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Lifetime measurements with SHOGUN

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Outline

- Lifetime measurements and effects for in-beam γ-ray spectroscopy
- Lifetime caused lineshapes for Ge-based RISING spectrometer
  - Simulations
  - Experimental Results
- Simulated lineshapes for SHOGUN

Lifetime Measurements and Effects for In-Beam γ-Ray Spectroscopy

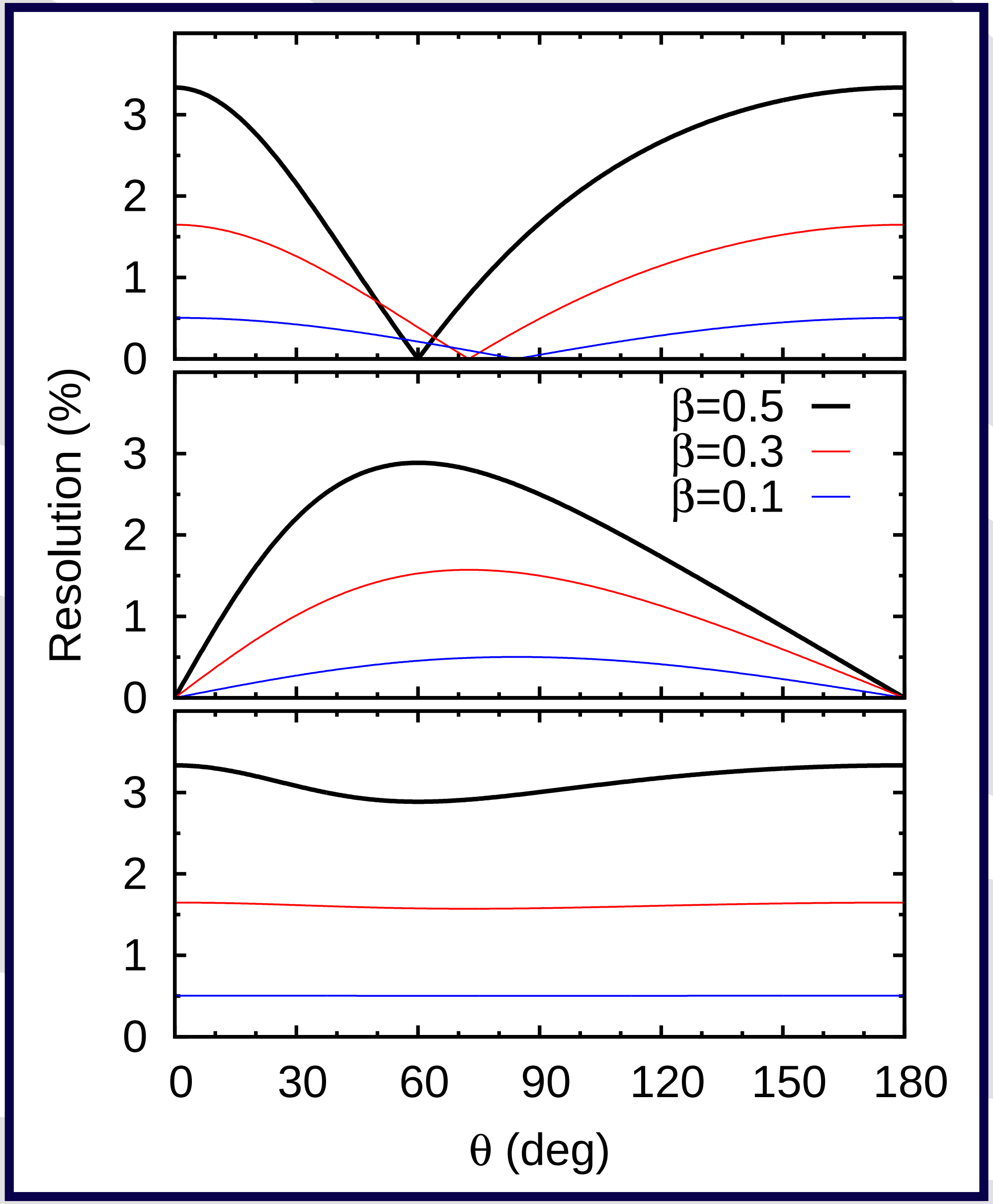
Measuring Techniques to Deduce Lifetimes of Excited States

- Direct methods:
  - Tagged spectroscopy $\rightarrow$ isomers ($\approx \mu s$)
  - γ–γ coincidence $\rightarrow$ centroid shift
    - With Ge: ns to several hundred ns
    - With $LaBr_3$: below 100 ps to several hundred ns
- Indirect methods:
  - Coulomb excitation, up to several ns
  - Recoil distance with plunger device
    - Low energies: ps to ns
    - High energies: ps to $\approx$ 100 ps
  - Doppler shift attenuation
    - Low energies: fs to several ps
    - **High energies: $\approx$ 100 fs to $\approx$ 100 ps**

Doppler Broadening Summary

- There is a sizable Doppler broadening even with a perfect detector, due to
  - Uncertainty in beam velocity (energy loss in the target)
  - Uncertainty in the emission point of the γ-ray (target thickness, lifetime of excited state)

