t2k-experiment.org

ν_μ CCπ^0 reaction in the Tracker of the ND280 detector in the T2K experiment

Marcela Batkiewicz, for the T2K collaboration
The Henryk Niewodniczański Institute of Nuclear Physics of the Polish Academy of Sciences
Kraków, Poland

Abstract: A good knowledge of both inclusive and exclusive neutrino interaction cross sections is one of the key issues for a precise determination of the neutrino oscillation parameters in the T2K experiment. These studies are performed at the near detector (ND280). Its central tracker part equipped with a water target serves, among others, to study the ν_μ CCπ^0 reaction. At the energies of the T2K neutrino beam its contribution to the total cross section is relatively large, so the reaction is a potential source of background for the quasi-elastic ν_μ CC reaction. Two different production mechanisms contribute to ν_μ CCπ^0: single pion resonance production and DIS. In addition, FSI have to be considered. Thus, the analysis of the ν_μ CCπ^0 reaction aims also at a better tuning of the MC models used to describe neutrino interactions in T2K.

This poster describes selection criteria leading to the determination of the inclusive and exclusive cross section for the π^0 production in the ν_μ CC interactions.

1. The T2K experiment

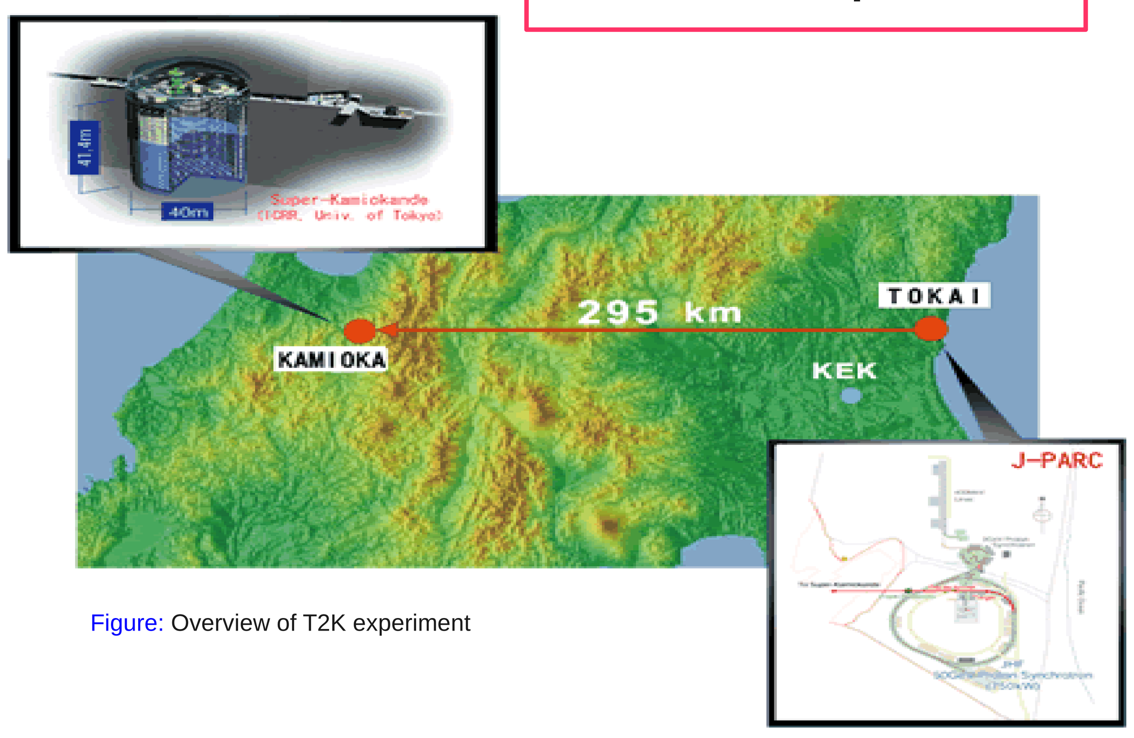

Figure: Overview of T2K experiment

The T2K experiment is a long baseline neutrino oscillation experiment. An intense muon neutrino beam is produced in the accelerator complex J-PARC in Tokai. The neutrino flux is measured before oscillations by the system of two detectors: INGRID and ND280 situated at a distance of 280m from the neutrino beam source (target). Then the beam is sent to the SuperKamiokande (SK) detector situated in Kamioka, where muon neutrino disappearance and electron neutrino appearance are studied. T2K is the first experiment which uses an off-axis neutrino beam. One of the near detectors, ND280, and the far detector SK are positioned 2.5º away from the beam axis. Such positioning helps to obtain a narrower neutrino energy peak at the 600 MeV. For this energy the far detector is in the first oscillation maximum for disappearance (appearance) and the charge current quasi elastic (CCQE) reaction dominates.

