Tau identification using machine learning image classification in Hyper−Kamiokande

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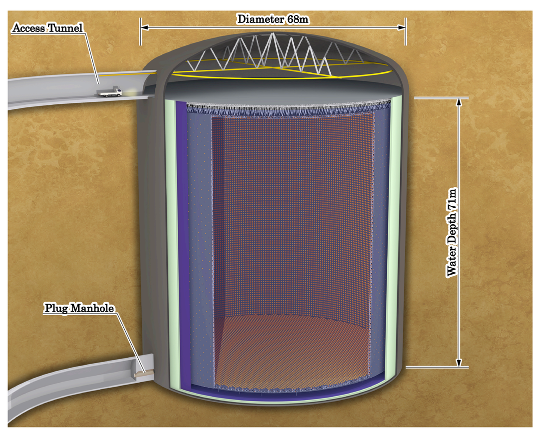
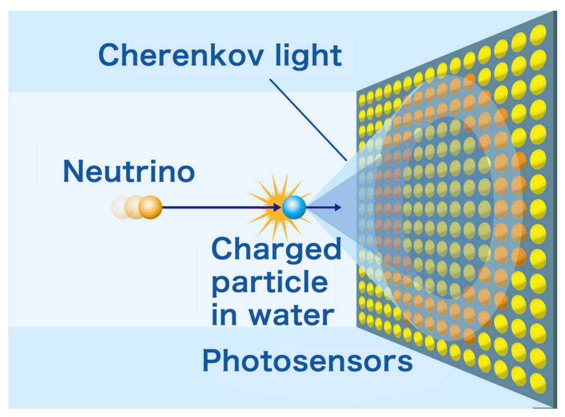
UGAP2022 Unraveling the History of the Universe and Matter Evolution with Underground Physics
#P31

1. Hyper-Kamiokande (HK)



- HK is a 260-kiloton (188-kiloton fiducial mass) water-Cherenkov detector in Japan
  - Cherenkov light produced by charged particles is observed using photomultiplier tubes (PMT).
- Multiple physics goals including:
  - Search for proton decay, Measurement of CP violation, Observation of supernova neutrinos, etc
  - High statistics ν_τ CC interactions from $\nu_\mu \rightarrow \nu_\tau$ oscillation are expected (>1000 ν_τ CC in 10 years)



2 . Analysis method

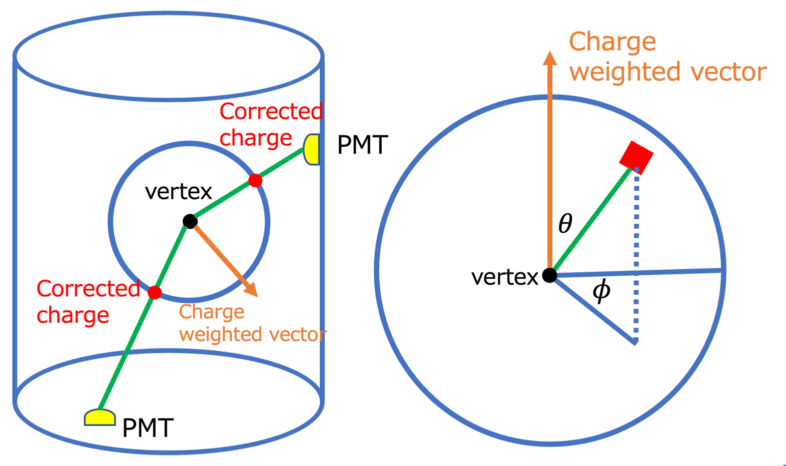
Motivation : The goal of this study is to distinguish tau from other particles.

