Collectivity of neutron-rich nuclei around N=40

RDDS lifetime measurement with AGATA and PRISMA
June 2010

A. Görgen et al.

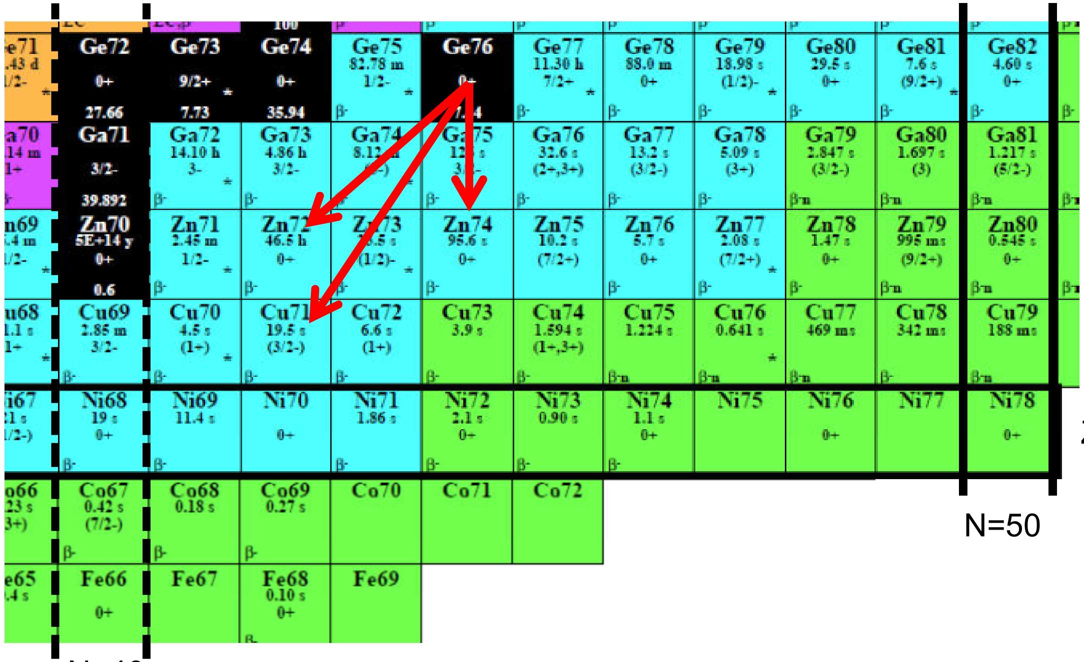
E. Sahin et al.

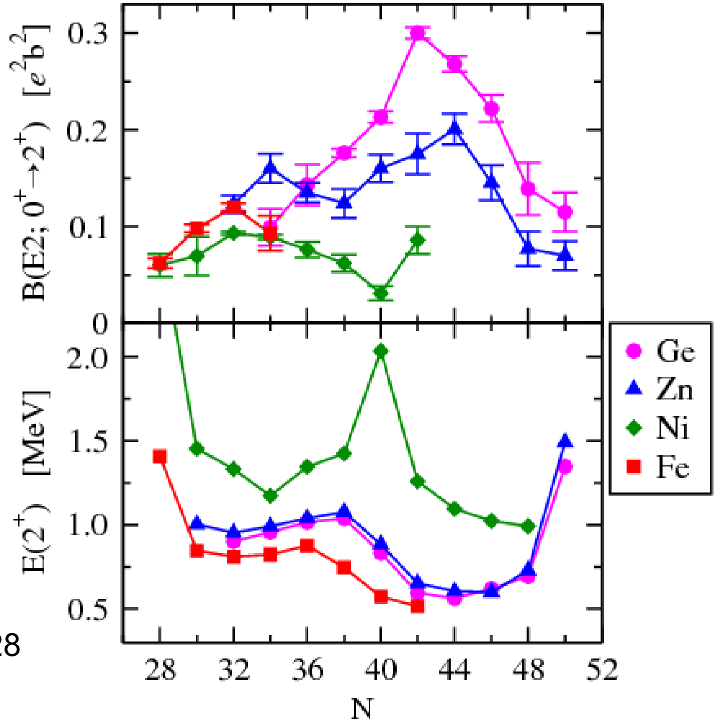
M. Doncel et al.

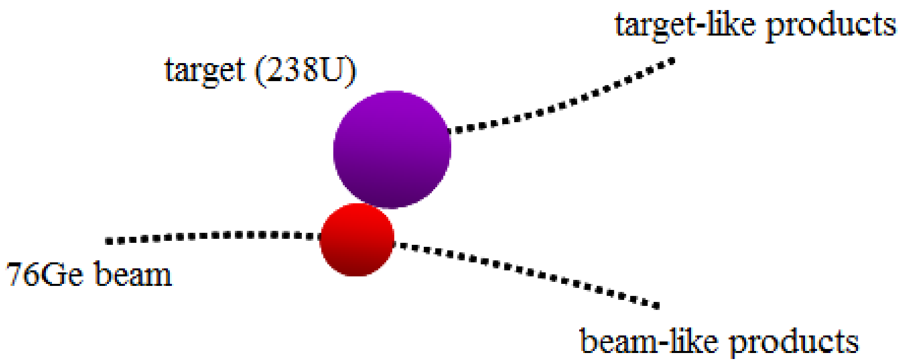
Evolution of collectivity at N ≈ 40

Persistence of N=40 sub-shell closure beyond ^{68}Ni ?

- $\pi-\nu$ correlations stronger than N=40 gap for Z≠28
- increased collectivity with filling of $\nu g_{9/2}$



