Faculté de physique et ingénierie
Université de Strasbourg

master PSA Physique Subatomique Astroparticules

Structure of heavy nuclei near ^{218}U

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université PARIS-SACLAY

Outline

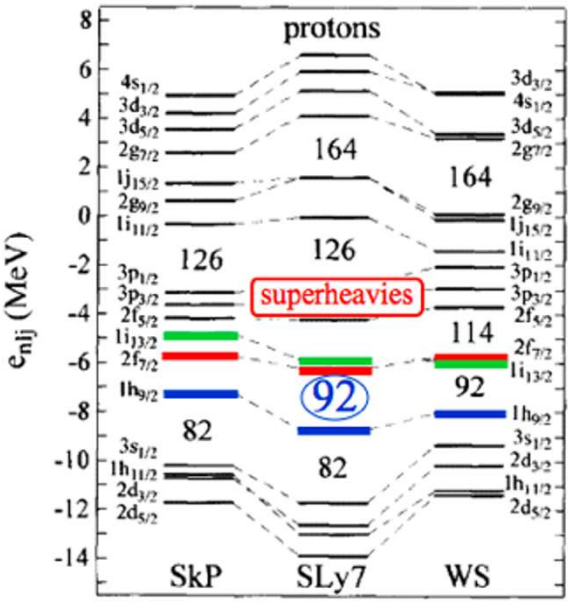
I. **Physics Motivations**

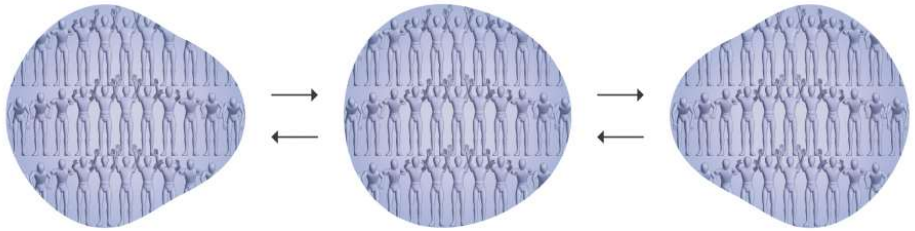
II. **Experimental setup**

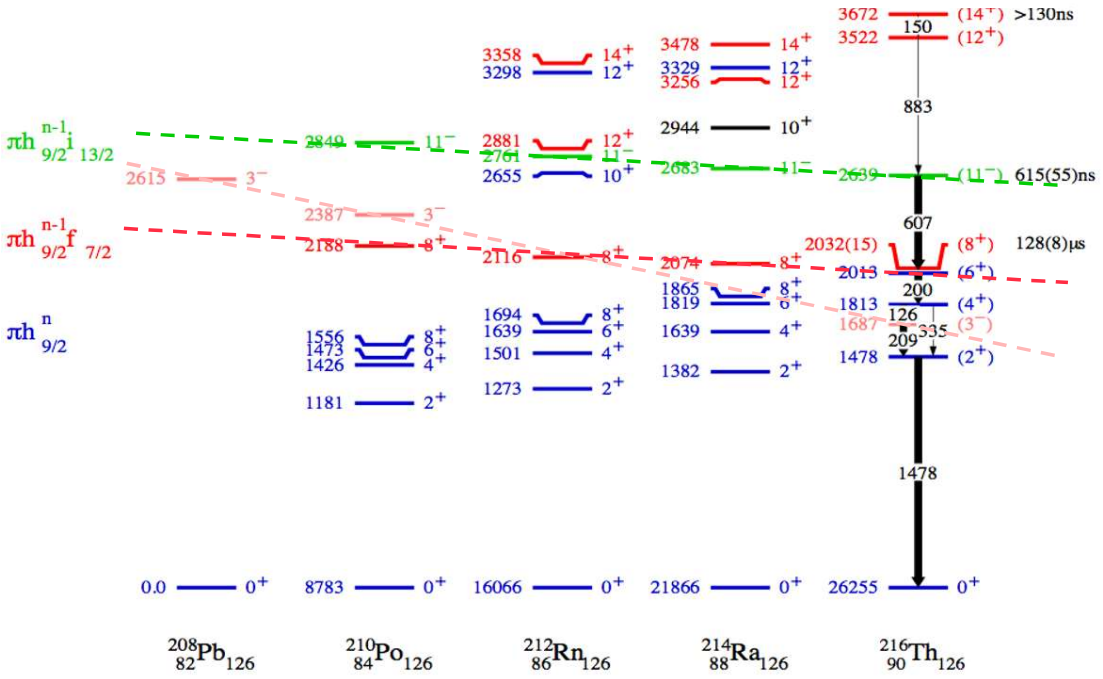
III. **Results**

IV. **Conclusion and perspectives**

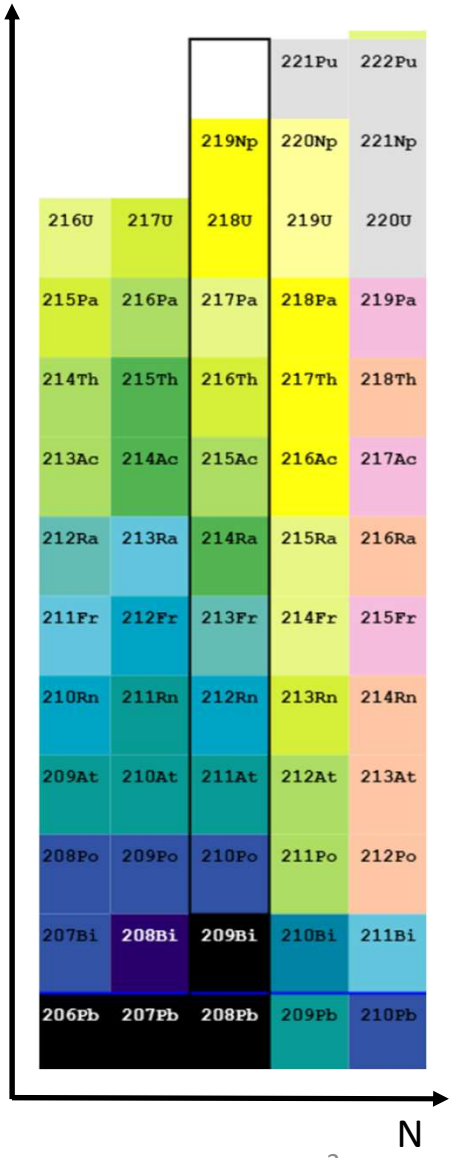
Motivations





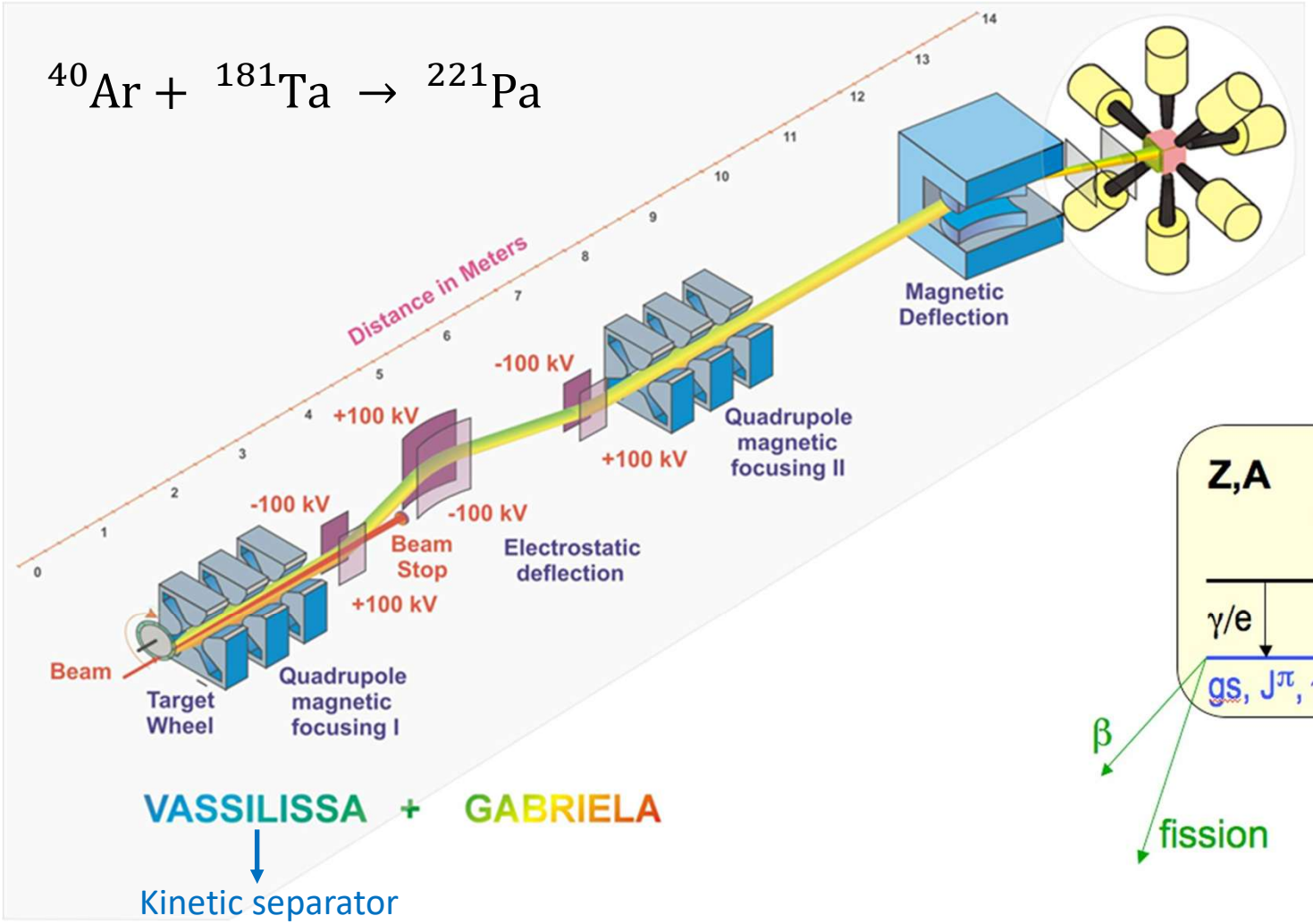


K. Haushild, et al., Phys. Rev. Lett. 87, 072501 (2001)

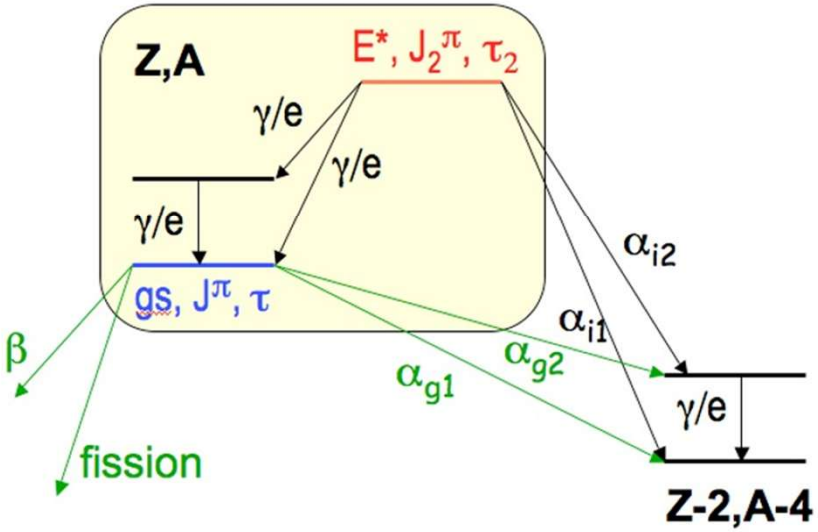


Experimental setup

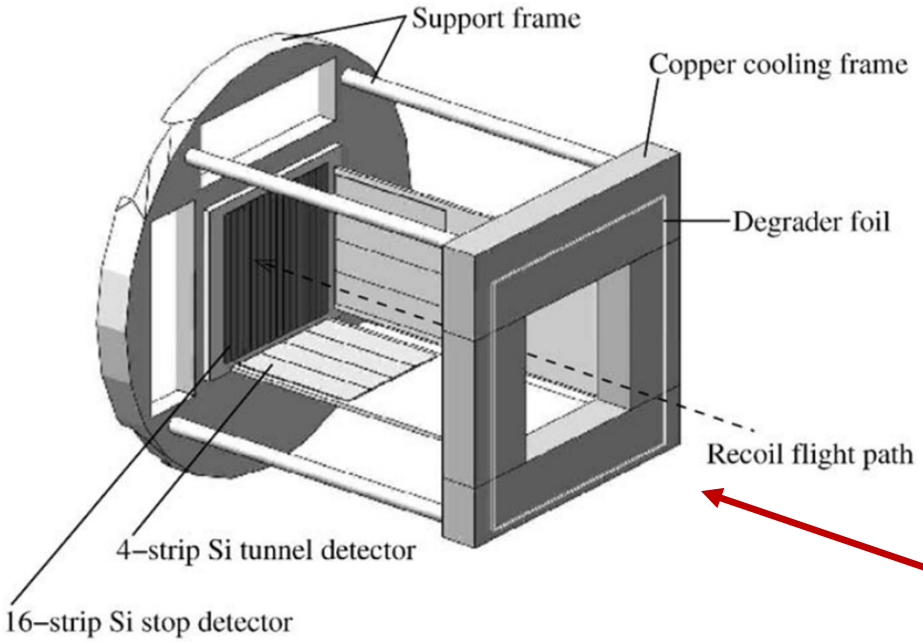
$^{40}\mathrm{Ar} + {}^{181}\mathrm{Ta} \rightarrow {}^{221}\mathrm{Pa}$

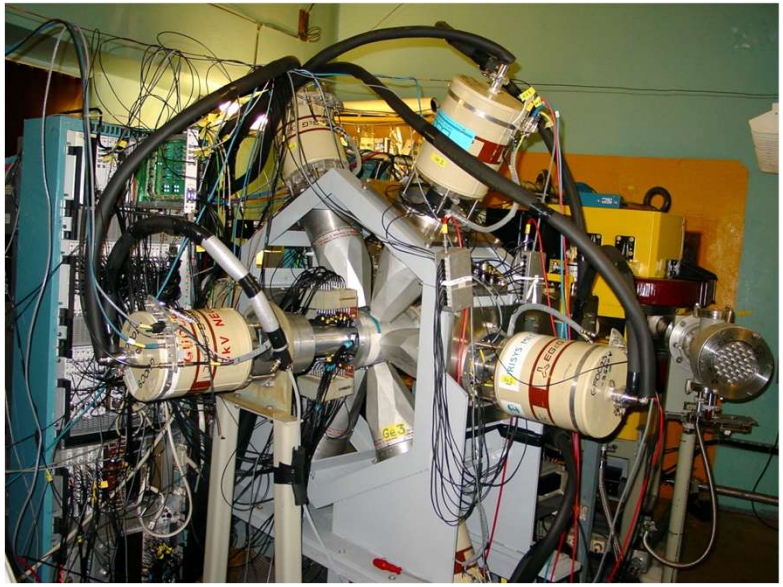


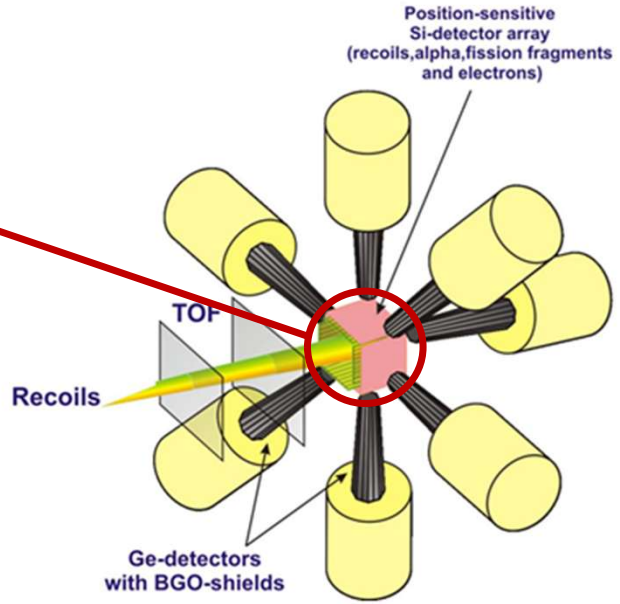
- Intense beam (7-12 μA)
- Rotating target
- 186 MeV $\leq E_{beam} \leq$ 200 MeV



