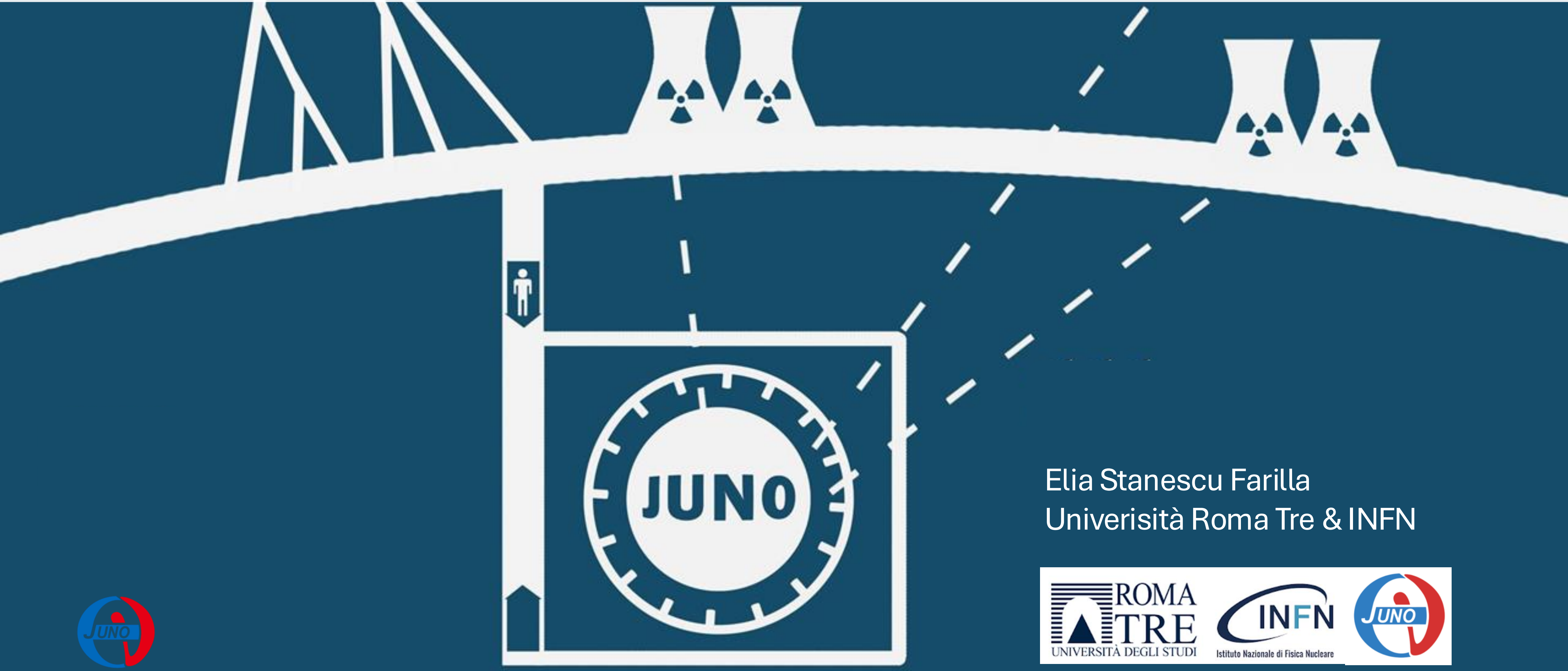
JUNO: un gigante sotterraneo per lo studio dei neutrini



Elia Stanescu Farilla
Univerisità Roma Tre & INFN

Outline della Presentazione

I. Rivelazione dei neutrini

II. Misura dei parametri d'oscillazione

III. L' esperimento JUNO

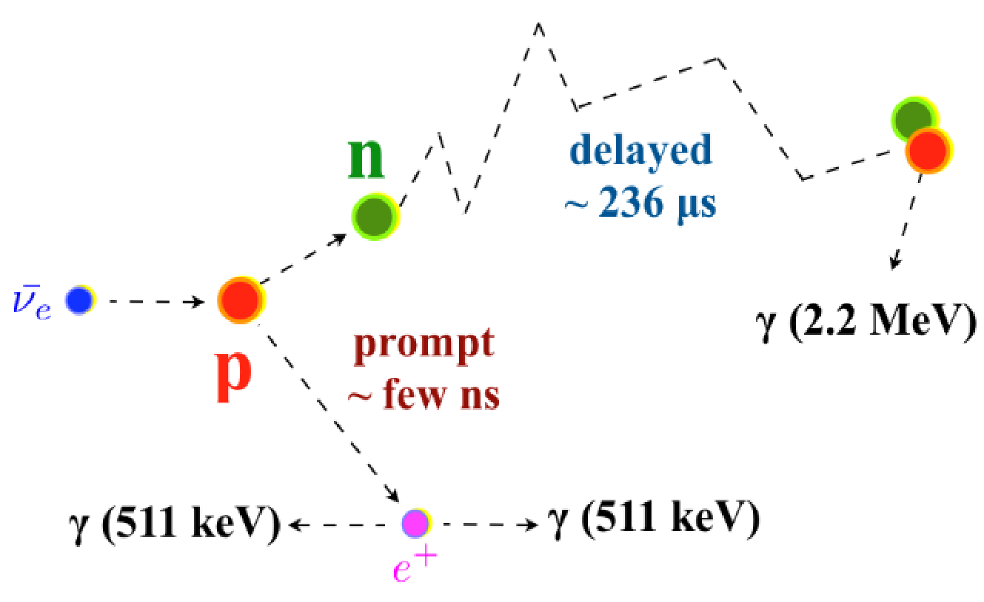
IV. Il reference detector TAO

Rivelazione dei neutrini

- **JUNO rivela neutrini sfruttando il decadimento beta inverso:**

Inverse Beta Decay (IBD)

$$\boxed{\bar{\nu}_e + p \rightarrow e^+ + n}$$



Segnatura IBD:

- **Annichilazione**
  $e^+e^- \rightarrow \gamma\gamma$
  (segnale prompt)
- **Cattura neutrone**
  $n + p \rightarrow p + \gamma$
  (segnale delayed)

Problema:
Sezione d'urto IBD molto bassa

$$\boxed{\sigma \approx 10^{-44} cm^2}$$

Soluzione:
- ✓ Rivelatori molto massivi $\mathcal{O}(\mathrm{kt})$
- ✓ Intenso flusso di neutrini:

  i. Solari
  ii. Atmosferici
  iii. Da acceleratore
  iv. Da reattore

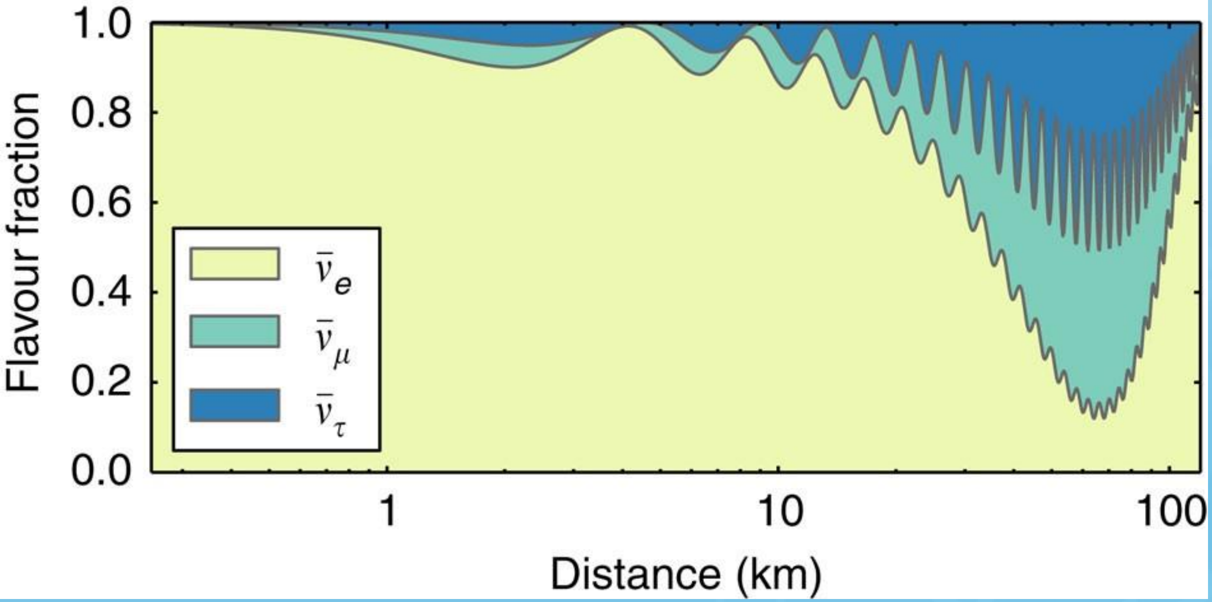
Misura dei parametri d'oscillazione

- **Per la misura dei parametri di oscillazione si sfrutta la probabilità di scomparsa di un certo sapore:**

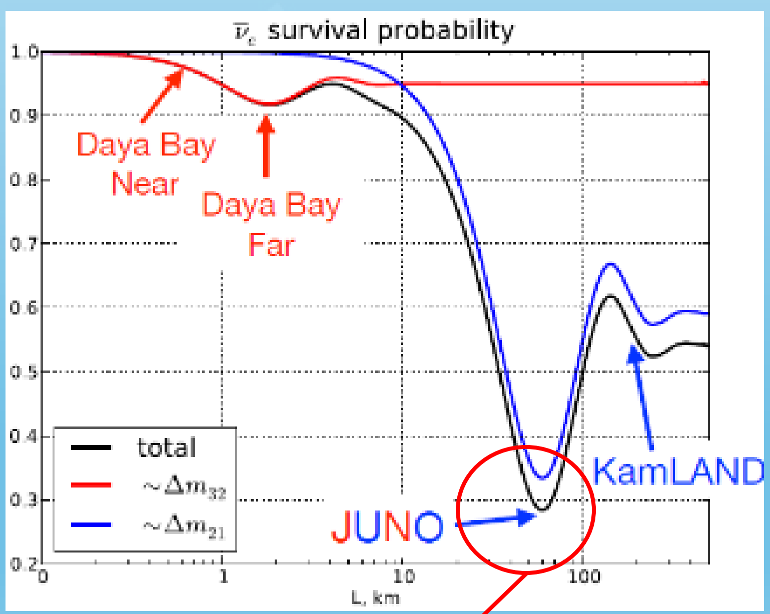
$$P_{ee} = 1 - \sin^2(2\theta_{13})\, sin^2\left(\frac{\Delta m^2_{ee} L}{4E}\right) - sin^2(2\theta_{12}) \cos^4(2\theta_{13})\, sin^2\left(\frac{\Delta m^2_{21} L}{4E}\right)$$