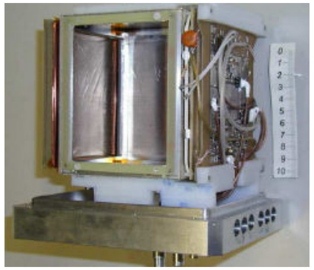


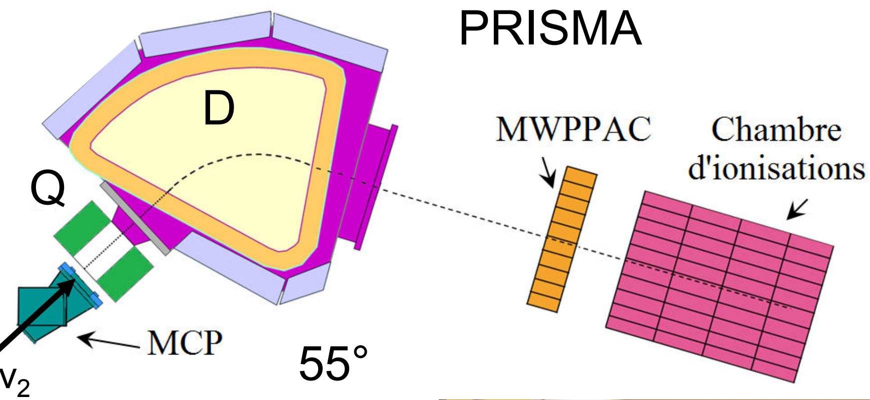


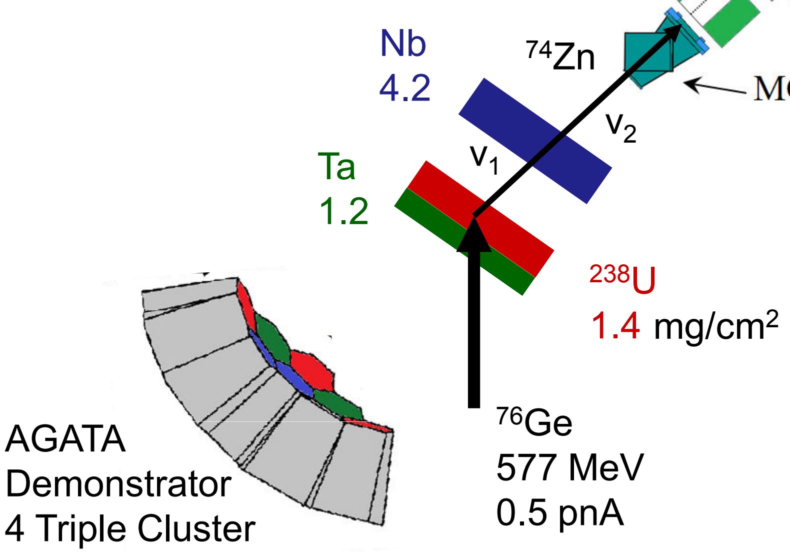
multi-nucleon transfer
^{76}Ge + ^{238}U @ 7.6 MeV/u
RDDS lifetime measurement

