Isomer physics in the TSR at ISOLDE

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- radioactive beams with a difference
- nuclear structure
- atomic/nuclear interface
- beam purification by resonance ionisation

nuclear isomers

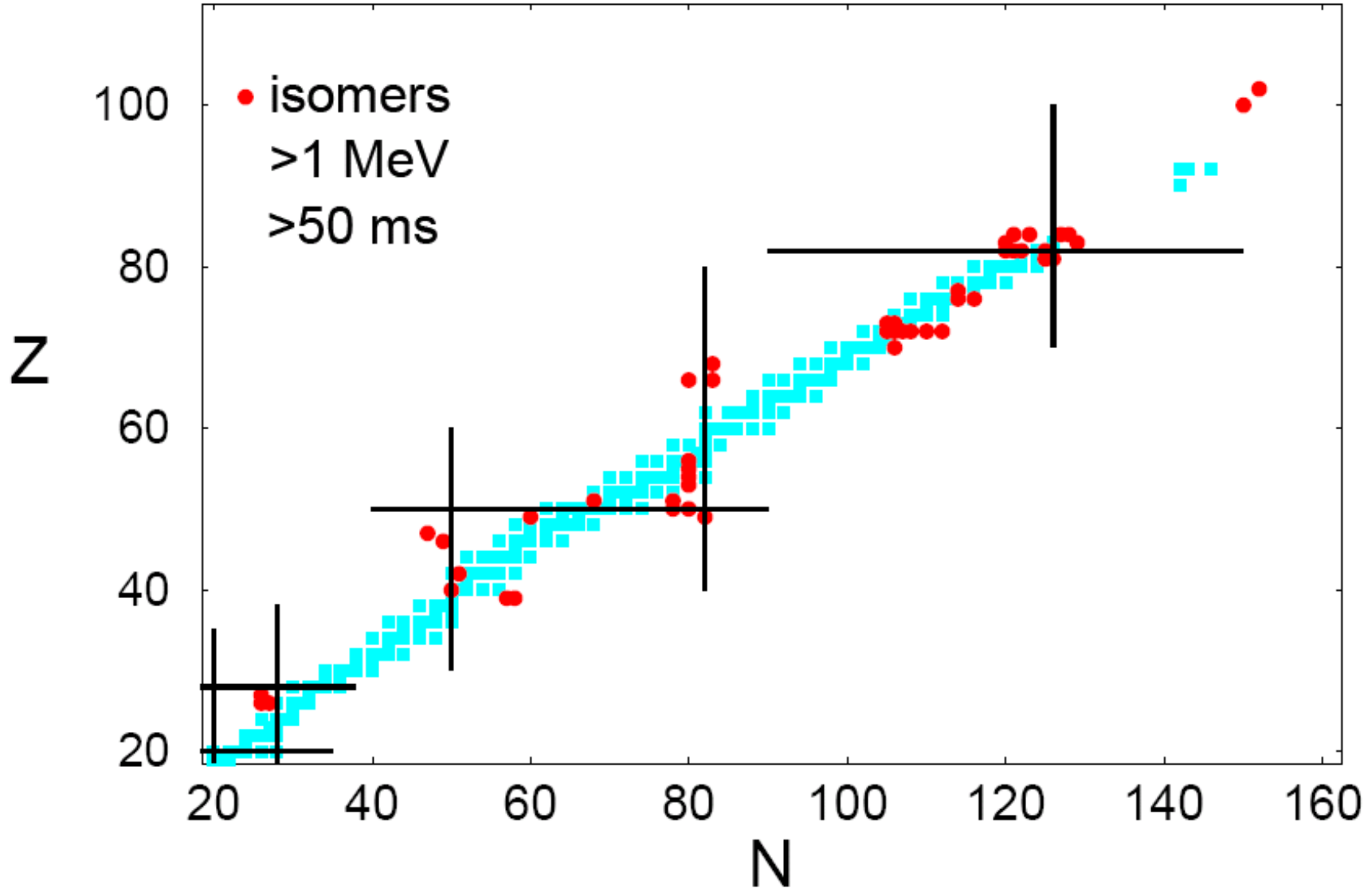
- half-life range: 1 ns to > 10^{16} years

