The low-Z boundary of the N=90 phase transition: ^{148}Ce near X(5)

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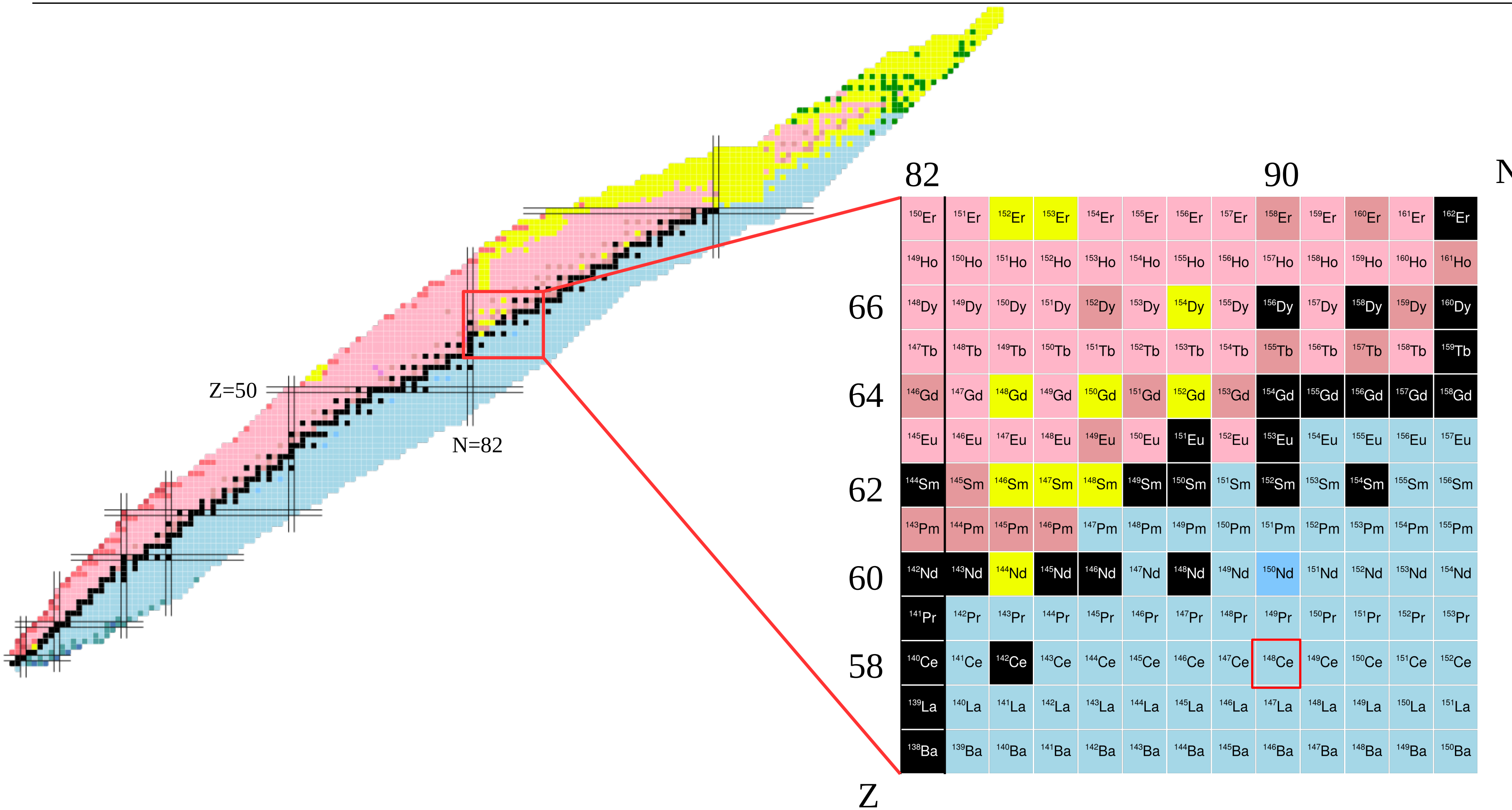
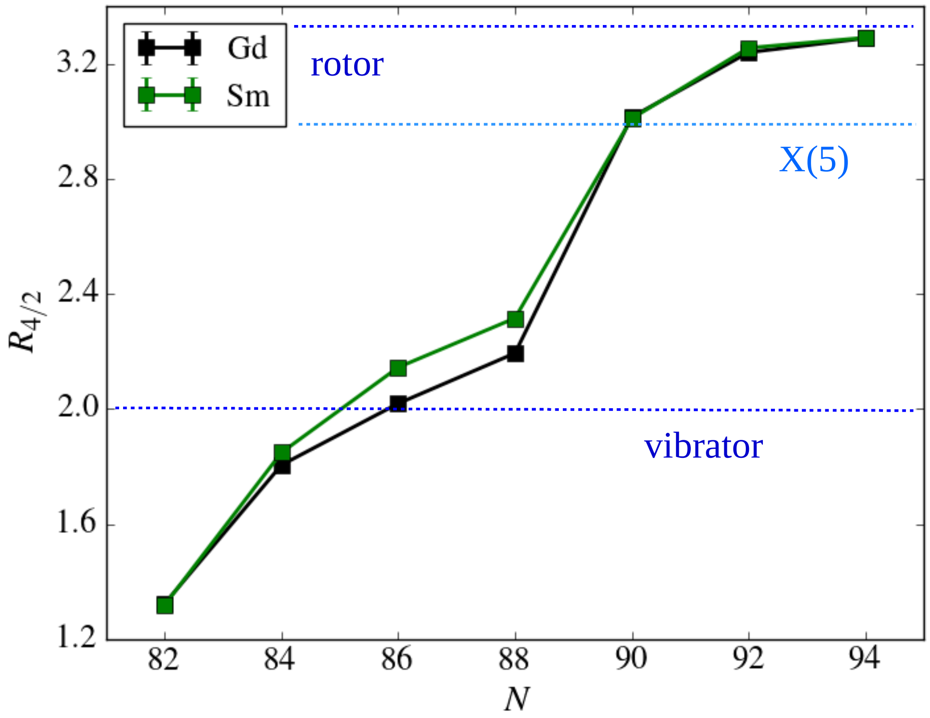
QPTn9 – Padova

Pavlos Koseoglou, V. Werner, N. Pietralla, S. Ilieva, M. Thürauf, C. Bernards, A. Blanc, A.M. Bruce, R.B. Cakirli, N. Cooper, G. de France, P. Humby, M. Jentschel, J. Jolie, U. Koester, T. Kröll, P. Mutti, Z. Patel, V. Paziy, Zs. Podolyak, P. H. Regan, J.-M. Régis, O.J. Roberts, N. Saed-Samii, G.S. Simpson, T. Soldner, C. A. Ur, W. Urban, D. Wilmsen, E. Wilson



Z=50
N=82
82
90
N
66
64
62
60
58
Z
^{150}Er ^{151}Er ^{152}Er ^{153}Er ^{154}Er ^{155}Er ^{156}Er ^{157}Er ^{158}Er ^{159}Er ^{160}Er ^{161}Er ^{162}Er
^{149}Ho ^{150}Ho ^{151}Ho ^{152}Ho ^{153}Ho ^{154}Ho ^{155}Ho ^{156}Ho ^{157}Ho ^{158}Ho ^{159}Ho ^{160}Ho ^{161}Ho
^{148}Dy ^{149}Dy ^{150}Dy ^{151}Dy ^{152}Dy ^{153}Dy ^{154}Dy ^{155}Dy ^{156}Dy ^{157}Dy ^{158}Dy ^{159}Dy ^{160}Dy
^{147}Tb ^{148}Tb ^{149}Tb ^{150}Tb ^{151}Tb ^{152}Tb ^{153}Tb ^{154}Tb ^{155}Tb ^{156}Tb ^{157}Tb ^{158}Tb ^{159}Tb
^{146}Gd ^{147}Gd ^{148}Gd ^{149}Gd ^{150}Gd ^{151}Gd ^{152}Gd ^{153}Gd ^{154}Gd ^{155}Gd ^{156}Gd ^{157}Gd ^{158}Gd
^{145}Eu ^{146}Eu ^{147}Eu ^{148}Eu ^{149}Eu ^{150}Eu ^{151}Eu ^{152}Eu ^{153}Eu ^{154}Eu ^{155}Eu ^{156}Eu ^{157}Eu
^{144}Sm ^{145}Sm ^{146}Sm ^{147}Sm ^{148}Sm ^{149}Sm ^{150}Sm ^{151}Sm ^{152}Sm ^{153}Sm ^{154}Sm ^{155}Sm ^{156}Sm
^{143}Pm ^{144}Pm ^{145}Pm ^{146}Pm ^{147}Pm ^{148}Pm ^{149}Pm ^{150}Pm ^{151}Pm ^{152}Pm ^{153}Pm ^{154}Pm ^{155}Pm
^{142}Nd ^{143}Nd ^{144}Nd ^{145}Nd ^{146}Nd ^{147}Nd ^{148}Nd ^{149}Nd ^{150}Nd ^{151}Nd ^{152}Nd ^{153}Nd ^{154}Nd
^{141}Pr ^{142}Pr ^{143}Pr ^{144}Pr ^{145}Pr ^{146}Pr ^{147}Pr ^{148}Pr ^{149}Pr ^{150}Pr ^{151}Pr ^{152}Pr ^{153}Pr
^{140}Ce ^{141}Ce ^{142}Ce ^{143}Ce ^{144}Ce ^{145}Ce ^{146}Ce ^{147}Ce ^{148}Ce ^{149}Ce ^{150}Ce ^{151}Ce ^{152}Ce
^{139}La ^{140}La ^{141}La ^{142}La ^{143}La ^{144}La ^{145}La ^{146}La ^{147}La ^{148}La ^{149}La ^{150}La ^{151}La
^{138}Ba ^{139}Ba ^{140}Ba ^{141}Ba ^{142}Ba ^{143}Ba ^{144}Ba ^{145}Ba ^{146}Ba ^{147}Ba ^{148}Ba ^{149}Ba ^{150}Ba

