CORE-COLLAPSE SUPERNOVA PHYSICS IN JUNO WITH NEUTRINO TIME DEPENDENT STUDIES

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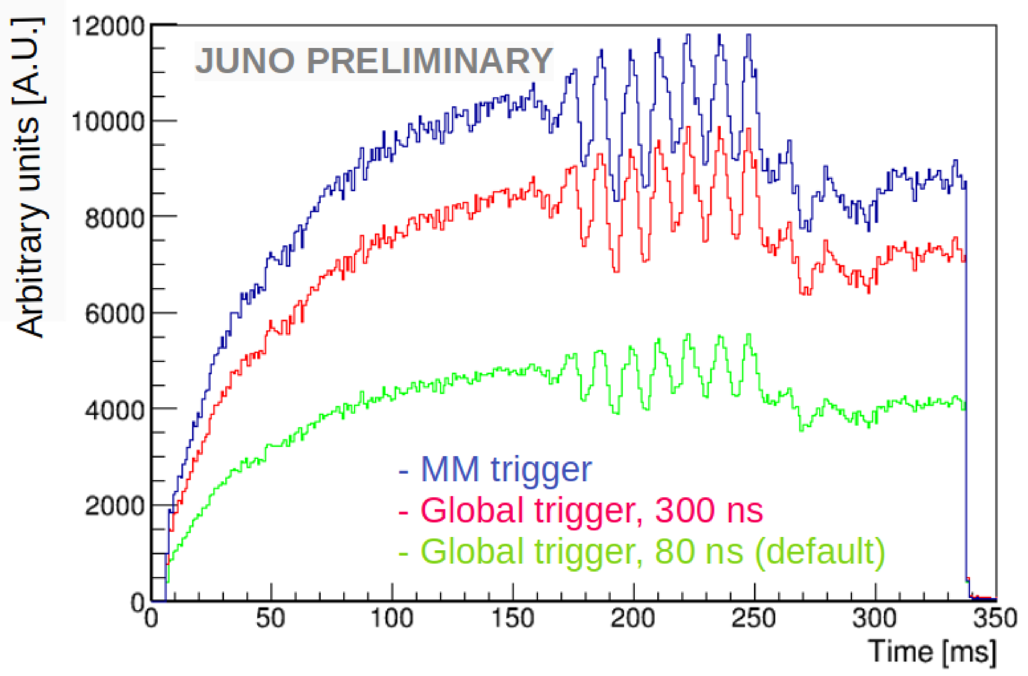
MOTIVATION

- CCSN neutrino lightcurve studies will bring information on CCSN physics and models: unique data of once-in-a-lifetime event
- High signal event statistics are crucial for time dependent lightcurve studies
- Lowering the energy threshold allows to increase signal statistics: better signal-to-noise ratio in lightcurve studies and capture more p-ν ES interactions

TRIGGERS IN JUNO

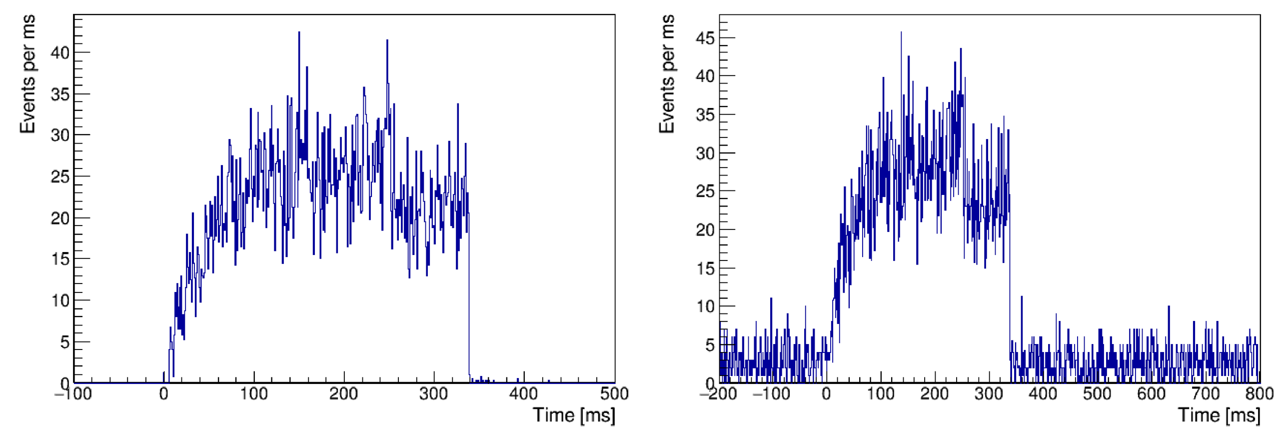
PHYSICS TRIGGERS:

- **Global multiplicity trigger:**
  - Parameters 1: 300 PMTs fired in 80 ns
  - Parameters 2: 300 PMTs fired in 300 ns
- **Multi-messenger trigger:**
  likelihood cut, low energy threshold



CCSN ν BURST TRIGGERS (real-time):

- **Prompt CCSN Monitor:** (see poster #288)
  - High energy threshold (~200 keV) to maximise the sensitivity horizon
  - Sliding window method, almost background free
- **Multi-messenger (MM) trigger:** (see poster #303)
  - Low threshold (~20 keV) to maximise signal statistics
  - Bayesian block algorithm, ^{14}C background
  (3 kHz remain of total initial 40 kHz rate)

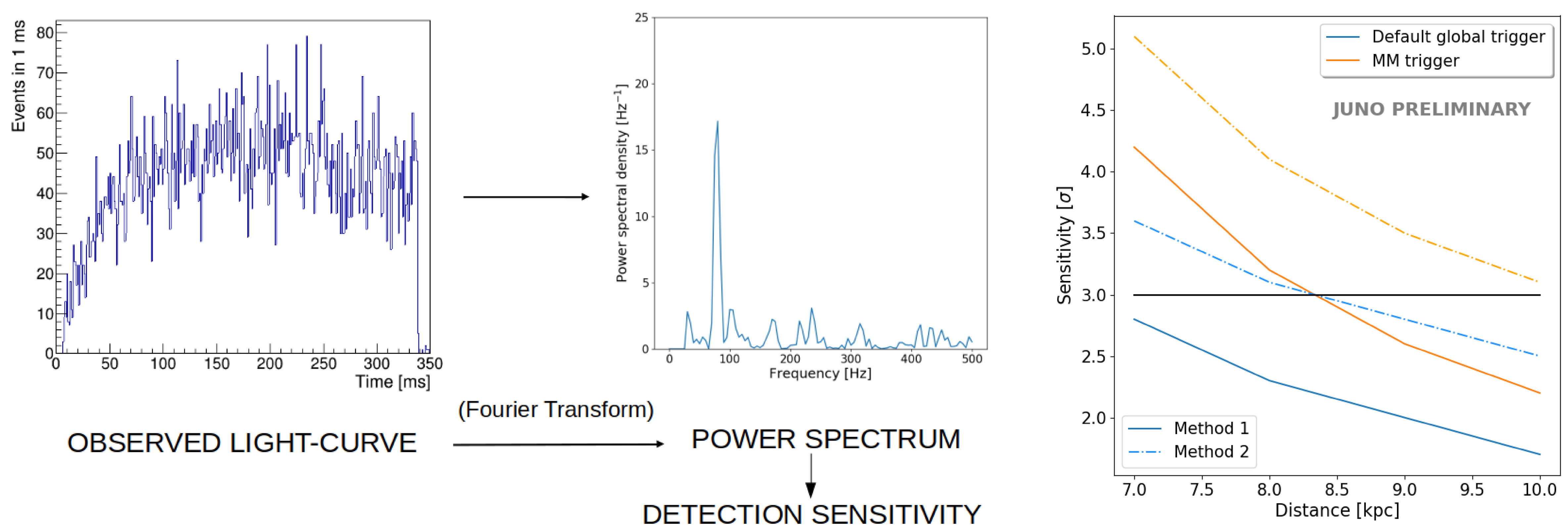


Without ^{14}C background → Including ^{14}C background

DETECTABILITY OF SASI INSTABILITY

- SASI = standing accretion shock instability: predicted by 3D CCSN simulations, favours explosion
- Observable: fast-time variations of the detected rates, oscillating with a characteristic frequency [1]

