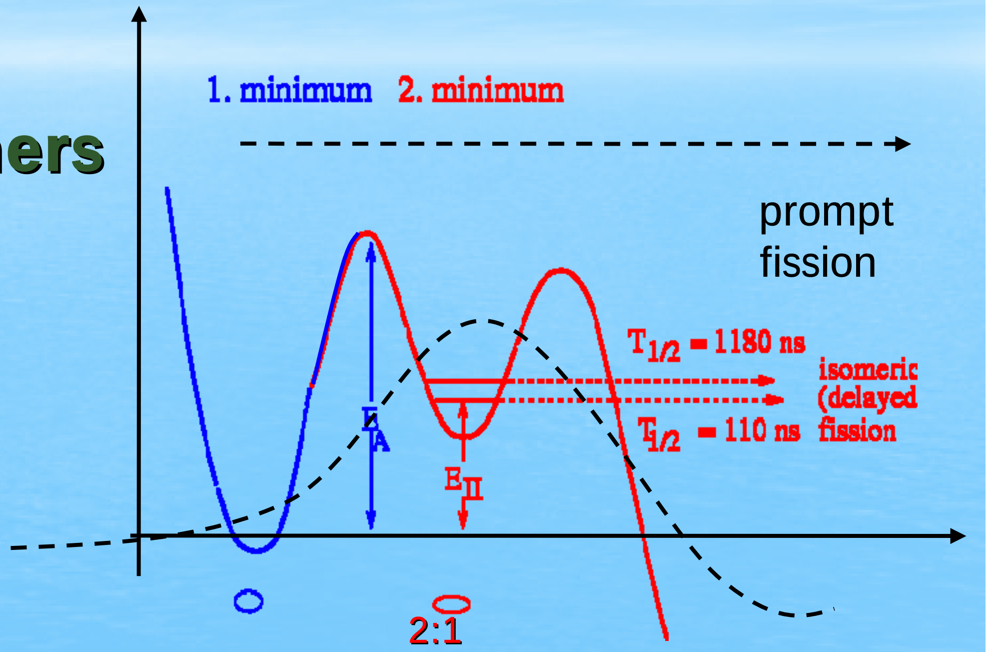
g-Spectroscopy of superdeformed ^{237}Pu

OUTLINE

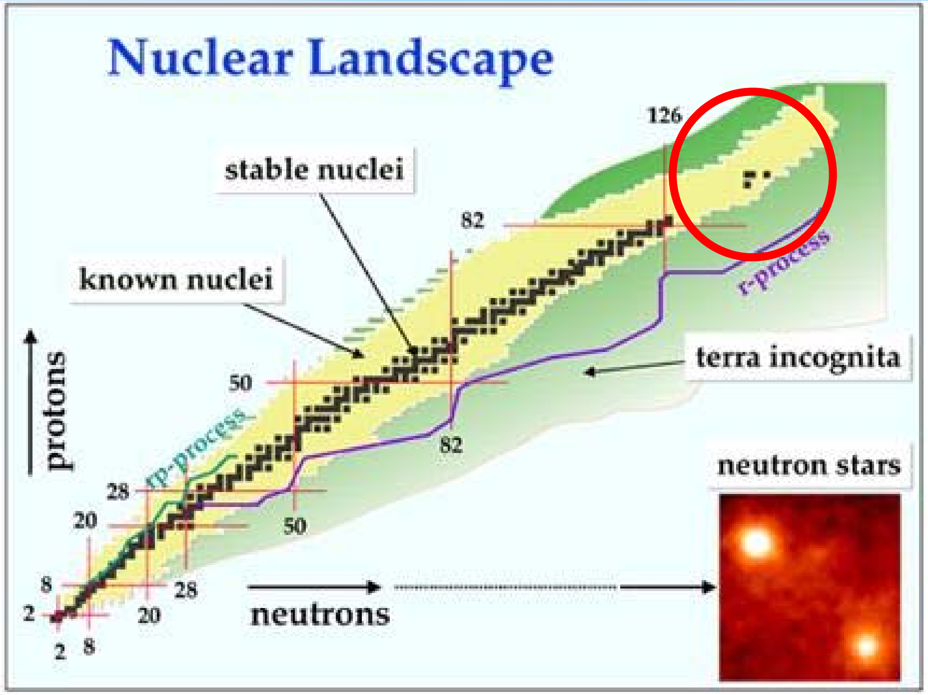
- **Motivation: fission isomers**
- **Spectroscopy of ^{237f}Pu:**
  - **measurement**
  - **results**
- **Outlook**



experimental goal: - first experimental identification of single-particle states in largely deformed actinides

