1924-2024
中山大學 世纪华诞
100th ANNIVERSARY
SUN YAT-SEN UNIVERSITY

Interview report for applying for CCAST postdoctoral position
申请CCAST博士后岗位的面试报告

Dr. Jun Wang from Sun Yat-sen University
中山大学，王俊
January 11, 2025

Contents

Neutrinos, JUNO, damping signatures, machine learning

Name：**Jun Wang (王俊)** Gender：Male

Age：32 Degree： PhD

Date of graduated: June 20, 2022 政治面貌：中共党员

Nationality: P. R. China

Employer：IFCEN of Sun Yat-sen University

Current position: Postdoctoral associate / 党支部纪检委员

Tel：17717014380 Email: wangj933@mail,sysu.edu.cn

Research interests： neutrino physics and experiment.

Expertises: neutrino phenomenology & machine learning.

Skills: C++, Python, PHP, Javascript, MySQL, Matlab, etc.

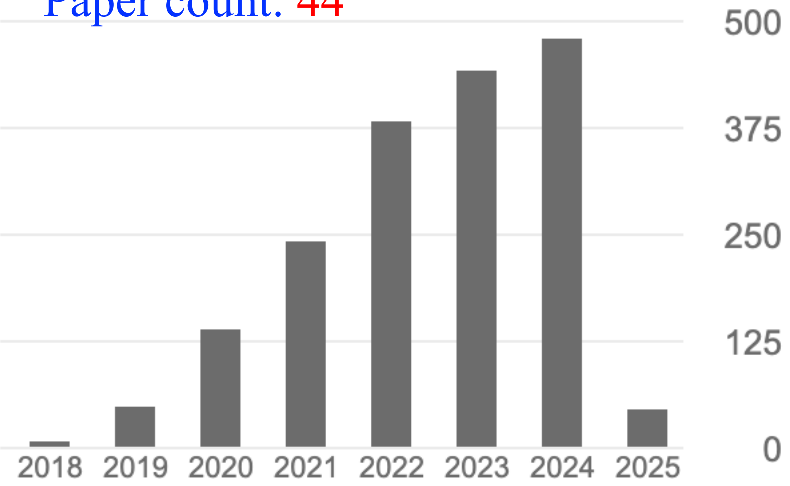
Main Education		Employment History	Application
Anhui University of Science and Technology • Bachelor of Science in Applied Physics • Supervisor: Assoc. Prof. Hu Li	**Sun Yat-sen University** • PhD in Particle Physics and Nuclear Physics • Supervisor: Prof. Wei Wang • Thesis: Research on Mass Ordering and New Physics Effects with the JUNO Experiment • Experiment: JUNO	**Sun Yat-sen University** • **Postdoctoral Associate** • Mentors: Prof. Wei Wang (Dean of IFCEN), Assoc. Prof. Yuehuan Wei • Report: Extraction of fissile isotope antineutrino spectra using feedforward neural network • Experiments: JUNO & NEREUS	**CCAST** • **Postdoctoral Associate for JUNO** • Mentor: Prof. Guofu Cao
2010.09 - 2014.07	**2016.08-2022.06**	**2022.11-Current**	**Future**

Achievement statistics

引用次数 Google Scholar

	总计	2020 年至今
引用	1804	1737
h 指数	22	22
i10 指数	28	28

Paper count: 44



First, co-first, co-corresponding authors: 8 papers.

	Published	Submitted	Inner reviewing
First author	2	0	1
Co-first author	1	0	0
Co-corresponding author	1	2	1

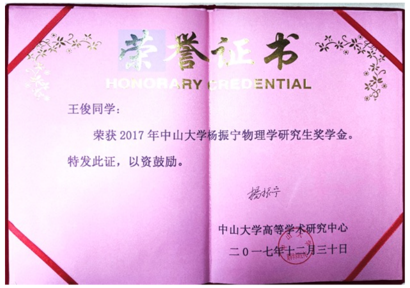
Including JHEP, NST, AM, Laser & Photonics Reviews, all are JCR-SCI Q1.

First completer:

- **2** invention patents;
- **17** software registration certificates;
- **1** artwork registration certificate.

GPA~4.0, Top 1

National Graduate Student Scholarship



Chen-Ning Yang Physics (award) Scholarship

National First Prize in CPMCM

The designer of HUNT's logo and the proposer of TAO's name.

