Detecting neutrinos from natural sources with the JUNO experiment

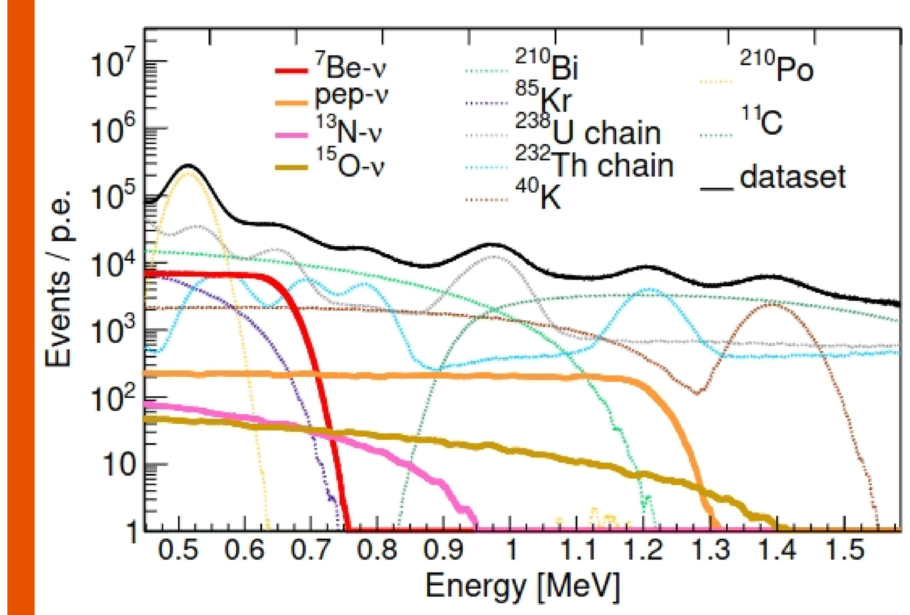
The broad JUNO physics program includes high-precision measurements of neutrino fluxes from natural sources (solar, atmospheric, terrestrial, and supernovae).

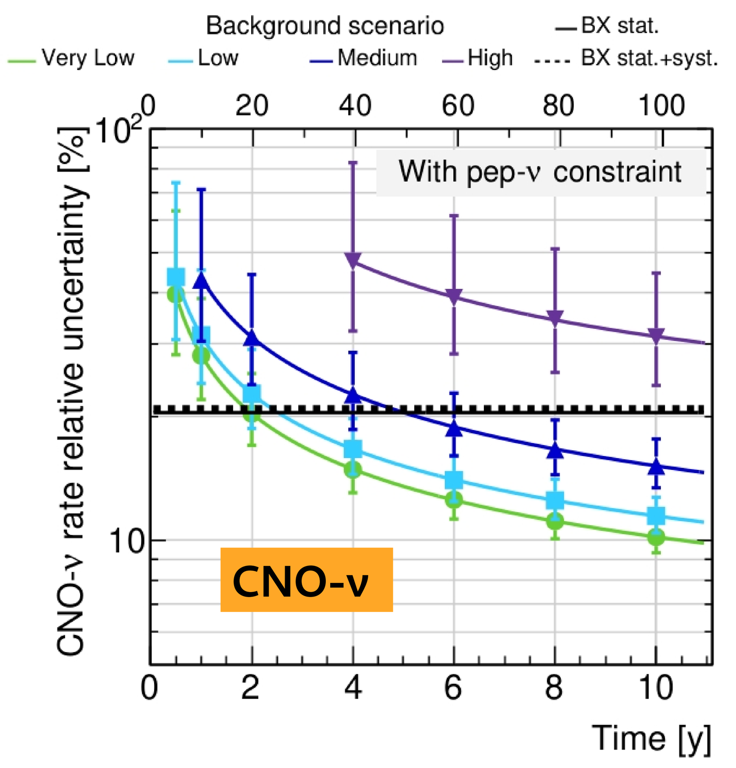
Davide Basilico (INFN)
davide.basilico@mi.infn.it
on behalf of JUNO Collaboration