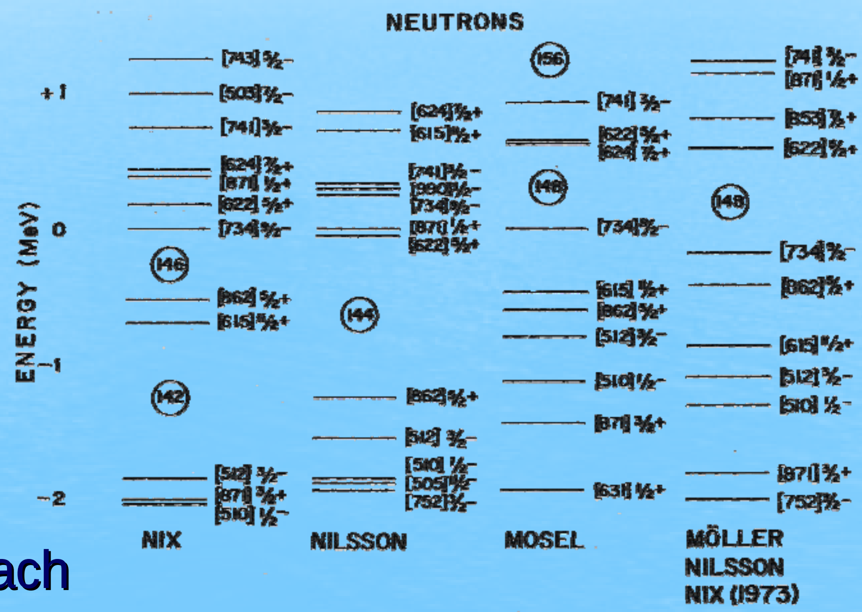
-> determination of fission barrier from level density

r-Process Path in Heavy Element Region



no experimental data

-> contradicting theoretical predictions:



- direct access to r-process path out of reach
- extrapolations of nuclear models require experimental data
- knowledge of fission barriers is crucial
- fission barriers: - determine end of chart of nuclides
  - change of shell correction energy by 1 MeV: fission lifetime changed by 10^5

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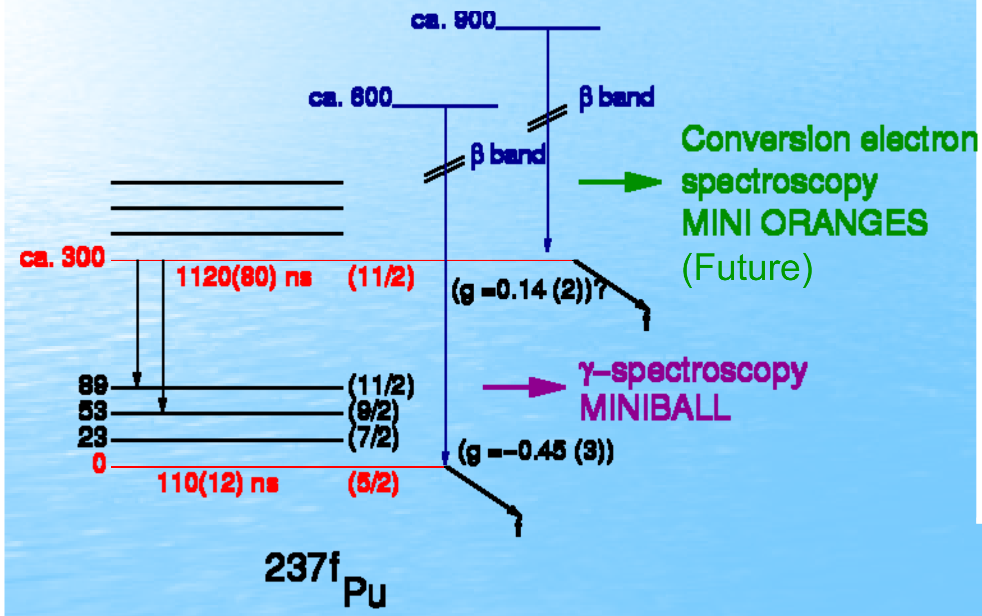
Spectroscopy of the first Odd-N fission isomer

- Present Knowledge



^{240f}Pu (even-even) (3.8 ns)	^{237f}Pu (odd-even) (110 ns)
^{238}U(a, 2n) 24 MeV	^{235}U(a, 2n) 24 MeV
s_{delay} = 10 mb	s_{delay} ~1 - 2 mb
$\frac{\sigma_{delay}}{\sigma_{prompt}} = 1.2\times10^{-4}$	$\frac{\sigma_{delay}}{\sigma_{prompt}} = 1.2\times10^{-5}$

