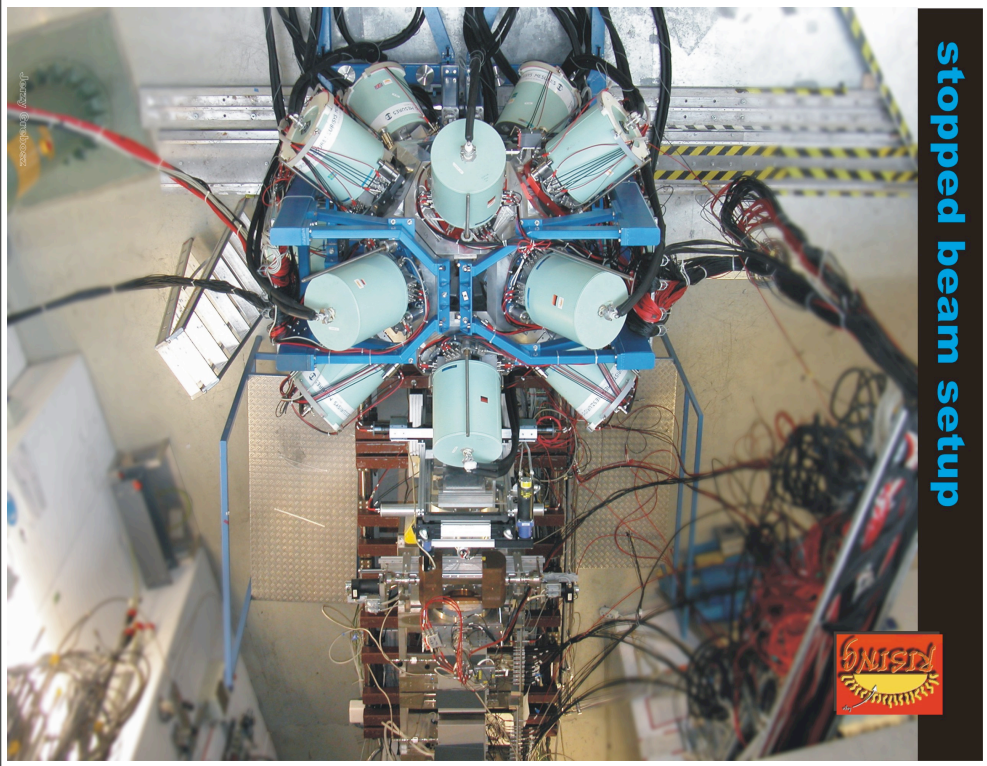
Review of the (Physics from the) Stopped RISING Campaign: (2001 → 2006 → 2011)

Paddy Regan
University of Surrey
Guildford
GU2 7XH

RISING

Rare **I**sotopic **S**pectroscopic **IN**vestigations @ **G**SI =

15 x Cluster germaniums for (the most) exotic gamma-ray spectroscopy



The RISING Project

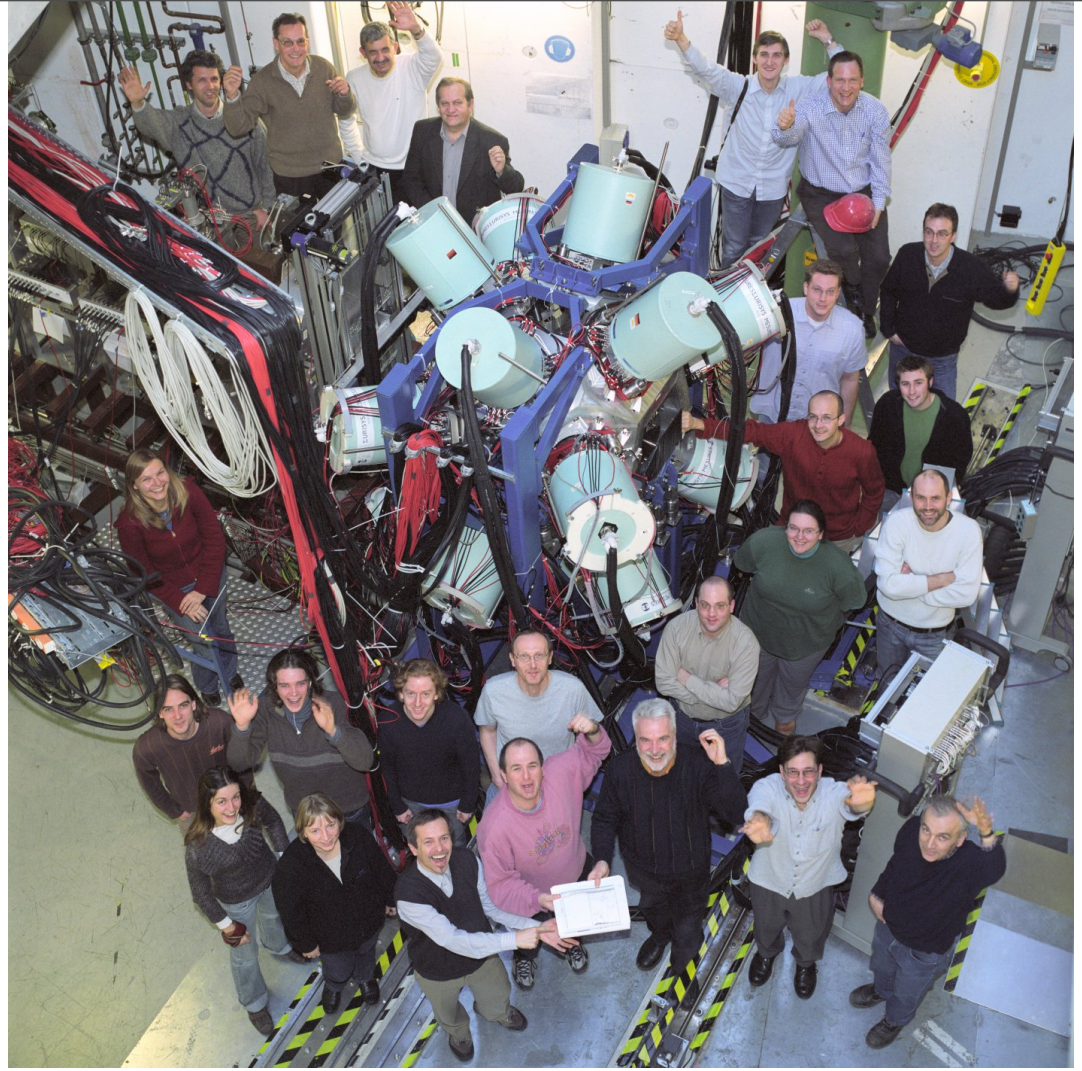
Letter of Intent

G. de Angelis, J. Gerl, H. Grawe, P. Regan, P.Reiter and H.-J. Wollersheim

On behalf of the RISING Steering Committee representing the RISING collaboration

June 2001

Stopped RISING Physics workshop; University of Surrey, Mar. 2004.



Stopped RISING Spokespersons:

Passive Stopper

^{58}Ni, A=54 mirrors: D. Rudolph

^{107}Ag, N=Z: P.H. Regan

^{208}Pb, N=126: Zs. Podolyak

^{136}Xe, N=82 ^{130}Cd: A. Jungclaus

^{238}U, A~110 fission A. Bruce,

Neutron-rich Pb: Javier Valiente (Legnaro)

Active Stopper

^{208}Pb, ~^{190}W, N=126, : P. Regan, J. Benlliure

^{54}Fe, T_z=-1: B. Rubio, Y. Fujita, W.Gelletly

^{62}Ga: A. Gadea, A.Algora

^{238}U: Z. Podolyak

Set-up:

Stephane Pietri (Surrey/GSI),

Henning Schaffner (GSI),

I. Kojouharov (GSI), H.J. Wollersheim (GSI)

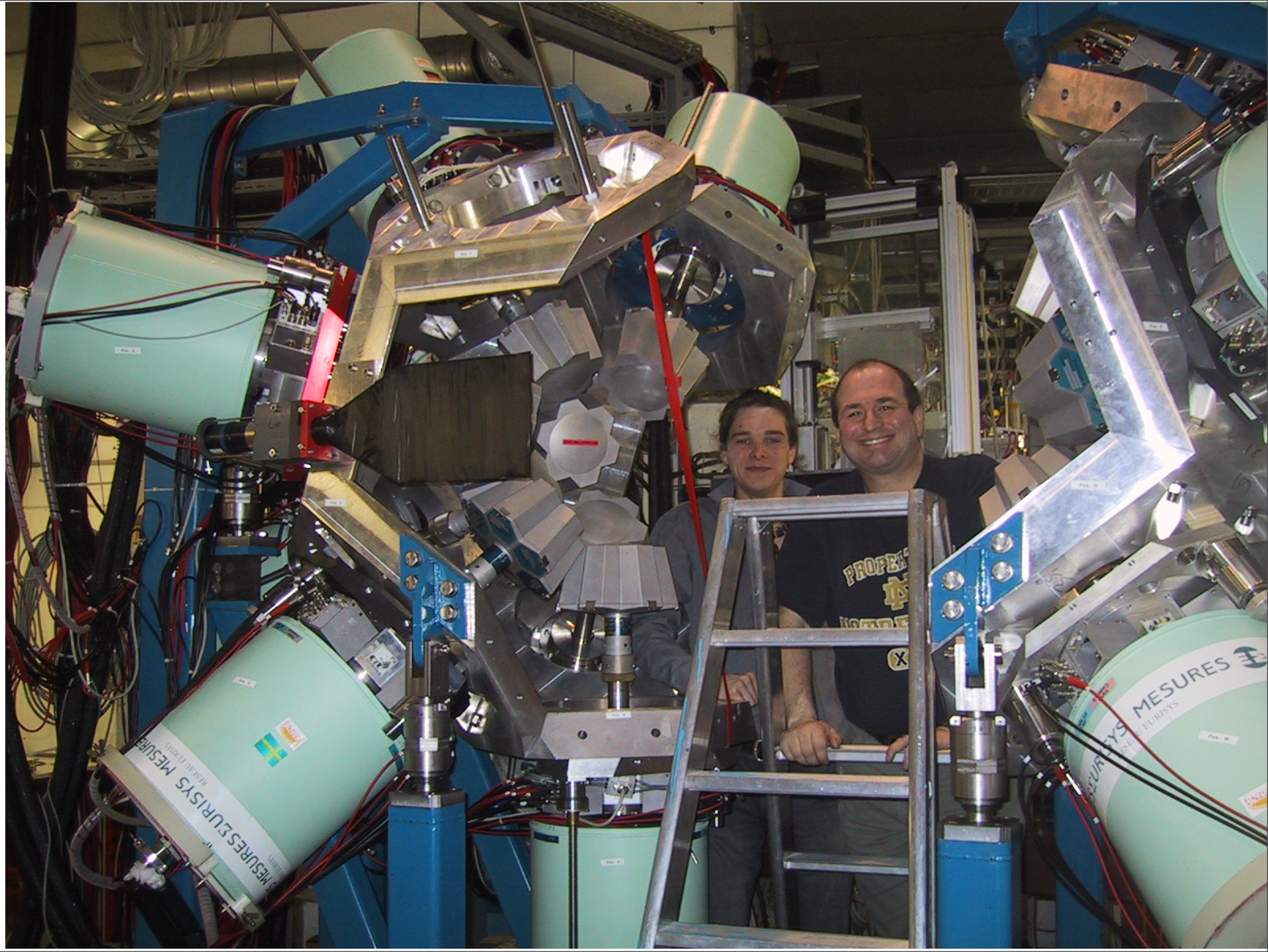
Stopped RISING Data - Analysers:

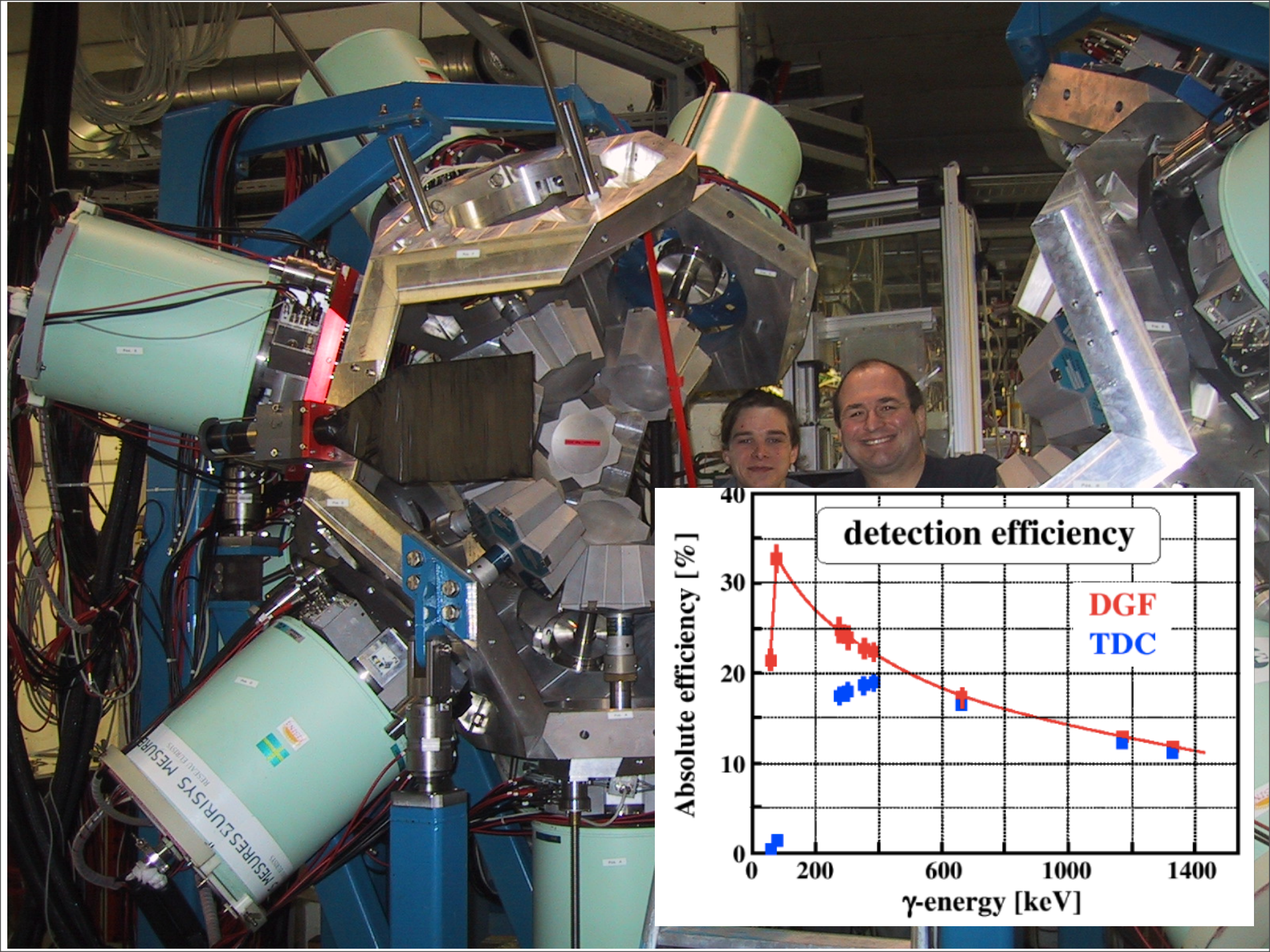
^{107}Ag, N=Z: Adam Garnsworthy

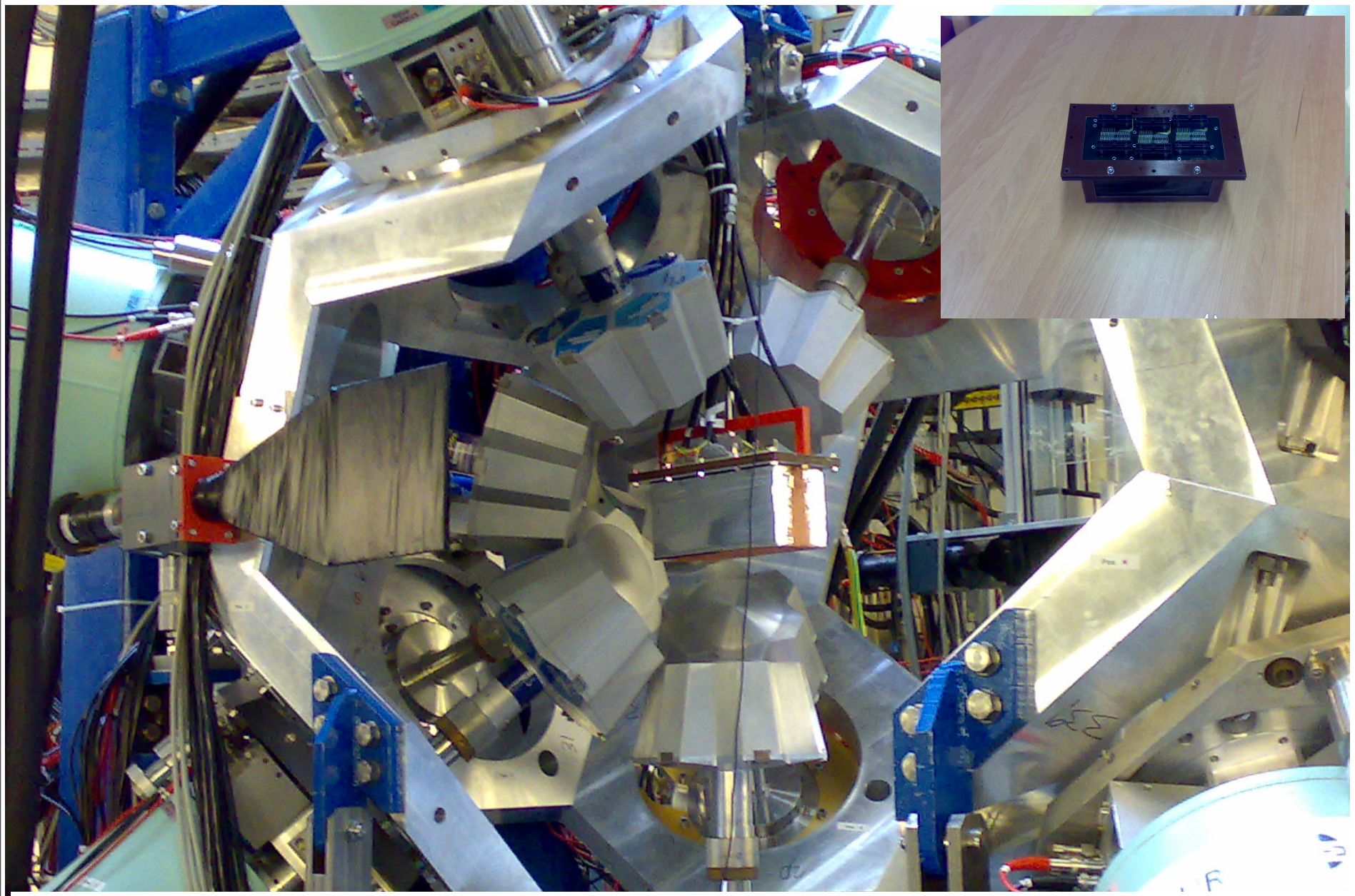
136Xe, N=82 130Cd: Lucia Caceres GSI) ; Farheen Naqvi (GSI/Koln)

^{208}Pb, N=126, ^{190}W: Steve Steer, Greg Farrelly

N~128 Michael Bowry, N.Al-Dahan

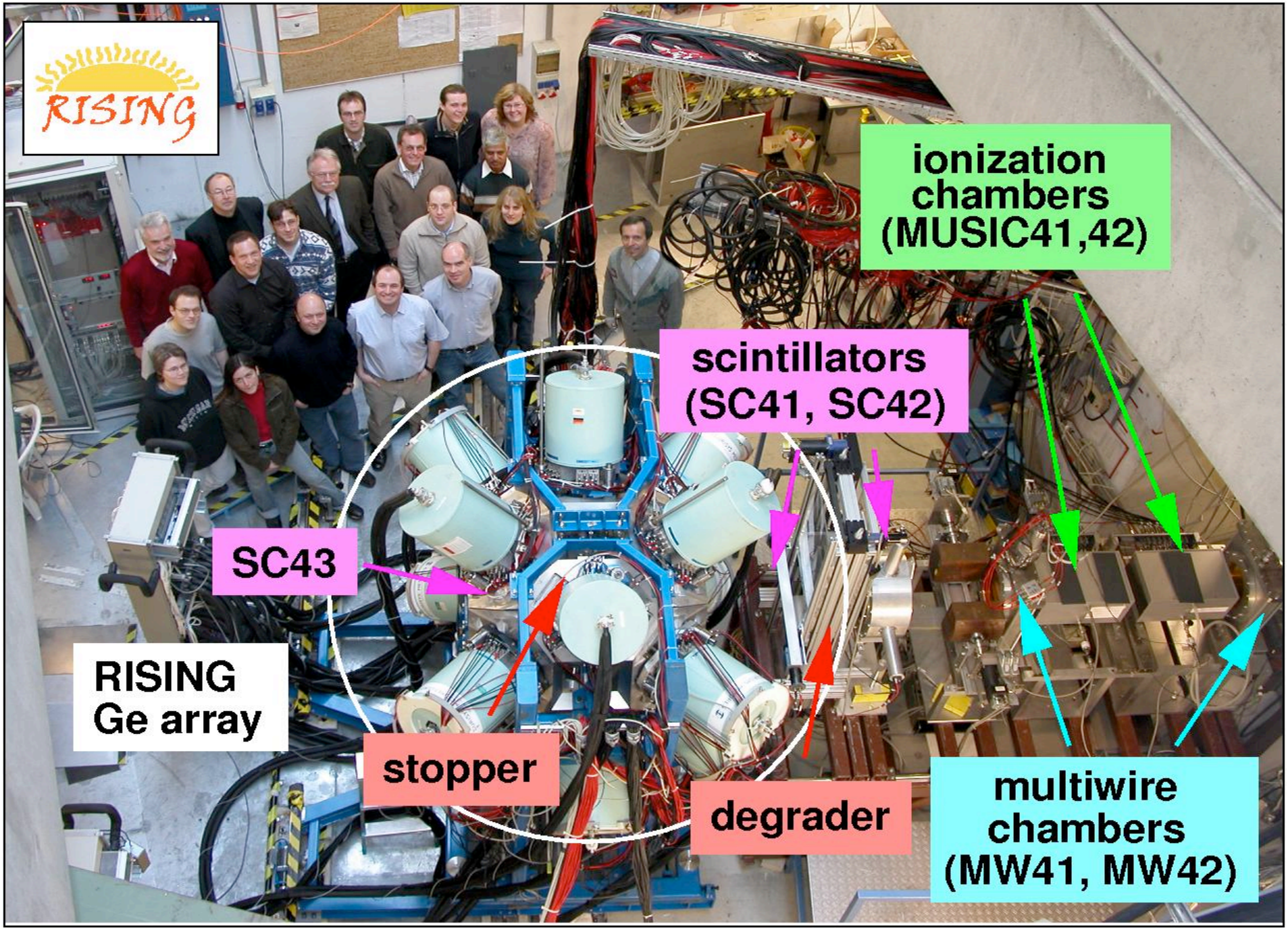

MESURES
HURSYS


detection efficiency
DGF
TDC
Absolute efficiency [%]
γ-energy [keV]
0
10
20
30
40
0
200
600
1000
1400



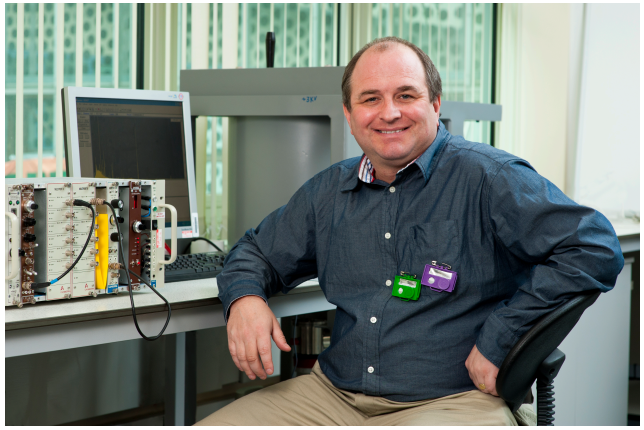
Passive Stopper measurements: γ-rays from isomer with $T_{1/2}$ for 10 ns → 1 ms.

Active Stopper measurements: β –particles, i.e. electrons, $T_{1/2}$ ms →mins


RISING
ionization chambers (MUSIC41,42)
scintillators (SC41, SC42)
SC43
RISING Ge array
stopper
degrader
multiwire chambers (MW41, MW42)

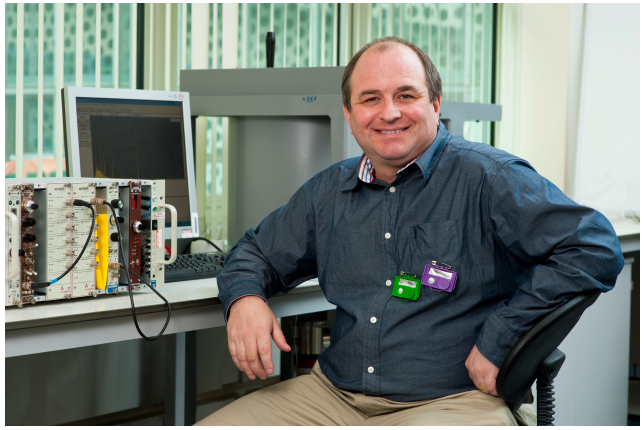
What do isomeric decays tell you about nuclear structure ?

Decay spectroscopy.
How quickly something decays….



2011

Decay spectroscopy.
How quickly something decays….



2011

1988

1985

How?

How?

$$T_{fi}(\lambda L) = \frac{8\pi(L+1)}{\hbar L\left((2L+1)!!\right)^2}\left(\frac{E_\gamma}{\hbar c}\right)^{2L+1} B(\lambda L : J_i \rightarrow J_f)$$

How?

$$T_{fi}(\lambda L) = \frac{8\pi(L+1)}{\hbar L\left((2L+1)!!\right)^2}\left(\frac{E_\gamma}{\hbar c}\right)^{2L+1} B(\lambda L : J_i \rightarrow J_f)$$

Transition probability (i.e., 1/mean lifetime as measured for state which decays by EM radiation)

How?

$$T_{fi}(\lambda L) = \frac{8\pi(L+1)}{\hbar L\left((2L+1)!!\right)^2}\left(\frac{E_\gamma}{\hbar c}\right)^{2L+1} B(\lambda L : J_i \rightarrow J_f)$$

Transition probability (i.e., 1/mean lifetime as measured for state which decays by EM radiation)

(trivial) gamma-ray energy dependence of transition rate, goes as. E_γ^{2L+1} *e.g.,* $E\gamma^5$ *for E2s for example.*

How?

The all important nuclear structure Information.
The 'reduced matrix element' tells us what the overlap between the initial and final nuclear quantum states is.

$$T_{fi}(\lambda L) = \frac{8\pi(L+1)}{\hbar L\left((2L+1)!!\right)^2}\left(\frac{E_\gamma}{\hbar c}\right)^{2L+1} B(\lambda L : J_i \rightarrow J_f)$$

Transition probability (i.e., 1/mean lifetime as measured for state which decays by EM radiation)

(trivial) gamma-ray energy dependence of transition rate, goes as. E_γ^{2L+1} *e.g.,* $E\gamma^5$ *for E2s for example.*

(Some) Stopped RISING Physics Highlights

- N~Z (proton-rich) nuclei & mirror symmetry
  - Shell Structure and mirror symmetries at N ~ Z ~ 28:
    - $^{54}Ni_{26}$ core excitation and proton radioactivity
  - T=1 and T=0 pn-pairing studies at the proton drip-line:
    - ^{82}Nb & ^{86}Tc isomers feeding T=1 ground state structures.
    - GT decay studies between T=1 triplets (Z=N-2 → Z=N)
      - $^{46}Cr \rightarrow {}^{46}V$; $^{50}Cr \rightarrow {}^{50}Mn$; $^{54}Ni \rightarrow {}^{54}Co$; $^{62}Ge \rightarrow {}^{62}Ga$
  - Shell model structure around N=Z=50 ^{100}Sn
    - Seniority isomers & core excitations: $^{94}Pd_{48}$, $^{96}Ag_{49}$ and $^{98}Cd_{50}$,
    - Beta-decay of ^{100}Sn
    - Seniority isomer decay in ^{102}Sn

Stopped RISING Physics Highlights

- Heavy, neutron-rich nuclei

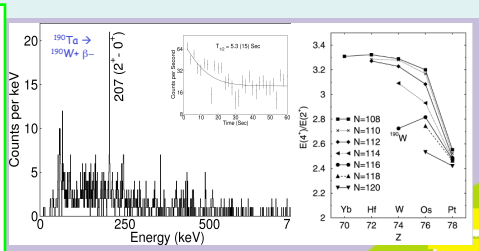
  - Z=50, N=82 (^{132}Sn): Shell model studies:
    - $^{130}Cd_{82}$ seniority isomer structure
    - $^{131}In_{82}$ core-excitation isomers (to establish the N=82 gap size)
    - Isomeric and other shell model structures in $^{125\text{-}128}$Cd

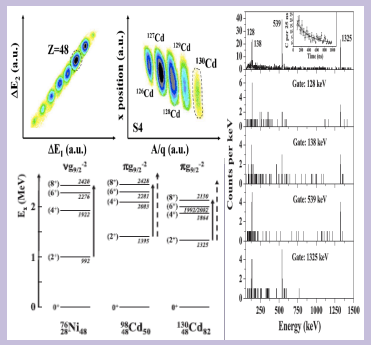
  - Structural evolution and decay half-lives
    - Beta-decay and half-lives of fission fragments around ^{106}Zr
    - Beta-decay and half-lives from triaxial ^{190}W up to N~126

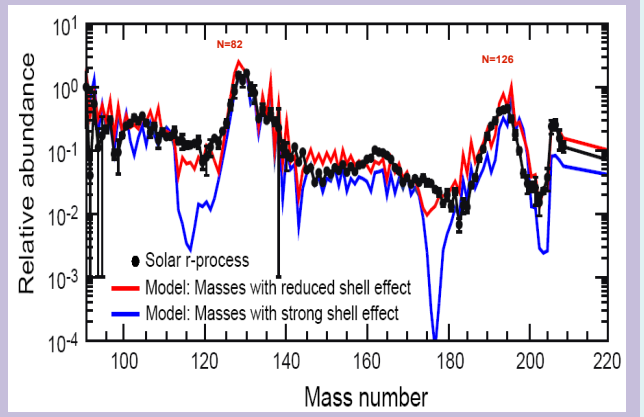
  - Z=82, N=126 (^{208}Pb): Shell model studies
    - N=126, proton-hole isomers ^{203}In, ^{204}Pt, ^{205}Au
    - N>128, Z<82 quadrant: first states in $^{208}Hg_{128}$, $^{209}Tl_{128}$
    - ^{212,214,216}Pb seniority isomers

‘BIG PHYSICS’ QUESTIONS ADDRESSED BY STOPPED RISING (isomer and beta-decays)

- How robust are the magic numbers?
- What are the limits of nuclear existence?
- Does neutron excess modify structure ?
- How ‘good’ are nuclear physics quantum numbers, such as isospin, K and seniority?







Experiment	Spokespersons	Dates	Publication
1. S244: ^{107}Ag beam; N=Z isomers	Regan	25 Feb –1 Mar 06	A.B. Garnsworthy et al., PL **B660** (2008) 326 A.B. Garnsworthy et al., PR **C80** (2009) 064303
2. S299; ^{208}Pb beam N~126 isomers	Podolyak	2 Mar – 8 Mar 06	S.J. Steer et al., PR **C78** (2008) 061302(R); Zs. Podolyak et al., PR **C79** (2009) 031305(R); Zs. Podolyak et al., PR **C79** (2009) 031305 (R) E.C. Simpson PR **C80** (2009) 064608 Zs. Podolyak et al., EPJ **A42** (2009) 489 S.J.Steer et al., IJMP **E18** (2009) 1002
3. S244: ^{58}Ni beam; A=54 mirrors	Rudolph	9 Mar –12 Mar 06	D. Rudolph et al., PR **C78** (2008) 021301(R) ;. Rudolph et al., EPJ **A36** (2008) 131.
4. S305: ^{136}Xe beam. N~82 isomers	Jungclaus	26 Jun – 9 July 06	A. Jungclaus et al. PRL **99** (2007) 132501
5. S244: ^{238}U beam. Isomers at N~82	Pfutzner / Gorska	10 Jul – 7 Jul 06	L. Caceres et al., PR **C79** (2009) 011301 (R); M. Gorska et al., PL **B672** (2009) 313.
6. S300; ^{238}U beam: A~110 isomers	Bruce	11 Dec – 7 Dec 06	
7. S313: ^{208}Pb beam active.; N→126	Regan / Benlliure	8 Mar -18 Mar 07	Zs. Podolyak et al., PL **B672** (2009) 116; N. Alkhomashi et al., PR **C80** (2009) 064308
8. S313: ^{208}Pb beam active. N →126	Benlliure / Regan	8 Jul –17 July 07	P.H. Regan et al., IJMP **E17** (2008) 8; A.I. Morales et al., Acta Phys. **B40** (2009) 867
9. S326: ^{78}Kr beam, GT in A=62	Gadea / Algora	18 Jul – 25 Jul 07	
10. S316: ^{58}Ni beam; GT A=46:50:54	Fujita / Gelletly / Rubio	27 July –1 Aug 07	
11.S330: ^{124}Xe beam: ^{100}Sn + SIMBA	Faestermann / Gorska	5 Mar – 26 Mar 08	
12. S347: ^{238}U beam; Z<82; N>126	Podolyak	27 Apr – 3 May 08	N.Al-Dahan et al., PR **C80** (2009) 061302 (R)
13. S352: ^{124}Xe beam; ^{96,8}Pd	Blazhev / Wadsworth / Liu / Boutachkov	5 Jun – 13 Jun 08	R Wadsworth et al., Acta Phys **B40** (2009) 611 A. Blazhev et al., J Phy. Conf. **205** (2010) 01
14. S361: ^{238}U beam, ^{104,6}Zr	Bruce	17 Sep -20 Sep 09	

16 successful experiments)

How it actually turned out….lots of nice (initial) conference

International Journal of Modern Physics E
Vol. 17, Supplement (2008) 8–20

World Scientific
www.worldscientific.com

FIRST RESULTS WITH THE RISING ACTIVE STOPPER*

ELSEVIER

Available online at www.sciencedirect.com
ScienceDirect

Nuclear Physics A 787 (2007) 491c–498c

NUCLEAR PHYSICS A

Isomer Spectroscopy Using Relativistic Projectile Fragmentation at the N=Z Line for A∼80→90.*

P.H. Regan[a] A.B. Garnsworthy[ab] S. Pietri[a], L. Caceres[c d], M. Górska[c], D. Rudolph[e], Zs. Podolyák[a], S.J. Steer[a], R. Hoischen[e], J. Gerl[c], H.J. Wollersheim[c], J.Grebosz[cf], H.Schaffner[c], W.Prokopwicz[c], I. Kojouharov[c], F. Becker[c], P.Bednarczyk[c] P.Doornenball[c], H. Geissel[c], H. Grawe[c], A. Kelic[c], N. Kurz[c], F. Montes[c], T. Saito[c], S. Tashenov[c], E. Werner-Malento[cg], A. Heinz[b], L. Atanasova[h], D. Balabanski[h], G. Benzoni[i] B. Blank[j], A. Blazhev[k], C. Brandau[ac], A.M. Bruce[l], W.N. Catford[a], F. Camera[i], I.J. Cullen[a], M.E. Estevez[m] C. Fahlander[e], W. Gelletly[a], G. Ilie[kn], A.Jungclaus[d], J. Jolie[k], T. Kurtukian-Nieto[m], Z. Liu[a], M. Kmiecik[f], A. Maj[f], S. Myalski[f], S. Schwertel[o], T. Shizuma[ap], A.J. Simons[aq], P.M. Walker[a], O. Wieland[i]

ELSEVIER

Available online at www.sciencedirect.com
ScienceDirect

Nuclear Instruments and Methods in Physics Research B 261 (2007) 1079–1083

NIM B
Beam Interactions with Materials & Atoms

www.elsevier.com/locate/nimb

Recent results in fragmentation isomer spectroscopy with rising

S. Pietri [a,*], P.H. Regan [a], Zs. Podolyák [a], D. Rudolph [b], S. Steer [a], A.B. Garnsworthy [a,c], E. Werner-Malento [d,e], R. Hoischen [b], M. Górska [d], J. Gerl [d], H.J. Wollersheim [d], I. Kojouharov [d], H. Schaffner [d], F. Becker [d], P. Bednarczyk [d,f], L. Caceres [d,g], P. Doornenbal [d], H. Geissel [d], J. Grębosz [d,f], A. Kelic [d], N. Kurz [d], F. Montes [d], W. Prokopowicz [d,h], T. Saito [d], S. Tashenov [d], A. Heinz [c], M. Pfützner [e], T. Kurtukian-Nieto [i], G. Benzoni [j], M. Hellström [b], A. Jungclaus [g], J. Simpson [k], L.-L. Andersson [b], L. Atanasova [l], D. Balabanski [l,m], M.A. Bentley [n], B. Blank [o], A. Blazhev [p], C. Brandau [a,d], J.R. Brown [n], A.M. Bruce [q], F. Camera [j], W.N. Catford [a], I.J. Cullen [a], Zs. Dombrádi [r], E. Estevez [i], C. Fahlander [b], W. Gelletly [a], G. Ilie [p], E.K. Johansson [b], J. Jolie [p], G.A. Jones [a], M. Kmiecik [f], F.G. Kondev [s], S. Lalkovski [l], Z. Liu [a], A. Maj [f], S. Myalski [f], T. Shizuma [a,t], A.J. Simons [a], S. Schwertel [u], P.M. Walker [a], O. Wieland [j]

Nuclear Instruments and Methods in Physics Research A 598 (2009) 754–758

Contents lists available at ScienceDirect

Nuclear Instruments and Methods in Physics Research A

journal homepage: www.elsevier.com/locate/nima

ELSEVIER

Testing of a DSSSD detector for the stopped RISING project

R. Kumar [a,b,*], F.G. Molina [c], S. Pietri [d], E. Casarejos [f], A. Algora [c,g], J. Benlliure [f], P. Doornenbal [e,b], J. Gerl [b], M. Gorska [b], I. Kojouharov [b], Zs. Podolyák [d], W. Prokopowicz [b], P.H. Regan [d], B. Rubio [c], H. Schaffner [b], S. Tashenov [b], H.-J. Wollersheim [b]

Some more ‘high profile’ publications….

RAPID COMMUNICATIONS

PHYSICAL REVIEW C **78**, 021301(R) (2008)

Isospin symmetry and proton decay: Identification of the 10^+ isomer in ^{54}Ni

D. Rudolph,[1] R. Hoischen,[1,2] M. Hellström,[1] S. Pietri,[3] Zs. Podolyák,[3] P. H. Regan,[3] A. B. Garnsworthy,[3,4] S. J. Steer,[3] F. Becker,[2,*] P. Bednarczyk,[2,5] L. Cáceres,[2,6] P. Doornenbal,[2,7,†] J. Gerl,[2] M. Górska,[2] J. Grębosz,[2,5] I. Kojouharov,[2] N. Kurz,[2] W. Prokopowicz,[2,5] H. Schaffner,[2] H. J. Wollersheim,[2] L.-L. Andersson,[1] L. Atanasova,[8] D. L. Balabanski,[8,9] M. A. Bentley,[10] A. Blazhev,[7] C. Brandau,[2,3] J. R. Brown,[10] C. Fahlander,[1] E. K. Johansson,[1] A. Jungclaus,[6] and S. M. Lenzi[11]

RAPID COMMUNICATIONS

PHYSICAL REVIEW C **79**, 011301(R) (2009)

Spherical proton-neutron structure of isomeric states in ^{128}Cd

L. Cáceres,[1,2,*] M. Górska,[1] A. Jungclaus,[2,3] M. Pfützner,[4] H. Grawe,[1] F. Nowacki,[5] K. Sieja,[1] S. Pietri,[6,†] D. Rudolph,[7] Zs. Podolyák,[6] P. H. Regan,[6] E. Werner-Malento,[4,‡] P. Detistov,[8,§] S. Lalkovski,[8,9] V. Modamio,[2] J. Walker,[2] K. Andgren,[10] P. Bednarczyk,[1,11] J. Benlliure,[12] G. Benzoni,[13] A. M. Bruce,[9] E. Casarejos,[12] B. Cederwall,[10] F. C. L. Crespi,[13] P. Doornenbal,[1,14,‖] H. Geissel,[1] J. Gerl,[1] J. Grębosz,[1,11] B. Hadinia,[10] M. Hellström,[7] R. Hoischen,[1,7] G. Ilie,[14,15] A. Khaplanov,[10] M. Kmiecik,[11] I. Kojouharov,[1] R. Kumar,[16] N. Kurz,[1] A. Maj,[11] S. Mandal,[17] F. Montes,[1,¶] G. Martínez-Pinedo,[1] S. Myalski,[11] W. Prokopowicz,[1] H. Schaffner,[1] G. S. Simpson,[18] S. J. Steer,[6] S. Tashenov,[1] O. Wieland,[13] and H. J. Wollersheim[1]

PRL **99,** 132501 (2007) PHYSICAL REVIEW LETTERS week ending 28 SEPTEMBER 2007

Observation of Isomeric Decays in the *r*-Process Waiting-Point Nucleus $^{130}Cd_{82}$

A. Jungclaus,[1] L. Cáceres,[1,2] M. Górska,[2] M. Pfützner,[3] S. Pietri,[4] E. Werner-Malento,[3] H. Grawe,[2] K. Langanke,[2] G. Martínez-Pinedo,[2] F. Nowacki,[5] A. Poves,[1] J. J. Cuenca-García,[2] D. Rudolph,[6] Z. Podolyak,[4] P. H. Regan,[4] P. Detistov,[7] S. Lalkovski,[8,7] V. Modamio,[1] J. Walker,[1] P. Bednarczyk,[2,9] P. Doornenbal,[2] H. Geissel,[2] J. Gerl,[2] J. Grebosz,[2,9] I. Kojouharov,[2] N. Kurz,[2] W. Prokopowicz,[2] H. Schaffner,[2] H. J. Wollersheim,[2] K. Andgren,[10] J. Benlliure,[11] G. Benzoni,[12] A. M. Bruce,[8] E. Casarejos,[11] B. Cederwall,[10] F. C. L. Crespi,[12] B. Hadinia,[10] M. Hellström,[6] R. Hoischen,[6,2] G. Ilie,[13,14] J. Jolie,[13] A. Khaplanov,[10] M. Kmiecik,[9] R. Kumar,[15] A. Maj,[9] S. Mandal,[16] F. Montes,[2] S. Myalski,[9] G. S. Simpson,[17] S. J. Steer,[4] S. Tashenov,[2] and O. Wieland[12]

RAPID COMMUNICATIONS

PHYSICAL REVIEW C **79**, 031305(R) (2009)

Weakly deformed oblate structures in $^{198}_{76}Os_{122}$

Zs. Podolyák,[1,*] S. J. Steer,[1] S. Pietri,[1] F. R. Xu,[2] H. L. Liu,[2] P. H. Regan,[1] D. Rudolph,[3] A. B. Garnsworthy,[1,4] R. Hoischen,[3,5] M. Górska,[5] J. Gerl,[5] H. J. Wollersheim,[5] T. Kurtukian-Nieto,[6] G. Benzoni,[7] T. Shizuma,[1,8] F. Becker,[5] P. Bednarczyk,[5,9] L. Caceres,[5,10] P. Doornenbal,[5] H. Geissel,[5] J. Gręboszˇ,[5,9] A. Kelic,[5] I. Kojouharov,[5] N. Kurz,[5] F. Montes,[5] W. Prokopowicz,[5,9] T. Saito,[5] H. Schaffner,[5] S. Tashenov,[5] A. Heinz,[4] M. Pfützner,[11] A. Jungclaus,[10] D. L. Balabanski,[12] C. Brandau,[1] A. M. Bruce,[13] W. N. Catford,[1] I. J. Cullen,[1] Zs. Dombrádi,[14] E. Estevez,[6] W. Gelletly,[1] G. Ilie,[15] J. Jolie,[15] G. A. Jones,[1] M. Kmiecik,[9] F. G. Kondev,[16] R. Krücken,[17] S. Lalkovski,[13] Z. Liu,[1] A. Maj,[9] S. Myalski,[9] S. Schwertel,[17] P. M. Walker,[1] E. Werner-Malento,[5,18] and O. Wieland[7]

and some more...