Doppler Broadening



$|\partial E/\partial \beta| \cdot \Delta\beta$

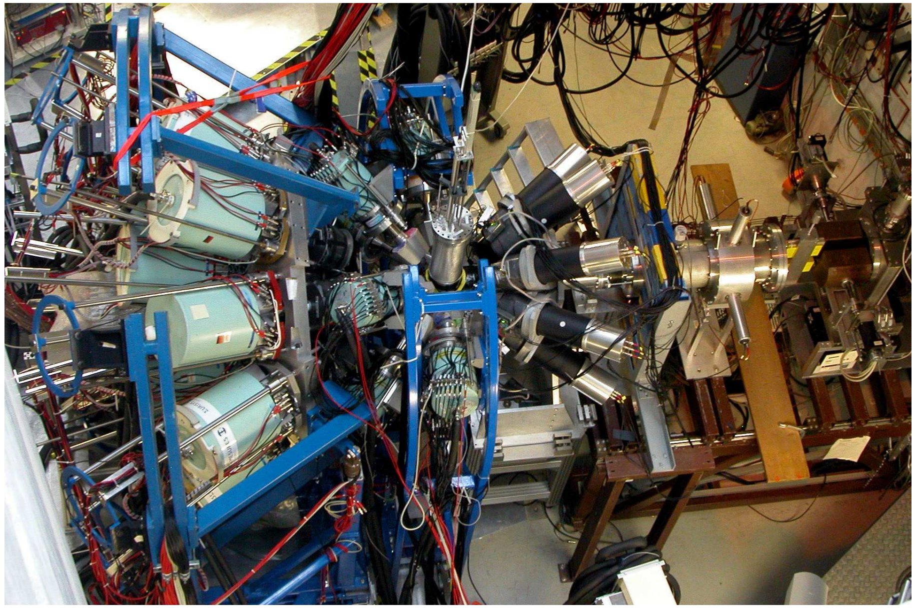
$\Delta\beta/\beta = 5\%$

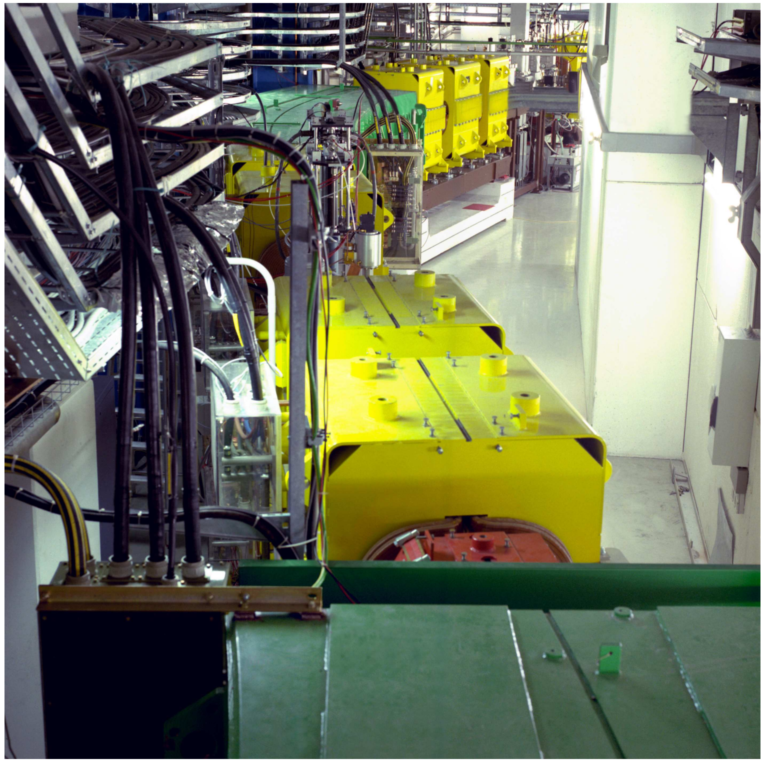
$|\partial E/\partial \theta| \cdot \Delta\theta$

