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

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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 for a complete analysis
- The next SN event can obviously procure important informations

Two main steps:
- Channel identification
- Spectrum Unfolding

Supernova neutrinos in JUNO

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

➢ IBD dominates at high energy range
➢ pES more consistent in low energy range
➢ eES cover most of the spectrum

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

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

\[ N_i = \sum_j U_{ij} M_j \]
\[ M_j = \sum_i A_{ji} N_i \]

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
\[ U_{ij} = P(E_{vi} | N_{pe_{LPMT_j}}) \]

**Spectrum Reconstruction**

**Unfolding matrix**

**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

Preliminary
SN ibd spectrum seen by JUNO

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 been 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
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