Evolution of nuclear deformation in neutron-rich Kr isotopes

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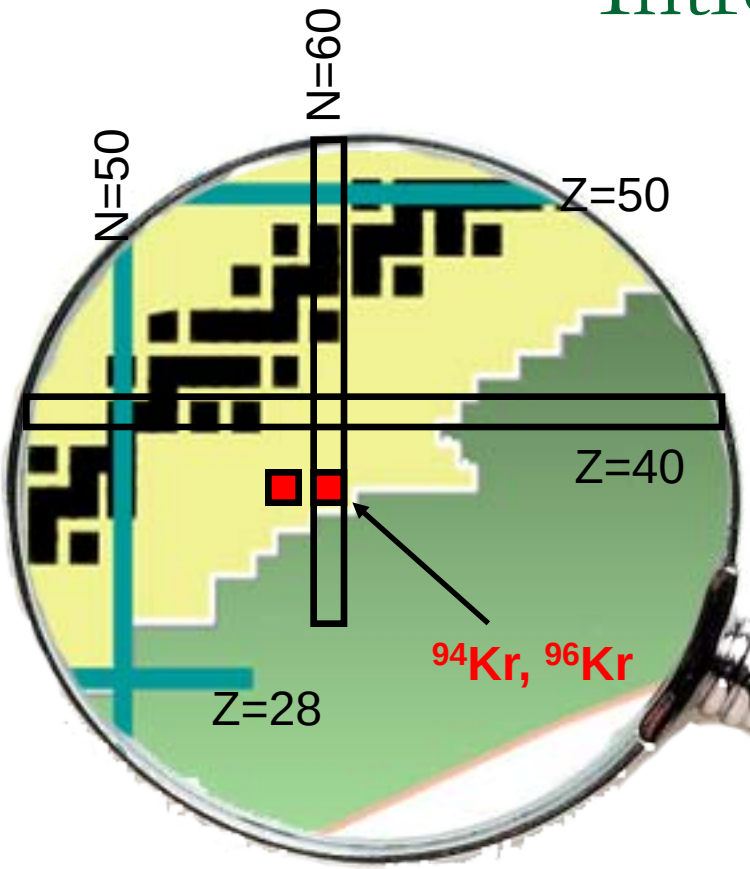
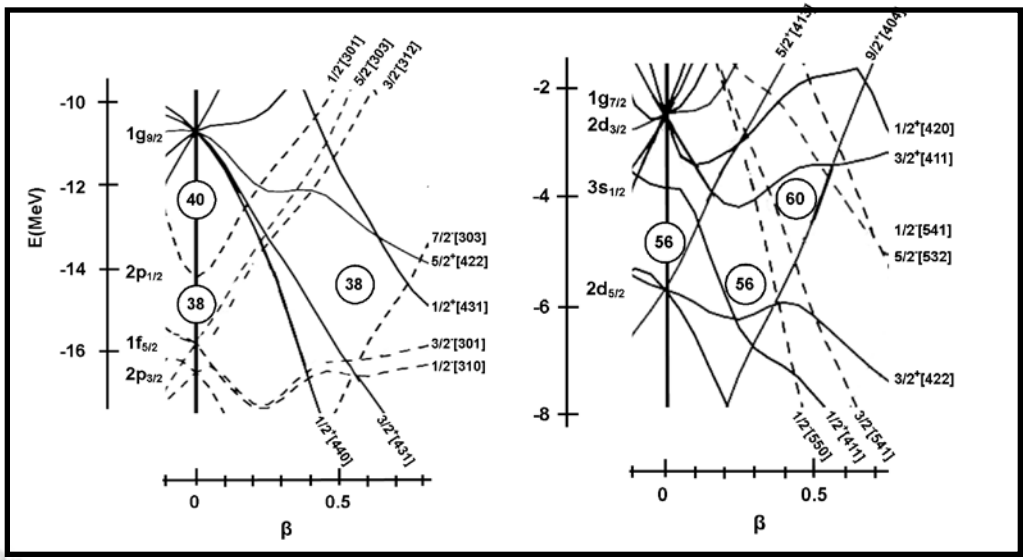
Introduction

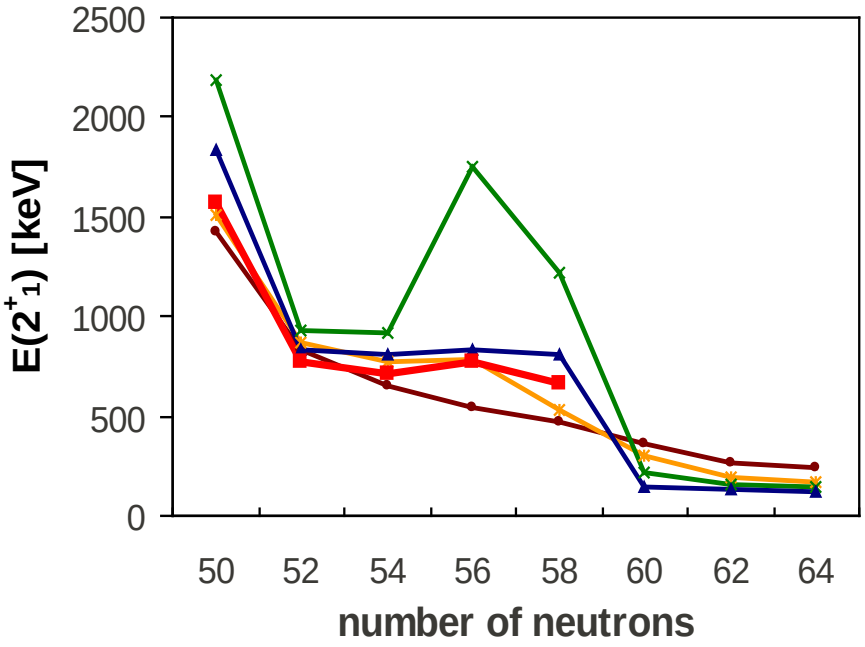


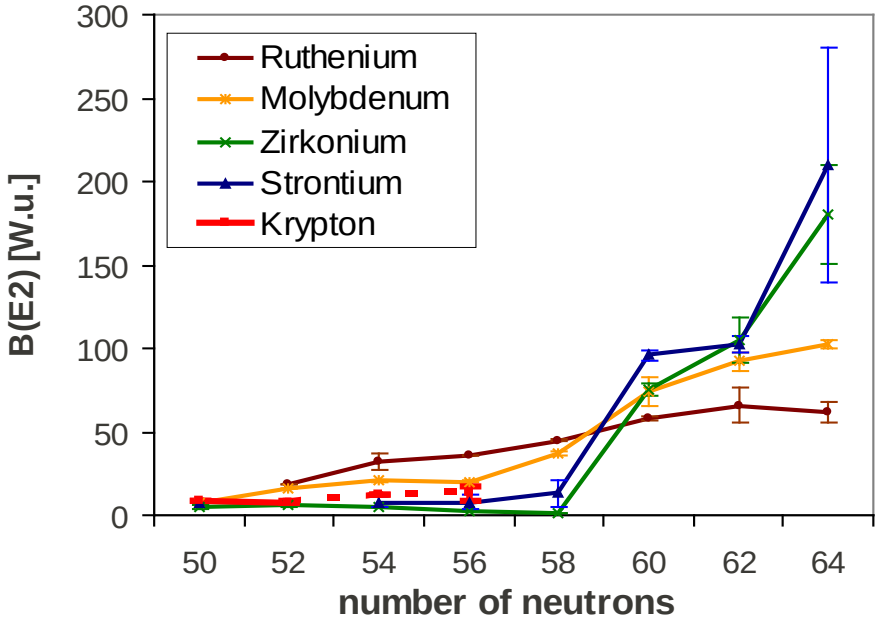


- At N=60 and around Z=40 a shape phase transition takes place: **spherical → deformed**
- Interpretation: correlated occupation of Nilsson states: $\pi g_{9/2} \leftrightarrow \nu h_{11/2}$

