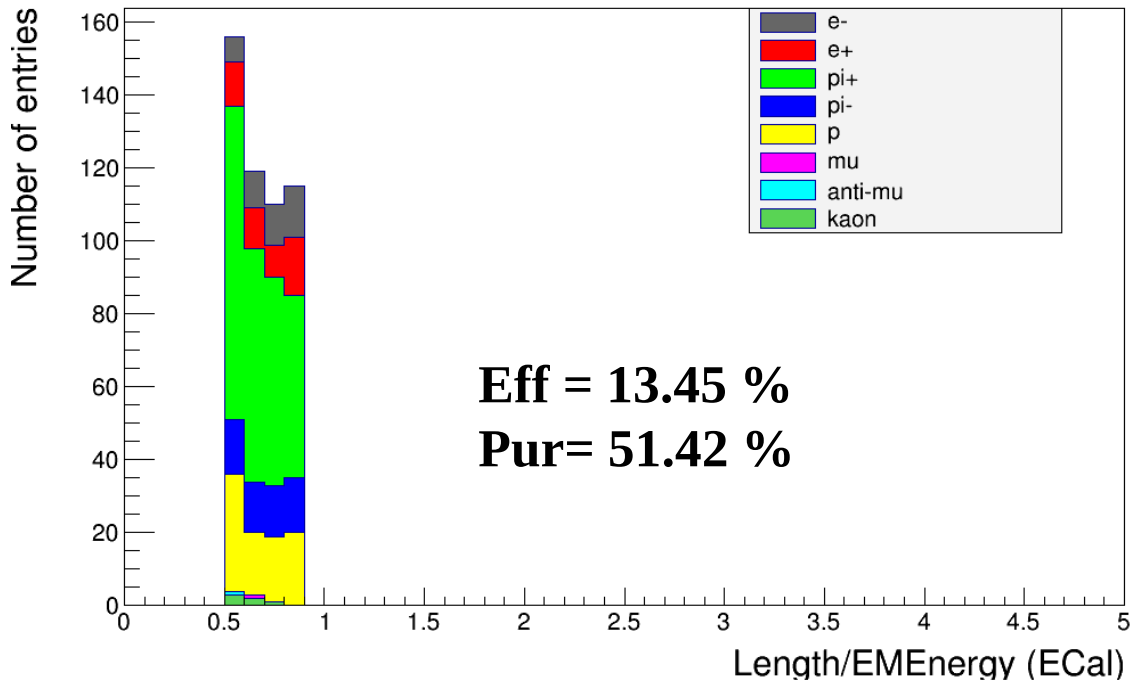




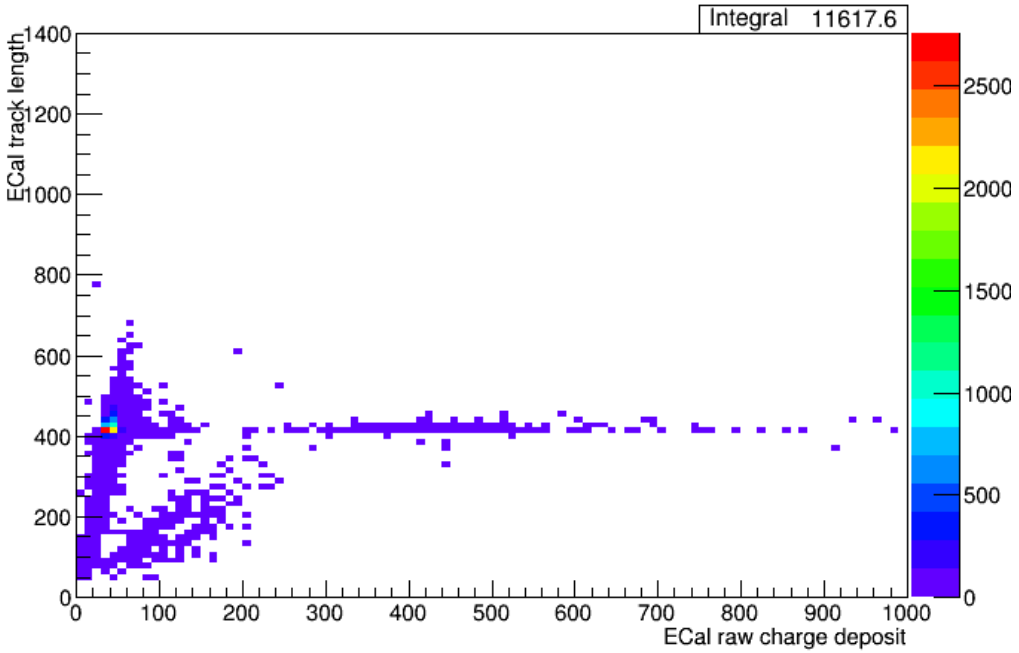
Find Pions Action: ECal Pions

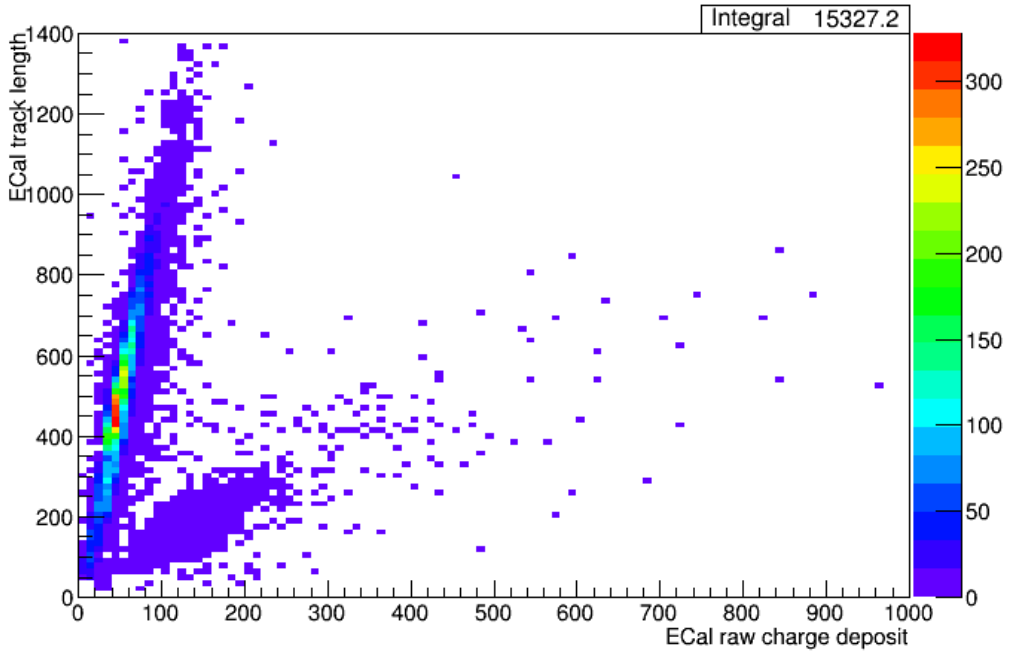
After the cuts:





Find Pions Action: ECal PID of μ, π and p





The plots are the correlation between charge and length for true muons, in the barrel and DS ecal respectively;

An anomaly in the relationship between ECal charge deposit and track length in Prod6 that is being investigate this (currently Gabriel is preparing a detailed talk about this for next week)

Stopping control sample

HA positive pion

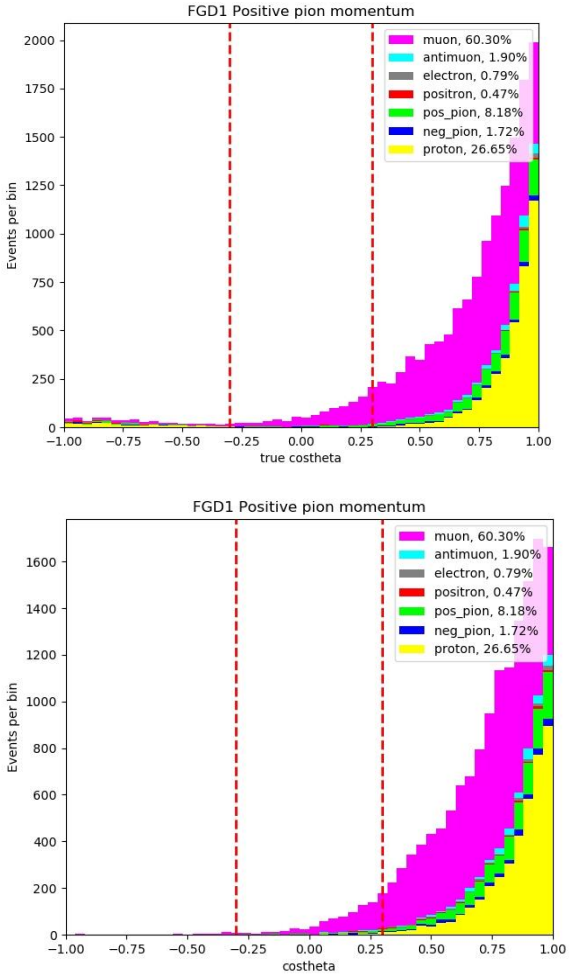
"Event quality",
“Both positive and negative candidates",

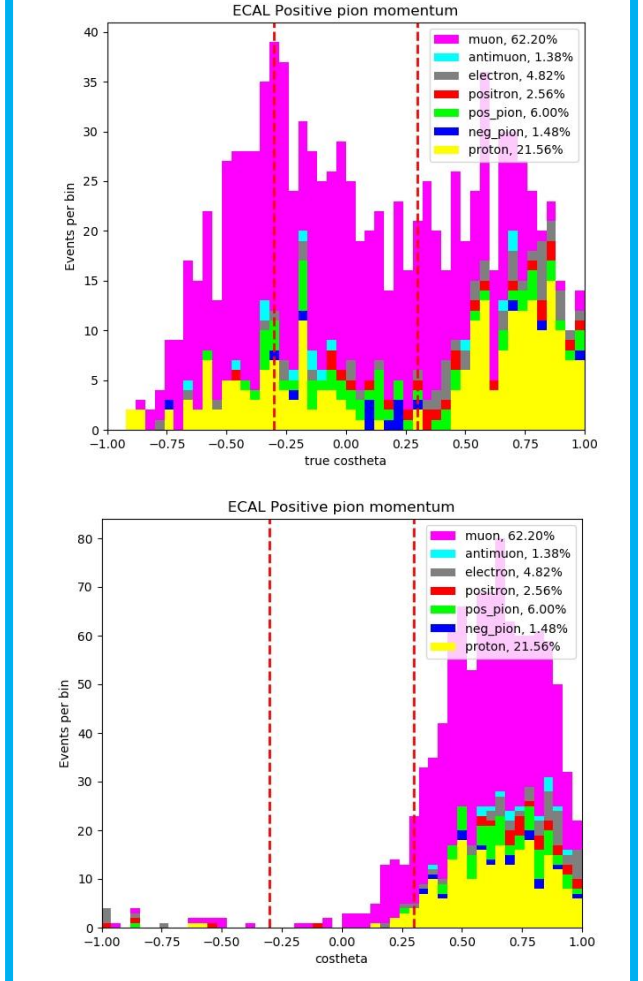
```
SetBranchAlias(0,"pos-FGD1",          0, 0);
SetBranchAlias(1,"pos-FGD2",          0, 1);
SetBranchAlias(2,"pos-DsECal",        0, 2);
SetBranchAlias(3,"neg-FGD1",          1, 0);
SetBranchAlias(4,"neg-FGD2",          1, 1);
SetBranchAlias(5,"neg-DsECal",        1, 2);
SetBranchAlias(6,"neg-FGD1-Barrel",   1, 3);
SetBranchAlias(7,"neg-FGD1-SMRD",     1, 4);
SetBranchAlias(8,"pi-FGD1",           2, 0);
SetBranchAlias(9,"pi-FGD1-Barrel",    2, 1);
```

" Candidate ends in FGD1 reduced FV",
" No TPC2 tracks",
" No FGD2 tracks",
" No ECAL tracks",
“No other FGD1 tracks”
" Pion PID"

" Candidate ends in Barrel ECal FV",
" Candidate crosses FGD1",
" No other ECAL tracks",
“No other FGD1 tracks”
" Pion HA PID"

