A latest measurement of $^{197}\mathrm{Au}(\mathrm{n},\gamma)$ cross section in the Resolved Resonance Region at Back-n terminal

Speaker: Cui, Zhanqiao Co-fellow: Yang, Gaole

Tutor: Jiang, Wei

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- Detection principle and data analysis of C_6D_6 experimental terminal at Back-n White Neutron Source
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  3. Unfolded process of double-bunch operation mode
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- Result of yield, resonance parameters and preliminary cross section

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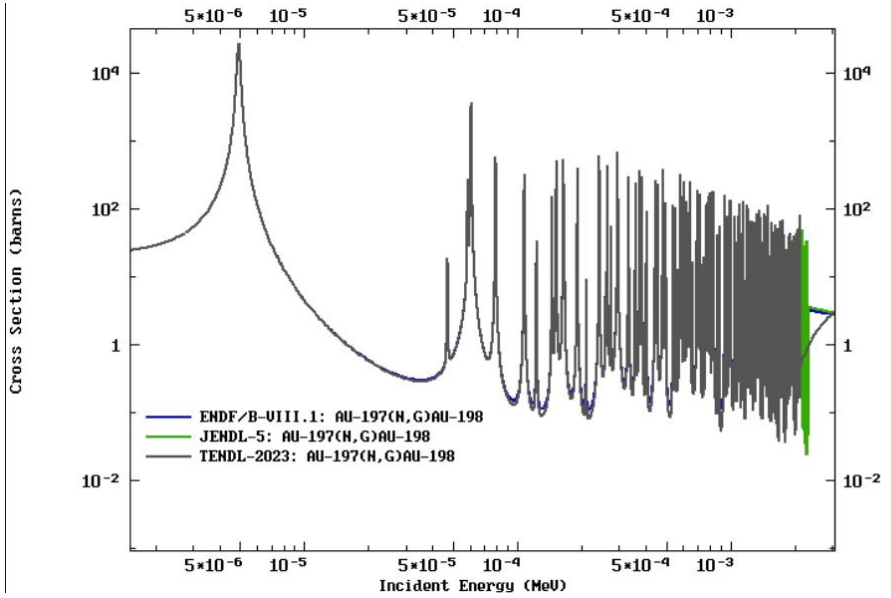
Research background

- Because of the stable chemical and physical propertis of gold, ^{197}Au(n,γ) reaction is the few of capture standard at thermal energy and between 0.2 and 2.5 MeV, gold is a vital referential target nucleus in the relative measurement of neutron-capture cross section
- While its resonance region could not considered as accurate as a standard due to the resonance structure, but the latest evaluated libraries like ENDF/B-VIII.1, JENDL-5 and TENDL-2023 left slight discrepencies under 2 keV



