DE LA RECHERCHE À L'INDUSTRIE

On the stability of heaviest elements

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CEA/SACLAY

NUCLEAR STRUCTURE AND DYNAMICS – NSD 2019

13-17 mai 2019 VENICE

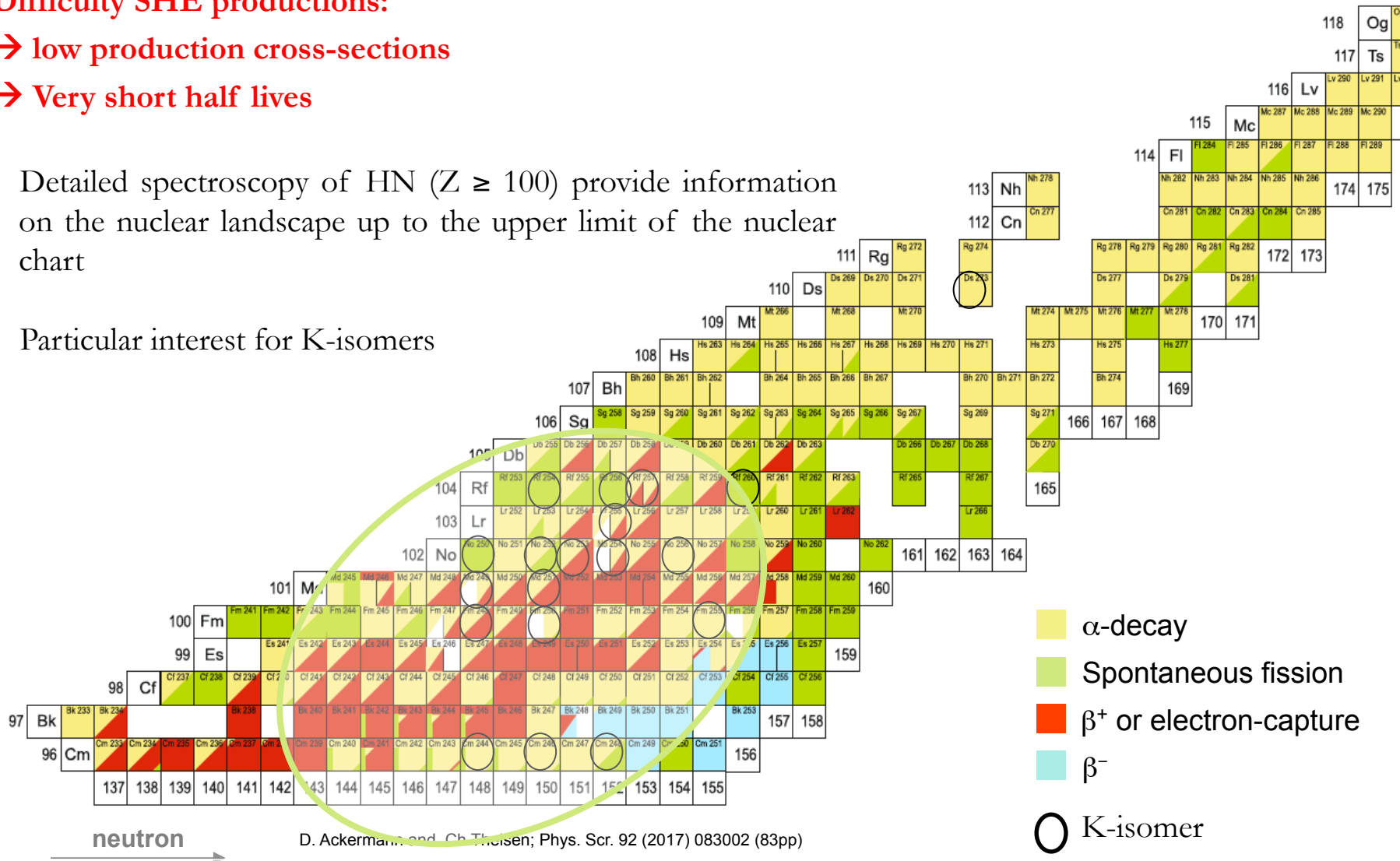
Introduction

Difficulty SHE productions:

→ low production cross-sections

→ Very short half lives

- Detailed spectroscopy of HN (Z ≥ 100) provide information on the nuclear landscape up to the upper limit of the nuclear chart
- Particular interest for K-isomers

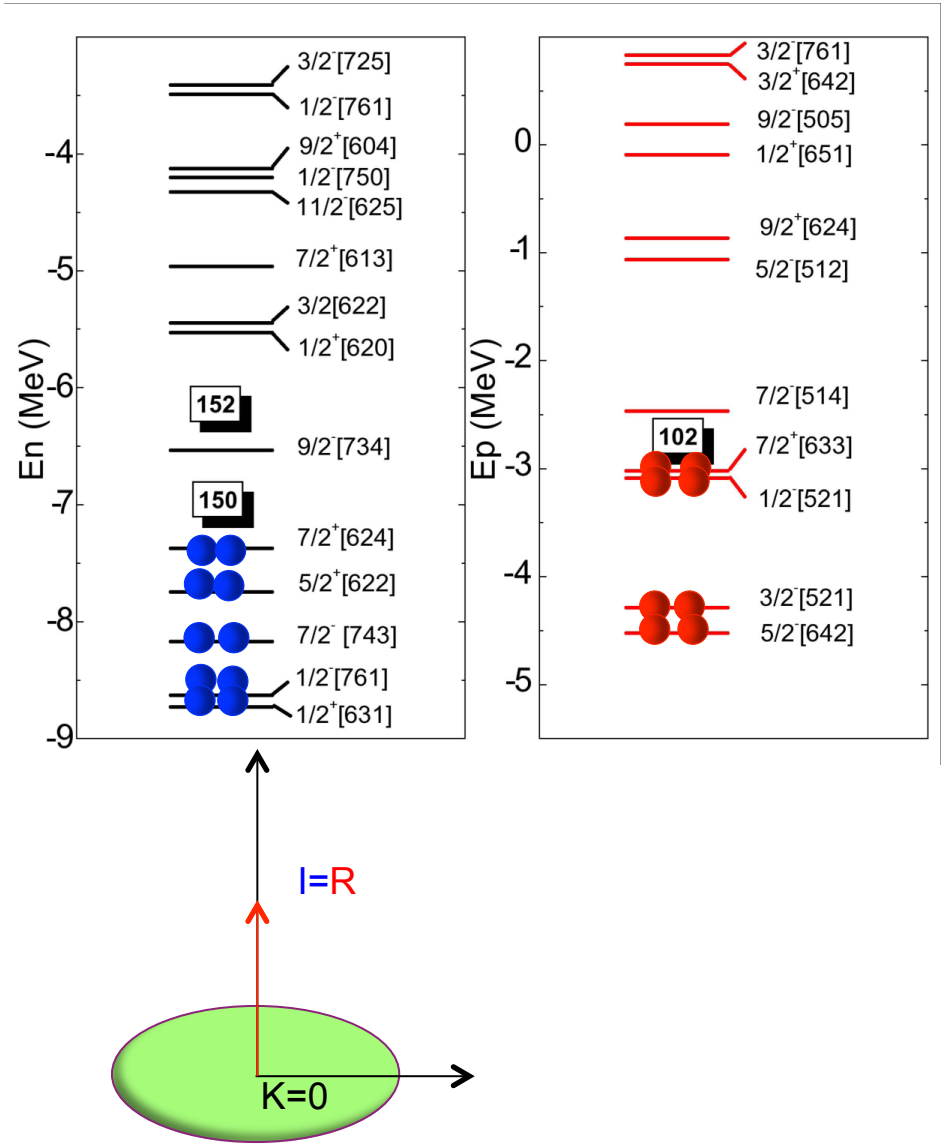


D. Ackermann and Ch. Theisen; Phys. Scr. 92 (2017) 083002 (83pp)

F.G. Kondev et al. / Atomic Data and Nuclear Data Tables 103–104 (2015) 50–105

ISOMERIC STATES IN EVEN EVEN NUCLEI

- Information about Nilsson level energy gaps
- The pairing interaction
- Influence on stability of super heavy elements