Stopping control sample



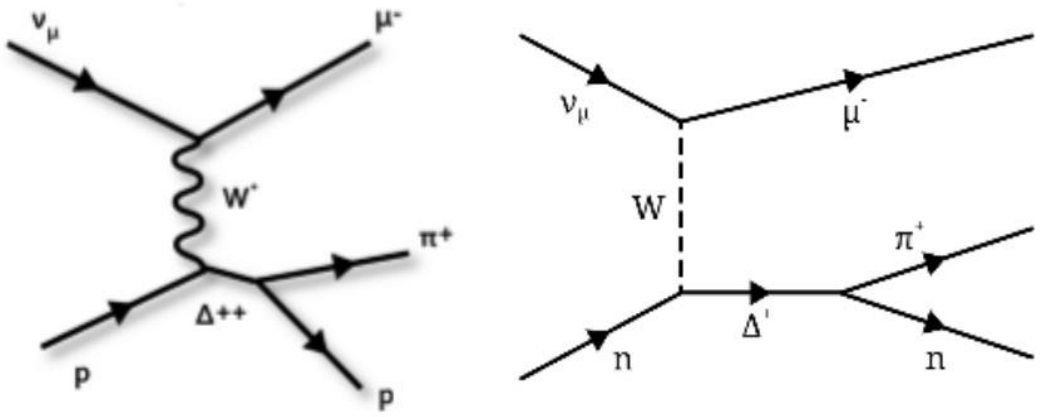


~~FGD1 Pions~~

Tracks

~~ECAL Pions~~

CC1π^+: Signal, Simulation and Software



Signal:

selecting events with a CC1π^+ topology in FGD1:

✓1 muon and 1 positive pion (in 4π acceptance)

✓ME tagging

Software:

✓nd280Highland v2r29 (in the future update to the v2r35)

✓numuCC4piMultiPiAnalysis v0r0

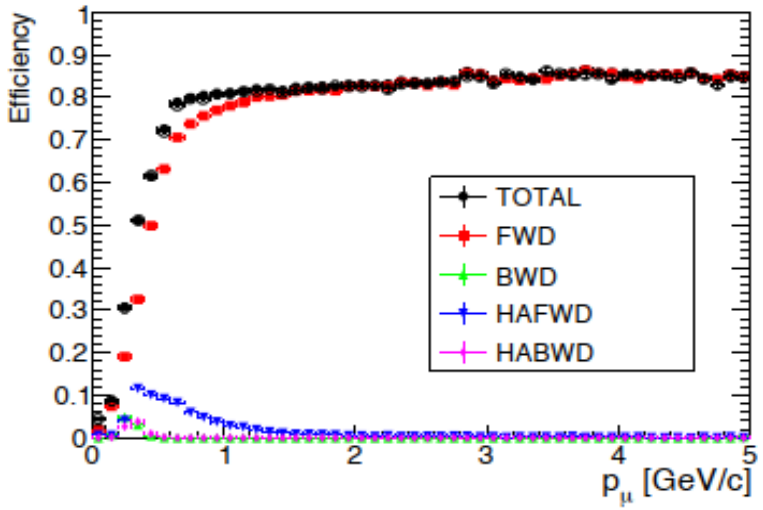
✓Production 6B for NEUT MC (runs 2+3+4)

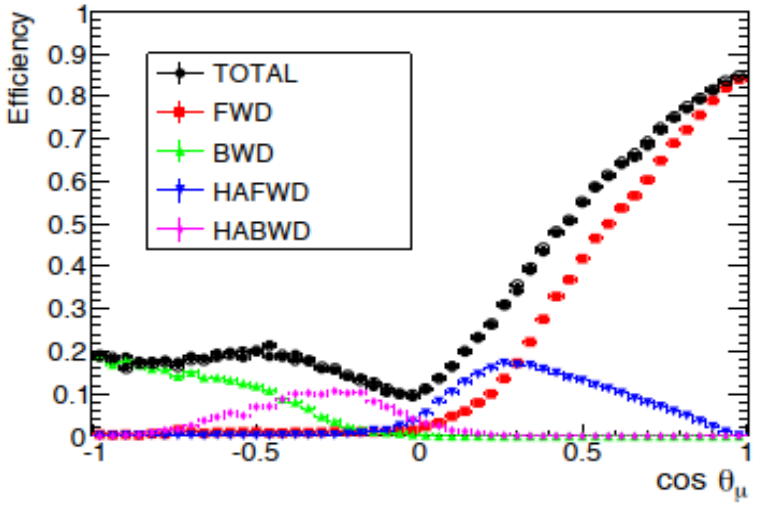
Simulation:

✓NEUT (official ν generator)

✓GENIE (alternative ν generator)

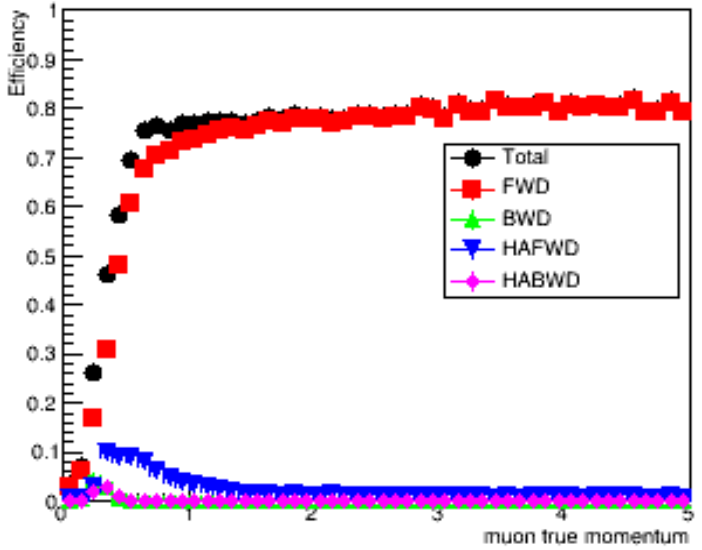
CC1π^+: Efficiency

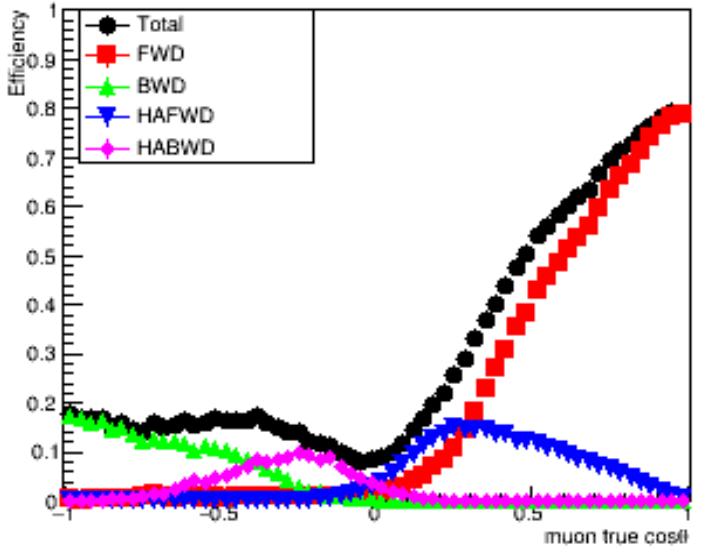




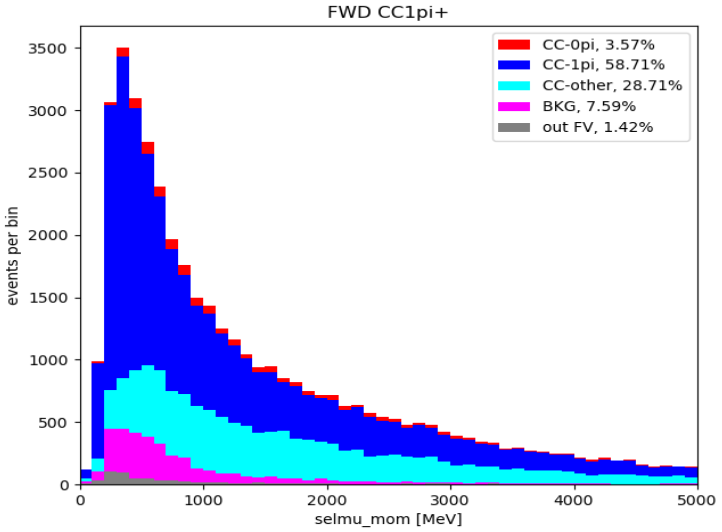
Efficiency of the CC inclusive for 4π aceptance with numuCC4pi by Alfonso (TN-245)

