First Physics with the Super-Separator Spectrometer S3
27.3. – 30.3, 2017
CEA Saclay, Orme des Merisiers

Nuclear structure and decay of rutherfordium and seaborgium isotopes

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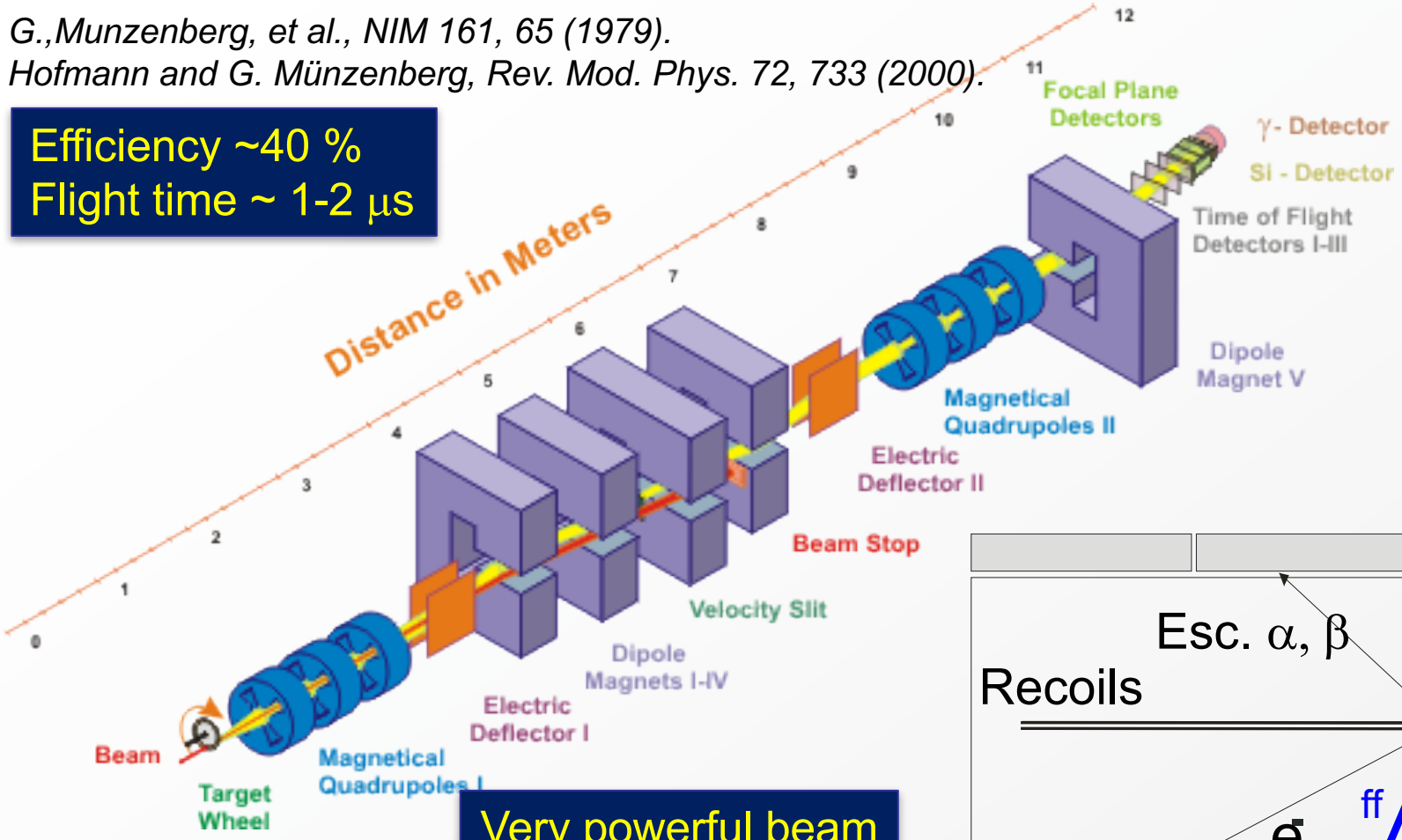
Outline

- Nuclear structure topic at SHIP in Fm region
- Examples for N=153 and 151 isotones
- Isomer in ^{253}Fm
- Decay spectroscopy of ^{259}Sg and ^{255}Rf
- Alpha- and EC decay studies of ^{257}Rf
- Conclusion

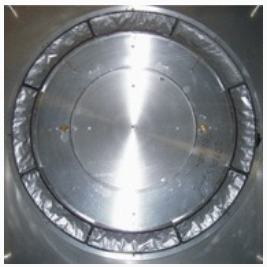
SHIP separator

G.,Munzenberg, et al., NIM 161, 65 (1979).
Hofmann and G. Münzenberg, Rev. Mod. Phys. 72, 733 (2000).

