Single-particle structure and Nuclear Pairing at the limits ...

Benoît GALL

IPHC - Strasbourg

ENAM- Sept. 9 2008

→ article à bosser pour le stage 237

Physica Scripta. Vol. 42, 515–521, 1990.

Pairing Correlations in Rotating Nuclei and the Frequency-Deformation Scaling

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Received January 18, 1990; accepted February 16, 1990

Abstract

The dynamical pairing correlations are discussed using the rotating harmonic oscillator model and the RPA formalism. The dependence of the pairing strength distribution on rotational frequency and deformation is given special attention. In particular, the influence of coupling between different oscillator shells is analyzed in detail. Explicit formulae are given for the overlap matrix elements between the rotating and nonrotating states of the

vibrational approximation has proved to be very accurate [4–6].

The systematics of high-spin experimental data indicate that at large rotational frequencies a gradual transition to the unpaired regime takes place [7]. Indeed, the near-yrast excitations observed in the 40–50 spin region have characteristic ?

STAGE DE DEA

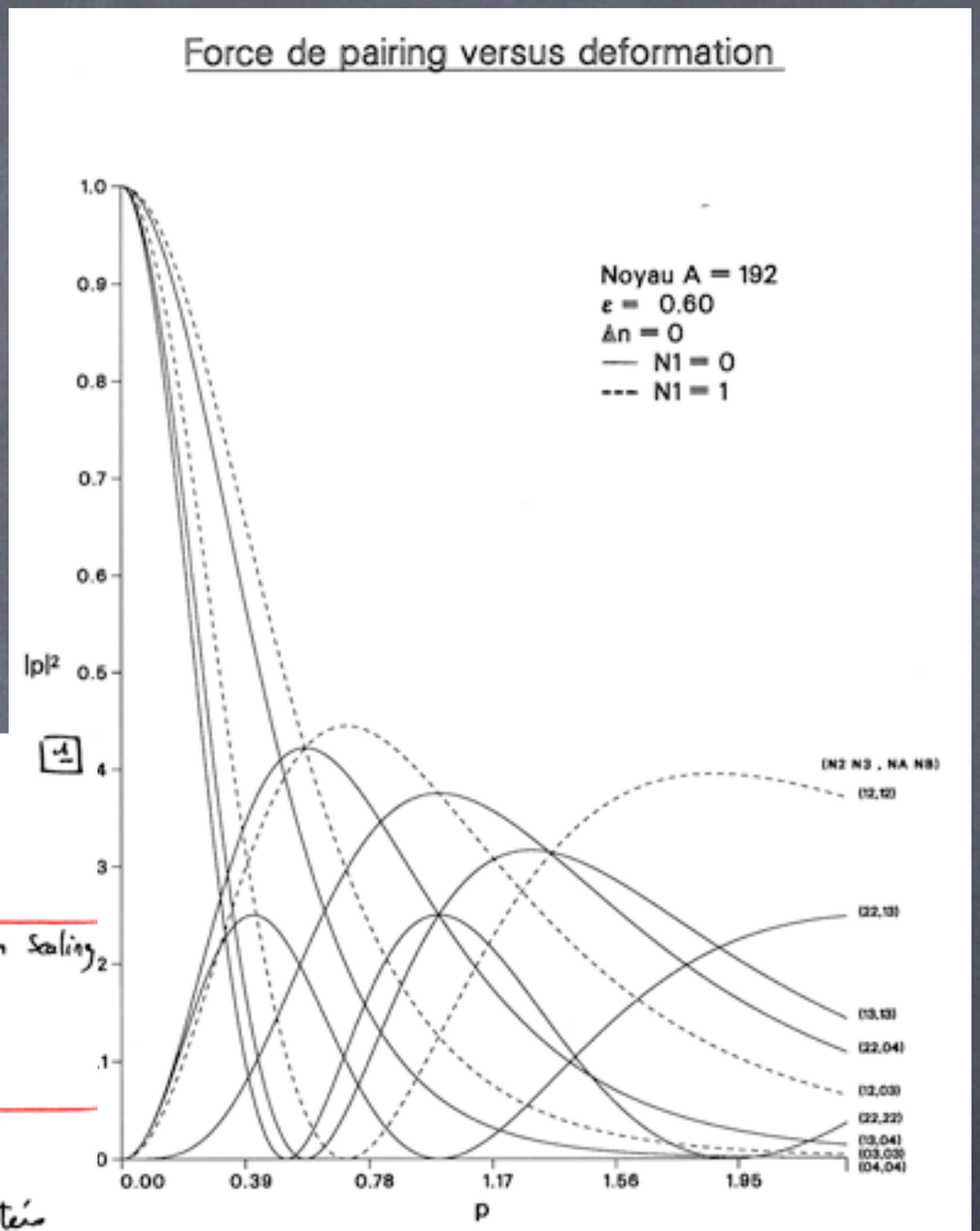
Etude de l'article Suivant :

Pairing Correlations in Rotating Nuclei and the Frequency Deformation Scaling

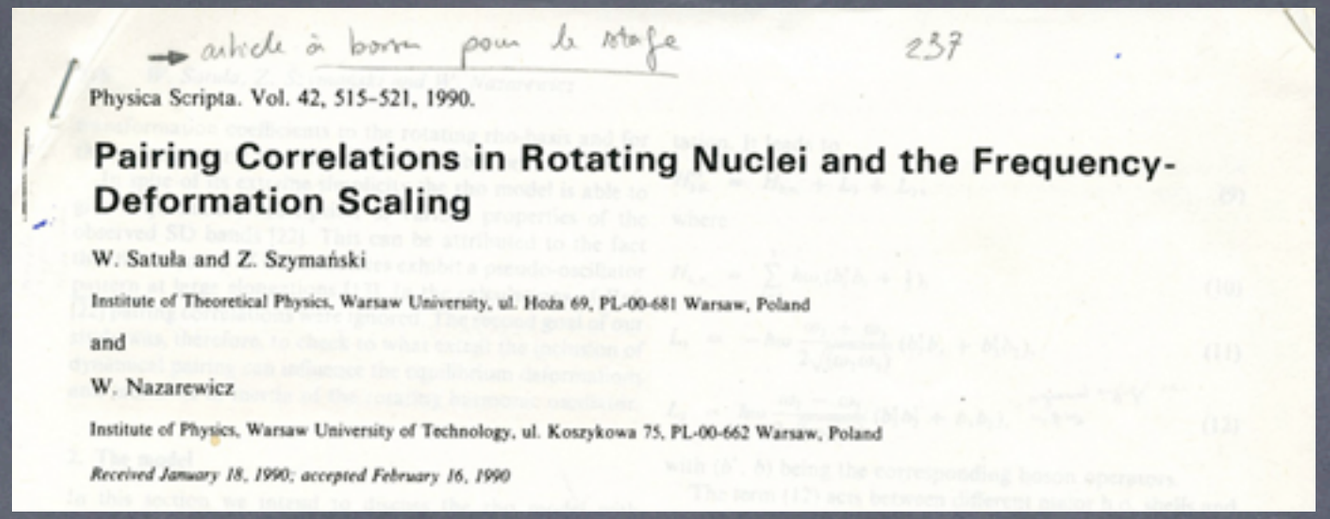
W. SATULA . Z SZYMANSKI W NAZAREWICZ

PHYSICA SCRIPTA. VOL 42, 515-521, 1990

Dans cet Article les correlation dynamiques de Pairing sont discutés dans le cadre du modele de l'oscillateur harmonique en rotation et du formalisme de la RPA. On donne une importance toute particulière à l'intensité de la force de pairing. L'analyse de l'influence du couplage de plusieurs couches de l'oscillateur est faite en détail. Les formules explicites des recouvrements des fonctions d'onde en rotation et non tournantes sont également données ici.



Outline



article à bonne pour la stage 237

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- Superdeformed Nuclei : effect of rotation alone on pairing correlations
- A=100 : combined effect of rotation and deformation on pairing correlations
- Heavy Elements Spectroscopy ... on the way to the Super-Heavies

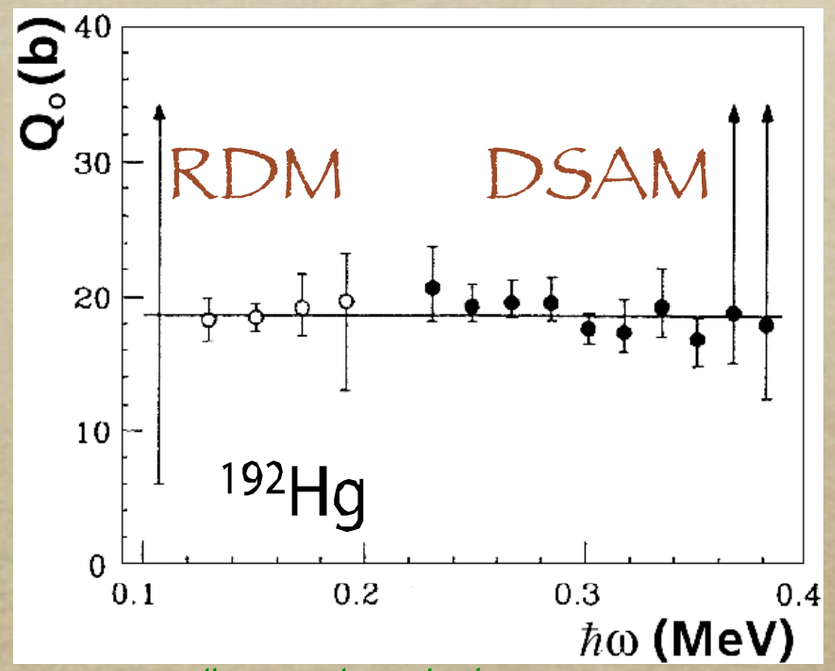
Nuclear Pairing dependance on Rotation - even-even SD Bands

Spectroscopy of Yrast ^{192}Hg and ^{194}Pb SD bands

- Quadrupolar moment measurement

—» DSAM

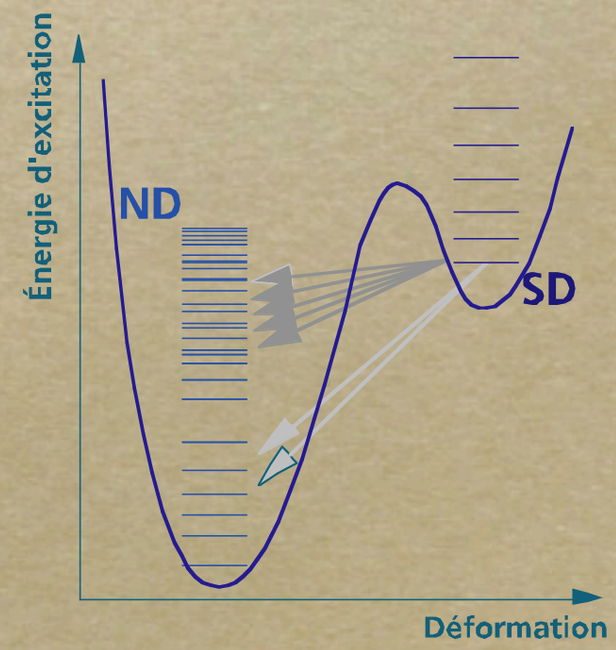
—» RDM



P. Willsau et al. Nucl. Phys A574 (1994)560

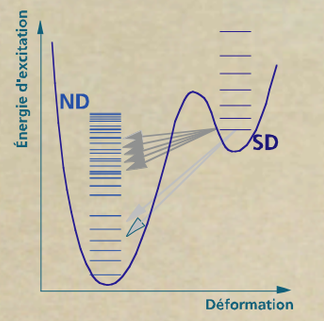
The deformation stays Constant from higher spin of the SD-band up to the lower spins of the band ...

Best "lab" to study the influence of rotation alone on nuclear pairing.



PhD Work in Paris

Nuclear Pairing dependance on Rotation



Spectroscopy of ^{192}Hg and ^{194}Pb SD bands

- Constant Quadrupolar Moment
- Dynamical Moment of inertia : $\mathcal{J}^{(2)}$

—» Steady increase

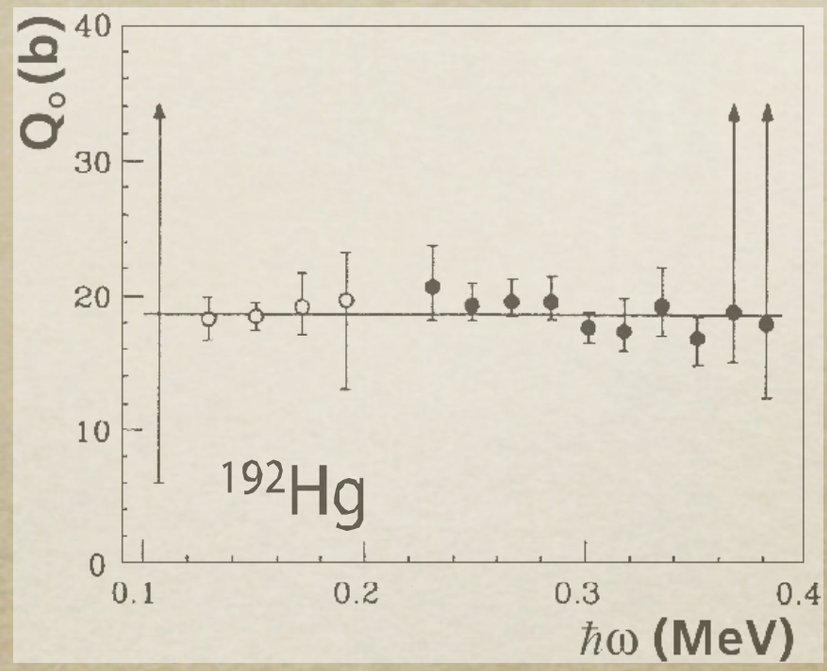
—» Saturation at high Frequency...

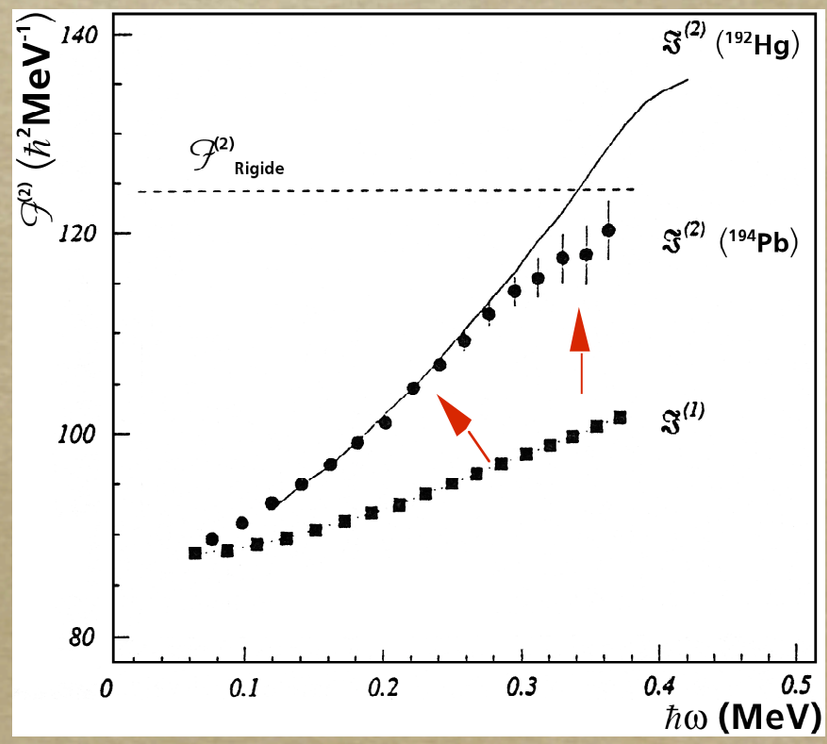
Sign of the progressive reduction of Pairing-Correlations Effects with Rotation

—» Different Saturation for different bands !