Systematics around N=90



$R_{4/2}=E(4^+_1)/E(2^+_1)$

Systematics around N=90

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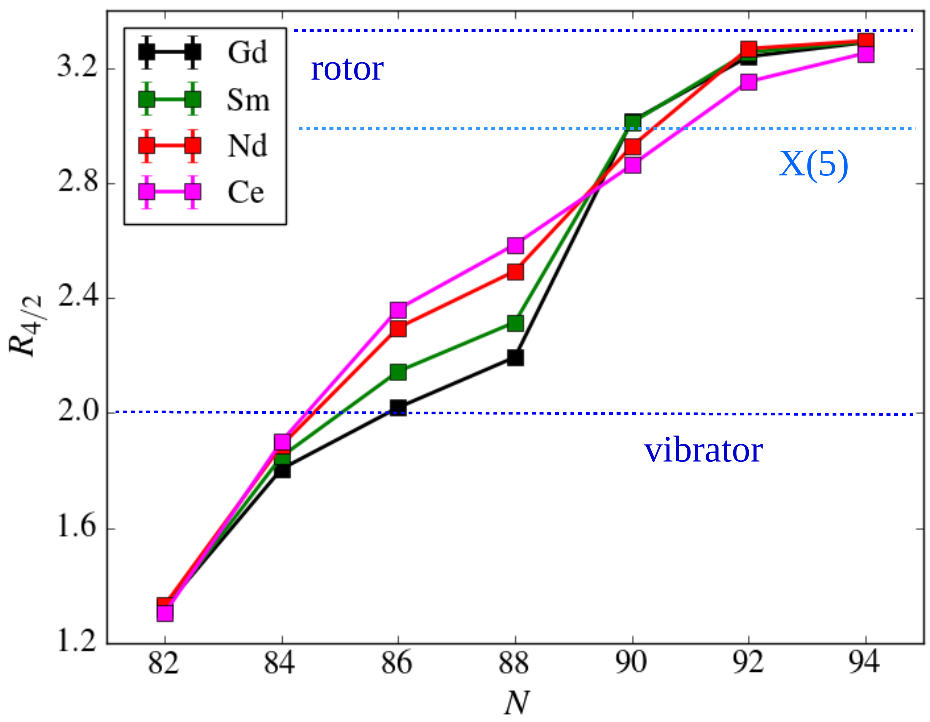
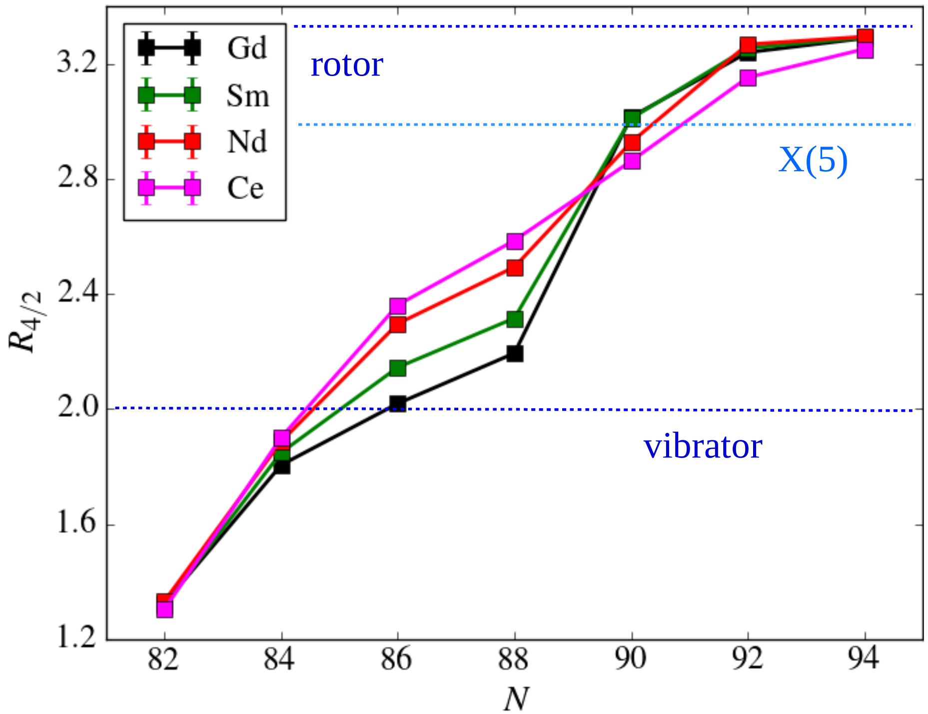
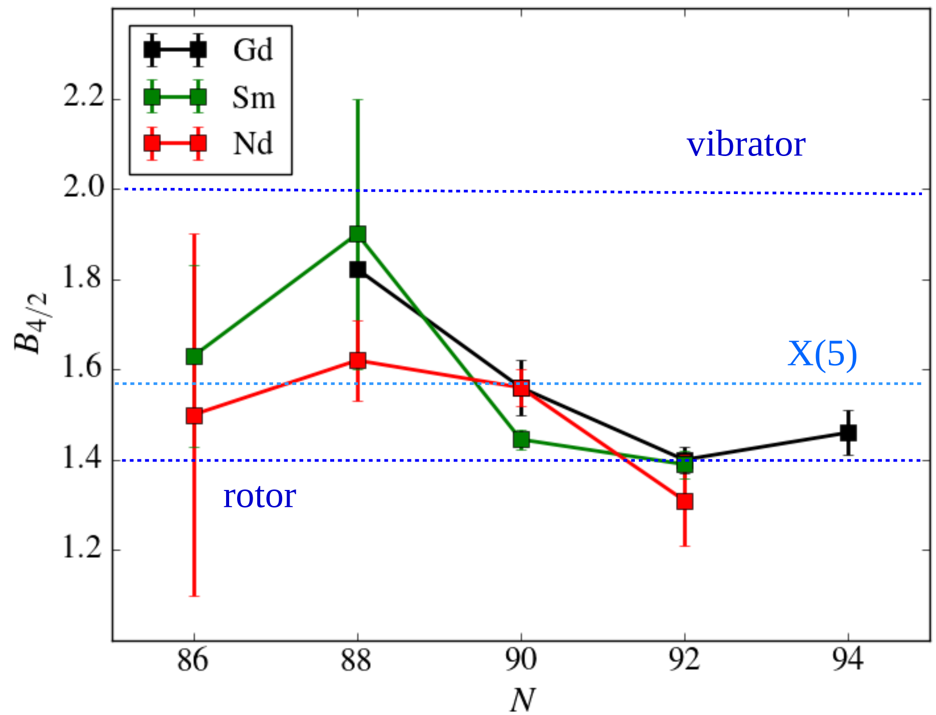


$$R_{4/2}=E(4^+_1)/E(2^+_1)$$

Systematics around N=90

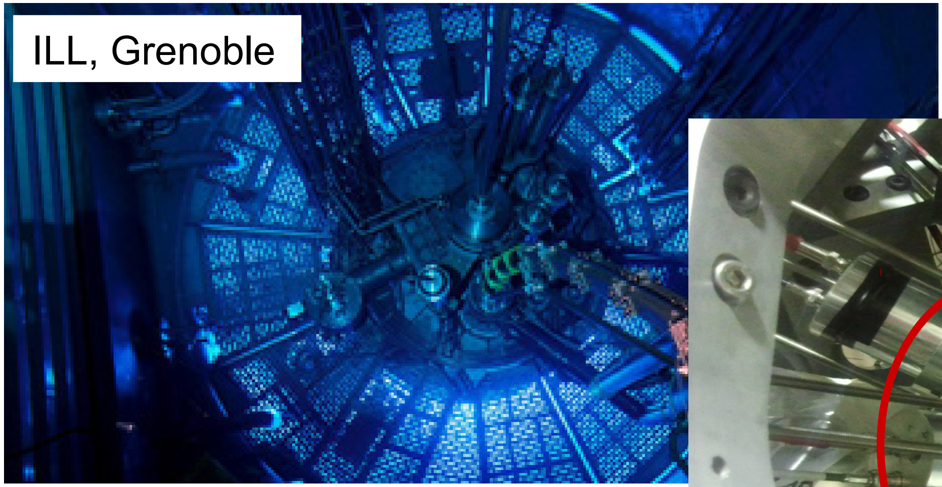


$R_{4/2}=E(4^+_1)/E(2^+_1)$



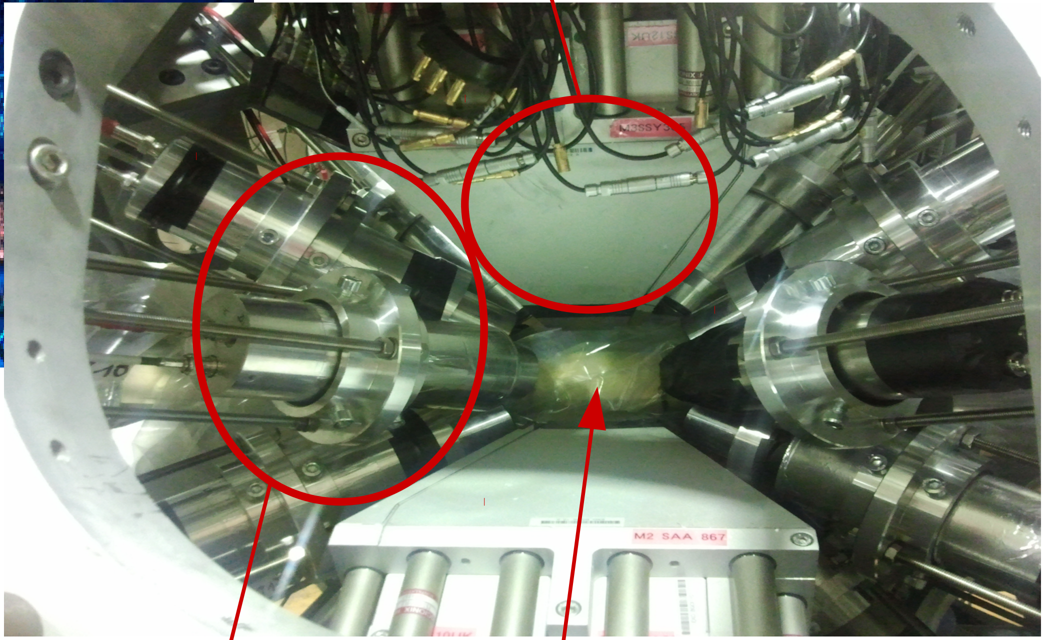
$B_{4/2}=B(E2;4^+_1\rightarrow 2^+_1)/B(E2;2^+_1\rightarrow 0^+_1)$

