Novel Methods for Lifetime Measurements in Atomic Nuclei

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GSI Helmholtzzentrum für Schwerionenforschung

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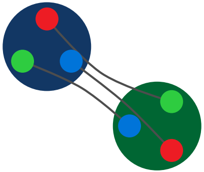
Symmetry breaking and collectivity



- atomic nuclei are relevant at all length and time scales of the Universe
- dual quantum liquid of interacting protons and neutrons
- leads to the well-known shell structure of atomic nuclei
- isospin dependence of the strong nuclear interaction
- shell evolution can change the spacing and ordering of the single-particle orbitals
  → degenerate levels in a nuclear Jahn-Teller effect
  → spontaneous symmetry breaking and quantum phase transitions
- collective quantum mechanical rotations or vibrations
- many nucleons are moving coherently in phase

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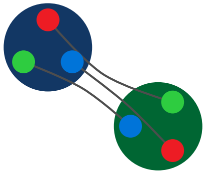

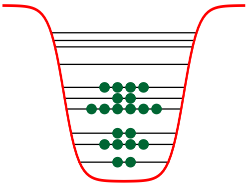

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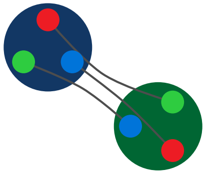

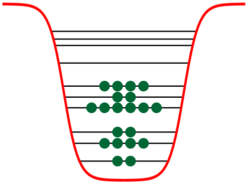

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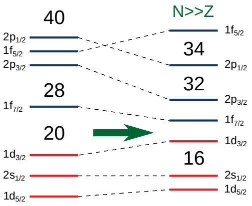

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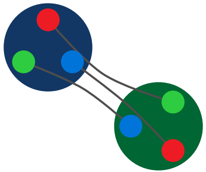

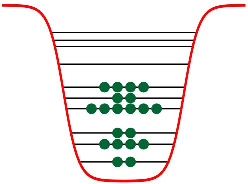

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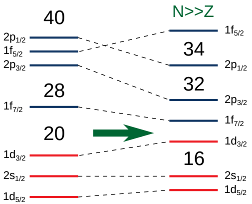

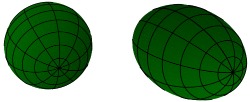

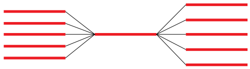

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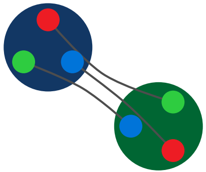

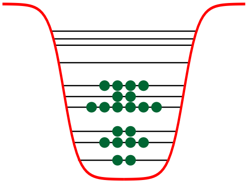

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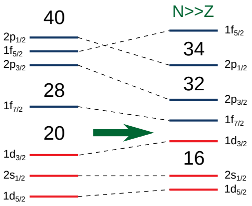
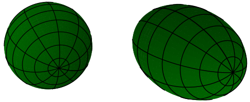
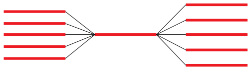


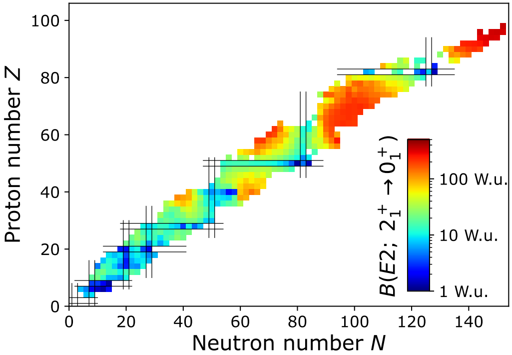




Where and how does collective motion and deformation of nuclei emerge from the single-particle degrees of freedom of the protons and neutrons?
How does this affect the structure of nuclei and their role in the Universe?

Lifetime measurements

- reduced transition probabilities measure how many nucleons participate in the excitation
- direct measure of nuclear quadrupole collectivity
- show discontinuities at shape and phase transitions
- data sparse in for exotic nuclei → opportunity for FAIR



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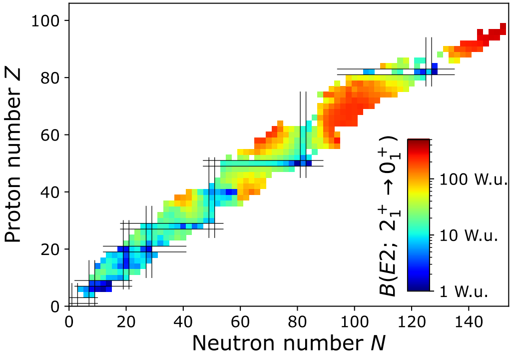

- γ rays emitted at a velocity β are subject to the Doppler effect

$$E_{\text{lab}} = E_0 \cdot \frac{\sqrt{1-\beta^2}}{1-\beta\cos\alpha}$$

- use precise measurement E_{lab} to access lifetime through velocity β and emission angle α

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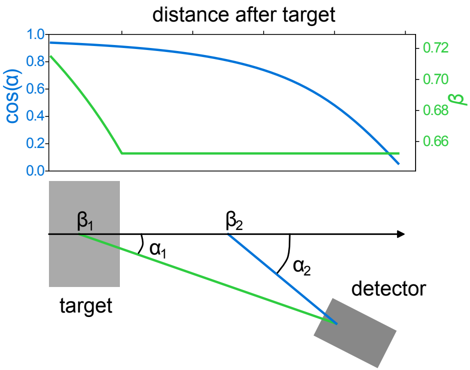

