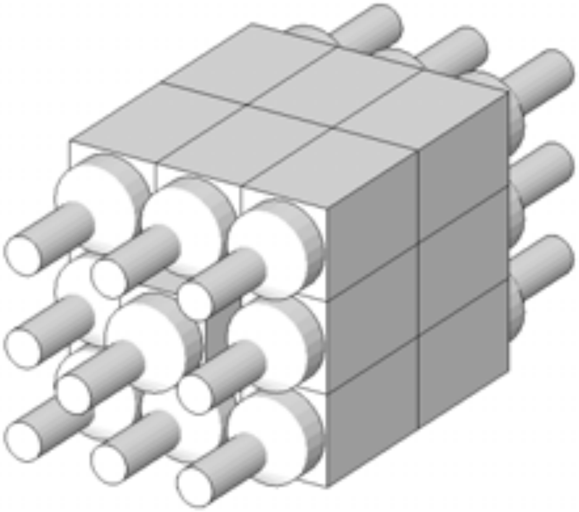
Total Absorption Gamma Spectroscopy (TAGS) Applications (beta decay)

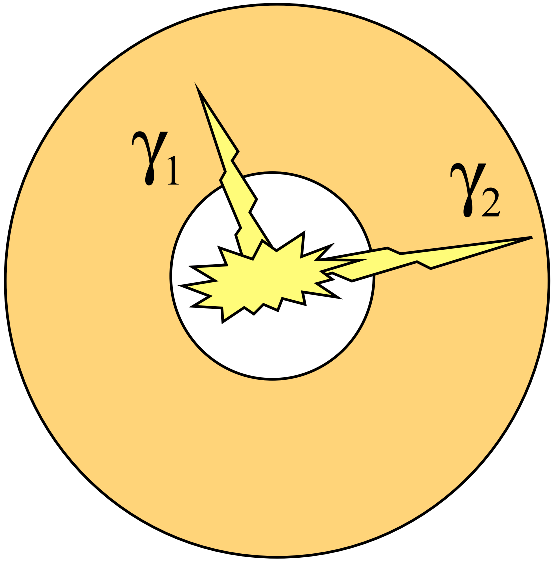
A. Algora

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



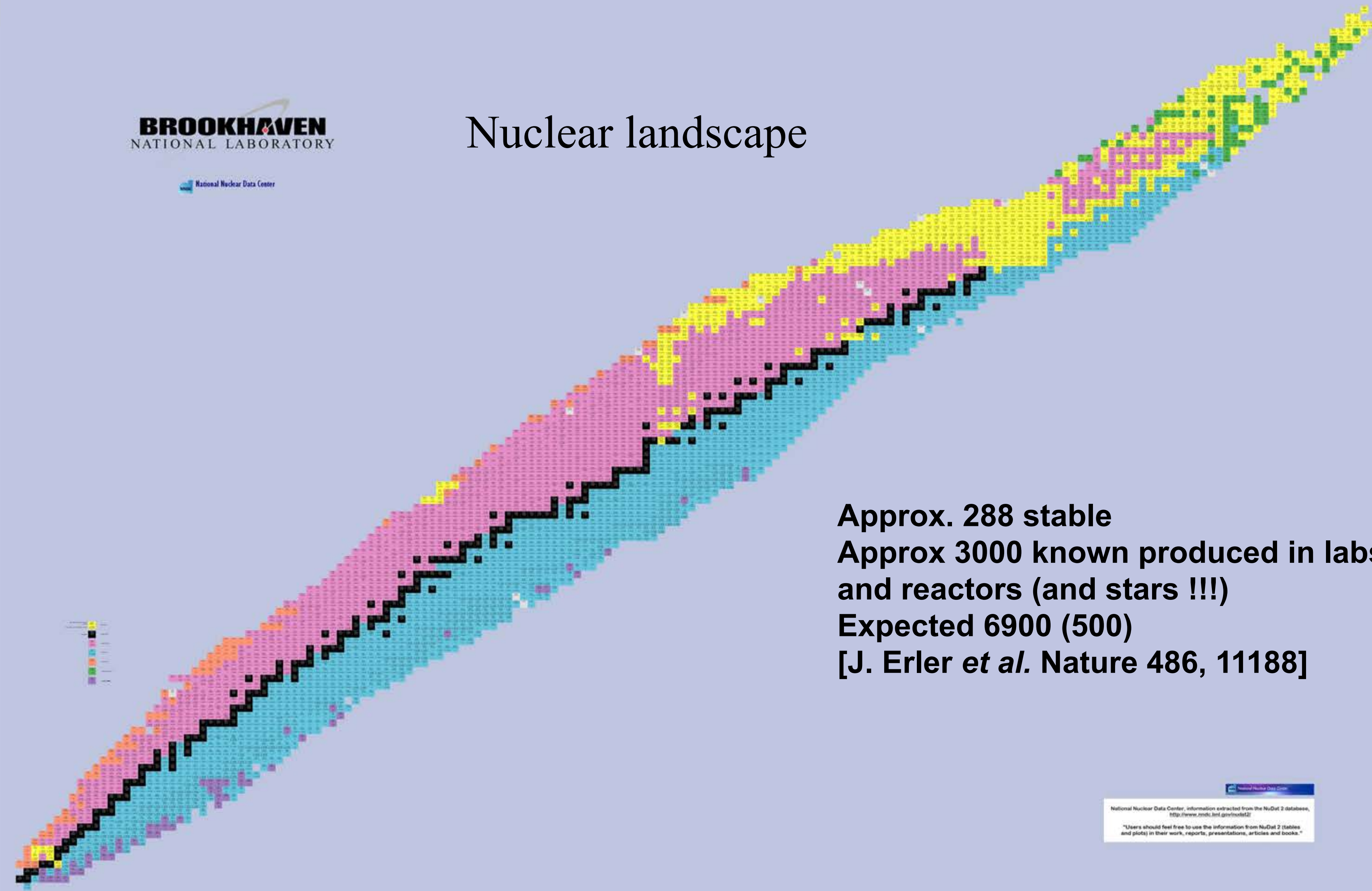
Master School Valencia

January 2020



Why beta decay is so important ?

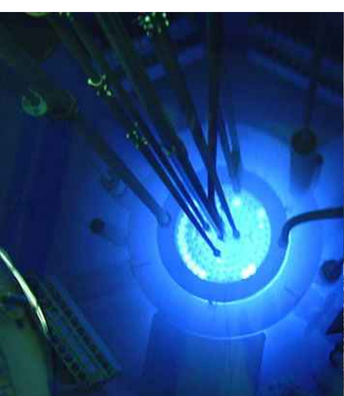
Nuclear landscape

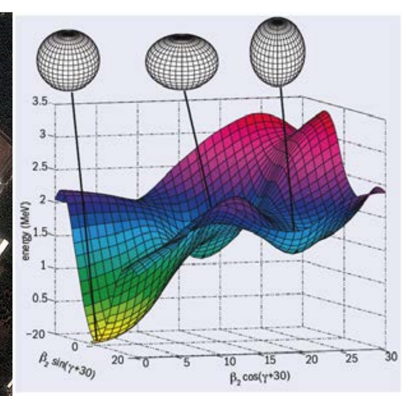


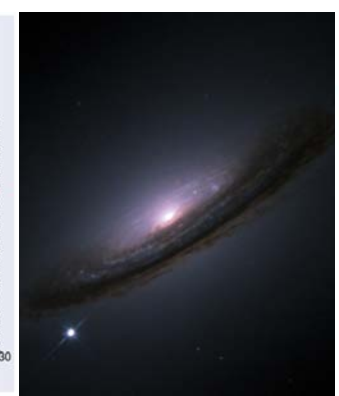
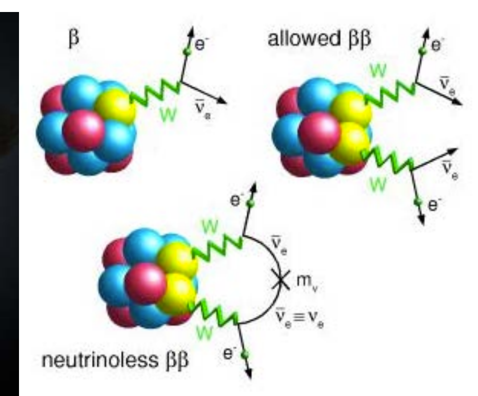
Approx. 288 stable
Approx 3000 known produced in labs and reactors (and stars !!!)
Expected 6900 (500)
[J. Erler *et al.* Nature 486, 11188]

Applications of the technique (all can not be covered)

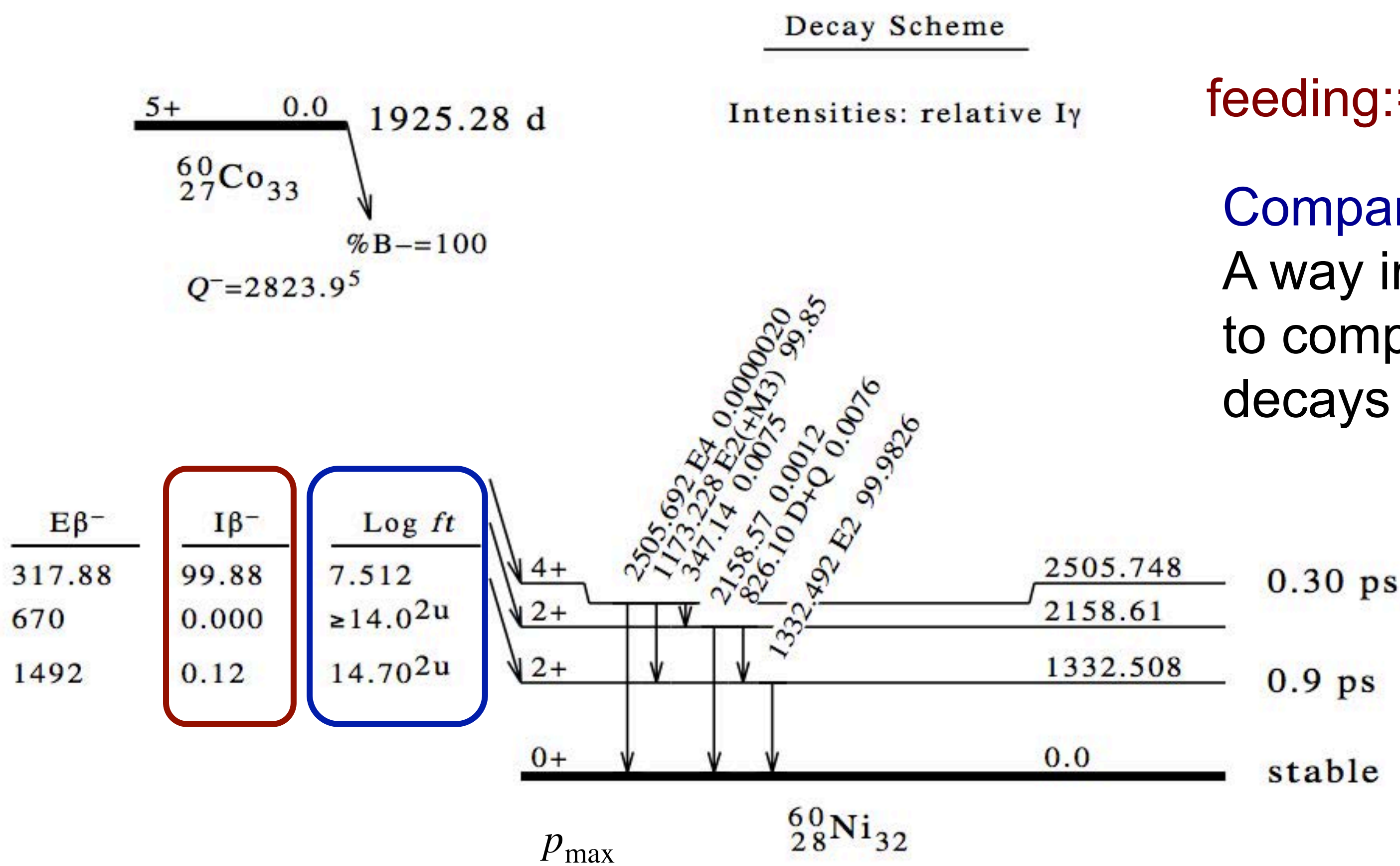
- Reactor applications (decay heat and neutrino physics)
- Nuclear structure applications (model validation and nuclear shape determination)
- Astrophysical applications (model validation and gamma and beta delayed neutron competition)
- Fundamental applications (double beta decay)





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



feeding:=I_β = P_f*100

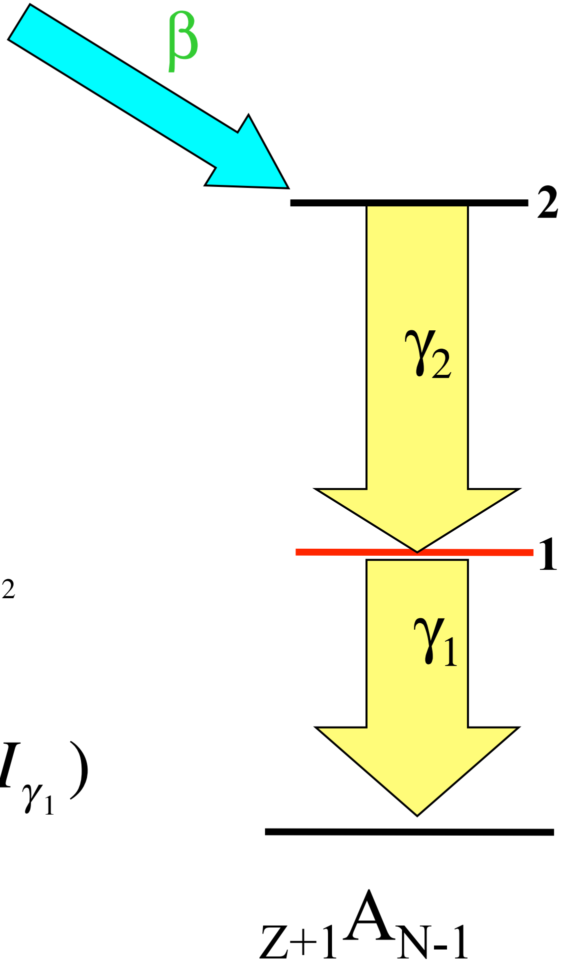
Comparative half-life: ft

A way introduced by Fermi to compare the different decays (Q, Z')

$$f(Z',Q) = const \cdot \int_0^{p_{max}} F(Z',p)p^2(Q-E_e)^2\,dp, \qquad t_f = \frac{T_{1/2}}{P_f}$$

$$ft_f = const'\frac{1}{\left|M_{if}\right|^2} \qquad B(GT) \sim \left|M_{if}^{\sigma\tau}\right|^2 \qquad T_{1/2} = \frac{\ln(2)}{\lambda} = \tau\ln(2)$$

The starting point: measuring the β-feeding

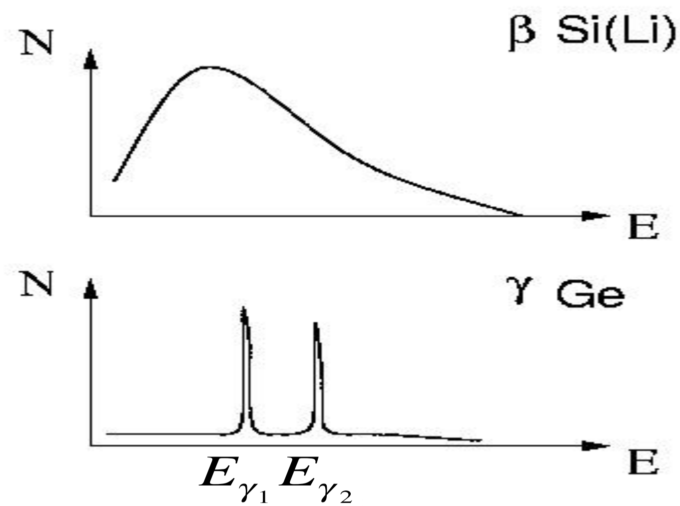


Real situation

$$f_2 = I_{\gamma_2}$$

$$f_1 = 0$$

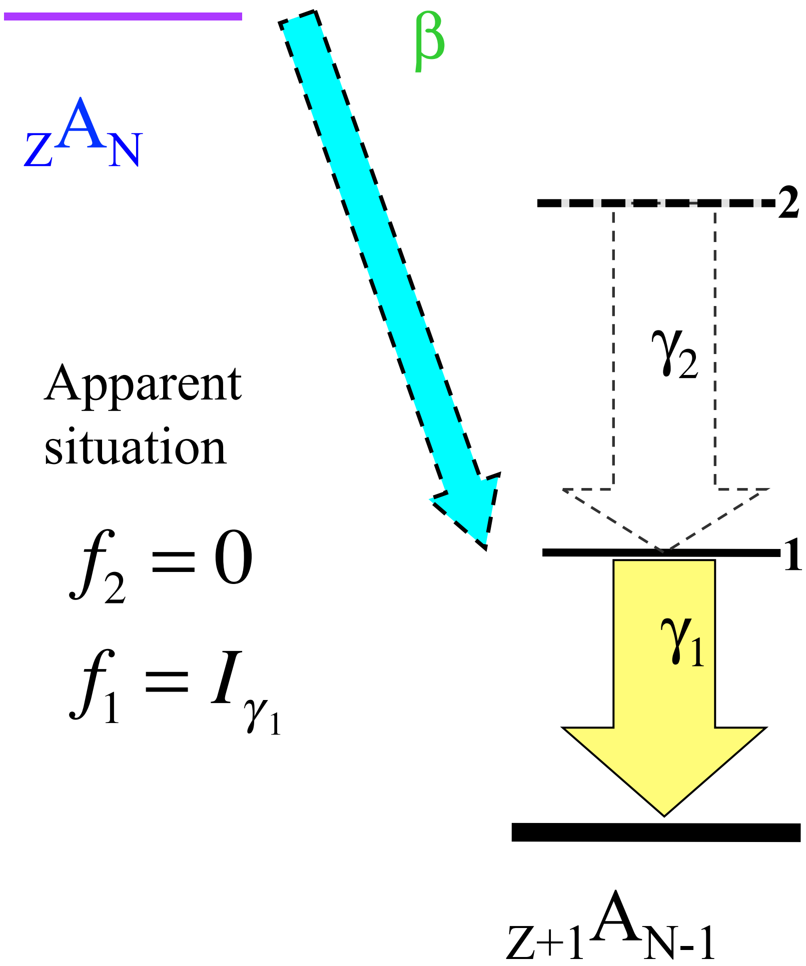
$$(I_{\gamma_2} = I_{\gamma_1})$$



- Ge detectors are conventionally used to construct the level scheme populated in the decay

- From the γ intensity balance we deduce the β-feeding

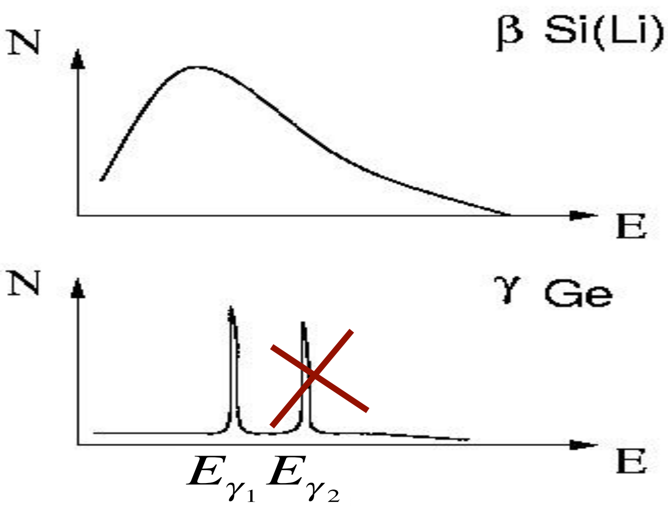
Experimental perspective: the problem of measuring the β- feeding



Apparent situation

$$f_2 = 0$$

$$f_1 = I_{\gamma_1}$$



• What happens if we miss some intensity

$$Single\ \gamma \sim \varepsilon$$

$$Coinc\ \gamma_1\gamma_2 \sim \varepsilon_1\varepsilon_2$$

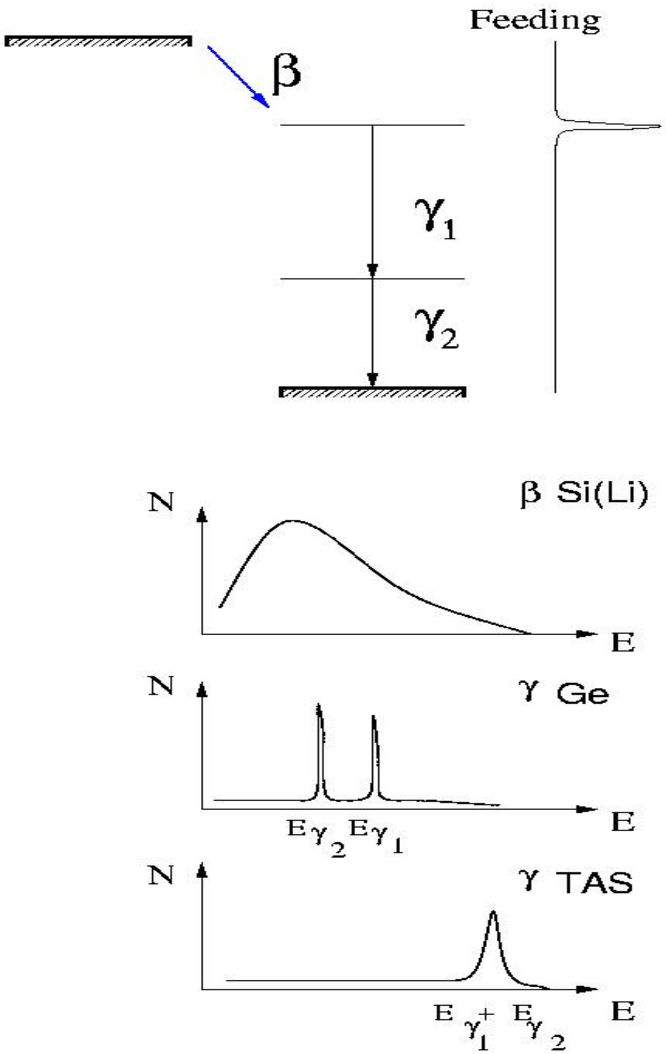
Pandemonium (The Capital of Hell)

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

John Martin (~ 1825), presently at Louvre

Hardy et al., Phys. Lett. 71B (1977) 307

TAGS measurements



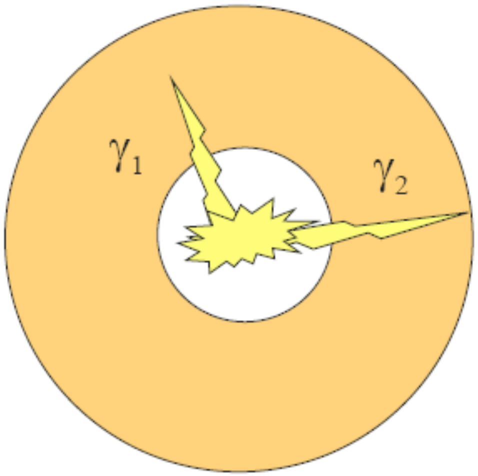
Since the gamma detection is the only reasonable way to solve the problem, we need a highly efficient device:

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.

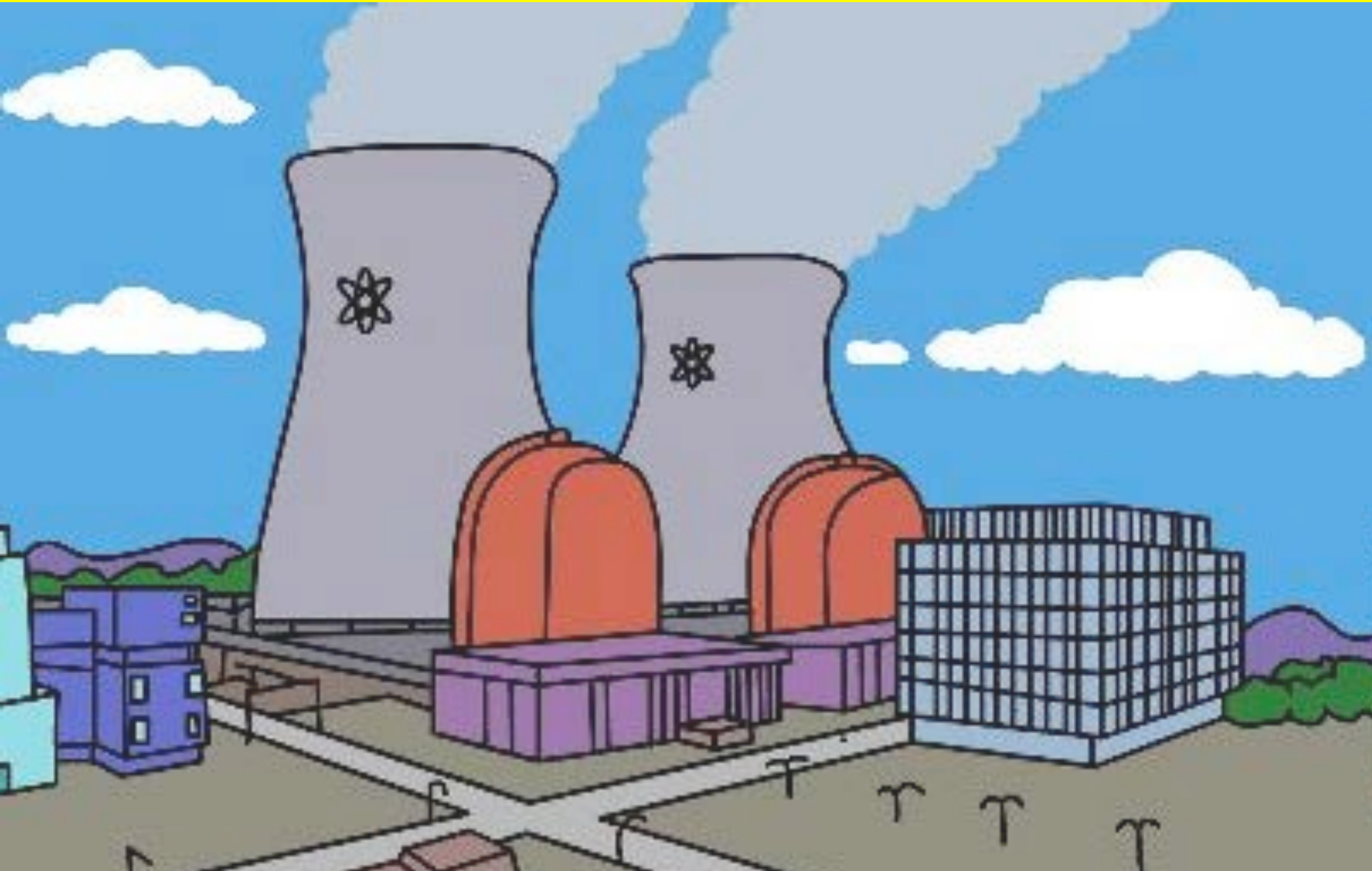
A TAS is like a calorimeter!

