Lifetime Measurement of Excited States in $^{115,117}Cd$ from ^{252}Cf Fission

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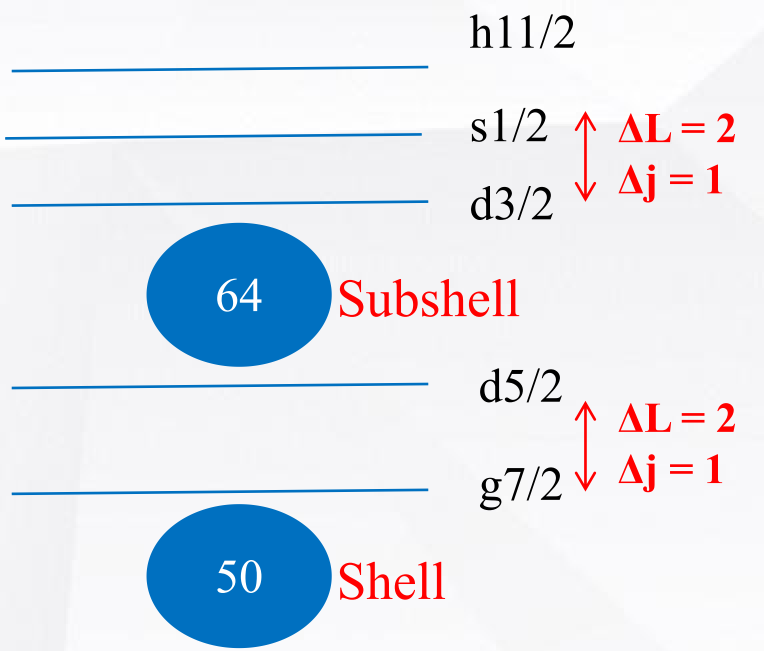
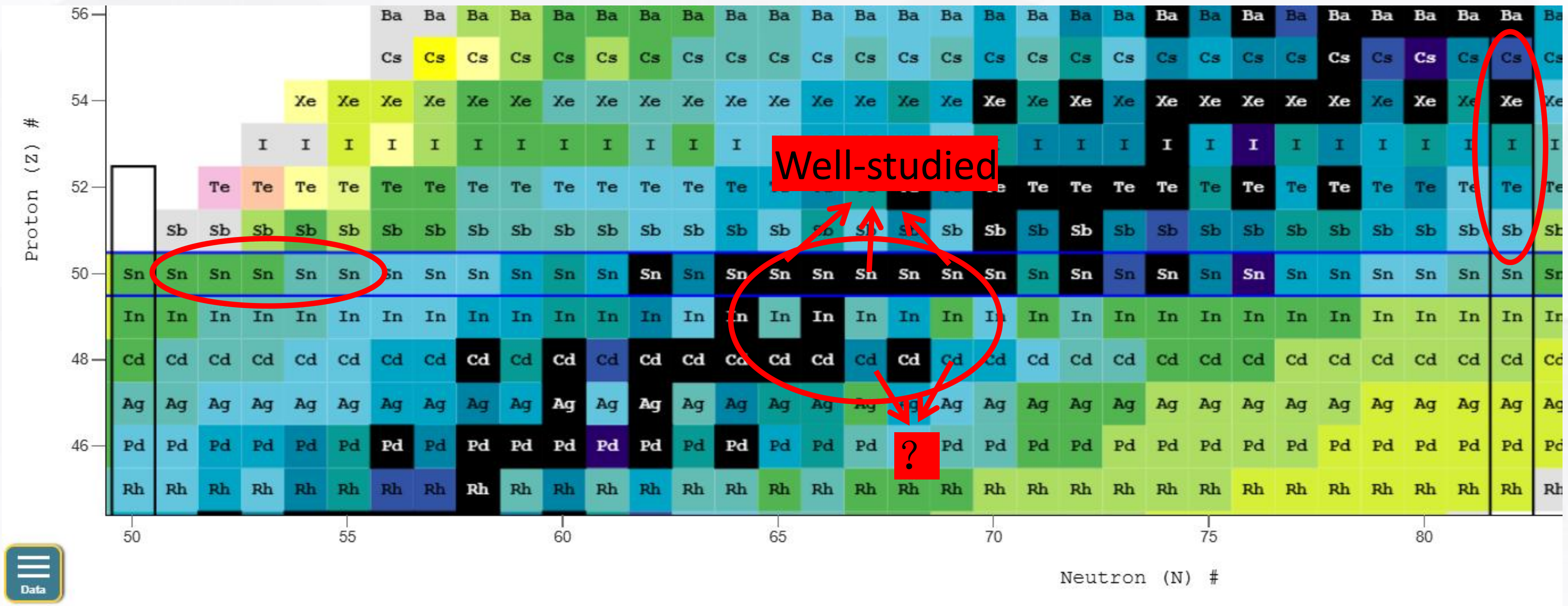
  Institute of Modern Physics, Chinese Academy of Sciences

Outline

Scientific motivation





$^{101}_{50}Sn_{51}$, $^{103}_{50}Sn_{53}$, $^{105}_{50}Sn_{55}$...: Valence neutron occupy d5/2 or g7/2

$^{133}_{51}Sb_{82}$, $^{135}_{53}I_{82}$, $^{137}_{55}Cs_{82}$...: Valence proton occupy d5/2 or g7/2

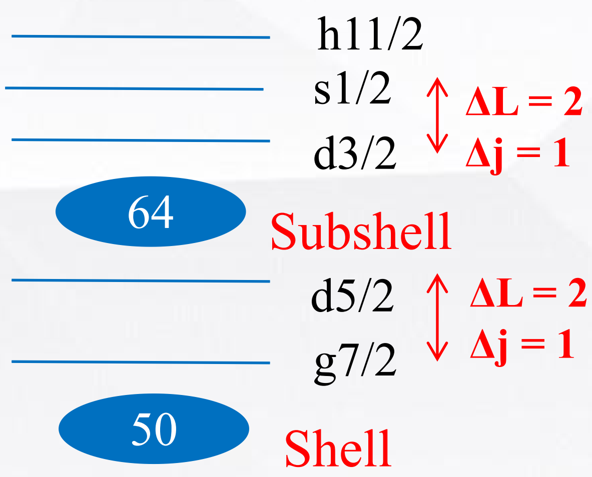
→ Far from stability line

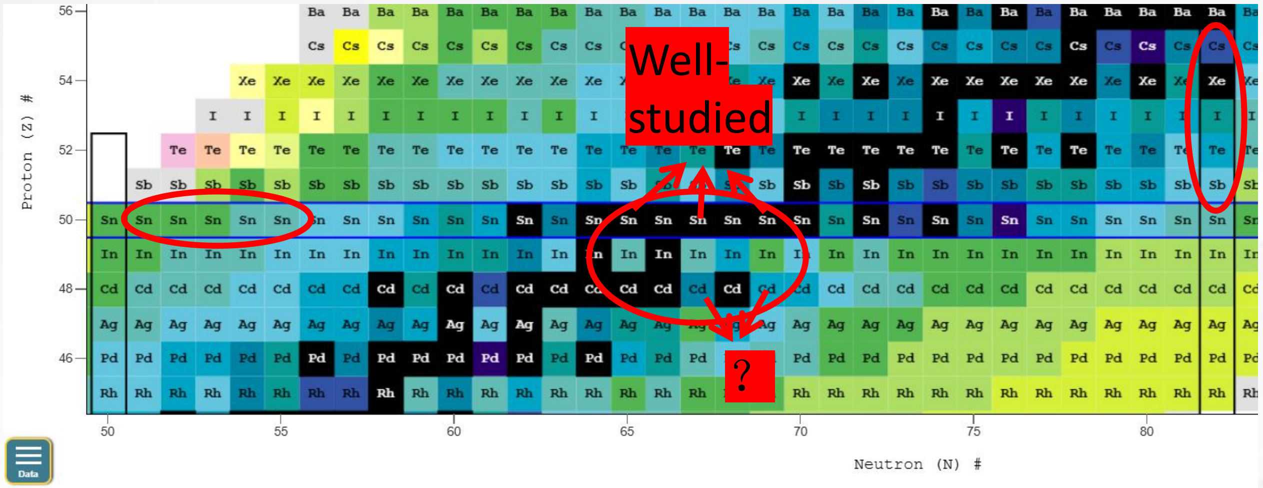
$^{115}_{50}Sn_{65}$, $^{117}_{50}Sn_{67}$, $^{119}_{50}Sn_{69}$...: Valence neutron occupy d5/2, g7/2

