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Angular Momentum in Fission through Isomeric Ratio measurements with the Lohengrin spectrometer

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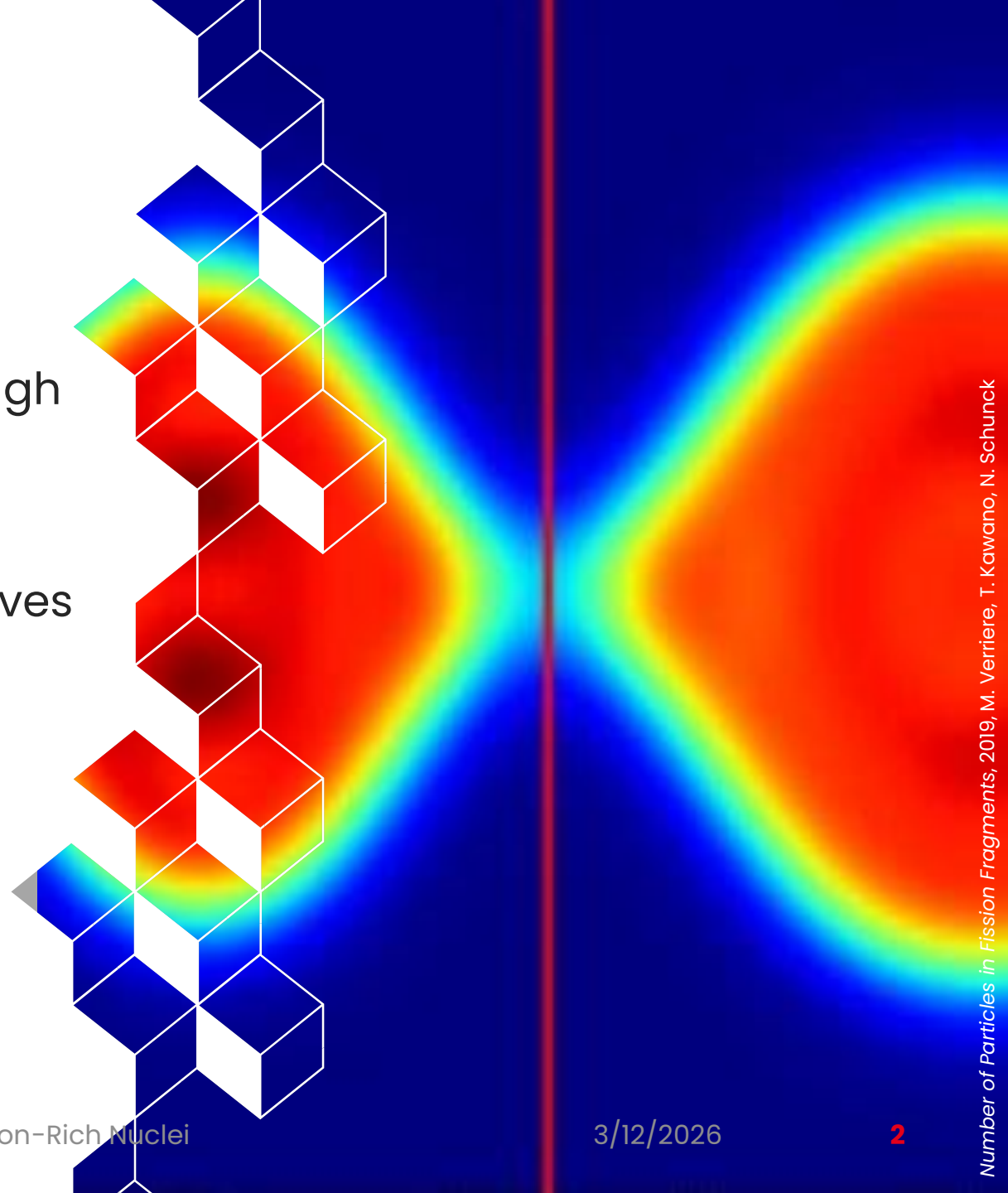
² National Technical University of Athens, Iroon polytechniou 9, Zografou Campus 15780, Athens, Greece

³ Institut Laue-Langevin, 38042 Grenoble Cedex 9, France

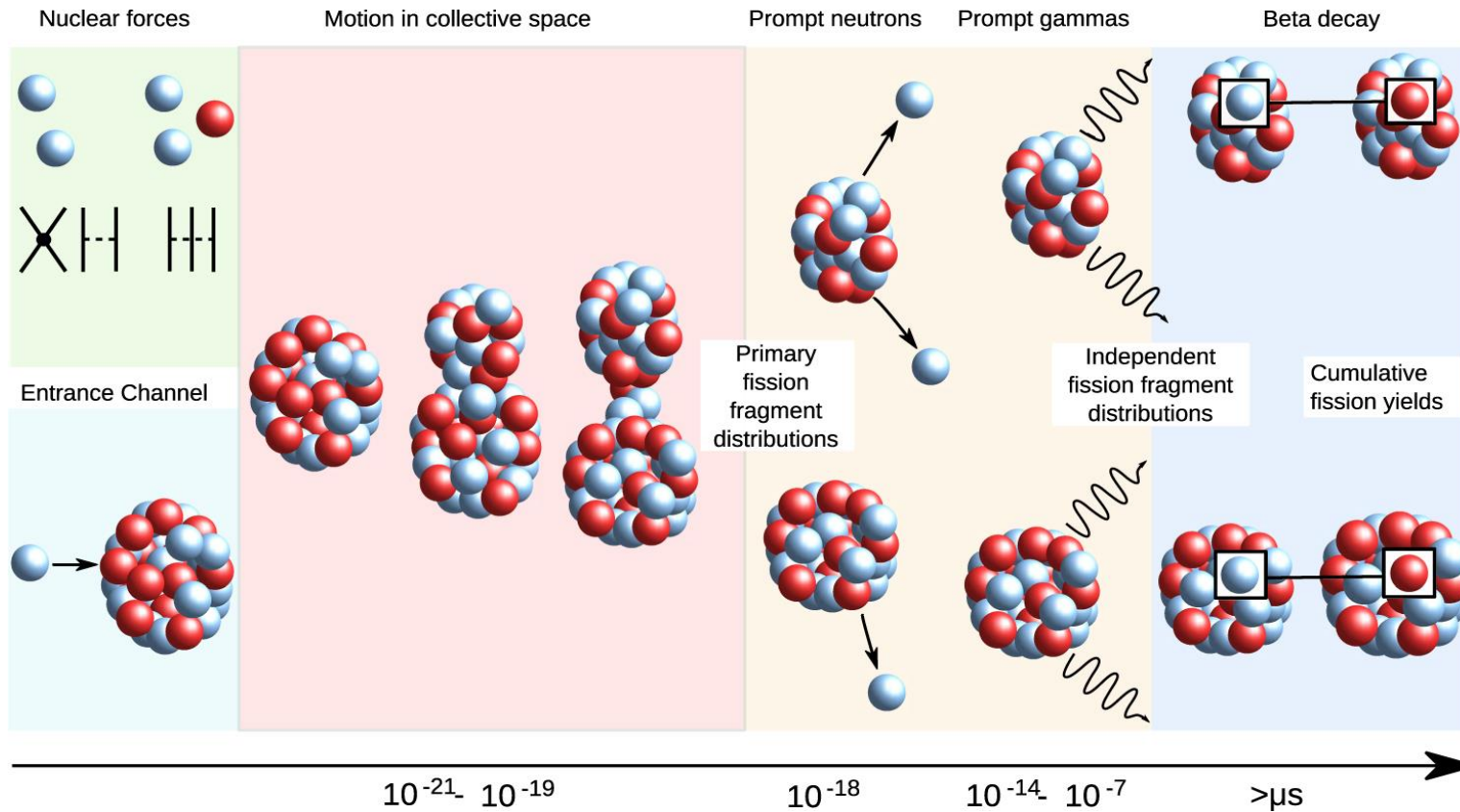
⁴ LPSC, Université Grenoble-Alpes, CNRS/IN2P3, 38026 Grenoble Cedex, France

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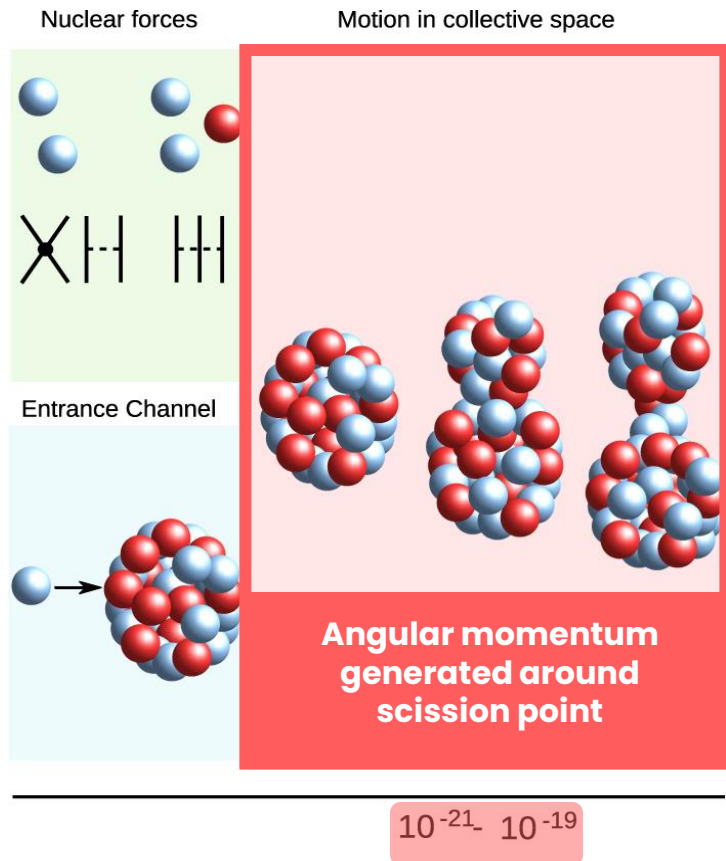
1. Motivation
2. **Isomeric Ratios of Fission Products** as observables of Angular Momentum through $^{241}\text{Am}(2n_{\text{th}},\text{f})$
3. Analysis Process
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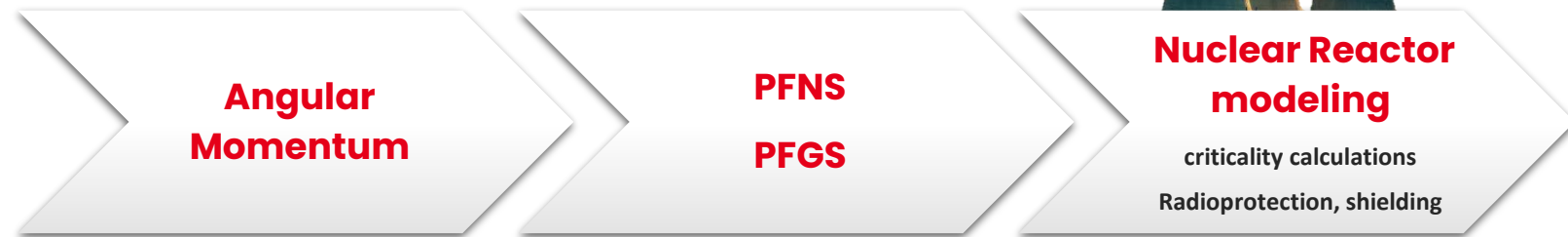
Motivation: Angular momentum generation mechanism of Fission Fragments



Motivation: Angular momentum generation mechanism of Fission Fragments



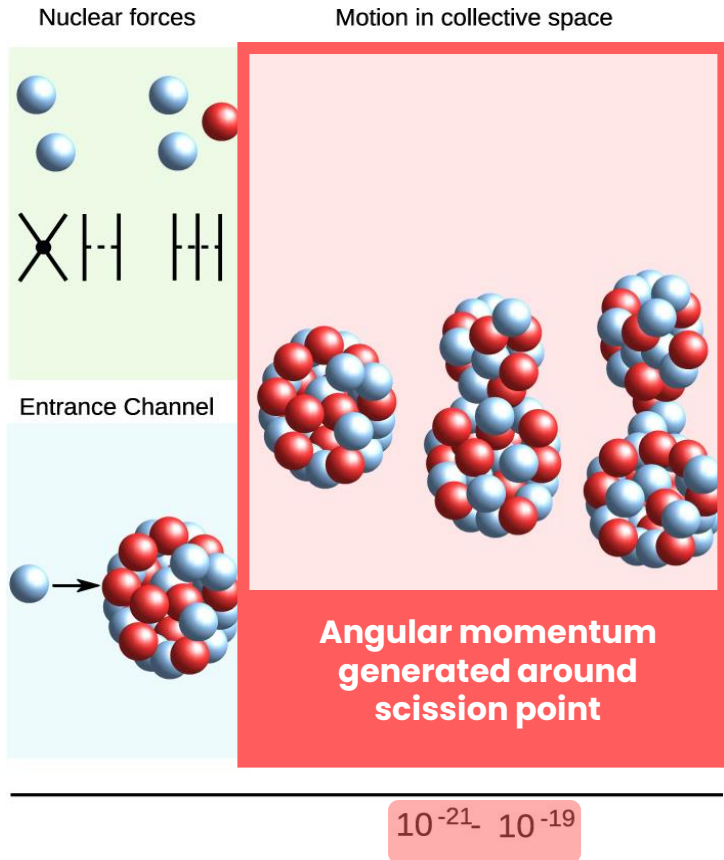
Applications:



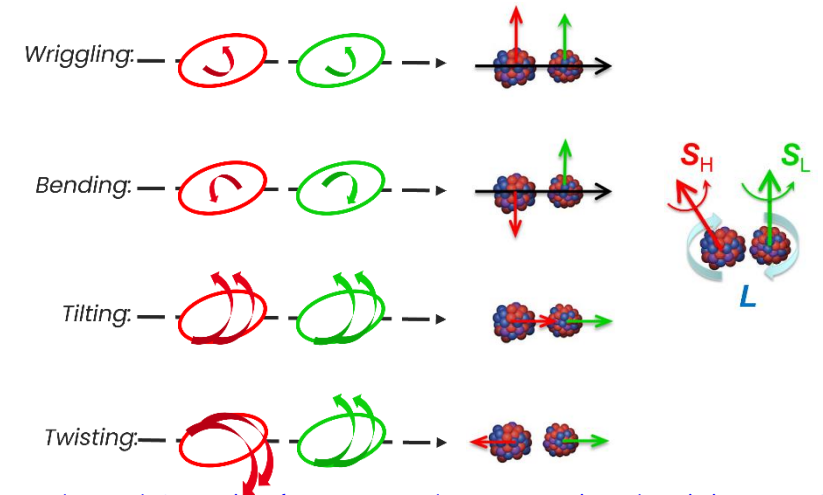
Open questions:

- ❑ the general properties of the Angular Momenta (AM)
- ❑ the mechanism(s) behind their generation and correlation of the angular momentum of the two fission fragments

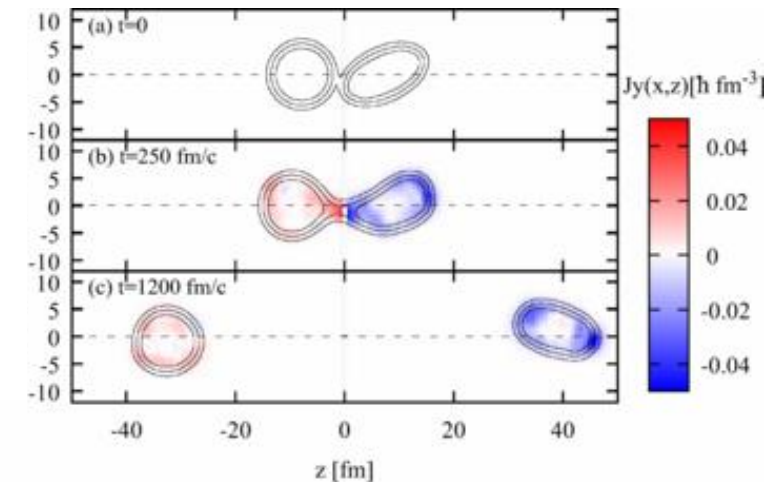
Motivation: Angular momentum generation mechanism of Fission Fragments



