

# Spectroscopy of Heavy Elements at Dubna

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on behalf of the GABRIELA collaboration

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tive Interaction = analytical  
option?

me limit = mass

ence of Super-Heavy  
ts (SHE : Z=108) in nature?

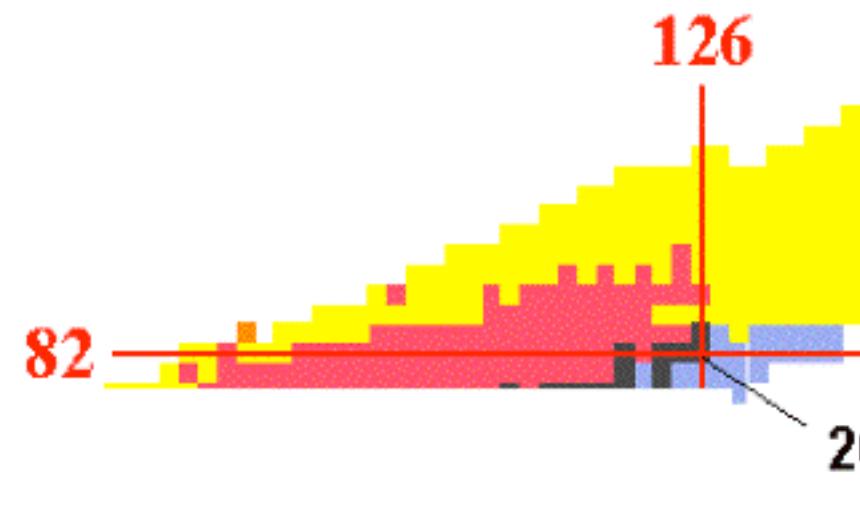
island of stability

consensus in the  
tical predictions

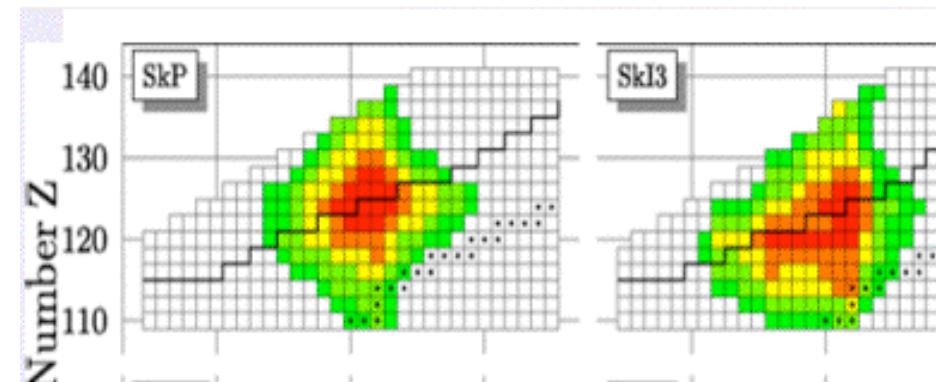
=114,120 or 126?

=172 or 184?

