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# Experimental Validation of Thermal Neutron Scattering Law Data for Innovative Reactor

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Acknowledgments

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# Contents

# 1. Motivation and Objective

# Motivation and Objective

In order to realize "carbon neutrality by 2050", the development of innovative nuclear reactor will be accelerated. In the situation, nuclear data associated with innovative reactor should be improved.

We have started the project entitled as "**Development of Nuclear Data Evaluation Framework for Innovative Reactor**" in 2021.

**Goals of the project**

- To establish a scheme to improve accuracy of nuclear data needed for developing innovative reactor system effectively
- To improve accuracy of nuclear data in collaboration with differential experiment, integral experiment ,and evaluation

**Targets of the project**

- Thermal neutron scattering law (TSL) data of candidate materials as moderators in an innovative reactor system
- The cross section data of charged particle emitting reactions which have a impact on the production of radio-active waste in a molten salt reactor system

# Nuclear Data Evaluation Framework for Innovative Reactor

## Differential Experiment

- DDSCS measurement
- Total CS measurement

by using **J-PARC(JAEA)**

A part of results were presented by **A. Kimura**.

- Charged particle emission CS Measurement

By using J-PARC, Pelletron

(Tokyo Institute of Technology)

## Integral Experiment

- Sample worth measurement

by using **UTR-KINKI(Kindai Univ.)**

A part of results were presented by **T. Sano**.

- Validation experiment

by using **KURNS-LINAC(Kyoto Univ.)**

A part of results are presented by **J. Hori**.(This talk)

## Evaluation

- Evaluation based on experimental results **(JAEA)**

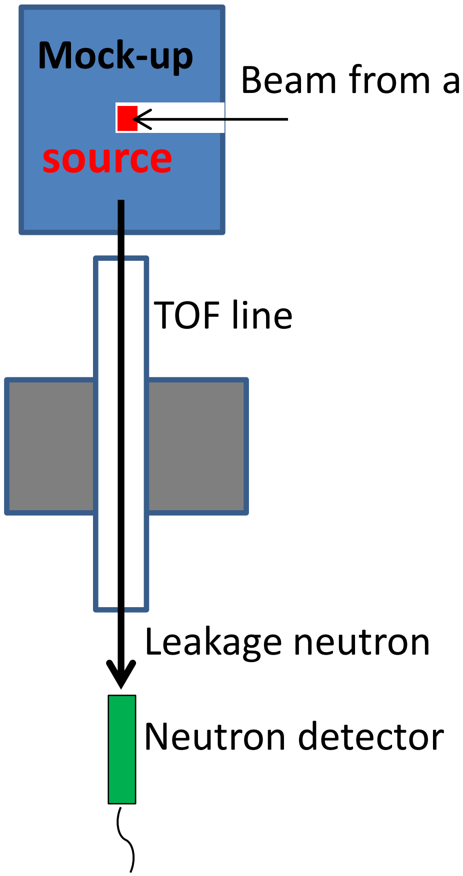
A part of results were presented by **S. Nakayama**.

- Impact Study (Kindai Univ.)

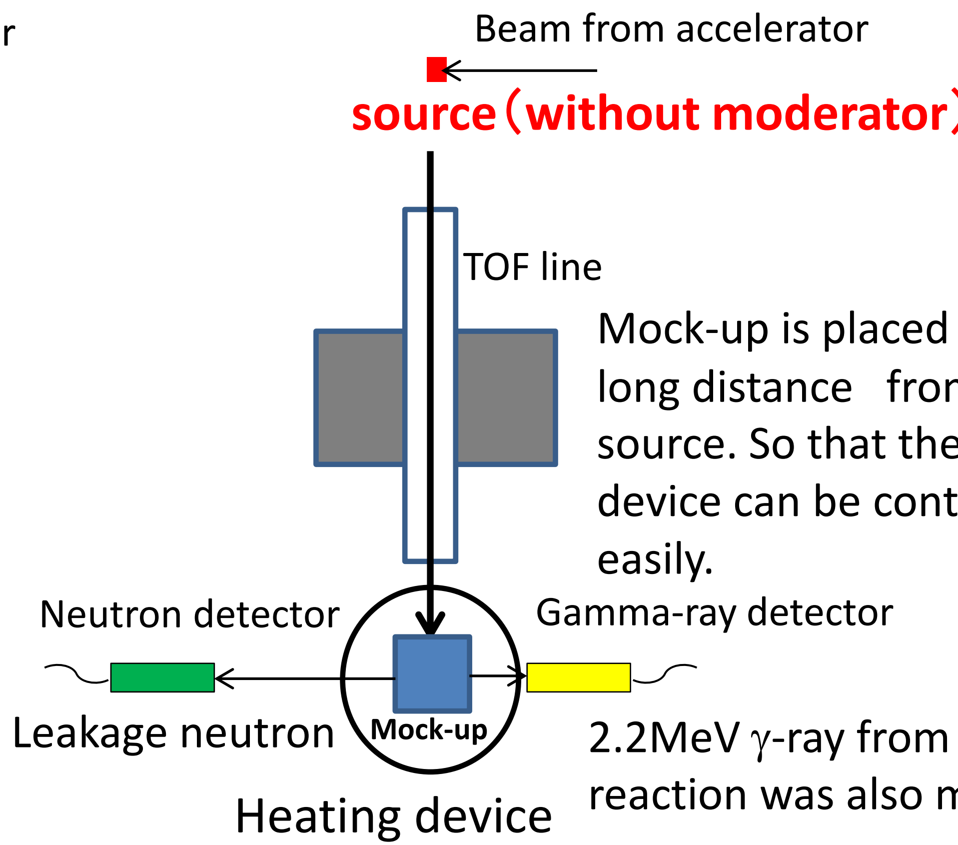
# How we can validate TSL?

## ①traditional method

Pulsed Slowing-Down-Time(PSDT) experiment




## ②new method




Mock-up is placed at the long distance from the source. So that the heating device can be controlled easily.

