Selection of muon neutrino charged-current interactions with improved acceptance in the T2K off-axis near detector

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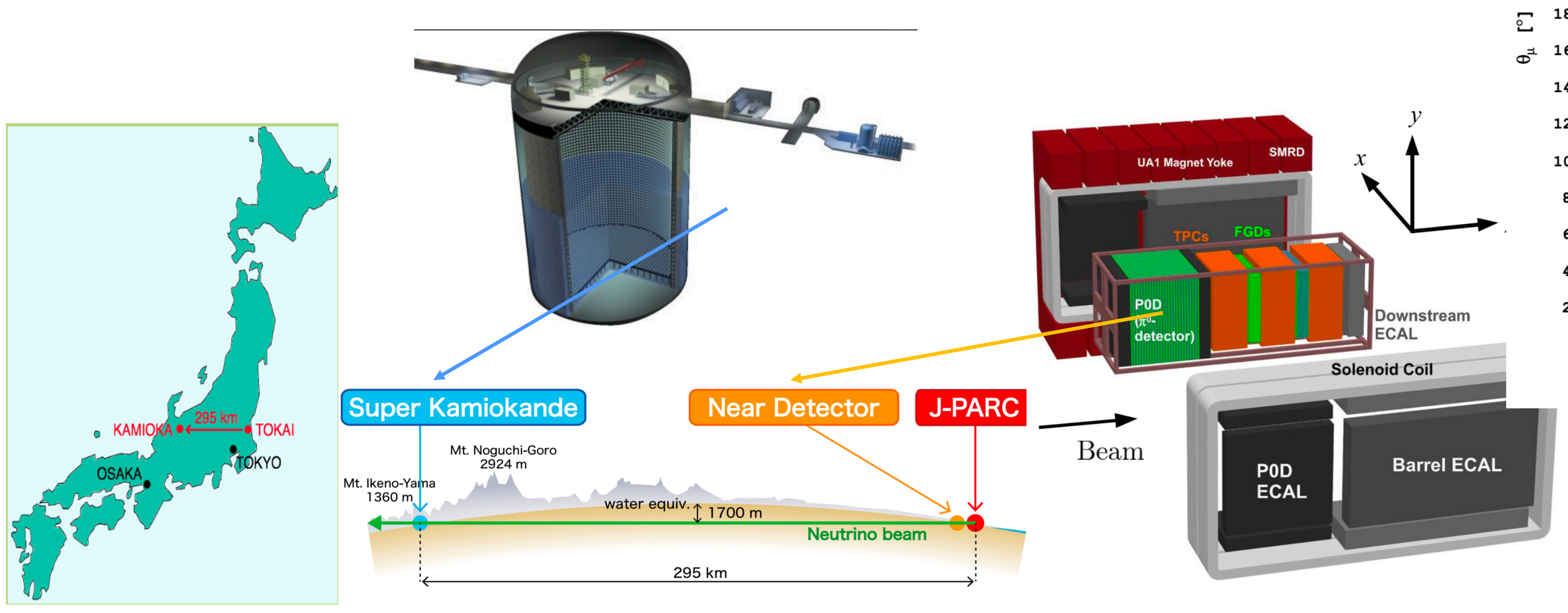
The T2K experiment and ND280 near detector

T2K produces neutrino by a 30 GeV proton beam incident on a carbon rod target, and measured at two sites: first at the near detectors, including ND280 and several other detectors, and then again at the Super-Kamiokande (SK) far detector.