⇒ in spite of low cross section comparable yields expected

- D. Pansegrau et al. *Phys. Lett*. B 484 (2000) 1
- D. Gaßmann et al. *Phys. Lett* B. 497 (2001) 181

^{237f}Pu: rigid rotor

=> regular rotational band structure

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Experimental Procedure

- Reaction: $^{235}U(a,2n)^{237f}Pu$;
- Beam: E_a = 24 MeV:
  pulsed, Dt = 400ns, width ~ 4 ns,
  Cologne Tandem
- Target: thick (rolled) ^{235}U; ≤ 3.7 mg/cm^2 → g-emission at rest
  metallic: low reaction background from e.g. oxygen and carbon
  but: highly oxidising, all handling under vacuum or Ar atmosphere

Detectors:

- fission fragments: compact PPAC array - 8 trapezoidal modules
  - 13 fold segmented anode
  - position sensitive for time of flight
  - large solid angle (73 %)
- g-rays: MINIBALL
  - 8 triple cryostats, distance to target ~10 cm
  - high resolution 2.3 keV (1.3 MeV)
  - high efficiency e_{ph} ~ 9% (1.3 MeV)
  - trigger: fission fragment & g-ray
  - 3 weeks beamtime

  ~ 2×10^4 delayed fission events (N_g = 1 ~ 90 %; N_g = 2 ~10 %)

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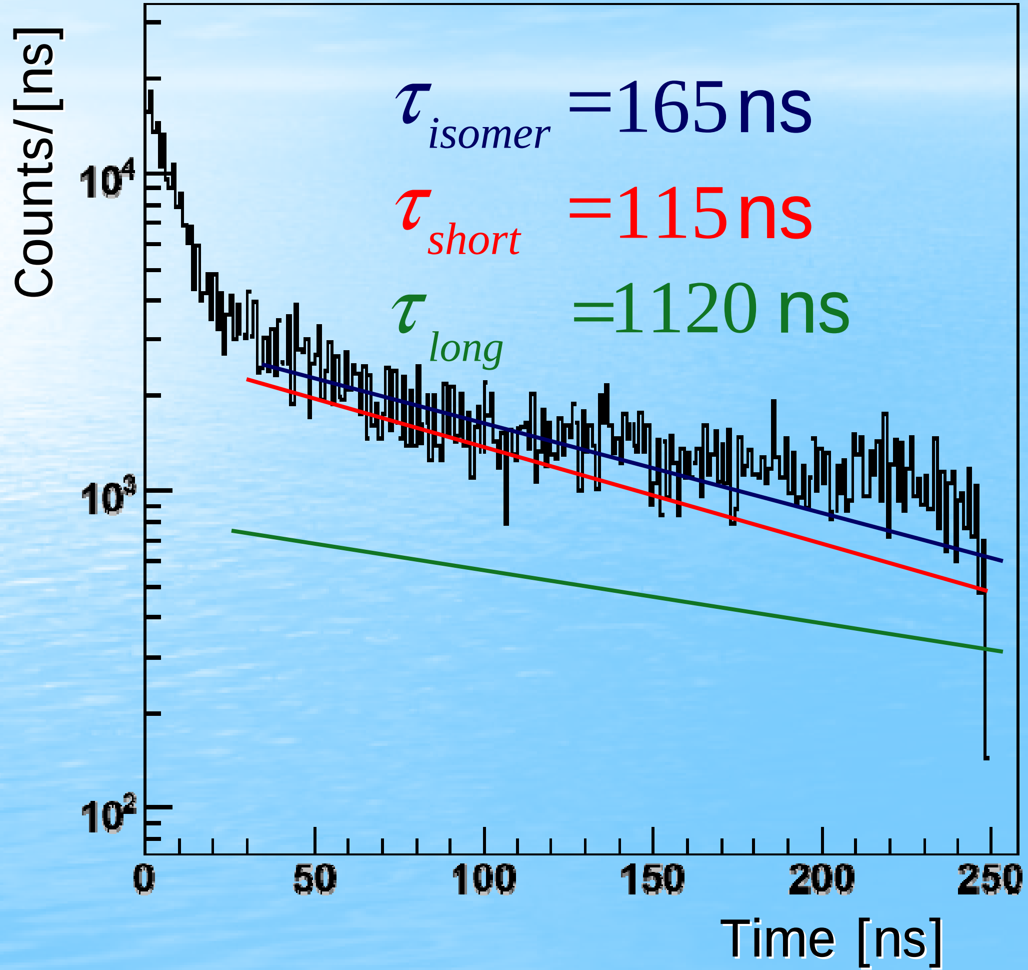
Isomeric Lifetime