- θ_{ij}: **angoli di mixing**
- $\Delta m^2_{ij} = \boldsymbol{m_i^2 - m_j^2}$

- **Scegliendo accuratamente la distanza L è possibile massimizzare la probabilità di scomparsa**

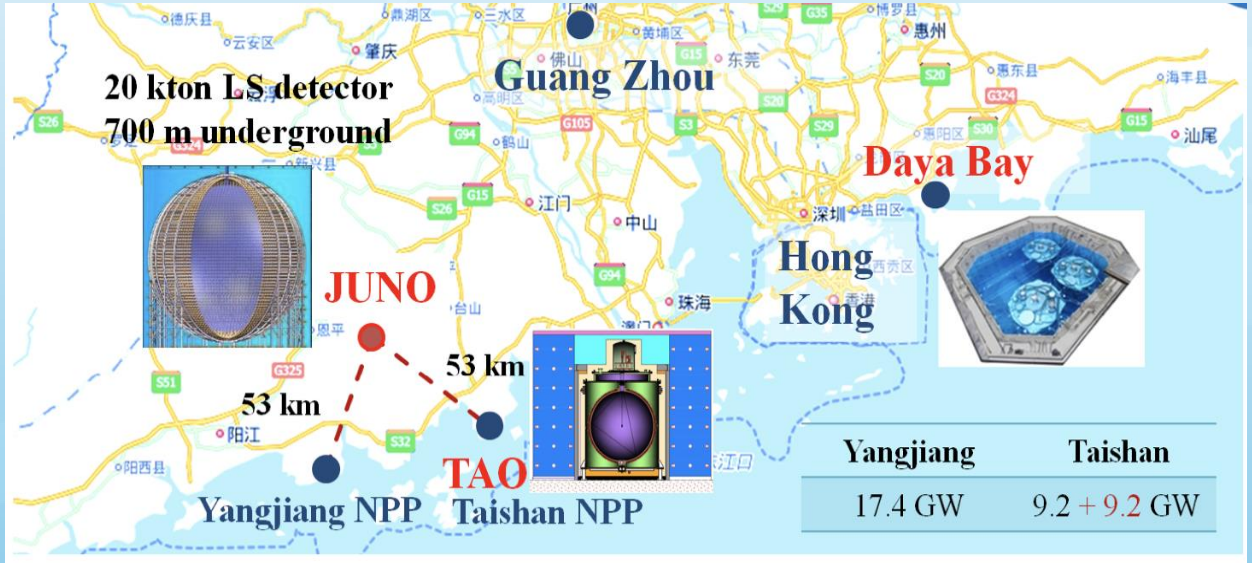


JUNO



$L \approx 50$ km

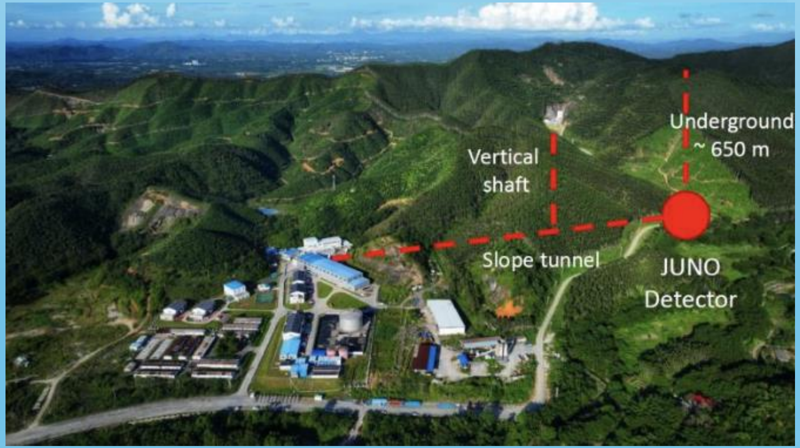
L' esperimento JUNO

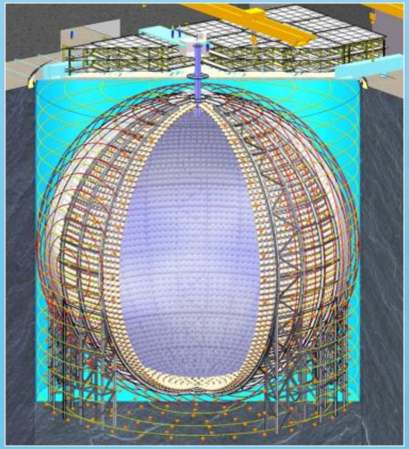


Yangjiang	Taishan
17.4 GW	9.2 + 9.2 GW

Jiangmen Underground Neutrino Observatory

- **Più grande LS detector mai costruito** $\sim$ **20 kt**
- ***Medium baseline*** **52.5 km, 700 m in profondità**
- **Ampia copertura di fotorivelatori (PMT)** $\sim 75\%$
- **Risoluzione energetica record:** $\sigma(E)/E \sim 3\%$ ❗



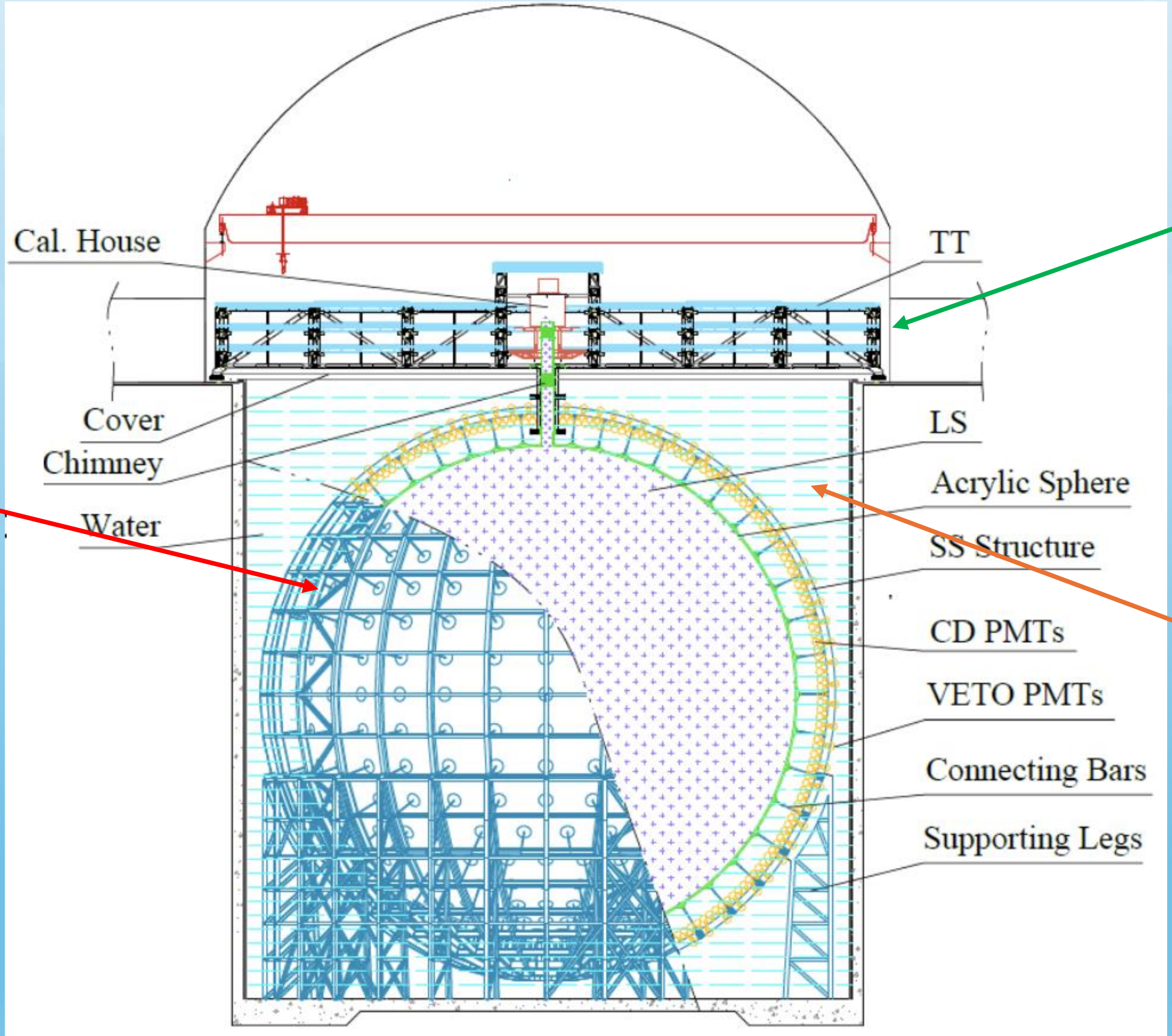


Installazione completata ✅
Inizio fase di *commissioning* ⏳

Il detector JUNO

Central Detector

- Diametro 35.4 m
- 20 kt di LS: Linear Alkyl Benzene (LAB)
- $\sim$17.000 large PMT
  $\sim$25000 small PMT



