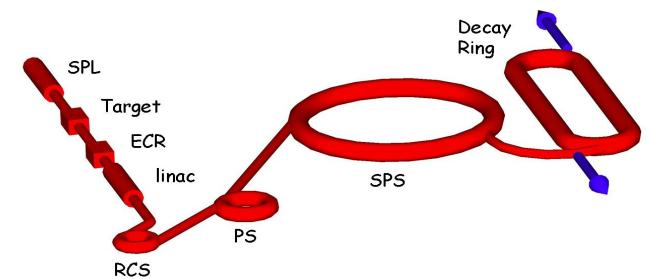
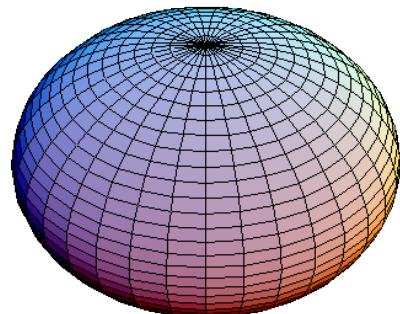


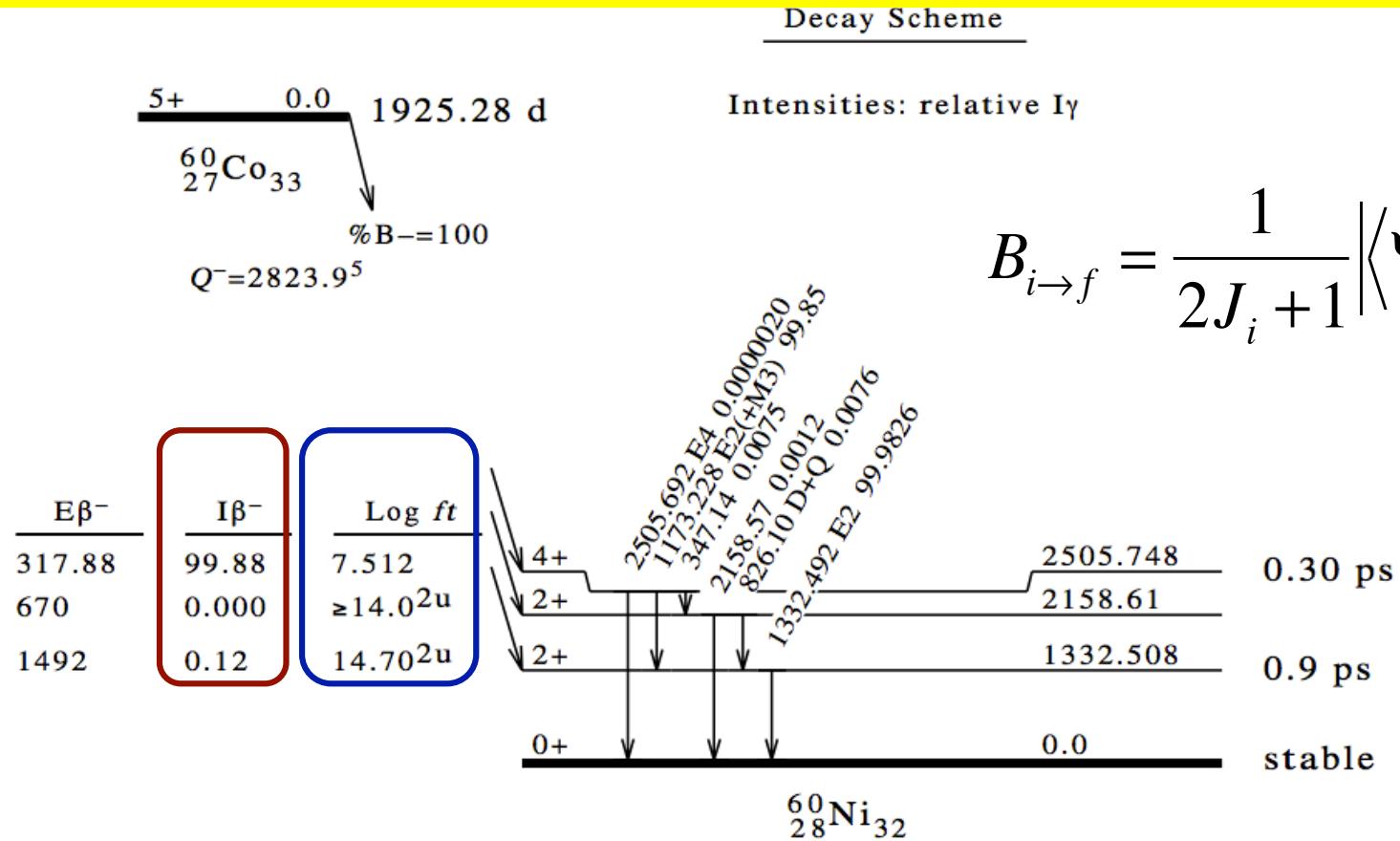
Former beta strength(& feeding) results obtained through TAS measurements

Alejandro Algora
IFIC (CSIC-Univ. Valencia), Spain



TAS –Workshop
January 2015, Nantes

Example: ^{60}Co decay from <http://www.nndc.bnl.gov/>

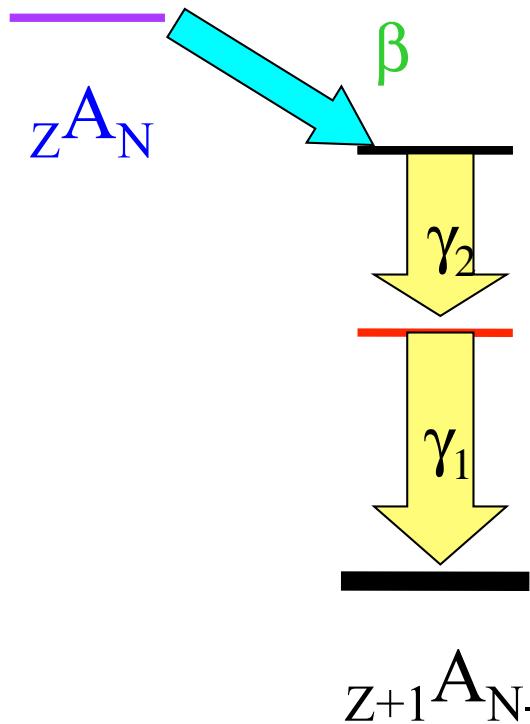


$$B_{i \rightarrow f} = \frac{1}{2J_i + 1} \left| \langle \Psi_f | \tau^\pm \text{ or } \sigma \tau^\pm | \Psi_i \rangle \right|^2$$

$$ft_f = const' \frac{1}{|M_{if}|^2} = const' \frac{1}{B_{i \rightarrow f}}$$

$$S_\beta(E) = \frac{P_\beta(E)}{f(Z', Q_\beta - E) T_{1/2}} = \frac{1}{ft(E)}$$

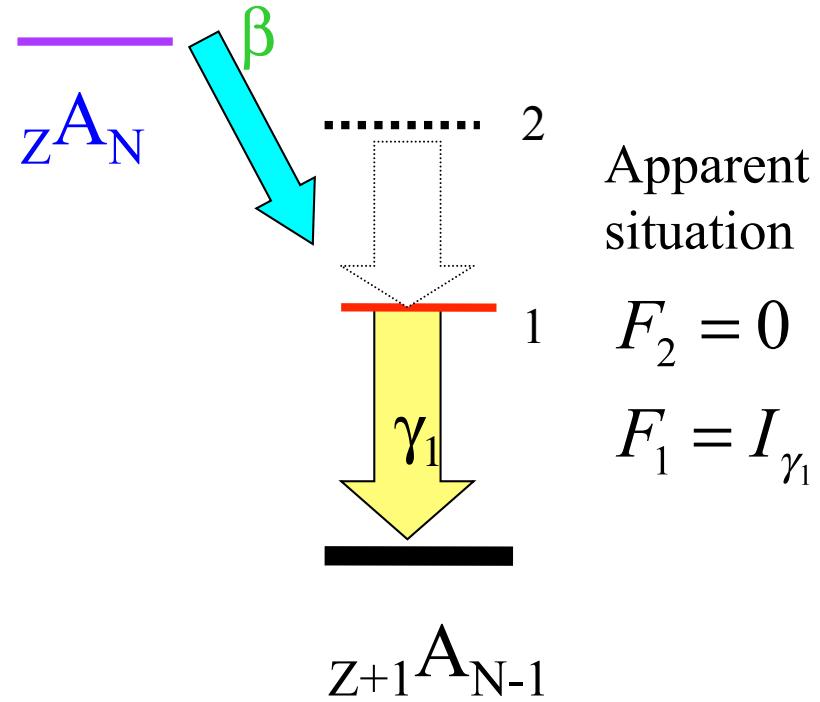
The problem of measuring the β - feeding (no delayed part.emission)



Real situation

$$F_2 = I_{\gamma_2}$$

$$F_1 = 0$$

$$(I_{\gamma_2} = I_{\gamma_1})$$


Apparent situation

$$F_2 = 0$$

$$F_1 = I_{\gamma_1}$$

- We use Ge detectors to construct the level scheme populated in the decay
- From the γ intensity balance we deduce the β -feeding
- What happens if we miss some gamma intensity???

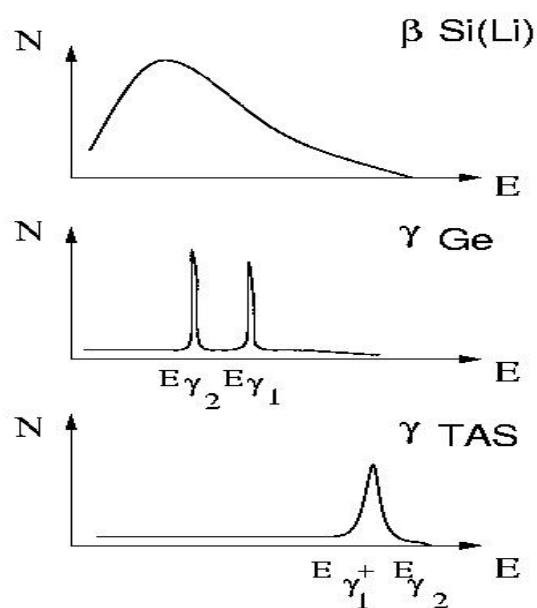
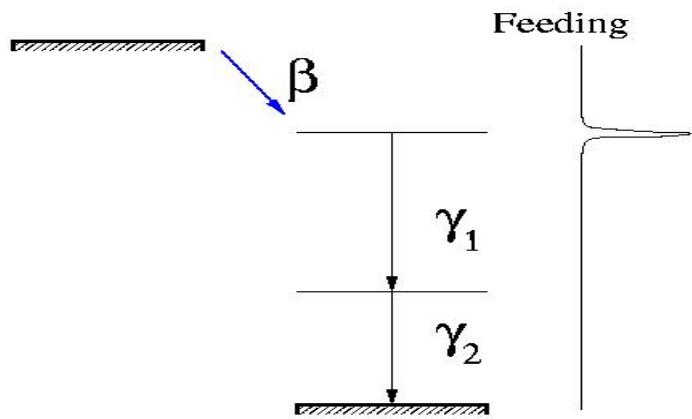
Pandemonium (The Capital of Hell)

introduced by John Milton (XVII) in his epic poem Paradise Lost



John Martin (~ 1825)

TAGS measurements



Since the gamma detection is the only reasonable way to solve the problem, we need a highly efficient device:

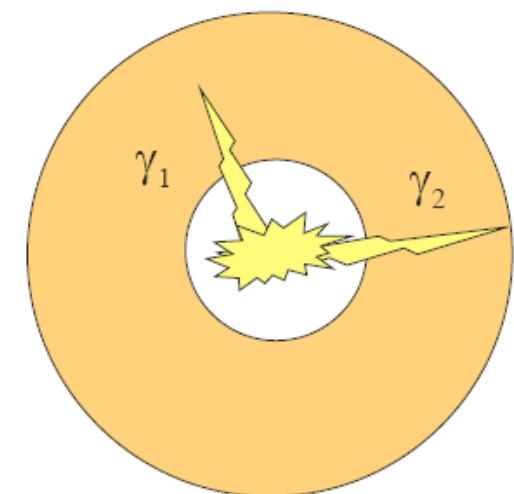
A TOTAL ABSORPTION SPECTROMETER

But if you built such a detector instead of detecting the individual gamma rays you can sum the energy deposited by the gamma cascades in the detector.

A TAS is like a calorimeter!

Big crystal, 4π

$$d = R(B) \cdot f$$



Analysis

$$d_i = \sum_j R_{ij} f_j \quad or \quad \mathbf{d} = \mathbf{R} \cdot \mathbf{f}$$

R is the response function of the spectrometer, R_{ij} means the probability that feeding at a level j gives counts in data channel i of the spectrum

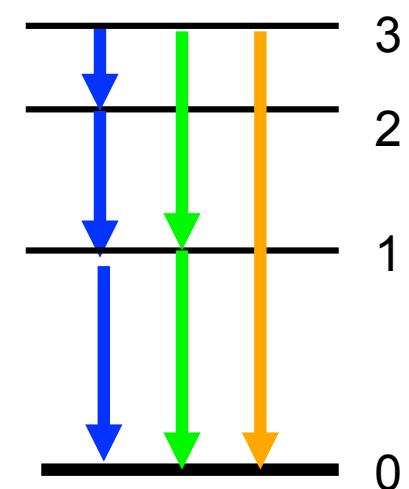
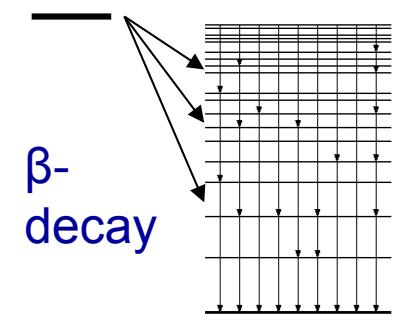
The response matrix R can be constructed by recursive convolution:

$$\mathbf{R}_j = \sum_{k=0}^{j-1} b_{jk} \mathbf{g}_{jk} \otimes \mathbf{R}_k$$

\mathbf{g}_{jk} : γ -response for $j \rightarrow k$ transition

\mathbf{R}_k : response for level k

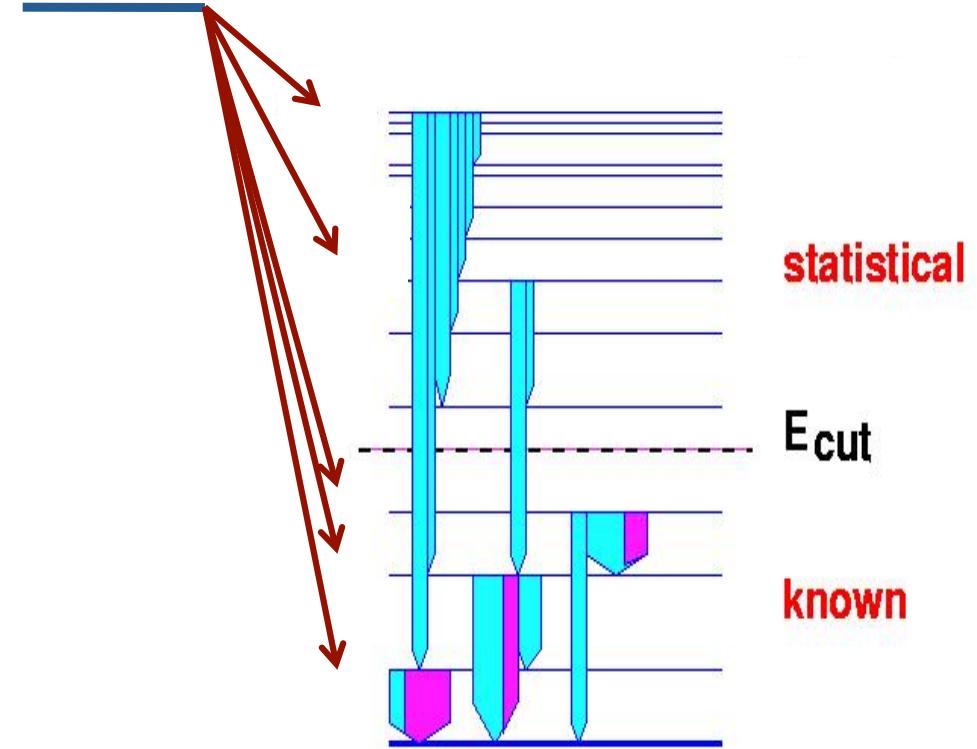
b_{jk} : branching ratio for $j \rightarrow k$ transition



Mathematical formalization by Tain, Cano, et al.

The complexity of the TAGS analysis: an ill posed problem

$$d = R(B) \cdot f$$



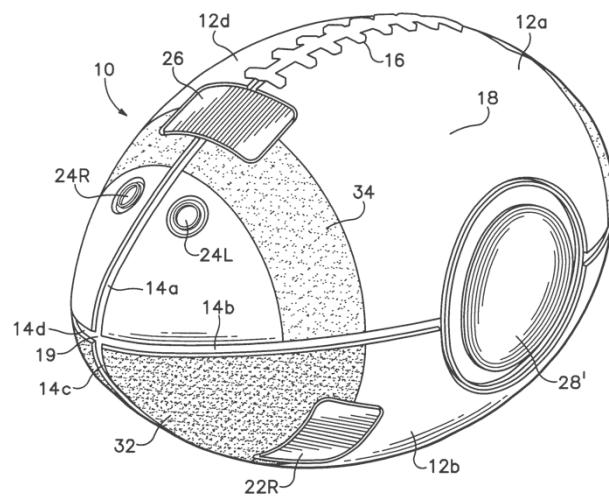
Expectation Maximization (EM) method:
modify knowledge on causes from effects

$$P(f_j | d_i) = \frac{P(d_i | f_j) P(f_j)}{\sum_j P(d_i | f_j) P(f_j)}$$

Algorithm:

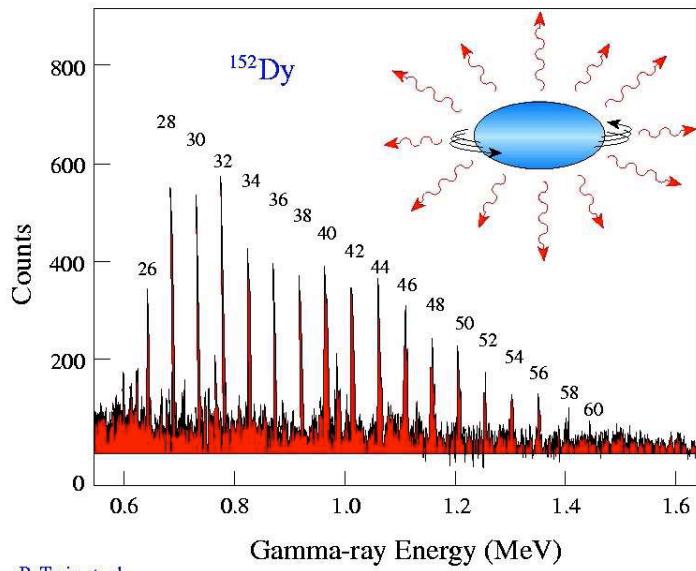
$$f_j^{(s+1)} = \frac{1}{\sum_i R_{ij}} \sum_i \frac{R_{ij} f_j^{(s)} d_i}{\sum_k R_{ik} f_k^{(s)}}$$

Strength and Nuclear Shapes

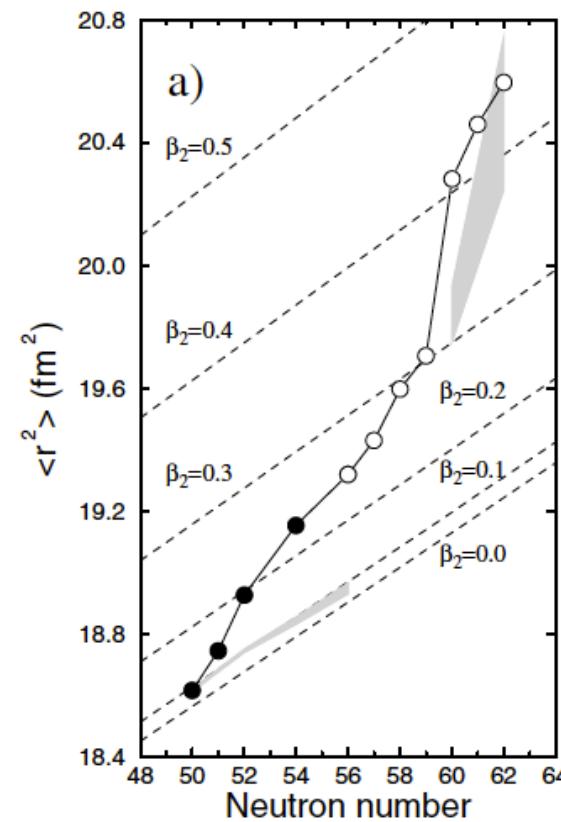


Experimentally how we determine shapes...

- Nuclear electric quadrupole measurements (not valid for $J=0, 1/2$ ground states)
- Nuclear radii measurements, by means of particle scattering experiments
- Nuclear radii determinations by means of isotopic shifts (laser spectroscopy, muonic atoms)
- Nuclear spectroscopic information: level life time measurements, $B(E2)$, transitions in a band, $E(0)$, etc.
- Coulomb excitation



$$|Q| = \sqrt{16\pi B(E2:2_1^+ \rightarrow 0_1^+)} = \frac{3Ze}{\sqrt{5\pi}} R_0^2 (\beta + 0.16\beta^2),$$

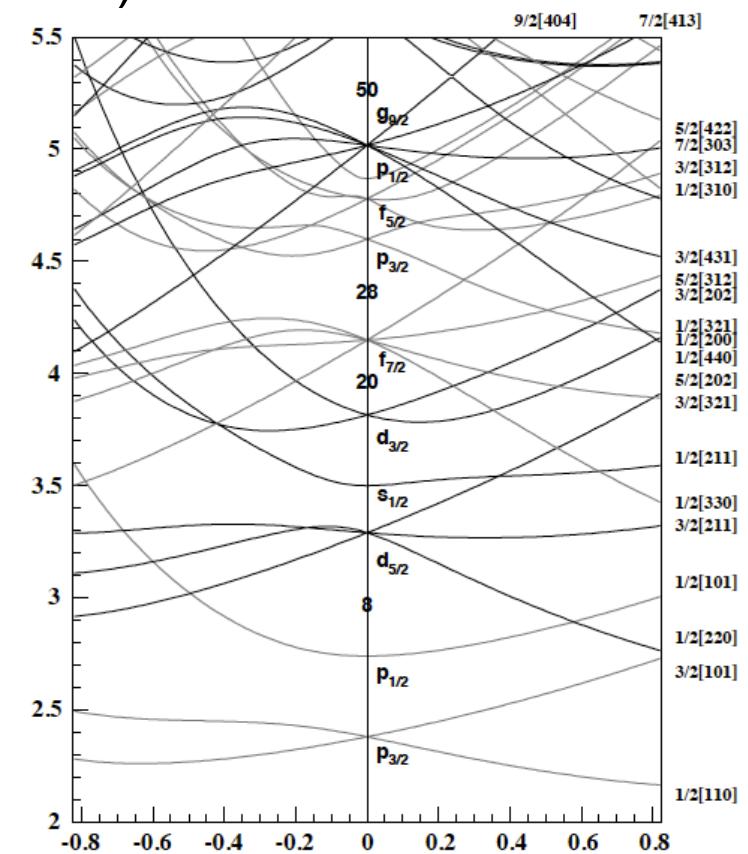
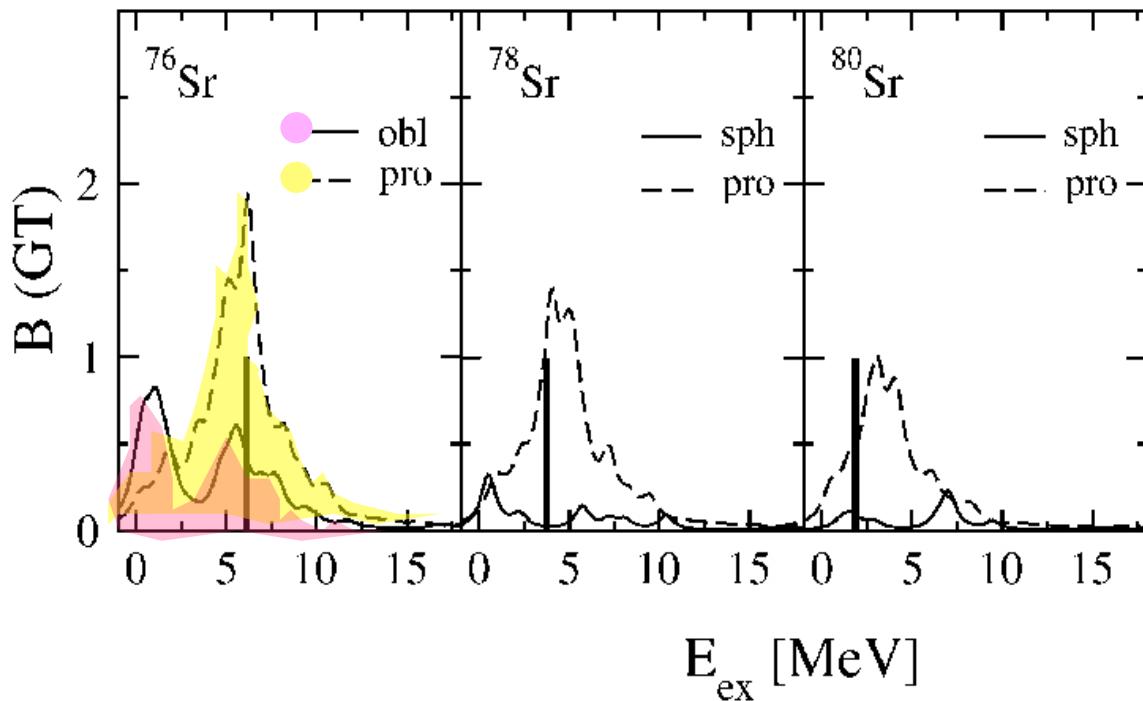


Laser spectroscopy of cooled Zr fission products (Campbell PRL 89, 2002)
Mean square charge radii deduced from the measurements compared with droplet model predictions.