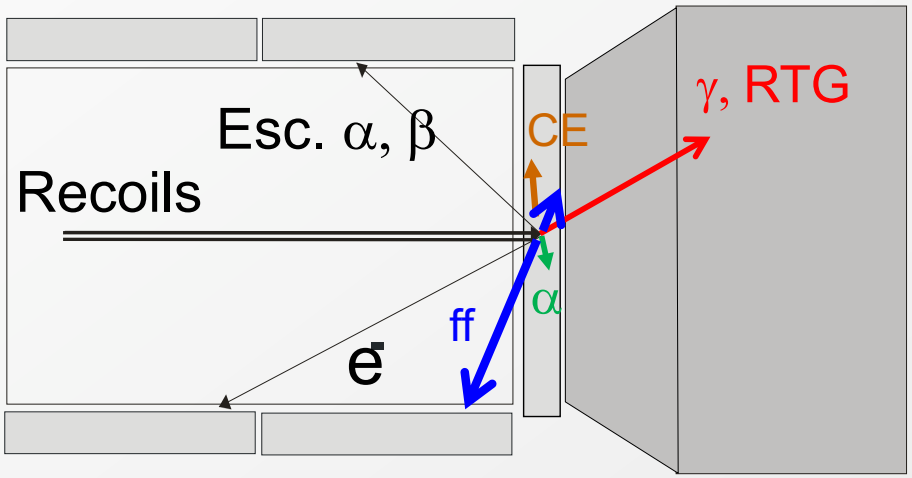
Efficiency ~40 %
Flight time ~ 1-2 μs



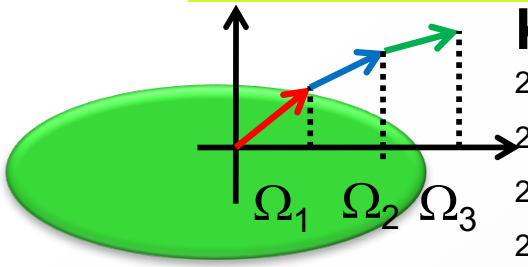
Very powerful beam
^{54}Cr ~ 720 pnA



Bi_2O_3, PbS target – 450 μg/cm^2
Rotating wheel – 31 cm diameter



Nuclear structure at SHIP

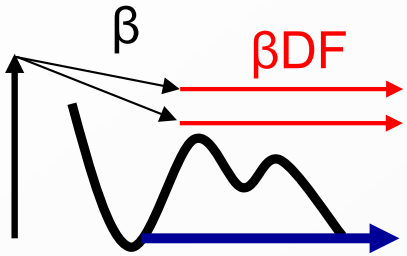


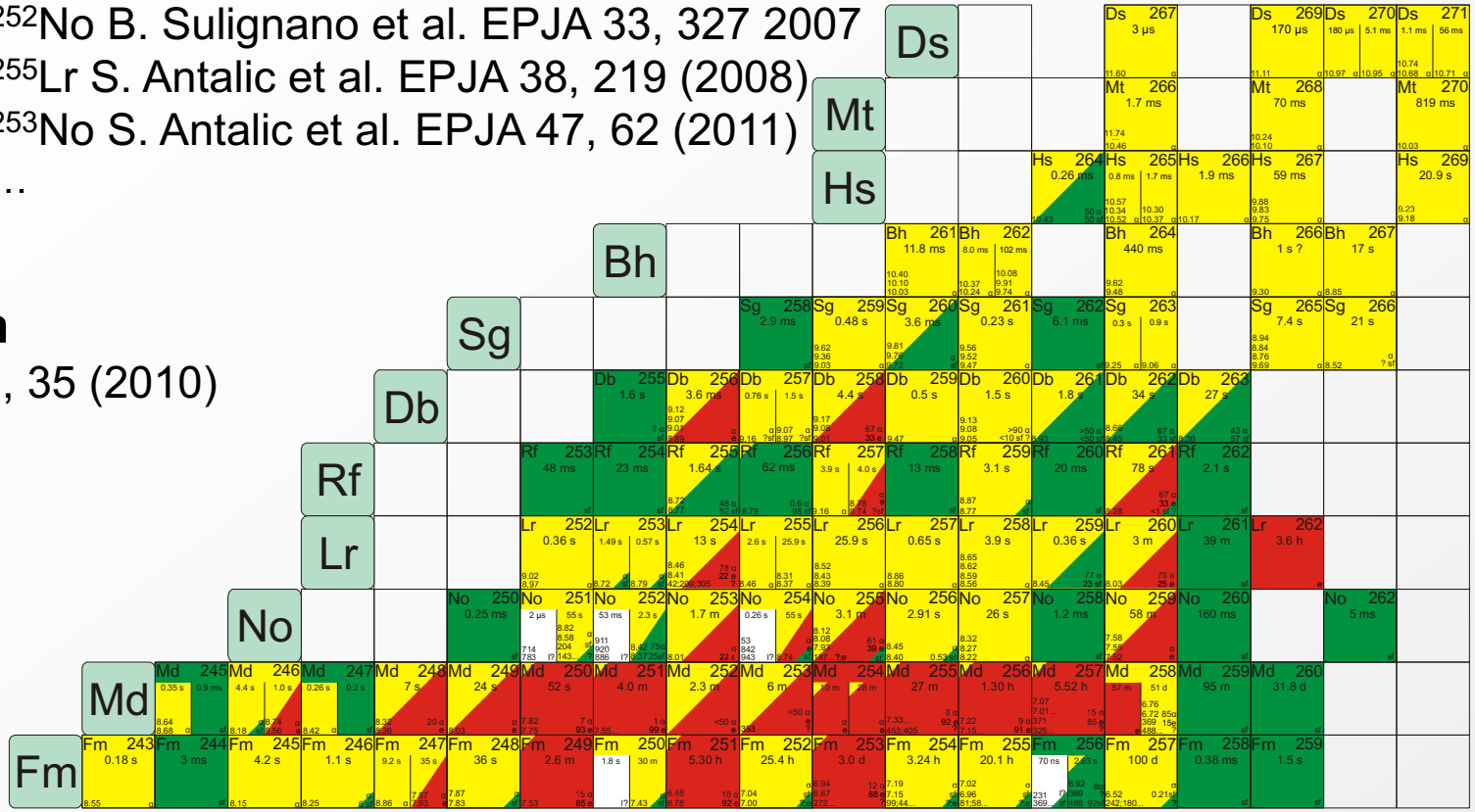
K isomers

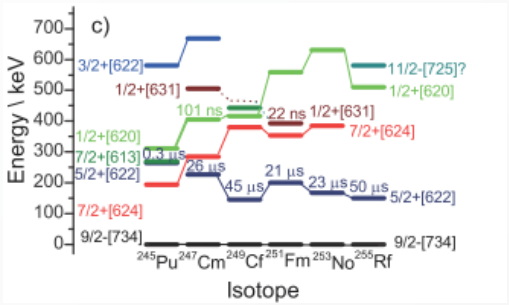
^{254}No,^{255}No F.P.Hessberger.et al. EPJA 43, 55 (2010)
^{252}No B. Sulignano et al. EPJA 33, 327 2007
^{255}Lr S. Antalic et al. EPJA 38, 219 (2008)
^{253}No S. Antalic et al. EPJA 47, 62 (2011)
…

Beta delayed fission

S. Antalic et al. EPJA 43, 35 (2010)







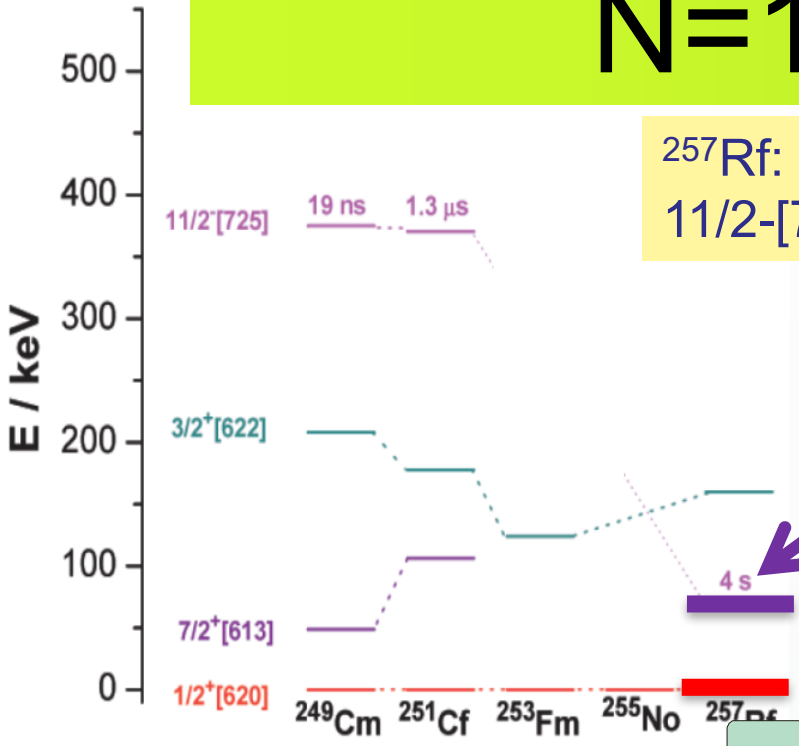
Single particle level systematics

Es isotopes F.P.Hessberger.et al. EPJA 26, 233 (2005)
N=151,153 isotones B. Streicher et al. EPJA 45, 275 (2010)
S. Antalic et al. EPJA 51, 41 (2015)
N=149 isotones F.P. Hessberger EPJA48, 75 (2012)
…

EXAMPLE: SINGLE PARTICLE LEVEL SYSTEMATICS N=153

N=153 isotones

^{257}Rf: Long lived (≈4 s) isomer due to 11/2-[725] close to the 1/2+[620] g.s.



