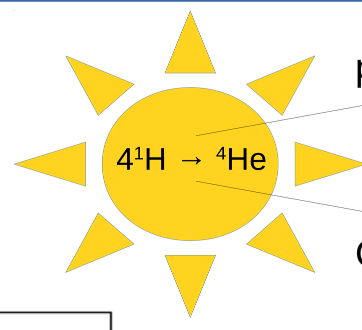
JUNO's sensitivity to ^{7}Be, *pep*, and CNO solar neutrinos

Apeksha Singhal for JUNO Collaboration

IKP-2, Forschungszentrum Jülich GmbH, 52428, Jülich & Physikalisches Institut III B, RWTH Aachen University, 52062, Aachen, Germany

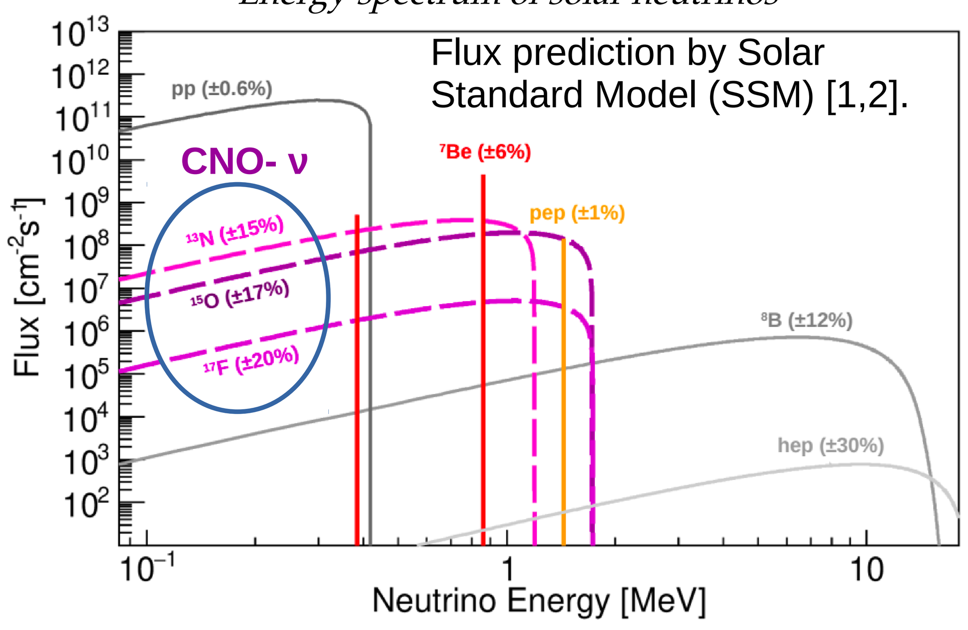
INTRODUCTION

Solar Neutrinos are the only carriers of information of energy production mechanism in the Sun's core and its chemical composition.



- Solar Metallicity Problem: High (HZ) or Low (LZ)?
- SSM predictions depend on Metallicity input [2].