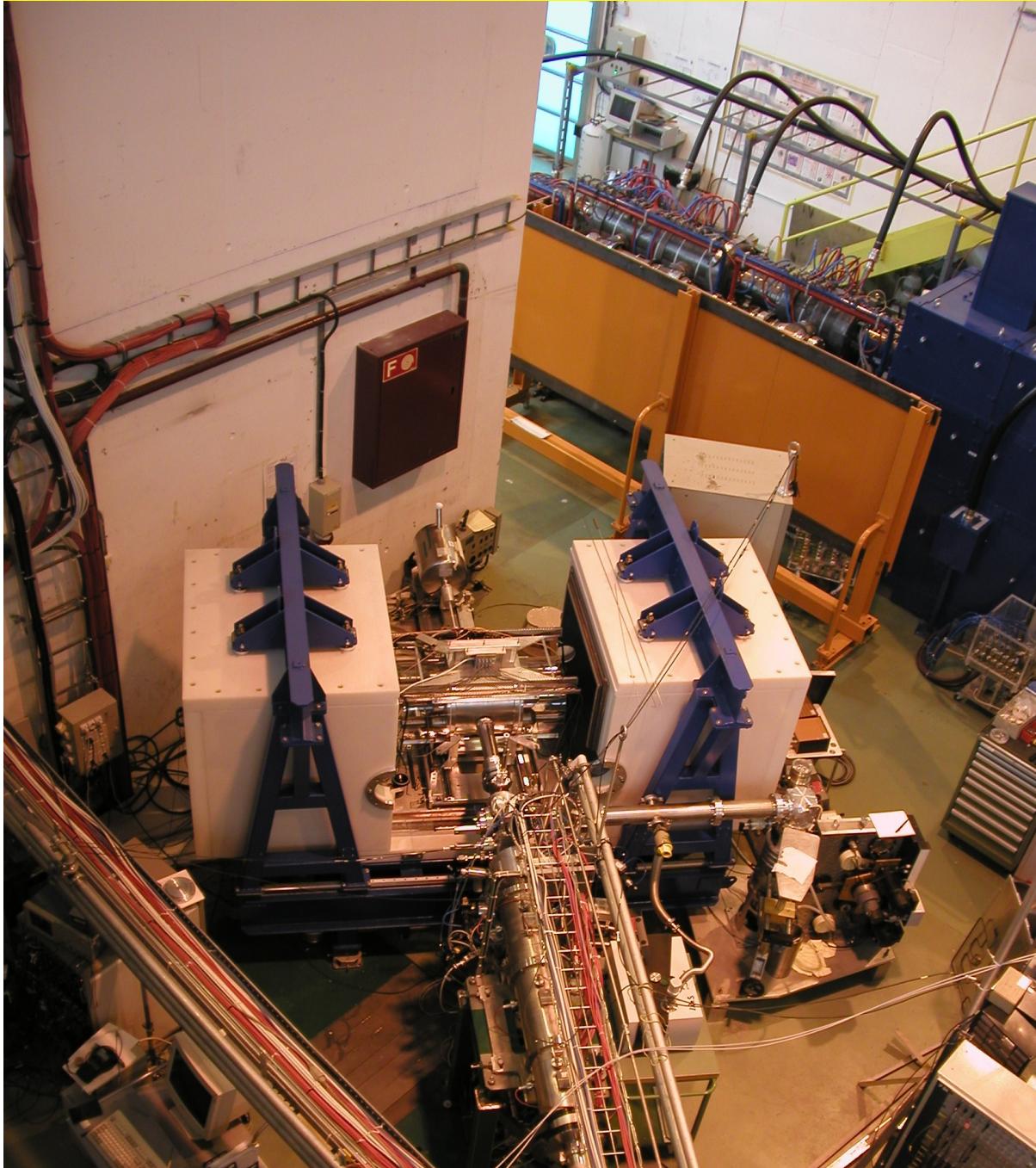
What can beta decay offer apart from spectroscopy ...

One alternative, based in the pioneering work of I. Hamamoto, (Z. Phys. A353 (1995) 145) later followed by studies of P. Sarriuguren *et al.*, Petrovici *et al.* is related to the dependency of the strength distribution in the daughter nucleus depending on the shape of the parent. It can be used when theoretical calculations predict different $B(GT)$ distributions for the possible shapes of the ground state (prolate, spherical, oblate).

P. Sarriuguren *et al.*, Nuc. Phys. A635 (1999) 13



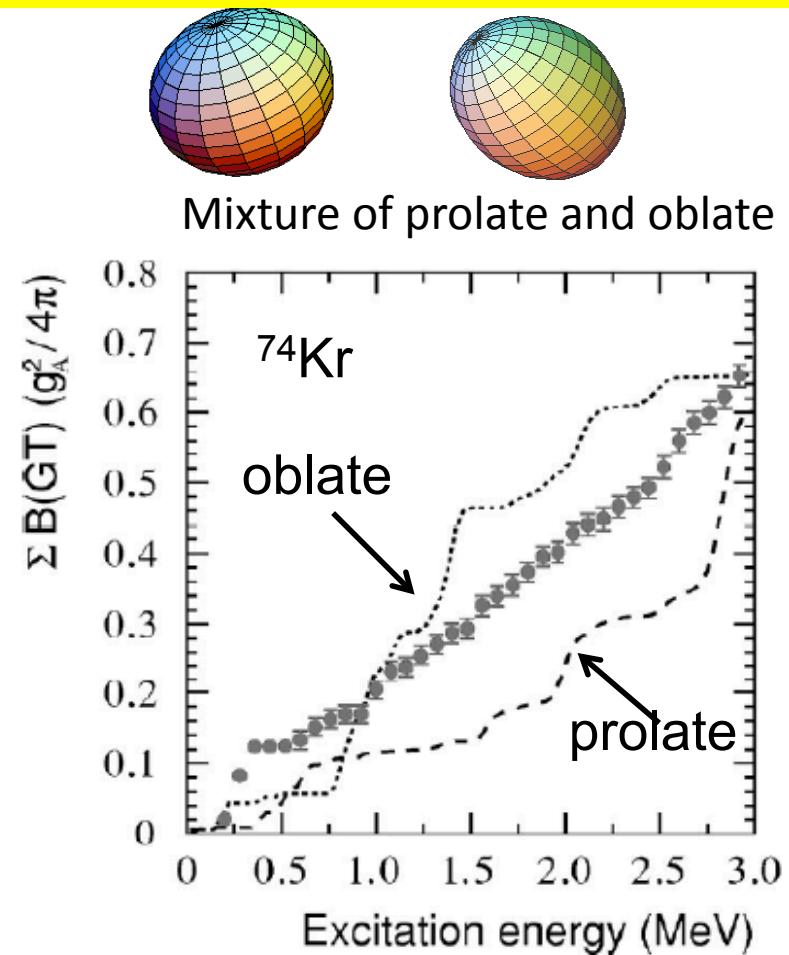
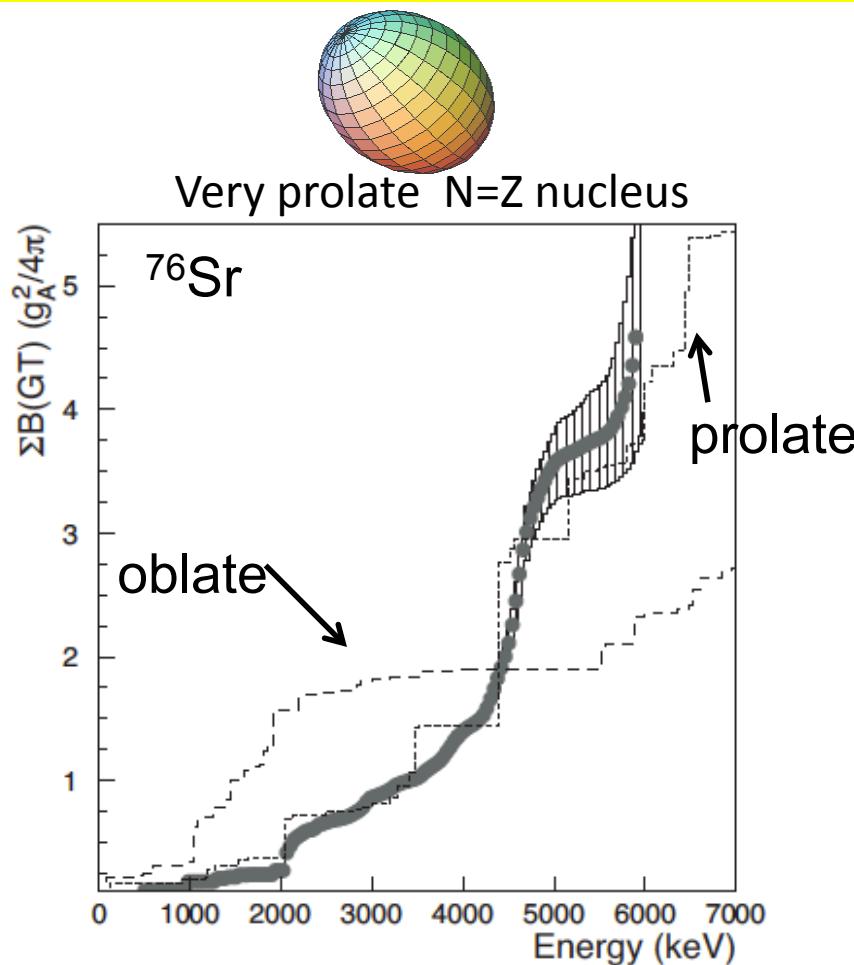
Lucrecia: the TAS at ISOLDE (CERN) (Madrid-Strasbourg-Surrey-Valencia)



- A large NaI cylindrical crystal 38 cm Ø, 38cm length
- An X-ray detector (Ge)
- A β -detector
- Possibility of collection point inside the crystal for short half-lives

Some earlier examples

(proposals of B. Rubio, W. Gelletly, P. Dessagne et al.)



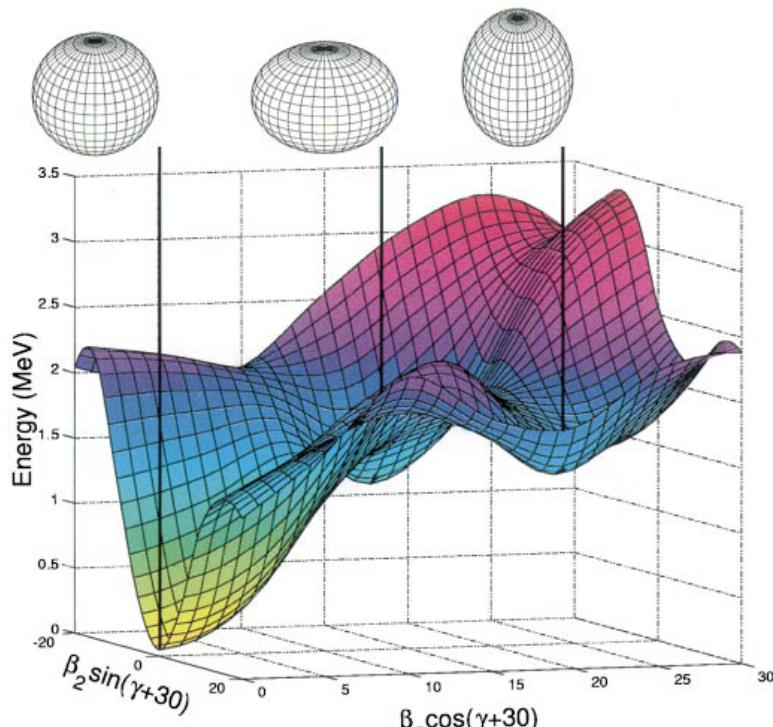
E. Nácher et al. *PRL* 92 (2004) 232501 and
PhD thesis Valencia
 Ground state of ^{76}Sr prolate ($\beta_2 \sim 0.4$) as
 indicated in Lister et al., *PRC* 42 (1990)
 R1191

E. Poirier et al., *Phys. Rev. C* 69, 034307
 (2004) and *PhD thesis Strasbourg*
 Ground state of ^{74}Kr : (60±8)% oblate, in
 agreement with other exp results and with
 theoretical calculations (A. Petrovici et al.)

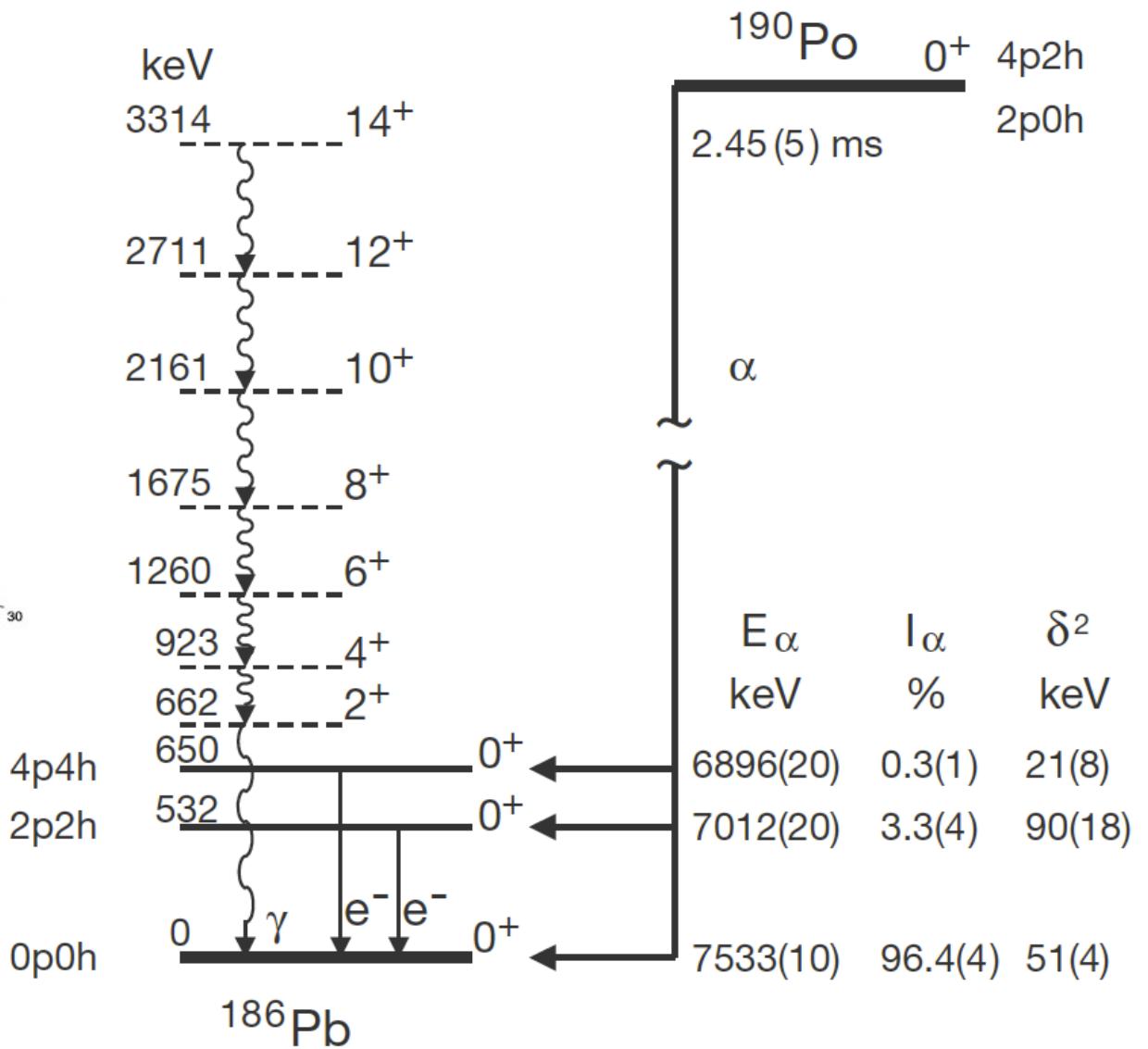
Possible questions

- is the method only valid for $A \sim 80$?
- was the excellent agreement accidental ?
- because the method can be useful for exotic nuclei in case you have no other means
- So it is worth explore heavier/different domains ...

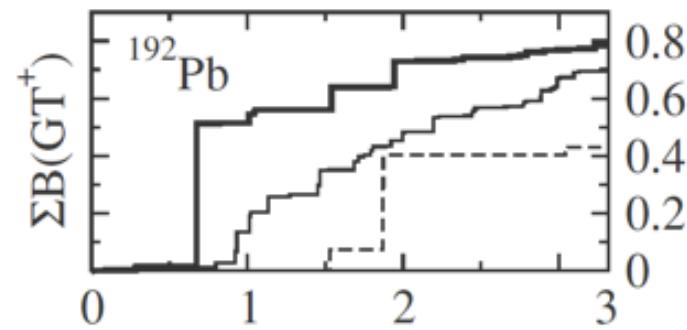
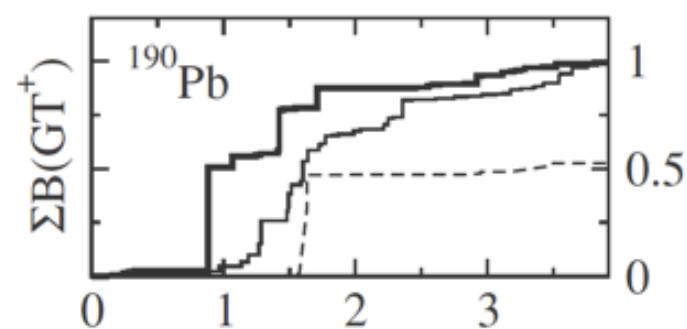
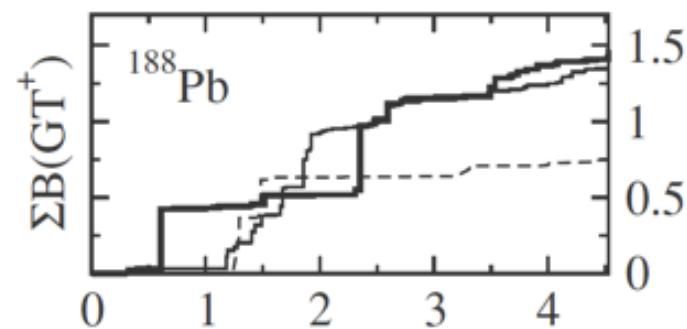
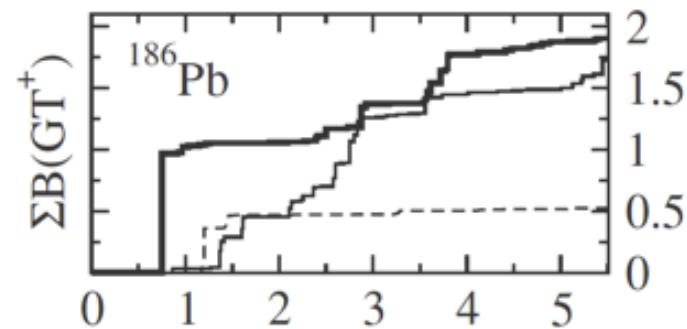
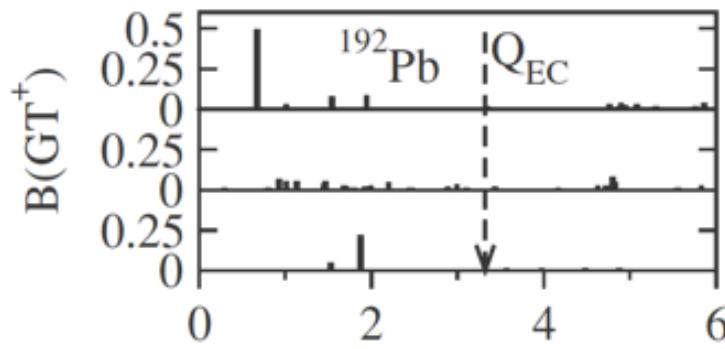
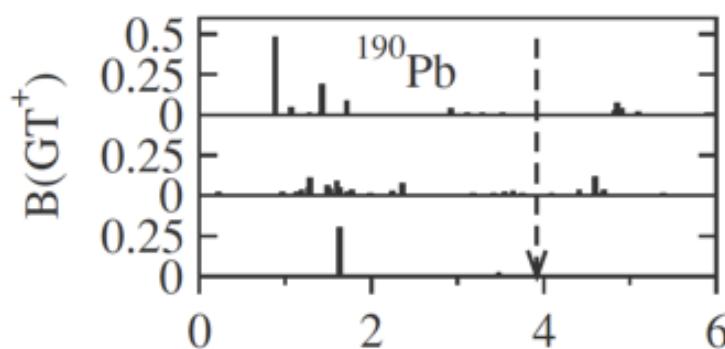
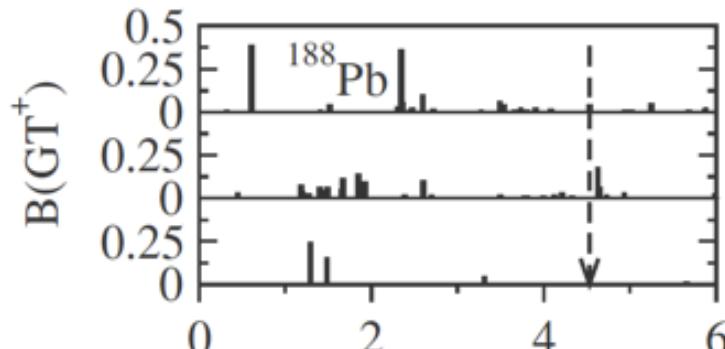
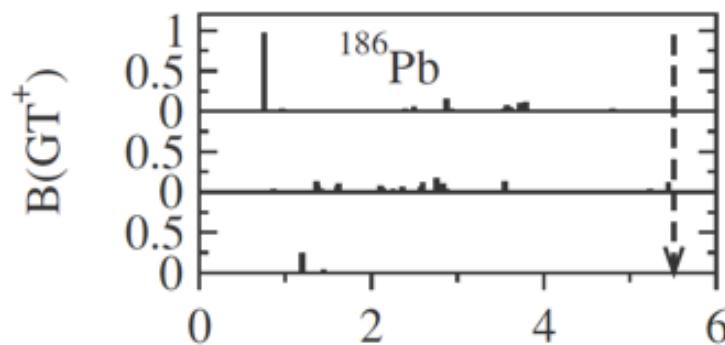
Intruder 0+ states in ^{186}Pb



A. N. Andreyev *et al.*
Nature 405 (2000) 430

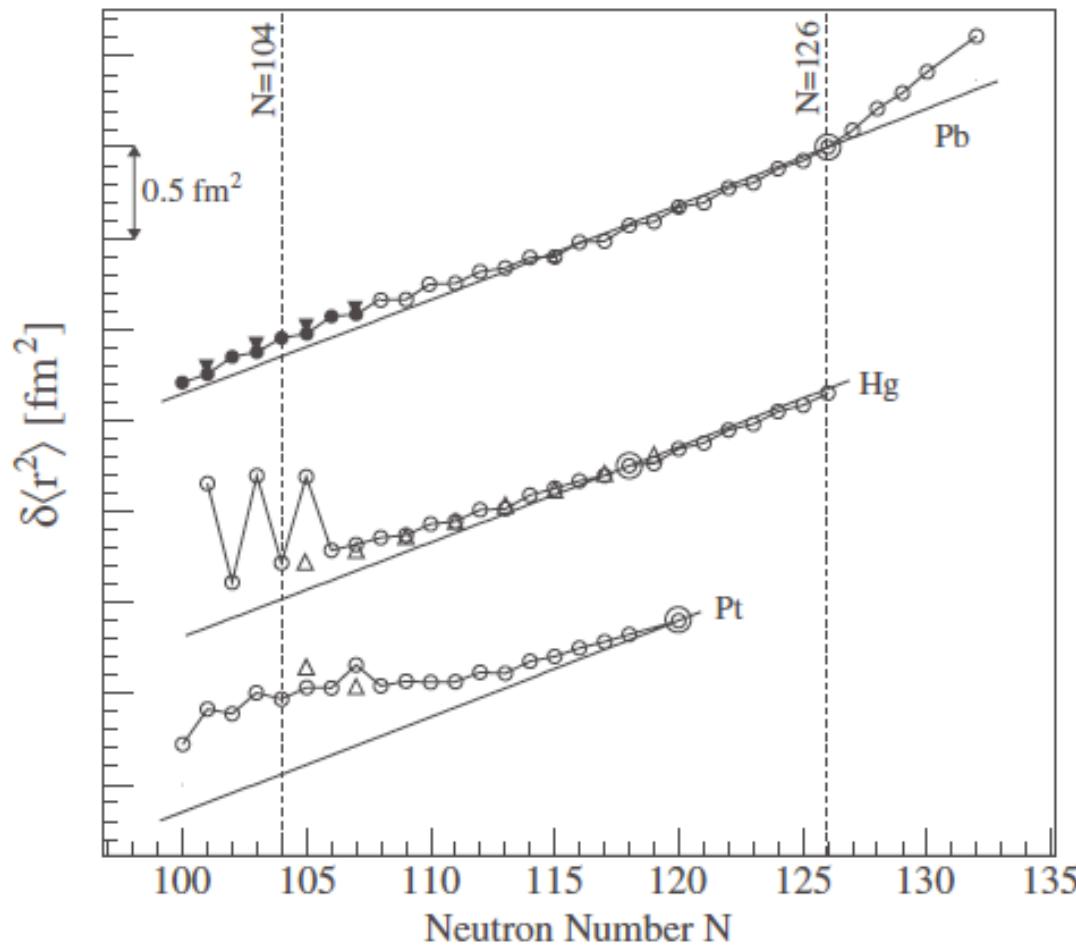


The B(GT)⁺ profiles

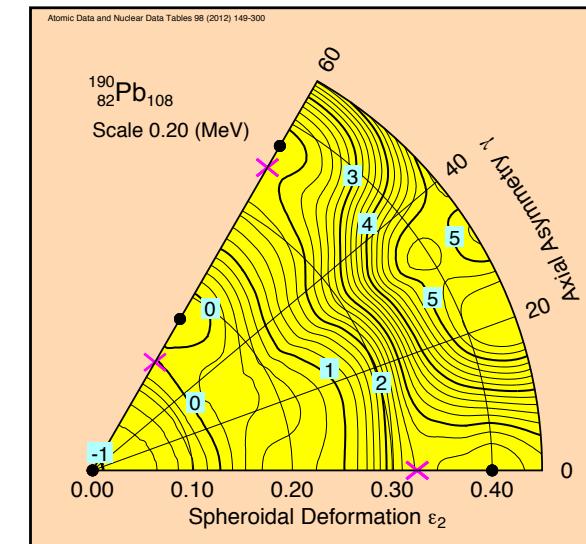
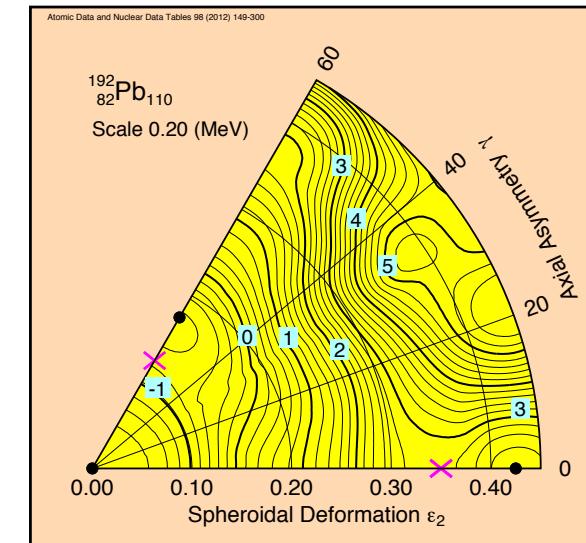


— spherical
— oblate
— prolate

Are the Pb-s spherical in their ground states ?



