Atmospheric Neutrino Event Selection and Classification for Oscillation Analysis at JUNO

Xinhai He[1,2,*] on behalf of the JUNO Collaboration

[1]Institute of High Energy Physics, Beijing, China

[2]University of Chinese Academy of Sciences, Beijing, China

[*]xhhe@ihep.ac.cn

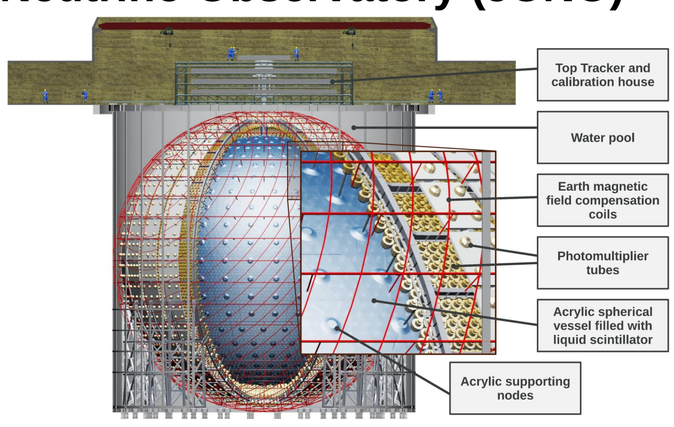
TAUP VIENNA 2023

University of Chinese Academy of Sciences

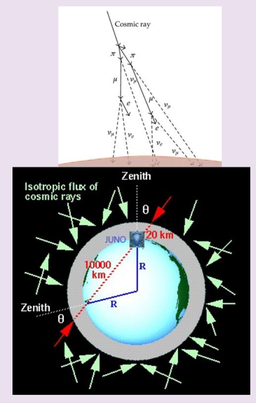
Jiangmen Underground Neutrino Observatory (JUNO)

JUNO is a multi-purpose liquid-scintillator experiment in China that aims to determine the Neutrino Mass Ordering (NMO) [1, 2].

- 20 kton liquid-scintillator detector
- ~78% optical coverage
  - 17,612 20-inch large PMTs and 25,600 3-inch small PMTs instrumented in the Central Detector (CD)
- ~700 m rock overburden
  - Natural shield to suppress cosmic muons

