Event selection for the measurement of the charged current muon antineutrino single pion production cross section in the T2K near detector

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Introduction

- T2K [1] is a long-baseline neutrino oscillation experiment based in Japan.
- Beam source and near detectors (*off-axis* ND280 and *on-axis* INGRID) in J-PARC, Tokai.
- *Off-axis* far detector is Super-Kamiokande, 295 km away.

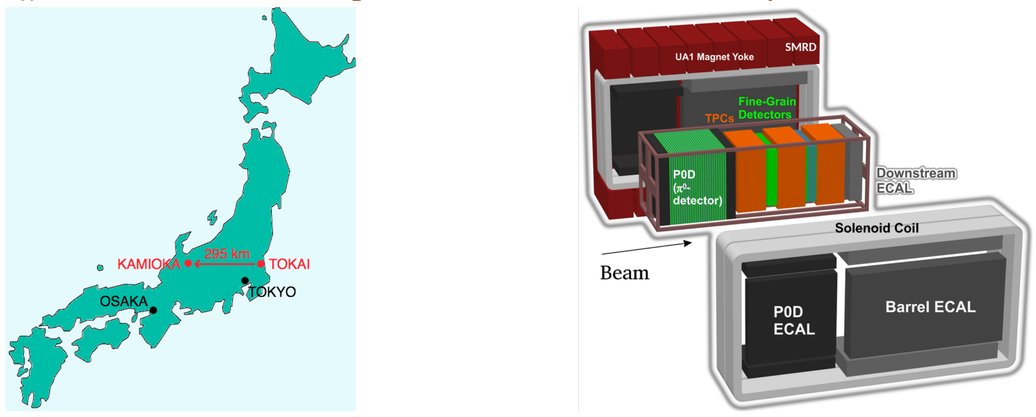

Figure 1: Left: Location of T2K experimental sites. Right: Cut-away drawing showing sub-detectors of ND280.

- Prediction of the oscillated spectrum at the far detector is improved thanks to fitting samples of charged-current (CC) interactions at ND280. [2]
- Cross-section is measured for different pion multiplicity topologies in order to evaluate cross-section for different types of neutrino interactions.
- $\bar{\nu}_\mu$ CC1π^- sample is enhanced in the interactions with baryon resonance.
- Tracker part of ND280: scintillator detectors (FGD) interleaved with gaseous time projection chambers.
- Studies obtained using Monte Carlo with the NEUT neutrino generator [3].

Characteristics and selection of $\bar{\nu}_\mu$ CC1π^- topology

- Defined as a topology with one μ^+ and one π^- in the final state, with no other types of pions:

$$\bar{\nu}_\mu + \mathrm{N} \rightarrow \mu^+ + \pi^- + \mathrm{X}$$

- ND280 magnetic field enables selection of π^- and μ^+ candidate.
- Selection: one track containing a segment in TPC and starting in FGD1 fiducial volume reconstructed as a μ^+ and the other track with a segment in TPC reconstructed as a π^- (Fig. 2: left).
- Also the isolated track in FGD1 with π-like energy loss dE/dx is considered to be a signature of π^- (Fig. 2: right).
- In both cases, no reconstructed π^+, π^0 nor Michel electrons.

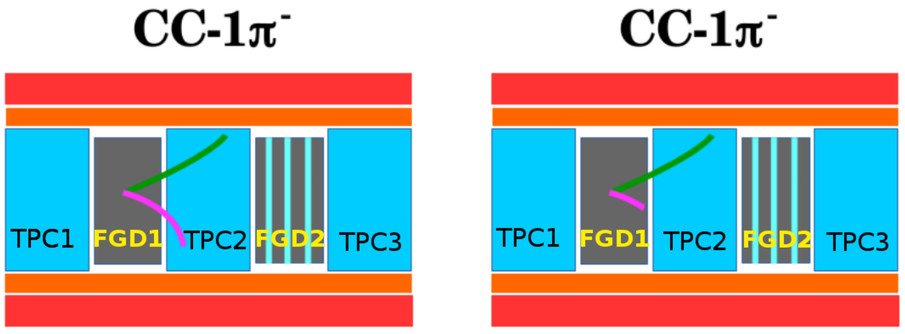

Figure 2: CC1π^- topology event in the ND280 tracker. Left: π^- candidate containing a segment in TPC. Right: with an isolated track in FGD1 interpreted as π^-.

First studies on purity improvement

- $\bar{\nu}_\mu$ beam contaminated with ν_μ!
- One of the main background topologies: CC1π^+:

$$\nu_\mu + \mathrm{N} \rightarrow \mu^- + \pi^+ + \mathrm{X}.$$

- $\mu^+\pi^-$ (signal) and $\mu^-\pi^+$ (background) events are difficult to distinguish due to the same μ/π-like energy loss.
- Idea for the additional selection criterion: range of the μ^+ candidate.
- True μ^+ more likely to reach TPC3 chamber than π^+ (Fig. 4).
- Eventual, additional cut: removal of events with multiple positive tracks originating from the FGD1 fiducial volume and μ^+ candidate not reaching TPC3. The impact on the selection presented in Table 1.