  here: > 50 ms

- excitation-energy range: ~10 eV to ~10 MeV

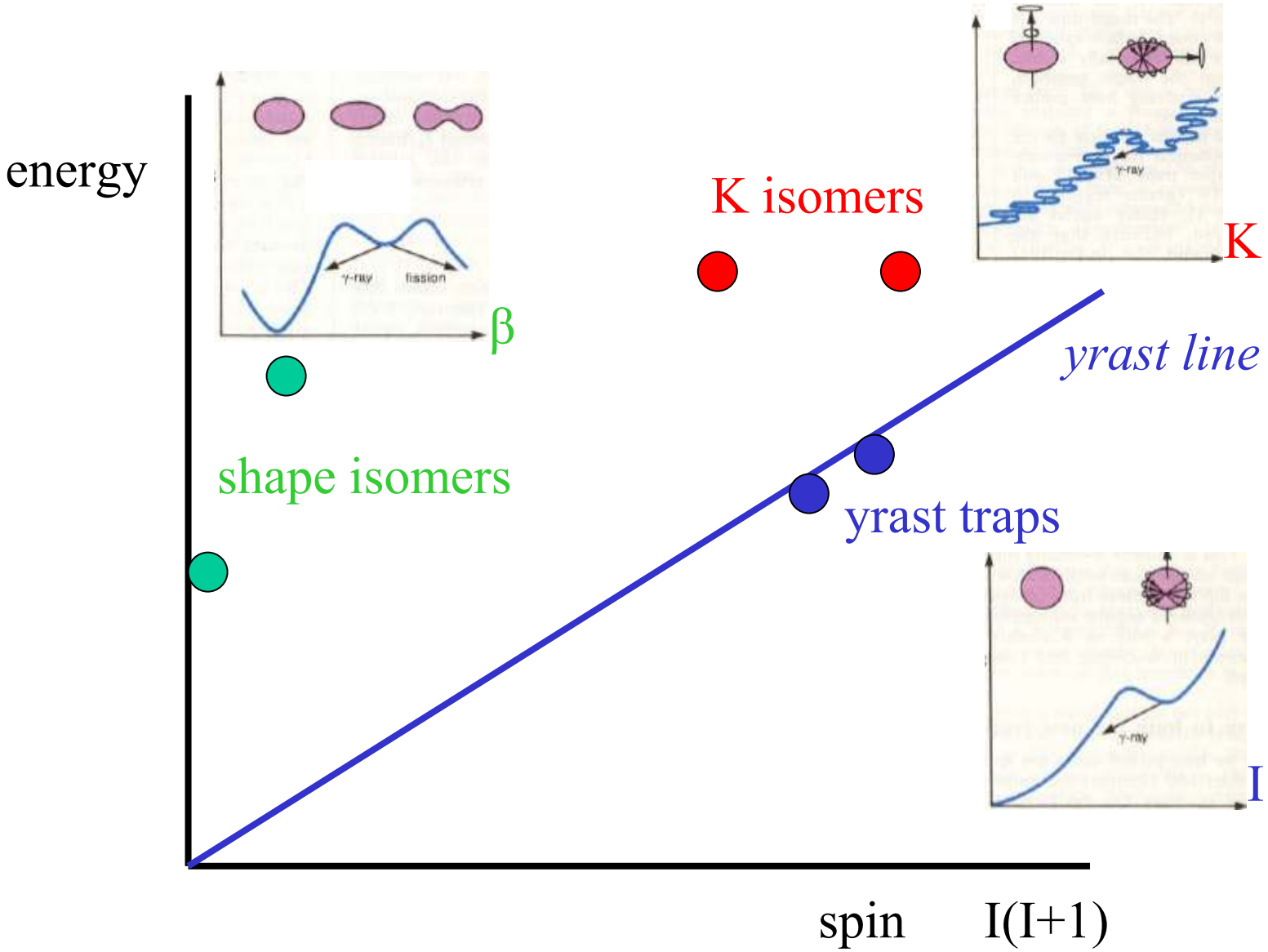
  here: > 100 keV

nuclear chart with isomers

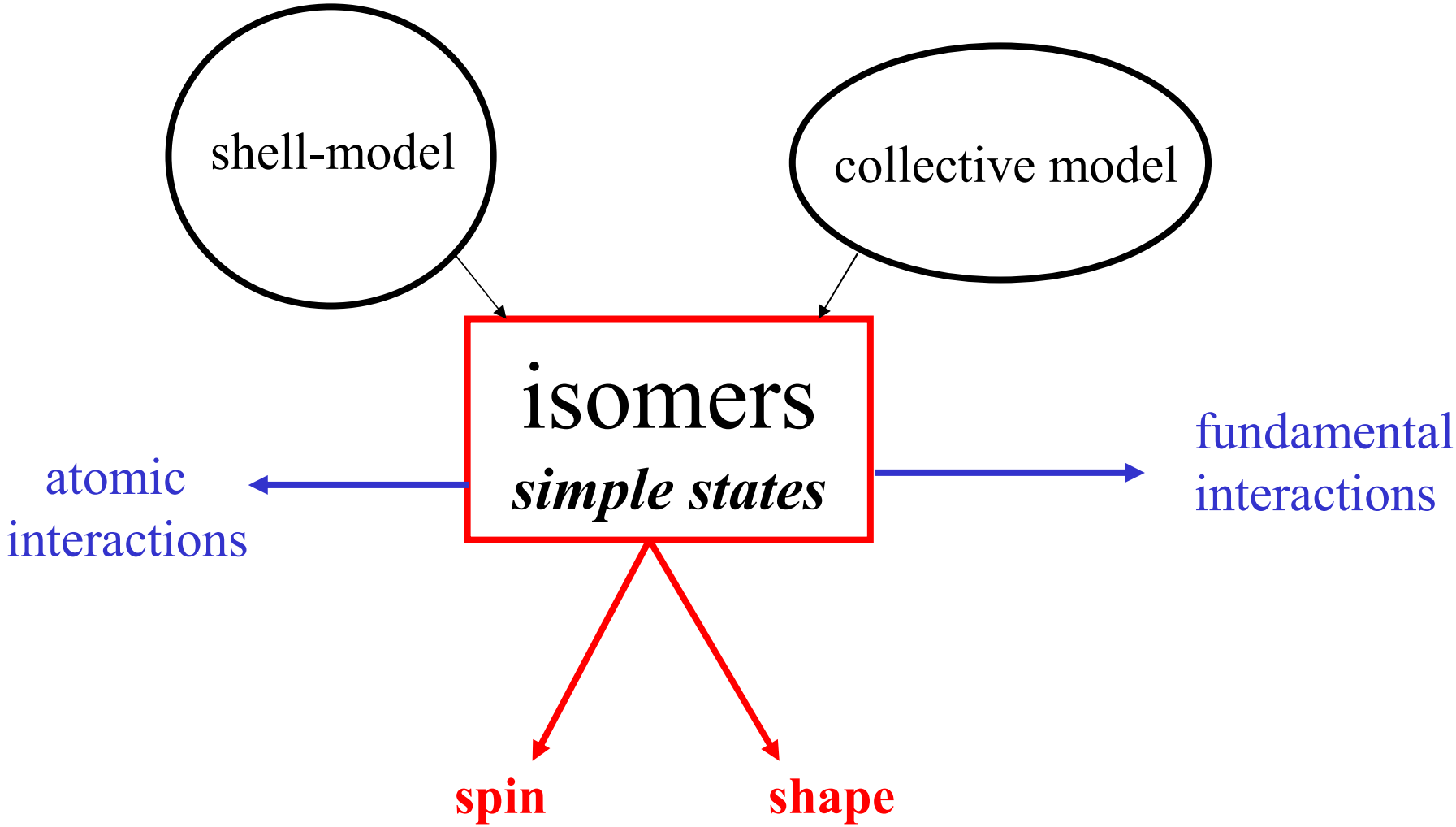


Walker, Int. J. Mod. Phys. E15 (2006) 1637; adapted from Walker and Dracoulis, Nature 399 (1999) 35

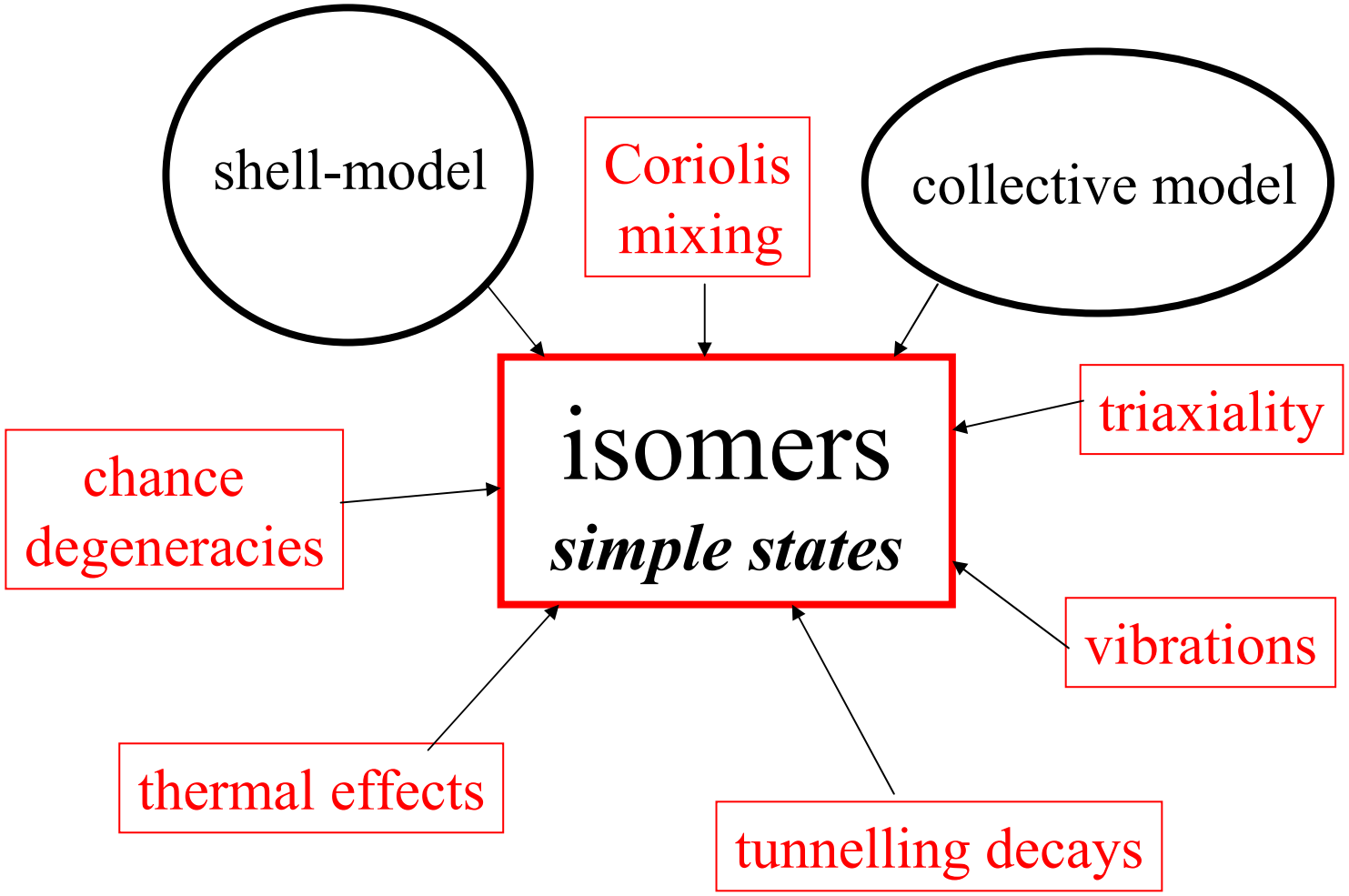
isomer beams: added dimensions



[Walker and Dracoulis, Physics World (Feb 1994) 39]


shell-model
collective model
isomers
simple states
atomic interactions
fundamental interactions
spin
shape

“forbidden” decays => sensitivity to different physics



... and "stepping stones" to the nuclear limits ...

TSR aspects

(i) Exotic isomers yet to be identified
(ii) Nuclear reactions with pure isomeric beams
(iii) Exploiting isomers to study the atomic/nuclear interface

Grieser et al., Eur. Phys. J. Special Topics 207 (2012) 1–117

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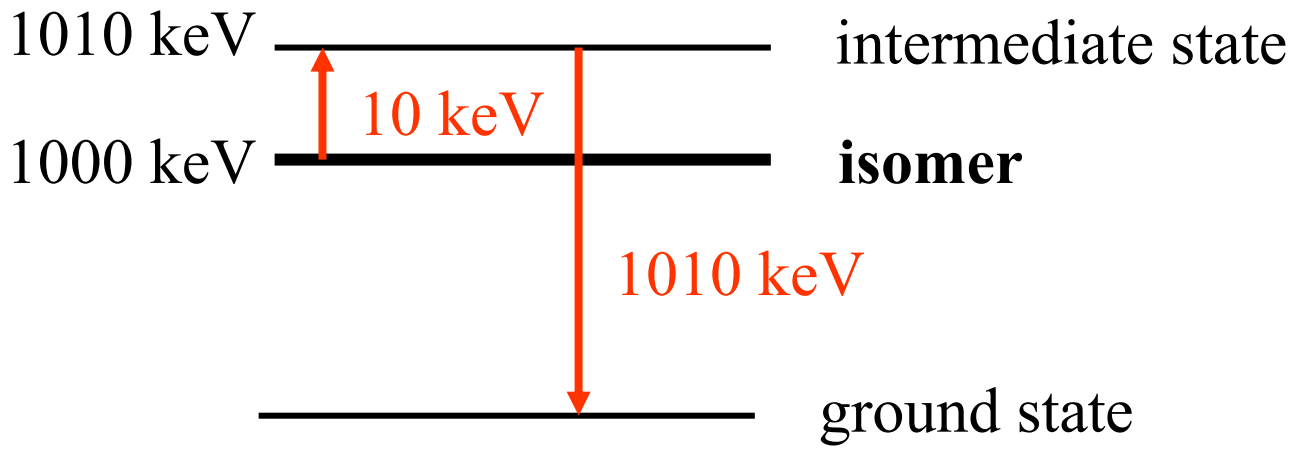
photo-induced isomer de-excitation

a unique aspect of isomers

conceptual picture:



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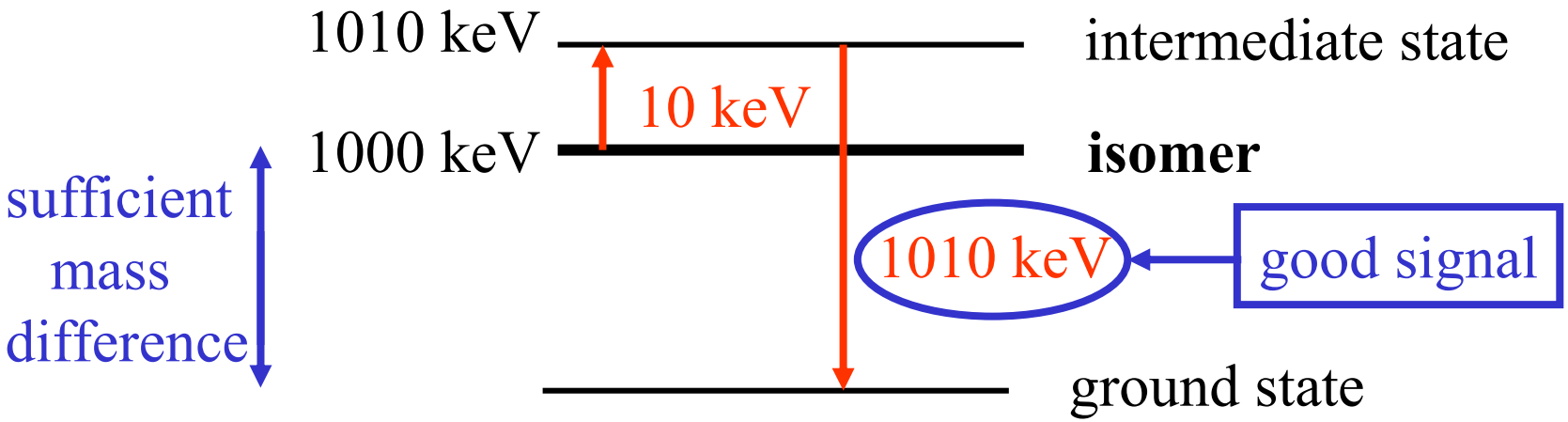


photo-induced isomer de-excitation

a unique aspect of isomers

nuclear astrophysics

nuclear structure

atomic/nuclear interface

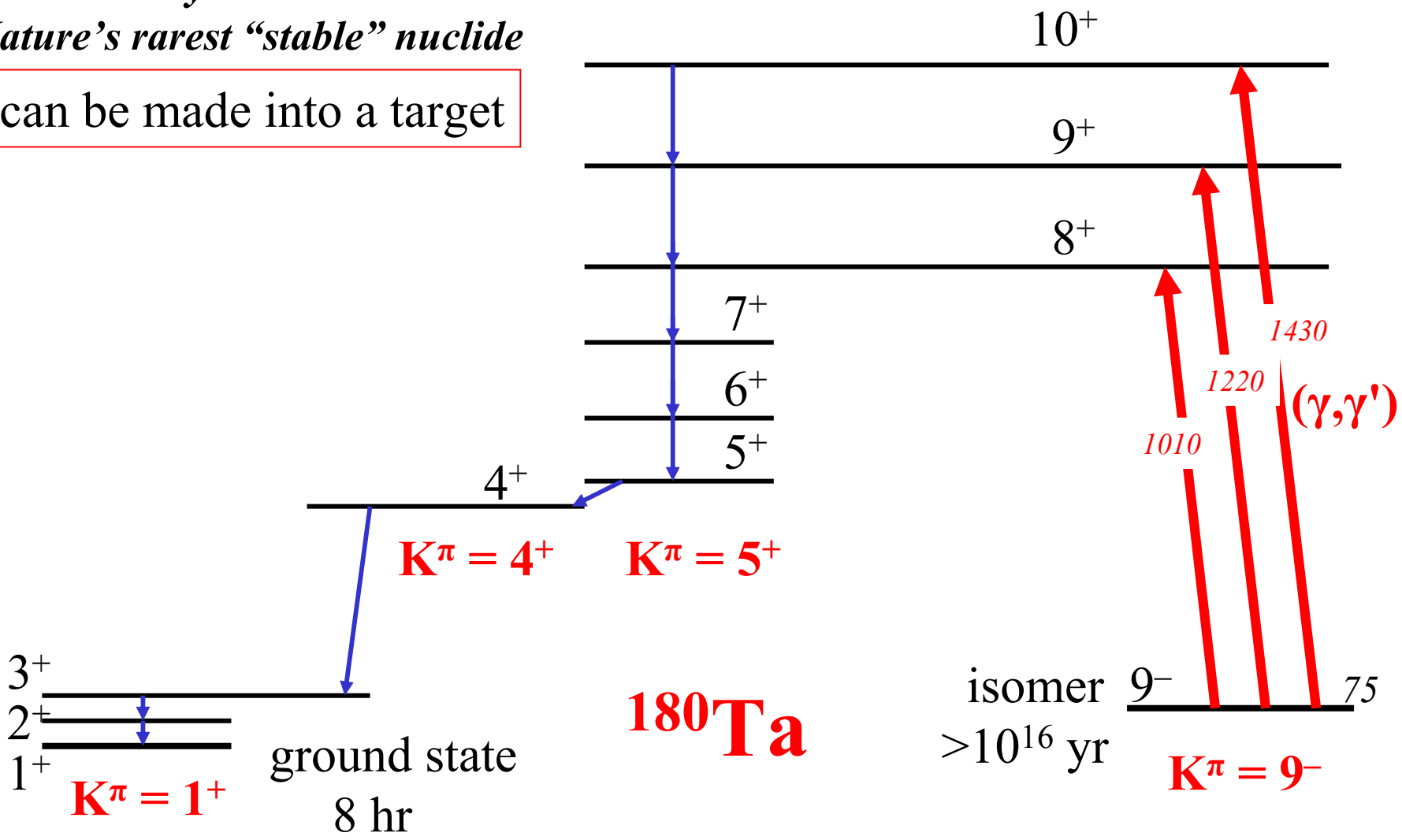
nuclear batteries?

γ-ray lasers?