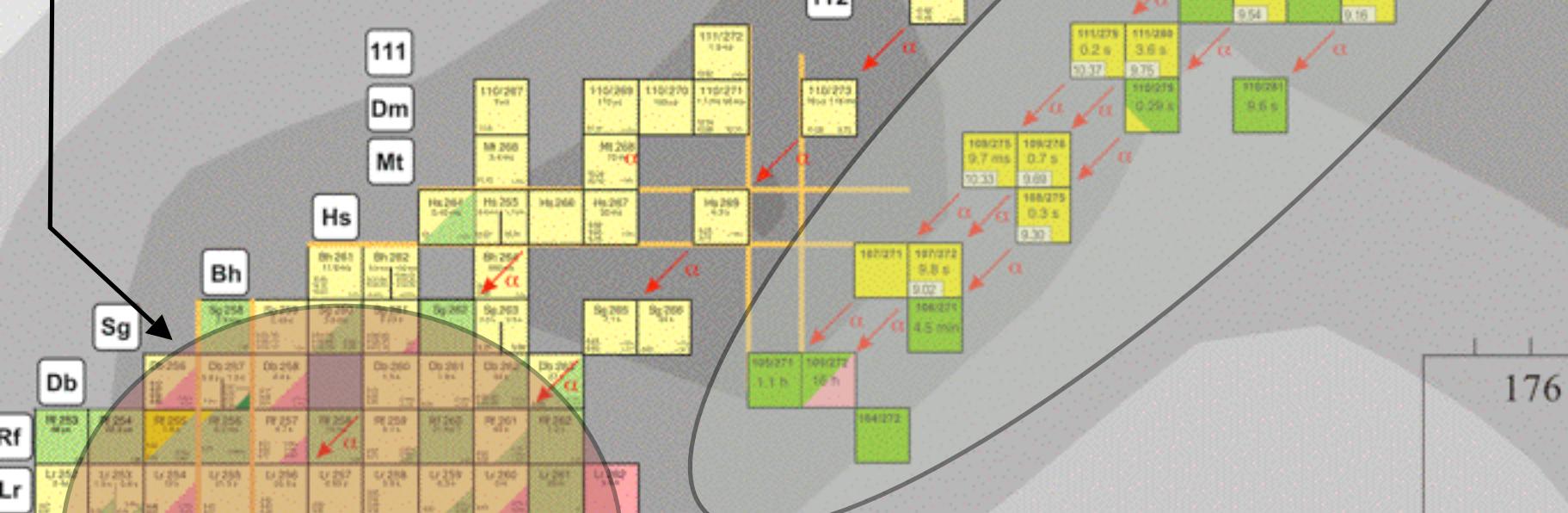
is the contribution of the



M. Bender et al, PL B515 (2001)



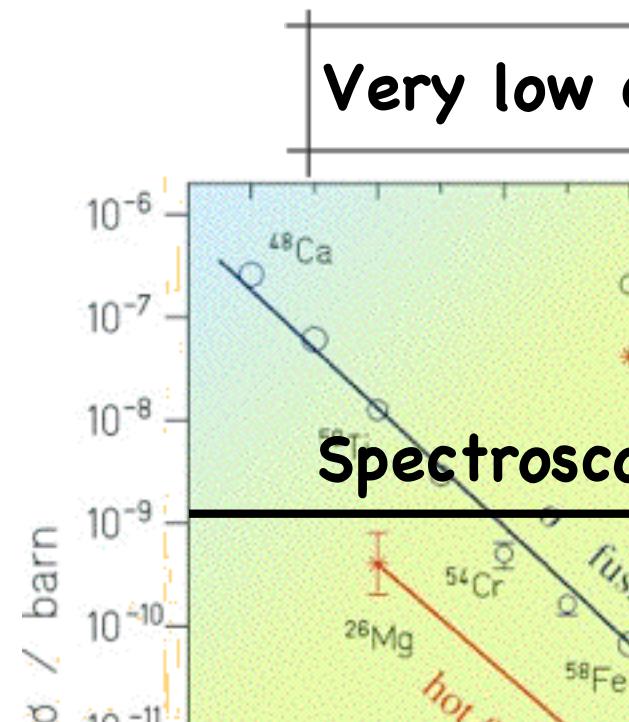
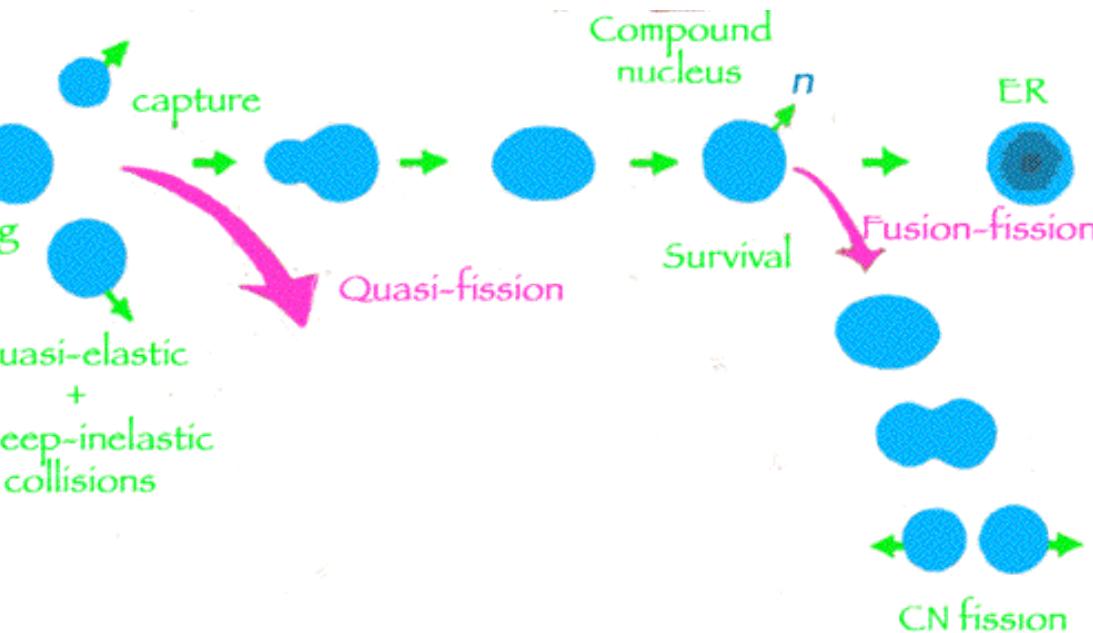
# VHE :Spectroscopy