De Witte PRL 98, also T. Cocolios et al. PRL 106, 052503 (compared with drop model)



P. Möller et al. Atomic Data and Nuclear Data Tables **98 (2012) 149**

Mixing prediction

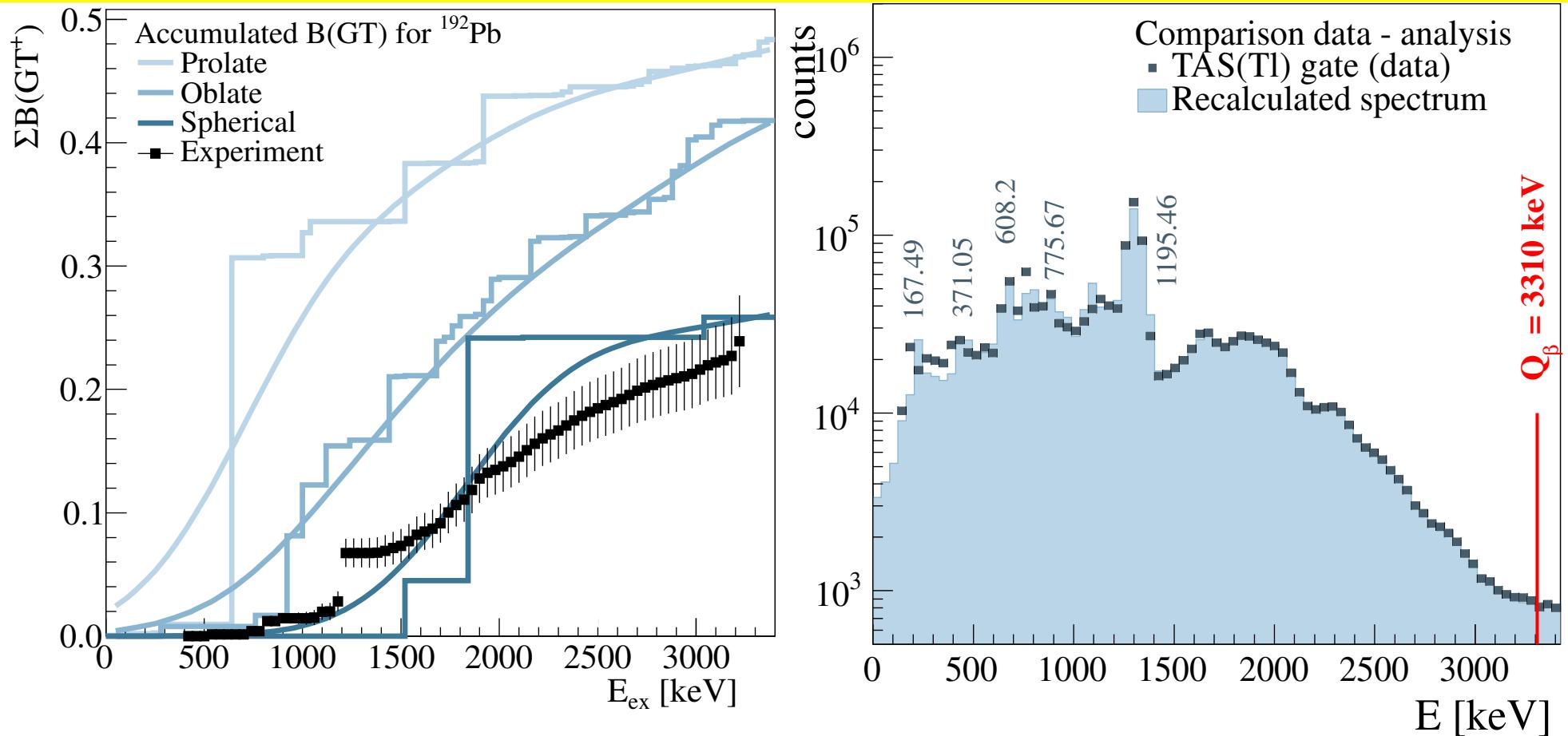
Fossion *et al.* PRC 73 (2006) 054317, within IBM

TABLE II. Magnitudes (in percentages, %) of the three different configurations (reg, 2p-2h, 4p-4h) in the first three 0_i^+ states of the Pb isotopes $186 \leq A \leq 196$, in the IBM calculation of Fig. 4 (left panel).

0_i^+	Configurations	$^{186}_{\text{82}}\text{Pb}_{104}$	$^{188}_{\text{82}}\text{Pb}_{106}$	$^{190}_{\text{82}}\text{Pb}_{108}$	$^{192}_{\text{82}}\text{Pb}_{110}$	$^{194}_{\text{82}}\text{Pb}_{112}$	$^{196}_{\text{82}}\text{Pb}_{114}$
0_1^+	reg	75	93	96	98	99	99
	2p-2h	18	7	4	2	1	1
	4p-4h	7	1	0	0	0	0
0_2^+	reg	20	6	4	2	2	1
	2p-2h	27	67	82	89	92	95
	4p-4h	52	27	14	9	6	4
0_3^+	reg	4	1	1	-	-	-
	2p-2h	51	28	43	-	-	-
	4p-4h	45	71	57	-	-	-

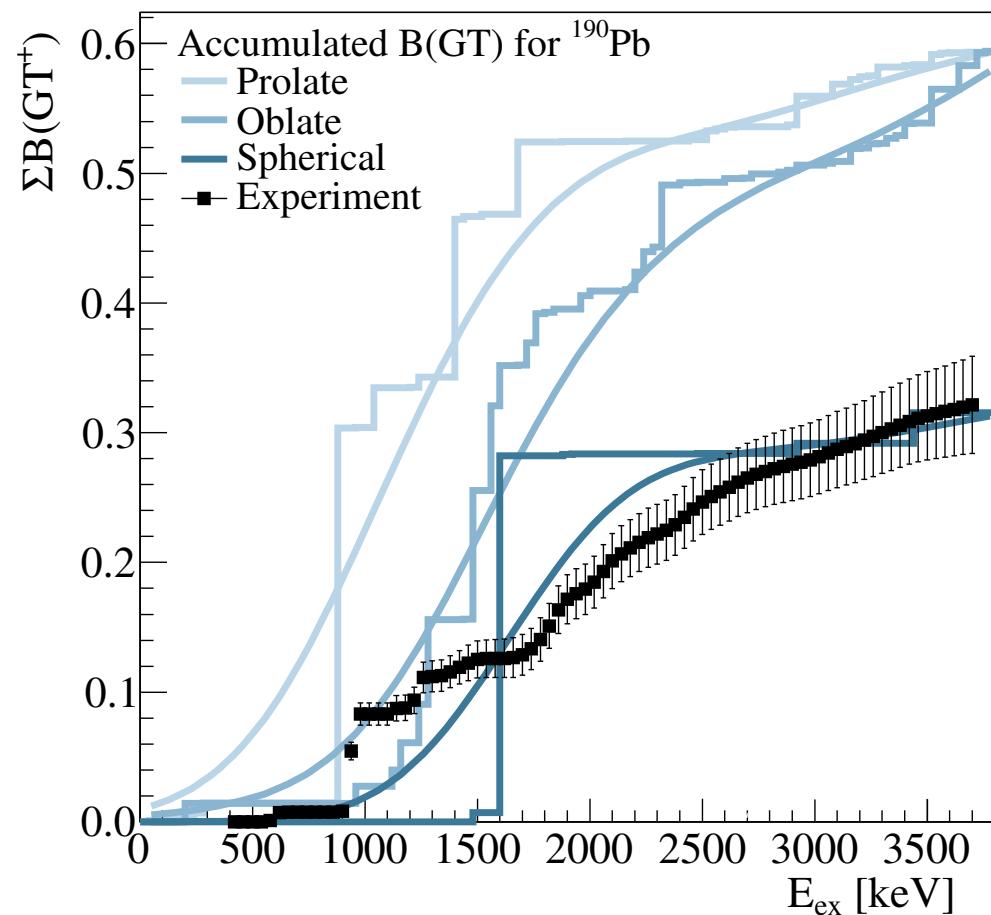
IS440 results: ^{192}Pb example

Spokespersons: Algora, Rubio, Gelletly



Thesis work of M. E. Estevez 2012, and
 M. E. Estevez *et al.* submitted to PLB. Theory from PRC 73 (2006) 054317
 Results consistent with spherical picture
Ideal cases $^{192,190}\text{Pb}$ because of the low degree of mixing

IS440 results: ^{190}Pb example



Thesis work of M. E. Estevez 2012, and M. E. Estevez *et al.* submitted to PLB
Theory from PRC 73 (2006) 054317
Results again consistent with spherical picture. Similar result also for ^{188}Pb
Still to be done the ^{186}Pb decay study !!!

Shape effects in the vicinity of the Z=82 line: study of the beta decay of $^{182,184,186}\text{Hg}$

The alchemist experiment: we were doing Au from Pb
(the target was molten lead)

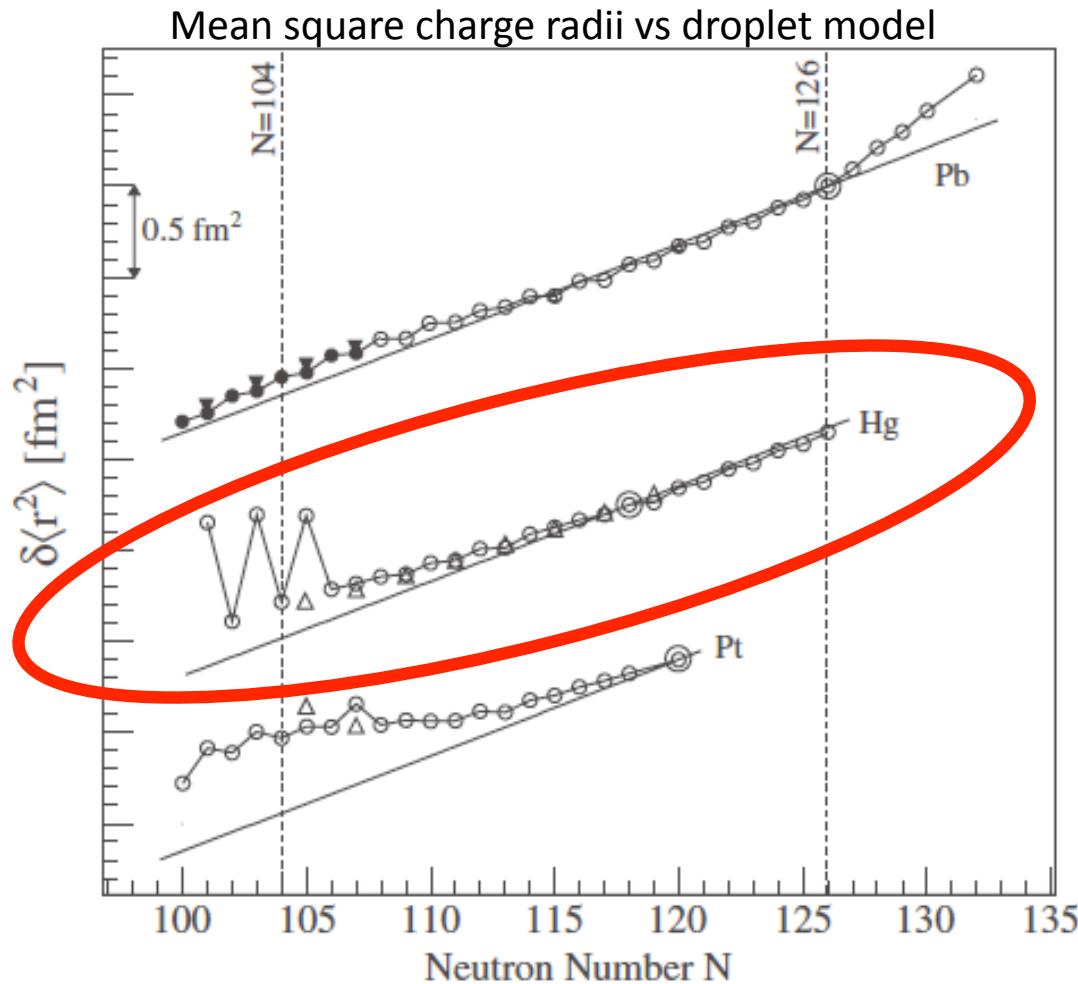


A. Algora, B. Rubio, J. L. Taín, M. E. Estevez, J. Agramunt, E. Valencia, C. Domingo, S. Origo, V. Guadilla, A. Montaner, A. Krasznahorkay, M. Csatlos, Zs. Dombrádi, D. Sohler, J. Timár, W. Gelletly, P. Walker, P. Regan, Z. Podolyák, S. Rice, P. Sarriguren, M. J. G. Borge, O. Tengblad, E. Nácher, A. Jungclaus, J. A. Briz, A. Perea, V. Pesudo, L. M. Fraile, O. Moreno, B. Olaizola, V. Paziy, J. M. Udias, V. Vedia, J. Cal, V. Fedosseev, B. A. Marsh, C. Guerrero, M. Kowalska, D. Fedorov, A. N. Andreyev, A. Frank, B. Akkus, Y. Oktem, E. Ganioglu, L. Susam, L. Kucuk, R. Burcu Cakirli

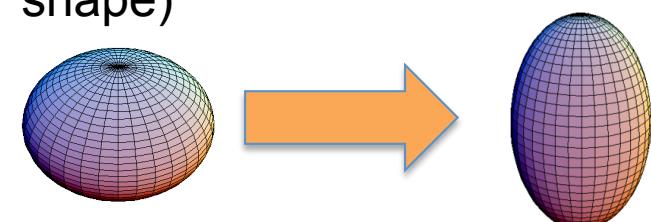
ISOLDE Experimental Proposal
CERN-INTC-2012-012, INTC-P-328
Spokespersons: A. Algora, L. M. Fraile, E. Nácher
ISOLDE contact: M. Kowalska
Experiment ID: IS539



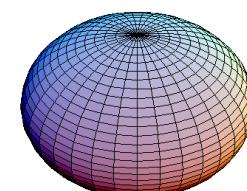
Why are the ^{80}Hg -s interesting?



Drastic shape change between the odd-mass $^{185,187}\text{Hg}$ (interpreted as a transition from **oblate** to a more deformed **prolate** shape)



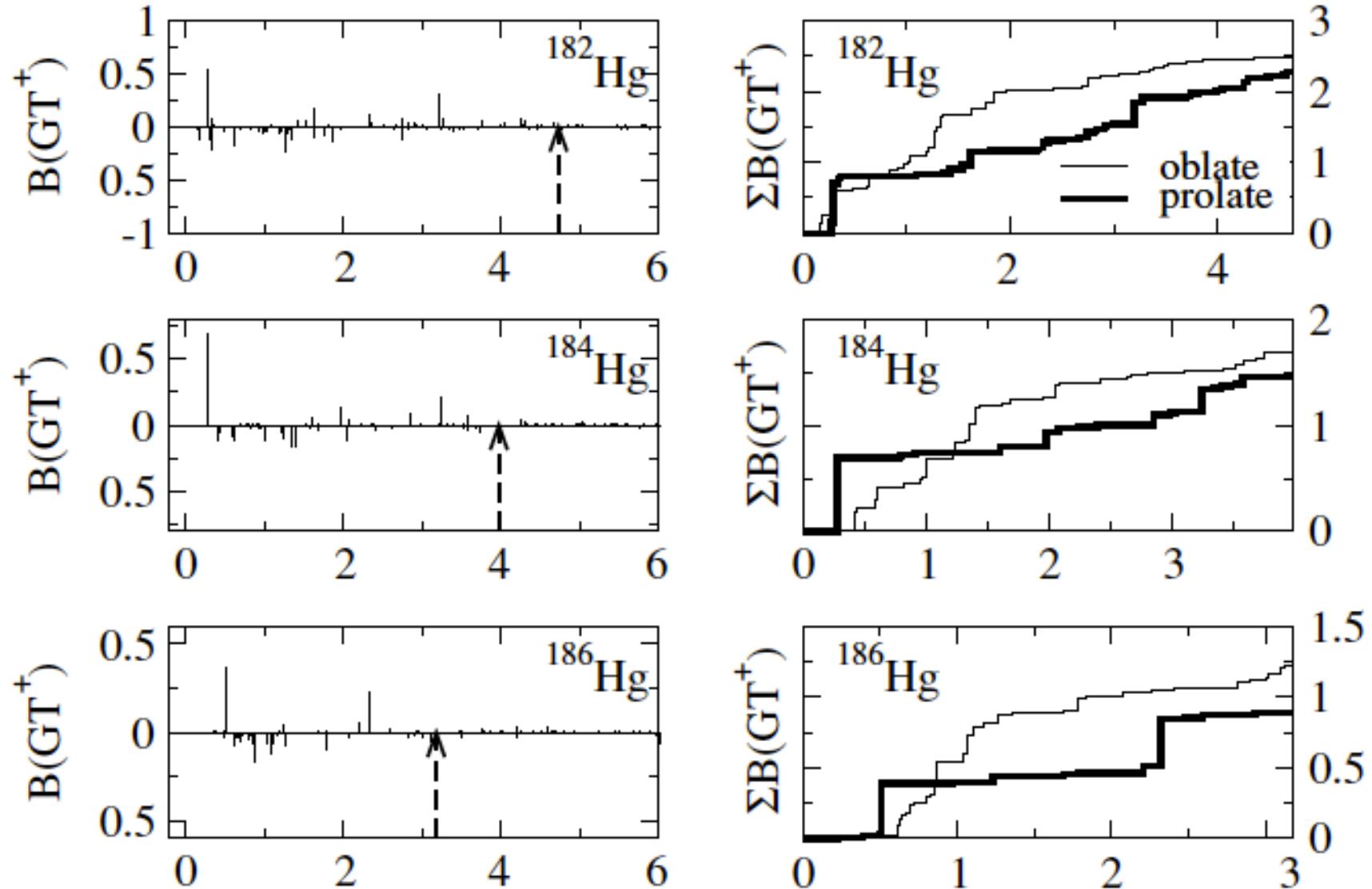
The even-mass nuclei are assumed to be **oblate** nuclei. Which are not so common in general !!



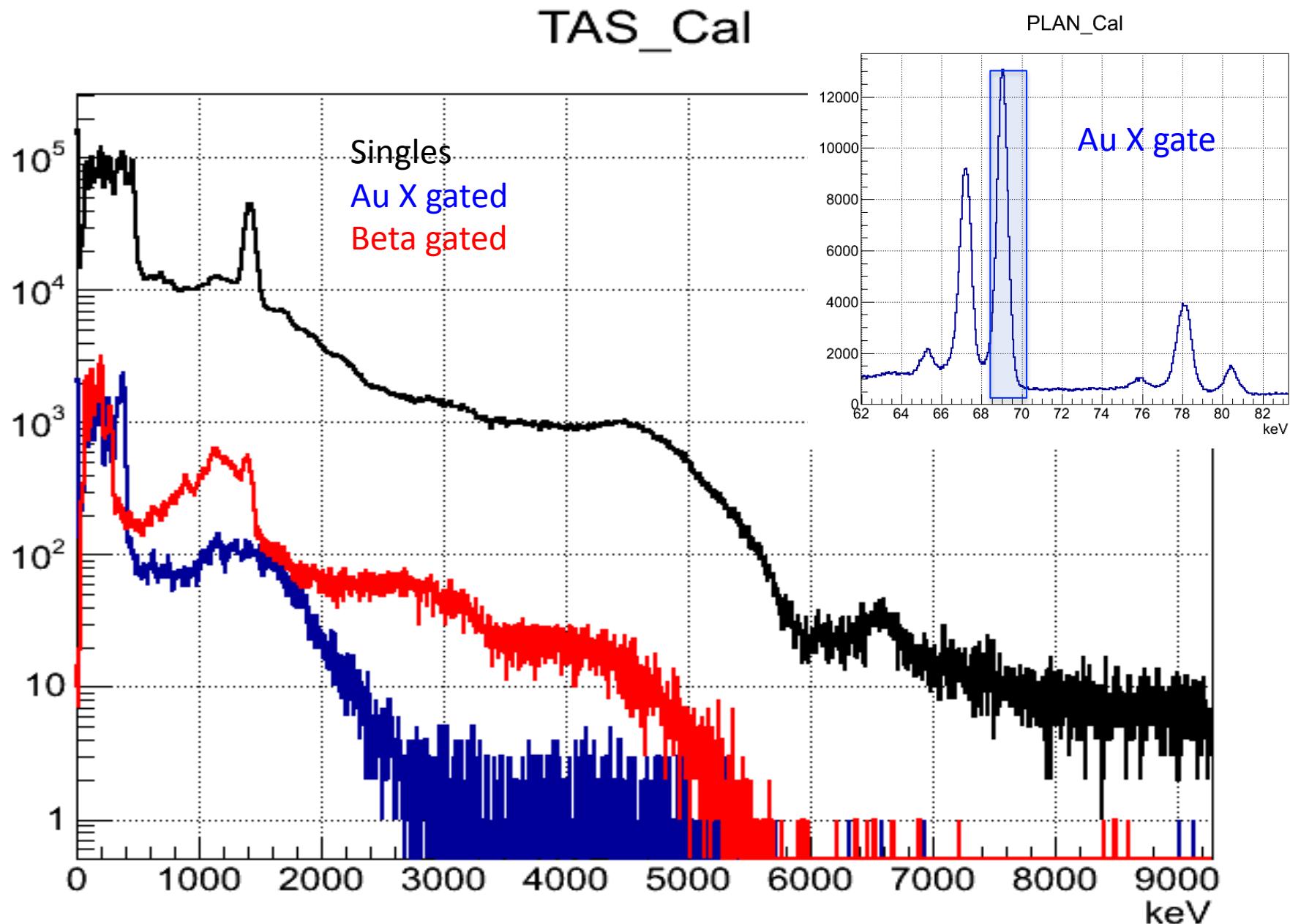
Ulm, Z.Phys. A325 (1986) 247 and De Witte PRL 98,
Also T. Cocolios et al. PRL 106, 052503

The $B(GT^+)$ profiles for the decay of the nuclei of interest

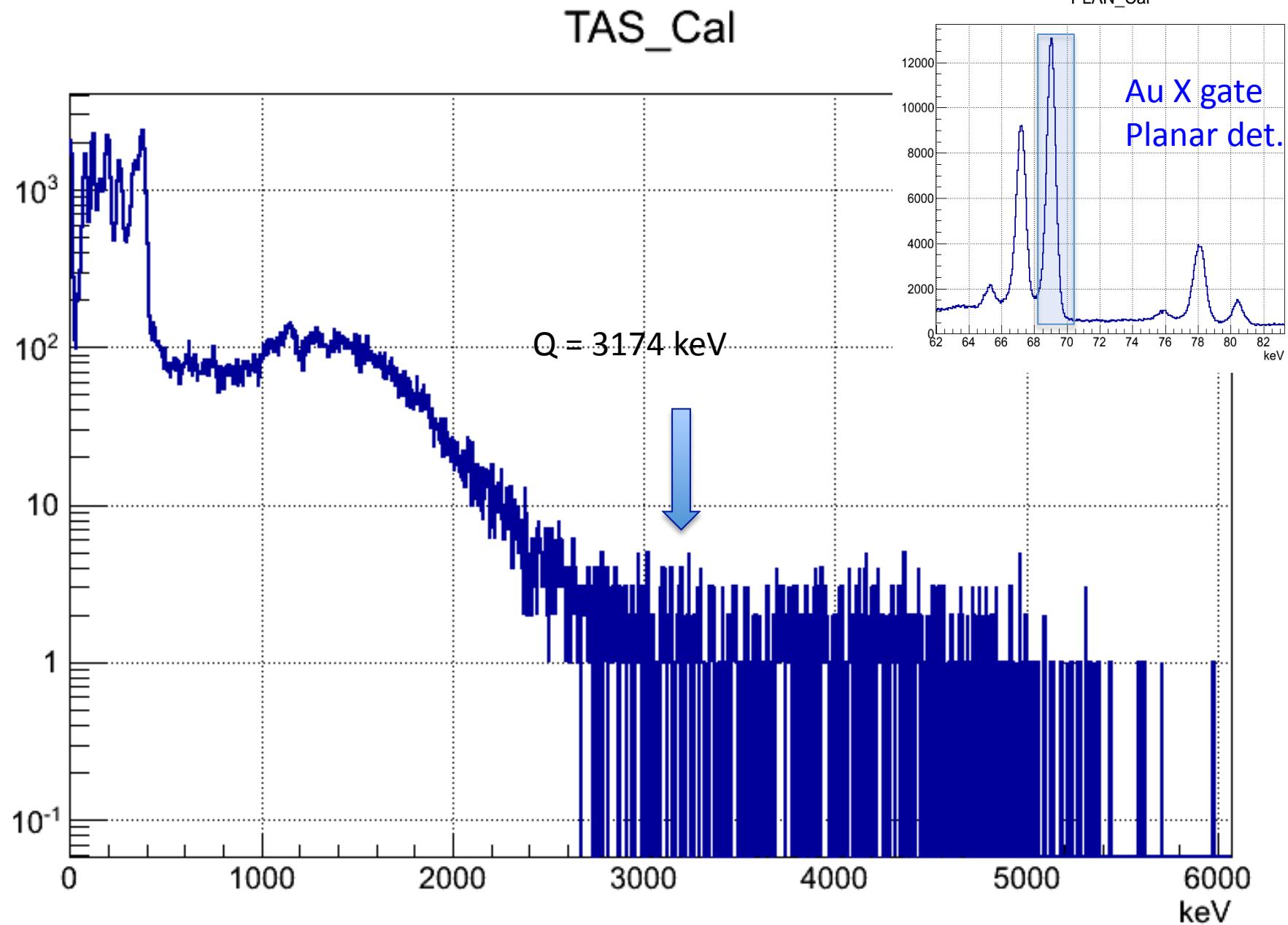
O. Moreno, P. Sarriuguren *et al.* PRC 73 (2006) 054317

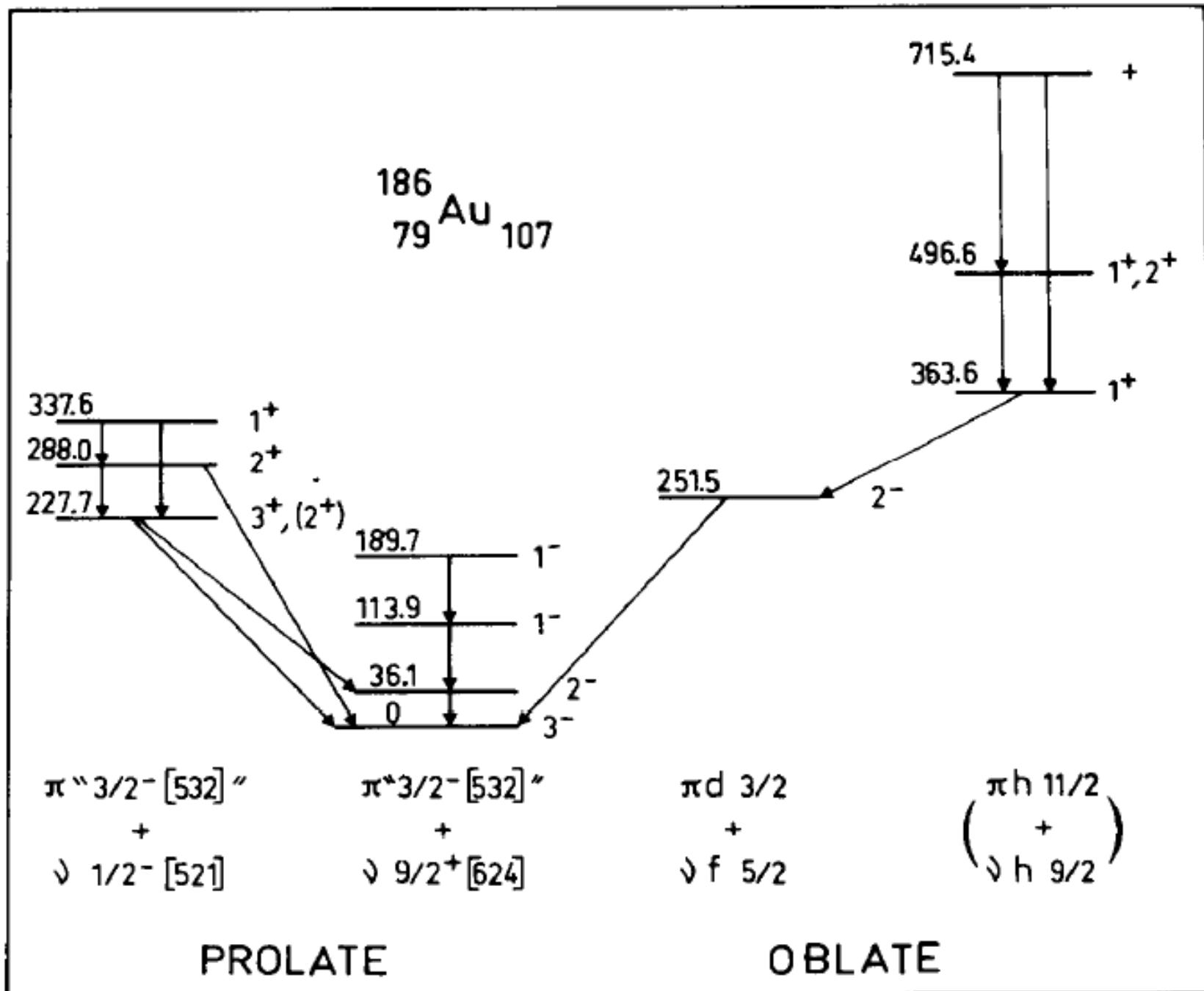


On-line spectra from the $^{186}\text{Hg} \rightarrow ^{186}\text{Au}$ decay



On-line spectra from the $^{186}\text{Hg} \rightarrow ^{186}\text{Au}$ decay: EC component only