Competing theories

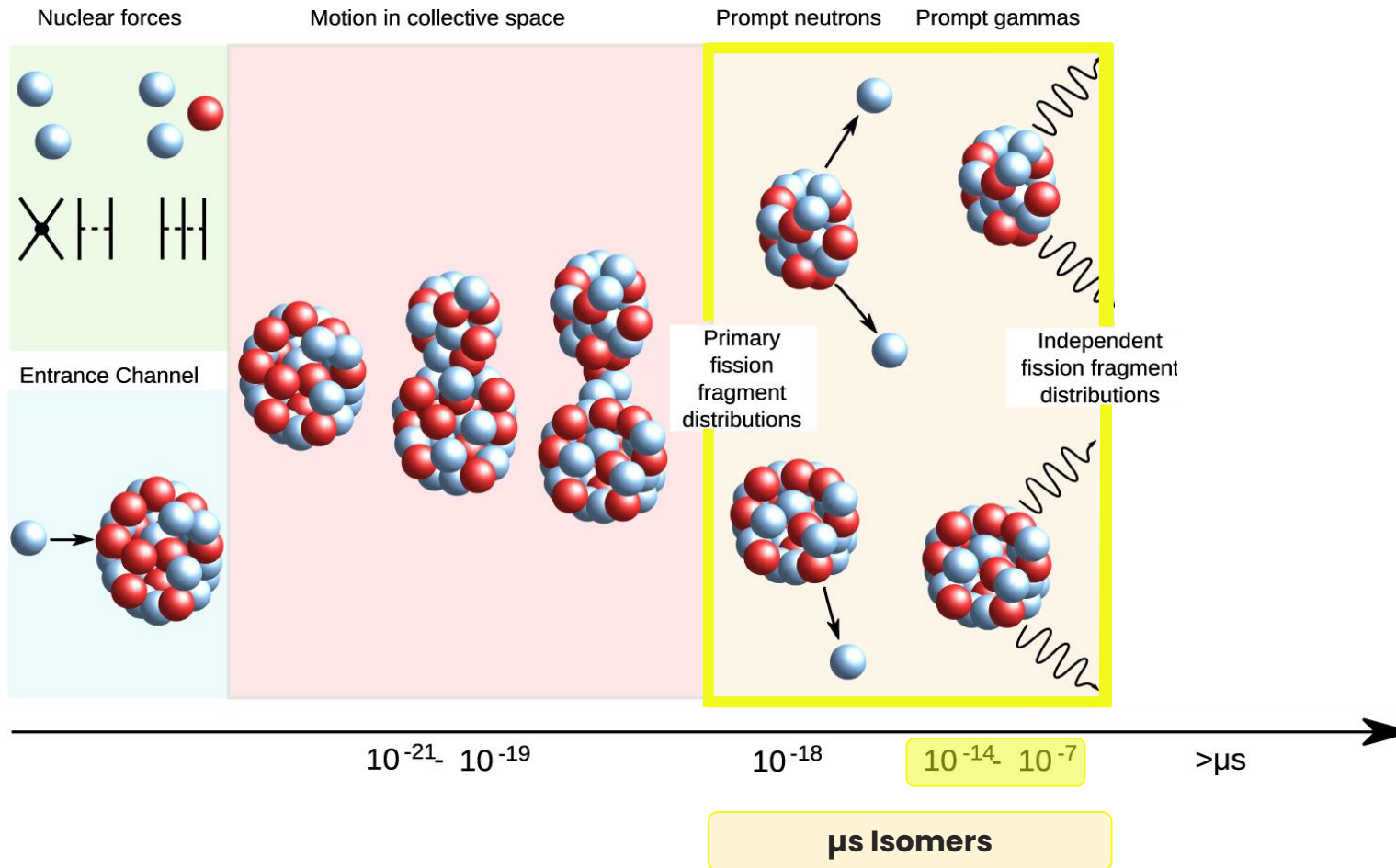


J. Randrup et al., Generation of Fragment Angular Momentum in Nuclear Fission, EPJ WoC, 284,04004 (2023)

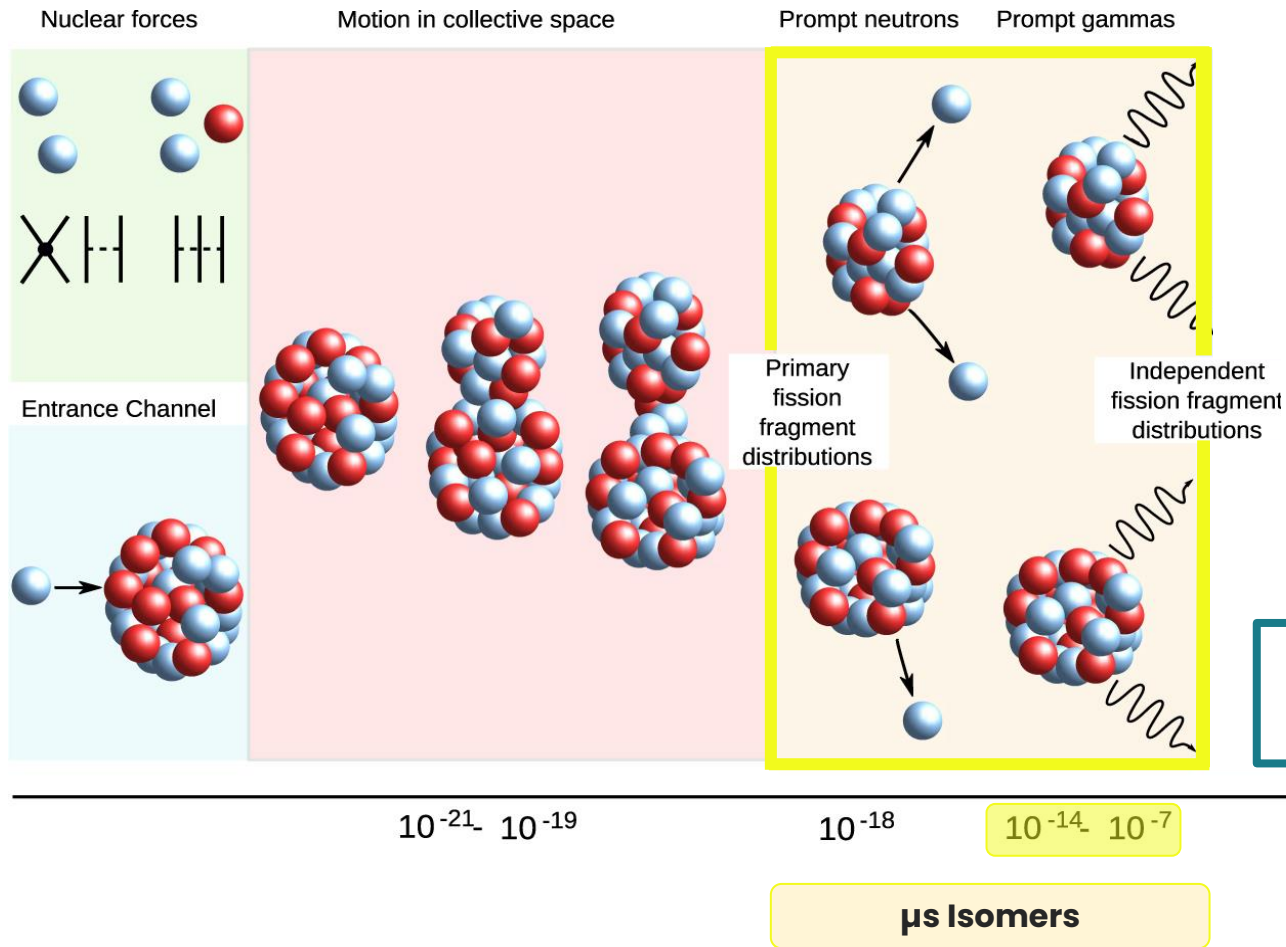


G. Scamps, Microscopic description of the torque acting on fission fragments, Phys. Rev. C 106, 054614 (2022)

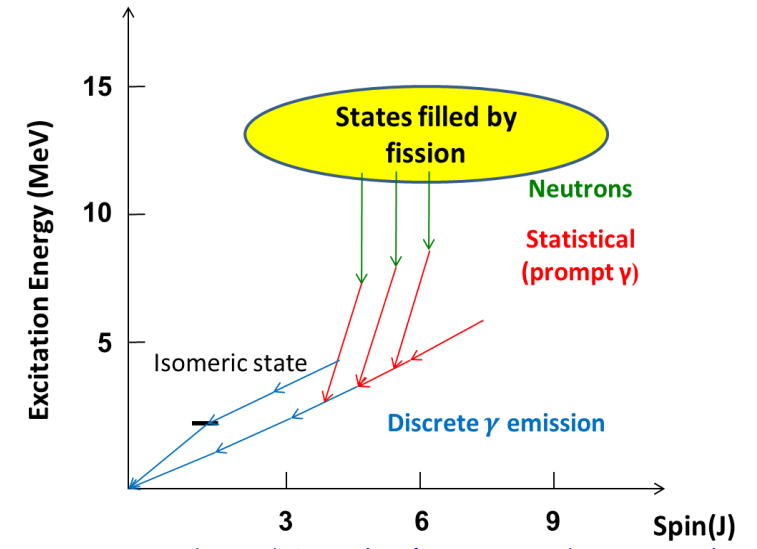
Motivation: Angular momentum generation mechanism of Fission Fragments



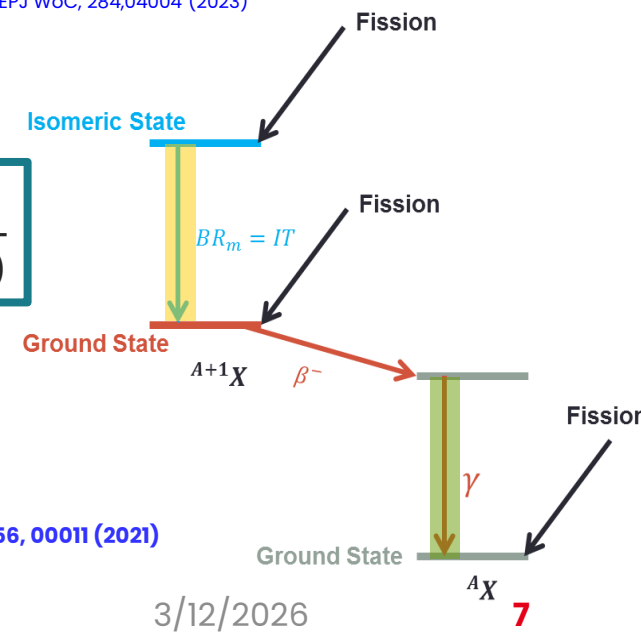
Motivation: Angular momentum generation mechanism of Fission Fragments



$$IR_{\text{exp}} = \frac{\tau_f(\text{IS})}{\tau_f(\text{IS}) + \tau_f(\text{GS})}$$



J. Randrup et al., Generation of Fragment Angular Momentum in Nuclear Fission, EPJ WoC, 284,04004 (2023)



Investigation of fission product isomeric ratios and angular momenta of ^{132}Sn populated in the $^{241}\text{Pu}(\text{nth},\text{f})$ reaction, A. Chebboubi, EPJ Web of Conferences 256, 00011 (2021)

M. Bender et al., Future of nuclear fission theory, J. Phys. G: Nucl. Part. Phys. 47 113002 (2020)

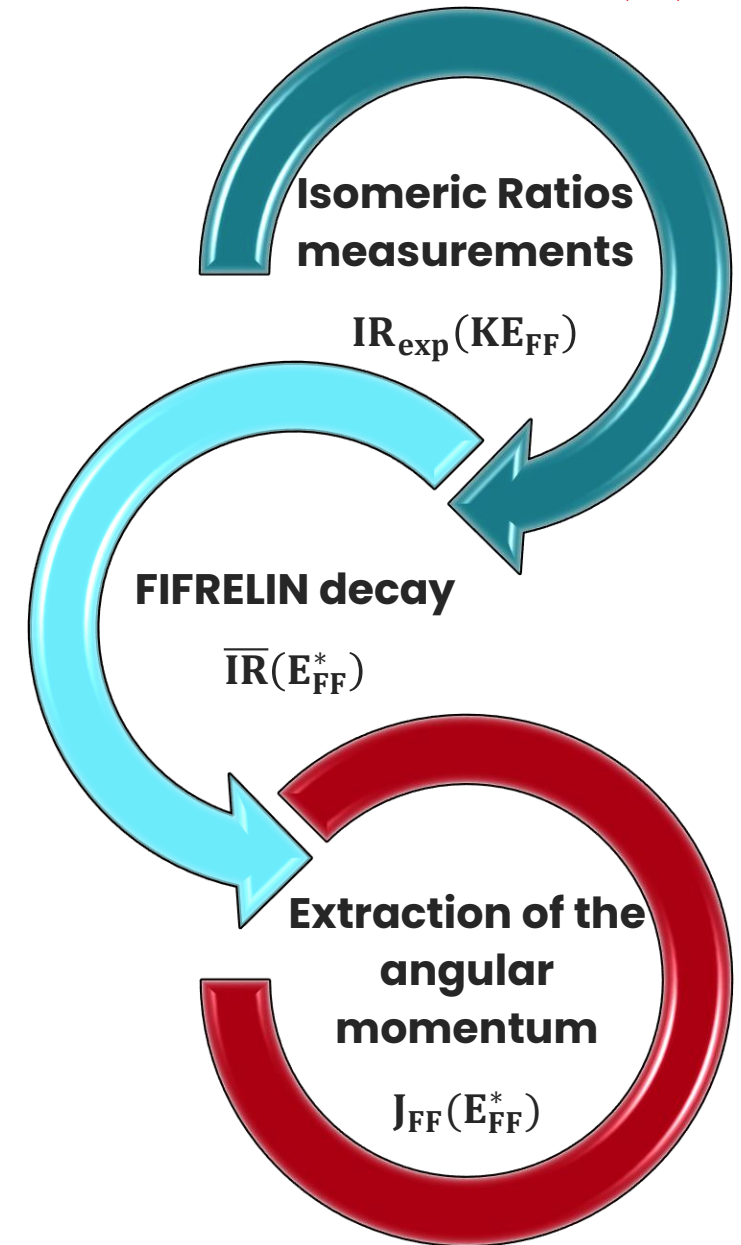
FISSION 2026: 7th Workshop on Nuclear Fission and Spectroscopy of Neutron-Rich Nuclei