$\Delta\theta = 50$ mrad

Lifetime Effects of Ge-based RISING Spectrometer

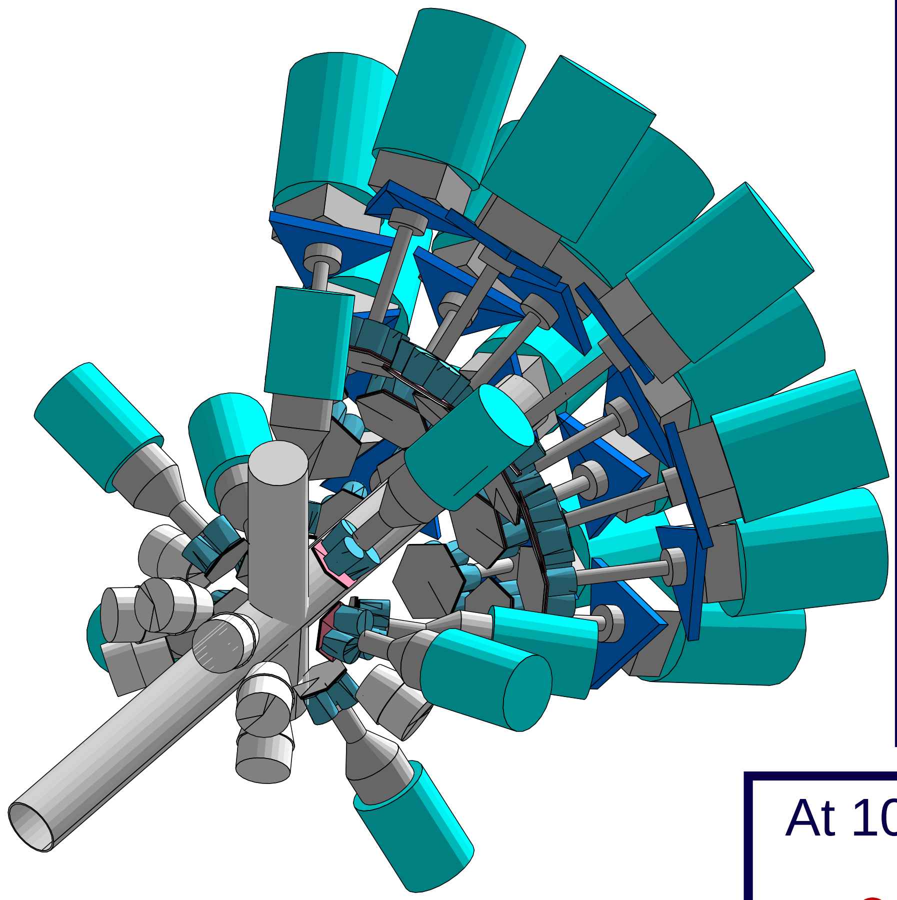
RISING Setup





- Located at GSI, Germany
- Gamma-ray spectrometer coupled to the fragment separator FRS

RISING Fast-Beam Spectrometer

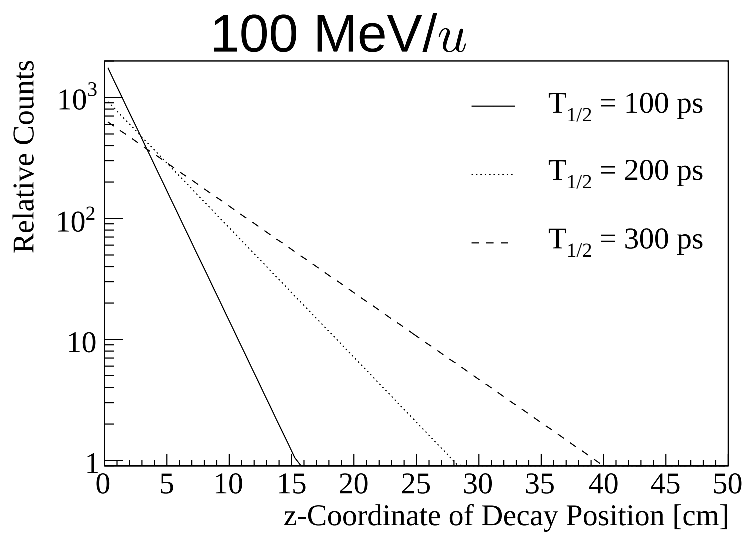


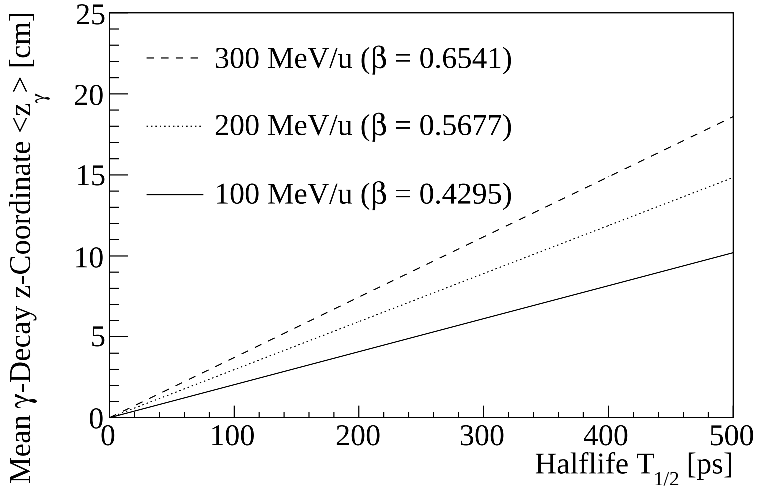
- 15 Euroball Ge Cluster detectors with 7 crystals each, in three rings at $\vartheta = 16, 33, 36°$, 700 mm to target
- 8 six-fold segmented Ge MINIBALL triple detectors, in two rings at $\vartheta = 45, 85°$, 200 mm to target
- 8 BaF_2 HECTOR detectors, in two rings at $\vartheta = 85, 145°$, 350 mm to target