2.2MeV γ-ray from H(n,γ) reaction was also measured.

# Objective

- Feasibility of a new method to validate TSL data of candidate hydride ($H_2O$, $ZrH_2$, $CaH_2$) as a moderator in a SMR.
- Confirmation of temperature dependency for leakage neutron and capture gamma-ray time distribution

$S(\alpha,\beta)$ of H in $H_2O$ was newly evaluated with the molecular dynamics in JENDL-5 [1].


[1] O. Iwamoto *et al.*, *J. Nucl. Sci. Technol.*, **60**, 1-60 (2023).

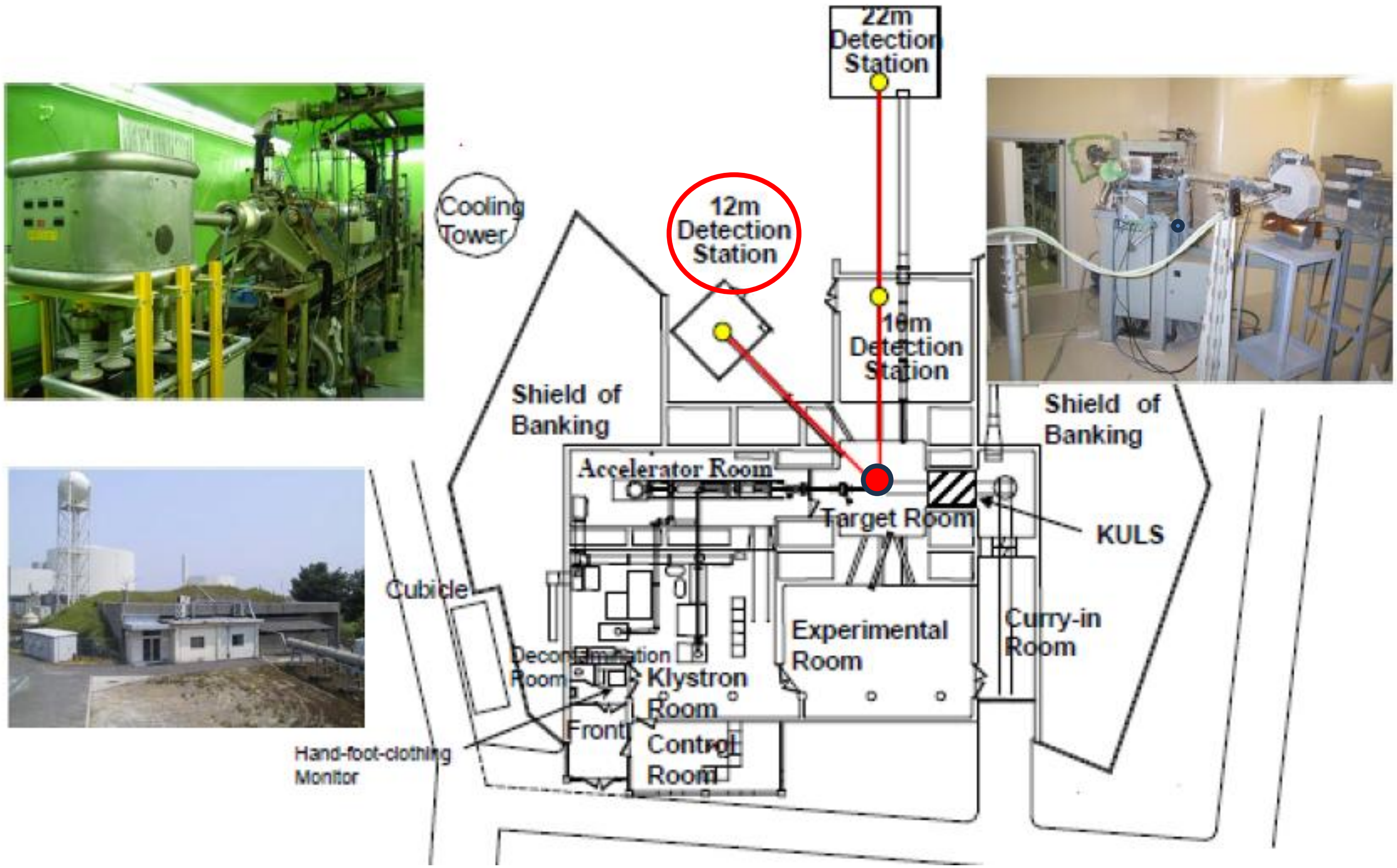
# 2. Experiment

# KURNS-LINAC

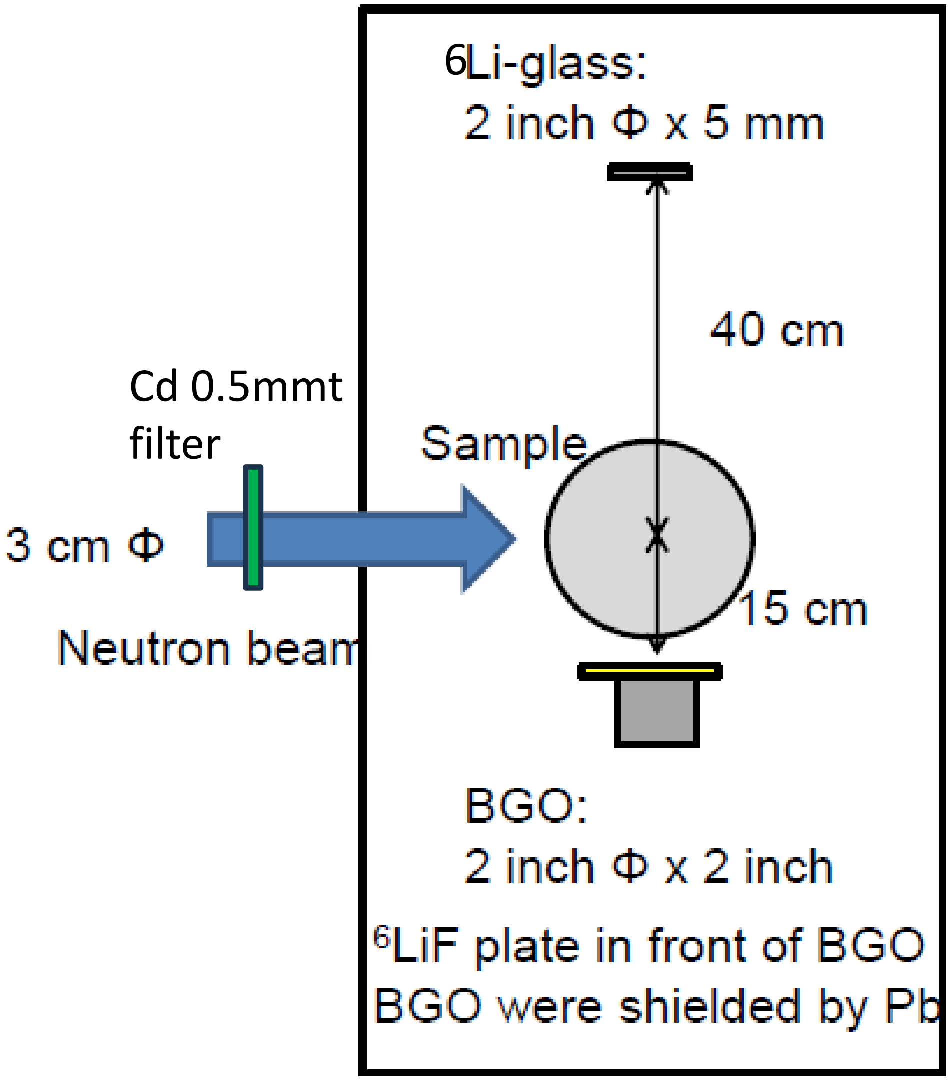
Maximum energy of electron: 46 MeV, Beam power: Max 6 kW

Neutron source : water cooled photoneutron Ta target

twelve Ta sheets were installed in Ti case (5cmϕ × 6.1cm)



# Experimental condition




Pulse width: 100 ns
Frequency: 200 Hz