W. Urban et al., Eur. Phys. J. A, 22:241–252, 2004

Introduction





D. Mücher et al., Prog. In Part. And Nucl. Phys. 59 (2007), 361

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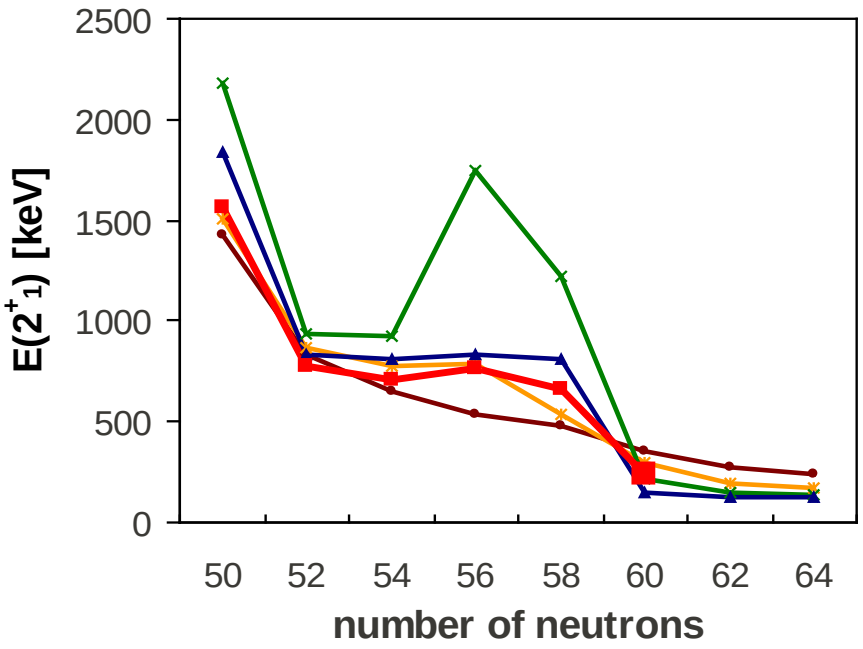
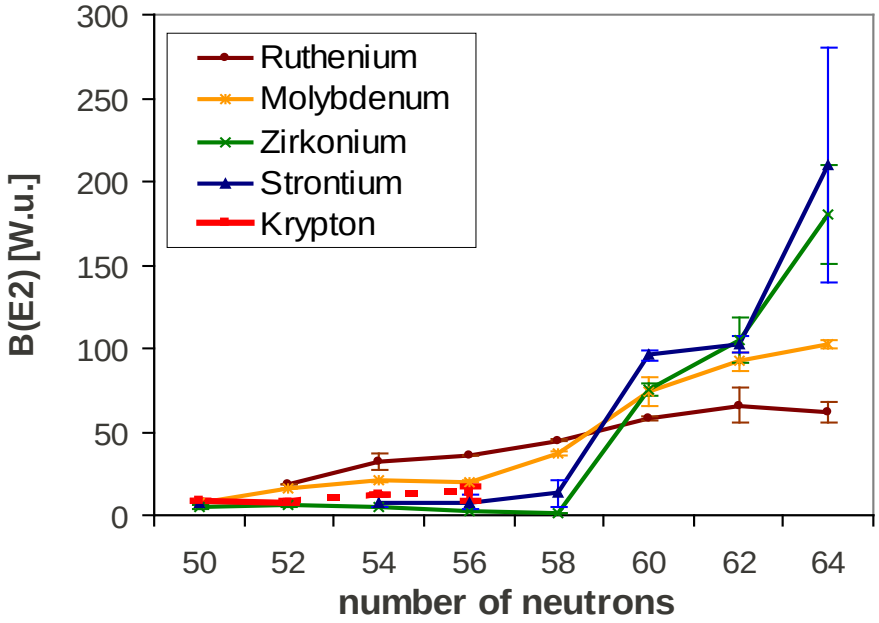
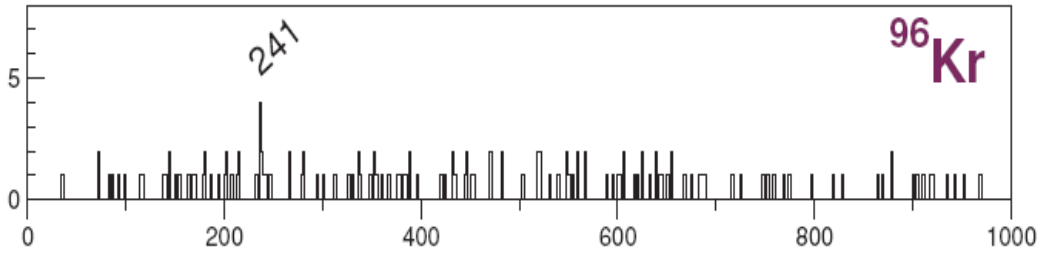




D. Mücher et al., Prog. In Part. And Nucl. Phys. 59 (2007), 361



N. Marginean et al., PRC80, (2009), 021301

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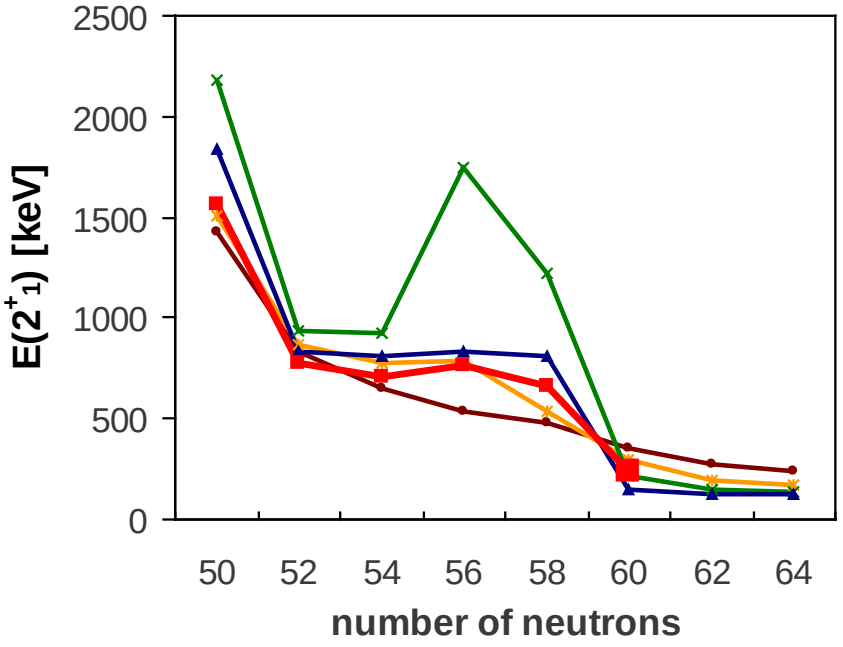
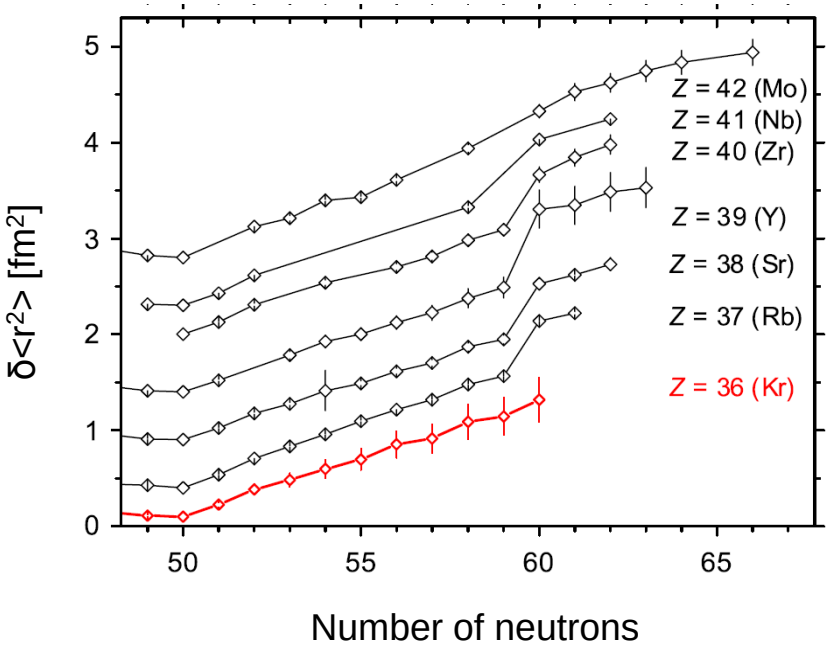
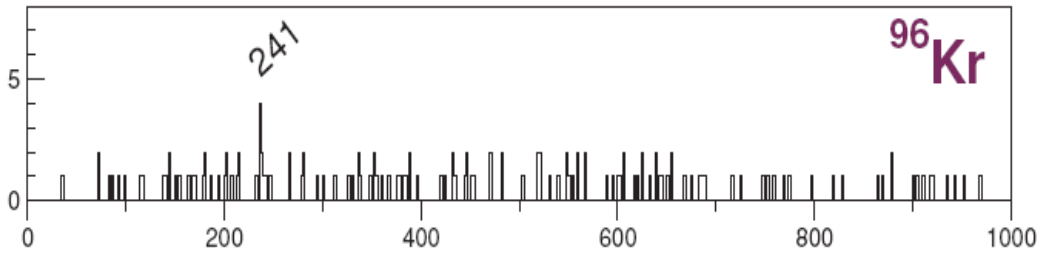


Mass measurements at
ISOLTRAP @REX-ISOLDE (2009)



