Coulomb excitation of neutron rich zinc isotopes

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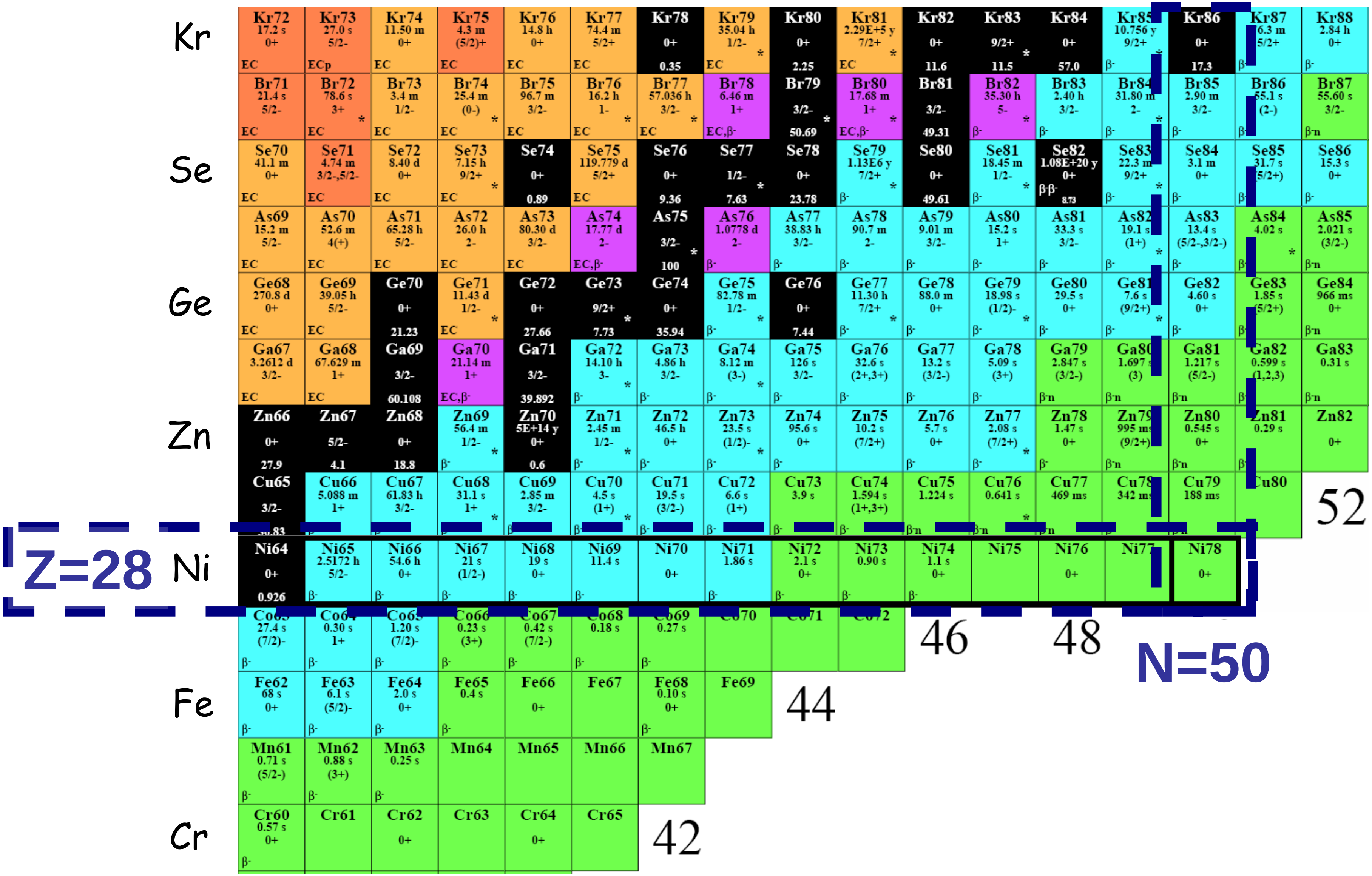
Kr
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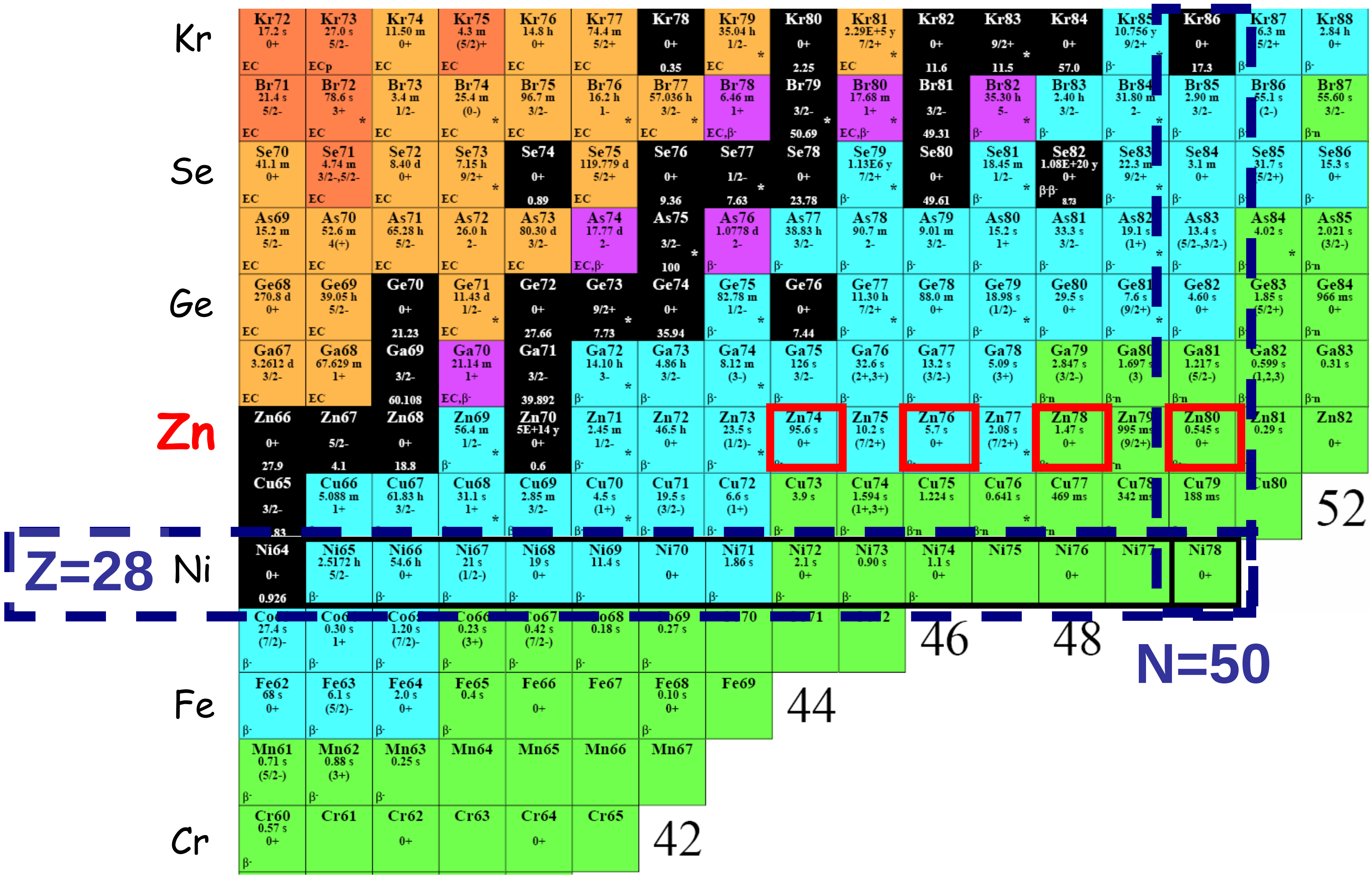
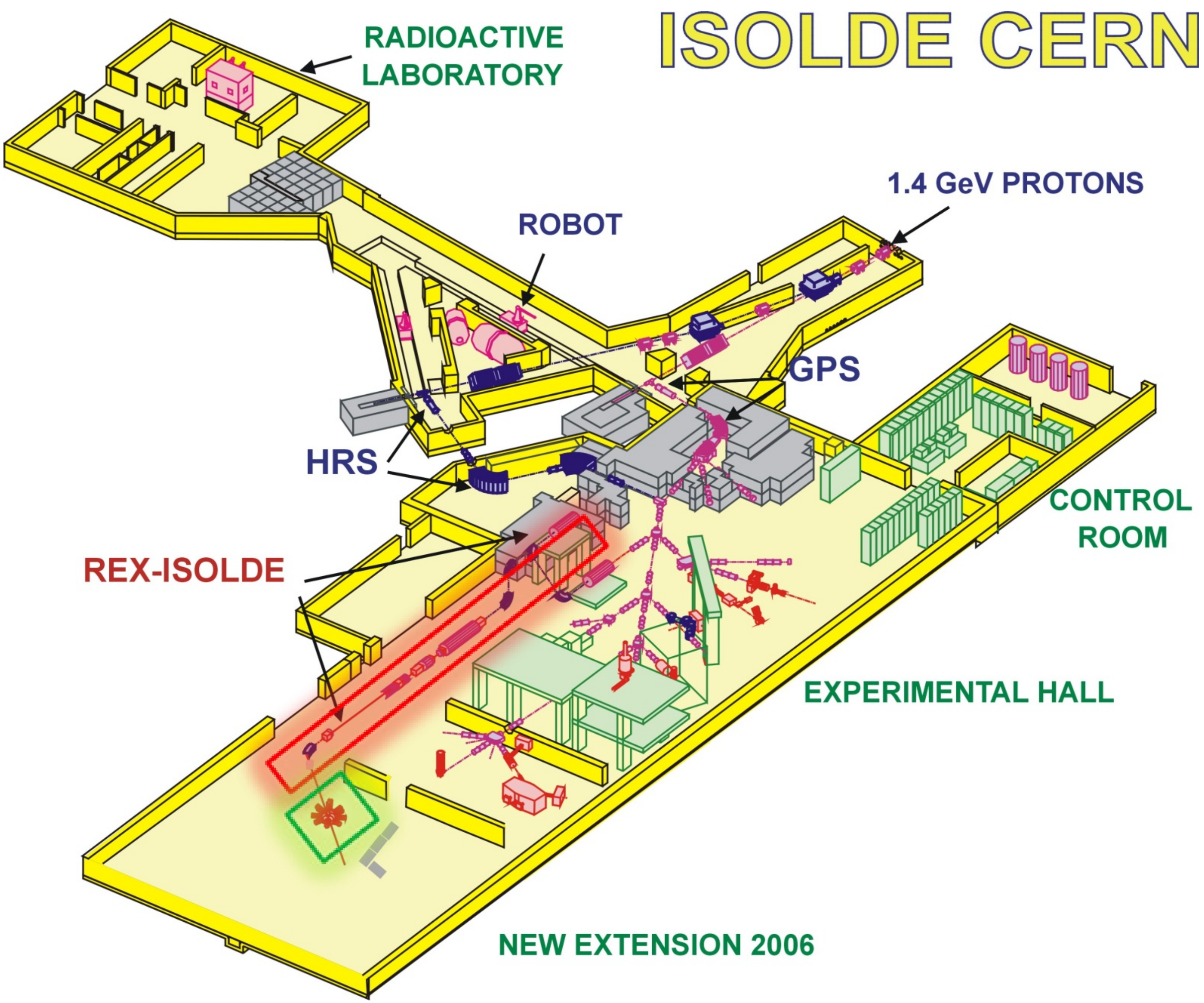
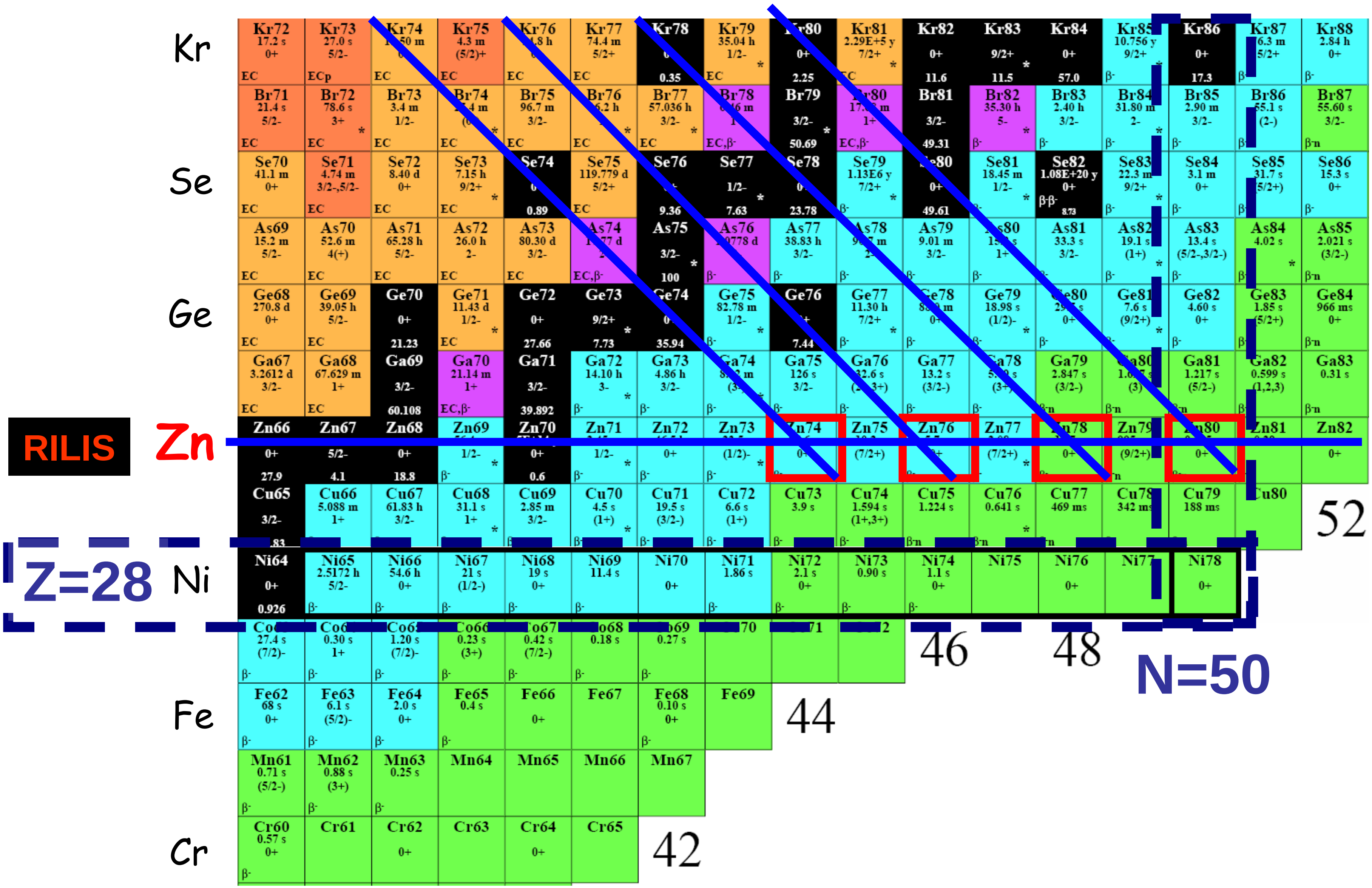
Se
As
Ge
Ga
Zn
Cu
Z=28 Ni
Co
Fe
Mn
Cr
52
46
48
N=50
44
42


Kr
Se
Ge
Zn
Z=28
Ni
Fe
Cr
Kr72 Kr73 Kr74 Kr75 Kr76 Kr77 Kr78 Kr79 Kr80 Kr81 Kr82 Kr83 Kr84 Kr85 Kr86 Kr87 Kr88
Br71 Br72 Br73 Br74 Br75 Br76 Br77 Br78 Br79 Br80 Br81 Br82 Br83 Br84 Br85 Br86 Br87
Se70 Se71 Se72 Se73 Se74 Se75 Se76 Se77 Se78 Se79 Se80 Se81 Se82 Se83 Se84 Se85 Se86
As69 As70 As71 As72 As73 As74 As75 As76 As77 As78 As79 As80 As81 As82 As83 As84 As85
Ge68 Ge69 Ge70 Ge71 Ge72 Ge73 Ge74 Ge75 Ge76 Ge77 Ge78 Ge79 Ge80 Ge81 Ge82 Ge83 Ge84
Ga67 Ga68 Ga69 Ga70 Ga71 Ga72 Ga73 Ga74 Ga75 Ga76 Ga77 Ga78 Ga79 Ga80 Ga81 Ga82 Ga83
Zn66 Zn67 Zn68 Zn69 Zn70 Zn71 Zn72 Zn73 Zn74 Zn75 Zn76 Zn77 Zn78 Zn79 Zn80 Zn81 Zn82
Cu65 Cu66 Cu67 Cu68 Cu69 Cu70 Cu71 Cu72 Cu73 Cu74 Cu75 Cu76 Cu77 Cu78 Cu79 Cu80
Ni64 Ni65 Ni66 Ni67 Ni68 Ni69 Ni70 Ni71 Ni72 Ni73 Ni74 Ni75 Ni76 Ni77 Ni78
Fe62 Fe63 Fe64 Fe65 Fe66 Fe67 Fe68 Fe69
Mn61 Mn62 Mn63 Mn64 Mn65 Mn66 Mn67
Cr60 Cr61 Cr62 Cr63 Cr64 Cr65
42
44
46
48
N=50
52


ISOLDE CERN
RADIOACTIVE
LABORATORY
ROBOT
1.4 GeV PROTONS
GPS
HRS
REX-ISOLDE
CONTROL
ROOM
EXPERIMENTAL HALL
NEW EXTENSION 2006


Kr
Se
Ge
RILIS
Zn
Z=28
Ni
Fe
Cr
Kr72 Kr73 Kr74 Kr75 Kr76 Kr77 Kr78 Kr79 Kr81 Kr82 Kr83 Kr84 Kr85 Kr86 Kr87 Kr88
Br71 Br72 Br73 Br74 Br75 Br76 Br77 Br79 Br81 Br82 Br83 Br84 Br85 Br86 Br87
Se70 Se71 Se72 Se73 Se74 Se75 Se76 Se77 Se78 Se79 Se81 Se82 Se83 Se84 Se85 Se86
As69 As70 As71 As72 As73 As74 As75 As76 As77 As79 As81 As82 As83 As84 As85
Ge68 Ge69 Ge70 Ge71 Ge72 Ge73 Ge75 Ge76 Ge77 Ge79 Ge81 Ge82 Ge83 Ge84
Ga67 Ga68 Ga69 Ga70 Ga71 Ga72 Ga73 Ga75 Ga76 Ga77 Ga79 Ga81 Ga83
Zn66 Zn67 Zn68 Zn69 Zn70 Zn71 Zn72 Zn73 Zn75 Zn77 Zn81 Zn82
Cu65 Cu66 Cu67 Cu68 Cu69 Cu70 Cu71 Cu72 Cu73 Cu74 Cu75 Cu76 Cu77 Cu79
Ni64 Ni65 Ni66 Ni67 Ni68 Ni69 Ni70 Ni71 Ni72 Ni73 Ni74 Ni75 Ni76 Ni78
Fe62 Fe63 Fe64 Fe65 Fe66 Fe67 Fe68 Fe69
Mn61 Mn62 Mn63 Mn64 Mn65 Mn66 Mn67
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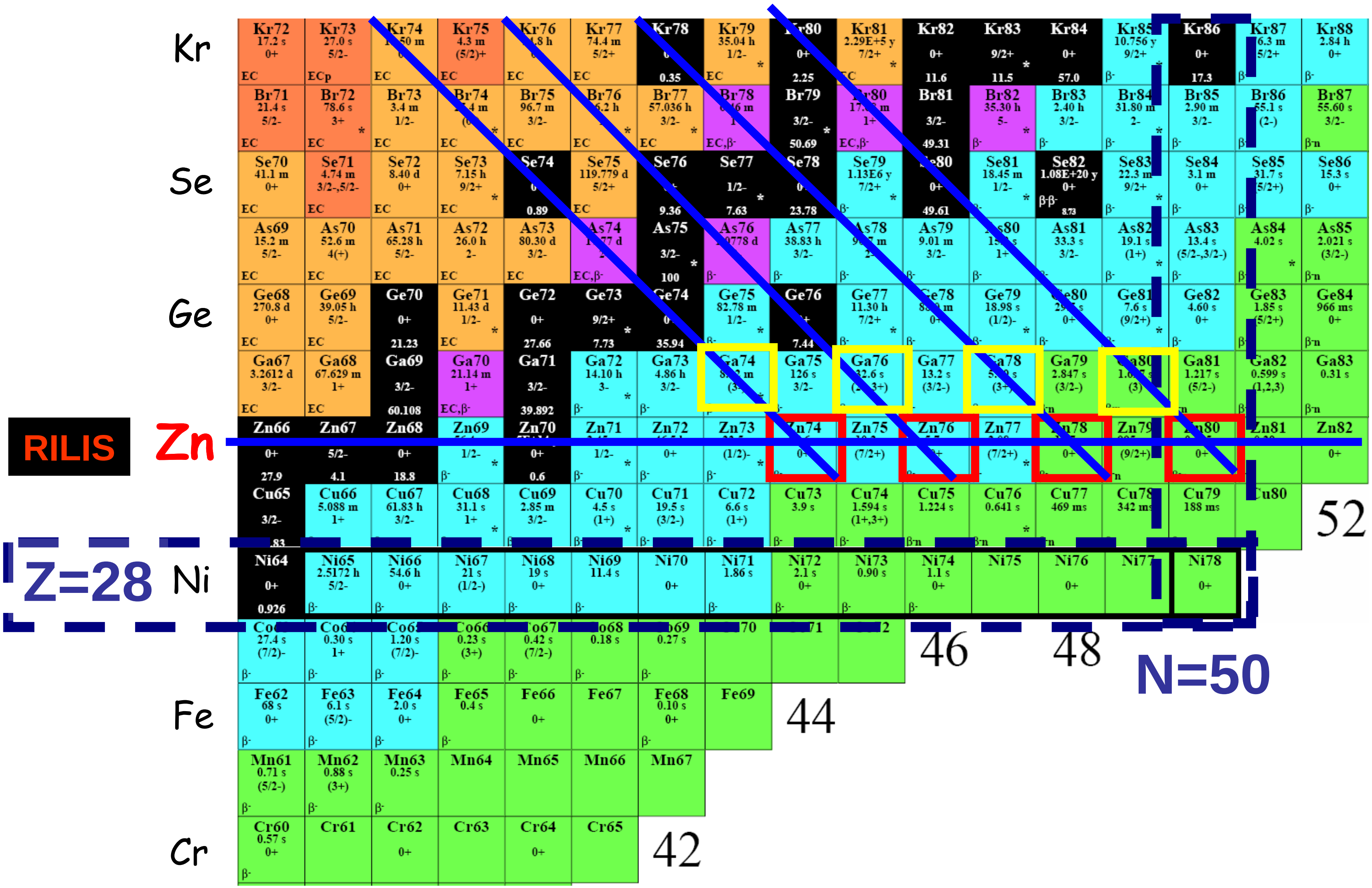
52
46
48
N=50
44
42