B. Streicher et al. EPJ A45, 275 (2010)

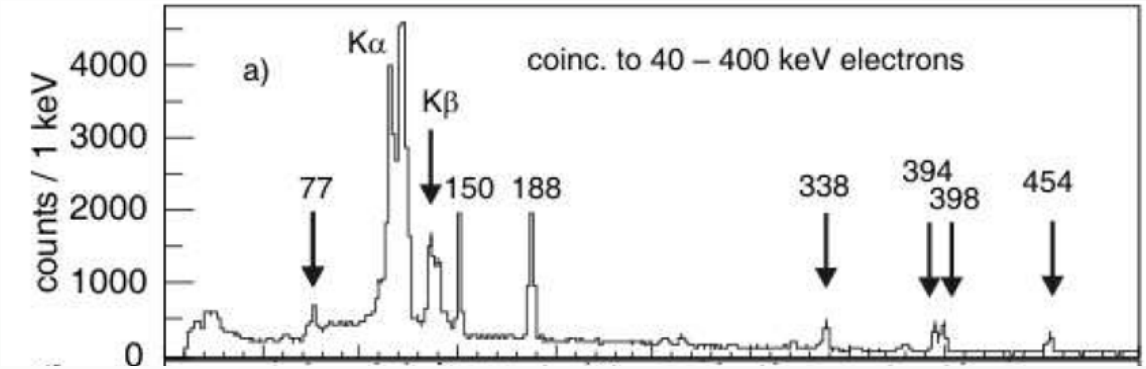
Typically only few levels are identified and assigned in this region.
Opened question: Decrease of 11/2- states responsible for isomer.
Possible switch for 11/2- and 1/2+ state (predicted at heavier isotones)

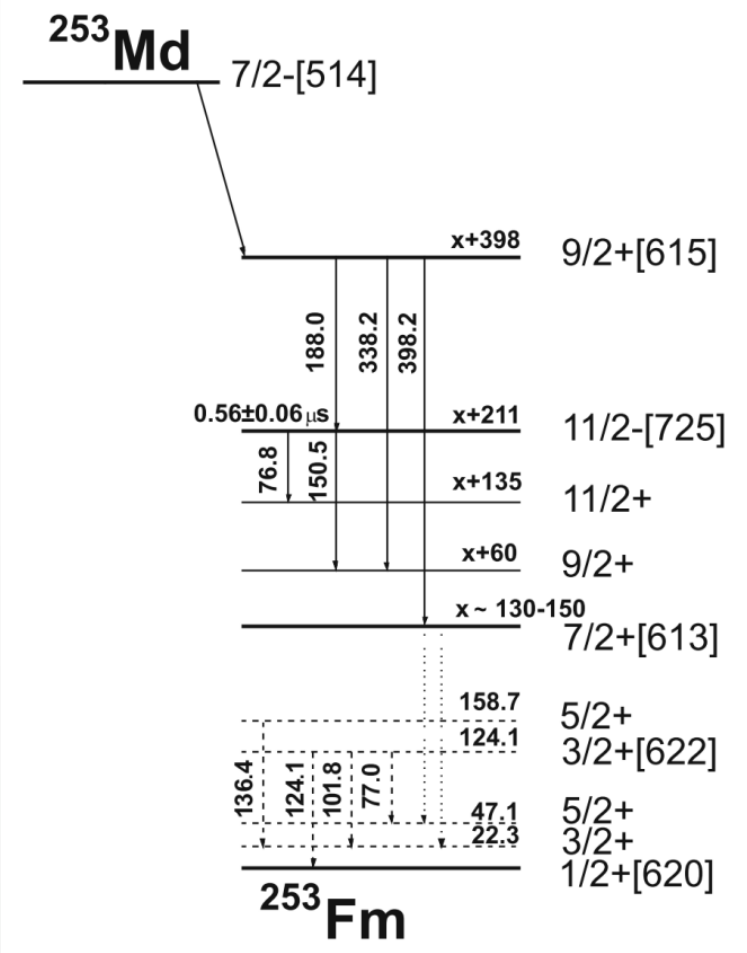
^{253}Md – beta decay to ^{253}Fm

Isomer identified via coincidences with K X-rays (+ coincidence with CE)

(see the talk by D. Ackerman on X-ray tagging)

Transitions for ^{253}Fm produced in beta decay of ^{253}Md identified and assigned via coincidences with Fm K-X rays