EXILL&FATIMA campaign



n

Fission measurements in ILL
$\Phi = 9 \times 10^7$ neutr. cm^{-2} s^{-1}



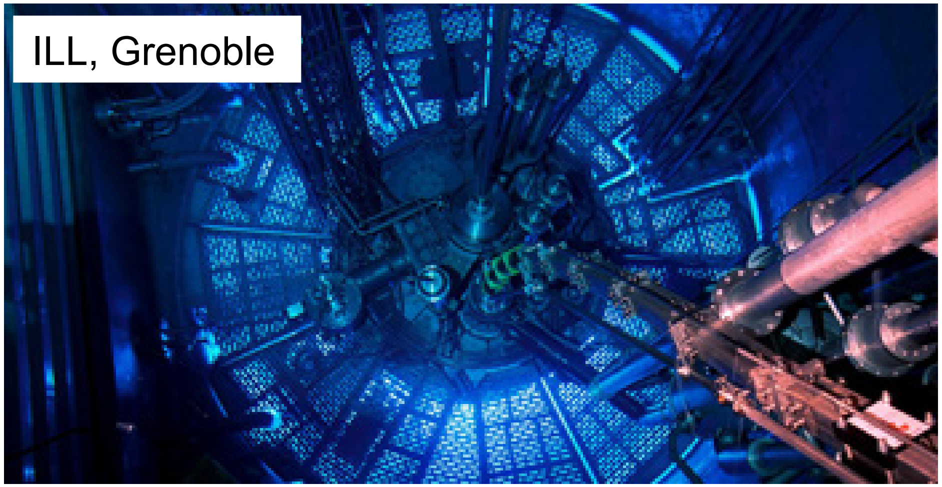
Ring of 8 BGO shielded EXOGAM clovers

Target position [^{235}U / ^{241}Pu]

2 rings of 8 $LaBr_3(Ce)$ each

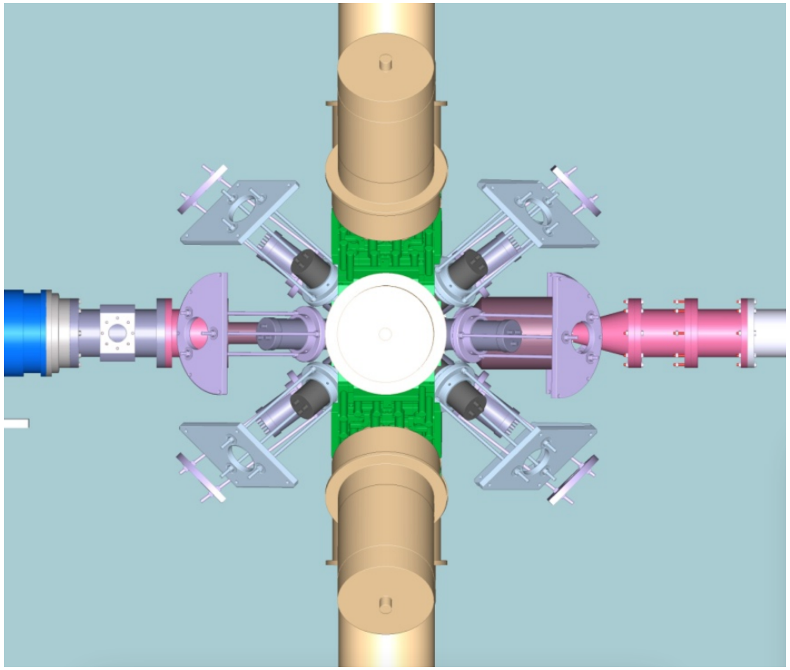
official ILL web www.ill.eu/reactor-environment-safety/high-flux-reactor/
Jean-Marc Régis, 2nd EXILL meeting in Cologne (2013)

EXILL&FATIMA campaign



- Ge: good energy resolution
- $LaBr_3$: excellent timing performance
- Ge-$LaBr_3$-$LaBr_3$ coincidences

Ring of 8 BGO shielded EXOGAM clovers



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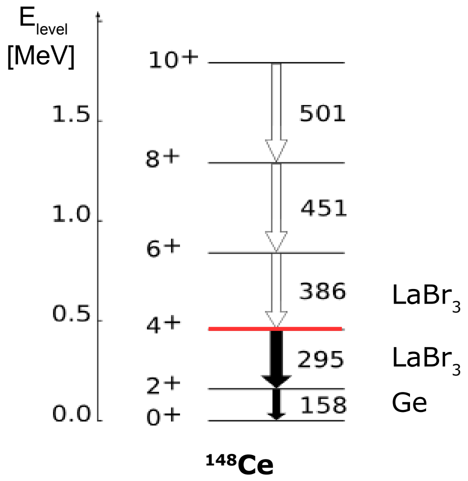
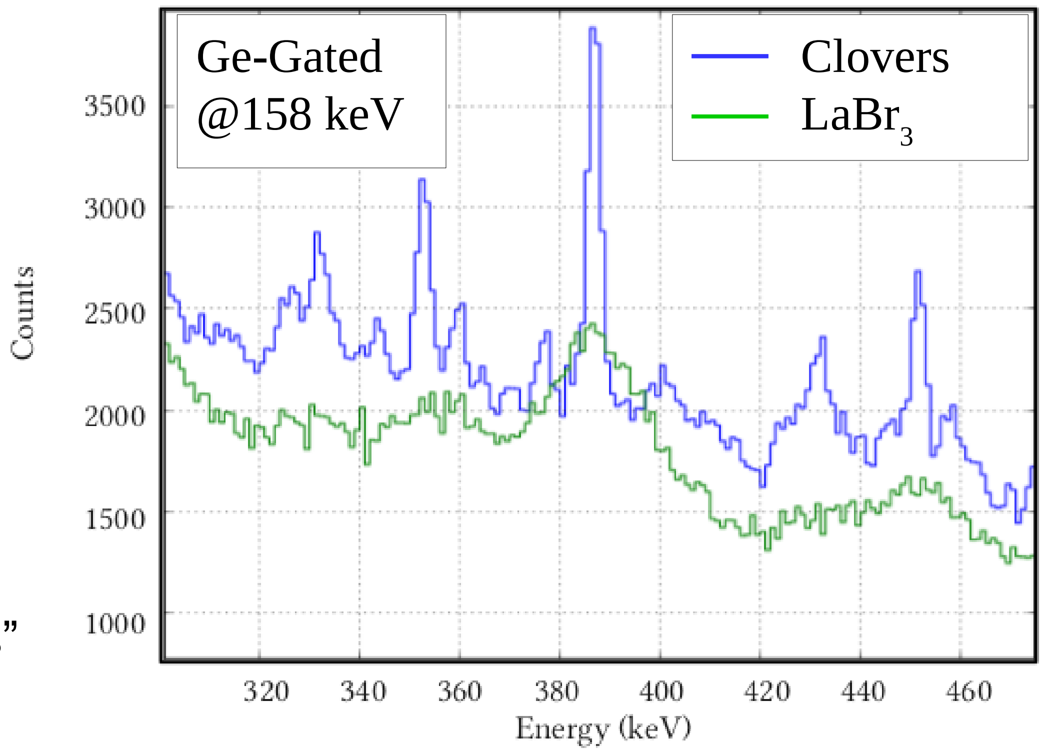
Jean-Marc Régis, 2nd EXILL meeting in Cologne (2013)

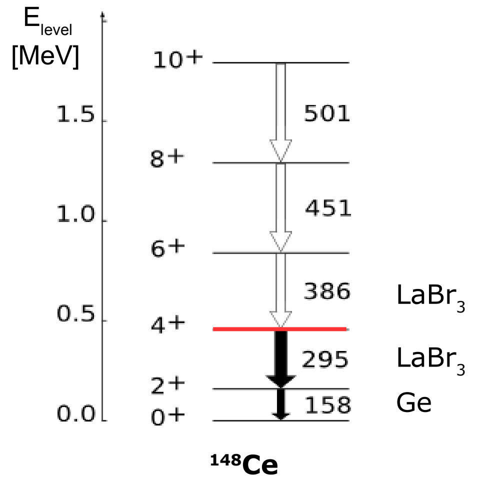
^{148}Ce 4^+_1 life-time analysis

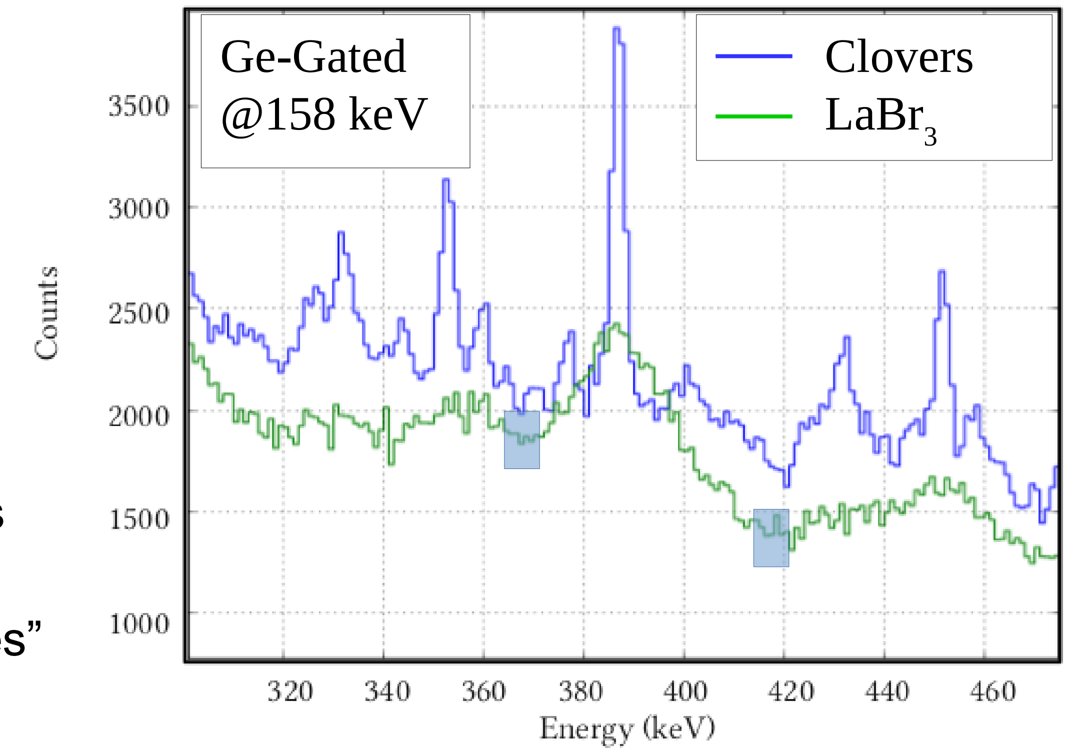




- Contribution of other transitions was checked
- Compton contribution: “Bg gates” on the right and left of the peak

