Internal γ Decay and the Superallowed Branching Ratio for the β+ Emitter $^{38}K^{m}$

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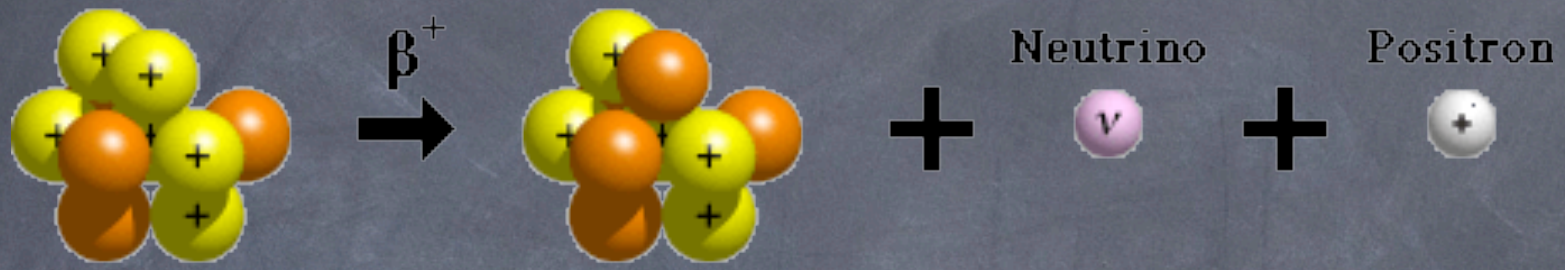
K. G. Leach et. al PRL **100**, 192504 (2008)

Outline

- Background
- Level scheme of $^{38}K^{m}$
- The experiment
- Results
- Implications

Superallowed β^+ decay



- Pure fermi decay (ν spin paired with β spin; S=0) between nuclear isobaric analogue states
- $I_P = I_D$ + L(=0 for allowed tranistions) + S(=0)
- G_V (Vector coupling constant), and the Fermi coupling constant, G_F, determine the first element of the Cabibbo-Kobayashi-Maskawa (CKM) matrix $V_{ud} = G_V/G_F$

[IMAGE] Jefferson Lab Webpage: http://education.jlab.org/glossary/betadecay.html

Link to nuclear physics

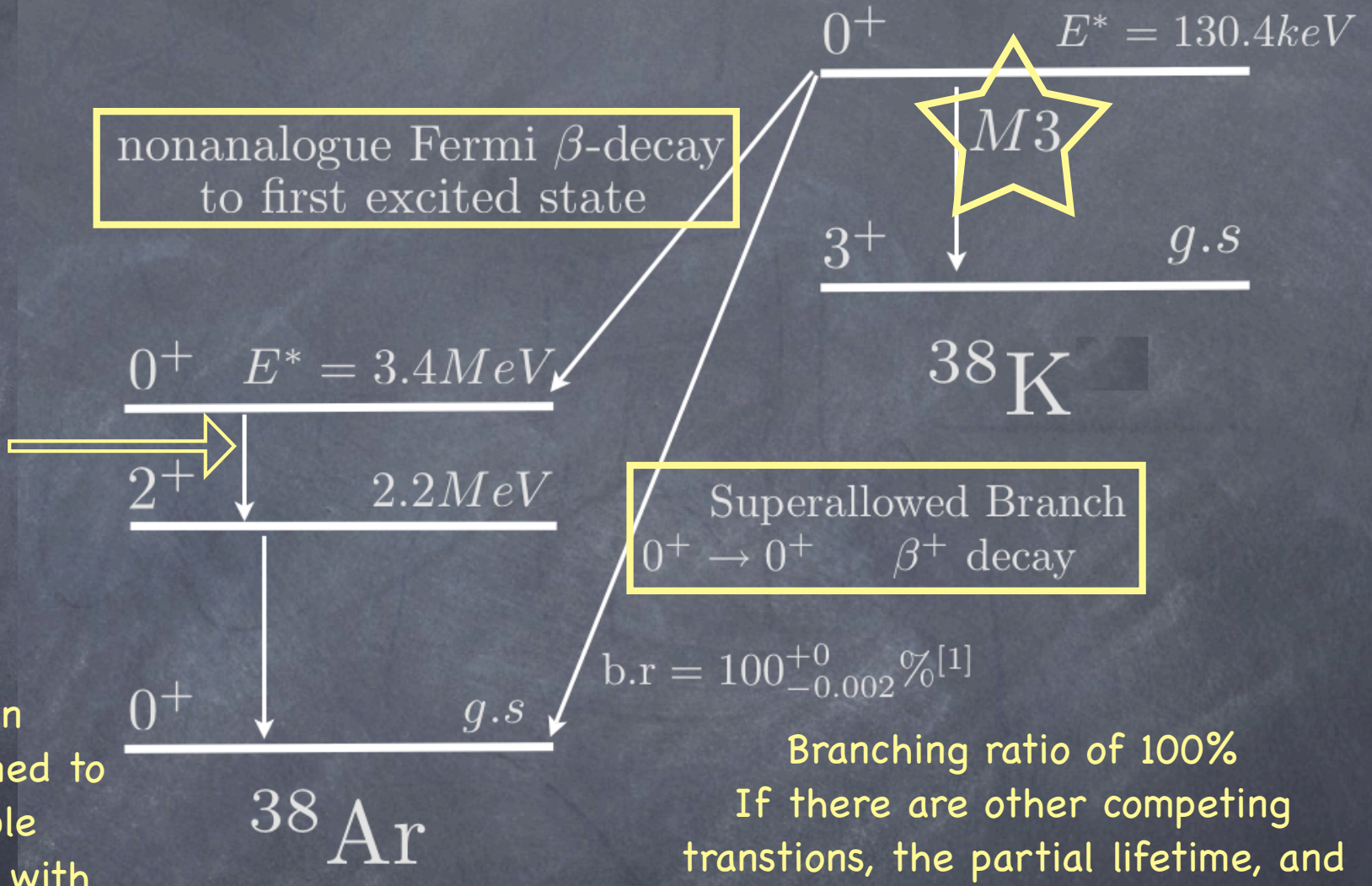
- f is the statistical rate function, and t, the partial half life of the superallowed branch
- ft values are almost nucleus independent
- Corrections for radiative and Coulomb effects, give a transition-independent Ft

