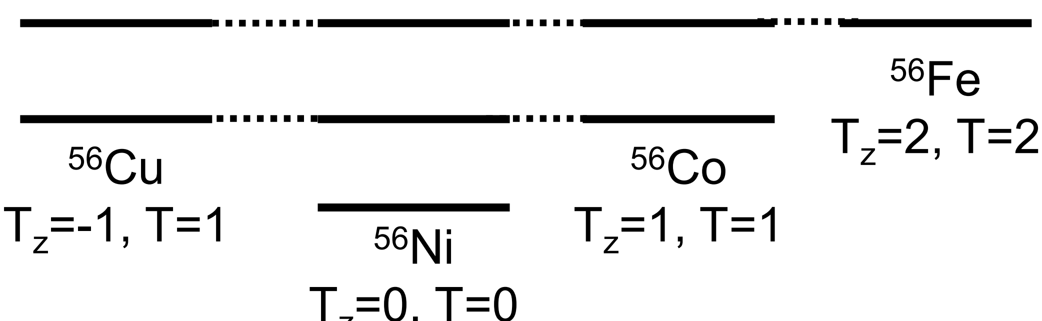
And now for something completely different

Isospin

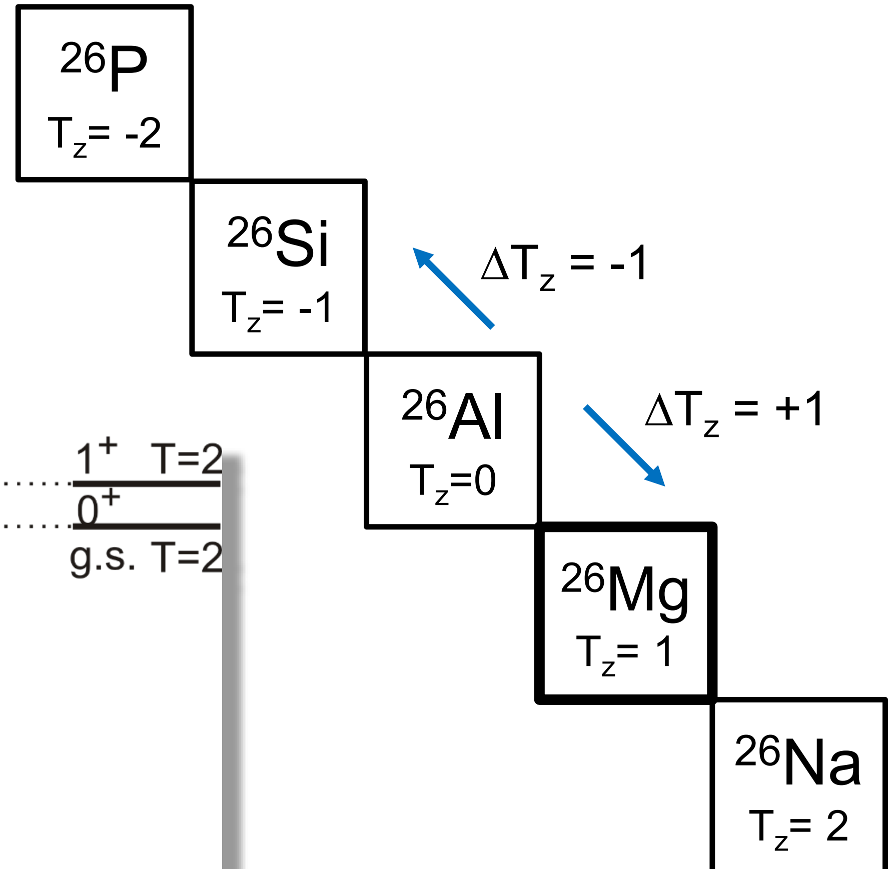
- Isospin formalism
  - assume nuclear force is charge independent.
- Introduce isospin, T
  - Proton, T = ½, T_z = -½
  - Neutron, T = ½, T_z = ½
  - $T_z = (N-Z)/2$
- General rule:
  - T has lowest possible value for given T_z.

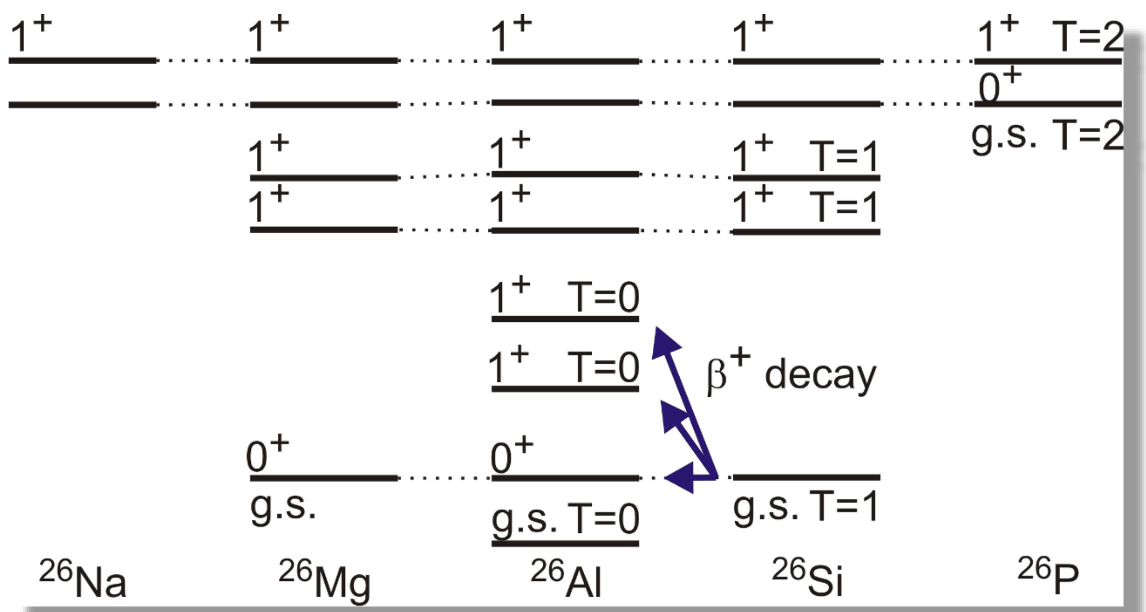
^{56}Cu	^{57}Cu	^{58}Cu	^{59}Cu
^{55}Ni	^{56}Ni	^{57}Ni	^{58}Ni
^{54}Co	^{55}Co	^{56}Co	^{57}Co
^{53}Fe	^{54}Fe	^{55}Fe	^{56}Fe



Fermi Matrix Elements

- Fermi
  - Only raise or lower T_z
  - T,J is unchanged.
  - accessibility of daughter state.

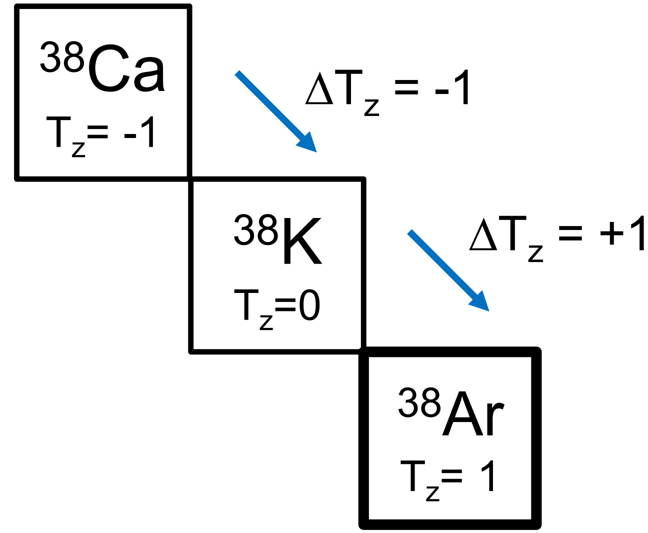




Courtesy R. Zegers

Super allowed Fermi transitions

- Standard model test
- Super allowed Fermi Transitions
  - $0^+ \rightarrow 0^+$ transitions
  - Same T
  - Gamow-Teller can't contribute
- Simple matrix element
- Constant log*ft*

