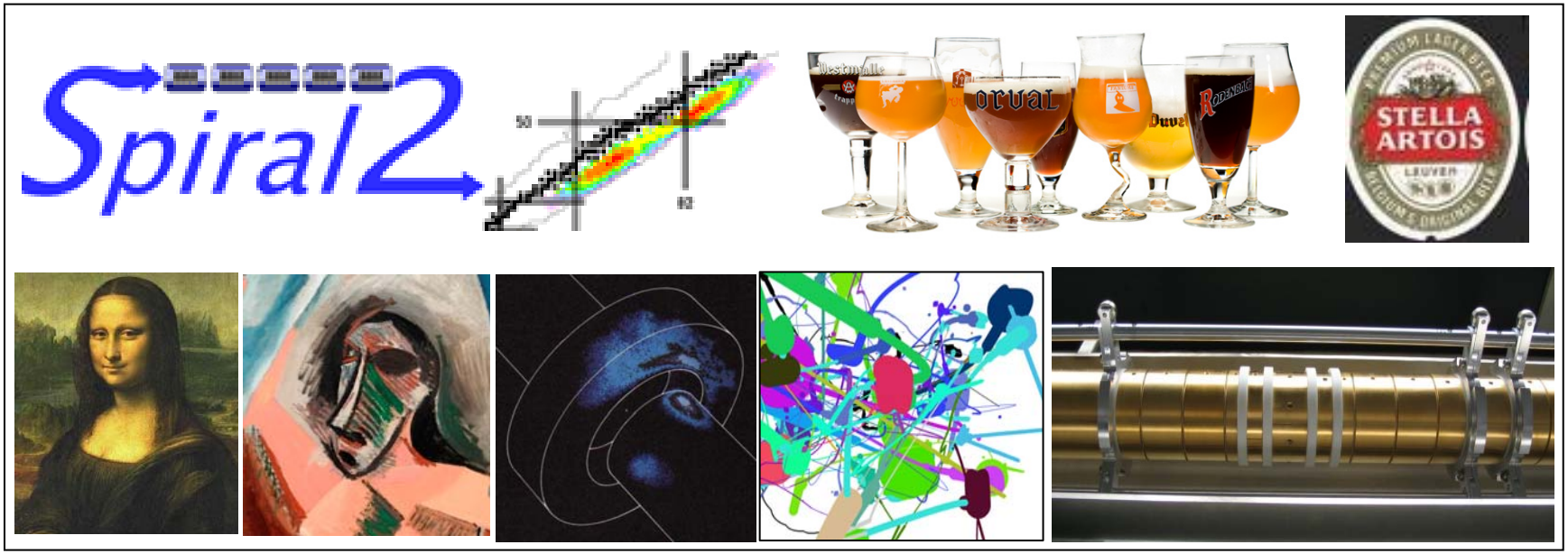
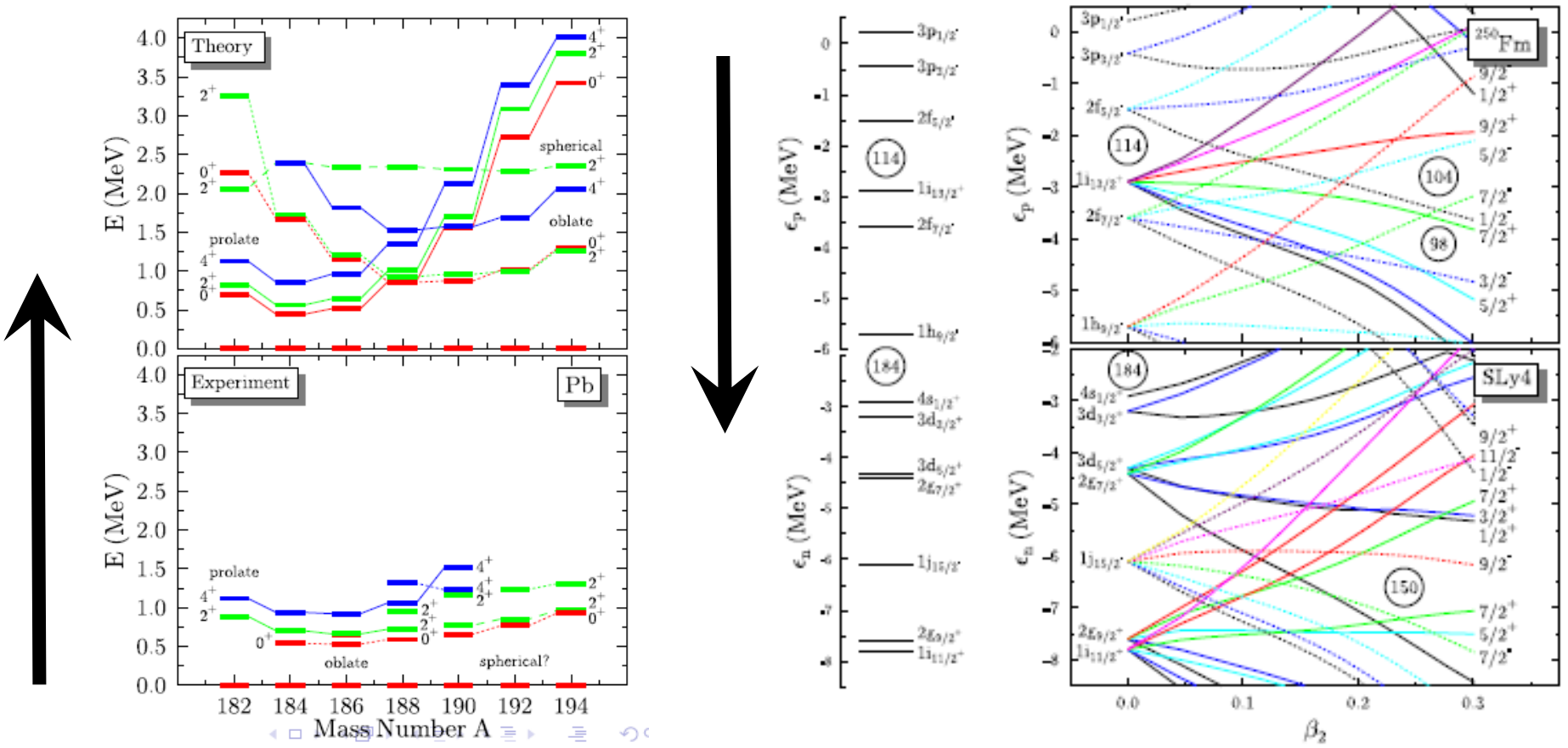
Why weigh nuclei (at DESIR) ?



David Lunney

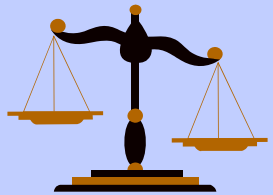
Centre de Spectrométrie Nucléaire et de Spectrométrie de Masse (CSNSM-IN2P3/CNRS)
Université de Paris Sud, Orsay

Not only does binding energy shape the nuclear landscape,
It also determines the very composition of the nucleus itself.



Figures from: M. Bender

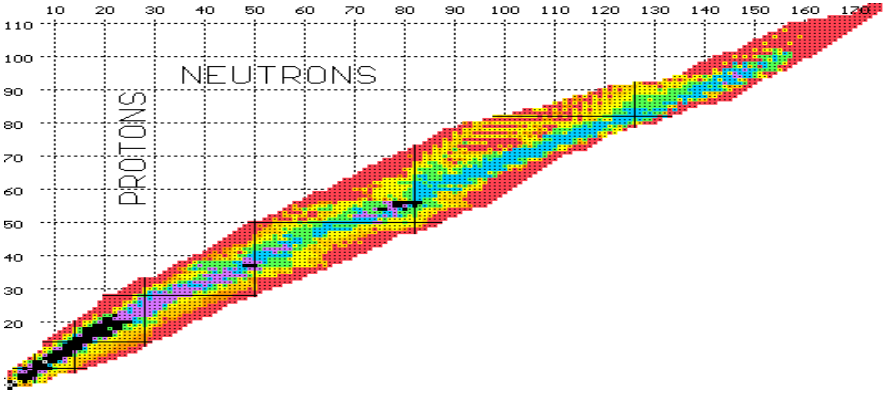
Motivation



metrology: ^{28}Si atomic mass standard (kg)
and other fundamental constants

atomic physics: QED test - *atomic* binding energy)

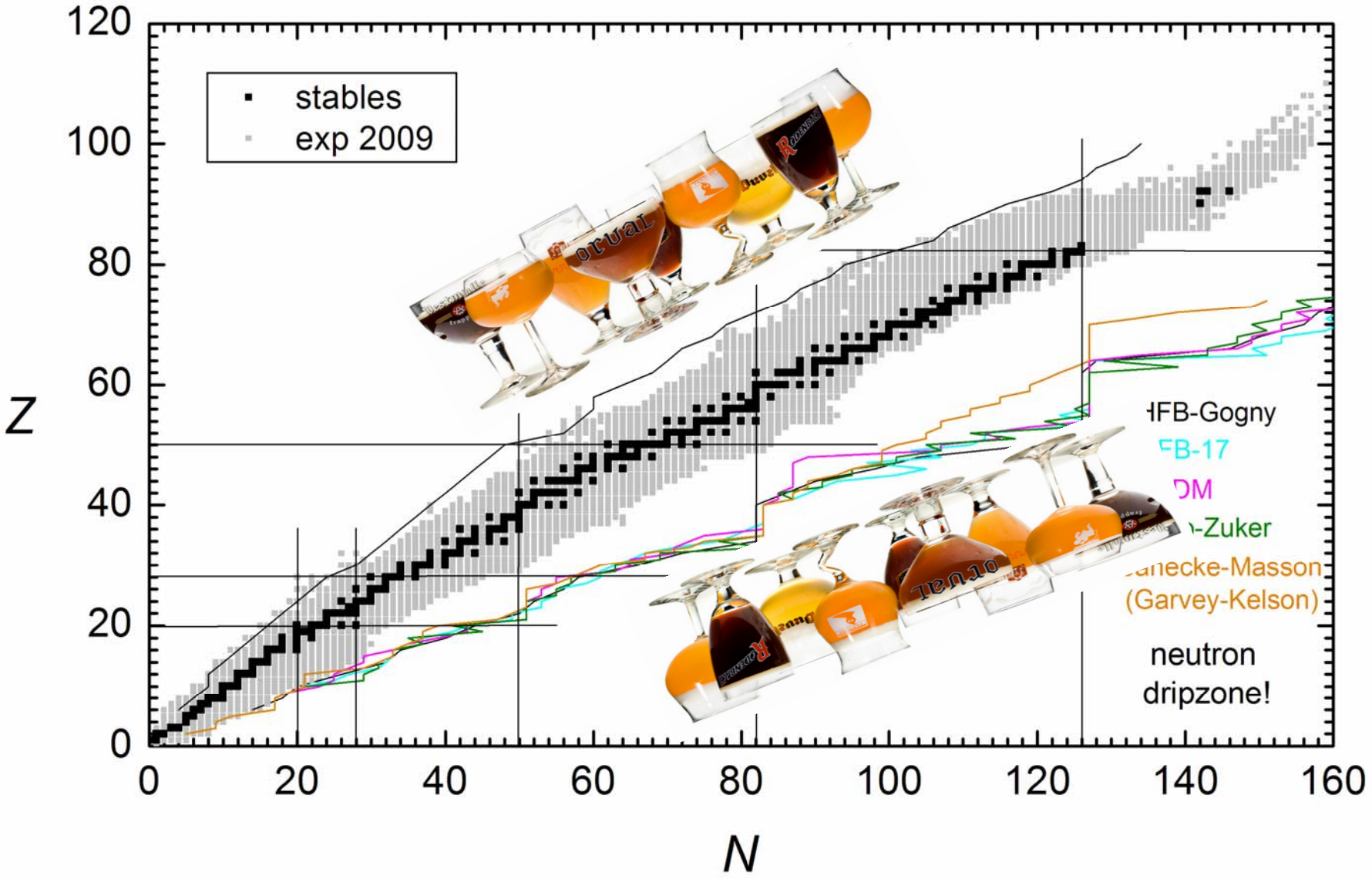
nuclear structure:
binding energy →
shells, shapes, pairs, halos
(talk of P. Thirolf)