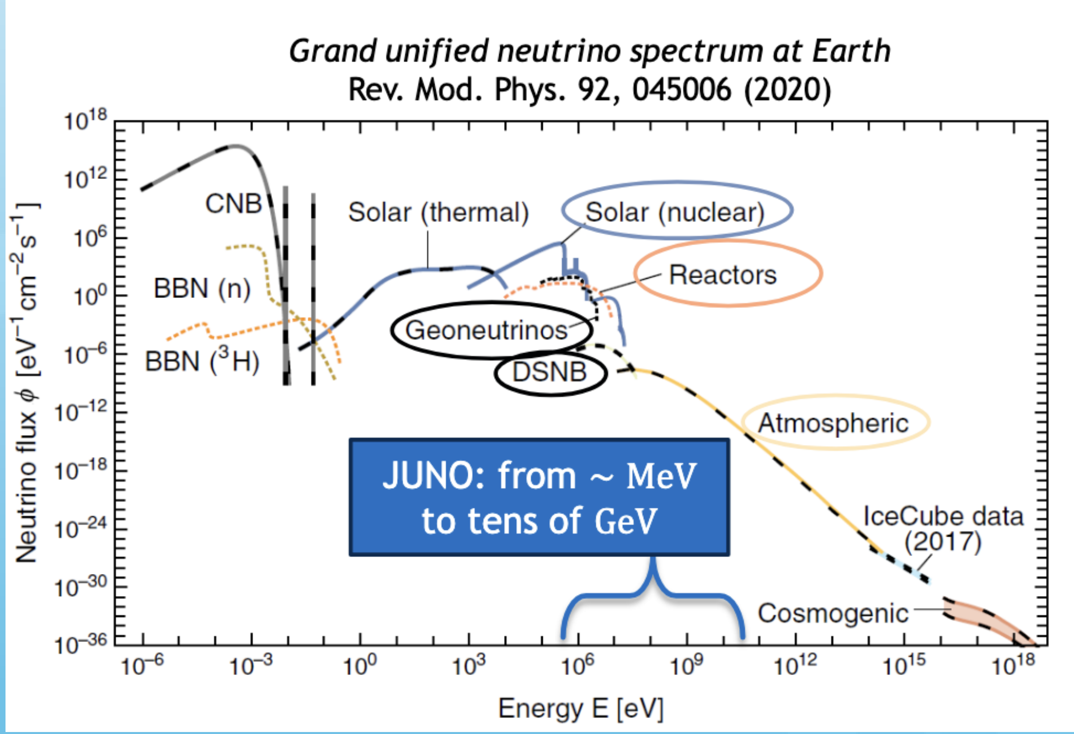
Top Veto Tracker

- Muon Veto system
- Scintillatore plastico
- γ letti da PMT

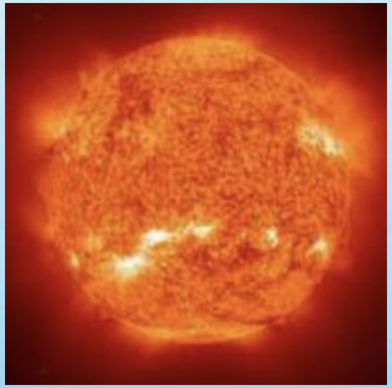
Water Tank:

- Muon Veto system
- γ Cherenkov letti da PMT

Obiettivi di fisica a JUNO

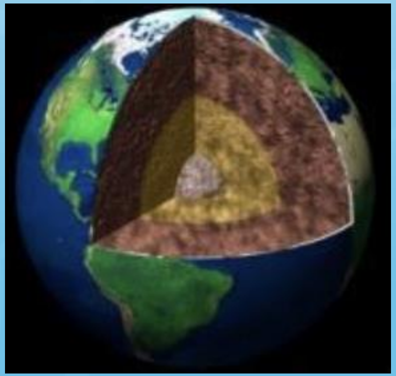


Reactor ν :
~50 IBD/day

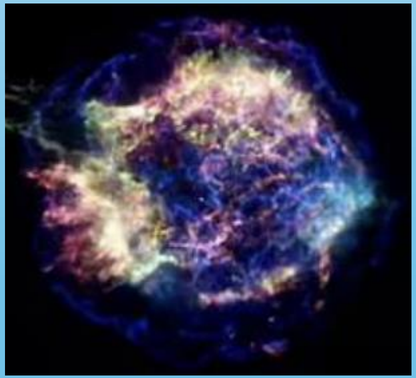


Solar ν :
~hundreds/day

Atmospheric ν :
~several/day



Geoneutrinos :
~400 IBD/year

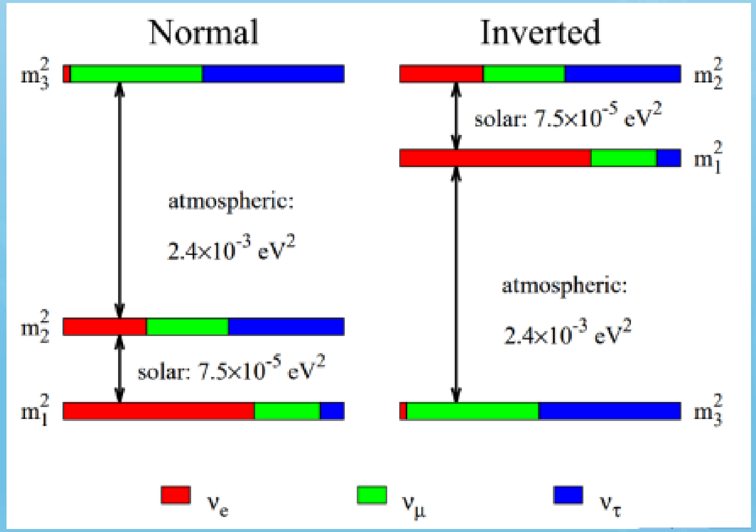


Supernova ν :
~5000 IBD in 10s for CCSN at 10 kp

Obiettivi di fisica a JUNO

- **Misure di 4 parametri d'oscillazione con precisione $< 1\%$:** $\boxed{sin^2\,\theta_{12}\,,sin^2\,\theta_{13}\,,\Delta m^2_{21}\,,\Delta m^2_{31}}$
- **Misura simultanea delle oscillazioni "lente" ($sin^2\,\theta_{12}\;,\Delta m^2_{21}$) e "veloci" ($sin^2\,\theta_{13}\;,\Delta m^2_{31}$)**
- **Risolvere il problema del Neutrino Mass Ordering (NMO) :**

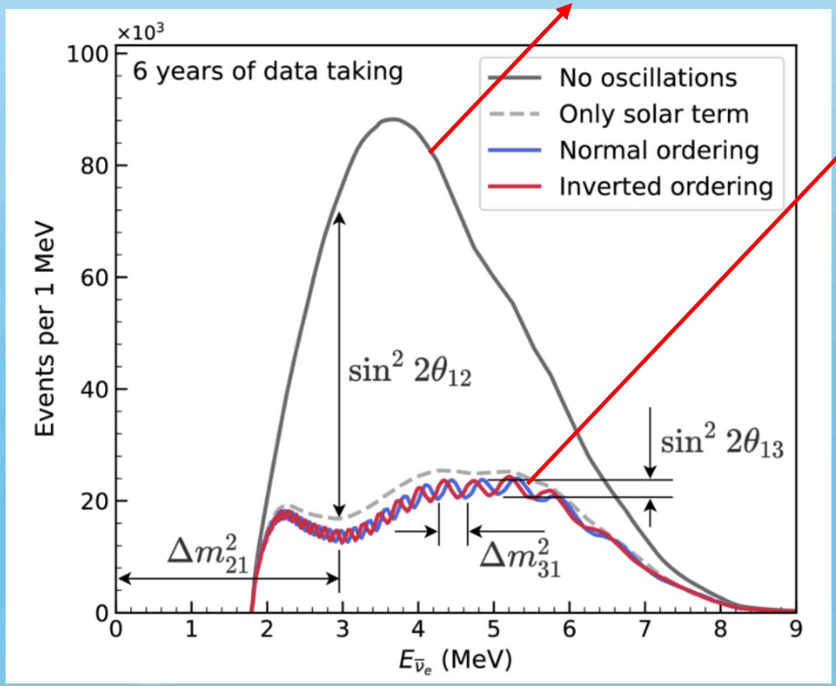
$\boxed{\Delta m^2_{31} > \Delta m^2_{32}\ ?}$



