Study of mid-shell nuclei based on the β-γ spectroscoy method

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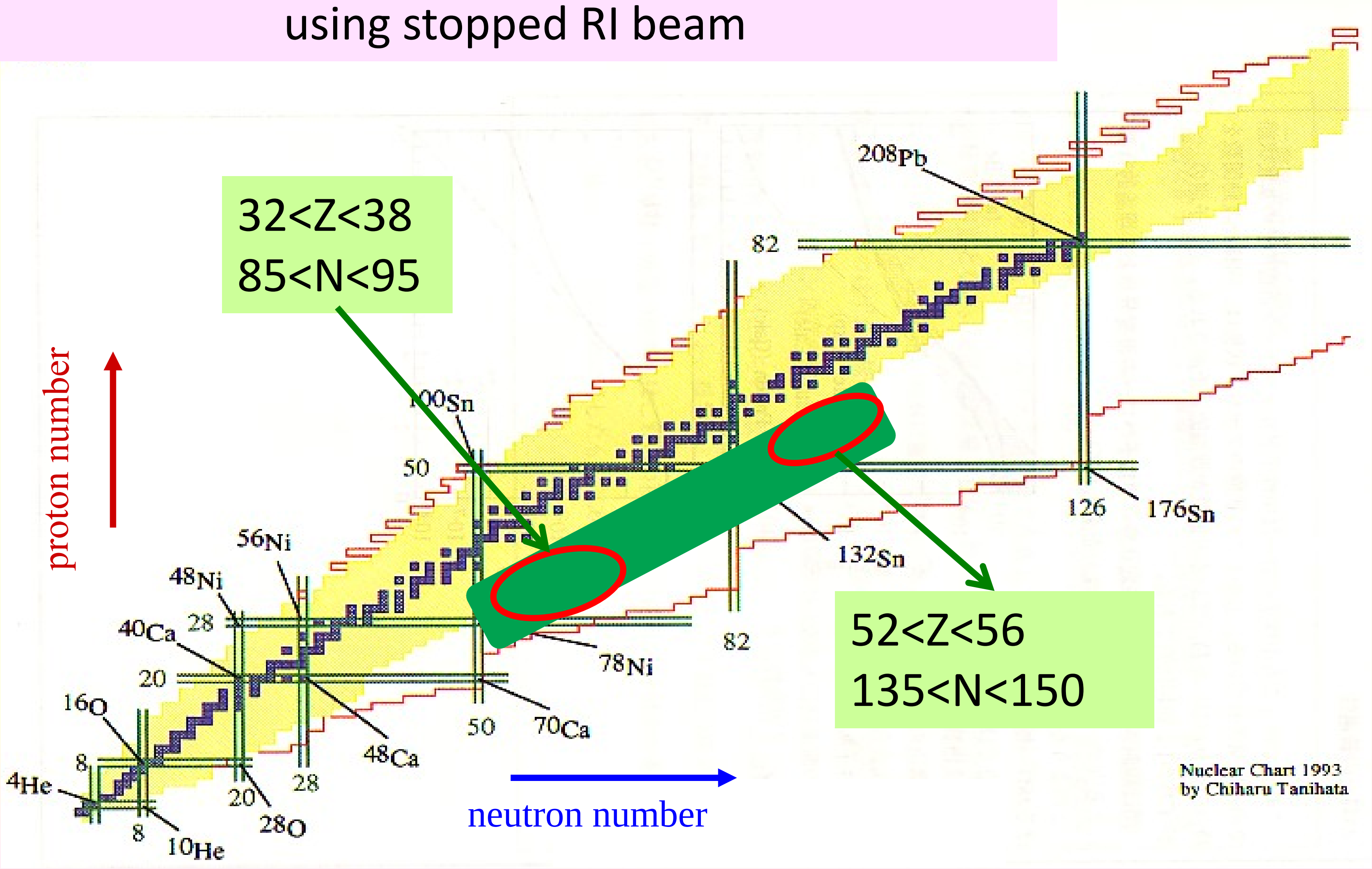
study of β decay and isomer search
using stopped RI beam
produced by in-flight fission of 345 MeV/u U beam
neutron-rich nuclei
with $28<Z<50$ and $Z>50$

study of β decay and isomer search
in neutron-rich nuclei with 28<Z<50 and Z>50
using stopped RI beam



neutron-rich nuclei far from the β-stablity line

1. nuclear structure
   * magic and semi-magic number
   * nuclear shape evolution
     effect of the residual interaction
     of valence particles (N > Z condition)

2. nucleosynthesis
   * r – process
     experimental physical values
     mass, $T_{1/2}$, spin and parity,
     β-decay scheme, b-delayed n branching
     and so on …

