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.

Characteristics and selection of $\nu_\mu$, CC$1\pi^-$ topology

- Defined as a topology with one $\mu^+$ and one $\pi^-$ in the final state, with no other types of pions: $\nu_\mu + N \rightarrow \mu^+ + \pi^- + X$.
- ND280 magnetic field enables selection of $\pi^-$ and $\mu^+$ candidate.
- Selection: one track containing a segment in TPC and starting in FGD1 fiducial volume reconstructed as a $\pi^-$ and the other track with a segment in TPC reconstructed as a $\pi^-$ (Fig. 2: left).
- Also the isolated track in FGD1 with $\pi$-like energy loss $dE/dx$ is considered to be a signature of $\pi^-$ (Fig. 2: right).
- In both cases, no reconstructed $\mu^+$, $\pi^0$ nor Michel electrons.

First studies on purity improvement

- $\nu_\mu$ beam contaminated with $\nu_\tau$.
- One of the main background topologies: CC$1\pi^+$: $\nu_\mu + N \rightarrow \mu^+ + \pi^- + X$.
- $\mu^+\pi^-$ (signal) and $\mu^+\pi^0$ (background) events are difficult to distinguish due to the same $\mu\pi$-like energy loss.
- Idea for the additional selection criterion: range of the $\mu^+$ candidate.
- True $\mu^+$ more likely to reach TPC3 chamber than $\pi^-$ (Fig. 4).
- Eventual, additional cut: removal of events with multiple positive tracks originating from the FGD1 fiducial volume and $\mu^+$ candidate not reaching TPC3. The impact on the selection presented in Table 1.

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

<table>
<thead>
<tr>
<th>topology or type of interaction</th>
<th>fraction</th>
<th>number of events$^a$</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC$1\pi^-$</td>
<td>1.2%</td>
<td>311</td>
</tr>
<tr>
<td>CC$1\pi^+$</td>
<td>52.2%</td>
<td>75</td>
</tr>
<tr>
<td>CCother</td>
<td>12.6%</td>
<td>145</td>
</tr>
<tr>
<td>BKG CC $\nu_\mu$</td>
<td>24.3%</td>
<td>36</td>
</tr>
<tr>
<td>BKG NC</td>
<td>6.1%</td>
<td>2</td>
</tr>
<tr>
<td>BKG other</td>
<td>0.3%</td>
<td>20</td>
</tr>
<tr>
<td>out of FV</td>
<td>3.4%</td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Composition of the CC$1\pi^-$ sample obtained with preliminary selection.

$^a$Number of events scaled to the data POT: $6.7 \times 10^{20}$.

Plans

- CC$1\pi^-$ preliminary selection is 52% pure.
- Other ideas for selection improvements are under studies. Some of the considered observables are: range of $\pi^-$ 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

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