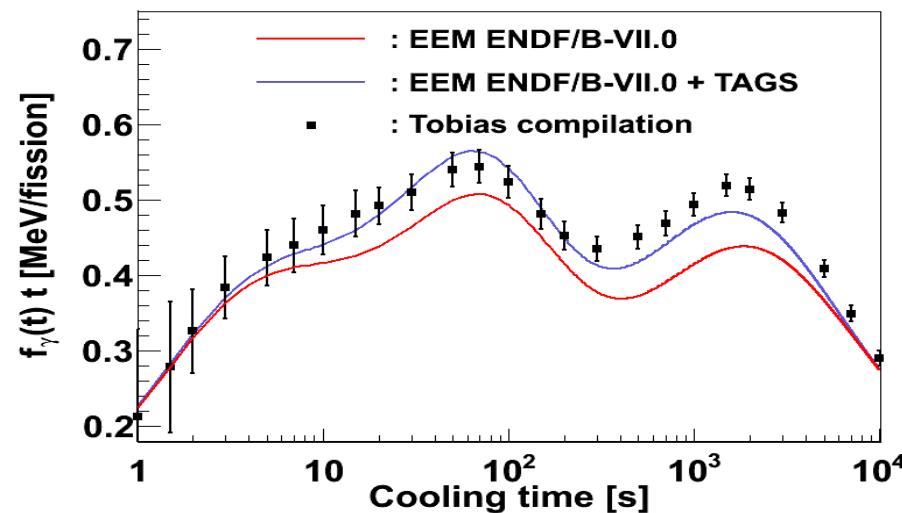


Collateral effects: recent neutron rich nuclei results



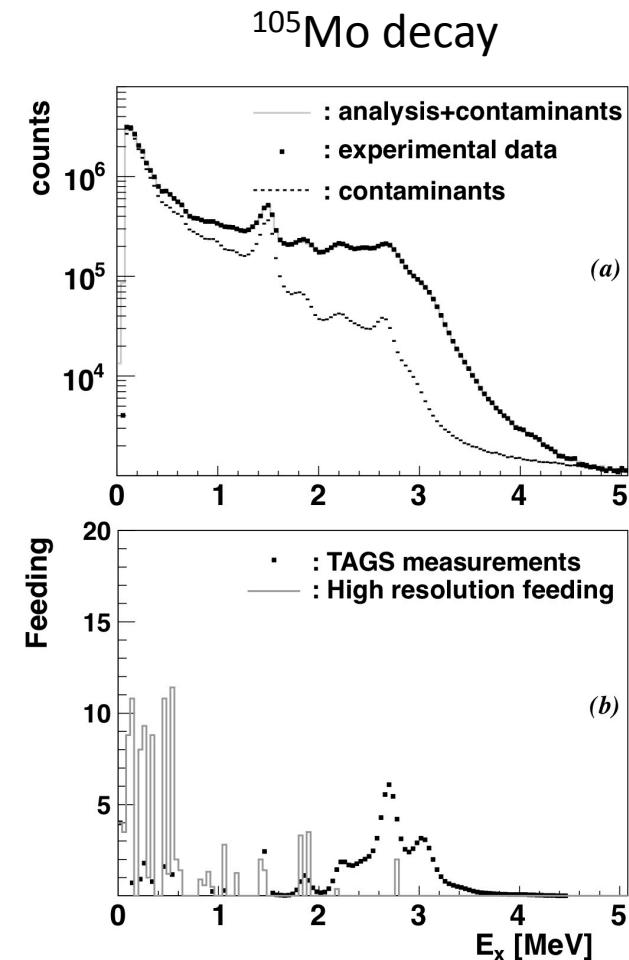
Impacts of the I116 experiment

β -decay of $^{102,104,105,106,107}\text{Tc}$, ^{101}Nb and ^{105}Mo using the TAGS technique



Dolores Jordan, PhD thesis, Univ. Valencia
D. Jordan, PRC 87, 044318
Algora et al., PRL 105, 202501, 2010

Also important in reactor neutrino calculations, see
Fallot et al. Phys. Rev. Letts. 109, 202504 (2012)



Collateral effect: testing nuclear models

- β -decay of $^{102,104,105,106,107}\text{Tc}$, ^{101}Nb and ^{105}Mo using the TAGS technique
- Region dominated by shape effects and shape coexistence
- Strength distribution of beta decays can provide stringent tests of nuclear models
- Relevant for astrophysical applications, we can test models used for global astrophysical predictions

- The FRDM-QRPA Model
- Gross theory of beta decay
- Excited Vampir

The FRDM-QRPA Model

- FRDM-QRPA model used for astrophysical predictions (**P. Möller et al.**, *Nucl.Phys. A 417 (1984) 419; Nucl. Phys. A 514 (1990) 1; Phys. Rev. C 67 (2003) 055802*)
- Allows the description of deformed nuclei
- Assumes axial symmetry in the calculations and same deformation for parent and daughter nucleus
- Implies adding pairing and Gamow-Teller (GT) residual interactions to the folded-Yukawa single-particle Hamiltonian and solving the resulting Schrödinger equation in the QRPA
- Combines calculations within the QRPA for the Gamow-Teller part of the decay with the gross theory for the first forbidden (ff) part of the decay

Description within the FRDM-QRPA model

- For each parent nuclei, a series of QRPA calculations are performed as a function of quadrupole deformation taking as starting point reasonable deformation parameters

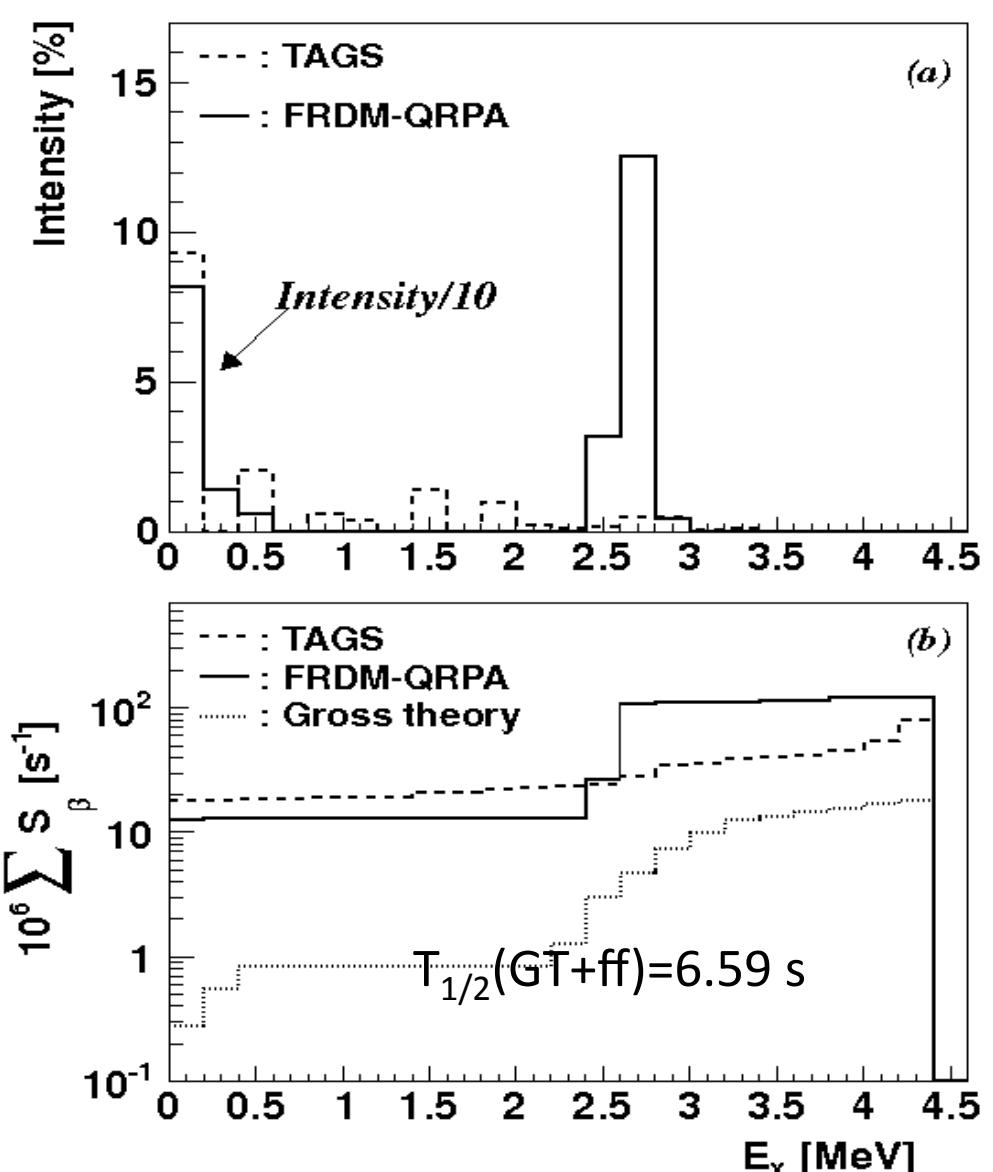
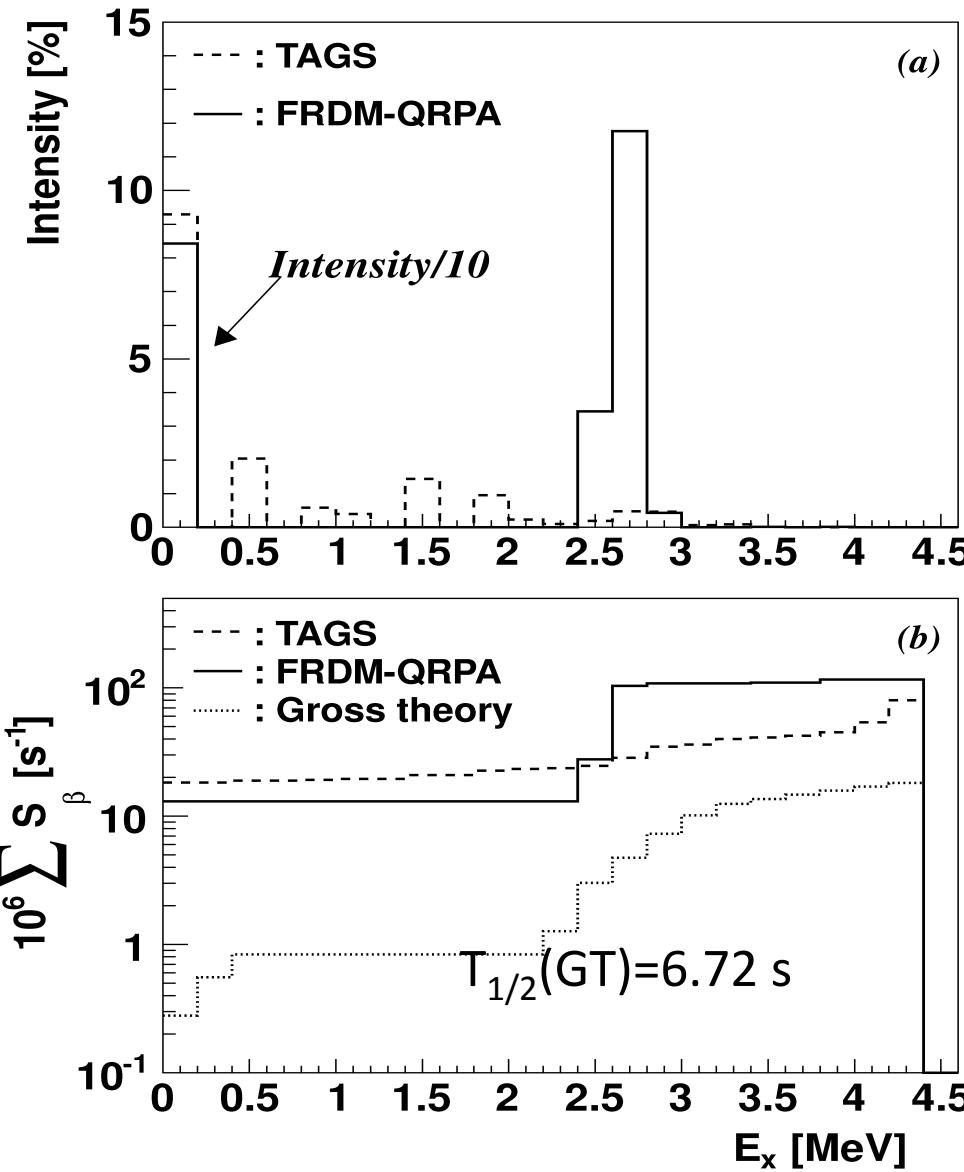
Selection criteria of the best description

1. Comparison of the experimental and the resulting theoretical $T_{1/2}$
2. Comparison of the overall β -strength distributions in the daughter with the TAS experimental data
3. Comparison of the corresponding experimental and theoretical predicted ground state spins and parities for both parent and daughter nuclei

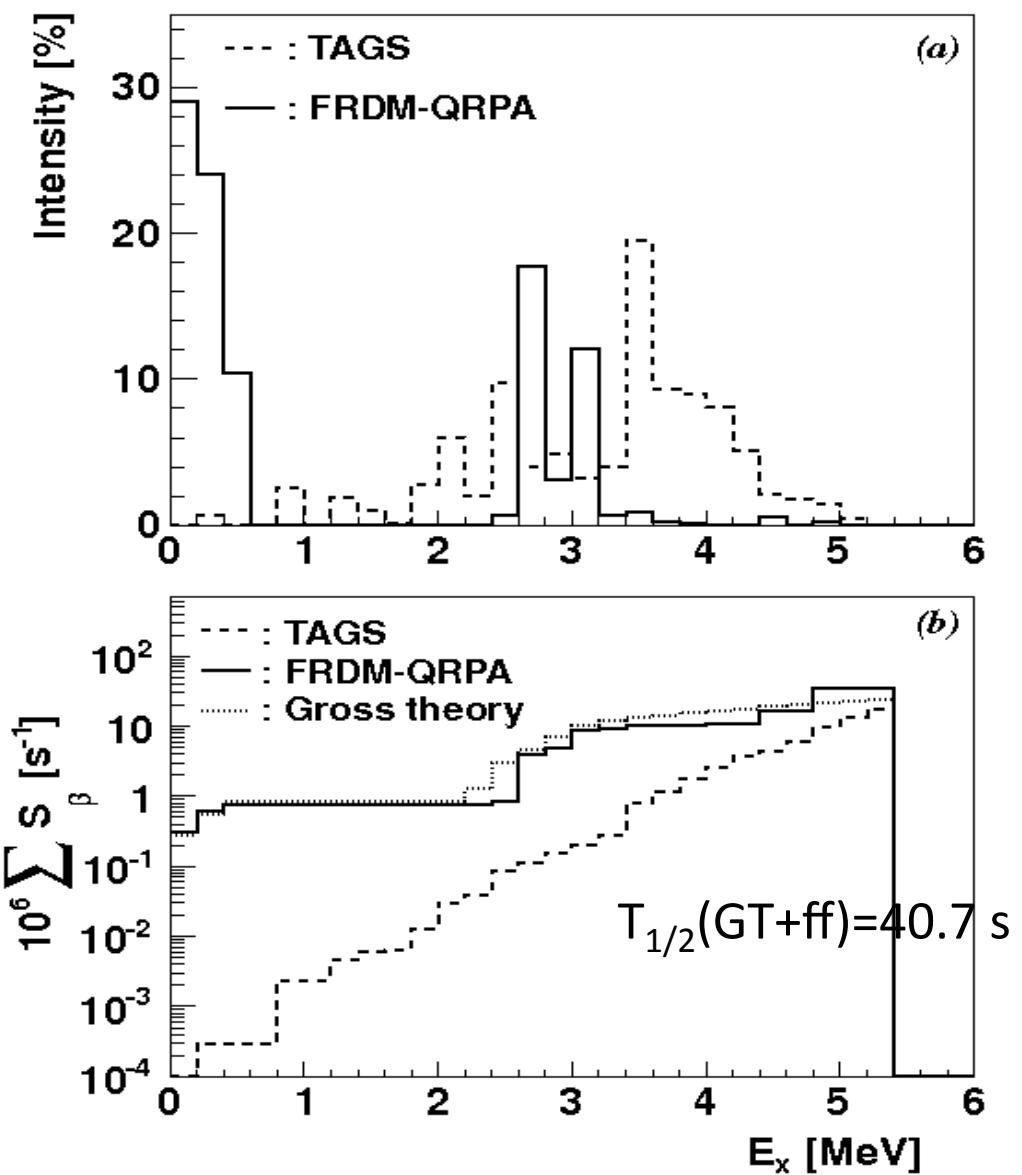
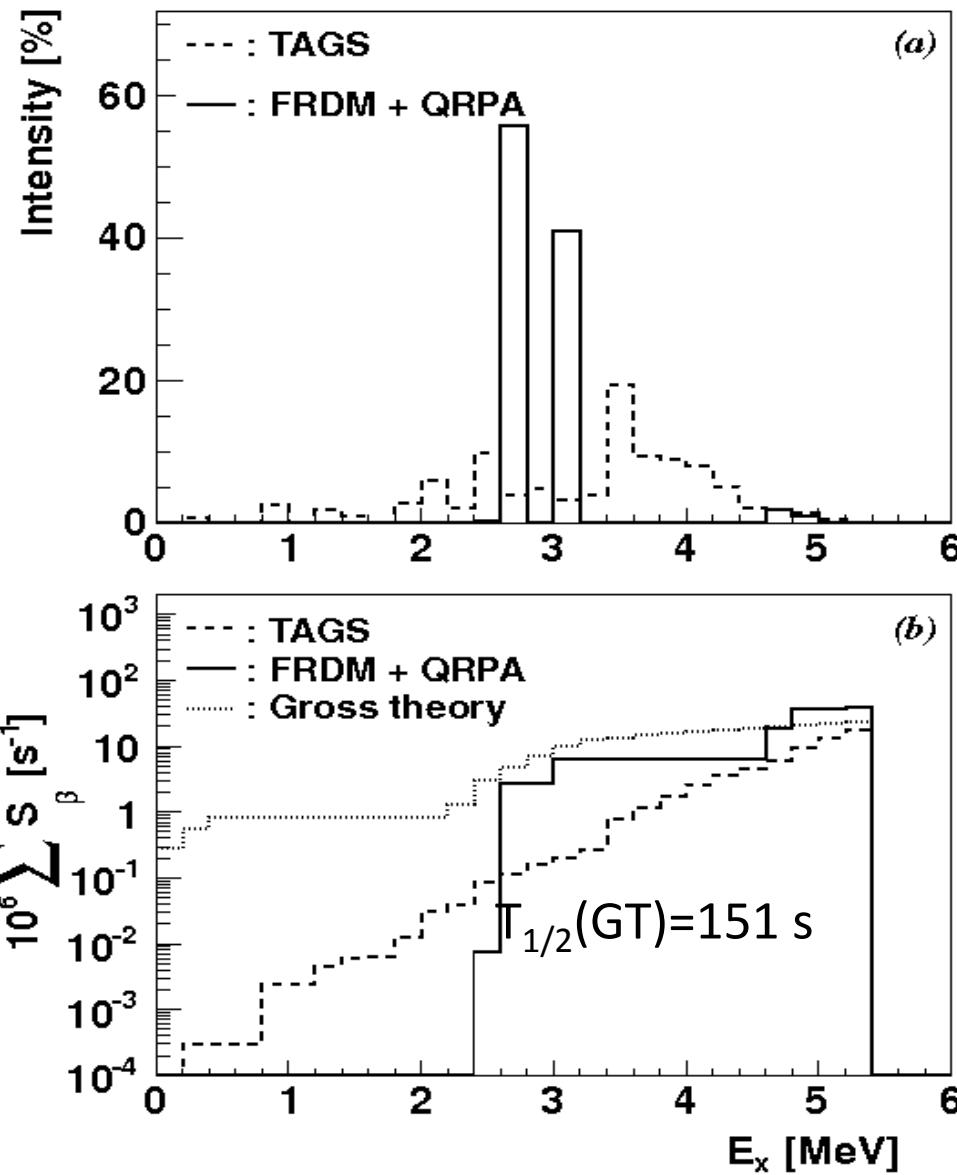
The deformation issue

Isotope	FRDM ϵ_2	HFB-14 ϵ_2	ETFSI-Q ϵ_2	QRPA ϵ_2
^{101}Nb	0.33	-0.20	0.332	0.33
^{101}Mo	0.28	-0.19	-0.258	0.33
^{105}Mo	0.33	-0.24	0.341	0.31
^{105}Tc	0.29	0.29	-0.245	0.31
^{102}Tc	0.25	0.18	-0.245	0.21
^{102}Ru	0.18	0.22	0.184	0.21
^{104}Tc	0.30	0.35	-0.245	0.30
^{104}Ru	0.23	0.25	-0.258	0.30
^{105}Tc	0.29	0.29	-0.245	0.29
^{105}Ru	0.27	0.31	-0.258	0.29
^{106}Tc	0.31	0.36	0.313	0.33
^{106}Ru	0.26	-0.20	-0.258	0.33
^{107}Tc	0.29	-0.22	-0.245	0.29
^{107}Ru	0.28	-0.22	-0.285	0.29

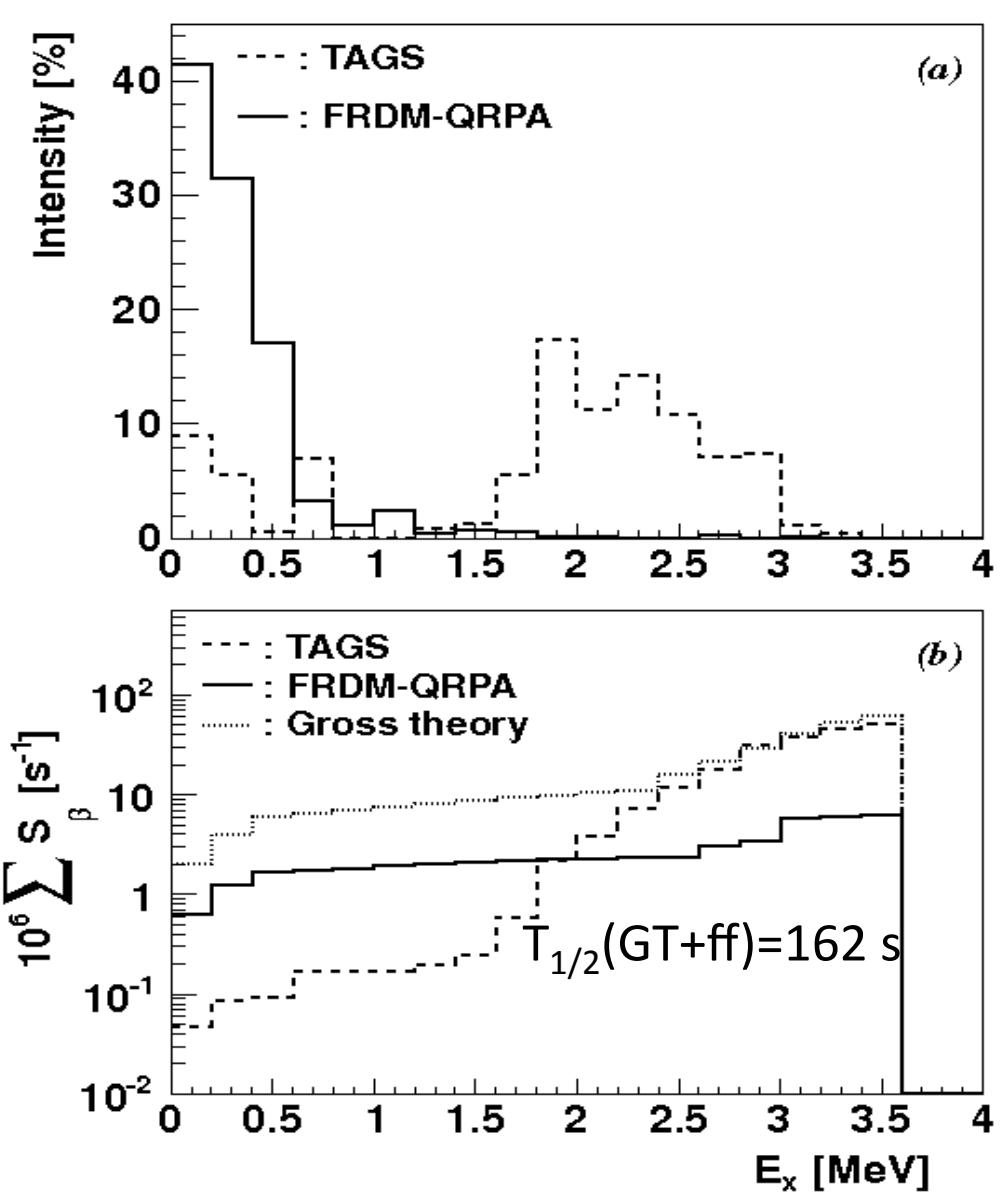
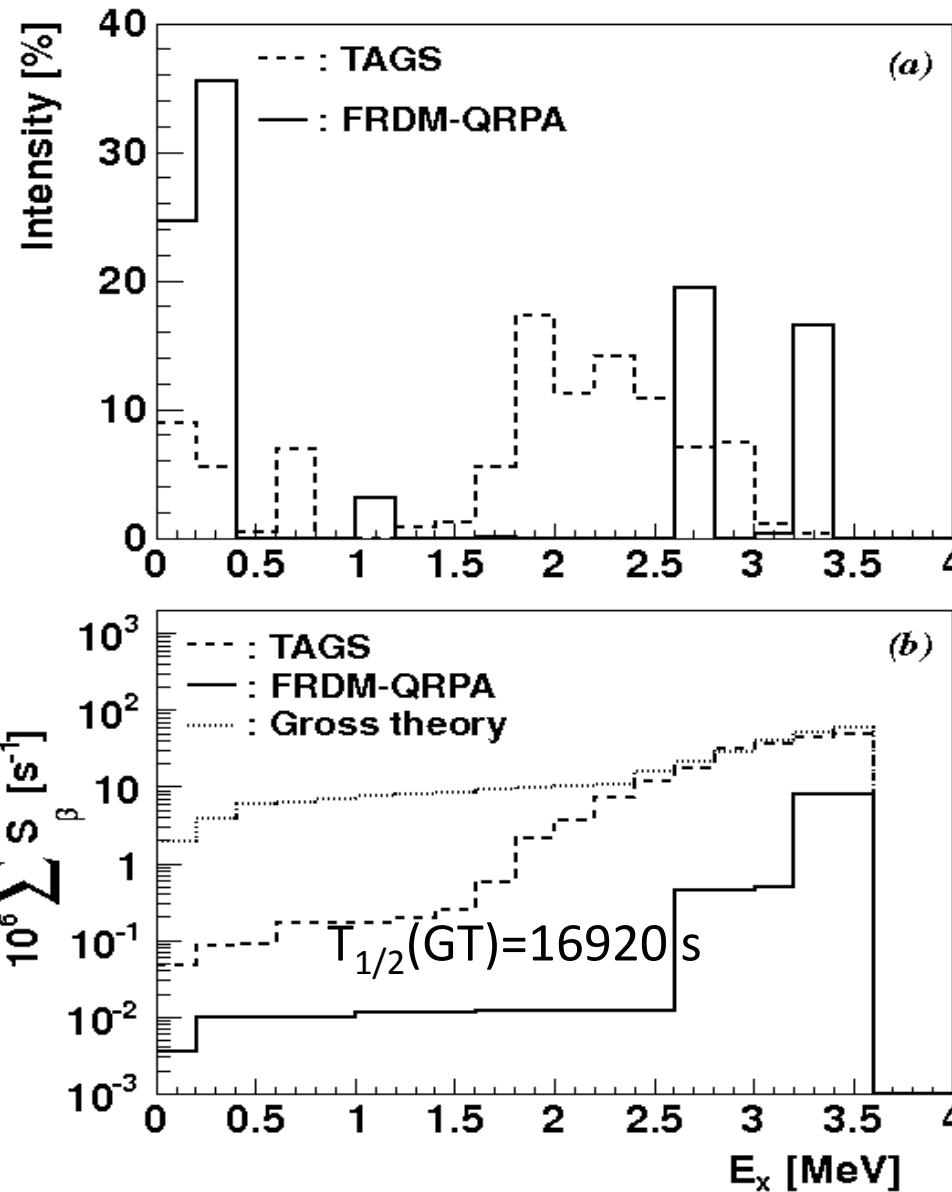
^{102}Tc decay ($\varepsilon=0.21$, $T_{1/2}(\text{exp})=5.3$ s)



