Evolution of quadrupole and octupole collectivity north-east of ^{132}Sn: the even ^{140,144}Xe isotopes

TECHNISCHE UNIVERSITÄT DARMSTADT

CERN-INTC-2021-033, CERN INTC-P-604

***Corinna Henrich, *Thorsten Kröll**

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University of Liverpool, United Kingdom University of Guelph, Canada
Lund University, Sweden University of Jyväskylä, Finland INFN LNL, Italy
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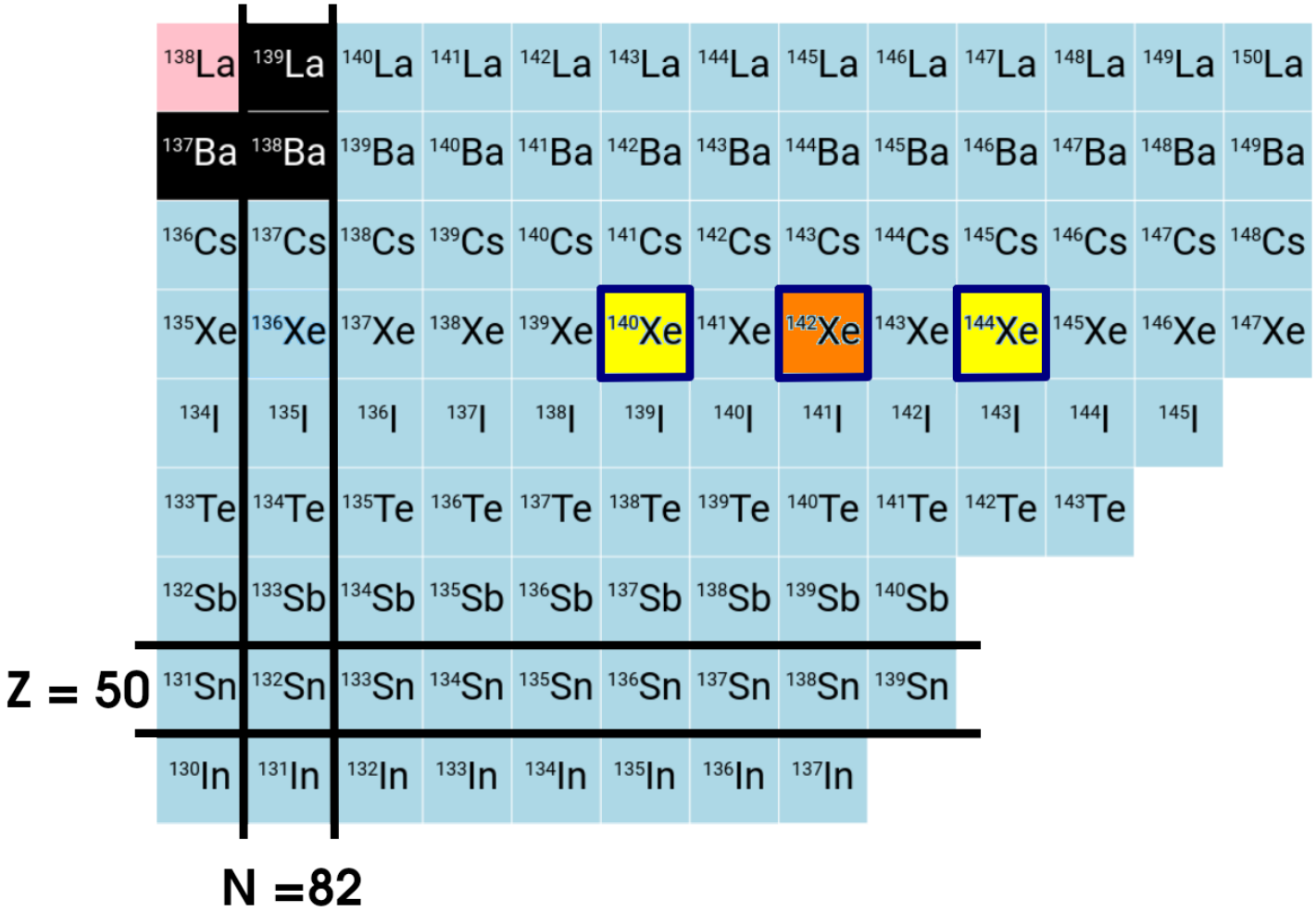
IJCLab, Orsay, France HIL, University of Warsaw, Poland SU Sofia, Bulgaria
ANU, Canberra, Australia CSIC Madrid, Spain UWS, Paisley, United Kingdom
SFU, Burnaby, Canada ORNL, Oak Ridge, USA LMU, München, Germany
UCM, Madrid, Spain

Region of interest



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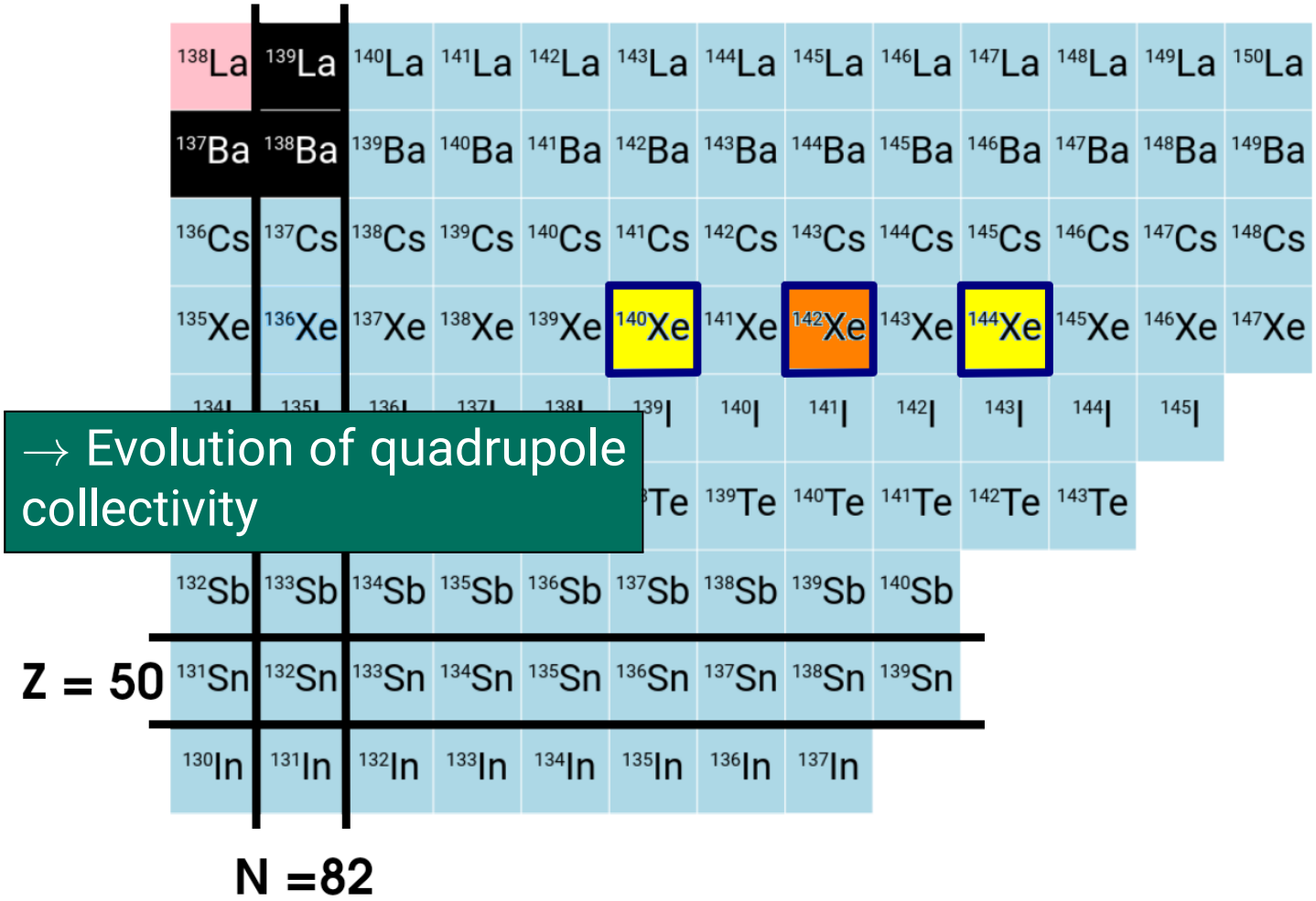

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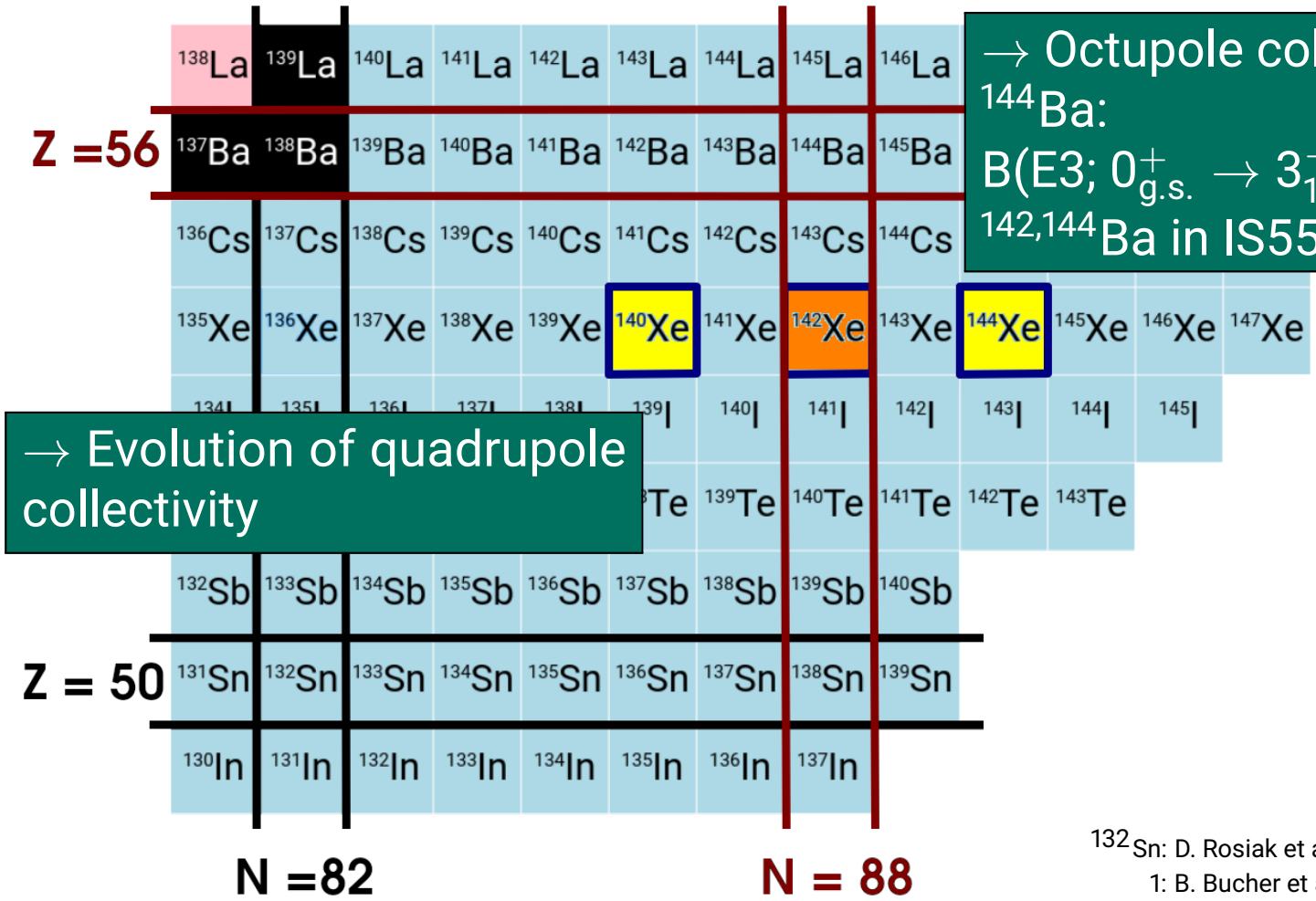