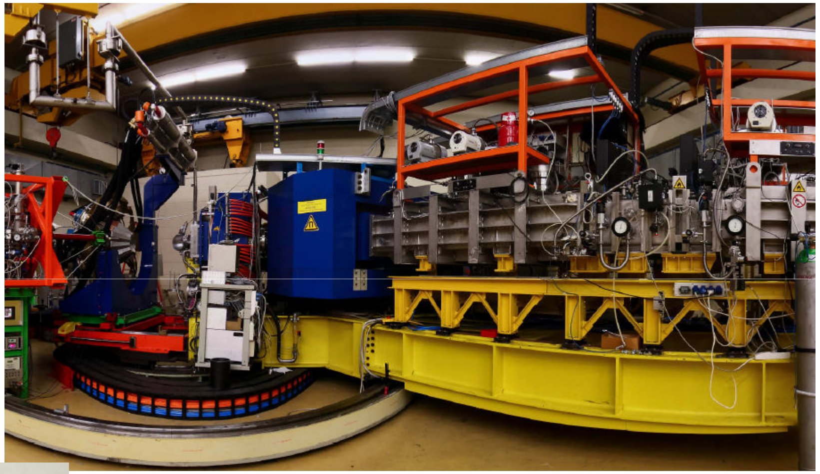
- ^{72,74}Zn
- ^{71}Cu

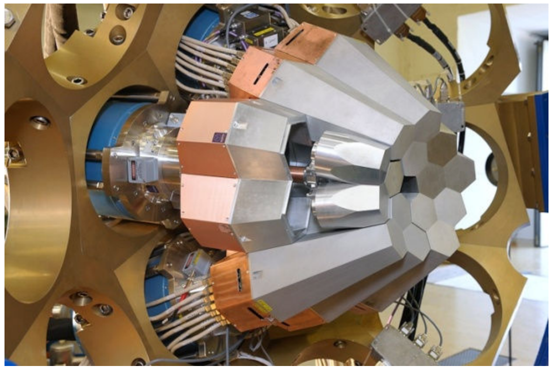
Setup

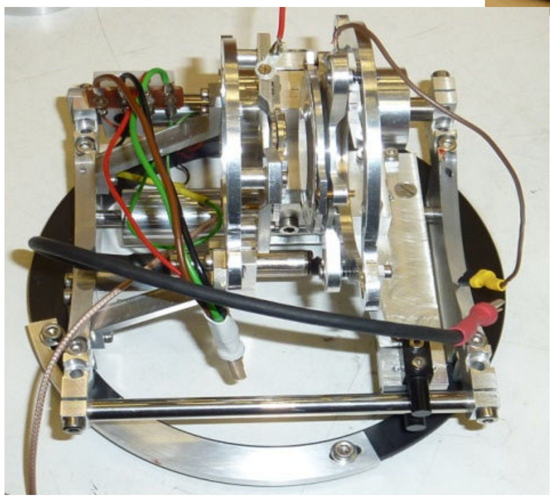










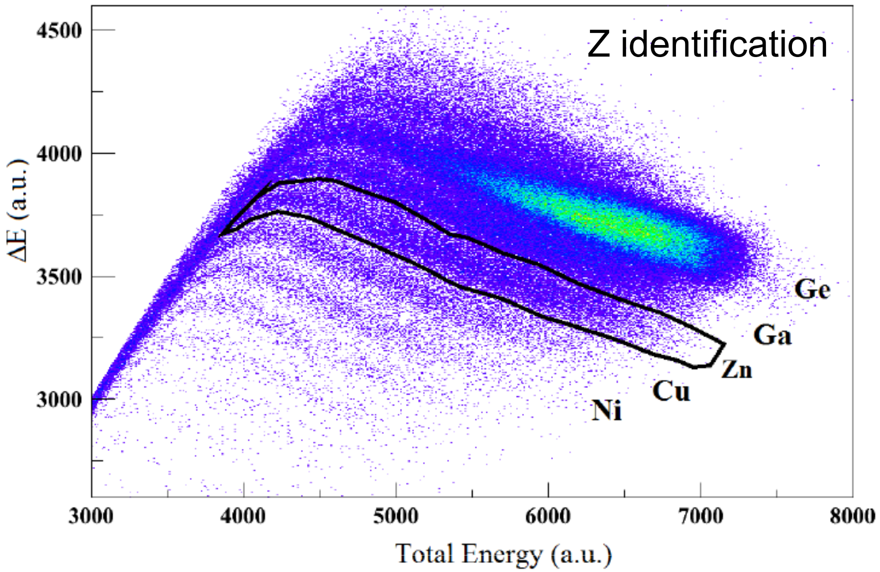


d = 18 cm, 135 – 175°
ε = 2.4 % @ 600 keV
60 kHz per crystal

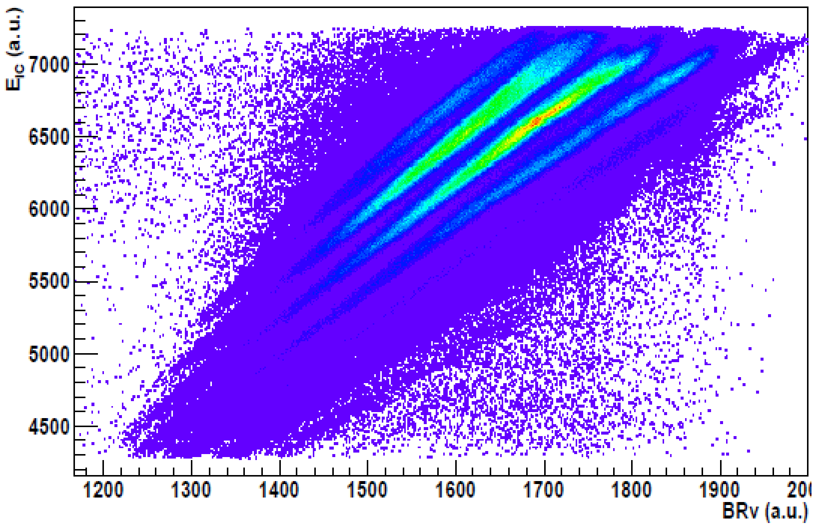
Plunger (Univ. Köln)