Procedure

1. Generate atmospheric neutrino events using HK MC simulation.
2. Create a 2D map of the hit PMT positions with respect to the neutrino interaction position (vertex).
3. Identify the type of charged particle by machine-learning image recognition using a 2D map as input.
   - Separation of ν_eCCQE and ν_μCCQE
   - Separation of ν_τCC and other neutrino interactions

Creating map

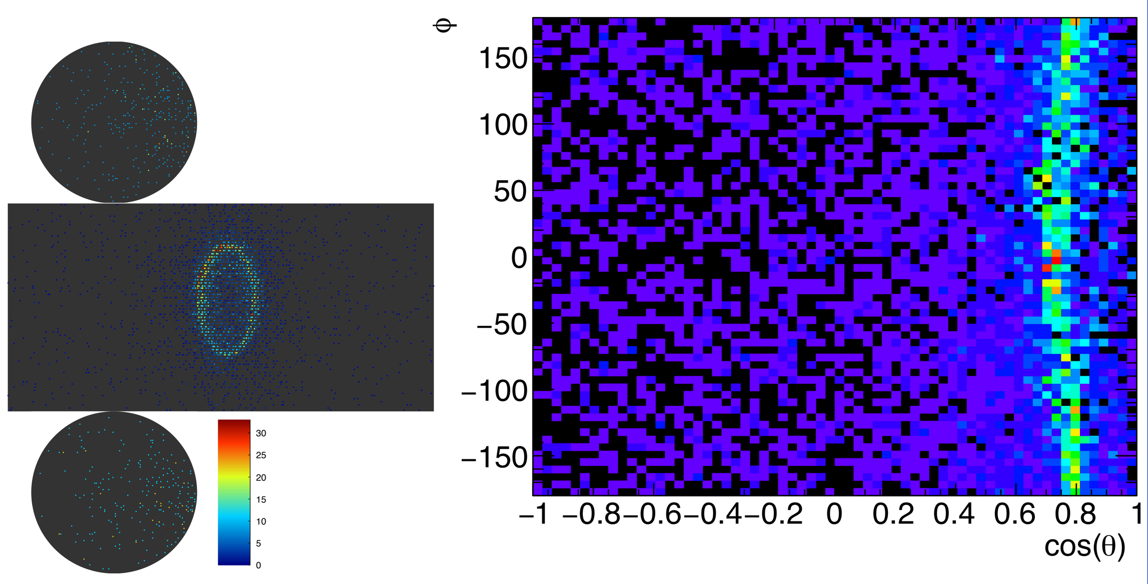
2D map is created with the correction for distance between PMT and vertex.



Machine-Learning

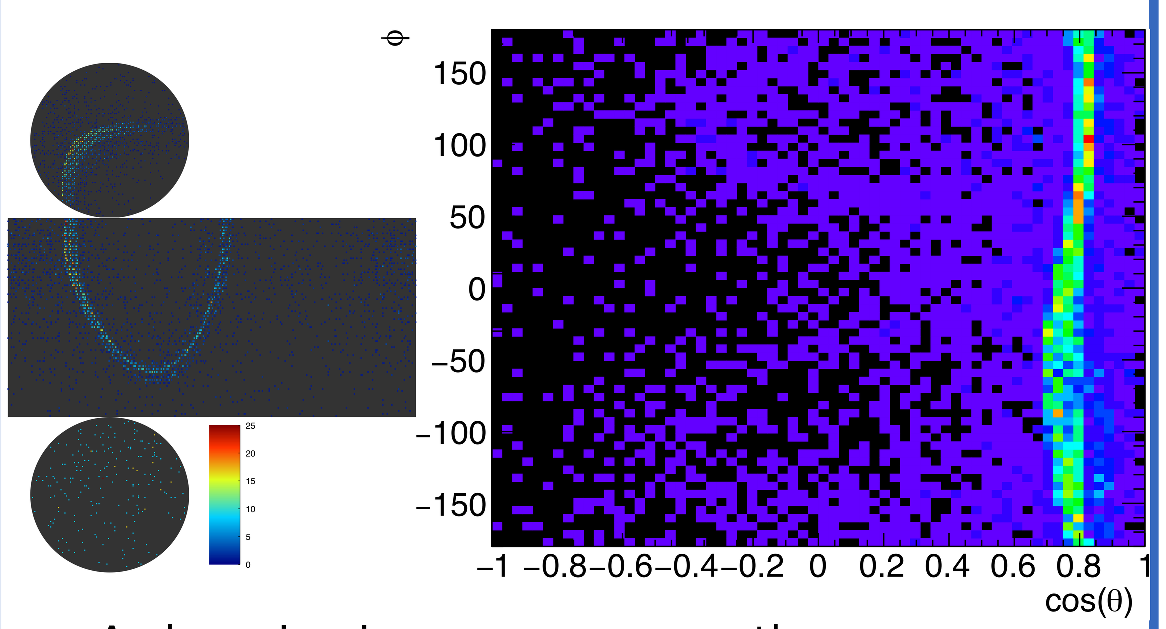
- The algorithm determines the parameters using a large amount of data.
- Machine-learning with convolutional neural networks (CNN) was used with Tensorflow2 and Keras. https://keras.io/