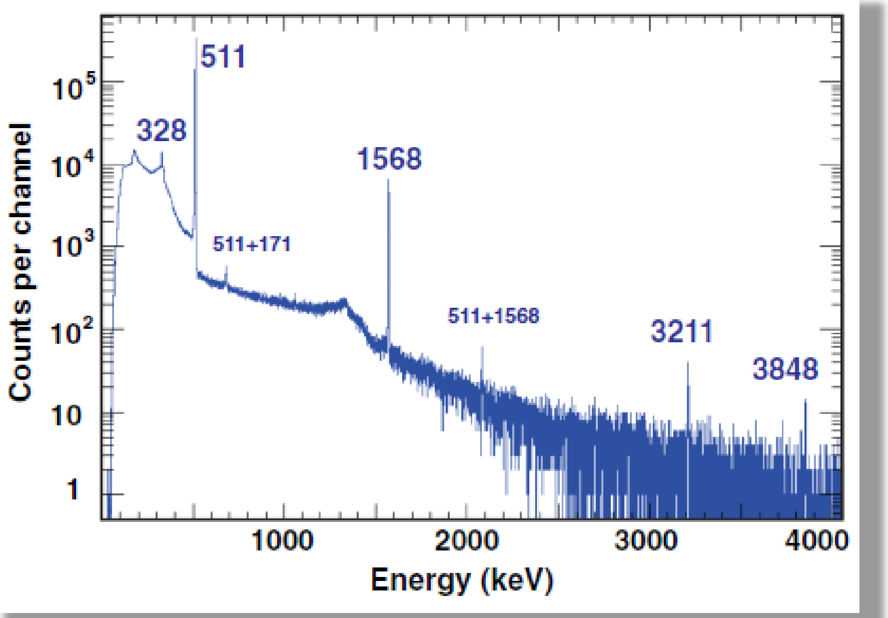


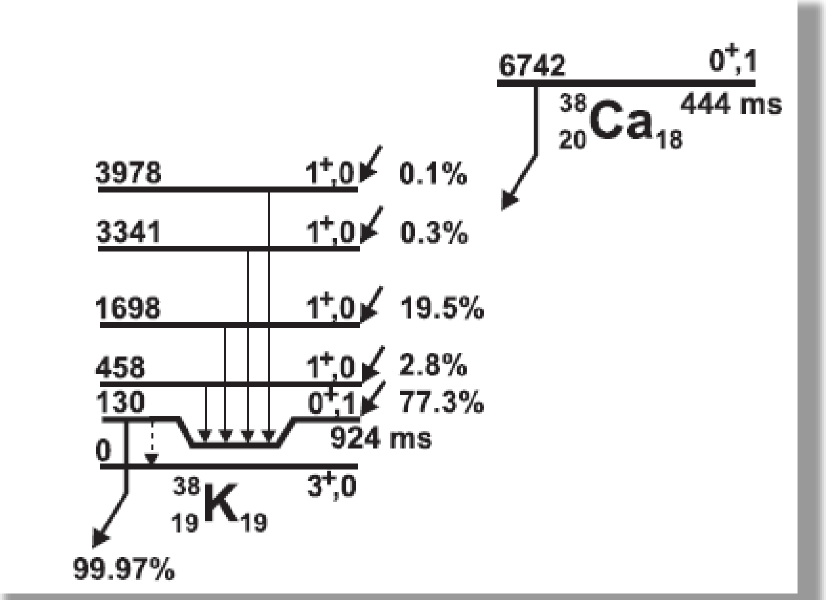
$$f(Z'E_0)t_{\frac{1}{2}} = \frac{K}{g^2 B(F)^2} = \frac{K}{2g^2}$$

Super allowed Fermi transitions: A = 38

- Experimental Constraints
  - $T_{1/2}$, branching ratios to 0.05%
  - Masses to 100's eV
  - Understanding of corrections

$$f(Z'E_0)t_{\frac{1}{2}} = \frac{K}{g^2 B(F)^2} = \frac{K}{2g^2}$$

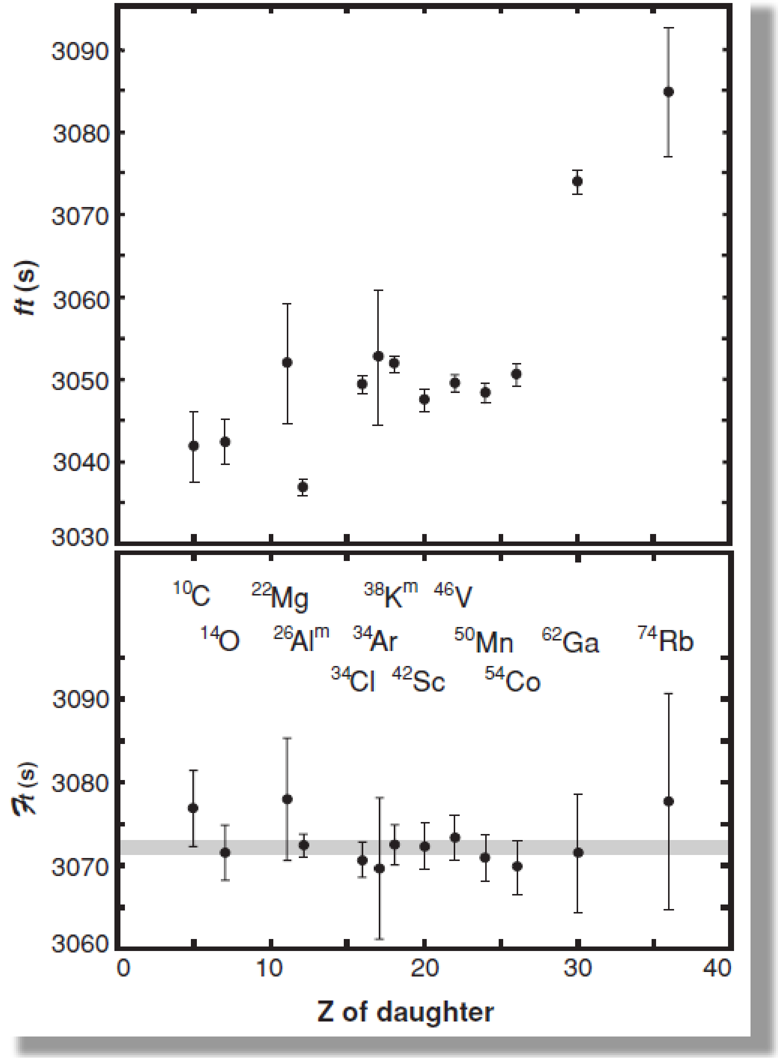




H.I. Park et al., PRL 112 102502 (2014)
J.C. Hardy and I.S.Towner, Hyperfine Int., 132, 115, (2001)

