Measurement of K^+ Production in Charged-Current Neutrino Interactions in the T2K Experiment

Katarzyna Kowalik on behalf of the T2K Collaboration
National Centre for Nuclear Research, Poland
email: Katarzyna.Kowalik@ncbj.gov.pl

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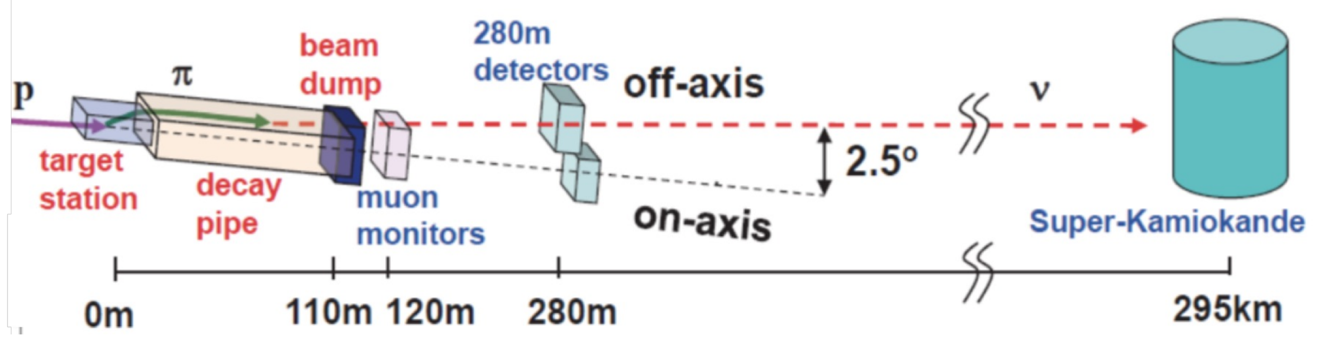
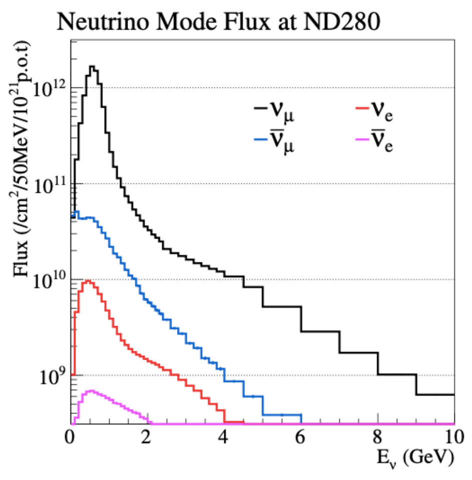
1. The T2K Experiment



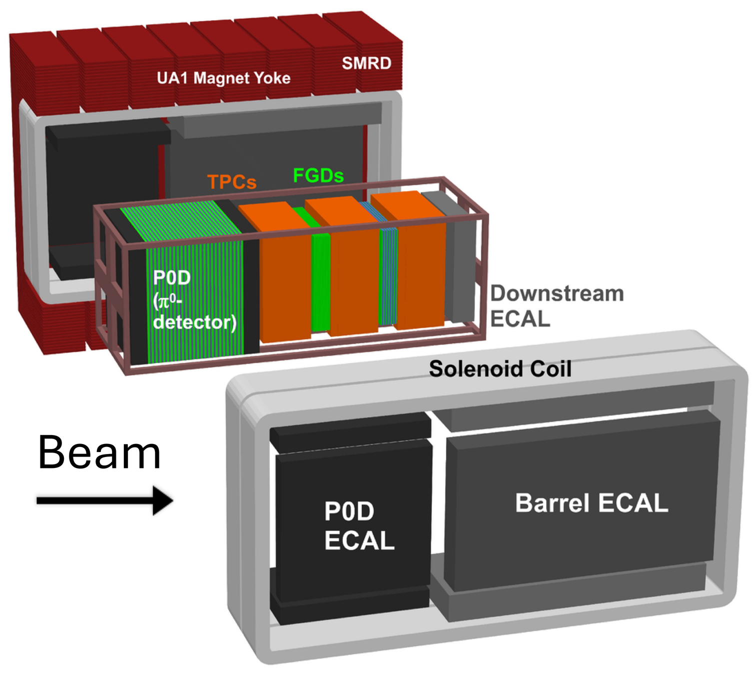
Tokai-**t**o-**K**amioka is a long-baseline neutrino oscillation experiment in Japan, optimised to study neutrino oscillations via measurements of ν_μ ($\overline{\nu}_\mu$) disappearance and ν_e ($\overline{\nu}_e$) appearance in the beam.

