Neutrino 2014 Poster Session-Boston, June 2-7, 2014

Physics Potential of the Jiangmen Underground Neutrino Observatory (JUNO)

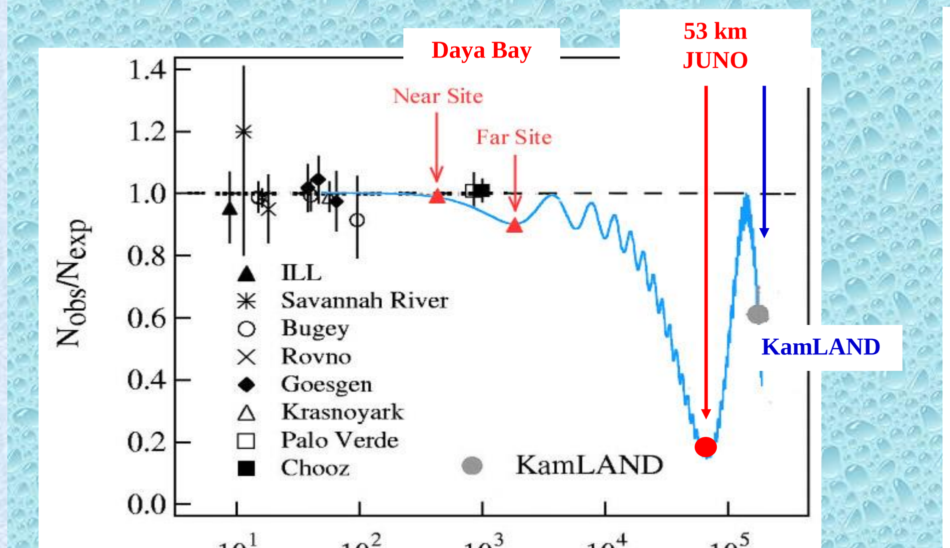
1. Introduction

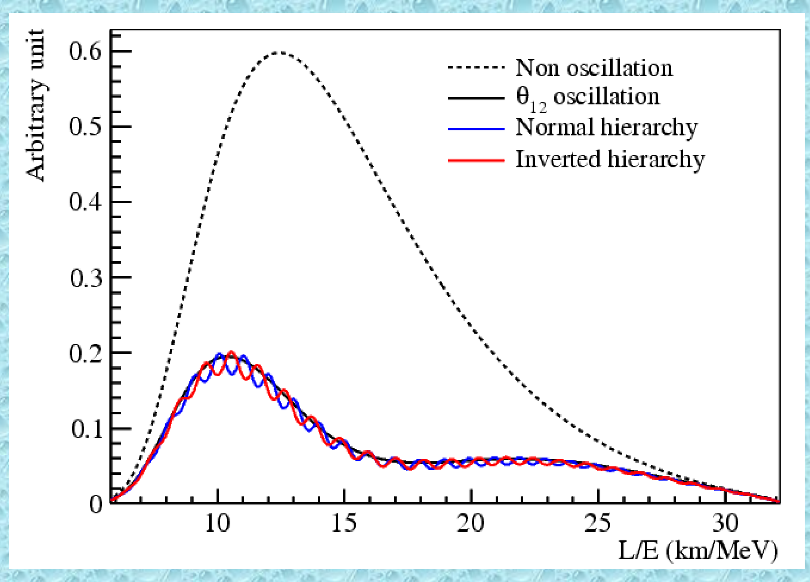
- After the discovery of non-zero theta_13, the **neutrino mass hierarchy (MH)** and the **lepton CP violation (CPV)** are the central concerns in neutrino oscillation experiments.
- The MH can be determined in the oscillations of accelerator neutrinos, reactor neutrinos and atmospheric neutrinos.
- The **Jiangmen Underground Neutrino Observatory (JUNO),** which is located at Kaiping, Jiangmen in South China, is designed to **determine the neutrino MH** using reactor neutrino oscillations **[PRD 78, 111103 (2008)].**
- We shall present some selected topics on the physics potential of JUNO,

  (a) the MH; (b) precision measurement; (c)supernova neutrinos;

  (d) diffuse supernova neutrinos; (e) Other opportunities.

