4π selection with ND280 Upgrade

CERN Workshop

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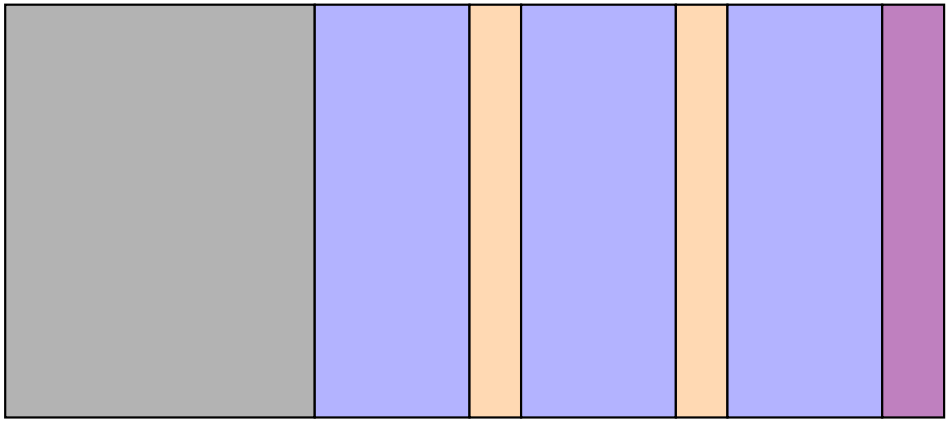
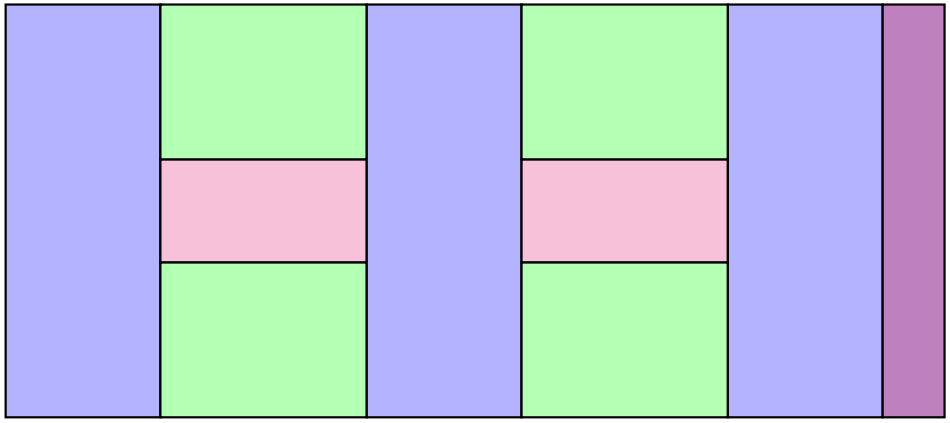
Configurations

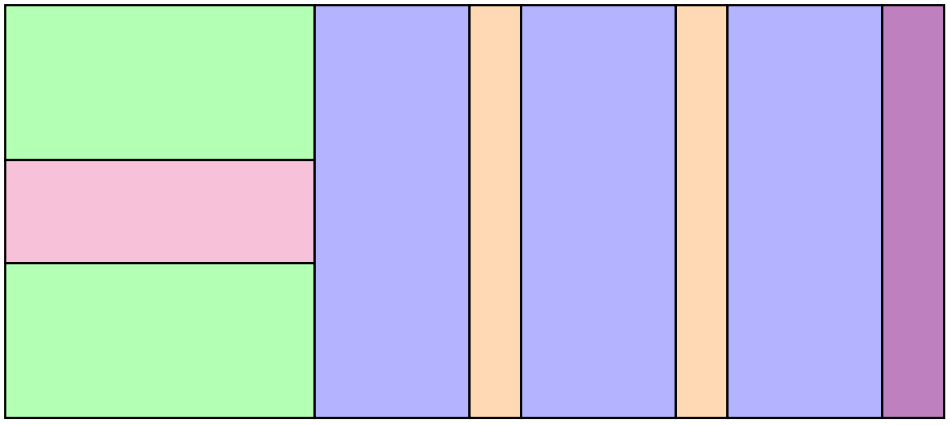
Current ND280



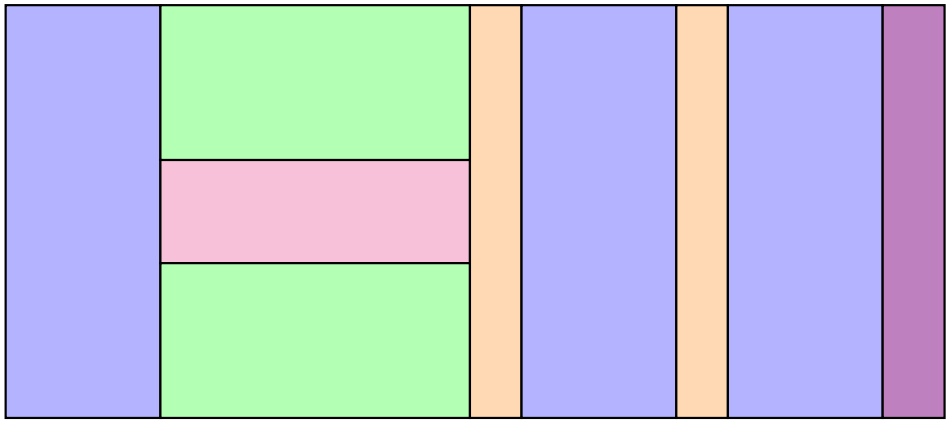
Upgrade reference



Alt.: Target → Fwd TPC 1



Alt.: Fwd TPC 1 → Target



Legend: WAGASCI-like target, FGD, VTPC, HTPC, P0D, DsECal

Schematics not on scale, only basket is represented

Motivations

Compare current ND280 performance with ND280 upgrade configurations (both reference and alternatives):

- selection efficiency
- expected statistics
- contaminations in the selection
- sensitivity to physics models