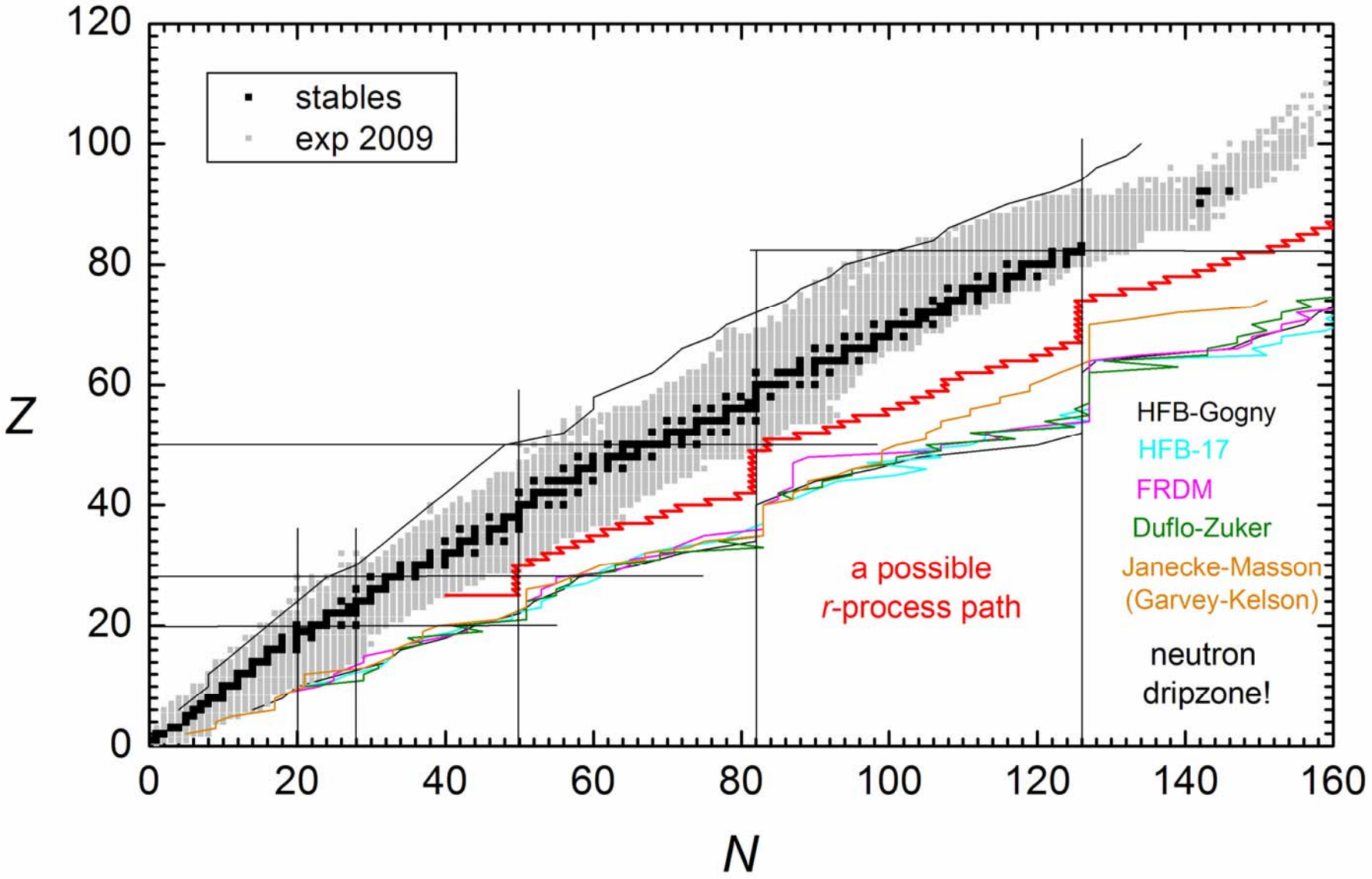
weak interaction:
CVC and SM tests
(talk of C. Weber)

nuclear astrophysics:
nucleosynthesis, cosmochronology
(talk of A. Herlert)

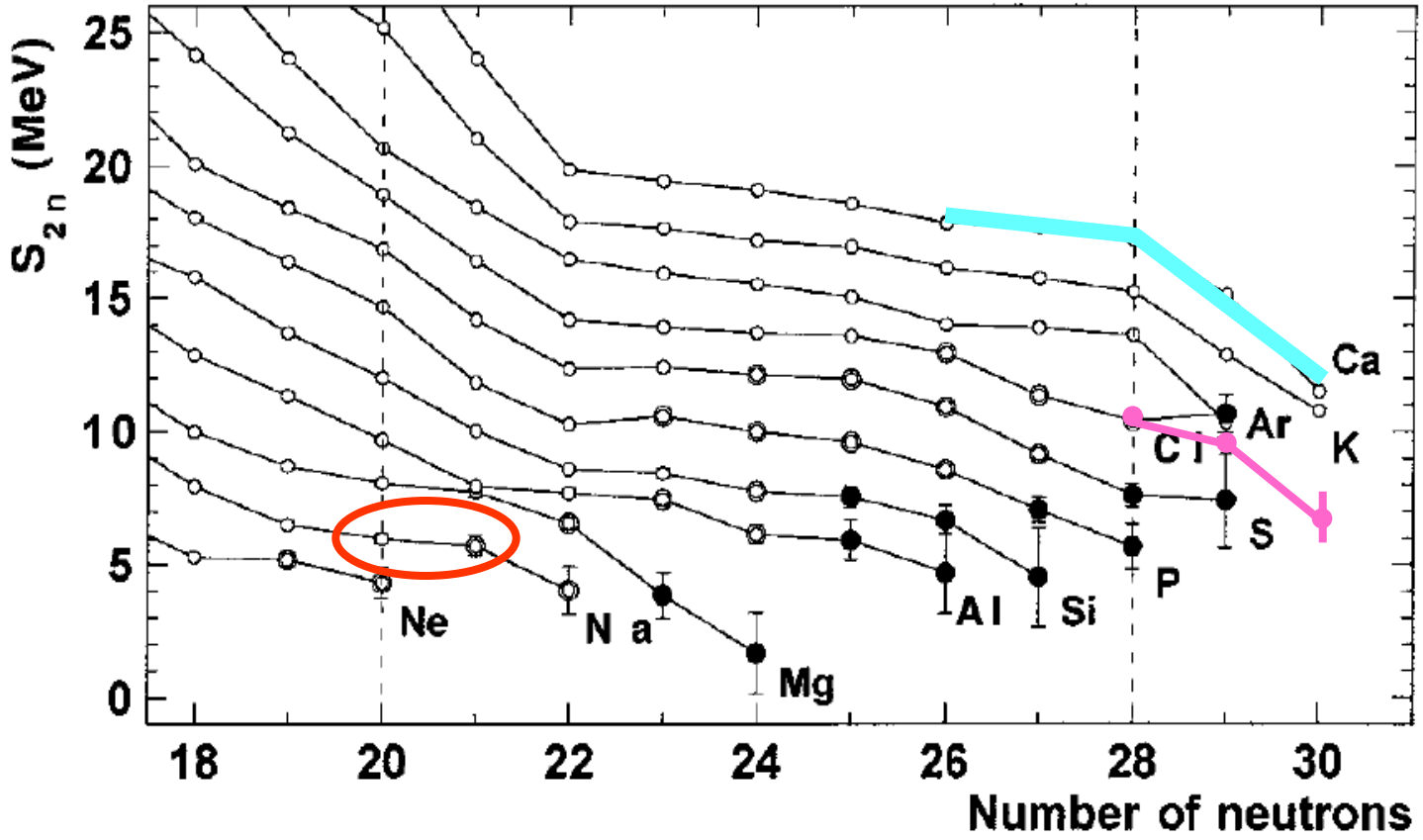
r-process nucleosynthesis and mass-models



r-process nucleosynthesis and mass-models



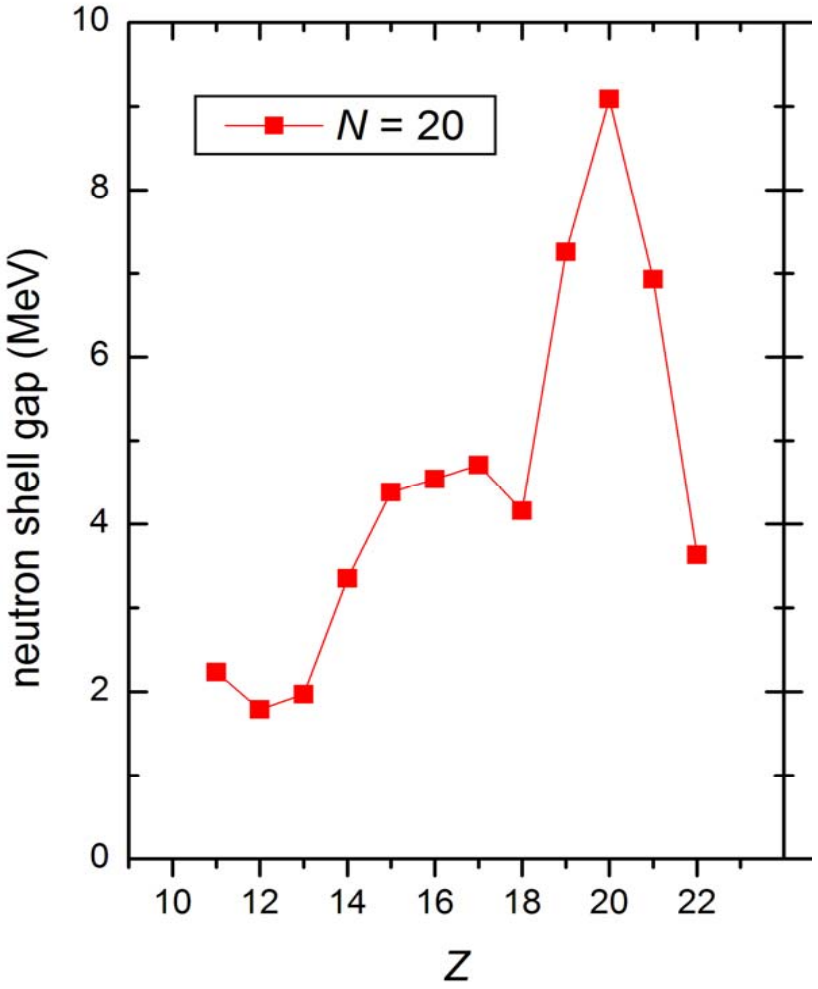
Mass measurements and (disappearing) shell structure



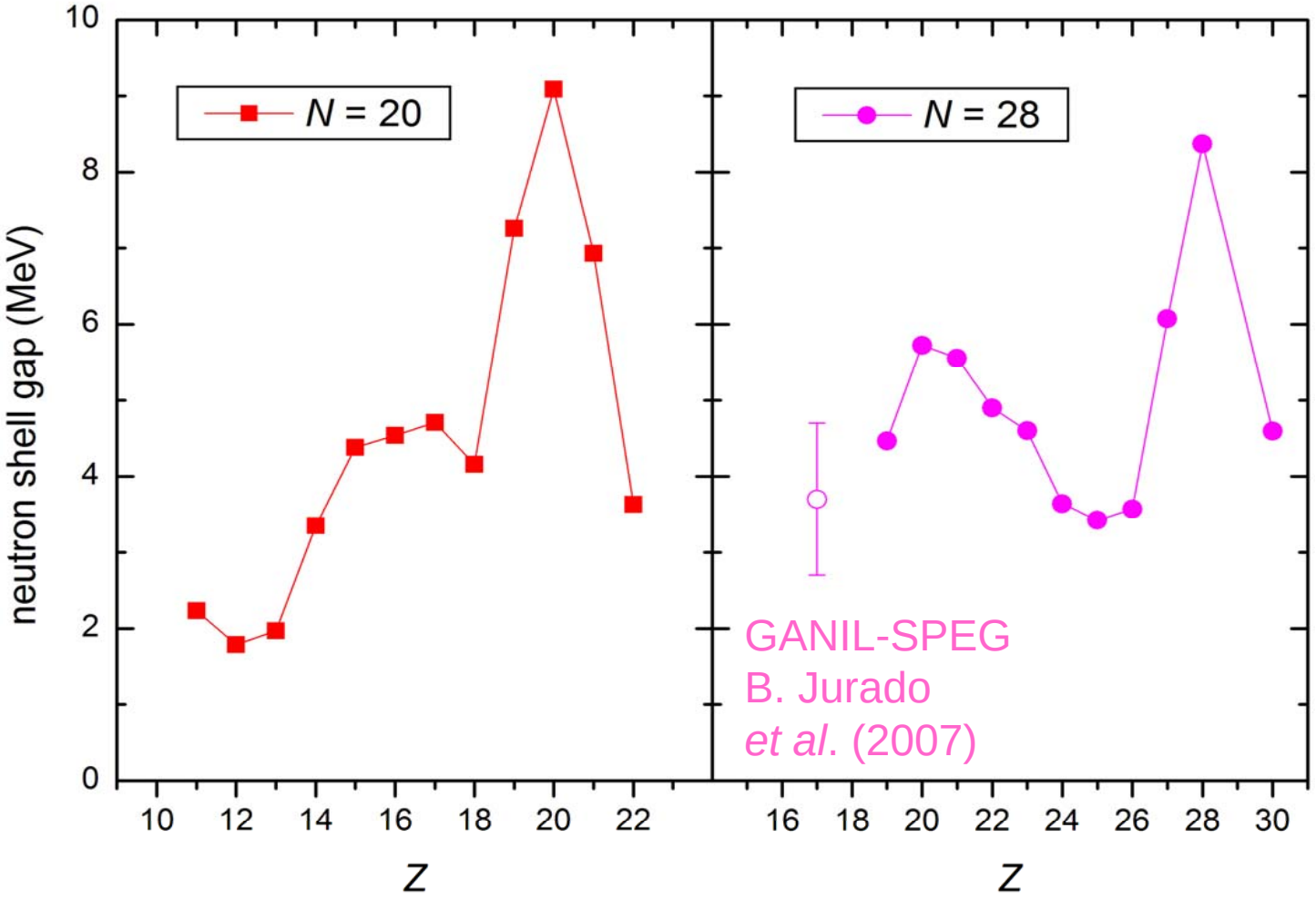
C. Thibault *et al*. (1975)