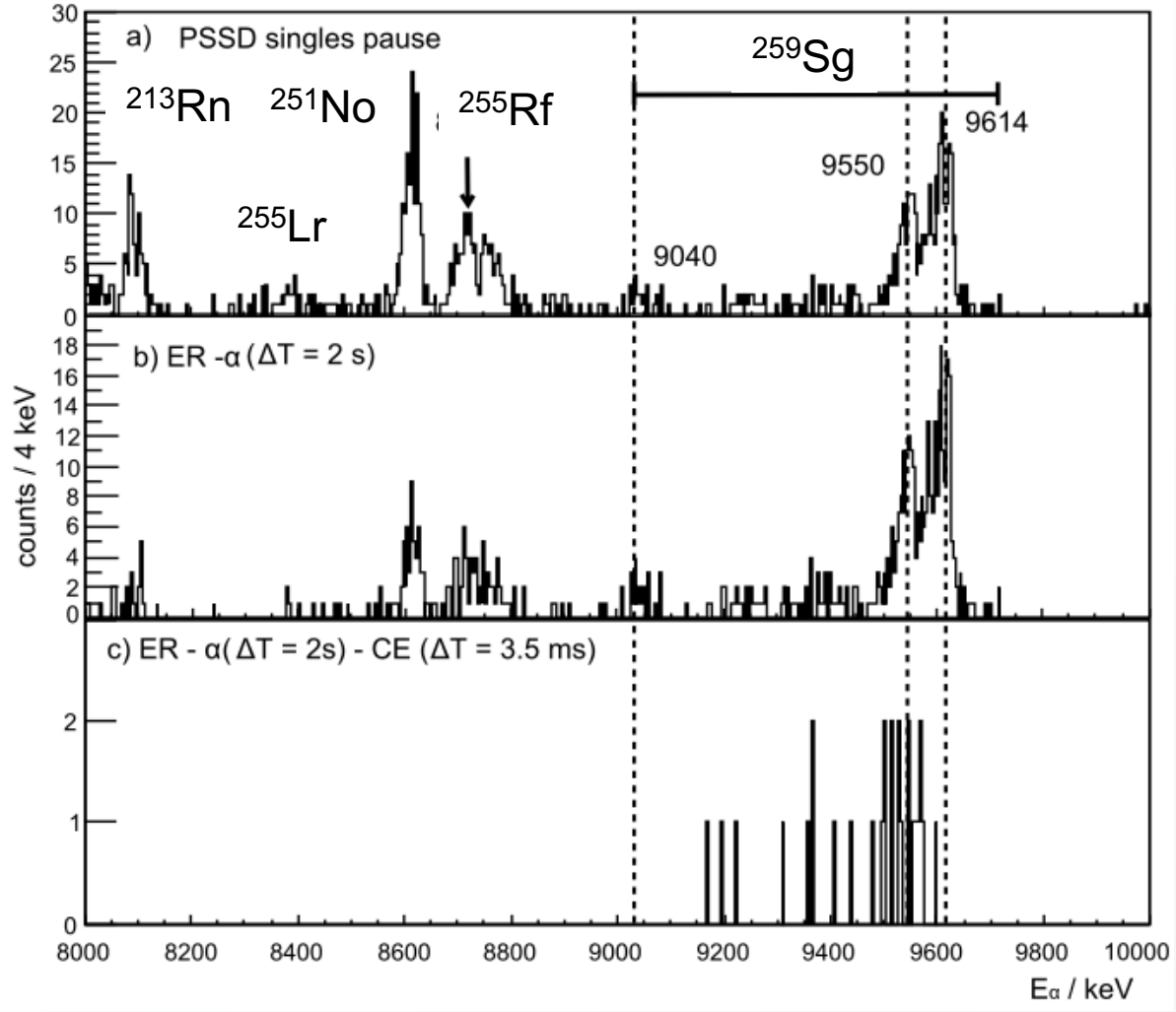




S. Antalic et al. EPJ A47, 62 (2011)

The method of delayed CE-X rays coincidences used in identification of 11/2-[725] isomer in ^{253}Fm (produced by beta decay of ^{253}Md).

alpha decay of ^{259}Sg

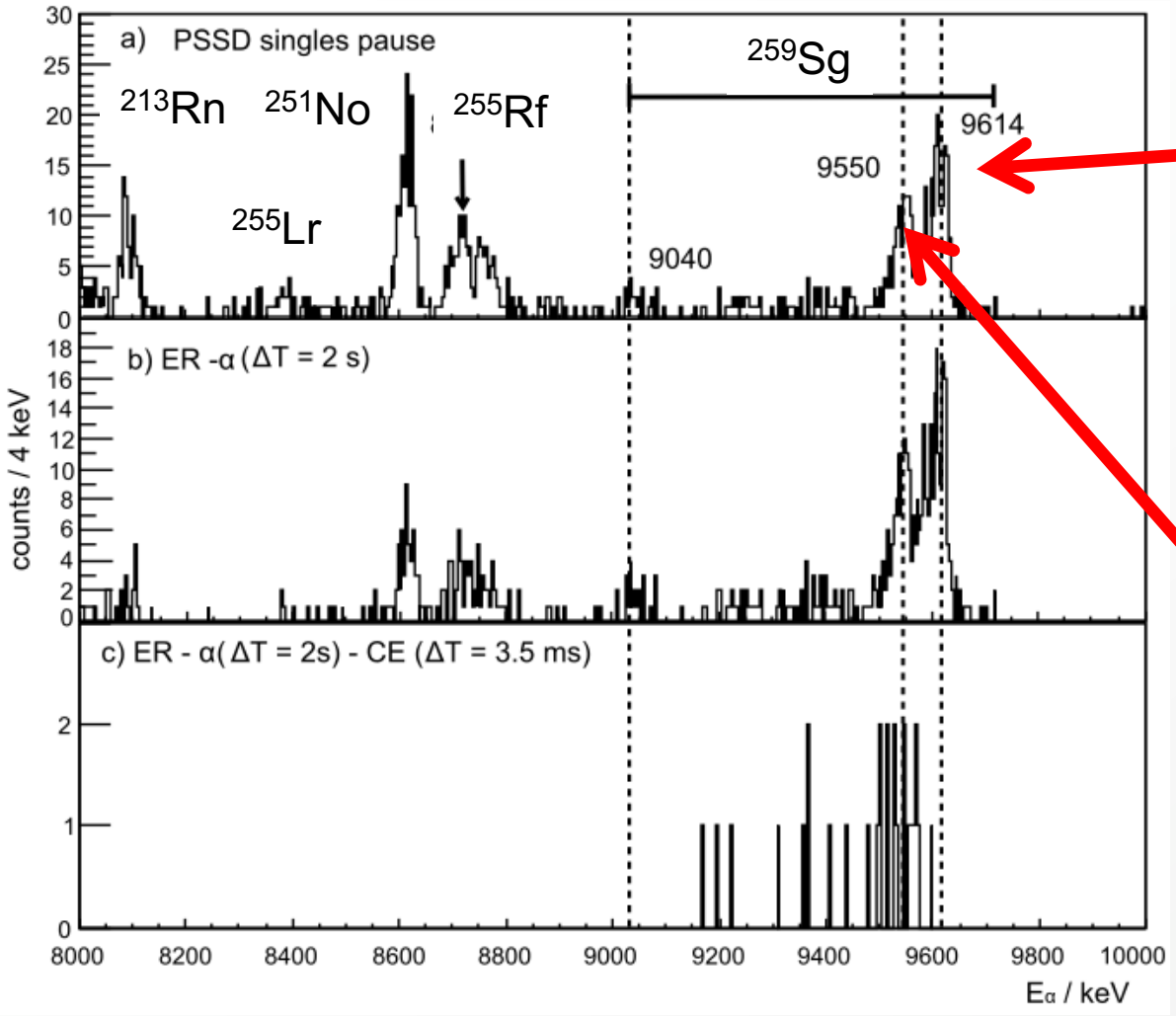


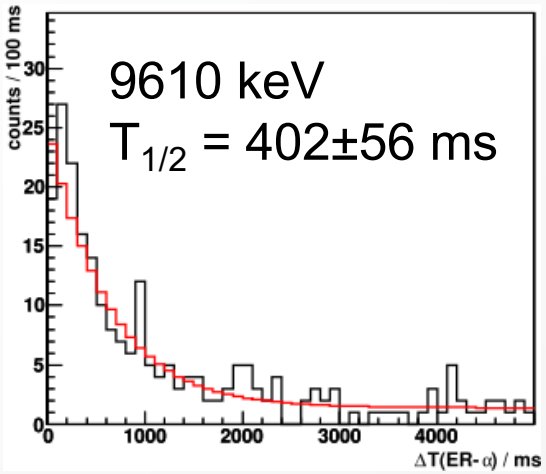
^{54}Cr+^{206}Pb→^{259}Sg + 1n

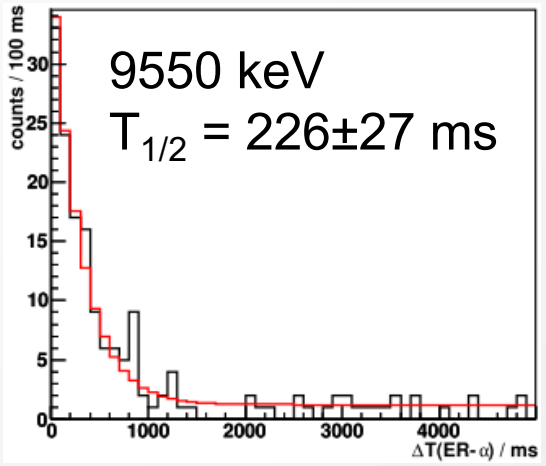
I(^{54}Cr^{8+}) = 720pnA

1 week of beamtime 750 nuclei of ^{259}Sg (assuming $b_\alpha \approx 97\%$)

