In-beam γ-ray Spectroscopy of ^{88,90,92,94}Se

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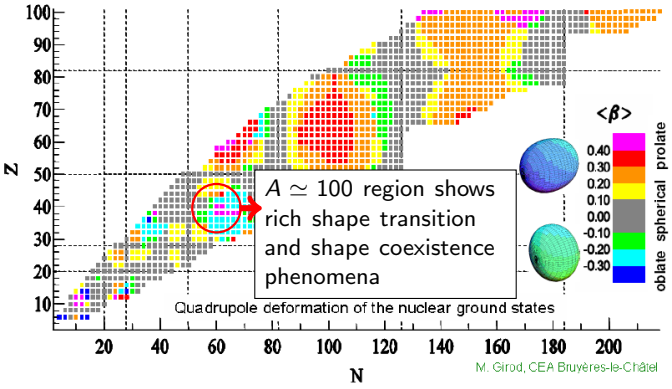
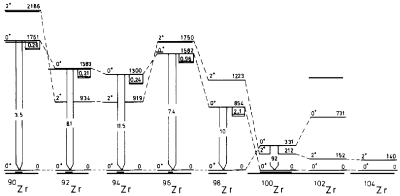
Motivation

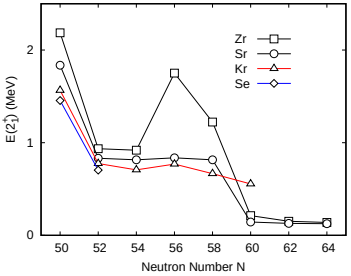


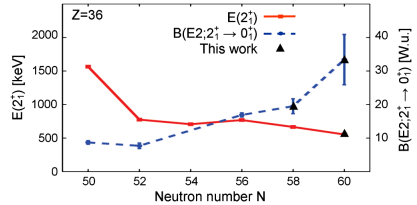


J.L. Wood, Physics Reports, 1992, 215, 101 - 201

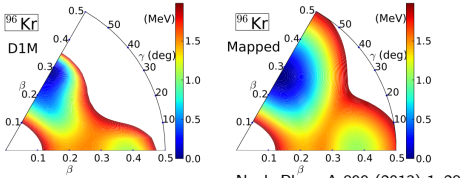
competition of coexisting spherical and well deformed prolate structures in Zr

Motivation





Phys. Rev. Lett 108, 062701 (2012)



Nucl. Phys. A 899 (2013) 1–28

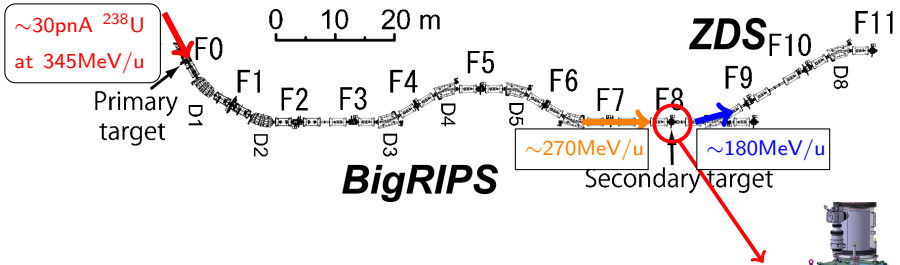
Smooth onset of deformation till $N = 60$

Possible shape coexistence in ^{96}Kr

For Se, level energies are only known until $N = 52$

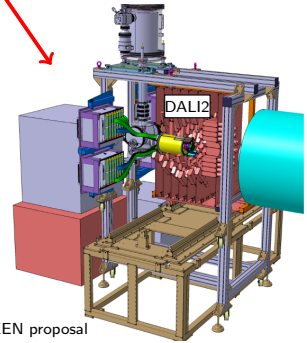
How is the evolution of Se until $N = 60$?

Experimental Setup at RIBF



Secondary Target: 100 mm liquid hydrogen
Reactions: (p,2p),(p,pn),(p,3p),(p,2pn)...

