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Experimental Evaluation of Energy Resolutions for Pulsed Neutron Beam in the KURNS-LINAC

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Introduction.1

KURNS-LINAC

Kyoto University Institute for Integrated Radiation and Nuclear Science , Linear Accelerator

Features of KURNS-LINAC

- Easy to change beam pulse width
- The facility has two operational modes depending on the beam pulse width.
  (Short pulse mode or Long pulse mode)

Table1. Operational condition

	Short pulse mode	Long pulse mode
Pulse width	0.002~0.1 μsec	0.1~4.5 μsec
Pulse shape	gaussian	square wave
Frequency	1~300 Hz	1~100 Hz
Peak curent	6 A	500 mA

- ✓ Time of flight (TOF) measurement are performed at the facility.
- ✓ In the measurement, resonance peak are broadened by time resolution.

Introduction.2

- ✓ Time resolution contributes to energy resolution.
- ✓ We need to evaluate energy resolution for accurate resonance analysis.
- ✓ In the KURNS-LINAC, numerical analysis of energy resolution has been performed[1], experimental evaluation of energy resolution has never been performed.

Objective

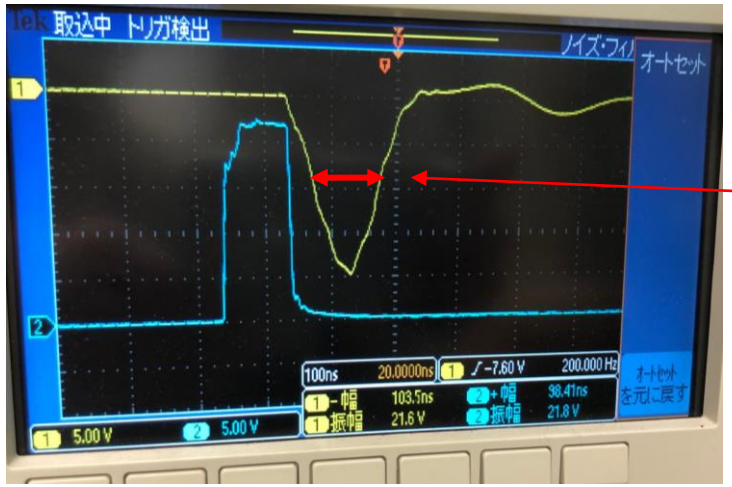
To perform experimental evaluation of energy resolution for pulsed neutron beam in the KURNS-LINAC

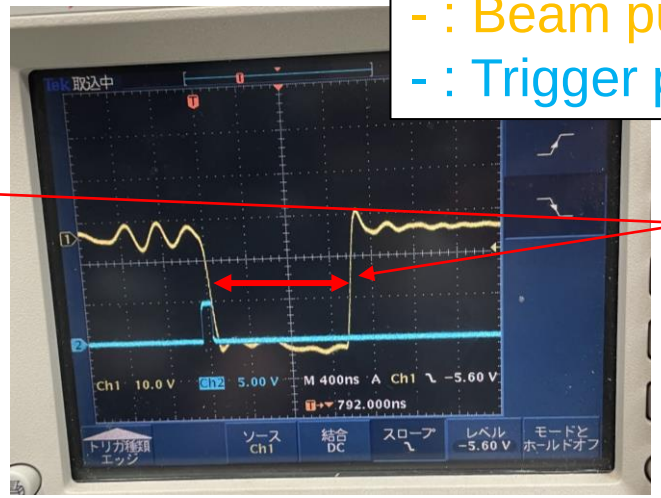
[1] T Sano, et al. Analysis of Energy Resolution in the KURRI-LINAC Pulsed Neutron Facility,EPJ Web Conf 146,03031(2017)

Time Resolution

✓ The time resolutions consist two main components.

①Pulse width of electron beam





- : Beam pulse
- : Trigger pulse

Pulse width of the electron beam

Short pulse mode
(pulse width 0.1 μsec)

Long pulse mode
(pulse width 4 μsec)

Pulse width contributes to the time resolutions.