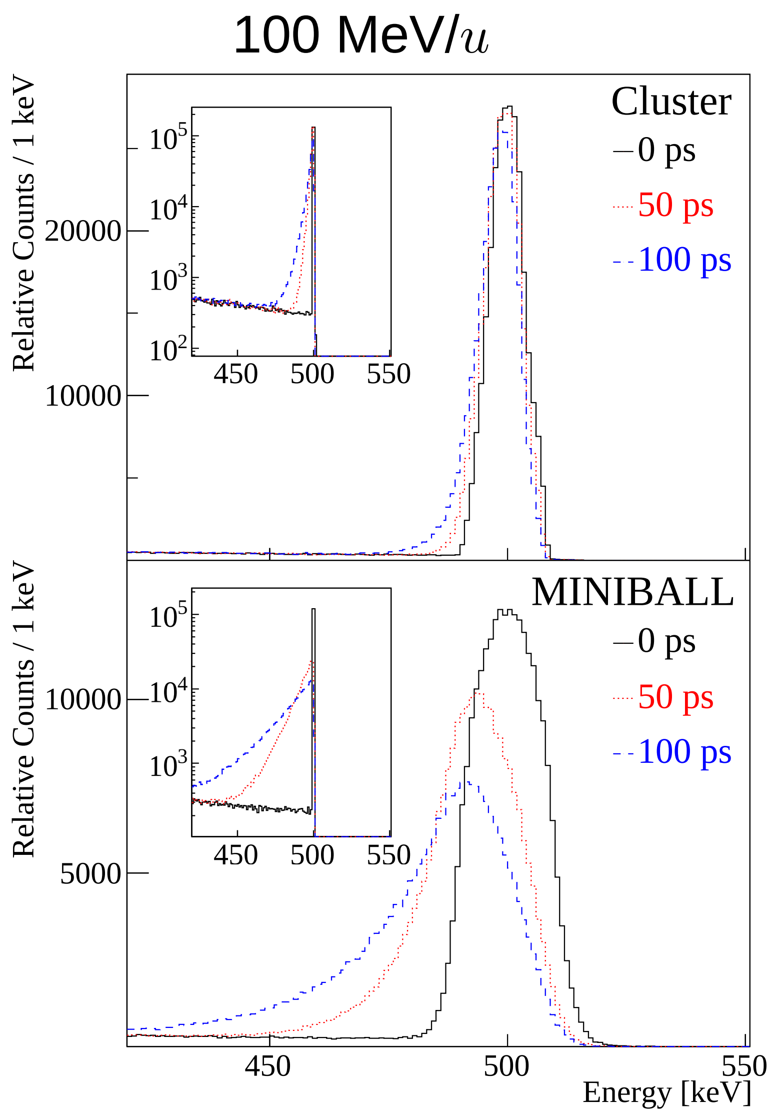
At 100 MeV/u, 1 MeV γ-ray energy:

- Euroball: $\Delta E/E = 1.9\%$, $\epsilon_\gamma = 2.8\%$
- MINIBALL: $\Delta E/E = 3.4\%$, $\epsilon_\gamma = 3.0\%$