Averaged current: about 70μA

Distance between Ta target and Sample was about 12 m.

Neutron source was used bare Ta target without moderator.

Neutron beam was collimated into 3cm in diameter.

# Exp.1(without heating device)

Sample: $H_2O$, $ZrH_2$, $CaH_2$

**$H_2O$**: Light water
Inner size 21 cm diam. x 30 cm in 3 mm thick Al tank
In the case of $H_2O$, the empty tank was used for background determination

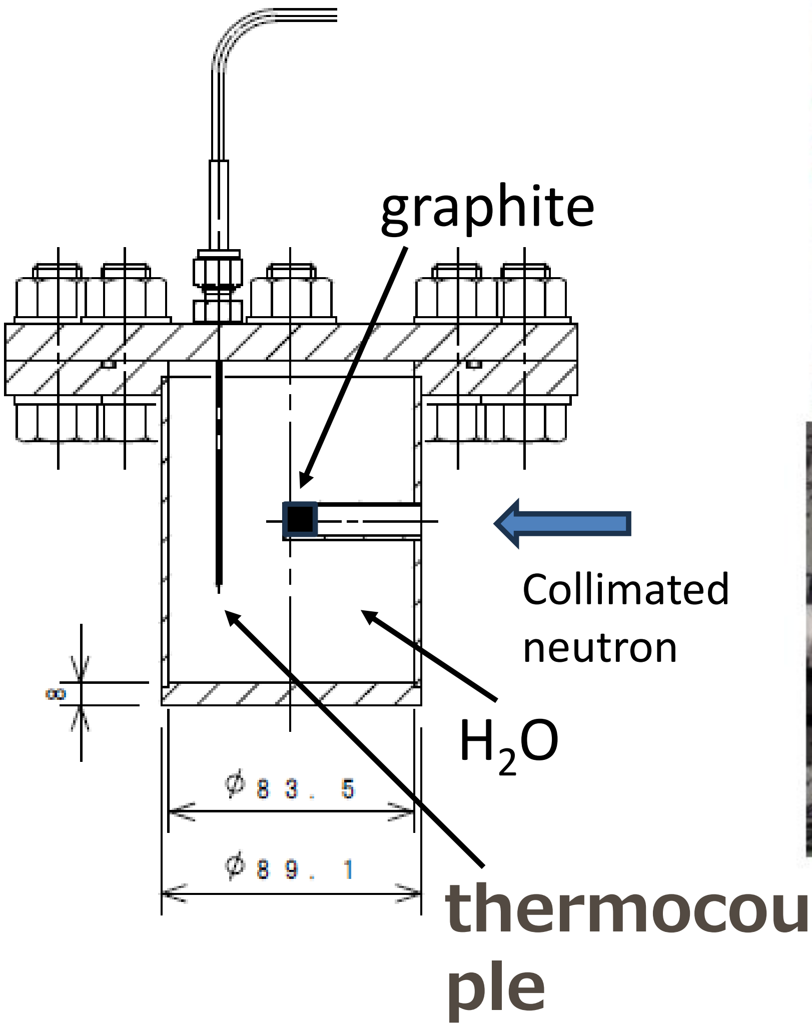
**$ZrH_2$**:
Inner size 5.65 cm diam x 5.5 cm in 0.5 mm thick Stainless container
Weight: 476 g, Density: 3.454 g/cm$^3$

**$CaH_2$**:
Inner size 5.65 cm diam x 5.5 cm in 0.5 mm thick Stainless container
Weight: 150 g, Density: 1.088 g/cm$^3$

In the case of $ZrH_2$ and $CaH_2$, the container covered by Cd was used for background determination