Eur. Phys. J. A **36**, 131–138 (2008)
DOI 10.1140/epja/i2008-10587-4

THE EUROPEAN PHYSICAL JOURNAL A

Regular Article – Experimental Physics

Evidence for an isomeric $3/2^-$ state in ^{53}Co

D. Rudolph[1,a], R. Hoischen[1,2], M. Hellström[1], S. Pietri[3], Zs. Podolyák[3], P.H. Regan[3], A.B. Garnsworthy[3,4], S.J. Steer[3], F. Becker[2,b], P. Bednarczyk[2,5], L. Cáceres[2,6], P. Doornenbal[2,7,c], J. Gerl[2], M. Górska[2], J. Grębosz[5,2], I. Kojouharov[2], N. Kurz[2], W. Prokopowicz[2,5], H. Schaffner[2], H.J. Wollersheim[2], L.-L. Andersson[1], L. Atanasova[8], D.L. Balabanski[8,9], M.A. Bentley[10], A. Blazhev[7], C. Brandau[2,3], J.R. Brown[10], C. Fahlander[1], E.K. Johansson[1], and A. Jungclaus[6]

Physics Letters B 672 (2009) 313–316

Contents lists available at ScienceDirect

Physics Letters B

www.elsevier.com/locate/physletb

Evolution of the $N = 82$ shell gap below ^{132}Sn inferred from core excited states in ^{131}In

M. Górska[a,*], L. Cáceres[a,b], H. Grawe[a], M. Pfützner[c], A. Jungclaus[b,d], S. Pietri[e,1], E. Werner-Malento[c,2], Z. Podolyák[e], P.H. Regan[e], D. Rudolph[f], P. Detistov[g], S. Lalkovski[g,h], V. Modamio[b], J. Walker[b], T. Beck[a], P. Bednarczyk[a,i], P. Doornenbal[a,j,3], H. Geissel[a], J. Gerl[a], J. Grębosz[a,i], R. Hoischen[f,a], I. Kojouharov[a], N. Kurz[a], W. Prokopowicz[a,i], H. Schaffner[a], H. Weick[a], H.-J. Wollersheim[a], K. Andgren[k], J. Benlliure[l], G. Benzoni[m], A.M. Bruce[h], E. Casarejos[l], B. Cederwall[k], F.C. L. Crespi[m], B. Hadinia[f], M. Hellström[f], G. Ilie[j,n], A. Khaplanov[k], M. Kmiecik[i], R. Kumar[o], A. Maj[i], S. Mandal[p], F. Montes[a], S. Myalski[i], G.S. Simpson[q], S.J. Steer[e], S. Tashenov[a], O. Wieland[m], Zs. Dombrádi[r], P. Reiter[j], D. Sohler[r]

Physics Letters B 672 (2009) 116–119

Contents lists available at ScienceDirect

Physics Letters B

www.elsevier.com/locate/physletb

Proton–hole excitation in the closed shell nucleus ^{205}Au

Zs. Podolyák[a,*], G.F. Farrelly[a], P.H. Regan[a], A.B. Garnsworthy[a], S.J. Steer[a], M. Górska[b], J. Benlliure[c], E. Casarejos[c], S. Pietri[a], J. Gerl[b], H.J. Wollersheim[b], R. Kumar[d], F. Molina[e], A. Algora[e,f], N. Alkhomashi[a], G. Benzoni[g], A. Blazhev[h], P. Boutachkov[b], A.M. Bruce[i], L. Caceres[b,j], I.J. Cullen[a], A.M. Denis Bacelar[i], P. Doornenbal[b], M.E. Estevez[c], Y. Fujita[k], W. Gelletly[a], H. Geissel[b], H. Grawe[b], J. Grębosz[b,l], R. Hoischen[m,b], I. Kojouharov[b], S. Lalkovski[i], Z. Liu[a], K.H. Maier[n,l], C. Mihai[o], D. Mücher[h], B. Rubio[e], H. Schaffner[b], A. Tamii[k], S. Tashenov[b], J.J. Valiente-Dobón[p], P.M. Walker[a], P.J. Woods[q]

Available online at www.sciencedirect.com

ScienceDirect

Physics Letters B 660 (2008) 326–330

PHYSICS LETTERS B

www.elsevier.com/locate/physletb

Neutron–proton pairing competition in $N = Z$ nuclei: Metastable state decays in the proton dripline nuclei $^{82}_{41}$Nb and $^{86}_{43}$Tc

A.B. Garnsworthy[a,b,*], P.H. Regan[a], L. Cáceres[c,d], S. Pietri[a], Y. Sun[e,f], D. Rudolph[g], M. Górska[c], Zs. Podolyák[a], S.J. Steer[a], R. Hoischen[c,g], A. Heinz[b], F. Becker[c], P. Bednarczyk[c,h], P. Doornenbal[c], H. Geissel[c], J. Gerl[c], H. Grawe[c], J. Grębosz[c,h], A. Kelic[c], I. Kojouharov[c], N. Kurz[c], F. Montes[c], W. Prokopowicz[c], T. Saito[c], H. Schaffner[c], S. Tachenov[c], E. Werner-Malento[c,i], H.J. Wollersheim[c], G. Benzoni[j], B.B. Blank[k], C. Brandau[a,c], A.M. Bruce[l], F. Camera[j], W.N. Catford[a], I.J. Cullen[a], Zs. Dombrádi[m], E. Estevez[n], W. Gelletly[a], G. Ilie[o,p], J. Jolie[o], G.A. Jones[a], A. Jungclaus[d], M. Kmiecik[h], F.G. Kondev[q], T. Kurtukian-Nieto[k,n], S. Lalkovski[l,r], Z. Liu[a], A. Maj[h], S. Myalski[h], M. Pfützner[i], S. Schwertel[s], T. Shizuma[a,t], A.J. Simons[a,u], P.M. Walker[a], O. Wieland[j], F.R. Xu[v]

and some more… 4 in Dec ‘09 PRC

PHYSICAL REVIEW C **80**, 064308 (2009)

β^--delayed spectroscopy of neutron-rich tantalum nuclei: Shape evolution in neutron-rich tungsten isotopes

N. Alkhomashi,[1,*] P. H. Regan,[1] Zs. Podolyák,[1] S. Pietri,[1] A. B. Garnsworthy,[1] S. J. Steer,[1] J. Benlliure,[2] E. Caserejos,[2] R. F. Casten,[3] J. Gerl,[4] H. J. Wollersheim,[4] J. Grebosz,[5] G. Farrelly,[1] M. Górska,[4] I. Kojouharov,[4] H. Schaffner,[4] A. Algora,[6,7] G. Benzoni,[8] A. Blazhev,[9] P. Boutachkov,[4] A. M. Bruce,[10] A. M. Denis Bacelar,[10] I. J. Cullen,[1] L. Cáceres,[4] P. Doornenbal,[4] M. E. Estevez,[2] Y. Fujita,[11] W. Gelletly,[1] R. Hoischen,[4,12] R. Kumar,[13] N. Kurz,[4] S. Lalkovski,[10] Z. Liu,[14] C. Mihai,[15] F. Molina,[6] A. I. Morales,[2] D. Mücher,[9] W. Prokopowicz,[4] B. Rubio,[6] Y. Shi,[16] A. Tamii,[17] S. Tashenov,[4] J. J. Valiente-Dobón,[18] P. M. Walker,[1] P. J. Woods,[14] and F. R. Xu[16]

RAPID COMMUNICATIONS

PHYSICAL REVIEW C **80**, 061302(R) (2009)

Nuclear structure “southeast” of ^{208}Pb: Isomeric states in ^{208}Hg and ^{209}Tl

N. Al-Dahan,[1,2] Zs. Podolyák,[1,*] P. H. Regan,[1] M. Górska,[3] H. Grawe,[3] K. H. Maier,[4] J. Gerl,[3] S. B. Pietri,[3] H. J. Wollersheim,[3] N. Alkhomashi,[1] A. Y. Deo,[1] A. M. Denis Bacelar,[5] G. Farrelly,[1] S. J. Steer,[1] A. M. Bruce,[5] P. Boutachkov,[3] C. Domingo-Pardo,[3] A. Algora,[6,7] J. Benlliure,[8] A. Bracco,[9] E. Calore,[10] E. Casarejos,[8] I. J. Cullen,[1] P. Detistov,[11] Zs. Dombrádi,[7] M. Doncel,[12] F. Farinon,[3] W. Gelletly,[1] H. Geissel,[3] N. Goel,[3] J. Grebosz,[4] R. Hoischen,[3,13] I. Kojouharov,[3] N. Kurz,[3] S. Lalkovski,[5] S. Leoni,[14] F. Molina,[6] D. Montanari,[9] A. I. Morales,[8] A. Musumarra,[3,15] D. R. Napoli,[10] R. Nicolini,[9] C. Nociforo,[3] A. Prochazka,[3] W. Prokopowicz,[3] B. Rubio,[6] D. Rudolph,[3,13] H. Schaffner,[3] P. Strmen,[16] I. Szarka,[16] T. Swan,[1] J. S. Thomas,[1] J. J. Valiente-Dobón,[10] S. Verma,[8] P. M. Walker,[1] and H. Weick[3]

PHYSICAL REVIEW C **80**, 064303 (2009)

Isomeric states in neutron-deficient $A \sim 80$–90 nuclei populated in the fragmentation of ^{107}Ag

A. B. Garnsworthy,[1,2,*] P. H. Regan,[1] S. Pietri,[1] Y. Sun,[3] F. R. Xu,[4] D. Rudolph,[5] M. Górska,[6] L. Cáceres,[6,7] Zs. Podolyák,[1] S. J. Steer,[1] R. Hoischen,[5,6] A. Heinz,[2] F. Becker,[6] P. Bednarczyk,[6,8] P. Doornenbal,[6] H. Geissel,[6] J. Gerl,[6] H. Grawe,[6] J. Grębosz,[6,8] A. Kelic,[6] I. Kojouharov,[6] N. Kurz,[6] F. Montes,[6] W. Prokopwicz,[6] T. Saito,[6] H. Schaffner,[6] S. Tachenov,[6] E. Werner-Malento,[9,†] H. J. Wollersheim,[6] G. Benzoni,[10] B. Blank,[11] C. Brandau,[1] A. M. Bruce,[12] F. Camera,[10] W. N. Catford,[1] I. J. Cullen,[1] Zs. Dombrádi,[13] E. Estevez,[14] W. Gelletly,[1] G. Ilie,[15,16] J. Jolie,[15] G. A. Jones,[1] A. Jungclaus,[7,17] M. Kmiecik,[8] F. G. Kondev,[18] T. Kurtukian-Nieto,[14] S. Lalkovski,[12,19] Z. Liu,[1] A. Maj,[8] S. Myalski,[8] M. Pfützner,[9] S. Schwertel,[20] T. Shizuma,[1,21] A. J. Simons,[1,22] P. M. Walker,[1] and O. Wieland[10]

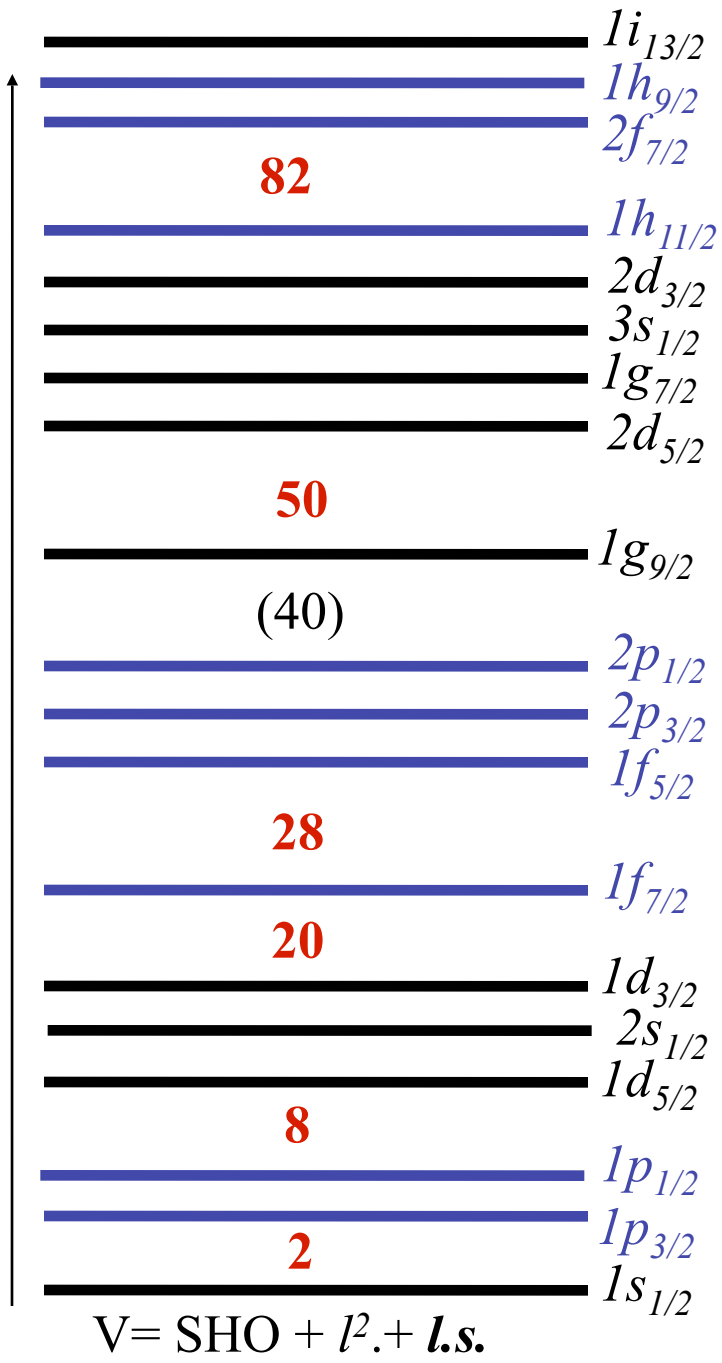
PHYSICAL REVIEW C **80**, 064608 (2009)

Population of low-seniority isomeric states of ^{206}Hg by two-proton knockout reactions at relativistic energies

E. C. Simpson, J. A. Tostevin, Zs. Podolyák, P. H. Regan, and S. J. Steer

Department of Physics, Faculty of Engineering and Physical Sciences, University of Surrey, Guildford, Surrey GU2 7XH, United Kingdom

(Received 5 October 2009; published 8 December 2009)



Basic, independent particle model (with very simple residual interactions added, such as δ - (contact) interaction) predicts large host of ***isomers in the vicinity of closed shells / magic numbers***.

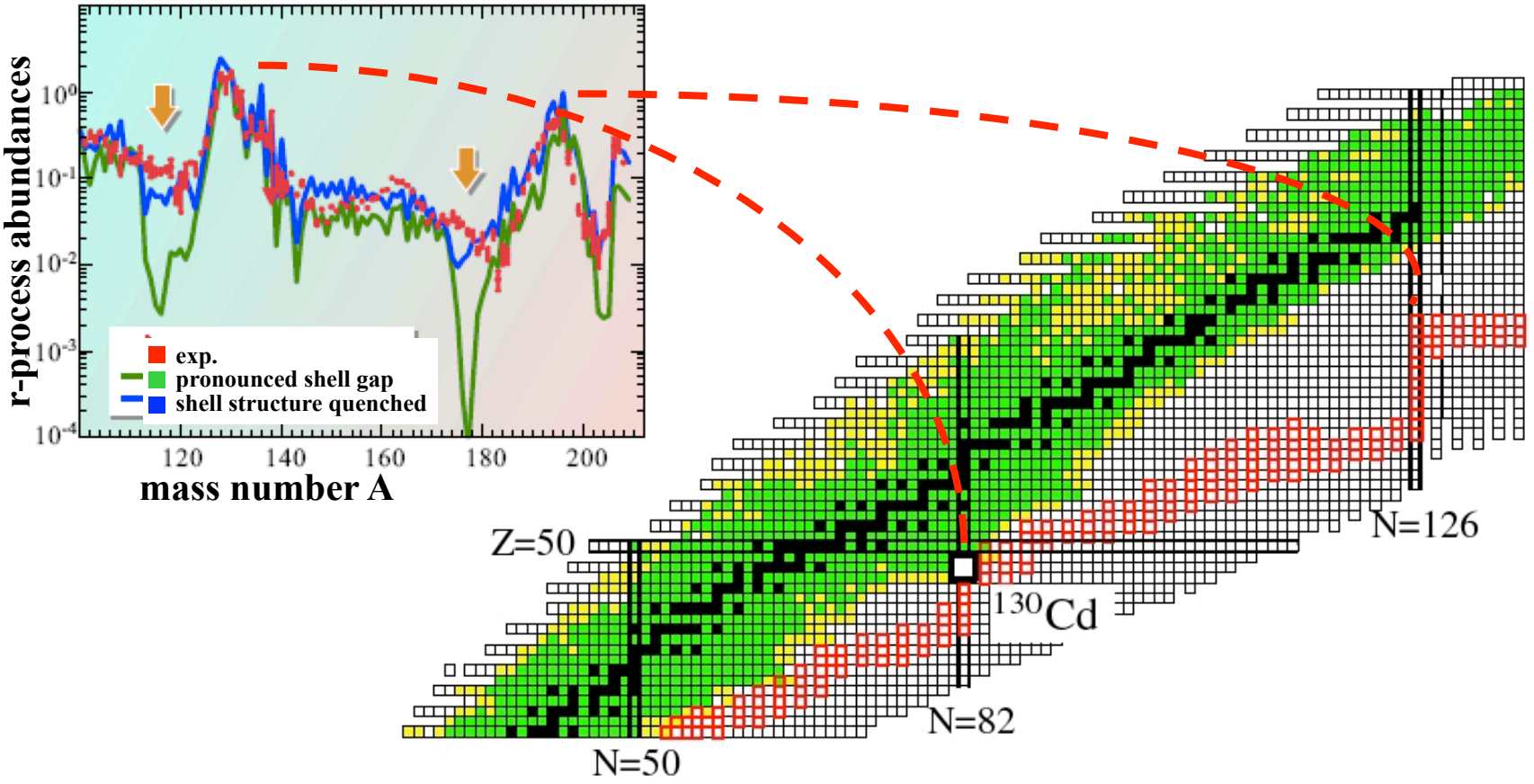
Two categories

1) **Spin-trap isomers** - from particularly favoured coupling of (often high-j intruder) particles gives rise to high-spin state at low excitation energy. This state 'has nowhere to decay to' unless decays by high multipolarity (thus slow) transition.

$$|J_i+J_f| > \Delta J > |J_i-J_f|$$

2) **Seniority isomers** – δ-interaction can demonstrate with geometric picture how (single) jn multiplet looks like j^2 multiplet. Small energy difference between J_{max} and $(J_{max}-2)$ states cause 'seniority isomers'.

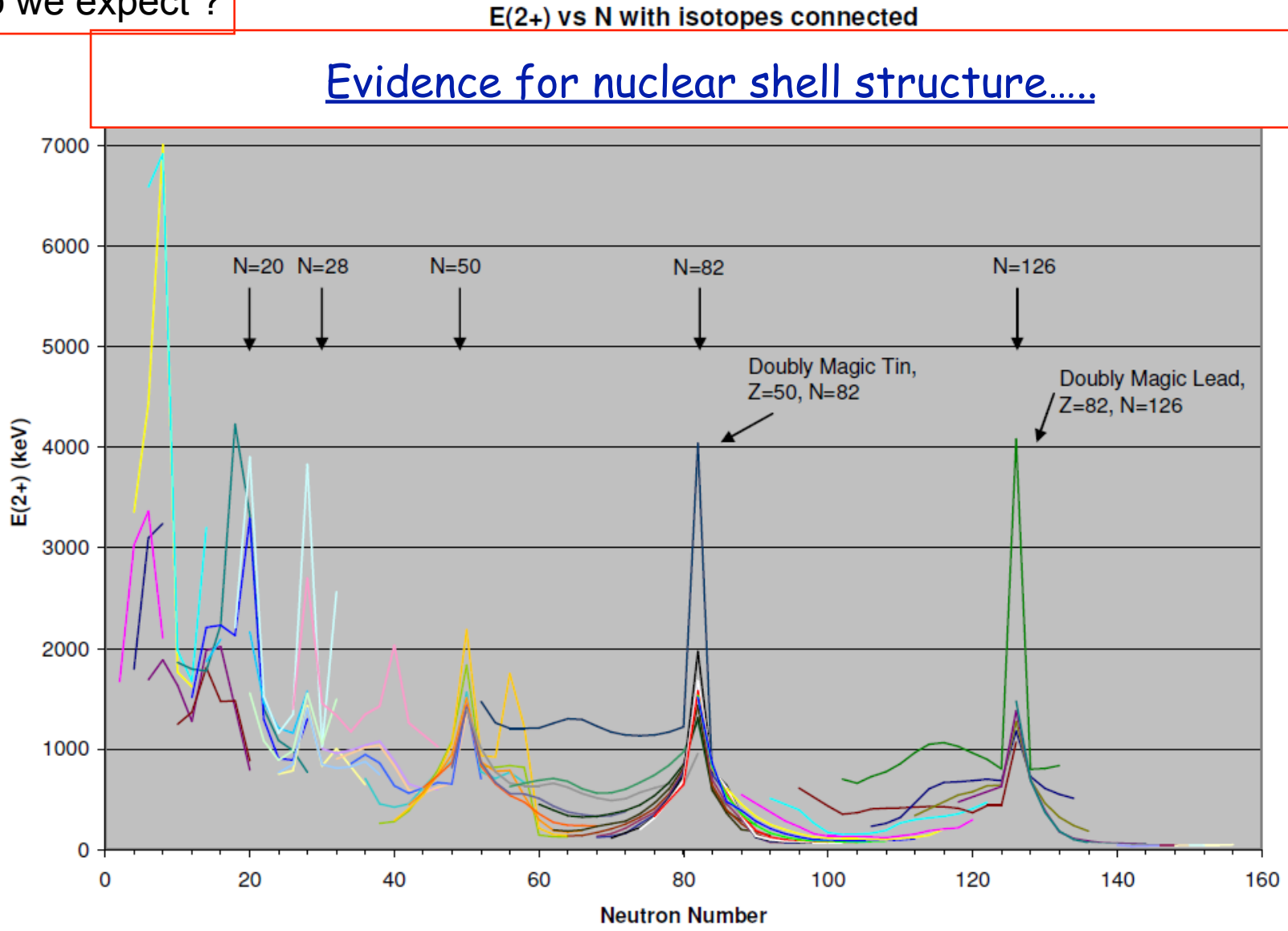
Physics….is there N=126 shell quenching ?

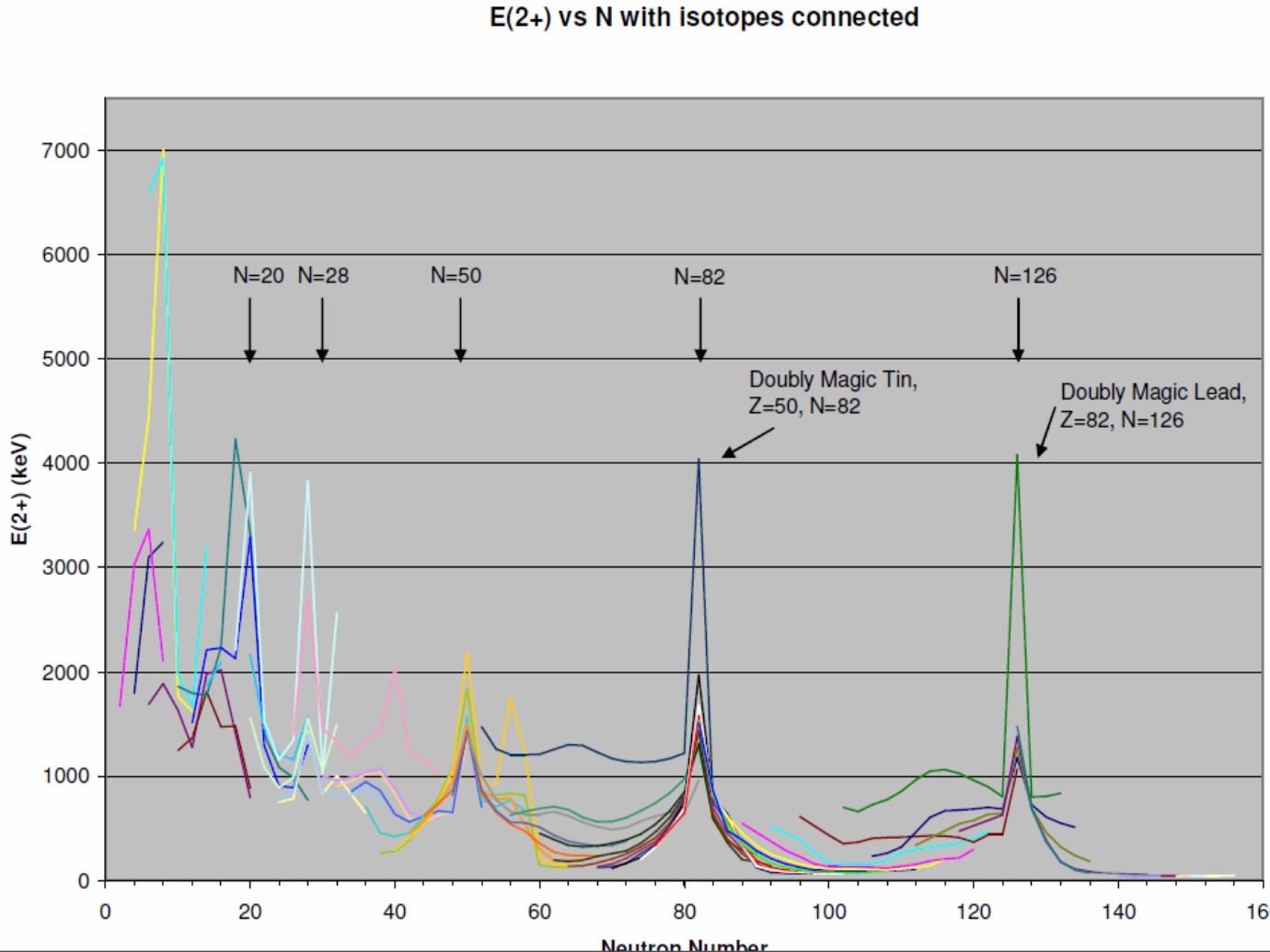


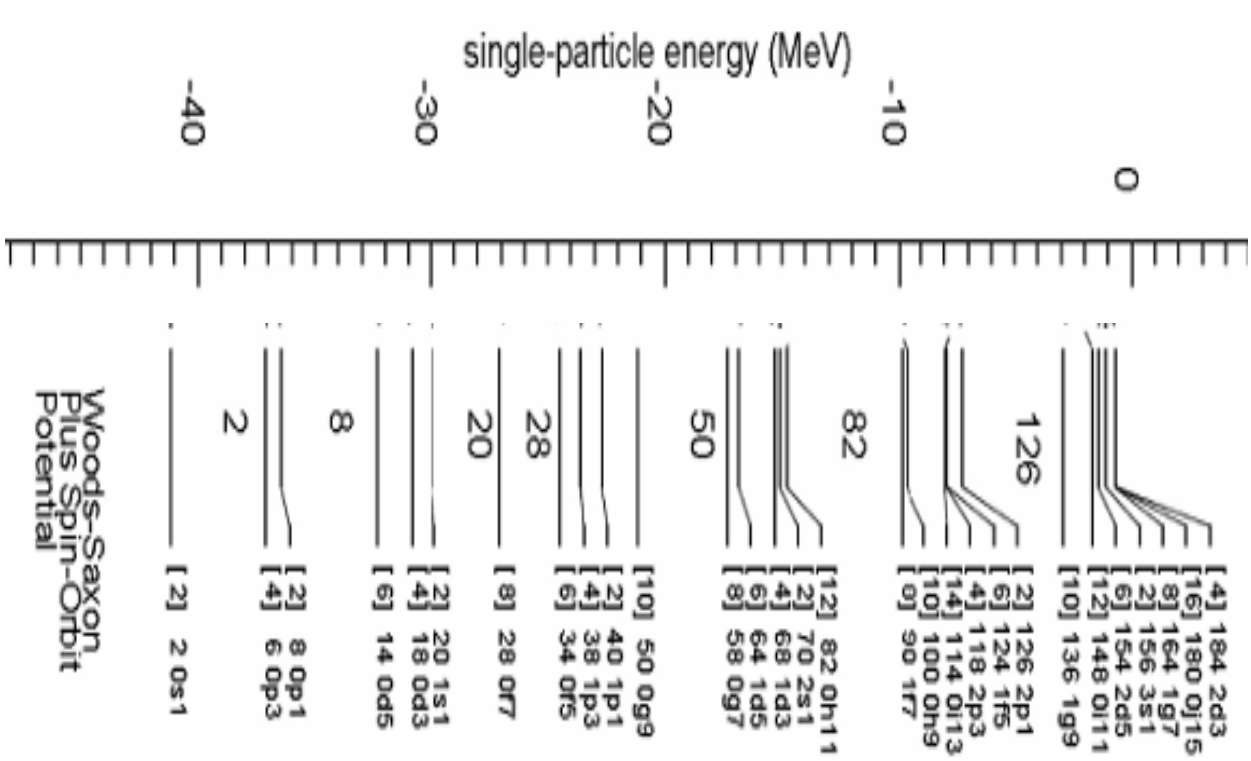
Assumption of a N=126 shell quenching leads to a considerable improvement in the global abundance fit in r-process calculations

What do we expect ?

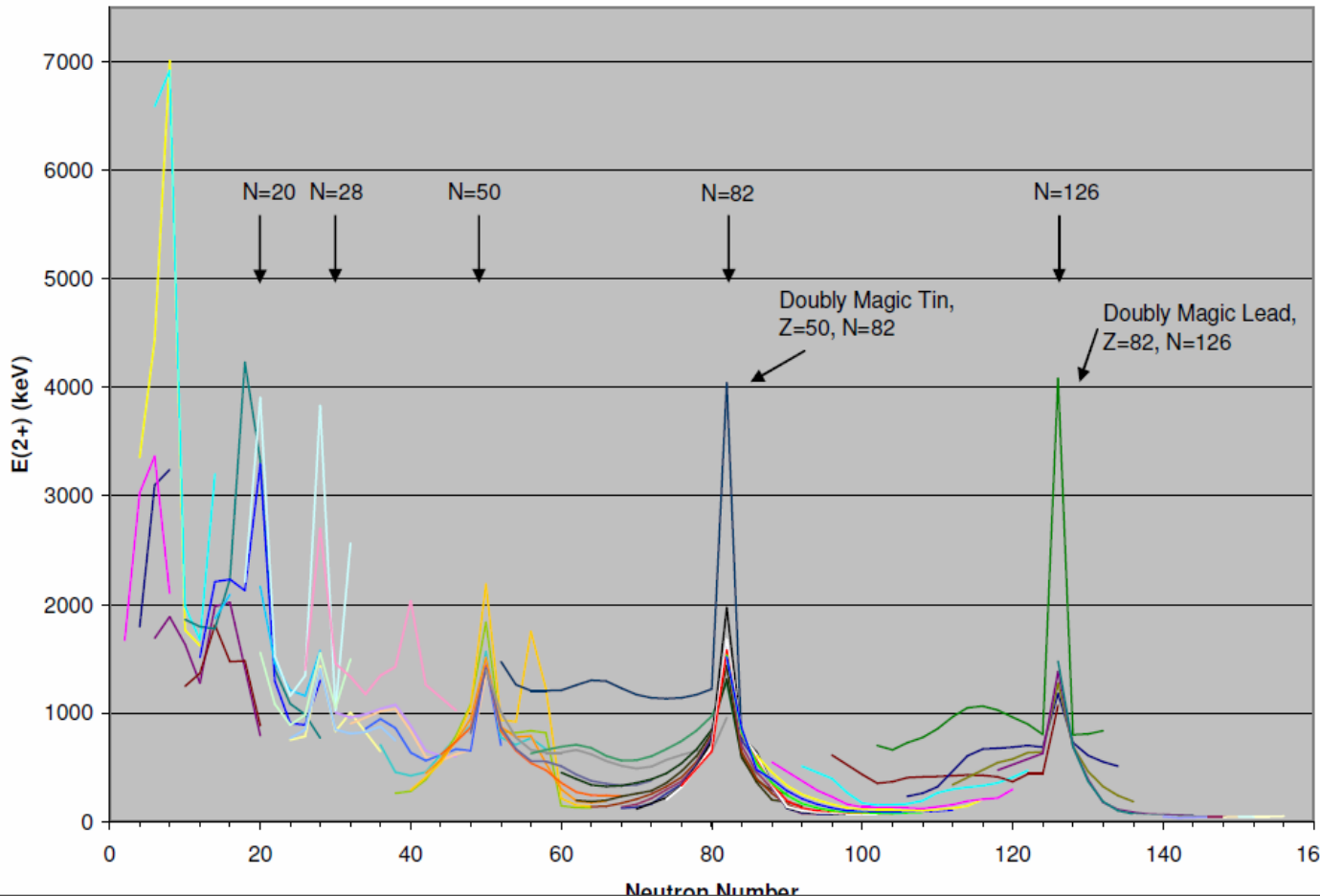
Evidence for nuclear shell structure.....

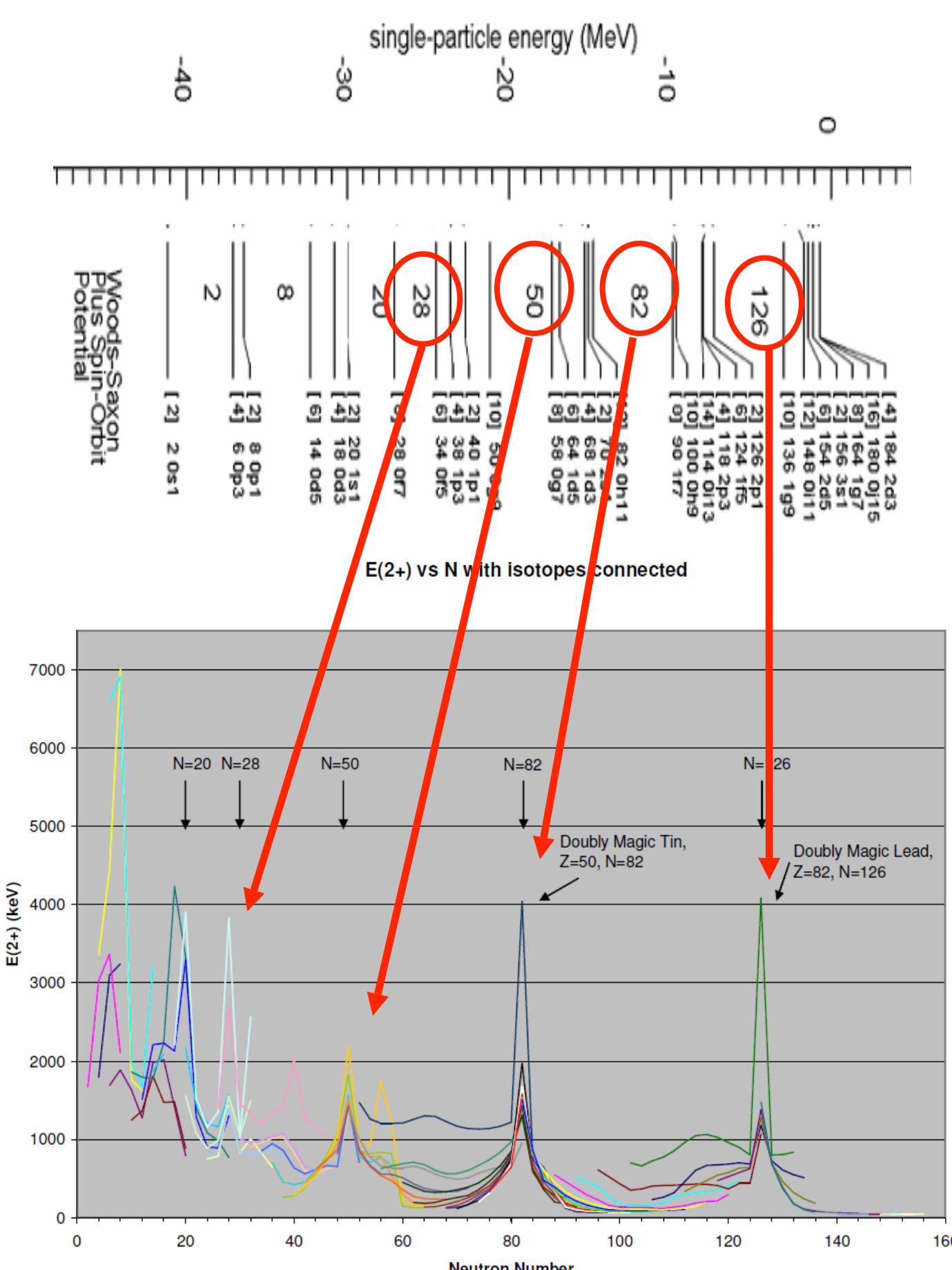


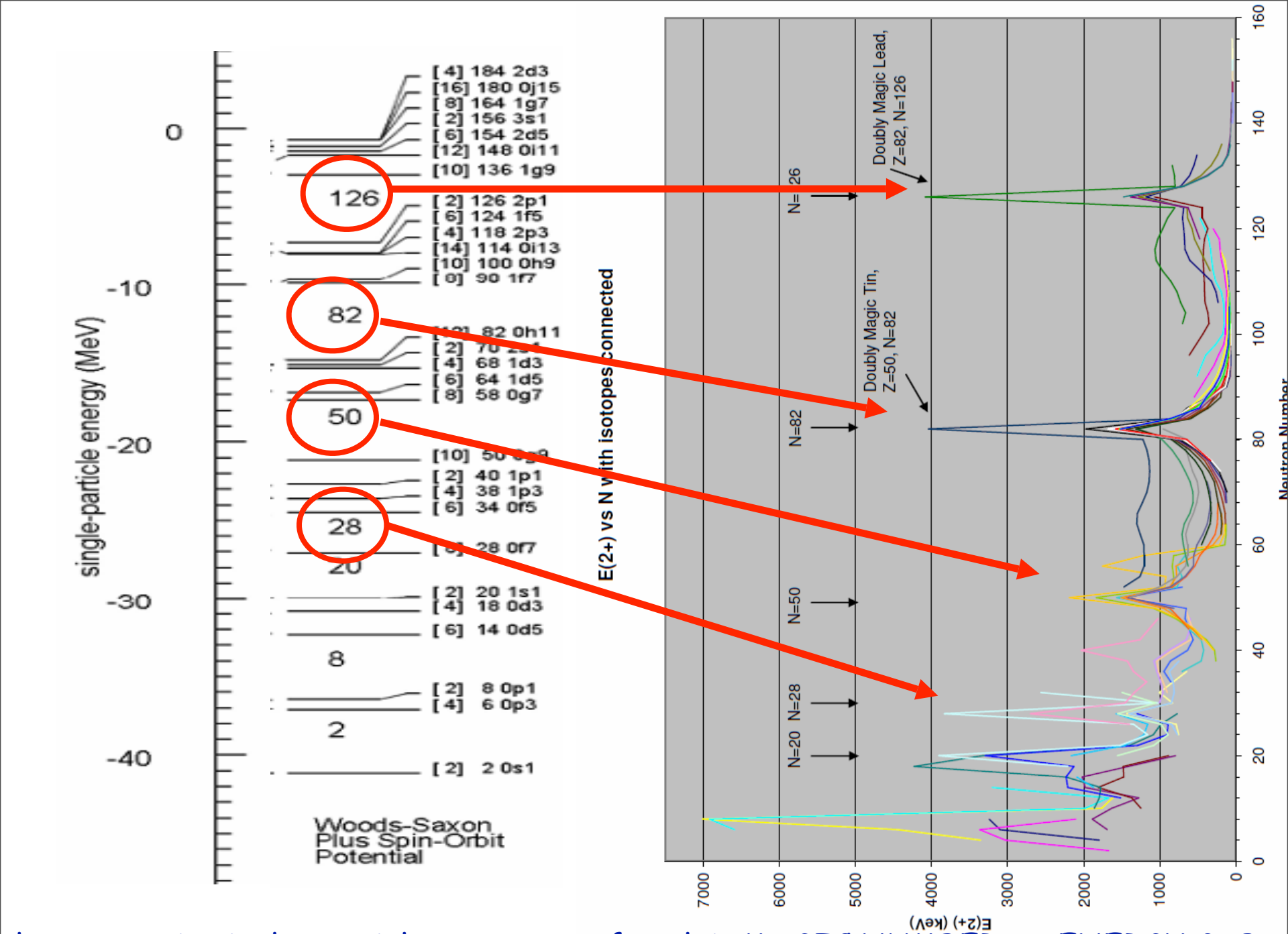

E(2+) vs N with isotopes connected
7000
6000
5000
4000
3000
2000
1000
0
E(2+) (keV)
N=20
N=28
N=50
N=82
N=126
Doubly Magic Tin,
Z=50, N=82
Doubly Magic Lead,
Z=82, N=126
0
20
40
60
80
100
120
140
160
Neutron Number



E(2+) vs N with isotopes connected




single-particle energy (MeV)
-40
-30
-20
-10
0
Woods-Saxon
Plus Spin-Orbit
Potential
2
8
20
28
50
82
126
[2] 2 0s1
[2] 8 0p1
[4] 6 0p3
[6] 14 0d5
[2] 20 1s1
[4] 18 0d3
[6] 34 0f5
[2] 40 1p1
[4] 38 1p3
[8] 58 0g7
[4] 68 1d3
[6] 64 1d5
[2] 126 2p1
[6] 124 1f5
[4] 118 2p3
[14] 114 0i13
[10] 100 0h9
[9] 90 1f7
[10] 136 1g9
[4] 184 2d3
[16] 180 0j15
[8] 164 1g7
[2] 156 3s1
[6] 154 2d5
[12] 148 0i11
E(2+) vs N with isotopes connected
7000
6000
5000
4000
3000
2000
1000
0
E(2+) (keV)
N=20
N=28
N=50
N=82
N=126
Doubly Magic Tin,
Z=50, N=82
Doubly Magic Lead,
Z=82, N=126
0
20
40
60
80
100
120
140
160
Neutron Number



large gaps in single-particle structure of nuclei…MAGIC NUMBERS = ENERGY GAPS

Table 1 -- Nuclear Shell Structure (from *Elementary Theory of Nuclear Shell Structure*, Maria Goeppert Mayer & J. Hans D. Jensen, John Wiley & Sons, Inc., New York, 1955.)