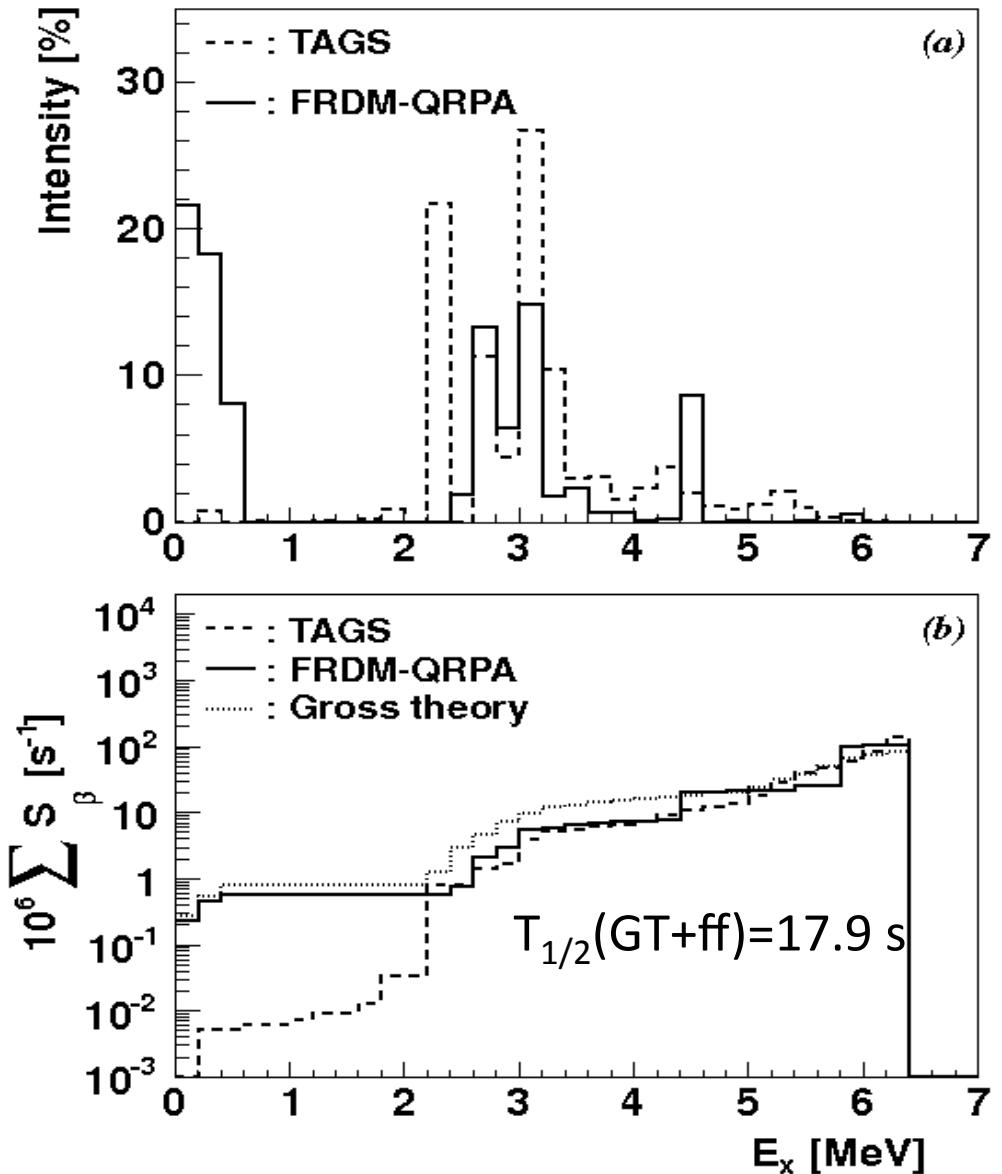
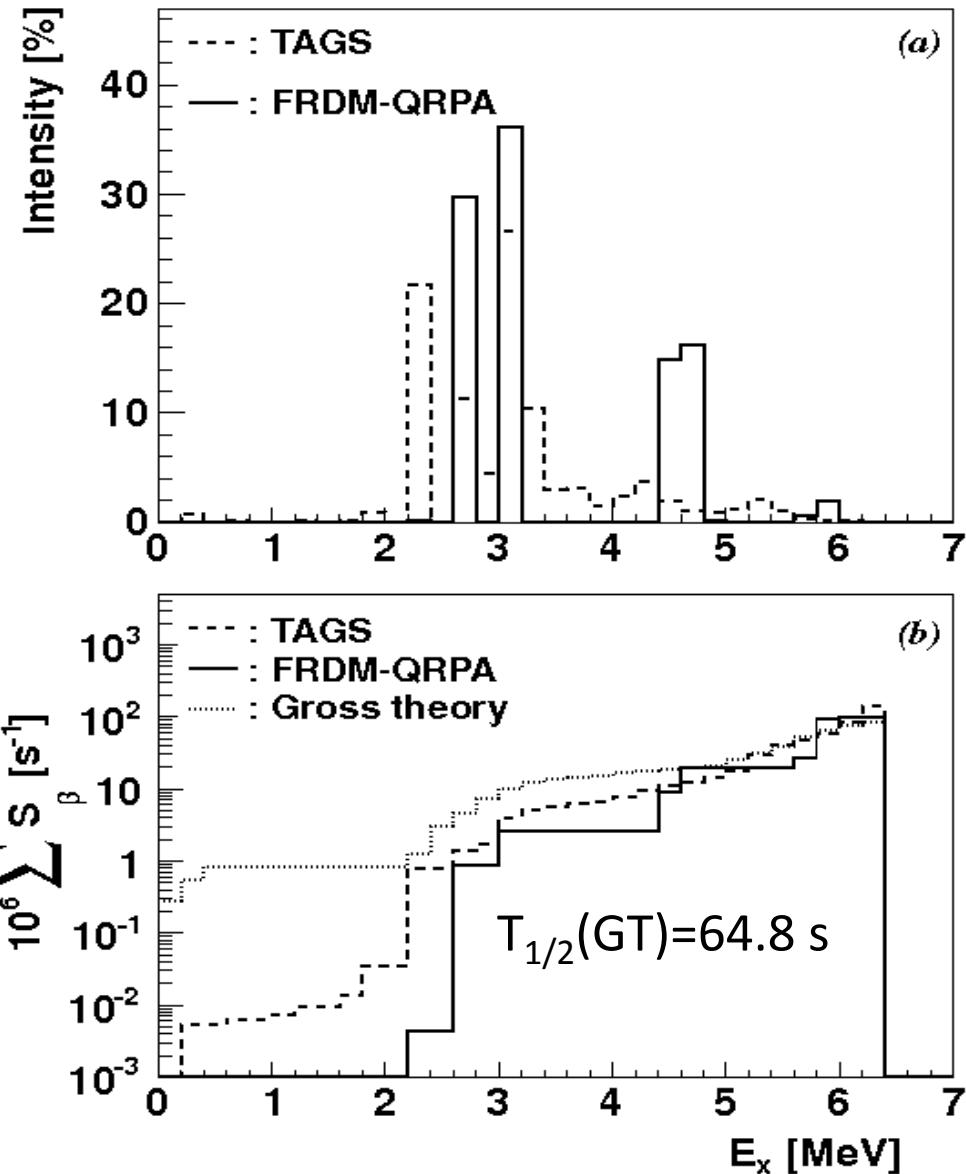
^{104}Tc decay ($\varepsilon=0.30$, $T_{1/2}(\text{exp})=1098$ s)



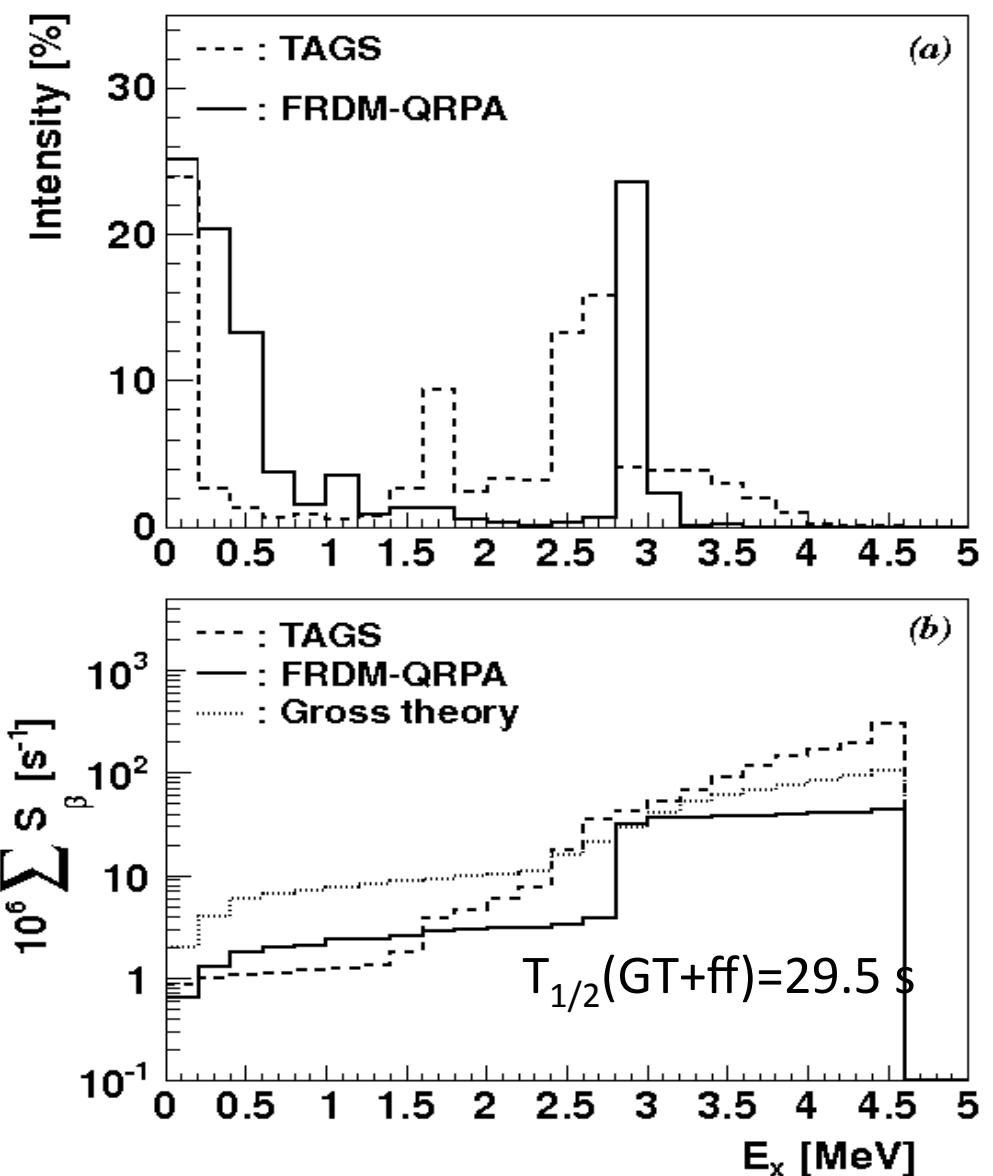
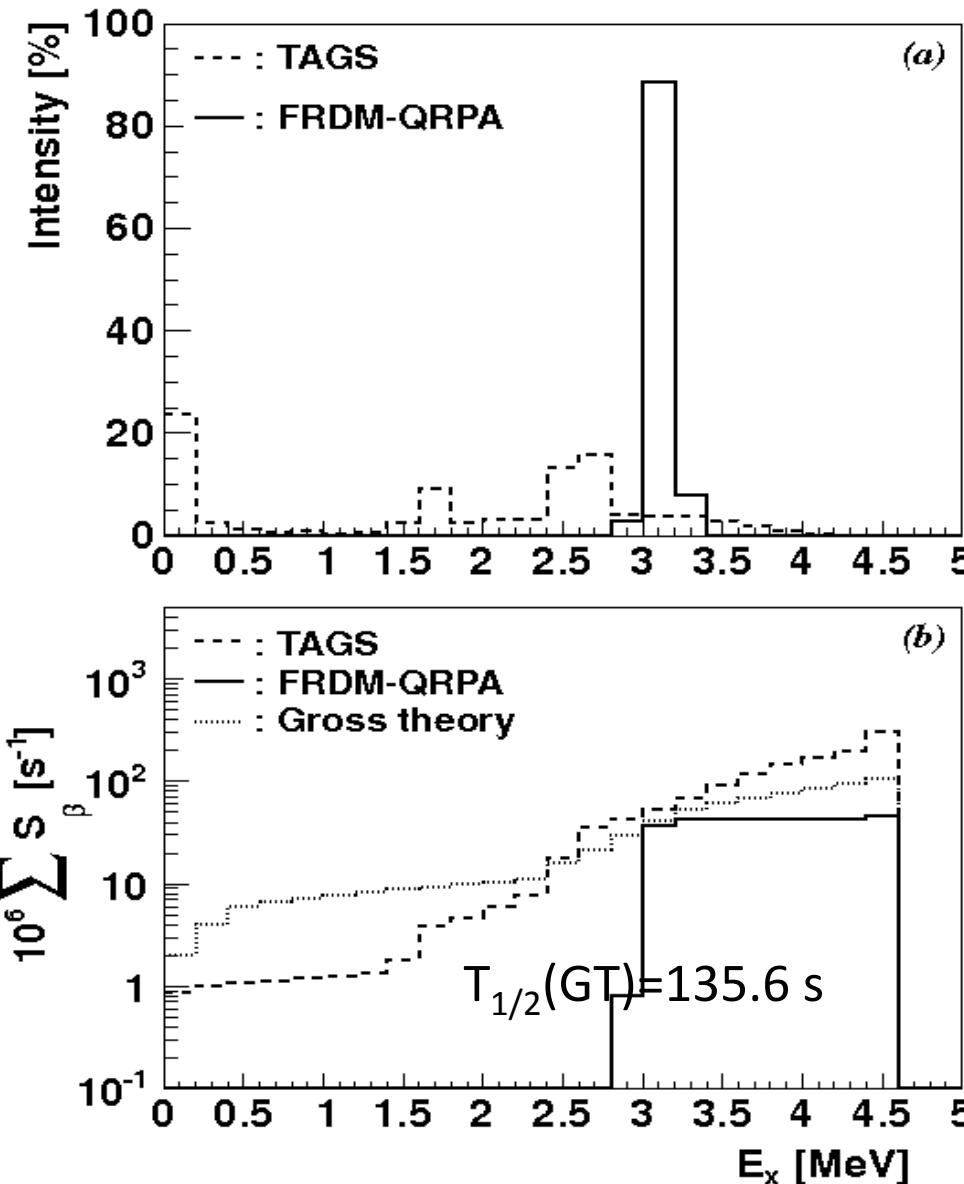
^{105}Tc decay ($\varepsilon=0.29$, $T_{1/2}(\text{exp})=456$ s)



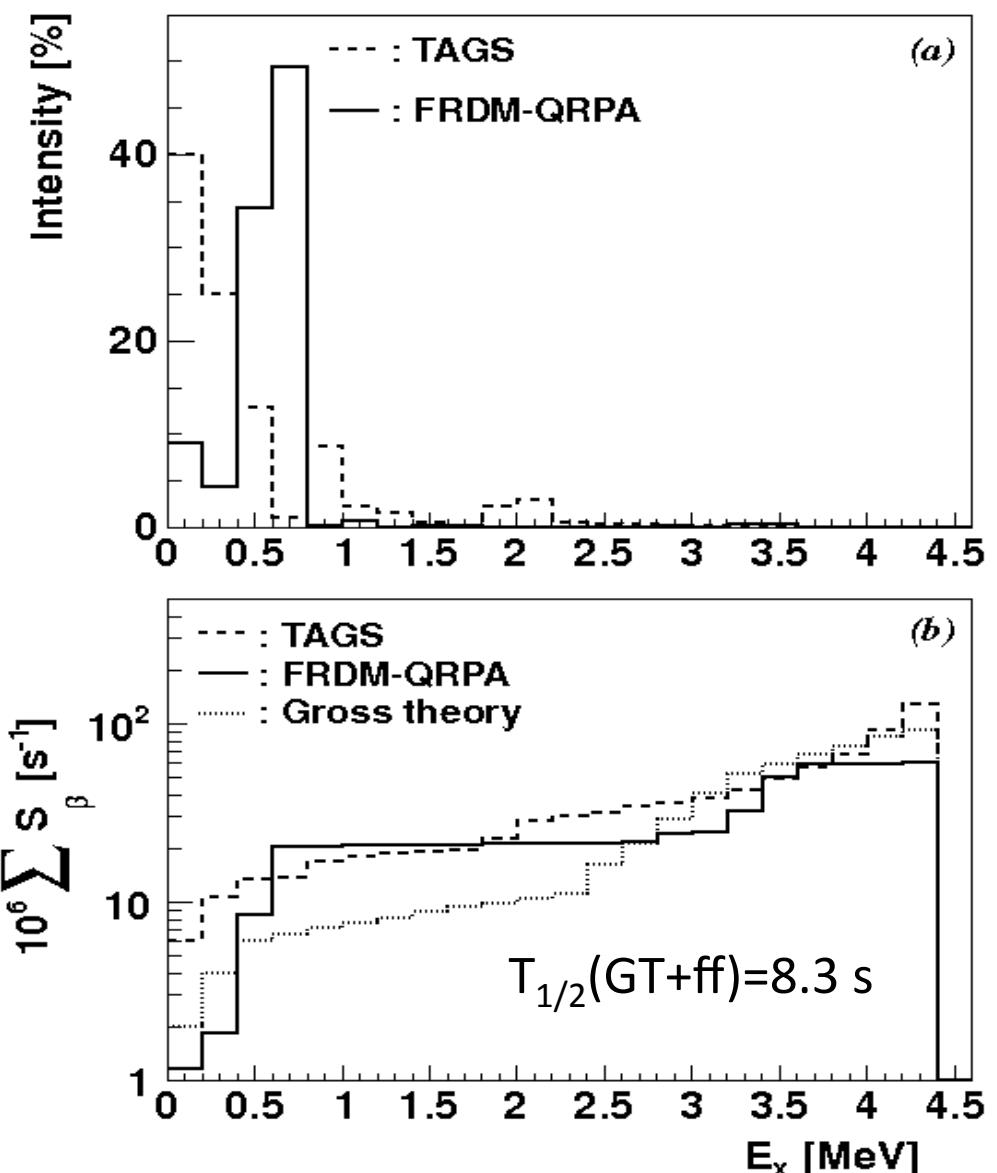
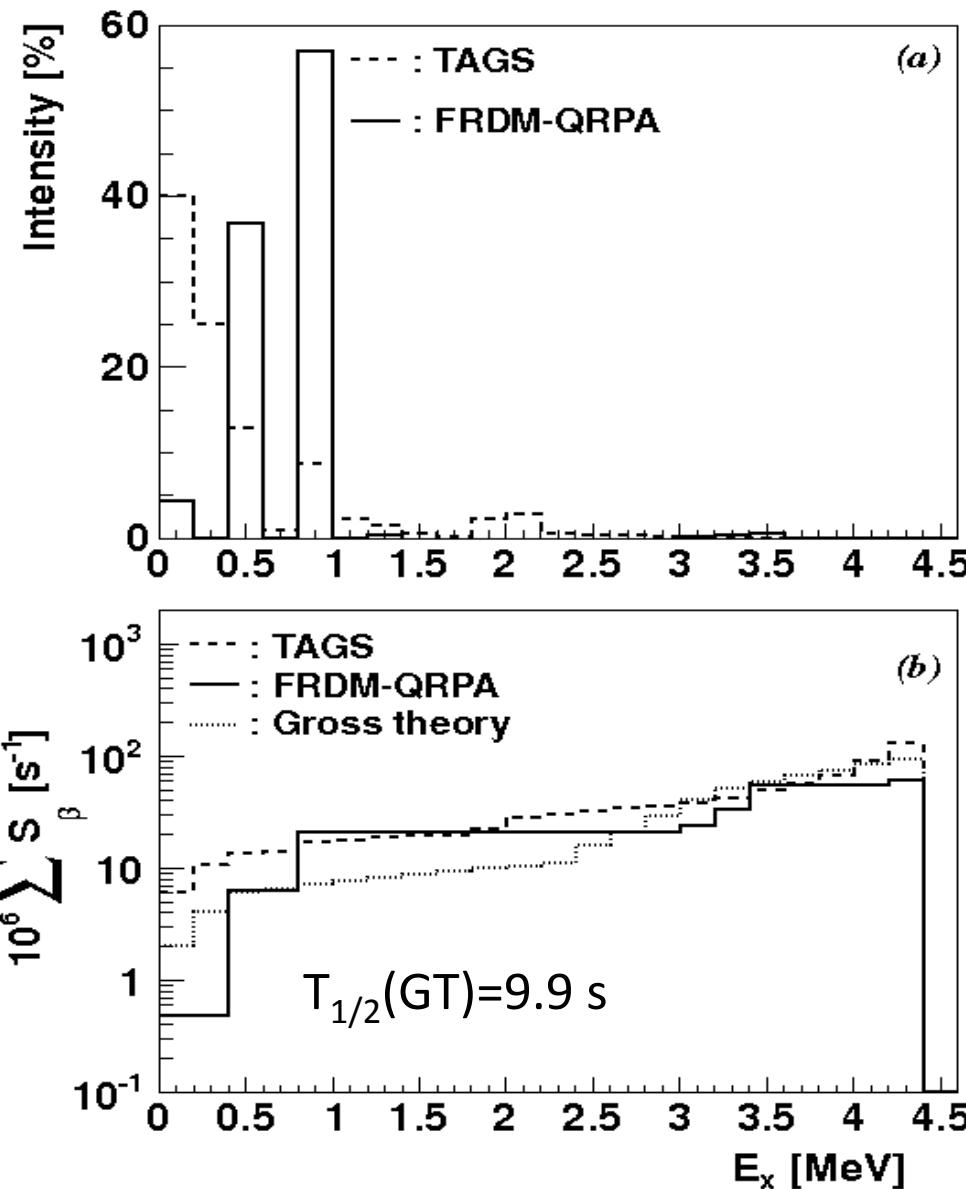
^{106}Tc decay ($\varepsilon=0.33$, $T_{1/2}(\text{exp})=35.6$ s)



