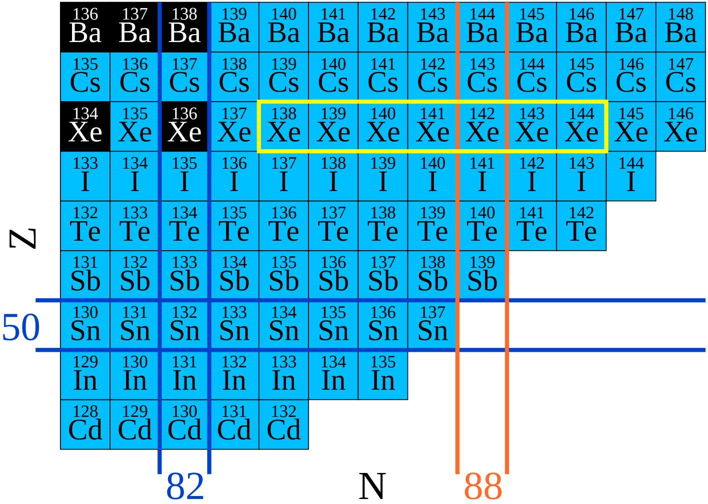
Lifetime measurements in neutron-rich Xe isotopes - evolution of quadrupole collectivity beyond ^{132}Sn

The region around ^{132}Sn



Reduced transition probabilities $B(E2)$ above $Z = 50$ and $N = 82$

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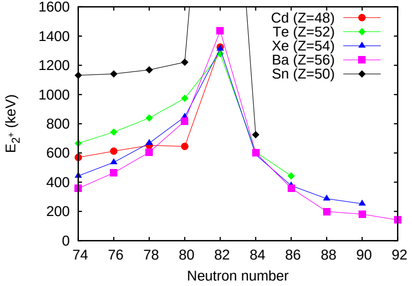
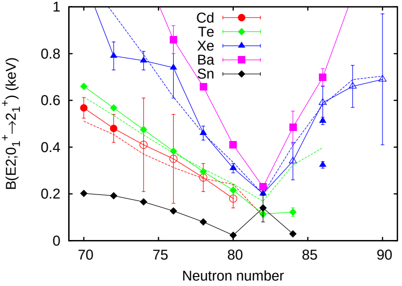
Modified Grodzins rule:

$$E_{2^+}[\text{keV}] \cdot B(E2; 0^+ \rightarrow 2^+)[e^2\text{b}^2] = 3.242 \cdot Z^2 \cdot A^{-\frac{2}{3}}(1.000 - 0.0608(N - \overline{N}))$$

S. Raman et al. (2001) and D. Habs et al. (2002)





full symbols: National Nuclear Data Center *www.nndc.bnl.gov*

empty symbols: **Xe (△):** T. Behrens, PhD thesis, TU München (2009); C. Henrich, Master thesis, TU Darmstadt (2014)

Cd (◯): S. Ilieva et al., PRC89 (2014) 014313; S. Bönig, PhD thesis, TU Darmstadt (2014)

Reduced transition probabilities $B(E2)$ above $Z = 50$ and $N = 82$

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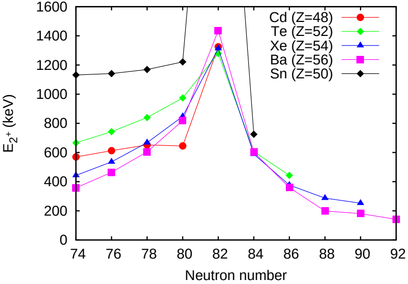
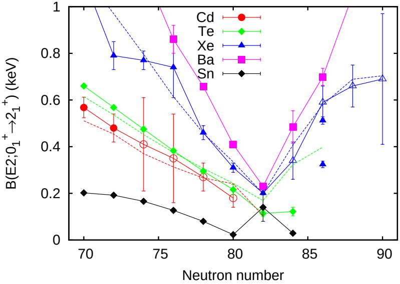
- "Safe" Coulomb excitation measurement: $\sigma_{CLX} = f(B(\sigma\lambda), Q_\lambda)$
- Direct lifetime measurement: $\tau \propto 1/B(\sigma\lambda)$
- (Precise) determination of quadrupole moments combining the above results!