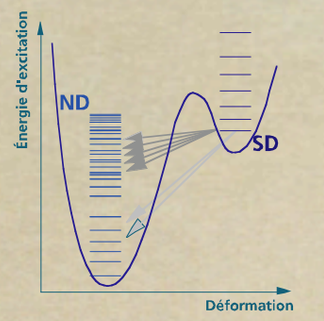
Sign of the single particule content of the nuclei especially in "intruder" orbitals

PhD Work in Paris





Nuclear Pairing dependance on Rotation



Spectroscopy of ^{192}Hg and ^{194}Pb SD bands

- Constant Quadrupolar Moment
- Dynamical Moment of inertia : $\mathcal{J}^{(2)}$

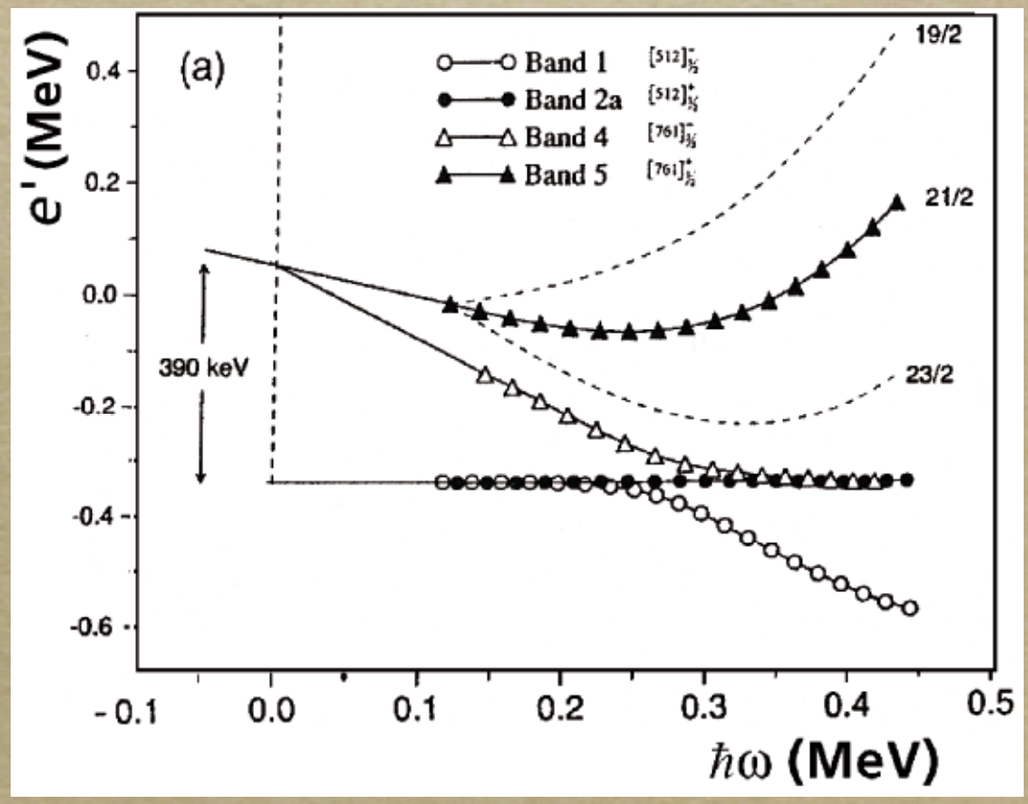
Spectroscopy of odd-even nuclei (example of ^{193}Hg)

—» Intensity splitted over several bands

—» The bands are linked together

—» Study of Routhains

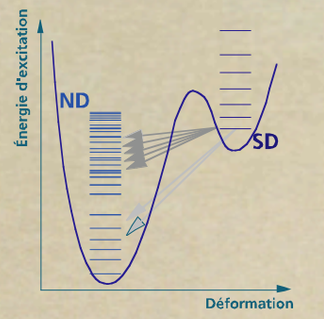
Possibility to extract experimental quasi-particle routhians



M J Joyce et al. Phys Rev. Lett. 71. 2176 (1993)

PhD Work in Paris

Nuclear Pairing dependance on Rotation



Cranked Hartree-Fock code

—» Pure HF almost flat

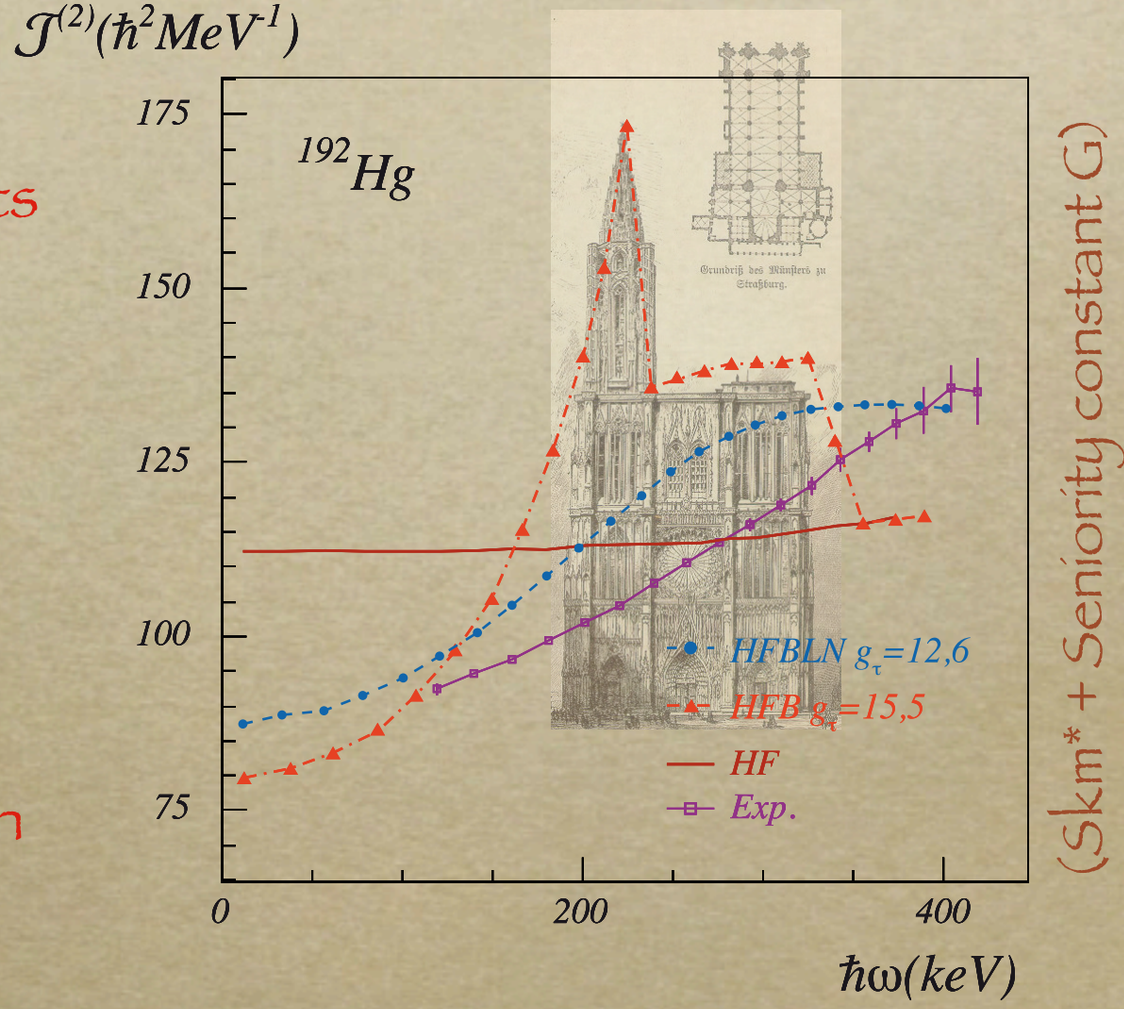
—» HFB Steady Increase but also sharp effects ends on the HF solution at high-spin ...due to Pairing dissapearance

Signature of the pairing content and underlying Single-Particles orbitals

—» HFB -LN approximate particle # projection

Behaviour in agreement with experiment

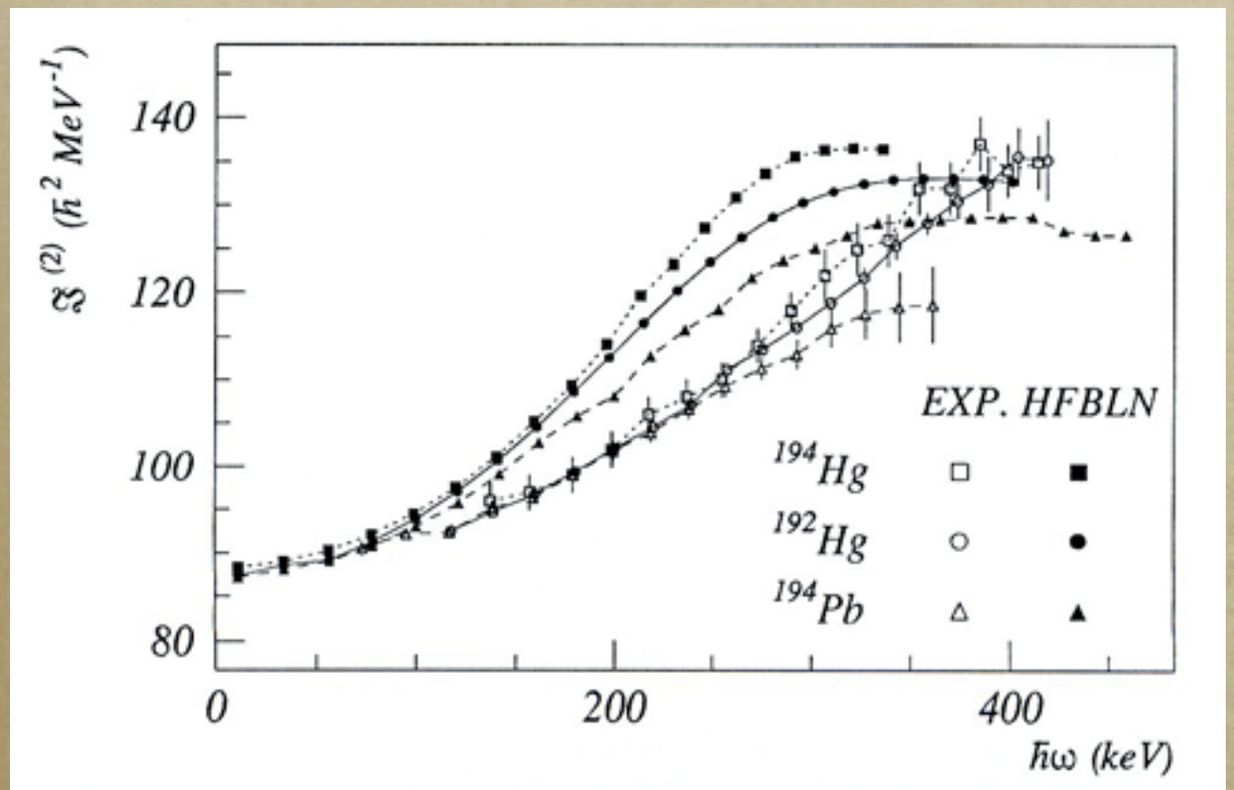
Need more investigations



On the good way ...

PhD Work in Paris

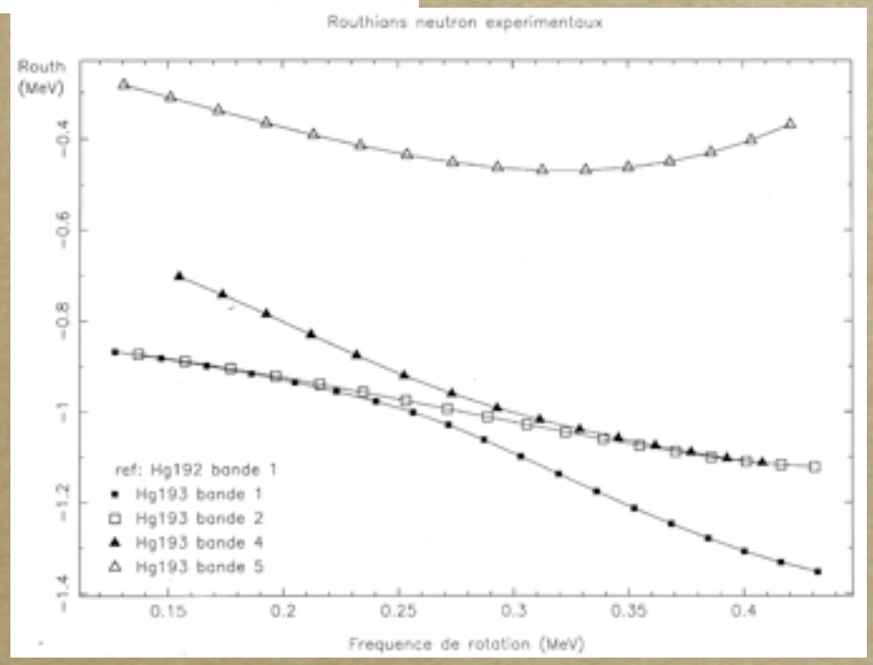
Experiment-Theory : complemantarity

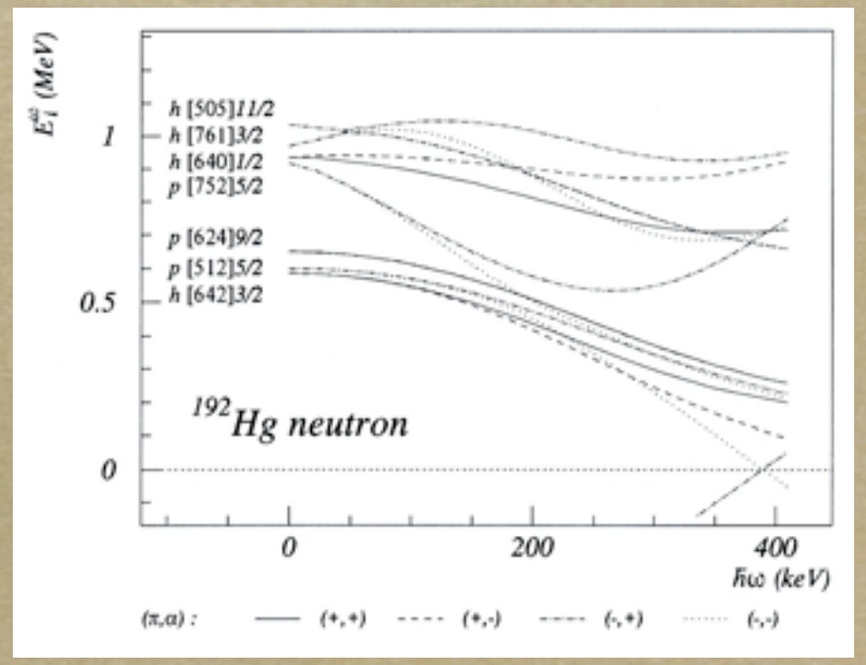


A ≈190 Sd Bands All Identical ?

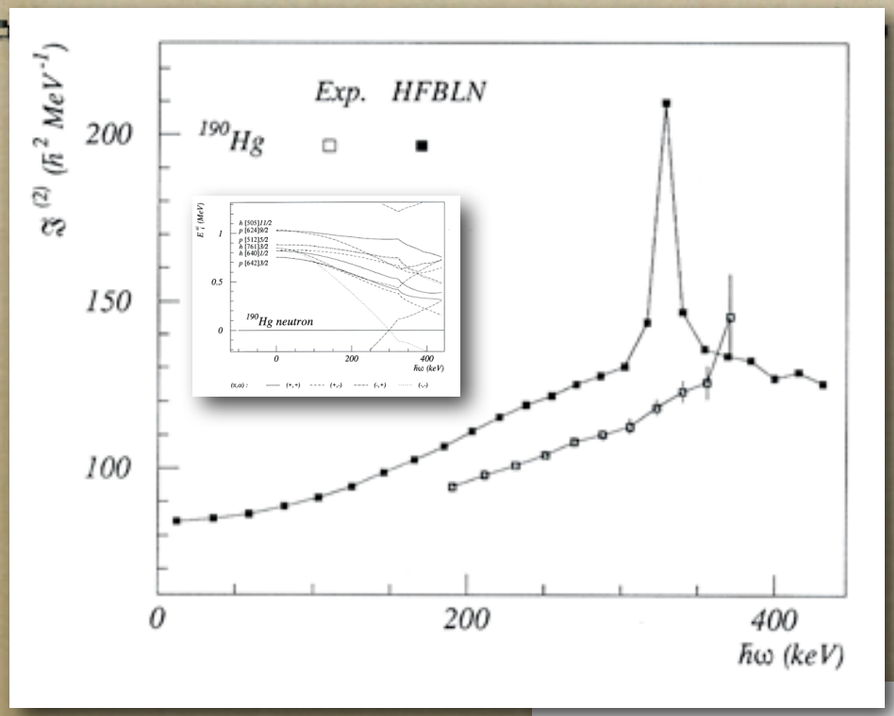
- Behaviour in agreement with experiment
- Signature of the pairing content and underlying Single-Particles orbitals