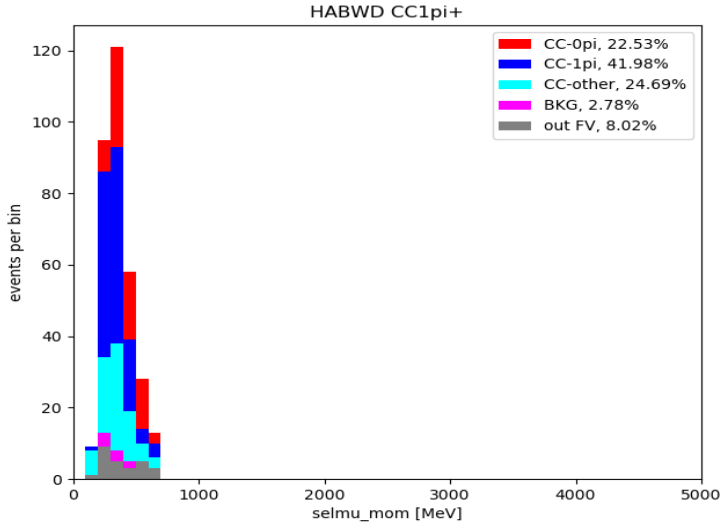
with numuCC4piMultiPi

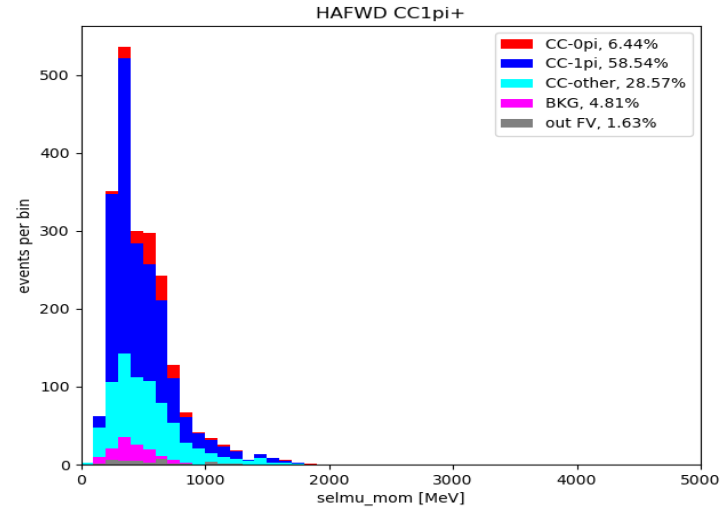


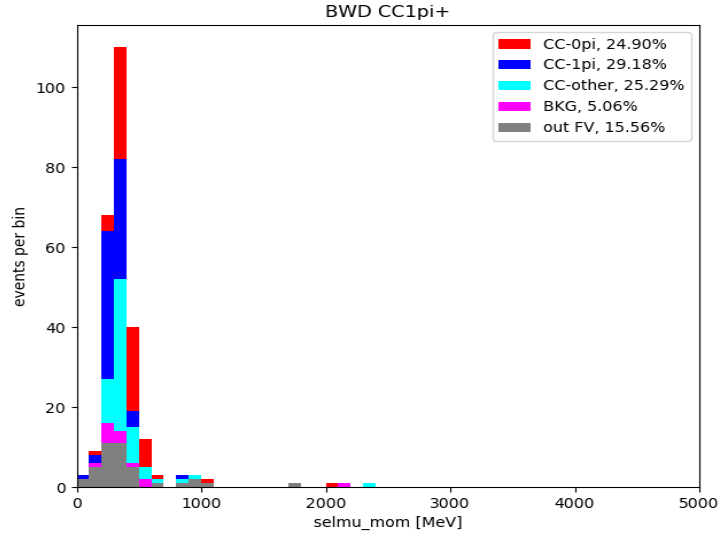


CC1π^+: Muon kinematics





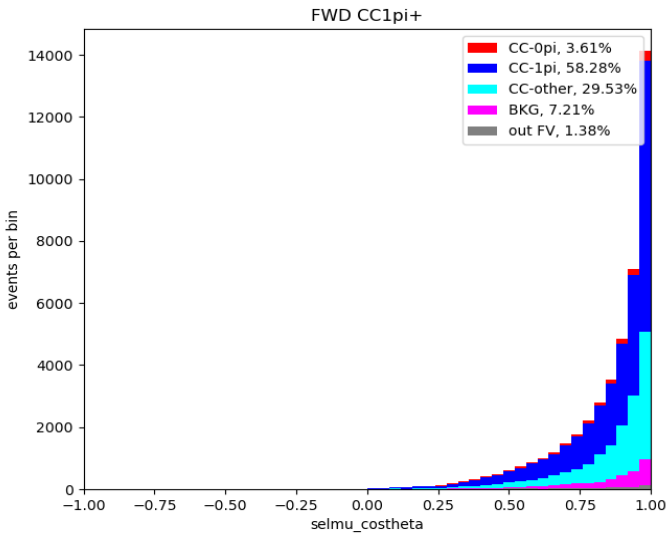


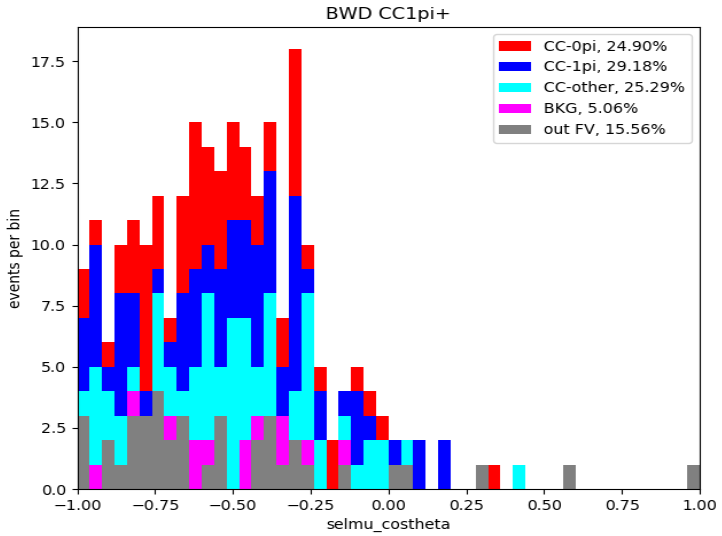


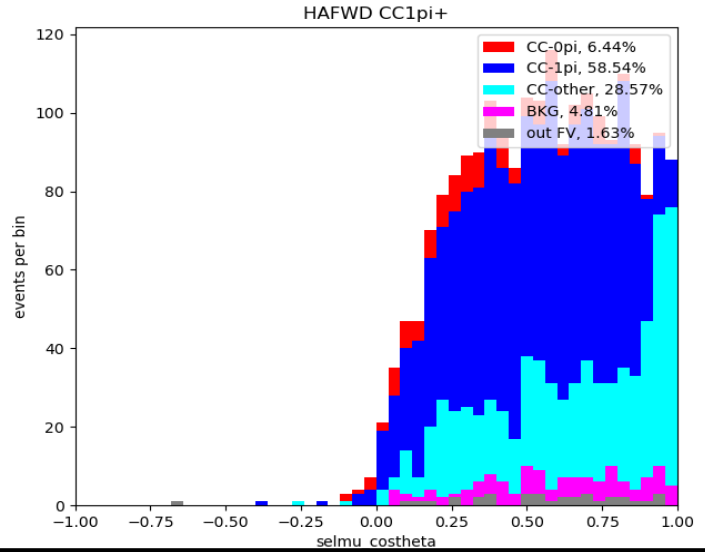
Momentum distributions for FWD, BWD, HAFWD and HABWD for muon candidate.

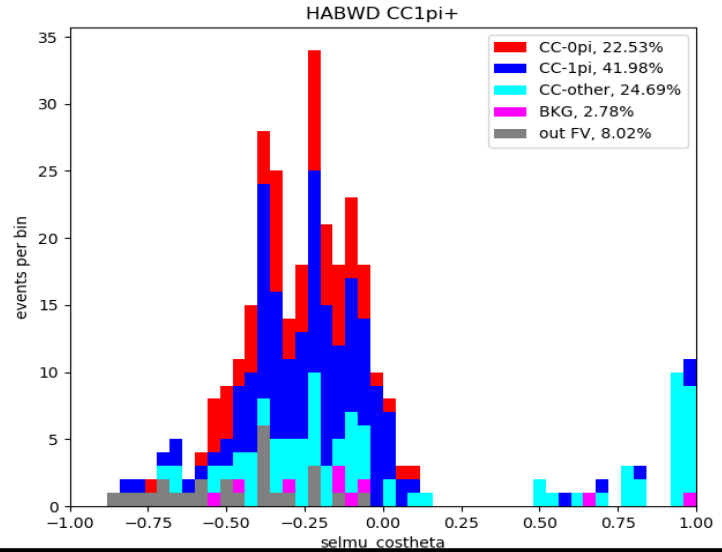
- **Note:** The large contribution of OOFV events for muon in the BWD and HABWD directions was reduced to 15% and 9% respectively.
- **Problem:** The CC other contribution for each direction go up to 30%.
- **Problem:** For BWD and HA BWD we see a contribution of the CC0π that rise until 25% in the BWD direction. **Solution:** Add more runs to increase statistics.

CC1π^+: Muon kinematics









Angular distributions for FWD, BWD, HAFWD and HABWD for muon candidate.

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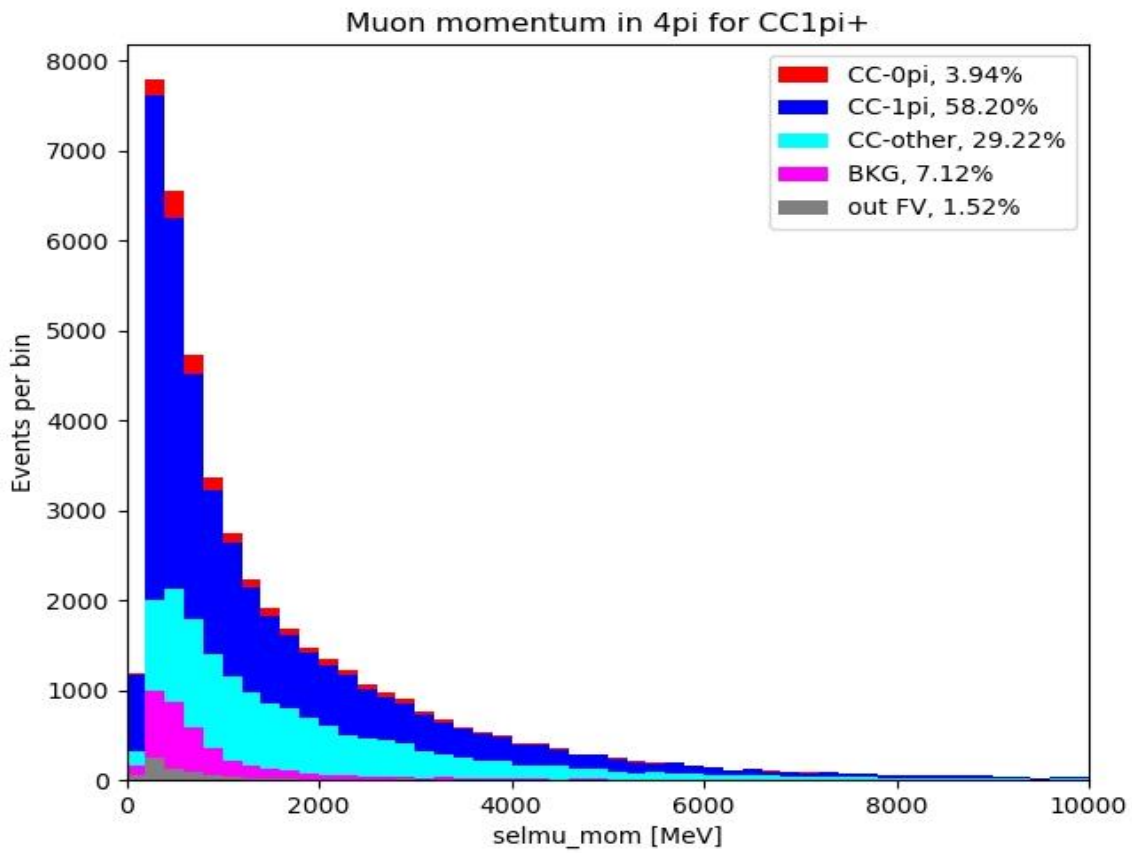
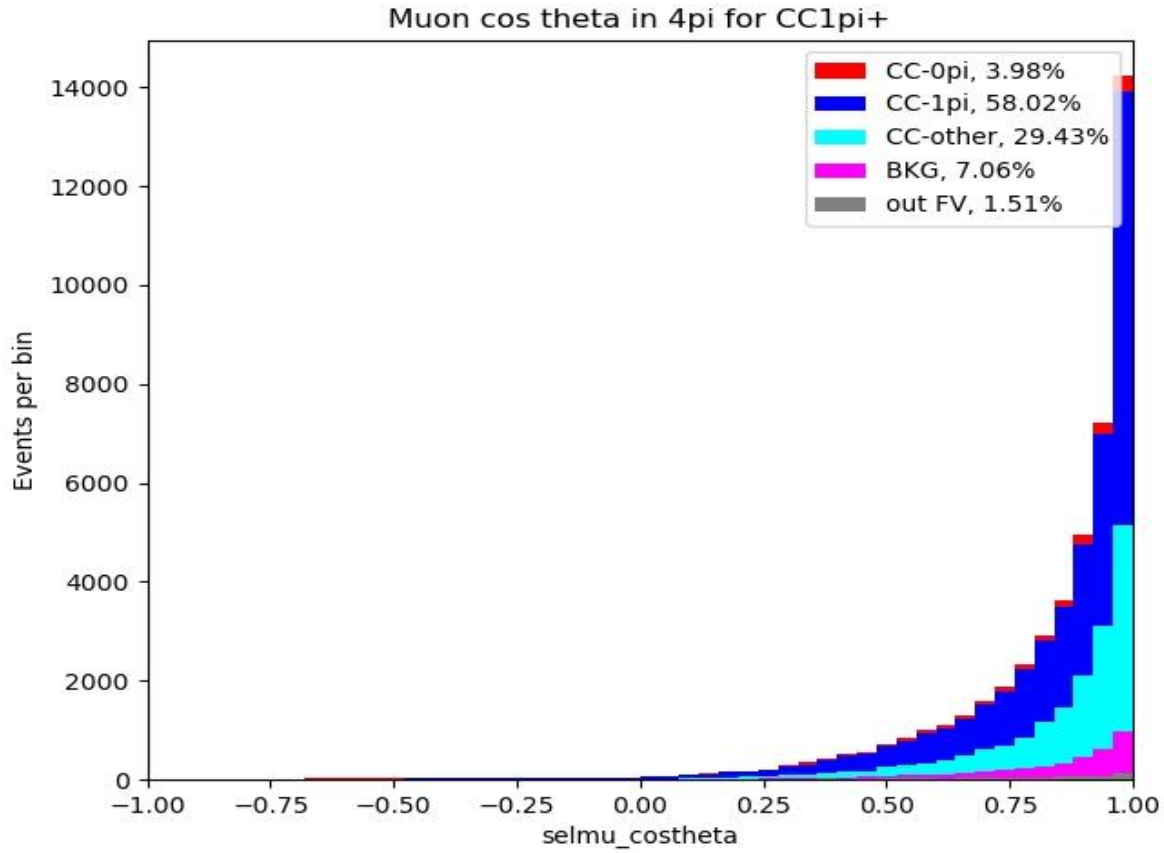
CC1π^+: Muon kinematics

