NORWEGIAN NUCLEAR RESEARCH CENTRE

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Nordic Network for Diversity in Physics

Investigating nuclear shape transitions through lifetime measurements.

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(they/them)

University of Oslo

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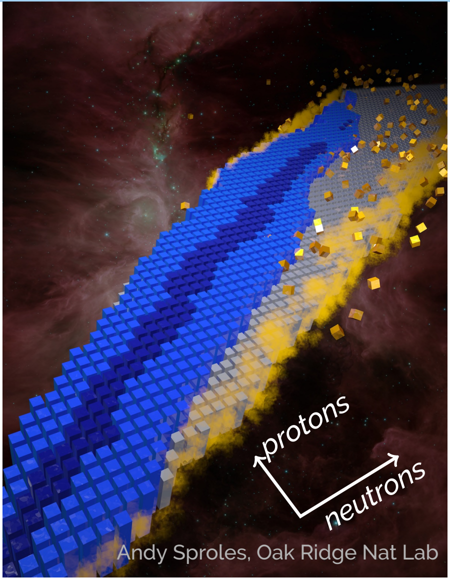
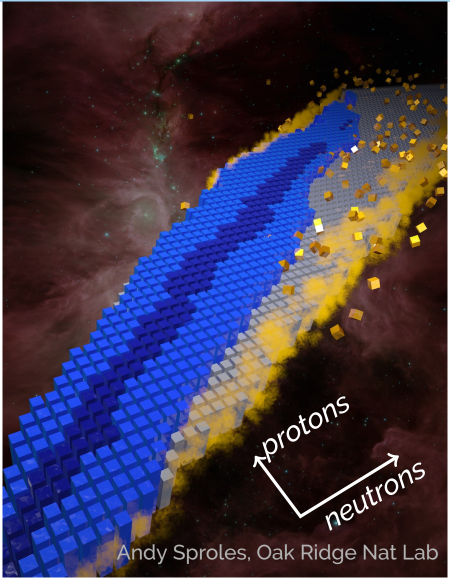
UNIVERSITY OF OSLO

Nuclear Structure

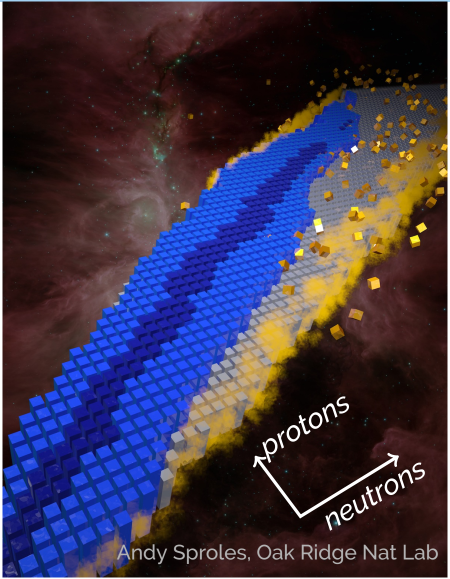


Nuclear Structure



How are nuclei created?

Nuclear Structure

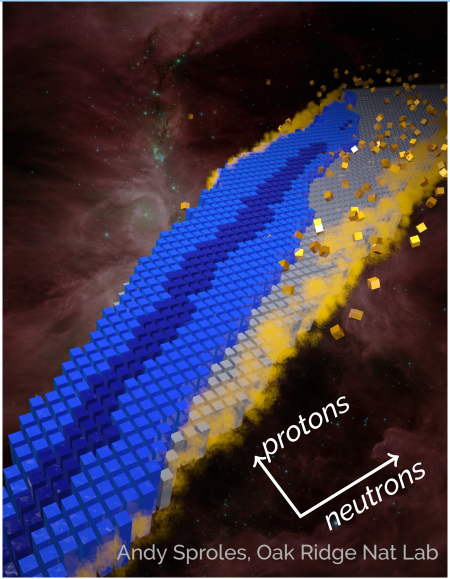


How are nuclei created?

Heavy nuclei:

- too big for first principles
- not quite statistical

Nuclear Structure



How are nuclei created?