B. Sulignano, et al. PHYSICAL REVIEW C **86**, 044318 (2012)

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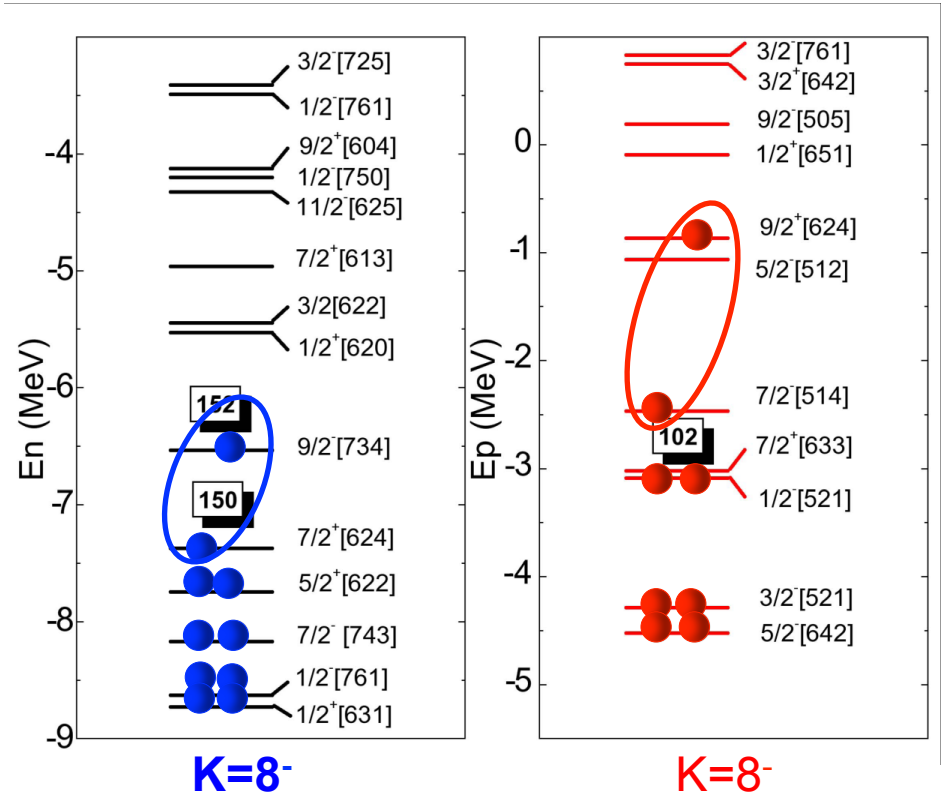
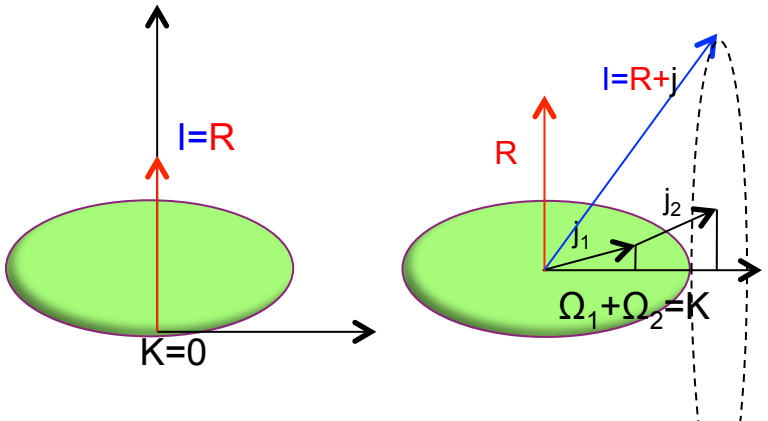
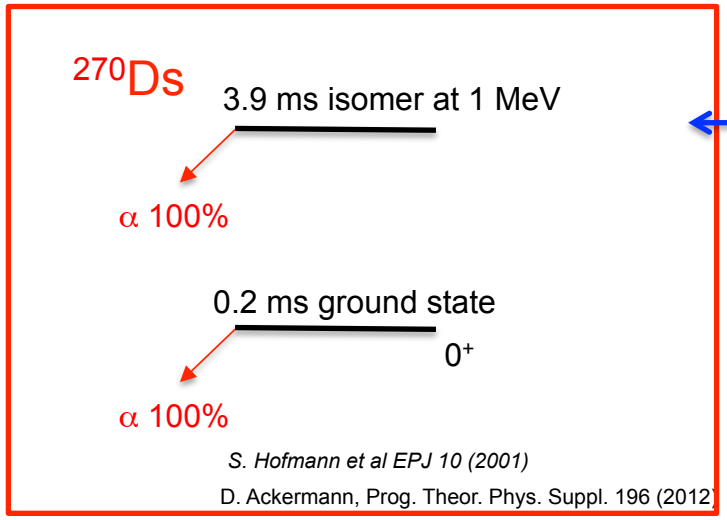