3/12/2026

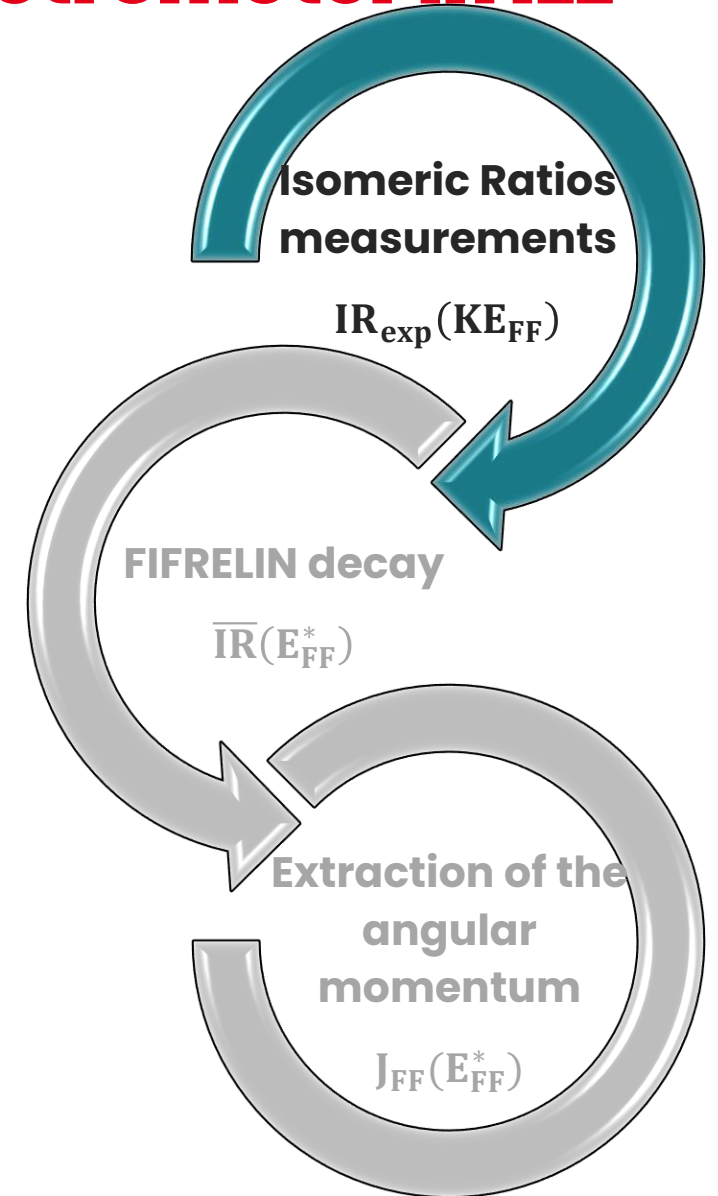
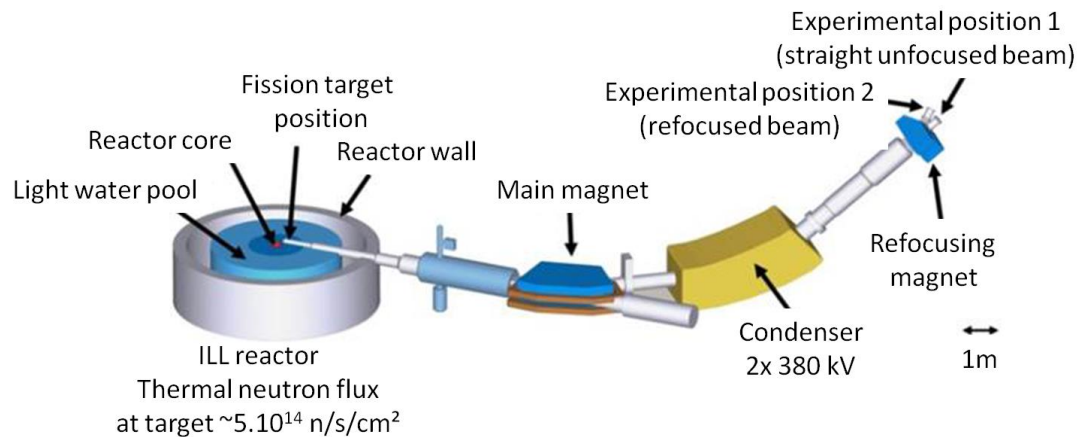
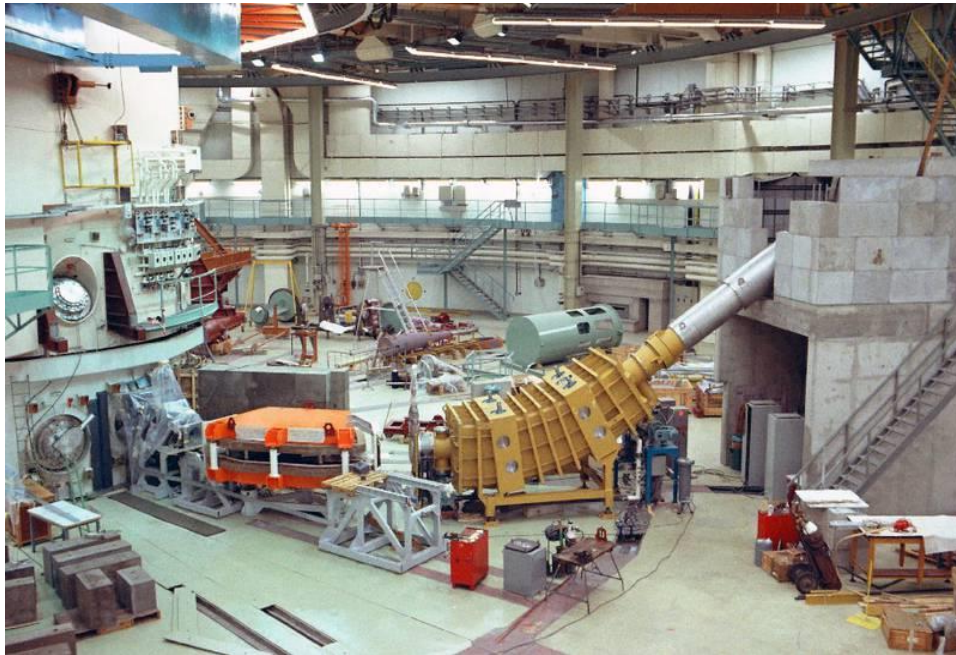
Goals

Through experimental campaigns and interpretation, coupled with theoretical models, we aim to:

- constrain the different models of generation of the angular momentum of fission fragments
- find a possible correlation with excitation energy, through Isomeric Ratio (IR) measurements.



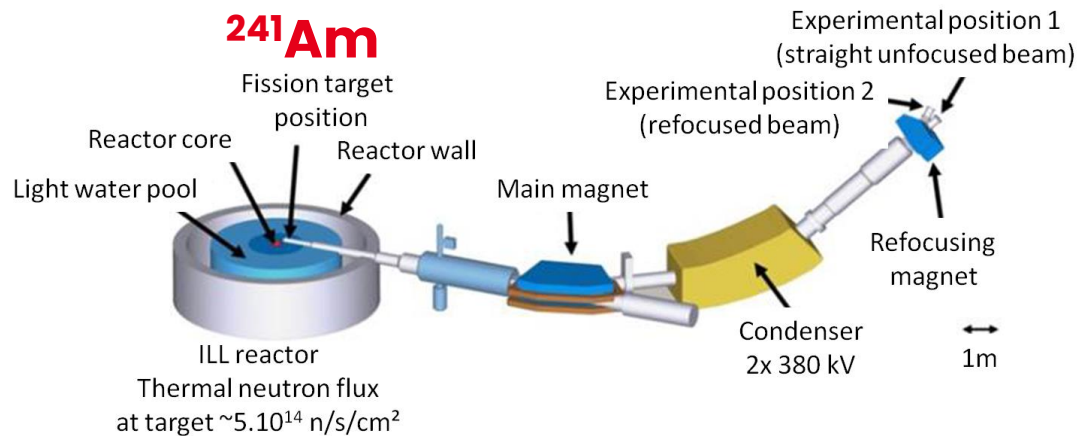
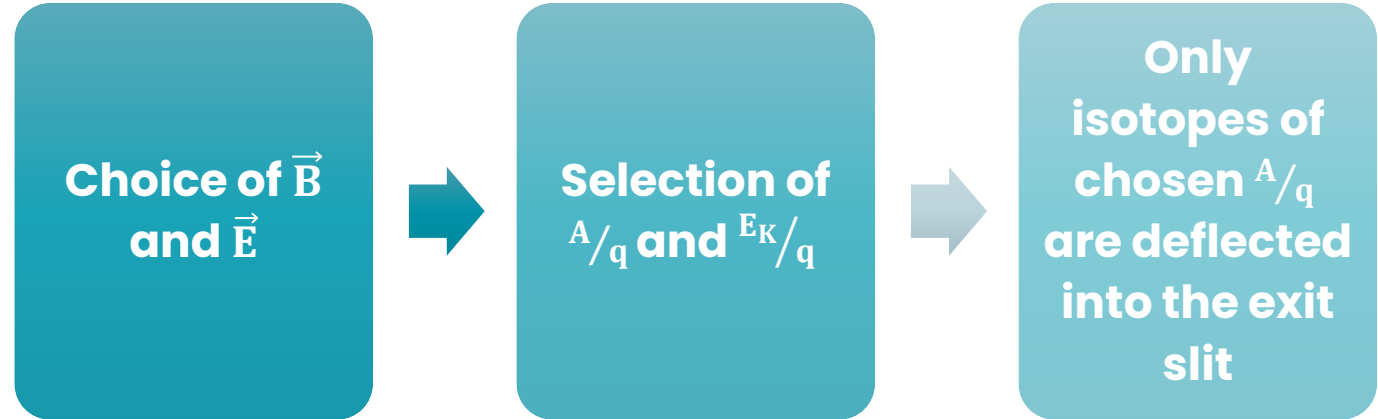
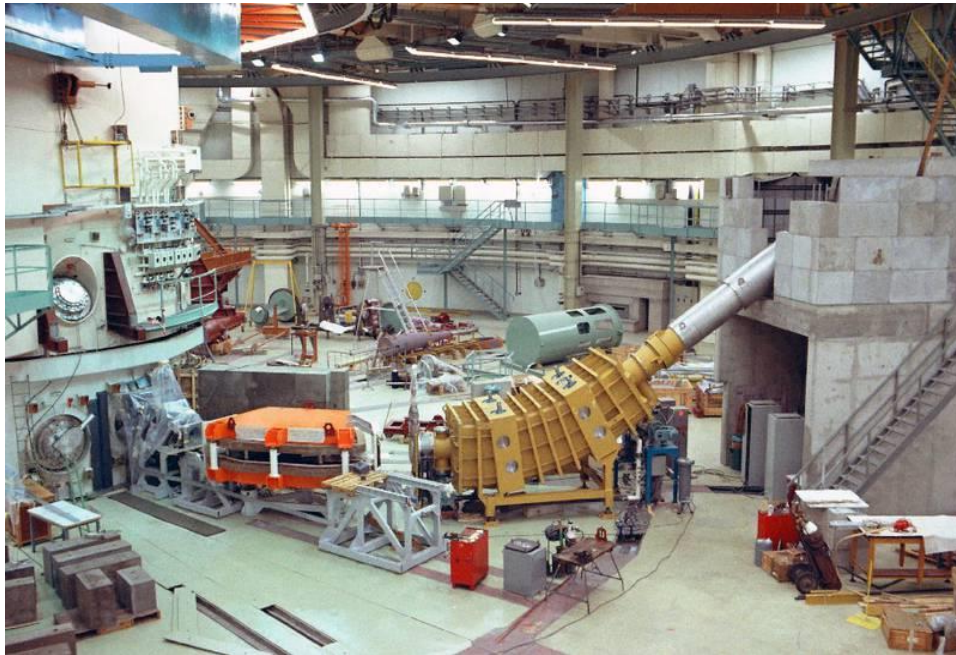
Experimental setup of LOHENGRIN spectrometer in ILL



J. M. Daugas, Session 9, 3/11/2026, FISSION 2026 workshop

FISSION 2026: 7th Workshop on Nuclear Fission and Spectroscopy of Neutron-Rich Nuclei