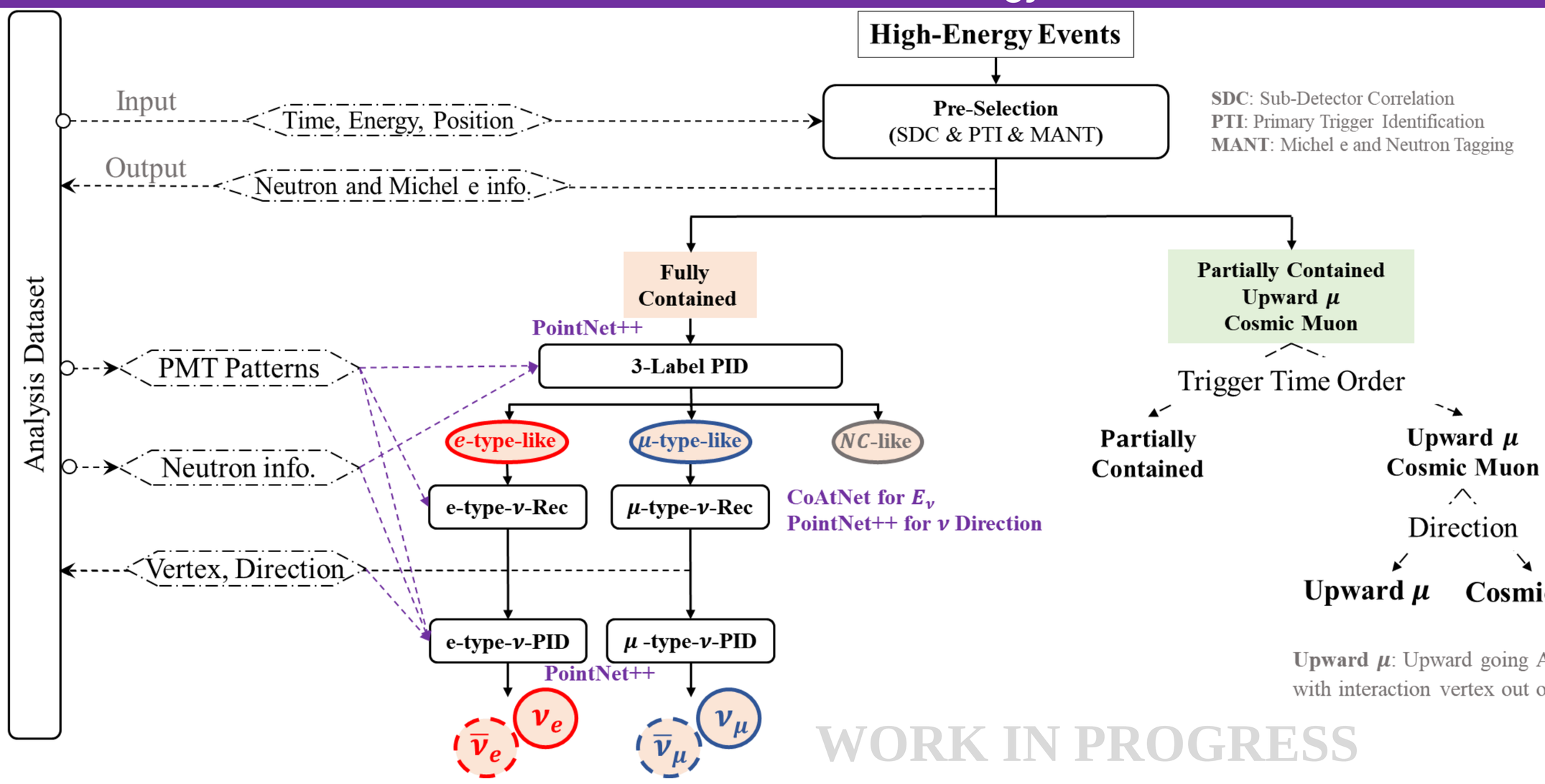


Motivation



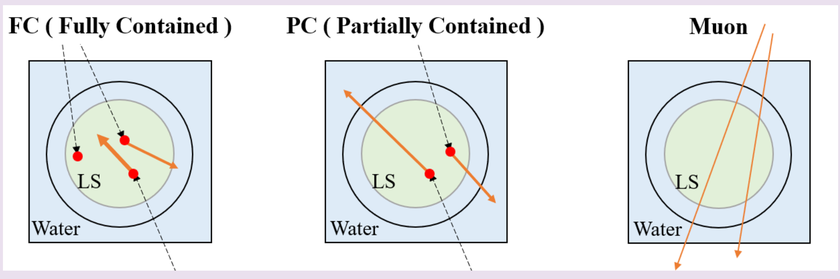
- JUNO with large target volume is capable of detecting large statistics atmospheric neutrinos.
- Atmospheric neutrinos can contribute to the NMO sensitivity with a complementary approach: using the matter effects on neutrino oscillations.
- Performance of event selection will directly impact the sensitivity of atmospheric neutrino oscillations.

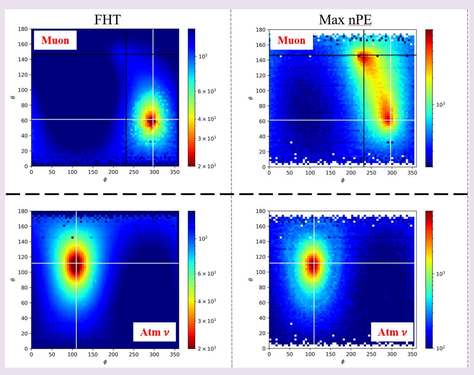
Event Selection Strategy



WORK IN PROGRESS

Cosmic Muon Suppression





- Direction
  - Cosmic Muon: Down-ward
- PMTs Hitting Pattern
  - Cosmic Muon: Multi Clusters
  - Atm ν PC: Single Cluster

Methodology of Atm ν Flavor Identification and Reconstruction

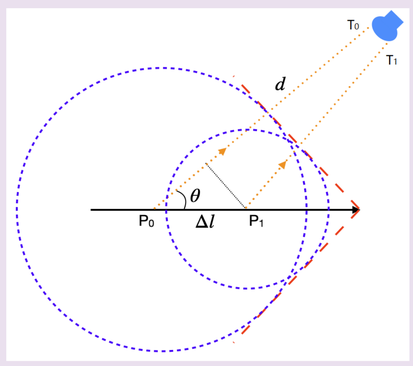
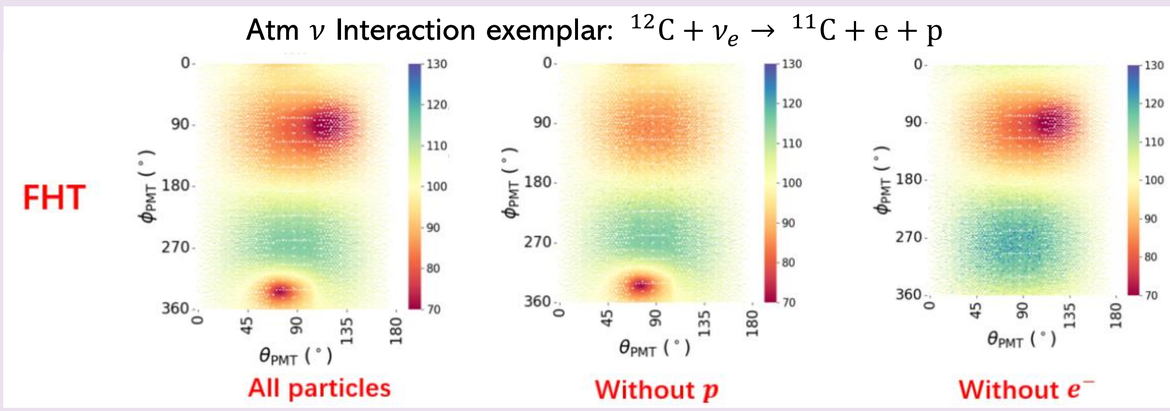


Illustration of the scintillation light (orange dash lines) from a charged particle track (black solid line) reaching a PMT.