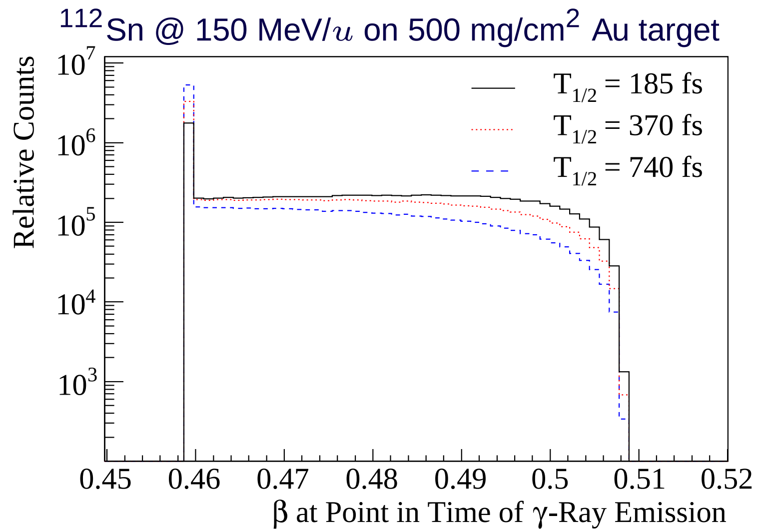
Lifetime Effects: $\Delta\vartheta$

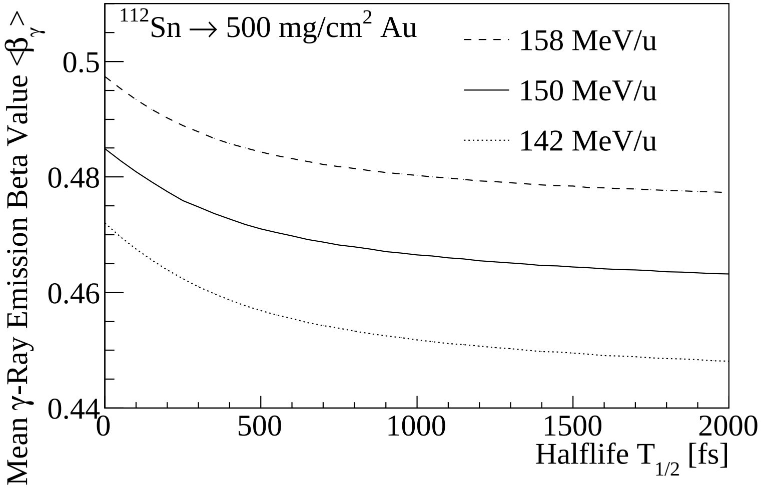


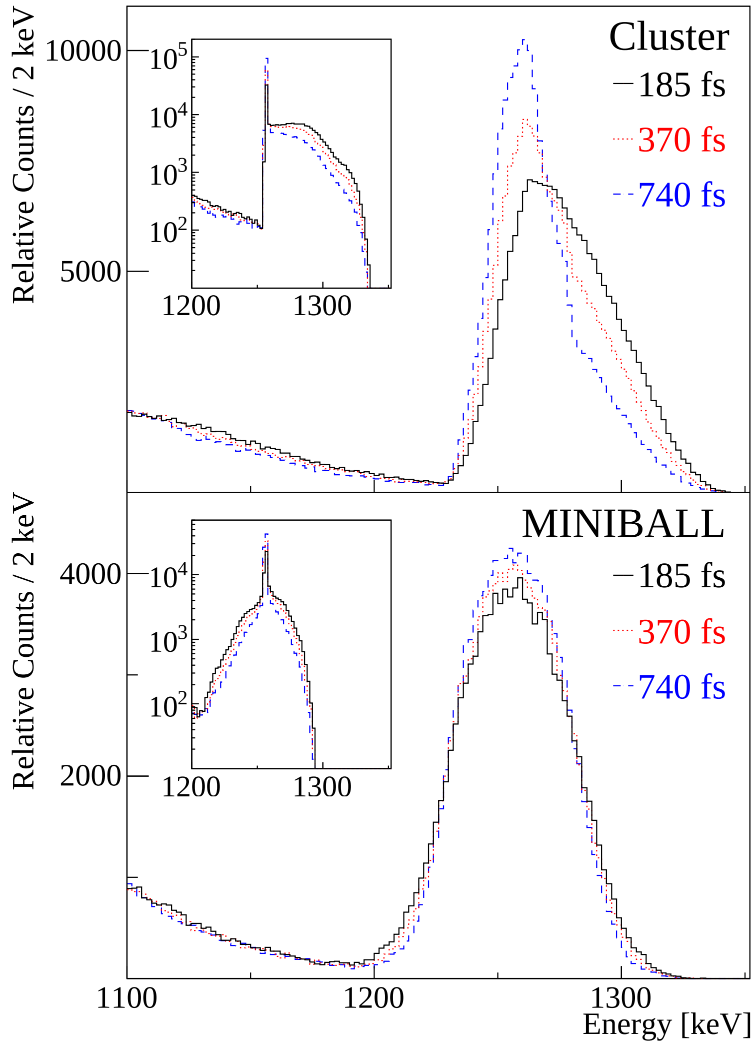




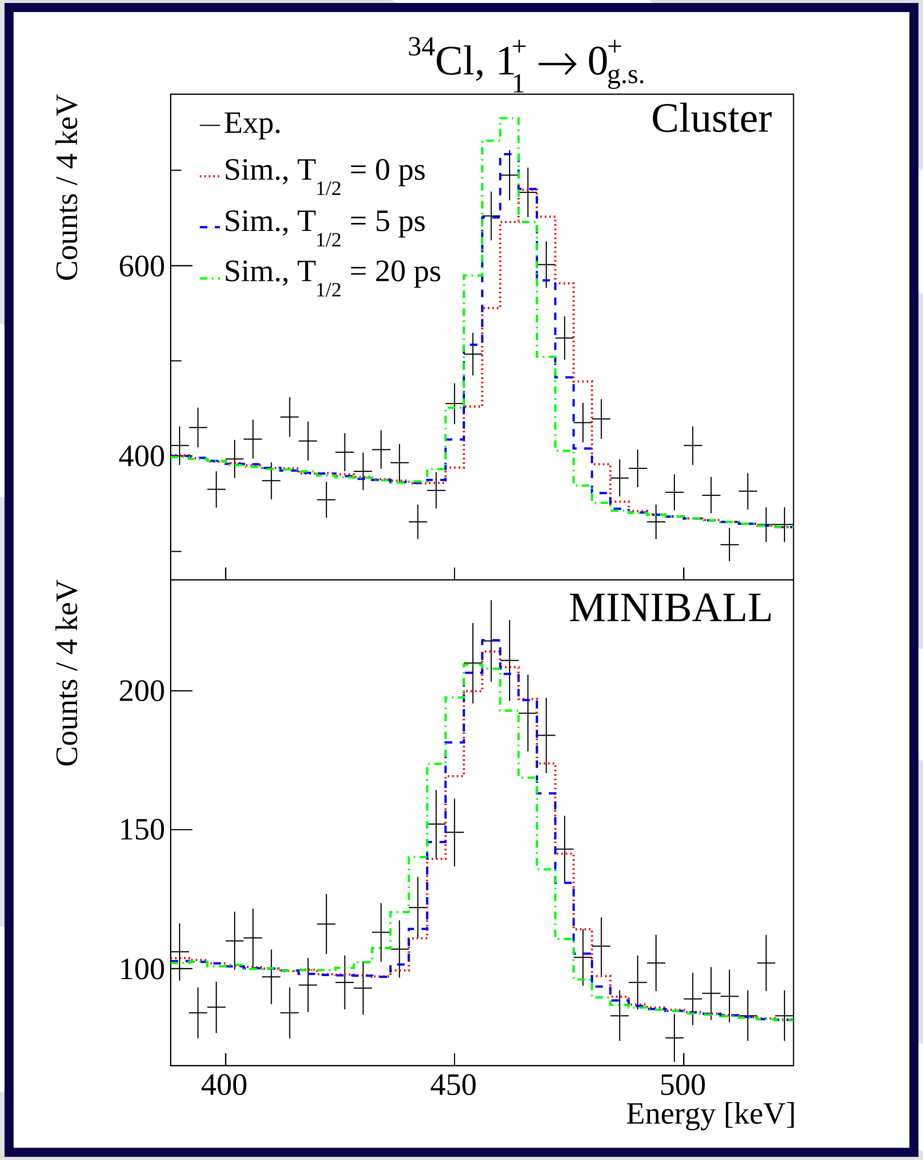
Lifetime Effects: $\Delta\beta$

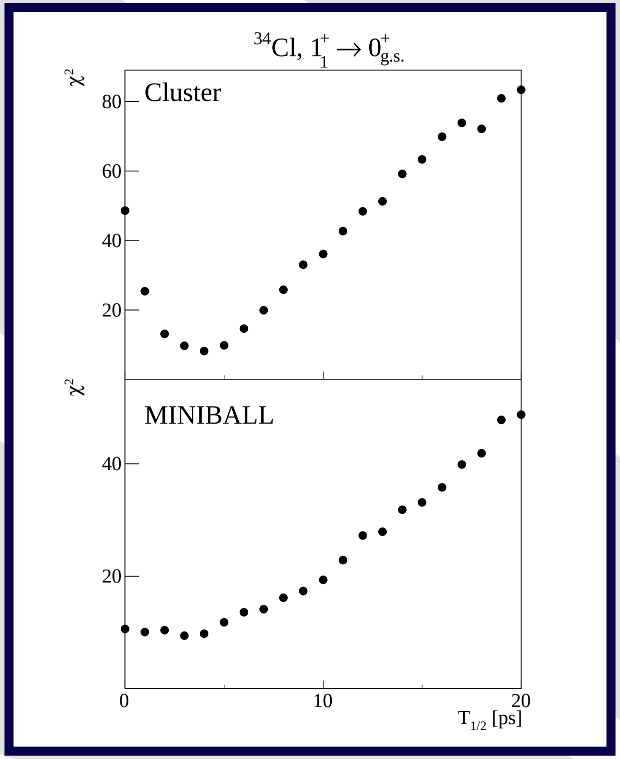






Experimental Results





- Secondary beam: ^{37}Ca @ 200 MeV/u
- 700 mg/cm^2 Be secondary target
- $E(1_1^+ \rightarrow 0^+_{g.s.}$ = 461 keV, $T_{1/2}$ = 5.2(3) ps
- Exp: $T_{1/2}$ =4.0±0.9(stat)$^{+1.3}_{-0.9}$(sys) ps

Lifetime Effects Summary

- The unavoidable Doppler broadening in $\Delta\vartheta$ and $\Delta\beta$ can be exploited to deduce excited states' lifetimes
- Characteristics for $\Delta\beta$ lifetime measurements:
  - Level has short halflife up to several tens ps.
  - Simplified if decay energy is accurately known.
  - Depends on target thickness, energy loss in target. The shorter the lifetime, the higher density, higher z material has to be chosen.
  - Depends on reaction cross-section as function of beam energy. Knockout cross-sections are thought to be nearly constant at 200 MeV/u.
  - Beam energy before and after the target must be accurately known.
  - Requires very stable gain of detectors.