DALI2: 186 NaI(Tl) detectors
9% (FWHM) resolution at 662keV
35% efficiency for 500 keV γ-ray

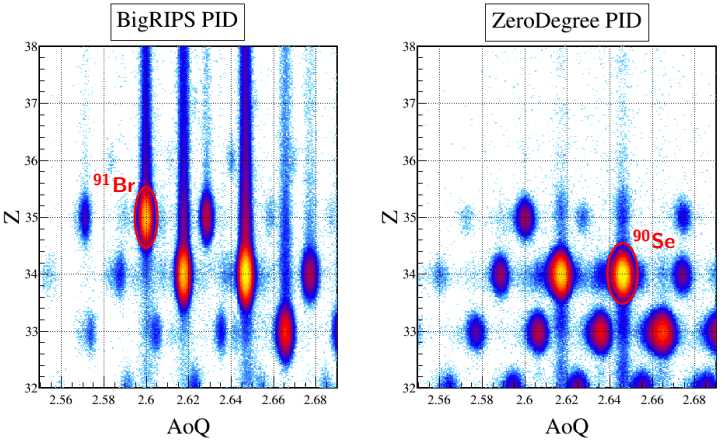


BigRIPS:Secondary Beam PID
ZDS:Fragments PID
DALI2:Deexcitation γ-ray
MINOS:Reaction Vertex

P. Doornenbal and A. Obertelli, RIKEN proposal

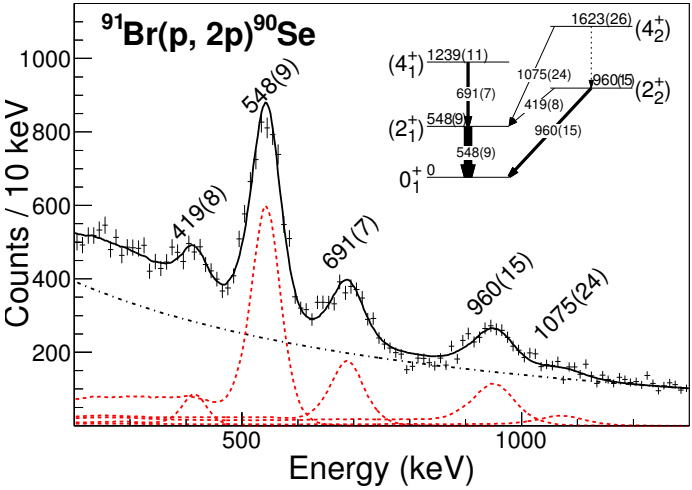
Particle Identification

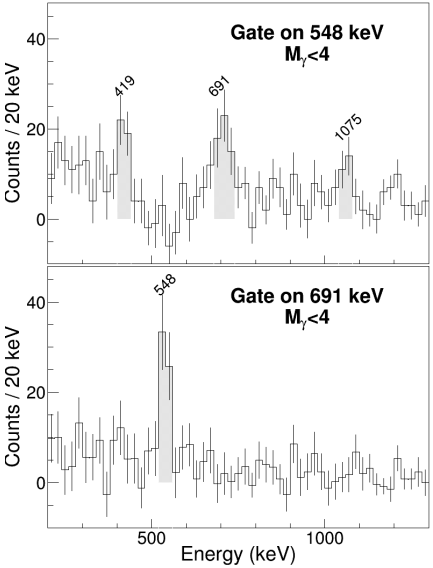
Selected Channel: ^{91}**Br(p,2p)^{90}Se**



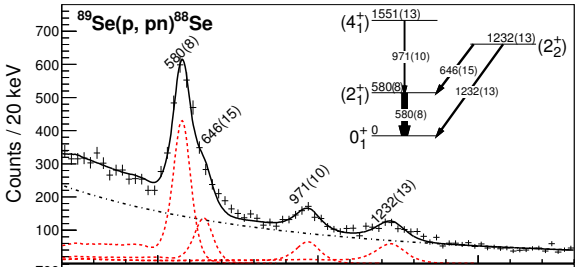
Channel	Events
^{89}Se(p, pn)^{88}Se	13413
^{91}Br(p, 2p)^{90}Se	29464
^{94}Br(p,2pn)^{92}Se	16601
^{95}Br(p, 2p)^{94}Se	1860