Kr
Se
Ge
RILIS
Zn
Z=28
Ni
Fe
Cr
52
46
48
N=50
44
42

	ISOLDE	MINIBALL	PURITY
^{74}Zn	2.0E7/ μC	3.0E5 pps	83(4)%
^{76}Zn	5.0E6/ μC	1.1E5 pps	73(7)%
^{78}Zn	3.9E5/ μC	4.3E3 pps	64(13)%
^{80}Zn	3.0E4/ μC	3.0E3 pps	44(5)%

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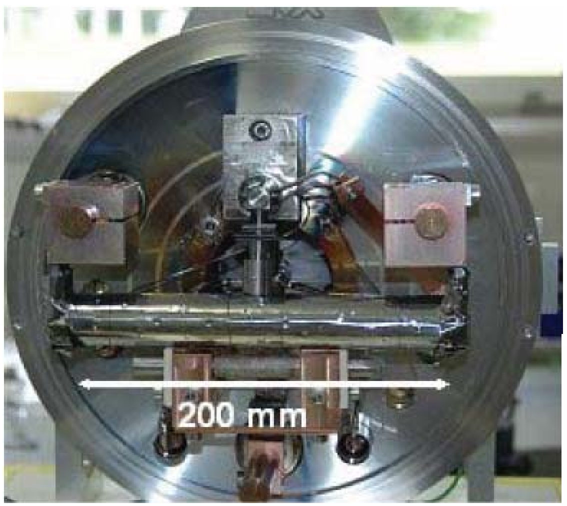
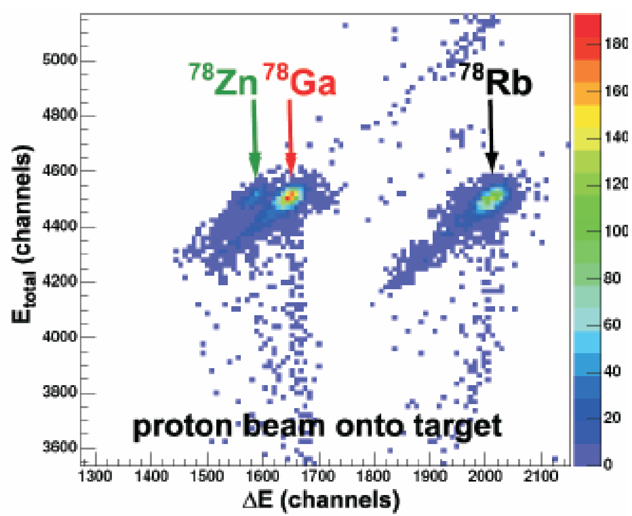
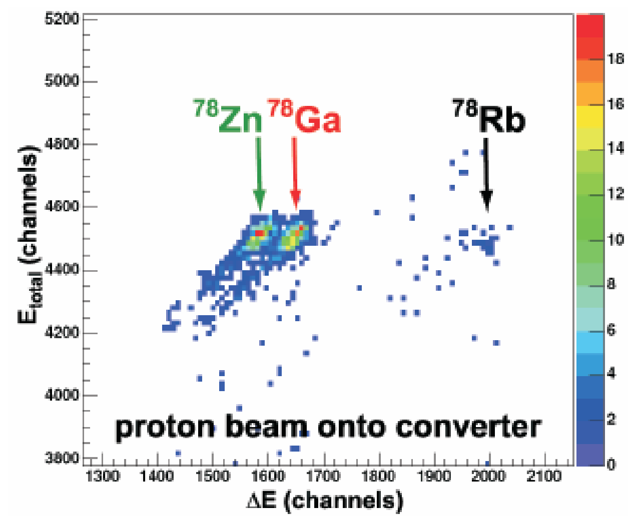
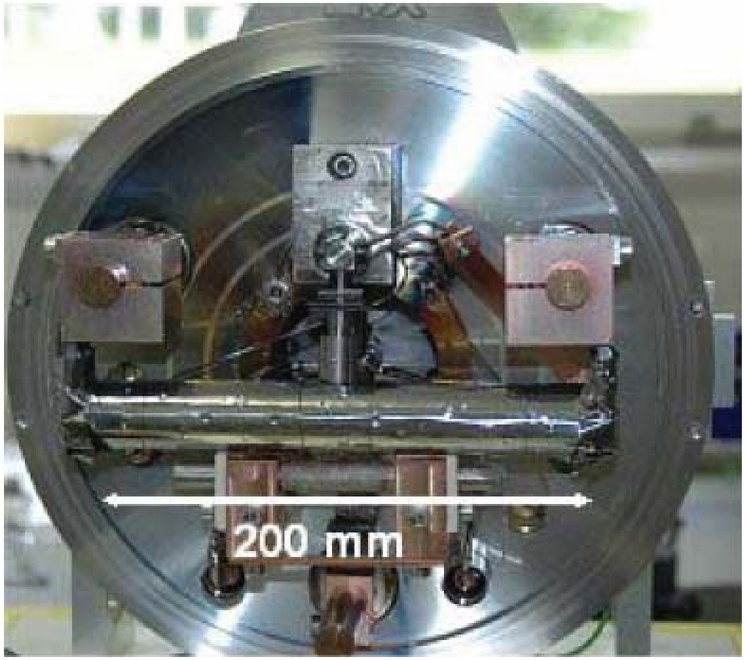
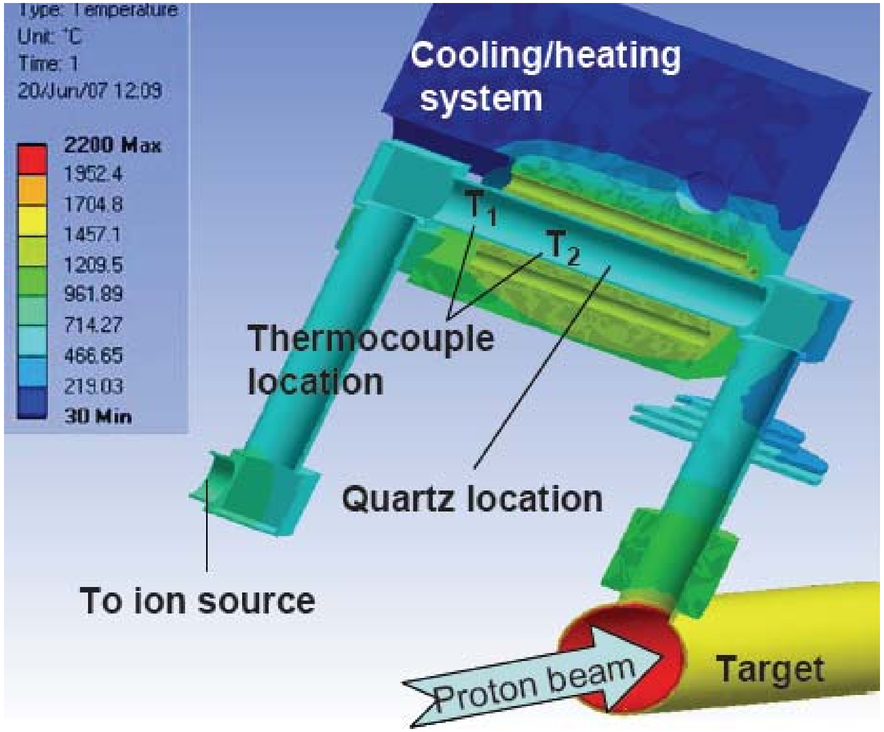




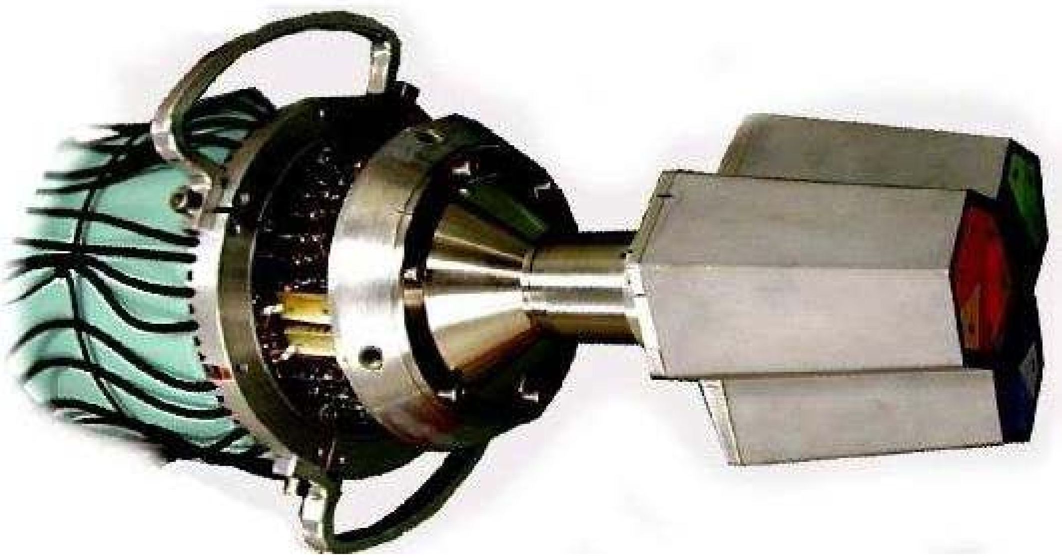


	ISOLDE	MINIBALL	PURITY
^{74}Zn	2.0E7/ μC	3.0E5 pps	83(4)%
^{76}Zn	5.0E6/ μC	1.1E5 pps	73(7)%
^{78}Zn	3.9E5/ μC	4.3E3 pps	64(13)%
^{80}Zn	3.0E4/ μC	3.0E3 pps	44(5)%





	ISOLDE	MINIBALL	PURITY	ENERGY	
^{74}Zn	2.0E7/ μC	3.0E5 pps	83(4)%	2.87 MeV/u	10h
^{76}Zn	5.0E6/ μC	1.1E5 pps	73(7)%	2.83 MeV/u	12h
^{78}Zn	3.9E5/ μC	4.3E3 pps	64(13)%	2.87 MeV/u	27h
^{80}Zn	3.0E4/ μC	3.0E3 pps	44(5)%	2.79 MeV/u	102h



	ISOLDE	MINIBALL	PURITY	ENERGY	
^{74}Zn	2.0E7/ μC	3.0E5 pps	83(4)%	2.87 MeV/u	10h
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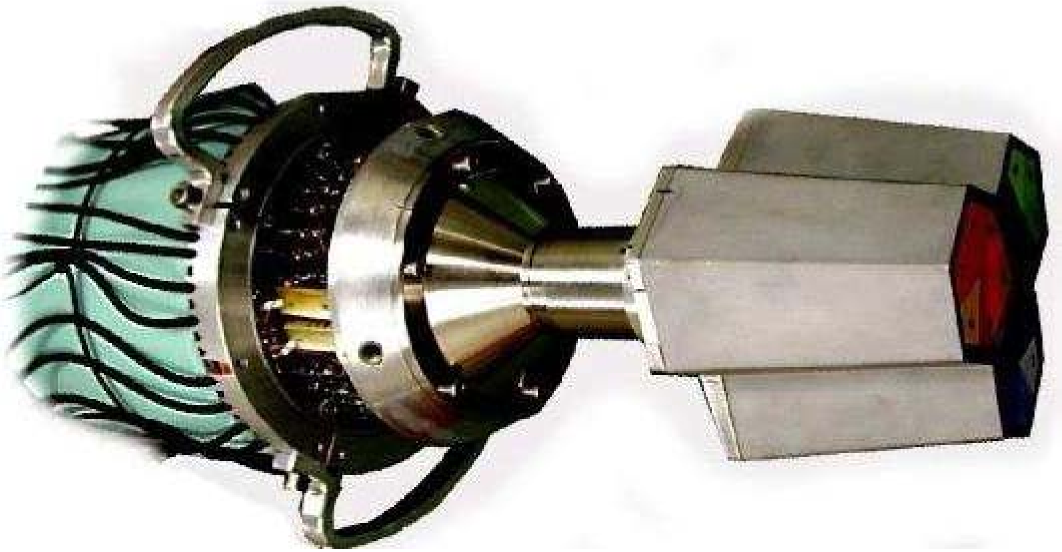
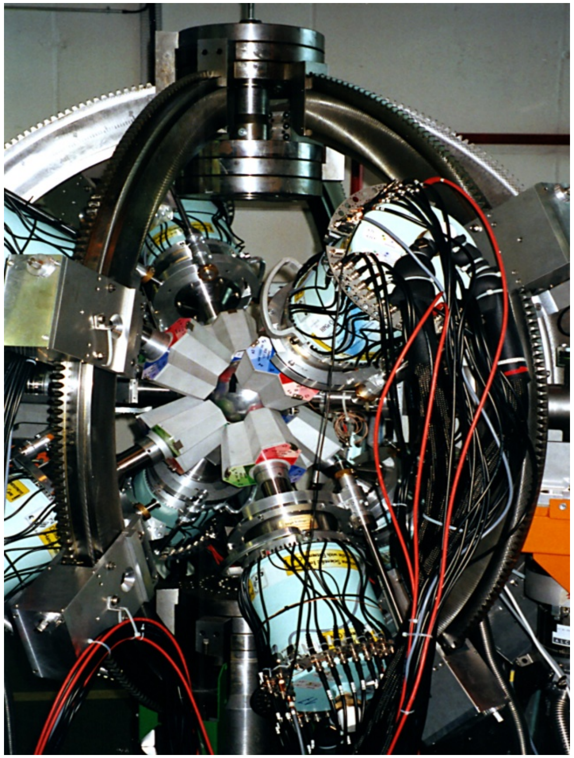
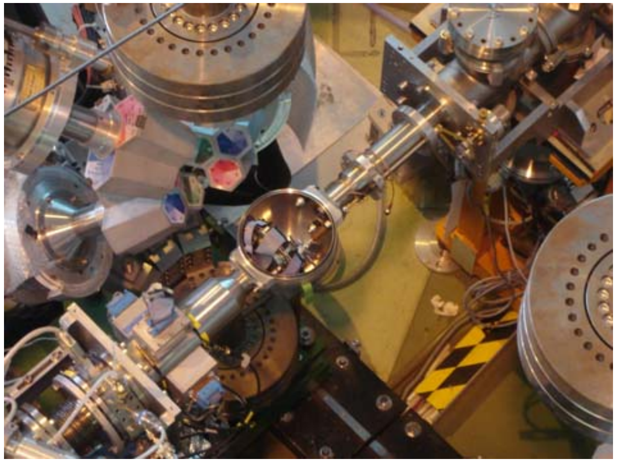
^{80}Zn	3.0E4/ μC	3.0E3 pps	44(5)%	2.79 MeV/u	102h



⇒ ideal tool to study low-lying 2^+ states in even-even isotopes

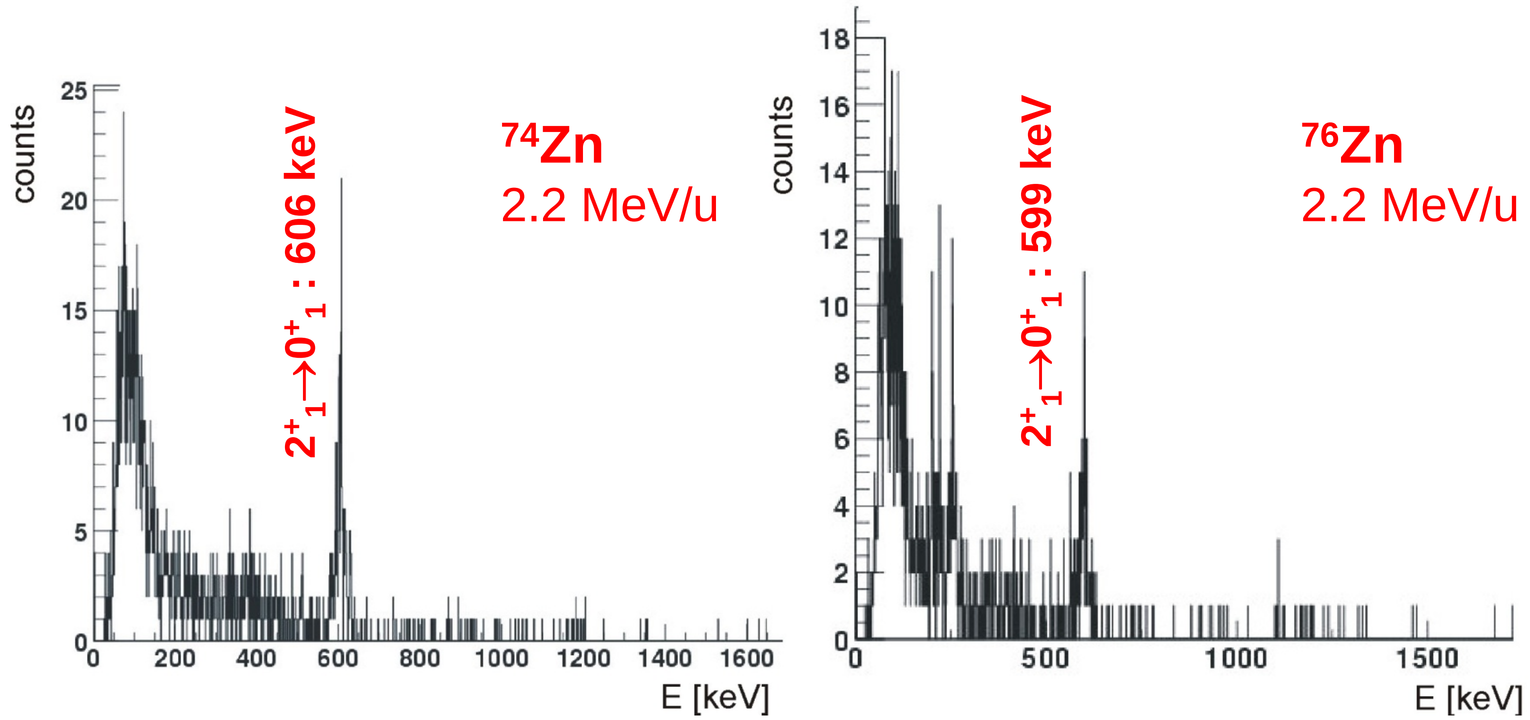




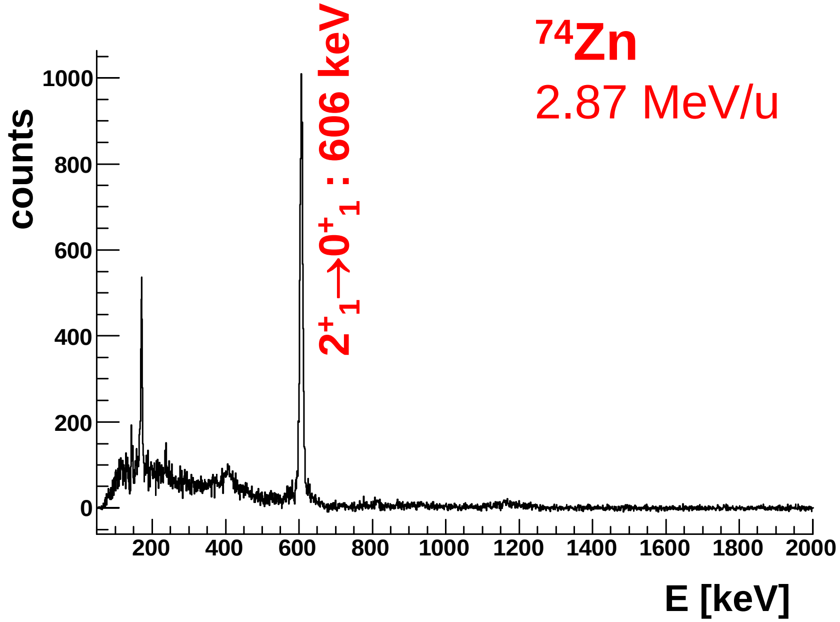
8 6-fold segmented MINIBALL detectors
+ 52 DGF rev C modules

1 DSSSD
+ analogue electronics (RAL108+RAL109)

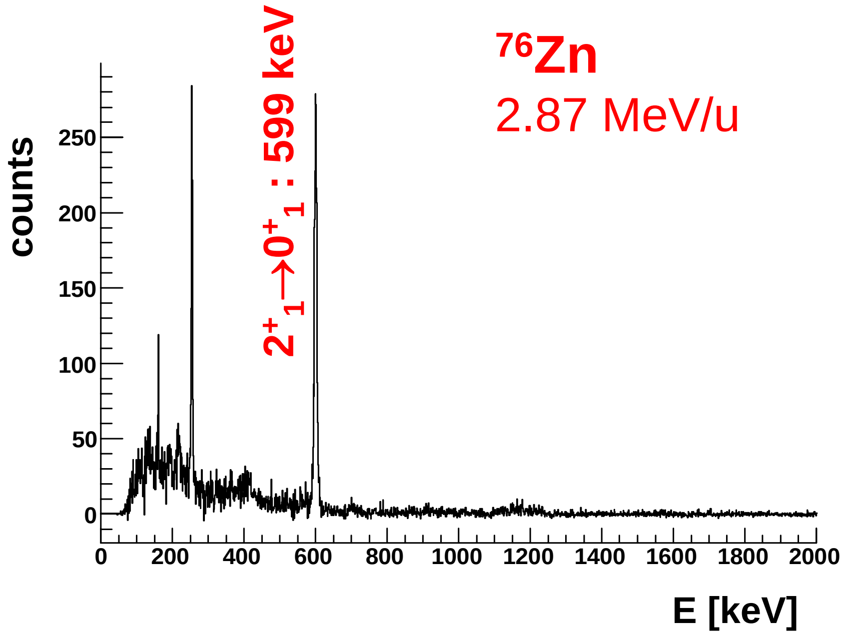
2003


counts
25
20
15
10
5
0
0
200
400
600
800
1000
1200
1400
1600
E [keV]
$2^+_1 \rightarrow 0^+_1$: 606 keV
^{74}Zn
2.2 MeV/u
counts
18
16
14
12
10
8
6
4
2
0
0
500
1000
1500
E [keV]
$2^+_1 \rightarrow 0^+_1$: 599 keV
^{76}Zn
2.2 MeV/u