Heavy nuclei:

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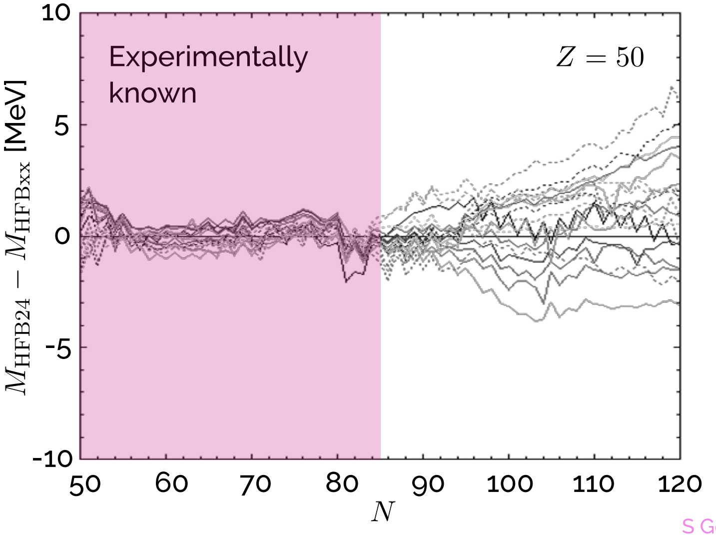
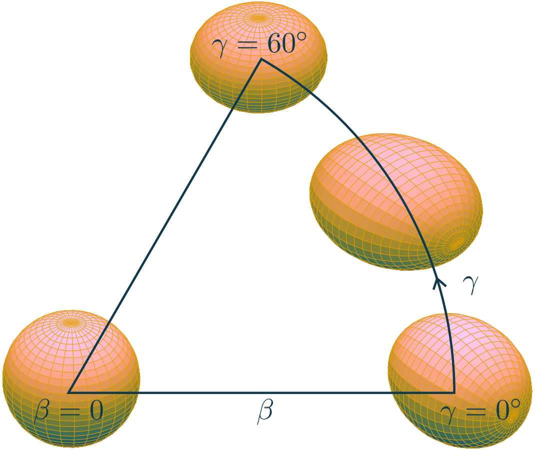
phenomenological models

Nuclear models diverge



S Goriely, ULB, Belgium

Nuclear Shapes



Macroscopic manifestation of nucleon interactions.

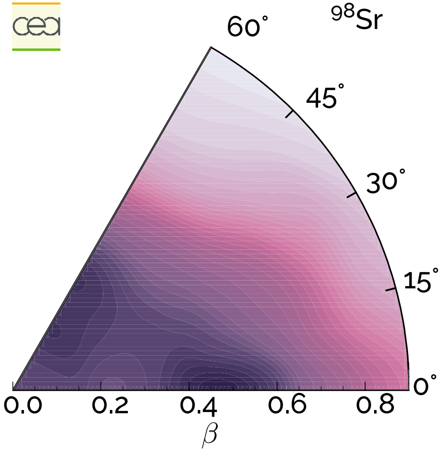
Quadrupole shape:

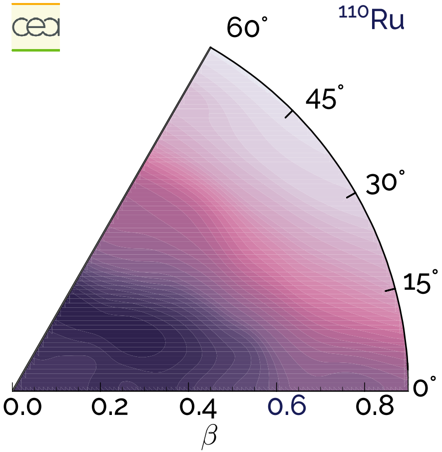
- degree of deformation β
- asymmetry angle γ

Stable nuclei are often less deformed.

Nuclear Shape Transitions

Potential energy as a function of deformation:

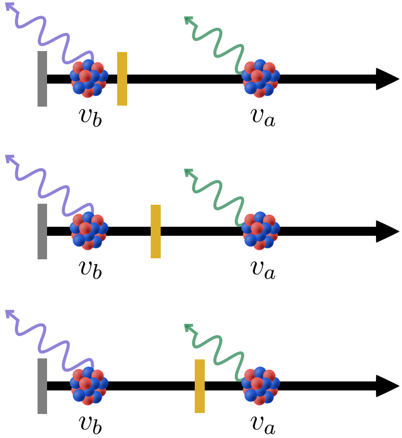


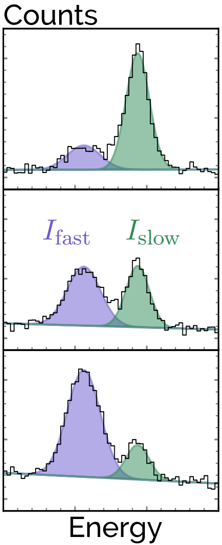


Nuclear Lifetimes

- Different configurations of nucleons
  $\Rightarrow$ different energy, spin and parity states.
- The nucleus seeks the lowest energy state.
  $\Rightarrow$ decays by emitting γ-rays.
- Lifetime of excited states is closely linked to deformation.