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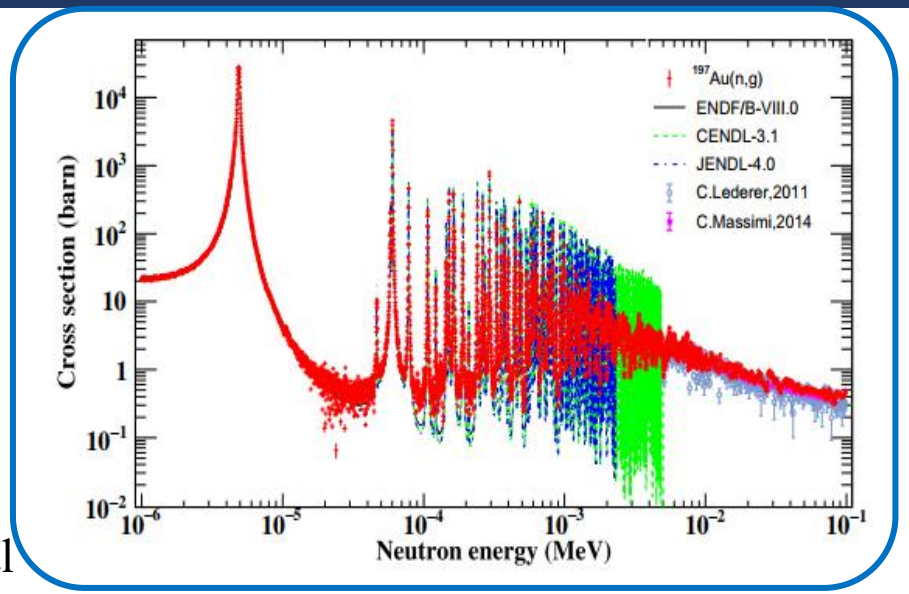
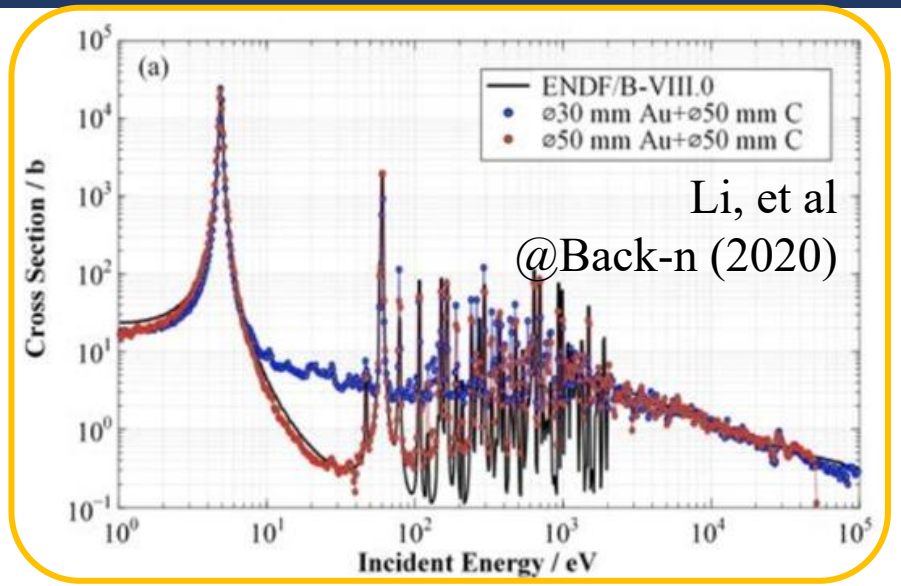
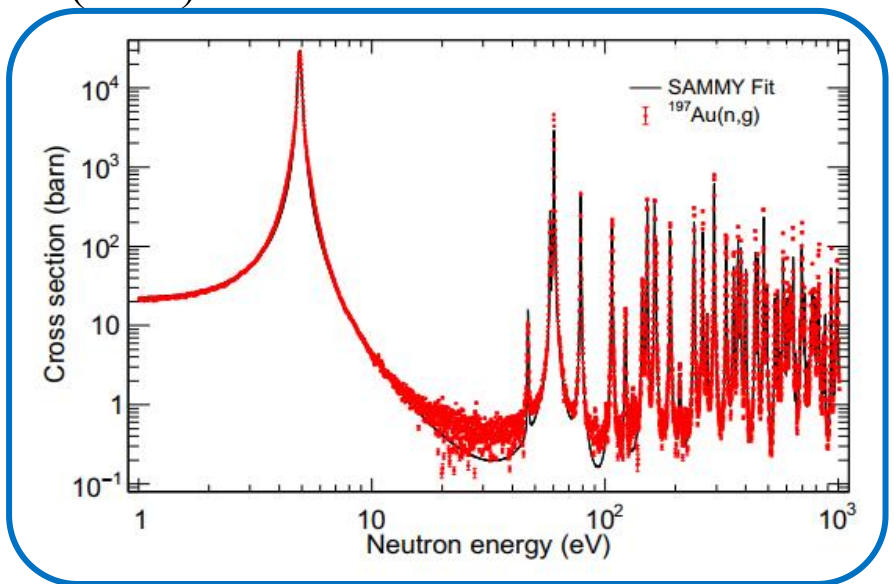
Research background



Hu, et al
@Back-n (2021)



Li, et al
@Back-n (2020)



Considering the incomplete measurement at Back–n beamline: high background and lack of results over than 1 keV, this work aims to give the result of resonance parameters covering the whole RRR and cross section up to 0.1 MeV with a lower background, as a further proving of n-capture experimental feasibility of Back-n and a possible reassessment to ENDF/B-VIII.1