Solar neutrinos

Physics goals: solving solar metallicity puzzle (mainly based on CNO neutrinos measurement) + oscillation physics + Non-Standard Interactions (JCAP 10 (2023) 022; ApJ, 2024-04, Vol.965 (2), p.122)

Expected energy spectrum for 6 years data and Medium background scenario (10x Borexino Phase-I levels) in 0.4-1.6 MeV range

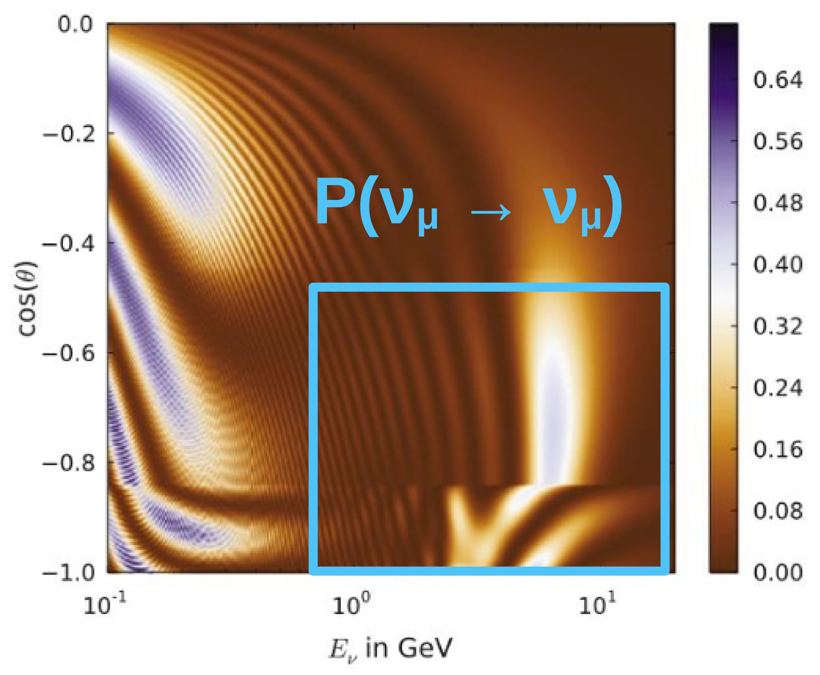


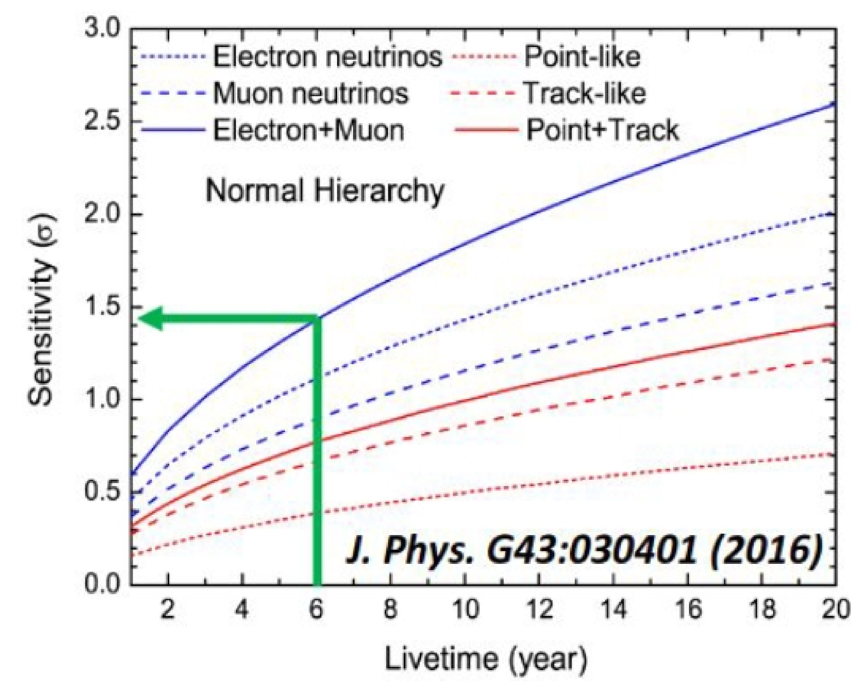


For most of the background scenarios JUNO will **improve the best results on solar ν fluxes**; for **CNO-ν**, this takes place if a constraint on the *pep*-ν rate is set.