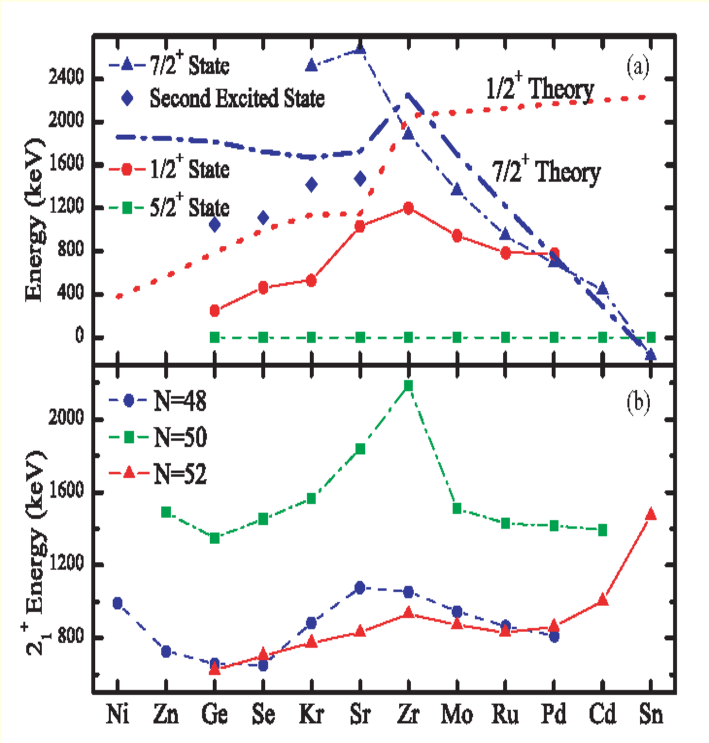
neutron-rich nuclei with 28 < Z < 50

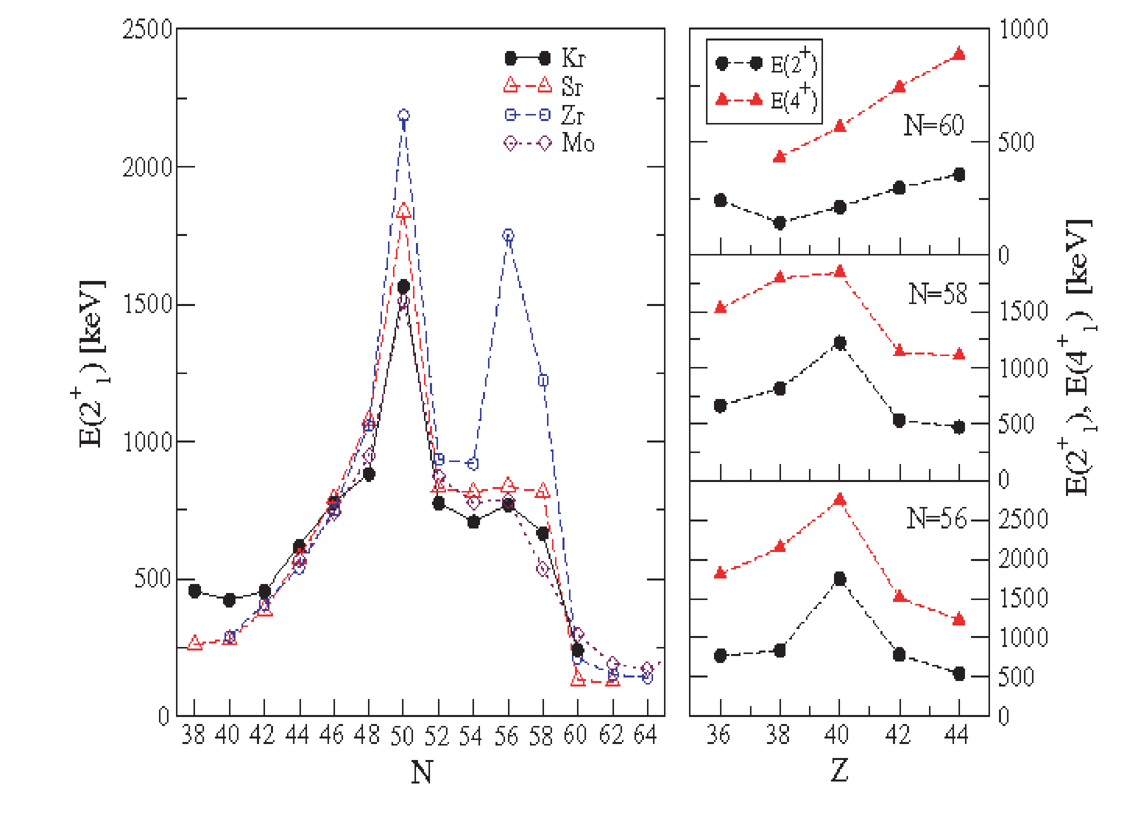
$_{36}$Kr, $_{38}$Sr, $_{40}$Zr, $_{42}$Mo

1. magic and semi-magic number

single-particle energy, E(2+) vs Z

E(2+), E(2+) / E(4+) vs N & Z





maximum of E(2+) at Z=40

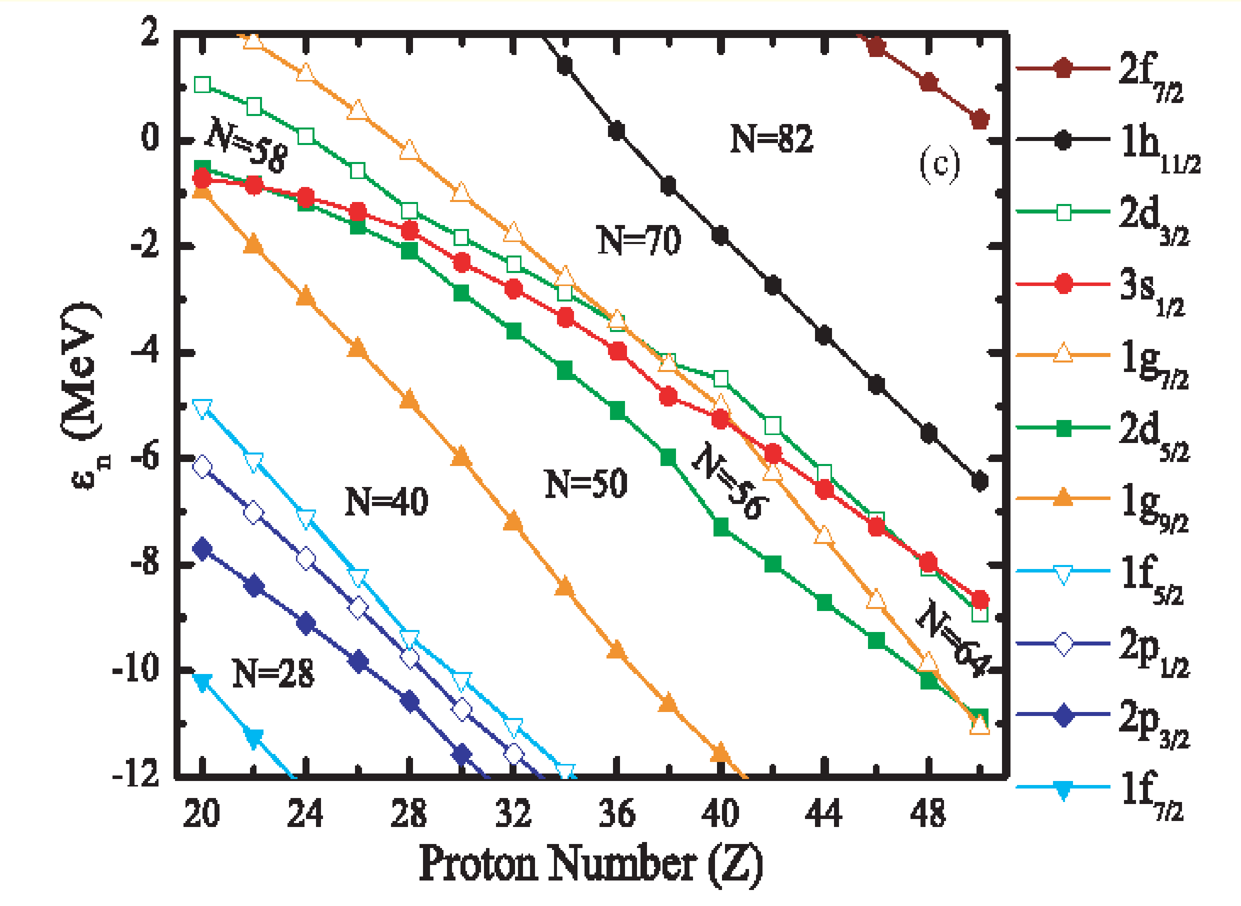
maximum of E(2+) at N=50 & 56 for Zr isotopes