Fig.1 Pulse shape of KURNS-LINAC

Time Resolution

②Moderation of neutrons

Pulsed neutron generation process at KURNS-LINAC

⑴When pulsed electron beams inject into a Ta target, bremsstrahlung X ray are emitted.

⑵High energy neutrons are emitted by (γ,n) reaction from the Ta target.

⑶The neutrons are moderated by light water.

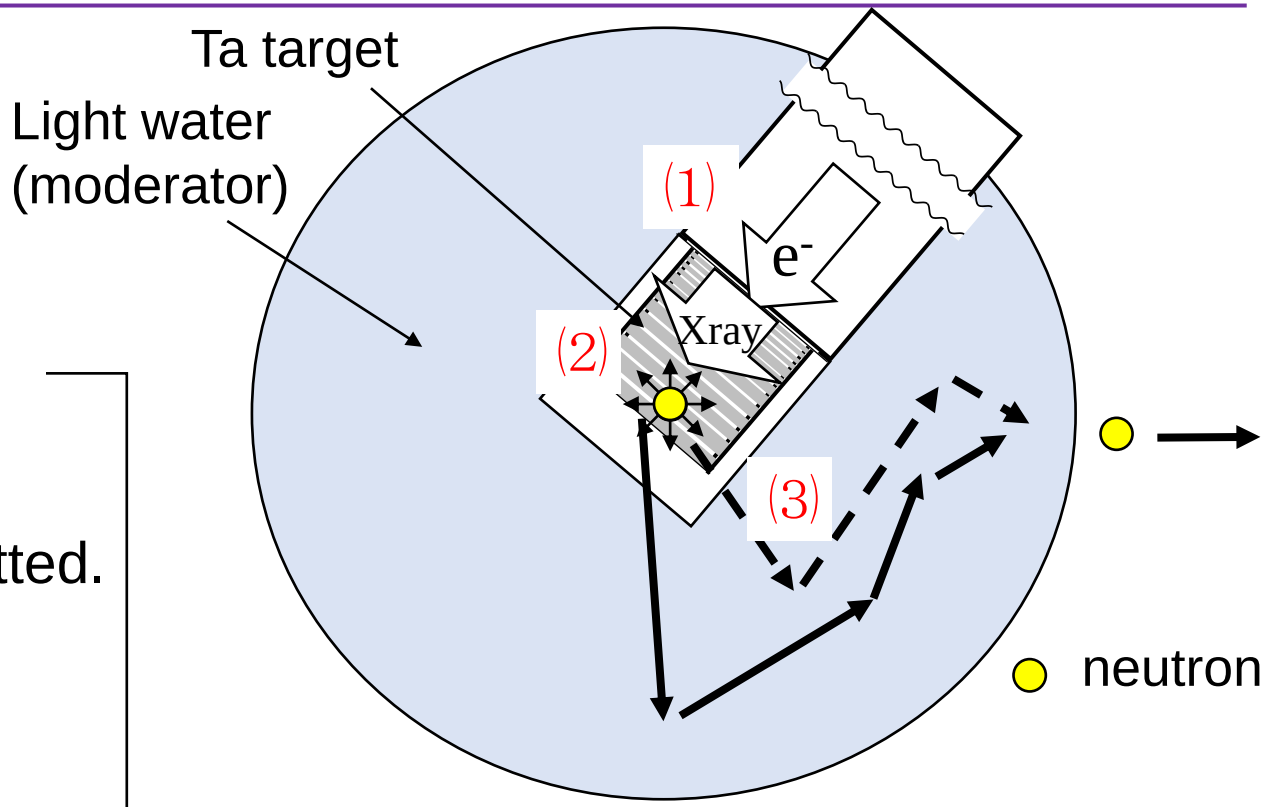
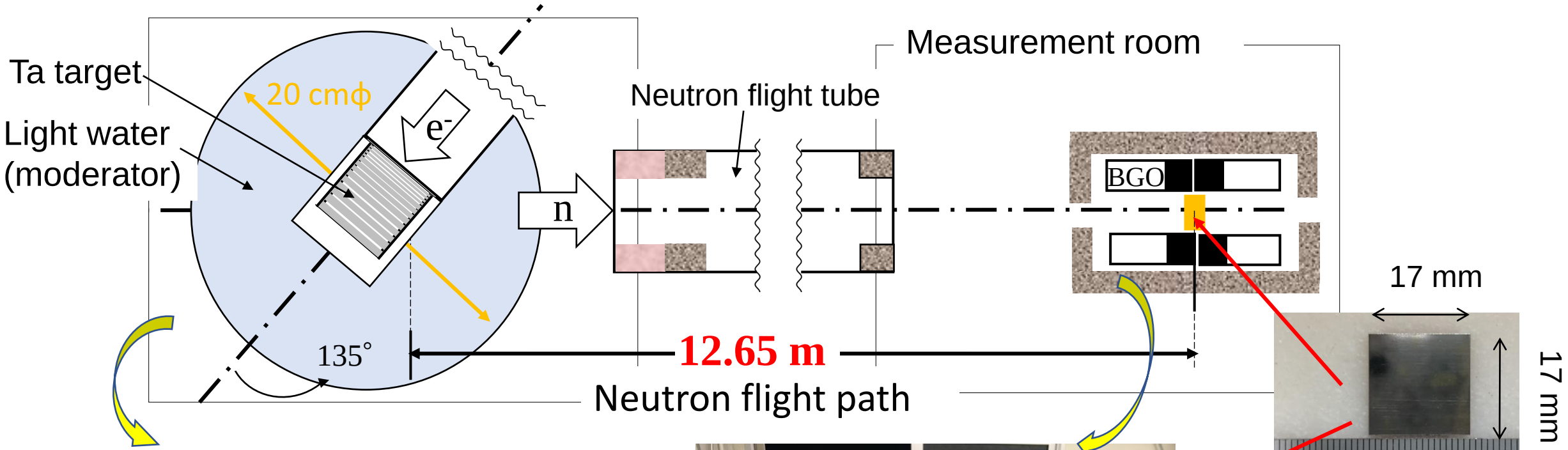