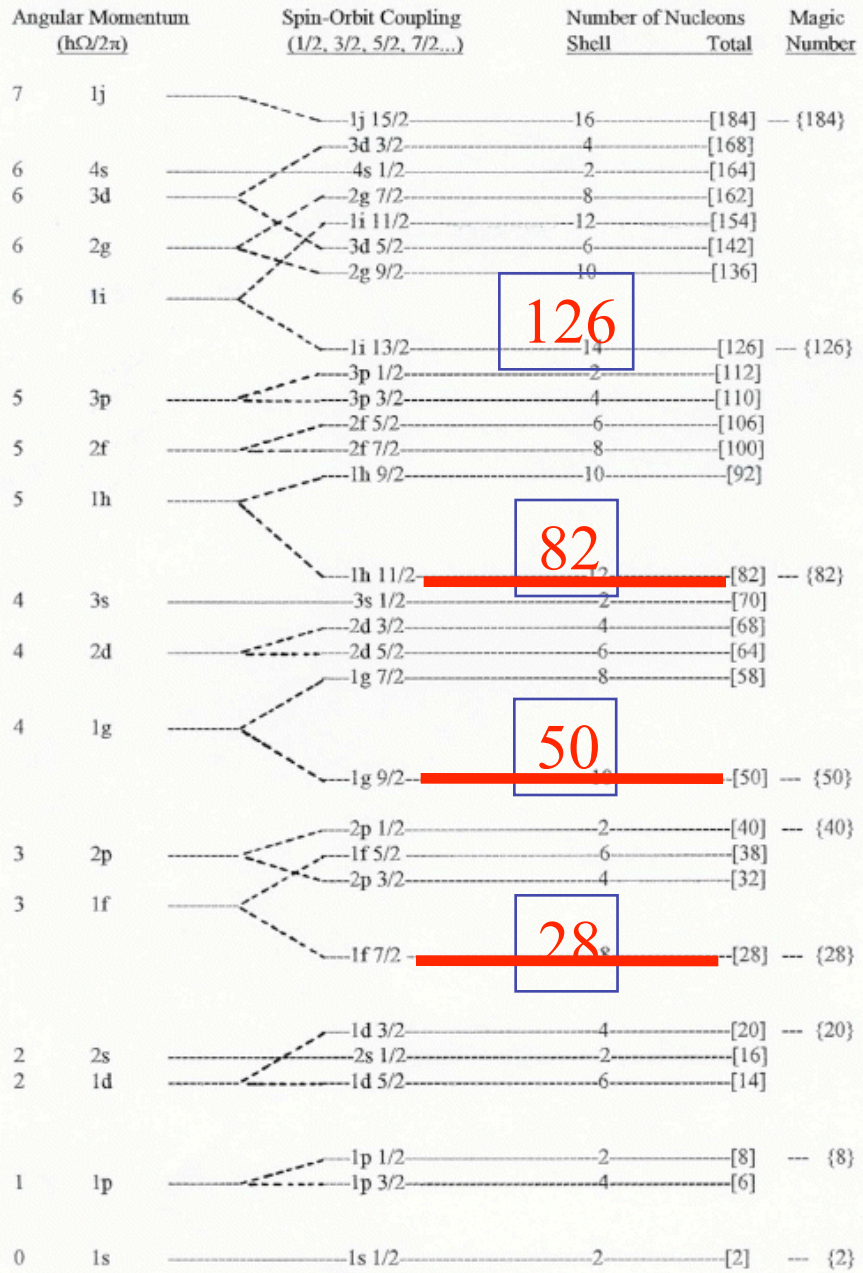
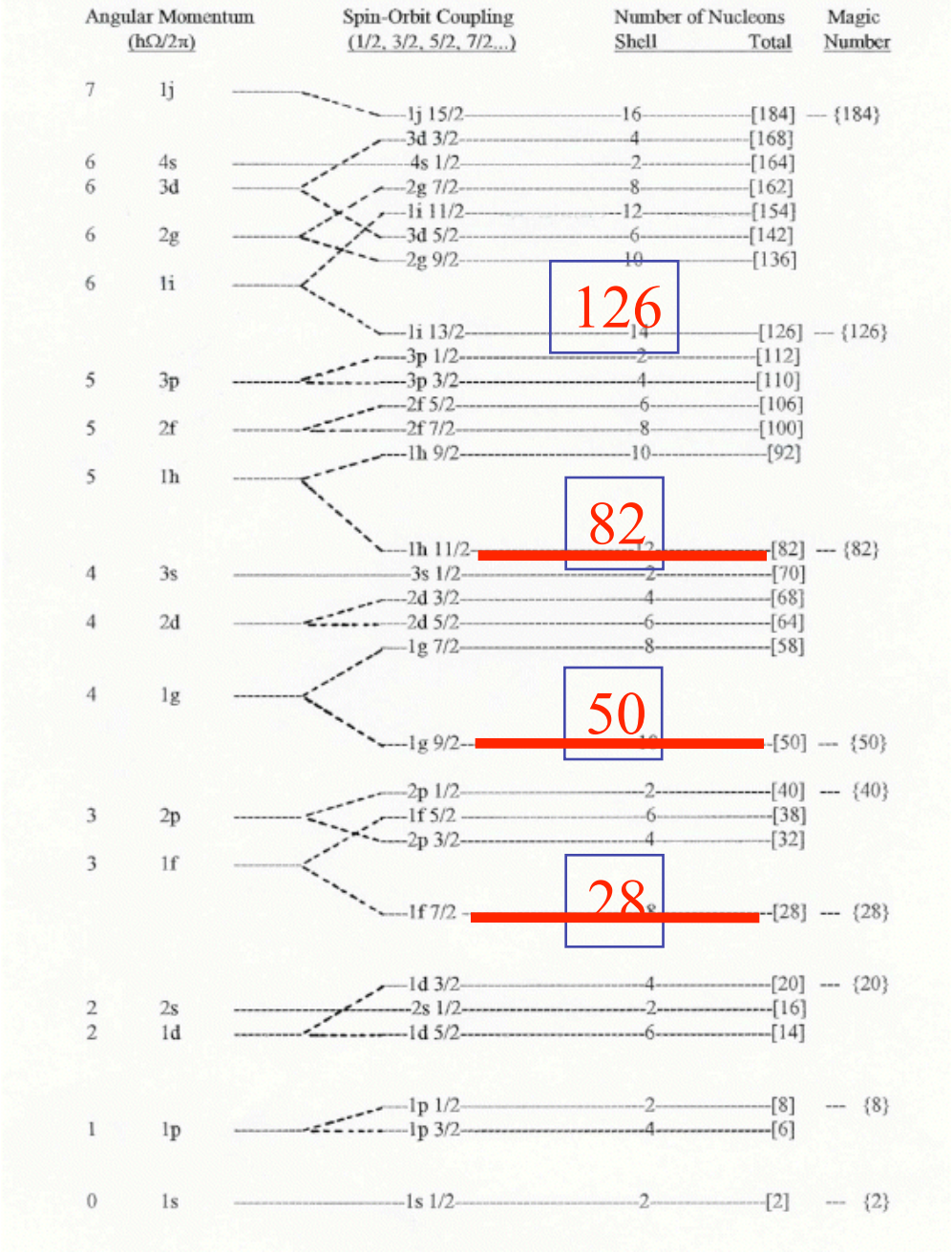


Table 1 -- Nuclear Shell Structure (from *Elementary Theory of Nuclear Shell Structure*, Maria Goeppert Mayer & J. Hans D. Jensen, John Wiley & Sons, Inc., New York, 1955.)



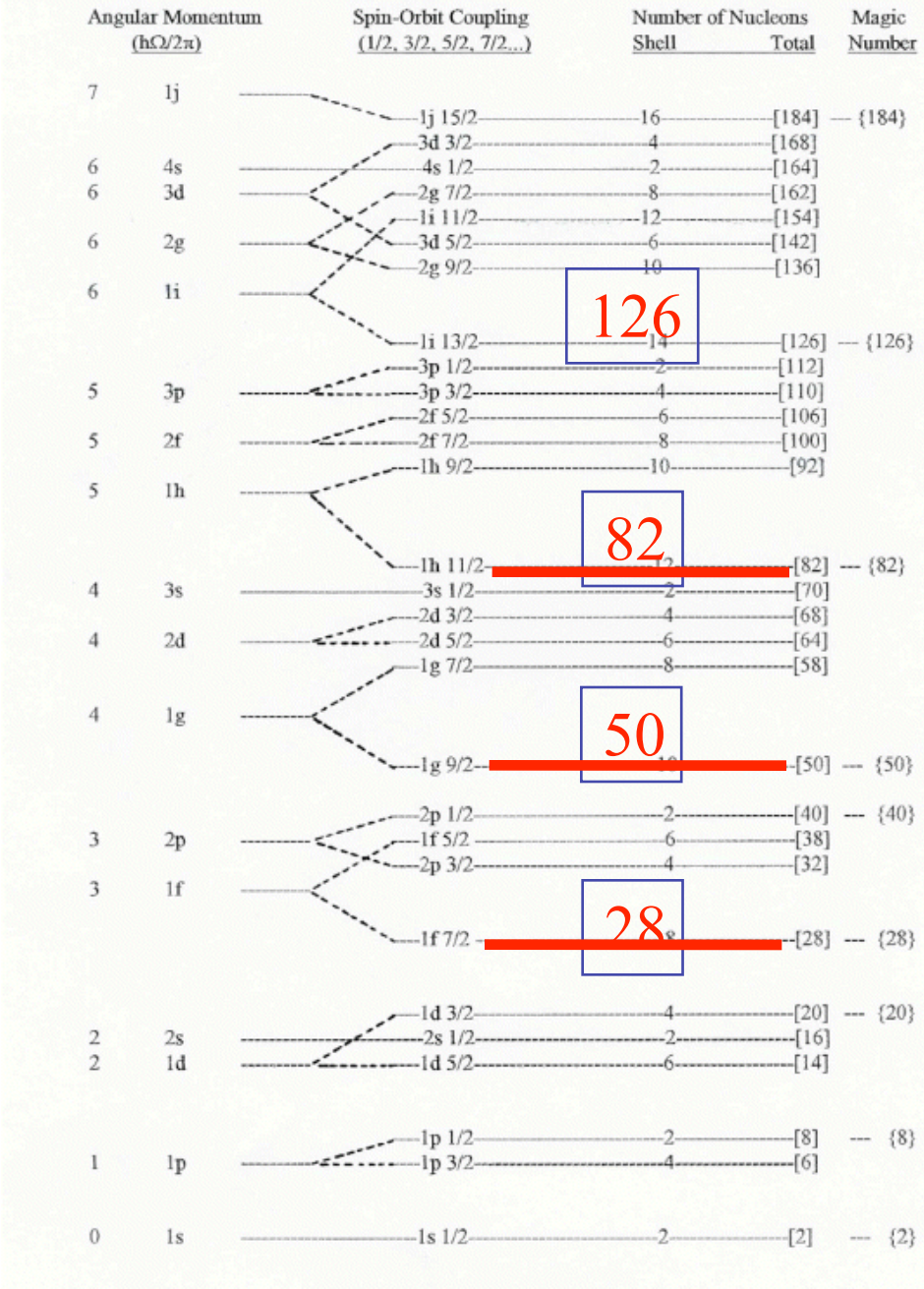
Study the evolution of shell structure as a function of N:Z ratio.

^{208}Pb (Z=82, N=126)

^{132}Sn (Z=50, N=82)

^{56}Ni (Z=28, N=28)

Table 1 -- Nuclear Shell Structure (from *Elementary Theory of Nuclear Shell Structure*, Maria Goeppert Mayer & J. Hans D. Jensen, John Wiley & Sons, Inc., New York, 1955.)



Study the evolution of shell structure as a function of N:Z ratio.

^{208}Pb (Z=82, N=126)

^{132}Sn (Z=50, N=82)

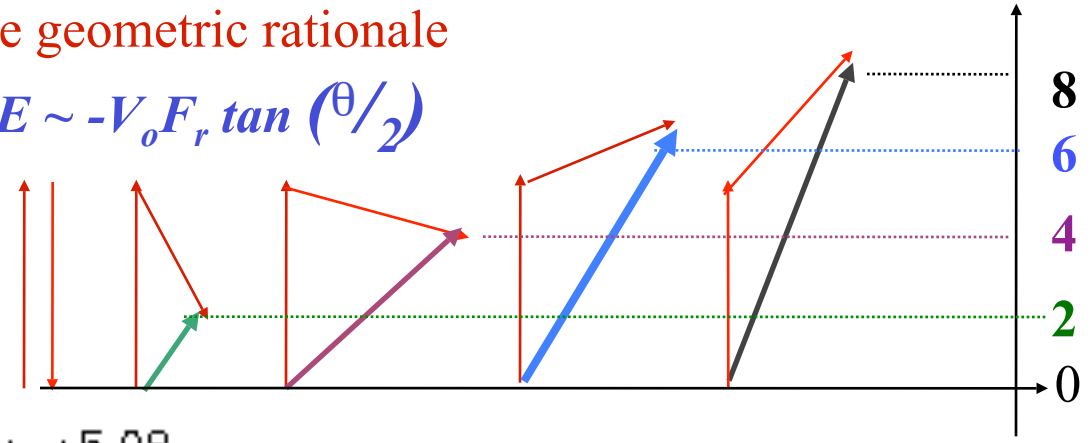
^{56}Ni (Z=28, N=28)

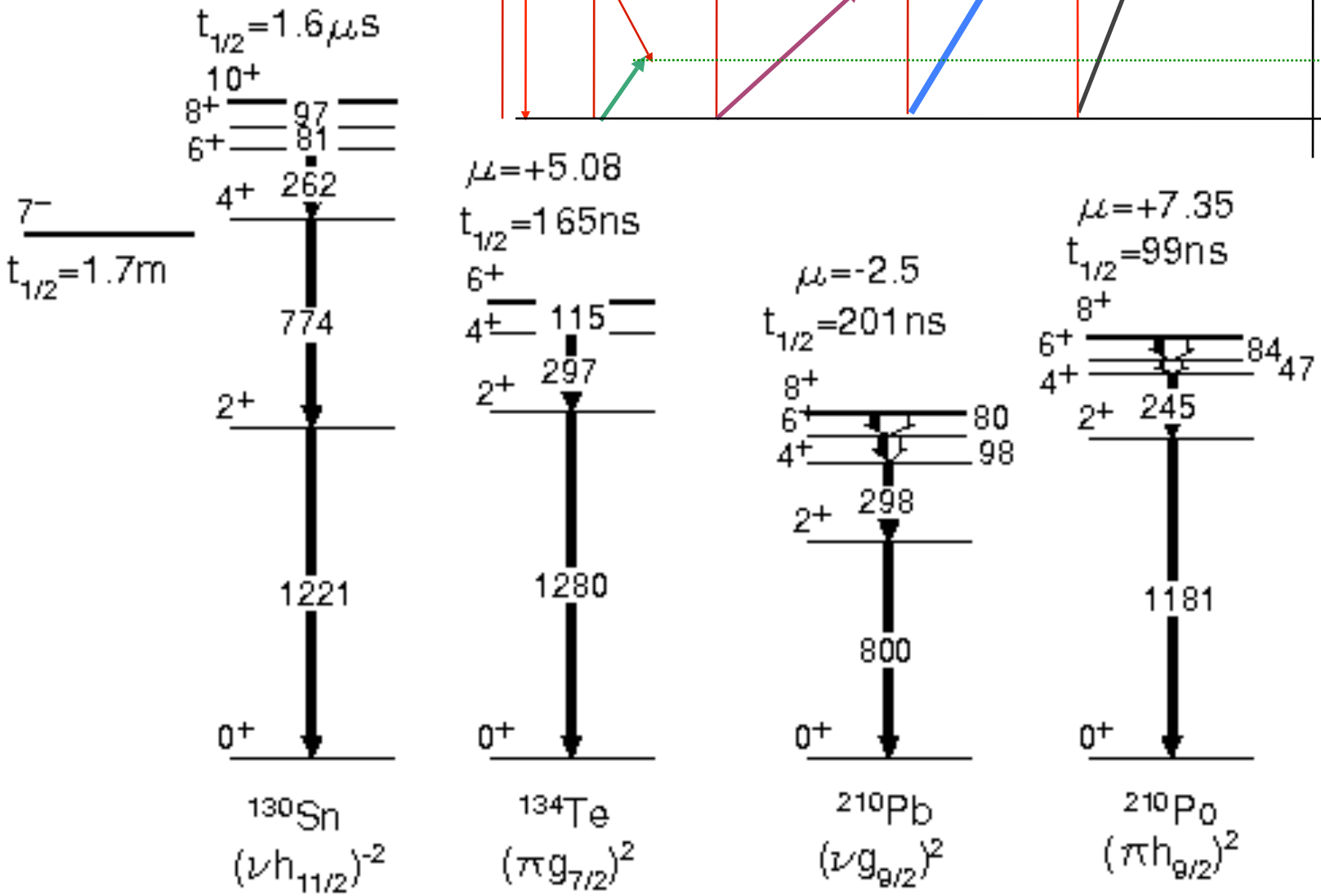
(Proton) holes in high-j intruders ($f_{7/2}$, $g_{9/2}$ & $h_{11/2}$) gives rise to seniority isomers' at magic shells.

δ–interaction gives nice simple geometric rationale

for **Seniority Isomers** from $\Delta E \sim -V_o F_r \tan(\theta/2)$

for $T=1$, even J

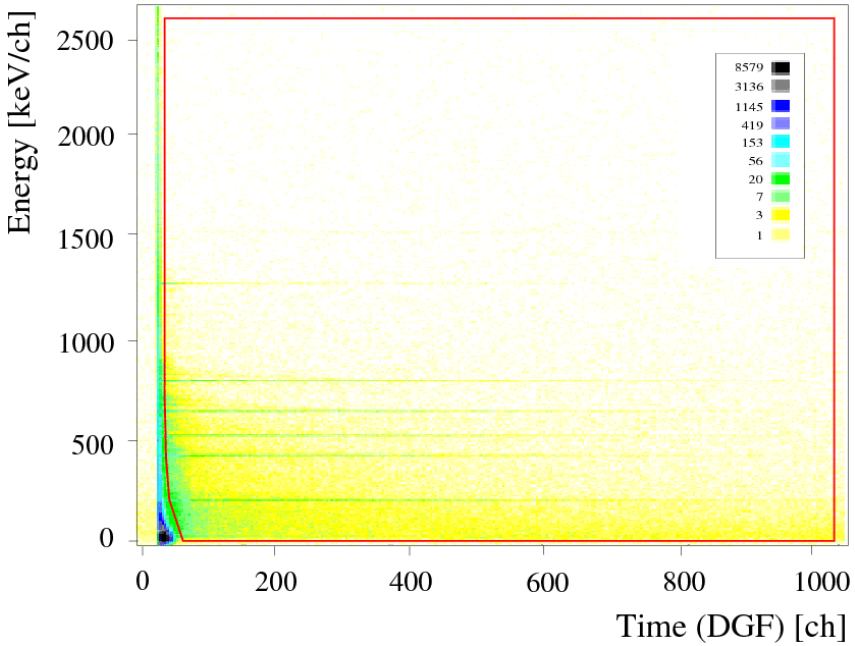




$Z < 50$; $N \sim 82$

^{128}Cd

L. Caceres et al., PRC 79 011301(R) 2009



T. Kautzsch et al., Eur. Phys. J. A 25, 117 (2005)
N. Hoteling et al., Phys. Rev. C 76, 044324 (2007)

3.29×10^5 identified ions

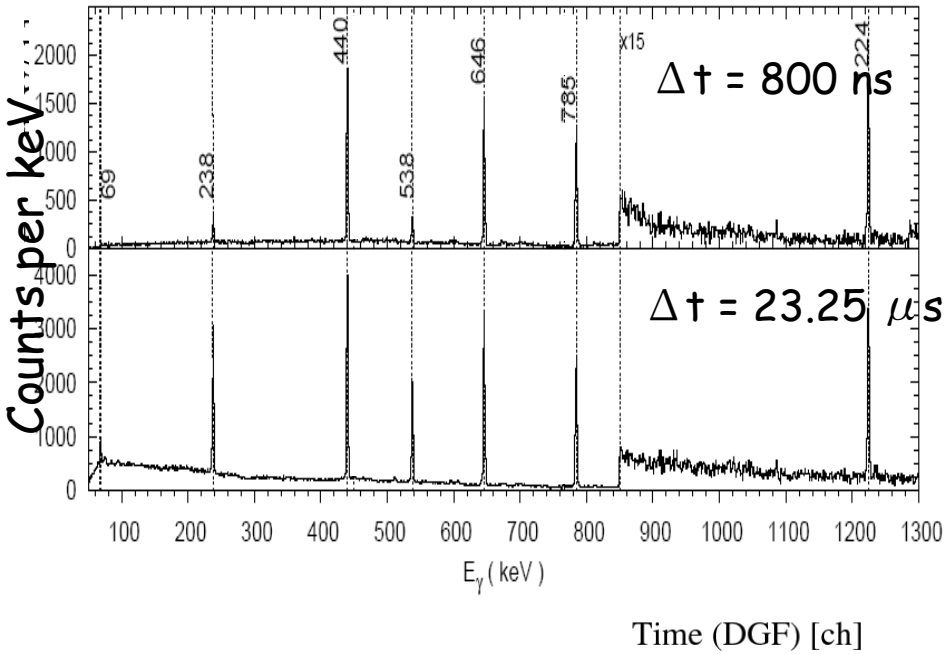
Fragmentation

+

Fission

^{128}Cd

L. Caceres et al., PRC 79 011301(R) 2009



T. Kautzsch et al., Eur. Phys. J. A 25, 117 (2005)
N. Hoteling et al., Phys. Rev. C 76, 044324 (2007)

3.29×10^5 identified ions

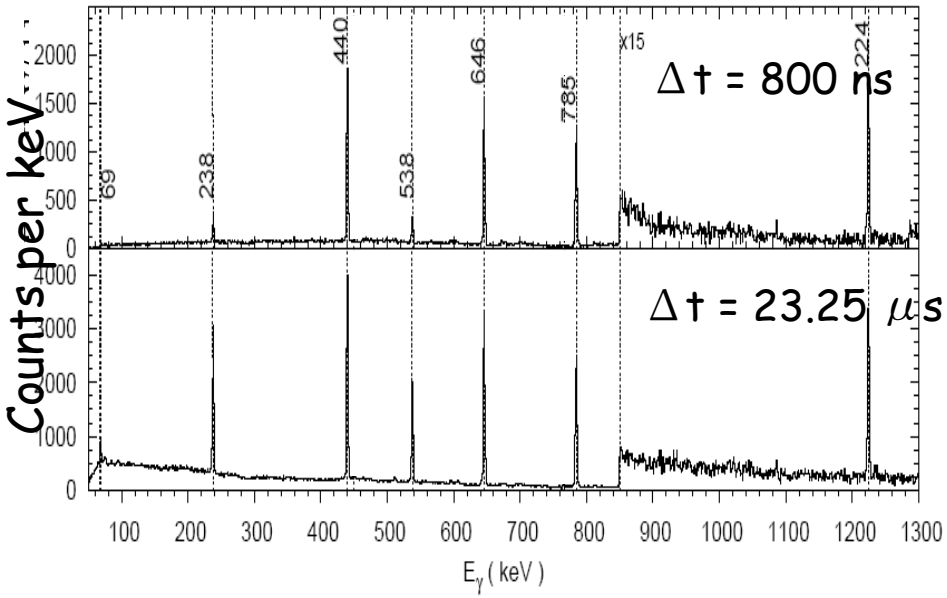
Fragmentation

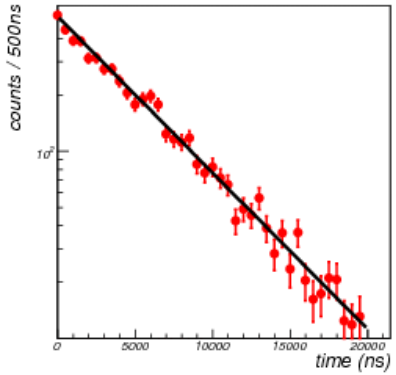
+

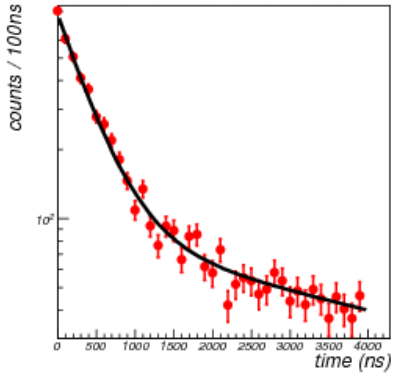
Fission

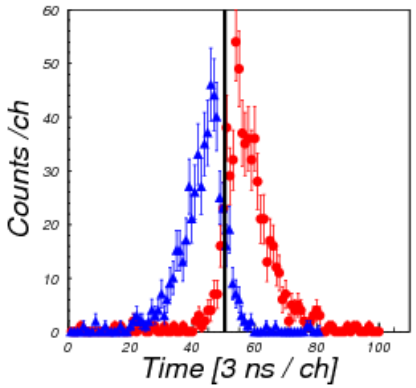
^{128}Cd

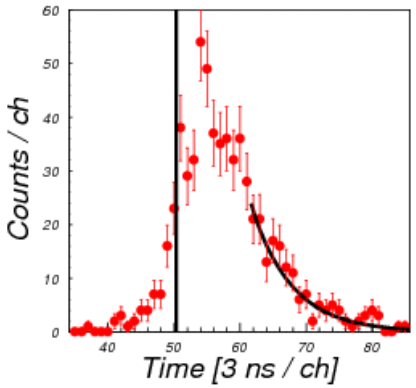
L. Caceres et al., PRC 79 011301(R) 2009











Time (DGF) [ch]

T. Kautzsch et al., Eur. Phys. J. A 25, 117 (2005)
N. Hoteling et al., Phys. Rev. C 76, 044324 (2007)

3.29×10^5 identified ions

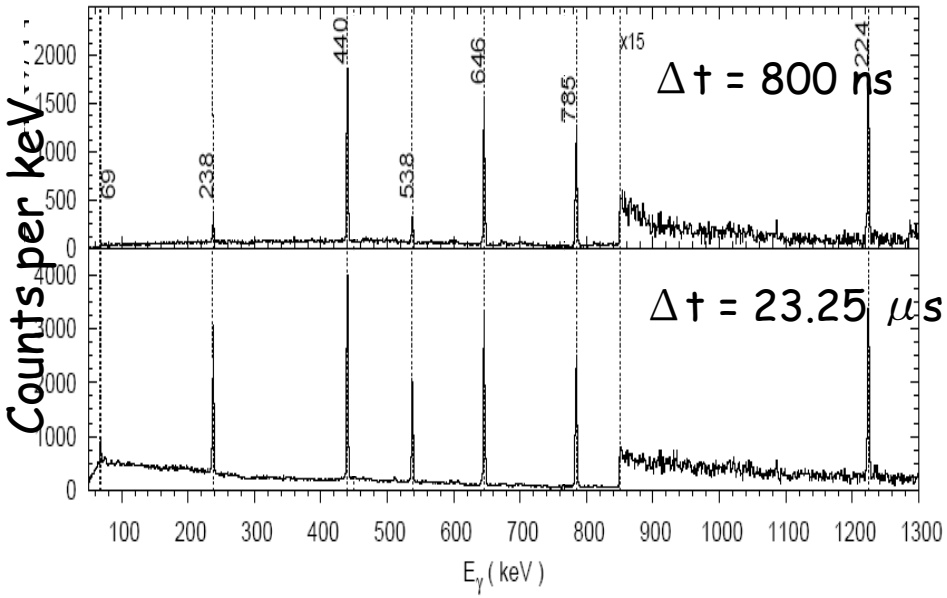
Fragmentation

+

Fission

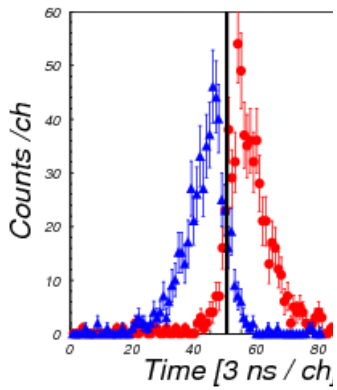
^{128}Cd

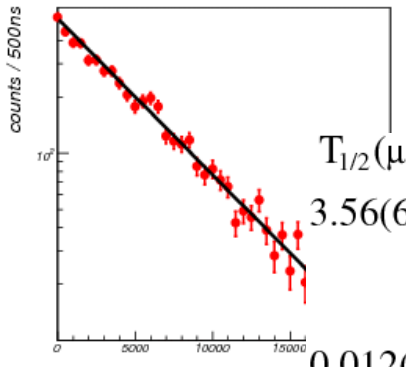
L. Caceres et al., PRC 79 011301(R) 2009

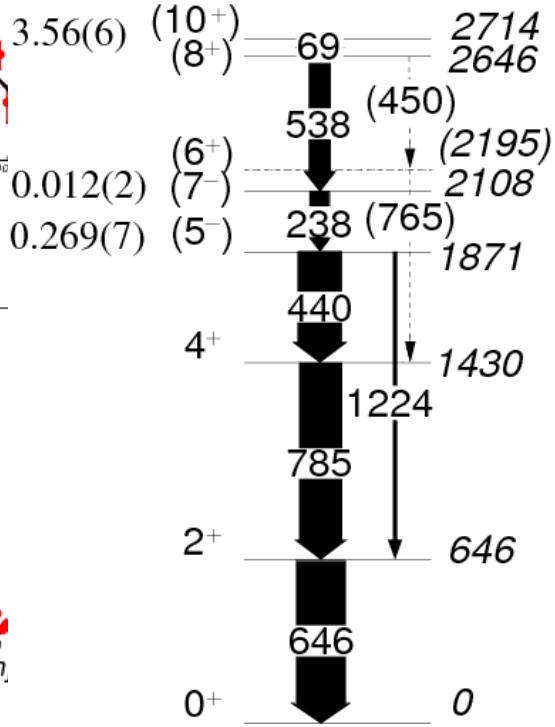


Time (DGF) [ch]

T. Kautzsch et al., Eur. Phys. J. A 25, 117 (2005)
N. Hoteling et al., Phys. Rev. C 76, 044324 (2007)







3.29x10^5 identified ions

Fragmentation

+

Fission

Observation of Isomeric Decays in the *r*-Process Waiting-Point Nucleus $^{130}Cd_{82}$

A. Jungclaus,[1] L. Cáceres,[1,2] M. Górska,[2] M. Pfützner,[3] S. Pietri,[4] E. Werner-Malento,[3] H. Grawe,[2] K. Langanke,[2] G. Martínez-Pinedo,[2] F. Nowacki,[5] A. Poves,[1] J. J. Cuenca-García,[2] D. Rudolph,[6] Z. Podolyak,[4] P. H. Regan,[4] P. Detistov,[7] S. Lalkovski,[8,7] V. Modamio,[1] J. Walker,[1] P. Bednarczyk,[2,9] P. Doornenbal,[2] H. Geissel,[2] J. Gerl,[2] J. Grebosz,[2,9] I. Kojouharov,[2] N. Kurz,[2] W. Prokopowicz,[2] H. Schaffner,[2] H. J. Wollersheim,[2] K. Andgren,[10] J. Benlliure,[11] G. Benzoni,[12] A. M. Bruce,[8] E. Casarejos,[11] B. Cederwall,[10] F. C. L. Crespi,[12] B. Hadinia,[10] M. Hellström,[6] R. Hoischen,[6,2] G. Ilie,[13,14] J. Jolie,[13] A. Khaplanov,[10] M. Kmiecik,[9] R. Kumar,[15] A. Maj,[9] S. Mandal,[16] F. Montes,[2] S. Myalski,[9] G. S. Simpson,[17] S. J. Steer,[4] S. Tashenov,[2] and O. Wieland[12]

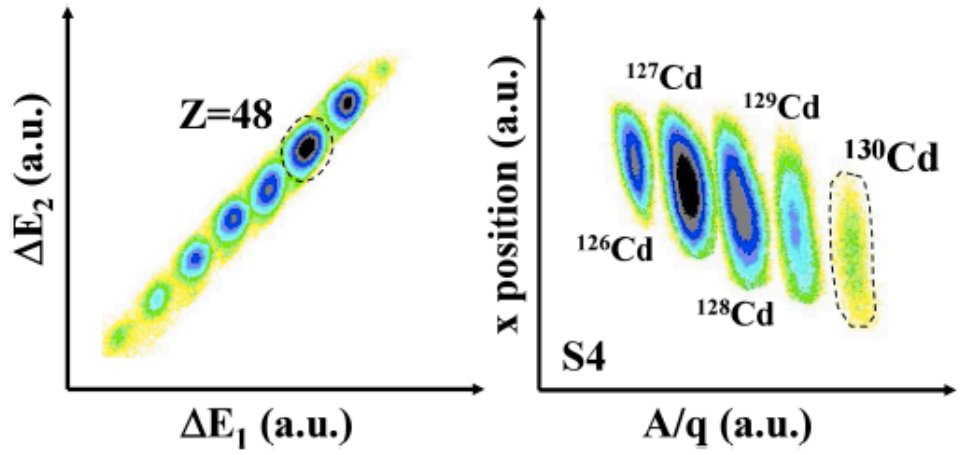
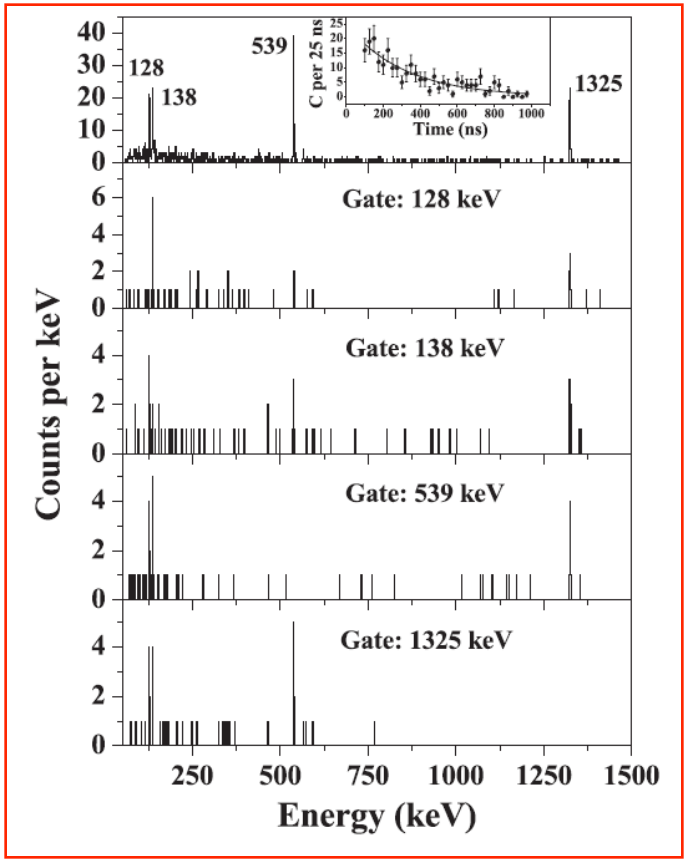


FIG. 1 (color online). Example of particle identification plots from the fragmentation of ^{136}Xe. Left: Z identification from the energy losses measured in two multiple sampling ionization chamber ionization chambers. Right: Isotope identification from the positions of the Cd ions in the final focal plane S4 of the FRS shown as a function of A/Q.



Observation of Isomeric Decays in the *r*-Process Waiting-Point Nucleus $^{130}Cd_{82}$

A. Jungclaus,[1] L. Cáceres,[1,2] M. Górska,[2] M. Pfützner,[3] S. Pietri,[4] E. Werner-Malento,[3] H. Grawe,[2] K. Langanke,[2]
udolph,[6] Z. Podolyak,[4] P. H. Regan,[4] P. Detistov,[7]
nenbal,[2] H. Geissel,[2] J. Gerl,[2] J. Grebosz,[2,9]
eim,[2] K. Andgren,[10] J. Benlliure,[11] G. Benzoni,[12]
nia,[10] M. Hellström,[6] R. Hoischen,[6,2] G. Ilie,[13,14]
dal,[16] F. Montes,[2] S. Myalski,[9] G. S. Simpson,[17]
Wieland[12]

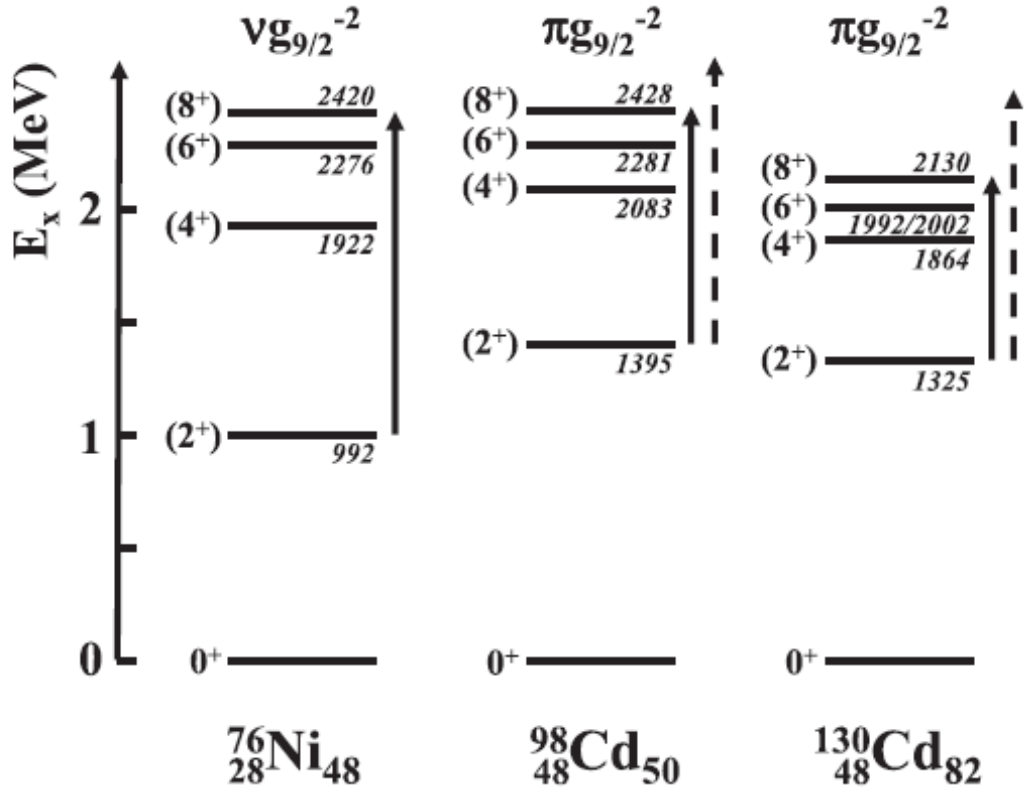
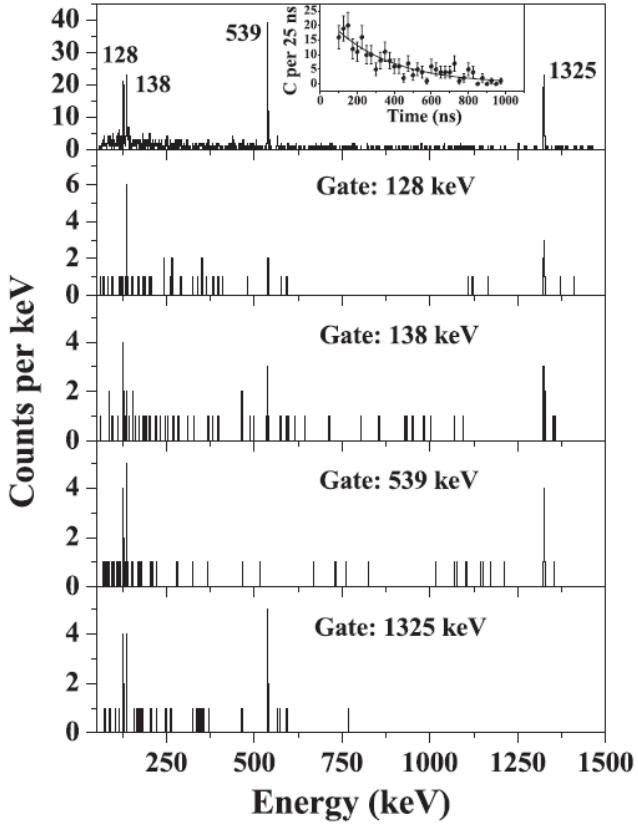


FIG. 4. Proposed level scheme of ^{130}Cd compared to the known level schemes of ^{76}Ni [29] and ^{98}Cd [13]. The solid arrows indicate the observed A^{-1} scaling, whereas the dashed arrows correspond to an $A^{-1/3}$ scaling of the $2^+ - 8^+$ energy spread.



Physics Letters B 672 (2009) 313–316

Evolution of the $N = 82$ shell gap below ^{132}Sn inferred from core excited states in ^{131}In

M. Górska [a,*], L. Cáceres [a,b], H. Grawe [a], M. Pfützner [c], A. Jungclaus [b,d], S. Pietri [e,1], E. Werner-Malento [c,2], Z. Podolyák [e], P.H. Regan [e], D. Rudolph [f], P. Detistov [g], S. Lalkovski [g,h], V. Modamio [b], J. Walker [b], T. Beck [a], P. Bednarczyk [a,i], P. Doornenbal [a,j,3], H. Geissel [a], J. Gerl [a], J. Grębosz [a,i], R. Hoischen [f,a], I. Kojouharov [a], N. Kurz [a], W. Prokopowicz [a,i], H. Schaffner [a], H. Weick [a], H.-J. Wollersheim [a], K. Andgren [k], J. Benlliure [l], G. Benzoni [m], A.M. Bruce [h], E. Casarejos [l], B. Cederwall [k], F.C. L. Crespi [m], B. Hadinia [f], M. Hellström [f], G. Ilie [j,n], A. Khaplanov [k], M. Kmiecik [i], R. Kumar [o], A. Maj [i], S. Mandal [p], F. Montes [a], S. Myalski [i], G.S. Simpson [q], S.J. Steer [e], S. Tashenov [a], O. Wieland [m], Zs. Dombrádi [r], P. Reiter [j], D. Sohler [r]

^{131}In; Z=49, N=82
A single valence proton hole in ^{132}Sn.

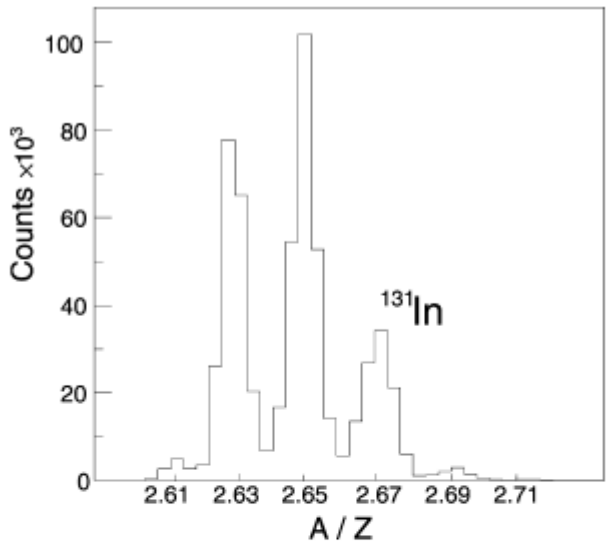
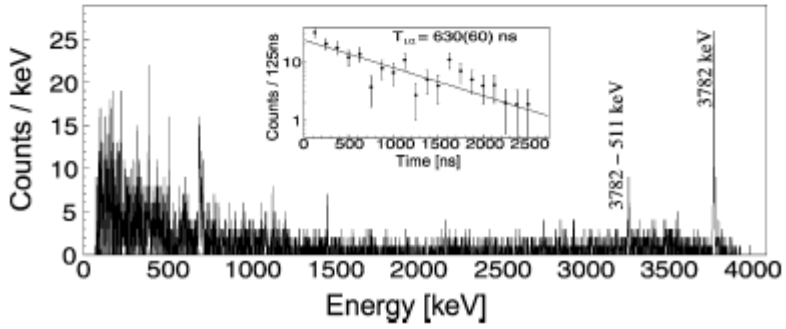


Fig. 1. The experimental spectrum of the A/Z value for In isotopes obtained in the fission experiment.