→ Octupole collectivity

^{144}Ba:

$B(E3; 0^+_{g.s.} \rightarrow 3^-_1)$ = 48(30) W.u. [1]

^{142,144}Ba in IS553 [2]

→ Evolution of quadrupole collectivity

^{132}Sn: D. Rosiak et al.: Phys. Rev. Lett. 121, 252501 (2018)

1: B. Bucher et al.: Phys. Rev. Lett. 116, 112503 (2016)

2: CERN-INTC-2012-047; INTC-P-348

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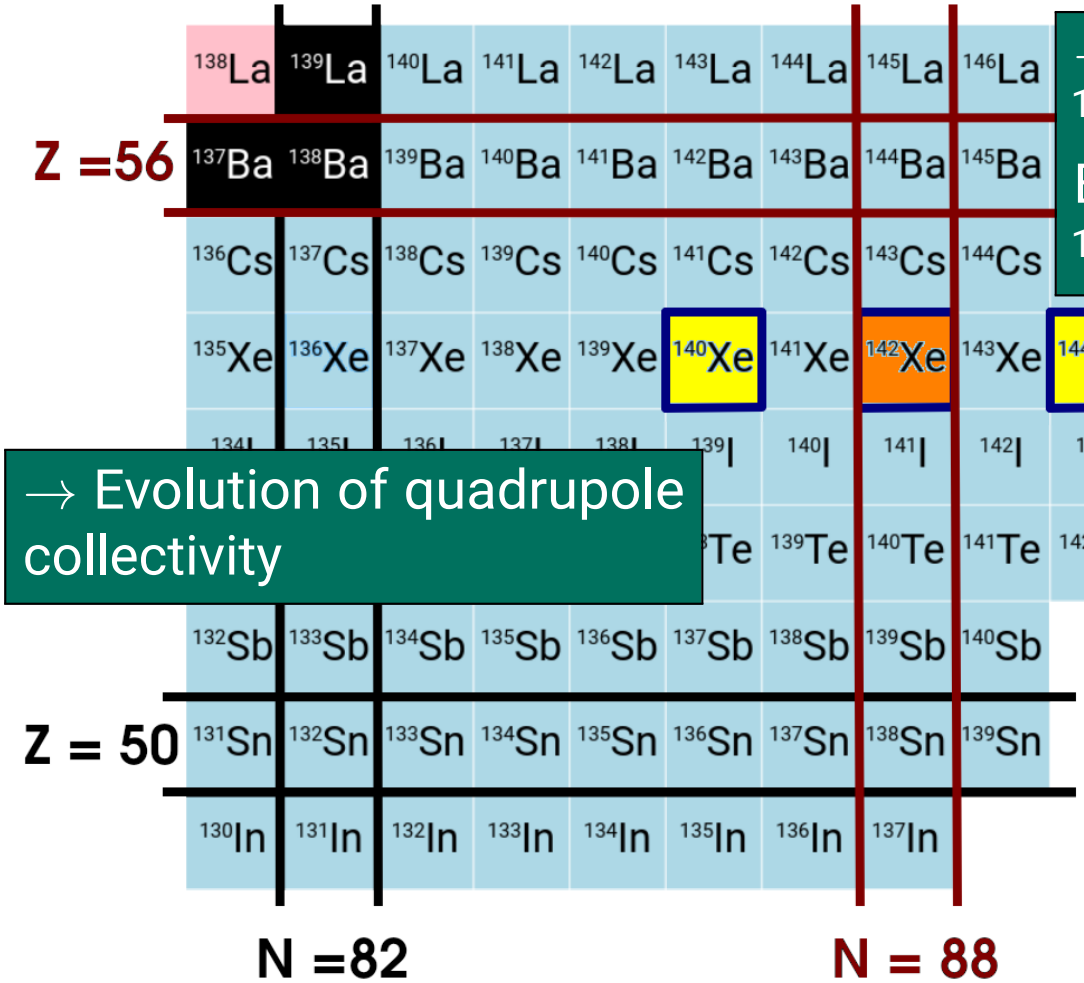

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Publication in preparation

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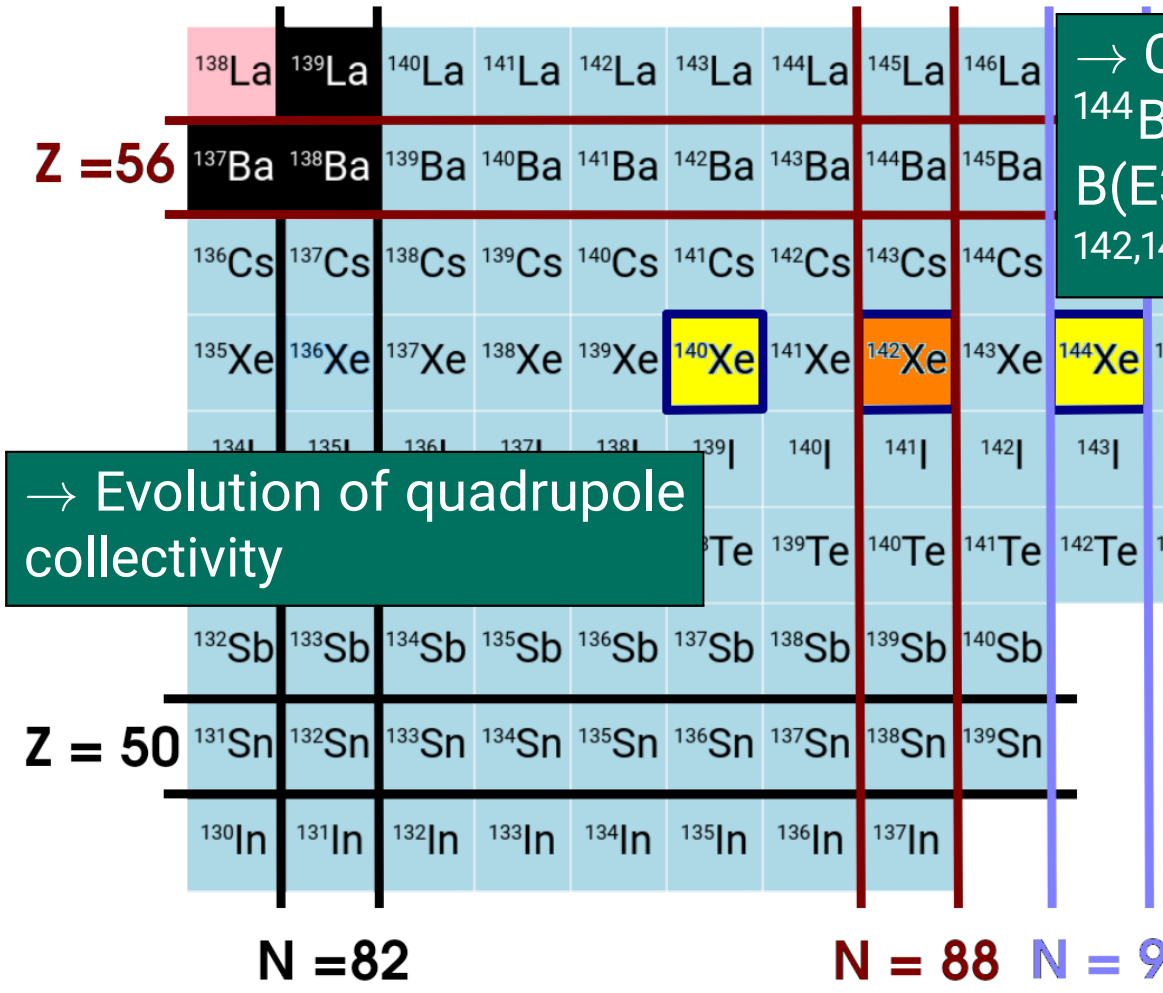

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Publication in preparation

→ N = 90 shell closure? [3]

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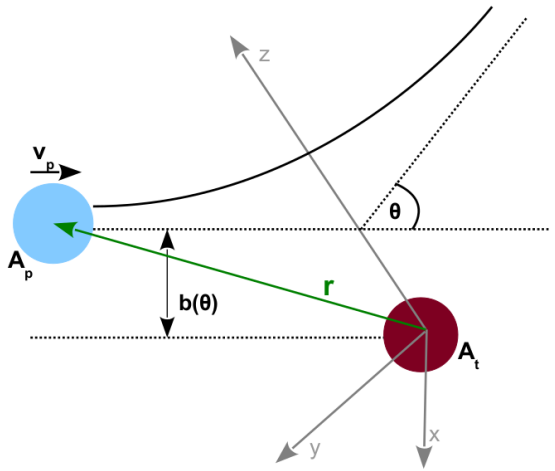
Physics aims / method

Safe multiple-step Coulomb excitation

- Observed γ**-ray yields** depend on many transitional and diagonal electromagnetic **matrix elements**
- **Relative analysis** (i.e., towards target or known lifetime of state)



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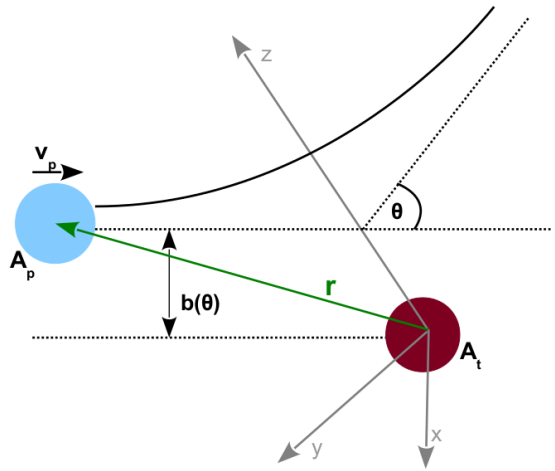

