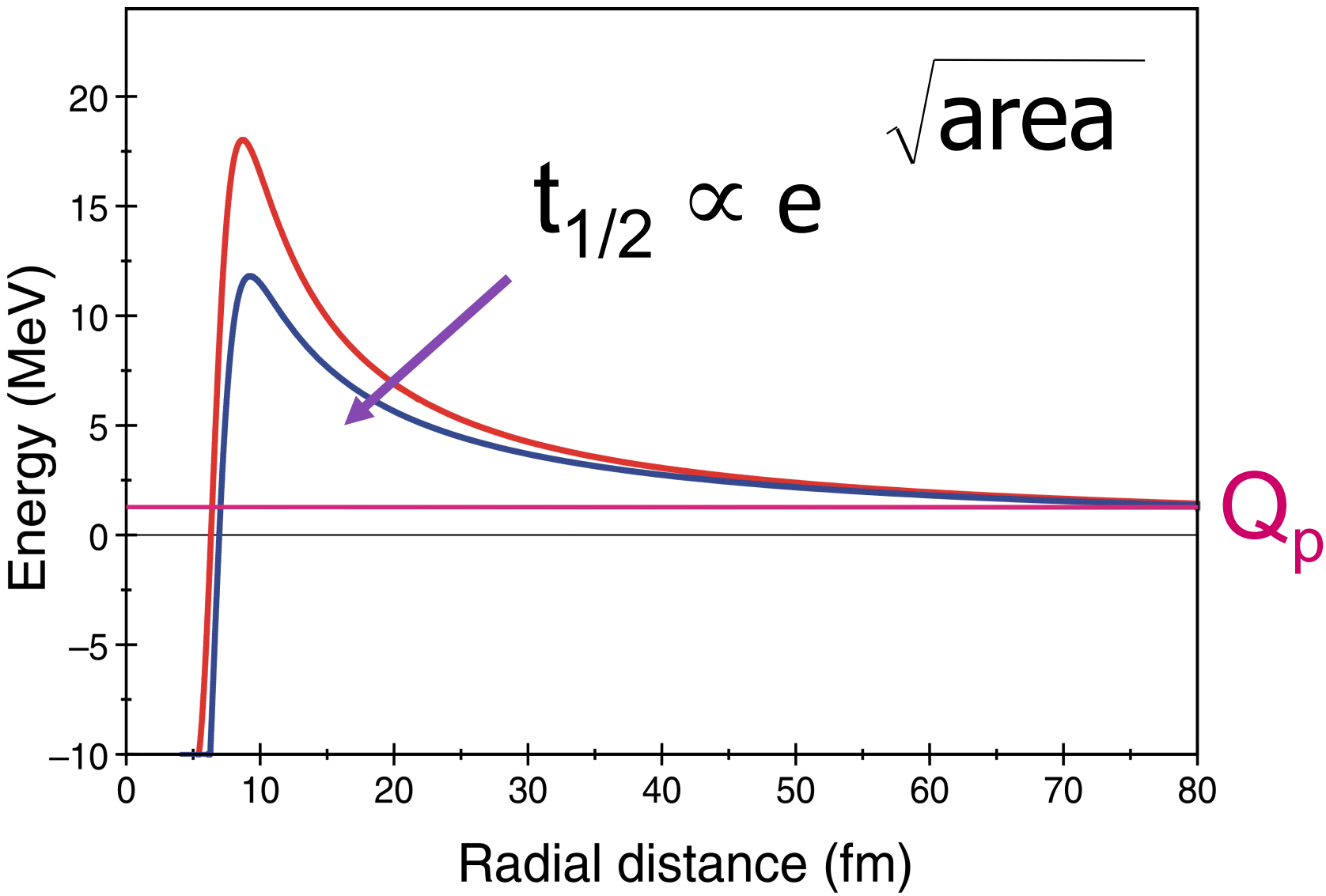
Proton emission - new results and future prospects

- Introduction
- A brief history
- New results
- Future prospects

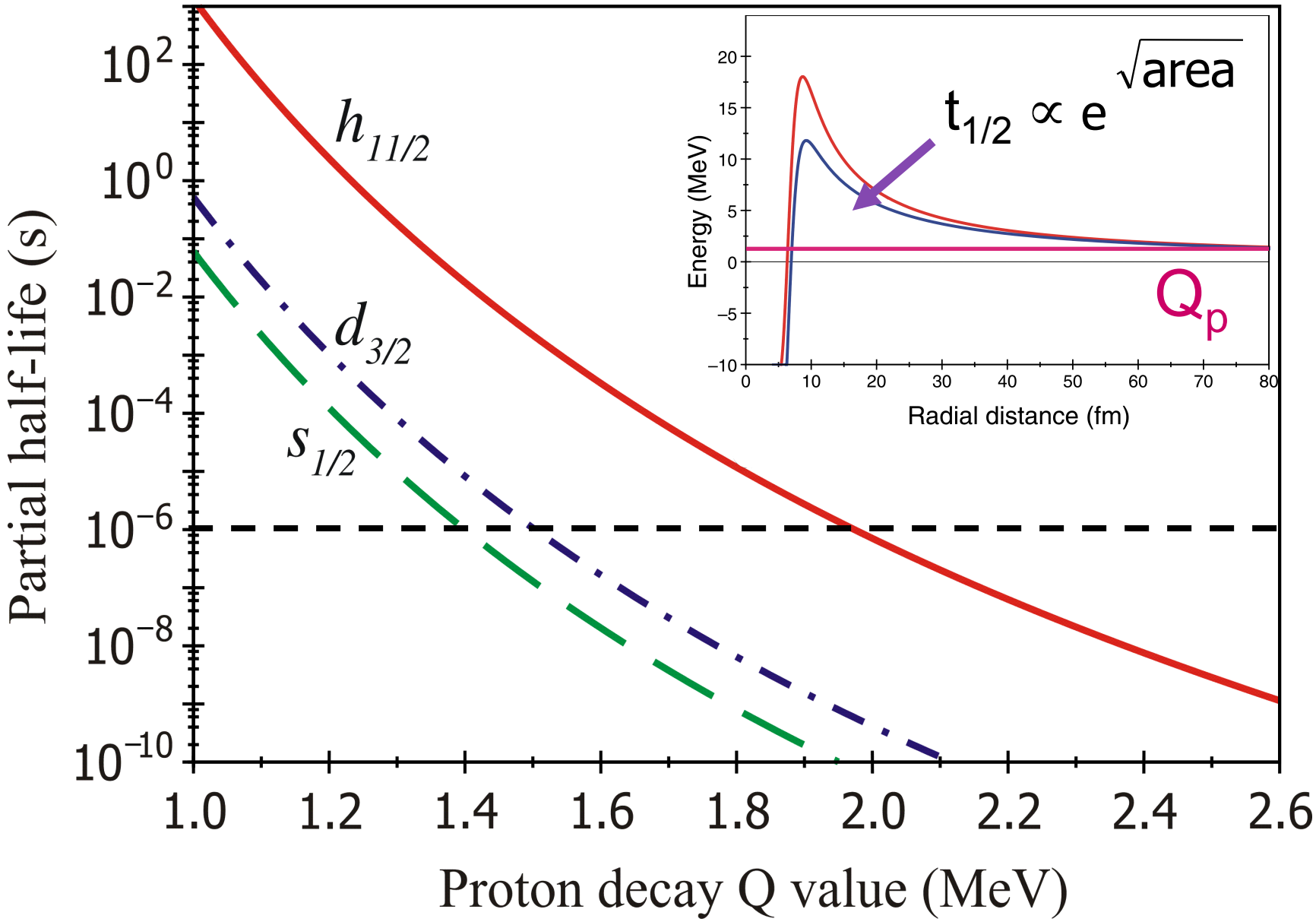
UNIVERSITY OF LIVERPOOL

Robert Page

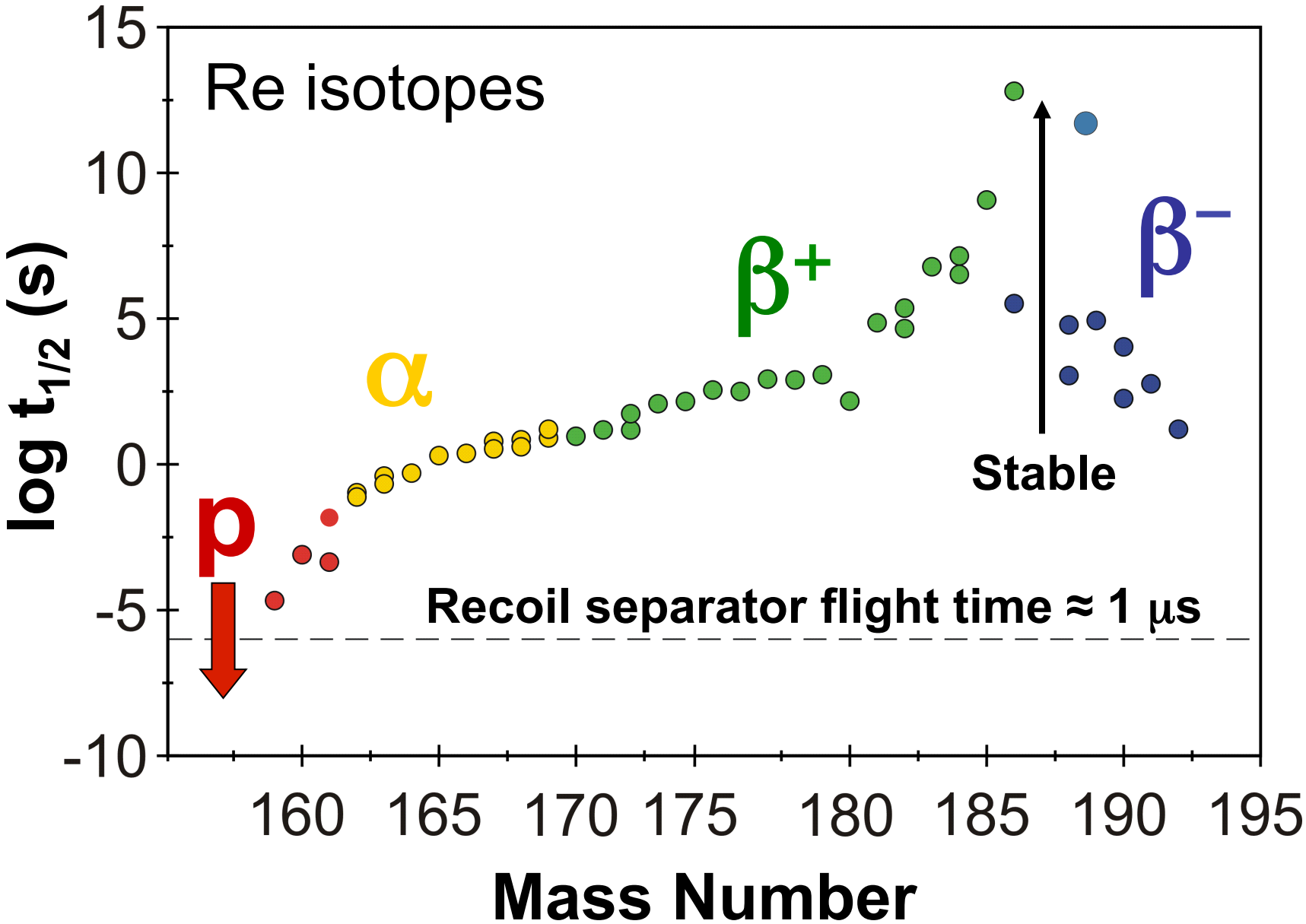
Proton emission – a simple process



Proton emission as a spectroscopic tool

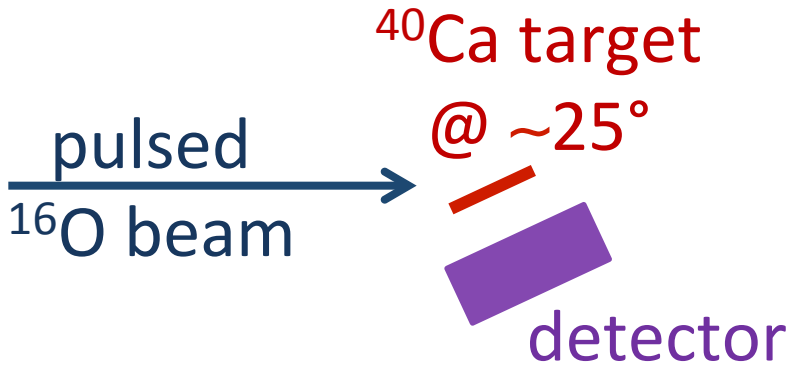


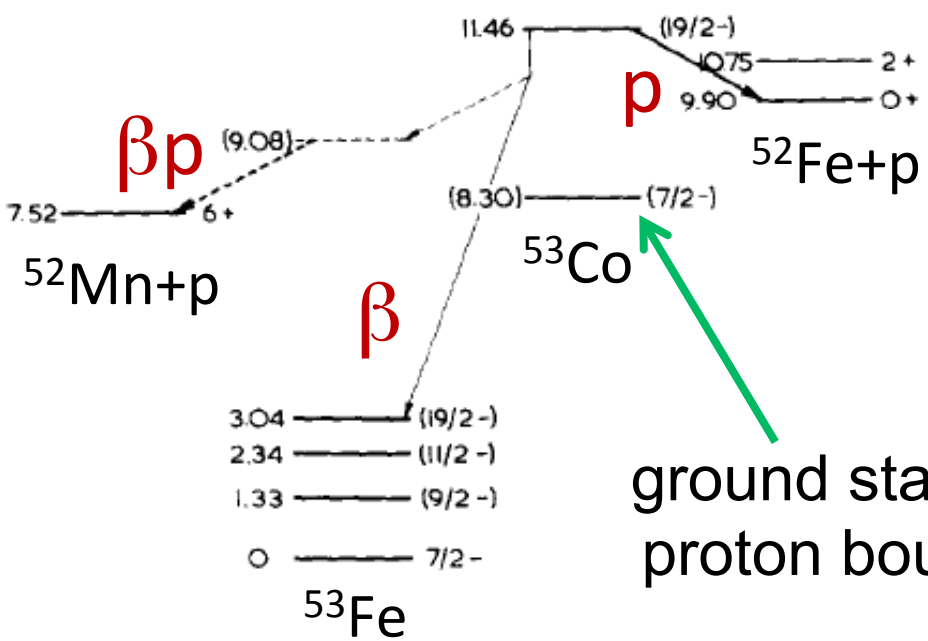
Limits of observable nuclei



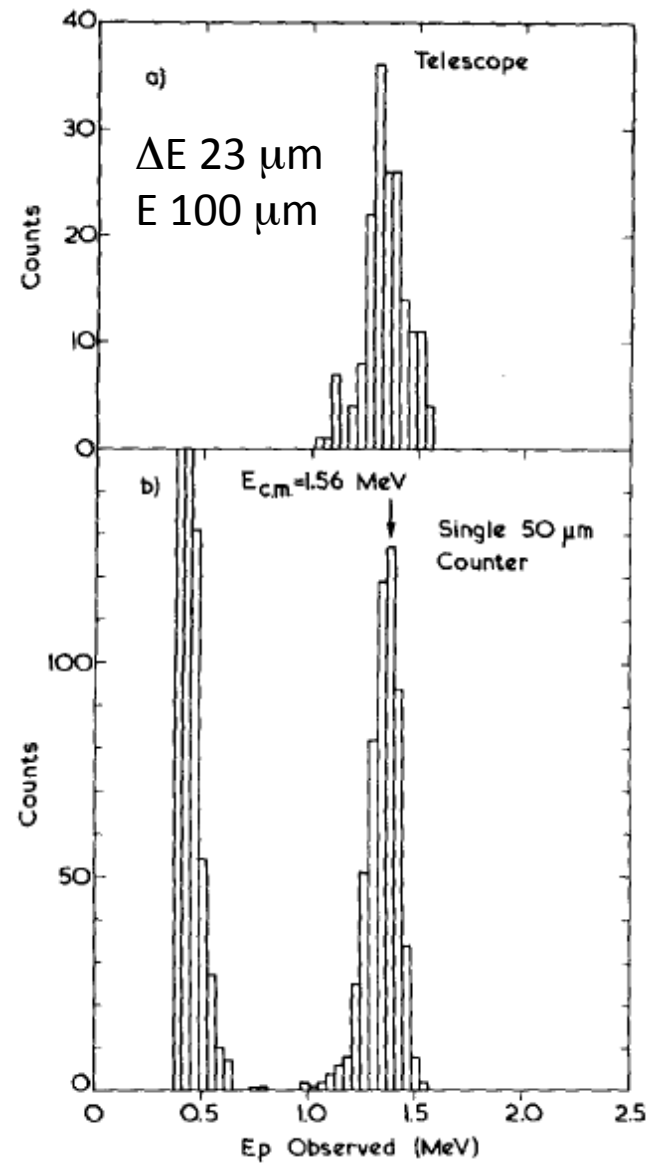
Discovery of direct proton emission: ^{53m}Co