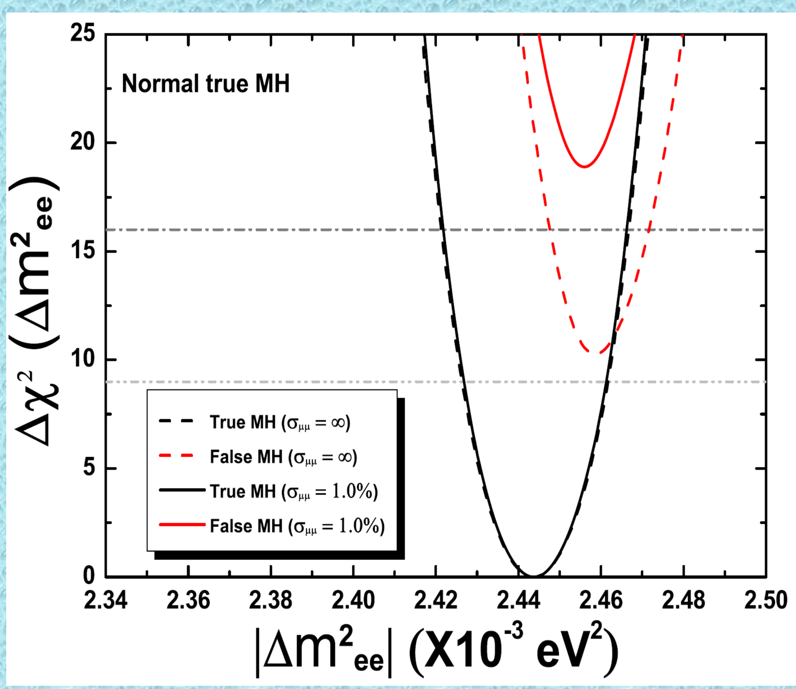
2. Baseline and Location





- The optimum baseline is required to be at the oscillation maximum of Δm^2_{21} .
- Fine structure of Δm^2_{31} oscillations is used to determine the MH.

3. Mass Hierarchy



The MH (median) sensitivity with 6 years' data of JUNO:

[PRD 88, 013008 (2013)]:

3-sigma for purely relative spectral measurement.

4-sigma with the external Δm^2 measurement

(if the accelerator neutrino experiment can measure Δm^2 to ~1% level)

after taking into account:

(a) the spread of reactor cores,

(b) the reactor uncertainties,

(c) the energy uncertainties

(d) residual non-linearity (1%).

Nominal setups:

20 kt liquid scintillator (LS) detector

3%/sqrt(E) energy resolution

52-53 km baselines, 36 GW and 6 years

4. Precision Measurement

- JUNO is the first experiment to **simultaneously** observe neutrino oscillations from both **atmospheric and solar** neutrino mass splitings.
- JUNO is the first experiment to observe **more than two oscillation cycles** of the atmospheric mass spliting.

	Current	JUNO
Δm^2_{12}	~3%	~0.5%
$\lvert\Delta m^2_{23}\rvert$	~4%	~0.6%
$\sin^2\theta_{12}$	~7%	~0.7%
$\sin^2\theta_{23}$	~15%	N/A
$\sin^2\theta_{13}$	~10% ~4%	~ 15%

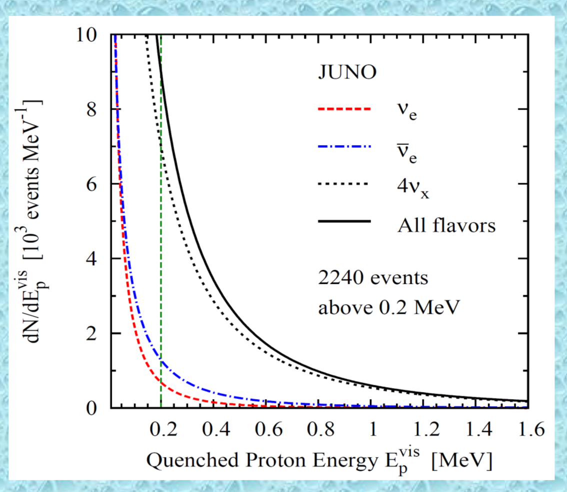
- JUNO will be unprecedented **precision measurements** of three of oscillation parameters to **better than 1%**.
- JUNO is a powerful tool to test the **standard three-neutrino model**.
- Precision spectral measurement is crucial to probe **additional neutrino species and interactions**.

