Supernova neutrino energy spectrum reconstruction in JUNO with a probabilistic unfolding method

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On behalf of the JUNO Collaboration

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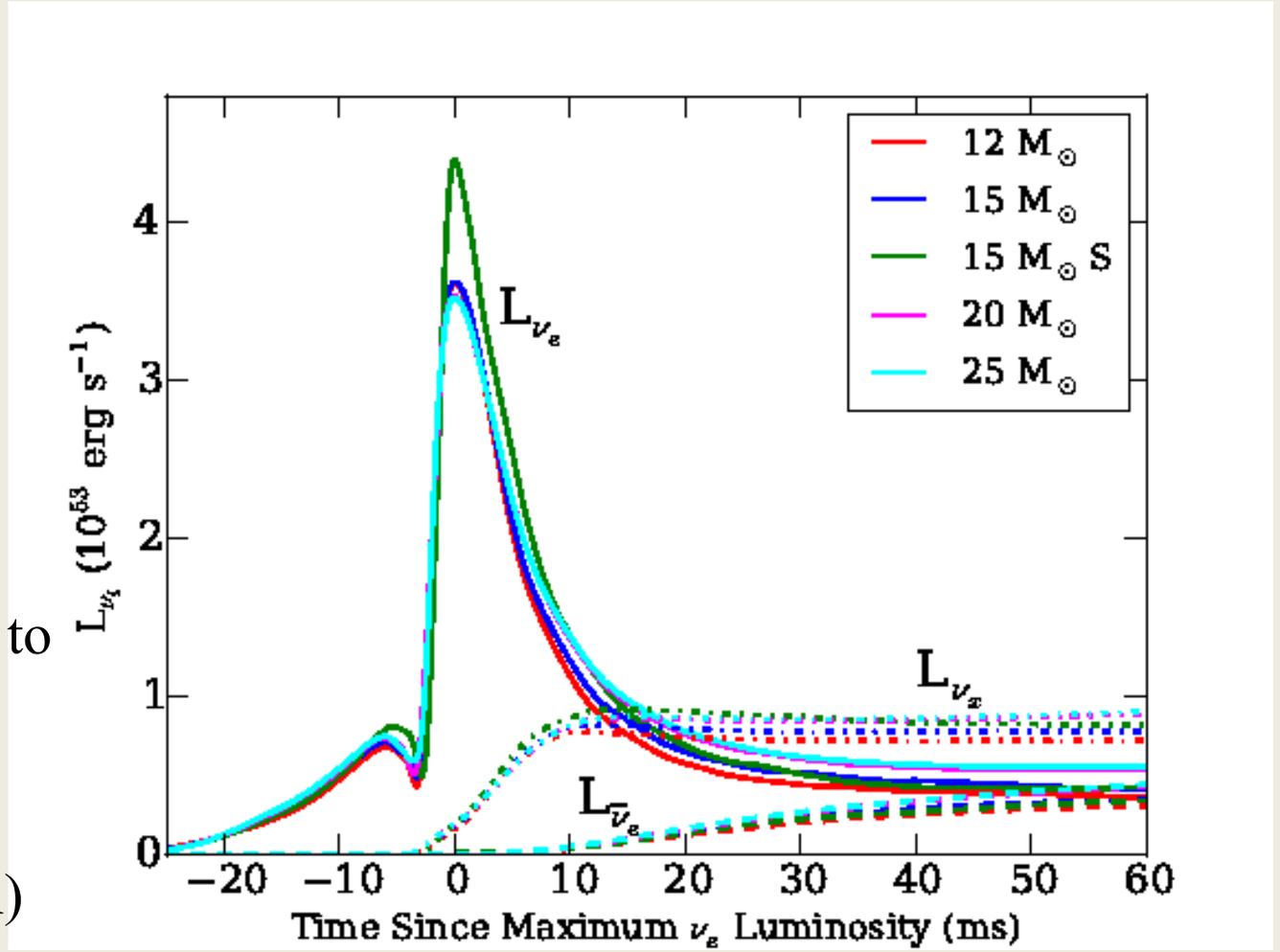
Supernova neutrinos

- 99 % of the energy in core collapse gets carried away by neutrinos
- Supernova neutrinos arrive to Earth in roughly 10-20 second burst
- Core collapse Supernovae are estimated to occur just a few times in a century
- Many models are provided for time and energy profile of the burst
  - Last observed Supernova (SN1987A) didn't provide enough data to a complete analysis