J.A. Winger et al., PRC 81 (2010) 044303

N. Marginean et al., PRC 80 (2009) 021301

neutron-rich nuclei with 28 < Z < 50

1. magic and semi-magic number



theoretical single-particle energy

spherical HFB with SkO_T function + tensor term

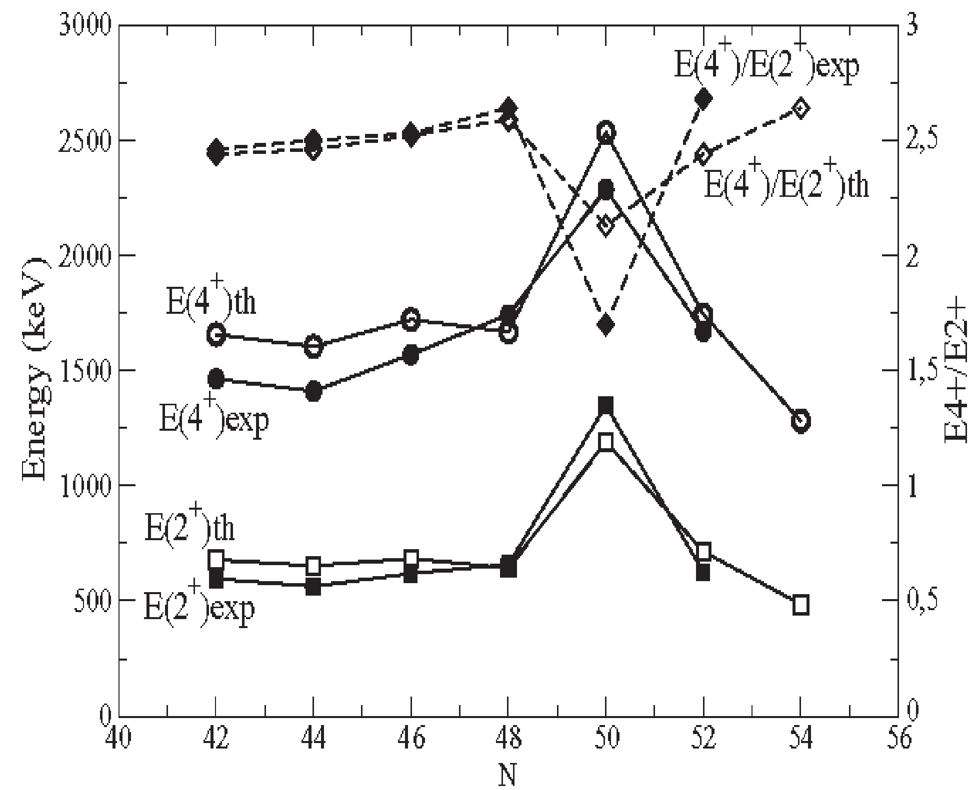
J.A. Winger et al., PRC 81 (2010) 044303

neutron-rich nuclei with 28 < Z < 50

2. shape evolution

Ge systematics

E(2+), E(4+), E(4+)/E(2+)



Spherical : N=50 magic

Collective : vibrational?

theoretical calculation : GCM+GOA

M. Lebois et al., PRC 80 (2009) 044308

neutron-rich nuclei with 28 < Z < 50

2. shape evolution

Ge isotopes 74 < A < 86

PES
（HFB +Gogny-DIS
effective interaction)

N=42

N=44

N=46

N=48

N=50

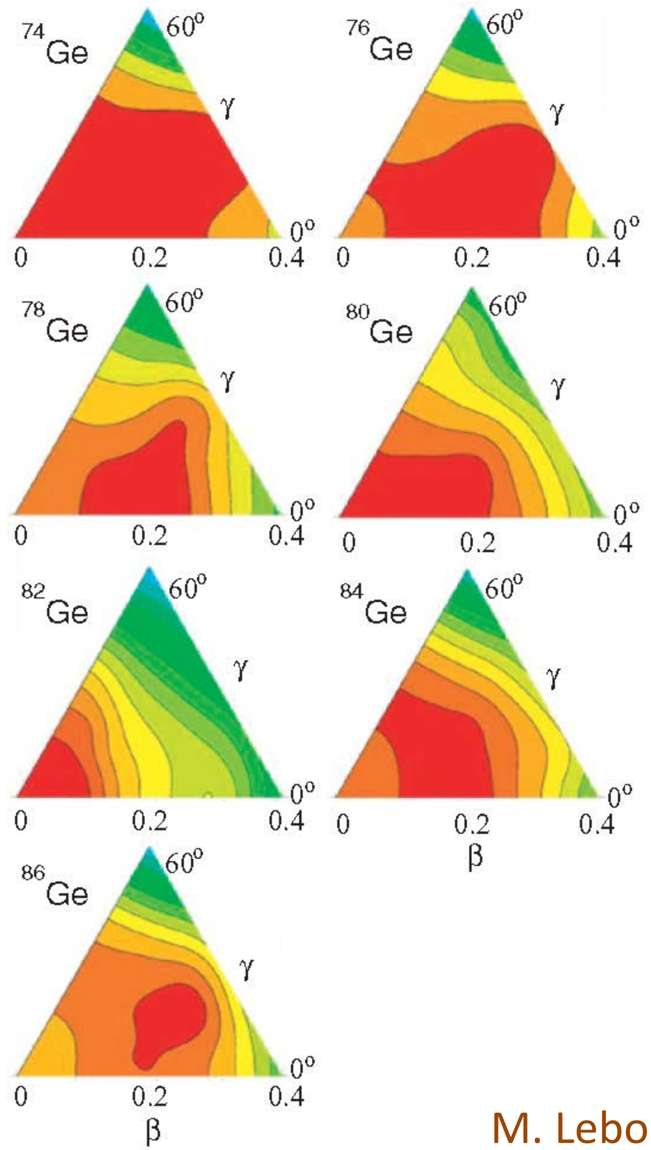
N=52

N=54

spherical
vibrational

γ sofft

triaxial rotor?