The Recoil Distance Doppler Shift Method





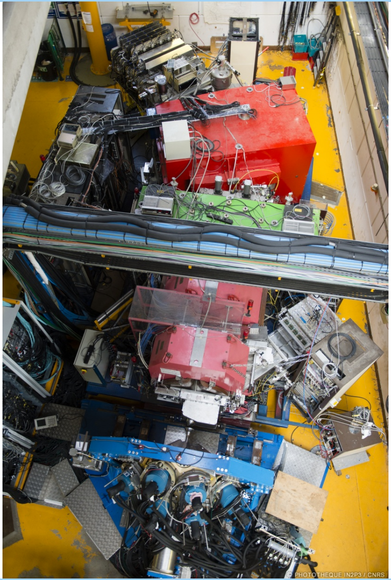
Time too short to measure:
work in distance

Different doppler shift before and after degrader

10 distances:
43 µm to 2664 µm

$\sim$ 18 h per distance

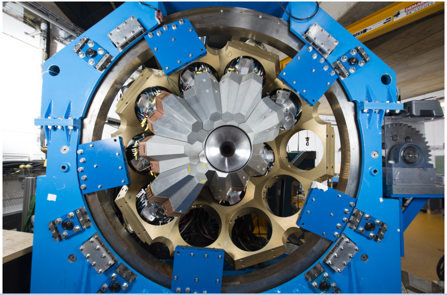
AGATA and VAMOS++



Produce nuclei in excited states.

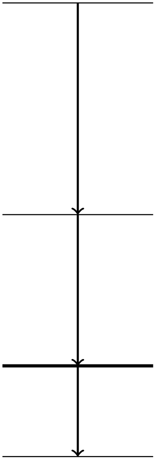
Measure γ-ray energies and

Which nucleus they came from.



Analysis techniques

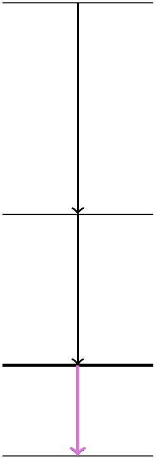
Single γ-ray



γ-γ coincidence

Analysis techniques

Single γ-ray



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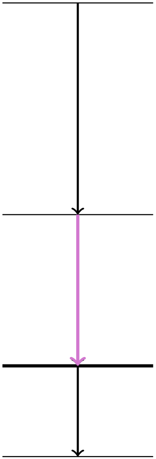
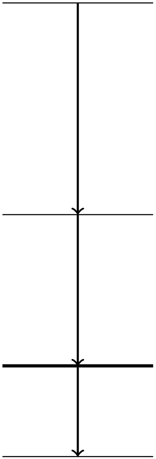


γ-γ coincidence

Analysis techniques

Single γ-ray

Can use all the detected γ-rays
$\Rightarrow$High statistics



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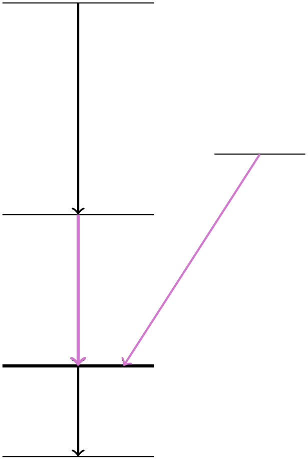
Side feeding

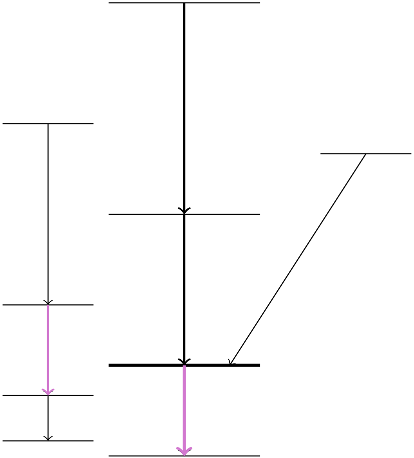


γ-γ coincidence

Analysis techniques

Single γ-ray

γ-γ coincidence



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Side feeding

contaminants

Analysis techniques

Single γ-ray

Can use all the detected γ-rays
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Side feeding