^{180m}Ta photo-excitation and decay

Nature's only "stable" isomer
Nature's rarest "stable" nuclide

can be made into a target

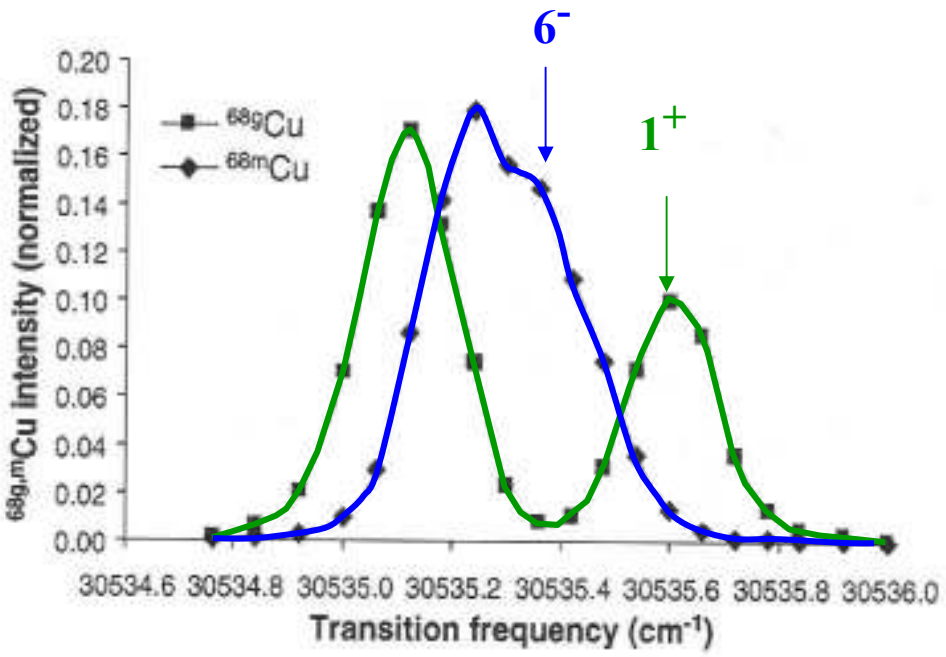


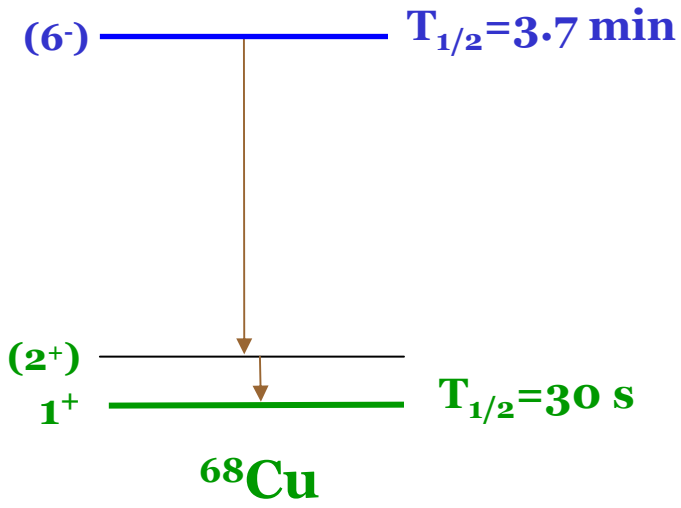
[Walker et al., Phys. Rev. C64 (2001) 061302(R)]

^{68m}Cu: production of isomeric beams

I. Stefanescu et al., Phys. Rev. Lett. 98 (2007) 122701 at CERN-ISOLDE

Example: ^{68}Cu using laser resonance ionisation



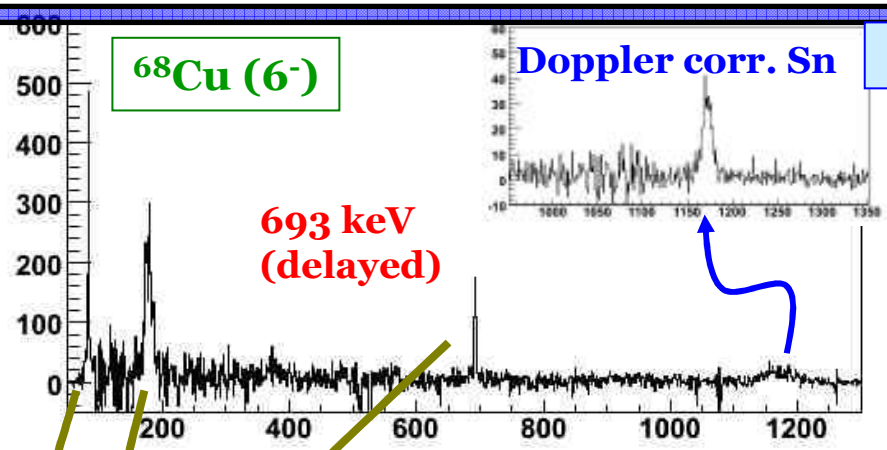


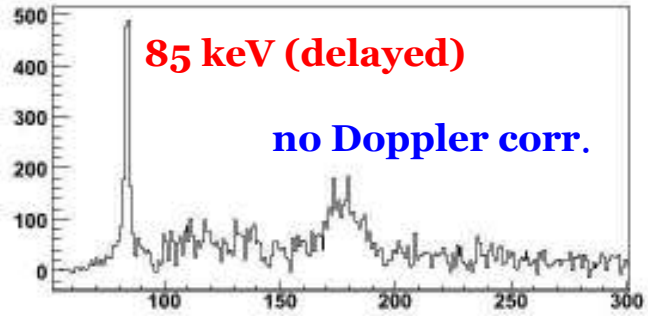
U. Koester et al., NIMB167(2000)528
^{70}Cu: J. Van Roosbroeck et al., PRL92(2004)112501

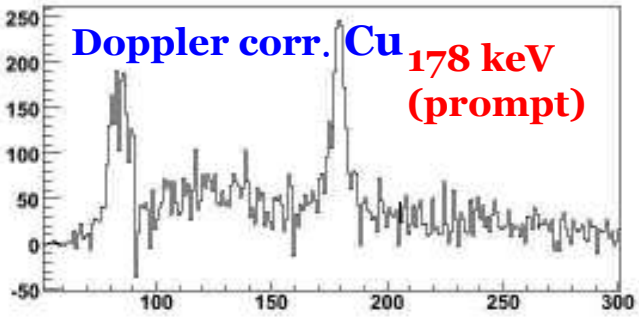
Coulomb excitation of ^{68m}Cu

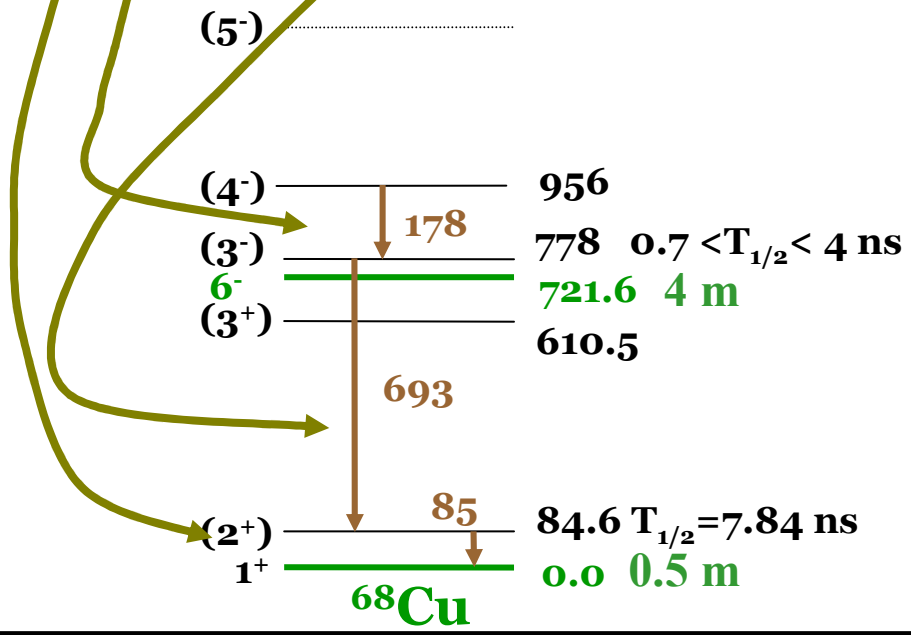
I. Stefanescu et al., Phys. Rev. Lett. 98 (2007) 122701 at CERN-ISOLDE

➢ ^{68,m}Cu (2.86 MeV/u) @ ^{120}Sn (2.3 mg/cm^2)

