



JO 150 VUOTTA  
TULEVAISUUDESSA

# HISPEC/DESPEC – a Finnish perspective

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NUSTAR week – Helsinki, 7-11 October 2013

# Outline

- Experimental nuclear structure physics in Finland
  - JYFL-ACCLAB
- (PreSPEC) HISPEC/DESPEC
- HISPEC/DESPEC vs. experimental nuclear physics in Finland

# Experimental nuclear structure physics in Finland

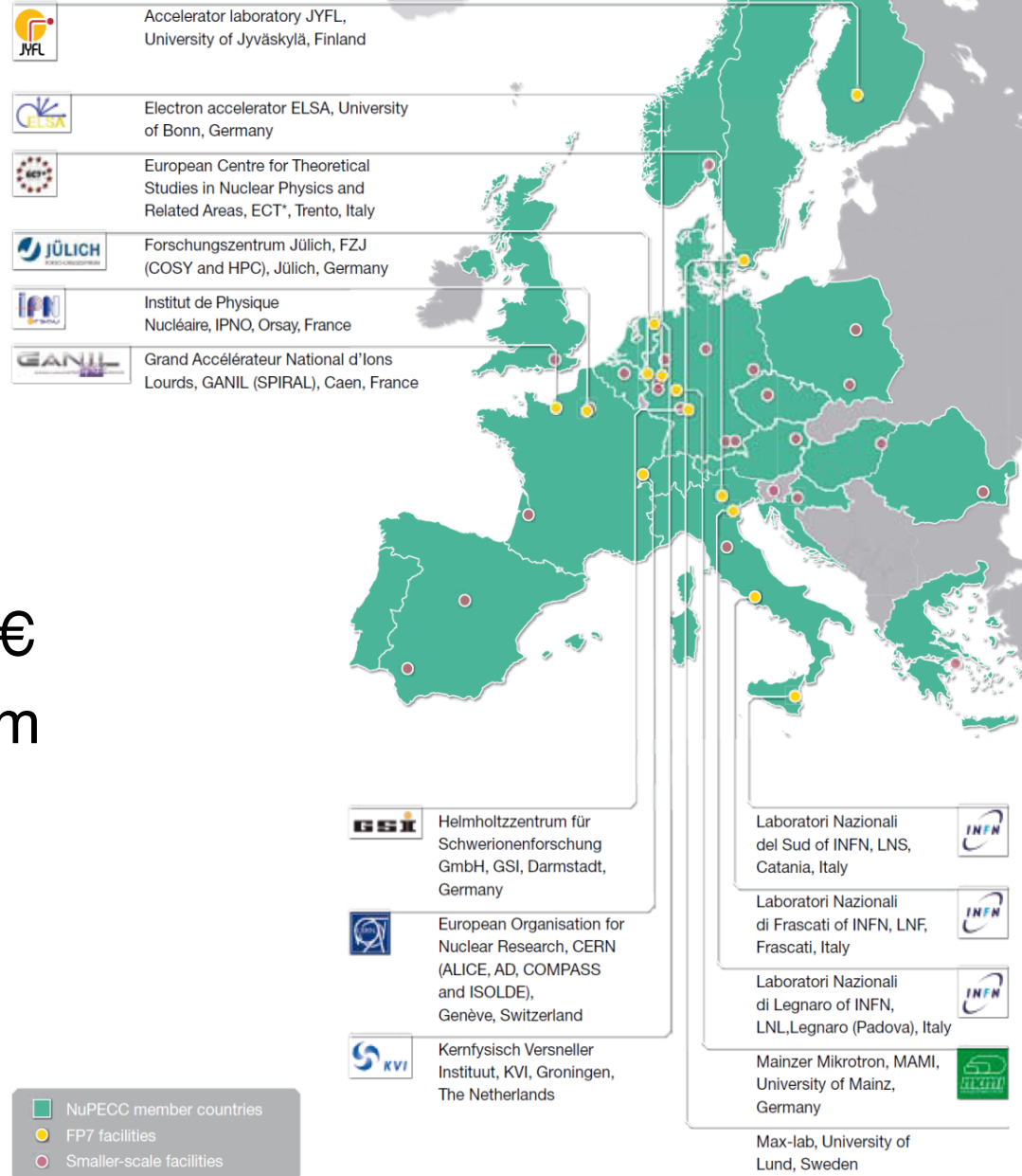
**Accelerator Laboratory, Department of Physics, University of Jyväskylä (JYFL-ACCLAB):** Centre of Excellence of the Academy of Finland since 2000

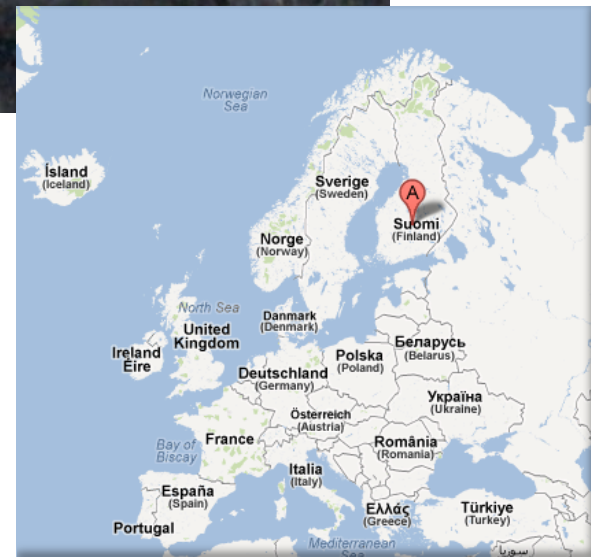
- Accelerator technology
- Rare isotope beam science (IGISOL)
- Nuclear structure at the limits (RITU+JUROGAM)
- Nuclear reactions
- Accelerator based material physics (PELLETRON)
- Industrial applications (RADEF)
- Nuclear theory

