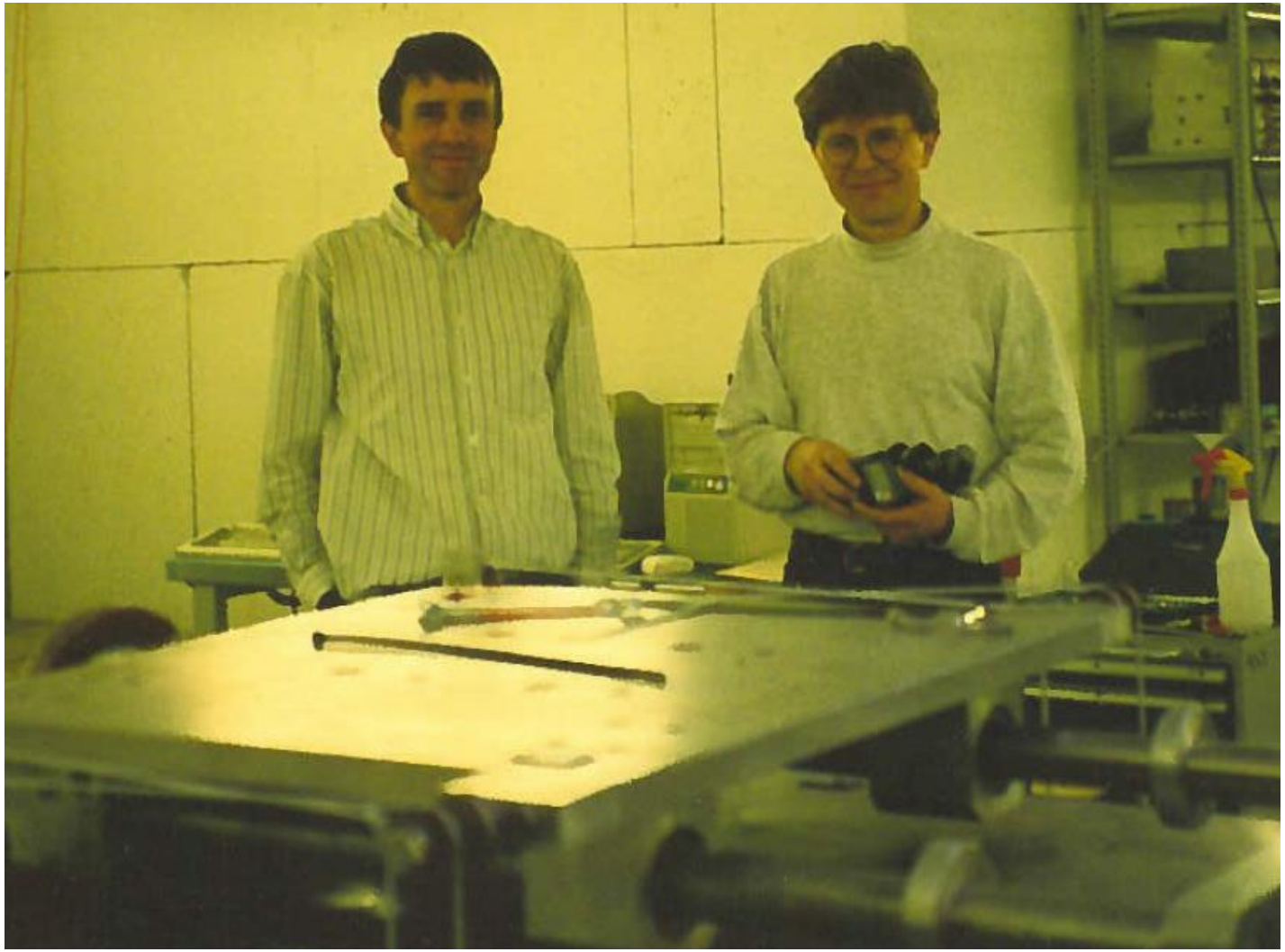
Reflections on the atomic nucleus

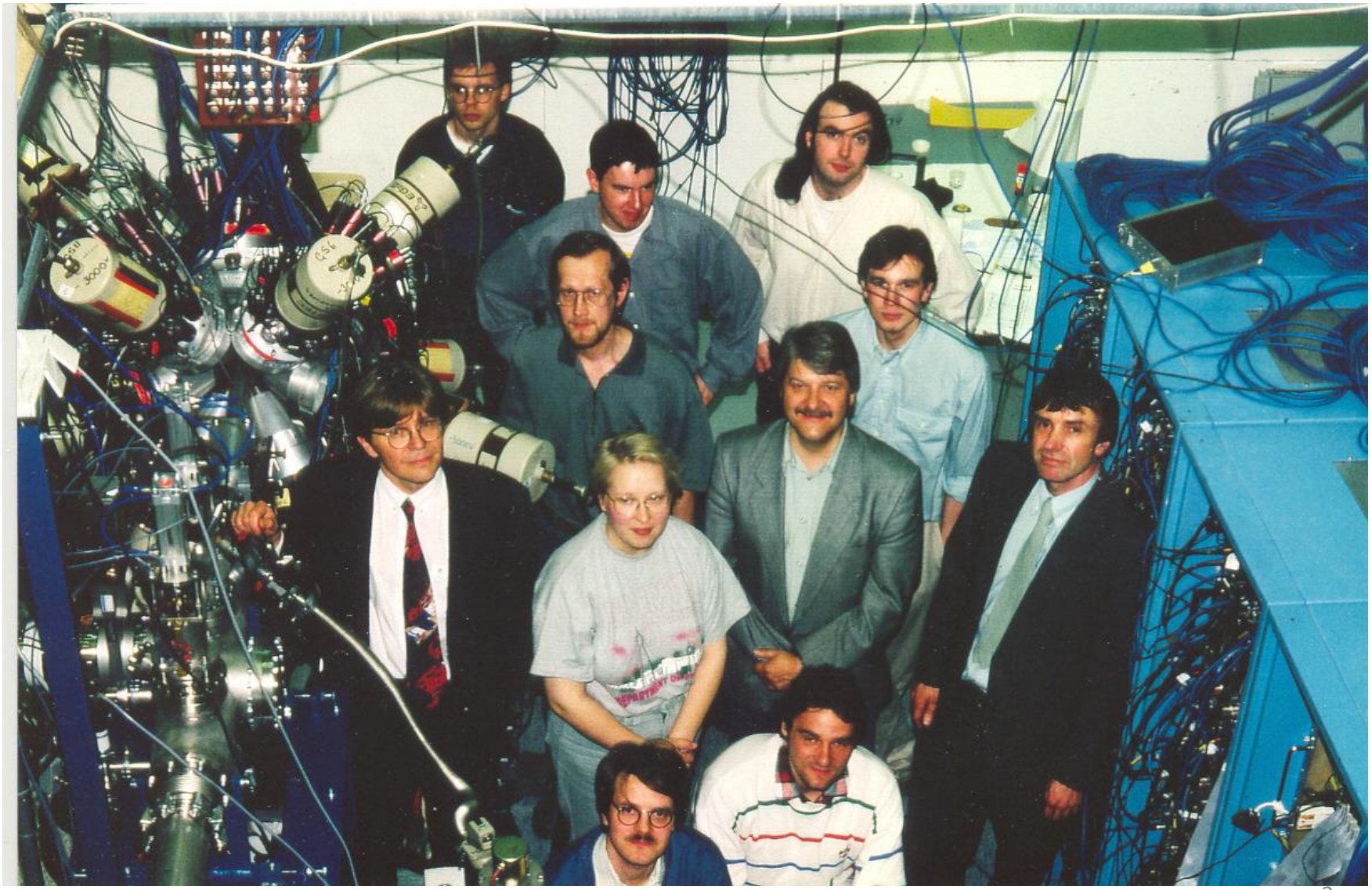
In-beam studies of the structure of exotic nuclei

Rauno Julin
Department of Physics
University of Jyväskylä
Finland
JYFL

1994



our team in 1994



Reflections:

E0 transitions and shape coexistence

Late 70's:

Still relevant for studies of exotic nuclei :