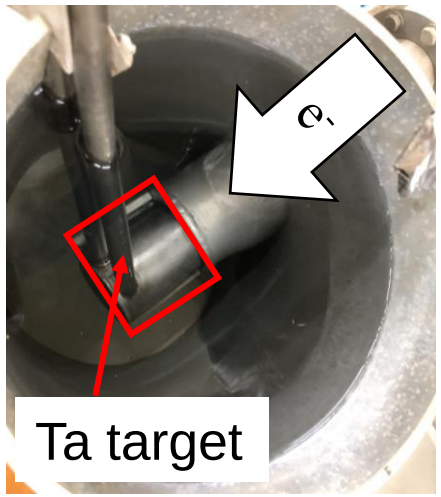
Fig.2 Pulsed neutron source with moderator at KURNS-LINAC

The moderation of neutrons contributes to time resolutions.

This component does not depend on neutron energy, and it is constant value.

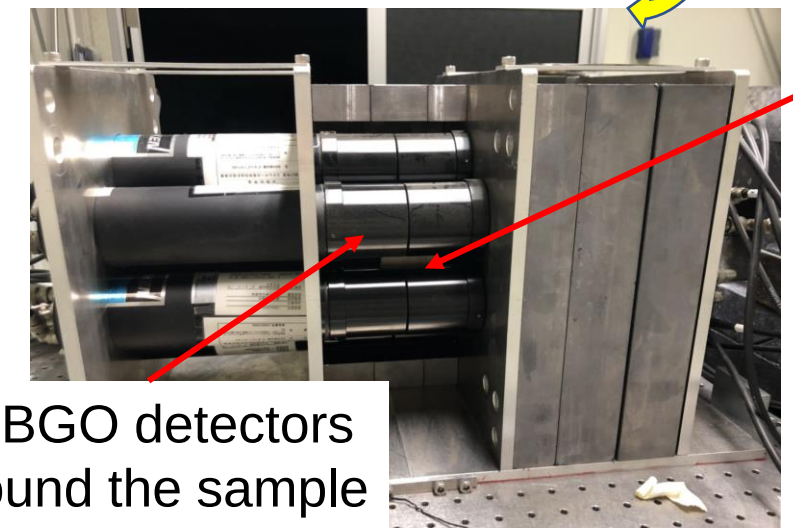
Experimental System





moderator

Height : 30cm
Diameter : 20cm



12 BGO detectors
around the sample

Sample : ^{181}Ta (0.03 mm^{t})

Reason for using Ta

Resonance parameters
are well known

Experimental condition

We performed the experiments with different pulse widths(4, 1, 0.1 μsec).