# JYFL-ACCLAB

- One of the leading stable-ion beam facilities in the world
- International infrastructure in Finland – over 200 users a year, foreign investments of 10 M€
- > 6000 hours of beam time annually

## NuPECC Long Range plan 2010



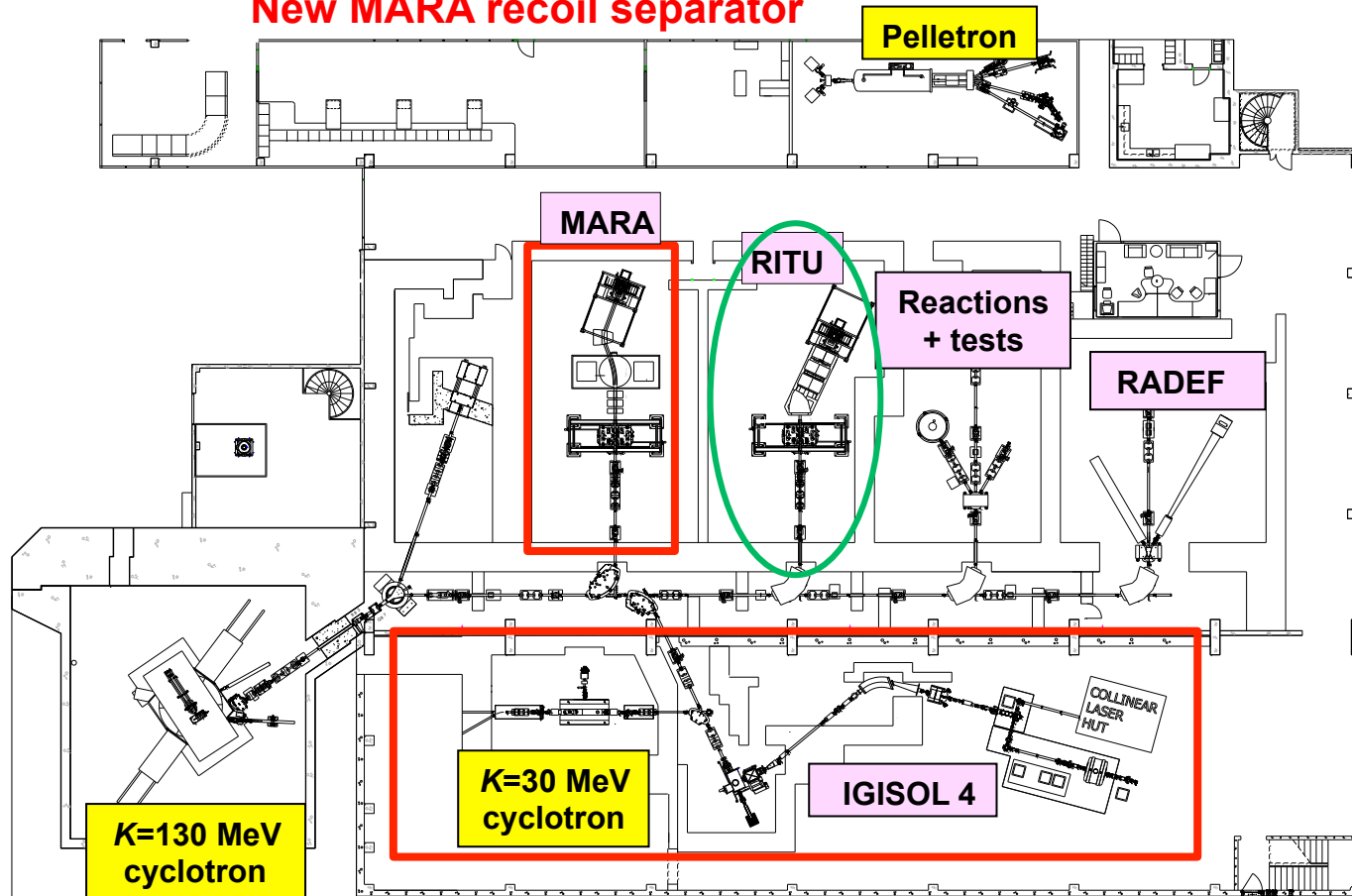


# Upgrade of JYFL-ACCLAB

New  $K=30$  MeV light-ion cyclotron

New IGISOL 4

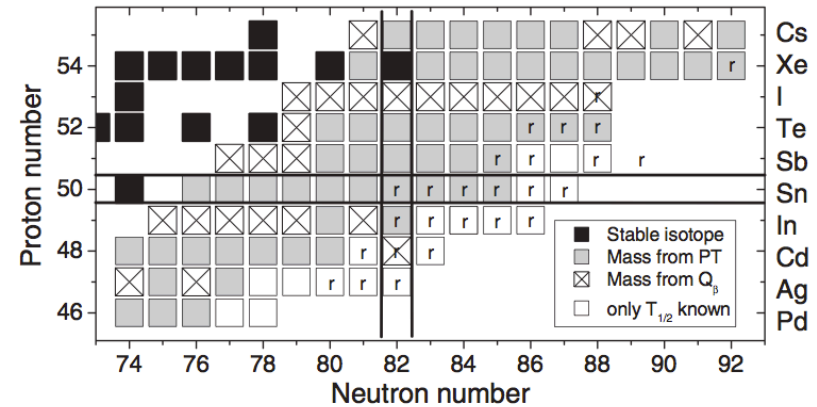
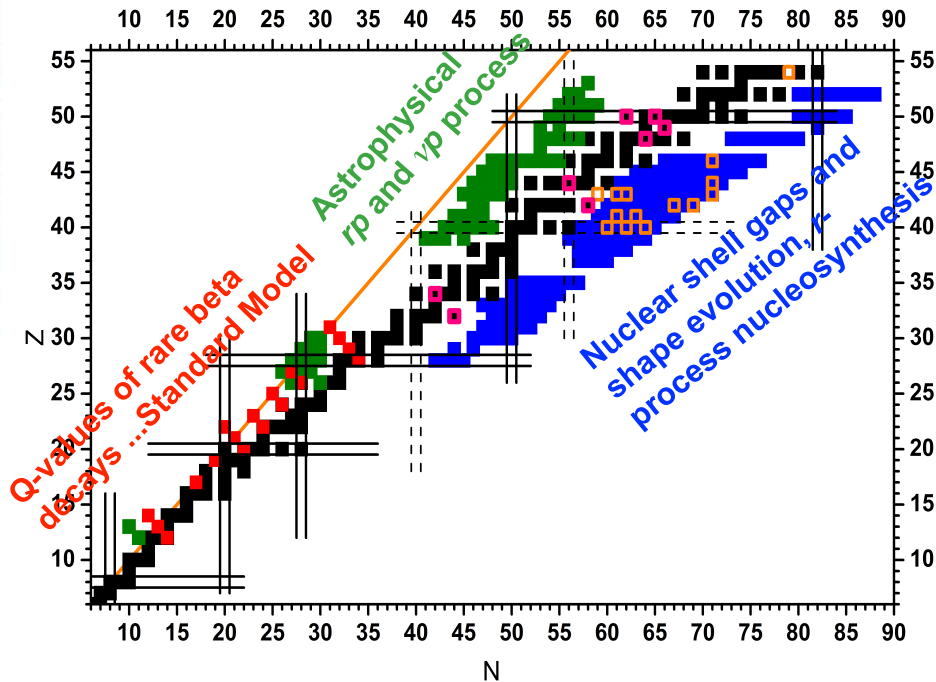
New MARA recoil separator