Fund statistics

Postdoctoral Science Foundation, ￥80k, chair 2024.07-2026.12
Name of Funding Organization: China Postdoctoral Science Foundation
Grant Number: 2024M753715
Title: Research on the application of deep learning in neutrino mass ordering determination in the JUNO experiment
Status: Ongoing

Fundamental Research Funds for the Central Universities, ￥51.3k, chair 2024.07-2024.12
Name of Funding Organization: Sun Yat-sen University (Funding source: Ministry of Education)
Grant Number: 24qnpy125
Title: Research on event reconstruction in the TAO experiment
Status: Ongoing

During my postdoctoral tenure, I chaired two grant projects with a total amount of 131.3K yuans (13.13万).

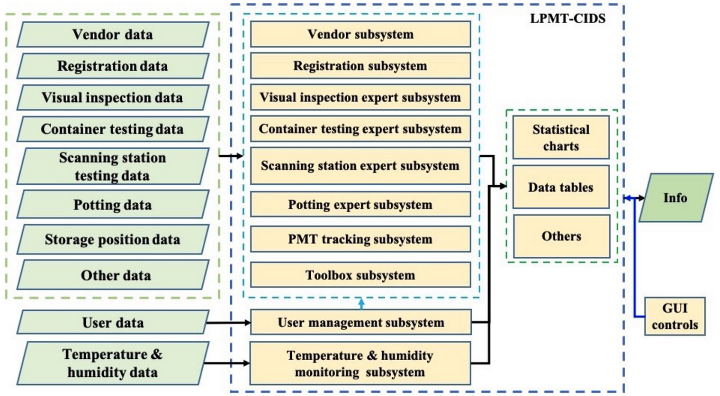
Strategic Priority Research Program of the Chinese Academy of Sciences, ￥11.245 millions, key personnel 2017.01-2023.12
Name of Funding Organization: Chinese Academy of Sciences
Grant Number: XDA10011102
Title: Photomultiplier tube test
Status: Completion

Youth Program of NSFC, ￥240k, key personnel 2022.01-2022.12
Name of Funding Organization: National Natural Science Foundation of China
Grant Number: 11905299
Title: Research on new physics with the JUNO experiment
Status: Completion

General Program of NSFC, ￥580k, key personnel 2017.01-2020.12
Name of Funding Organization: National Natural Science Foundation of China
Grant Number: 11675273
Title: Study on quantum decoherence effects in reactor neutrino oscillations
Status: Completion

During my graduate studies, I participated in three grant projects as a key personnel with a total amount of 12.065 million yuans (1206.5万).

Database system for managing 20,000 20-inch PMTs at JUNO



Structure and data flow

Highlights:

- ■ **The first database system for large-scale PMT testing and self-developed.**
- ■ Reducing human resources & improving testing efficiency;
- ■ **Smoothly serving over 7 years.**

First author

NUCL SCI TECH **33**, 24 (2022)

2 invention patents

12 software registration certificates.