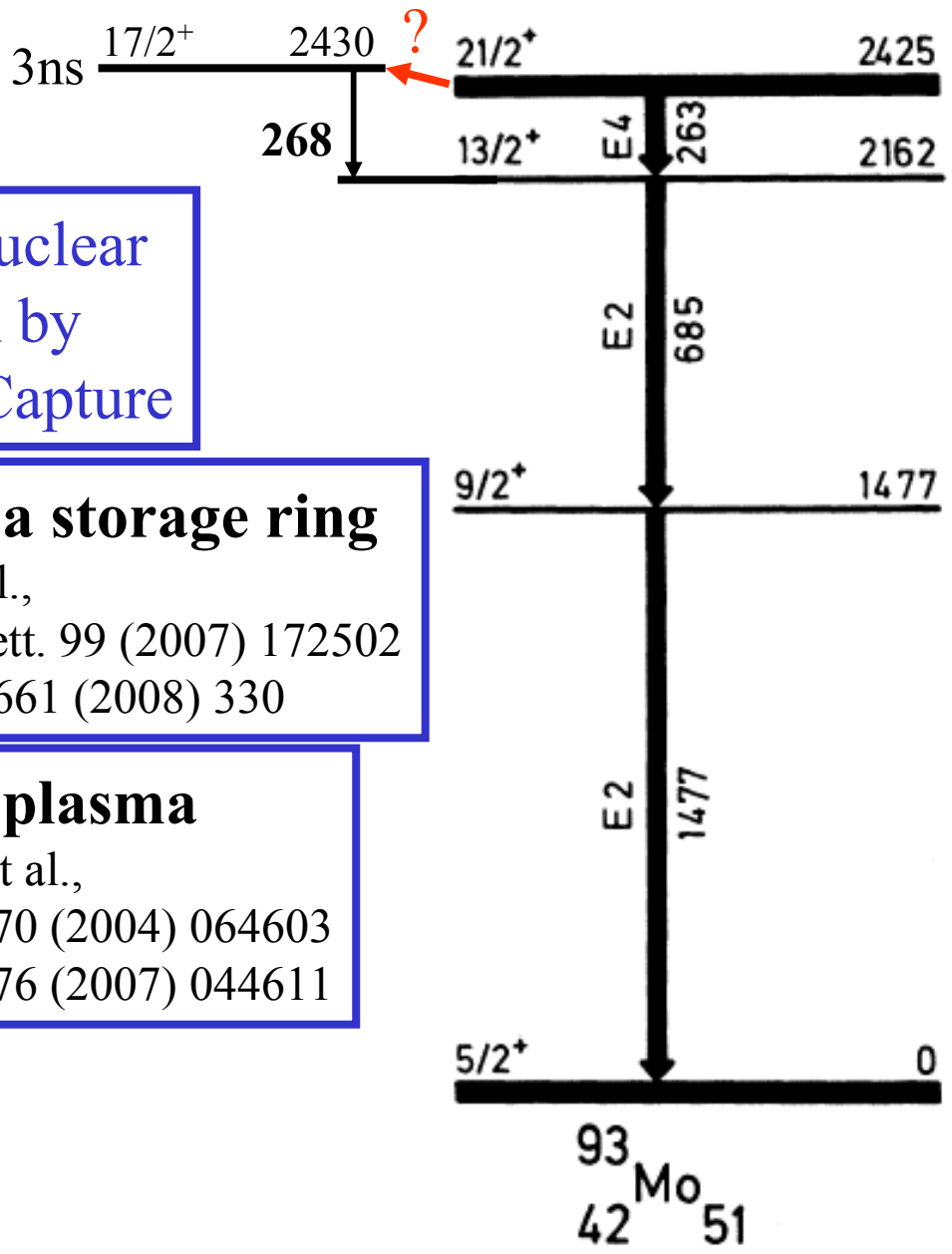








^{93}Mo



Role of Nuclear Excitation by Electron Capture

NEEC in a storage ring

A. Palffy et al.,
Phys. Rev. Lett. 99 (2007) 172502
Phys. Lett. B661 (2008) 330

NEEC in plasma

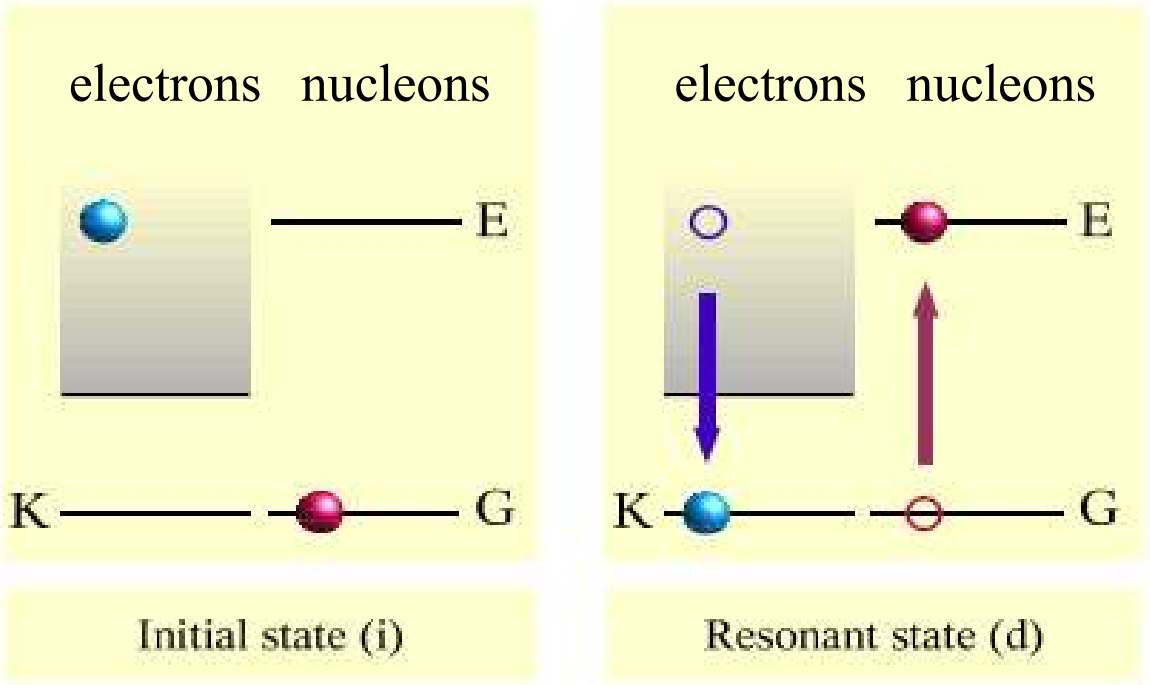
G. Gosselin et al.,
Phys. Rev. C70 (2004) 064603
Phys. Rev. C76 (2007) 044611

possible 5 keV transition to release 2.4 MeV

[Hagn et al., Phys. Rev. C23 (1981) 2252]

Nuclear Excitation by Electron Capture

an as-yet unobserved process

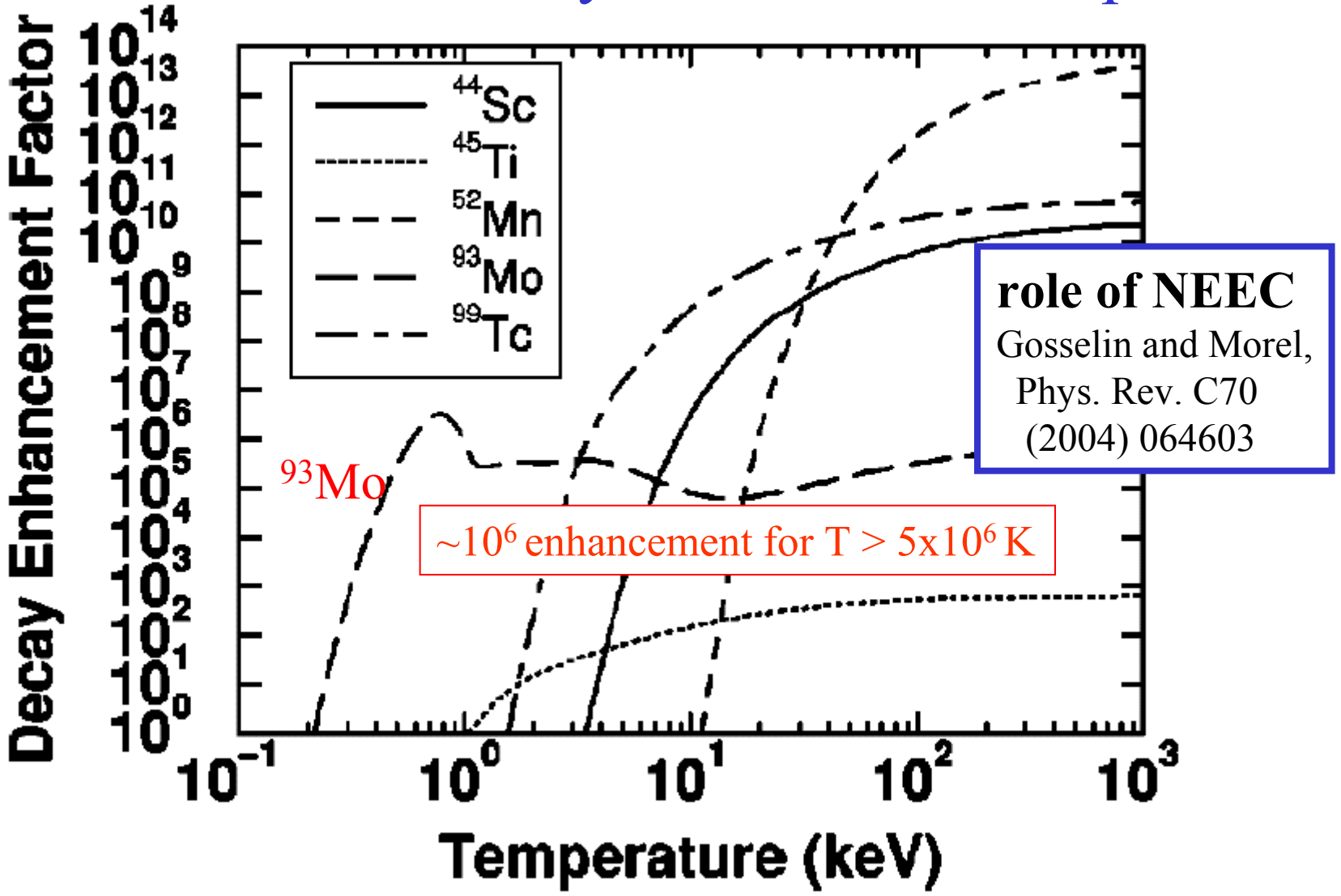


difficulty: NEEC competes with much stronger, but non-resonant process of radiative capture: X-ray emitted, instead of nuclear excitation.