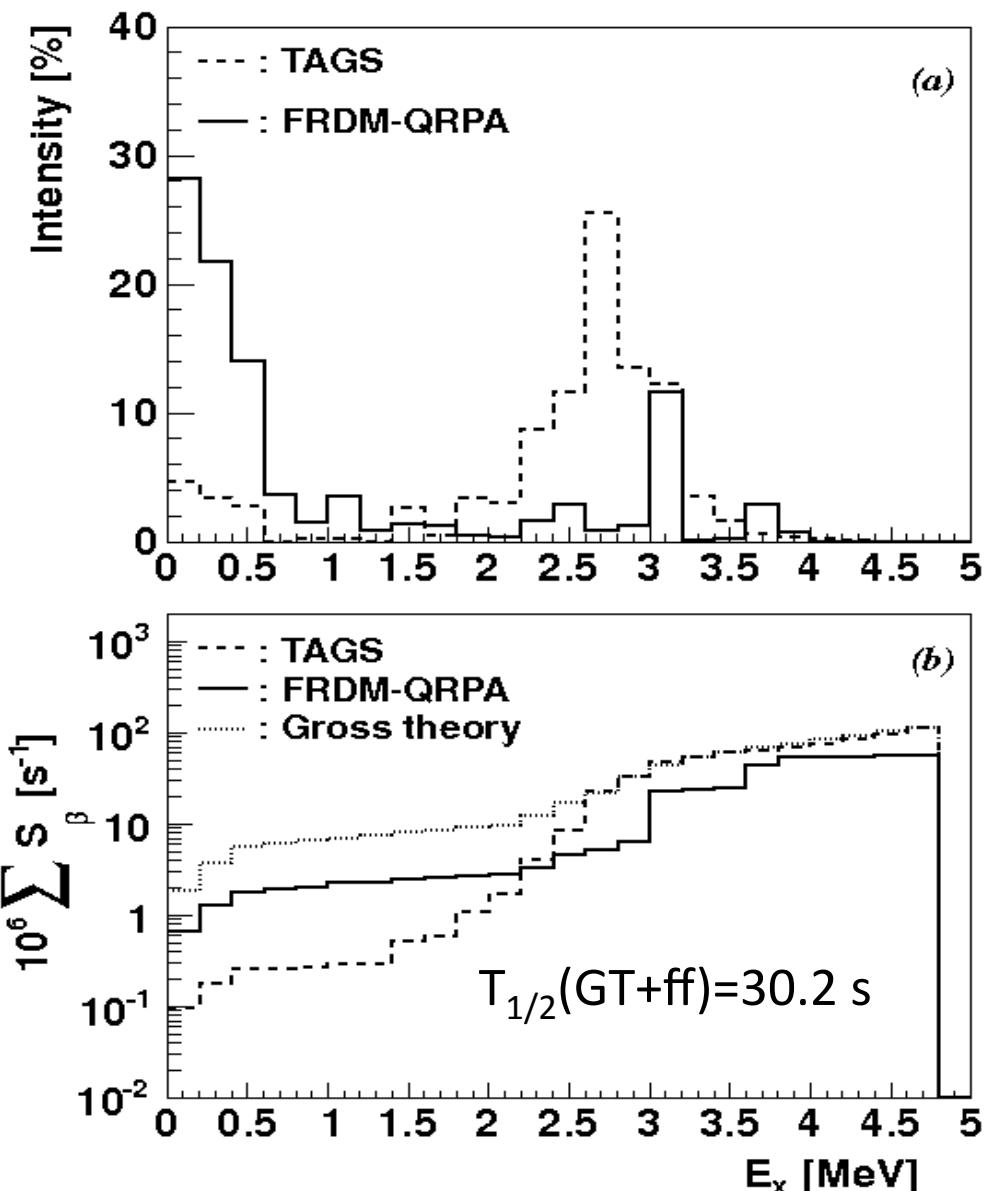
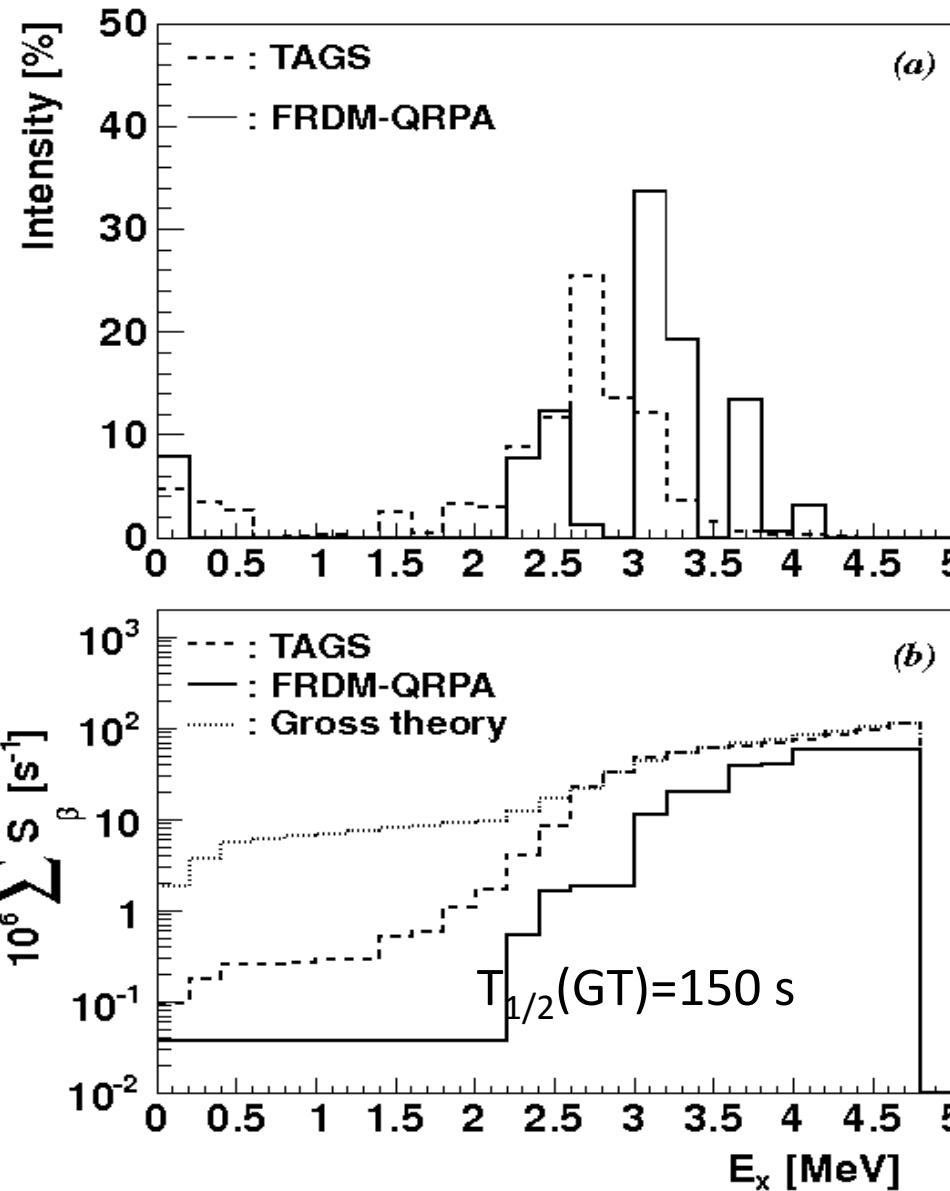
^{107}Tc decay ($\varepsilon=0.29$, $T_{1/2}(\text{exp})=21.2$ s)



^{101}Nb decay ($\varepsilon=0.33$, $T_{1/2}(\text{exp})=7.1$ s)



^{105}Mo decay ($\varepsilon=0.31$, $T_{1/2}(\text{exp})=35.6$ s)



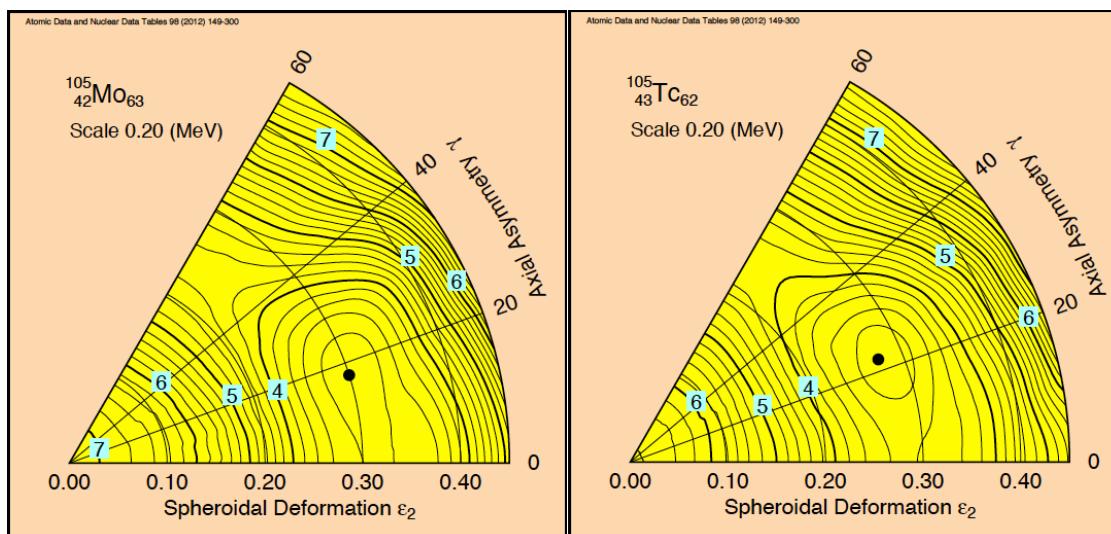
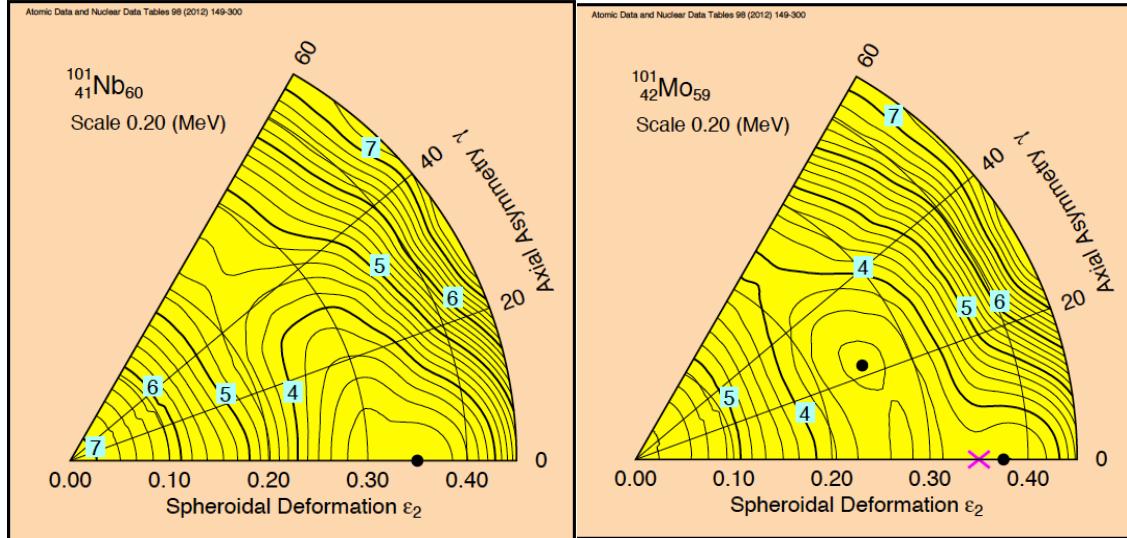
Comparison of half-lives

Decay	$T_{1/2}$ [s] (Exp)	$T_{1/2}$ [s] (GT)	$T_{1/2}$ [s] (GT-ff)
^{101}Nb ^{101}Mo	7.1	9.9	8.3
^{105}Mo ^{105}Tc	35.6	150	30.2
^{102}Tc ^{102}Ru	5.3	6.72	6.69
^{104}Tc ^{104}Ru	1098	151	40.7
^{105}Tc ^{105}Ru	456	16920	162
^{106}Tc ^{106}Ru	35.6	64.8	17.9
^{107}Tc ^{107}Ru	21.2	135.6	29.7

Conclusions of this work

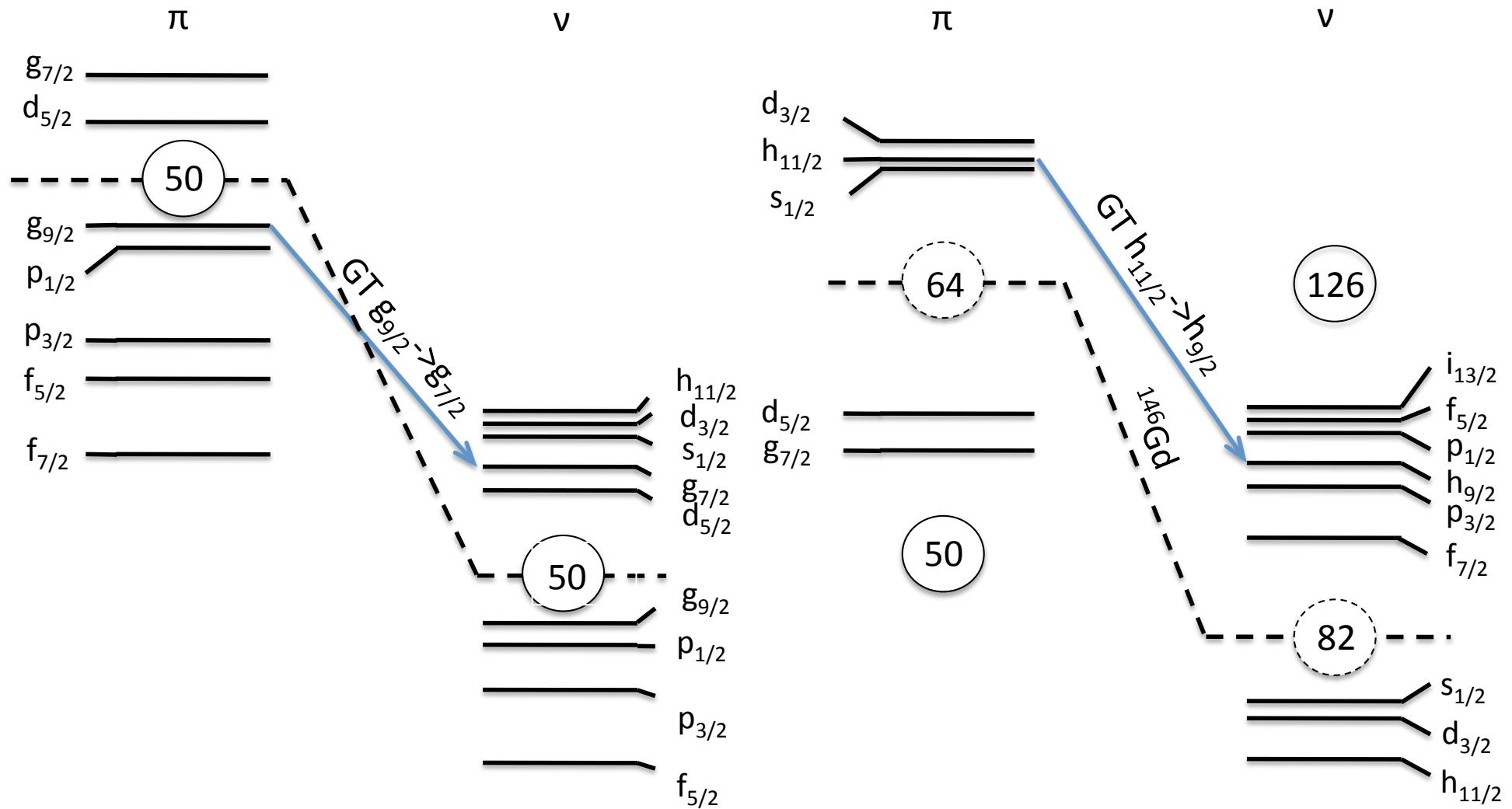
- The isotopes under study can also be considered interesting from the perspective of nuclear structure and astrophysics
- The studied decays were located in a region of the nuclear chart characterized by shape coexistence and shape effects
- Almost all the nuclei show triaxial minima and both parent and daughter nuclei have different predicted ground state deformations. The decay of ^{101}Nb to ^{101}Mo is the only case with well defined prolate minima.
- As a general pattern the half-lives and feeding patterns are better described assuming only the GT component. The inclusion of a ff component in the calculations does not show a clear improvement except for the decay of ^{101}Nb to ^{101}Mo .

How triaxial are they ?



With the exception of the A=101 system, all show triaxial minima, and parent and daughter present different deformations, which obviously represents a problem for the description of the beta decays.

Studies in the ^{100}Sn and ^{146}Gd Region



TAS Studies in the ^{100}Sn region

51	Sb 121.760 $\sigma 5.2$	Sb 103 >1.5 μs $\beta^+ ?$	Sb 104 0.44 s β^+	Sb 105 1.12 s β^+	Sb 106 1.1 s β^+	Sb 107 4.6 s $\gamma 1280; 819; 151; 704$	Sb 108 7.6 s β^+	Sb 109 16.7 s $\beta^+ 4.4; 5.4... \gamma 925; 1062; 1599; 1273...$	Sb 110 24.0 s $\beta^+ 6.9... \gamma 1212; 985; 665; 1496...$	Sb 111 75 s $\beta^+ 3.3... \gamma 154; 489; 1243; 827...$	Sb 112 53.5 s $\beta^+ 4.8... \gamma 1257; 991...$	
Sn 118.710 0.64	Sn 100 0.94 s $\beta^+ 3.4$	Sn 101 3 s $\beta^+ 0.5$	Sn 102 3.8 s $\beta^+ 3.2; 3.5... \gamma 1356; 314; 320; 94; 69; 1397; 1078...$	Sn 103 7.0 s $\beta^+ \gamma 133; 913; 401; 1407...$	Sn 104 20.8 s $\beta^+ 2.4... \gamma 1282; 1466; 309; g; m$	Sn 105 34 s $\beta^+ \gamma 387; 253; 1001...$	Sn 106 2.1 m $\epsilon \beta^+ 1.2...$	Sn 107 2.9 m $\beta^+ \gamma 1129; 1542; 1001...$	Sn 108 10.3 m $\epsilon; \beta^+ 0.4... \gamma 396; 273; 331; g; m$	Sn 109 18.0 m $\epsilon; \beta^+ 1.6... \gamma 1099; 1321; 331; g; m$	Sn 110 4.11 h $\epsilon; \beta^+ 1.5... \gamma 1153; 1915; 762; 1610...$	
In 98 1.7 s β^+	In 99 3.1 s β^+	In 100 5.9 s $\beta^+ 1.2$	In 101 16 s $\beta^+ 3.5... \gamma 777; 861; 593; 21; 801...$	In 102 22.1 s $\beta^+ 3.5... \gamma 777; 861; 593; 21; 801...$	In 103 34 s $\beta^+ 4.2... \gamma 168; 725; 724...$	In 104 60 s $\beta^+ 4.3... \gamma 658; 824; 823...$	In 105 1.8 m $\beta^+ 4.8... \gamma 131; 261; 674...$	In 106 4.8 m $\beta^+ 3.9... \gamma 483; 133; 1716; 673...$	In 107 5.33 m $\beta^+ 2.0... \gamma 133; 133; 221...$	In 108 50.4 s $\beta^+ 2.3... \gamma 203; 135; 163; 876; 243...$	In 109 58.0 m $\beta^+ 1.3... \gamma 204; 624...$	
Cd 97 2.8 s $\beta^+ 1.5... 5.0$	Cd 98 9.2 s $\beta^+ 3.4... 1176; 107; 61...$	Cd 99 16 s $\beta^+ 3.4... 1343; 672; 583... g; m$	Cd 100 49.1 s $\beta^+ 9.8... 1723; 937; 140; 1259; 925... m$	Cd 101 1.2 m $\beta^+ 8.2... \gamma 481; 1037; 505; 415...$	Cd 102 5.5 m $\beta^+ 8.2... \gamma 481; 1037; 505; 415...$	Cd 103 7.3 m $\beta^+ 8.2... \gamma 1482; 1449; 1080; 387... m; g, m$	Cd 104 57.7 m $\beta^+ 8.2... \gamma 84; 709...$	Cd 105 55.5 m $\beta^+ 8.2... \gamma 962; 1302; 347; 607; 1693... m; g; m$	Cd 106 1.25 $\sigma 0.20$	Cd 107 6.5 h $\beta^+ 8.2... \gamma 829...$	Cd 108 0.89 $\sigma 1.0$	Cd 109 462.6 d $\epsilon; no \gamma; m; \sigma \sim 180; \alpha; \sigma < 0.05$
Ag 96 4.40 s $\beta^+ 6.9 s$	Ag 97 25.3 s $\beta^+ 6.86; 1295; 1256...$	Ag 98 46.7 s $\beta^+ 6.86; 679; 571...$	Ag 99 10.5 s $\beta^+ 4.2... \gamma 264; 64; 806...$	Ag 100 2.1 m $\beta^+ 5.4... \gamma 47; 666; 751; 751; 1694; 1773...$	Ag 101 2.3 m $\beta^+ 5.4... \gamma 47; 666; 751; 751; 1694; 1773...$	Ag 102 8 m $\beta^+ 5.4... \gamma 257; 342; 1745; 1835...$	Ag 103 11.1 m $\beta^+ 5.4... \gamma 257; 342; 1745; 1835...$	Ag 104 8 m $\beta^+ 5.4... \gamma 557; 719; 856; 148; 267; 1274...$	Ag 105 5.7 s $\beta^+ 1.7... \gamma 119; 148; 267; 768; 942...$	Ag 106 1.1 h $\beta^+ 2.7... \gamma 556... 93...$	Ag 107 33.5 m $\beta^+ 1.7... \gamma 614; 723; 434... \gamma 633; 234...$	Ag 108 69.2 m $\beta^+ 1.7... \gamma 614; 723; 434... \gamma 633; 234...$
Pd 95 14 s $\beta^+ 1.5... 7.5; 382; 717; 382; pp 1.3... 3.7; g$	Pd 96 2.0 m $\epsilon; \beta^+ 1.5... \gamma 125; 762; 500; 1099... m$	Pd 97 3.1 m $\beta^+ 3.5... \gamma 265; 475; 793... g$	Pd 98 17.7 m $\epsilon; \beta^+ 0.7... \gamma 112; 663; 107... g$	Pd 99 21.4 m $\beta^+ 2.2... \gamma 138; 264; 673... m$	Pd 100 3.7 d $\epsilon; no \beta^+ \gamma 84; 75; 126... g$	Pd 101 8.47 h $\epsilon; \beta^+ 0.8... \gamma 296; 590; 270... m$	Pd 102 1.02 $\sigma 3.2$	Pd 103 16.96 d $\epsilon; \gamma (357...) m$	Pd 104 11.14 $\sigma 22 \alpha; \sigma 0.0000005$	Pd 105 22.33 $\sigma 22 \alpha; \sigma 0.013 + 0.28$	Pd 106 27.33 $\sigma 21 \alpha; \sigma 1.15$	Pd 107 21.3 s $\beta^+ 1.0... \sigma 0.03 \alpha; \sigma 9.18$
Rh 94 70.6 s $\beta^+ 5.4... 7.5; 1431; 1431; 756; 312; 1073... \beta^+ 146...$	Rh 95 25.8 s $\beta^+ 5.4... 7.5; 1431; 1431; 756; 312; 1073... \beta^+ 146...$	Rh 96 1.96 m $\beta^+ 5.4... 7.5; 1431; 1431; 756; 312; 1073... \beta^+ 146...$	Rh 97 5.0 m $\beta^+ 5.4... 7.5; 1431; 1431; 756; 312; 1073... \beta^+ 146...$	Rh 98 9.9 m $\beta^+ 5.4... 7.5; 1431; 1431; 756; 312; 1073... \beta^+ 146...$	Rh 99 44 m $\beta^+ 2.6... \gamma 189; 422; 840; 745...$	Rh 100 31 m $\beta^+ 2.6... \gamma 341; 616; 1261...$	Rh 101 8.7 m $\beta^+ 2.6... \gamma 528; 353; 90...$	Rh 102 16 d $\beta^+ 0.7... \gamma 507; 545; 157...$	Rh 103 20.8 h $\beta^+ 0.7... \gamma 507; 545; 157...$	Rh 104 56.1 m $\beta^+ 0.7... \gamma 475; 631; 697; 142...$	Rh 105 100 $\beta^+ 0.7... \gamma 475; 631; 697; 142...$	Rh 106 44.4 m $\beta^+ 0.6... \gamma 319; 305; 1046; 717...$
Ru 93 10.8 s $\beta^+ 5.3... 1111; \beta^+ 681; \beta^+ 734; 1433... \beta^+ 248... g$	Ru 94 59.7 s $\beta^+ 5.3... 1111; \beta^+ 681; \beta^+ 734; 1433... \beta^+ 248... g$	Ru 95 51.8 m $\epsilon; \beta^+ 1.2... \gamma 336; 1097; 627... g$	Ru 96 1.65 h $\epsilon; \beta^+ 1.2... \gamma 336; 1097; 627... g$	Ru 97 5.54 $\epsilon; \beta^+ 0.23$	Ru 98 2.9 d $\epsilon; \beta^+ 0.23$	Ru 99 1.87 $\epsilon; \beta^+ 0.23$	Ru 100 12.76 $\epsilon; \beta^+ 0.23$	Ru 101 12.60 $\epsilon; \beta^+ 0.23$	Ru 102 17.06 $\epsilon; \beta^+ 0.23$	Ru 103 31.55 $\epsilon; \beta^+ 0.23$	Ru 104 39.35 d $\beta^- 0.2; 0.7... \gamma 497; 610... m$	Ru 105 18.62 $\beta^- 0.2; 0.7... \gamma 497; 610... m$
Ru 105 4.44 h $\beta^- 1.2; 1.8... \gamma 724; 469; 676; 316... g; m; \sigma 0.29$												

Physics goals

- Study the GT resonance in a region where it can be accessible within the Q_{EC} window ($\pi g9/2 \rightarrow vg7/2$)
- Study the quenching of the GT strength. The measurement of the strength distribution and its comparison with theory provides a stringent test of theory
- Study of the shell structure of nuclei in the vicinity of $N=Z=50$
- Study of the $\pi g9/2 \rightarrow vg9/2$ and $\pi g9/2 \rightarrow vg7/2$ transitions and their competition (south-west of ^{100}Sn)

Studies performed earlier at GSI
On-line Mass-Separator

Studies still to be done

Some summaries of the ^{100}Sn region results

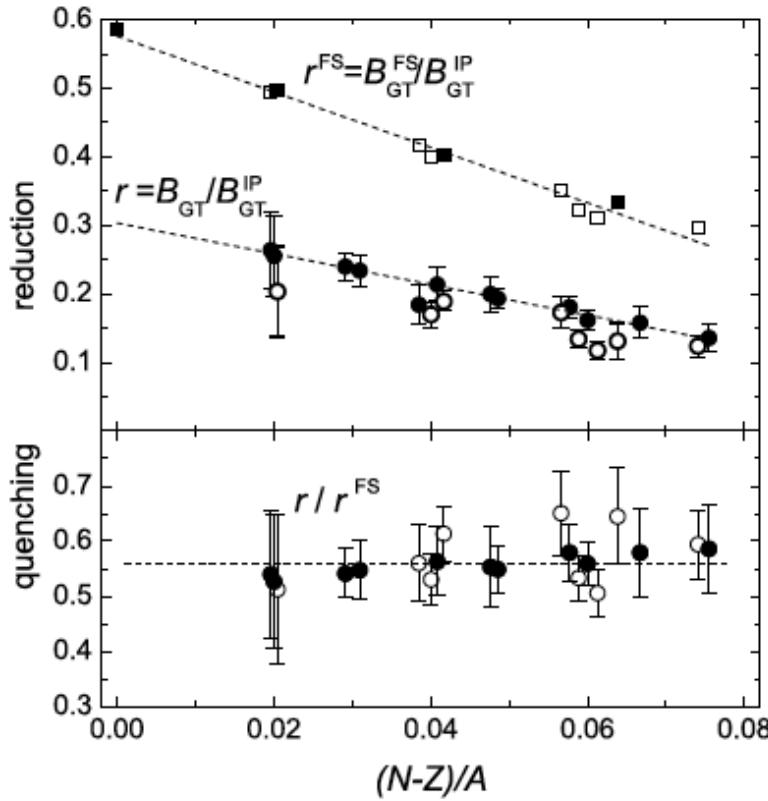


Fig. 4. Upper panel: reduction of the summed experimental (circles) and theoretical (squares) GT_+ strength relative to the prediction of the independent-particle model (10). The experimental $B_{\text{GT}}/B_{\text{GT}}^{\text{IP}}$ data shown as filled and empty circles stem from TAS and HR experiments, respectively. The theoretical data displayed as filled and empty squares represent results obtained from the SMMC calculation [37,38] and the schematic QRPA calculation, respectively (see sect. 2.3). Lower panel: higher-order reduction factor r/r^{FS} (see sect. 2.3).