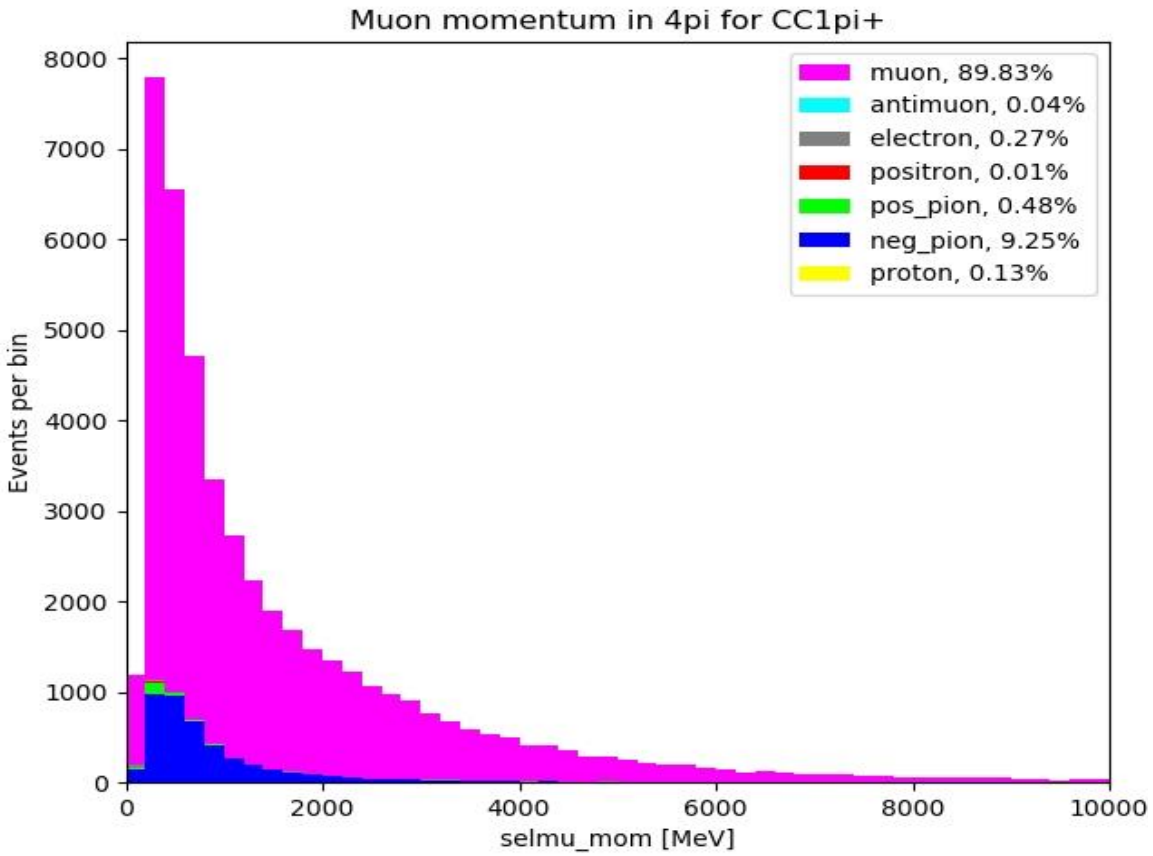


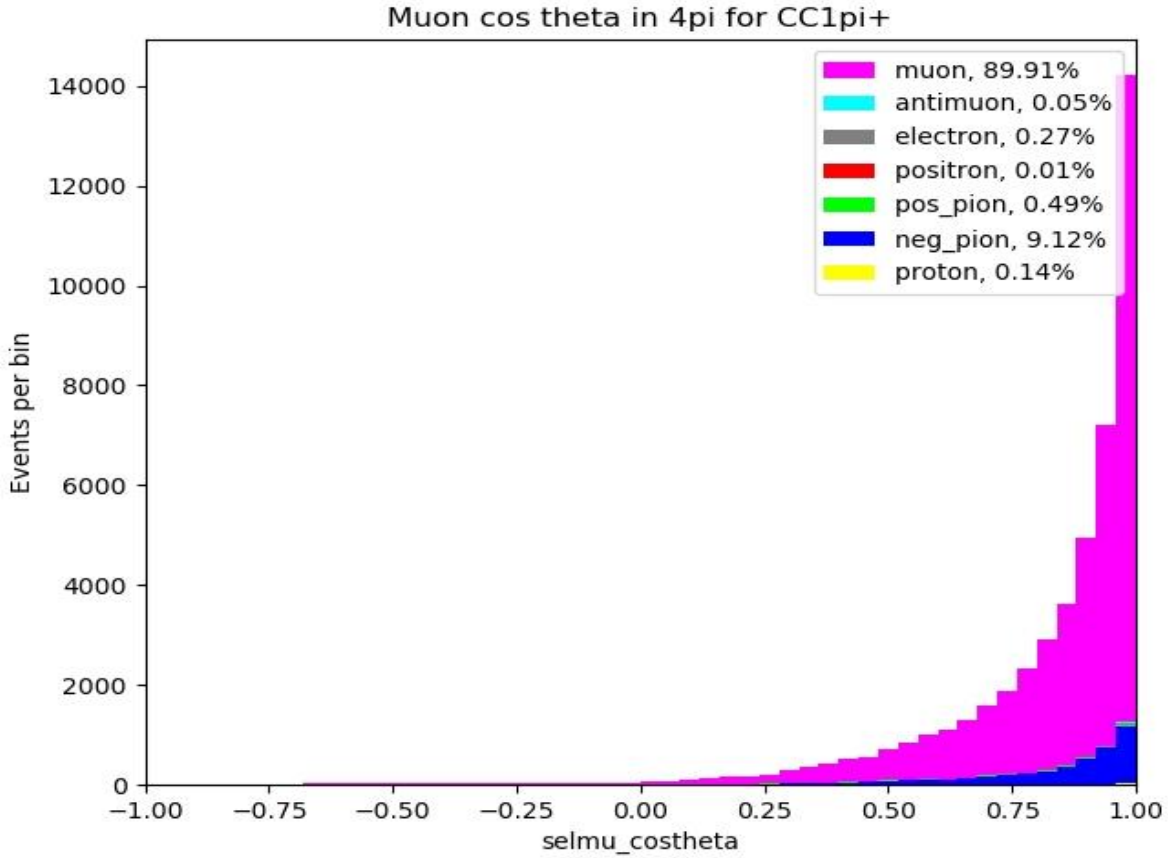


Muon momentum and angular distributions for 4π based on topology

- The main contamination is comin from CC other, ~30%.

CC1π^+: Muon kinematics

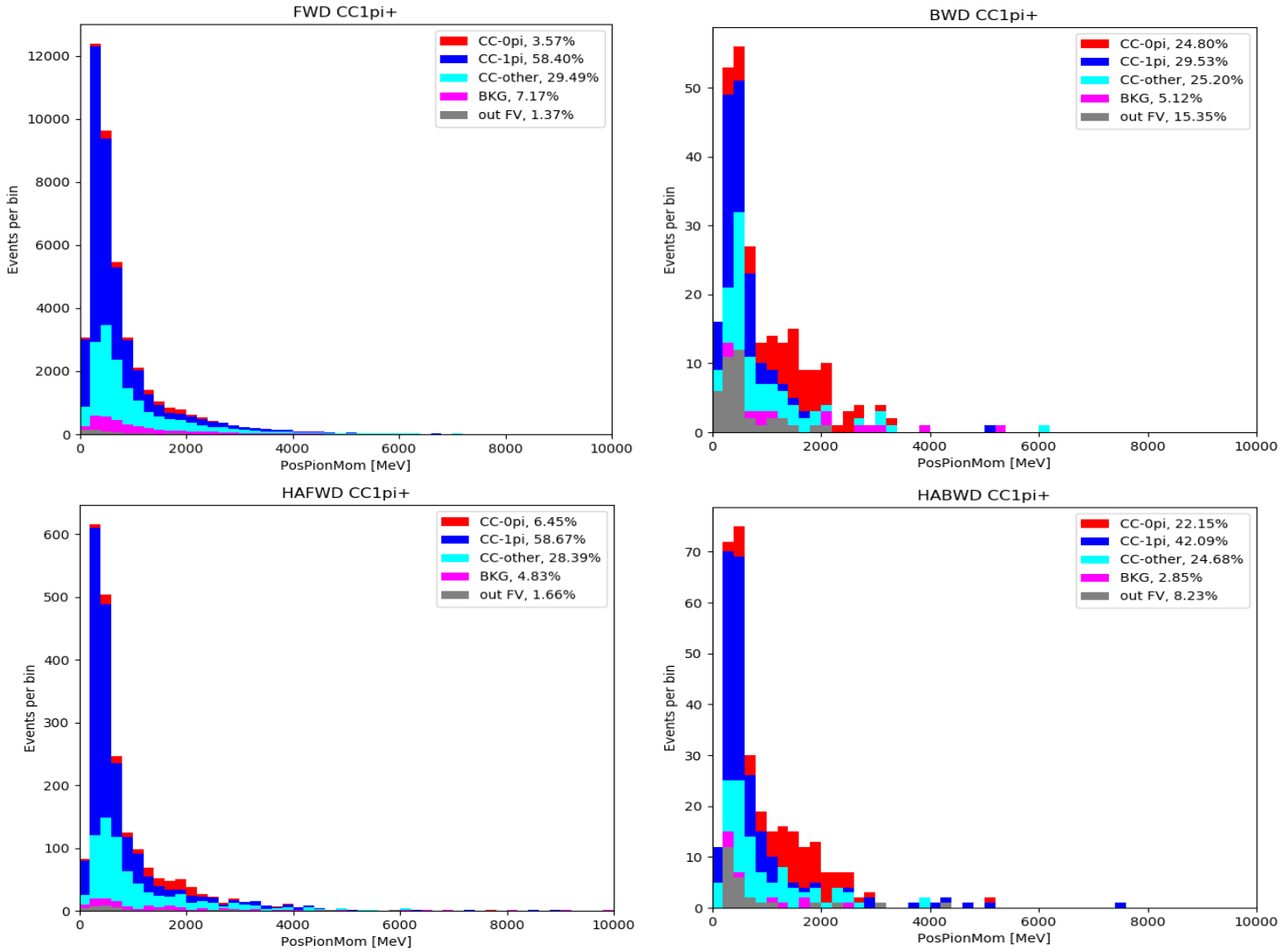




Muon momentum and angular distributions for 4π based on true particle ID

- The main contamination is comin from π^-, ~9%.

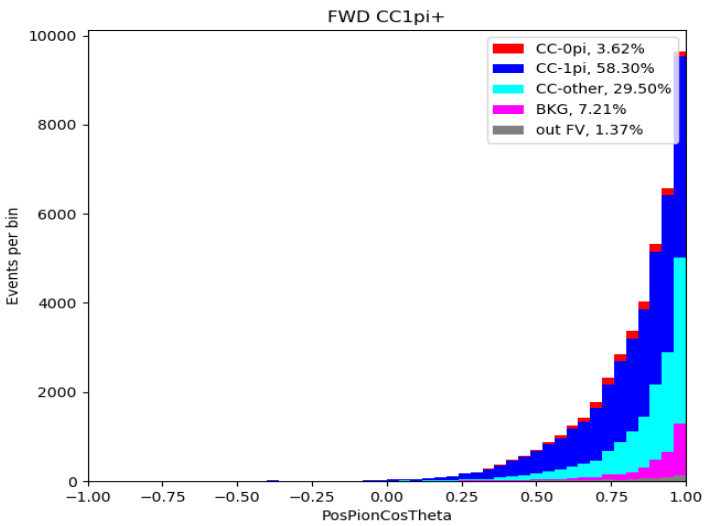
CC1π^+: Positive pion kinematics

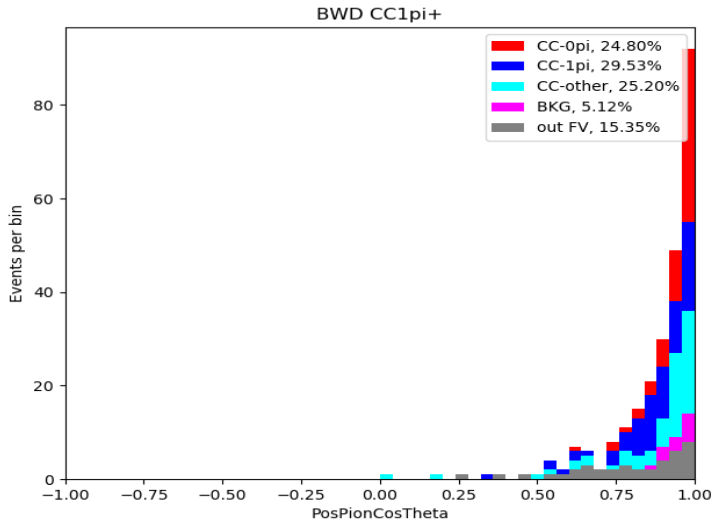


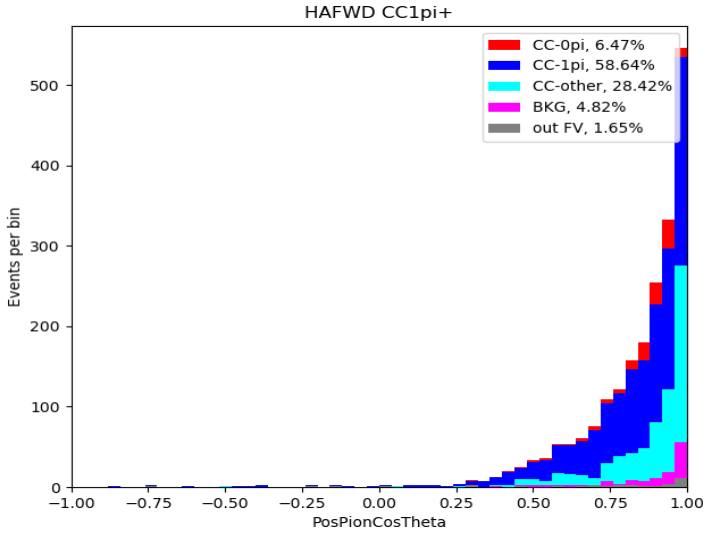
Momentum distributions for FWD, BWD, HAFWD and HABWD for TPC positive pion candidate.