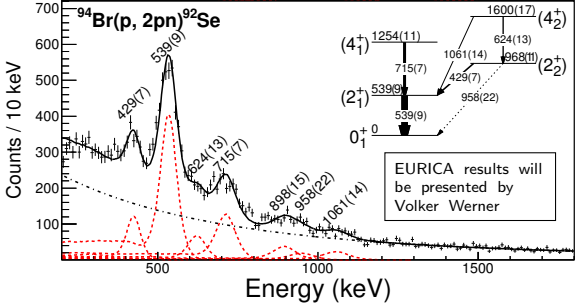
γ-ray Spectra of ^{90}Se

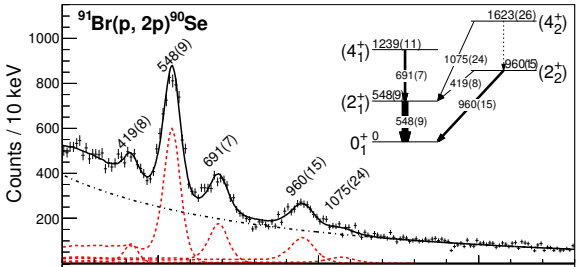


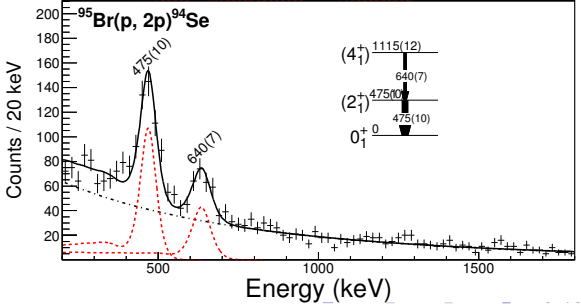


γ-ray Spectra of ^{88,90,92,94}Se

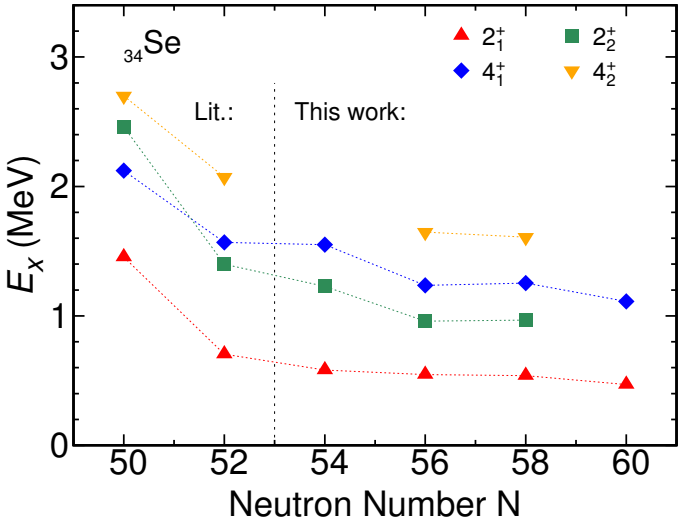


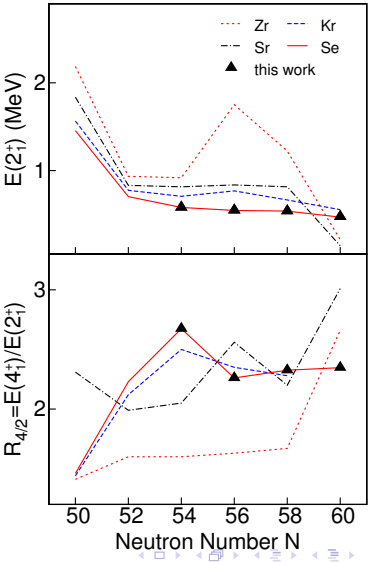






Systematics of neutron-rich Se isotopes

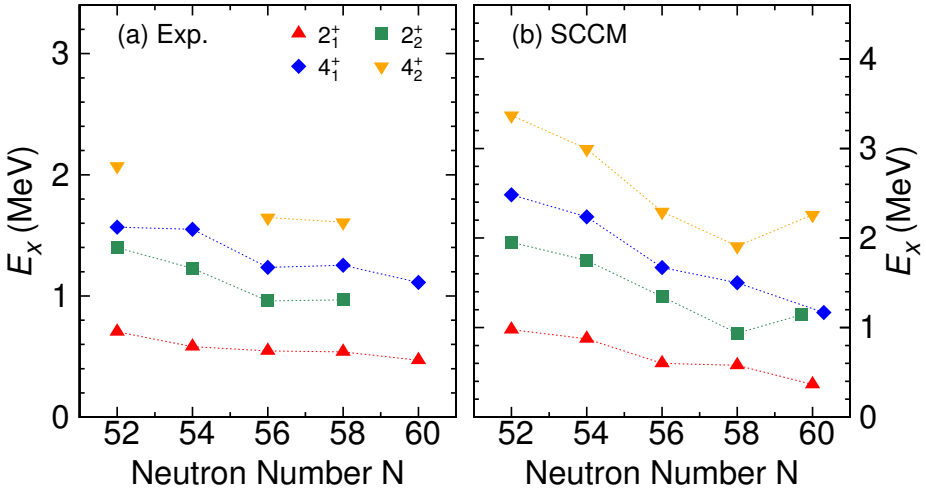




Theoretical framework

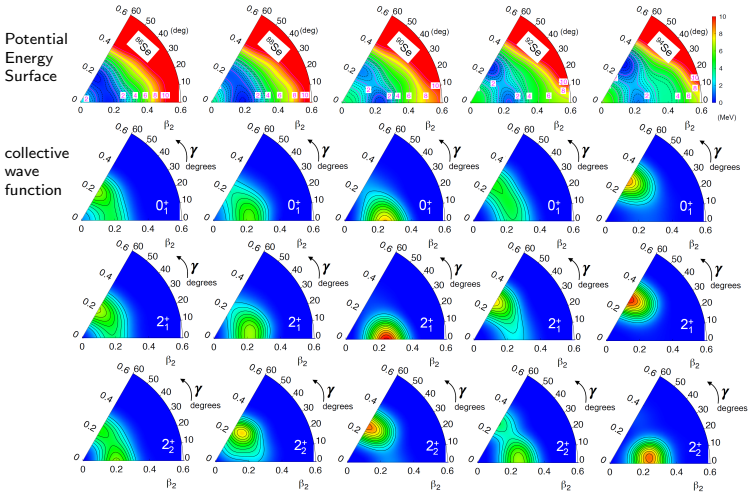
- **self-consistent beyond-mean-field** calculation based on **Gogny D1S** interaction
- **symmetry-conserving configuration mixing (SCCM)** method based on GCM and including particle number and angular momentum restorations and shape mixing of axial and triaxial intrinsic states
- time-reversal-symmetry-breaking (cranked) states are not included, a systematic stretching of energy levels is expected
- same calculations have been performed for Kr isotopes (T.R.Rodríguez, PRC 90,034306), for the low-lying properties, good agreements with experimental data are obtained.