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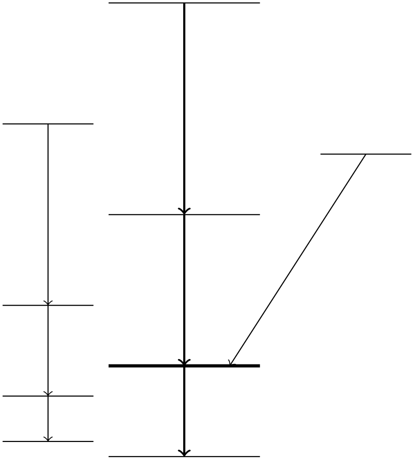

γ–γ coincidence

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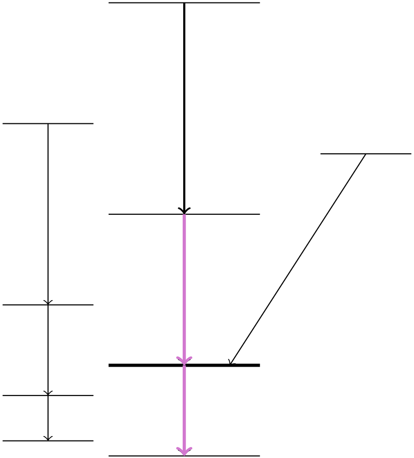

γ-γ coincidence

Only γ-rays detected together
$\Rightarrow$Low statistics

Analysis techniques

Single γ-ray

Can use all the detected γ-rays
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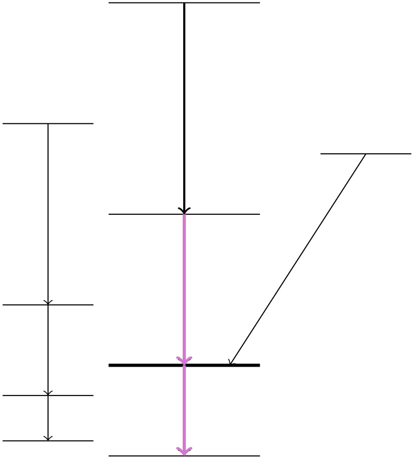
Side feeding

contaminants



γ-γ coincidence

Only γ-rays detected together
$\Rightarrow$Low statistics

Eliminates side feeding and contaminants

Results

Confirmed shape coexistence in zirconium (Pasqualato *et al.*, EPJ A 2023)

Evidence of rigid triaxiality in ruthenium (Preliminary)

Thank you

Allmond, J. M.[1] Ansari, S.[2] Arici, T.[3] Beckmann, K. S.[4] Berry, T.[5] Bruce, A. M.[6]
Clement, E.[7] Doherty, D.[5] Dudouet, J.[8] Esmaylzadeh, A.[9] Gamba, E.[6]
Gerhard, L.[9] Gerl, J.[3] Georgiev, G.[10] Görgen, A.[4] Jolie, J.[9] Ljungvall, J.[10]
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Sahin, E.[4] Siem, S.[4] Singh, P.[2] Theisen, C.[2] Tornyi, T.[17] Vandebroucke, M.[2]
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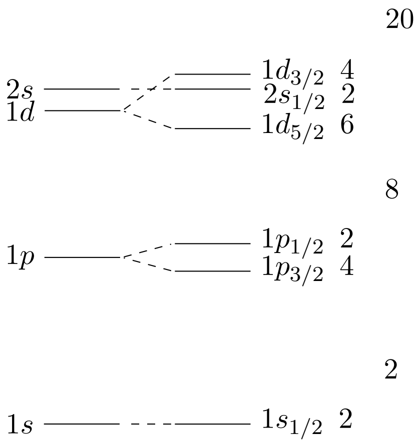
[1]Oak Ridge Nat. Lab. [2]IRFU [3]GSI [4]Univ. Oslo [5]Univ. Surrey [6]Univ. Brighton
[7]GANIL [8]IPN Lyon [9]Univ. Koeln [10]IJCLab [11]TU Darmstadt [12]STFC Daresbu
[13]Univ. Sofia [14]Argonne Nat. Lab. [15]IN2P3/CNRS [16]HIL Warsaw [17]Debreczen

And the AGATA, FATIMA and VAMOS collaborations.