GABRIELA detection system







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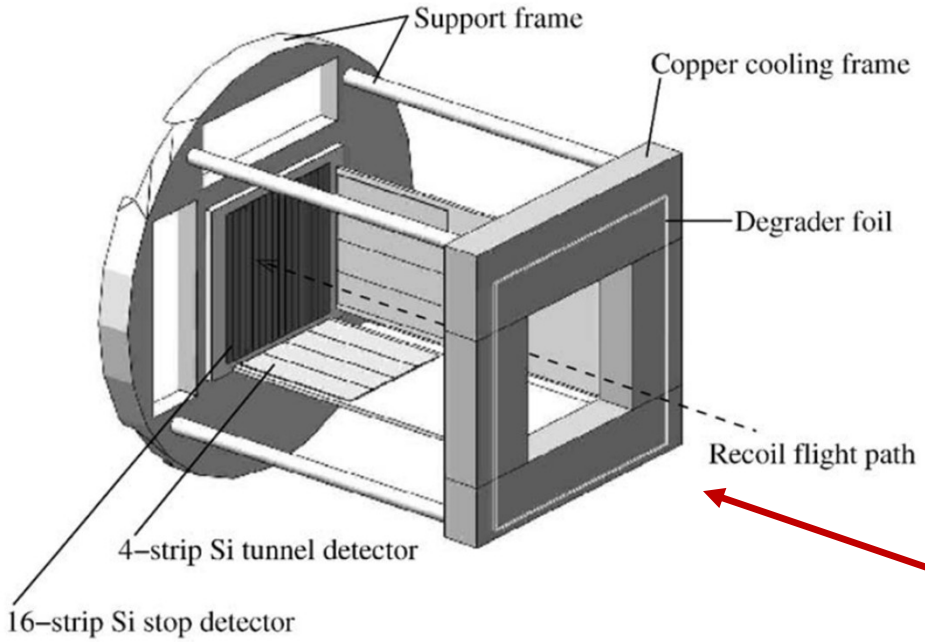
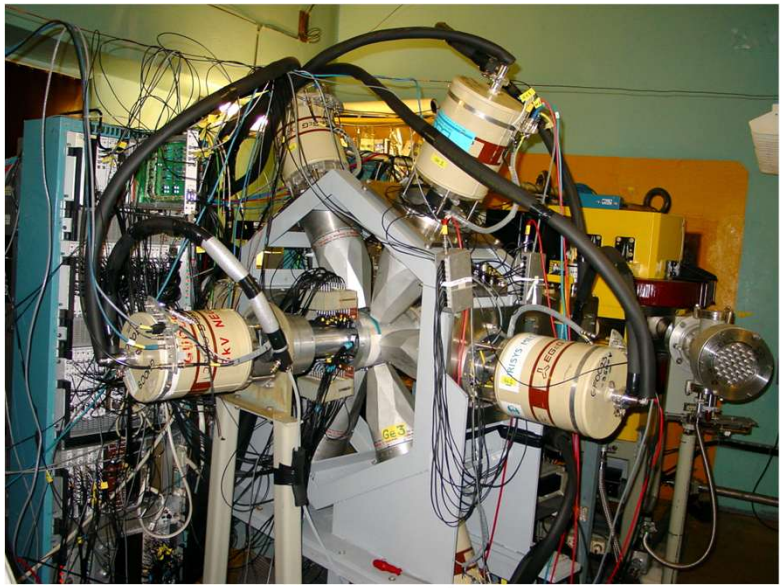
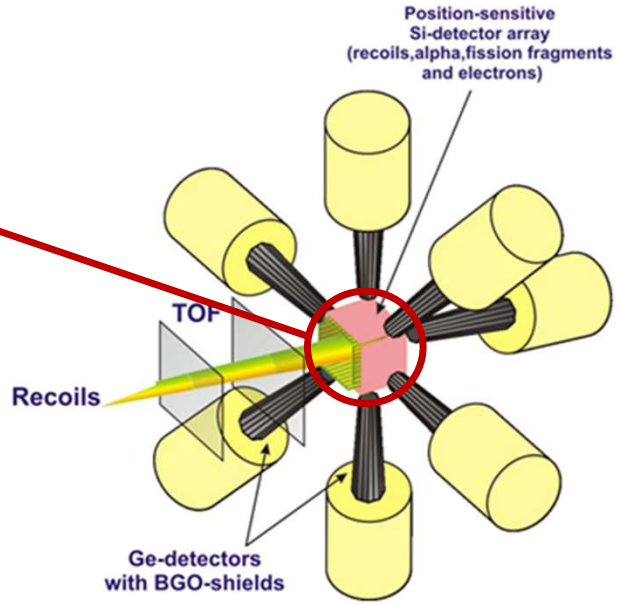
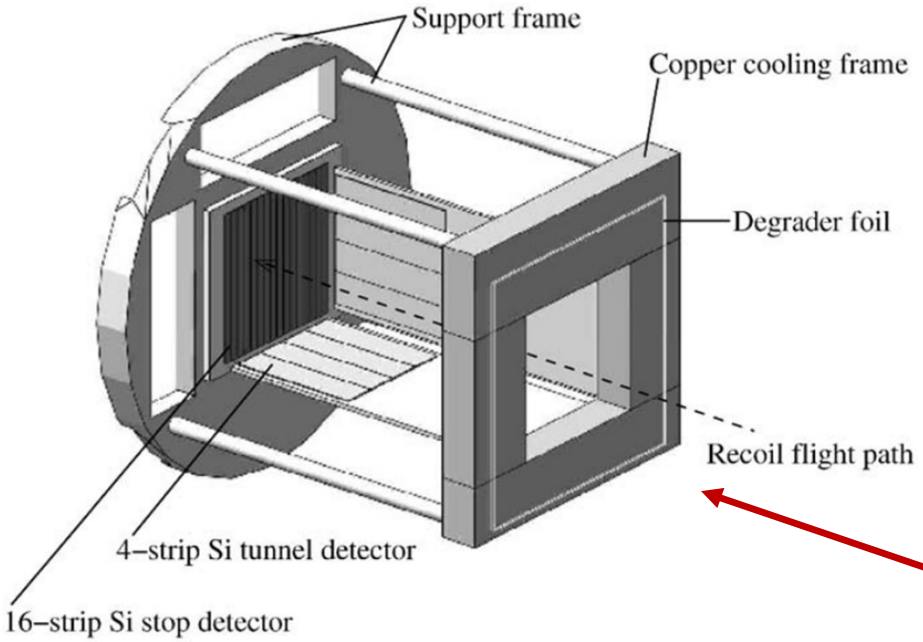


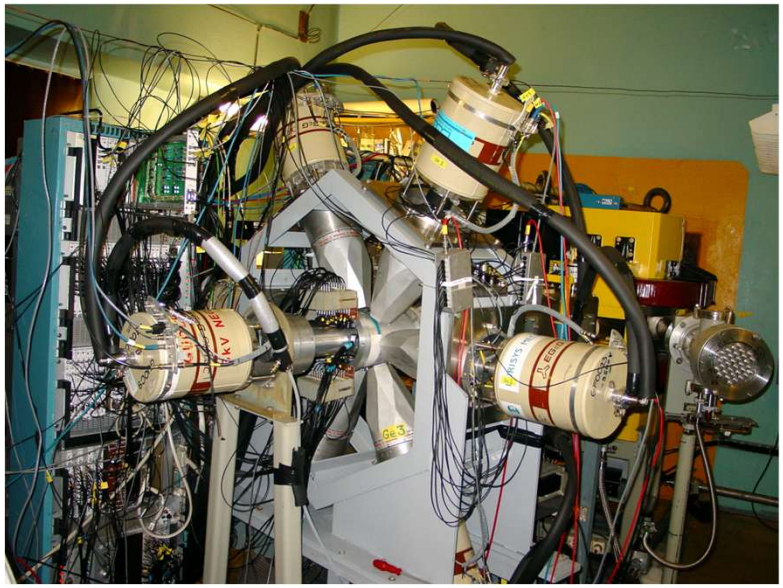


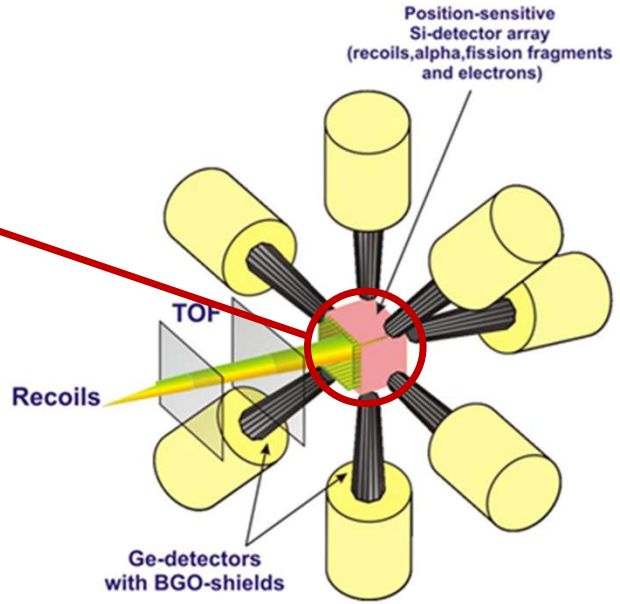


- TOF → velocity

GABRIELA detection system

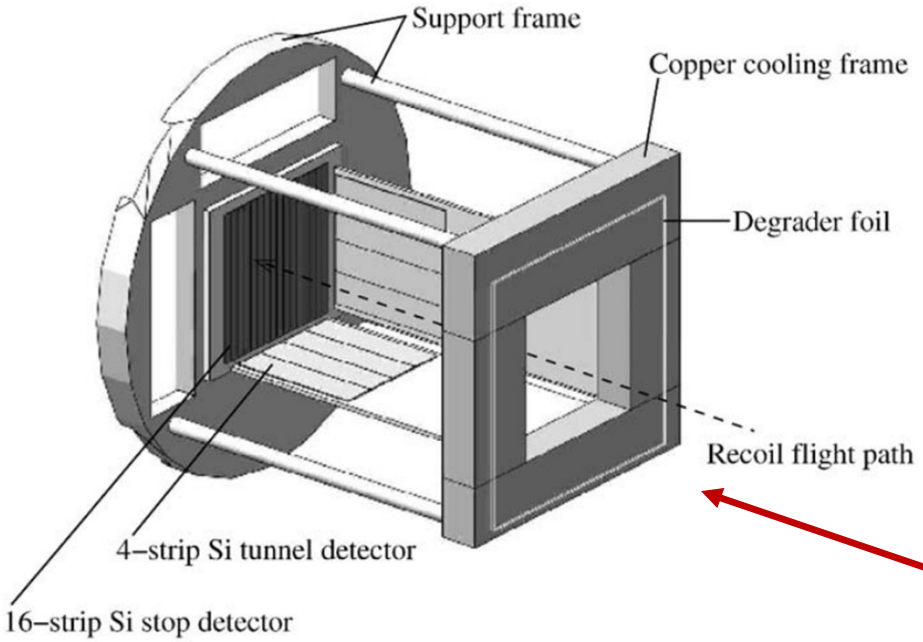


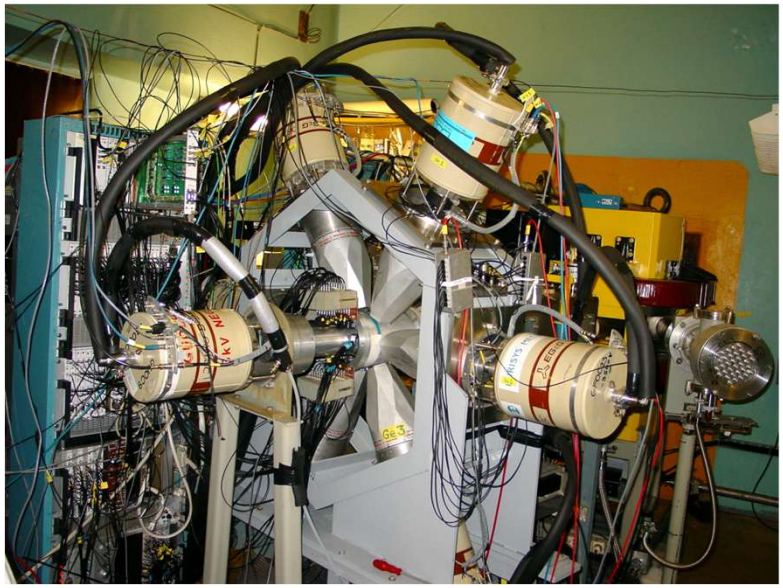


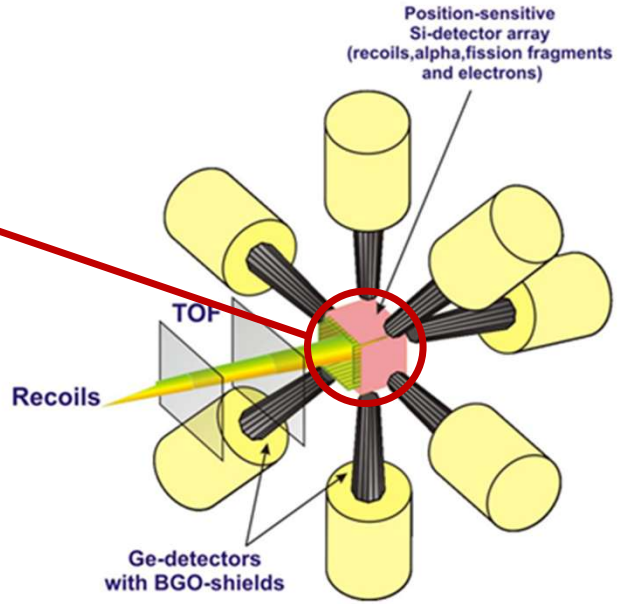


- TOF → velocity
- Si stop detector → recoils and alpha particle energies

GABRIELA detection system







- TOF → velocity
- Si stop detector → recoils and alpha particle energies
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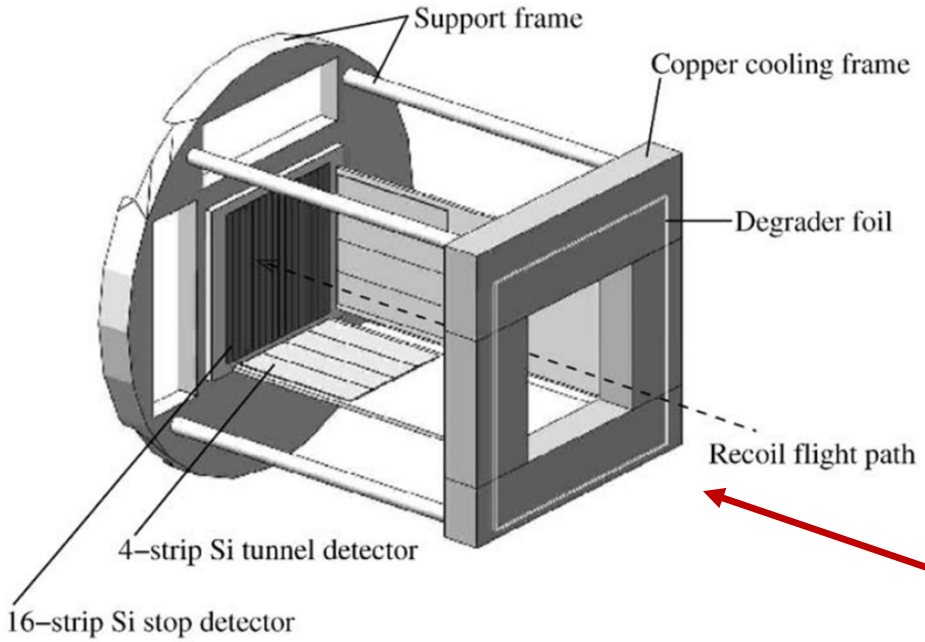
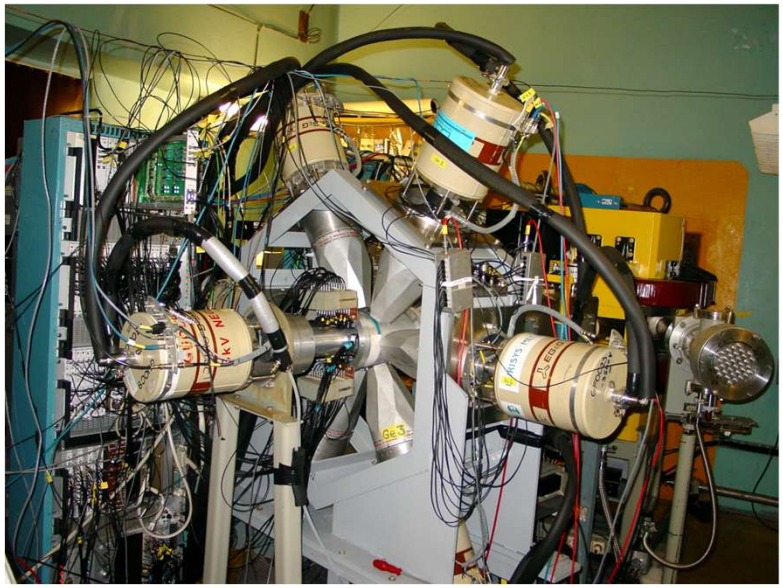
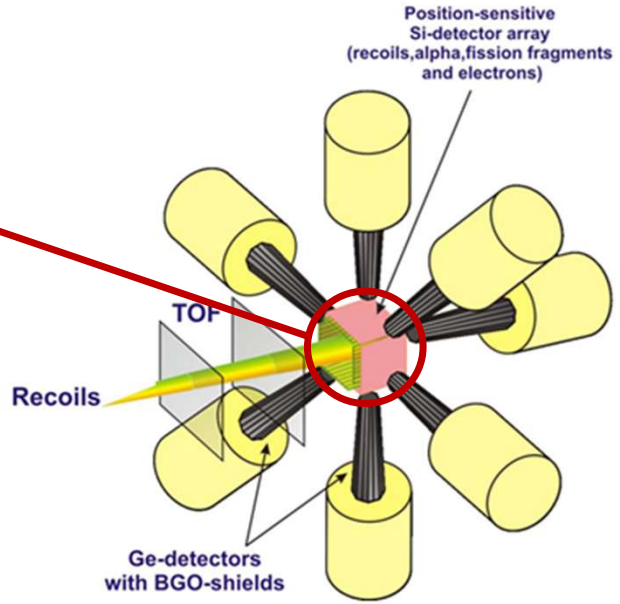
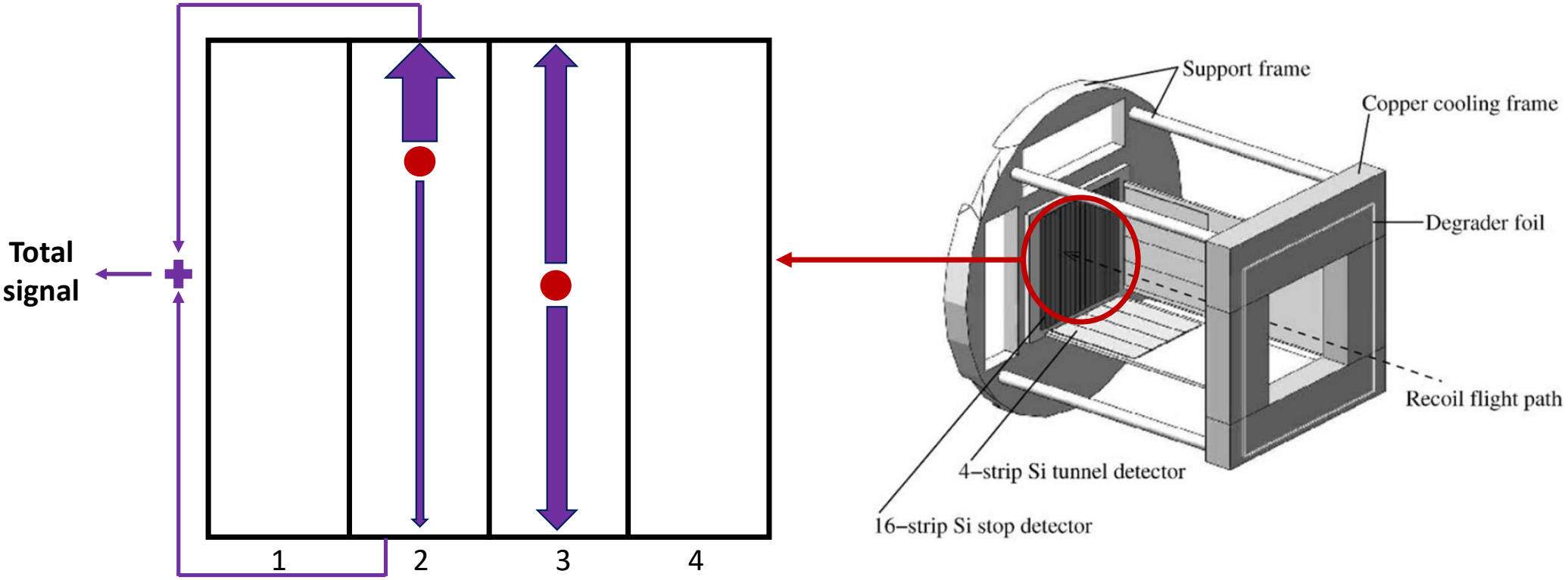




