A comparison of n-^{16}O inelastic scattering between the experiment and simulations towards understanding neutrino reaction

Poster: #118

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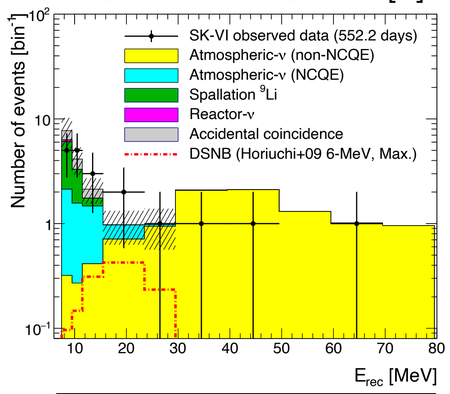
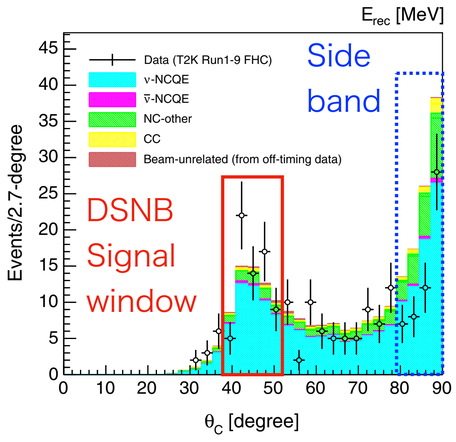
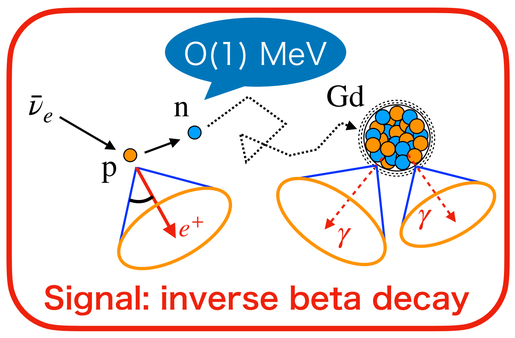
1. n-O scattering in DSNB Search

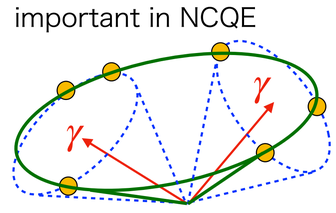
DSNB Search in SK-Gd [1]



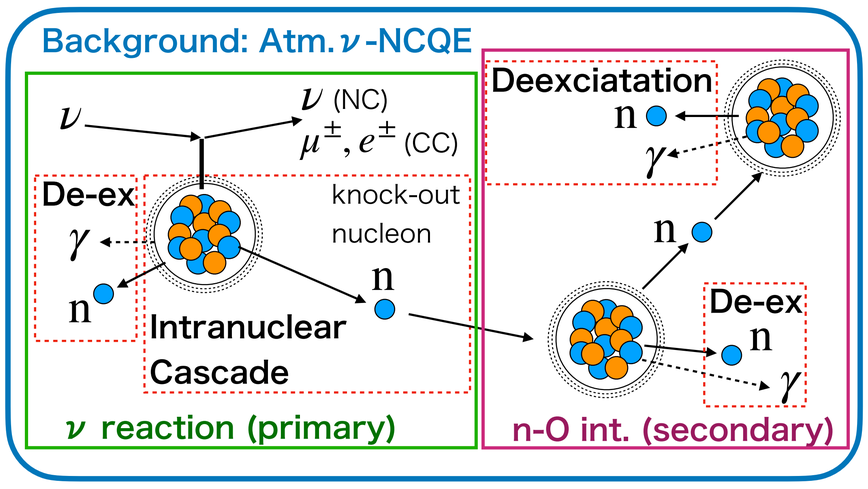




Multi-γs reconstructed as a ring w/ large angle. Secondary interaction is important in NCQE