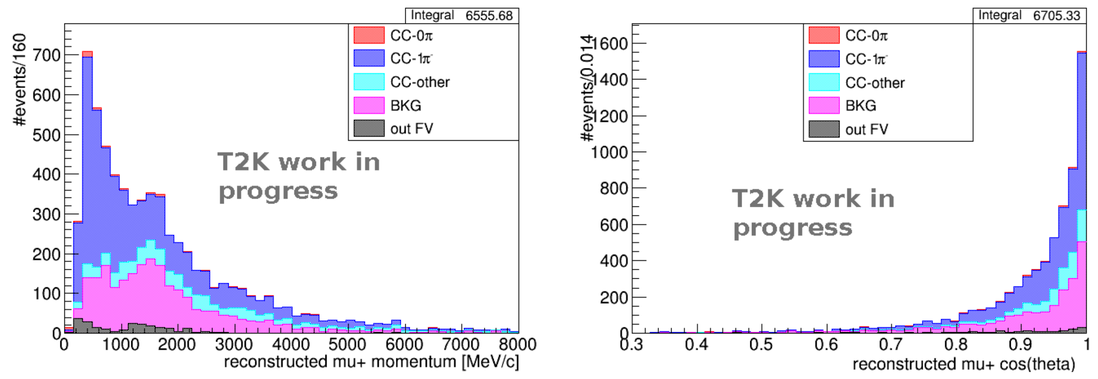

Figure 3: Kinematics of μ^+ candidate in the selected CC1π^- sample. Colors indicate the true topology. Left: Momentum distribution. Right: cos(θ) distribution. Monte Carlo POT: 6.7×10^{21}.

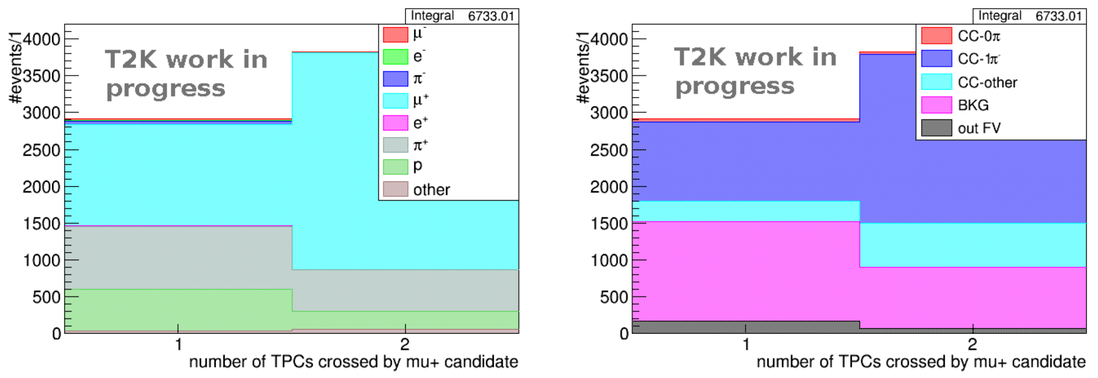

Figure 4: Events with μ^+ candidate crossing one (left bin) or two TPC chambers (right bin). Left plot: Colors indicate the true particle selected as μ^+ candidate. Right plot: Colors indicate the true topology of the event.

	selection without presented cut	selection with presented cut
efficiency	0.186 ± 0.003	0.182 ± 0.003
purity	0.500 ± 0.006	0.522 ± 0.006
product	0.093 ± 0.002	0.095 ± 0.002

Table 1: Comparison of the selection without and with the presented cut.

topology or type of interaction	fraction	number of events*
CC0π	1.2%	7
CC1π^-	52.2%	311
CCother	12.6%	75
BKG CC ν_μ	24.3%	145
BKG NC	6.1%	36
BKG other	0.3%	2
out of FV	3.4%	20

Table 2: Composition of the CC1π^- sample obtained with preliminary selection.
*Number of events scaled to the data POT: 6.3×10^{20}.

Plans

- CC1π^- preliminary selection is 52% pure.
- Other ideas for selection improvements are under studies. Some of the considered observables are: range of π^- candidate track, vertex activity, number of tracks in FGD1.
- Selection will be optimized based on known detector systematics and evaluation of the additional uncertainty related to TPC-FGD-TPC matching.
- Analysis will incorporate control regions (sidebands) after selection is finalized.

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] Y. Hayato, Acta Phys. Polon. B **40** (2009) 2477. Used version: NEUT 5.3.2