Method

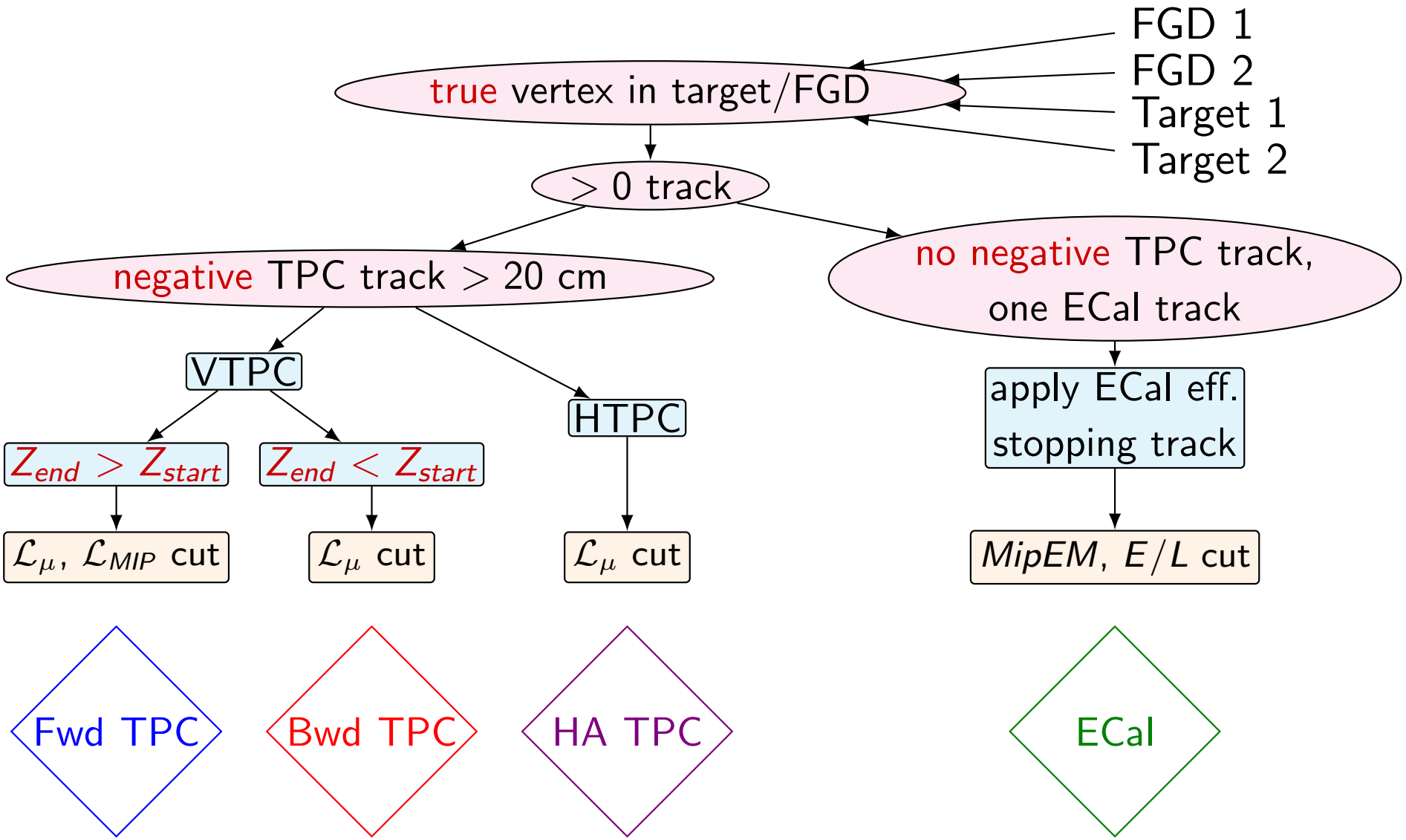
All is done inside a simplified framework (with pseudo-reconstruction and simple selection criteria) with simplified geometries (current-like, upgrade-like)

In the following, all the studies have been performed with these simplified geometries.