Summary

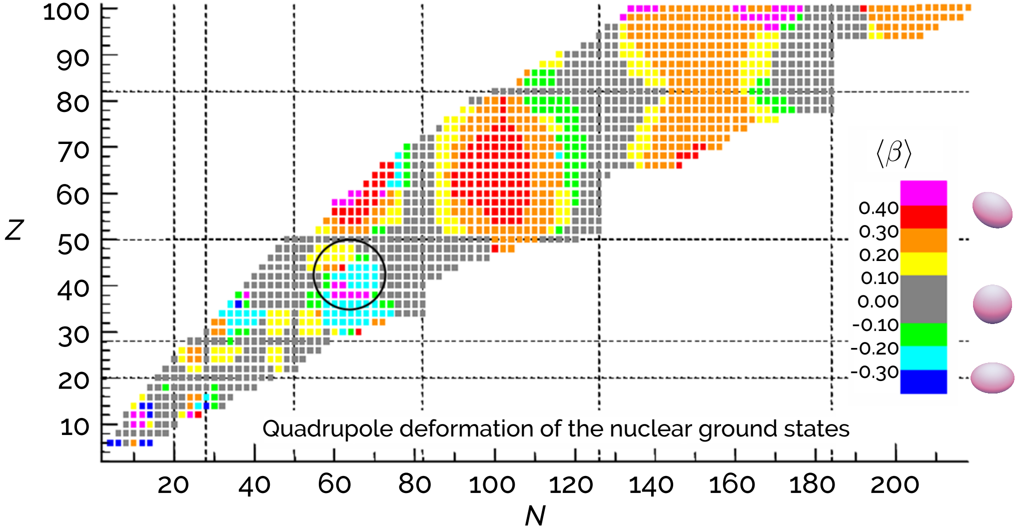
- Overarching goal: understand how nuclei are created.
- Nuclear models diverge: we need experimental data to constrain them.
- Compare predicted and experimental deformation.
- We determine deformation through lifetimes of excited states.
- Lifetimes $\mathcal{O}(\text{ps}) \Rightarrow$ measure distance travelled.

The Nuclear Shell Model

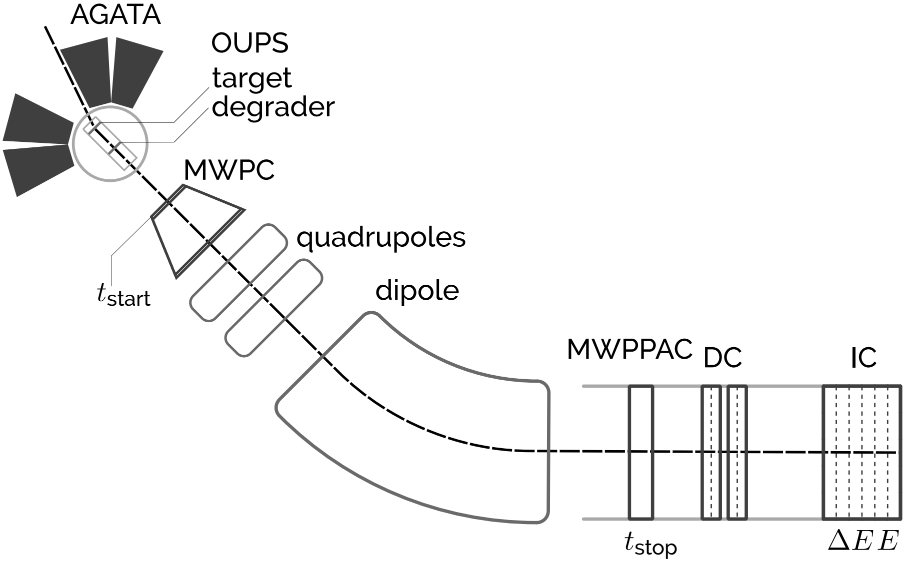


- Protons and neutron are separate.
- Closed shells mean more stable nuclei.
- Single-particle or collective excitations.
- Nucleons influence orbital energies