→Spectral analysis of the neutrino data (20 $M_\odot$ CCSN, SASI direction):



Compare SASI (H1) hypothesis with NON-SASI (H0) hypothesis (CCSN with same yield but SASI is no present)

- Method 1, model independent: search for significant peak in the power spectrum
- Method 2, model dependent: search for a power excess around known SASI frequency

DISTANCE ESTIMATE

Source distance estimate is a crucial parameter for the multi-messenger follow-up

Distance estimate method from [2], based on observable $N50$ = number of events in the first 50 ms:

1. Using the expected signal weighted over initial mass function (IMF_{N50}): $d_1 = d_{\text{ref}}\sqrt{\text{IMF}_{N50}/N50}$
   - Lower stat uncertainty, larger model systematics
2. Linear relation between $N50$ and $f_\Delta = \frac{N50}{N(100-150)}$: $d_2 = d_{ref}\sqrt{N50_{fit}/N50}$, with $N50_{fit} = a \times (f_\Delta - b)$
   - Larger stat uncertainty, lower model systematics
3. Mean weighted average of d_1 and $d2$, with main systematic uncertainty from IMF_{N50}: $\sigma_d(\text{syst}) = ^{+12\%}_{-7\%}$

*Results shown for the MM trigger, with model σ_d(syst)
*Algorithm implemented into SNEWS (see poster #629)