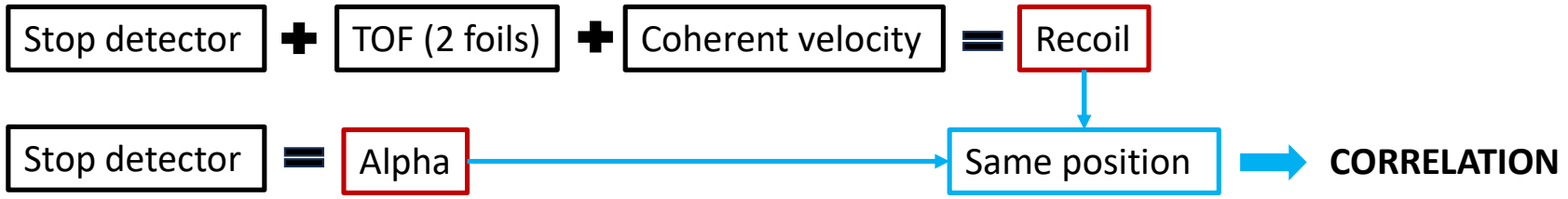


- TOF → velocity
- Si stop detector → recoils and alpha particle energies
- Si tunnel detector → escaping charged particles energies
- Ge detectors → photons energies

Position in the stop detector



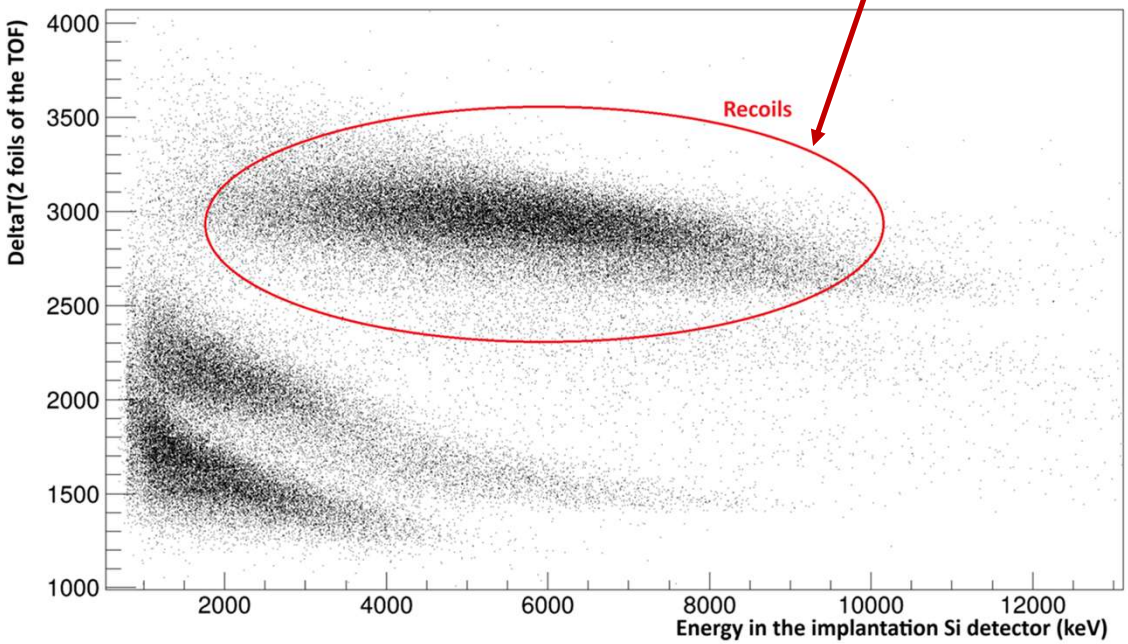
Identification of evaporation residues



Identification of evaporation residues

Stop detector + TOF (2 foils) + Coherent velocity = Recoil

Stop detector = Alpha → Same position → **CORRELATION**



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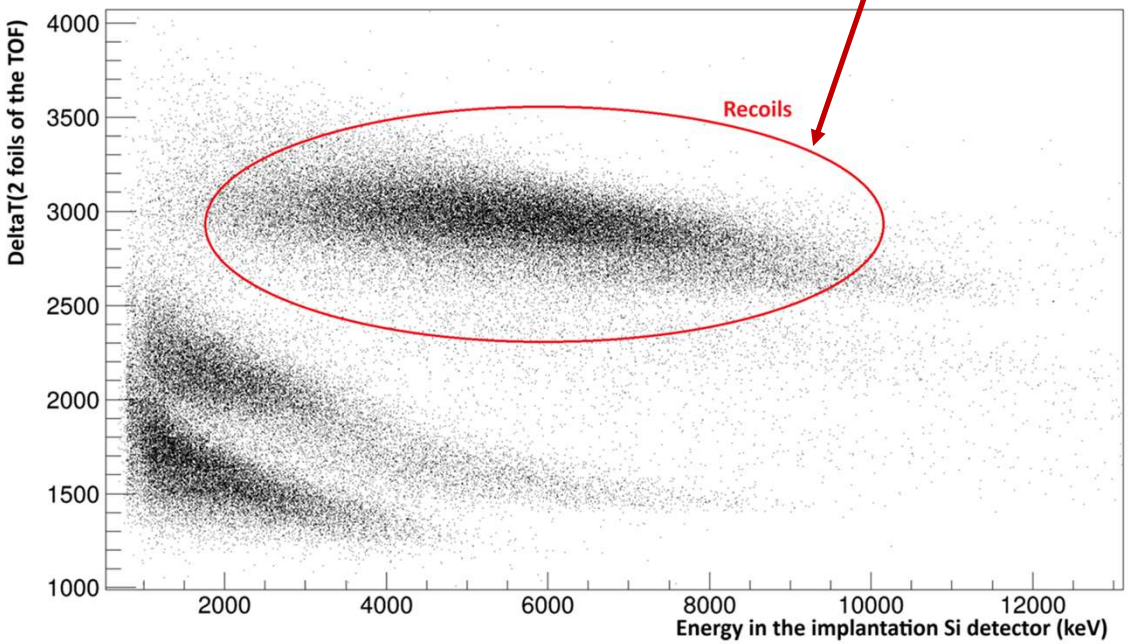
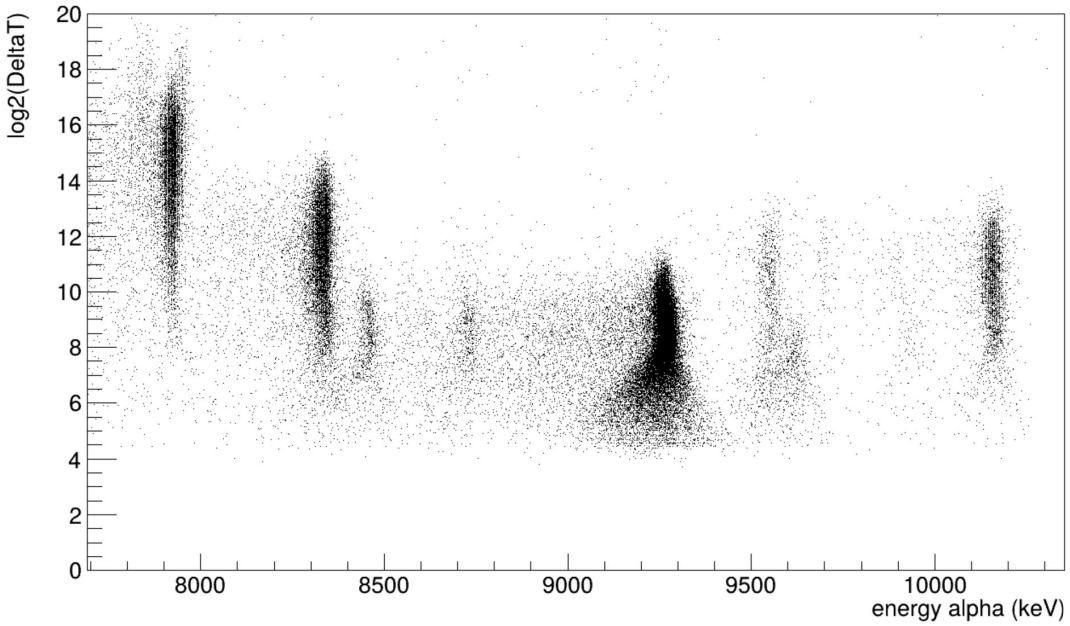
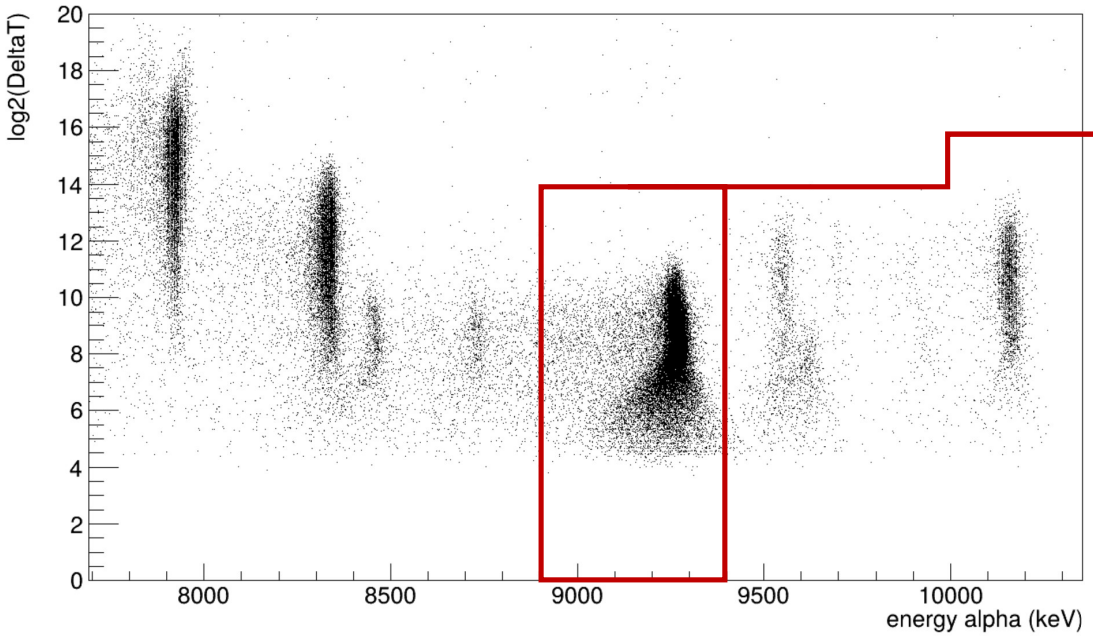
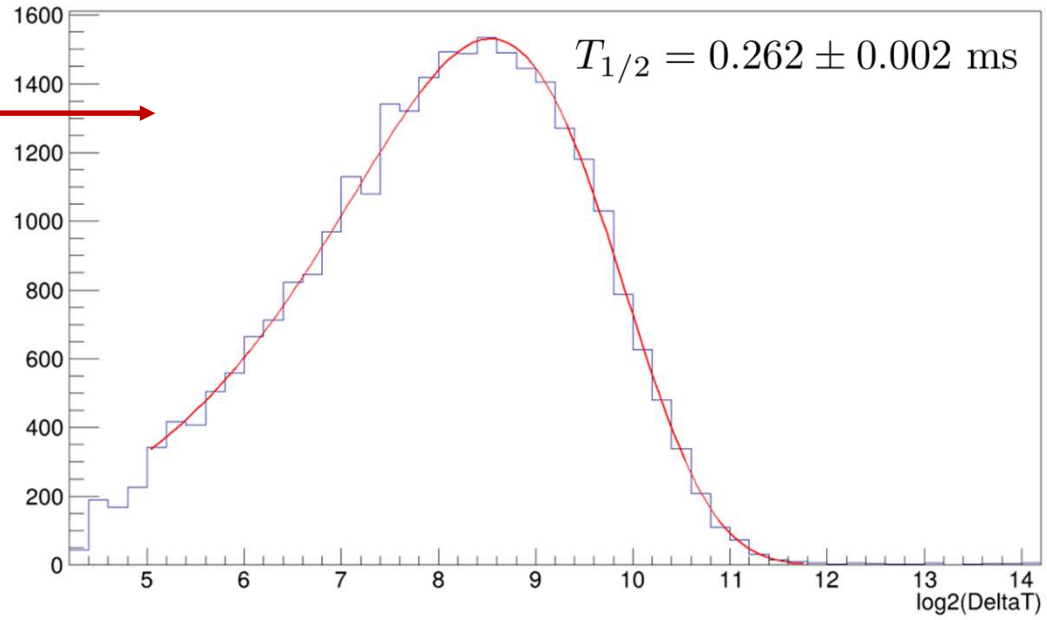




Identification of evaporation residues

$$\frac{dN(t)}{dt} = N_0 \lambda e^{-\lambda t}$$





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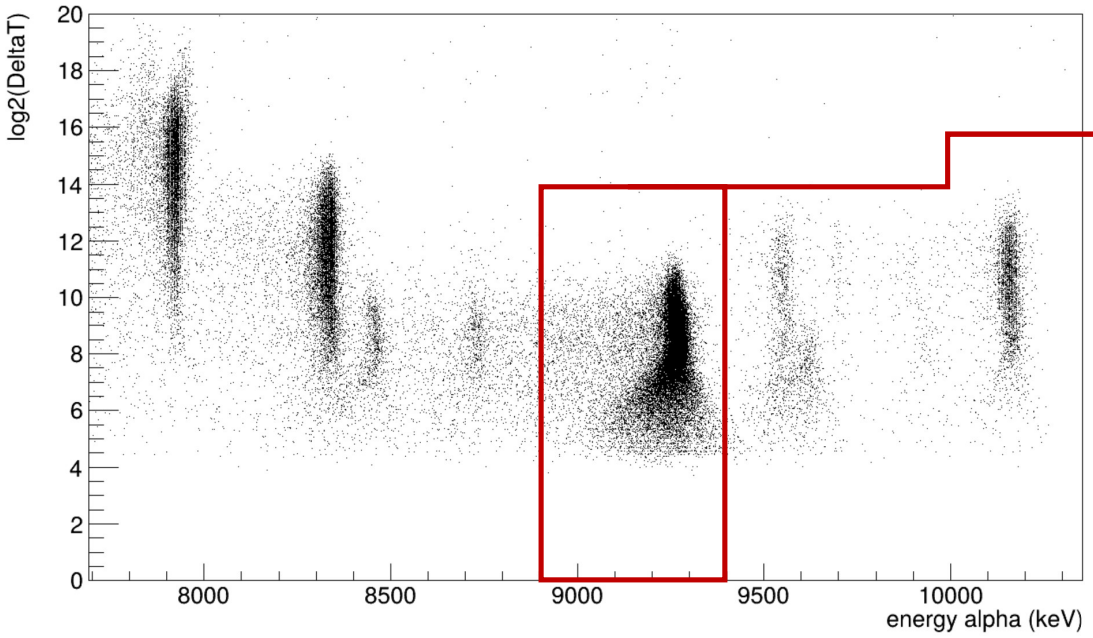

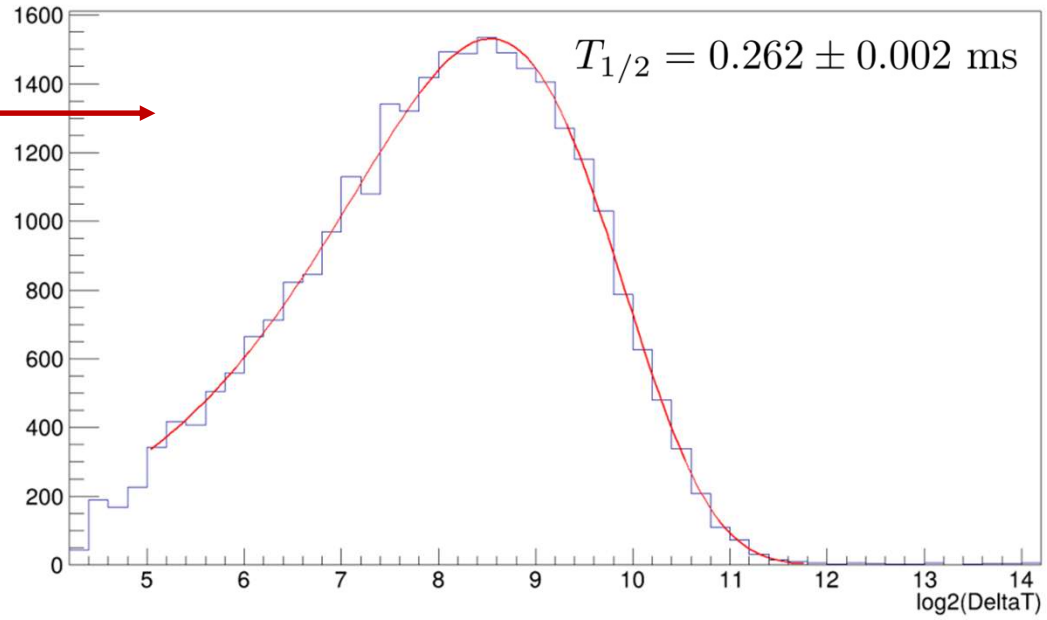

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Identification of evaporation residues

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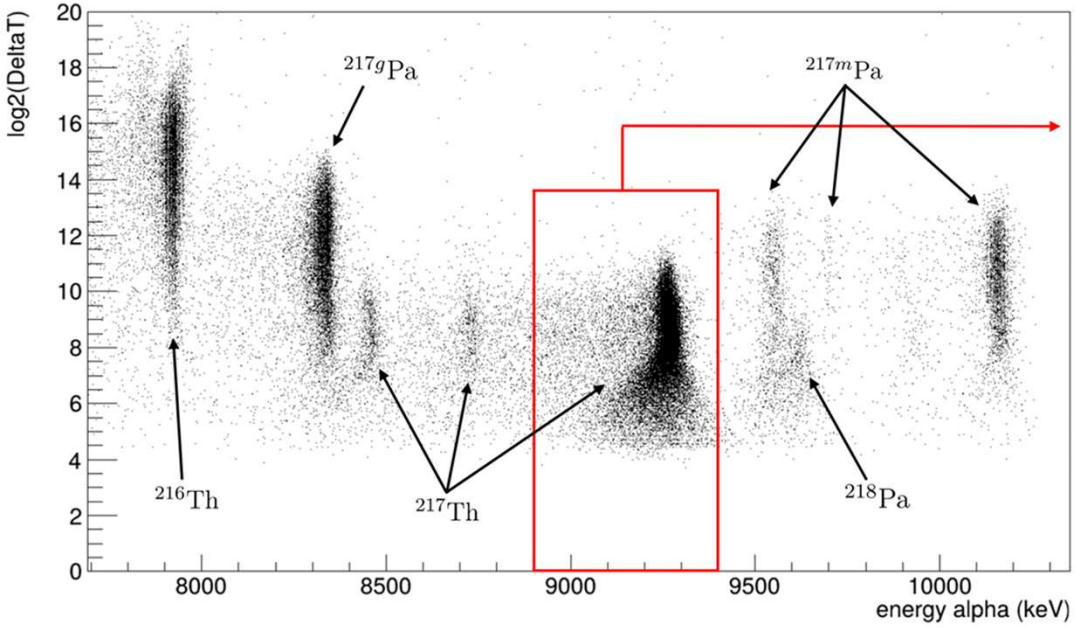