Energy spectrum of solar neutrinos



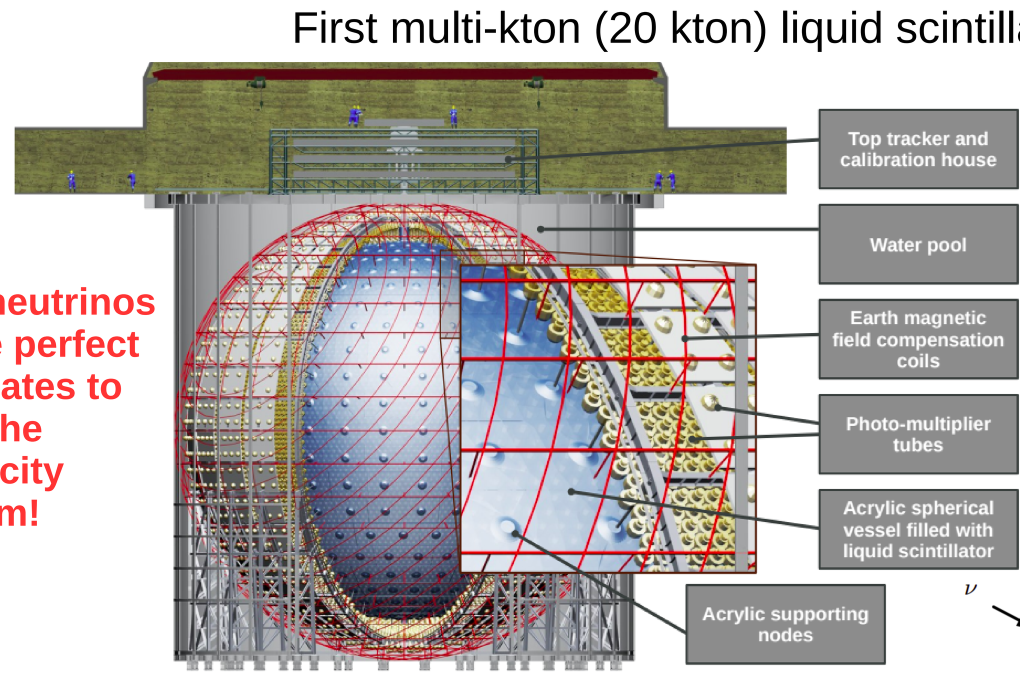
Species	HZ-Flux (cm^{-2}s^{-1})	LZ-Flux (cm^{-2}s^{-1})	% Difference
pp	5.98(1 ± 0.006)×10^{10}	6.03(1 ± 0.005) ×10^{10}	-0.8
pep	1.44(1 ± 0.01) ×10^{8}	1.46(1 ± 0.009) ×10^{8}	-1.4
^{7}Be	4.93(1 ± 0.06) ×10^{9}	4.50(1 ± 0.06) ×10^{9}	8.9
^{8}B	5.46(1 ± 0.12) ×10^{6}	4.50(1 ± 0.12) ×10^{6}	17.6
^{13}N	2.78(1 ± 0.15) ×10^{8}	2.04(1 ± 0.14) ×10^{8}	26.6
^{15}O	2.05(1 ± 0.17) ×10^{8}	1.44(1 ± 0.16) ×10^{8}	29.7
^{17}F	5.29(1 ± 0.20) ×10^{6}	3.26(1 ± 0.18) ×10^{6}	38.3

Solar neutrinos are the perfect candidates to solve the metallicity problem!

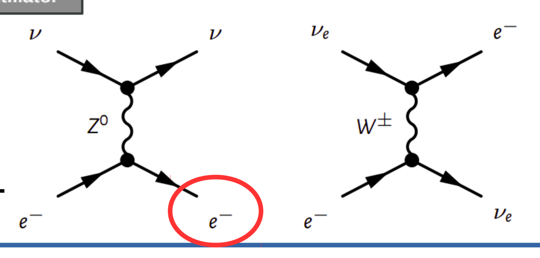
Jiangmen **U**nderground **N**eutrino **O**bservatory Experiment

Under construction in southern China

First multi-kton (20 kton) liquid scintillator (LS) detector [3].



- Excellent energy resolution: 3% at 1 MeV.
- Large photocathode coverage (78%): 17612 20" PMTs and 25600 3" PMTs.
- 1% energy scale uncertainty, controlled by several calibration sources.



Solar neutrinos detected via elastic scattering of e-

METHODS

Region of Interest: 0.45-1.6 MeV

Internal Backgrounds
(^{210}Bi, ^{210}Po, ^{85}Kr, ^{40}K, ^{238}U & ^{232}Th chain)
Levels of Concentration:
- **High Background** : minimum requirement for NMO studies.
- **Medium Background**: 10x improvement from High Background.
- **Low Background**: 10x improvement from Medium Background.
- **Very Low Background**: Borexino Phase-III.