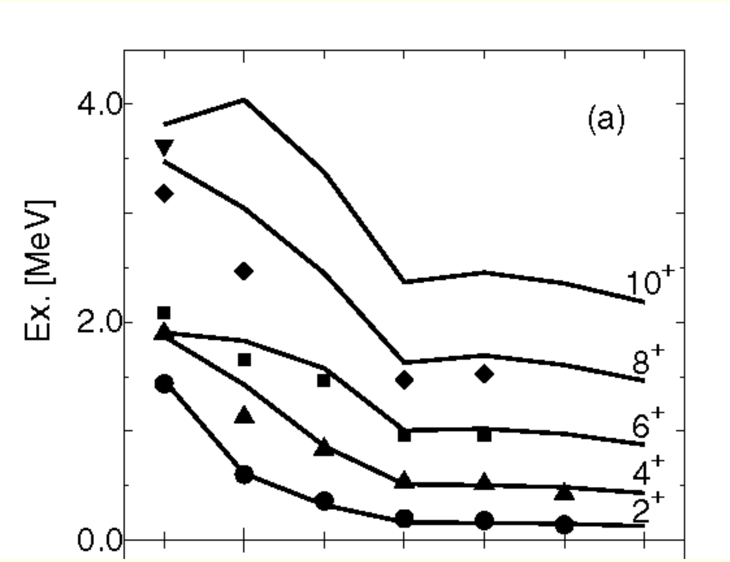


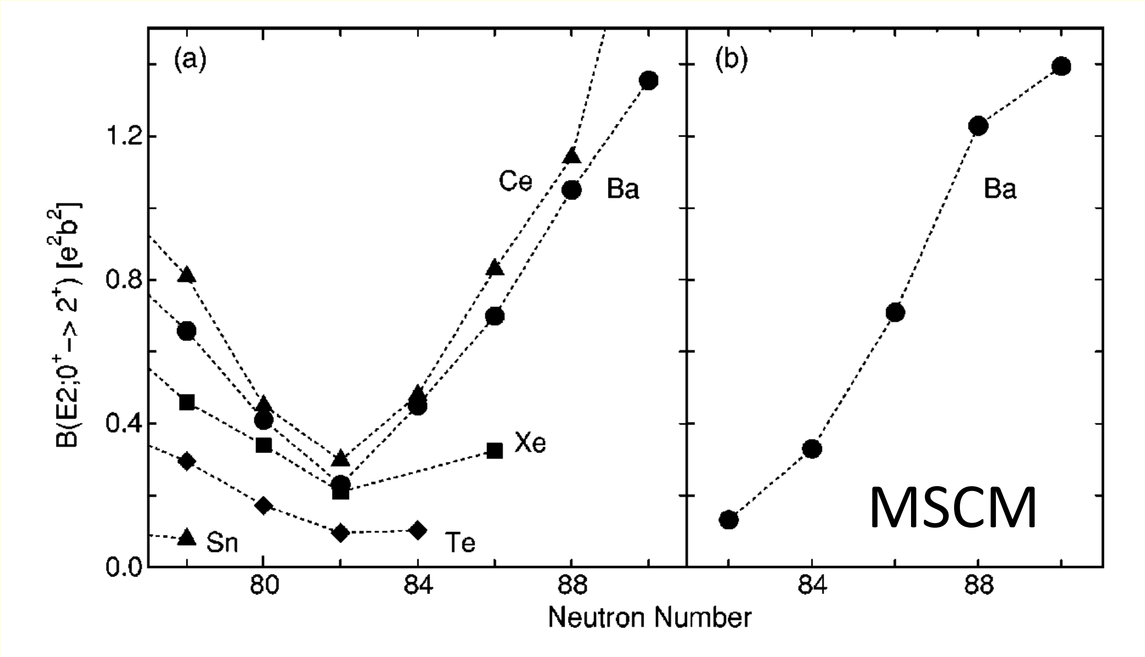
M. Lebois et al., PRC 80 (2009) 044308

neutron-rich nuclei with Z > 50

1. shape evolution

Ba isotopes



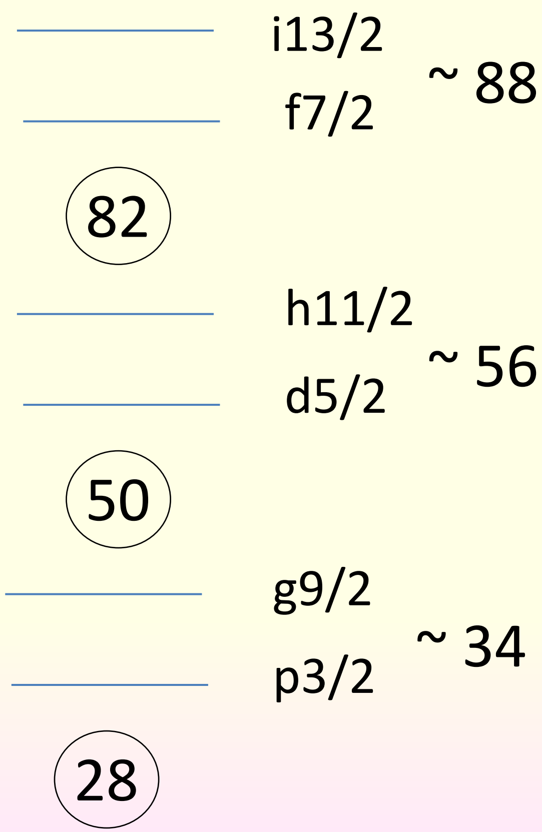


N. Shimizu et al., PRL 86 (2001) 1171

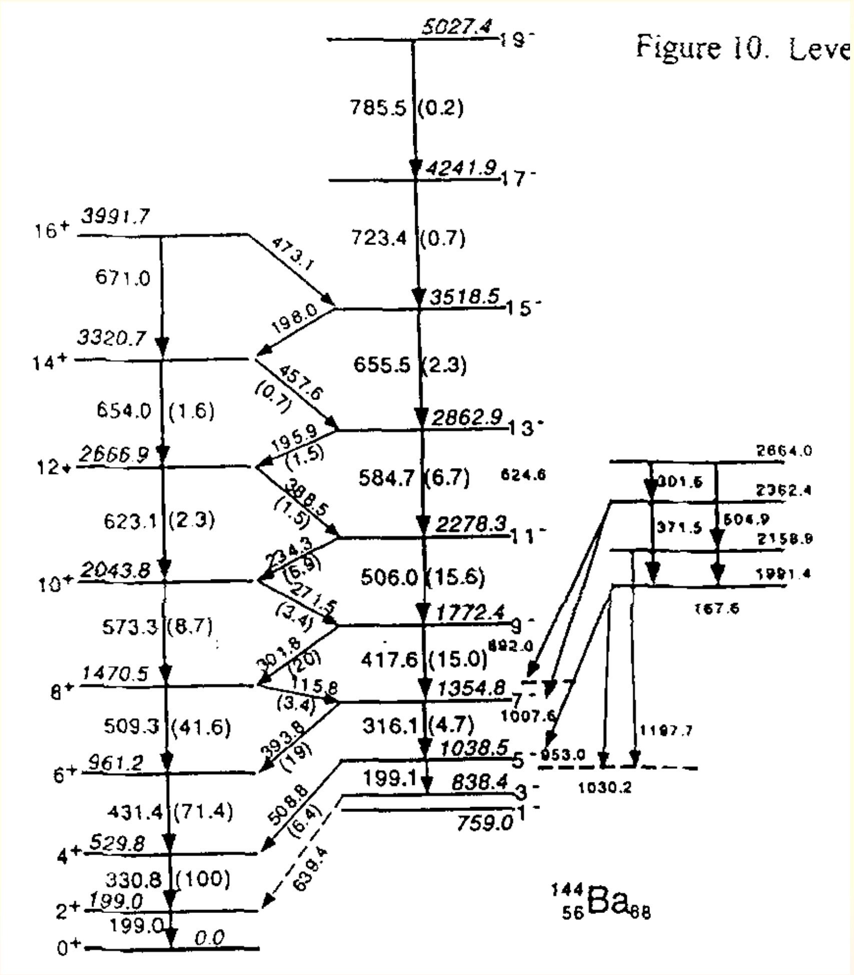
N. Shimizu et al., PRC 70 (2004) 054313