# Exp.2(with heating device)

Sample: $H_2O$



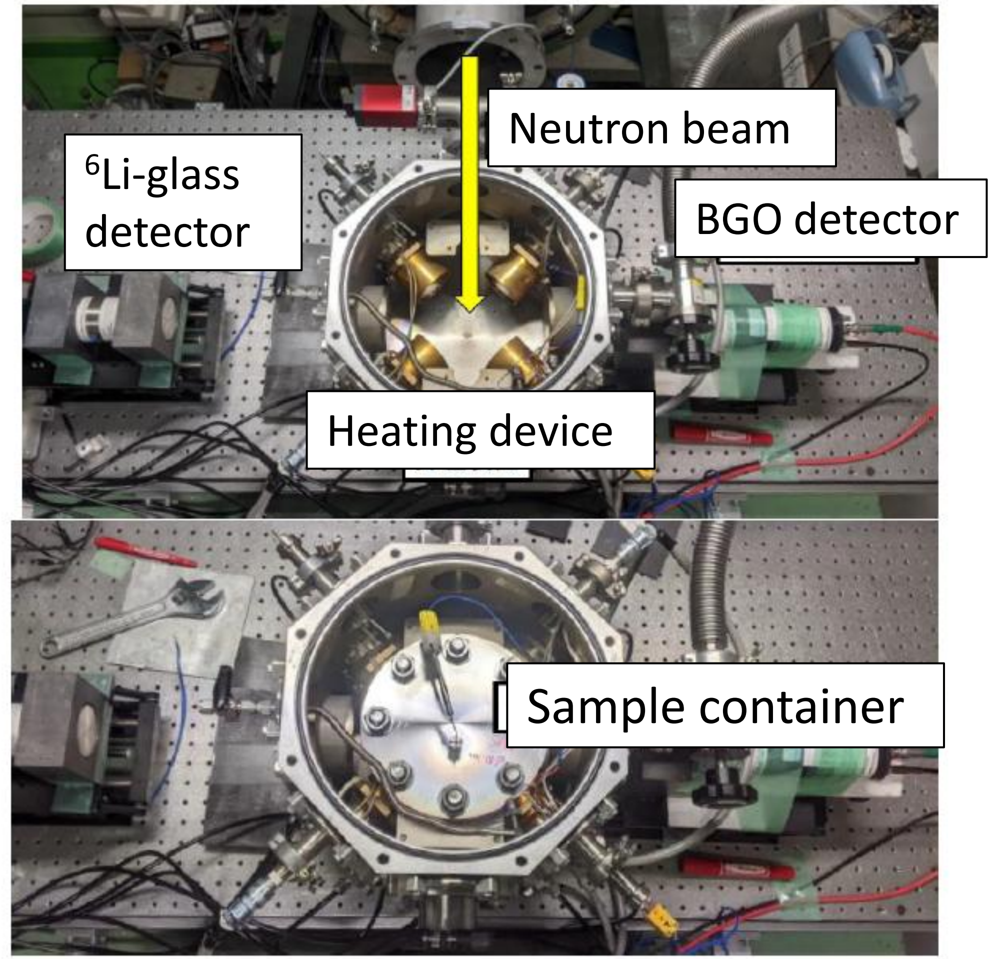
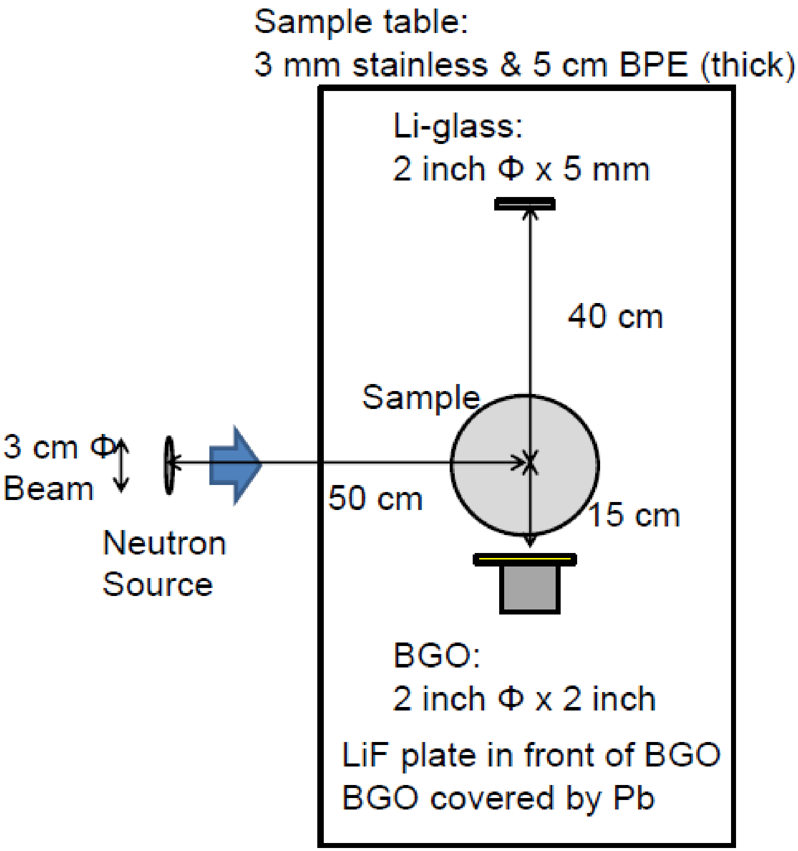