$$Ft = ft(1+\delta_R^1)(1+\delta_{NS}-\delta_C) = \frac{K}{2G_V^2}(1+\Delta_R)$$

- For high precision, good calculations of these corrections are necessary
- Updated correction calculations[2] reduced the uncertainty on the V_{ud} matrix element by half, and shifted the central value by 1.5σ (largest in 20 years)

[2] I.S. Towner and J. C. Hardy, Phys. Rev. C **77**, 025501 (2008)

Superallowed β^+ decay of $^{38}K^m$



characteristic γ of nonanalogue branch E = 1209.96(12) keV[7]

M3 transition previously assumed to have negligible branching ratio, with B(M3) values predicted to be heavily quenched (1.2×10^{-4} W.u.) in shell model calculations[8]

Branching ratio of 100%
If there are other competing transtions, the partial lifetime, and hence the ft value will be altered

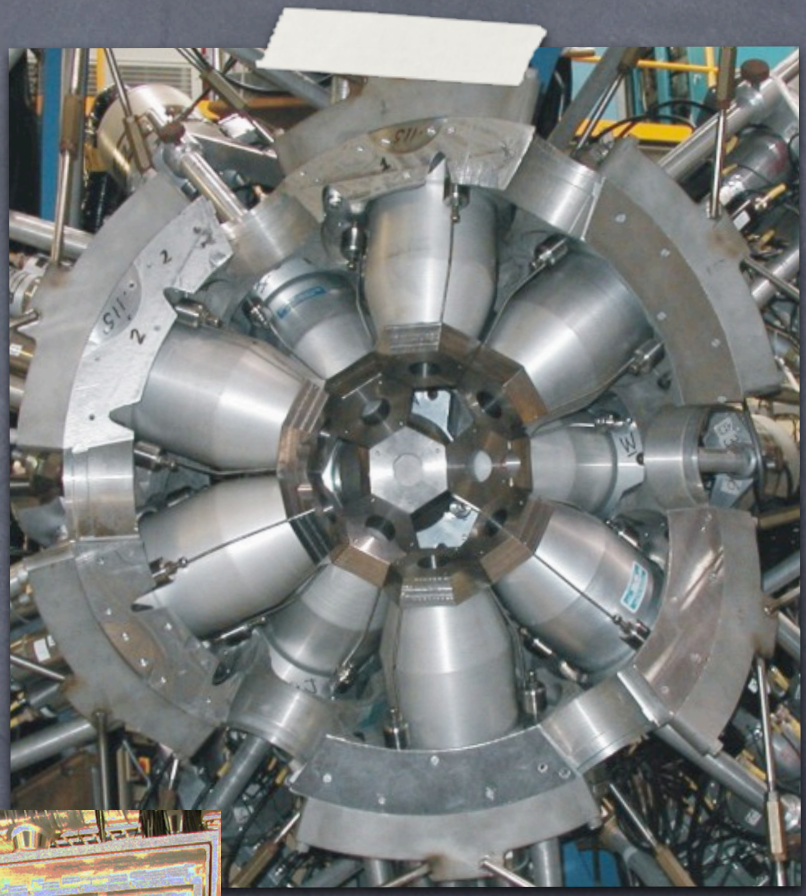
[1] J. C. Hardy and I.S. Towner, Phys. Rev. C **71**, 055501 (2005)