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EXILL-FATIMA setup at ILL

EXILL-FATIMA: EXOGAM@ILL - FAst TIMing Array

- Experimental setup for measuring pico-second lifetimes ($\gtrsim$ 10 ps)

- 8 Clover detectors (4 HPGe crystals in each)
- 16 $LaBr_3$(Ce) fast scintillators

Foto from: N. Saed-Samii, Diploma thesis, University of Cologne

EXILL-FATIMA setup at ILL

EXILL-FATIMA: EXOGAM@ILL - FAst TIMing Array

- Prompt γ-ray spectroscopy following neutron-induced fission
- Cold neutron flux: $\Phi = 5 \times 10^7/\text{cm}^2\text{s}$
- Targets used:
  - ^{235}U
  - ^{241}Pu

Foto from: N. Saed-Samii, Diploma thesis, University of Cologne

The Generalized Centroid Difference Method

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- Delayed time distribution $D(t)$ is a convolution of the normalised prompt response function of the setup P(t) with an exponential decay:

$$D(t) = n\lambda \int_{-\infty}^{t} P(t' - t_0) e^{-\lambda(t-t')} dt' \text{ , with } \lambda = 1/\tau$$

- The centroid of the delayed spectrum (D) is displaced by the mean lifetime from the centroid of its convoluted prompt response function (P):

$$\tau = C^D_{stop} - C^P_{stop} \quad \text{and} \quad \tau = C^P_{start} - C^D_{start}$$

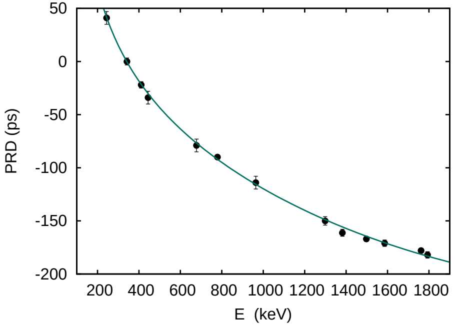
$$\rightarrow 2\tau = |\overline{\Delta C} - \overline{PRD}|$$

where PRD describes the energy dependent timing response $T(E_\gamma)$ of the detector setup.

J.-M. Régis et al., Nucl. Instr. Meth. Phys. Res. A726 (2013) 191

Mean PRD curve for the 2013 run

- obtained with coincidence data from ^{152}Eu calibration source and from the neutron capture reaction $^{48}Ti(n,\gamma)^{49}Ti$;
- contains all systematic uncertainties of the method.



Lifetime of the first excited state in ^{138}Xe

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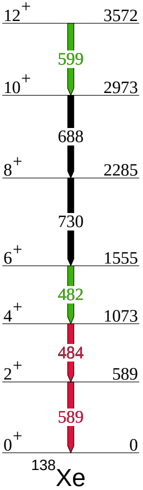

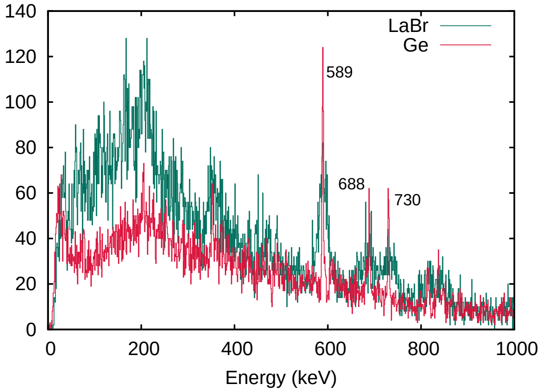

Lifetime of the first excited state in ^{138}Xe

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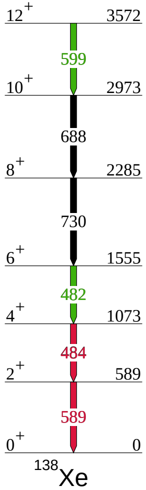
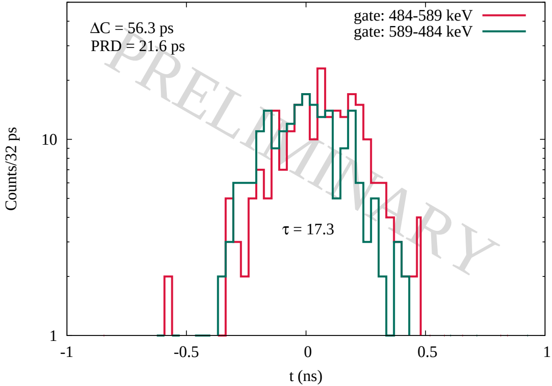
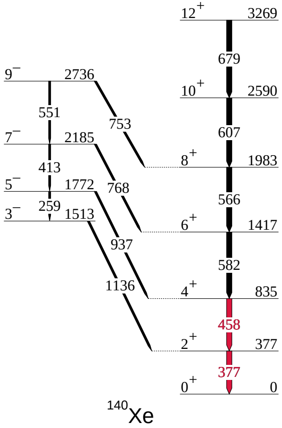
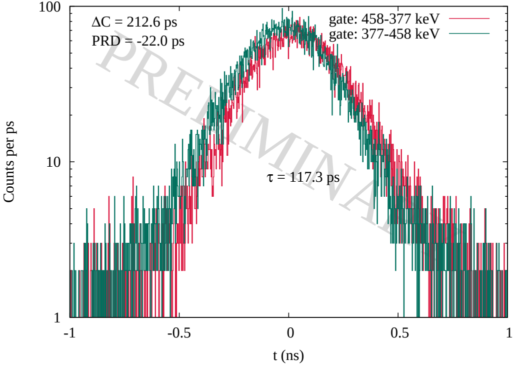