- The next SN event can obvioulsy can procure important informations

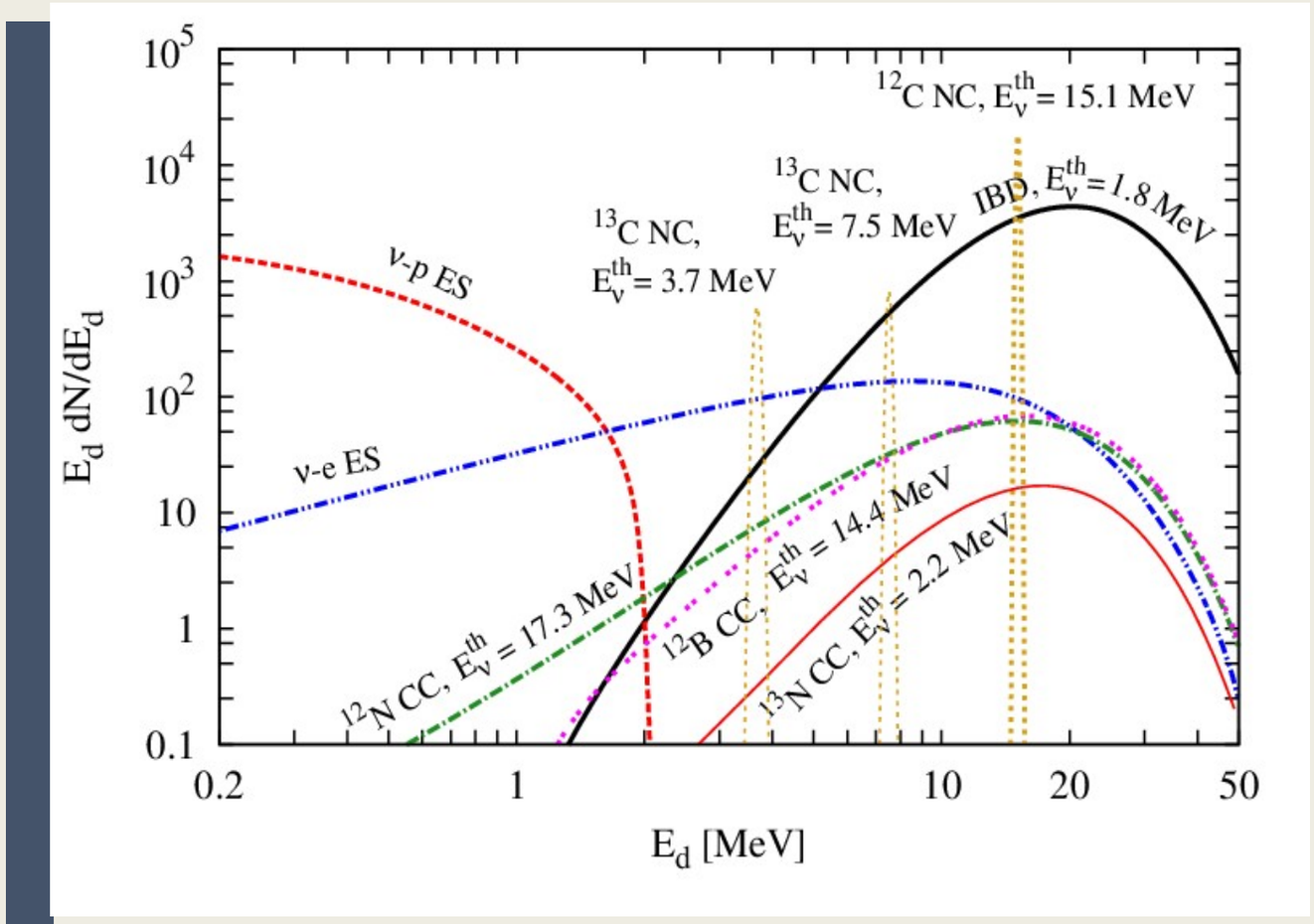


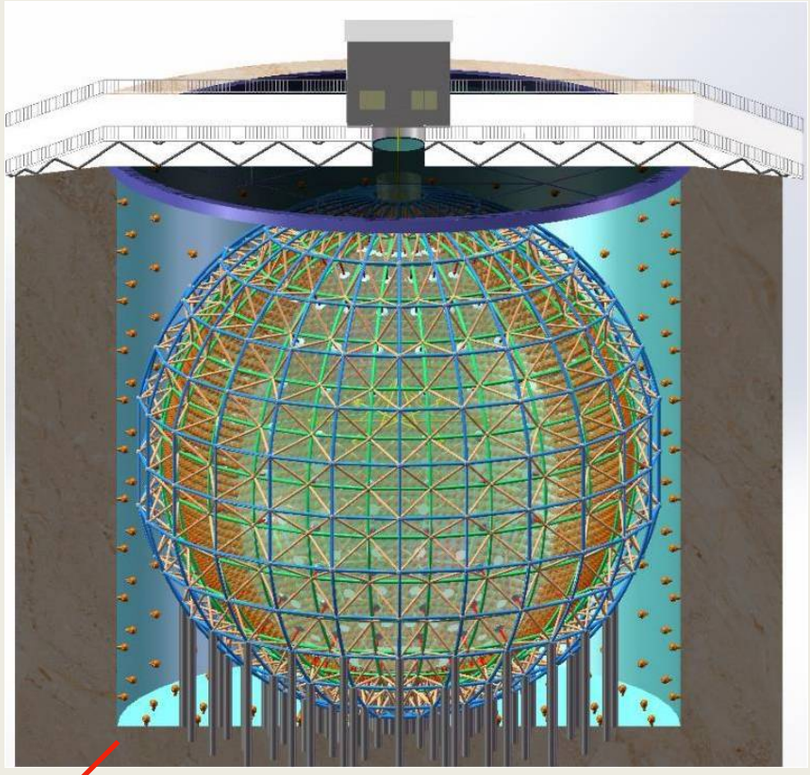
Kate Scholberg 2018 *J. Phys. G: Nucl. Part. Phys.* **45** 014002

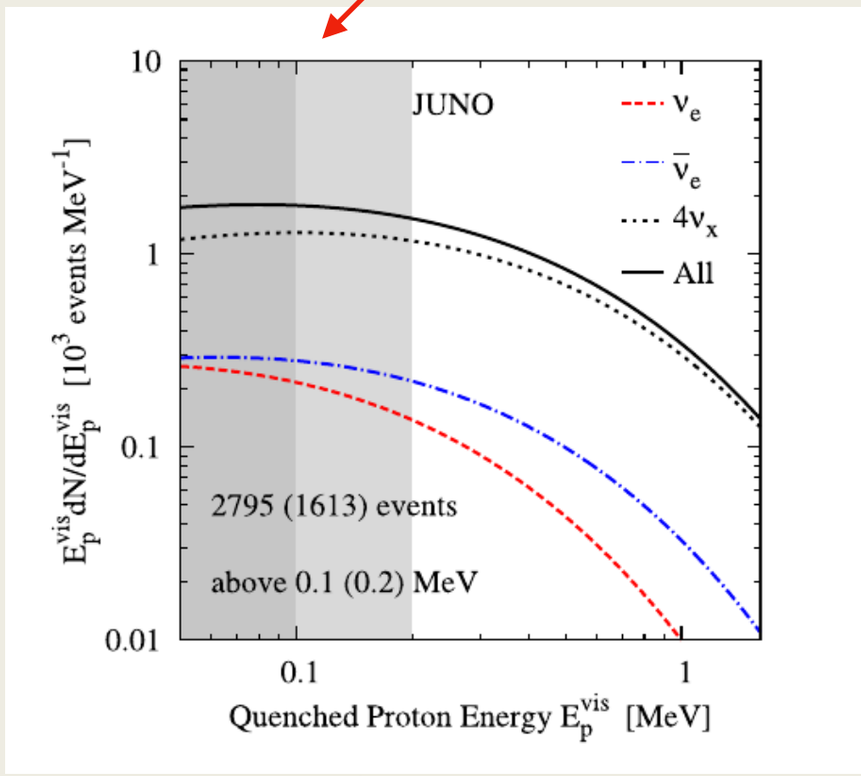
Two main steps:

- Channel identification
- Spectrum Unfolding

Supernova neutrinos in JUNO







Figs. From arXiv:1507.05613 **[physics.ins-det]**

$$\langle E_{\nu_e} \rangle < \langle E_{\bar{\nu}_e} \rangle < \langle E_{\nu_x} \rangle$$