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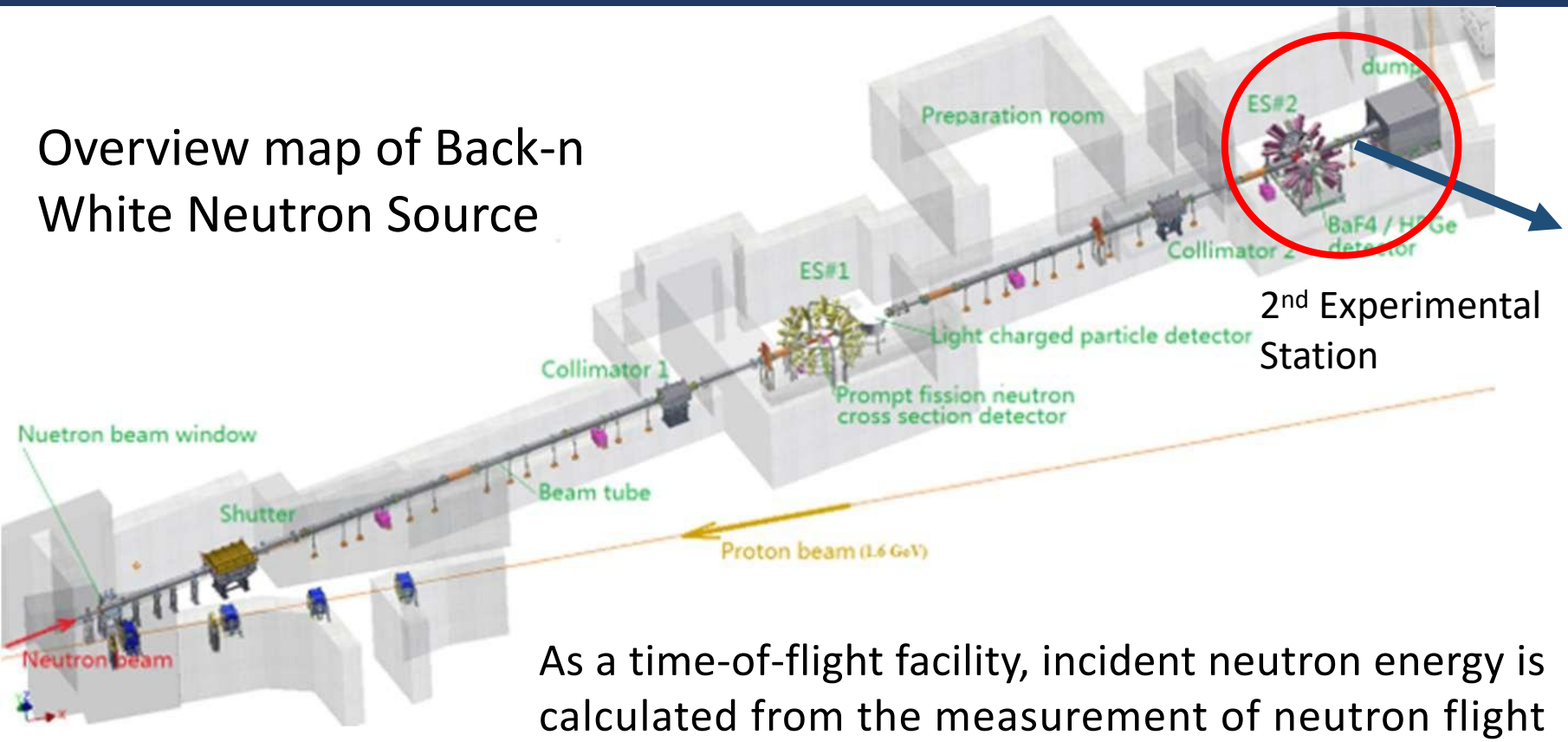
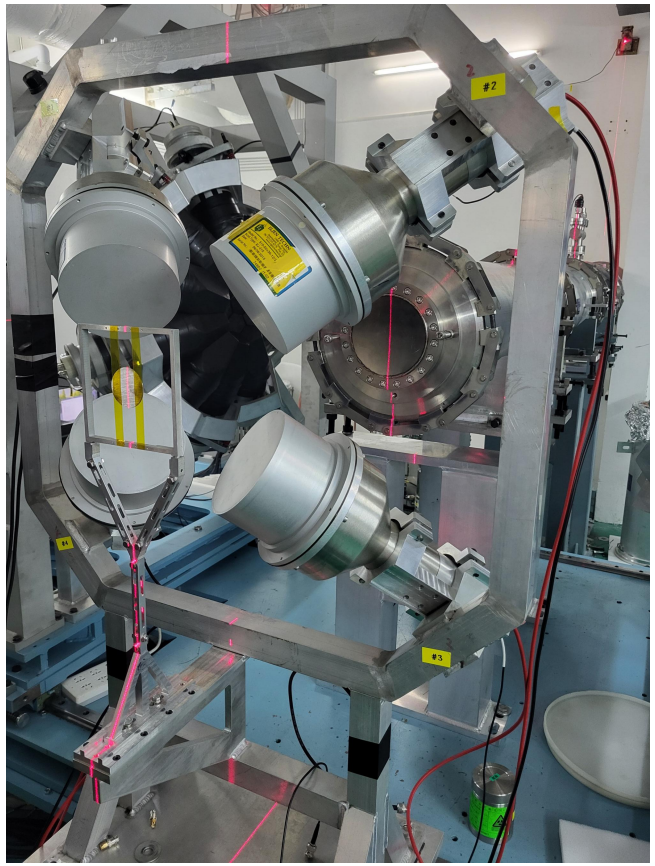
Back-n beamline

Overview map of Back-n White Neutron Source



2nd Experimental Station

Four-items deuterated benzene detector system



As a time-of-flight facility, incident neutron energy is calculated from the measurement of neutron flight path and flight time

$$E_n = \left(\frac{72.7977 * L}{tof}\right)^2$$

Usually, the flight path is around 76.0 m, time of flight is got from a sub between time stamps of γ flash and neutron

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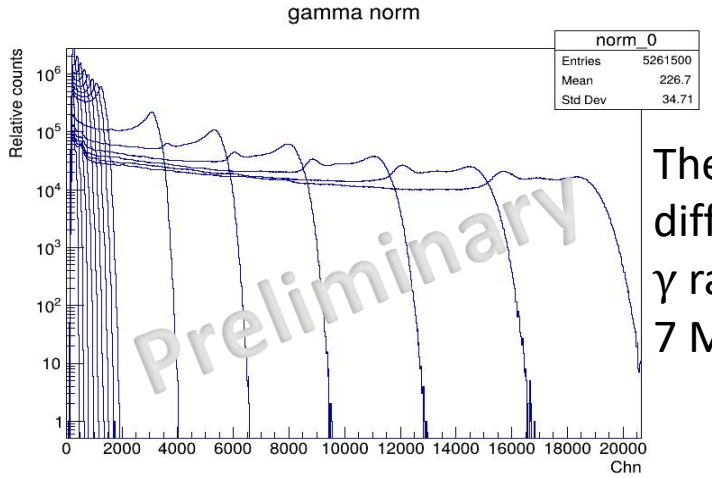
Pulsed Height Weighting Technique (PHWT)