5. Supernova Neutrinos

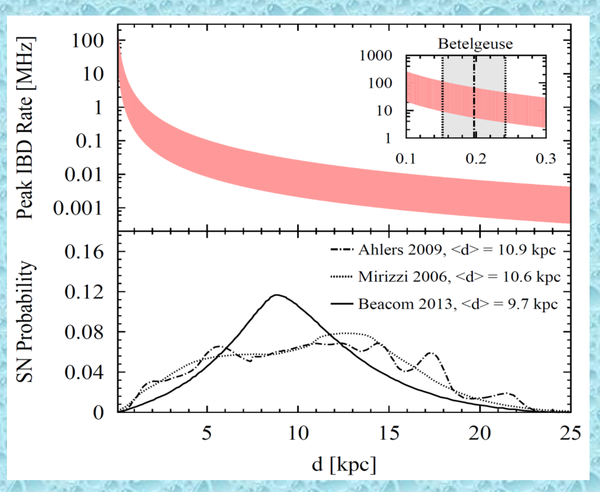
Channel	Type	Events for different $\langle E_\nu \rangle$ values 12 MeV	14 MeV	16 MeV
$\overline{\nu}_e + p \to e^+ + n$	CC	4.3×10^3	5.0×10^3	5.7×10^3
$\nu + p \to \nu + p$	NC	6.0×10^2	1.2×10^3	2.0×10^3
$\nu + e \to \nu + e$	NC	3.6×10^2	3.6×10^2	3.6×10^2
$\nu + {}^{12}\text{C} \to \nu + {}^{12}\text{C}^*$	NC	1.7×10^2	3.2×10^2	5.2×10^2
$\nu_e + {}^{12}\text{C} \to e^- + {}^{12}\text{N}$	CC	4.7×10^1	9.4×10^1	1.6×10^2
$\overline{\nu}_e + {}^{12}\text{C} \to e^+ + {}^{12}\text{B}$	CC	6.0×10^1	1.1×10^2	1.6×10^2

Numbers of neutrino events at JUNO for a SN at a distance of 10 kpc.

- For a galactic supernova (SN) at 10 kpc, JUNO will register about **5000 events** from inverse beta decay (IBD),
- **2000 events** from **all-flavor** elastic neutrino-proton scattering if the energy threshold of **0.2 MeV** is achieved.



Elastic neutrino-proton events

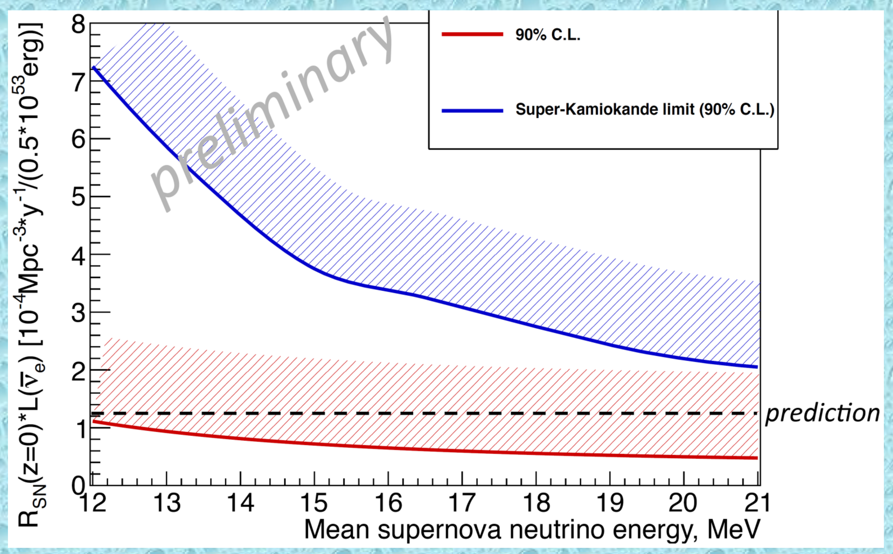


Maximum IBD rate as a function of the distance

- SN neutrino events with **high statistics**, **flavor information**, **good energy resolution,** give us a great oppotunity to study **astrophysical** pictures of SN and **physical** pictures of the neutrino oscillation.