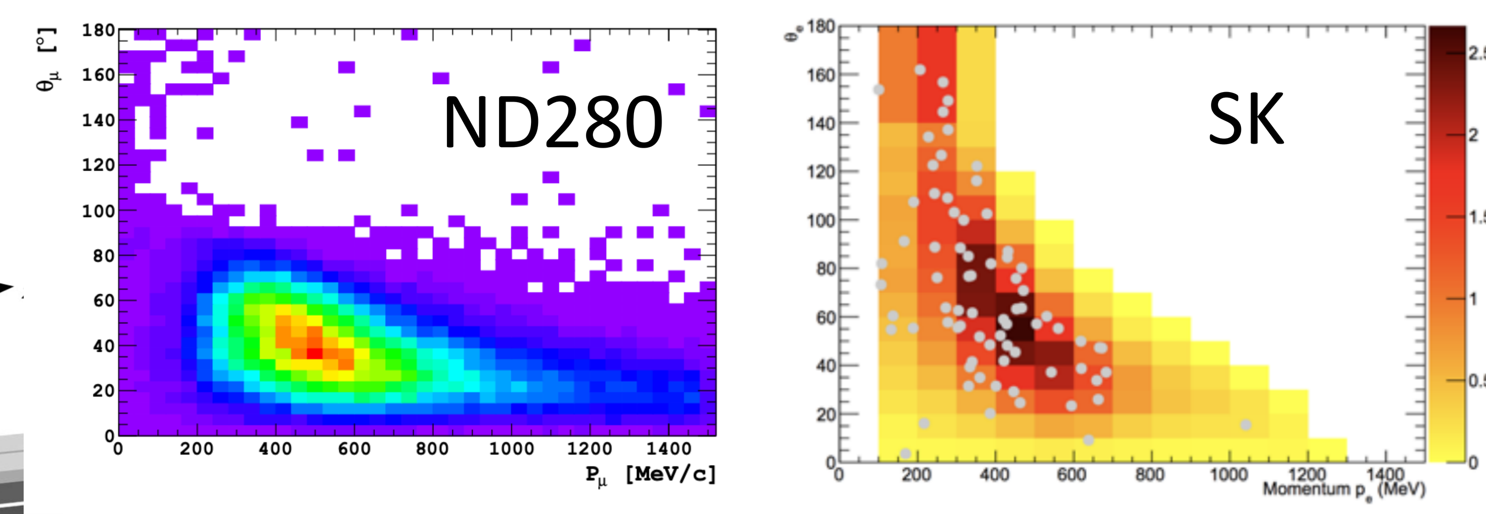
ND280, on which this study is performed, has two carbon based FGDs as its main target mass and tracks event particles using gaseous TPCs and ECALs. FGD2 also has water layers for cross-section study purpose.

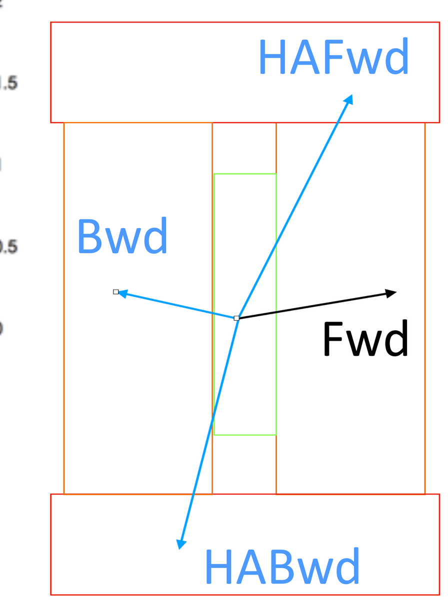


Motivation and signal definition

The 4π selection aims at removing the angular limits on ND280 event selection and expanding ND280 angular acceptance to 4π solid angle, as shown in [3]. In addition to the forward (FWD) sample, this selection introduces backward (BWD), high-angle forward (HAFWD) and high-angle backward (HABWD) to the ND280 fit.

