Measurement of neutron-oxygen interaction cross section using neutron beam

Tomohiro TANO[A], Yusuke KOSHIO[A], Yuki SHIRAISHI[A], Toshiaki HORAI[A], Yosuke ASHIDA[B], Tsuyosi NAKAYA[B], Roger WENDELL[A], Masamitsu MORI[A], Gianmaria COLLAZOUOL[C], Fabio IACOB[C], Akira KONAKA[D], Tatsushi SHIMA[E]

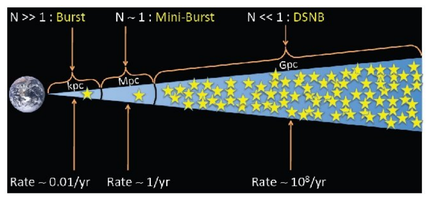
Okayama Univ.[A], Kyoto Univ.[B], Padova Univ.[C], TRIUMF[D], RCNP[E]

NNN22
21st International Workshop on Next Generation Nucleon Decay and Neutrino Detectors
September 28-30, 2022 Hida-city, Gifu, Japan

Introduction

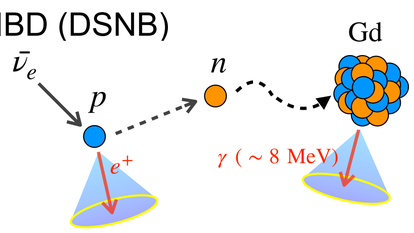
Diffuse Supernova Neutrino Background (DSNB)

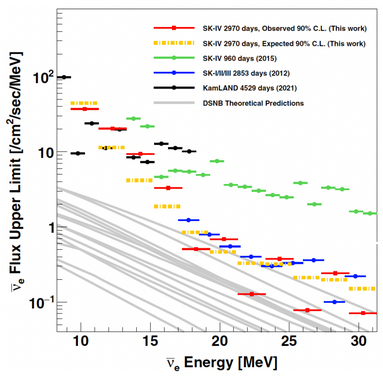
- Integrated neutrino flux from all of the supernova in the past
  - Supernova mechanism
  - Nucleosynthesis



Super-Kamiokande (SK)

- Searching inverse beta decay events by DSNB
- Gd have been loaded in water (SK-Gd)
  - Coincidence with e+ and n
- Most serve restrictions for DSNB flux
- Hyper-K, whose fiducial volume is ten times larger than SK, will start taking data in 2027

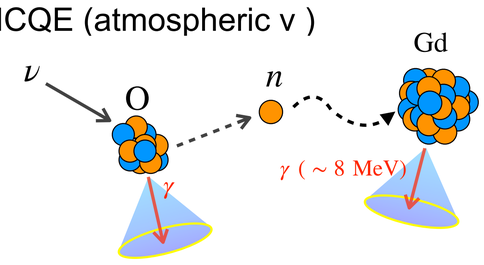


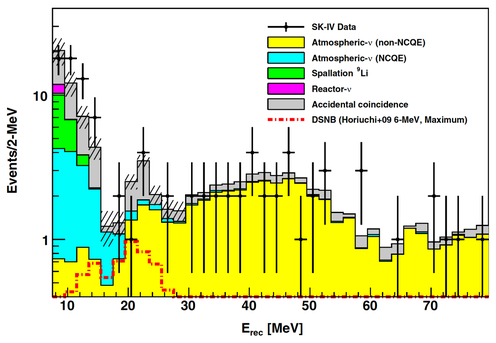


Neutral Current Quasielastic Scattering (NCQE)

- One of the main background for DSNB search

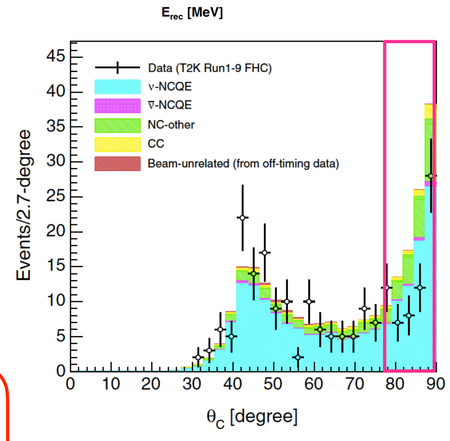
NCQE (atmospheric ν)

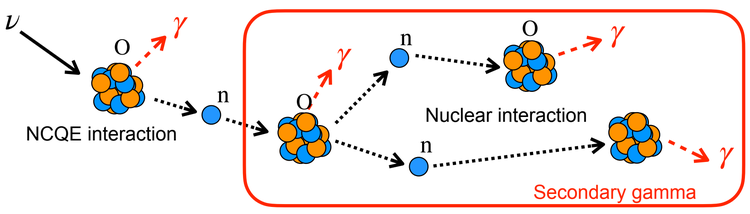


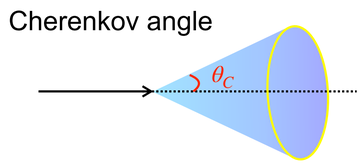


T2K experiment

- NCQE cross section were measured
- Cherenkov angle distribution has differences between the data at high angles and MC
  - Caused by gamma ray from neutron-^{16}O reaction







