

# Nuclear Structure Studies of Transfermium Isotopes

Steffen Ketelhut

Department of Physics  
University of Jyväskylä

EGP Workshop 2008  
Paris, May 27th-30th 2008

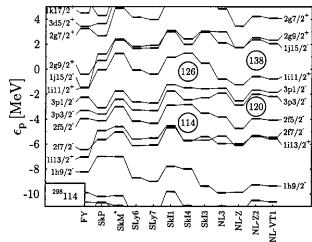
# Outline

- 1 The Heaviest Elements
- 2 Experimental Tools
- 3 Experimental Results
  - In-beam  $\gamma$ -ray Spectroscopy
  - High-K Isomer
- 4 Outlook

# Outline

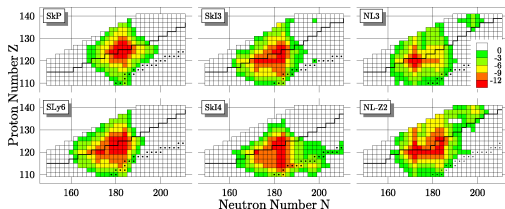
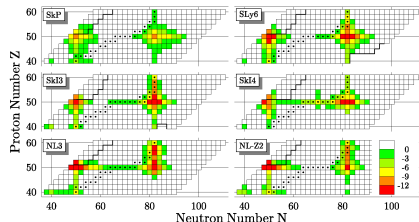
- 1 The Heaviest Elements
- 2 Experimental Tools
- 3 Experimental Results
  - In-beam  $\gamma$ -ray Spectroscopy
  - High-K Isomer
- 4 Outlook

# The Next Doubly-Magic Nucleus

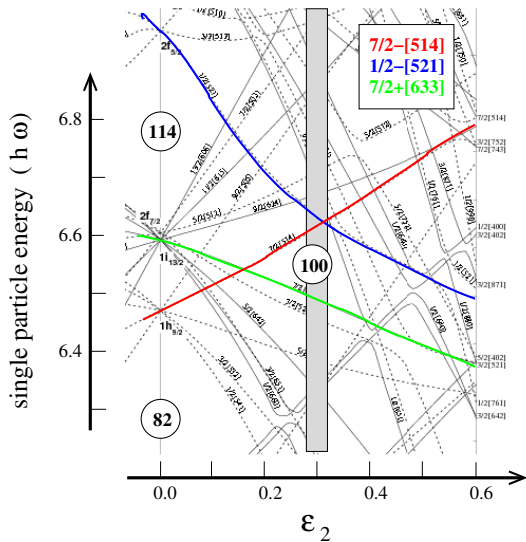


M. Bender *et al.*, PRC60, 034304 (1999)

- High density of states.
- Broad regions of shell effects.
- Different models/parametrisations.
- Different shell gaps.



M. Bender, W. Nazarewicz, P.-G. Reinhard, PLB 515, 42 (2001)

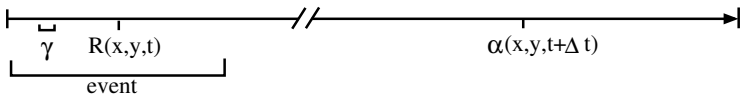
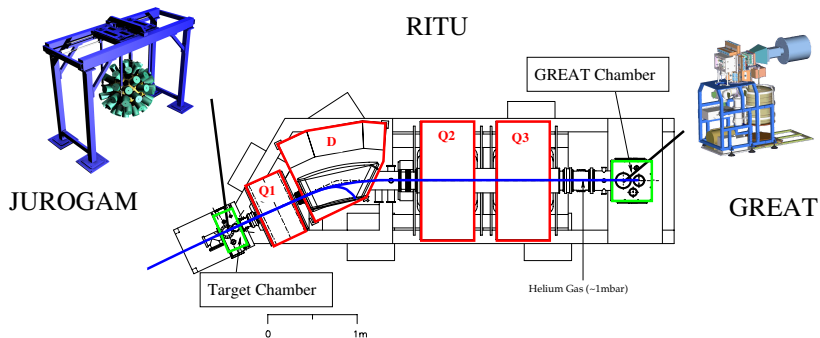
The Region Around  $^{254}\text{No}$ 

- Cross section  $\simeq \mu\text{b}$ .
- Deformed shell gap - higher stability.
- Direct link to the spherical shell gap.