Table.2 Experimental condition

Run No	Pulse Width [μsec]	Operational Mode	Measurement time[h]	Frequency [Hz]	Peak Current [mA]	Average Current[μsec]	Filter
Run1	4.22	Long	10	50	100	20.7	-
Run2	1.35	Long	12	50	340	21.6	-
Run3	0.1	Short	23	200	430	72.5	Cd

We measured pulse height and detection time of gamma ray.

Experimental results & FWHM derivation

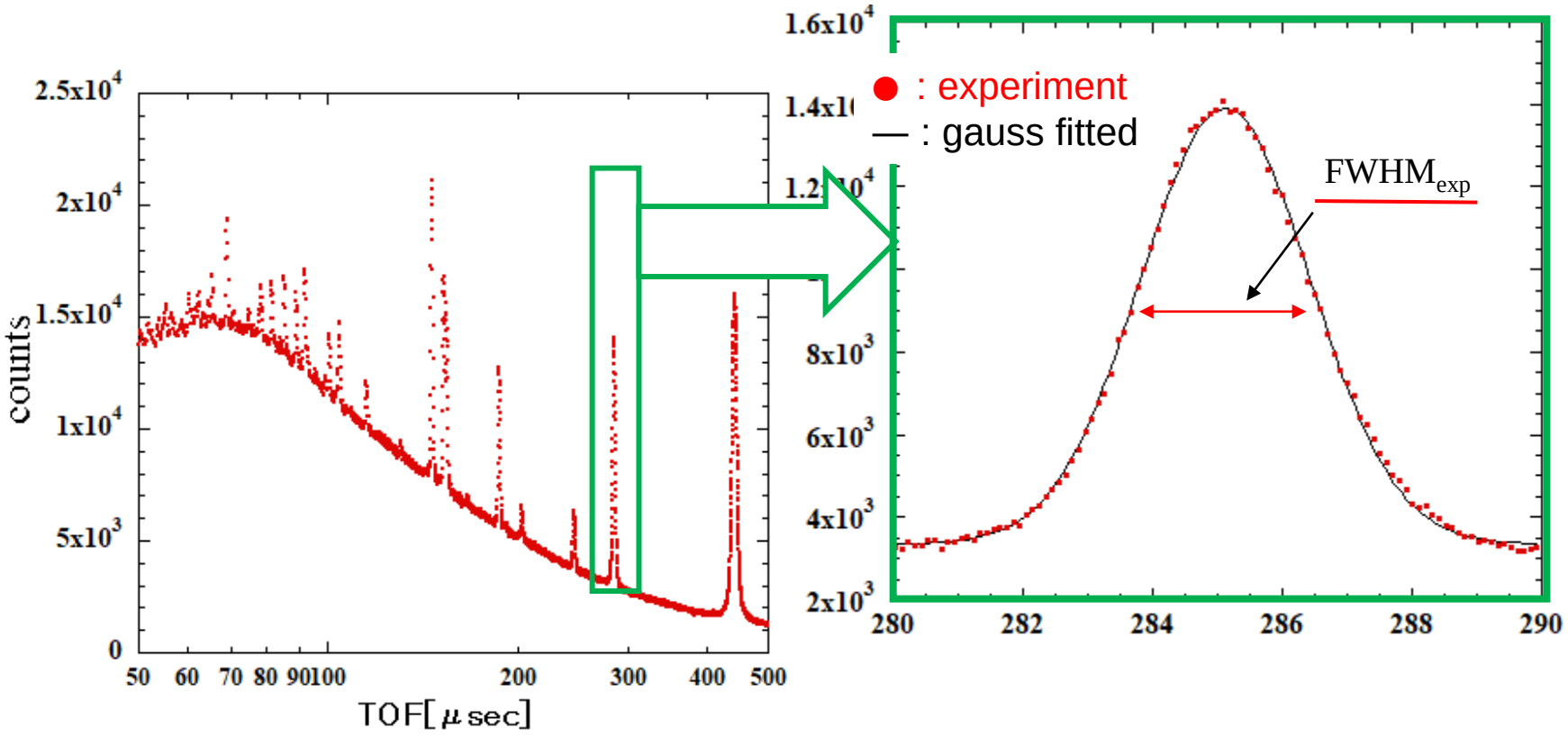


Fig.3 TOF spectrum (pulse width 0.1 μsec)

Gaussian function