Three accelerators → More beam time for long experiments and beam developments

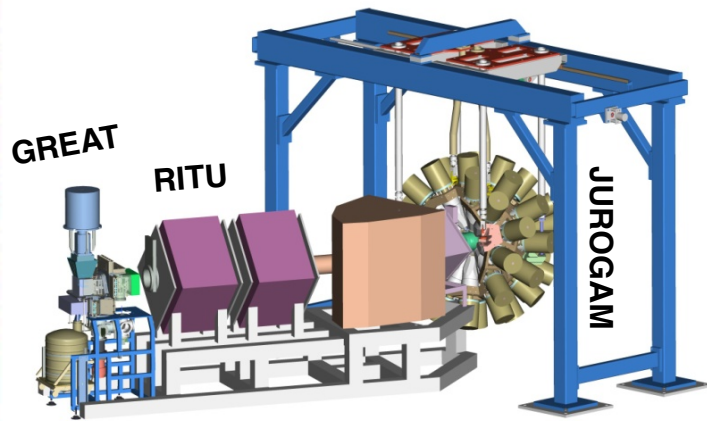
# Rare Isotope Science (IGISOL)

- IGISOL ion guide + laser spectroscopy + Penning trap + decay spectroscopy
- Leader in precision measurements of ground-state properties of rare isotopes

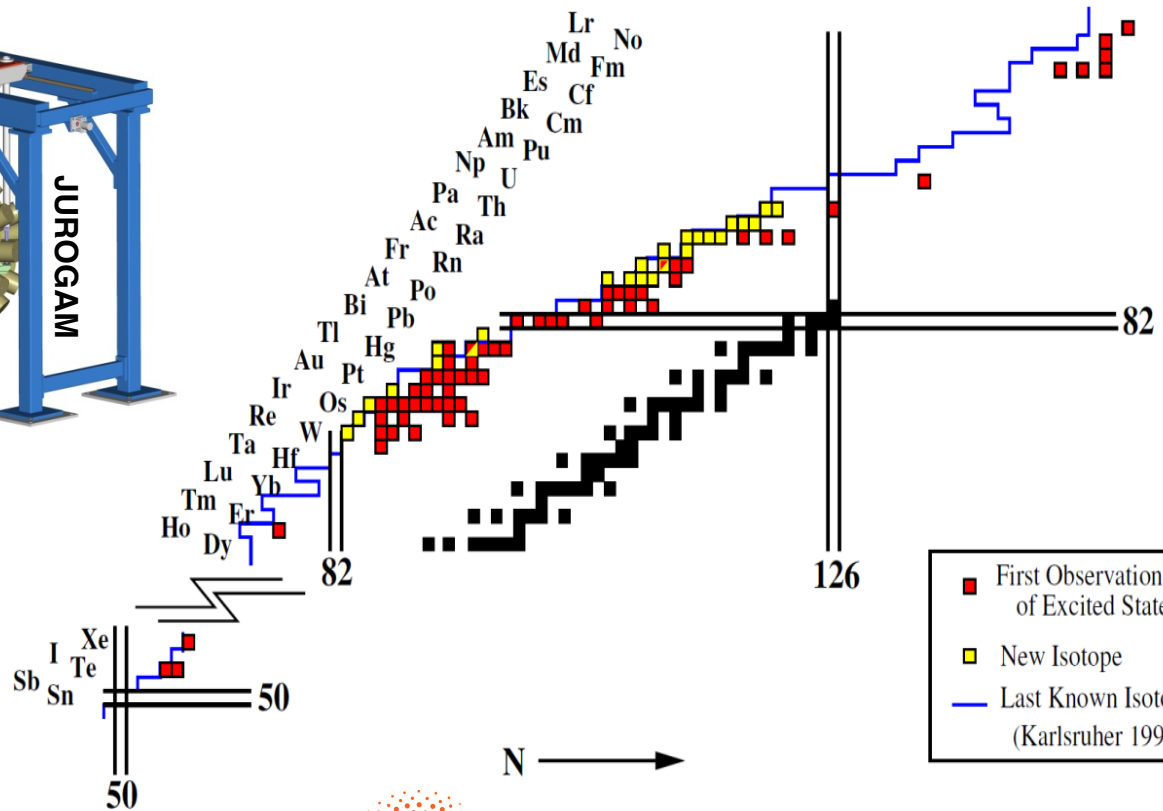


J. Hakala et al., PRL 109, 032501 (2012)

# Nuclear structure at the limits (RITU + JUROGAM)



Leader in nuclear structure studies of super-heavy and heavy proton-drip-line nuclei