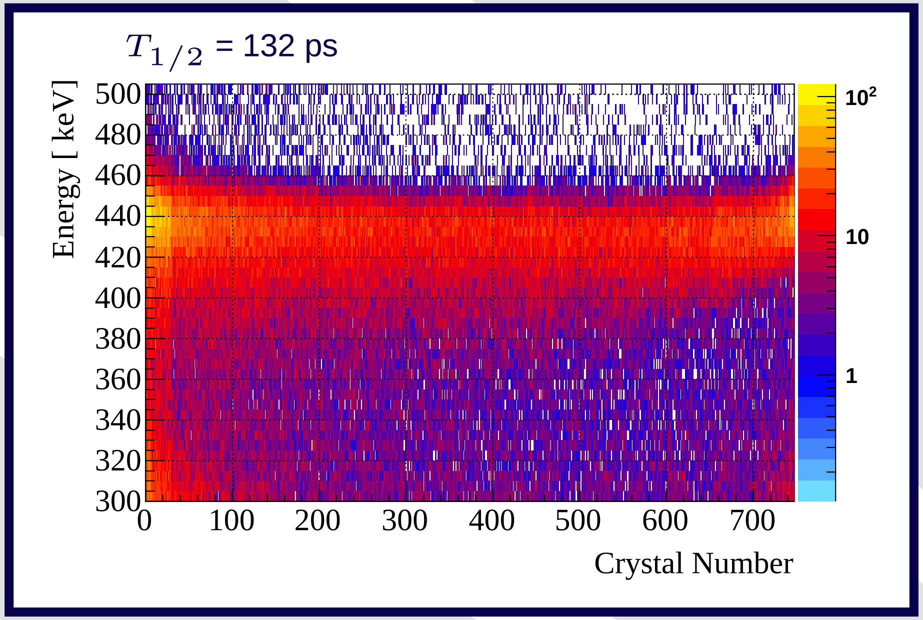
Lifetime Effects Summary

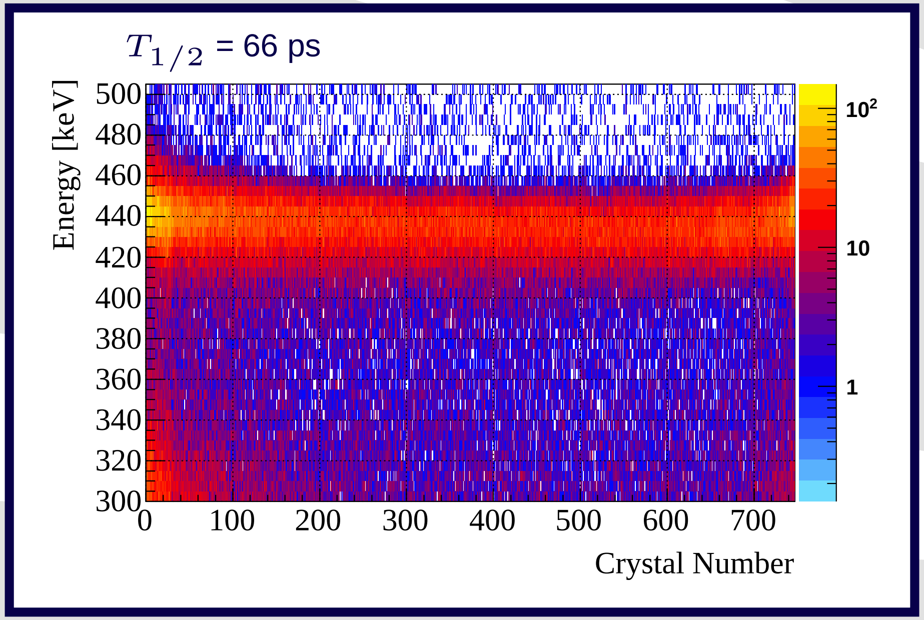
- Characteristics for $\Delta\theta$ lifetime measurements:
  - Level has halflife longer than several tens of ps.
  - Simplified if decay energy is accurately known.
  - Nearly independent of reaction mechanism.
  - Can/have to put detectors close to target.
  - The larger the lifetime, the less stable gain required.