Batist *et al.*, Eur. Phys. J. A 46, 45–53 (2010)

$$h = \frac{\sum_f B_{\text{GT}}^{\text{th}}}{\sum_f B_{\text{GT}}^{\text{exp}}} = h_{\text{low}} h_{\text{high}},$$

$$h_{\text{high}} = 1/q^2$$

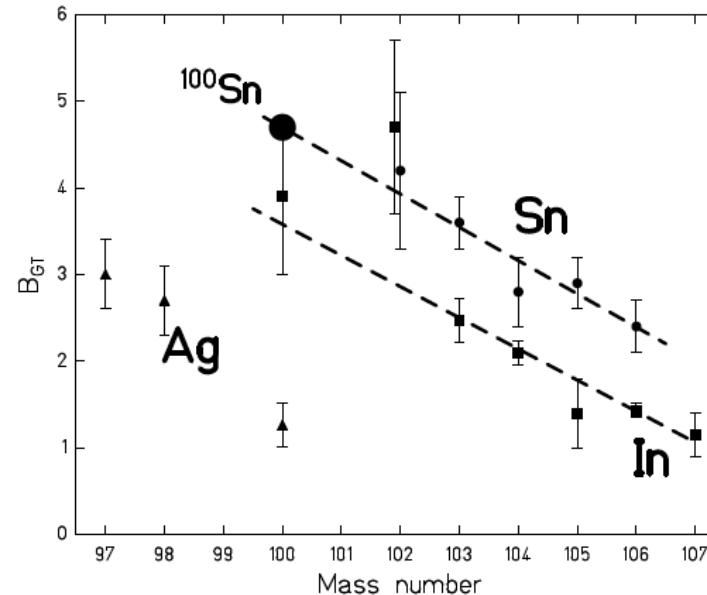
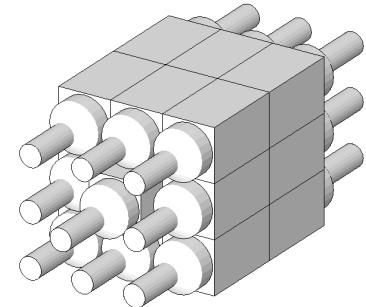


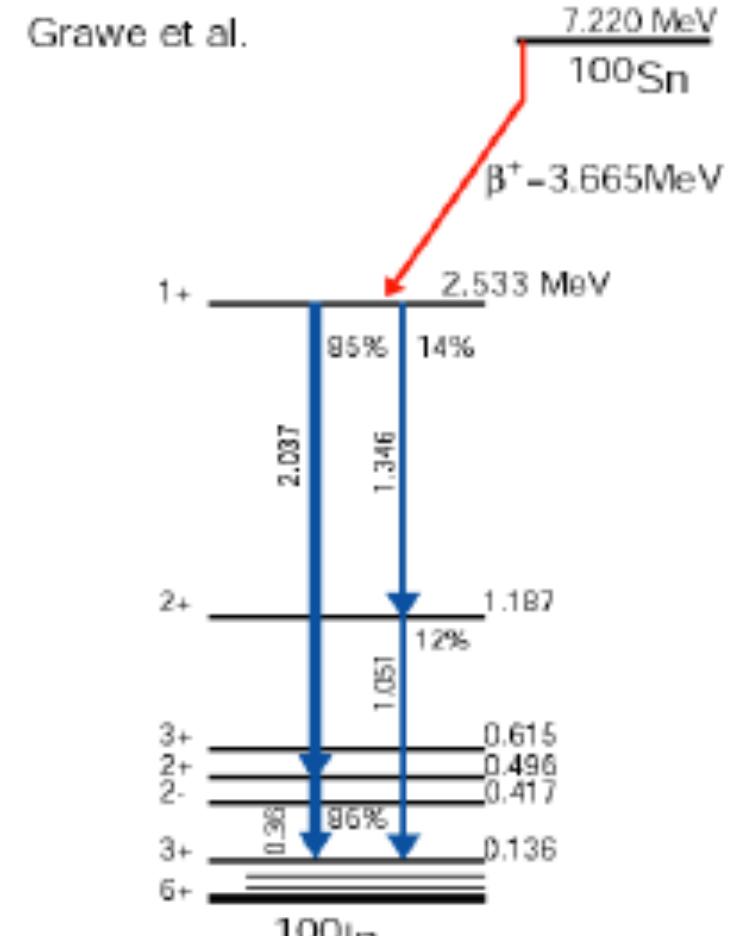
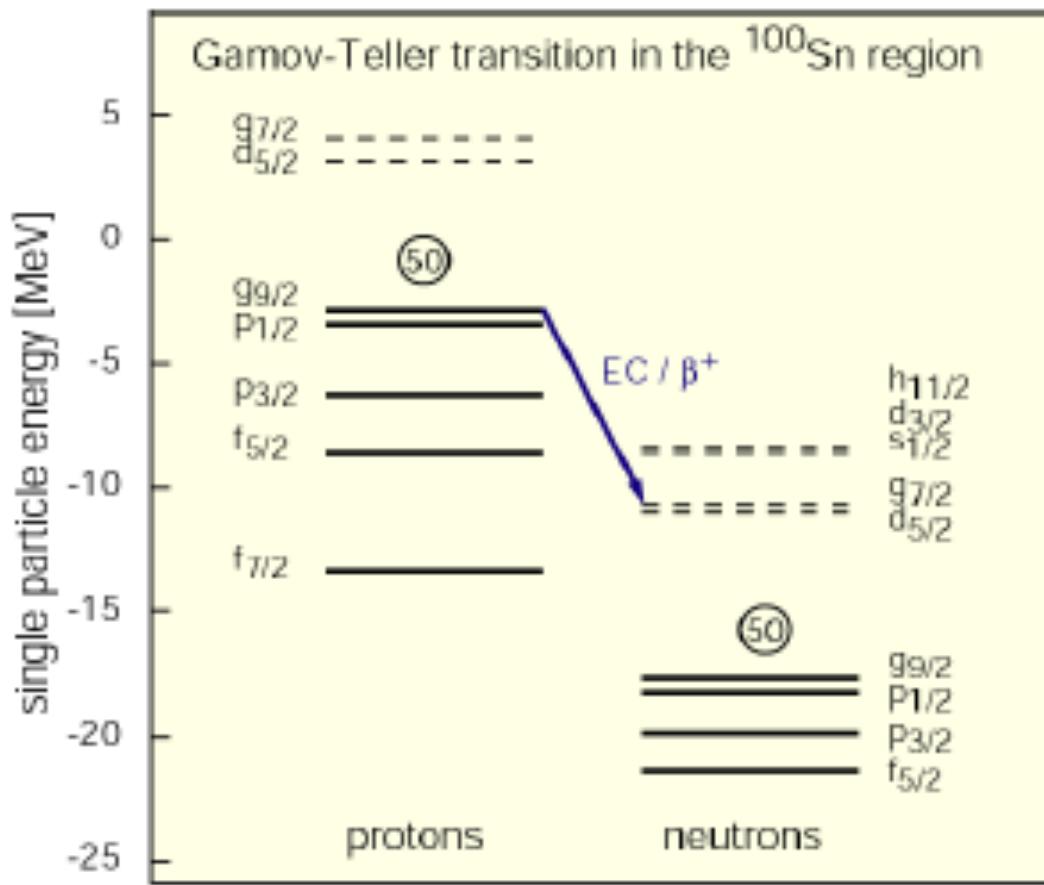
Fig. 5. Experimental total $B_{\text{GT}}^{\text{exp}}$ values of isotopes studied at the GSI on-line mass separator. Dashed lines mark the fitted linear dependency for tin and indium isotopes. The large black dot represents the extrapolated B_{GT} value for ^{100}Sn .

Karny *et al.*, Eur. Phys. J. A 25, 135 (2005)

A=100 region dream



^{100}Sn , calculated



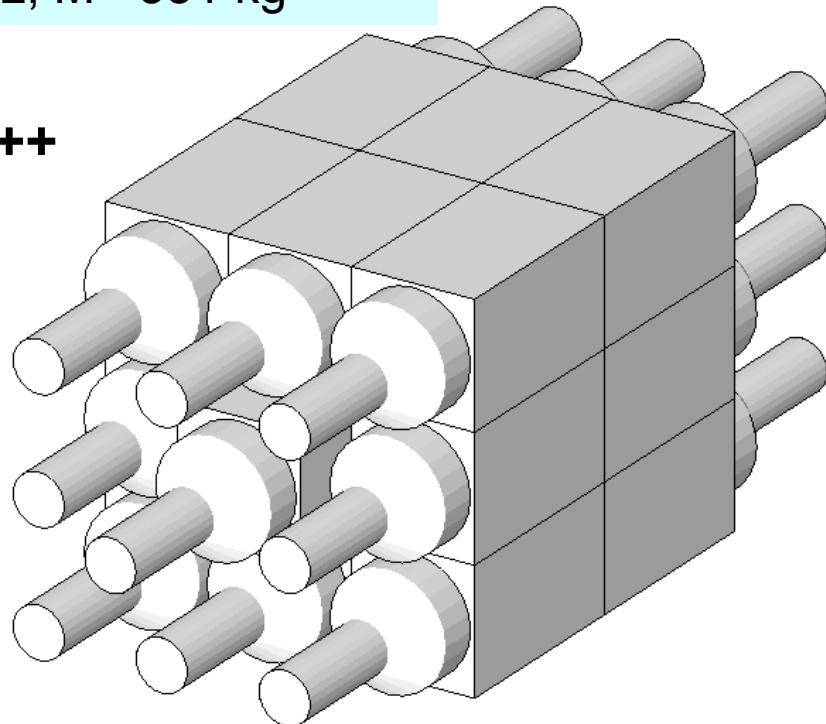
^{100}Sn can be studied at the level of 3000 counts in the TAS to pinpoint the energy of the 1+ state (proposal submitted to RIKEN (D), spokespersons: Algora, Rubio)

DTAS detector for DESPEC

16 + (2) modules:

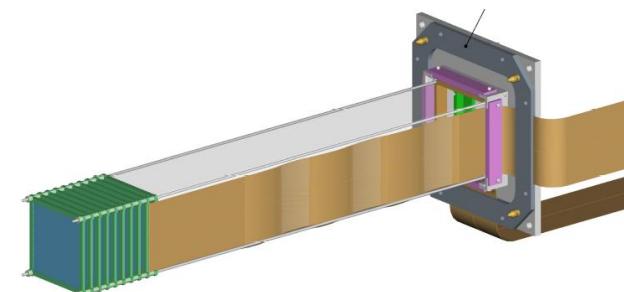
15 x15 x 25 cm³ **Nal(Tl)**
+ 5" PMT (50% light col.)
V= 95 L, M= 351 kg

TAS++



Tot eff ~90%

**Fast ions active stopper: AIDA
(Stack of DSSSD)**



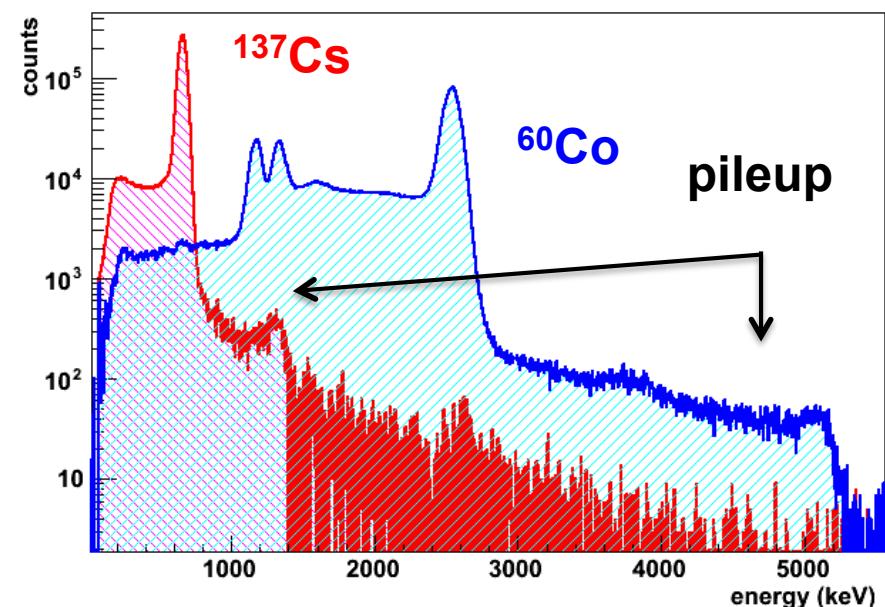
Convener: J. L. Tain (IFIC)

Funded by : 2 FPA and 1 AIC project

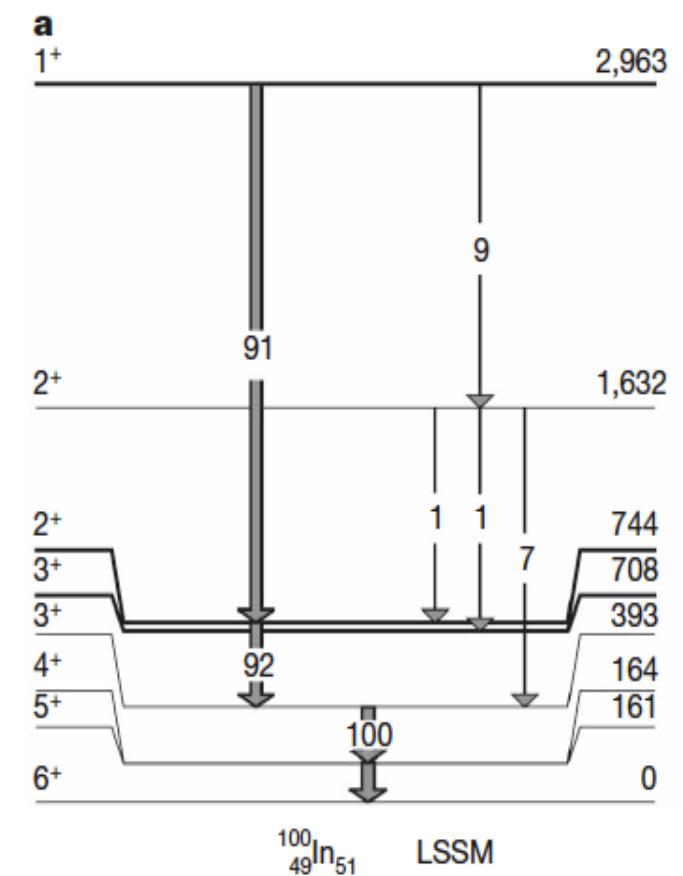
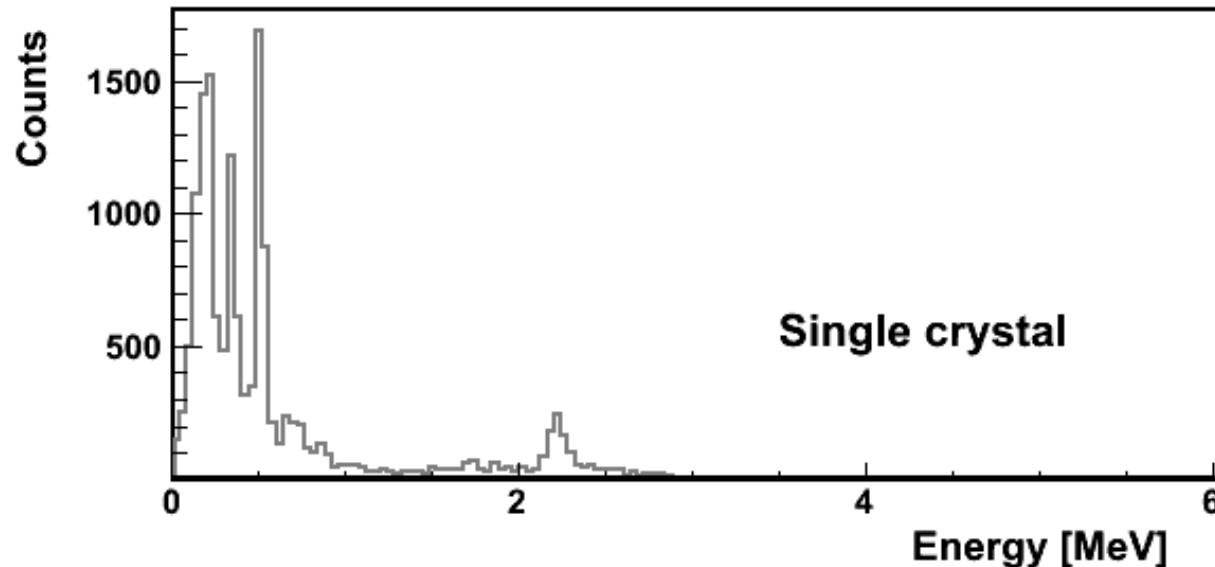
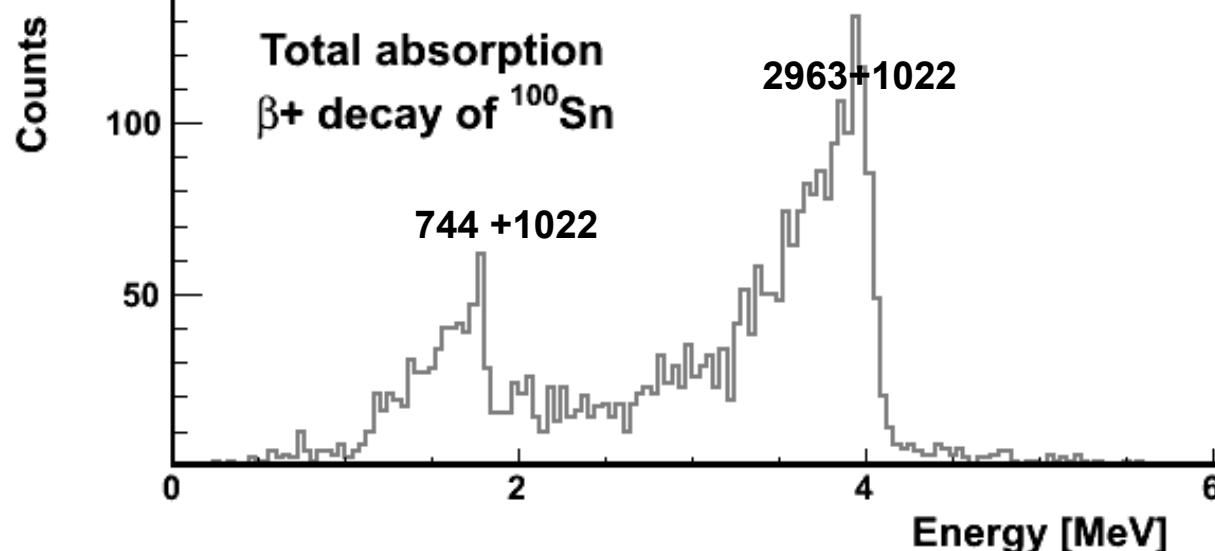
TDR approved (01/2013)

Commissioning at IFIC (01/2014)

First experiments at JYFL (02-03/2014)

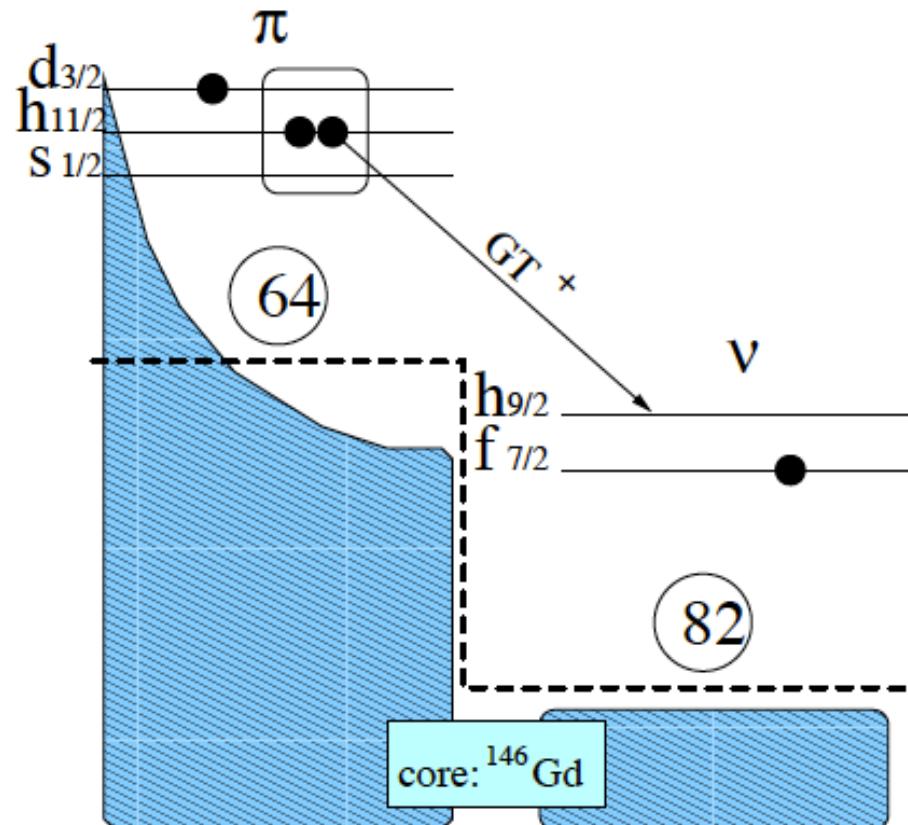


A=100 region dream

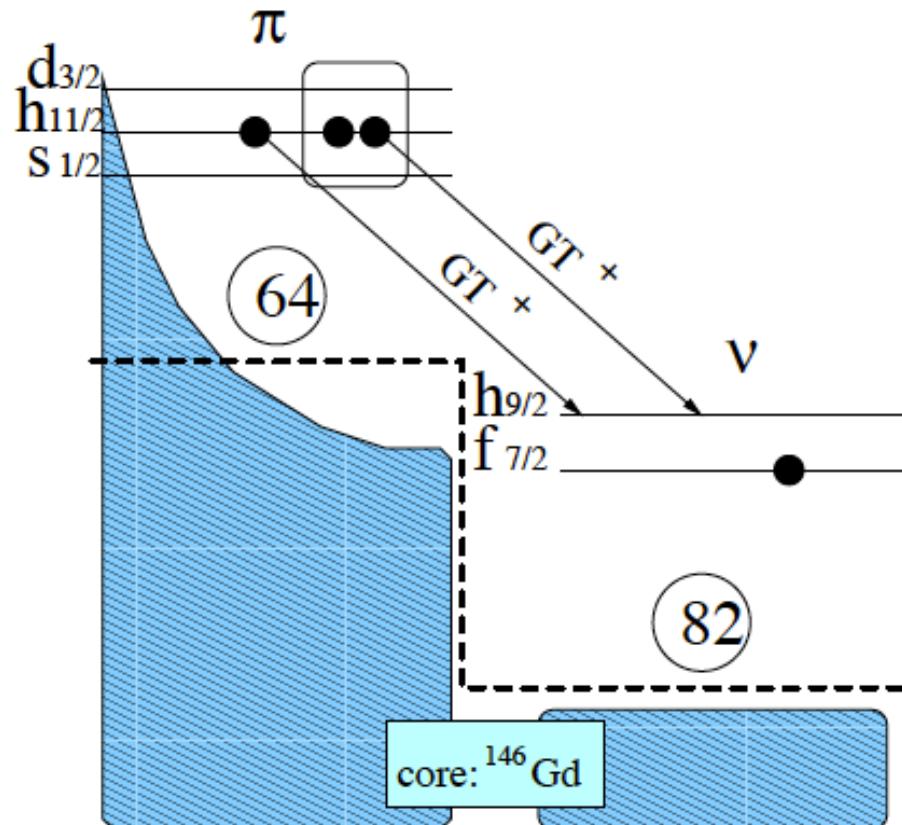


3000 beta-gated events
seen by the DTAS, level
scheme taken from Nature

Studies in the ^{146}Gd region

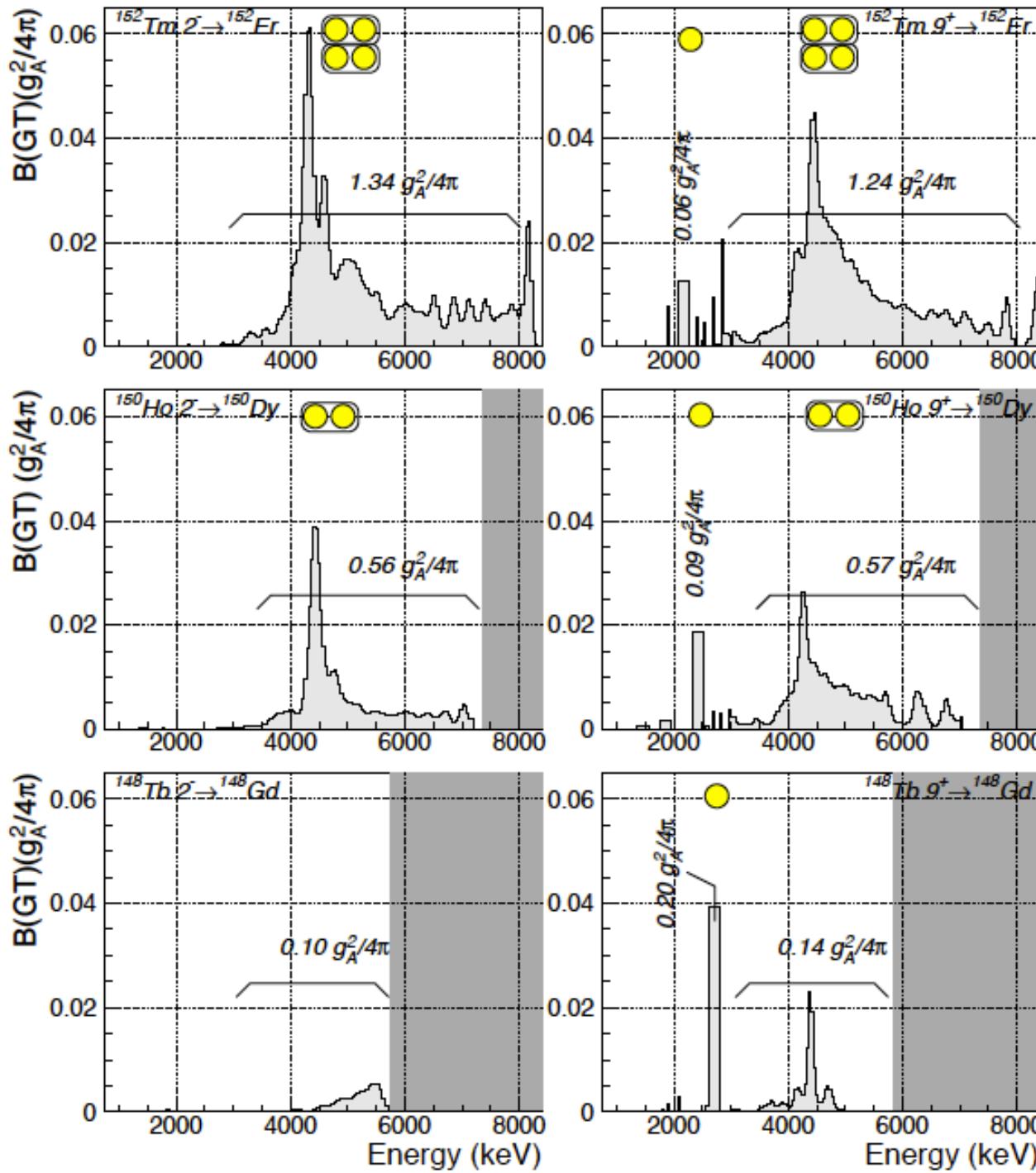


Low-spin isomer
(2-) decay



High-spin isomer
(9+) decay

Figs from E. Nácher thesis



Results from PhD theses
of E. Nácher and D. Cano
Experiments performed at
Mass Separator (GSI)

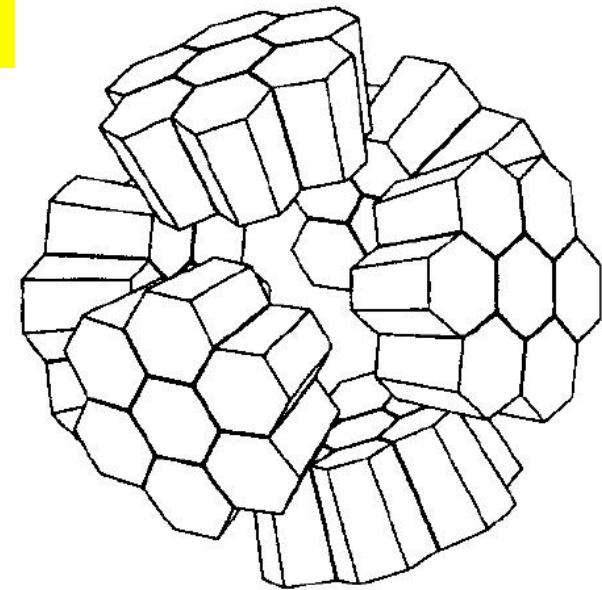
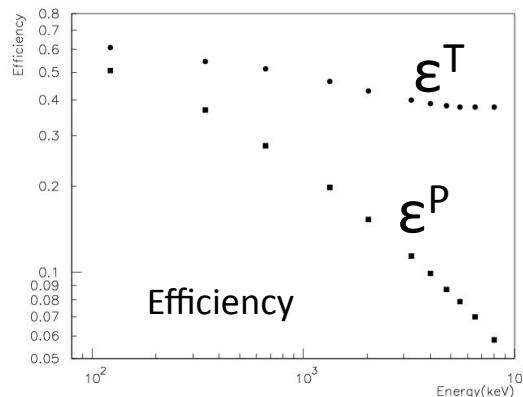
Spokesperson of the
experiments: B. Rubio