Big crystal, 4π

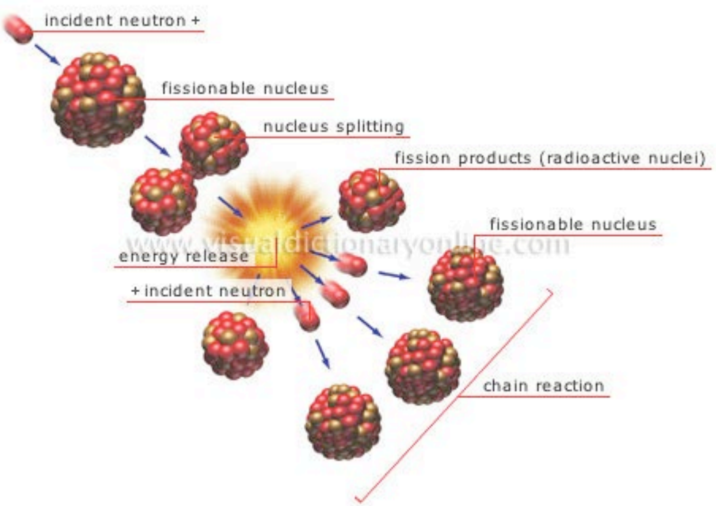


$$d = R(B) \cdot f$$

TAS and reactor applications



Fission process energy balance



Energy released in the fission of ^{235}U	
Energy distribution	MeV
Kinetic energy light fission fragment	100.0
Kinetic energy heavy fission fragment	66.2
Prompt neutrons	4.8
Prompt gamma rays	8.0
Beta energy of fission fragments	7.0
Gamma energy of fission fragments	7.2
Subtotal	192.9
Energy taken by the neutrinos	9.6
Total	202.7

Each fission is approximately followed by 6 beta decays (sizable amount of energy)

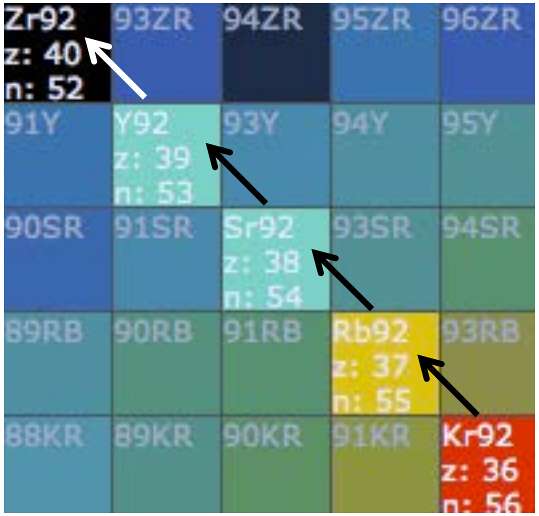
A reactor produces 10^{20} ν/s

James, J. Nucl. Energy 23 (1969) 517

Example of elementary fission

$$n + {}^{235}U \rightarrow {}^{236}U \rightarrow {}^{92}Kr + {}^{141}Ba + 3n$$

4 decays



3 decays

$${}^{236}U \qquad Z/N = 92/144 = 0.64$$

$$SN(Z=40) \qquad \mathrm{Z/N} = 40/52 = 0.77$$

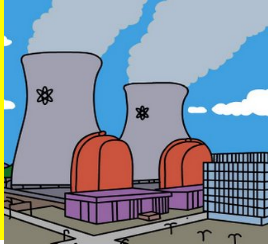
$${}^{92}Kr \qquad \mathrm{Z/N} = 36/56 = 0.64$$

$$SN(Z=59) \qquad \mathrm{Z/N} = 59/82 = 0.72$$

$${}^{141}Ba \qquad \mathrm{Z/N} = 56/85 = 0.66$$

Fision products will have a neutron excess compared with stable nuclei around Z=50. So they will decay beta minus towards stability

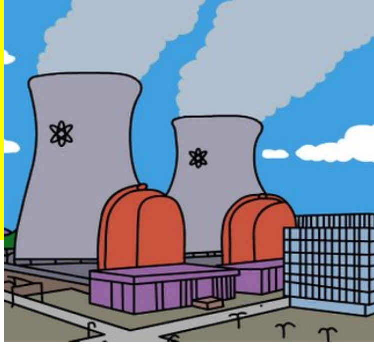
1. Problem: decay heat



"Definition": Energy released when you turn off the reactor. It is mainly related to the decay of the fission products, not including the part taken away by the neutrinos (obviously).
This is the dominant part, but there are additional sources (decay of actinides produced by succesive neutron captures, fission induced by delayed neutrons and reactions induced by spontaneus fission, etc.)
The total can be divided in an electromagnetic component (EM,gamma part), ligth particle component (LP,beta part) and heavy particle part (alphas, spont. fission products, etc). This division is of interest for dosimetry (charge particles get contained).

$$\begin{aligned}
\overline{E}_{LP} &= \overline{E}_{\beta-} + \overline{E}_{\beta+} + \overline{E}_{e-} + \cdots \\
\overline{E}_{EM} &= \overline{E}_{\gamma} + \overline{E}_{x-ray} + \overline{E}_{anni.rad.} + \cdots \\
\overline{E}_{HP} &= \overline{E}_{\alpha} + \overline{E}_{SF} + \overline{E}_{p} + \overline{E}_{n} + \cdots
\end{aligned}$$

Decay heat: how to determine it ?



- Measure it (lacks flexibility and it is costly)
- Try to predict or calculate in the best way
  - Statistical method (the first solution)

    Way and Wigner, Phys. Rev. 73 (1948) 1318

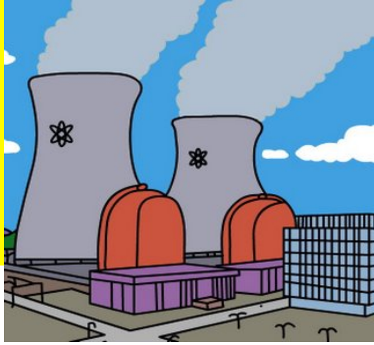
$$B(t) = 1.26 t^{-1.2} MeV/s$$

$$\Gamma(t) = 1.40 t^{-1.2} MeV/s$$

later, Griffin, Phys. Rev. 134 (1964) B817

  - Summation calculations (next slide)

Decay heat: summation calculations



$$f(t) = \sum_i E_i \lambda_i N_i(t)$$

E_i Decay energy of the nucleus i (gamma, beta or both)

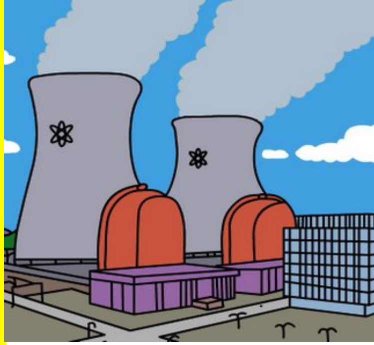
λ_i Decay constant of the nucleus i $\quad \lambda = \dfrac{\ln(2)}{T_{1/2}}$

N_i Number of nuclei i at the cooling time t

Requirements for the calculations: large databases that contain all the required information (half-lives, mean γ- and β-energies released in the decay, n-capture cross sections, fission yields, this last information is needed to calculate the inventory of nuclides)

The inventory of nuclides:

$$f(t) = \sum_i E_i \lambda_i N_i(t)$$



Solve a linear system of coupled first order differential equations

$$\frac{dN_i}{dt} = -(\lambda_i + \sigma_i \phi) N_i + \sum_j f_{j \to i} \lambda_j N_j$$

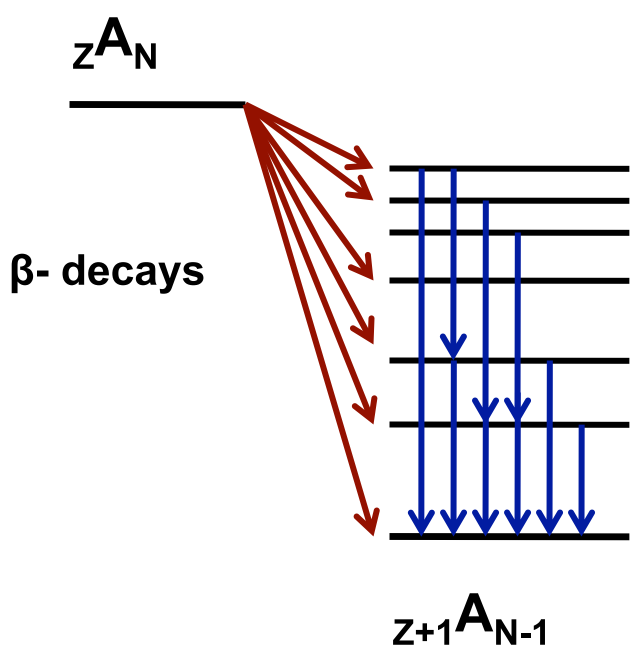
$$+ \sum_k \mu_{k \to i} \sigma_k \phi N_k + y_i F$$

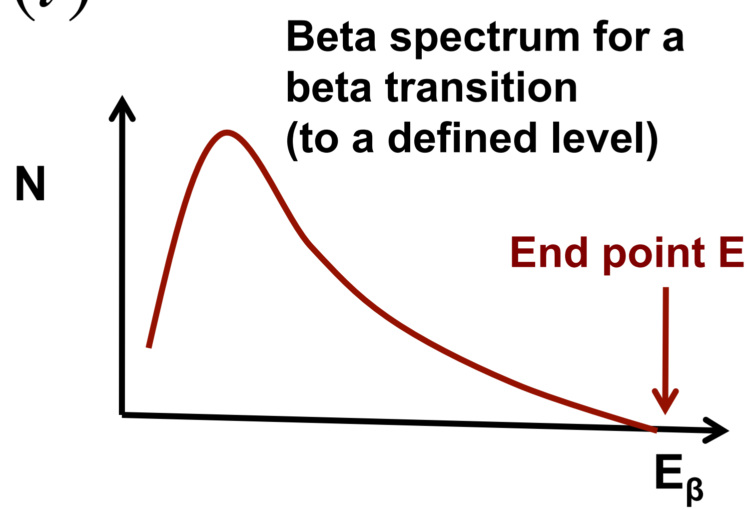
N_i	Number of nuclides i
λ_i	decay constant i
σ_i	capture cross section i
ϕ	neutron flux
$f_{i \to j}$	branching ratio of j to i decay
$\mu_{k \to i}$	production rate of i per one neutron capture of k
y_i	fission yield of i
F	fission rate

How the mean energies are determined ?

$$f(t) = \sum_i E_i \lambda_i N_i(t)$$

DATABASES:
feeding or beta decay prob. distributions



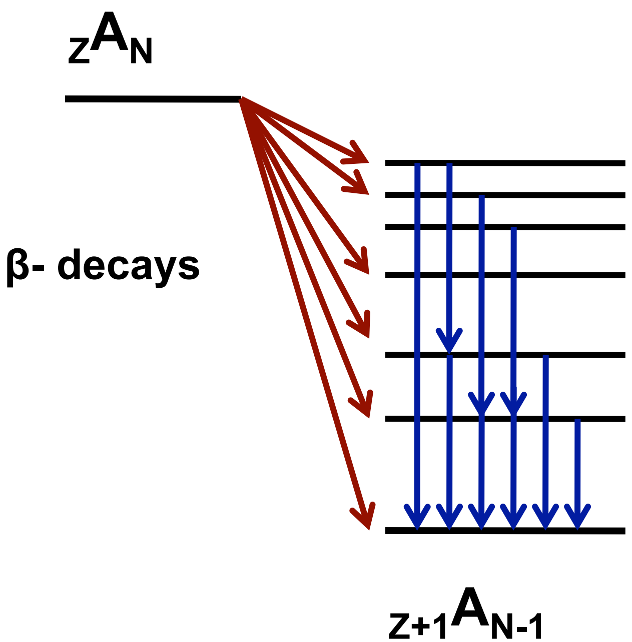


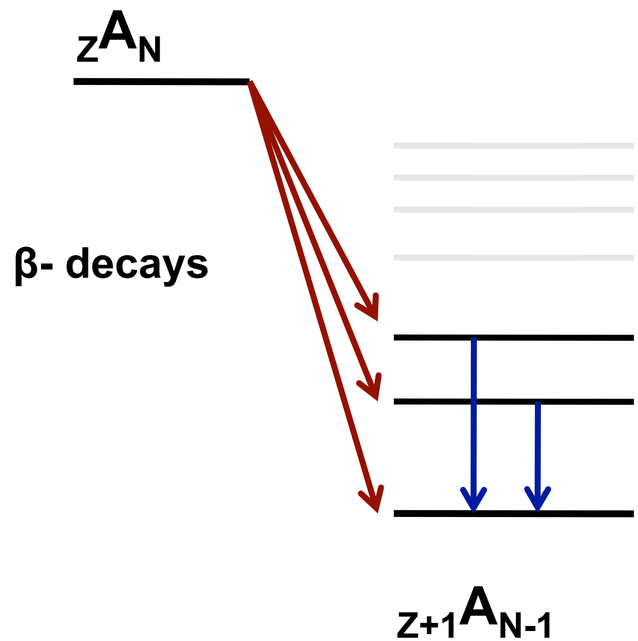
$$\bar{E}_\beta = \sum_i I_\beta(E_i)\langle E_{\beta,i}\rangle$$

$$\bar{E}_\gamma = \sum_i I_\beta(E_i) E_i$$

Mean energies and Pandemonium

$$f(t) = \sum_i E_i \lambda_i N_i(t)$$





$$\overline{E}_\beta = \sum_i I_\beta(E_i)\langle E_{\beta,i}\rangle$$

$$\overline{E}_\gamma = \sum_i I_\beta(E_i) E_i$$

$\overline{E}_\beta$ overestimation

$\overline{E}_\gamma$ underestimation

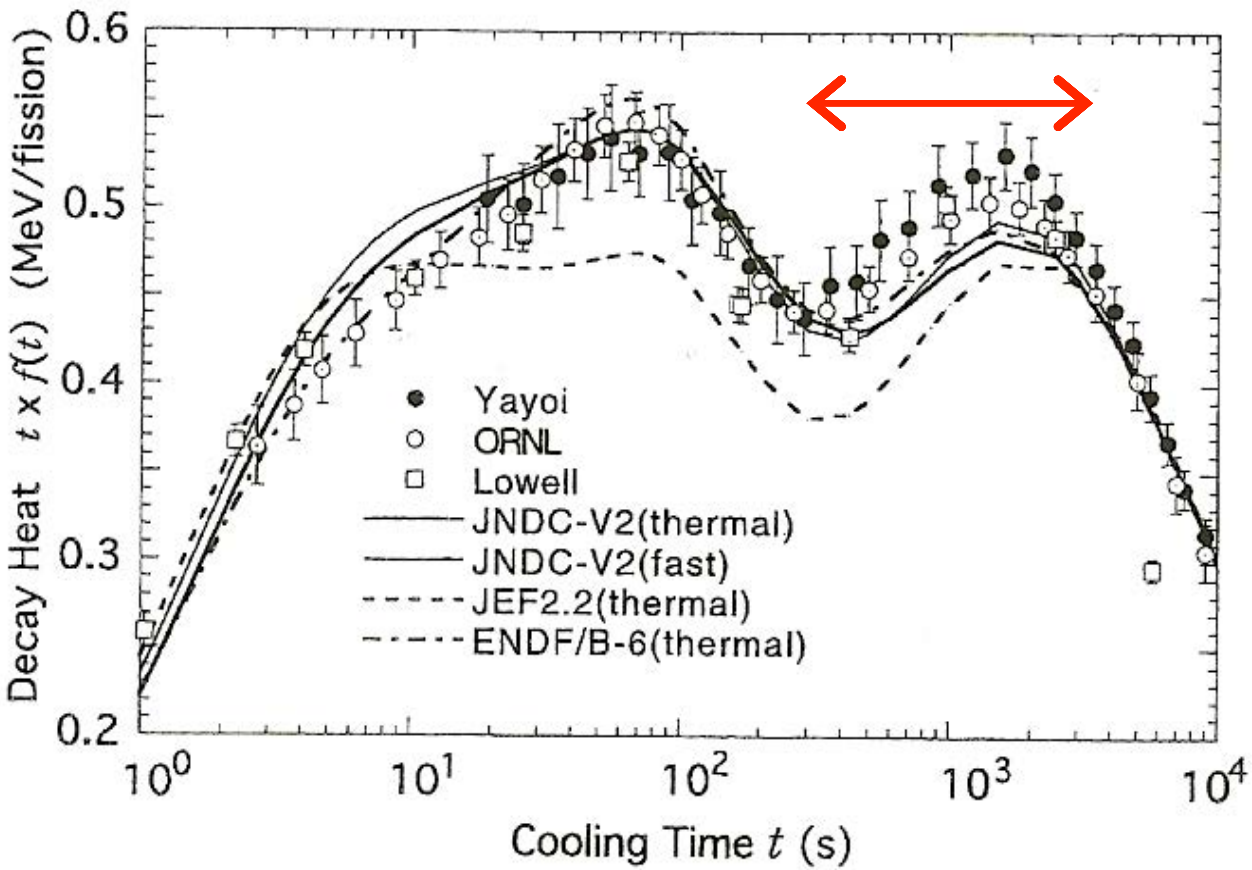
The beginning (for us) …

We got interested in the topic after the work of Yoshida and co-workers (Journ. of Nucl. Sc. and Tech. 36 (1999) 135)

^{239}Pu example (similar situation for ^{235,238}U)

Detective work: identification of some nuclei that could be blamed for the anomaly ^{102,104,105}Tc

^{239}Pu example (γ component)



The famous list
WPEC-25 (IAEA working group)

Radionuclide	Priority	Radionuclide	Priority	Radionuclide	Priority
35-Br-86	1	41-Nb-99	1	52-Te-135	2
35-Br-87	1	41-Nb-100	1	53-I-136	1
35-Br-88	1	41-Nb-101	1	53-I-136m	1
36-Kr-89	1	41-Nb-102	2	53-I-137	1
36-Kr-90	1	42-Mo-103	1	54-Xe-137	1
37-Rb-90m	2	42-Mo-105	1	54-Xe-139	1
37-Rb-92	2	43-Tc-102	1	54-Xe-140	1
38-Sr-89	2	43-Tc-103	1	55-Cs-142	3
38-Sr-97	2	43-Tc-104	1	56-Ba-145	2
39-Y-96	2	43-Tc-105	1	57-La-143	2
40-Zr-99	3	43-Tc-106	1	57-La-145	2
40-Zr-100	2	43-Tc-107	2		
41-Nb-98	1	51-Sb-132	1		

37 nuclides, of which 23 were given first priority. In blue what has been measured by us

Our favorite place for “polar” experiences

Published cases until know:

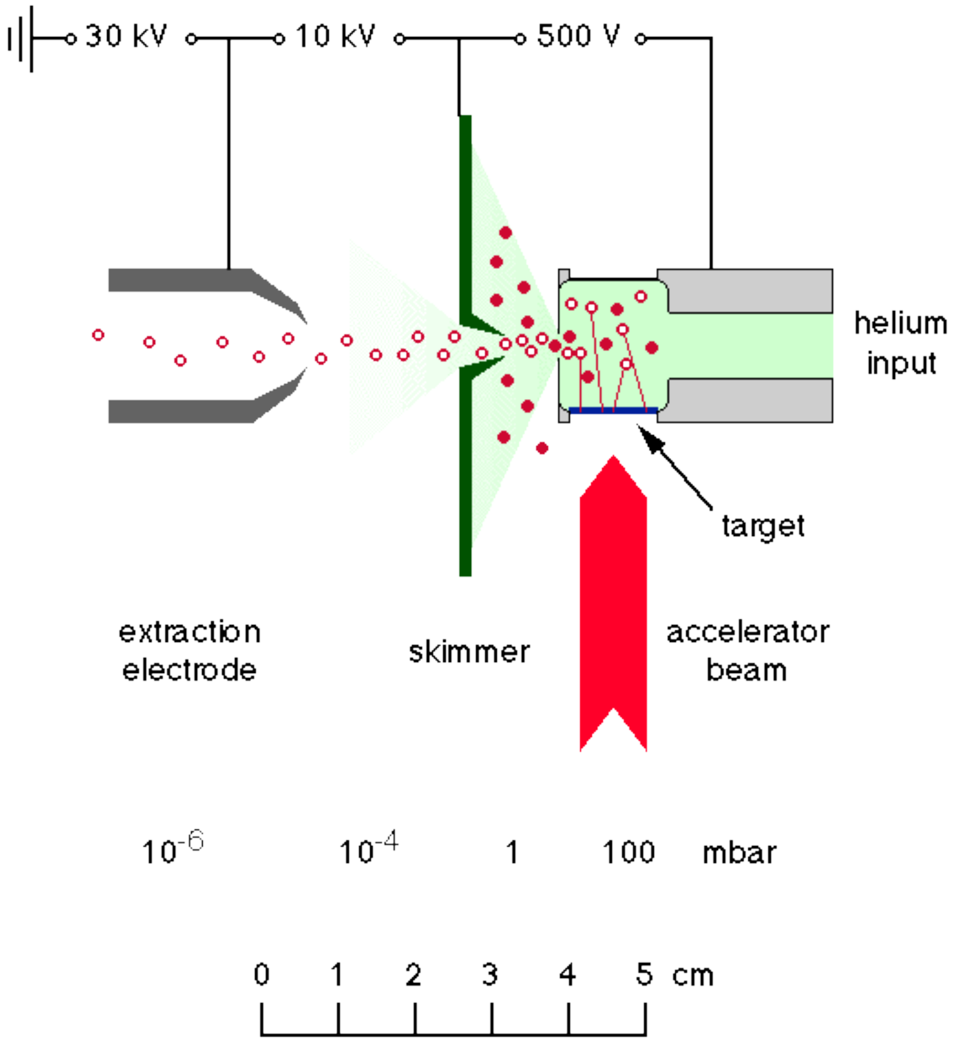
In relation to Yoshida’s work (^{102,104,105}Tc)

WPEC-25 (^{102,104,105,106,107}Tc, ^{105}Mo, ^{101}Nb)

More recently ^{86,87,88}Br, ^{90,92,94}Rb

^{100,100m,102,102m}Nb, etc., etc.

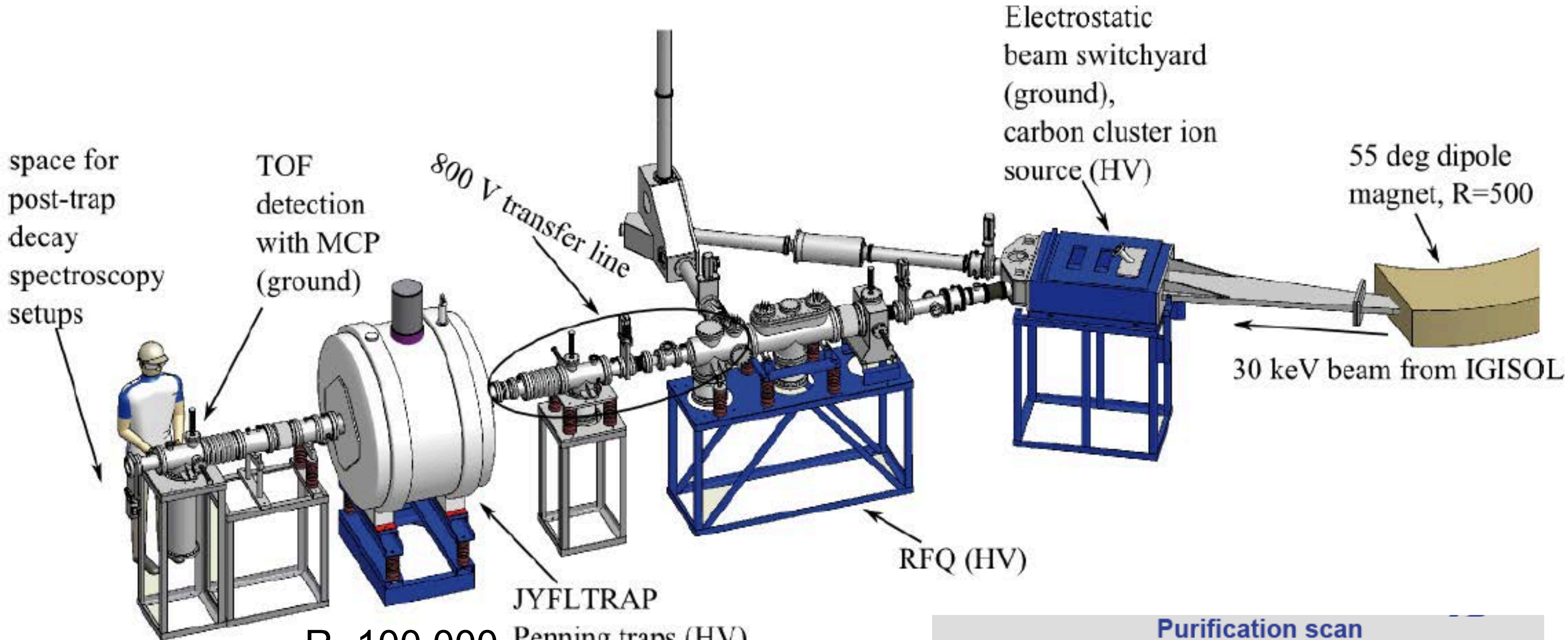
Odd ISOL case: The ion guide technique



Generic ion guide: the nuclear reaction products are stopped in a gas and are transported through a differential pumping system into the accelerator stage of the mass separator.