^{259}Sg – alpha decay

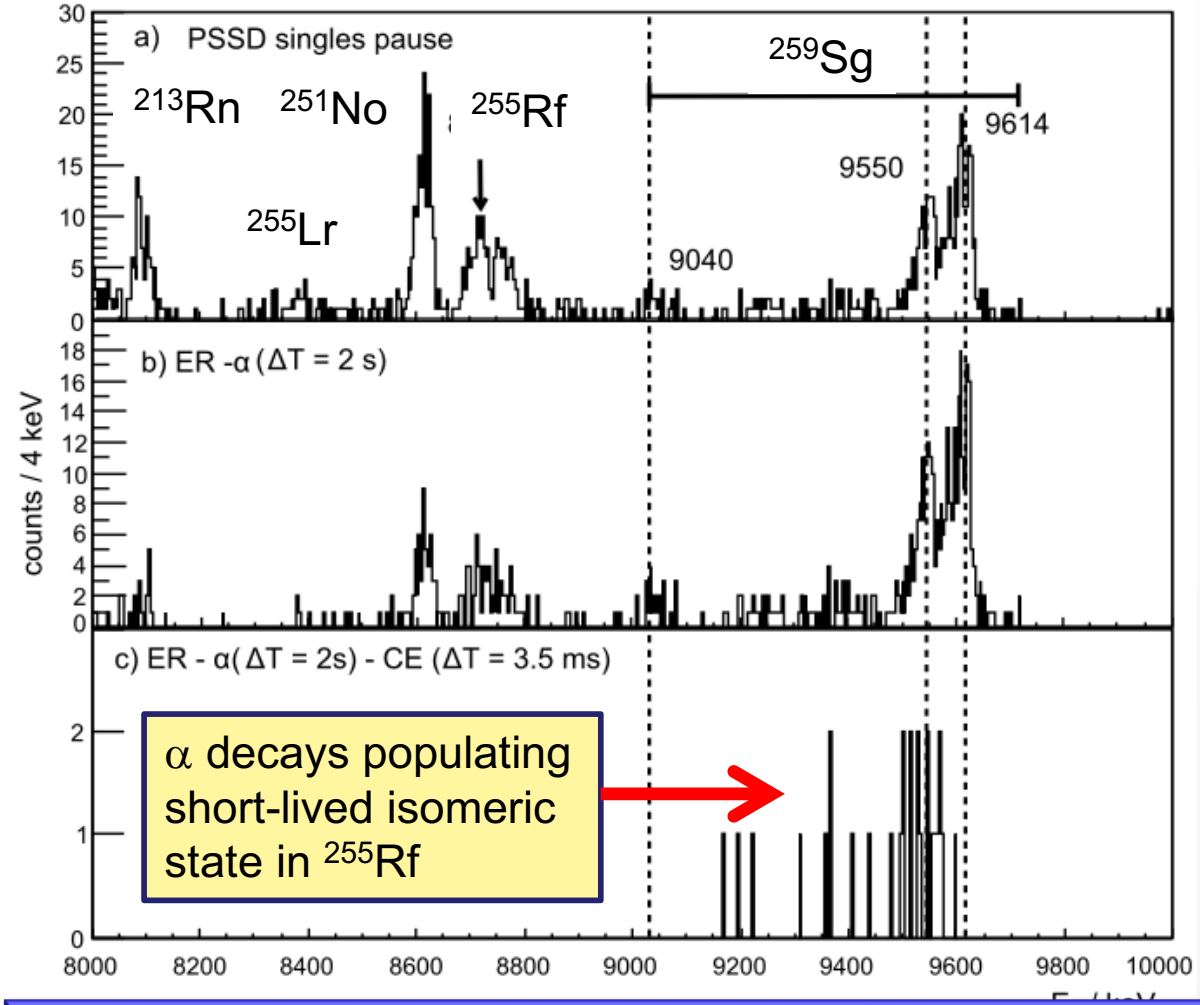


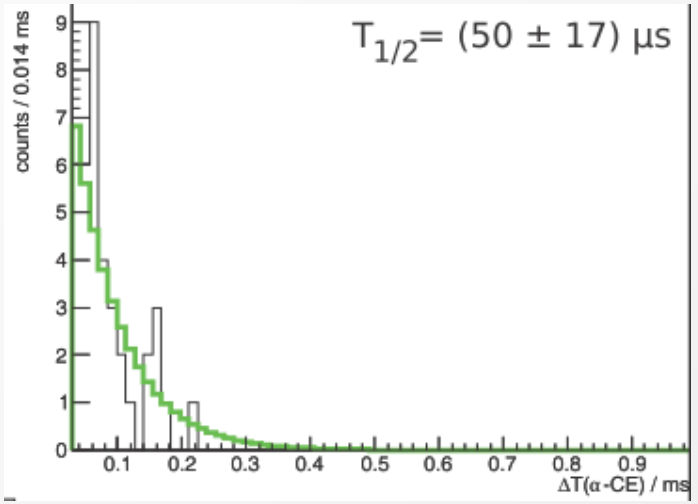




New long-lived isomeric state in ^{259}Sg existing due to the presence 11/2-[725] and 1/2+[620] nilsson levels known in lighter N=153 isotones.