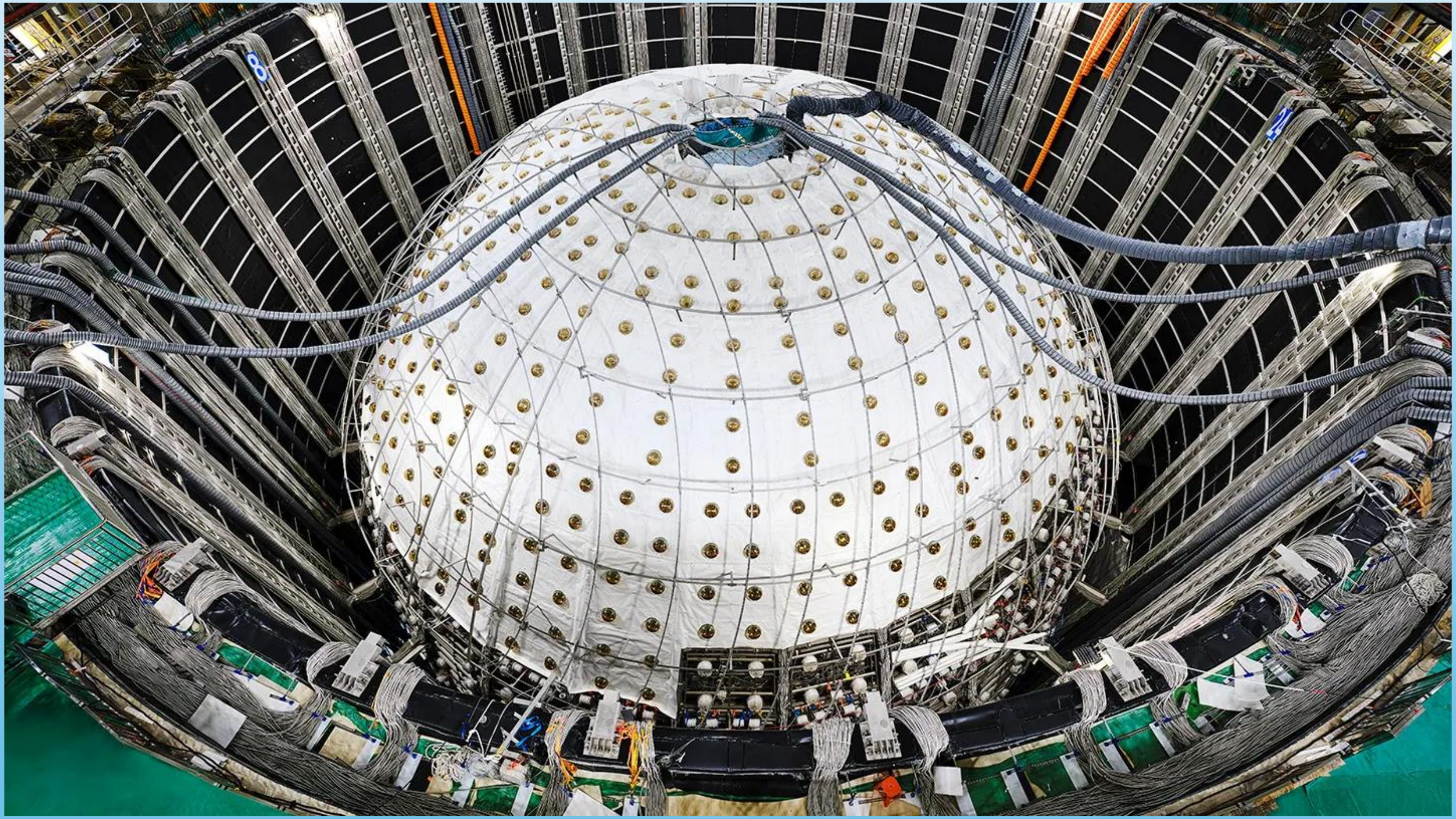
NMO @JUNO

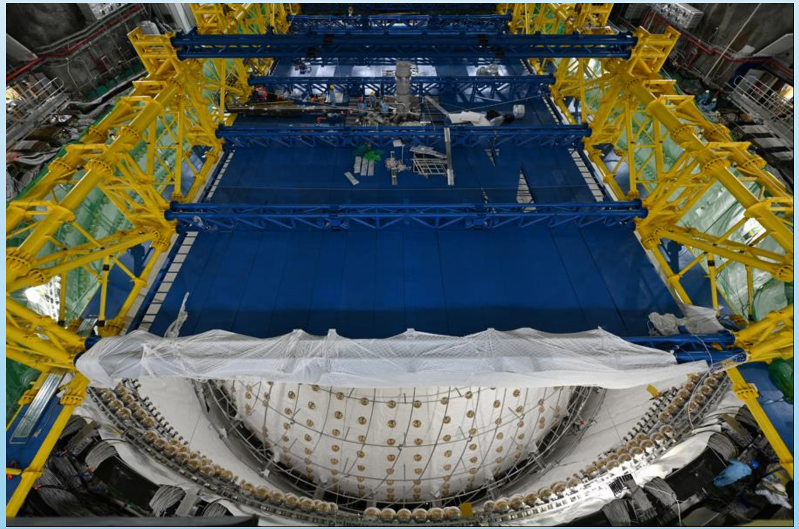
Spettro IBD di riferimento: TAO

Spettro IBD oscillato: JUNO

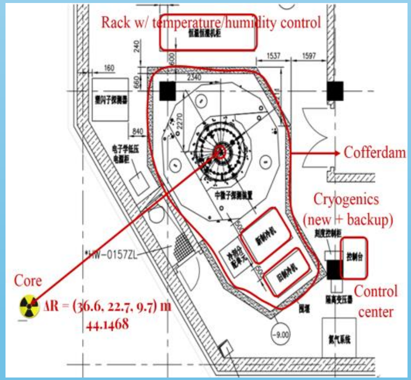


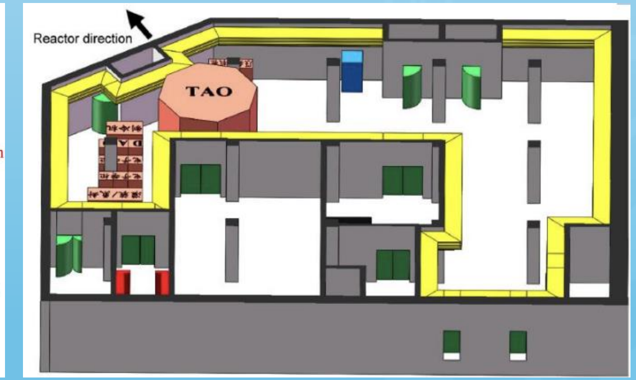
L' esperimento JUNO





Il reference detector TAO





Taishan Antineutrino Observatory

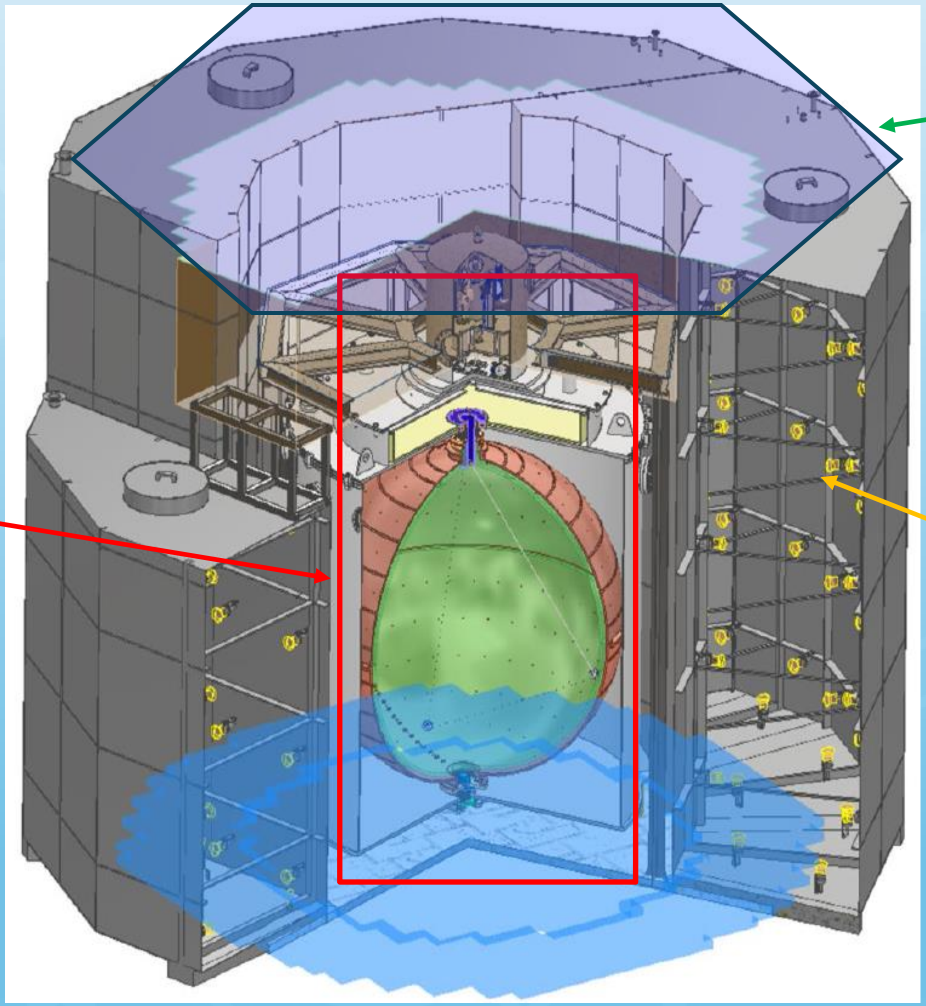
- Esperimento satellite di JUNO
- Posizionato a 44 m da Taishan-1
- Potenza reattore Taishan-1 ~ 4.6 GW_{th}
- LS detector ton-level allo stato dell'arte
- Risoluzione energetica senza precedenti: $\sigma(E)/E < 2\%$ ❗

TAO with-respect-to JUNO

- Copertura di fotorivelatori: $\sim 95\%$ (SiPM) vs $\sim 75\%$ (PMT)
- PDE fotorivelatori: $\sim 50\%$ (SiPM) vs $\sim 27\%$ (PMT)
- Dimensioni ridotte: 1.8 m vs 35.4 m → meno fotoni riassorbiti → statistica di fotoelettroni aumentata del 40%
- IBD da reattore al giorno: ~ 1000 vs ~ 50

Installazione quasi completata ⌛

Il reference detector TAO



Top Veto Tracker:

- Muon Veto system
- Scintillatore plastico
- γ letti da SiPM

Central Detector:

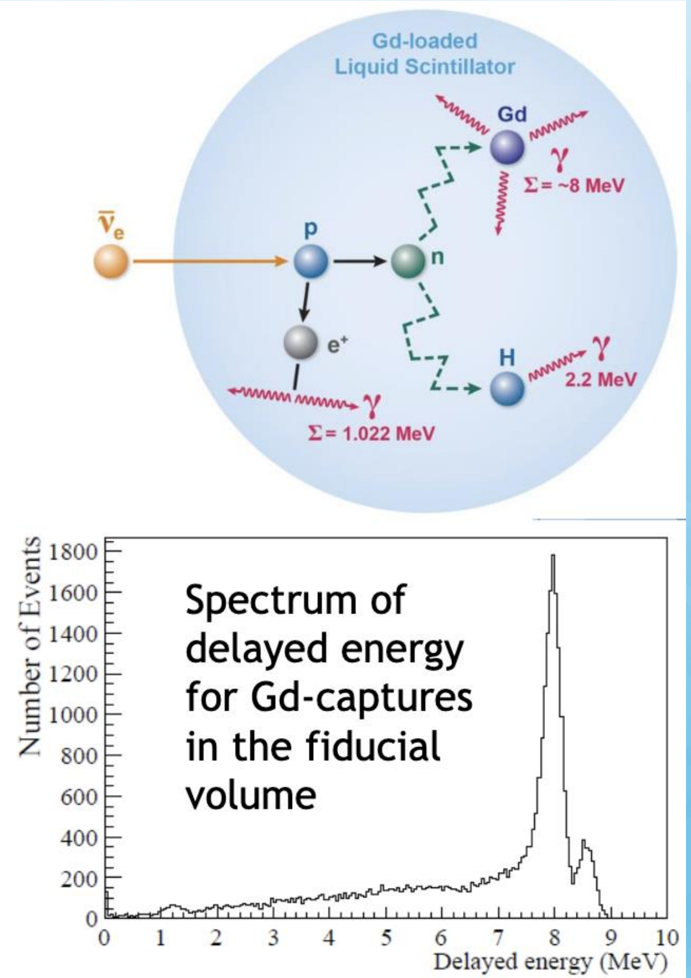
- Diametro 1.8 m
- 2.8 kt di Gd-LS (LAB)
- 4024 SiPM per γ
- Opera a -50℃

