Towards a Reconstruction of Supernova neutrino spectra with JUNO

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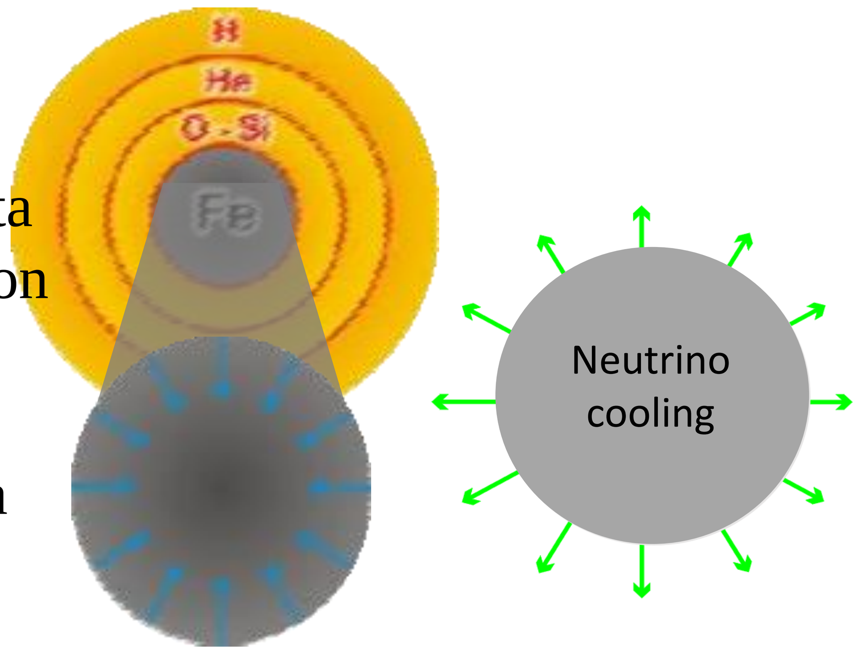
1. SN neutrino burst

- The spare SN1987A neutrino data provide us precious information on the total energy and average energy of the SN neutrinos. But details of the SN neutrino spectra are still unkown.



- Future large liquid scintillator detectors(e.g. JUNO) can give a high-statistics observation of supernova neutrino burst.

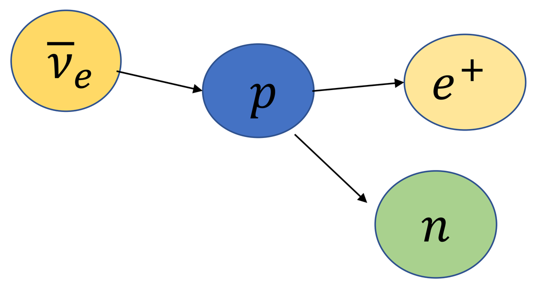
Grav. binding energy $E_{th} \approx 3 \times 10^{53}\ erg$

This shows up as:

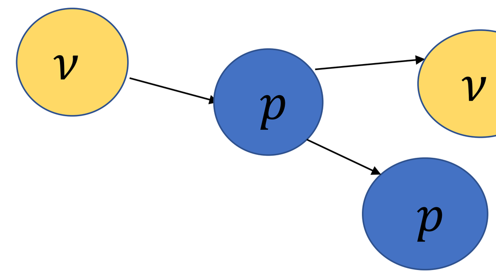
99% Neutrinos
1% Kinetic energy of the explosion
(1% of this into Cosmic Rays)
0.01% Photons, outshine host galaxy

2. Detection channels in JUNO

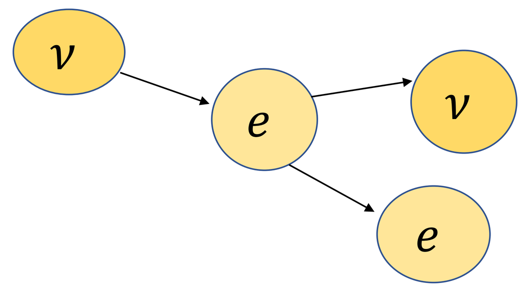
IBD: $\bar{\nu}_e + p \rightarrow e^+ + n$