Super allowed Fermi transitions: All data

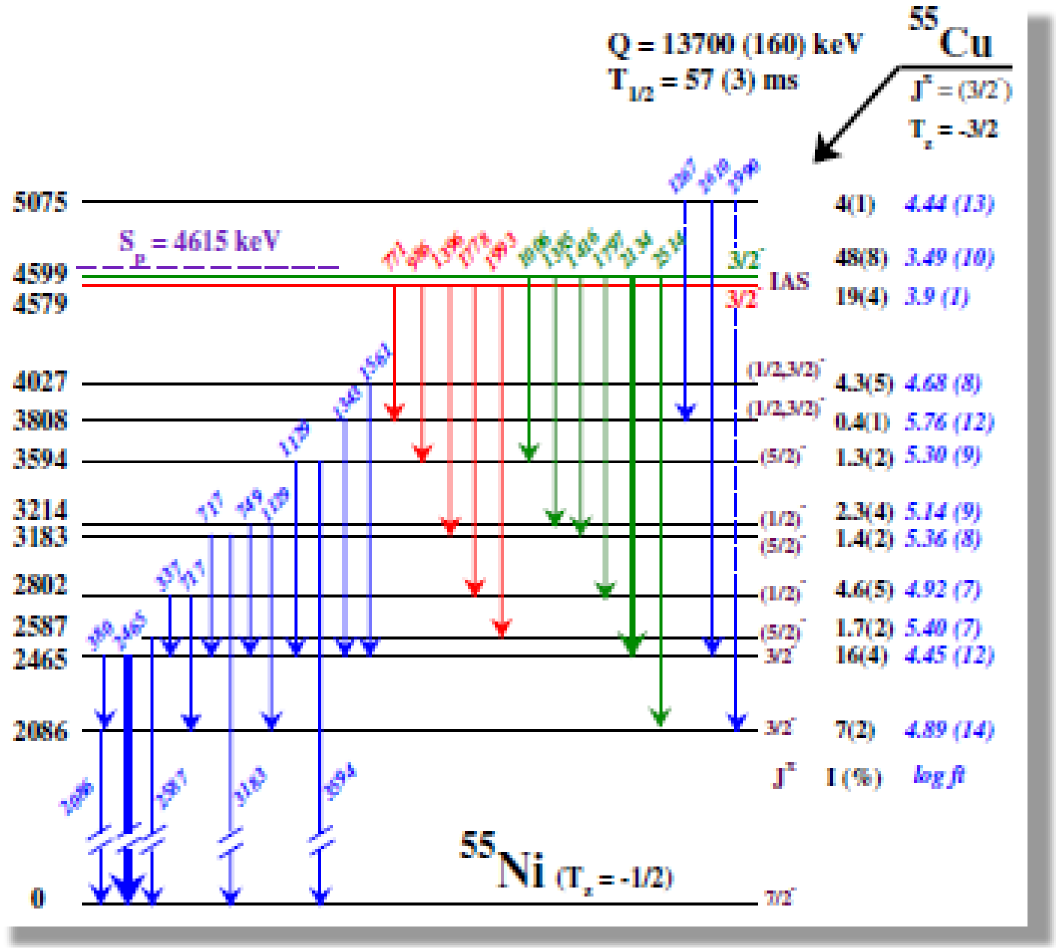
- Uncorrected ft values
  - Large spread due to corrections
- Corrected ft values
  - Isospin-symmetry breaking
  - Radiative corrections
- Current value
  - 3072 s



H.I. Park et al., PRL 112 102502 (2014)
J.C. Hardy and I.S.Towner, Hyperfine Int., 132, 115, (2001)

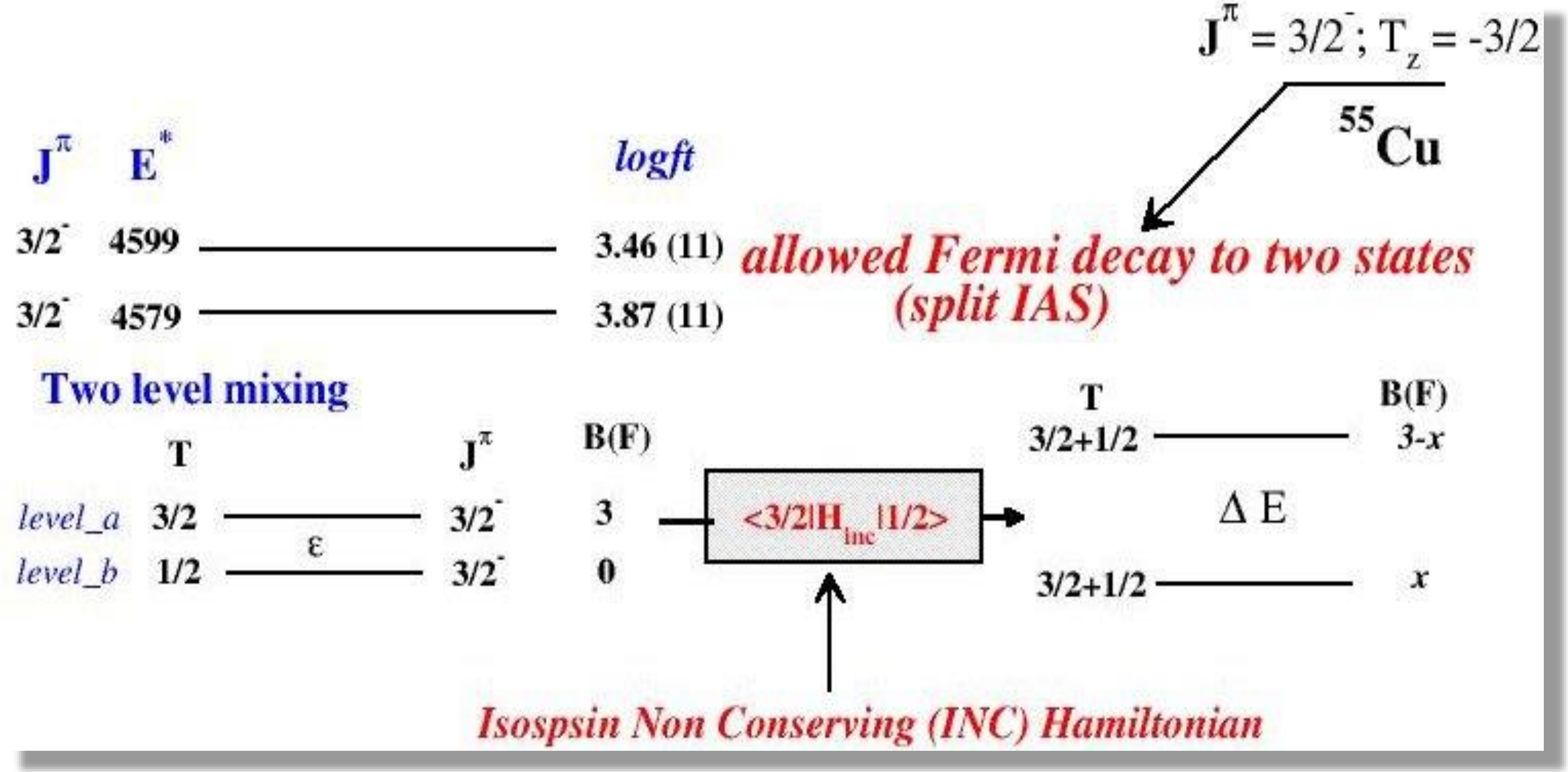
Isospin mixing

- Isospin not perfect.
- States with same J$^{\pi}$ and different isospin can mix



Courtesy V. Tripathi

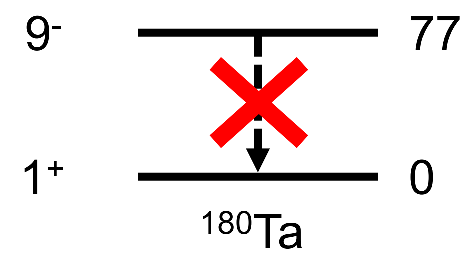
Isospin mixing

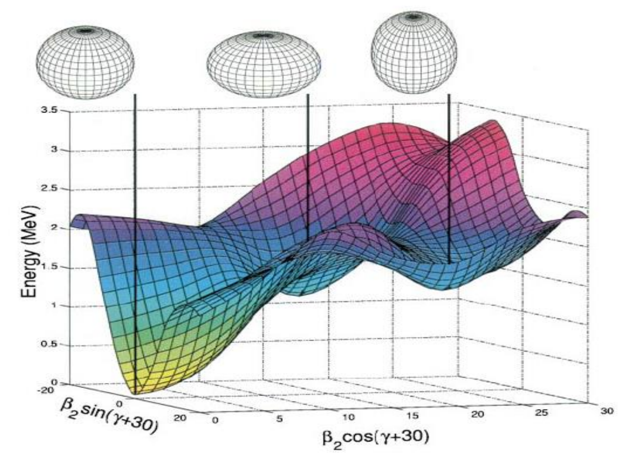


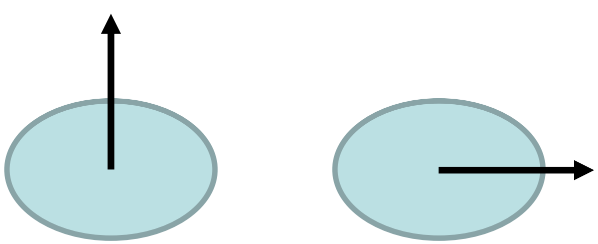
Courtesy V. Tripathi

Isomers

- Excited metastable nuclear states.
- Half-life greater than ns.
- Wide range of excitation energies and half-lives.
- Simple configurations.
  - Many can be related to a few single-particle shell model states.
- Energies and half-lives can inform nuclear models.
- Isomer decay is varied
  - Gamma-ray, Beta-decay, Proton, Fission, …