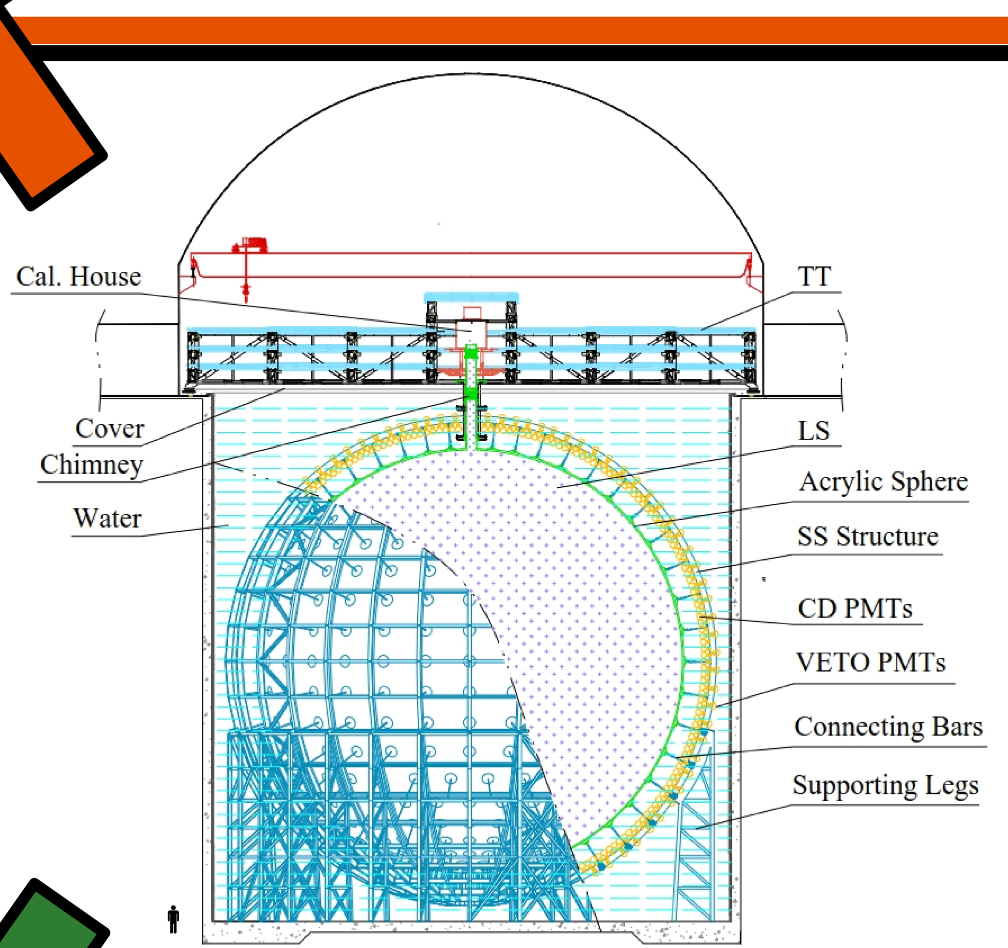
Atmospheric neutrinos

- Contribute to the NMO sensitivity (combined with reactor ν) with a complementary approach: using the matter effects on neutrino oscillations.
- JUNO will be the first to study atmospheric neutrino osc. with liquid scint.: e/μ separation, ν/anti-ν separation, ν energy (instead of lepton energy), track direction





The synergy between reactor and atmospheric ν sectors will **increase the NMO sensitivity** (0.8 - 1.4 in 6 years from atm.) and can be further improved with more advanced GeV-events reconstruction methods.



Jiangmen Underground Neutrino Observatory (JUNO)

is a 20 kton, radiopure, multi-purpose liquid-scintillator detector located in South China.

- Data taking starting in 2025.
- Low background levels: internal radiopurity + passive shielding (1900 m.w.e.).
- Excellent energy resolution: scintillator light yield (~10^4 emitted photons/MeV) + 43600 PMTs coverage (~78%) with quantum efficiency ~35%.
- Designed to measure reactor anti-neutrinos from two NPP at 52.5 km distance.
- Multipurpose: aiming to measure neutrinos from several natural sources.