B. Jurado *et al*. (2007)

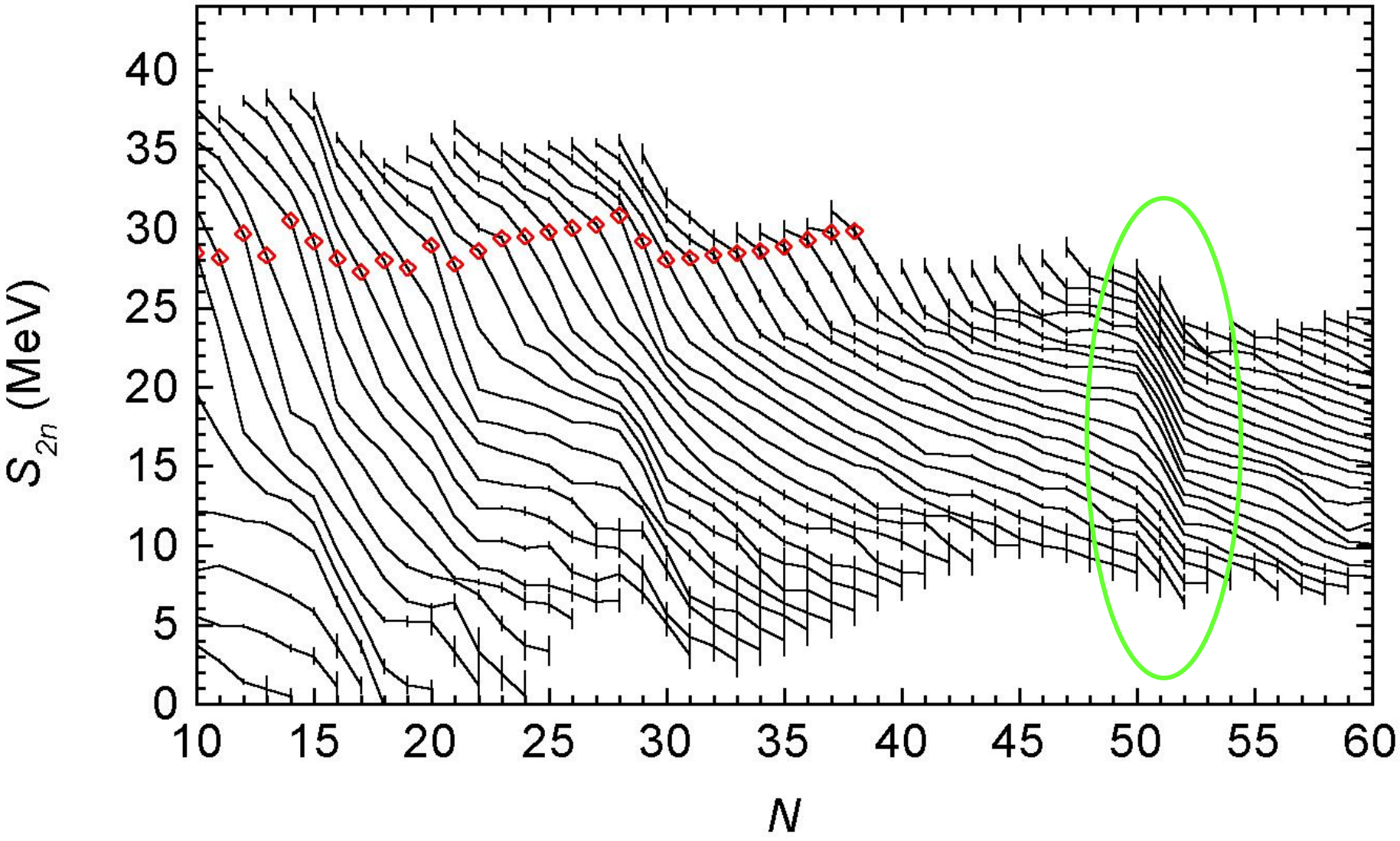
Neutron shell gaps and quenching



Neutron shell gaps and quenching

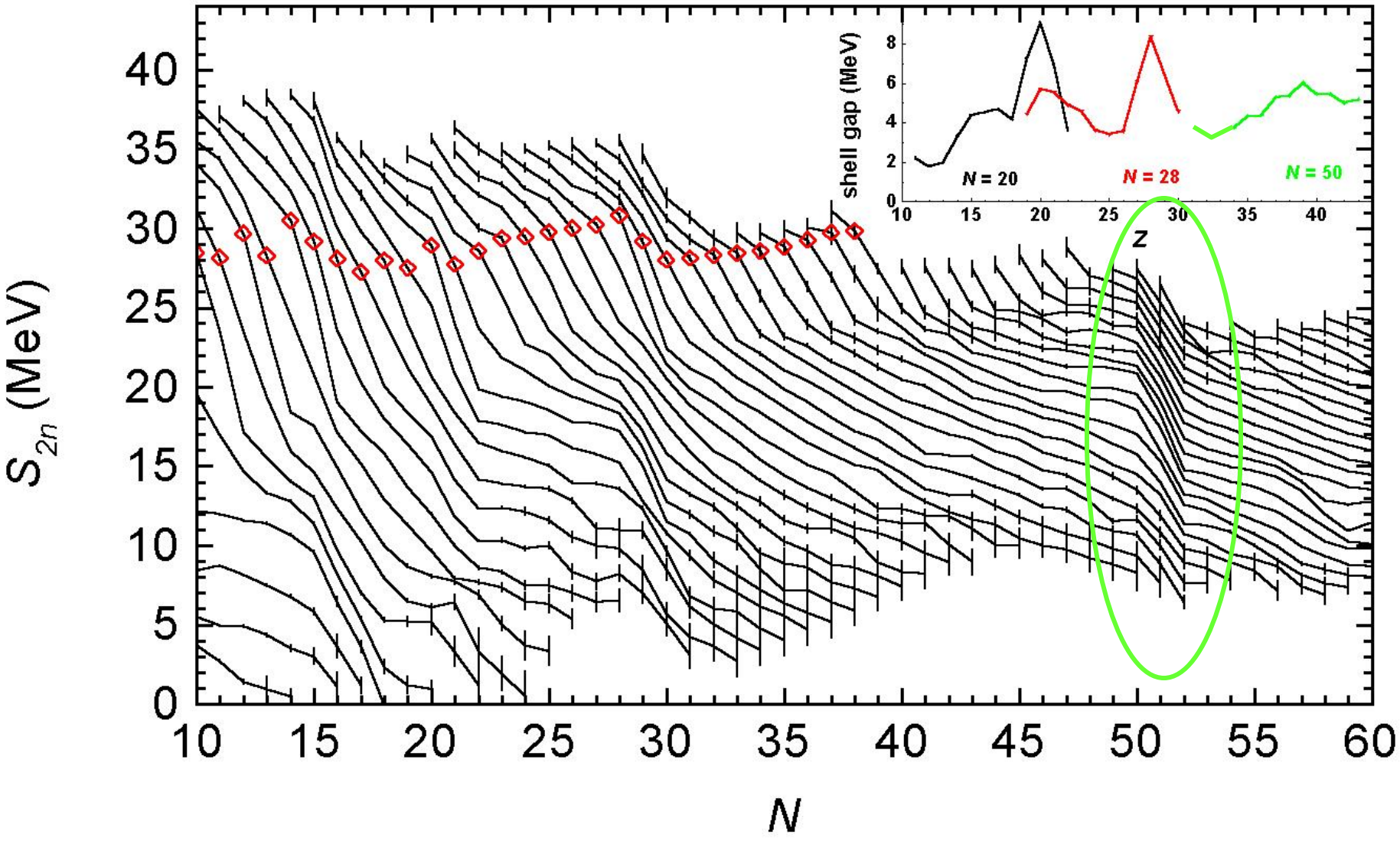


nuclear structure from the mass surface

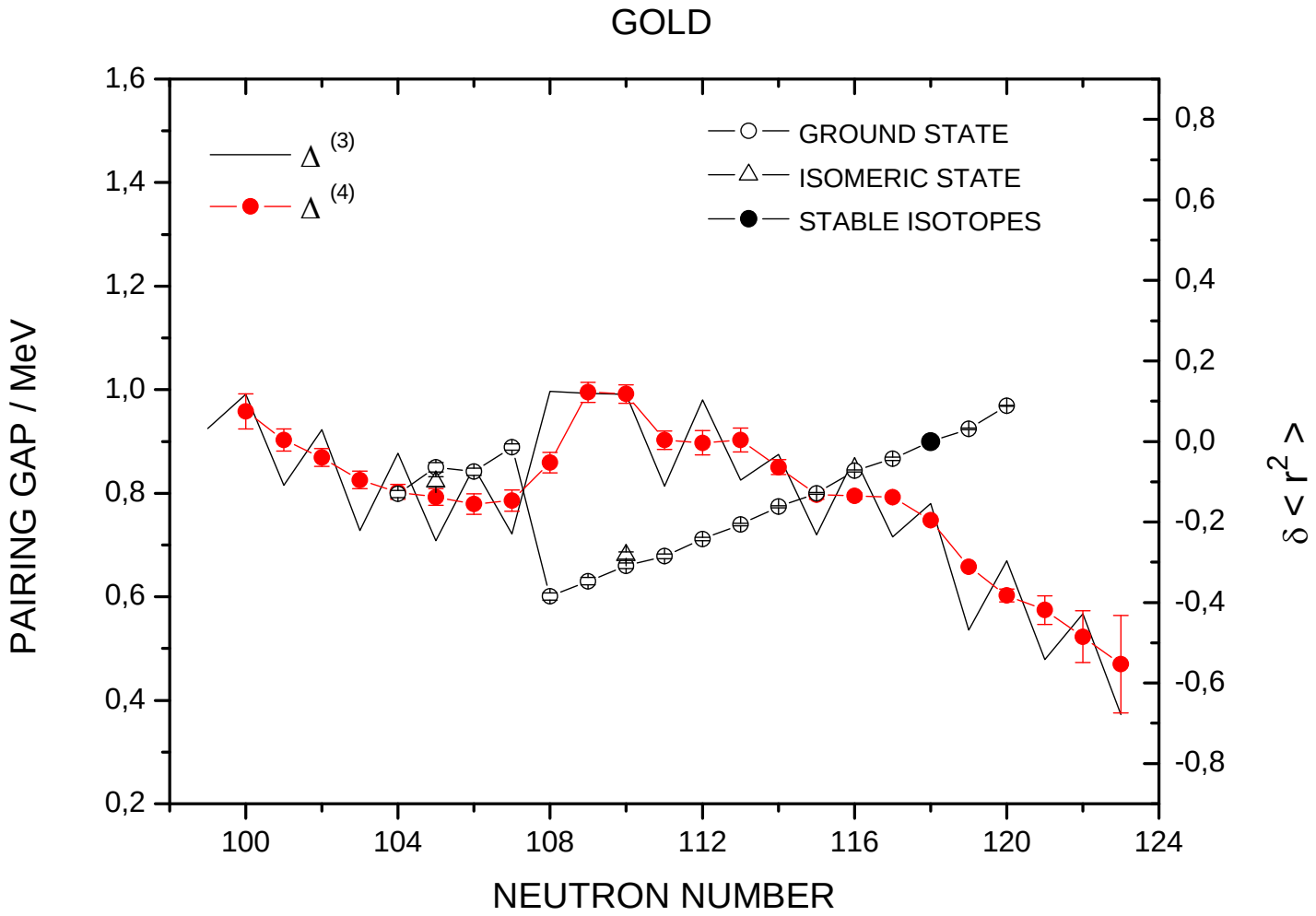


nuclear structure from the mass surface

JYFLTRAP