2004

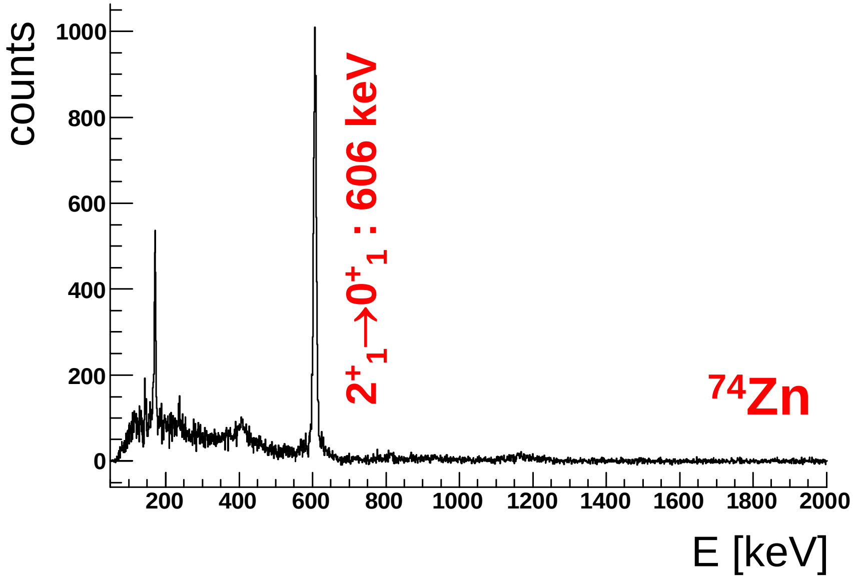


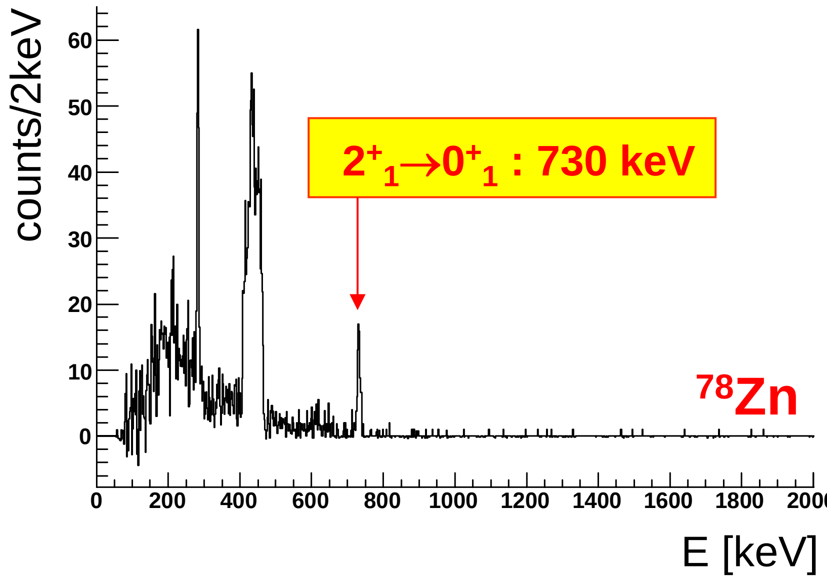
^{74}Zn
2.87 MeV/u
$2^+_1 \rightarrow 0^+_1$: 606 keV
counts
E [keV]
0
200
400
600
800
1000
1200
1400
1600
1800
2000

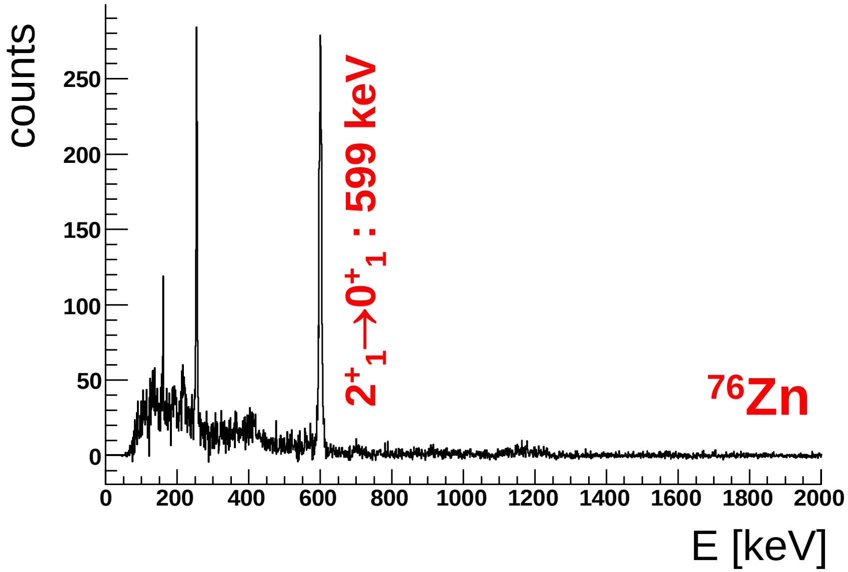


^{76}Zn
2.87 MeV/u
$2^+_1 \rightarrow 0^+_1$: 599 keV
counts
E [keV]
0
50
100
150
200
250
400
600
800
1000
1200
1400
1600
1800
2000

2004

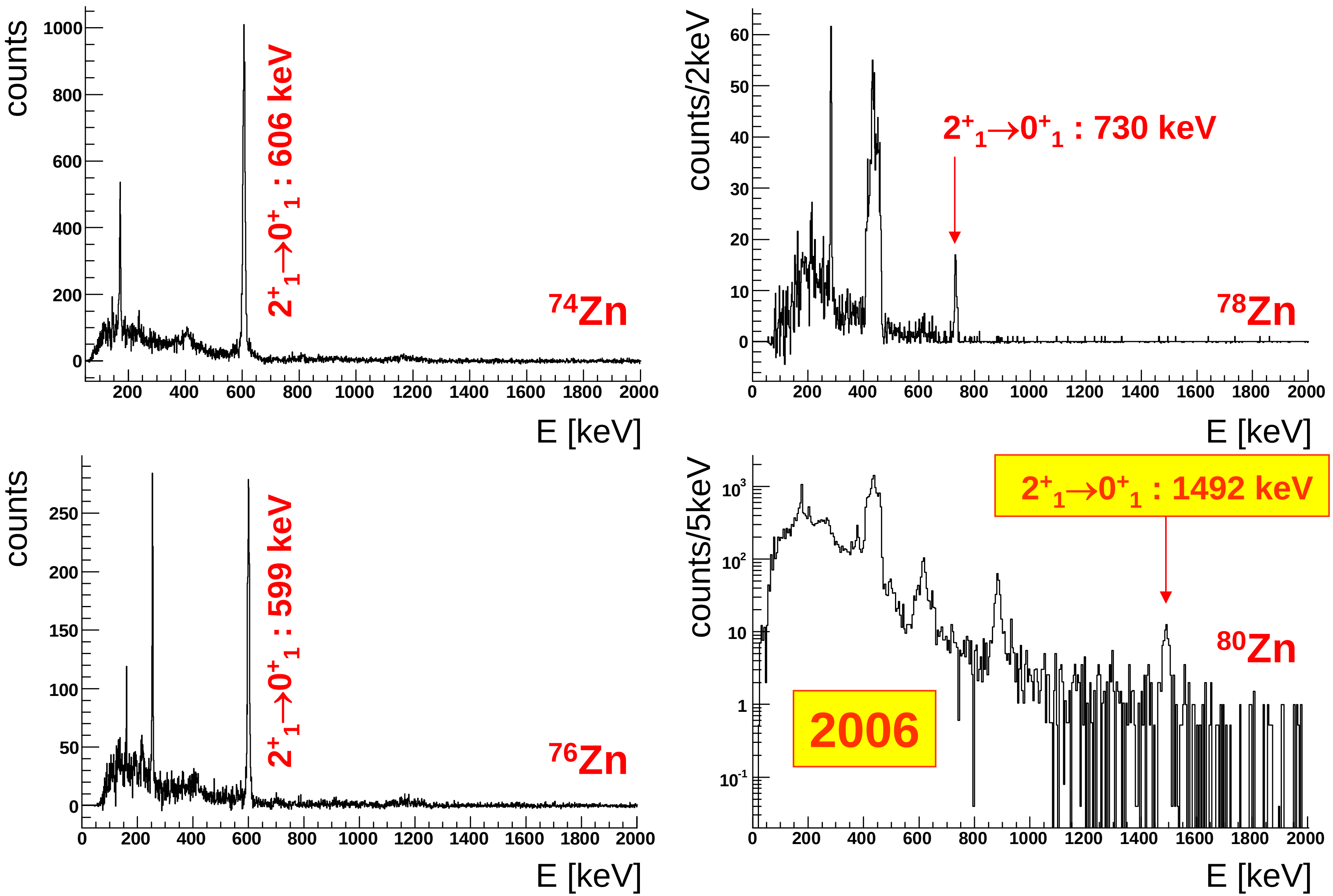






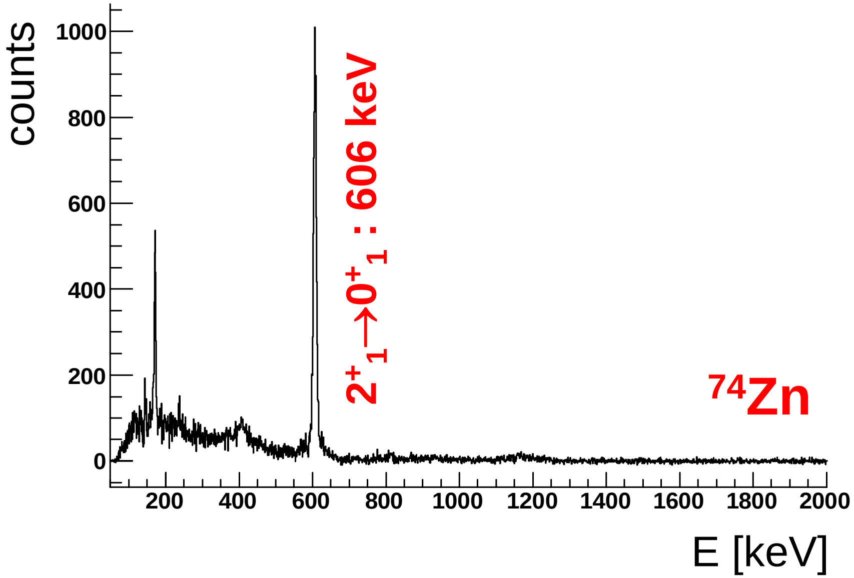
Doppler corrected $2^+_1 \rightarrow 0^+_1$ transitions

2004 + 2006

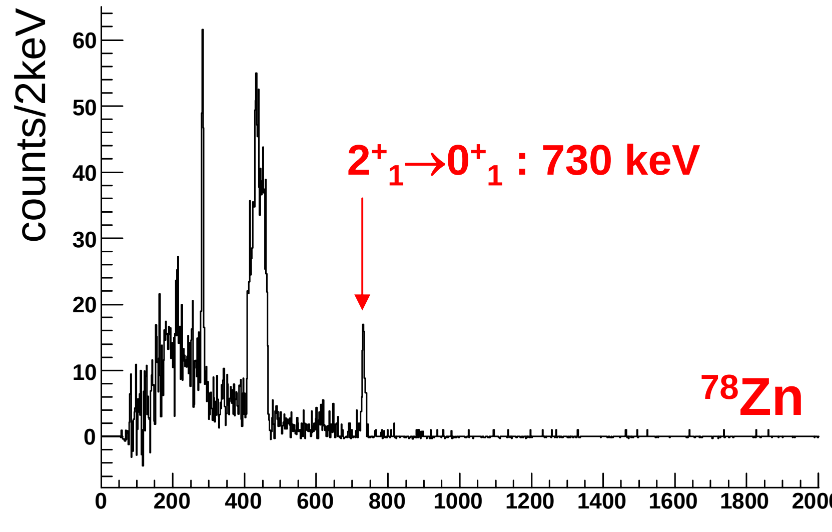


counts
E [keV]
2+1→0+1 : 606 keV
74Zn
counts/2keV
E [keV]
2+1→0+1 : 730 keV
78Zn
counts
E [keV]
2+1→0+1 : 599 keV
76Zn
counts/5keV
E [keV]
2+1→0+1 : 1492 keV
80Zn
2006

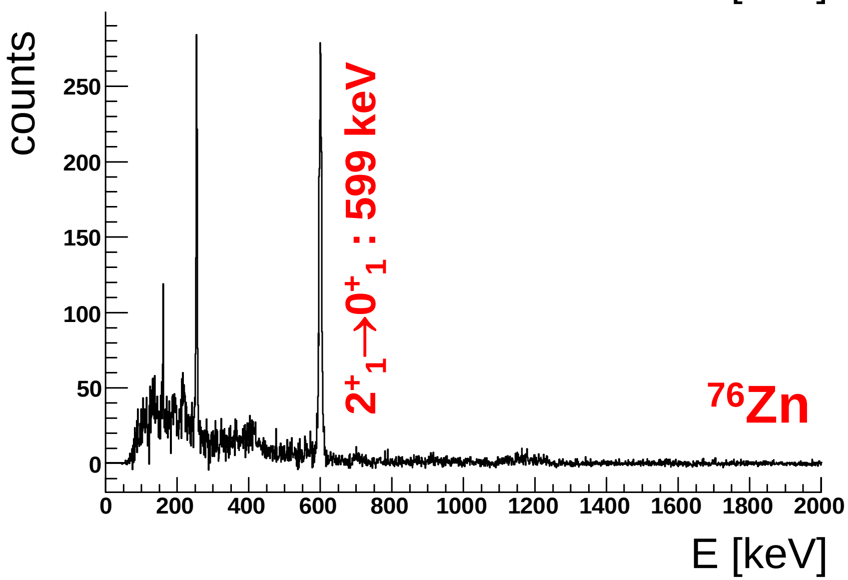
2004 + 2006



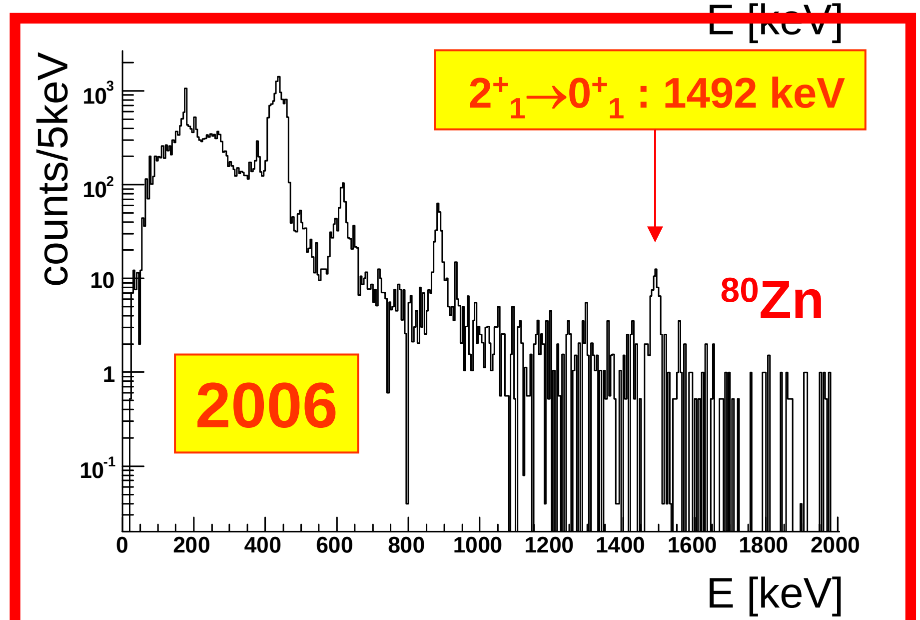
counts
E [keV]
$2^+_1 \rightarrow 0^+_1$: 606 keV
^{74}Zn



counts/2keV
E [keV]
$2^+_1 \rightarrow 0^+_1$: 730 keV
^{78}Zn

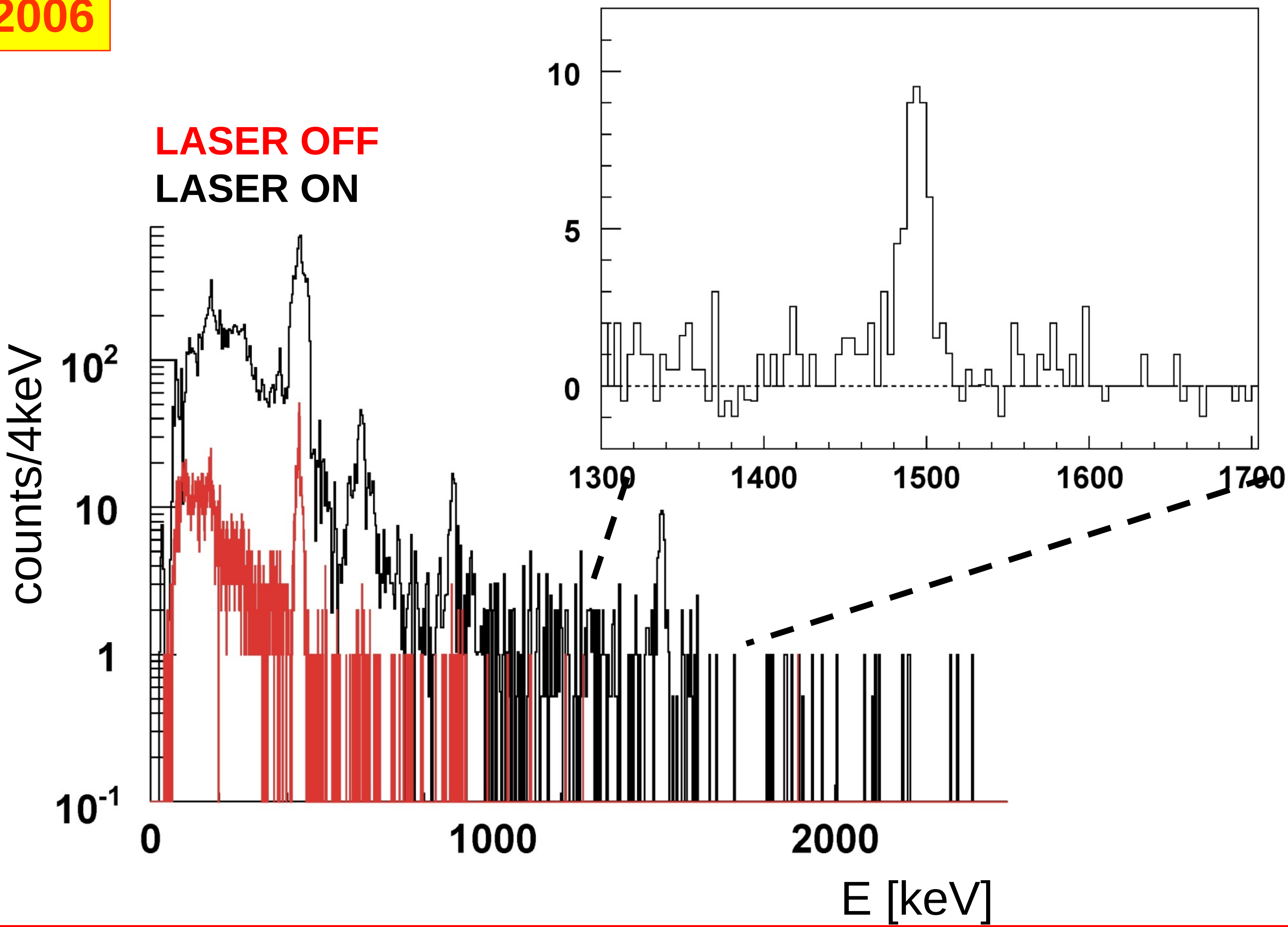


counts
E [keV]
$2^+_1 \rightarrow 0^+_1$: 599 keV
^{76}Zn

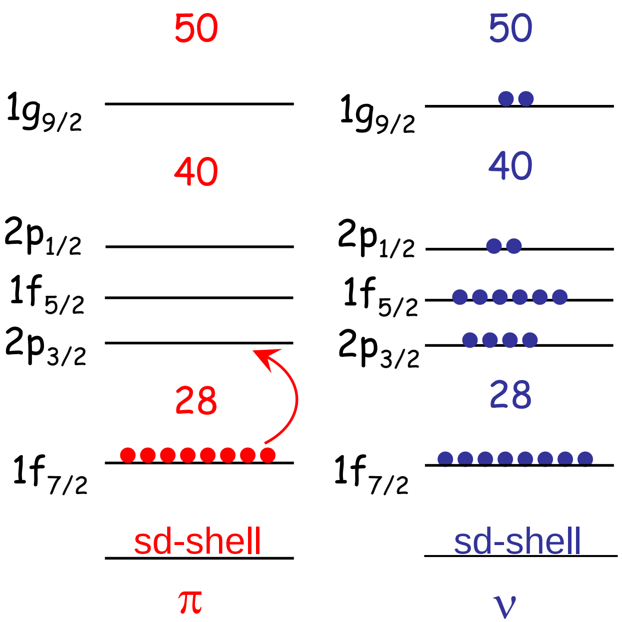


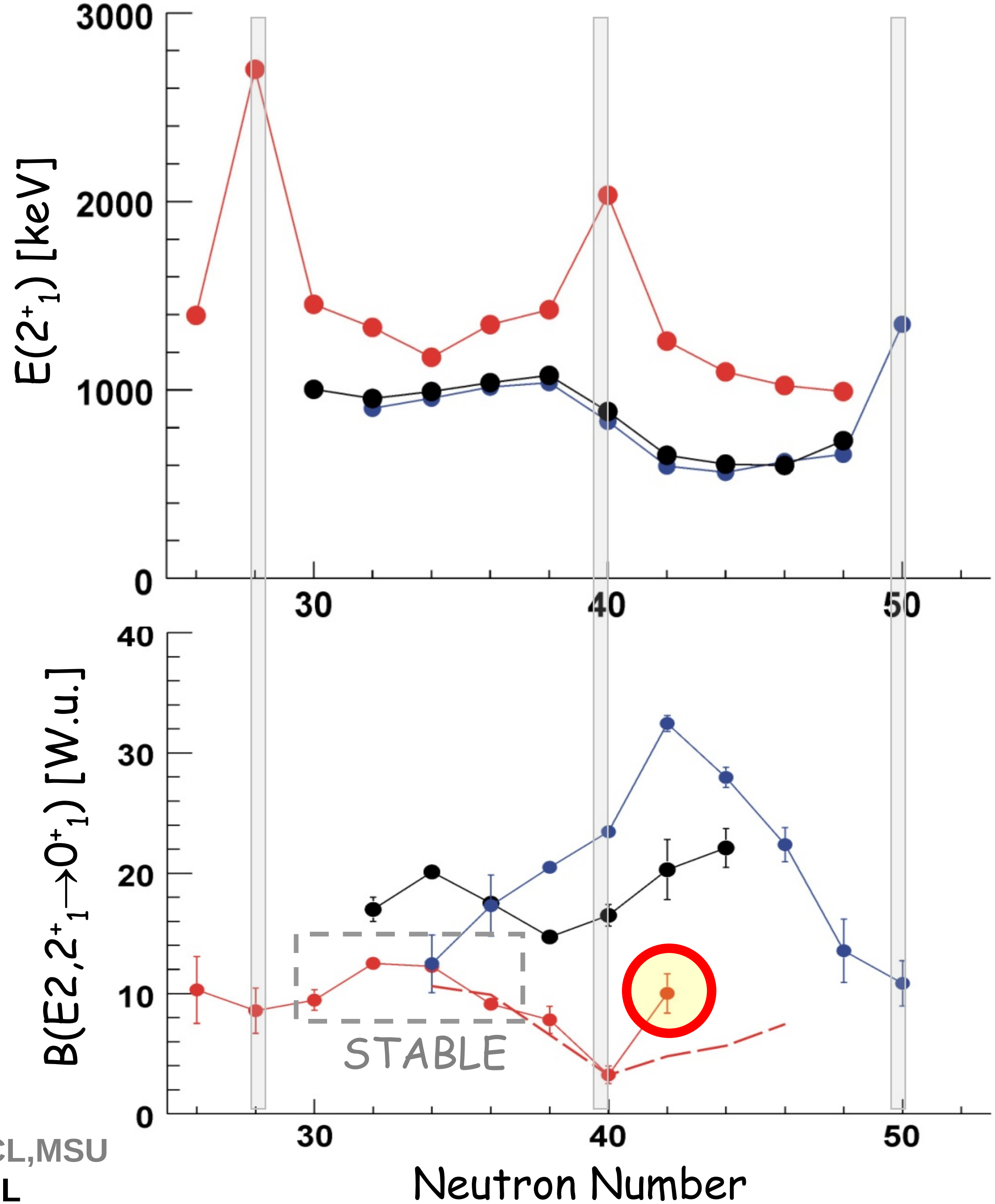
counts/5keV
E [keV]
$2^+_1 \rightarrow 0^+_1$: 1492 keV
^{80}Zn
2006

