TAU NEUTRINO APPEARANCE IN THE FLUX OF ATMOSPHERIC NEUTRINOS AT SUPER-KAMIOKANDE

Maitrayee Mandal, NCBJ Poland ✉ **maitrayee.mandal@ncbj.gov.pl** **mai_trayee**

Supported by NCN grant number: UMO-2018/30/E/ST2/00441

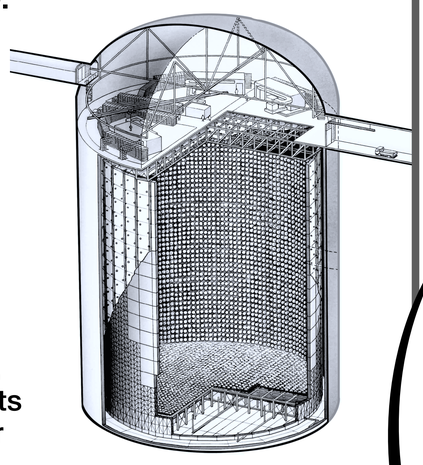
Atmospheric neutrinos

Secondary cosmic rays decay to produce atmospheric neutrinos which are mainly of μ and e flavors.

MUON NEUTRINOS IN THE FLUX OF ATMOSPHERIC NEUTRINOS ARE EXPECTED TO OSCILLATE PREDOMINANTLY TO TAU NEUTRINOS.

Super-Kamiokande (SK)

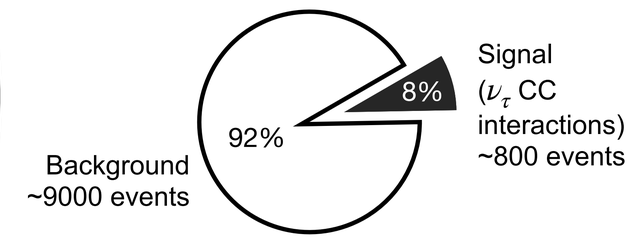
- Water Cherenkov detector.
- Cylindrical tank filled with ultra-pure water until 2019.
- Lined inside with ~11000 PMTs.



In 2019, SK water was doped with gadolinium, increasing its capacity for detecting neutron captures.

AN UNAMBIGUOUS CONFIRMATION OF NEUTRINO OSCILLATIONS -

DIRECT DETECTION OF OSCILLATION INDUCED TAU NEUTRINOS IN THE ATMOSPHERE IN THE ENERGY RANGE OF ~3.5 GeV TO 100 GeV.



The background to the ν_τ CC signal is made up of the following interactions of the atmospheric neutrinos,

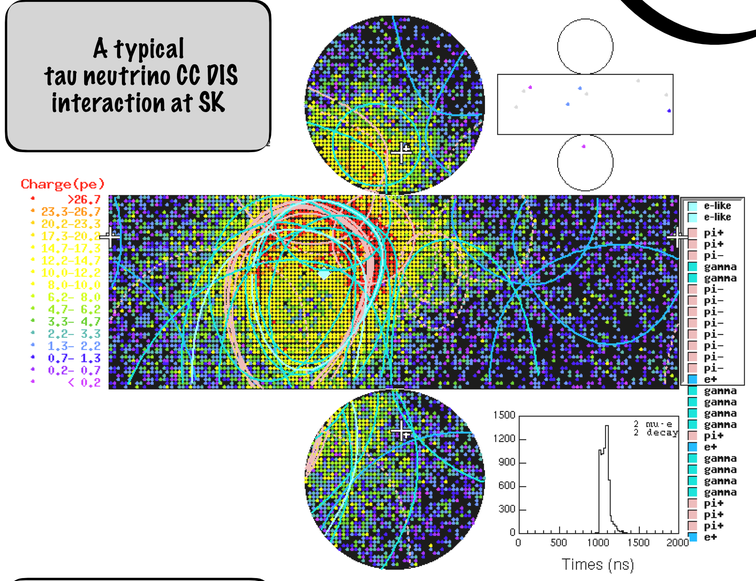
- ν_μ CC interactions,
- ν_e CC interactions,
- and NC interactions of all flavors.

Tau produced in ν_τ CC interactions, decay to produce many particles, which makes the reconstruction of the tau difficult.

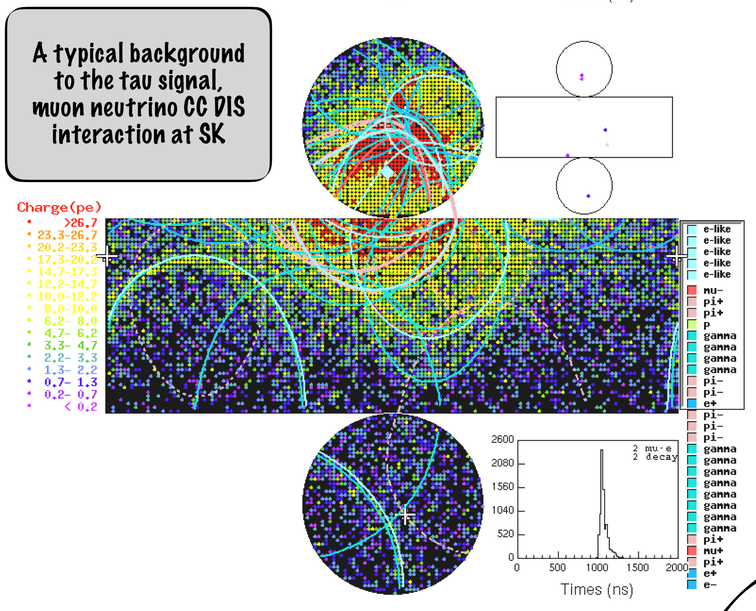
SK USES A NEURAL NETWORK (NN) TO PICK THE TAU SIGNAL.