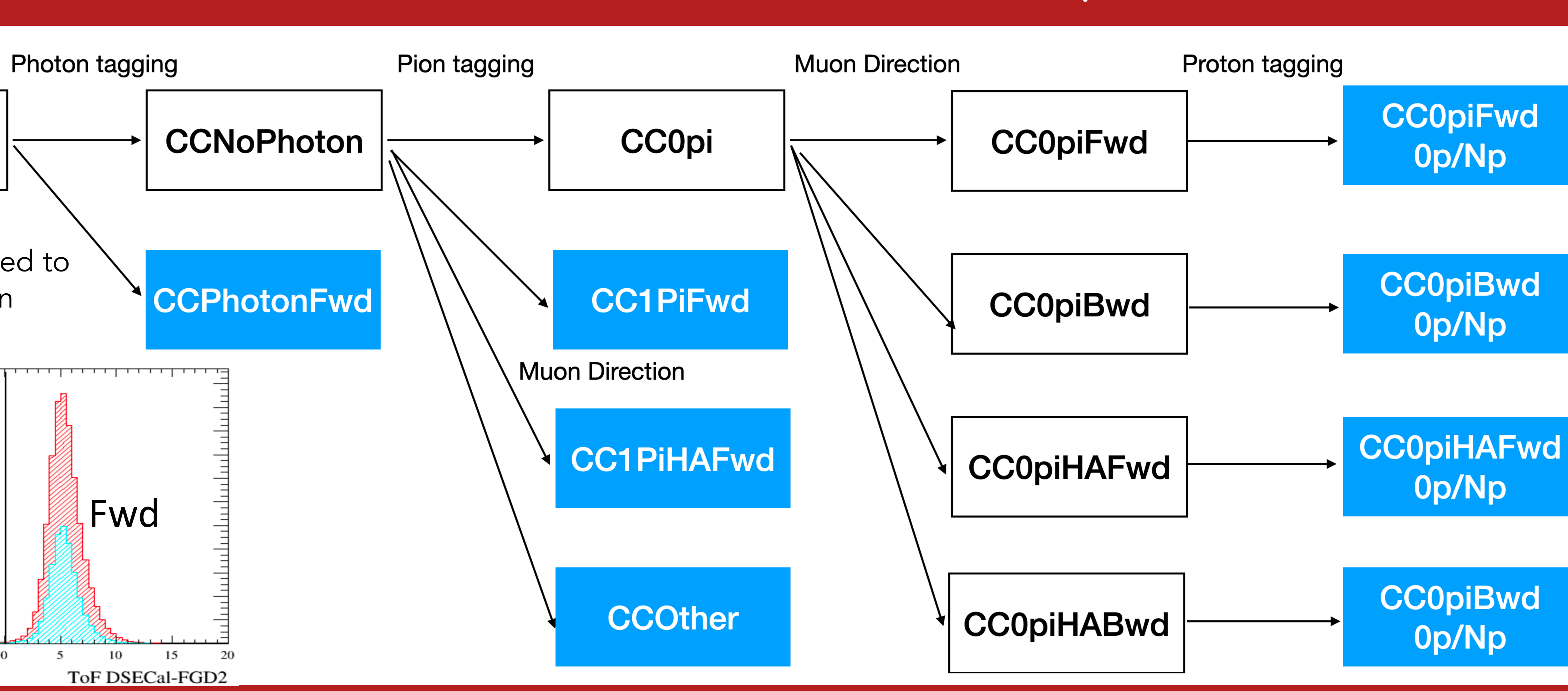
This will allow for more statistics to be included in the ND280 sample, and better compare the near detector data to the already- 4π far detector data.



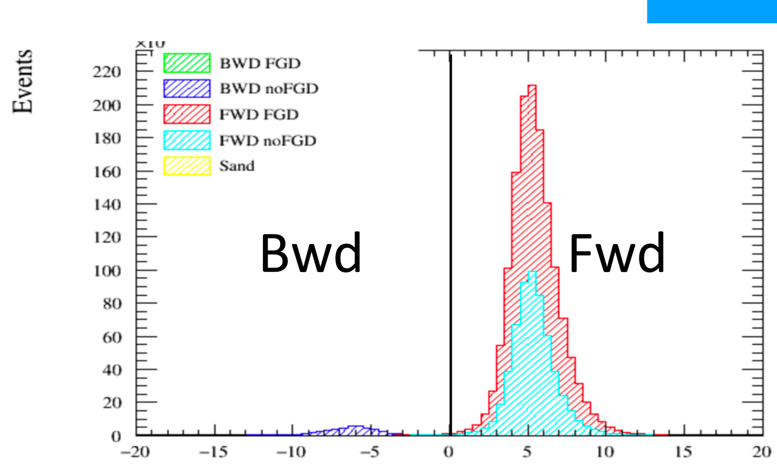


Top: Measured events' 2D distribution on the event muon momentum-angle theta plane[3].
Right: schematic illustration of new samples.