Comparison between Exp. and SCCM calculation



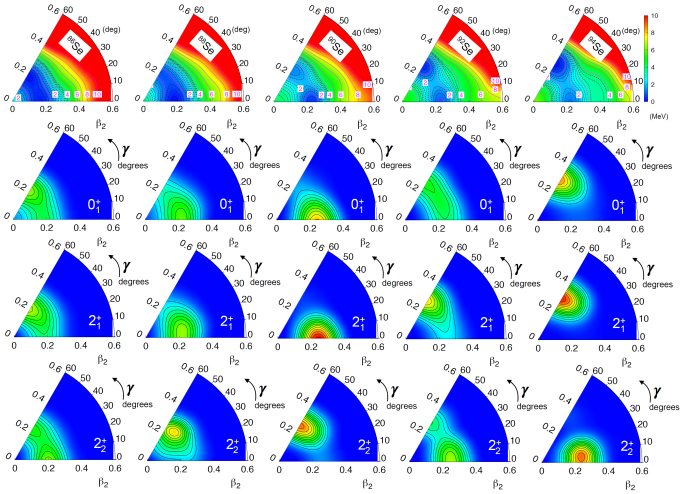
The SCCM calculation was preformed by T. R. Rodríguez.

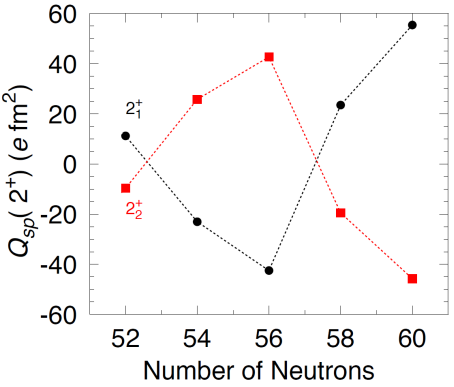
SCCM calculation – potential energy surfaces and collective wave function



- PES: γ-soft in ^{86,88}Se, two local minima in ^{90,92,94}Se
- 0_1^+ and 2_1^+ evolve from oblate-γ-soft (^{86}Se) to prolate (^{88,90}Se), then from prolate to oblate (^{94}Se) through oblate-γ-soft (^{92}Se)
- 2_2^+ show opposite transitions

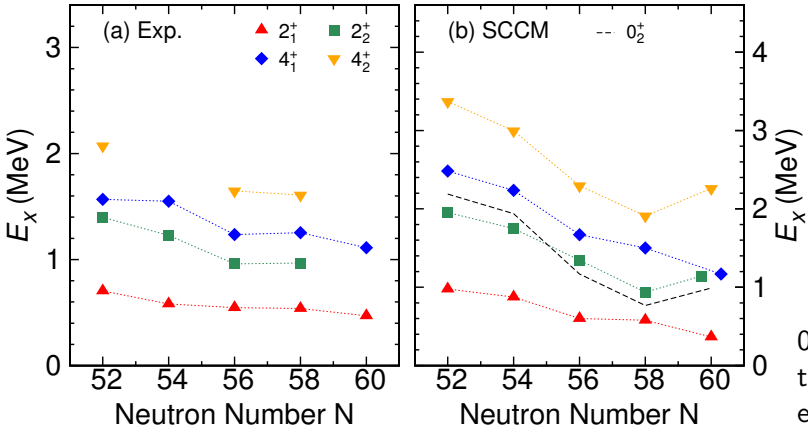
SCCM calculation – electric spectroscopic quadrupole moments





The calculated Q_{sp} values fully consistent with collective wave functions

SCCM calculation – predicted low-lying 0_2^+



0_2^+ are predicted to lie close to 2_2^+, thus not observed in experiment.

Summary

- Excited states of ^{88,90,92,94}Se were measured and level schemes were established
- A smooth, shallow drop of $E(2_1^+)$ was observed up to $N = 60$, suggests a smooth onset of collectivity in Se isotopic chain
- By comparing with beyond-mean-field calculation, a prolate-oblate shape transition was suggested with ^{92}Se be the transitional nucleus.
- low-lying 0_2^+ states are predicted by the calculation, suggests possible shape coexistences in this region