THE MANY CHARGED PARTICLES PRODUCED IN THESE EVENTS ARE SEEN AS MULTIPLE RINGS AT SK.

A typical tau neutrino CC DIS interaction at SK

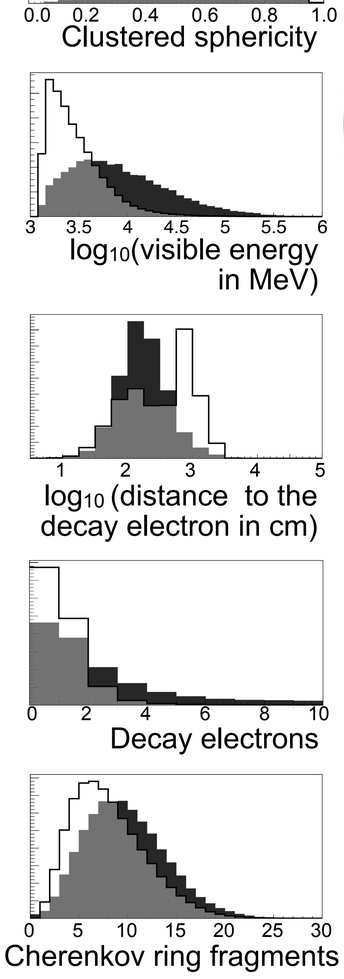


A typical background to the tau signal, muon neutrino CC DIS interaction at SK

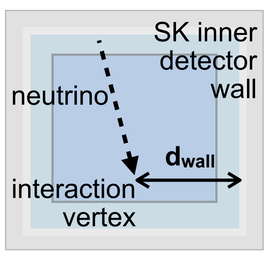


Inputs to the NN

MC studies shown here are with 500 years of signal and background, each weighed to a live-time of the detector of ~9 years (SK-IV run period). The tau events have been scaled to the background, unless stated otherwise.



LARGER FIDUCIAL VOLUME (FV) IS EXPECTED TO ADD 12% MORE TAU EVENTS.

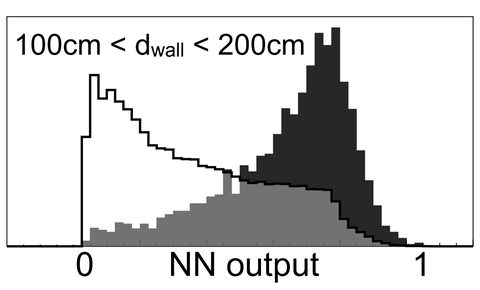


WHAT'S NEW?

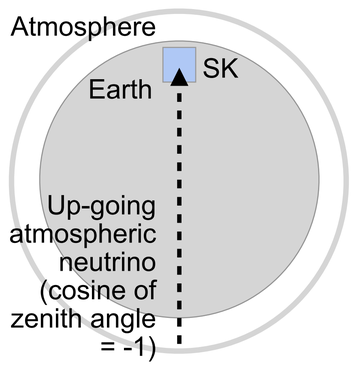
SK NN performs well in the expanded FV, selecting tau neutrinos with an efficiency of 74% (signal purity of 75%).

Standard FV, d_{wall} > 200cm.

Expanded FV, d_{wall} >100cm.



FURTHER MOTIVATION



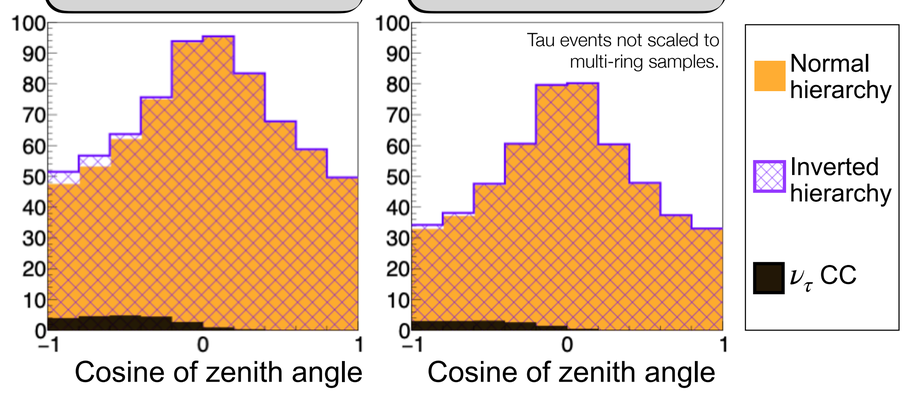
Due to matter effects, for normal (inverted) hierarchy, a resonance of $\nu_e(\bar{\nu}_e)$ appearance from the oscillation of muon neutrinos is expected in the multi-GeV upward-going sample.