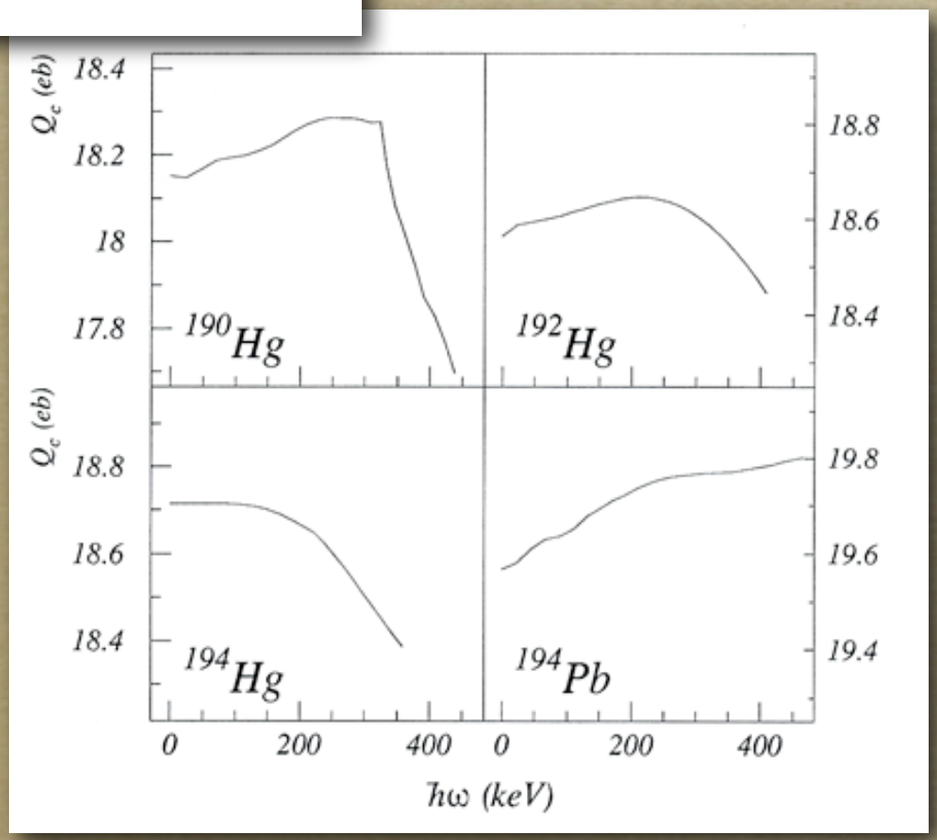
Complementarity

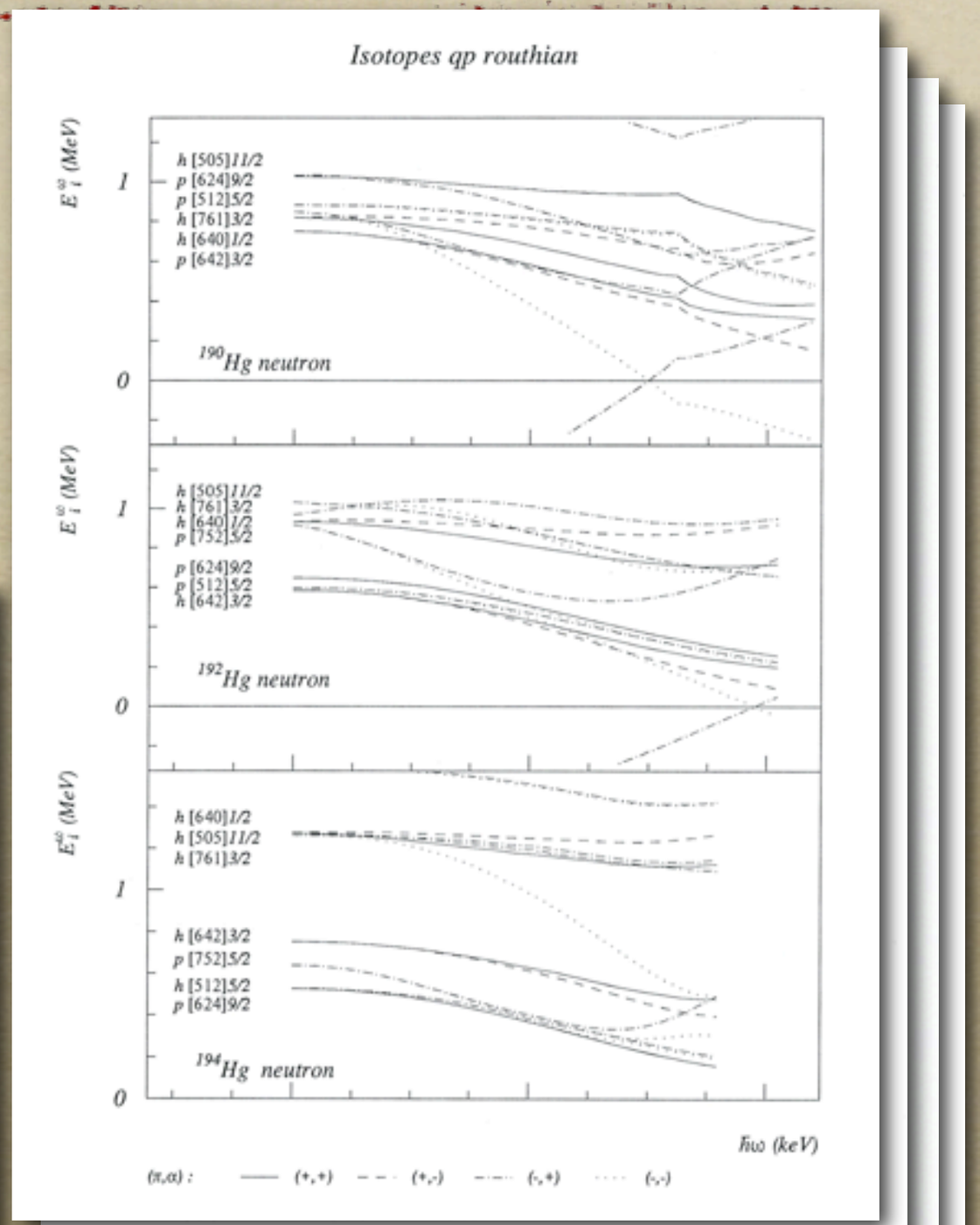




Experiment-Theory : complemantarity







Improvements of the nuclear pairing description

SD-Bands in A=150 ...

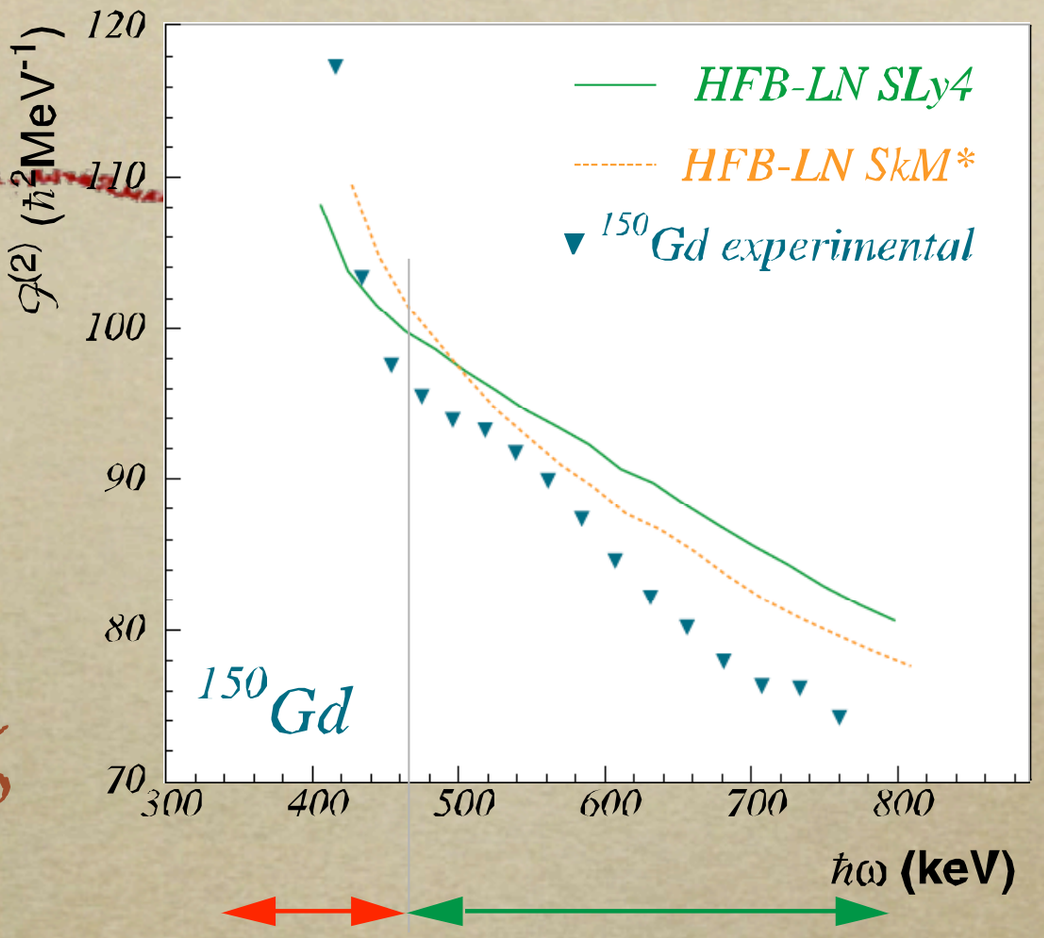
... Nuclear pairing still alive !

Implementation of a delta Pairing

$$V_p = \frac{V_0}{2}.(1 - P^{\sigma}).\left(1 - \frac{\rho(r_1)}{\rho_c}\right).\delta(r_1 - r_2)$$

[J. Terasaki et al., NP A593(1995)1]

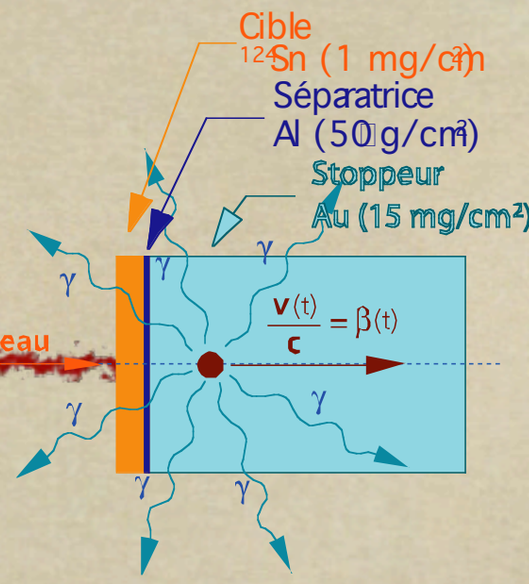
- determination of the right intensity
- Behaviour in agreement with experiment
- ID- Bands : Signature of the underlying Single-Particles orbitals (intruders)



	SLy4	SkM*
1 cut	1000	880
2 cuts	1250	nd

C. Rigollet PhD at CRN Strasbourg

A=150 Identical Bands and quadrupole moments



	protons	neutrons	Q_0 (H.S.)	Q_0 (C.R.)	Q_0 (HFB)	Q_0 (OH)	ε_2 (ε_4)
^{148}Gd(Y)	6^2 ● ●	7^1 ● ● ● ○ ○ ○	14,6 0,2	-	x	16,0 (14,7)	0,545 (0,029)
^{148}Gd(2)	6^2 ● ●	7^1 ● ● ○ ● ○ ○	14,8 0,3	-	x	16,0 (14,7)	0,545 (0,029)
^{148}Gd(5)	6^4 ○ ○	7^2 ○ ○ ● ● ○ ○	17,8 1,3	-	x	19,6 (18,0)	0,618 (0,029)
^{149}Gd(Y)	6^2 ● ●	7^1 ● ● ● ● ○ ○	15,0 0,2	-	15,5	16,5 (15,2)	0,555 (0,029)
^{149}Gd(2)	6^2 ● ●	7^2 ● ● ● ○ ○ ○	15,6 0,3	-	-	16,7 (15,4)	0,556 (0,029)
^{149}Gd(3)	6^3 ○ ●	7^1 ● ● ● ● ○ ○	15,2 0,4	-	-	17,4 (16,0)	0,576 (0,029)
^{149}Gd(4)	6^4 ○ ○	7^2 ● ● ● ○ ○ ○	17,5 0,6	-	-	19,3 (17,8)	0,612 (0,029)
^{152}Dy(Y)	6^4 ● ●	7^2 ● ● ● ● ○ ○	17,5 0,4	18,5 0,5	17,5	18,9 (17,4)	0,582 (0,029)
^{153}Dy(Y)	6^2 ● ●	7^3 ● ● ● ● ○ ○	-	18,4 0,5	17,6	-	-
^{153}Dy(2)	6^2 ● ●	7^2 ● ● ● ● ● ○	-	17,9 0,5	17,2	-	-
^{153}Dy(3)	6^2 ● ●	7^2 ● ● ● ● ○ ●	-	18,2 0,5	17,2	-	-
Config ->	6^x [301]1/2,-1/2 [301]1/2,+1/2	7^y [411]1/2,-1/2 [411]1/2,+1/2 [651]1/2,-1/2 [651]1/2,+1/2 [402]5/2,-1/2 [402]5/2,+1/2	Experiment		Theory		

DSAM experiments with same stopper :

^{124}Sn(^{30}Si,6-5n)^{148,149}Gd à 158 MeV (@EGII)

^{120}Sn(^{36}S,4n)^{152}Dy à 170 MeV(@EGII)

^{120}Sn(^{34}S,6-5n)$^{152\text{-}153}$Dy à 175 MeV(@GS)

Absolute errors due to stopping power remains but relative errors are small

HFB-LN (SLy4, pub, 2 cuts) Calculations

Good agreement with experimental quadrupolar moments

Important Influence of intruders orbitals

Identical bands correspond to similar quadrupole moments but to slightly different deformation (see last row)

PhD Thesis of H. SAVAJOL & C. RIGOLLET

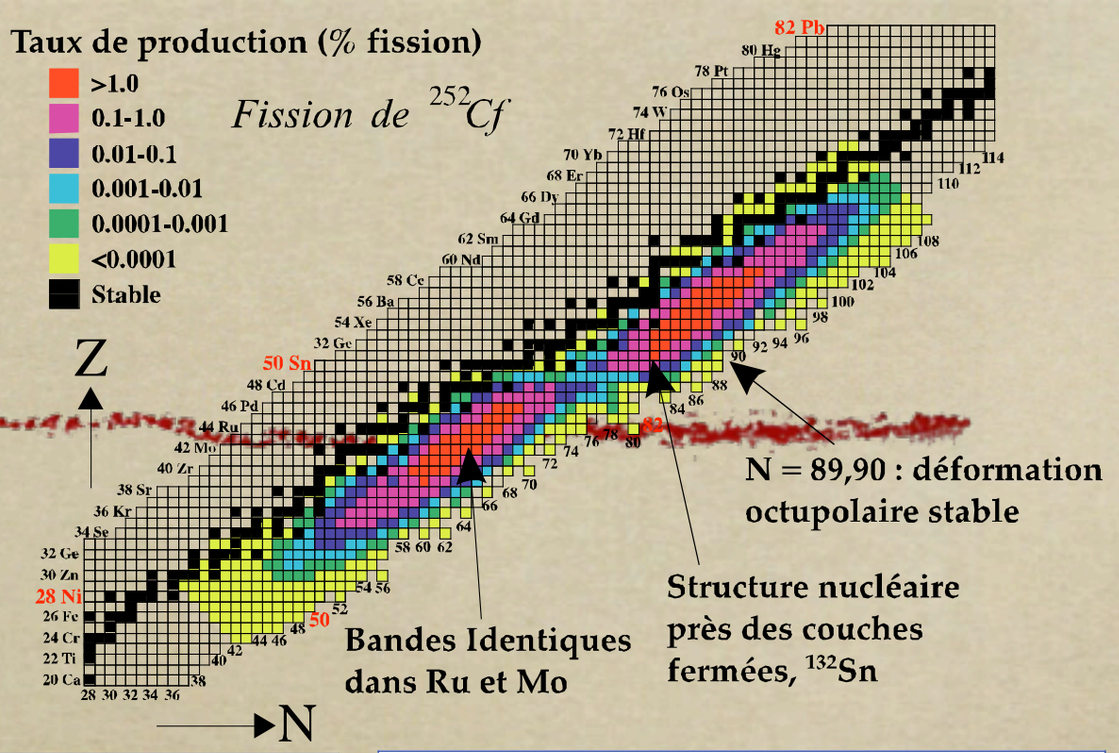
Outline

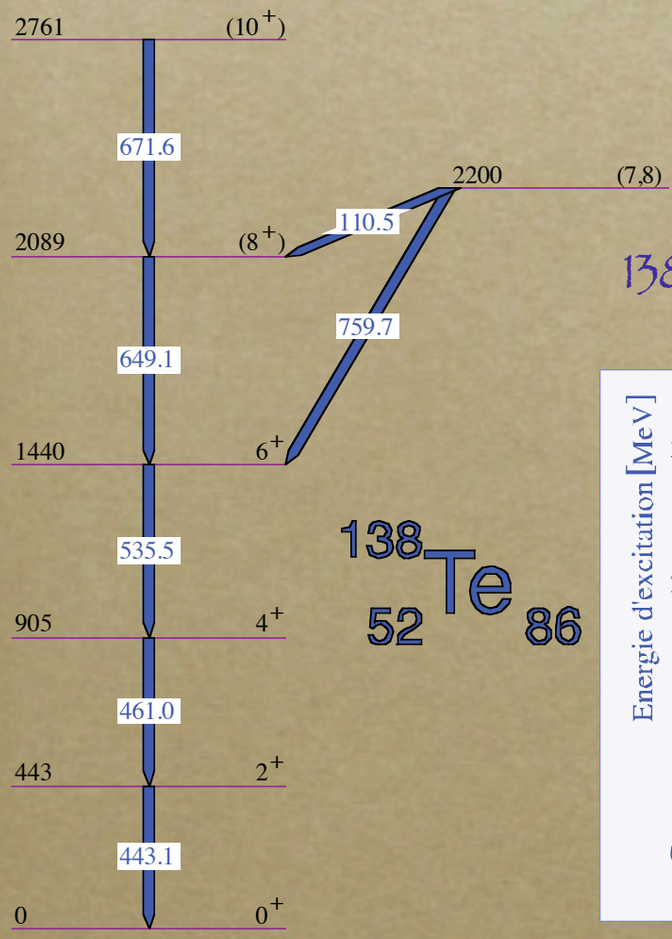
- Superdeformed Nuclei : effect of rotation alone on pairing correlations
- A=100 : combined effect of rotation and deformation on pairing correlations
- Heavy Elements Spectroscopy ... on the way to the Super-Heavies