E0- transitions in Z ≈ 50 nuclei

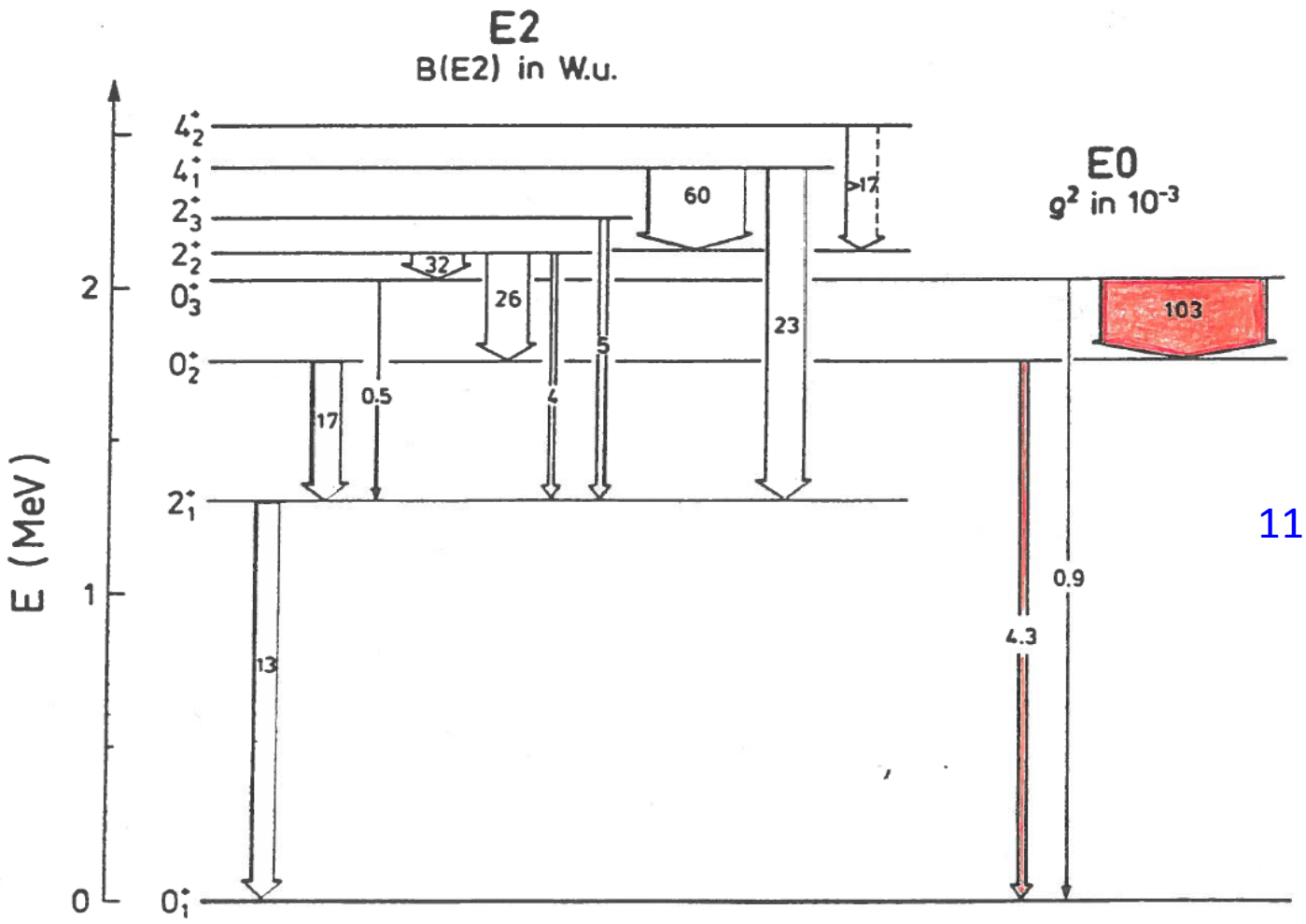
Probing exotic states and shape coexistence in

^{208}Pb, ^{186}Pb and ^{194}Po

Hunting of E0's at JYFL: electron spectrometers, fast timing, coulex

We saw strong and weak E0($0^+ \rightarrow 0^+$)'s

$B(E0) = R^4\rho^2$



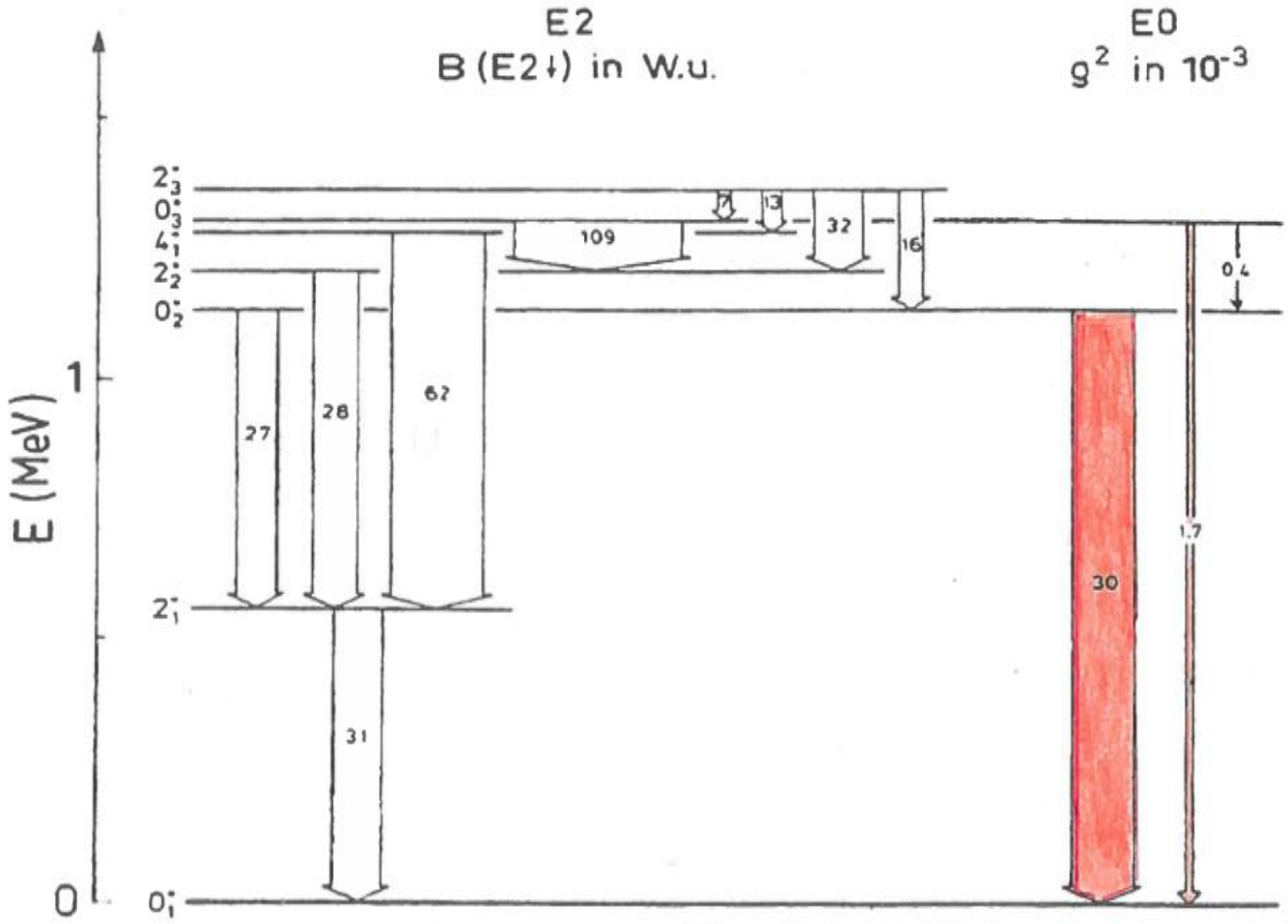
$^{116}Sn_{66}$

R. Julin thesis 1979, ZP289, 157(1979)

Hunting of E0's at JYFL: electron spectrometers, fast timing, coulex

We saw strong and weak E0($0^+ \rightarrow 0^+$)'s

$B(E0) = R^4\rho^2$



$^{114}Cd_{66}$

R. Julin thesis 1979, ZP A296, 315 (1980)

How to explain $\rho^2 = \mathbf{100} \times 10^{-3}$ in ^{116}Sn ?