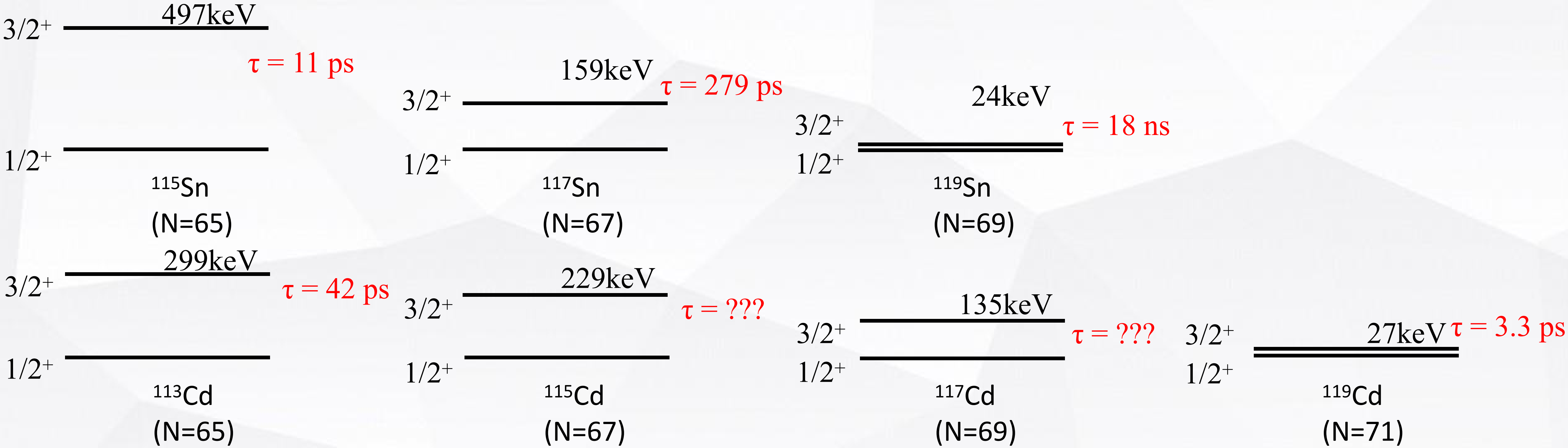
→ They are well-studied xxxx

L-forbidden M1 transition:
An M1 transition requires ΔJ=1 and ΔL=0 or ±1. So a transition with ΔJ=1 but ΔL=2 is forbidden in the single-particle model.