➢**IBD** dominates at high energy range

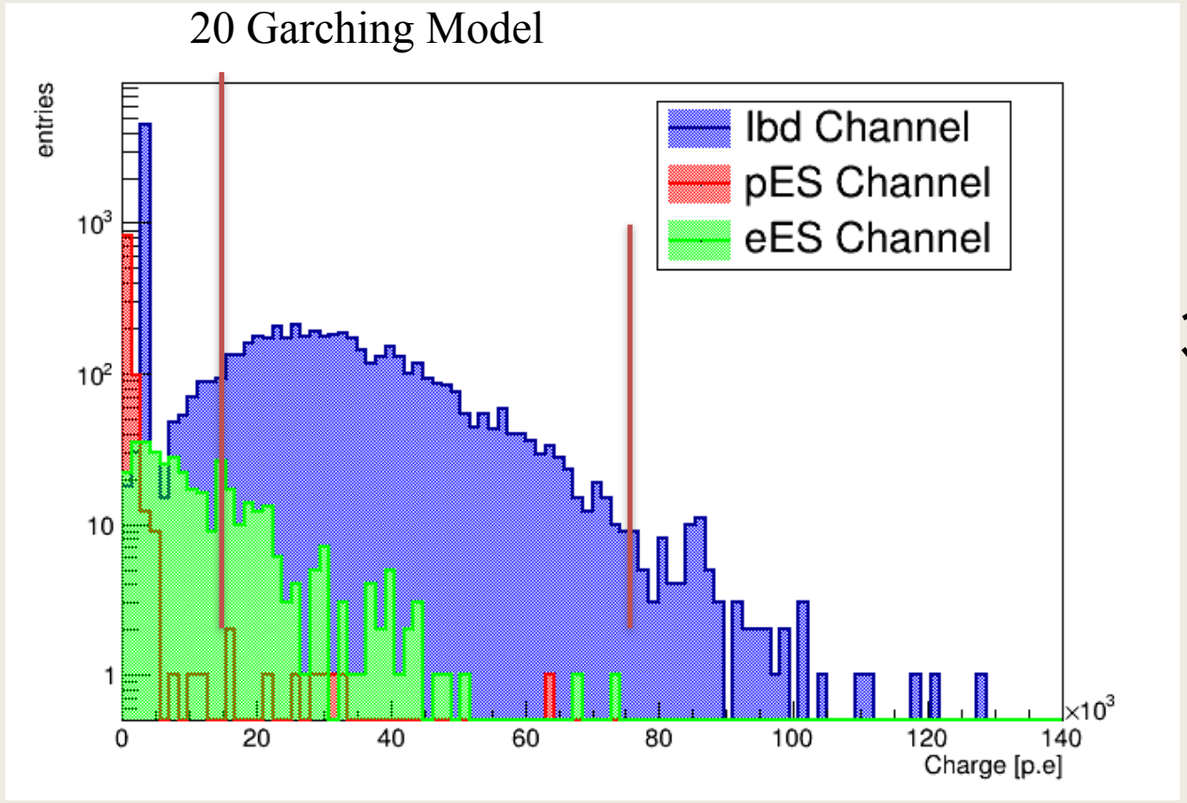
➢pES more consistent in low energy range

➢eES cover most of the spectrum

GOLDEN CHANNEL

- The event rate for a CCSN burst can vary between hundreds of events to thousands of them,

Channel Separation

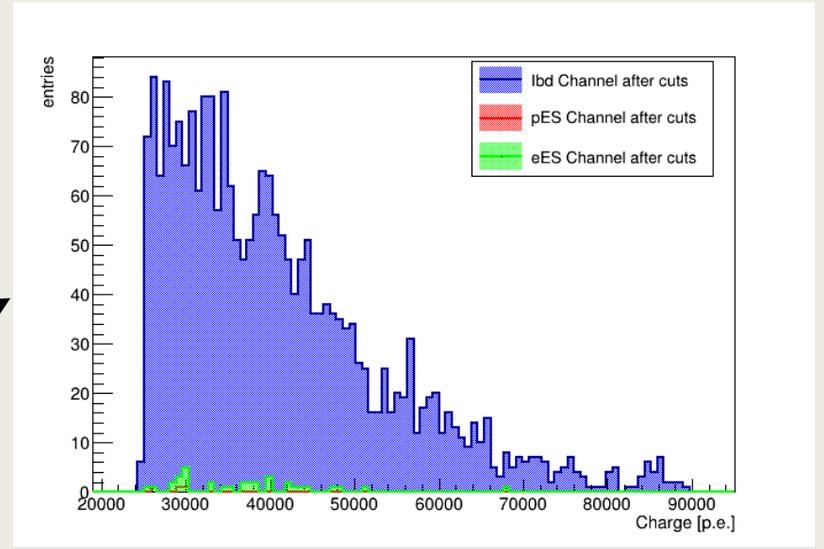


Reconstructed Charge [p.e] Distribution obtained by running the full chain simulation for Garching Model

