上海科技大学
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p-process chaser detector

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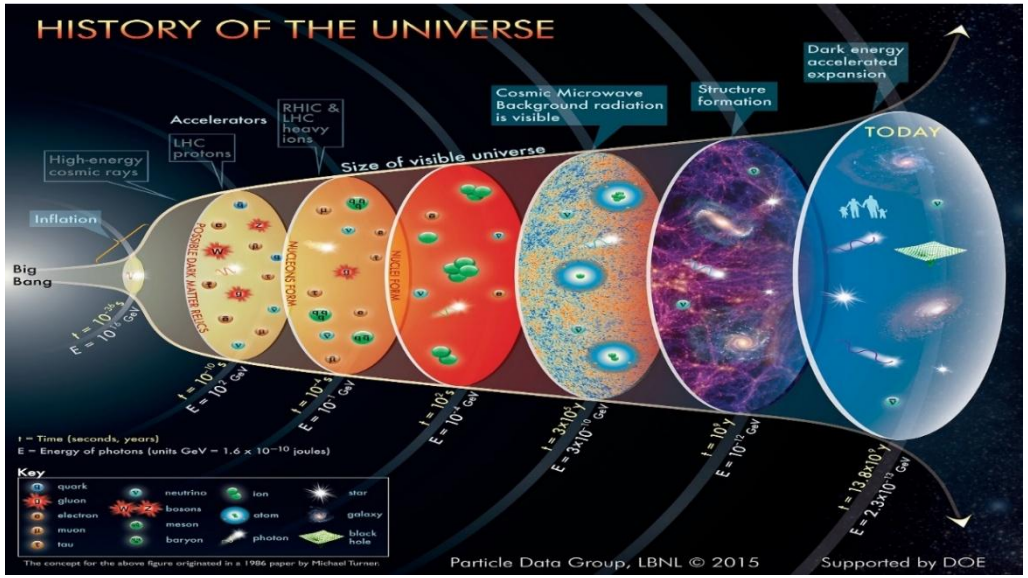
Background I: The ^{180}Ta Puzzle



^{180}Ta^{m} （9^- isomeric state, T1/2>7.1×10^{15}yr）

✗ Direct γ decay is strongly hindered by ΔK = 8.

? mediating states

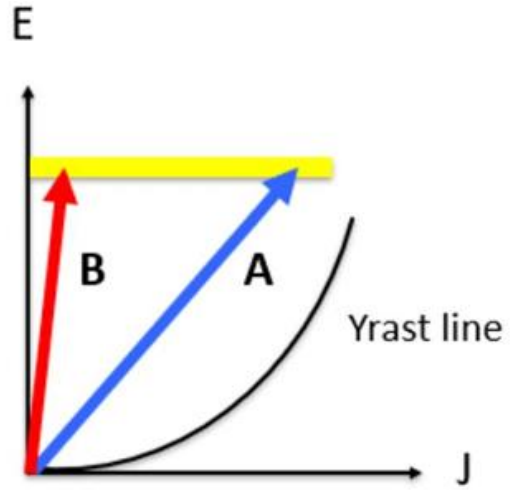
^{180}Ta^{gs} （1^+ ground state, T1/2≈8.15hr）

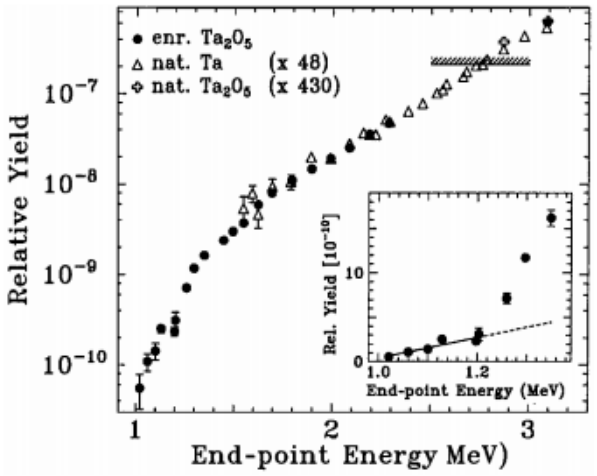
Significance：

- Search for mediating states connecting ^{180}Ta^{m} and the ground state
- Quantify the depletion pathway from the isomer to the ground state
- Test the temperature, cooling/mixing time scale, and reaction path in stellar models
- Understand how heavy elements are produced and preserved in stellar environments

[1] D. Belic et al., Phys. Rev. Lett. 83, 5242 (1999).
[2] H. Utsunomiya et al., NIM A 1034, 166819 (2022).