Selection Steps



ToF information are used to estimate track direction

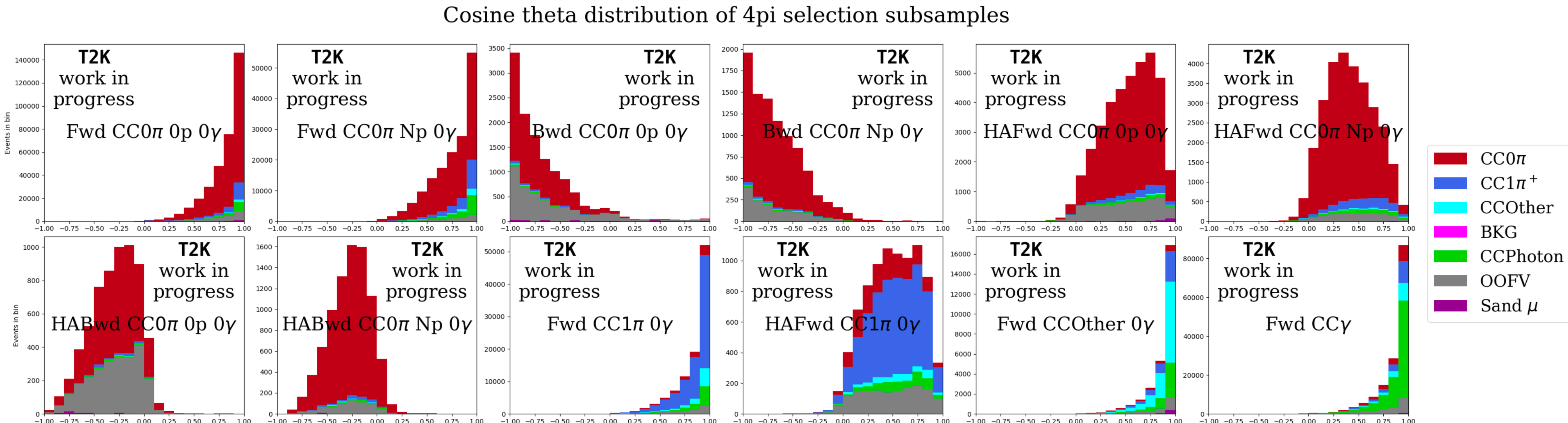


A Charged-Current (CC) interactions sample is first selected using cuts in common with previous studies. It is then split into two subsamples according to the presence of photons. Events with photons form a dedicated CCPhoton sample.

Furthermore, for events with no photon, those also with no pions are further broken down by muon direction and proton presence.

