# Latin American Contributions to JUNO

III LASF4RI for HECAP Symposium
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For the JUNO Collaboration

- JUNO in the Latin America Context
- Introduce the JUNO observatory
- Discuss important physics opportunities
- Discuss the Latin America Contributions
- Final considerations

# China and Latin America HECAP

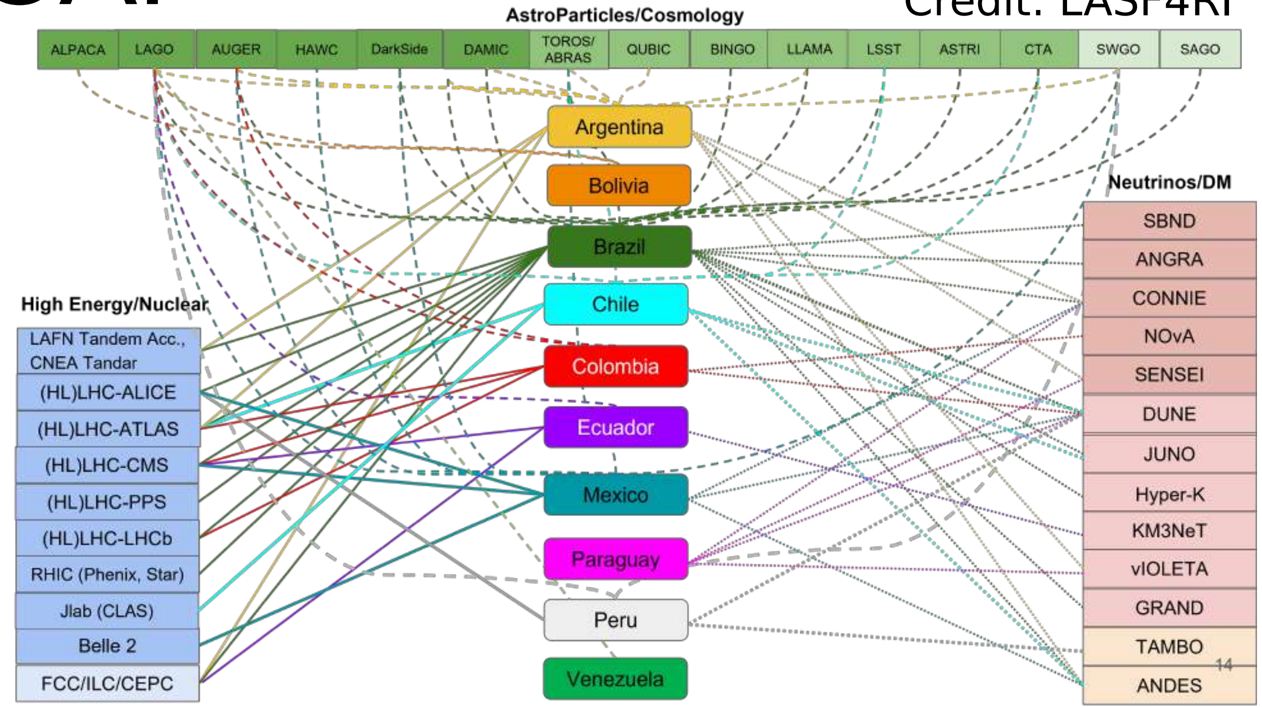
Credit: LASF4RI

Brazilian commercial balance:

Export:
1) China: US$ 87,696 bi (31,28%)
2) U.S.: US$ 31,104 bi (11,09%)
3) Argentina: US$ 11,881 bi (4,24%)

Import:
1) China: US$ 47,651 bi (21,72%)
2) U.S.: US$ 39,382 bi (17,95%)
3) Argentina: US$ 11,948 bi (5,45%)

Credit: Globonews (2021)




China is a strategic partner for many L.A. countries.
Direct collaboration in HECAP should be improved.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# Reactor Neutrinos in L.A.

L.A. institutions contributed to major reactor neutrino exteriments such as Daya Bay and Double Chooz.

There is a strong community of theoretical physicists with important contributions in this field.

There are ongoing experiments with reactor neutrinos in L.A.: see talks by E.Kemp and C.Bonifazi

L.A. has both experties and local infrastructure for important contributions in this field.