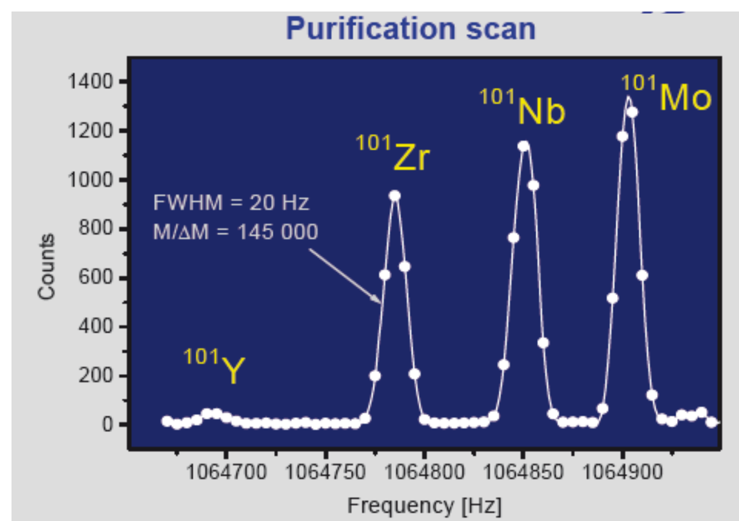
The process is fast enough for the ions to survive as single charged ions. The system is chemically insensitive and very fast (sub-ms).

Why JYFL?: IGISOL + a bonus

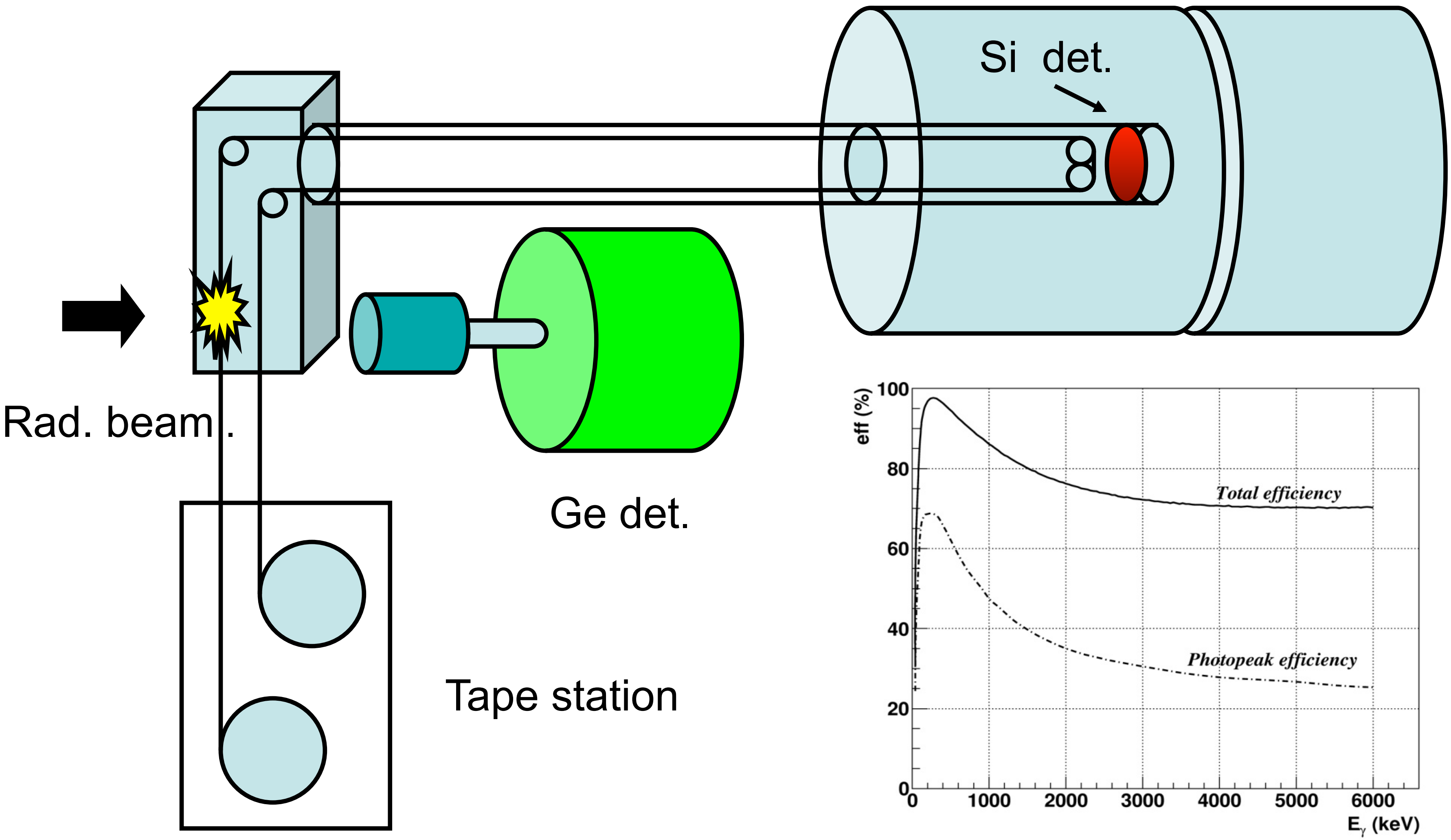


R~100 000

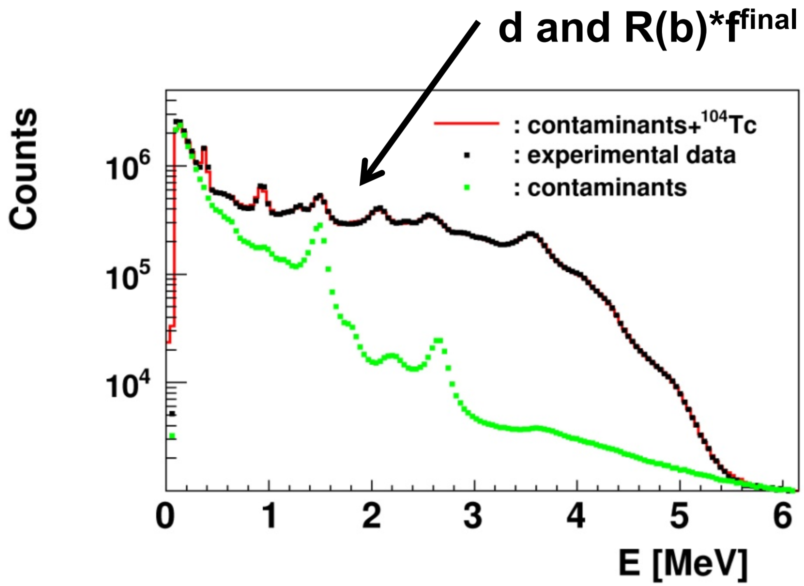
The main reasons are the chemical insensitivity (ion guide technique), high purity by means of purification of the beam using the JYFLTRAP and acceptable yields!



First experimental setup at Jyväskylä



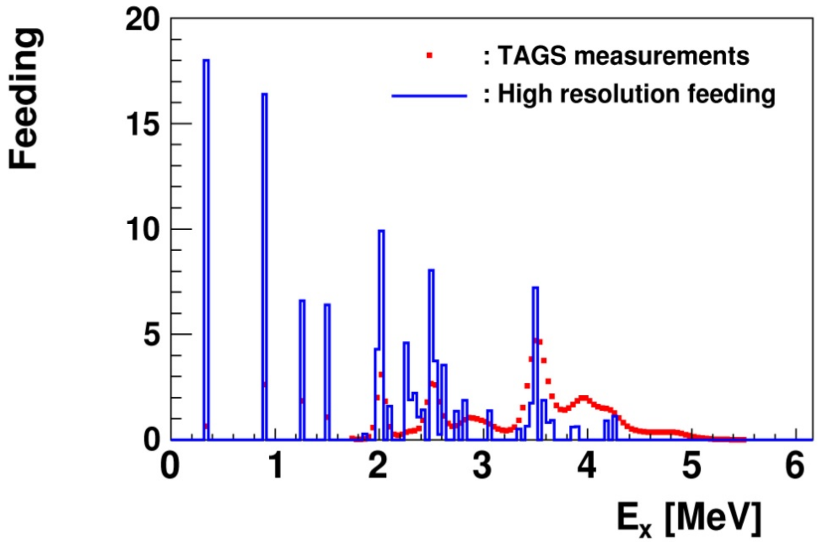
Results of the analysis for ^{104}Tc

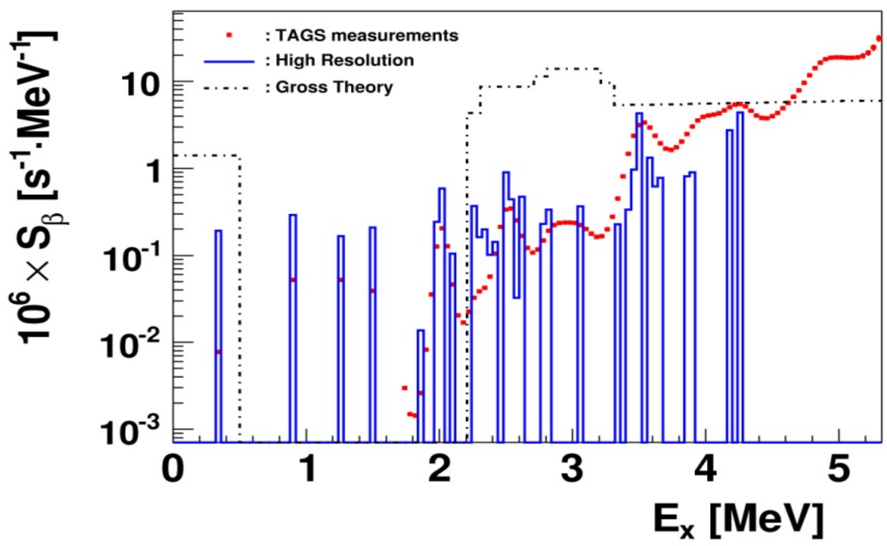


$T_{1/2}$ = 1098(18) s; Q_β= 5516(6) keV

E_β(TAGS) = 931 (10) keV
E_β(JEFF-3.1) = 1595 (75) keV
ΔE_β = -664 keV

E_γ(TAGS) = 3229 (24) keV
E_γ(JEFF-3.1) = 1890 (31) keV
ΔE_γ = 1339 keV

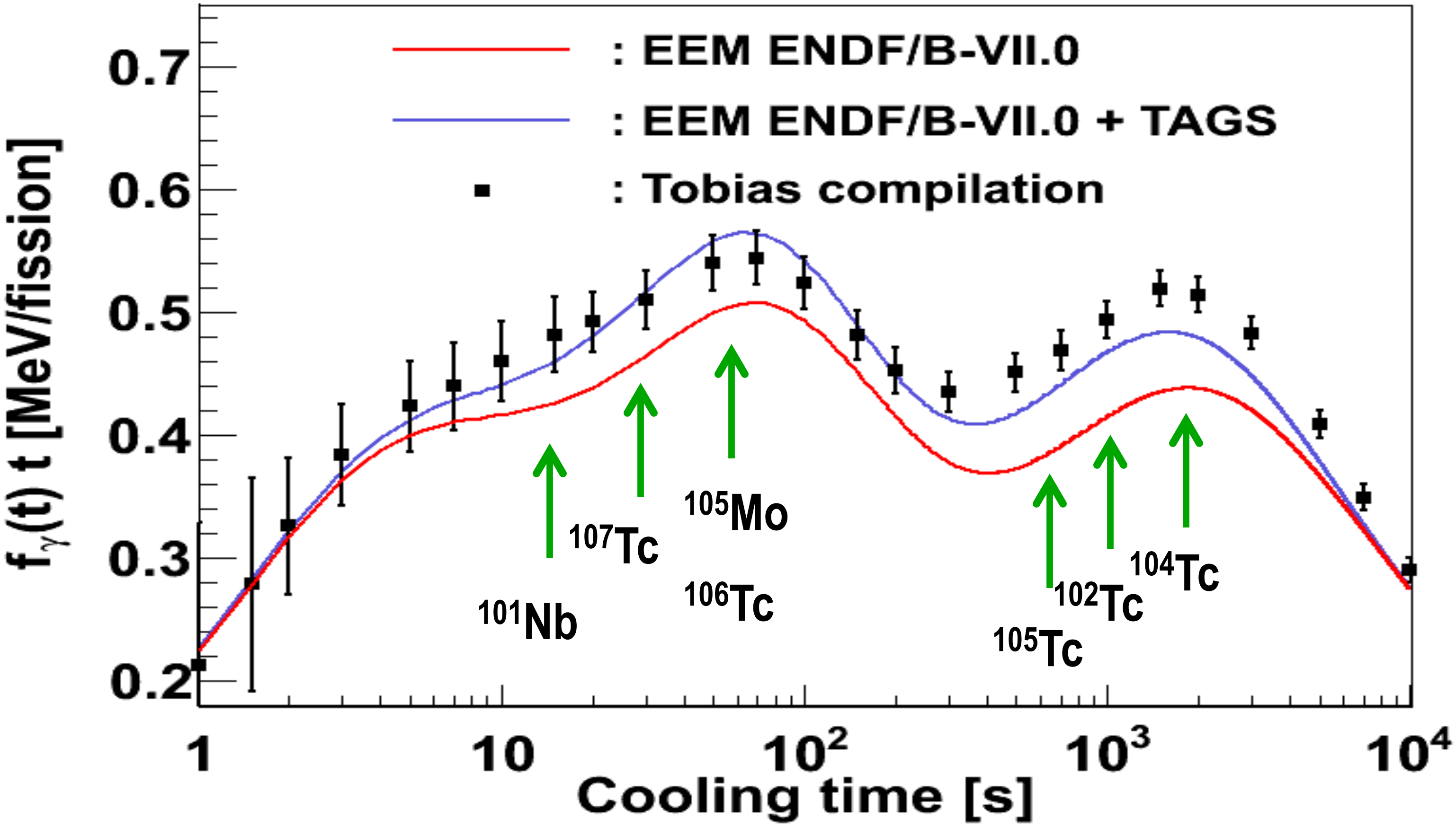




D. Jordan, PhD Thesis, Valencia, 2010

Impact of the results for ^{239}Pu: electromagnetic component

Motivated by Yoshida *et al.* (Journ. of Nucl. Sc. and Tech. 36 (1999) 135) and WPEC-25



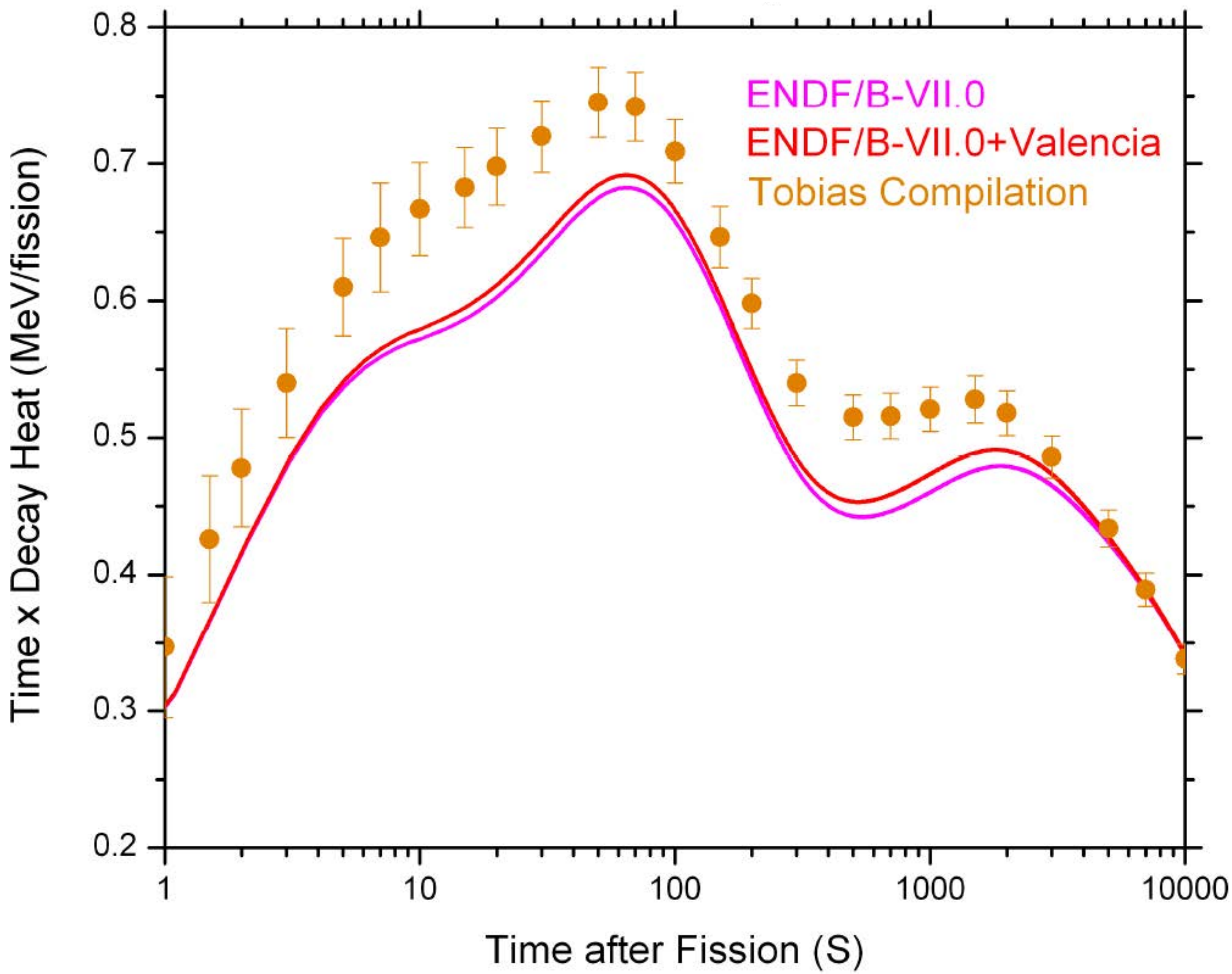
DH Courtesy A. Sonzogni

PhD Thesis D. Jordan , A. Algora, Phys. Rev. Letts. 105, 202505,

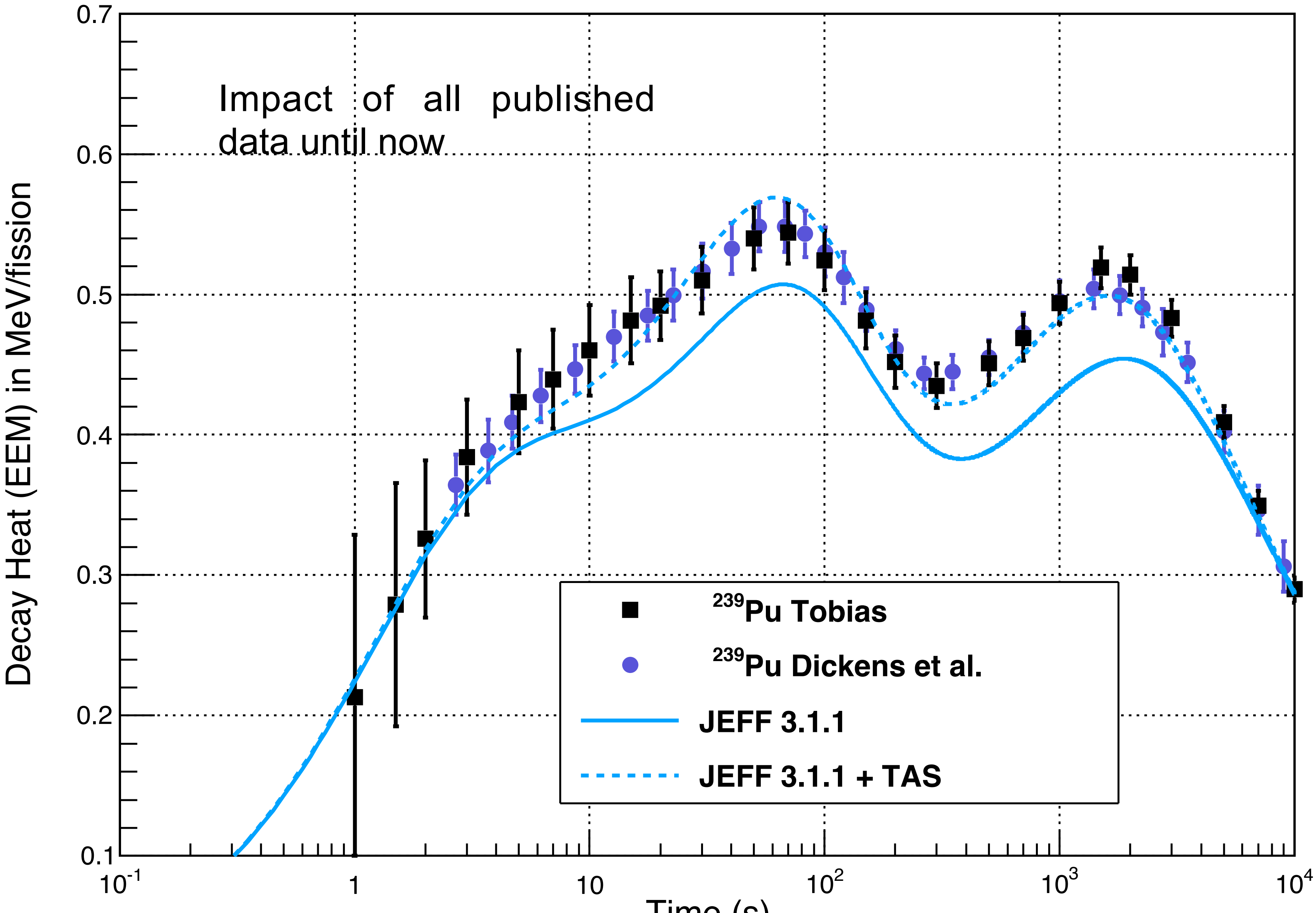
K. P. Rykaczewsky, Physics 3, 94 (2011)