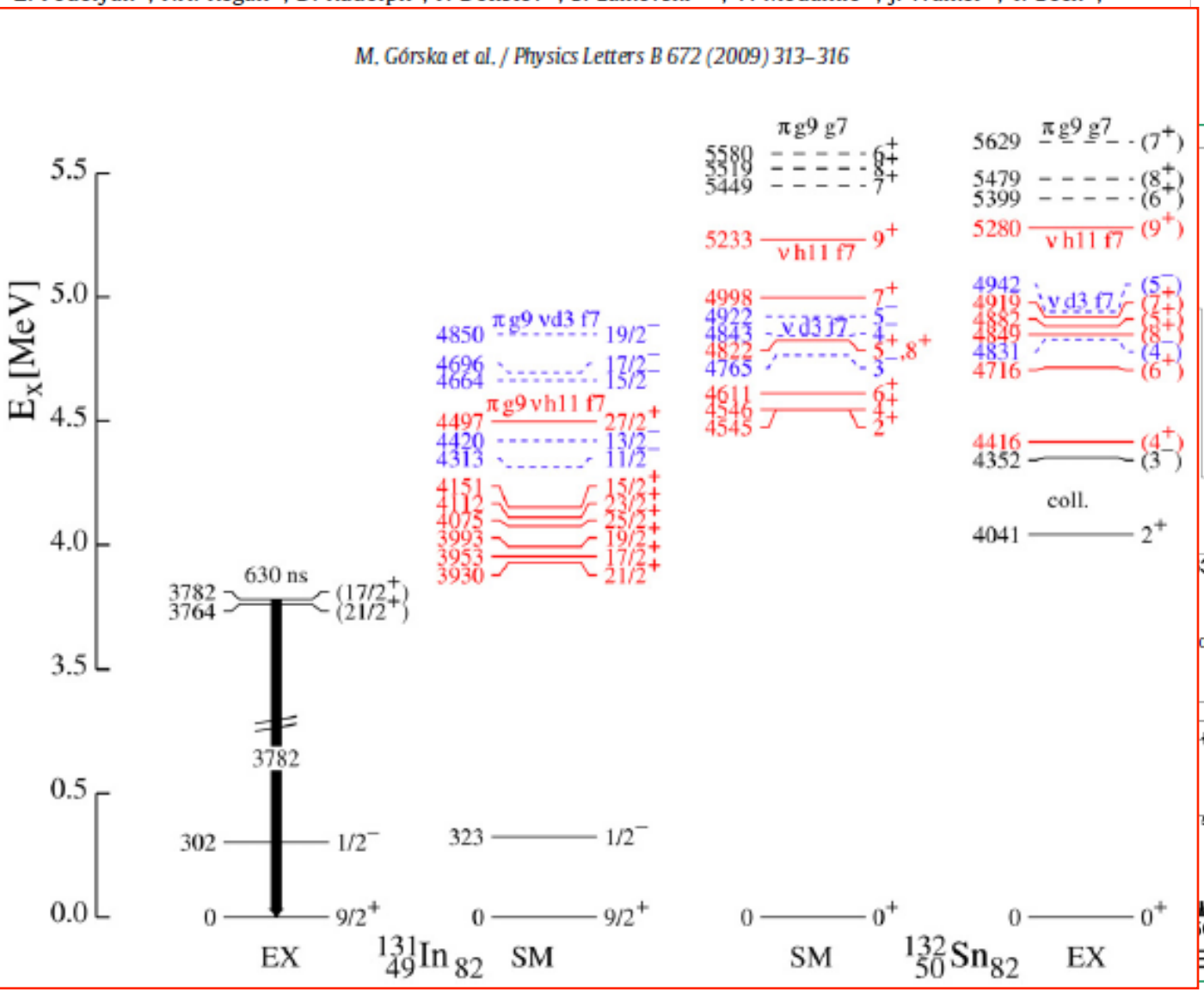


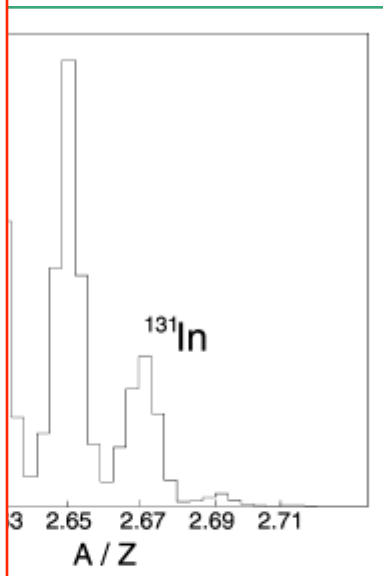
Physics Letters B 672 (2009) 313–316

Evolution of the $N = 82$ shell gap below ^{132}Sn inferred from core excited states in ^{131}In

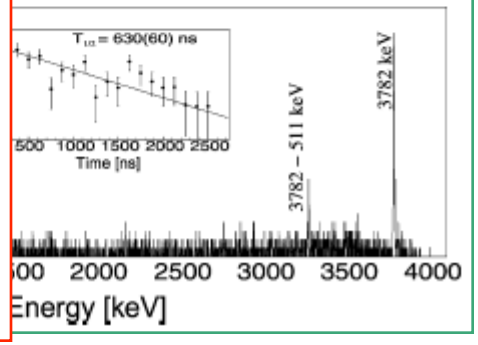
M. Górska [a,*], L. Cáceres [a,b], H. Grawe [a], M. Pfützner [c], A. Jungclaus [b,d], S. Pietri [e,1], E. Werner-Malento [c,2], Z. Podolyák [e], P.H. Regan [e], D. Rudolph [f], P. Detistov [g], S. Lalkovski [g,h], V. Modamio [b], J. Walker [b], T. Beck [a],

^{131}In; Z=49, N=82
A single valence proton hole in ^{132}Sn.



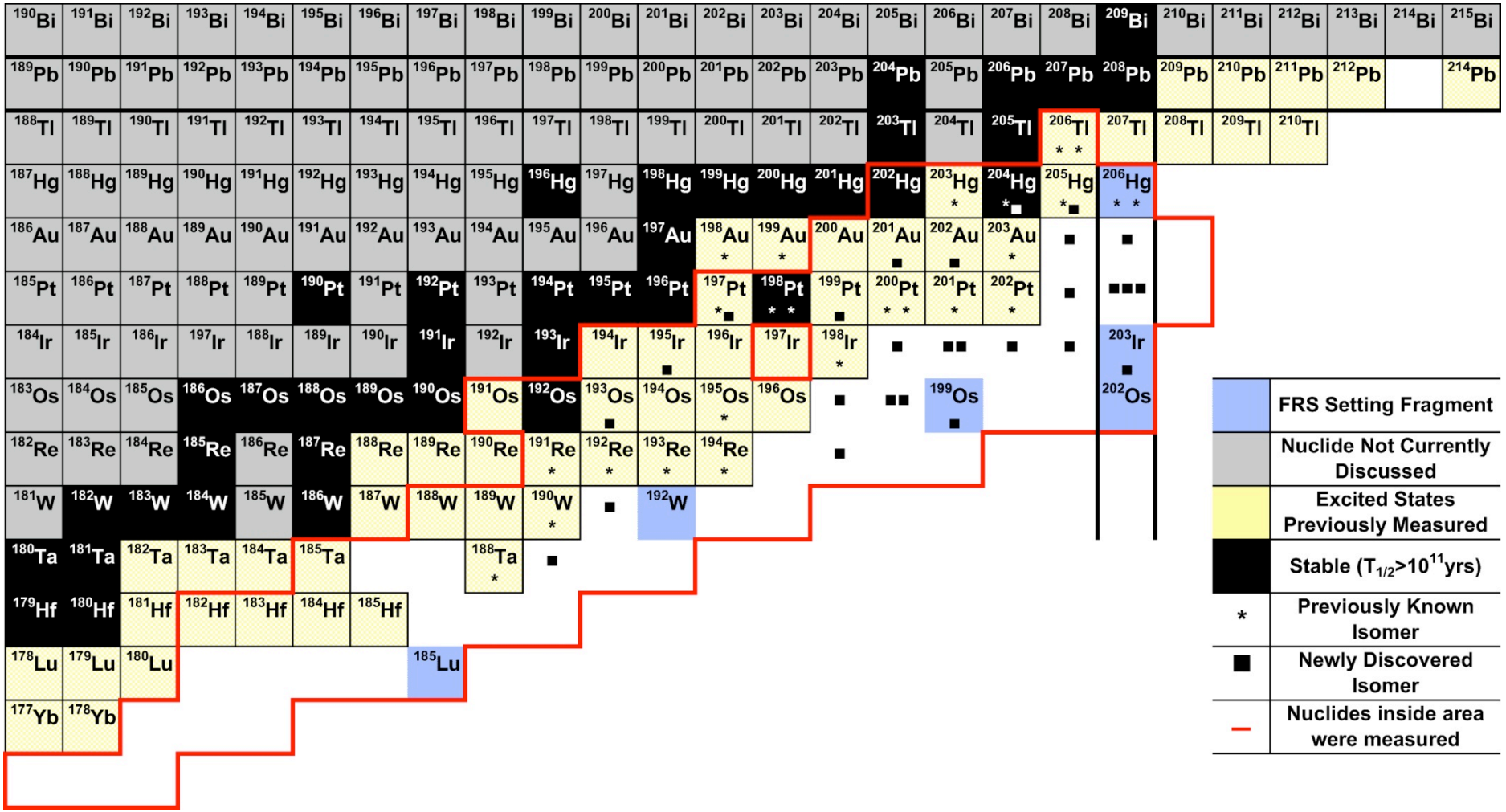


of the A/Z value for In isotopes obtained in the



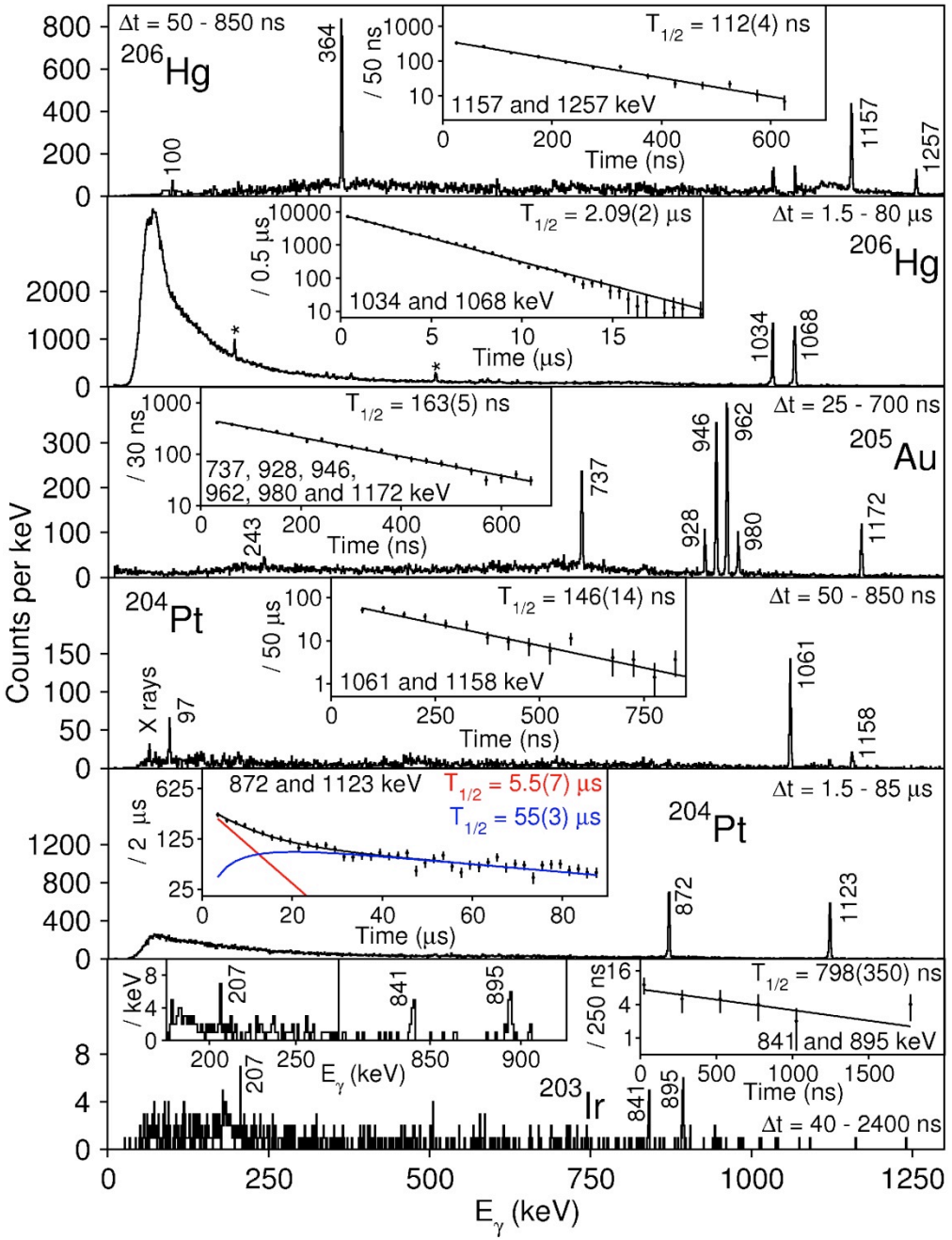
N~126 ; Z ~82

Summary of the Passive Stopper Z< 82, N≤126 Nuclei Experiment



A total of 5.3 days of beam time focusing the FRS on 6 different nuclides. Gamma-ray spectroscopy on 83 nuclides. 47 isomers (27 of which are newly discovered) measured in 37 nuclides,. This has provided the first nuclear structure information on 15 nuclides.
34 isomeric ratios measured.

Isomer Gamma-ray Spectroscopy of N = 126, Z<82 Nuclei



Z=80, N=126
^{206}Hg

Z=79,
N=126,
^{205}Au

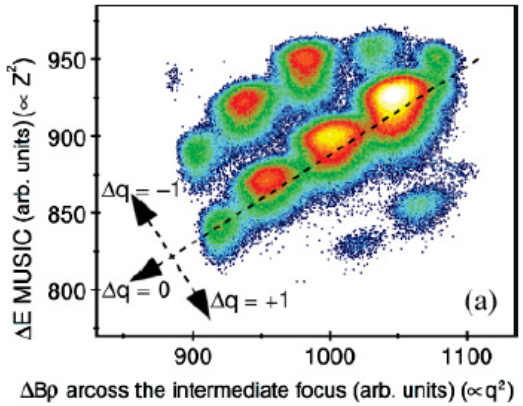
Z=78, N=126
^{204}Pt

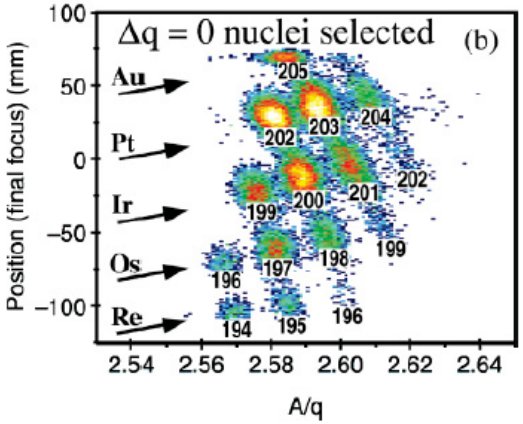
Z=77, N=126
^{203}Ir

PHYSICAL REVIEW C **78**, 061302(R) (2008)

Single-particle behavior at $N = 126$: Isomeric decays in neutron-rich ^{204}Pt

S. J. Steer,[1,*] Zs. Podolyák,[1] S. Pietri,[1] M. Górska,[2] P. H. Regan,[1] D. Rudolph,[3] E. Werner-Malento,[2] A. B. Garnsworthy,[1,4] R. Hoischen,[3] J. Gerl,[2] H. J. Wollersheim,[2] K. H. Maier,[5,6] H. Grawe,[2] F. Becker,[2] P. Bednarczyk,[2,6] L. Cáceres,[2,7] P. Doornenbal,[2,8] H. Geissel,[2] J. Grębosz,[2,6] A. Kelic,[2] I. Kojouharov,[2] N. Kurz,[2] F. Montes,[2] W. Prokopowicz,[2] T. Saito,[2] H. Schaffner,[2] S. Tashenov,[2] A. Heinz,[4] M. Pfützner,[9] T. Kurtukian-Nieto,[10] G. Benzoni,[11] A. Jungclaus,[7] D. L. Balabanski,[12,13] C. Brandau,[1] B. A. Brown,[1,14] A. M. Bruce,[15] W. N. Catford,[1] I. J. Cullen,[1] Zs. Dombrádi,[16] M. E. Estevez,[17] W. Gelletly,[1] G. Ilie,[8,18] J. Jolie,[8] G. A. Jones,[1] M. Kmiecik,[6] F. G. Kondev,[19] R. Krücken,[20] S. Lalkovski,[15,21] Z. Liu,[1] A. Maj,[6] S. Myalski,[6] S. Schwertel,[20] T. Shizuma,[1,22] P. M. Walker,[1] and O. Wieland[11]

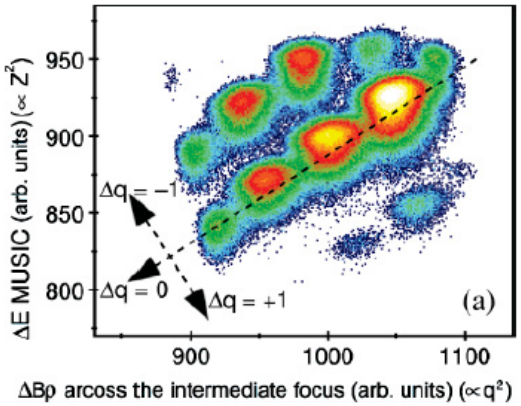


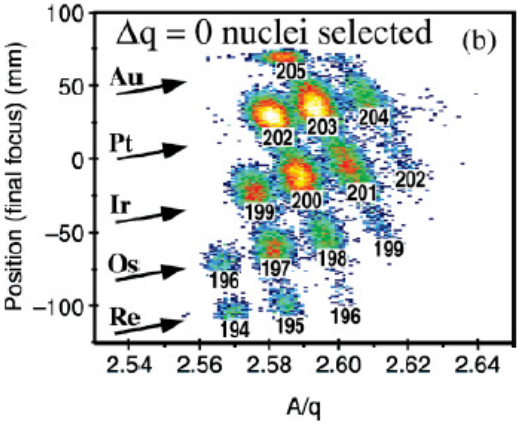


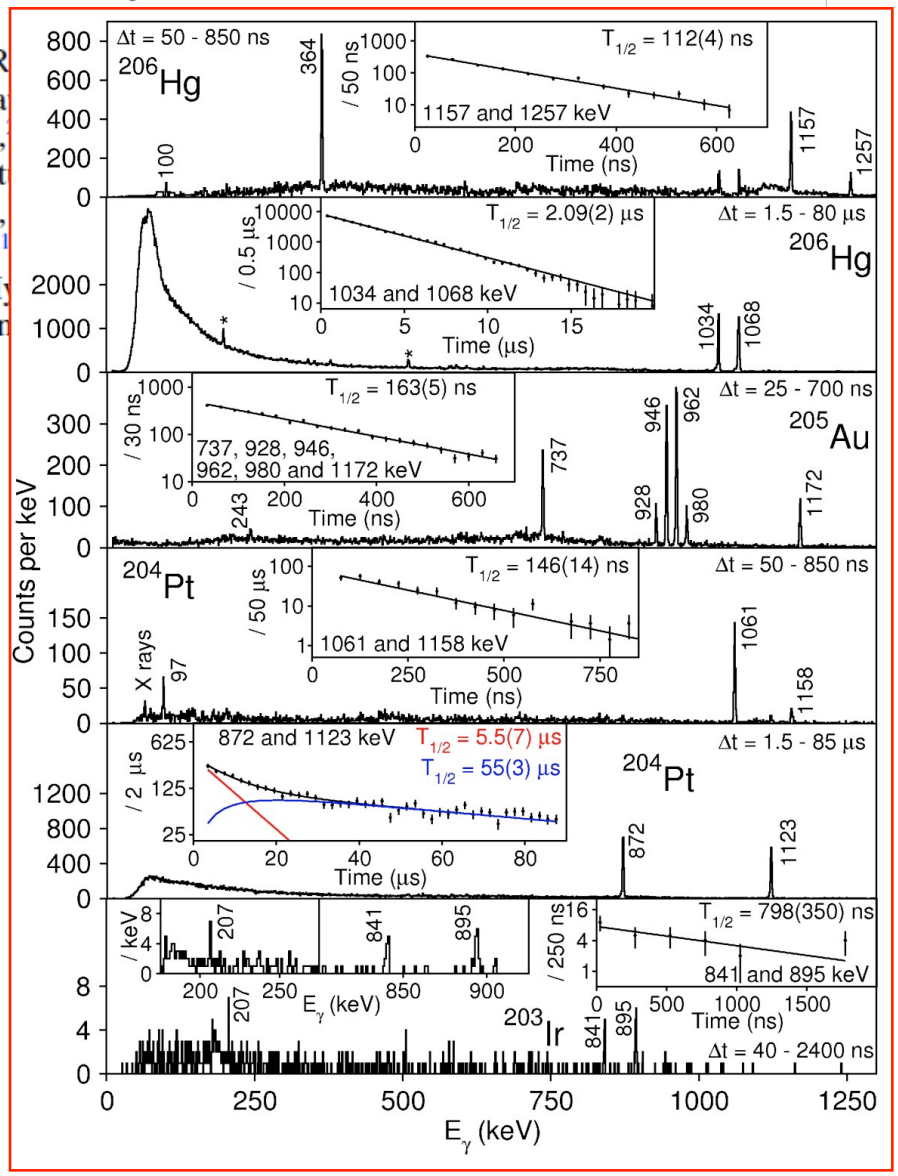
PHYSICAL REVIEW C 78, 061302(R) (2008)

Single-particle behavior at $N = 126$: Isomeric decays in neutron-rich ^{204}Pt

S. J. Steer,[1,*] Zs. Podolyák,[1] S. Pietri,[1] M. Górska,[2] P. H. Regan,[1] D. R
R. Hoischen,[3] J. Gerl,[2] H. J. Wollersheim,[2] K. H. Maier,[5,6] H. Gra
P. Doornenbal,[2,8] H. Geissel,[2] J. Grębosz,[2,6] A. Kelic,[2] I. Kojouharov,
H. Schaffner,[2] S. Tashenov,[2] A. Heinz,[4] M. Pfützner,[9] T. Kurt
D. L. Balabanski,[12,13] C. Brandau,[1] B. A. Brown,[1,14] A. M. Bruce,
M. E. Estevez,[17] W. Gelletly,[1] G. Ilie,[8,18] J. Jolie,[8] G. A. Jones,
S. Lalkovski,[15,21] Z. Liu,[1] A. Maj,[6] S. M
T. Shizuma,[1,22] P. M. Walker,[1] a



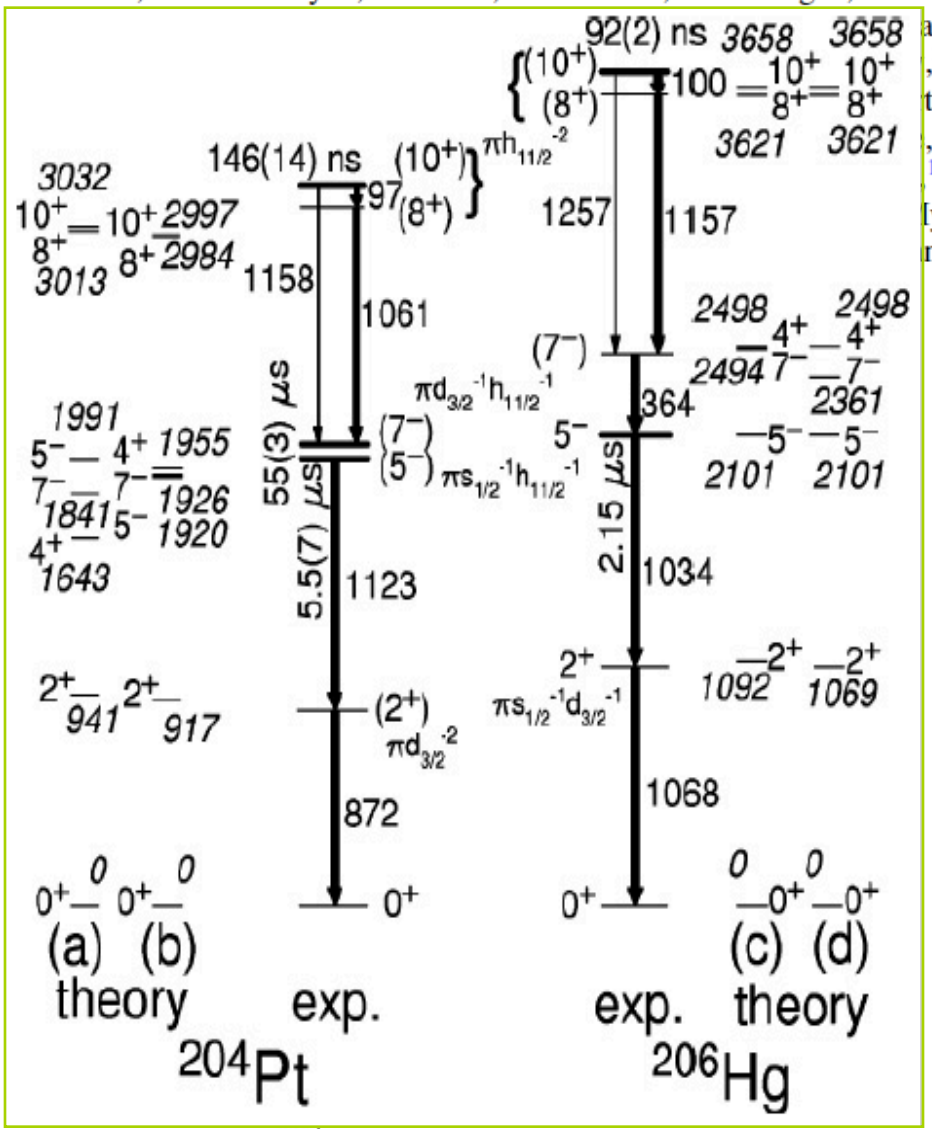


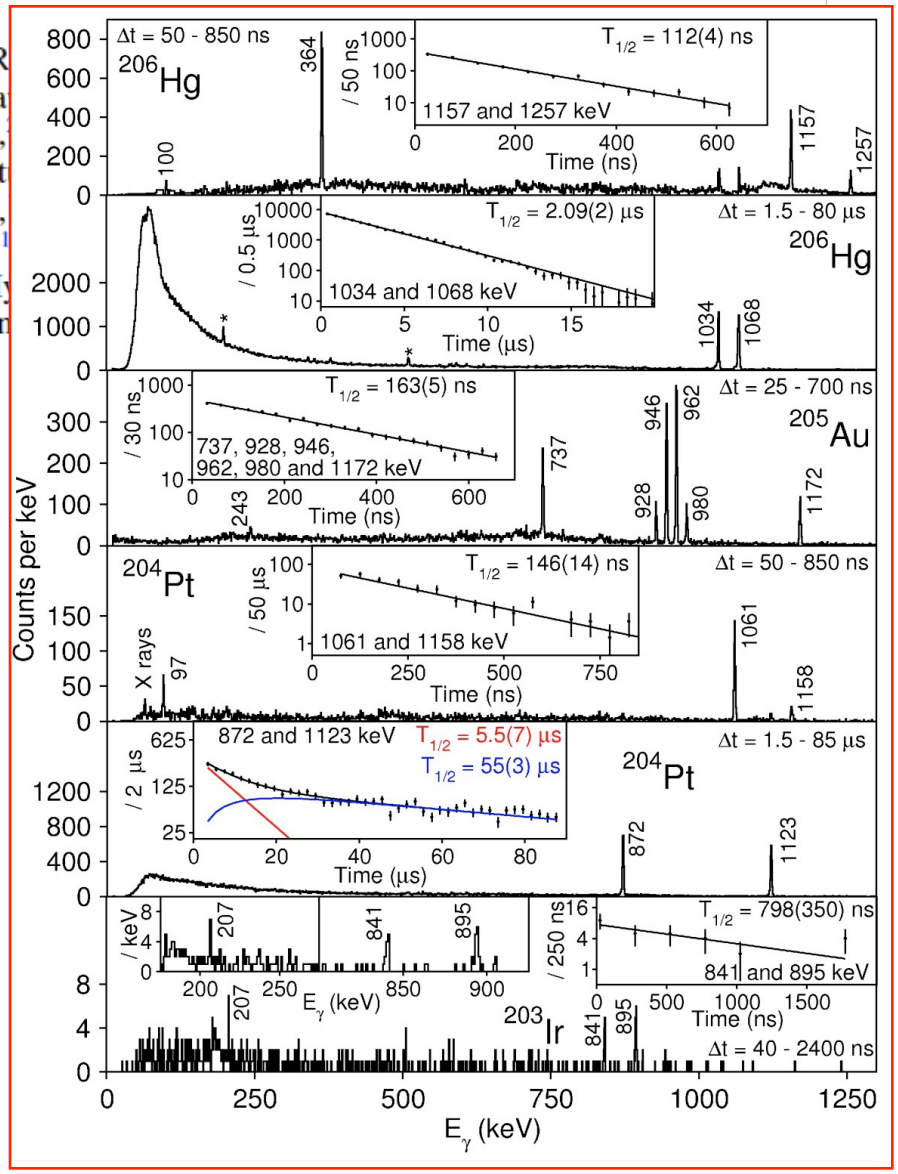


PHYSICAL REVIEW C 78, 061302(R) (2008)

Single-particle behavior at $N = 126$: Isomeric decays in neutron-rich ^{204}Pt

S. J. Steer,[1,*] Zs. Podolyák,[1] S. Pietri,[1] M. Górska,[2] P. H. Regan,[1] D. R

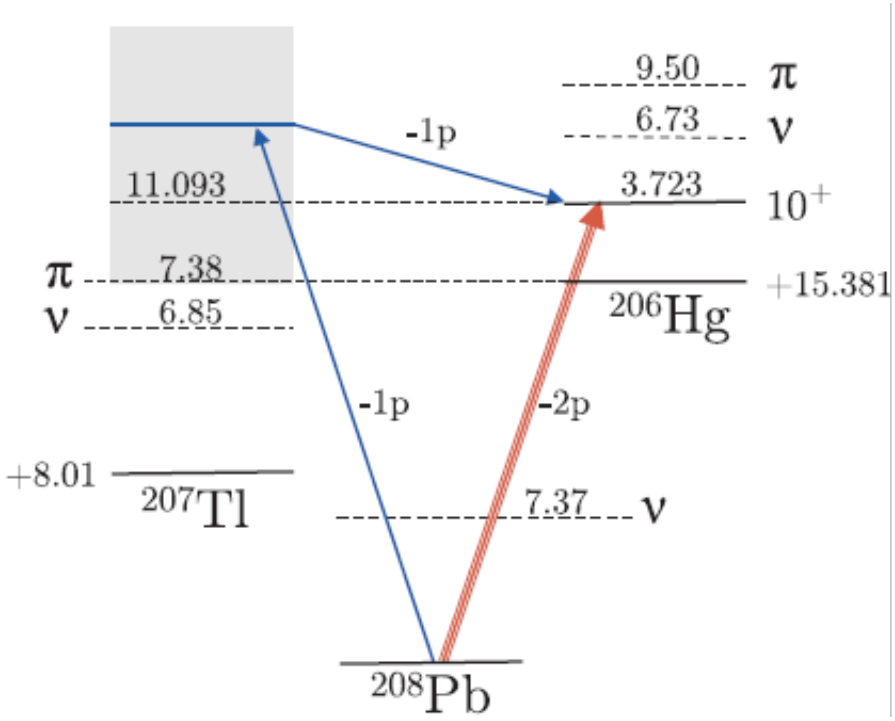


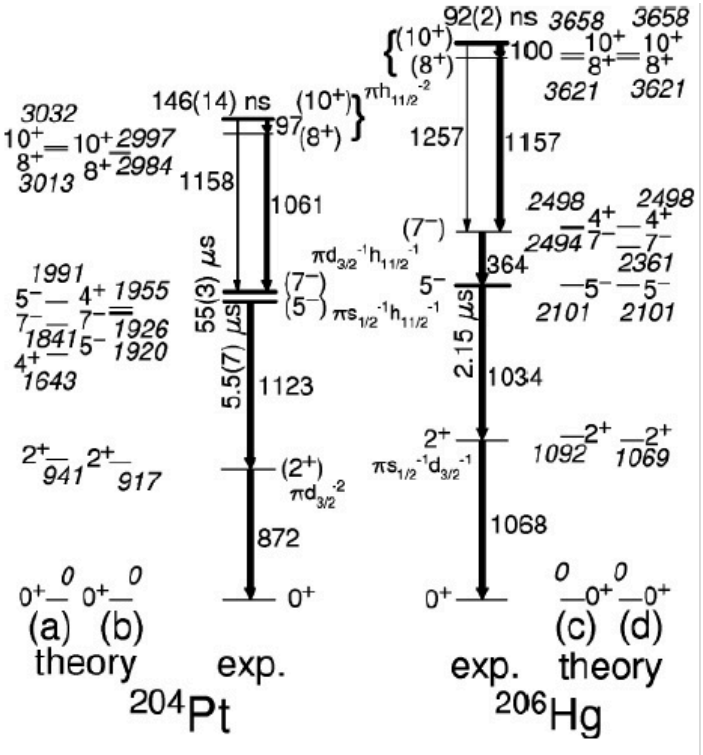


PHYSICAL REVIEW C **80**, 064608 (2009)

Population of low-seniority isomeric states of ^{206}Hg by two-proton knockout reactions at relativistic energies

E. C. Simpson, J. A. Tostevin, Zs. Podolyák, P. H. Regan, and S. J. Steer
Department of Physics, Faculty of Engineering and Physical Sciences, University of Surrey, Guildford, Surrey GU2 7XH, United Kingdom
(Received 5 October 2009; published 8 December 2009)





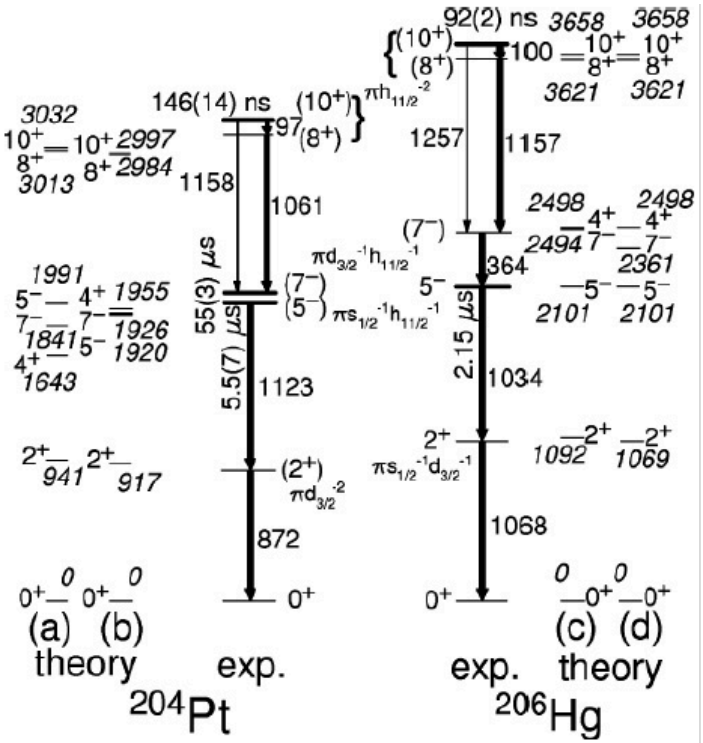
Isomer ratios also used to improve/test knockout reaction theory…
isomeric states tend to be rather ‘pure’ shell model configurations.

PHYSICAL REVIEW C **80**, 064608 (2009)

Population of low-seniority isomeric states of ^{206}Hg by two-proton knockout reactions at relativistic energies

E. C. Simpson, J. A. Tostevin, Zs. Podolyák, P. H. Regan, and S. J. Steer
Department of Physics, Faculty of Engineering and Physical Sciences, University of Surrey, Guildford, Surrey GU2 7XH, United Kingdom
(Received 5 October 2009; published 8 December 2009)

	State I^π	Isomeric ratio (%)
Experiment	5^-	$21.9^{+1.2}_{-2.9}$
	$(10^+)^a$	$3.1^{+1.0}_{-1.2}$
	$(10^+)^b$	$2.2^{+0.7}_{-0.8}$
Theory	5^- (direct only)	4.8
	5^- (includes 7^-, 8^+, and 10^+)	18.8
	10^+	4.7
	5^-	32.5 [14]

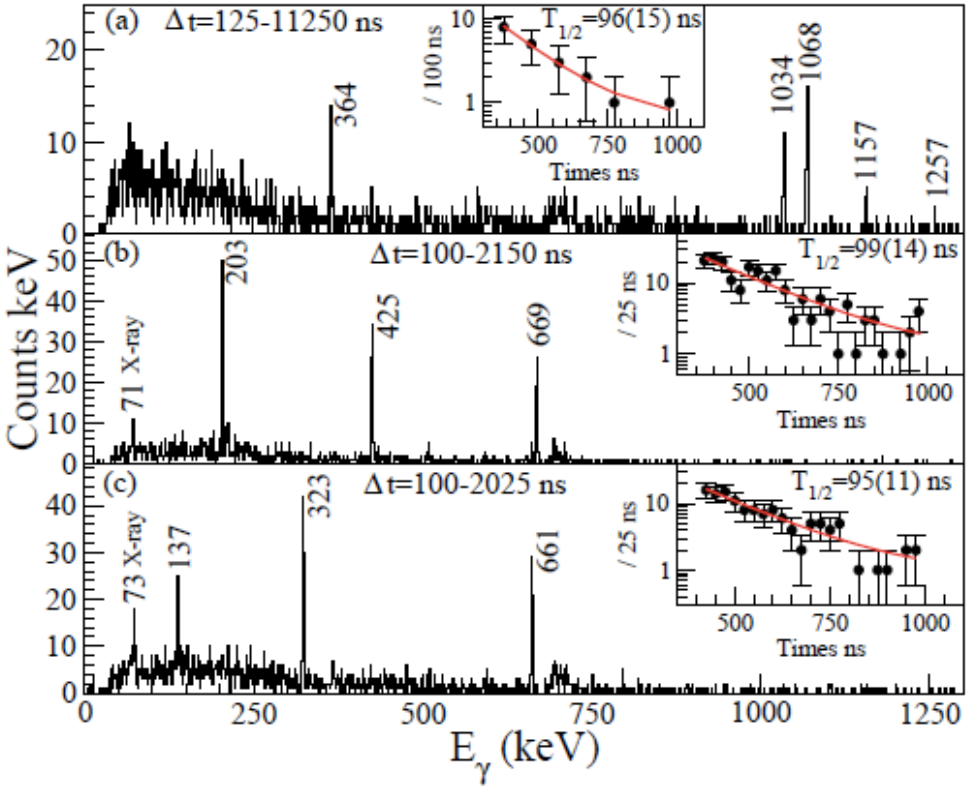


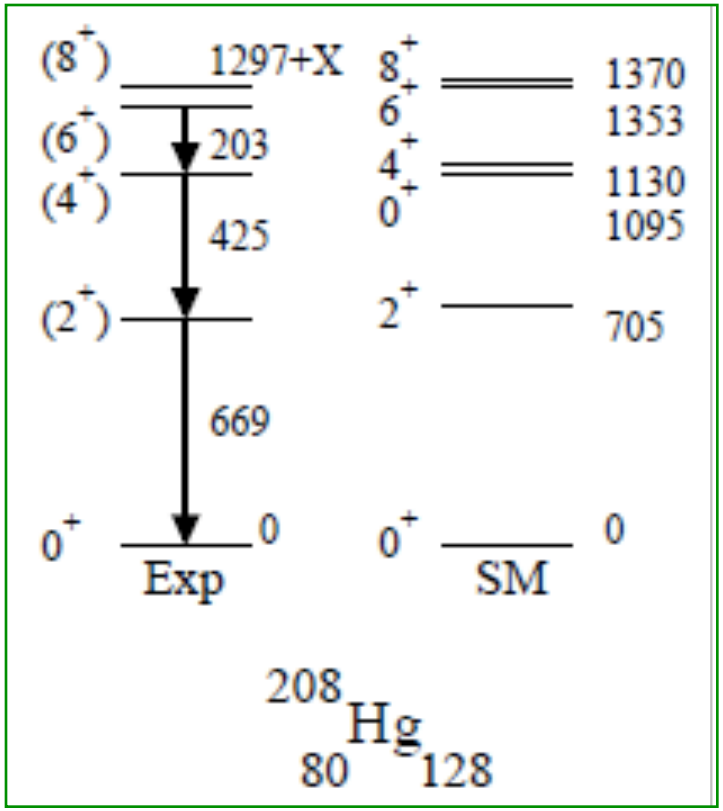
Isomer ratios also used to improve/test knockout reaction theory…
isomeric states tend to be rather ‘pure’ shell model configurations.