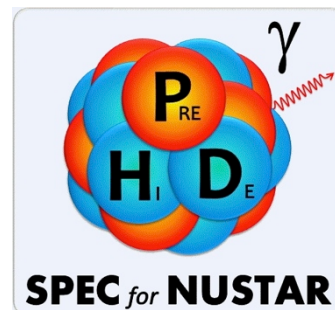
**nature** LETTERS

**Nuclear isomers in superheavy elements as stepping stones towards the island of stability**



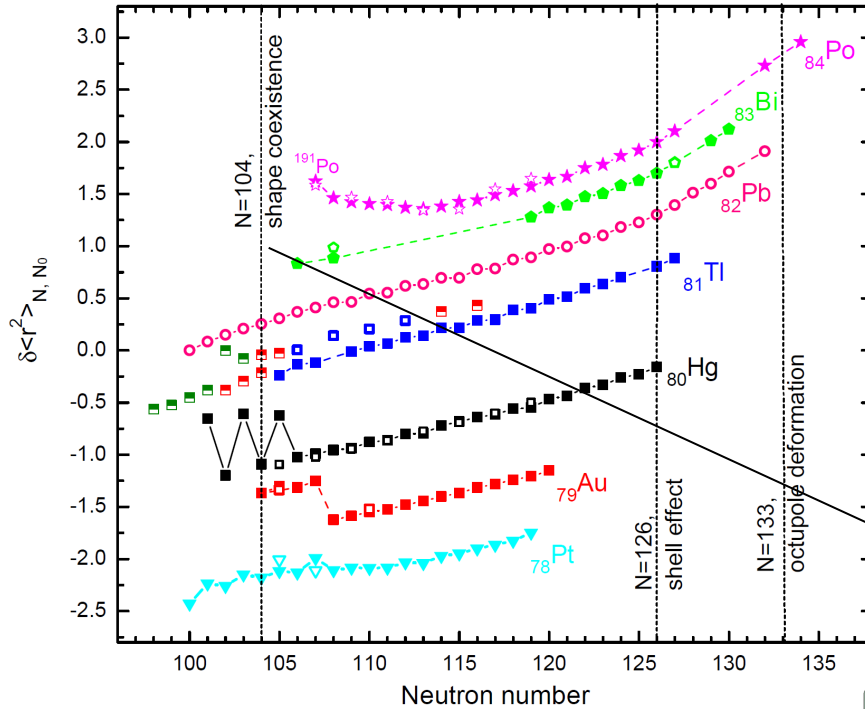
# HISPEC (High-Resolution In-flight SPEctroscopy)/ DESPEC (DEcay SPEctroscopy)

- Nuclear structure, reactions and nuclear astrophysics studies
- Super-FRS beams at 100-300 AMeV
- HISPEC: High-resolution  $\gamma$ -ray spectrometer (AGATA) coupled to particle identification spectrometer (LYCCA)
  - C.f. PreSPEC AGATA
- DESPEC: Highly segmented Si-detector setup to detect radioactivity from stopped ions, surrounded by  $\gamma$ -ray and neutron spectrometers



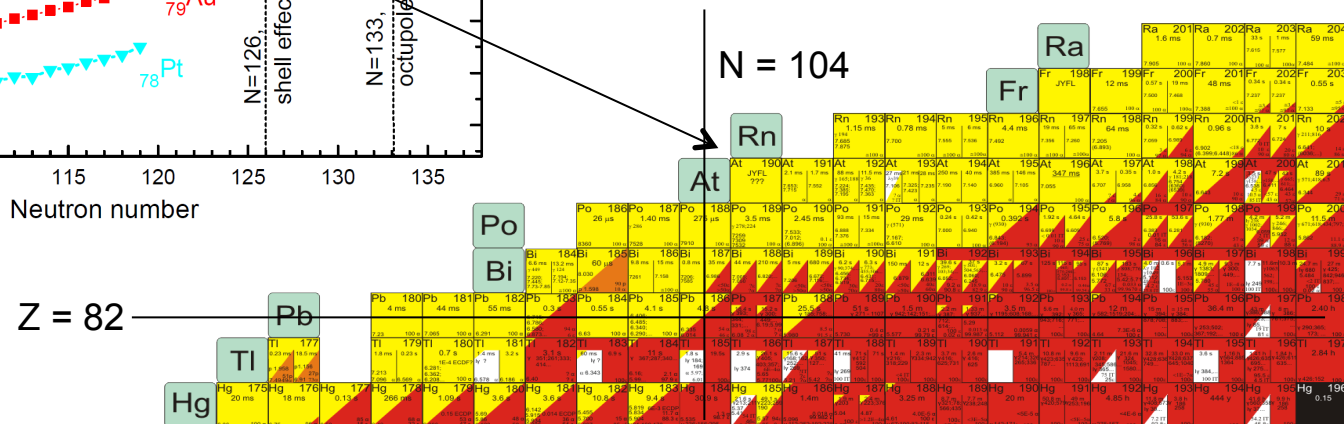
# HISPEC vs. in-beam $\gamma$ -ray spectroscopy at JYFL