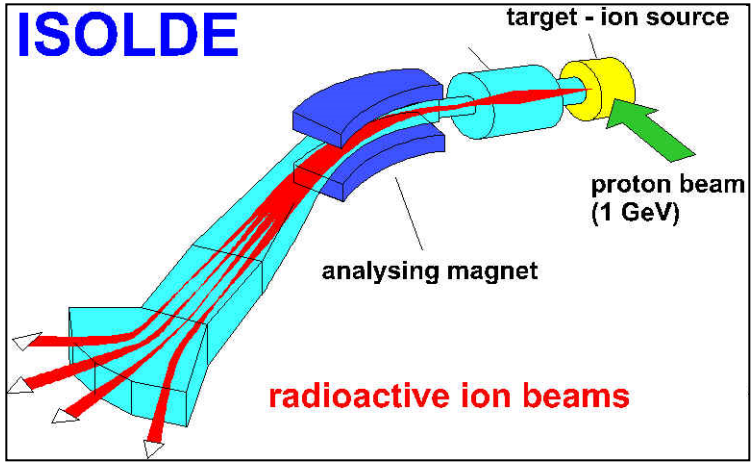
S. Naimi et al., Phys Rev Lett 105 (2010) 032502

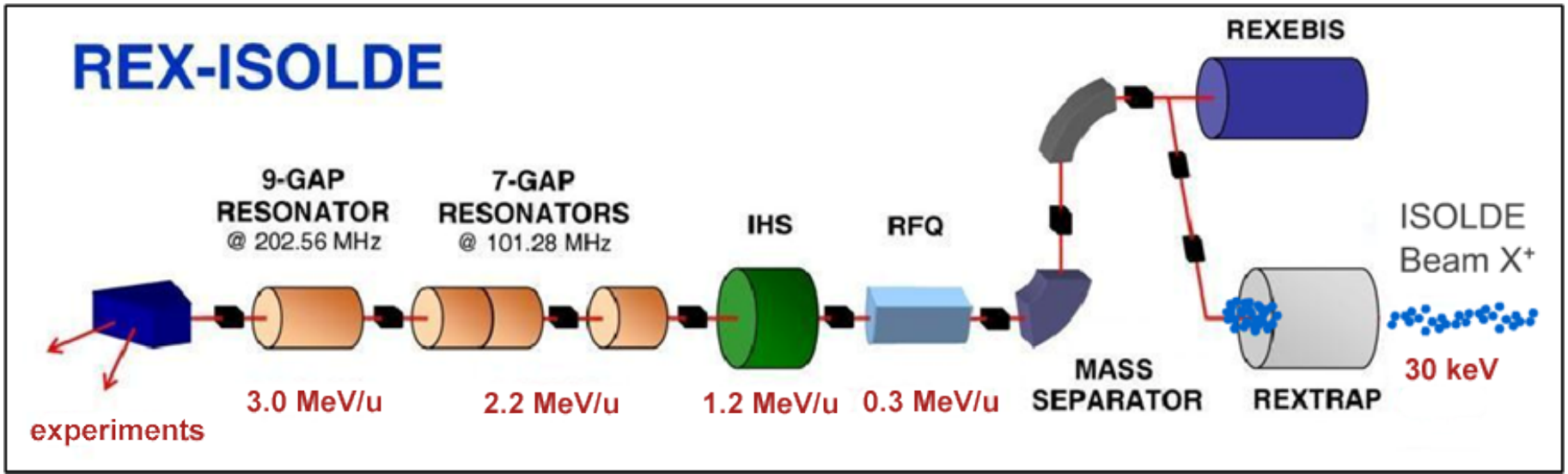


N. Marginean et al., PRC80, (2009), 021301

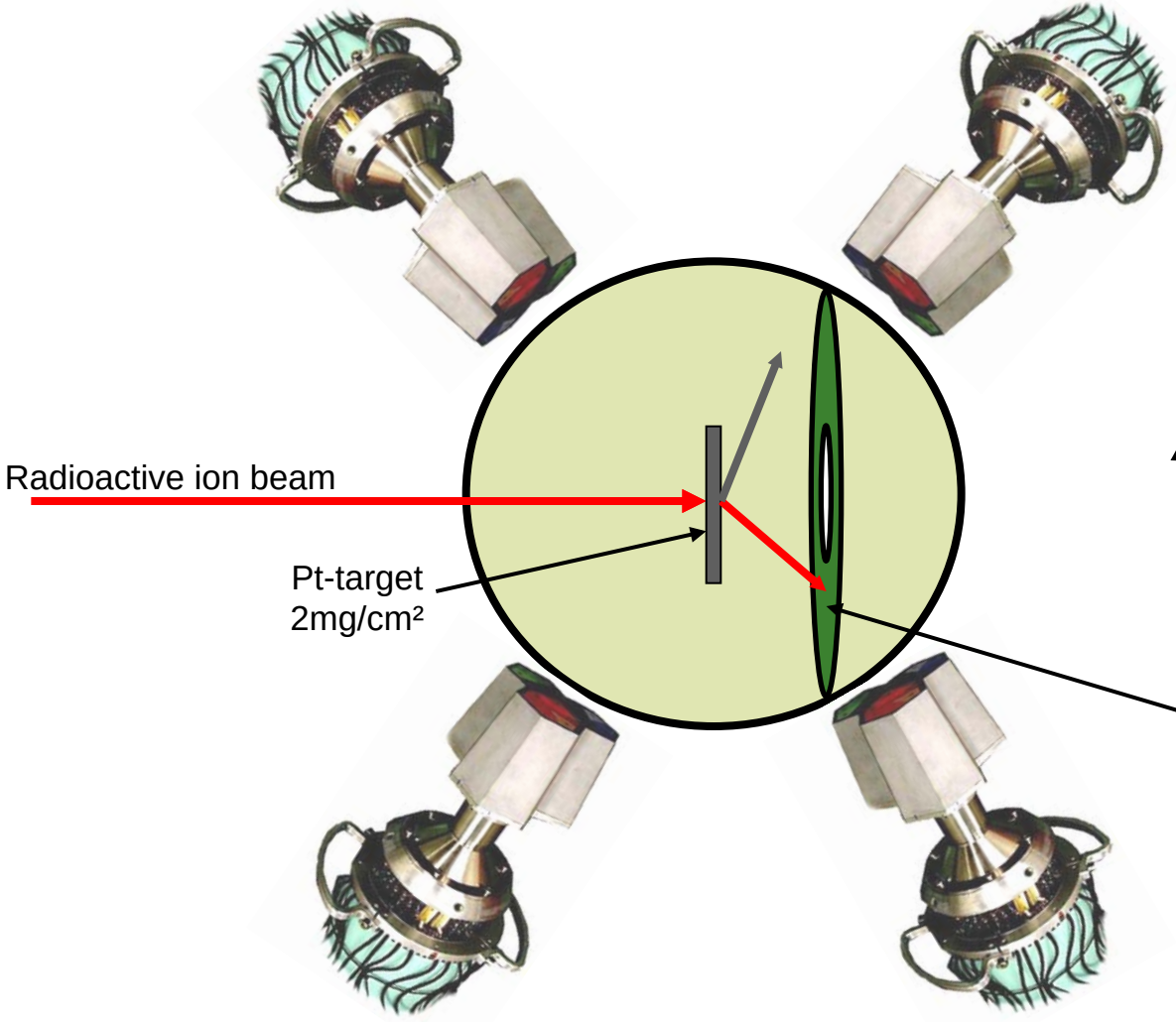
Experimentall setup at REX/ISOLDE at CERN

	^{94}Kr		^{96}Kr	
	2009	2010	2009	2010
Lifetime: [ms]	**212 (5) ms**		**80(6) ms**	
Beam energy: [MeV]	267.9		273.6	
$t_{collect} + t_{breed}$ [ms]	~ 80	~ 132	~ 100	~132
Charge state	22+		23+	
A/q	4.27		4.17	
# ions at target [Ions/sec]	$3 \cdot 10^6$	$2.8 \cdot 10^6$	$5.2 \cdot 10^4$	$4.4 \cdot 10^4$
Secondary target	^{196}Pt		^{196}Pt	^{194}Pt
Beam time	17h	12h	9h	16.5h





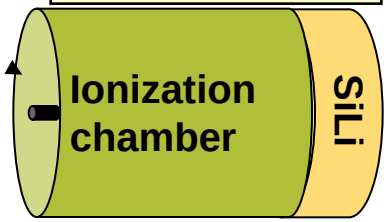
The MINIBALL γ – spectrometer



24 HPGe detectors

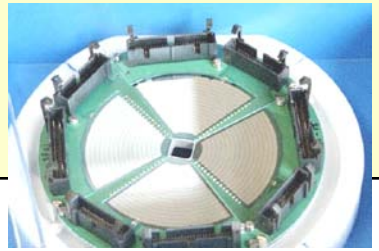
- combined to in total 8 MINIBALL Cluster detectors
- efficiency: 7% at 1.3 MeV
- resolution: 2-2.5 keV at 1.3 MeV