PHYSICAL REVIEW C **80**, 061302(R) (2009)

Nuclear structure "southeast" of ^{208}Pb: Isomeric states in ^{208}Hg and ^{209}Tl

N. Al-Dahan,[1,2] Zs. Podolyák,[1,*] P. H. Regan,[1] M. Górska,[3] H. Grawe,[3] K. H. Maier,[4] J. Gerl,[3] S. B. Pietri,[3] H. J. Wollersheim,[3] N. Alkhomashi,[1] A. Y. Deo,[1] A. M. Denis Bacelar,[5] G. Farrelly,[1] S. J. Steer,[1] A. M. Bruce,[5] P. Boutachkov,[3] C. Domingo-Pardo,[3] A. Algora,[6,7] J. Benlliure,[8] A. Bracco,[9] E. Calore,[10] E. Casarejos,[8] I. J. Cullen,[1] P. Detistov,[11] Zs. Dombrádi,[7] M. Doncel,[12] F. Farinon,[3] W. Gelletly,[1] H. Geissel,[3] N. Goel,[3] J. Grebosz,[4] R. Hoischen,[3,13] I. Kojouharov,[3] N. Kurz,[3] S. Lalkovski,[5] S. Leoni,[14] F. Molina,[6] D. Montanari,[9] A. I. Morales,[8] A. Musumarra,[3,15] D. R. Napoli,[10] R. Nicolini,[9] C. Nociforo,[3] A. Prochazka,[3] W. Prokopowicz,[3] B. Rubio,[6] D. Rudolph,[3,13] H. Schaffner,[3] P. Strmen,[16] I. Szarka,[16] T. Swan,[1] J. S. Thomas,[1] J. J. Valiente-Dobón,[10] S. Verma,[8] P. M. Walker,[1] and H. Weick[3]

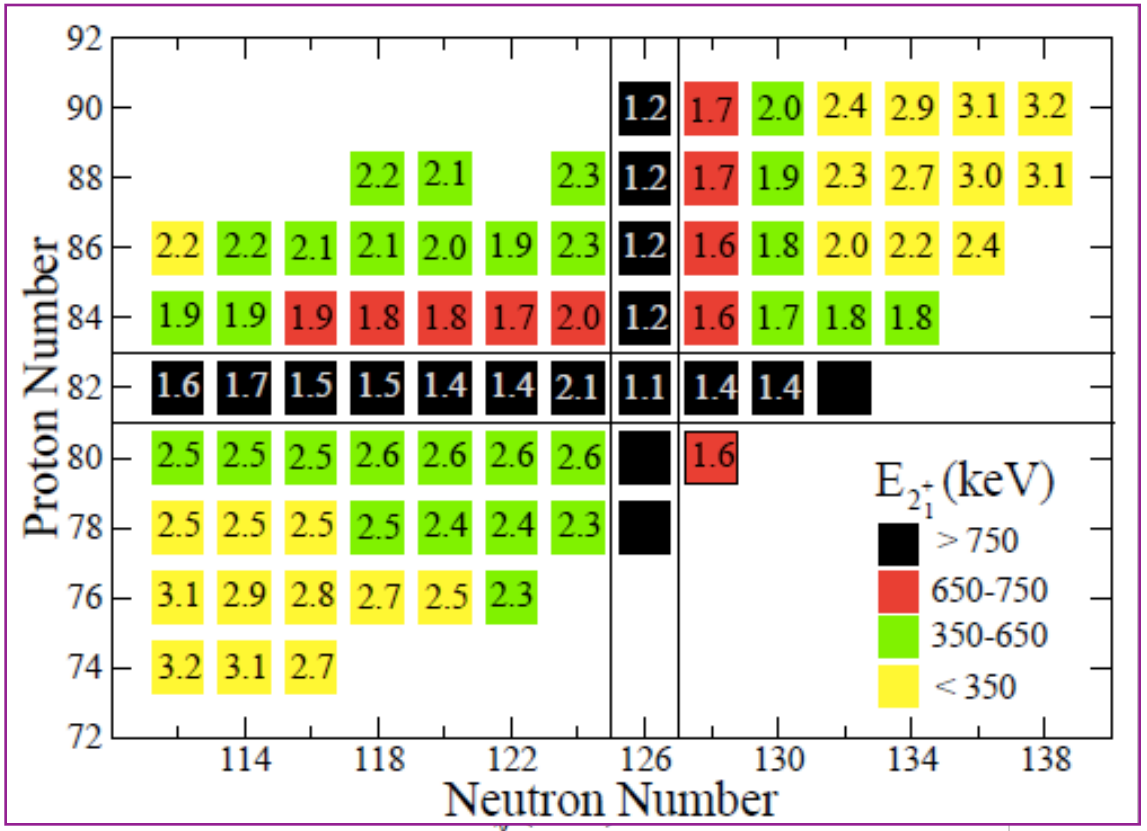


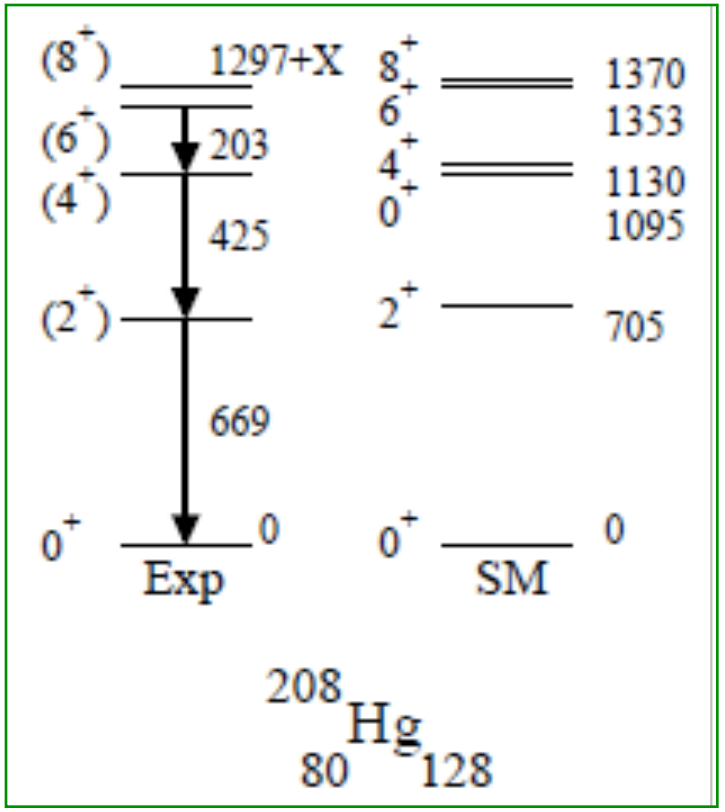


PHYSICAL REVIEW C **80**, 061302(R) (2009)

Nuclear structure "southeast" of ^{208}Pb: Isomeric states in ^{208}Hg and ^{209}Tl

N. Al-Dahan,[1,2] Zs. Podolyák,[1,*] P. H. Regan,[1] M. Górska,[3] H. Grawe,[3] K. H. Maier,[4] J. Gerl,[3] S. B. Pietri,[3] H. J. Wollersheim,[3] N. Alkhomashi,[1] A. Y. Deo,[1] A. M. Denis Bacelar,[5] G. Farrelly,[1] S. J. Steer,[1] A. M. Bruce,[5] P. Boutachkov,[3] C. Domingo-Pardo,[3] A. Algora,[6,7] J. Benlliure,[8] A. Bracco,[9] E. Calore,[10] E. Casarejos,[8] I. J. Cullen,[1] P. Detistov,[11] Zs. Dombrádi,[7] M. Doncel,[12] F. Farinon,[3] W. Gelletly,[1] H. Geissel,[3] N. Goel,[3] J. Grebosz,[4] R. Hoischen,[3,13] I. Kojouharov,[3] N. Kurz,[3] S. Lalkovski,[5] S. Leoni,[14] F. Molina,[6] D. Montanari,[9] A. I. Morales,[8] A. Musumarra,[3,15] D. R. Napoli,[10] R. Nicolini,[9] C. Nociforo,[3] A. Prochazka,[3] W. Prokopowicz,[3] B. Rubio,[6] D. Rudolph,[3,13] H. Schaffner,[3] P. Strmen,[16] I. Szarka,[16] T. Swan,[1] J. S. Thomas,[1] J. J. Valiente-Dobón,[10] S. Verma,[8] P. M. Walker,[1] and H. Weick[3]





Physics Letters B 672 (2009) 116–119

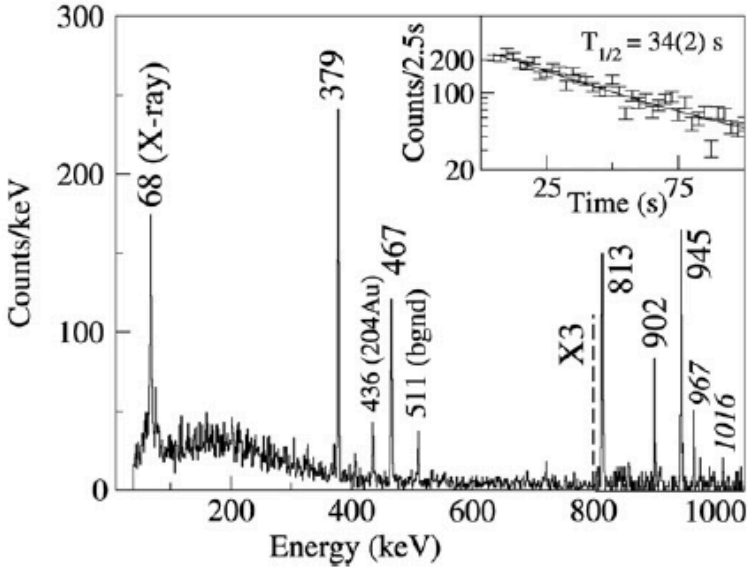
Contents lists available at ScienceDirect

Physics Letters B

www.elsevier.com/locate/physletb

Proton–hole excitation in the closed shell nucleus ^{205}Au

Zs. Podolyák [a,*], G.F. Farrelly [a], P.H. Regan [a], A.B. Garnsworthy [a], S.J. Steer [a], M. Górska [b], J. Benlliure [c], E. Casarejos [c], S. Pietri [a], J. Gerl [b], H.J. Wollersheim [b], R. Kumar [d], F. Molina [e], A. Algora [e,f], N. Alkhomashi [a], G. Benzoni [g], A. Blazhev [h], P. Boutachkov [b], A.M. Bruce [i], L. Caceres [b,j], I.J. Cullen [a], A.M. Denis Bacelar [i], P. Doornenbal [b], M.E. Estevez [c], Y. Fujita [k], W. Gelletly [a], H. Geissel [b], H. Grawe [b], J. Grębosz [b,l], R. Hoischen [m,b], I. Kojouharov [b], S. Lalkovski [i], Z. Liu [a], K.H. Maier [n,l], C. Mihai [o], D. Mücher [h], B. Rubio [e], H. Schaffner [b], A. Tamii [k], S. Tashenov [b], J.J. Valiente-Dobón [p], P.M. Walker [a], P.J. Woods [q]



Physics Letters B 672 (2009) 116–119

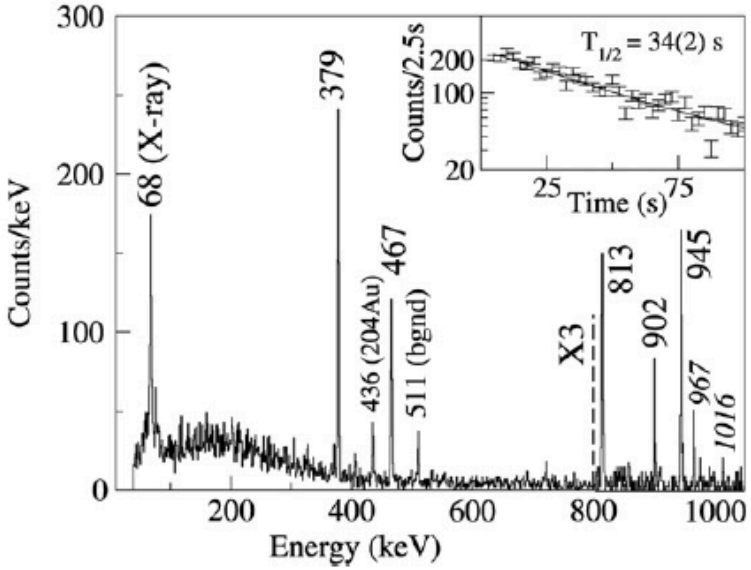
Contents lists available at ScienceDirect

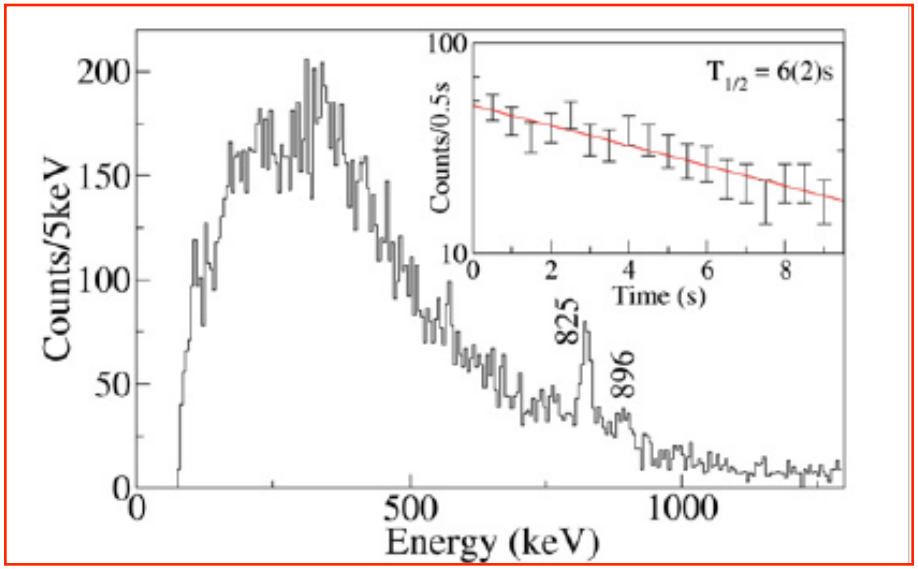
Physics Letters B

www.elsevier.com/locate/physletb

Proton–hole excitation in the closed shell nucleus ^{205}Au

Zs. Podolyák [a,*], G.F. Farrelly [a], P.H. Regan [a], A.B. Garnsworthy [a], S.J. Steer [a], M. Górska [b], J. Benlliure [c], E. Casarejos [c], S. Pietri [a], J. Gerl [b], H.J. Wollersheim [b], R. Kumar [d], F. Molina [e], A. Algora [e,f], N. Alkhomashi [a], G. Benzoni [g], A. Blazhev [h], P. Boutachkov [b], A.M. Bruce [i], L. Caceres [b,j], I.J. Cullen [a], A.M. Denis Bacelar [i], P. Doornenbal [b], M.E. Estevez [c], Y. Fujita [k], W. Gelletly [a], H. Geissel [b], H. Grawe [b], J. Grębosz [b,l], R. Hoischen [m,b], I. Kojouharov [b], S. Lalkovski [i], Z. Liu [a], K.H. Maier [n,l], C. Mihai [o], D. Mücher [h], B. Rubio [e], H. Schaffner [b], A. Tamii [k], S. Tashenov [b], J.J. Valiente-Dobón [p], P.M. Walker [a], P.J. Woods [q]





Physics Letters B 672 (2009) 116–119

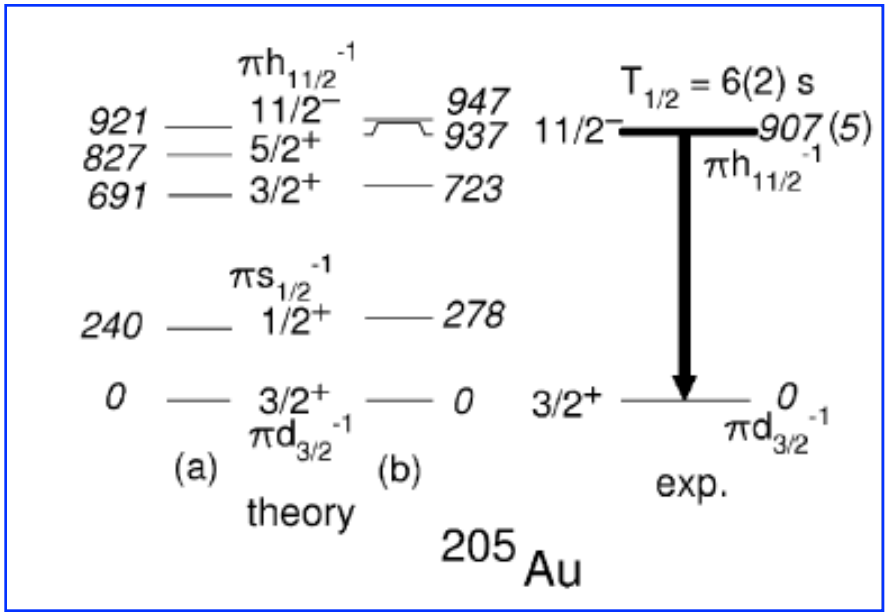
Contents lists available at ScienceDirect

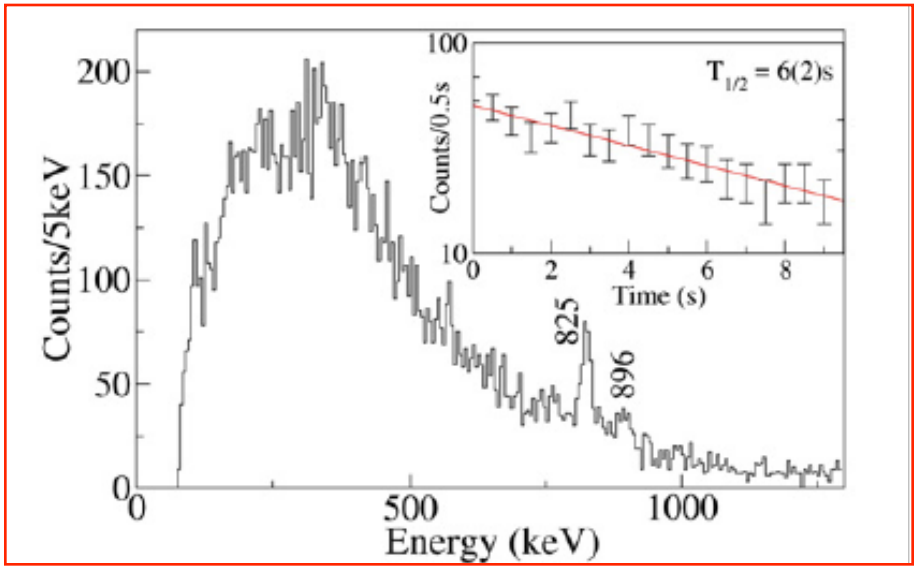
Physics Letters B

www.elsevier.com/locate/physletb

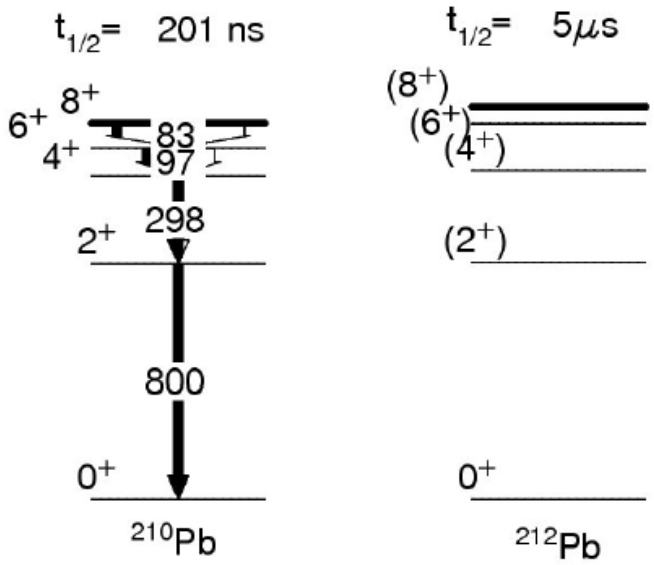
Proton–hole excitation in the closed shell nucleus ^{205}Au

Zs. Podolyák [a,*], G.F. Farrelly [a], P.H. Regan [a], A.B. Garnsworthy [a], S.J. Steer [a], M. Górska [b], J. Benlliure [c], E. Casarejos [c], S. Pietri [a], J. Gerl [b], H.J. Wollersheim [b], R. Kumar [d], F. Molina [e], A. Algora [e,f], N. Alkhomashi [a], G. Benzoni [g], A. Blazhev [h], P. Boutachkov [b], A.M. Bruce [i], L. Caceres [b,j], I.J. Cullen [a], A.M. Denis Bacelar [i], P. Doornenbal [b], M.E. Estevez [c], Y. Fujita [k], W. Gelletly [a], H. Geissel [b], H. Grawe [b], J. Grębosz [b,l], R. Hoischen [m,b], I. Kojouharov [b], S. Lalkovski [i], Z. Liu [a], K.H. Maier [n,l], C. Mihai [o], D. Mücher [h], B. Rubio [e], H. Schaffner [b], A. Tamii [k], S. Tashenov [b], J.J. Valiente-Dobón [p], P.M. Walker [a], P.J. Woods [q]

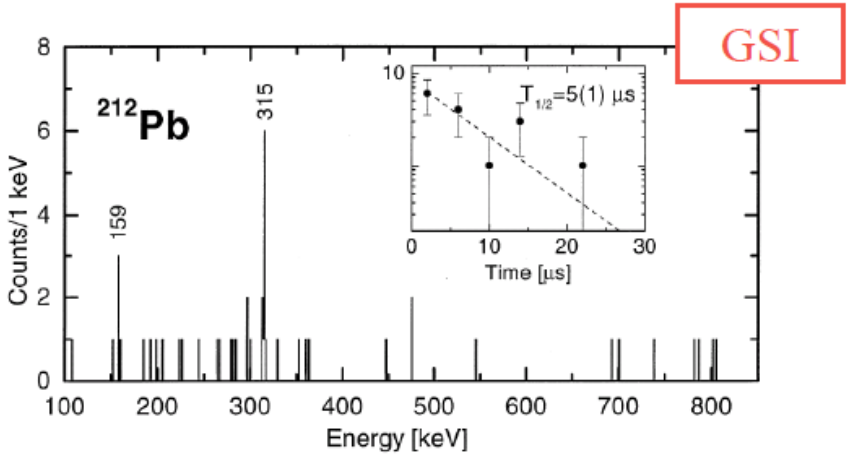




The experimental challanges



GSI



- **5x10^6 pps**
- **2 HPGe detectors (Eff$_\gamma$=1%)**
- **350 ions implanted**

M. Pfutzner, PLB 444 (1998) 32

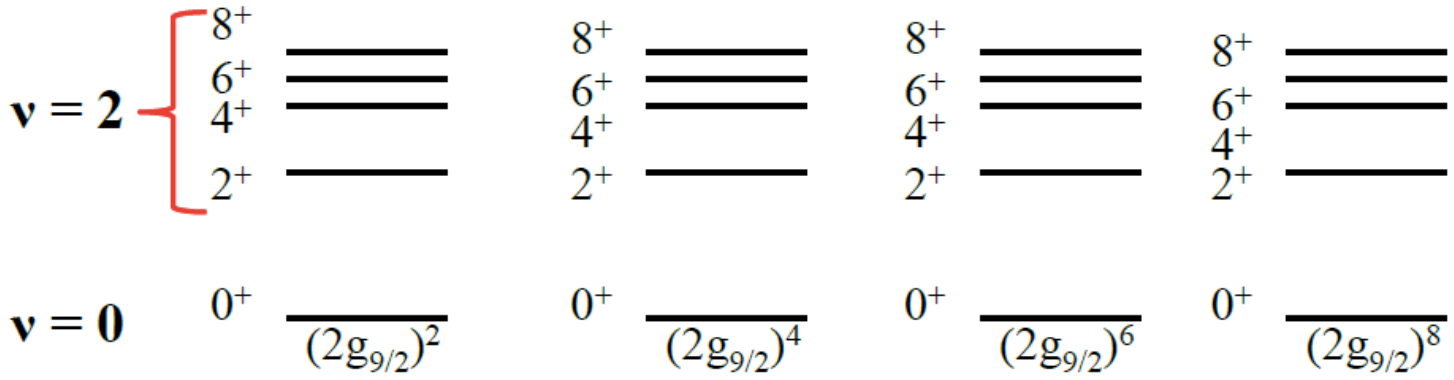
	$COFRA(mb)$	Ions/hour
^{212}Pb	9.05×10^{-4}	41.60×10^{3}
^{214}Pb	1.84×10^{-4}	9.30×10^{3}
^{216}Pb	3.01×10^{-5}	1.30×10^{3}
^{218}Pb	3.69×10^{-6}	1.80×10^{2}
^{220}Pb	3.17×10^{-7}	15.0

Difficult region to explore: only fragmentation possible, primary beam charge states!

The seniority scheme

Nucleons in a valence j^n configuration behave according to a seniority scheme: the states can be labelled by their seniority ν

SENIORITY SCHEME

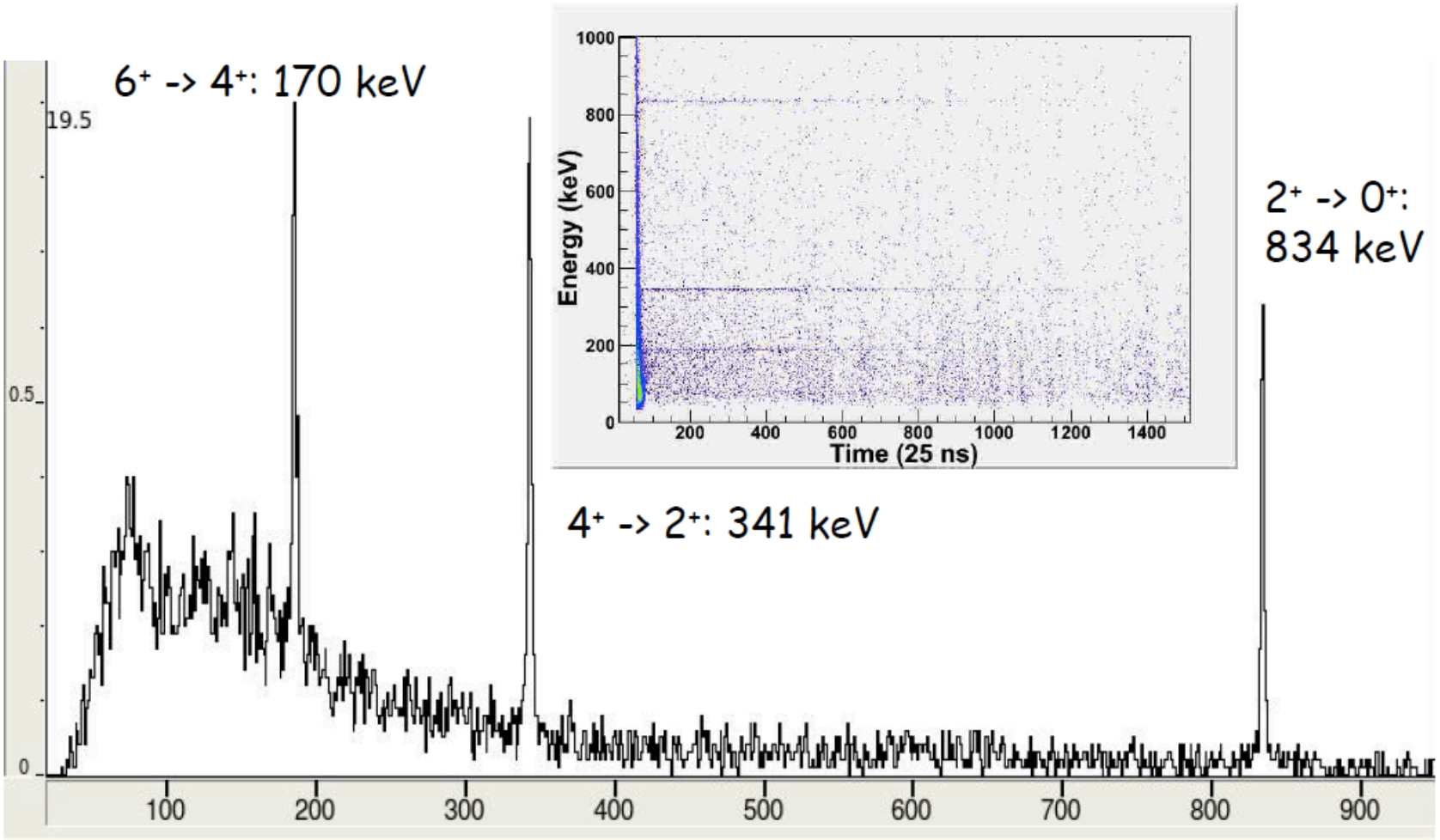


For even-even nuclei, the 0^+ ground state has seniority $\nu = 0$, while the 2^+, 4^+, 6^+, 8^+ states have $\nu = 2$

In a pure seniority scheme, the relative level energies do not depend on the number of particles in the shell j

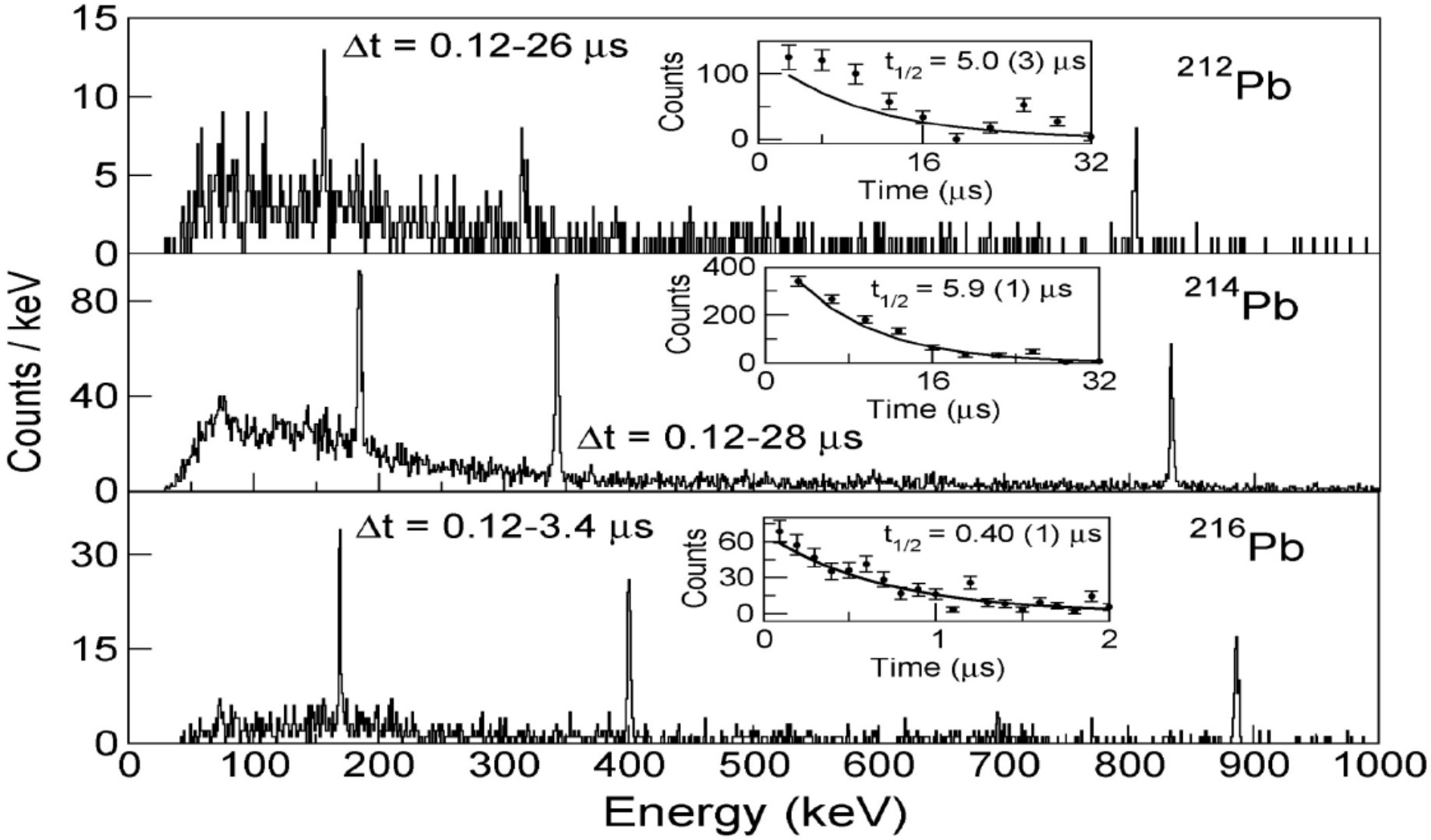
^{214}Pb : 8^{+} isomer

$T_{1/2}$ = 5.9 (1) µs



A. Gottardo, J.J. Valiente Dobon,
B. G. Benzoni et al., for RISING

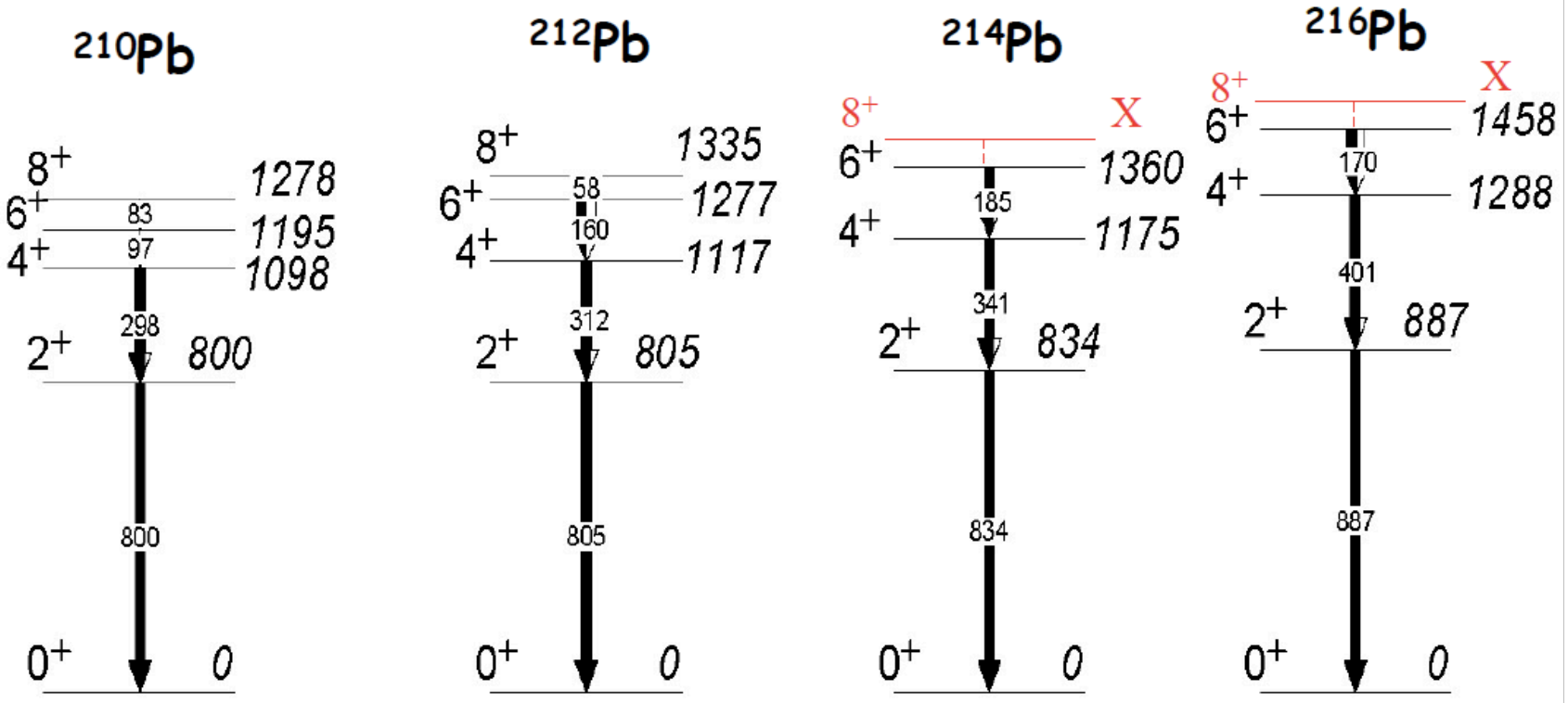
^{212,214,216}Pb: 8^+ isomer



A. Gottardo, J.J. Valiente Dobon, G. Benzoni et al.,

The experimental levels and the seniority scheme

The 8^+ isomer is a seniority isomer, involving neutrons in the $2g_{9/2}$

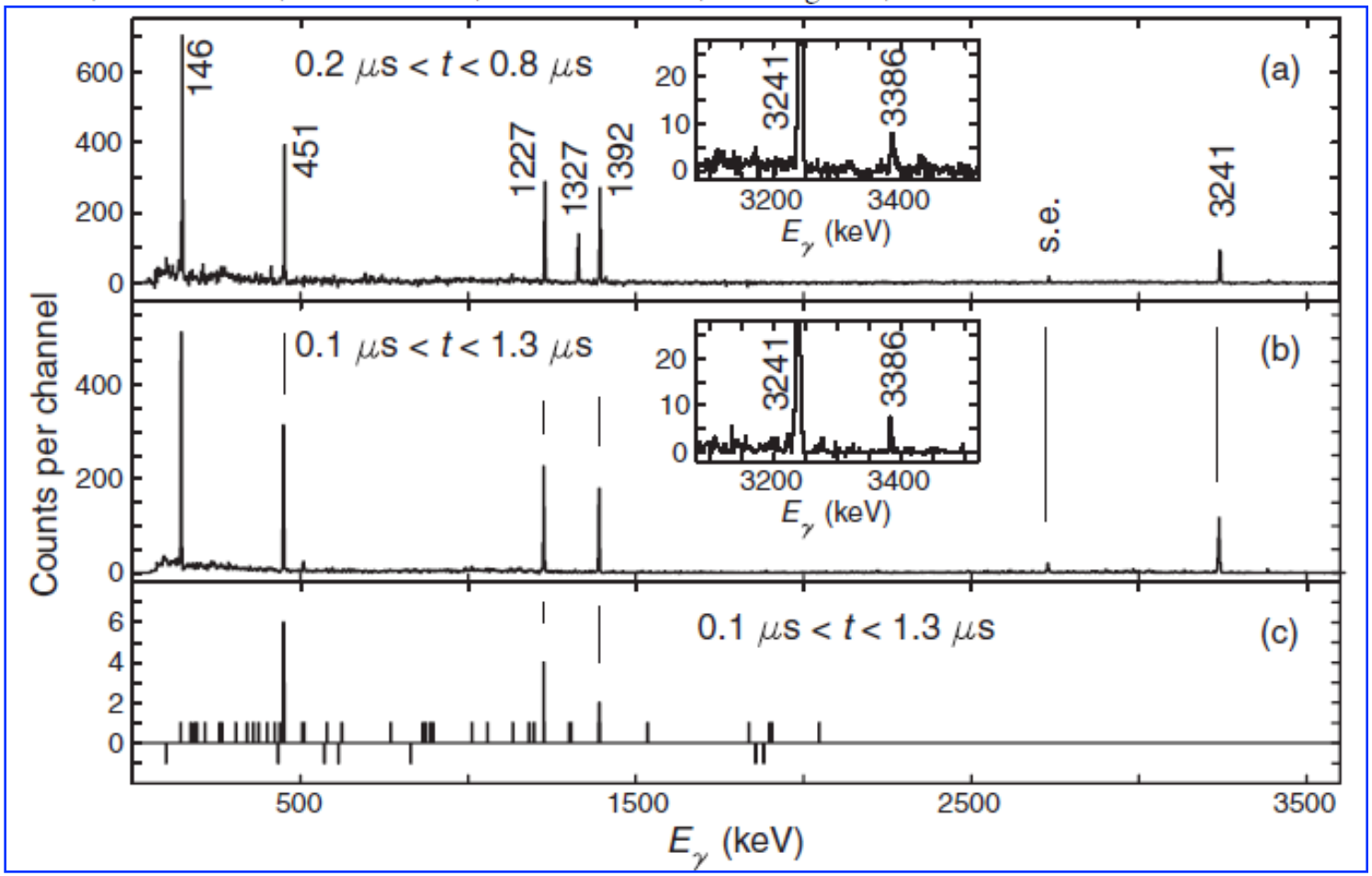


Z ~28 N~28

PHYSICAL REVIEW C **78**, 021301(R) (2008)

Isospin symmetry and proton decay: Identification of the 10^+ isomer in ^{54}Ni

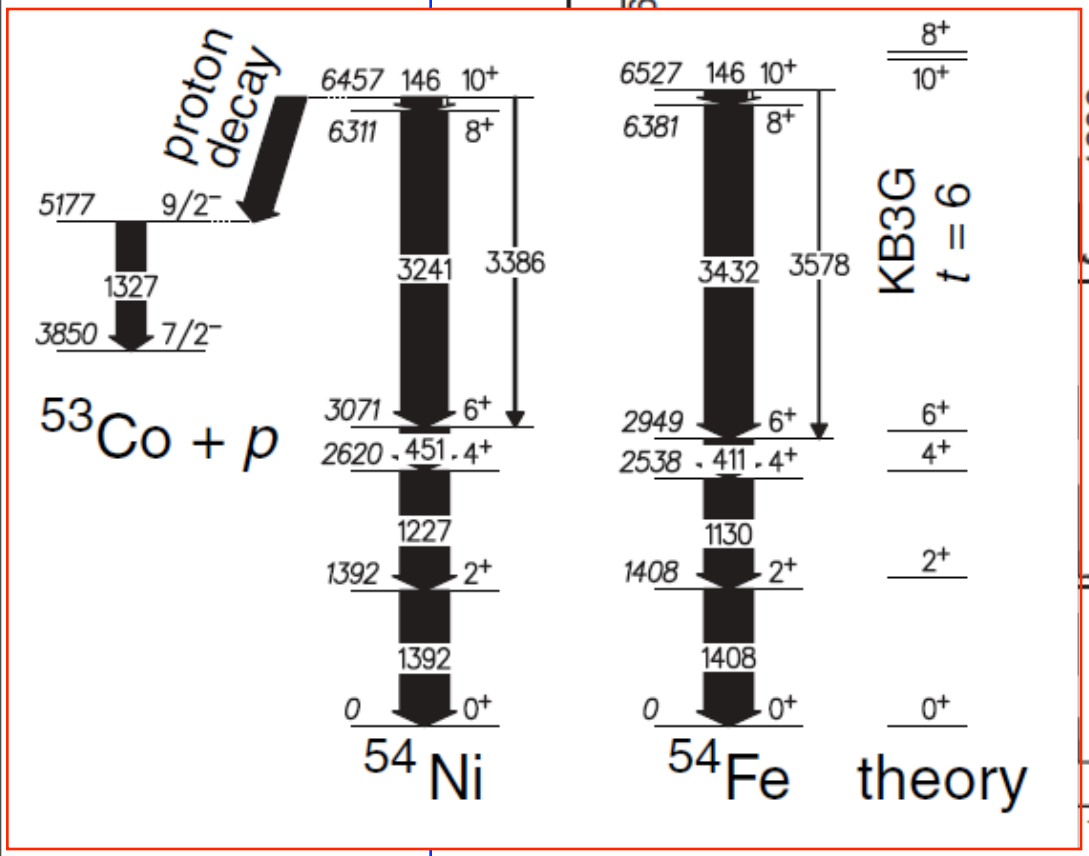
D. Rudolph,[1] R. Hoischen,[1,2] M. Hellström,[1] S. Pietri,[3] Zs. Podolyák,[3] P. H. Regan,[3] A. B. Garnsworthy,[3,4] S. J. Steer,[3] F. Becker,[2,*] P. Bednarczyk,[2,5] L. Cáceres,[2,6] P. Doornenbal,[2,7,†] J. Gerl,[2] M. Górska,[2] J. Grębosz,[2,5] I. Kojouharov,[2] N. Kurz,[2] W. Prokopowicz,[2,5] H. Schaffner,[2] H. J. Wollersheim,[2] L.-L. Andersson,[1] L. Atanasova,[8] D. L. Balabanski,[8,9] M. A. Bentley,[10] A. Blazhev,[7] C. Brandau,[2,3] J. R. Brown,[10] C. Fahlander,[1] E. K. Johansson,[1] A. Jungclaus,[6] and S. M. Lenzi[11]