## CHART OF THE NUCLIDES

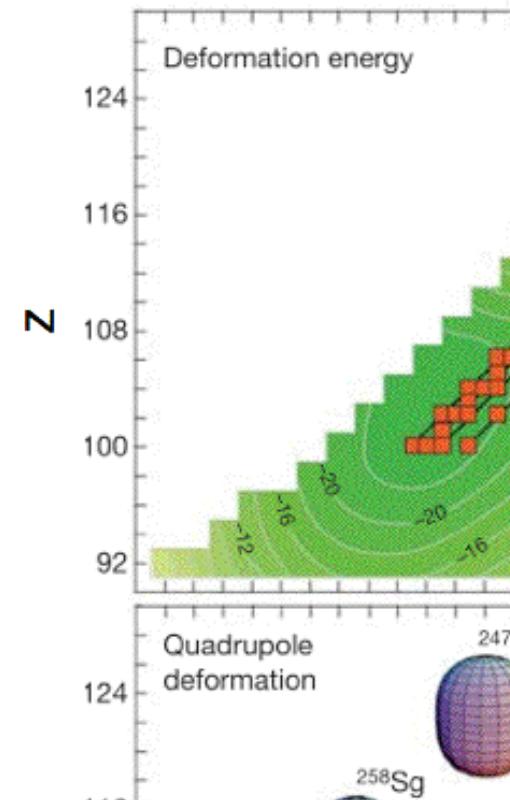
# SHE :Synthesis

# domination of the fission processes

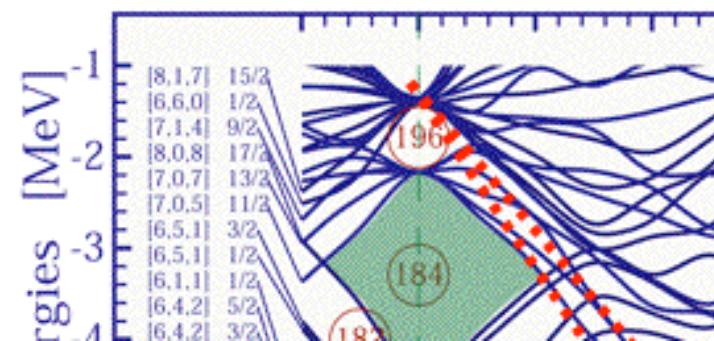
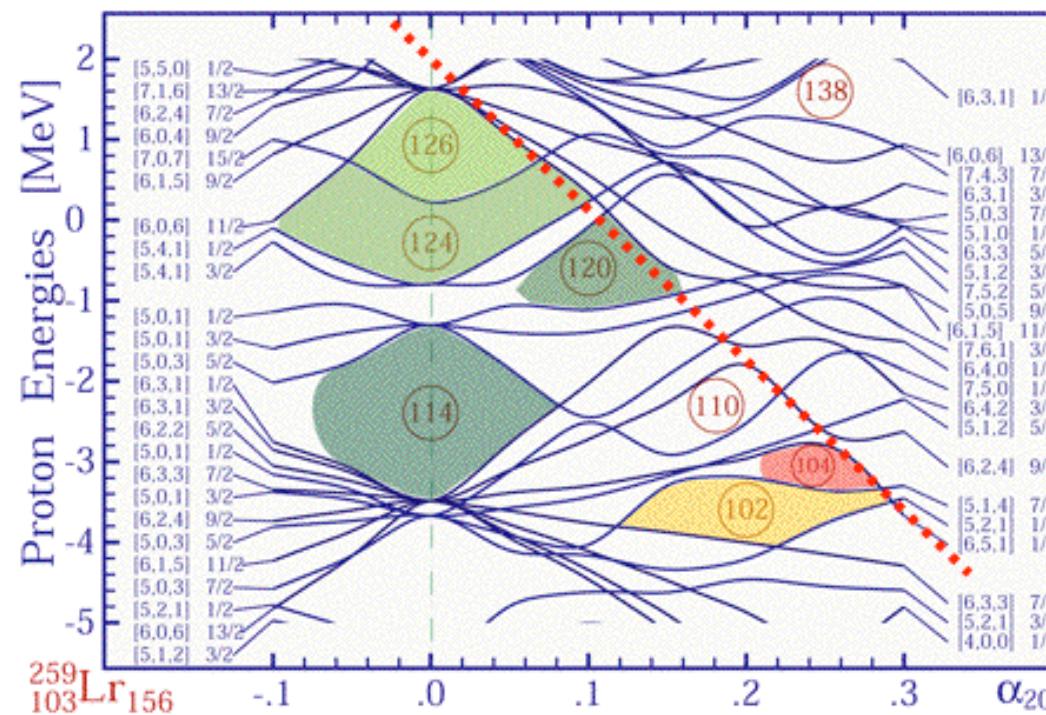


- Probe of the extreme states of the nuclear matter
- Many parameters are interpolated...when they diverge by

ps are strongly correlated with the spin-  
t interaction  
importance of the nucleus deformation ?  
the SHE gap spherical ?  
what is the real Coulomb effect ?



ence of high angular  
 quantum orbitals ?  
 e-particle states  
 starting from levels above  
 below the potential  
 critical Z=114 shell closure  
 close to the Fermi energy  
 the deformed ground  
 s of SHE in the Z~100  
 ~150 region" (M. Bender)



Spectroscopy will give access  
to nuclear parameters  
(I,  $\pi$ , deformation, g factor)

The VHE nuclear chain  
excellent laboratory for  
orbitals involved in the n

# N~152 to N'

via cold and hot fusion

Stable targets		105	Ha Hahnium							Ha 259 209Bi + 50Ti				
Radioactive targets		104	Rf Rutherfordium (263,1125)		Rf 253	Rf 254 206Pb+48Ti	Rf 255 207Pb+48Ti	Rf 256 208Pb+48Ti	Rf 257 233U+24Mg 207Pb+48Ti	Rf 258 208Pb+50Ti 226Ra+32S 230Th+28Si 234U+24Mg	Rf 259 235U+24Mg 230Th+30Si 232Th+28Si	Rf 260 236U+24Mg 230Th+30Si 232Th+28Si	Rf 261 238U+24Mg 234Th+30Si 236Th+28Si	
		103	Lr Lawrencium (262,107)		Lr 252	Lr 253 203Ti+50Ti 205Ti+48Ti	Lr 254	Lr 255 205Ti+50Ti	Lr 256 236Np+20Ne	Lr 257 237Np+20Ne 209Bi+48Ca 230Th+27Al	Lr 258 237Np+21Ne	Lr 259 237Np+22Ne 232Th+27Al	Lr 260 238Np+22Ne 232Th+27Al	
		102	No Nobelium (259,100)		No 250	No 251	No 252	No 253 233U+Ne20	No 254 234U+Ne20 206Pb+48Ca 230Th+24Mg 226Ra+28Si	No 255 235U+Ne20 207Pb+48Ca 236Np+19F	No 256 236U+Ne20 208Pb+48Ca 232Th+24Mg 226Ra+30Si	No 257 236U+21Ne	No 258 236U+Ne22 238U+Ne20	No 259 238U+21Ne 247Cm+12C
	Md 245	Md 246	Md 247 197Au+50Ti	Md 248	Md 249 209Bi+40Ar	Md 250	Md 251 203Ti+48Ca	Md 252 233U+19F 230Th+16O 236Np+16O	Md 253 234U+19F 205Ti+48Ca 237Np+16O 226Ra+27Al	Md 254 235U+19F 236Np+18O	Md 255 236U+19F 237Np+18O	Md 256	Md 257 238U+19F	Md 258 244Pu+14N 247Cm+11B
Fm 243	Fm 244 209Bi+35Cl	Fm 245	Fm 246 209Bi+37Cl 206Pb+40Ar	Fm 247 207Pb+40Ar	Fm 248 208Pb+40Ar	Fm 249 233U+16O	Fm 250 234U+16O 226Ra+24Mg 230Th+20Ne	Fm 251 235U+16O 236Np+15N 237Ra+14N	Fm 252 236U+16O 232Th+20Ne 237Np+15N	Fm 253 232Th+21Ne	Fm 254 238U+16O	Fm 255	Fm 256 244Pu+12C	Fm 257 247Cm+11B

