Gamma Ray Spectrum Measurement from Capture Reactions of Uranium-238 for Thermal and Resonance Energy Neutrons

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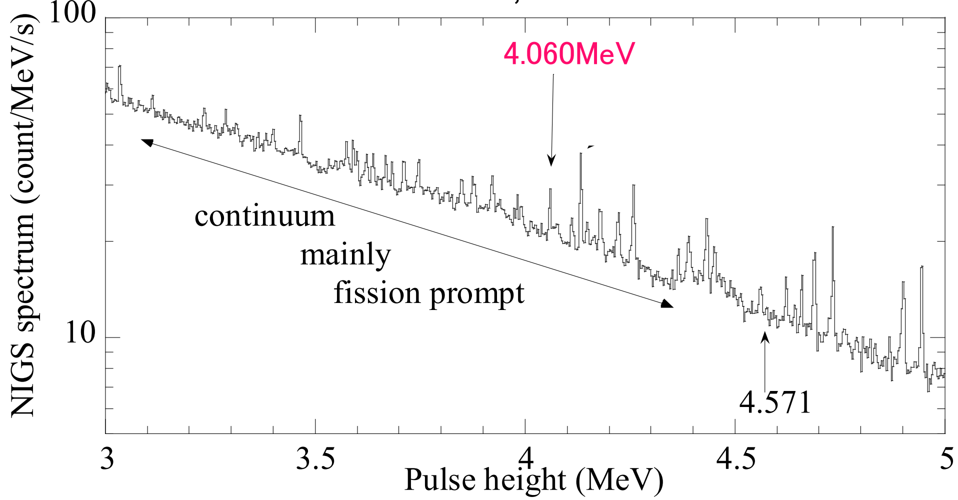
Background

- ^{238}U is most major isotope in nuclear fuels.
- ^{238}U(n,γ) reaction is significant in reactor safety & economy.
- For the reason, quantification of ^{238}U(n,γ) reaction by measurement is desirable.
- As a in-situ technique, we focus on γ ray spectroscopy.
- We've succeeded in detection of 4.060 MeV γ rays from ^{238}U(n,γ) in a sub-critical system.

Nauchi et al., Proc. ICNC2019



Background & Objectives

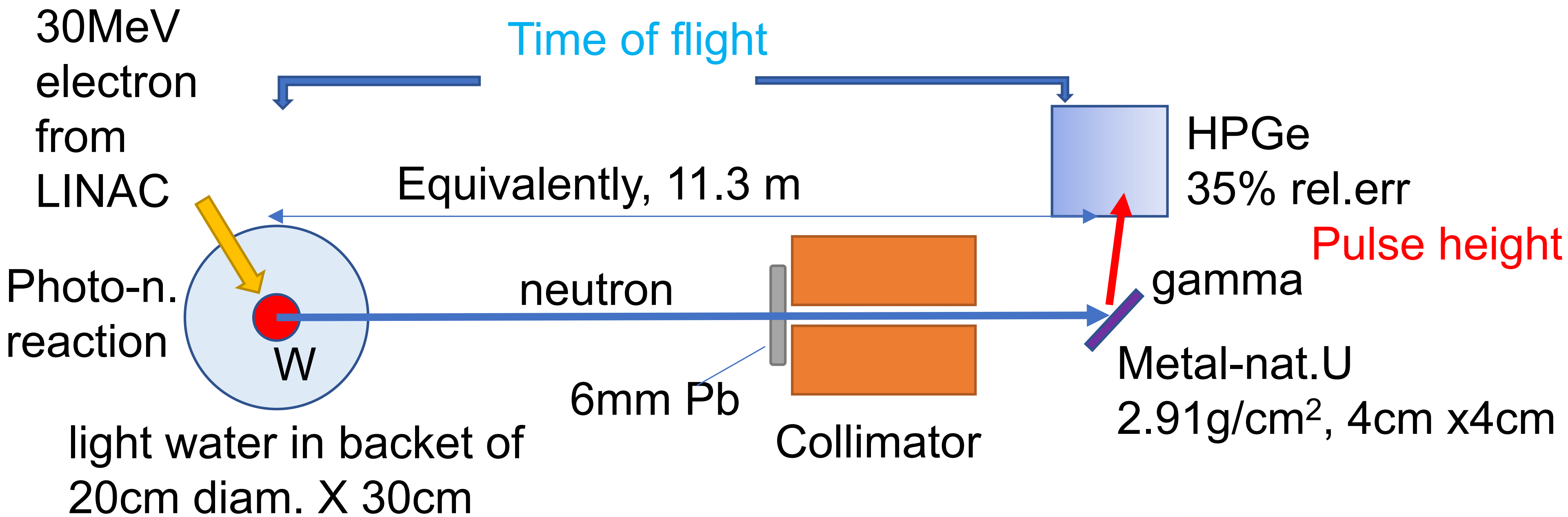
- H. Harada et al. reported the γ ray spectrum from $^{238}U(n,\gamma)$ varies with incident neutron energy. (JKPS59(2)1547, 2011).
- If so, γ ray spectrum in critical & sub-critical cores might give information on the neutron spectrum inducing $^{238}U(n,\gamma)$ reactions in the cores.