5 distances:
100 – 1900 μm
20 hours each

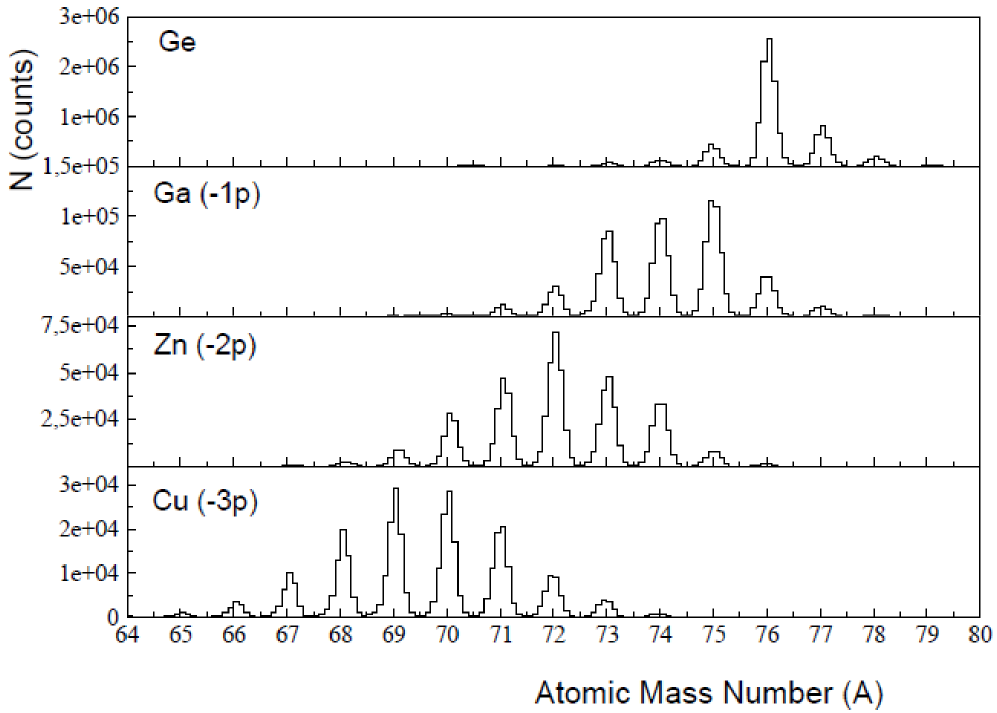
Identification in PRISMA



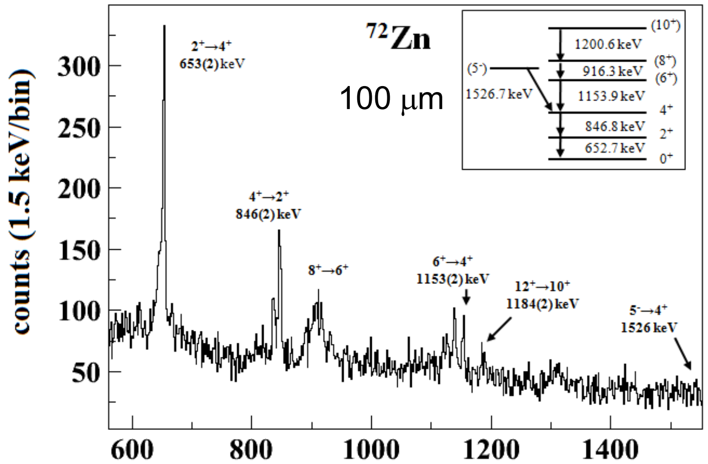
Q identification



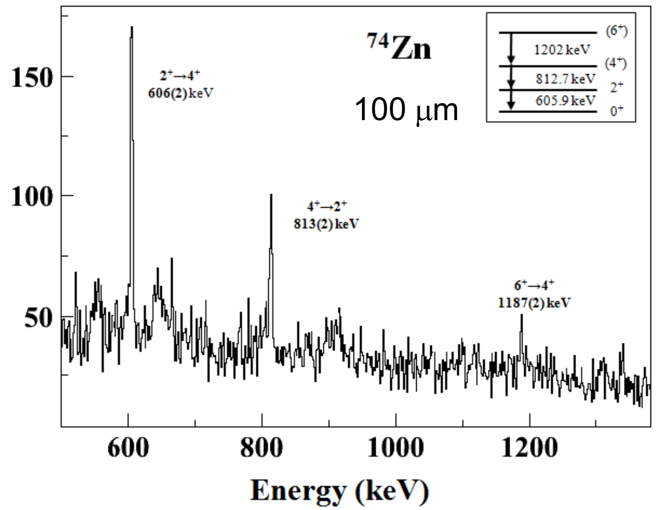
mass identification

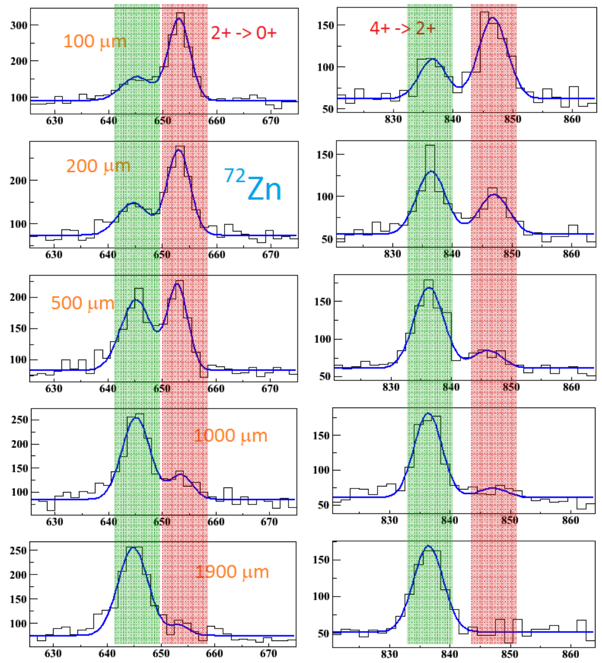


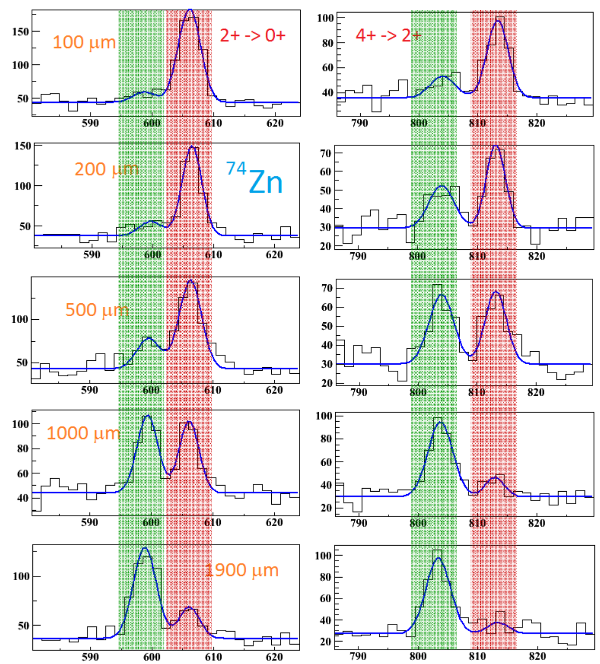
RDDS spectra

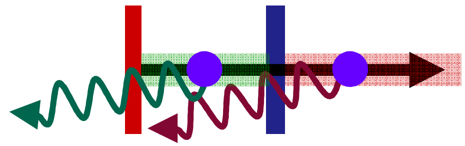


C. Louchart et al.
to be published







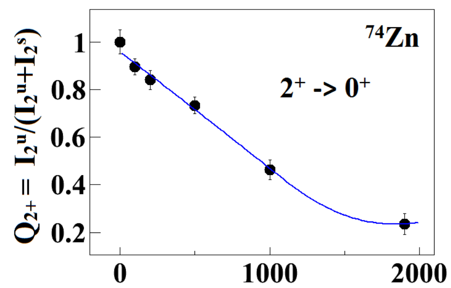


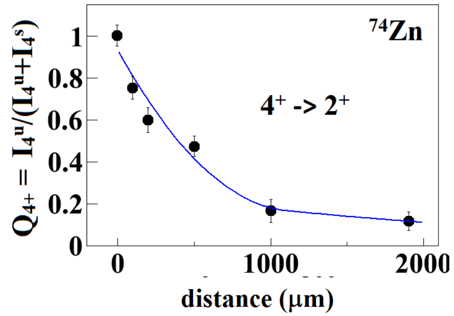
feeding transitions

$$\tau_i(x) = -\frac{Q_i(x) - \sum_k \alpha_k Q_k(x)}{v * \frac{dQ_i}{dx}(x)}$$

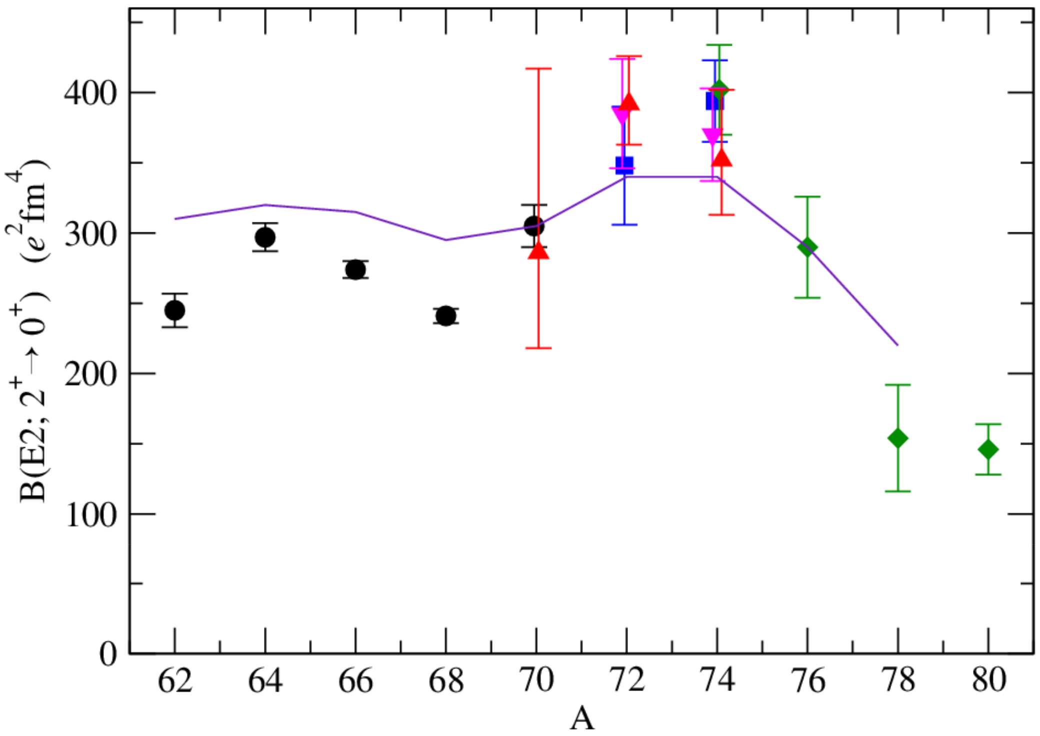
$$Q_i = \frac{I_i^u}{I_i}$$

$$I_i = I_i^u + I_i^s$$



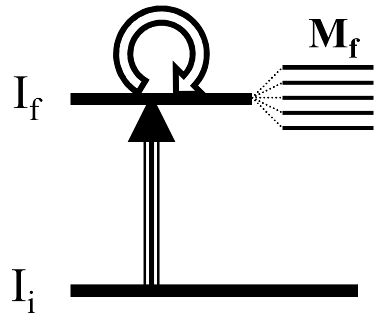


Systematics of B(E2; $2^+ \rightarrow 0^+$) values for Zn isotopes