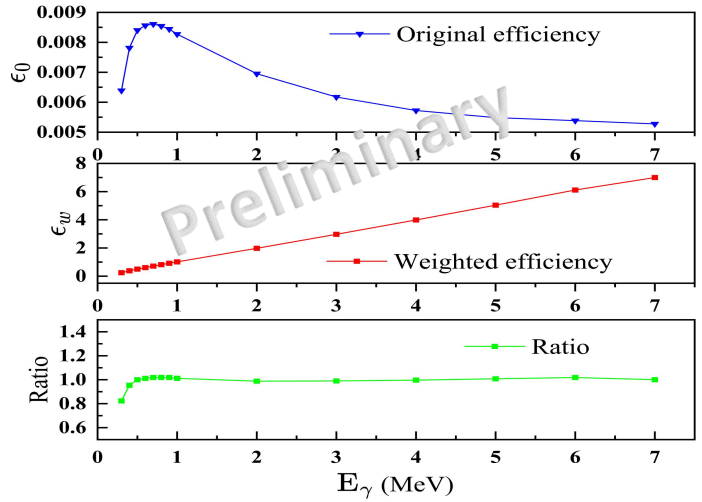
As a total energy γ detector, the C_6D_6 detectors` response to γ ray should be weighted as following to establish a clear connect between detection efficiency of capture event and observable physical quantity such as energy:

$$\epsilon_\gamma = \int R(E_d)\, WF(E_d) dE_d = E_\gamma ,$$

where ϵ_γ, $R(E_d)$, $WF(E_d)$ are the detection efficiency of γ with energy E_γ, normalized response spectrum and weighting function to be determined respectively



The response to 14 different mono-energy γ rays between 0.2 and 7 MeV from Geant4



Efficiency before and after weighting

Ratio is ϵ_w / E_γ

a0	a1	a2	a3	a4
1.3060	0.132478	9.6442e-06	-6.8508e-10	e-14

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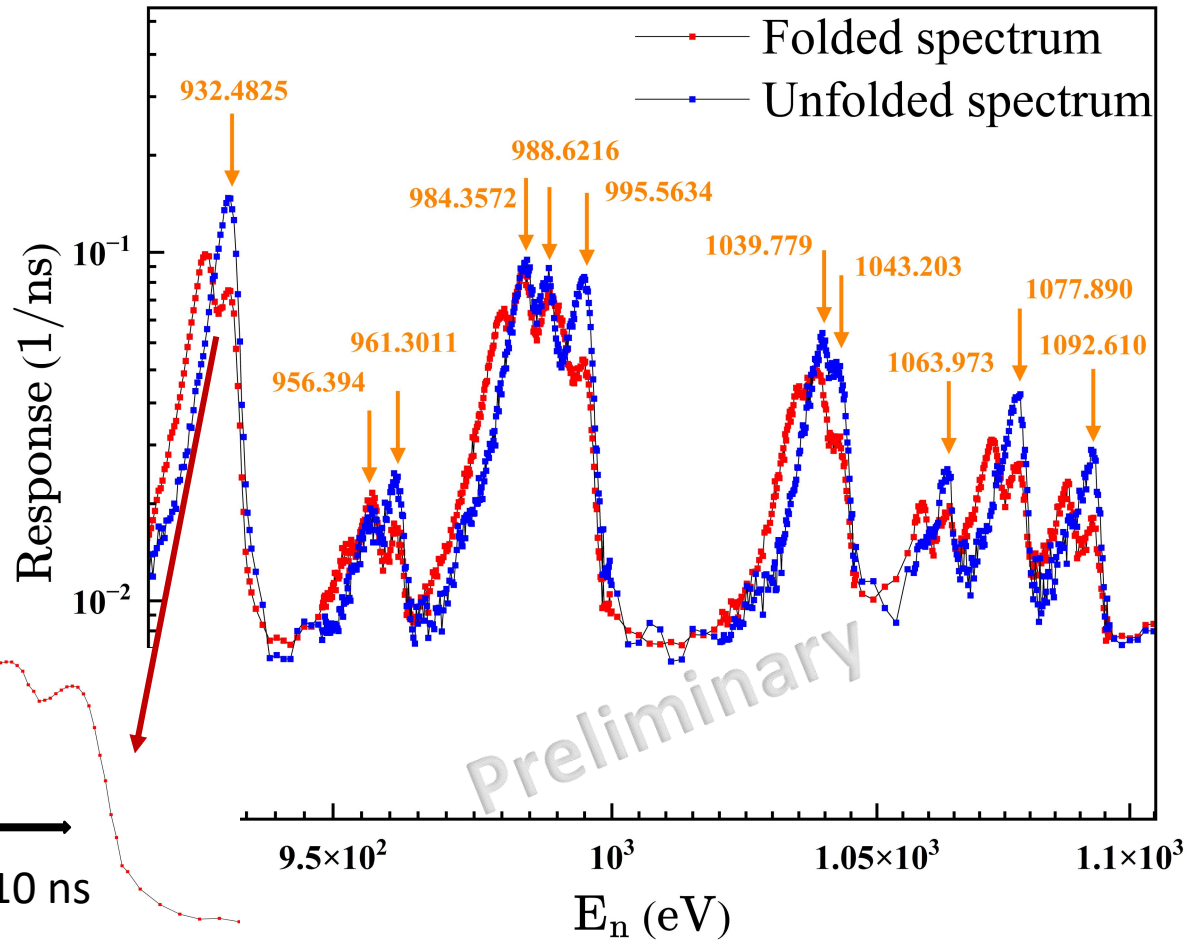
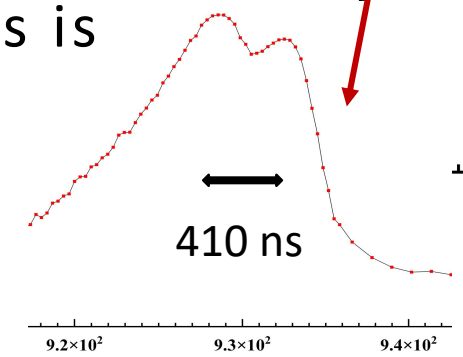
Double-bunch operation mode