図 3. 2. 1-8　昇温装置周辺の写真

# 3. Numerical calculation

# Numerical calculation

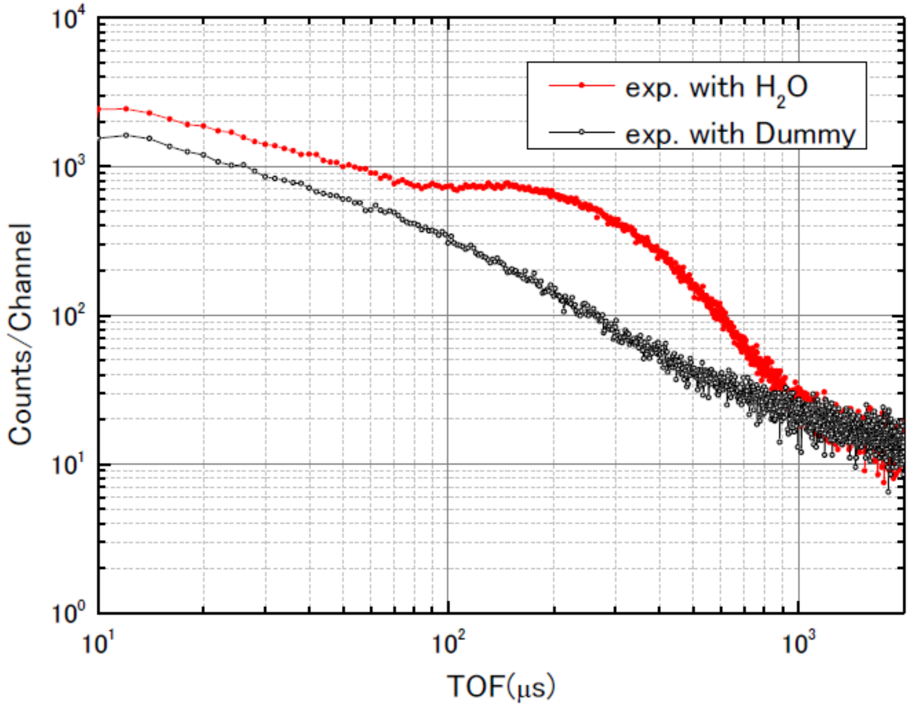
Code: MCNP-6
Nuclear Data library: JENDL-5
S(α, β) :
JENDL-5 or JENDL-4 for $H_2O$,
JENDL-5 for H in ZrH
JEFF-3.3 for H in $CaH_2$
Tally:
For neutron: time tally of Li-6 neutron absorption reaction rate in Li-6 of detector
For gamma: time tally of deposit energy at 2.22 MeV region in BGO

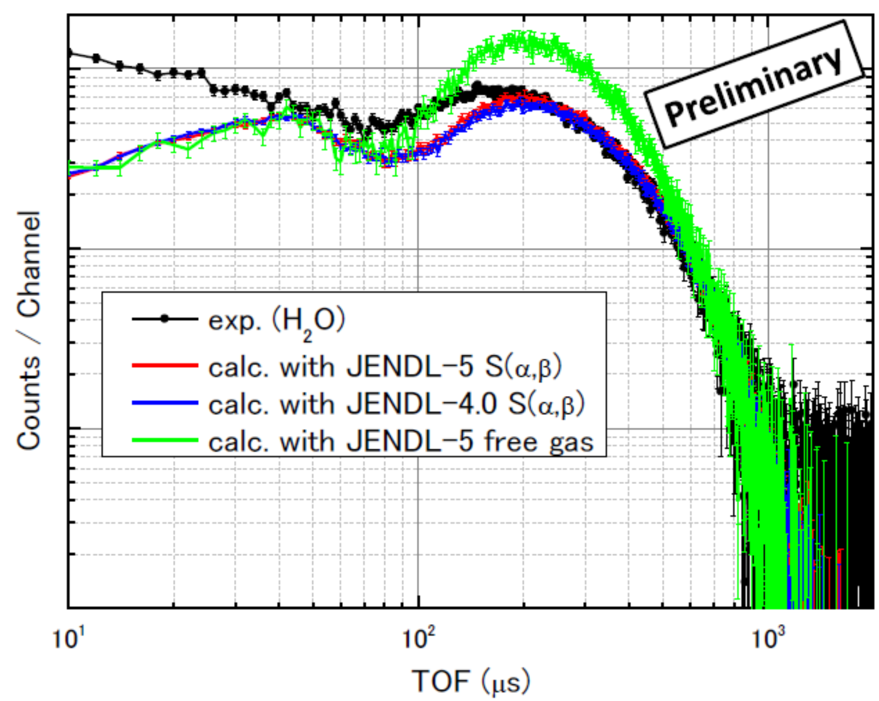



Initial neutron spectrum was estimated by calculation separately.

