28 Oxygen ion beam experiment for precise prediction of neutrino-oxygen quasielastic interactions

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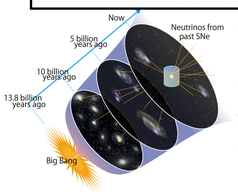
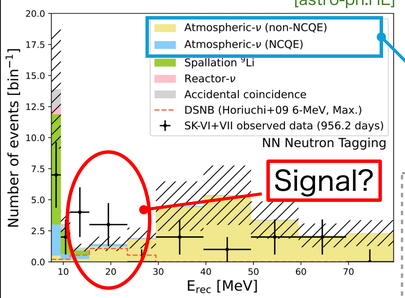
Neutrino 2026 @ University of California, Irvine, 2026/6/22 - 26

1. Diffuse Supernova Neutrino Background

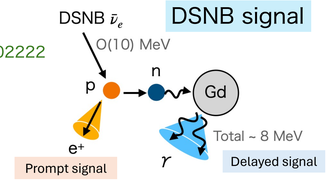


- Neutrino background produced from all the past supernova
- Probe of the history of the universe
- **Not discovered yet**
- Super-Kamiokande (SK) gives the world-leading searches

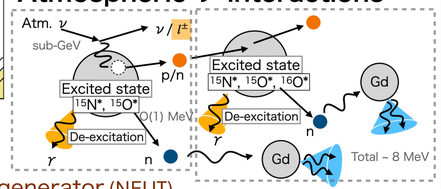
Latest result at SK K. Abe, et al. arXiv:2511.02222 [astro-ph.HE]



DSNB signal



Large uncertainty background: Atmospheric ν interactions



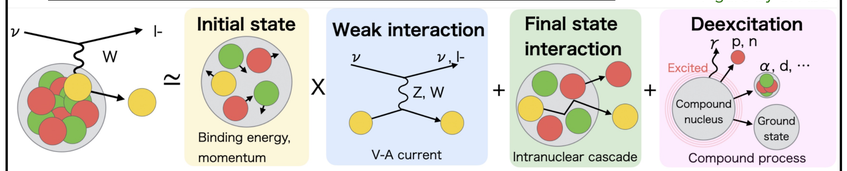
- Large uncertainties (~60%) on the prediction of γ & neutron emission

→Aiming to reduce to ~ 10% and improve the sensitivity to DSNB

ν generator (NEUT) Detector simulation (Geant4)

2. Neutrino-nucleus Interaction

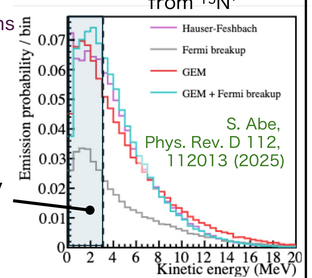
Figure by S. Abe



- Key process: De-excitation of ^{15}N*, ^{15}O*, ^{16}O*

Various processes are involved in ν-nucleus interactions →Difficult to understand them based on ν-nucleus interaction measurements alone…

Prediction of neutron from ^{15}N*



- Measurement of branching ratio of ^{15}N* (proton beam & oxygen target)
  M. Yosoi, et al., Phys. of Atomic Nuclei, 67, 10, (2004)
  - Neutron detection threshold at 3 MeV
  - Limitted acceptance
- ^{15}O*, ^{16}O*: No experimental data
- Measure **branching ratios of ^{15}N*, ^{15}O*, and ^{16}O* as a fuction of excitation energy**
- Optimize de-excitation model
- Implement the optimized model into ν simulations (NEUT, Geant4)

Improve neutrino-nucleus interaction prediction

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3. SAMURAI-79 Experiment

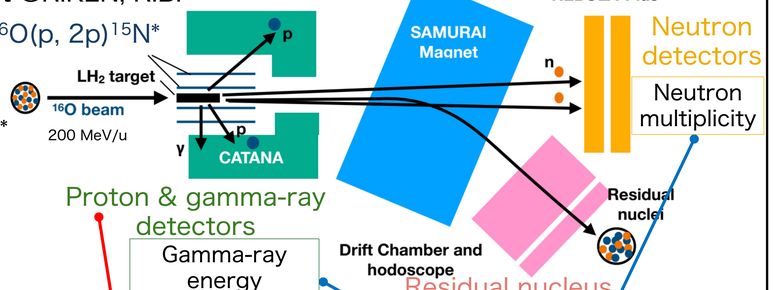
Approved at 25th RIBF PAC (2024)

- **Inverse kinematics** experiment with oxygen beam and hydrogen target @RIKEN, RIBF

T. Kobayashi, et al., NIMB 317, 294 (2013)

Measurement of ^{16}O(p, 2p)^{15}N*

1. Bombard a 200 MeV/u ^{16,17}O beam at a liquid hydrogen target, producing ^{15}N*, ^{15}O*, ^{16}O*
2. Reconstruct the excitation energy of ^{15}N*, ^{15}O*, ^{16}O* by detecting knocked-out nucleons
3. Detect de-excitation products (residual nuclei, neutron, light ions)