Background: Atm.ν-NCQE



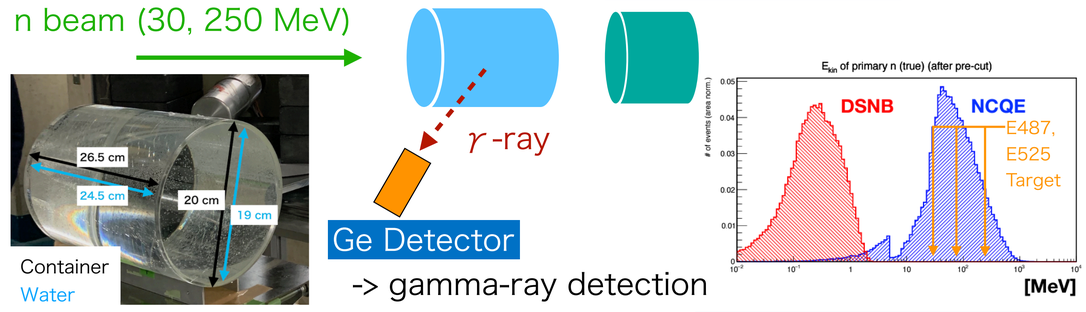
- Poor understanding of atmospheric neutrino induced neutral current quasi-elastic (NCQE) leads to a large systematics in the DSNB search in SK-Gd [1].
- T2K measurement indicated **inappropriate neutron-nucleus interaction model** [2].

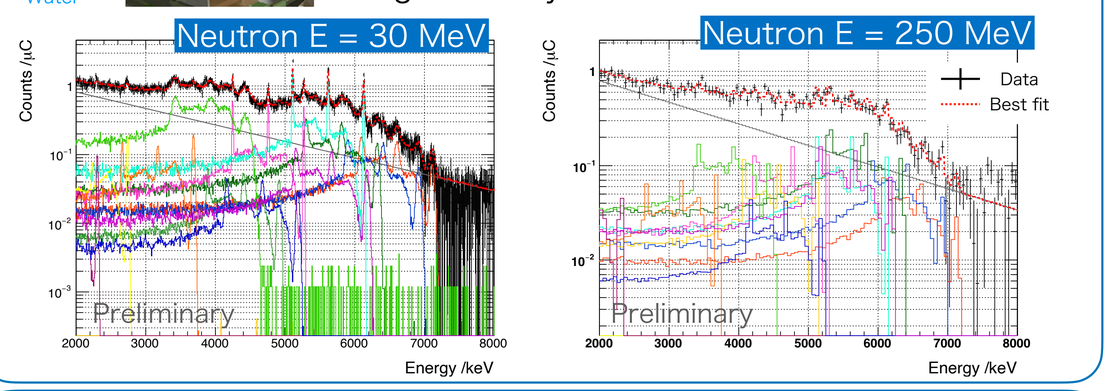
-> Sure **understanding of neutron behavior in water** is important!

2. Experimental Dataset

- E525 experiment: gamma-ray measurement via n+O scattering [3]
  - mono-energy neutron beam (30, 250 MeV)
  - Observed gamma-ray using Ge detector. -> Spectroscopy

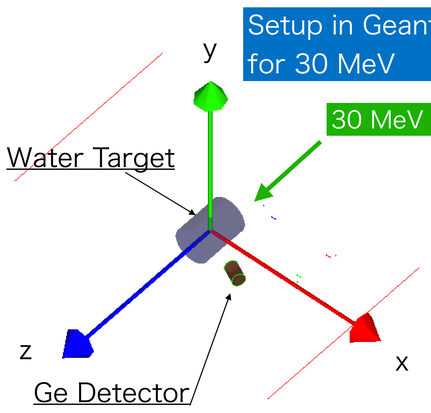
-> **good sample to validate** neutron-nucleus interaction model!

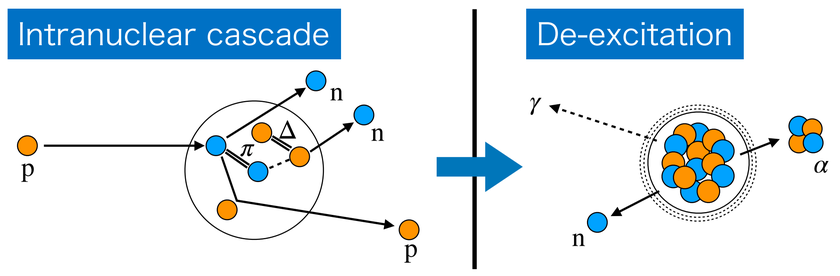




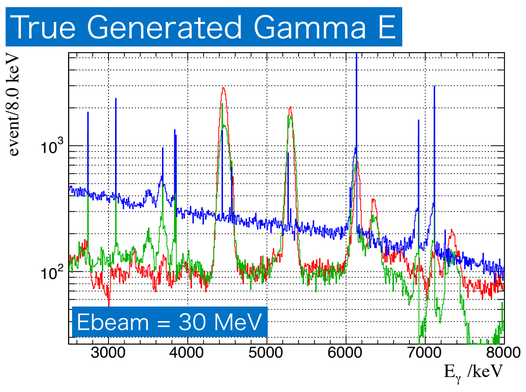
3. Simulation

- **MC simulation v.s. the E525 result.**
- Made Geant4-based E525 MC simulation using 4.10.5.1 (same as G4-based SK detector sim.)
- We used the following models available in G4:
  - Liege Intranuclear Cascade (INCL++)
  - Binary Cascade (BIC)
  - Bertini Cascade (BERT)