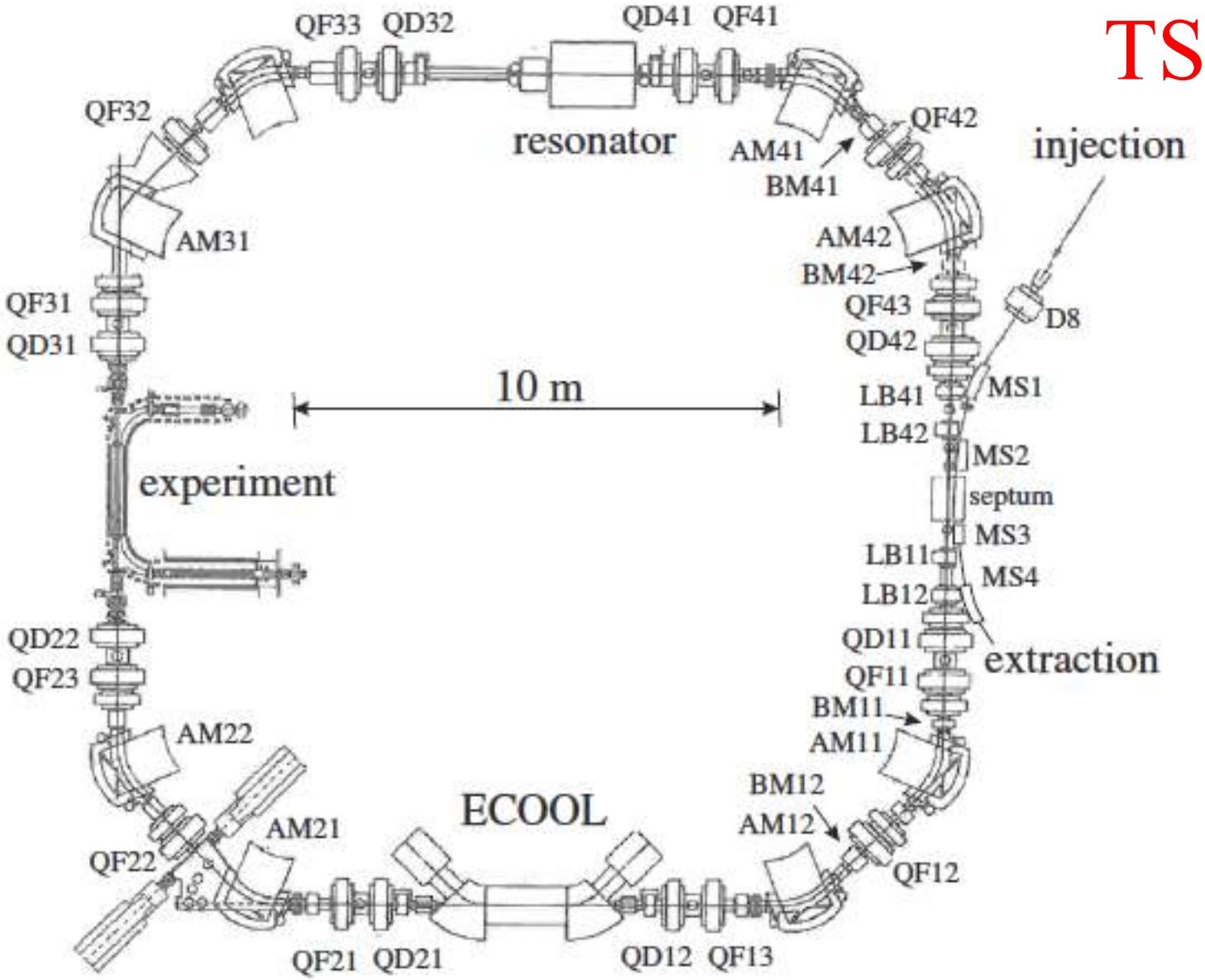
- nuclear analogue of dielectronic recombination
- inverse of electron conversion

[A. Palffy et al., Phys. Rev. Lett. 99 (2007) 172502]

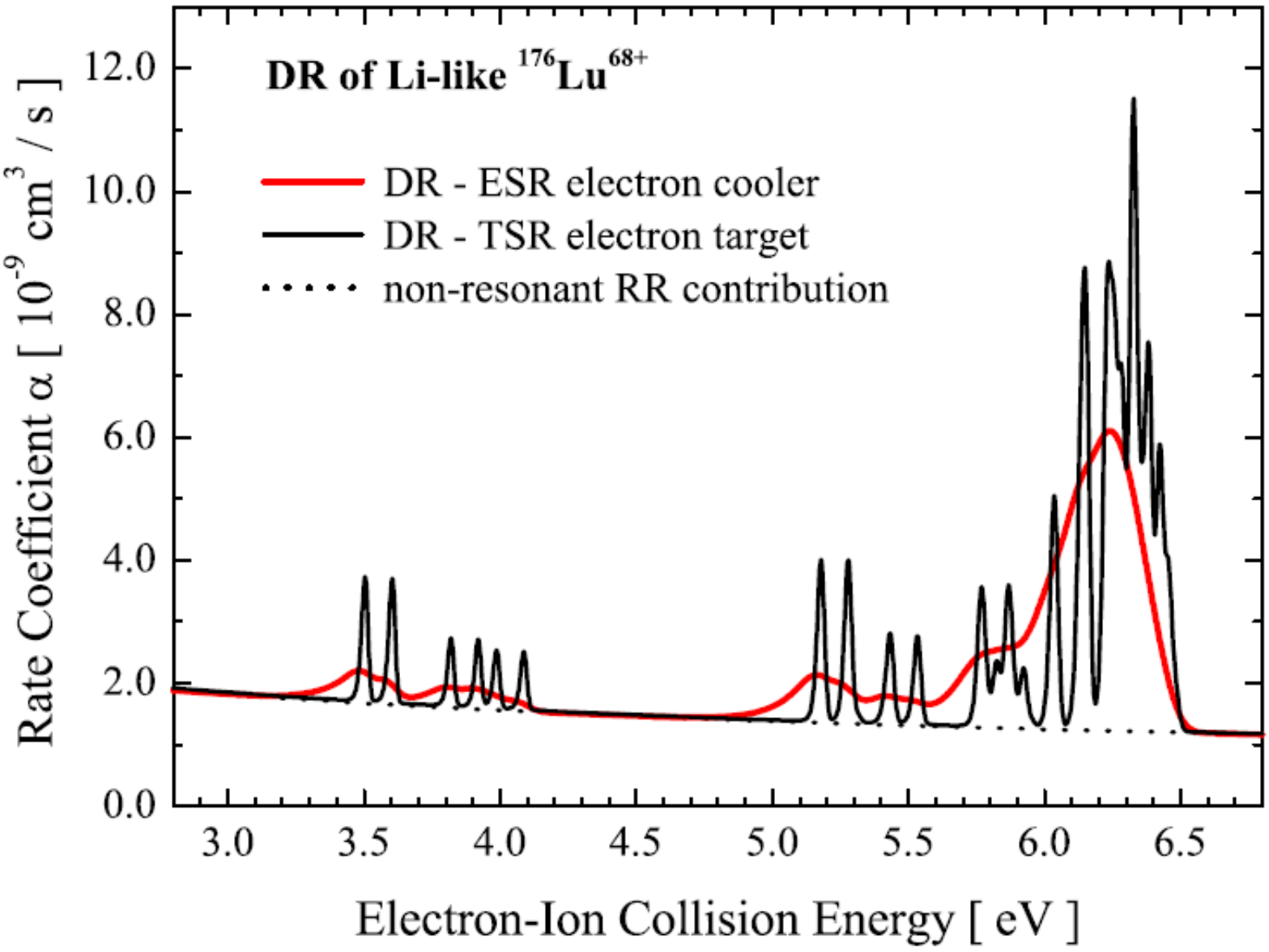
Enhanced isomer decay rate in hot dense plasma