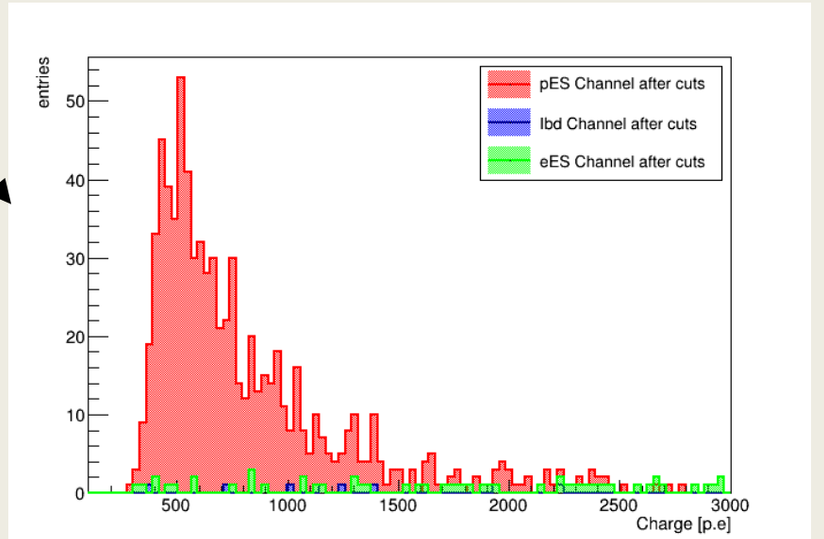
A probabilistic bayesian procedure is used to extract the spectrum

$$N_i = \sum_j U_{ij} M_j \qquad M_j = \sum_i A_{ji} N_i$$

Which can be inverted through the Bayes theorem to infer the neutrino energy spectra from the detector observable distribution



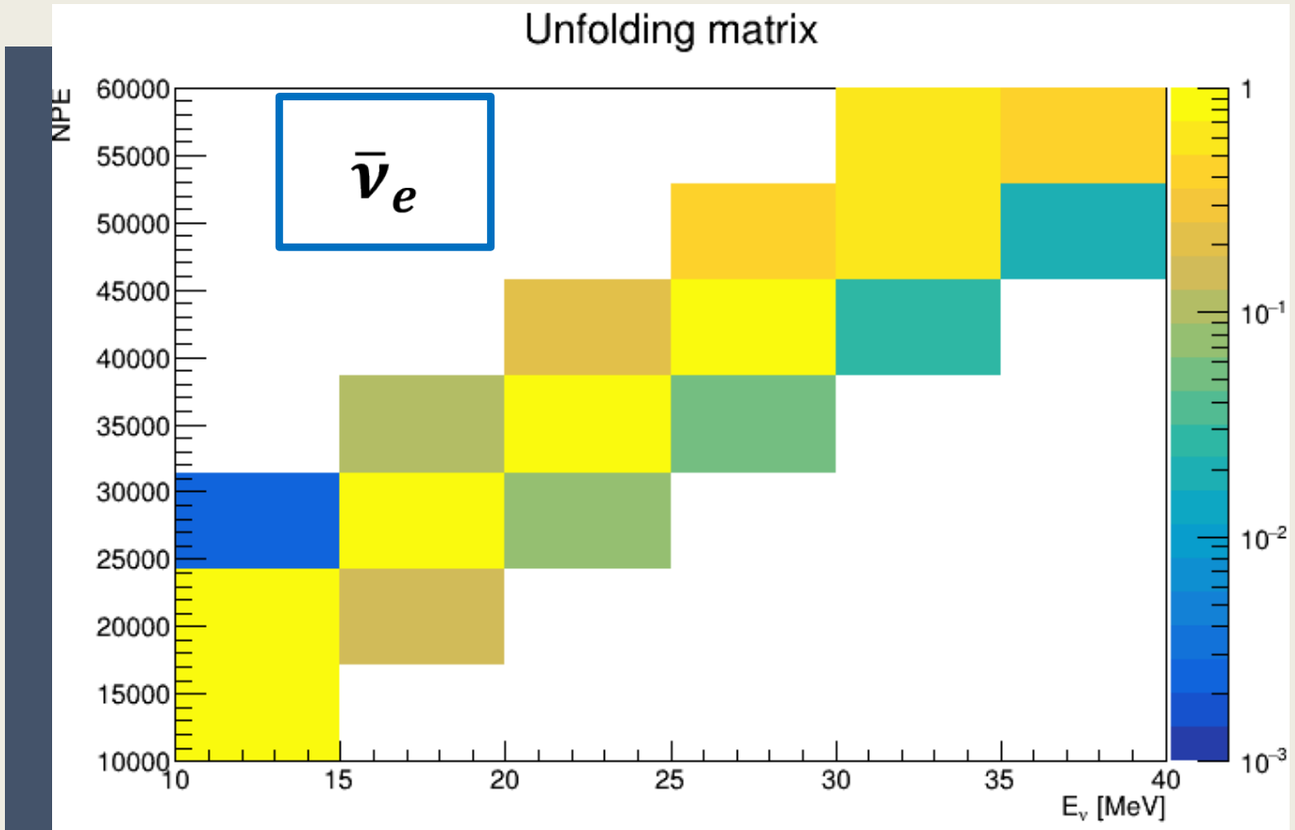
Cut performed on the Charge [p.e] for the IBD channel, on the model provided by the Garching Group