Reasonable description
obtained with Shell model
calculations in a restricted
model space (matrix
elements deduced from
experiments, from
Blomqvist)

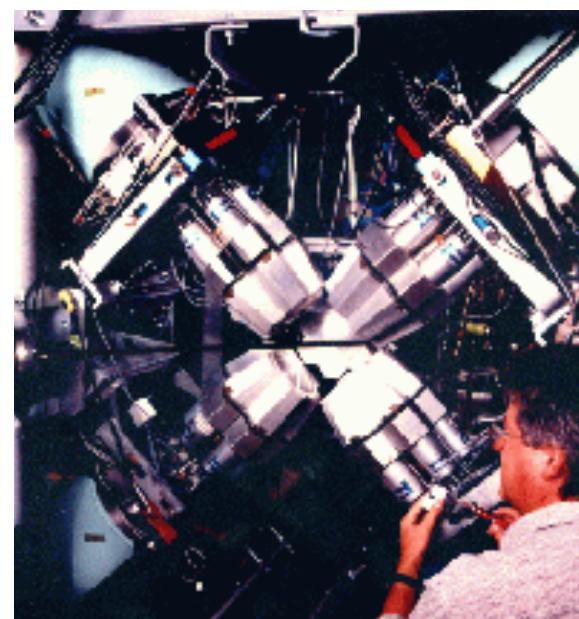
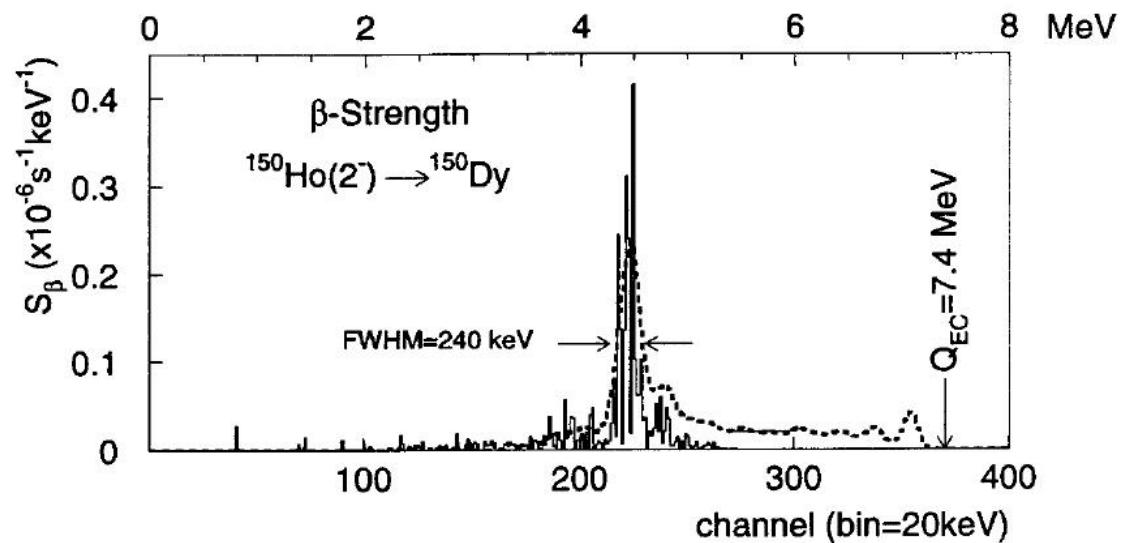
Pandemonium in ^{150}Ho decay

CLUSTER-CUBE: 6
EUROBALL Clusters
in cubic geometry

CLUSTER: 7
Ge detectors, 60%
each



CLUSTER-CUBE at GSI

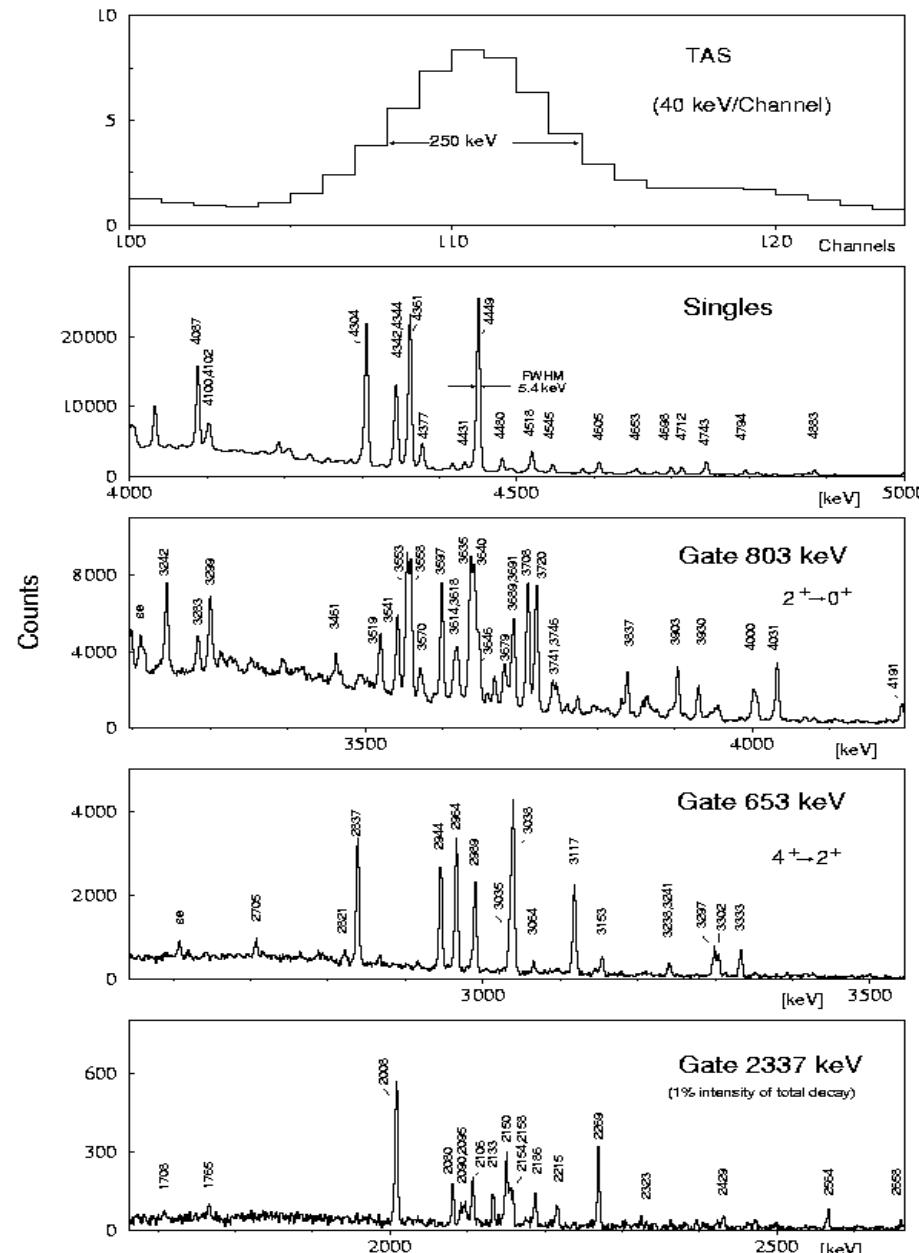


The decay of ^{150}Ho 2 $^+$ isomer

High resolution results

- No. total of γ : ~ 1064
- No. total of levels: ~ 295
- Sharp resonance ~ 4.4 MeV
- $B(\text{GT})$ is approx. 47 % of the TAS result.

Algora, Rubio et al. PRC
68 (2003) 034301
(the 10 m level scheme)



^{148}Dy decay

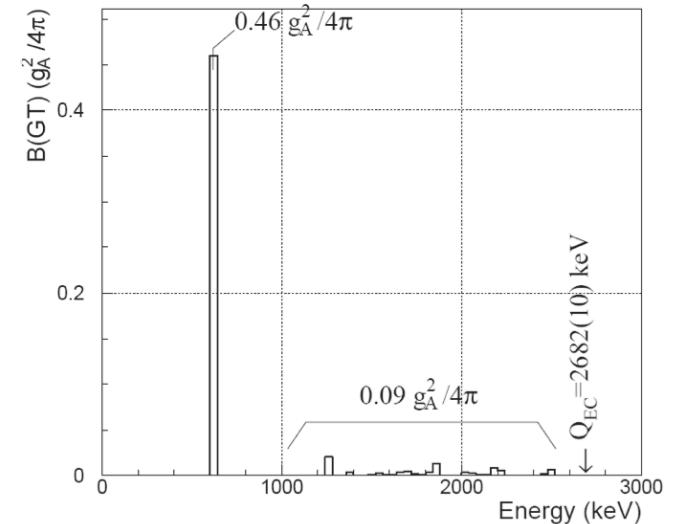
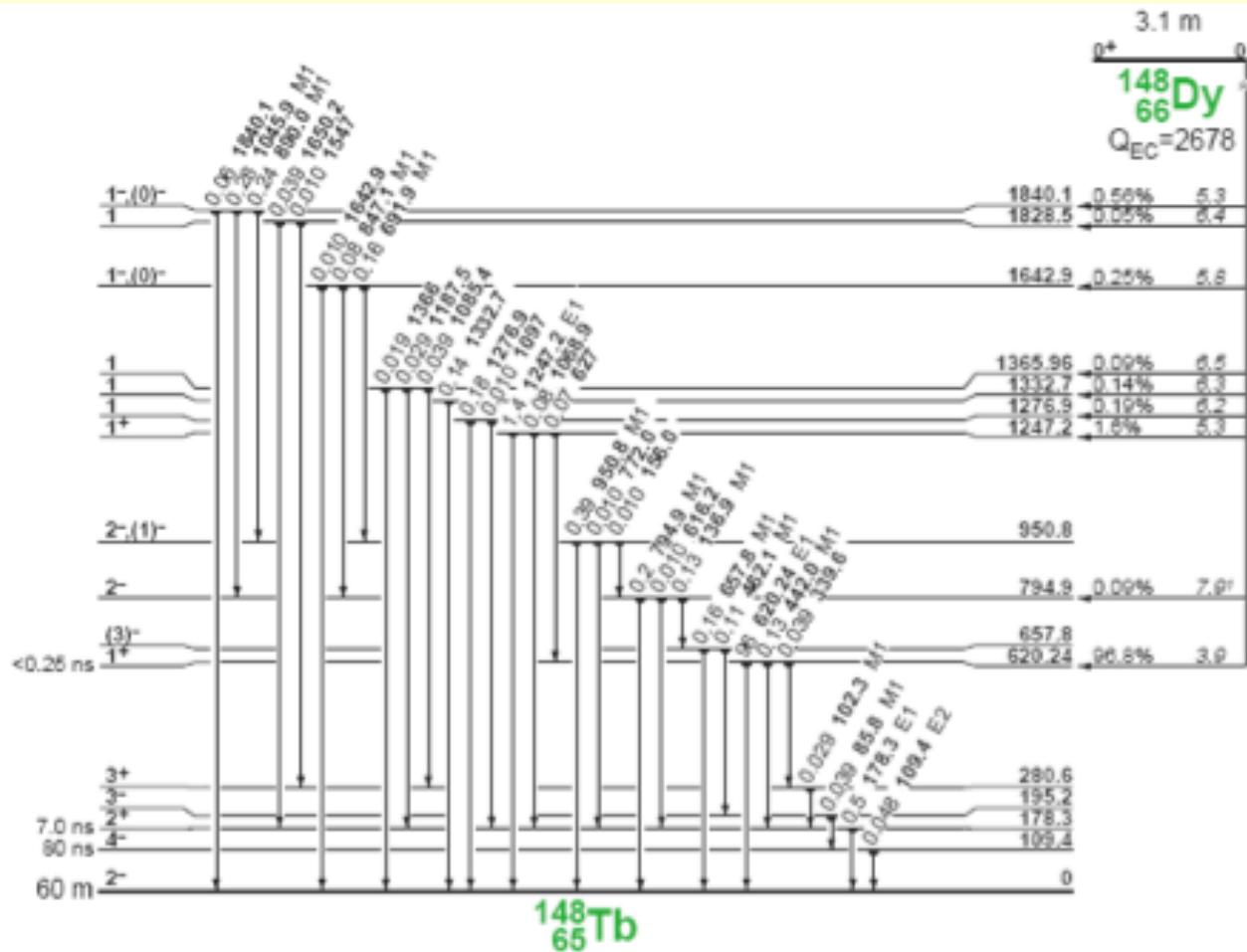
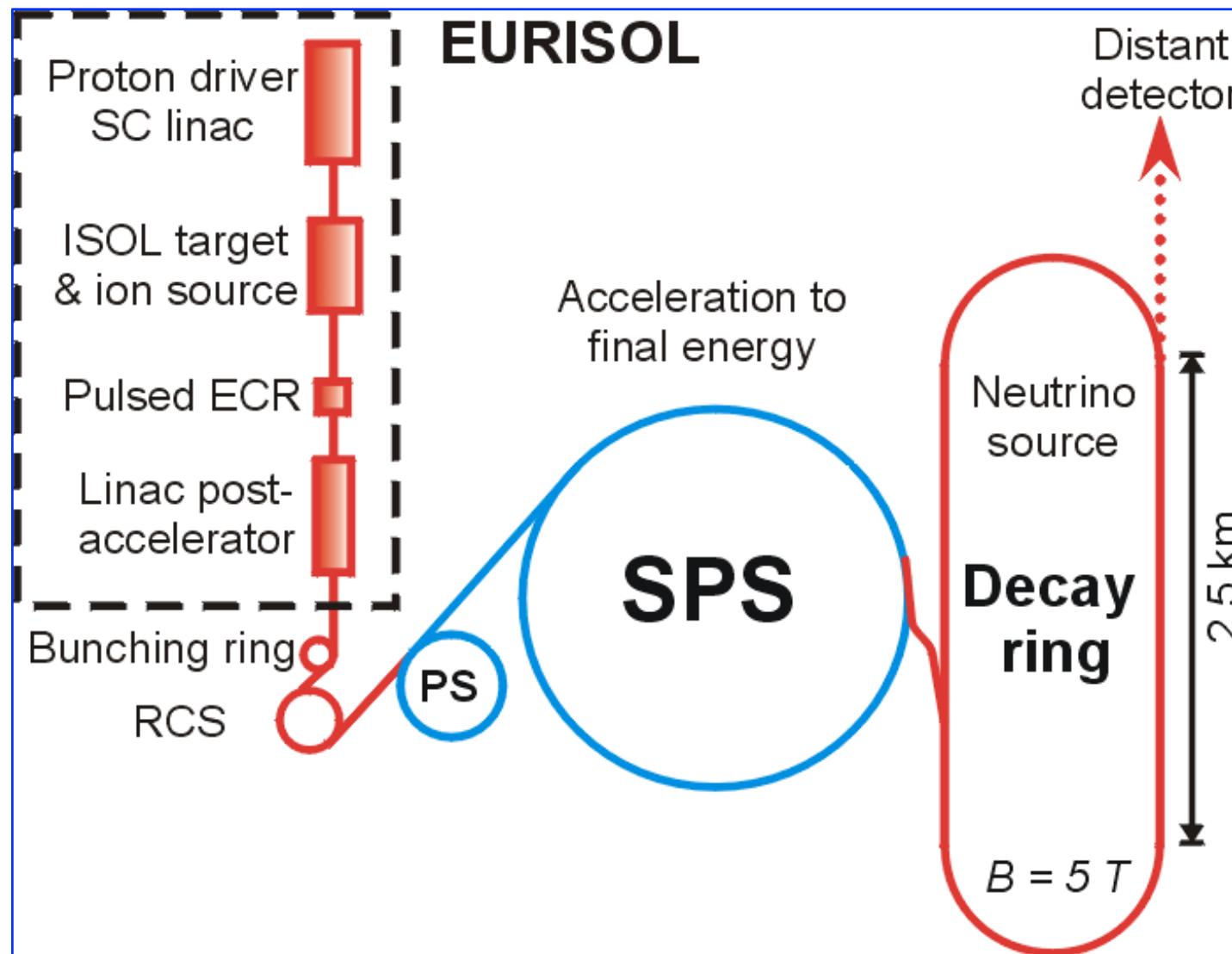


Figure 2. Gamow-Teller strength distribution in the EC/ β^+ decay of ^{148}Dy .

Algora *et al.*, PRC 70 (2004) 064301,
E. Nácher, Phd Thesis, Valencia

Beta-beam facility



$^6\text{He}, ^{18}\text{Ne}$

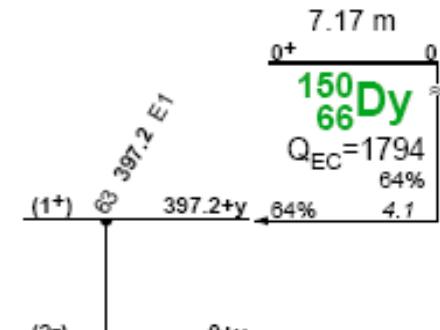
P. Zucchelli
Phys. Let. B532
(2002) 166

Project under
study, related to
EURISOL

Monocromatic neutrino beams: selection of candidates

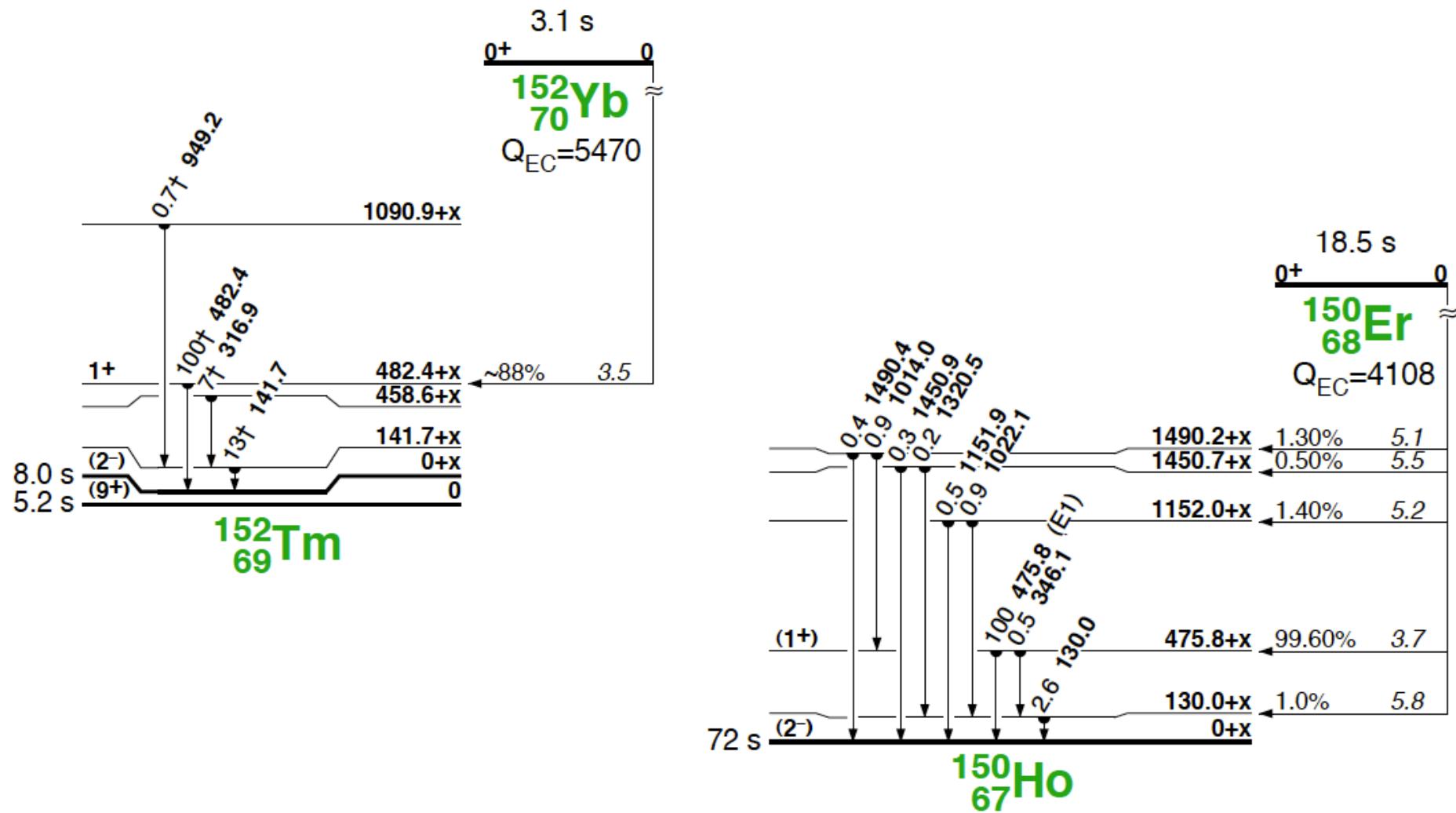
EC beam ideal candidates:

- “single” state populated
- large EC/ β^+ ratio
- appropriate half life (acceleration, vacuum loses, etc)
- small other-radioactivities
- good production

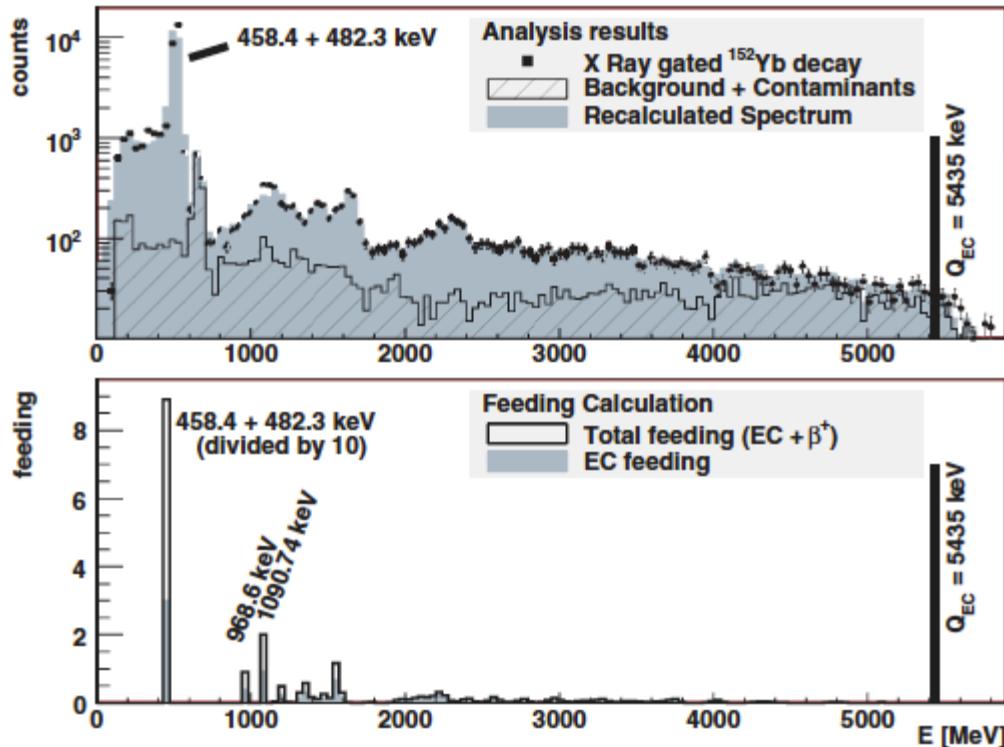


ID	Parent Nucleus	Daugther Nucleus	Half-life	(EC+ β^+) / α branch of the decay	EC int. [%] (to the level of interest)	Ex Daugther Level [keV]	I [%]	Q value [keV]	Yield (ISOLDE) [atoms/ μC]
1	$^{148}_{66}\text{Dy}_{82}$	$^{148}_{65}\text{Tb}_{83}$	3.1 m	100*	92.5	620	96	2678	2.9×10^8
2	$^{148}_{66}\text{Er}_{80}$	$^{148}_{67}\text{Ho}_{81}$	4.6 s	100*	8.8	0.0 (+?)	70 (+?)	6800	-
3	$^{150}_{66}\text{Er}_{82}$	$^{150}_{67}\text{Ho}_{83}$	18.5 s	100*	59.4*	476+X	99.6	4108	7×10^6
4	$^{150}_{66}\text{Dy}_{84}$	$^{150}_{65}\text{Tb}_{85}$	7.17m	64/36	64.0*	397+Y	64	1794	2.4×10^8
5	$^{152}_{70}\text{Yb}_{82}$	$^{152}_{69}\text{Tm}_{83}$	3.1s	100*	29.0	482	88	5470	-
6	$^{152}_{69}\text{Tm}_{83}$	$^{152}_{68}\text{Er}_{84}$	8s	100*	50	4300	Res.	8700	-
7	$^{152}_{68}\text{Er}_{84}$	$^{152}_{67}\text{Ho}_{85}$	10.3s	(10/90)	8.0	179.4	10%	3105	7×10^7
8	$^{154}_{72}\text{Hf}_{82}$	$^{154}_{71}\text{Lu}_{83}$	2s	100*	-	-	-	6700	(Difficult)
9	$^{154}_{70}\text{Yb}_{84}$	$^{154}_{69}\text{Tm}_{85}$	0.404s	(7.2/92.8)	3.3	133.2	7.2	4490	2×10^8
10	$^{154}_{66}\text{Er}_{86}$	$^{154}_{65}\text{Ho}_{87}$	3.73m	99.53/0.47	96.8	26.9	99.53	2032	6×10^8
11	$^{156}_{72}\text{Hf}_{84}$	$^{156}_{71}\text{Lu}_{85}$	25ms	(alpha>81%)	-	-	-	5910	-
12	$^{156}_{70}\text{Yb}_{86}$	$^{156}_{69}\text{Tm}_{87}$	26.1s	90/10	61.0	115.2	90	3570	3.2×10^7
13	$^{156}_{66}\text{Er}_{88}$	$^{156}_{65}\text{Ho}_{89}$	19.5m	100*	58 (+38)	82.1 (+87.5)	58 (+38)	1370	6×10^8

Beta-beam facility: the NP relation



Our TAS results for $^{152}\text{Yb} \rightarrow ^{152}\text{Tm}$ decay



E. Estevez, et al. PRC 84, 034304 (2011)

E. Estevez, PhD thesis, Valencia

Other isotopes of interest: ^{150}Er , ^{156}Yb

Nuclear Data Sheets

$$\text{EC} + \beta^+ = 87.2(5)\%$$

$$\text{EC} = 29(3)\%$$

Our results:

$$\text{EC} + \beta^+ = 89(2)\%$$

$$\text{EC} = 30(3)\%$$

E_{lev} (keV)	J^π	$I_{\text{EC}} (\%)$		$I_{\text{EC}+\beta^+} (\%)$	
		TAS	HR	TAS	HR
141.6	1^+			1.0(3)	3.5(9)
458.4	$0^+, 1^+$			2.7(4)	8.0(6)
482.3	1^+	30(3)	29(3)	89(2)	87.2(5)
968.6	$0^+, 1^+$	0.4(2)	0.22(5)	0.9(5)	0.52(9)
1090.7	$0^+, 1^+$	0.9(2)	0.4(1)	2.0(3)	0.8(3)
1120-Q		5.7(2)		8.0(3)	
Total		37.0(7)	33.3(3)	99.9(2)	100.0(1)

THANK YOU

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