- theoretical expectation:

$$\frac{\sigma_{isomer}}{\sigma_{prompt}} \approx 1.2 \bullet 10^{-5}$$

- experimental finding:

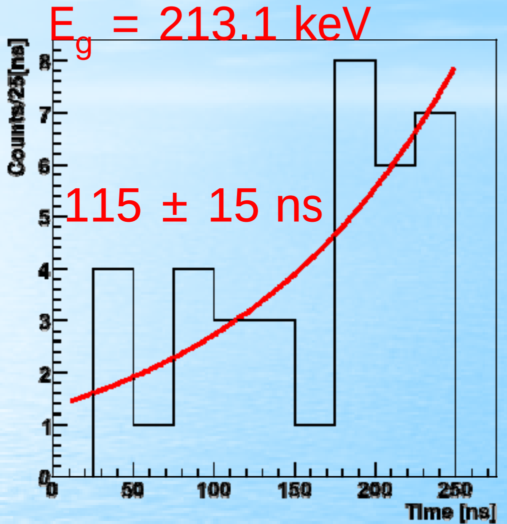
$$\frac{\sigma_{isomer}}{\sigma_{prompt}} \approx 1.2 \bullet 10^{-5} \sim 2\text{mb}$$

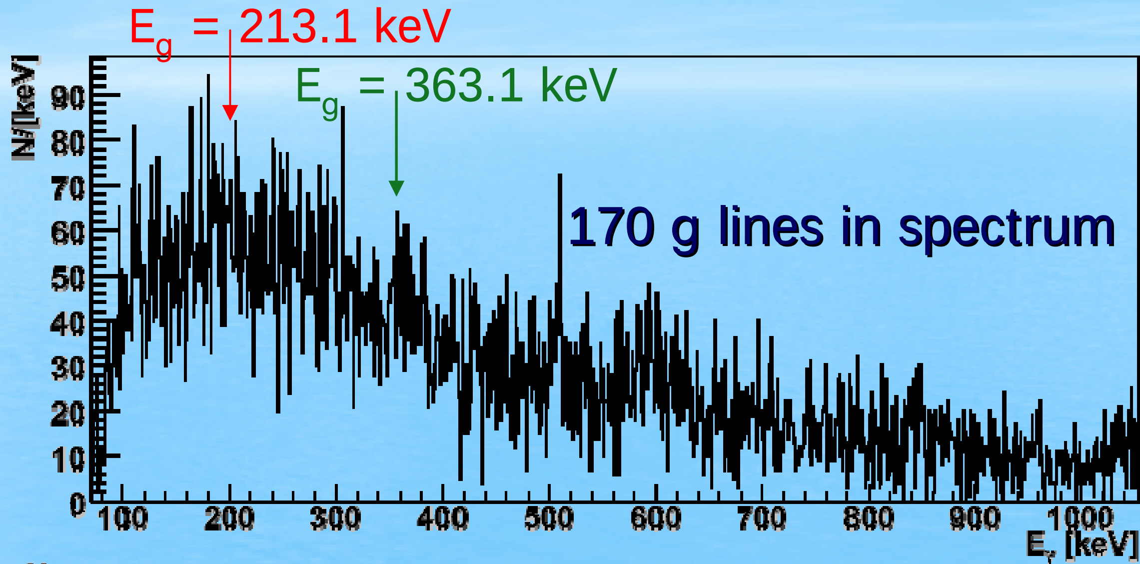
- relative isomeric population

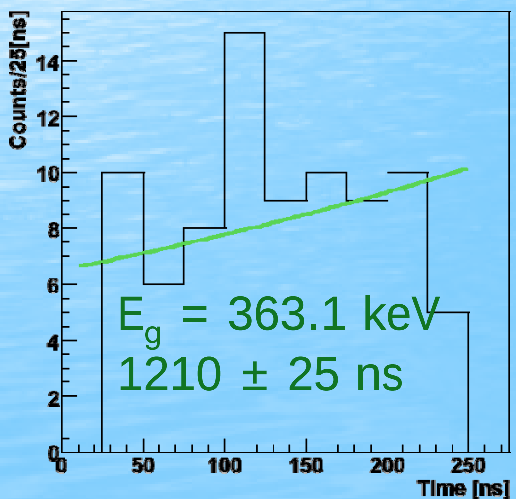
$$\frac{\sigma_{short}}{\sigma_{long}} \sim \frac{2}{1}$$

