PHYSICS POTENTIAL OF THE JIANGMEN UNDERGROUND NEUTRINO OBSERVATORY

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GENERAL

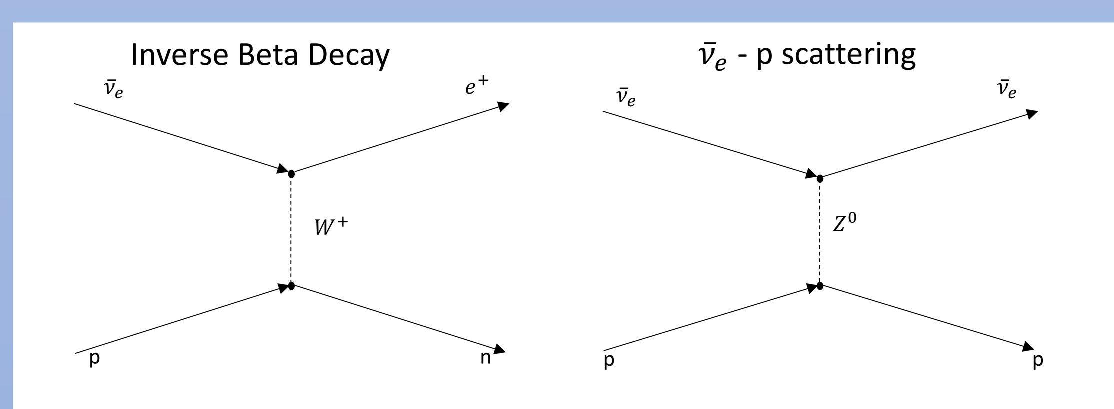
JUNO (Jiangmen Underground Neutrino Observatory) is a 20 kton multipurpose neutrino detector under construction in China and it will be completed in 2021. JUNO will be located in an underground laboratory, ~700 m under sea level, 53 km away from 2 nuclear power plants, total power ~36.6 GW, which will provide the flux of $\bar{\nu}_e$.

Two main channels to identify neutrino events, Inverse Beta Decay and elastic scattering:

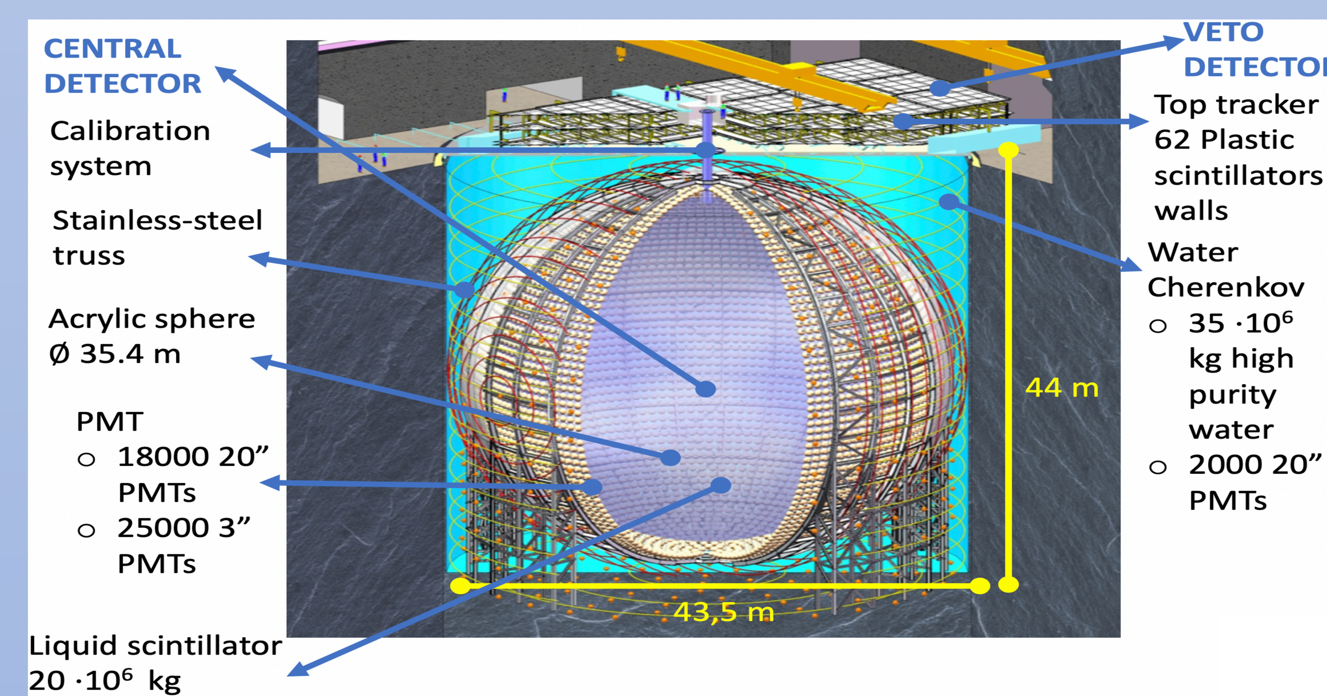
- $\bar{\nu}_e + p \rightarrow e^+ + n$ (Inverse Beta Decay)
- $\bar{\nu}_e + e^- \rightarrow \bar{\nu}_e + e^-$ (Scattering on electron)