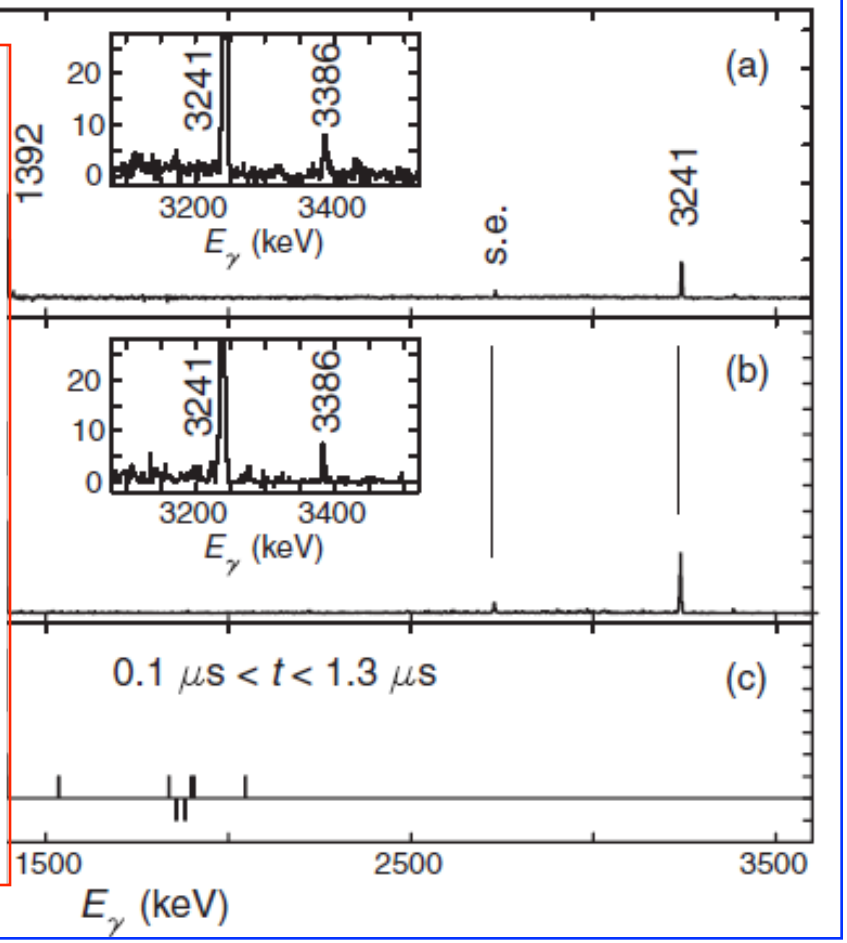


PHYSICAL REVIEW C **78**, 021301(R) (2008)

Isospin symmetry and proton decay: Identification of the 10^+ isomer in ^{54}Ni

D. Rudolph,[1] R. Hoischen,[1,2] M. Hellström,[1] S. Pietri,[3] Zs. Podolyák,[3] P. H. Regan,[3] A. B. Garnsworthy,[3,4] S. J. Steer,[3] F. Becker,[2,*] P. Bednarczyk,[2,5] L. Cáceres,[2,6] P. Doornenbal,[2,7,†] J. Gerl,[2] M. Górska,[2] J. Grębosz,[2,5] I. Kojouharov,[2] N. Kurz,[2] W. Prokopowicz,[2,5] H. Schaffner,[2] H. J. Wollersheim,[2] L.-L. Andersson,[1] L. Atanasova,[8] D. L. Balabanski,[8,9] M. A. Bentley,[10] A. Blazhev,[7] C. Brandau,[2,3] J. R. Brown,[10] C. Fahlander,[1] E. K. Johansson,[1] A. Jungclaus,[6] and S. M. Lenzi[11]

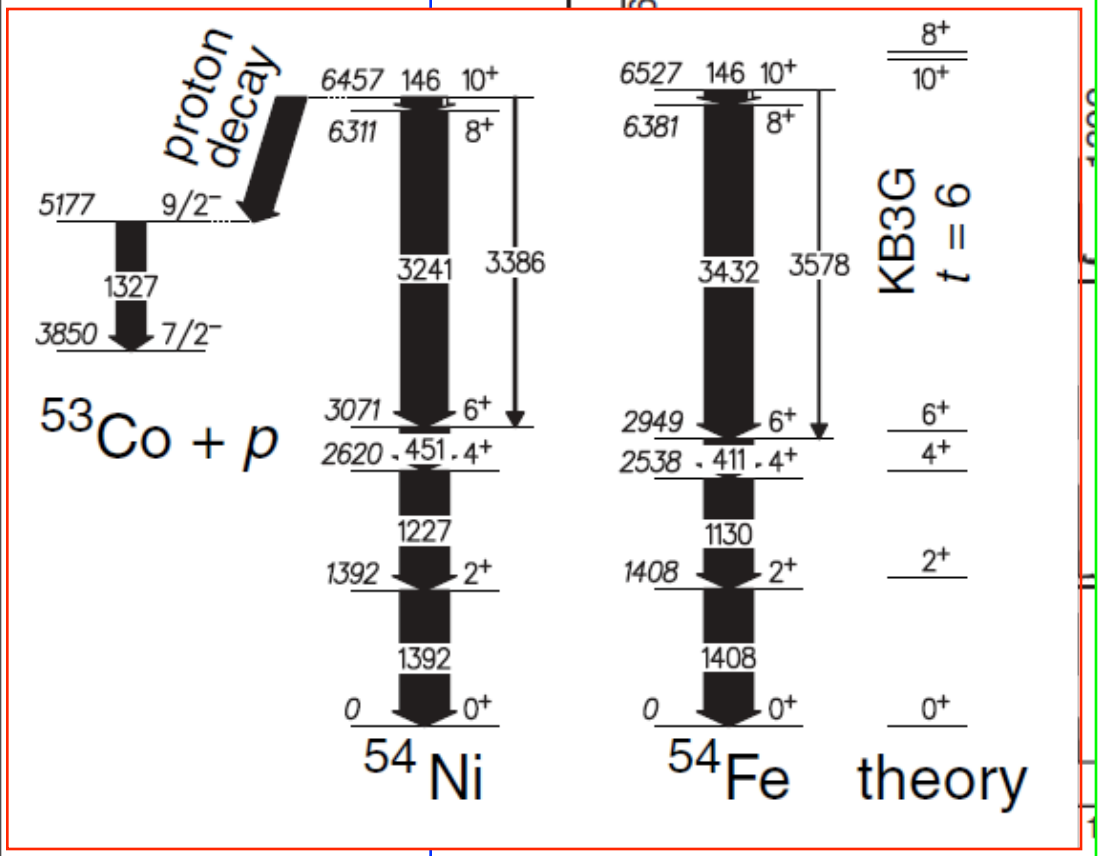




PHYSICAL REVIEW C **78**, 021301(R) (2008)

Isospin symmetry and proton decay: Identification of the 10^+ isomer in ^{54}Ni

D. Rudolph,[1] R. Hoischen,[1,2] M. Hellström,[1] S. Pietri,[3] Zs. Podolyák,[3] P. H. Regan,[3] A. B. Garnsworthy,[3,4] S. J. Steer,[3] F. Becker,[2,*] P. Bednarczyk,[2,5] L. Cáceres,[2,6] P. Doornenbal,[2,7,†] J. Gerl,[2] M. Górska,[2] J. Grębosz,[2,5] I. Kojouharov,[2] N. Kurz,[2] W. Prokopowicz,[2,5] H. Schaffner,[2] H. J. Wollersheim,[2] L.-L. Andersson,[1] L. Atanasova,[8] D. L. Balabanski,[8,9] M. A. Bentley,[10] A. Blazhev,[7] C. Brandau,[2,3] J. R. Brown,[10] C. Fahlander,[1] E. K. Johansson,[1] A. Jungclaus,[6] and S. M. Lenzi[11]



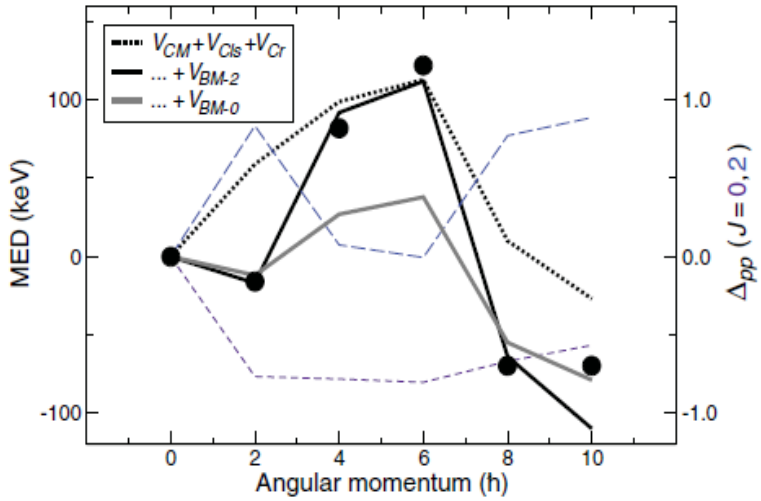


FIG. 4. (Color online) Mirror energy difference, $E_x(^{54}\mathrm{Ni}) - E_x(^{54}\mathrm{Fe})$, as a function of spin. Solid circles denote the experimental values. The dotted line accounts only for Coulomb related isospin breaking terms [11], while the solid black and grey lines include the V_{BM-2} [7] and V_{BM-0} terms, based on the KB3G interaction. The long- and short-dashed lines provide the difference between ^{54}Fe and ^{54}Ni of $T = 1$ proton pairs, Δ_{pp}, coupled to either $J = 2$ or $J = 0$, respectively.

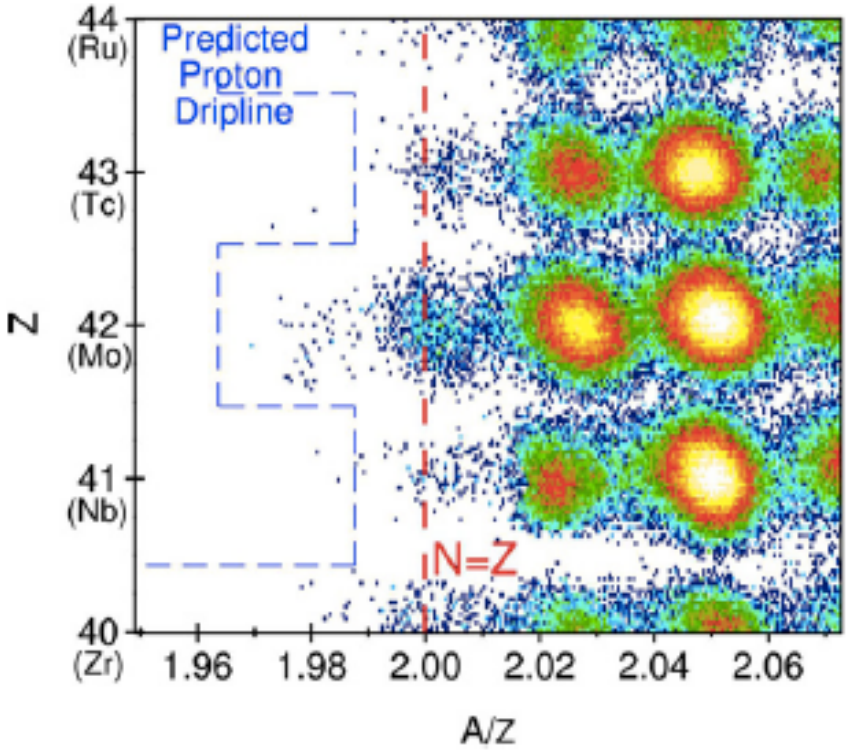
ELSEVIER

Physics Letters B 660 (2008) 326–330

www.elsevier.com/locate/physletb

Neutron–proton pairing competition in $N = Z$ nuclei: Metastable state decays in the proton dripline nuclei $^{82}_{41}$Nb and $^{86}_{43}$Tc

A.B. Garnsworthy [a,b,*], P.H. Regan [a], L. Cáceres [c,d], S. Pietri [a], Y. Sun [e,f], D. Rudolph [g], M. Górska [c], Zs. Podolyák [a], S.J. Steer [a], R. Hoischen [c,g], A. Heinz [b], F. Becker [c], P. Bednarczyk [c,h], P. Doornenbal [c], H. Geissel [c], J. Gerl [c], H. Grawe [c], J. Grębosz [c,h], A. Kelic [c], I. Kojouharov [c], N. Kurz [c], F. Montes [c], W. Prokopowicz [c], T. Saito [c], H. Schaffner [c], S. Tachenov [c], E. Werner-Malento [c,i], H.J. Wollersheim [c], G. Benzoni [j], B.B. Blank [k], C. Brandau [a,c], A.M. Bruce [l], F. Camera [j], W.N. Catford [a], I.J. Cullen [a], Zs. Dombrádi [m], E. Estevez [n], W. Gelletly [a], G. Ilie [o,p], J. Jolie [o], G.A. Jones [a], A. Jungclaus [d], M. Kmiecik [h], F.G. Kondev [q], T. Kurtukian-Nieto [k,n], S. Lalkovski [l,r], Z. Liu [a], A. Maj [h], S. Myalski [h], M. Pfützner [i], S. Schwertel [s], T. Shizuma [a,t], A.J. Simons [a,u], P.M. Walker [a], O. Wieland [j], F.R. Xu [v]



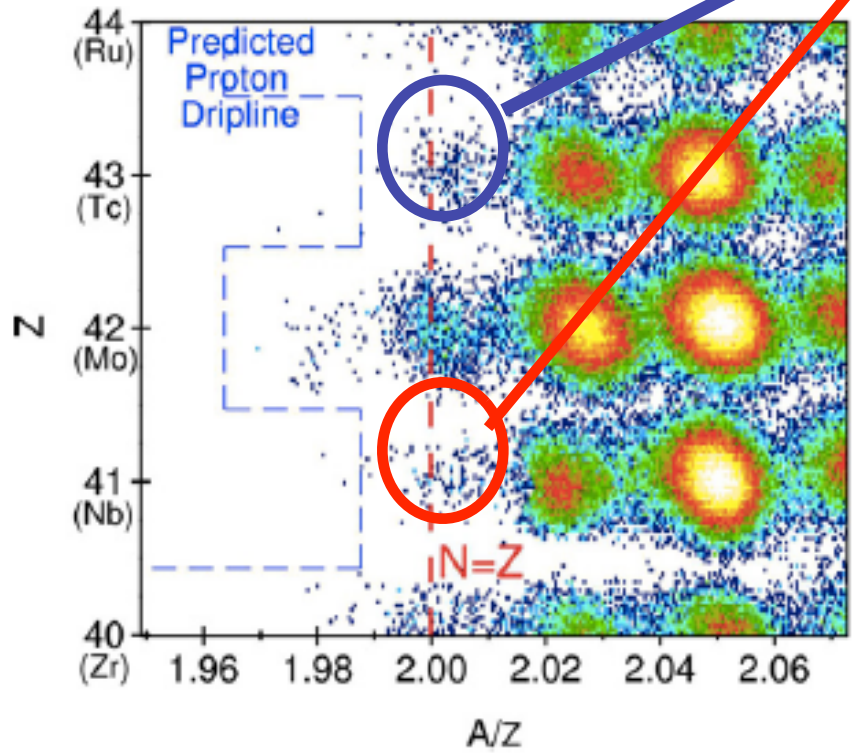
ELSEVIER

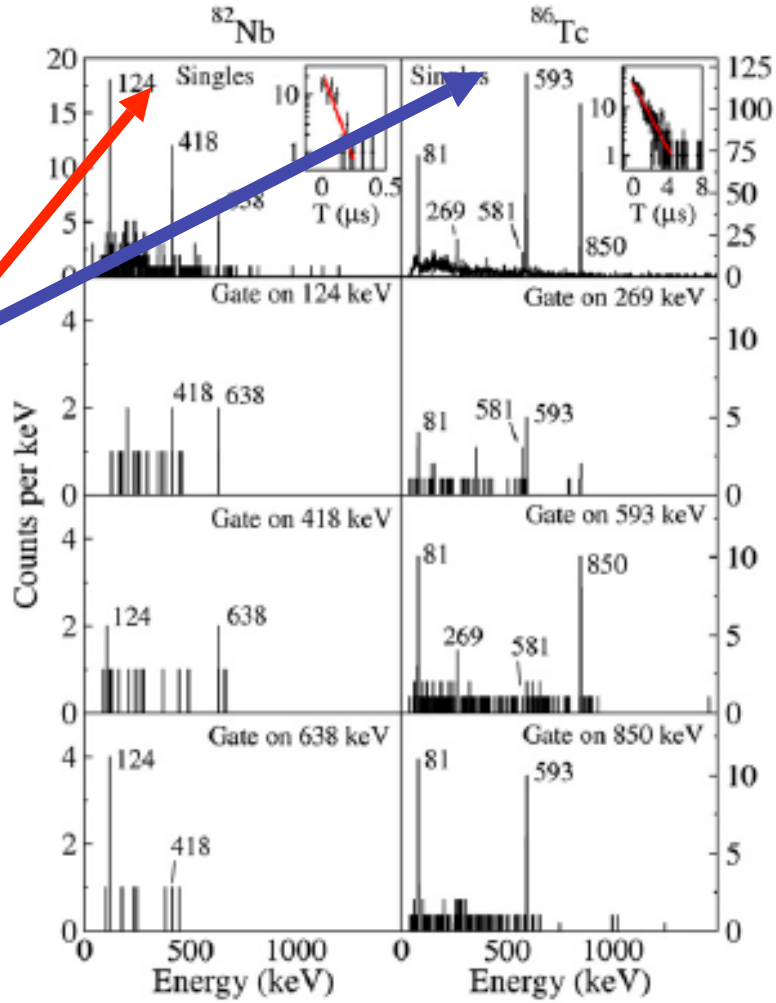
Physics Letters B 660 (2008) 326–330

www.elsevier.com/locate/physletb

Neutron–proton pairing competition in $N = Z$ nuclei: Metastable state decays in the proton dripline nuclei $^{82}_{41}$Nb and $^{86}_{43}$Tc

A.B. Garnsworthy [a,b,*], P.H. Regan [a], L. Cáceres [c,d], S. Pietri [a], Y. Sun [e,f], D. Rudolph [g], M. Górska [c], Zs. Podolyák [a], S.J. Steer [a], R. Hoischen [c,g], A. Heinz [b], F. Becker [c], P. Bednarczyk [c,h], P. Doornenbal [c], H. Geissel [c], J. Gerl [c], H. Grawe [c], J. Grębosz [c,h], A. Kelic [c], I. Kojouharov [c], N. Kurz [c], F. Montes [c], W. Prokopowicz [c], T. Saito [c], H. Schaffner [c], S. Tachenov [c], E. Werner-Malento [c,i], H.J. Wollersheim [c], G. Benzoni [j], B.B. Blank [k], C. Brandau [a,c], A.M. Bruce [l], F. Camera [j], W.N. Catford [a], I.J. Cullen [a], Zs. Dombrádi [m], E. Estevez [n], W. Gelletly [a], G. Ilie [o,p], J. Jolie [o], G.A. Jones [a], A. Jungclaus [d], M. Kmiecik [h], F.G. Kondev [q], T. Kurtukian-Nieto [k,n], S. Lalkovski [l,r], Z. Liu [a], A. Maj [h], S. Myalski [h], M. Pfützner [i], S. Schwertel [s], T. Shizuma [a,t], A.J. Simons [a,u], P.M. Walker [a], O. Wieland [j], F.R. Xu [v]





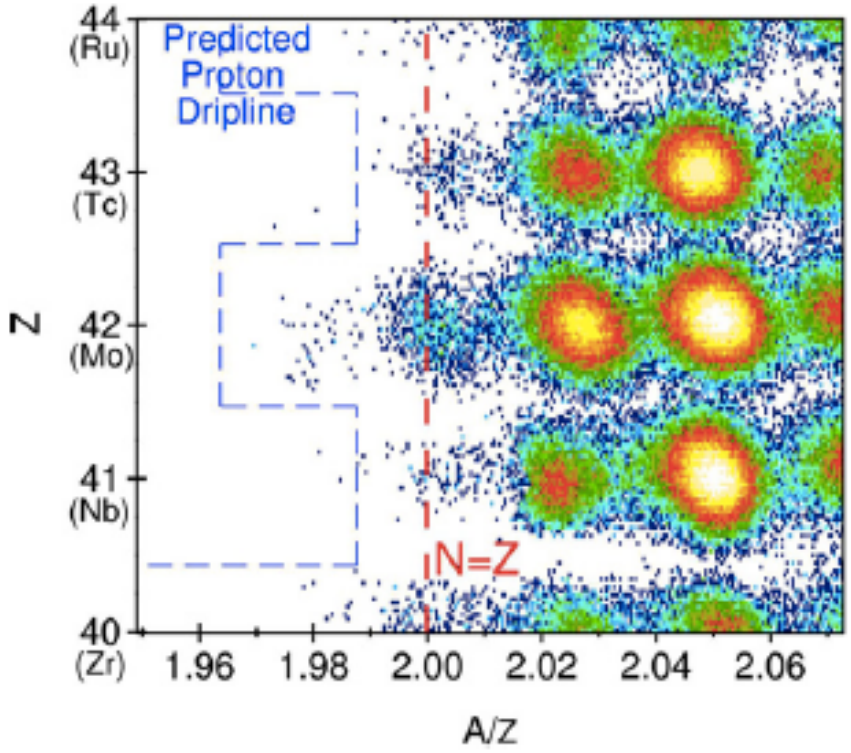
ELSEVIER

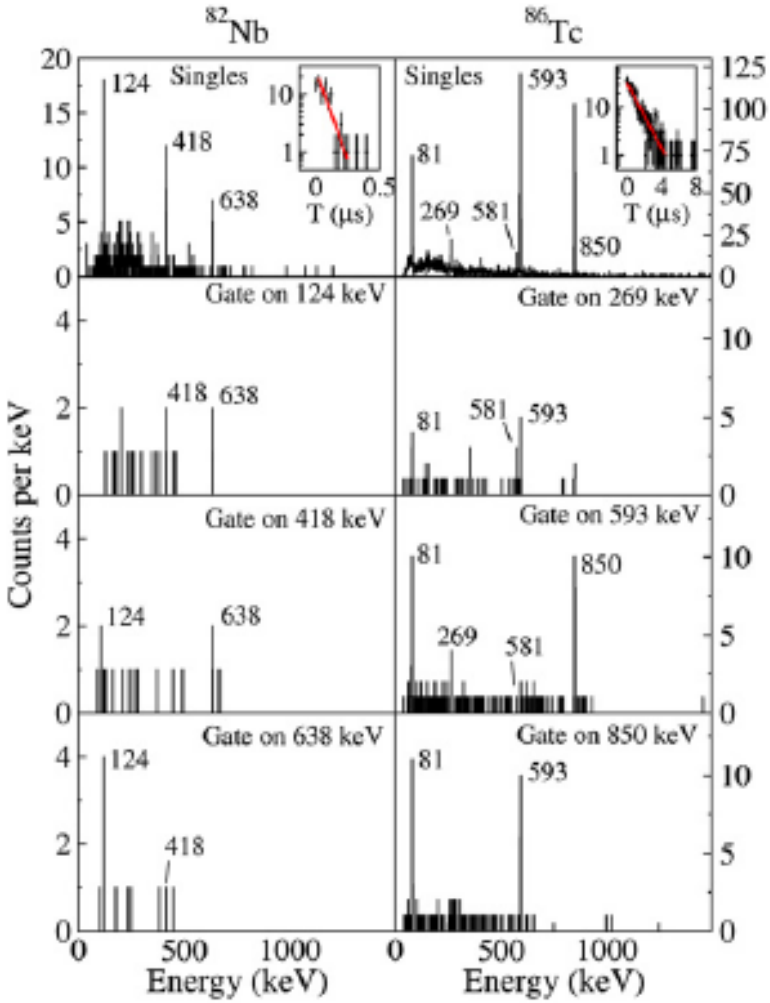
Physics Letters B 660 (2008) 326–330

www.elsevier.com/locate/physletb

Neutron–proton pairing competition in $N = Z$ nuclei: Metastable state decays in the proton dripline nuclei $^{82}_{41}$Nb and $^{86}_{43}$Tc

A.B. Garnsworthy [a,b,*], P.H. Regan [a], L. Cáceres [c,d], S. Pietri [a], Y. Sun [e,f], D. Rudolph [g], M. Górska [c], Zs. Podolyák [a], S.J. Steer [a], R. Hoischen [c,g], A. Heinz [b], F. Becker [c], P. Bednarczyk [c,h], P. Doornenbal [c], H. Geissel [c], J. Gerl [c], H. Grawe [c], J. Grębosz [c,h], A. Kelic [c], I. Kojouharov [c], N. Kurz [c], F. Montes [c], W. Prokopowicz [c], T. Saito [c], H. Schaffner [c], S. Tachenov [c], E. Werner-Malento [c,i], H.J. Wollersheim [c], G. Benzoni [j], B.B. Blank [k], C. Brandau [a,c], A.M. Bruce [l], F. Camera [j], W.N. Catford [a], I.J. Cullen [a], Zs. Dombrádi [m], E. Estevez [n], W. Gelletly [a], G. Ilie [o,p], J. Jolie [o], G.A. Jones [a], A. Jungclaus [d], M. Kmiecik [h], F.G. Kondev [q], T. Kurtukian-Nieto [k,n], S. Lalkovski [l,r], Z. Liu [a], A. Maj [h], S. Myalski [h], M. Pfützner [i], S. Schwertel [s], T. Shizuma [a,t], A.J. Simons [a,u], P.M. Walker [a], O. Wieland [j], F.R. Xu [v]





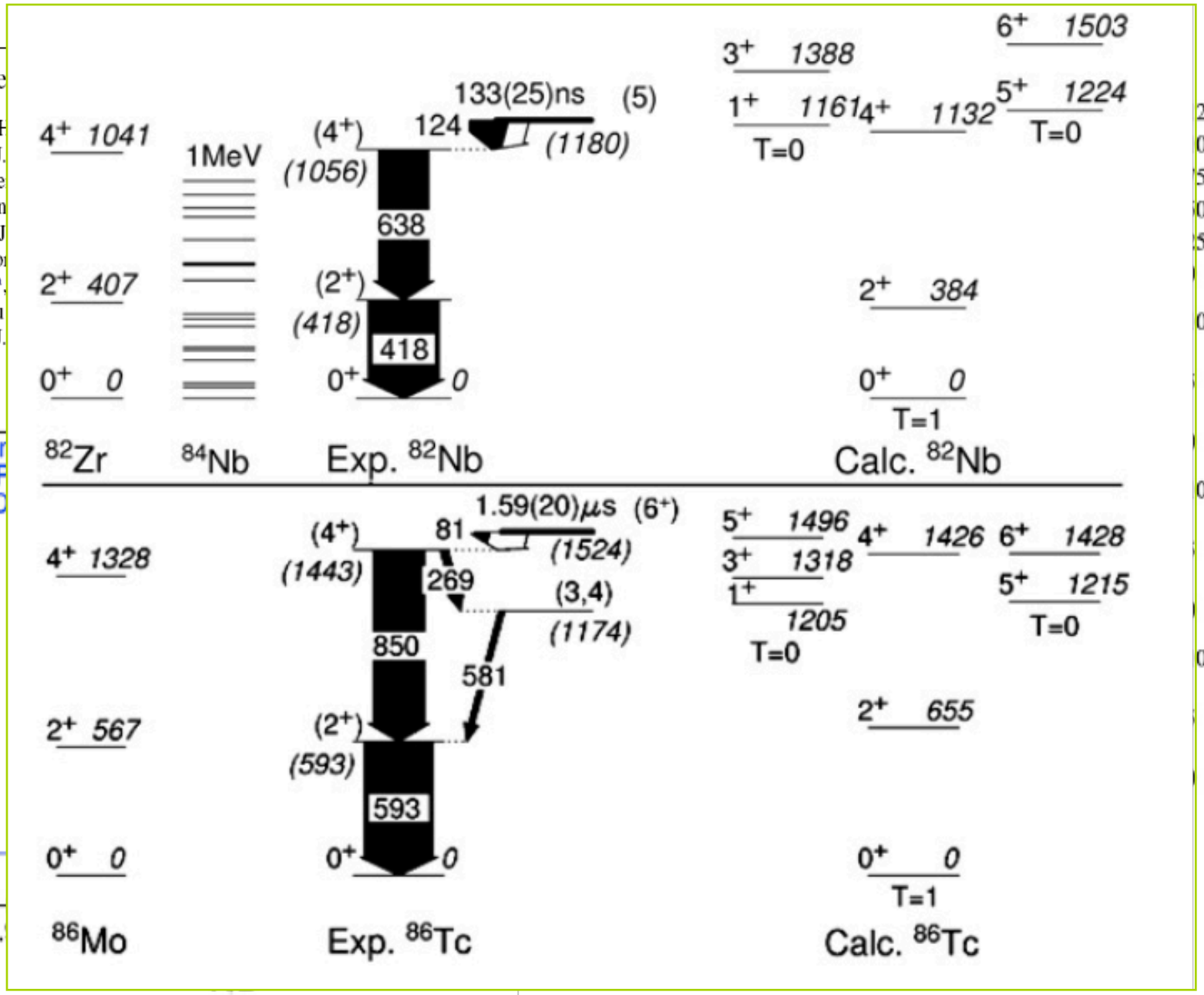
ELSEVIER

Physics Letters B 660 (2008) 326–330

www.elsevier.com/locate/physletb

Neutron–
Metastable state

A.B. Garnsworthy [a,b,*], P.H
Zs. Podolyák [a], S.J.
P. Doornenbal [c], H. Ge
N. Kurz [c], F. Mon
E. Werner-Malento [c,i], H.J
F. Camera [j], W.N. Catfo
J. Jolie [o], G.A. Jones [a],
S. Lalkovski [l,r], Z. Liu
A.J.

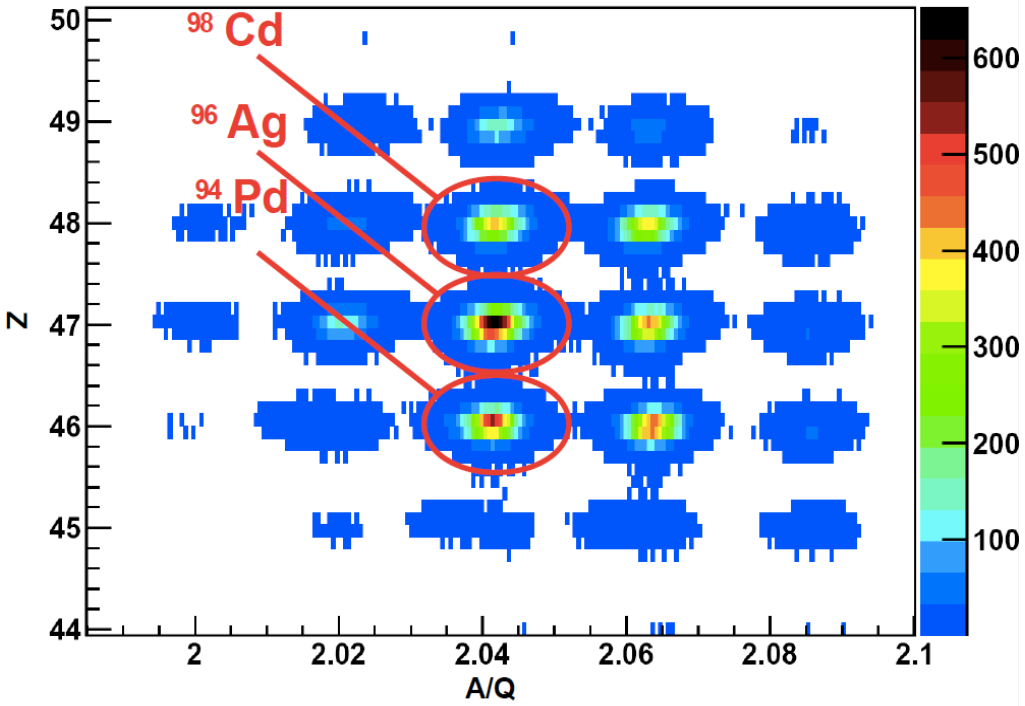


N~Z~50 nuclei

Study of $N \geq Z$ proton drip-line nuclei ^{96,97,98}Cd with astrophysical consequences

Spokespersons:
A. Blazhev, P. Boutachkov Z. Liu, R. Wadsworth

- Study the isospin symmetry as a function of mass, at N~Z.
- Shell Model residual interaction.
- Study the neutron-proton pairing.
- Study the competition between pairing and deformation for N~Z, A~90-100
  (the π and ν occupy the $g_{9/2}$ shell).
- rp-process.



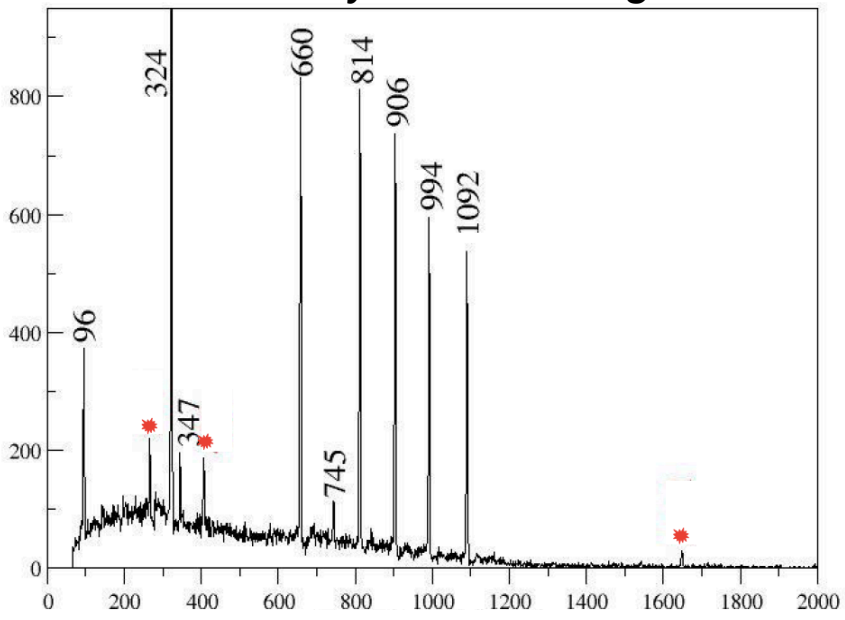
15 Shifts: ^{124}Xe: 850 MeV/u I_0~10^9 pps
on ^{9}Be target
15 Shifts remaining

S352

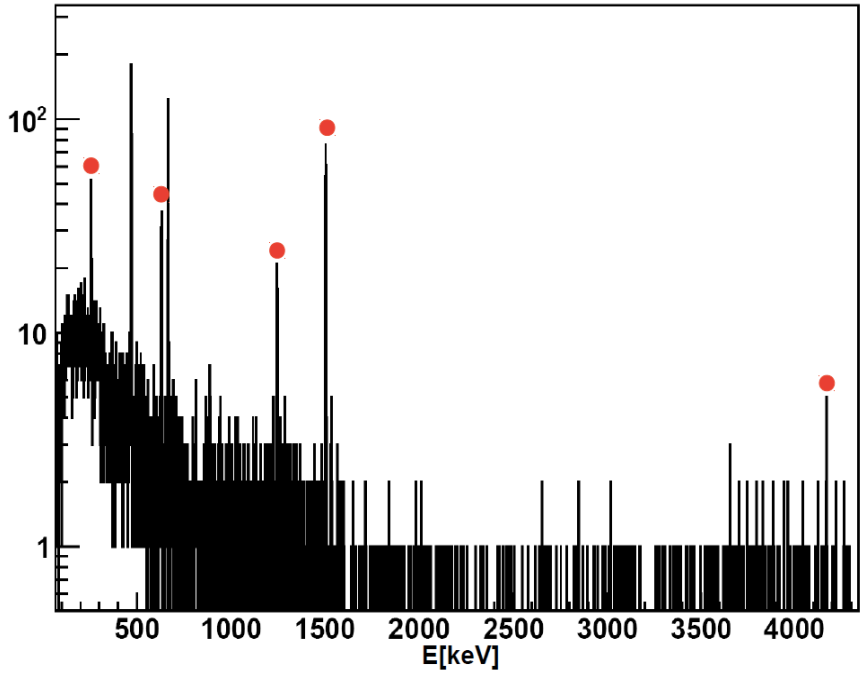
NuSTAR 2010

Preliminary Results

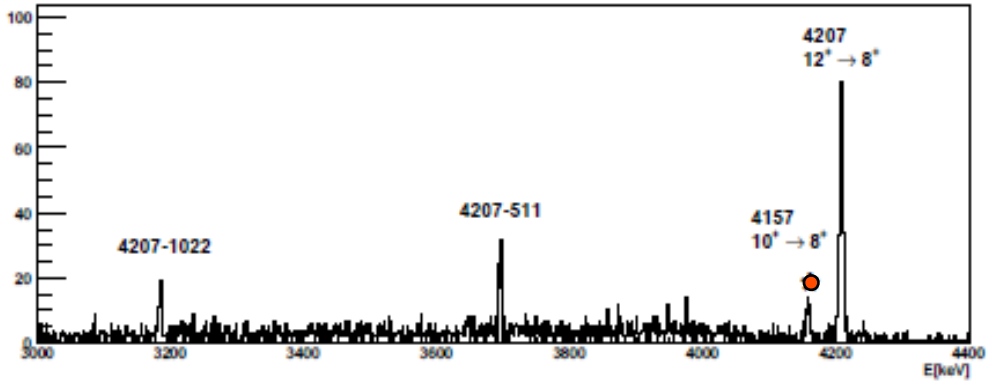
Isomeric decays of ^{94}Pd fragments.



Isomeric decays of ^{96}Ag fragments.



Isomeric decays of ^{98}Cd fragments.



Analyzed to date:

- ^{94}Pd: new, high-spin isomer.
- ^{96}Ag: two new isomers, including core-excited states.
- ^{98}Cd: new high-energy, isomeric γ-ray transition from core breaking.