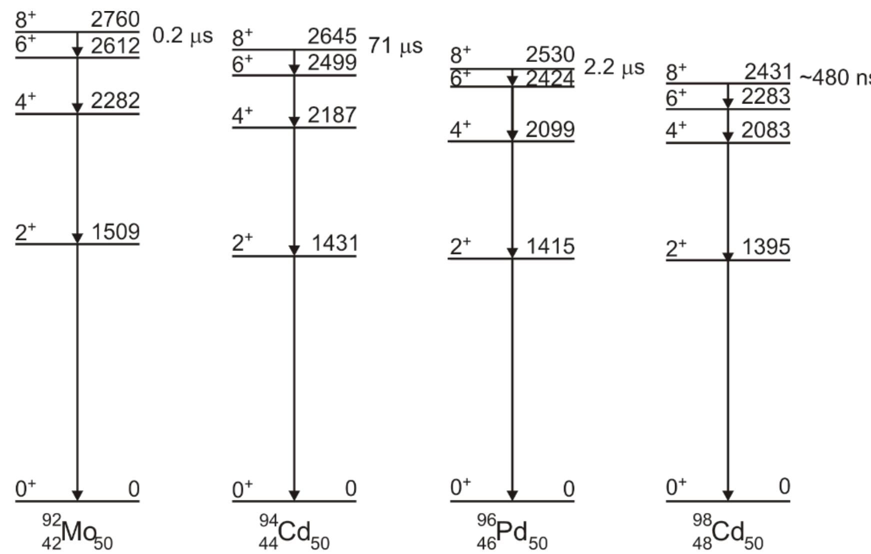
A. Andreyev *et al.*, Nature 405, 430 (2000)

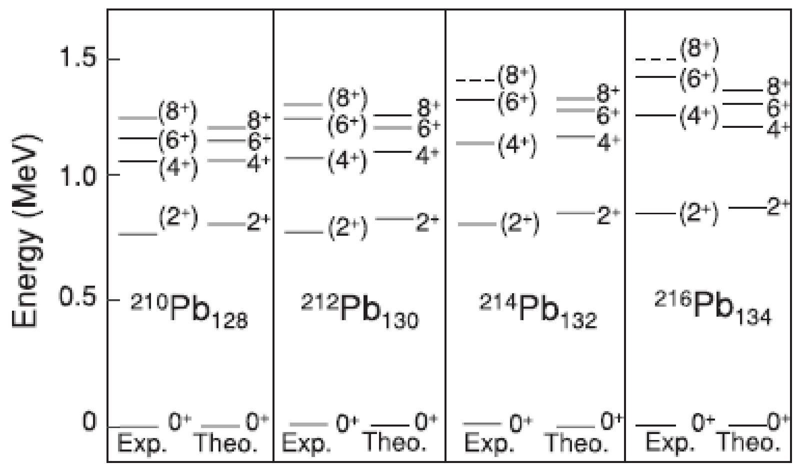
Question

- Consider a pair of nucleons isolated to a $g_{9/2}$ single-particle state.
- What are the allowed spins?
- A – 0^+, 1^+, 2^+, 3^+, 4^+, 5^+, 6^+, 7^+, 8^+, 9^+
- B – 0^+, 2^+, 4^+, 6^+, 8^+
- C – 0^+, 1^+, 3^+, 7^+, 9^+
- D – 1^+, 3^+, 7^+, 9^+
- E – 0^+, 8^+

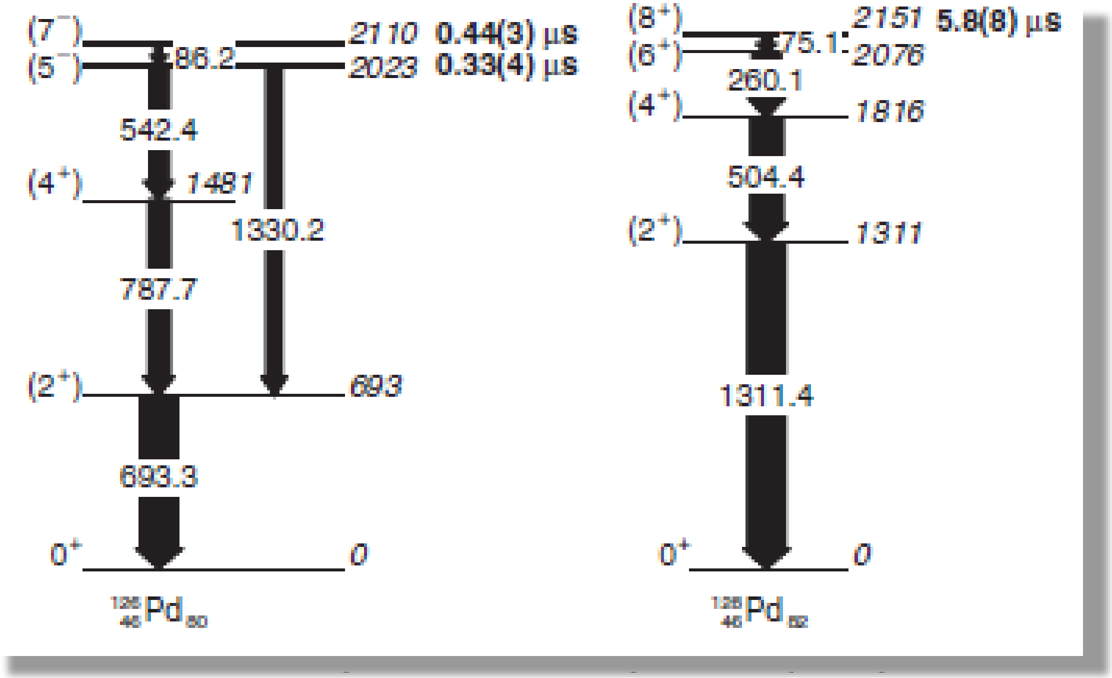
Isomers

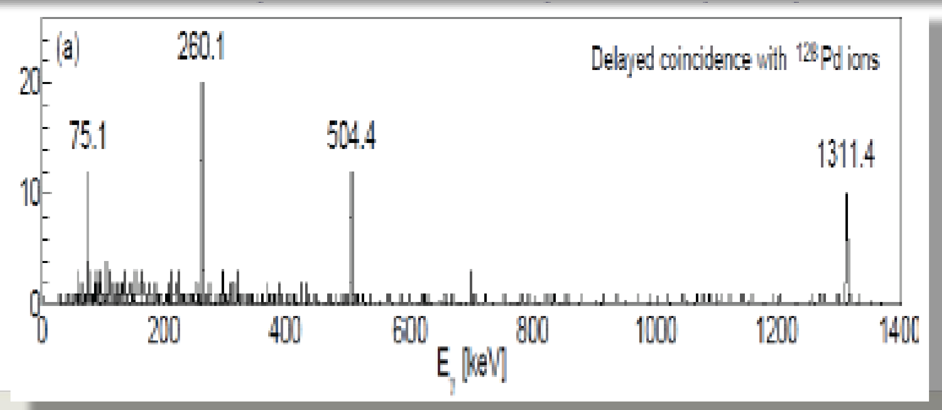
- Pair of particles in well isolated single particle orbital.
  - Protons at N = 50
  - Neutrons at Z = 82
- Low-energy transition.