ΔE-E Telescope



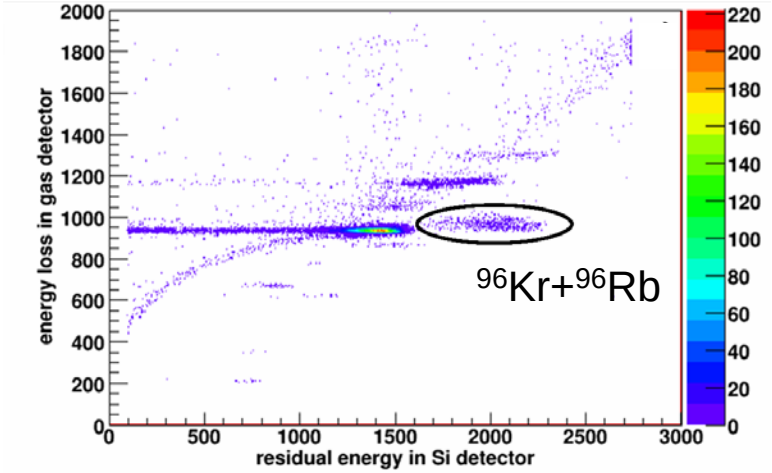
Double Sided Silicon Strip Detektor (DSSSD)

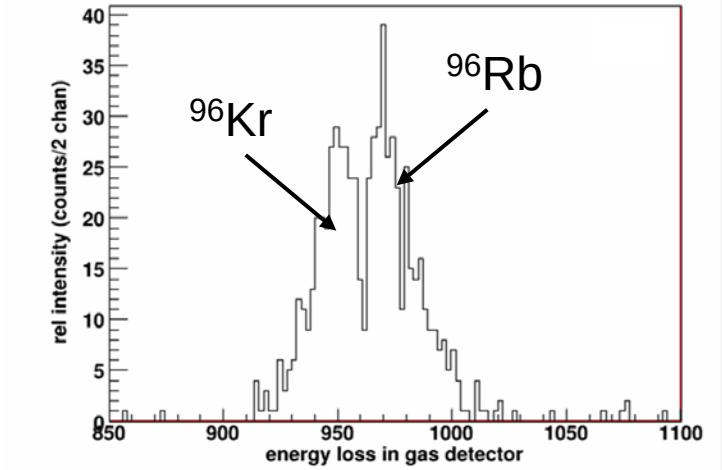
- highly segmented
- efficiency: 100%
- resolution: ~ 20 keV at 1 MeV



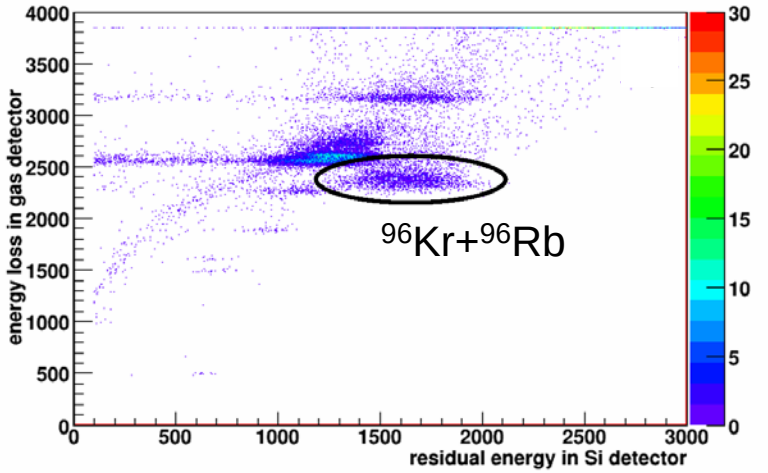
Determination of the beam composition during the ^{96}Kr experiments in