2006


LASER OFF
LASER ON
counts/4keV
10^2
10
1
10^{-1}
0
1000
2000
E [keV]
10
5
0
1300
1400
1500
1600
1700

Ni





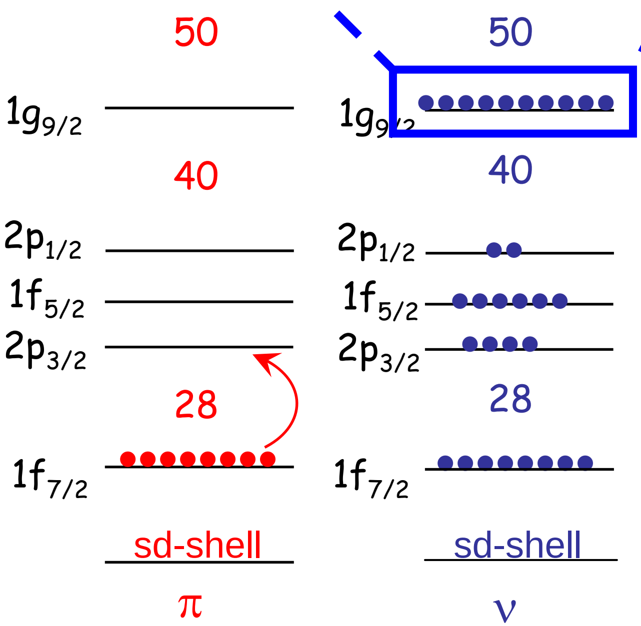
C. Mazzocchi *et al*, PLB622 45 (2005) - NSCL,MSU

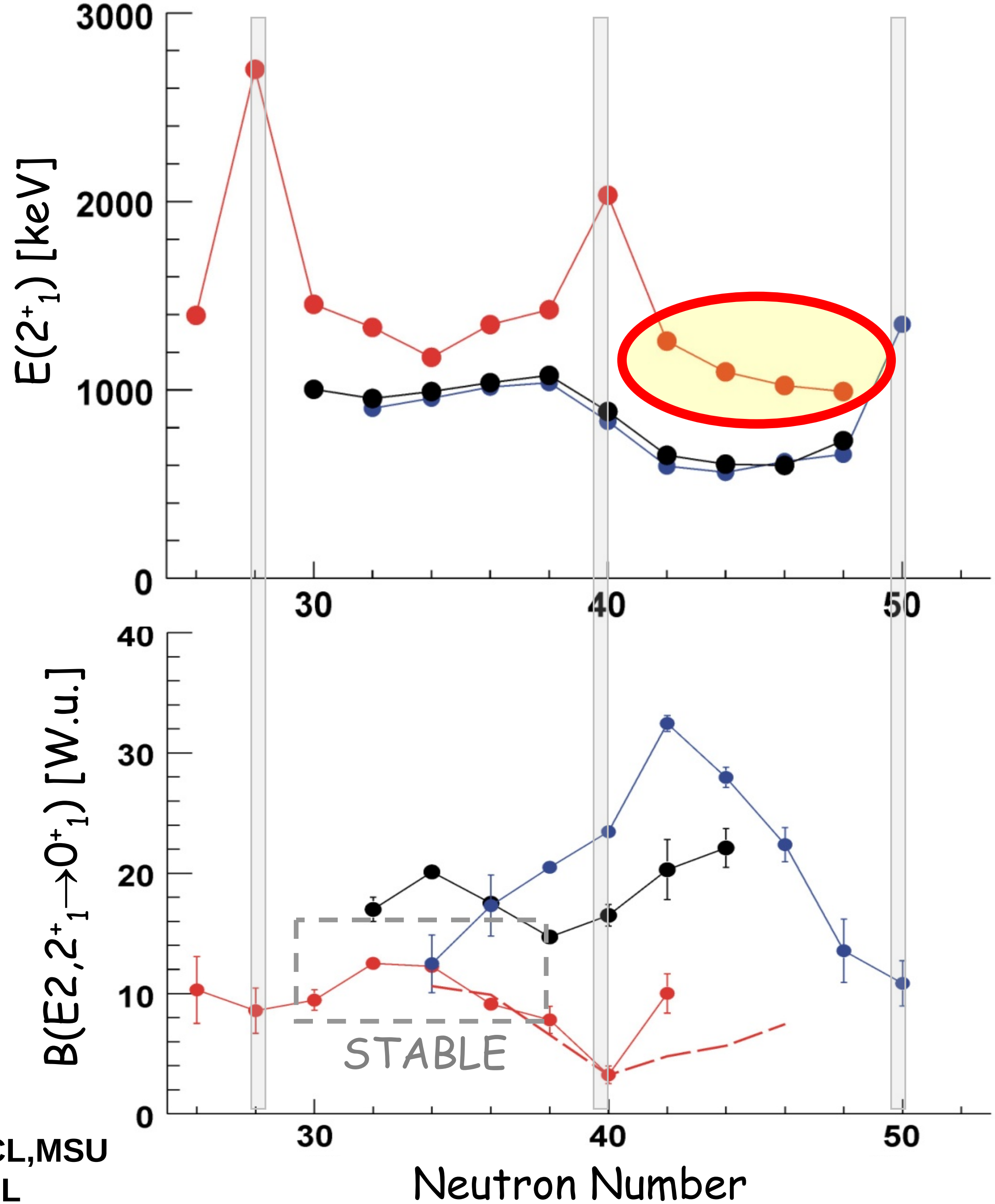
O. Perru *et al*, PRC96 232501 (2006) - GANIL

Ni

Neutron Rich Nuclei

N/Z ≈ 1.5 ... 1.8



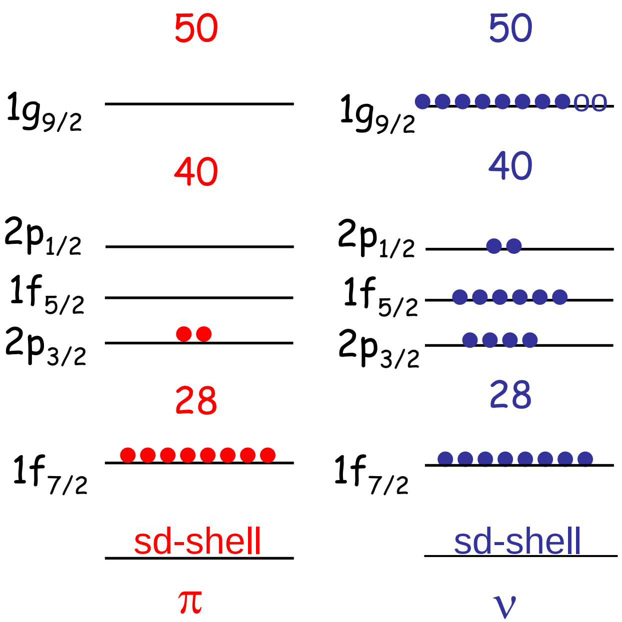


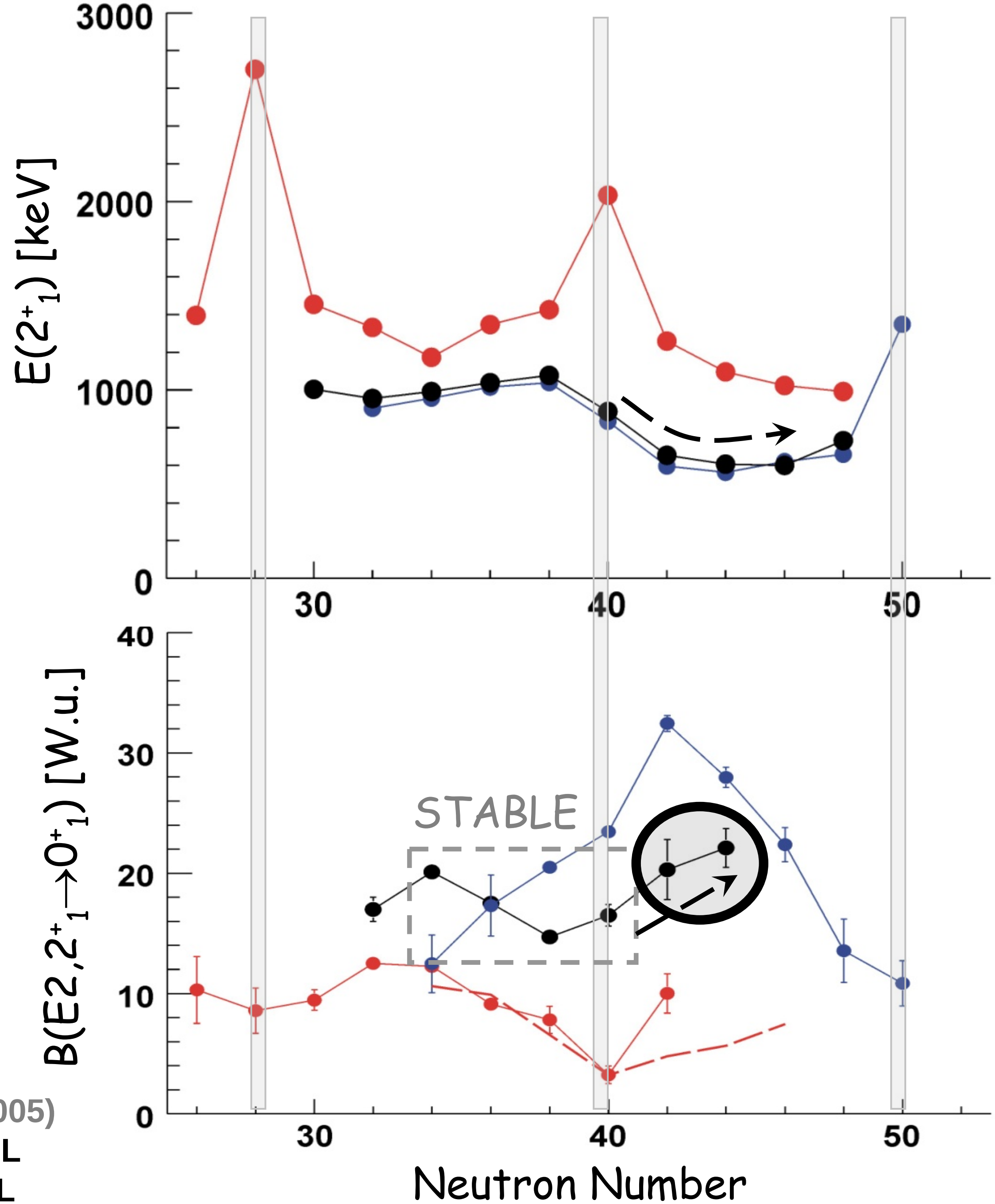
C. Mazzocchi *et al*, PLB622 45 (2005) - NSCL,MSU

O. Perru *et al*, PRC96 232501 (2006) - GANIL

Zn

COLLECTIVE behavior setting in ...

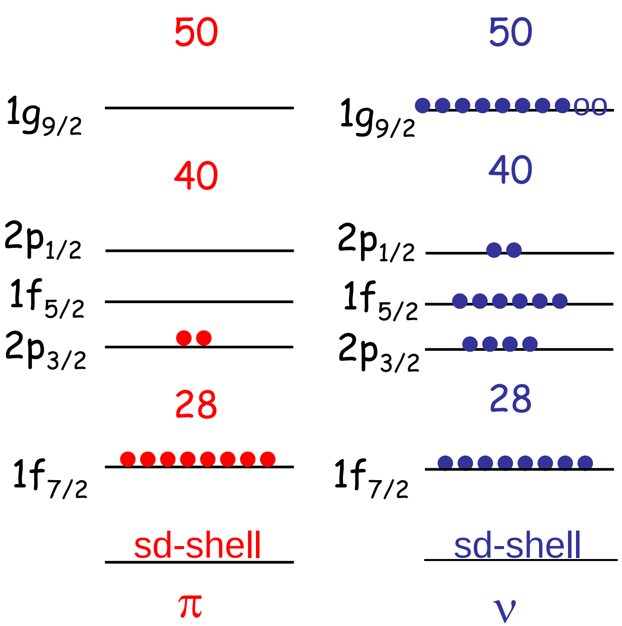


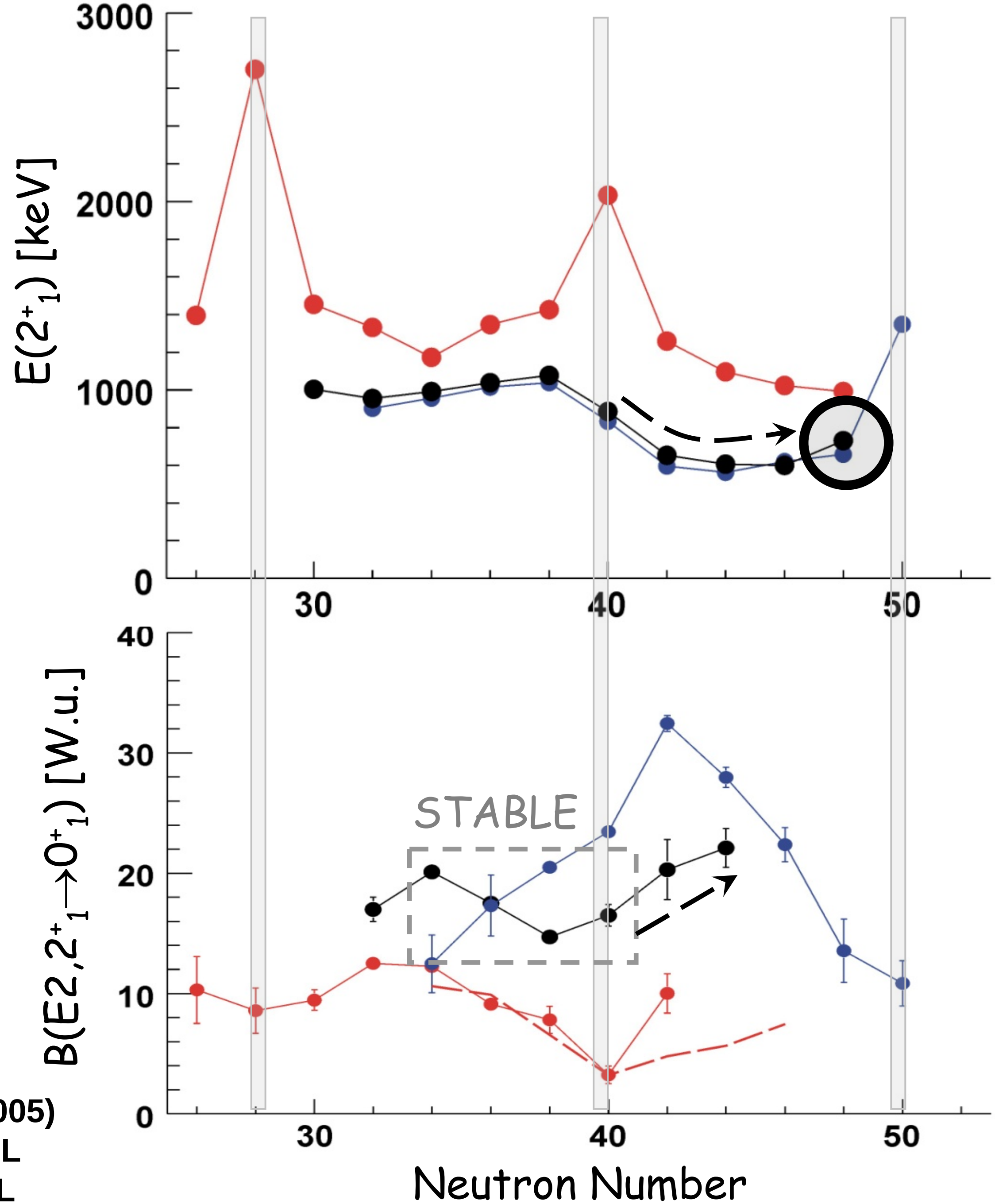


J. Van Roosbroeck *et al*, PRC67 054307 (2005)
O. Perru *et al*, PRC96 232501 (2006) - GANIL
S. Leenhardt *et al*, EPJA14 1 (2002) - GANIL

Zn

COLLECTIVE behavior setting in ...

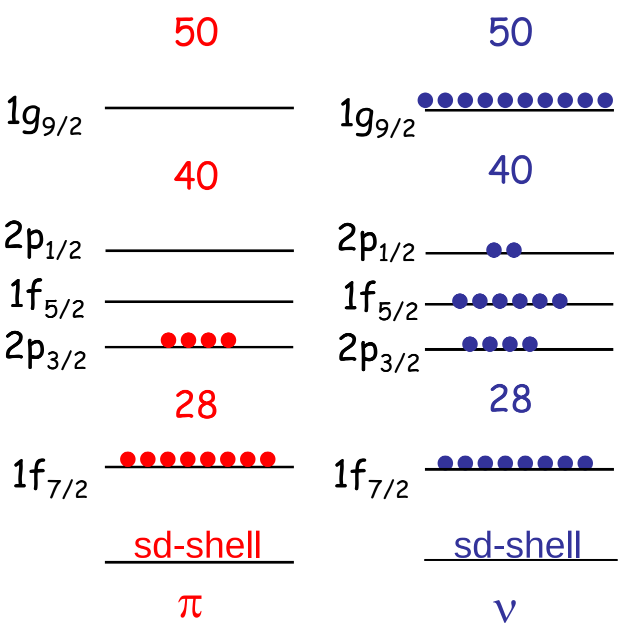


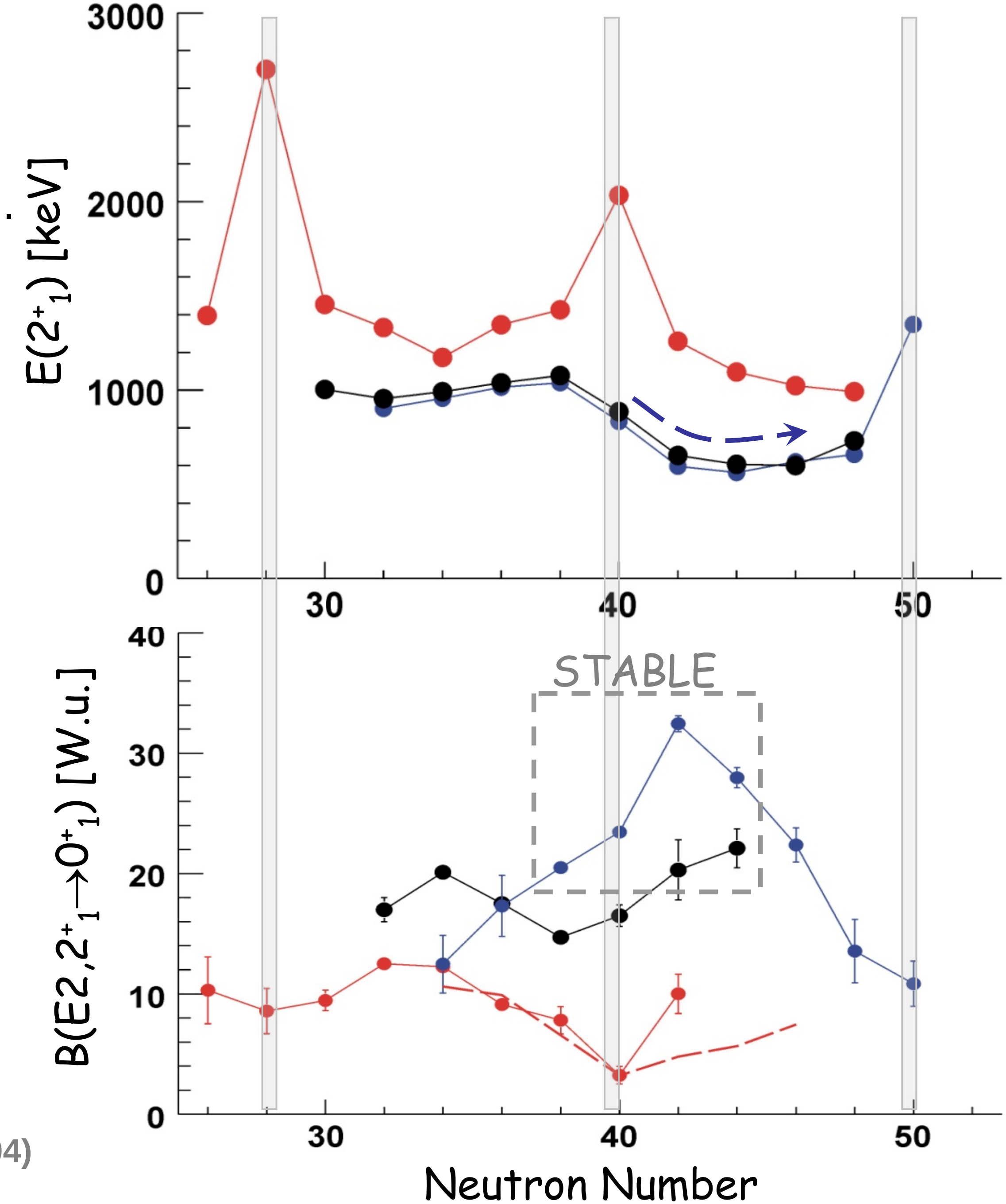


J. Van Roosbroeck *et al*, PRC67 054307 (2005)
O. Perru *et al*, PRC96 232501 (2006) - GANIL
S. Leenhardt *et al*, EPJA14 1 (2002) - GANIL

Ge

COLLECTIVE behavior setting in ...