Cut performed on the Charge [p.e] for the pES channel, on the model provided by the Garching Group

Spectrum Reconstruction

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



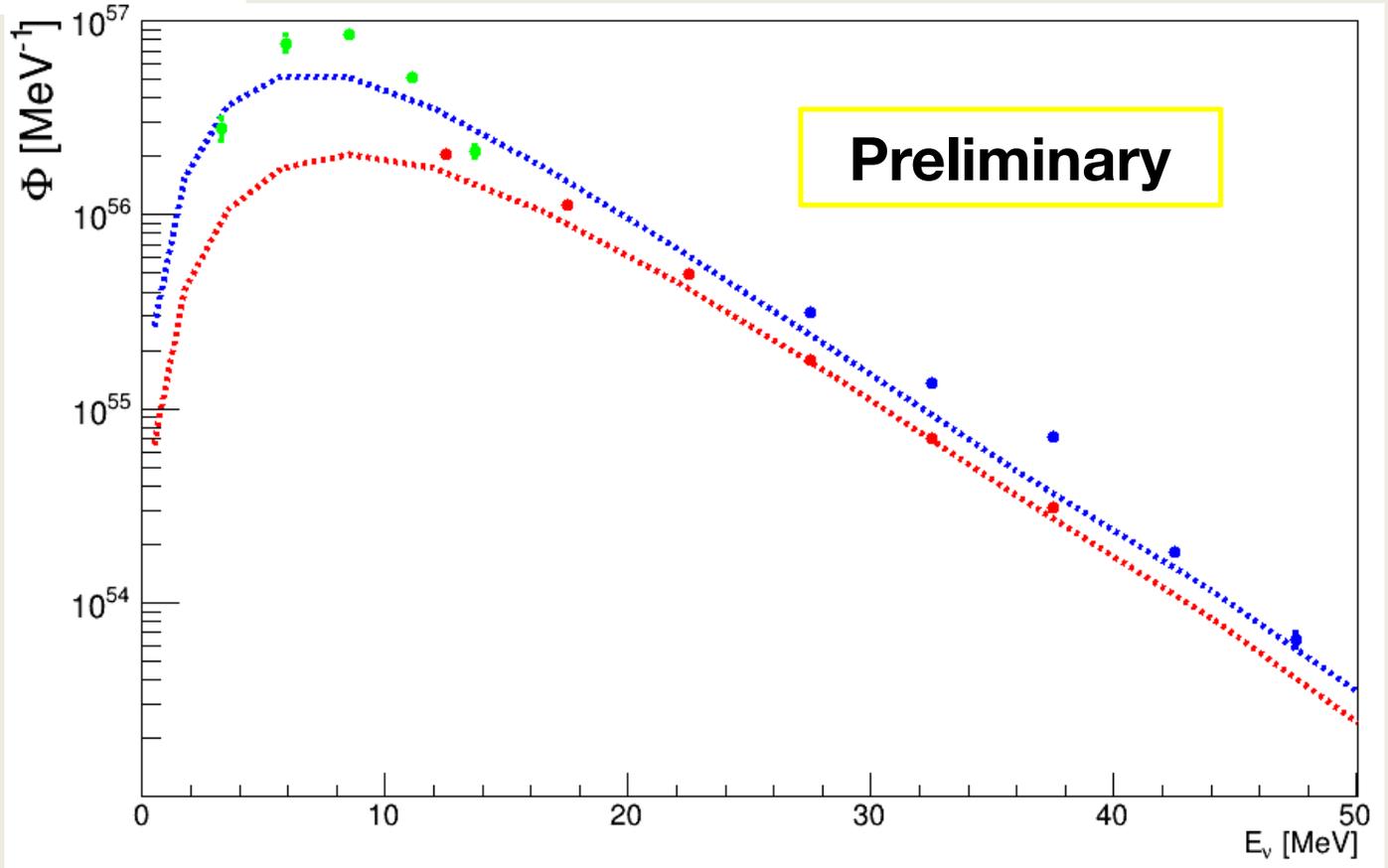
IBD golden channel

The SN spectrum for the three main channels of detection in JUNO has been unfolded.