$$f(t) = a \times \exp\left(\frac{(t-b)^2}{2\sigma^2}\right) + c \quad (1)$$

$$\mathrm{FWHM} = 2\sigma\sqrt{2\ln 2} \quad (2)$$

t : TOF[μsec]
σ^2 : variance
a : normalization factor
b : median
c : background
FWHM : half width

FWHM$_{exp}$ is obtained by gauss fitting to resolved resonances.

Numerical results

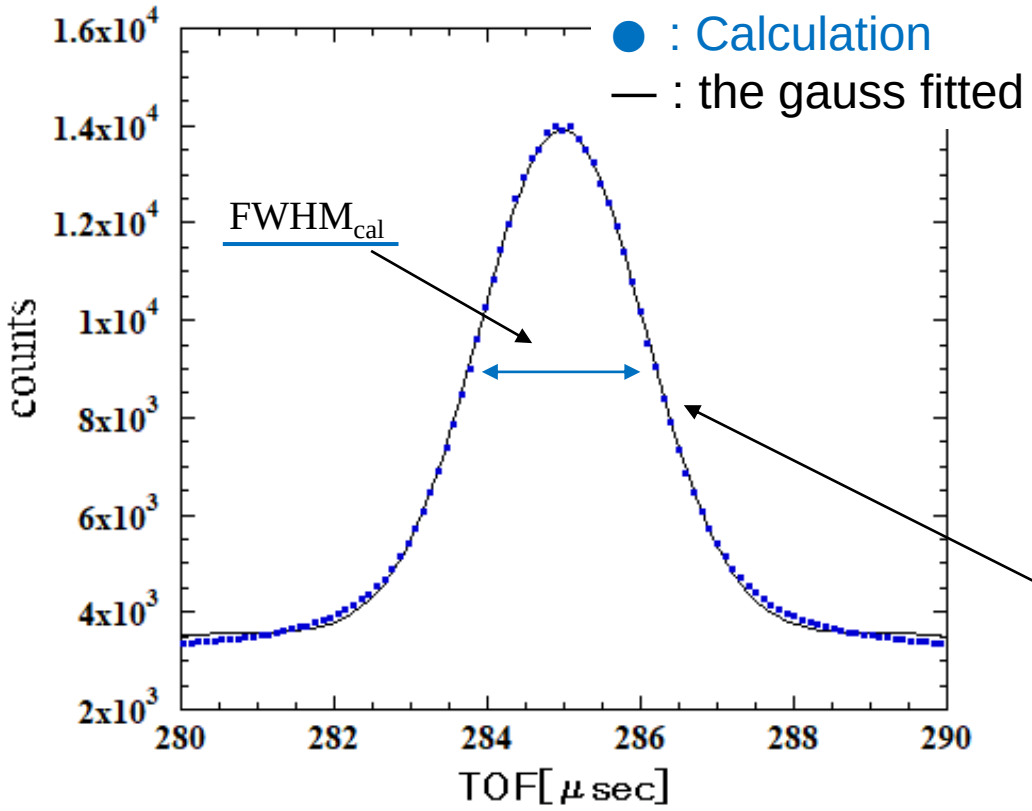


Fig.4 Calculation results

In order to evaluate Broadening by Self shielding & Doppler effect, we performed calculation.