neutron-rich nuclei with Z > 50

2. octupole deformation

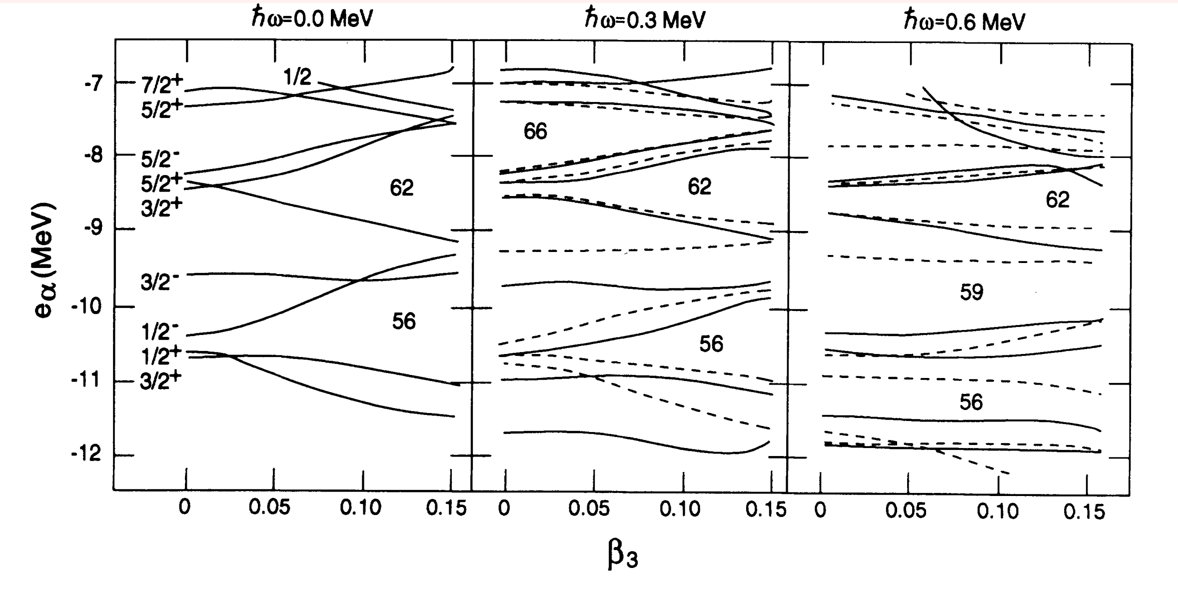


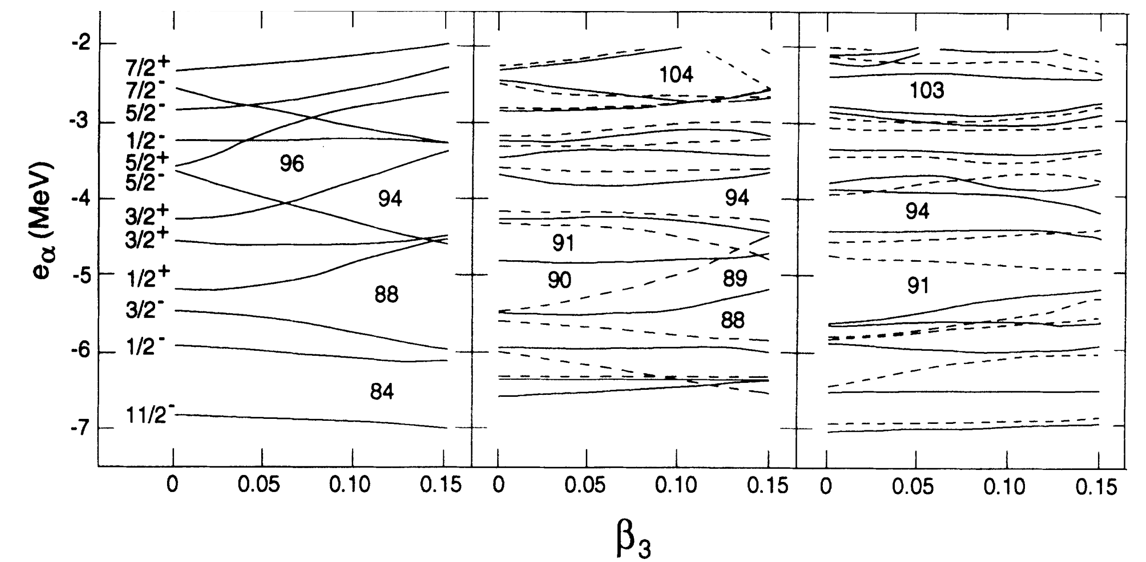
^{144}Ba (Z=56, N=88)



J.H. Hamilton et al.,
Prog. Part. Nucl. Phys. 38 (1997) 273

neutron-rich nuclei with Z > 50





octupole deformation
vibration

N=88

more neutron-rich

N=94, 96?