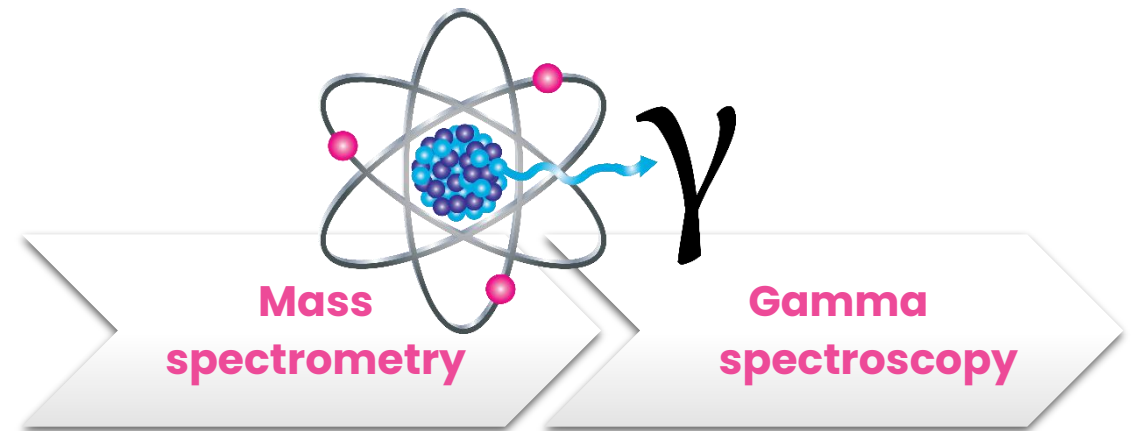
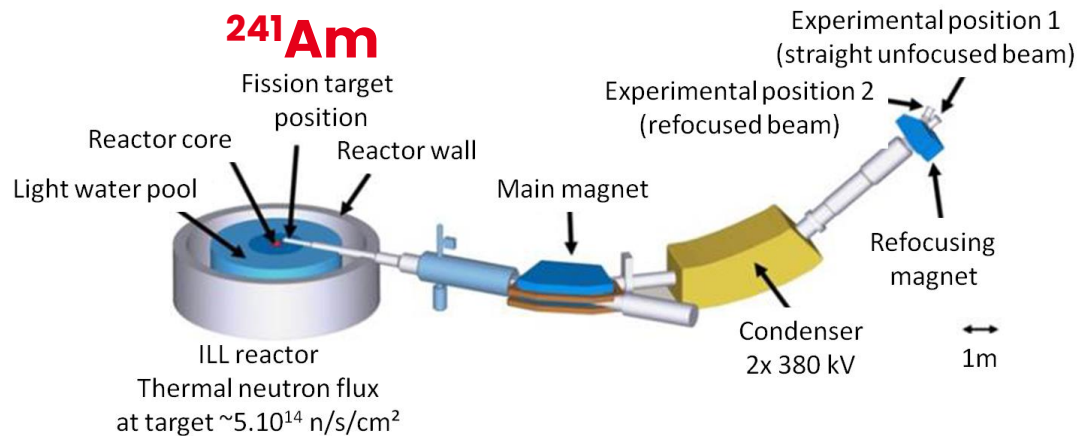
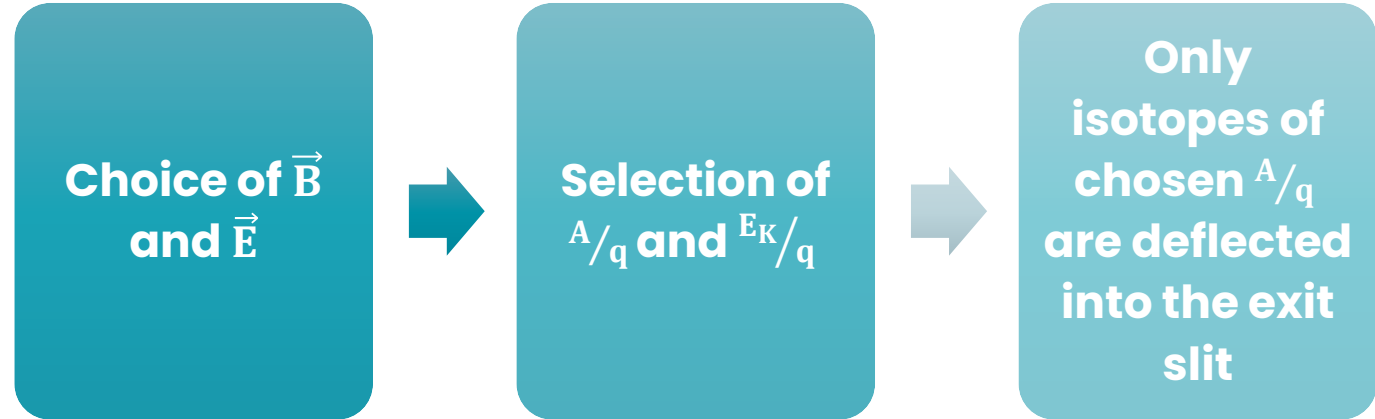
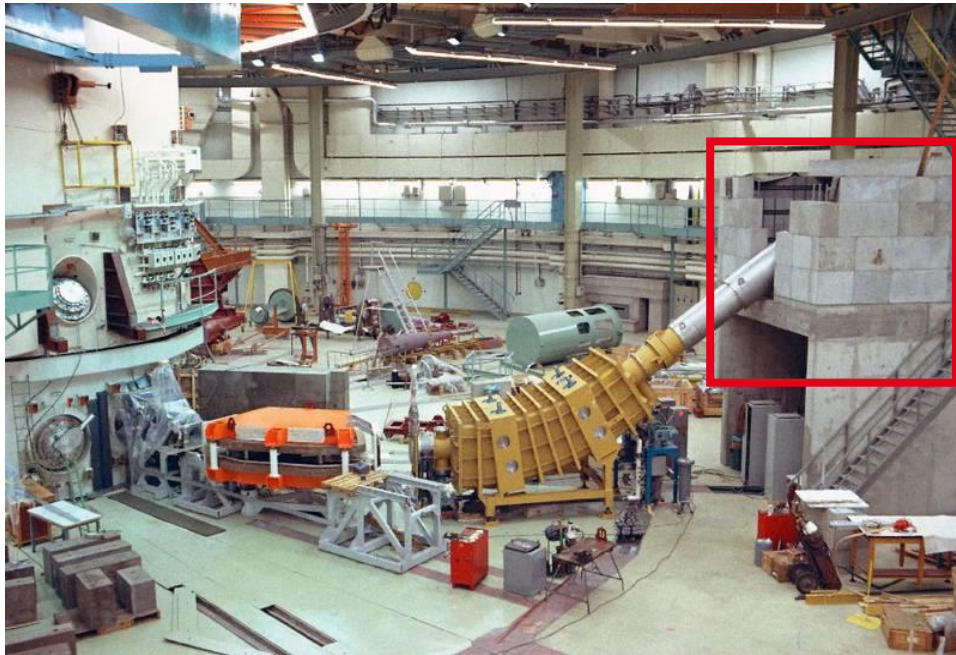
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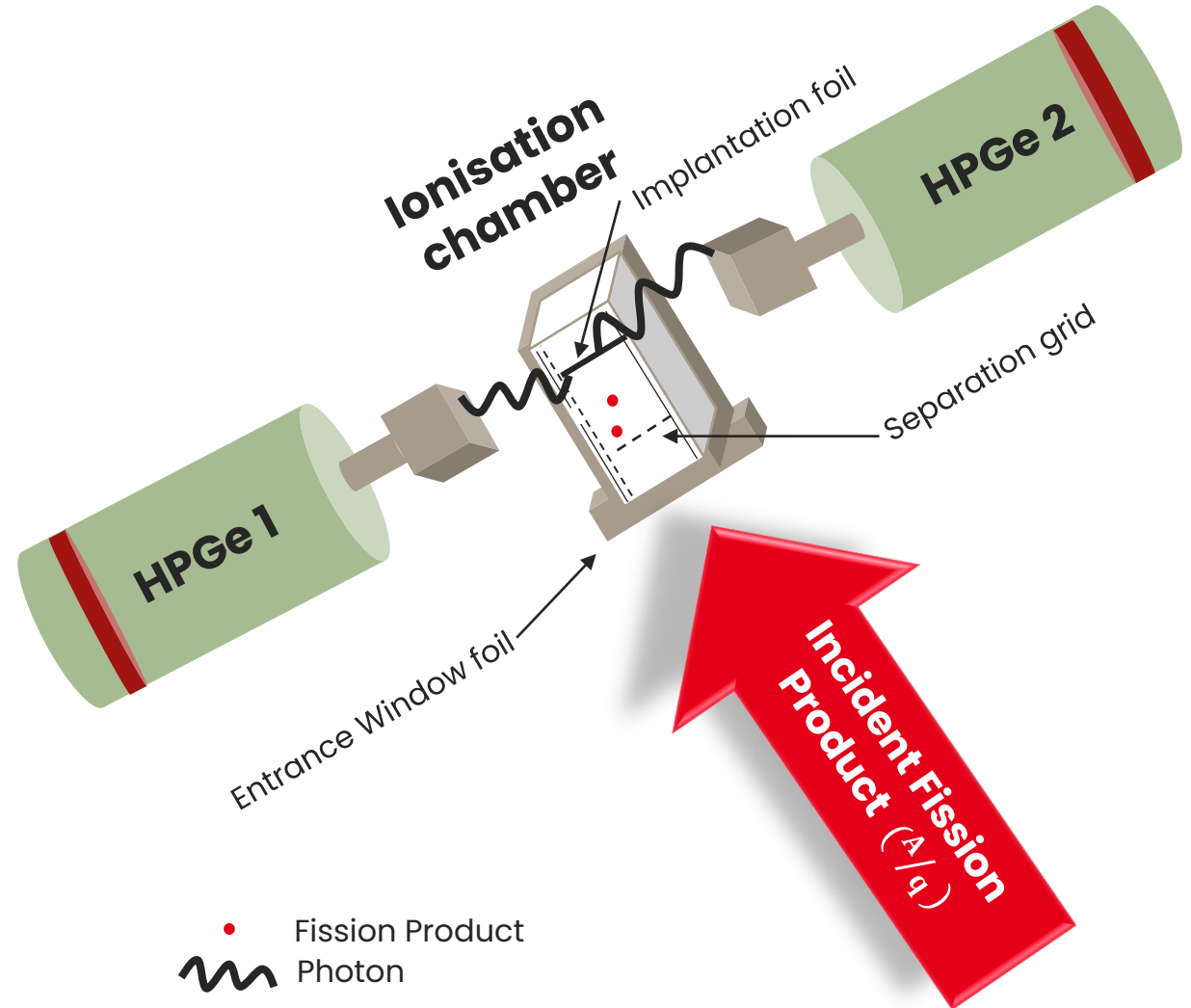
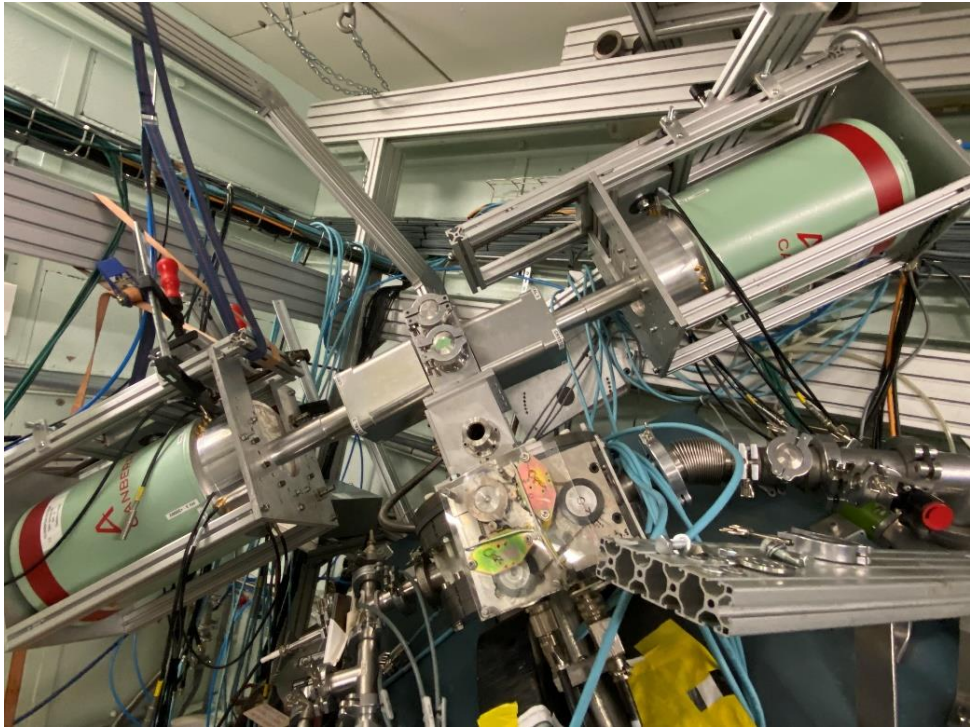
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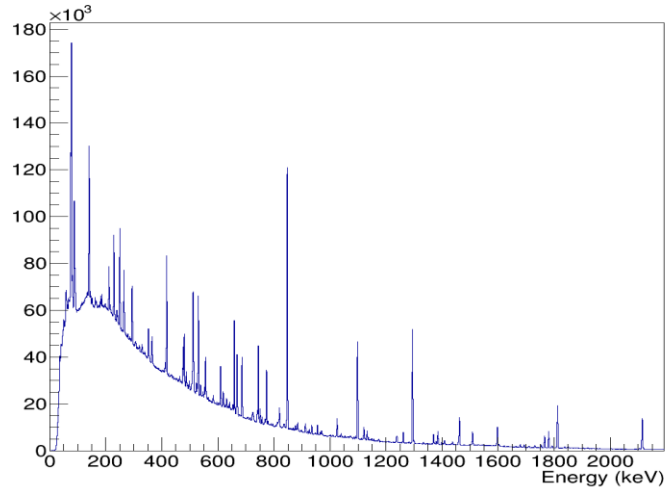


Experimental setup of LOHENGRIN spectrometer in ILL



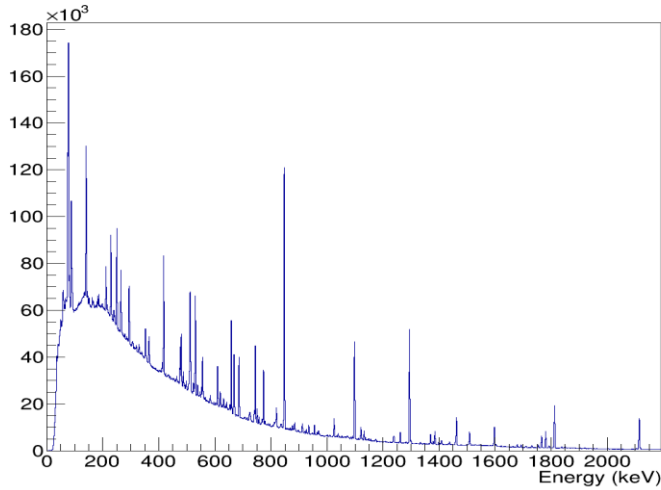
Analysis - ^{100}Nb from $^{241}\text{Am}(2n_{\text{th}},f)$

Delayed γ -Spectrum without selection



Analysis - ^{100}Nb from $^{241}\text{Am}(2n_{th},f)$

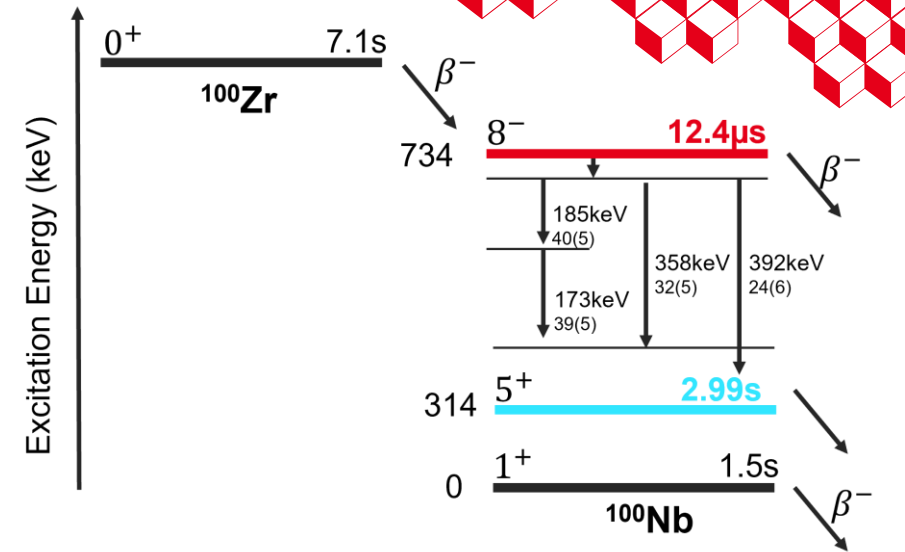
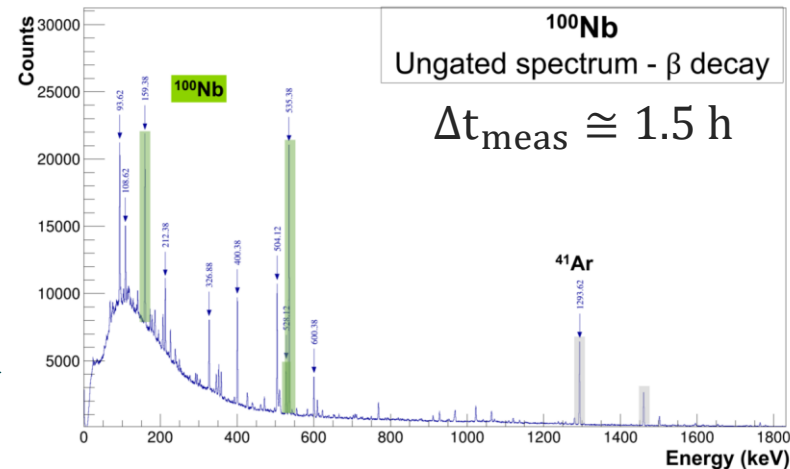
Delayed γ -Spectrum without selection



LOHENGRIN: mass separator

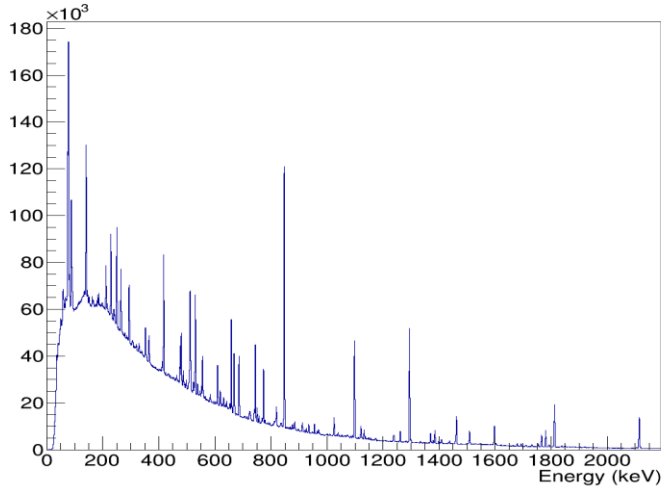
Ungated Spectrum

→ β -decay states measurement → N_{γ} , N_{γ}



Analysis - ^{100}Nb from $^{241}\text{Am}(2n_{th},f)$

Delayed γ -Spectrum without selection

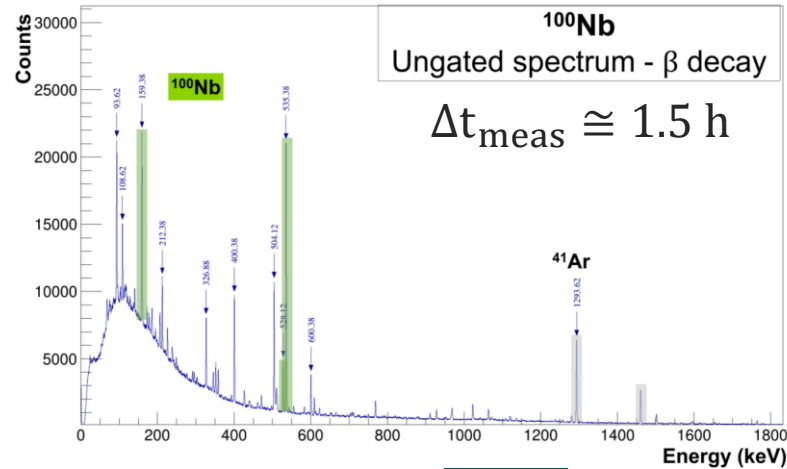


Mass, KE Filter

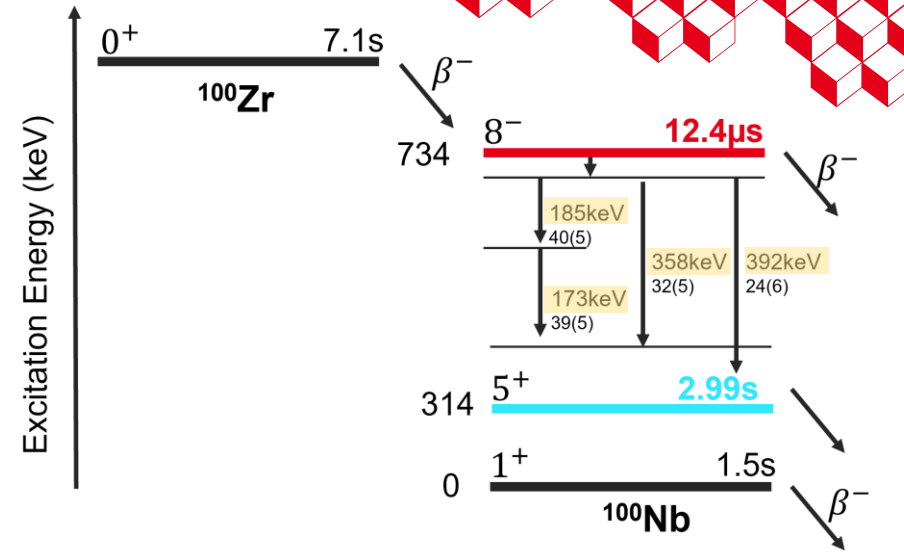
LOHENGRIN: mass separator

Ungated Spectrum

$\rightarrow \beta$ -decay states measurement $\rightarrow N_{\gamma}, N_{\beta}$

