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Study of charged current interactions on carbon with a single positively charged pion in the final state at the T2K off-axis near detector with 4π solid angle acceptance

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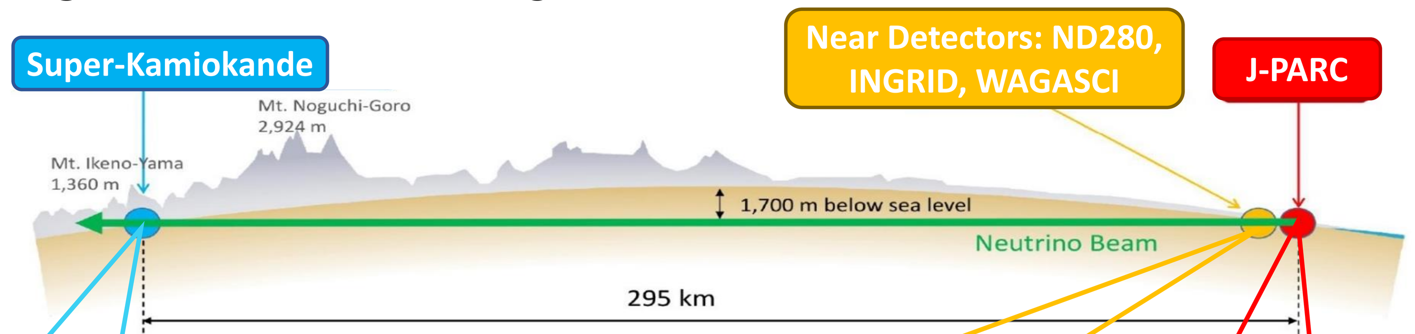
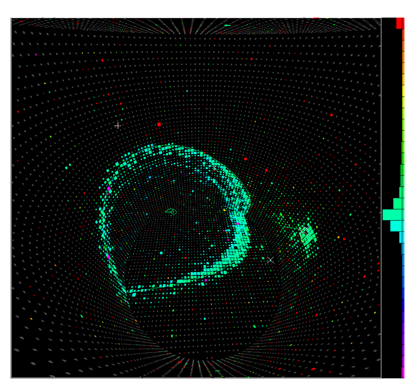
1. T2K experiment

- T2K is a long-baseline neutrino oscillation experiment.
- Goal: make precise measurements of oscillation parameters via observation of $\bar{\nu}_\mu/\nu_\mu$ disappearance and $\bar{\nu}_e/\nu_e$ appearance.

Figure 1: T2K baseline diagram.



Measure oscillated spectrum



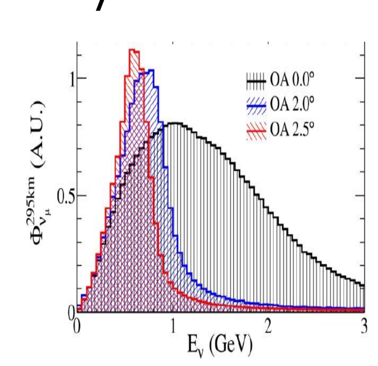
4π symmetry of the detector.

Measure un-oscillated spectrum

Are used to constrain the flux and cross section parameters reducing the systematic errors in the T2K oscillation analyses.