The peak was obtained using PHITS3.23[2]& JENDL-4.0[3].

FWHM$_{cal}$ is obtained by gauss fitting to calculation results.

・Broadening by moderation & pulse width is not considered.

[2] T. Sato, et. al., Nucl. Sci. and Technol. 55,684-690(2018)
[3] K. Shibata, et. al., J. Nucl. Sci. and Technol., Vol. 48, pp.172-187,(2011)

Time resolution

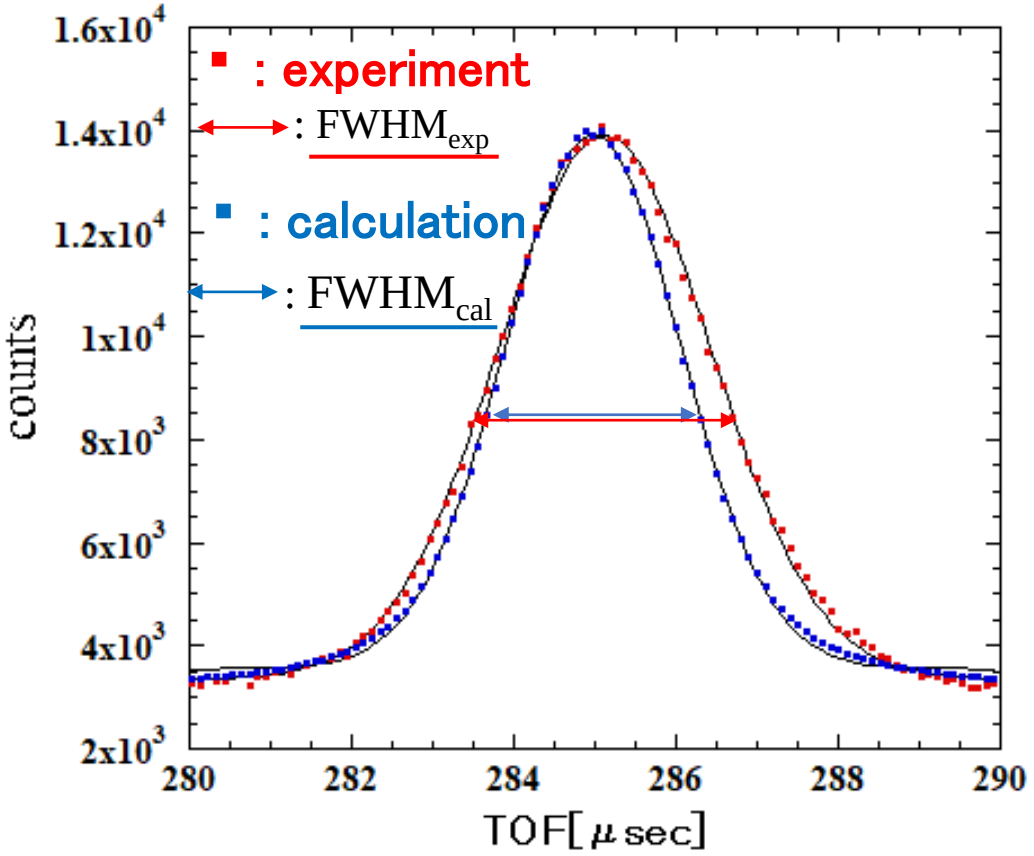


Fig.5 Comparison of FWHM between experiment and calculation

Time resolution : Δt

=

Broadening by moderation and pulse width

$$\Delta t = \sqrt{(FWHM_{exp})^2 - (FWHM_{cal})^2} \qquad (3)$$

Relationship between time resolution and energy resolution