Target energy resolution:

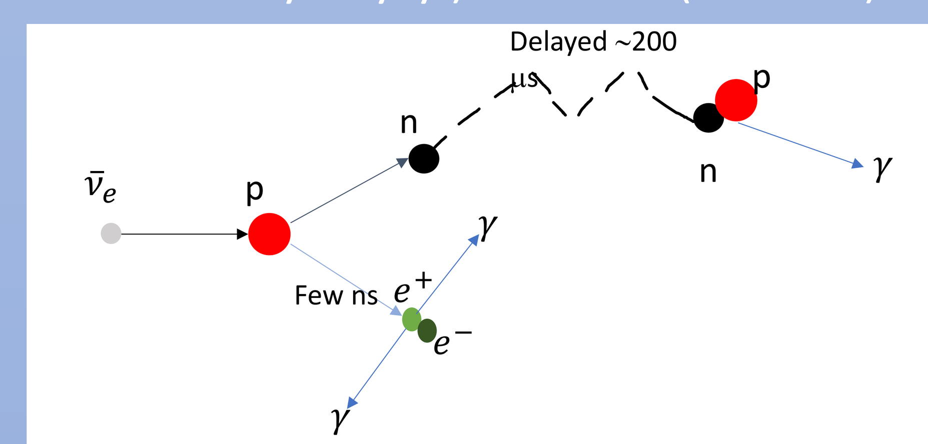
$$\frac{3\%}{\sqrt{E[MeV]}}$$



DETECTOR



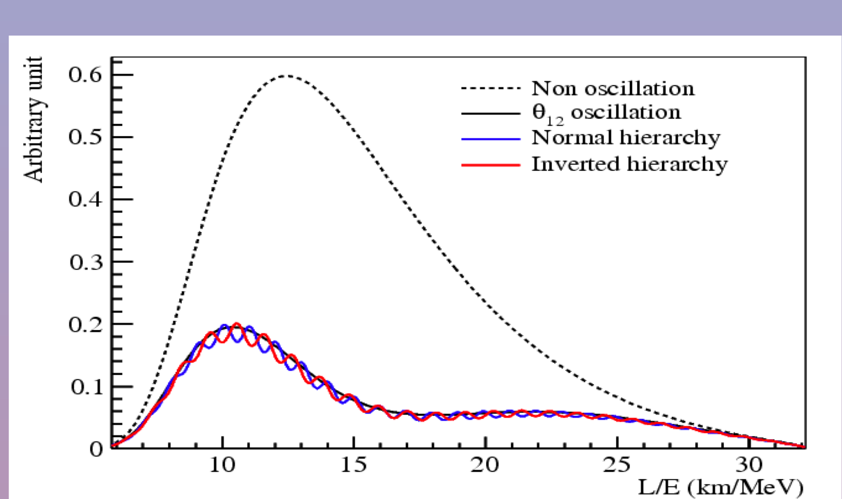
Linear Alkylbenzene (LAB) + 2.5-dyphenyloxazhole (PPO) + 1.4-bis-(2-methylstryryl)-benzene (bis MSB)



MASS HIERARCHY

Main physics goal is the determination of the neutrino Mass Hierarchy. To see it JUNO can use two different methods:

Atmospheric mass squared difference manifest itself cyclically in the energy spectrum so comparing the experimental spectrum with the theoretical one JUNO will extract the infromation about the hierarchy after performing a χ^2 test.