# Dubna Alpha Beta Recoil Investigation at the ELectrostatic separator

<http://www.csnsm.in2p3.fr/groupes/strucnuc/gabriela.html>

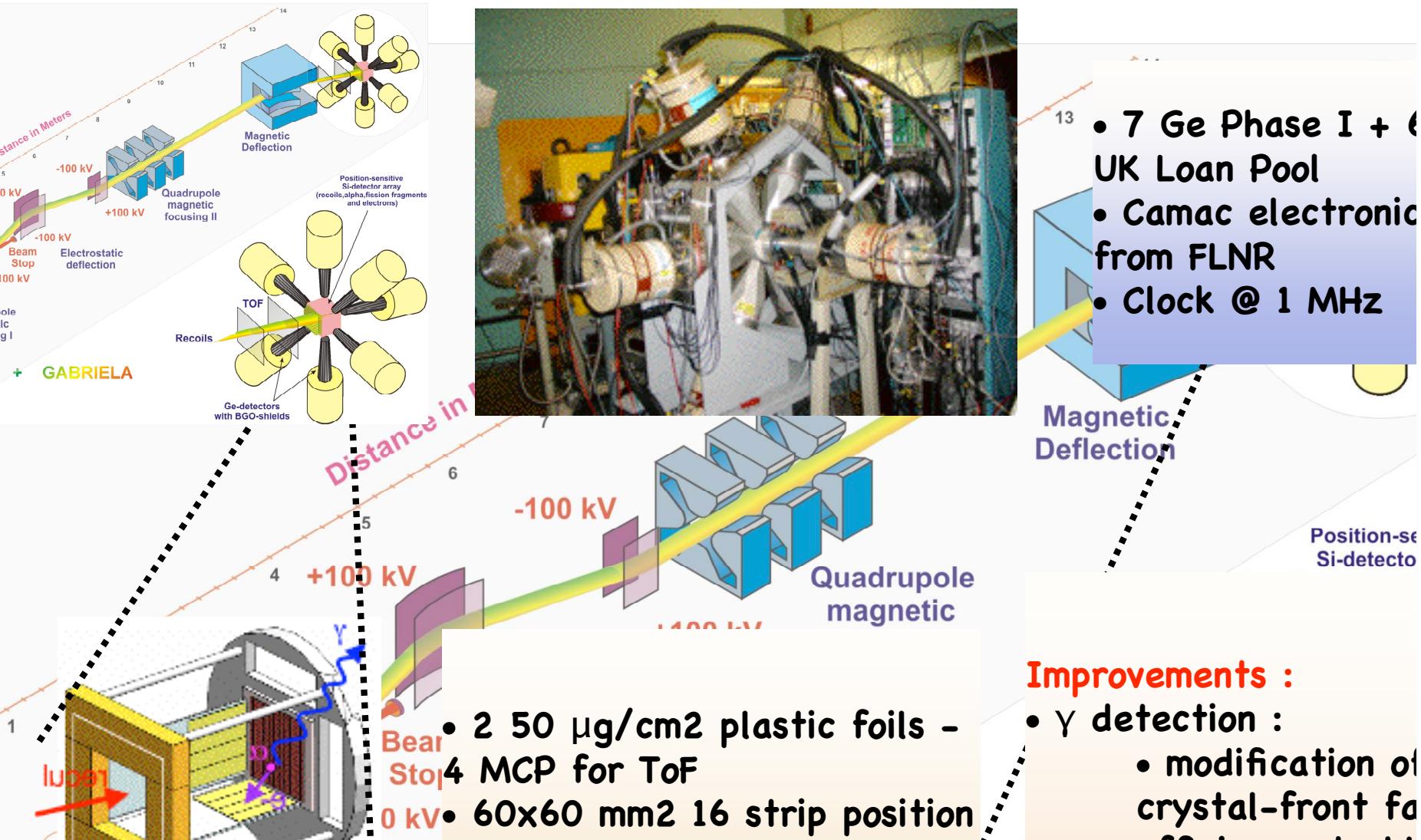
Project launched by a French (CSNSM and IPHC) - Russian (FLNP JINR) collaboration  
Project dedicated to spectroscopy studies of Transfermium elements using radioactive targets

