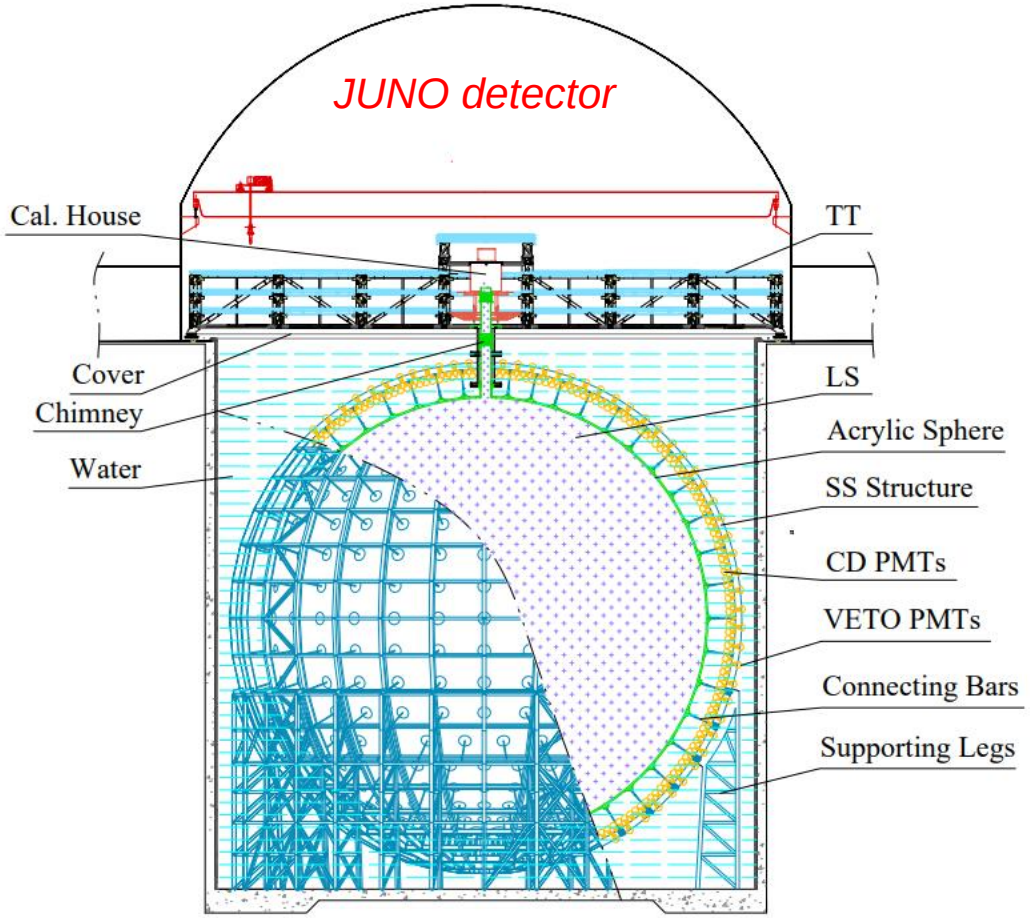
GENIE in JUNO

Jie Cheng on behalf of JUNO
North China Electric Power University
chengjie@ncepu.edu.cn

GENIE Forum 2023/01/18

Jiangmen Underground Neutrino Observatory

- **Jiangmen Underground Neutrino Observatory (JUNO):** a multiple-purpose neutrino experiment.
- **Detector assembly and installation:** to be completed by 2023

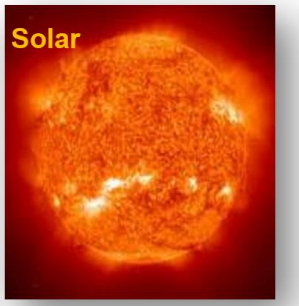


- **20 kton LS detector**
- **3% energy resolution**
- **700 m underground**
- **Rich physics possibilities**
  - ➔ **Reactor neutrino for Mass Ordering and precision measurement of oscillation parameters**
  - ➔ **Supernovae neutrino**
  - ➔ **Geoneutrino**
  - ➔ **Atmospheric neutrino**
  - ➔ **Proton decay**
  - ➔ **Exotic searches**

A multi-purpose observatory

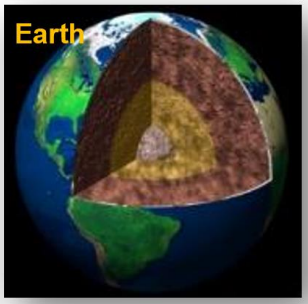
~60 IBDs per day

Several per day



Hundreds per day

~5000 IBDs for CCSN @10 kpc



Several IBDs per day

\+ New physics

Neutrino oscillation & properties

Neutrinos as a probe

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

CCSN: core-collapse supernova

Atmospheric neutrinos can be:

- important signal in neutrino oscillation study: Mass ordering, CP phase
- significant background in rare event researches: DSNB, proton decay

JUNO GANYMEDE physics working group

JUNO Neutrino Interaction, a.k.a. GANYMEDE, Working Group

The understanding of GeV-neutrino interactions inside the JUNO detector relies on the modelling of nuclear medium effects. These effects are crucial ingredients not only for the neutrino mass ordering measurement using atmospheric neutrinos but also for the searches for rare phenomena like nucleon decays and diffuse supernova neutrinos. The **Gev v-A high-eNergY MEDium Effect (GANYMEDE)** Working Group aims to study neutrino interactions in the few-GeV regime in JUNO and is actively pursuing a better understanding of the relevant systematic effects. (☛ The real Ganymede / 木卫三)

Convenors：

- **Jie Cheng (NCEPU)**
- **Xianguo Lu (Warwick)**

Using GENIE in atmospheric ν oscillation

Topics		Genie usage	Genie version	reference
Physics	Neutrino oscillation studies	Generate atmospheric νCC events and νNC events for the input of detector simulation	2.8	*J. Phys. G43:030401 (2016)*
Reconstruction	Neutrino directionality		3.0.6	*Neutrino 2022 poster #524*
	Neutrino flavor (PID)			*Neutrino 2022 poster #356*
	Neutrino energy		2.12	*Eur.Phys.J.C 81 (2021), 10*

Using GENIE in rare event researches

Topics		Genie usage	Genie version	Reference
Physics	DSNB	1. Prediction of atmospheric neutrino νNC background 2. As one of the generators, to study the dependence on the nuclear model	2.12	*Phys.Rev.D 103 (2021) 5, 053001* *JCAP 10 (2022) 033*
	Proton decay	Generate nucleon decay events from ^{12}C and atmospheric neutrino background	3.0.2	*arXiv:2212.08502*

A request for GENIE

- **Request:** GENIE implements the de-excitation process of residual nuclei when ^{12}C is the target.

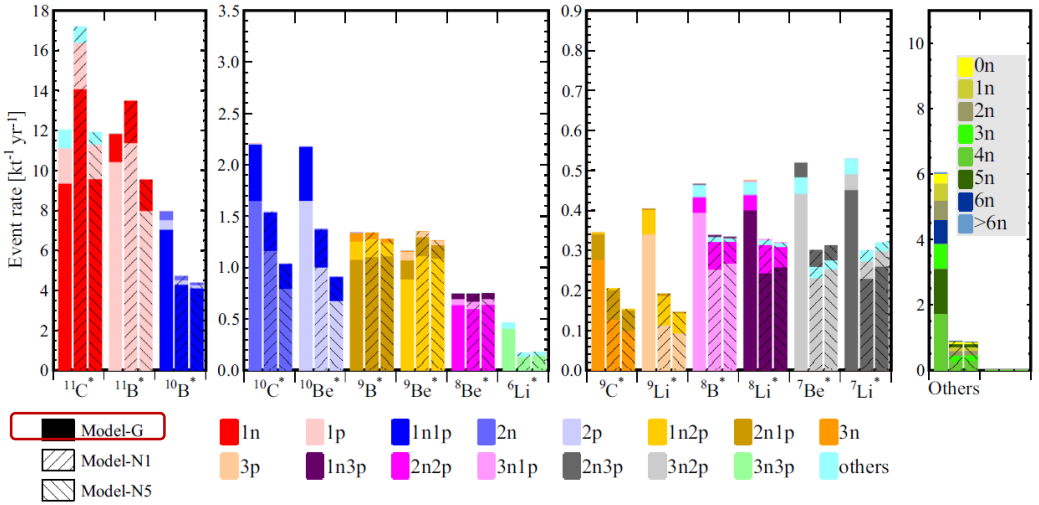
Because JUNO as an LS detector, has a high efficiency of neutron tagging and a low energy threshold, we very care about the exclusive final-state information, such as the neutron multiplicity, the charge pion multiplicity, the unstable nuclei, which is important for tagging the signal and background in atmospheric ν studies and rare event researches.

