OEC and AQUA: Ensuring JUNO and Data Quality

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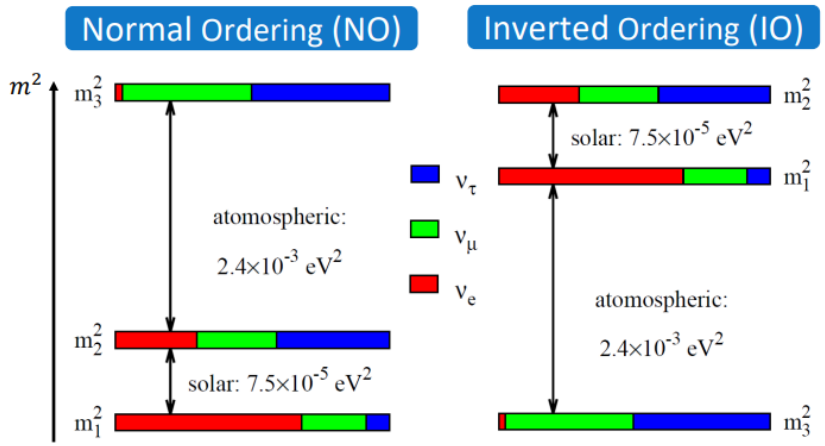
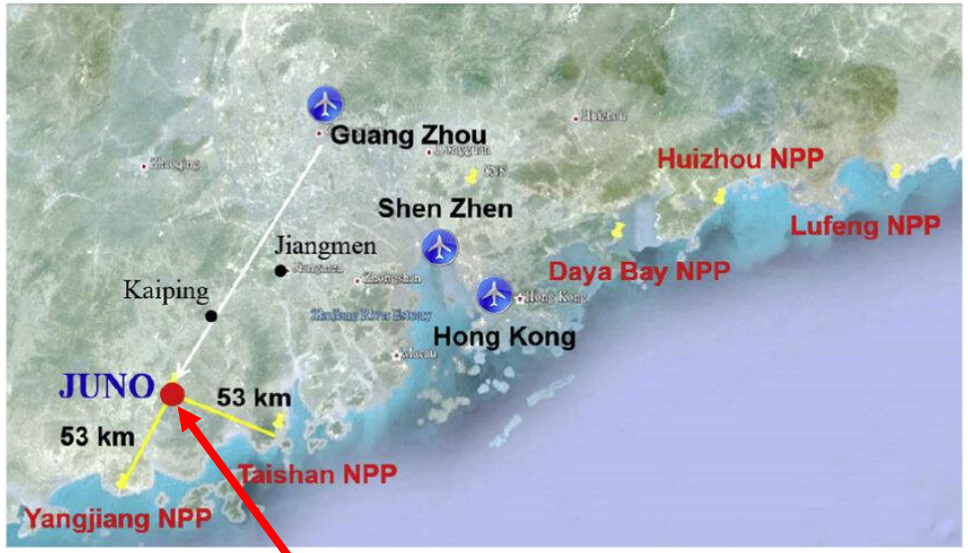
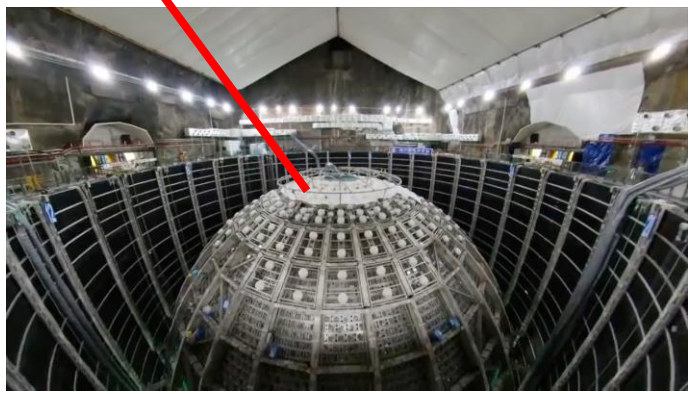
JUNO Physics and Motivation