"Single-particle" value: $\rho^2_{sp} = 0.49\, A^{-2/3}$ = **20** × 10^{-3} (A=116)

(= E0 connecting 50/50 mixed 0^+ states involving **2 protons** occupying orbitals from different oscillator shells)

E0's involving **neutron** excitations : $\rho^2 = 0$

How to explain $\rho^2 = \mathbf{100}\times 10^{-3}$ in ^{116}Sn ?

R. Julin thesis 1979, Kantele et al. ZP289, 157(1979)

Introduction of the simple shape-mixing model (Jan Blomqvist 's idea)

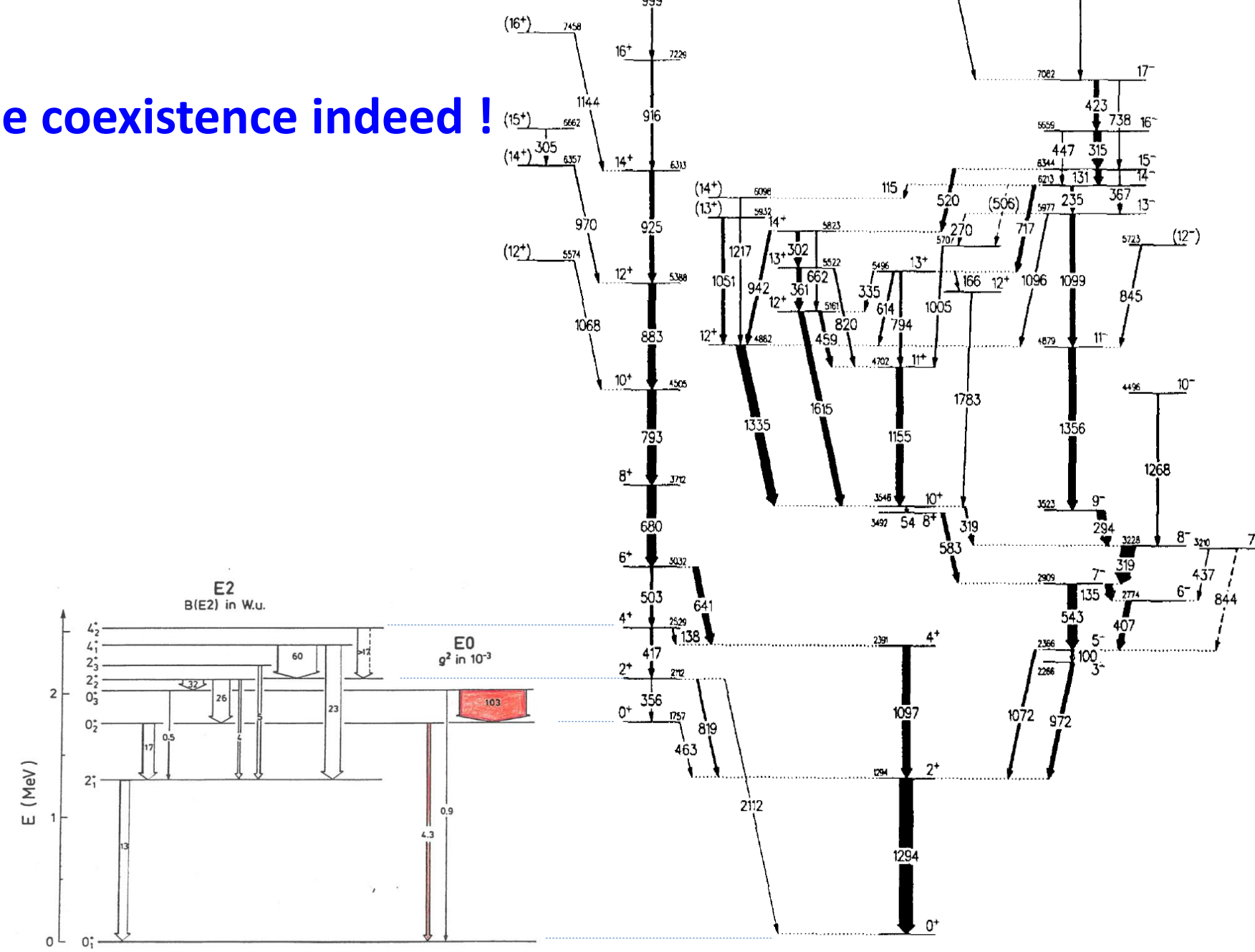
$$0_1^+ = +a|sph\rangle + b|def\rangle$$
$$0_2^+ = -b|sph\rangle + a|def\rangle$$

$$\rightarrow \quad \rho^2 \propto a^2 b^2 \beta^4$$

^{116}Sn : take 50/50 mixing and ß = 0.22 → $\rho^2 = \mathbf{100}\times 10^{-3}$

shape coexistence !

Shape coexistence indeed !



^{116}Sn

A. Savelius et al. NP A637 (1998) 491

Kantele:

E0 transitions are fast in heavy nuclei

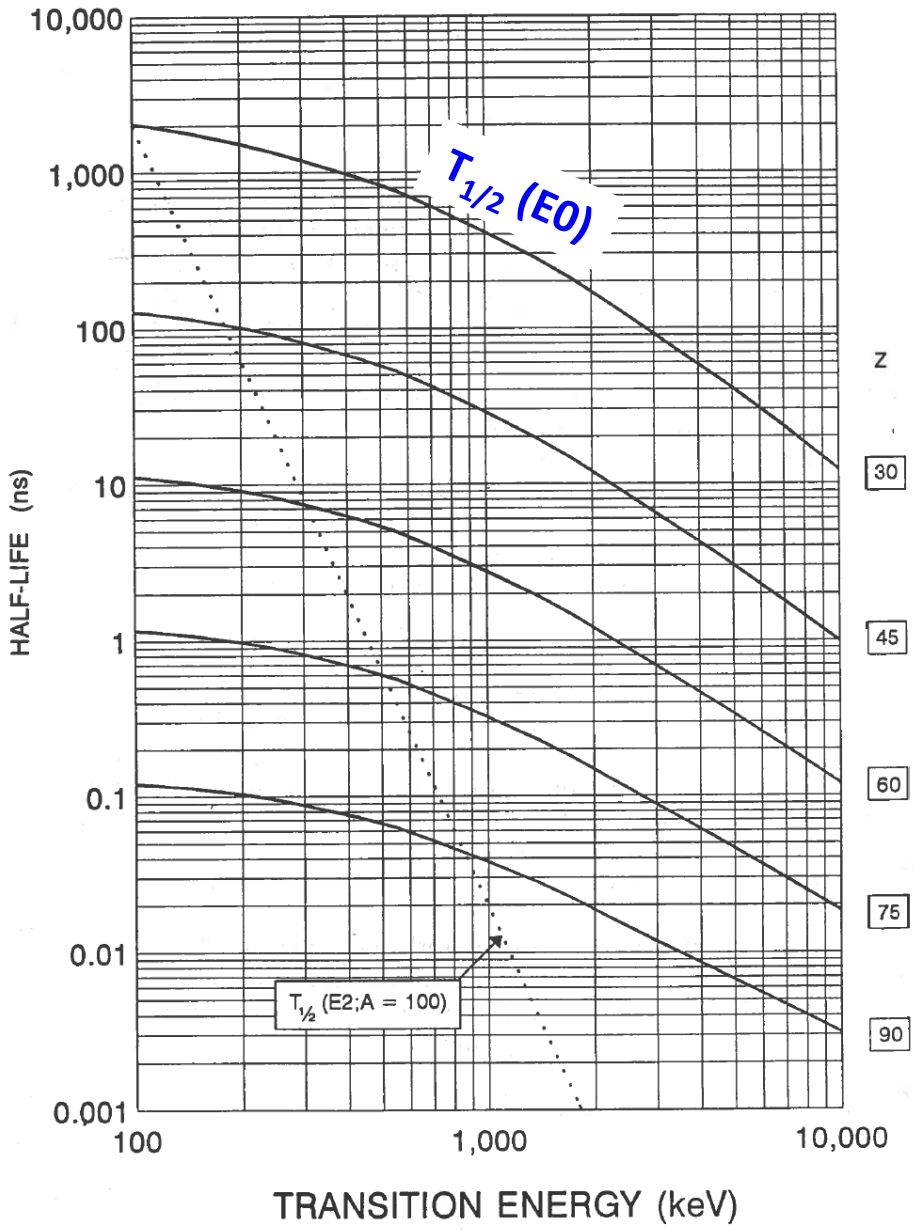


Figure 6-8 Speeds of E0 transitions with $\rho^2 = 0.010$. For comparison, the Weisskopf estimate half-life for E2 ($A = 100$) is also shown.