Hakala *et al.*

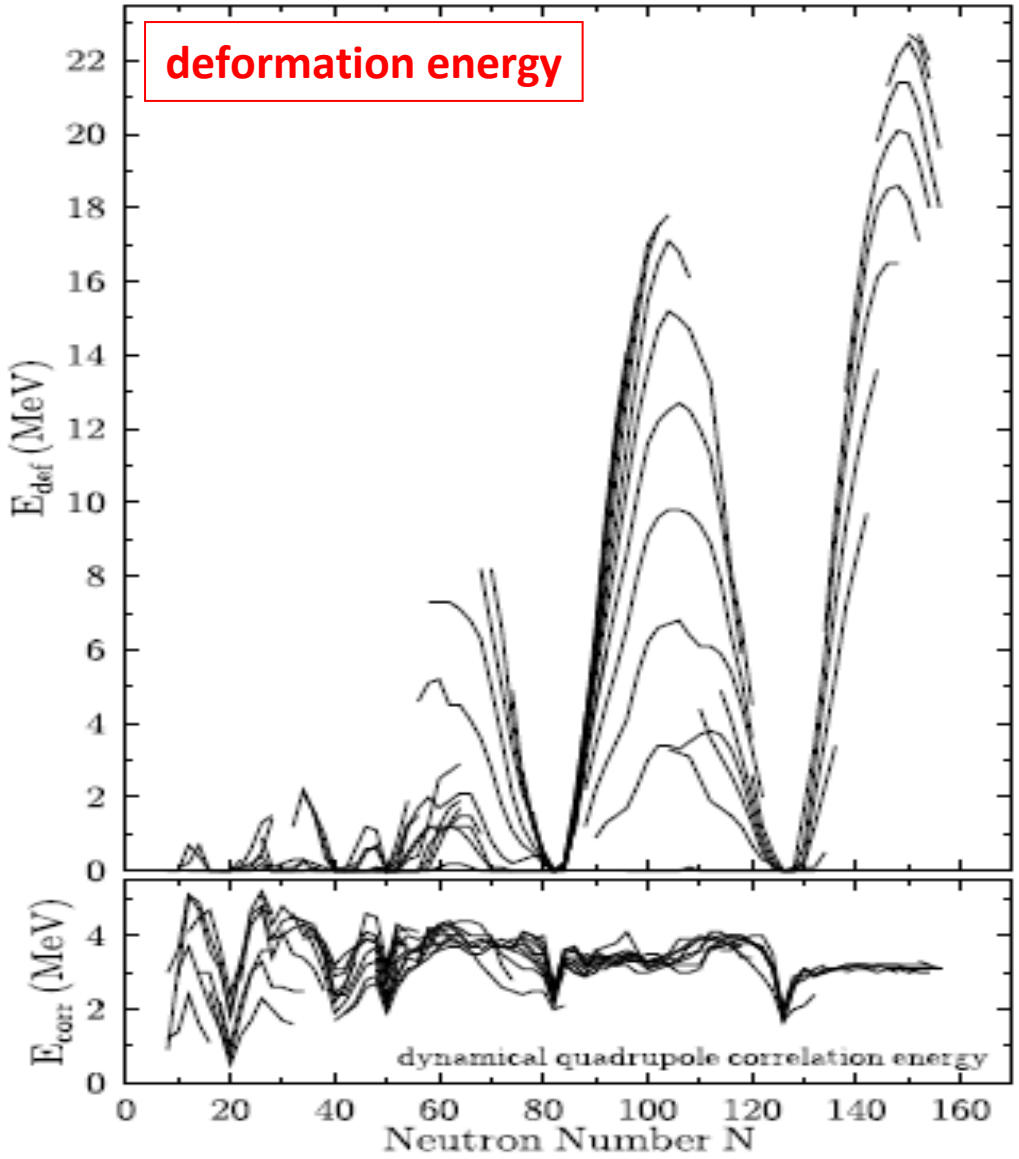


nuclear fine structure from the mass surface

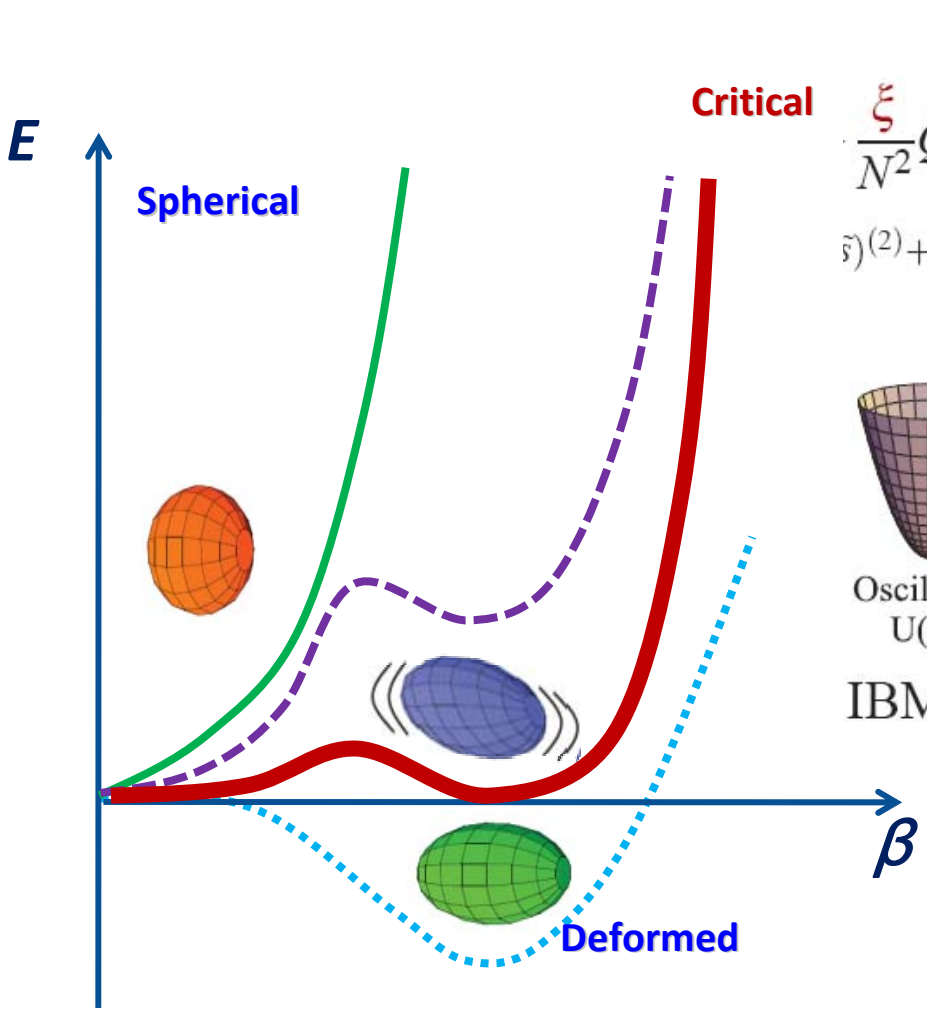


(C. Weber and the ISOLTRAP Collaboration, Nuc. Phy. A 2008)

S_{2n} : 30 MeV; shell gap: 3 MeV; pairing gap: 0.3 MeV $\Rightarrow \frac{\delta m}{m} \leq 10^{-7}$