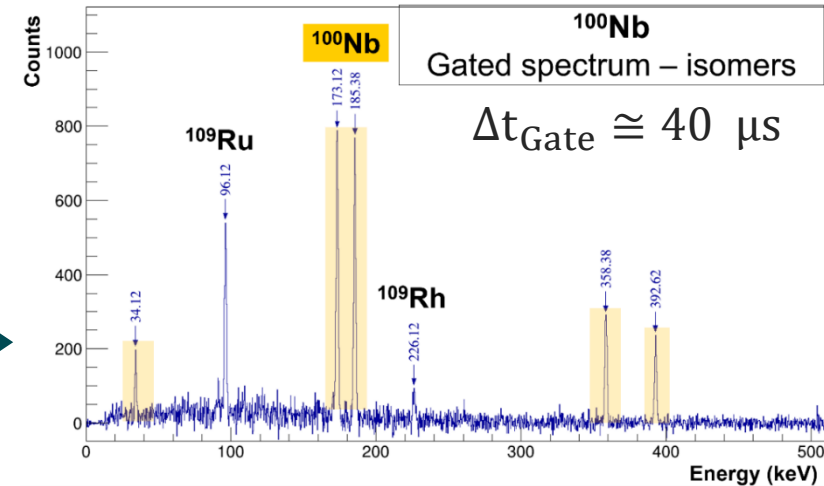


Time Coincidence Filter



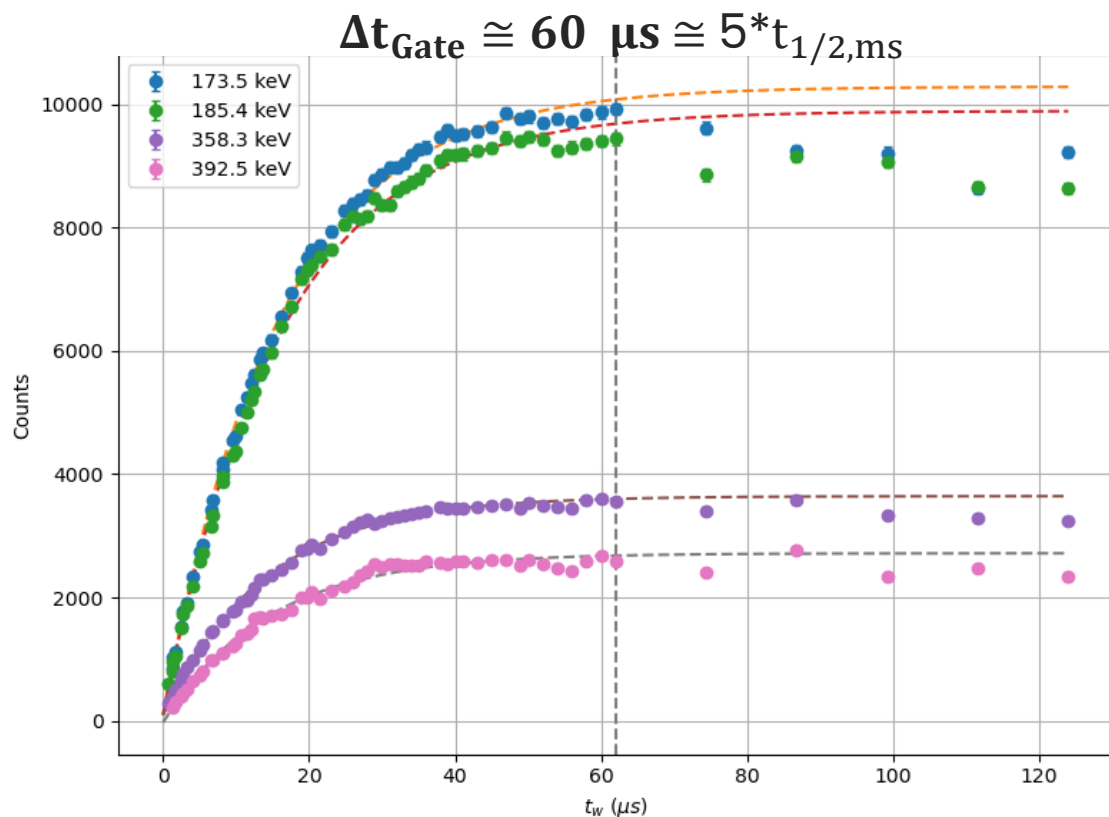
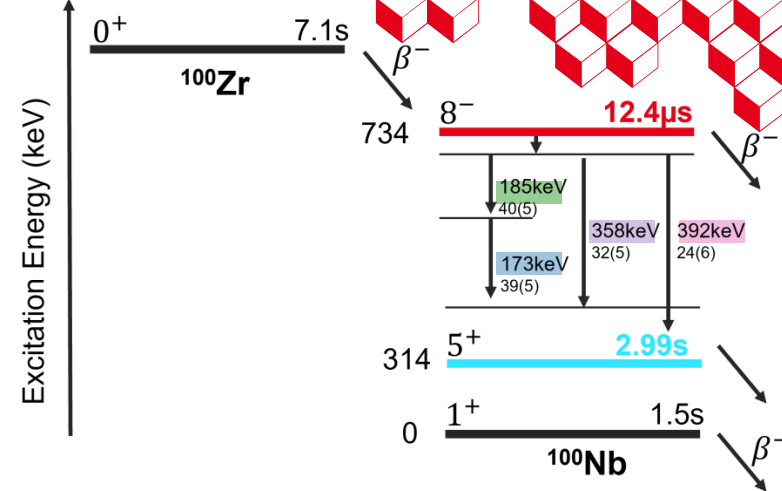
Gated Spectrum

Time coincidence between ionization chamber and HPGe detectors
 $\rightarrow \mu\text{s}$ Isomeric state measurement $\rightarrow N_{\gamma}$



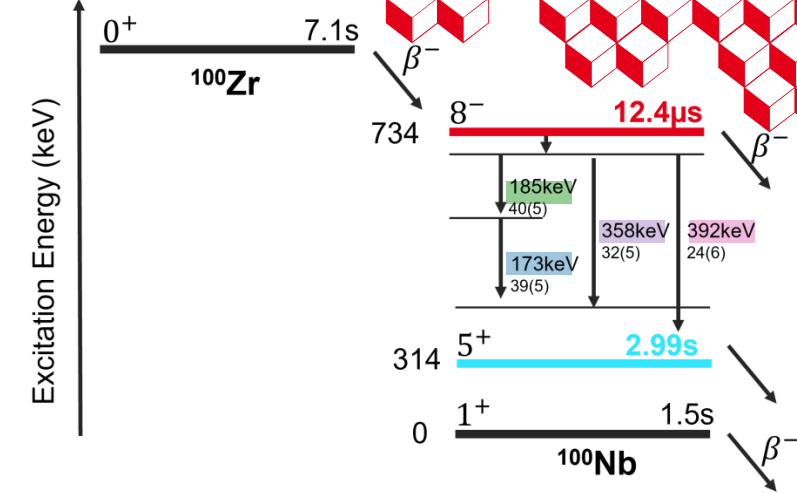
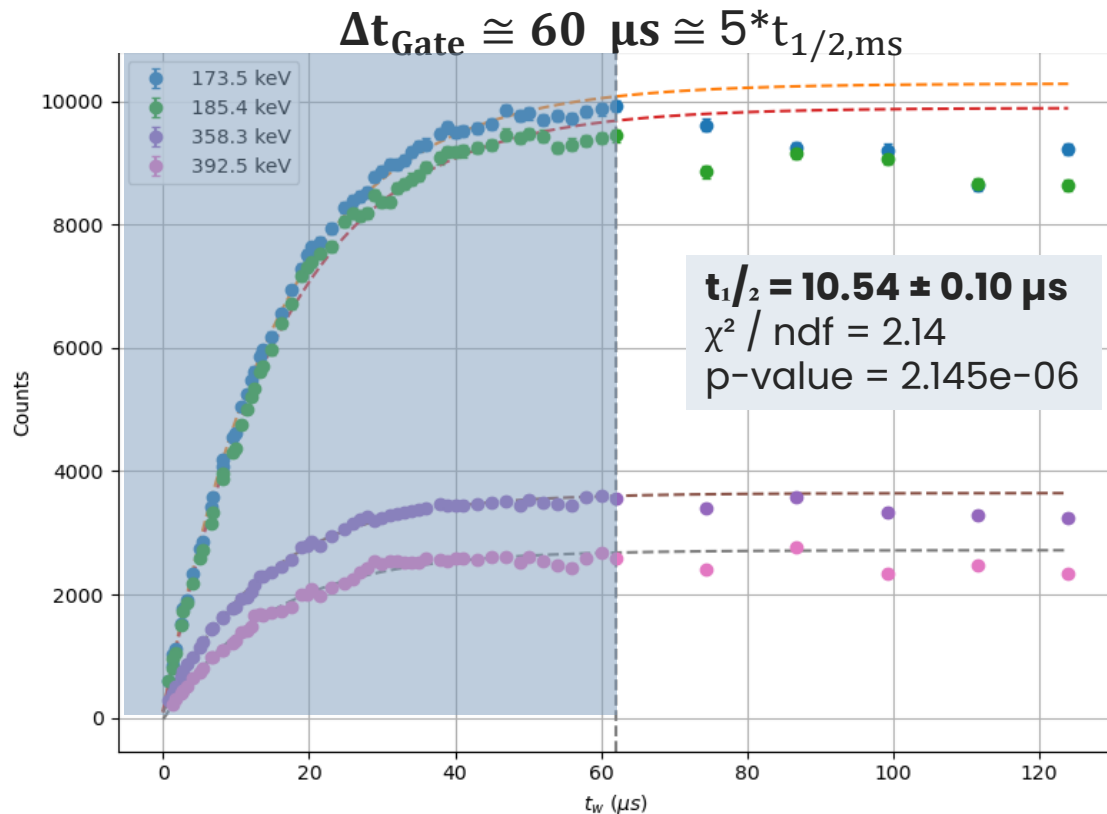
Analysis - Δt_{Gate} - ^{100}Nb

For which Δt_{Gate} is the $t_{1/2}$ of the isomeric level re-produced ?



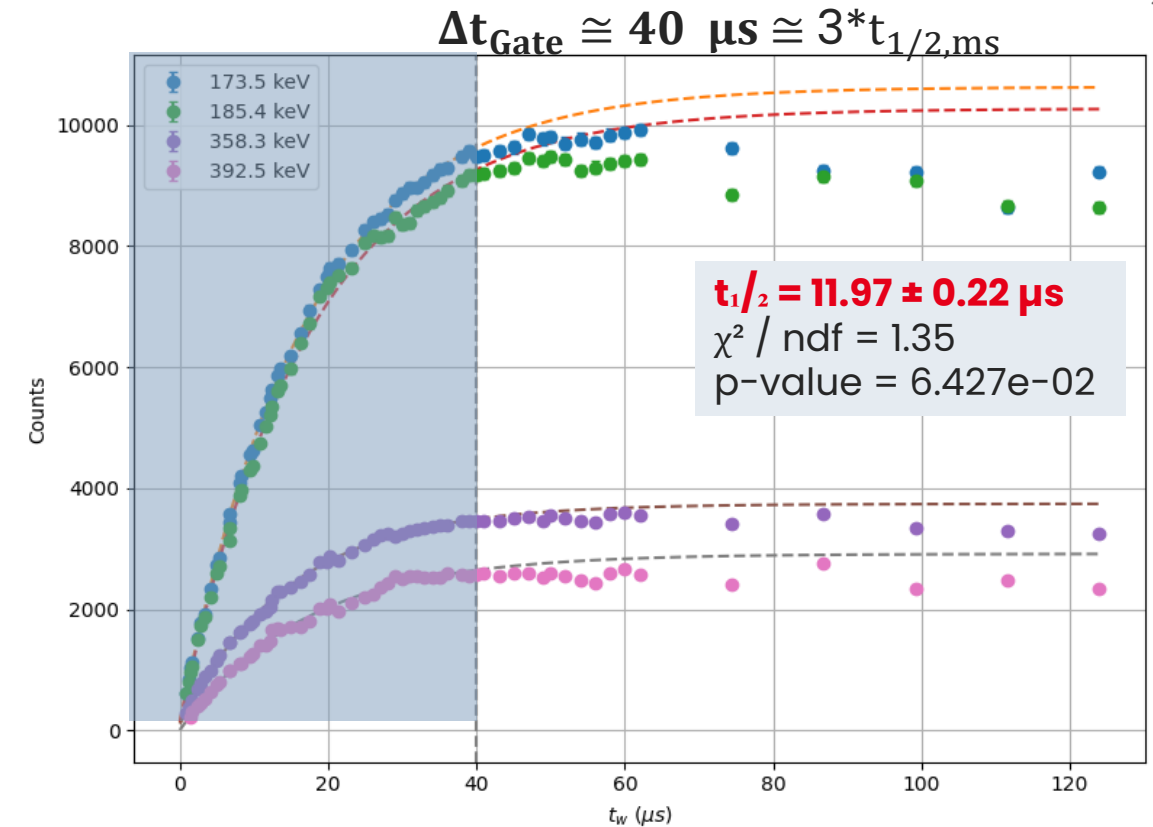
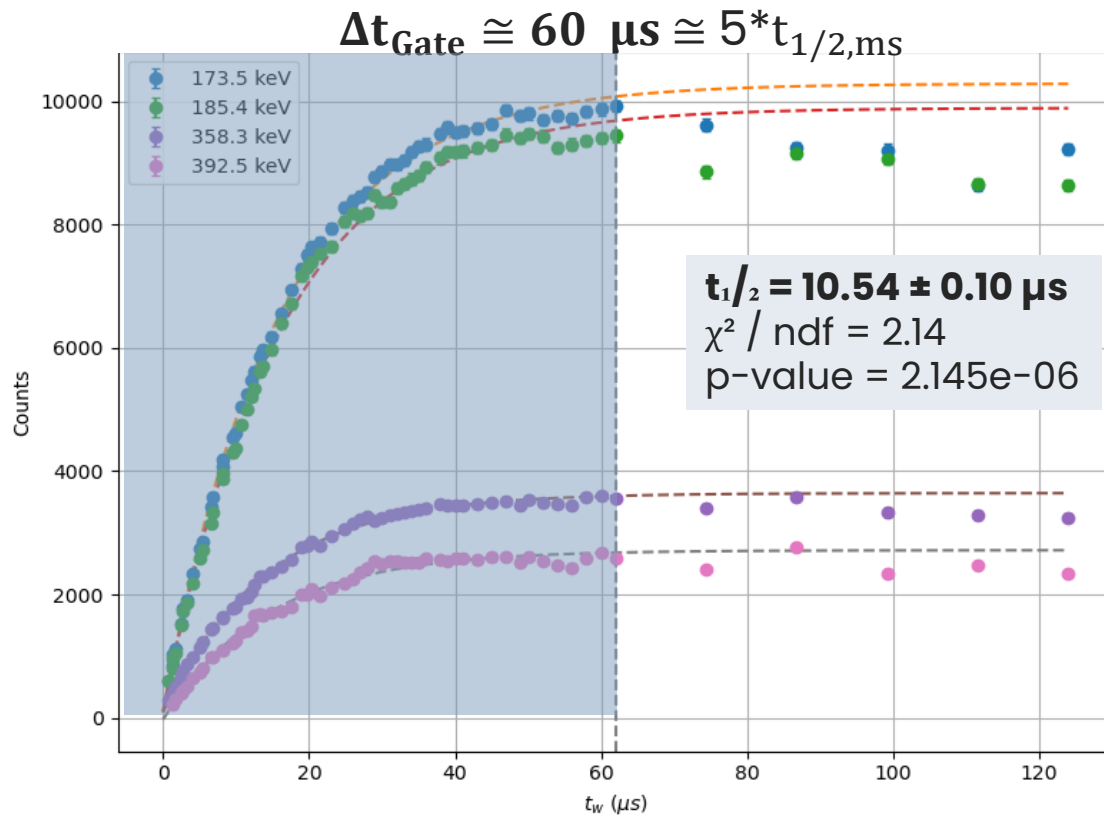
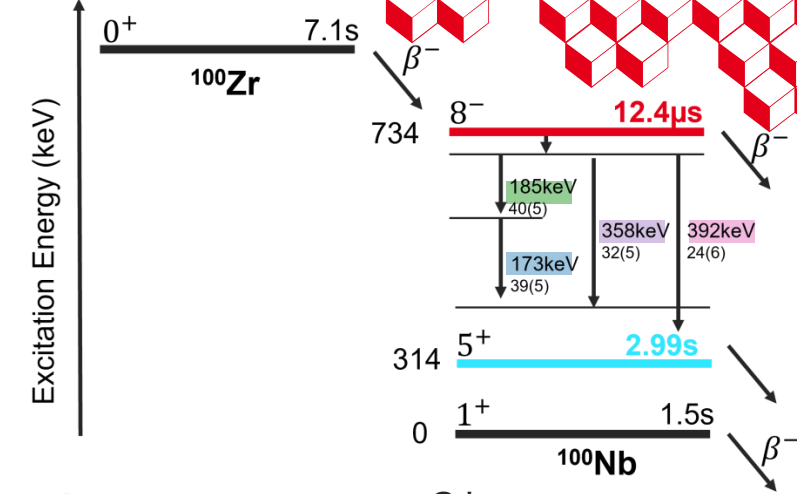
Analysis - $\Delta t_{\text{Gate}} - {}^{100}\text{Nb}$