N = 82

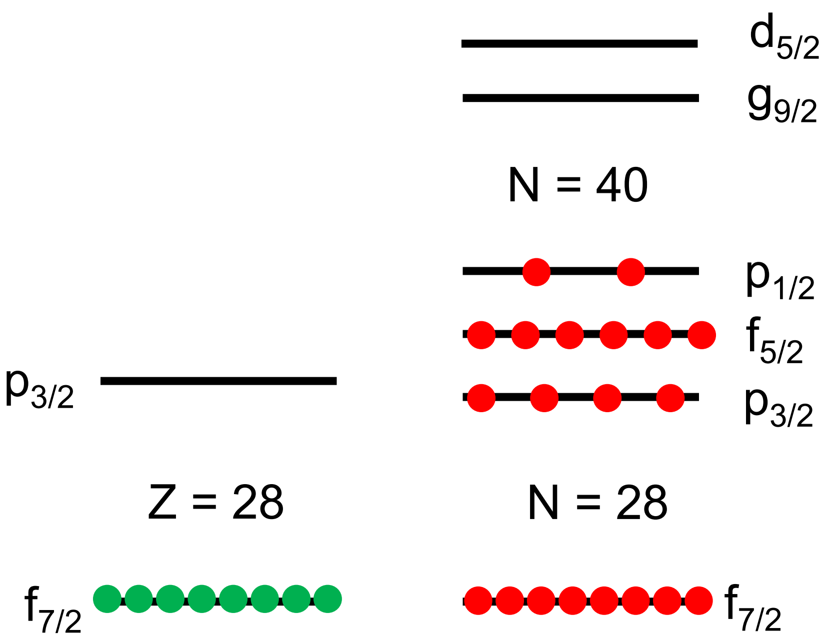


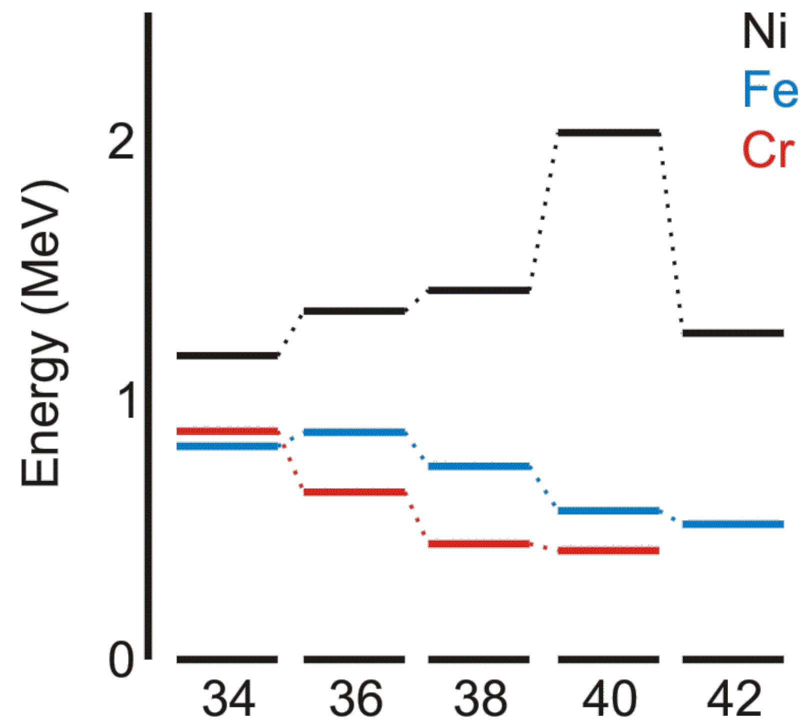


Courtesy S. Nishimura

N = 40

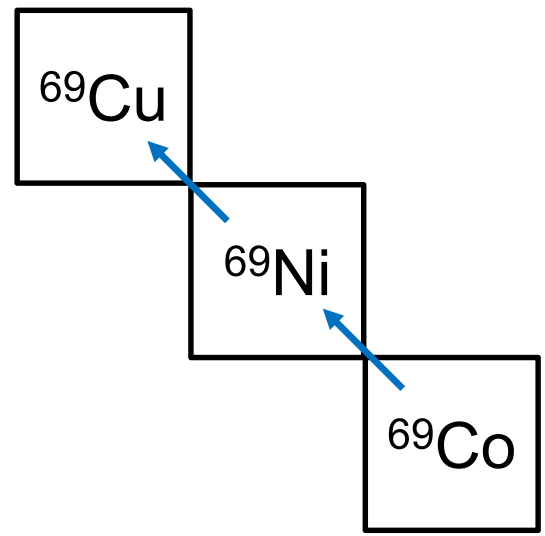
- Region around N = 40
- Drop in 2^+ energy below ^{68}Ni.

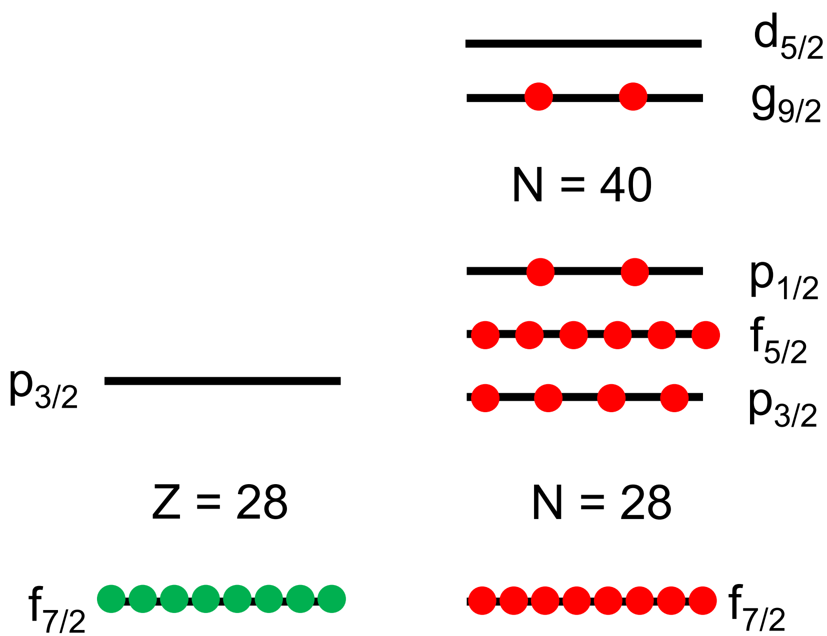




N = 40

- Region around N = 40
- Drop in 2^+ energy below ^{68}Ni.