^{148}Ce 4^+_1 life-time analysis





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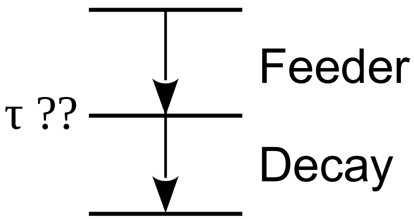
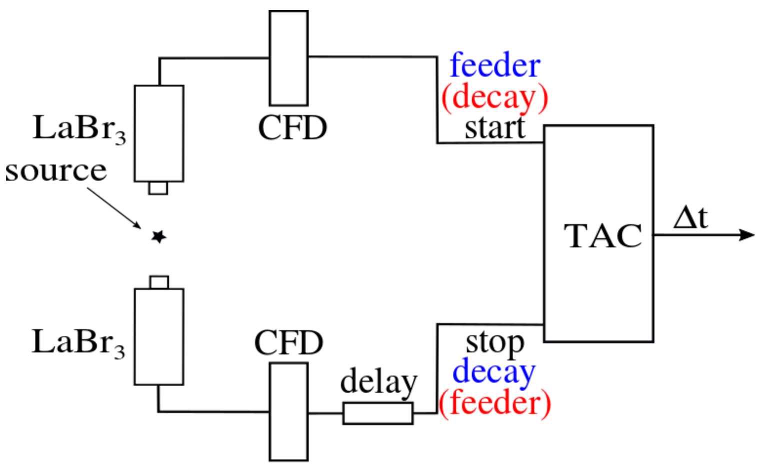
Fast-time measurements
General Centroid Difference method

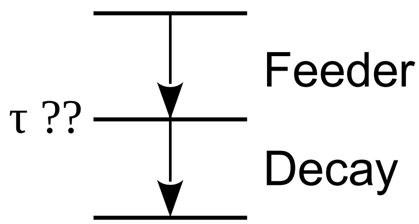


Time difference between the **start-stop** signals:

- Feeder-Decay
- Decay-Feeder



Fast-time measurements
General Centroid Difference method



Time difference between the **start-stop** signals:

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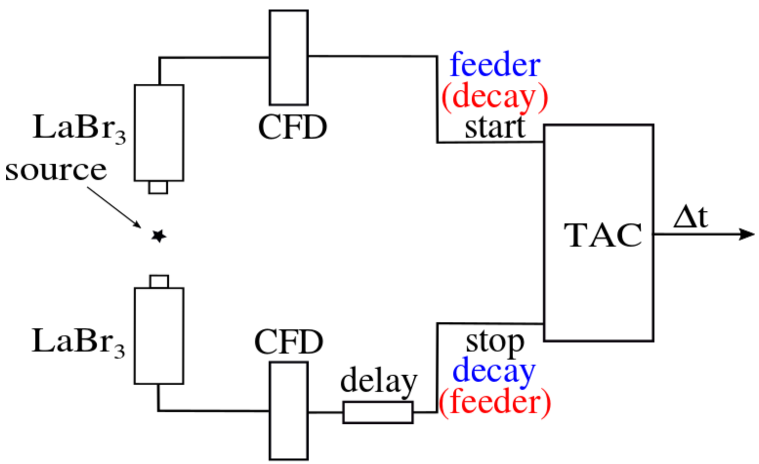
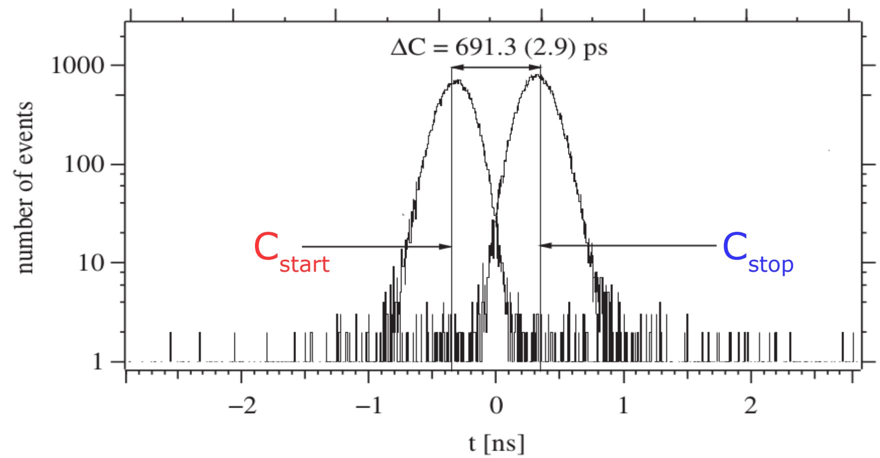
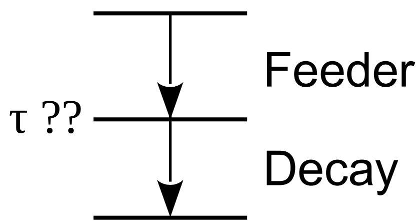




Fast-time measurements
General Centroid Difference method



Time difference between the **start-stop** signals:

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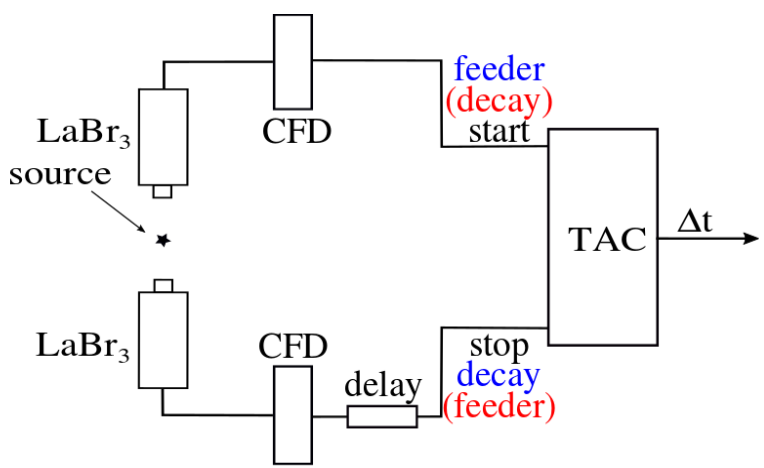

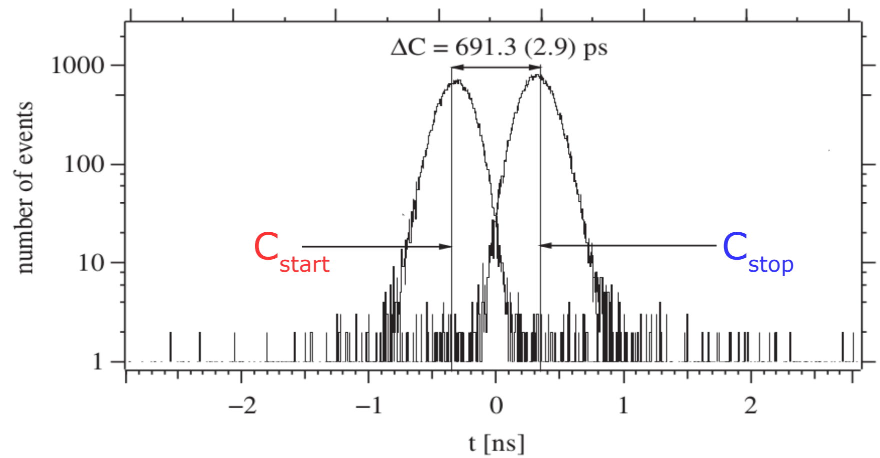

The Centroid Difference contains the life-time information

$$|\Delta C| = |C_{stop} - C_{start}| = PRD(\Delta E_\gamma) \pm 2\tau$$

Calibrated from known lifetimes

J.-M. Regis, et al., Nucl. Instr. Meth., A 622, 83-92 (2010)