Water Tank:

- Muon Veto system
- γ Cherenkov letti da PMT
- Scherma da radioattività ambientale e neutroni cosmogenici

Il reference detector TAO

- **Lo scintillatore LAB a TAO viene drogato con 0.1 % di Gadolinio → Gd-LS**



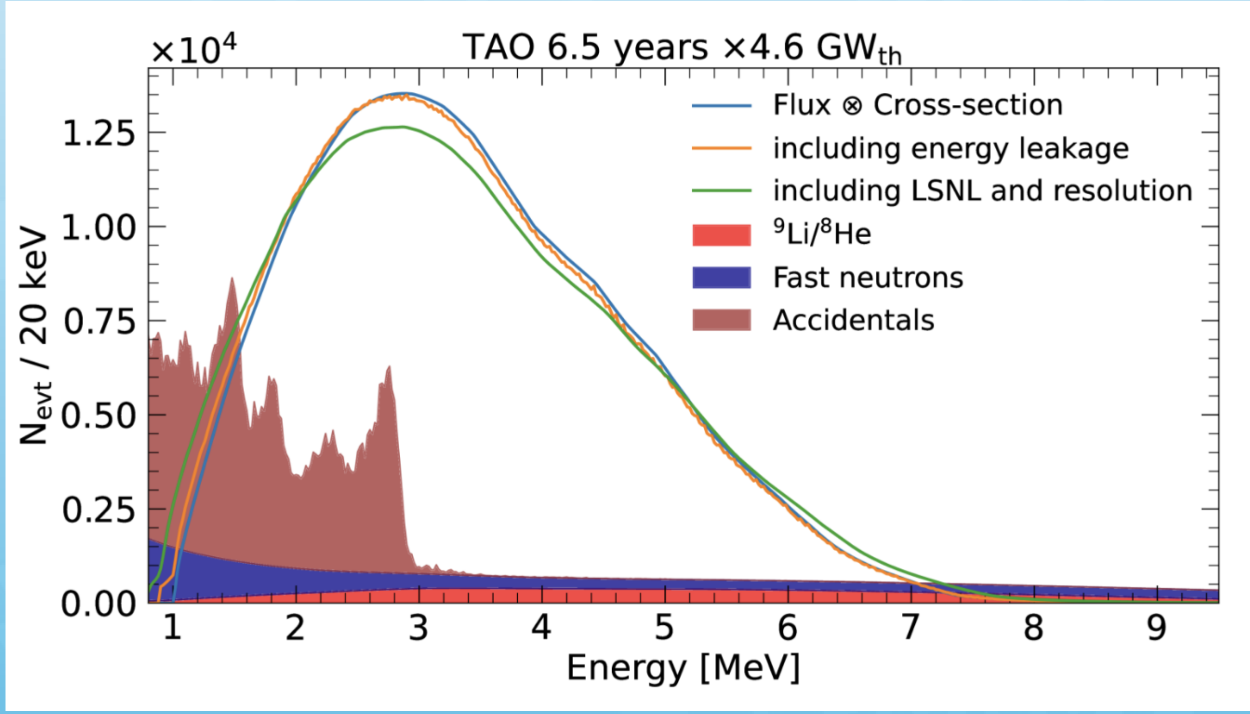
	Efficiency
Captures by Gd	87%
Delayed energy cut	59%
Prompt energy cut	99.8%
Time coincidence cut	97%

Overall detection efficiency ~ 50%

In questo modo aumenta l'efficienza di rivelazione e la reiezione del fondo

Obiettivi di fisica a TAO

- **Misura di precisione dello spettro energetico degli $\overline{\nu}_e$ da reattore → *reference spetrum* per JUNO**



$$S(E_\nu, t) = \frac{W_{\text{th}}(t)}{\sum_{i=1}^{4} E_i f_i(t)} \sum_{i=1}^{4} f_i(t) S_i(E_\nu, t)$$

Where $i \in \{^{235}\text{U}, ^{238}\text{U}, ^{239}\text{Pu}, ^{241}\text{Pu}\}$

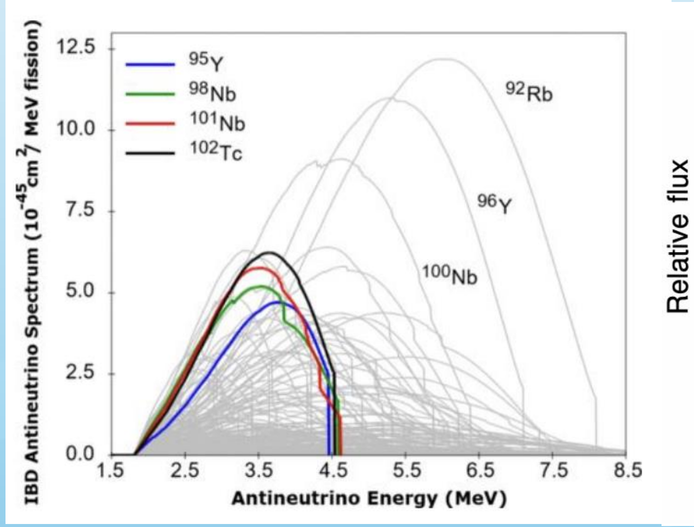
- f_i fission fraction;
- $S_{\nu,i}$ weighted sum of antineutrino spectra
- W_{th} reactor thermal power;
- E_i energy released per fission.

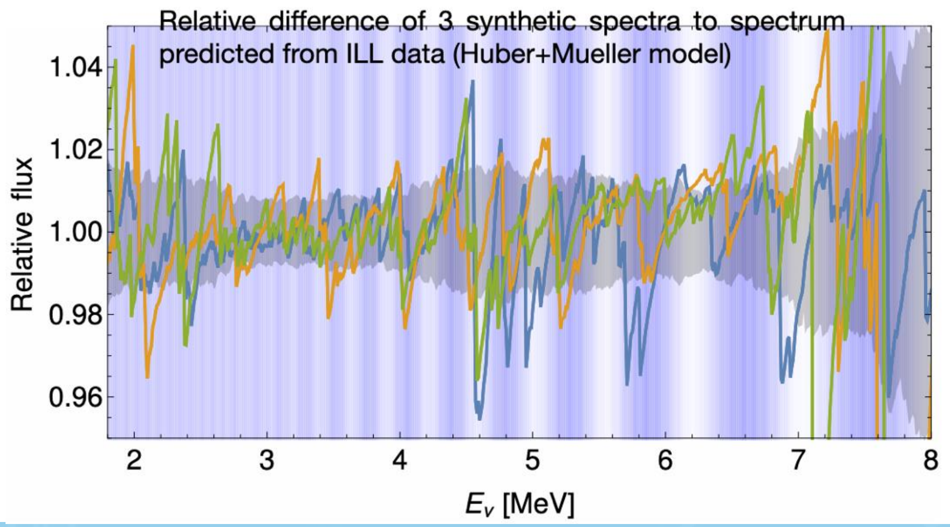
Type	Rate [day^{-1}]
Signal	1000
Fast neutron	86
^{9}Li/^{8}He	54
Accidental	190

TAO non è solo un reference detector

Obiettivi di fisica a TAO

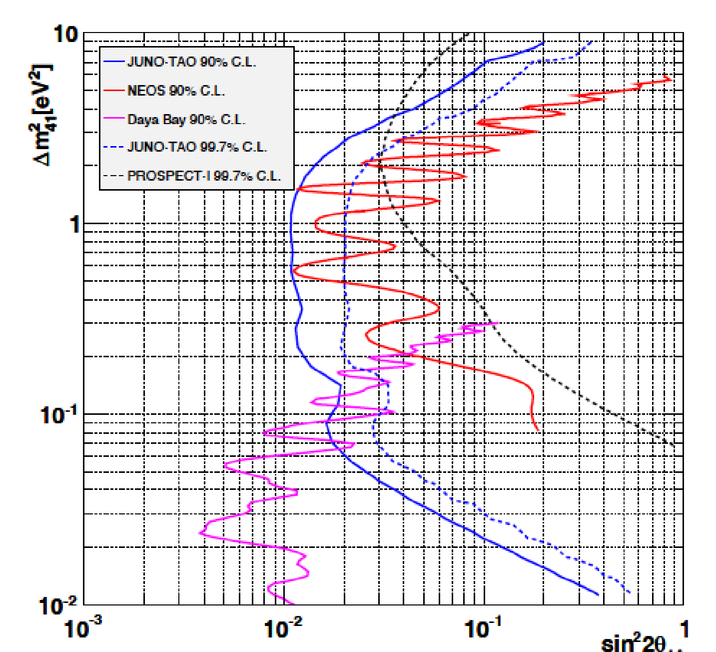
- Ricerca di strutture fini e *shape anomalies* (RAA)





