# Detection of Core-Collapse Supernova Neutrino (CCSN) at JUNO

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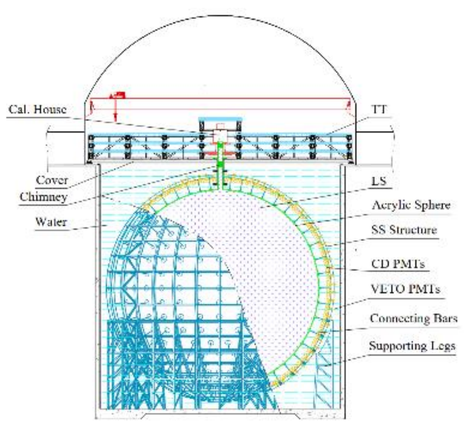
## Introduction of JUNO

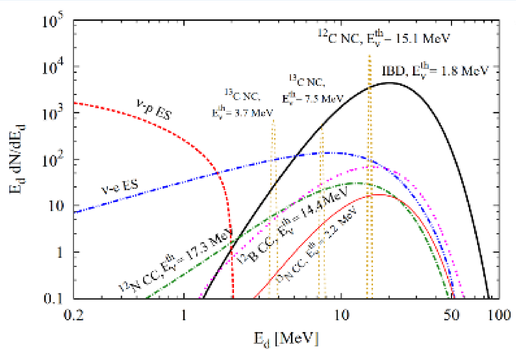
**The detector:** [1]
- 20k ton LS
- 30k ton water
- 3% energy resolution @1MeV
- ~18000 20-inch large PMTs
- ~26000 3-inch small PMTs




**Multi-purpose:**
- Neutrino mass ordering
- Precision measurement of oscillation parameters
- **Supernova neutrino**
- Solar neutrino, DSNB, geo-neutrino, …

## Multi-channel detection of CCSN

Figure [1]: The neutrino event spectra with respect to the visible energy in JUNO for a SN at 10kpc.



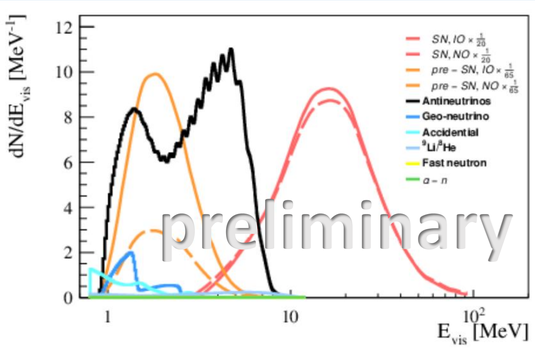




Figure: The energy spectra of SN, pre-SN IBDs and their backgrounds. Here, the spectrum of SN and pre-SN IBDs are scaled by different factors. Nakazato[2] and Patton[3] models with 30 solar mass are used.

| Interaction channels | IBD | pES | eES | C12, NC | C12, CC |
|---|---|---|---|---|---|
| Expected statistics@10kpc | 5000 | 2000 | 300 | 300 | 200 |

## CCSN real time monitor system

The real time monitor system at JUNO is aimed at providing early alerts and record CCSN data as much as possible. Hence, a redundancy design consists of prompt monitor and online monitor is proposed. If an alert is found, it will be sent to the internal collaboration and astronomical communities.

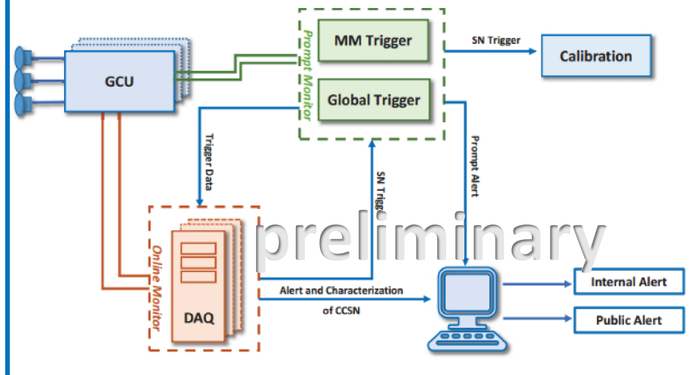
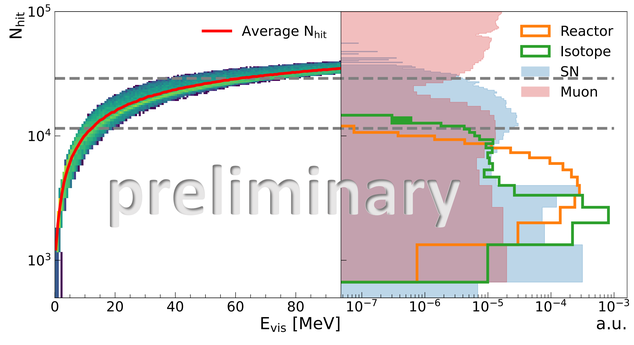



Figure: The schematic overview of JUNO's real time monitor system design. It includes two sub-systems: the prompt monitor and online monitor.

## Prompt monitor

Based on MM trigger:
- Lower energy threshold: ~20keV
- Online particle identification




Based on global trigger:
- Based on global trigger to monitor SN neutrinos.
- Select SN neutrino events by utilizing *nHit,* which is proportional to the visible energy, as is shown in the figure.
- Water pool trigger is performed to suppress backgrounds related to muons.

References:
[1] JUNO Physics and Detector, arXiv:2104.02565
[2] Astrophys. J. Suppl.205(2013), 2
[3] Astrophys. J.851(2017) no.1, 6
[4] *M.~Mukhopadhyay et al, Astrophys.J.* 899 (2020) 2, 153

## Online monitor

Perform at **DAQ** stage.
- Using trigger-less T/Q data given by FPGA.
- Software trigger to extract events.
- **Maximizing alert ability** using offline reconstruction algorithms.
- Selecting SN and pre-SN candidates to monitor their event rate separately: SN monitor and pre-SN monitor.
- **Fast characterization** using the accumulated events: CCSN direction reconstruction from both SN and pre-SN, …

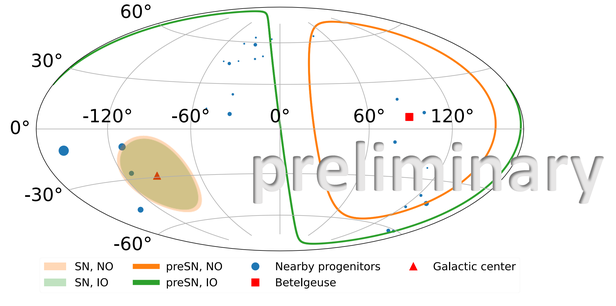



Figure: Schematic diagram for demonstration of CCSN direction reconstruction of JUNO using IBD events for SN@10kpc and pre-SN@0.2kpc. Direction is reconstructed by the average of unit vectors of IBD events [4]. The unit vector is calculated by connecting the vertex of prompt and delayed signal.