# The JUNO collaboration

74 Institutions
700+ Collaborators

Brazil:
- PUC-Rio
- UEL

Chile:
- SAPHIR
- UNAB

PUC-Chile left the collaboration in 2024 due to completion of hardware responsibilities.

| Country | Institute | Country | Institute | Country | Institute |
|---|---|---|---|---|---|
| Armenia | Yerevan Physics Institute | China | Tsinghua U. | Germany | U. Tuebingen |
| Belgium | Universite libre de Bruxelles | China | UCAS | Italy | INFN Catania |
| Brazil | PUC | China | USTC | Italy | INFN di Frascati |
| Brazil | UEL | China | U. of South China | Italy | INFN-Ferrara |
| Chile | SAPHIR | China | Wu Yi U. | Italy | INFN-Milano |
| Chile | UNAB | China | Wuhan U. | Italy | INFN-Milano Bicocca |
| China | BISEE | China | Xi'an JT U. | Italy | INFN-Padova |
| China | Beijing Normal U. | China | Xiamen University | Italy | INFN-Perugia |
| China | CAGS | China | Zhengzhou U. | Italy | INFN-Roma 3 |
| China | ChongQing University | China | NUDT | Pakistan | PINSTECH (PAEC) |
| China | CIAE | China | CUG-Beijing | Russia | INR Moscow |
| China | DGUT | China | ECUT-Nanchang City | Russia | JINR |
| China | Guangxi U. | China | CDUT-Chengdu | Russia | MSU |
| China | Harbin Institute of Technology | Czech | Charles U. | Slovakia | FMPICU |
| China | IHEP | Finland | University of Jyvaskyla | Taiwan-China | National Chiao-Tung U. |
| China | Jilin U. | France | IJCLab Orsay | Taiwan-China | National Taiwan U. |
| China | Jinan U. | France | LP2i Bordeaux | Taiwan-China | National United U. |
| China | Nanjing U. | France | CPPM Marseille | Thailand | NARIT |
| China | Nankai U. | France | IPHC Strasbourg | Thailand | PPRLCU |
| China | NCEPU | France | Subatech Nantes | Thailand | SUT |
| China | Pekin U. | Germany | RWTH Aachen U. | U.K. | U. Liverpool |
| China | Shandong U. | Germany | TUM | U.K. | U. Warwick |
| China | Shanghai JT U. | Germany | U. Hamburg | USA | UMD-G |
| China | IGG-Beijing | Germany | GSI | USA | UC Irvine |
| China | SYSU | Germany | U. Mainz | | |

# Detector Design

Highlights:

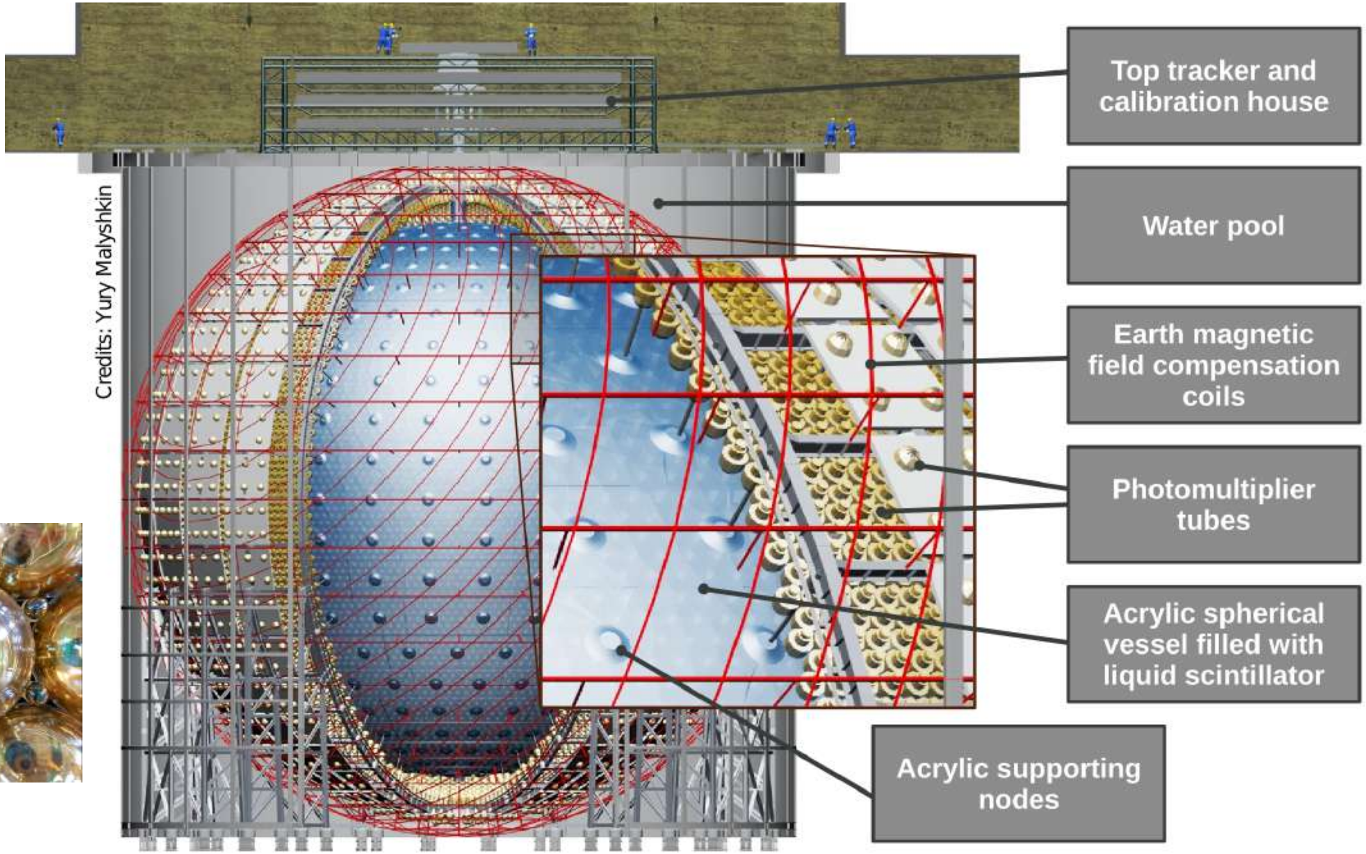
Target Mass: 20 kt
Resolution @ 1 MeV: 3%

Liquid Scintillator

- Not loaded
- High transparency (>20 m)
- High emission efficiency (~$10^4$ Photons/MeV)

Two types of Photomultipliers:
17612 20-inch
25600 3-inch

78% PMT coverage!

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# Experimental site and Civil construction


~650 m overburden



Taishan 1: experimental site @ 40m from reactor core!

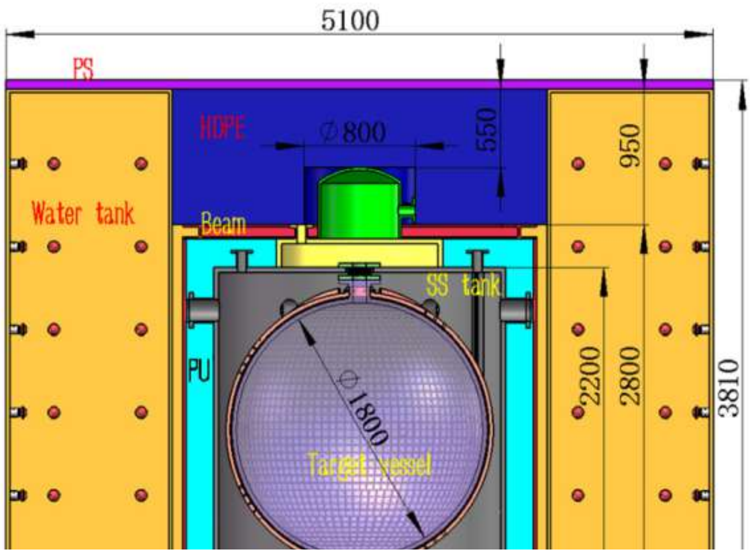
# JUNO TAO

-> Taishan Antineutrino Observatory

- ~40 m from a 4.6 $GW_{th}$ reactor
- 2.8 ton Gd-LS @ -50°C
- 2,000 IBD's/day
- 10 $m^2$ SiPM (~95% photo-coverage)
- Energy resolution: < 2% @ 1 MeV!!! (4500 PE/MeV)