Electron



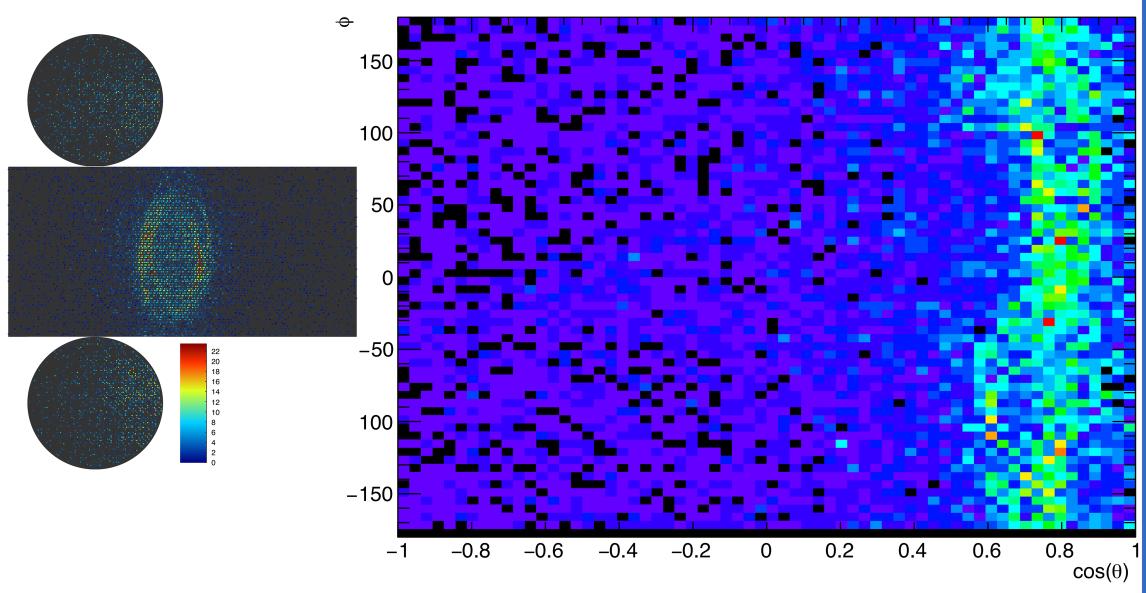
The ring is blurred by electromagnetic shower from an electron and the multiple scatterings.

Muon



A clear ring image appears as the muons move straight through the water.