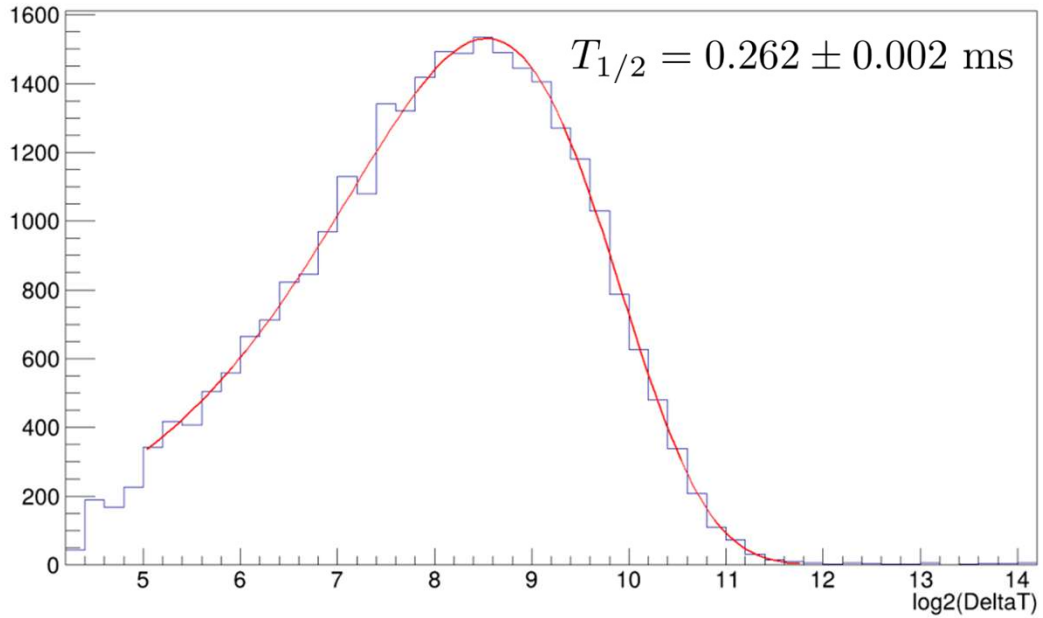

$E_\alpha + T_{1/2}$ + literature = Identification of the most intense evaporation residues

$$^{40}\mathrm{Ar} + ^{181}\mathrm{Ta} \longrightarrow ^{221}\mathrm{Pa} \longrightarrow \begin{cases} ^{217}\mathrm{Th} + p3n \\ ^{216}\mathrm{Th} + p4n \\ ^{217}\mathrm{Pa} + 4n \\ ^{218}\mathrm{Pa} + 3n \end{cases}$$

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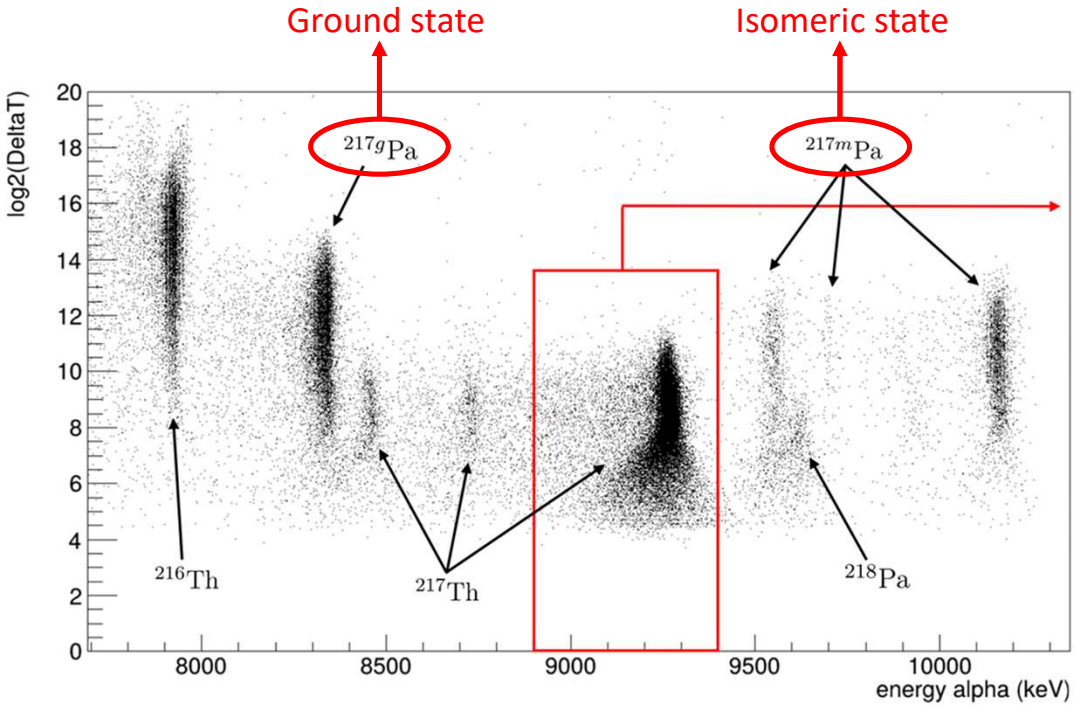

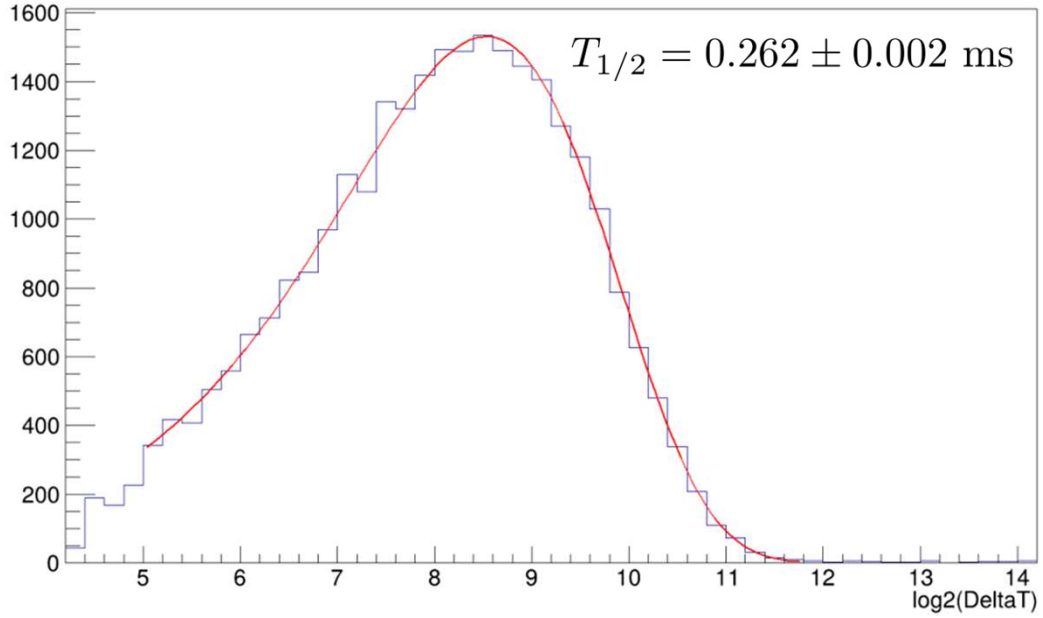

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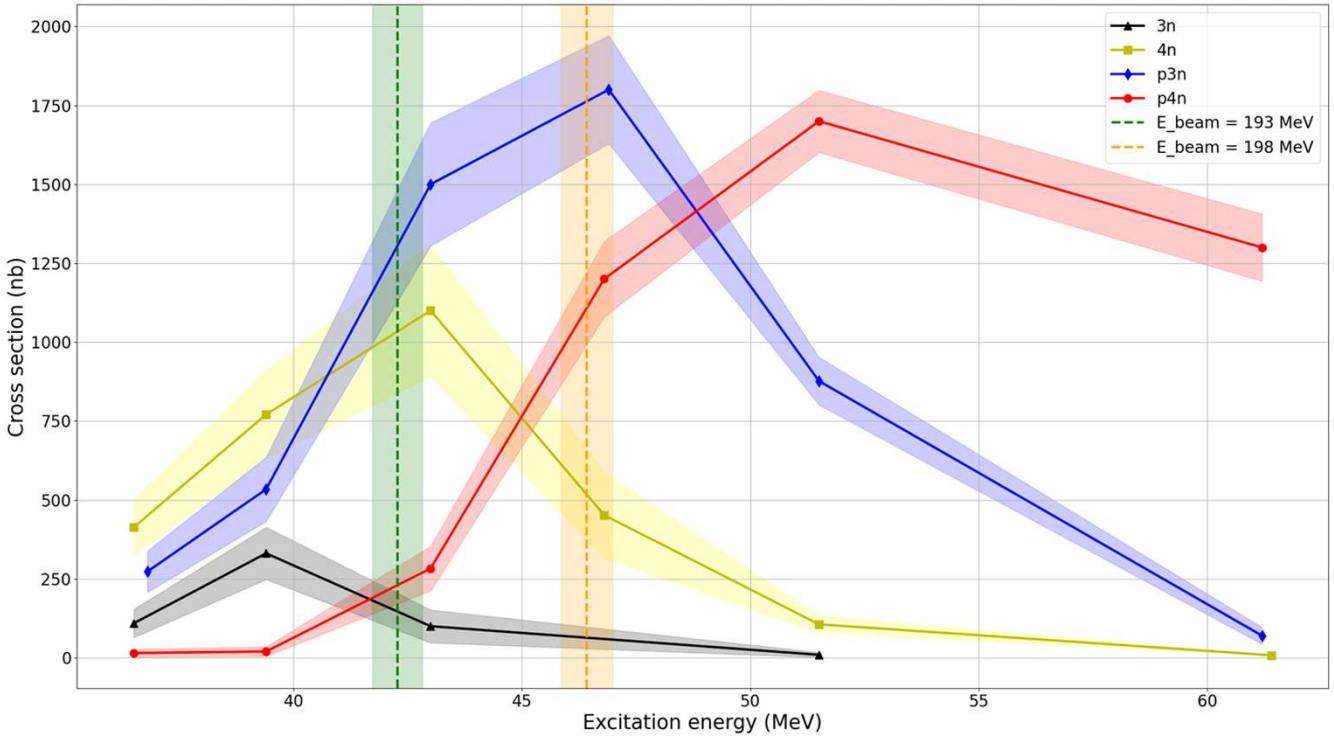
Transmission efficiency of VASSILISSA and excitation energy of 221Pa

$$\frac{\sigma_{4n}}{\sigma_{p4n}} = \frac{N_{217Pa}}{N_{216Th}} \begin{cases} \geq 1 \; if \; E^* \leq 45MeV \\ \leq 1 \; if E^* \geq 45MeV \end{cases}$$

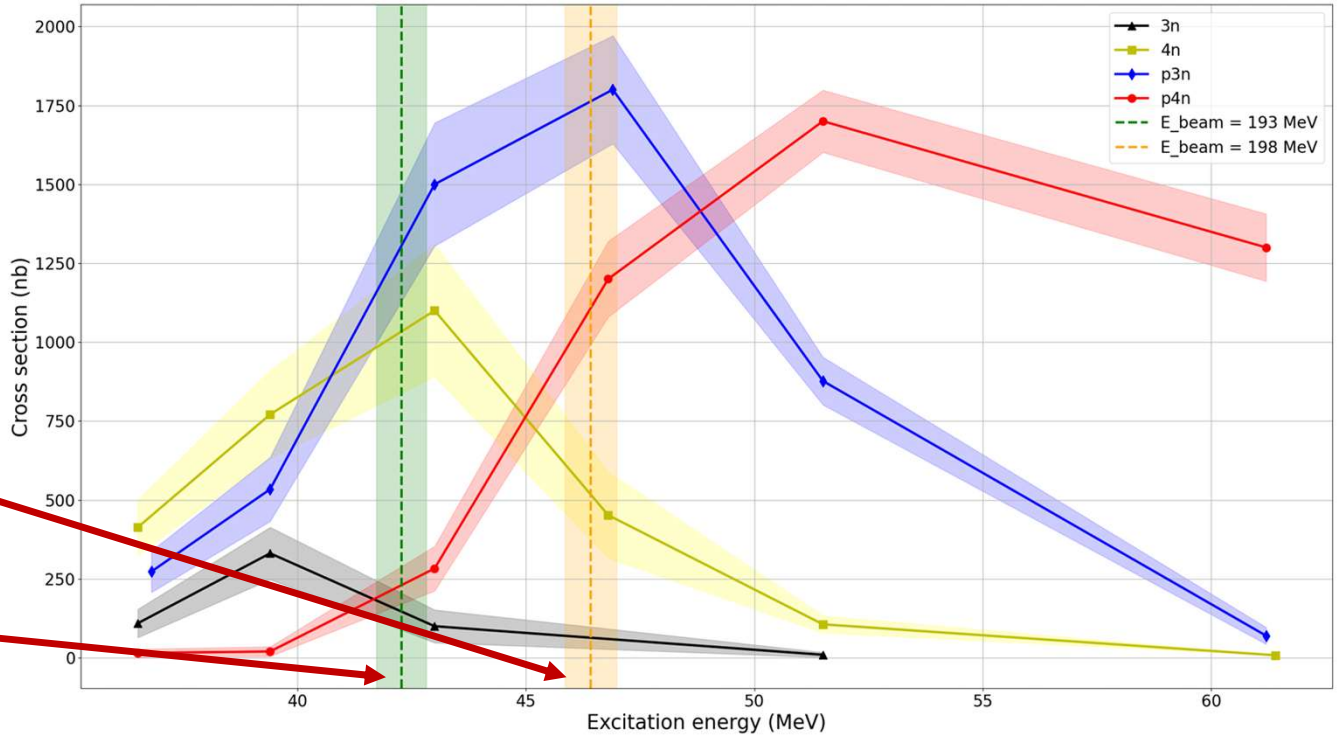
Beam energy → production rate of nuclei



D. Vermeulen, et al., Z. Phys. A- Atoms and Nuclei 318, 157-169 (1984)

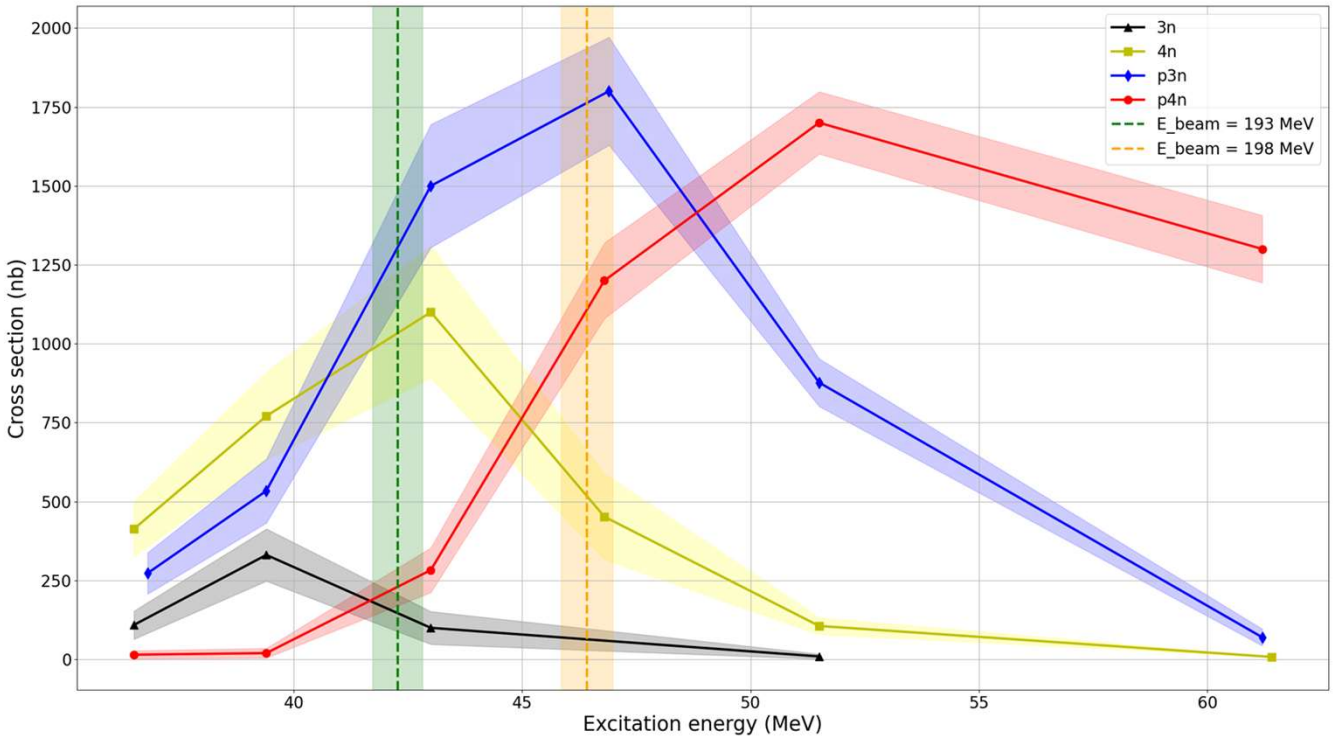
$$E^* = 46.41^{+0.56}_{-0.56}\ \text{MeV}$$

$$E^* = 42.37^{+0.45}_{-0.65}\ \text{MeV}$$



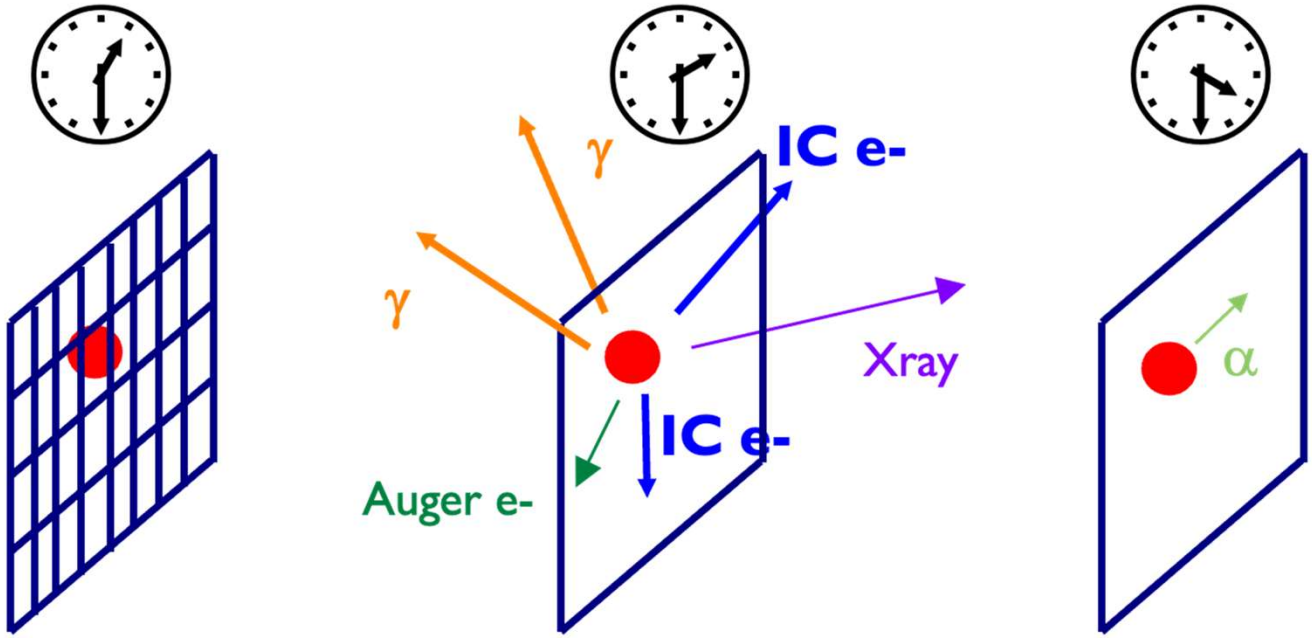
D. Vermeulen, et al., Z. Phys. A- Atoms and Nuclei 318, 157-169 (1984)