Results also confirmed by R. W. Mills using JEFF 3.1

Impact of the earlier results for ^{235}U

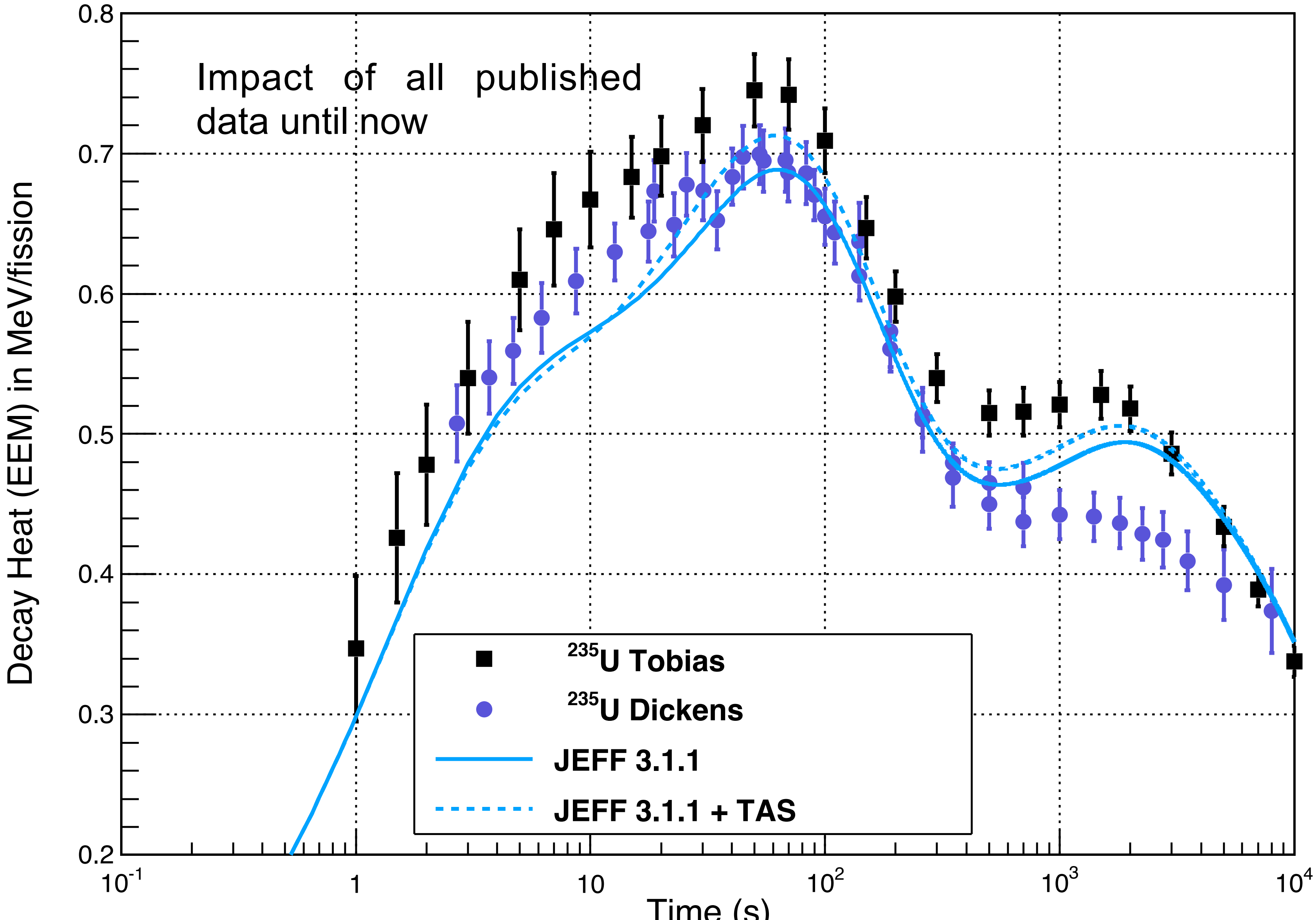


Impact of the measurements for ^{239}Pu



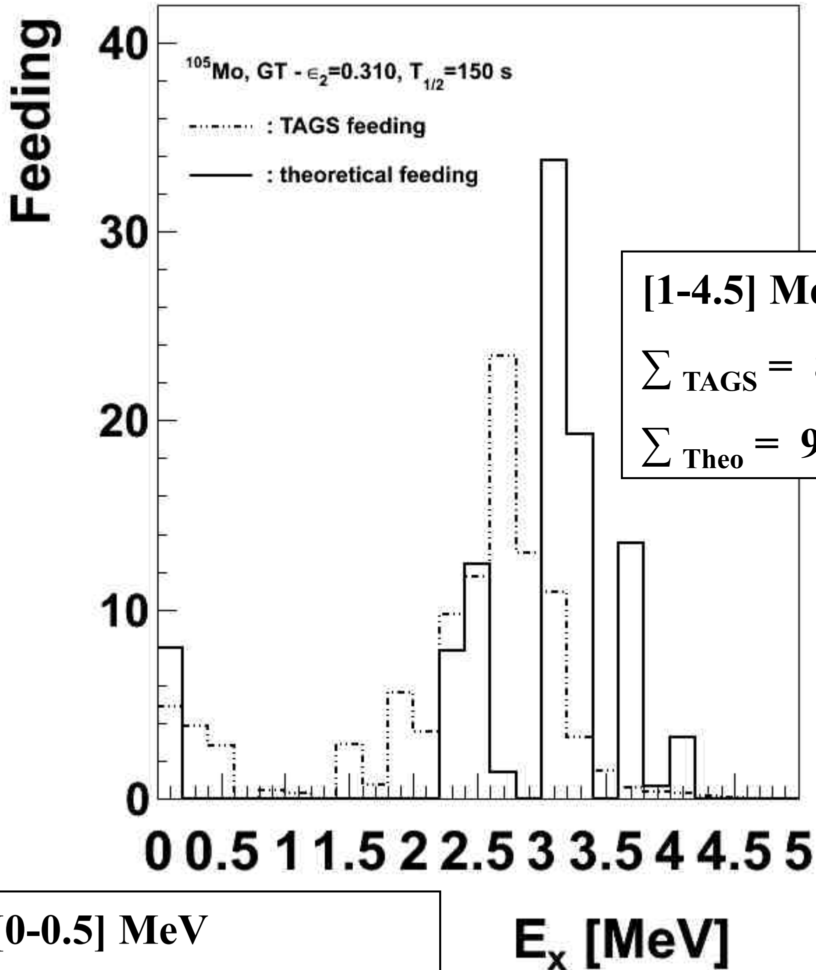
Courtesy of L. Giot

Impact of the measurements for ^{235}U



Courtesy of L. Giot

Nuclear structure I: QRPA calculations
$T_{1/2}$(exp) = 35.6 s



[1-4.5] MeV

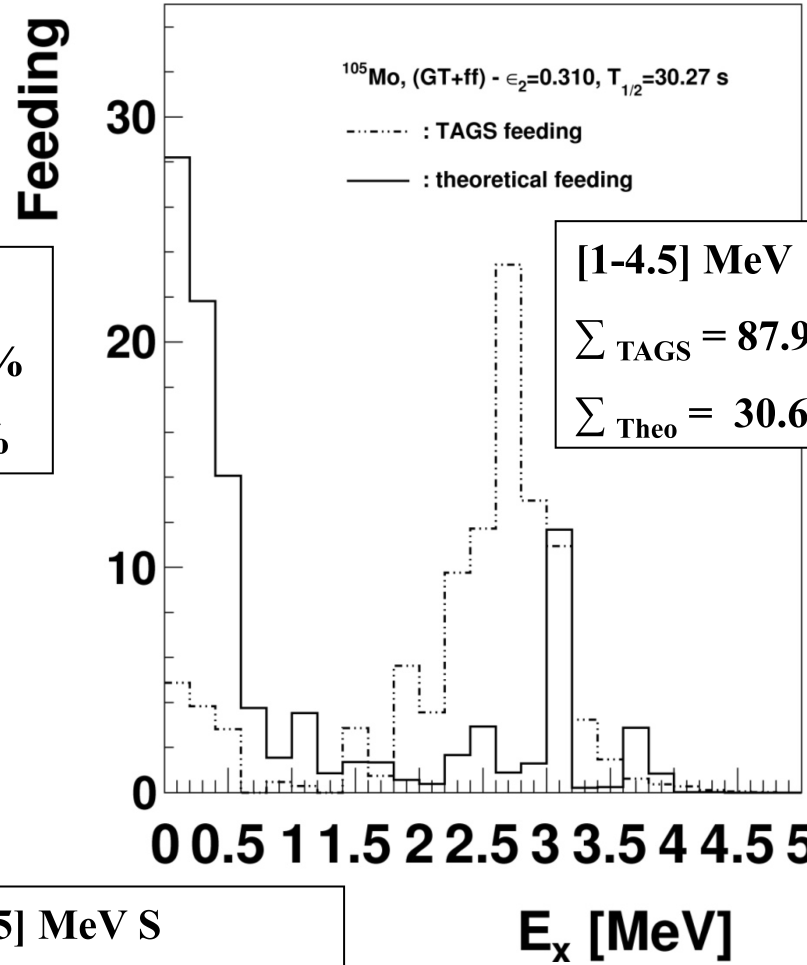
$\sum_{TAGS}$ = 87.99%

$\sum_{Theo}$ = 92.05%

[0-0.5] MeV

$\sum_{TAGS}$ = 11.51%

$\sum_{Theo}$ = 7.94%



[1-4.5] MeV

$\sum_{TAGS}$ = 87.99 %

$\sum_{Theo}$ = 30.62%

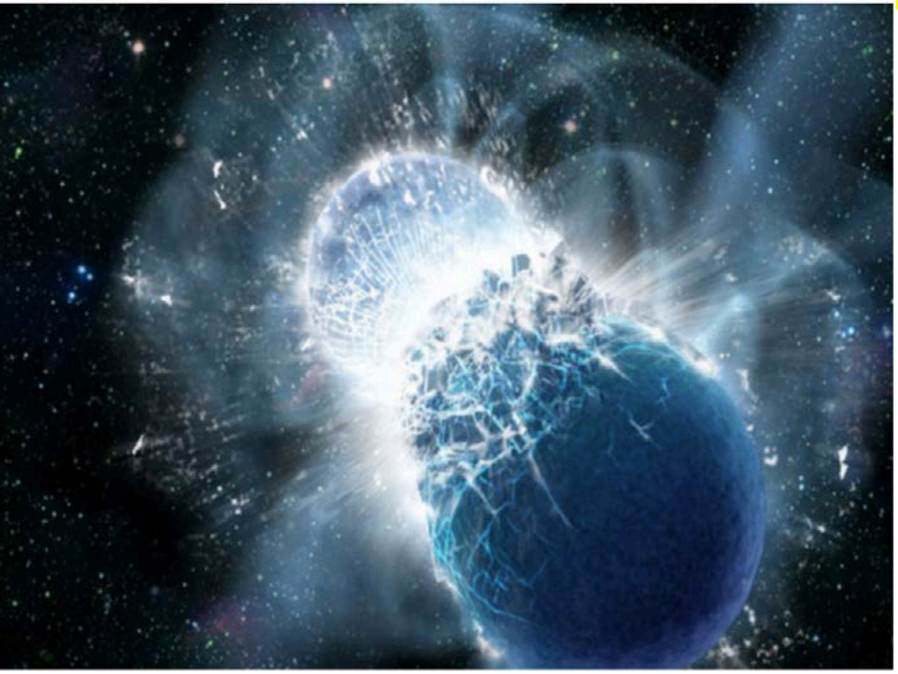
[0-0.5] MeV S

$\sum_{TAGS}$ = 11.51%

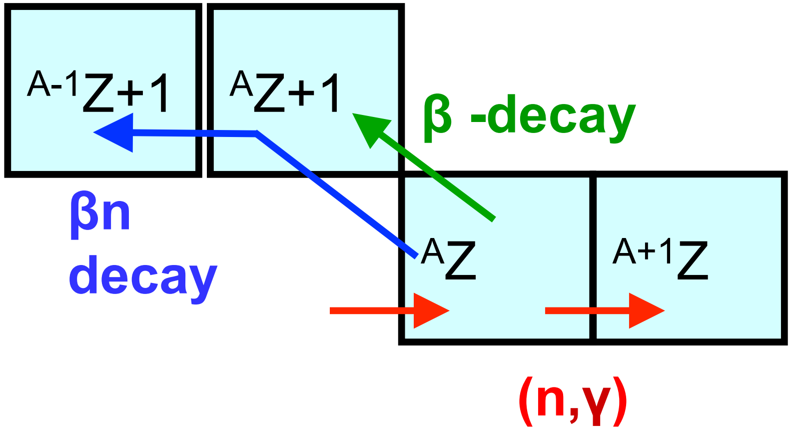
$\sum_{Theo}$ = 67.84 %

Kratz, Moeller *et al.*

Astrophysics I: r-process input from models



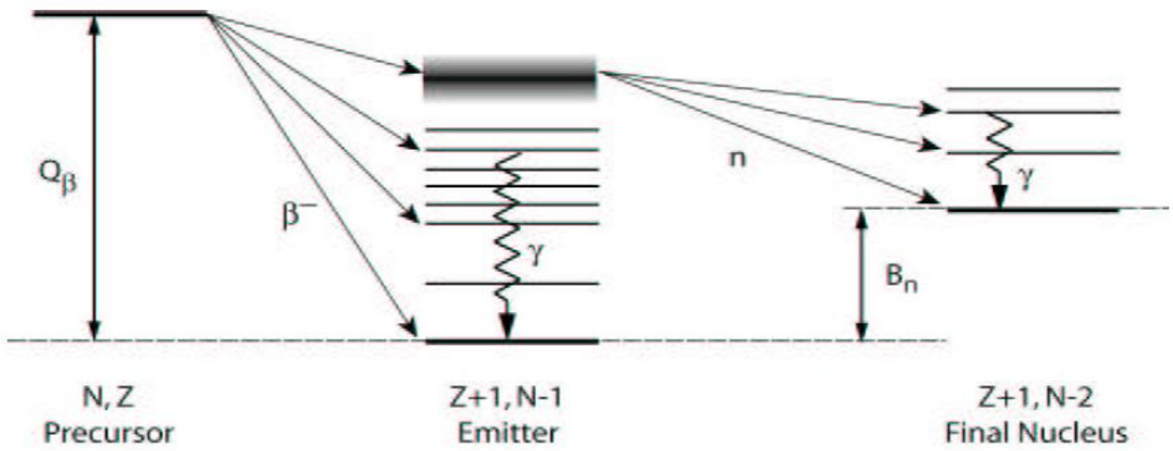
r-process: A short and very high neutron flux produces very neutron-rich nuclei in a short time, which then decay to stability.



- The β-decay half-life determines the speed of the process and shapes the abundance distribution
- The delayed neutron emission probability modifies the abundance distribution

Another problem of astrophysical interest

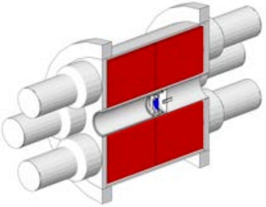
Competition between gamma and neutron emission above the Sn value

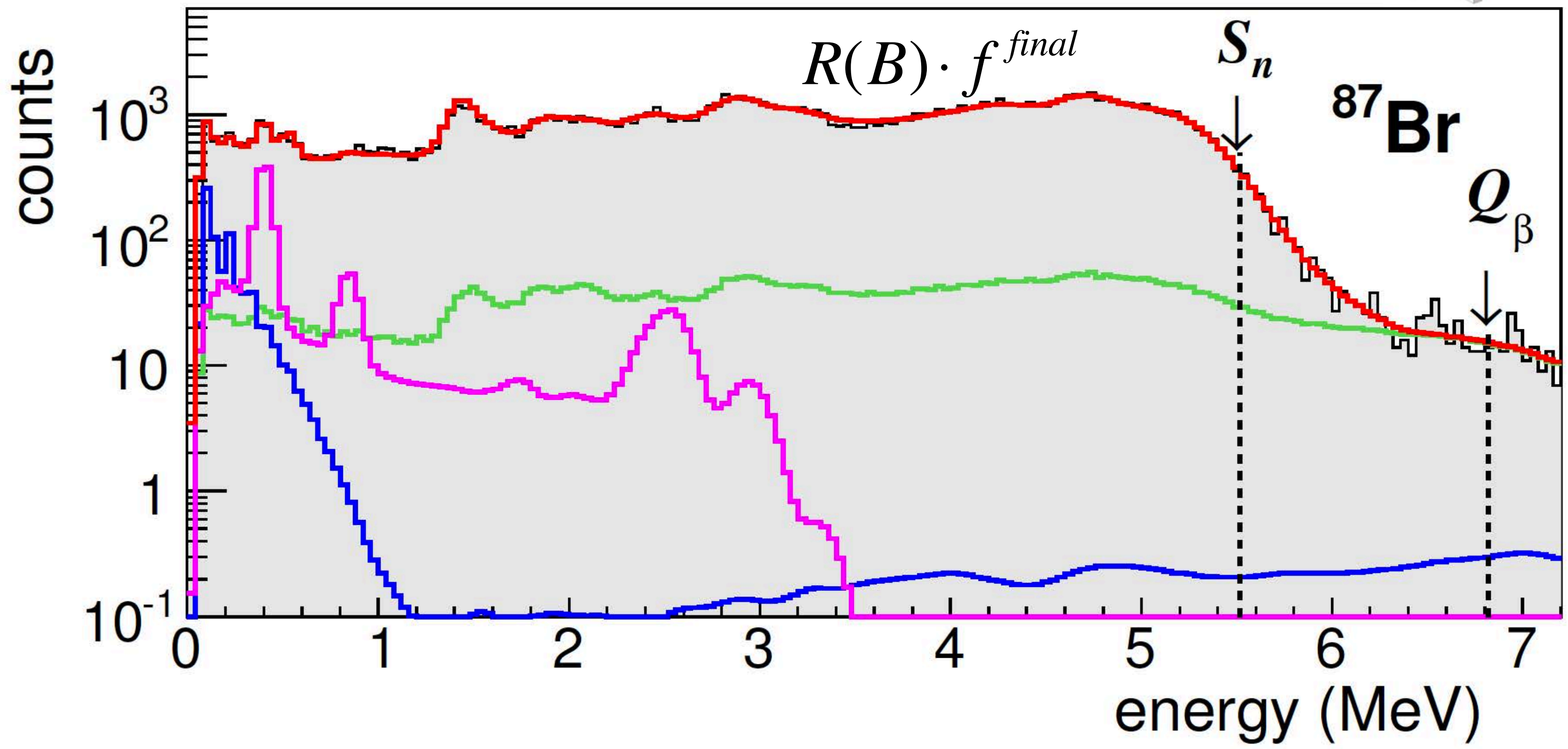


$$\frac{1}{T_{1/2}} = \int_0^{Q_\beta} S_\beta(E_x) \cdot f(Q_\beta - E_x)\, dE_x$$

$$P_n = \frac{\int_{S_n}^{Q_\beta} S_\beta(E_x) \cdot f(Q_\beta - E_x) \cdot \frac{\Gamma^n}{\Gamma^n + \Gamma^\gamma}\, dE_x}{\int_0^{Q_\beta} S_\beta(E_x) \cdot f(Q_\beta - E_x)\, dE_x}$$

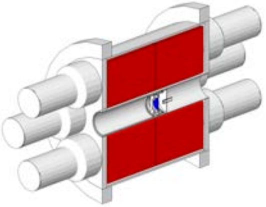
Beta delayed neutron emitters, example: ^{87}Br

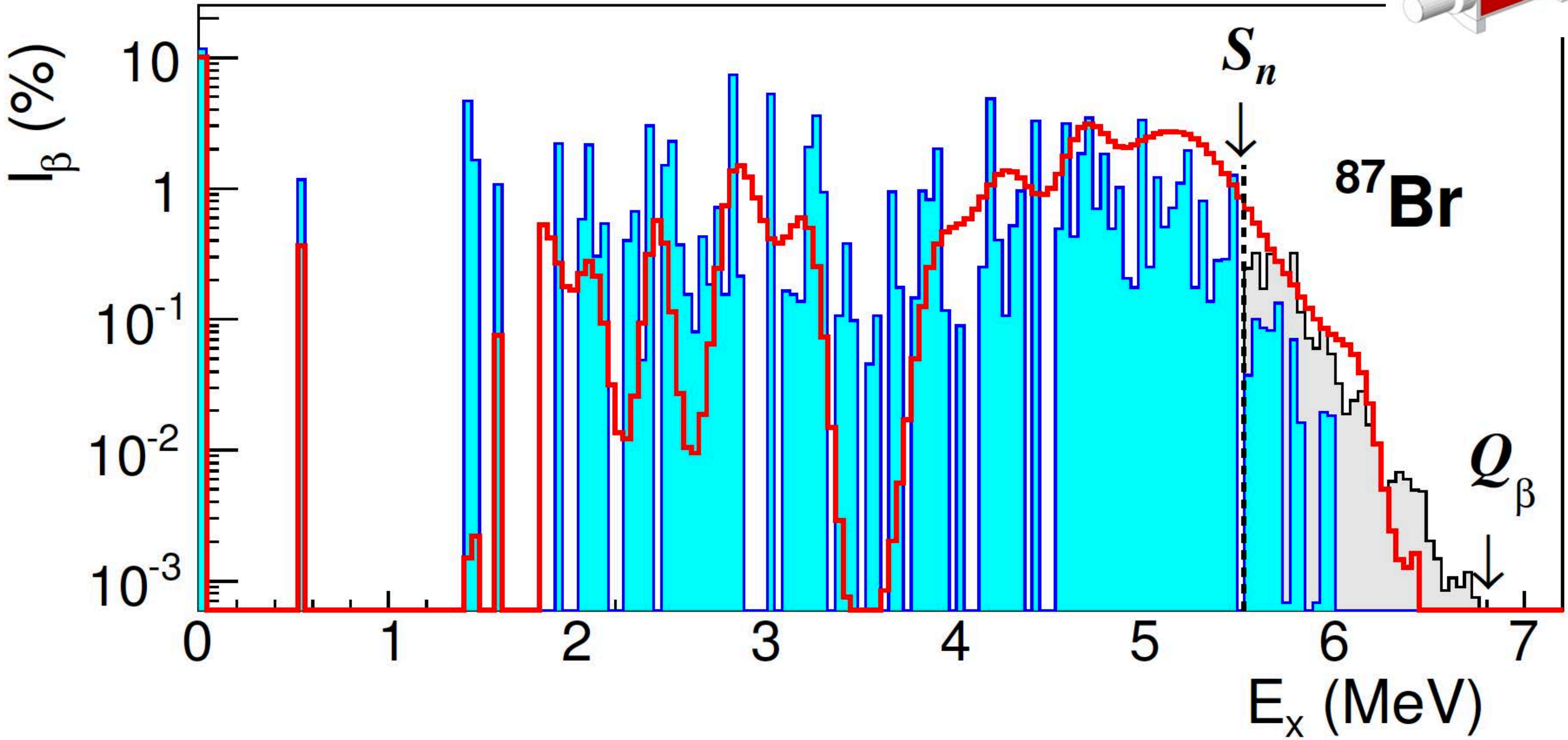




E. Valencia, et al, PRC95, 024320 (2017)
Tain et al. PRL 115, 062502

Beta delayed neutron emitters, example: 87Br

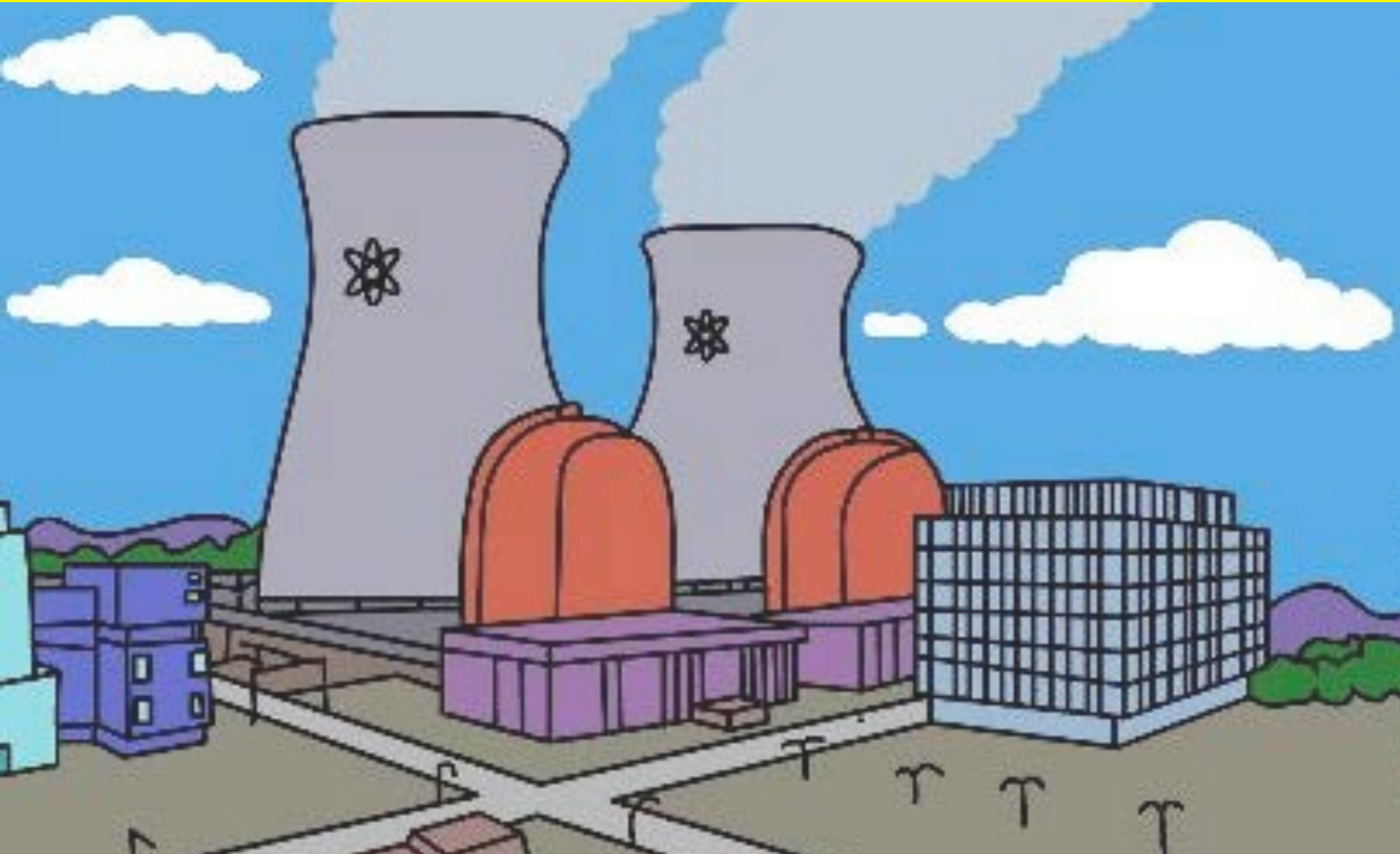




E. Valencia, et al, PRC95, 024320 (2017)
Tain et al. PRL 115, 062502

Pγ=3.50 (+49-40) %
Pn=2.60 (4) %

TAS and reactor neutrinos (in collaboration with Subatech, Nantes)