# 4. Results and discussion

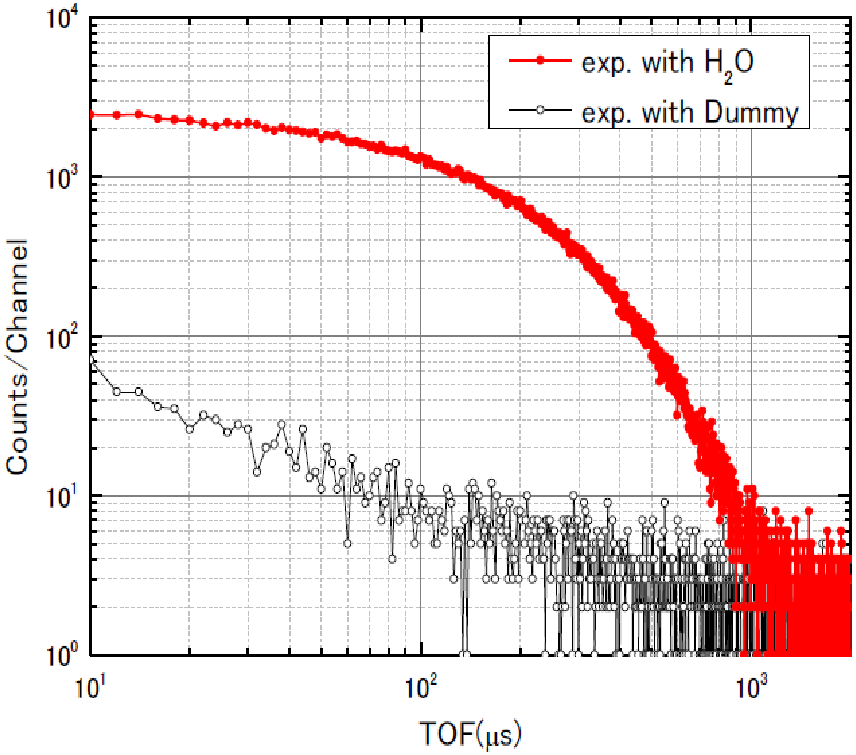
# Exp.1 $H_2O$ by $^6$Li-glass detector

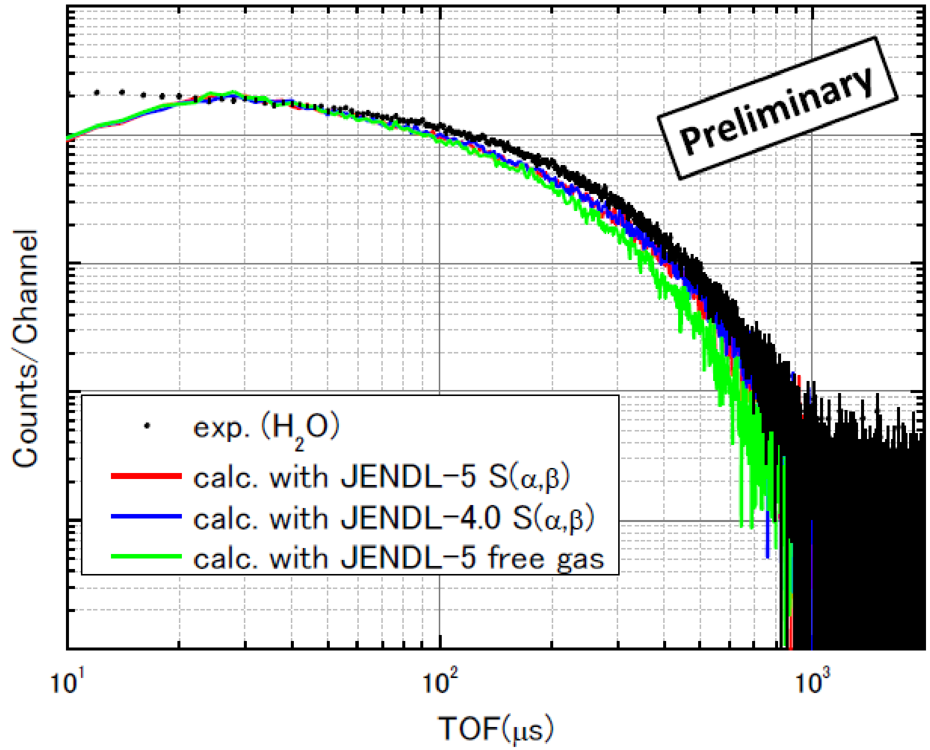



The thermal bump was suppressed by considering S(α,β).
The present results were agreement with the calculation results considering S(α,β) in the right side of thermal bump.
The calculation result with JENDL-5 is agreement with the experimental one slightly better than that with JENDL-4.0.