Since GENIE does not provide the de-excitation processes, JUNO adds de-excitation and decay processes of residual nuclei

- **^{12}C shell model: predict the possible states of residual nuclei**
- **Deexcitation samples: provided by TALYS**

Comparison

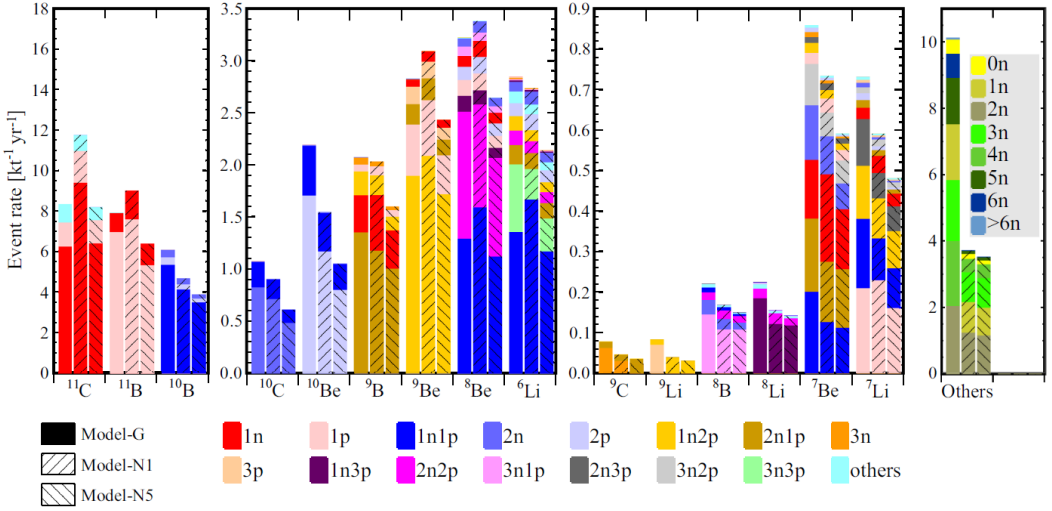
E.g., Phys. Rev. D 103 (2021) 5, 053001: **NC interactions of atm-ν (100 MeV-10 GeV) with ^{12}C**



GENIE 2.12.0

Without deexcitation

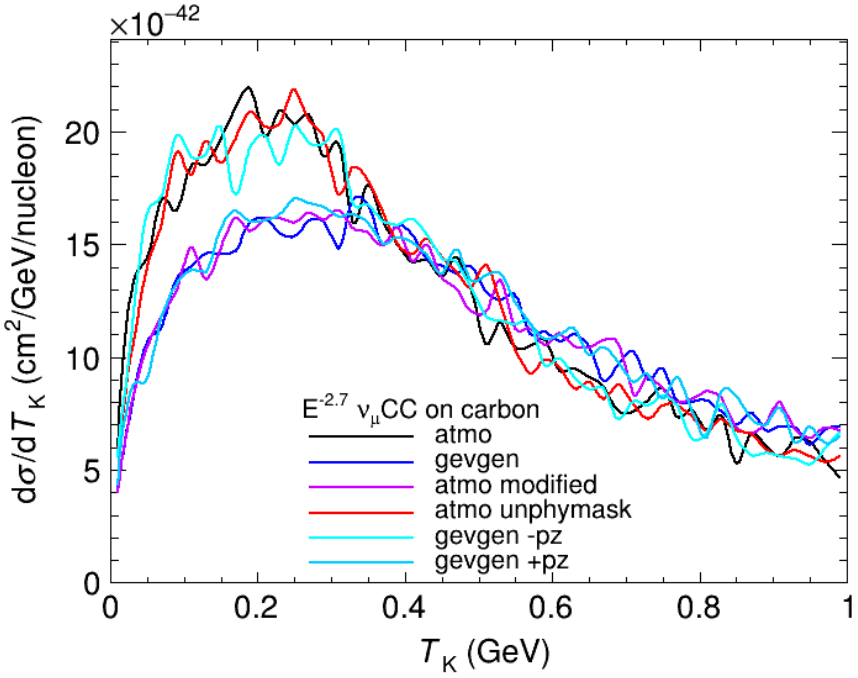
- **Before the de-excitation process, C11, B11, B10 dominated**



With deexcitation

- **After de-excitation process, C11, B11, B10 reduced, with more lighter nuclei**

GENIE “directionality” bug (Qiyu Yan, UCAS)



- Full thread of discussion: https://github.com/GENIE-MC/Generator/issues/226
- GENIE xsec depends on flux’s direction
- **Status: GENIE authors investigating… For the moment, use gengev until GENIE experts provide feedback. (gengev_atmo has unique 3D flux functionality)**

Summary

- GENIE has been applied in atmospheric neutrino oscillation studies and rare event researches in JUNO
  - generate neutrino interactions and proton decay events
- GENIE is one of the official neutrino generators in JUNO
- Our work gradually is updated from using GENIE2 to GENIE3
- We have a request to GENIE authors to implement the deexcitation when ^{12}C is the target
- A issue has been found that GENIE cross section depends on the flux's direction and we are looking forward to feedback from GENIE experts.

Welcome to JUNO

@Kaiping, Jiangmen

Thanks