MC selection results

Cosine theta distribution of 4pi selection subsamples



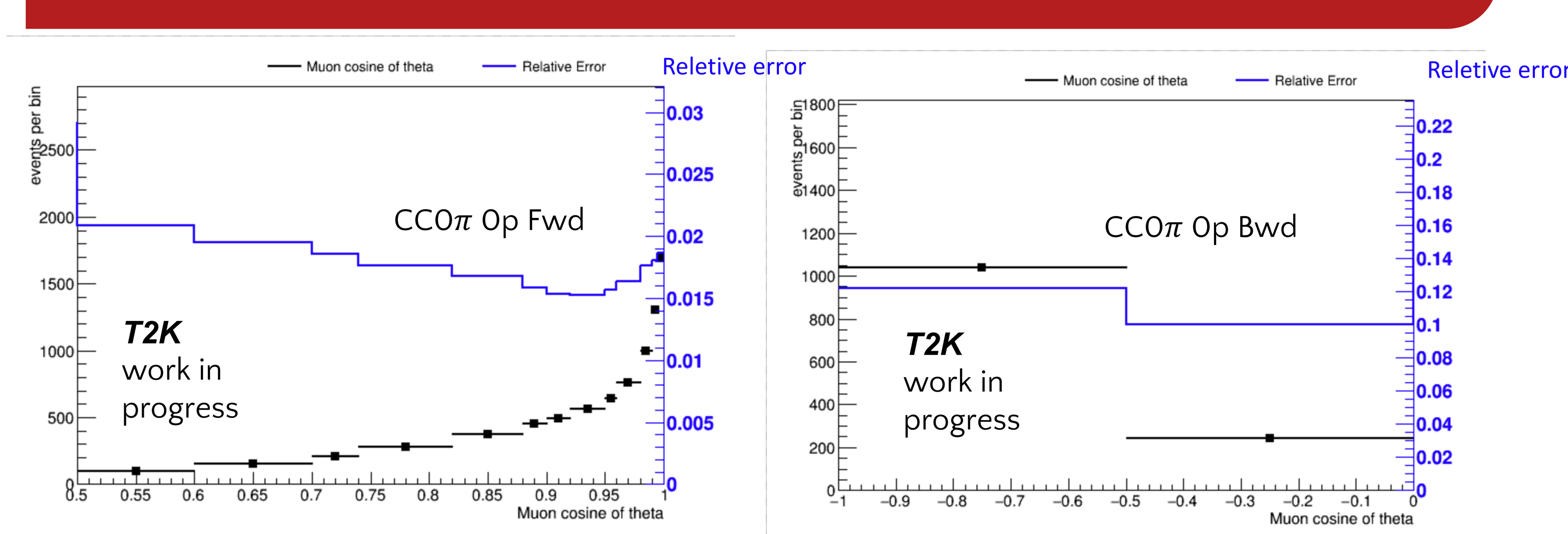
Reconstructed MC muon cosine θ distribution for each sub-sample are given in the plots to the left.

The selection ensures enough statistics in high-angle and backward samples for fitting purpose.

CC 0pi 0p Fwd	CC 0pi Np Fwd	CC 0pi 0p Bwd	CC 0pi Np Bwd	CC 0pi 0p HAFwd	CC 0pi Np HAFwd
81%	74%	61%	82%	77%	84%
CC 0pi 0p HABwd	CC 0pi Np HABwd	CC 1pi Fwd	CC 1pi HAFwd	CC Other	CC Photon
58%	89%	67%	56%	46%	55%

MC selection purities

Detector Systematic Uncertainties



The expected detector systematic uncertainties for the total number of events in CC0pi 0p forward and backward sample evaluated using MC files.

CC 0pi 0p Fwd	CC 0pi Np Fwd	CC 0pi 0p Bwd	CC 0pi Np Bwd	CC 0pi 0p HAFwd	CC 0pi Np HAFwd
1.7%	3.8%	9.7%	7.2%	14.7%	14.5%
CC 0pi 0p HABwd	CC 0pi Np HABwd	CC 1pi Fwd	CC 1pi HAFwd	CC Other	CC Photon
26.2%	14.8%	2.3%	6.3%	3.8%	2.3%

The total errors on the total number of events in subsamples.

Conclusions

In this study, a new sample selection scheme in ND280 is proposed to expand its angular acceptance to 4π solid angle. To achieve this, time of flight information are used to estimate track directions. This selection features also pion, proton and photon splits to enhance constraining power to hadronic interactions. MC Efficiency, purity and distribution have been evaluated. This analysis also makes predictions on the uncertainty of the expected number of events.

The next improvements are to finalise detector systematics and perform nominal MC and data fits to quantify how much these new samples helps constrain flux and neutrino cross-section parameters, and eventually physical neutrino parameters.

References

[1] K. Abe et al. [T2K Collaboration], Nucl. Instrum. Meth. A 659 (2011) 106 doi:10.1016/j.nima.2011.06.067
[2] K. Abe et al. [T2K Collaboration], Phys. Rev. Lett. 118 (2017) no.15, 151801 doi:10.1103/PhysRevLett.118.151801 [arXiv:1701.00432 [hep-ex]]
[3] K. Abe et al. [T2K Collaboration], [arXiv:1901.03750 [hep-ex]]