Damping signatures at JUNO

Damping type Parameter [units]	Phenomenological limits (experiment: original results, CL [Ref]) {Experimental limits (experiment: original results, CL [Ref])}	Exclusion sensitivities for JUNO (CL)
QD I α [$\times 10^{-6}\ \frac{\mathrm{MeV}^2}{\mathrm{m}}$]	$< 1.62 \times 10^5$ (MINOS+T2K+reactor: $\alpha < 3.2 \times 10^{-23}$ GeV^3, 90% [33]) < 0.41 (solar+KL: $\alpha < 0.81 \times 10^{-28}$ GeV^3, 95% [20])	< 3.72 (90%) < 4.42 (95%)
QD II α [$\times \frac{10^{-6}}{\mathrm{m}}$]	< 3.45 (KL: 6.8×10^{-22} GeV, 95% [40]) < 0.33 (MINOS+T2K+reactor: $\alpha < 6.5 \times 10^{-23}$ GeV, 90% [33]) < 0.18 (SK: $\alpha < 3.5 \times 10^{-23}$ GeV, 90% [35]) $< 3.40 \times 10^{-3}$ (solar+KL: $\alpha < 0.67 \times 10^{-24}$ GeV, 95% [20])	< 0.80 (90%) < 0.95 (95%)
QD III α [$\times \frac{10^{-8}}{\mathrm{MeV}^2\cdot\mathrm{m}}$]	$< 2.38 \times 10^{-3}$(solar+KL: $\alpha < 0.47 \times 10^{-20}$ GeV^{-1}, 95% [20]) $< 1.42 \times 10^{-5}$ (MINOS+T2K+reactor: $\alpha < 2.8 \times 10^{-23}$ GeV^{-1}, 90% [33]) $< 4.56 \times 10^{-10}$ (SK: $\alpha < 0.9 \times 10^{-27}$ GeV^{-1}, 90% [35])	< 1.22 (90%) < 1.46 (95%)
Absorption α [$\times \frac{10^{-7}}{\mathrm{MeV}\cdot\mathrm{m}}$]	< 7.60 (KL: $\alpha < 1.5 \times 10^{-19}$, 95% [40]) < 0.10 (SK: $\alpha < 2.0 \times 10^{-21}$, 90% [35]) $< 2.94 \times 10^{-3}$ (solar+KL: $\alpha < 0.58 \times 10^{-22}$, 95% [20])	< 1.04 (90%) < 1.23 (95%)
ν_3 decay $\alpha \equiv \frac{m_3}{\tau_3}$ [$\times 10^{-4}\ \frac{\mathrm{MeV}}{\mathrm{m}}$]	< 256.59 (OPERA: $\frac{\tau_3}{m_3} > 1.3 \times 10^{-13}\ \frac{\mathrm{s}}{\mathrm{eV}}$, 90% [43]) $< 22.[illegible]$ (NOνA+T2K: $\frac{\tau_3}{m_3} > 1.5 \times 10^{-12}\ \frac{\mathrm{s}}{\mathrm{eV}}$, 90% [17]) < 0.36 ([illegible]K+K2K+[illegible]INOS: [illegible] $\frac{\mathrm{s}}{\mathrm{eV}}$, 99% [41]) {$< 15.88$ (MINOS: $\frac{\tau_3}{m_3} > 2.1 \times 10^{-12}\ \frac{\mathrm{s}}{\mathrm{eV}}$, 90% [15])} ↑~36 times	< 0.44 (90%) < 0.53 (95%) < 0.75 (99%)
WPD I $\alpha \equiv (4\sqrt{2}\sigma_x)^{-2}$ [$\times 10^{-3}$MeV^2]	$< 116.[illegible]$ (RENO+DYB: $\sigma_x > 1.02 \times 10^{-4}$ nm, 90% [24]) < 27.59 (RENO+DYB+KL: [illegible] nm, 90% [49]) ↑~24 times	< 0.18 (90%) < 0.22 (95%)
WPD II α [$\times 10^{-4}$]		< 0.14 (95%)
WPD III $\alpha \equiv \sigma_{\mathrm{rel}}$ [$\times 10^{-2}$]	{[illegible] (DYB: [illegible], [22])} ↑~22 times	< 1.04 (95%)
$\sigma_x \equiv (2\alpha E)^{-1}$ [$\times 10^{-3}$ nm]	{$> 10^{-1}$ (DYB: $\sigma_x > 10^{-4}$ nm, 95% [22])}	> 2.32 (95%)

Sensitivity results

Highlights:

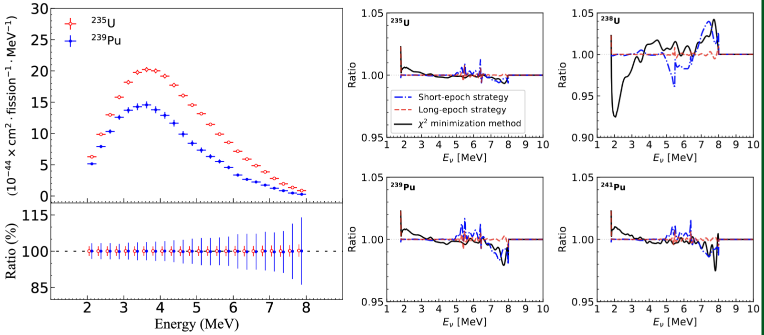
- ■ **Revealed the advantages of JUNO in measuring v3 decay and WPD effects.**
- ■ Revealed JUNO's ability to distinguish between eight types of damping effects.

First author

JHEP 06 (2022) 062

Selected as a collaboration paper.