ND280 4π solid angle acceptance

Production of high intensity ν / $\bar{\nu}$ beam



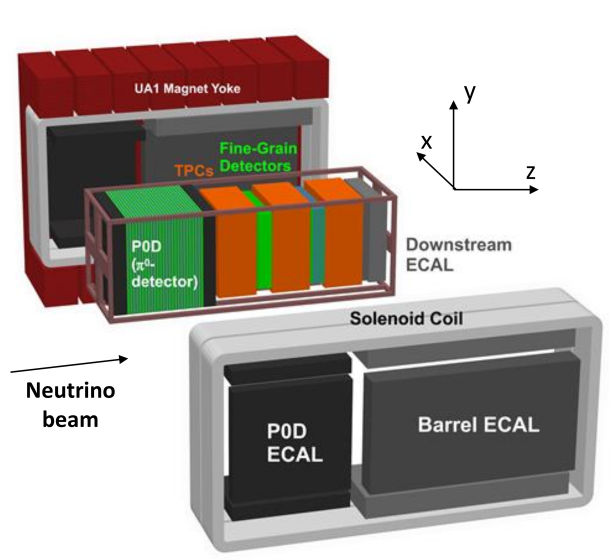


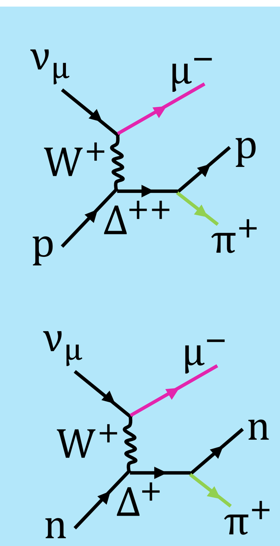
Figure 2: Schematic view of ND280 off-axis near detector.

2. Off-axis ND280 detector

- 0.2 T magnetized tracking detector
- π^0 detector (P0D)
- Electromagnetic calorimeters (ECals)
- Side Muon Range Detectors (SMRD)
- The tracker (located downstream of the P0D) is made up of :
  - 3 gas Time Projection Chambers (TPCs)
  - 2 Fine Grained Detectors (FGDs)

3. Motivation

- $CC1\pi^+$ constitutes the main background for the muon neutrino disappearance measurement when the charged pion is not observed.
- The aim of the distributions presented here is to provide results in a model independent way, to make their comparison to other experiments easier and to contribute to the improvement of current models.



- The $CC1\pi^+$ cross section will be extracted using the present event selection (wiht 4π solid angle acceptance).
- We can study the nuclear effects, FSI and Fermi momentum by computing and comparing the Adler angles.

4. Event selection

- Pion production is dominated by resonant interactions in the T2K energy range.
- The signal is defined in terms of the experimentally observable particles exiting the nucleus.

Using NEUT as the default MC generator. We select events with a $CC1\pi^+$ topology in FGD1:

- 1 muon in 4π solid angle acceptance using time of flight (ToF):
  - Low angle tracks (FGD-TPC):
    i. Forward (FWD) or backward (BWD)
  - High angle tracks (FGD-ECAL or FGD-TPC-ECAL):
    i. FWD or BWD
- One and only one pion of positive charge is required:
  - In TPC, contained in FGD and by Michel electron (ME) tagging.
- The event is rejected if additional pions, either charged or neutral, or photons are identified in the event either by looking at TPC tracks or electromagnetic showers in ECal.