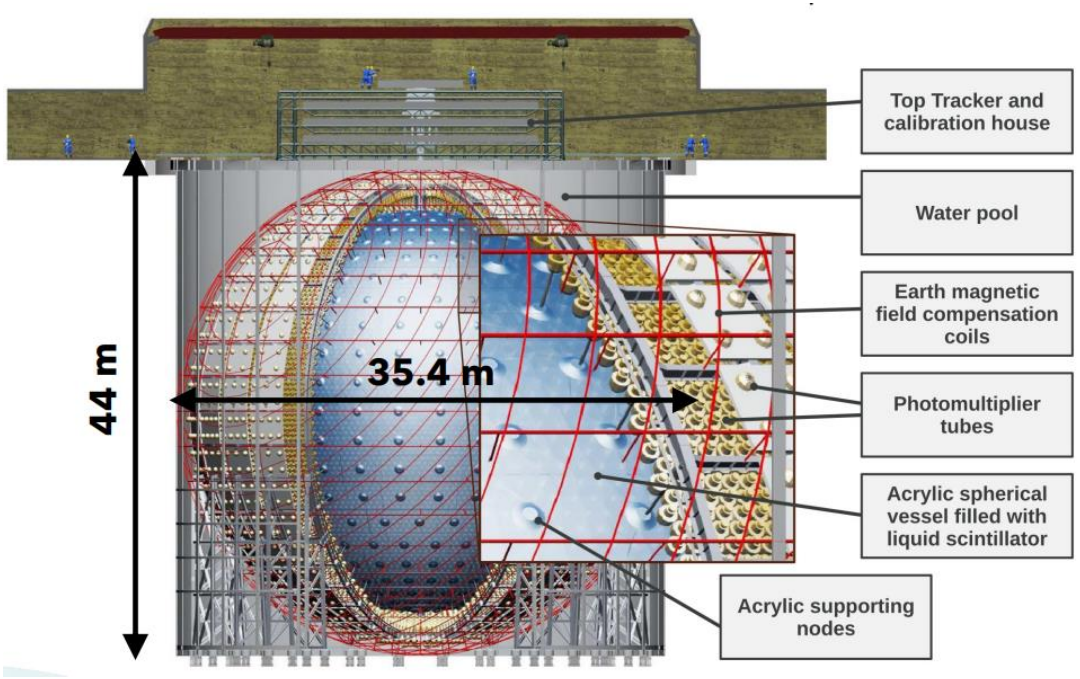
- The Jiangmen Underground Neutrino Observatory (**JUNO**) is a next-generation medium baseline reactor neutrino experiment at Jiangmen, China.
- **Main Target:** Determine neutrino mass hierarchy
  - Disappearance of reactor electron antineutrino
  - Matter effects in the atmospheric neutrino







JUNO Detector



- Energy Resolution < 3%@1MeV
- 20 kton LAB-based LS target
- 17612 20-inch Large PMTs
- 25600 3-inch Small PMTs
- Low background levels

Detector	Channel	Data Size (Byte)	Rate	Data Volume
CD LPMT	17612	2032	1 kHz	35.8 GB/s
CD LPMT-T/Q	17612	16	30 kHz	8.5 GB/s
CD SPMT	25600	30	500 Hz	375 MB/s
CD Calibration	17612	2032	200 Hz	7.2GB/s
WP LPMT	2400	2032	205 Hz	984 MB/s
WP Calibration	2400	2032	200 Hz	960 MB/s
TT				1 MB/s

JUNO can detect a wide range of events across a broad energy spectrum; however, this also imposes significant challenges on the online data processing, as the raw data stream with full waveform info must be reduced from **~50GB/s** to **60 MB/s.**