Extraction of fissile isotope $\bar{\nu}_e$ spectra using machine learning



Relative errors

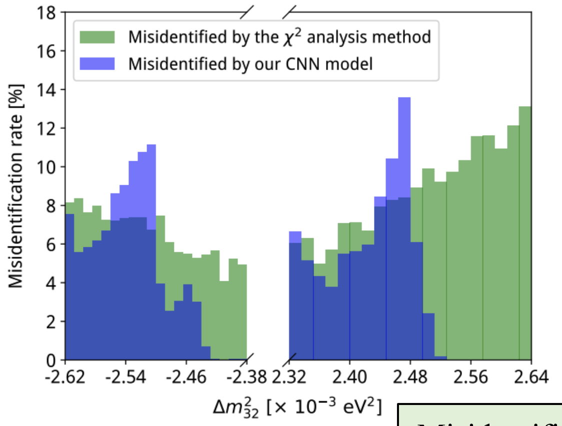
Highlights:

- ■ **Developed two neural network models, both are white-box models with interpretability.**
- ■ **Better than the χ^2 analysis method.**
- ■ **All relative errors < 1%.**

Co-first author, NUCL SCI TECH 34, 79 (2023)

Co-corresponding author, accepted by NUCL SCI TECH at Dec. 2024.

Determination of the neutrino mass ordering with machine learning

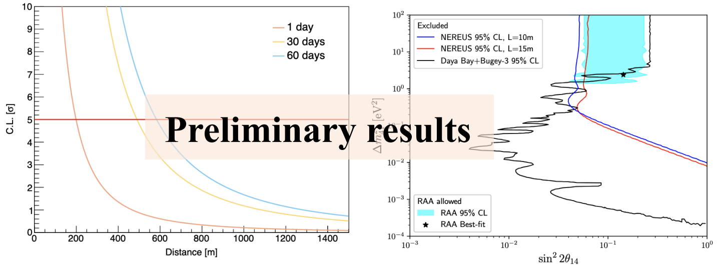


Misidentification rate distribution

Highlights:

- **The first to use machine learning to identify the neutrino mass ordering.**
- The accuracies are higher than the χ2 analysis method within the [2.0%, 4.0%] energy resolution range during generalization and robustness tests.

Reactor monitoring with mobile NEREUS antineutrino detector

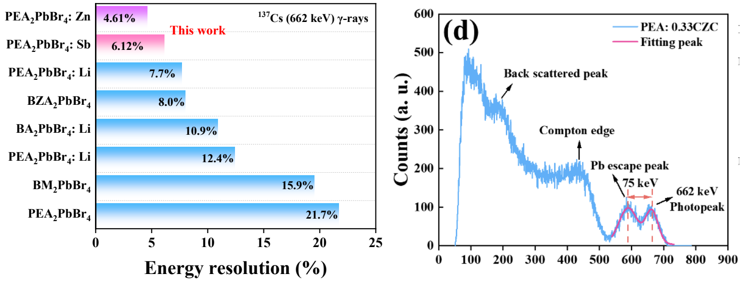


Main results

Highlights:

- A mobile neutrino detector for reactor monitoring.

R&D and and testing of new scintillator materials



Main results

Highlights:

- Achieving the best energy resolution in current 2D perovskite scintillators.
- Demonstrates unprecedented separation of the photopeak and escape peak.

First author

JUNO inner reviewing, DocDB # 7428

Co-corresponding author

Team inner reviewing

Co-corresponding author

Two papers were submitted to AM and LPR, respectively.

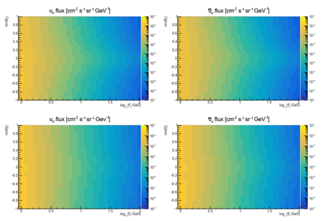
Atmospheric neutrino phenomenology & data analysis at JUNO

Completed | **Ongoing** | **Future**

Honda Flux → Osc. Flux (NO) → Interaction event rates → Reconstructed event rates → χ^2 analysis → Analysis and discussion