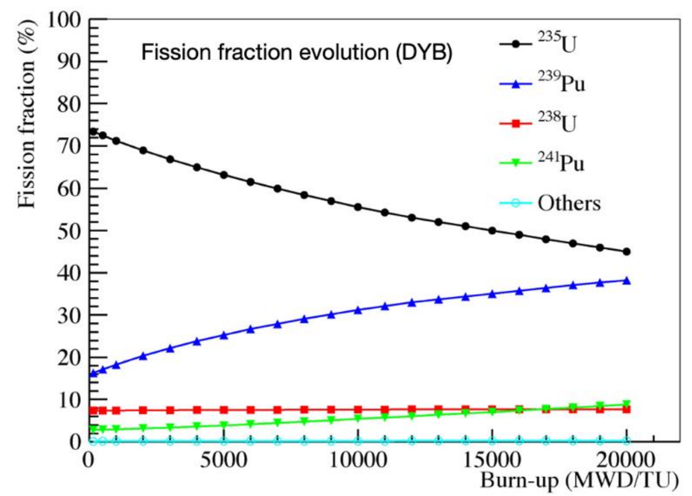
- Ricerca di *light sterile neutrino*

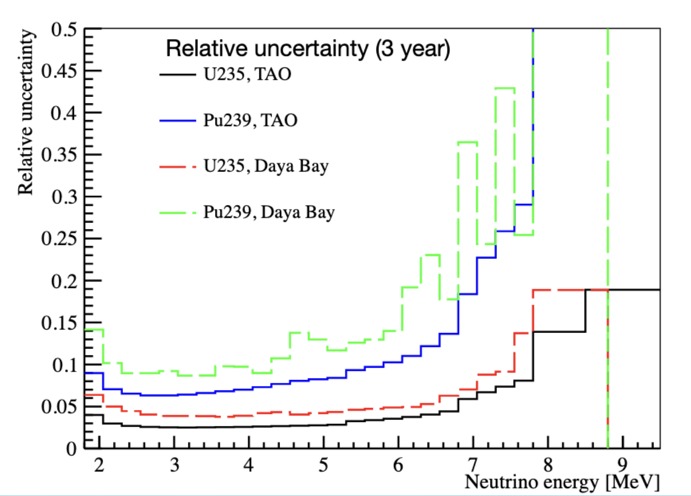
$$P_{\bar{\nu}_e \to \bar{\nu}_e}(L, E) = 1 - 4\sum_{i=1}^{3} |U_{ei}|^2 |U_{e4}|^2 \sin^2 \frac{\Delta m_{4i}^2 L}{4E}$$



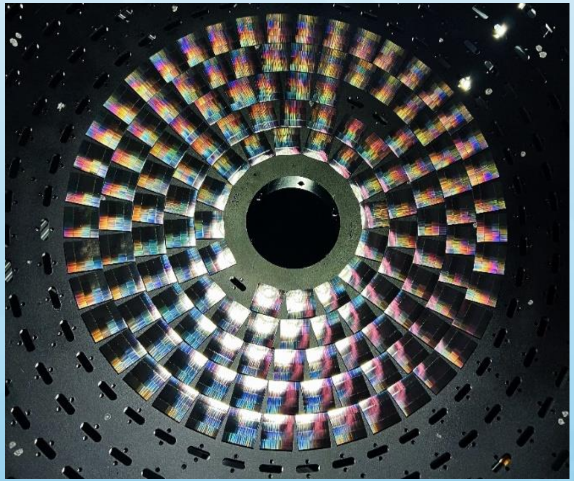
arXiV: 2005.08745

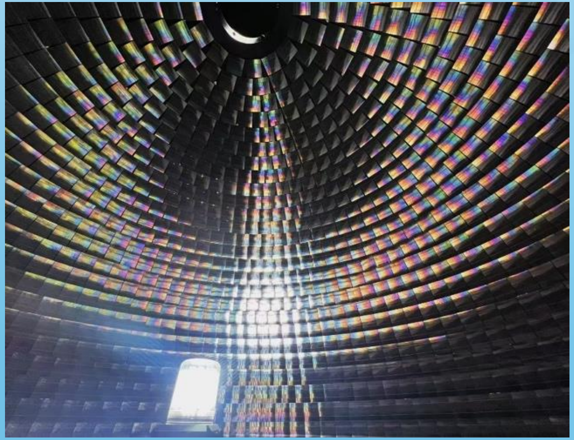
- **Reactor monitoring: status, fuel**

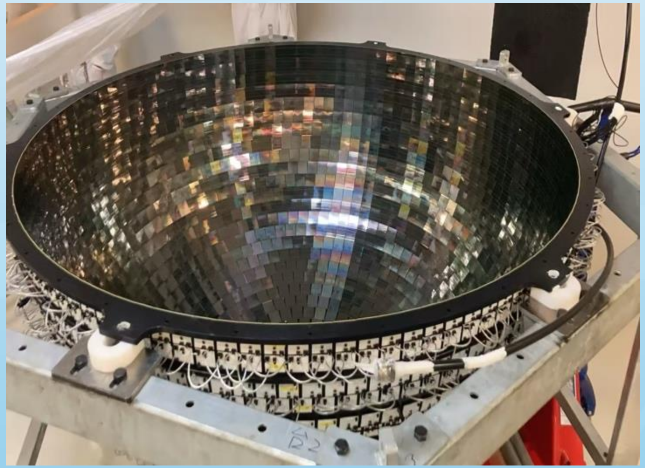




Il reference detector TAO







Il reference detector TAO

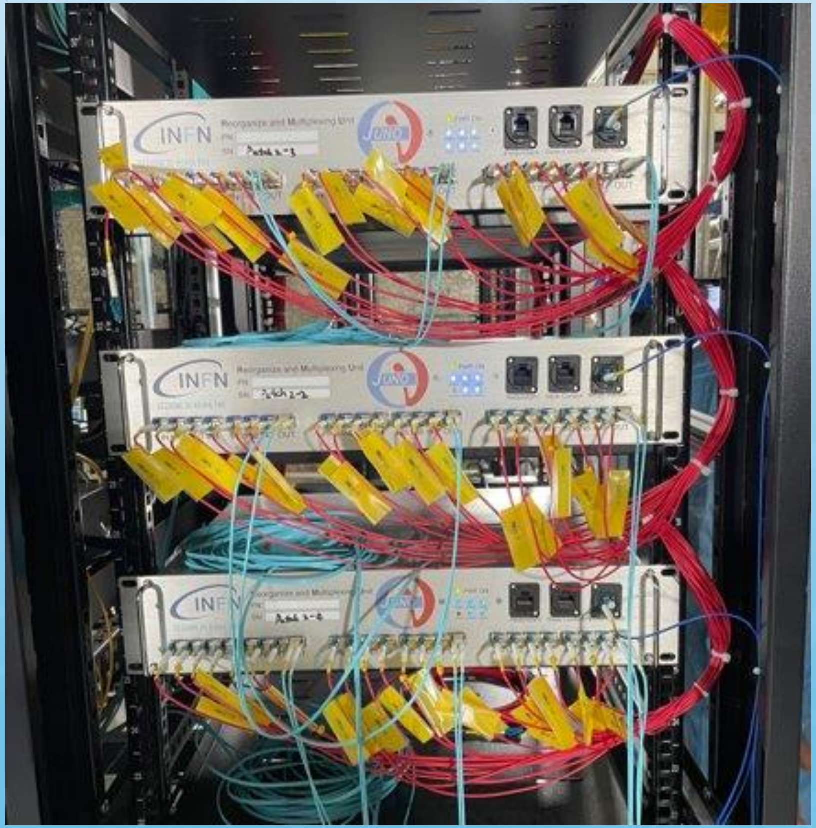
Il gruppo JUNO di Roma Tre

Gruppo JUNO @Roma Tre:

Fabrizio Petrucci (coordinator), Stefano Maria Mari, Andrea Fabbri, Domenico Riondino, Carlo Venettacci, Elia Stanescu Farilla