A ~ 100 Neutron-rich Nuclei

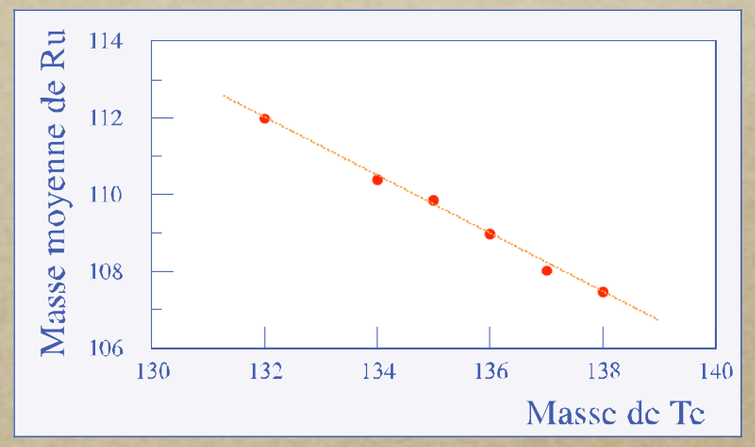
Fission-Fragments Spectroscopy

^{138}Te correspond to a vibrationnal structure

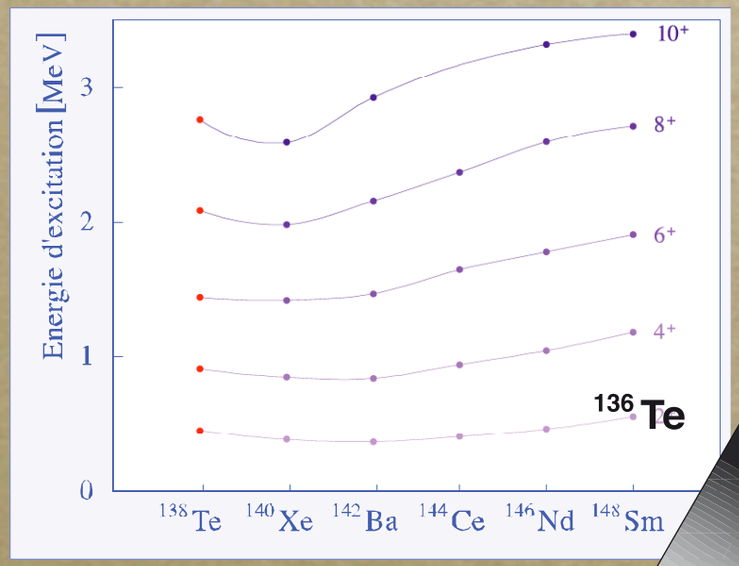




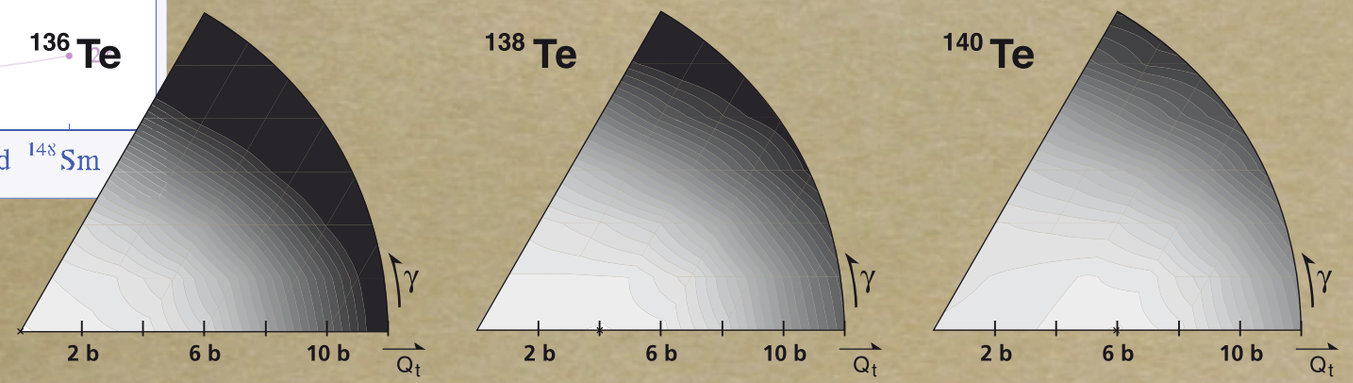
	Vibration	Rotation	^{138}Te
$E(4^+)/E(2^+)$	2	3,3	2,06
$E(6^+)/E(2^+)$	3	7,0	3,26
$E(8^+)/E(2^+)$	4	12,0	4,71



^{138}Te is calculated prolate ...



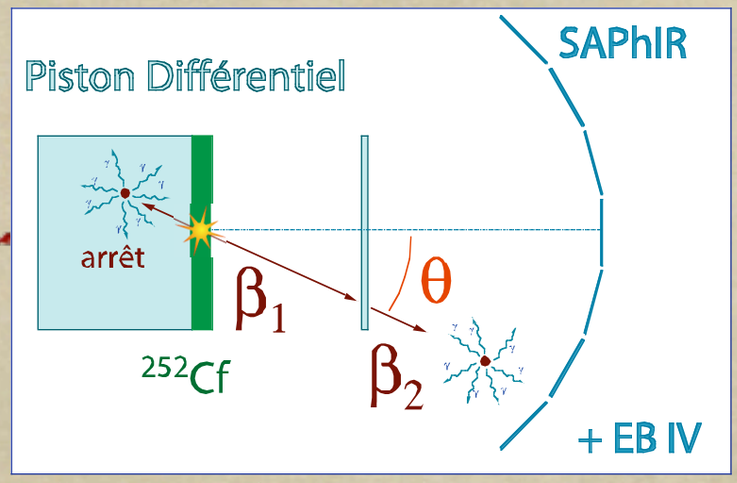
The spherical to prolate shape transition is higher in mass for Te's



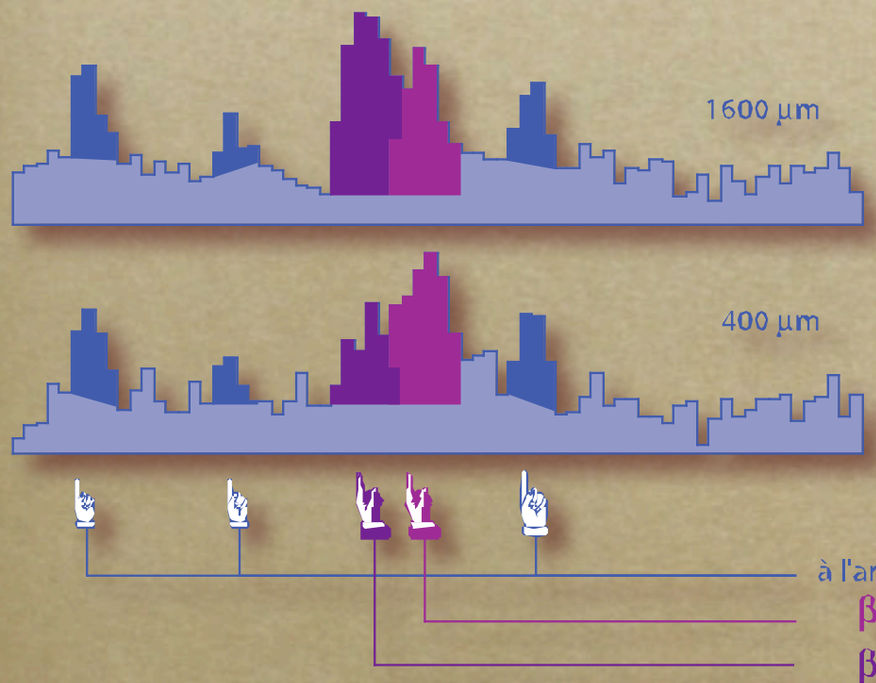
PhD Thesis of F. HOELLINGER

A ~ 100 Neutron-rich Nuclei Spectroscopy

Quadrupole Moment Measurments



A.G. SMITH et al. (Manchester University)

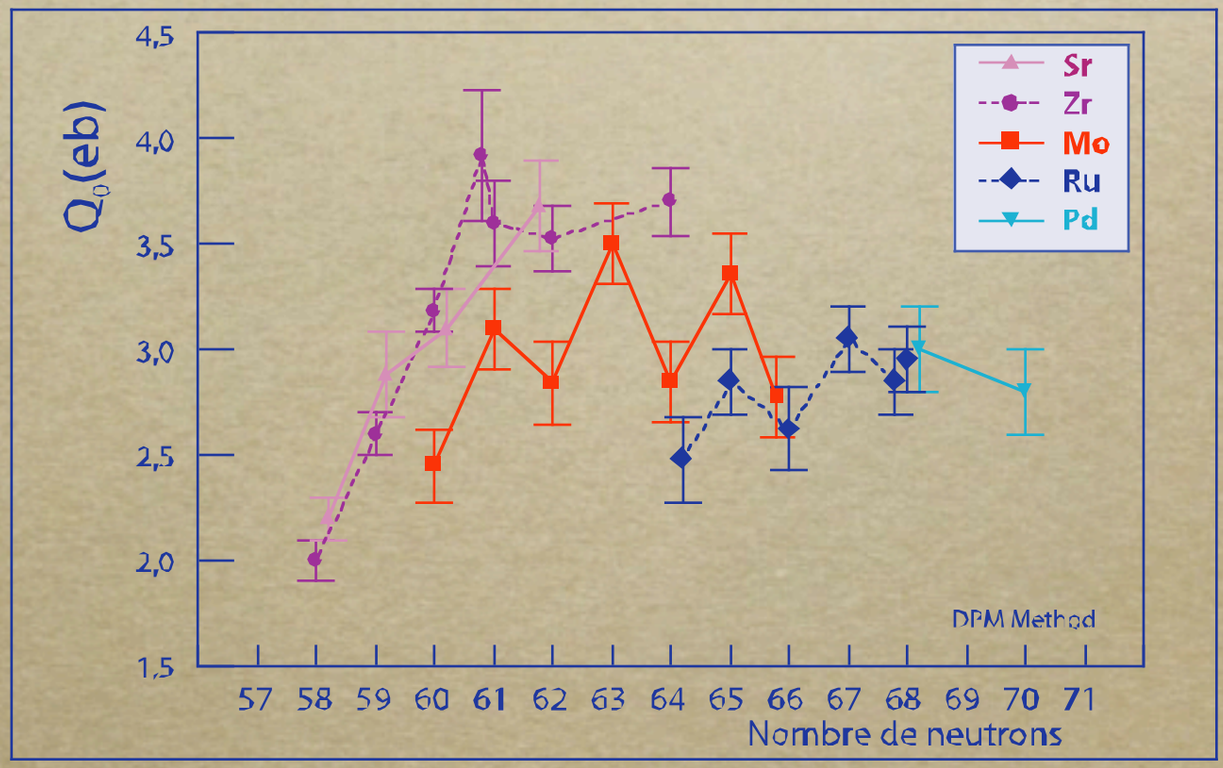


^{104}Mo $4^+ \rightarrow 2^+$

gaté sur ^{104}Mo $2^- \rightarrow 0^+$

$30\ ps < \tau < 120\ ps$

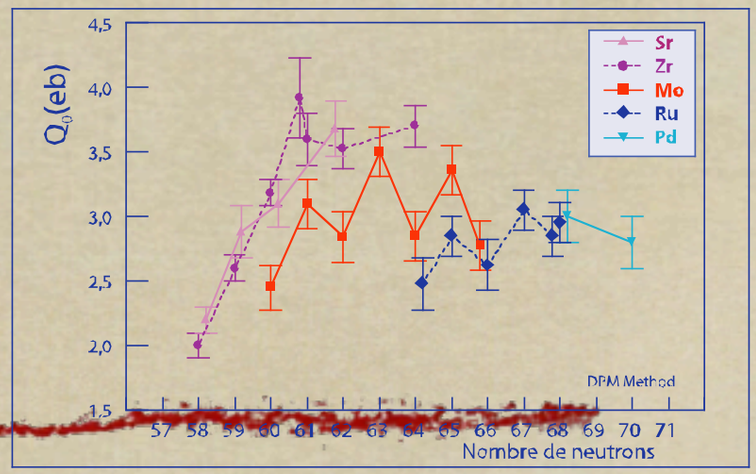
à l'arrêt	368,0 keV
β_2	359,2 keV
β_1	354,5 keV

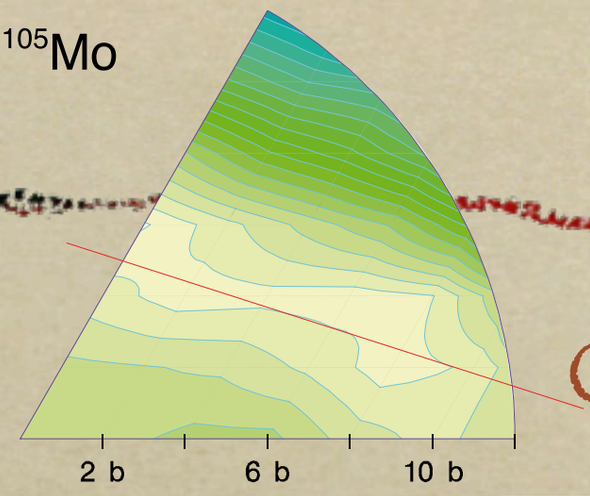


The Mo isotopes oscillate between two behaviors (Sr, Zr) and (Ru, Pd) ... Shape transition Région