Cross sections → Interaction event rates

Response Matrixes → Reconstructed event rates



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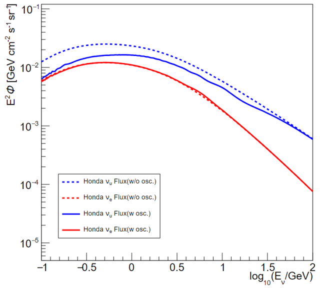
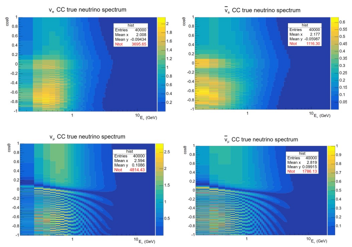
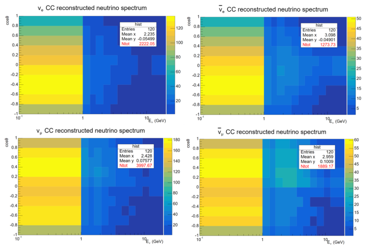
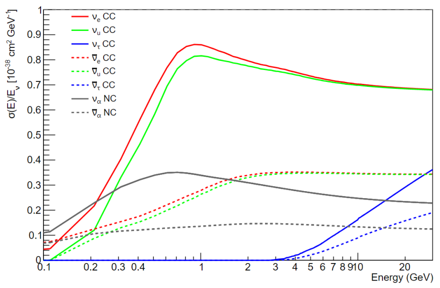






Atmospheric neutrino source

$$\pi^+ \rightarrow \mu^+ + \nu_\mu$$
$$\mu^+ \rightarrow e^+ + \nu_e + \bar{\nu}_\mu$$
$$\pi^- \rightarrow \mu^- + \bar{\nu}_\mu$$
$$\mu^- \rightarrow e^- + \bar{\nu}_e + \nu_\mu$$



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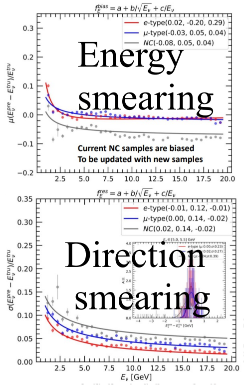
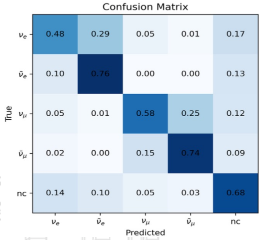


JUNO-docDB-11086

PID category smearing



Confusion Matrix

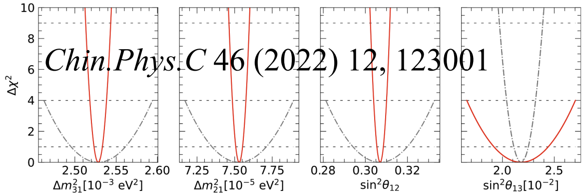
True \ Predicted	ν_e	$\bar{\nu}_e$	ν_μ	$\bar{\nu}_\mu$	nc
ν_e	0.48	0.29	0.05	0.01	0.17
$\bar{\nu}_e$	0.10	0.76	0.00	0.00	0.13
ν_μ	0.05	0.01	0.58	0.25	0.12
$\bar{\nu}_\mu$	0.02	0.00	0.15	0.74	0.09
nc	0.14	0.10	0.05	0.03	0.68

JUNO DocDB #12760-v3

Atmospheric neutrino phenomenology & data analysis at JUNO

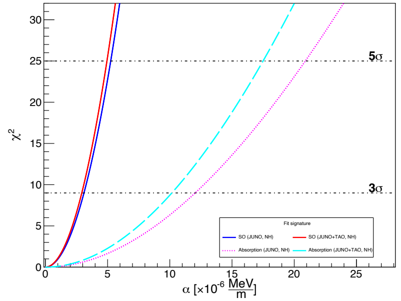
Our team currently consists me (left), two PhD students from SYSU, Yifei Pan (middle) and Jing Chen (right).