Scientific motivation

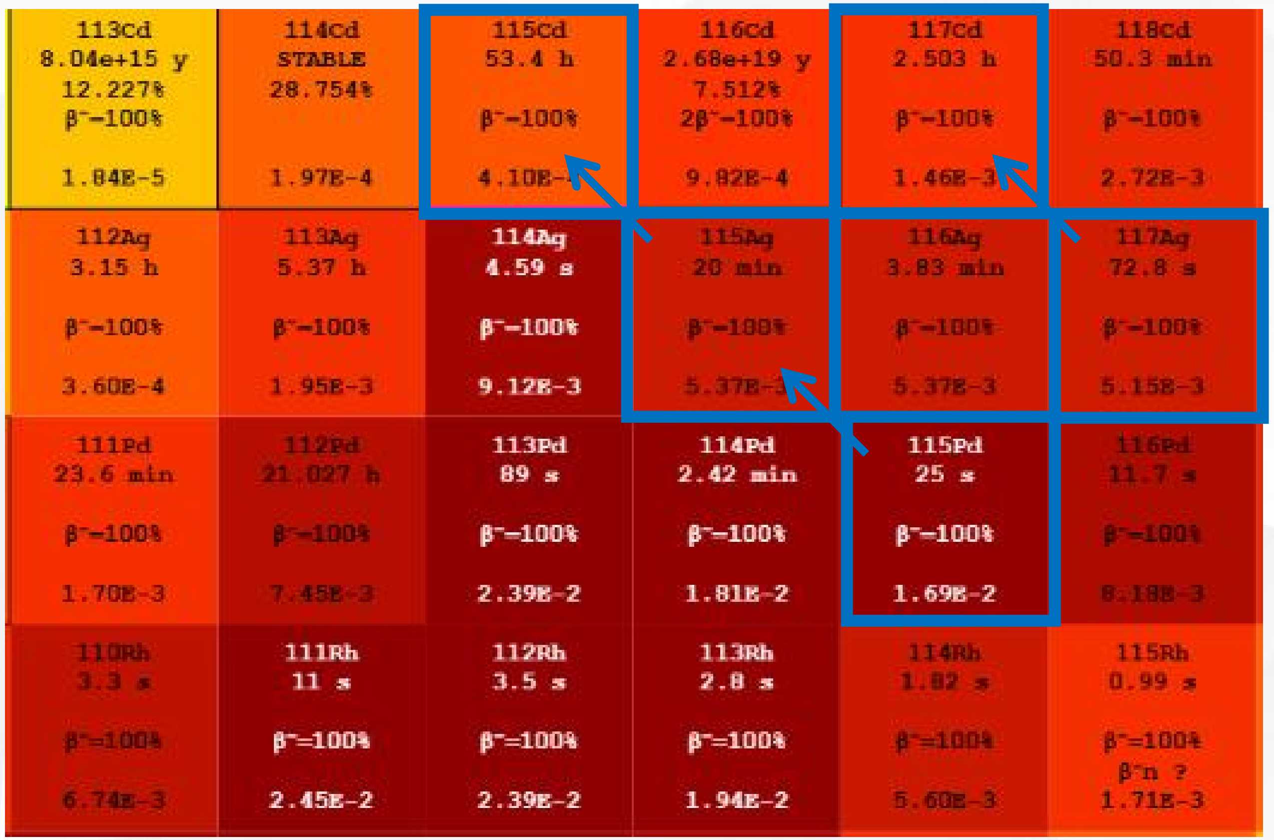




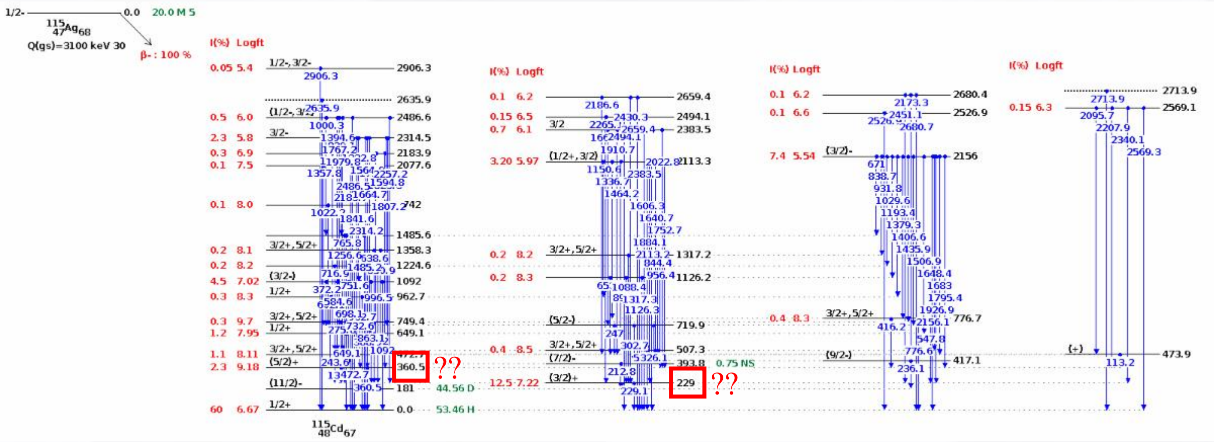


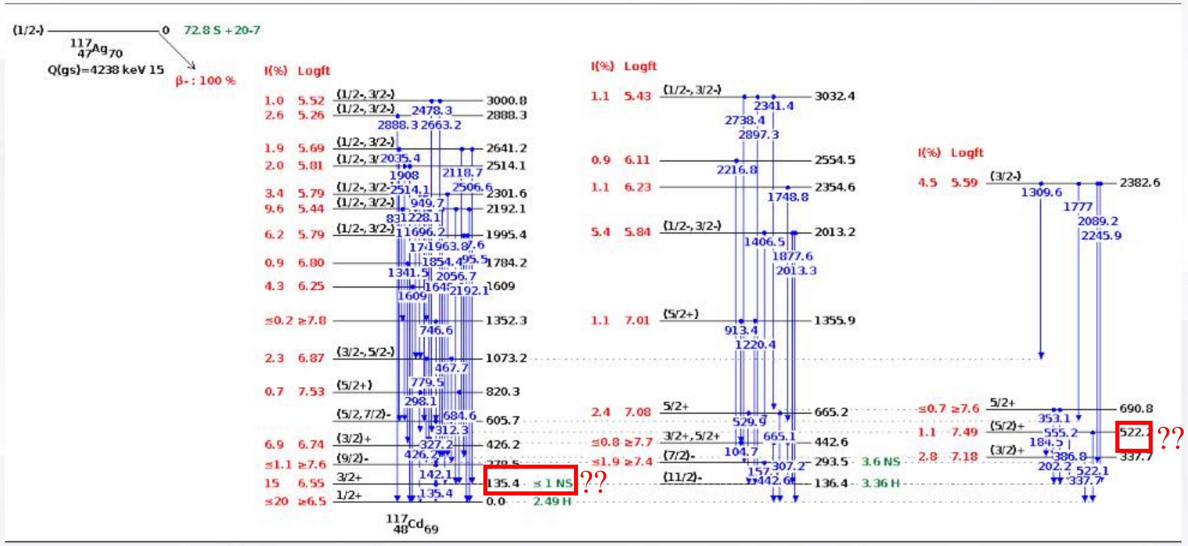
Scientific motivation

- ^{252}Cf fission fragment yields



- ^{115,117}Ag decay scheme

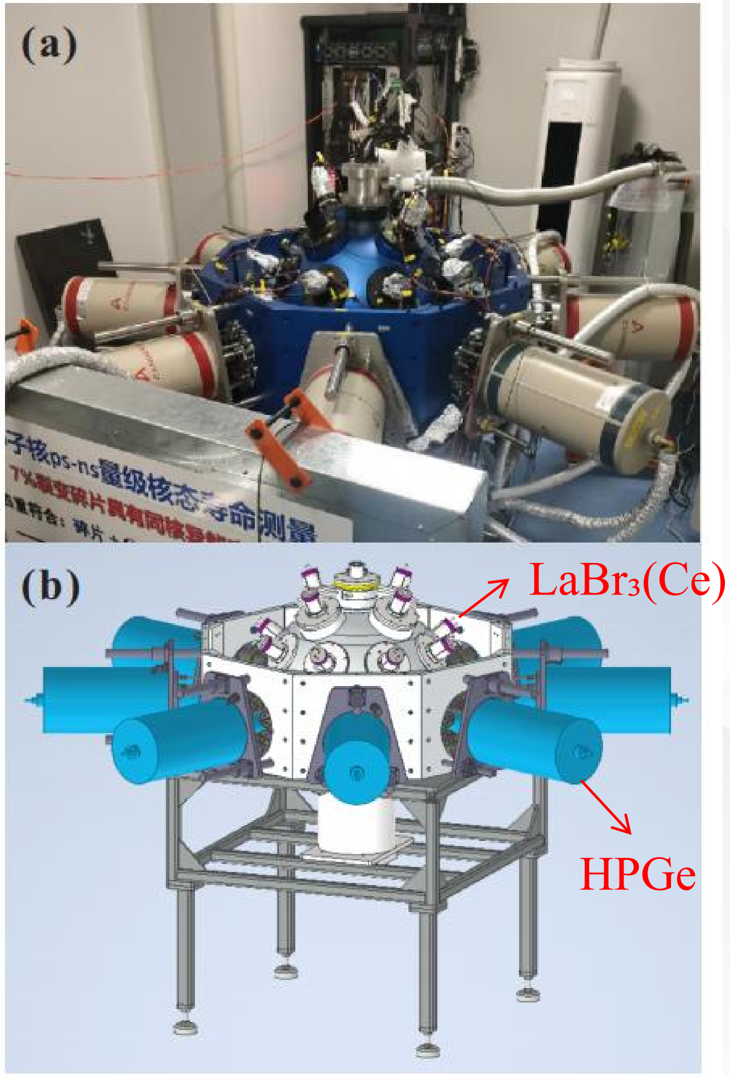


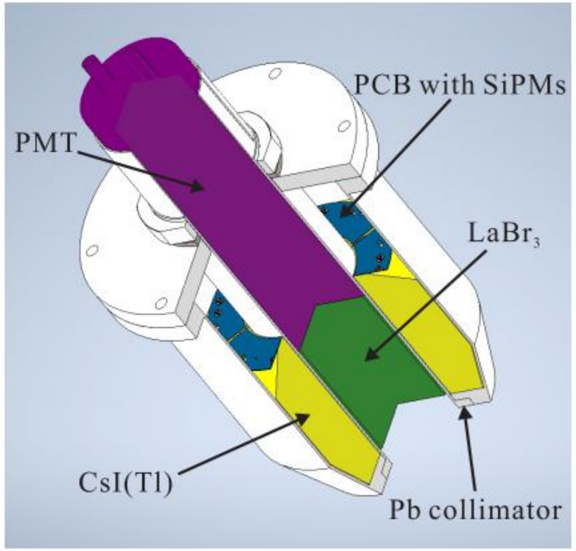


Good opputunity to measure the lifetimes of 3/2+ states in ^{115,117}Cd from beta decay of ^{115,117}Ag

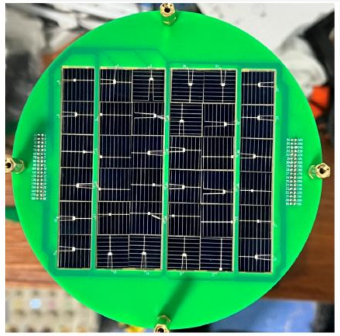
2 Experimental Setup

- HALIMA (Hybrid Array for LIfetime MeAsurement)
  At the Institute of Modern Physics (IMP)

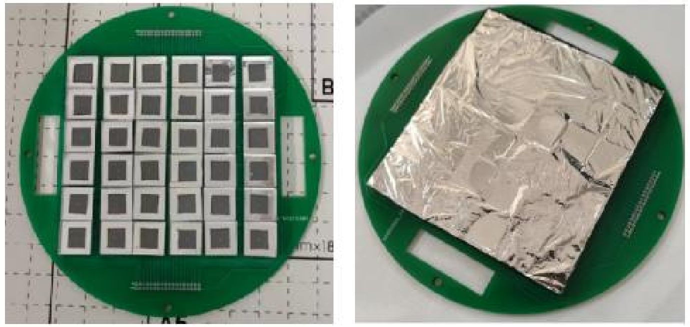




$LaBr_3(Ce)$ Detectors



Solar Cells



Fast Plastic Scintillators

- **8 HPGe detectors**
  - BGO Anti-Compton shields - Energy Resolution : 2.5 keV @ 1.33 MeV
- **20 $LaBr_3(Ce)$ detectors** 2 inch diameter and 3 inch length
  - CsI(Tl) Anti-Compton shields - Time Resolution : 348.9(2) ps @ 1173 keV-1332 keV
- **36 Fission Fragment (FF) detectors(Solar Cells):**
  - FF implantation tagging
- **36 Fast Plastic Scintillators :**
  - β-particle tagging

Key Performances of HALIMA Detector Array

- Compton Suppression with CsI(Tl) Shields

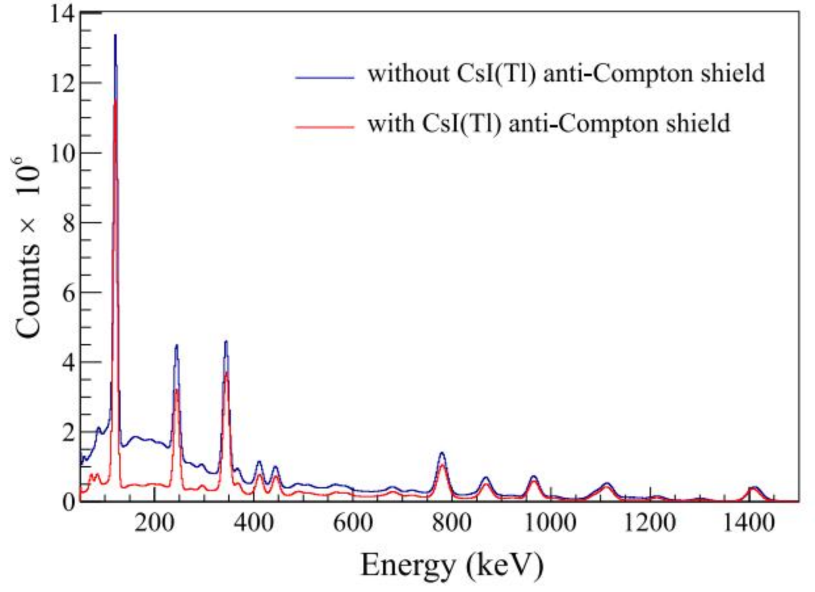


Fig. 4. The energy projection spectra of the symmetric γ-γ coincidence matrix of $LaBr_3$(Ce) detectors obtained using ^{152}Eu standardized source. Compared to the spectrum without CsI(Tl) anti-Compton shields (blue), the background continuums are effectively reduced with the use of CsI(Tl) anti-Compton shields in the energy spectrum (red).

- Time Resolution of $LaBr_3$(Ce) Array (^{60}Co)

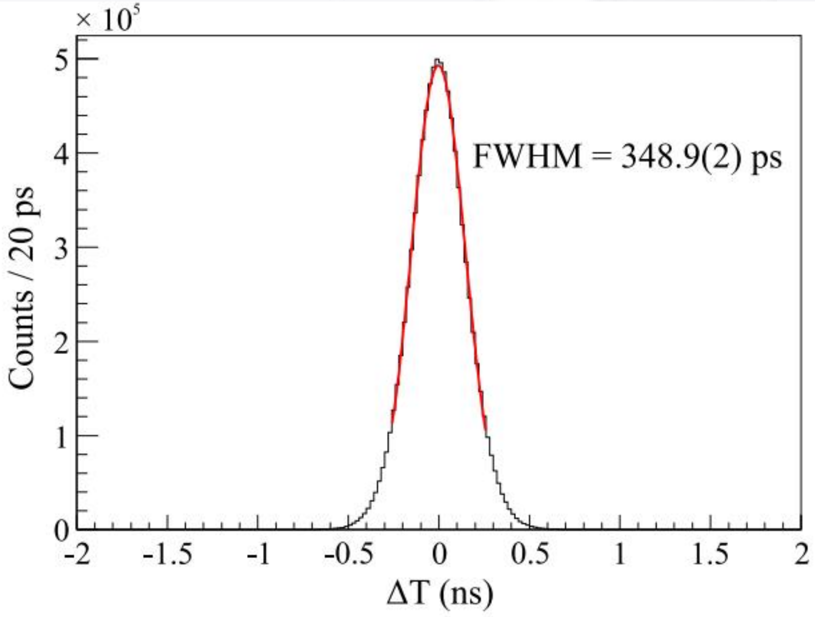


Fig. 5. Time distribution of twenty $LaBr_3$(Ce) detectors in HALIMA from the 1173 keV-1332 keV γ ray cascade of ^{60}Co source. Time resolution for twenty $LaBr_3$(Ce) detectors was fitted by Gaussian function.