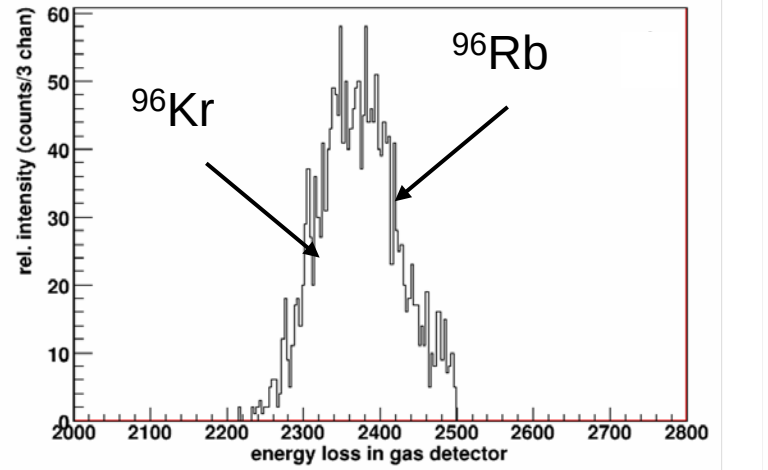
2009





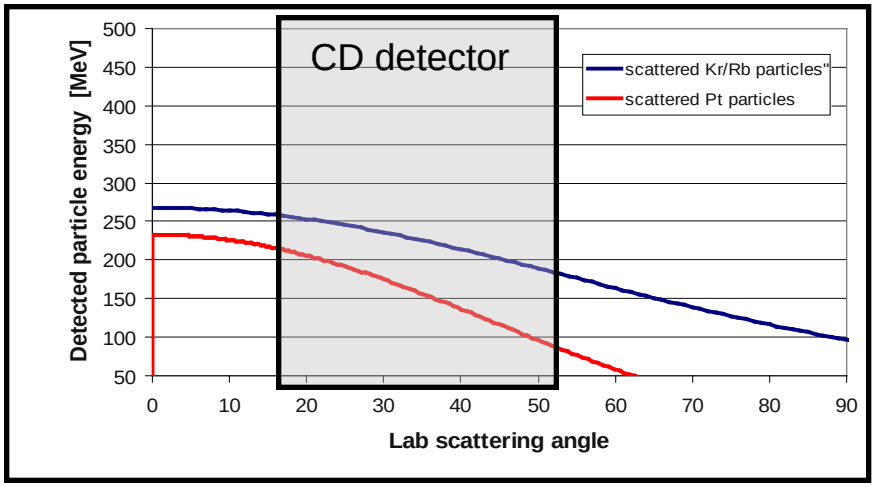
2010



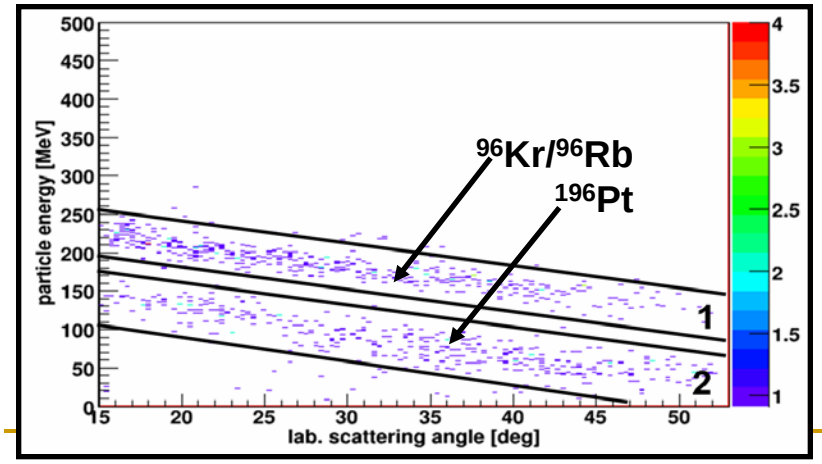


The Coulomb excitation experiments with ^{96}Kr

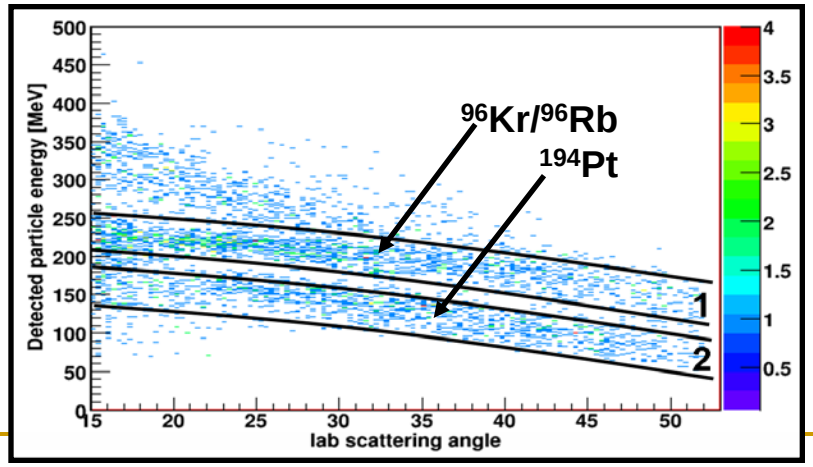
Calculated reaction kinematics



reaction kinematics 2009

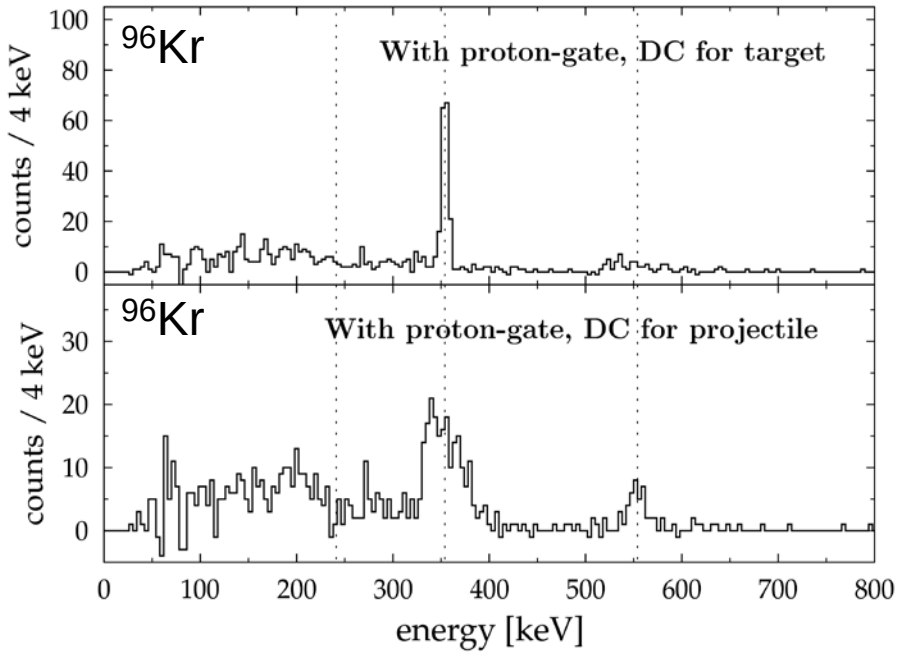


reaction kinematics 2010

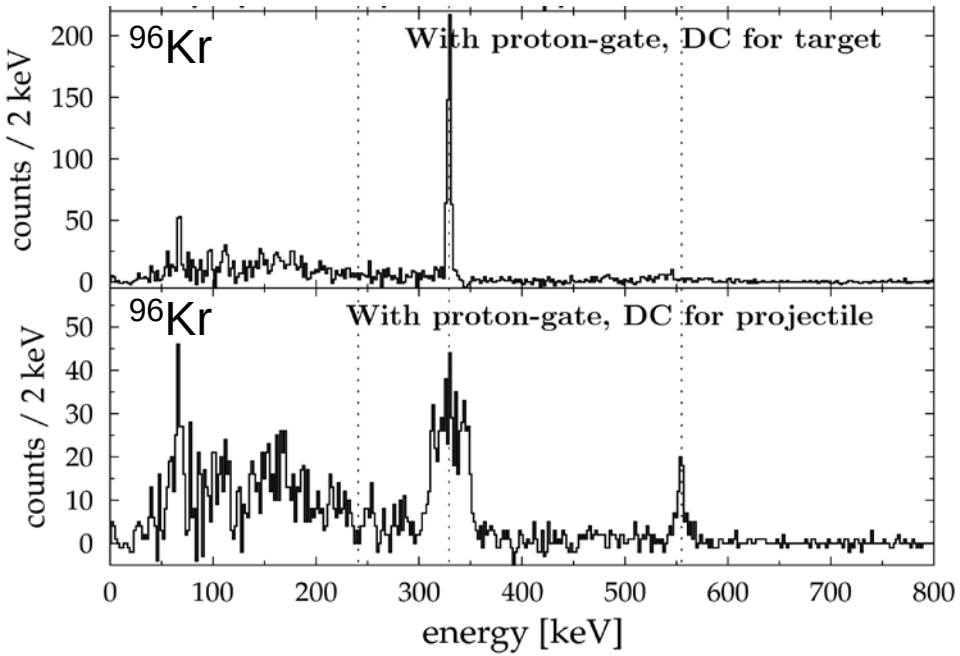


Preliminary γ-spectra of the ^{96}Kr experimental runs in

2009

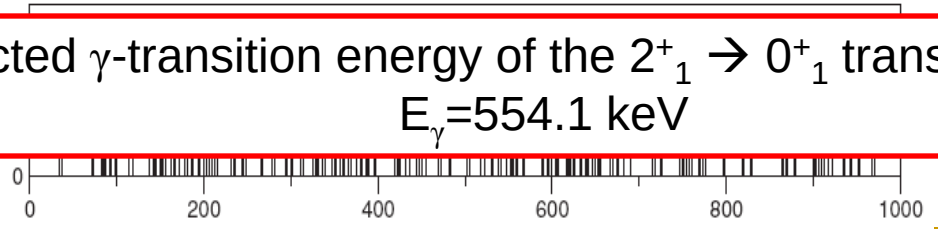


2010



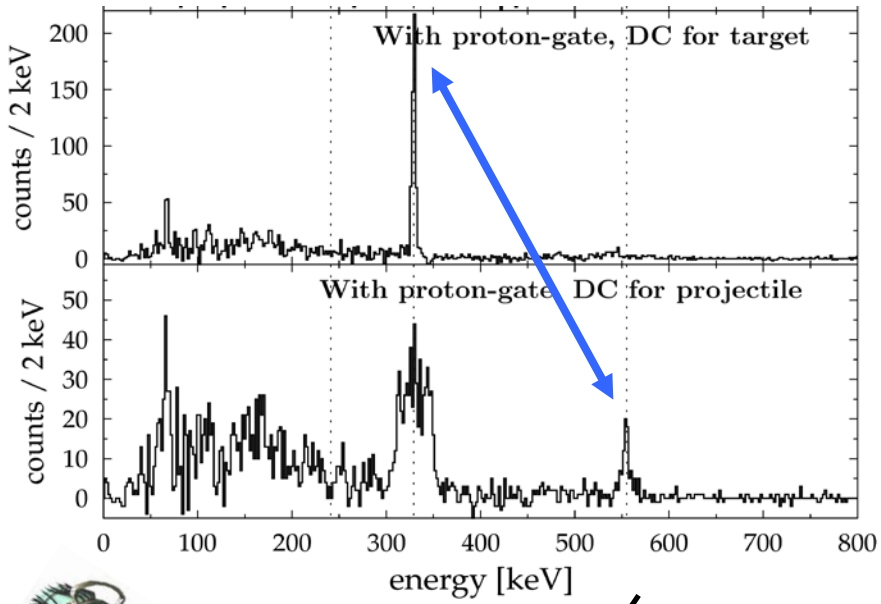
Doppler

Corrected γ-transition energy of the $2^+_1 \rightarrow 0^+_1$ transition in ^{96}Kr:
E_γ=554.1 keV



N. Marginean et al., PRC80, (2009), 021301

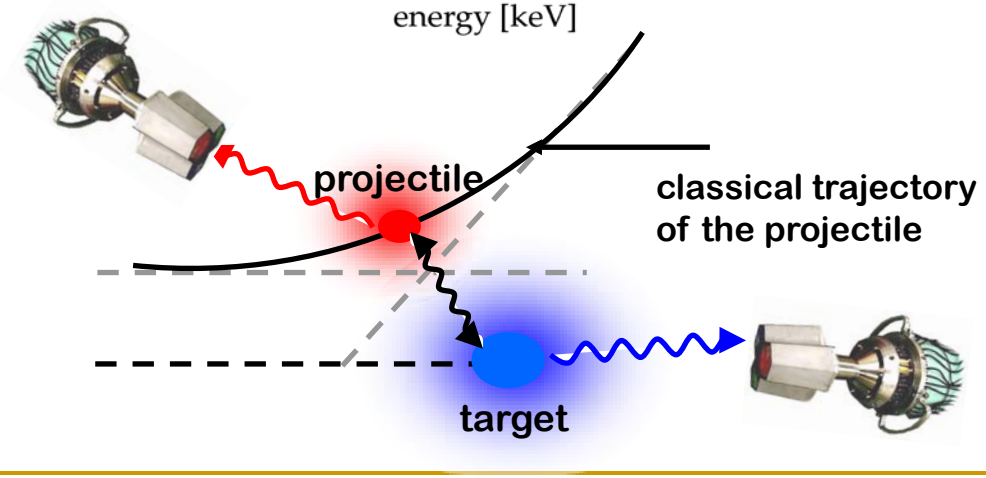
Determination of the B(E2; $2^+_1 \rightarrow 0^+_1$) values with the „normalization method“