-> Mesurement of antineutrino spectrum with unprecedented resolution

- Reference for JUNO and benchmark for nuclear database
- Search for sterile neutrinos
- Study spectral evolution with reactor fuel burn up




arXiv:2005.08745

# Scientific Goals

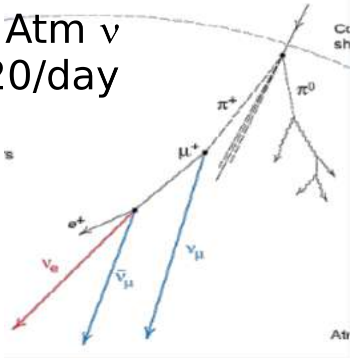
Solar ν
(~2000)/day

Supernova ν
~$10^4$ in 10s

(@10kpc)

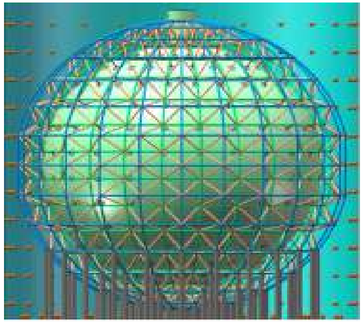
DSNB: few/year

Atm ν
10-20/day

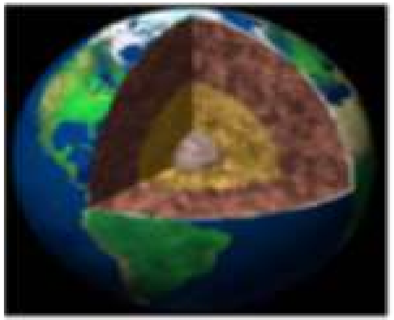


Reactor ν
~50/day

Proton decay, Non standard interactions etc.



Geo ν
(~1)/day



# Reactor $\overline{\nu}_e$ in JUNO (1)

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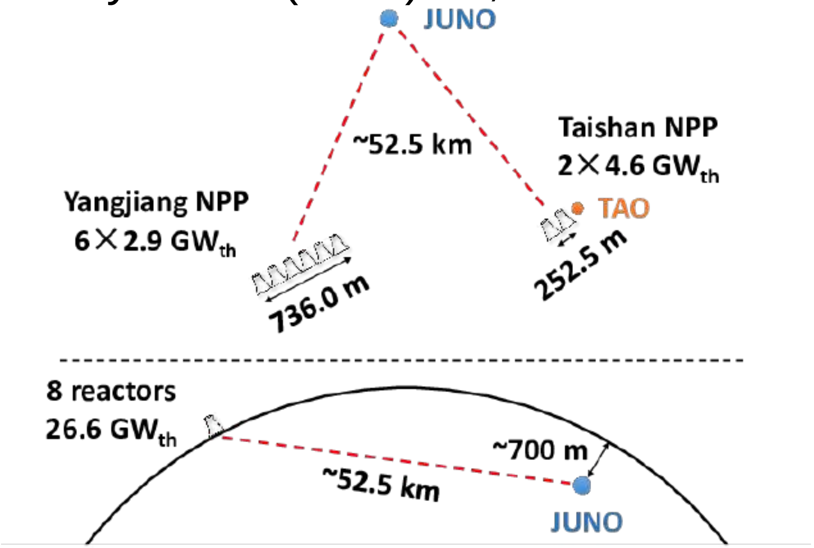
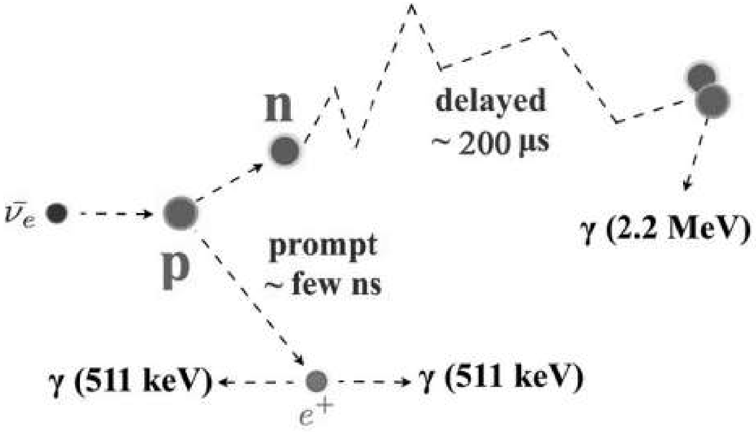