Project approved by the SC of the IN2P3 in Dec. 2003

Project approved by the SC of JINR Dubna in Jan. 2004

First results presented at the EXOTAG Workshop at JYFL in Jyväskylä, Finland

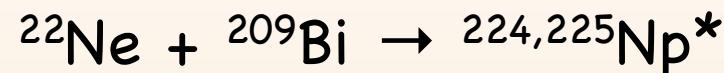




first full scale experiment : September 23 - October 25 2004



full scale experiment : October 3 - November 9 2005, 36 days

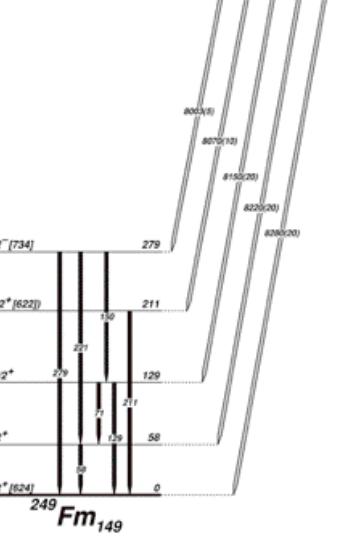


full scale experiment : October 30 - December 4 2006, 35 days



**GABRIEL REGALIS**

A. Lopez-Martens et al., PRC 74 (2006) 044303

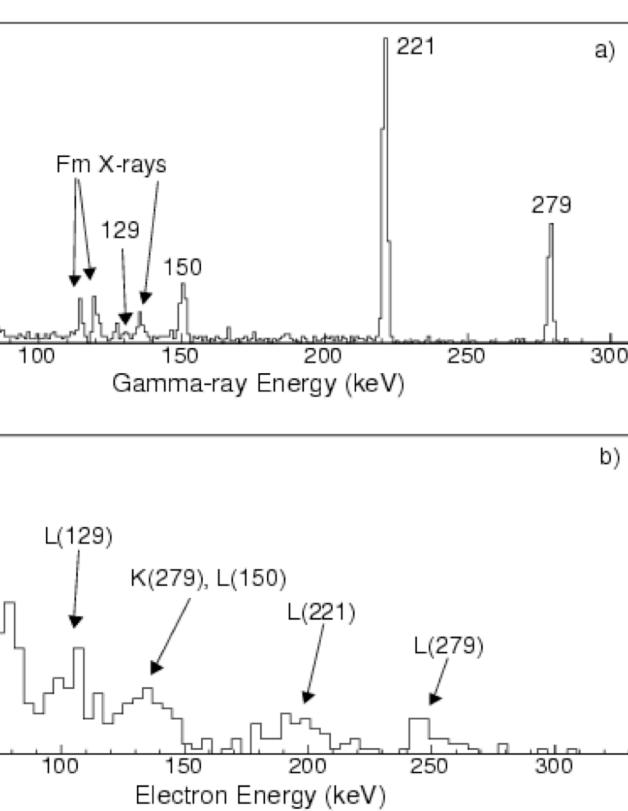


		<b>104Rf</b>			Rf253	<b>Rf254</b>	Rf255	Rf256	Rf257	Rf258	Rf259	Rf260	
		105Lr			Lr252	Lr253	Lr254	<b>Lr255</b>	Lr256	Lr257	Lr258	Lr259	
	<b>102No</b>				No250	No251	No252	<b>No253</b>	No254	No255	No256	<b>No257</b>	No258
	<b>101Md</b>	Md245	Md246	Md247	Md248	Md249	Md250	<b>Md251</b>	Md252	Md253	Md254	Md255	Md256
<b>100Fm</b>	Fm242	Fm243	Fm244	Fm245	Fm246	Fm247	<b>Fm248</b>	<b>Fm249</b>	Fm250	<b>Fm251</b>	Fm252	<b>Fm253</b>	Fm254

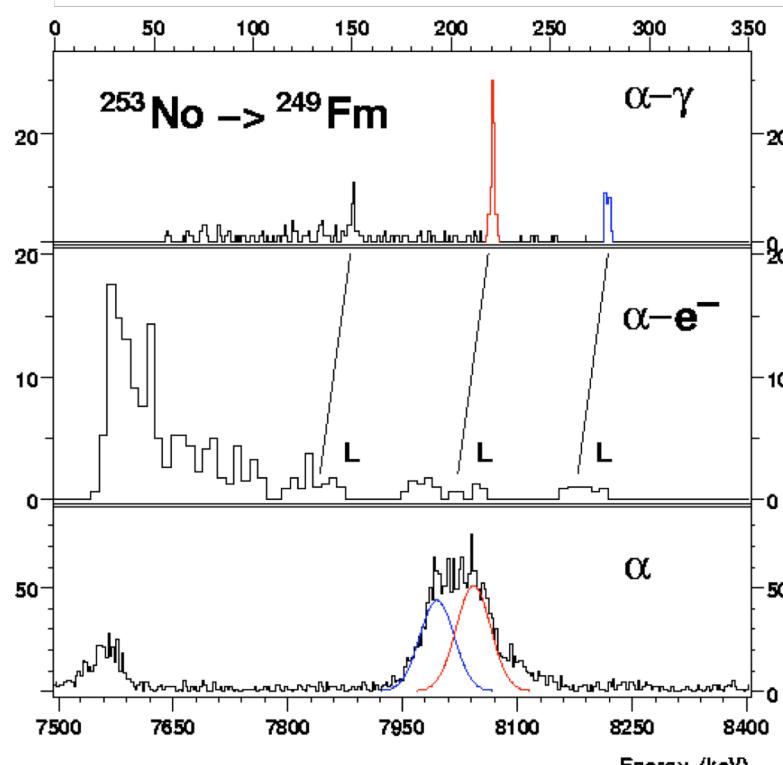
ja, in preparation

Preparation		$^{93}\text{Np}$							$\text{Np}^{224}$	$\text{Np}^{225}$	$\text{Np}^{226}$	$\text{Np}^{226}$	$\text{Np}^{227}$	$\text{Np}^{228}$	$\text{Np}^{229}$
$^{92}\text{U}$	U217	U218	U219	U220	U221	U222	U223	U224	U225	U226	U227	U228	U229		
$^{91}\text{Pa}$	Pa215	Pa216	Pa217	Pa218	Pa219	Pa220	Pa221	Pa222	Pa223	Pa224	Pa225	Pa226	Pa227	Pa228	
$^{90}\text{Th}$	Th213	Th214	Th215	Th216	Th217	Th218	Th219	Th220	Th221	Th222	Th223	Th224	Th225	Th226	Th227