The high intensity ν_μ ($\overline{\nu}_\mu$) beam is produced at J-PARC accelerator complex and travels towards the near and far detector. The energy of the beam peaks ~600 MeV at 2.5^0 off-axis angle.



2. The ND280 Near Detector

The ND280 detector is magnetised detector (0.2T), situated 280m from the neutrino production target and at 2.5^0 off-axis angle.

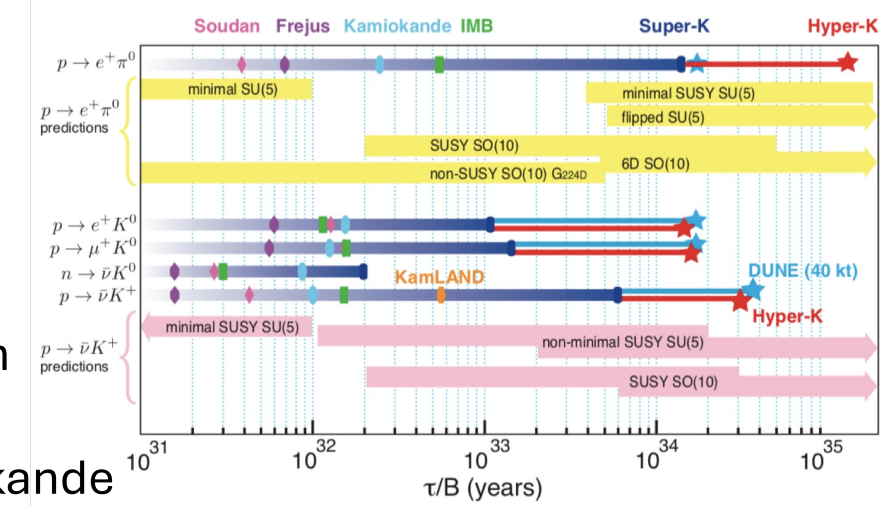


- 3 **T**ime **P**rojection **C**hambers (TPC) provide tracking and particle identification
- 2 **F**ine **G**rained **D**etectors (FGD) used as tracker and target for interactions:
  - FGD1 is CH scintillator tracker
  - FGD2 has CH and H_2O layers
- POD is the π^0 detector
- ECAL is electromagnetic calorimeter
- SMRD is muon detector

The ND280 detector upgrade was completed in May 2024. The P0D detector was replaced with a new scintillator tracker and two more TPCs.

3. Proton Decay Searches

- The proton decay channel $p \to K^+\bar{\nu}$ is predicted in SUSY models
- Interactions of atmospheric neutrinos with K^+ production are background that we aim to constrain
- Best limit comes from Super Kamiokande
- Unique opportunity for Liquid Argon TPC