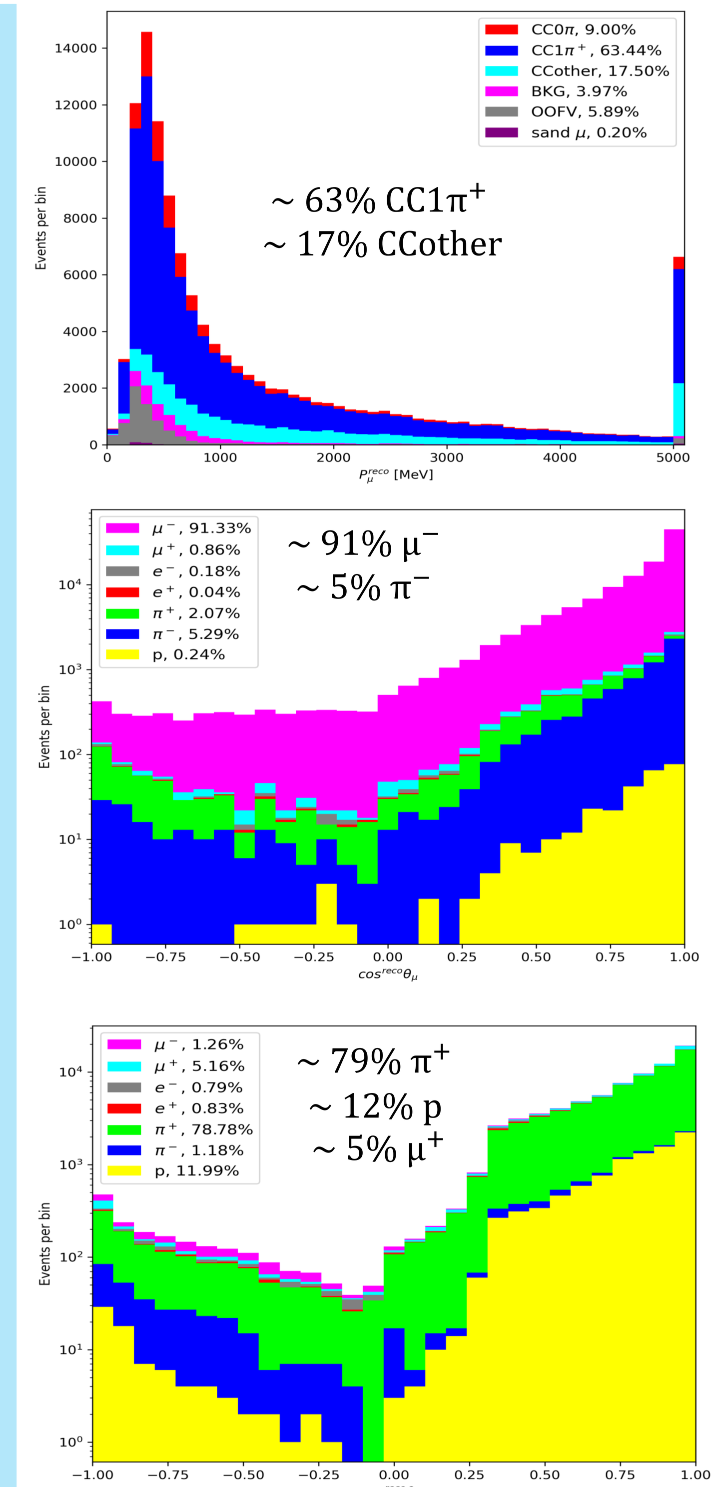


Figure 3: Reconstructed muon momentum (top) , muon cos theta (center), TPC + FGD positive pion cos theta (bottom), with 4π solid angle acceptance for FGD1 sample.