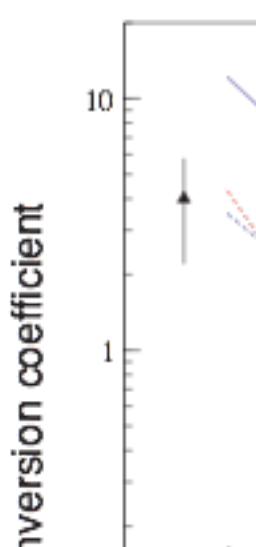
This work



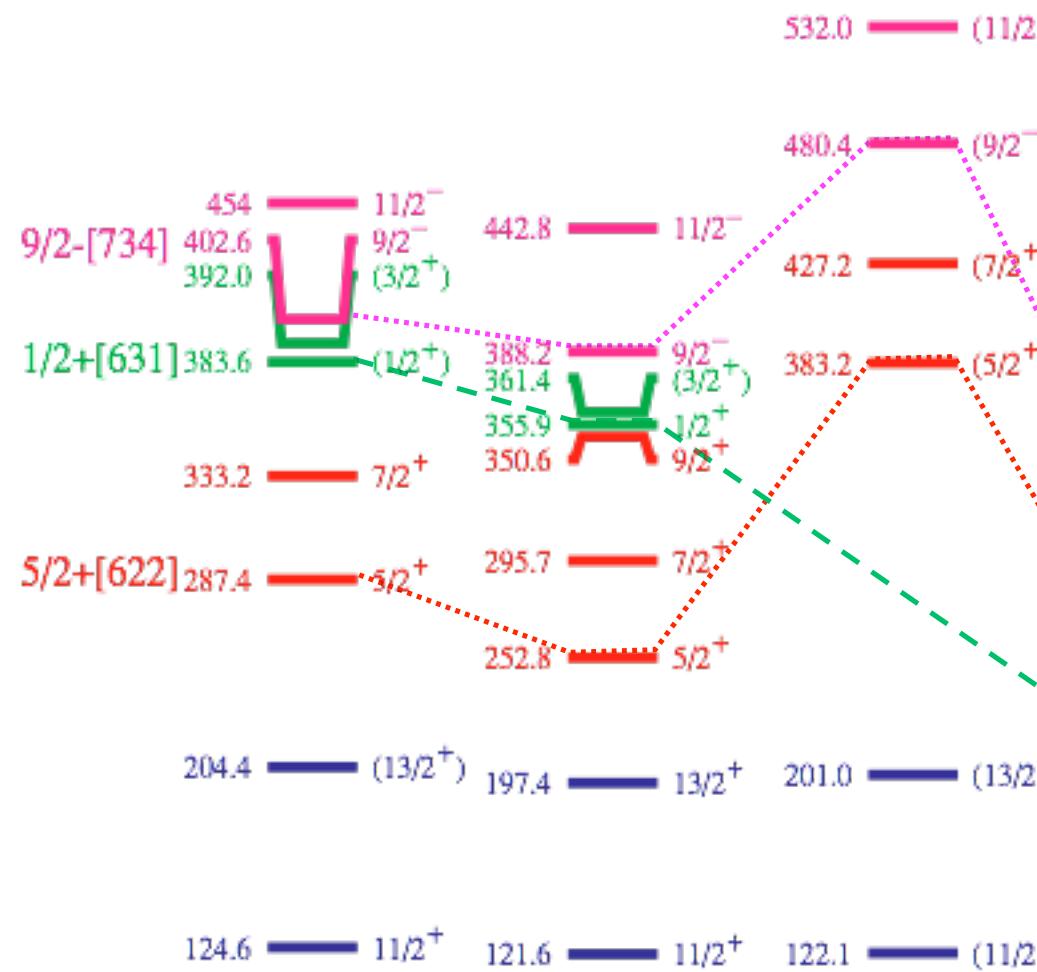
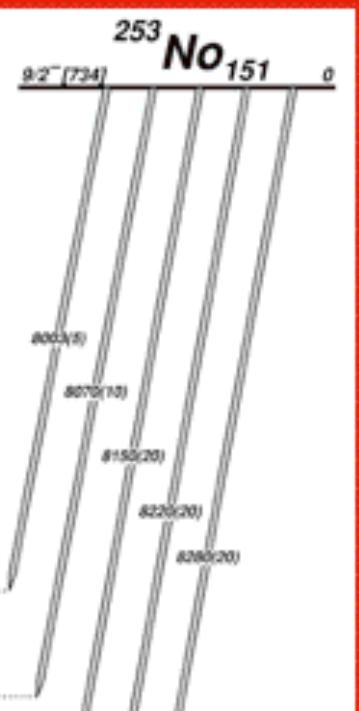
R-D. Herzberg et al.,  
J. Phys G30 R123 (2004)



2  
0.7 p  
10500

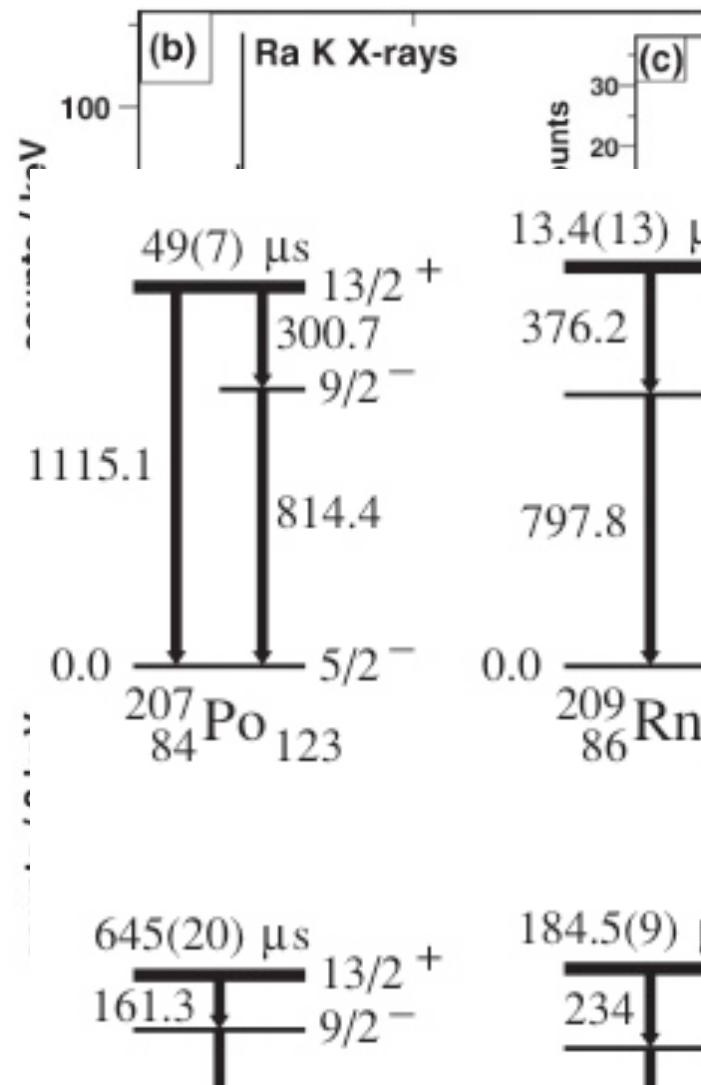


Hoerger et al., EPJ A22 (2004) 417  
 Herzberg et al., J. Phys G30 R123 (2004)  
 work



$^{209}\text{Ar}$ , 5n)  $^{209}\text{Ra}$   
 MeV beam energy with  
 intensity of 0.6 p $\mu$ A  
 alphas of  $^{209,210}\text{Ra}$

New isomer observed in  $^{209}\text{Ra}$   
 Measured to be 117(5)  $\mu$ s  
 $^{209}\text{Ra}^m$  state assigned to  
 $+v(i13/2)-1$  excitation.