Contents

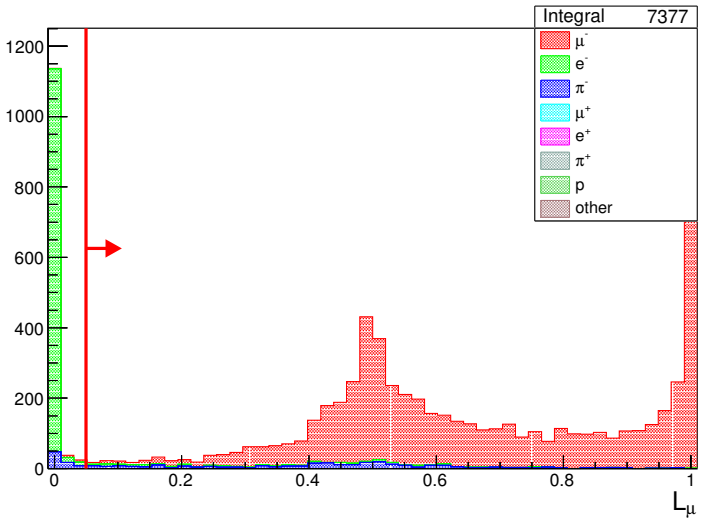
Selection

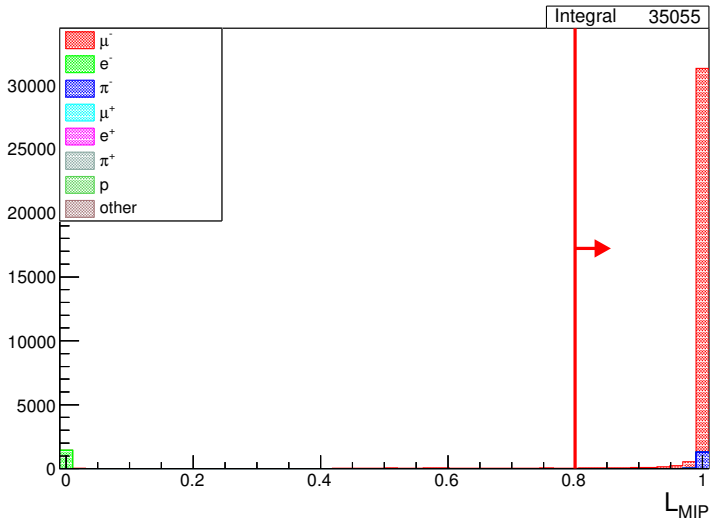
Selection in Highland



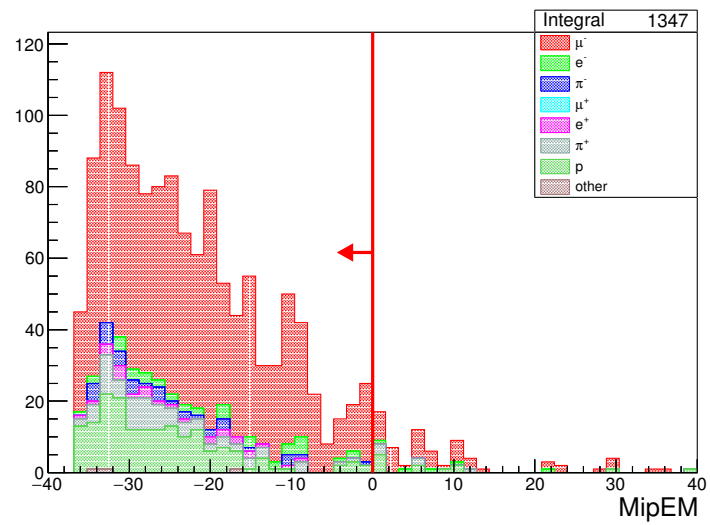
PID cuts

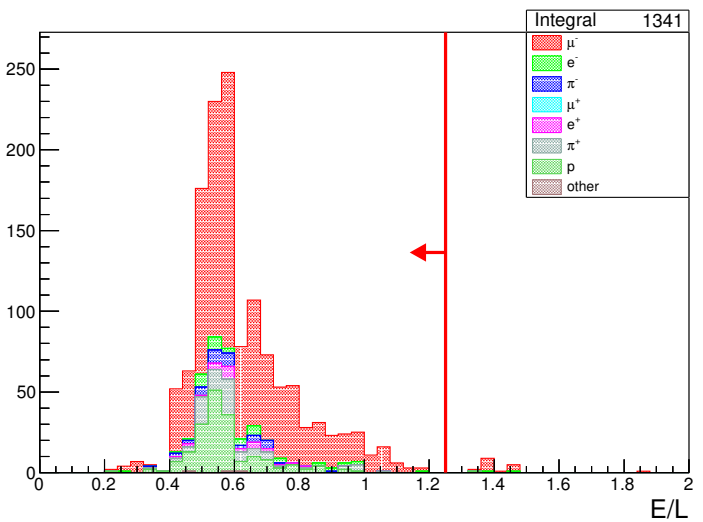
TPC PID using muon and MIP likelihood





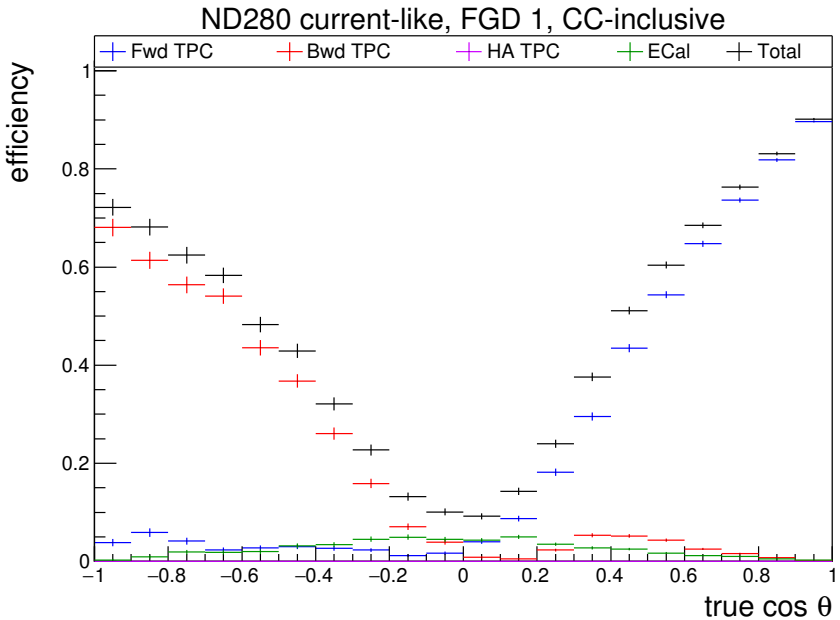
ECal PID using MipEM and E/L

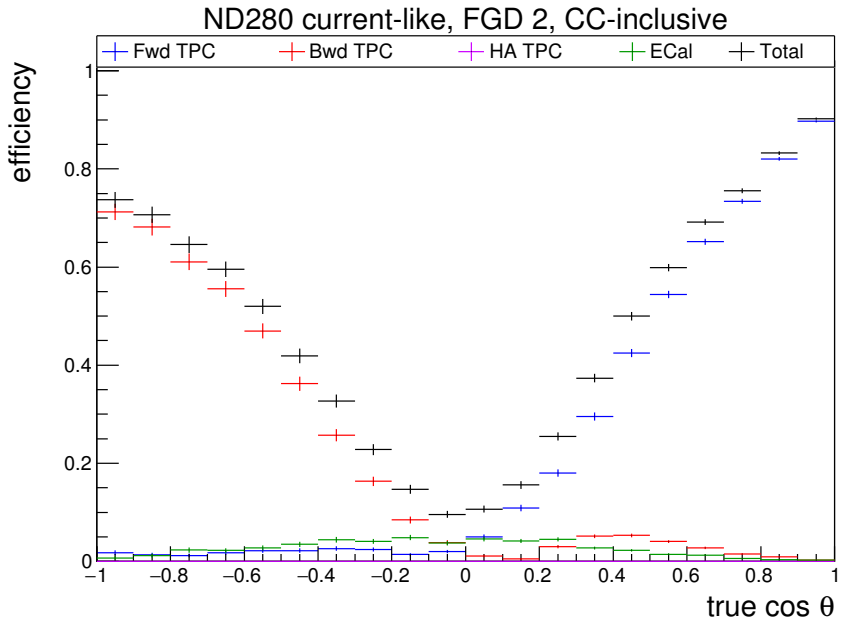




Efficiencies

Current configuration

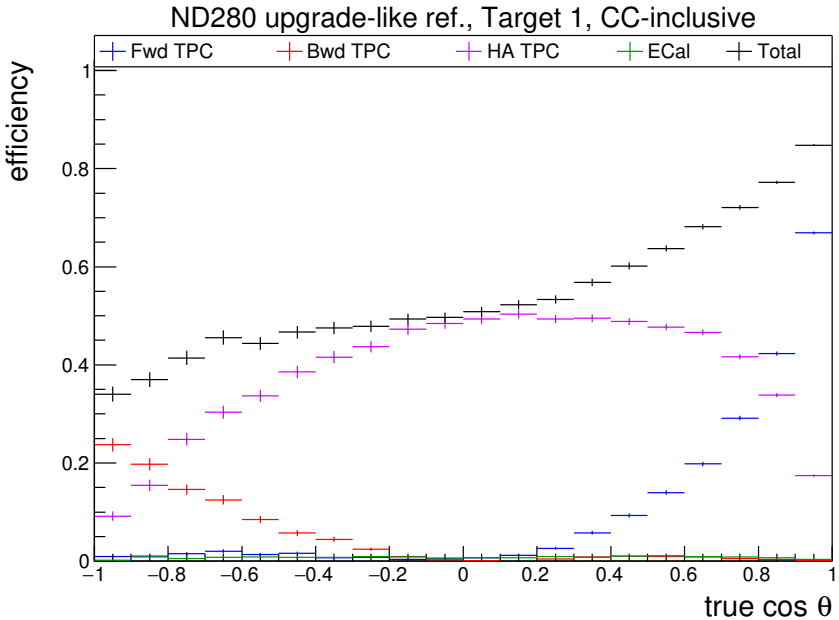




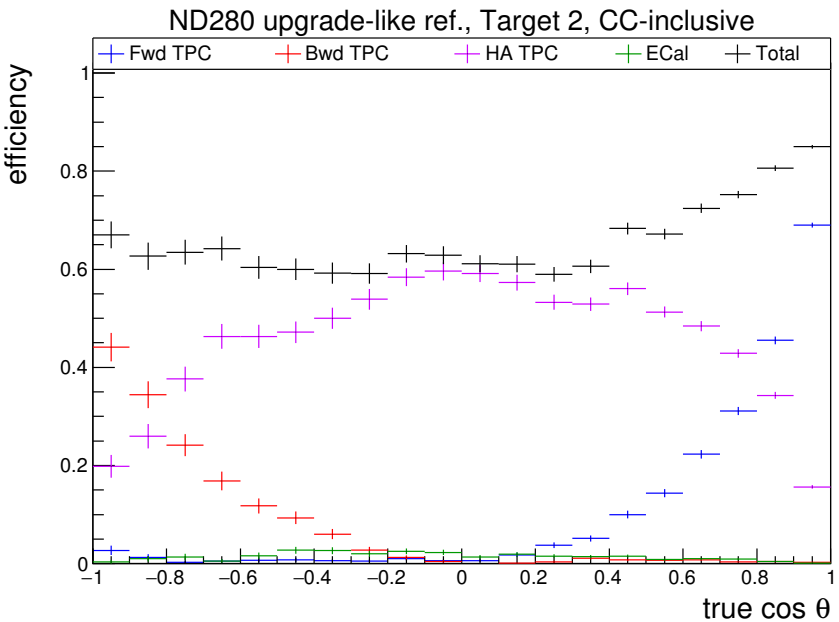
- Forward eff. is similar to current ND280 analysis ones
- Backward eff. is higher as we assume perfect sense determination
- No HA TPC component (as there is no horizontal TPCs)