Joint anaylsis

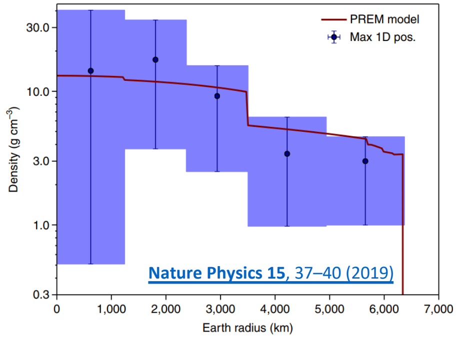


Chin. Phys. C 46 (2022) 12, 123001

Neutrinos decay



Earth Tomograghy



Nature Physics 15, 37–40 (2019)

Schedule

Me
Before 2028

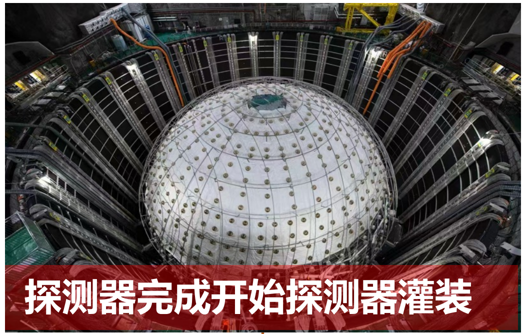
Yifei Pan
Before 2026

Jing Chen
Before 2026

Thanks for your attention!

Questions & Comments

Timeline of JUNO



土木建设

2013

2022

2025

2015

2024

项目批准

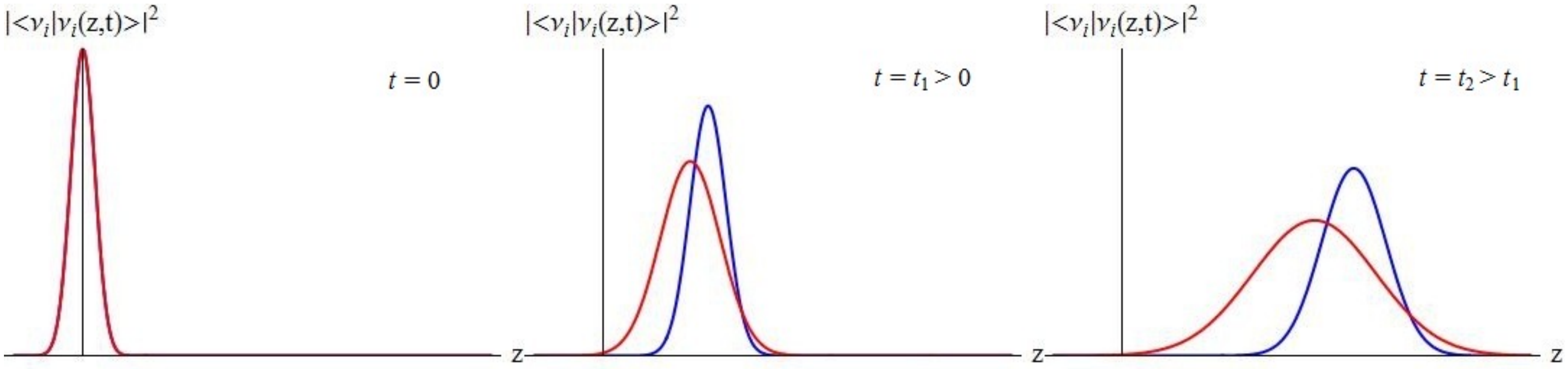
探测器搭建

开始采数

模型	阻尼效应	参考文献	阻尼因子 D_{ij}	α 的单位
(1)	QD I	[239–245]	$\exp(-\alpha L/E^2)$	MeV^3
(2)	QD II	[106, 239–252]	$\exp(-\alpha L)$	MeV
(3)	QD III	[1, 106, 239–247, 249–251]	$\exp(-\alpha L E^2)$	MeV^{-1}
(4)	Absorption	[1, 239–244, 248]	$\exp(-\alpha L E)$	无
(5)	ν_3 decay	[160, 253–258]	$\{\exp\left(-\alpha \frac{L}{E}\right), \exp\left(-\alpha \frac{L}{2E}\right)\}$	$(\mathrm{s/eV})^{-1}$
(6)	WPD I	[1, 101–103, 165, 259–261]	$\exp\left(-\alpha \frac{(\Delta m_{ij}^2)^2 L^2}{E^4}\right)$	MeV^2
(7)	WPD II	[1, 172, 262]	$\exp\left(-\alpha \frac{(\Delta m_{ij}^2)^2 L^2}{E^2}\right)$	无
(8)	WPD III	[37, 172, 263–265]	$\exp(-R - \mathbf{i}X)$	无

$$\begin{aligned}\exp(-R-\mathbf{i}X) &= \exp\left\{-\left[\frac{1}{4}\ln(1+y_{ij}^2)+\lambda_{ij}+\eta_{ij}\right]-\mathbf{i}\left[\frac{1}{2}\tan^{-1}(y_{ij})-\lambda_{ij}y_{ij}\right]\right\} \\ &= \left(\frac{1}{1+y_{ij}^2}\right)^{\frac{1}{4}}\exp(-\lambda_{ij})\exp\left(-\frac{\mathbf{i}}{2}\tan^{-1}(y_{ij})\right)\exp(\mathbf{i}\lambda_{ij}y_{ij})\exp(-\eta_{ij})\end{aligned} \tag{4-3}$$