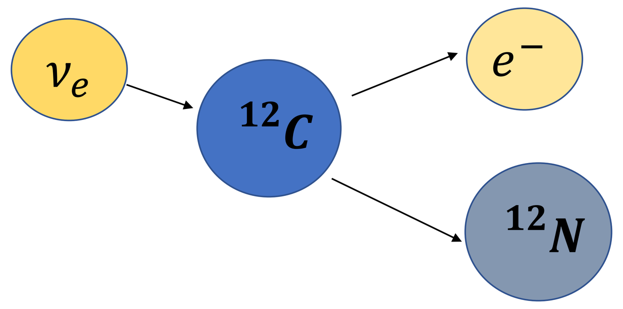
pES: $\nu + p \rightarrow \nu + p$



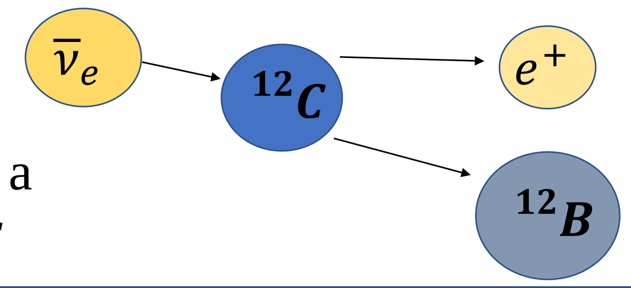
eES: $\nu + e \rightarrow \nu + e$



$\nu_e - {}^{12}C$ ***Scattering***: $\nu_e + {}^{12}C \rightarrow e^- + {}^{12}N$



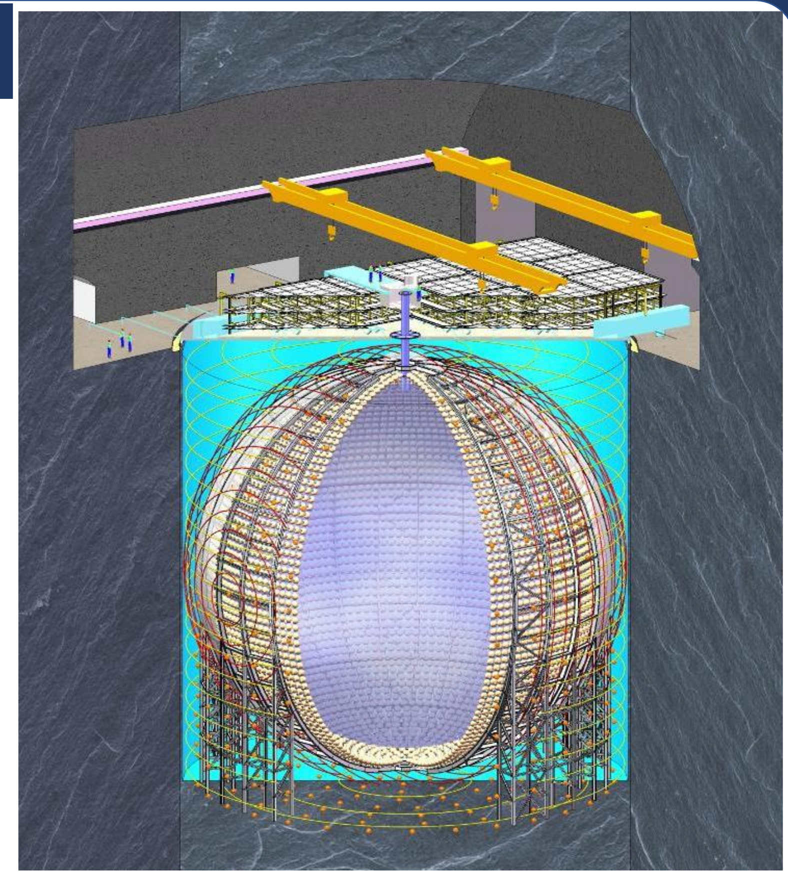
$\bar{\nu}_e - {}^{12}C$ ***Scattering***: $\bar{\nu}_e + {}^{12}C \rightarrow e^+ + {}^{12}B$