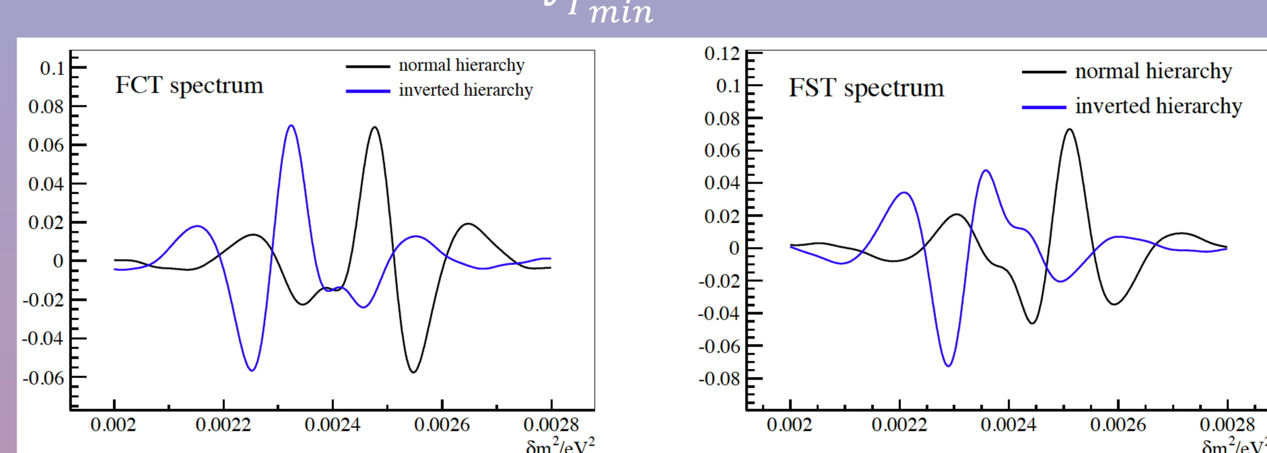
The oscillation interference effect is more visible in the frequency domain after a Fourier transformation of the spectrum. There are two possibilities:

- Fourier sine transform (FST)

$$FST(\omega) = \int_{t_{min}}^{t_{max}} F(t)\sin(\omega t)\,dt$$

- Fourier cosine transform (FCT)

$$FCT(\omega) = \int_{t_{min}}^{t_{max}} F(t)\cos(\omega t)\,dt$$



JUNO is also sensitive to:

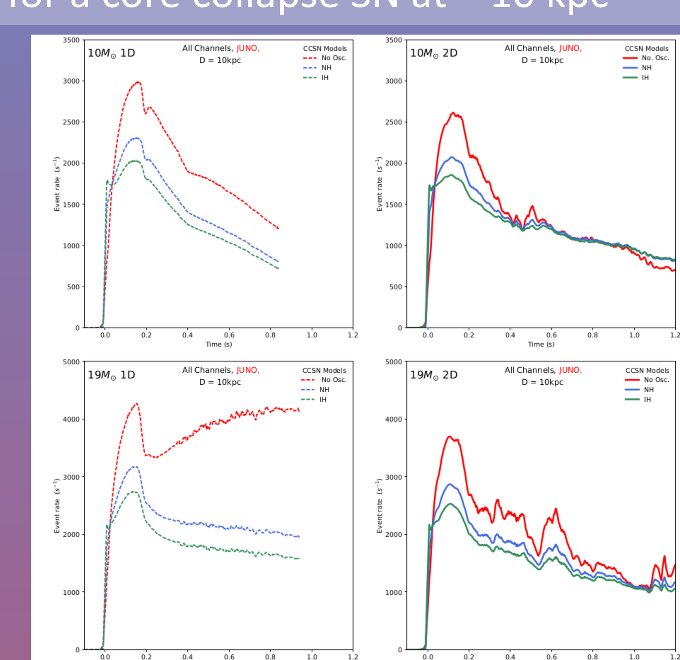
- Geoneutrino with 300 events/year[2];
- Solar neutrino, low threshold and high energy sensitivity make studies on the solar metallicity possible with high statistic;
- Atmospheric neutrino, test on Lorentz invariance, search for sterile neutrinos and DM annihilation, search for nucleon decay.