TSR layout

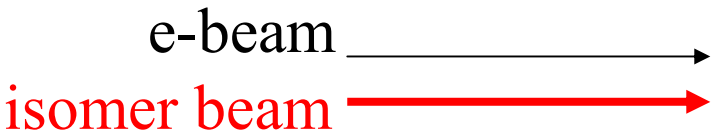


Grieser et al., Eur. Phys. J. Special Topics 207 (2012) 1–117

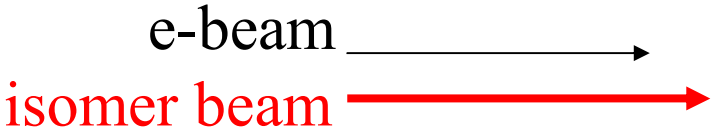


Grieser et al., Eur. Phys. J. Special Topics 207 (2012) 1–117

ion-electron interactions



~equal velocities
=> cooling

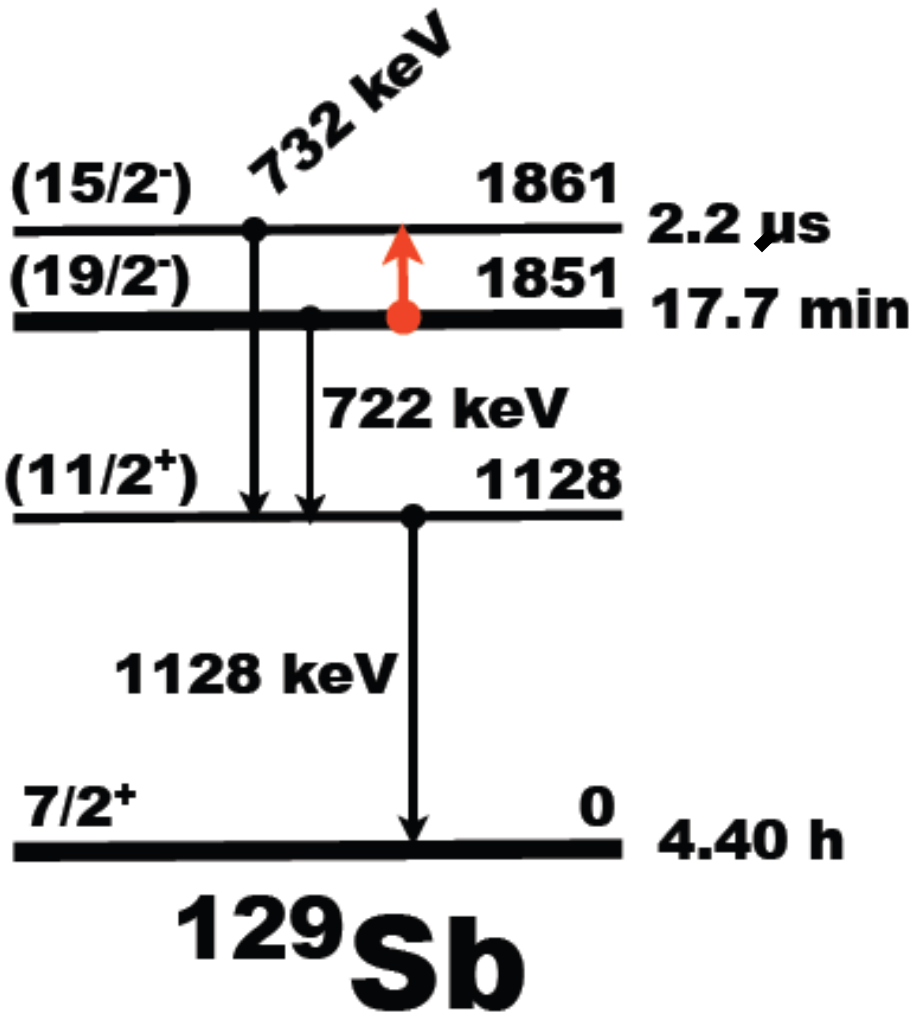


offset velocities
=> possibility of
resonant nuclear excitation
(NEEC)

signal: (i) frequency change that corresponds to "simultaneous"
electron capture and isomer de-excitation
(ii) deflected ions associated with changed charge state
(iii) delayed coincidences with gamma rays

The case of ^{129}Sb

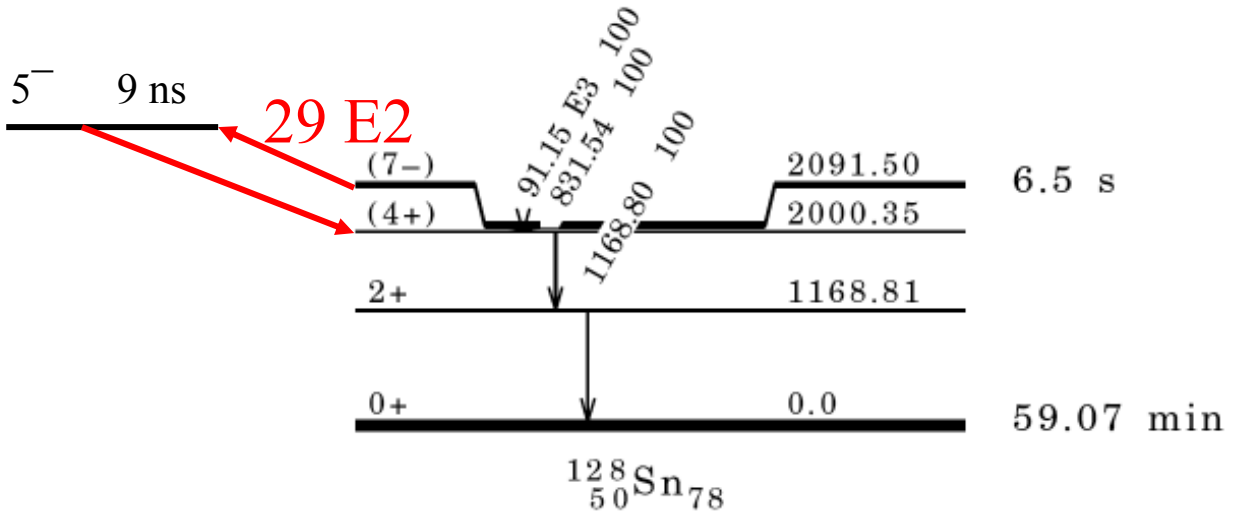
possible **10 keV** transition to release 1.9 MeV