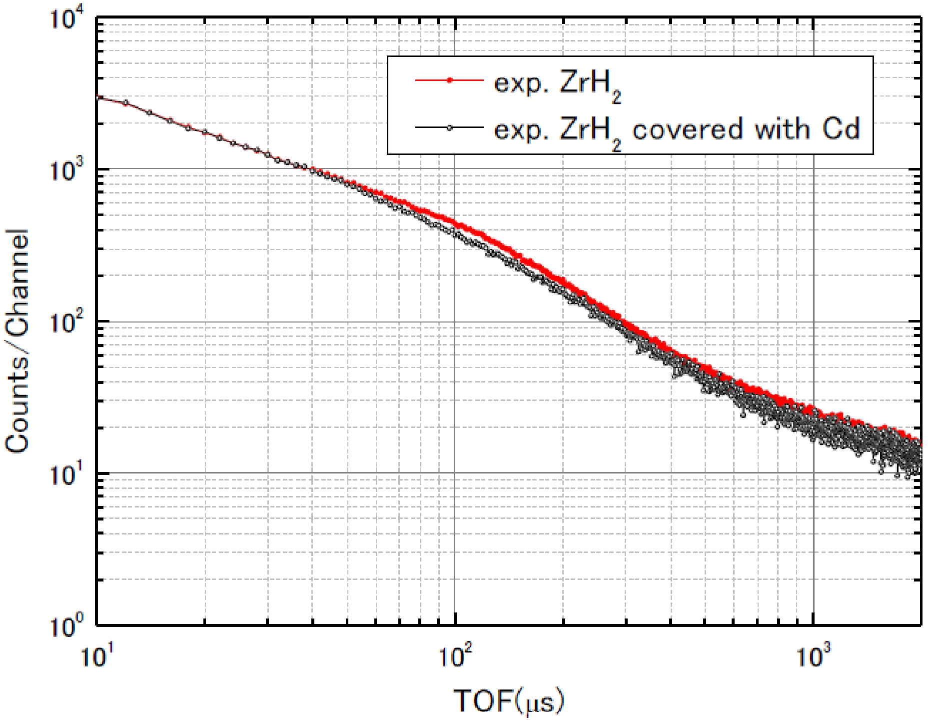
# Exp.1 $H_2O$ by BGO detector

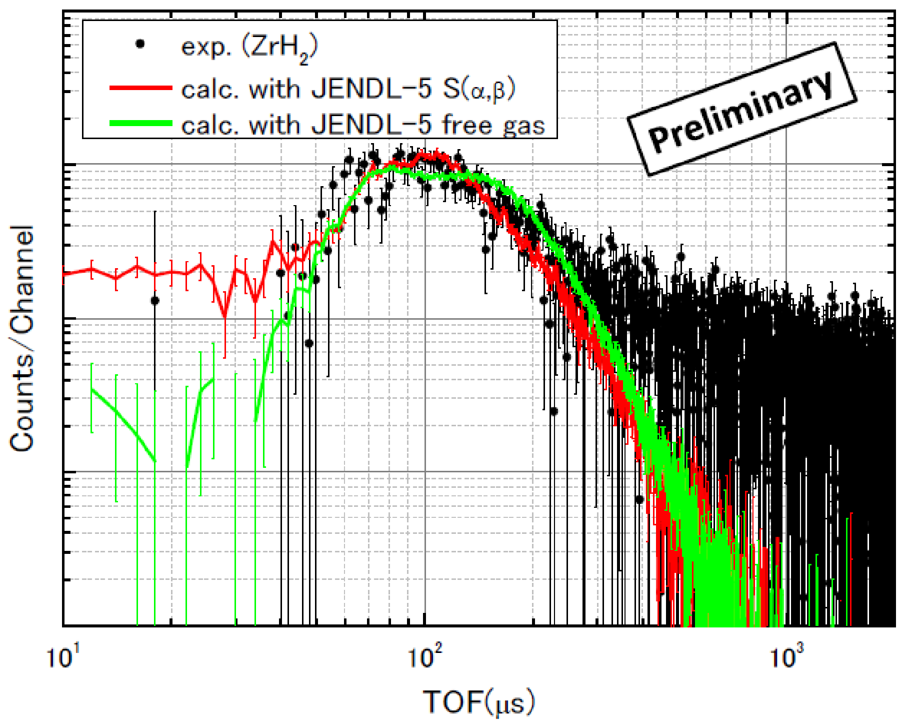



The time distribution was obtained by gating on the 2.2 MeV gamma-ray peak. There are no differences between calculation results with JENDL-5 and JENDL-4.0. On the other hands, the calculation results get closer to the experimental results by considering TSL.

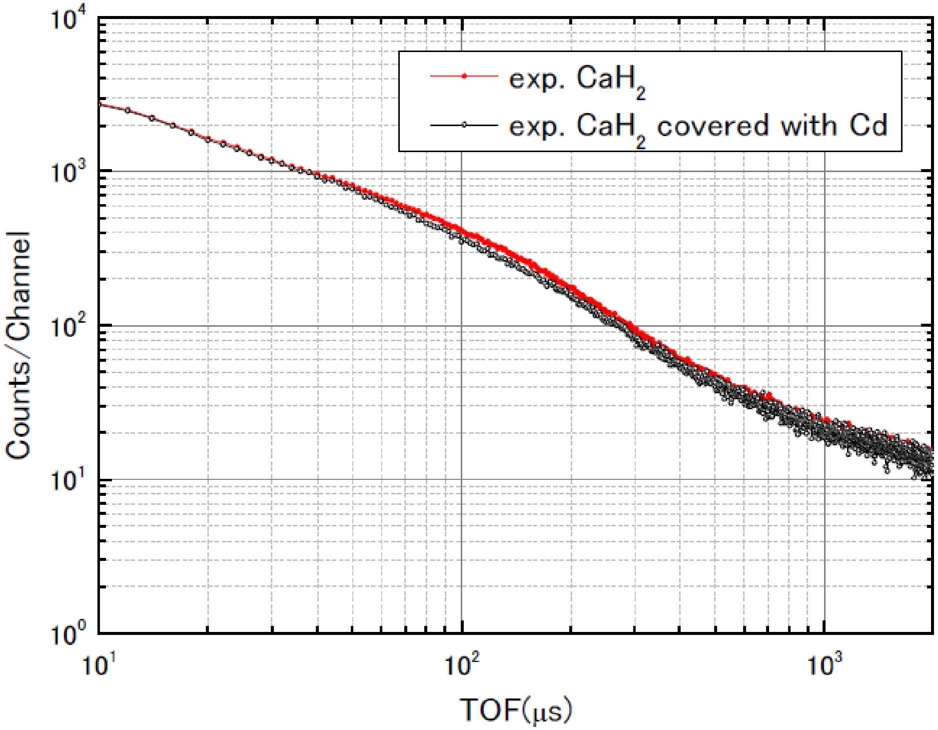
# Exp.1 $ZrH_2$ by $^6$Li-glass detector

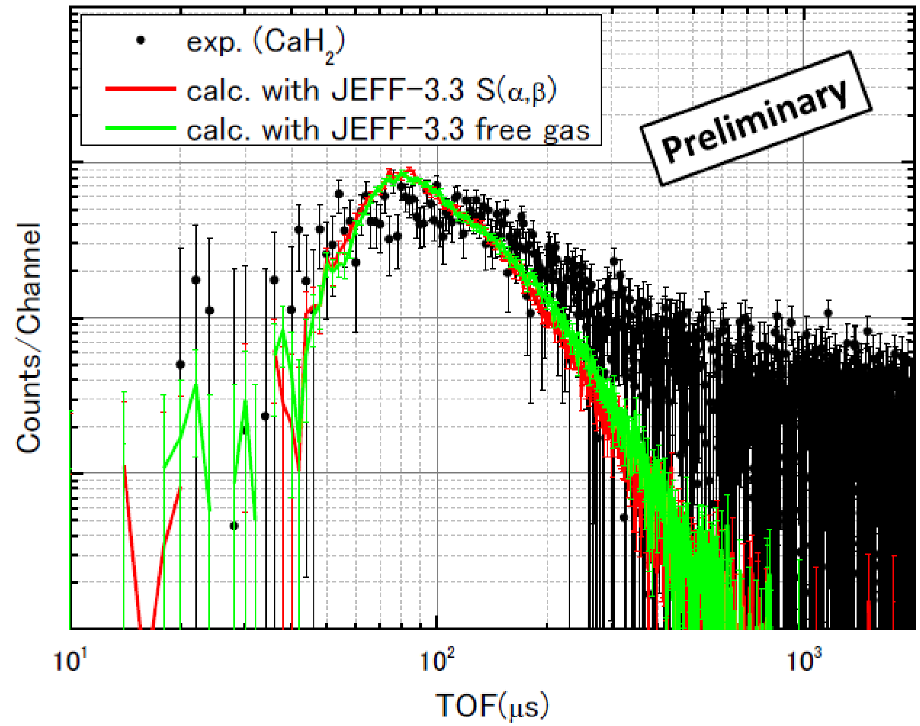



Thermal bump was observed around 100 μs.
The tendency seems to be agreement with the calculation results.
However, the statistics precision is not enough to validate nuclear data.