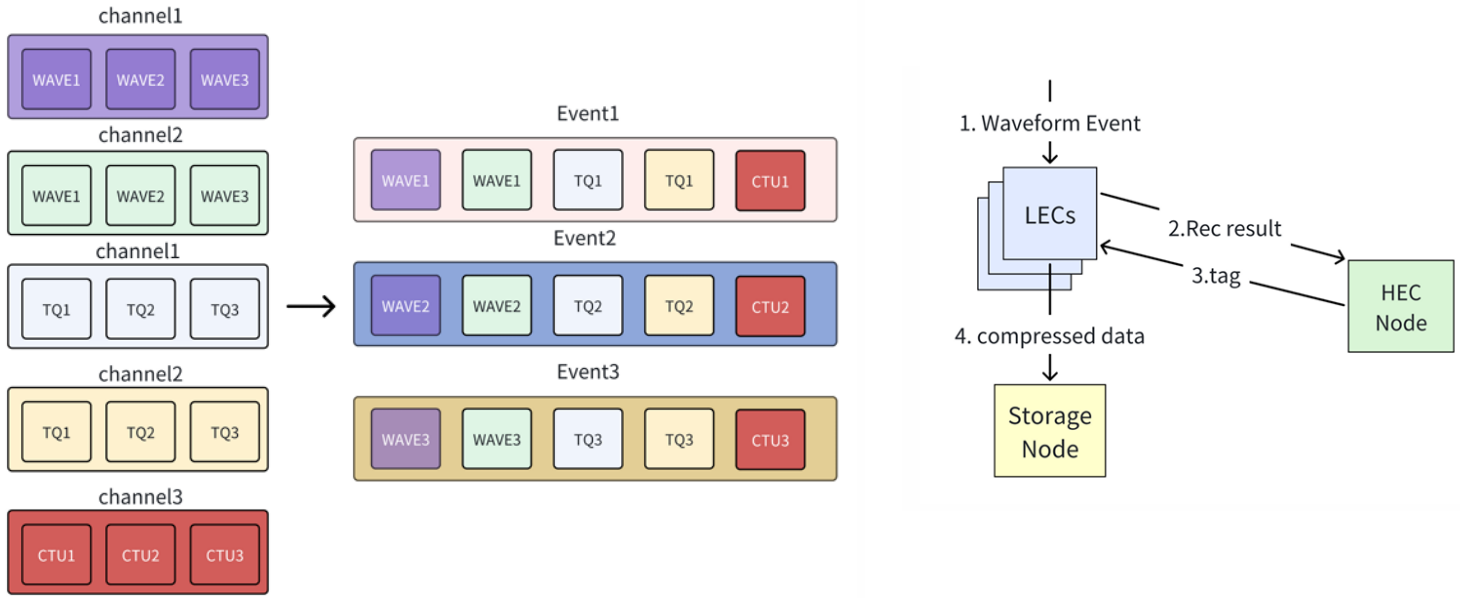
Online Event Classification

Low-Level Event Classification (LEC)
Single event classification nodes

- **Input:** waveform
- **LEC processing:**
  - ✓ Fast waveform reconstruction
  - ✓ Fast reconstruct of event info
  - ✓ Single event classification
- **Output:** Single event tag