## Nuclear structure near closed shells



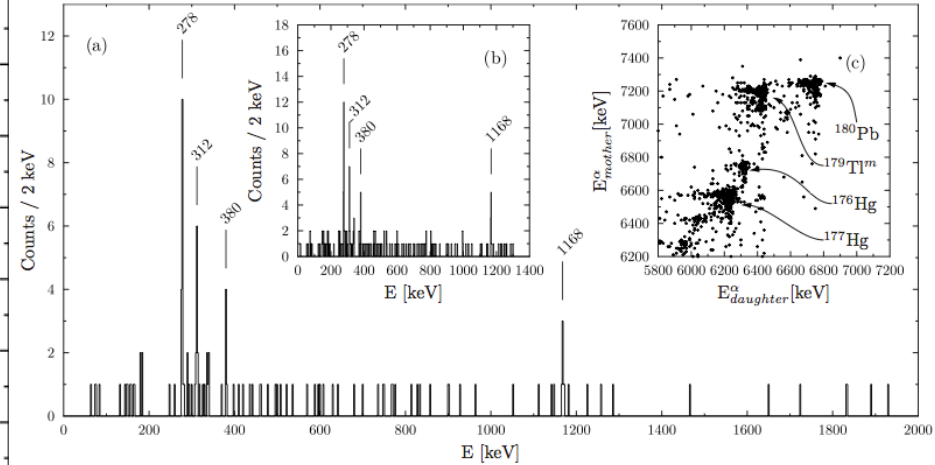
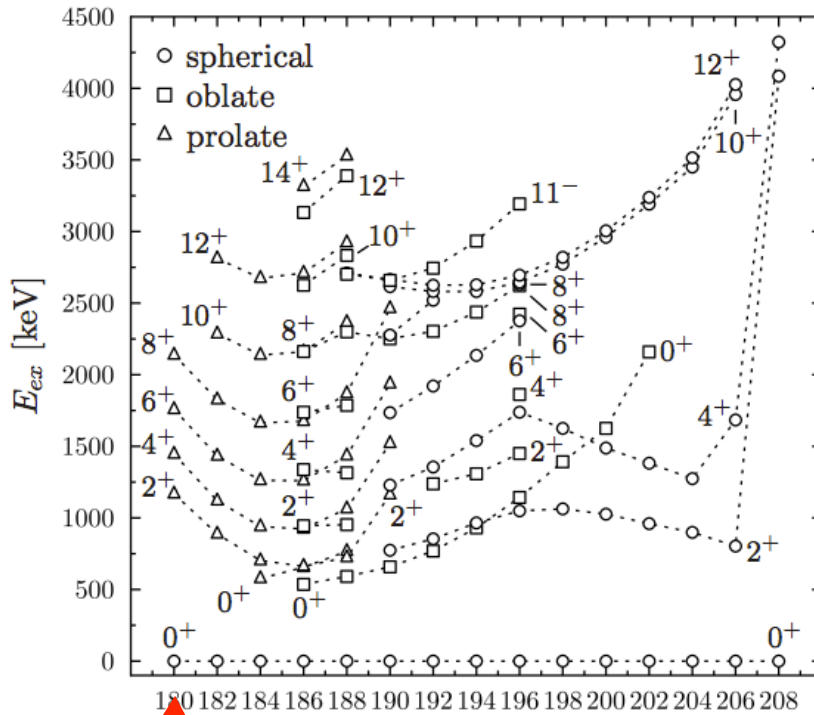
Charge Radii in Pt-Po isotopes from isotope shifts at CERN-ISOLDE