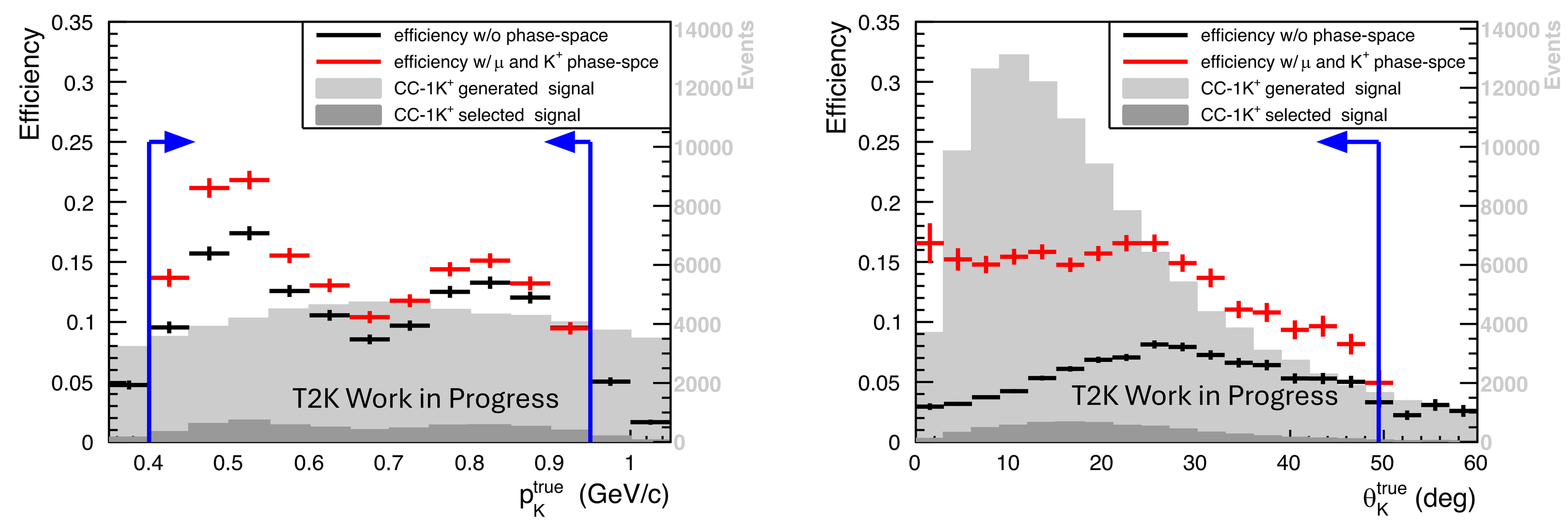


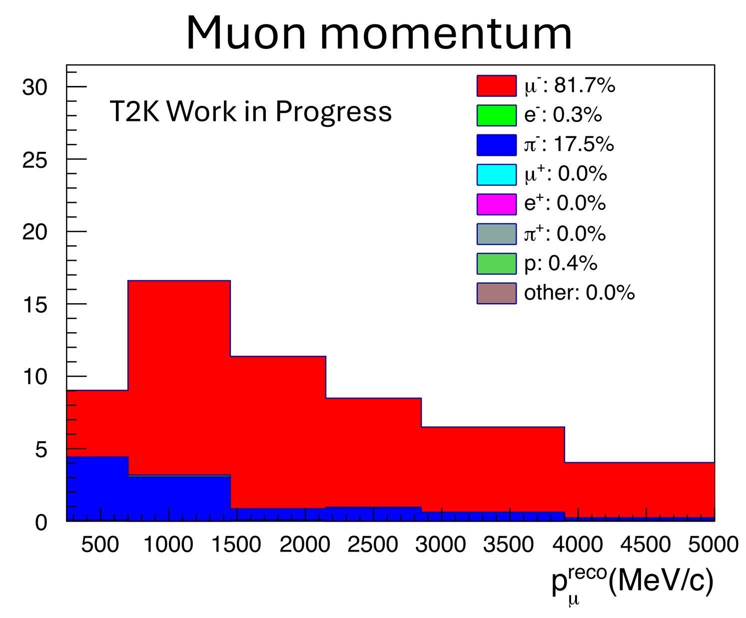
4. ν_μCC-1K+ Sample in ND280

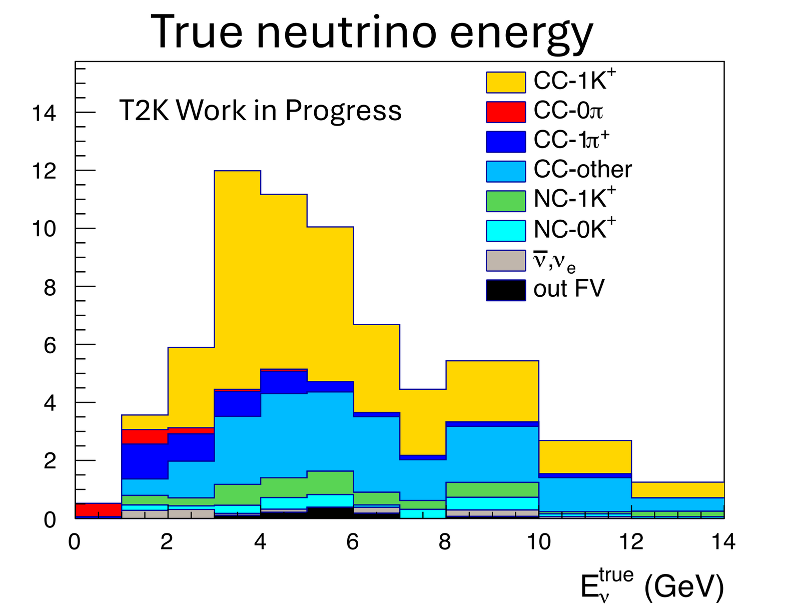
We start with selection of μ^- in FGD1 and search for K^+ using TPC PID cuts. Both tracks must reach TPC2 to be identified there and have common vertex. The phase-space is restricted to:

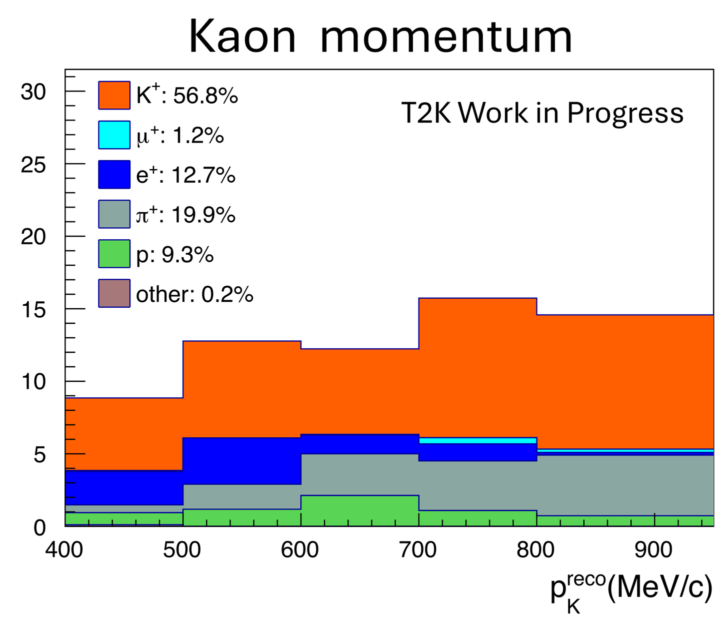
- $p_\mu > 0.25$ GeV, $\cos_\mu(\theta) > 0.4$
- $0.4 < p_{K+} < 0.95$ GeV, $\cos_{K+}(\theta) > 0.65$

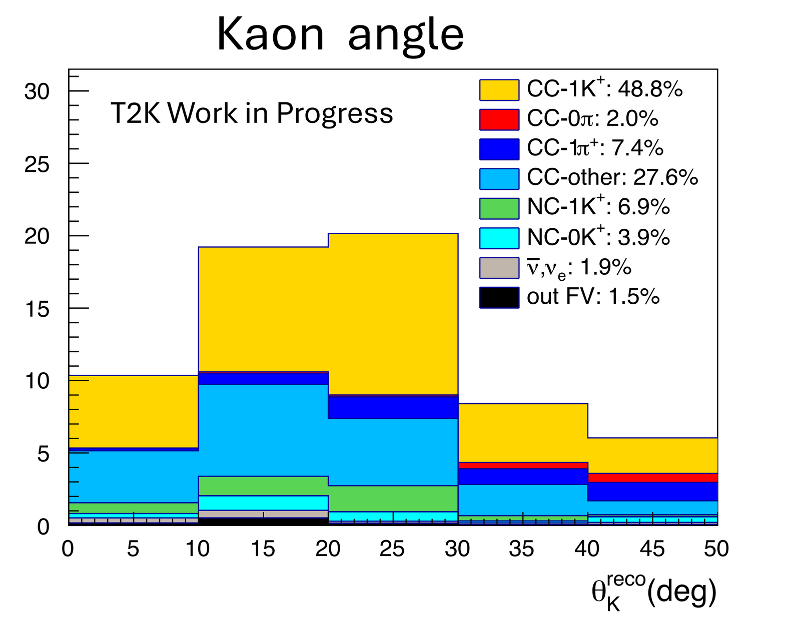
GENIE large signal sample: efficiency ~15% , purity ~49%











5. Cross-section Extraction

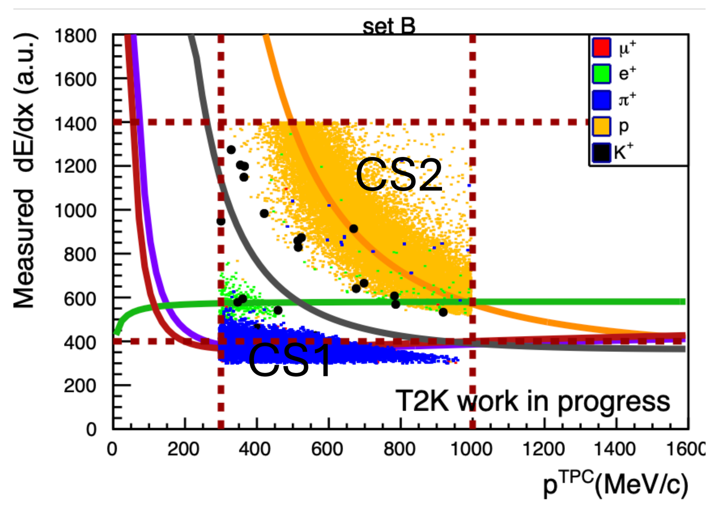
Background subtraction method is used with control samples constraining main CC-backgrounds. The GENIE fit to data for control samples gives factors that are used to scale the true MC background topologies in the signal region.