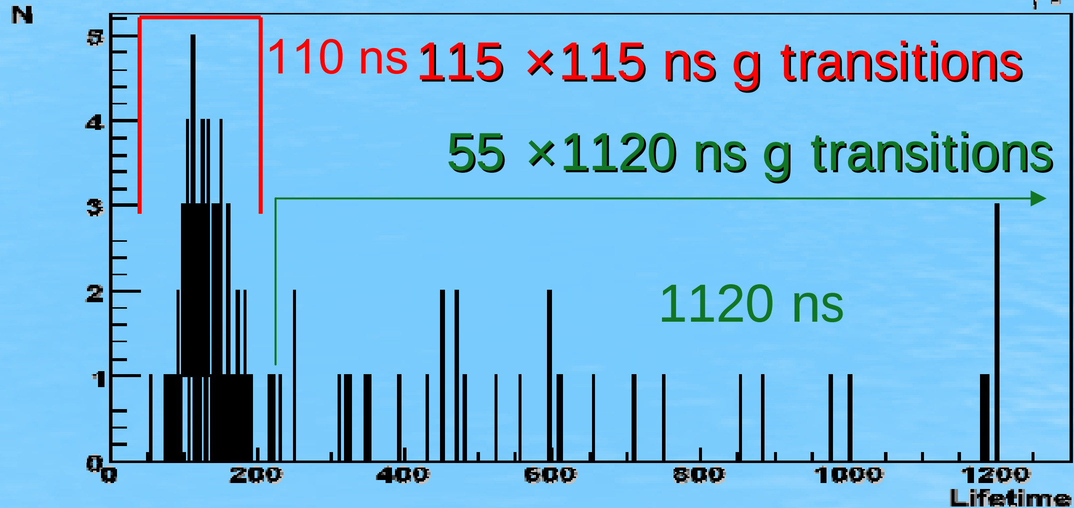
=> consistent with literature

Disentanglement of isomeric g-rays









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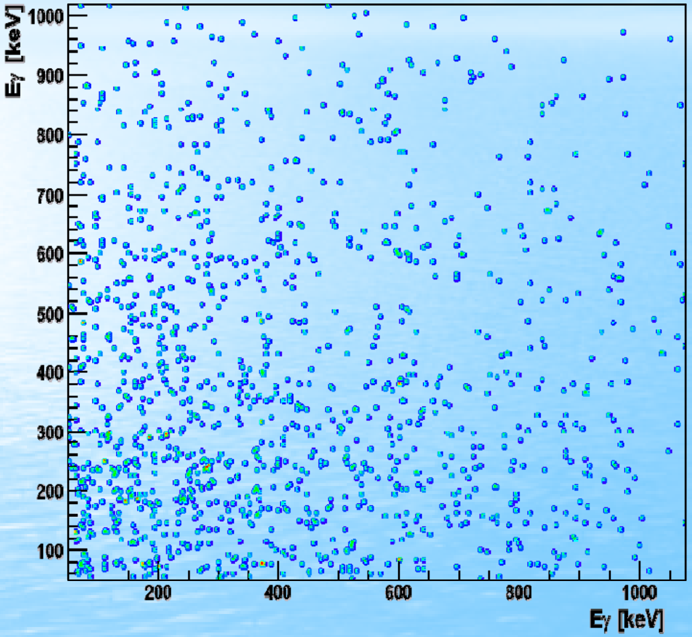
Identification of rotational bands

g-g correlation (2000 N_g = 2 events):



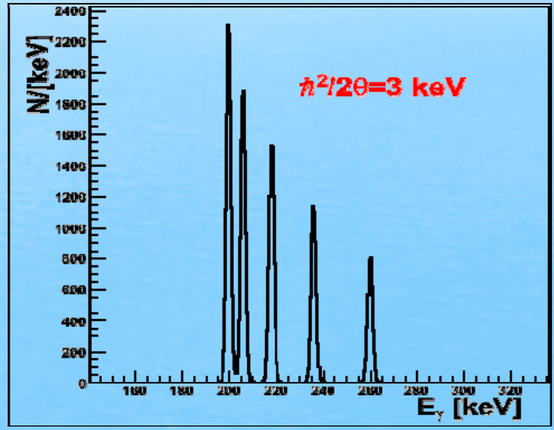
→ No obvious correlations

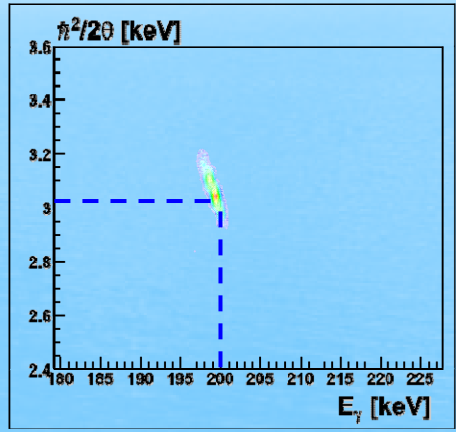
→ automatic search via peak correlation

^{237f}Pu: rigid rotor $E_\gamma = J(J+1)\cdot\frac{\hbar^2}{2\theta}$

=> regular rotational band structure

test case for peak correlation algorithm:





Variation of rotational parameter $\frac{\hbar^2}{2\theta}$

=> result:

- 9 rotational bands
- $\frac{\hbar^2}{2\theta} = 3.28\ [20]$ keV

(SD axis ratio 2:1 ~ 3.3 keV)

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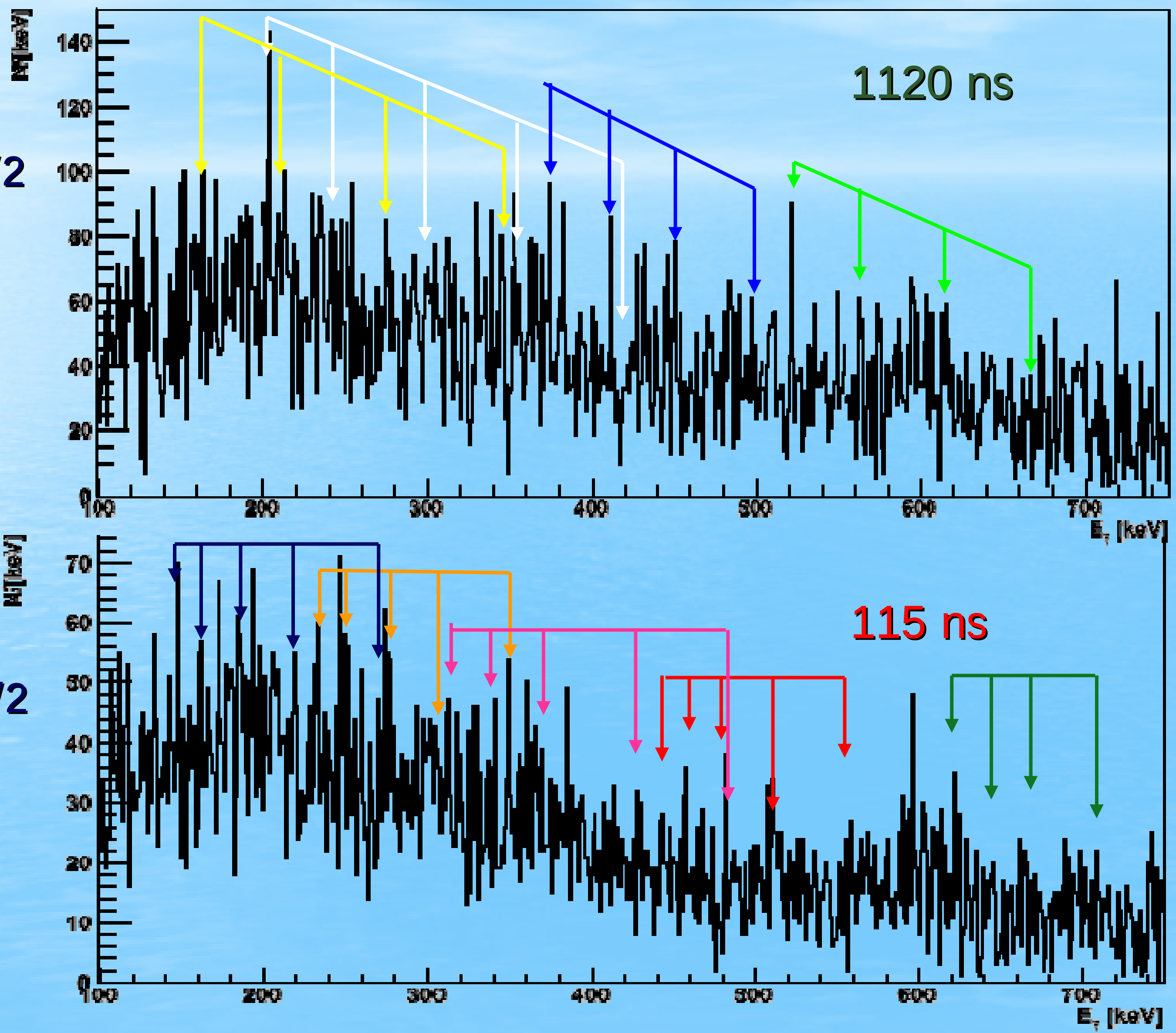
Isomeric rotational bands