→ Perfect tool to investigate the low-lying structure

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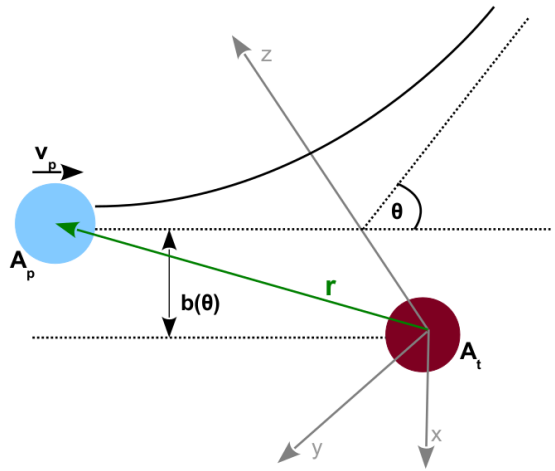

$\rightarrow$ Perfect tool to investigate the low-lying structure

Observables:

- **B(E2) values**
- **Quadrupole moments** $Q_s \rightarrow$ shape
- **B(E3; $0^+_{g.s.} \rightarrow 3^-_1$)** $\rightarrow$ octupole collectivity
- **Magnetic moments** via RIV [1]

1: A. E. Stuchbery et al., Phys. Rev. C 96, 014321 (2017)

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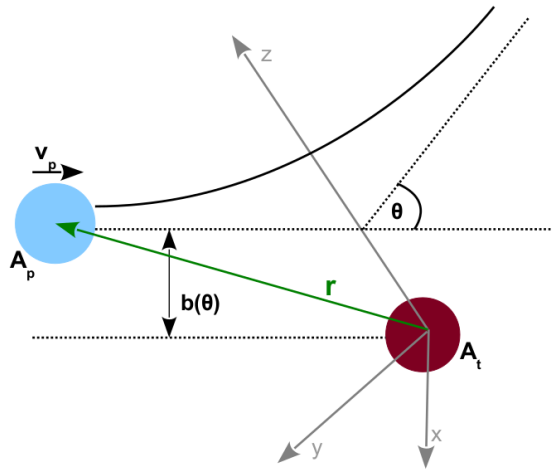

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$\rightarrow$ Quantities only accessible using Coulomb excitation

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Experimental setup

- **Cold plasma ion source** with xenon (estimate by S. Rothe, ISOLDE TISD):

Isotope	Yield ($/\mu$C)	Requested shifts (8h)
^{140}Xe	$8 \cdot 10^7$	15
^{142}Xe	$2 - 7 \cdot 10^6$	/ $\rightarrow$ measured in IS548
^{144}Xe	$1.8 \cdot 10^5$	4

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→ ^{140}Xe: 10x intensity of ^{142}Xe..

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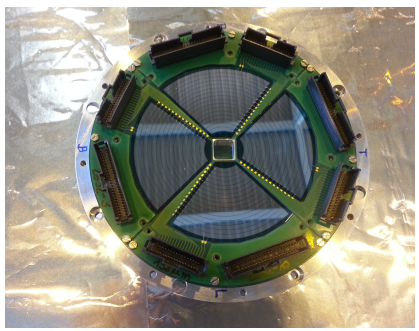
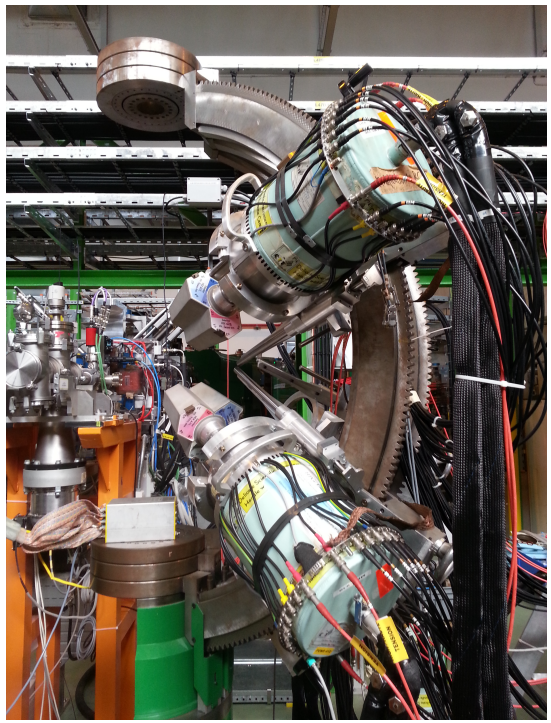


MINIBALL array:



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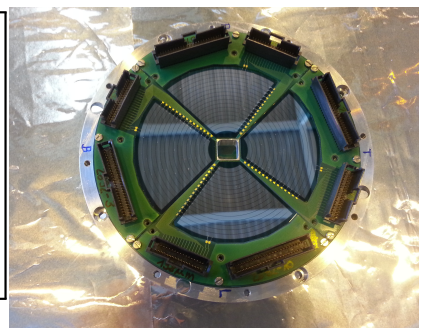

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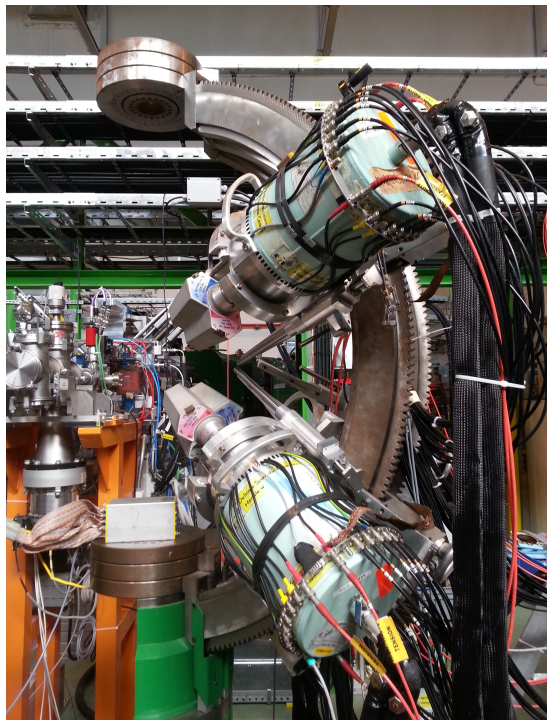

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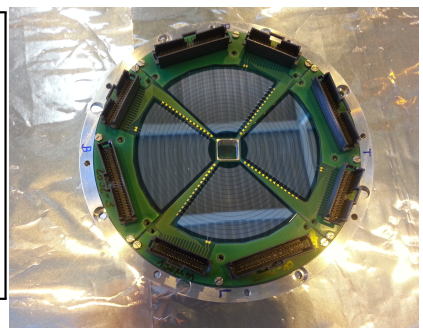

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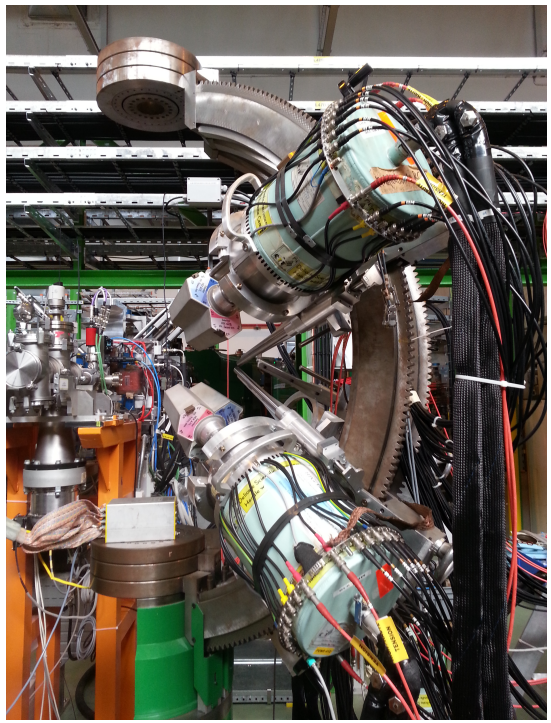

→ Experiment only possible at ISOLDE

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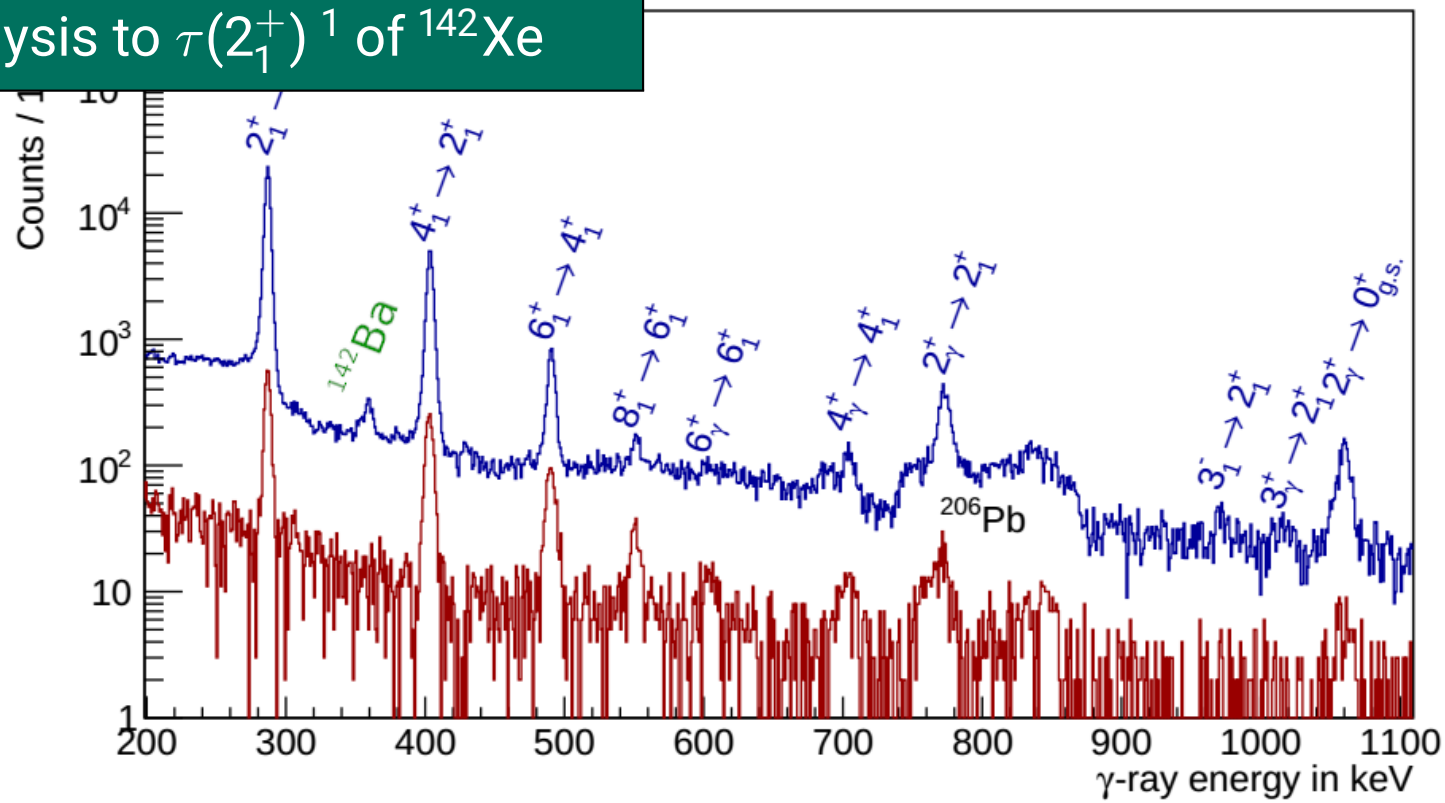
Reminder (IS548) - ^{142}Xe