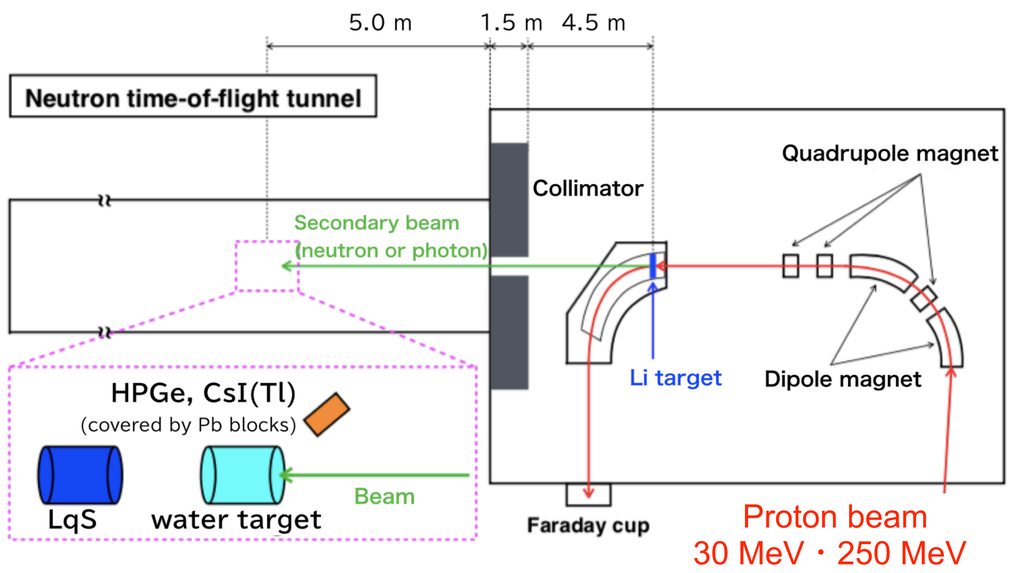
Motivation

Understand gamma-rays emitted from neutron-^{16}O interaction

E525 experiment

Oct. 18th and Dec. 16th, 2018
at Research Center for Nuclear Physics, Osaka Univ.

Neutron beam made incident on water target interact with ^{16}O and gamma ray are emitted.