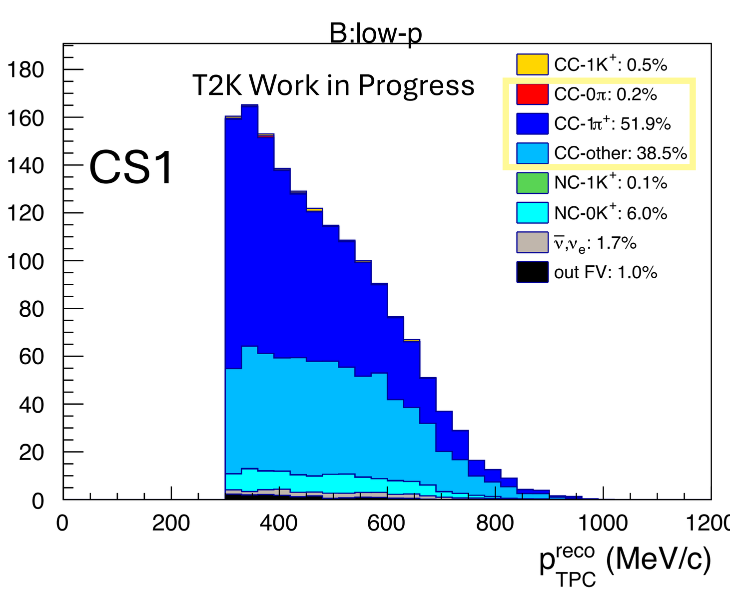
$$B_{data} = \frac{N^{CS}_{data}}{N^{CS}_{MC}} B_{MC}$$

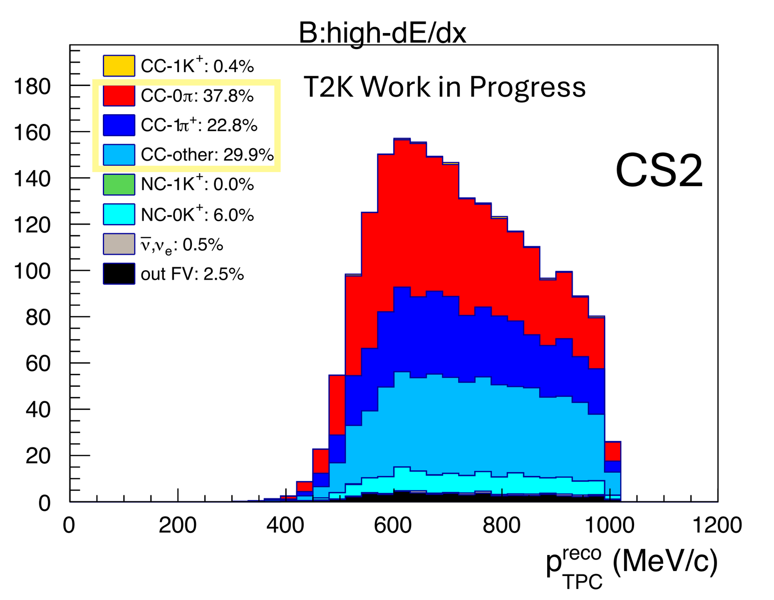
$$\sigma = \frac{N - B_{data}}{\epsilon \cdot \phi \cdot T}$$

- N: Selected data events
- B_{data}: from data-MC fit
- ε : efficiency
- ϕ : ND280 flux
- T : the number of targets in FGD1 FV

Control Samples (CS)







6. Systematic Uncertainties

We repeat sidebands fit and cross-section calculations for different MC toy sets describing detector systematics, cross section model and flux uncertainties to obtain systematic errors (here GENIE as fake data).

Error source	Xsec. relative error
Statistics data	26%
Statistics mc	5%
Detector systematics	12%
Model systematics and Flux	20%

T2K Work in Progress

7. Status and Plans

- Single bin measurement in the restricted phase-space
- We expect ~60 events selected in GENIE for 11.53x10^{20} POT
- Cross-section predictions vary up to 30% between generators

- Signal region has been unblinded and the analysis is under the review
- Results with data and publication in near future

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