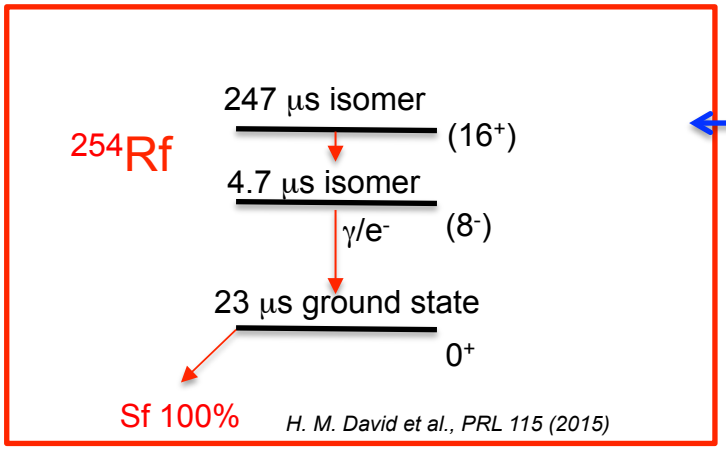


B. Sulignano, et al. PHYSICAL REVIEW C **86**, 044318 (2012)

EXAMPLE OF K-ISOMERS



K isomer can provide extra stability for super heavy elements

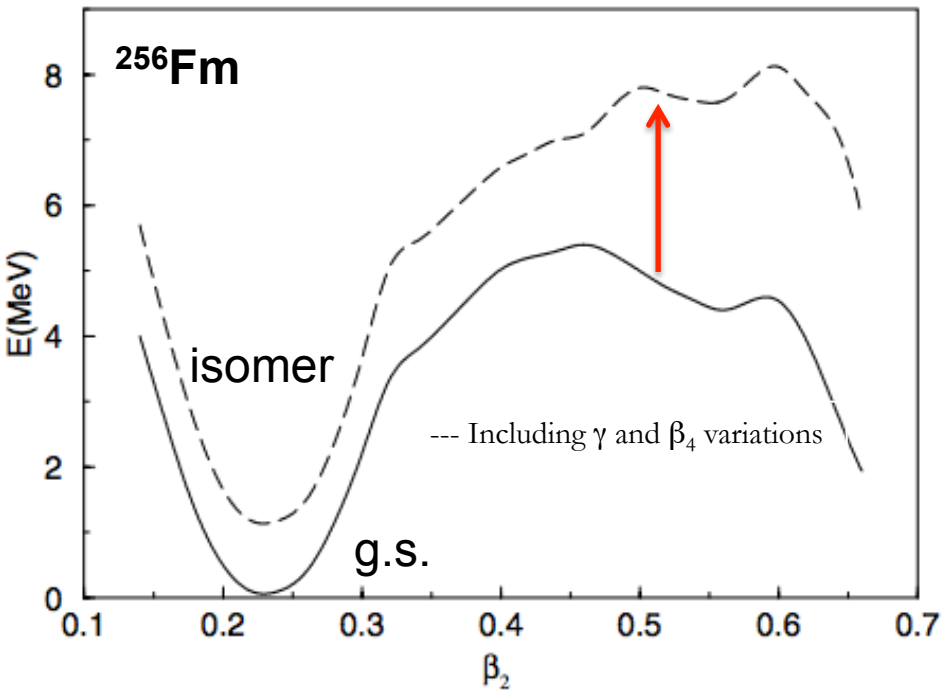


K-isomer fission decay

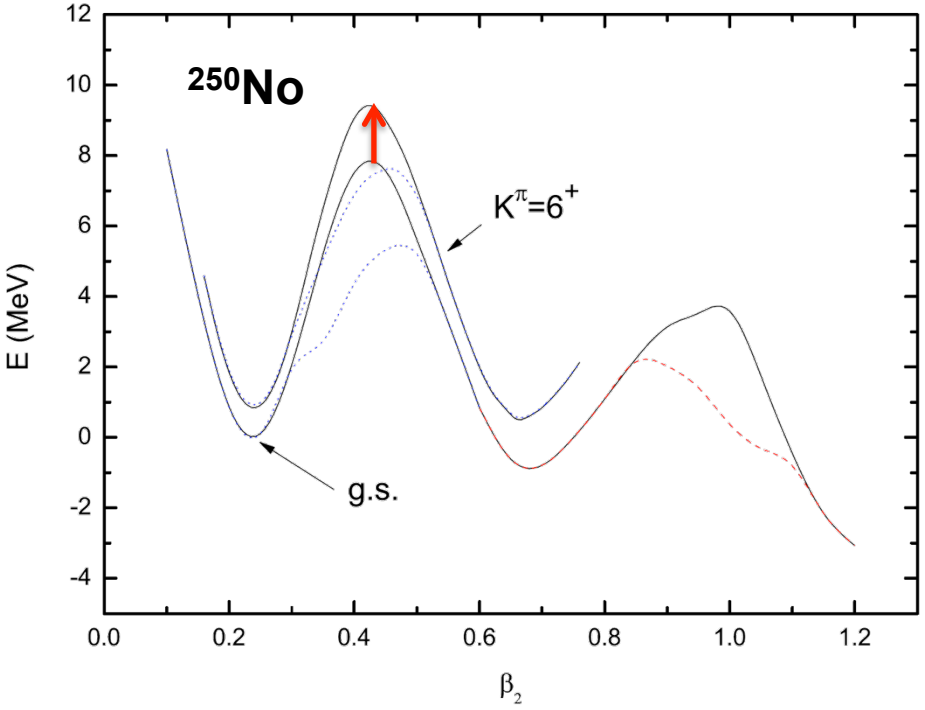
INVERSION OF STABILITY : ^{256}FM

Configuration–constrained PES calculation for broke pairs excitation. Fission barrier calculation

F. R. Xu et al PRC 92 (2004)



P. M. Walker J. Phys. G: Nucl. Part. Phys. 39 (2012) 105106

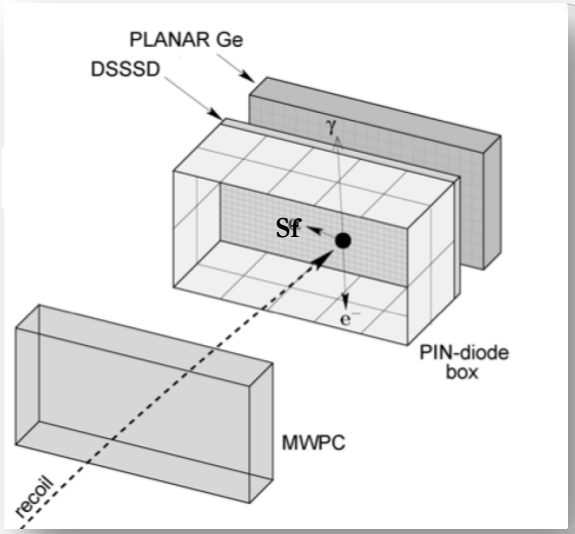


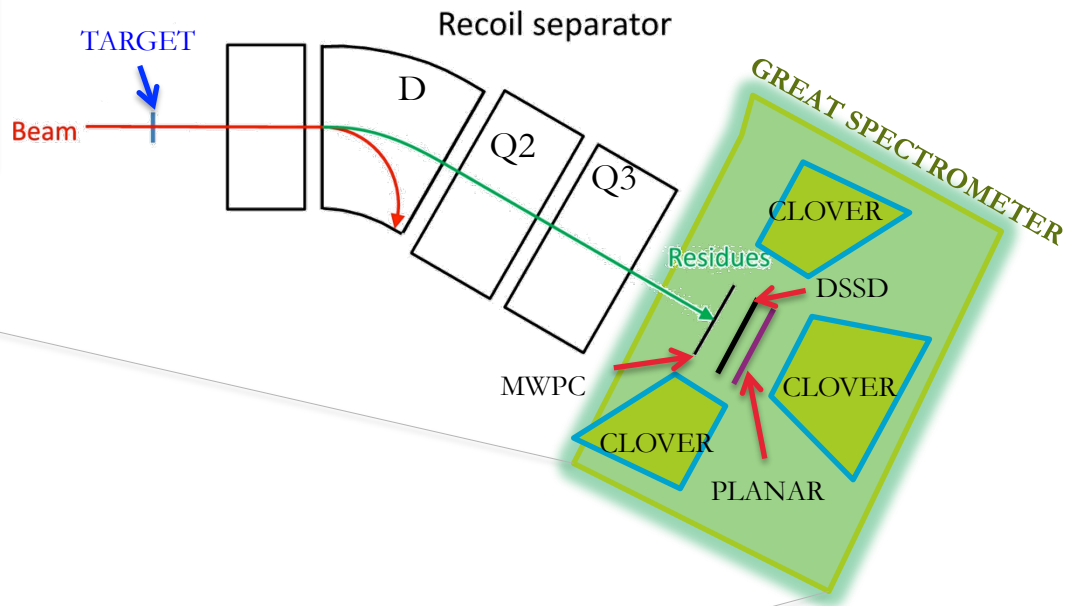
- The calculations indicate higher fission barriers for the isomers
- The inclusion of the non axial deformation is important → Can affect the shape of fission barrier
- The calculated K isomer fission barrier is bout 1.4 MeV higher than the corresponding ground state fission barrier.
- The increase of the fission barrier in both height and width implies → an increase in the fission lifetime

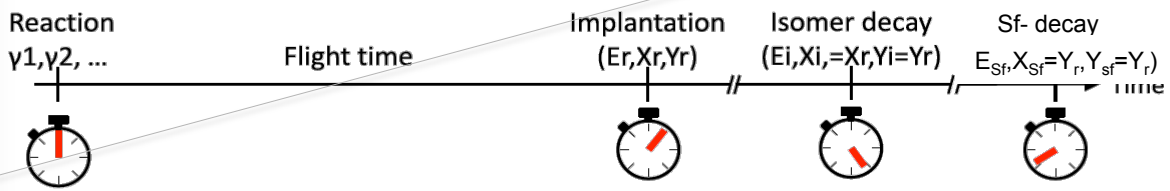
$^{48}Ca+^{204}Pb \rightarrow ^{250}No$ @ JYVÄSKYLÄ

$^{204}Pb(^{48}Ca,2n)$ 5 days :

- DSSD-Y (80 strips) "digital" electronics
- 700 recoil-fission correlation
- s ≈ 30.54(4.2) nb I_{beam}=30 pnA