# Outline

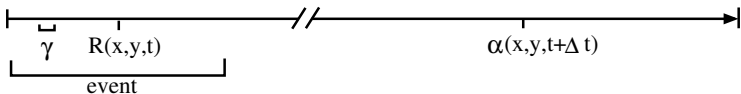
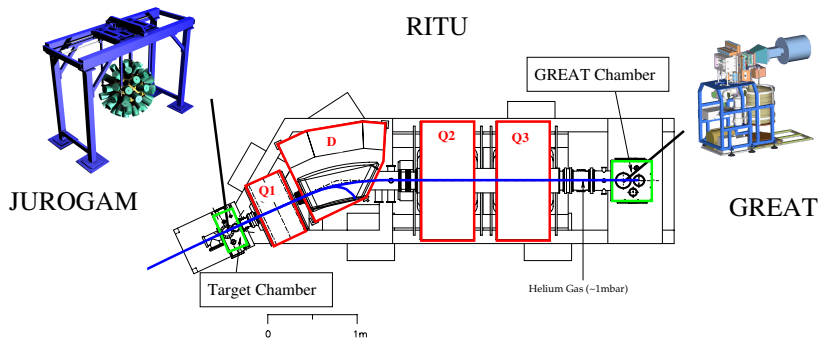
- 1 The Heaviest Elements
- 2 Experimental Tools**
- 3 Experimental Results
  - In-beam  $\gamma$ -ray Spectroscopy
  - High-K Isomer
- 4 Outlook

# Recoil-Decay Tagging



# Recoil-Decay Tagging

$^{209}\text{Bi}(^{48}\text{Ca},2n)^{255}\text{Lr}$ :  $\sigma=200\text{nb}$   $\leftrightarrow$  Ge rate  $\simeq 400\,000\text{Hz}$ , 5 alphas/hour!



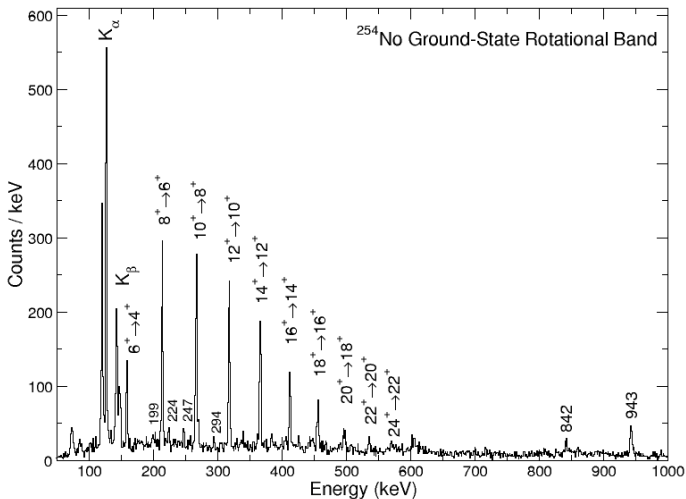


# Outline

- 1 The Heaviest Elements
- 2 Experimental Tools
- 3 Experimental Results**
  - In-beam  $\gamma$ -ray Spectroscopy
  - High-K Isomer
- 4 Outlook

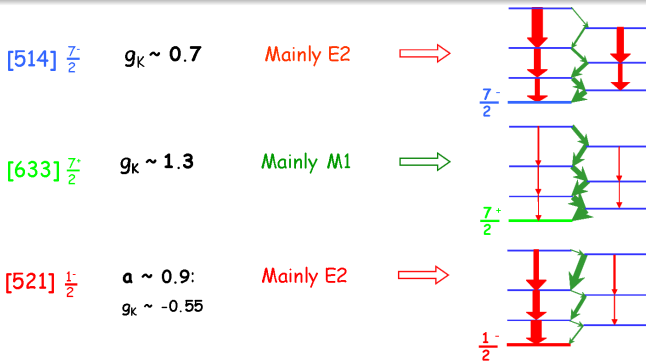
# In-beam $\gamma$ -ray Spectroscopy of $^{254}\text{No}$