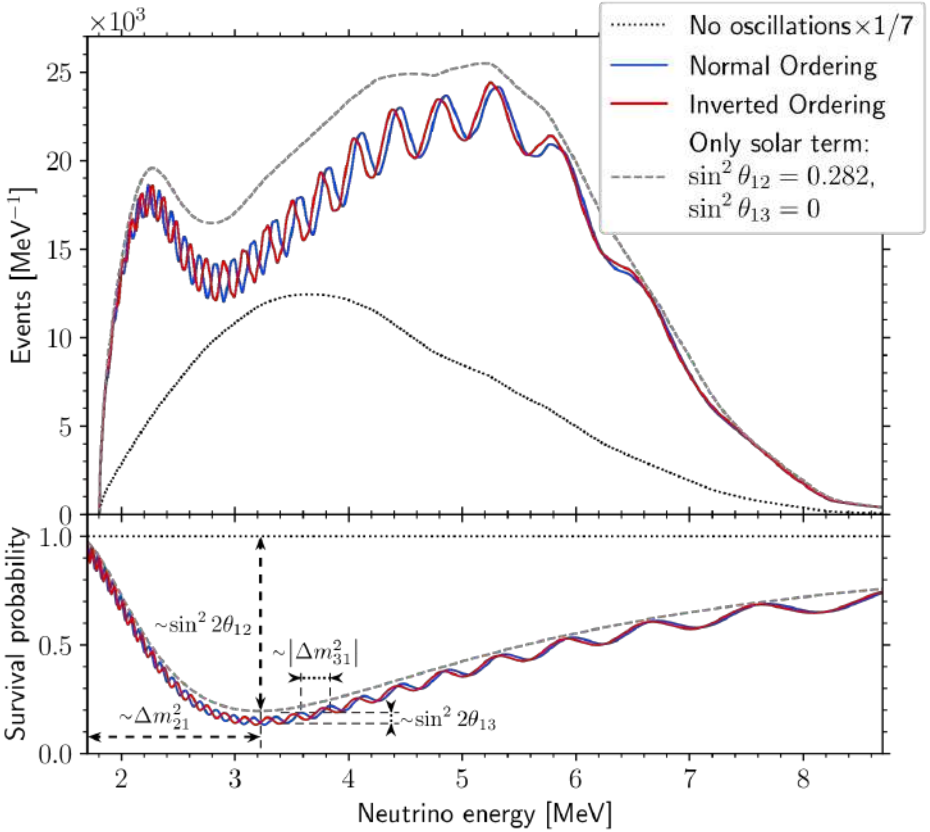




Production → Oscillation → Detection

$$P_{\bar{\nu}_e \to \bar{\nu}_e} = 1 - \sin^2 2\theta_{13}\left(\cos^2\theta_{12}\sin^2\frac{\Delta m^2_{31}L}{4E} + \sin^2\theta_{12}\sin^2\frac{\Delta m^2_{32}L}{4E}\right) - \cos^4\theta_{13}\sin^2 2\theta_{12}\sin^2\frac{\Delta m^2_{21}L}{4E}$$

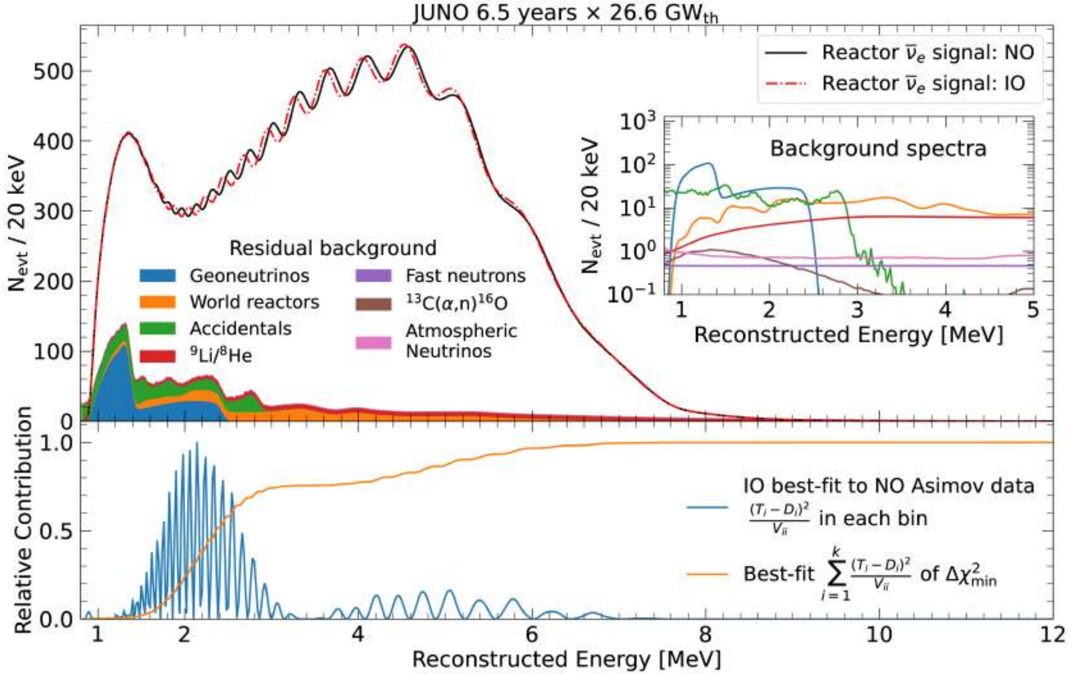
# Reactor $\bar{\nu}_e$ in JUNO (2)