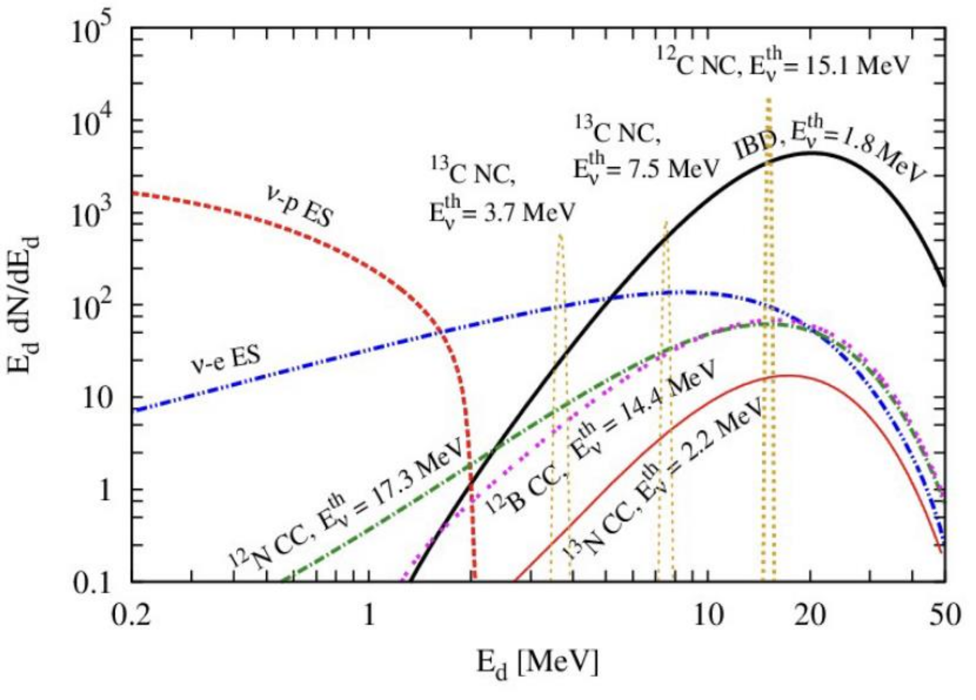
Attività passate gruppo JUNO Roma Tre

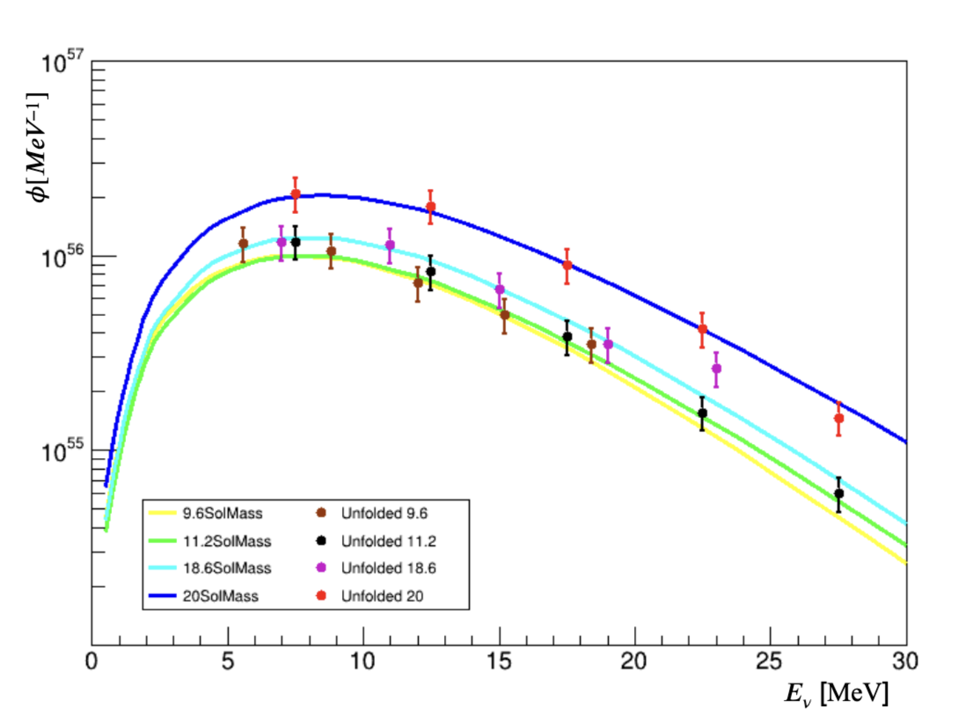
- **Realizzazione schede Reorganizer Multiplexer Units (RMU) del sistema trigger di JUNO**



Attività passate gruppo JUNO Roma Tre

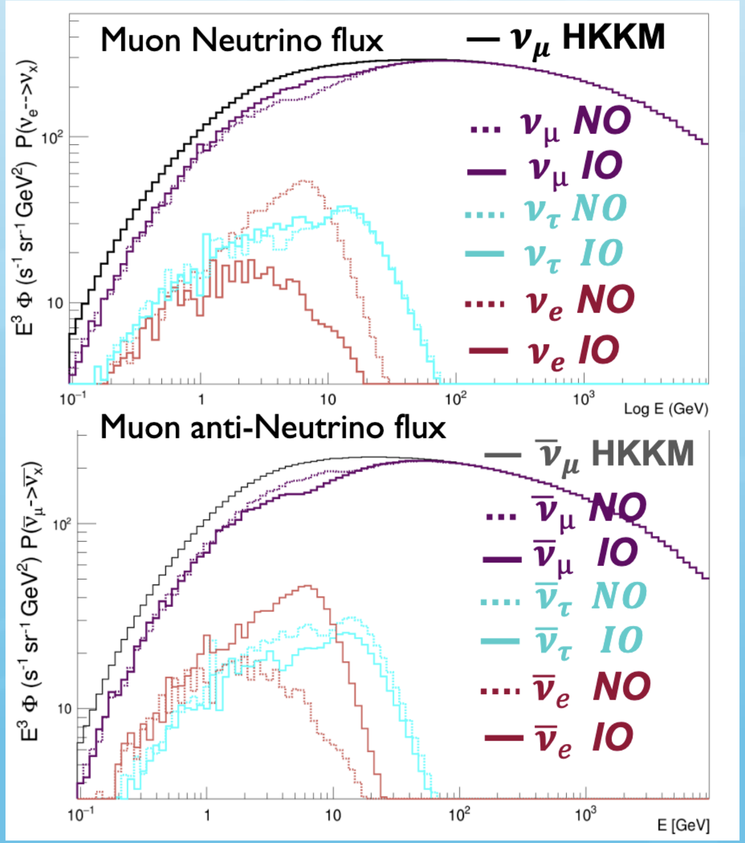
- **Studio dello spettro energetico dei neutrini da supernova a JUNO:**

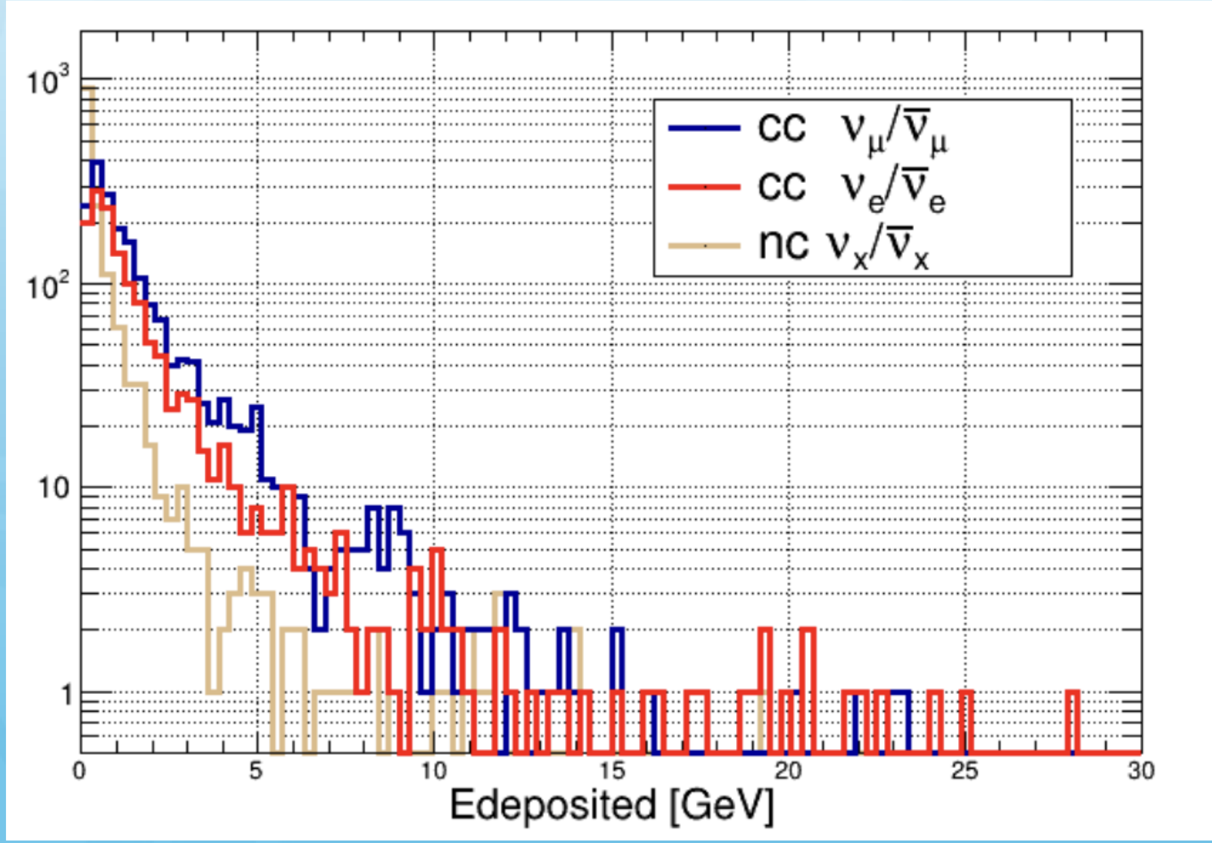




Attività passate gruppo JUNO Roma Tre

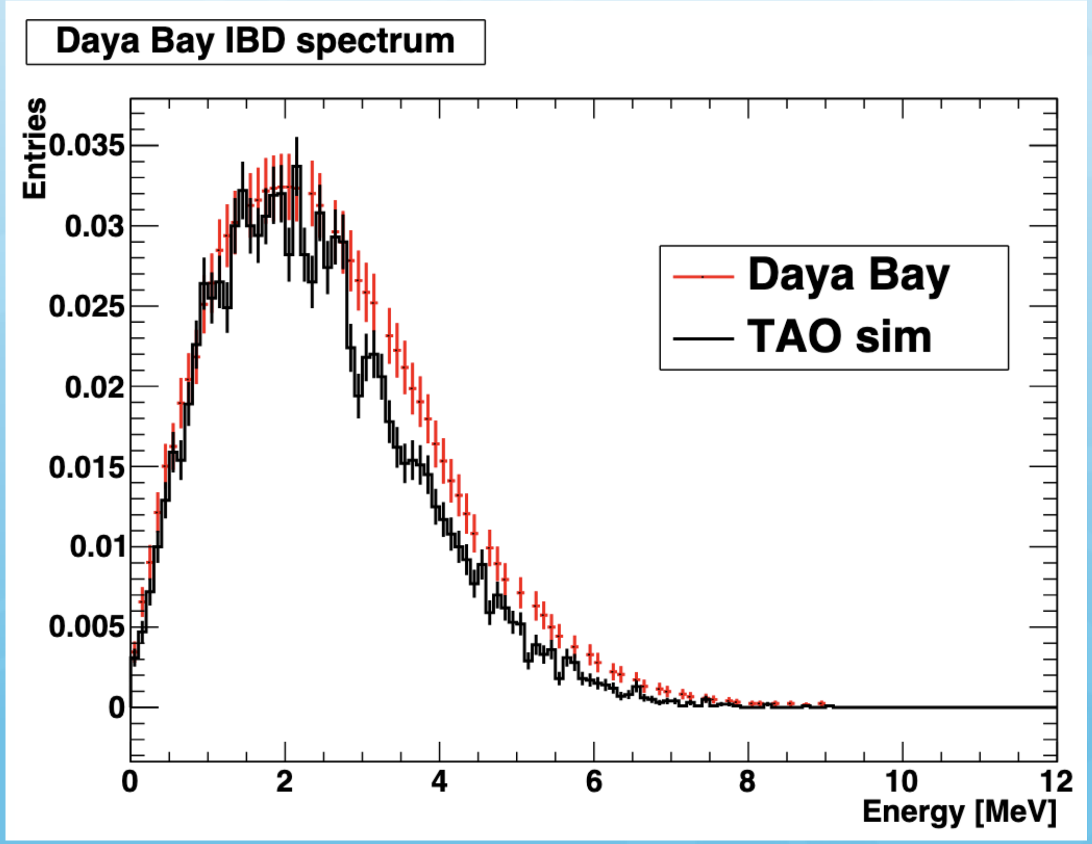
- **Studio delle oscillazioni nei neutrini atmosferici a JUNO:**