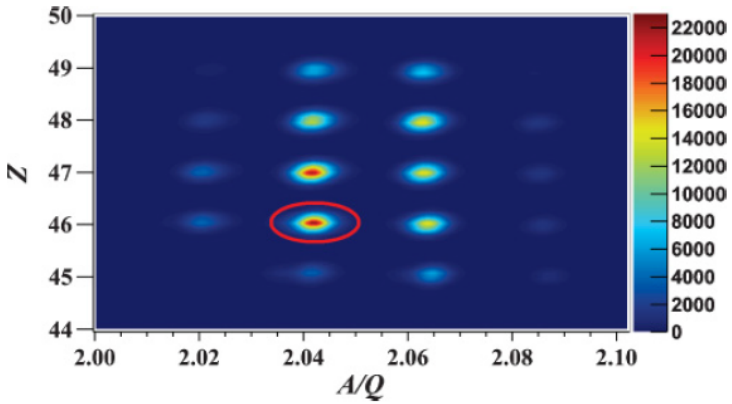
More to come …

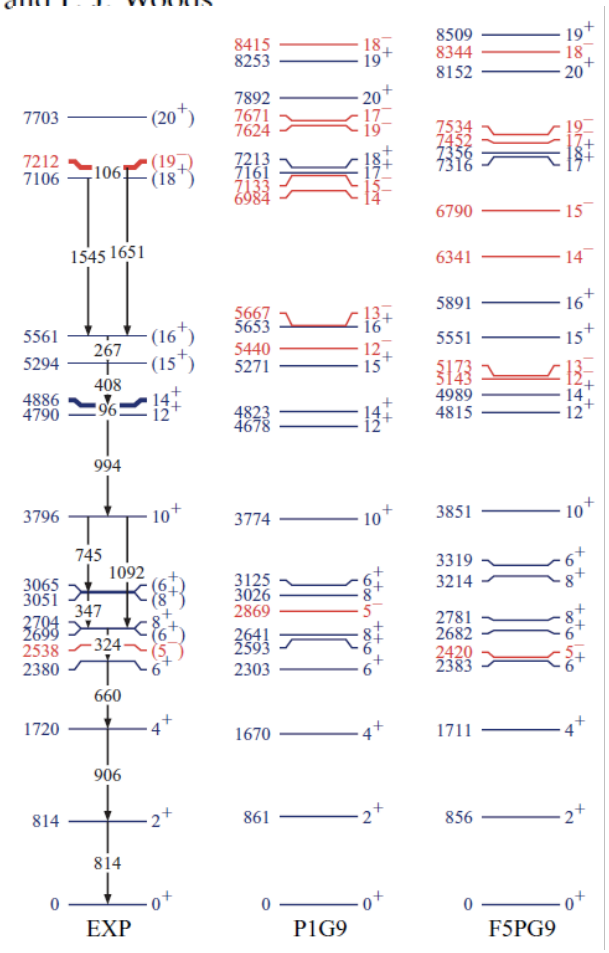
S352

PHYSICAL REVIEW C **82**, 061309(R) (2010)

Observation of a new high-spin isomer in ^{94}Pd

T. S. Brock,[1] B. S. Nara Singh,[1] P. Boutachkov,[2] N. Braun,[3] A. Blazhev,[3] Z. Liu,[4] R. Wadsworth,[1] M. Górska,[2] H. Grawe,[2] S. Pietri,[2] C. Domingo-Pardo,[2] D. Rudolph,[5] S. J. Steer,[6] A. Ataç,[7] L. Bettermann,[3] L. Cáceres,[2] T. Engert,[2] K. Eppinger,[8] T. Faestermann,[8] F. Farinon,[2] F. Finke,[3] K. Geibel,[3] J. Gerl,[2] R. Gernhäuser,[8] N. Goel,[2] A. Gottardo,[4] J. Grębosz,[9] C. Hinke,[8] R. Hoischen,[2,5] G. Ilie,[3] H. Iwasaki,[3] J. Jolie,[3] A. Kaşkaş,[7] I. Kojuharov,[2] R. Krücken,[8] N. Kurz,[2] E. Merchán,[10] C. Nociforo,[2] J. Nyberg,[11] M. Pfützner,[12] A. Prochazka,[2] Zs. Podolyák,[6] P. H. Regan,[6] P. Reiter,[3] S. Rinta-Antila,[13] H. Schaffner,[2] C. Scholl,[3] P.-A. Söderström,[11] N. Warr,[3] H. Weick,[2] H.-J. Wollersheim,[14] and P. J. Woods[4]
(RISING Collaboration)

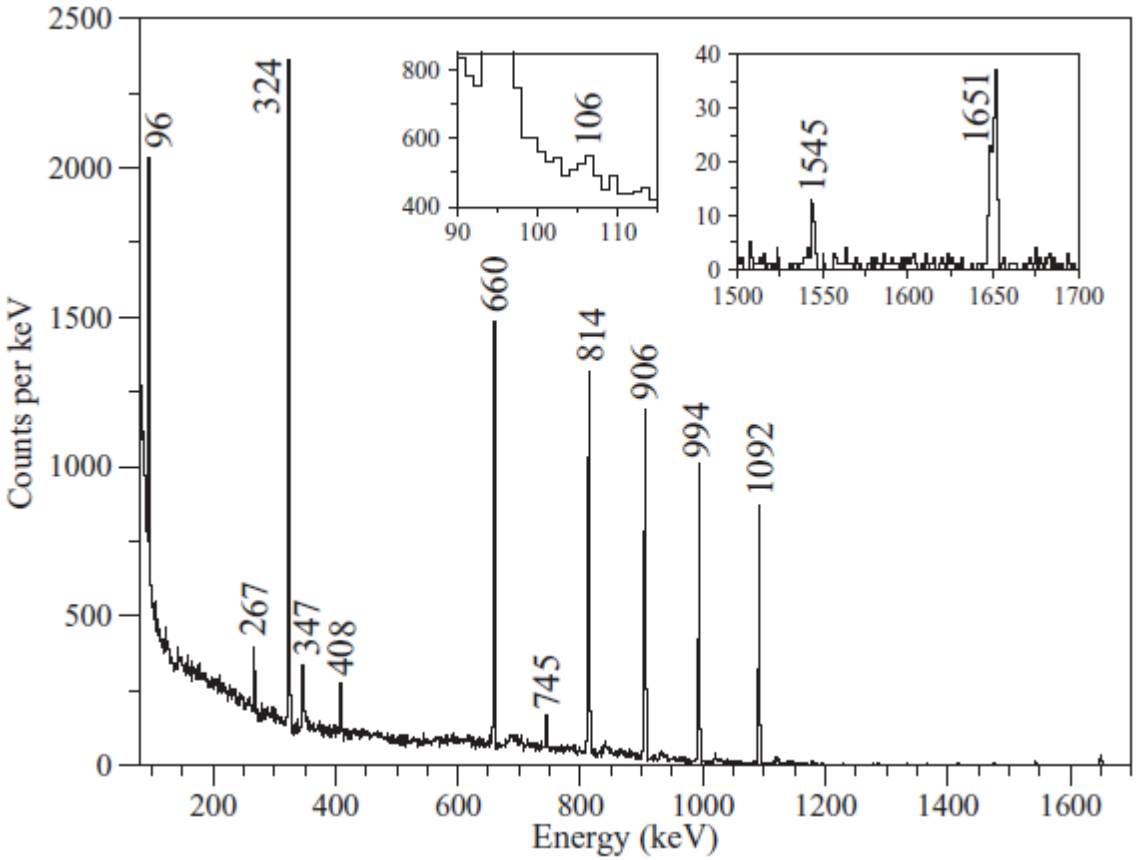


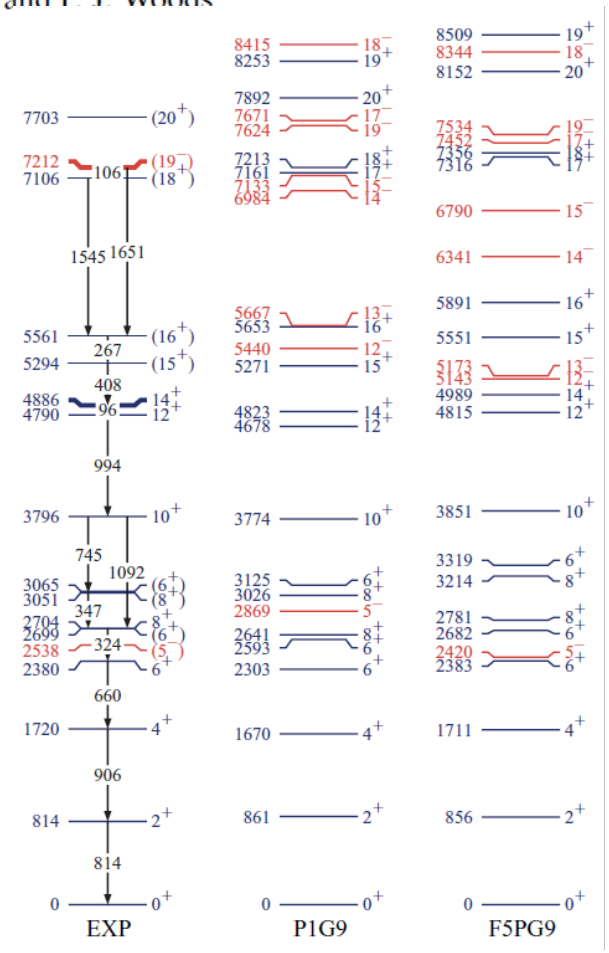


PHYSICAL REVIEW C **82**, 061309(R) (2010)

Observation of a new high-spin isomer in ^{94}Pd

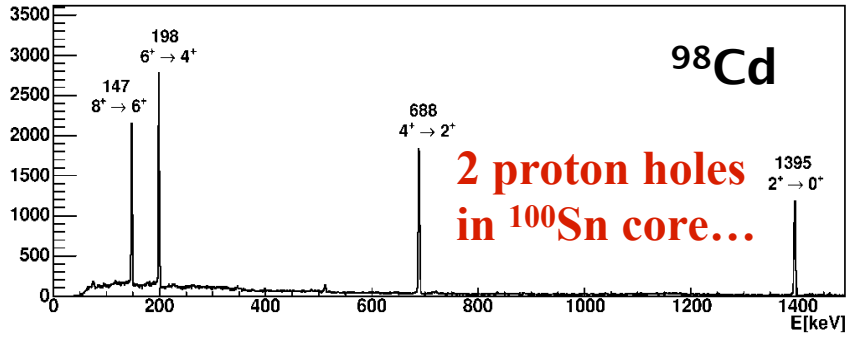
T. S. Brock,[1] B. S. Nara Singh,[1] P. Boutachkov,[2] N. Braun,[3] A. Blazhev,[3] Z. Liu,[4] R. Wadsworth,[1] M. Górska,[2] H. Grawe,[2] S. Pietri,[2] C. Domingo-Pardo,[2] D. Rudolph,[5] S. J. Steer,[6] A. Ataç,[7] L. Bettermann,[3] L. Cáceres,[2] T. Engert,[2] K. Eppinger,[8] T. Faestermann,[8] F. Farinon,[2] F. Finke,[3] K. Geibel,[3] J. Gerl,[2] R. Gernhäuser,[8] N. Goel,[2] A. Gottardo,[4] J. Grębosz,[9] C. Hinke,[8] R. Hoischen,[2,5] G. Ilie,[3] H. Iwasaki,[3] J. Jolie,[3] A. Kaşkaş,[7] I. Kojuharov,[2] R. Krücken,[8] N. Kurz,[2] E. Merchán,[10] C. Nociforo,[2] J. Nyberg,[11] M. Pfützner,[12] A. Prochazka,[2] Zs. Podolyák,[6] P. H. Regan,[6] P. Reiter,[3] S. Rinta-Antila,[13] H. Schaffner,[2] C. Scholl,[3] P.-A. Söderström,[11] N. Warr,[3] H. Weick,[2] H.-J. Wollersheim,[14] and P. J. Woods[4]
(RISING Collaboration)

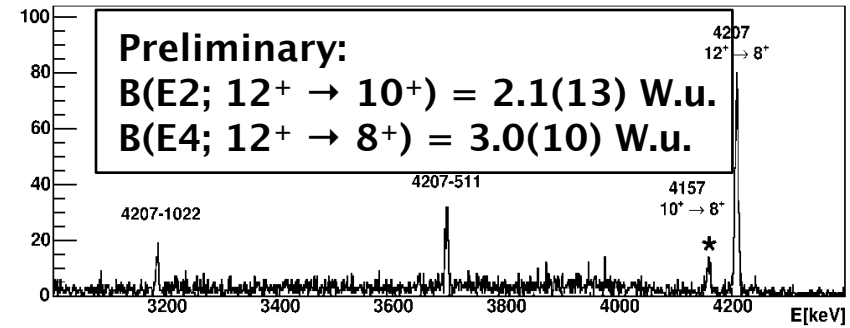




Isomer spectroscopy of ^{98}Cd

XVIII International School on Nuclear Physics, Neutron Physics and Applications
of Physics: Conference Series **205** (2010) 012035
doi:10.1088/1742-6596/205/1/012

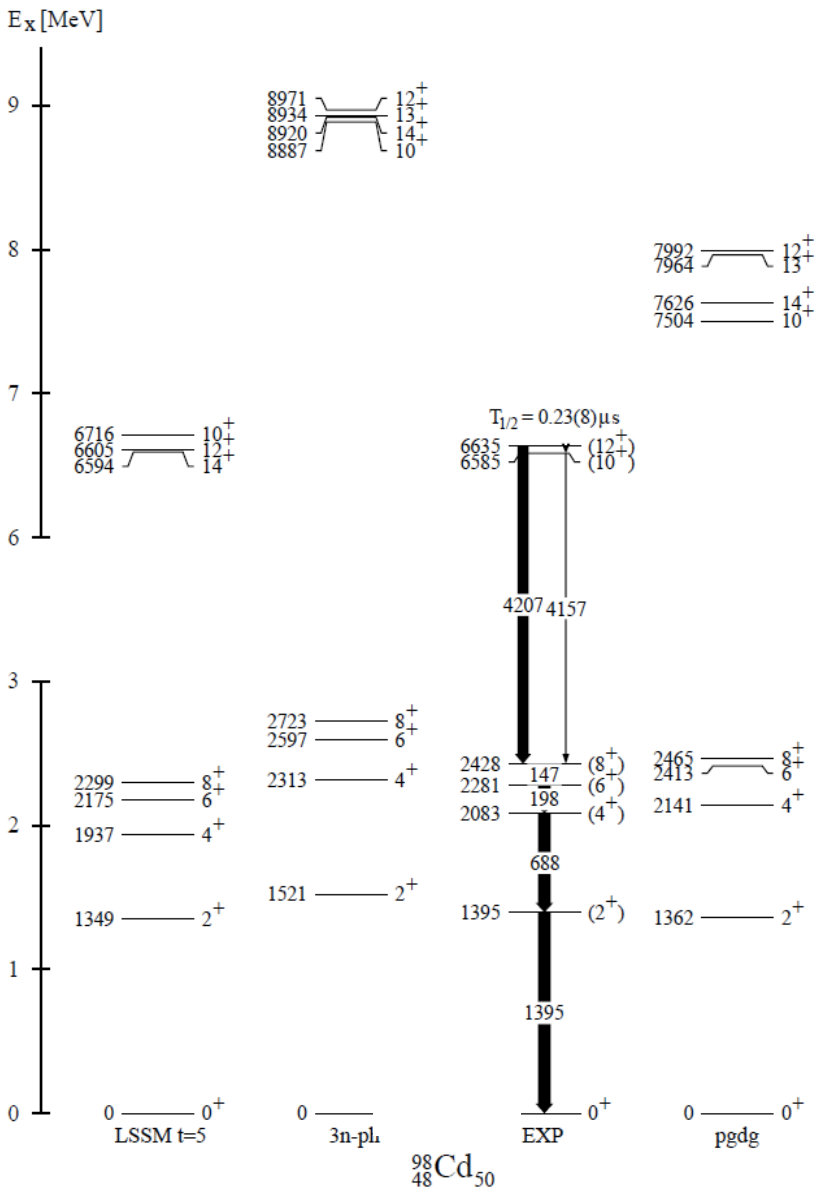




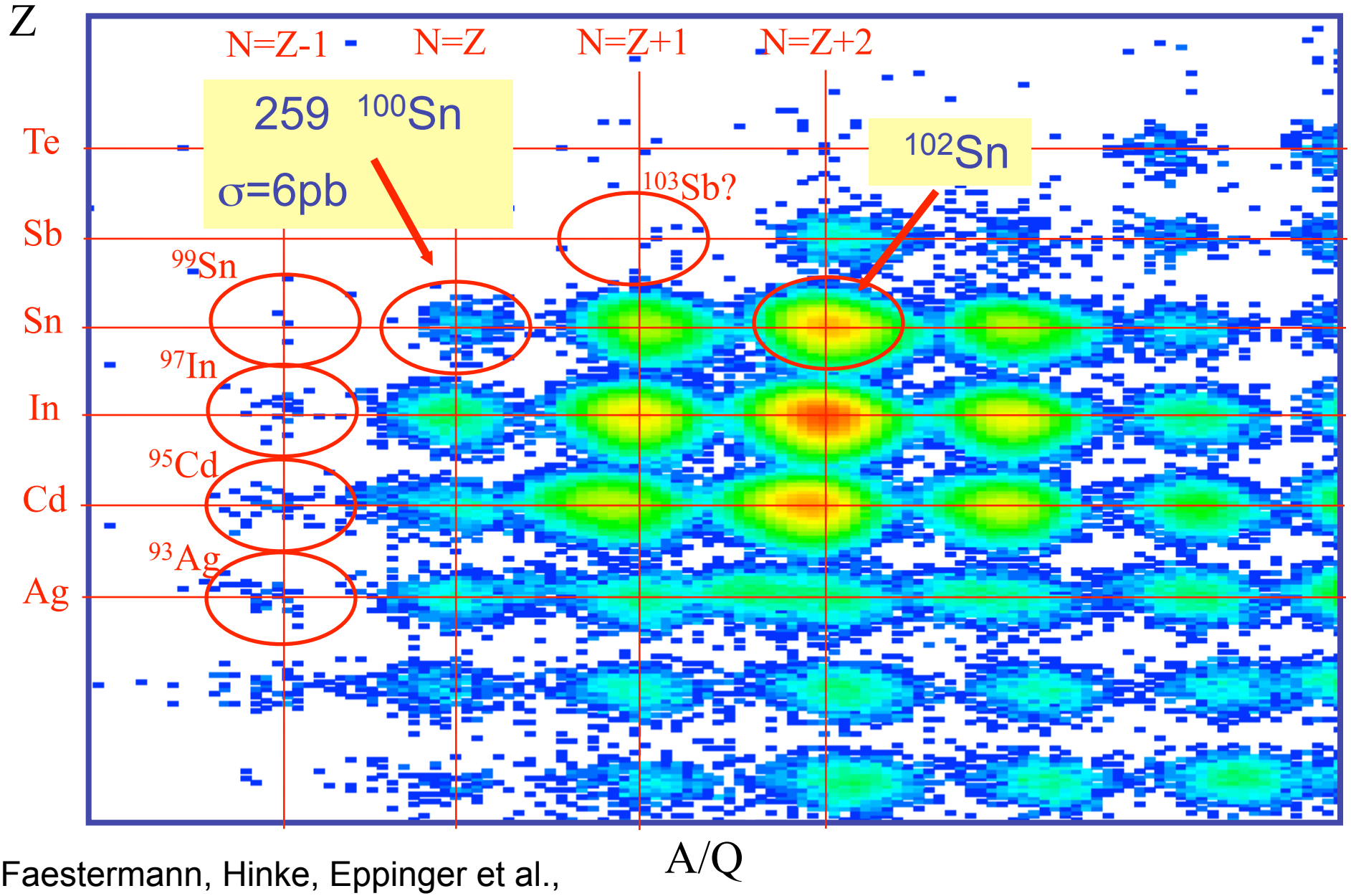
- Transition (* 4157 keV) identified in ^{98}Cd
- data suggests (10^+) state 50 keV below the (12^+)

➢ B(E4; 12^+ -> 8^+) and B(E2; 12^+ -> 10^+) estimates

➢ Ordering of the (10^+) and (12^+) levels – not reproduced by previous shell-model calculations.



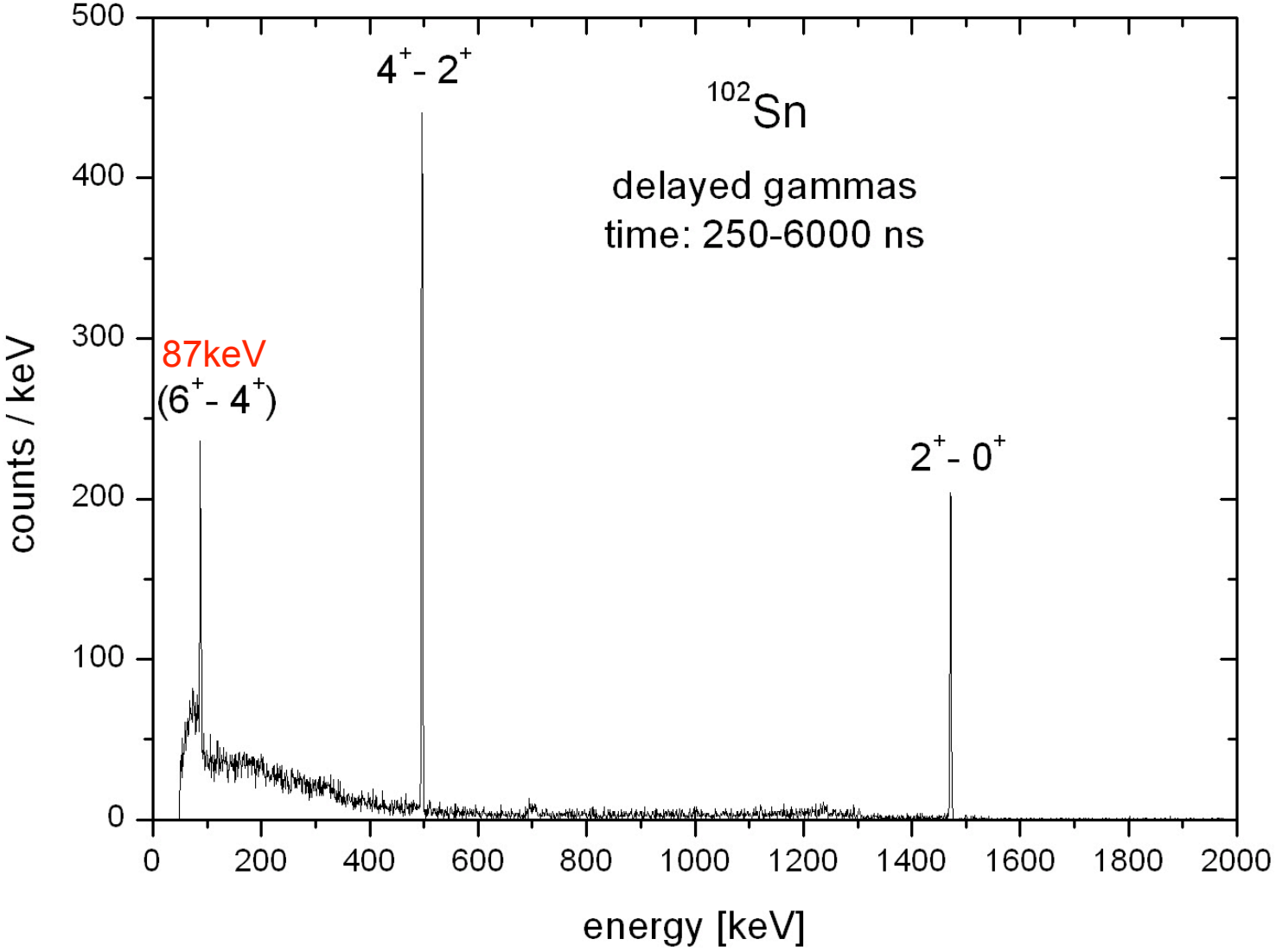
^{100}Sn setting (15 days ^{124}Xe beam)



Faestermann, Hinke, Eppinger et al.,

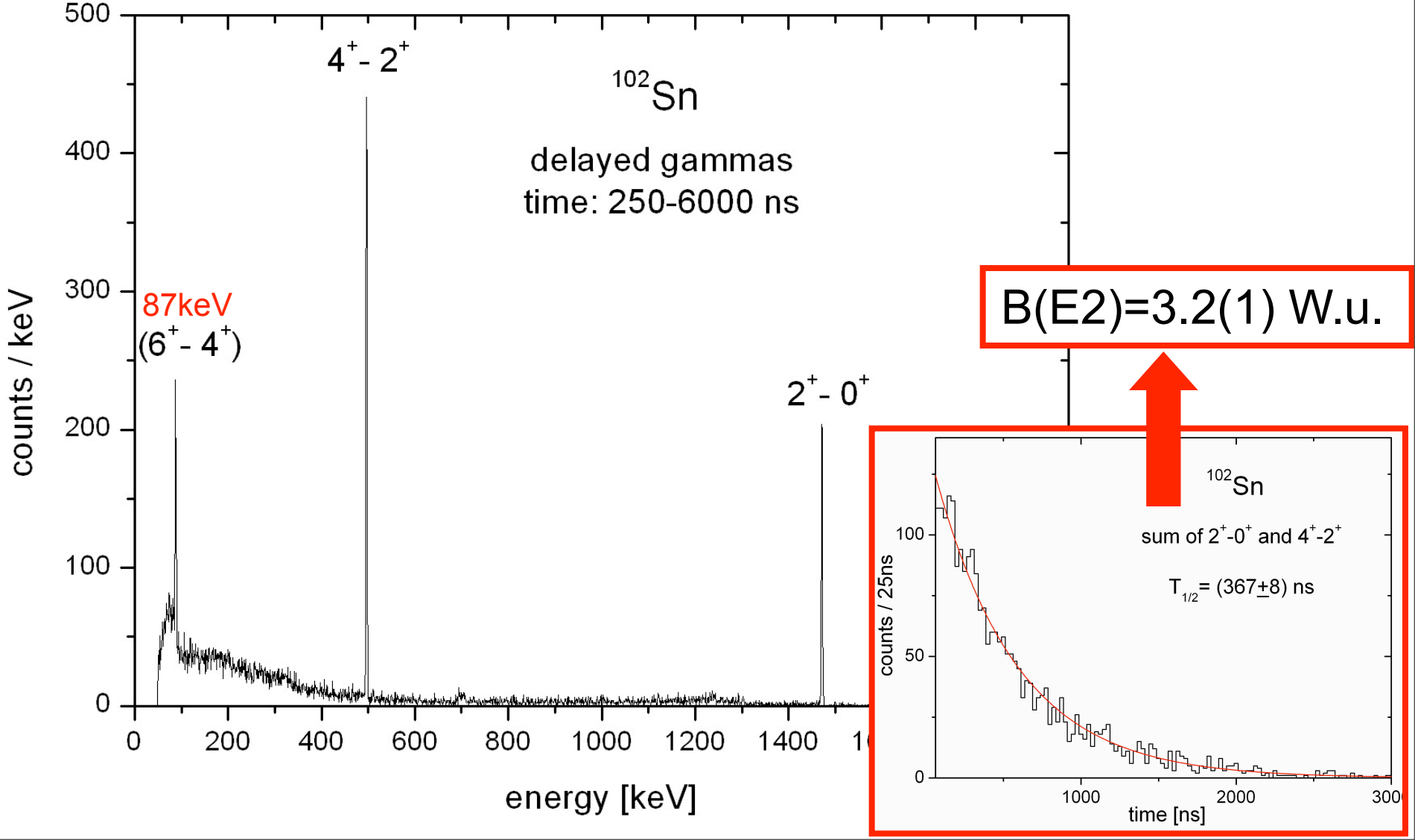
6^+ Isomer in ^{102}Sn

(2 neutron particles above ^{100}Sn core)



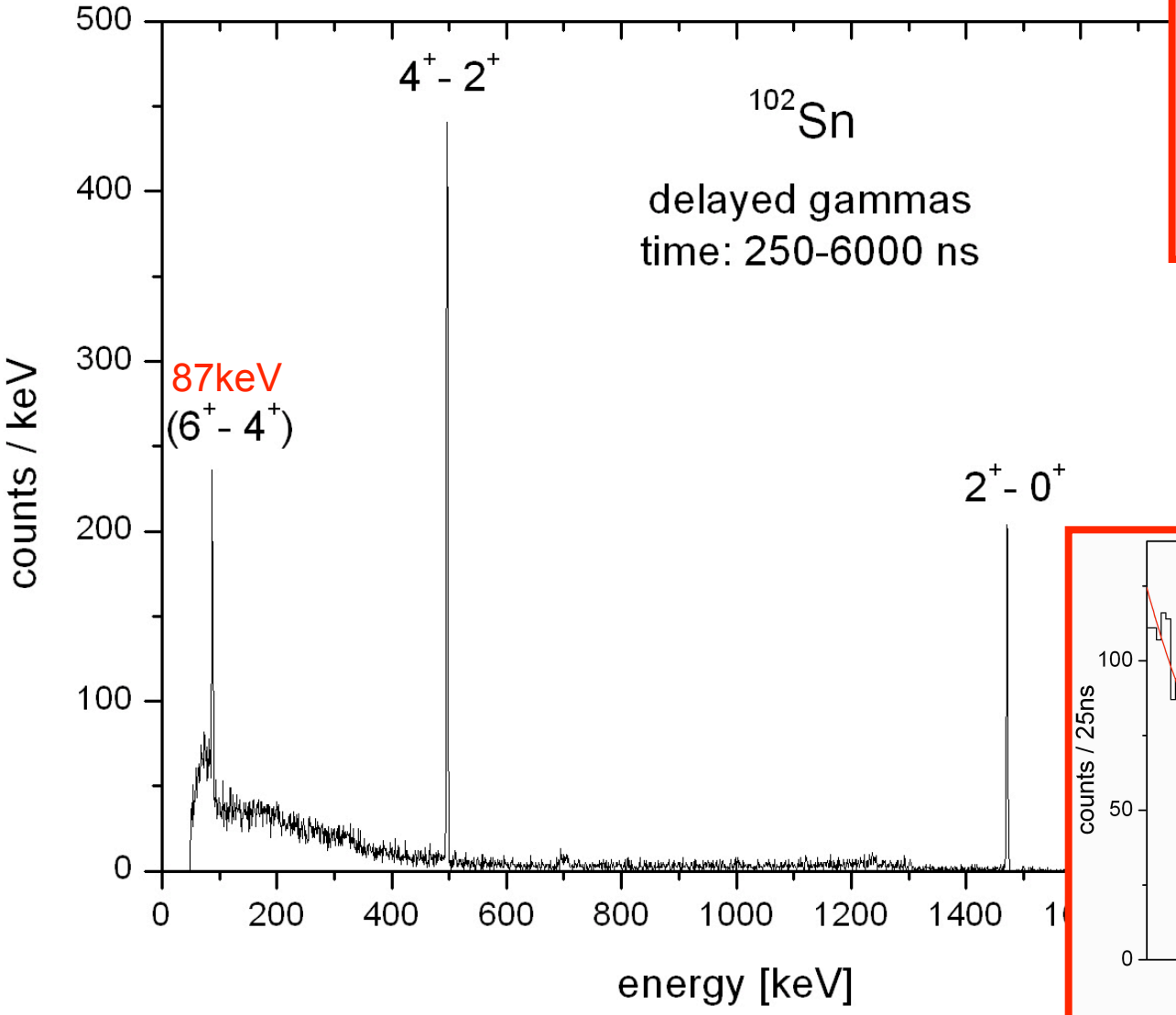
6^+ Isomer in ^{102}Sn

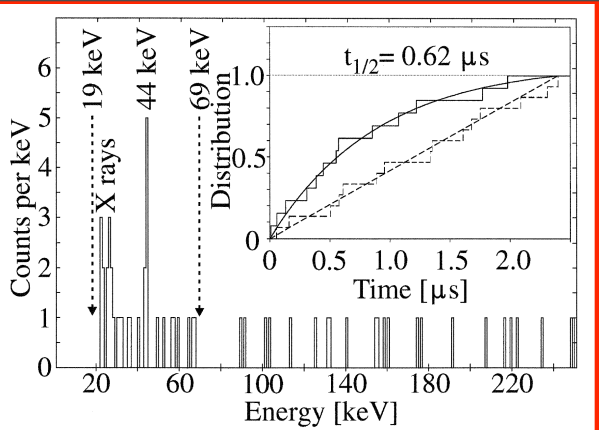
(2 neutron particles above ^{100}Sn core)



6^+ Isomer in ^{102}Sn

(2 neutron particles above ^{100}Sn core)

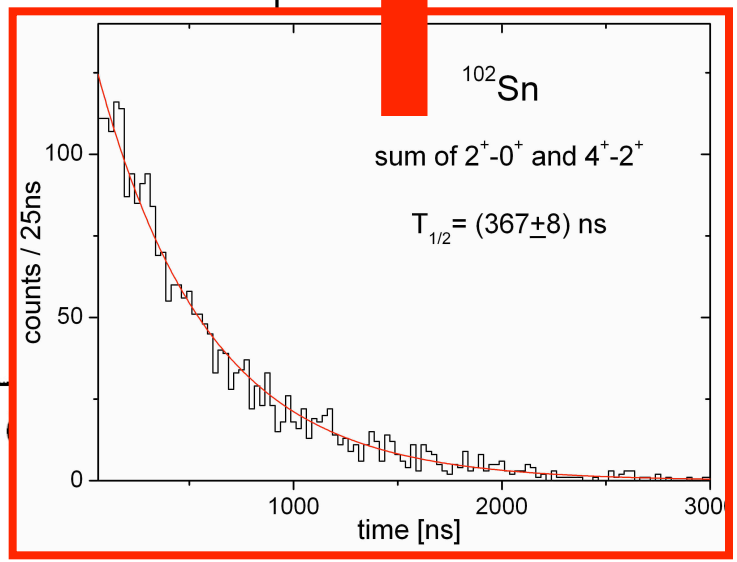




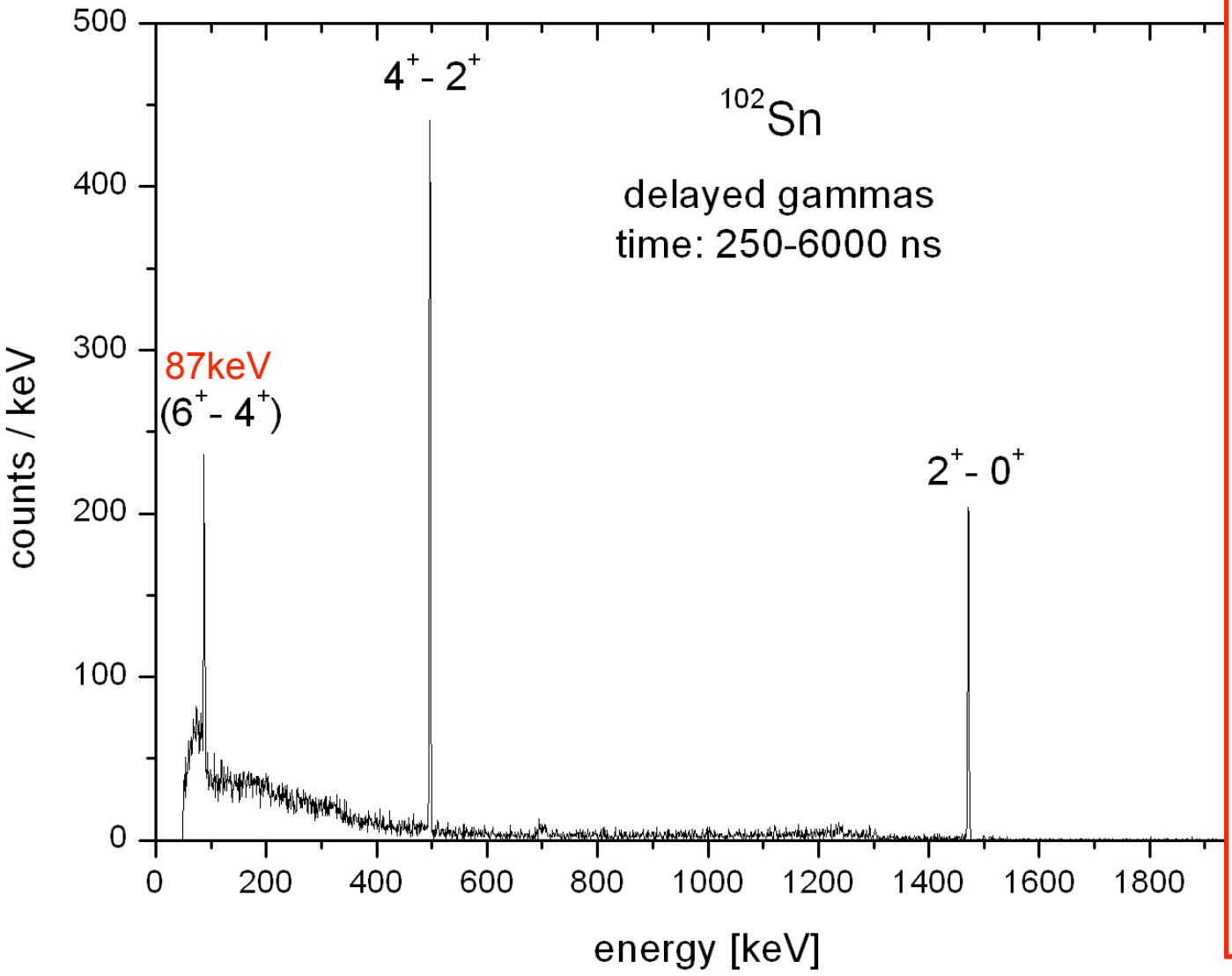
Lipoglavsek et al., PLB 1998

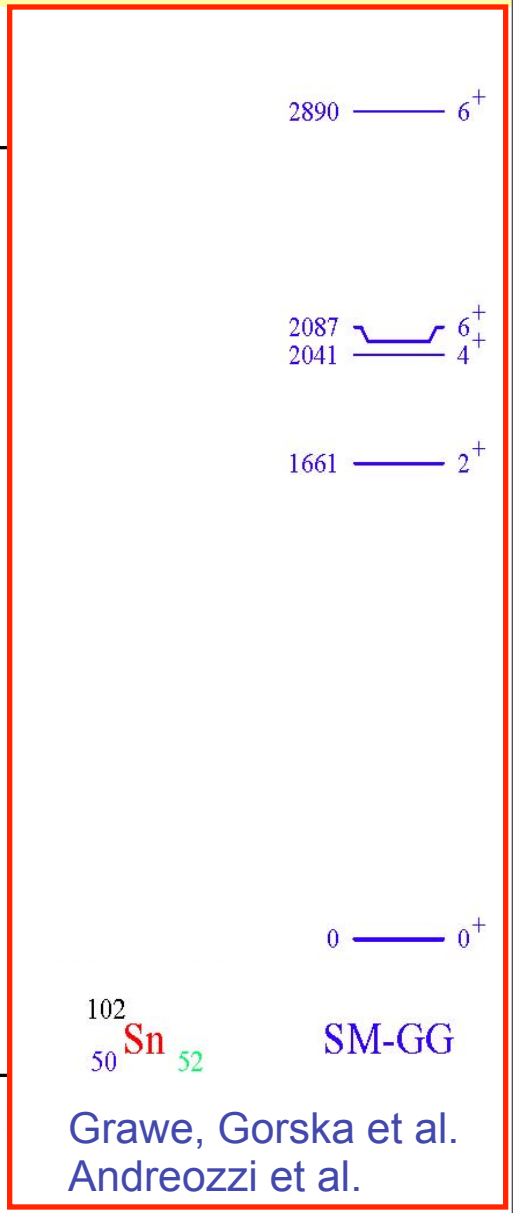
E(6-4) = 48keV

B(E2)=3.2(1) W.u.



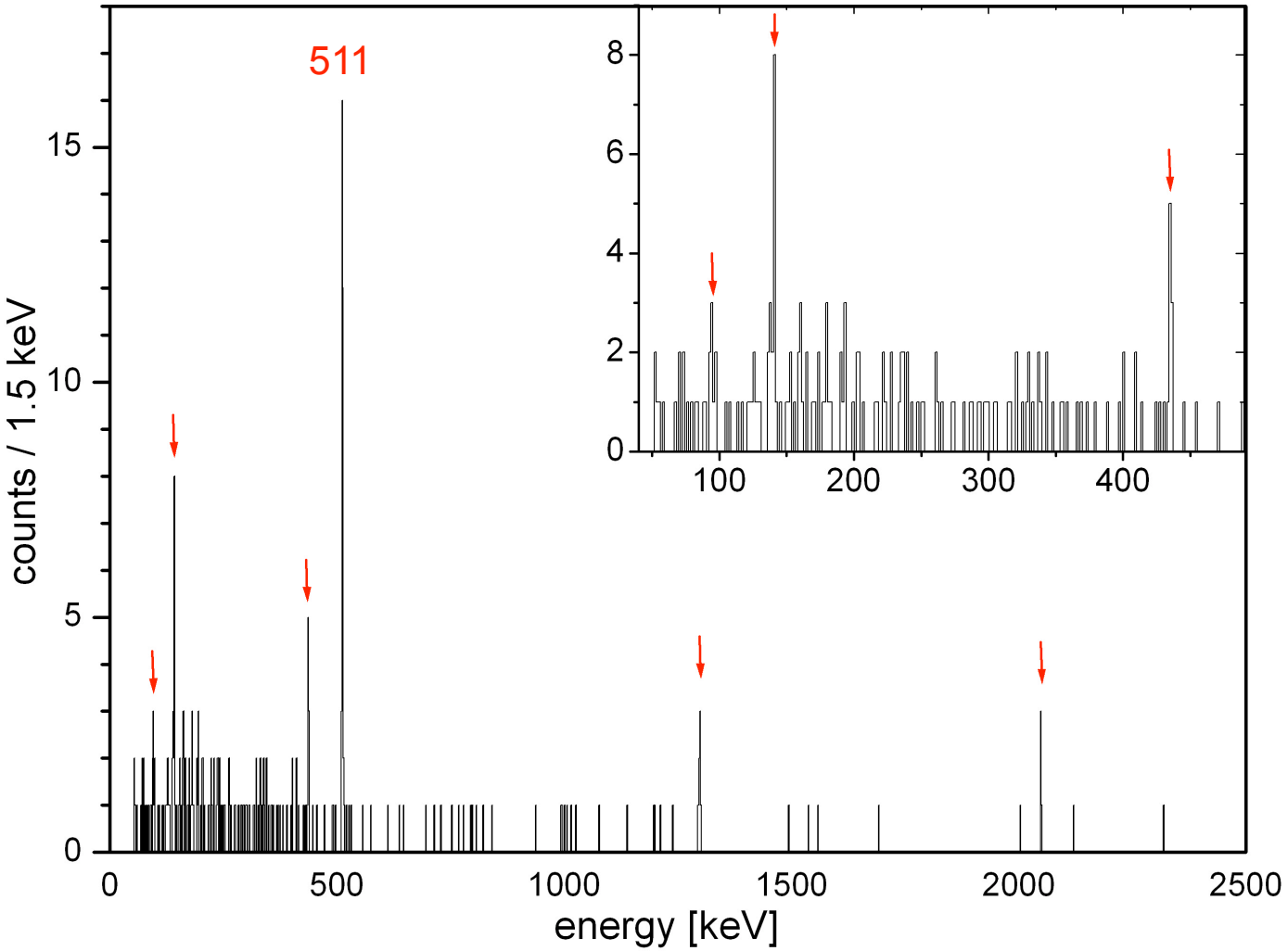
6^+ Isomer in ^{102}Sn





Gamma Spectrum after Beta Decay of ^{100}Sn

all events within 4 s after implantation

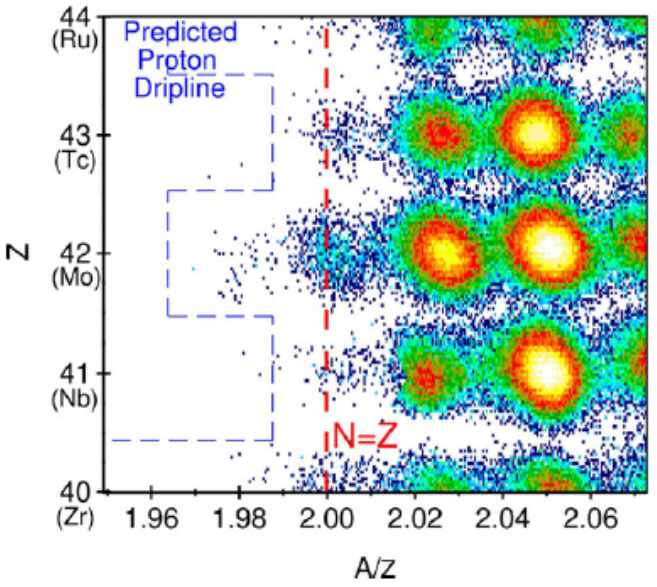


Other N~Z nuclei…

Available online at www.sciencedirect.com
ScienceDirect
Physics Letters B 660 (2008) 326–330
PHYSICS LETTERS B
www.elsevier.com/locate/physletb

Neutron–proton pairing competition in $N = Z$ nuclei: Metastable state decays in the proton dripline nuclei $^{82}_{41}$Nb and $^{86}_{43}$Tc

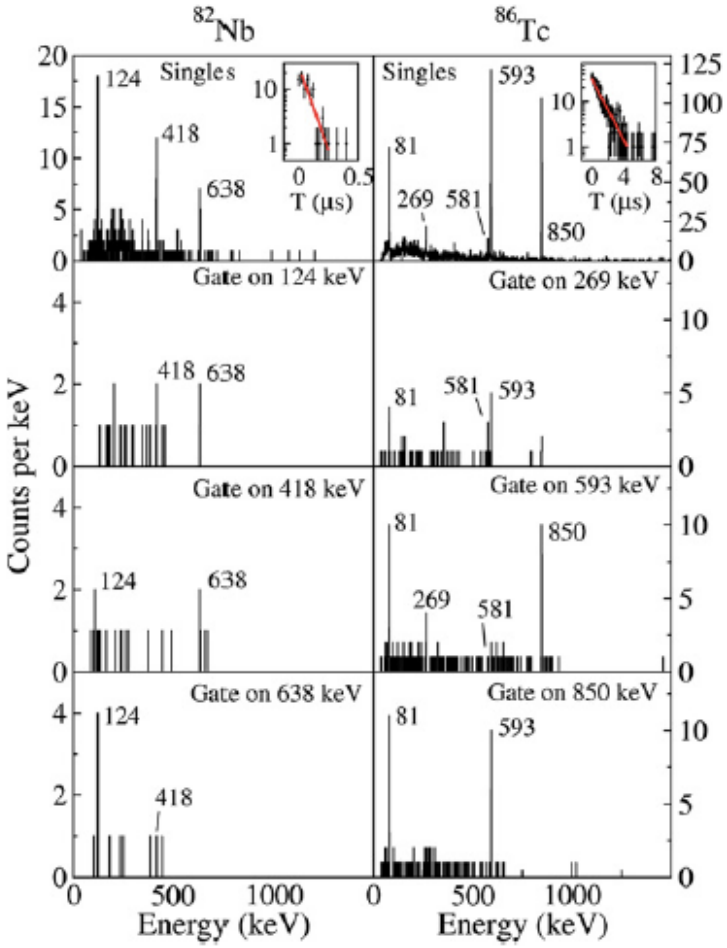
A.B. Garnsworthy [a,b,*], P.H. Regan [a], L. Cáceres [c,d], S. Pietri [a], Y. Sun [e,f], D. Rudolph [g], M. Górska [c], Zs. Podolyák [a], S.J. Steer [a], R. Hoischen [c,g], A. Heinz [b], F. Becker [c], P. Bednarczyk [c,h], P. Doornenbal [c], H. Geissel [c], J. Gerl [c], H. Grawe [c], J. Grębosz [c,h], A. Kelic [c], I. Kojouharov [c], N. Kurz [c], F. Montes [c], W. Prokopowicz [c], T. Saito [c], H. Schaffner [c], S. Tachenov [c], E. Werner-Malento [c,i], H.J. Wollersheim [c], G. Benzoni [j], B.B. Blank [k], C. Brandau [a,c], A.M. Bruce [l], F. Camera [j], W.N. Catford [a], I.J. Cullen [a], Zs. Dombrádi [m], E. Estevez [n], W. Gelletly [a], G. Ilie [o,p], J. Jolie [o], G.A. Jones [a], A. Jungclaus [d], M. Kmiecik [h], F.G. Kondev [q], T. Kurtukian-Nieto [k,n], S. Lalkovski [l,r], Z. Liu [a], A. Maj [h], S. Myalski [h], M. Pfützner [i], S. Schwertel [s], T. Shizuma [a,t], A.J. Simons [a,u], P.M. Walker [a], O. Wieland [j], F.R. Xu [v]