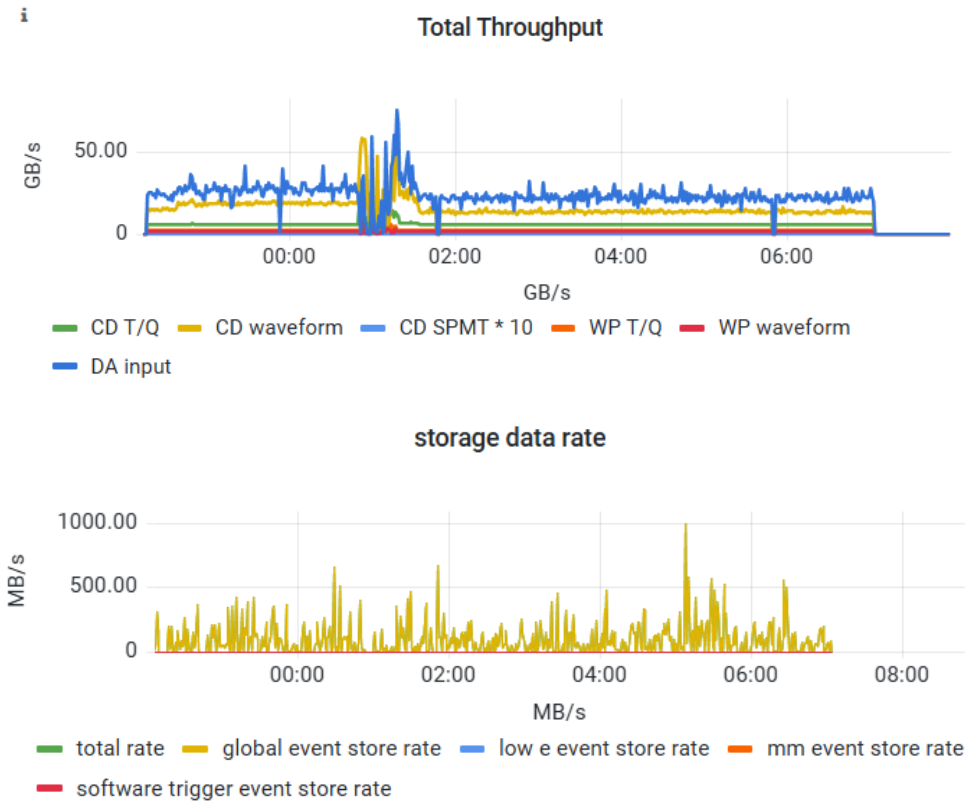
High-Level Event Classification (HEC)
Correlated event classification

- **Input:** Single event tag
- **HEC processing:**
  - ✓ Correlated event classification via offline algorithms
- **Output:** Final OEC Tag
- **Tag send back and decide strategy**



Online Event Classification (OEC) aims to compress the data size via the fast reconstruction/selection based on the physics requirement and decide whether to save the waveform and how to.

Online Event Classification



Shown here is a comparison between the input data rate and the storage data, based on real data collected during the LS filling on **Apr 2nd 2025.**

A substantial reduction in data size is observed after compression process.

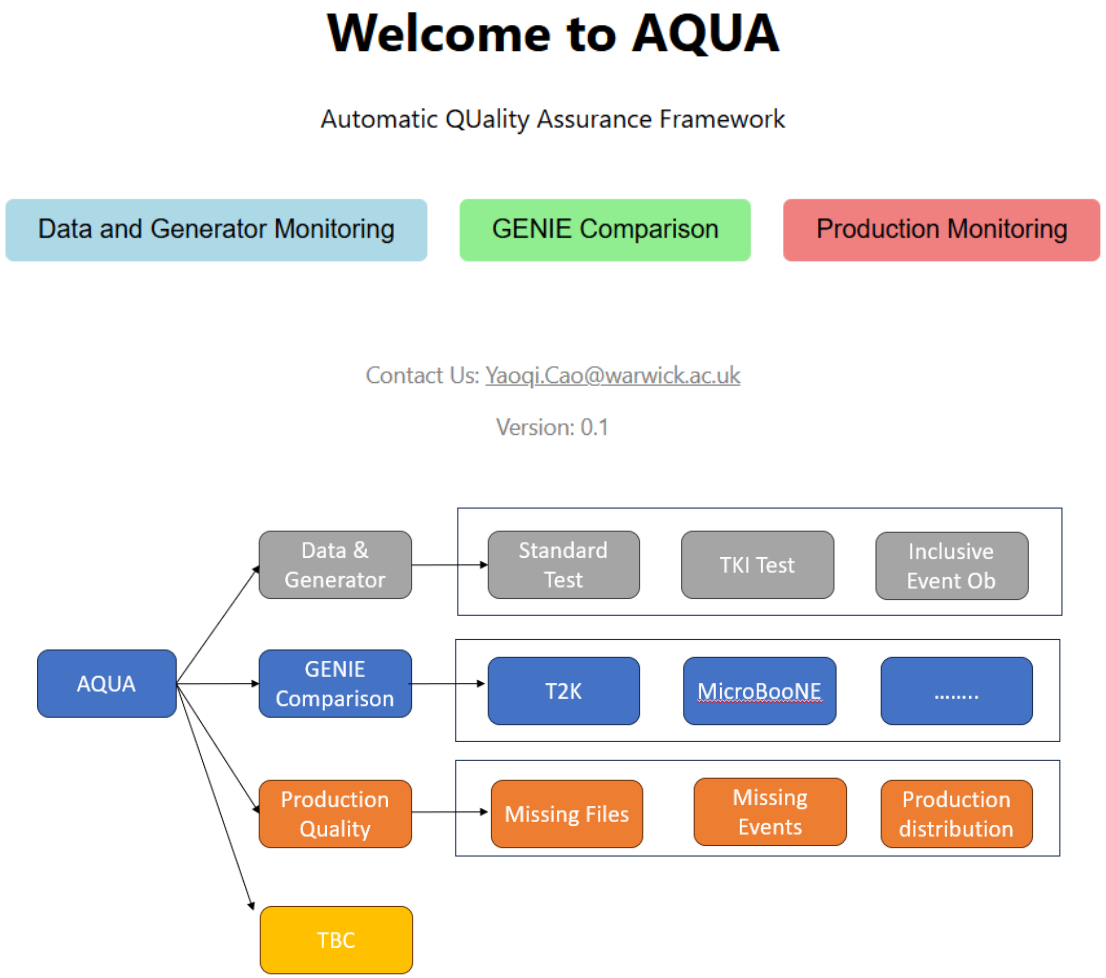
I am currently working on using OEC PMT info to do Water Phase event Reconstruction