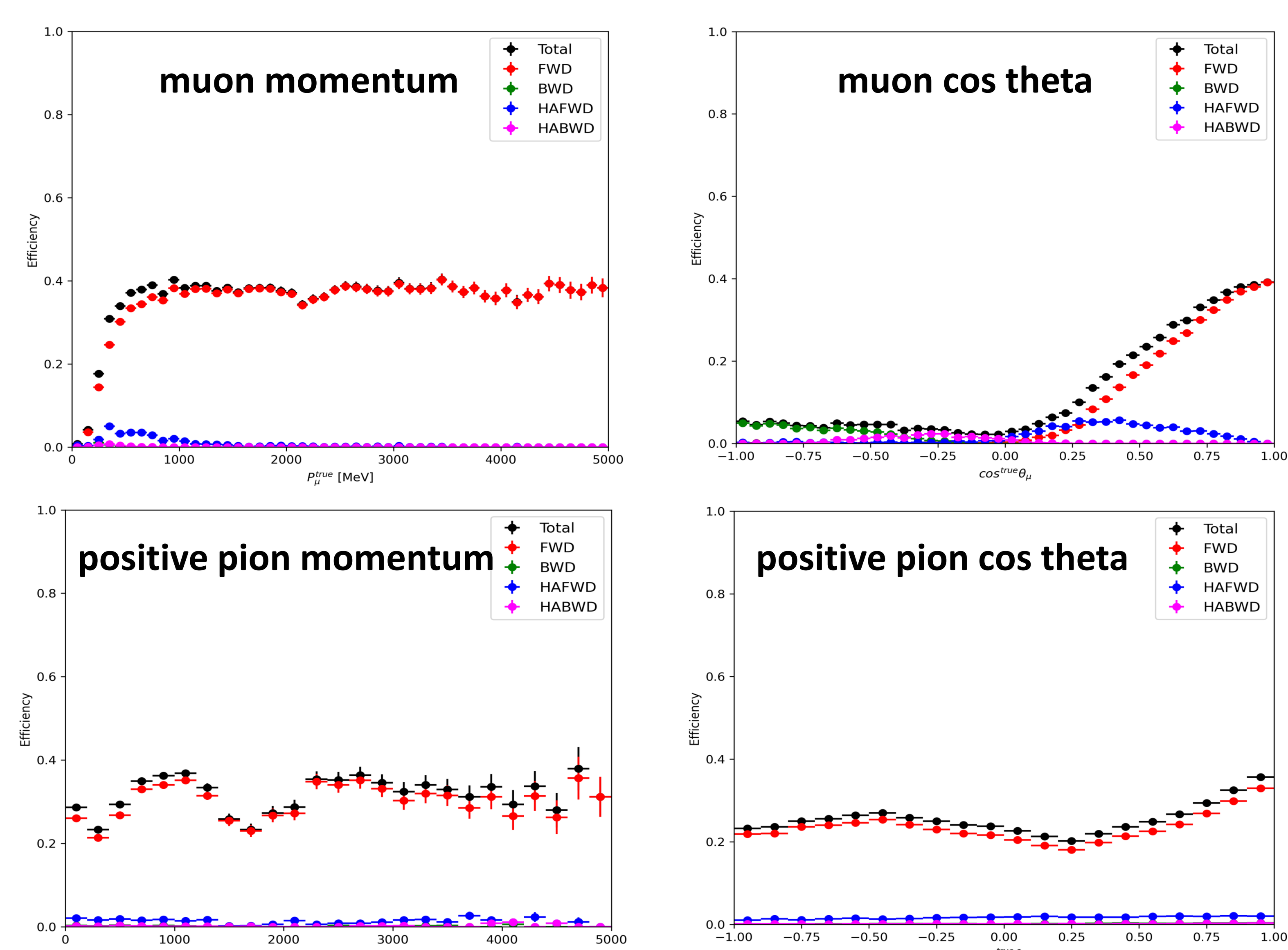


Figure 4: $CC1\pi^+$ efficiency vs. muon momentum (top left), muon cos theta (top right), positive pion momentum (bottom left) and positive pion cos theta (bottom right), with 4π solid angle acceptance for FGD1 sample.