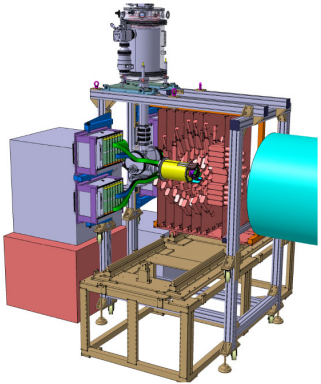
Collaboration

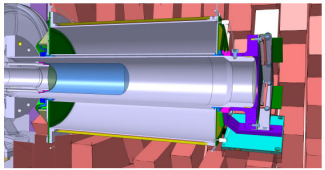
S. Chen, P. Doornenbal, A. Obertelli, T. R. Rodríguez, G. Authelet, H. Baba, D. Calvet, F. Château, A. Corsi, A. Delbart, J.-M. Gheller, A. Giganon, A. Gillibert, V. Lapoux, T. Motobayashi, M. Niikura, N. Paul, J.-Y. Roussé, H. Sakurai, C. Santamaria, D. Steppenbeck, R. Taniuchi, T. Uesaka, T. Ando, T. Arici, A. Blazhev, F. Browne, A. M. Bruce, R. Caroll, L. X. Chung, M. L. Cortés, M. Dewald, B. Ding, F. Flavigny, S. Franchoo, M. Górska, A. Gottardo, A. Jungclaus, J. Lee, M. Lettmann, B. D. Linh, J. Liu, Z. Liu, C. Lizarazo, S. Momiyama, K. Moschner, S. Nagamine, N. Nakatsuka, C. R. Nita, C. Nobs, L. Olivier, R. Orlandi, Z. Patel, Zs. Podolyak, M. Rudigier, T. Saito, C. Shand, P.-A. Söderström, I. Stefan, V. Vaquero, V. Werner, K. Wimmer, and Z. Xu

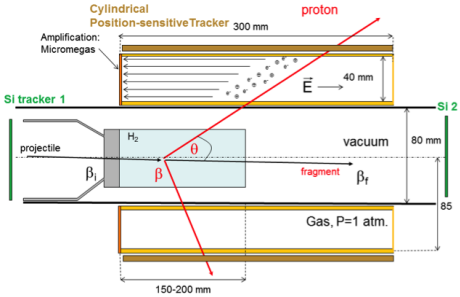
Thank you for listening

Backup

MINOS



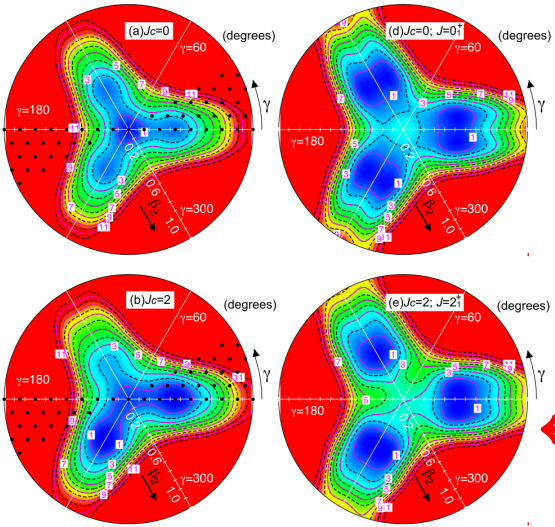


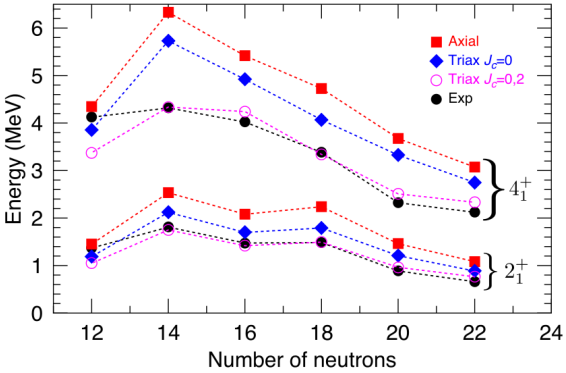


MINOS: vertex resolution better than 5 mm (FWHM)
95% effiency for (p,2p) channel

A. Obertelli et al., Eur. Phys. Jour. A 50, 8 (2014)

Cranked state in SCCM





time-reversal symmetry breaking states

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