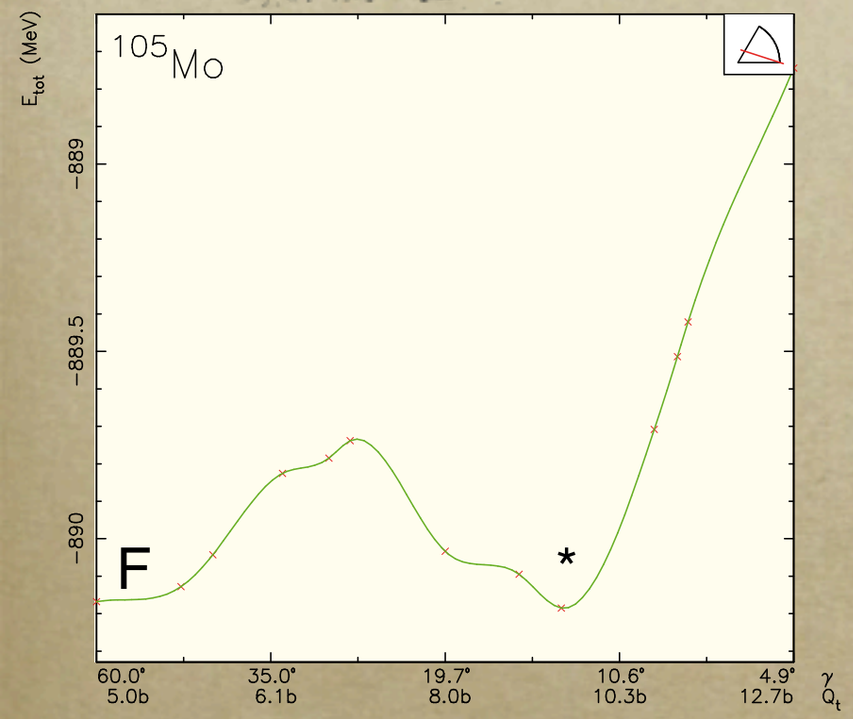
Experiments in Strasbourg

A ~ 100 Neutron-rich Nuclei Spectroscopy

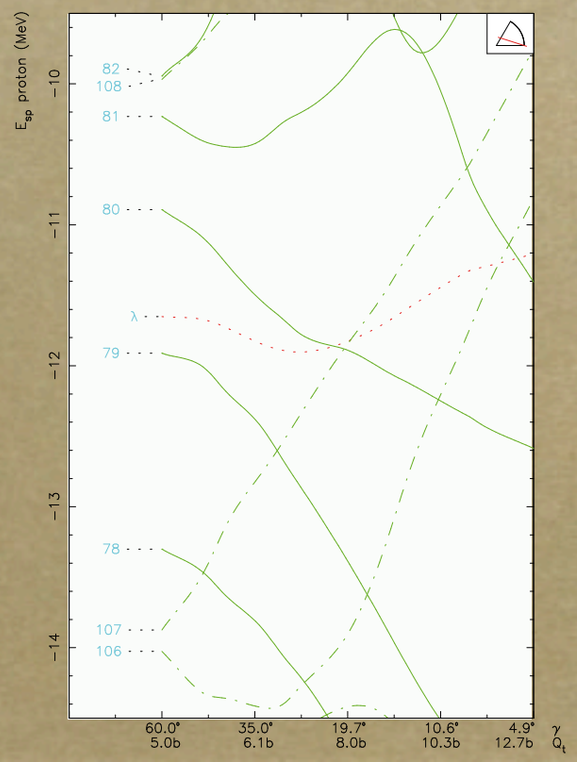


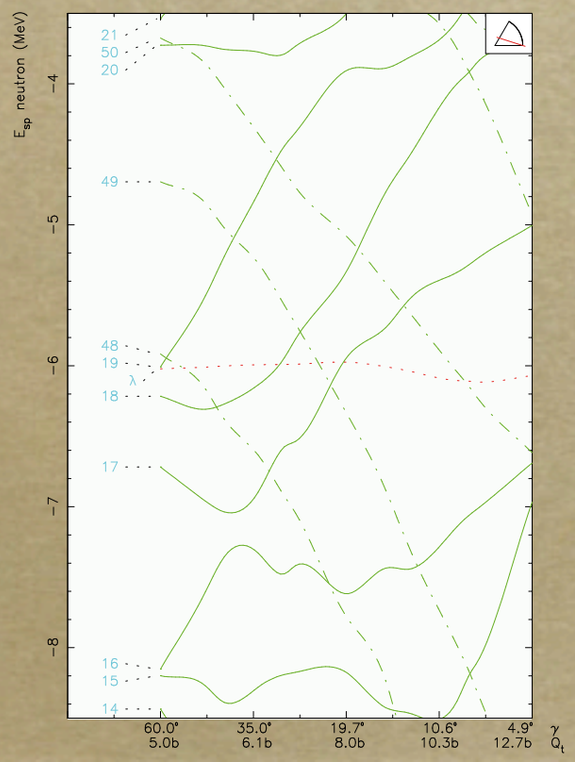


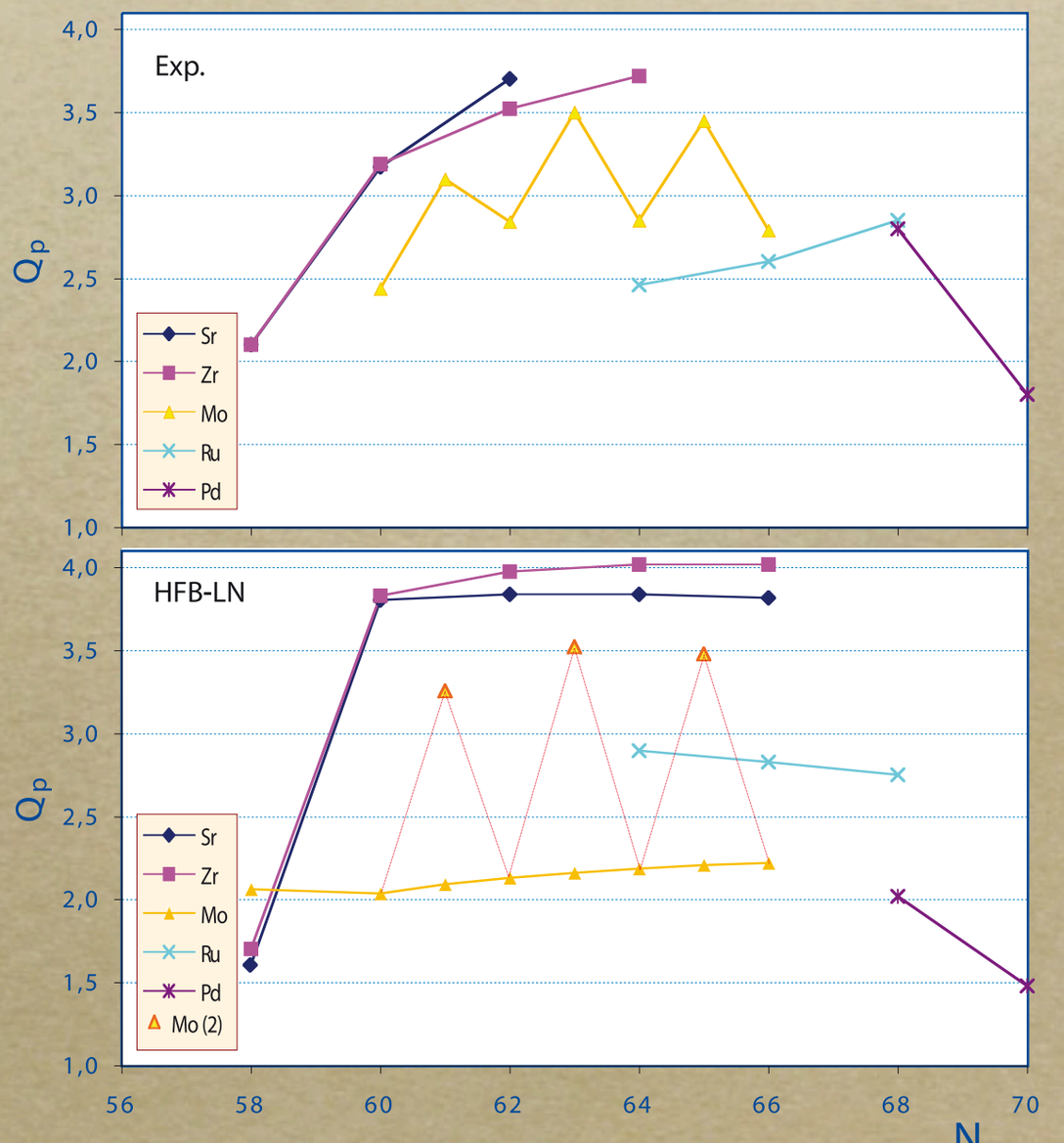
Gamma-soft nucleus



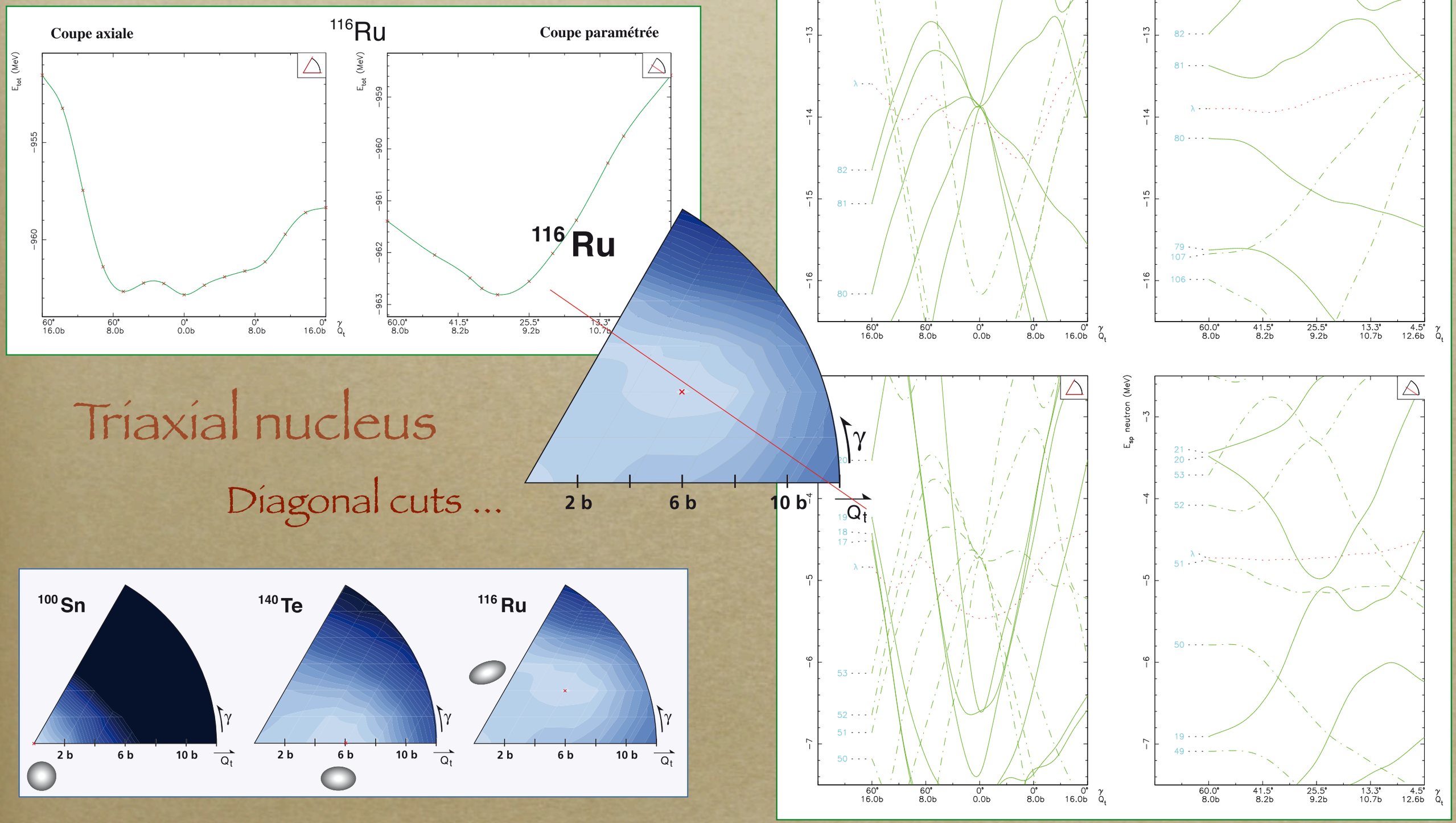
Diagonal cuts ...







A ~ 100 Neutron-rich Nuclei Spectroscopy



Triaxial nucleus

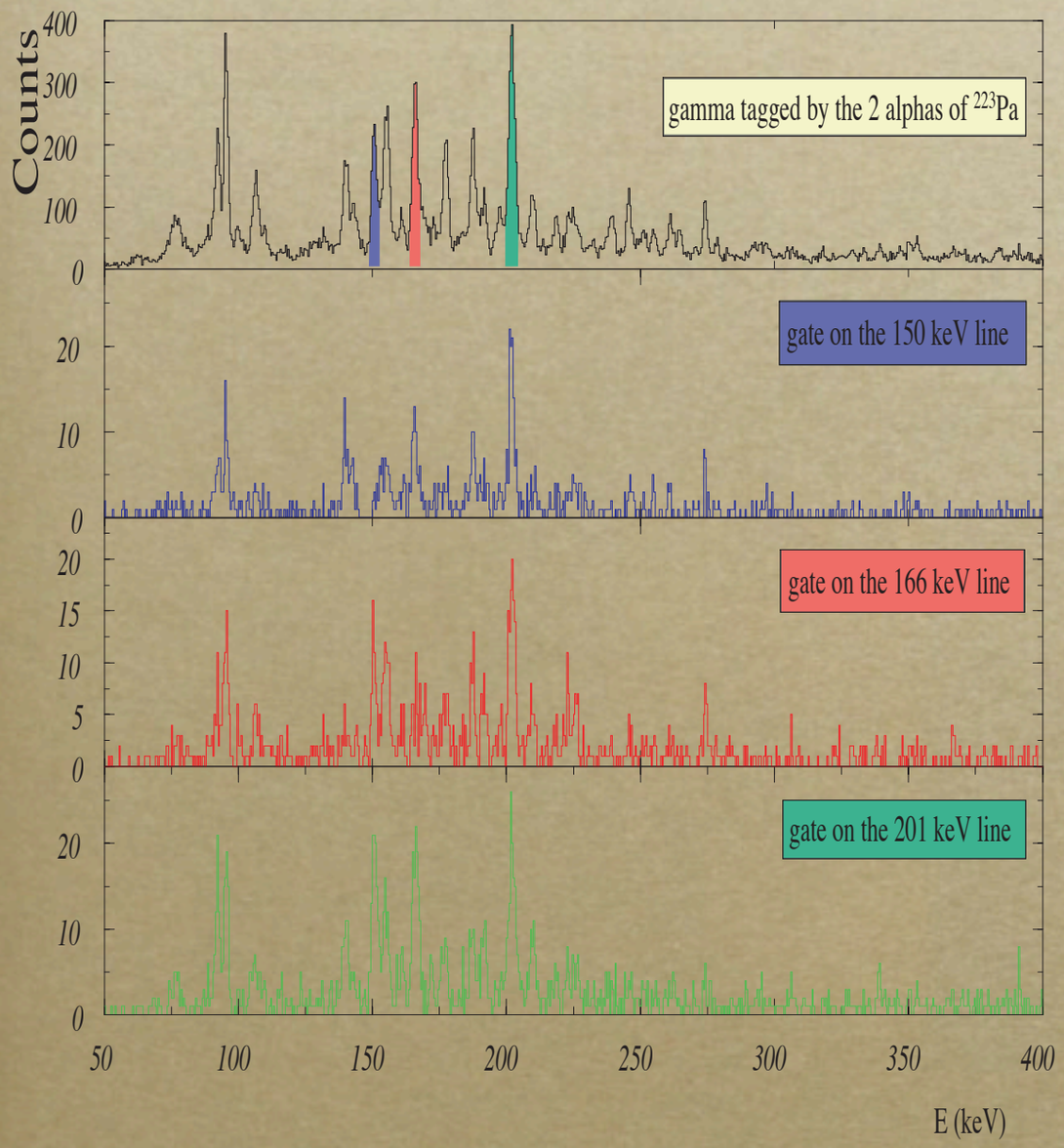
Diagonal cuts ...

Outline

- Superdeformed Nuclei : effect of rotation alone on pairing correlations
- A=100 : combined effect of rotation and deformation on pairing correlations
- Heavy Elements Spectroscopy ... on the way to the Super-Heavies

Octupole Deformation in ^{223}Pa

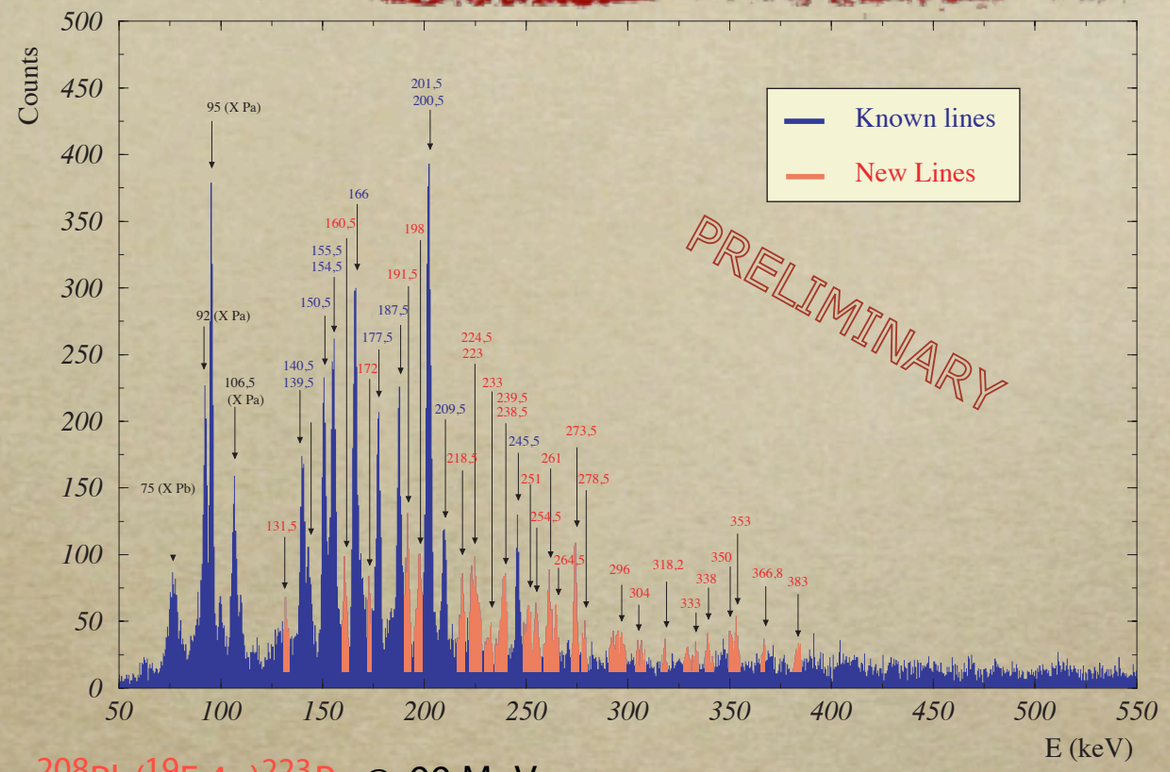
Gamma gated spectra Tagged by the 2 alpha lines of $^{223}_{91}$Pa



PhD Thesis F. HOELLINGER & F. KHALFALLAH

Gamma-rays spectrum Tagged by the 2 alpha lines of $^{223}_{91}$Pa

RITU + JUROGAM, 8-19 December 2003



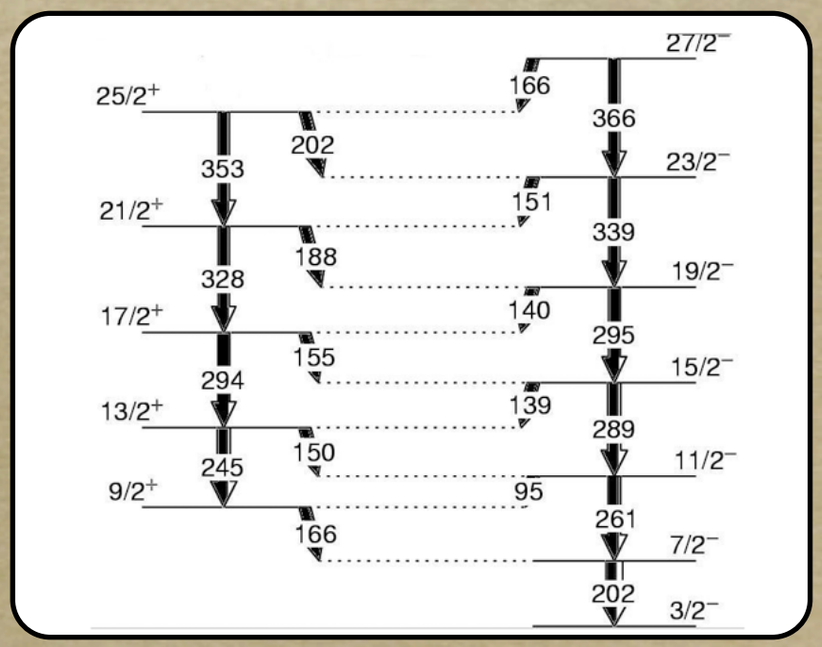
Reaction : ^{208}Pb(^{19}F,4n)^{223}Pa @ 99 MeV,

v/c = 0.8 %,

e = 150 - 250 µg/cm^2,

I ~ 40 pnA,

σ ~ 100 µb



Les VHE ...

on the road to SHE

What are the SHE gaps ?

Deformed gaps in VHE ...

Common Orbitals ? ...