^{148}Ce 4^+_1 life-time analysis

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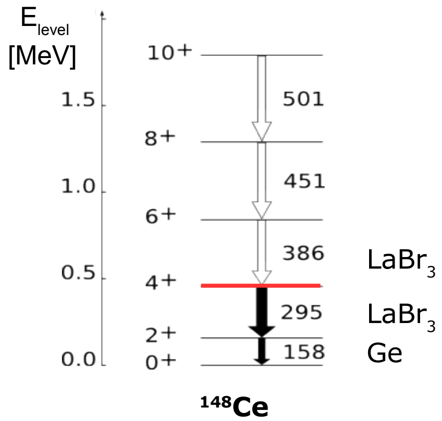
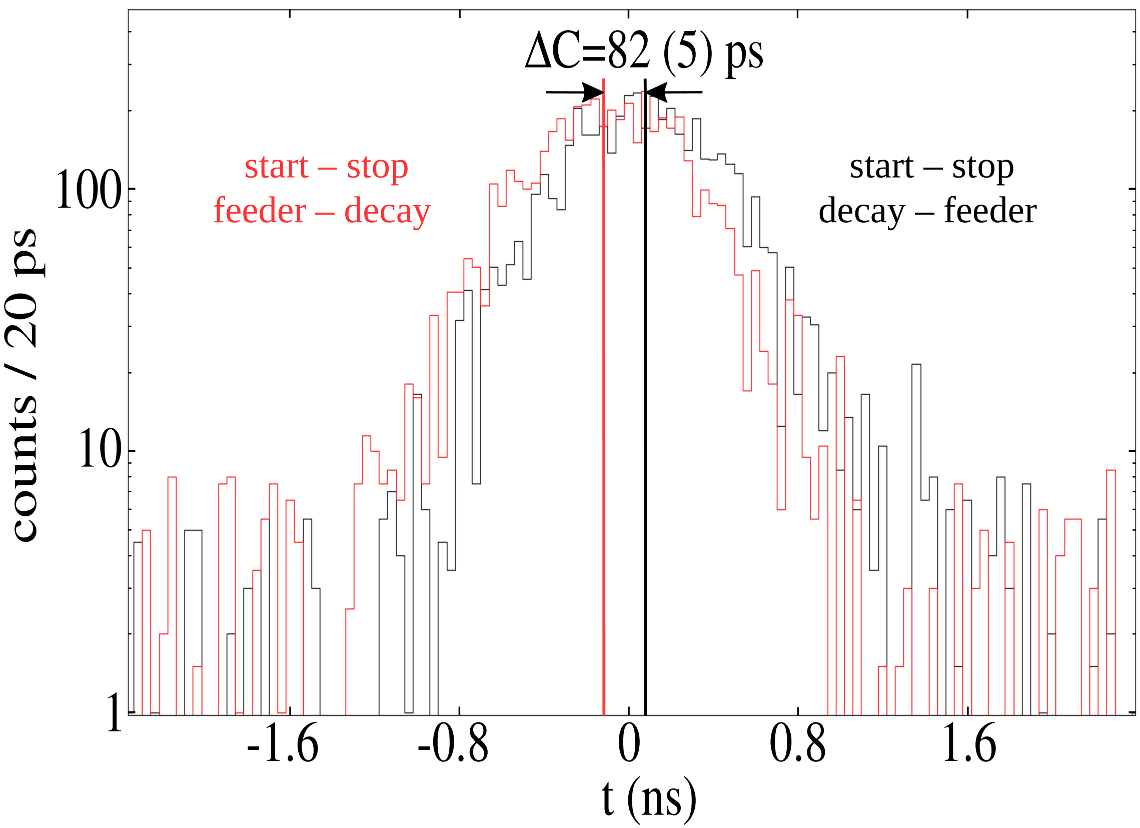


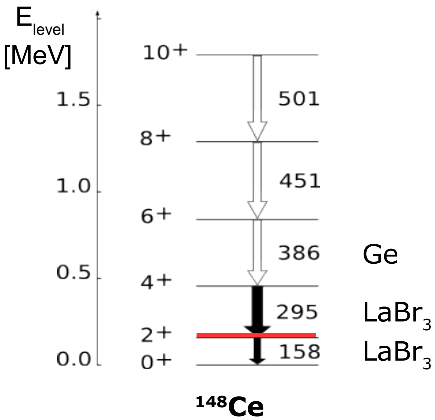
General Centroid Difference method

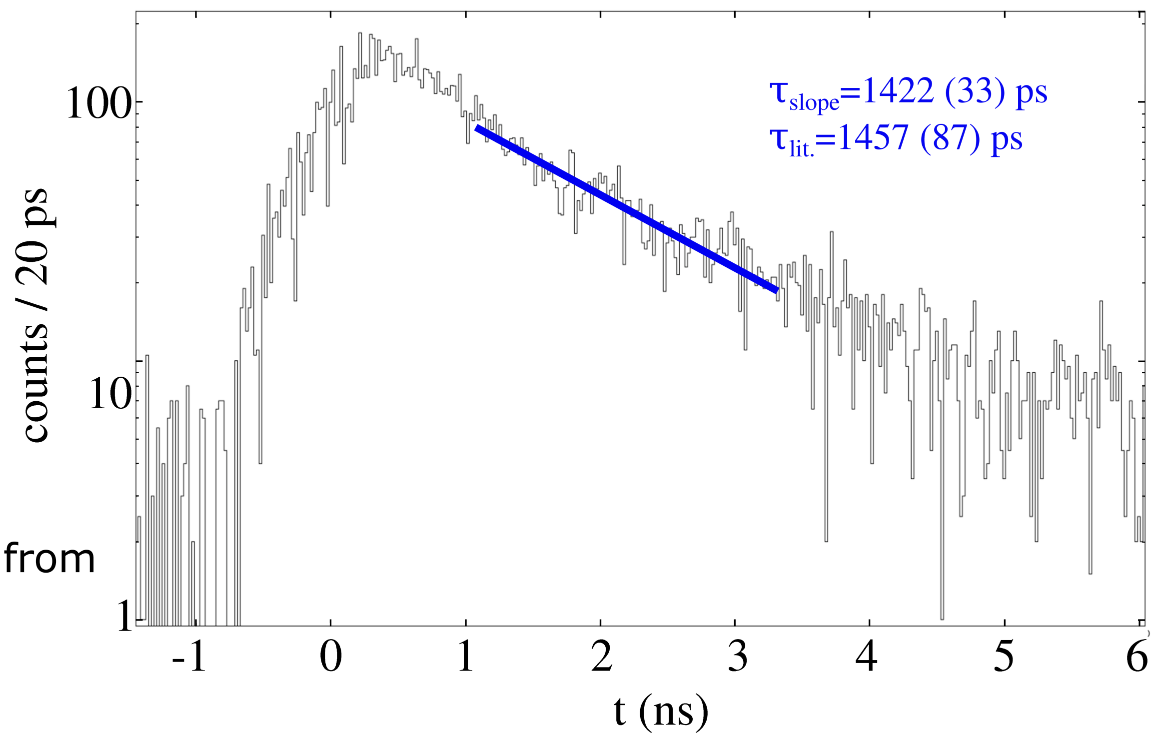
$$\tau = \frac{1}{2}(\Delta C - PRD)$$

τ_{4+} = 54 (3) ps
$B(E2; 4^+_1 \rightarrow 2^+_1)$ = 139 (7) W.u.



^{148}Ce 2^+_1 life-time analysis





Slope method

- The life-time derives directly from the slope

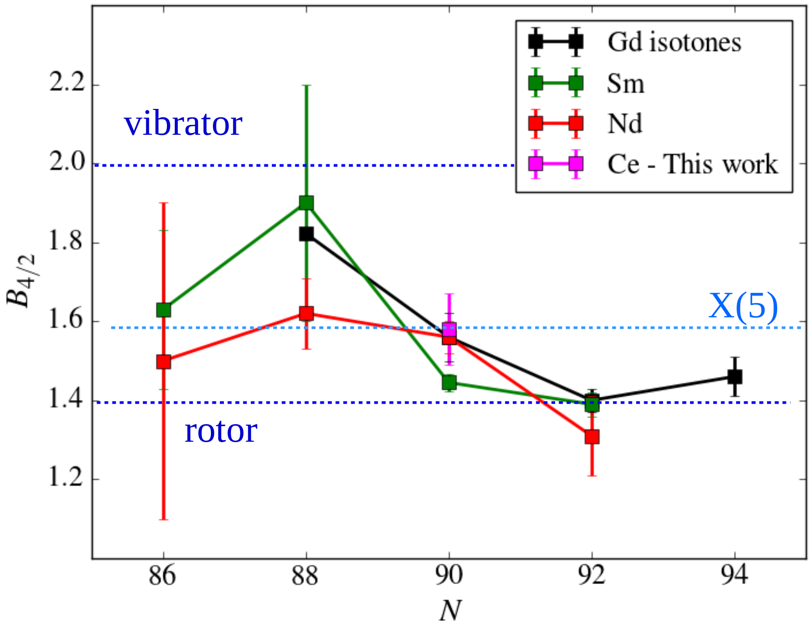
τ_{2+} = 1422 (33) ps
B(E2; $2^+_1 \rightarrow 0^+_1$) = 88 (3) W.u.