New isomer in ^{255}Rf

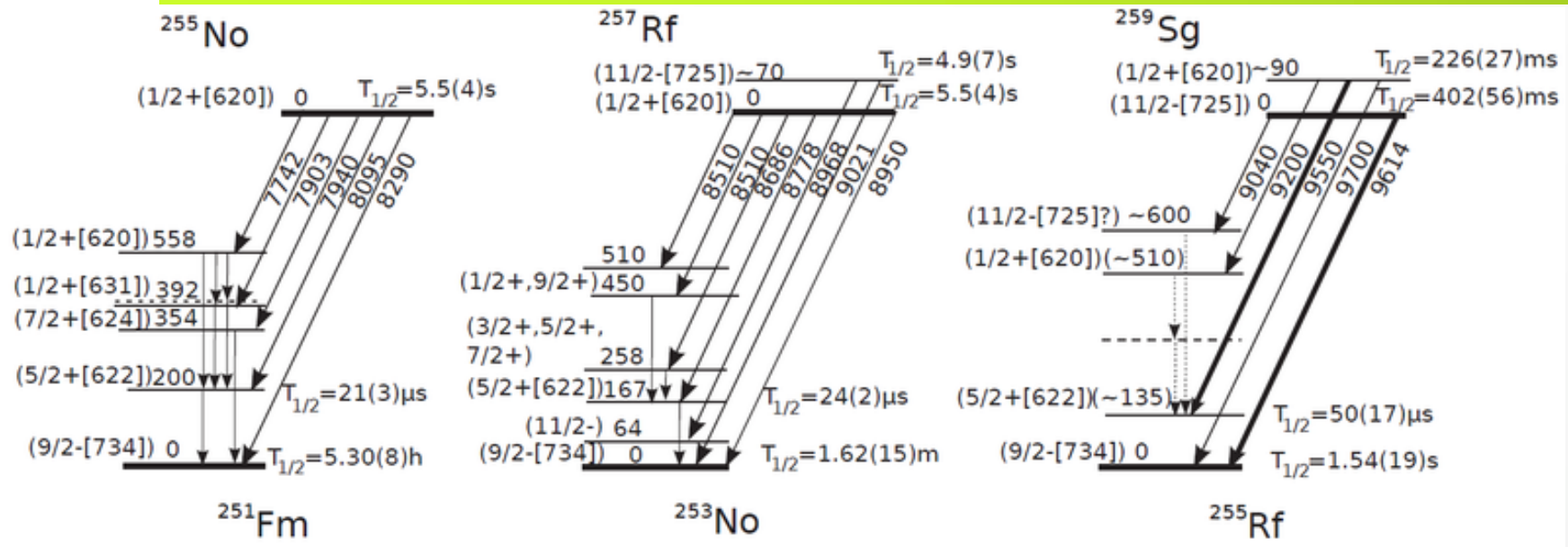


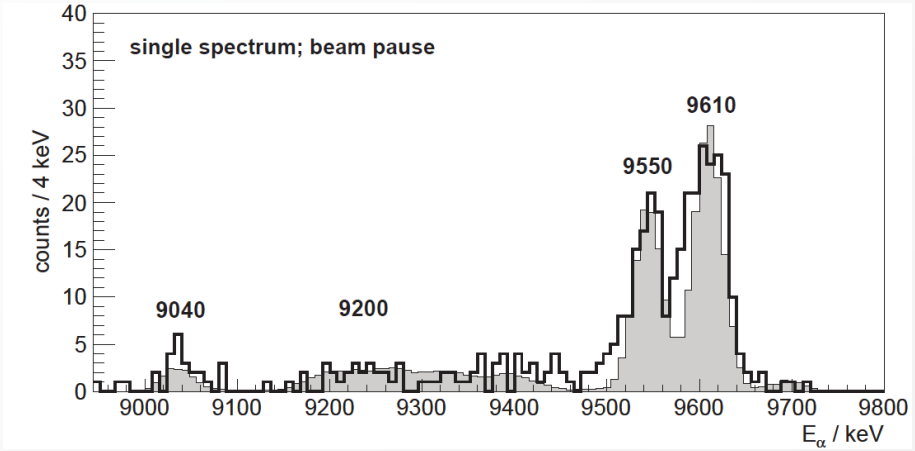


New short-lived (50 ± 17) μs isomeric state in ^{255}Rf at ≈ 135 keV assigned as 5/2+[622] state.

First decay scheme for ^{259}Sg from the α- and α-CE spectroscopy

Decay scheme for ^{259}Sg



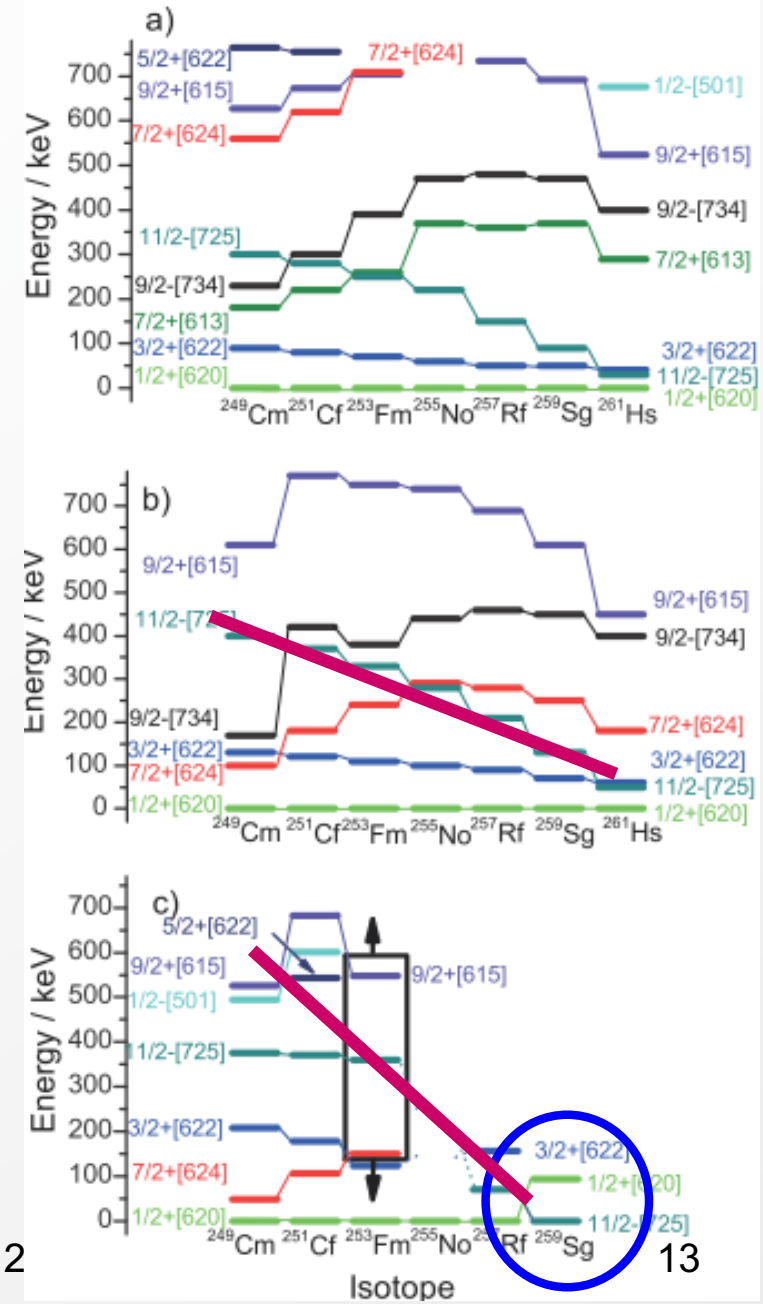


Cross-check with GEANT4 simulation
(including conversion and Auger electrons)

[S. Antalic et al. AIP Conf. Proc. 1681, 030013 (2015)]