$$\frac{\Delta E}{E} = 2\frac{\Delta t}{t} \qquad (4)$$

Energy resolution

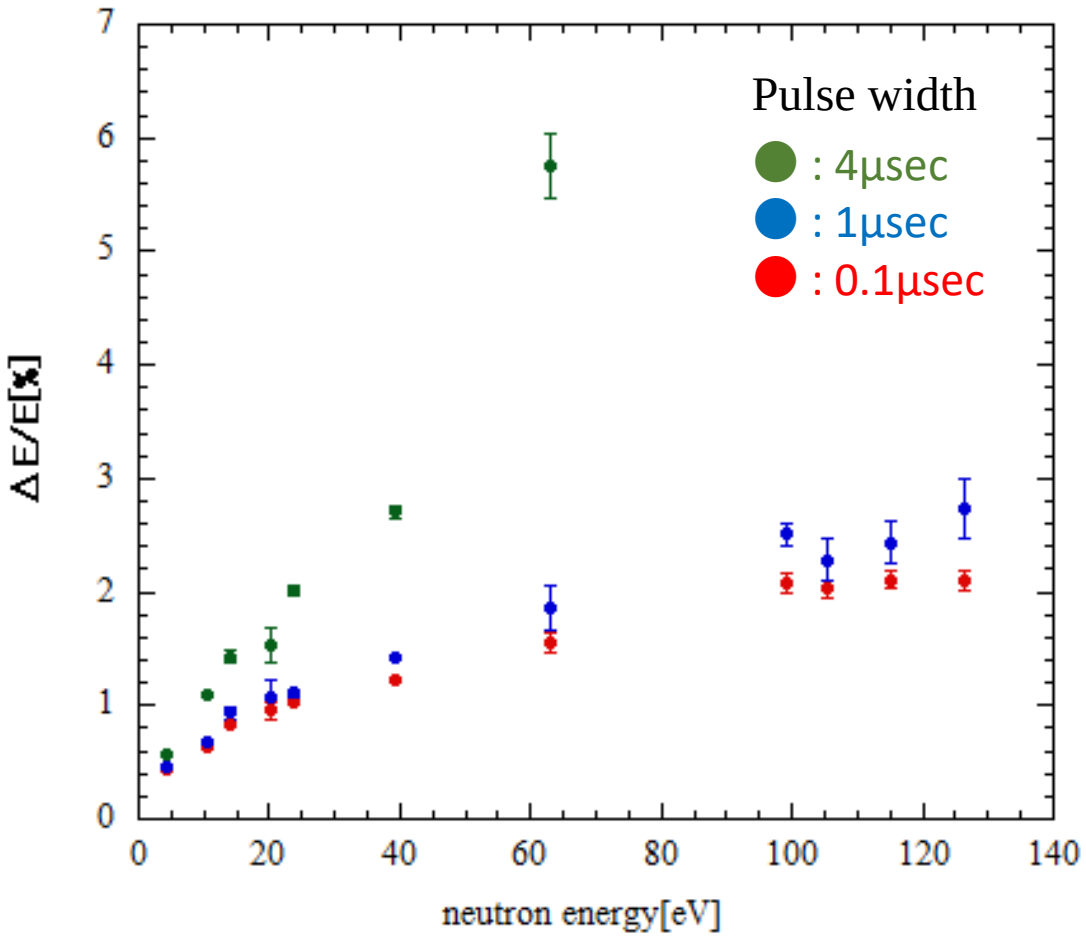


Fig.6 Energy resolutions

- ✓ Evaluated range
  - 4~125 eV (pulse widths : 0.1, 1 μsec)
  - 4~ 60 eV (pulse width : 4 μsec)

- ✓ Simplified formula for energy resolution and time resolution

$$\frac{\Delta E}{E} = 2\frac{\Delta t}{T} = \frac{2\Delta t'}{\mu L}\sqrt{E} + \Delta E_m \qquad (5)$$

Δt' : time resolution by accelerator and detector (include pulse width)
ΔE_m : energy resolution of moderator
L : neutron flight path[m]
μ : constant value 72.3[$eV^{1/2}$ μsec/m]