For which Δt_{Gate} is the $t_{1/2}$ of the isomeric level re-produced ?

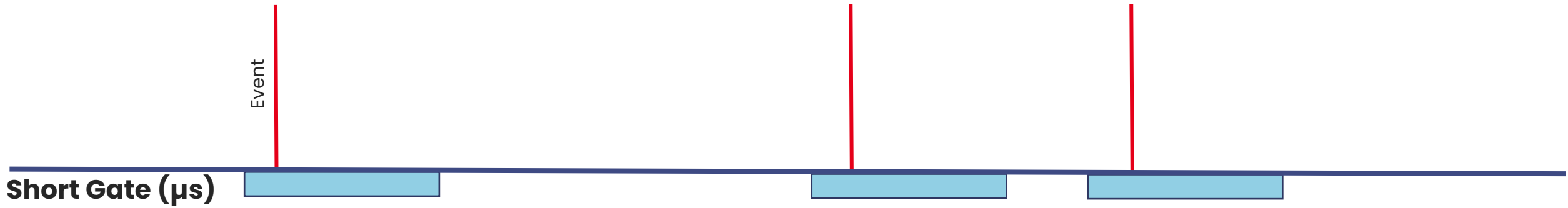


Analysis - Δt_{Gate} - ^{100}Nb

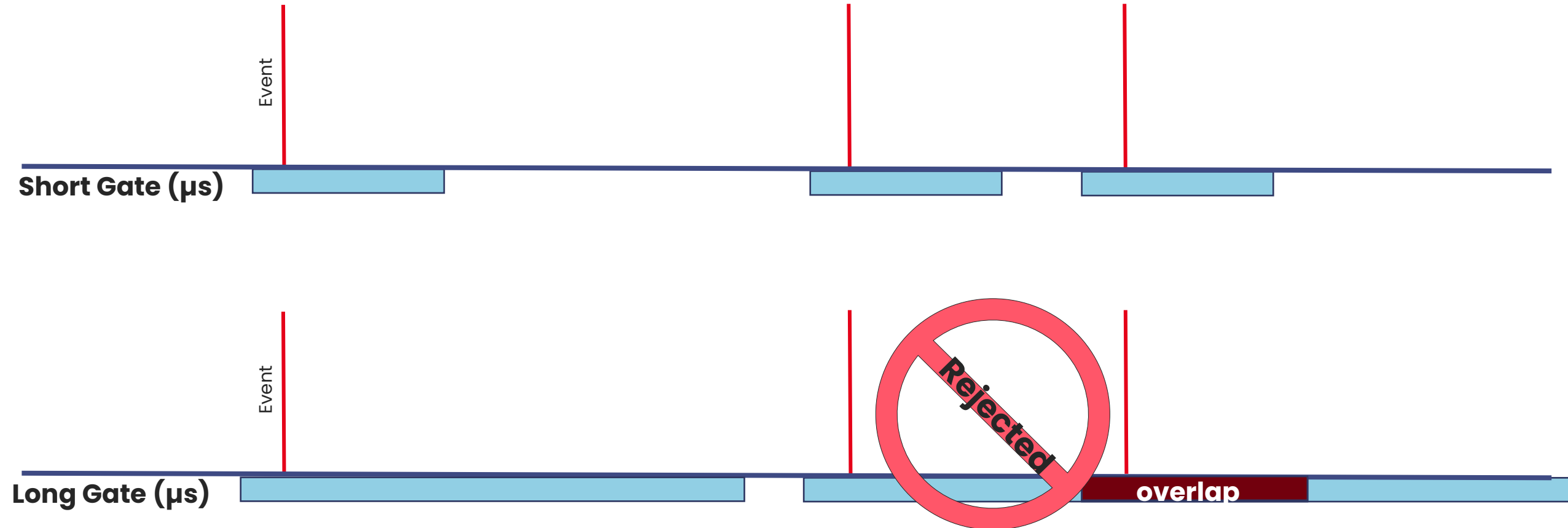
For which Δt_{Gate} is the $t_{1/2}$ of the isomeric level re-produced?



Analysis - Δt_{Gate}



Analysis - Δt_{Gate}



Importance of data sorting

Analysis - ^{100}Nb from $^{241}\text{Am}(2n_{\text{th}},f)$

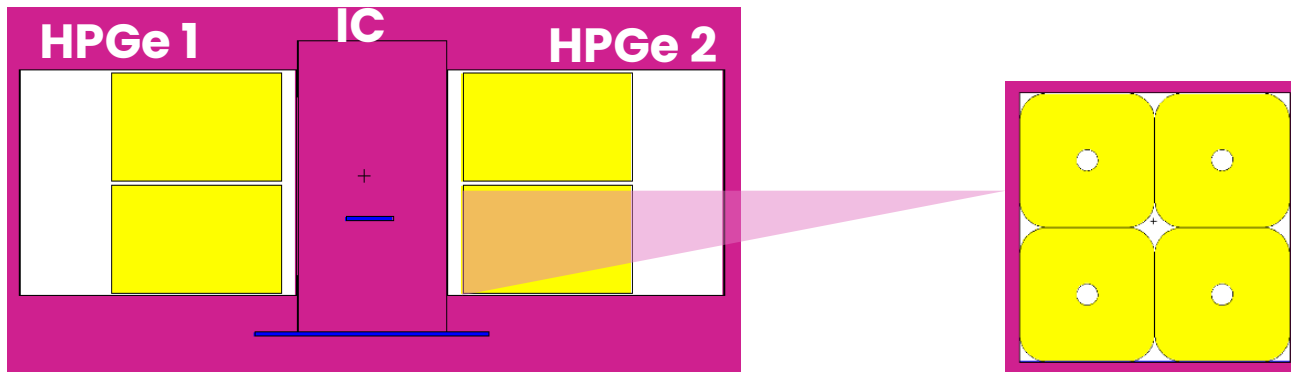
$$N_{\gamma} \rightarrow N_d = \frac{N_{\gamma}}{\epsilon_{\gamma} \times I_{\gamma} \times f_{\gamma}} \xrightarrow{\text{Average}} \overline{N_d} \xrightarrow{\text{Bateman Equation Resolution}} \tau_f \rightarrow \boxed{\text{IR}_{\text{exp}} = \frac{\tau_f(\text{IS})}{\tau_f(\text{IS}) + \tau_f(\text{GS})}}$$

IR: Isomeric Ratio, IS: Isomeric State, GS: Ground State

ϵ_{γ} : Detector Efficiency,

f_{γ} : Correction factor for Sum-Effect,

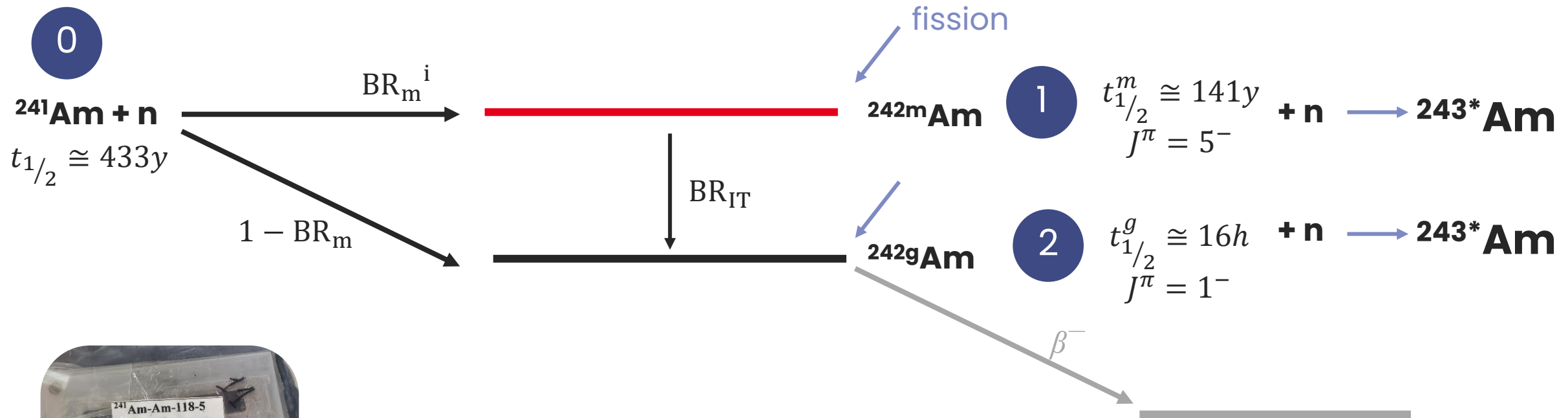
will be derived from **TrueCoinc**¹ and Monte Carlo Simulation **MCNP6**² (in progress).



1. Sudar, S. (2002). 'TrueCoinc' software utility for calculation of the true coincidence correction (IAEA-TECDOC--1275). International Atomic Energy Agency (IAEA)