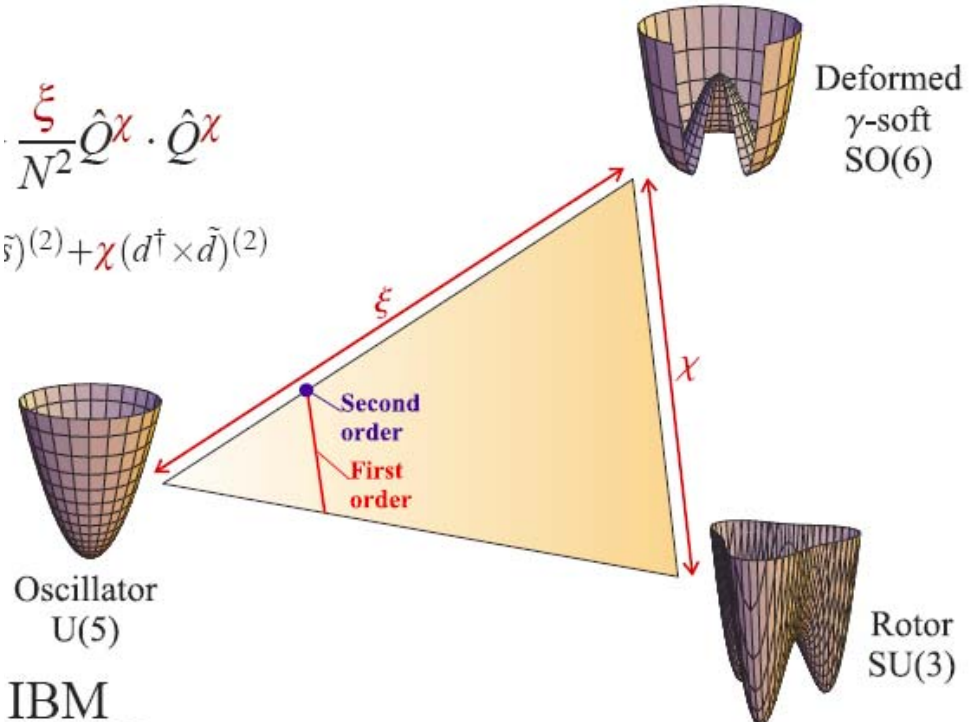


M. Bender, P.-H. Heenen (2006)



$$\frac{\xi}{N^2}\hat{Q}^{\chi}\cdot\hat{Q}^{\chi}$$

$$\tilde{s})^{(2)}+\chi(d^{\dagger}\times\tilde{d})^{(2)}$$



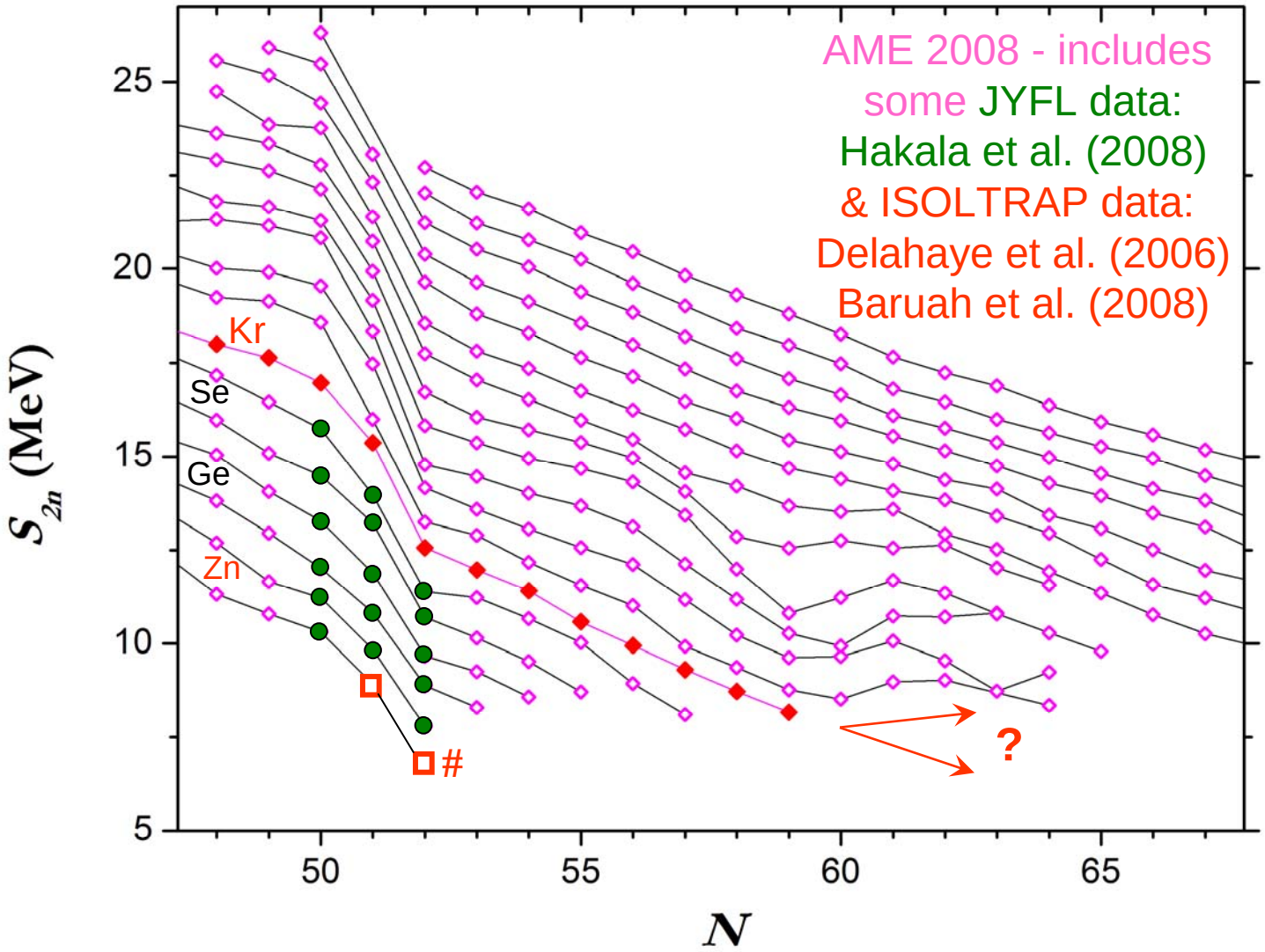
E(5): F. Iachello, PRL (2000)
X(5): F. Iachello, PRL (2001)

First and second order QPT can occur between systems characterized by different ground-state **shapes**.

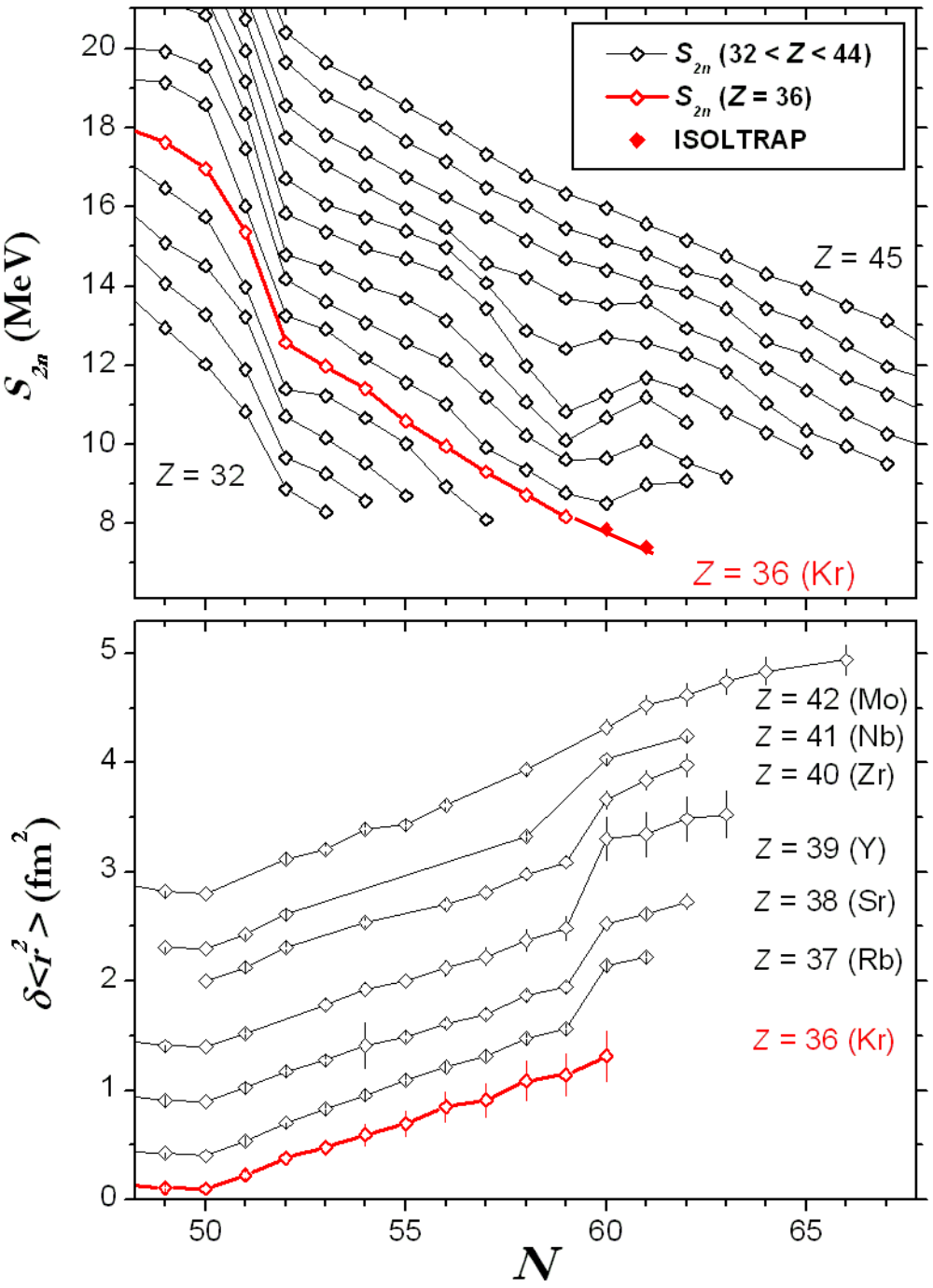
Control Parameter: **Number of nucleons**

Figure: R.F. Casten; Slide: P. Ring

Kr: deformation from N = 60 ?



ISOLTRAP: (S. Naimi et al.) have the answer!



^{97,98}Kr masses

S. Naimi et al. (ISOLTRAP)
submitted to PRL (2010)
(in arbitration…)

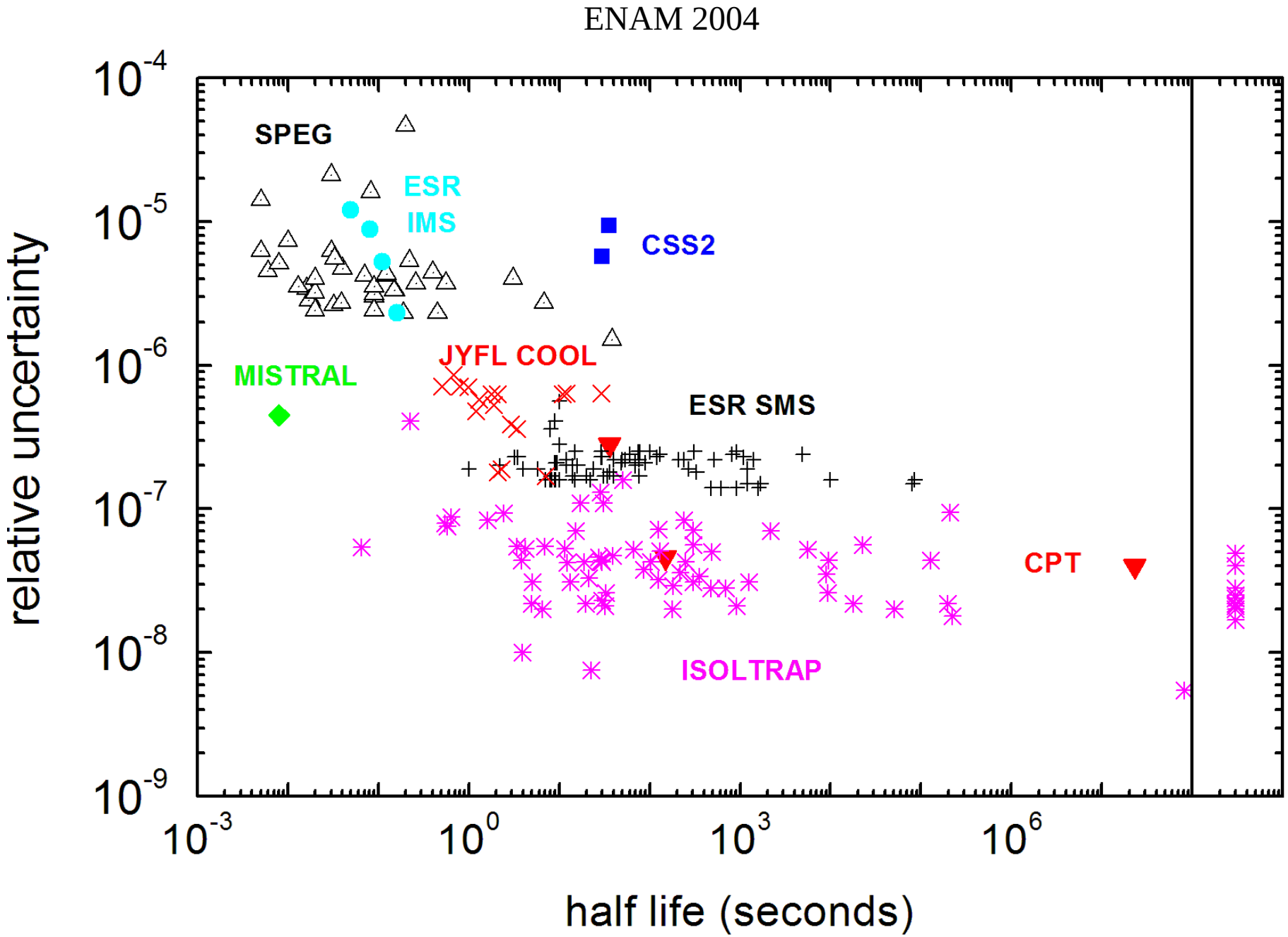
[16] G. Audi, A.H. Wapstra, C. Thibault, Nucl. Phys. A 729, 337 (2003).
[17] P. Delahaye *et al.*, Phys. Rev. C 74, 034331 (2007).
[18] U. Hager *et al.*, Phys. Rev. Lett. 96, 042504 (2006).
[19] U. Hager *et al.*, Nucl. Phys. A 793, 20 (2007).
[20] M. Keim *et al.*, Nucl. Phys. A 586, 219 (1995).
[21] C. Thibault *et al.*, Phys. Rev. C 23, 2720 (1981).
[22] F. Buchinger *et al.*, Phys. Rev. C 41, 2883 (1990).
[23] P. Lievens *et al.*, Phys. Lett. B 256, 141 (1991).
[24] B. Cheal *et al.*, Phys. Lett. B 645, 133 (2007).
[25] P. Campbell *et al.*, Phys. Rev. Lett. 89, 082501 (2002).
[26] B. Cheal *et al.*, Phys. Rev. Lett. 102, 222501 (2009).
[27] F.C. Charlwood *et al.*, Phys. Lett. B 674, 23 (2009).