- Simultaneous detection of de-excitation products with high efficiency

Multiple detectors

Boosted to the beam axis →Large energy and narrow angle @lab frame

Reaction	Expected run period
^{16}O(p, 2p)^{15}N*	2027 Spring
^{16}O(p, pn)^{15}O*	2027 Autumn
^{17}O(p, pn)^{16}O*	

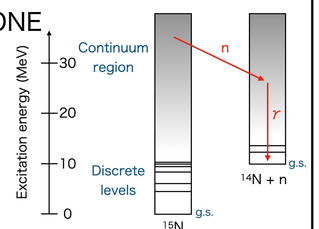
Proton & gamma-ray detectors → Gamma-ray energy

Measurement of recoil proton (2p) → ^{15}N* excitation energy

4. Optimization of De-excitation Model

- Calculate de-excitation of ^{15}N* using CCONE
  O. Iwamoto, J. Nucl. Sci. Technol. Vol. 44, No. 5, 687-697 (2007).
  O. Iwamoto et. al., Nuclear Data Sheets, 131, 259-288 (2016).
- De-excitation model: Hauser-Feshbach model
  W. Hauser, H. Feshbach, Phys. Rev., 87(2):366-373 (1952)

Emit single particle until nucleus reaches ground state

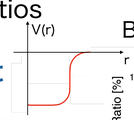


(Transition prob.) ∝ (Transmission coefficient) × (Level density)

→Change parameters in the Hauser-Feshbach model and check thier effect on branching ratios

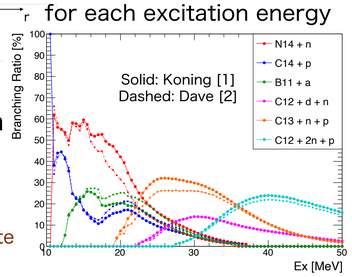
Transmission coefficient

How easily particle can pass through potential (Optical model potential (OMP))



- Changed OMP for neutron emission from ^{15}N
- Observed change in low Ex

Branching ratios of ^{15}N* (1/2+) for each excitation energy

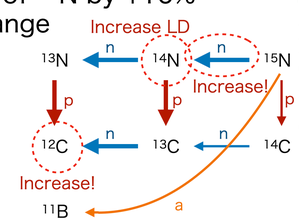


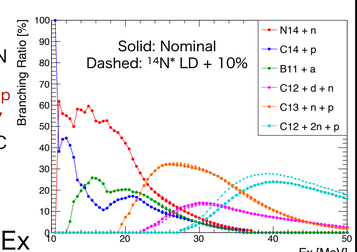
[1] A.J.Koning, J.P.Delaroche, Nucl. Phys. A713, 231 (2003)
[2] J. H. Dave and C. R. Gould, Phys. Rev. C 28, 2212 (1983)

Level density (LD)

How dense the state after transition is

- Increased LD of ^{14}N by +10%
- Observed change in high Ex





- OMP affects low Ex, LD affects high Ex

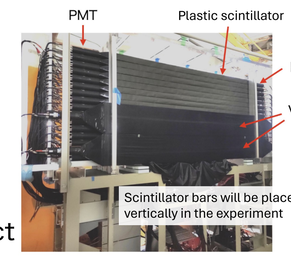
→ Planning to optimize these parameters simultaneously to fit the data

5. Development of Neutron Detector

MNEUT
- Detect recoil neutron
- Prototype of MNEUT exsists

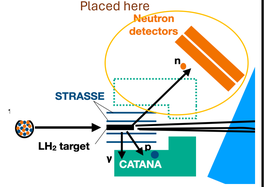
Parasitic measurement

- Placed the prototype of MNEUT during the beam time in June 2025
- Investigated its neutron detection performance and background effect

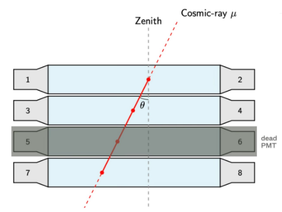


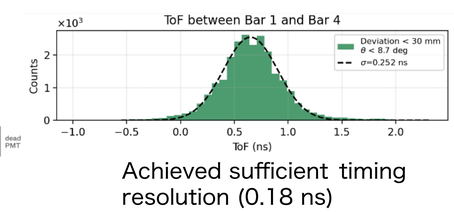
DAQ upgrade of MNEUT

- Performance evaluation of new digitizer: MDPP-32
- Verified that MDPP-32 meets the requirements for use in the experiment
- Planning to use in the experiment



Timing performance measurement w/ cosmic W. Cai





Achieved sufficient timing resolution (0.18 ns)

6. Summary & Prospects

- Preparing for the oxygen ion beam experiment, SAMURAI-79
- Planing to measure de-excitation of ^{15}N*, ^{15}O*, ^{16}O* using inverse kinematics
- Aiming to improve the prediction of neutrino-oxygen quasielastic interactions