Background II: Previous Studies and Limitations

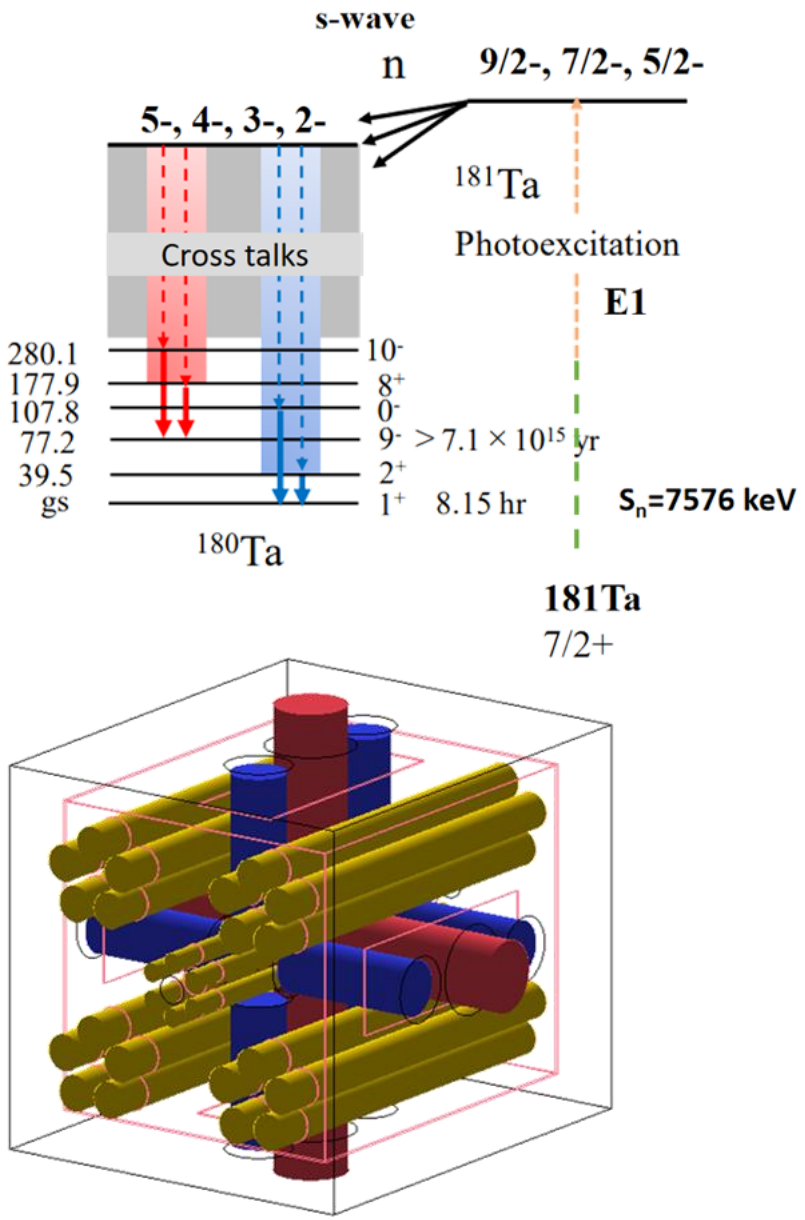




Experiment	Method	Main Results	Limitations
Heavy-ion γ spectroscopy Dracoulis et al.	^{176}Yb(^{11}B,α3n)^{180}Ta ^{176}Yb(^{7}Li,3n)^{180}Ta Time-correlated γ spectroscopy	Rich level scheme 9^- isomeric band; Low-lying states	High-spin / yrast paths No clear $9^- \leftrightarrow 1^+$ MS
Bremsstrahlung photoactivation Belic et al.	irradiate ^{180}Ta^{m} with 0.8-3.1 MeV bremsstrahlung Off-line Hf X-ray and γ-ray detection	MS evidence near 1 MeV; Suggested low-lying mediating states	Indirect yield curve Broad spectrum No J, K, or γ branches

[1] D. Belic et al., Phys. Rev. Lett. 83, 5242 (1999).
[3] G. D. Dracoulis et al., Phys. Rev. C 58, 1444 (1998).