Energy resolution

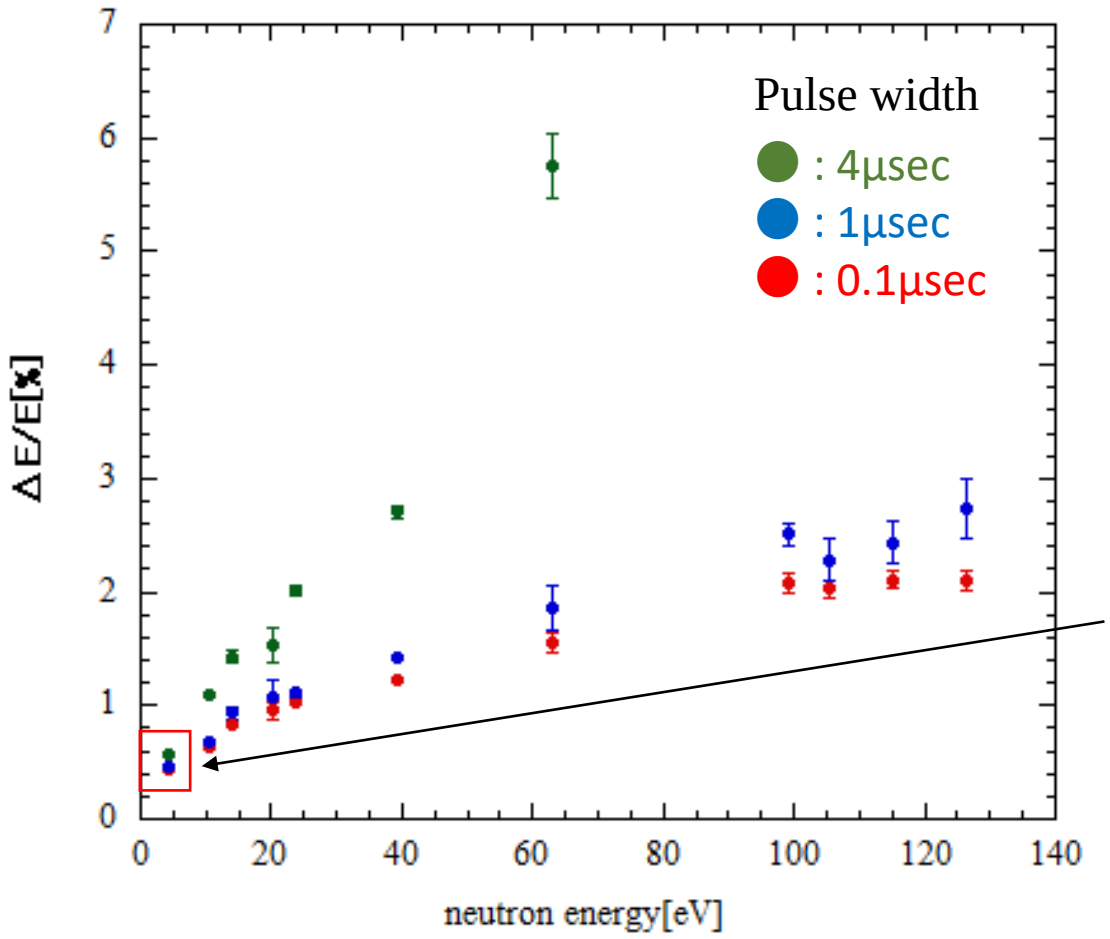


Fig.6 Energy resolutions

$$\frac{\Delta E}{E} = 2\frac{\Delta t}{T} = \frac{2\Delta t'}{\mu L}\sqrt{E} + \Delta E_m \qquad (5)$$

First term including $\Delta t'$ depends on neutron energy

Second term (ΔE_m) is constant

✓ Energy resolution at 4eV was 0.5 %

We confirmed that energy resolution of the moderator is less than 0.5 %.

✓ Energy resolution increased with neutron energy by first term

Conclusion

✓ We performed experimental evaluation of energy resolution
for pulsed neutron beam in the KURNS-LINAC.

(Conditions : Flight path 12.65 m & Cylindrical light water moderator with 20 cmϕ)

✓ In the energy range 4-125eV for each pulse width (0.1, 1 ,4 μsec),
we obtained the energy resolution.

✓ We confirmed that energy resolution of the moderator is less than 0.5 %.

✓ There was not much difference between results of
0.1 μsec pulse width and 1 μsec.

↳ evaluate resolution components.

Thank you for your attention !

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