The A $\sim$ 100 region



AGATA and VAMOS++



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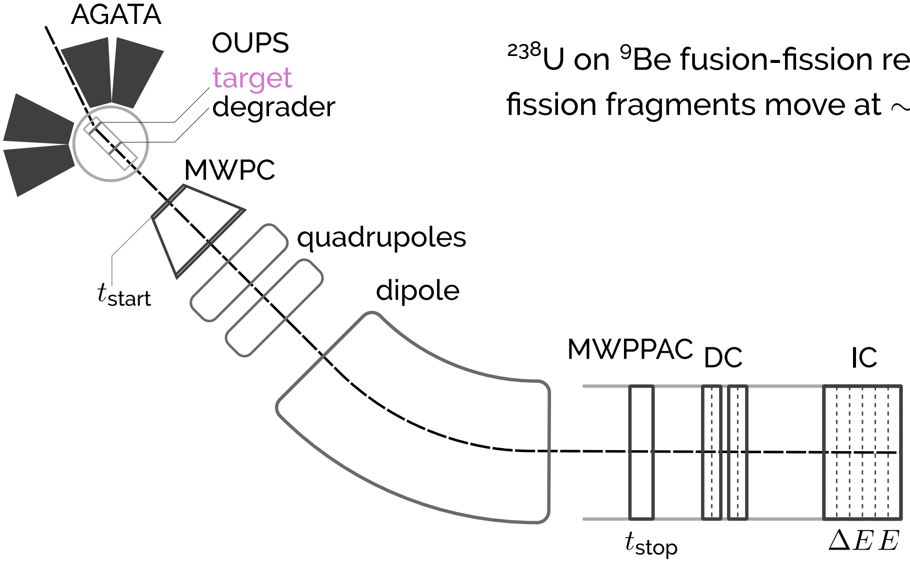

^{238}U on ^{9}Be fusion-fission reaction.

fission fragments move at $\sim$0.13 c.

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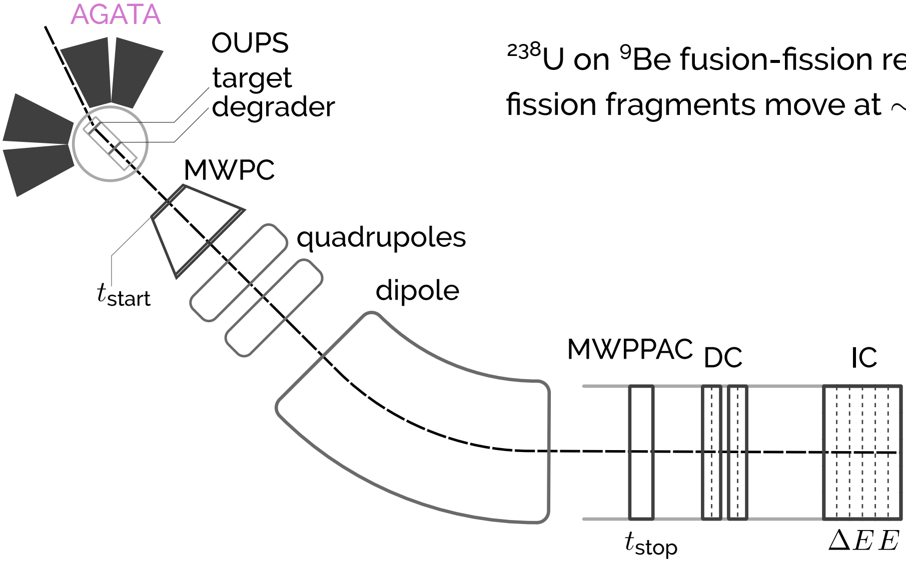

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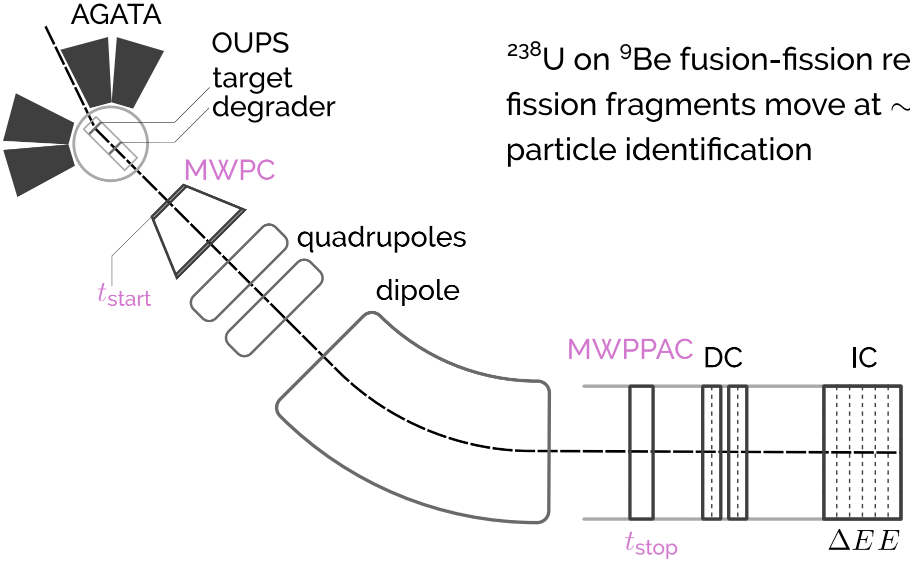