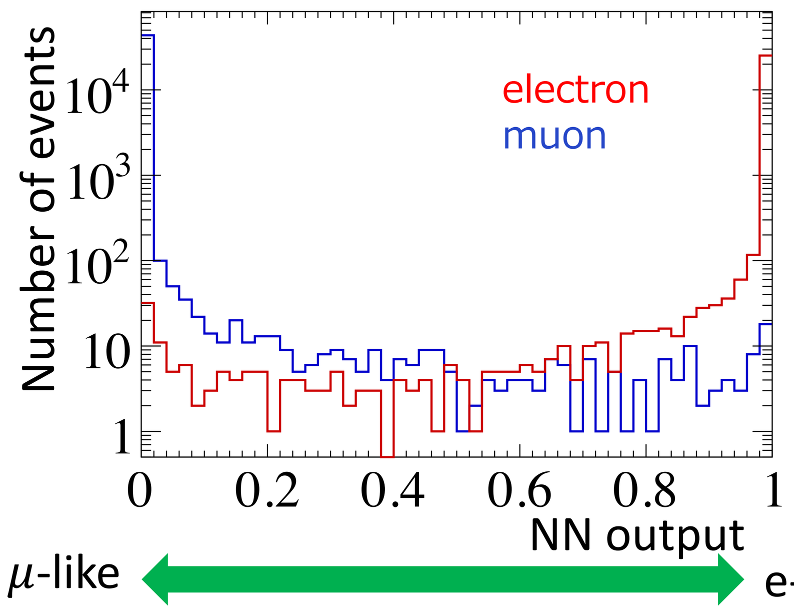
Tau



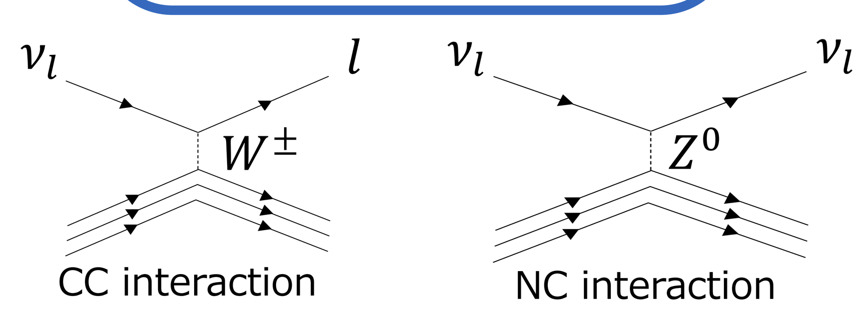
Multiple rings are observed by hadrons generated by the decay of tau.

3. Separation of ν_eCCQE and ν_μCCQE

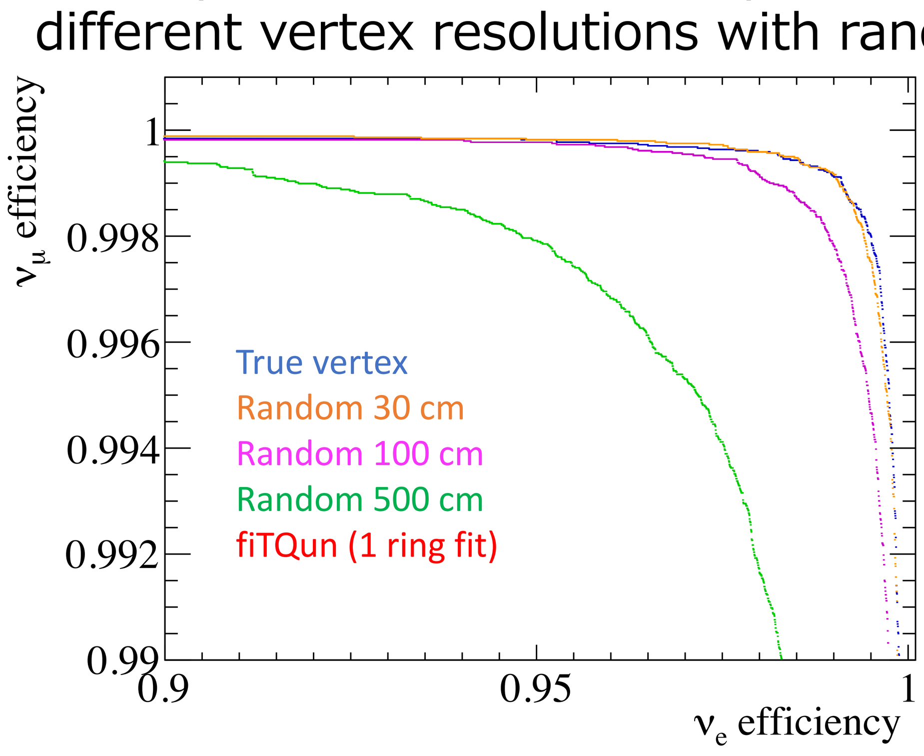
The CCQE interaction produces charged leptons corresponding to the neutrino flavors.