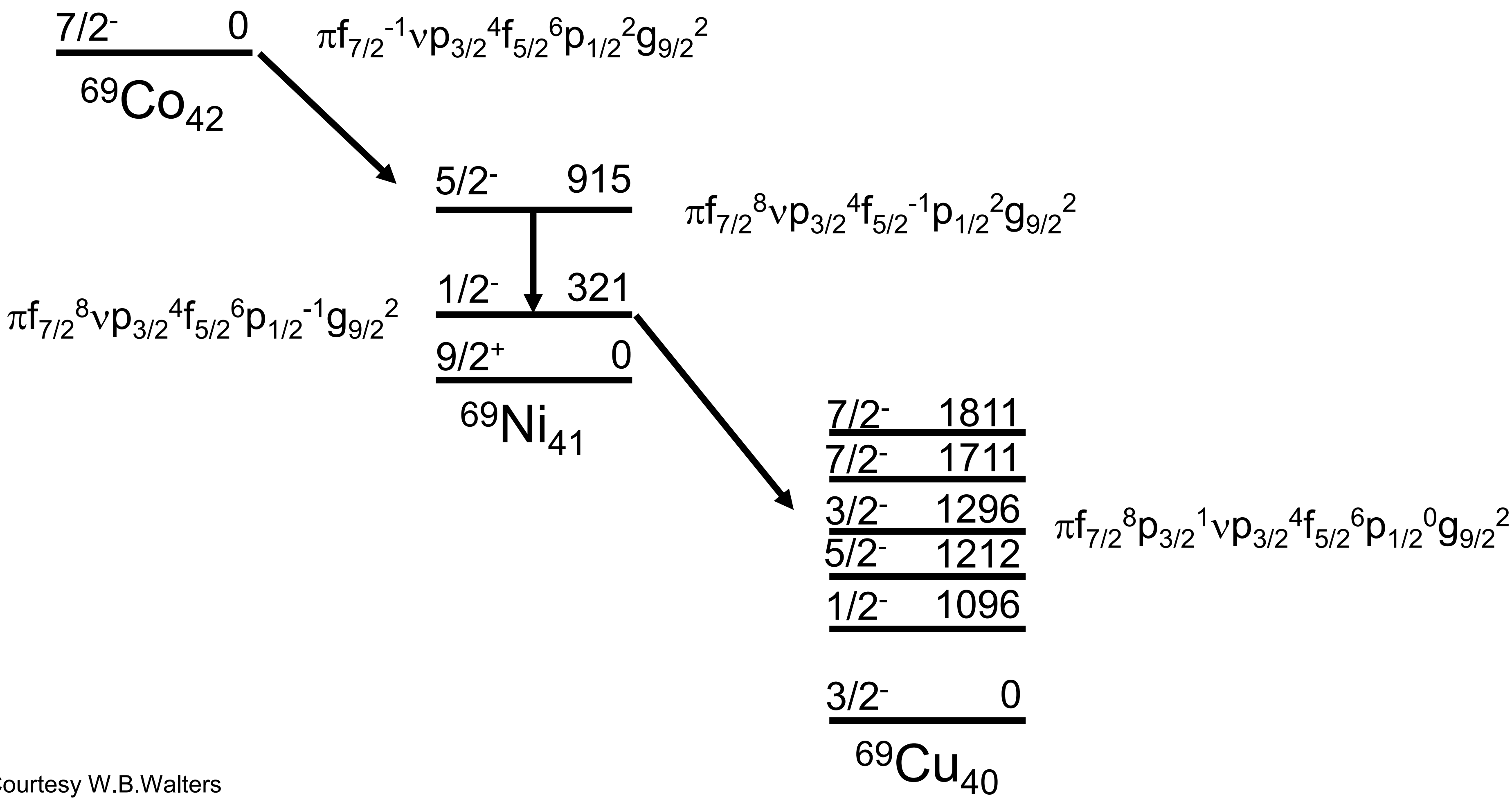


$$M_{fi} = \langle \varphi_f^* | \sigma\tau | \varphi_i \rangle$$

Strong preference for spin-flip transition:

$$f_{5/2} \longrightarrow f_{7/2}$$

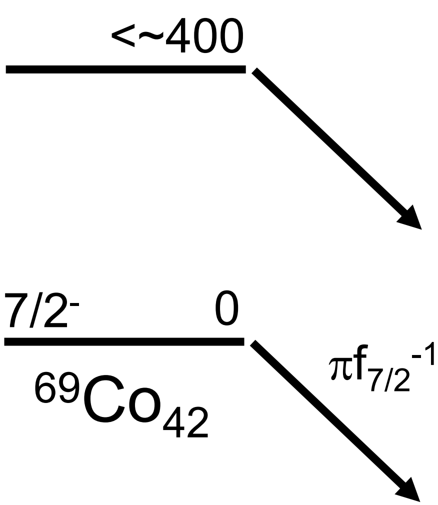
Mass 69 chain

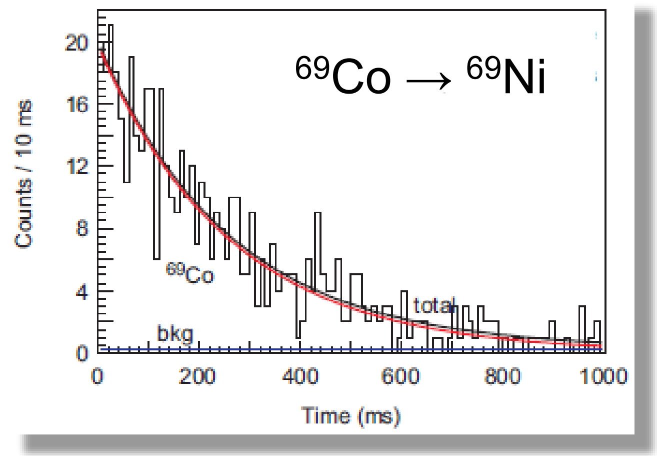


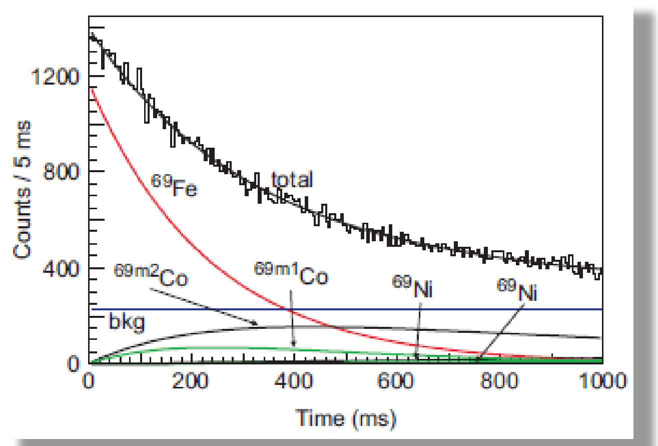
Courtesy W.B.Walters

^{69}Co isomer

- Multiple beta-decaying states inferred.

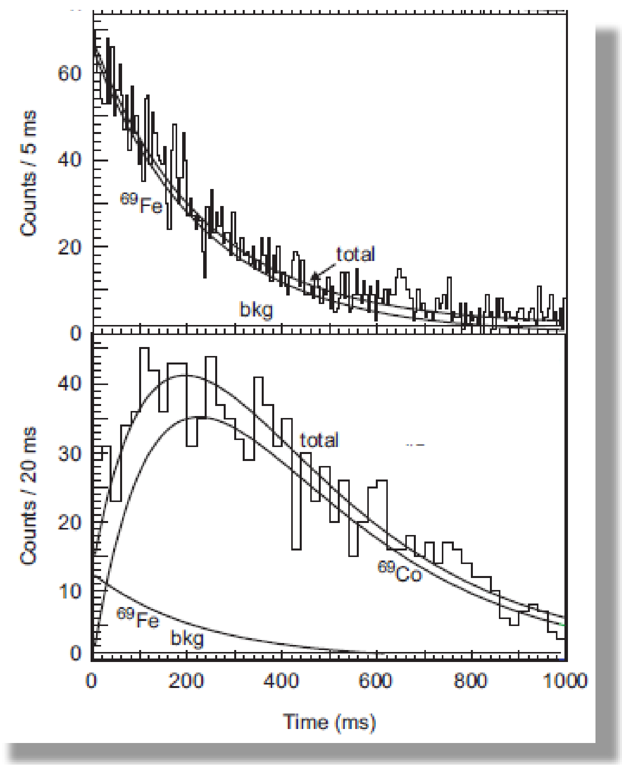






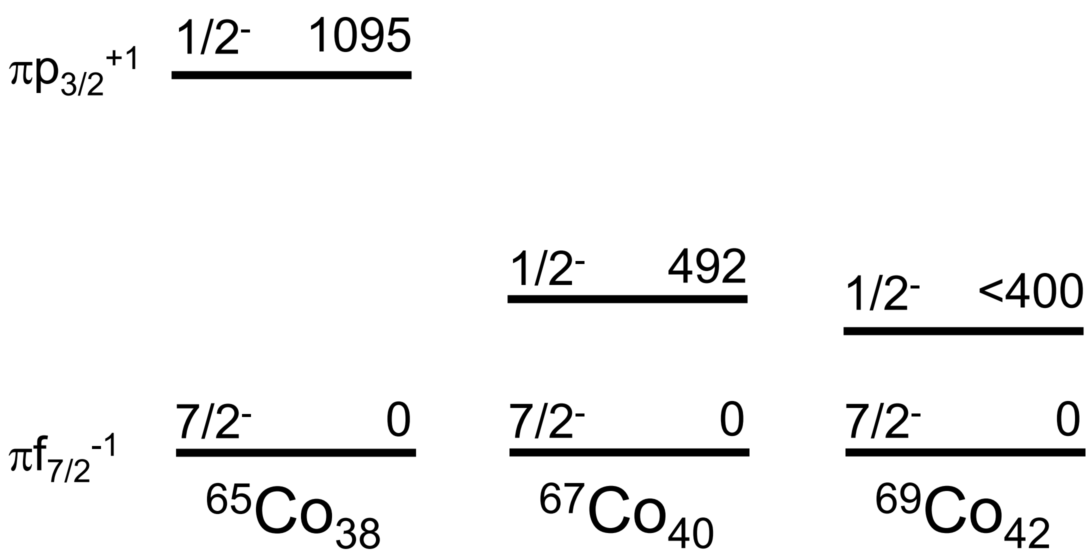
- Population of isomer changes based on production.