Unpublished spectrum, see also S. Eeckhaudt, P.T. Greenlees et al., EPJA **26**, 227 (2005)

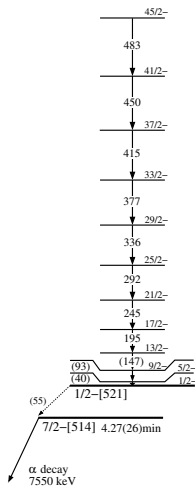
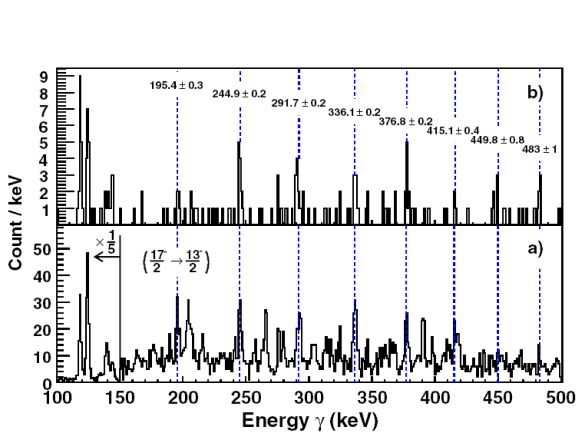


# In-beam Spectroscopy of $^{251}\text{Md}$ and $^{255}\text{Lr}$

- Cross-section  $< 1\mu\text{b}$ , fragmented over several bands.
- Odd-proton orbitals in  $^{251}\text{Md}$  and  $^{255}\text{Lr}$ .
- $B(M1)/B(E2)$  depends on  $(g_K - g_R / Q_0)$ .

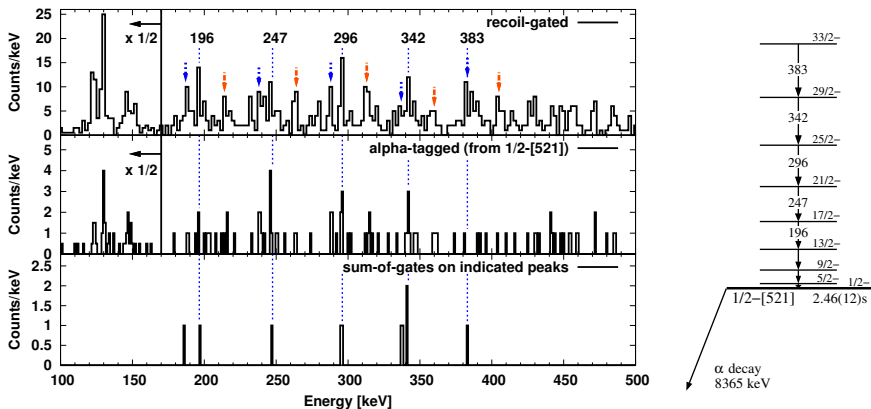


# In-Beam Spectroscopy of $^{251}\text{Md}$



$^{205}\text{Tl}(^{48}\text{Ca}, 2n)^{251}\text{Md}$ ,  $\sigma \simeq 800$ nb, A. Chatillon *et al.*, PRL 98 132503

# In-Beam Spectroscopy of $^{255}\text{Lr}$ - Heaviest Nucleus so far!

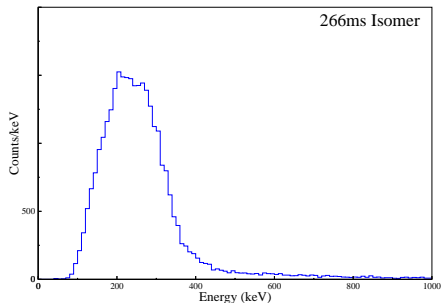


$^{209}\text{Bi}(^{48}\text{Ca}, 2n)^{255}\text{Lr}$ ,  $\sigma \simeq 200\text{nb}$ , P.T. Greenlees *et al.*