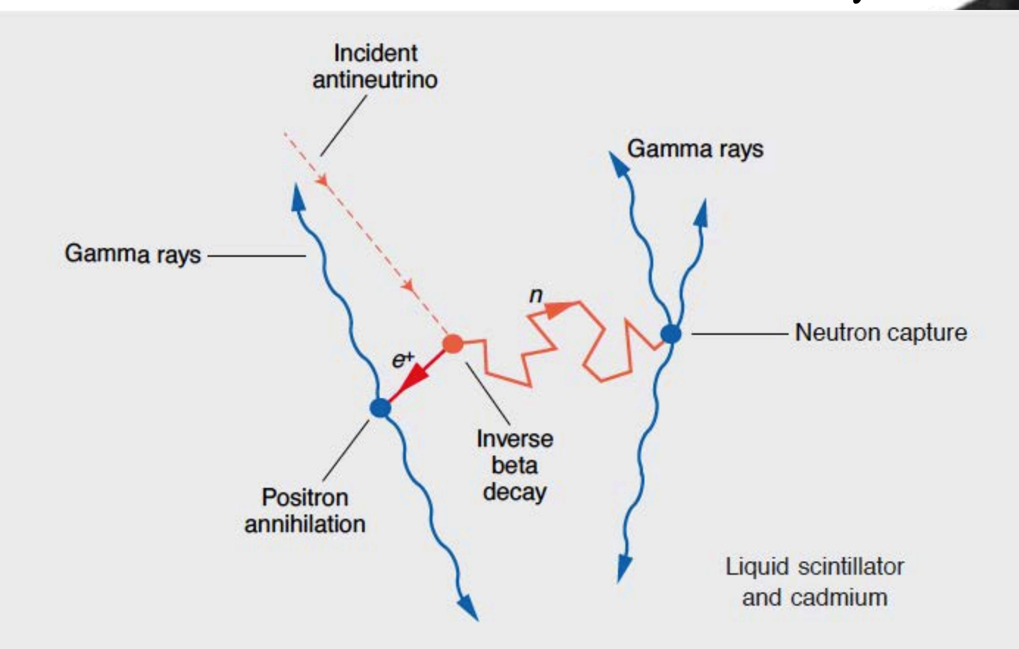


Nuclear reactors and neutrino phyisics I

Neutrino postulated by Pauli, 1930
Nuclear reactors are the strongest (peaceful) human source of antineutrinos .
Reines, Cowan,1956

$$\bar{\nu} + p \rightarrow e^{+} + n$$

$$n + {}^{108}Cd \rightarrow {}^{109m}Cd \rightarrow {}^{109}Cd + \gamma$$



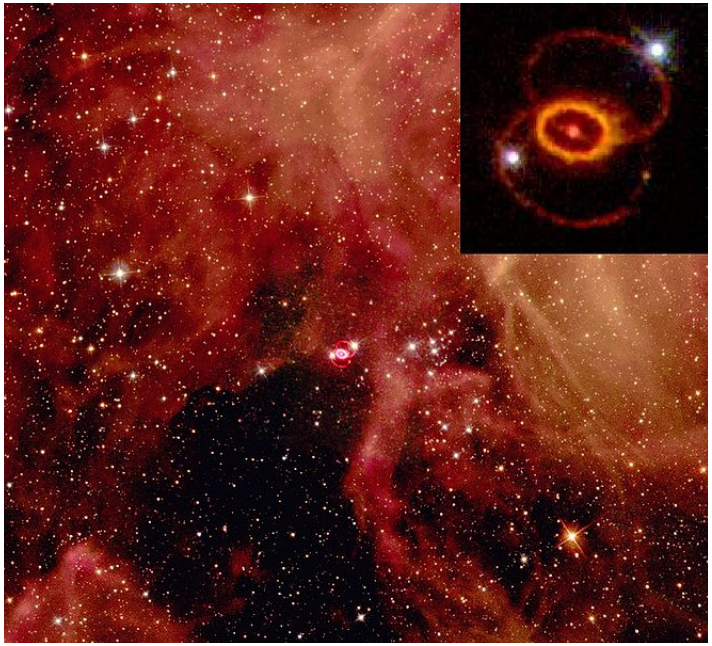
Neutrino flux at the *Savannah River* reactor: $5{\times}10^{13}$ neutrino/s.cm^2
They detected 3 neutrinos/h
Science 20, vol 124 no. 3212 pp. 103-104

Why worth studying: neutrinos as messengers

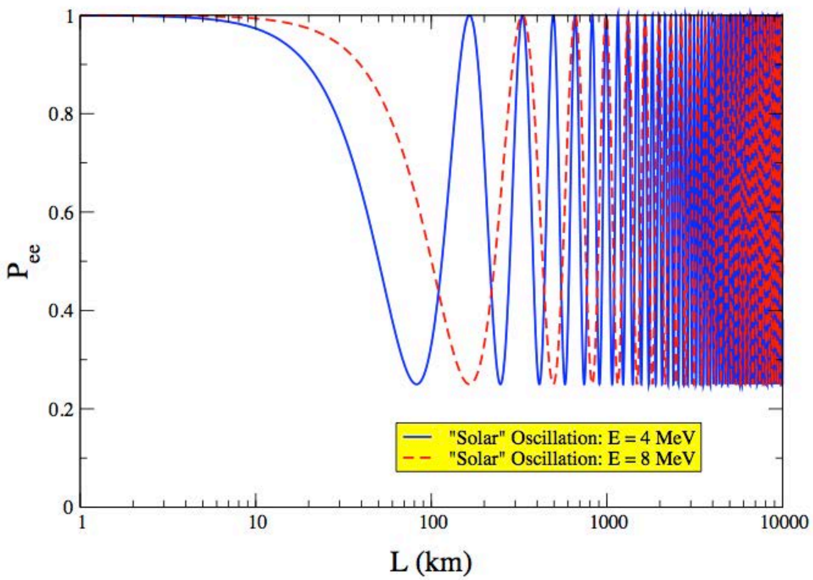
•We hear about many types of neutrinos: solar neutrinos, geo-neutrinos, atmospheric neutrinos, supernova neutrinos, Big Bang neutrinos, reactor neutrinos, etc., etc.

• They can provide information about the processes that happen inside those objects, because they can travel very long distances without interaction.

•Quantum effects at macroscopic scales



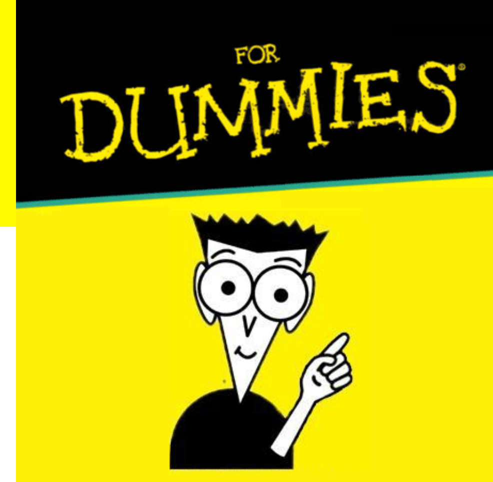
Supernova SN1987A



Osscilations !!!

(solar neutrino deficit, atm. neutrino deficit, ^{238}U,^{232}Th, ^{40}K content, etc.)

Neutrino oscillations



(including myself !)

- In the weak interaction neutrinos are produced and detected in flavours (electron, muon, tau)
- The Hamiltonian (of the propagation) depends on mass (free moving particle)

$$\begin{pmatrix} \nu_e \\ \nu_\mu \end{pmatrix} = \begin{pmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{pmatrix} \begin{pmatrix} \nu_1 \\ \nu_2 \end{pmatrix}$$

$$P(\nu_e \rightarrow \nu_\mu) = \sin^2(2\theta)\sin^2(1.27\Delta m^2 L/E)$$

$$\Delta m^2 = m_2^2 - m_1^2$$

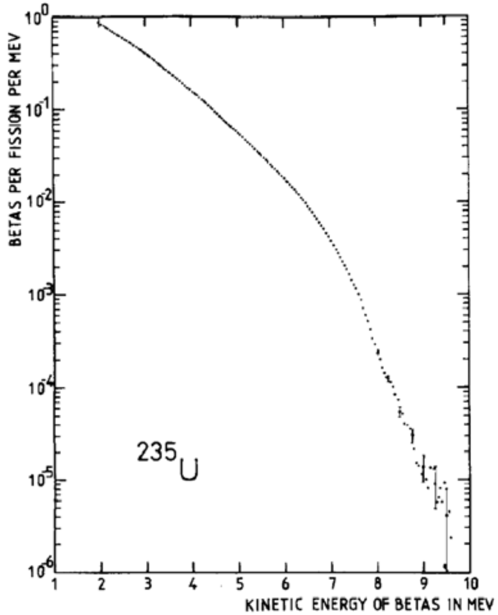
[L in m, E in MeV, Δm^2 in eV^2]

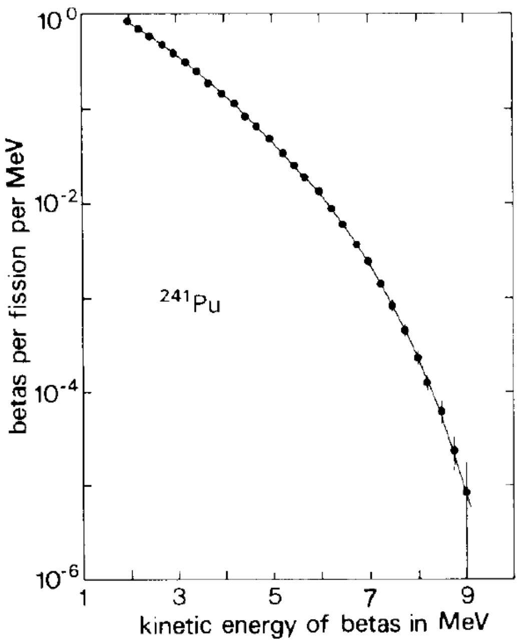
In three flavours we need the Pontecorvo-Maki-Nakagawa-Sakata unitary matrix !!!

Example of reactor neutrino oscillation experiment: Double Chooz, Θ_{13}

Determination of the primary antineutrino spectrum

- "Pure conversion procedure": using the beta spectrum measured by Schreckenbach et al. from different fissile nuclides (^{235}U,$^{239,241}Pu$) and more recently ^{238}U (Haag et al.), which requires complex conversion procedures

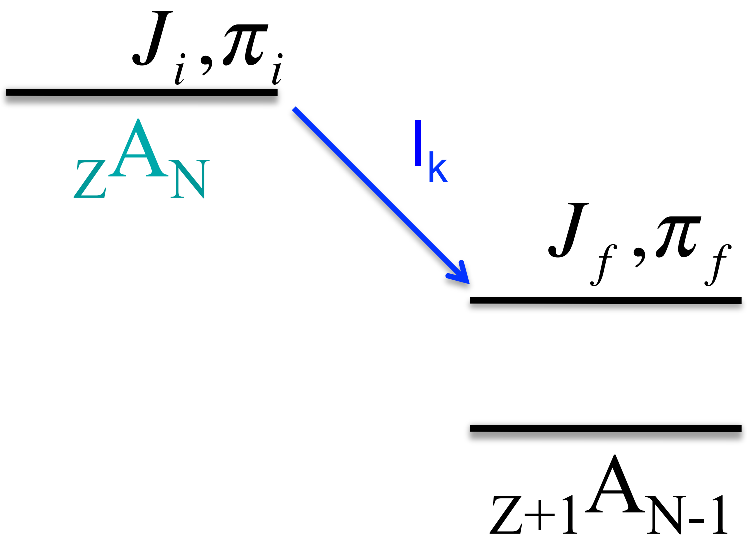




- "Pure" summation calculations (next slide), for many years the only posibility for ^{238}U
- "Mixed" solution (Huber-Mueller model), recently the most used one

Neutrino and decay heat summation calculations

Beta decay (β⁻)



Spectrum for each transition

$$J_i, \pi_i \rightarrow J_f, \pi_f$$

$$S(Q - E_k, J_i \pi_i, J_f \pi_f)$$

Spectrum for the decay (n)

$$S_n(E) = \sum_k I_k S(Q - E_k, J_i \pi_i, J_f \pi_f)$$

Anti-neutrino rate per fission (Vogel, 1981)

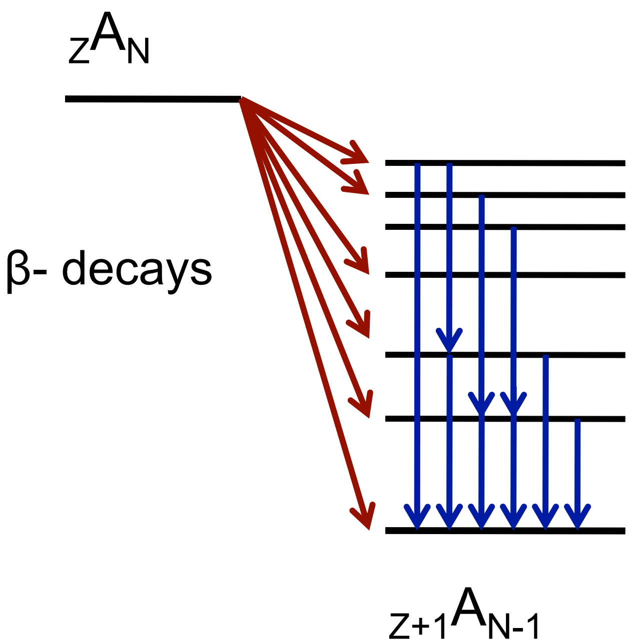
$$S(E) = \sum_n \lambda_n N_n S_n(E)/r = \sum_n CFY_n S_n(E)$$

Decay heat summation calculation

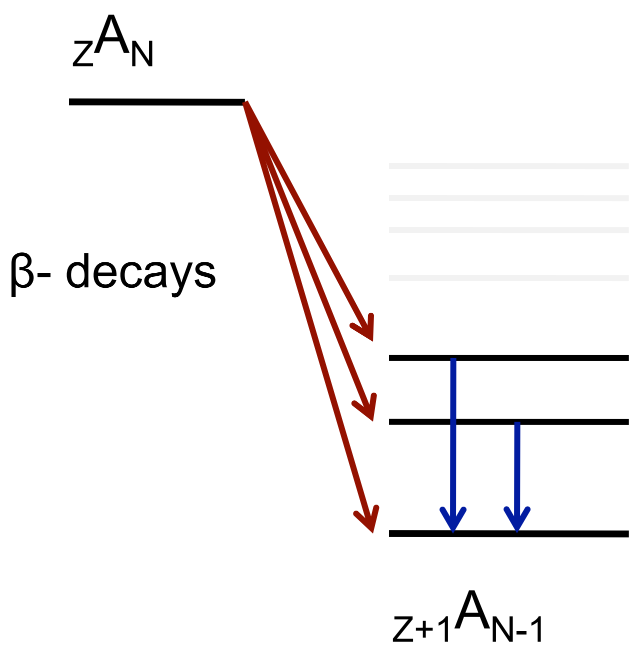
$$f(t) = \sum_i E_i \lambda_i N_i(t)$$

Pandemonium and summation calculations

Real situation

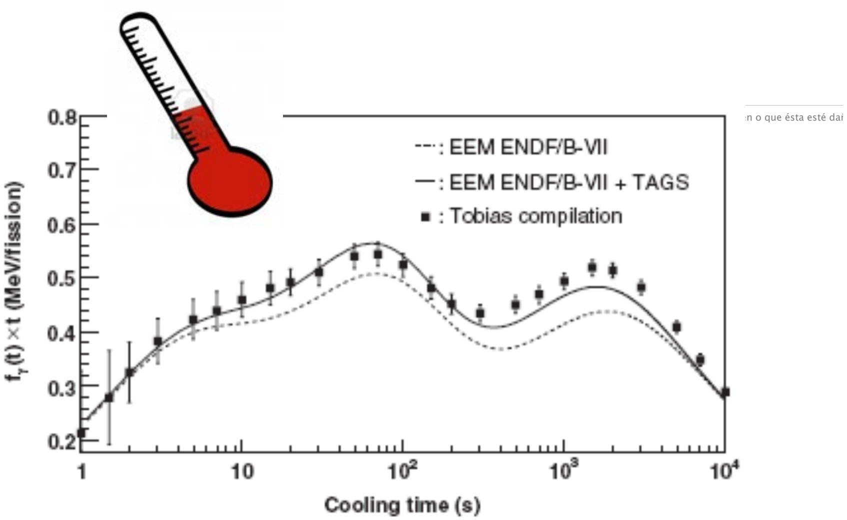


Pandemonium situation



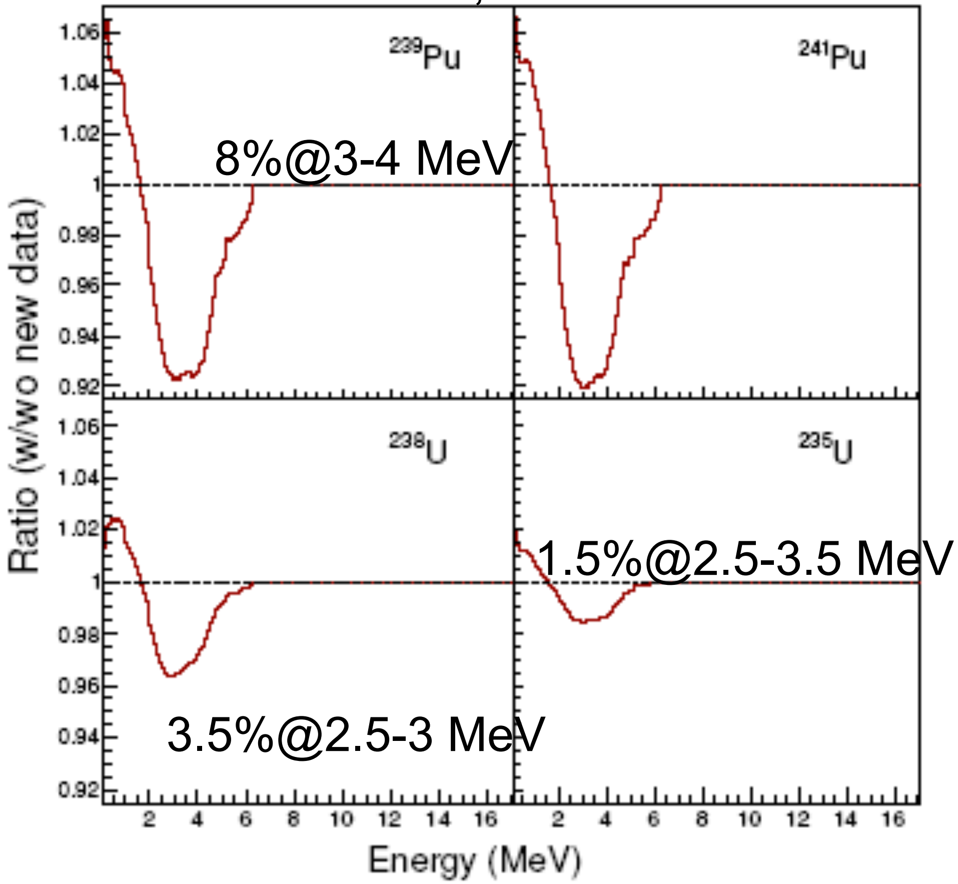
As a result of the Pandemonium, betas and neutrinos are estimated with higher energies from databases. This is why TAS data is very important

Impact of our first data



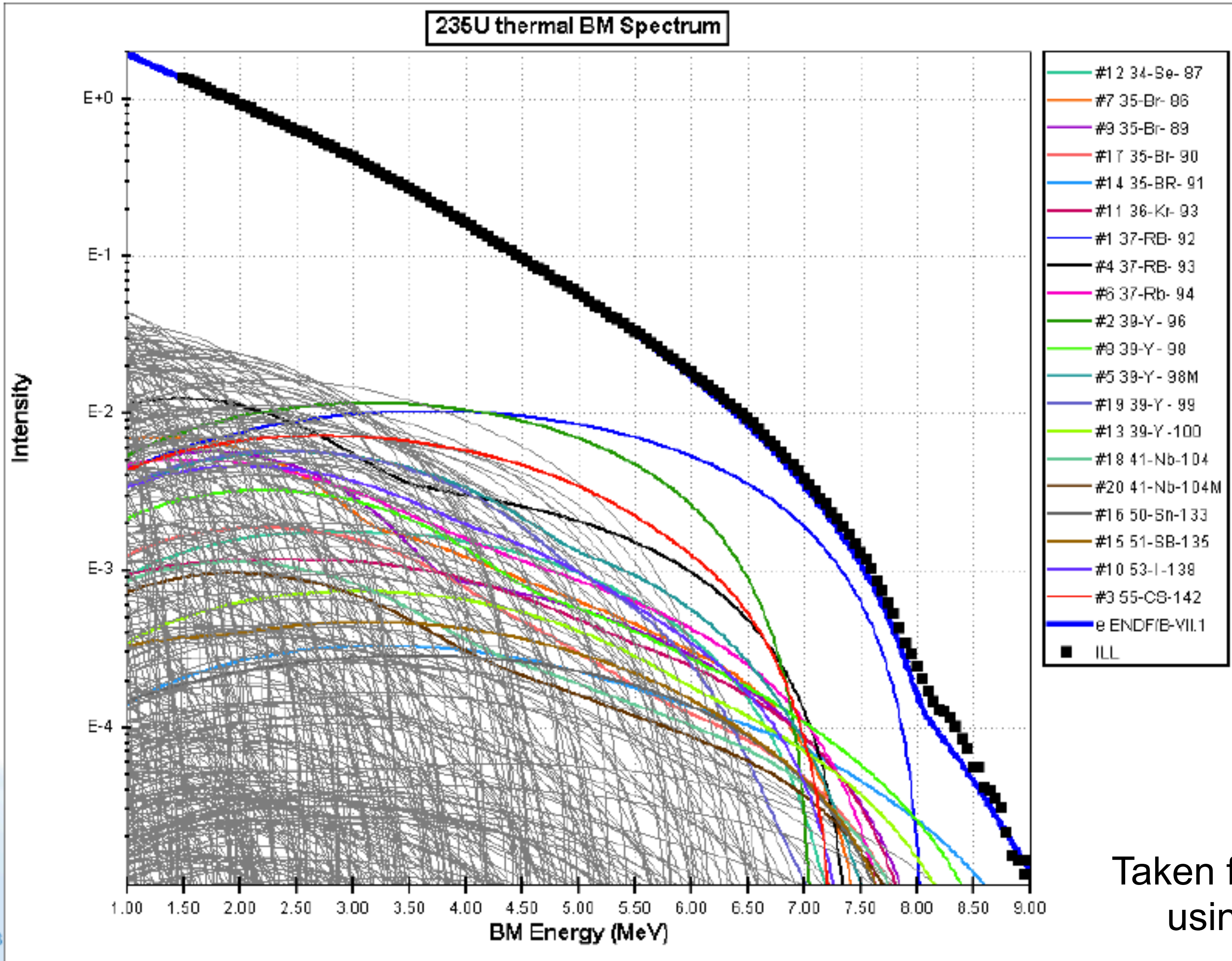
Dolores Jordan, PhD thesis
Algora et al., PRL 105, 202501, 2010

M. Fallot et al., PRL 109.202504



Ratio between 2 antineutrino spectra built with and without the $^{102,104,105,106,107}Tc$, ^{105}Mo, ^{101}Nb TAS data