2. ND280 detector

A tracker part of ND280 detector consists of two scintillating detectors (Fine Grain Detectors – FGD) located between three Time Projection Chambers (TPC). The tracker is surrounded by the electromagnetic calorimeter (TECal) and a magnet generating a homogeneous magnetic field of 0.2T.

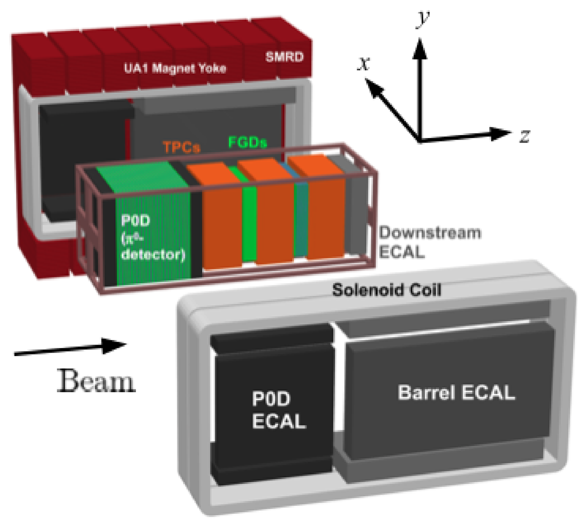

Figure: Overview of the Near Detector ND280

3. Final State Interactions (FSI)

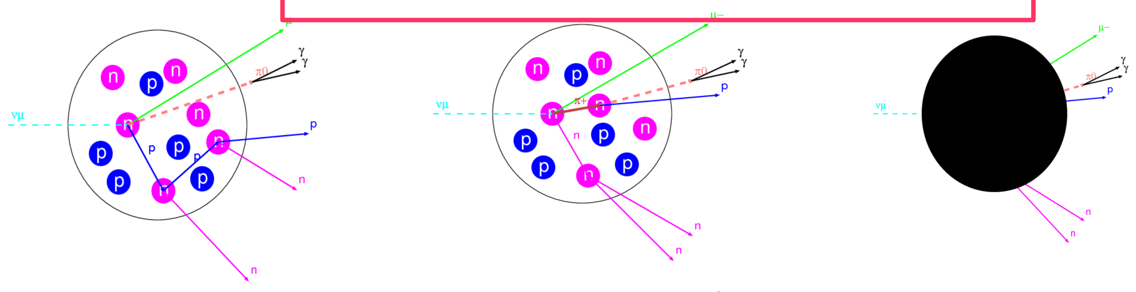

Figure: Example of two different primary neutrino interactions (CCπ^0 and CCπ^+) which are indiscernible after FSI

Due to FSI products of the primary neutrino interaction can differ from particles going out of the nucleus. Only the latter can be observed in the detector. That is why I use them to define reaction types.
This issue is discussed in more detail in M. Antonello et al. , Acta Phys. Polon. B 40, 2519 (2009)

4. Signal and background definition

All reactions in the FGD Fiducial Volume (FV) are defined based on particles going out of a nucleus.

Signal reactions contributing to the inclusive π^0 production in the ν_μ CC interactions (inclusive ν_μ CC π^0):

1. $CC1\pi^0$: $\nu_\mu + N \rightarrow \mu^- + N's + \pi^0$
2a. $CC\pi^0 + X$: $\nu_\mu + N \rightarrow \mu^- + N's + \pi^0 + other$, $other$ can be π^0
2b. $CC\,Sec\,\pi^0$ (secondary π^0): $\nu_\mu + N \rightarrow \mu^- + N's + other$, $other$ is not π^0, but decays / produces π^0

Background reactions:

$CCQE$: $\nu_\mu + N \rightarrow \mu^- + N's$
$CC+X$: $\nu_\mu + N \rightarrow \mu^- + N's + other$, $other \neq \pi^0$
$NC1\pi^0$: $\nu_\mu + N \rightarrow \nu_\mu + N's + \pi^0$
$NC\pi^0 + X$: $\nu_\mu + N \rightarrow \nu_\mu + N's + \pi^0 + other$, $other$ can be π^0
$NC+X$: $\nu_\mu + N \rightarrow \nu_\mu + N's + other$, $other \neq \pi^0$

$\bar{\nu}_\mu$, ν_e and $\bar{\nu}_e$ reactions are divided into same categories, but they all are background reactions.