2. D.B. Pelowitz *et al.*, Tech. Rep. LA-CP-13-00634, Los Alamos National Laboratory, Los Alamos, NM, USA, 2013

$^{241}\text{Am}(2n_{\text{th}},f)$ mechanism

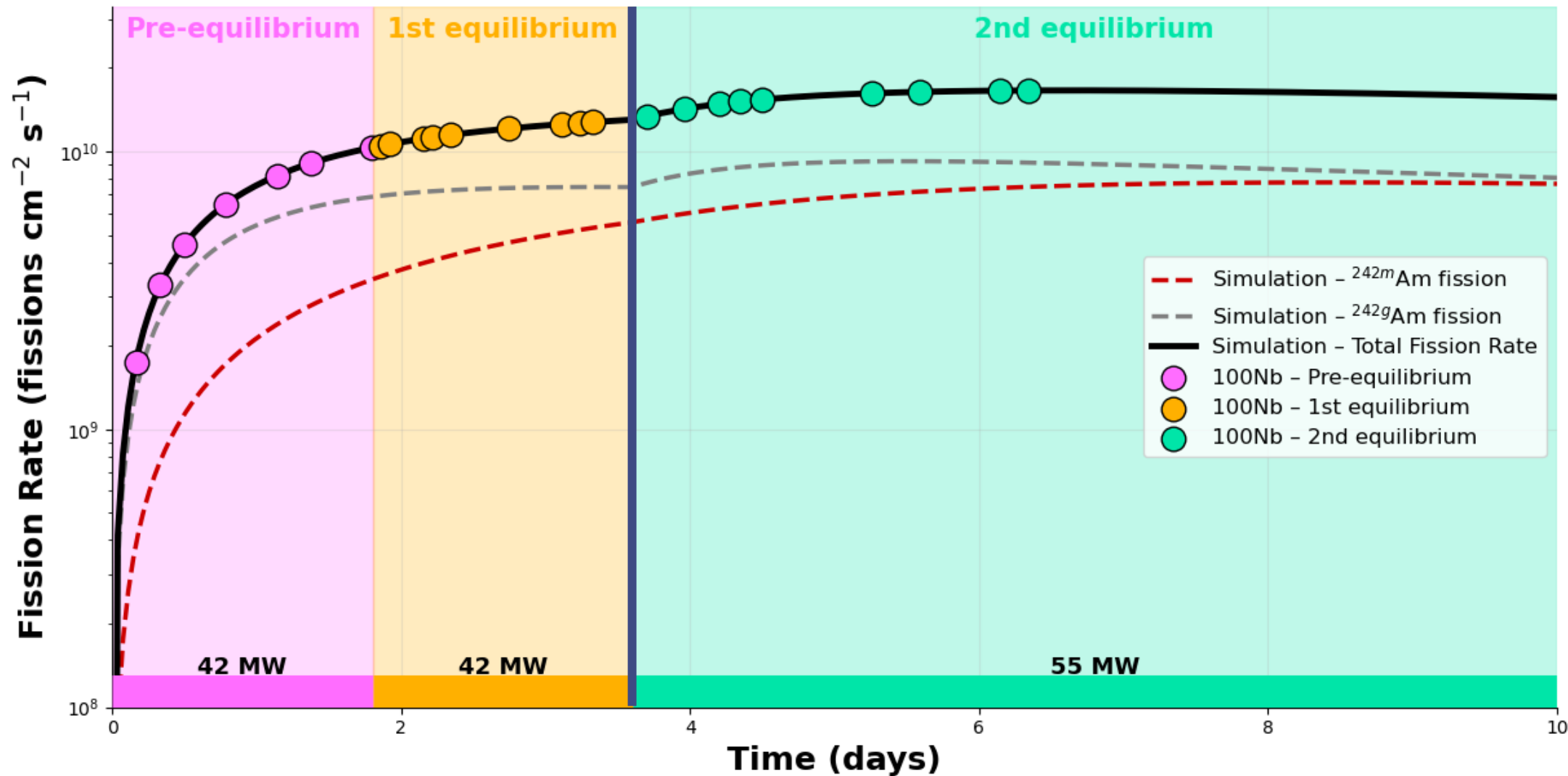


The branching ratio of ^{241}Am is spectrum dependent

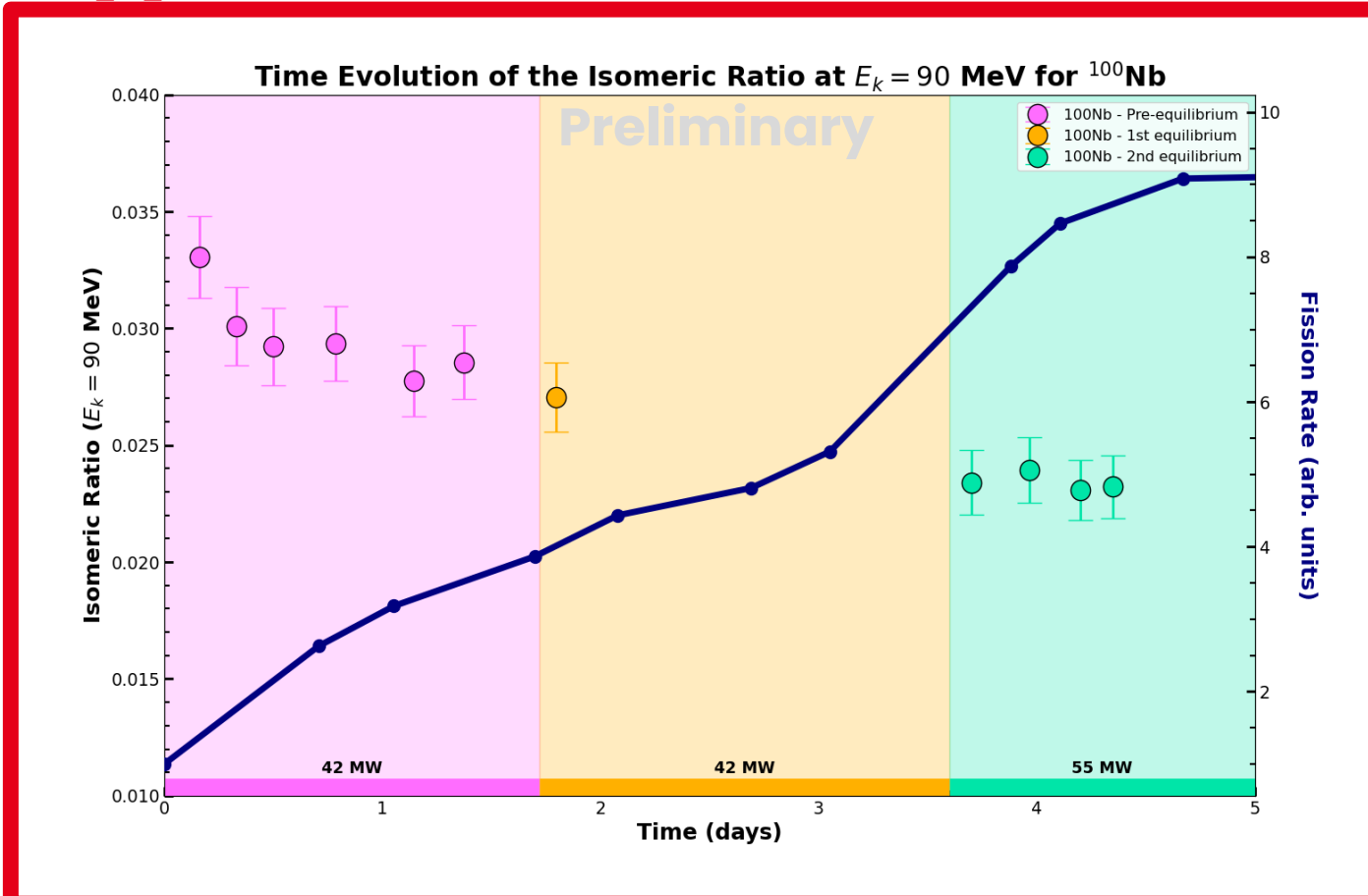
$$i : BR_m = 0.093$$

Preliminary Results - ^{100}Nb from $^{241}\text{Am}(2n_{\text{th}},f)$

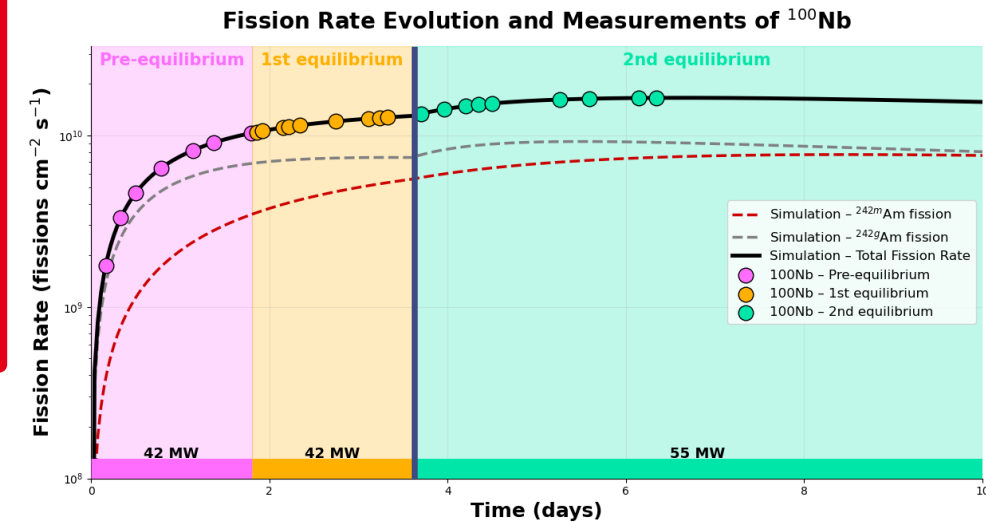
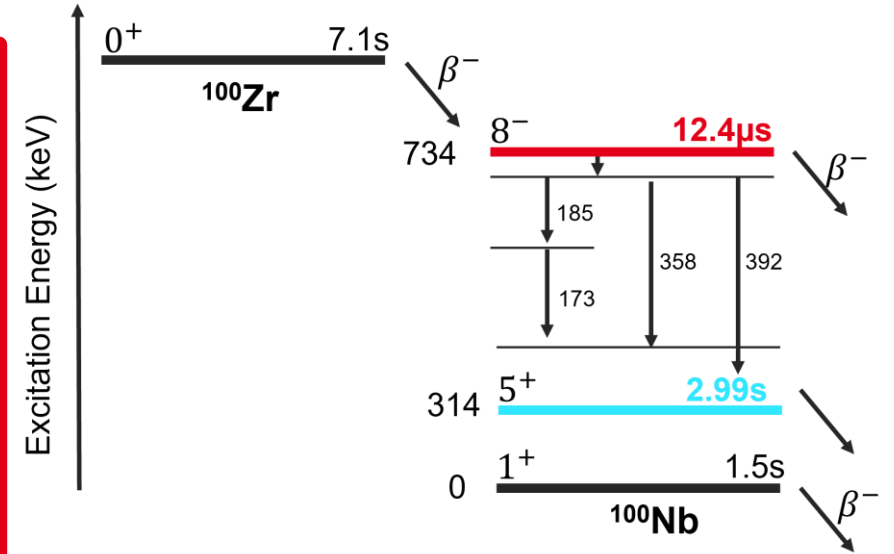
Fission Rate Evolution and Measurements of ^{100}Nb



Preliminary Results - ^{100}Nb from $^{241}\text{Am}(2n_{\text{th}},f)$ IR(t)

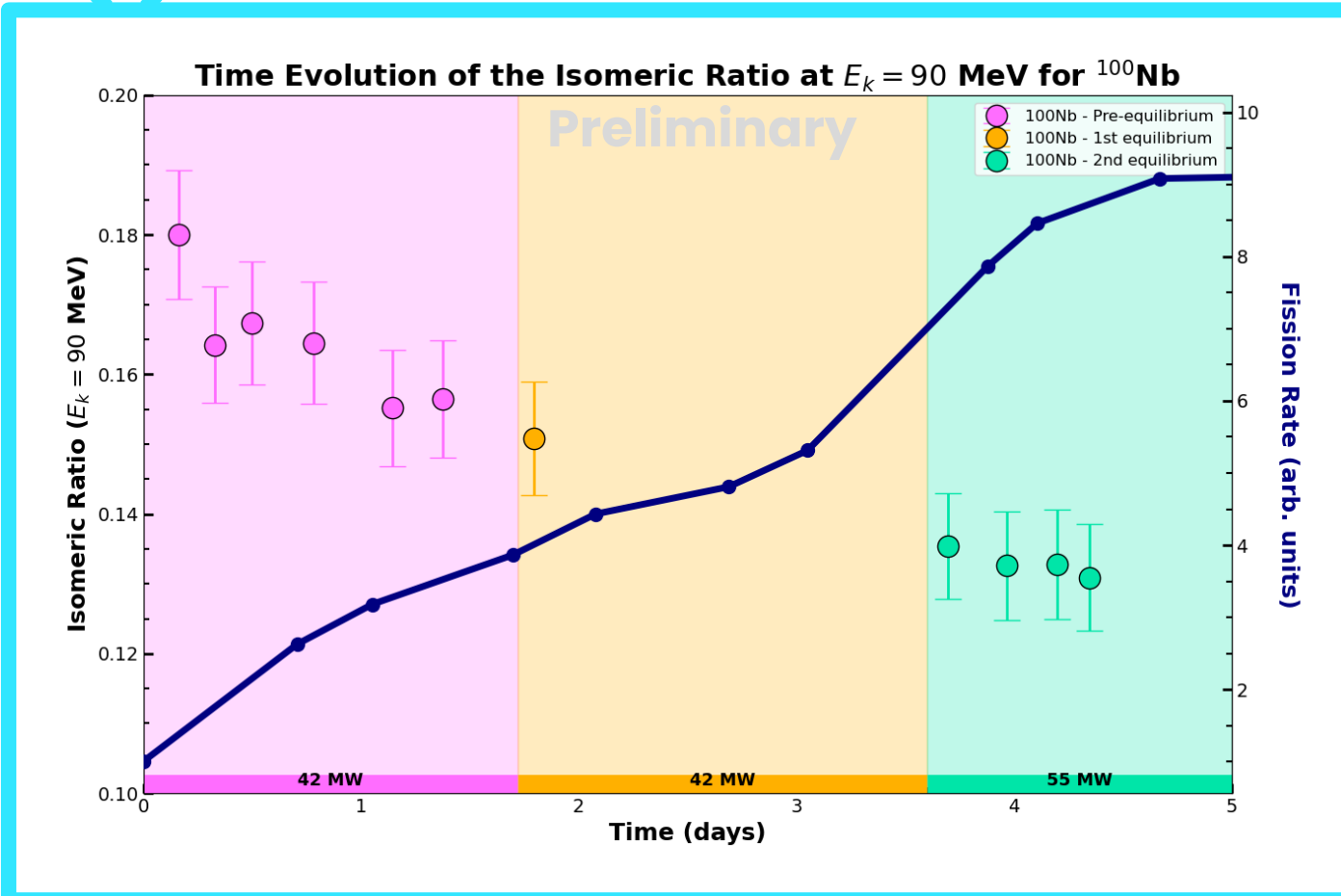


$J^\pi = 8^-$
 $t_{1/2}^m \cong 12 \mu\text{s}$

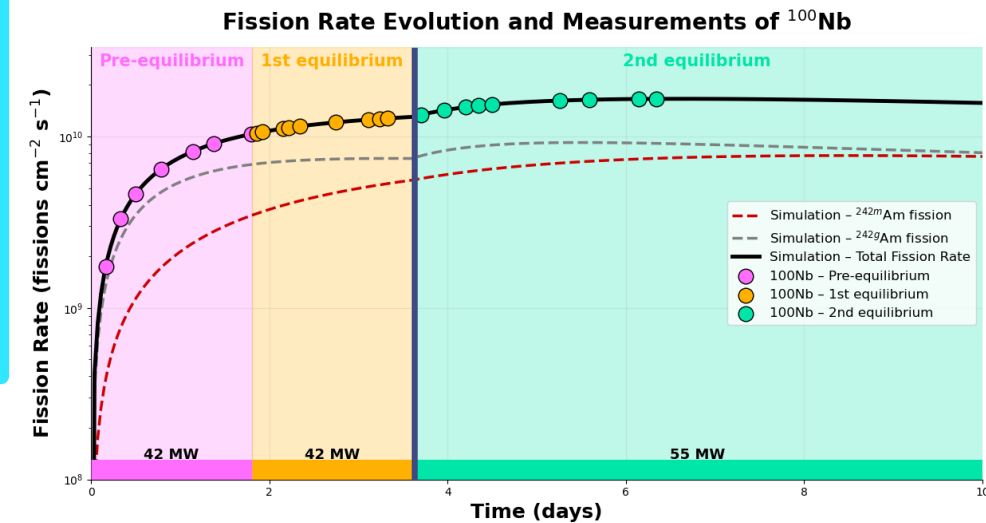
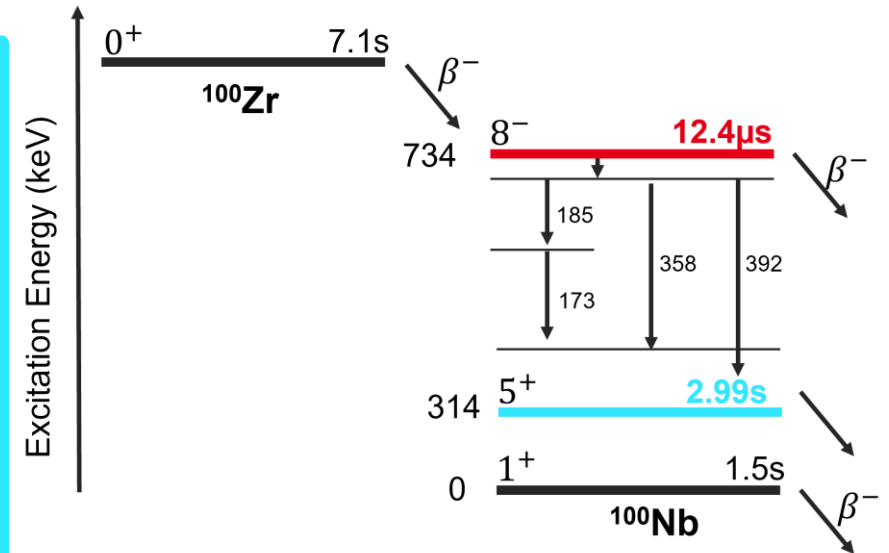