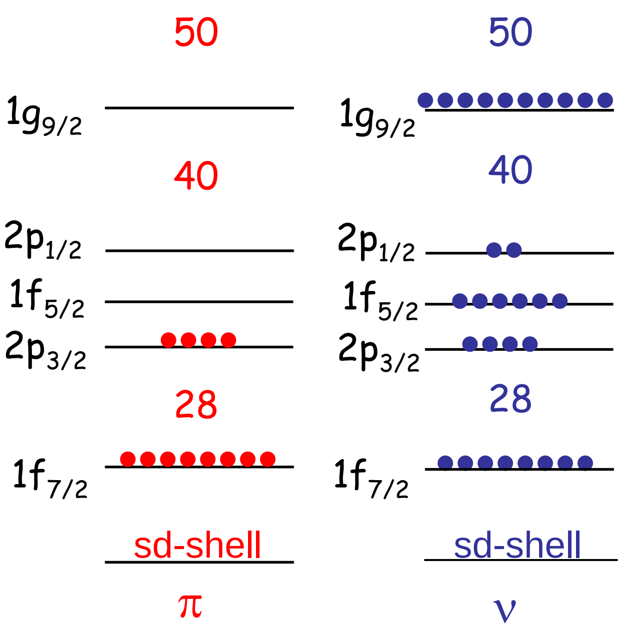


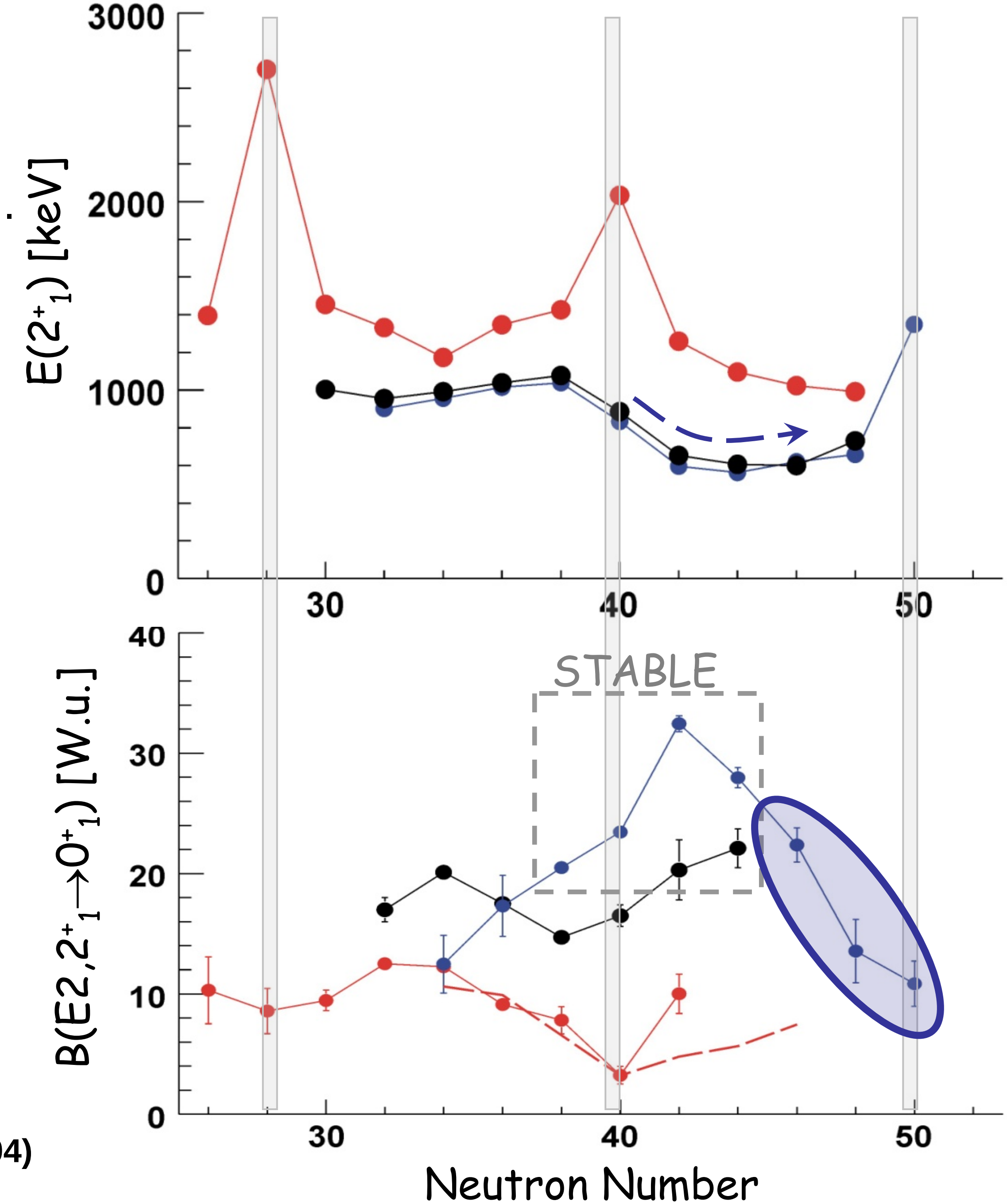
E. Padilla-Rodal *et al*, PRL70 024301 (2004)
Oak Ridge National Laboratory

Ge

COLLECTIVE behavior setting in ...

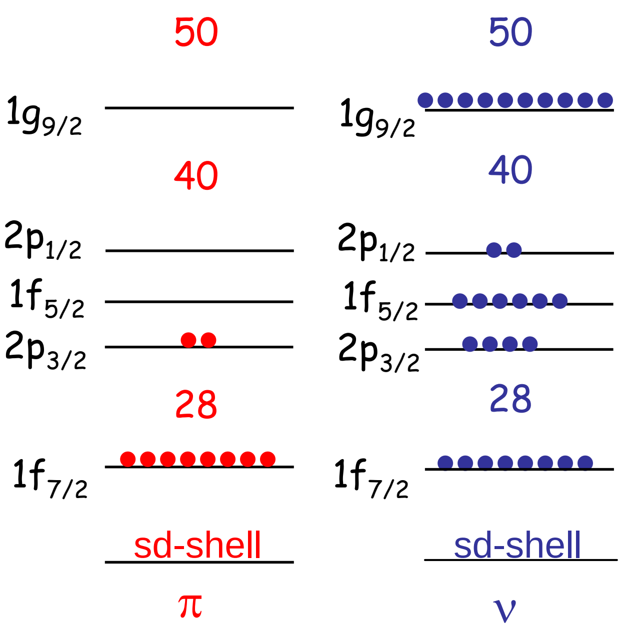
N=50 SHELL CLOSURE
"still good shell closure down to Z=32 for the low lying 2+ state !"

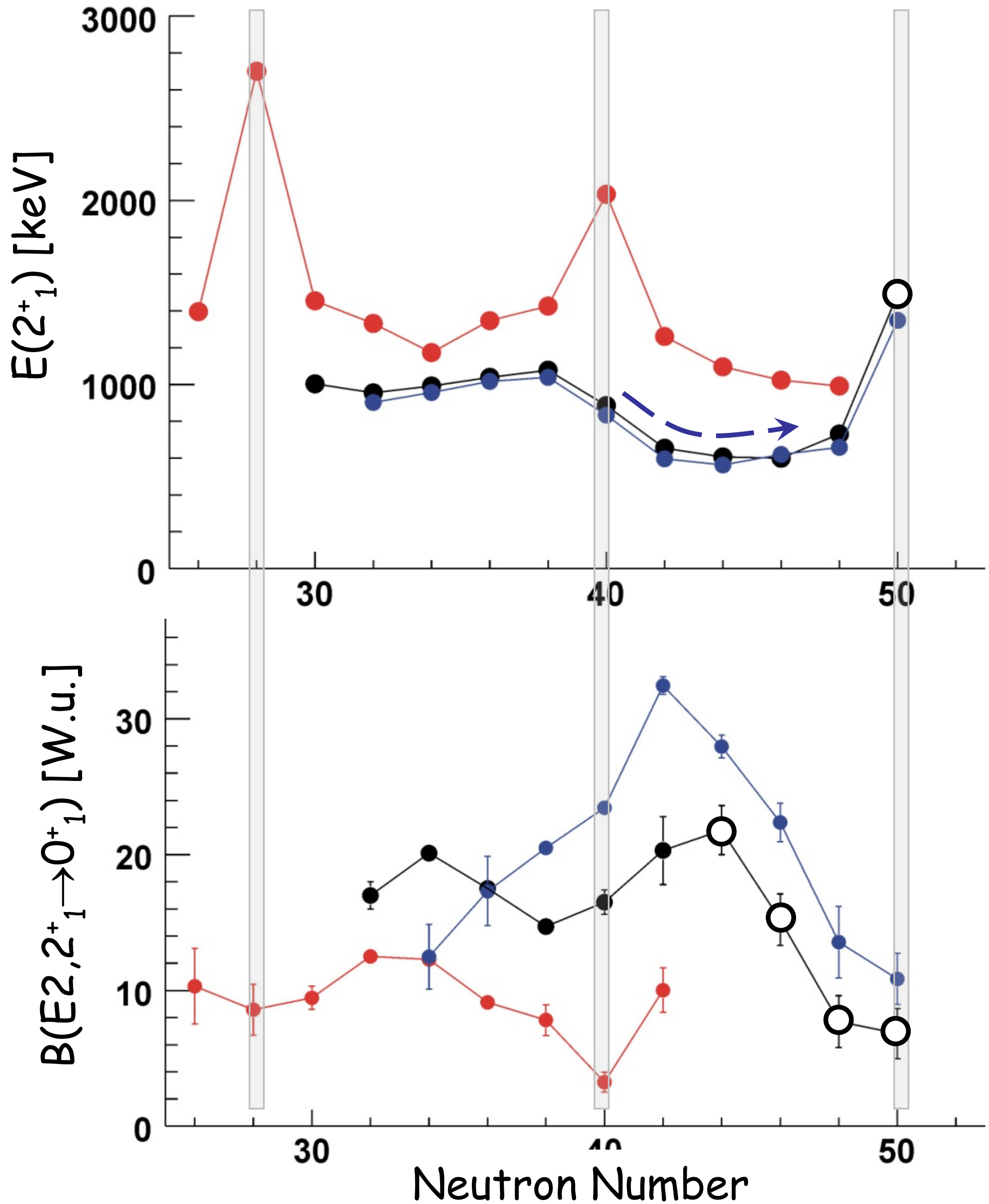




E. Padilla-Rodal *et al*, PRL70 024301 (2004)
Oak Ridge National Laboratory

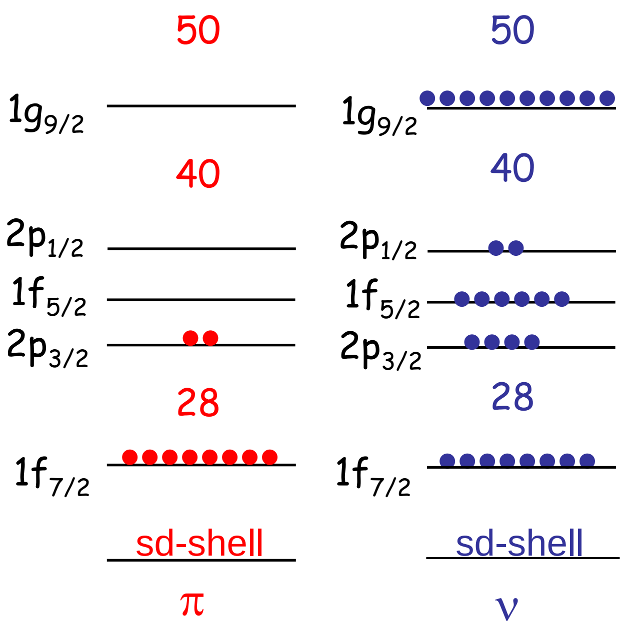
Zn - new results

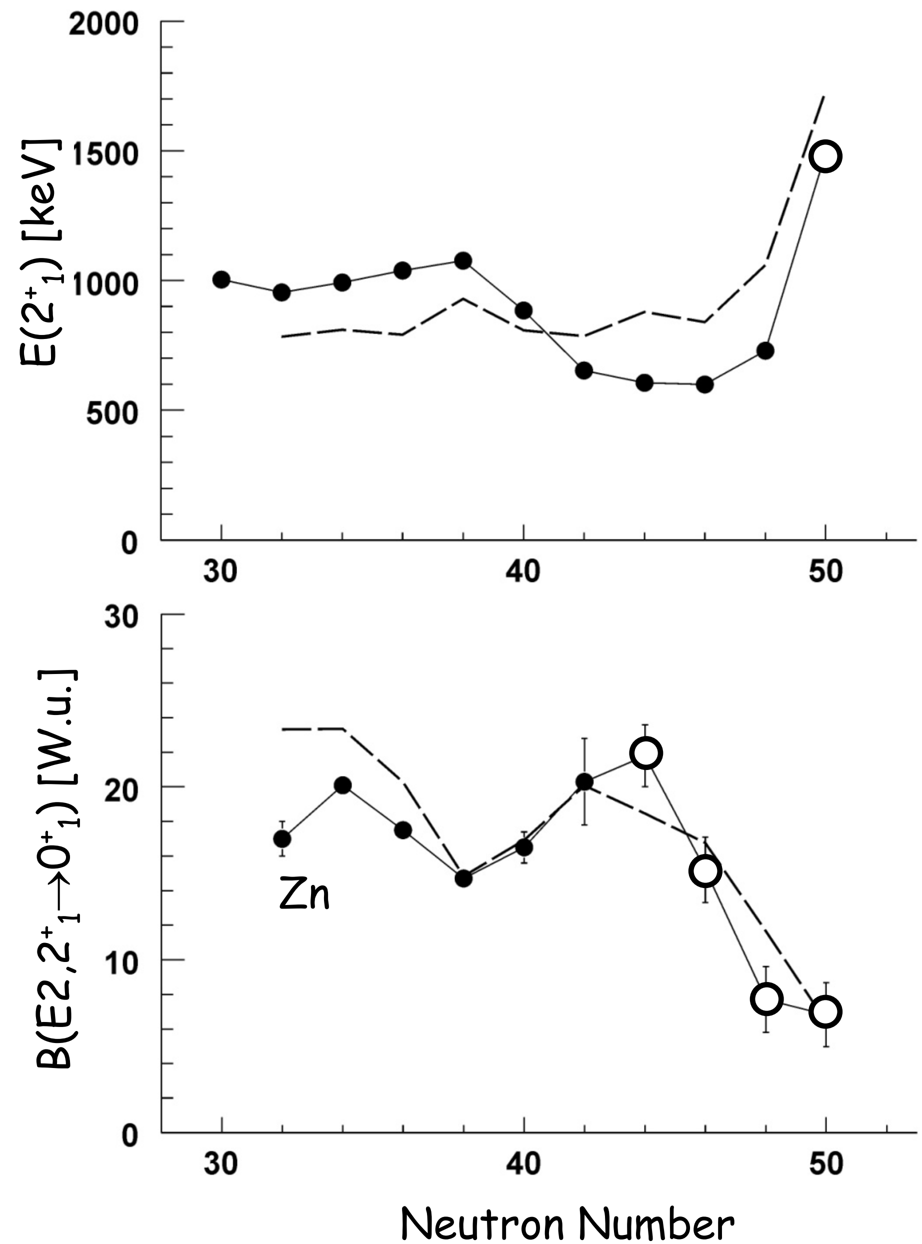




Zn – *new results*

Shell Model (1) :
M. H. Jensen + monopole adjusted by Nowacki
(e_π,e_ν)=(1.9e,0.9e) - (N. Smirnova *et al*, 2006)



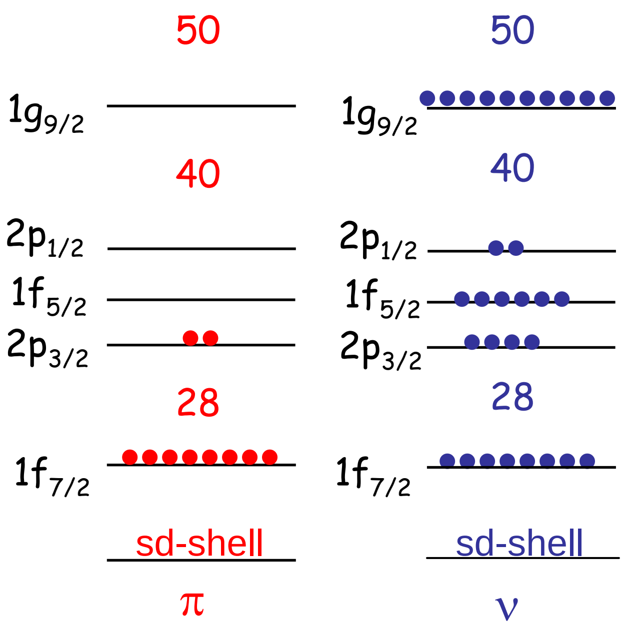


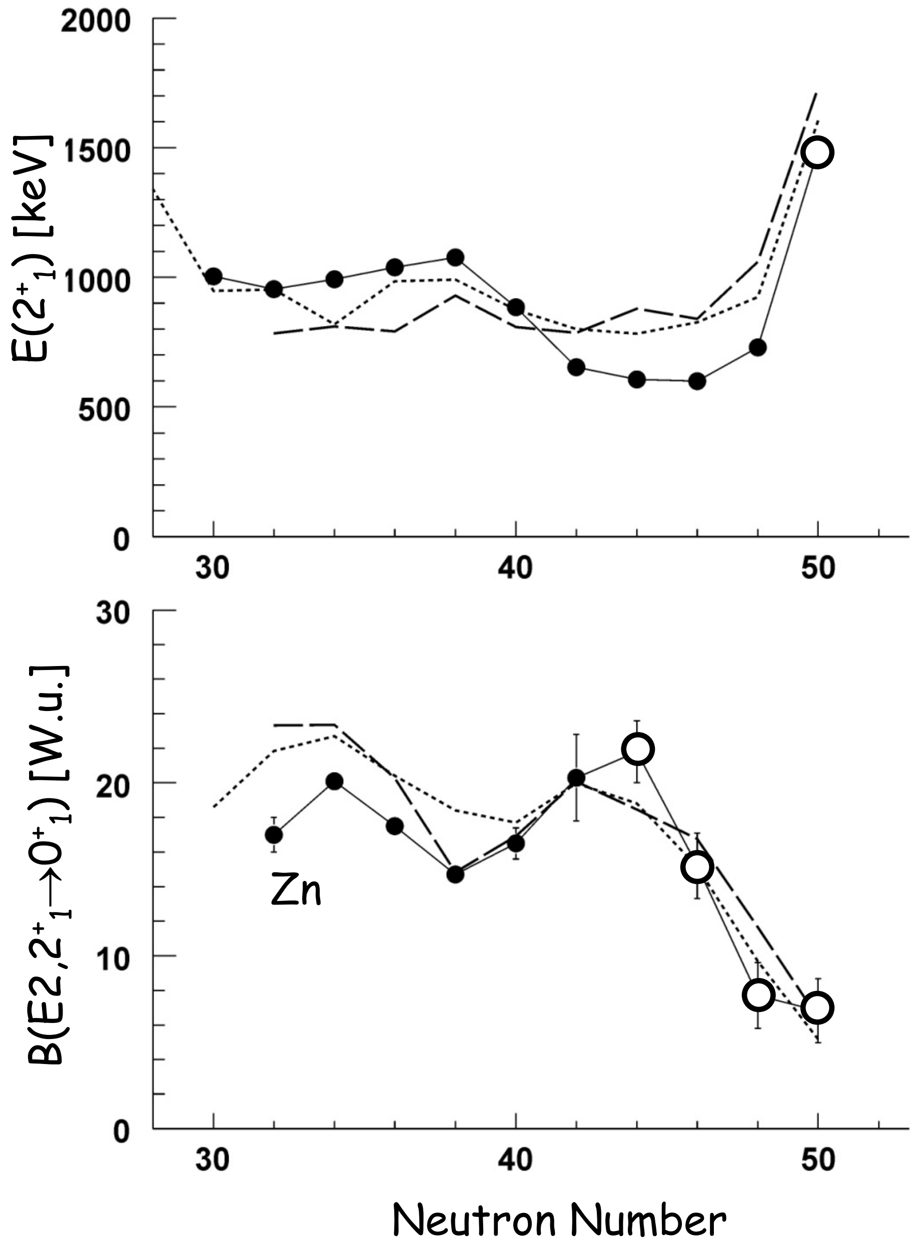
Zn – *new results*

Shell Model (2) :