(C. Henrich, doctoral thesis, Publication in preparation)

Multiple-step Coulex at ISOLDE
Pure beam
Rel. analysis to $\tau(2_1^+)$ [1] of ^{142}Xe



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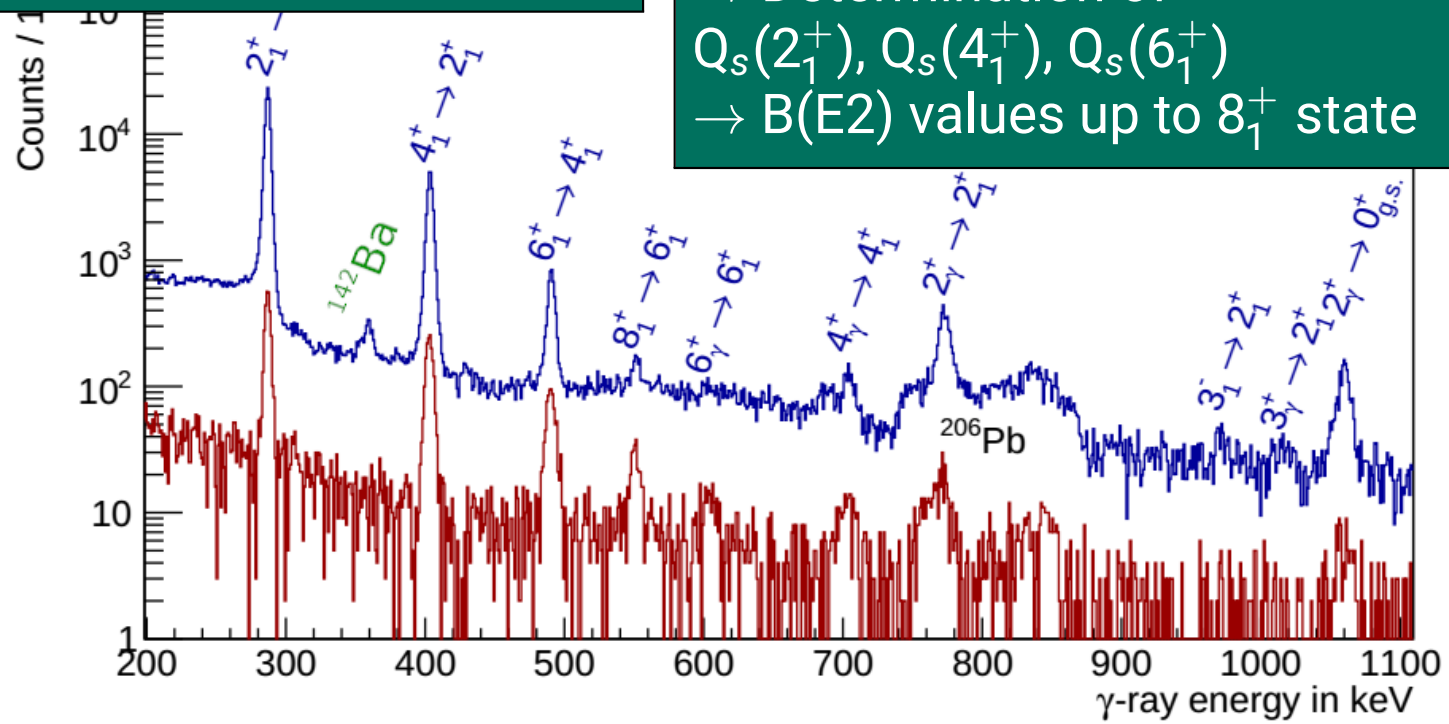
Population of yrast band up to 8_1^+ state

→ Determination of
$Q_s(2_1^+)$, $Q_s(4_1^+)$, $Q_s(6_1^+)$
→ B(E2) values up to 8_1^+ state



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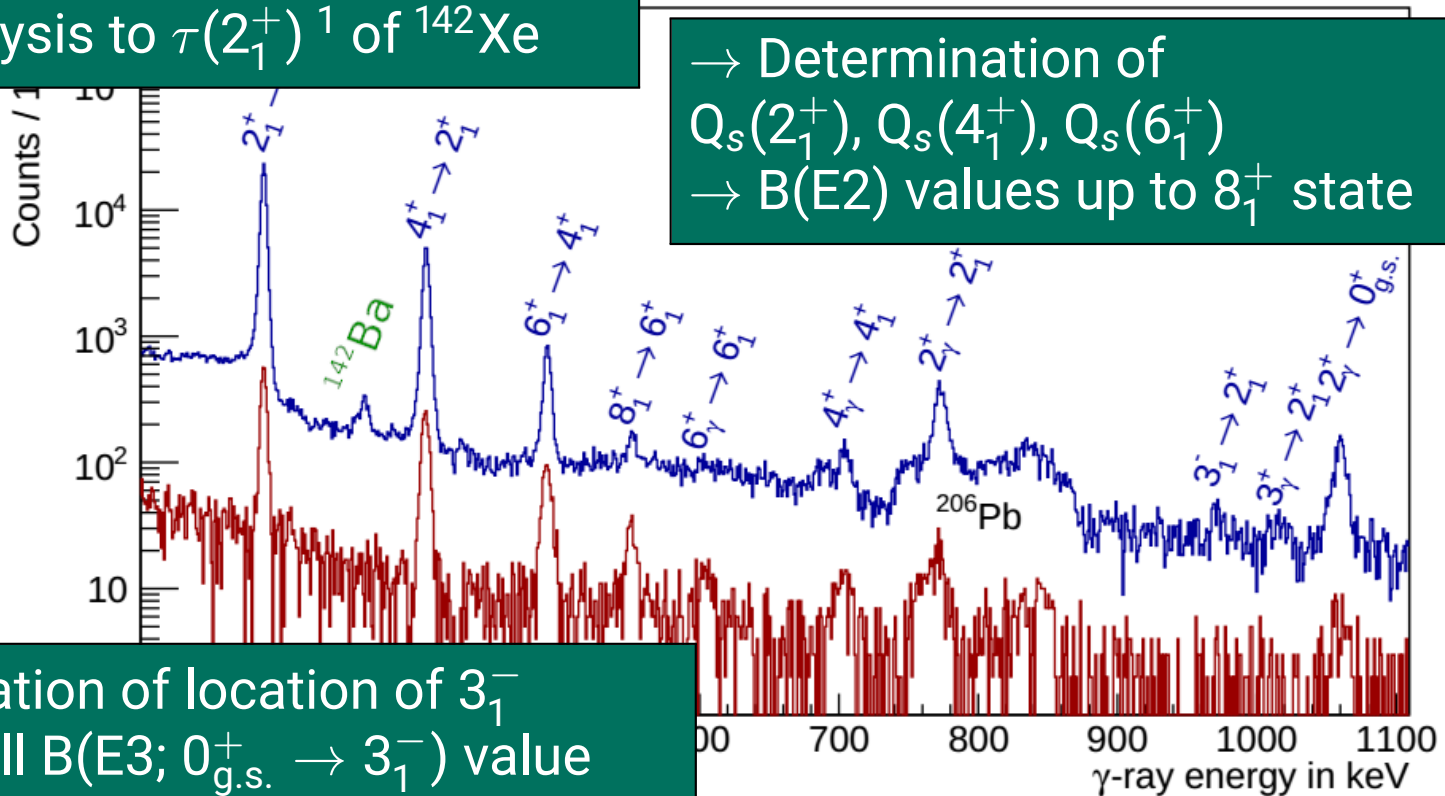

Confirmation of location of 3_1^-
and small B(E3; $0_{g.s.}^+ \to 3_1^-$) value
comparable to Raman systematics [2]

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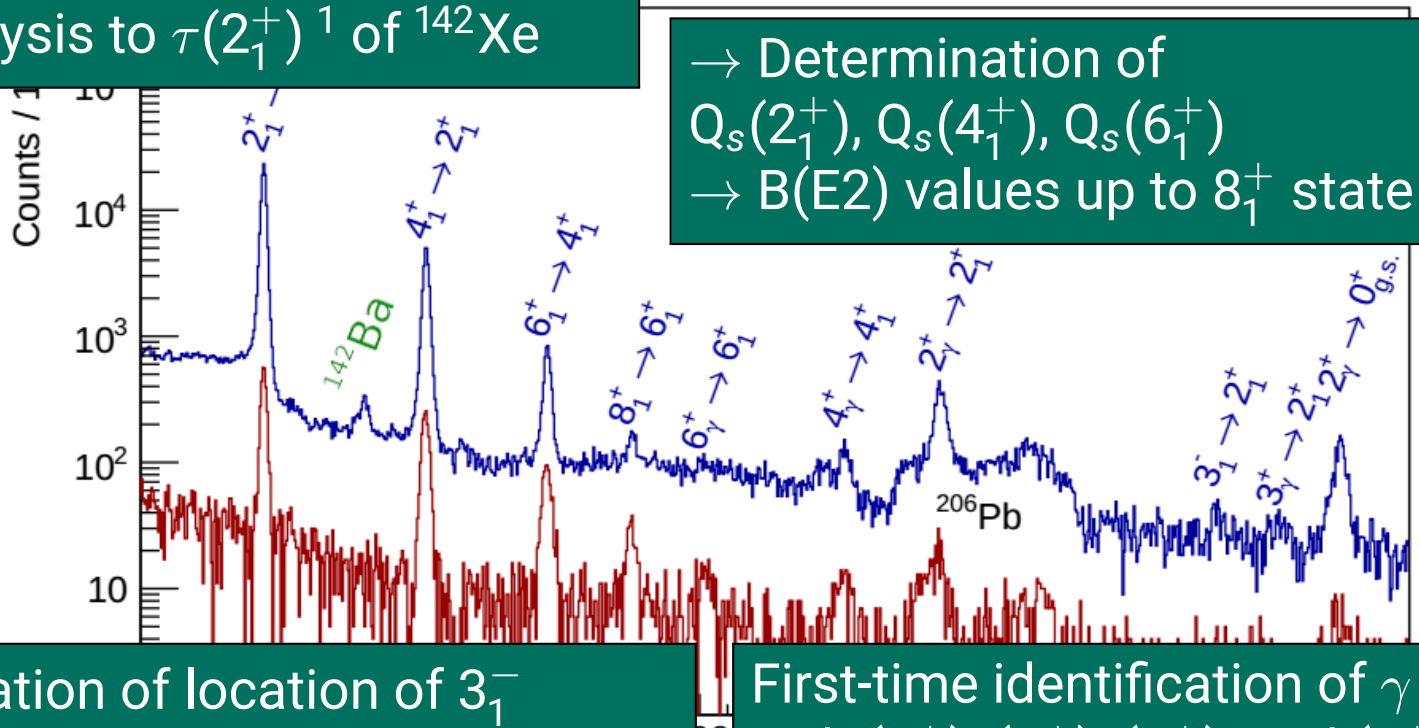