- The main operation mode in China Spallation Neutron Source is double-bunch mode, which means there are two proton bunches react with spallation target with a time interval of 410 ns per round in a frequency of 25 Hz, so do the neutrons
- As a consequence, original event distribution have double-bunch charac-teristics. An unfolding process is applied to solve this problem





A typical double-bunch effect ←

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Experimental background

- $N_w = N_o * WF = [N_{\mathrm{Au}} - N_{emp} - N_{el} - N_{\gamma}] * WF$ (where $*$ means a convolution)

Background in empty target — Measured

Background from scattering neutrons — Calculated

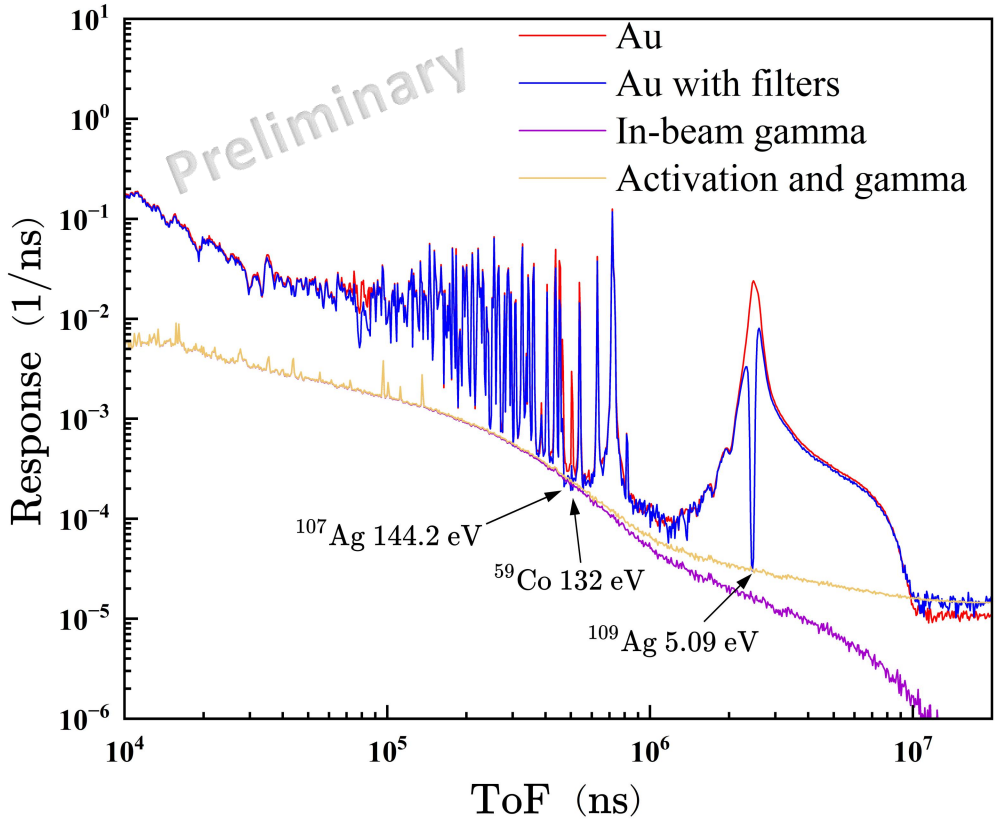
Background from in-beam γ — Normalized

$$N_{el} = \eta_1 (N_{\mathrm{C}} - N_{emp})$$

$$N_{\gamma} = \eta_2 \left[N_{\mathrm{Pb}} - N_{emp} - \eta_3 \left(N_{\mathrm{C}} - N_{emp} \right) \right],$$