Method: n-γ-γ Coincidences Following $^{181}Ta(\gamma,n)^{180}Ta$



Reaction Path

- $^{181}Ta(\gamma,n)^{180}Ta$
- 12 MeV γ → E1 photoexcitation
- s-wave neutron emission → 2^- - 5^- low-spin states

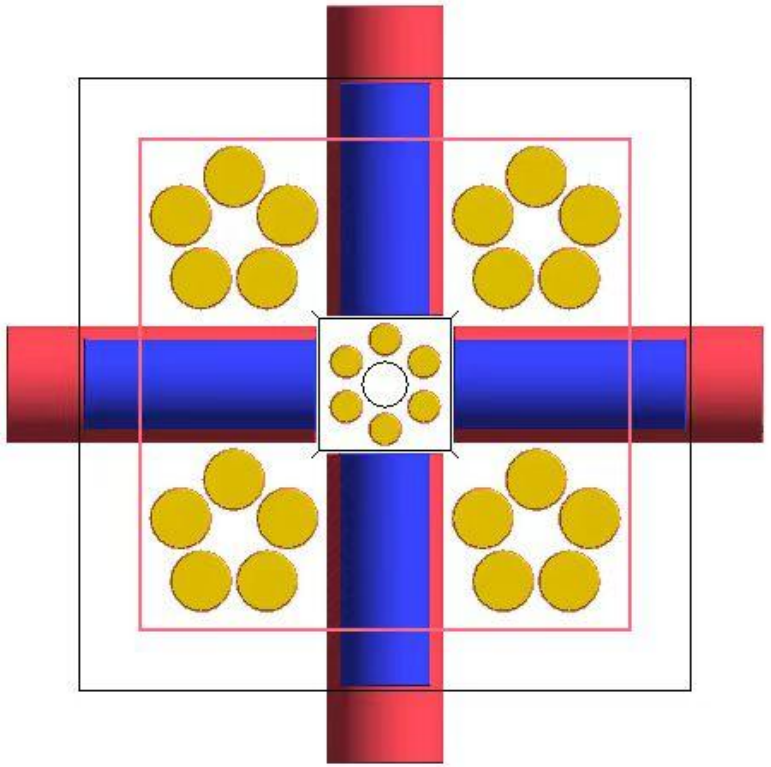
Detection Method

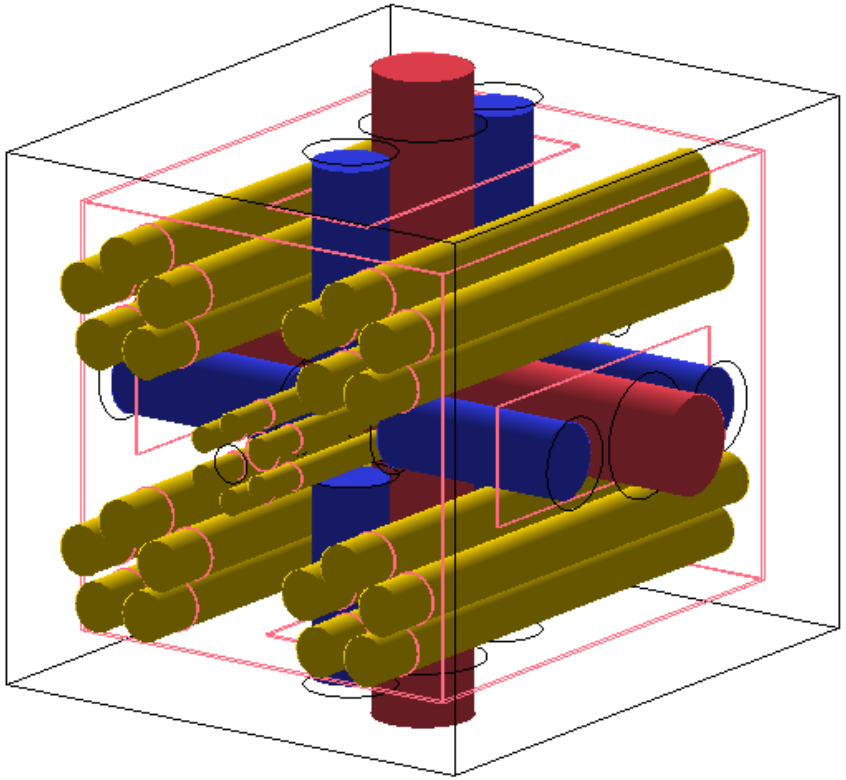
- ✓ ^3He counters: neutron tagging
- ✓ HPGe/Clover + $LaBr_3(Ce)$: γ-cascade detection
- ✓ n-γ-γ triple coincidence: event selection