True Generated Gamma E



- INCL++
- BIC
- Bertini

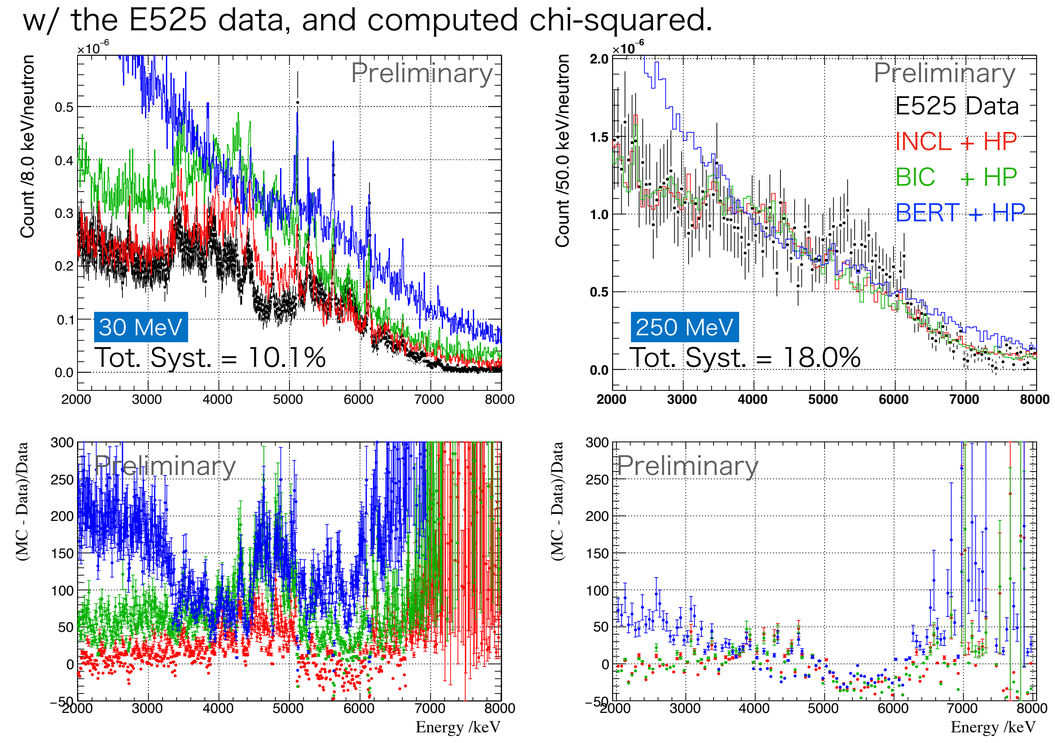
solid line: default choice

- G4PreCompound
- ABLA
- NucDeEx v2.1 [4,5]
- G4cascade unique

- INCL++ compatible w/ some de-excitation models -> find out the best cascade-deexcitation pair.
- N.B.: SKG4 default is currently “Bertini cascade”[6].

4. Cascade Models

- Compared each cascade model (coupled w/ its default de-ex. module) w/ the E525 data, and computed chi-squared.



Model	χ^2/ndf @30 MeV	χ^2/ndf @250 MeV
INCL++	1933.4 / 750	303.1 / 120
BIC	2405.5 / 750	348.7 / 120
BERT	4632.9 / 750	592.7 / 120

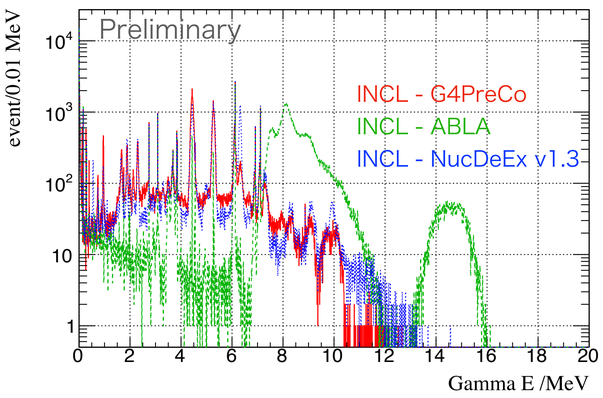
$$\chi^2 = \sum \left(\frac{N^{\mathrm{data}} - f \times N^{\mathrm{mc}}}{\sigma^{\mathrm{stat.}}} \right)^2 + \left(\frac{1-f}{\sigma^{\mathrm{syst.}}} \right)^2$$

- **Both dataset prefer INCL++** model.
  - BIC: similar due to the syst. error.
- Bertini shows a large inconsistency.