Upgrade reference configuration

Assumed 100% water

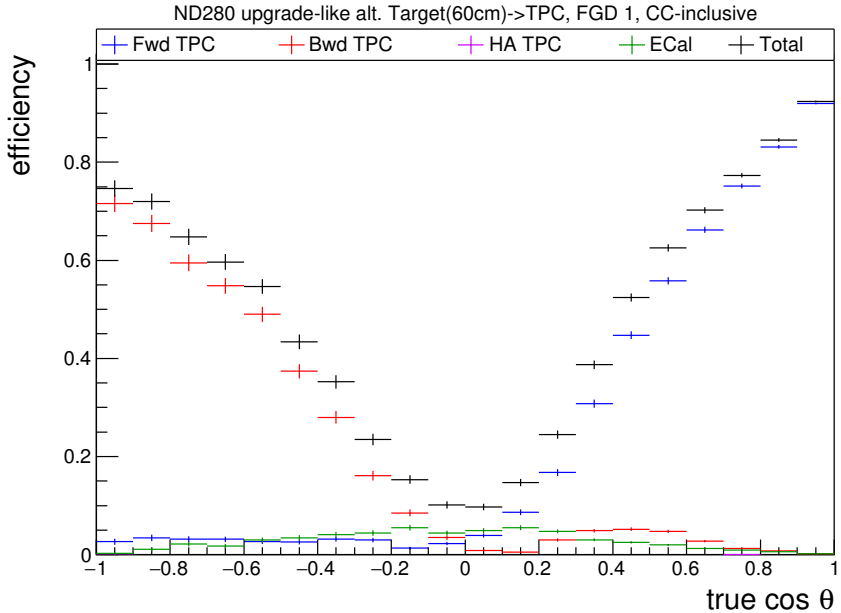


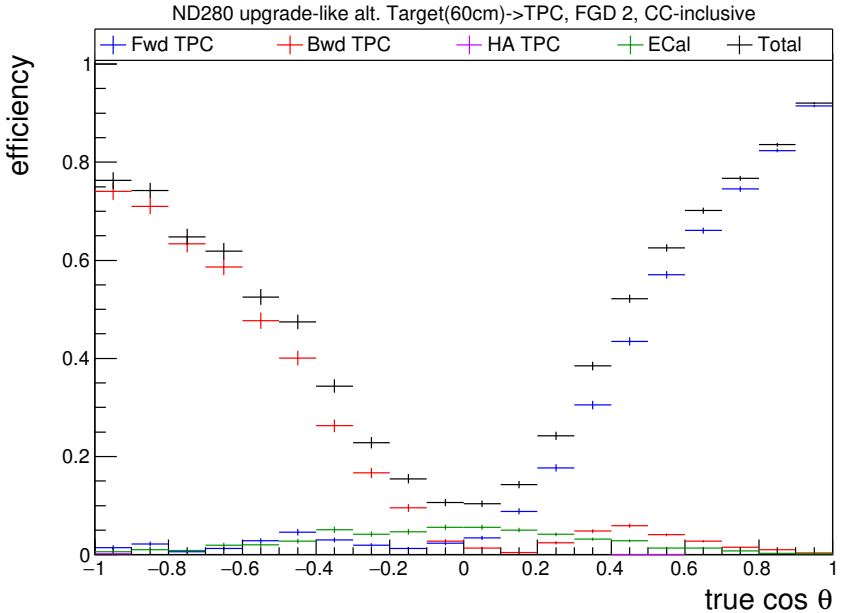
Assumed scintillator-only

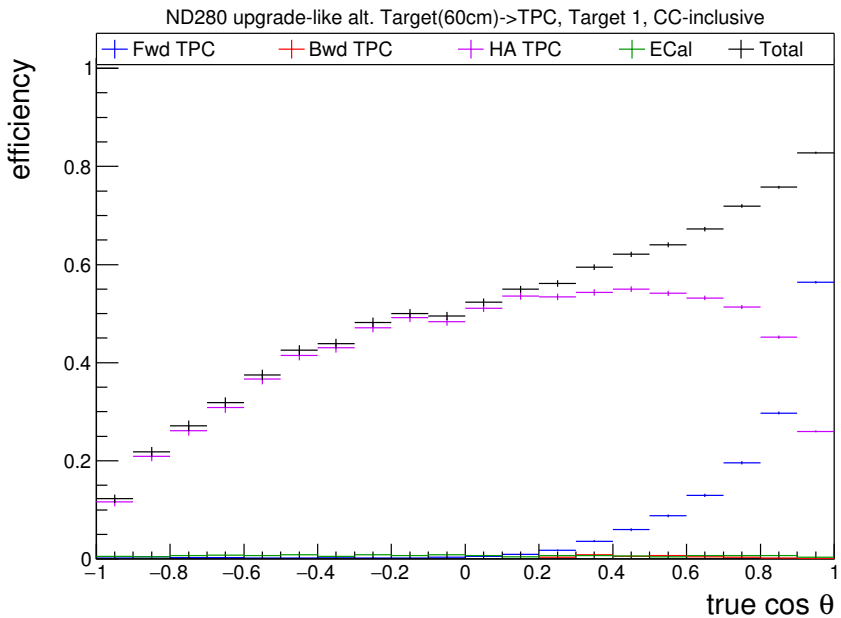


- Forward eff. is similar to current ND280
- Important HA TPC component

Alternative: Target (water) → Fwd TPC 1

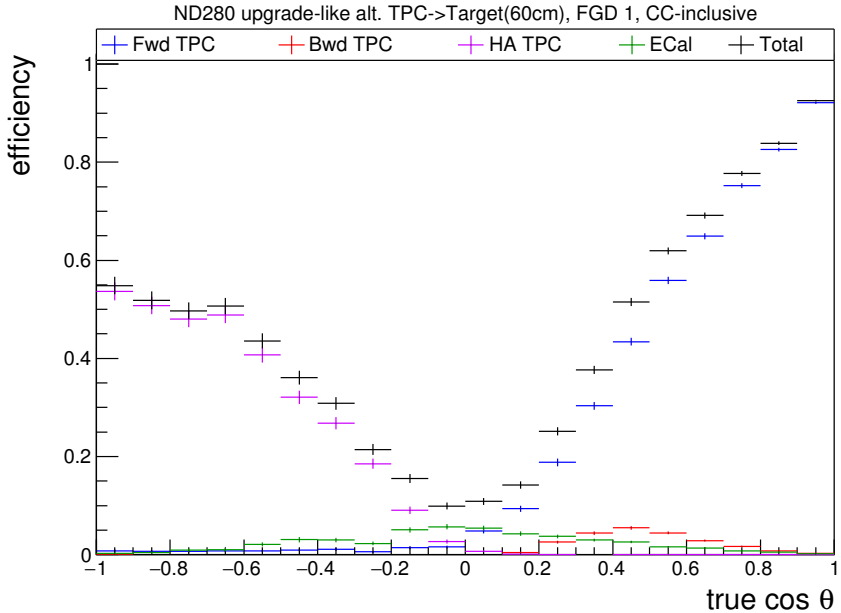


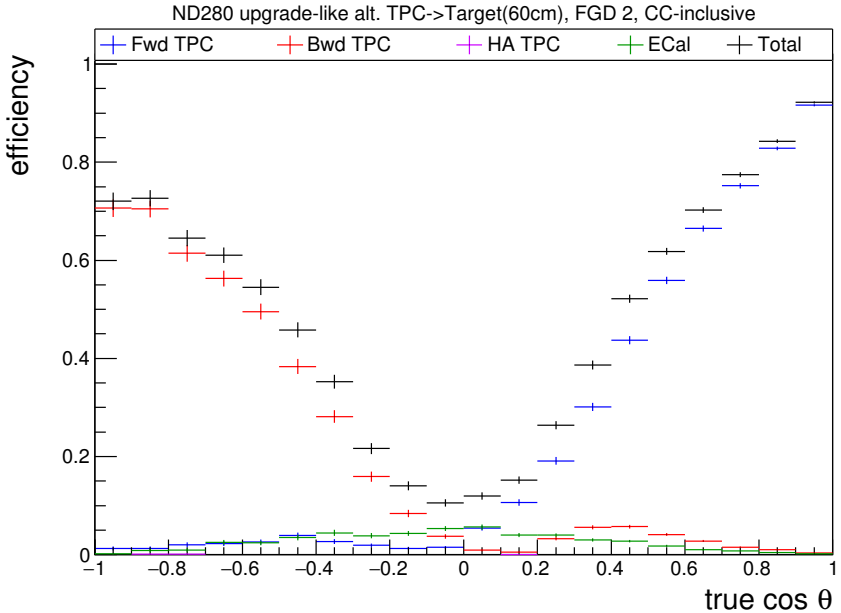


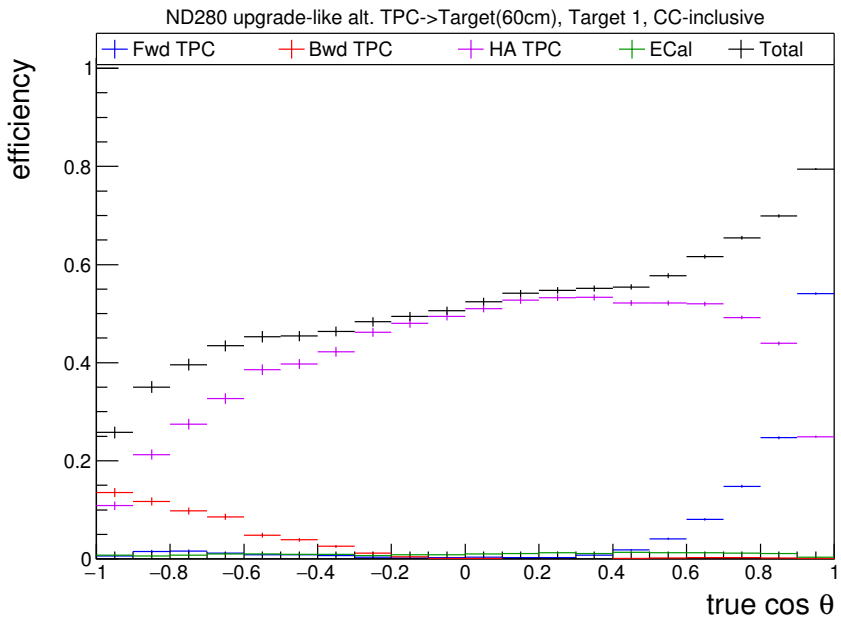


- "Standard" behaviour for FGDs
- Large HA TPC efficiency for Target

Alternative: Fwd TPC 1 → Target (water)