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particle identification

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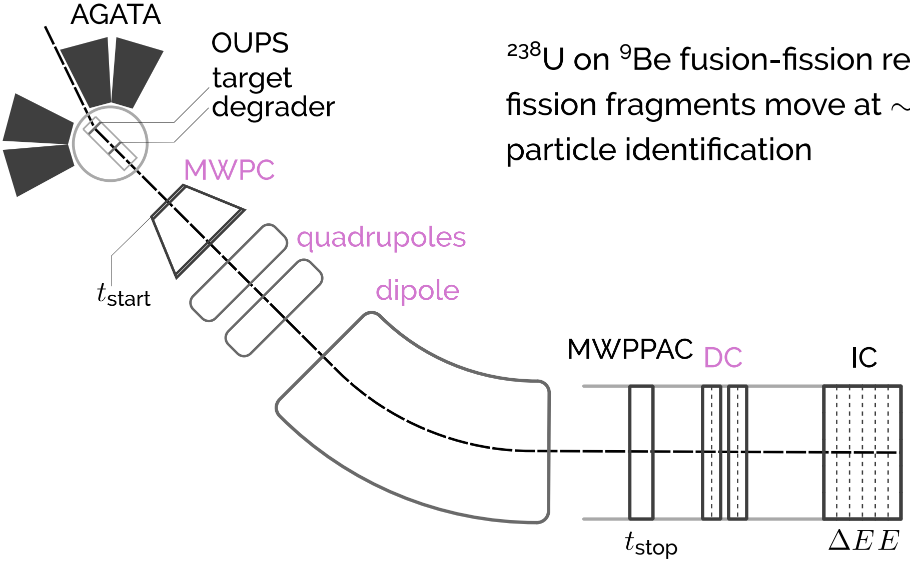

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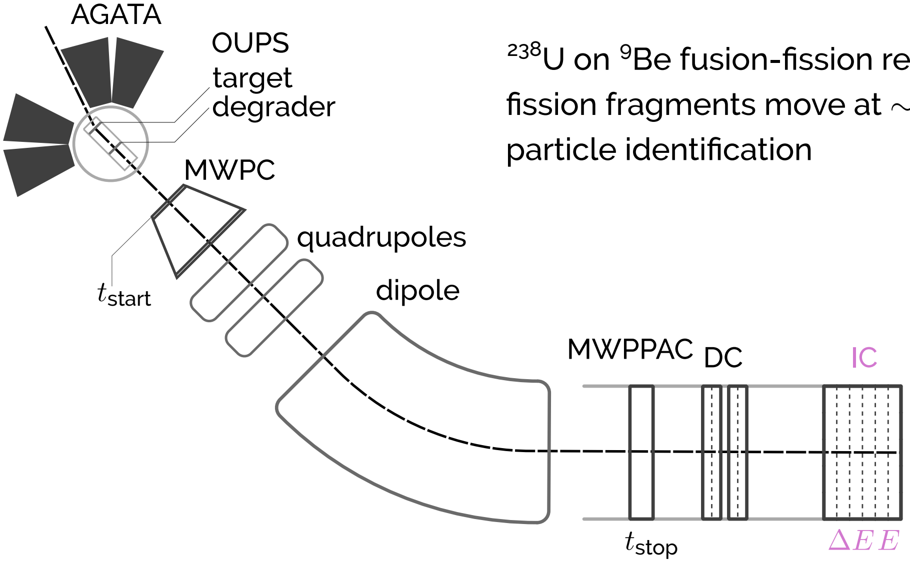

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