Cosmogenic Backgrounds
(^{11}C, ^{10}C and ^{6}He)

$$\mu + {}^{12}\mathrm{C} \rightarrow \mu + {}^{11}\mathrm{C} + n$$

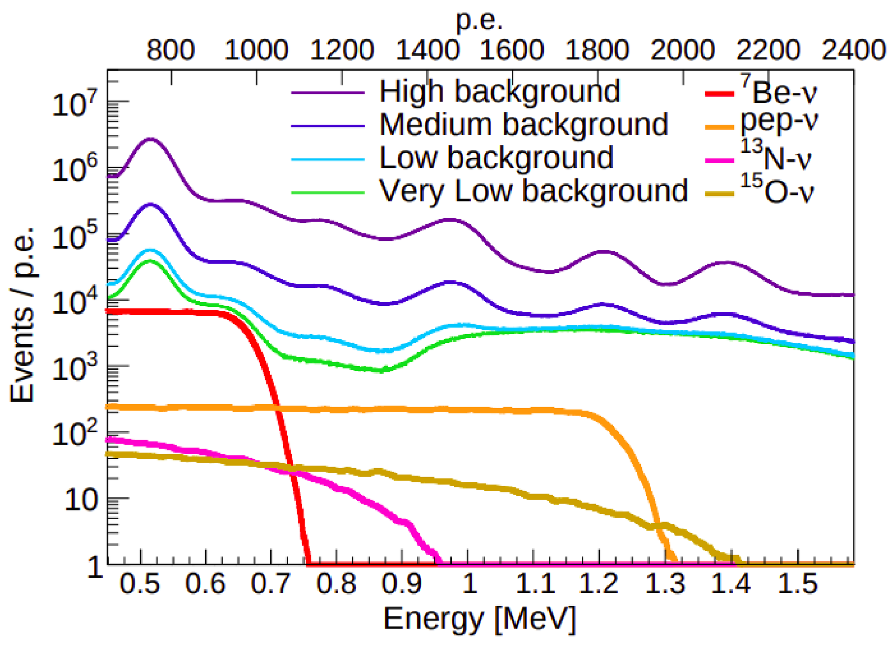
$$ {}^{11}\mathrm{C} \rightarrow {}^{11}\mathrm{B} + e^{+} + \nu_e$$

Identify cosmogenic backgrounds by finding space - time correlation between parent muon, ^{11}C decay and neutron capture using **Three Fold Coincidence Algorithm (TFC) [4]**.

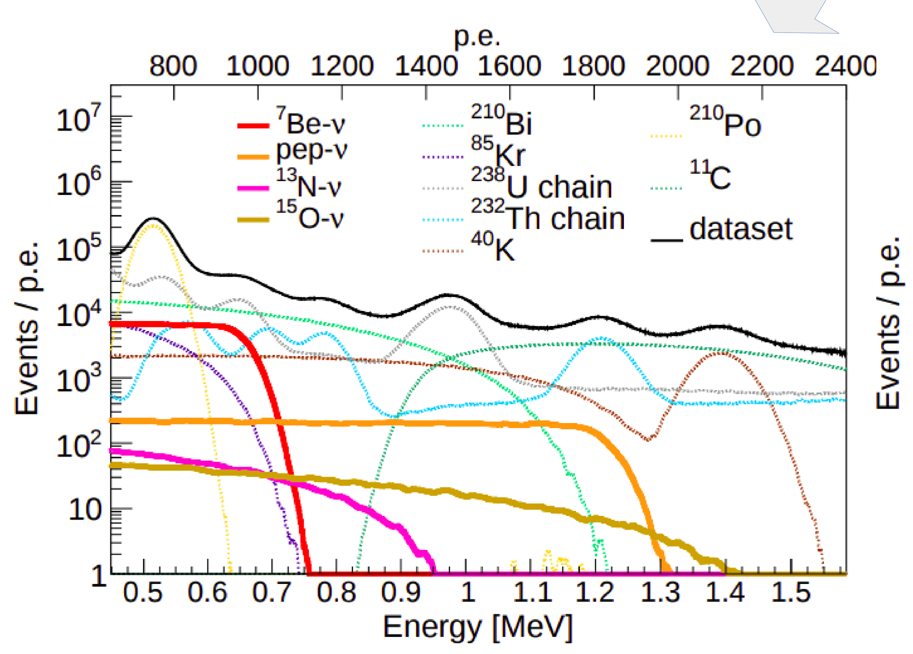
TFC parameters:

Tagging Power (TP): percentage of correctly identified cosmogenic events.
Subtracted Exposure (SE): remaining exposure in ^{11}C depleted dataset.