arXiv:2405.18008



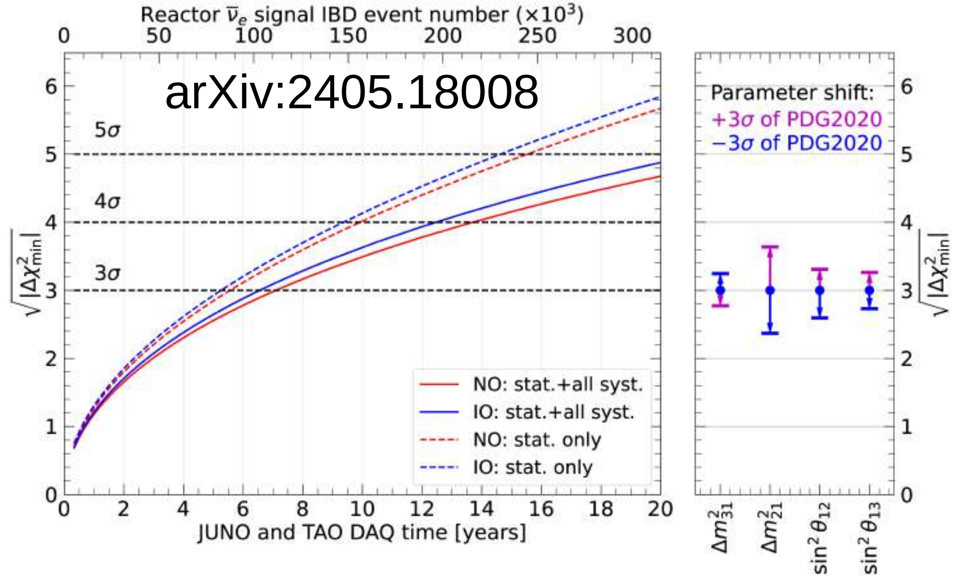

**Goals:** **Neutrino Mass Ordering**

**$\Delta m^2_{31}$, $\Delta m^2_{21}$ and $\sin^2(\Theta_{12})$ measurements < 1%**

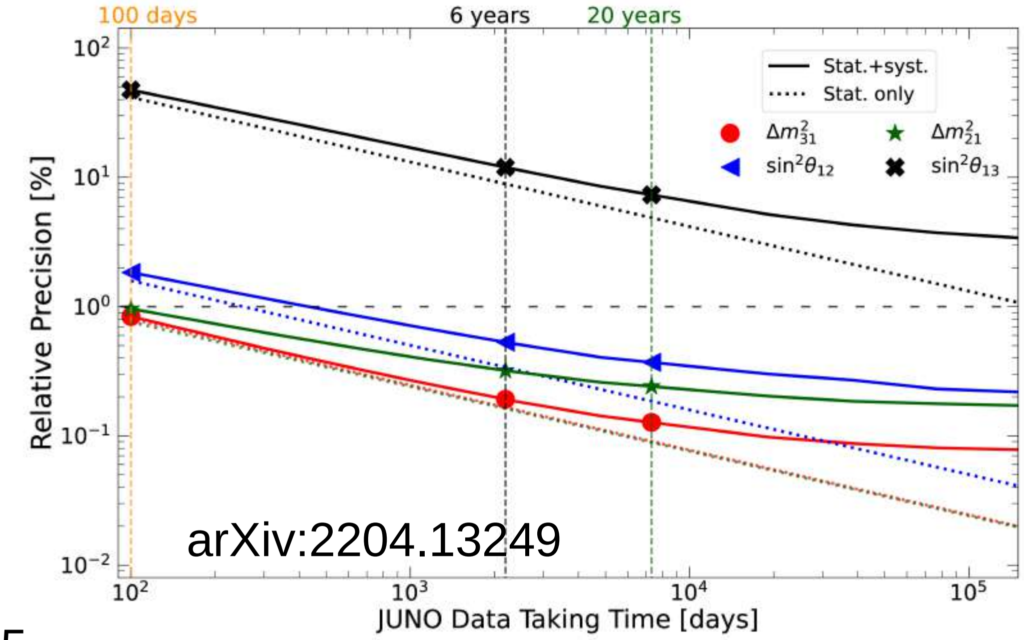


# Reactor $\bar{\nu}_e$ in JUNO (3)

**Neutrino mass ordering**



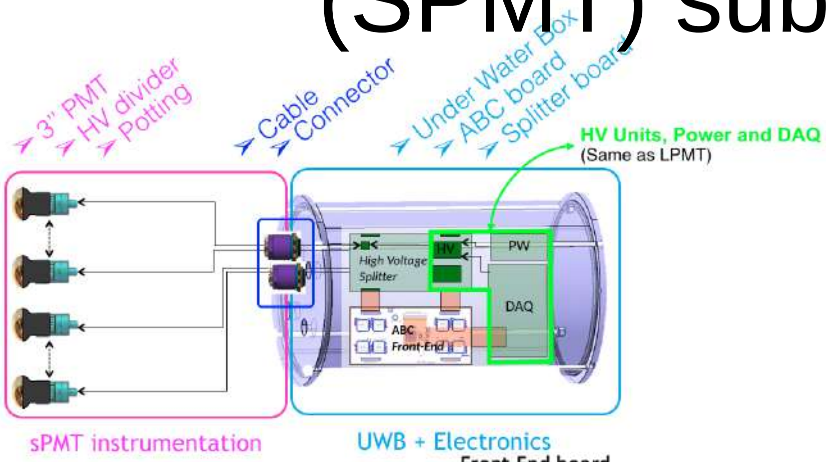

**Sub-percent precision level on $\Delta m^2_{21}$ , $\Delta m^2_{31}$ and $\sin^2\theta_{12}$ in 1-2 years**

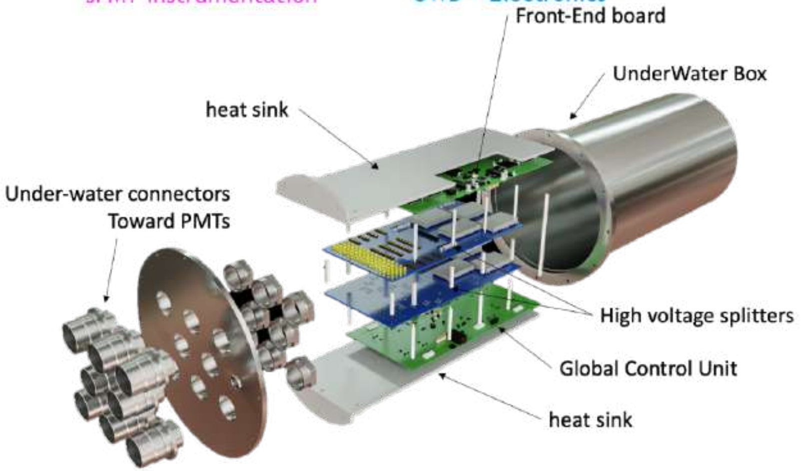



Examples of synergies for NMO:
JUNO+KM3NeT/ORCA: JHEP 03 (2022) 055
JUNO+Long Baseline: Sci.Rep. 12 (2022) 1, 5393

See also: Phys.Rev.D 72 (2005) 013009

# Small Photomultiplier Tubes (SPMT) subsystem




Principle: measure the same event with two types of PMTs working in different regimes (low vs. high occupancy) to control systematic uncertainties.

Additional benefits:

- Improve position reconstruction
- Improve muon reconstruction
- Aid to SN burst neutrino measurements
- Semi-independent physics (measurement of solar parameters).