Prompt Spectroscopy :

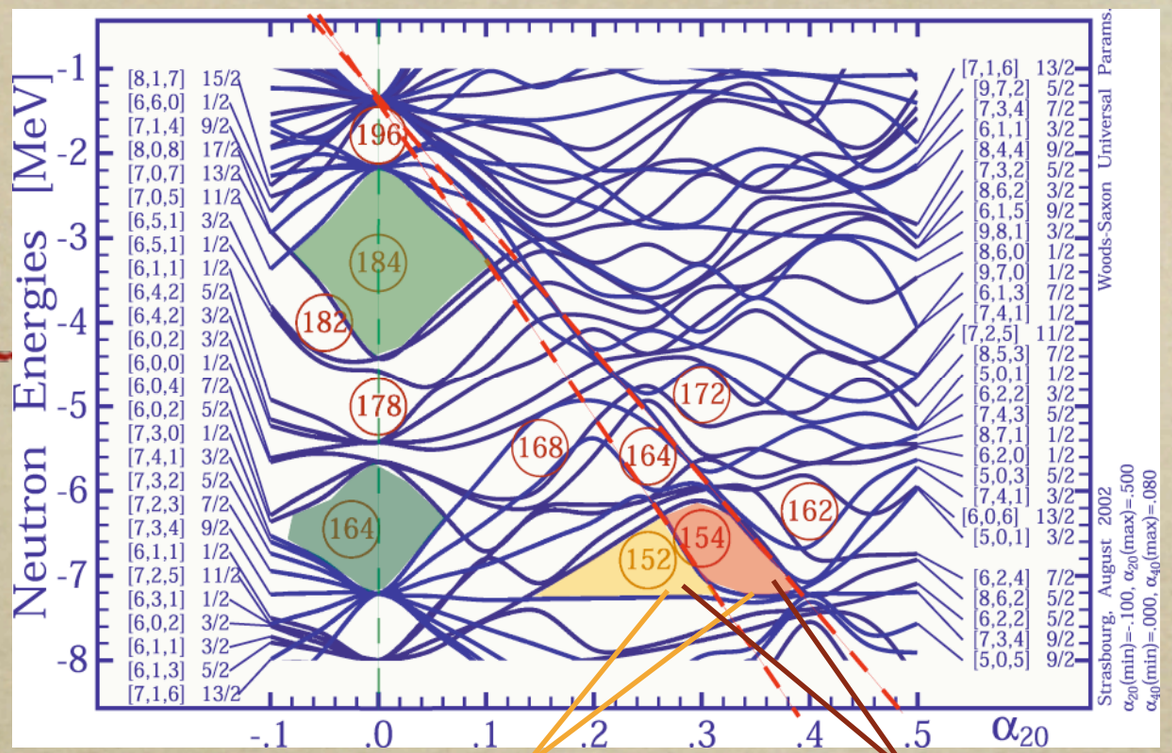
- Moment of inertia
- g-factor (odd nuclei)

Decay spectroscopy

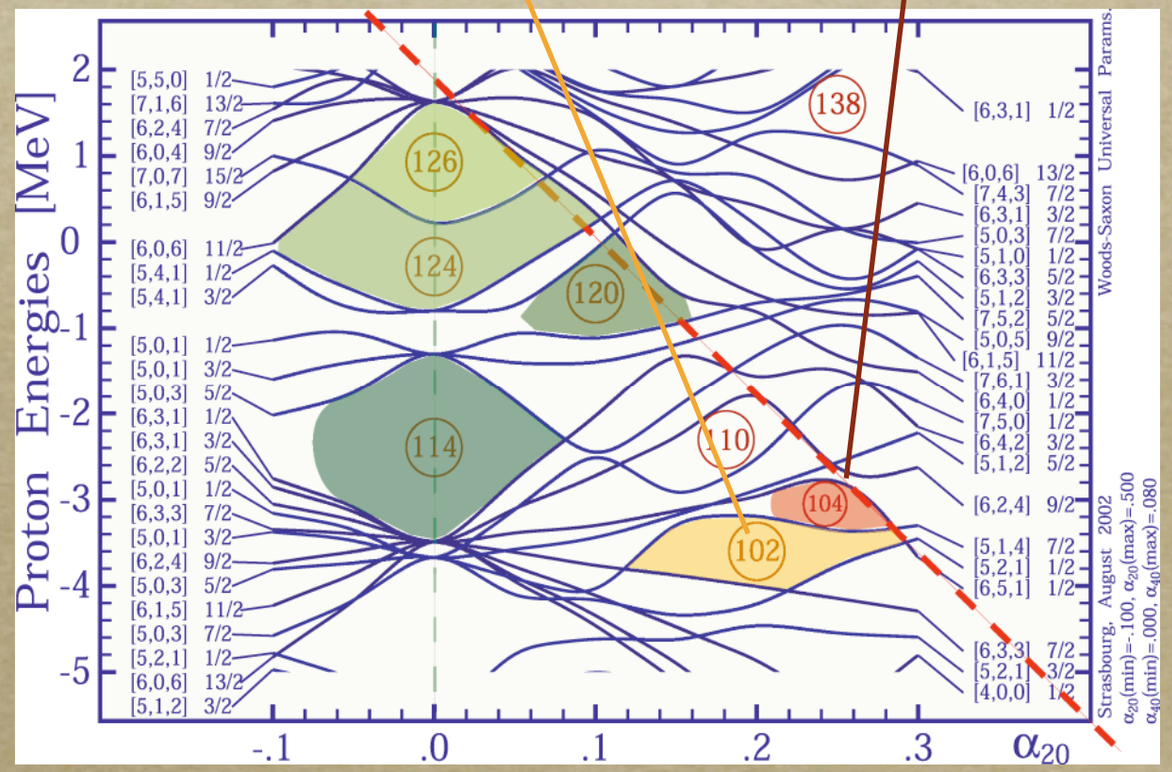
- isomers

Contraints on the different theories

Cf. R.-D. Herzberg's talk



$^{254\text{-}256}No$ $^{256\text{-}258}Rf$

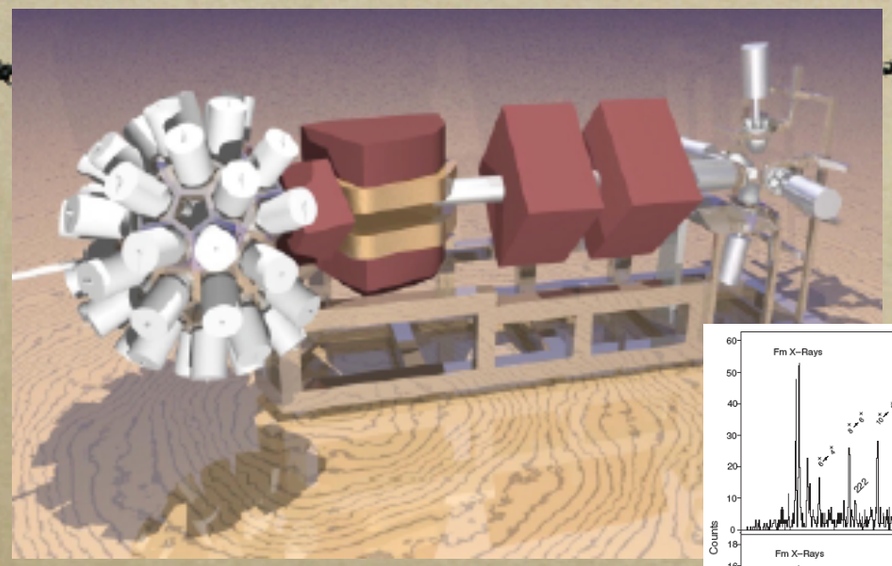


Spectroscopy of Z >100 fruitfull but...

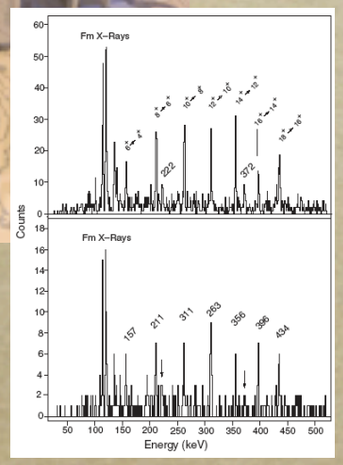
- Very low production cross-sections
- and low-energy transitions highly-converted ...

Need of new developpments

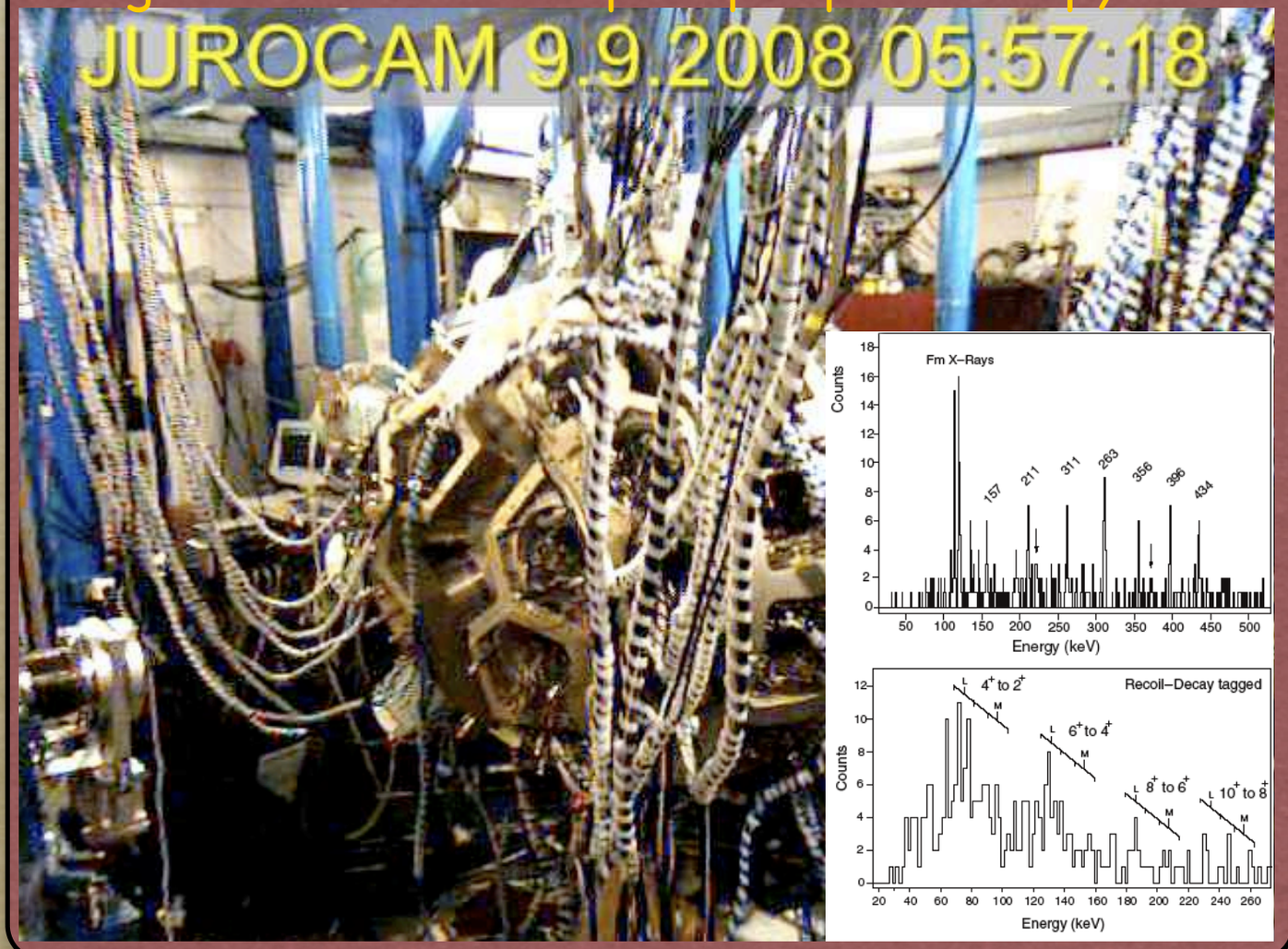
R&D and Coming systems



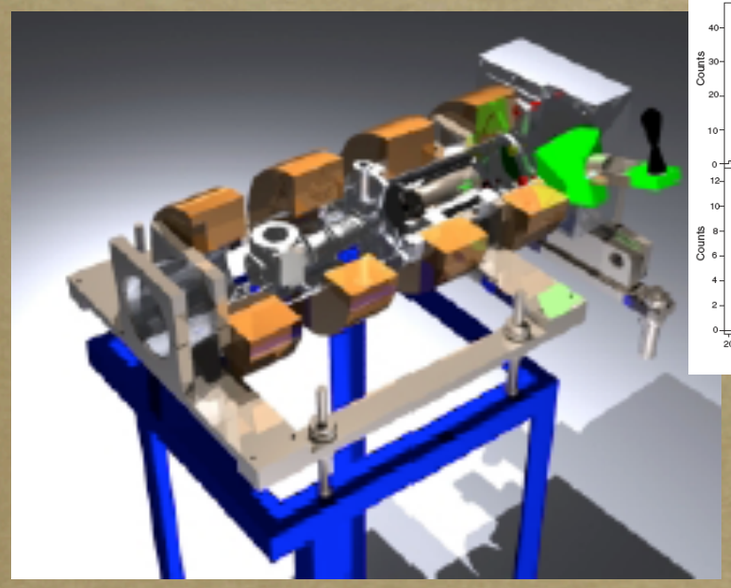
JUROGAM + RITU : Tagged
Prompt Gamma Spectroscopy +
Focal-Plane spectroscupy

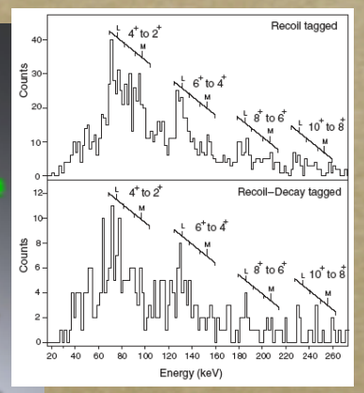


SAGE JUROGAM II + RITU : decay-Tagged
gamma & electron prompt spectroscopy ...

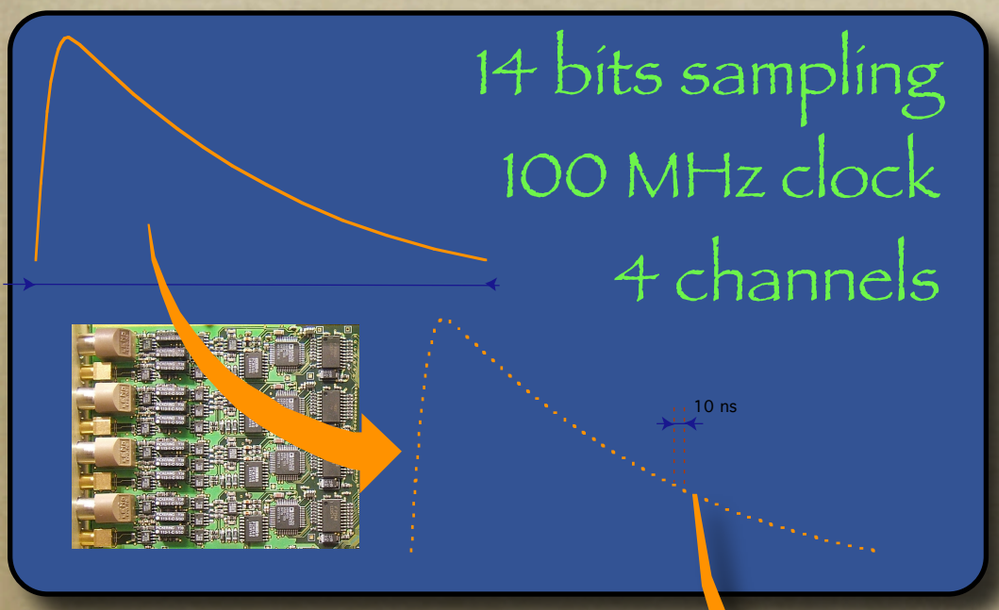


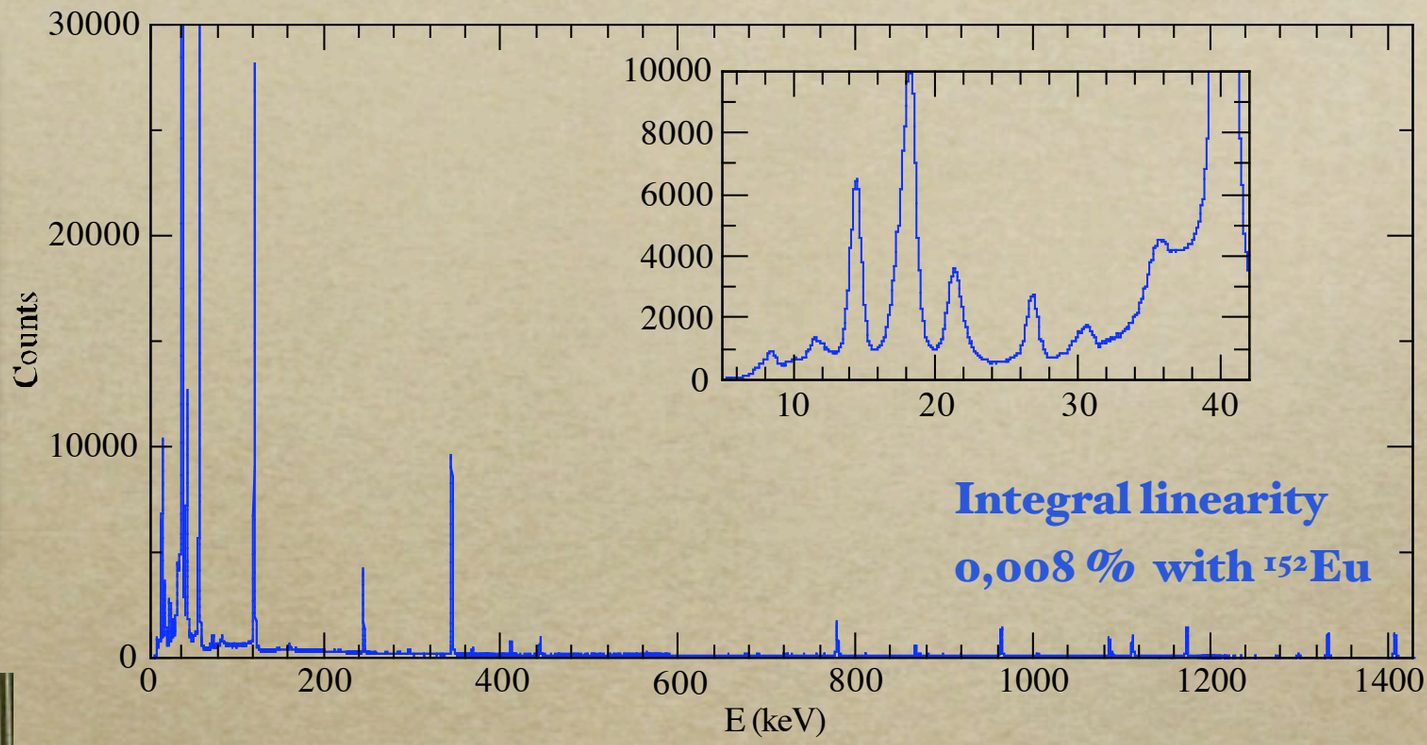
SACRED : electrons specroscopy
tagged by alpha-decay in RITU