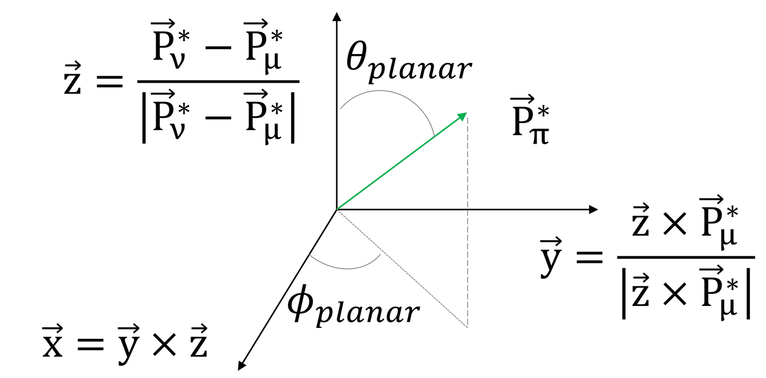
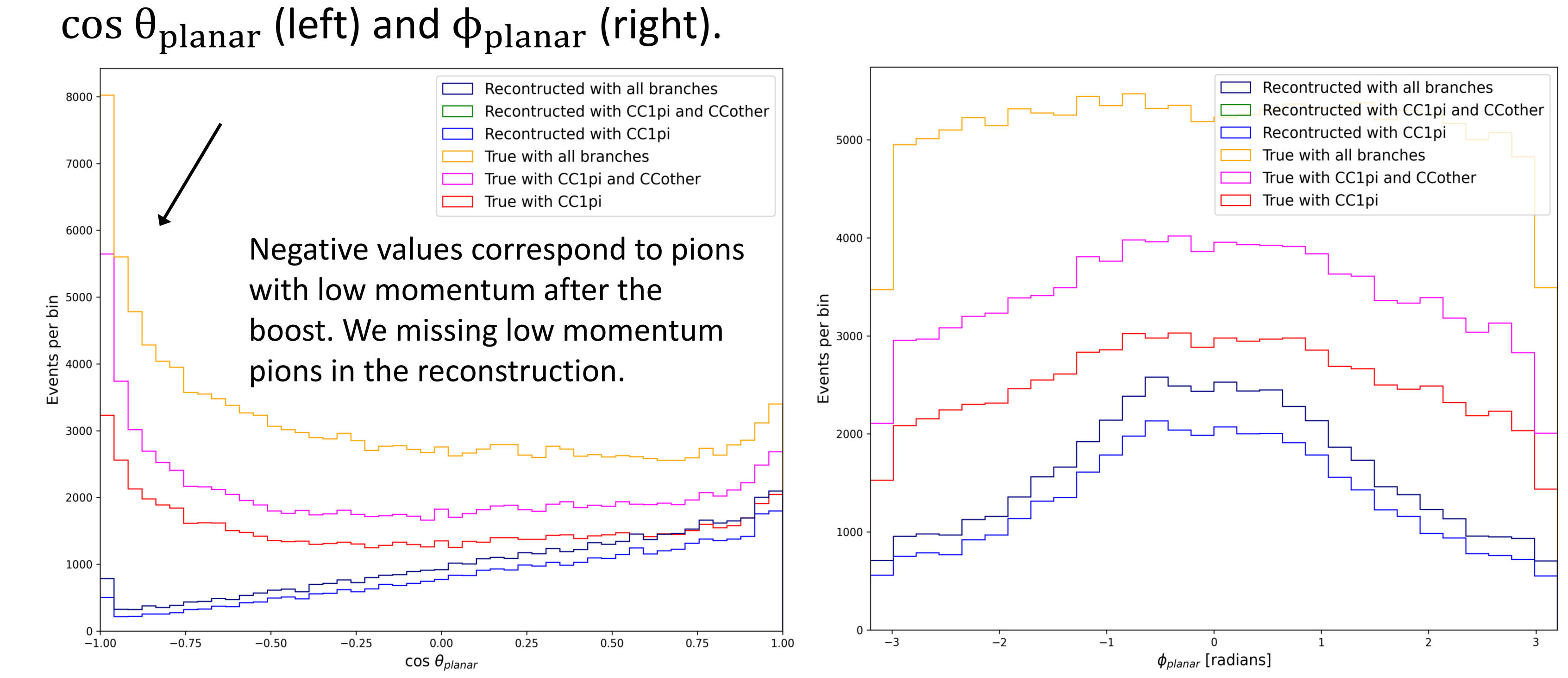


Figure 5: Definition of the Adler's Angles at the nuclear level. The momenta of the particles are defined in the rest frame $\vec{q} = \vec{p}_\nu - \vec{p}_\mu$.

5. Adler angles

- The angles θ_{planar} and ϕ_{planar} define the direction of the pion in the Adler system ($p - \pi^+$ final state in the Δ reference system).
- Are computed with particles leaving the nucleus.
- Carry information about the polarization of the Δ resonance, the interference with non resonant single pion production and they can provide hints of parity violation due to the lack of preference in the Δ direction.

Figure 6: Comparison between reconstructed and true Adler angles distributions $\cos\theta_{planar}$ (left) and ϕ_{planar} (right).



6. Conclusion

- Using NEUT as the default MC generator we observe a purity of the $CC1\pi^+$ signal of ~63%. CCother events being the main contamination.
- We have presented the Adler angles observables that will be most useful for comparison with neutrino interaction models.
  - This is the second time those angles are measured in interactions of neutrinos on heavy nuclei (first time was also in ND280, 2 years ago in a constrained phase space and with less statistics).
- Negative values of the cos θ_{planar} correspond to pions with low momentum after the boost. We are missing low momentum pions in the reconstruction due to nuclear effects.
- The Adler angles can be used to improve our interaction models.

6. References

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7. Acknowledgements

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