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First-time identification of γ band
with (2_γ^+), (3_γ^+), (4_γ^+), and (6_γ^+)

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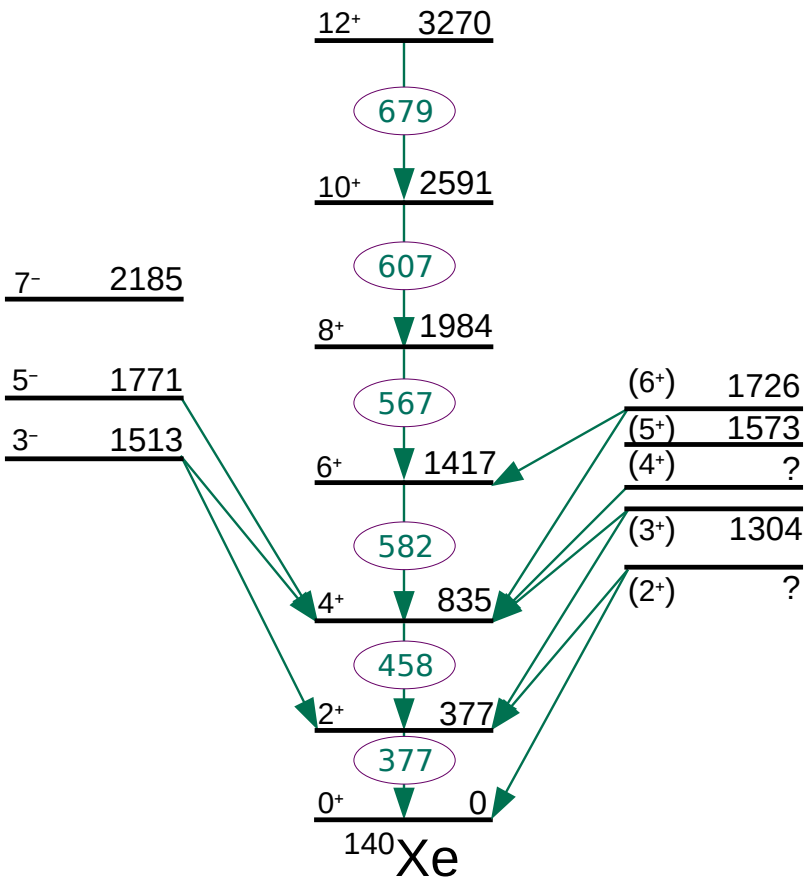
^{140}Xe - high-statistics data set

(5x statistics of ^{142}Xe (IS548))



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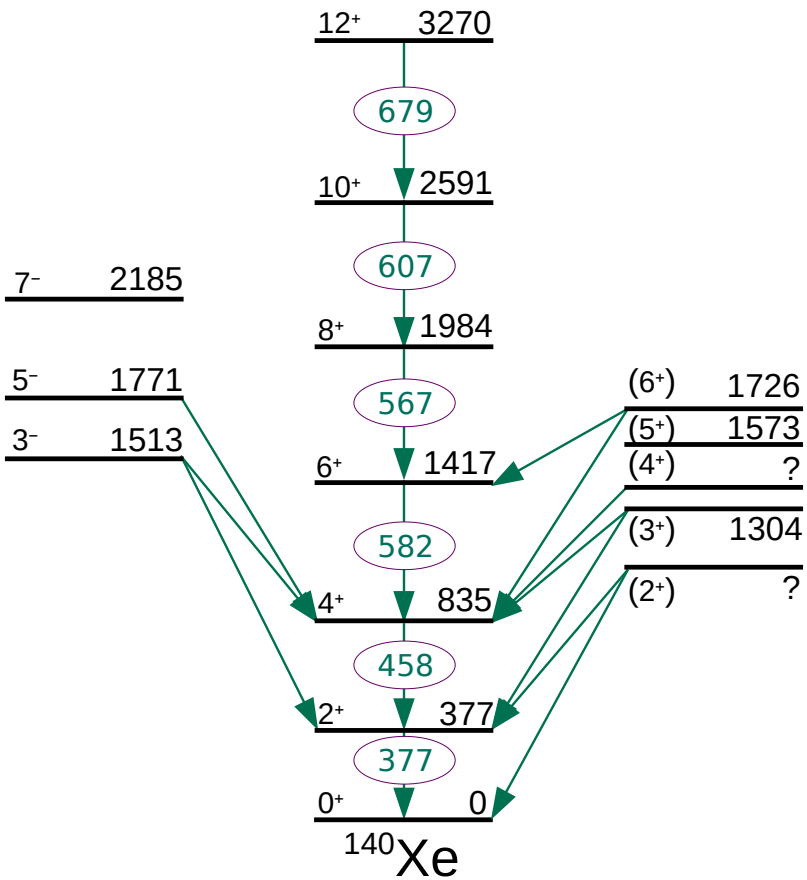

- Comparatively well known level scheme
- **Normalization to known lifetimes** in ^{140}Xe [1]:
  - $\tau(2_1^+)$ = 102 (7) ps
  - $\tau(4_1^+)$ = 17 (5) ps

  $\rightarrow$ ^{208}Pb target: 2 $\frac{\text{mg}}{\text{cm}^2}$
- Determination of B(E3)
  $\rightarrow$ **octupole collectivity**
- Determination of **B(E2)**s and **Q_s**
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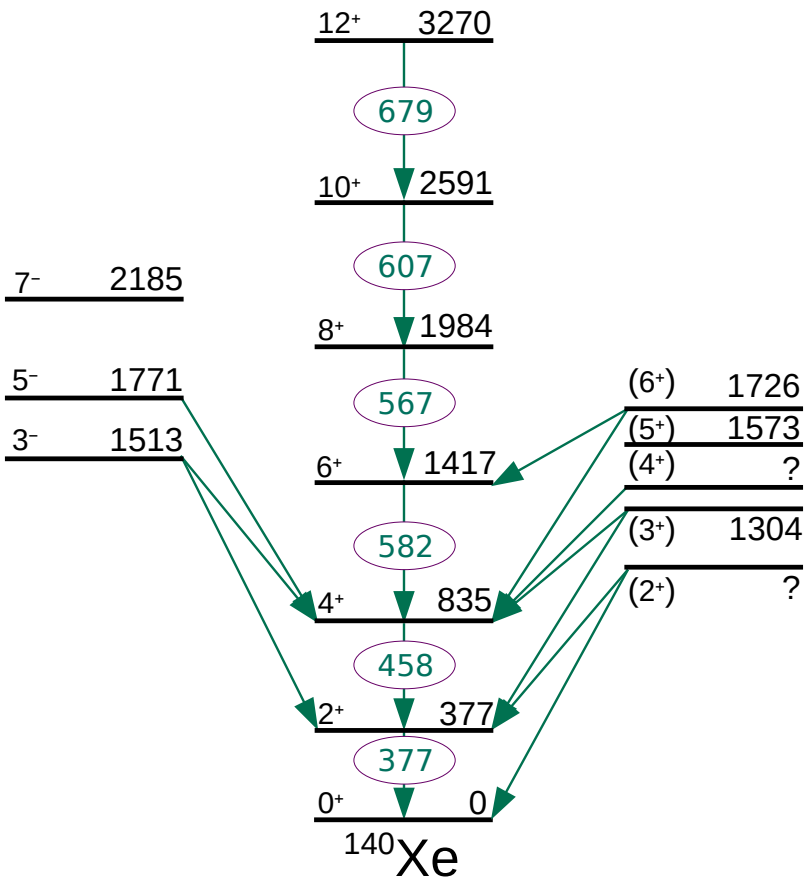

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→ 15 shifts

- Determination of B(E3) → **octupole collectivity**
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- Location of **2_γ^+** a

→ compare ^{142}Xe:
lower stat. uncertainty
lower sys. uncertainty
better resolution

140Xe: W. Urban et al., Phys. Rev. C, 93:034326 (2016)
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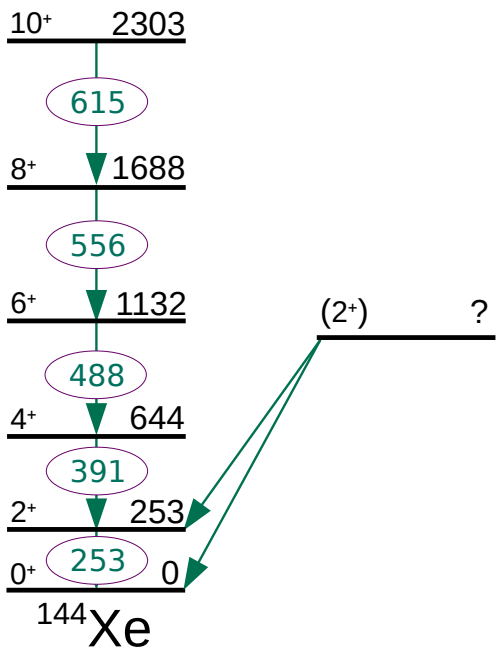
^{144}Xe - exploratory data set

(1/30 x statistics of ^{142}Xe (IS548))



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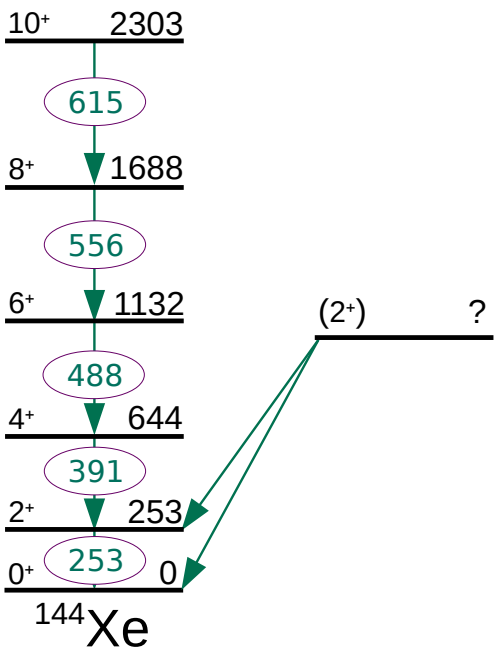