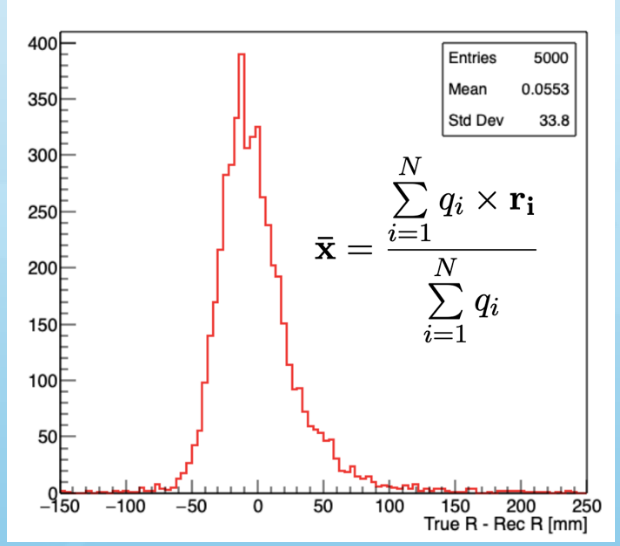


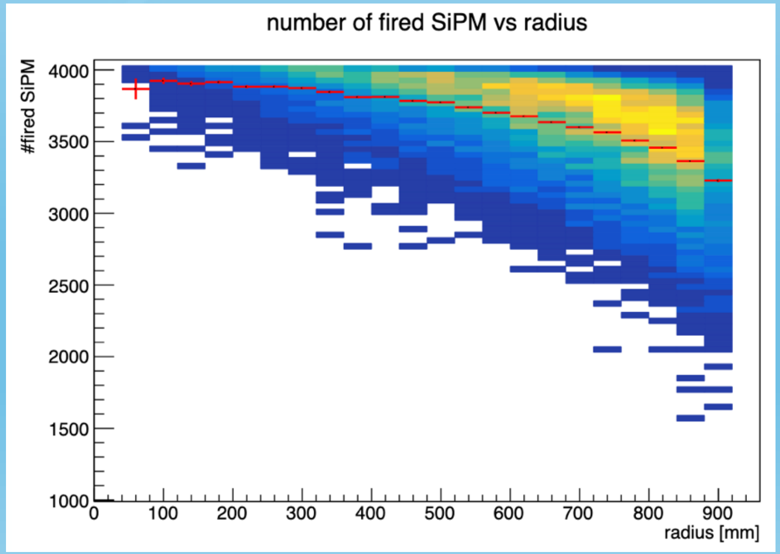


Attività passate gruppo JUNO Roma Tre

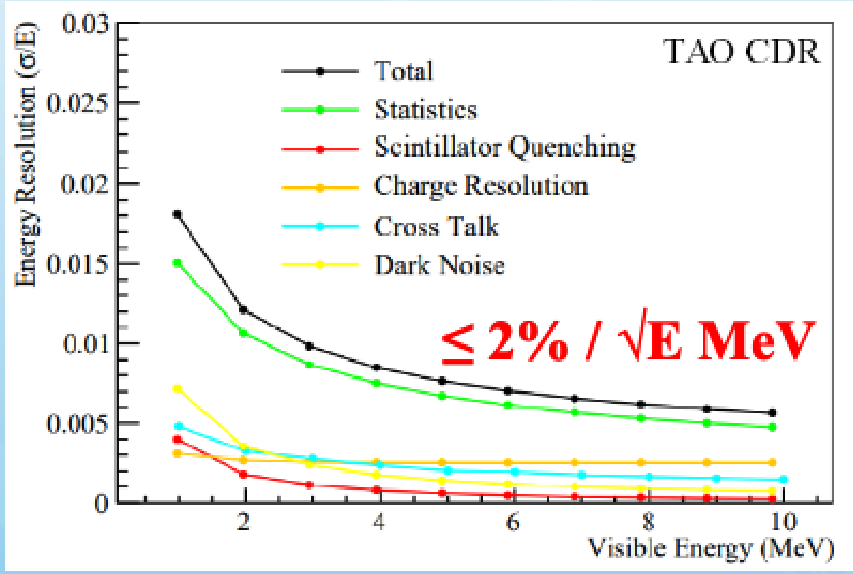
- **TAO Montecarlo Simulations e computing:**







Attività presenti gruppo JUNO Roma Tre

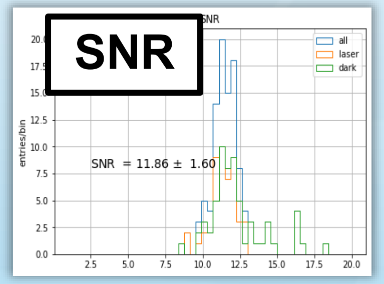


Elettronica:

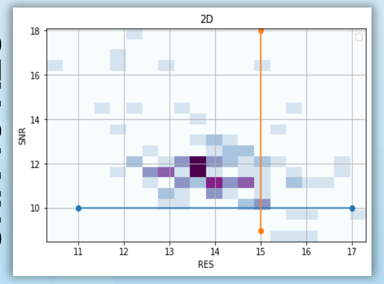
Caratterizzazione SiPM + front-end electronics

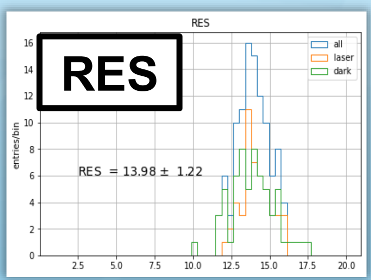
$\sigma(E)/E$ ***requirements***

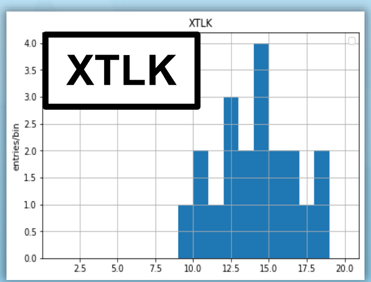
MC simulations

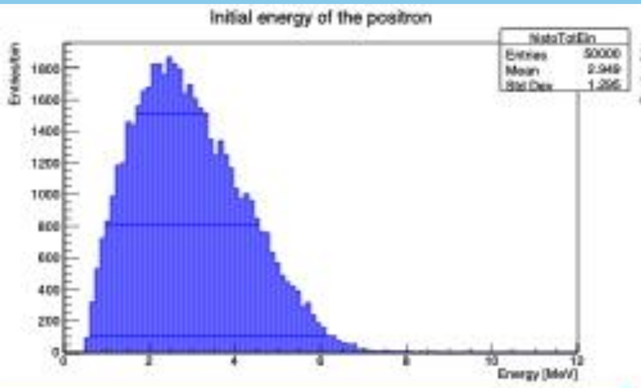


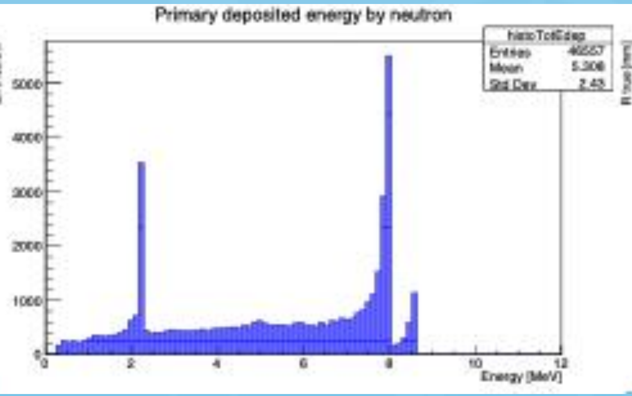
SNR vs RES

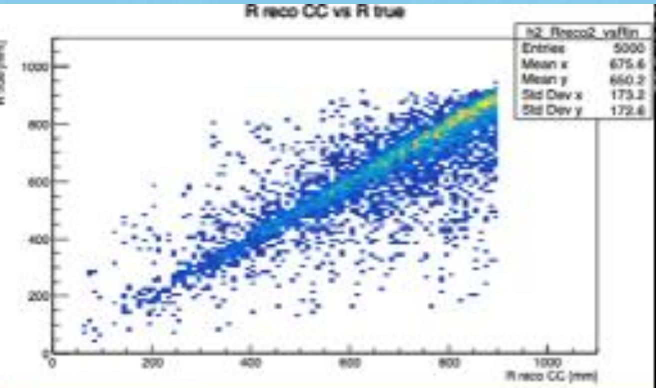


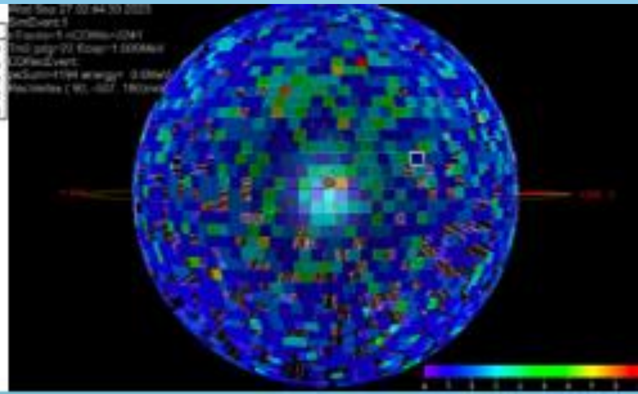












To be continued..

Grazie per l'attenzione!

Contatti: elia.stanescufarilla@uniroma3.it, fabrizio.petrucci@uniroma3.it