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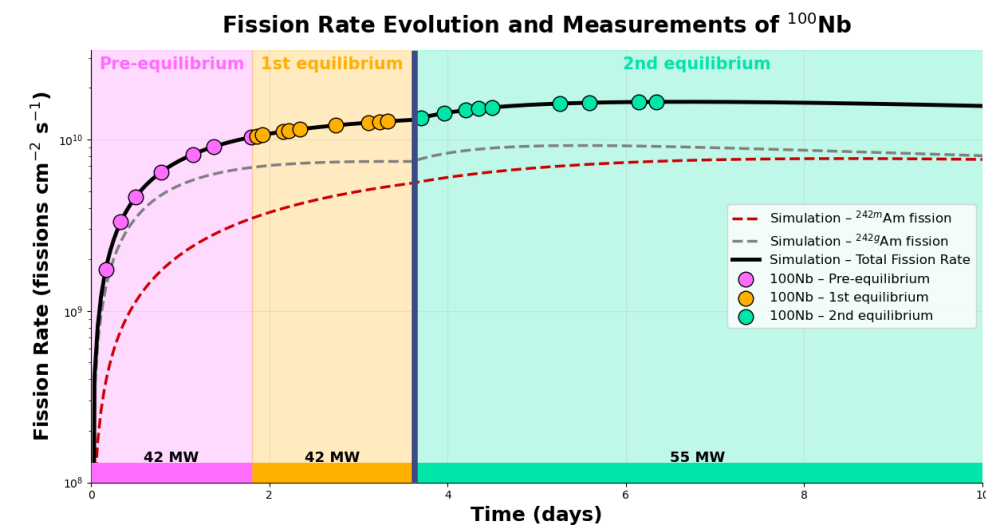
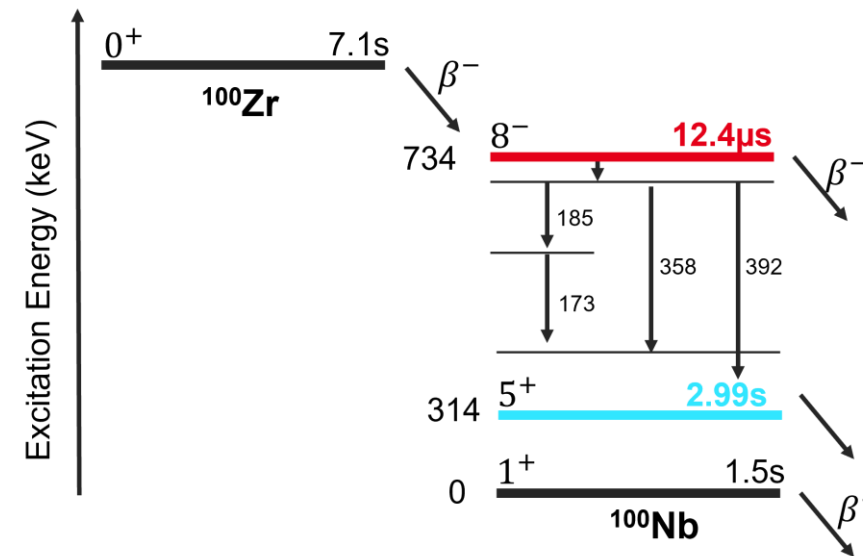
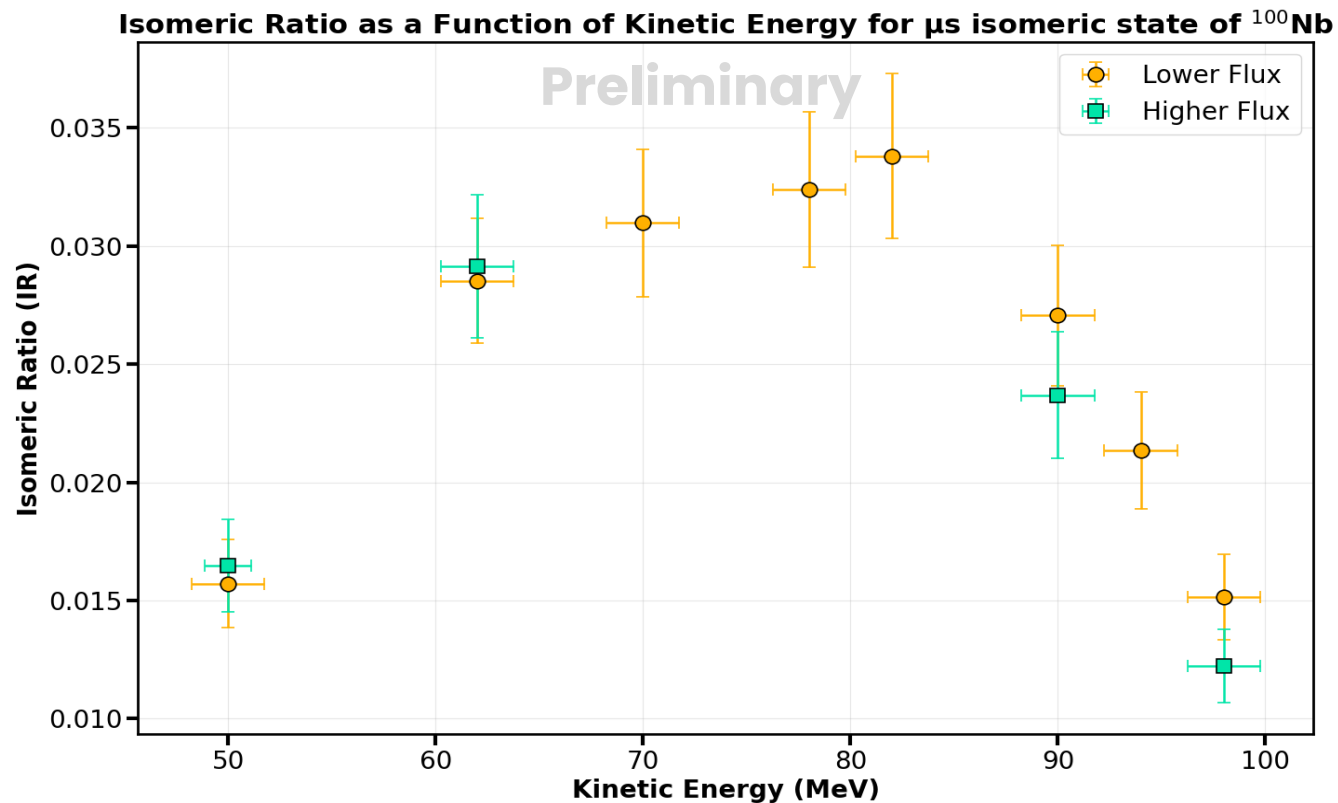
IR(t)



$J^\pi = 5^+$
 $t_{1/2}^m \cong 3$ s



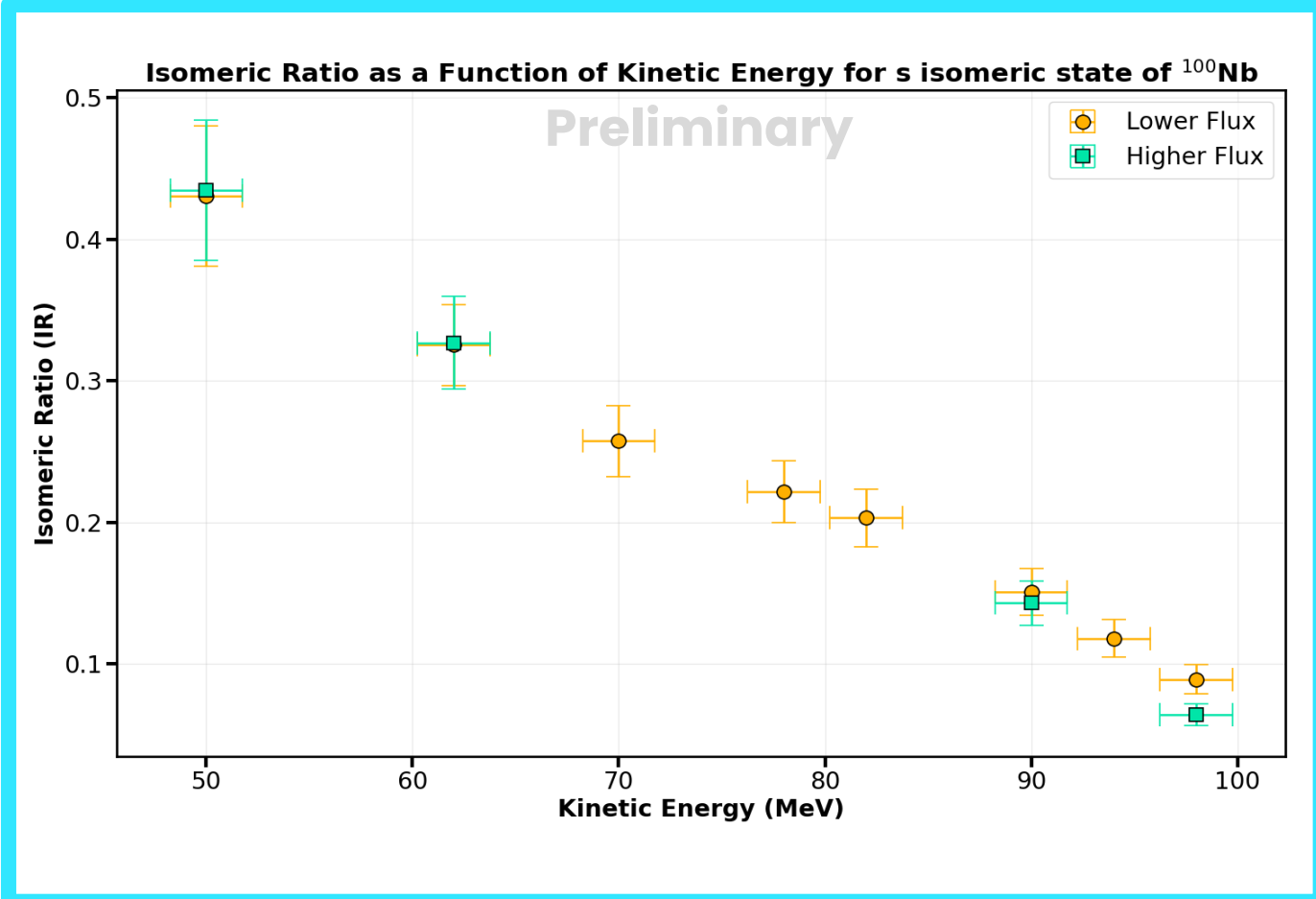
Preliminary Results - ^{100}Nb from $^{241}\text{Am}(2n_{\text{th}},f)$ IR(KE)



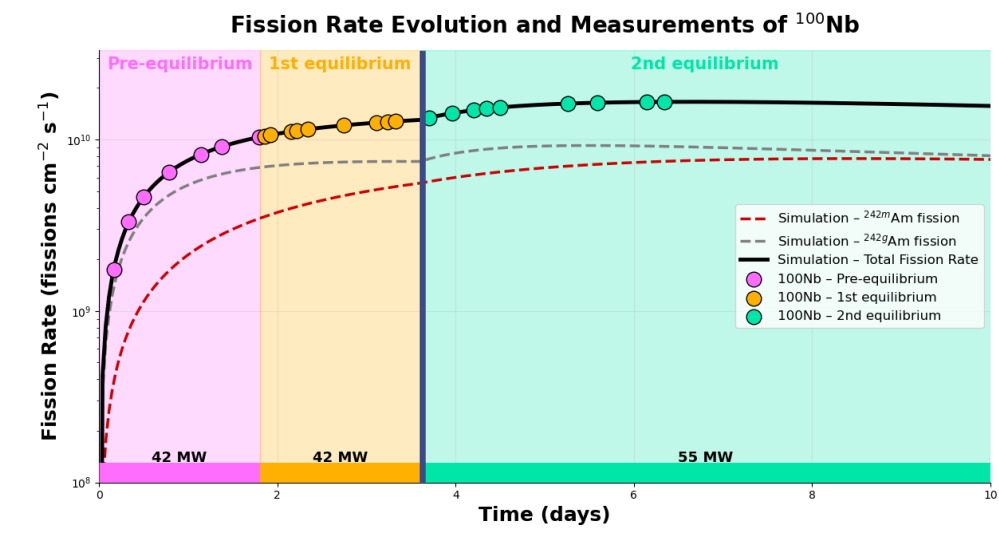
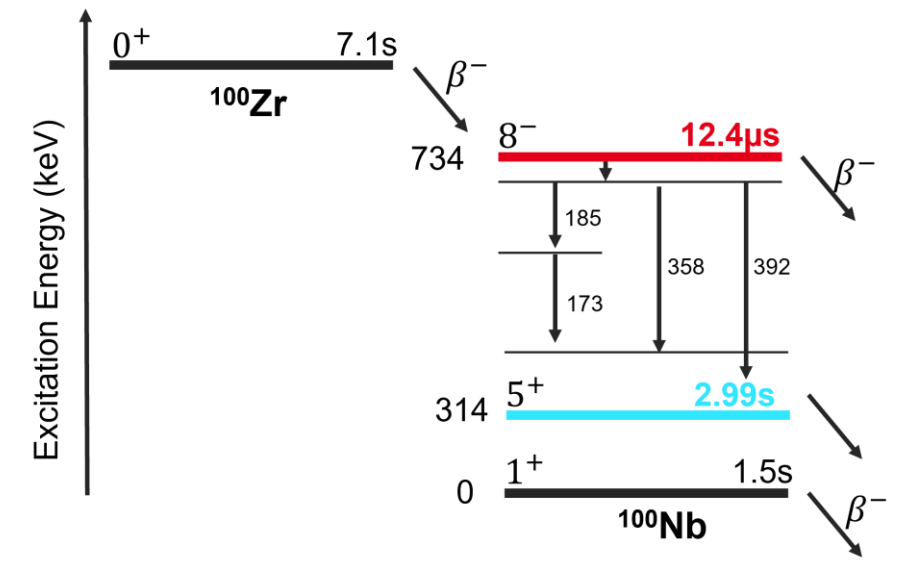
$J^\pi = 8^-$
 $t_{1/2}^m \cong 12 \mu\text{s}$

Preliminary Results - ^{100}Nb from $^{241}\text{Am}(2n_{\text{th}},f)$

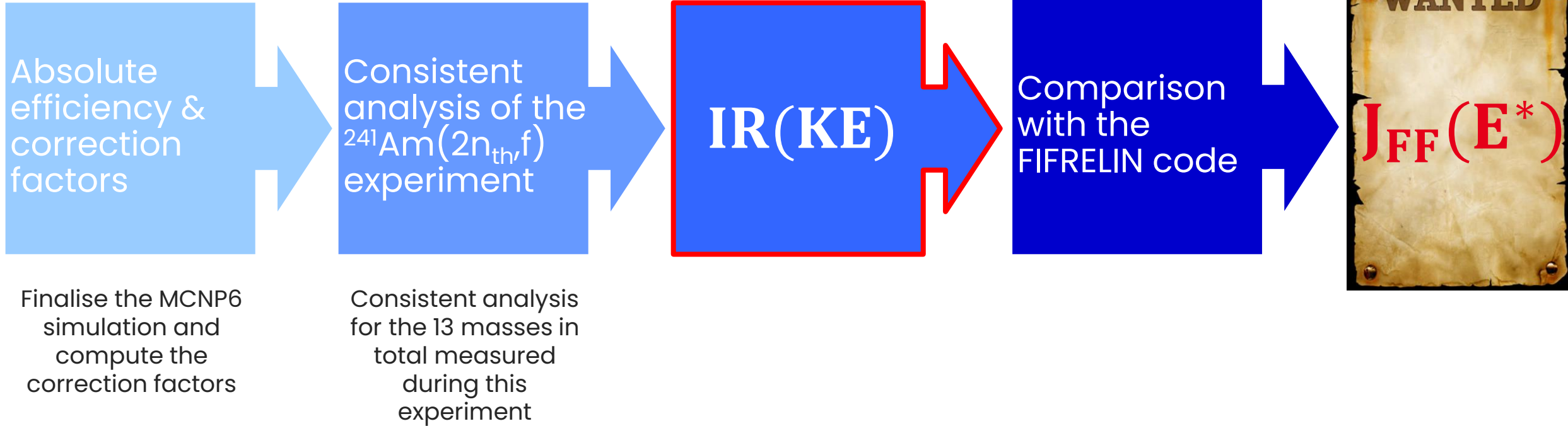
IR(KE)



$J^\pi = 5^+$
 $t_{1/2}^m \cong 3 \text{ s}$



Future prospects



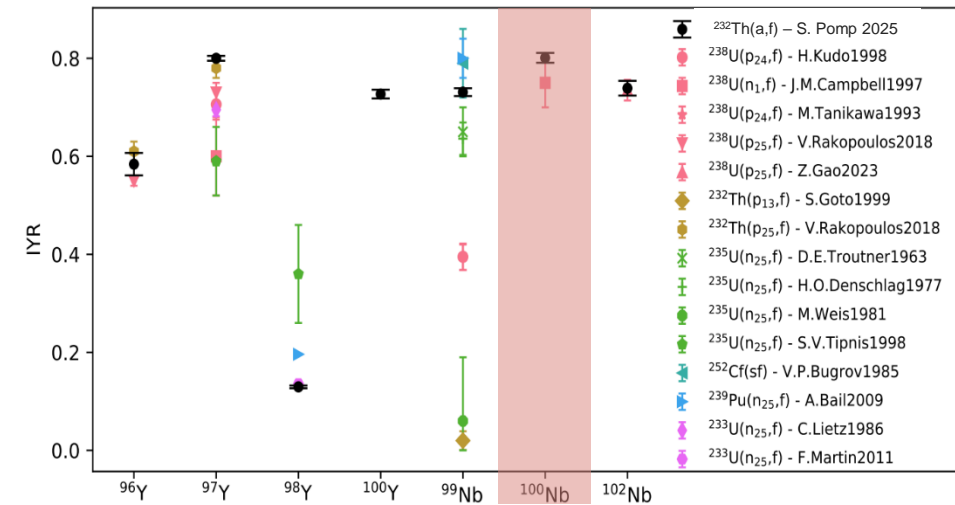
Future prospects



Finalise the MCNP6 simulation and compute the correction factors

Consistent analysis for the 13 masses in total measured during this experiment

+ Upcoming experiment $^{237}\text{Np}(2n_{\text{th}},f)$ & Analysis of existing data for $^{239, 241}\text{Pu}(n_{\text{th}},f)$





Thank you for your attention !