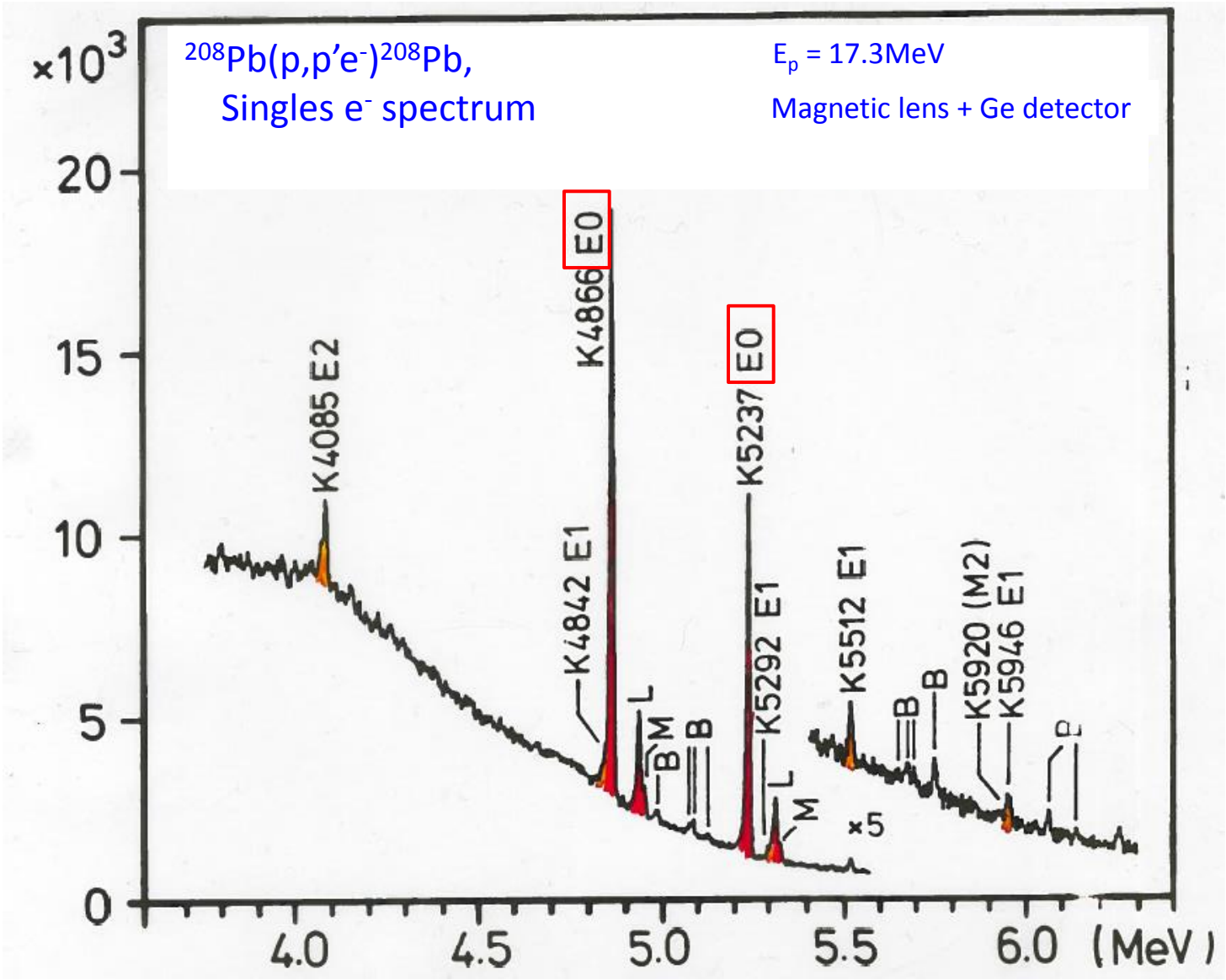
$\lambda_{E0} = \Omega \times \rho^2$

Ω increases with Z

Pb isotopes: ^{208}Pb

Julin et al. PR C36 (1987) 1129

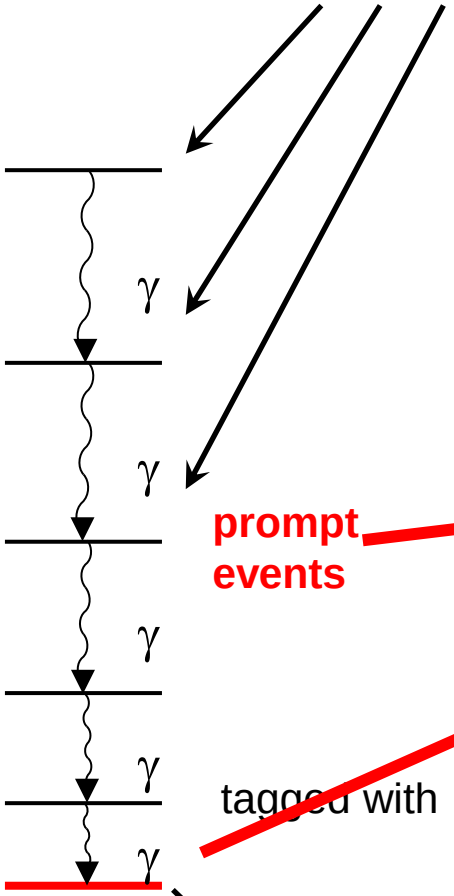
^{208}Pb



E0's from 0^+(2n-2h), 0^+(2p-2h), $0^+(3^- \times 3^-) \rightarrow 0^+_{gs}$

Combination of in-beam and delayed events

Recoil-Decay-Tagging



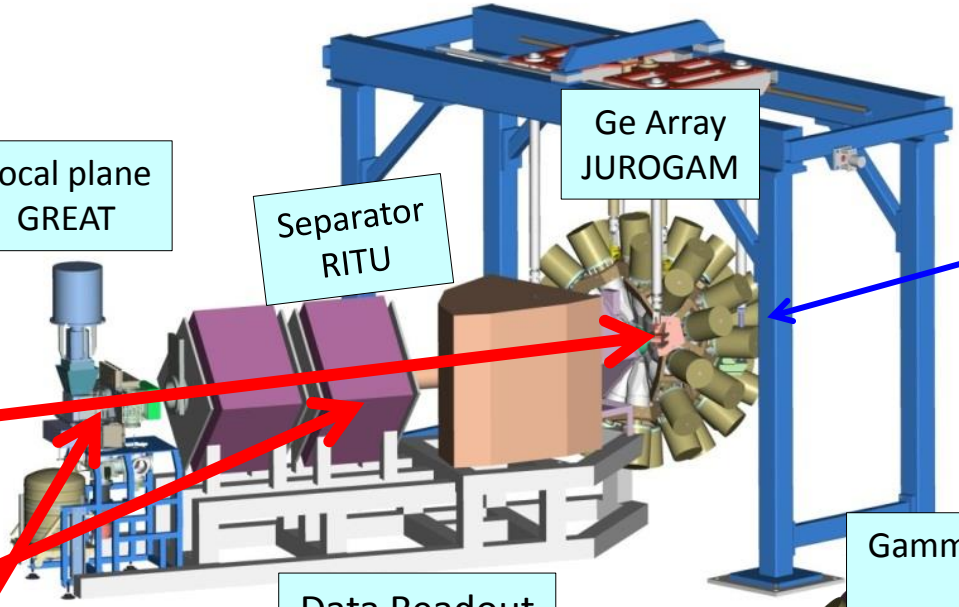
prompt events

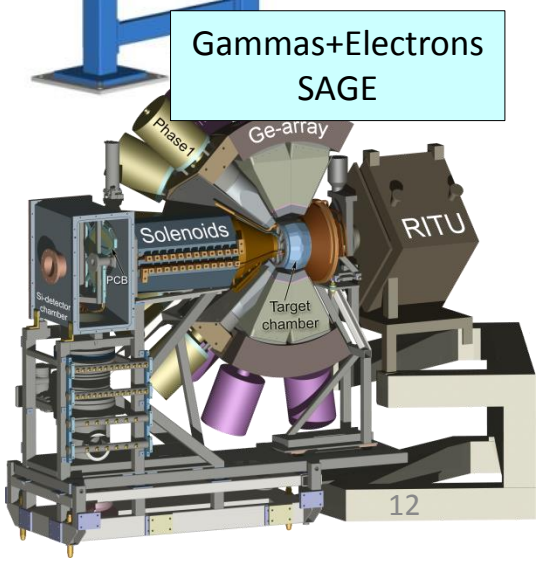
tagged with

delayed events

α, p, β,