Automatic Quality Assurance

Automatic **QU**ality **A**ssurance: To provide an automated testing framework that enable us to track

- If any part of JUNOSW is working as us intended
  - ✓ Production quality checking
  - ✓ Generator Standard Test
  - ✓ Generator Comparisons
- Open to add new physics topic or things need to track
- Customized and developed for JUNO

AQUA already released to JUNO collaboration members via website from 2025



Production Quality in AQUA

Production

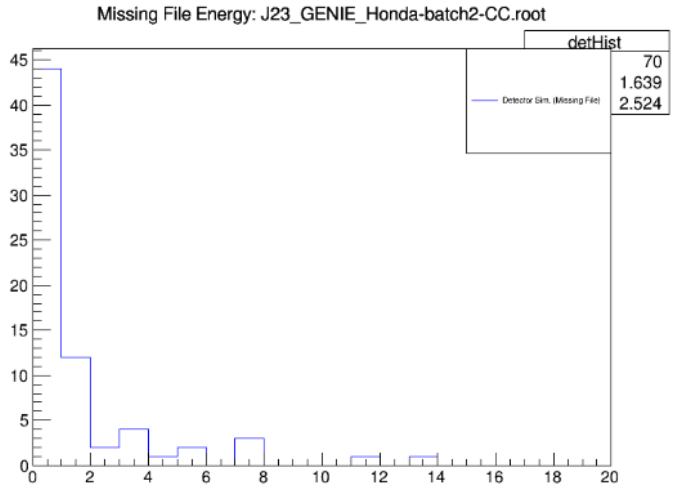
Production Summary | Missing Files | Missing Events

Missing File Selection

Select Missing File Type: Honda
Select CC or NC: CC
Select Batch: Batch 2

Production	Batch	CC/NC	EDM-Det	EDM-Reco	Ratio	User-Det	User-Reco	Ratio
J23_GENIE_Honda	batch2	CC	9999	9999	0.00%	9999	9993	0.06%

Image for Selected Production



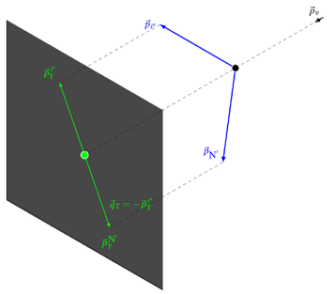
AQUA is keep tracking the missing event and file in JUNO simulation production which are using in JUNO analysis work