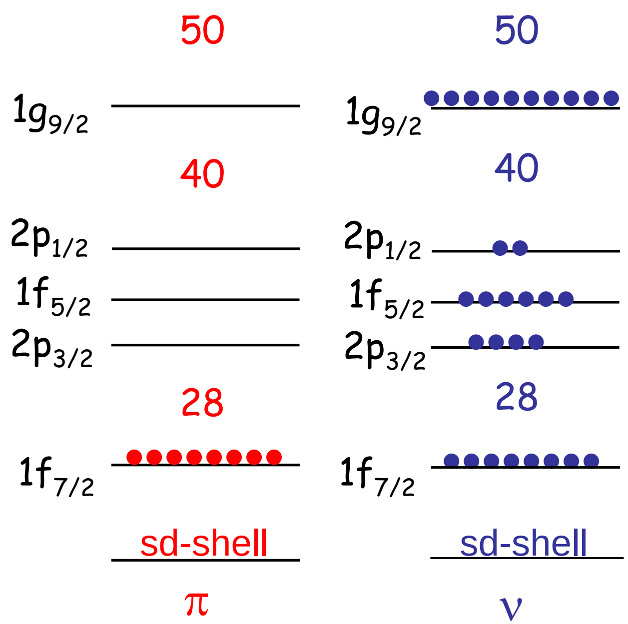
empirical matrix elements fitted to Ni and N=50

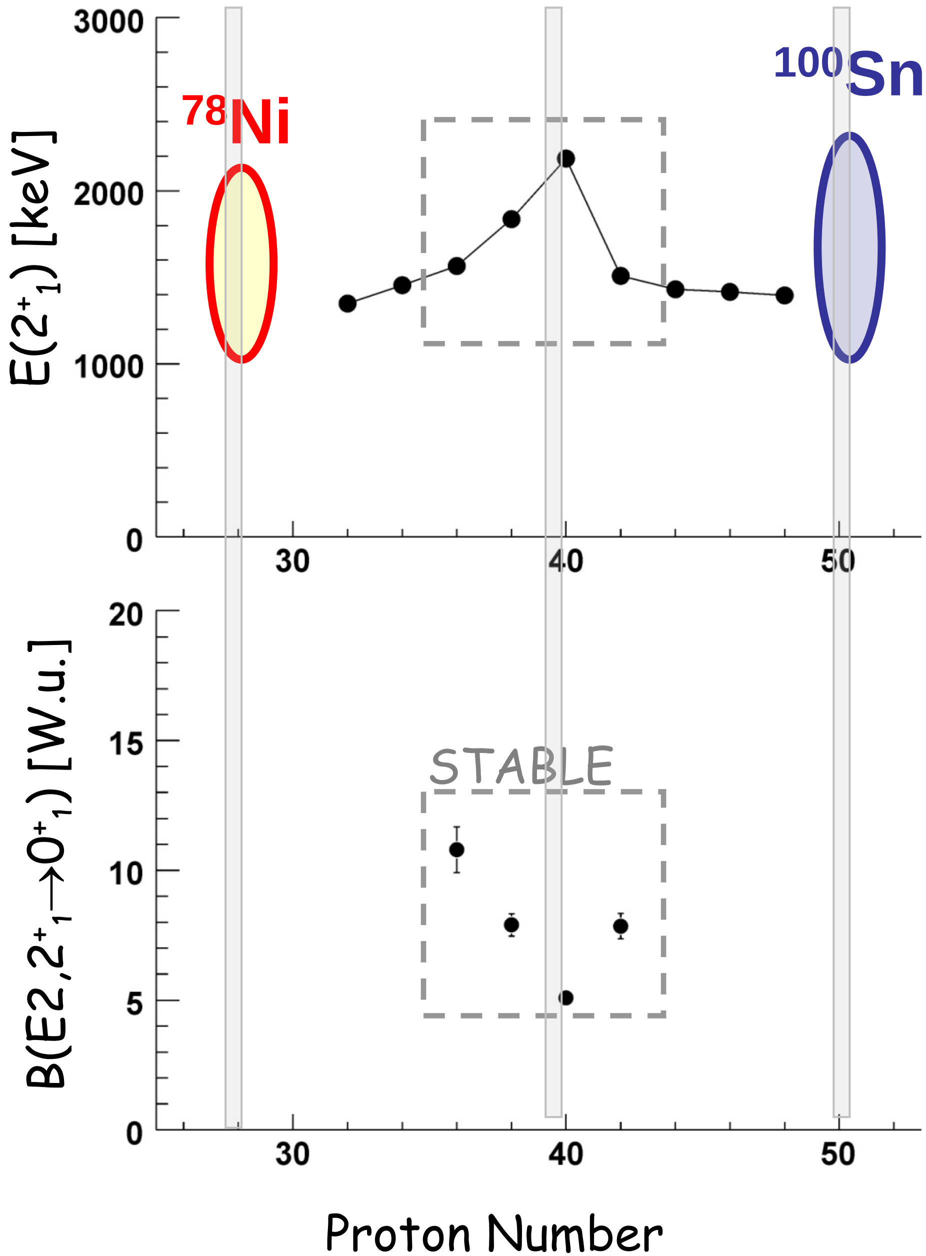
(e_π, e_ν)=(1.56e,1.00e) - (A.F. Lisetskiy *et al*, 2006)





N=50 isotones

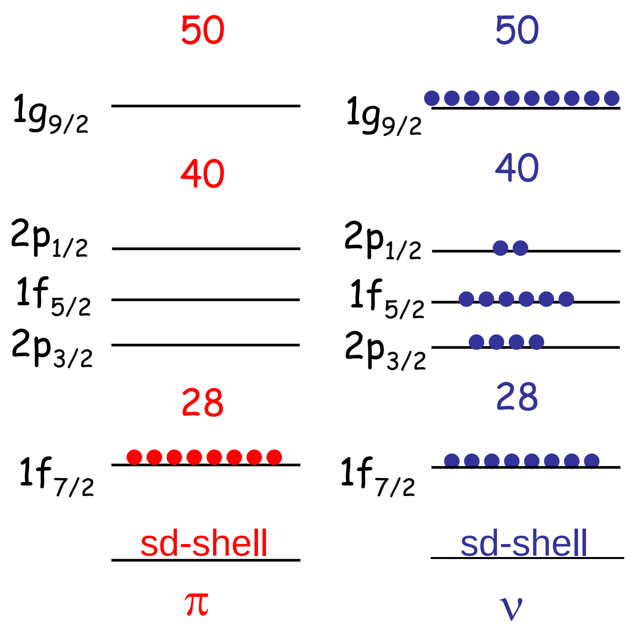


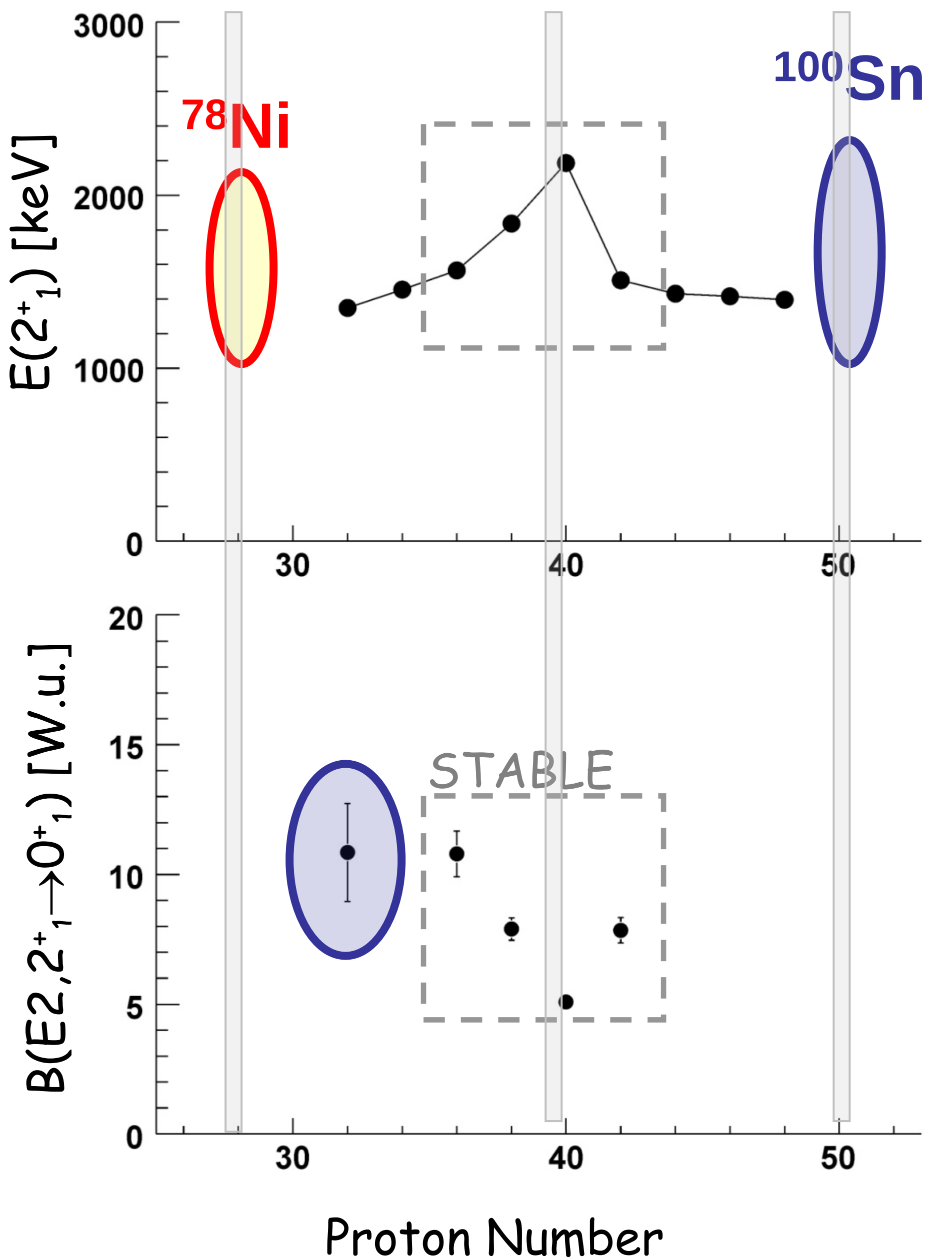


N=50 isotones

FIRST RIB B(E2) measurement
on N=50 line

E. Padilla-Rodal *et al*, PRL**70** 024301 (2004)
Oak Ridge National Laboratory





N=50 isotones

PHYSICAL REVIEW C 70, 024301 (2004)

Stability of the N=50 shell gap in the neutron-rich Rb, Br, Se, and Ge isotones

Y. H. Zhang,[1,2] Zs. Podolyàk,[3] G. de Angelis,[1,4] A. Gadea,[1] C. Ur,[5] S. Lunardi,[5] N. Marginean,[1] C. Rusu,[1] R. Schwengner,[6] Th. Kröll,[1] D. R. Napoli,[1] R. Menegazzo,[5] D. Bazzacco,[5] E. Farnea,[5] S. Lenzi,[5] T. Martinez,[1] M. Axiotis,[1] D. Tonev,[1] W. Gelletly,[3] S. Langdown,[3] P. H. Regan,[3] J. J. Valiente Dobon,[3] W. von Oertzen,[4,7] B. Rubio,[8] B. Quintana,[9] N. Medina,[10] R. Broda,[11] D. Bucurescu,[12] M. Ionescu-Bujor,[12] and A. Iordachescu[12]

FIRST RIB B(E2) measurement
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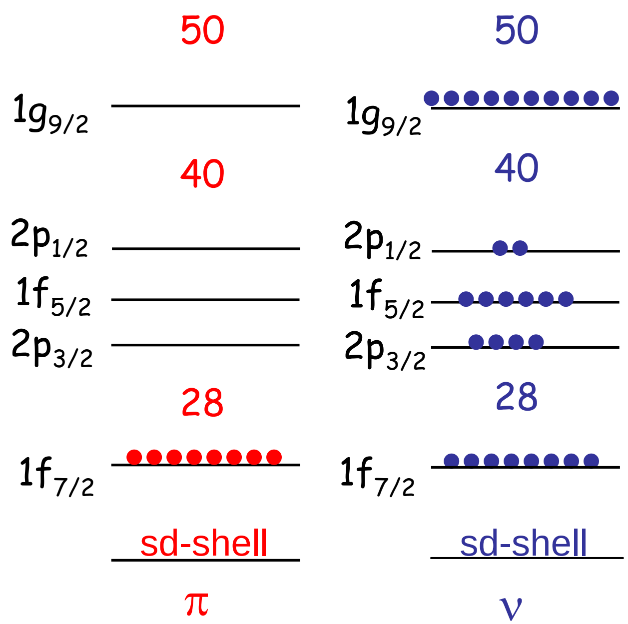
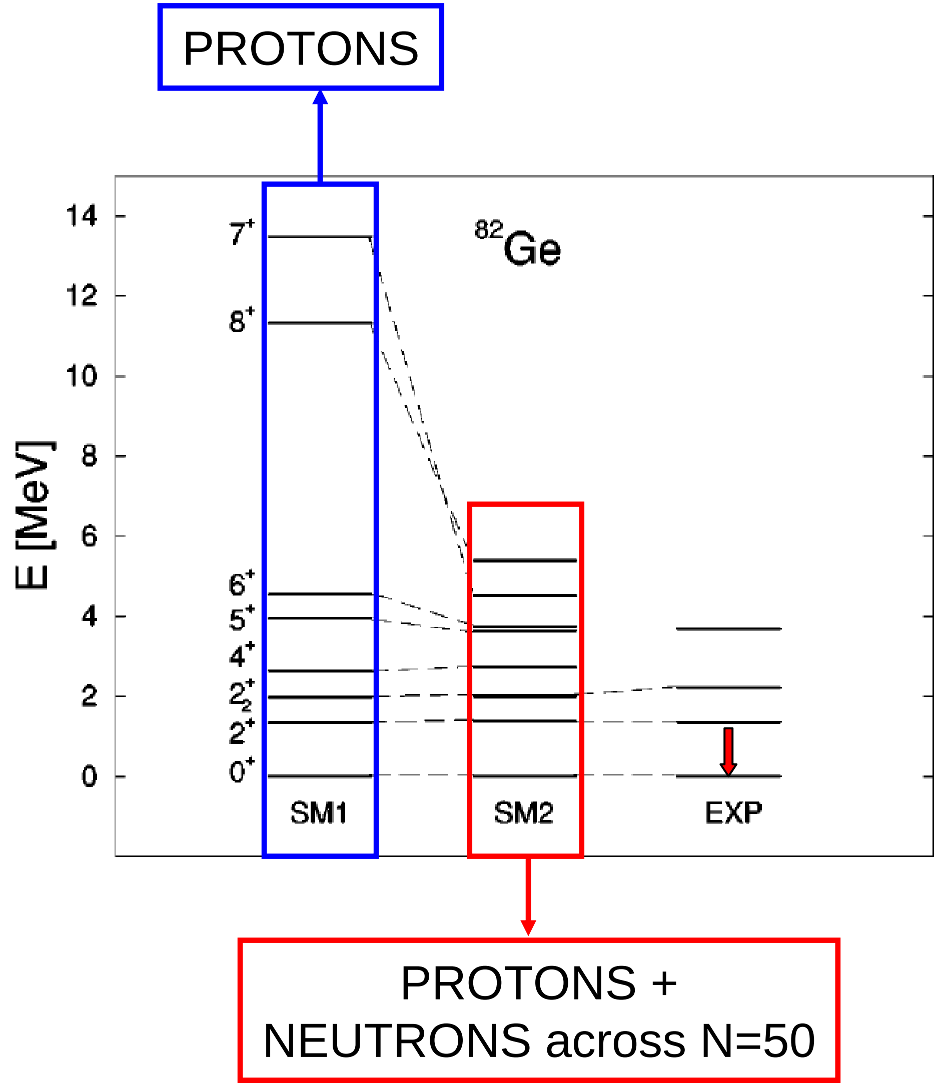
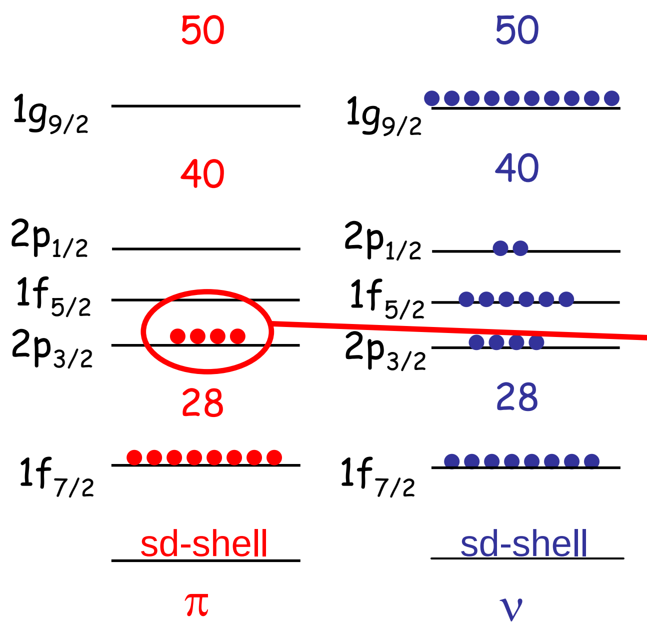
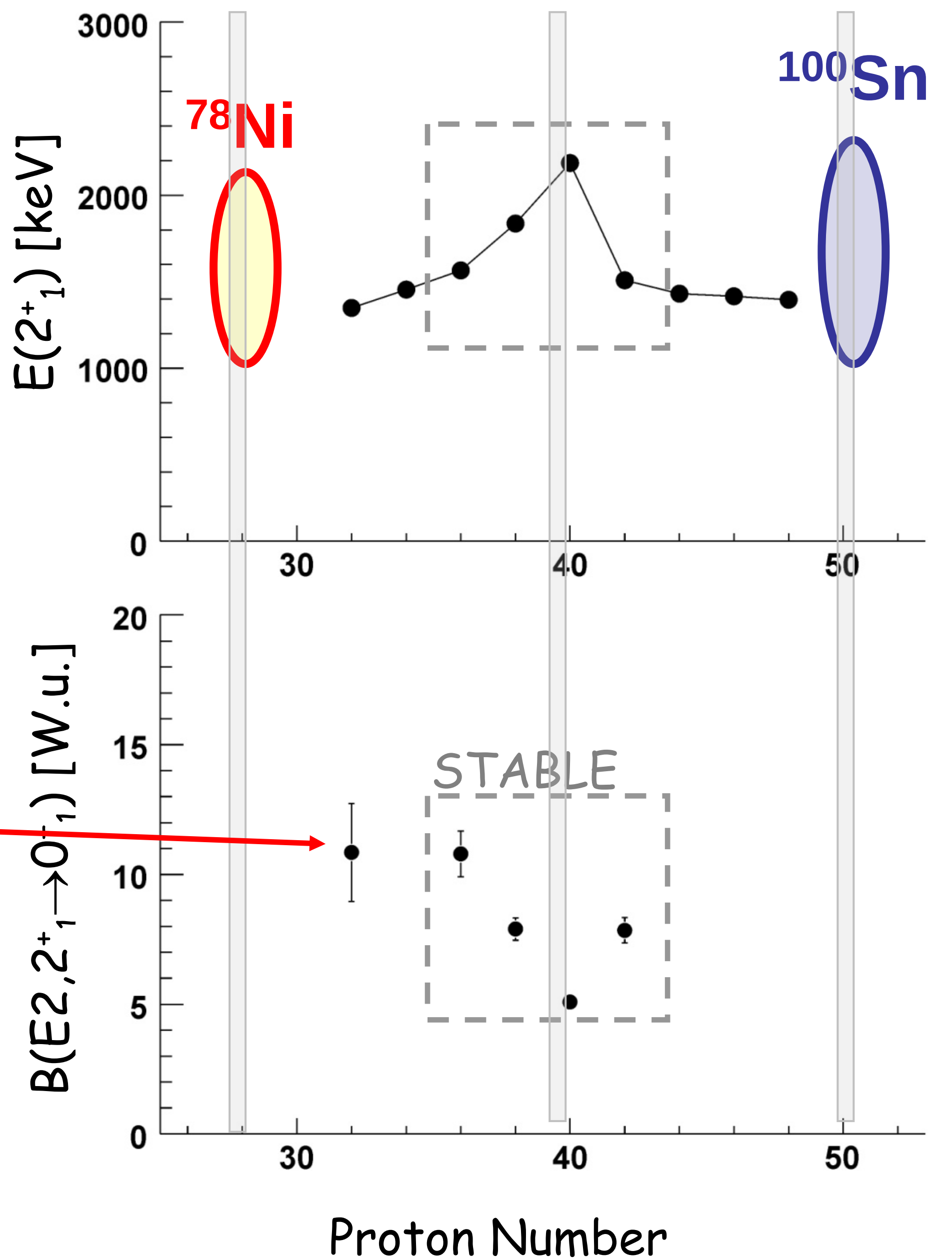




N=50 isotones

What about the Z=28 shell closure ?