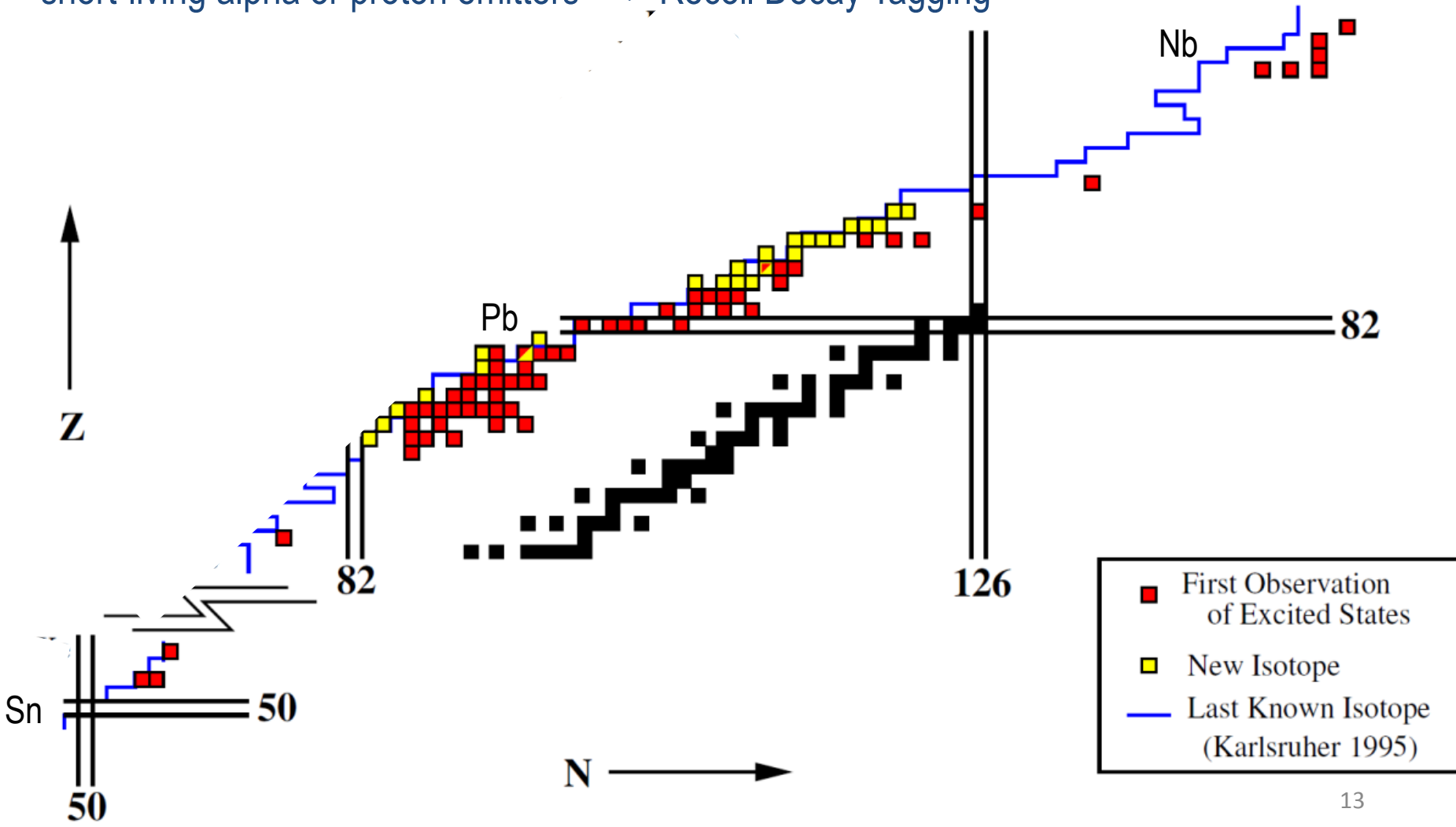
… e^-, γ





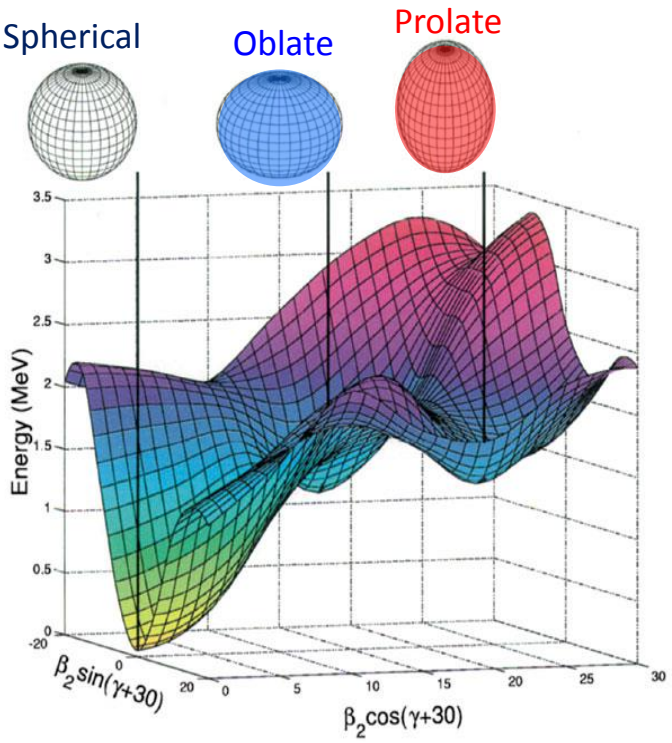
Very neutron deficient heavy nuclei

+ can be produced via fusion evaporation reactions
- only levels close to the yrast line populated
- cross-sections down to 1 nb
+ short-living alpha or proton emitters → Recoil Decay Tagging



Three low-lying 0^+ states in ^{186}Pb observed in the α- decay of ^{190}Po

^{186}Pb



$^{186}Pb_{104}$

... but can we identify band structures on top of those ?