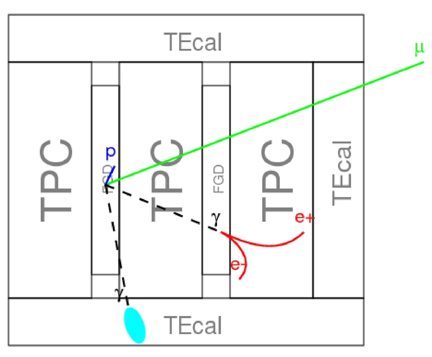

Figure: FGD FV ν_μ CC1π^0 reaction seen in the Tracker of the ND280 detector

5. Sample

The sample used in this analysis is **a minimum bias Monte Carlo** corresponding to **2.25e21 POT** which is equal to 8 times the present statistics for real data.

6. Muon selection

1. good quality track in TPC
2. front position in FGD FV
3. muon-like particle ID
4. reject electron-like tracks
5. highest momentum negative track
6. TPC1 veto

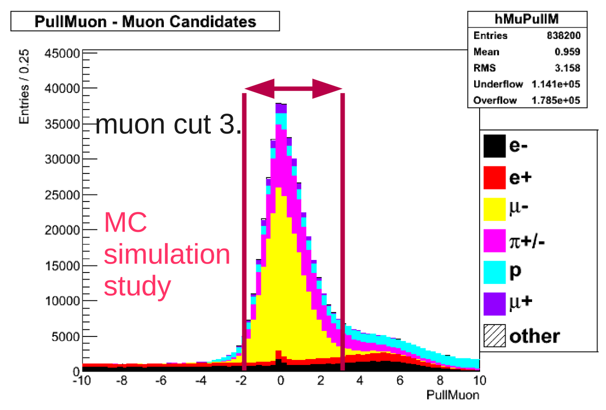

Figure: PullMuon distribution for muon candidates – particle identification

Particle identification

$$Pull_\alpha = \frac{dE/dx_{meas} - dE/dx^\alpha_{expec}}{\sigma_\alpha}$$

$$\alpha - e^\pm, \mu^\pm, \pi^\pm, p, K^\pm$$

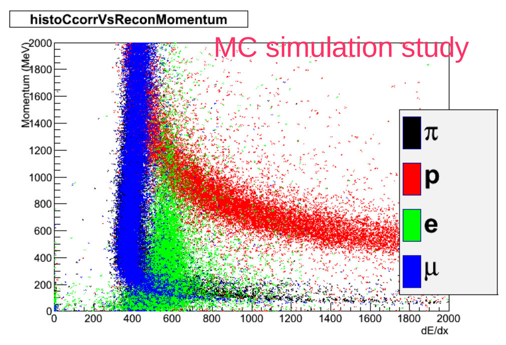

Figure: dE/dx vs reconstructed momentum – particle identification

FGD FV ν_μ CC selection (MC):
- number of events: 204975
- efficiency: 53.91%
- purity: 86.55%
- signal subsamples:
  - ν_μ CC1π^0 : 4.02%
  - ν_μ CCπ^0+X: 12.41%
  - ν_μ CCSecπ^0 : 1.01%

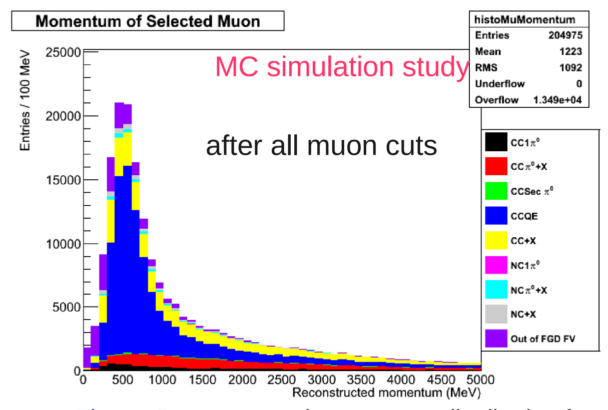

Figure: Reconstructed momentum distribution for selected muons – influence of FSI

7. π^0 selection

➔ photon converting in calorimeter – shower in ECal:
1. isolated object in ECal
2. shower like object

➔ photon converting in FGD or TPC – $e^\pm$ tracks in TPC:
1. good quality track in TPC
2. front position in FGD or TPC
3. electron-like track
4. reject proton-like tracks
5. momentum > 50 MeV

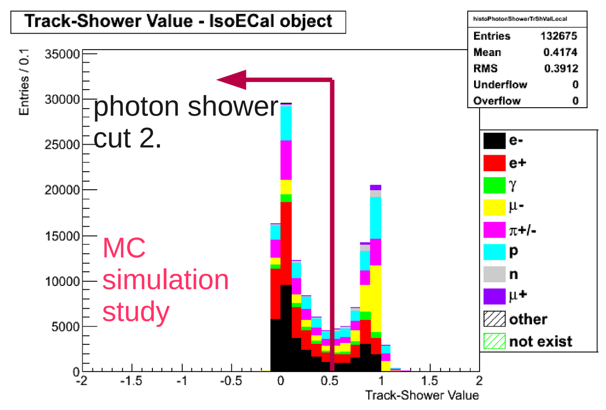

Figure: Track-shower discriminator distribution for photon shower candidates – particle identification