SUPERNOVA NEUTRINO

Another important topic for JUNO is the study of neutrinos coming from astrophysical sources, in particular SuperNova neutrino burst and SN neutrino diffusive flux. JUNO can see SN's ν through different channels:

- inverse beta decay, is the golden channel with ~5000*[1];
- ν-p elastic scattering, it can provide information about ν_x ~1000*[2];
- ν-e elastic scattering, it can provide information about ν_x ~300*[2].

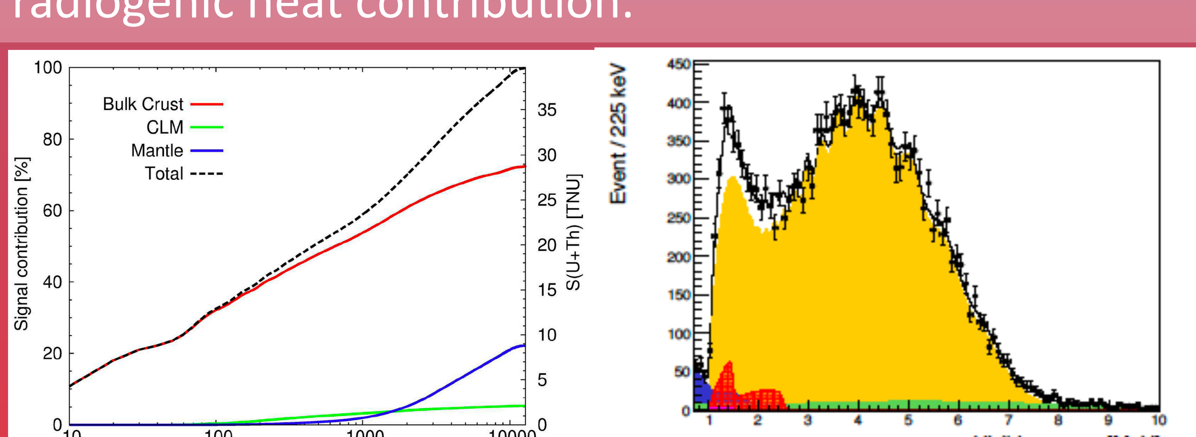
*Events are for a core collapse SN at ~10 kpc



All channels event rates (in units of s^{-1}) for a SN at 10 kpc for the 1D model for all 3 flavours oscillations theory (left) and 2D model (right).
This is shown for a progenitor of 10 $M_\odot$ (top plots) and for a progenitor of 19 $M_\odot$ (bottom plots) [3].

GEONEUTRINO

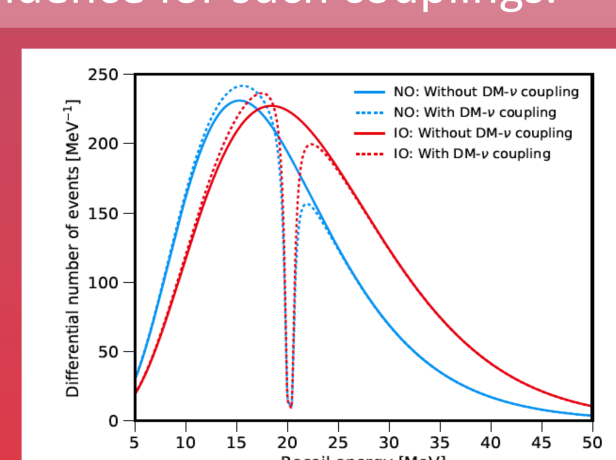
Measuring the $\bar{\nu}_e$, emitted in the ^{238}U and ^{232}Th radioactive decay chains (called geoneutrinos), helps in testing the Th/U rate. This is important to understand the abundance of radioactive elements (to know exactly the composition of Earth) and the radiogenic heat contribution.