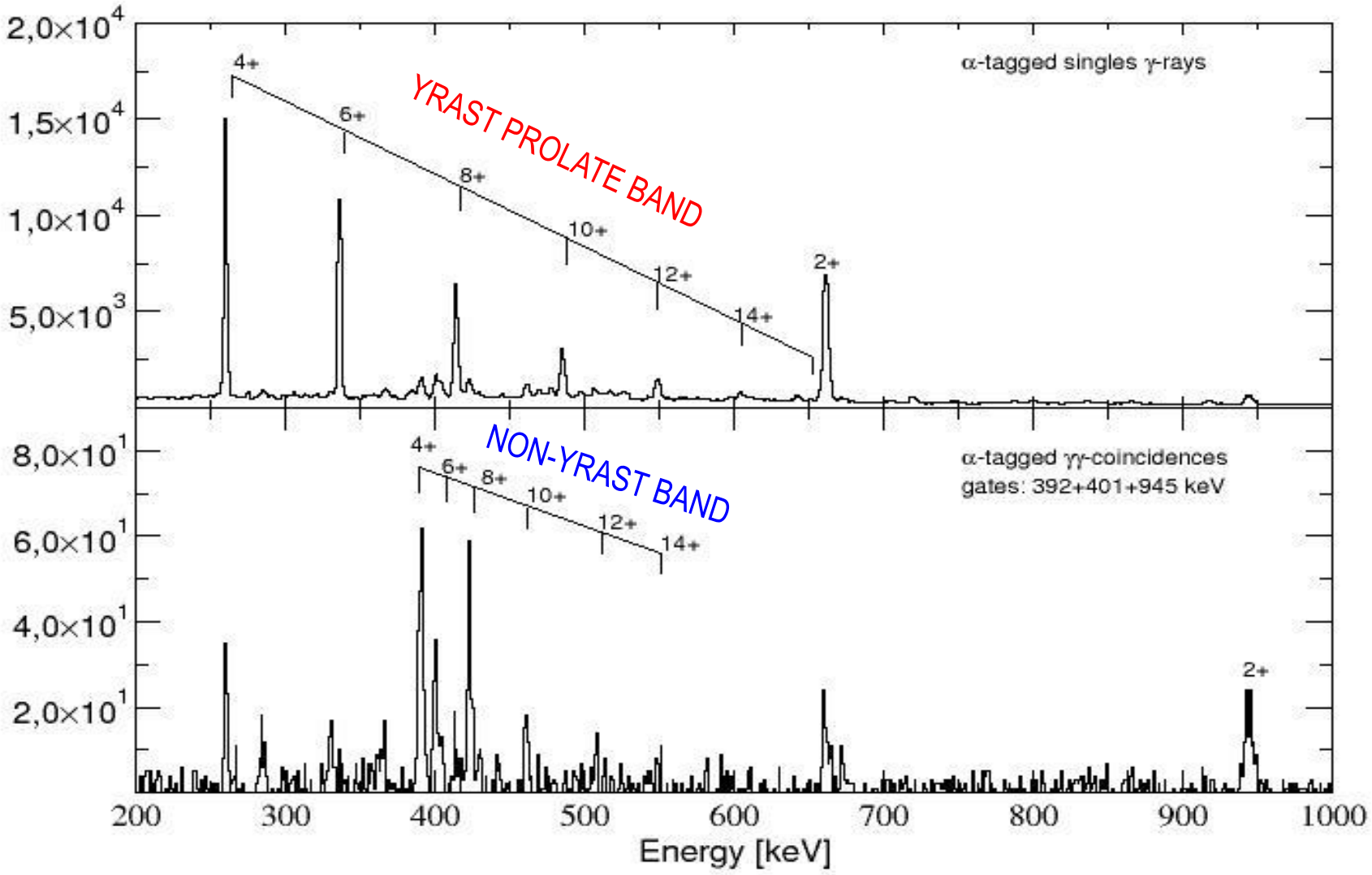
... can we see any E0's ?