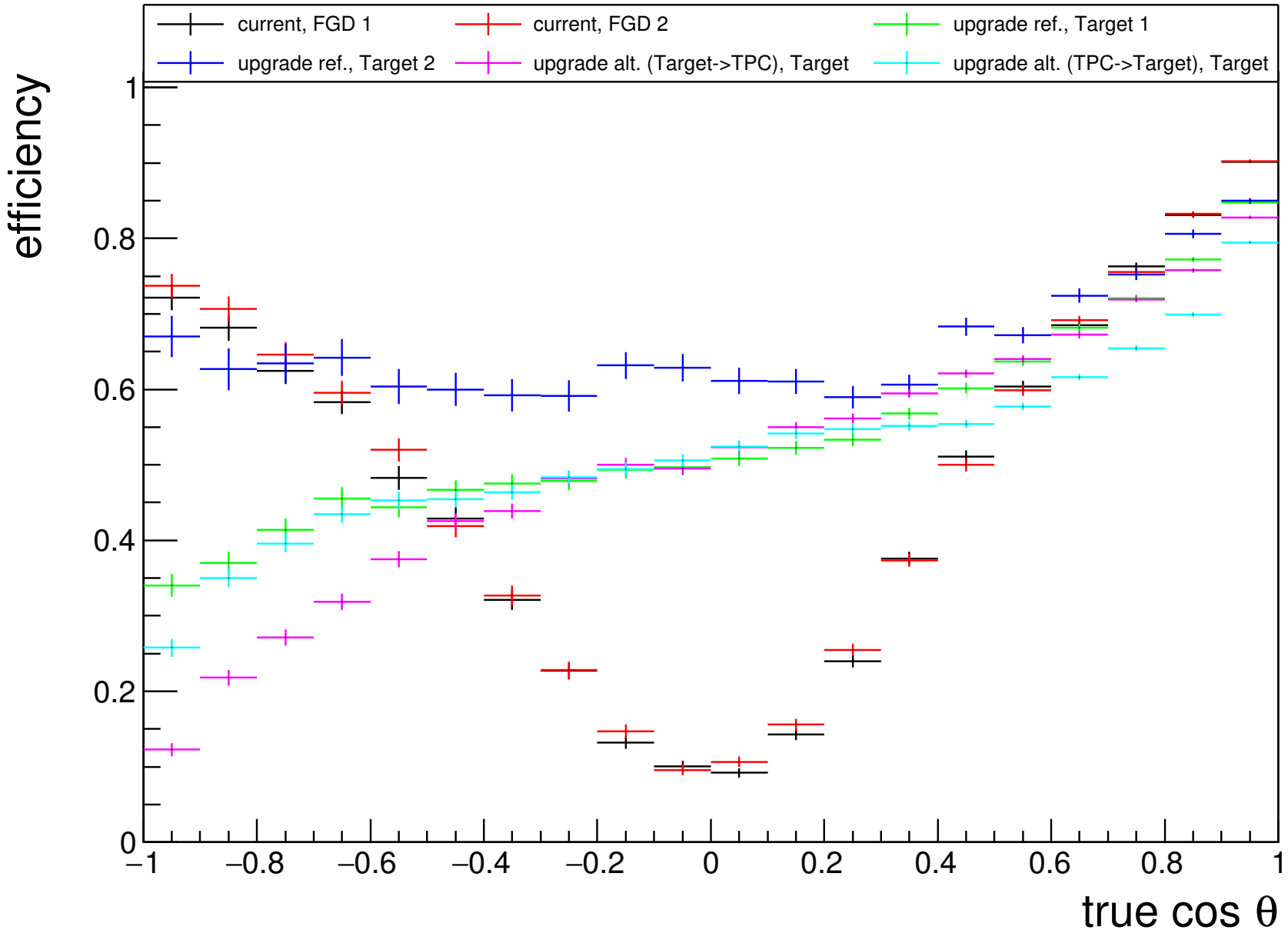




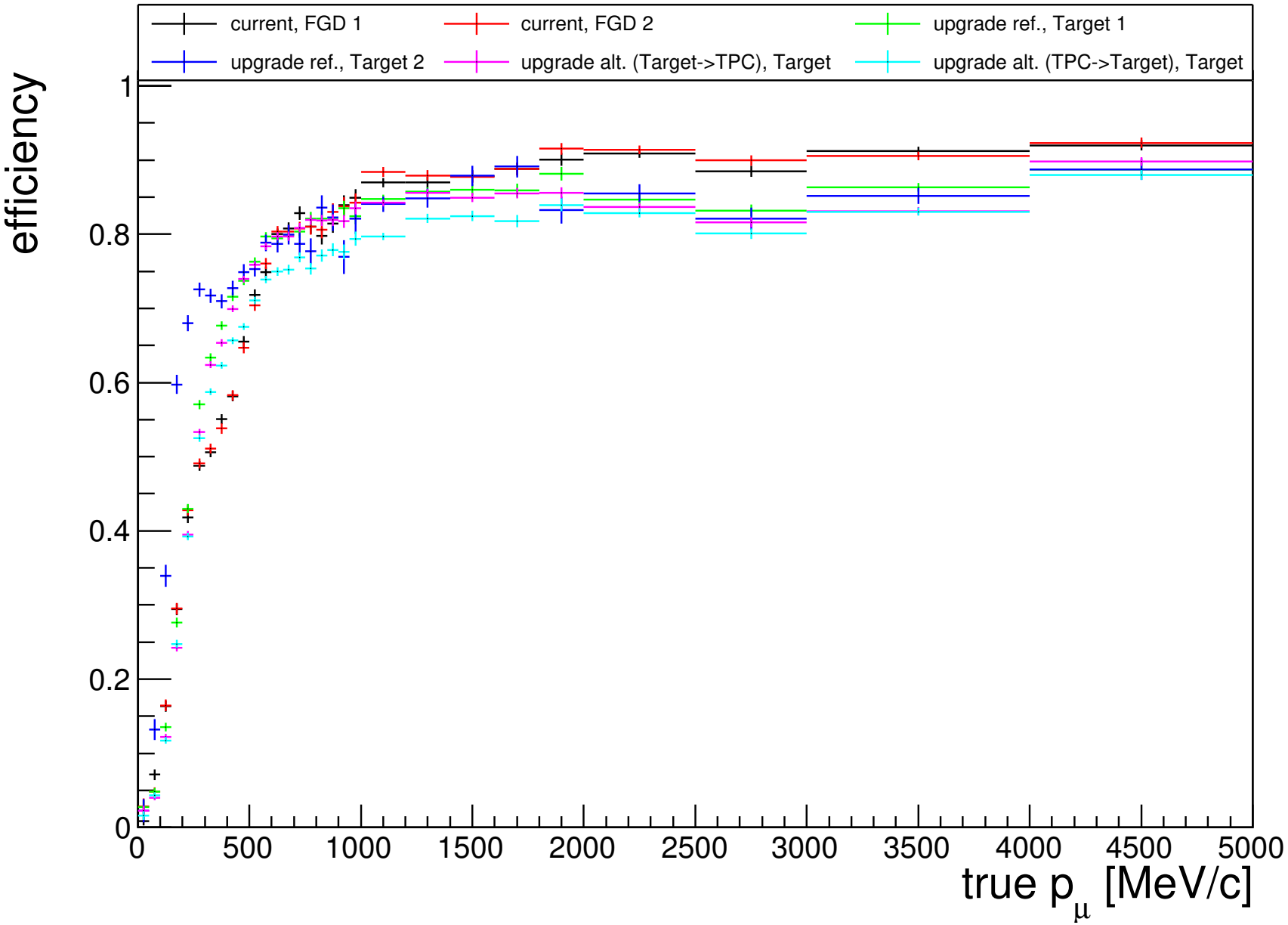


- Contribution of the new horizontal TPCs for backward events in FGD1
- HA TPC component dominates for Target

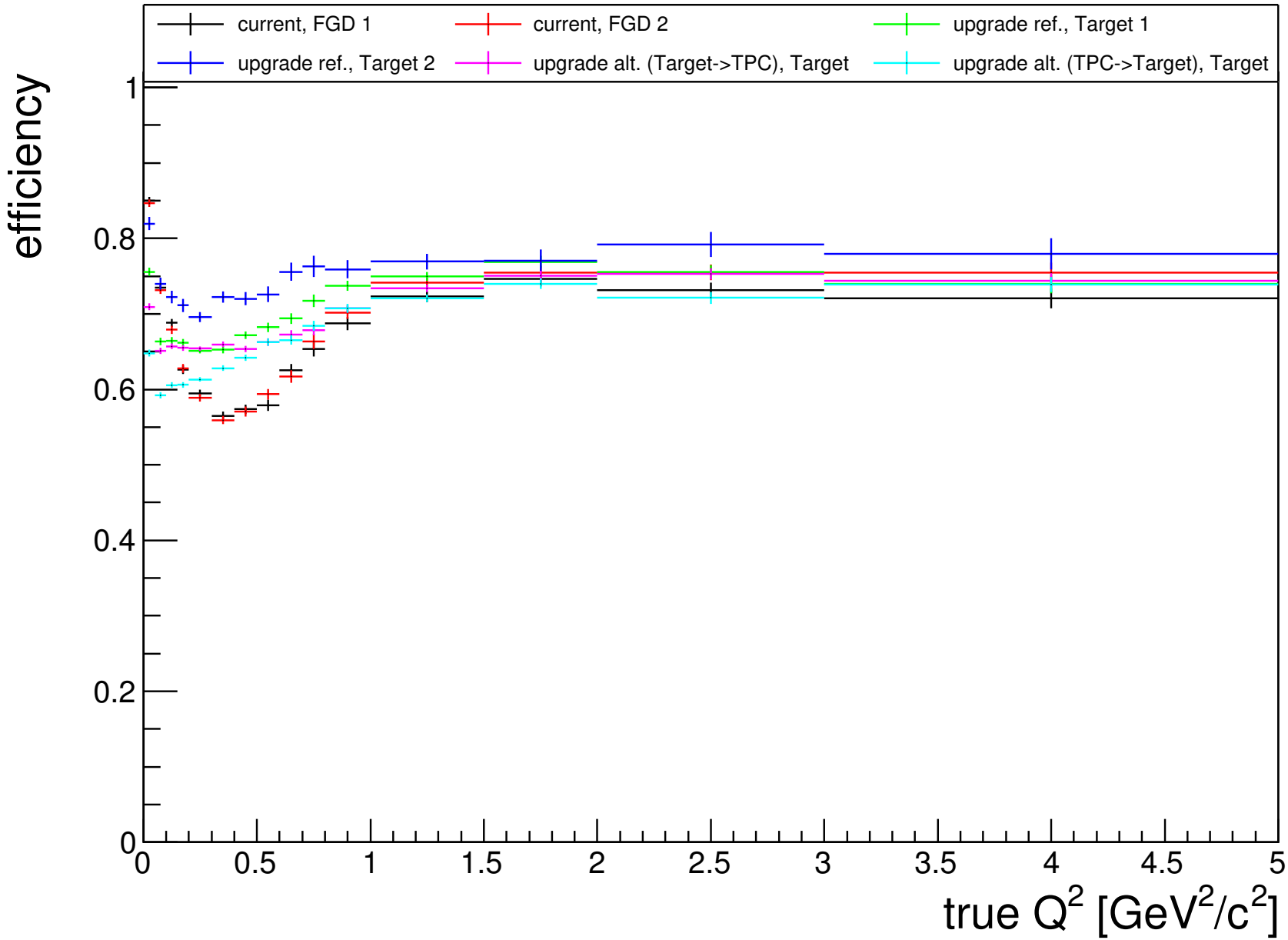
Efficiencies: summary



Efficiencies: summary



Efficiencies: summary



Number of events (summary)

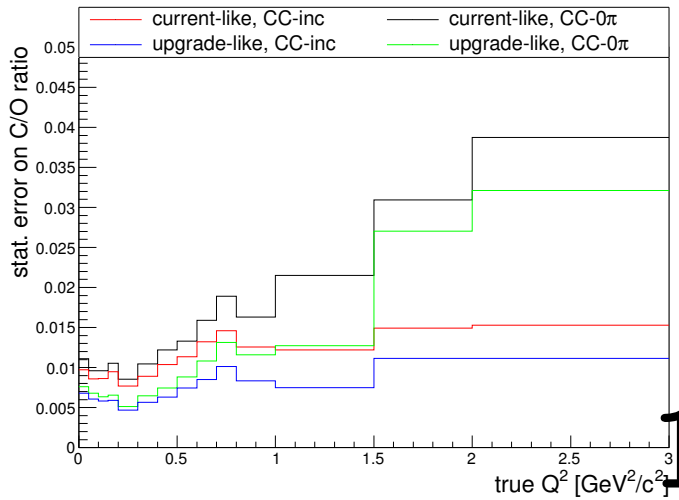
Events after selection ($/10^{21}$ POT)

configuration	Tgt/FGD 1	Tgt/FGD 2	Tgt (for alt.)
current	51417	49825	
ref.	72012	24251	
alt. Target(60cm)→TPC	51601	49699	108045
alt. TPC→Target(60cm)	51596	49593	102807

- Similar number of events for current and upgrade ref. configuration
- More events in alternative thanks to the new water-target

Example of study with this statistics:
Carbon-Oxygen cross-section ratio:
What is the improvement on the statistical error on the ratio?

preliminary plot with reference upgrade ⟶



Topology separation

Strategy

Goal

To be able to check possible contaminations with the different geometries and to make a near detector fit

- TPC pions: using TPC PID, identify π^+/π^- and e^+/e^- from π^0
- Target/FGD pions: target only tracks > 5 cm and true pion ID[1]
- Michel Electrons: true electrons with $t_{vtx} - t_{ME} > 100$ ns