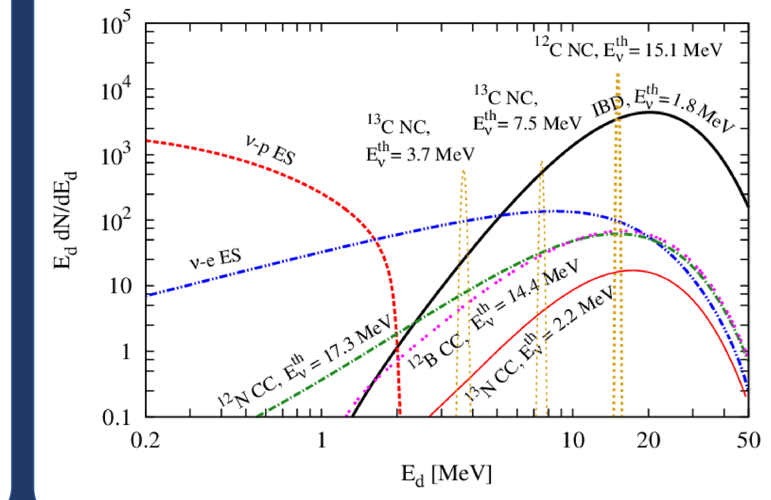


For an average SN at ~10 kpc JUNO could detect ~ 5000 IBD, 1500 pES, 400 eES and a few hundreds of events of scattering on ${}^{12}C$

3. Juno Detector

- 20 kton of liquid scintillator detector
- Acrylic sphere :35.4 m diameter
- **Double PMT system**
  - 18.000 large PMTs (20'' diameter)
  - 25.000 small PMTs (3'' diameter)
- **Outer Water Pool**
  - 2.400 20'' PMTs , Cherenkov veto
- **Top Tracker** made with scintillator stripes
- 650 m underground
- 3%/$\sqrt{E/MeV}$ resolution





SN visible energy spectra in JUNO

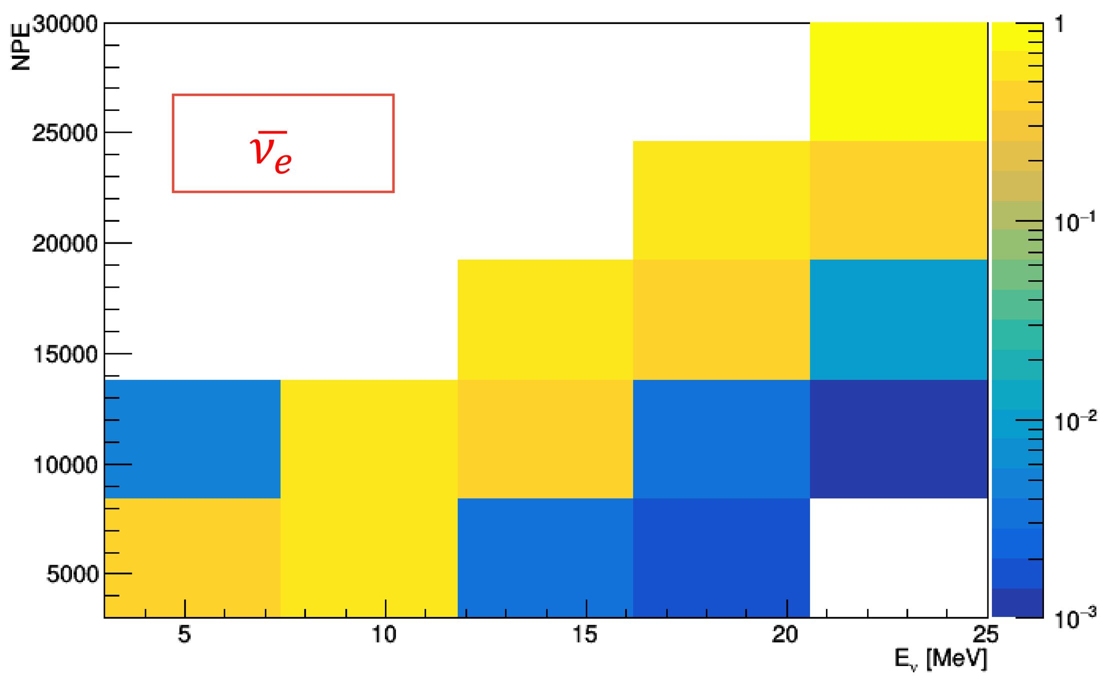
4. Bayesian Unfolding of the Energy Spectra

Requirements for SN Early Warning

- Non-stop continuous monitoring
- No affected by any RUN mode

→ (Q,T,W)

Reconstructed Charge [p.e]