cranking model
with the Woods-Saxon potential
and pairing

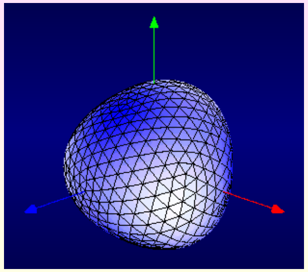
W. Nazarewicz et al., PRC 45 (1992) 2226

neutron-rich nuclei in both region

tetrahedral and octahedral symmetry

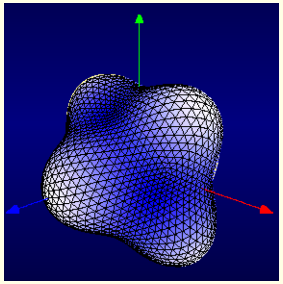
J. Dudek et al,

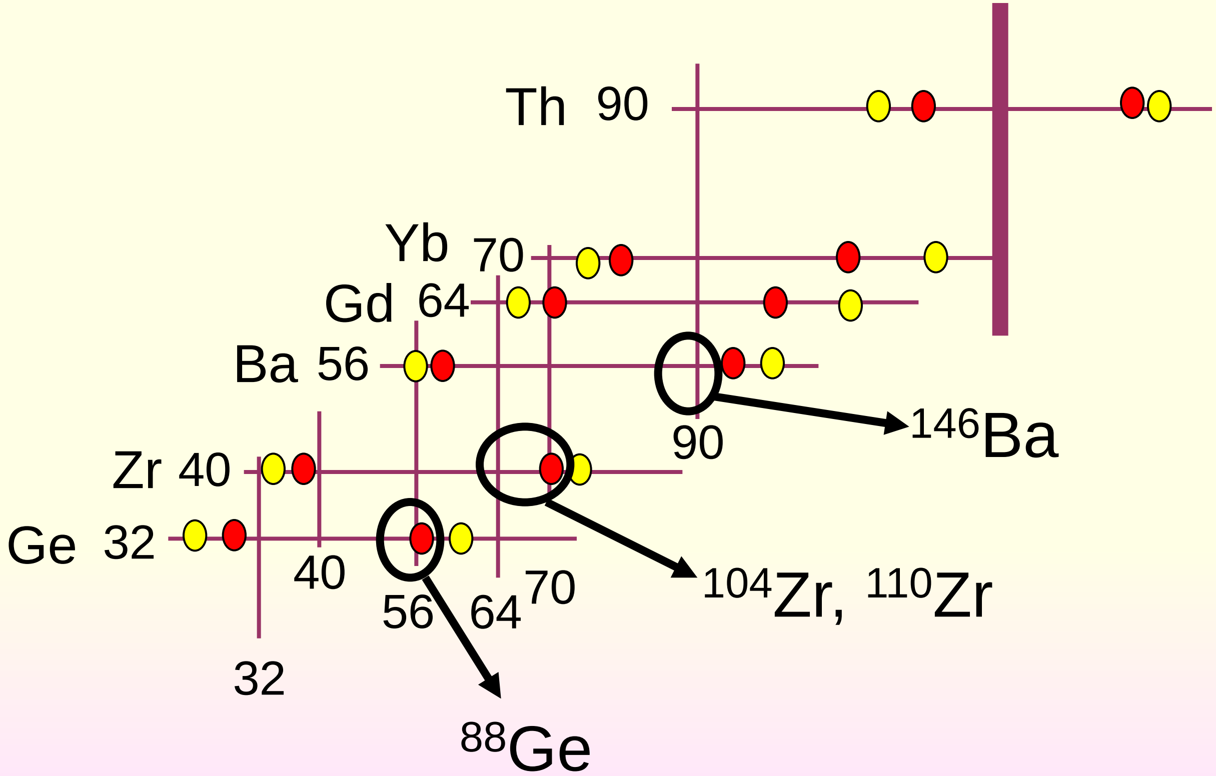
30, 40, 56, 64, 70, 90, 132-136



tetrahedaral

(pyramid)





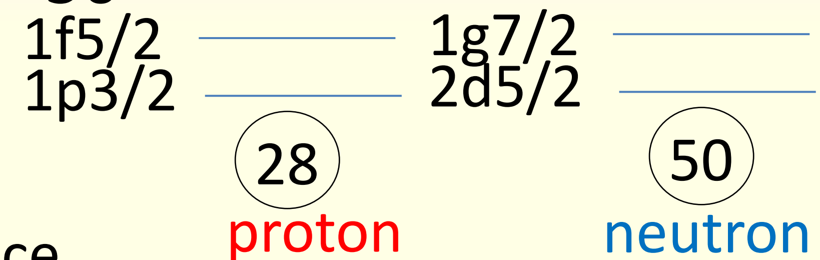
octahedral

(diamond)

Physics motivation [No. 1]

Study of β decay and isomer search

neutron-rich nuclei with $28 < Z < 50$



1. shape coexistence ?

proton-rich Ge, Se, Kr close to N=Z

prolate-oblate shape coexsistence

How about in neutron-rich Ge, Se, Kr ?

^{90}Se ? (Z=34, N=56)

2. octupole collectivity?

Z=34, N=56

Octupole collectivity can be expected.

How about in neutron-rich Ge, Se, Kr ?

^{90}Se ? (Z=34, N=56)

3. exotic shape ?

tetrahedral and octahedral symmetry

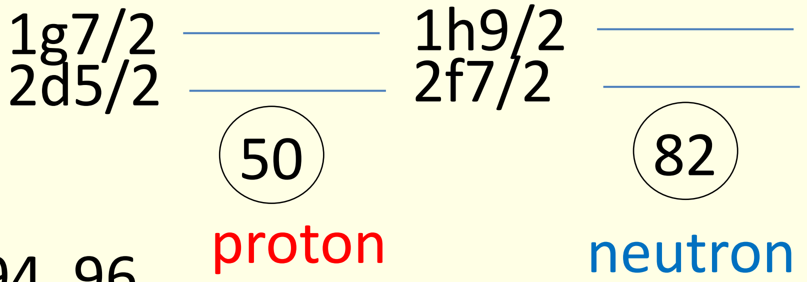
triaxial shape, and so on …

^{88}Ge ? (Z=32, N=56)

Physics motivation [No. 2]

Study of β decay and isomer search

neutron-rich nuclei with Z > 50



1. octupole collectivity?

octupole collectivity

neutron-rich Te, Xe, Ba with N=90, 92, 94, 96

2. shape coexistence ?

Possibility of shape coexistence

neutron-rich Te, Xe, Ba ?

^{142}Te? (Z=52, N=90)

^{144}Xe? (Z=54, N=94)

^{150}Ba? (Z=56, N=94)

3. exotic shape ?

tetrahedral and octahedral symmetry

triaxial shape, and so on …

^{146}Ba ? (Z=56, N=90)

β-γ detection system

day two exp

β-γ spectroscopy to study nuclei A~110

in-flight fission of 345 MeV/u ^{238}U

on Dec. 2009

$T_{1/2}$: S. Nishimura et al.,

PRL 106 (2011) 052502

^{109}Nb isomer :