$\eta_1 \equiv \frac{\sigma_{\mathrm{Au}}}{\sigma_{\mathrm{C}}}$, $\eta_3 \equiv \frac{\sigma_{\mathrm{Pb}}}{\sigma_{\mathrm{C}}}$ cross sections come from ENDF

η_2 is a coefficient obtained from the normalization between measured in-beam shape and absorption valley due to black filters Co and Ag



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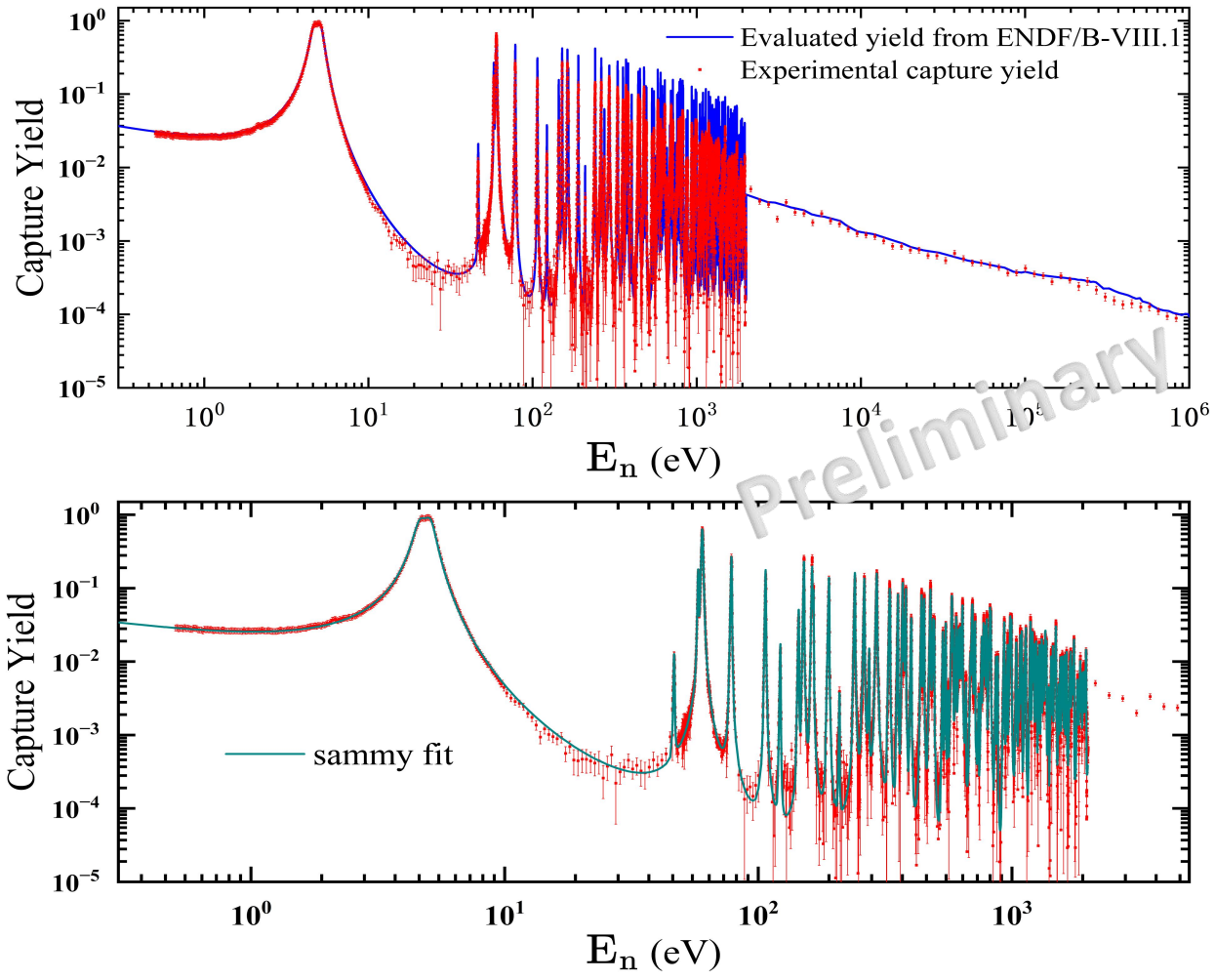
Results: yield



$$Y = C\frac{N_w}{I\epsilon} = C\frac{N_w}{I(S + E_n)}$$

I is neutron flux provided by Back-n and S is the binding energy of ^{197}Au. Then, yield is normalized to the first saturated resonance peak at 4.9 eV

Using parameters from ENDF/B-VIII.1 as the starting value of **sammy** code, we fitted capture yield and got new resonance parameters in RRR