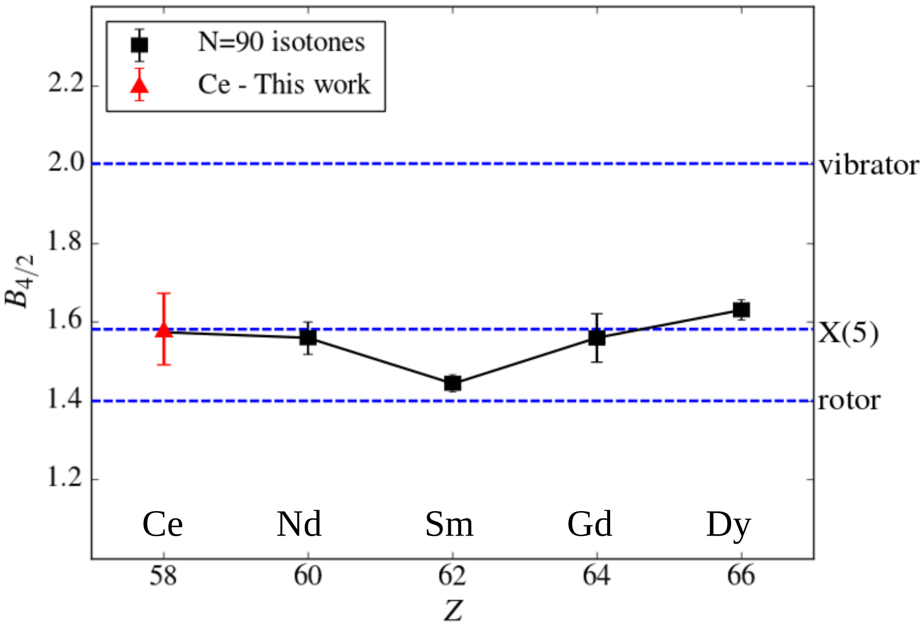
^{148}Ce $B_{4/2}$ ratio

τ_{4+} = 54 (3) ps

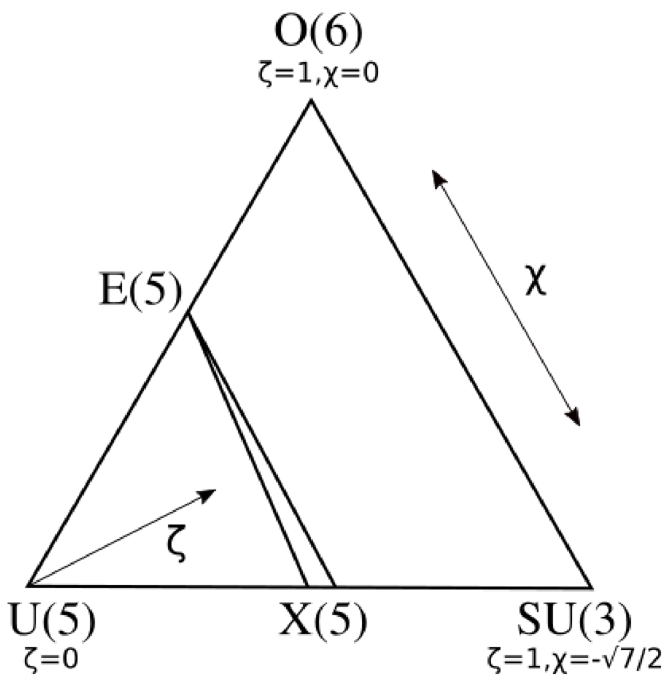
τ_{2+} = 1422 (33) ps

$B_{4/2}$ = 1.58 ± 0.09





IBA-1 picture



IBA-1 calculations with IBAR code along the triangle.

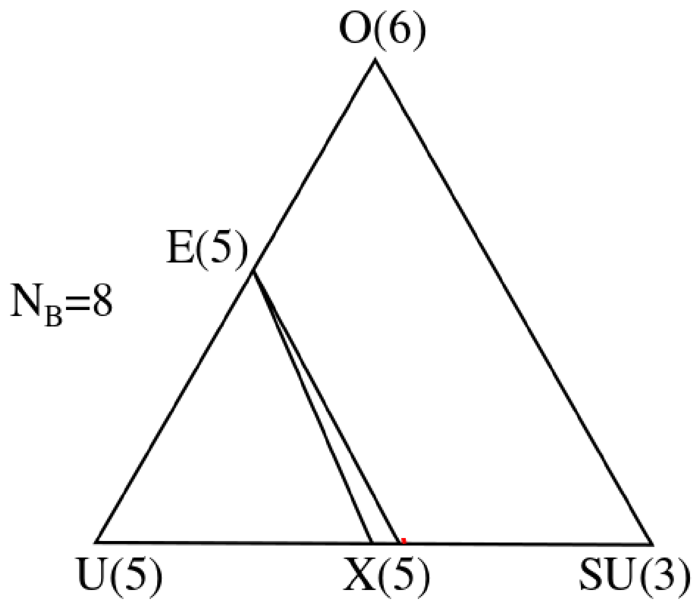
$$H(\zeta) = c\left[(1-\zeta)\hat{n}_d - \frac{\zeta}{4N_B}\hat{Q}^\chi \cdot \hat{Q}^\chi\right]$$

$$\hat{n}_d = d^\dagger \tilde{d}$$

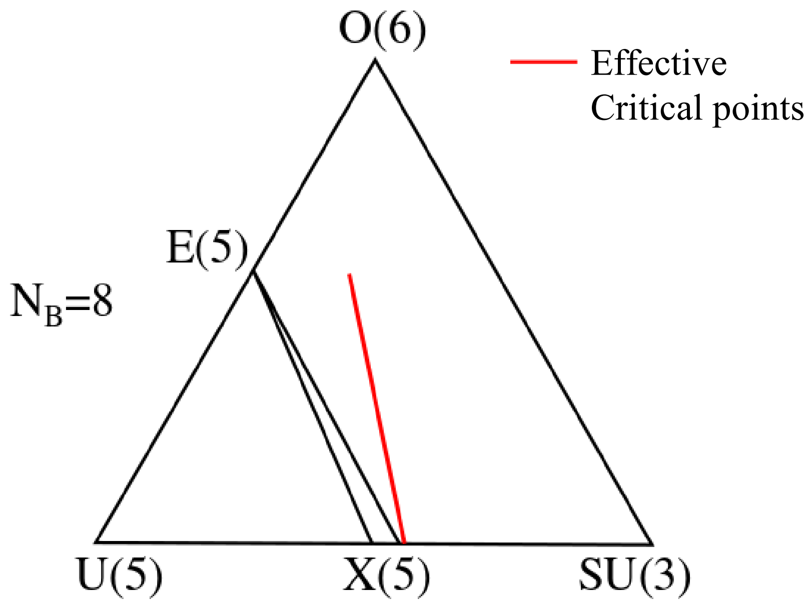
$$\hat{Q}^\chi = (s^\dagger \tilde{d} + d^\dagger s) + \chi(d^\dagger \tilde{d})$$

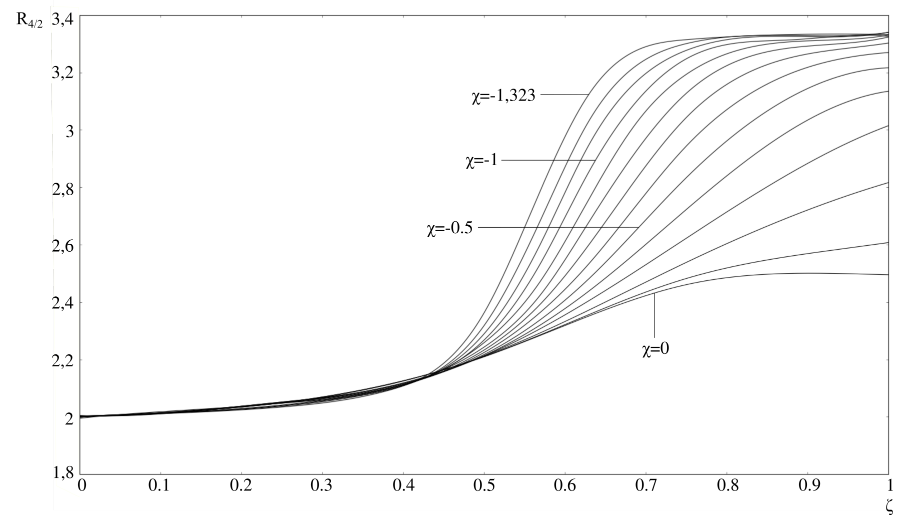
R. Casperson, Ibar: Interacting boson model calculations for large system sizes, Computer Physics Communications 183 (4) (2012) 1029 – 1035.

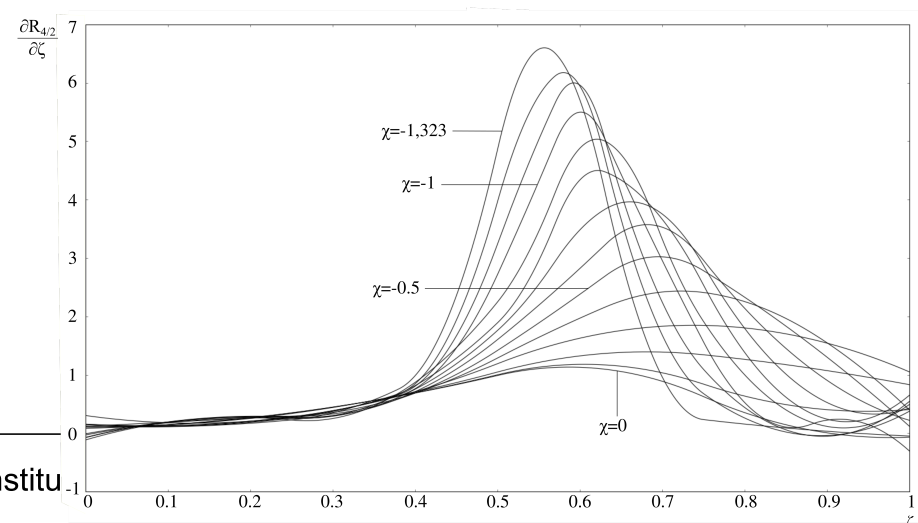
Effective Critical Point mapped in the IBA symmetry triangle