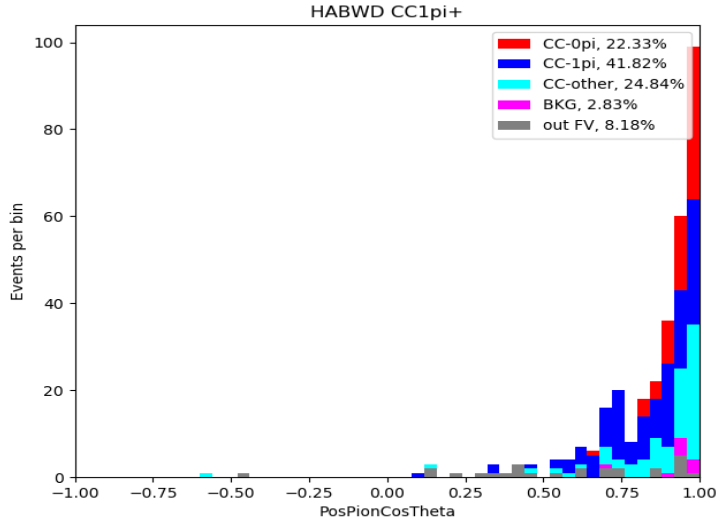
- **Note:** The large contribution of OOFV events for muon in the BWD and HABWD directions was reduced to 15% and 9% respectively.
- **Problem:** The CC other contribution for each direction go up to 30%.
- **Problem:** For BWD and HA BWD we see a contribution of the CC0π that rise until 25% in the BWD direction. **Solution:** Add more runs to increase statistics.

CC1π^+: Positive pion kinematics









Angular distributions for FWD, BWD, HAFWD and HABWD for TPC positive pion candidate.

- **Note:** The large contribution of OOFV events for muon in the BWD and HABWD directions was reduced to 15% and 9% respectively.
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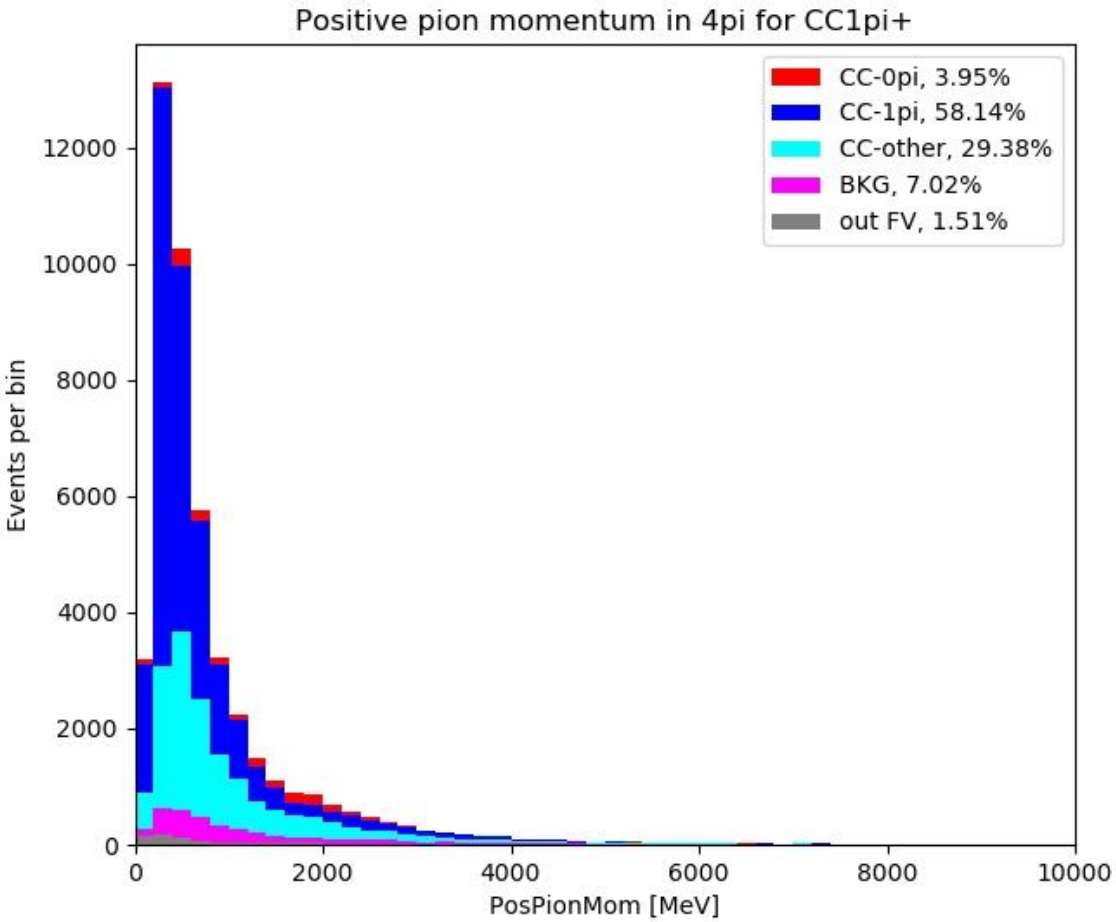
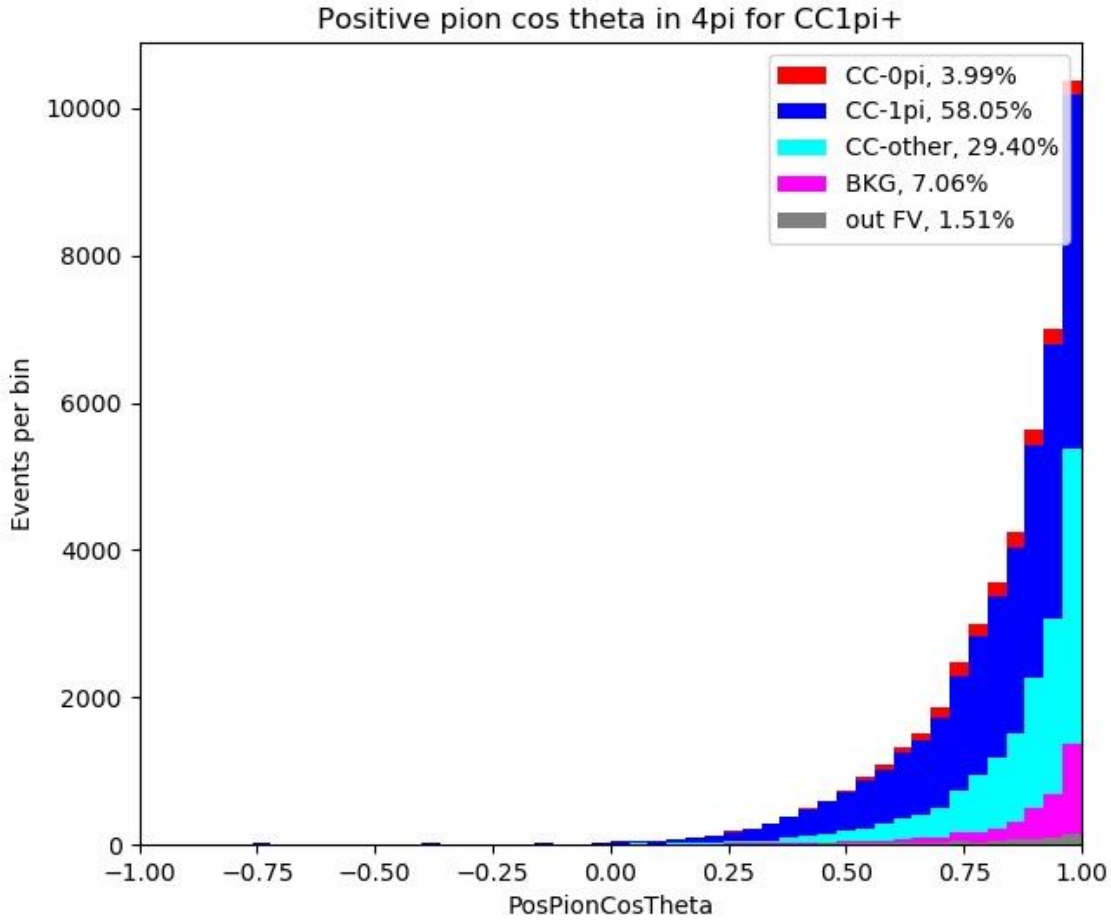
CC1π^+: Positive pion kinematics