K. P. Jackson et al., PLB33 (1970) 281



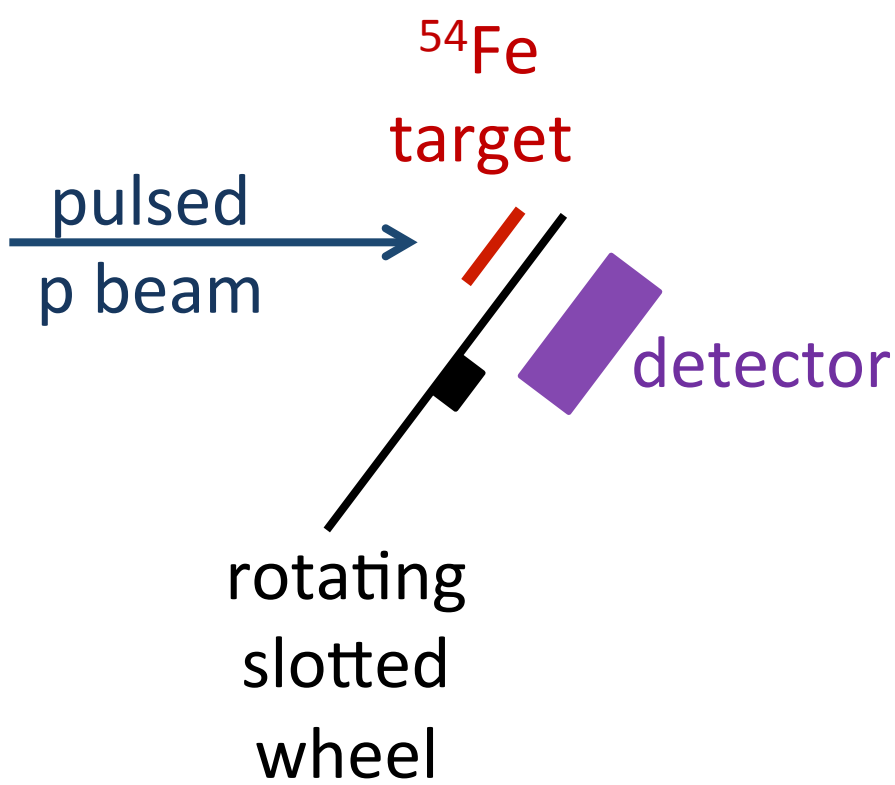


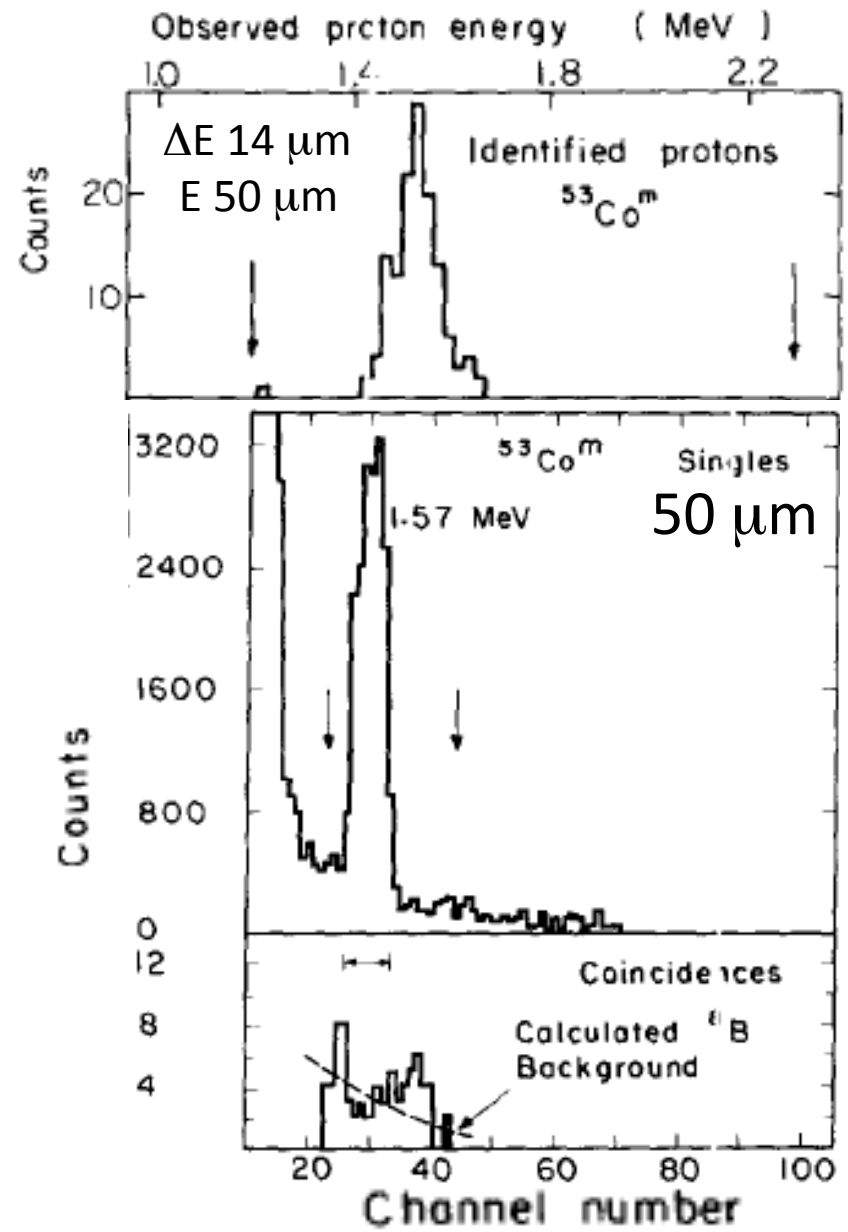
ground state is proton bound!



Discovery of direct proton emission: ^{53m}Co

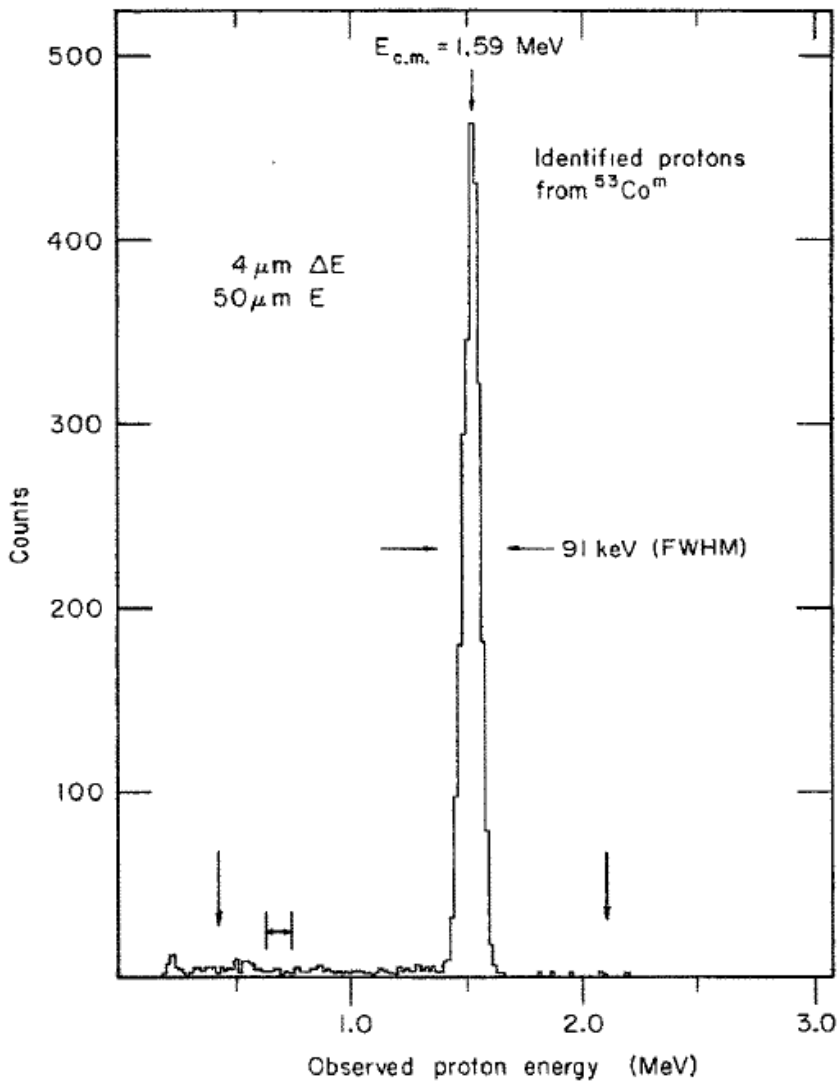
J. Cerny et al., PLB33 (1970) 284

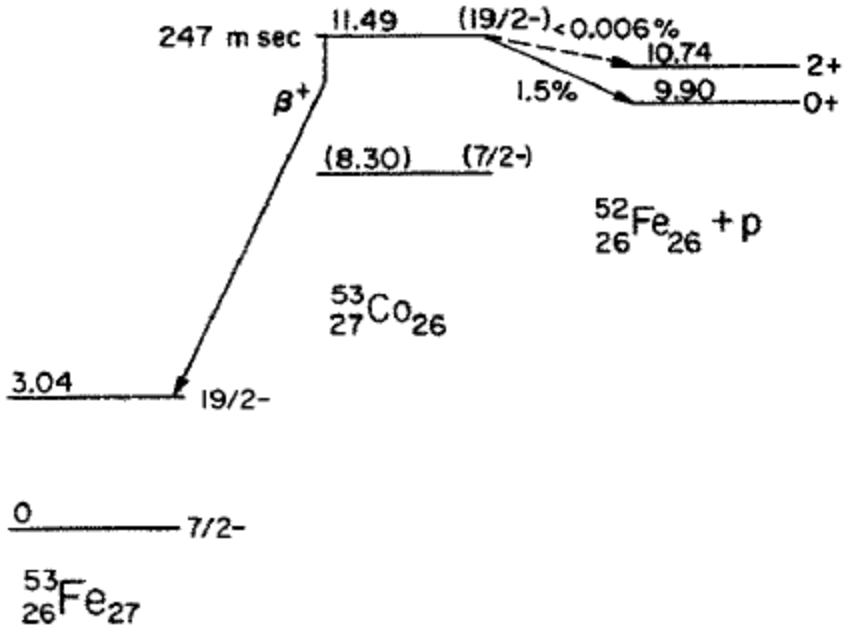




Precision study of ^{53m}Co

J. Cerny et al., NPA188 (1972) 666





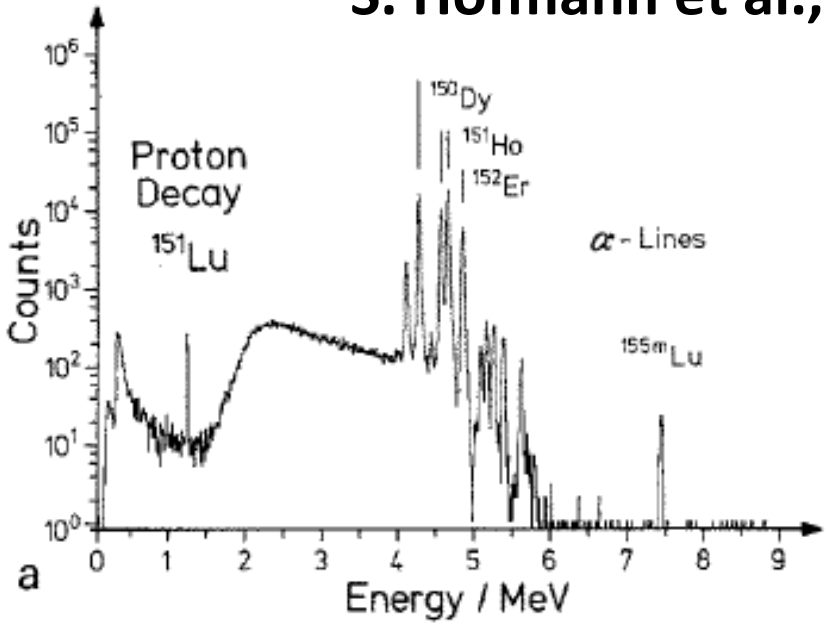
Energy (MeV)	1.59 ± 0.03
Half-life (ms)	247 ± 12
Branching ratio	≈ 1.5 %