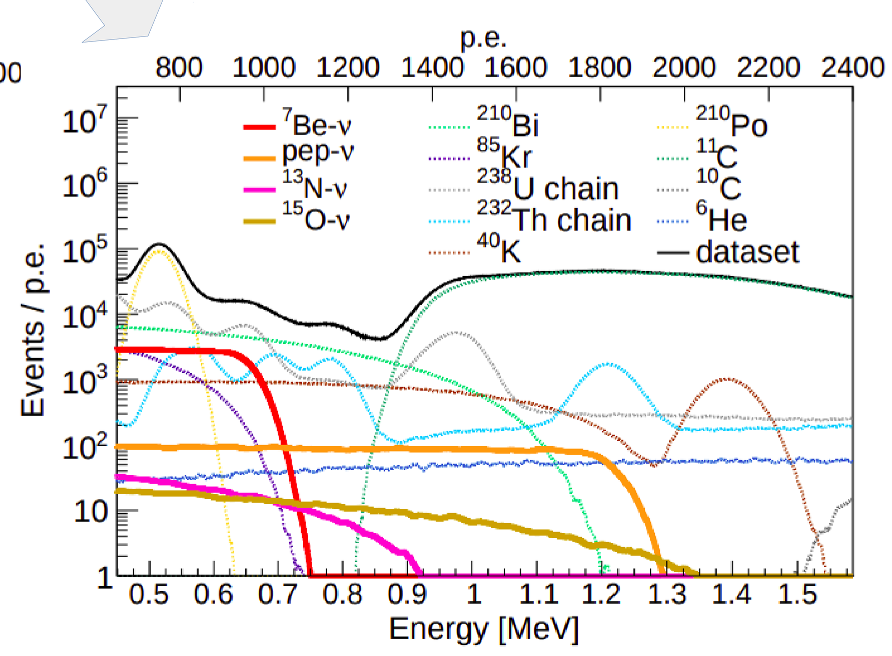
Data is split using TFC:



^{11}C depleted spectrum

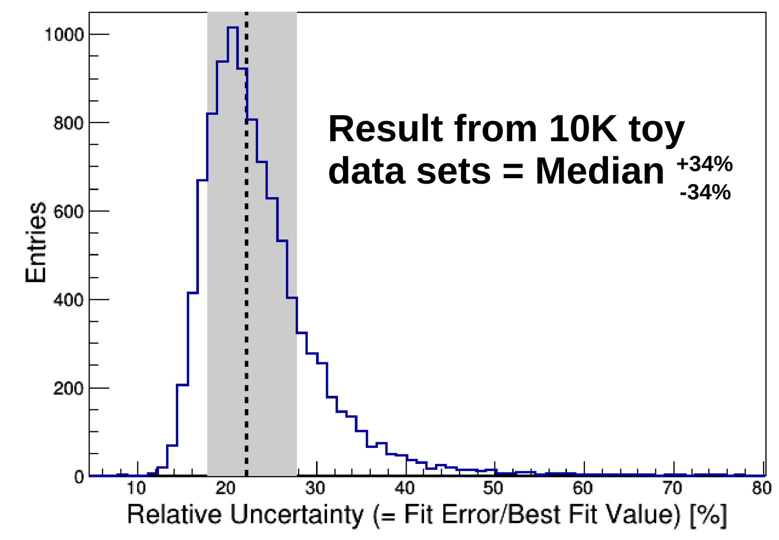


^{11}C enriched spectrum



Toy MC approach to extract Sensitivity

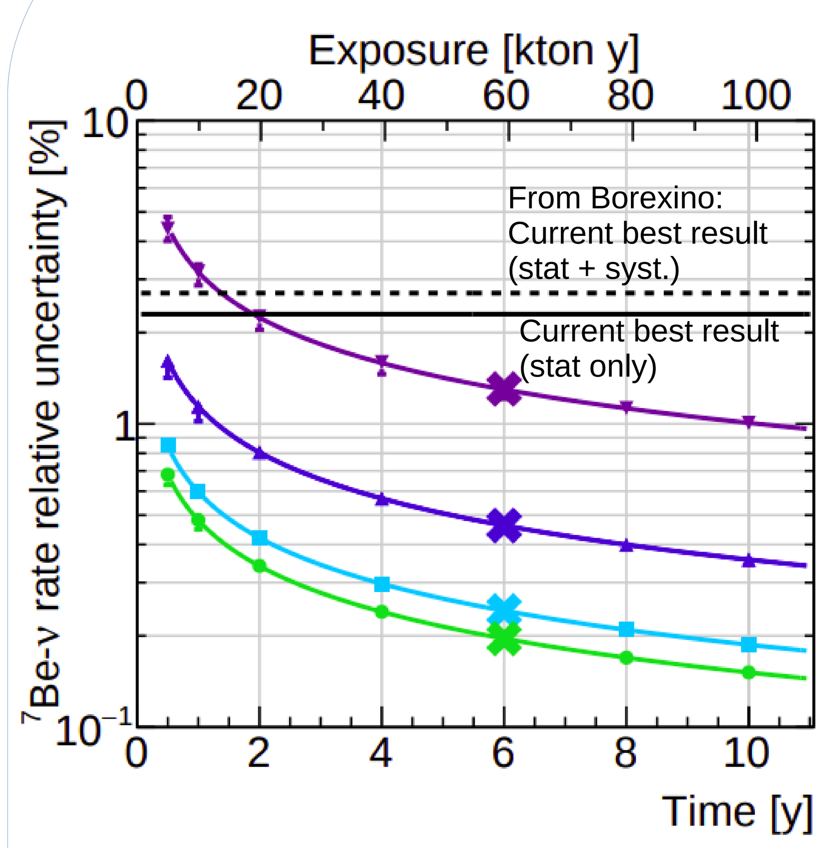
Energy spectra from full Monte Carlo → **Sampling** → Thousands of pseuso-datasets (each species with expected rates) → Simultaneous Poisson Likelihood Fit → Best Fit Value / Fit Error (statistical only)