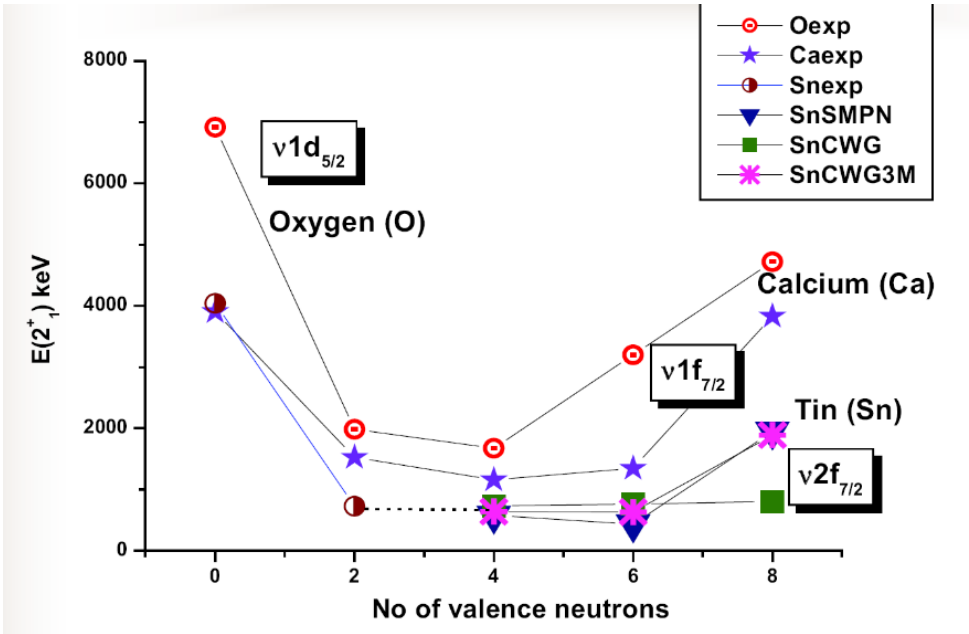

- Empirical interaction (SMPN): **Shell closure at N = 90**
- Realistic interaction (CWG): **No closure**
- Realistic interaction + 3NF (CWG3M): **Shell closure..**

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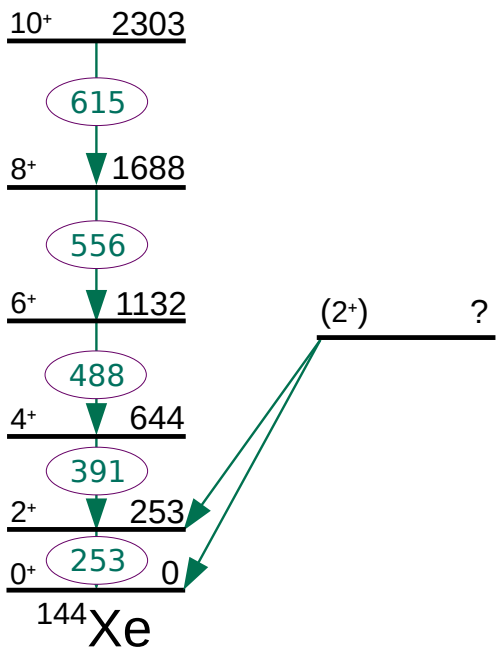

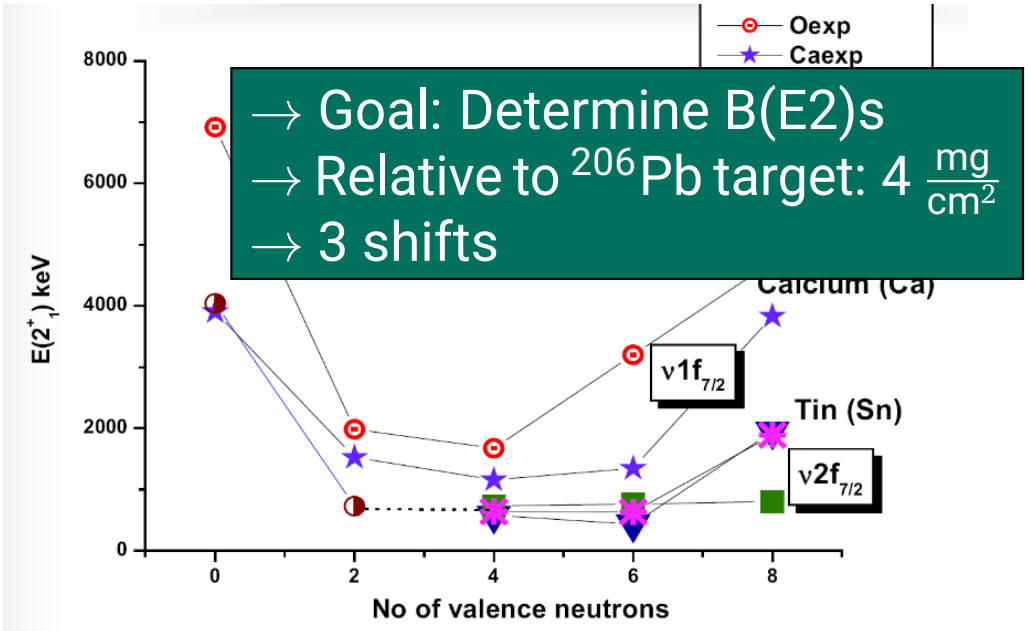

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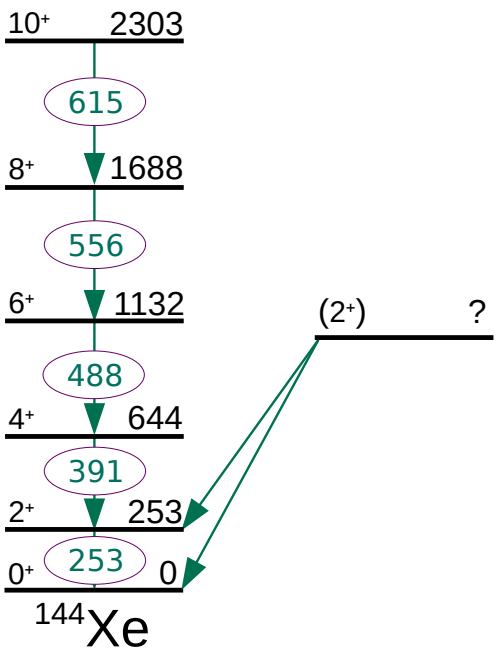

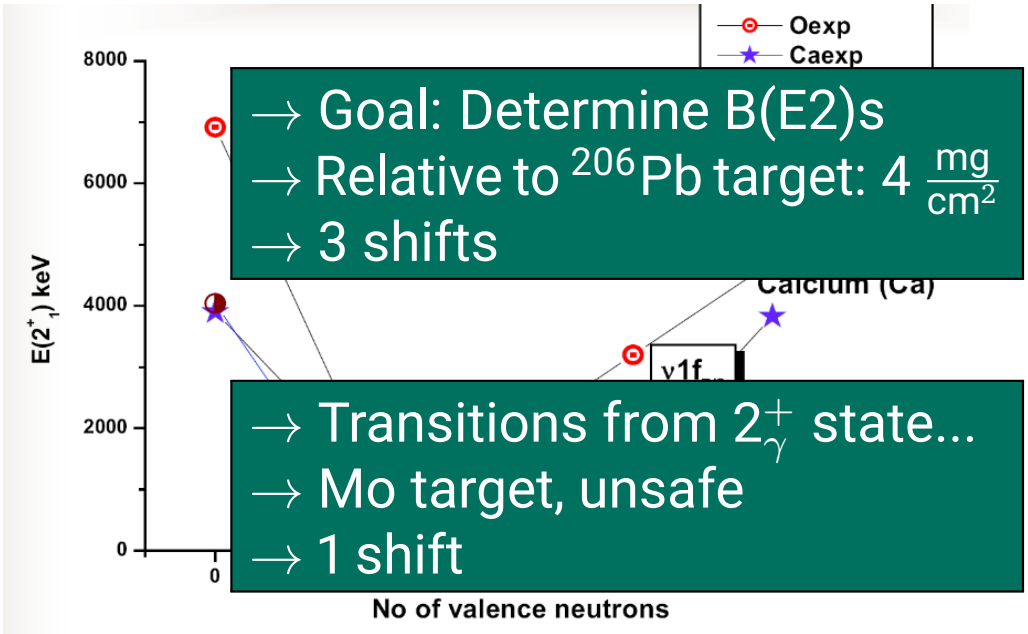

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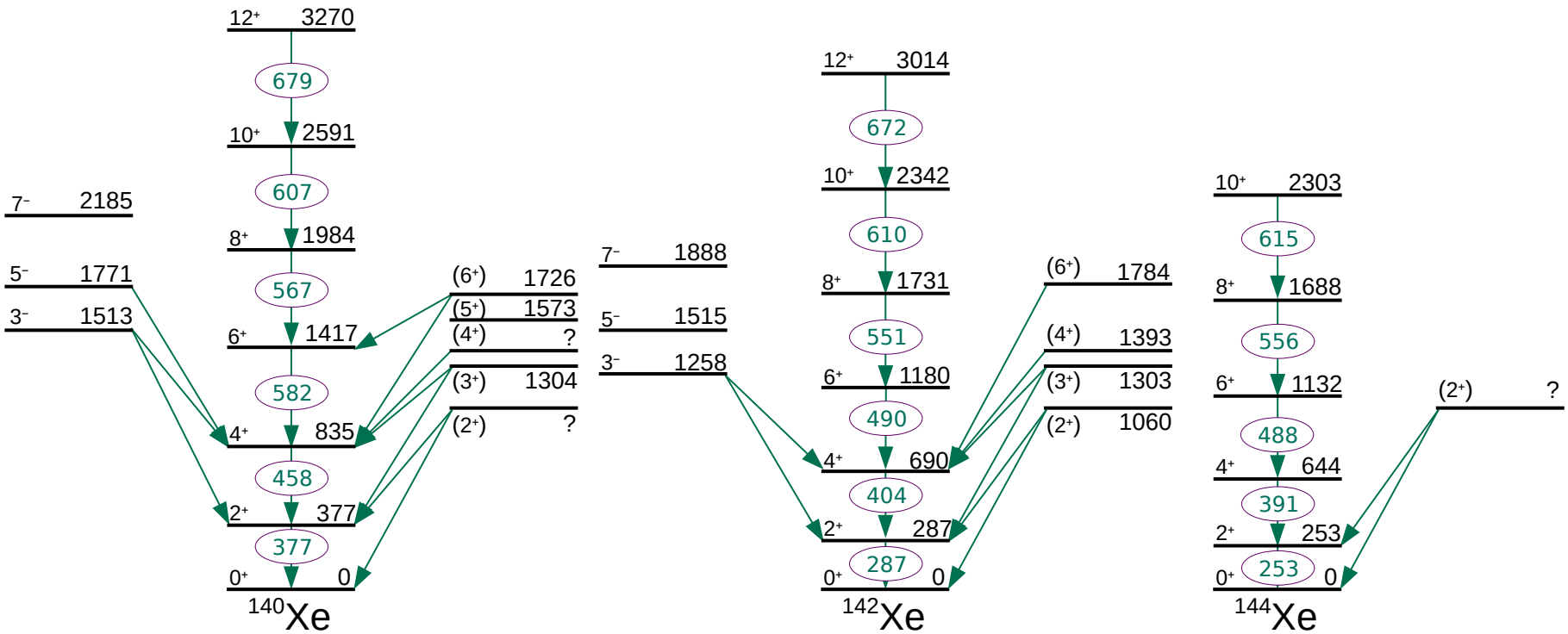
Comparison level schemes ^{140,142,144}Xe



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- Octupole collectivity via **B(E3)**
- Development of γ **band**