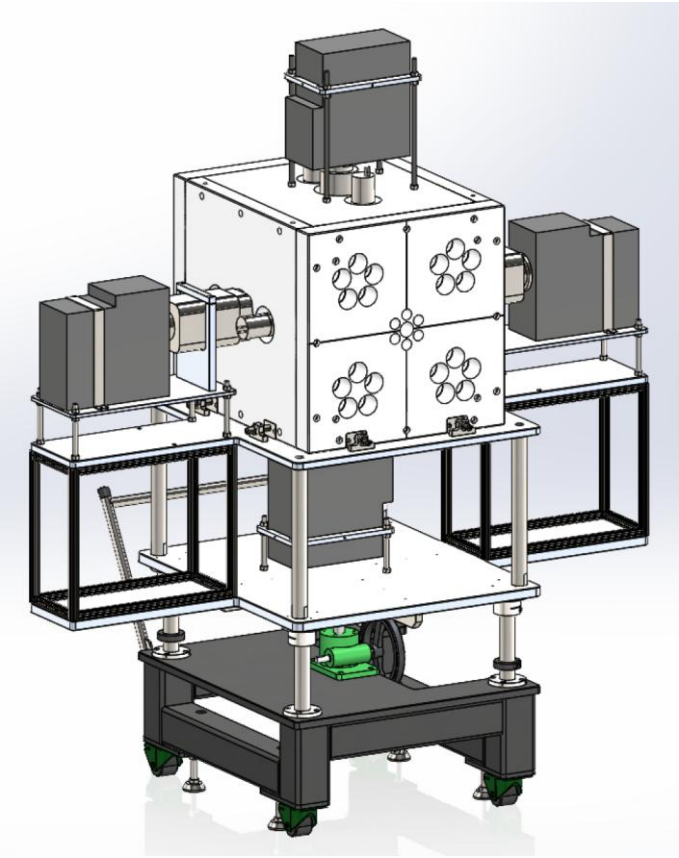
Expected Signature

- Cross-links between:
  - 9^- isomer-feeding cascades
  - 1^+ ground-state-feeding cascades
- Direct evidence for mediating states

Detector System: p-process Chaser Detector







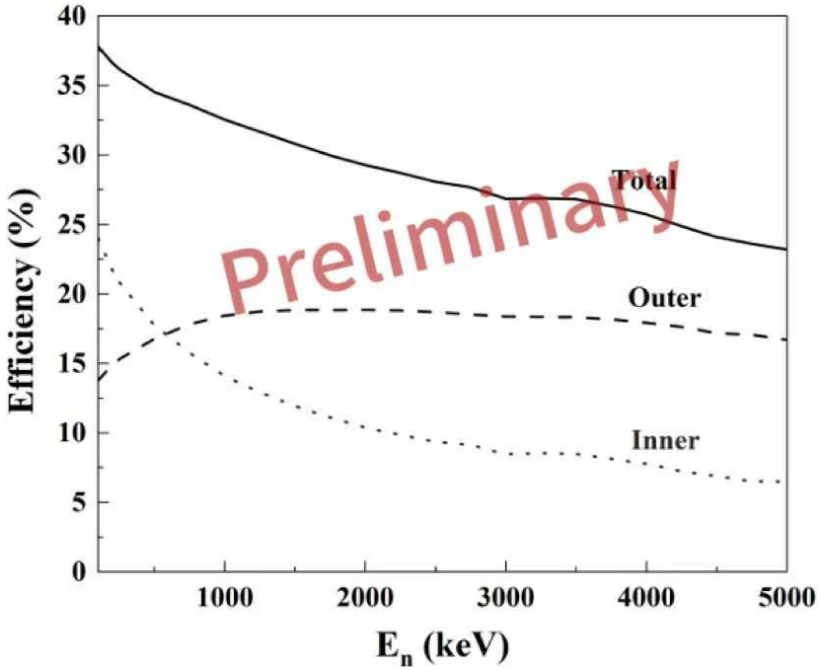
Neutron tagging: 26 ^{3}He counters in polyethylene moderator