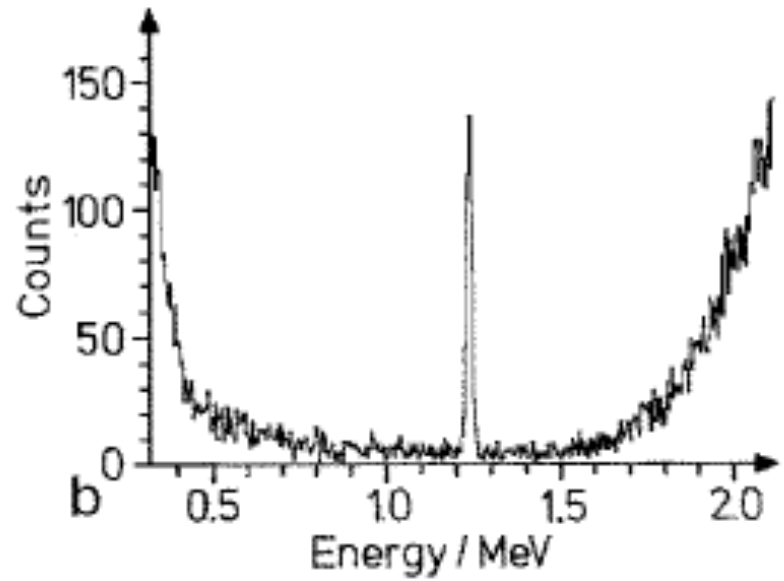
⇒ reduced proton-decay width

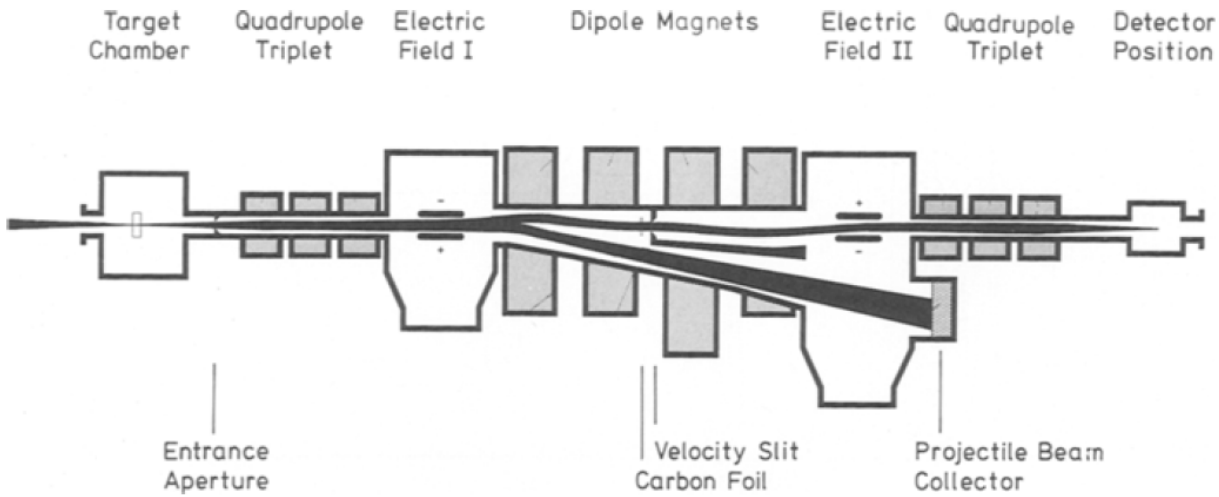
$f_{7/2}^{-3}$ isomer

Ground-state proton emission: ^{151}Lu

S. Hofmann et al., ZPA305 (1982) 111



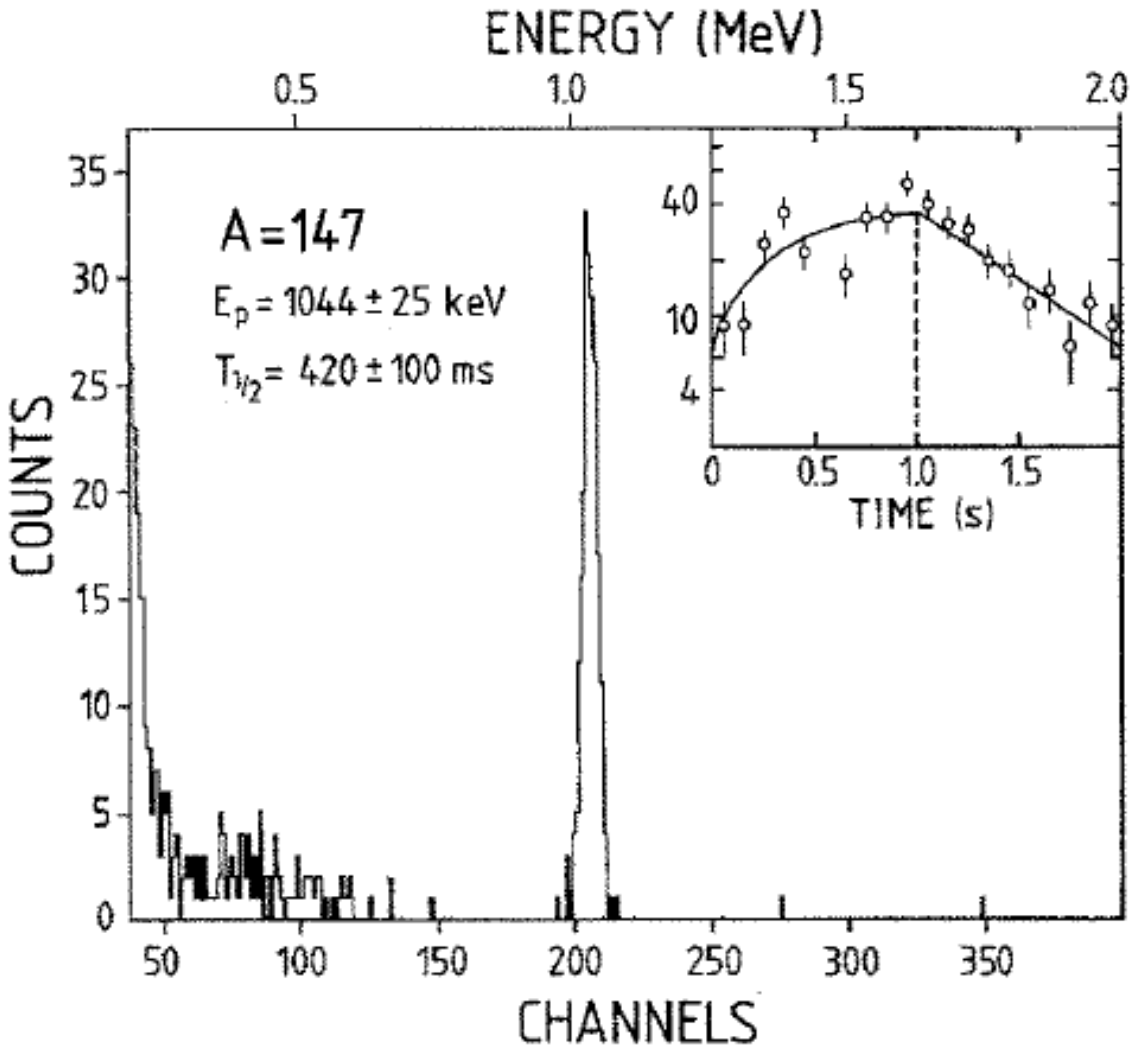




Velocity Filter SHIP

Ground-state proton emission: ^{147}Tm

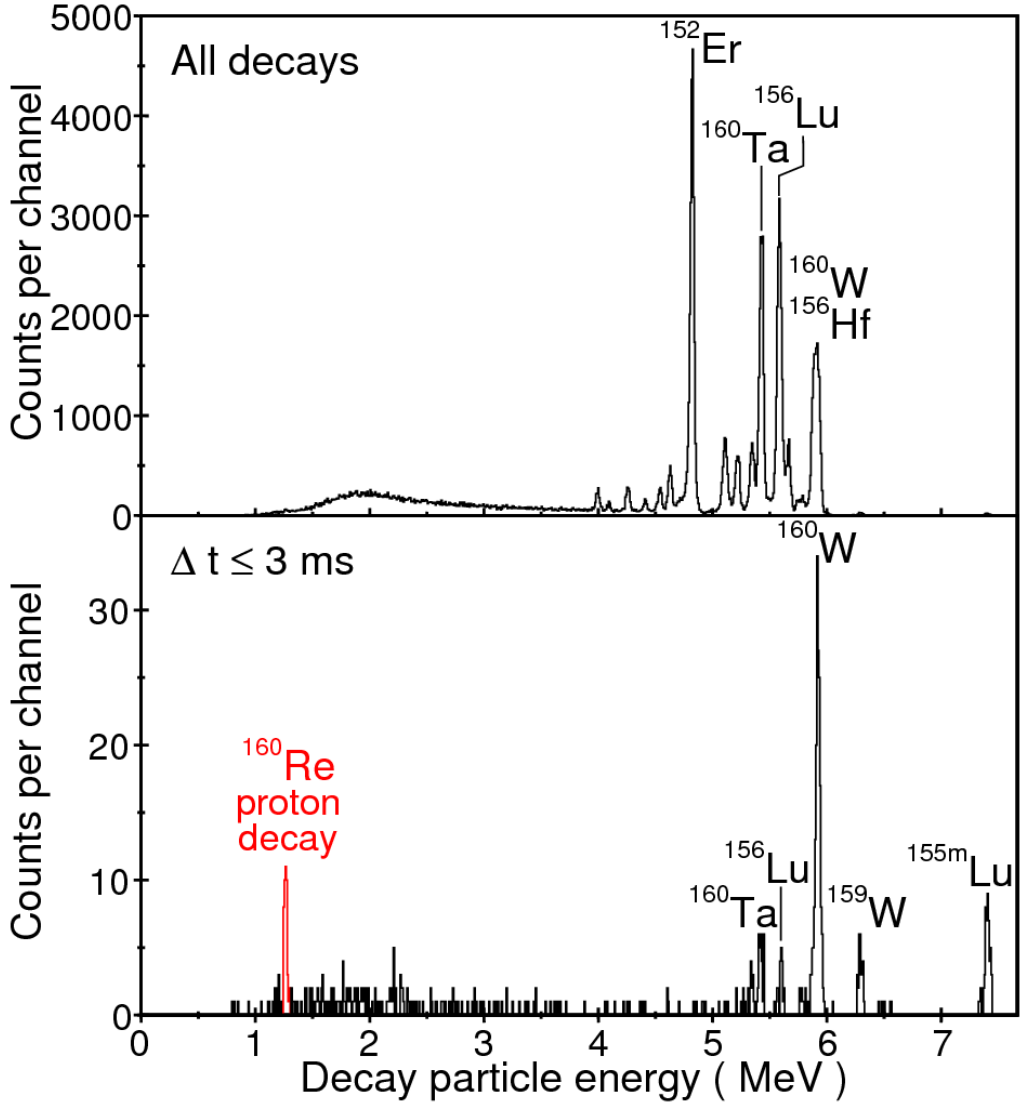
O. Klepper et al., ZPA305 (1982) 125



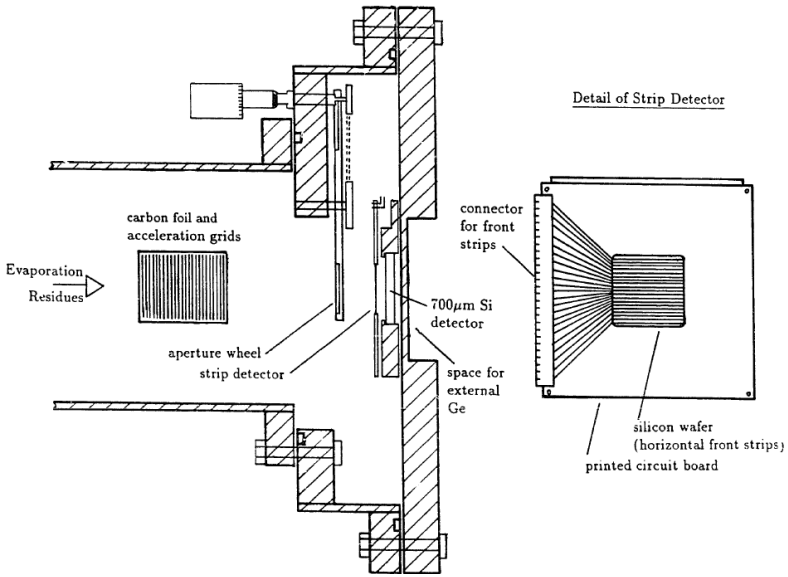
GSI on-line mass separator

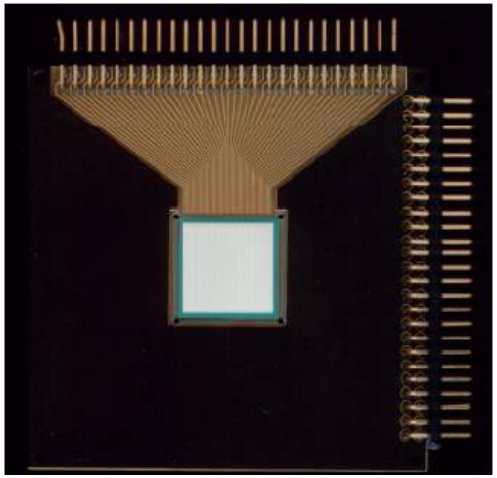
Recoil Mass Separator + DSSD

R.D. Page et al., PRL68 (1992) 1287

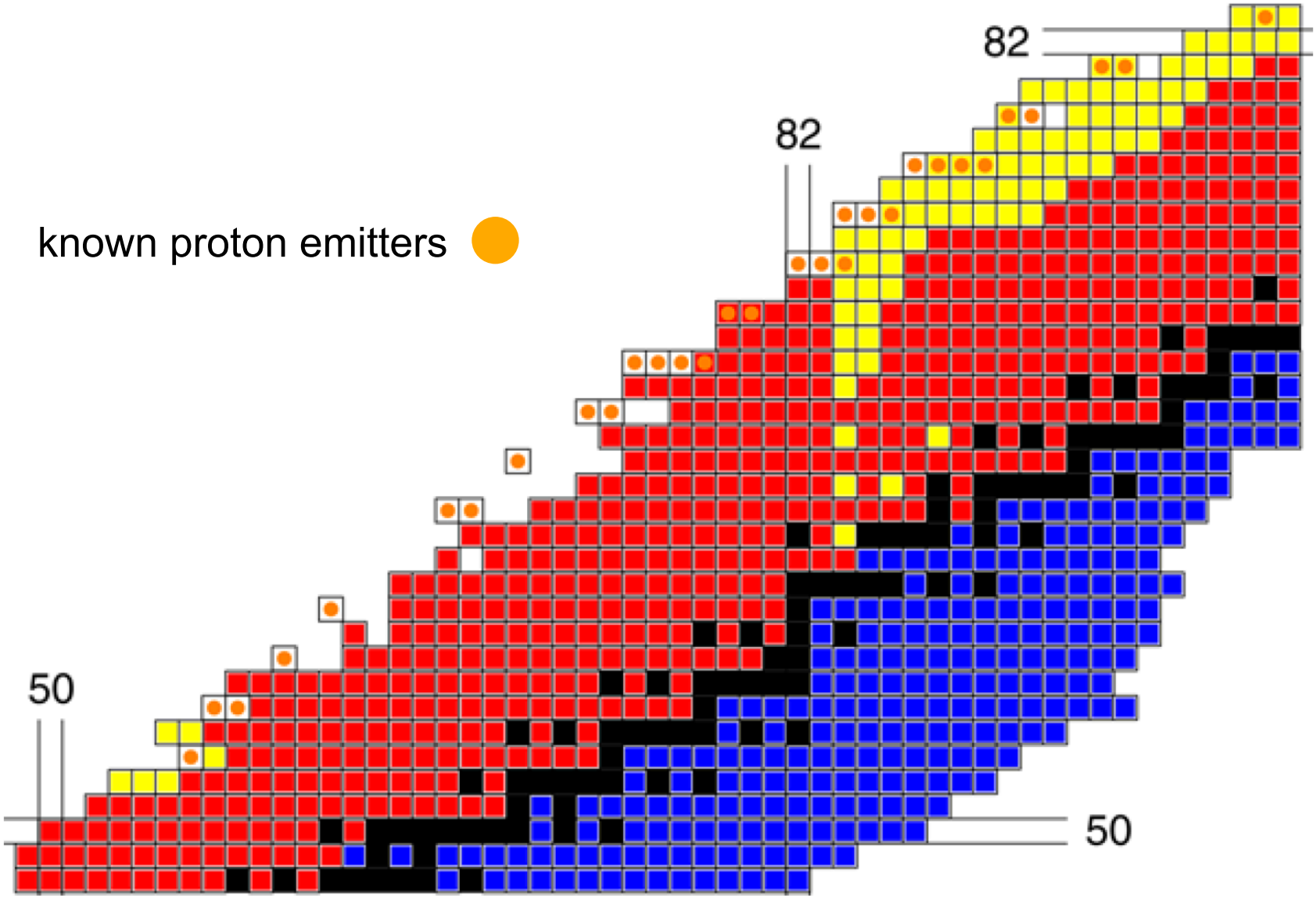


P.J. Sellin et al., NIMA311 (1992) 217



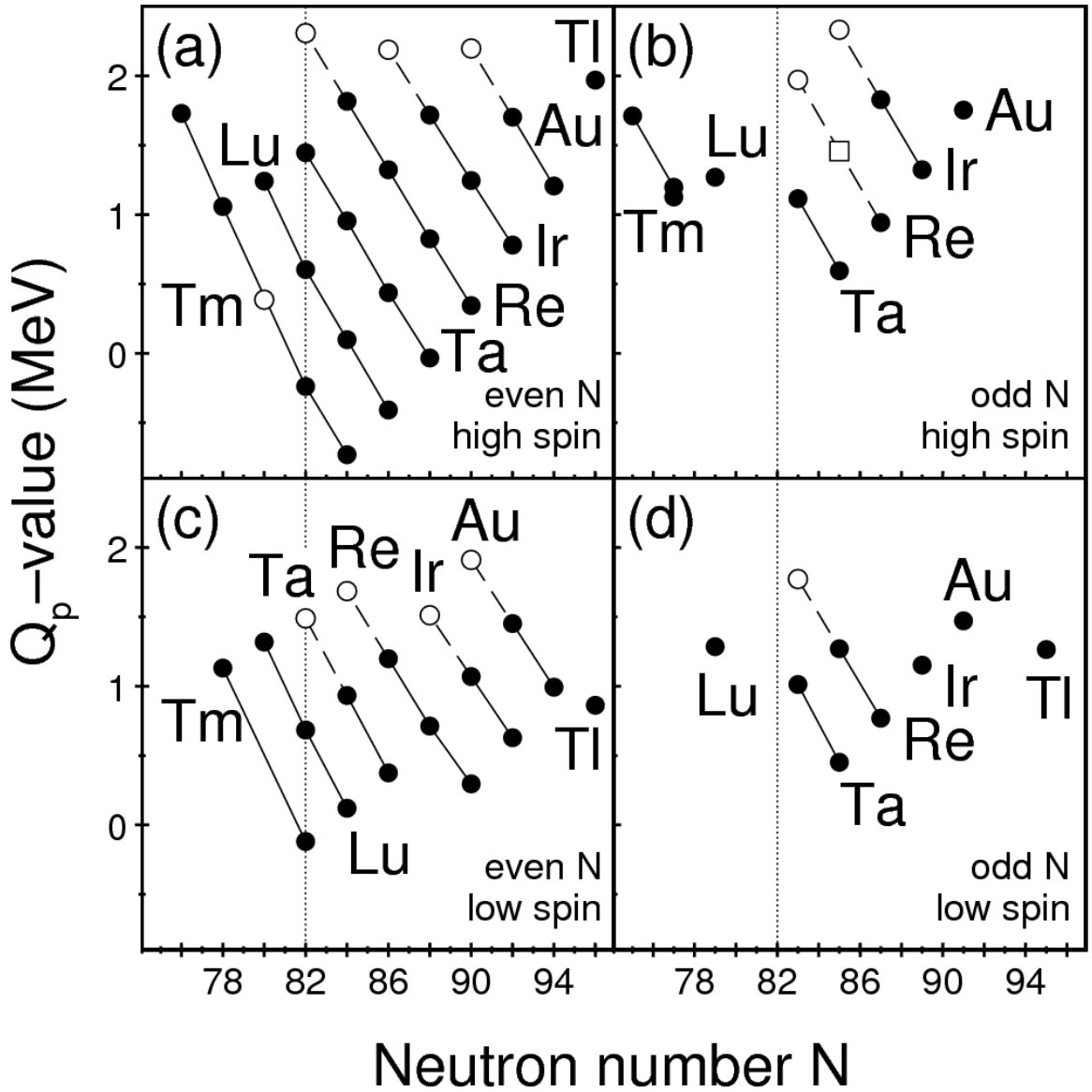


Proton emitters above Z = 50



B. Blank & M.J.G. Borge, Progress in Particle and Nuclear Physics 60 (2008) 403

Proton-decay Q-values



$\pi h_{11/2}$

$\pi s_{1/2}$

$\pi d_{3/2}$

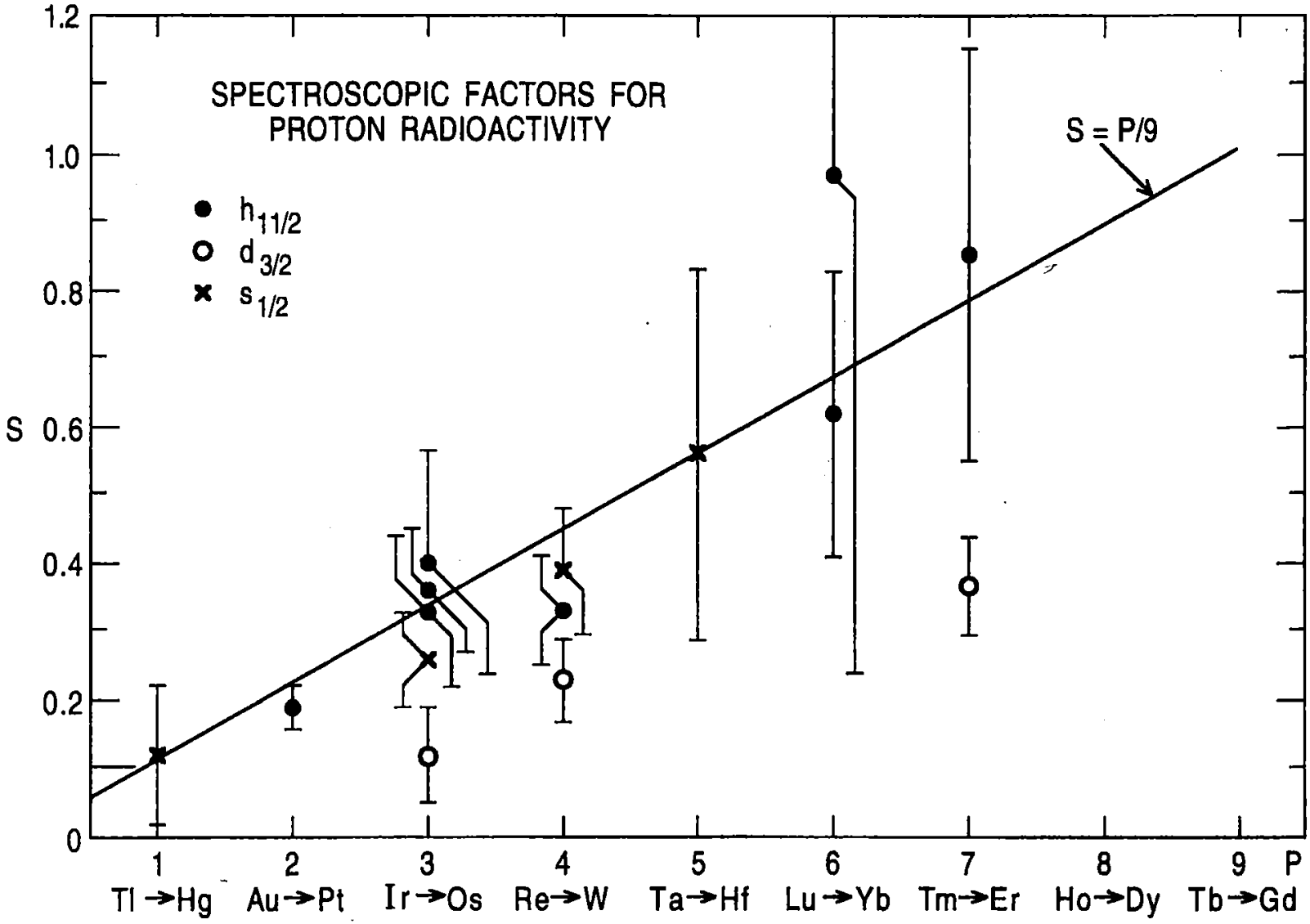
● measured

○ extrapolated

□ interpolated

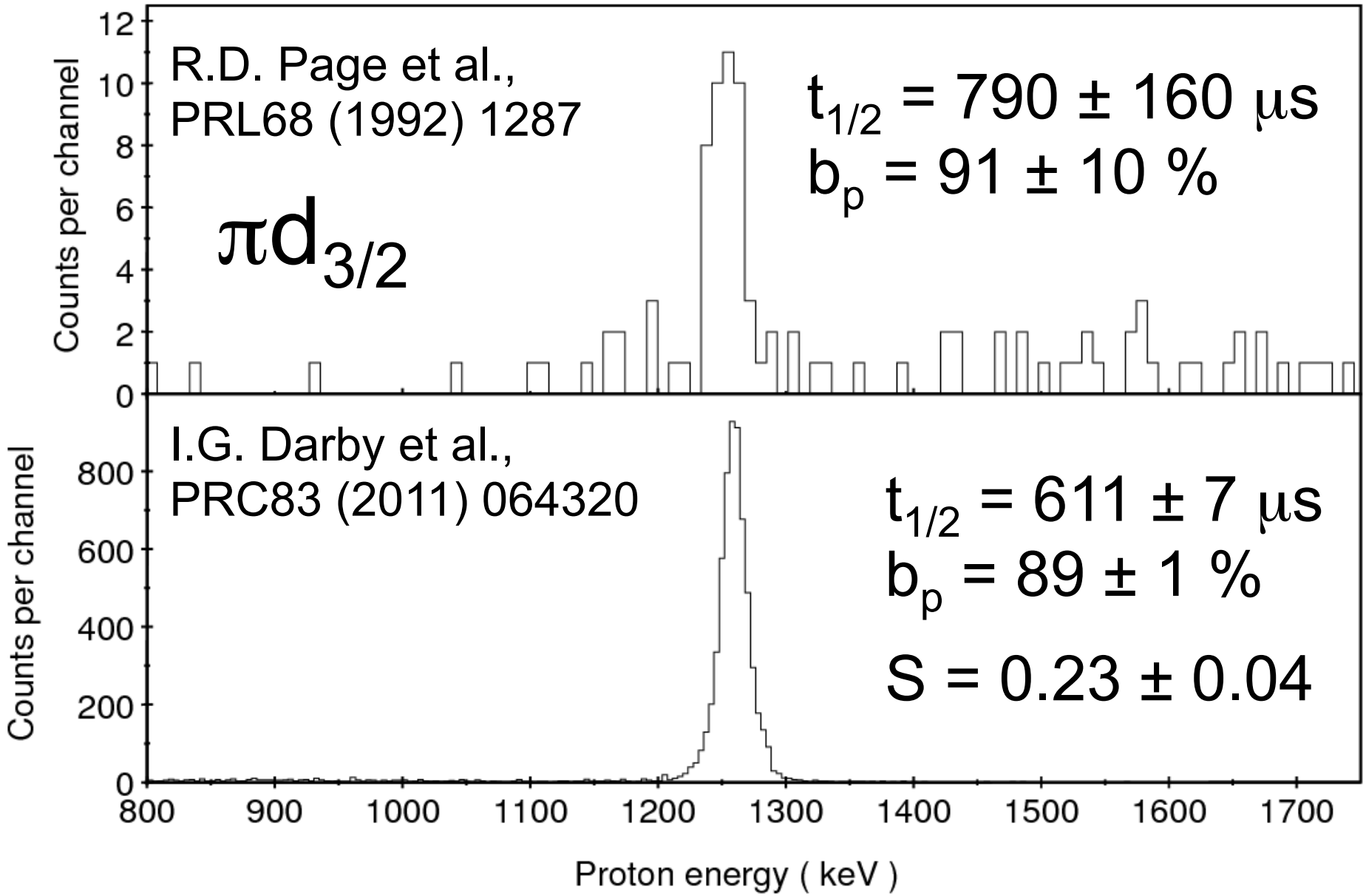
R.D. Page, Physical Review C83 (2011) 014305