⬇

- We started to quantify γ ray emission per capture from $^{238}U(n,\gamma)$ for thermal and resonance energy neutrons.
- As the first step, $^{238}U(n,\gamma)$ γ ray spectra were measured for a U metal sample with better γ ray energy resolution in differential manner.

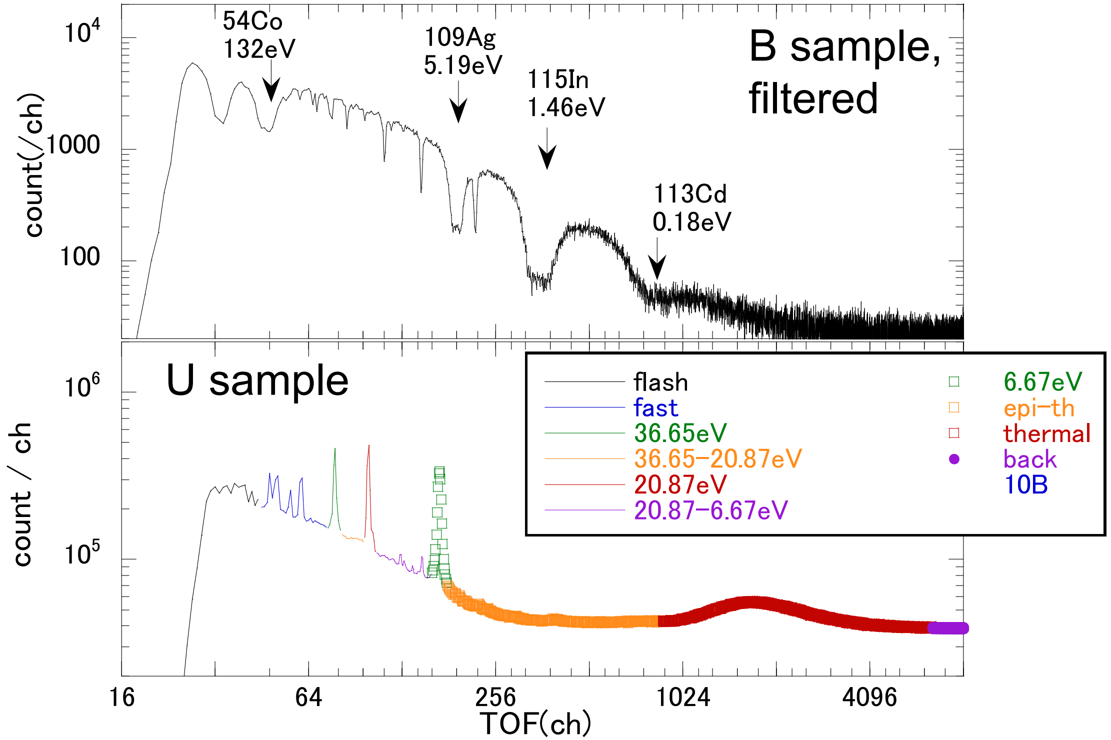
Experiment at KURNS LINAC

- Differential experiments were conducted in LINAC white neutron source facility in KURNS.
  - Pulse width 1 μs, 27 μA, Frequency 50 Hz