Role of individual decays

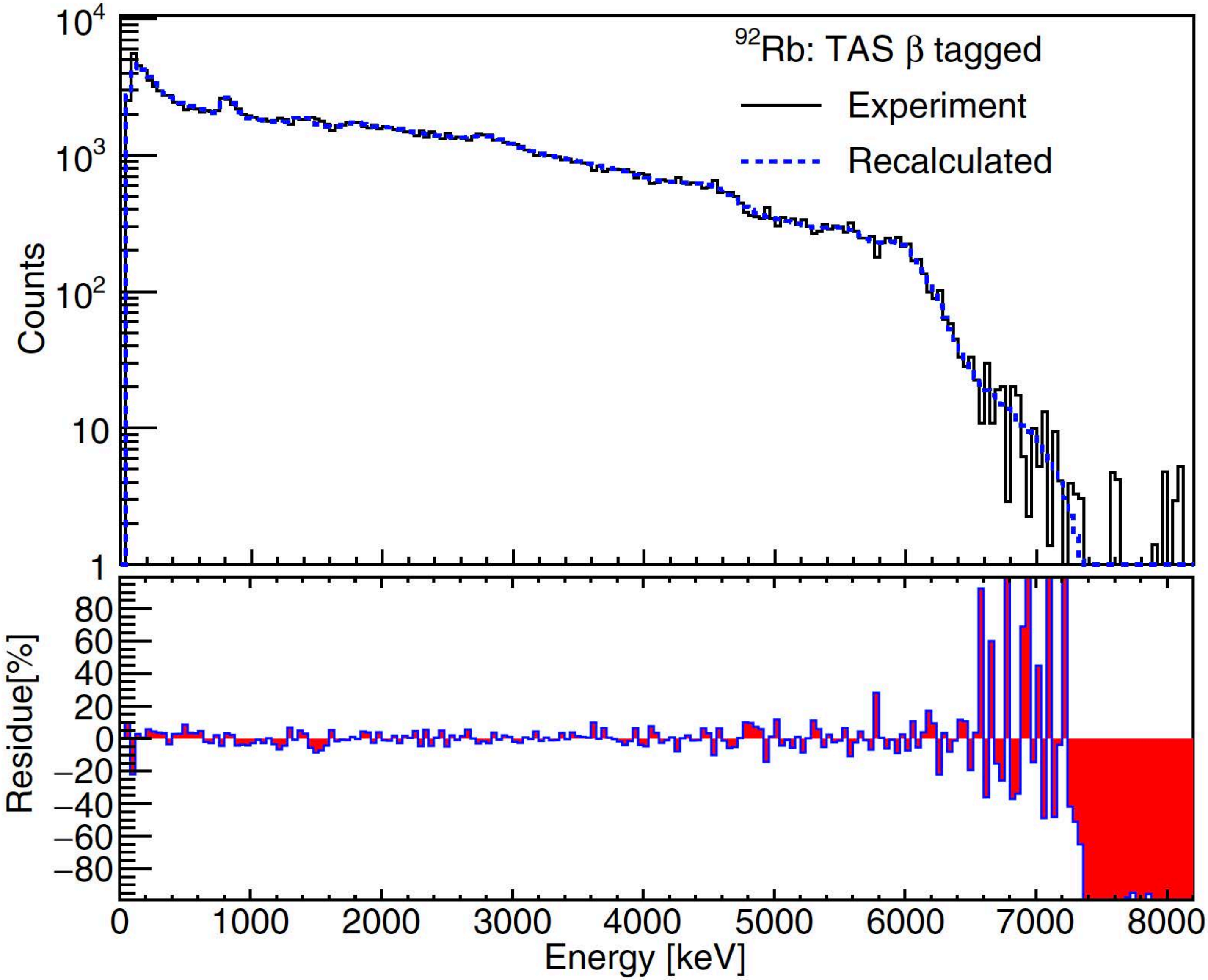


How to identify the main players

- Large cum. fission yields
- Large decay Q_{beta}
- Large beta feeding to gs

Taken from A. Sonzogni using ENDF VII.1

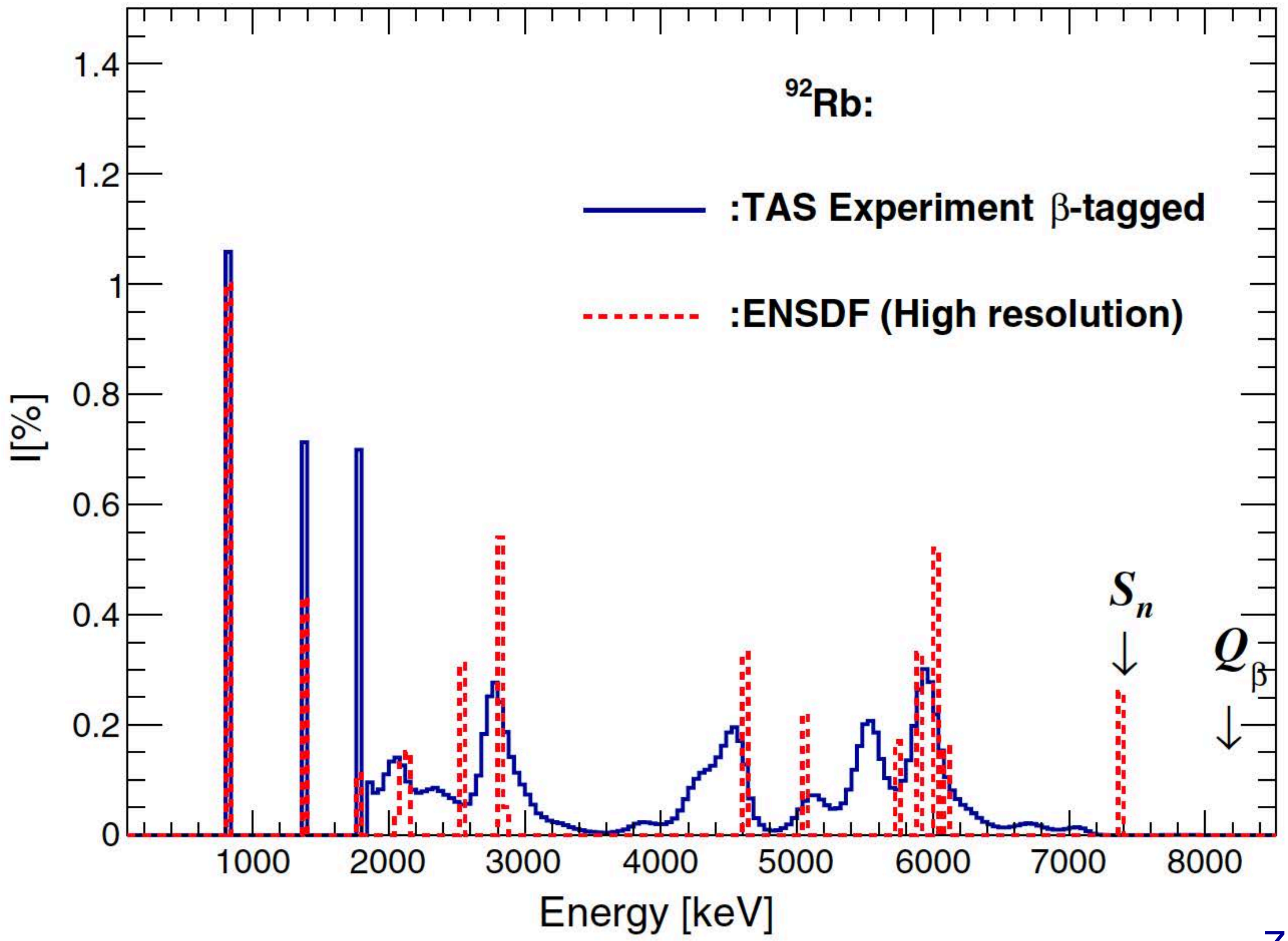
92Rb: TAS measurement, 2009 exp. Analized by the Nantes group



Zakari-Issoufou et al.
PRL 115.102503(2015)

Another recent measurement by Rasco et al.
PRL 117.092501 (2016)
(Oak Ridge group)

92Rb: star case



Gs to gs feeding Evolution

94(+6−20)(<2000)
Olson et al.
51(18) % (<2012)
NDS 2000
95.2(7) % (2012)
NDS 2012
G. Lhersonneau
(PRC74 (2006)017308)
87.5(2.5)% (2015)
TAS result

Zakari-Issoufou et al.
PRL 115.102503(2015)

Question: reactor anomaly ?

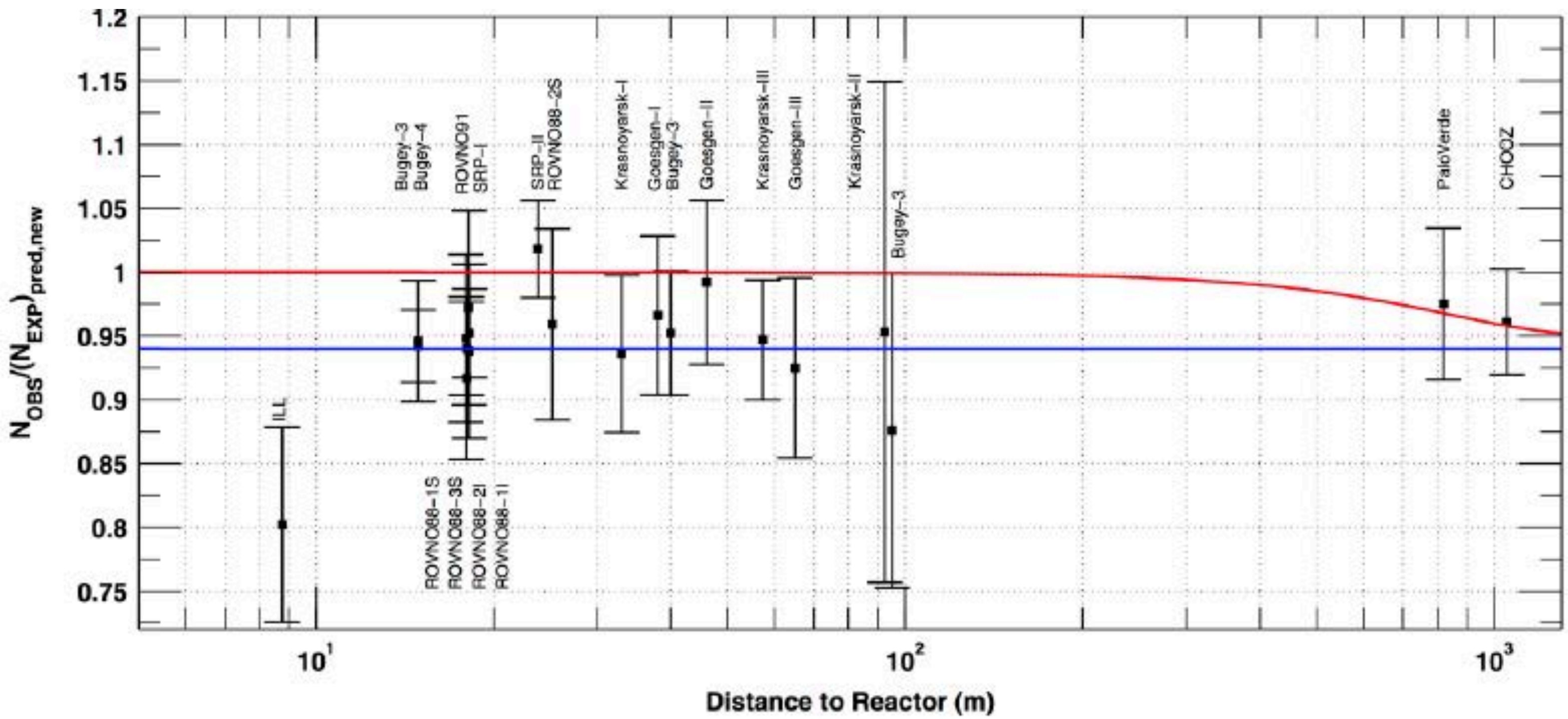


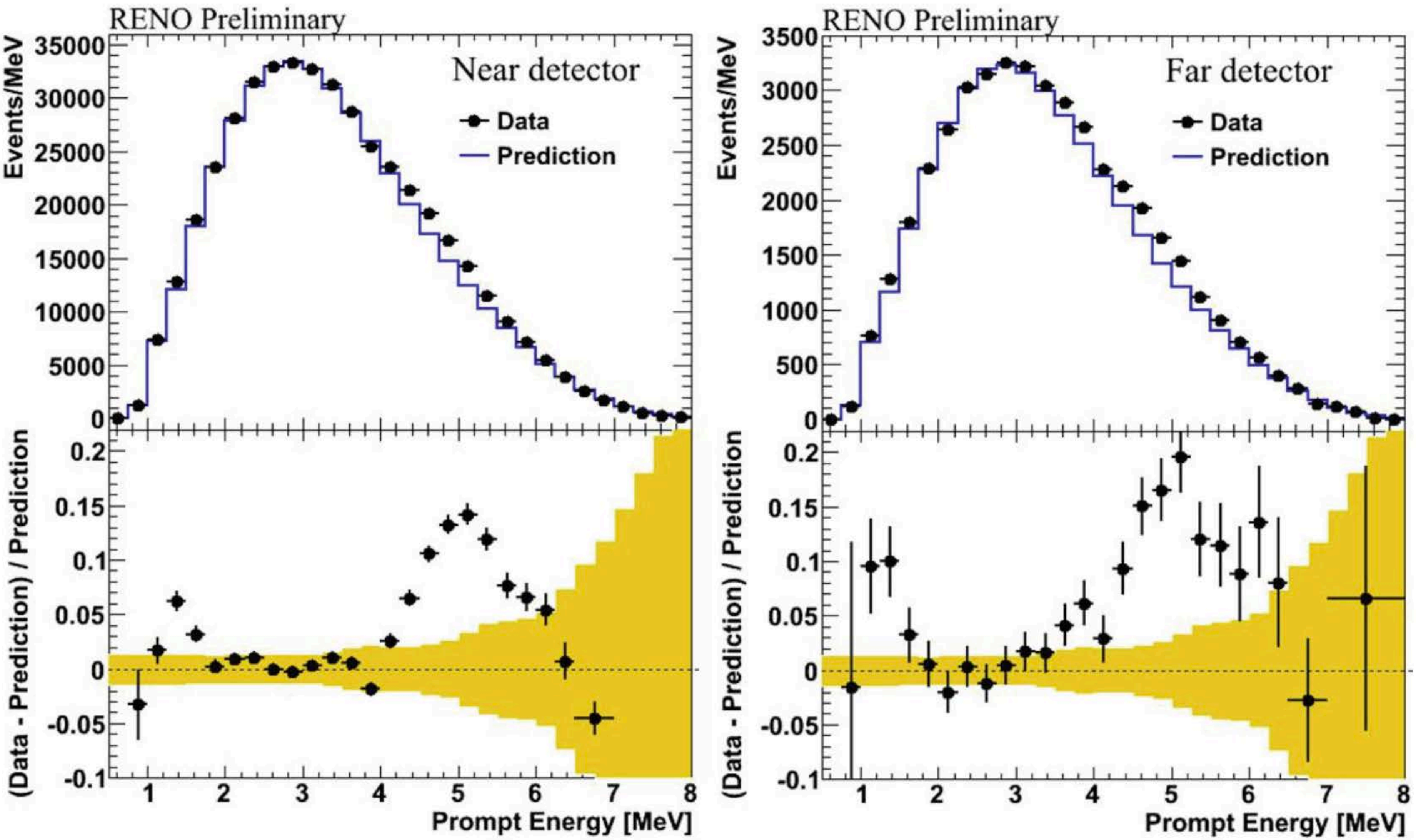
Illustration of the reactor anomaly. Rates in various experiments are compared with the expectations based on the Mueller et al. (2011) spectrum. The mean is 0.943+-0.023.

Possible explanation:
1)Wrong reactor flux or its error
2)Bias in all experiments
3)New physics at short baseline involving a sterile 4th neutrino
ν_{new} with $\Delta m^2 \sim 1eV^2$ and mixing with ν_e with $\theta_{new} \sim 10^0$

The explanation 3) could be supported by several other, so far unconfirmed anomalies. It would involve unexpected but significant "New Physics"

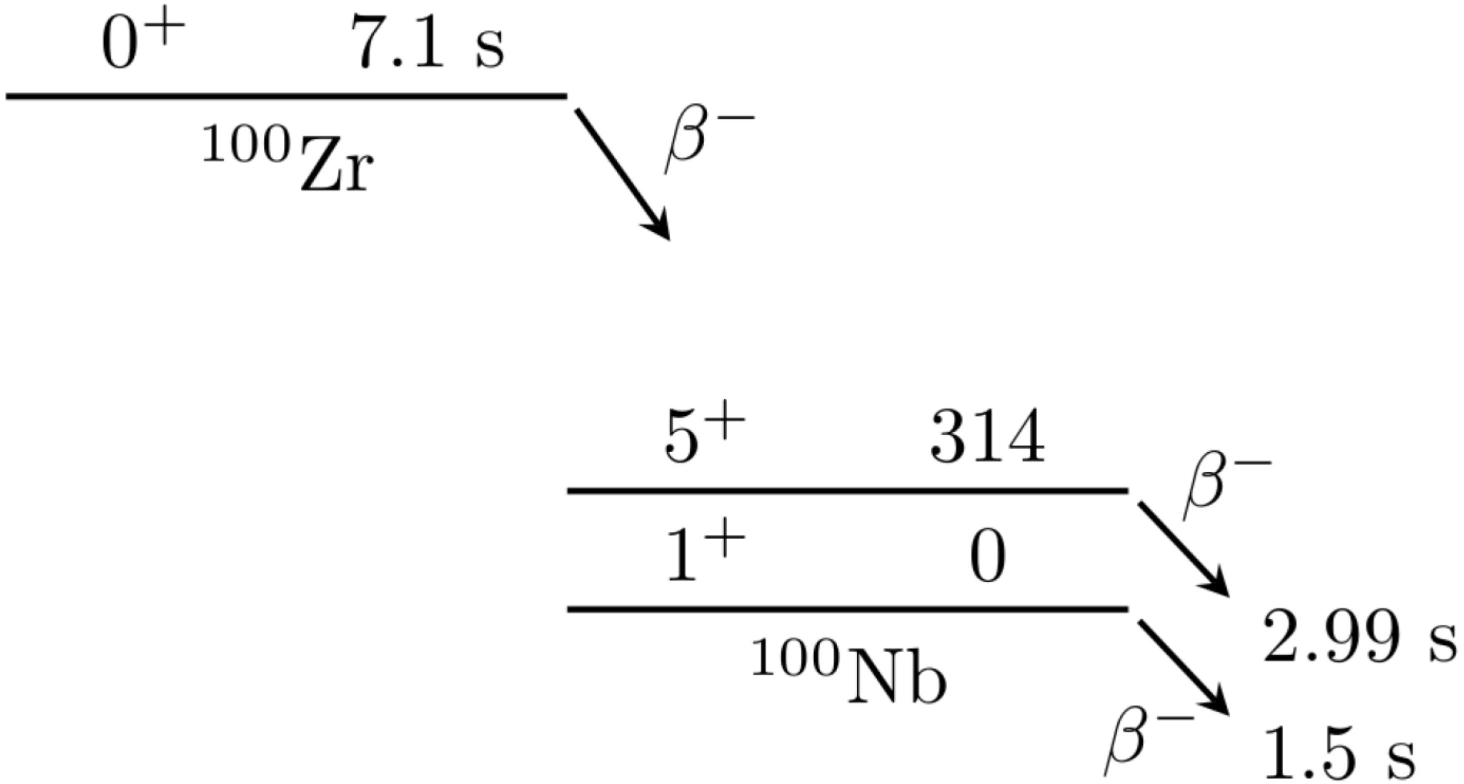
From P. Vogel

A new famous bump !!!



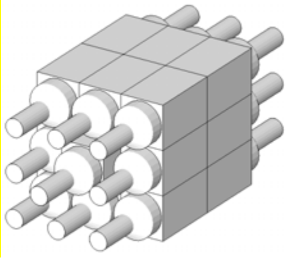
RENO results, arXiv:1504.08268
Also seen in DAYA BAY

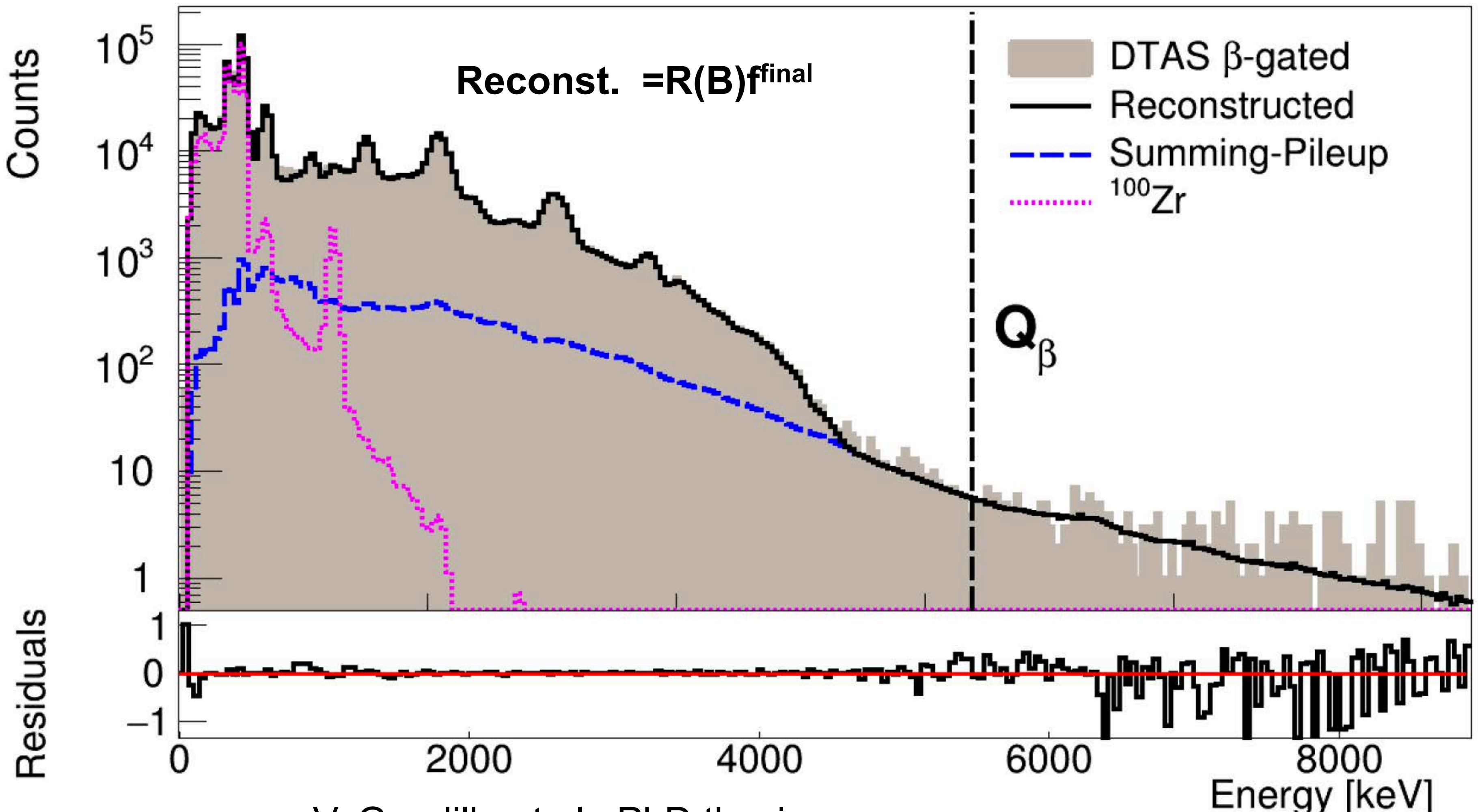
Example: 100Nb
(from approx. 14 relevant decays)



CFY of the order of 5% and ~1 % respectively
(for both 235U and 239Pu)
Thesis work: V. Guadilla (Univ. Valencia 2017)
V. Guadilla et al PRL122, 042502 (2019)