26,000 3-inch PMTs custom-made for JUNO.
→ NIM A 1005 (2021) 165347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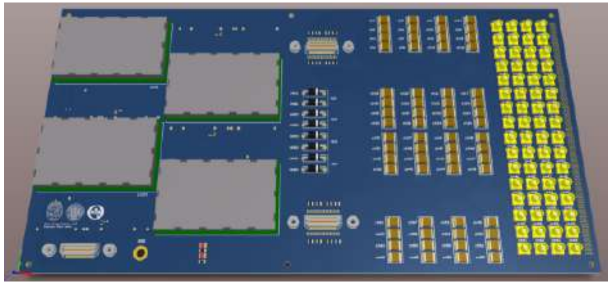
# L.A. Contributions

PUC (Pontificia Universidad Católica de Chile), SAPHIR and UCI (University of California, Irvine) led the design and manufacture of the High Voltage Splitters (HVS) and the Under Water Boxes (UWBs) in partnership with our French and Chinese colleagues.



The UCI group also contributes to the leadership of the experiment.

Hiroshi Nunokawa has significantly contributed to JUNO in recent years, primarily through discussions and writing. He served as one of the editors for the JUNO paper arXiv:2204.13249, and as internal reviewer for other JUNO papers.

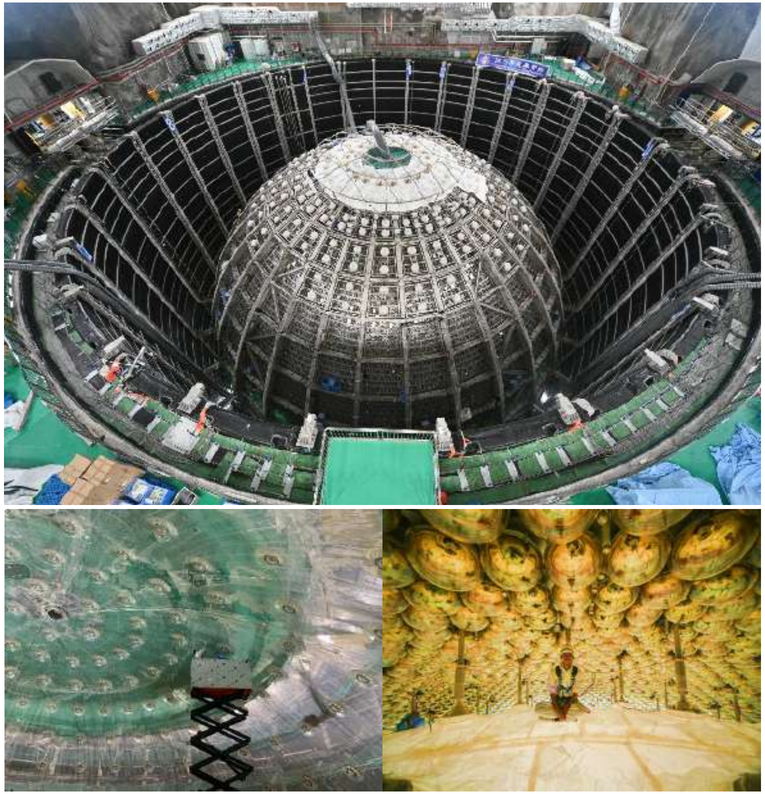
I first contributed to simulations of the SPMT subsystems and later within the analysis group for sensitivity studies.

# Contruction Status

Status

- Construction of stainless steel structure completed
- Acrylic vessel in the center detector:78%3 completed
- PMT, electronics, muon veto system installation ongoing
- Installation of purification plants for the LS completed

→ See time lapse video



JUNO construction is near completion

Detector will be finished in the end of 2024, then start filling, and data taking in 2025

# Funding in L.A.

Funding for Chile’s contributions came from multiple sources, including the Quimal 170005 grant, the FONDECYT regular grant 1181035, as well as support from PUC and SAPHIR. All of this funding ultimately originates from ANID, the Chilean National Agency of Research and Development.

On the Brazilian side JUNO has received partial funding from CNPq through research grants 432848/2016-9 (coordinated by Prof. H. Nunokawa) and 407149/2021-0 (coordinated by Prof. P. Chimenti), as well as “Bolsas de Produtividades”.

# Final considerations

Important results from JUNO are expected soon: exciting moment!

JUNO is important for Latin American Science.

Stronger institutional support now is important.

Thanks to the organizers for the support.

Obrigado! 谢谢 Thanks!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