For all (77644) selected cascades:
- 63.81% are $e^\pm$ or γ
- 39.94% come from π^0

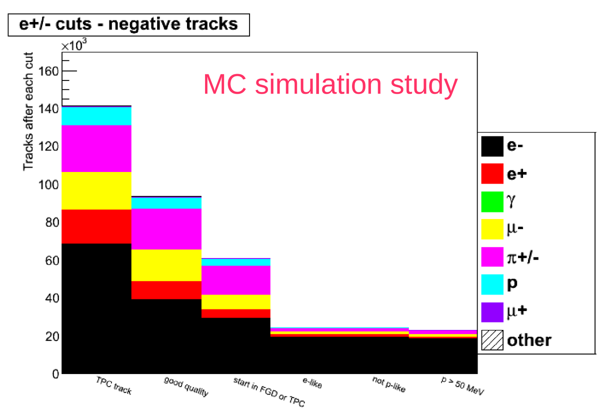

Figure: Electron candidates sample after each cut – particle identification

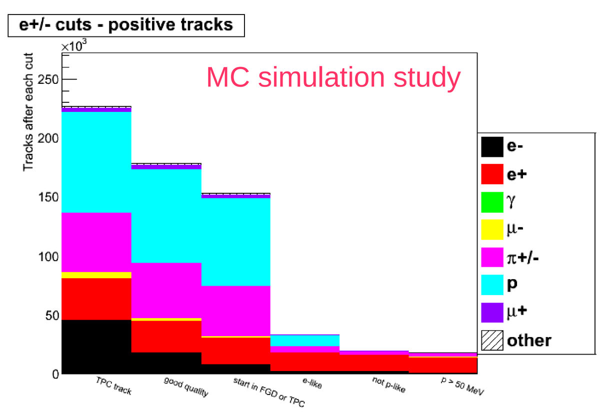

Figure: Positron candidates sample after each cut – particle identification

For selected e^+ (e^-) sample:
- number of tracks is 17939 (22934)
- true e^+ (e^-) is 73.16% (80.64%)
- π^0 is primary particle for 54.89% (54.10%)

8. Inclusive ν_μ CCπ^0 event selection

➔ Inclusive ν_μ CCπ^0 event topologies – requirement of at least two π^0 decay products in ECal and/or in TPC:
1. two showers in ECal
2. two $e^\pm$ tracks in TPC
3. one shower in ECal and one $e^\pm$ track in TPC
4. more then two π^0 decay products (in ECal or in TPC)
5. **total inclusive ν_μ CCπ^0 sample** – sum of topologies 1. - 4.

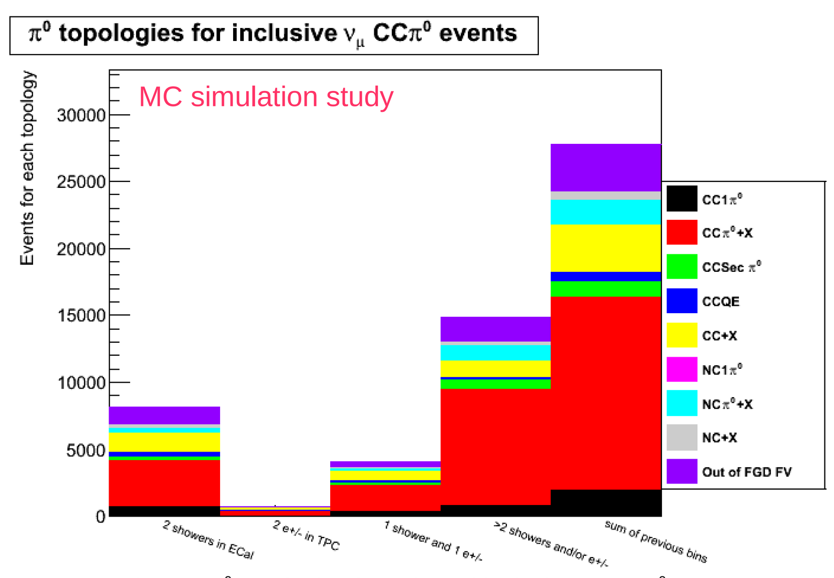

Figure: π^0 topologies for selected inclusive ν_μ CCπ^0 events – influence of FSI

FGD FV inclusive ν_μ CCπ^0 selection:
- **number of selected events: 27785**
- **efficiency: 31.79%**
- **purity: 61.76% , among them:**
  - **ν_μ CC1π^0 : 6.83%**
  - **ν_μ CCπ^0+X: 50.75%**
  - **ν_μ CCSecπ^0 : 4.18%**