- Absolute full energy peak efficiency

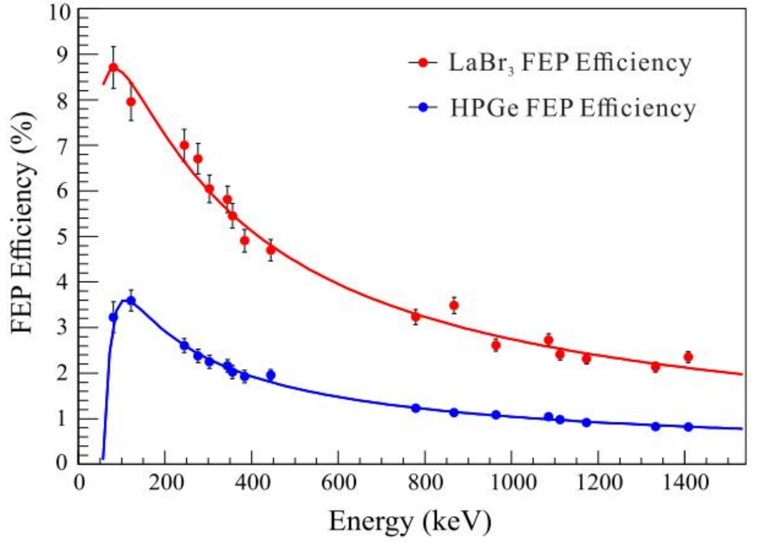
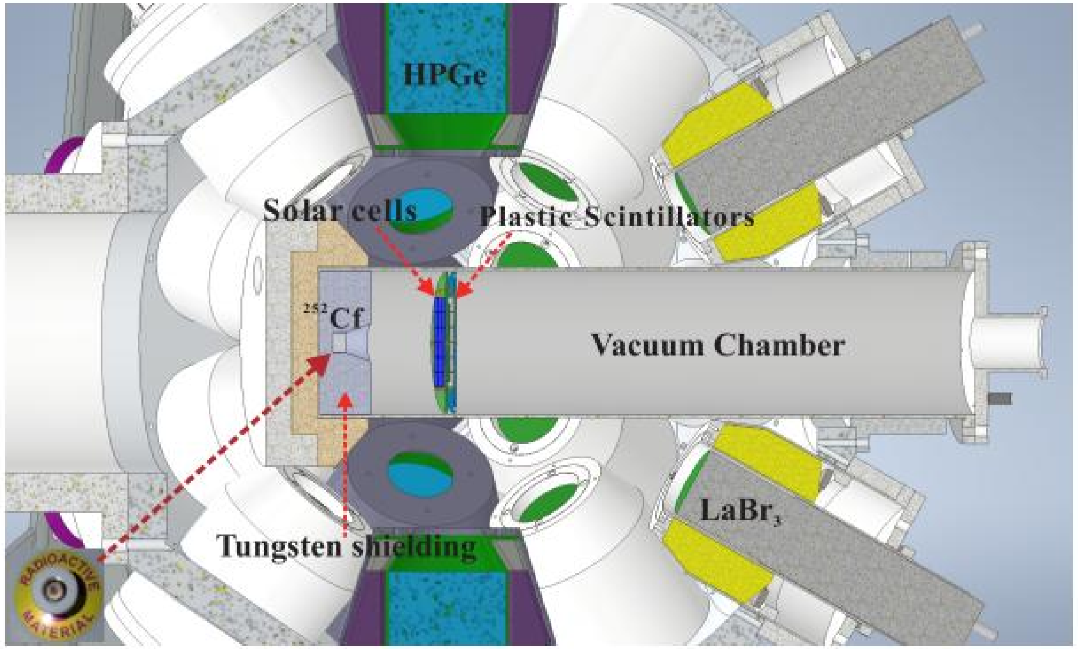


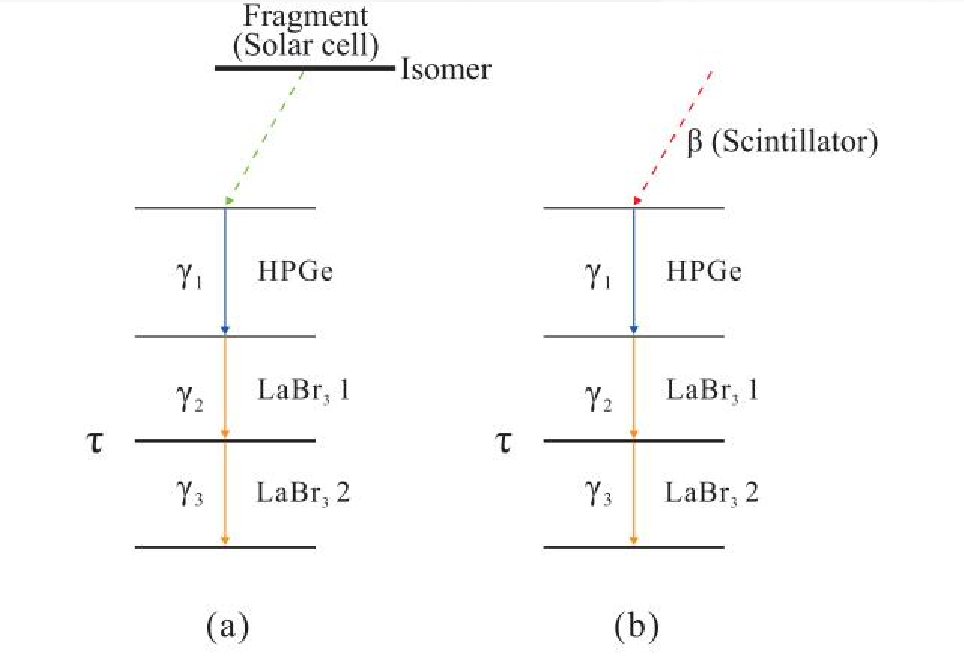
Fig. 2. The absolute full energy peak efficiency as a function of γ energy as measured using ^{152}Eu, ^{133}Ba and ^{60}Co γ sources. The red circle represents the FEP of $LaBr_3$(Ce) detectors fitted in red line, while the FEP of HPGe detectors is shown in blue circle fitted in blue line.

Experimental Setup

- **Sectional view of the HALIMA setup**



- **Coincidence Technique**



(a) Fission Fragments(FF)-γ_1-γ_2-γ_3 Coincidence

- Solar cell tags FF → γ_1 (HPGe) → γ_2/γ_3 ($LaBr_3$(Ce))

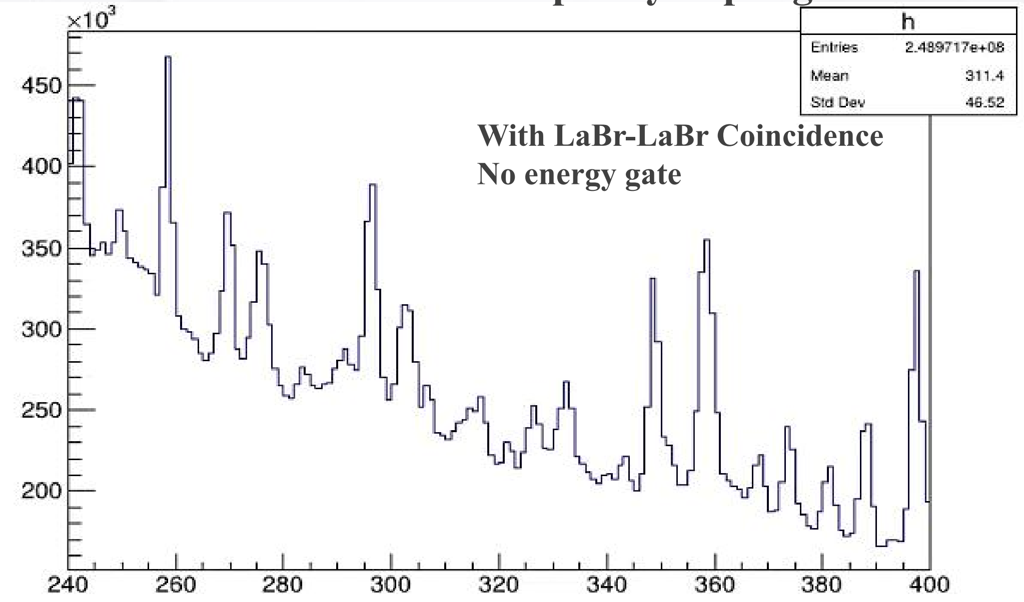
- Allowing uppression of uncorrelated γ background from β-decay

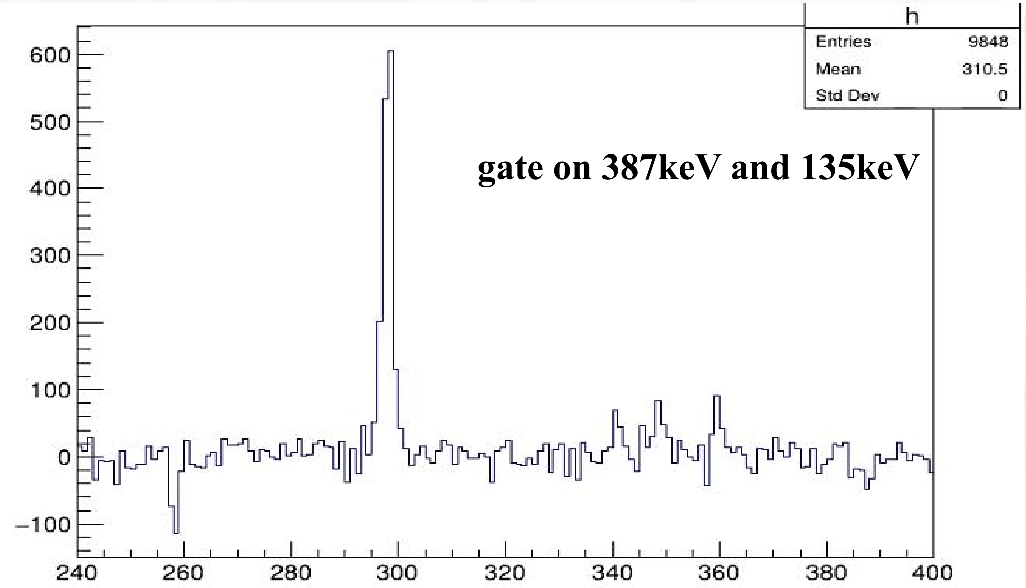
(b) β-γ_1-γ_2-γ_3 Coincidence

- Plastic scintillator tags β decay → γ_1 (HPGe) → γ_2/γ_3 ($LaBr_3$(Ce))