Reduced proton-decay widths



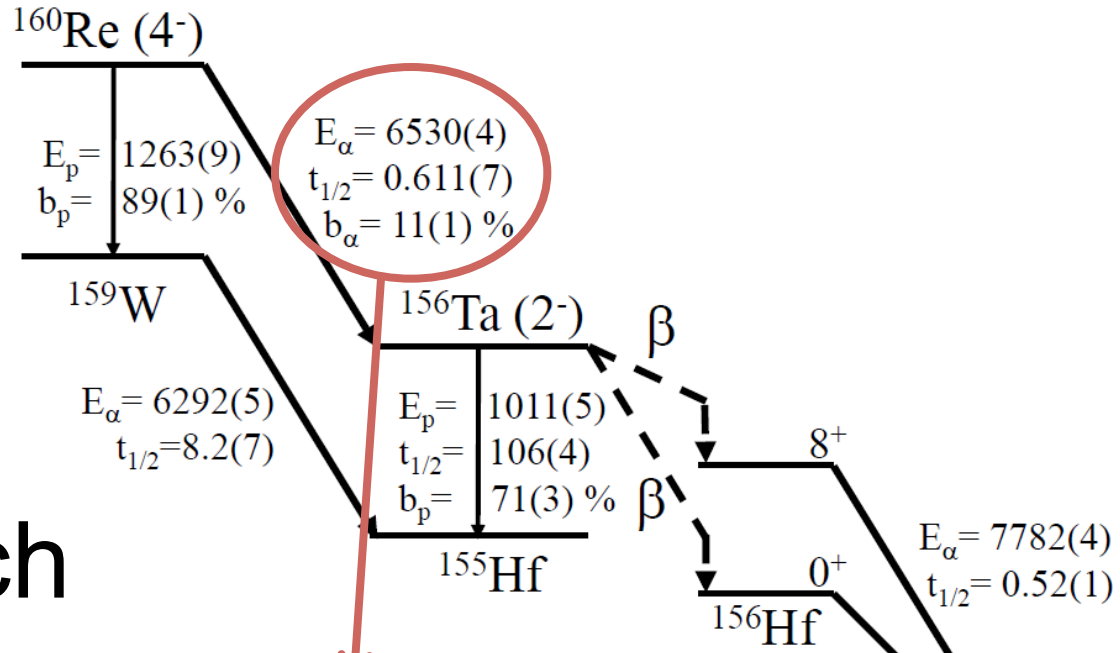
C.N. Davids et al., PRC55 (1997) 2255

Precision Measurements – ^{160}Re

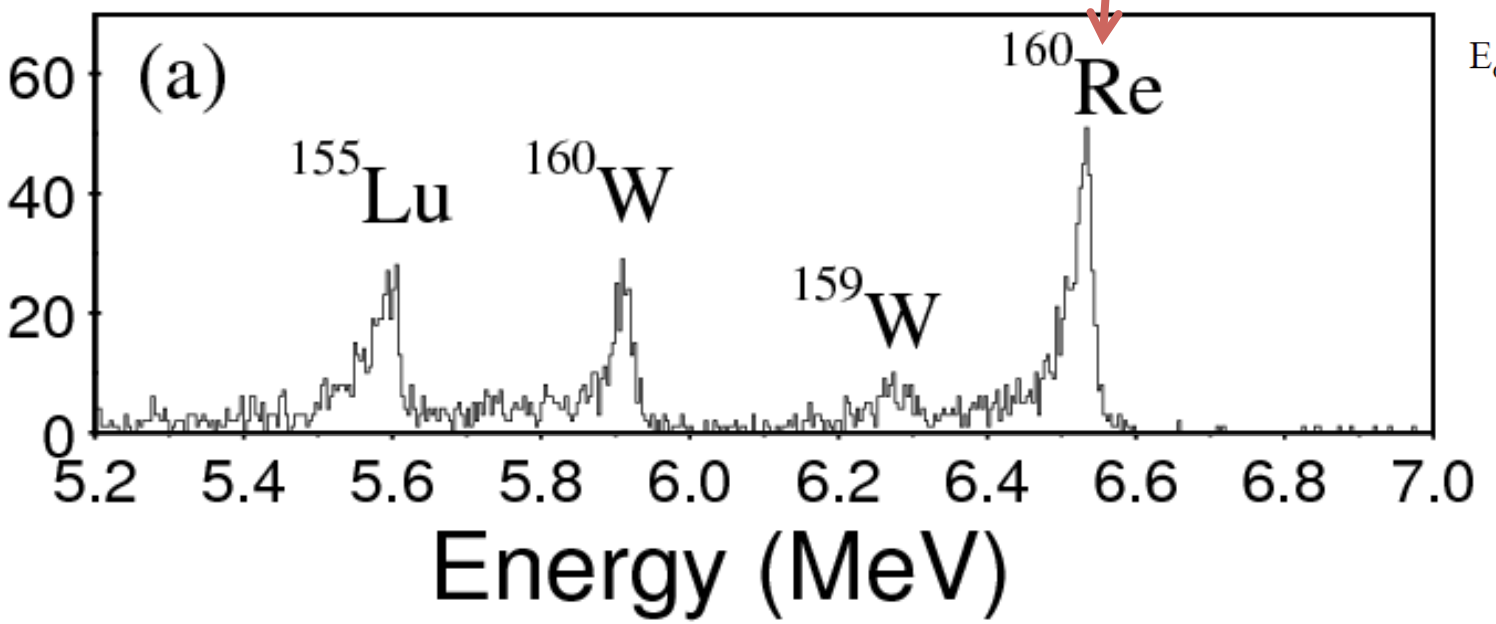


Precision Measurements – ^{160}Re

I.G. Darby et al.,
PRC83 (2011) 064320



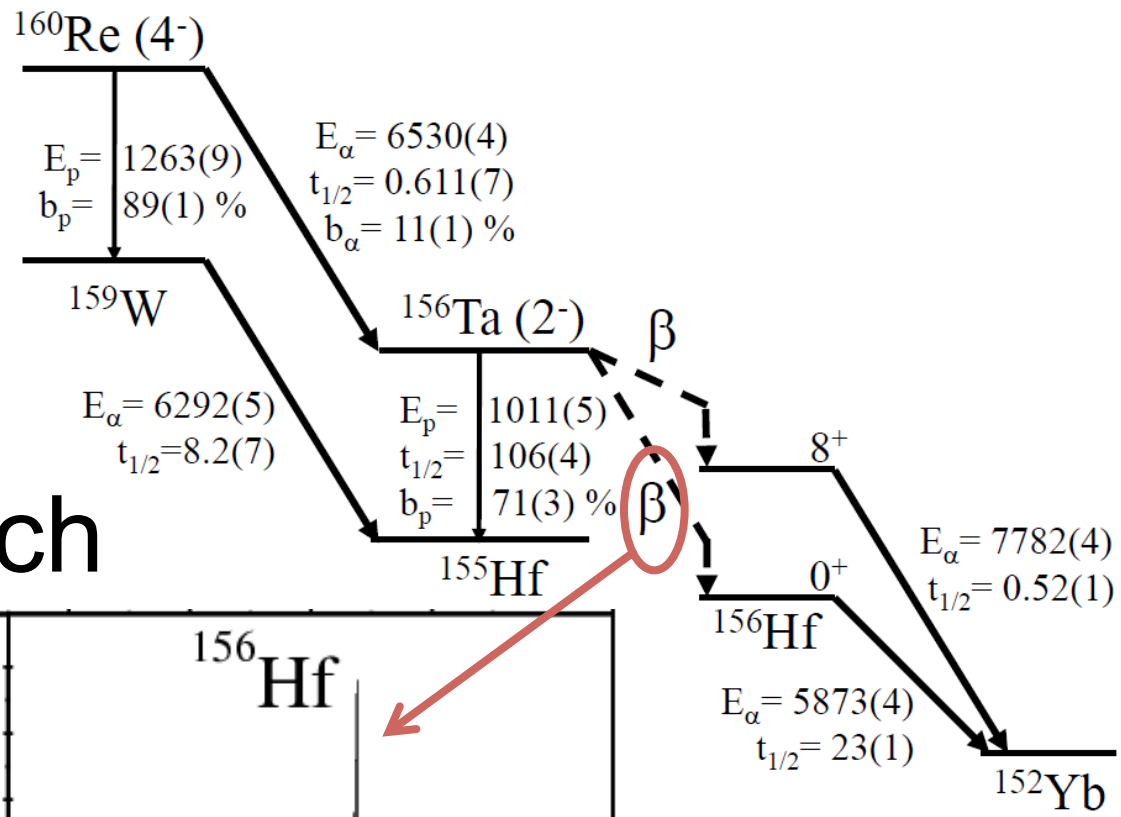
α-decay branch



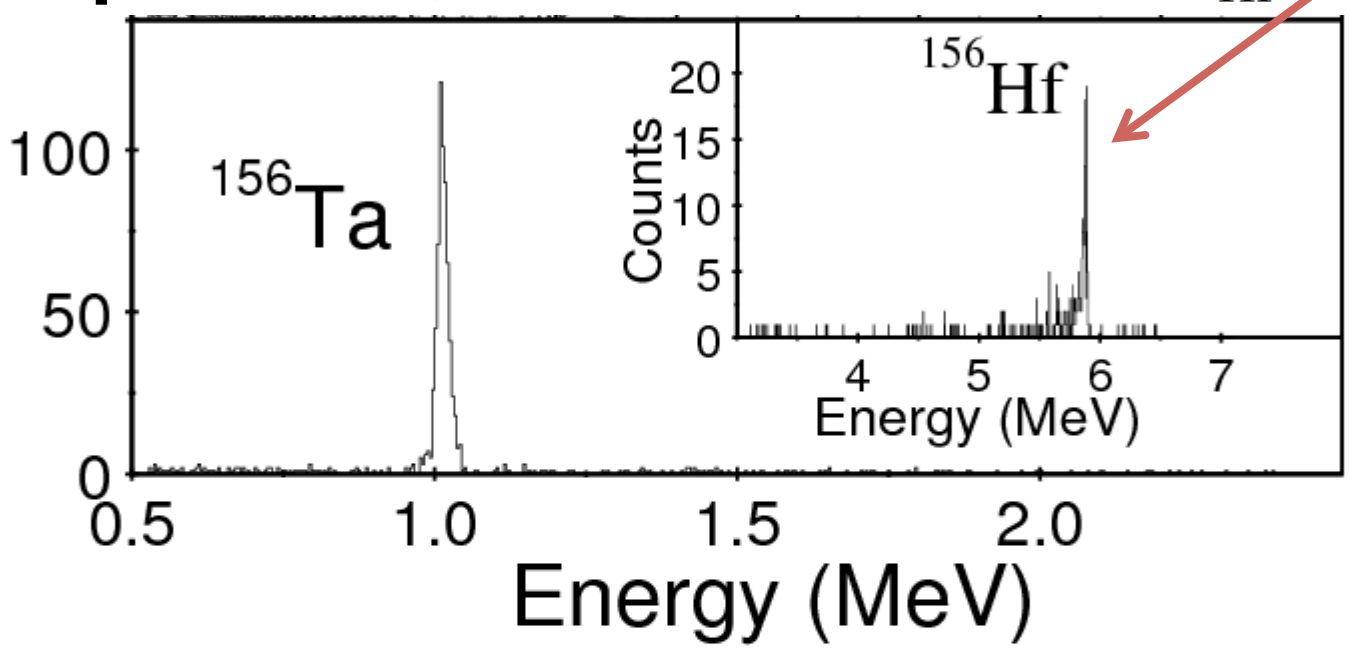
Precision Measurements – ^{156}Ta

I.G. Darby et al.,
PRC83 (2011) 064320

S = 0.40 ± 0.07