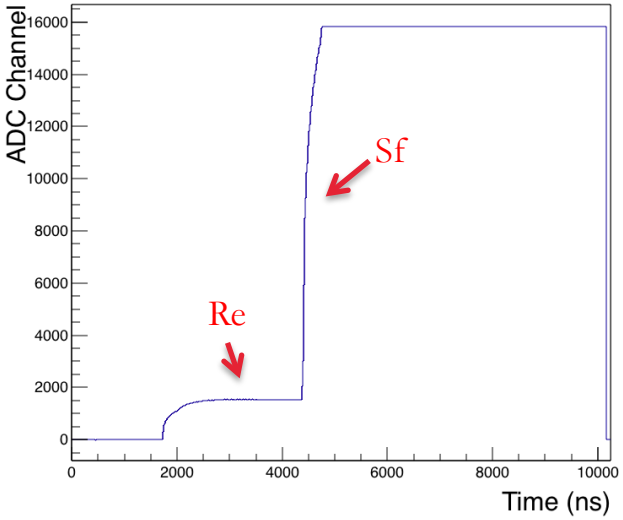




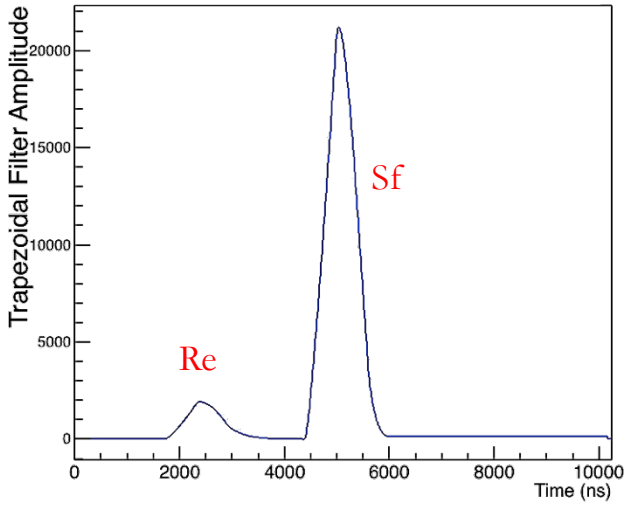
J. Kallunkatharyil, B.Sulignano, P.T. Greenlees et al. in preparation

^{250}NO @ JYVÄSKYLÄ USING PSA

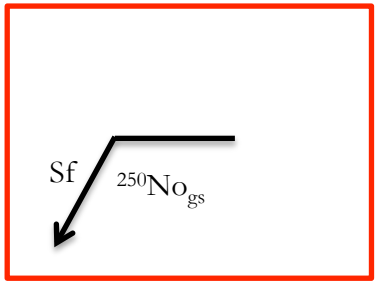
Example of digitized trace of recoil followed by an Sf event.

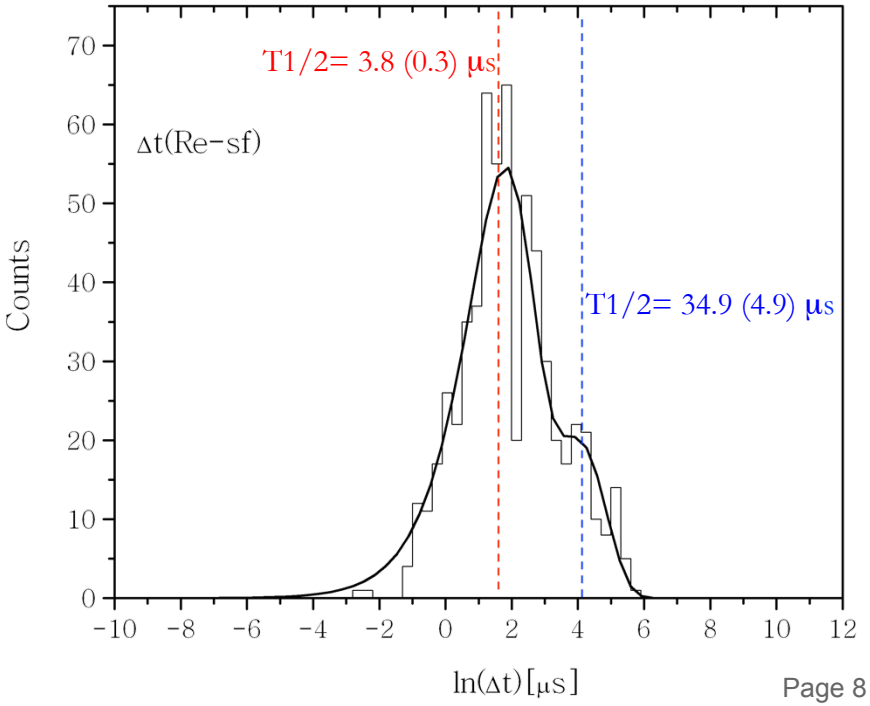


Trapezoidal filtered Recoil-Sf trace.



Decay of ^{250}No

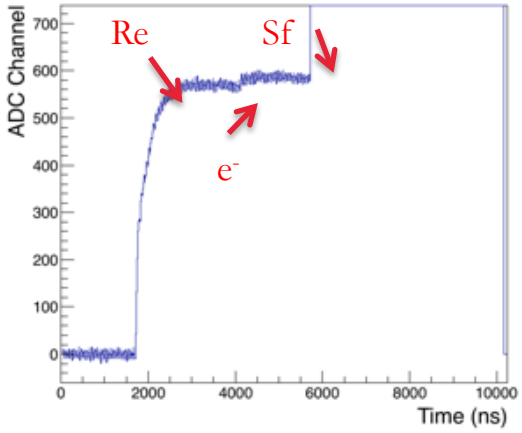


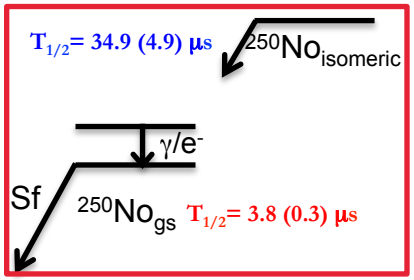


J. Kallunkathayil, B.Suligmano, P.T. Greenlees et al. in preparation

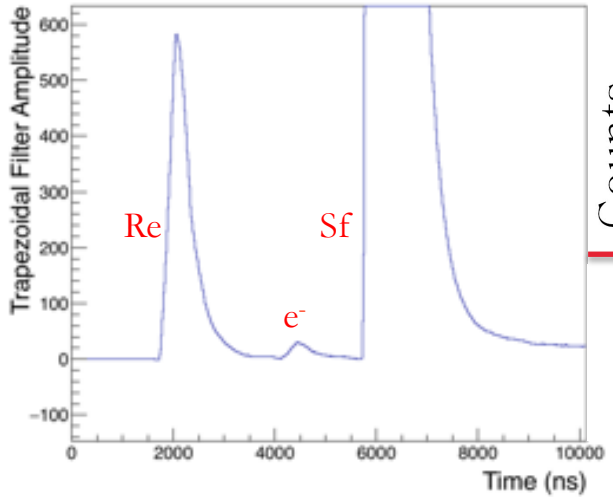
Looking for electromagnetic branch

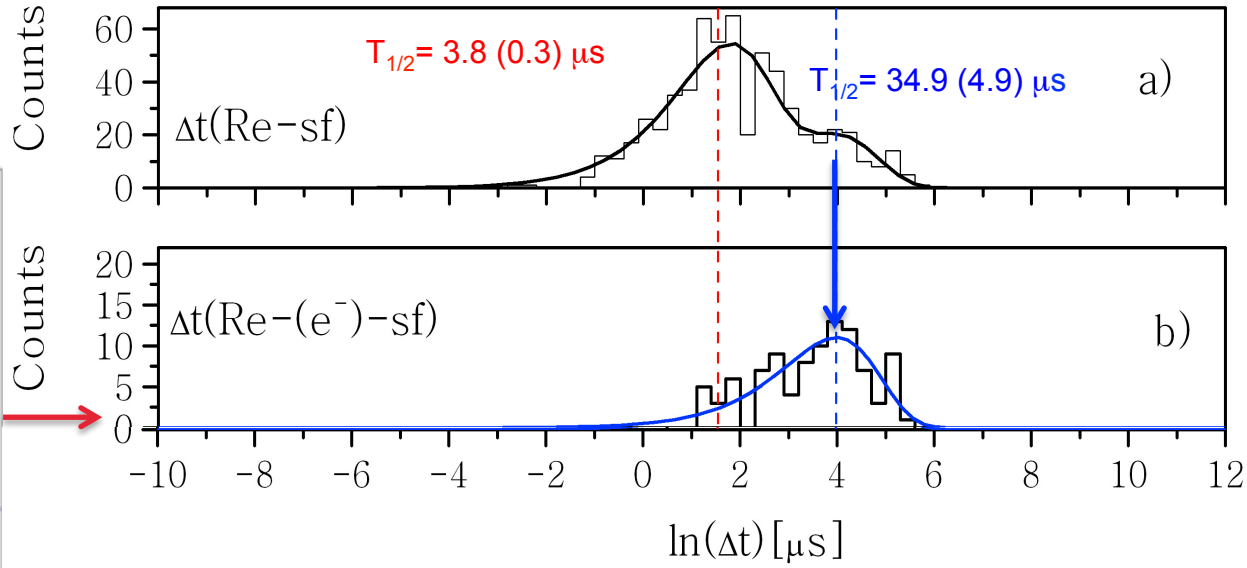
Example of digitized trace of recoil followed by an electron and Sf event.