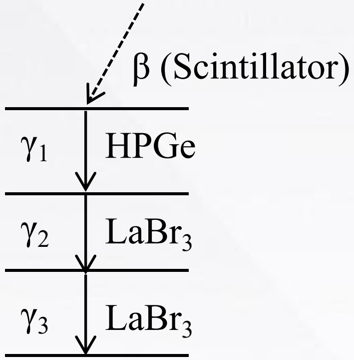
- Allowing measurement of the γ after the beta decay

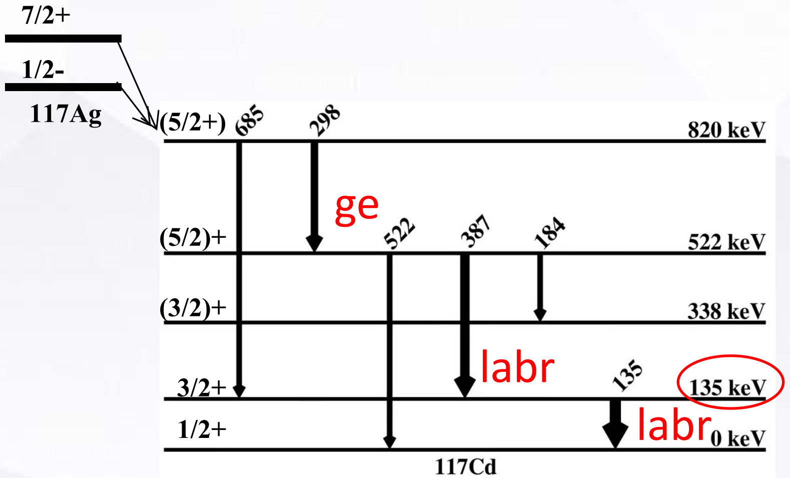
Selection of different isotopes by triple-gamma coincidence





Triple-gamma coincidence after beta decay clearly identify different isotopes



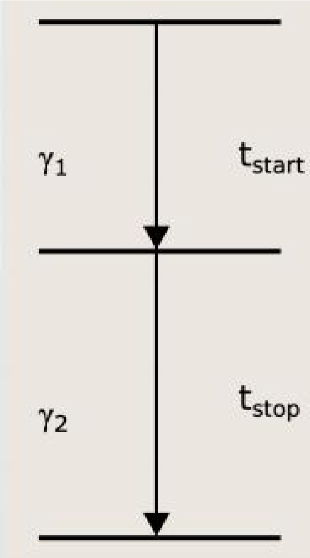


- Direct electronic timing measurement

1. When τ is significantly larger than the time resolution (FWHM of the prompt time-difference distribution), slope fitting of the measured time distribution with an EXPO function,

2. When τ is comparable to the time resolution, convolution fitting (between the Gaussian and EXPO)

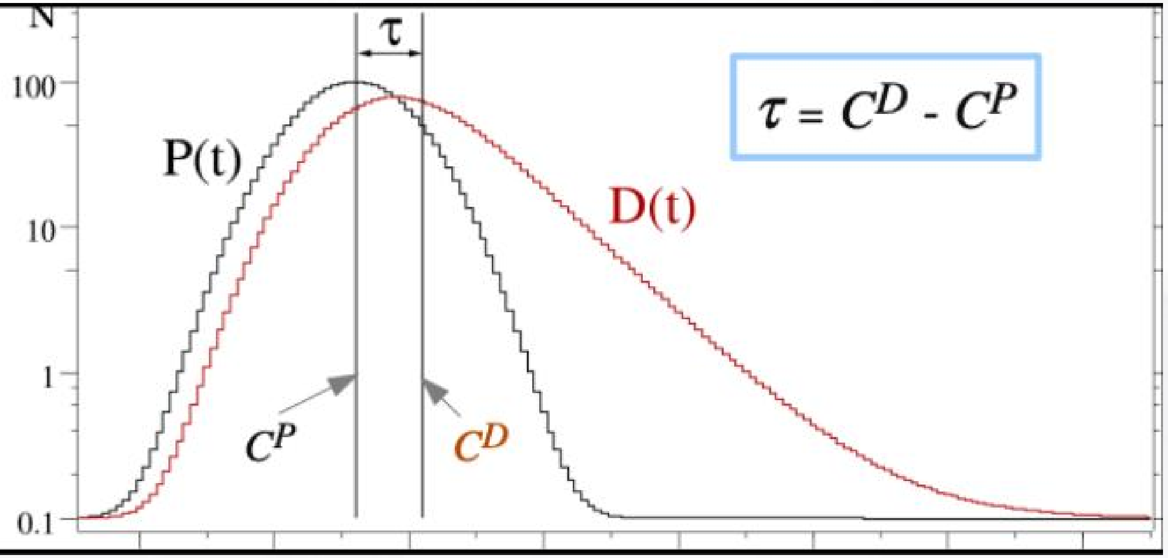
3. When τ is smaller than the time resolution, only the centroid of time distribution deviates from the prompt one (centroid shift or centroid difference method)



The centroid or center of gravity is the first moment of a time distribution $D(t)$:

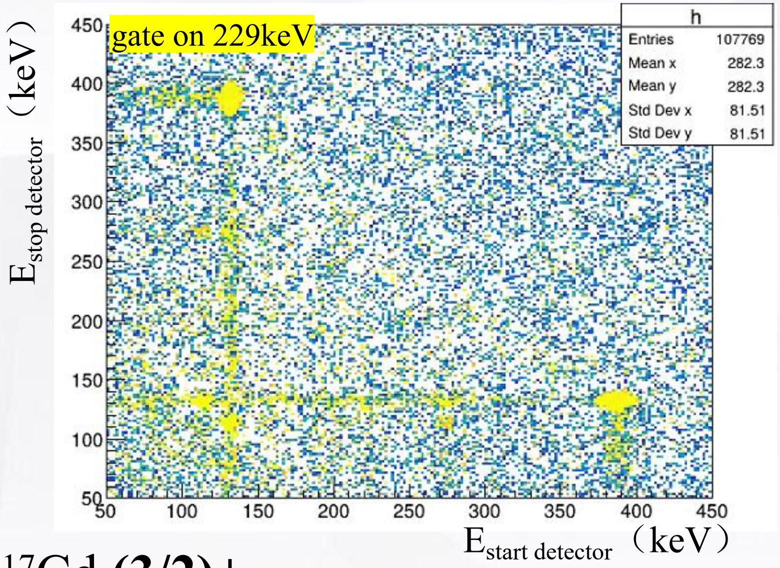
$$C^D = \langle t \rangle = \frac{\int t\, D(t)\, dt}{\int D(t)\, dt}$$

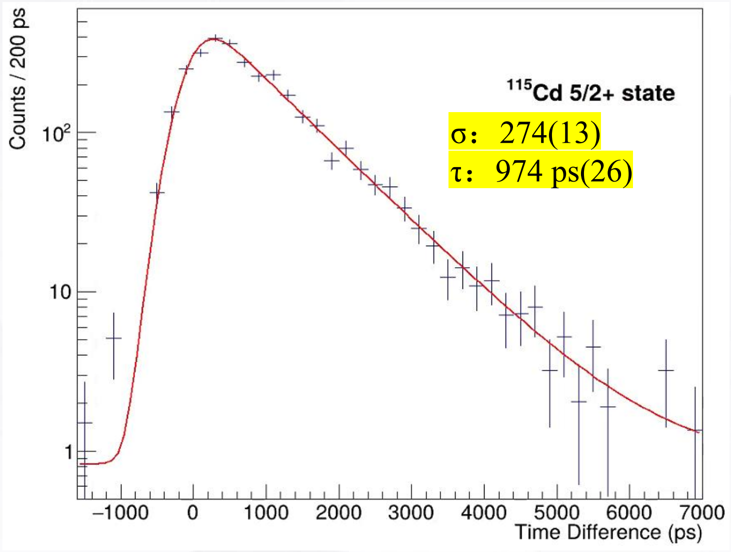
The statistical uncertainty is given by the standard deviation σ=FWHM/2.355 of the PRF:

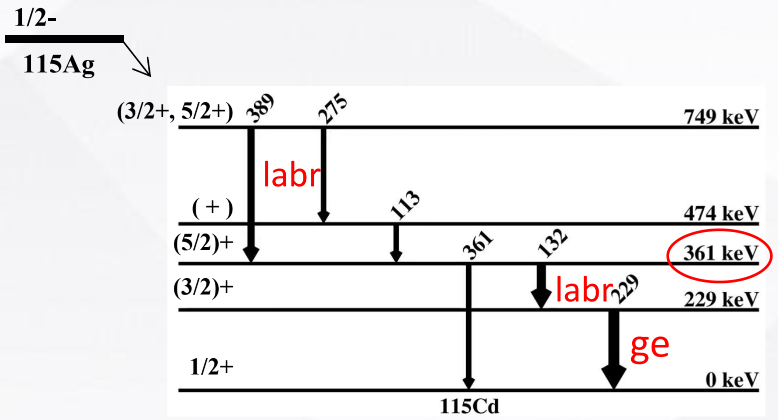


Lifetime Measurement Results using Convolutional Fitting

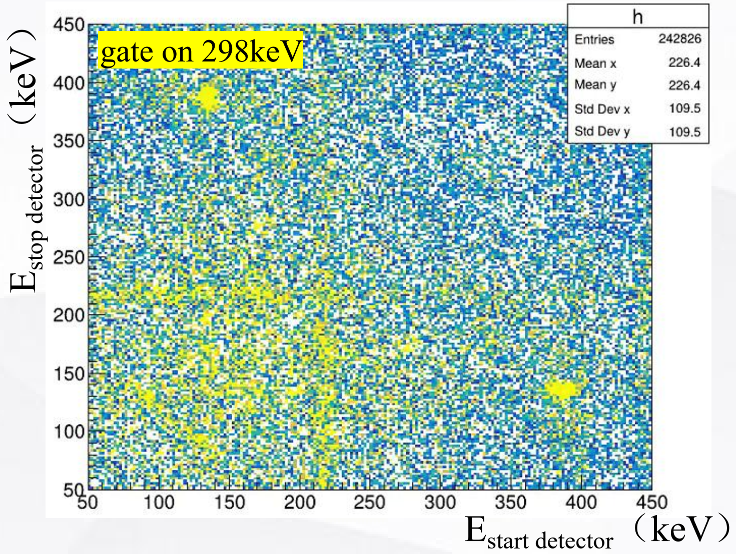
^{115}Cd (5/2)+

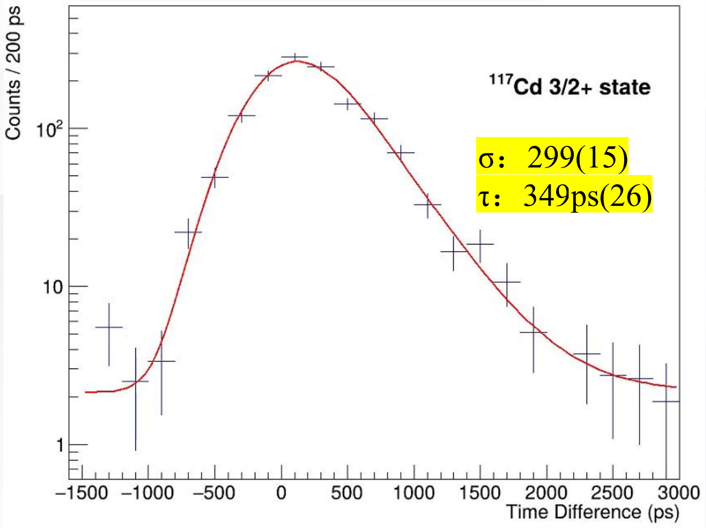


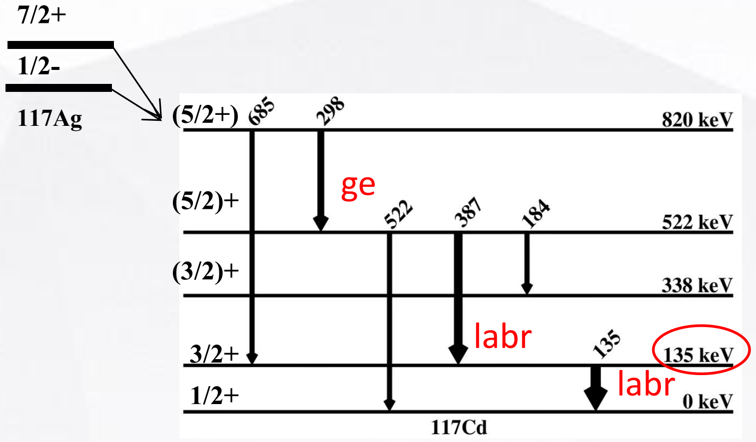




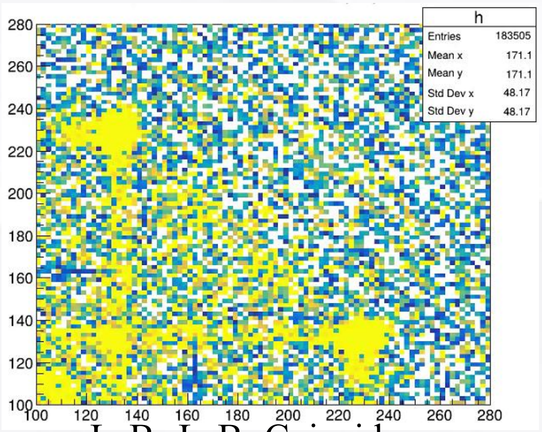
^{117}Cd (3/2)+



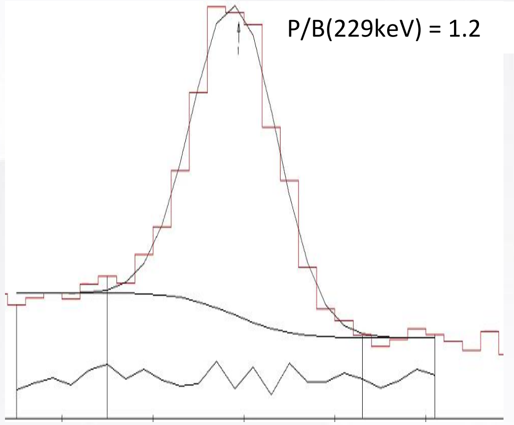


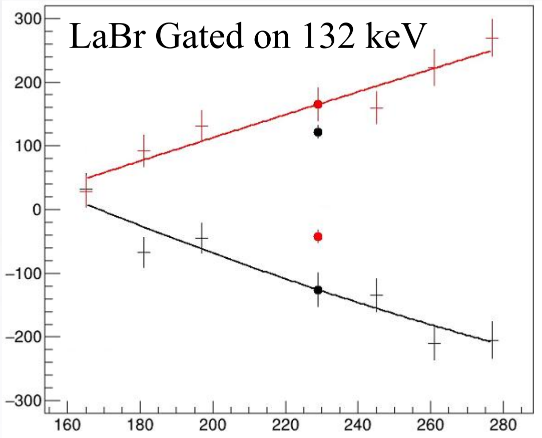


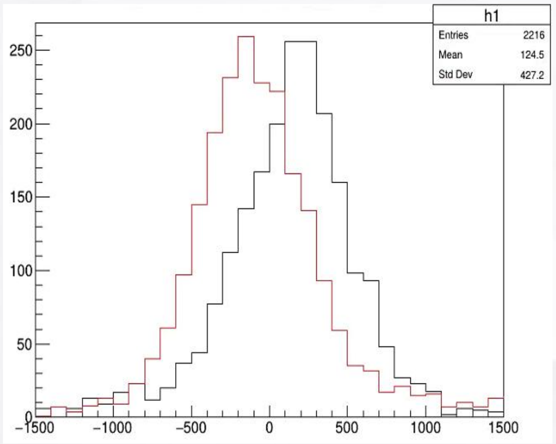
Lifetime Measurement Results using Centroid-difference method



LaBr-LaBr Coincidence
(HPGe Gated on 389 keV)



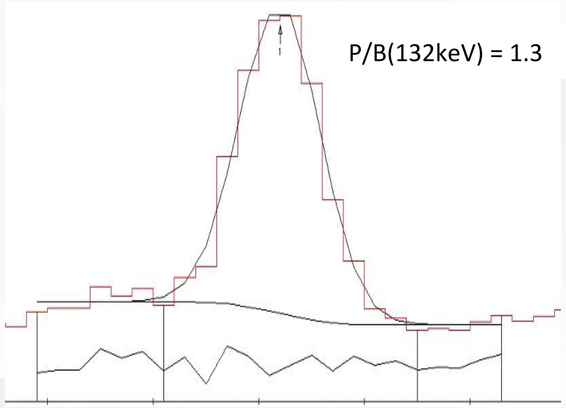




Delayed and Anti-Delayed Coincidence Spectra

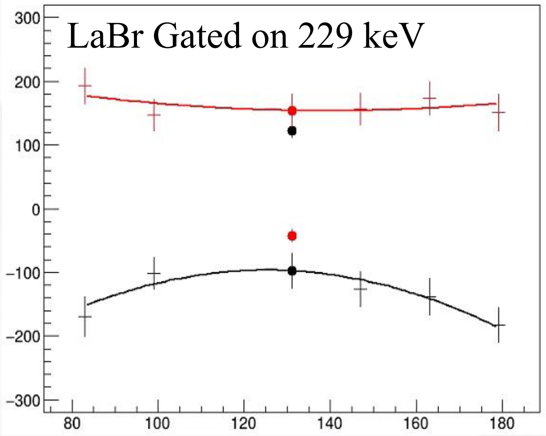
$$\tau = \frac{\Delta C_t - PRD(131, 229)}{2}$$