On left panel the contribution in the signal from different components of Earth in function of distance from JUNO. On right panel IBD signal (simulated) after 1 year: in red geoneutrinos' signal, in yellow signal from reactor neutrinos while in green background from Li and in blue background from accidental events

DARK MATTER

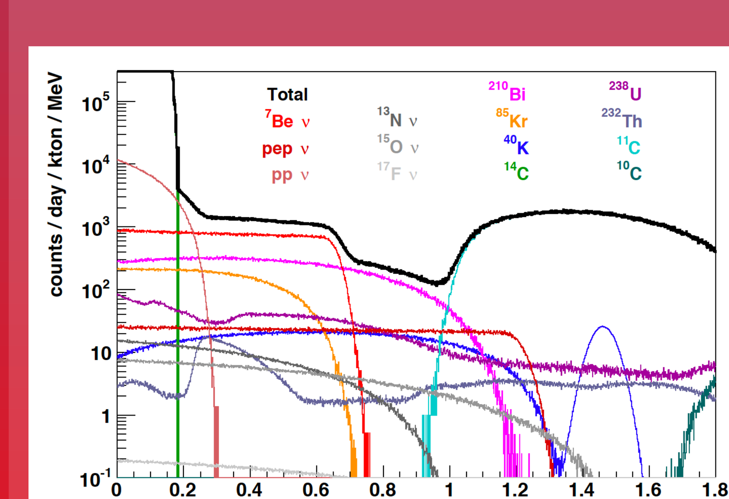
Resonant interactions between neutrinos from a Galactic supernova and dark matter particles can lead to a sharp dip in the neutrino energy spectrum. Due to its excellent energy resolution, measurement of this effect can provide evidence for such couplings.



Differential number of electron antineutrinos observed in JUNO for a typical supernova at a distance of 10 kpc, as a function of the detected positron recoil energy[4].

SOLAR NEUTRINO

The JUNO detector has many advantages in performing solar neutrinos measurements. It has the benefit of high light yield, very high energy resolution and low energy threshold. Thanks to this features JUNO will remeausure the flux of ^{7}Be and ^{8}B



Internal radiopurity requirements		
	baseline	ideal
^{210}Pb	5×10^{-24} [g/g]	1×10^{-24} [g/g]
^{85}Kr	500 [counts/day/kton]	100 [counts/day/kton]
^{238}U	1×10^{-16} [g/g]	1×10^{-17} [g/g]
^{232}Th	1×10^{-16} [g/g]	1×10^{-17} [g/g]
^{40}K	1×10^{-17} [g/g]	1×10^{-18} [g/g]
^{14}C	1×10^{-17} [g/g]	1×10^{-18} [g/g]
Cosmogenic background rates [counts/day/kton]		
^{11}C	1860	
^{10}C	35	
Solar neutrino signal rates [counts/day/kton]		
pp ν	1378	
^{7}Be ν	517	
pep ν	28	
^{8}B ν	4.5	
^{13}N/^{15}O/^{17}F ν	7.5/5.4/0.1	

Expected singles spectra at JUNO and radiopurity requirements.

[1] An, F. et al. *Neutrino physics with JUNO*, Journal of Physics G: Nuclear and Particle Physics 43.3 (2016): 03040.
[2] Miramonti, L. *Neutrino Physics and Astrophysics with the JUNO Detector.*, Universe 4.11 (2018): 126.
[3] Seadrow, S. et al. *Neutrino signals of core-collapse supernovae in underground detectors*. Monthly Notices of the Royal Astronomical Society 480.4 (2018): 4710-4731.
[4] Liao, Jiajun, Danny Marfatia, and Kerry Whisnant. "Light scalar dark matter at neutrino oscillation experiments." Journal of High Energy Physics 2018.4 (2018): 136.

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