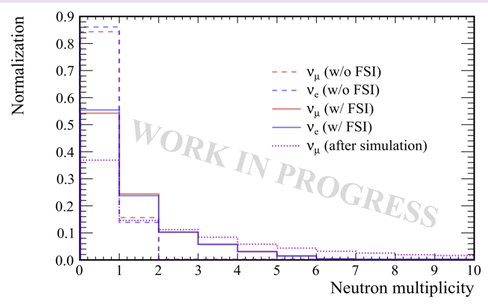
- Atm ν information such as flavor and incident direction are reflected in the PMT waveforms.
- Features extracted from PMT waveforms can be used as inputs to machine learning models

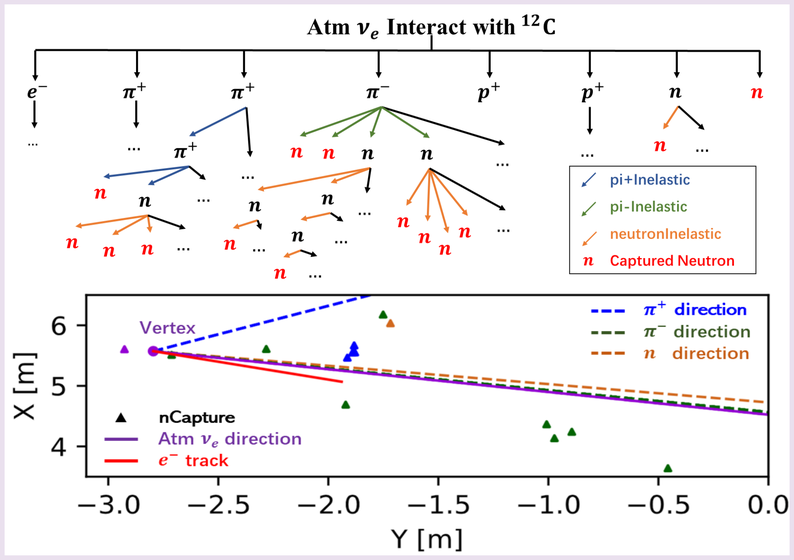
Atm ν Interaction exemplar: $^{12}\mathrm{C} + \nu_e \rightarrow {}^{11}\mathrm{C} + \mathrm{e} + \mathrm{p}$



Methodology of Atm $\nu/\bar{\nu}$ Discrimination

$$\nu_e + \mathrm{n} \rightarrow e^- + \mathrm{p}$$
$$\bar{\nu}_e + \mathrm{p} \rightarrow e^+ + \mathrm{n} \quad + \text{FSI in } {}^{12}\mathrm{C}$$





- $\bar{\nu}$ tends to produce more neutrons than ν
- Neutrons can be produced by Atm ν interactions and also secondary processes
- Neutron tagging and features extraction are in progress

Atm ν Oscillation Analysis in Progress

	Yellow Book Assumptions [2]	New Developments	Potential Improvement
Event Selection $\nu_e/\bar{\nu}_e$	$E_{vis} > 1$ GeV $Y_{vis} = E_h/E_{vis} < 0.5$	$E_{vis} > 1$ GeV	~30% more stats.
Directionality	$\sigma_{\theta_\mu} = 1°$ $\sigma_{\theta_\nu} = 10°$	$\sigma_{\theta_\nu} < 10°$ $(E_\nu > 3$ GeV)	Energy dependent
Classification	CC-e/CC-μ/NC: 100% eff.	CC-e/CC-μ/NC: 80%~95% eff.	--
	ν vs $\bar{\nu}$: simple classification with N_e, Y_{vis}	ν vs $\bar{\nu}$: 50%~80% eff.	Better ν vs $\bar{\nu}$ separation
Energy	$\sigma_{E_{vis}} = 1\%/\sqrt{E_{vis}}$	σ_{E_ν}	E_ν instead of E_{vis}

* N_e: The Michel electron numbers * E_h: The visible energy of hadron showers

References:

[1] JUNO Collaboration, JUNO physics and detector, Prog. Part. Nucl. Phys. 123, 103927(2022)

[2] JUNO, F. An et al., Neutrino Physics with JUNO, J. Phys. G 43, 030401 (2016)