Geo-neutrinos

Abundance of the radioactive elements → Radiogenic heat

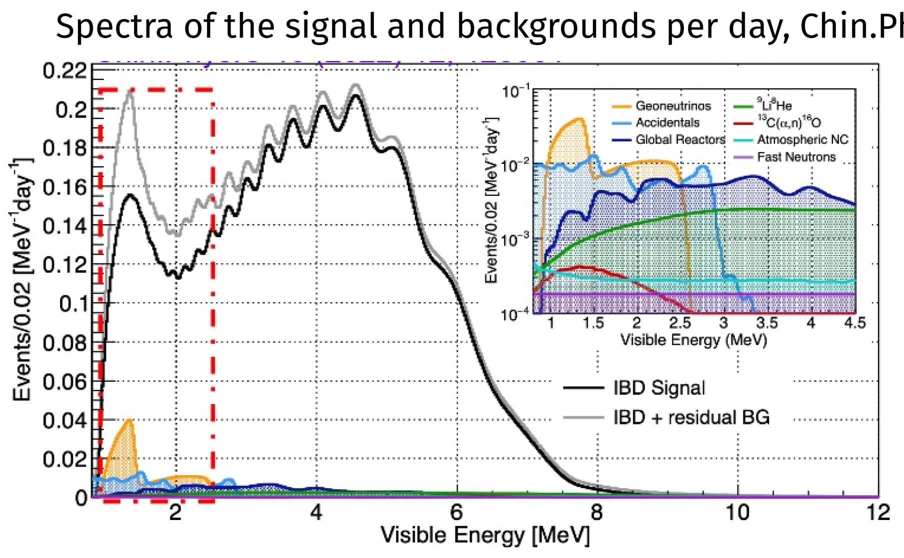
$$^{238}\mathrm{U} \rightarrow {}^{206}\mathrm{Pb} + 8\alpha + 8e^- + 6\overline{\nu}_e + 51.7\,\mathrm{MeV}$$

$$^{238}\mathrm{Th} \rightarrow {}^{208}\mathrm{Pb} + 6\alpha + 4e^- + 4\overline{\nu}_e + 42.7\,\mathrm{MeV}$$

Geoneutrino flux

→ **Unique and independent probe** to study the Earth composition and structure
→ JUNO as a **third geological location** (+ Borexino and KamLAND) for homogeneity of the radiogenic heat from the mantle
→ JUNO will collect more geo-neutrino events than all the other experiments with 1 year data (~1-2 IBDs/day) → **flux precision ~22% for 1 year and ~8% for 10 years**

Spectra of the signal and backgrounds per day, Chin.Phys.C 46 (2022) 12, 123001



Preliminary expected sensitivity [%] (Th and U free)

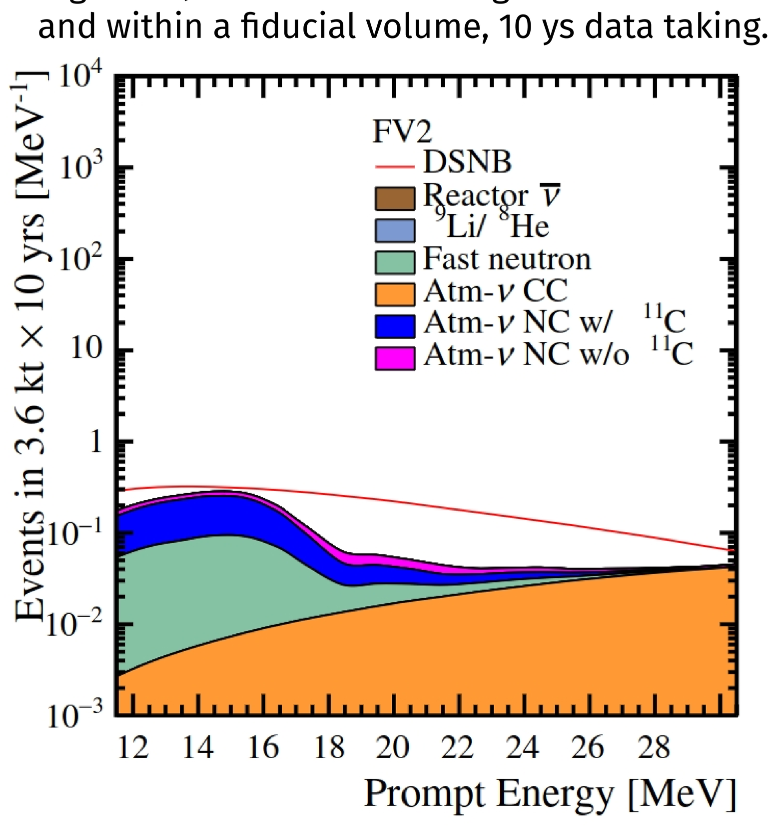
Time	U	Th	U+Th	U/Th
6 years	~35	~40	~18	~70
10 years	~30	~35	~15	~55