6. Diffuse Supernova Neutrinos

- **Supernova explosions** occurred in both the past and present universe make a diffuse neutrino background, i.e., **diffuse supernova neutrinos.**
- **Detecting or even setting limits on their flux** can give us quite useful and unique implications for astrophysics, cosmology and particle physics.
- **Expected event rate: 3-6 events per year.**
- Main background:
  reactor antineutrino events,
  atmospheric neutrino CC and NC events,
  fast neutrons
- Pulse shape analysis
- Signal to background ratio **better than 1**.
- JUNO: Chance for discovery
  (2-3 sigma for 10 years)



7. Other opportunities

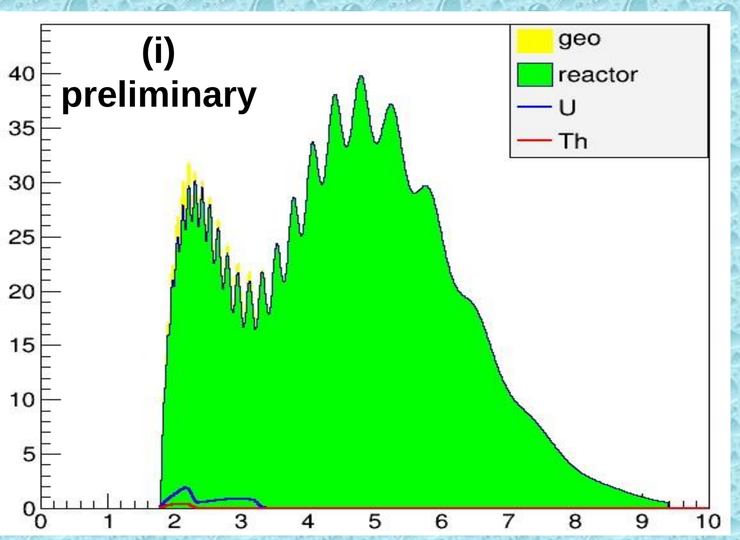
(i) Geoneutrinos

KamLAND: **30±7 TNU** [PRD 88 (2013) 033001]

Borexino: **38.8±12.0 TNU** [PLB 722 (2013) 295]

JUNO (expected, preliminary):

37 ± 10%(stat) ± 10%(syst) TNU



(ii) Proton decay

- JUNO is competitive and complementary in search for nucleon decays. In particular, in the SUSY favored decay channel:

$$P \to K^+ + \bar{\nu}$$

- Pulse shape for background reduction
- If no candidate found (assuming 0.5 bg/10 yr)

$$\tau > 1.9 \times 10^{34}\ \text{yr}\ (90\%\ \text{C.L.})$$

(iii) Solar neutrinos

Radioactive and/or **cosmogenic** backgrounds are crucial for the detection of **pp** and **CNO** solar neutrinos.

(iv) Atmospheric neutrinos

- LS detector has some advantages for low energy atmospheric neutrinos.

8. Conclusion

- JUNO is a **multipurpose neutrino Observatory** with the physics potential ranging from neutrino physics to neutrino astronomy and neutrino geoscience.
- With the precision spectral measurement, JUNO can resolve the **neutrino mass hierarchy** and measure three of oscillation parameters **to better than 1%.**
- JUNO is competitive in observing the supernova neutrinos with the advantages of high statistics, flavor identification and good energy resolution.
- JUNO is also competive in the aspects of diffuse supernova neutrinos, geoneutrinos and neucleon decays.
- **A yellow book** to explore the full physics potential is being written, and will release to the community by the end of this year.

- **I am grateful to** Dr. Shun Zhou (supernova neutrinos), Dr. Michael Wurm (diffuse supernova neutrinos), Dr. Ran Han (geoneutrinos), and Dr. Zhe Wang for their useful inputs; and to the whole proto-Collabaration for giving me the opportunity to present this poster at **Neutrino 2014.**

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On behalf of the JUNO proto-Collaboration

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