$U_{ij} = P(E_{\nu_i}|Npe_{LPMT_j})$

Requirements for SN data taking :

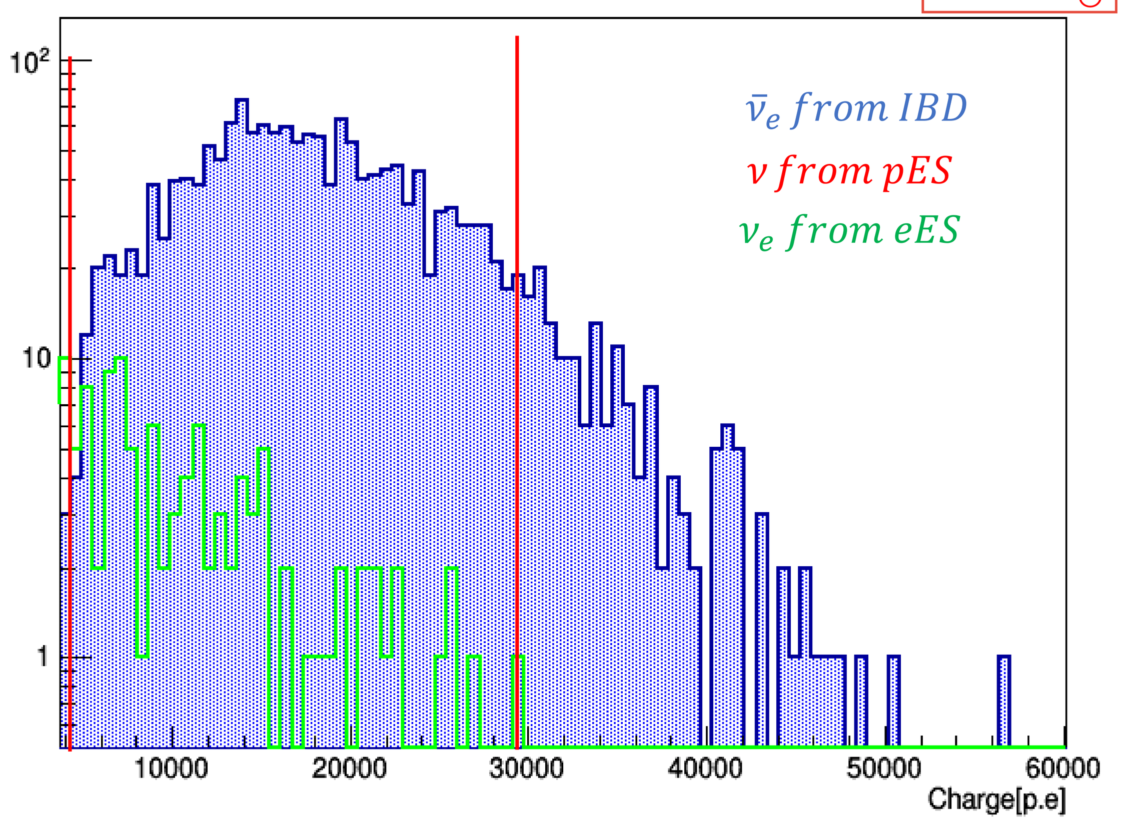
- For D>1kpc there is no data loss
- For D<1kpc due to the high event rate there is the need