JUNO will provide the **world most precise geoneutrino measurements** and will measure U and Th individual contributions with high statistical significance. Potential to observe signal from mantle in JUNO is ongoing

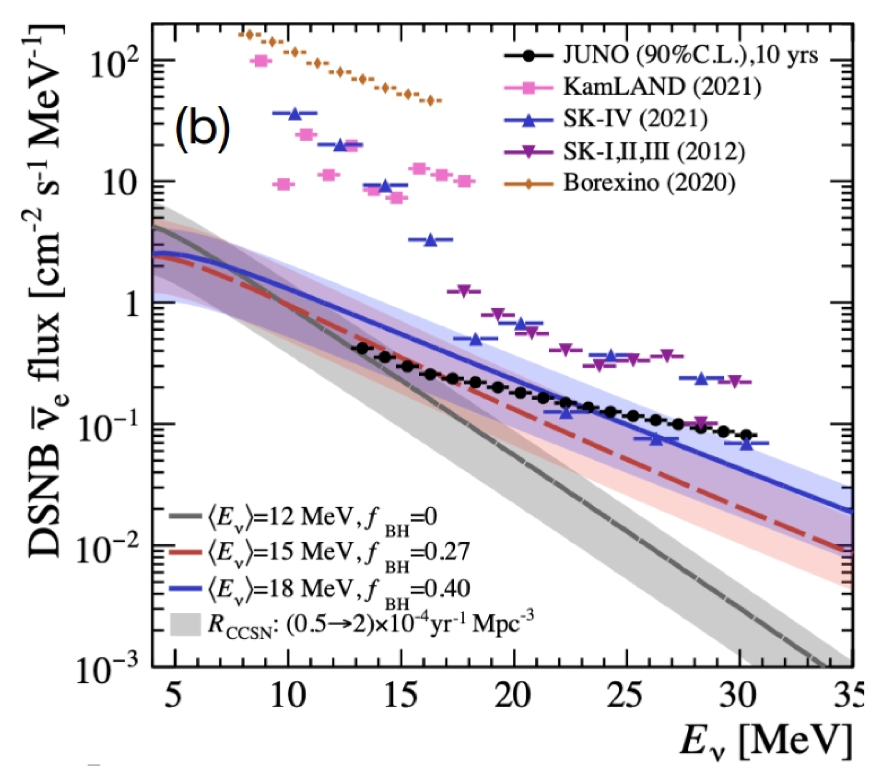
Diffuse Supernova background neutrinos

Core-Collapse Supernova (CCSN) is the final stage of $m > 8M_\odot$ stars. The large number of neutrinos produced by all SN explosions form the DSNB, still undetected.

Prompt energy spectra of the reference DSNB signal in JUNO after the background reduction and within a fiducial volume, 10 ys data taking.



90% confidence level upper limits on the DSNB fluxes.
JUNO Collaboration, JCAP 10 (2022), 033.



For the reference DSNB model, JUNO can reach the **significance of 3σ for ~3 years** of data taking, and >5σ after 10 years. Compared to KamLAND and SK, JUNO can improve the DSNB flux limits by 0.5 to 2 order of magnitude.