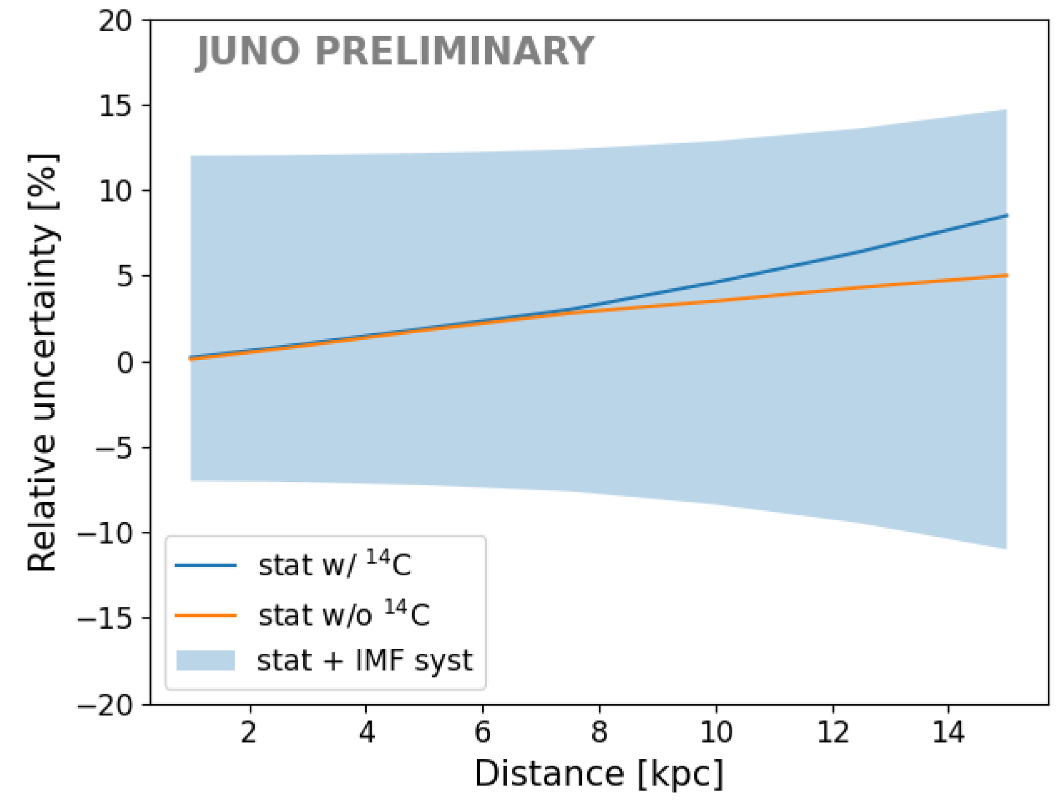
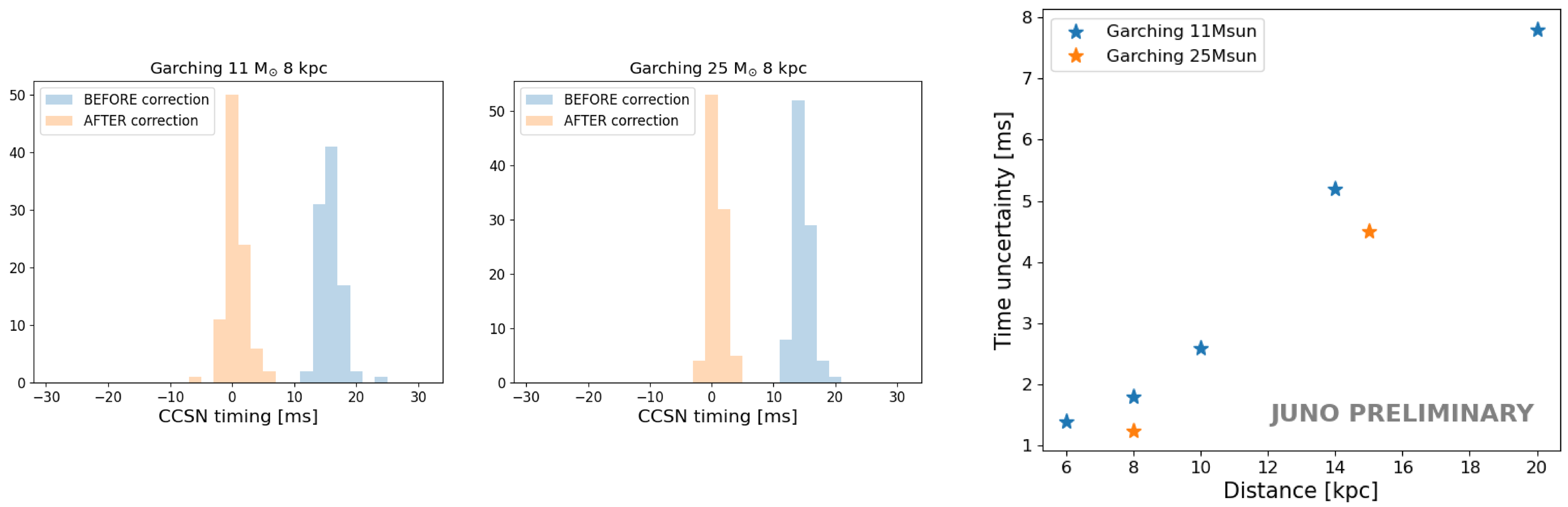


Figure: Statistical uncertainties (solid lines) for the mean weighted average. The blue bands include the IMF systematic uncertainty on top.

TIMING OF THE NEUTRINO SIGNAL ARRIVAL

→ Crucial to catch the multi-messenger counterparts and needed to point to the source by triangulation

How? Using the high-significance Prompt CCSN Monitor trigger time (see poster #288)
But... The trigger time will be biased with respect to the truth arrival time (T_0= 0, core bounce time)
Bias correction: Fit the relation between the expected trigger time and the number of events in the first 50 ms



CONCLUSIONS

- JUNO will bring results on CCSN physics using the neutrino lightcurve
- The multi-messenger trigger will enhance the JUNO physics potential
- More physics parameters, CCSN models and systematics to be studied

MORE INFO:

Related posters: 288,303,629
Contact: *marta.colomer@ulb.be*

REFERENCES

[1] I. Tamborra et al., Phys. Rev., D90(4):045032 (2014)
[2] M. Segerlund et al., arXiv:2101.10624