A. Anreyev et al. Nature 405, 430

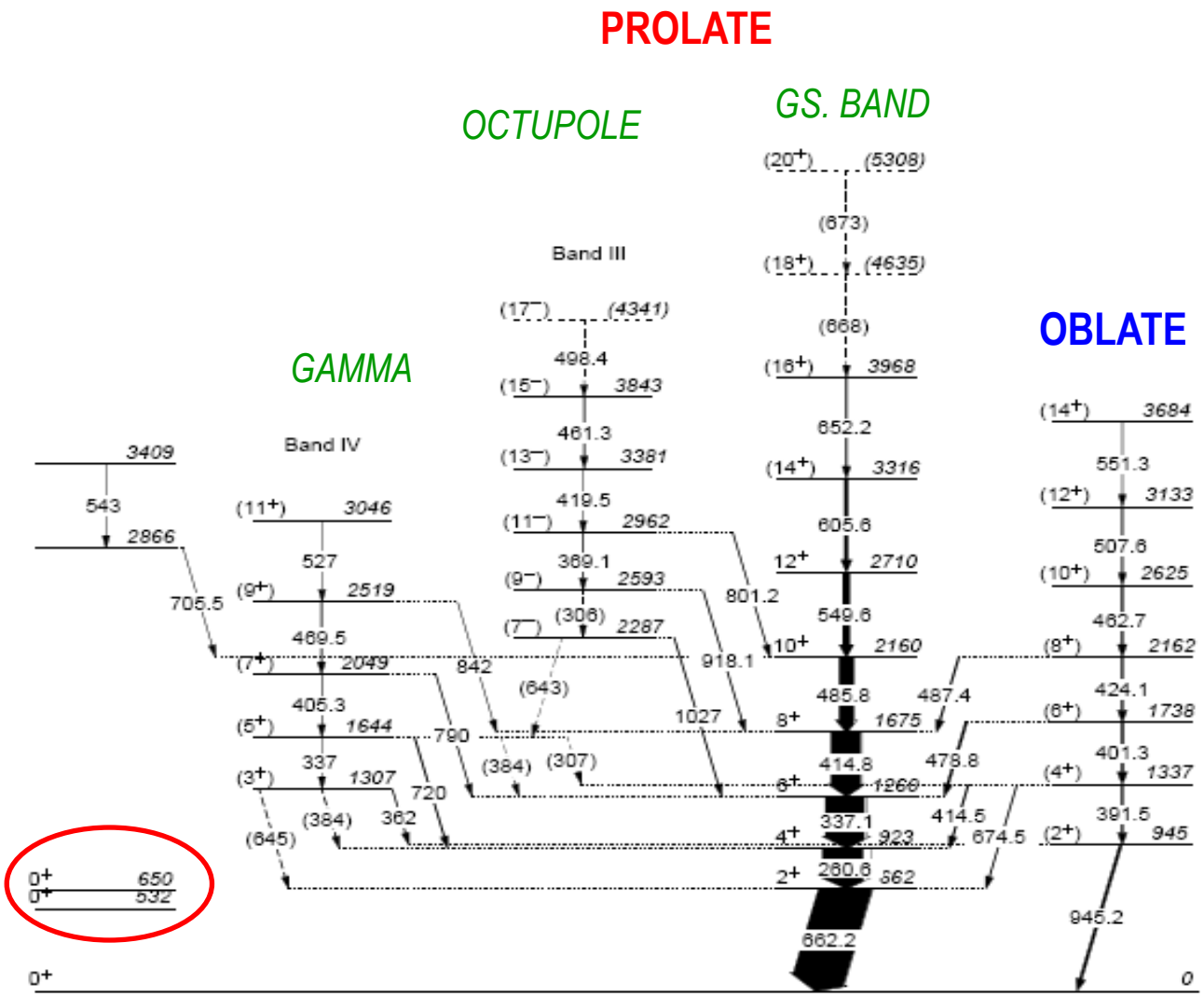
RDT γ rays from ^{186}Pb

^{106}Pd(^{83}Kr,3n) ^{186}Pb

^{186}Pb



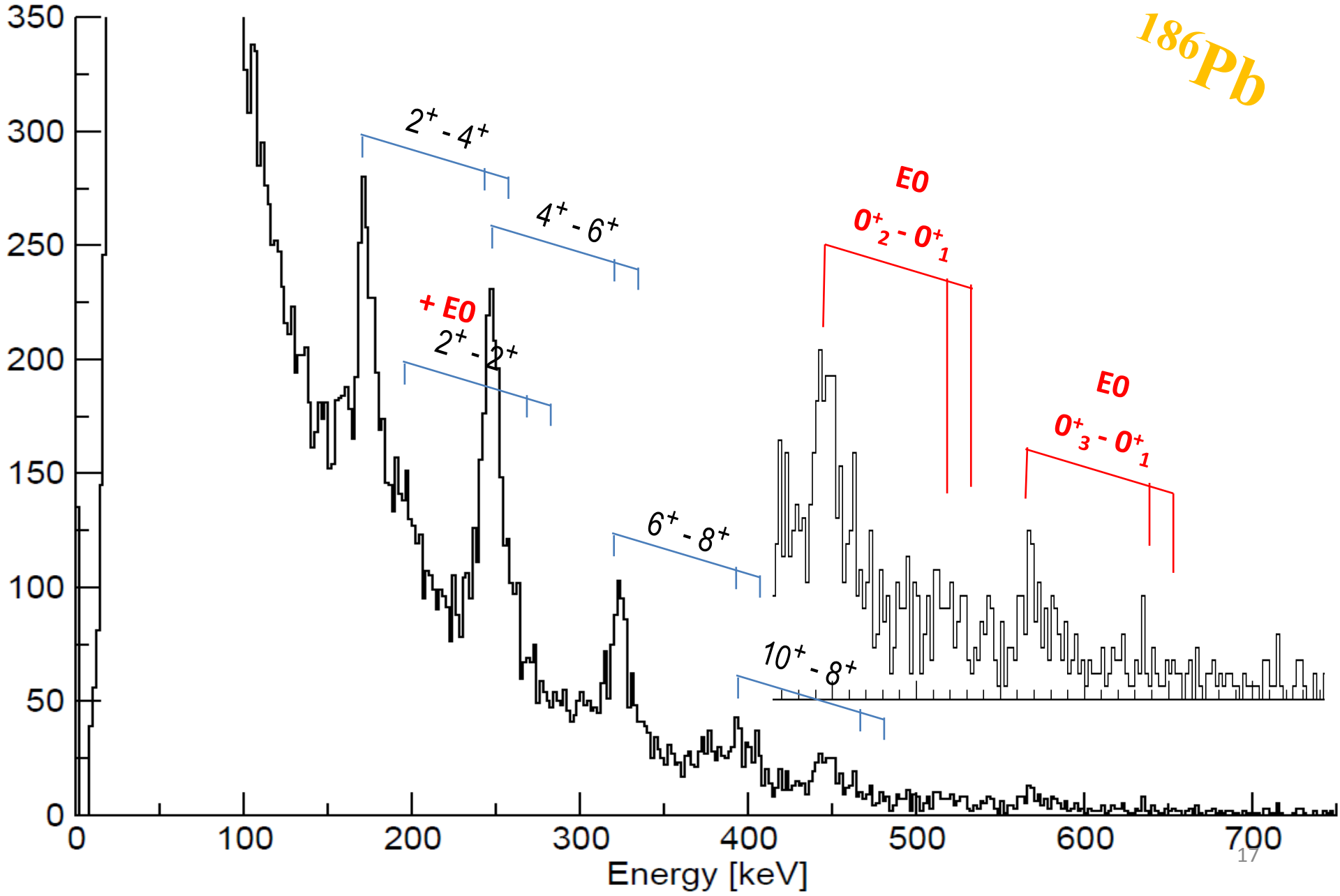
J. Pakarinen et al. PR C75, 014302, 2009



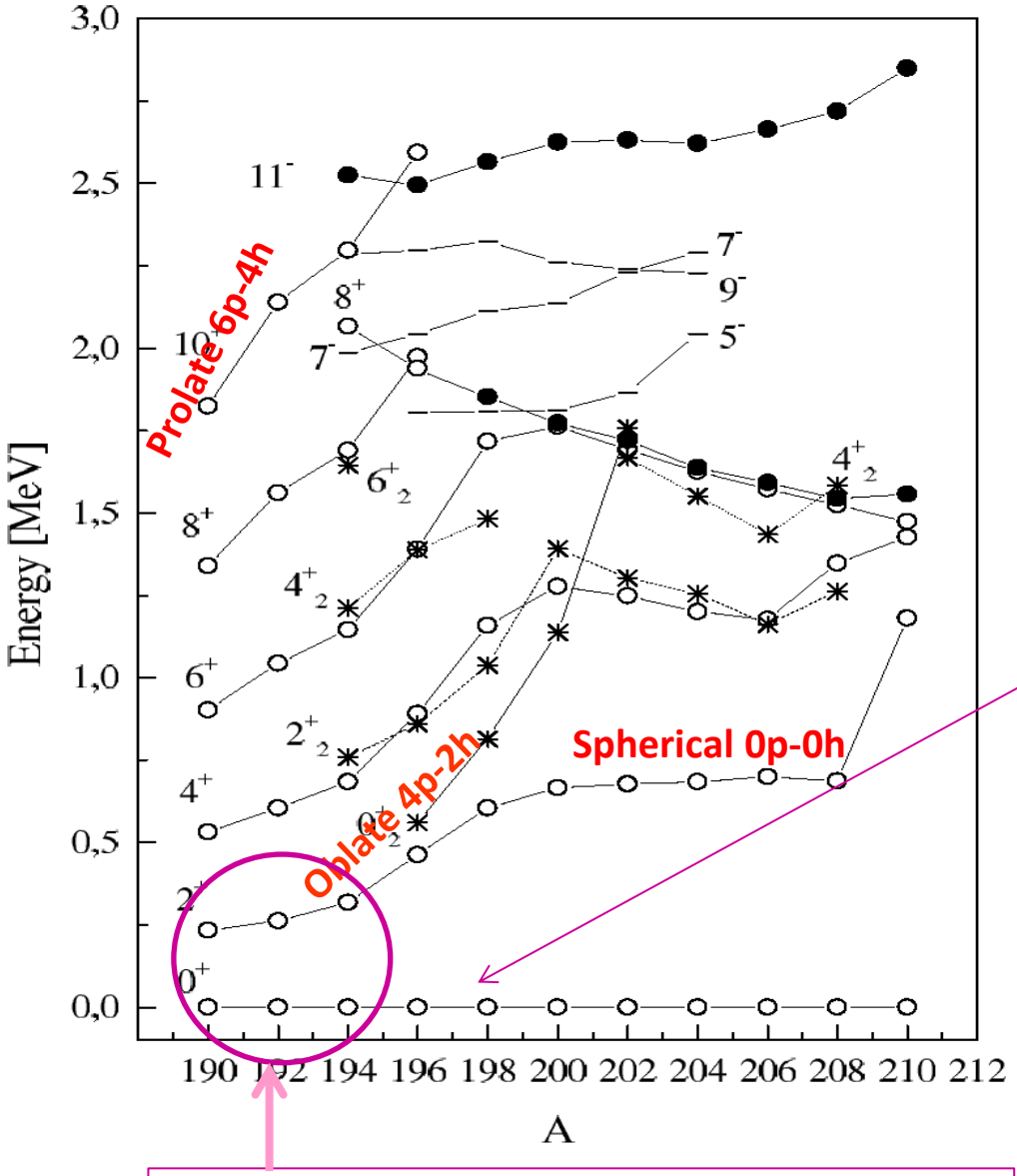
Above 1MeV ^{186}Pb looks like any deformed nucleus except ……

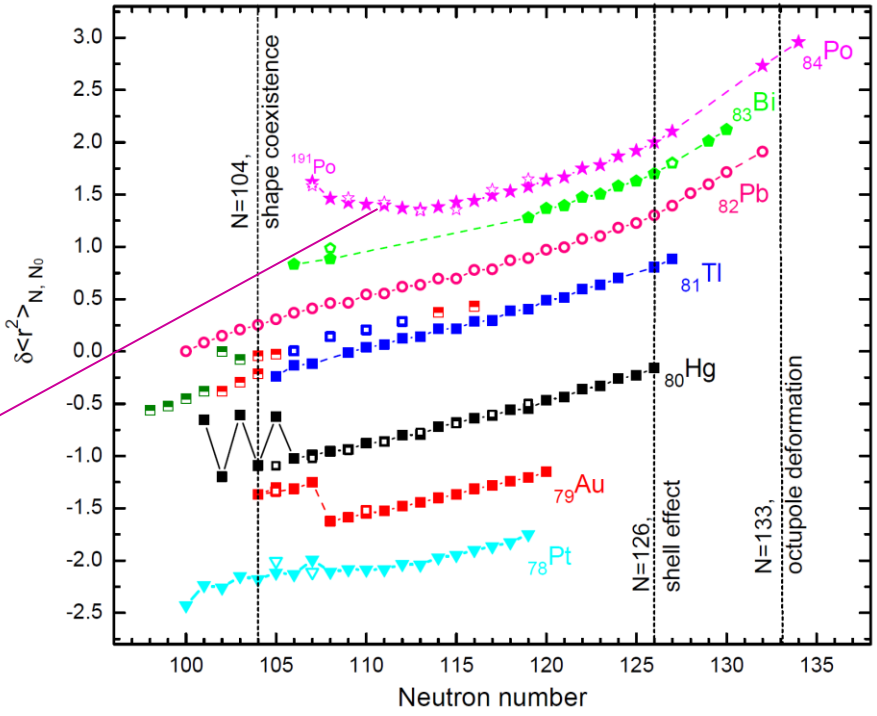
J. Pakarinen et al. PR C75, 014302, 2009