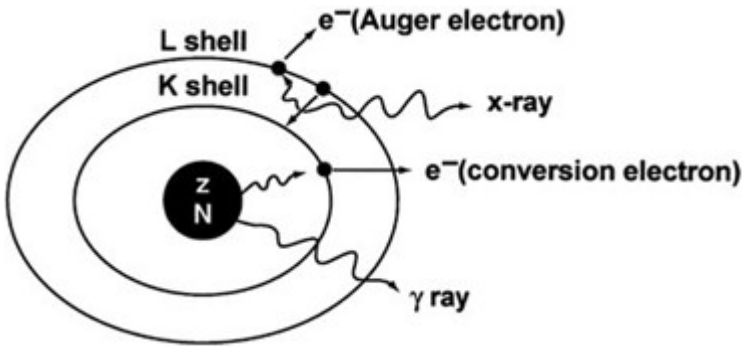
$$\varepsilon = \frac{Number\ of\ detected\ nuclei}{Number\ of\ produced\ nuclei}$$

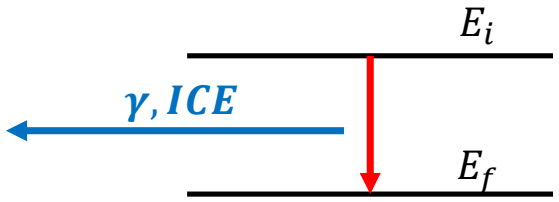


$$\varepsilon = 3.4^{+1.0}_{-0.4}\%$$

Isomeric states

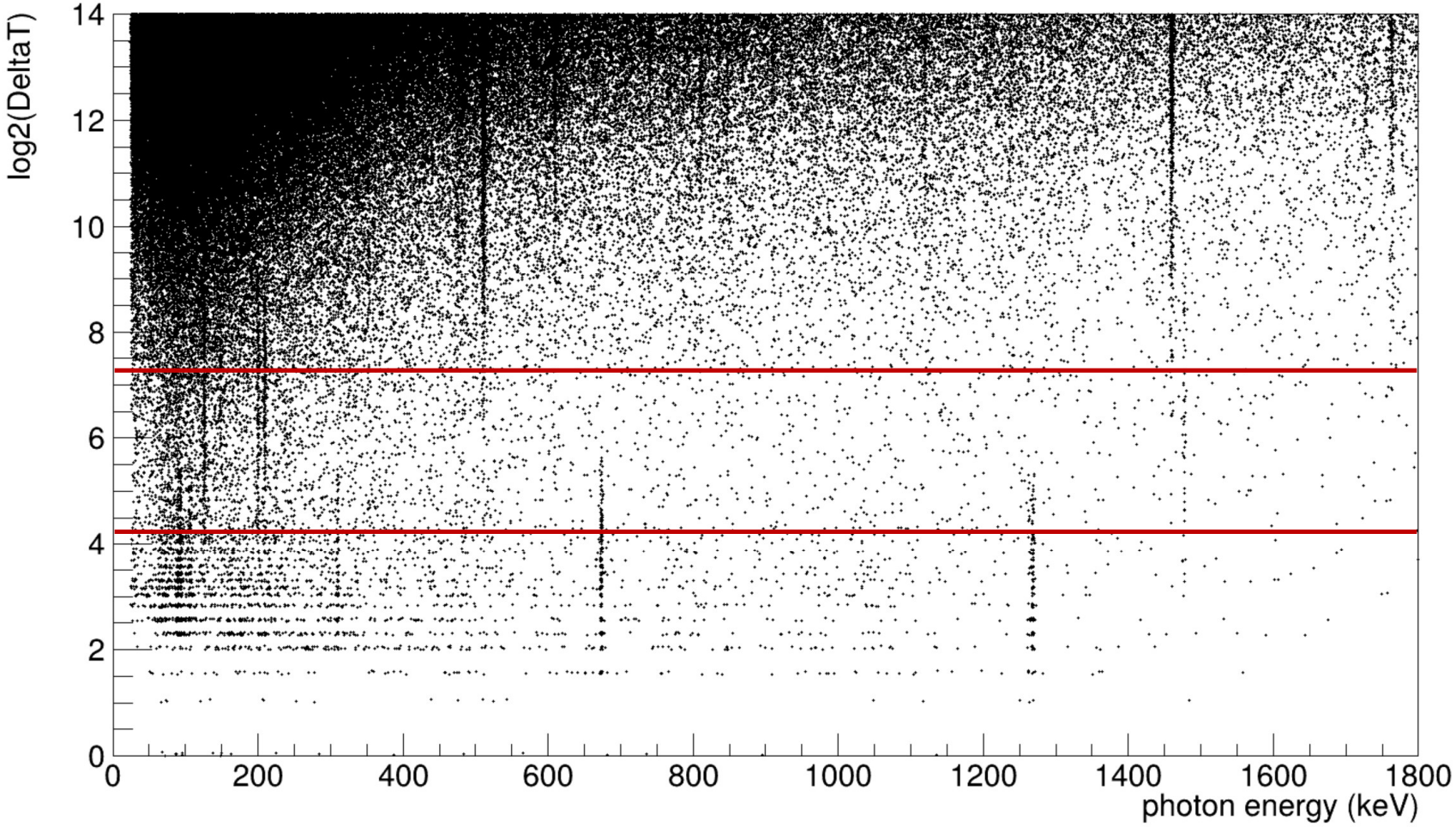




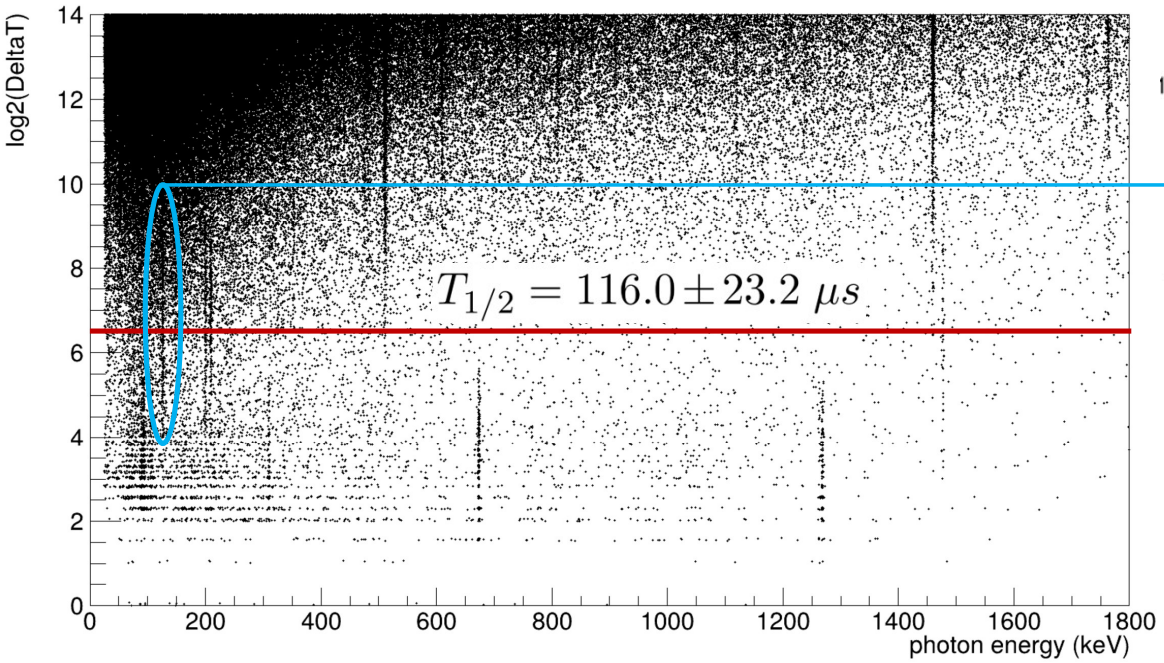


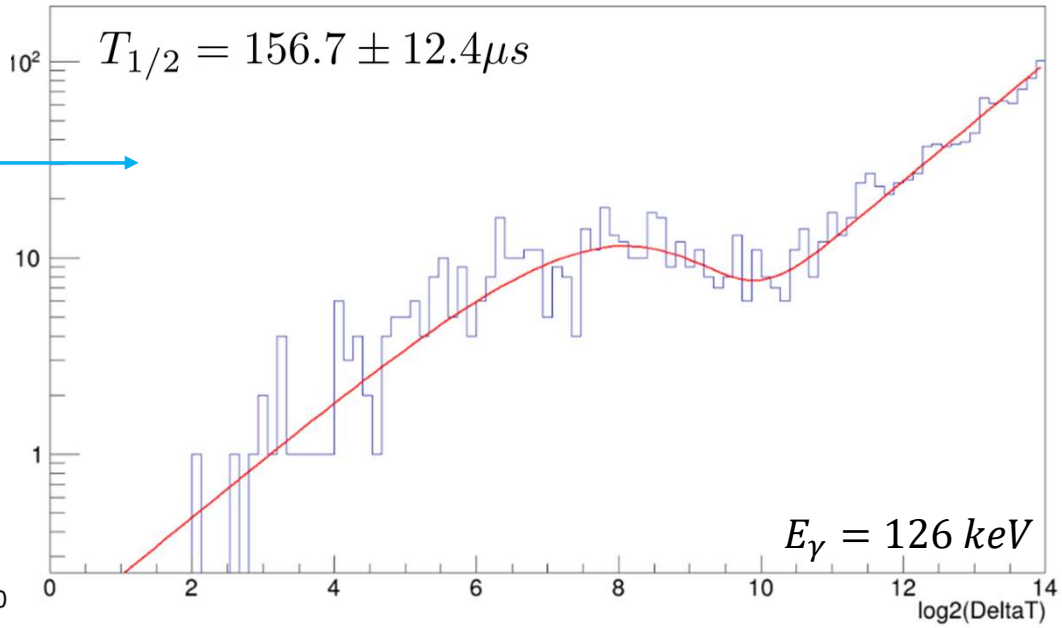
$$E(ICE) = E_i - E_f - E_{binding\ energy}$$

Recoils-photons correlations



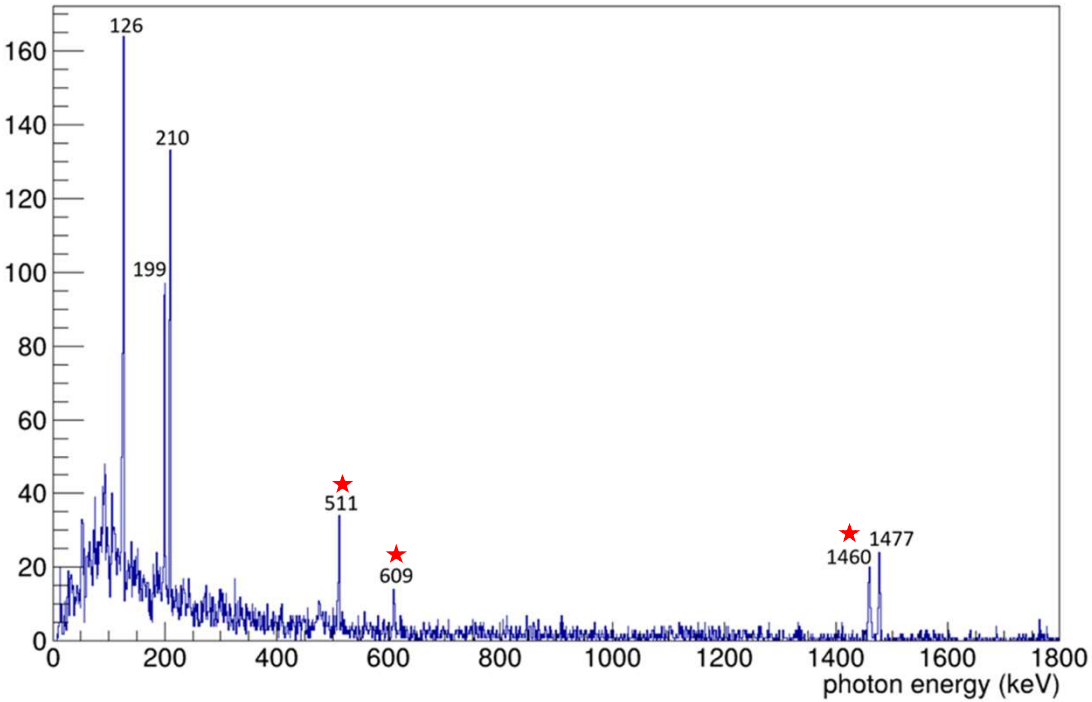
Which nuclei do these photons belong to ?

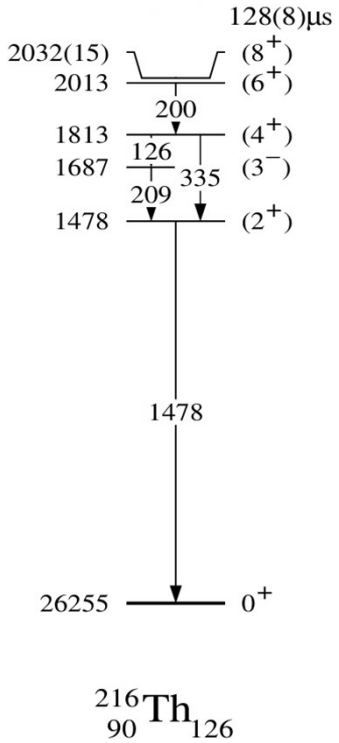




Alpha of the ^{216}Th ground state

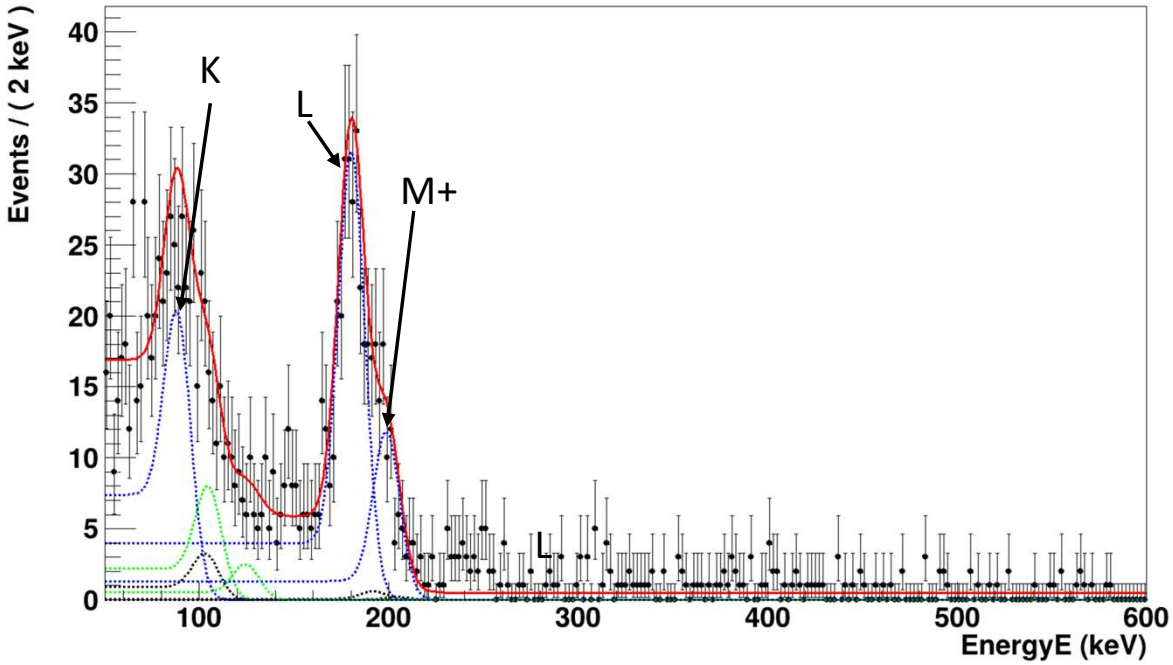
$T_{1/2} = 128 \pm 8\ \mu s$ → Isomeric state of ^{216}Th in the literature





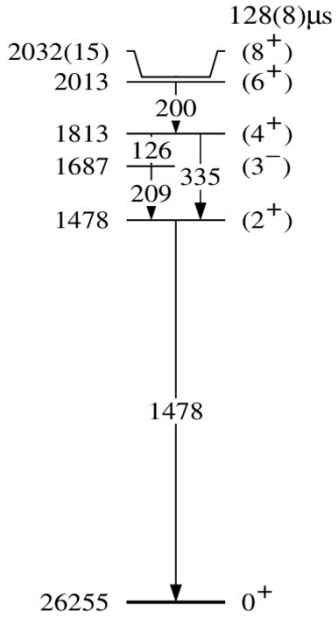
$^{216}_{90}Th_{126}$

K. Hauschild, et al., Phys. Rev. Lett. 87, 072501 (2001).



E_γ (keV)	Type of transition
126 ± 0.5	E1
199 ± 1	E2
209 ± 0.5	E1
1477 ± 0.5	?