RESULTS

^{7}Be neutrinos

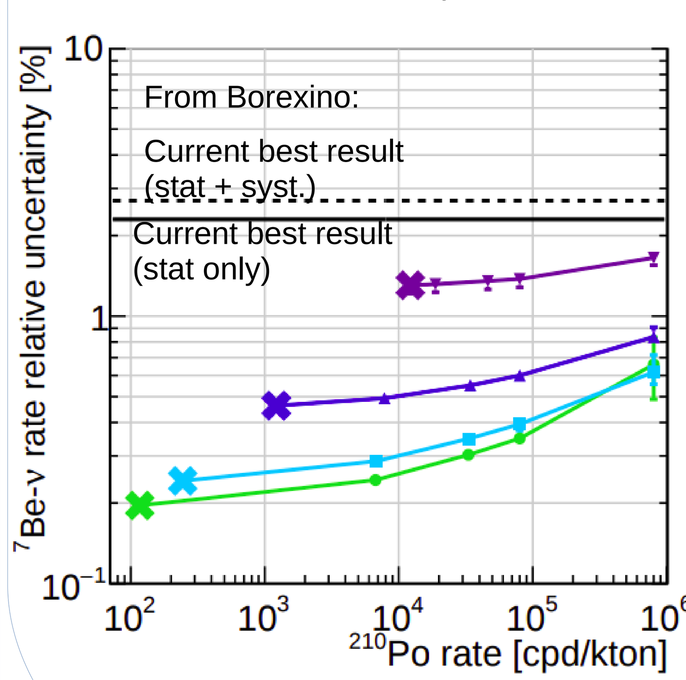
TP = 90%
SE = 70%

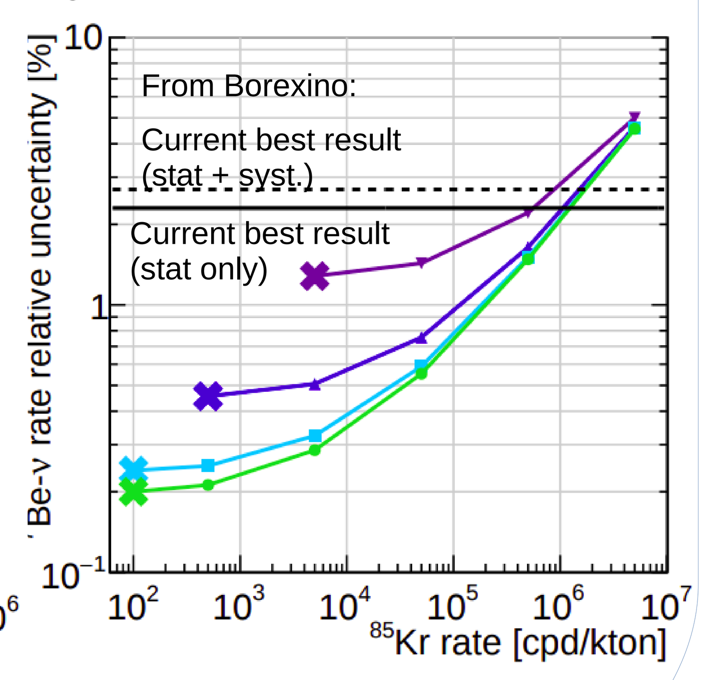


After 1 year of data-taking, JUNO can reach and overcome the current best result on ^{7}Be solar neutrino rate: 2.3% (stat.) and 2.7% (stat. +syst) from Borexino [5].