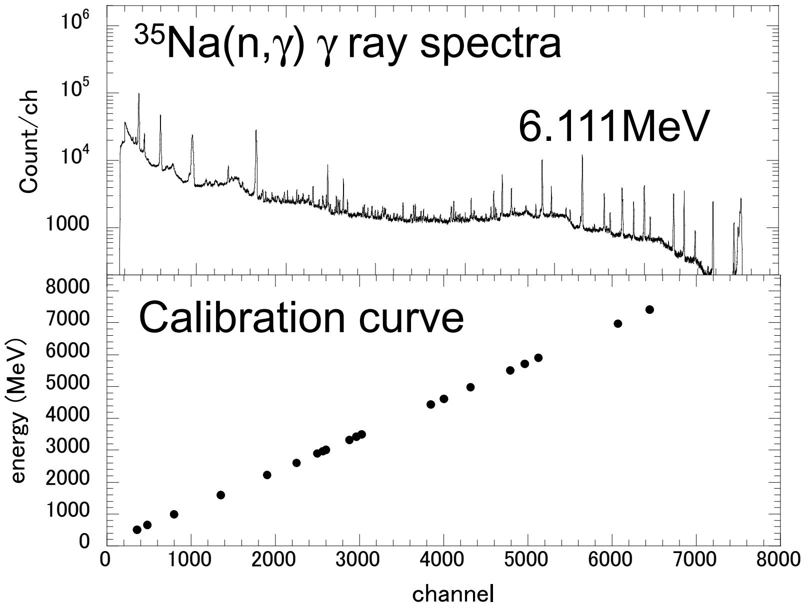
TOF data to determine neutron energy

- Incident neutron energy is determined by TOF data
  - TOF data with filtered by Cd, In, Ag, & Co were used for calibrate n-energy.
  - Thermal neutron event & resonance energy neutron events are identified. 6.7, 21, 37 eV



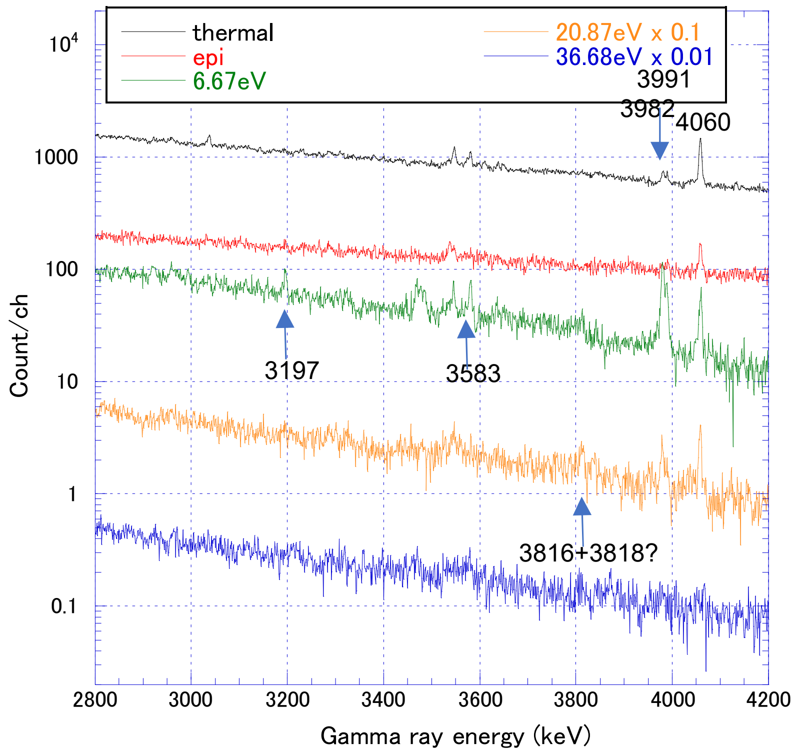
Sorting pulse height spectrum & calibration

- γ ray spectrum for E_n is sorted
- γ ray energy was calibrated with ^{35}Cl(n,γ) γ ray spectrum for thermal-neutron as well as γ ray , etc.