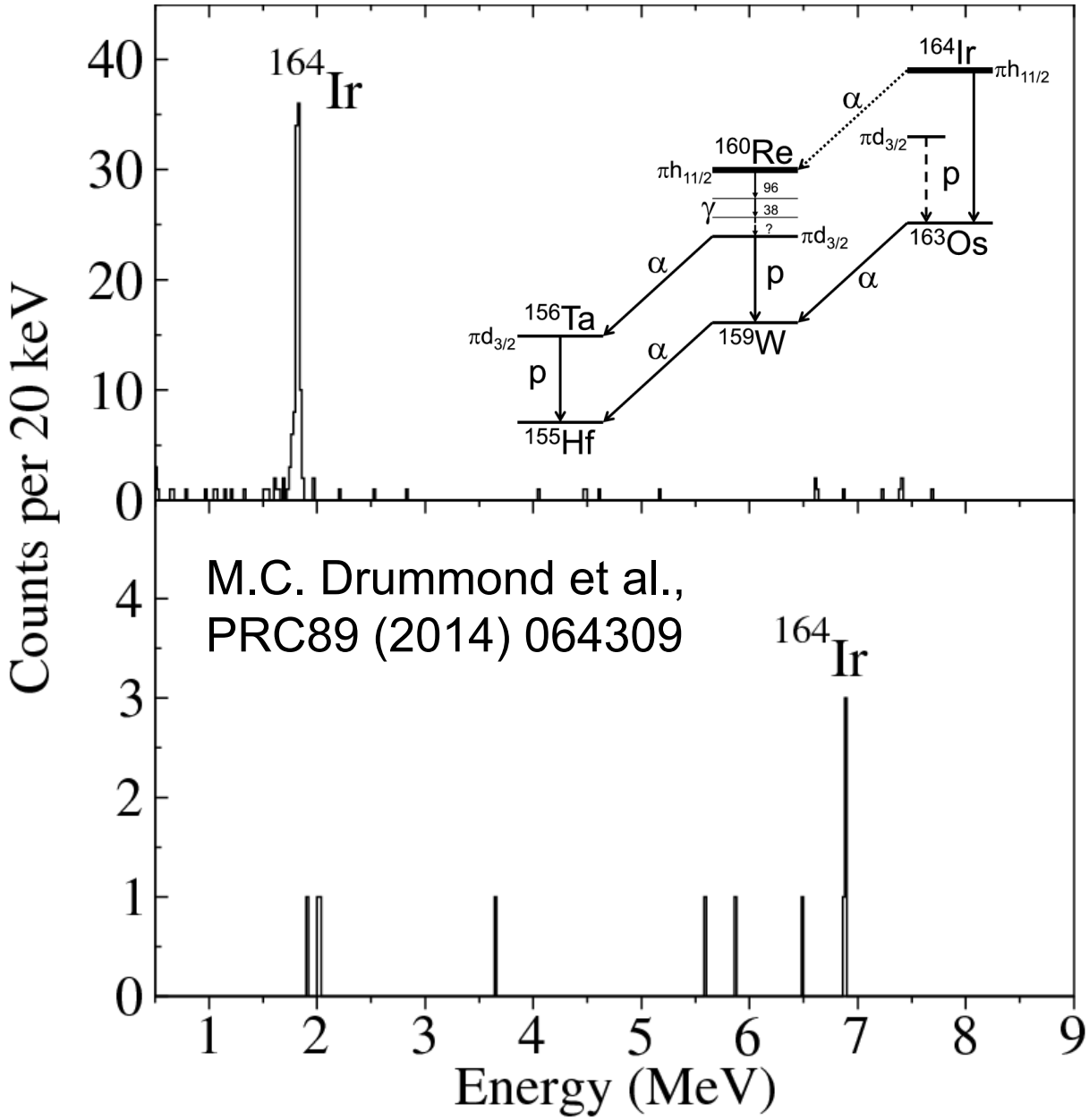


β-decay branch

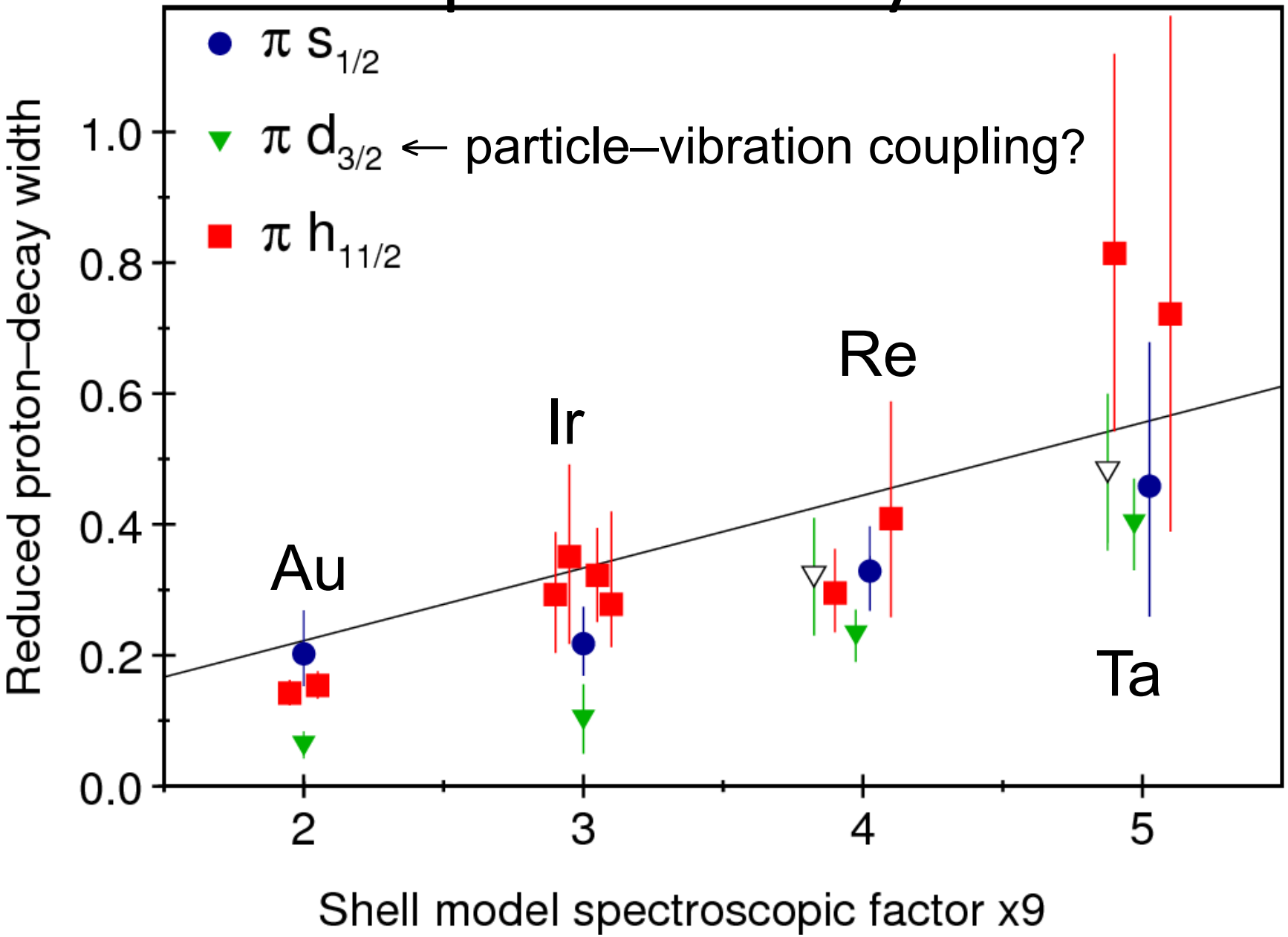


$\pi d_{3/2}$

Precision measurements – ^{164}Ir

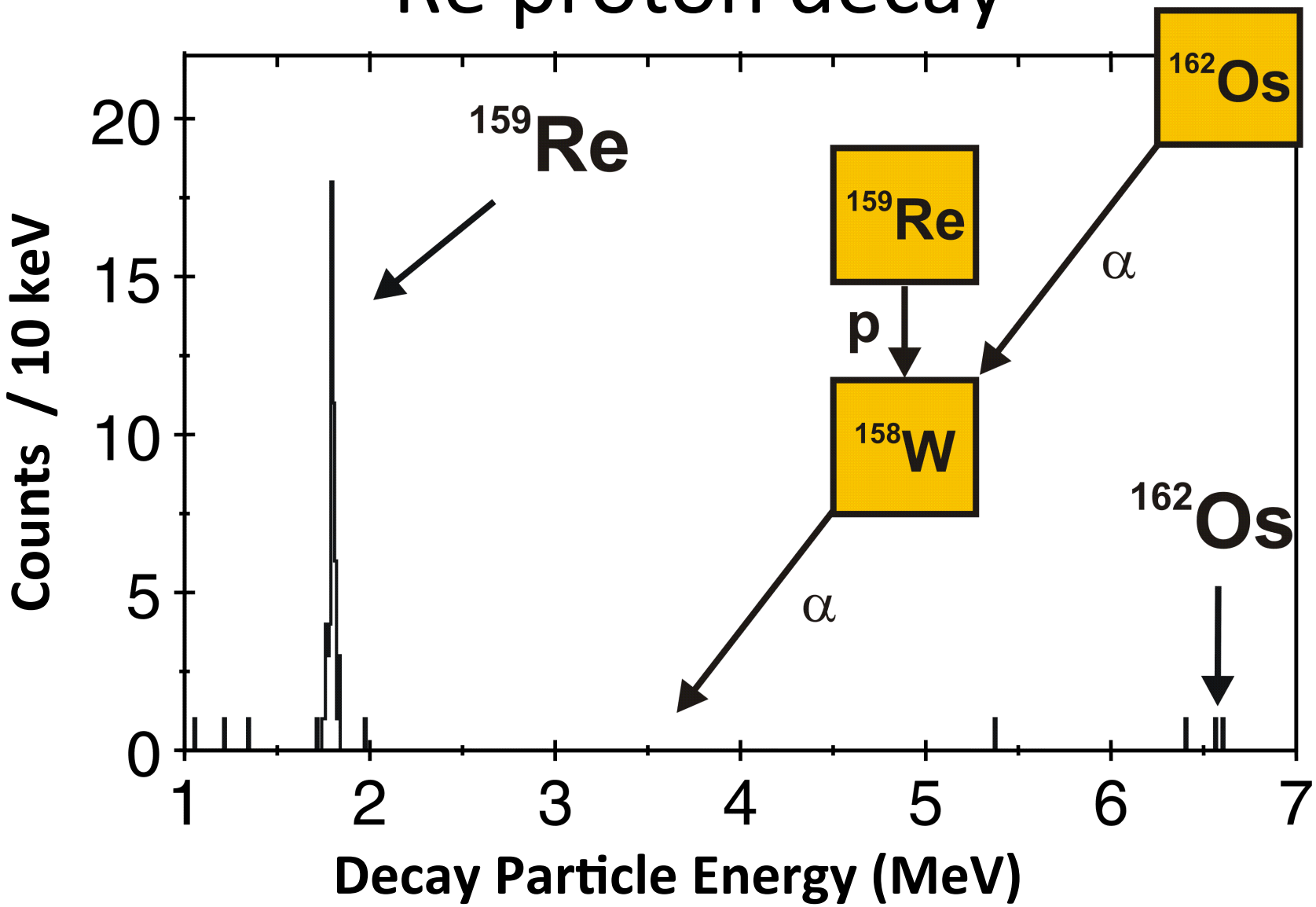


Reduced proton-decay widths



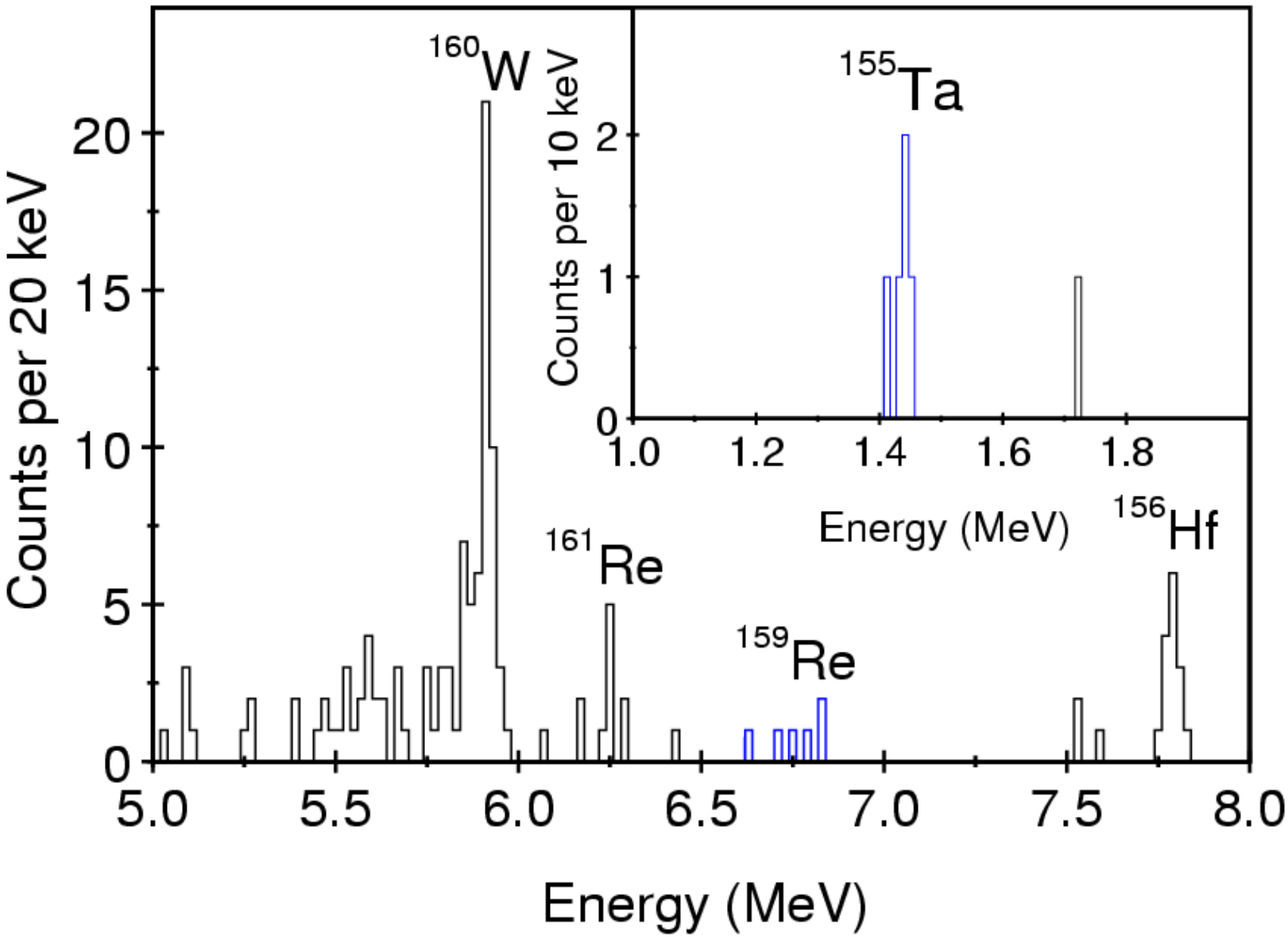
C.N. Davids & H. Esbensen, PRC64 (2001) 034317, K. Hagino, PRC64 (2001) 041304

^{159}Re proton decay



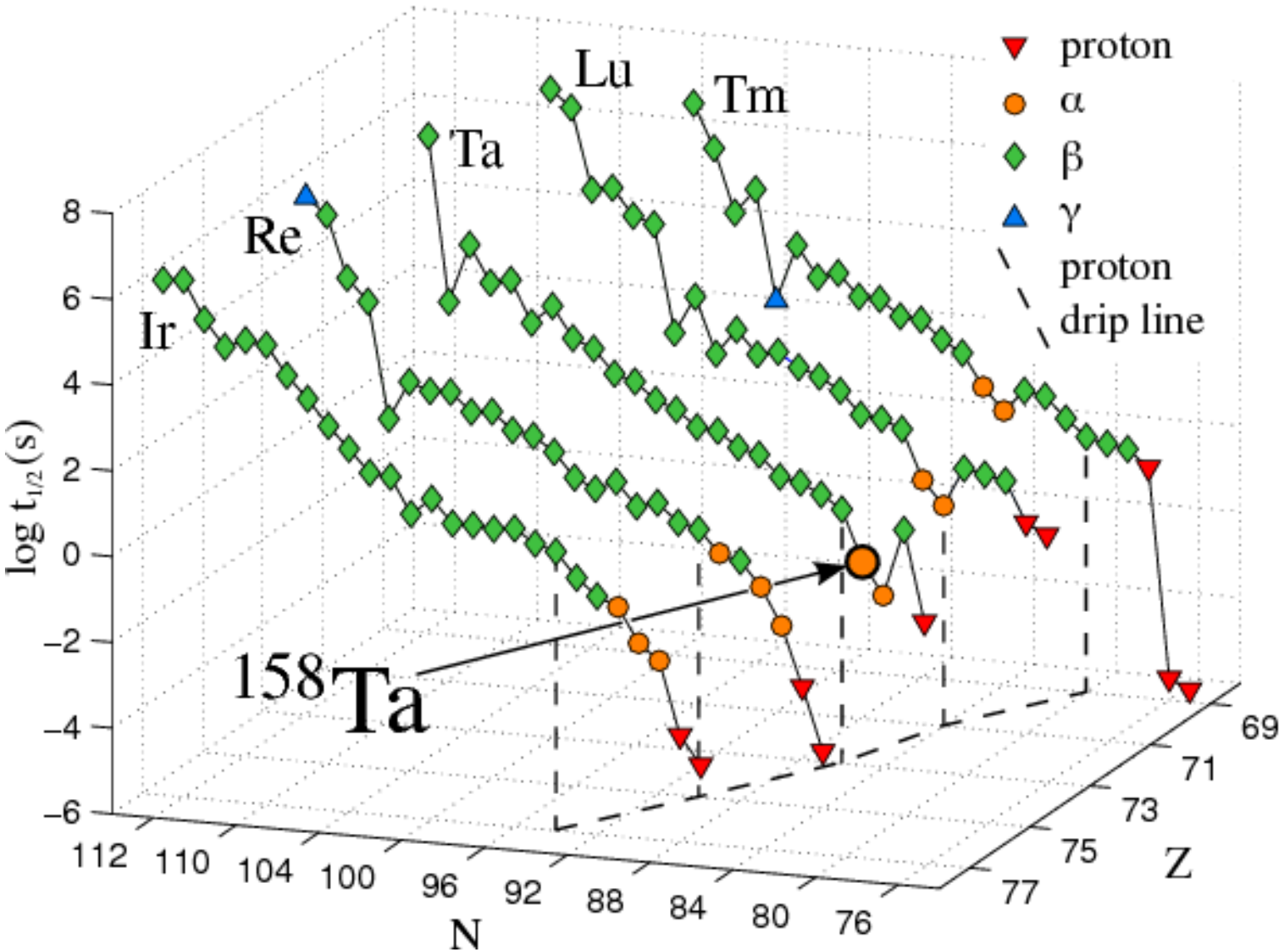
D.T. Joss et al., Physics Letters B641 (2006) 34