Critical backgrounds: ^{210}Po, ^{85}Kr, and ^{226}Ra

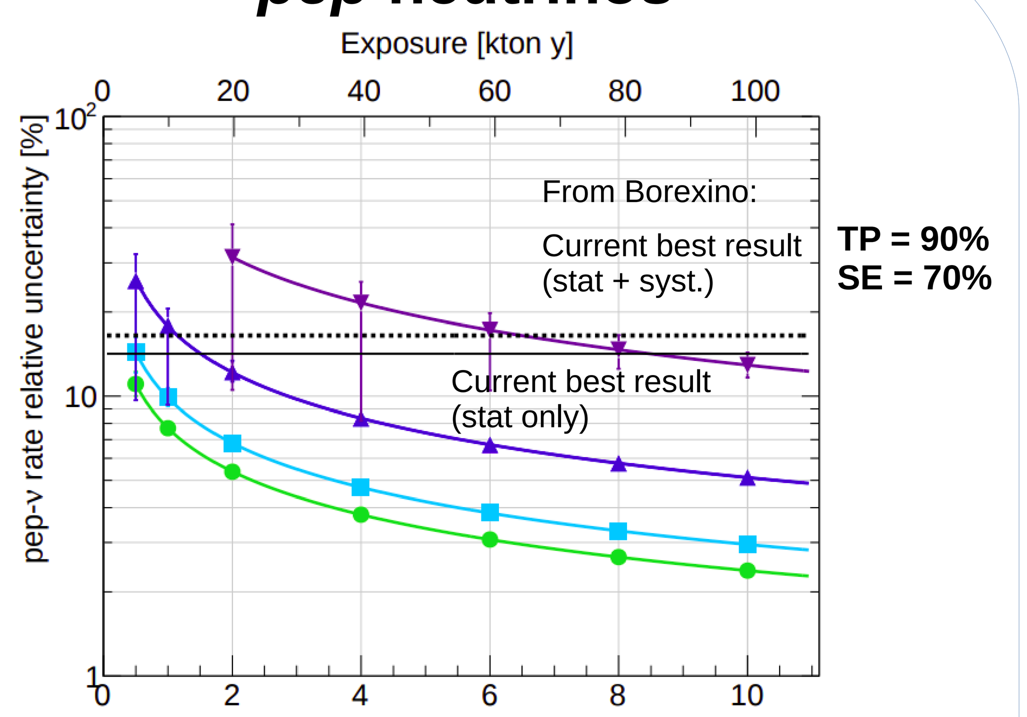
Impact of critical backgrounds levels





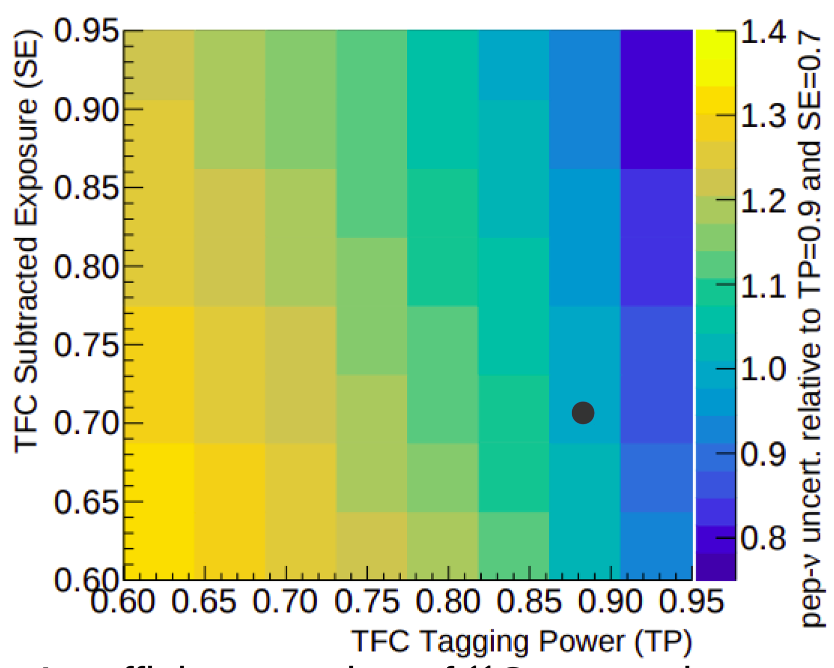
Measured ^{7}Be rate precision worsens as a function of increased backgrounds levels.

pep neutrinos



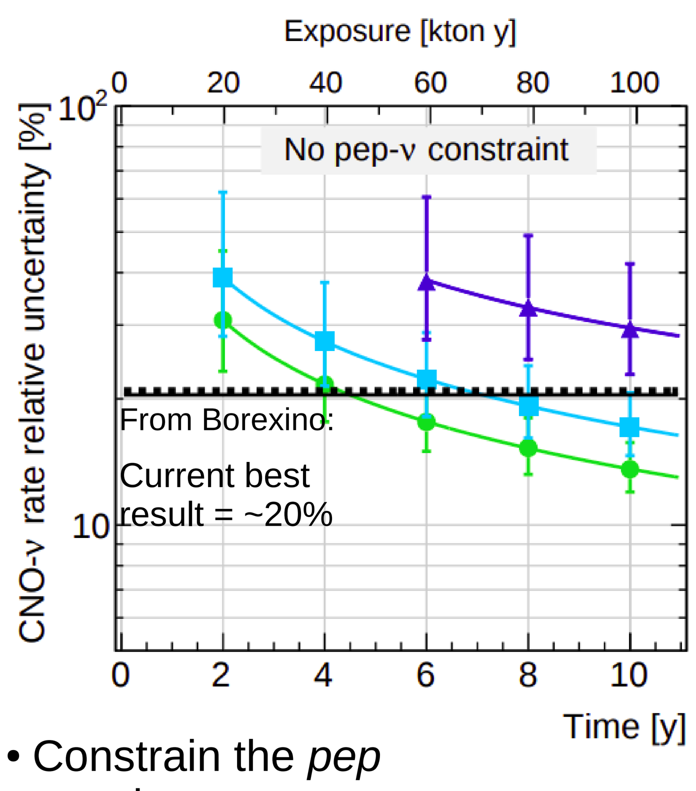
After 2 years of data-taking (except for the High background level) JUNO exceeds current best result : 14.2% (stat.) and 16.5% (stat. +syst.).