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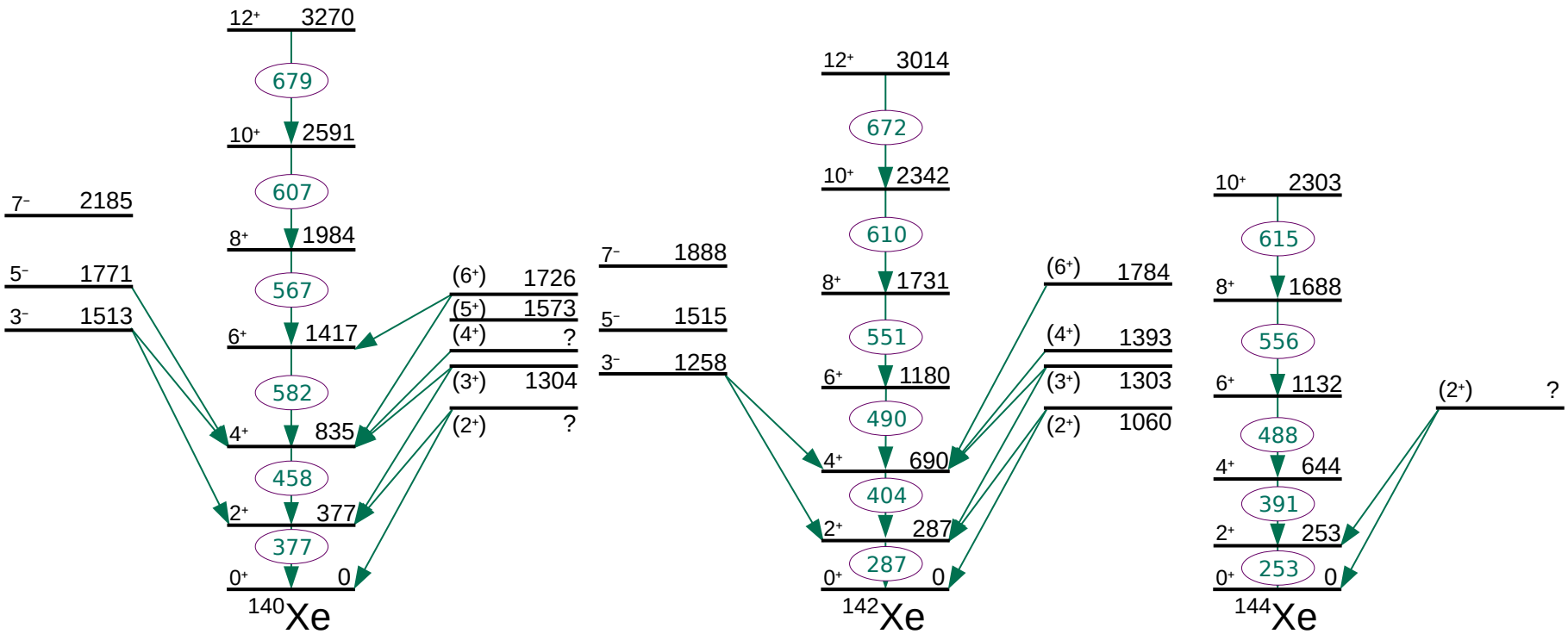

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→ Challenge for theory LSSM, SCCM

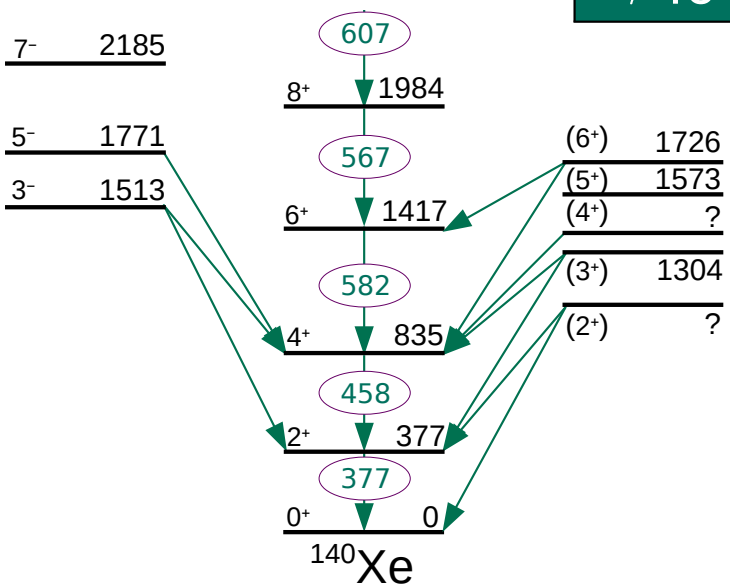
LSSM: H. Naïdja
SCCM: T. R. Rodríguez

Sum up -
Coulomb excitation of ^{140,144}Xe at HIE-ISOLDE

High-statistics data set: ^{140}Xe

- **B(E2)**s and **Q_s**s up to 8_1^+ state
- Location of **2_γ^+** and **4_γ^+**
- **B(E3; $0^+_{g.s.} \rightarrow 3^-_1$)**
  $\rightarrow$ octupole collectivity

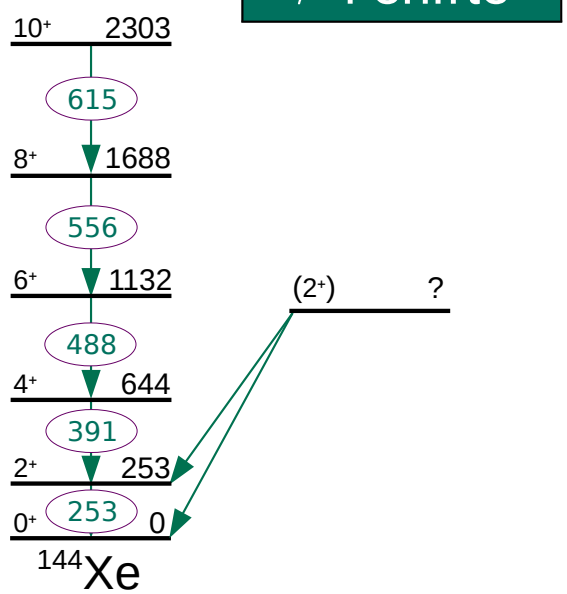
$\rightarrow$ 15 shifts



Exploratory data set: ^{144}Xe

- **B(E2)**s up to 6_1^+ state
  $\rightarrow$ first info on N = 90 (closest to ^{140}Sn)
- Location of **2_γ^+**

$\rightarrow$ 4 shifts

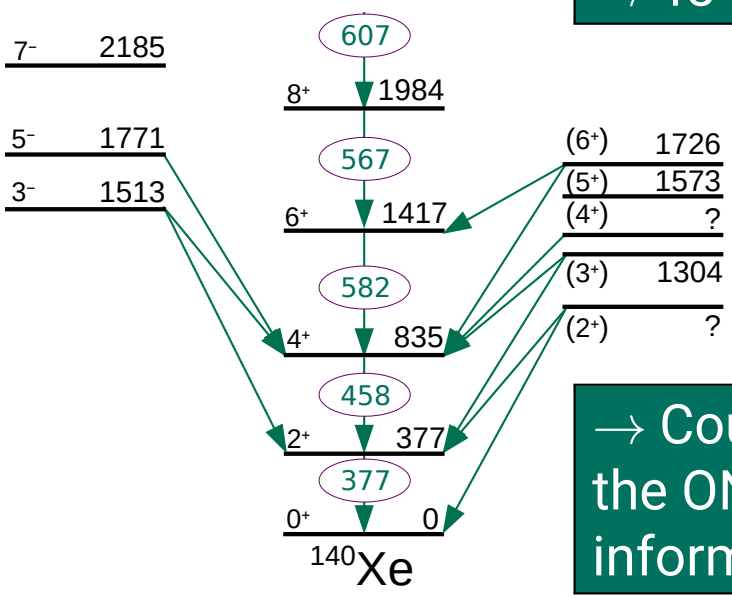


Sum up -
Coulomb excitation of ^{140,144}Xe at HIE-ISOLDE

High-statistics data set: ^{140}Xe

- **B(E2)**s and **Q_s**s up to 8_1^+ state
- Location of **2_γ^+** and **4_γ^+**
- **B(E3; $0^+_{g.s.} \rightarrow 3^-_1$)**
  $\rightarrow$ octupole collectivity

$\rightarrow$ 15 shifts



Exploratory data set: ^{144}Xe

- **B(E2)**s up to 6_1^+ state
  $\rightarrow$ first info on N = 90 (closest to ^{140}Sn)
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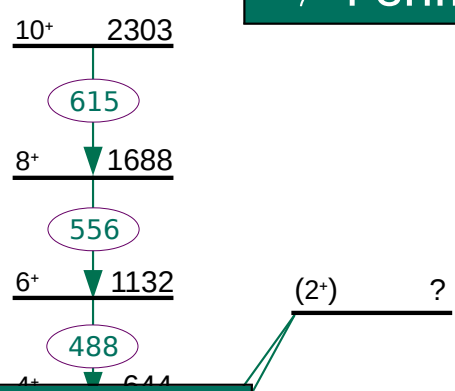
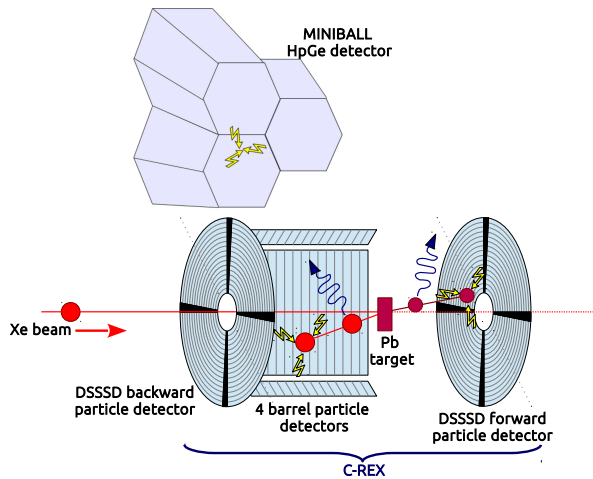


$\rightarrow$ Coulomb excitation at ISOLDE is the ONLY way to get this rich set of information!