Strong deviations from smooth behaviour near  $Z=82$



# HISPEC vs. in-beam $\gamma$ -ray spectroscopy at JYFL

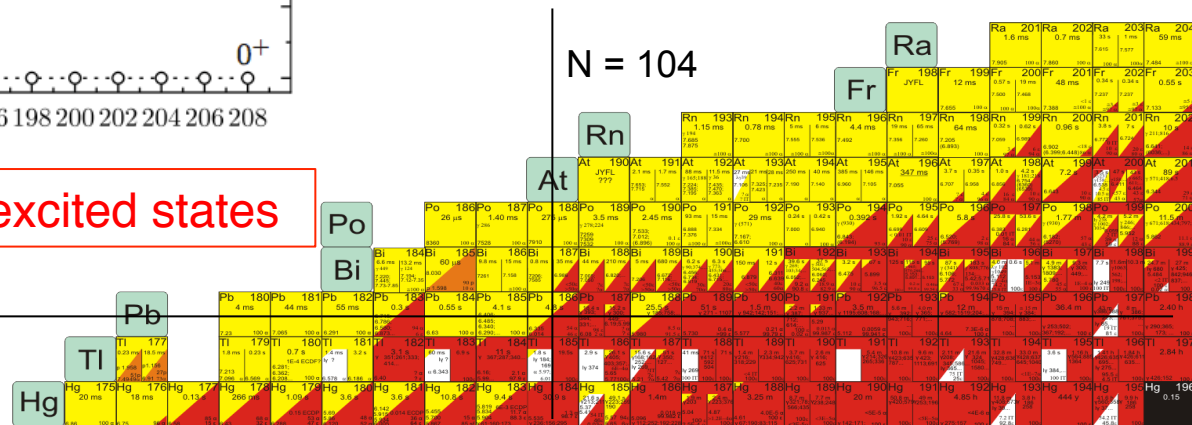
## Nuclear structure near closed shells



$^{180}\text{Pb}$  Proton-unbound excited states

P. Rahkila et al. PRC  
82 (2010) 011303(R)

$Z = 82$

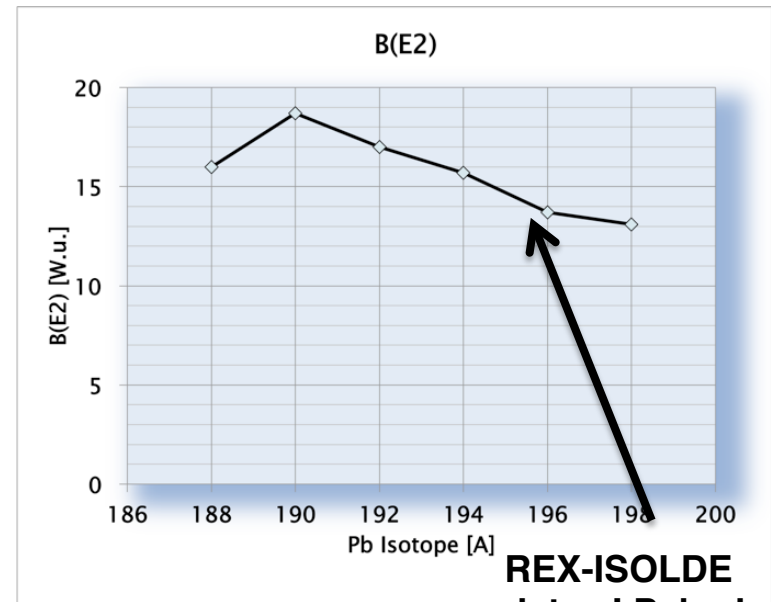
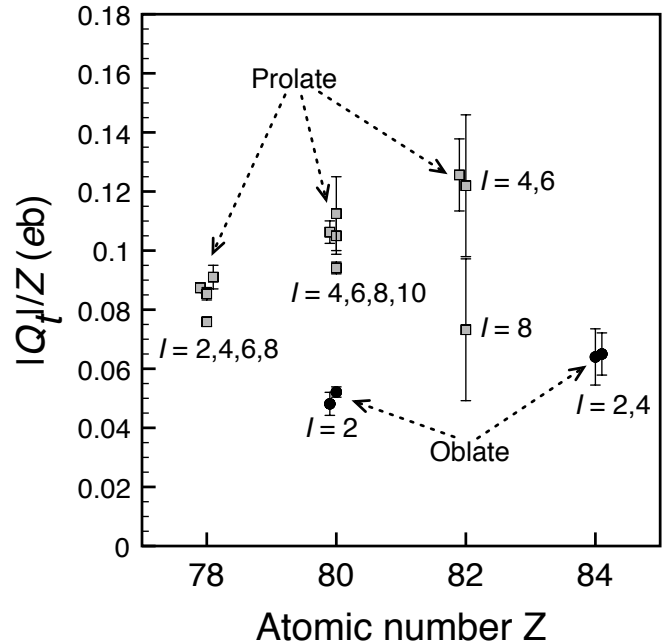


# HISPEC vs. in-beam $\gamma$ -ray spectroscopy at JYFL

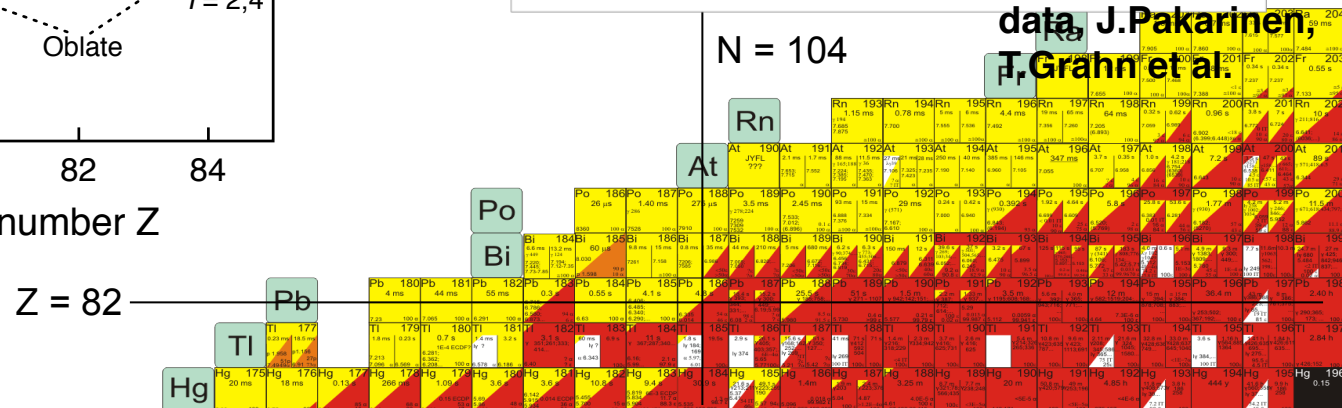
## Nuclear structure near closed shells

Measurements of transition probabilities:

- Doppler-shift methods (plunger)
- Coulomb excitation (REX-ISOLDE)



REX-ISOLDE data, J. Pakarinen, J. Grahn et al.