Effective Critical Point mapped in the IBA symmetry triangle

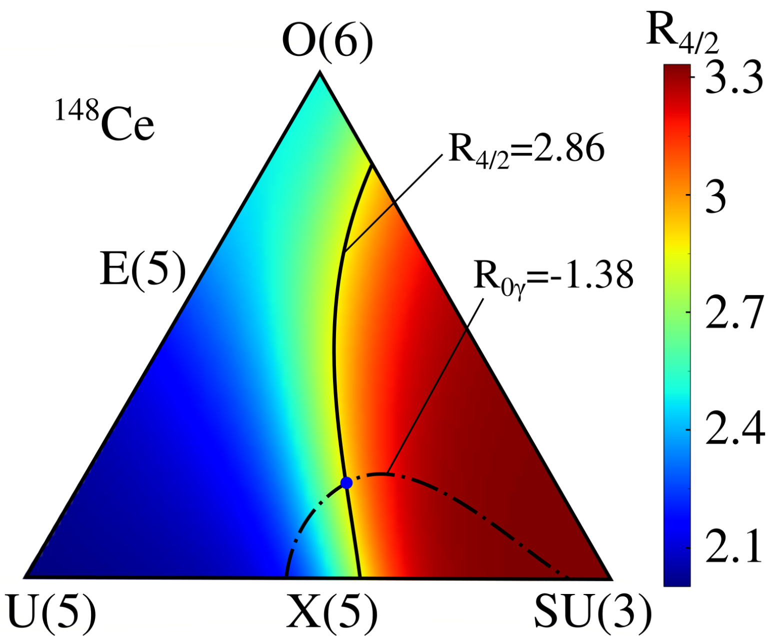






Effective Critical point: where $\frac{\partial R_{4/2}}{\partial \zeta}$ peaks

^{148}Ce in IBA symmetry triangle



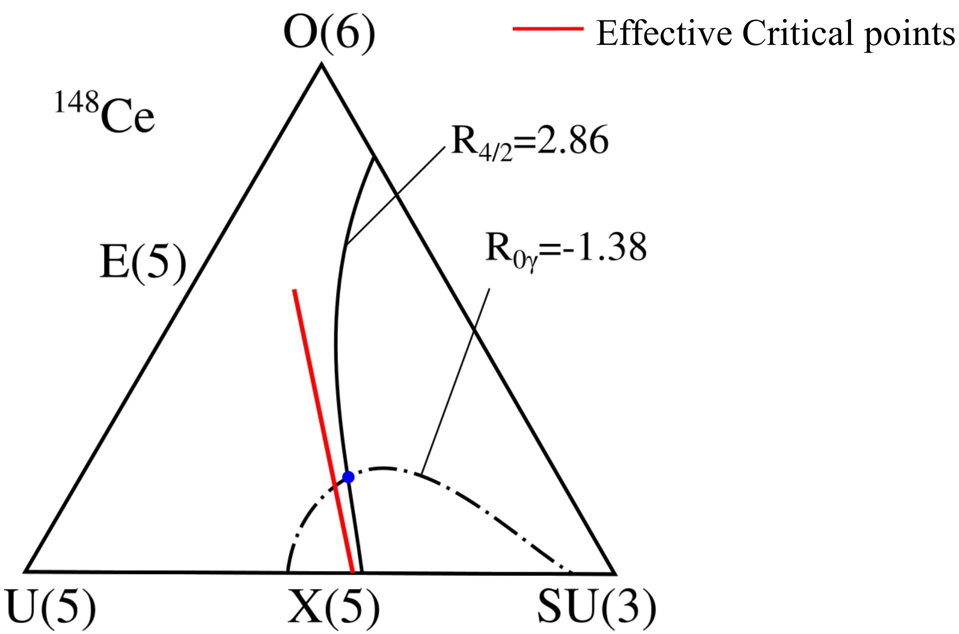
The orthogonal crossing of constant contours of basic observables can place a nucleus in the triangle.

$$R_{4/2} = E(4_1^+)/E(2_1^+)$$

$$R_{0\gamma} = \frac{E(0_2^+) - E(2_\gamma^+)}{E(2_1^+)}$$

W.-T. Chou, N.V. Zamfir and R.F. Casten, Phys. Rev. C 56, 829 (1997)
E. A. McCutchan and R.F. Casten, Phys. Rev. C 74, 0.57302 (2006)