9/2 and 11/2

3/2 and 5/2



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Construction of isomeric level scheme(s)

ground state rotational bands:

$$E_J = J(J+1)\cdot\frac{\hbar^2}{2\theta}$$

$$E_{J+1} - E_J = 2\cdot(J+1)\cdot\frac{\hbar^2}{2\theta}$$

$\frac{\hbar^2}{2\theta} = 3.28\ [20]$ keV

→ **Ritz combinatorial search program used** (courtesy of T. v. Egidy, E18 TU München):

ground state bands + 170 g transitions

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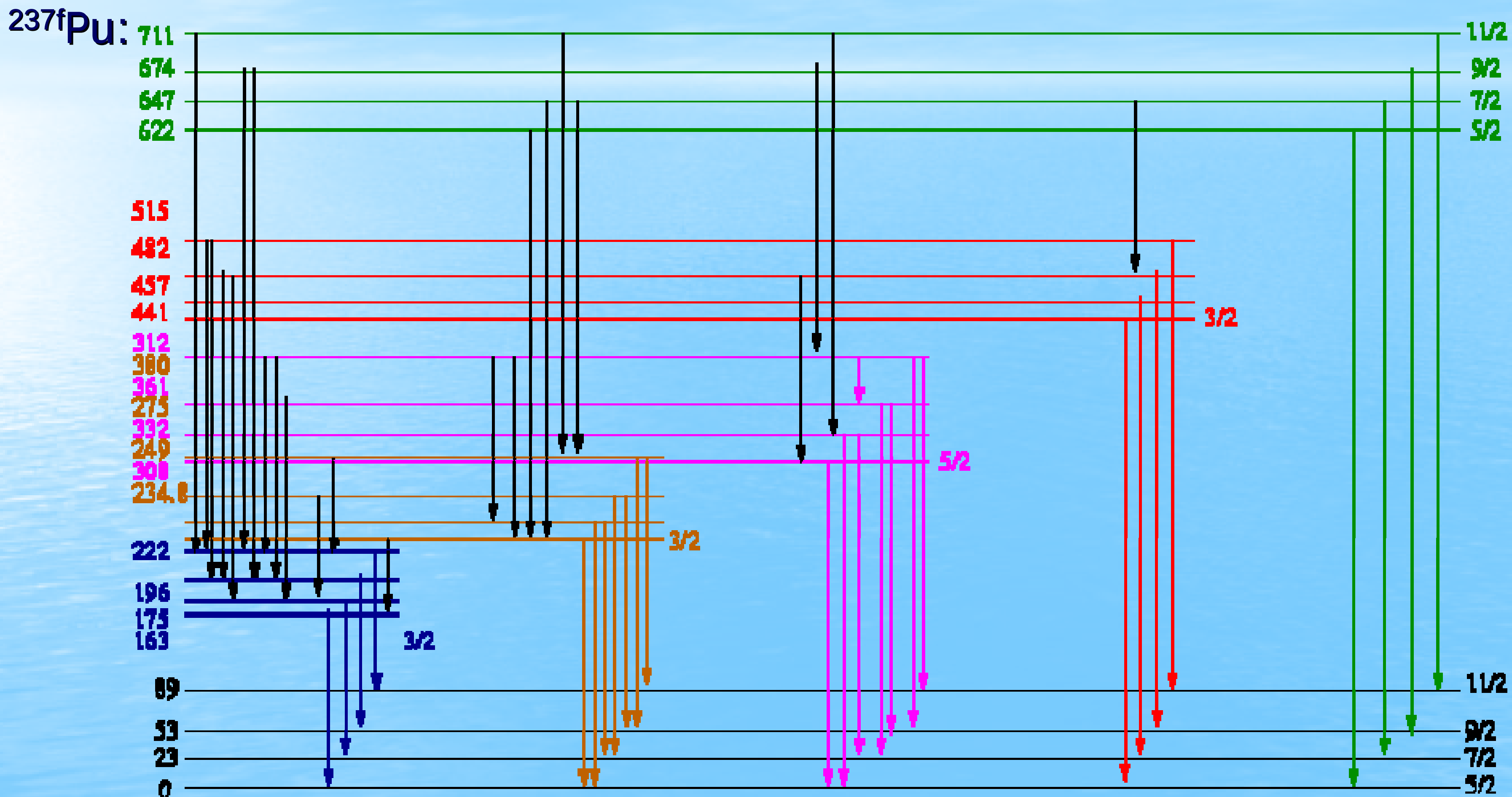
Rotational level scheme for short lived isomer (115 ns)