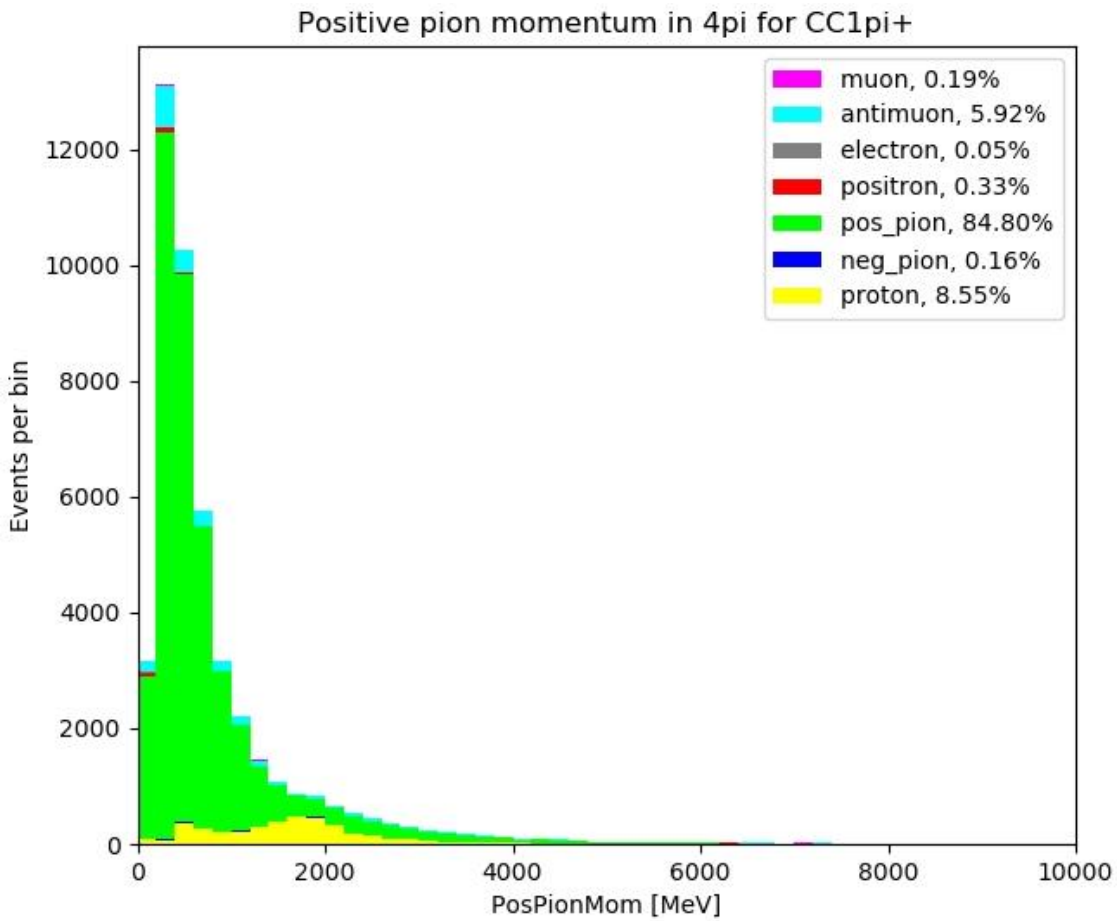


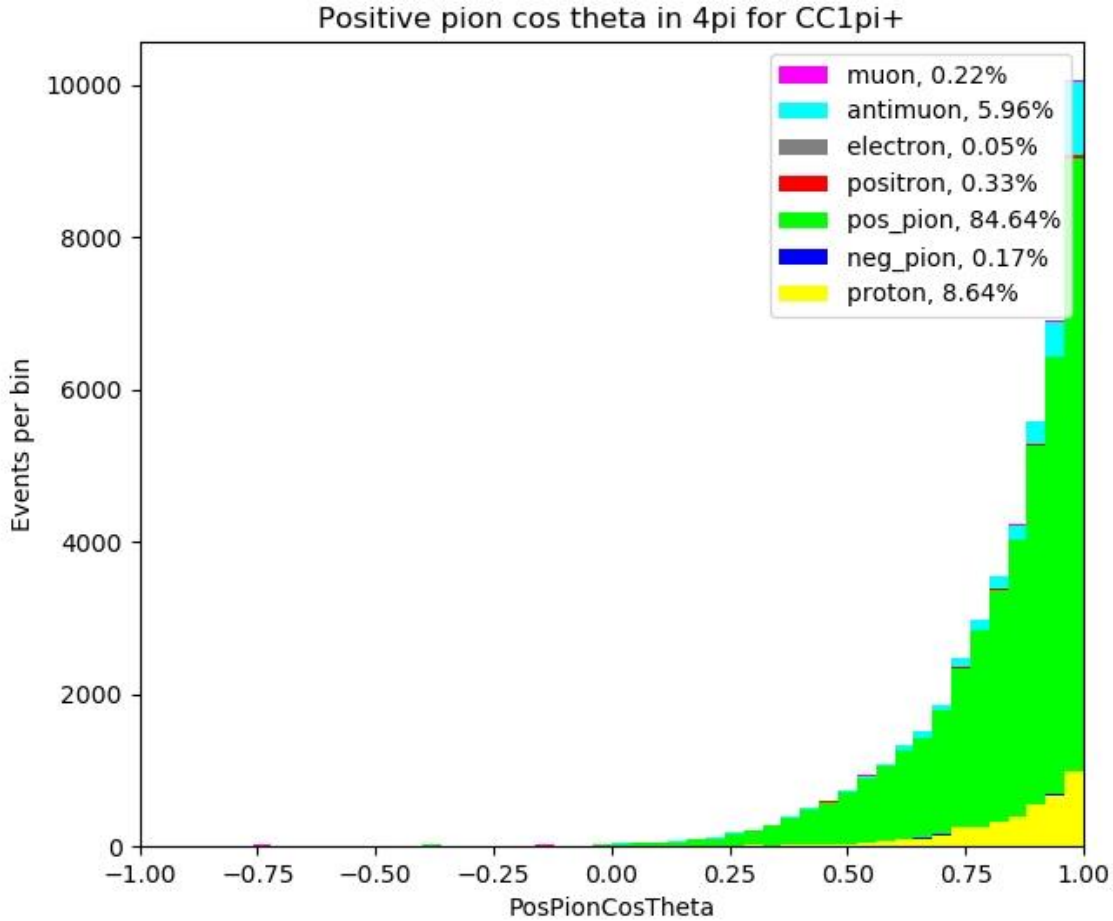


Positive pion momentum and angular distributions for 4π based on topology

- The main contamination is comin from CC other, ~30%.

CC1π^+: Positive pion kinematics





Positive pion momentum and angular distributions for 4π based on true particle ID

- The main contamination is comin from **p**, ~9%.

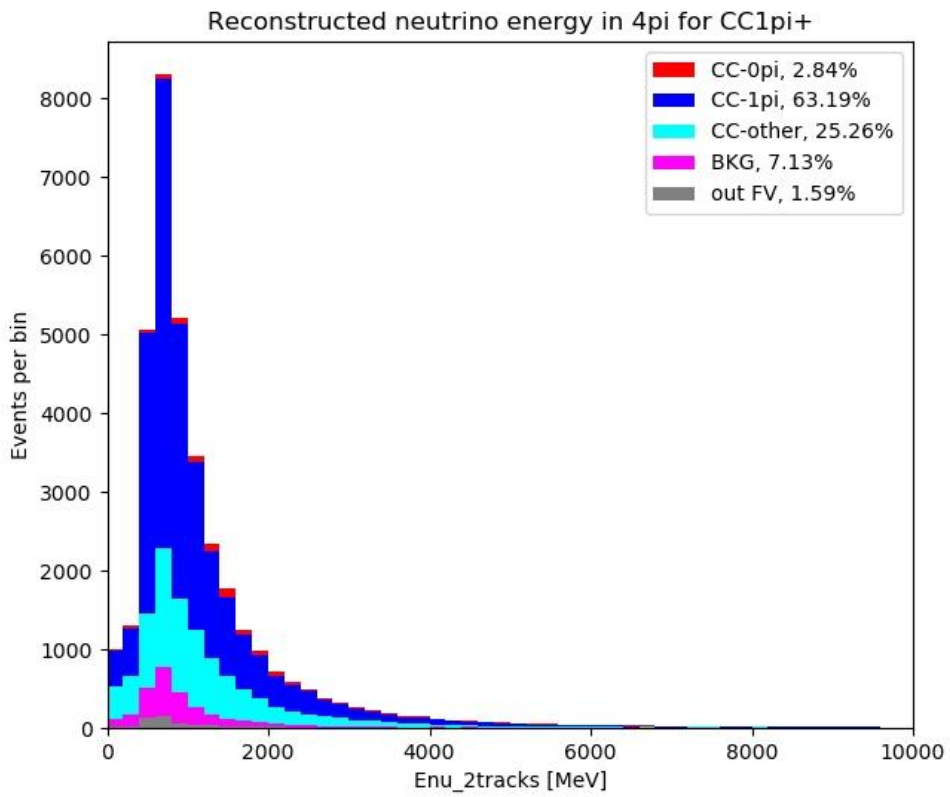
CC1π^+: Some variables:

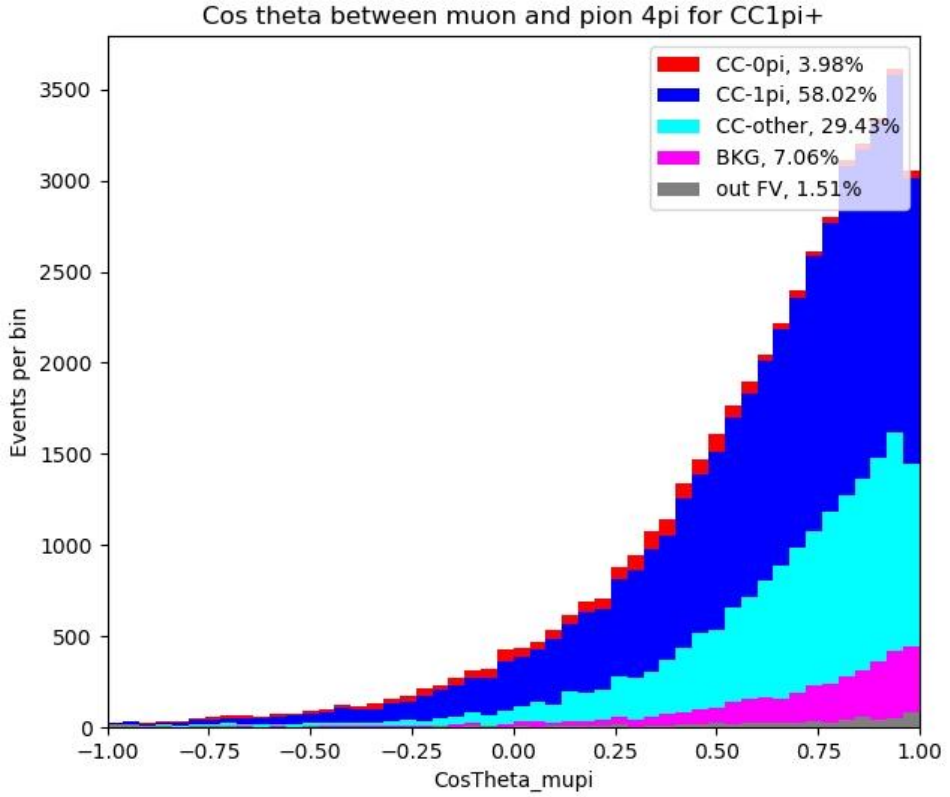
- The neutrino energy is reconstructed assuming $m_\nu = 0, P_N = 0$ and the nucleon in the final state is not reconstructed.

$$E_\nu^{rec} = \frac{m_\mu^2 + m_\pi^2 - 2m_N(E_\mu + E_\pi) + 2P_\mu P_\pi}{2(E_\mu + E_\pi - |\vec{k}_\mu| \cos\theta_\mu - |\vec{k}_\pi| \cos\theta_\pi - m_N)}$$

- Reconstructed momentum transfer is calculated like: $Q^2_{rec} = 2E_\nu^{rec}(E_\mu - |\vec{k}_\mu| \cos\theta_\mu) - m_\mu^2$
- Delta momentum: $P_\Delta = |Q_3| = |\vec{P}_\nu - \vec{P}_\mu|$
- The invariant mass is calculated like: $W_{rec} = \sqrt{(E_\nu^{rec} + m_p - E_\mu)^2 - (|P_\nu| - |P_\mu|)^2}$
- The angle between the muon and the pion will be: $\cos\theta_{\mu\pi} = \frac{\vec{k}_\mu * \vec{k}_\pi}{|\vec{k}_\mu| * |\vec{k}_\pi|}$

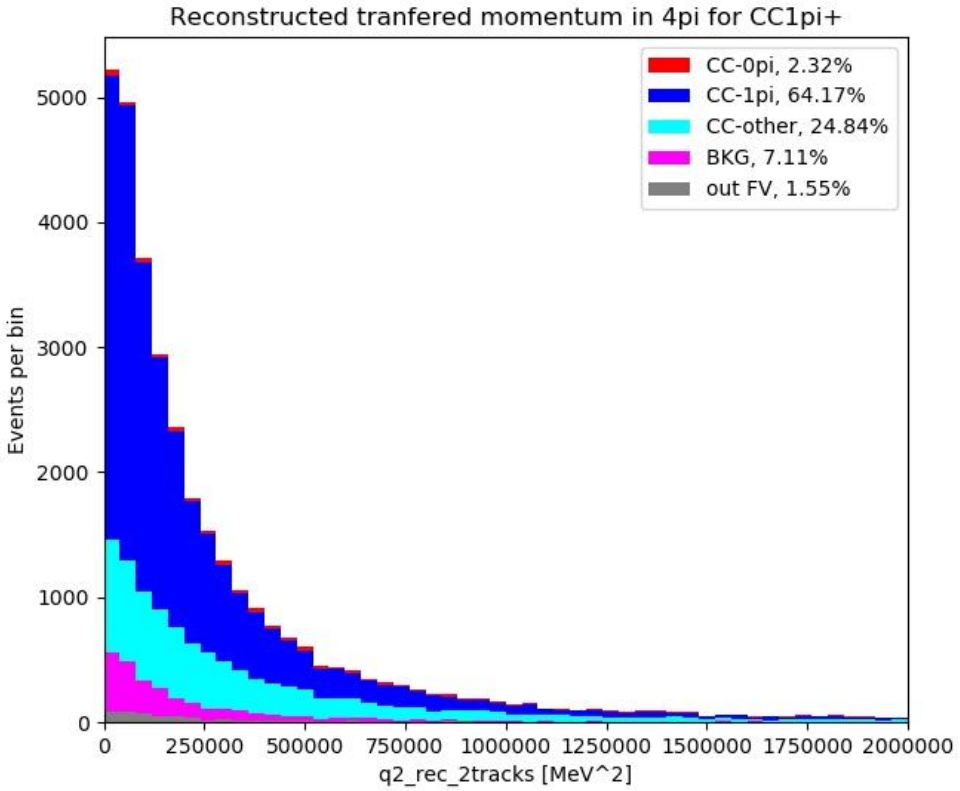
CC1π^+: Some variables (E_ν^{rec}, $\cos\theta_{\mu\pi}$,)