Impact of TFC-parameters – very low background level



An efficient tagging of ^{11}C events is more relevant than having high fraction of exposure.

CNO neutrinos

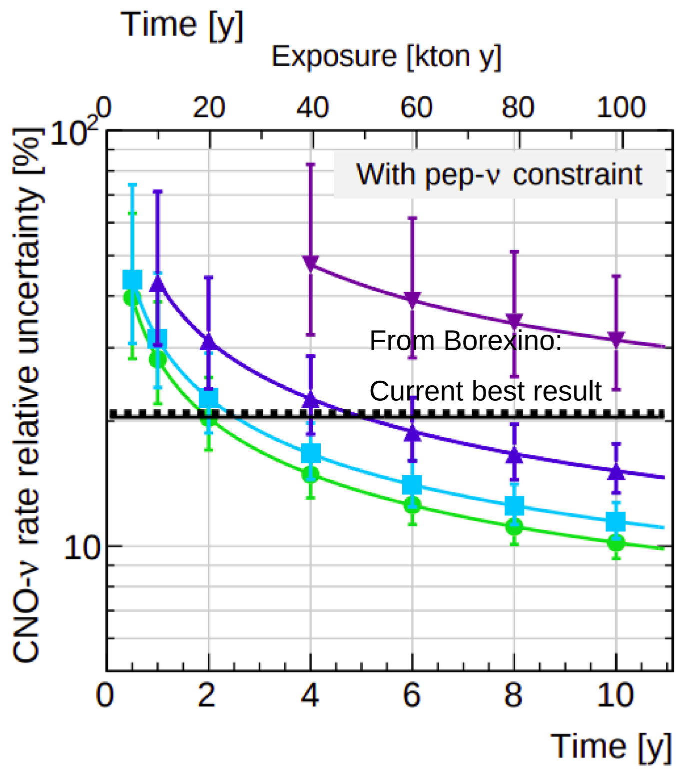


TP = 90%
SE = 70%

CNO spectral shape degeneracy with the *pep* neutrinos.

No CNO measurements possible for High background levels.

- Constrain the *pep* neutrino rate at 1.4% from theoretical and experimental info.
- JUNO can overcome the current best results (~20%) for long data-taking period (>6 years).
- No ^{210}Bi constraint used.



JUNO also has the potential to measure individually for the first time the rate of the two main components of the CNO flux, ^{13}N, and ^{16}O solar neutrinos, except in case of the High background level.

CONCLUSIONS

- After the first data-taking year, JUNO is able to provide unprecedented ^{7}Be and *pep* solar neutrino results (except for the High background scenario).
- JUNO is also able to provide the first simultaneous ^{7}Be, *pep* and CNO measurement for > 6 years of data taking in case of optimistic radio-purity scenario.
- Except for the High background scenario, JUNO will be highly competitive for the CNO measurements for long data-taking using *pep* constraint.
- The first separation of ^{13}N and ^{15}O neutrinos is also possible!

arXiv:2303.03910, accepted in Journal of Cosmology and Astroparticle Physics (JCAP)

REFERENCES

[1] John N. Bahcall et al, "New Solar Opacities, Abundances, Helioseismology, and Neutrino Fluxes" , 2005 ApJ 621 L85.
[2] Vinyoles et al. , A New Generation of Standard Solar Models , Astr.J. 835 (2017) 202.
[3]A. Abusleme et al., JUNO physics and detector, Progr. Part. Nucl. Ph. 123 (2022) 103927.
[4] M. Agostini et al.,Identification of the cosmogenic ^{11}C background in large volumes of liquid scintillators with Borexino, Eur. Phys. Journal C 81 (2021) 1075.
[5] M. Agostini et al., "Comprehensive measurement of pp-chain solar neutrinos," Nature, vol. 562, pp. 505–510, Oct 2018.