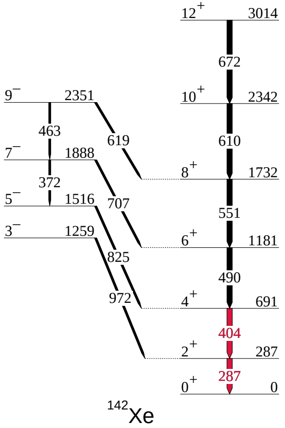


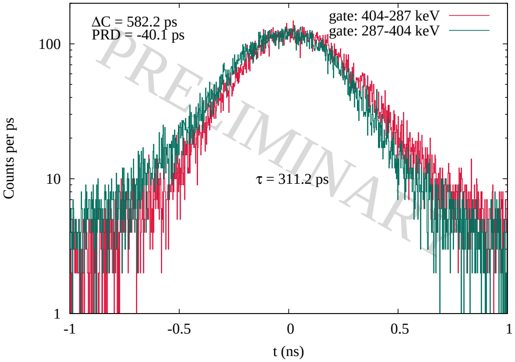
Lifetime of the first excited state in ^{140}Xe





Lifetime of the first excited state in ^{142}Xe





Comparison with existing measurements

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Isotope	τ (ps) this work	τ (ps) direct measurement	τ (ps) calculated from $B(E2)$ @ $Q(2^+) = 0$
^{138}Xe	17.3	-	16.8(39)[2]
^{140}Xe	117.3	101.7(32)[1]	90.1(107)[2]
^{142}Xe	311.2	-	310 (40)[2]

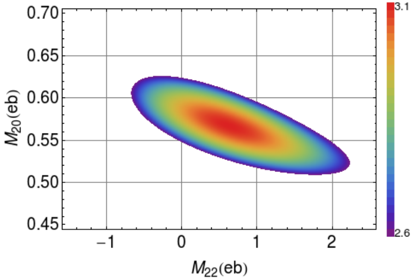
[1] Lindroth et al., PRL 82(1999)4783

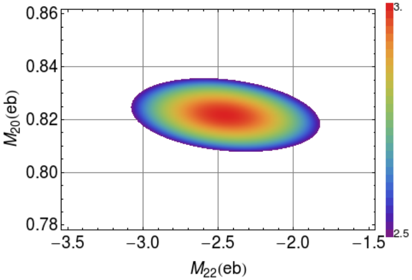
[2] T. Behrens, PhD thesis, TU München

Combined analysis of Coulomb excitation and lifetime data - determination of quadrupole moments

- ^{138}Xe
- $B(E2; 0_1^+ \rightarrow 2_1^+) = e^2b^2$
- $Q_{2^+}^{sp} = eb$

- ^{142}Xe
- $B(E2; 0_1^+ \rightarrow 2_1^+) = e^2b^2$
- $Q_{2^+}^{sp} = eb$





C. Henrich, Master Thesis, TU Darmstadt

Summary and Outlook

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- Pico-second lifetimes of excited states in neutron-rich xenon isotopes were measured in the EXILL-FATIMA campaign at ILL:
  - isotopes studied: $^{138-144}$Xe;
  - excited states populated in neutron-induced fission of ^{235}U and ^{241}Pu;
  - analysis via the generalized centroid difference method.
- Combined analysis of the Coulomb excitation measurement at REX-ISOLDE (CERN) and lifetime data allows for (precise) determination of nuclear quadrupole moments of the excited states.
- HIE-ISOLDE: Influence of multiple Coulomb excitation increases due to higher beam energy (additional matrix elements - e.g. E3) $\rightarrow$ knowledge of the lifetimes very useful for the analysis.

The EXILL-FATIMA Collaboration

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Thank you for your attention!

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