N=153 isotones systematics

a) Parkhomenko, Sobiczewski , Act. Phys. Pol. B36, 3115 (2005)
b) S. Cwiok et al. Nucl. Phys. A573, 356 (1994)
c) experimental data



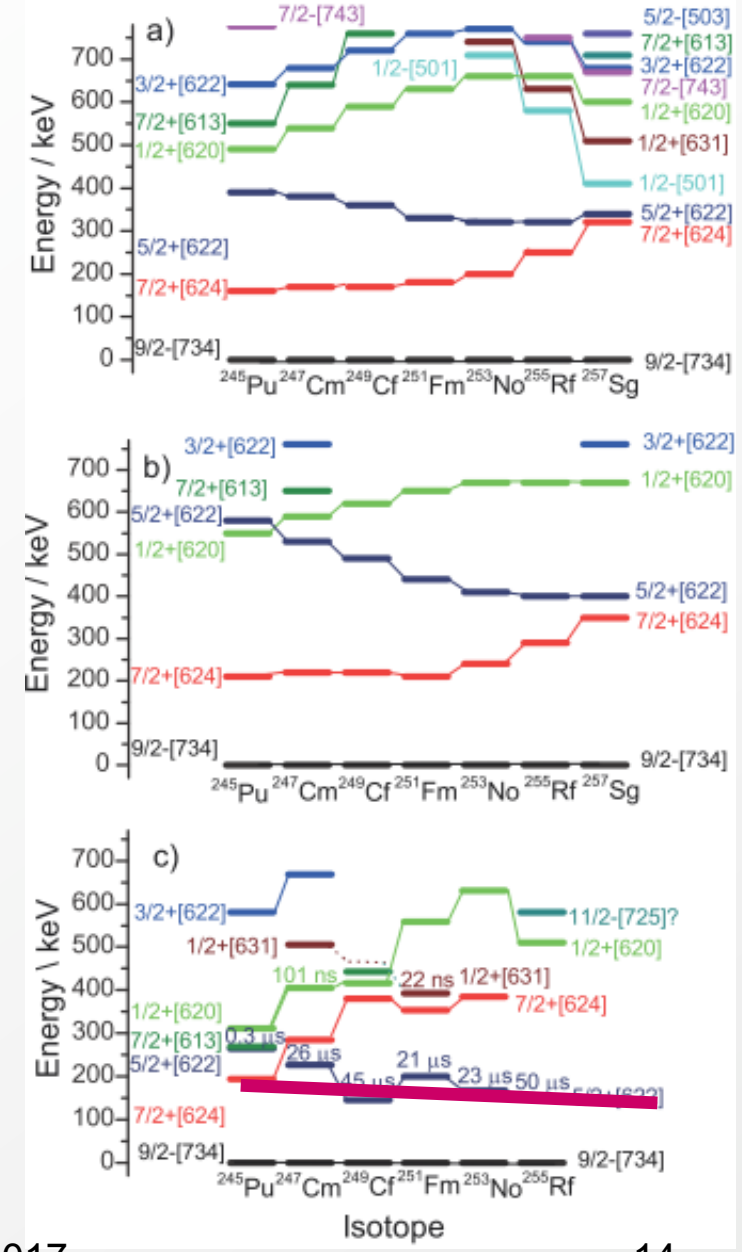
Extension of the single-particle level systematics up to the ^{259}Sg

Confirmation of the energy decrease for 11/2-[725] state.

First change of the g.s. configuration for N=153 isotones.

N=151 isotones systematics

a) Parkhomenko, Sobiczewski , Act. Phys. Pol. B36, 3115 (2005)
b) S. Cwiok et al. Nucl. Phys. A573, 356 (1994)
c) experimental data



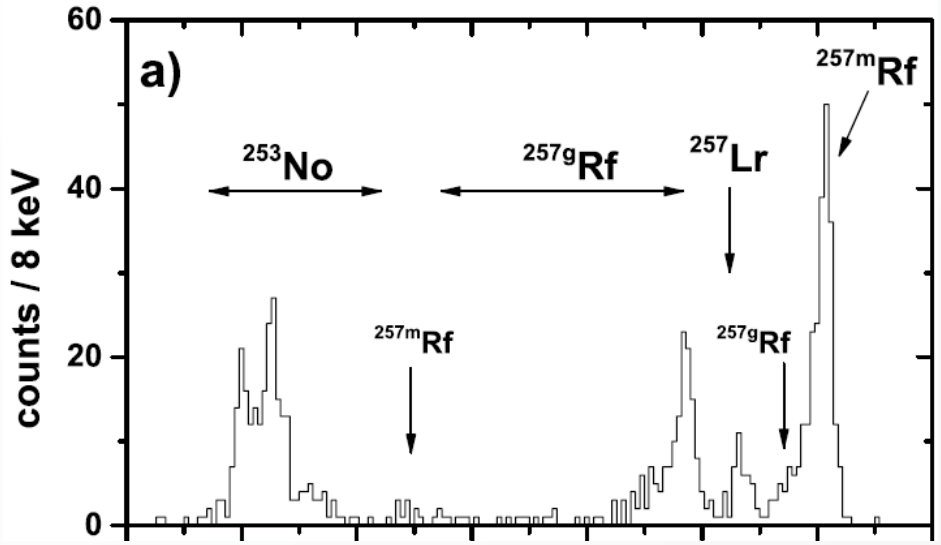
Extension of the single-particle level systematics up to the ^{255}Rf

Short lived isomers (20 – 60 μs) at 140 – 250 keV states, unpredicted by available theoretical models, known up to the ^{255}Rf

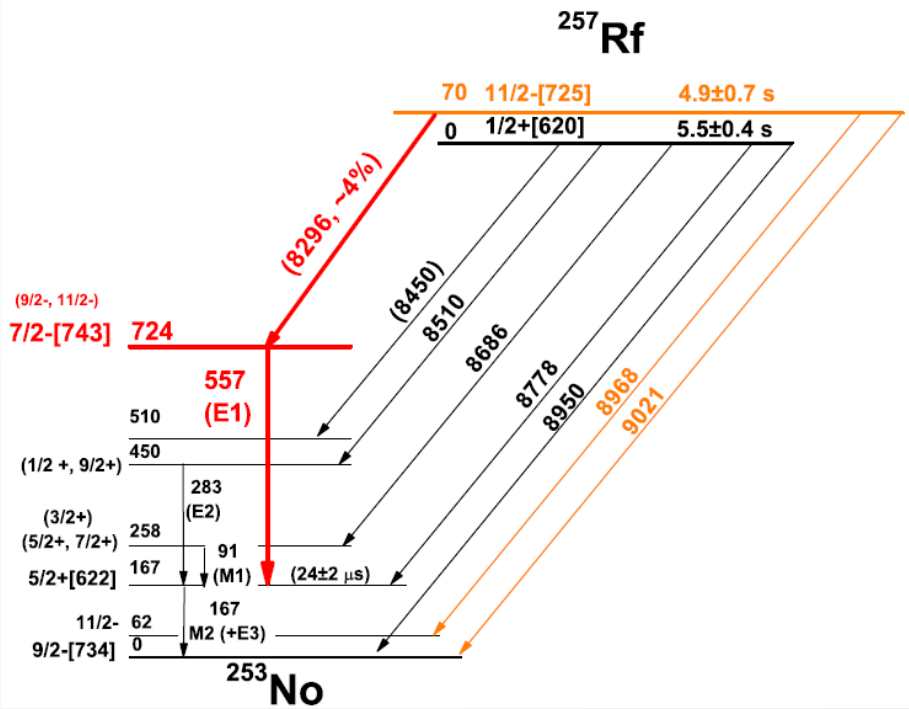
Alpha-decay studies ^{257}Rf

^{50}Ti+^{208}PbS$\rightarrow$^{257}Rf + 1n I(^{50}Ti) = 500 pnA

480 full energy alphas in ~22 hours
~50 nuclei per hour
(considering b_α≈80% [B. Streicher et al. EPJA45, 275 (2010)])