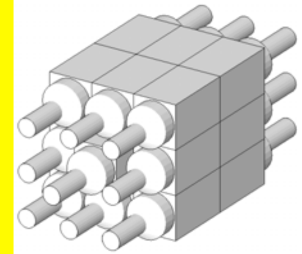
$^{100gs}Nb$

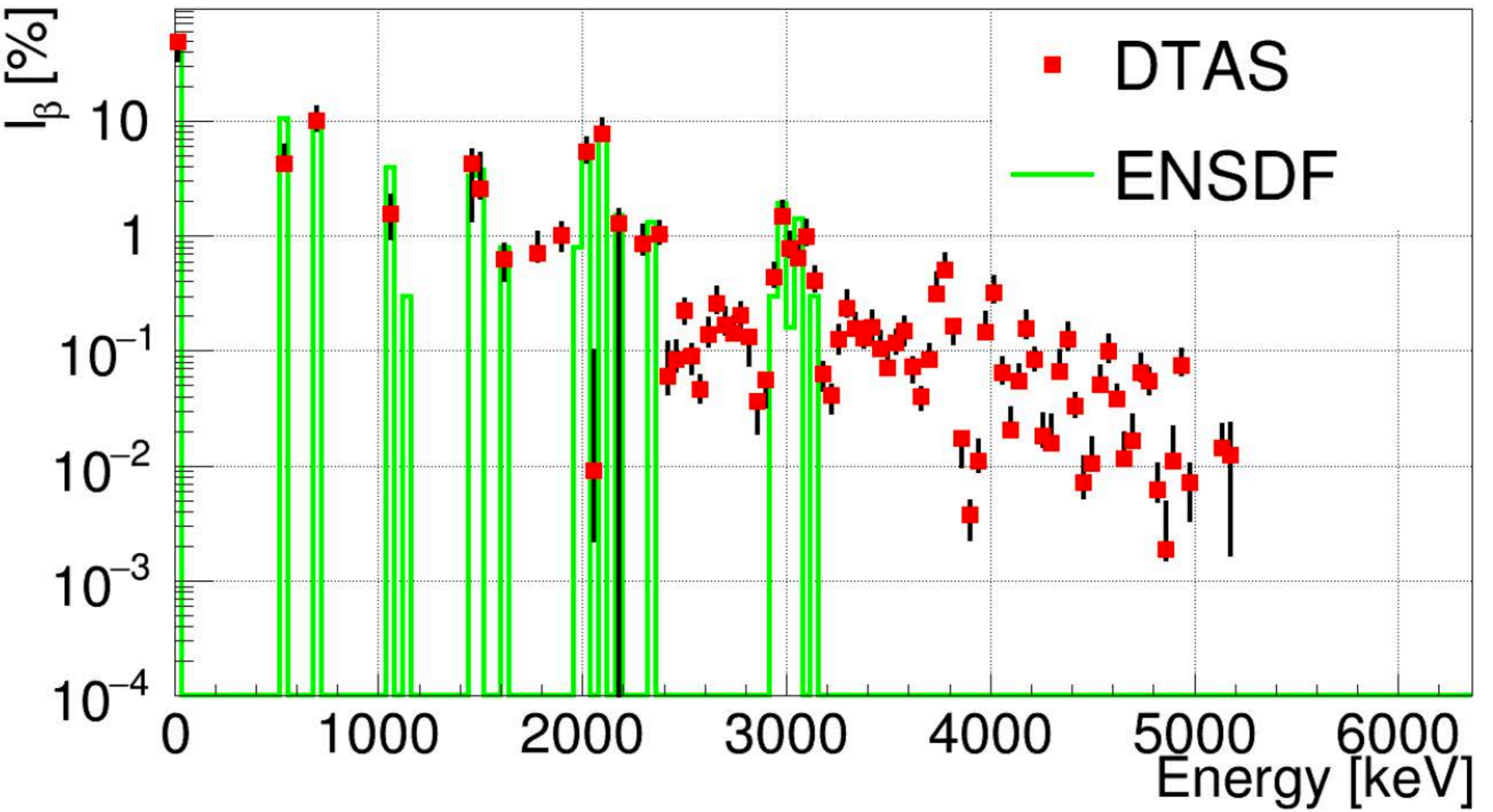




V. Guadilla et al., PhD thesis
V. Guadilla et al PRL122, 042502 (2019)

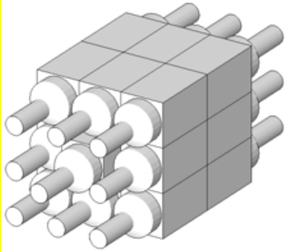
$^{100gs}Nb$

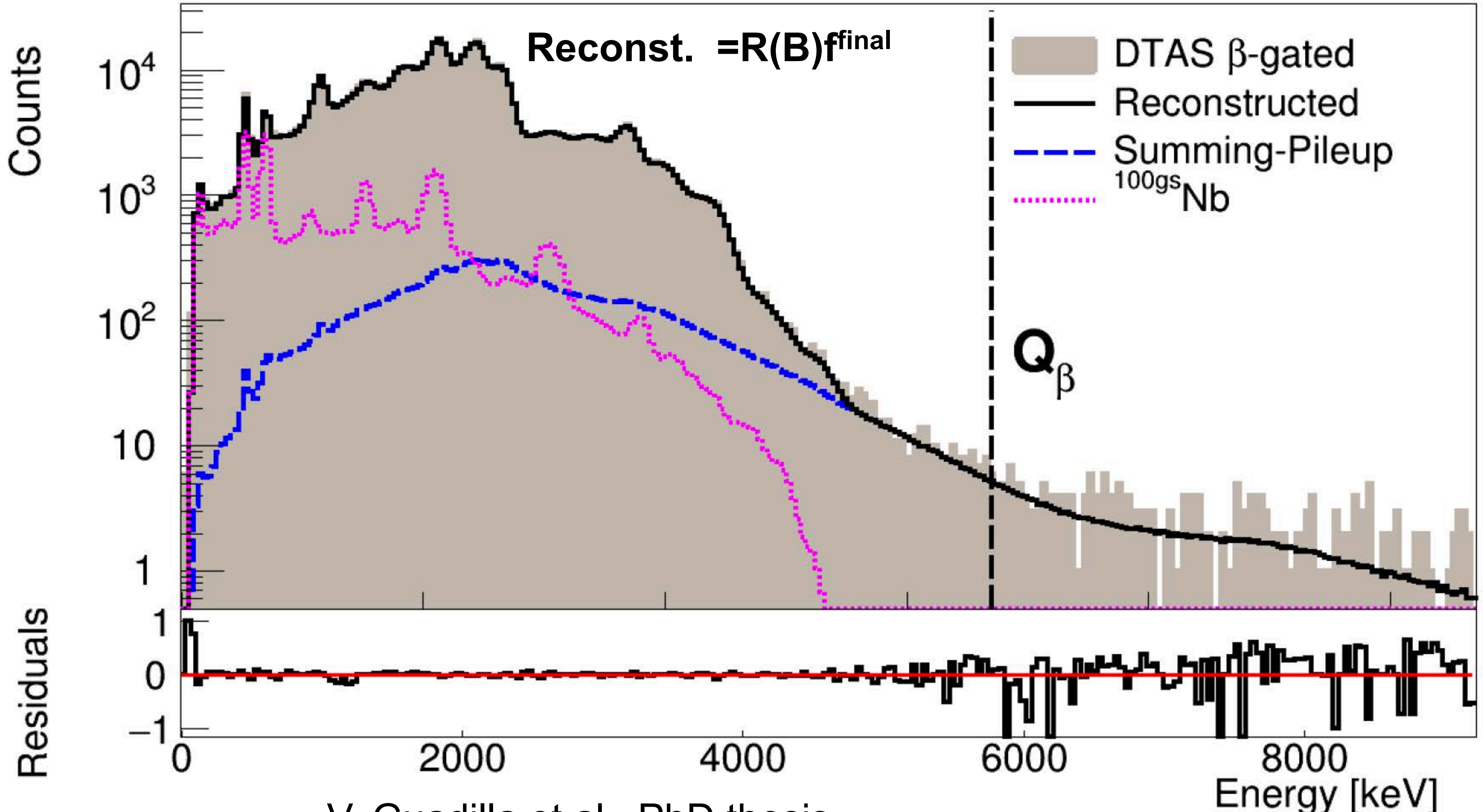




I_β [%]
10
1
10^−1
10^−2
10^−3
10^−4
0
1000
2000
3000
4000
5000
6000
Energy [keV]
DTAS
ENSDF

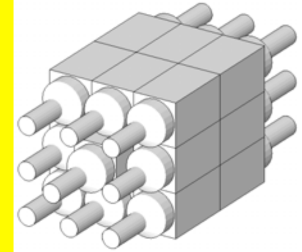
^{100m}Nb

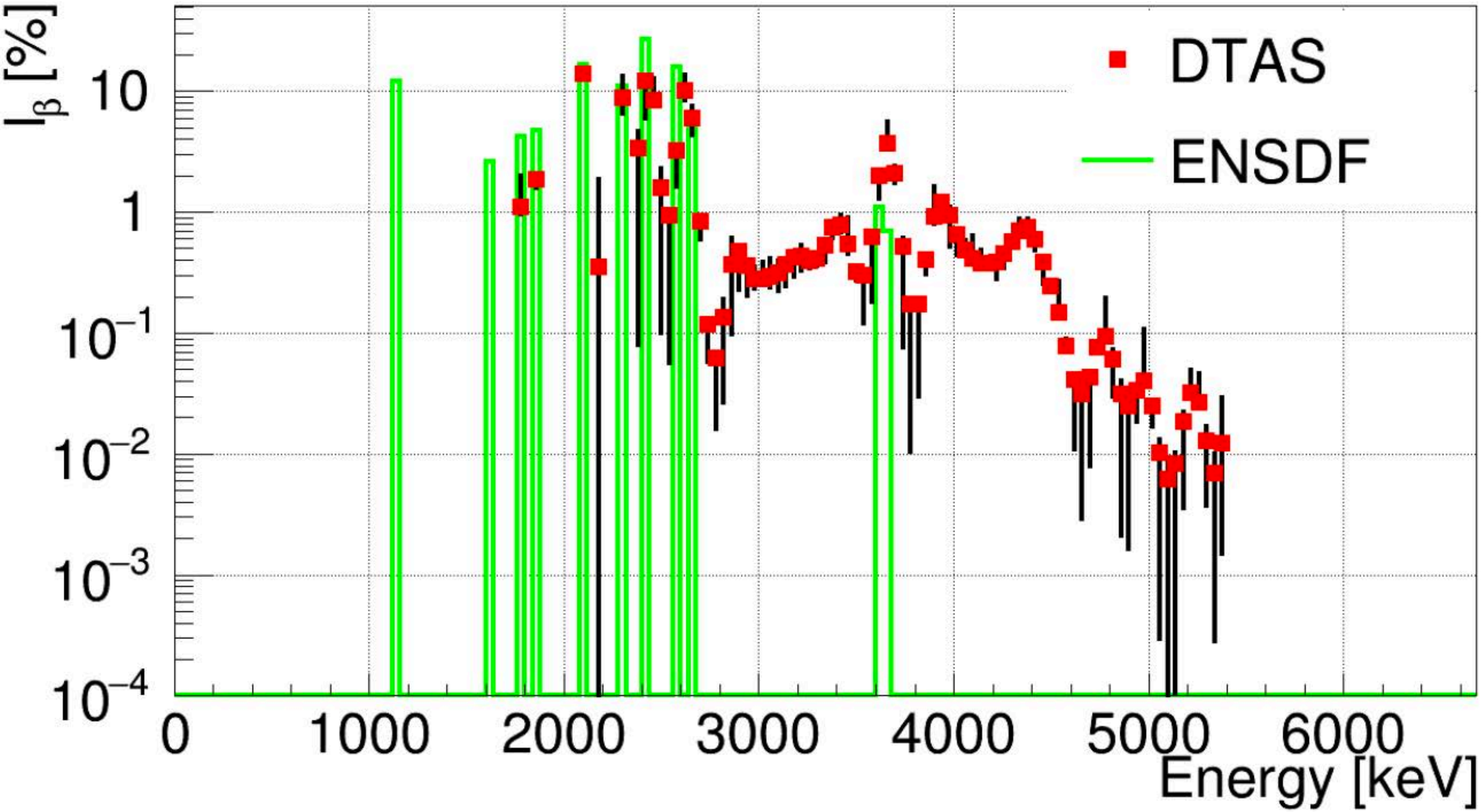




V. Guadilla et al., PhD thesis
Guadilla et al PRL122, 042502 (2019)

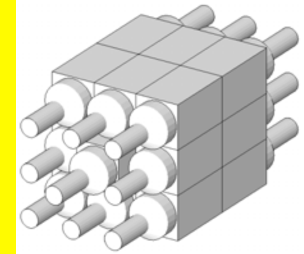
^{100m}Nb



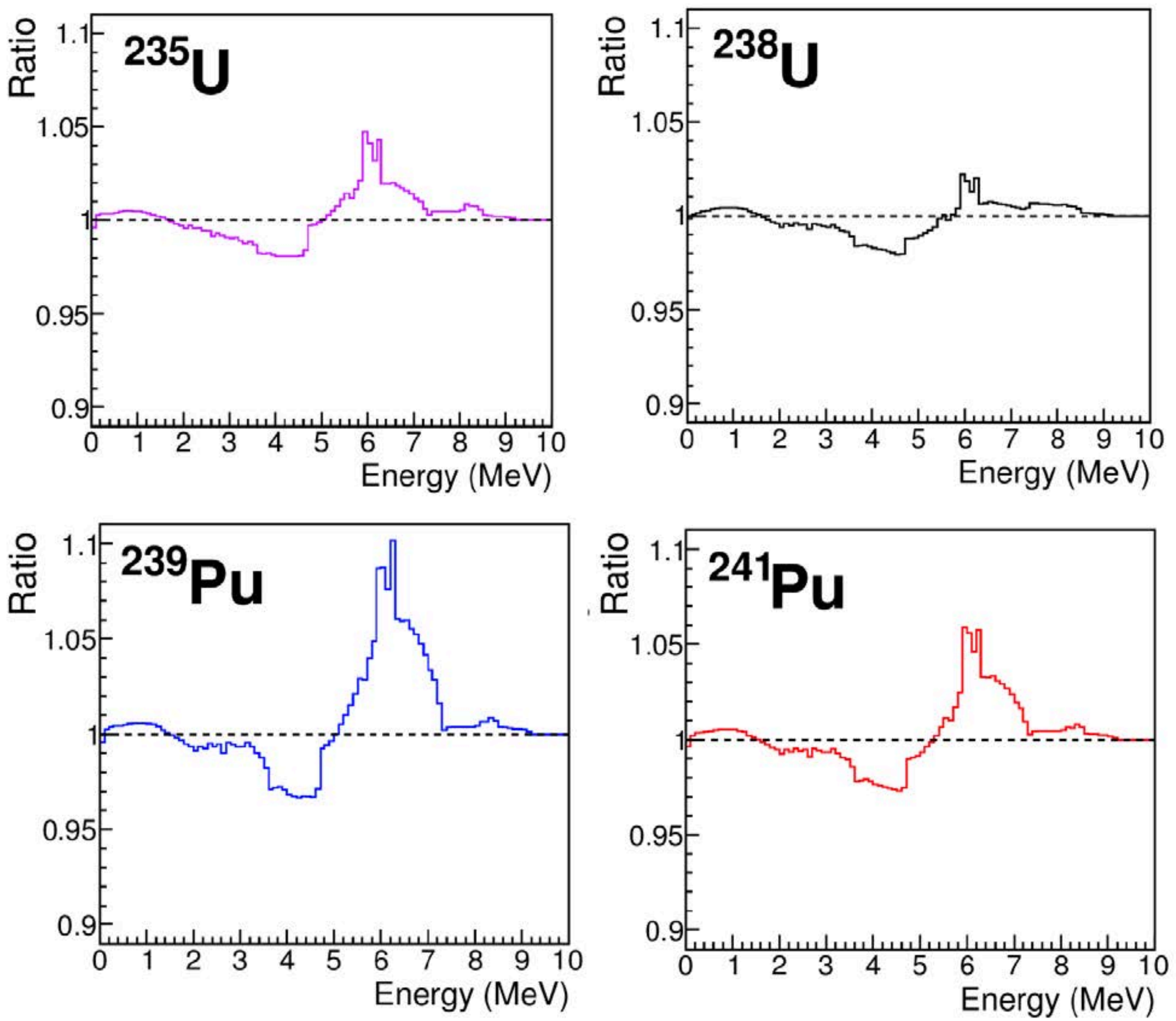


I_β [%]
10
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
0
1000
2000
3000
4000
5000
6000
Energy [keV]
DTAS
ENSDF

Impact on the neutrino summation calc. (preliminary)



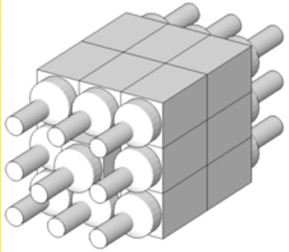
Neutrino summation calculation
Courtesy of M. Fallot, M. Estienne et al, PhD thesis of V. Guadilla

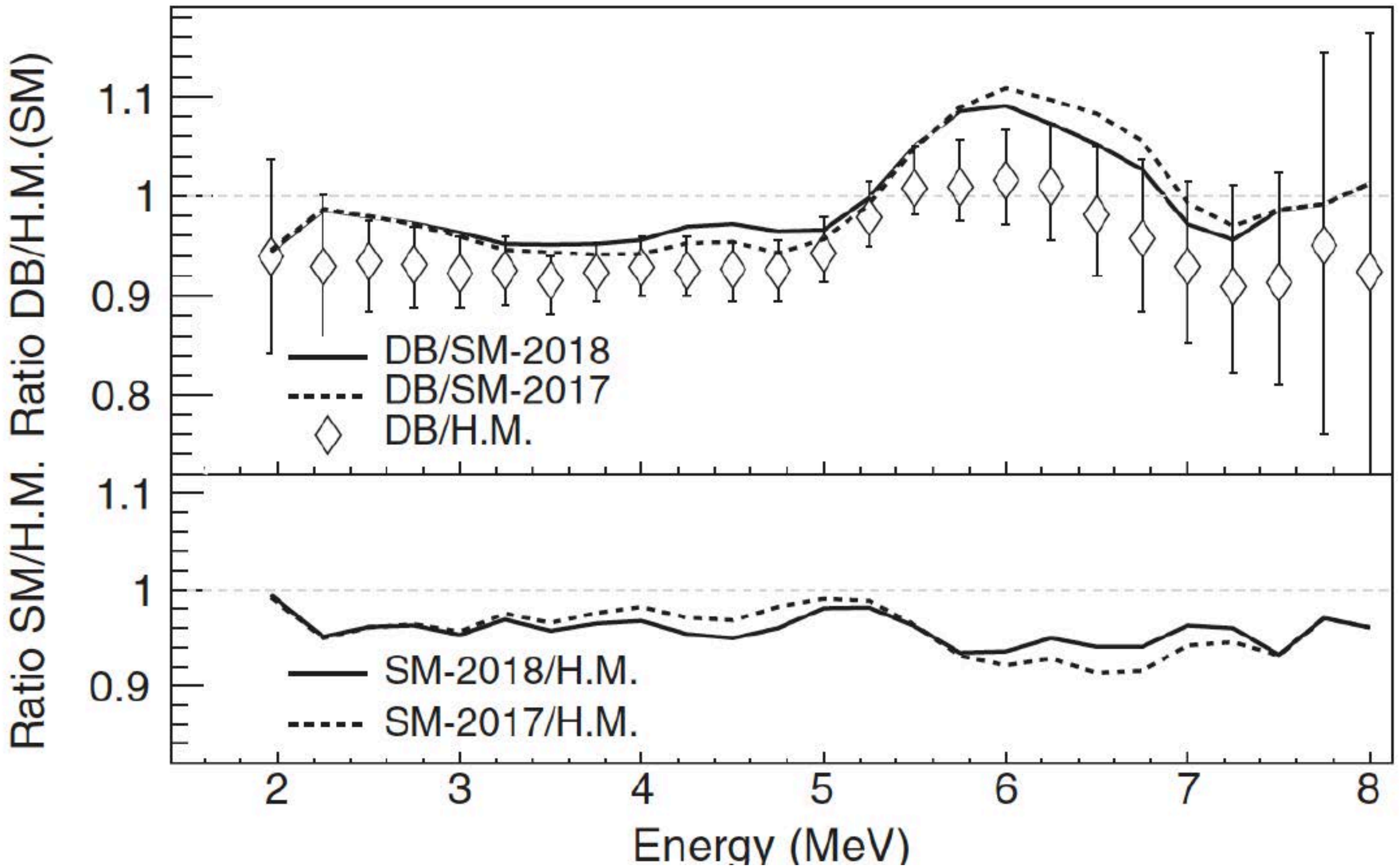


Impact of 8 new decays, some with decaying isomers, Still some to be analyzed by the Nantes group

Other groups are also working in the topic, see for example Rasco et al. PRL117.092501

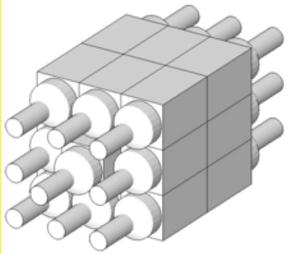
Impact on the neutrino summation calculations: is the anomaly killed?

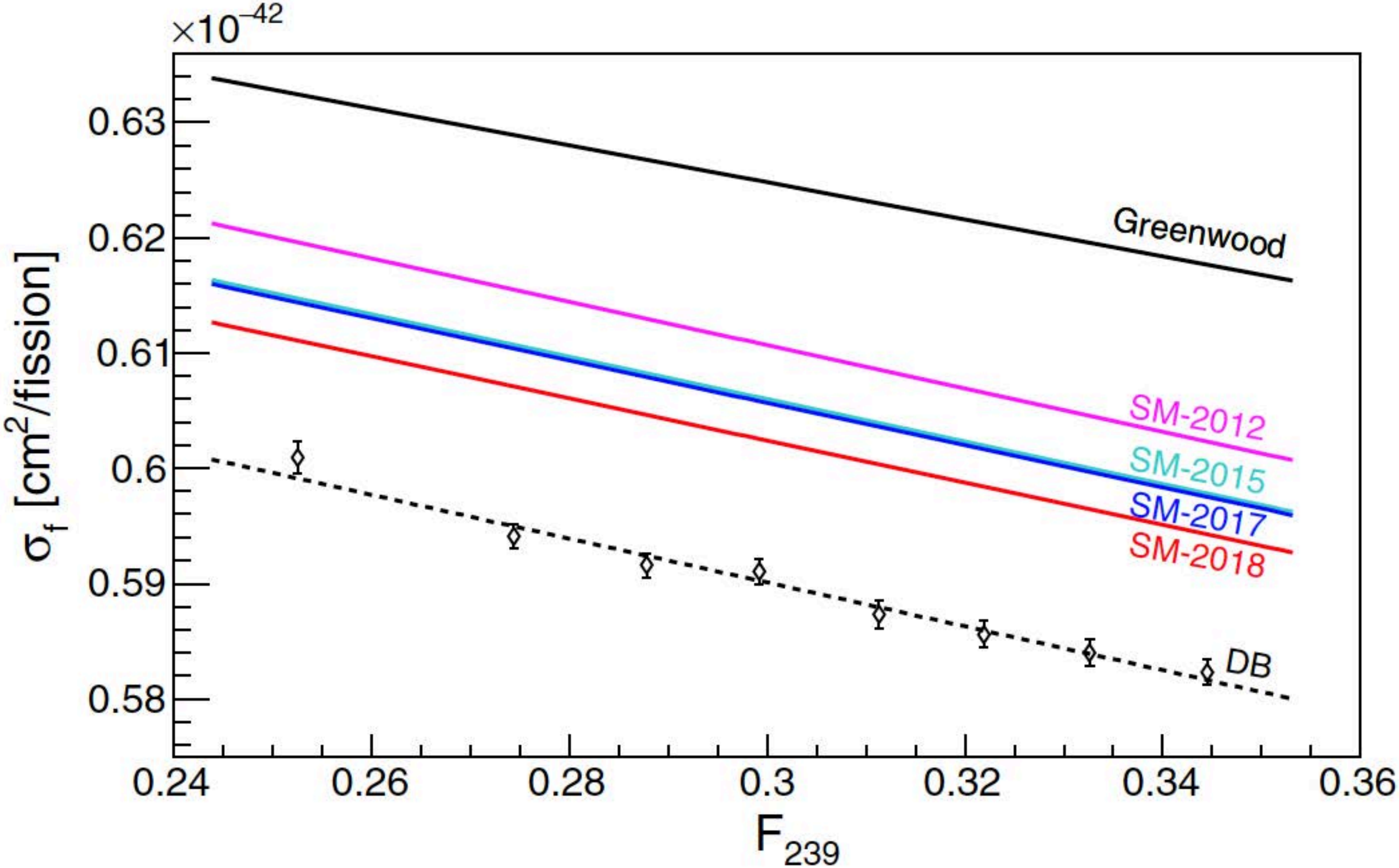




Estienne et al., Phys. Rev. Letts 123, 022502 (2019)

Impact on the neutrino summation calculations





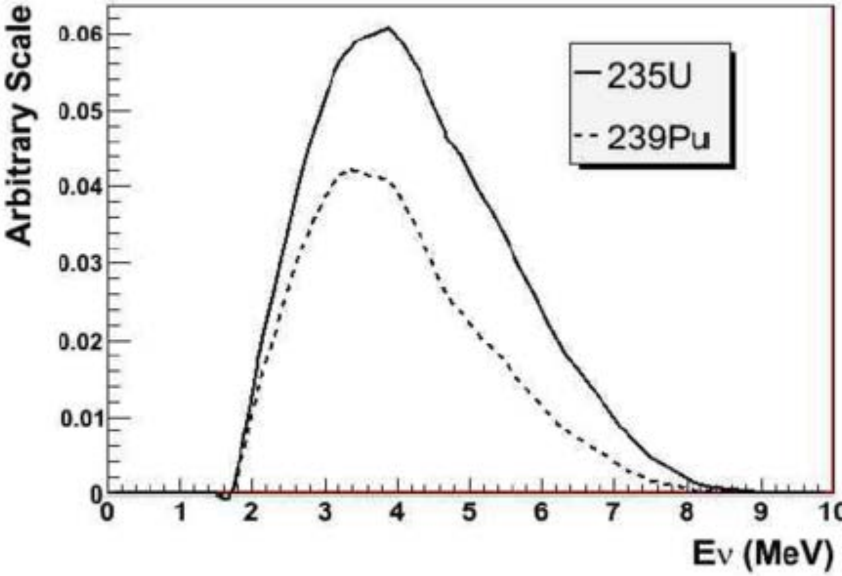
Estienne et al., Phys. Rev. Letts 123, 022502 (2019)

Another application: prediction of the neutrino spectrum from reactors for non-proliferation

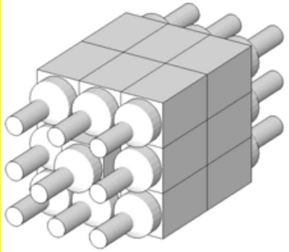
	235U	239Pu
Released E per fission	201.7 MeV	210.0 MeV
Mean neutrino E	2.94 MeV	2.84 MeV
Neutrinos/fission >1.8 MeV	1.92	1.45
Aver. Int. cross section	$3.2 \times 10^{-43} cm^2$	$2.8 \times 10^{-43} cm^2$

$$\bar{\nu} + p \rightarrow e^+ + n$$ (threshold 1.8 MeV)

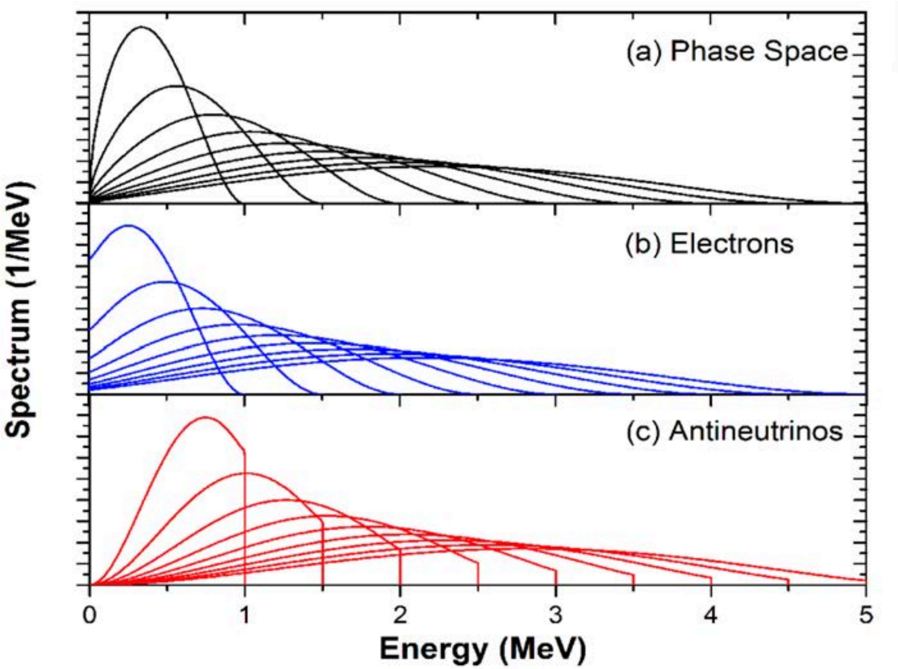
Relevance for non-proliferation studies (working group of the IAEA). Neutrino flux can not be shielded. Study to determine fuel composition and power monitoring. Non-intrusive and remote method.