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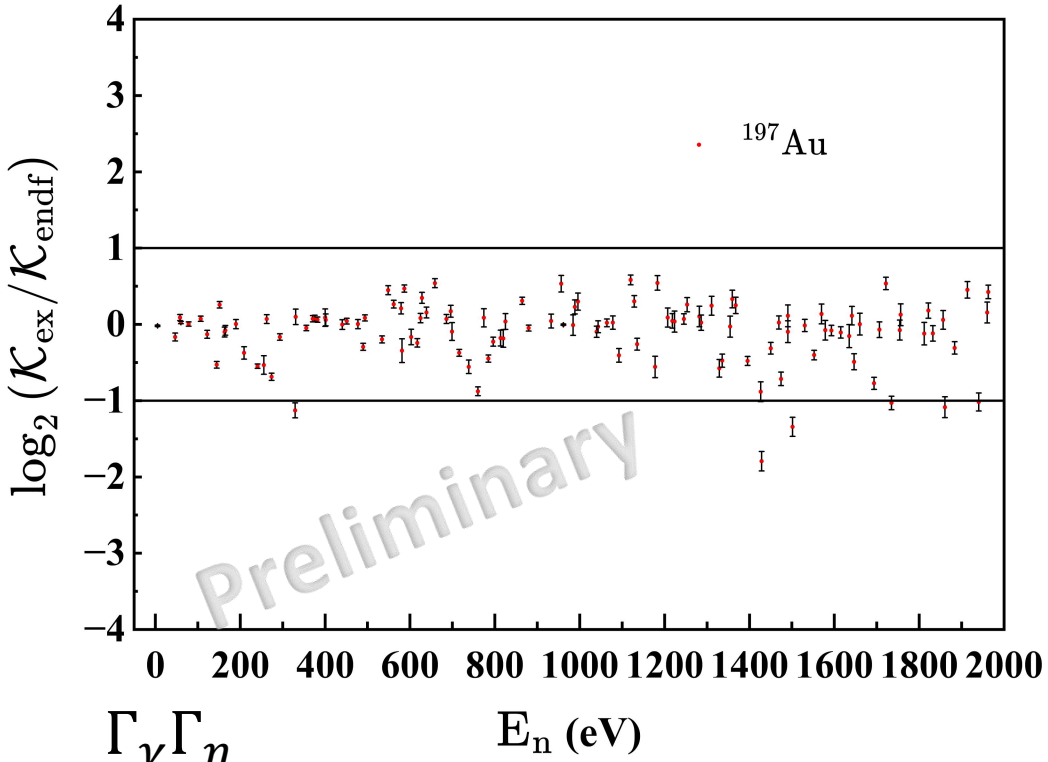
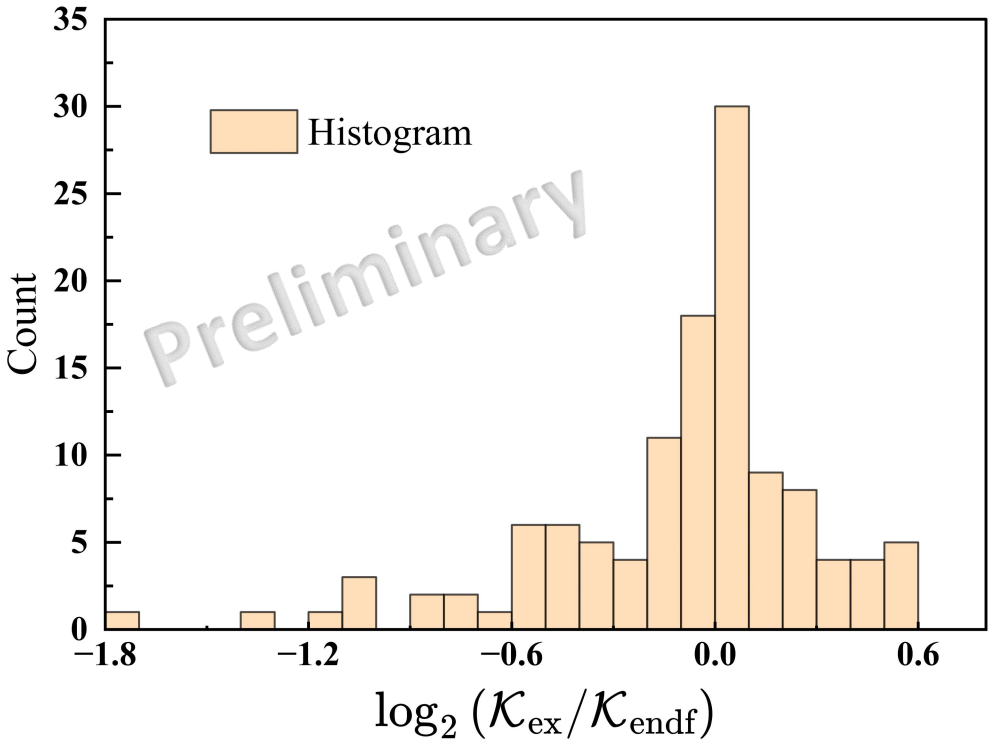
Results: total comparison of resonance parameters





$$K = g\frac{\Gamma_\gamma \Gamma_n}{\Gamma_\gamma + \Gamma_n}$$

$$g = \frac{2J+1}{(2s+1)(2I+1)}$$

Kernel K is usually used as a comprehensive description of resonance peak, the ratio between experimental kernel and kernel from ENDF shows little difference except for few peaks overlapping with adjacent peak