Energy too high for the electrons to be stopped by the silicon detector

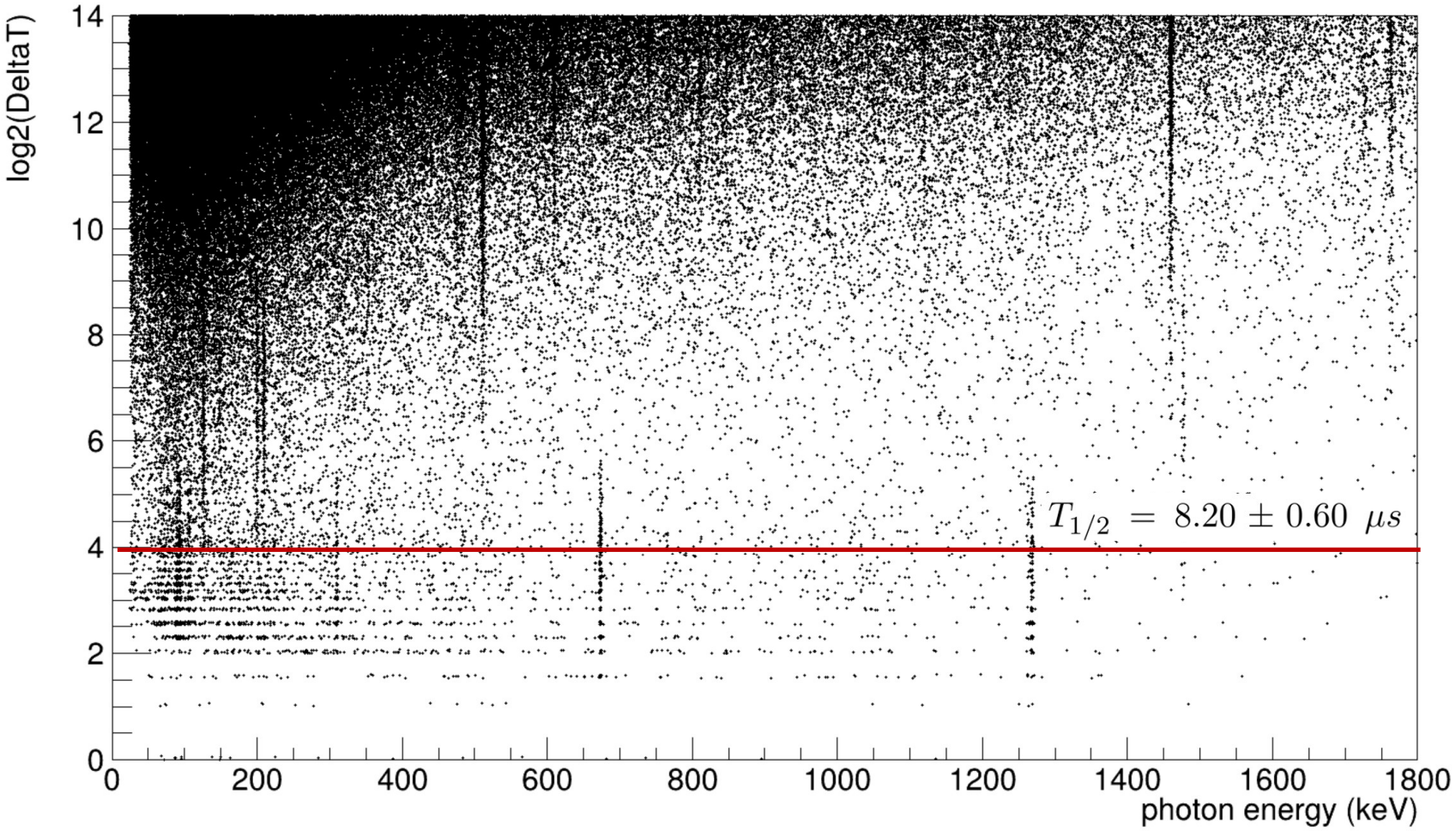


$^{216}_{90}\mathrm{Th}_{126}$

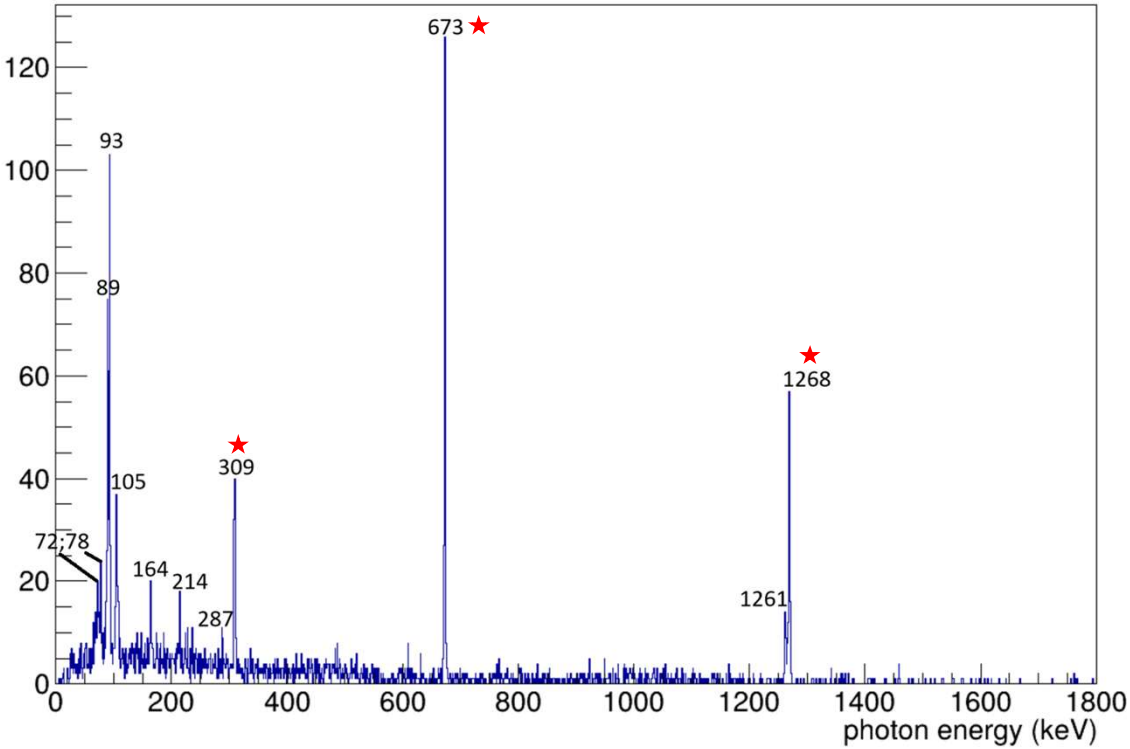
K. Hauschild, et al., Phys. Rev. Lett. 87, 072501 (2001).

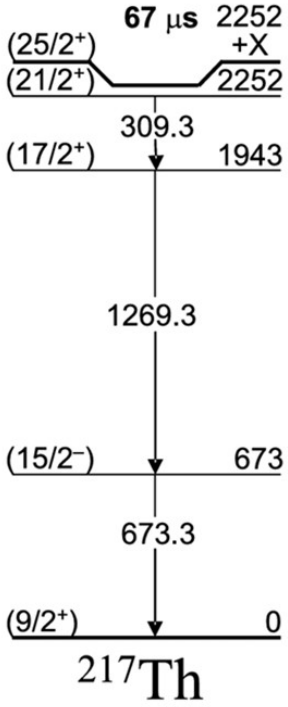
- Internal conversion electrons allow us to directly infer the type of transition from which they originate
- $\alpha = \frac{Number\ of\ electrons}{Number\ of\ photons}$ → BRICC conversion coefficient calculator

Type of transition	Exp	E1	E2	E3	M1
$\alpha(E_\gamma = 199\ keV)$	0.993 ± 0.108	0.095	0.67	7.44	2.64

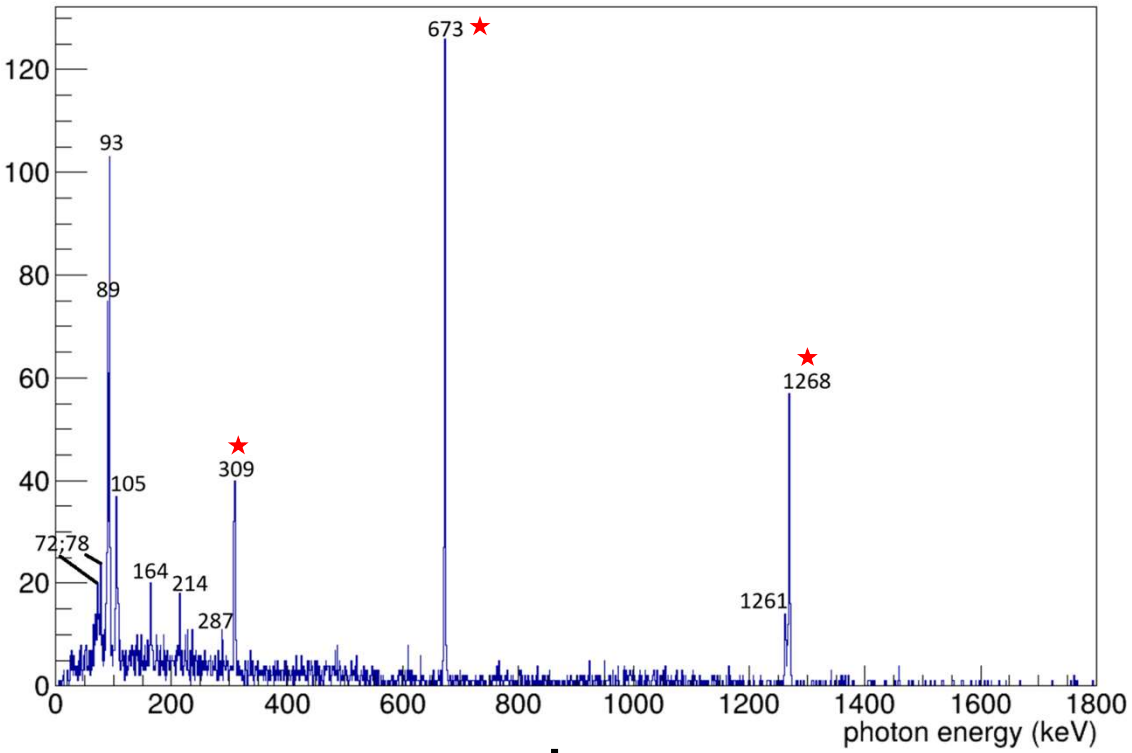


Isomeric state of ^{217}Th: $T_{1/2} = 8.20 \pm 0.60\ \mu s \neq T_{1/2} = 67^{+17}_{-11}\ \mu s$ → In the literature

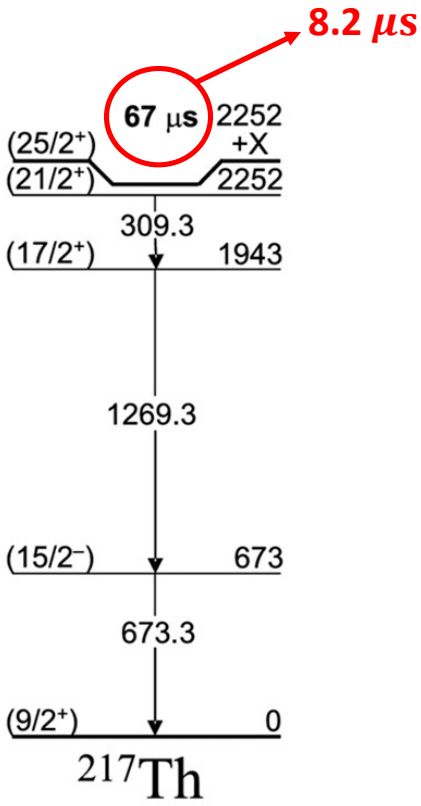




P. Kuusiniemi, et al., Eur. Phys. J. A 25, 397–404 (2005).



More transitions than in the literature



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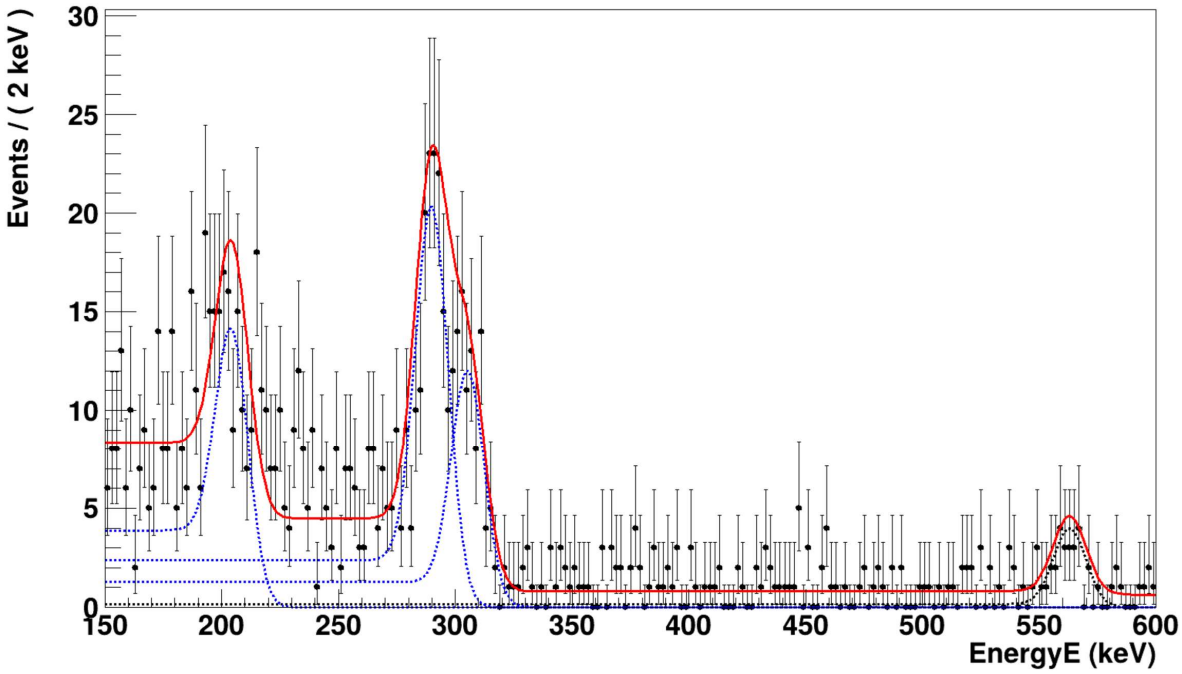
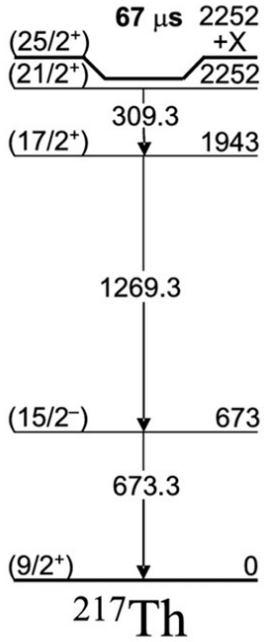


E_γ (keV)	Type of transition
72 ± 0.5	?
78 ± 0.5	?
89 ± 0.5	E1 or M1
93 ± 0.5	X-ray
105 ± 0.5	E1, E2 or M1
164 ± 0.5	E1 or E2
214.5 ± 1.0	E1 or E2
287 ± 0.5	E1, E2 or M1
309.5 ± 1.0	E3
673 ± 0.5	E3
1261 ± 0.5	?
1268 ± 0.5	?



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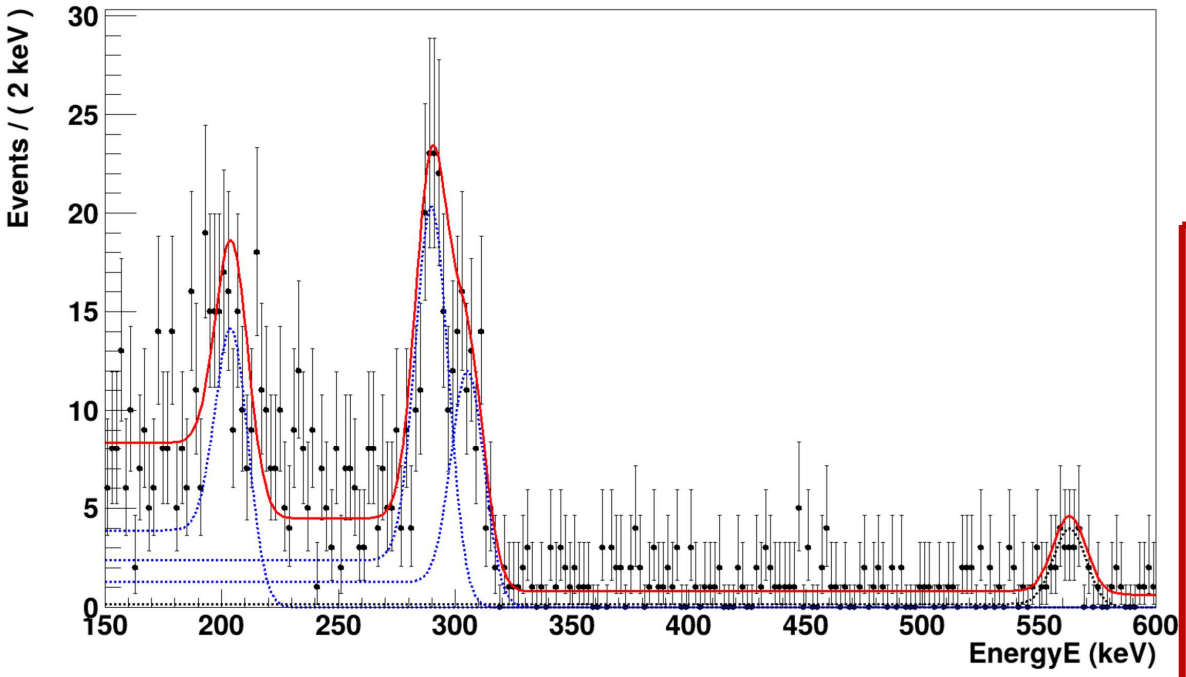

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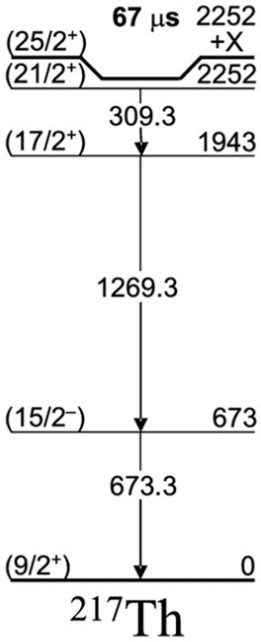
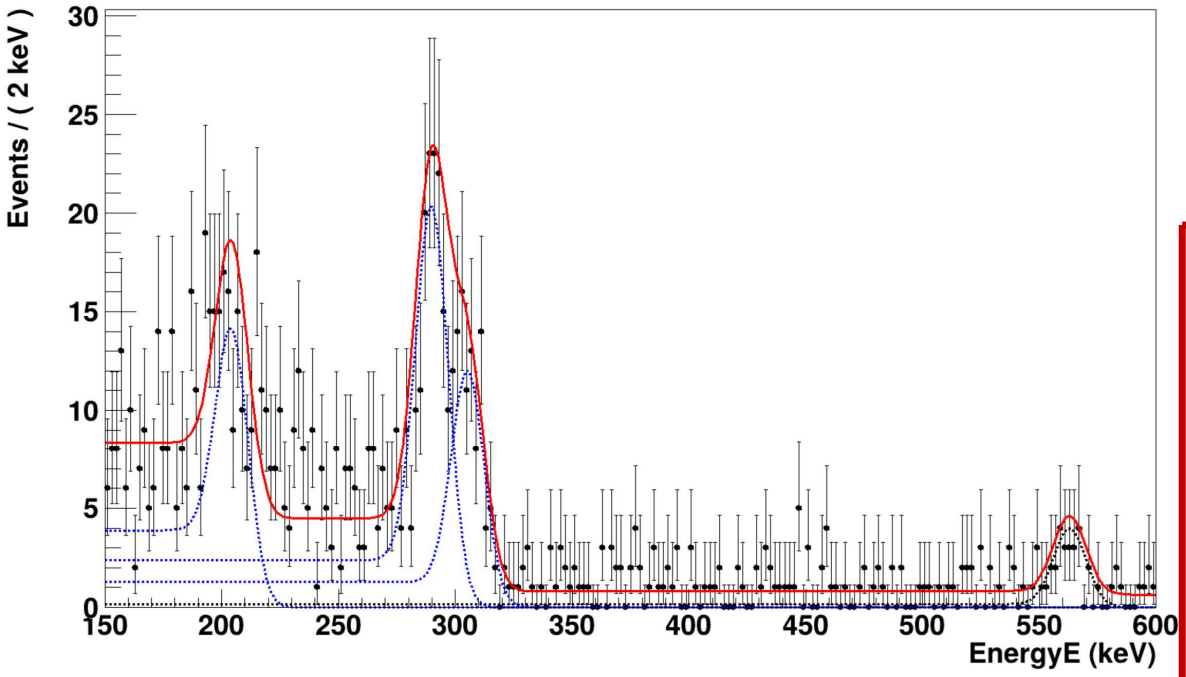