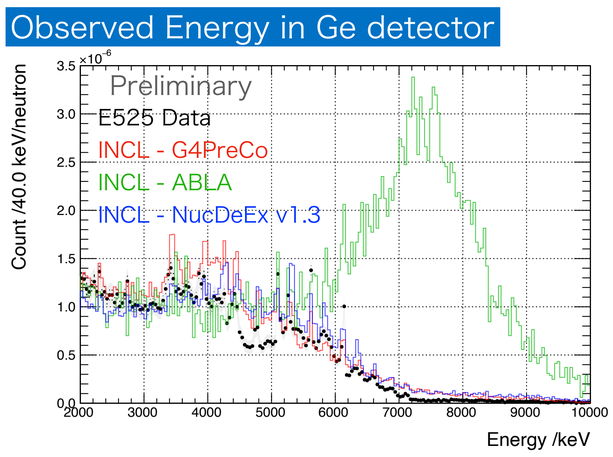
5. Deexcitation Models

- Compared de-excitation models w/ the E525 data (cascade model: INCL++).

True Generated Gamma E @30 MeV

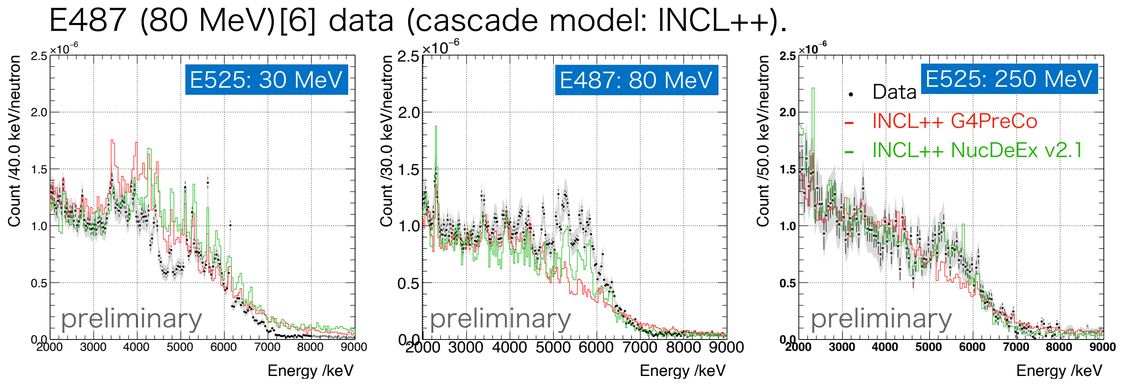


Observed Energy in Ge detector



- ABLA shows a large overestimation in E > 6 MeV. Inappropriate for water detector!
- G4PreCompound and NucDeEx shows better agreement. -> Check other energies.

- **G4PreCo v.s. NucDeEx v2.1** with the E525 (30, 250 MeV)[3] and E487 (80 MeV)[6] data (cascade model: INCL++).



Model	χ^2/ndf @30 MeV	χ^2/ndf @80 MeV	χ^2/ndf @250 MeV
G4PreCompound	1063.7 / 151	3599.6 / 201	303.1 / 121
NucDeEx v2.1	925.7 / 151	647.3 / 201	200.9 / 121
Syst. Error	10%	11%	18%

- NucDeEx v2.1 shows the better agreement at each neutron energy. -> INCL++ with NucDeEx v2.1 is the best choice for SKG4!

6. Conclusion & Reference

- Compared the E525 data with Geant4-based simulation with the different pairs of intranuclear cascade and de-excitation models in order to find a better secondary interaction model in G4-based detector simulation.
- χ^2 test shows **INCL++ w/ NucDeEx v2.1 has the best agreement** at all neutron energy.
- NEXT: Compare w/ the T2K data[2] to examine improvement by this update, Use in the DSNB search in SK-Gd.

[1] Harada et al., ApJ Let. 951:L27
[2] K. Abe et al, Phys. Rev. D 100, 112009 (2019)
[3] T. Tano et al, arXiv:2405.15366
[4] S. Abe, Phys. Rev. D 109, 036009 (2024)
[5] S. Abe, Neutrino2024 Poster #168
[6] S. Sakai et al, Phys. Rev. D 109, L011101 (2023)