CONSTRAINING ν_τ CC BACKGROUND IN THE MULTI-GeV e-LIKE SAMPLES WOULD IMPROVE THE CONSTRAINTS ON THE STUDY OF NEUTRINO MASS-HIERARCHY AT SK.

In SK's atmospheric neutrino oscillation analysis, ν_τ appearance contaminates these samples.

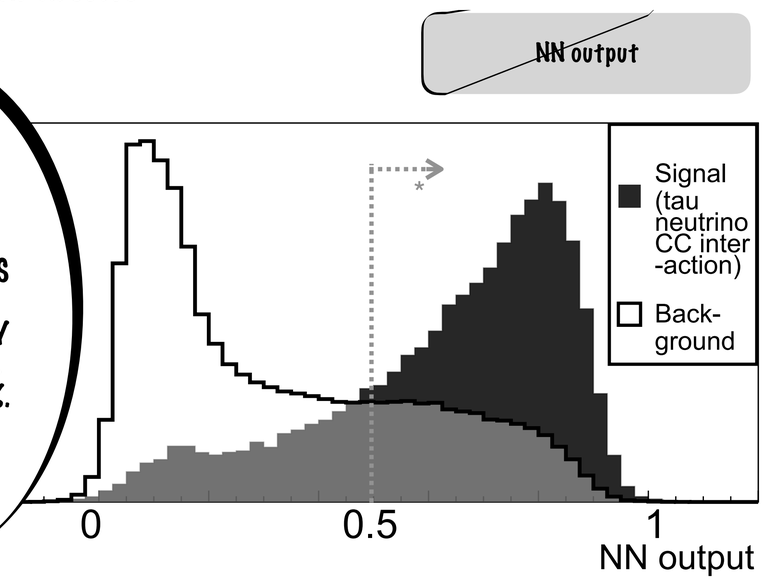
Electron neutrino multi-ring multi-GeV sample

Electron anti-neutrino multi-ring multi-GeV sample



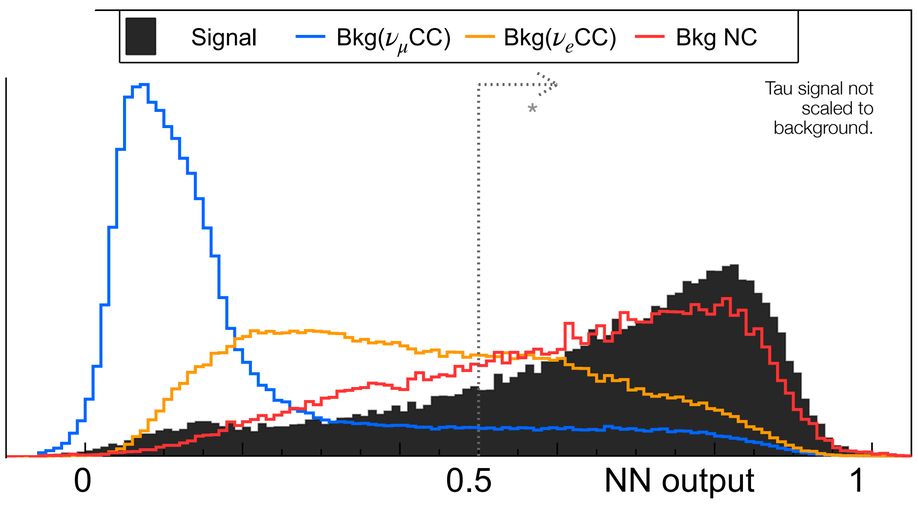
METHOD AND RESULTS

THE SK NN IDENTIFIES TAU NEUTRINOS WITH 72% EFFICIENCY AND A SIGNAL PURITY OF 77%.



* Events with NN ouput > 0.5 are classified as tau-like.

OF ALL THE BACKGROUND, 22% IS MISIDENTIFIED AS TAU-LIKE.



% of misclassified background	ν_μCC	ν_eCC	NC
	13%	37%	70%

On average, more neutrons are expected to be produced in the NC interactions than in the tau signal. NN inputs related to neutron captures could declassify the misidentified NC background.

WHAT'S NEXT?

- Data from the latest SK periods, combined with the results of higher neutron tagging efficiency from the SK-Gd upgrade.
- Software upgrades to the SK NN.

NEW TAU CC CROSS-SECTION AND NORMALISATION MEASUREMENTS, AND IMPROVED MASS-HIERARCHY RESULTS.

Sincere thanks to Justyna Lagoda (NCBJ), Magdalena Posiadala-Zezula (UW), Roger A. Wendell (Kyoto U)

Previous analysis:
Z. Li et al. (SK Collaboration)
Phys. Rev. D 98, 052006