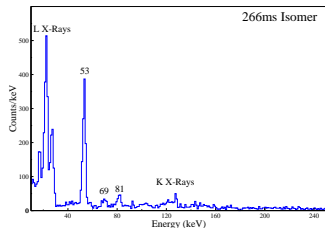
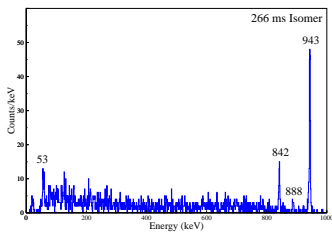
# K-Isomerism in $^{254}\text{No}$

- Study of 2-quasiparticle excitations.
- Postulated first by Ghiorso *et al.* PRC7 (1973) 2032.
- Recoil-electron tagging - method proposed by Jones, NIM A488 (2002) 471.

## Recoil-correlated electrons

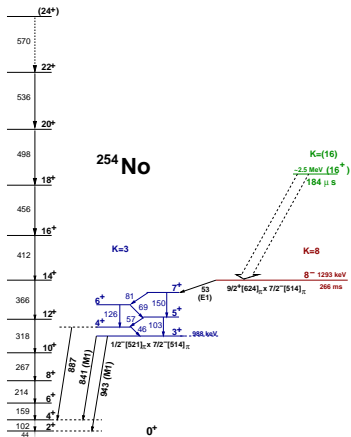


## Clover and Planar spectra



# K-Isomerism in $^{254}\text{No}$

R.-D. Herzberg, P.T. Greenlees et al., Nature **442**, 896-899 (2006)



## Configurations

Intermediate state:

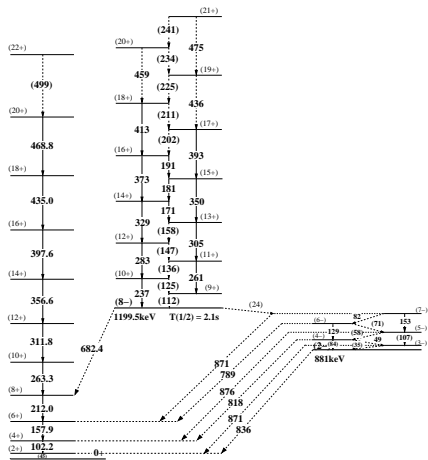
$3^+ - p[514]7/2^- \otimes p[521]1/2^-$

Slow K-Isomer:

$8^- - p[514]7/2^- \otimes p[624]9/2^+$

# K-Isomerism in $^{250}\text{Fm}$

$^{204}\text{Hg}(^{48}\text{Ca},2n)^{250}\text{Fm}$ , P.T. Greenlees *et al.*, to be published



## Configurations

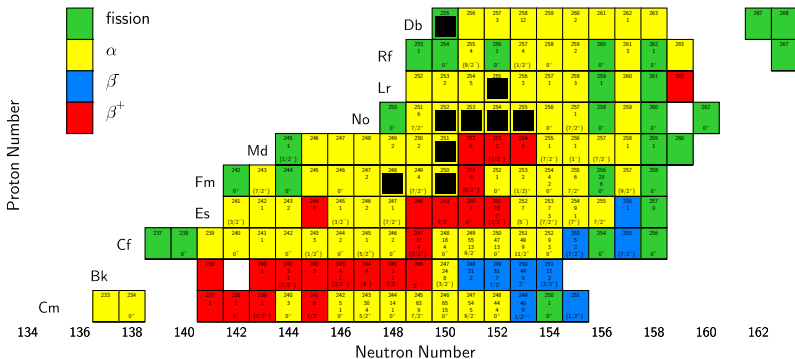
$2^-$  - octupole intermediate state

Slow K-Isomer:

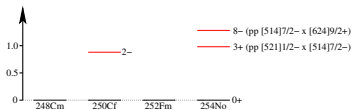
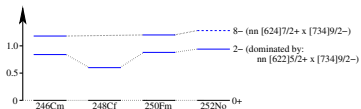
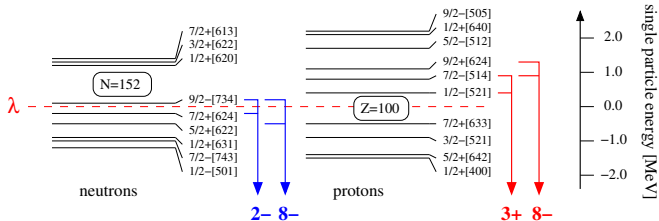
$8^- - n[734]9/2^- \otimes n[622]5/2^+$



# Nuclei Studied in Jyväskylä



# 2-Quasiparticle Excitation and Systematics



N=150 and N=152

- Proton states for  $^{254}\text{No}$ , neutron states for  $^{250}\text{Fm}$ .
- Isomer in  $^{252}\text{No}$  (GSI/Germany) and  $^{248}\text{Fm}$  (JYFL).
- No indication of isomer in  $^{246}\text{Fm}$  (GSI/Germany).
- Experiments on  $^{256}\text{Rf}$  (LBL, ANL/USA).

# Outline

- 1 The Heaviest Elements
- 2 Experimental Tools
- 3 Experimental Results
  - In-beam  $\gamma$ -ray Spectroscopy
  - High-K Isomer
- 4 Outlook

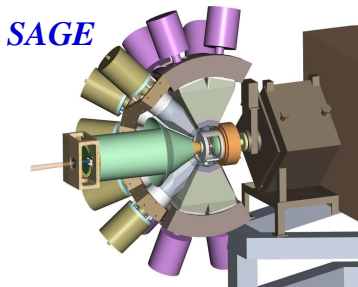
# Future Plans (End 2008/Beginning 2009)

## SAGE and JUROGAMII

- SAGE: Simultaneous measurement of conversion electrons and gamma rays.
- JUROGAMII: Combination of Clover and PhaseI detectors.
- Equipped with digital electronics.

## Physics cases

- Towards even heavier nuclei:  $^{256}\text{Rf}$  (12nb!)
- Extend knowledge about e.g.  $^{251}\text{Md}$ ,  $^{255}\text{Lr}$ ,  $^{248}\text{Fm}$
- Many new cases, e.g.  $^{255}\text{No}$ ,  $^{249}\text{Md}$



# Collaborating Institutes

Institutes Collaborating in JYFL Experiments:



UNIVERSITY OF JYVÄSKYLÄ



THE UNIVERSITY  
of LIVERPOOL



CCLRC



HELSINGIN YLIOPISTO



ISOLDE  
CERN

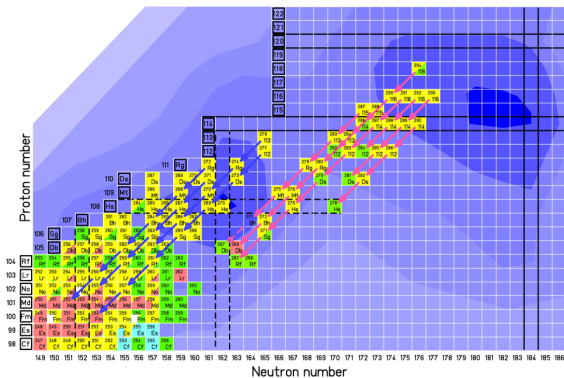


Institut de  
Recherches Subatomiques  
STRASBOURG

# Outline

## 5 Additional Material

# Experimental Approach



S. Hofmann, Nucl. Phys. News. Intl.

- Low production cross section - level of  $\simeq$  pb.
- Half life and alpha energy.
- Branching ratio and production cross section.
- Isomers prevalent.
- In-beam spectroscopy impossible.