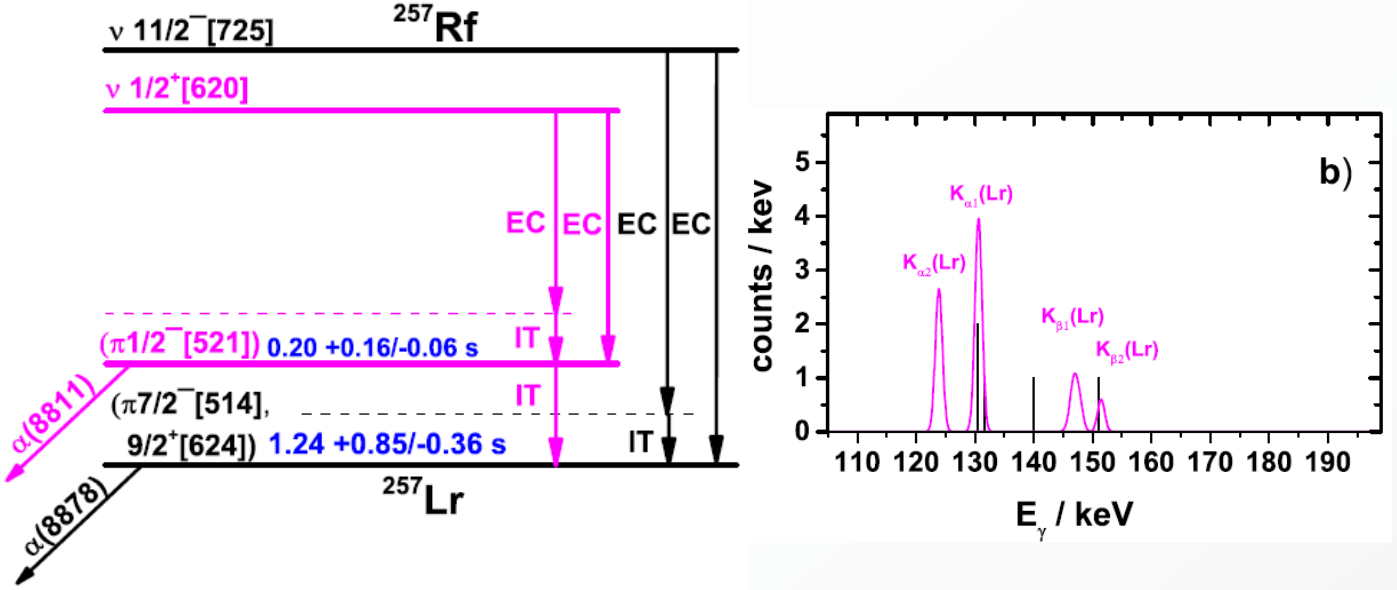


F.P. Hessberger et al. EPJ A52, 192 (2016)



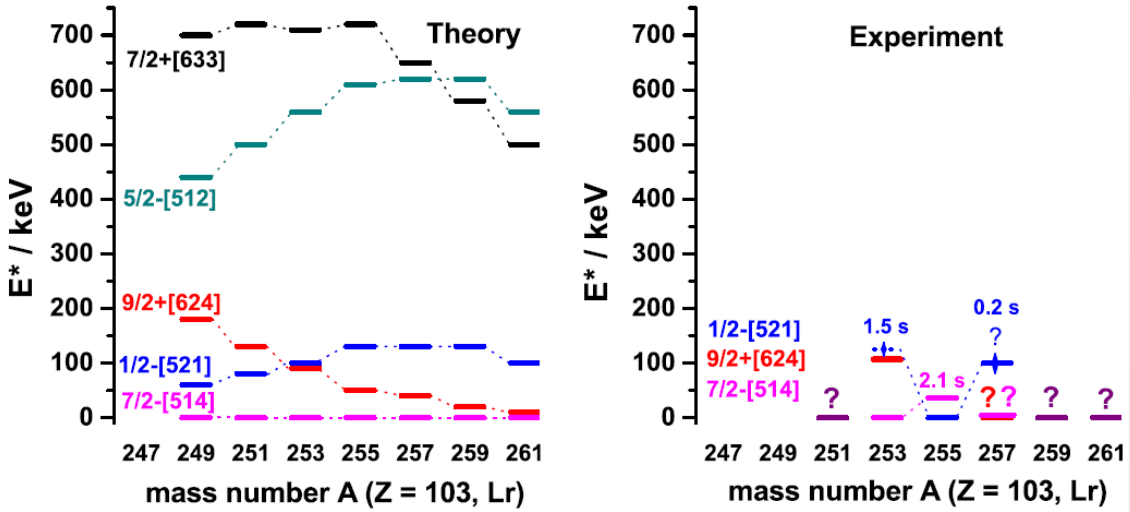
Improved decay scheme

Beta-decay studies ^{257}Rf



Search for a EC decay by looking at correlation with CE(+X-ray) from de-excitation cascade

F.P. Heßberger, EPJ Web of Conferences 131, 02005 (2016)



1/2-[521] and 7/2-[514] states stem from $2f_{5/2}$ and $2f_{7/2}$ defining possible the shell gap at Z=114. Both responsible for isomers in Lr isotopes.
Uncertain g.s. configuration for isotopic chain (we need more experimental data…).

Conclusion

- New nuclear structure data for heaviest elements (K isomers, alpha-decay spectroscopy, single particle level systematics).
- Many new data also in Z = 82 region (new Fr isotopes, betaDF of At isotopes, isomers in Po isotopes… not discussed in this talk).
- EC decay studies via search for correlation with CE+X-ray coincidences.
- Extension of single-particle level systematics for N=153 and 151 isotones up to the ^{259}Sg and ^{255}Rf. Level systematics for isotopic chains above fermium remains very uncertain (isotopic chains with Z>100 need new data).

- Present limit for detailed $\alpha(-\gamma)$-decay spectroscopy might be considered up to the Z=106… looking forward to S3. ☺

Thank you