- stable beam
  S. Raman, At. Nucl. Data Tab. 78, 1 (2001)
  O. Kenn et al. PRC 65, 034308 (2002)
  B. Pritychenko arXiv:1102.3365
- intermediate-energy coulex
  S. Leenhardt EPJ A 14, 1 (2002)
  O. Perru PRL 96, 232501 (2006)
- low-energy coulex
  J. Van de Walle PRL 99, 142501 (2007)
  J. Van de Walle PRC 79, 014309 (2009)
- RDM after fragmentation
  M. Niikura PRC 85, 054321 (2012)
- RDM after multi-nucleon transfer
  C. Louchart et al. to be published
- shell model JUN45
  M. Honma PRC 80, 064323 (2009)

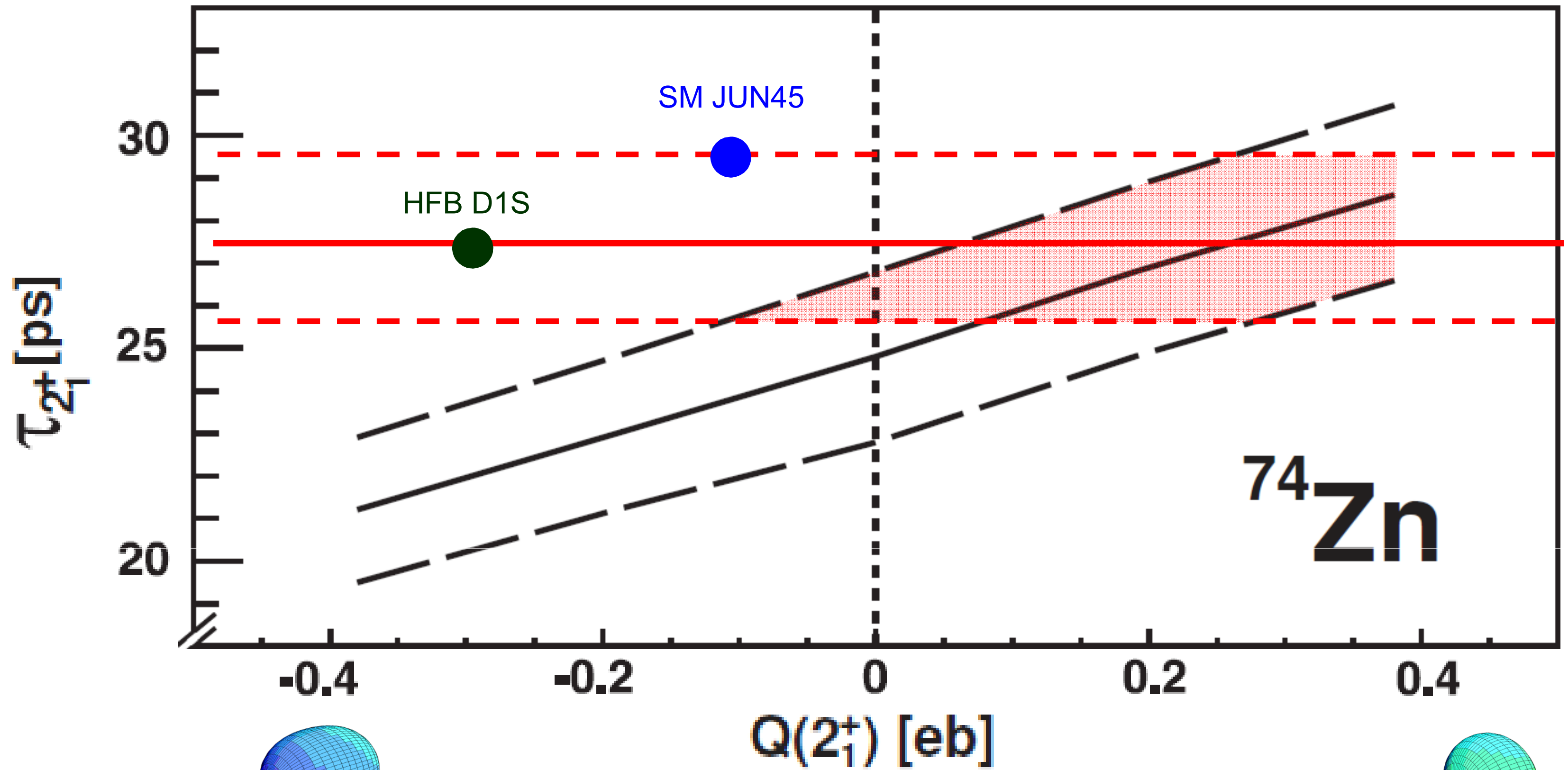
lifetime measurement:
decay probability depends
on transitional ME only

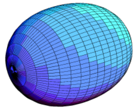


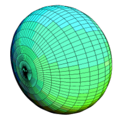
low-energy coulex:
excitation probability depends on
- transitional ME ⇒ B(E2)
- diagonal ME ⇒ Q