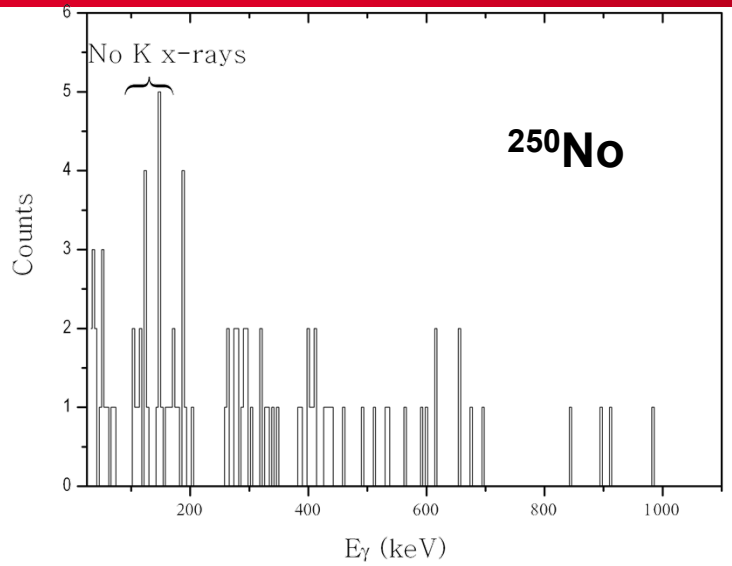
Trapezoidal filtered Recoil-electron-Sf trace.



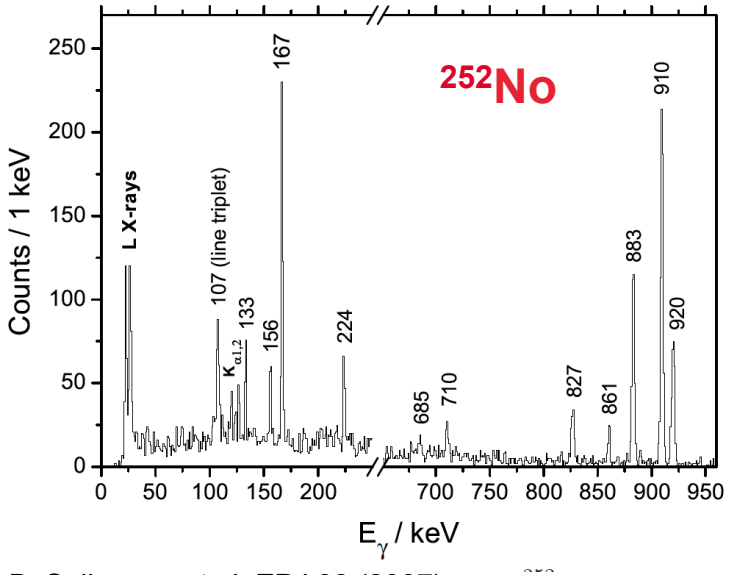


➢ **K isomer has a lifetime longer than that of the ground state**

WHICH DECAY PATH?



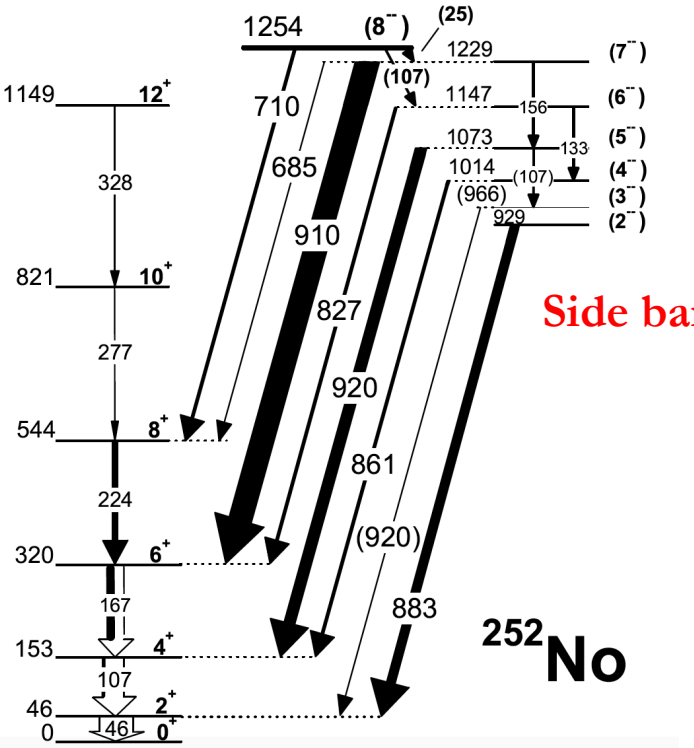
Example of de-excitation of isomeric state