The global mass market

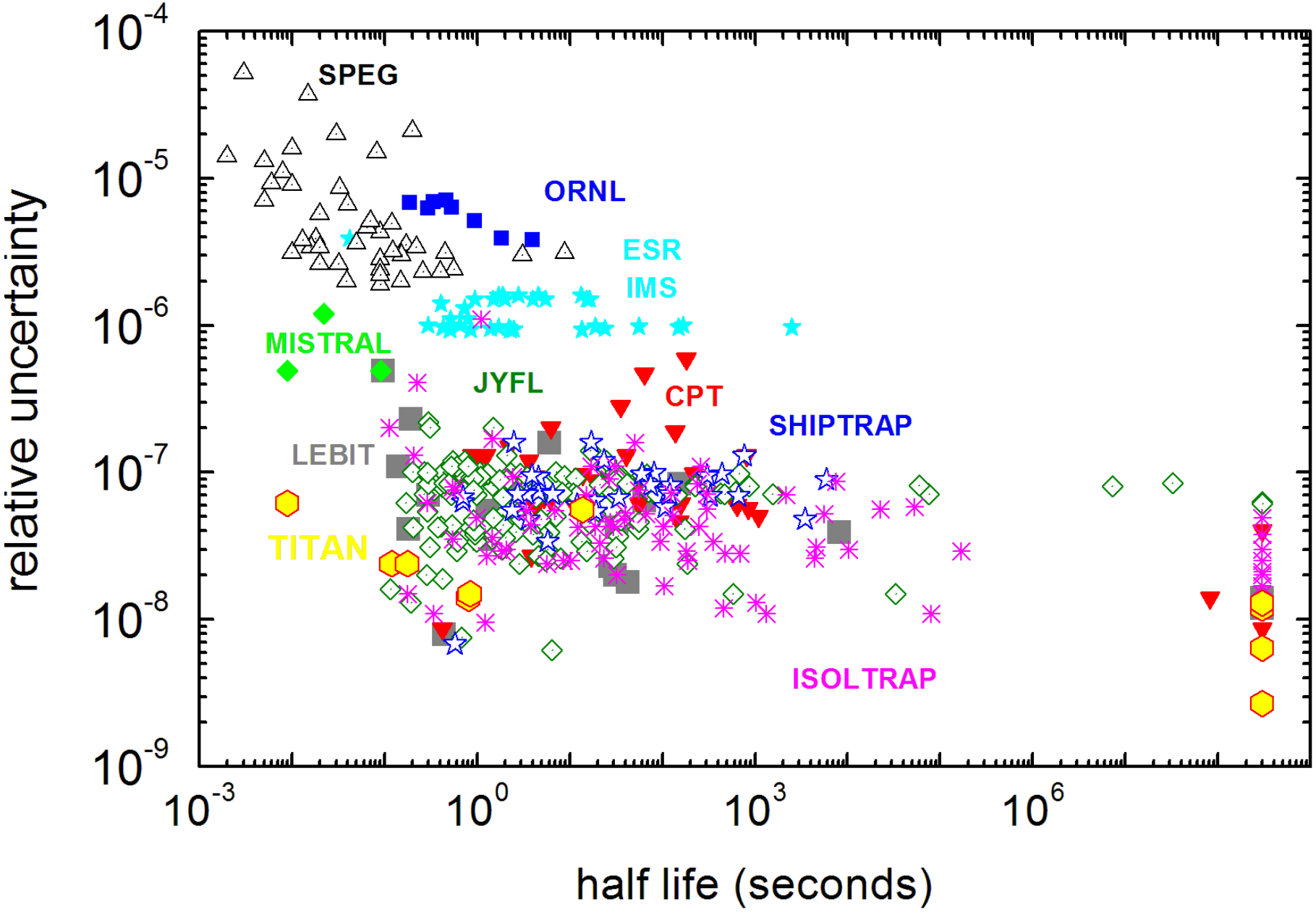
The global mass market

MLLTRAP-DESIR: Destiny of Bavaria and Normandy

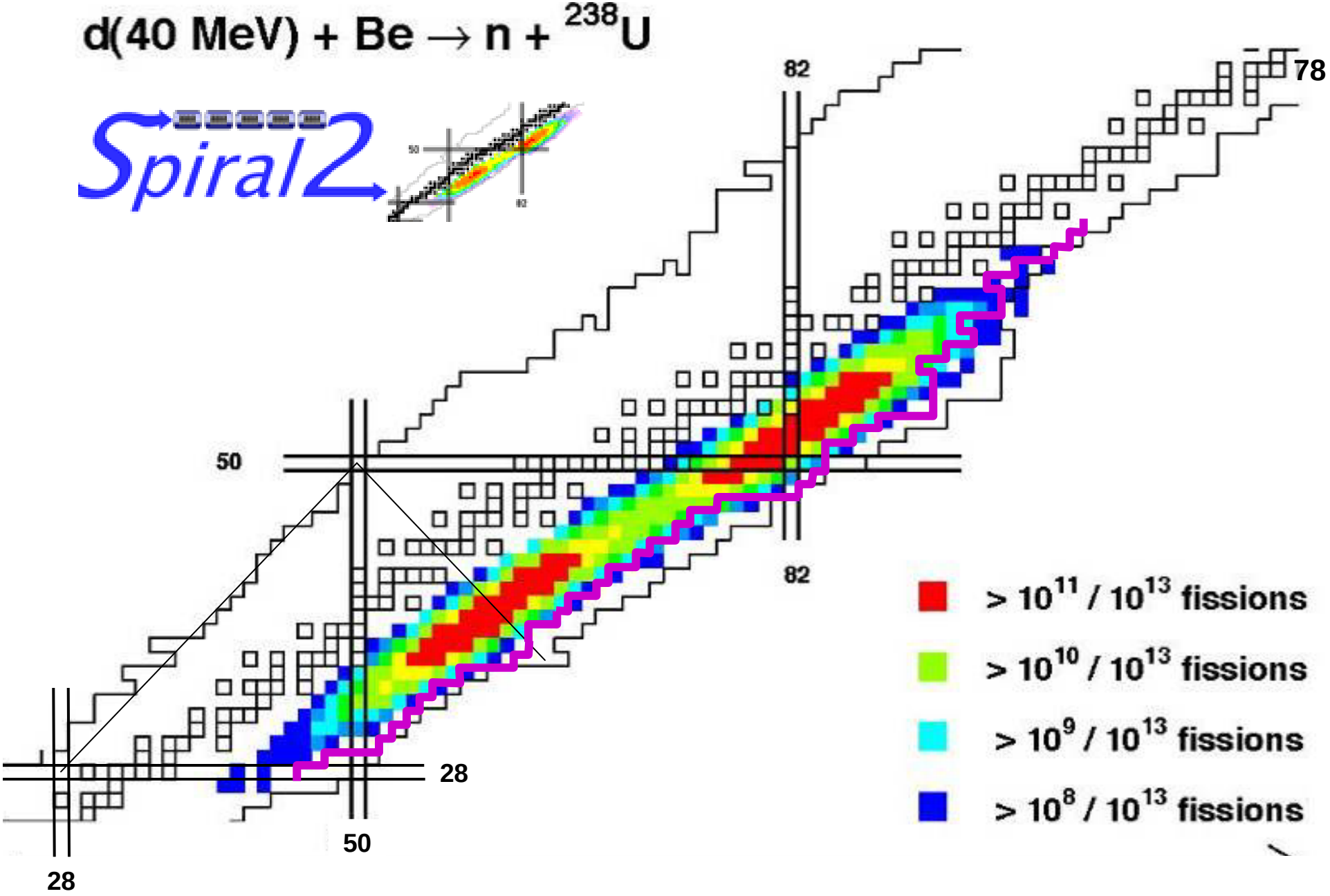
See Peter Thirolf's talk


ENAM 2004
relative uncertainty
half life (seconds)
SPEG
ESR
IMS
CSS2
JYFL COOL
MISTRAL
ESR SMS
CPT
ISOLTRAP