^{69}Fe → ^{69}Co → ^{69}Ni



^{69}Co isomer

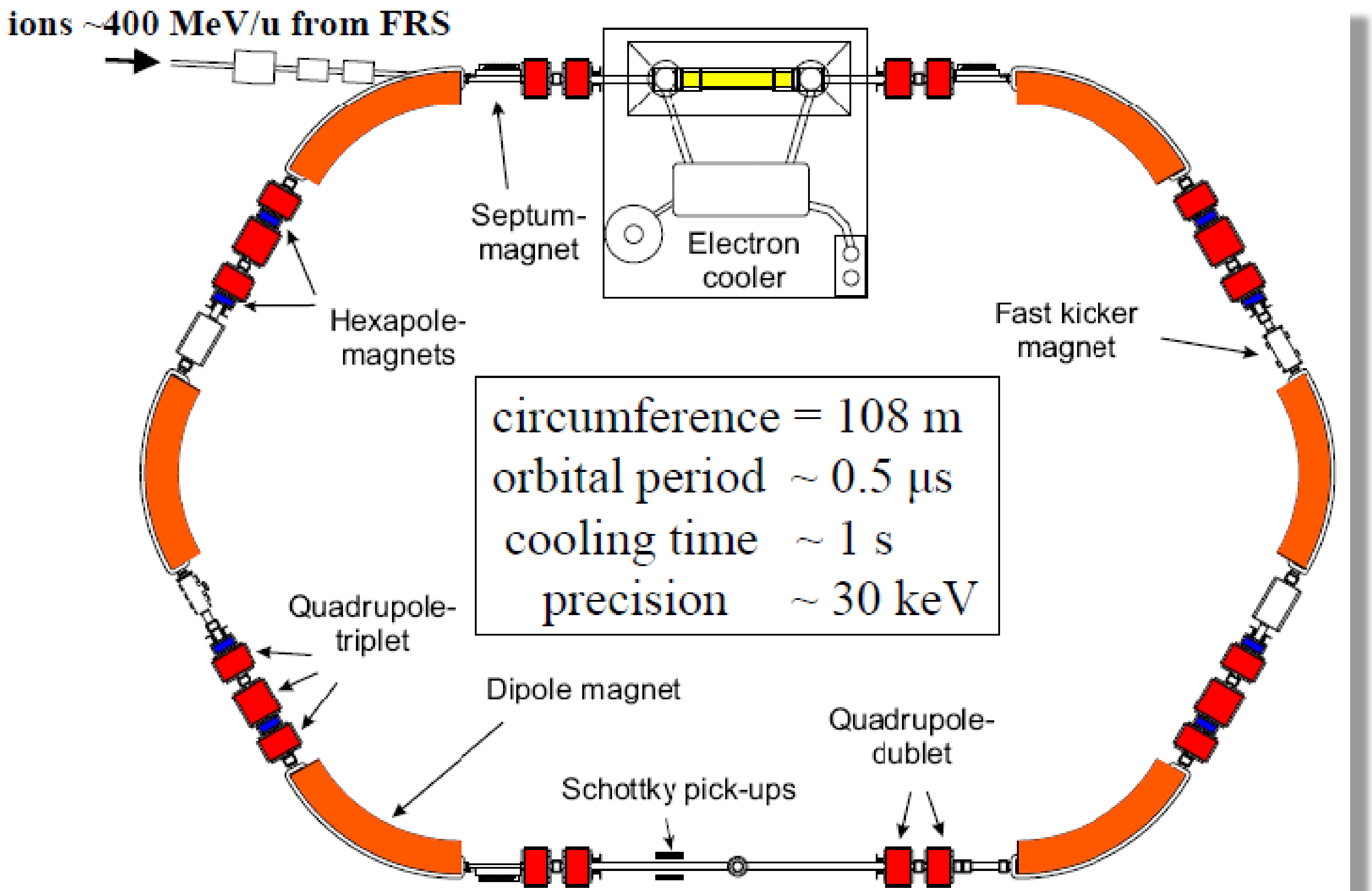
- States attributed to excitations across Z = 28 observed throughout the Co, Ni, Cu isotopic chains.
- Require the application if multiple complimentary probes.



Long-lived Isomers: ^{212}Bi

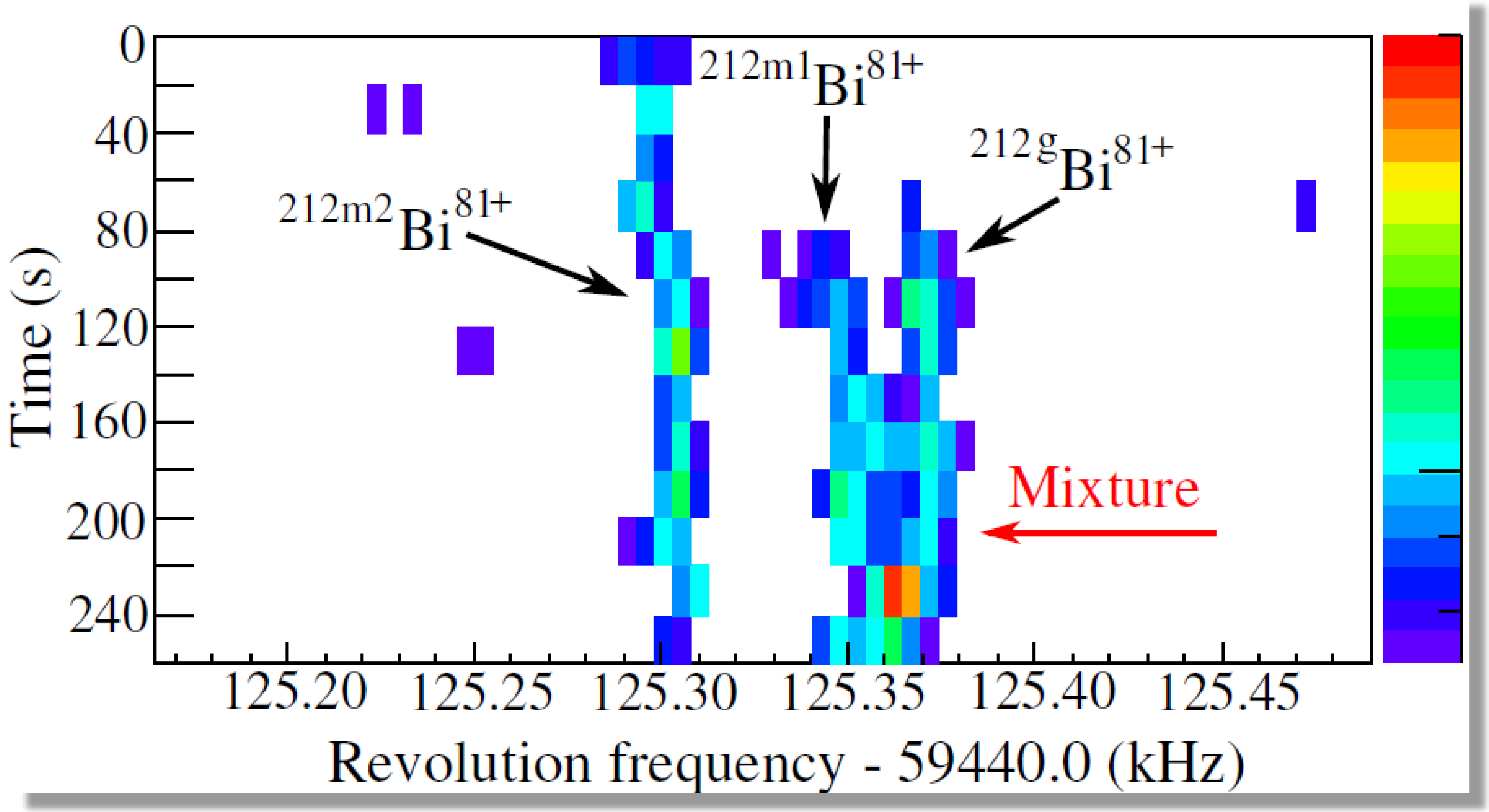
- One proton, three neutrons removed from ^{208}Pb.
- Proton – $h_{9/2}$
- Neutron – $i_{11/2}$, $g_{9/2}$
- Should be amenable to shell model treatment.
- Isomer predicted at 1486 keV.
- Inferred from beta decay at higher energy.