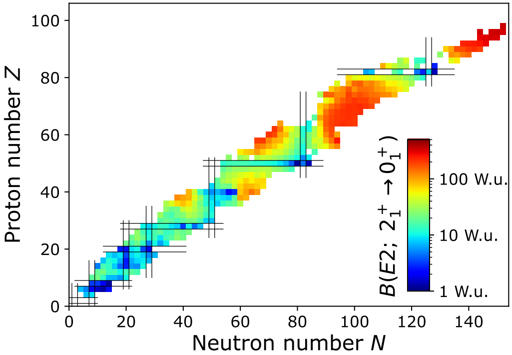

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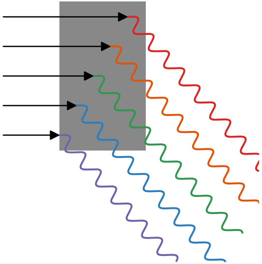
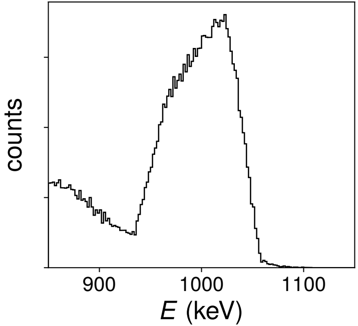
Lifetime measurements

- to access the most exotic nuclei thick targets have to be used
- reaction and emission at different velocities
- (angle dependent) spread in Doppler reconstructed spectrum
- different mean decay velocities and different depths in the target
- with an active target the resolution can be greatly improved





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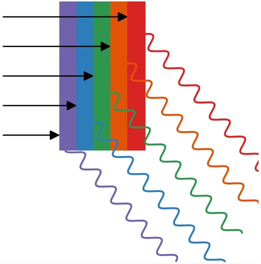

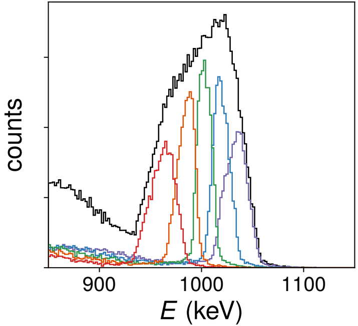

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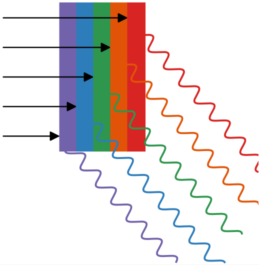

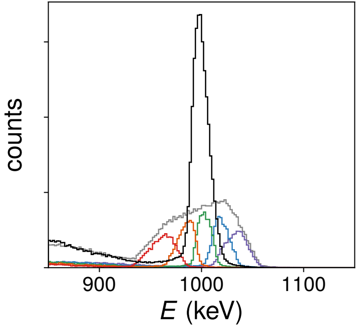

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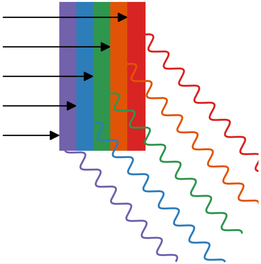
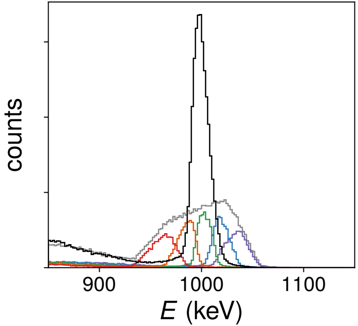


LIfetime measurements with Solid Active targets



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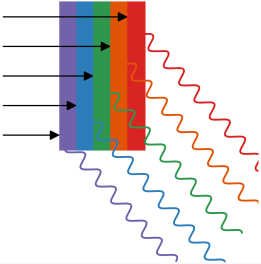
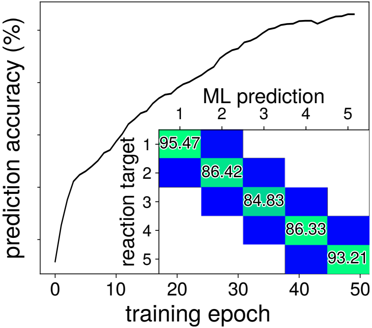


LIfetime measurements with Solid Active targets

- array of CVD single-crystalline diamond detectors
- measure element-specific energy loss
- fast readout and charge sensitive electronics, ML analysis
- reaction point reconstruction $\rightarrow$ correct α and β



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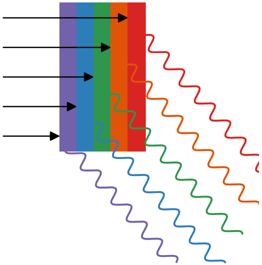

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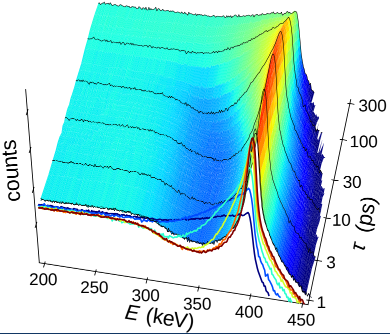

removes present limitation for in-beam γ-ray spectroscopy experiments with fast radioactive beams

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