- In red the IBD channel
- In blue the pES channel
- In green the eES channel

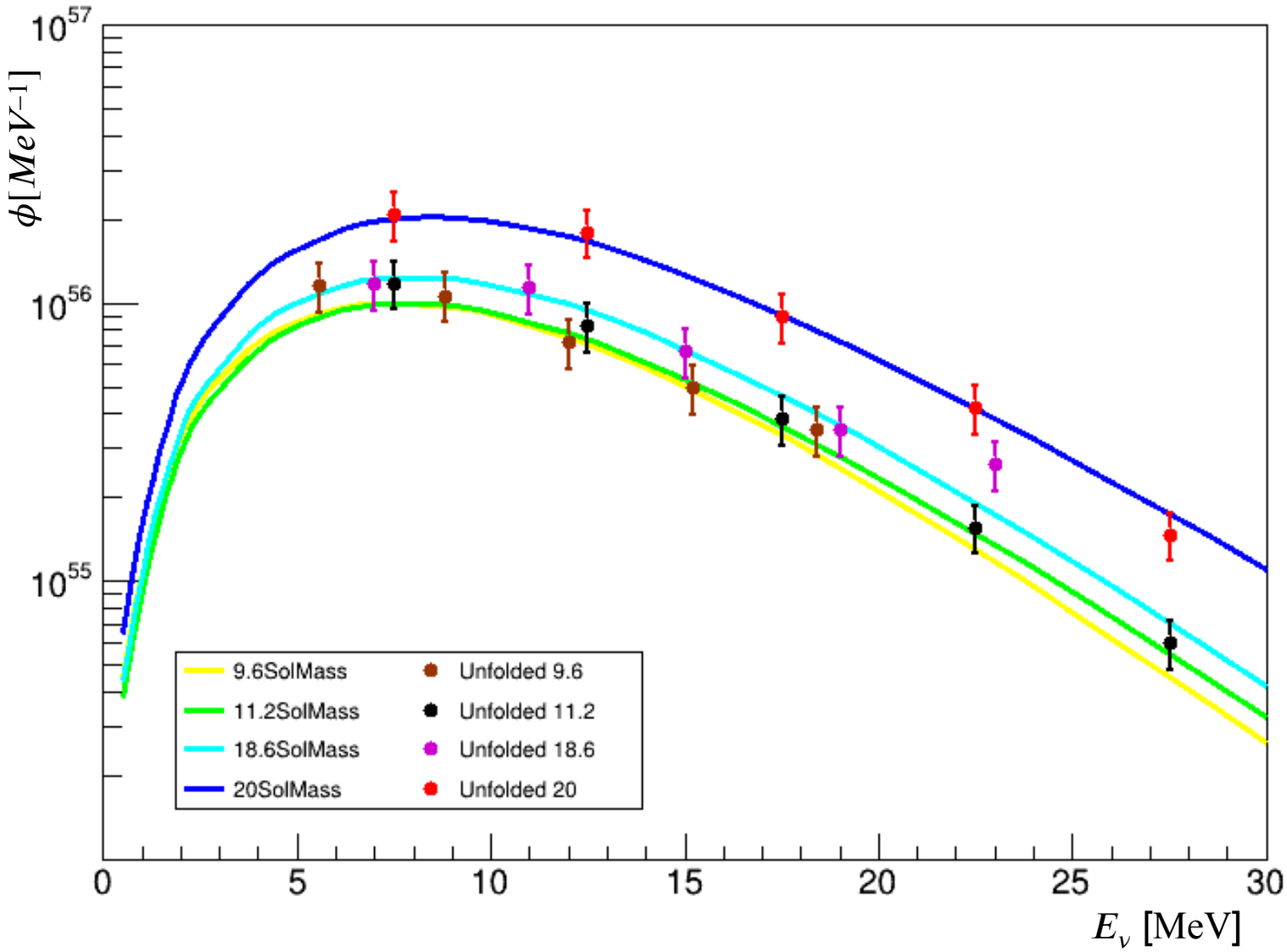
➢ **We selected 6 energy bins for the spectrum unfolding**

Uncertainties showed here are just statistical



SN ibd spectrum seen by JUNO

IBD reconstructed spectrum for different Garching Group models



The SN spectrum for the IBD channel has been retrieved for the 20 Solar Mass Progenitor available within the Garching Group model set.