^{159}Re α decay & ^{155}Ta$_{82}$ p decay



R.D. Page et al., PRC75 (2007) 061302

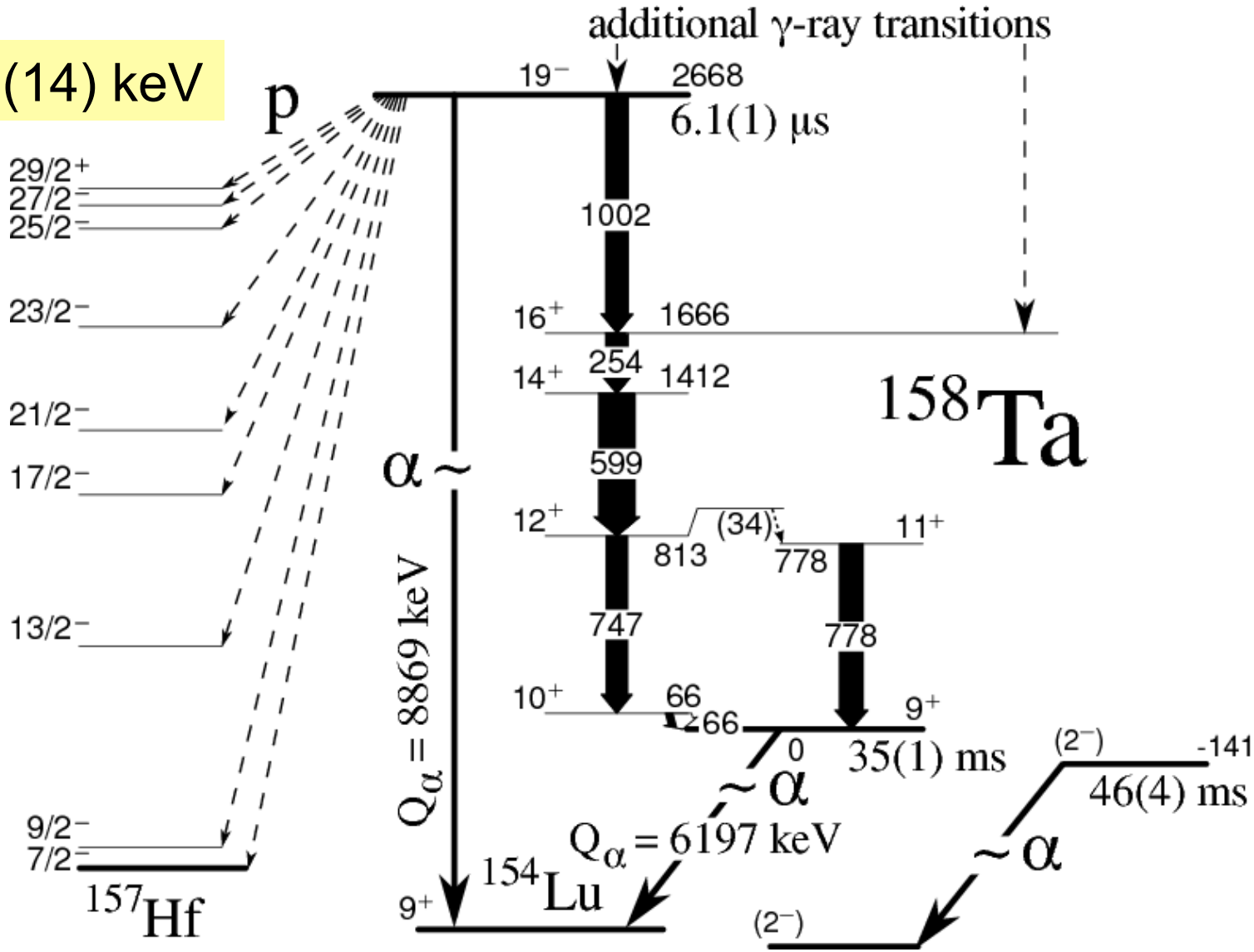
Limits of observable nuclei



R. Carroll et al., PRL112 (2014) 092501

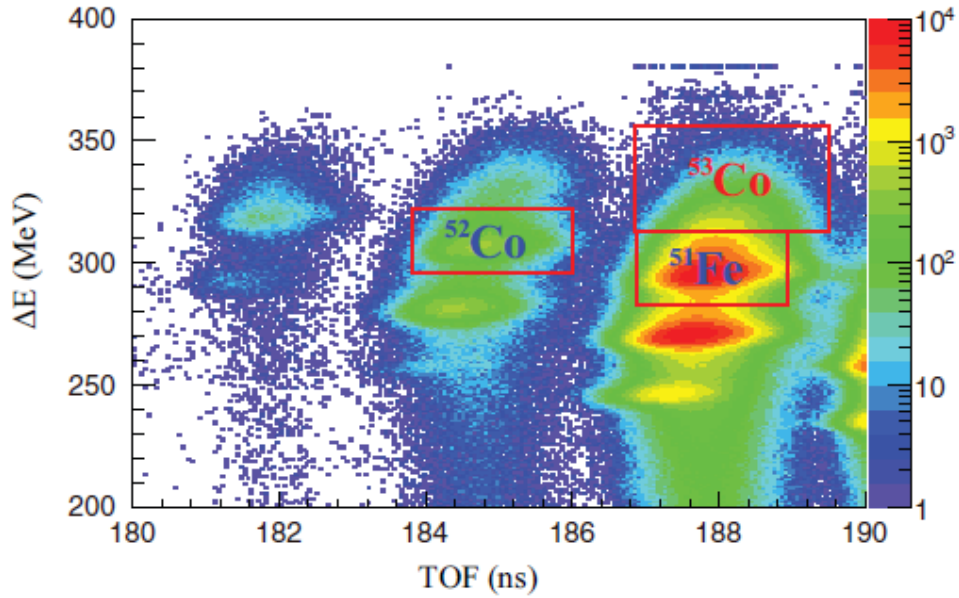
Multiparticle isomer in ^{158}Ta

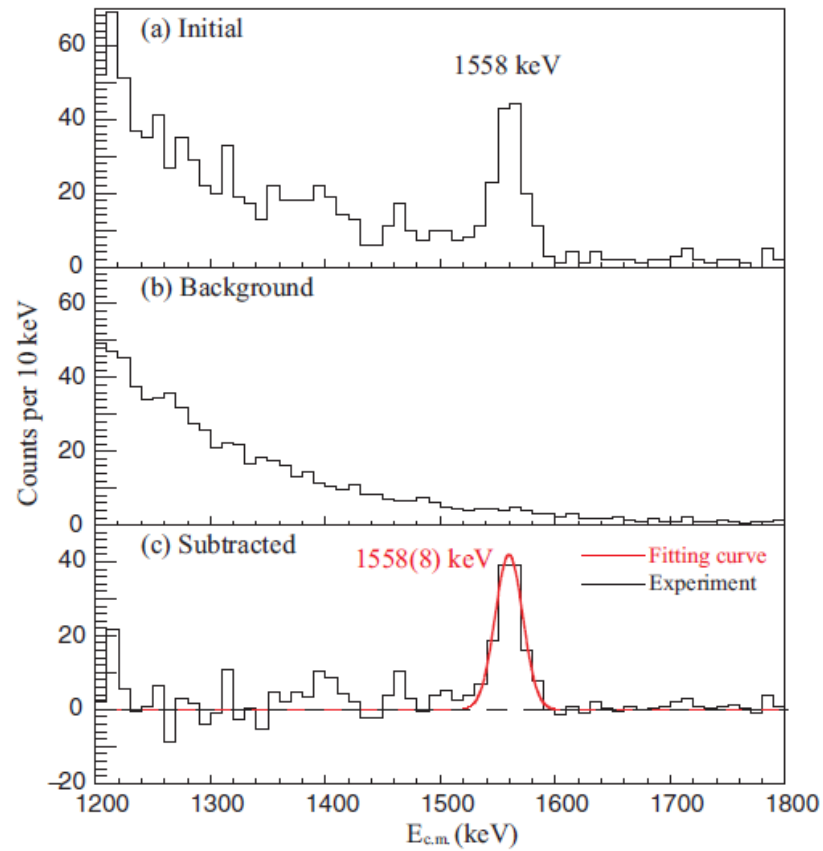
Q_p = 3261(14) keV

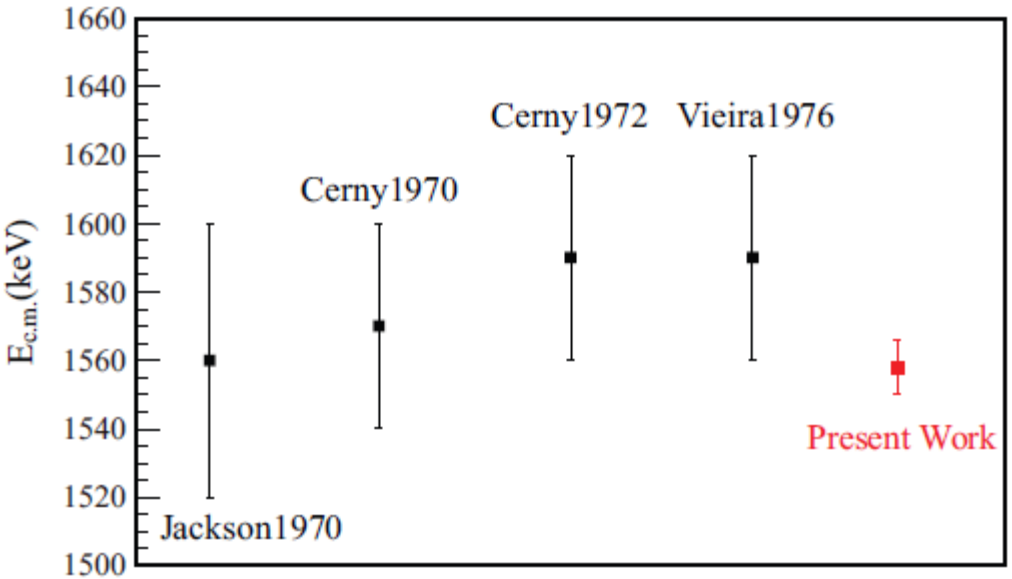


R. Carroll et al., PRL112 (2014) 092501

(Another) precision study of ^{53m}Co



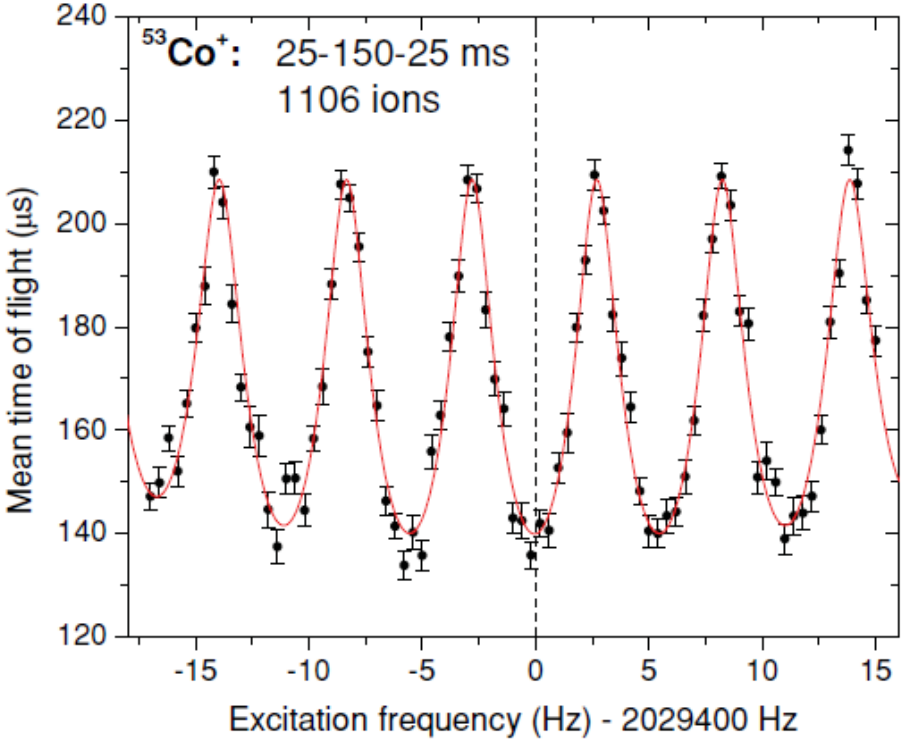


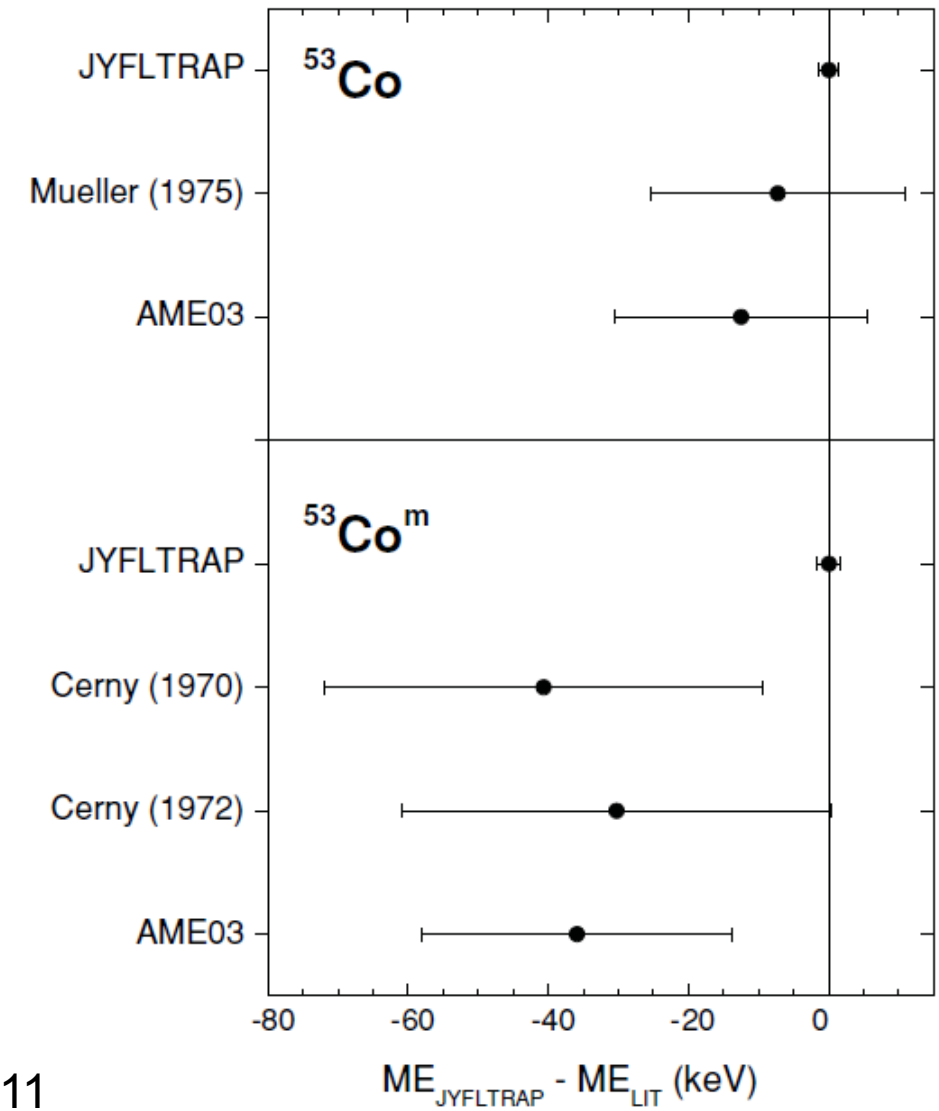


Y.P. Shen et al.,
PRC91 (2015) 047304
^{52}Fe mass measurement

^{53m}Co mass measurement

IGISOL + JYFLTRAP

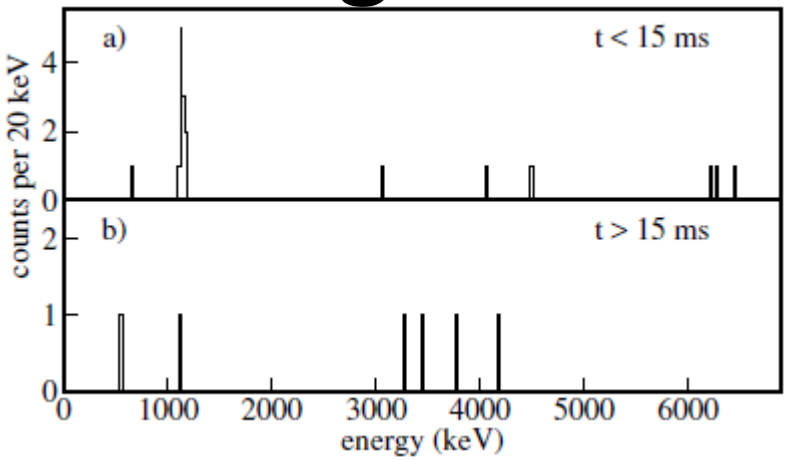




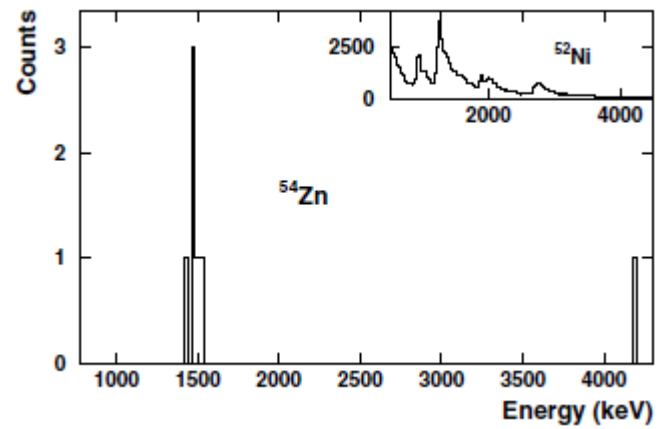
ME(^{53m}Co) = −39 482.9(16) keV

A. Kankainen et al., PRC82 (2010) 034311

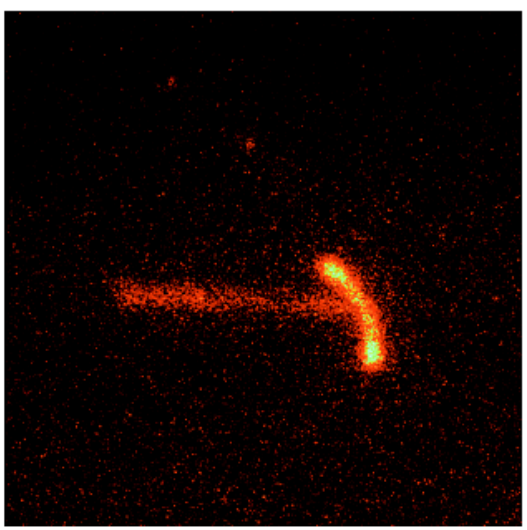
Light nuclei – 2p emission



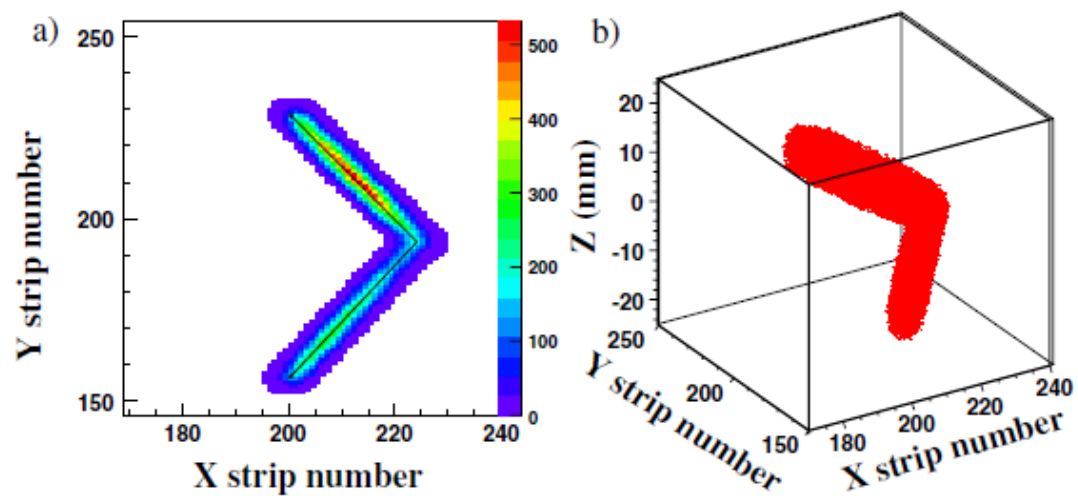
^{45}Fe – J. Giovinazzo et al., PRL89 (2002) 102501