B(E2) obtained assuming $Q(2^+) = 0$

Combining Coulomb excitation and lifetimes to extract Q(2⁺) for ^{74}Zn







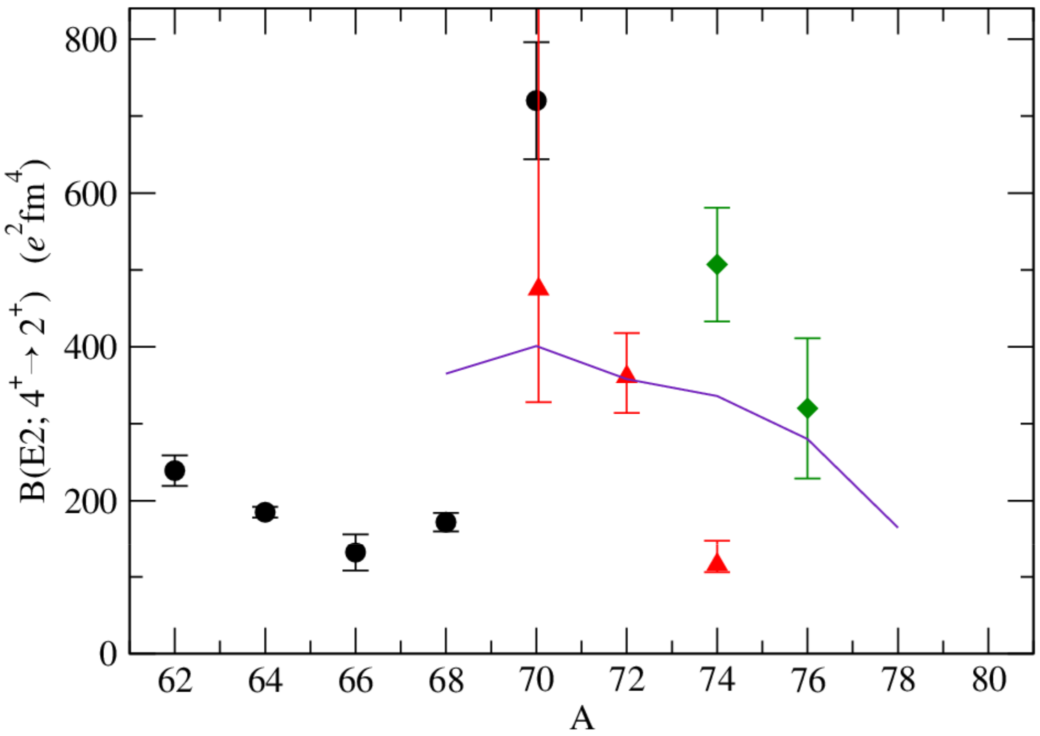
$Q(2^+) > 0$
oblate shape

- low-energy Coulex
  J. Van de Walle PRC 79, 014309 (2009)

- RDM lifetimes $\tau(2^+)$

after fragmentation:	27.0 (24) ps	M. Niikura PRC 85, 054321 (2012)
multi-nucleon transfer:	28.5 (36) ps	this experiment (C. Louchart et al.)
weighted average	27.5 (20) ps	

Systematics of B(E2; $4^+ \rightarrow 2^+$) values for Zn isotopes

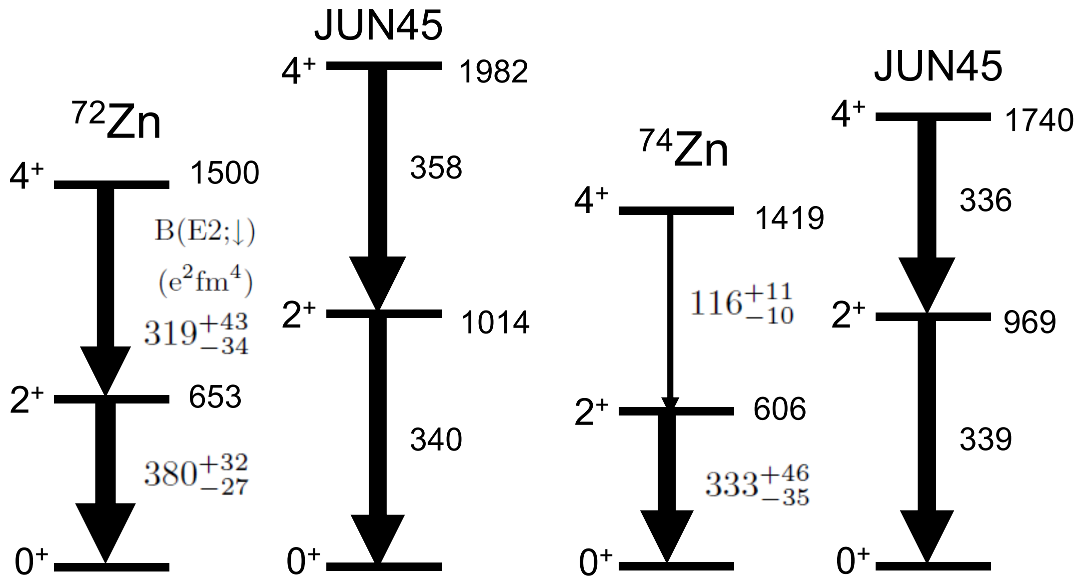


- DSAM lifetimes after Coulomb excitation (combined with g-factor measurement)
  O. Kenn et al. PRC 65, 034308 (2002)
  J. Leske et al. PRC 71, 034303 (2005)
  J. Leske et al. PRC 72, 044301 (2005)
  J. Leske et al. PRC 73, 064305 (2006)
  D. Mücher et al. PRC 79, 054310 (2009)
- low-energy Coulomb excitation
  J. Van de Walle PRC 79, 014309 (2009)
- lifetimes from present experiment
- shell model JUN45

very large B(E2; $4^+ \rightarrow 2^+$) in ^{70}Zn not understood

Large discrepancy between ISOLDE Coulomb excitation and lifetime measurement for ^{74}Zn