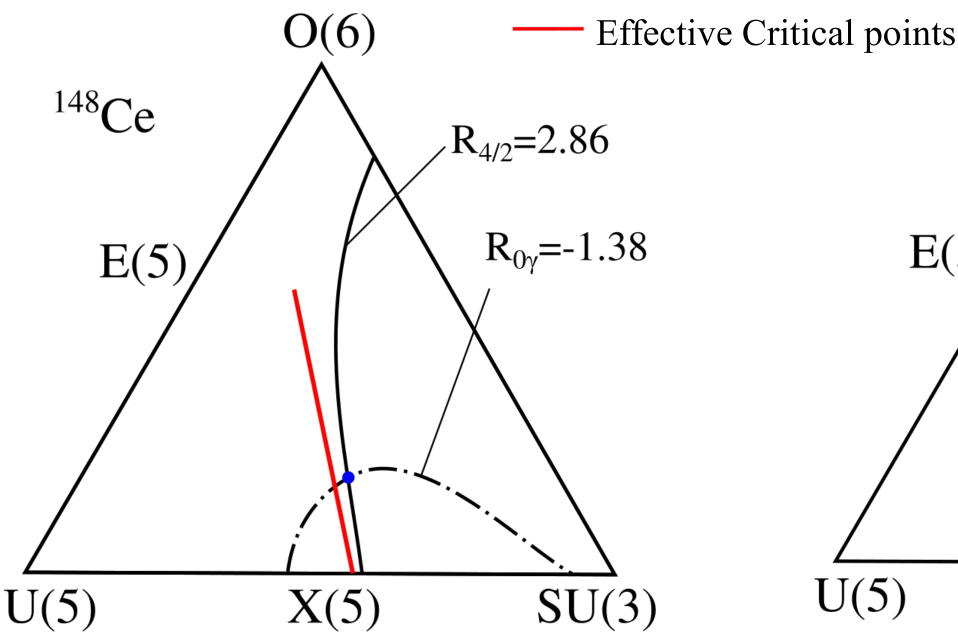
^{148}Ce in IBA symmetry triangle

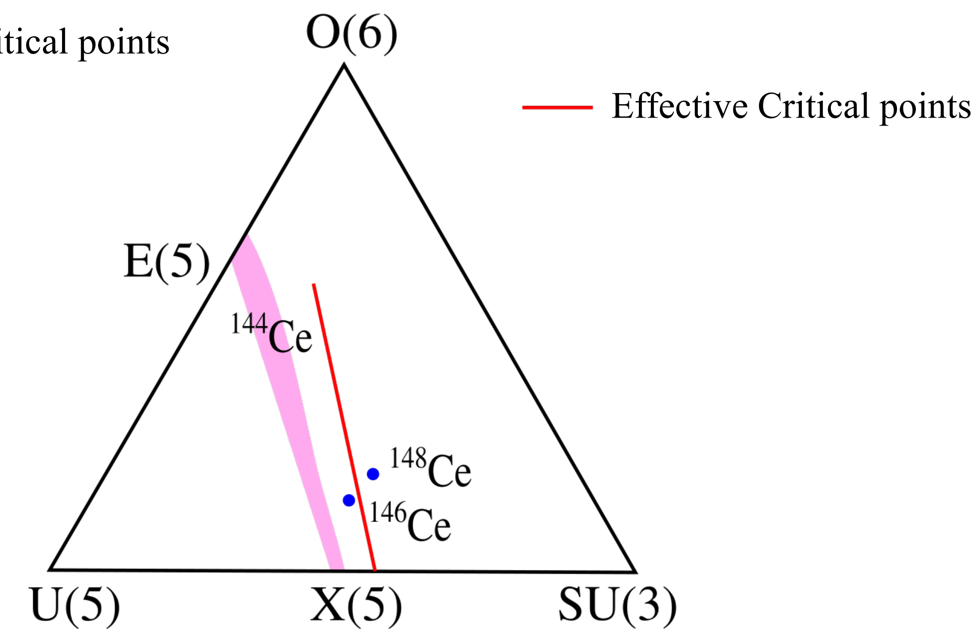


$$R_{4/2} = E(4_1^+)/E(2_1^+)$$

$$R_{0\gamma} = \frac{E(0_2^+) - E(2_\gamma^+)}{E(2_1^+)}$$

^{148}Ce in IBA symmetry triangle

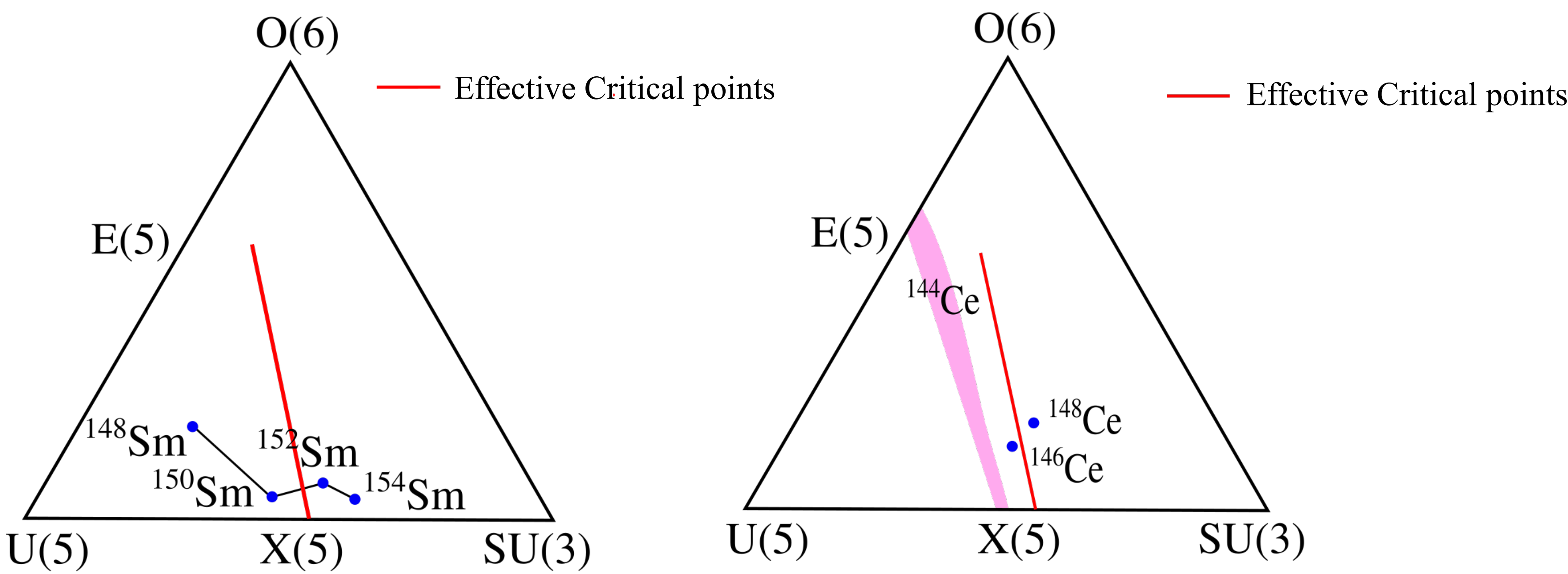




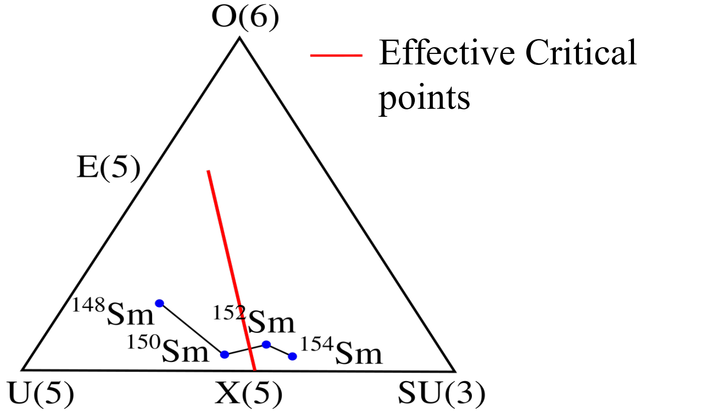
$$R_{4/2} = E(4_1^+)/E(2_1^+)$$

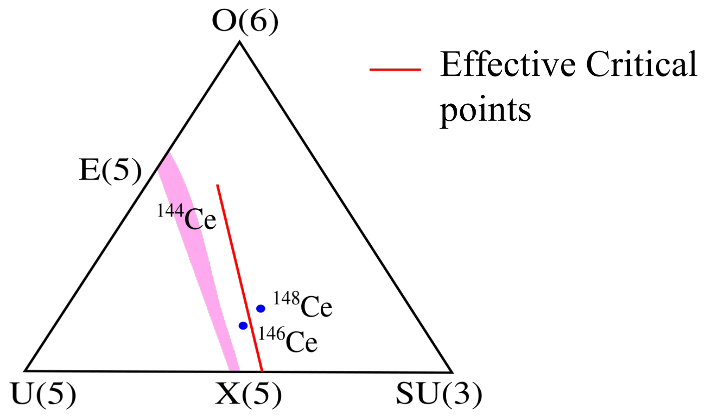
$$R_{0\gamma} = \frac{E(0_2^+) - E(2_\gamma^+)}{E(2_1^+)}$$

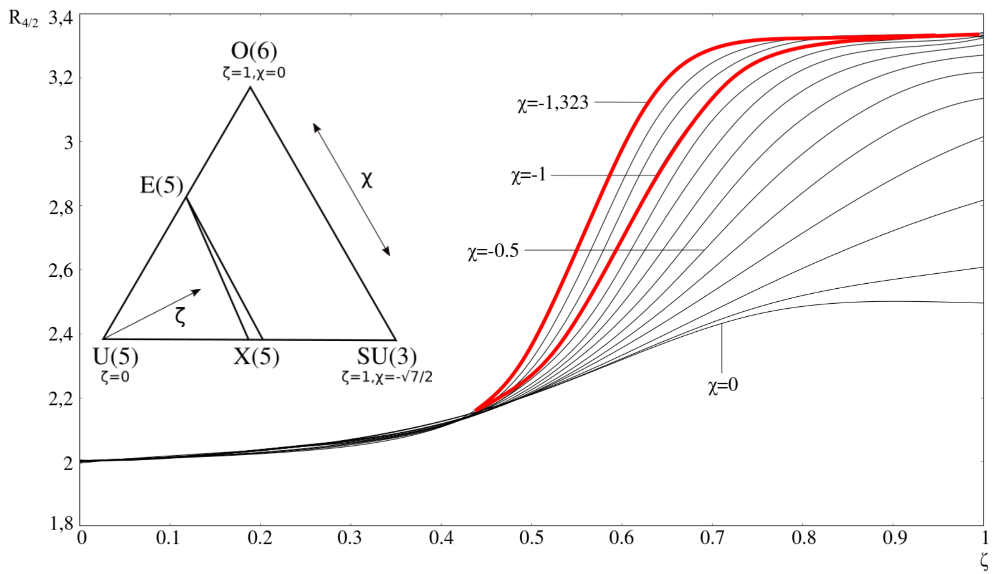
Sm isotopic chain in the triangle



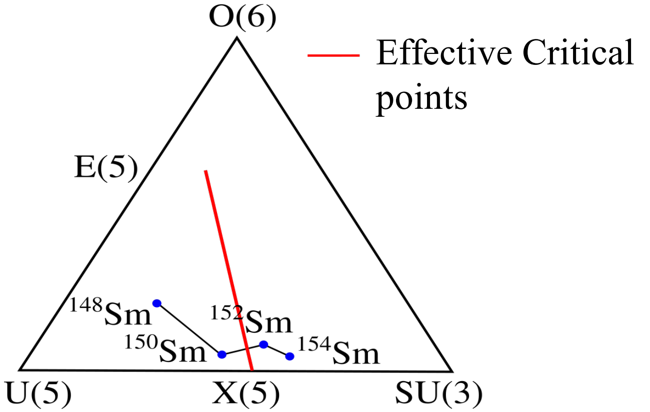
"Crossing" the critical point

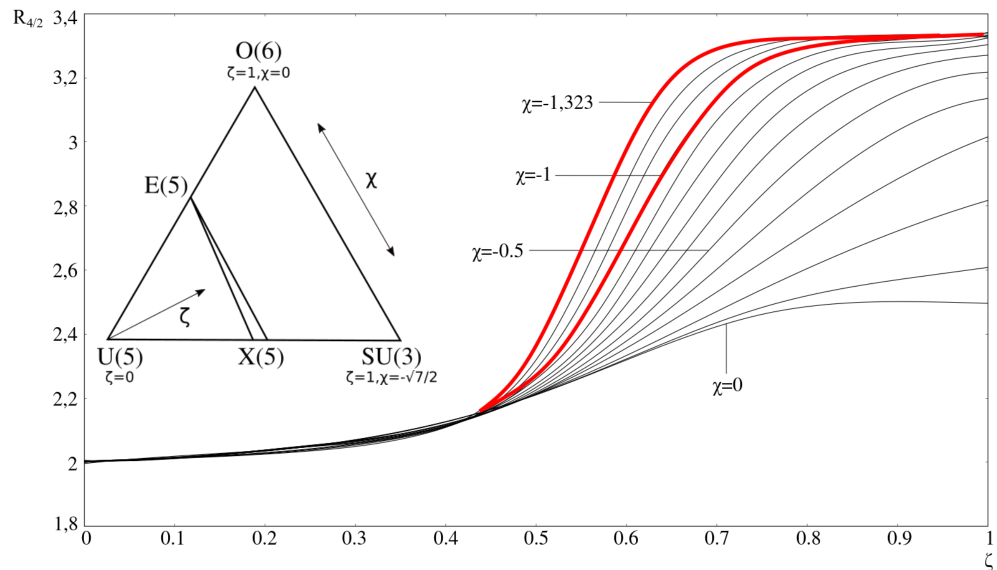


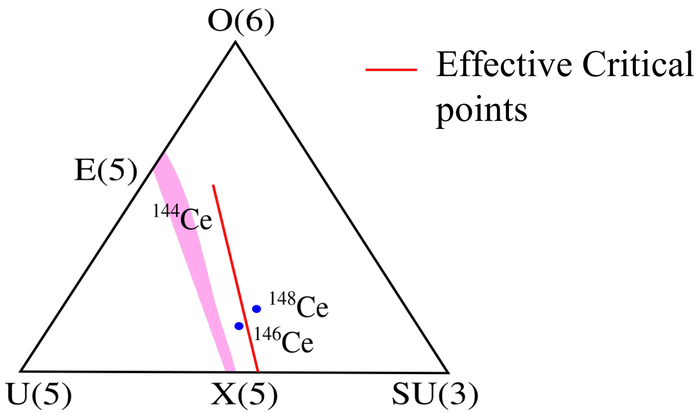


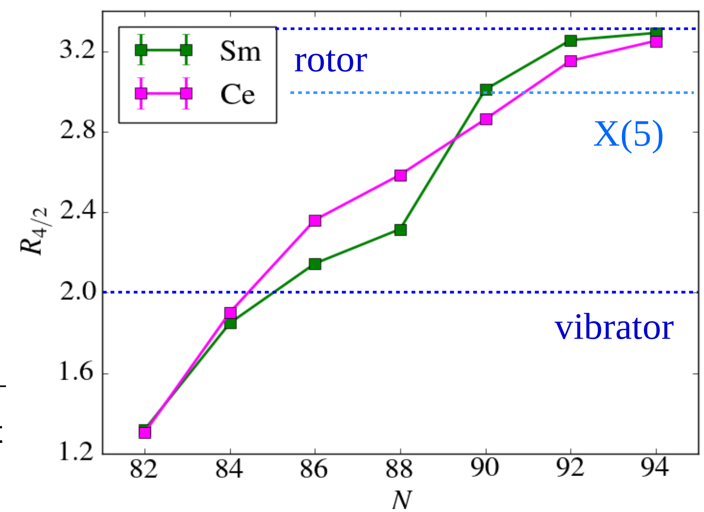


"Crossing" the critical point









Summary

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- The lifetime of the first 2^+ and 4^+ states of ^{148}Ce were measured.
  - The $B_{4/2}$ ratio indicates the transitional flavor of the nucleus.
- IBA-1 calculations were made to place the Ce isotopic chain in the IBA symmetry triangle.
  - The isotopes are "heading" inside the triangle.
  - The effective critical point is between ^{146}Ce and ^{148}Ce.

Thank you for your attention!

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P. Koseoglou[1,2], V. Werner[1,3], N. Pietralla[1], S.Ilieva[1], M. Thürauf[1], C. Bernards[3], A. Blanc[4], A. M. Bruce[5], R. B. Cakirli[6,7], N. Cooper[3], L. M. Fraile[8], G. de France[9], M. Jentschel[4], J. Jolie[10], U. Koester[4], W. Korten[11], T. Kröll[1], S. Lalkovski[12], H. Mach[13,†], N. Mărginean[14], P. Mutti[4], Z. Patel[15], V. Paziy[9], Z. Podolyák[15], P. H. Regan[15,16], J.-M. Régis[10], O. J. Roberts[5], N. Saed-Samii[10], G. S. Simpson[17], T. Soldner[4], C. A. Ur[18], W. Urban[4], D. Wilmsen[9], E. Wilson[15]

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