^{54}Zn – B. Blank et al., PRL94 (2005) 232501

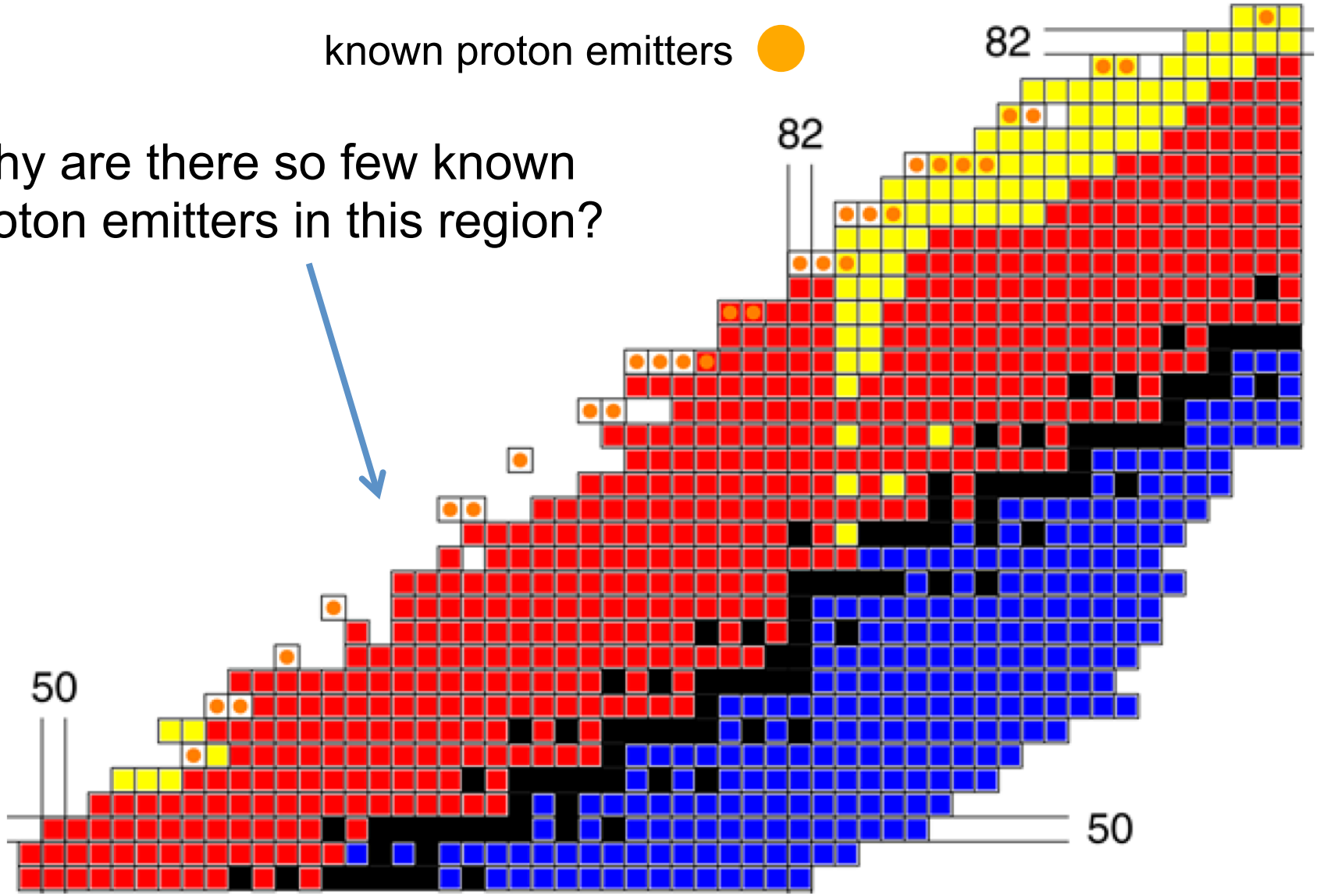


^{45}Fe – K. Miernik et al., PRL99 (2007) 192501



^{54}Zn – P. Ascher et al., PRL107 (2011) 102502

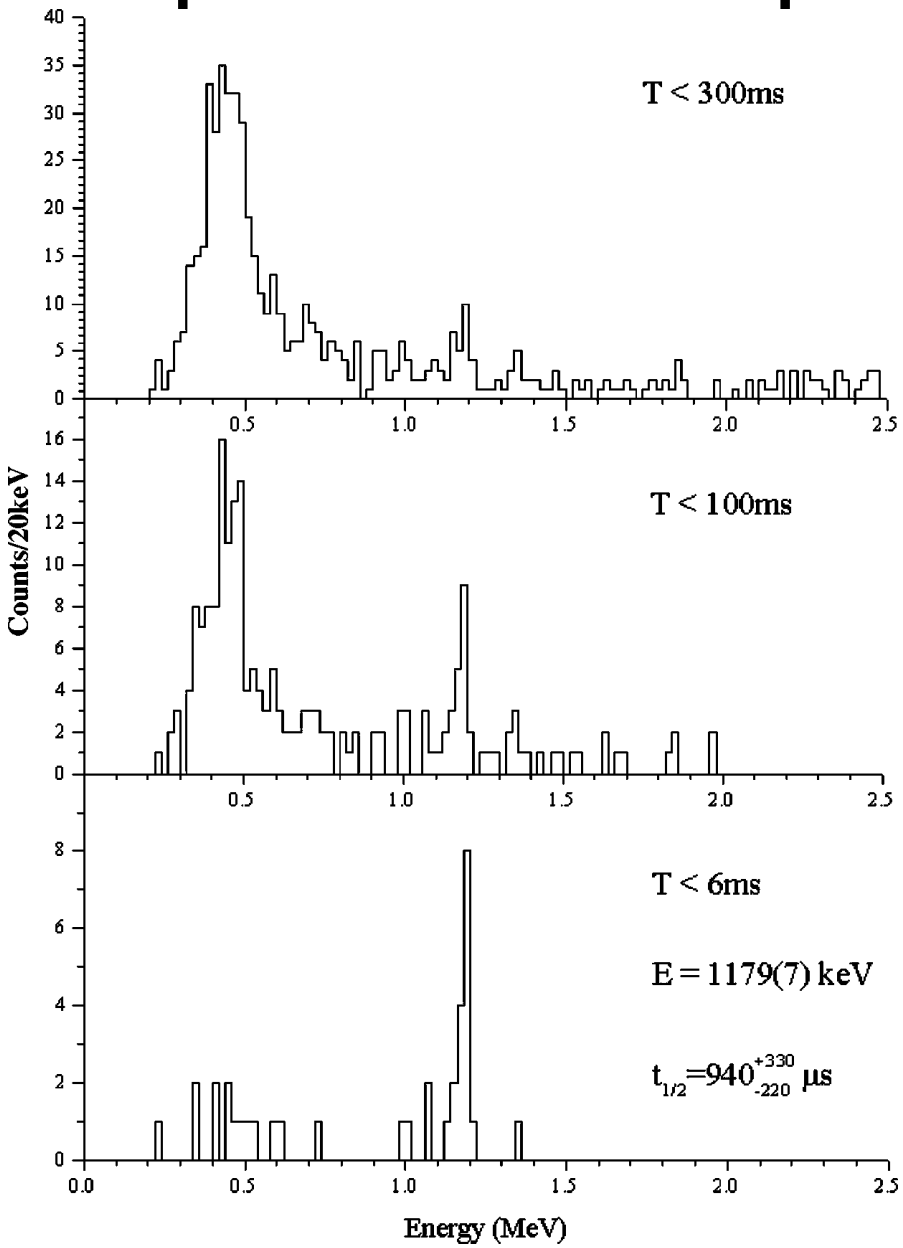
Fragmentation in heavier regions?



Why are there so few known proton emitters in this region?