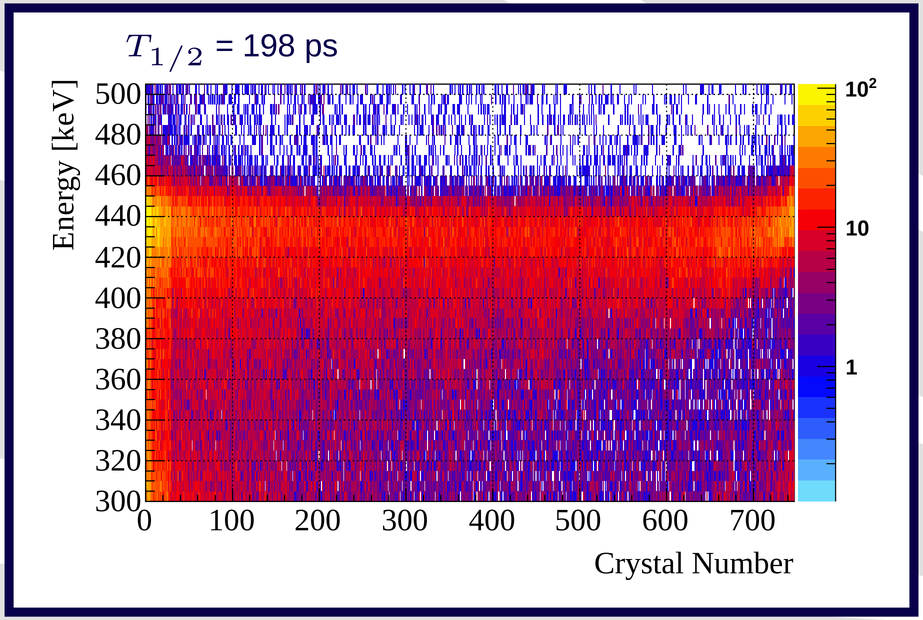
Lifetime Measurements with SHOGUN

SHOGUN Simulations

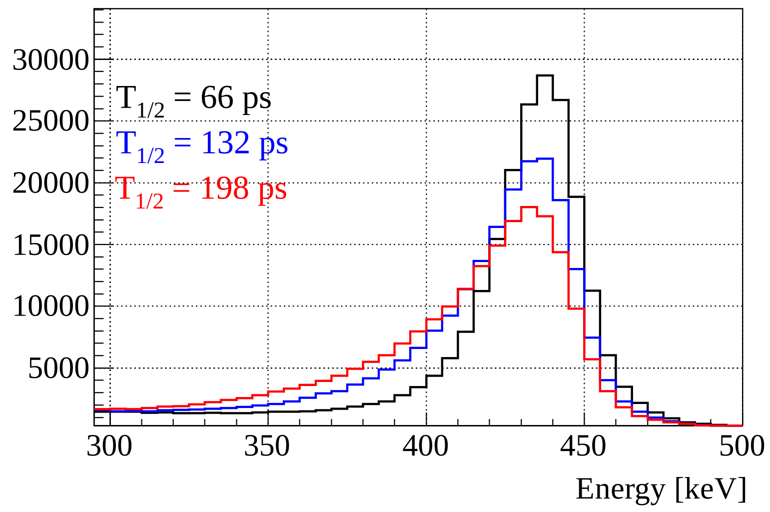
- ^{62}Cr @ 200 MeV/u on 1.5 g/cm^2 Be target
- Time of flight through target $\approx$ 55 ps
- ^{62}Cr 2_1^+ at 446 keV, $T_{1/2}$ = 66, 132, 198 ps
- ^{62}Cr 4_1^+ at 1178 keV, $T_{1/2}$ = 7.7 ps

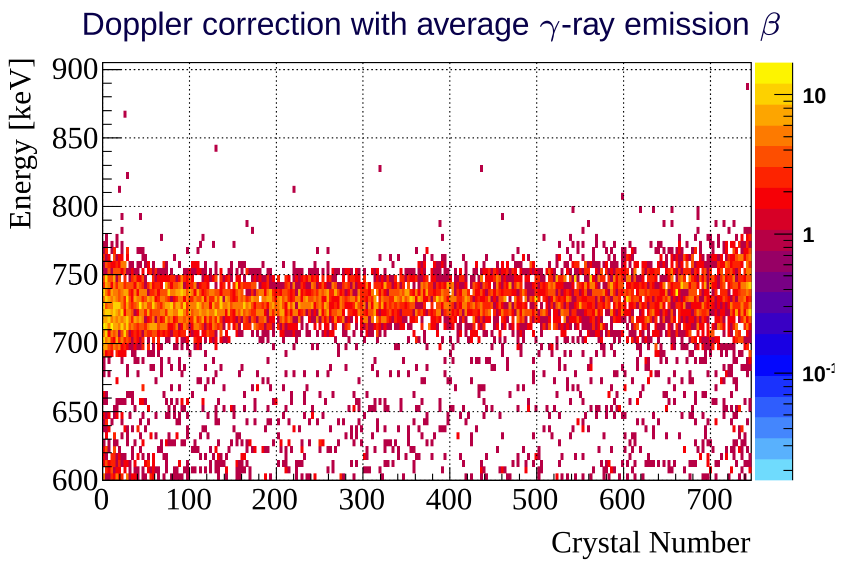


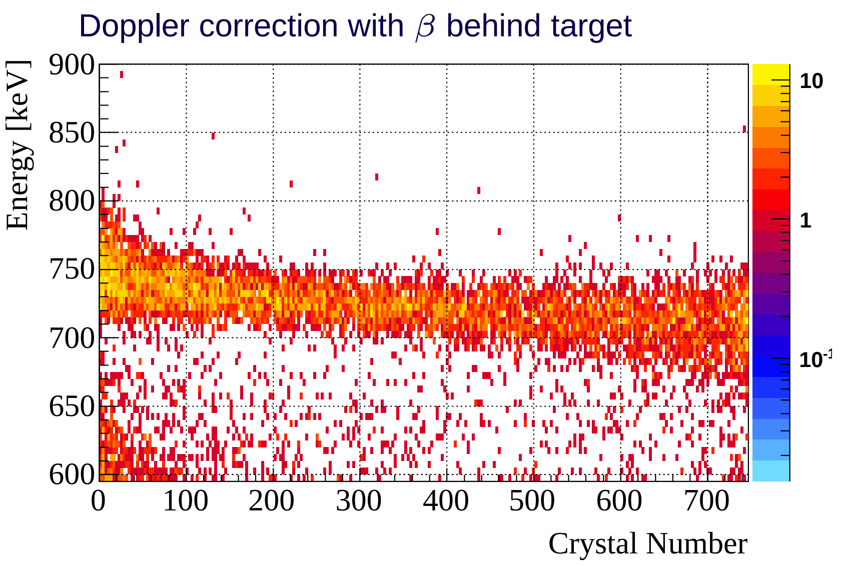




SHOGUN Simulations







Summary

Summary and Outlook

- Lineshapes and peak position shifts can be utilized to determine lifetimes at high energies.
- Can be measured for free in many experiments.
- Need very stable gain.

THE END

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