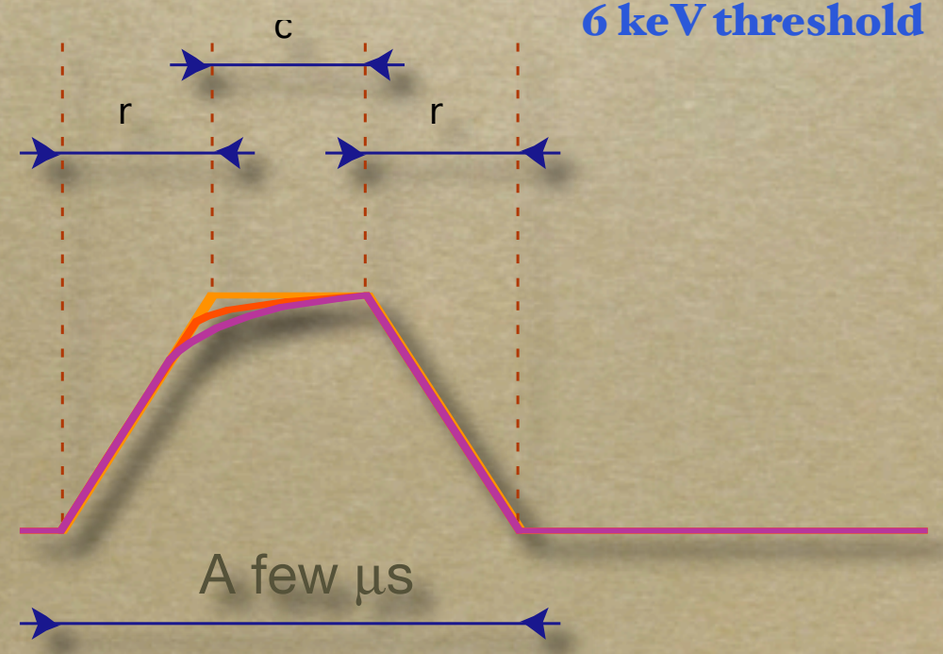
R&D and Coming systems





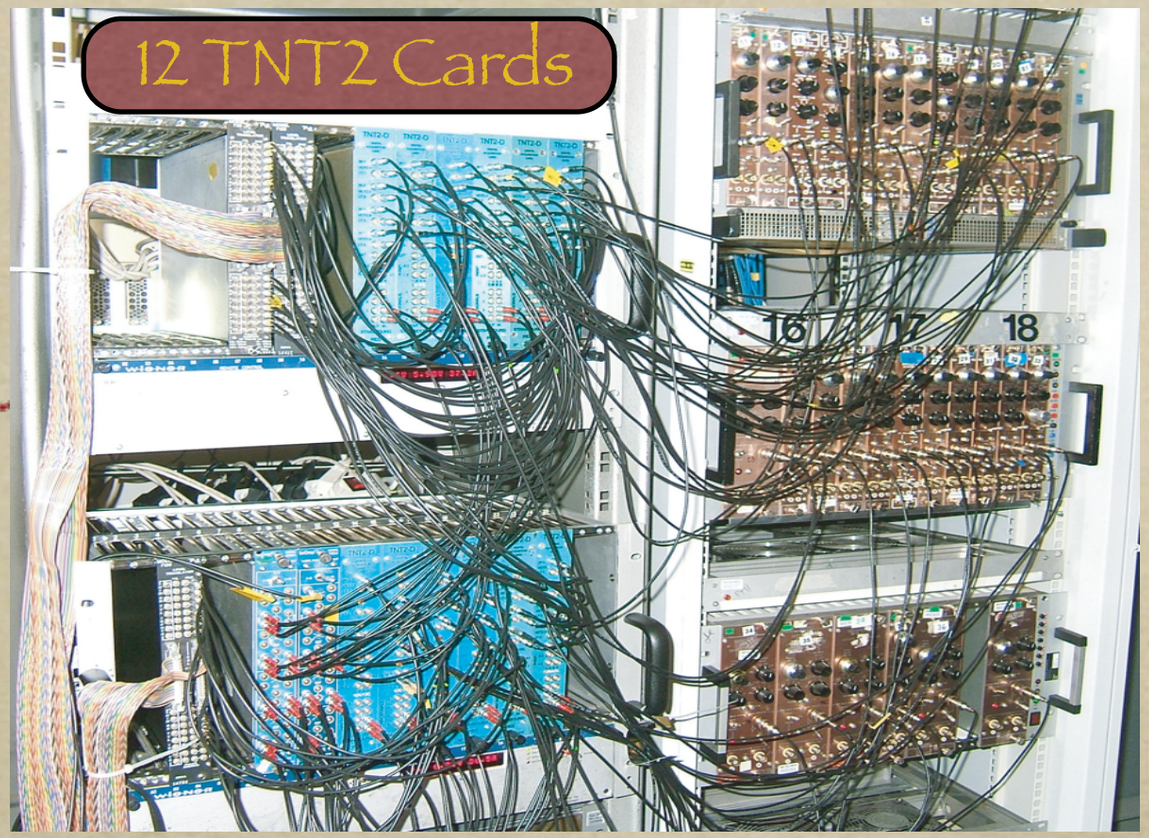
6 keV threshold

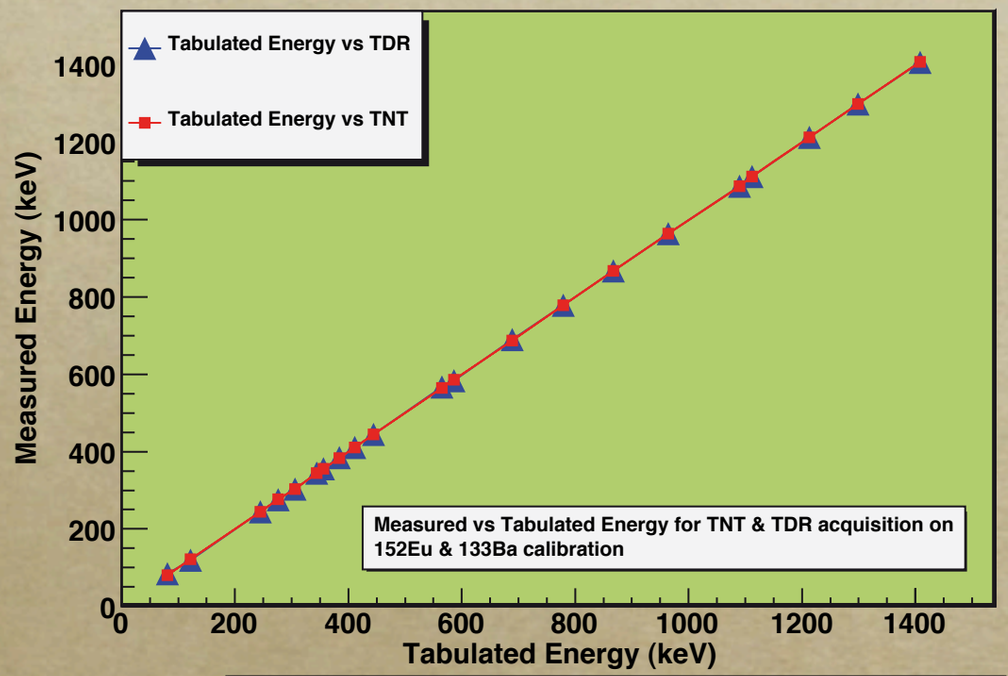
Virtex 2 (3 Mgates)



TNT2 Cards, IPHC Strasbourg

1st Full digital experiment at JUROGAM

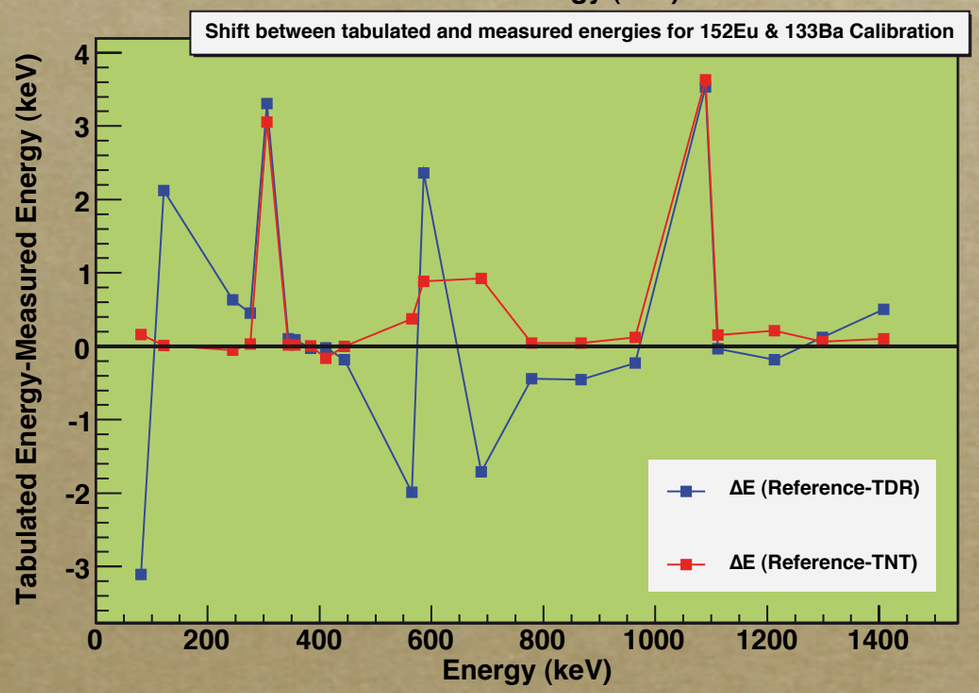


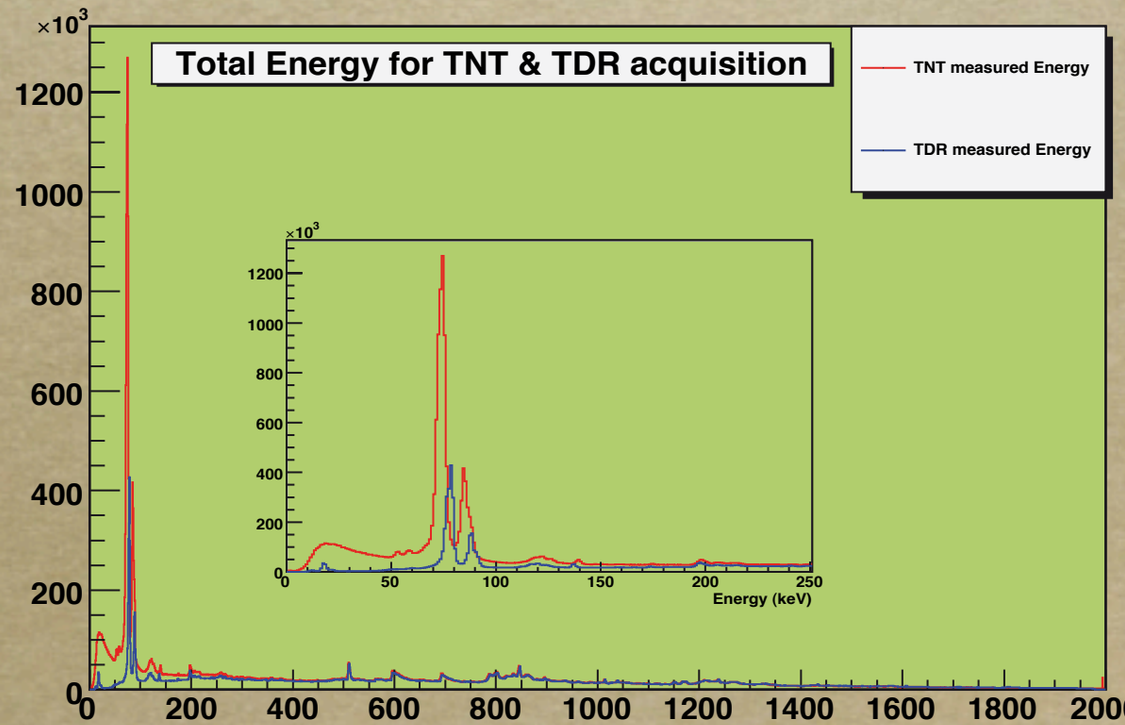


More compact & easy to set-up

Better linearity (Low energy)