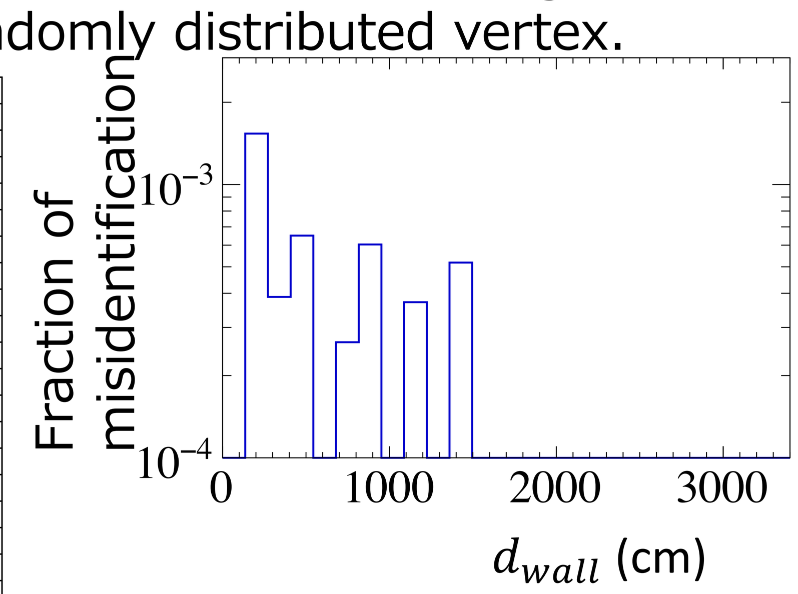


Neutrino interaction



- The true vertex positions are assumed to generate the map
  →The performance was compared with the case assuming different vertex resolutions with randomly distributed vertex.