B. Sulignano et al. EPJ 33 (2007)

γ- rays : decay spectroscopy

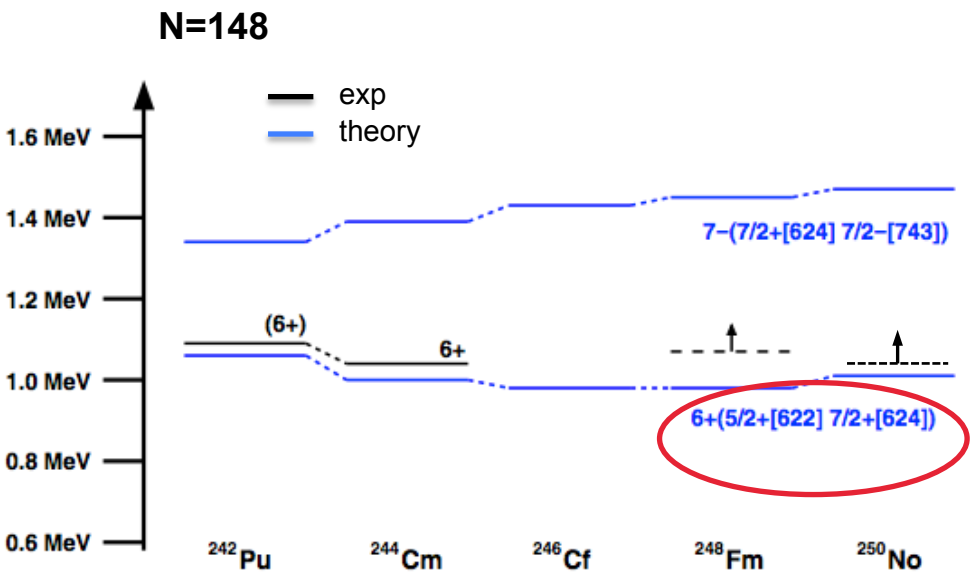
Isomeric state k= 8^-

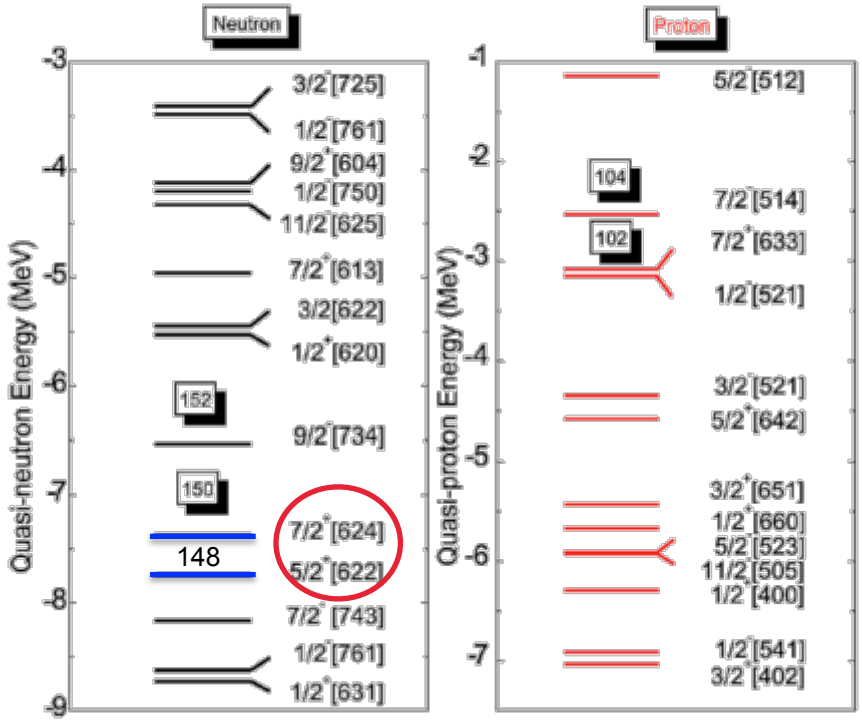


Side band k = 2^-

Ground state band k=0^+

STRUCTURE OF THE ^{250}NO ISOMERIC STATE





D. Peterson calculated for the ^{250}No* using multi-quasiparticle blocking calculation:

→ E*=1050 keV

→ Configuration: $\nu^2(5/2^+[622],7/2^+[624])_{6+}$

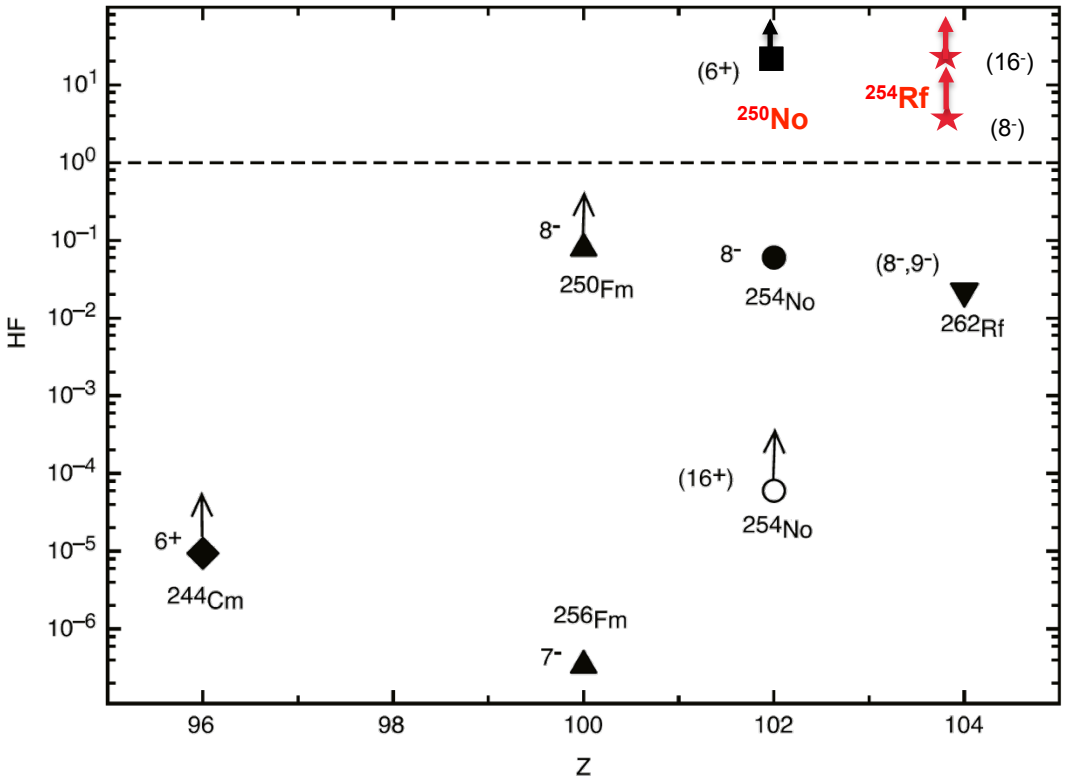
- **J.-P. Delaroche** et al., Nucl. Phys. A 771, 103 (2006)
- B. Sulignano, et al. Phys. Rev. C 86, 044318 (2012)

CONCLUSION : K ISOMER FISSION HINDRANCE

- Isomeric fission lifetimes in ^{250}No is 10 times longer compared to the ground state
- Isomers can provide extra "stability"
- New data show higher stability; old data are either limits or based on low statistics
  → New experimental data are need
- This phenomena may extend the landscape of super heavy nuclei beyond Z=118