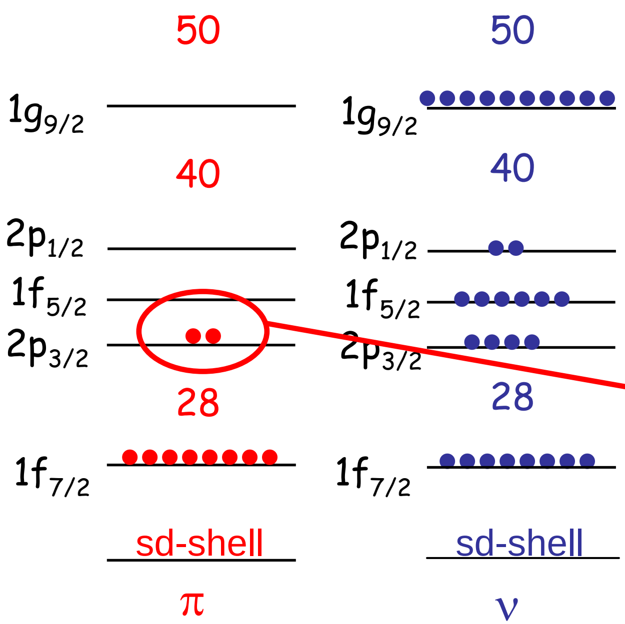


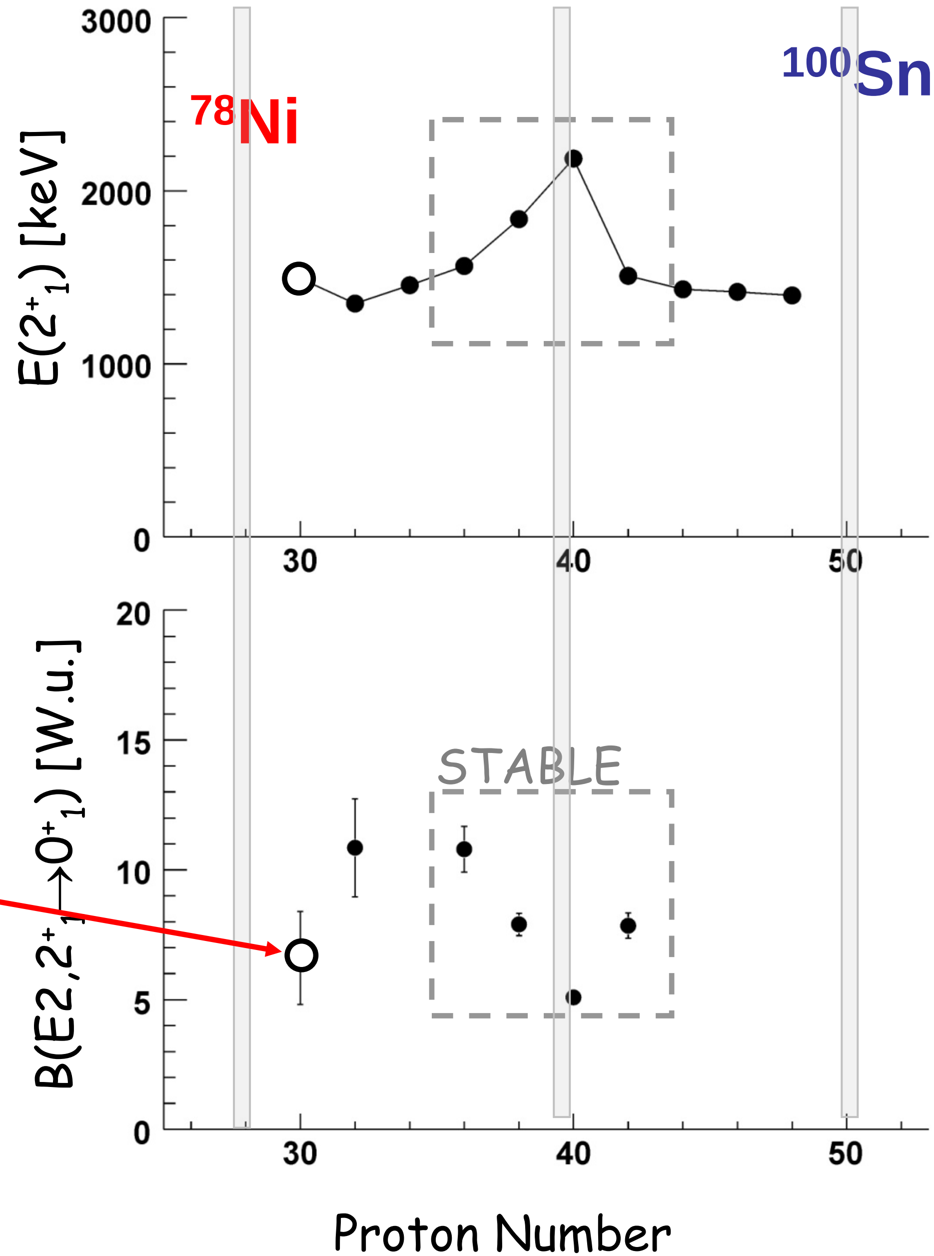


N=50 isotones

What about the Z=28 shell closure ?

new results ...





N=50 isotones

SMI :

M. H. Jensen + monopole adjusted by Nowacki
(e_π, e_ν)=(1.9e,0.9e) - (N. Smirnova *et al*, 2006)

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empirical matrix elements fitted to Ni and N=50
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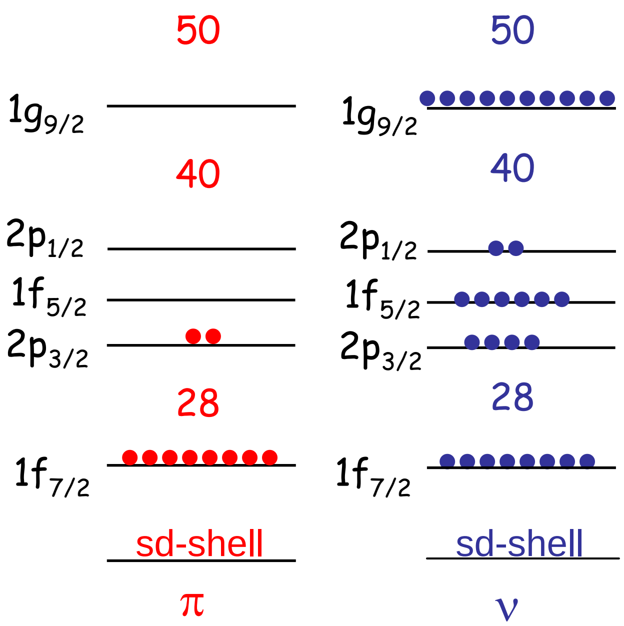
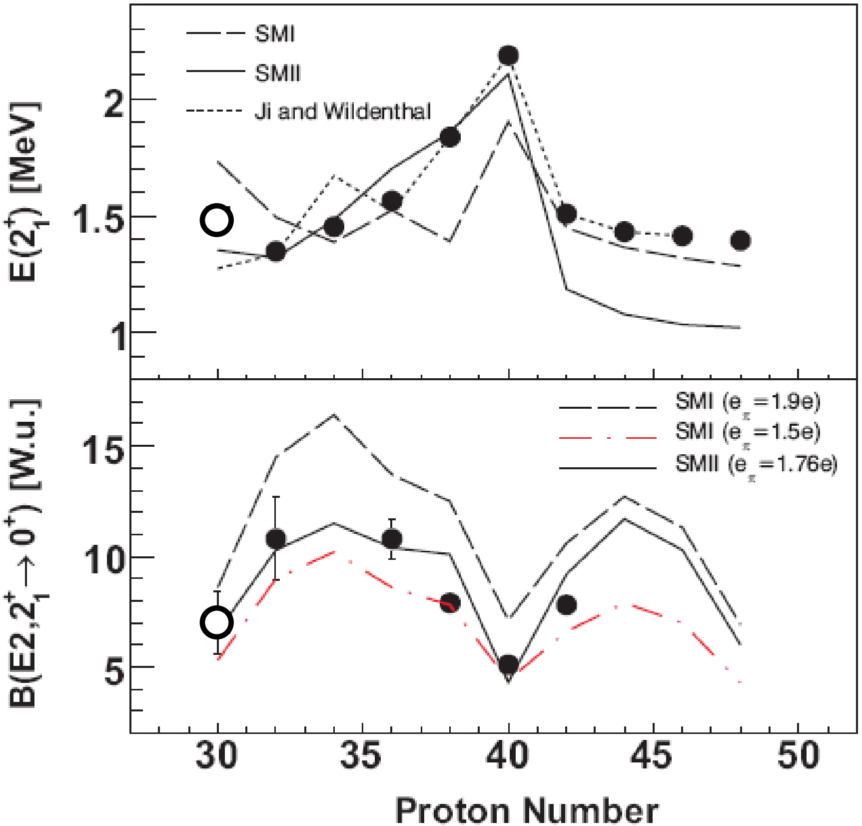
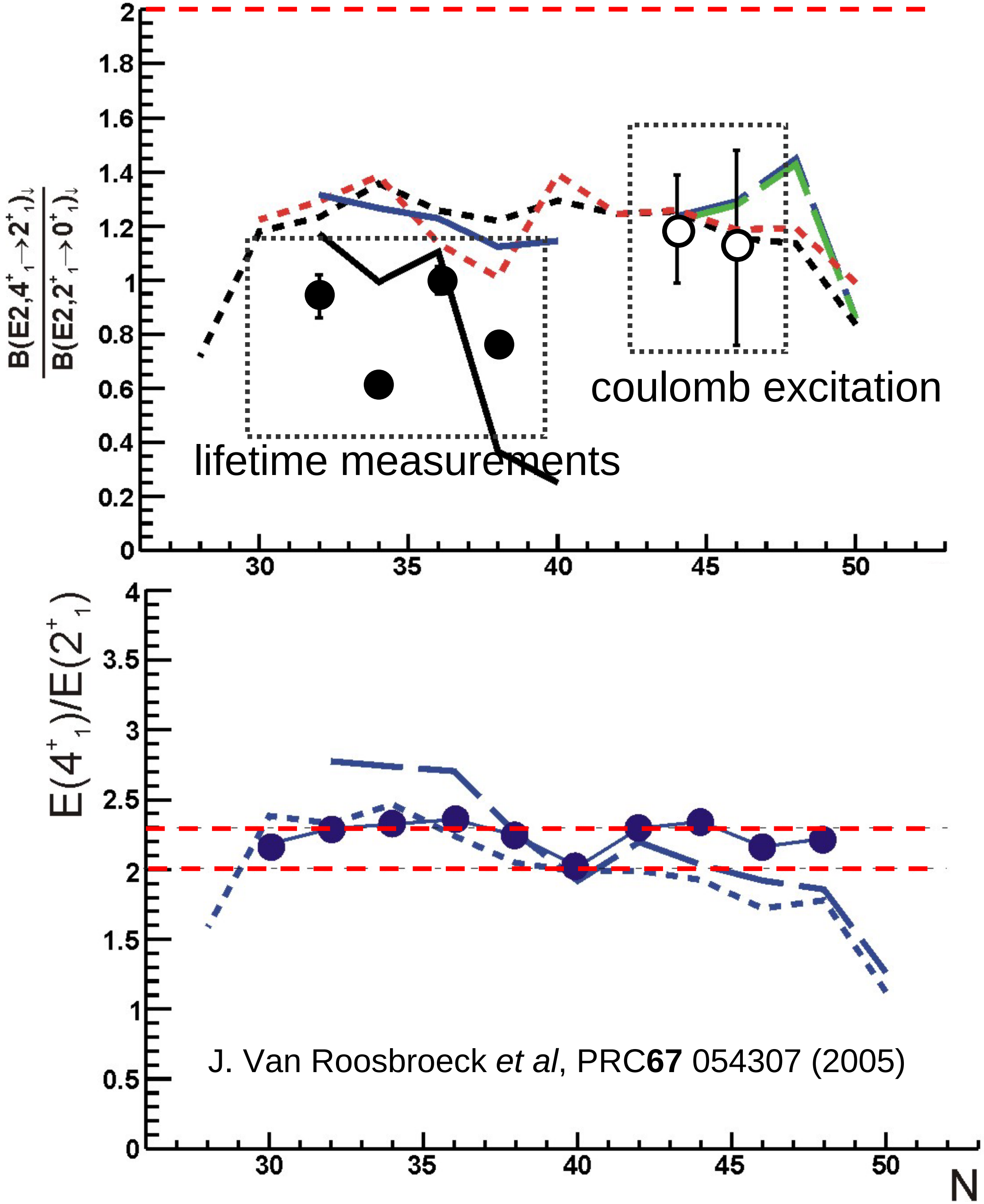




Vibrational character ?

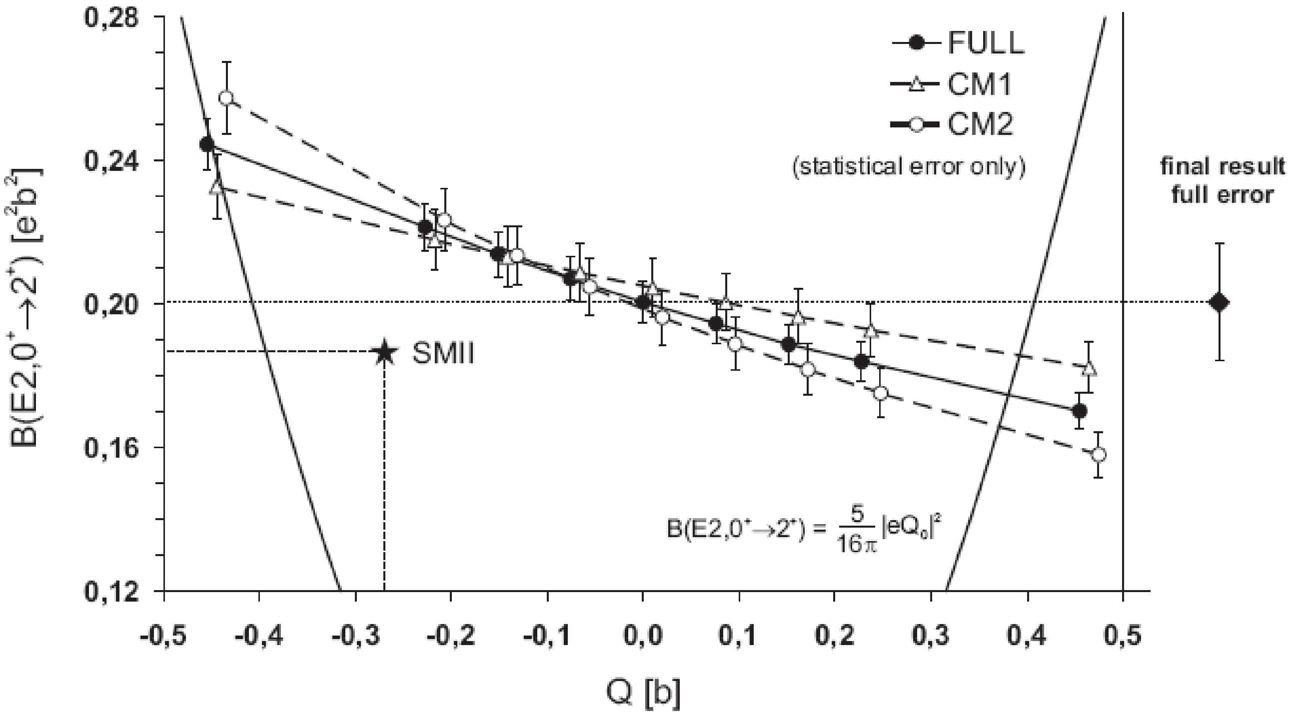
$B(E2,4^+ \rightarrow 2^+)/B(E2,2^+ \rightarrow 0^+) = 2$

$E(4^+)/E(2^+) = 2 – 2.3$



NOTE : these B(E2) results depend on the quadrupole moment of the 2+ state!
LIFETIME measurements are COMPLEMENTARY

Example : ^{74}Zn

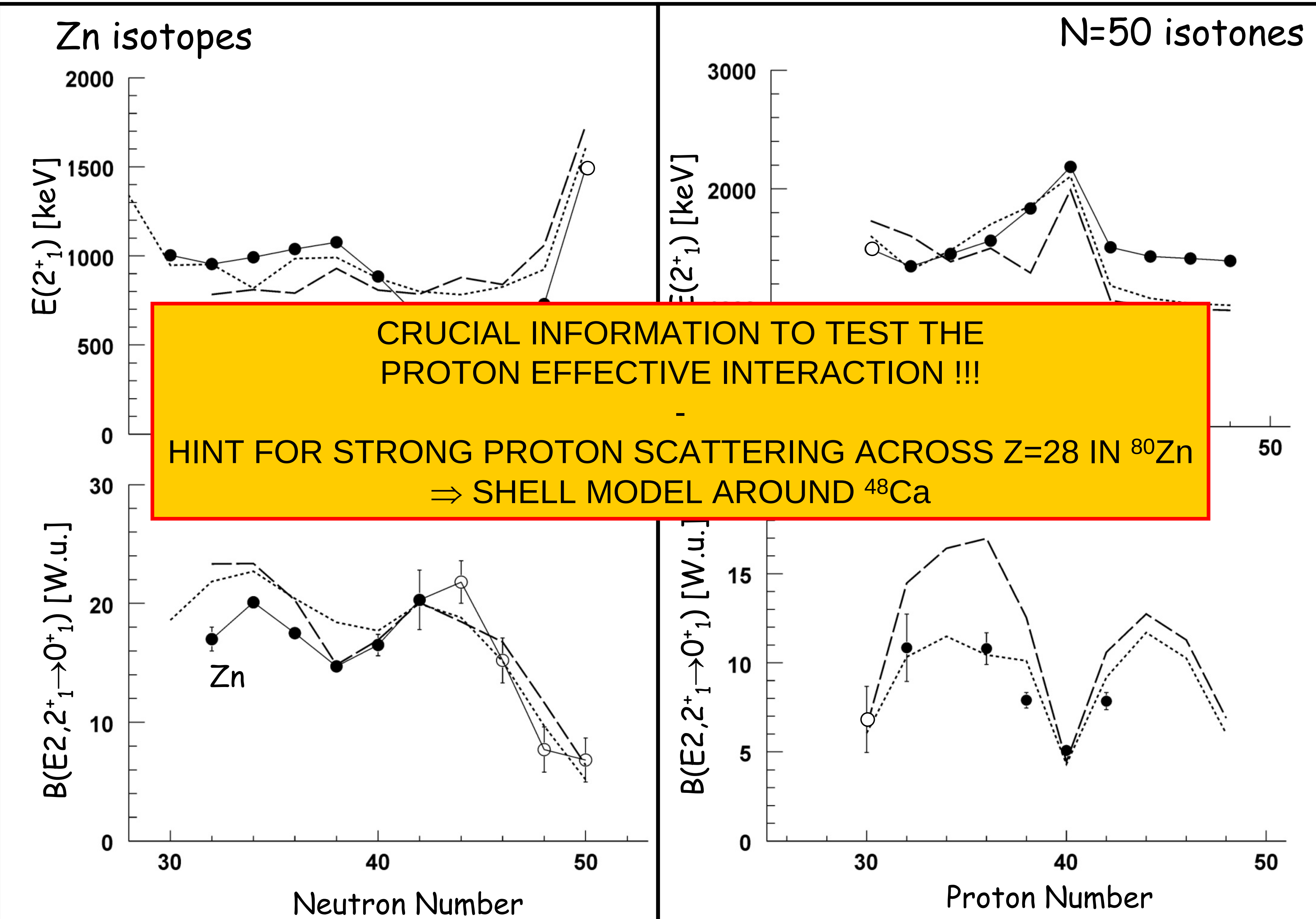


CONCLUSIONS

-B(E2) and E(2^+_1) systematics for Zn isotopes up to N=50;
-Good agreement with Large Scale Shell Model calculations;
-Lifetime measurements can be complementary to get information on the quadrupole moment of the 2+ state

EXPERIMENTAL OUTLOOK (in the region)

-Transfer reactions @ REX-ISOLDE
-Coulomb Excitation / β-decay in Fe region (Z=26)



CRUCIAL INFORMATION TO TEST THE PROTON EFFECTIVE INTERACTION !!!

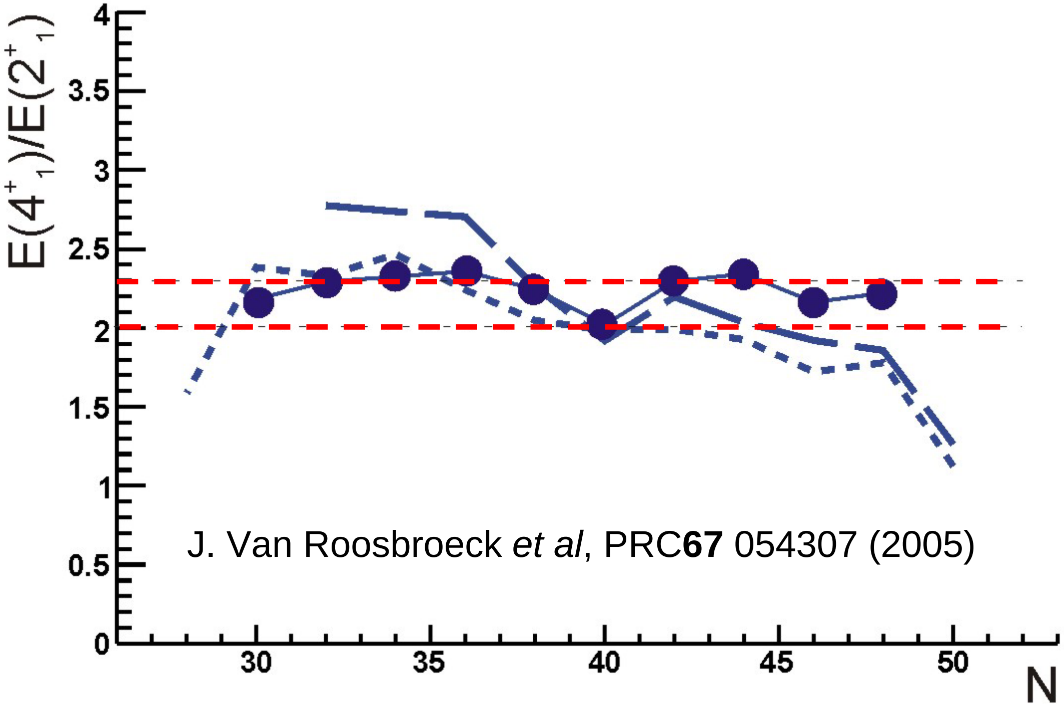
-

HINT FOR STRONG PROTON SCATTERING ACROSS Z=28 IN ^{80}Zn

⇒ SHELL MODEL AROUND ^{48}Ca

Vibrational character ?