E_γ (keV)	Occurence (%)
93	45.4
89	28.1
105	16.3
108	4.1



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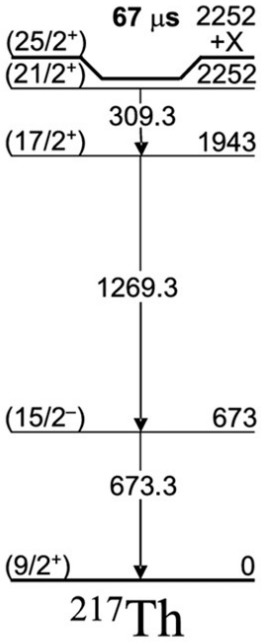

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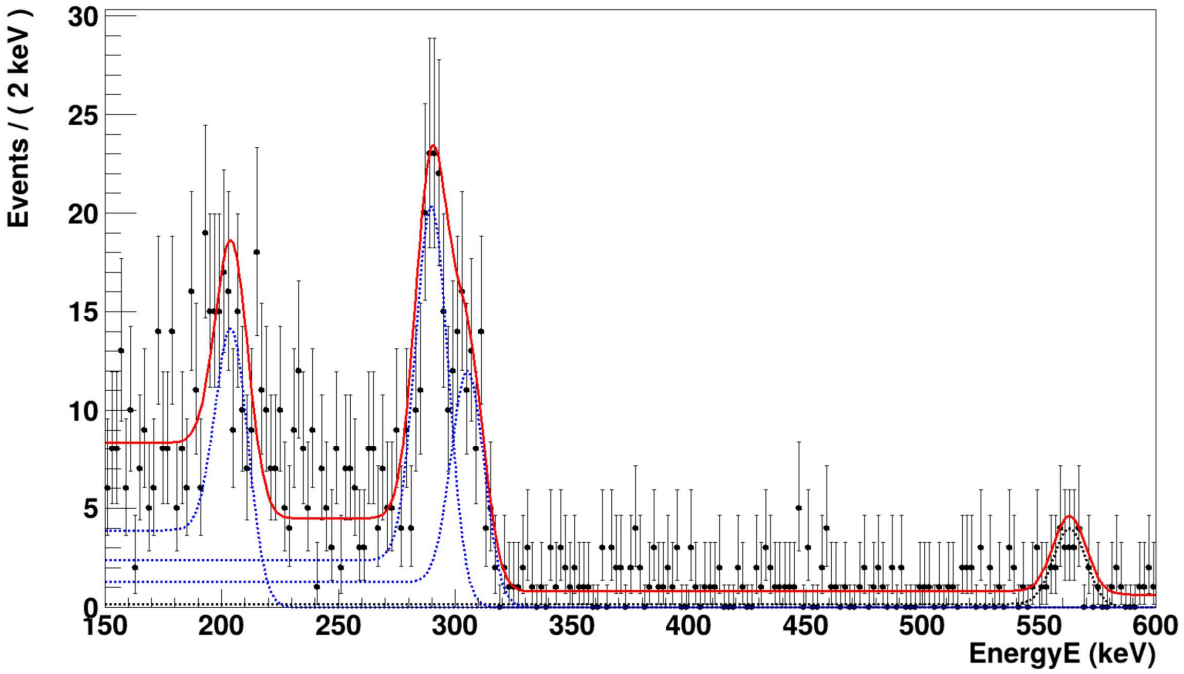
→ 35.6% surplus

→ 37.1% surplus



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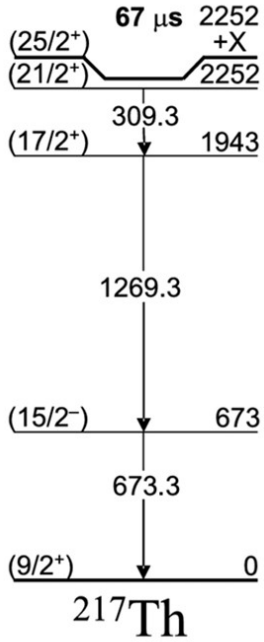
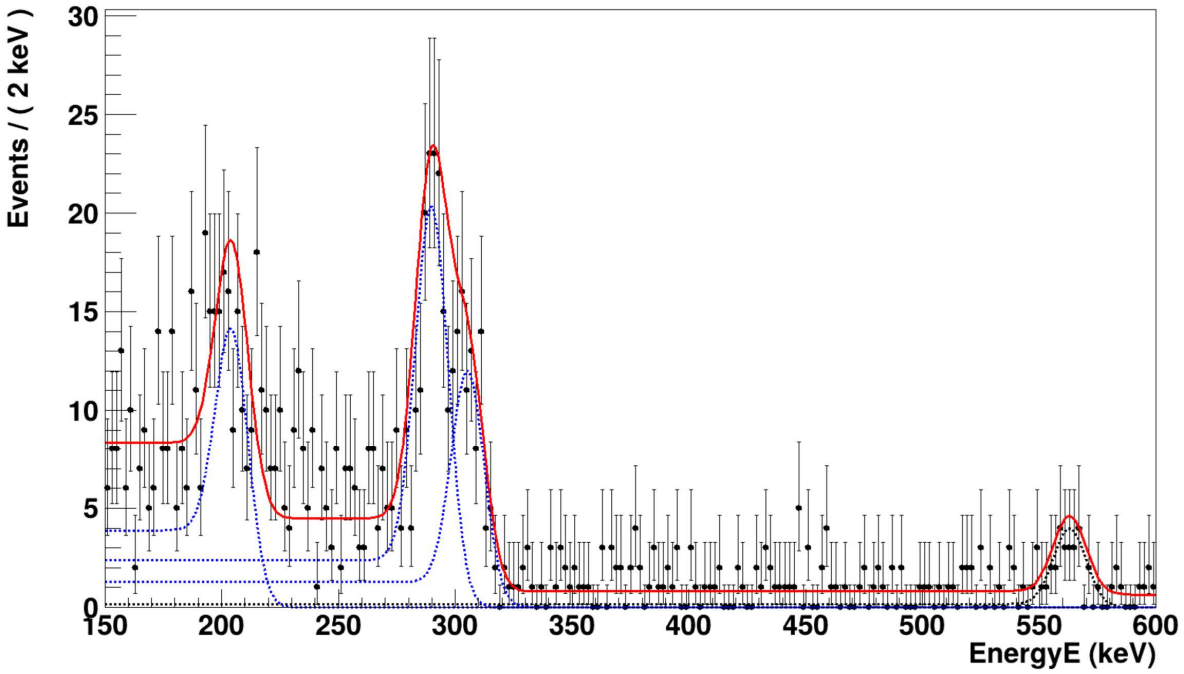


- $\frac{N_{309\,keV}}{N_{673\,keV}} = 0.40 \pm 0.03 \neq 1$



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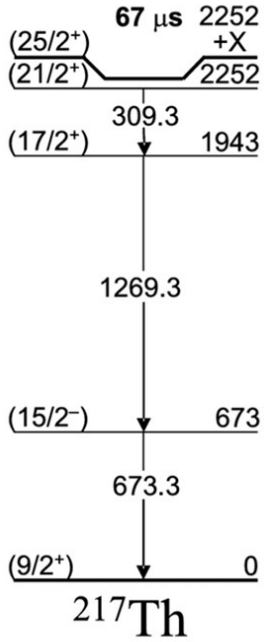
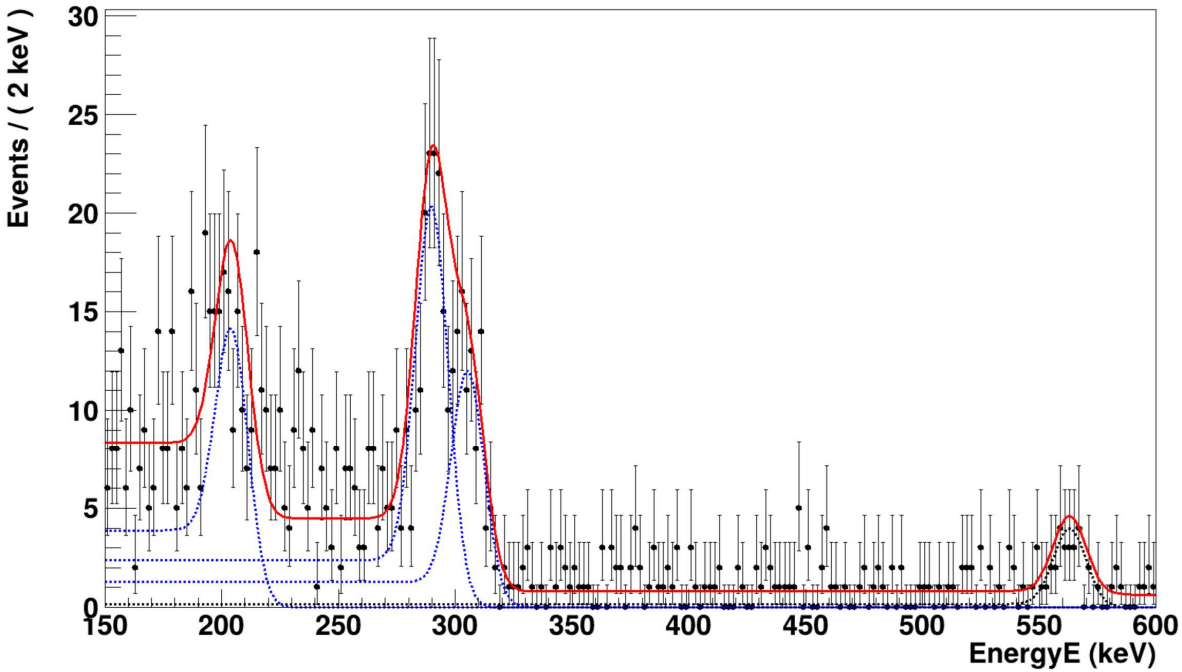


- $\frac{N_{309\,keV}}{N_{673\,keV}} = 0.40 \pm 0.03 \neq 1$ ⟶ Not a single cascade



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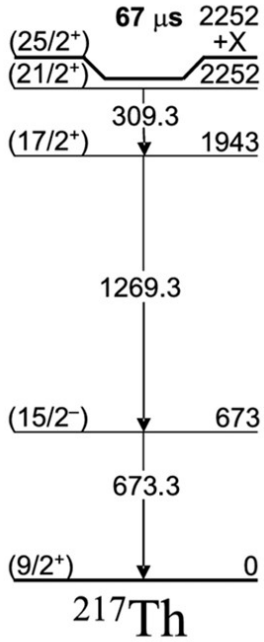
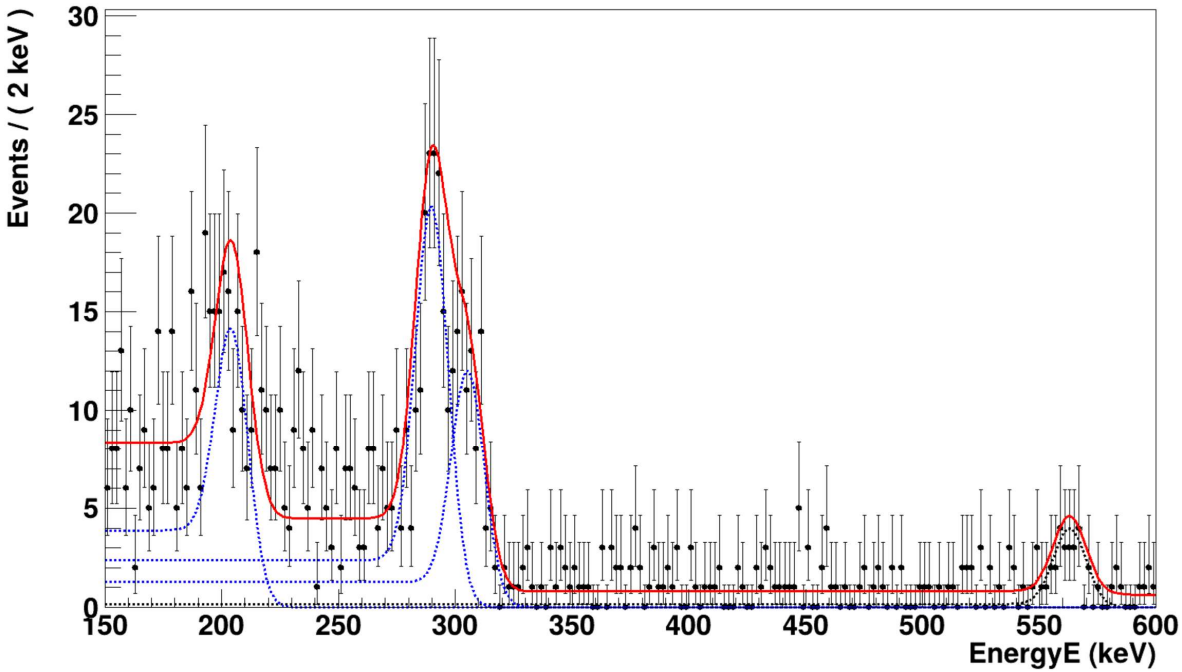


- $\frac{N_{309\,keV}}{N_{673\,keV}} = 0.40 \pm 0.03 \neq 1$ ⟶ Not a single cascade
- The 309 keV transition isn't an E2 but an E3 → longer half-life expected



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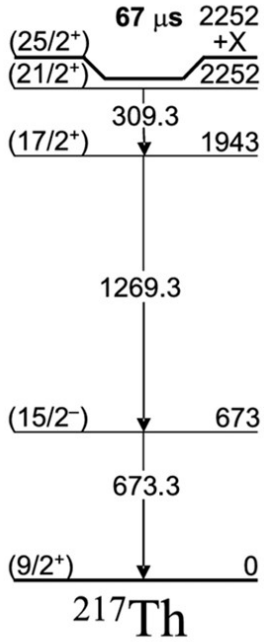

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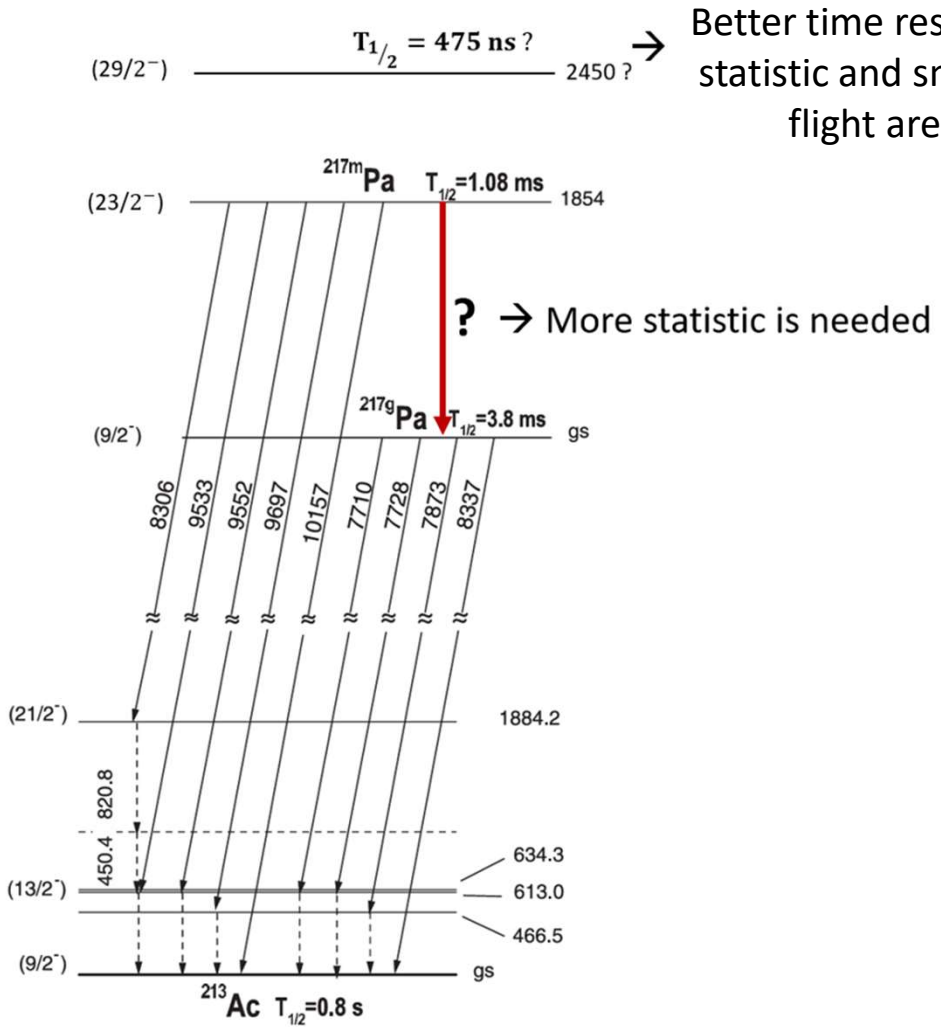
This transition deexcites the isomer

What about 217Pa ?



→ Better time resolution, more statistic and smaller time of flight are needed

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F.P. Heßberger, et al., Eur. Phys. J. A 15, 335–342 (2002).