Hindrance Factor

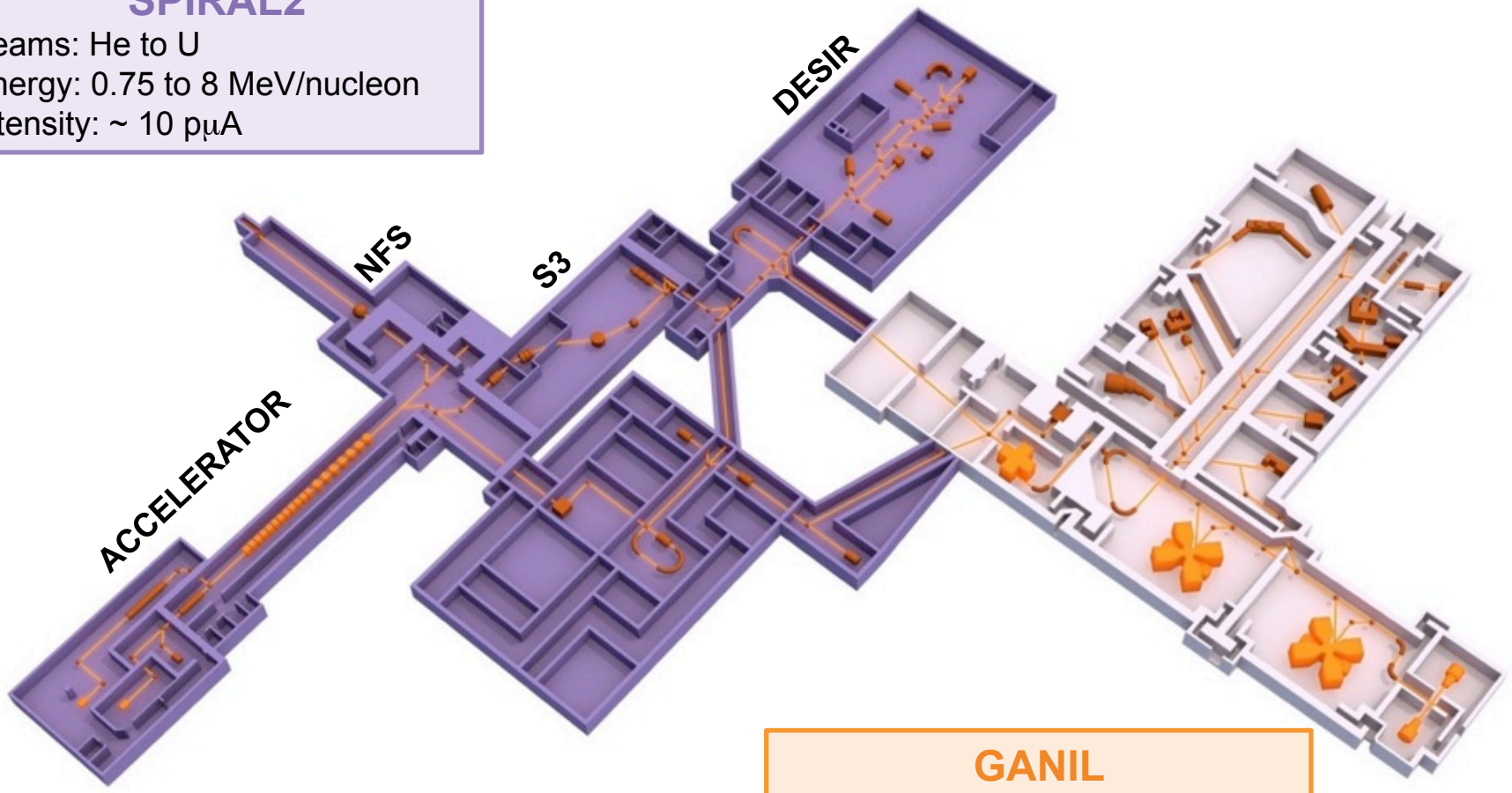
$HF = T_{SF}(iso)/T_{SF}(g.s.)$



F.G. Kondev et al. / Atomic Data and Nuclear Data Tables 103–104 (2015) 50–105

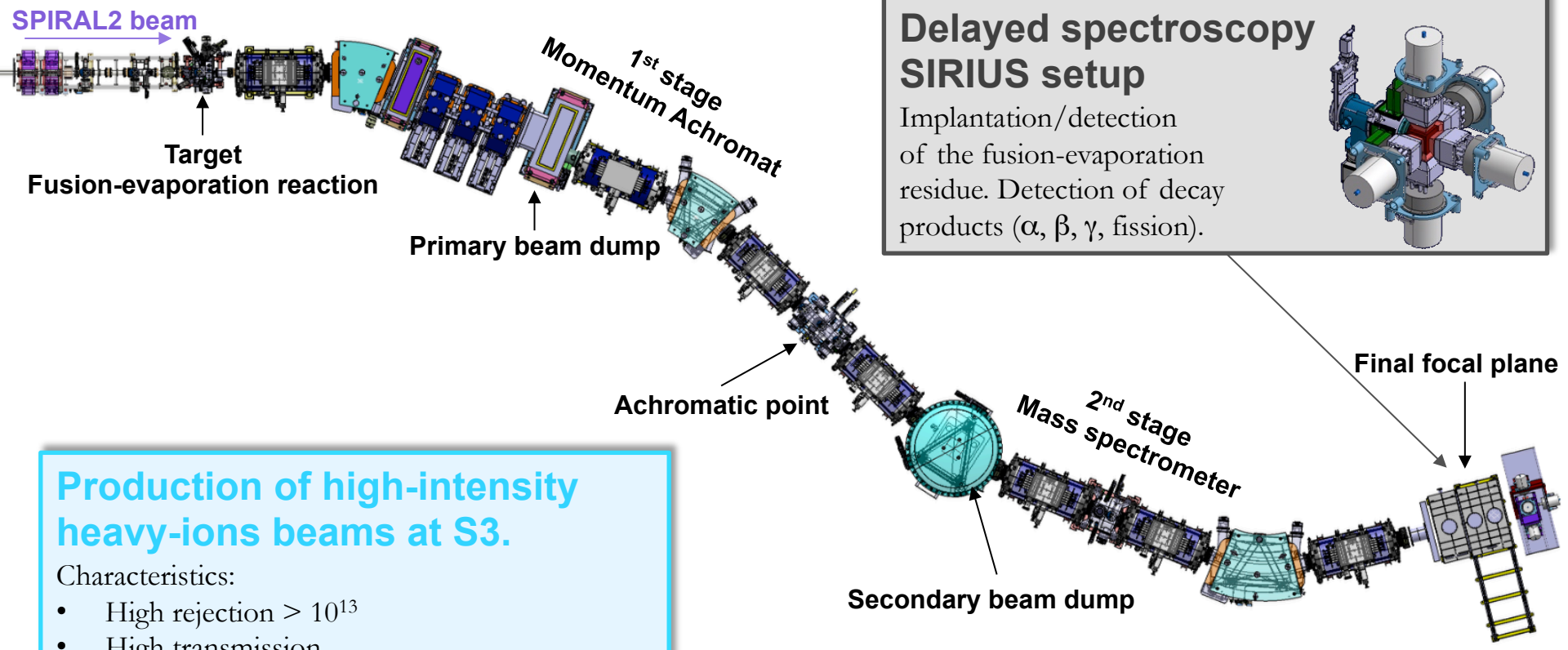
GANIL – SPIRAL2

SPIRAL2
Beams: He to U
Energy: 0.75 to 8 MeV/nucleon
Intensity: ~ 10 pμA



GANIL
Beams: He to U
Energy: few to 100 MeV/nucleon
Intensity: ~ pμA

Super Separator Spectrometer S³



Delayed spectroscopy SIRIUS setup

Implantation/detection of the fusion-evaporation residue. Detection of decay products (α, β, γ, fission).

Production of high-intensity heavy-ions beams at S3.

Characteristics:

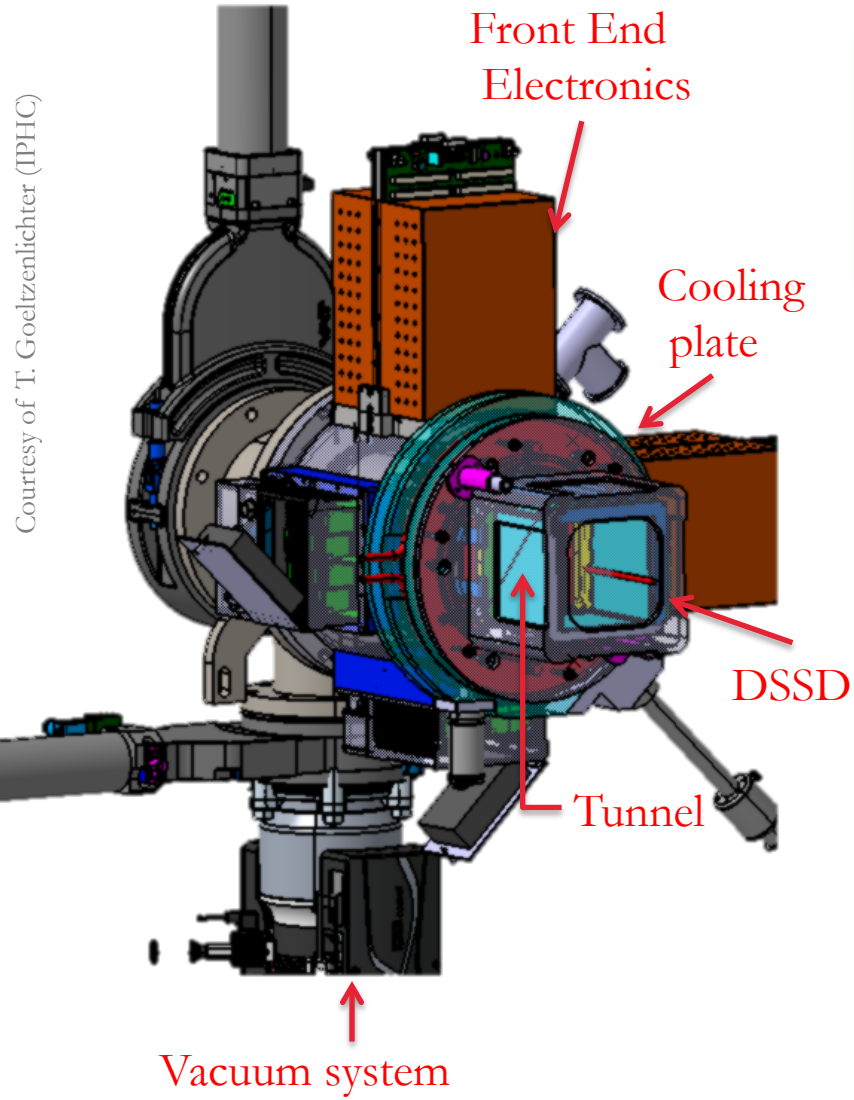
- High rejection > 10^{13}
- High transmission
- Mass resolution > 1/300