Generator Quality in AQUA

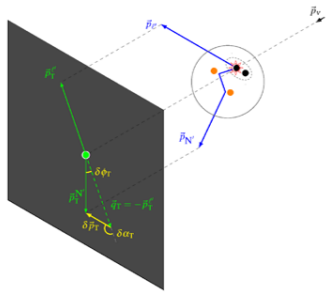
- **AQUA provides TKI-based comparisons to alert collaboration members — particularly those not directly involved in generator development — to performance differences or potential mis-modelling in various generator versions and tunes.**

Here, **TKI (Transverse Kinematic Imbalance)** refers to the imbalance of final-state transverse momentum in neutrino interactions, which is sensitive to nuclear effects and interaction modeling.

Transverse Kinematic Imbalance (TKI)

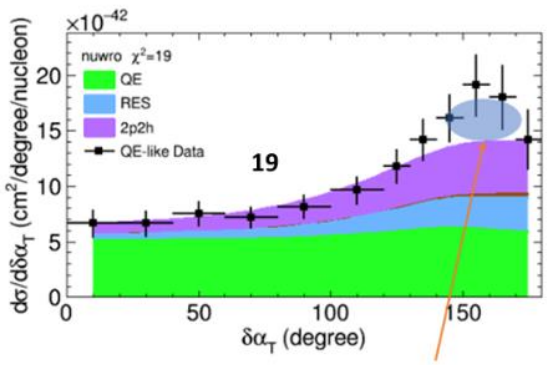


Stationary free nucleon target



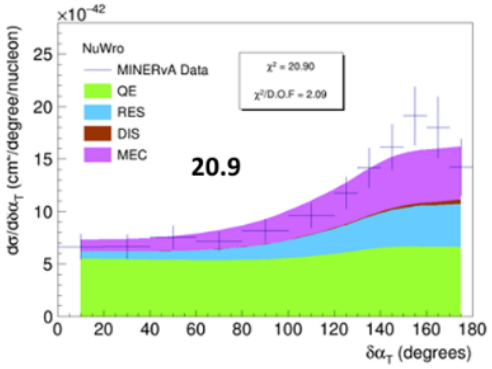
Nuclear target ($A > 1$)
- ❑ Fermi motion
- ❑ FSI
- ❑ 2p2h

0pi alphat - Reference



Path: /physics/TKI/nuwro/local_fermi_gas_0pi_alphat_r.png

0pi alphat - AQUA Update



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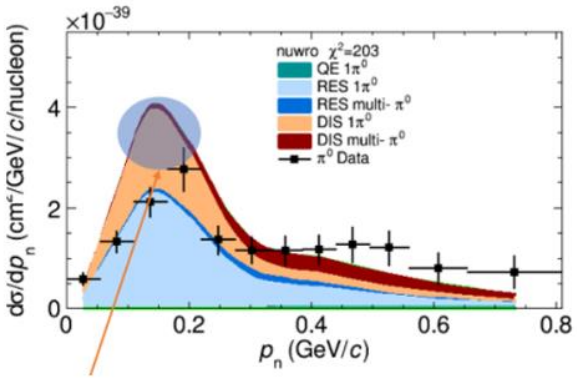
Timestamp: 2025/1/14 04:51:54

pi0 pn - Reference



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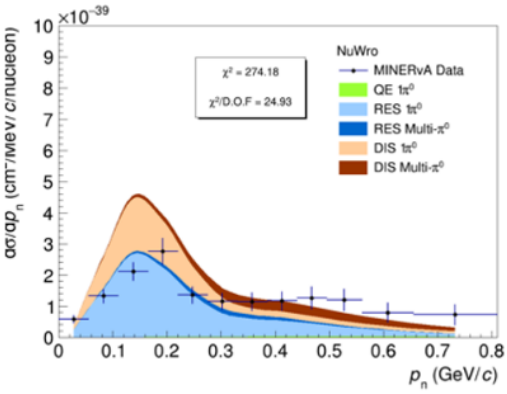
pi0 pn - AQUA Update