Collectivity of ^{72}Zn and ^{74}Zn

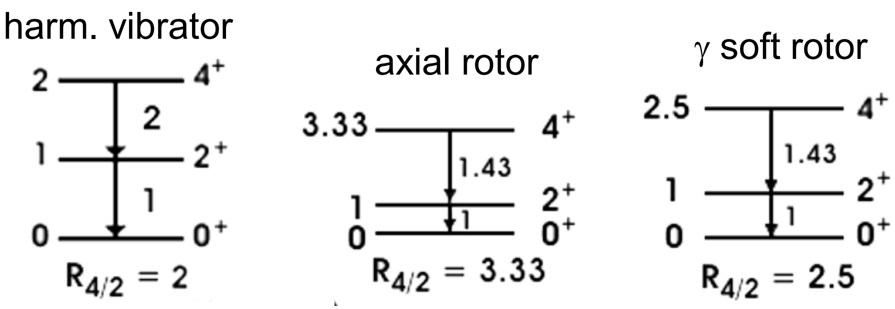


$R_{42} = 2.30$
$B_{42} = 0.84$

$R_{42} = 1.95$
$B_{42} = 1.05$

$R_{42} = 2.34$
$B_{42} = 0.35$

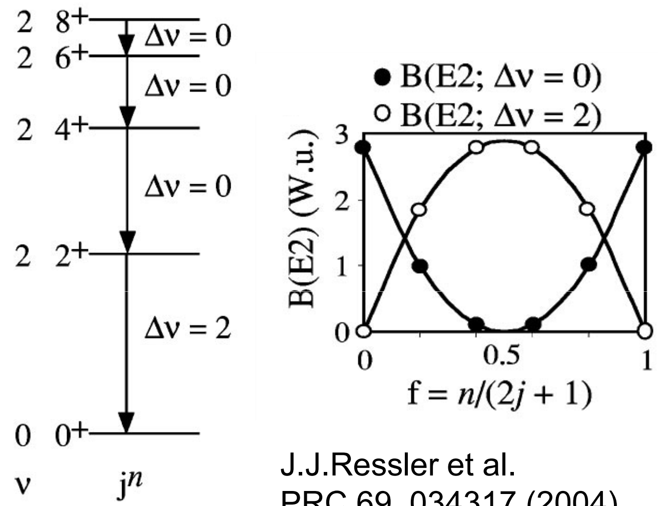
$R_{42} = 1.80$
$B_{42} = 0.99$



2+ lifetime + systematics
M. Niikura et al.
PRC 85, 054321 (2012)

How can B(E2; 4+ → 2+) be significant smaller than B(E2; 2+ → 0+) ?

- single high-j shell
- good seniority

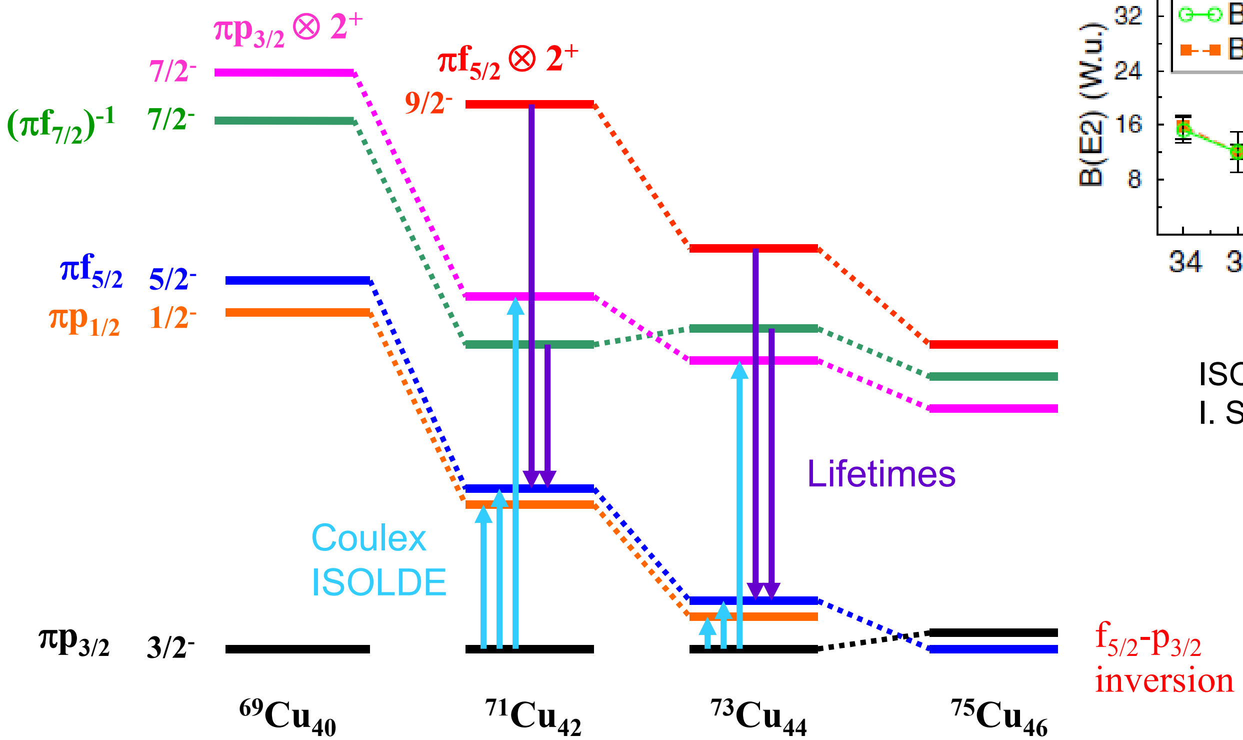


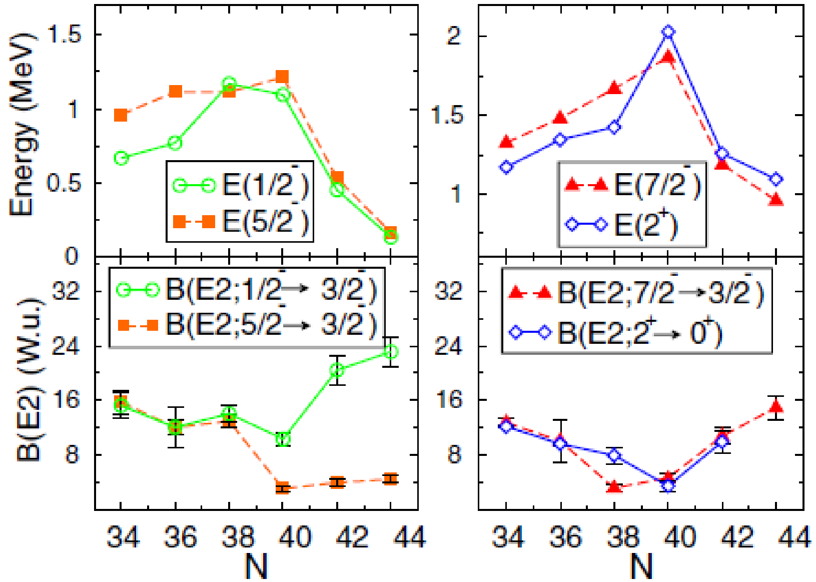
J.J.Ressler et al.
PRC 69, 034317 (2004)

then $R_{42} < 2$, $B_{42} < 1$

- small B(E2; 4+ → 2+) values suggest non-collective structure dominated by ν $g_{9/2}$