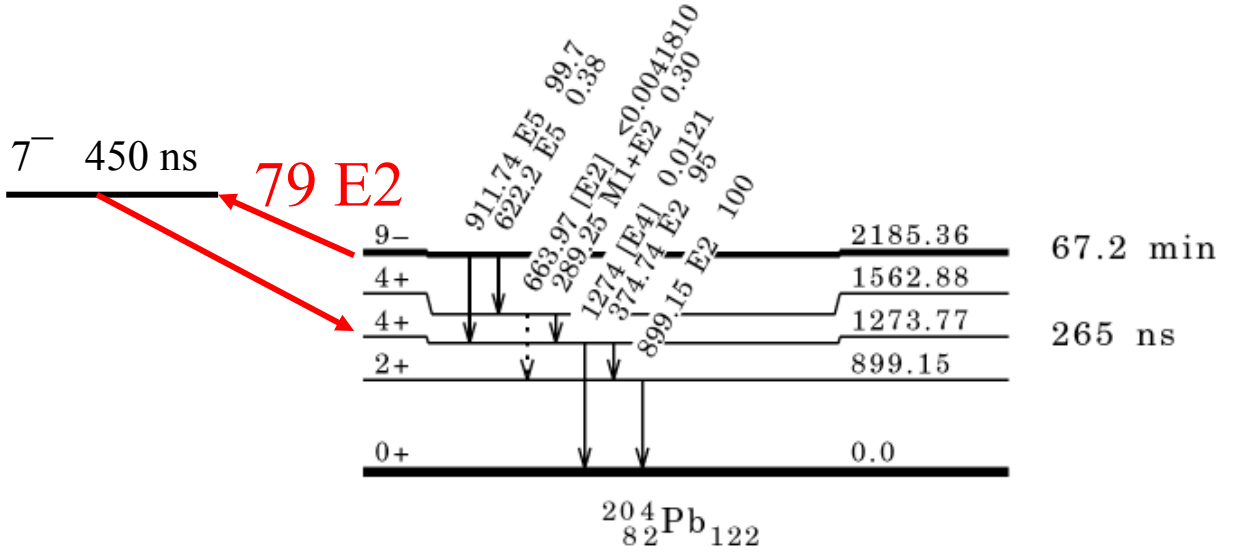
Physics case
CRYRING@ESR

other candidate isomers

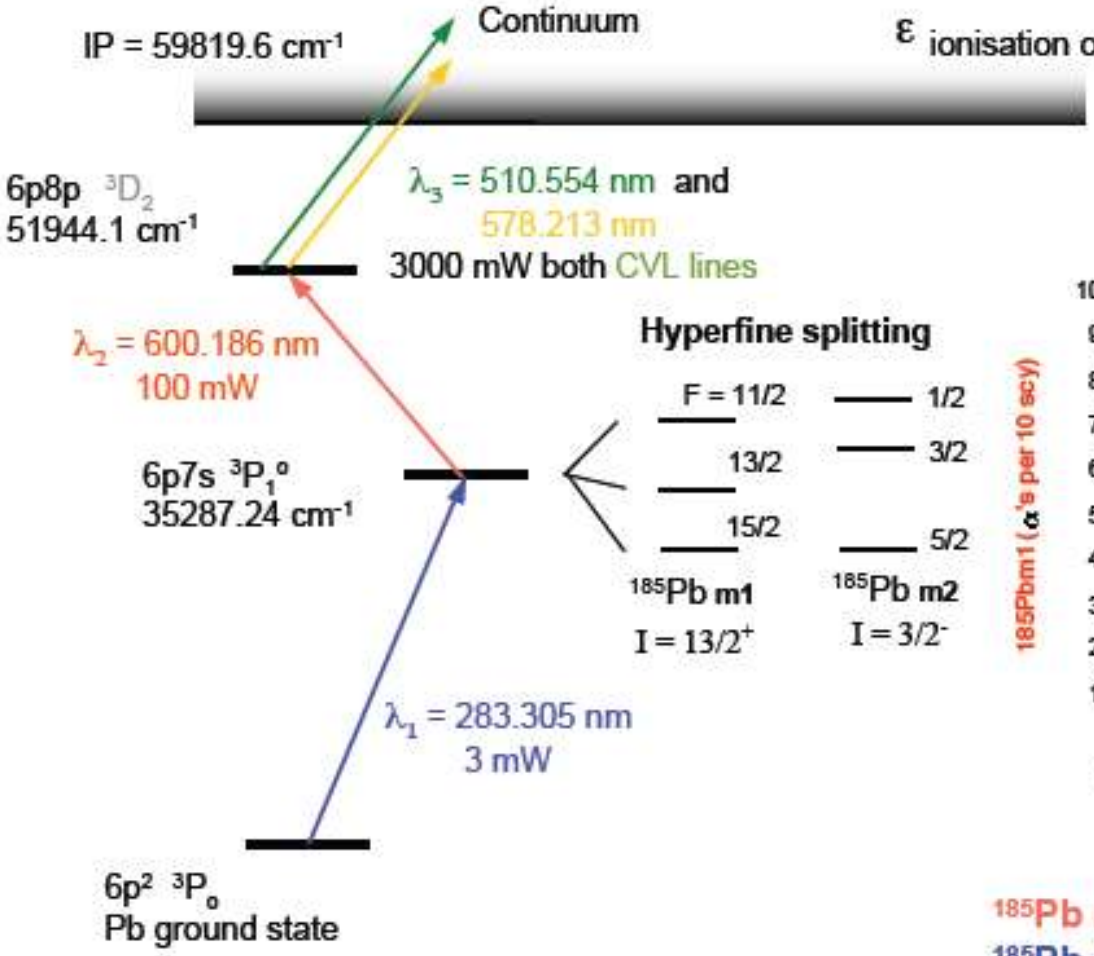
^{128m}Sn



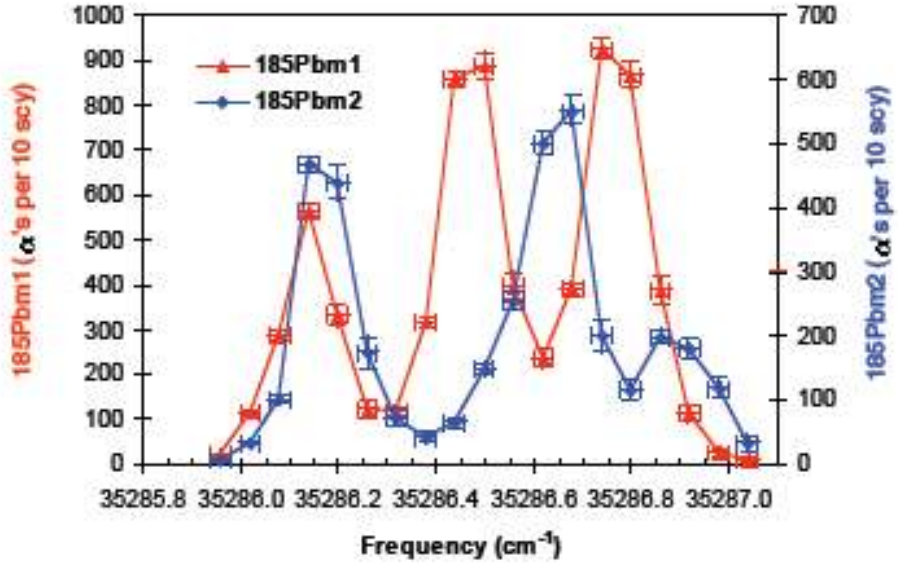
^{204m}Pb



Lead RILIS excitation and laser-spectroscopy



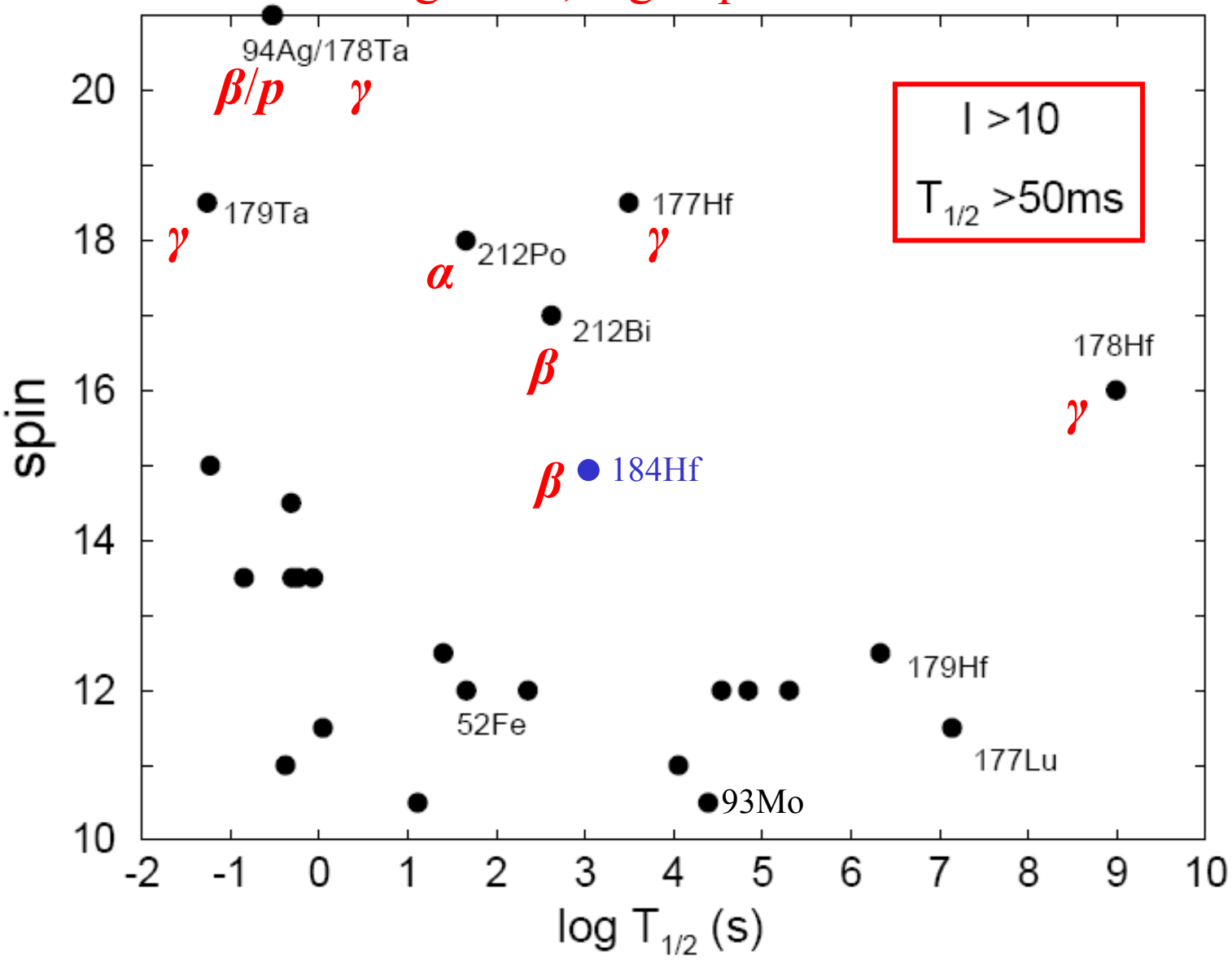
Scan of laser frequency λ_1



^{185}Pb m1 - α- particles of **6.406 MeV**
^{185}Pb m2 - α- particles of **6.290 MeV** and **6.485 MeV**

E.B. Saloman et al., Spectrochim. Acta 45B (1990) 37.
M. Anselment et al., Nucl. Phys. A451 (1986) 471.

long-lived, high-spin isomers



[adapted from: Walker and Dracoulis, Hyp. Int. 135 (2001) 83]

in conclusion – stored isomers

- electromagnetic de-excitation – unique to isomers
- highly charged ions in a storage ring – unique probe
- search for the NEEC process
- many nuclear structure issues ...

Thanks to Carsten Brandau,
George Dracoulis and Yuri Litvinov