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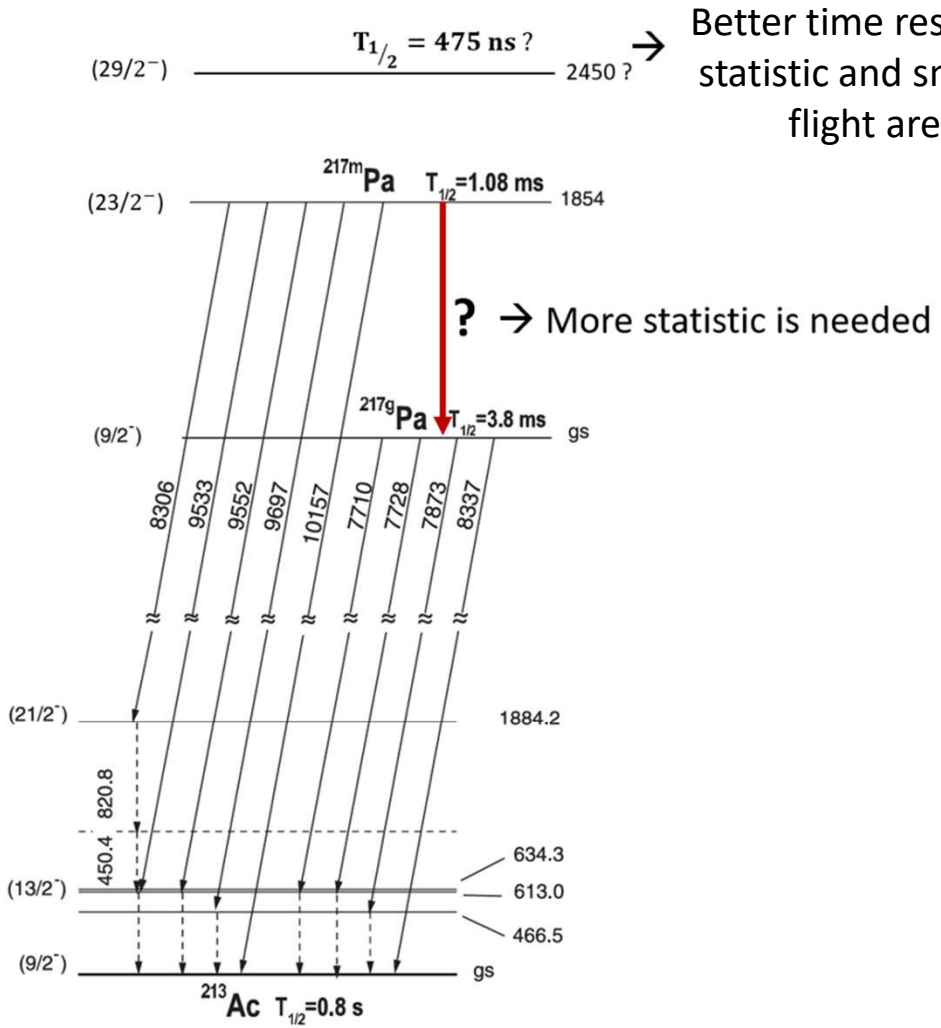

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→ Better time resolution, more statistic and smaller time of flight are needed

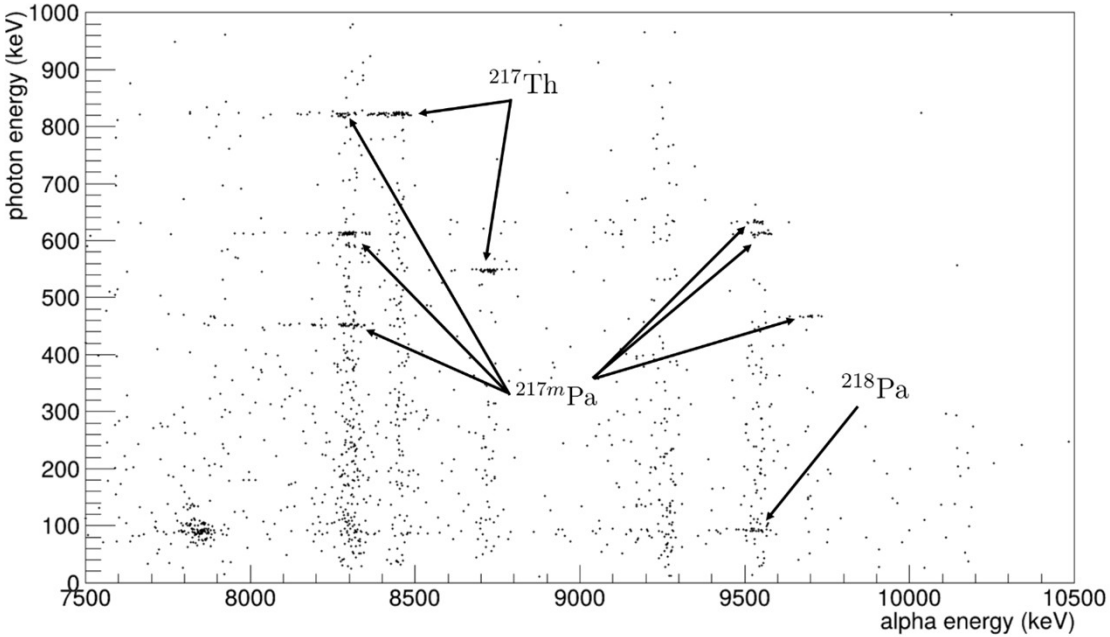
JYFL (Finland) experiment in December:

- Time resolution $\times$ 100
- Statistic $\times$ 60
- Smaller separator → smaller time of flight

What remains to be done during the last month of internship

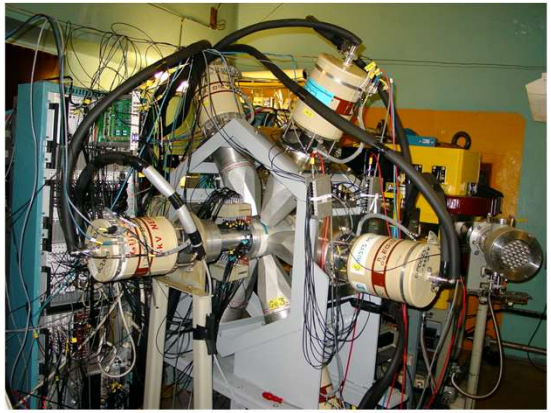
Alpha-gamma / Alpha-ICE correlations → Information about the structure of daughter nuclei

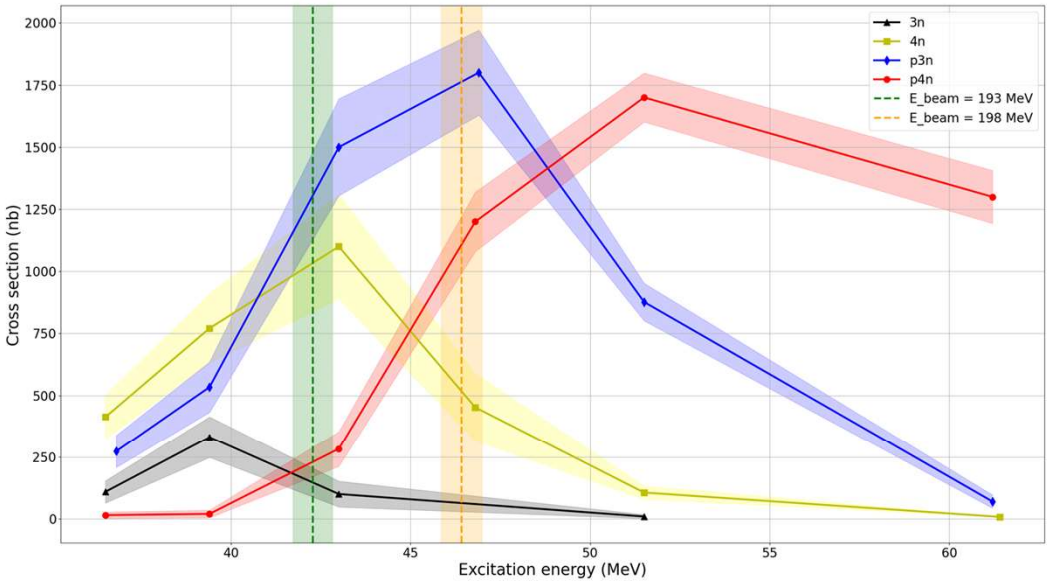
Alpha-gamma / Alpha-ICE correlations → Information about the states of parent nuclei from the hindrance factor

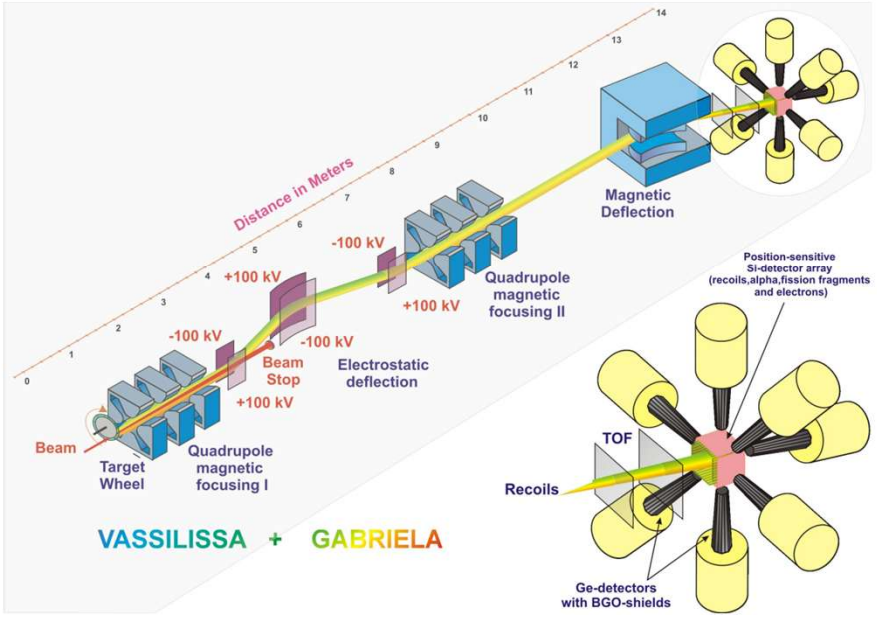


Conclusion

$$^{40}\mathrm{Ar} + ^{181}\mathrm{Ta} \longrightarrow ^{221}\mathrm{Pa} \longrightarrow \begin{cases} ^{217}\mathrm{Th} + p3n \\ ^{216}\mathrm{Th} + p4n \\ ^{217}\mathrm{Pa} + 4n \\ ^{218}\mathrm{Pa} + 3n \end{cases}$$







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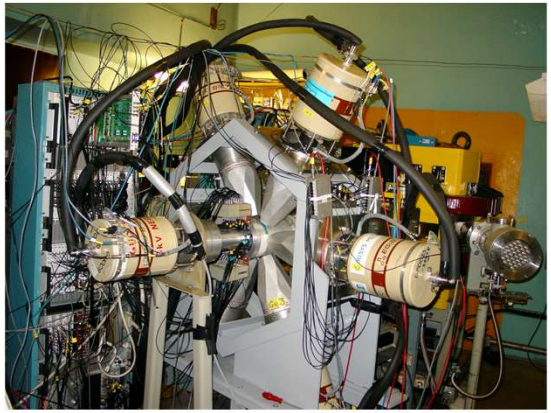

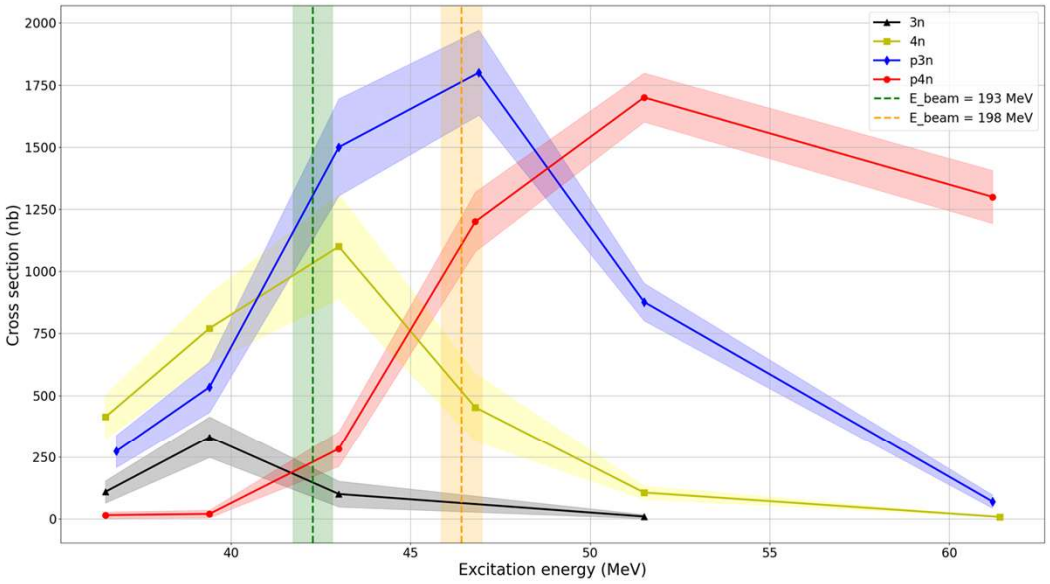

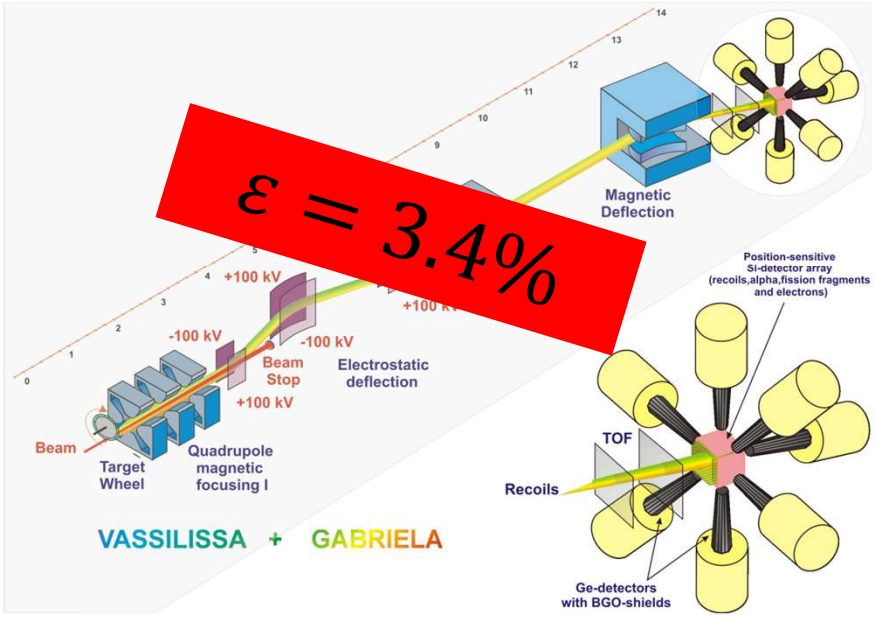

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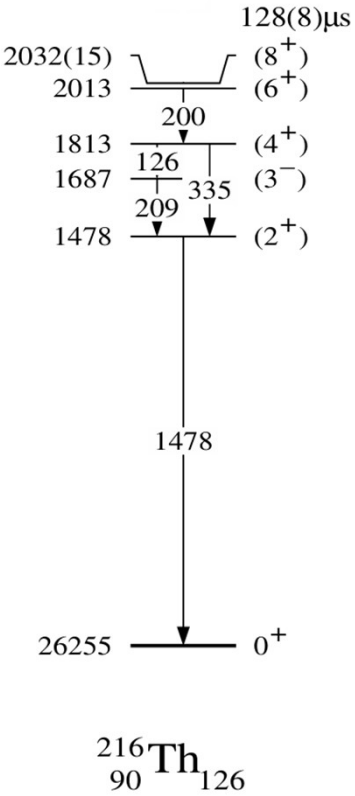
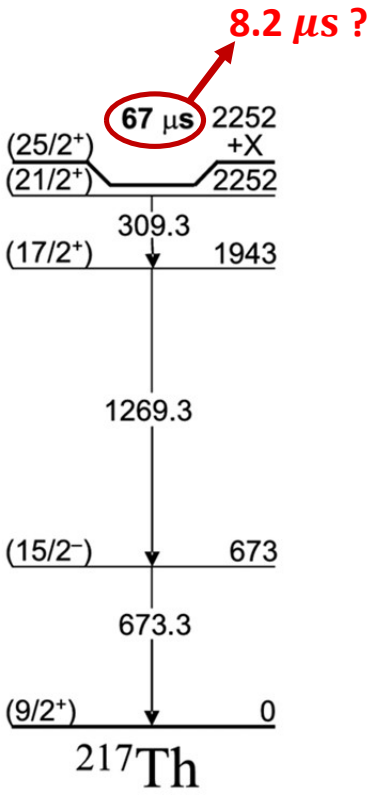


$^{216}_{90}Th_{126}$

K. Hauschild, et al., Phys. Rev. Lett. 87, 072501 (2001).



^{217}Th

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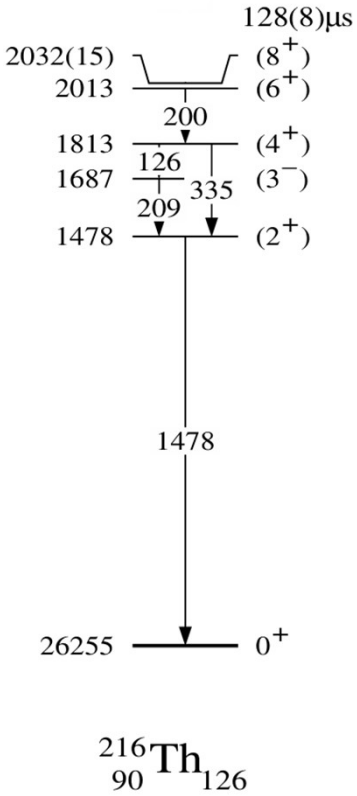
Conclusion



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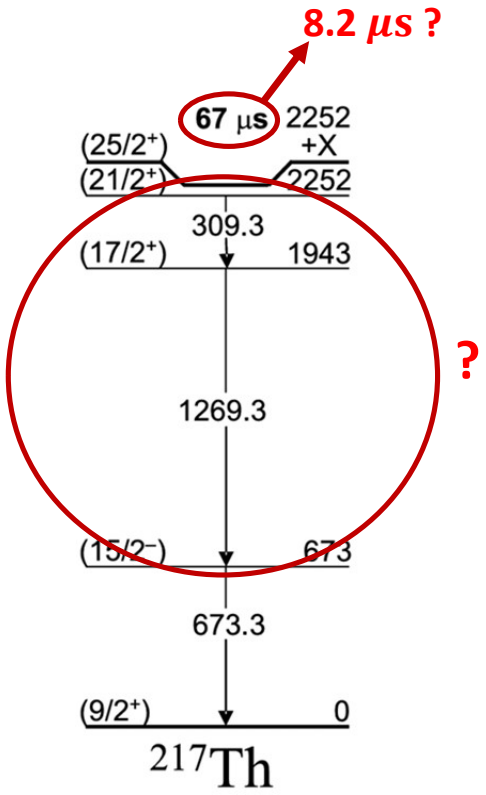

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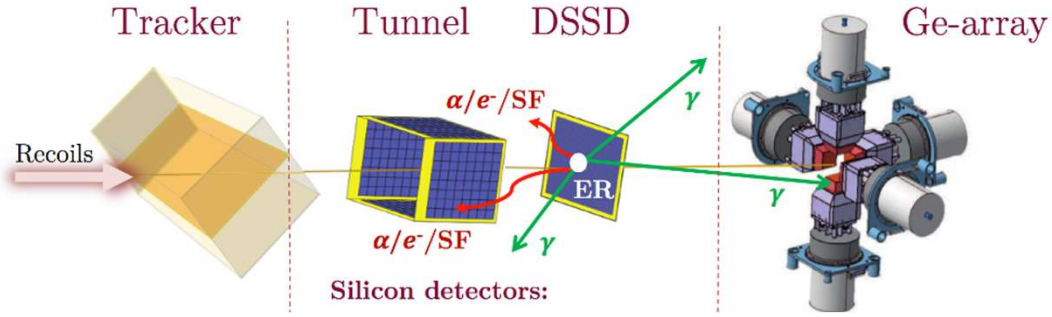
Perspectives

Physics department of the Jyväskylä university



Sirius at the focal plane of S3 + upgrade SHEXI