- Uncertainties evaluation includes statistical evaluation and syst combined together to a contribution of 30 %, 10% coming from stat contribution and 20 % from syst

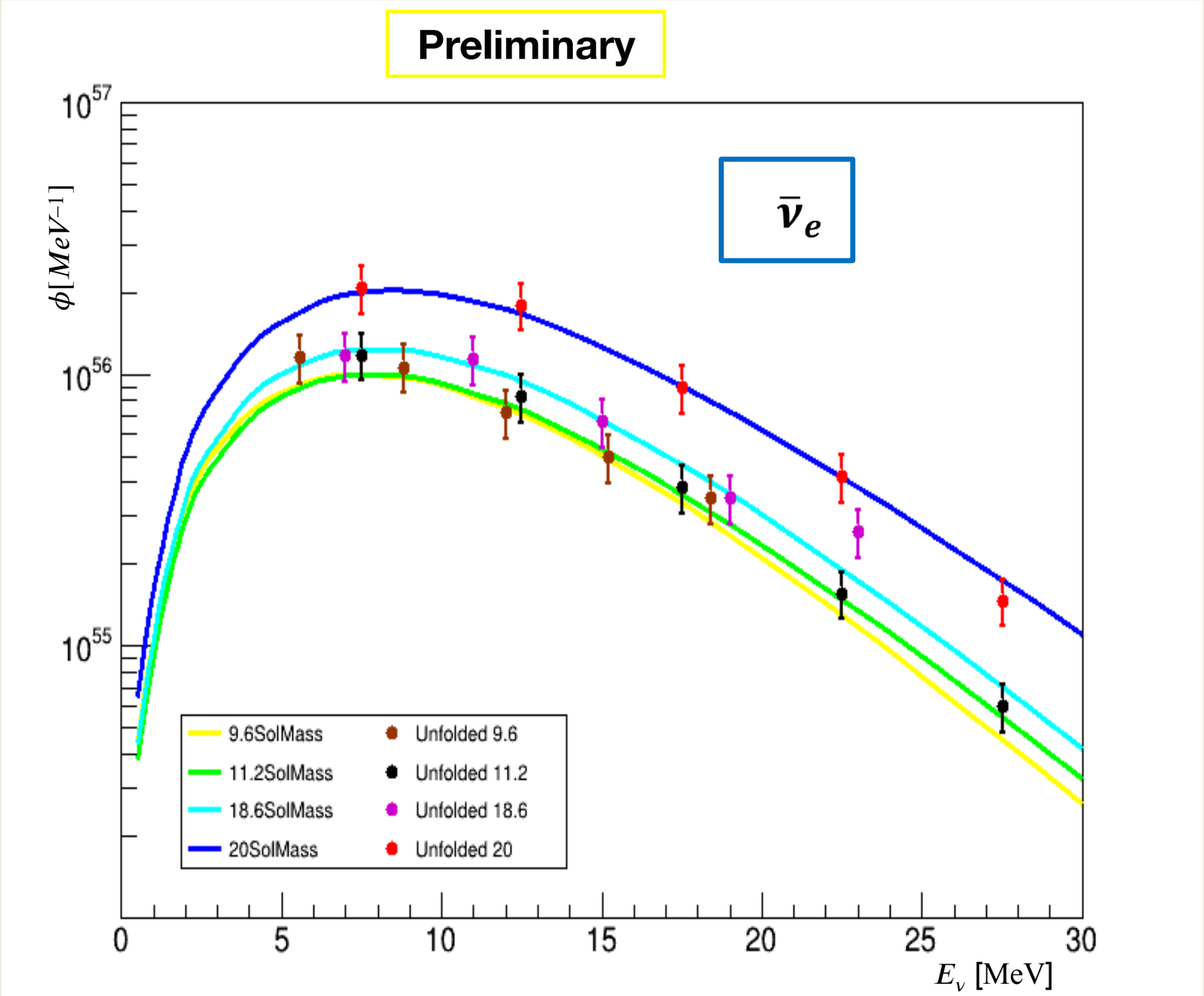
Conclusions and Summary

- A probabilistic methodology has ben set to retrieve the energy from a direct experimental observable (Charge/NPE)
- The method has been successfully used to unfold the neutrino spectrum for the three main channels of a SN burst
- A more accurate evaluation of the systematic and the total uncertainties in ongoing

THANK YOU FOR YOUR ATTENTION

Back up slides

SN ibd spectrum seen by JUNO



The SN spectrum for the IBD channel has been retrieved for all the SN mass progenitor available for the Garching Model

- Uncertainties evaluation includes statistical evaluation and syst combined together to a contribution of 30 %, 10% coming from stat contribution and 20 % from syst