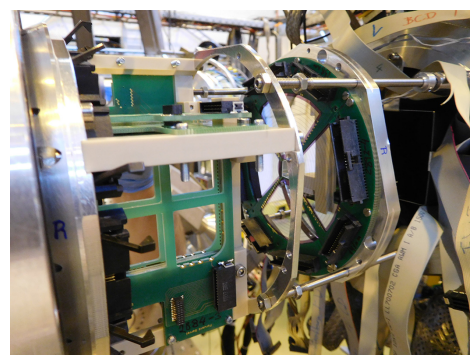
DSSSD only vs C-REX - I

C-REX silicon array:

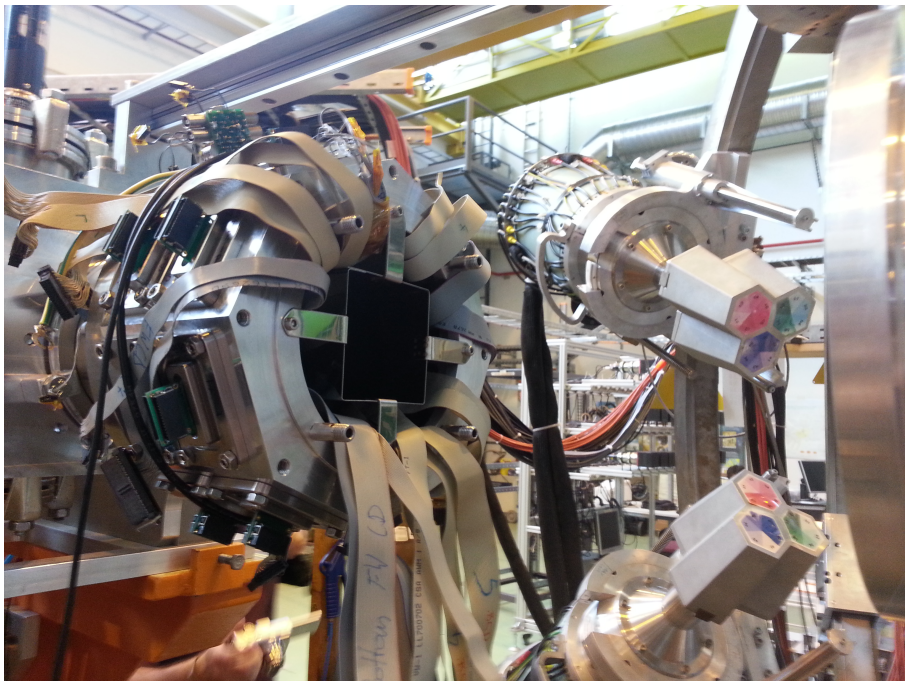
- 2 DSSSDs and 4 barrel silicon detectors
- More complete angular coverage than forward DSSSD only
- Not necessary for ^{140,144}Xe:
  - ^{140}Xe: Level scheme known quite well
  - ^{140}Xe: Position of weaker transitions is known, new ones have high statistics
  - ^{144}Xe: Close to no statistics in backward direction due to low beam intensity
- Build up is a lot of work (next slide!), more channels
- New MINIBALL DAQ has no firmware for MUXs, lack of funding

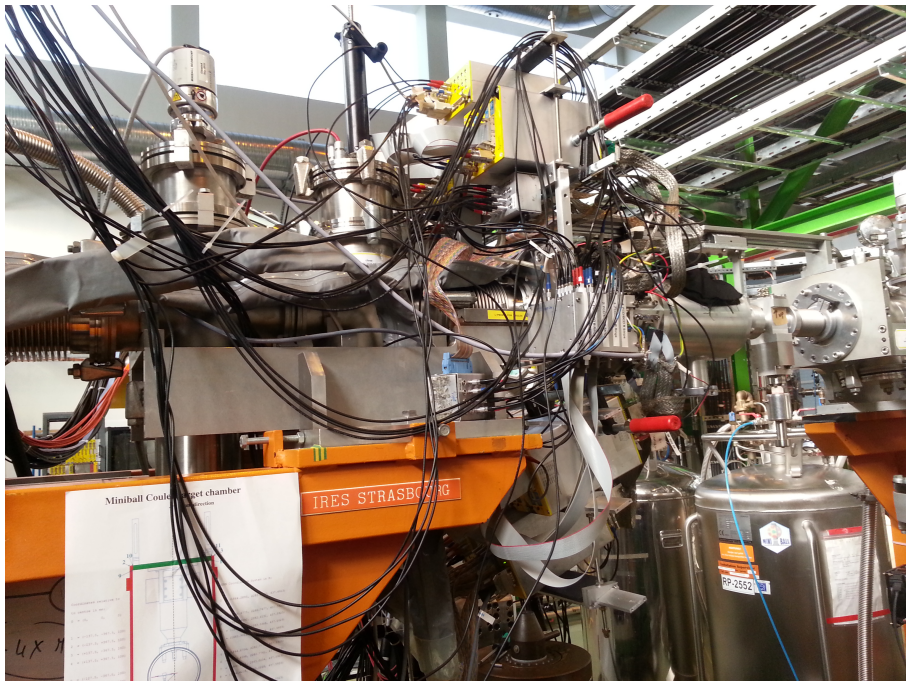


C-REX on target location:



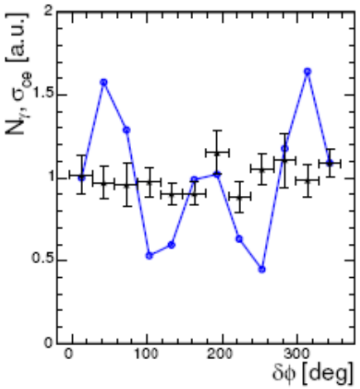
DSSSD only vs C-REX - II
set up and cables..

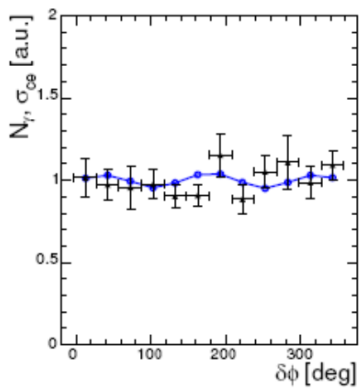




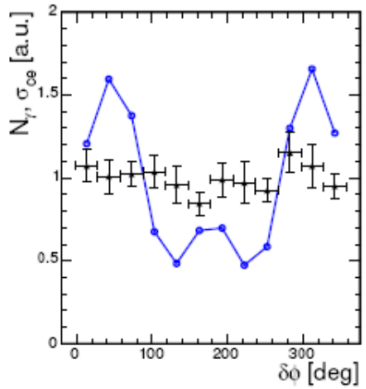
Recoil In Vacuum (RIV) method - I
Angular correlations ($2_1^+ \rightarrow 0_{g.s.}^+$, ^{140}Xe)

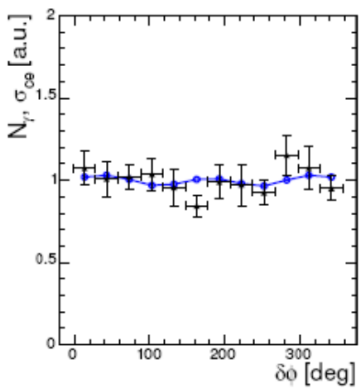
28° < θ_{Xe} < 34.5°



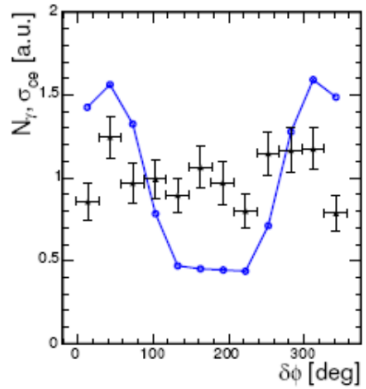


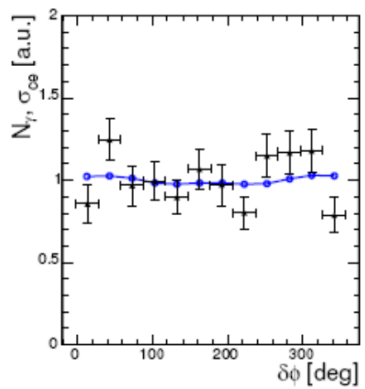
34.5° < θ_{Xe} < 41°





41° < θ_{Xe} < 47.5°





Forward MINIBALL detectors

λ_2 = 0.0 ps^{-1}

Abragam, Pound

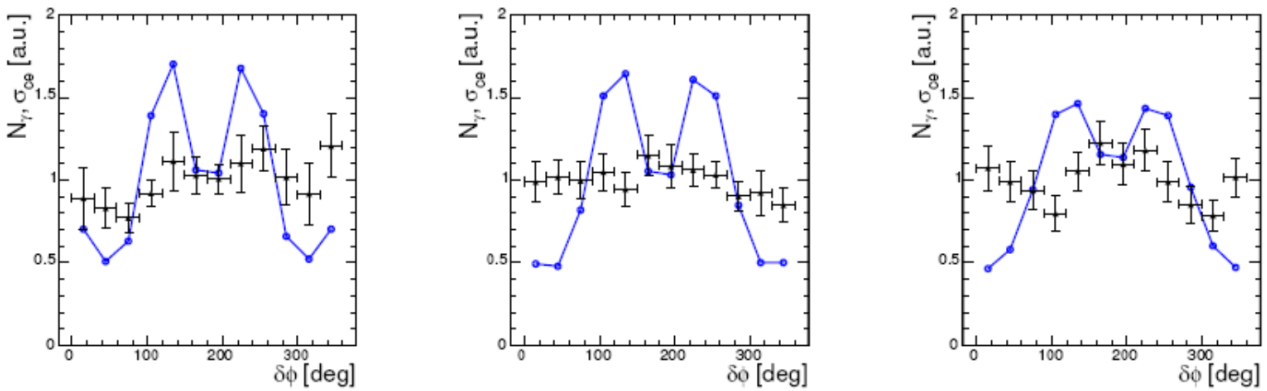
λ_2 = 0.046 ps^{-1}

Best fit

REX-ISOLDE data
Doctoral Thesis
T. Behrens
(TU München)

Recoil In Vacuum (RIV) method - II
Angular correlations ($2_1^+ \rightarrow 0_{g.s.}^+$, ^{140}Xe)

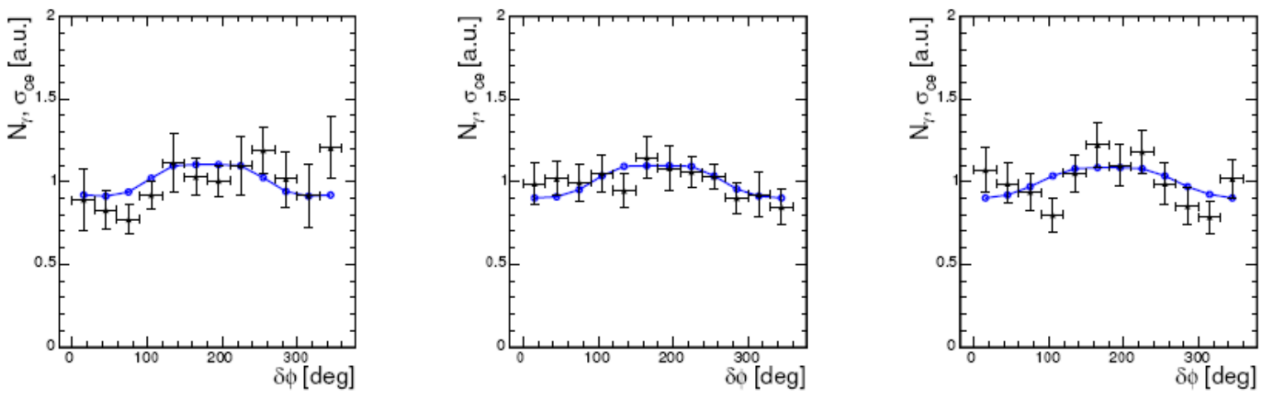
$28° < \theta_{Xe} < 34.5°$ | $34.5° < \theta_{Xe} < 41°$ | $41° < \theta_{Xe} < 47.5°$



Backward MINIBALL detectors

$\lambda_2 = 0.0$ ps^{-1}

Abragam, Pound



$\lambda_2 = 0.046$ ps^{-1}

Best fit

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