这里的 $\lambda_{ij}=\frac{x_{ij}^2}{1+y_{ij}^2}$， $x_{ij}=\frac{\sqrt{2}\Delta m_{ij}^2 L}{4E}\sigma_{\rm rel}$， $y_{ij}=\frac{\Delta m_{ij}^2 L}{E}\sigma_{\rm rel}^2$， $\eta_{ij}=\frac{1}{2}\left(\frac{\Delta m_{ij}^2}{4\sigma_{\rm rel}E^2}\right)^2$ 和 $\sigma_{\rm rel}=(2\sigma_x E)^{-1}$。



Eur.Phys.J.C 76 (2016) 6, 310

Earth tomograghy

Experiment/Paper	Mantle	Outer core / Inner core / Core	Primary methods
IceCube (2018)	Compatible with the seismological model (PREM) within the **68% to 95%** confidence interval	Core/mantle distinguishable at the **10% to 20%** error level	TeV~PeV atmospheric neutrino 'absorption effect ; **First measurement** of Earth's mass using neutrinos;
ORCA (2022)	**±(6%~20%)** (optimal–worst case)	**±(12%~40%)** (optimal–worst case) Inadequate resolution of the inner core	GeV-scale oscillation matter effects ; After 10 years of observation.
DUNE (2022)	Upper/lower mantle : **~14%/22%**	Core : **~9%** (400 kton-year)	0.1~10 GeV atmospheric neutrinos ; If only 60 kton·year exposure is available, the core uncertainty increases to around **30%.**
supernova neutrinos(2023)	The mantle can be somewhat distinguished, but not as prominently as the core along "core-crossing paths"	**core resolution is approximately 10%** (1σ) requires 10 kpc SN、 a favorable direction	Short-term observations of supernova explosions ; Differentiating chemical composition is even more challenging
Hyper-K (2024)	**±(10%~20%)** (optimal–worst case)	**±(10%~30%)** 10 years (optimal–worst case) subdividing the inner core becomes difficult	atmospheric neutrino oscillations ; a cumulative data period of 10–20 years, combined with mass constraints.

ν_3 decay

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Experiment [reactor neutrino-RN atmospheric neutrino-AN accelerator neutrino-ACN]	Upper limits(90% CL) $[10^{-6}eV^2]$	Lower limits(90% CL) $[ps/eV]$	Reference
KM3NeT/ORCA (3 yr) [AN]	5.7	120	Journal of High Energy Physics, 2023, 2023(4): 1-30.
KM3NeT/ORCA (10 yr) [AN]	3.7	180	Journal of High Energy Physics, 2023, 2023(4): 1-30.
T2K, NOvA [ACN]	290	2.3	Journal of High Energy Physics, 2018, 2018(8): 1-15.
T2K, MINOS [ACN]	240	2.8	Physics Letters B, 2015, 740: 345-352.
K2K, MINOS, SK I+II [AN]	2.3	290	Physics Letters B, 2008, 663(5): 405-409.
MOMENT (10 yr) [ACN]	24	28	Journal of High Energy Physics, 2019, 2019(4): 1-19.
ESSnuSB $(5\nu + 5\bar{\nu})$ yr [ACN]	16-13	42-50	Journal of High Energy Physics, 2021, 2021(5): 1-23.
DUNE $(5\nu + 5\bar{\nu})$ yr [ACN]	13	51	Journal of Physics G: Nuclear and Particle Physics, 2021, 48(5): 055004.
JUNO (5 yr) [RN]	7	93	Journal of High Energy Physics, 2015, 2015(11): 1-25.
INO-ICAL (10 yr) [AN]	4.4	151	Physical Review D, 2018, 97(3): 033005.