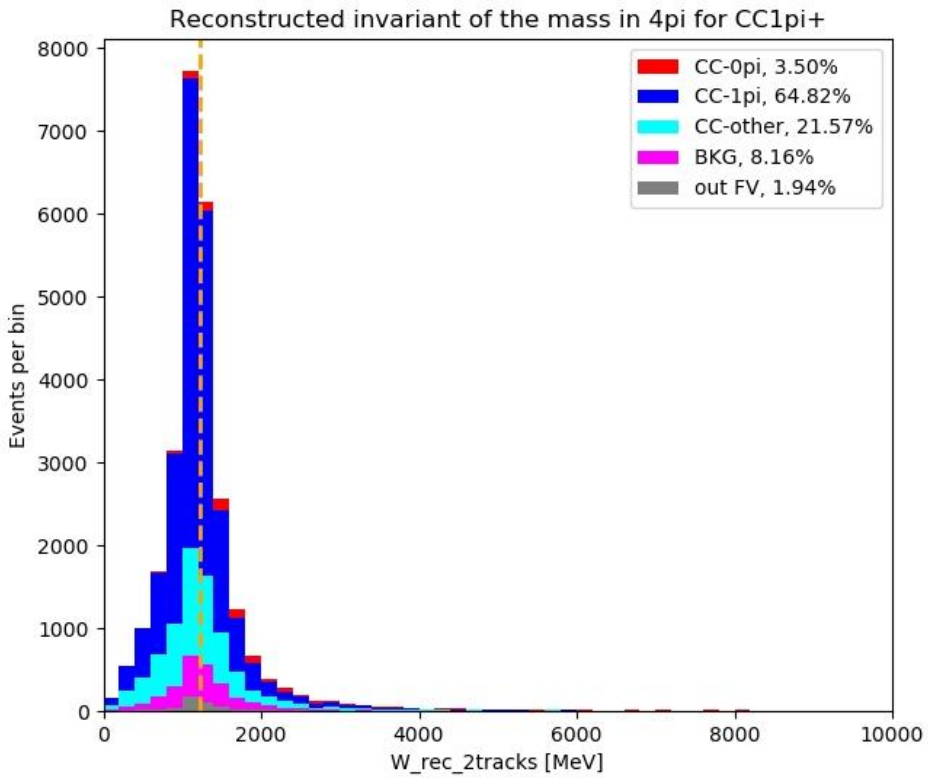




Preliminary results of reconstructed neutrino energy and the angle between the muon and the pion for CC1π^+ in 4π using only TPC pion information.

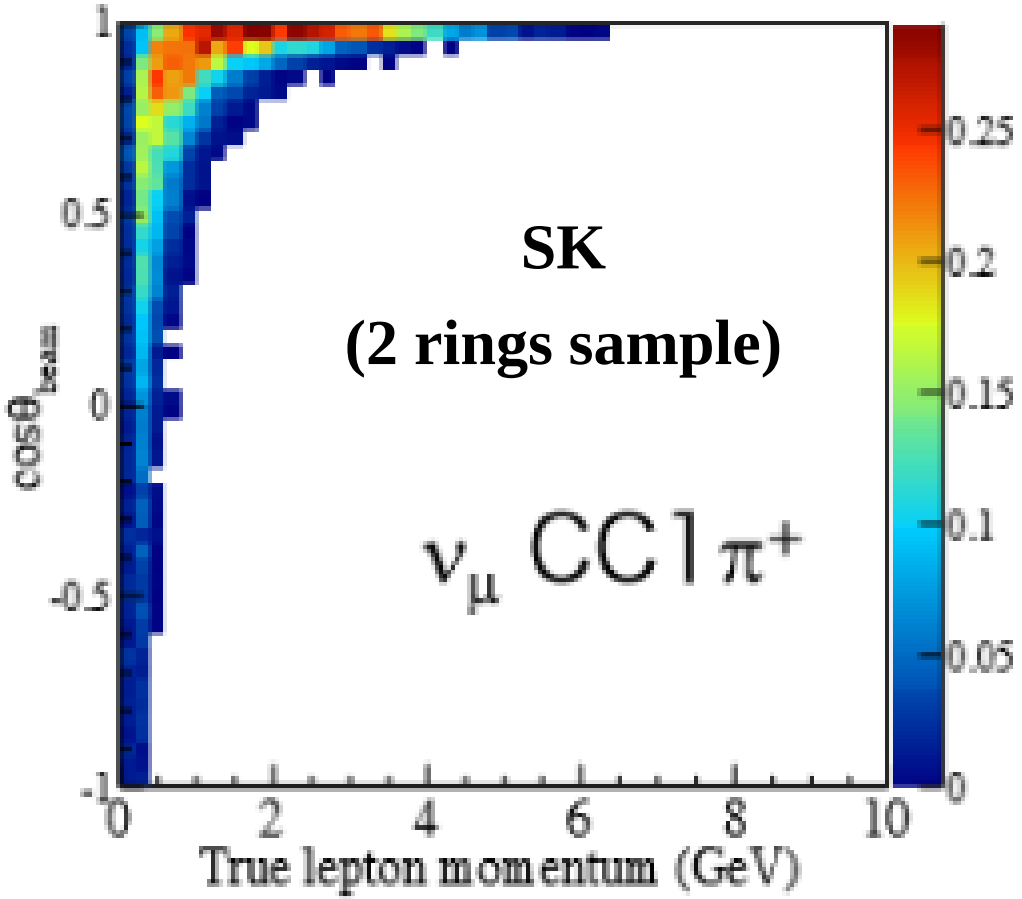
CC1π^+: Some variables (Q^2_{rec} , W_{rec})

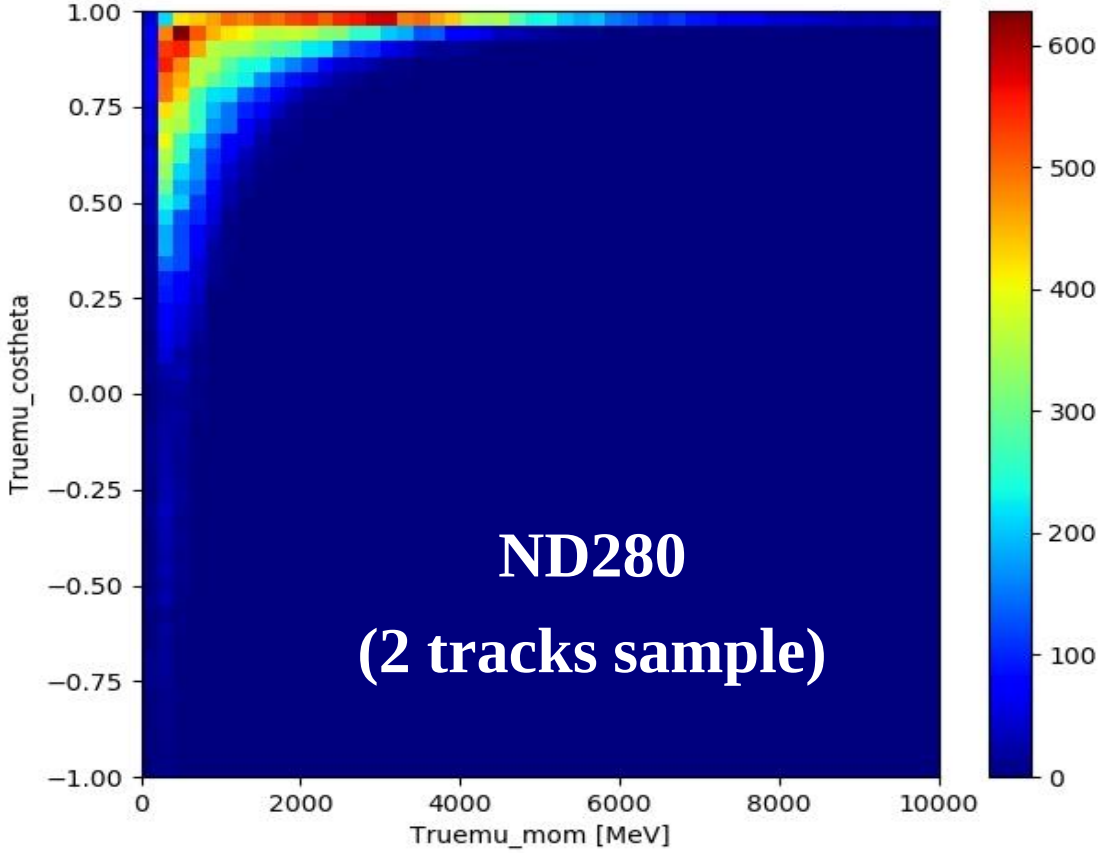




Preliminary results of reconstructed transferred momentum and mass invariance for CC1π^+ in 4π using only TPC pion information.