RDT singles conversion-electron spectrum (SAGE)



Triple - shape coexistence in Po isotopes (Z = 84)

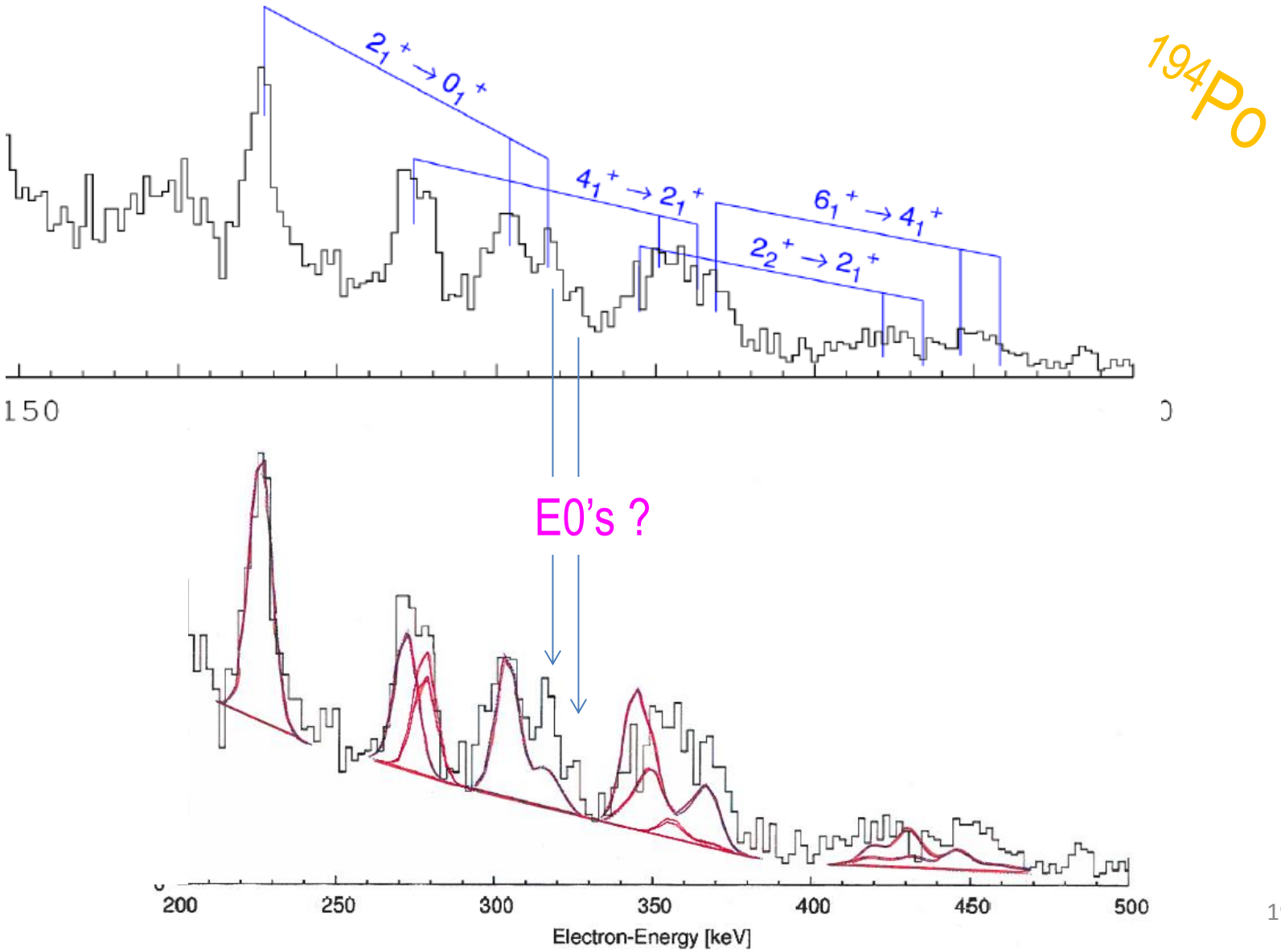




Three 0+ states close to each other ??

^{194}Po alpha-tagged singles

conversion-electron spectrum (SAGE)



Future challenges:

Analysis of the existing SAGE γ-ray and electron data + new SAGE measurements
→ E0's

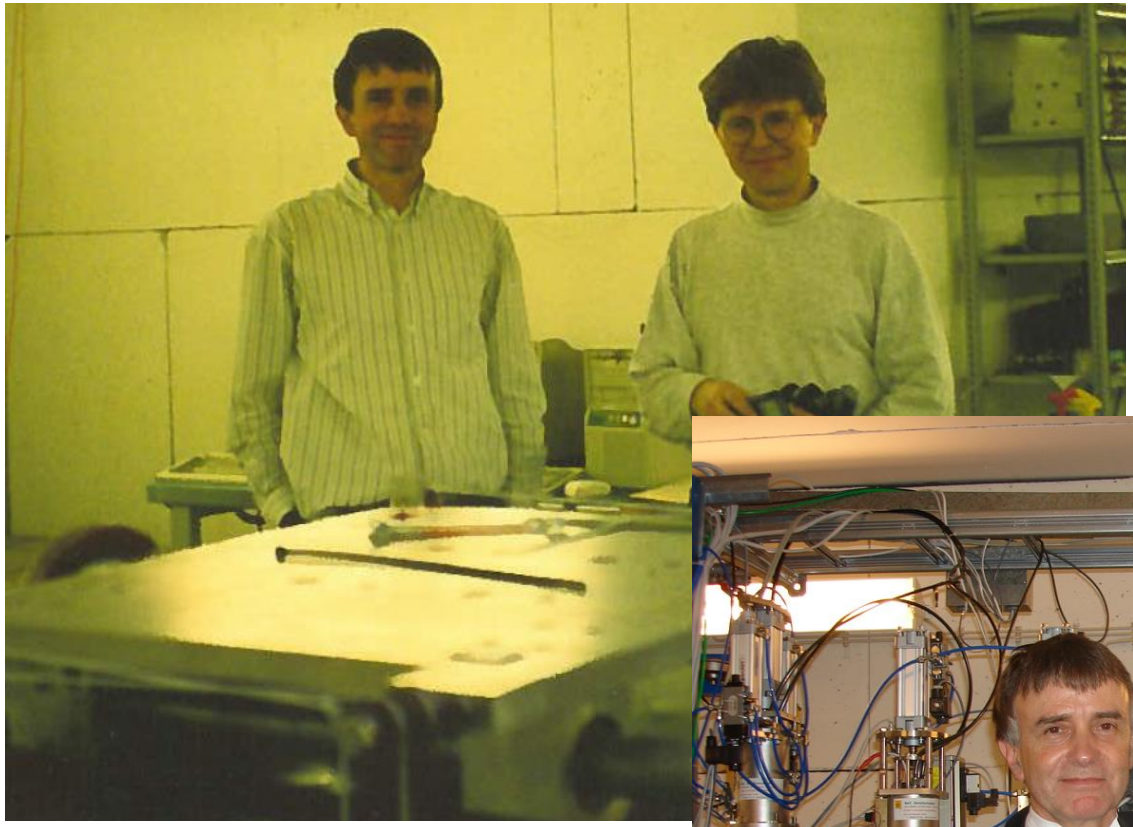
Recoil-shadow electron measurements with RDT
→ lifetimes → ρ^2 , B(E2)

Coulex with heavy RIB's
→ B(E2), ρ^2

Electron spectroscopy with RIB's (SPEDE)
→ E0's, ρ^2

Transfer reactions with heavy RIB's
→ configurations of intruder states

Peter and me since 1994



Thank you !