^{212}Bi: Storage rings



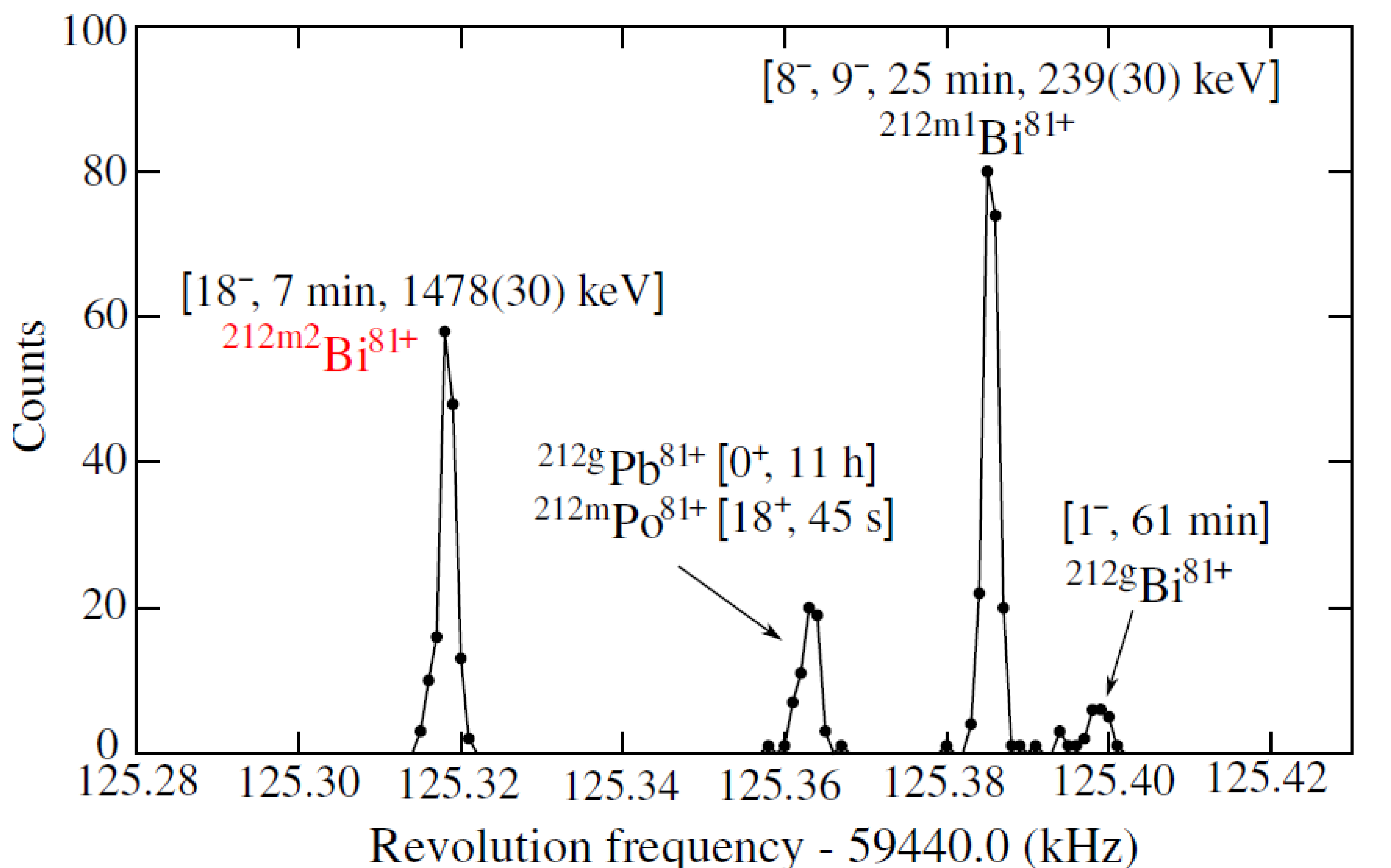
Courtesy P. Walker

^{212}Bi: Schottky mass spectrometry



Courtesy P. Walker

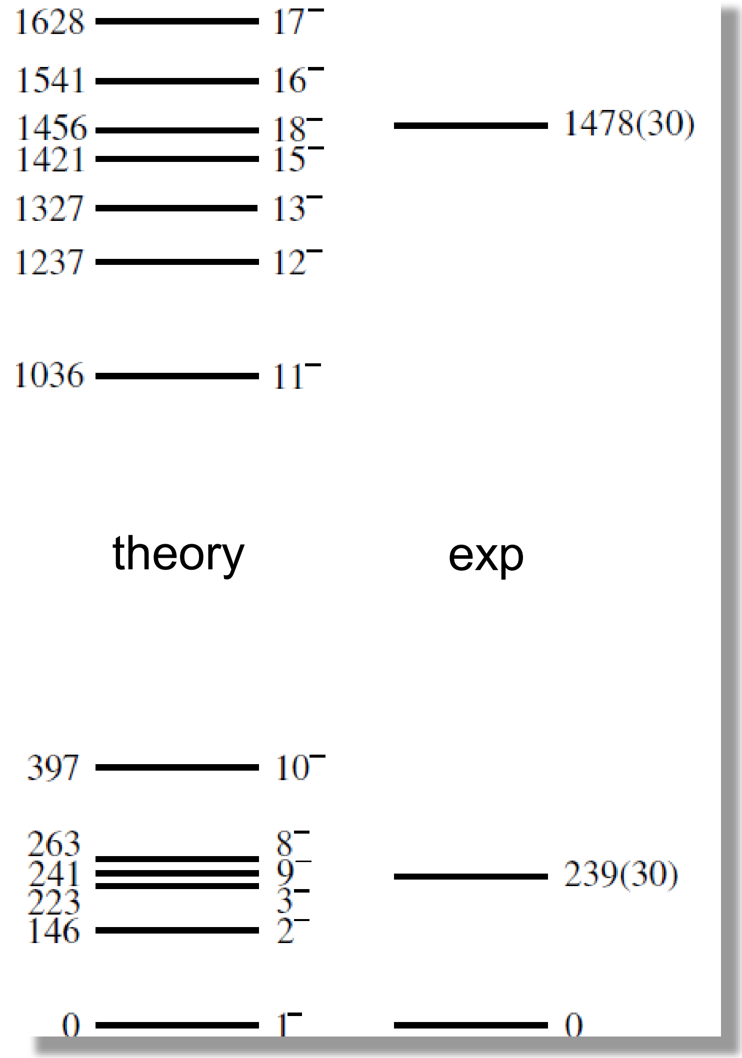
^{212}Bi: Schottky mass spectrometry



Courtesy P. Walker

^{212}Bi

- Half-life of ^{212}Bi.
  - Previous value 7.0 (3) min
  - Current value > 30 min
  - Difference due to high charge state
- Implies highly converted electron conversion transition.
- New half-life resolves log *ft* problem with previous measurement.



Courtesy P. Walker

Questions