Antieutrino summation calculations: reactor spectroscopy



Fine structure of the antineutrino spectrum from a reactor reflects what is going on inside a reactor



A. Sonzogni et al., PRC 98.014323

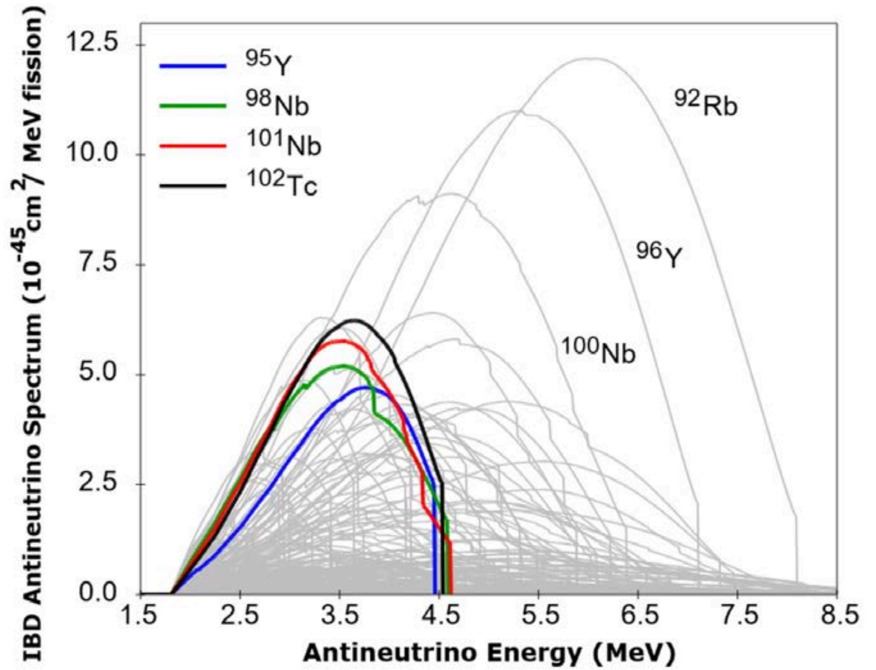
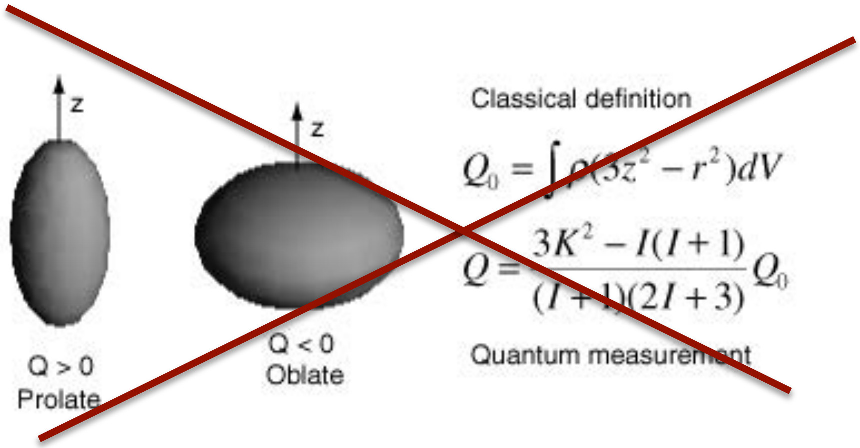


FIG. 6. Calculated Daya Bay IBD antineutrino spectra from all the fission products, highlighting the ^{95}Y, ^{98,101}Nb, and ^{102}Tc ones.

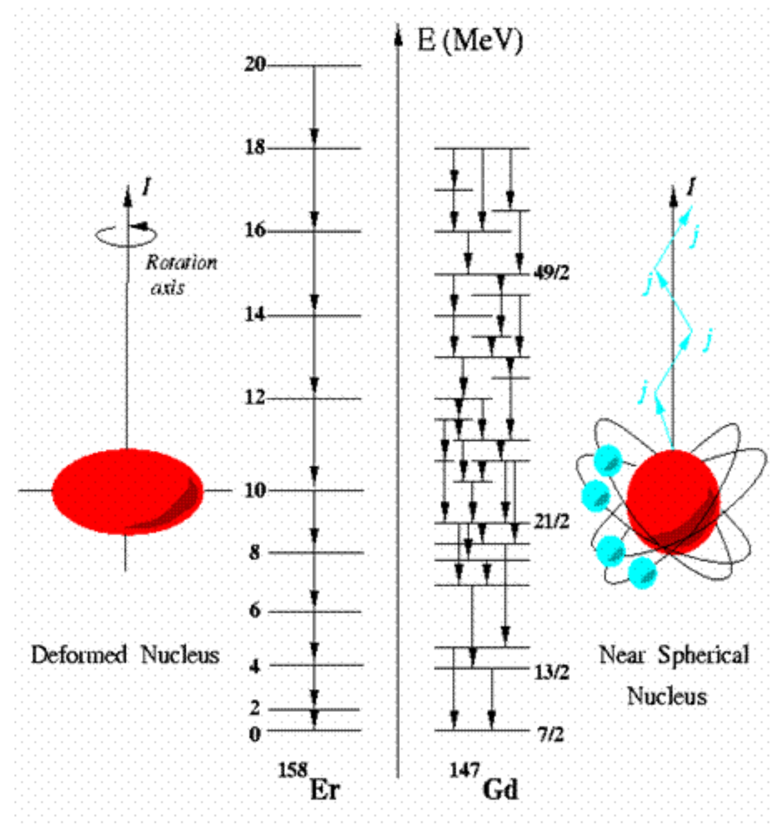
Window to new physics: it can be also relevant for antineutrino experiments of new generation like JUNO and TAO, that address fundamental questions like the mas hierarchy

THANK YOU

How do we deduce the nuclear shape of the ground state when it is a 0+ state …



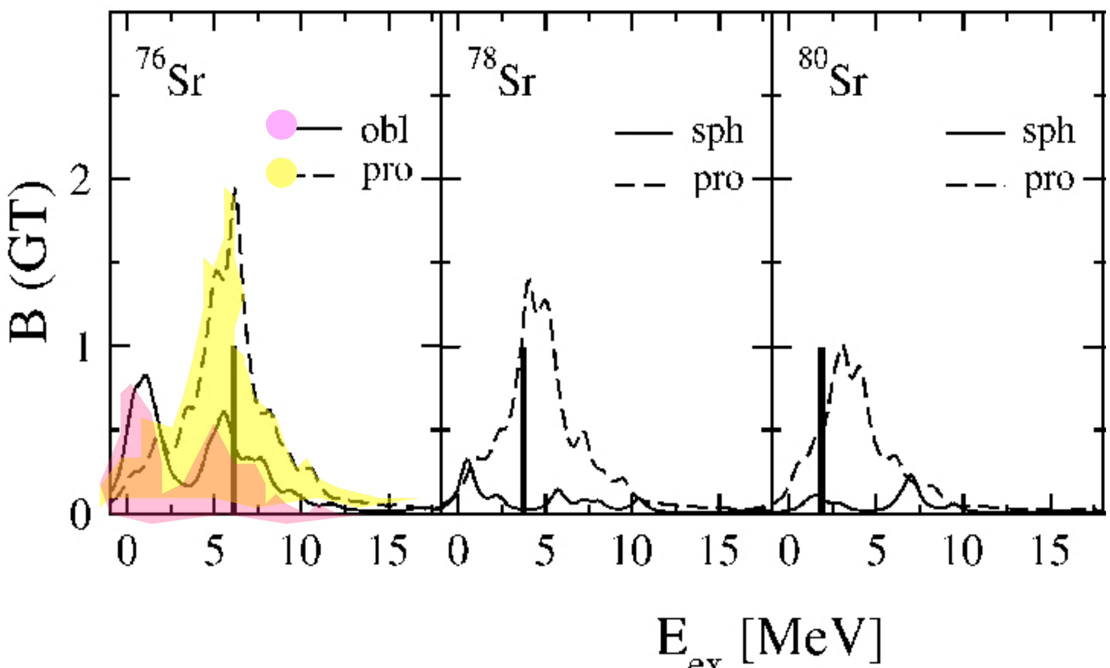
- Nuclear radii determination (isotope shifts)
- Analysis of spectroscopic information (B(E2)-s, $T_{1/2}$ and assuming that we have a band with the same deformation
- ???

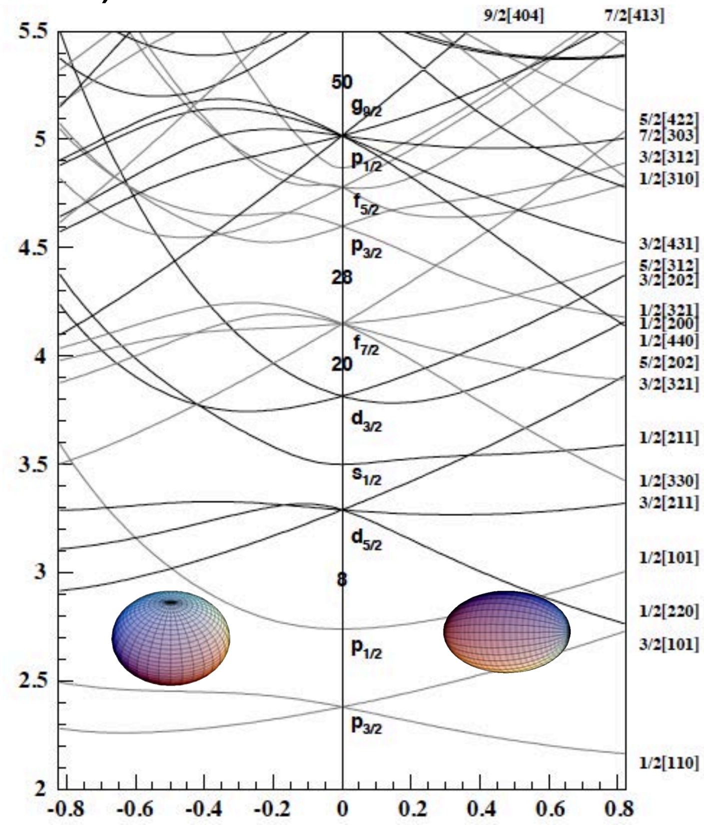


What can beta decay offer apart from spectroscopy …

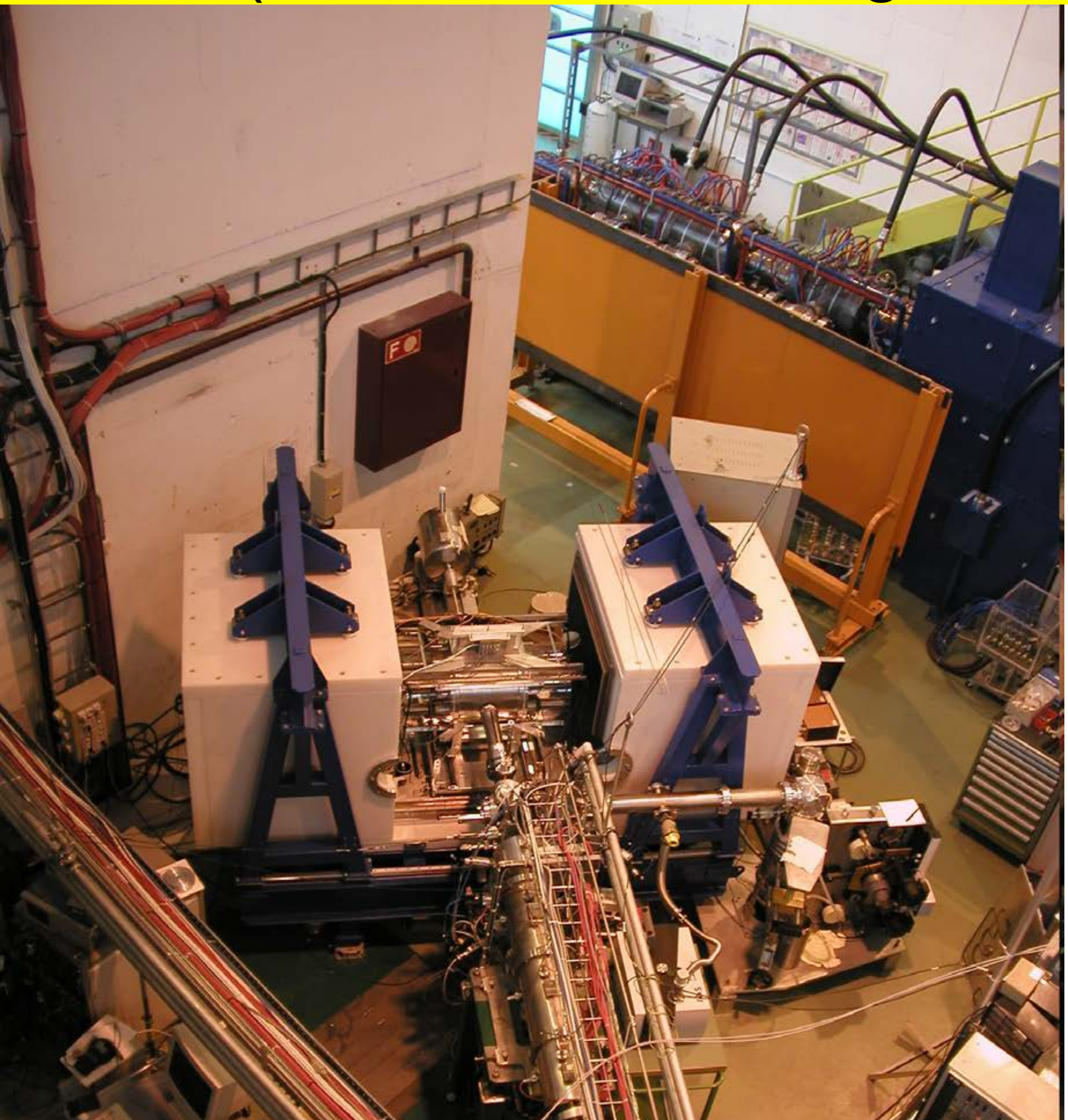
Another alternative, based in the pioneering work of I. Hamamoto, (Z. Phys. A353 (1995) 145) later followed by studies of P. Sarriguren *et al*., Petrovici *et al*. is related to the dependency of the strength distribution in the daugther nucleus depending on the shape of the parent. It can be used when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

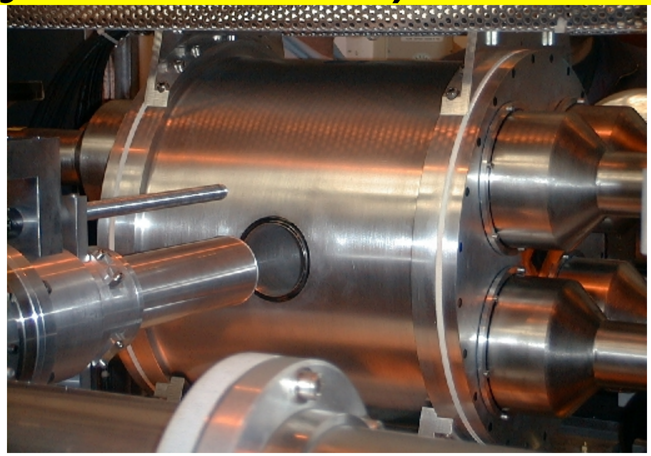
P. Sarriguren *et al*., Nuc. Phys. A635 (1999) 13





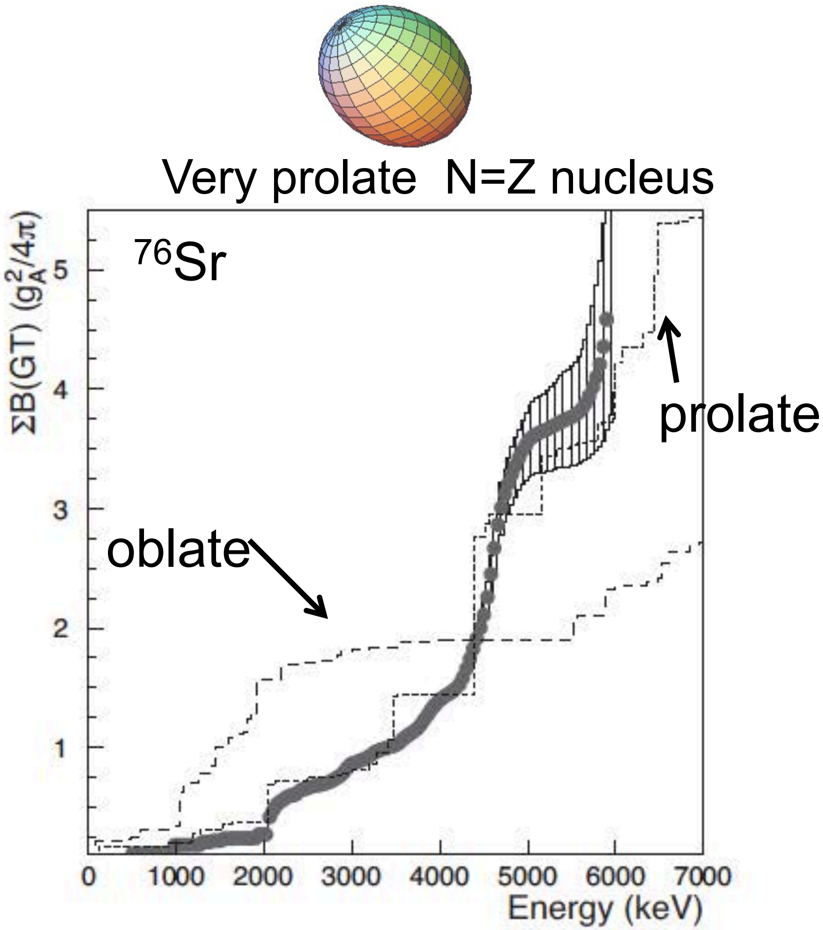
Lucrecia: the TAS at ISOLDE (CERN)
(Madrid-Strasbourg-Surrey-Valencia)

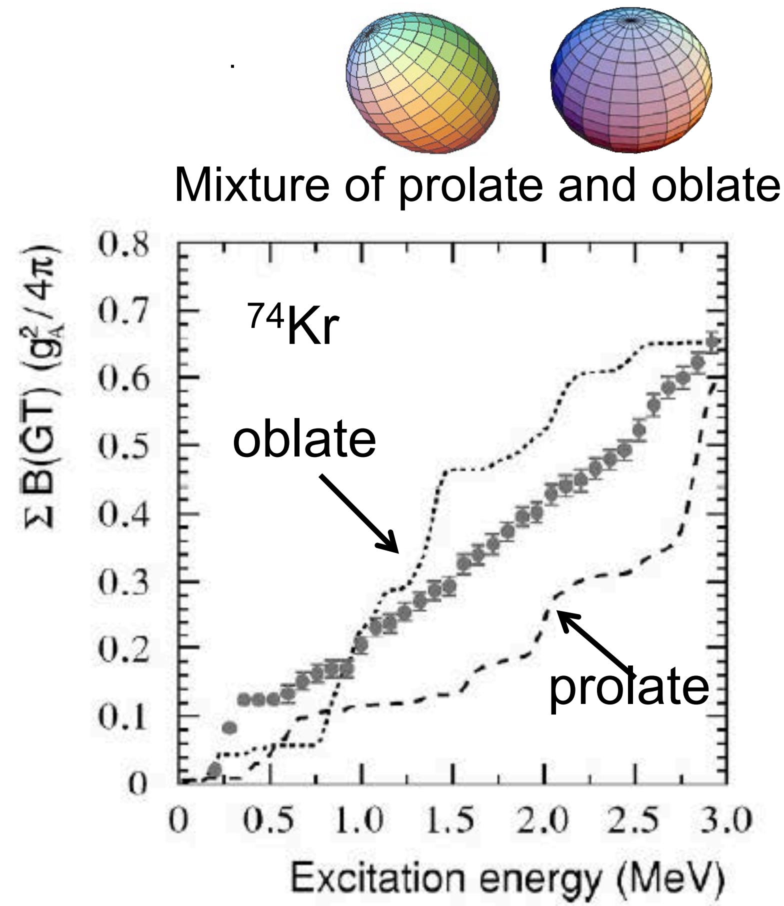




- A large NaI cylindrical crystal 38 cm Ø, 38cm length
- An X-ray detector (Ge)
- A β detector
- Possibility of collection point inside the crystal

Some earlier examples (proposals of Rubio and Dessagne)

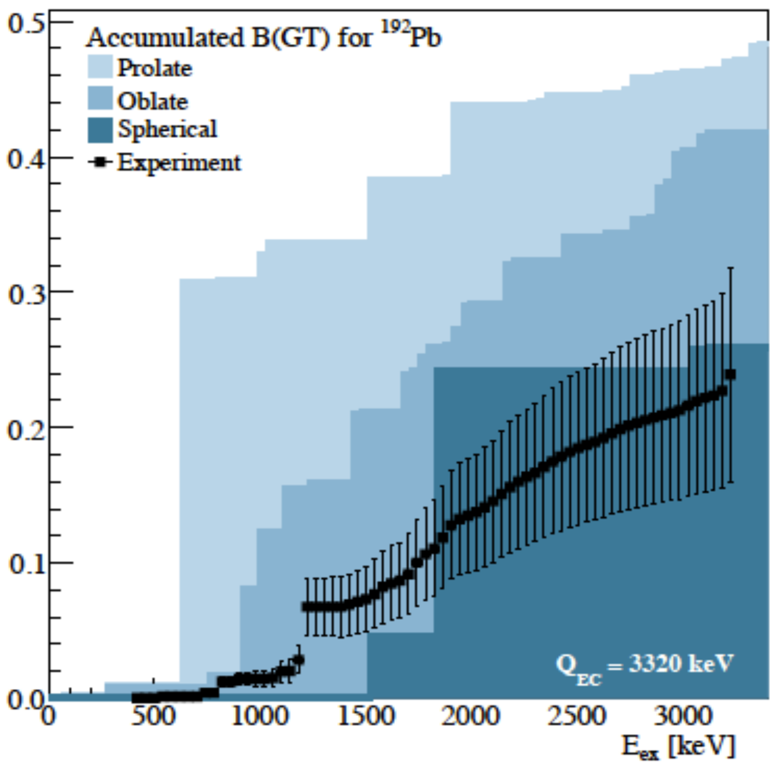


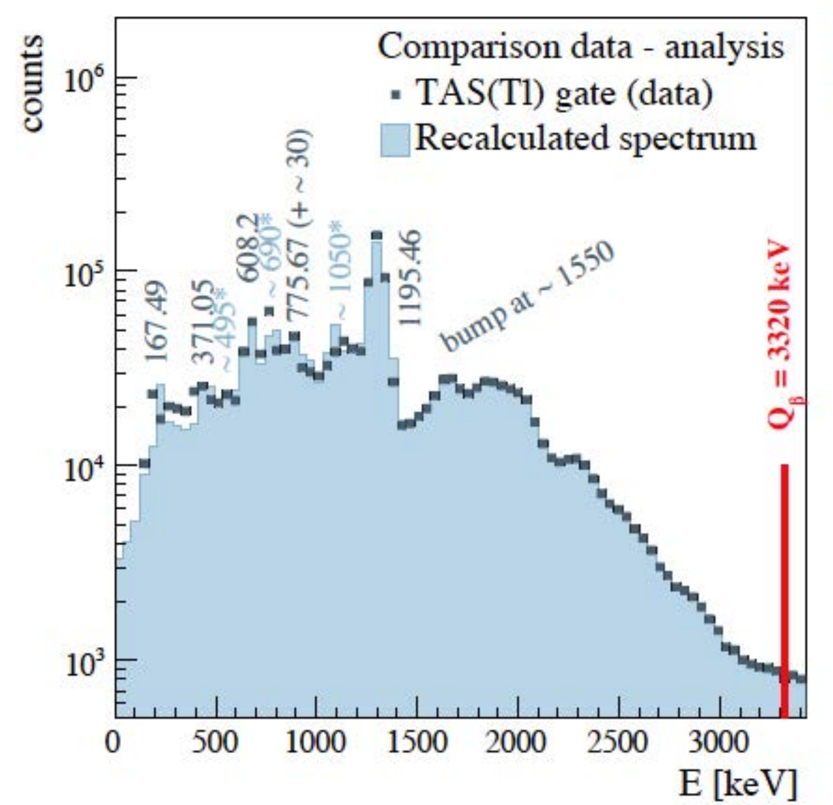


E. Nácher *et al. PRL 92 (2004) 232501 and PhD thesis Valencia*
Ground state of ^{76}Sr prolate (β_2 ~0.4) as indicated in Lister et al., PRC 42 (1990) R1191

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.)

IS440 results: ^{192}Pb example





Thesis work of M. E. Estevez 2011 (Univ. Valencia), and M. E. Estevez *et al. PRC 92, 044321*
Theory from PRC 73 (2006) 054317)
Results consistent with spherical picture, but less impressive than in the A≈80 region. Similar situation for ^{190}Pb. *Possible explanation, the spherical character of the Pb nuclei, but requires further testing.*

IS539, ISOLDE CERN analysis on-going (Spokespersons: Algora, Fraile, Nacher), Hg isotopes
IS570, ISOLDE CERN analysis on-going (Spokespersons: Nacher, Domingo, Algora), Se, Ge