$E(4^+)/E(2^+)$ = 2 – 2.3

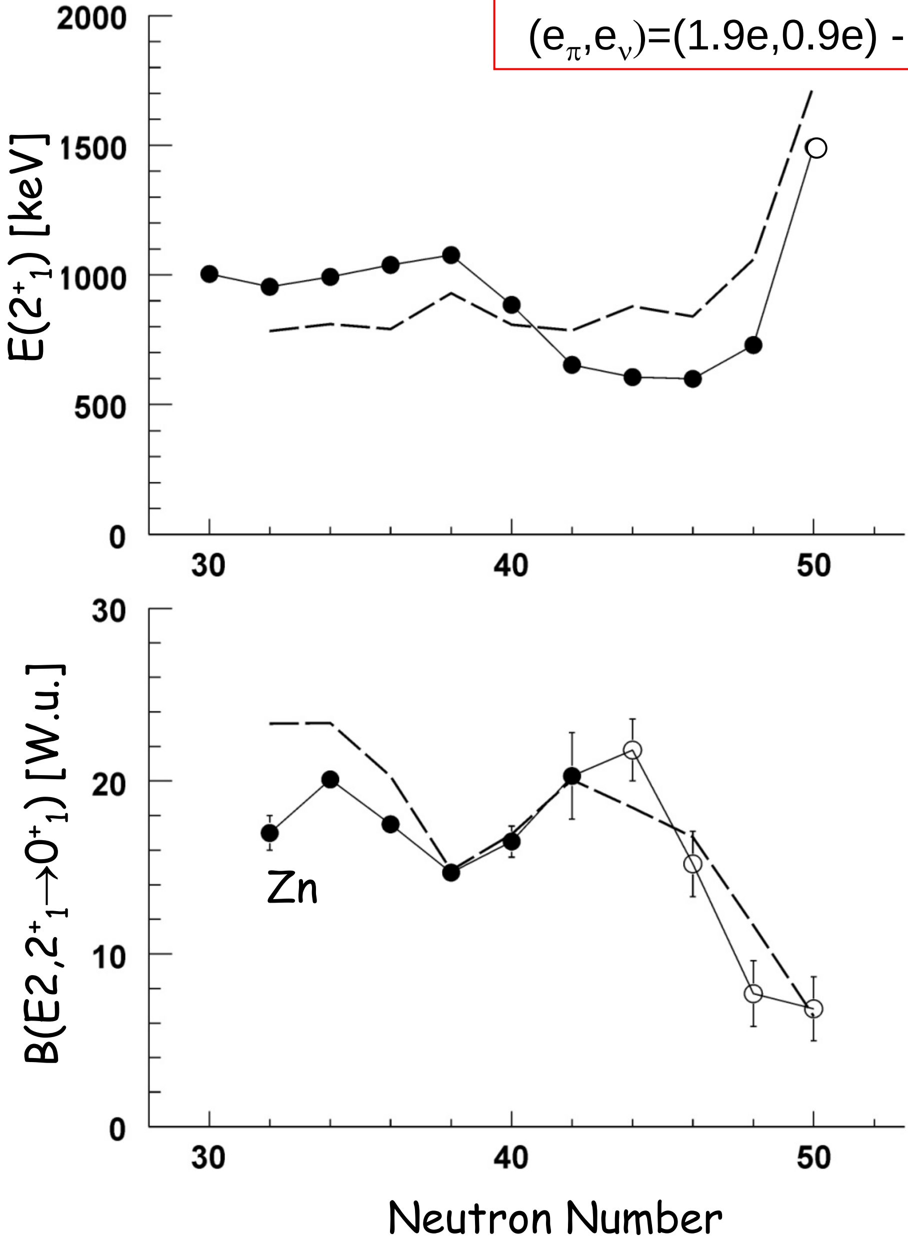


Shell Model (1) :

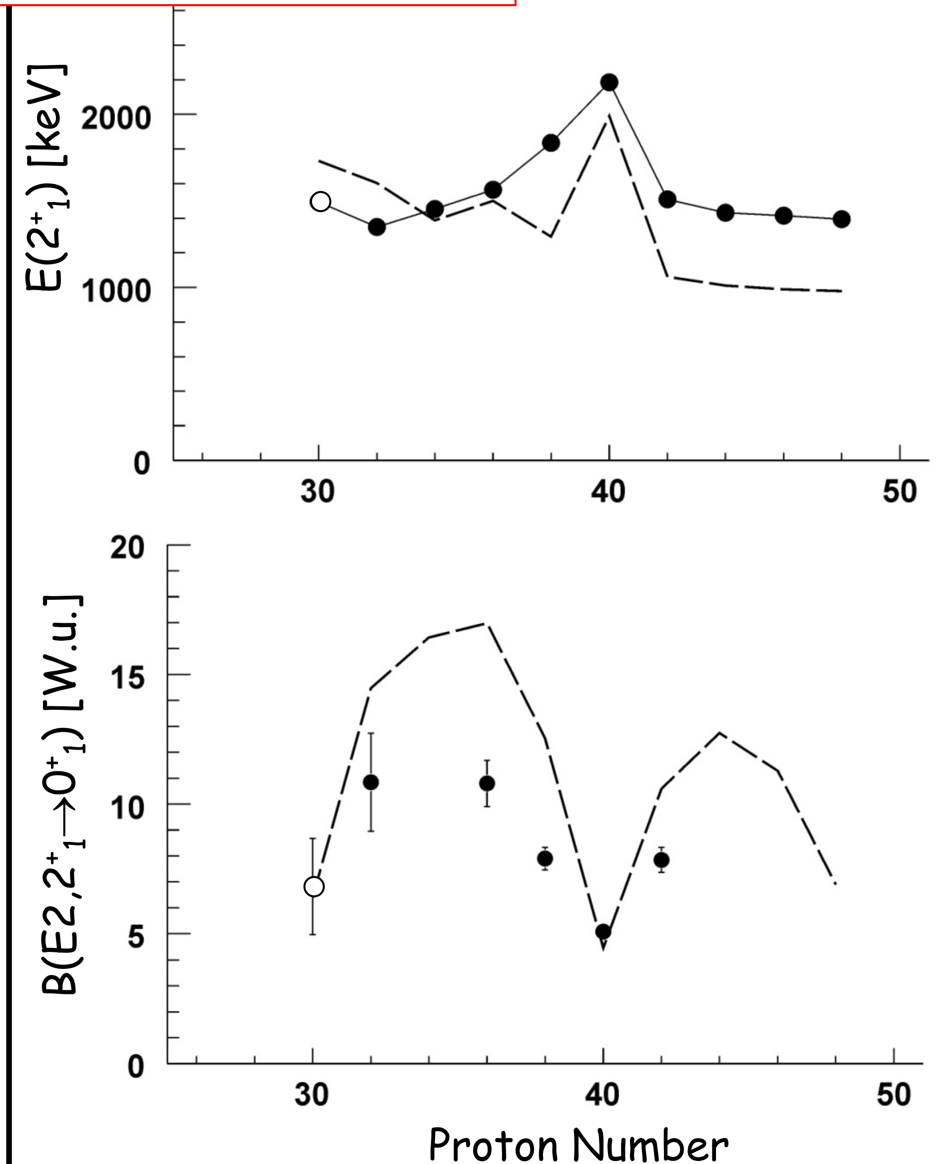
M. H. Jensen + monopole adjusted by Nowacki

$(e_\pi, e_\nu) = (1.9e, 0.9e)$ - (N. Smirnova *et al*, 2006)

Zn isotopes



N=50 isotones



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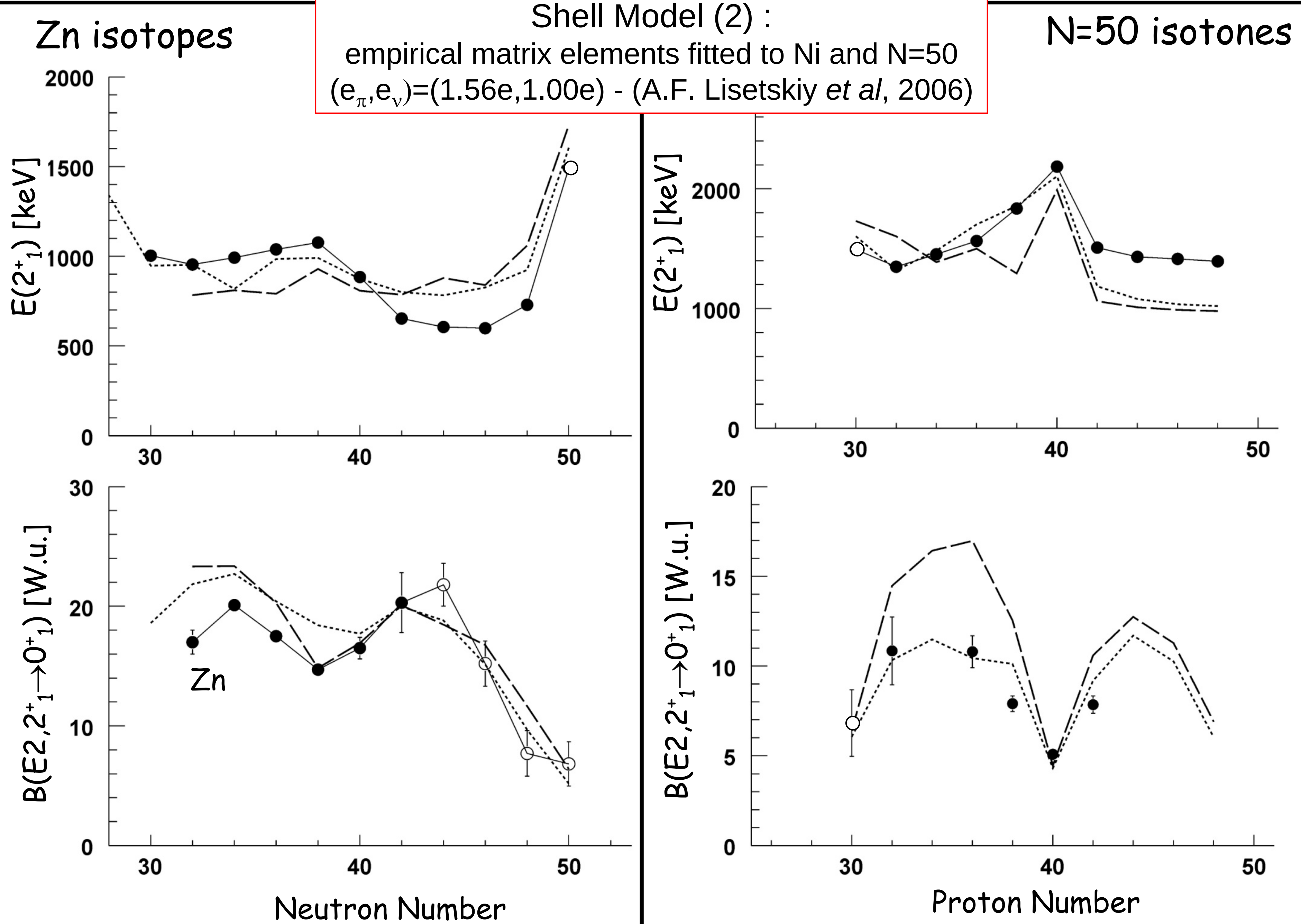

N=50 isotones

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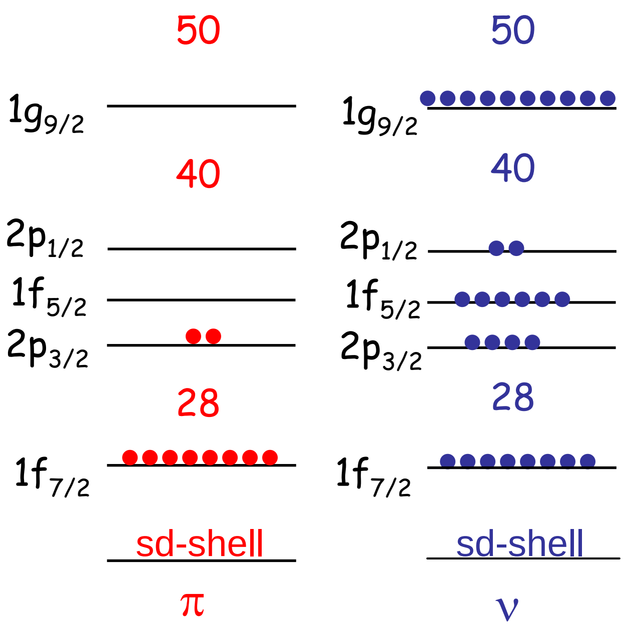

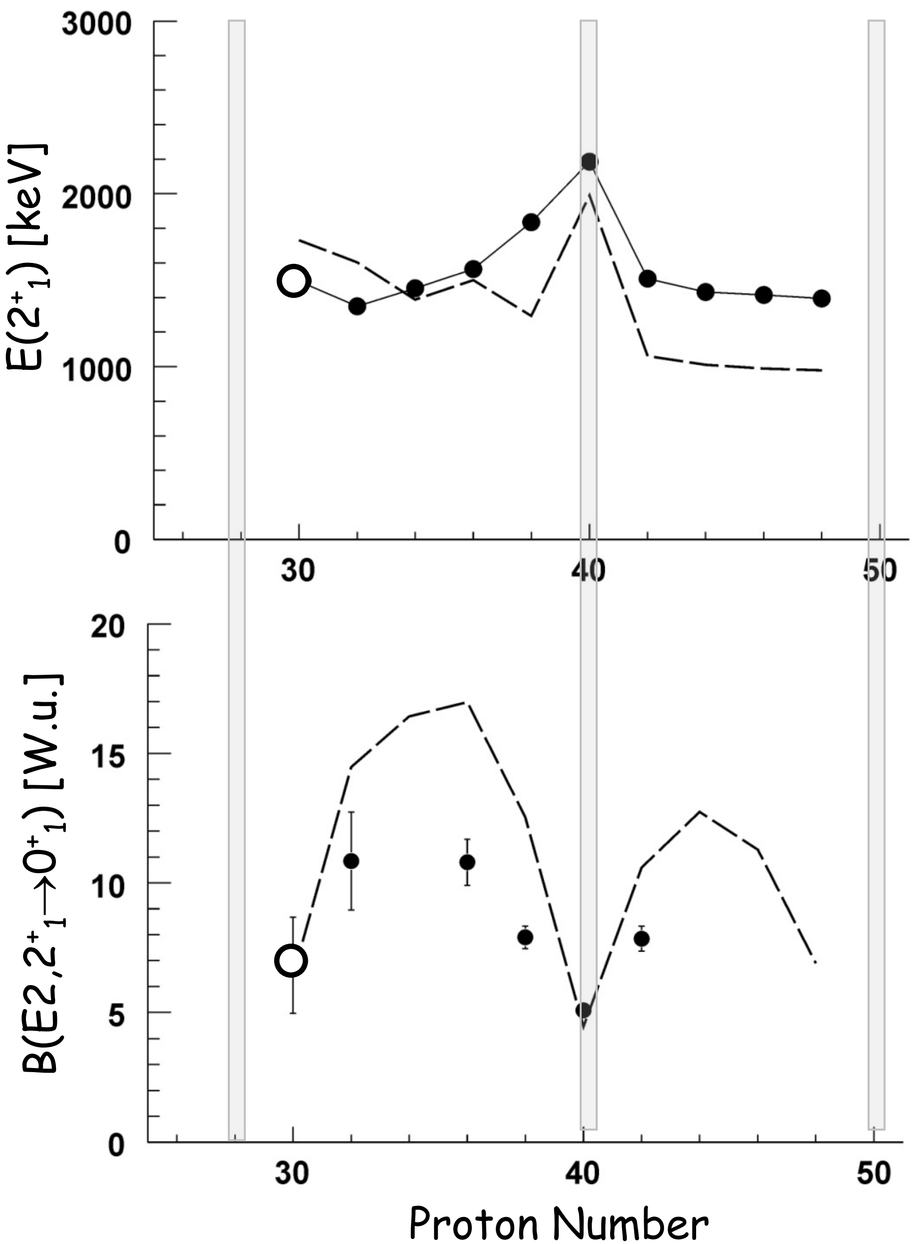

N=50 isotones

Shell Mc
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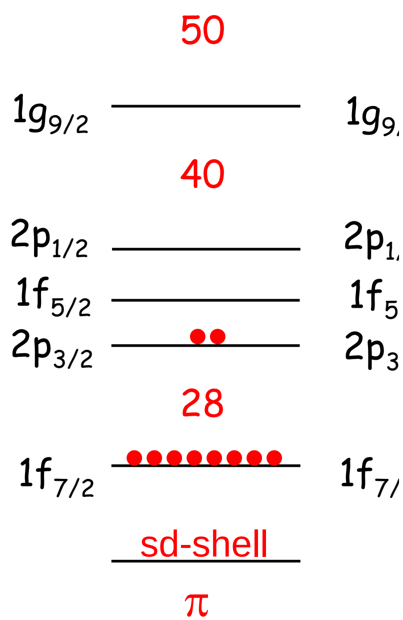
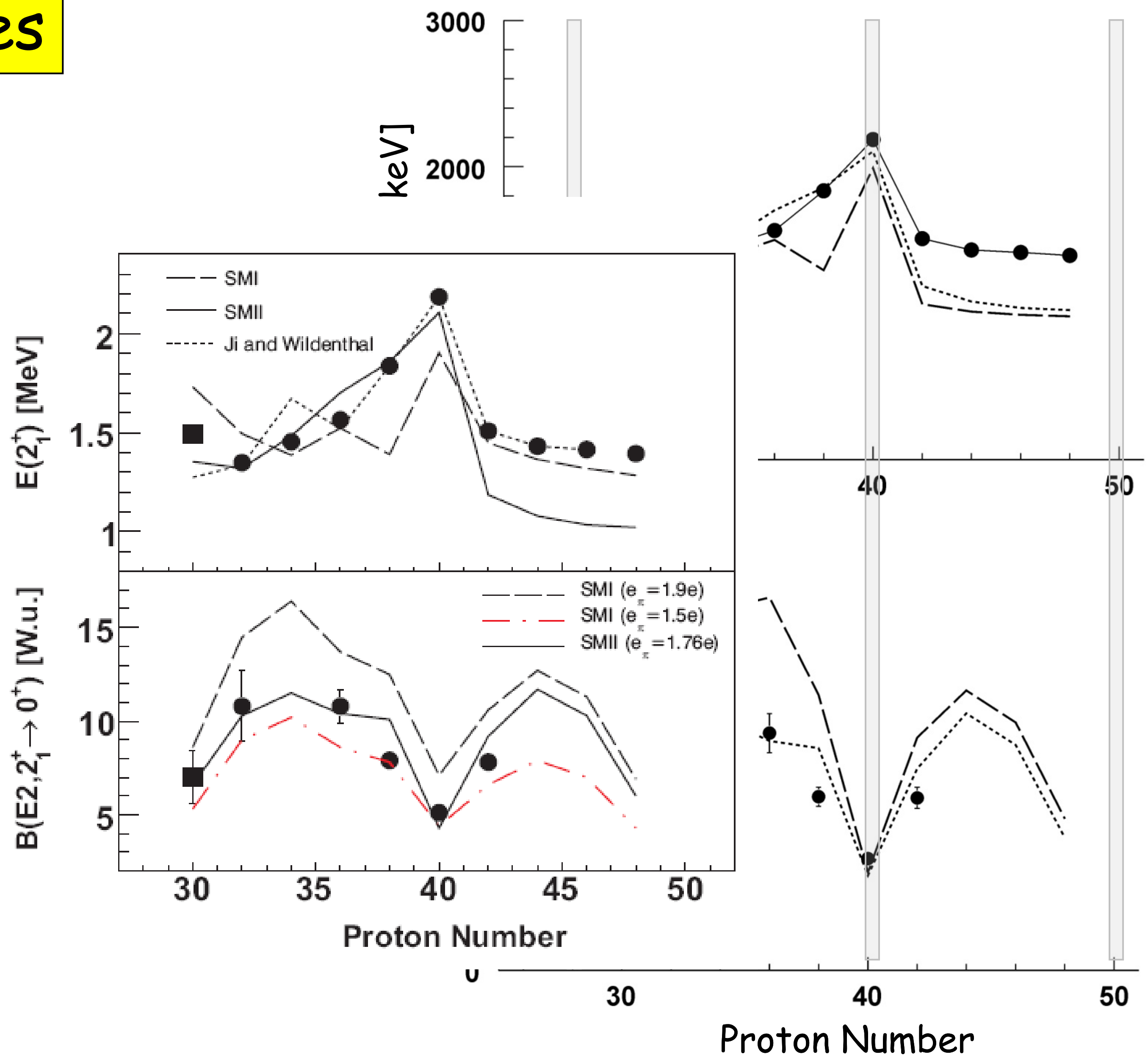
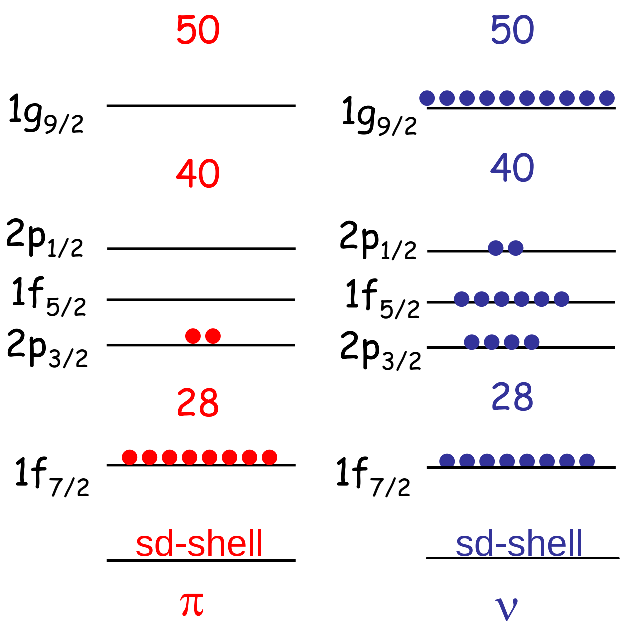
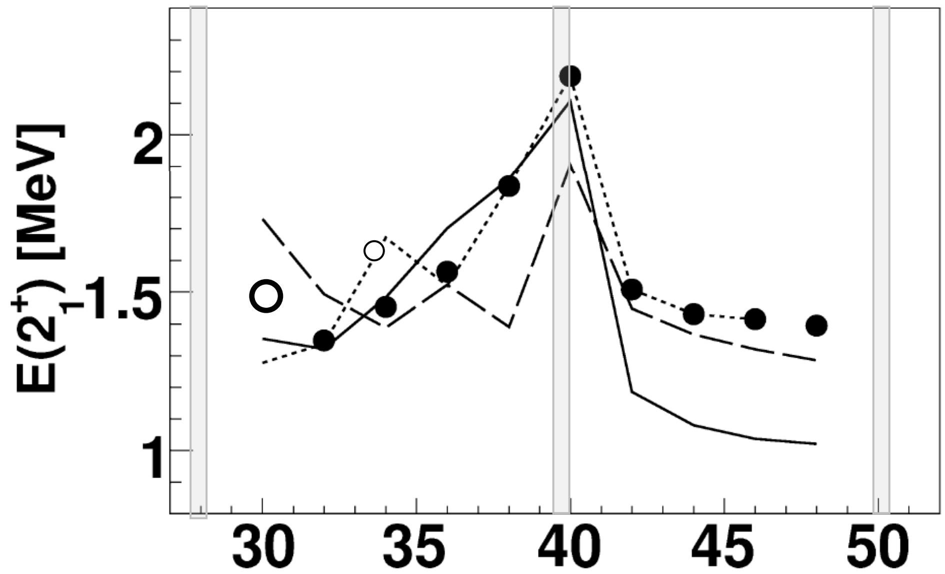




N=50 isotones :
empirical matrix elements





Smirnova et al. (G-matrix by M.Hjorth-Jensen) – – – –
Ji and Wildenthal *et al.* (1989) ....
A.F. Lisetskiy *et al*, (2006) ——