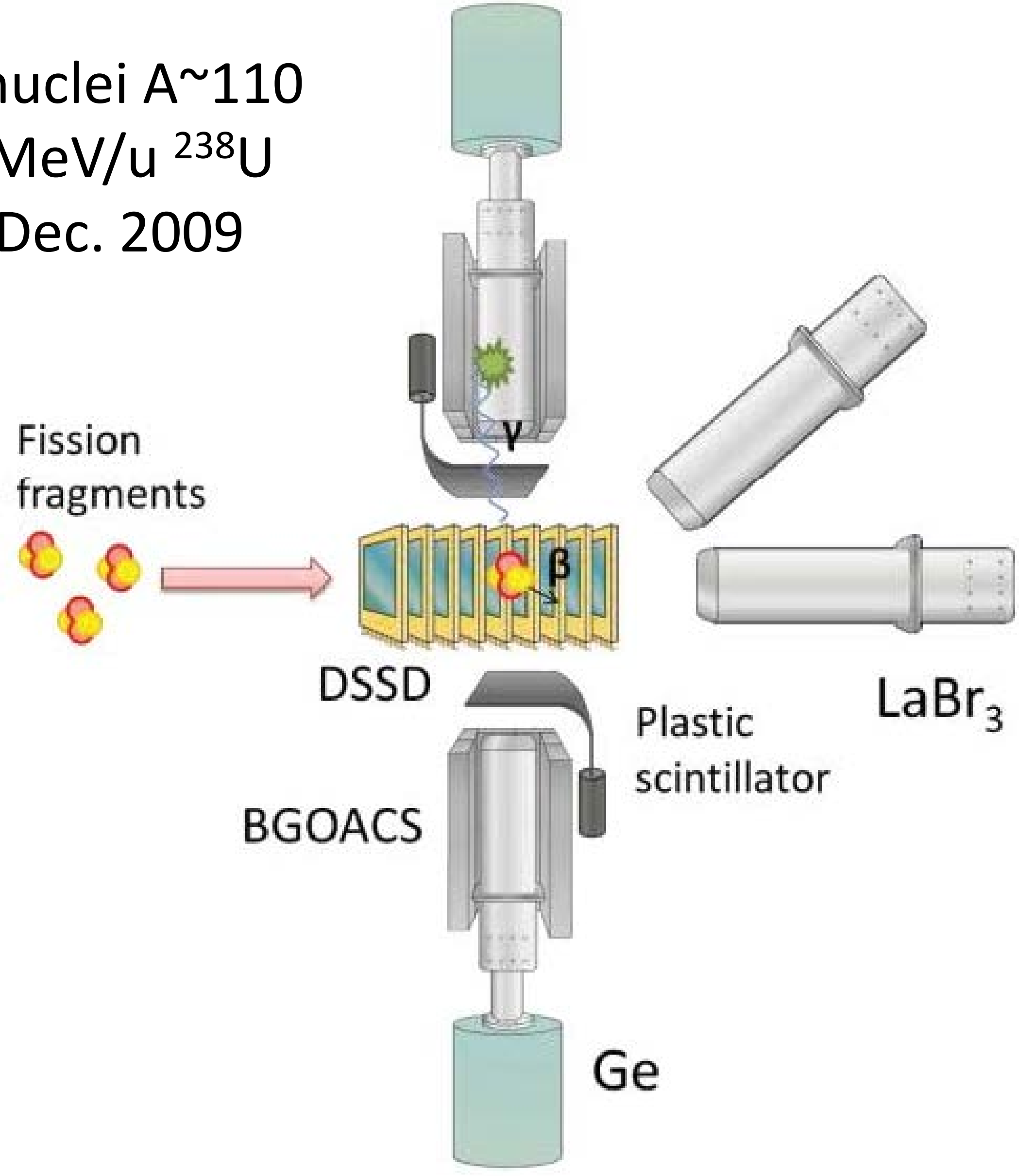
H. Watanabe et al.,

PLB 696 (2011) 186

$^{106,108}Zr$ isotopes :

T. Sumikama et al.,

PRL 106 (2011) 202501

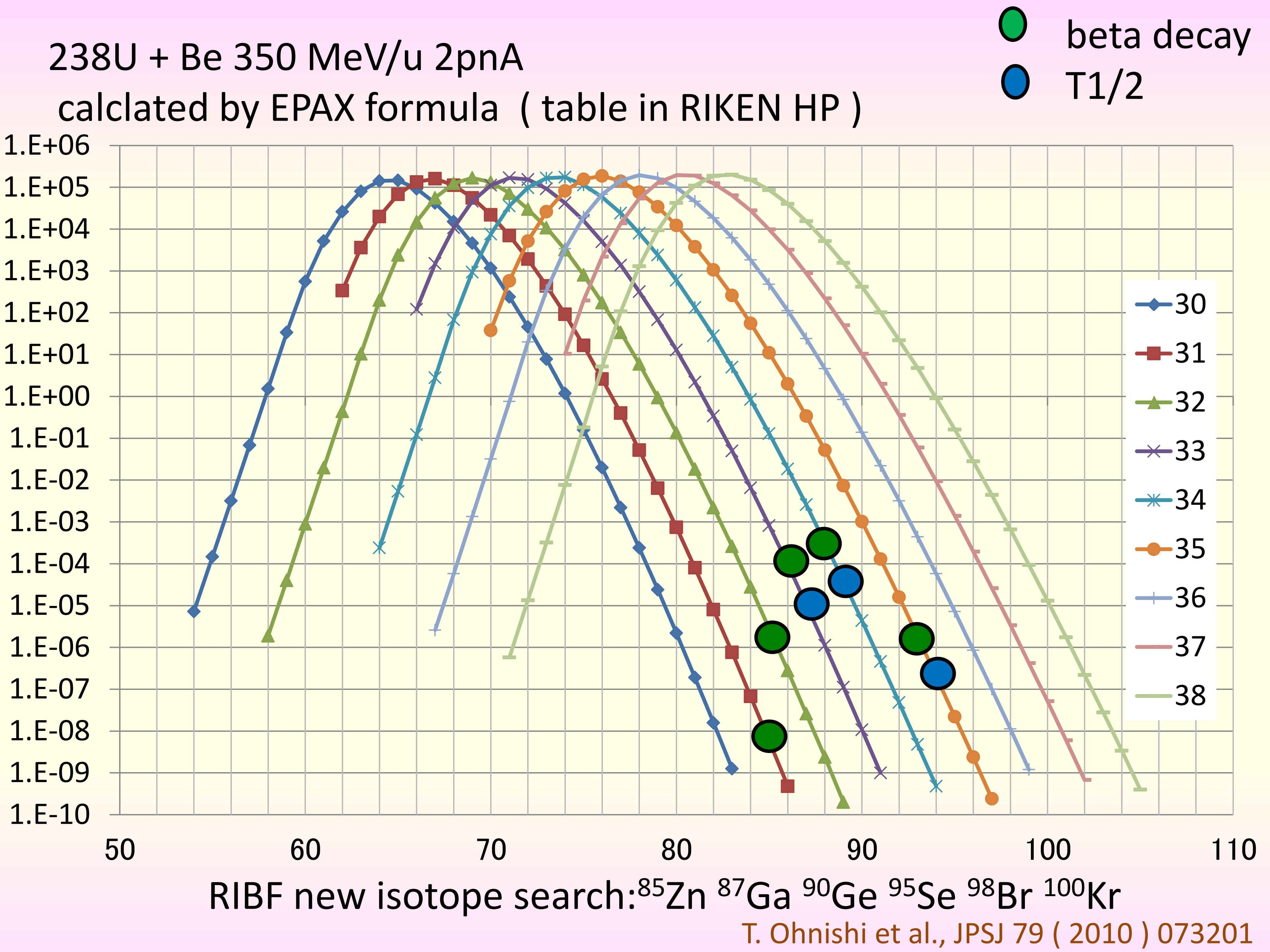


* DSSD :
  detection of RI beam and β ray
* clover type Ge det. :
  detection of γ ray