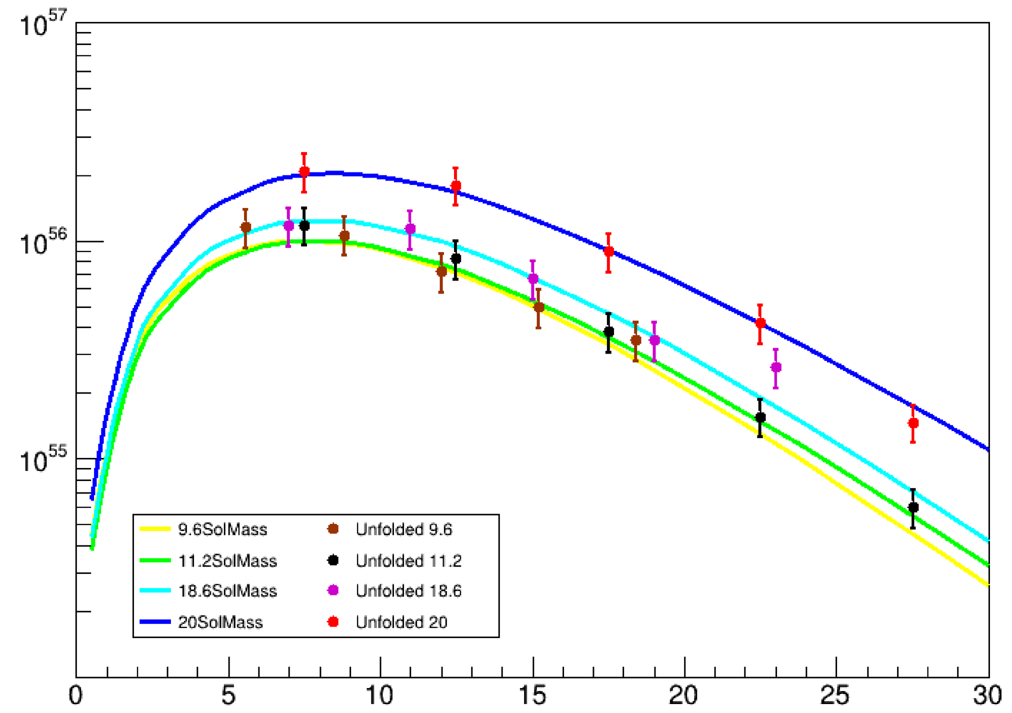
to acquire more informations as it is possible

$$M_j = \sum_i A_{ji} N_i$$

$$N_i = \sum_j U_{ij} M_j$$

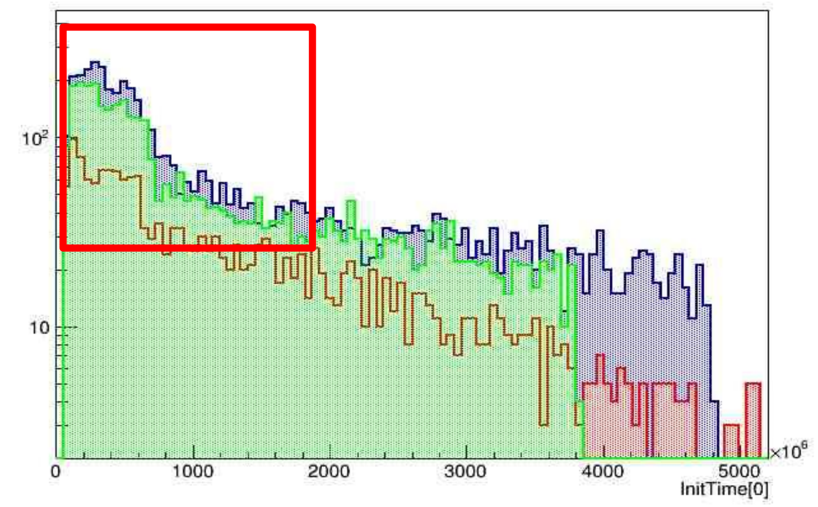
4.E3 < Charge$_{LPMT}$ < 30.E3





Reconstructed Energy spectra for the IBD channel in JUNO for 9.6$M_\odot$, 11.2$M_\odot$, 18.6 $M_\odot$, 20$M_\odot$ for the Garching Model

5. Unfolding Method on Mass Progenitor



- We are approaching the possibility to develop an algorithm to distinguish different masses region and create a first classification based on the time profile of the different Progenitors

Time profile for 3 different Mass Progenitors

The observable will be evaluated with a Bayesian procedure to evaluate the probability of a different Mass progenitor

	9.6 $M_\odot$	11.2 $M_\odot$	18.6 $M_\odot$	20 $M_\odot$	25 $M_\odot$
Time [ns]	In progress	$0 < t < 1.6x10^8$	$0 < t < 1.6x10^8$	In progress	$1.6x10^8 < t < 3.6x10^8$
Max peak value	In Progress	$0 < m < 60$	$60 < m < 90$	In progress	$100 < m < 140$

6. Conclusion

- JUNO has the capability to detect SN neutrinos and to act together with other neutrino experiments as an alert system
- Reconstruction of the SN energy neutrino spectra gives us the chance to learn useful information about the SN evolution mechanism
- This method allows us to extract the SN physical parameters

7. References

[1] TechNote: Supernova burst neutrino generator in JUNO (JUNO DocDB-3883)