PRD: Prompt response difference



Peak to background ratios

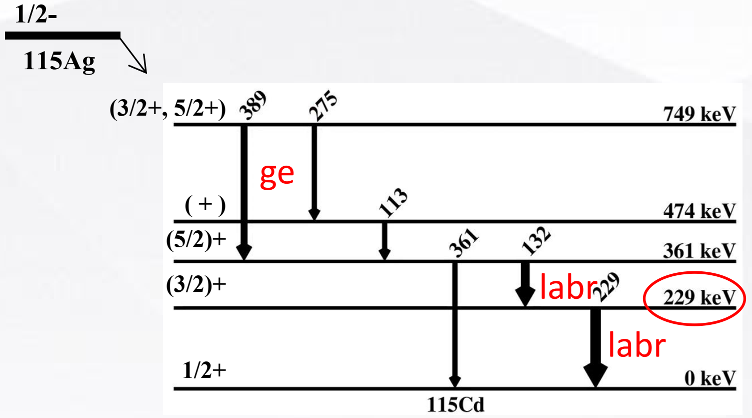
$$C_t = C_{ob} + \frac{C_{ob} - C_{bg}}{P/B}$$



Background interpolation C_{bg} and the uncorrected centroid C_{ob}

PRD(131,229) = -136(8) ps

τ_{final} = 324(30) ps



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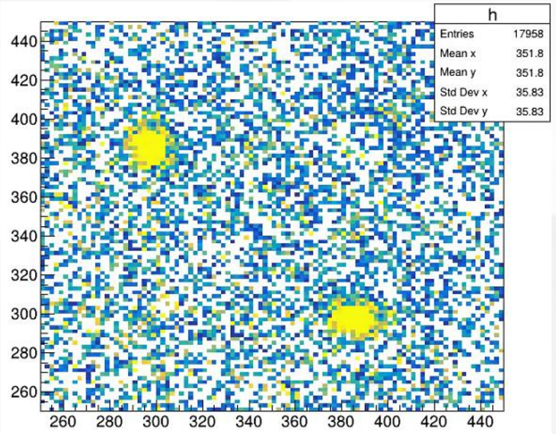
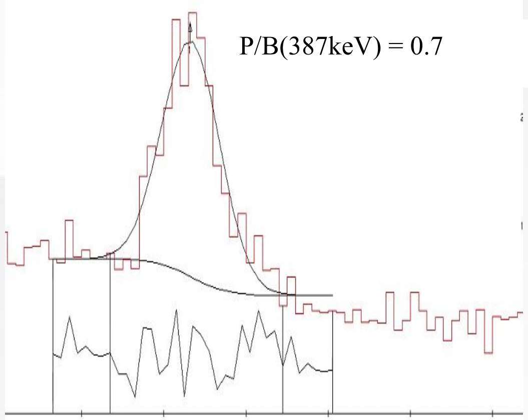
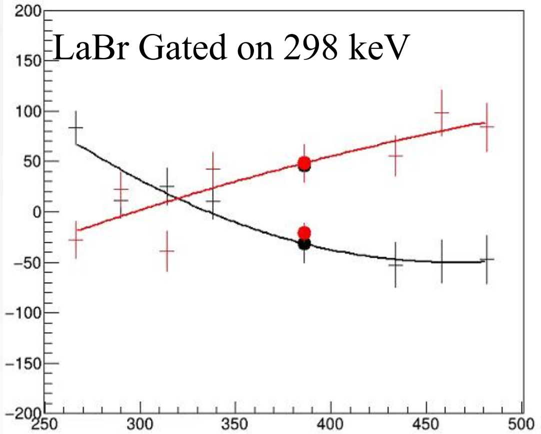
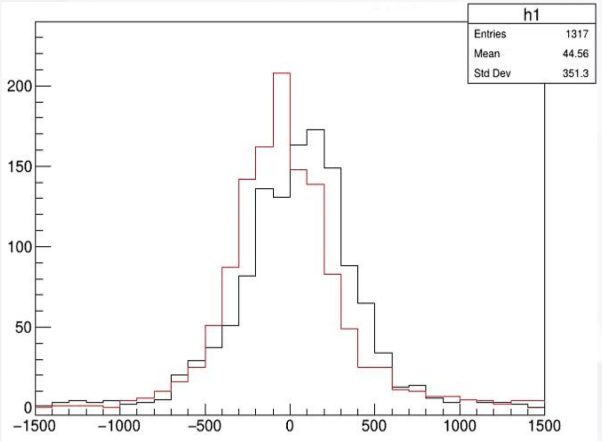
Lifetime Measurement Results using Centroid-difference method



LaBr-LaBr Coincidence
(HPGe Gated on 135 keV)

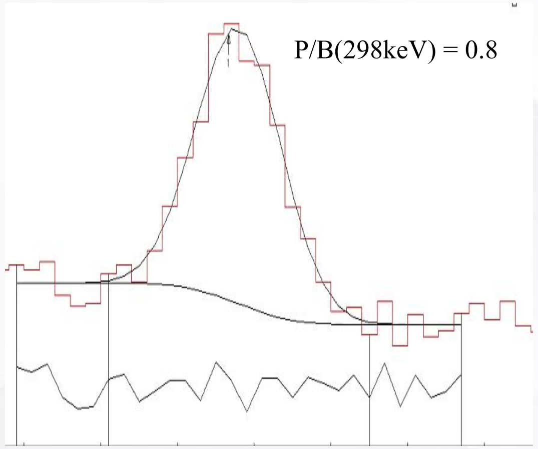






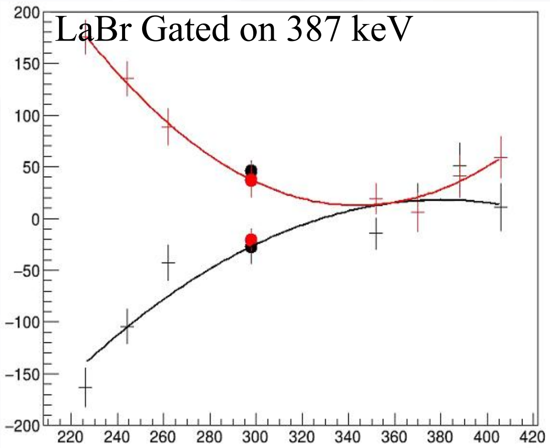
Delayed and Anti-Delayed Coincidence Spectra

$$\tau = \frac{\Delta C_t - PRD(298,386)}{2}$$



Peak to background ratios

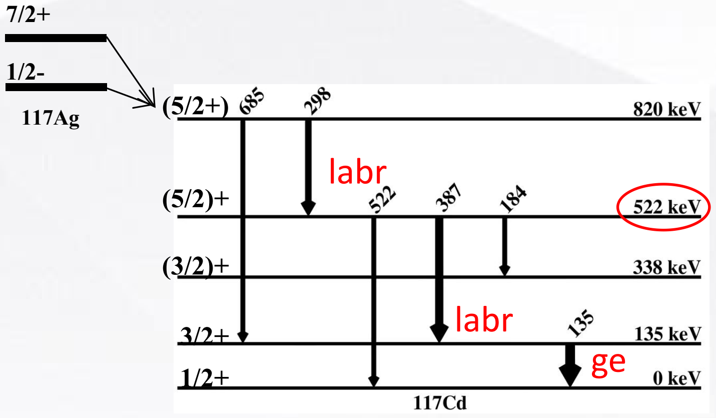
$$C_t = C_{ob} + \frac{C_{ob} - C_{bg}}{P/B}$$



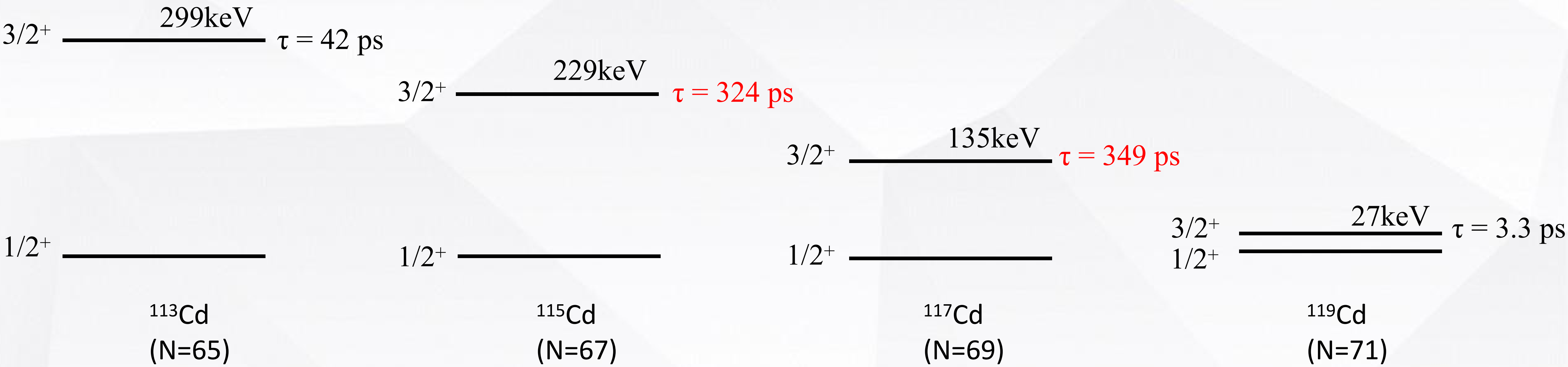
Background interpolation C_{bg} and the uncorrected centroid C_{ob}