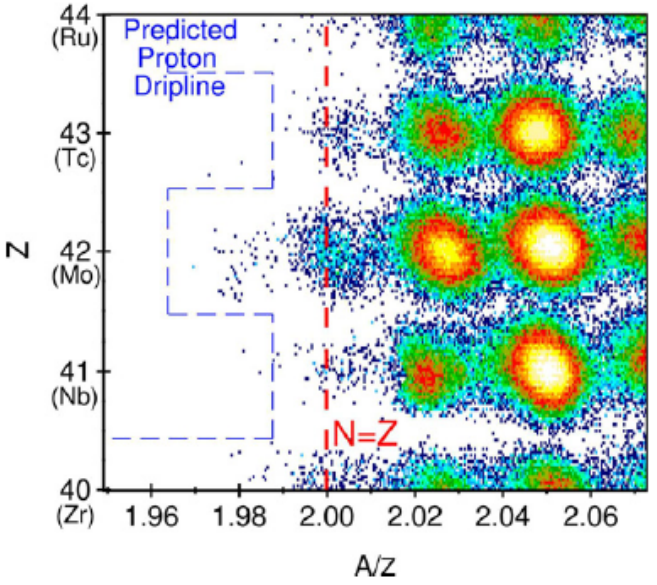


Available online at www.sciencedirect.com
ScienceDirect
Physics Letters B 660 (2008) 326–330
PHYSICS LETTERS B
www.elsevier.com/locate/physletb

Neutron–proton pairing competition in $N = Z$ nuclei: Metastable state decays in the proton dripline nuclei $^{82}_{41}$Nb and $^{86}_{43}$Tc

A.B. Garnsworthy [a,b,*], P.H. Regan [a], L. Cáceres [c,d], S. Pietri [a], Y. Sun [e,f], D. Rudolph [g], M. Górska [c], Zs. Podolyák [a], S.J. Steer [a], R. Hoischen [c,g], A. Heinz [b], F. Becker [c], P. Bednarczyk [c,h], P. Doornenbal [c], H. Geissel [c], J. Gerl [c], H. Grawe [c], J. Grębosz [c,h], A. Kelic [c], I. Kojouharov [c], Schaffner [c], S. Tachenov [c], nk [k], C. Brandau [a,c], A.M. Bruce [l], stevez [n], W. Gelletly [a], G. Ilie [o,p], ndev [q], T. Kurtukian-Nieto [k,n], S. Schwertel [s], T. Shizuma [a,t], j, F.R. Xu [v]

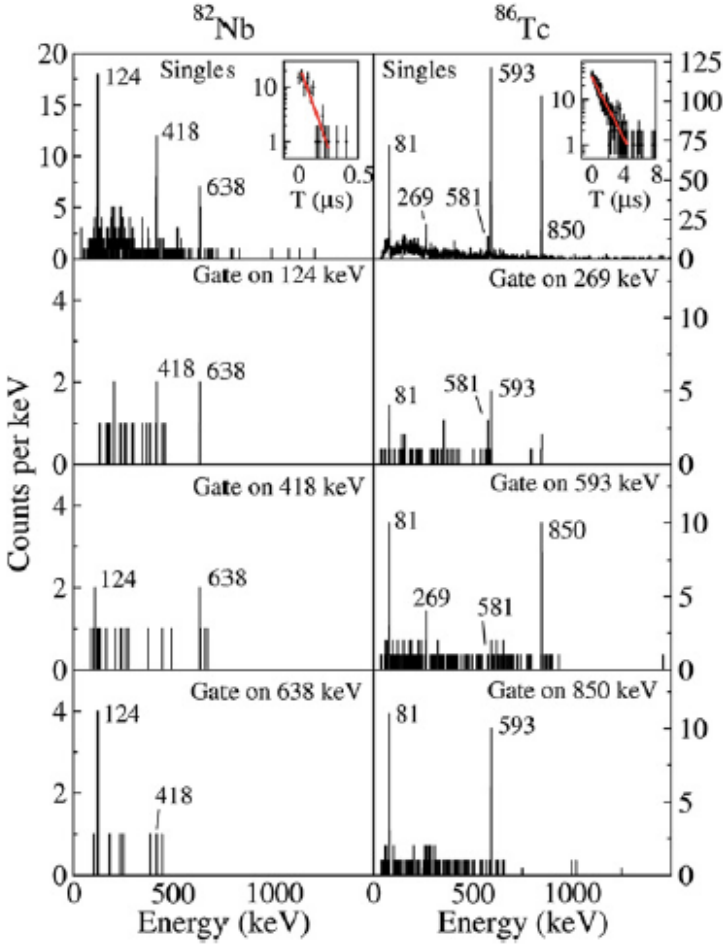


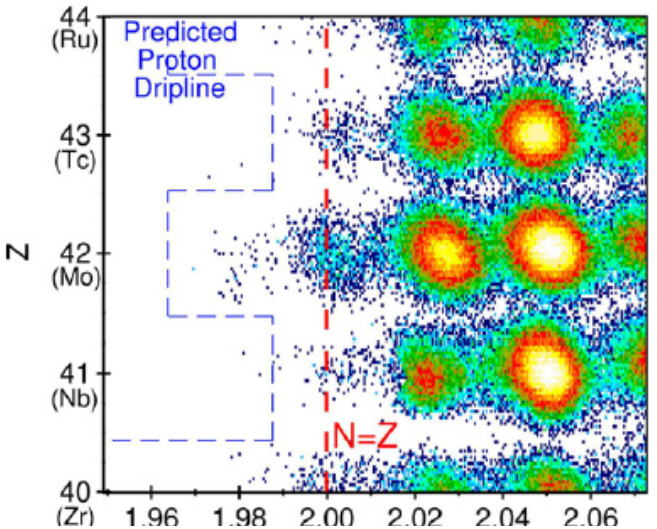


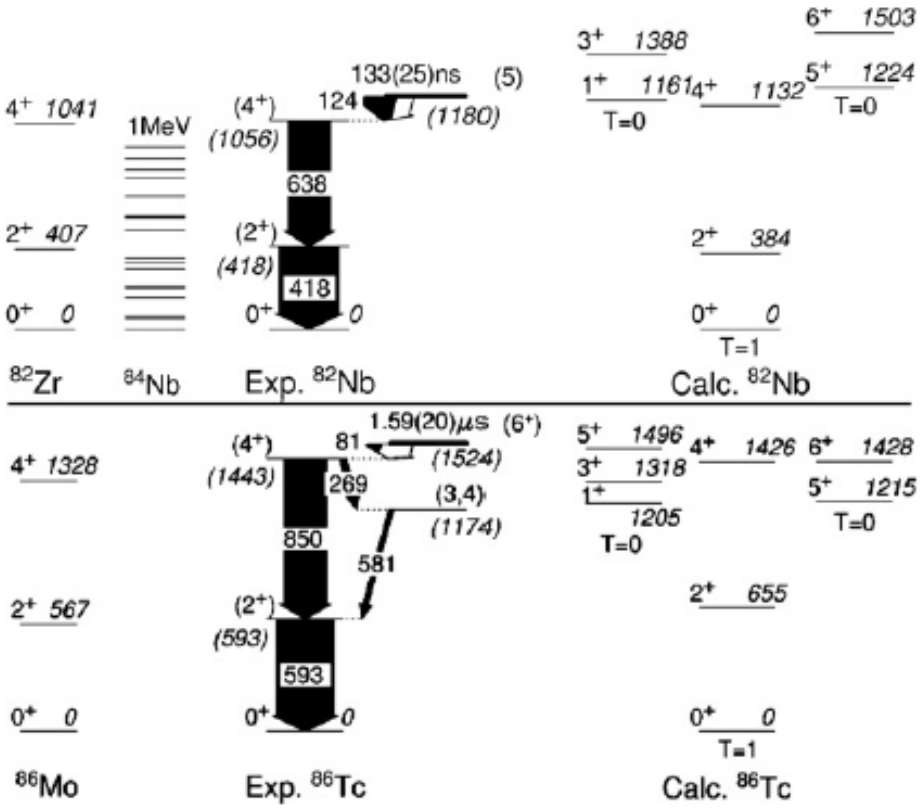
Available online at www.sciencedirect.com
ScienceDirect
Physics Letters B 660 (2008) 326–330
PHYSICS LETTERS B
www.elsevier.com/locate/physletb

Neutron–proton pairing competition in $N = Z$ nuclei: Metastable state decays in the proton dripline nuclei $^{82}_{41}$Nb and $^{86}_{43}$Tc

A.B. Garnsworthy [a,b,*], P.H. Regan [a], L. Cáceres [c,d], S. Pietri [a], Y. Sun [e,f], D. Rudolph [g], M. Górska [c], Zs. Podolyák [a], S.J. Steer [a], R. Hoischen [c,g], A. Heinz [b], F. Becker [c], P. Bednarczyk [c,h], P. Doornenbal [c], H. Geissel [c], J. Gerl [c], H. Grawe [c], J. Grębosz [c,h], A. Kelic [c], I. Kojouharov [c], Schaffner [c], S. Tachenov [c], nk [k], C. Brandau [a,c], A.M. Bruce [l], stevez [n], W. Gelletly [a], G. Ilie [o,p], ndev [q], T. , S. Schwe , F.R. Xu



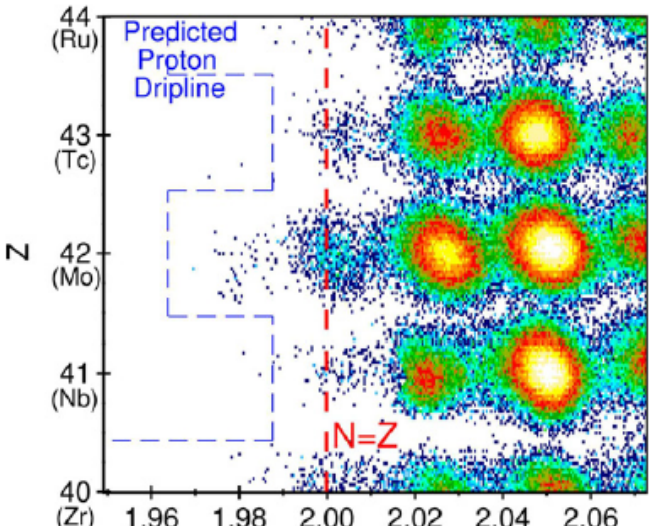


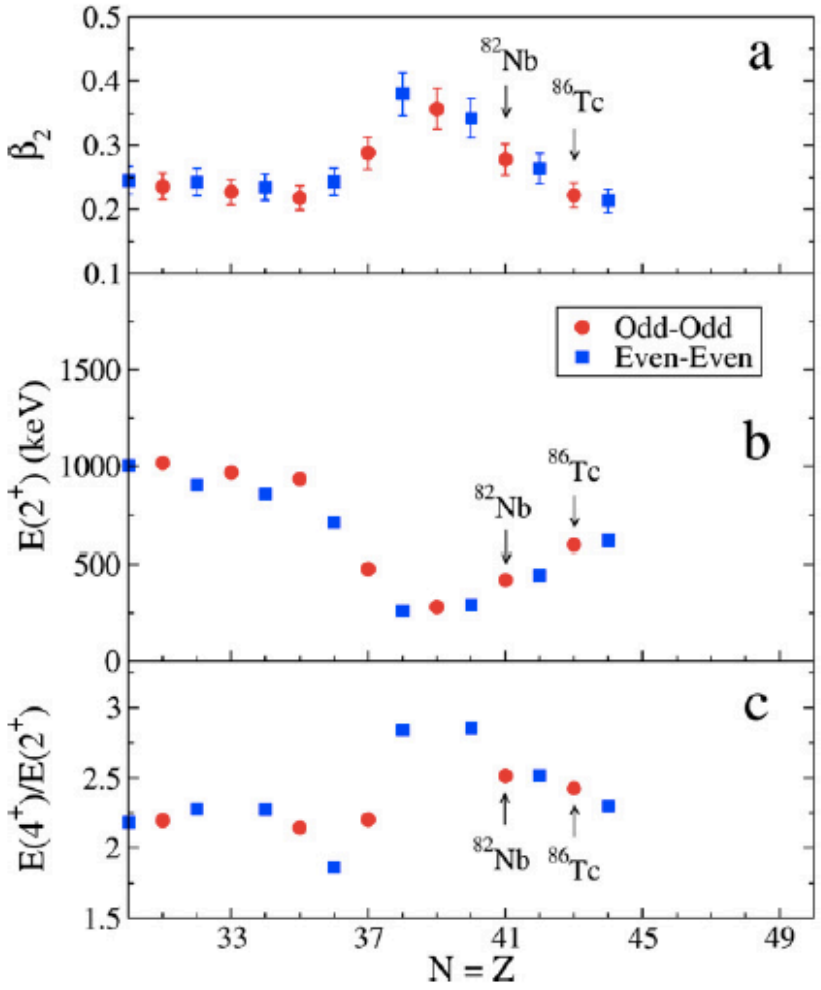


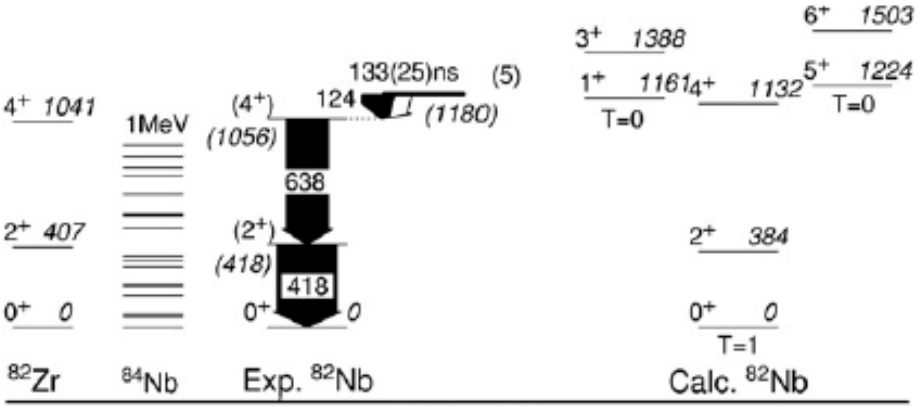
Available online at www.sciencedirect.com
ScienceDirect
Physics Letters B 660 (2008) 326–330
PHYSICS LETTERS B
www.elsevier.com/locate/physletb

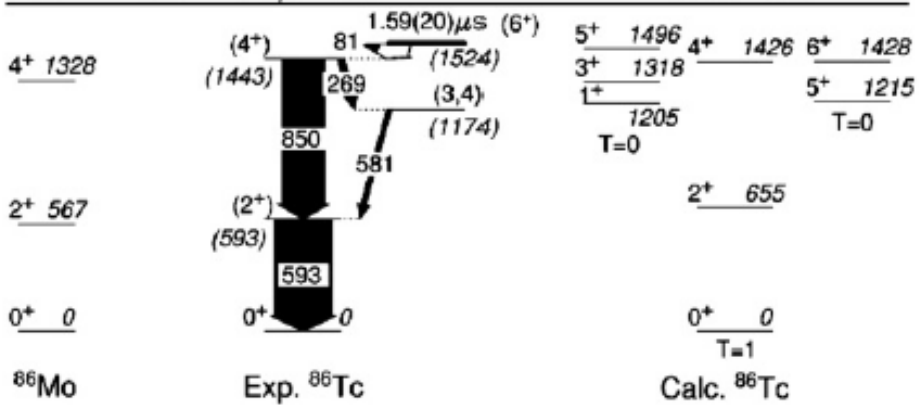
Neutron–proton pairing competition in $N = Z$ nuclei: Metastable state decays in the proton dripline nuclei $^{82}_{41}$Nb and $^{86}_{43}$Tc

A.B. Garnsworthy [a,b,*], P.H. Regan [a], L. Cáceres [c,d], S. Pietri [a], Y. Sun [e,f], D. Rudolph [g], M. Górska [c], Zs. Podolyák [a], S.J. Steer [a], P. Heischen [c,g], A. Heinz [b], F. Becker [c], P. Bednarczyk [c,h], ic [c], I. Kojouharov [c], S. Tachenov [c], randau [a,c], A.M. Bruce [l], . Gelletly [a], G. Ilie [o,p],



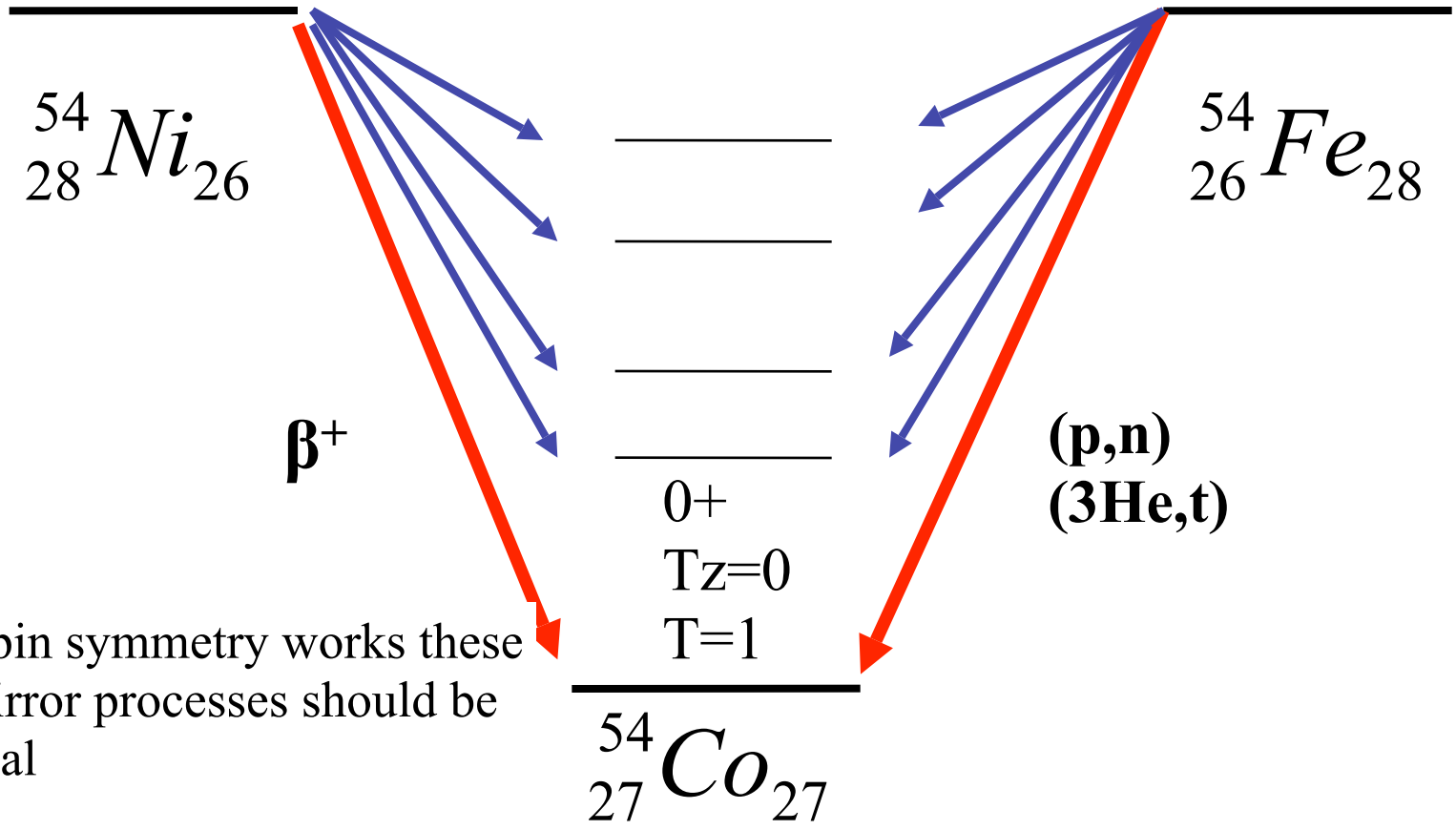






Study of $T_z=\pm1$ decays into $T_z=0$: GT transitions in the f shell

B. Rubio, Y. Fujita & W. Gelletly
Analysis F. Molina (Valencia)



If isospin symmetry works these two mirror processes should be identical

This work tests if isospin symmetry is good enough to justify the combined analysis of ***charge exchange reactions*** and ***beta-decay*** In mirror nuclei.

When the B_{GT} values are obtained from Charge Exchange Reactions, absolute normalisation is needed and can be obtained using the combined analysis

Y. Fujita et al.
PRL **95** (2005)

$$\frac{1}{T_{1/2}} = \frac{1}{t_{Fermi}} + \sum_{i=GT} \frac{1}{t_i}$$

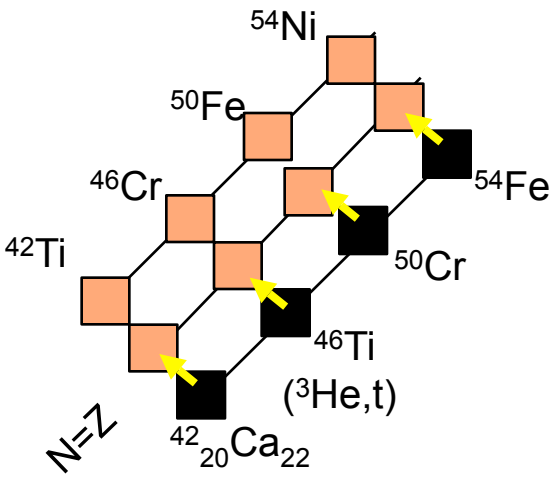
From β-decay

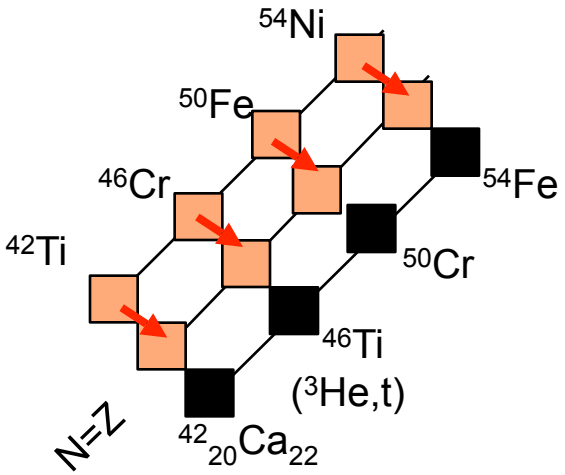
B(F)=N-Z

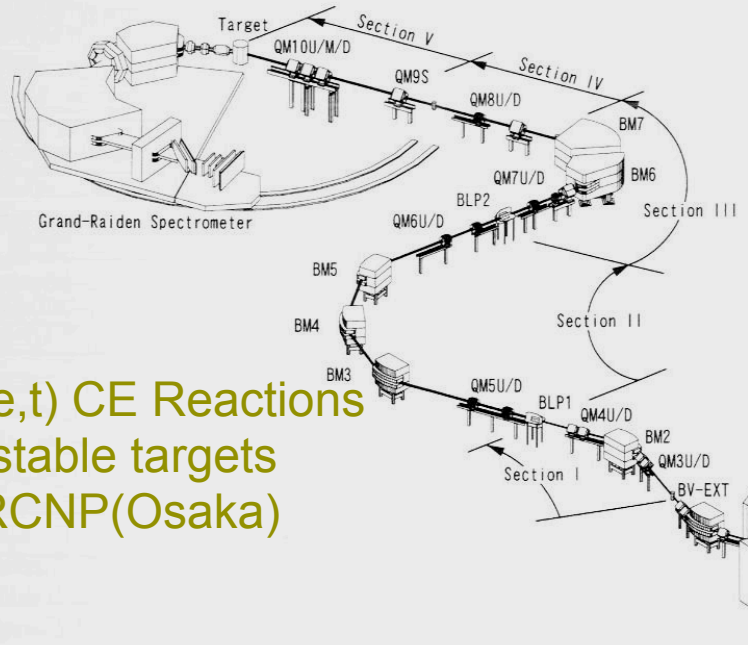
From (3He,t)

There were a series of experiments at RISING to test this idea

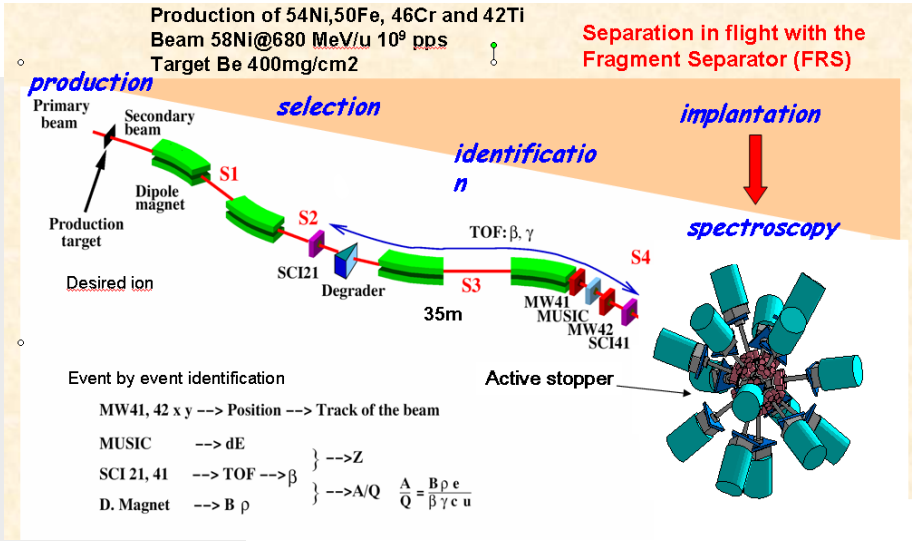
And a facility at RCNP Osaka where these reactions can be studied in high resolution





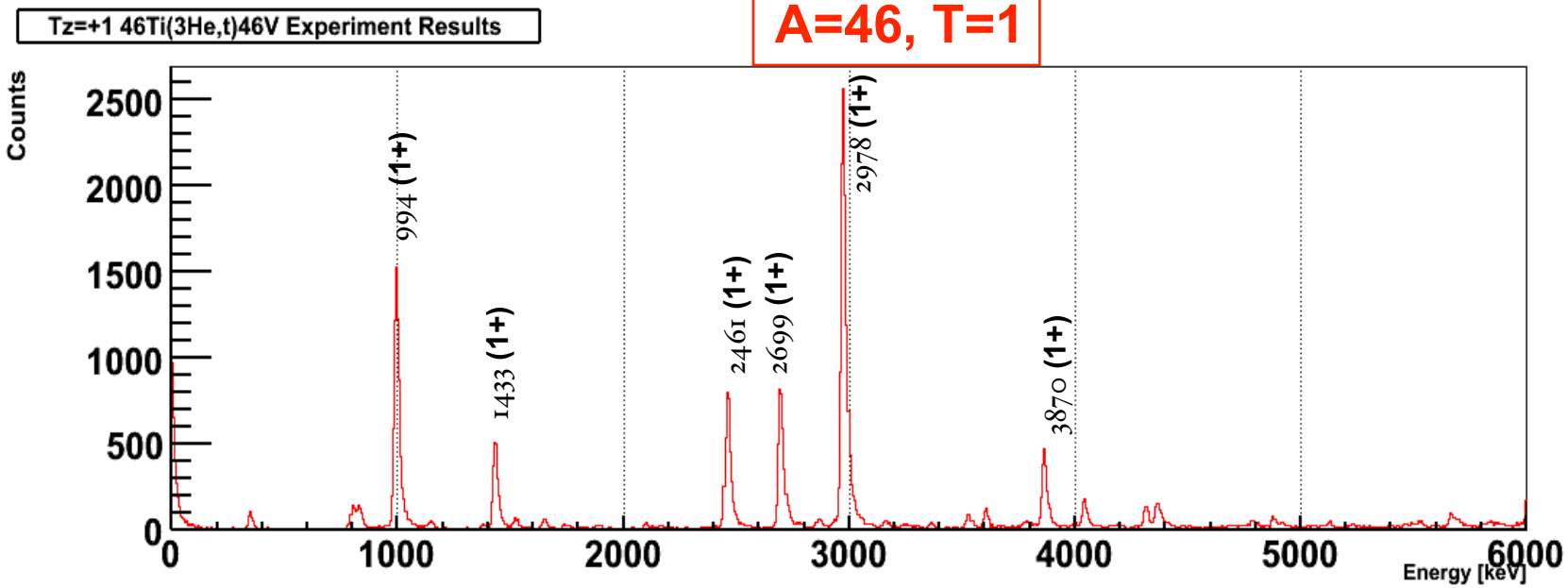


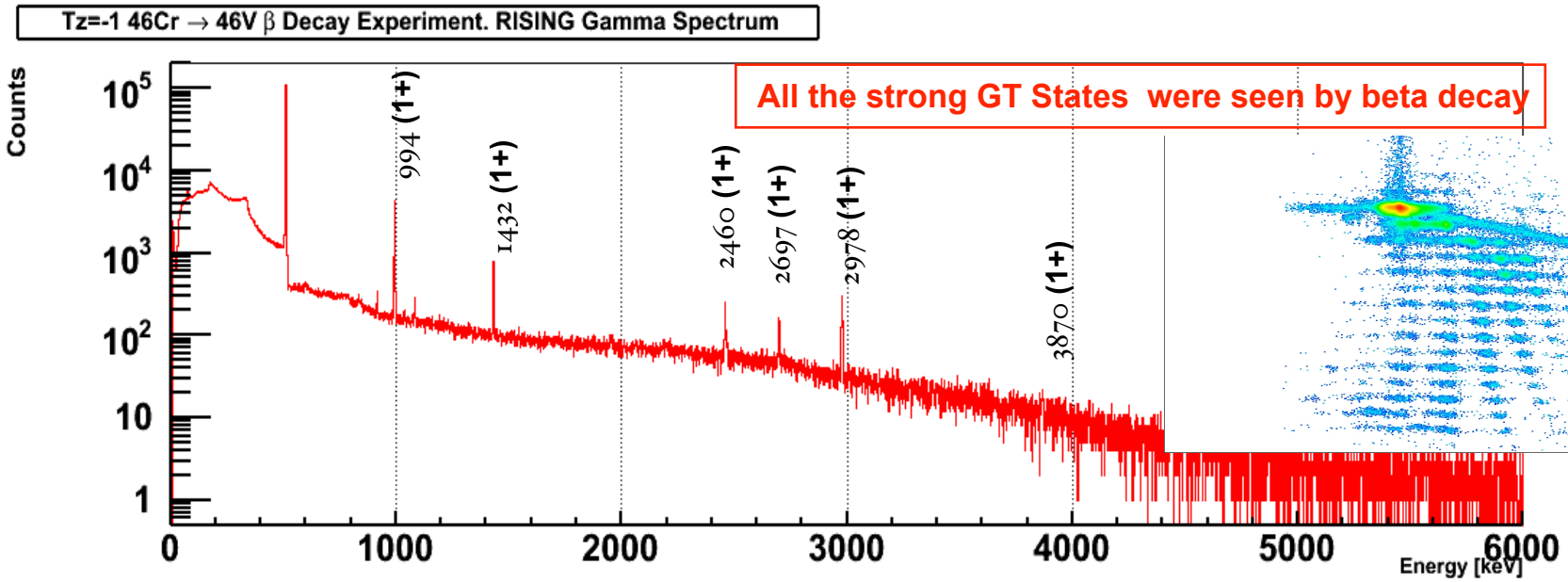
(3He,t) CE Reactions
On stable targets
@ RCNP(Osaka)



Beta-decay studies
@ GSI-Rising

A=46, T=1


Tz=+1 46Ti(3He,t)46V Experiment Results
Counts
Energy [keV]
994 (1+)
1433 (1+)
2461 (1+)
2699 (1+)
2978 (1+)
3870 (1+)


Tz=-1 46Cr → 46V β Decay Experiment. RISING Gamma Spectrum
Counts
Energy [keV]
994 (1+)
1432 (1+)
2460 (1+)
2697 (1+)
2978 (1+)
3870 (1+)
All the strong GT States were seen by beta decay

Results: preliminary B_{GT} values from beta decay

A=54	B(GT) decay	B(GT) CE
937 keV	0.471(55)	0.493(62)
3378 keV	0.074(14)	0.079(11)
3889 keV	0.064(17)	0.103(14)
4544 keV	0.075(27)	0.147(20)
A=50		
652 keV	0.547(90)	0.510(14)
2404 keV	0.126(23)	0.151(40)
2685 keV	0.090(19)	0.106(28)
3380 keV	0.281(55)	0.350(93)
A=46		
994 keV	0.330(329)	0.368(44)
1433 keV	0.107(107)	0.122(15)
2462 keV	0.146(146)	0.201(24)
2698 keV	0.111(111)	0.205(25)
2978 keV	0.479(478)	0.625(75)
3870 keV	0.105(119)	0.117(14)

Francisco Molina et al., analysis, in progress IFIC (Valencia)

Isospin symmetry works in general (full strength) but some differences appear at high excitation energy, which should be understood

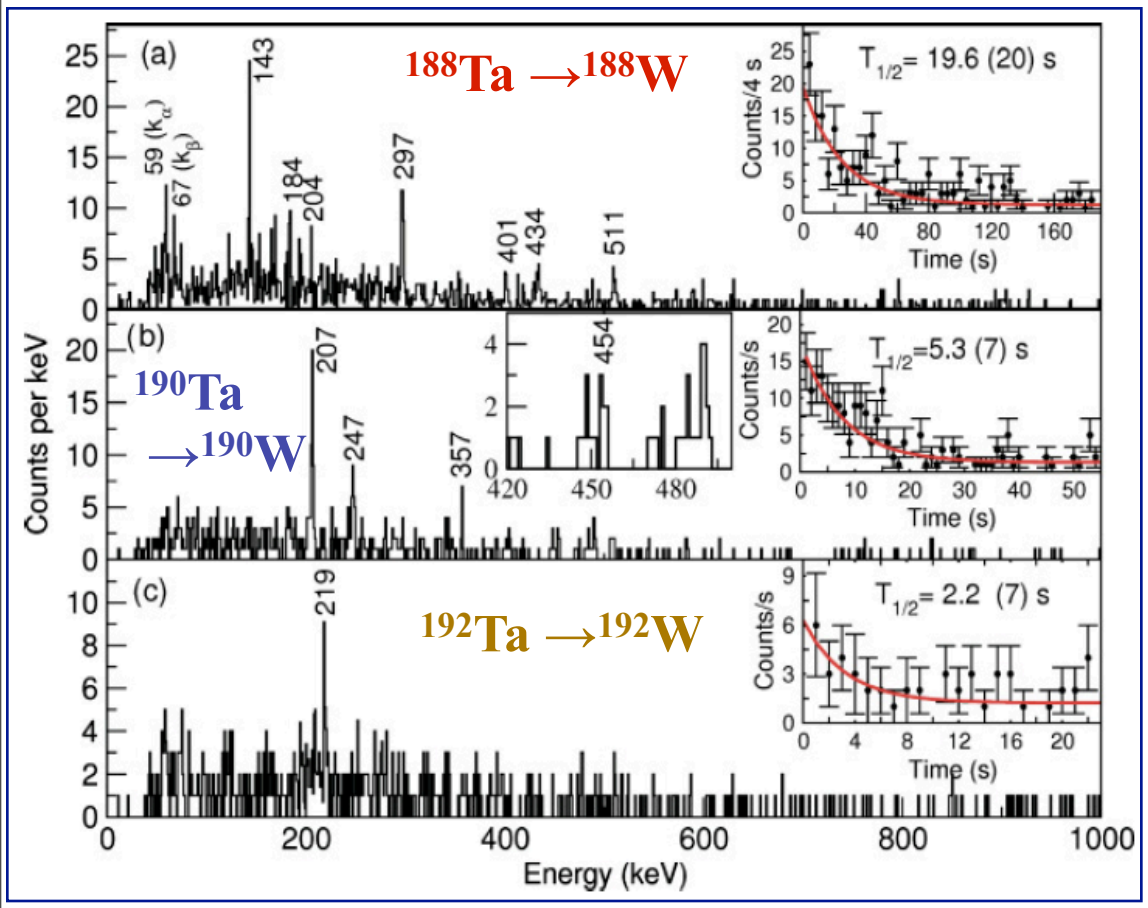
This is the first experimental test of B_{GT} gs symmetry in the f shell.

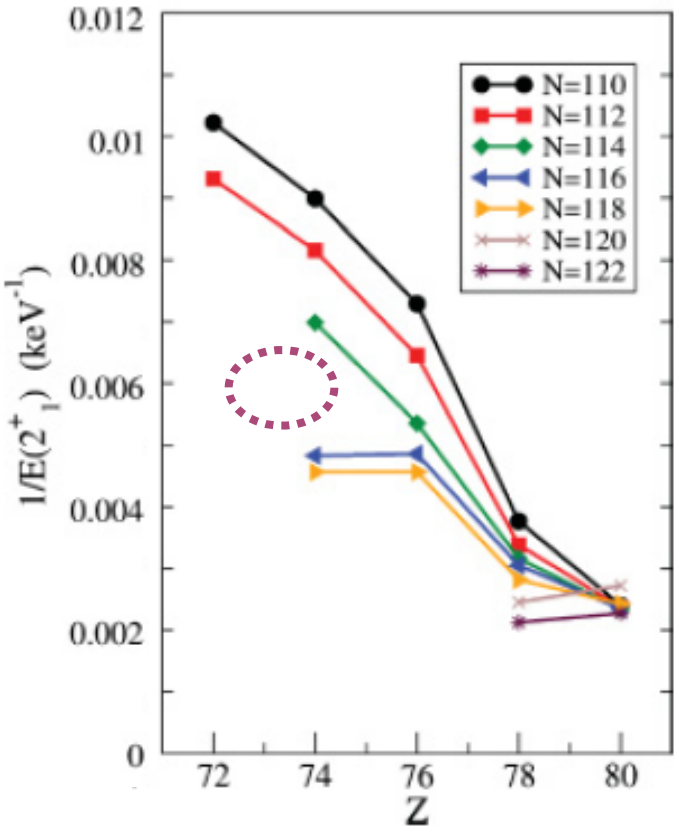
Rubio, Fujita, Gelletly et al.,

PHYSICAL REVIEW C **80**, 064308 (2009)

β^--delayed spectroscopy of neutron-rich tantalum nuclei: Shape evolution in neutron-rich tungsten isotopes

N. Alkhomashi,[1,*] P. H. Regan,[1] Zs. Podolyák,[1] S. Pietri,[1] A. B. Garnsworthy,[1] S. J. Steer,[1] J. Benlliure,[2] E. Caserejos,[2] R. F. Casten,[3] J. Gerl,[4] H. J. Wollersheim,[4] J. Grebosz,[5] G. Farrelly,[1] M. Górska,[4] I. Kojouharov,[4] H. Schaffner,[4] A. Algora,[6,7] G. Benzoni,[8] A. Blazhev,[9] P. Boutachkov,[4] A. M. Bruce,[10] A. M. Denis Bacelar,[10] I. J. Cullen,[1] L. Cáceres,[4] P. Doornenbal,[4] M. E. Estevez,[2] Y. Fujita,[11] W. Gelletly,[1] R. Hoischen,[4,12] R. Kumar,[13] N. Kurz,[4] S. Lalkovski,[10] Z. Liu,[14] C. Mihai,[15] F. Molina,[6] A. I. Morales,[2] D. Mücher,[9] W. Prokopowicz,[4] B. Rubio,[6] Y. Shi,[16] A. Tamii,[17] S. Tashenov,[4] J. J. Valiente-Dobón,[18] P. M. Walker,[1] P. J. Woods,[14] and F. R. Xu[16]





(some) of The ‘Jedi Masters’ needed to make it all work…

- Design group at Daresbury/Liverpool (Dave Seddon/Paul Morrall) for design of RISING holding structure.
- Peter Reiter + Koln group….use the DGF modules for gamma DAQ.
- Nick Kurz; Henning Schaffner – letting us see the signals.
- Ivan Koj. – the ‘shepherd of the detectors’
- Jurek Greb. – with Cracow we could ‘see where we were going’
- W. Prokopowicz – making it all fit together
- Rakesh Kumar – testing the DSSSDs
- Stephane Pietri – keeping it all together, making it work.
- Hans-Juergen – keeping it moving forward…taking the ‘bullets’ when needed.

Future….PreSpec –DECAY & DESPEC to look forward to,

Future….PreSpec –DECAY & DESPEC to look forward to,

(some) of the PhD / Masters Theses….

1. Adam Garnsworthy (Surrey – PhD 2007)
2. Steven Steer (Surrey – PhD 2008)
3. Nasser Alkhomashi (Surrey – PhD 2010)
4. Greg Farrelly (Surrey - 2010)
5. Nawras Al-Dahan (Surrey - 2010)
6. Mike Bunce (Surrey -2012)
7. Mike Bowry (Surrey -2012)
8. Lucia Caceres (Madrid/GSI – PhD 2008)
9. Robert Hoischen (Lund/GSI)
10. Christophe Hinke (TU Munich)
11. Katrin Eppinger (TU Munich)
12. Farheen Naqvi (GSI/Koln)
13. Namita Goel (GSI/Koln)
14. Anna Denis-Bacelar (Brighton)
15. Maria Domcel (Salamaca)
16. Roberto Nicolini (Milano)
17. Andrea Gottadro (Padova)
18. Tom Brook (York)
19. Norbert Braun (Koln)
20. …….

Experiment	Spokespersons	Dates	Publication
1. S244: ^{107}Ag beam; N=Z isomers	Regan	25 Feb –1 Mar 06	A.B. Garnsworthy et al., PL **B660** (2008) 326 A.B. Garnsworthy et al., PR **C80** (2009) 064303
2. S299; ^{208}Pb beam N~126 isomers	Podolyak	2 Mar – 8 Mar 06	S.J. Steer et al., PR **C78** (2008) 061302(R); Zs. Podolyak et al., PR **C79** (2009) 031305(R); Zs. Podolyak et al., PR **C79** (2009) 031305 (R) E.C. Simpson PR **C80** (2009) 064608 Zs. Podolyak et al., EPJ **A42** (2009) 489 S.J.Steer et al., IJMP **E18** (2009) 1002
3. S244: ^{58}Ni beam; A=54 mirrors	Rudolph	9 Mar –12 Mar 06	D. Rudolph et al., PR **C78** (2008) 021301(R) ;. Rudolph et al., EPJ **A36** (2008) 131.
4. S305: ^{136}Xe beam. N~82 isomers	Jungclaus	26 Jun –9 July 06	A. Jungclaus et al. PRL **99** (2007) 132501
5. S244: ^{238}U beam. Isomers at N~82	Pfutzner / Gorska	10 Jul – 7 Jul 06	L. Caceres et al., PR **C79** (2009) 011301 (R); M. Gorska et al., PL **B672** (2009) 313.
6. S300; ^{238}U beam: A~110 isomers	Bruce	11 Dec – 7 Dec 06	
7. S313: ^{208}Pb beam active.; N→126	Regan / Benlliure	8 Mar -18 Mar 07	Zs. Podolyak et al., PL **B672** (2009) 116; N. Alkhomashi et al., PR **C80** (2009) 064308
8. S313: ^{208}Pb beam active. N →126	Benlliure / Regan	8 Jul –17 July 07	P.H. Regan et al., IJMP **E17** (2008) 8; A.I. Morales et al., Acta Phys. **B40** (2009) 867
9. S326: ^{78}Kr beam, GT in A=62	Gadea / Algora	18 Jul –25 Jul 07	
10. S316: ^{58}Ni beam; GT A=46:50:54	Fujita / Gelletly / Rubio	27 July –1 Aug 07	
11.S330: ^{124}Xe beam: ^{100}Sn + SIMBA	Faestermann / Gorska	5 Mar –26 Mar 08	
12. S347: ^{238}U beam; Z<82; N>126	Podolyak	27 Apr –3 May 08	N.Al-Dahan et al., PR **C80** (2009) 061302 (R)
13. S352: ^{124}Xe beam; ^{96,8}Pd	Blazhev / Wadsworth / Liu / Boutachkov	5 Jun – 13 Jun 08	R Wadsworth et al., Acta Phys **B40** (2009) 611
14. S361: ^{238}U beam, ^{104,6}Zr	Bruce	17 Sep -20 Sep 09	
15. S337: ^{238}U beam, ^{132}Cd decay	Gadea	21 Sep–24 Sep 09	

16 successful experiments)