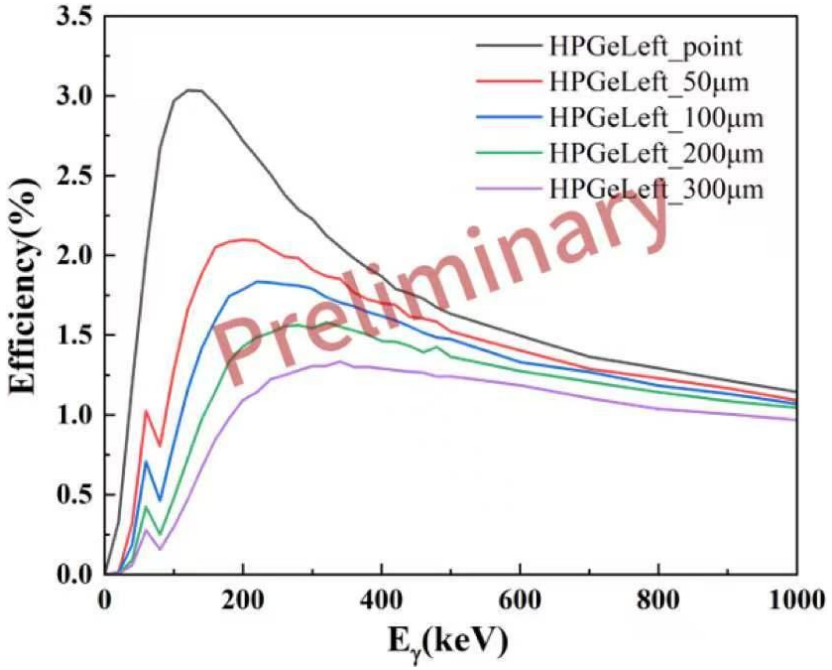
γ-ray detection: 4 HPGe detectors (2 single-crystal HPGe + 2 Clover HPGe)

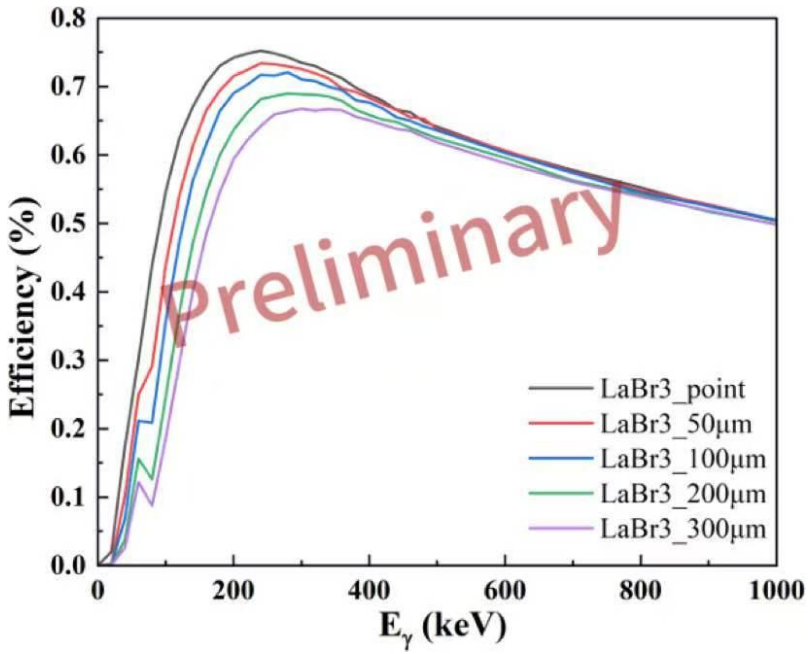
Fast γ response: 8 $LaBr_3(Ce)$ detectors

Coincidence goal: select n-γ-γ events and measure γ-γ cascades

Geant4: Detection Efficiency and Target Thickness Effect







- ✓ Neutron tagging efficiency: 22%-40%
- ✓ γ photopeak efficiency: simulated for HPGe/Clover and $LaBr_3(Ce)$
- ✓ Target self-absorption: thicker Ta foils suppress low-energy γ rays
- ✓ Target configuration: combined 50 μm + 300 μm Ta foils
- ✓ Optimization trade-off: reaction yield vs. low-energy γ transmission

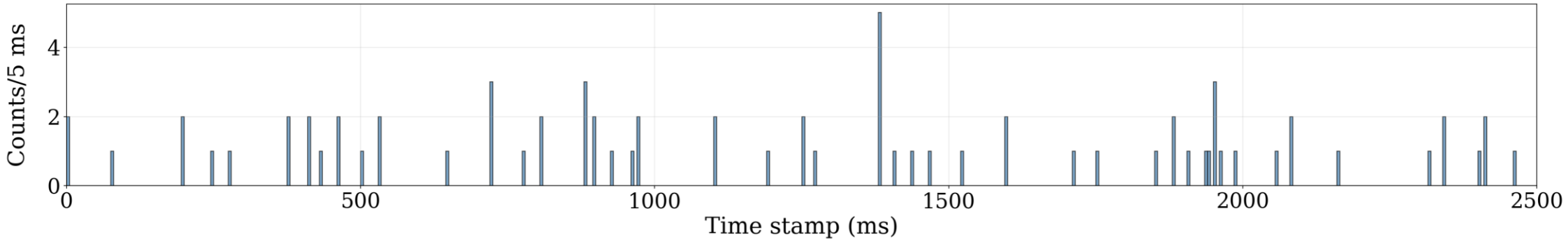
Test Measurement: ^{252}Cf as an n-γ-γ Validation Source

Why ^{252}Cf?