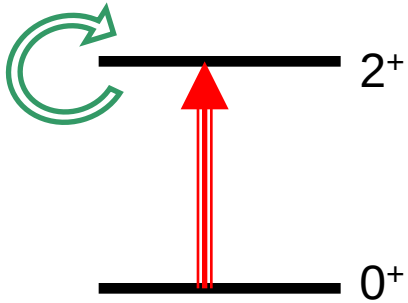


$$\sigma^{projectile} \propto \frac{N^{projectile}}{N^{target}} \frac{\varepsilon^{target}}{\varepsilon^{projectile}} \cdot \sigma^{target}$$

$$\sigma_{Coulex}(2^+_1) \propto \left\langle 2^+_1 \middle| ME \middle| 0^+_1 \right\rangle \propto B(E2; 2^+_1 \rightarrow 0^+_1)$$

$$\sigma_{Coulex}(2^+_1) \propto \left\langle 2^+_1 \middle| ME \middle| 2^+_1 \right\rangle \propto Q(2^+_1)$$





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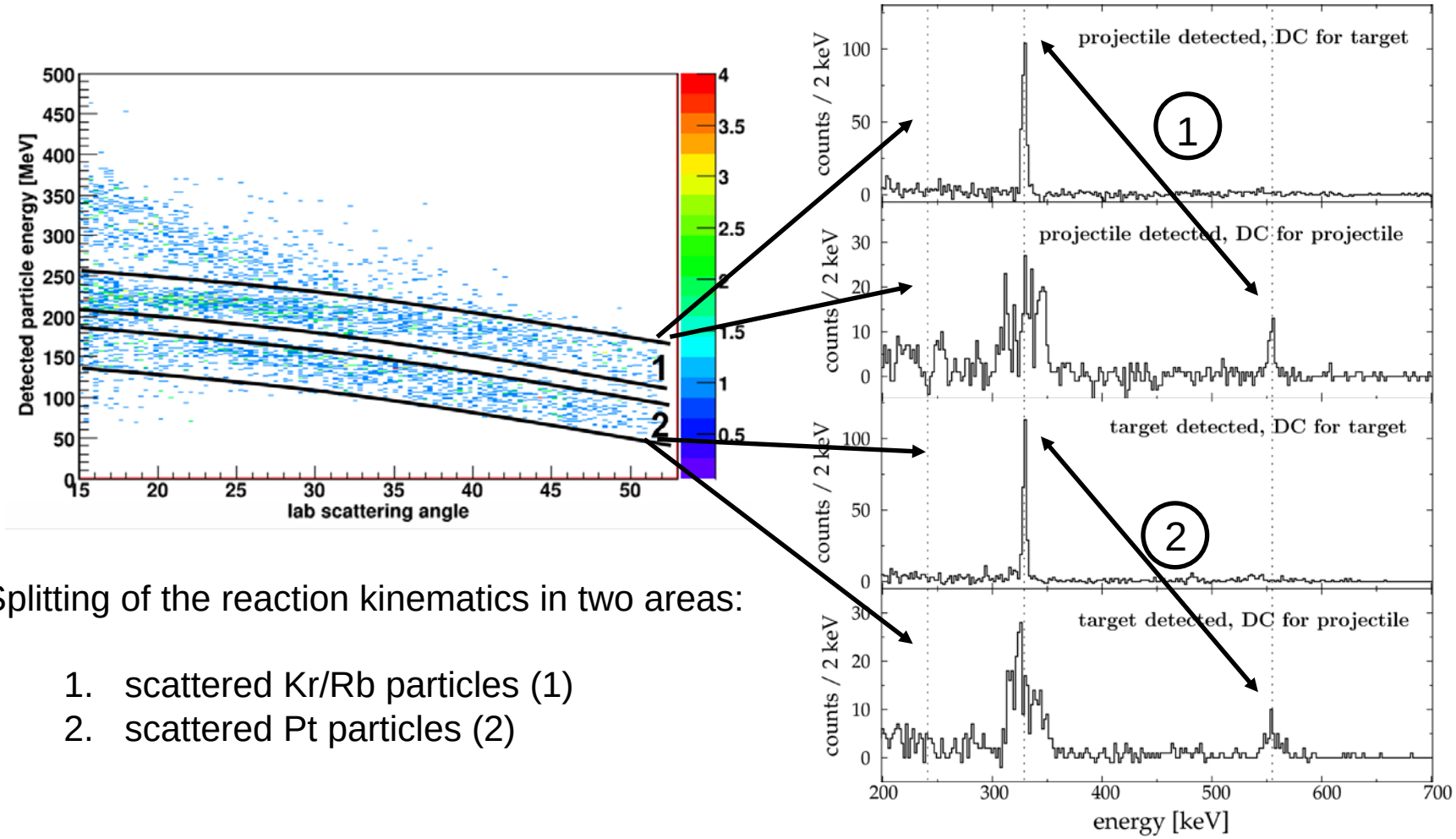


Splitting of the reaction kinematics in two areas:

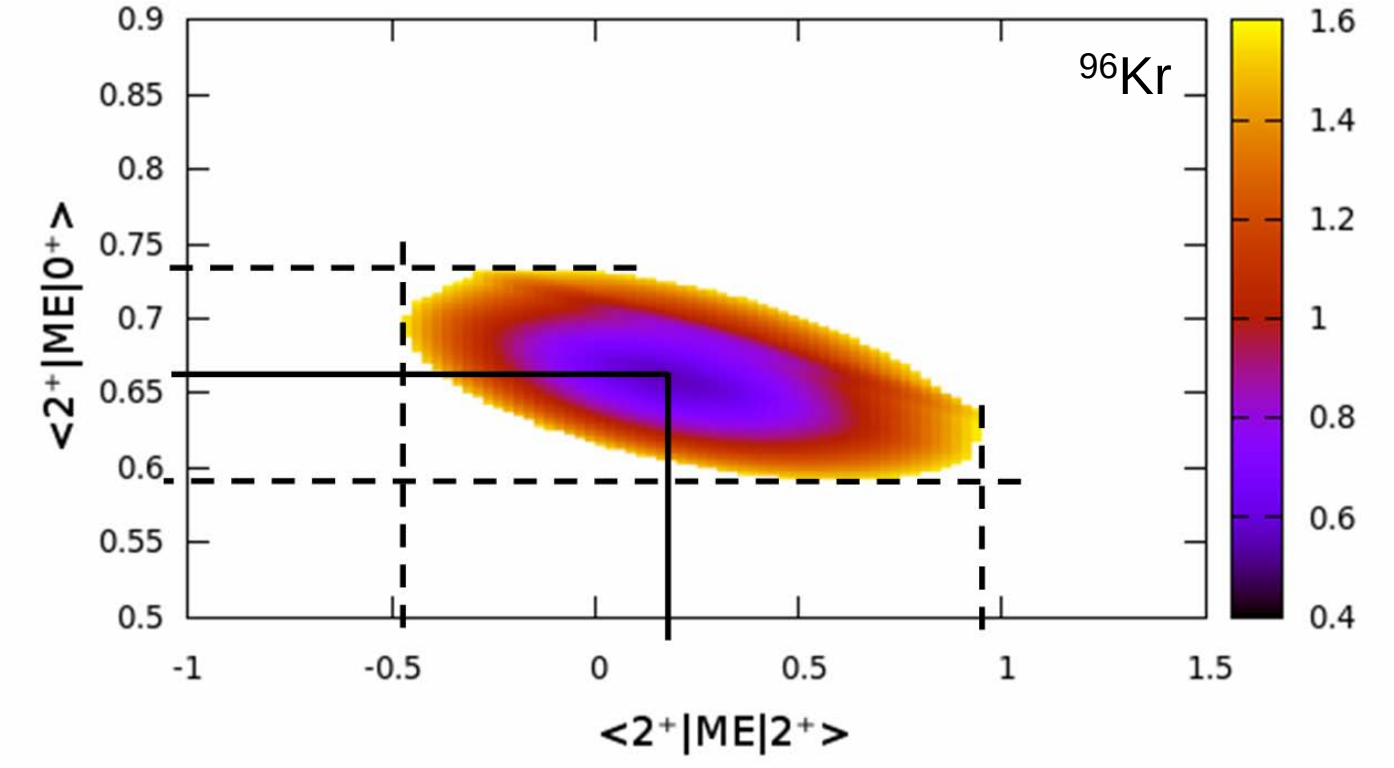
1. scattered Kr/Rb particles (1)
2. scattered Pt particles (2)