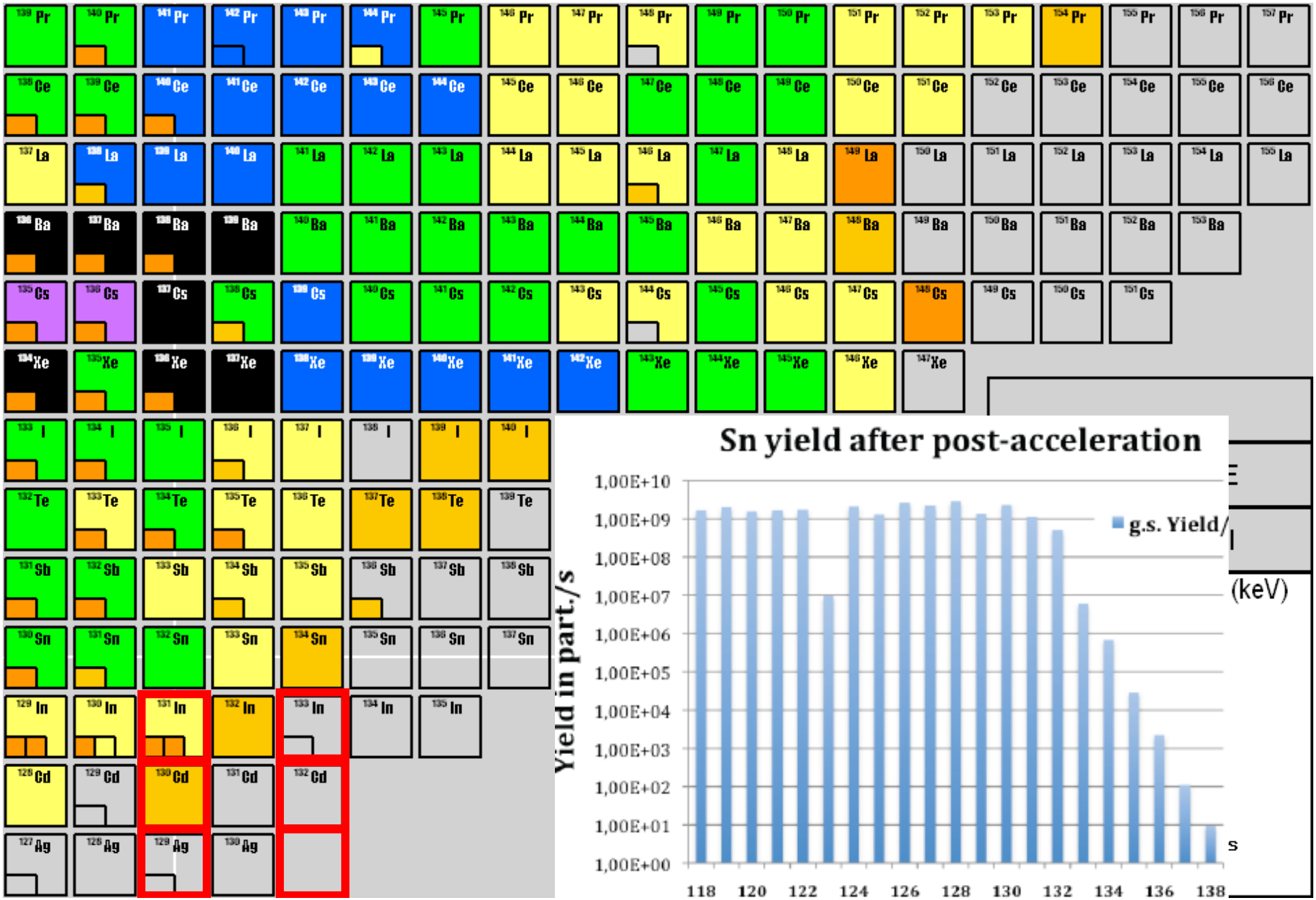
ENAM 2008

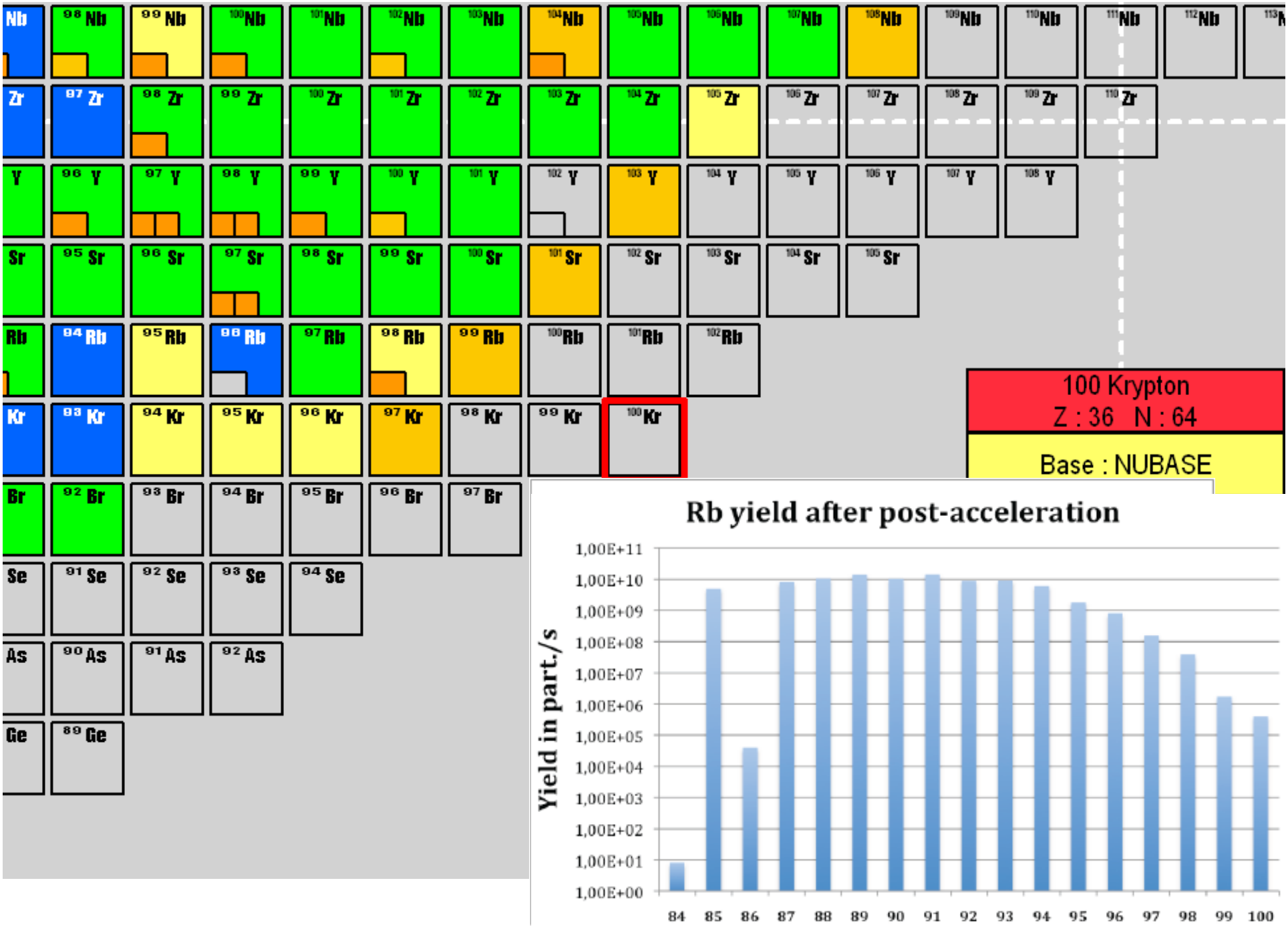


D. Lunney, proceedings of ENAM 2008


d(40 MeV) + Be → n + ^{238}U
Spiral2
82
78
50
82
28
50
28
> 10^{11} / 10^{13} fissions
> 10^{10} / 10^{13} fissions
> 10^{9} / 10^{13} fissions
> 10^{8} / 10^{13} fissions

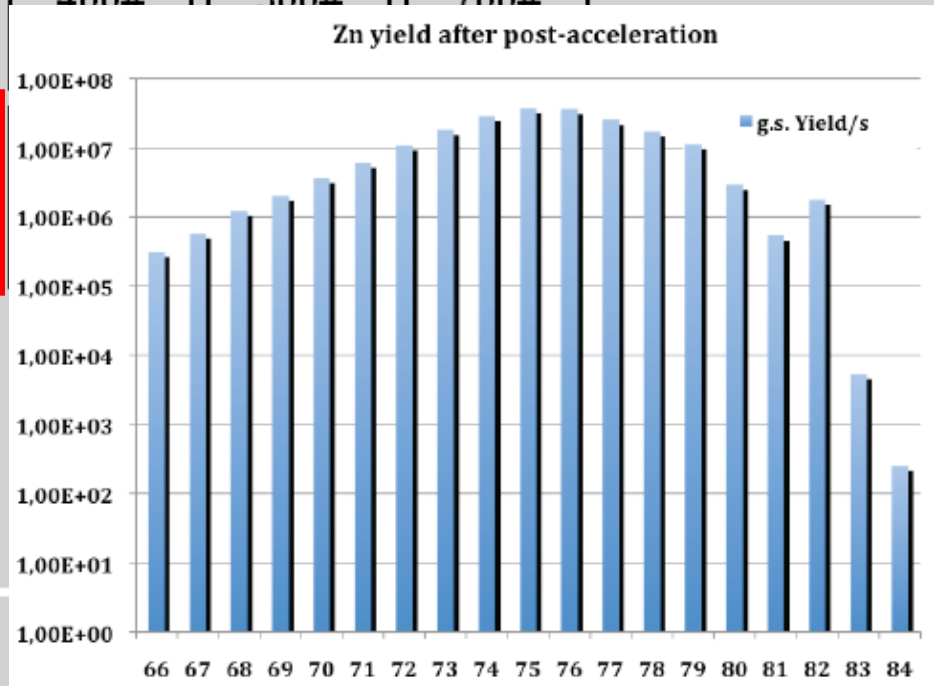
N = 82


139 Pr 140 Pr 141 Pr 142 Pr 143 Pr 144 Pr 145 Pr 146 Pr 147 Pr 148 Pr 149 Pr 150 Pr 151 Pr 152 Pr 153 Pr 154 Pr 155 Pr 156 Pr 157 Pr
138 Ce 139 Ce 140 Ce 141 Ce 142 Ce 143 Ce 144 Ce 145 Ce 146 Ce 147 Ce 148 Ce 149 Ce 150 Ce 151 Ce 152 Ce 153 Ce 154 Ce 155 Ce 156 Ce
137 La 138 La 139 La 140 La 141 La 142 La 143 La 144 La 145 La 146 La 147 La 148 La 149 La 150 La 151 La 152 La 153 La 154 La 155 La
136 Ba 137 Ba 138 Ba 139 Ba 140 Ba 141 Ba 142 Ba 143 Ba 144 Ba 145 Ba 146 Ba 147 Ba 148 Ba 149 Ba 150 Ba 151 Ba 152 Ba 153 Ba
135 Cs 136 Cs 137 Cs 138 Cs 139 Cs 140 Cs 141 Cs 142 Cs 143 Cs 144 Cs 145 Cs 146 Cs 147 Cs 148 Cs 149 Cs 150 Cs 151 Cs
134 Xe 135 Xe 136 Xe 137 Xe 138 Xe 139 Xe 140 Xe 141 Xe 142 Xe 143 Xe 144 Xe 145 Xe 146 Xe 147 Xe
133 I 134 I 135 I 136 I 137 I 138 I 139 I 140 I
132 Te 133 Te 134 Te 135 Te 136 Te 137 Te 138 Te 139 Te
131 Sb 132 Sb 133 Sb 134 Sb 135 Sb 136 Sb 137 Sb 138 Sb
130 Sn 131 Sn 132 Sn 133 Sn 134 Sn 135 Sn 136 Sn 137 Sn
129 In 130 In 131 In 132 In 133 In 134 In 135 In
128 Cd 129 Cd 130 Cd 131 Cd 132 Cd
127 Ag 128 Ag 129 Ag 130 Ag
Sn yield after post-acceleration
Yield in part./s
1,00E+10
1,00E+09
1,00E+08
1,00E+07
1,00E+06
1,00E+05
1,00E+04
1,00E+03
1,00E+02
1,00E+01
1,00E+00
g.s. Yield/
(keV)
s
118 120 122 124 126 128 130 132 134 136 138

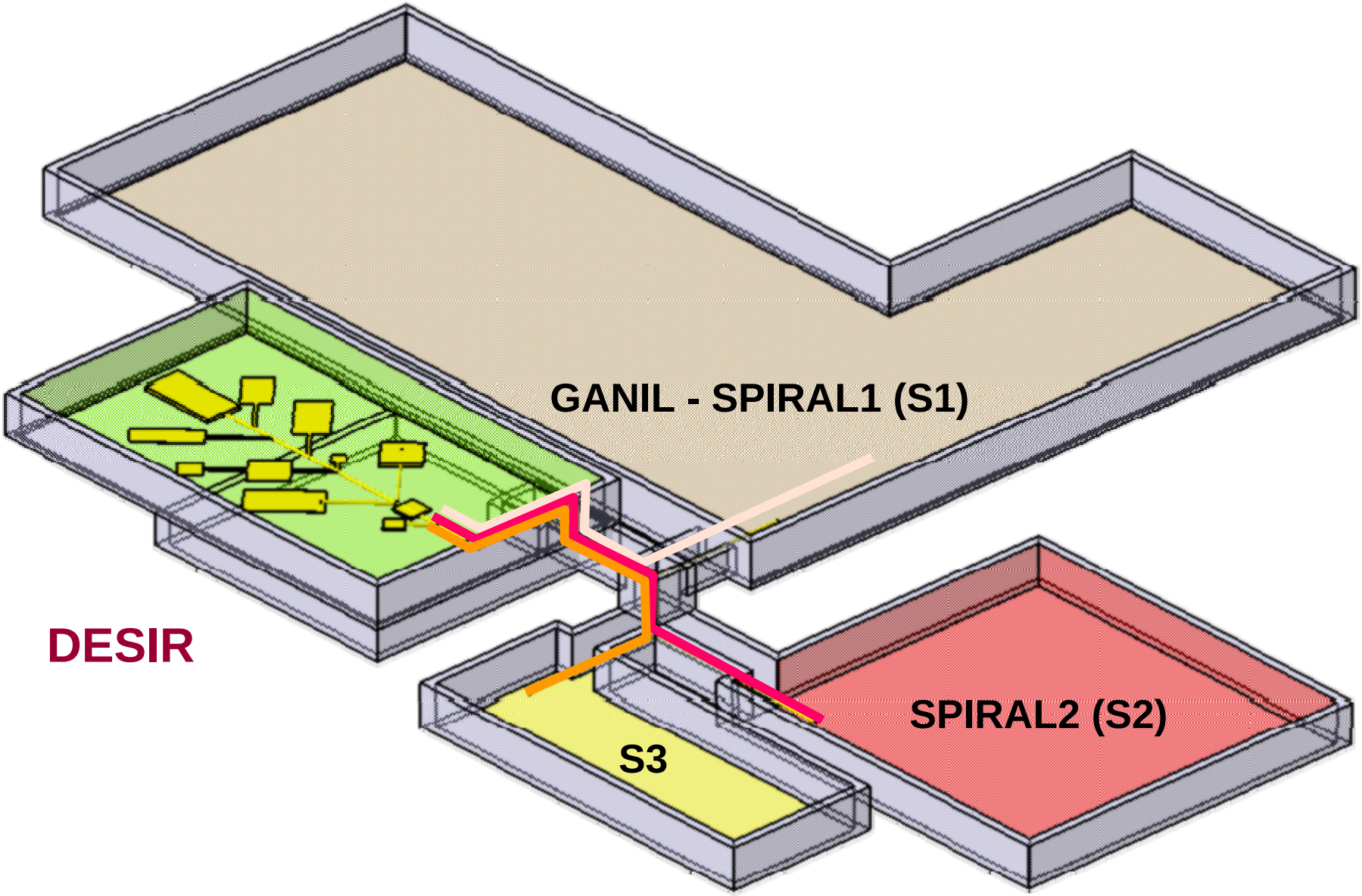

Nb 98 Nb 99 Nb 100 Nb 101 Nb 102 Nb 103 Nb 104 Nb 105 Nb 106 Nb 107 Nb 108 Nb 109 Nb 110 Nb 111 Nb 112 Nb
Zr 97 Zr 98 Zr 99 Zr 100 Zr 101 Zr 102 Zr 103 Zr 104 Zr 105 Zr 106 Zr 107 Zr 108 Zr 109 Zr 110 Zr
Y 96 Y 97 Y 98 Y 99 Y 100 Y 101 Y 102 Y 103 Y 104 Y 105 Y 106 Y 107 Y 108 Y
Sr 95 Sr 96 Sr 97 Sr 98 Sr 99 Sr 100 Sr 101 Sr 102 Sr 103 Sr 104 Sr 105 Sr
Rb 94 Rb 95 Rb 96 Rb 97 Rb 98 Rb 99 Rb 100 Rb 101 Rb 102 Rb
Kr 93 Kr 94 Kr 95 Kr 96 Kr 97 Kr 98 Kr 99 Kr 100 Kr
Br 92 Br 93 Br 94 Br 95 Br 96 Br 97 Br
Se 91 Se 92 Se 93 Se 94 Se
As 90 As 91 As 92 As
Ge 89 Ge
100 Krypton
Z : 36 N : 64
Base : NUBASE

Rb yield after post-acceleration
Yield in part./s
1,00E+11
1,00E+10
1,00E+09
1,00E+08
1,00E+07
1,00E+06
1,00E+05
1,00E+04
1,00E+03
1,00E+02
1,00E+01
1,00E+00
84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100