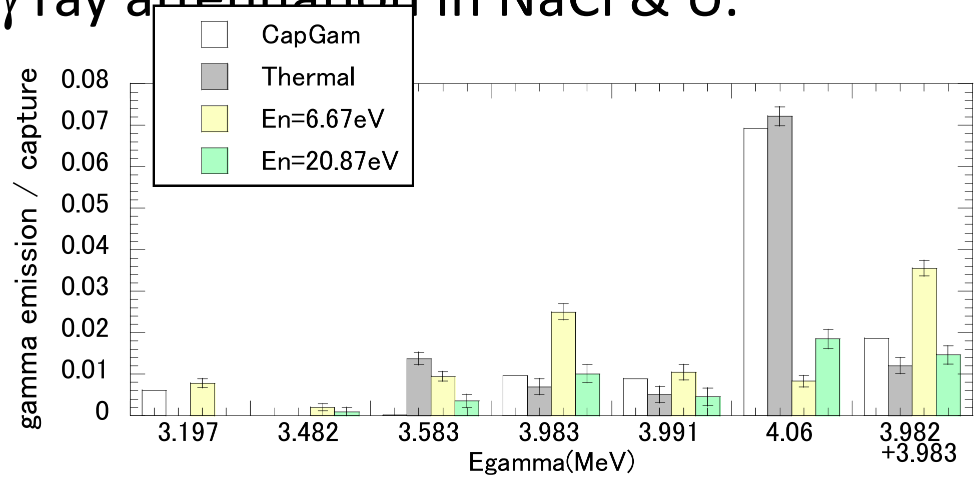
Observed γ ray Pulse height spectrum

- For resonance neutrons, base fission prompt component (continuum) is small so that peak/base ratio in γ ray spectrum is larger for En=6.67 & 21 eV.
- 3.982 & 3.912 MeV are resolved ＝ better resolution than Harada's.
- For thermal-n, 3.297MeV peak is not although it is listed in CapGam.
- γ ray spectrum difference between events induced by Thermal-n, En=6.67 & 21 eV are clarified.



Preliminary deduction of γ emission/ capture

- Efficiencies are preliminary quantified.
  - Neutron flux is determined by $^{10}B(n,a_1)$ 478 keV γ ray measurement
    - Absolute efficiency for 478 keV was determined by standard γ ray source
    - Attenuation of neutron flux in B sample was considered.
  - γ ray detection efficiency for E_γ : 2.8 ~ 4.2MeV was determined by $^{35}Cl(n,\gamma)$ considering neutron and γ ray attenuation in NaCl & U.
  - $^{238}U(n,\gamma)$ reaction rate was calculated based on JENDL-5.
  - The 4.060 MeV γ ray emission per capture for thermal neutron is consistent with CapGam data.



Summary

- $^{238}U(n,\gamma)$ γ ray spectrum was measured with better energy resolution for thermal & resonance neutrons (6.7 & 21eV).
- Prominent γ ray of 3.297 MeV listed in CapGam was not observed.
- γ ray spectrum for thermal & resonance neutrons (6.7 & 21eV) are different so that γ ray spectrum from cores would indicate the neutron spectrum inducing $^{238}U(n,\gamma)$.
- As for 4.060 MeV γ ray for thermal neutron induced $^{238}U(n,\gamma)$, the deduced γ ray emission / capture based on measured one is consistent with CapGam so that data handling is credible.

Future Work

- Enhancement of statistical accuracy would be examined.
  - Check the reproductivity of data
  - Enhancement of beam current paying attention to γ ray flash
  - Background shall be subtracted.
    - Delayed γ ray
    - Prompt fission γ rays
- Pulse-Height weighting measurement with a BGO to determine absolute capture reaction rate.

Thank you for your kind attention!

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