# Exp.1 $CaH_2$ by $^6$Li-glass detector

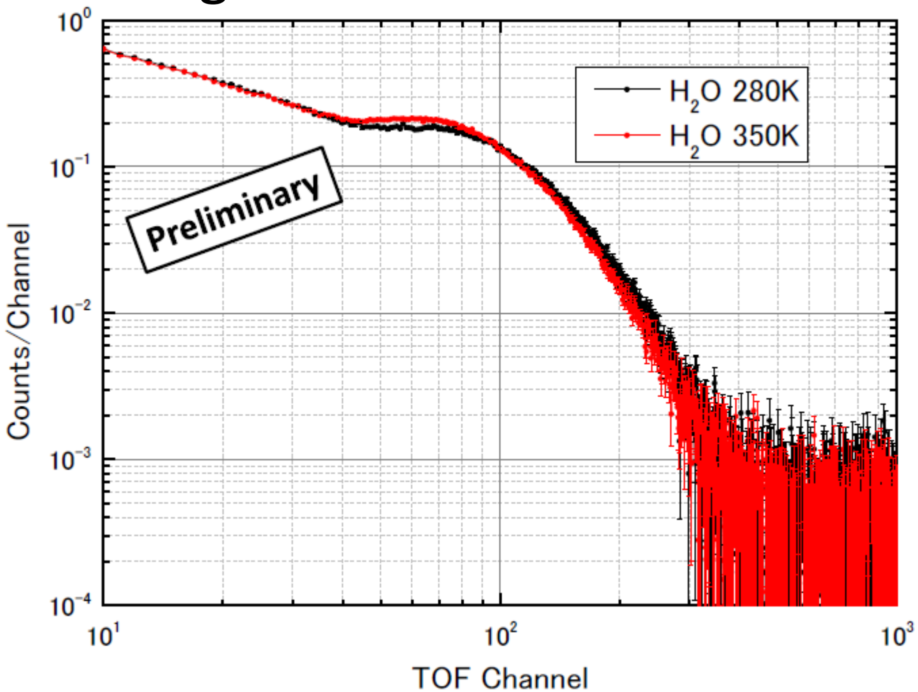


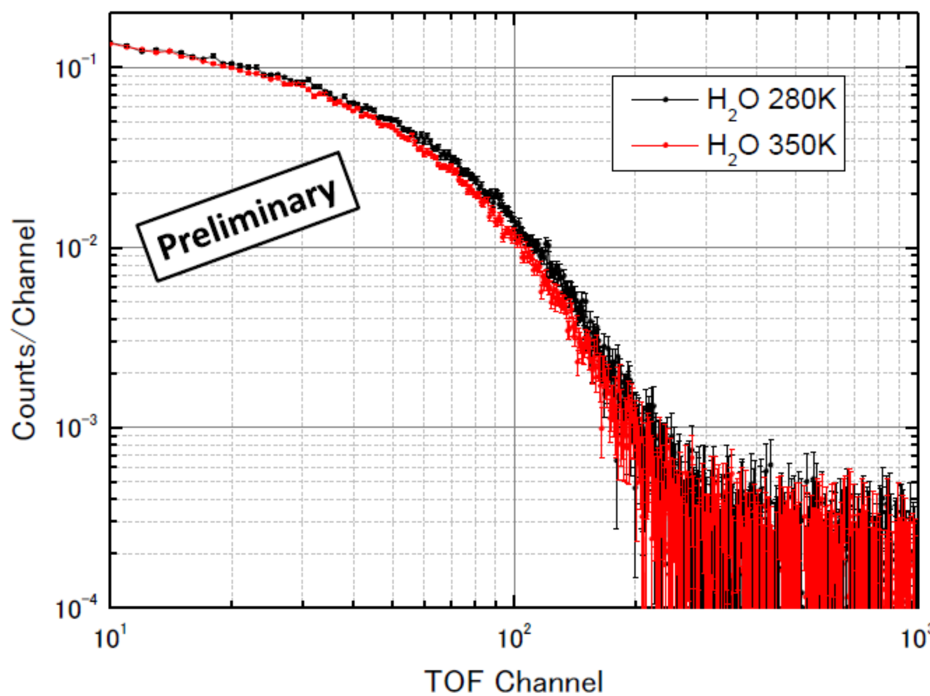

Thermal bump was observed around 80 μs.
The tendency seems to be agreement with the calculation results.
The different between spectra with and without S(α,β) is very small in the calculated results.
The statistics precision is not enough to validate nuclear data.

# Exp.2 $H_2O$

$^6$Li-glass detector




BGO detector




By raising the temperature of sample by 70 degrees, the thermal bump of neutron TOF shifts to harder and the time distribution of 2,2MeV gamma-ray shifts to shorter.
It was confirmed that the temperature dependency can be observed with this method.

# 5. Summary

# Summary

- To validate TSLs data, new method was applied to the candidate hydride ($H_2O$, $ZrH_2$, $CaH_2$) as a moderator in a SMR.
- For light water, the present results agree with the TSL of JENDL-5 better than JENDL-4.0 partially.
- There are no differences in the 2,2MeV gamma-ray time distribution between the calculations with JENDL-5 and JENDL-4.0.
- For $ZrH_2$ and $CaH_2$, thermal bump could be observed around the TOF channel estimated by calculation. However, statistical precision should be improved to validate TSLs data.
- It was confirmed that the temperature dependency for leakage neutron and capture gamma-ray time distribution can be observed.

Thank you for your kind attention !!

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