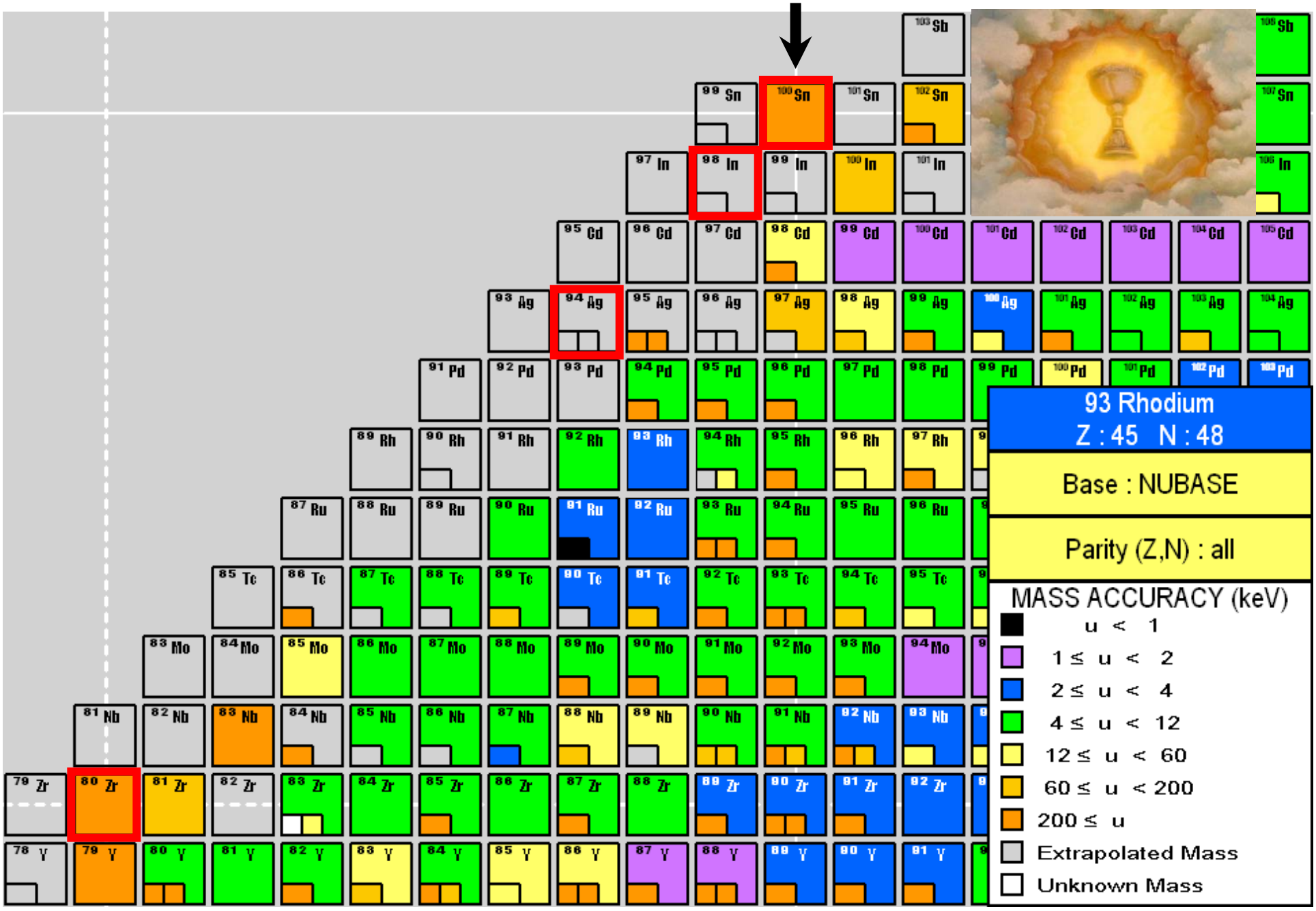
82 Se 1.5	83 Se 3	84 Se 2.0	85 Se 2.6	86 Se 2.5	87 Se 2.2	88 Se 3	89 Se 4	90 Se 400#	91 Se 500#
81 As 2.7	82 As 4	83 As 2.8	84 As 3	85 As 3	86 As 3	87 As 3.0	88 As 400#	89 As 500#	90 As 600#
80 Ge 2.1	81 Ge 2.1	82 Ge 2.2	83 Ge 2.4	84 Ge 3	85 Ge 4	86 Ge 400#	87 Ge 500#	88 Ge 700#	89 Ge 800#
79 Ga 1.9	80 Ga 2.9	81 Ga 3	82 Ga 2.4	83 Ga 2.6	84 Ga 400#	85 Ga 500#	86 Ga 700#		
78 Zn 1.9	79 Zn 2.2	80 Zn 2.6	81 Zn 5	82 Zn 400#					
77 Cu 500	78 Cu 500	79 Cu 400#	80 Cu 600#						
76 Ni 500#	77 Ni 500#								



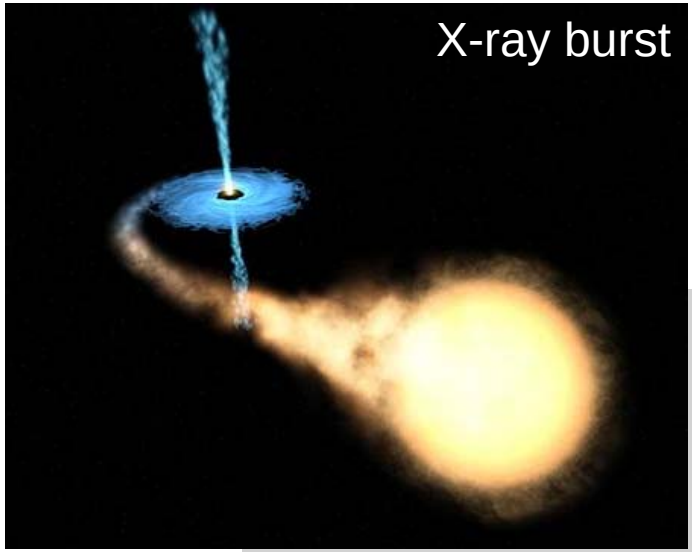
Various beams to DESIR

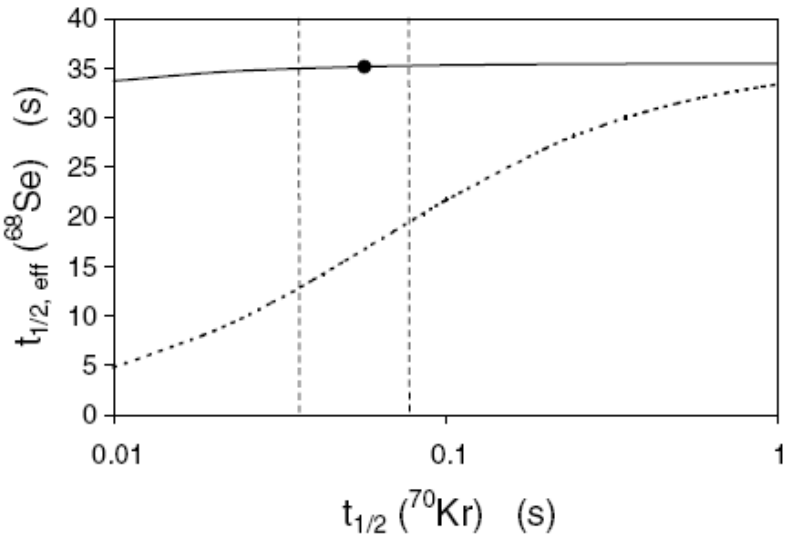


S3: proton-rich candidates

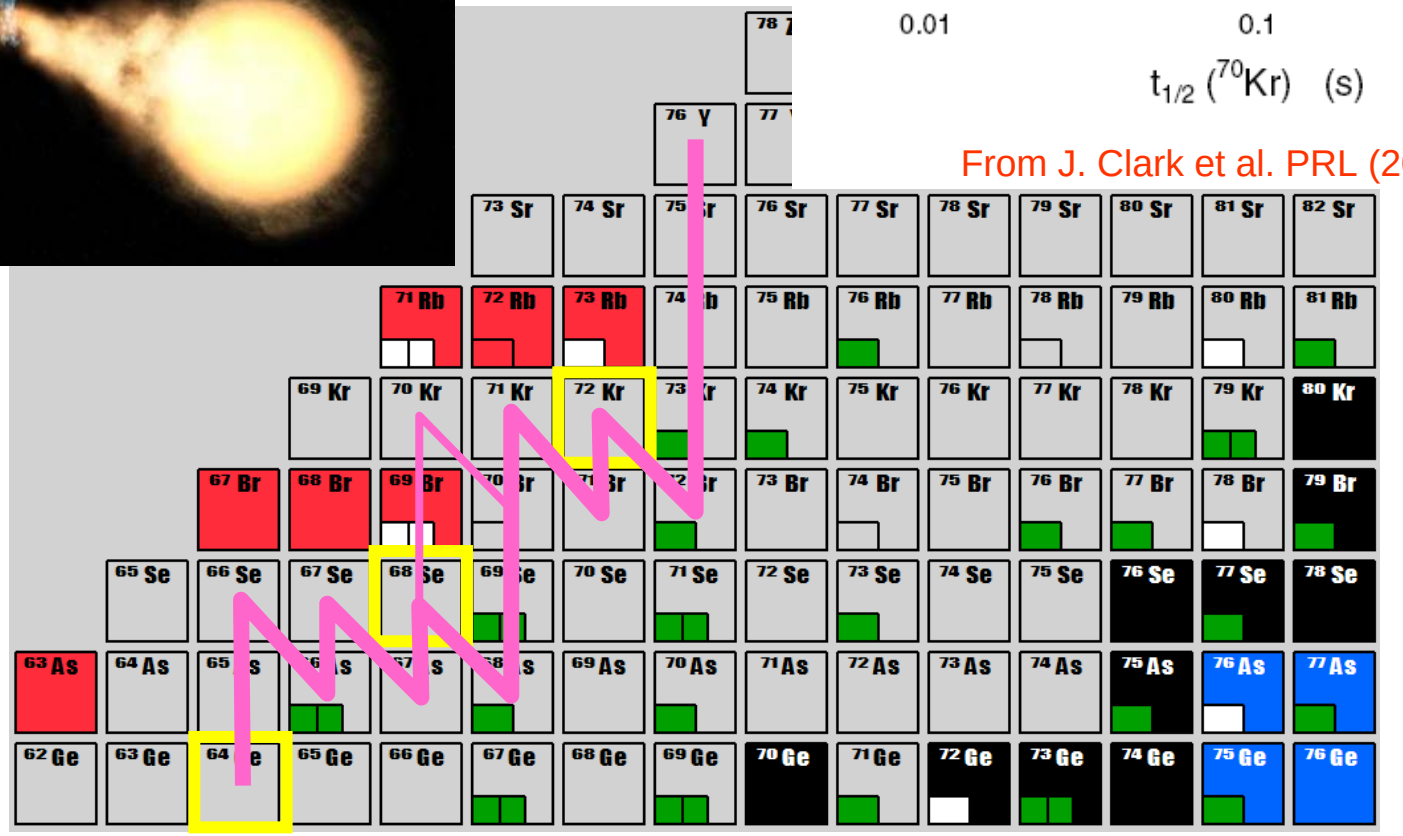


Nucleosynthesis and the rp process



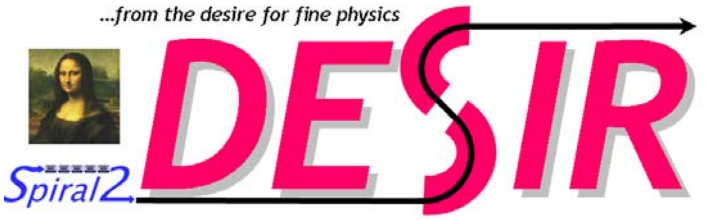


From J. Clark et al. PRL (2004)



Letter of Intent:

Rather than a long shopping list
a few key nuclides and
“day-one” candidates



S3: ^{100}Sn; ^{98}In (^{98}Cd); ^{94}Ag; ^{80}Zr (^{82}Zr)

N = *Z* nuclides + rp-process nuclides

S2: ^{133}In (HRS); ^{132}Cd
^{100}Rb; ^{98}Kr; ^{82}Zn

r-process nuclides

S1: ^{48}Ar

other nuclides (day one?)

Thanks for getting up this morning…