Determination of E2 transition strengths GOSIA2

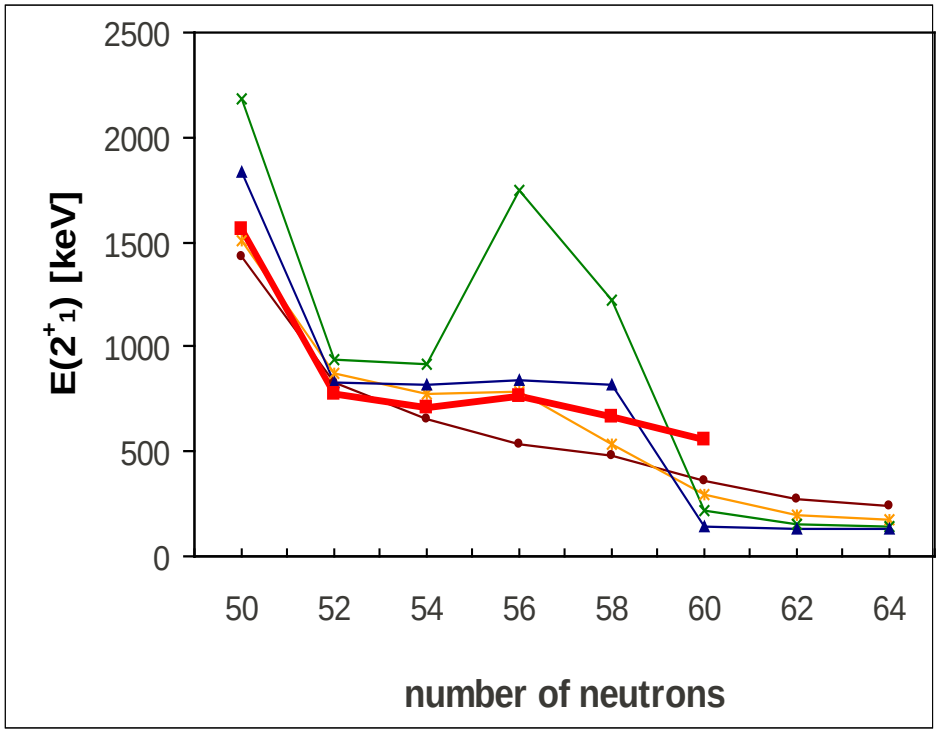
- Coupled-channel Coulomb-excitation code GOSIA2[1], based on the Coulomb-excitation theory of Winther and deBoer [2]:
  - Information about the experimental setup:
    - Position of the CD detector
    - Positions of the 24 Miniball cluster detectors
    - Reaction kinematics for both, projectile and target nuclei
  - Information about the target:
    - A, Z, thickness
    - low-lying level energies, diagonal and transitional matrix elements
    - Experimental data (lifetimes, multipole mixing ratios, …)
  - Information about the projectile:
    - A, Z, beam energy, energy loss in target
    - Low-lying level scheme (as far as known)
    - Start parameter for the diagonal and transitional matrix elements
  - Variation of the projectile matrix elements of the 2^+_1 state, until experimental yields are reproduced, or
  - Determination of the χ^2 value with respect to a set of start parameters for the matrix elements of the 2^+_1 state

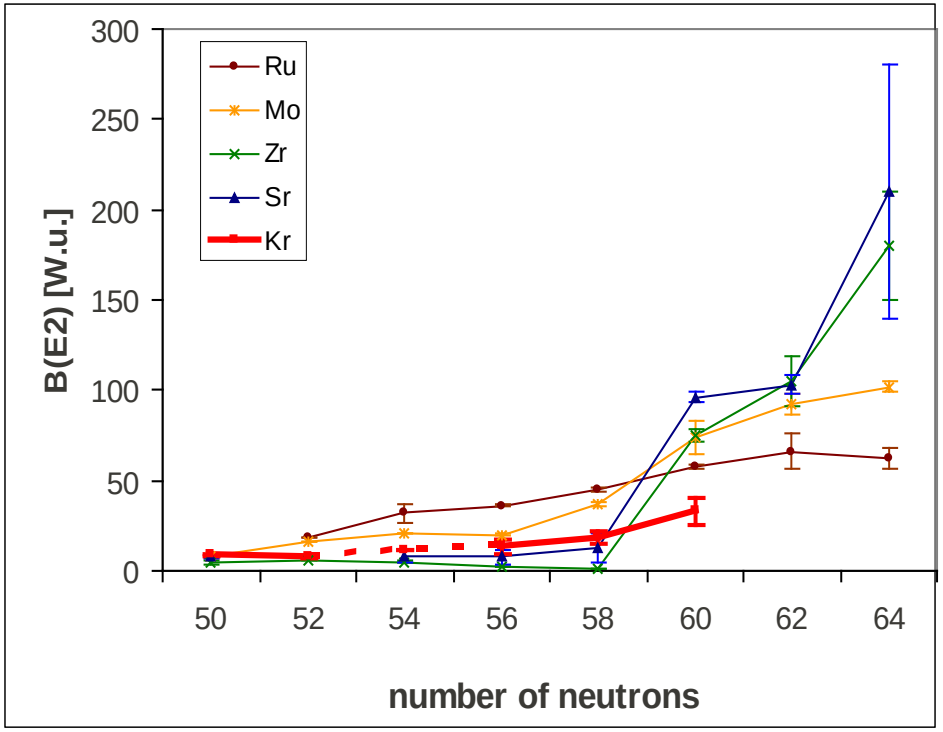
[1]: T. Czosnyka, D. Cline, and C.Y. Wu. Bull. Am. Phys. Soc., 28:745, 1983.
[2]: A. Winther and J. de Boer, *Coulomb Excitation*, (Academic, New York, 1965)