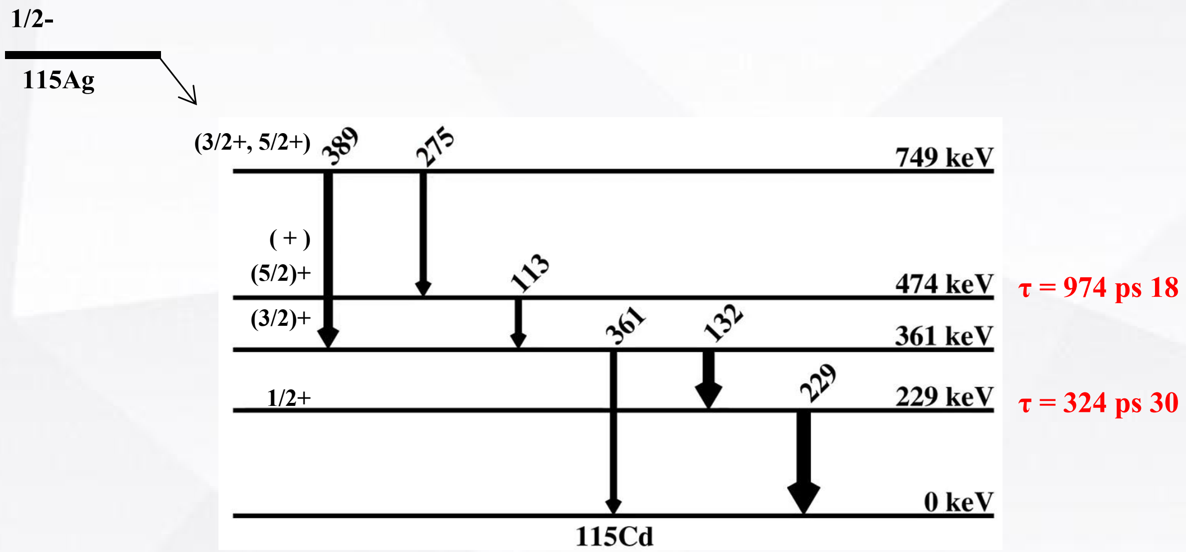
PRD(298,386) = -24(8) ps

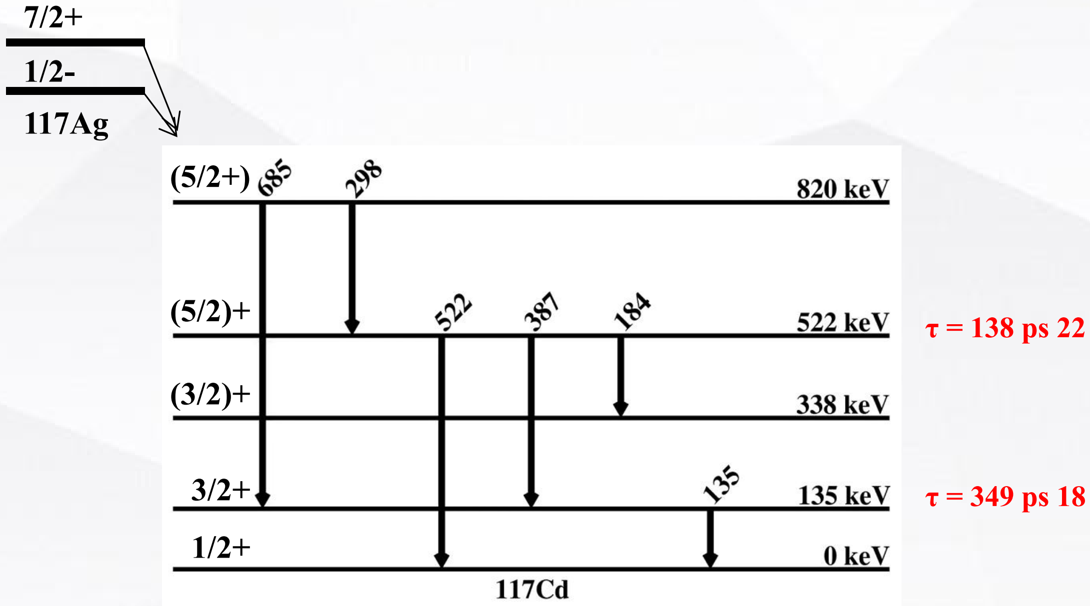
τ_{final} **= 138(22) ps**



3 Result and Discussion







Perspective

HALIMA is quite suitable for lifetime measurement of excited states in exotic nucleus;

Compared with ^{252}Cf spontaneous fission, fast neutron induced fission of ^{238}U produce more exotic nucleus;

Our goal is to apply HALIMA at back-n of CSNS

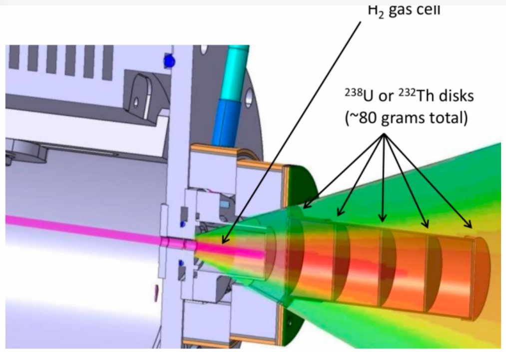


Figure 2: LICORNE fission source with ^{238}U target installed. The ^{7}Li beam is indicated by a pink line, the neutron cone is shown with intensity colour coding.

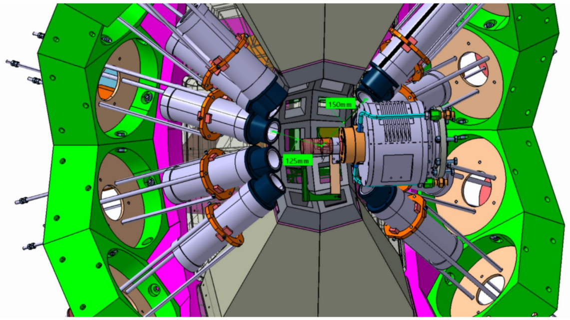
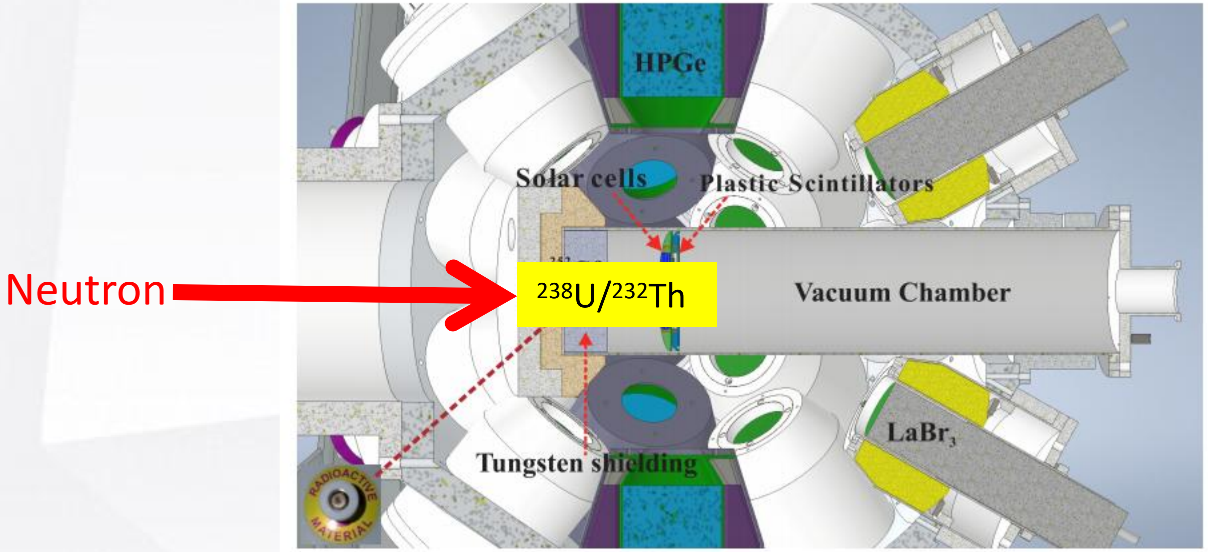


Figure 3: Proposed arrangement of the gamma detectors for the ν-Ball 2 induced fission campaign. $LaBr_3$ detectors are arranged in two rings, one at forward and one at backward angle, to maximise efficiency while avoiding the neutron cone.



- Institute of Modern Physics

- ALTO facility of the IJCLab

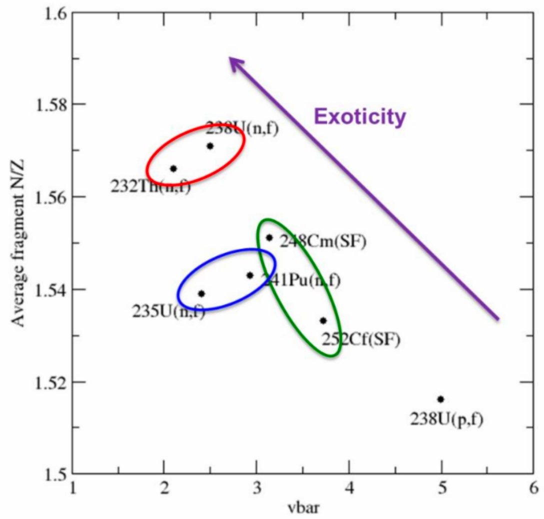


Figure 1: Different fission reactions used to study the prompt γ-decay of neutron-rich nuclei. The spontaneous fission sources are circled in green. Nuclei fissioned with thermal neutrons during the EXILL campaign are circled in blue. The new reaction mechanisms currently only available at the IPN Orsay with LICORNE/ν-ball are circled in red.

Thanks for listening

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