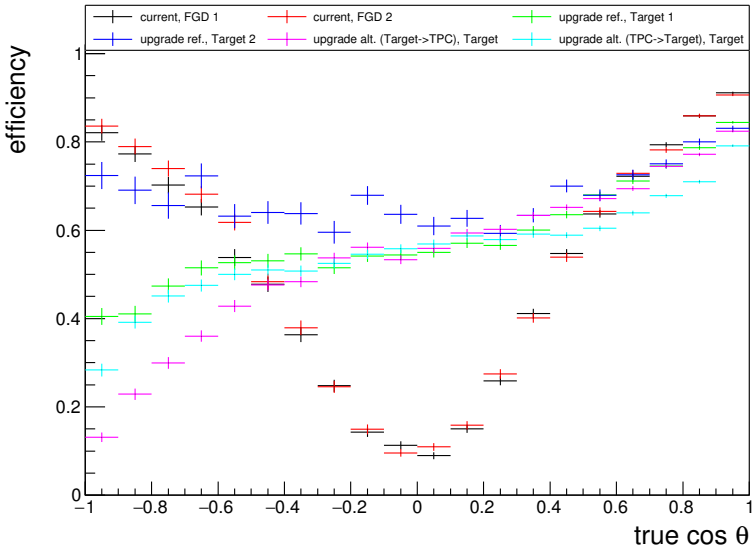
Separation

- CC0π selection: $N_{\pi^+} = 0$, $N_{\text{other}} = 0$
- CC1π^+ selection: $N_{\pi^+} = 1$, $N_{\text{other}} = 0$
- CC-other selection: $N_{\pi^+} > 1$ or $N_{\text{other}} > 0$

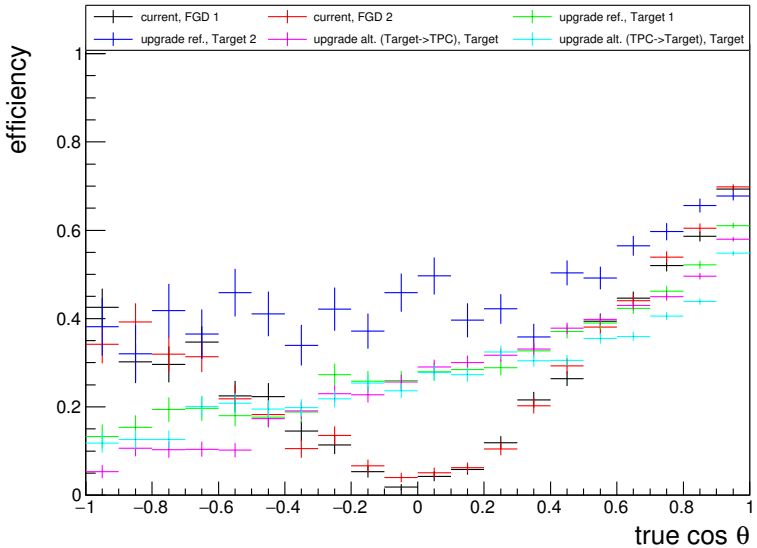
[1] separation between proton and muon in FGD is actually quite good, see T2K-TN-103

Preliminary selection efficiencies

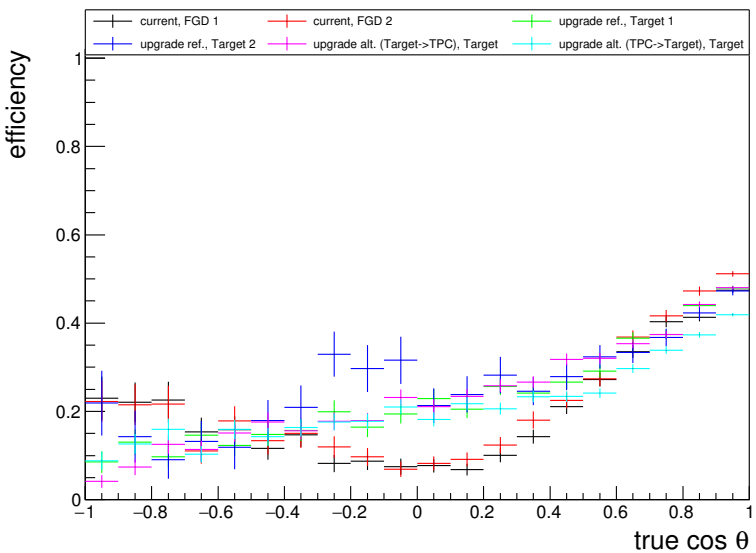
CC-0π



CC-$1\pi^+$



CC-other



Selection purity for CC-0π

When applying CC-0π selection, what is the composition of events?

	%	CC-0π	CC-1π	CC-oth	BKG
current	FGD 1	**84.7**	3.06	9.14	3.06
	FGD 2	**85.3**	3.03	8.59	3.08
reference	Tgt 1	**89.7**	2.05	6.57	1.64
	Tgt 2	**87.9**	1.29	8.1	2.75
alt. Target(60cm)$\rightarrow$TPC	FGD 1	**85.1**	2.76	9.24	2.88
	FGD 2	**85.3**	3.04	8.8	2.9
	Tgt 1	**89.6**	2.08	6.86	1.5
alt. TPC$\rightarrow$Target(60cm)	FGD 1	**85.1**	2.89	9.13	2.85
	FGD 2	**85.4**	3.01	8.64	2.94
	Tgt 1	**88.9**	2.14	7.33	1.64

Selection purity for CC-1π

When applying CC-1π selection, what is the composition of events?

	%	CC-0π	CC-1π	CC-oth	BKG
current	FGD 1	1.63	**63.2**	31.3	3.88
	FGD 2	2.09	67.9	25.9	4.14
reference	Tgt 1	1.88	**68.8**	26.7	2.67
	Tgt 2	1.12	**77.4**	18.4	3.1
alt. Target(60cm)$\rightarrow$TPC	FGD 1	1.49	**63.4**	31.3	3.86
	FGD 2	2.31	**67.8**	26.2	3.73
	Tgt 1	2.1	**66.5**	28.9	2.49
alt. TPC$\rightarrow$Target(60cm)	FGD 1	1.67	**62.8**	31.6	3.94
	FGD 2	2.29	**67.7**	25.8	4.22
	Tgt 1	2.14	**61.4**	33.7	2.69

Selection purity for CC-other

When applying CC-other selection, what is the composition of events?

	%	CC-0π	CC-1π	CC-oth	BKG
current	FGD 1	2.93	16.8	**73.8**	6.47
	FGD 2	2.79	16.8	**73.9**	6.49
reference	Tgt 1	3.3	19.3	**72.2**	5.25
	Tgt 2	2.94	21.4	**69.3**	6.35
alt. Target(60cm)$\rightarrow$TPC	FGD 1	3.33	16.7	**73.7**	6.2
	FGD 2	3.03	18.1	**71.6**	7.34
	Tgt 1	3.38	19	**72.6**	5
alt. TPC$\rightarrow$Target(60cm)	FGD 1	3.18	16.7	**74**	6.08
	FGD 2	2.87	17.3	**73.6**	6.28
	Tgt 1	2.51	19.5	**72.9**	5.04