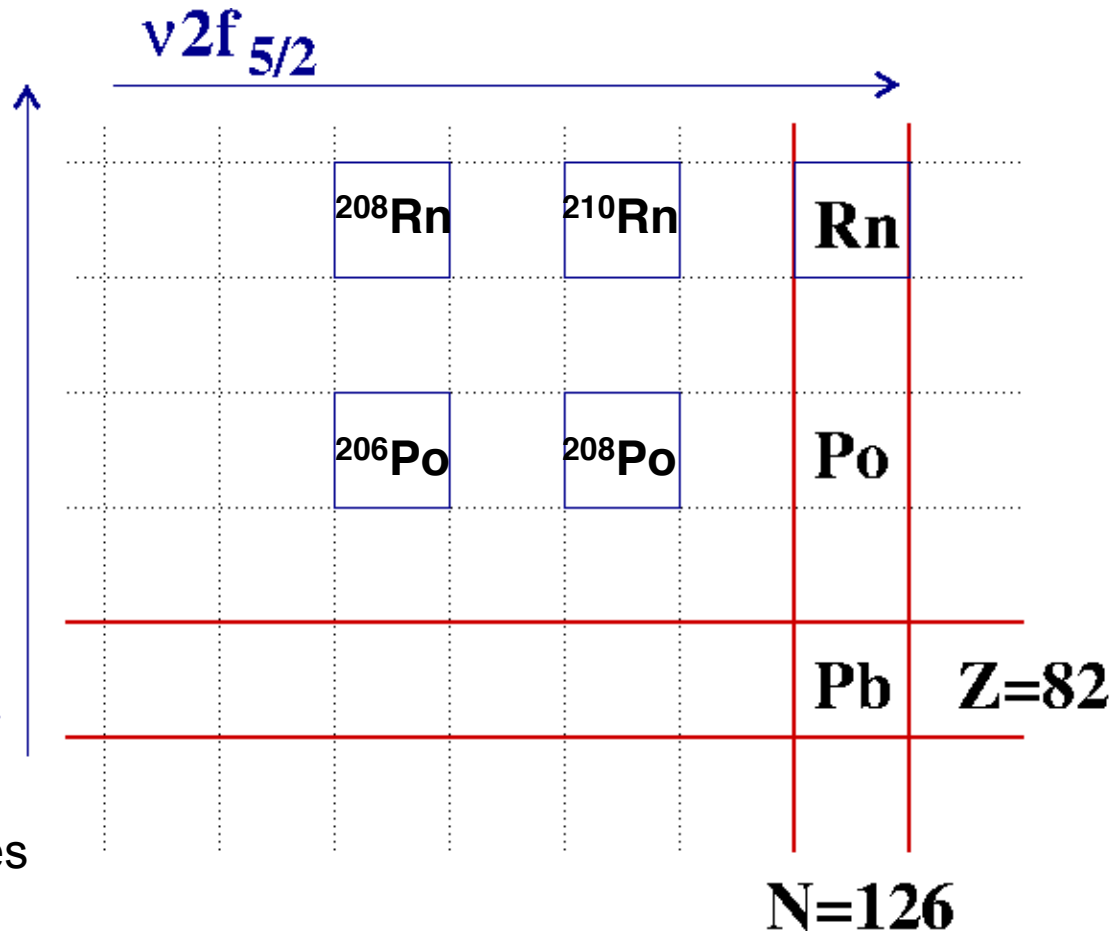


# HISPEC vs. in-beam $\gamma$ -ray spectroscopy at JYFL

## Nuclear structure near closed shells

$B(E2;0^+ \rightarrow 2^+)$  values  
measured  
at REX-ISOLDE

$\pi 1h_{9/2}$

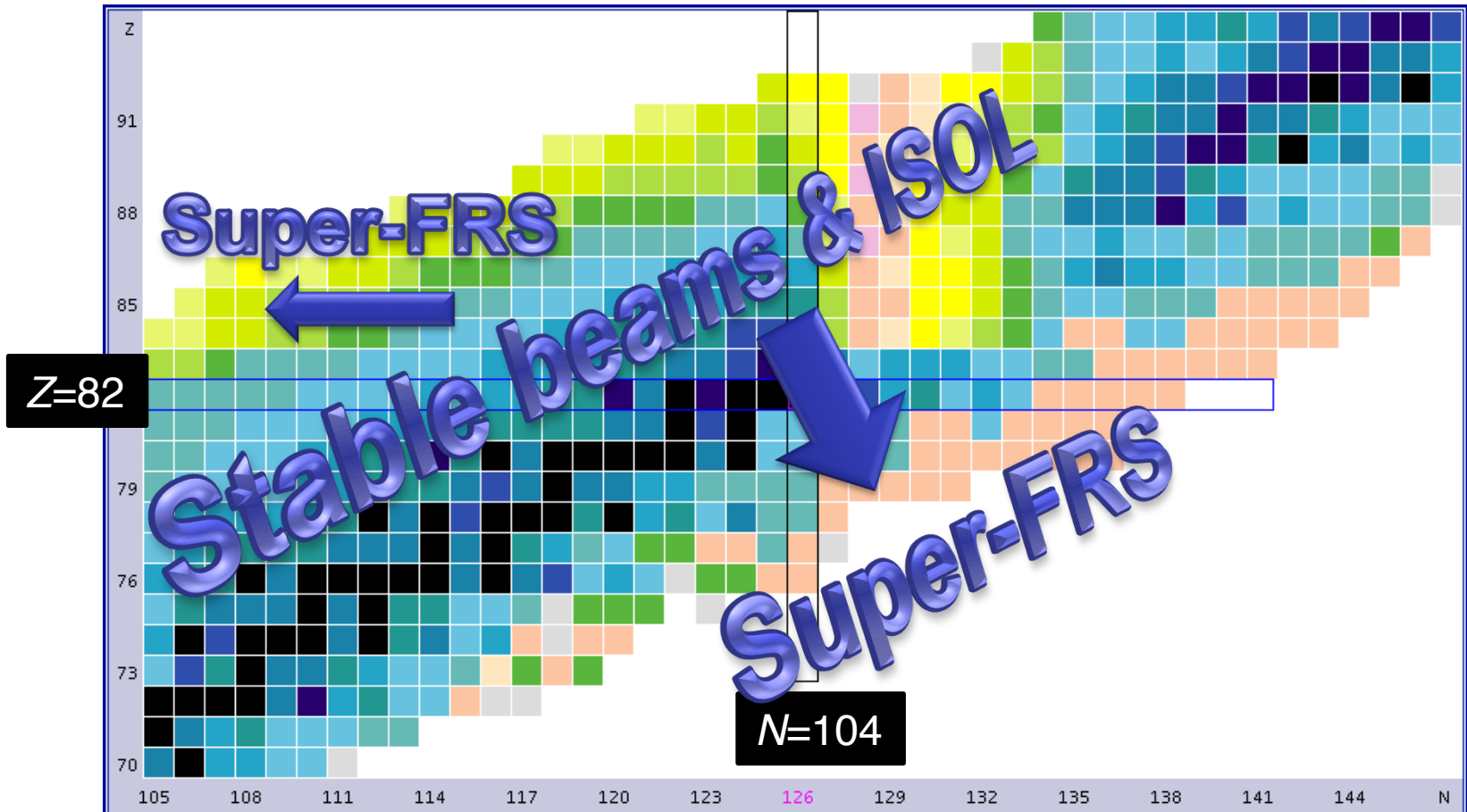


Complementary to  
PreSPEC-AGATA studies  
by D. Rudolph and Zs.  
Podolyak et al.