B. Blank & M.J.G. Borge, Progress in Particle and Nuclear Physics 60 (2008) 403

Implantation – proton correlations



$^{50}Cr + ^{92}Mo \rightarrow ^{135}Tb + p6n$

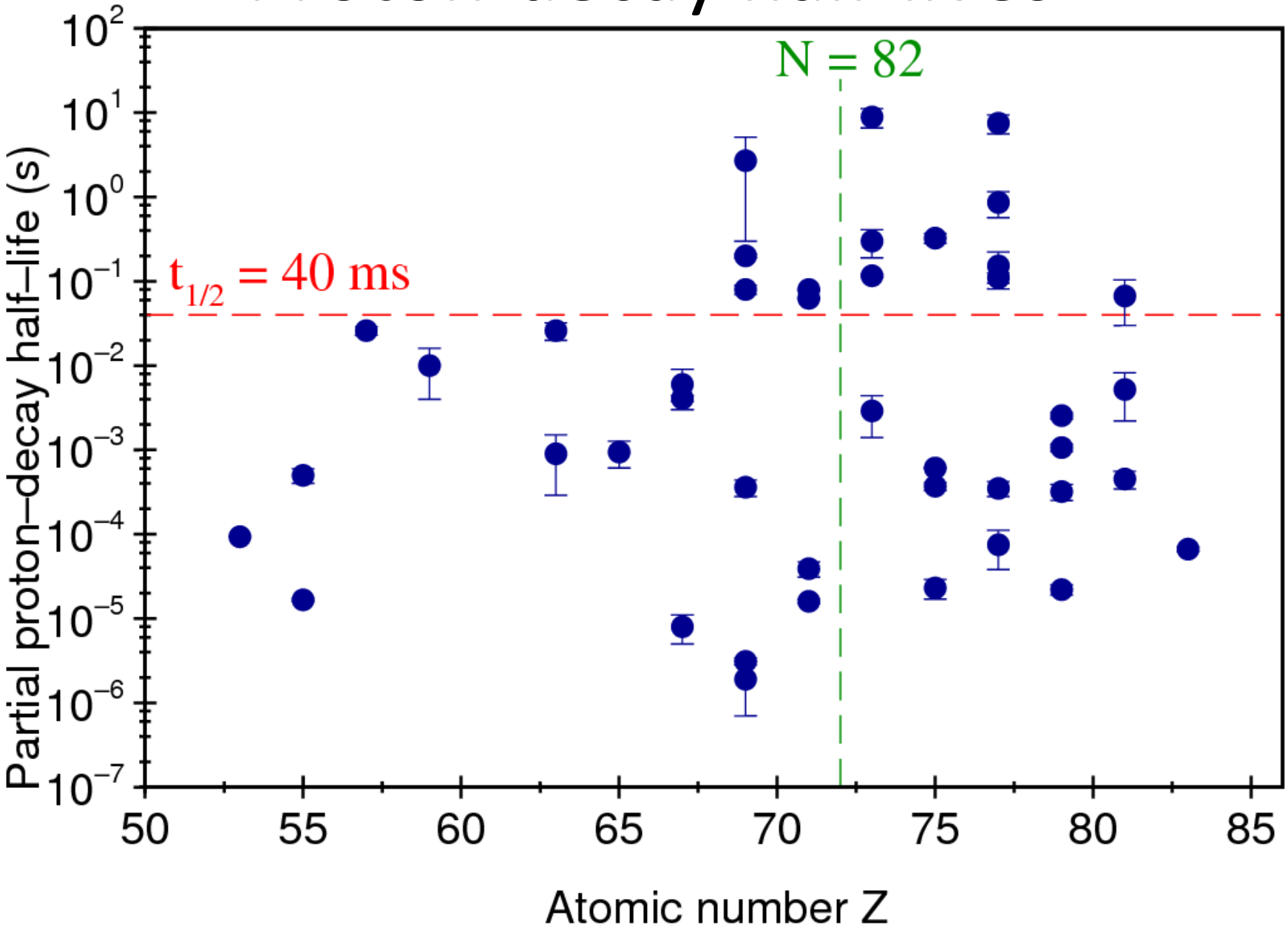
Argonne FMA

A = 135 only

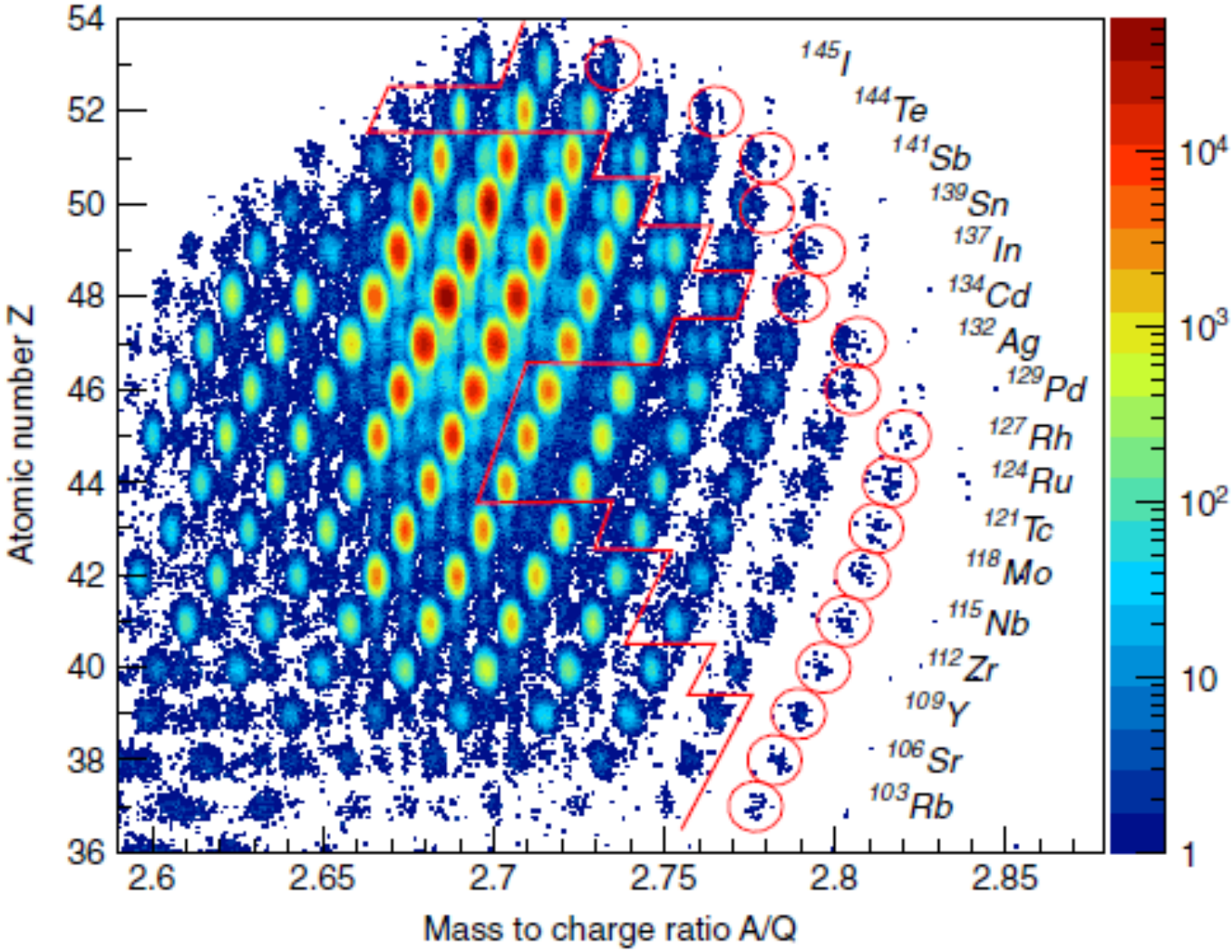
60 μm thick DSSD

P.J. Woods et al., PRC69 (2004) 051302

Proton-decay half-lives



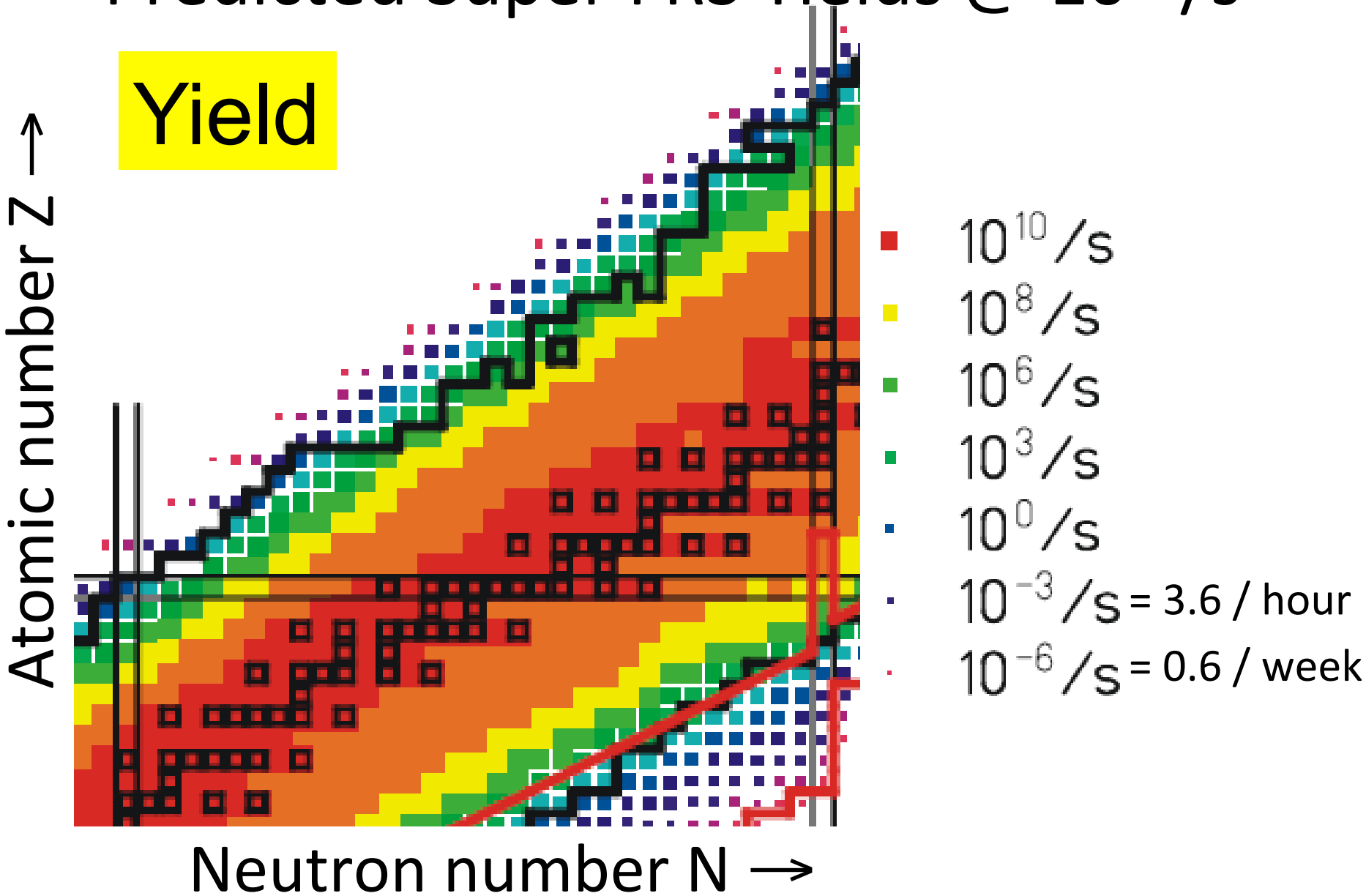
Fragment separator ⇒ A & Z



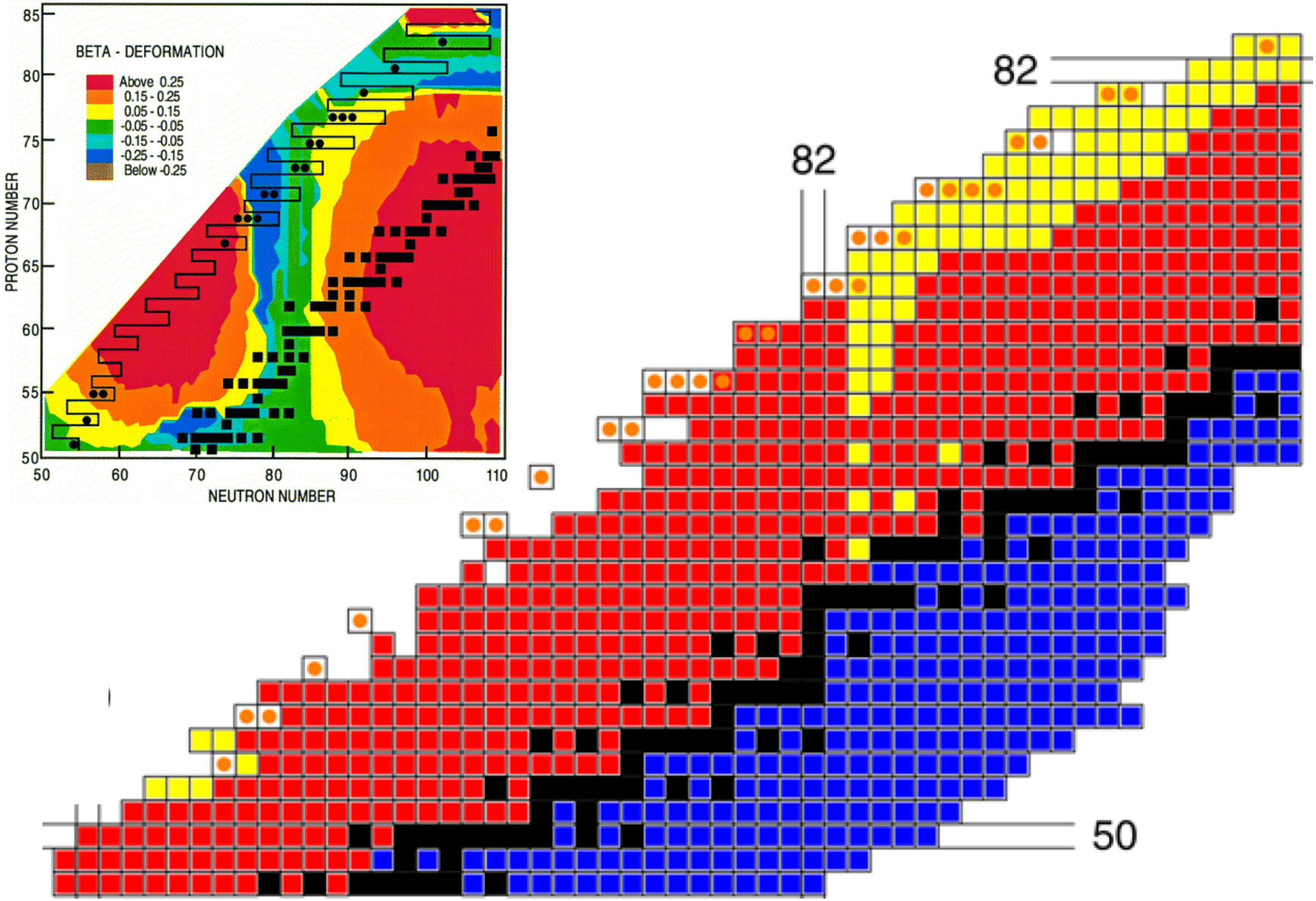
G. Lorusso et al., PRL114 (2015) 192501

Isomer γ decays or known p for unique A & Z identification

Predicted Super FRS Yields @ 10^{12}/s



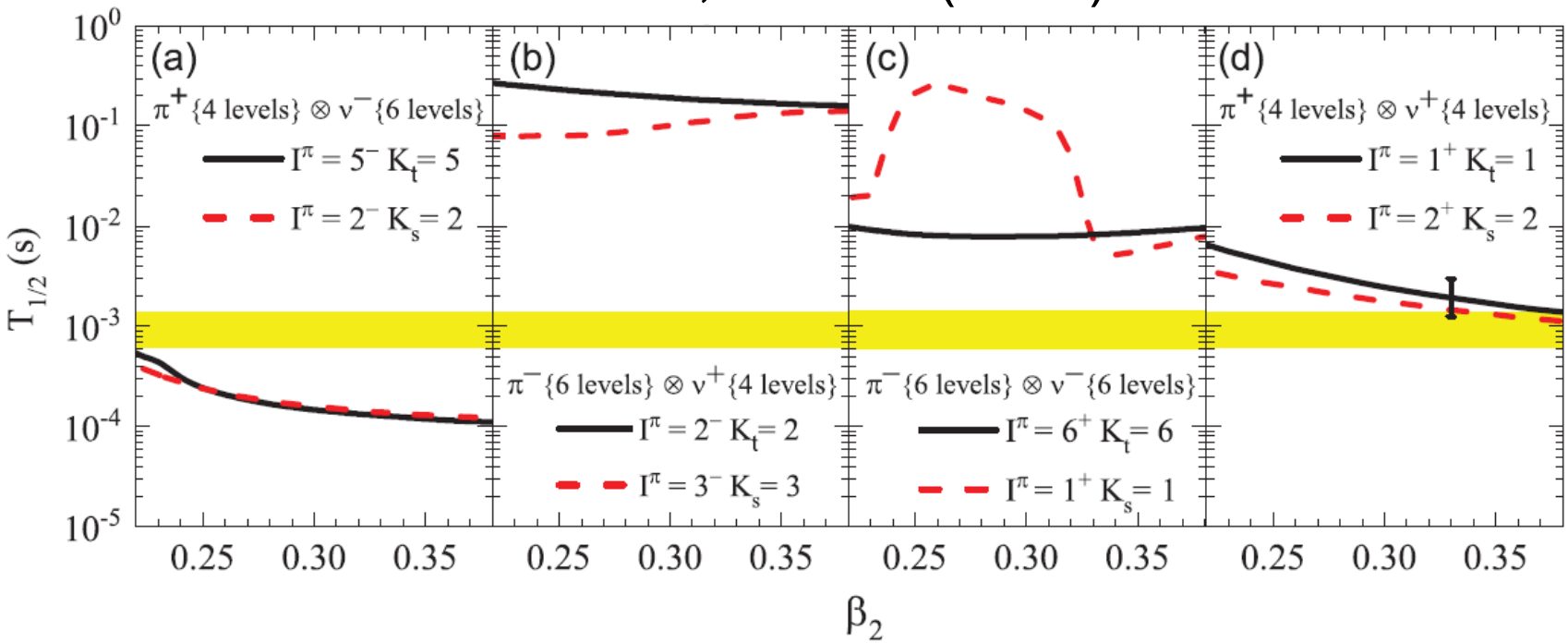
Known Proton Emitters



B. Blank & M.J.G. Borge, Progress in Particle and Nuclear Physics 60 (2008) 403

Deformed proton emitters

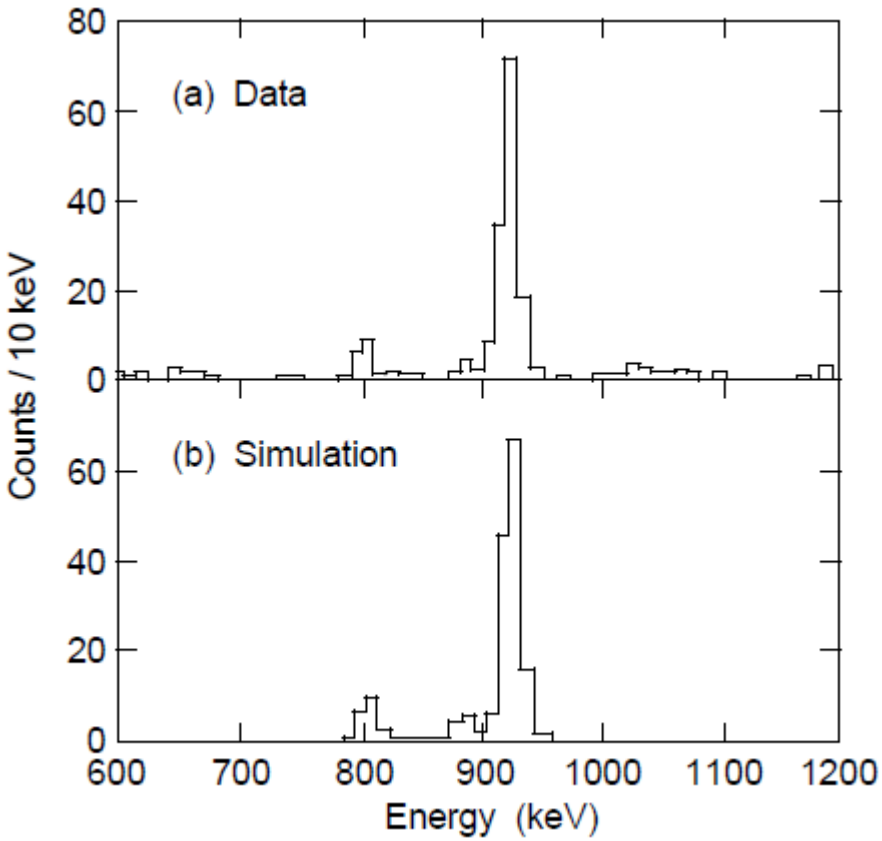
M. Patial et al., PRC88 (2013) 054302



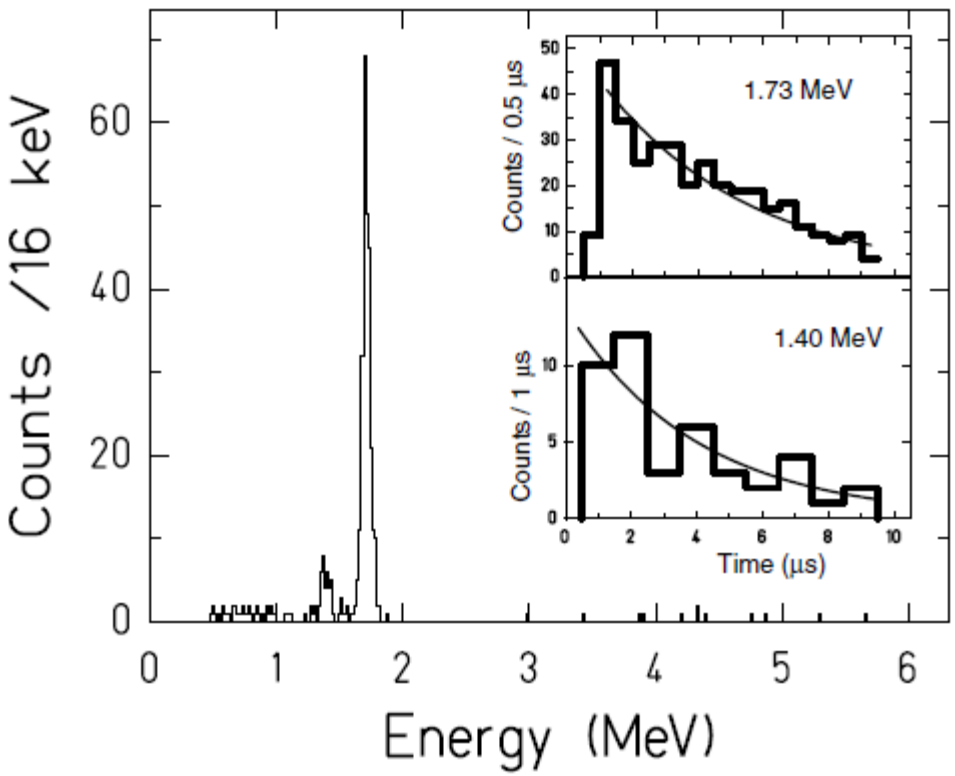
fragmentation + gas catcher / ISOL decay station
→ laser spectroscopy
⇒ determine spin and deformation!

Proton-decay fine structure

^{131}Eu



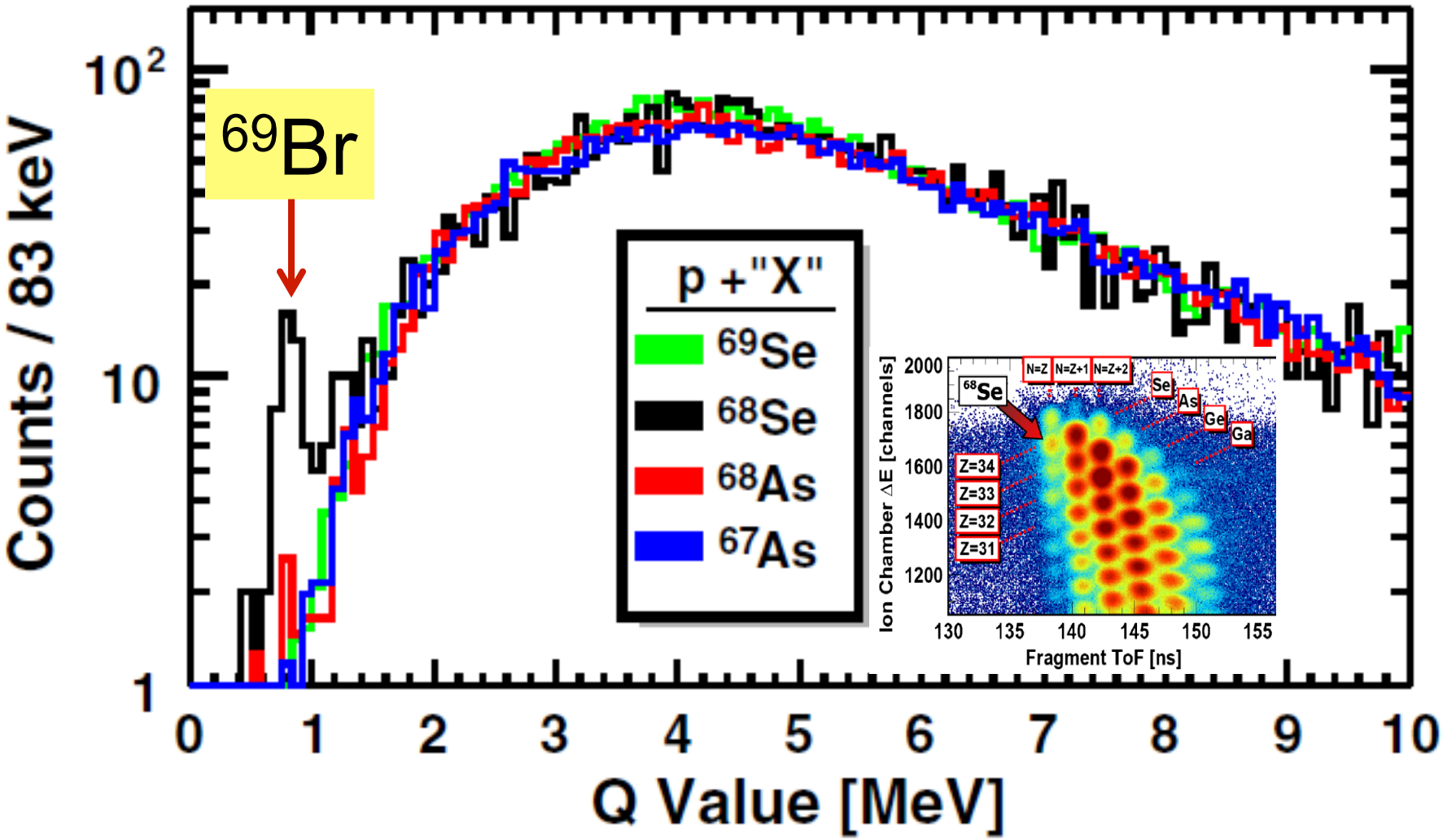
^{145}Tm



A.A. Sonzogni et al., PRL83 (1999) 1116

M. Karny et al., PRL90 (2003) 012502

In-flight proton emission



A.M. Rogers et al., PRL106 (2011) 252503

Proton emission - future prospects

RIB facilities

- New proton emitters
- Short-lived proton emitters (in-flight)
- Laser spectroscopy? ($\Rightarrow$ spin, β_2)
- Proton-decay fine structure
- Isomers can throw up surprises!

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