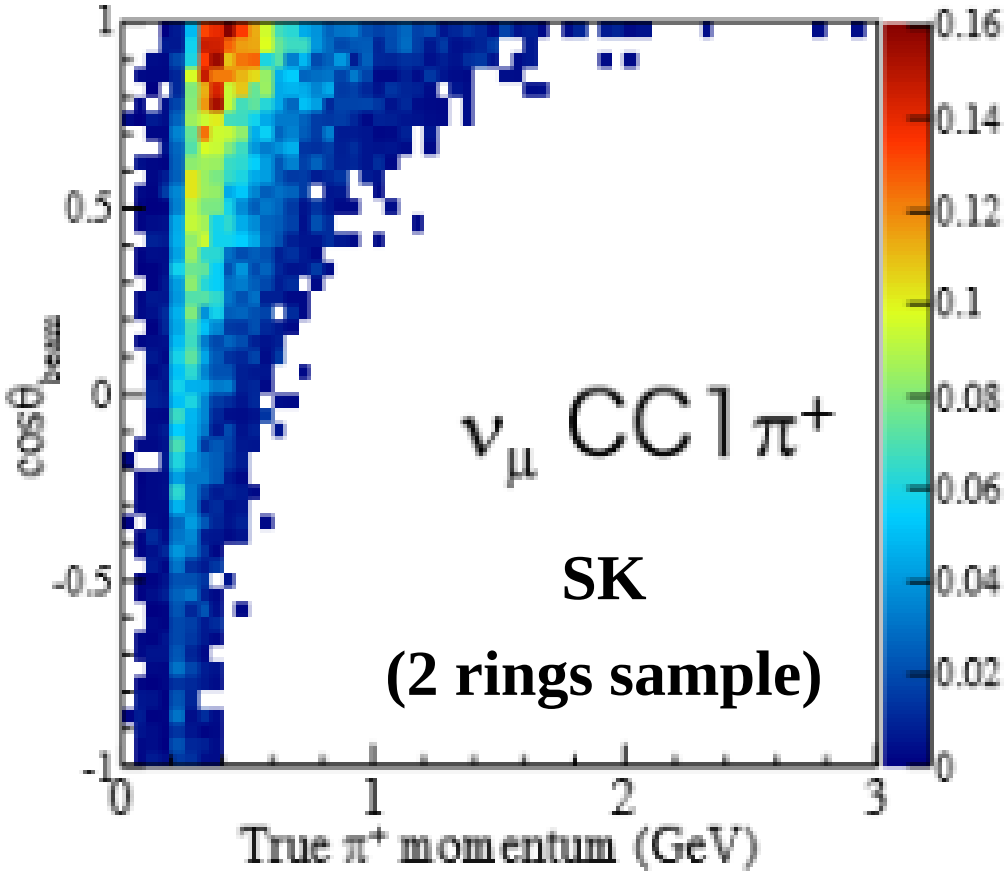
CC1π^+: SK vs. ND280

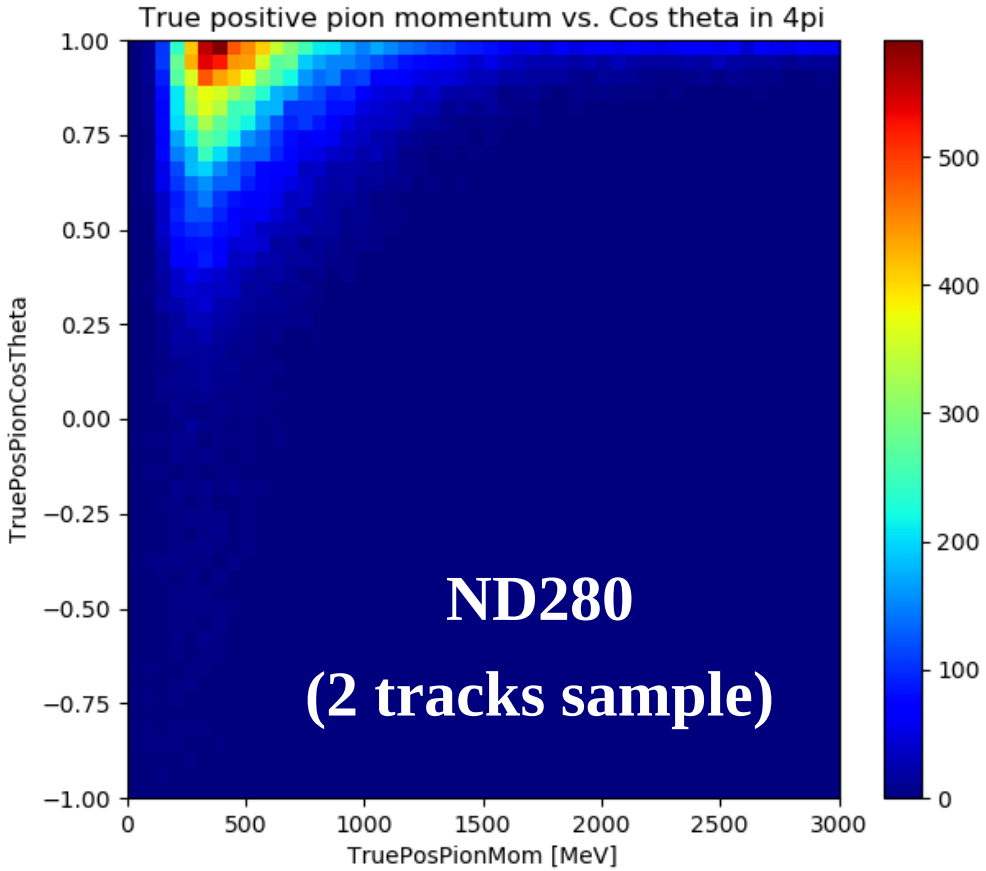




Note: I need more information about the samples in SK!!!

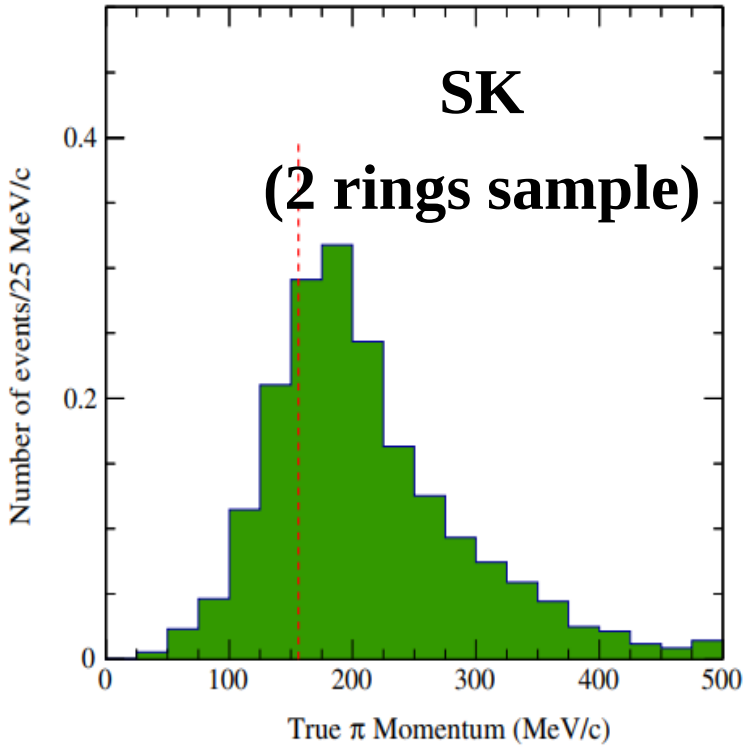
CC1π^+: SK vs. ND280

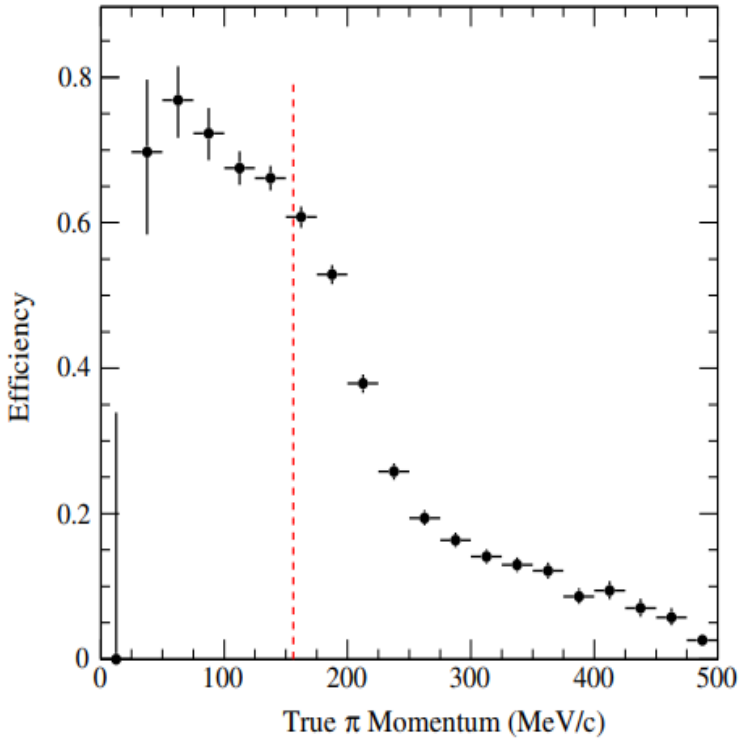




Note: I need more information about the samples in SK!!!

CC1π^+: SK vs. ND280





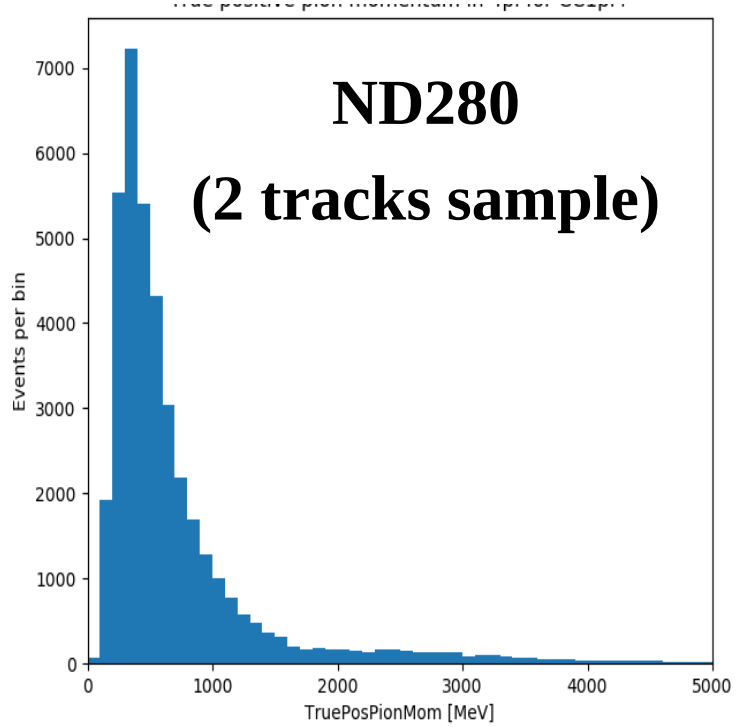
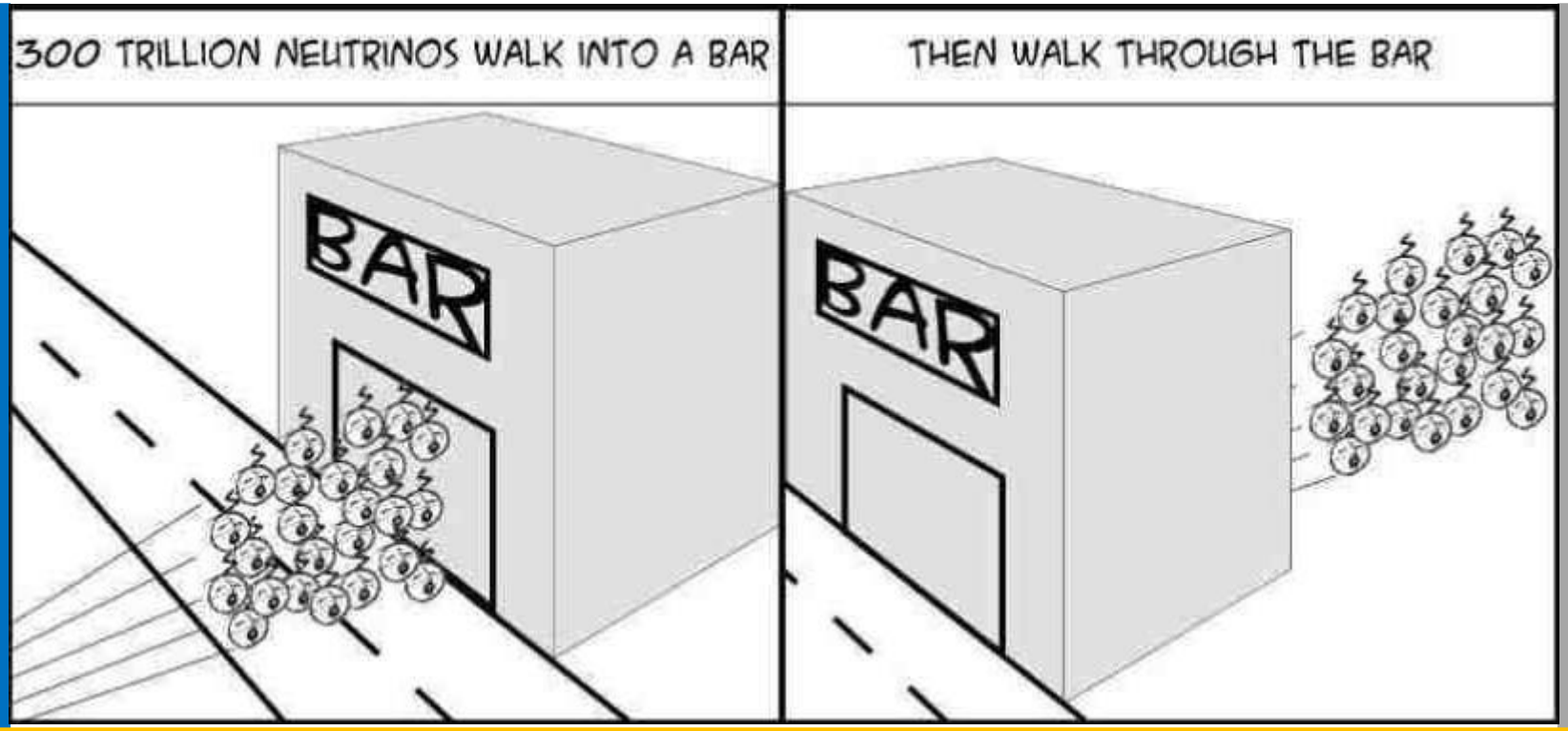


FIG. 23. The true momentum distribution for selected simulated signal events in the CC1π^+ candidate sample (left) and the selection efficiency for these events (right). The expectation is based on the parameters of Table XIII. The red dashed line indicates the Cherenkov threshold for charged pions.

Note: The efficiency is being computed and I need more information about the samples in SK!!!


300 TRILLION NEUTRINOS WALK INTO A BAR
BAR
THEN WALK THROUGH THE BAR
BAR

Thank you !!!