Single-particle vs collective states in odd-mass Cu isotopes





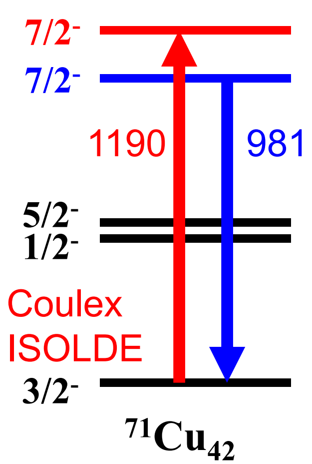
ISOLDE Coulomb excitation
I. Stefanescu et al. PRL 100, 112502 (2008)

Coulomb excitation:
- ➢ population from below

Lifetime measurement:
- ➢ population from above

⇒ access to different states

$7/2^-$ states in ^{71}Cu

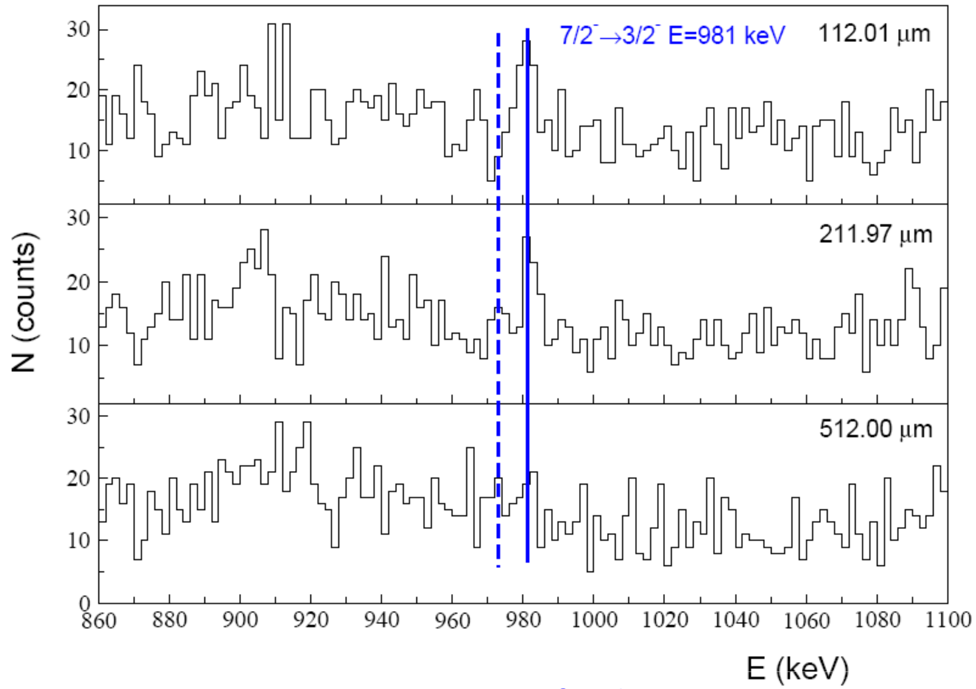


$\pi\, p_{3/2} \otimes 2^+ (^{70}\mathrm{Ni})$

$\pi\, f_{7/2}^{-1} p_{3/2}^{2}$

AGATA
lifetime

τ= 20(16) ps



$B(E2; 7/2_2^- \rightarrow 3/2^-) = 187(21)\ e^2\mathrm{fm}^4$

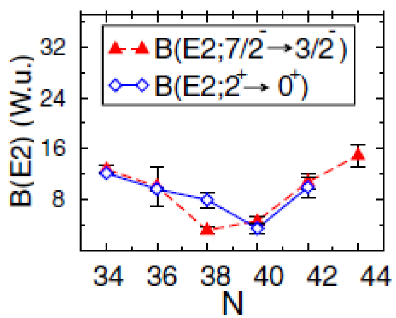
I. Stefanescu et al. PRL 100, 112502 (2008)

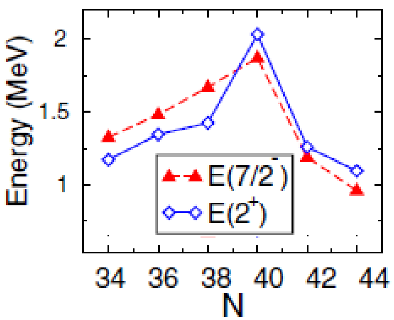
$B(E2; 7/2_1^- \rightarrow 3/2^-) = 45(36)\ e^2\mathrm{fm}^4$

M. Doncel et al., to be published

SM: fpg valence space
$B(E2; 7/2_2^- \rightarrow 3/2^-) = 26\ e^2\mathrm{fm}^4$

N.A. Smirnova *et al.*, PRC 69, 044306 (2004)





	E (keV)		$B(E2;\downarrow)$ (e^2fm^4)	
	exp	SM: fpgd	exp	SM: fpgd
$7/2_1^- \rightarrow 3/2^-$	981	1336	45(36)	40
$7/2_2^- \rightarrow 3/2^-$	1190	1041	187(21)	157

SM calculations: LNPS, K. Sieja priv. comm.

Summary

- RDDS plunger lifetime measurement with AGATA Demonstrator + PRISMA
- ^{76}Ge + ^{238}U multi-nucleon transfer
- highly complementary to Coulomb excitation with RIB
- B(E2; $2^+ \rightarrow 0^+$) $\Rightarrow$ constraints on Q(2+) $\Rightarrow$ oblate shape for ^{74}Zn
- very small B(E2; $4^+ \rightarrow 2^+$) $\Rightarrow$ non-collective structure
- structure of $7/2^-$ states in ^{71}Cu

Collaboration

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- Corinne Louchart, CEA Saclay / Université Paris XI, September 2012