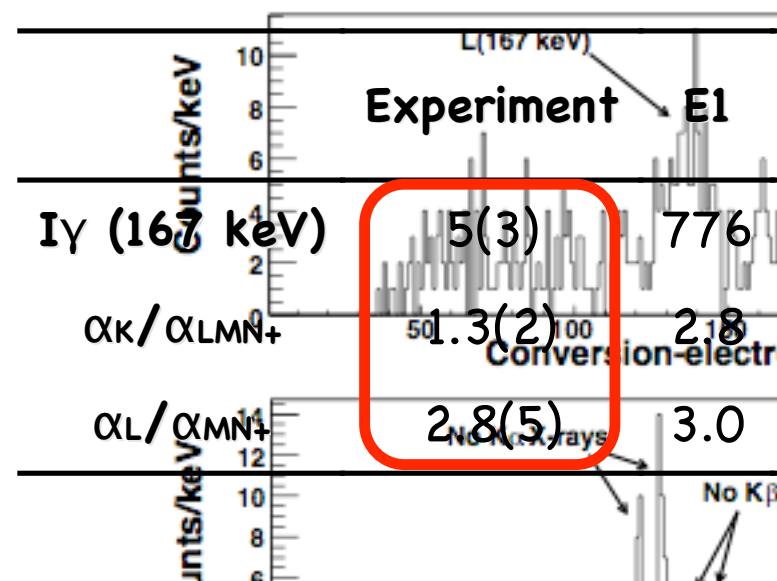
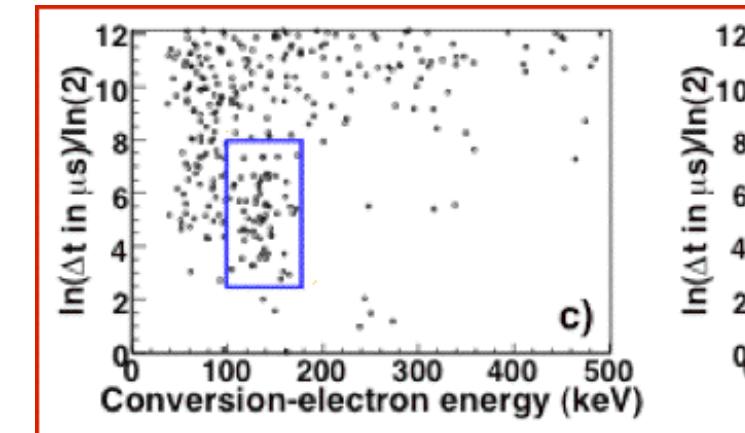


A. Lopez-Martens et al., EPJ A32 (2007) 245

$^{48}\text{Ca}, 2n)$   $^{253}\text{No}$   
 MeV beam energy with  
 intensity of 0.7 p $\mu\text{A}$   
 and alphas of  $^{253,254}\text{No}$

Lifetime Measurement

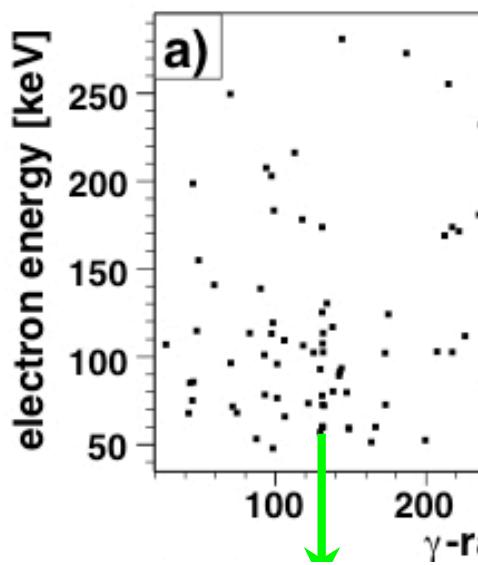
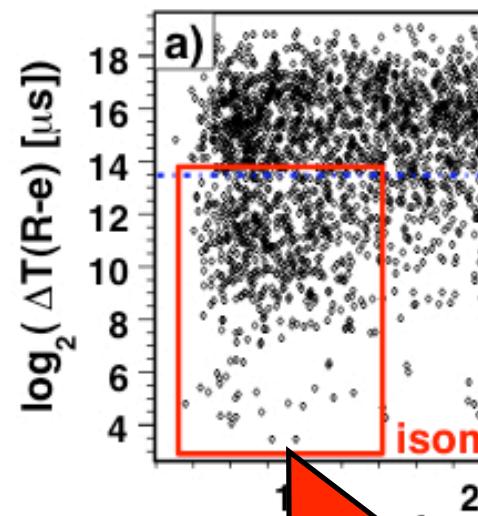
1/2+ [6201]