$^{208}Pb(^{48}Ca,2n)^{254}No$

- ^{48}Ca beam at 10 pμA
- Cross section production σ = 2 μb
- Transmission ~50%

➡ 60000 ^{254}No /h (15-20 times more than at GSI)

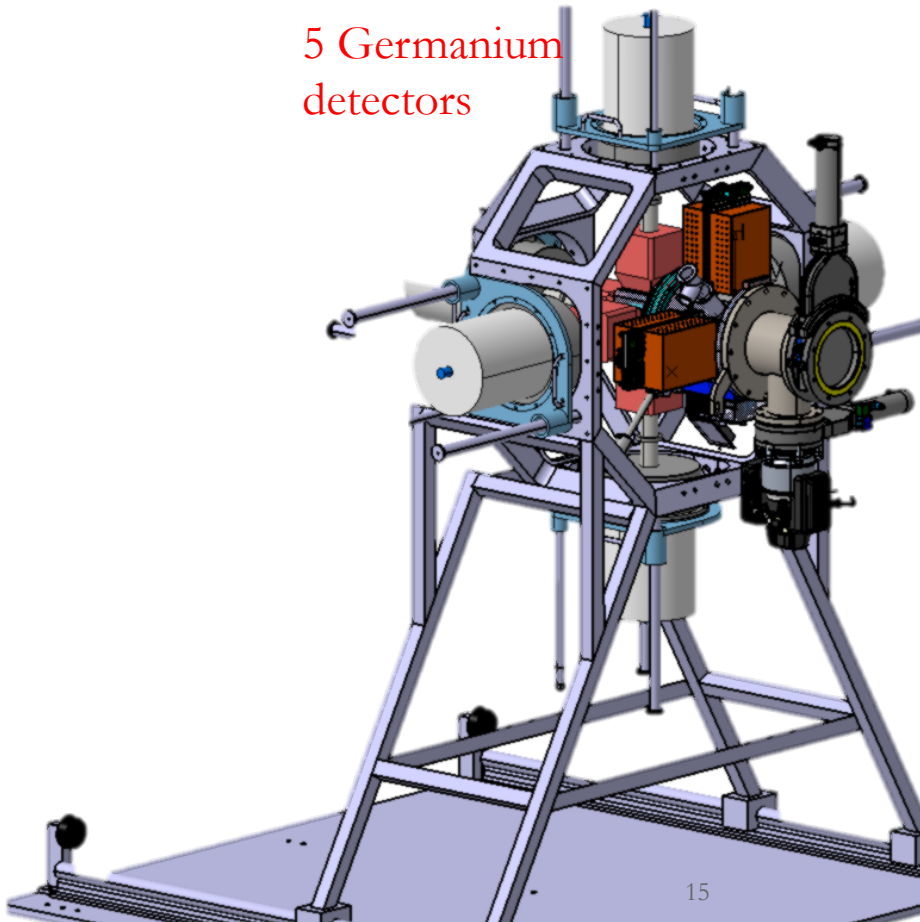
SPECTROSCOPY AND IDENTIFICATION OF RARE IONS USING S3



Courtesy of T. Goeltzenlichter (IPHC)

- Time of flight (**σ(t) < 1ns**) and tracking (**σ(x) <0.5mm**)
- Large size Implantation detecotor (**10x10cm²**, 128x128ch DSSD)
- Digital electronics : ability to detect large> 50MeV pulse

followed (≈ 10µs) by a weak (<15MeV) pulse with good energy resolution.



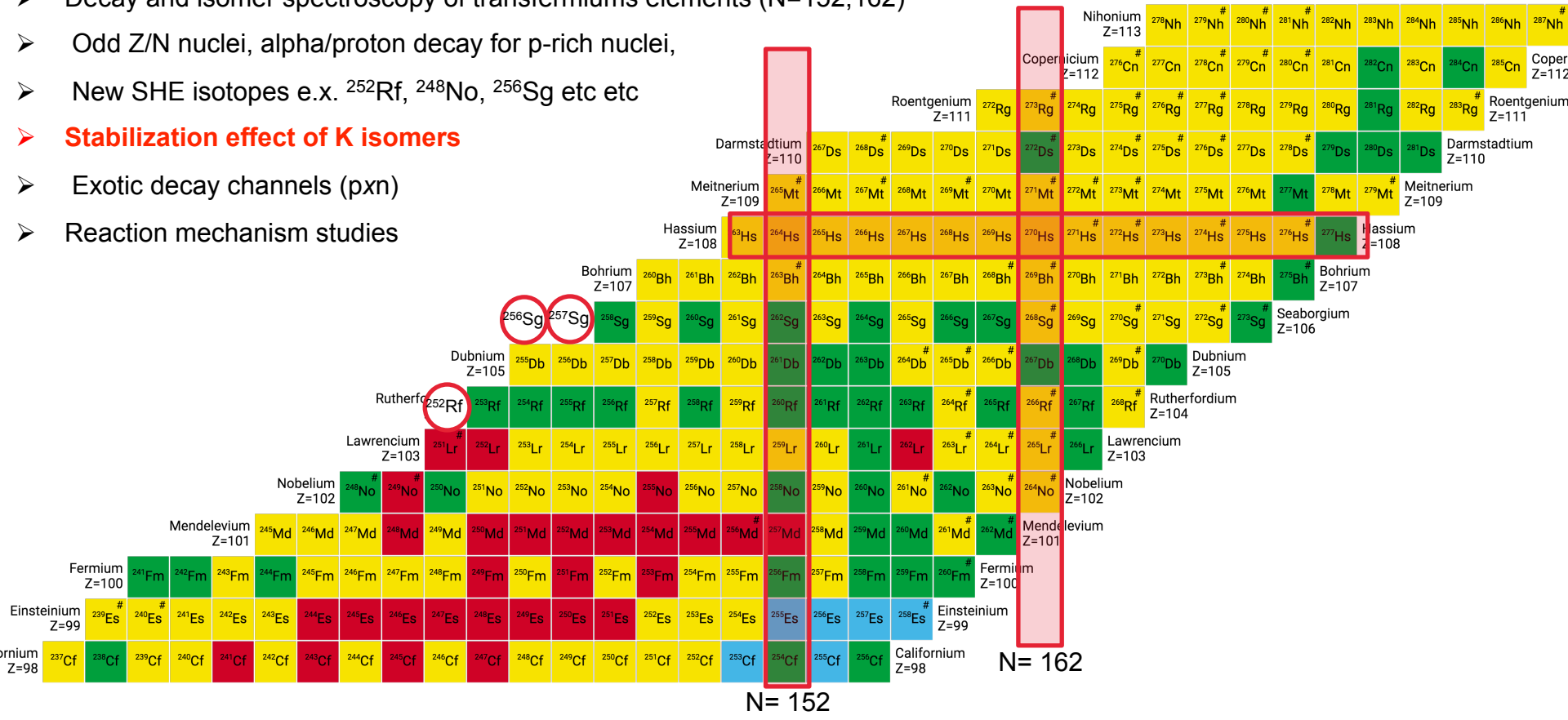
OUTLOOK

First experiments @ S3+ SIRIUS

(LOI S3 Collaboration Workshop 18-22 June 2018)

Understanding nuclear structure responsible for shell stabilization in SHE and understand the influence of nuclear structure on fusion-evaporation for SHE.

- Decay and isomer spectroscopy of transfermiums elements (N=152,162)
- Odd Z/N nuclei, alpha/proton decay for p-rich nuclei,
- New SHE isotopes e.x. ^{252}Rf, ^{248}No, ^{256}Sg etc etc
- **Stabilization effect of K isomers**
- Exotic decay channels (pxn)
- Reaction mechanism studies



5 research groups from France, and from Germany, UK, Finland, Slovakia, Russia

TASK FORCE

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GRAZIE !