Detectors

Liquid Scintillator : neutron
High Purity Ge : gamma-rays

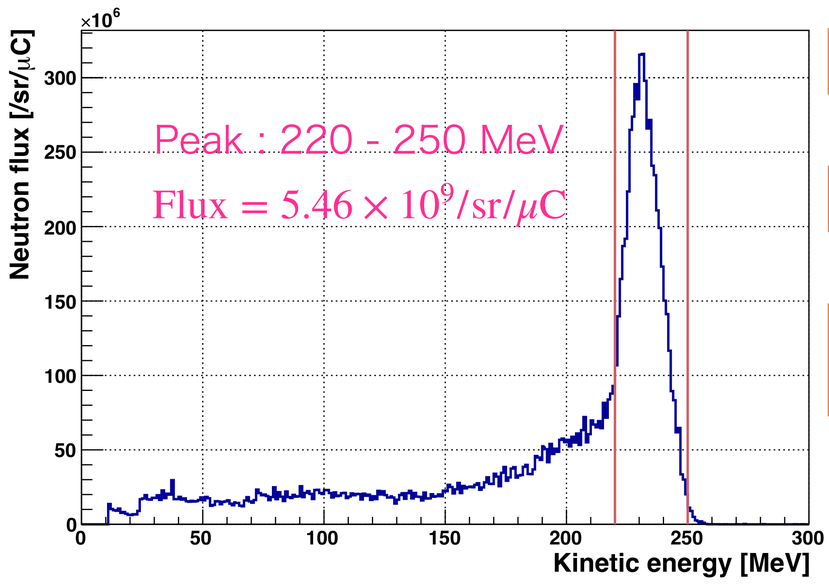
Proton beam energy

30 MeV and 250 MeV

- In this study, **250 MeV proton beam data is analyzed**

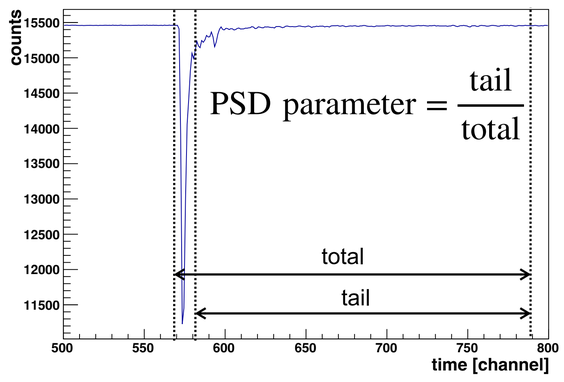
Analysis

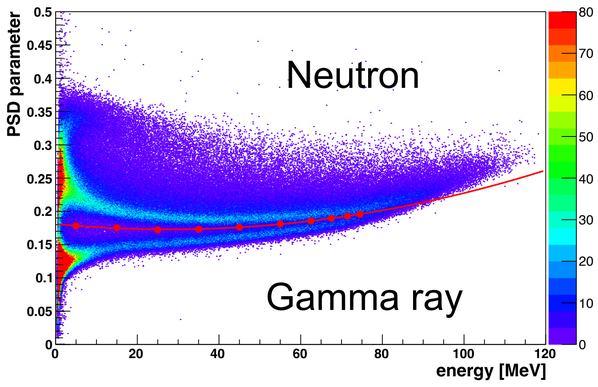
Neutron flux



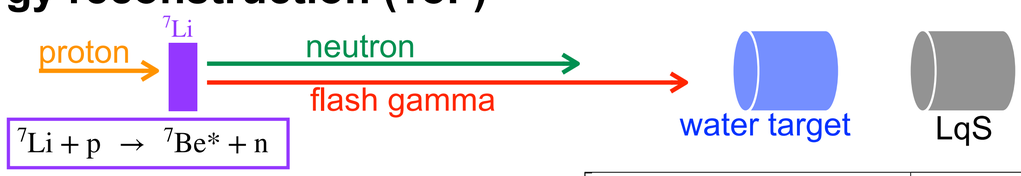
Particle identification
↓
Energy reconstruction
↓
Detection efficiency (simulation)
↓
Neutron flux

Pulse Shape Discrimination (PSD)





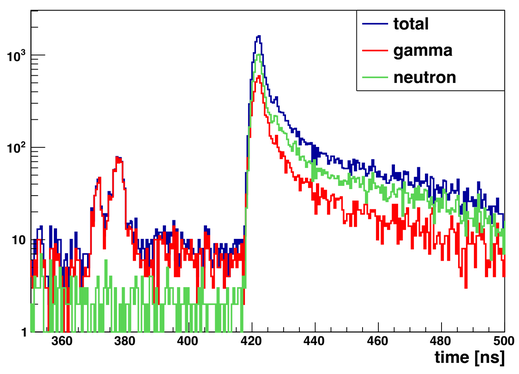
Energy reconstruction (ToF)



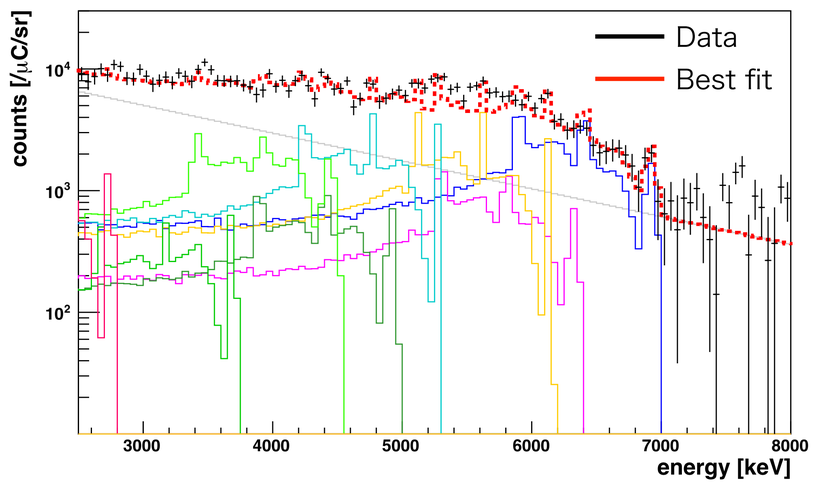
$^{7}Li + p \rightarrow {}^{7}Be^{*} + n$

$$K = \frac{mc^2}{\sqrt{1 - \left(\frac{1}{1+\frac{c}{L}}\Delta t\right)^2}} - mc^2$$

mc^2 : neutron mass
L : distance of Li to water
Δt : time difference



Gamma-ray spectrum



Relative intensity (6.32 MeV : 1.00)

Energy [MeV]	Intensity
6.92	$2.96^{+0.35}_{-0.44}$
6.32	$1.00^{+0.37}_{-0.37}$
6.13	$2.23^{+0.60}_{-0.37}$
5.27	$2.35^{+0.63}_{-0.40}$
5.10	$0.00^{+0.33}$
4.91	$0.63^{+0.33}_{-0.33}$
4.44	$2.08^{+0.38}_{-0.29}$
3.84	$0.00^{+0.13}$
3.68	$0.33^{+0.15}_{-0.23}$
2.74	$0.56^{+0.27}_{-0.19}$

- Relative intensity for each gamma-rays were extracted by fitting
- Strongest peak is 6.92 MeV
  - Reaction : ^{16}O(n, n')^{16}O*
    3rd excited state
- The uncertainty of neutron-^{16}O interaction will be reduced by introducing these results into the simulation

Summary and Outlook

- Understanding neutron-^{16}O interaction leads to reduce the NCQE uncertainty in DSNB search
- E525 experiment was conducted and we analyze 250 MeV data
- We got neutron flux and gamma-ray spectrum and relative intensity for each gamma-rays were extracted by fitting the spectrum
- Introducing cross section into simulation, the uncertainty will be reduced, which is helpful for DSNB search in SK-Gd