χ^2-surface scan of the ^{96}Kr data from 2009 and 2010

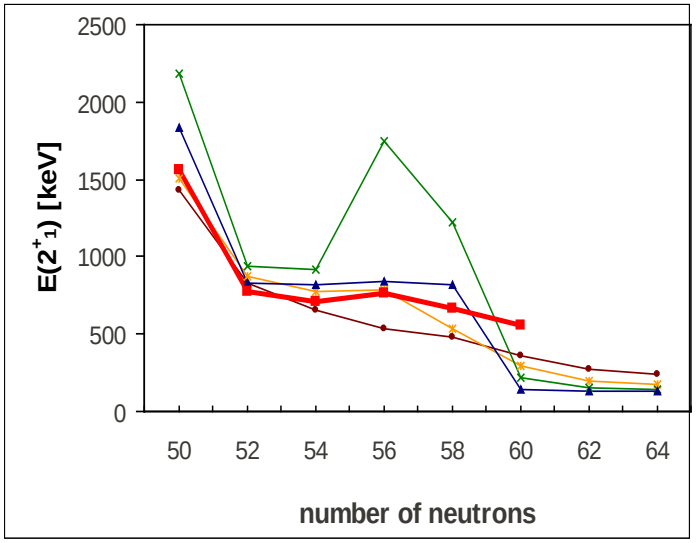


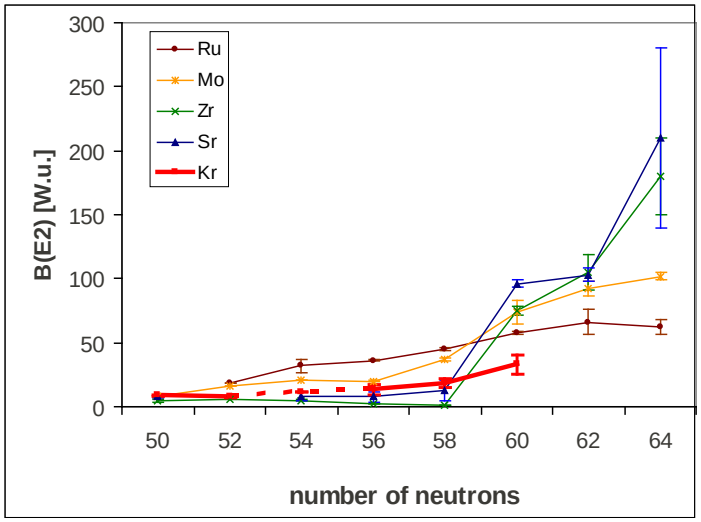
Summary of the experimental results



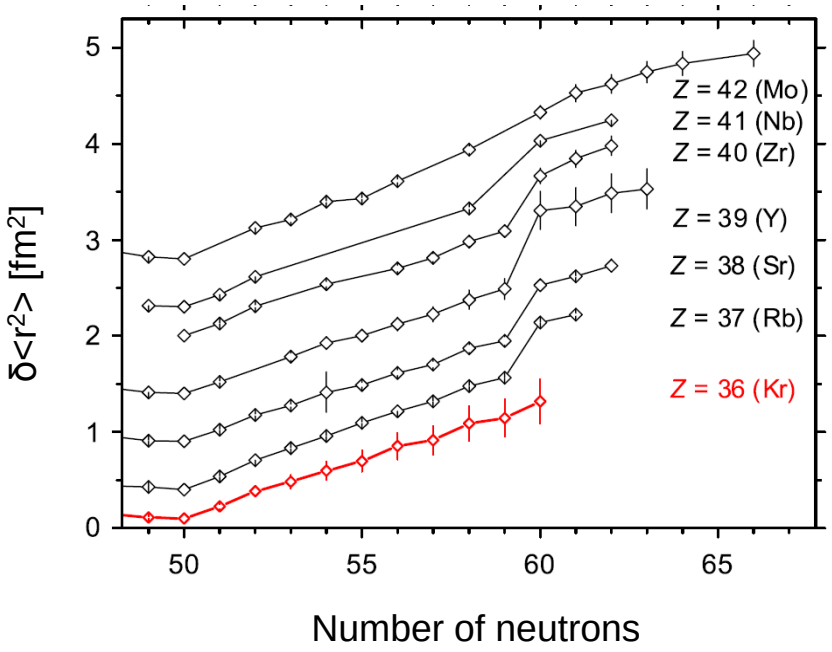


Summary of the experimental results





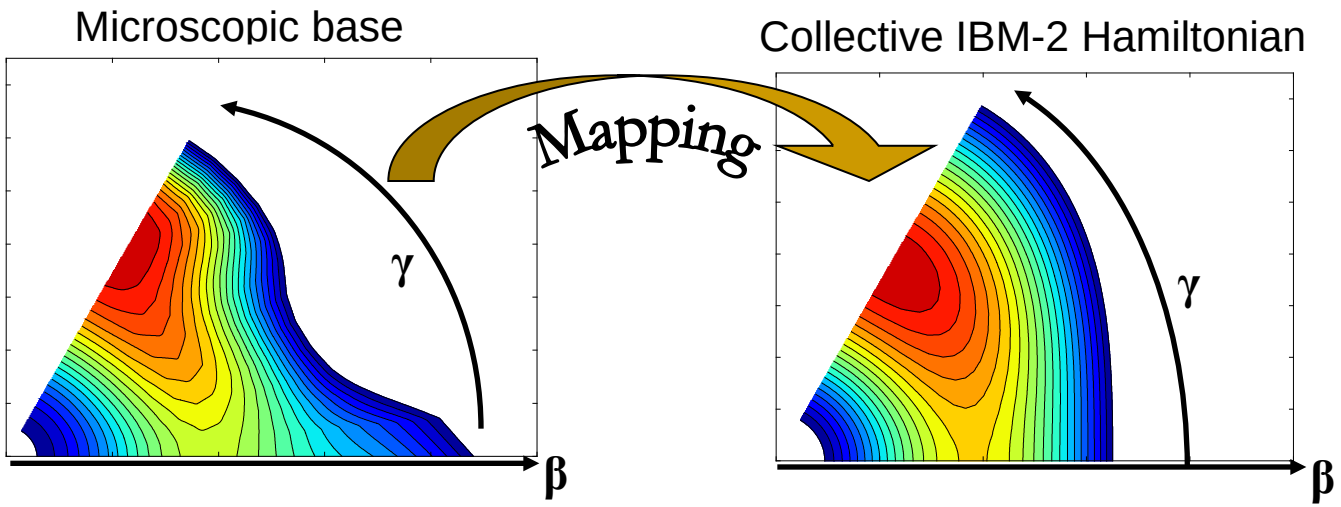
Mass measurements at
ISOLTRAP @REX-ISOLDE (2009)



S. Naimi et al., Phys Rev Lett 105 (2010) 032502

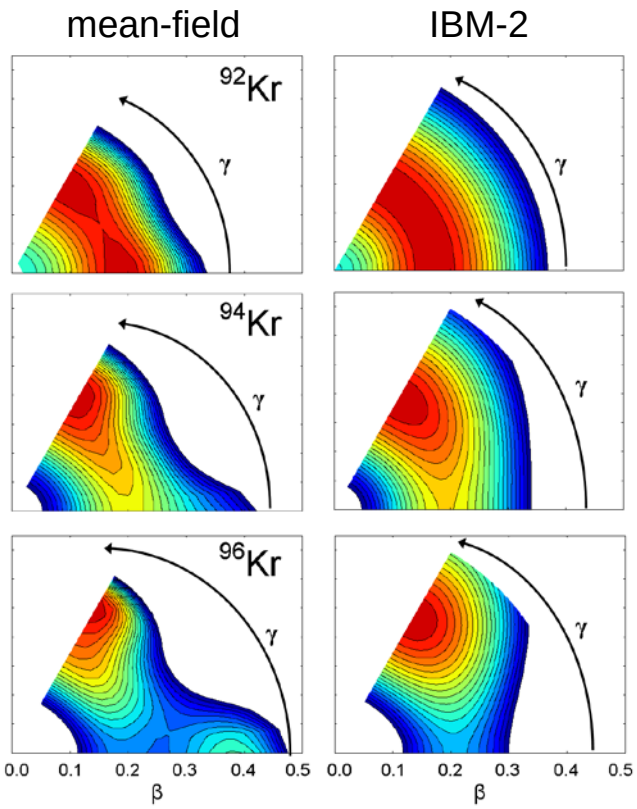
Derivation of the IBM-2 Hamiltonian based on mean-field calculations for the neutron-rich Kr isotopes

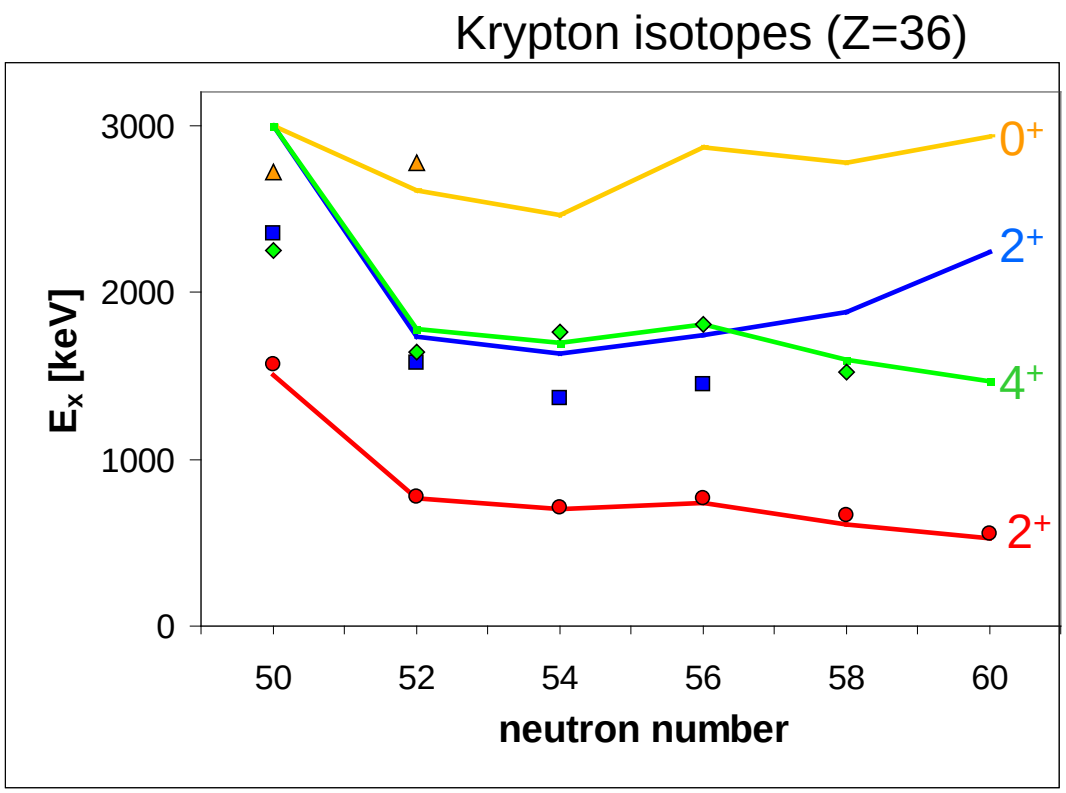
1. **Calculation of the Potential Energy Surface (PES)** in the ($\beta\gamma$) plain from mean-field calculations, based on the effective Gogny-D1S interaction
2. **Reproduction of the PES** by varying the parameter in the IBM-2 Hamiltonian ζ and χ
3. **Calculation of level energies** based on this parameters



K.Nomura, T. Otsuka et al., PRL101, 142501 (2008)

Derivation of the IBM-2 Hamiltonian based on mean-field calculations for the neutron-rich Kr isotopes





K. Nomura, priv. comm., (2011)

Summary

- The energy of the 2^+_1 state in ^{94}Kr was confirmed
- For ^{96}Kr, the level energy of the 2^+_1 state was corrected
- For both nuclei E2 decay transition strengths were obtained for the first time
- The extended $E(2^+_1)$ and $B(E2; 2^+_1 \rightarrow 0^+_1)$ systematics confirm the results from mass measurements at ISOLTRAP and imply a smooth change of nuclear deformation in the neutron-rich Kr isotopes
- Calculation within the interacting boson model 2 are in good agreement with the experimental data

Collaborators

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REX-ISOLDE Collaboration
MINIBALL Collaboration

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