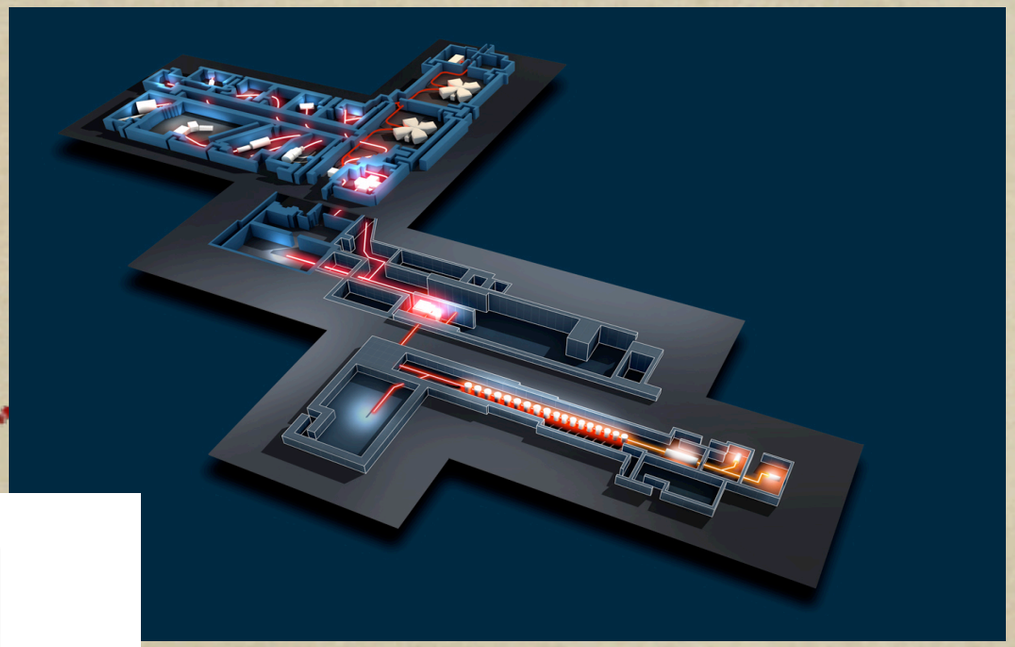
Better efficiency

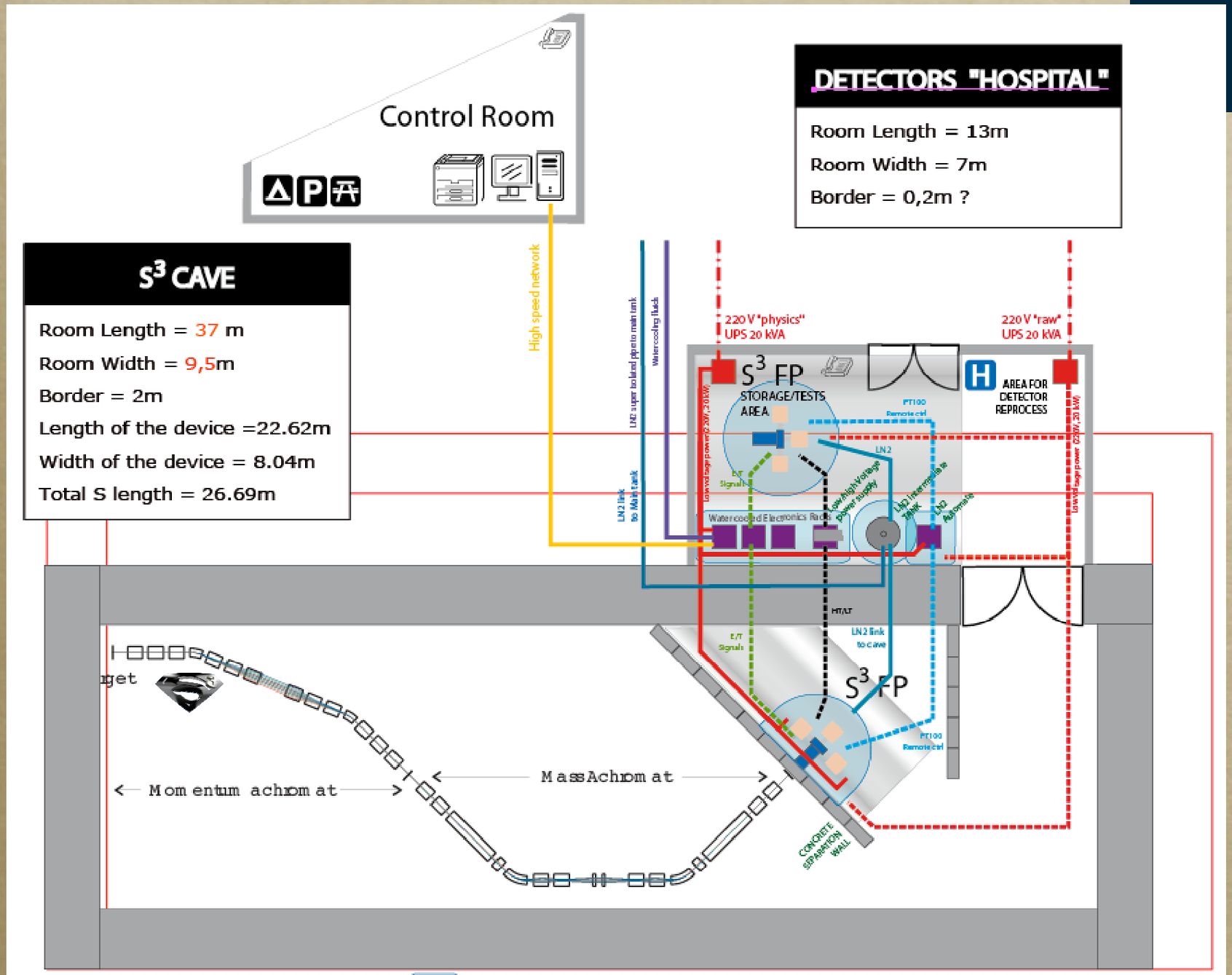




PhD Thesis of J PIOT & P. PEURA

Project





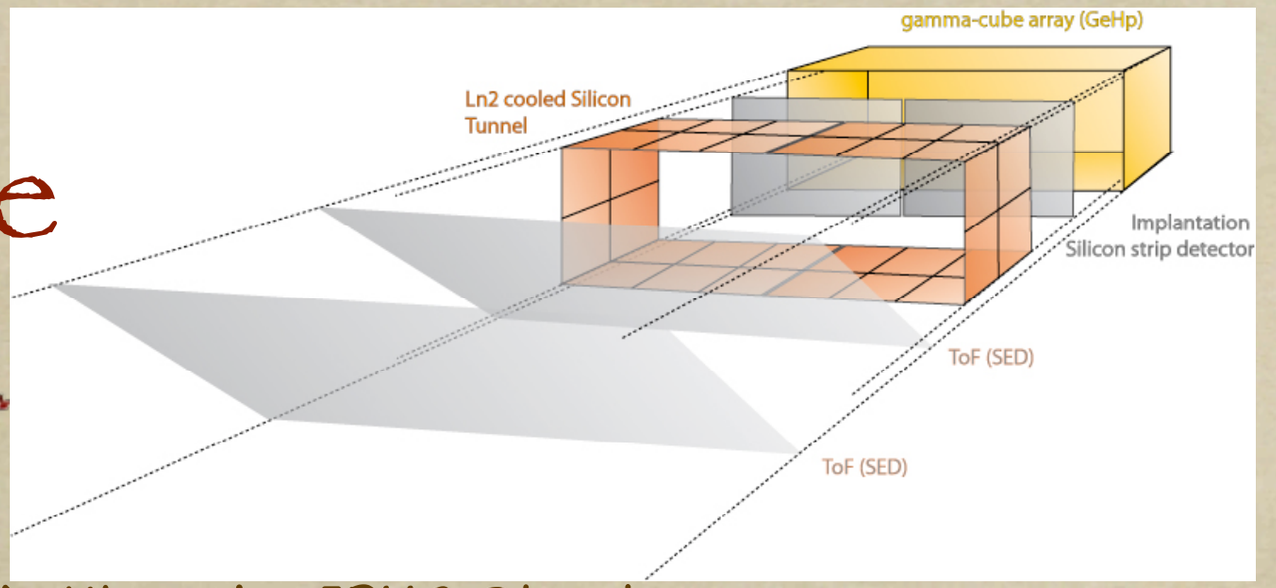
Optimised for
Heavy elements studies
but other fields foreseen

10^{14} particle/s on target
2 stages
- momentum achromat
- mass achromat

beam spot : +/- 0.5 x 10 mm
Angular acceptance: +/- 80 mrad X and Y
Brho acceptance: +/- 10%
Variable focal plane (from 50 x 50 mm to ???)
M/q selection – 1/350 resolution
Beam rejection: 10^{13}
Electric rigidity: <10MV

In progress …

Focal-Plane



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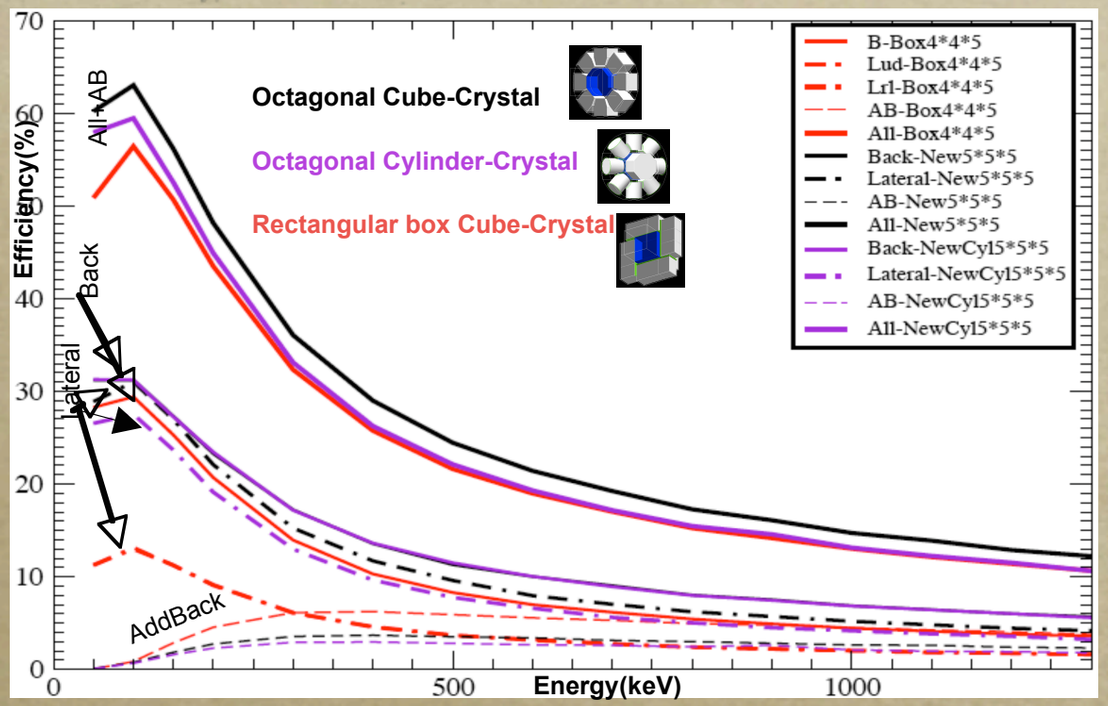
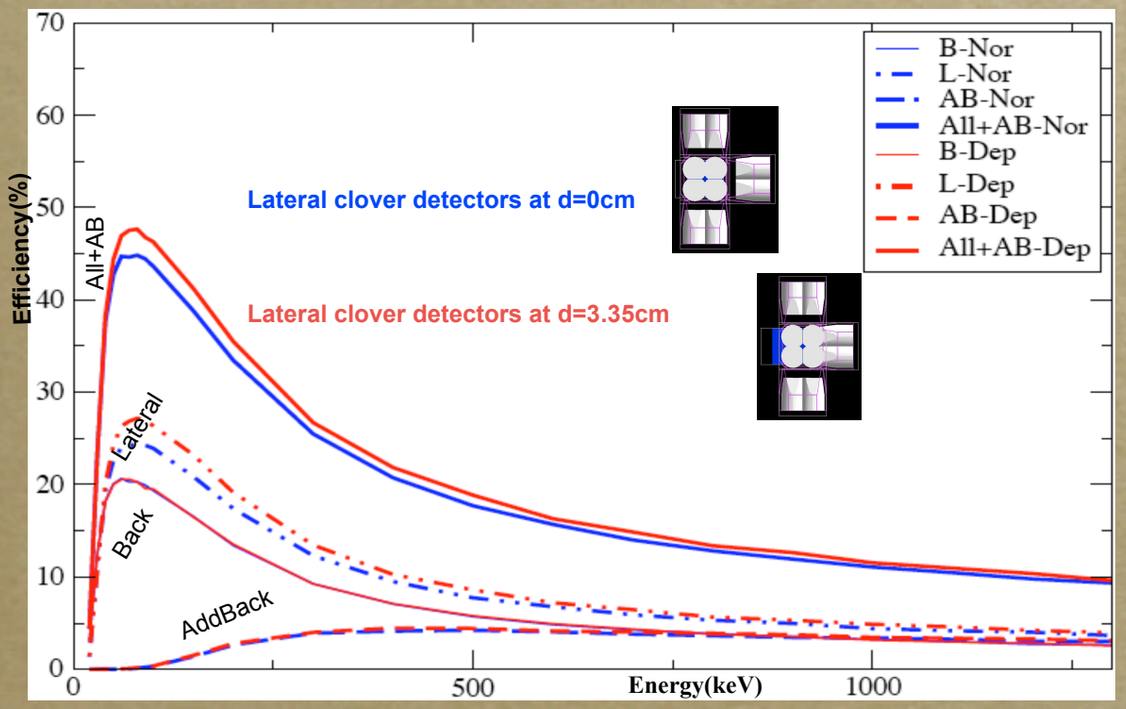
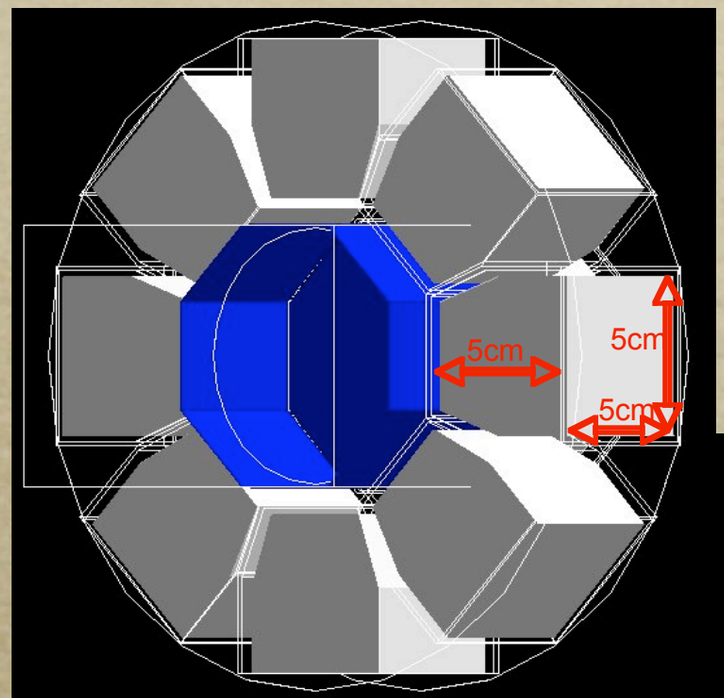
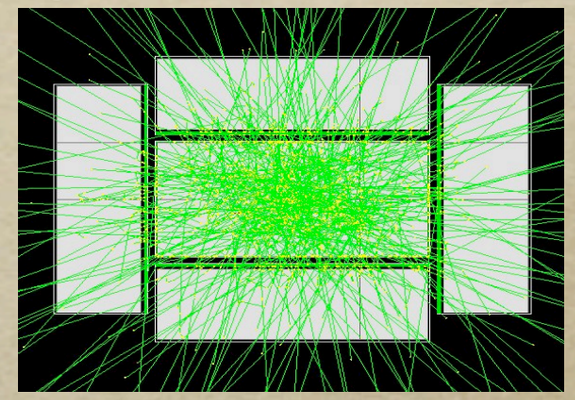
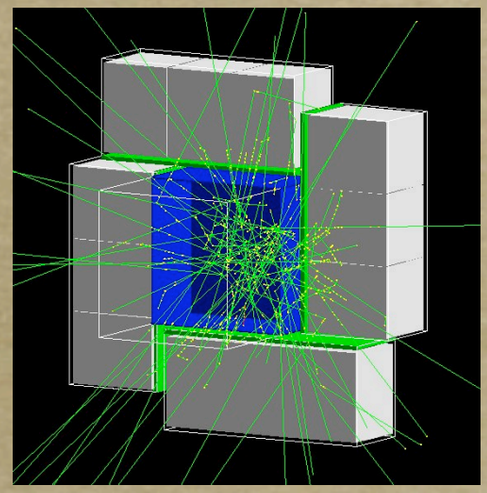
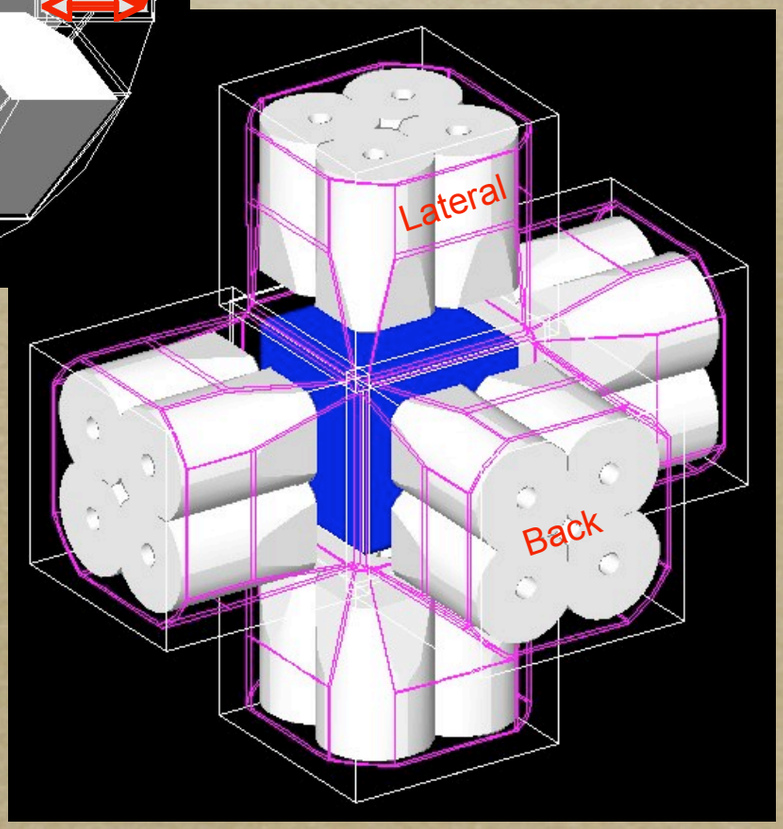




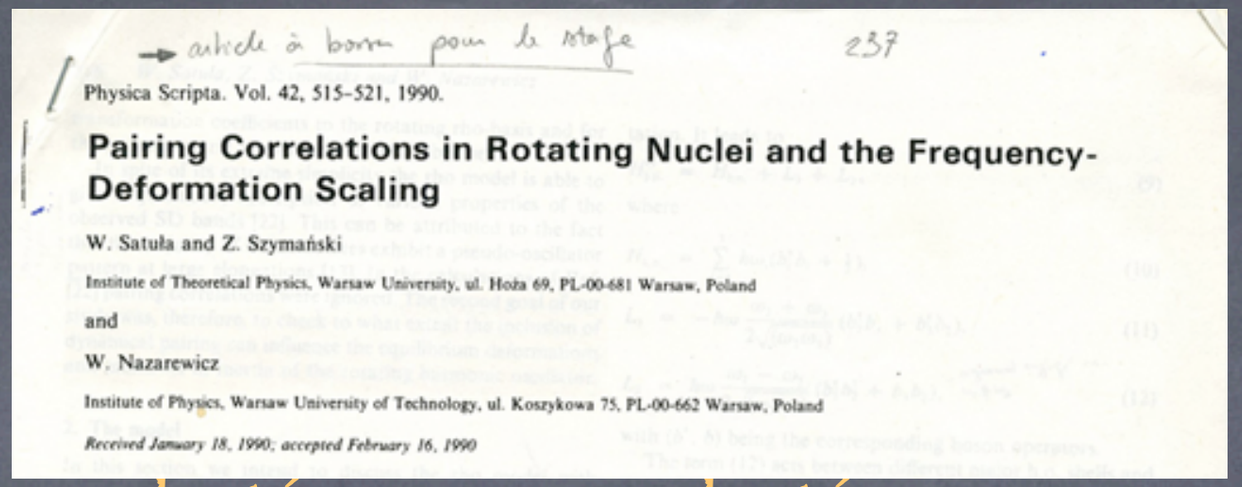








Summary



article à bonn pour la Nafe 237

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Pairing Correlations in Rotating Nuclei and the Frequency-Deformation Scaling

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- Studies of pairing correlations evolution with rotation alone first

  => HFBLN code + expt/theory complementarity

- Rotation / deformation competition (A100)

- Heavy Elements Spectroscopy ... new developpments on the way to the Super-Heavies

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and... My family