- ^{252}Cf undergoes spontaneous fission.
- Each fission emits prompt neutrons and multiple prompt γ rays.
- This makes it a practical source for testing the full n-γ-γ coincidence chain.

prompt neutrons ≈ 3.8

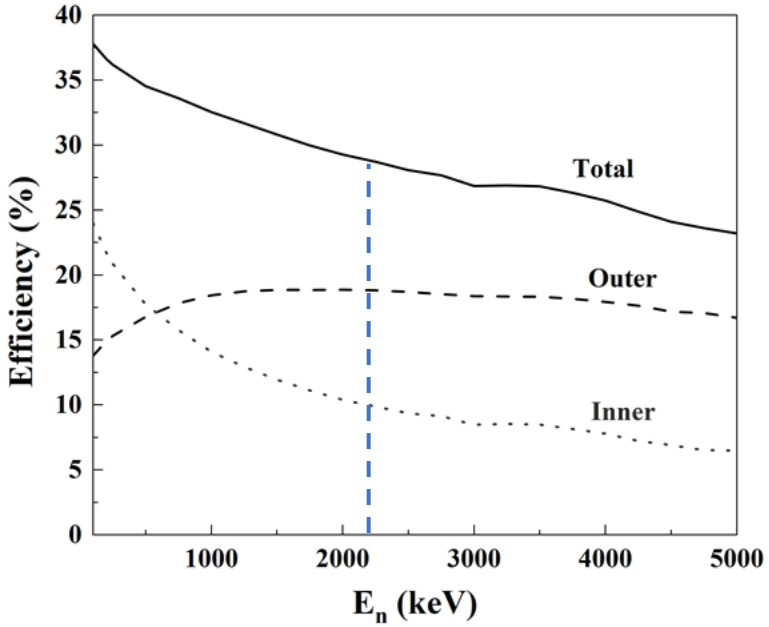
γ rays ≈ 8

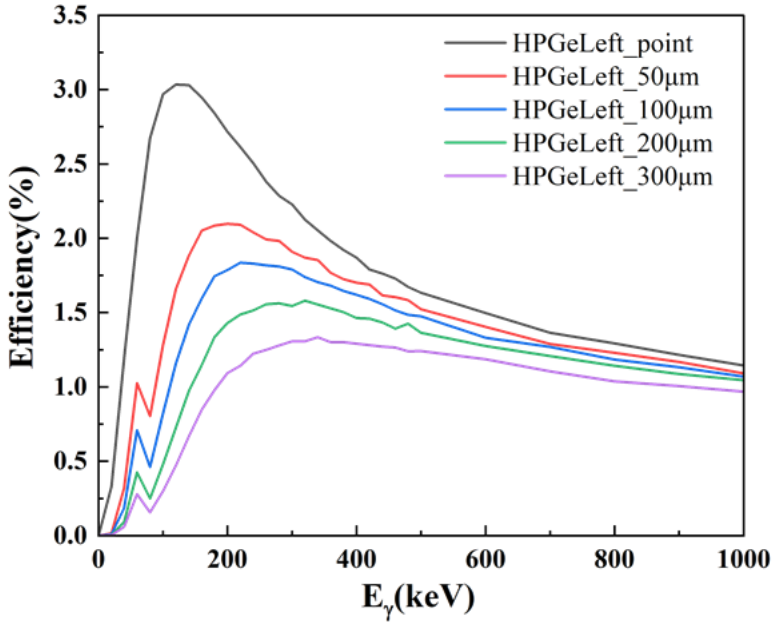


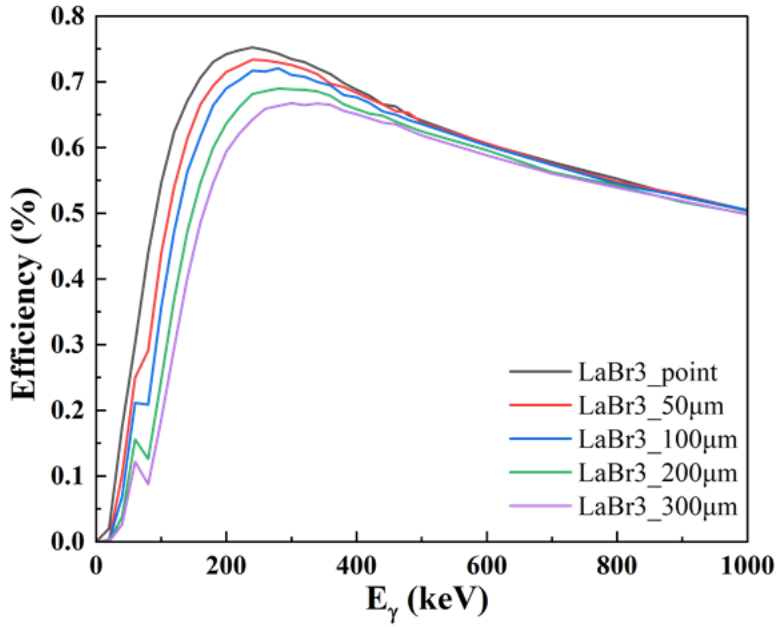
✓ Observed neutron rate: , consistent with 110.7 cps × 28% ≈ 31 cps.