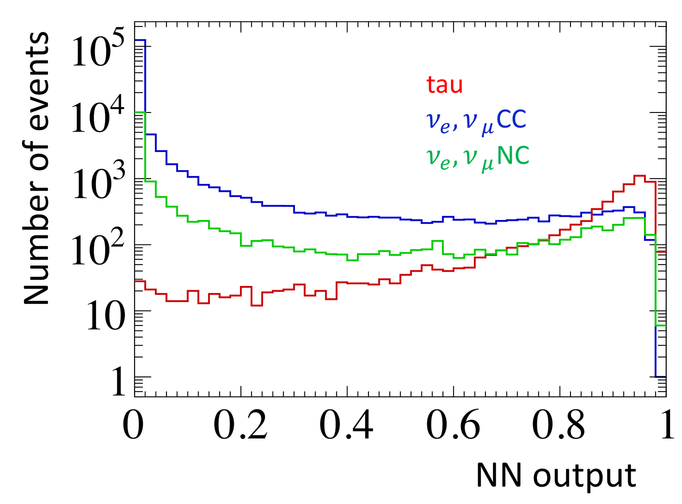


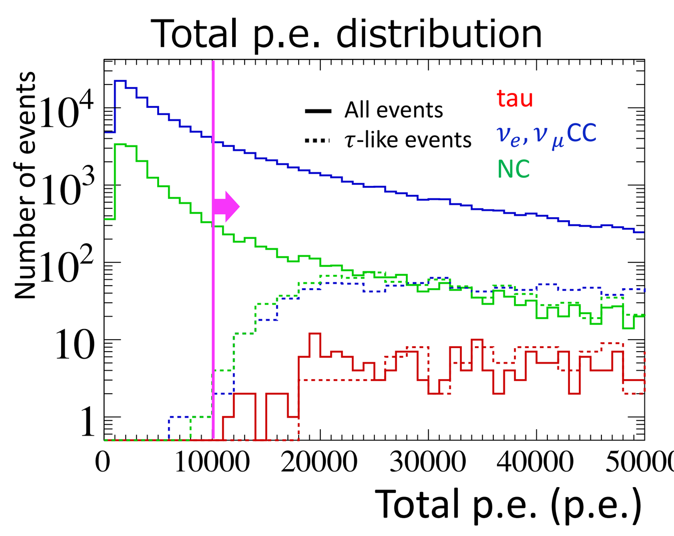


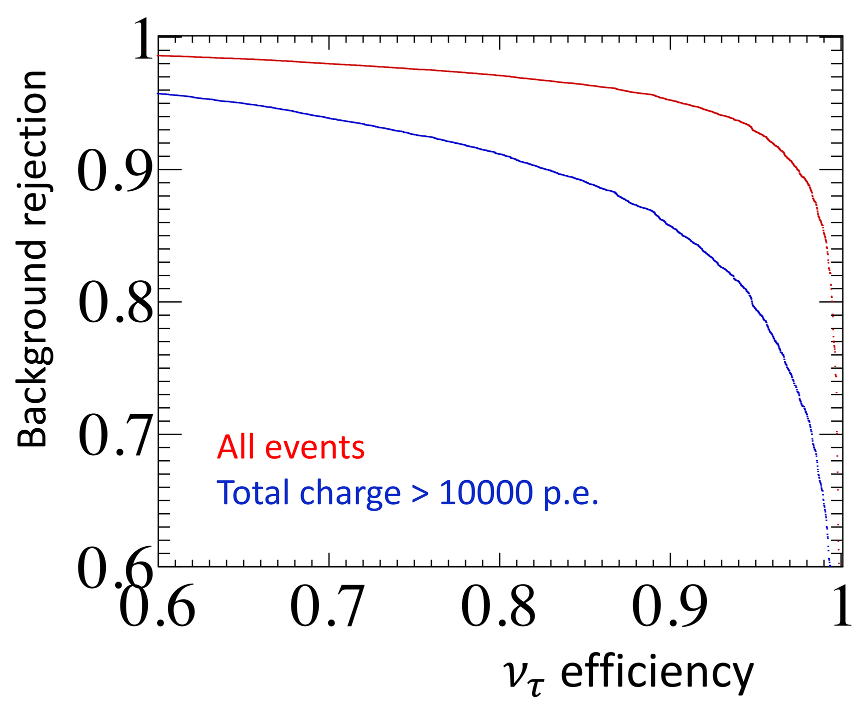
Misidentified events were found at small d_{wall}
d_{wall}:The distance between the wall and vertex

4. Identification of ν_τ CC

- Classified atmospheric neutrino events into ν_τ CC (hadronic decay*), ν_e & ν_μ CC and NC.
  *tau decays into leptons is indistinguishable from ν_e&ν_μ CC.







- Background:ν_e&ν_μCC and NC
- Tau is identified with 95% efficiency for > 90% background rejection.
- Almost the same amounts of ν_e&ν_μ CC and NC remain as background.

Summary

- I developed an algorithm based on machine-learning image classification to identify ν_τ CC hadronic decay against the other neutrino interactions.
- Oscillation probability to $\nu_\tau$will be measured in Hyper-Kamiokande with high statistics ν_τ data.

Hyper-Kamiokande

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