Conclusion

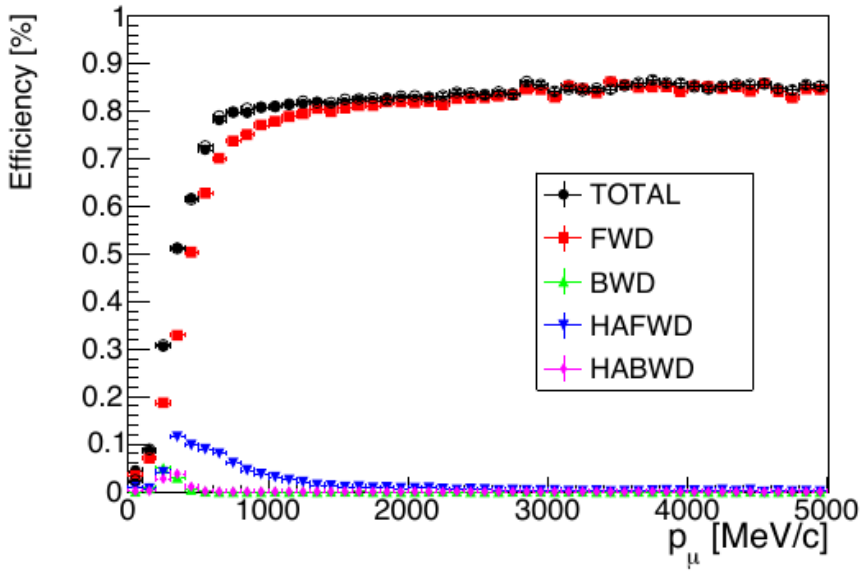
Summary

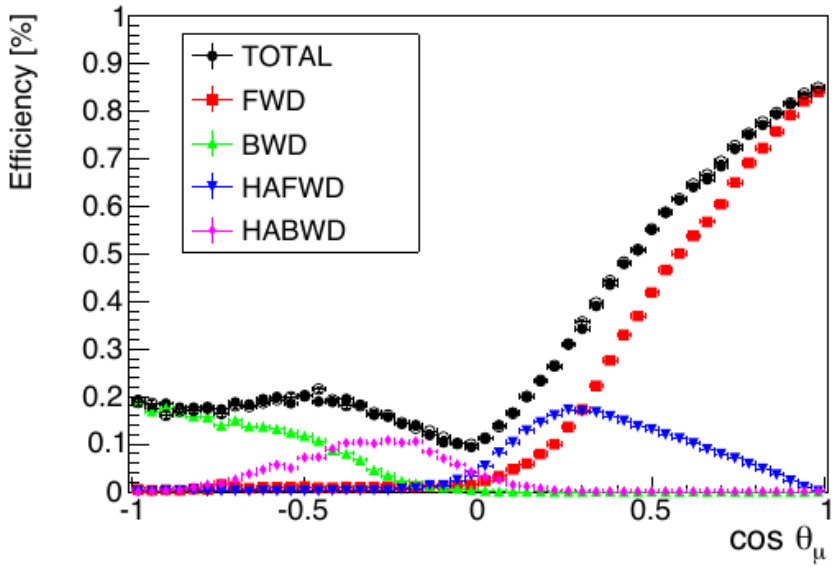
- $\nu_\mu CC$-inclusive selection is implemented and selection efficiencies have been computed, with still some approximations
  - targets in upgrade configurations covers better high angle region ($\varepsilon \sim 50 - 60\%$) $\Rightarrow$ **important for physics !**
  - water target has a lower backward efficiency than FGD, even though it is either compensated by empty target (upgrade reference) or FGDs (upgrade alternatives)
- CC-0π, CC-1π^+, CC-other selections have been implemented.
  - still preliminary as target/FGD-reconstruction is not implemented in the software
- Next steps:
  - implement time-of-flight to determine track sense / use for PID
  - propagate selection efficiencies to BANFF-like fit
  - software is ready to begin real physics analysis (transverse variables, C/O cross-section ratio, ...)

Backups

Current ND280 analysis efficiencies

From T2K-TN-245
"ν_μ CC event selections in the ND280 tracker using Run 2+3+4 data"





ECal branch selection

ECal efficiencies

The upgrade framework does not have full ECal reconstruction (building a track from the hits).

- We take all the true tracks reaching ECal
- We apply ECal efficiencies on it:
  - $\varepsilon_{reco} \sim 30\%$ for $0 < p_\mu < 300$ MeV/c
  - $\varepsilon_{reco} \sim 50\%$ for $300 < p_\mu < 900$ MeV/c
  - $\varepsilon_{reco} \sim 40\%$ for $p_\mu > 900$ MeV/c
- Same thing is done for FGD-ECal matching efficiencies (we assume same for Target-ECal matching)
- Muon is asked to stop in ECal to reconstruct momentum-by-range

ECal PID

ECal PID variables MipEM and E/L are thrown randomly using pdf from current ECal reconstruction. The PID cuts are done on these variables.

Pion reconstruction

Done similarly to current ND280 analysis

- TPC tracks: look for Target-TPC or FGD-TPC tracks
  - if charge > 0 and not proton PID
    - if $\mathcal{L}_\pi > \mathcal{L}_e \Rightarrow$ identified as $\pi^+ \Rightarrow N_{\pi^+,TPC}$
    - else $\Rightarrow$ identified as positron from $\pi^0 \Rightarrow N_{\pi^0,e^+,TPC}$
  - if charge < 0 and not muon candidate
    - if $\mathcal{L}_\pi/(\mathcal{L}_\pi + \mathcal{L}_e) > 0.8 \Rightarrow$ identified as $\pi^- \Rightarrow N_{\pi^-,TPC}$
    - else $\Rightarrow$ identified as electron from $\pi^0 \Rightarrow N_{\pi^0,e^-,TPC}$
- Iso-target tracks: look for Target/FGD-only tracks
  - if length < 5 cm, it is considered not reconstructed
  - if length > 5 cm, it is considered perfectly identified (separation between protons and pions is actually quite good) $\Rightarrow N_{iso,\pi}$
- Michel Electrons: look for true electronsin target/FGD more than 100 ns away from vertex time
  - apply 50% efficiency on these electrons (T2K TN 104) $\Rightarrow N_{ME}$

Topology separation

$$N_{\pi^+} = N_{\pi^+,TPC} + max(N_{iso,\pi}, N_{ME})$$
$$N_{\text{other}} = N_{\pi^-,TPC} + N_{\pi^0,e^+} + N_{\pi^0,e^-}$$

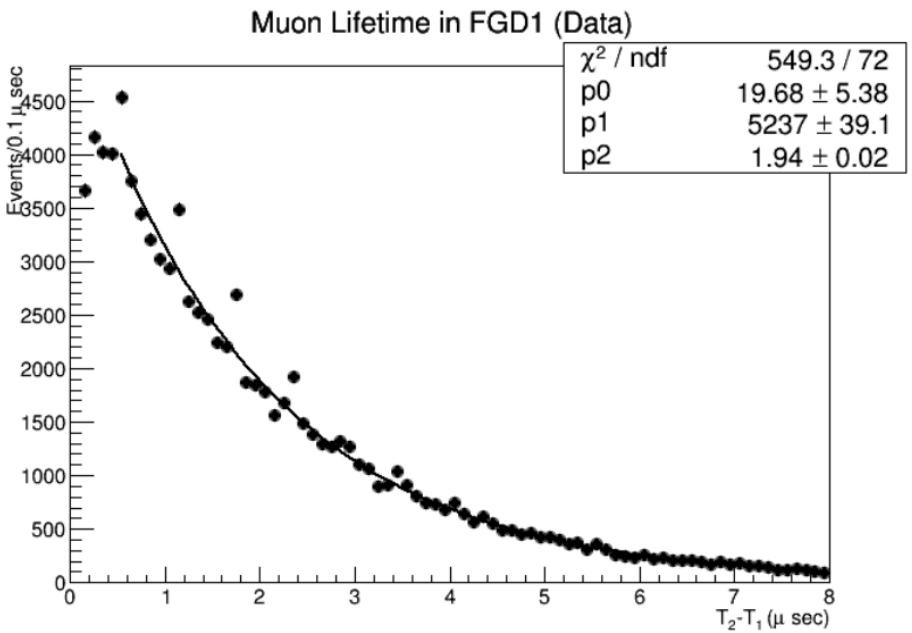
Separation

- CC0π selection: $N_{\pi^+} = 0$, $N_{\text{other}} = 0$
- CC1π^+ selection: $N_{\pi^+} = 1$, $N_{\text{other}} = 0$
- CC-other selection: $N_{\pi^+} > 1$ or $N_{\text{other}} > 0$

Michel electron tagging

- Following T2K-TN-104, we look for electrons with delay > 100 ns.
- As we don't have any FGD/Target reconstructions, we cannot look for hits, but for a true electron and apply 50% selection efficiency (final ME selection efficiency of T2K-TN-104)

TN-104



This selection