✓ This validates the neutron-tagging efficiency of the ^{3}He moderator detector.

Geant4 Simulation: Detection Efficiency and Target Thickness







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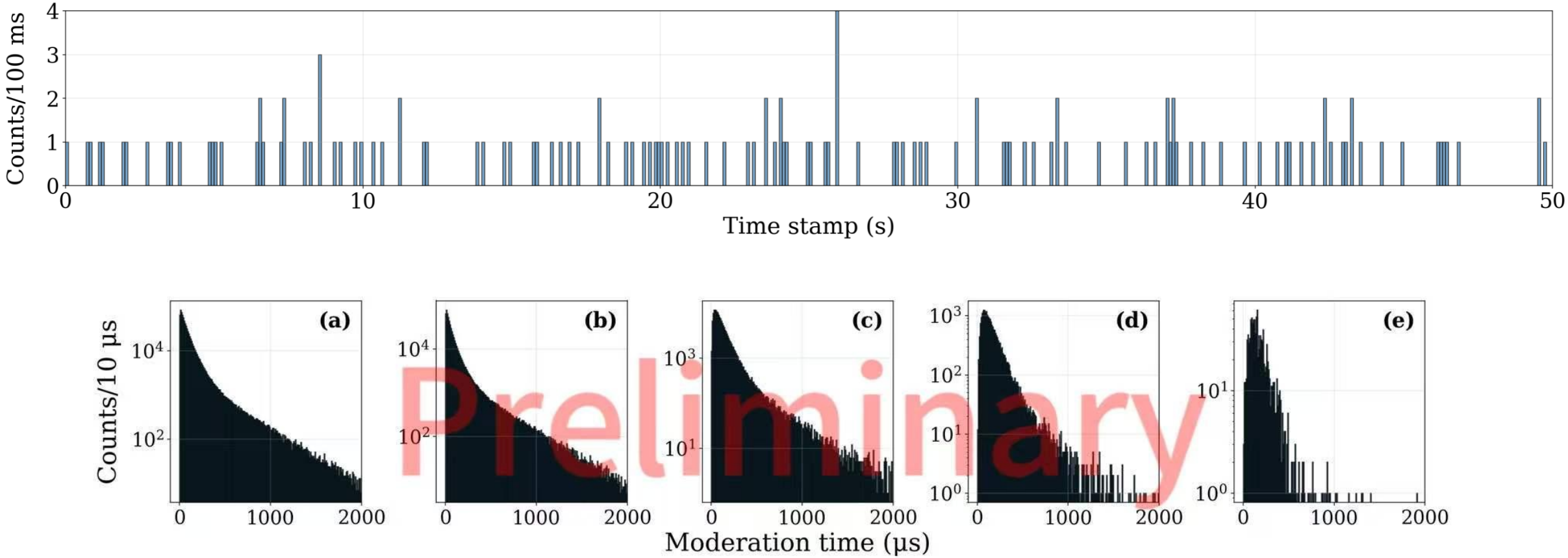
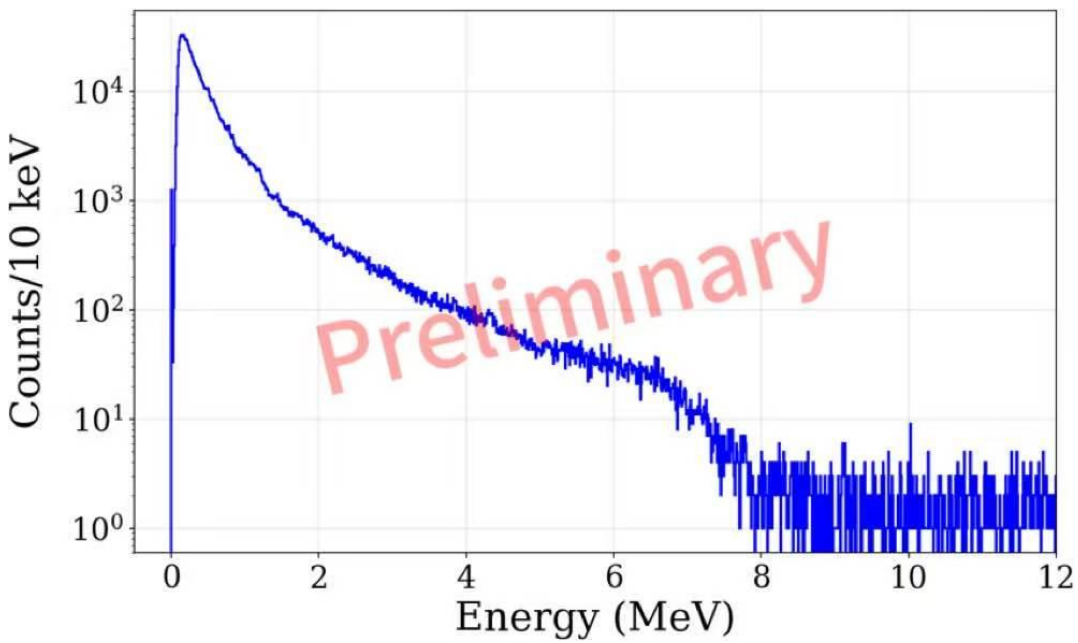
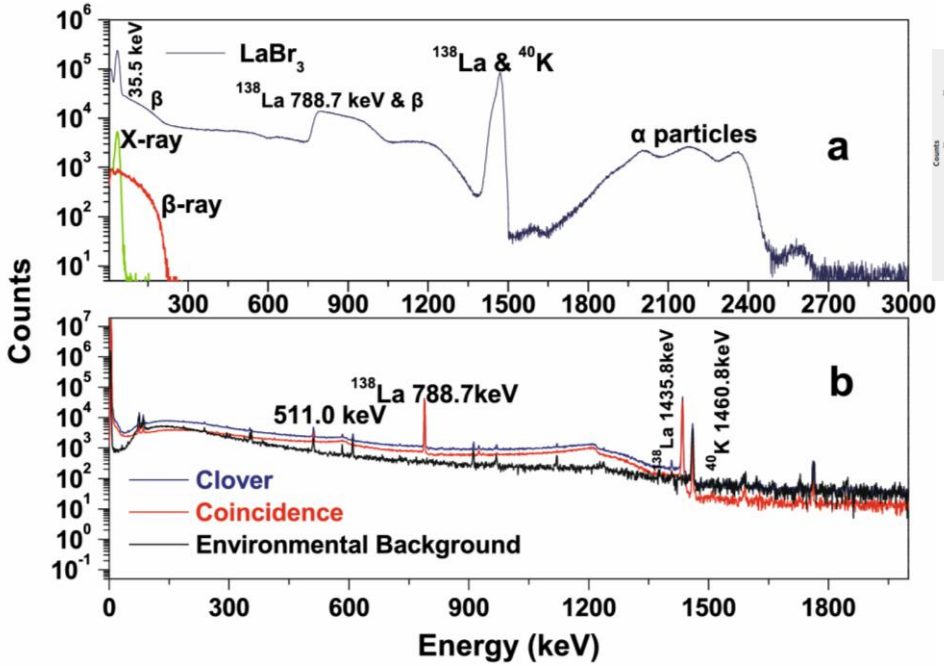
^{252}Cf Test: n-γ-γ Coincidence

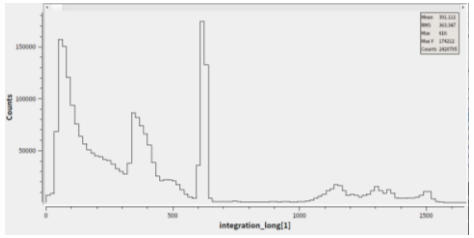


✓ This result confirms that the system can perform n-γ-γ coincidence event selection.

^{252}Cf Test







- ✓ n-γ-γ triple-coincidence selection can pick out ^{252}Cf fission events
- ✓ $LaBr_3$ intrinsic background peaks are strongly suppressed
- ✓ reduce uncorrelated backgroun

[4] H. Cheng et al., Nucl. Sci. Tech. 31, 99 (2020).

Conclusion and Outlook

- ✓ We designed and built the upgraded p-process chaser detector.
- ✓ We tested the nγγ triple-coincidence capability of the detector system.
- ➢ The experiment is planned at the SLEGS beamline of SSRF in 2026/2027.