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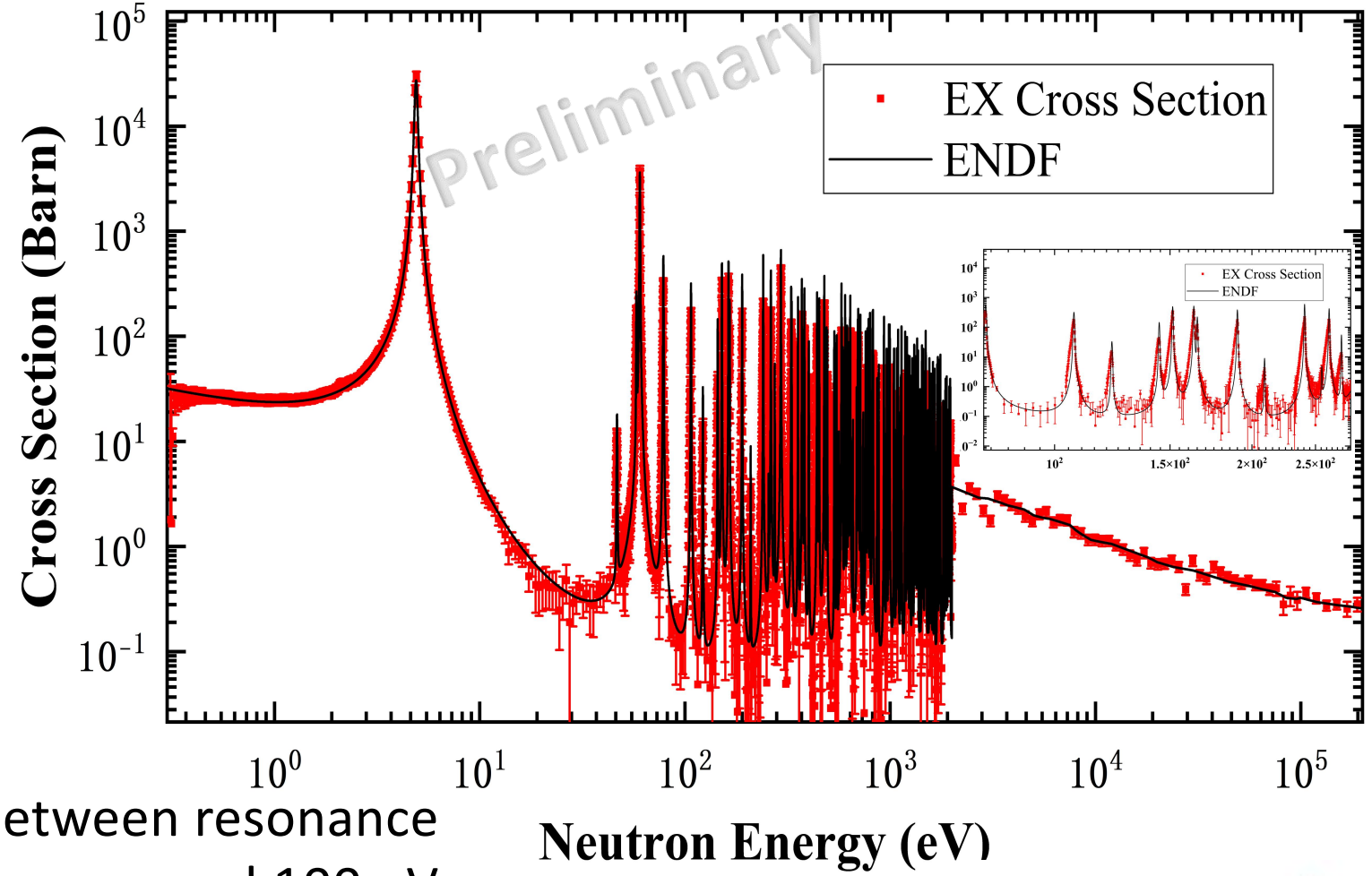
Results

Very preliminarily, we calculated capture cross section from 0.3 eV to 0.2 MeV

$$Y = [1 - \exp(-N_V \sigma_{nt} d)] \frac{\sigma_{n\gamma}}{\sigma_{nt}}$$

$$\sigma_{n\gamma} = Y \frac{\sigma_{nt}}{1 - \exp(-N_V \sigma_{nt} d)}$$



A quite pure result at the valleys between resonance peak is obtained, as an example, see around 100 eV in subfigure

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Summary

- ^{197}Au(n,γ) yield was measured between 0.3 eV and 0.2 MeV, and the cross section in same region was calculated, results showed pretty performance especially at the bottom of valleys. In addition, results in continuum region are well consistent with the data from ENDF/B-VIII.1
- A new set of resonance parameters were fitted from the capture yield, which are also in agreement with the existing evaluated data
- So, this work gave a further validation to the feasibility of Back-n C_6D_6 terminal both in the resonance region and continuum region of ^{197}Au(n,γ) reaction

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Thanks!

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