connecting inter-band transitions identified
-> consistent picture

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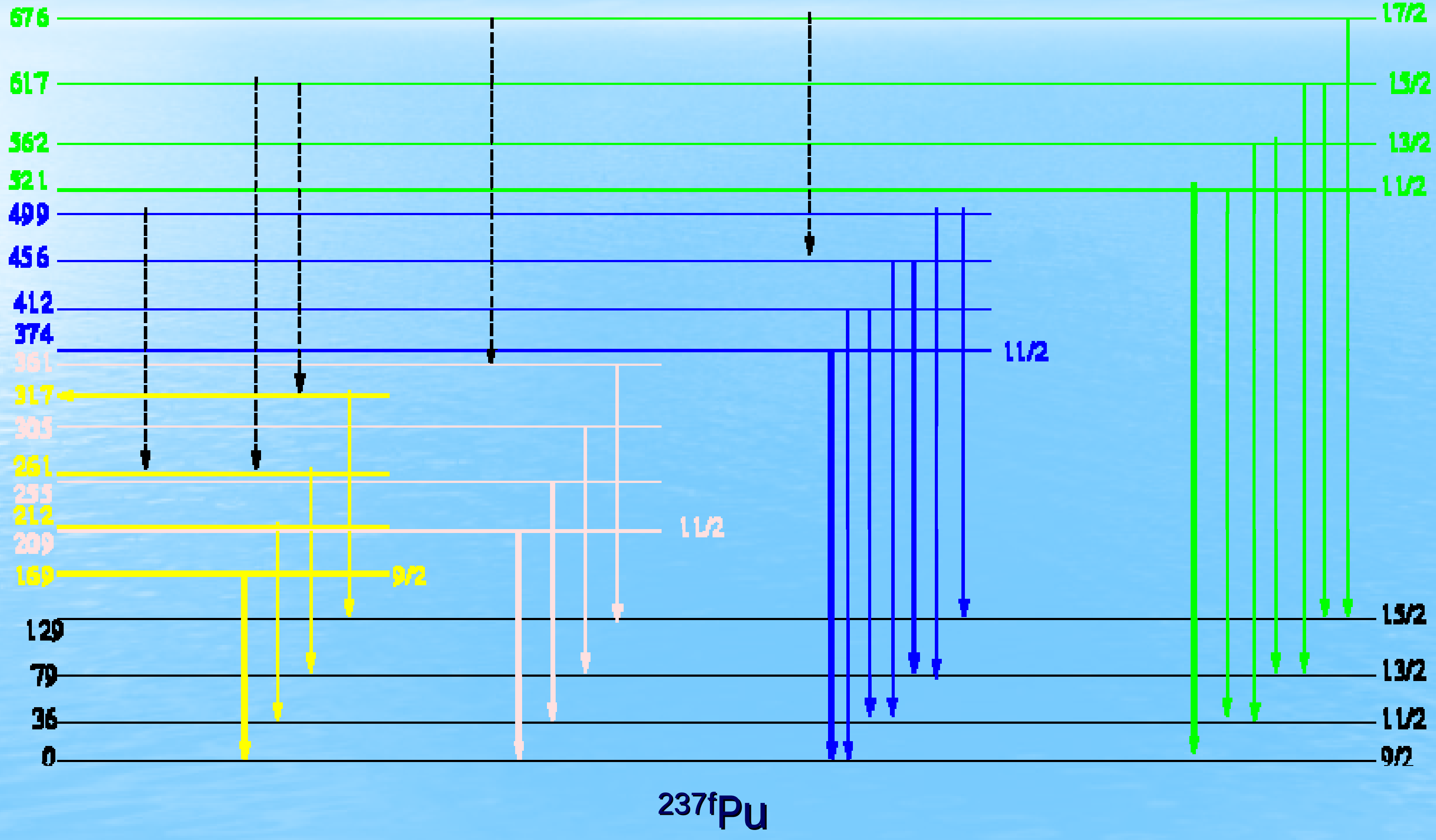
Rotational level scheme for long lived isomer (1120 ns)

work in progress:



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Summary and Outlook

Summary:

- first high resolution g-spectroscopy in Odd-N fission isomers
- regular rigid rotor pattern allows to interpret low-statistics spectra
- 9 rotational bands identified with SD moment of inertia
- g-spectra disentangled into contributions from 2 fission isomers
- level schemes constructed with Ritz combination (gs-band and interband transitions)

Outlook:

- finalise analysis
- complementary conversion electron spectroscopy (Mini Oranges)
  => b-vibration, E0 transitions
- g-spectroscopy of ^{239f}Pu
  - conversion electron data already available
  - identification of Nilsson orbitals
  - localisation of r-process path via fission barriers (theory)

Collaboration

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