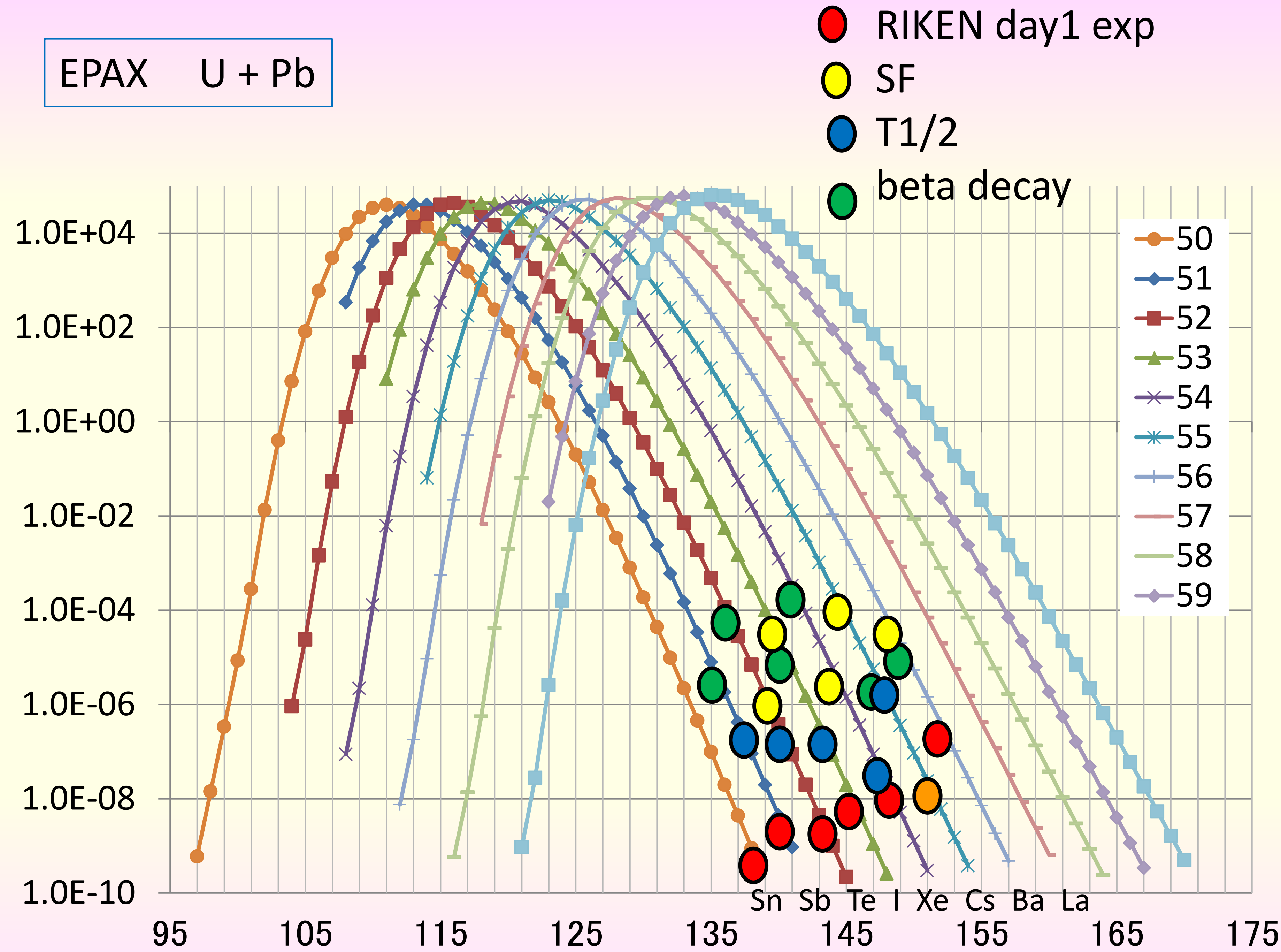
improvement of β-γ detector system

1. Ge detector : E(U)RICA (RISING Ge detector array)
   Detection efficiency and
   number of combination of Ge detectors
   will be improved.

2. We would like to get additional information,
   if it is possible.
   As example,
   (1) β-ray energy
   (2) conversion electron
   (3) detection of β delayed neutron ?
   β delayed – n
   β delayed – 2n



238U + Be 350 MeV/u 2pnA
calclated by EPAX formula (table in RIKEN HP)
beta decay
T1/2
1.E+06
1.E+05
1.E+04
1.E+03
1.E+02
1.E+01
1.E+00
1.E-01
1.E-02
1.E-03
1.E-04
1.E-05
1.E-06
1.E-07
1.E-08
1.E-09
1.E-10
50
60
70
80
90
100
110
30
31
32
33
34
35
36
37
38
RIBF new isotope search:^{85}Zn ^{87}Ga ^{90}Ge ^{95}Se ^{98}Br ^{100}Kr
T. Ohnishi et al., JPSJ 79 (2010) 073201


EPAX U + Pb
RIKEN day1 exp
SF
T1/2
beta decay
50
51
52
53
54
55
56
57
58
59
1.0E+04
1.0E+02
1.0E+00
1.0E-02
1.0E-04
1.0E-06
1.0E-08
1.0E-10
95
105
115
125
135
145
155
165
175
Sn Sb Te I Xe Cs Ba La

Summary

1. Study of β decay and isomer search using stopped beam
   in neutron-rich nuclei with $28<Z<50$ and $Z>50$

2. EURICA combined with β-γ detection system used day two exp.
   will be very effective tool to search for the β decay of n-rich nuclei.

3. Study of neutron-rich nuclei
   by the aspects of nuclear structure and nucleosynthesis
   neutron-rich nuclei with $28<Z<50$ and $Z>50$
   change of magic number
   nuclear shape evolution
   (shape coexistence ? octupole deformation ?
   exotic shape : tetrahedral / octahedral shape ? and so on)

4. isomer search ex. odd-odd nuclei ms isomer near ground state
   shape isomer ?