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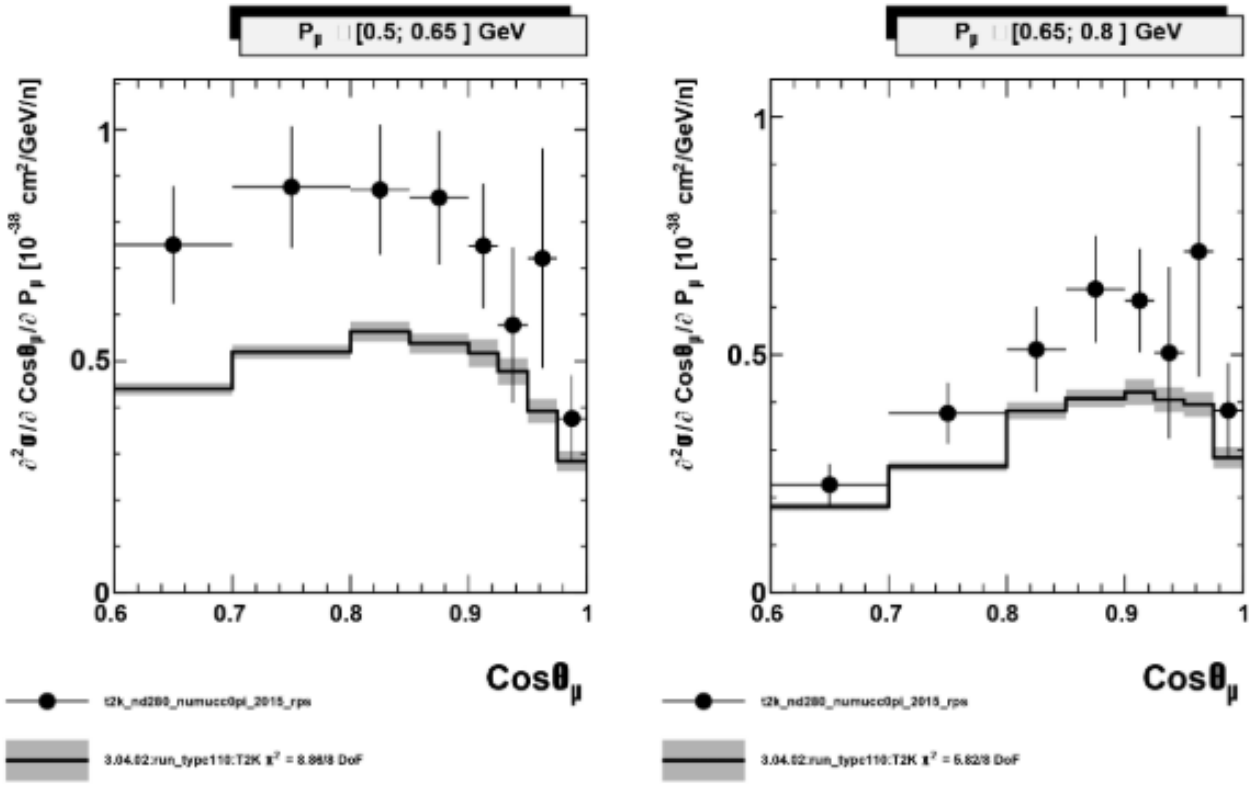
GENIE Comparison in AQUA

- **GENIE Comparison** is an official component of the GENIE framework that includes a comprehensive archive of neutrino, charged-lepton, and hadron scattering data.
- It offers side-by-side comparisons between experimental data and generator predictions, making it easier to study model uncertainties and flag possible issues. **AQUA** includes this tool to help monitor and validate generator performance in a practical way.



Path: /genie_comparison/g18_10b_02_11b/t2k_nd280-2015-numu_4.jpg

Future Steps

- Based on OEC to develop new method to do event reconstruction for Water Phase
- Keeping update and monitor the quality for JUNO
  - ✓ For OEC, about tag efficiency and purity, the difference between FPGA from frontend to OEC
  - ✓ For AQUA, include more generators and tunes