K. Hauschild et al., submitted

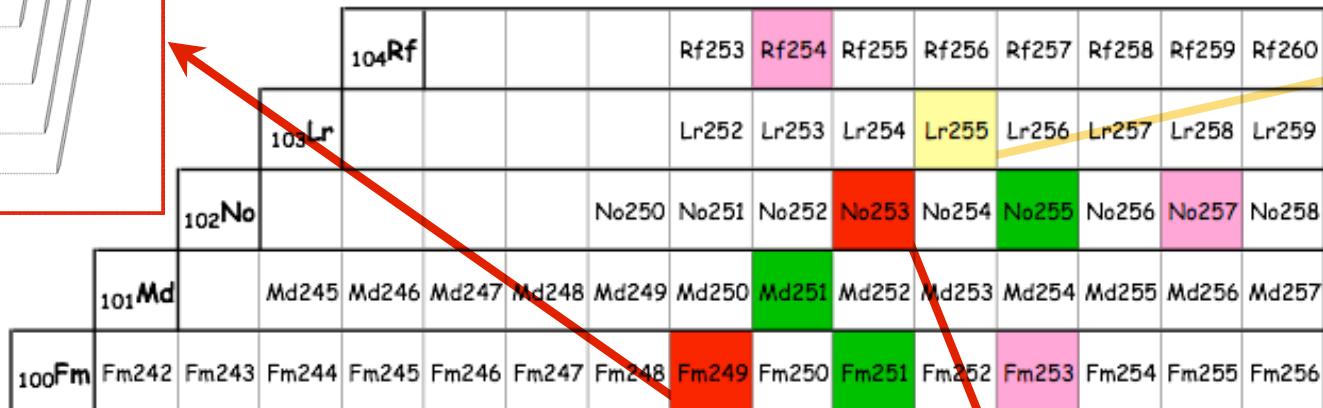
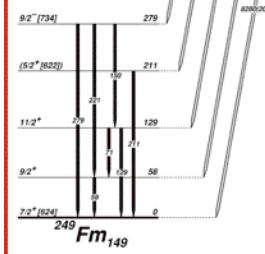
$(^{48}\text{Ca}, 2n)$   $^{255}\text{Lr}$   
MeV beam energy with  
intensity of 0.7 p $\mu$ A

New isomer observed in  $^{255}\text{Lr}$  of 1.4 ms  
lower limit @ 720 keV (assuming LM  
conversion)  
with K-isomer 3qp states but not enough  
spectroscopic information

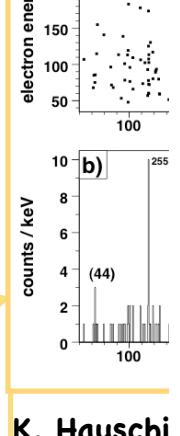


# **QABRILLA Summary**

A. Lopez-Martens et al., PRC 74 (2006) 044303



K. Hauschi



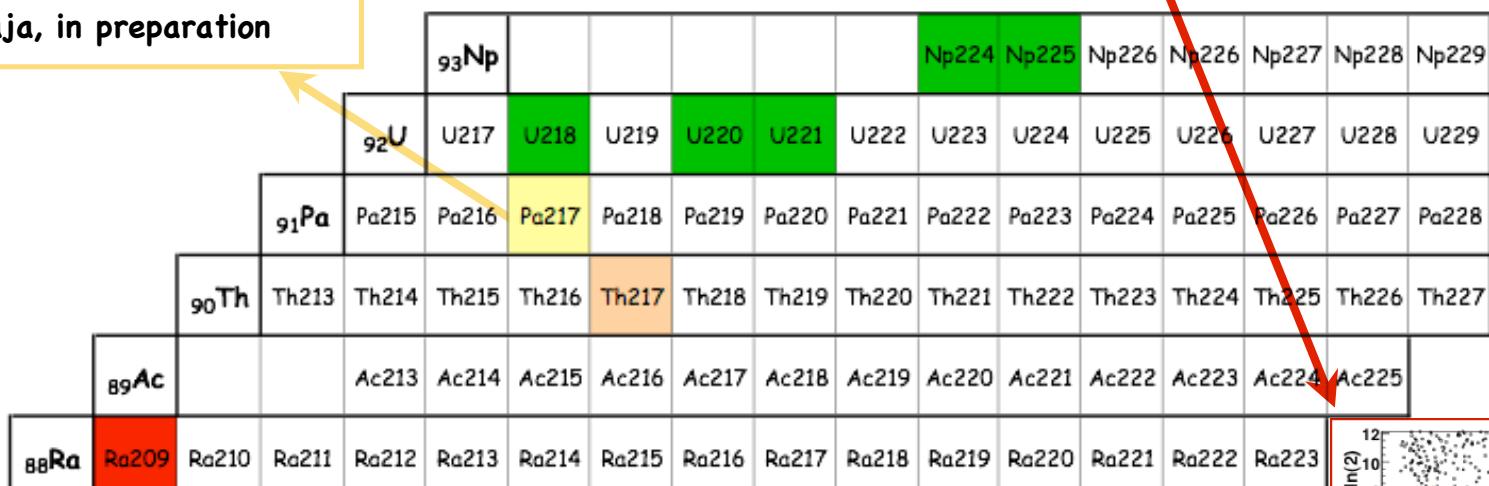
Pub

In |

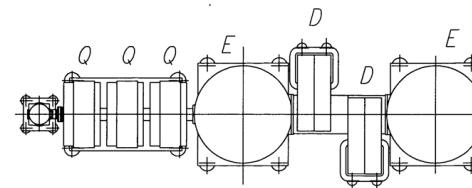
In |

Fail

A. Khouaja, in preparation



## mass separator (see A. POPEKO's talk)



Dedicated to Transfermium spectroscopy elements using radioacti  
Need test efficiency for lighter beams ( $^{18}O$ ,  $^{12}C$ , ...)  
Estimated transmission efficiency for asymmetric reactions using ac  
such as  $^{22}\text{Ne} + ^{238}\text{U}$ : >5% (instead of 1%)  
Optimization for symmetric reactions such as  $\text{Xe} + \text{Xe}$

A

sensitivity to low energy EC (new amplifiers/digital electronics)

~ 1 mm thick electron Si detectors

Si implantation detector - DECD

## IPN/IN2P3, Strasbourg, France

J. Devaux, A. Khouaja, D. Curien, B. Gall, F. Khalfallah, J. Piot, M. Rousseau, N. Stuttge

## IPN/IN2P3, Orsay, France

A. Lopez-Martens, K. Hauschild, Ch. Briançon, P. Désesquelles, A. Korichi ... and others

## JINR, Dubna, Russia

V. Beremin, A.V. Belozerov, M.L. Chelnokov, V.I. Chepigin, V.A. Gorshkov, A.P. Kostyuk, Yu. Ts. Oganessian, A.G. Popeko, R.N. Sagaidak, A.V. Shutov, A.I. Svirikhii

## University, Norway

H. Form森, A.C. Larsen, S. Siem, N.U.H. Syed

## IFIN-HH, Bucharest, Romania

D. Pantelica, R. Borcea, V. Zaitsev