# The $Z=82$ and $N=104$ shell closures

- In-beam studies ( $Z=82$ ) utilising stable beams:
  - Cross section limit may have been reached (c.f.  $^{180}\text{Pb} \sim 10 \text{ nb}$ )
  - Lifetime measurements carried out down to  $^{186}\text{Pb}$  ( $\sigma \sim 200 \mu\text{b}$ )
- Coulomb excitation of ISOL beams ( $Z=82$ ):
  - Yield and purity sufficient down to  $^{188}\text{Pb}$
- Fragmentation of  $^{238}\text{U}$  and Super-FRS required to push measurements beyond current limits

# The $Z=82$ and $N=104$ shell closures



# *r*-process nuclei near $N=126$ and $Z=82$

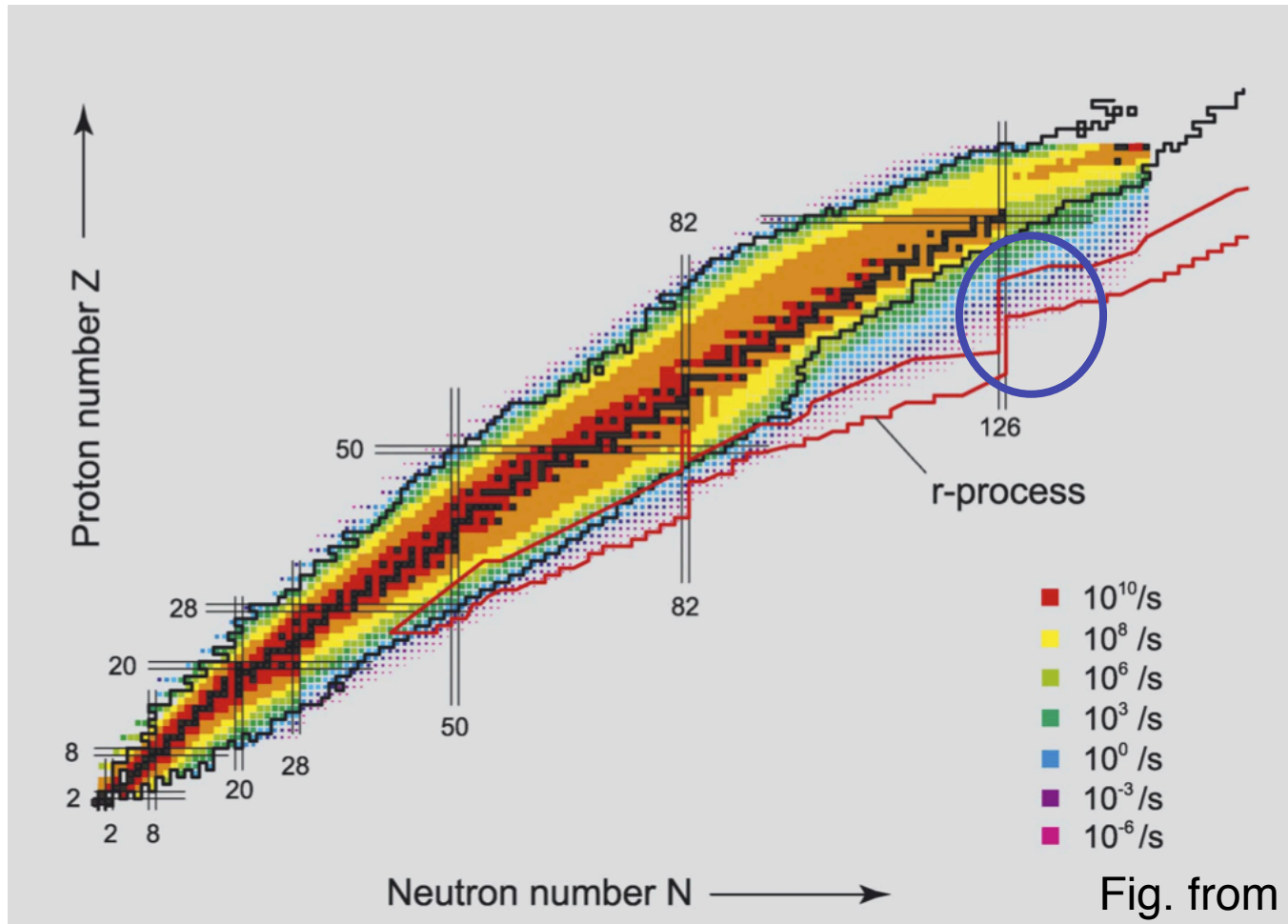


Fig. from FAIR CDR



# $r$ -process nuclei near $N=126$ and $Z=82$

- Stellar nucleosynthesis  $r$ -process path predicted to run through  $N=126$  towards  $Z=82$
- Mainly unknown nuclei, but properties such as half-lives needed to model  $r$  process
- Experimental studies provide invaluable data to contemporary theories: *HIP theory programme* (talk by M. Kortelainen)
- Predicted Super-FRS yields should make studies possible

# Summary & Outlook

- Complementarity: JYFL & HISPEC/DESPEC
- JYFL can provide important training for modern methodologies: IGISOL, JUROGAM & RITU/MARA, DAQ (Total Data Readout)...
- Testing/using instrumentation at JYFL
  - ✓ E.g. ongoing feasibility studies to use FATIMA detectors at RITU focal plane