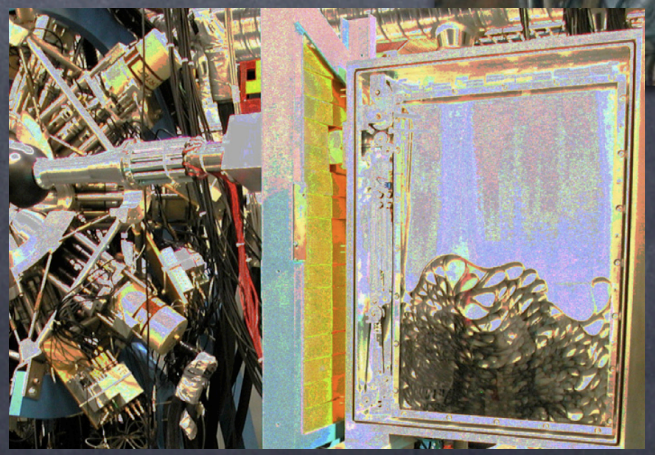
[7] P. M. Endtm, Nucl. Phys. A **521**, 1 (1990)

[8] B. A. Brown et al., Phys. Rev. C **22**, 842 (1980)

The Experiment

- TRIUMF - ISAC
- 500MeV, 65μA proton beam on 22 g cm^{-2} Ta target
- 30keV beam of ^{38}K and ^{38}K^{m} ions
- Implanted in mylar tape
- SPECTAR for β detection
- 8π array for γ spectrometry



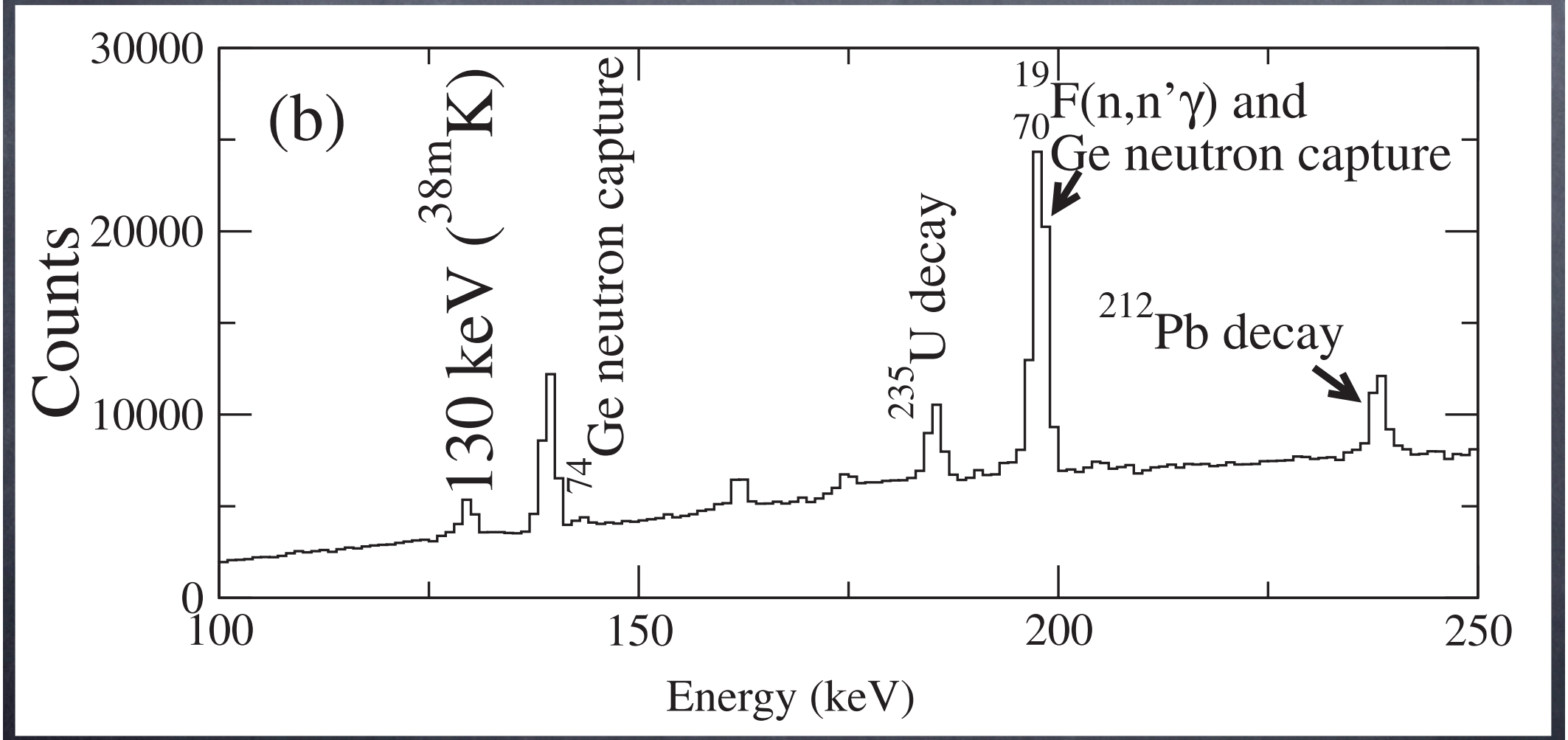


Photos of 8π array (above) and the tape system (left) taken from ref.

[10] G.C. Ball et al., J. Phys. G **31**, S1491 (2005) and
[11] C. E. Svensson et al., Nucl. Instrum. Methods. Phys. Res. Sect. B **204**, 660(2003)

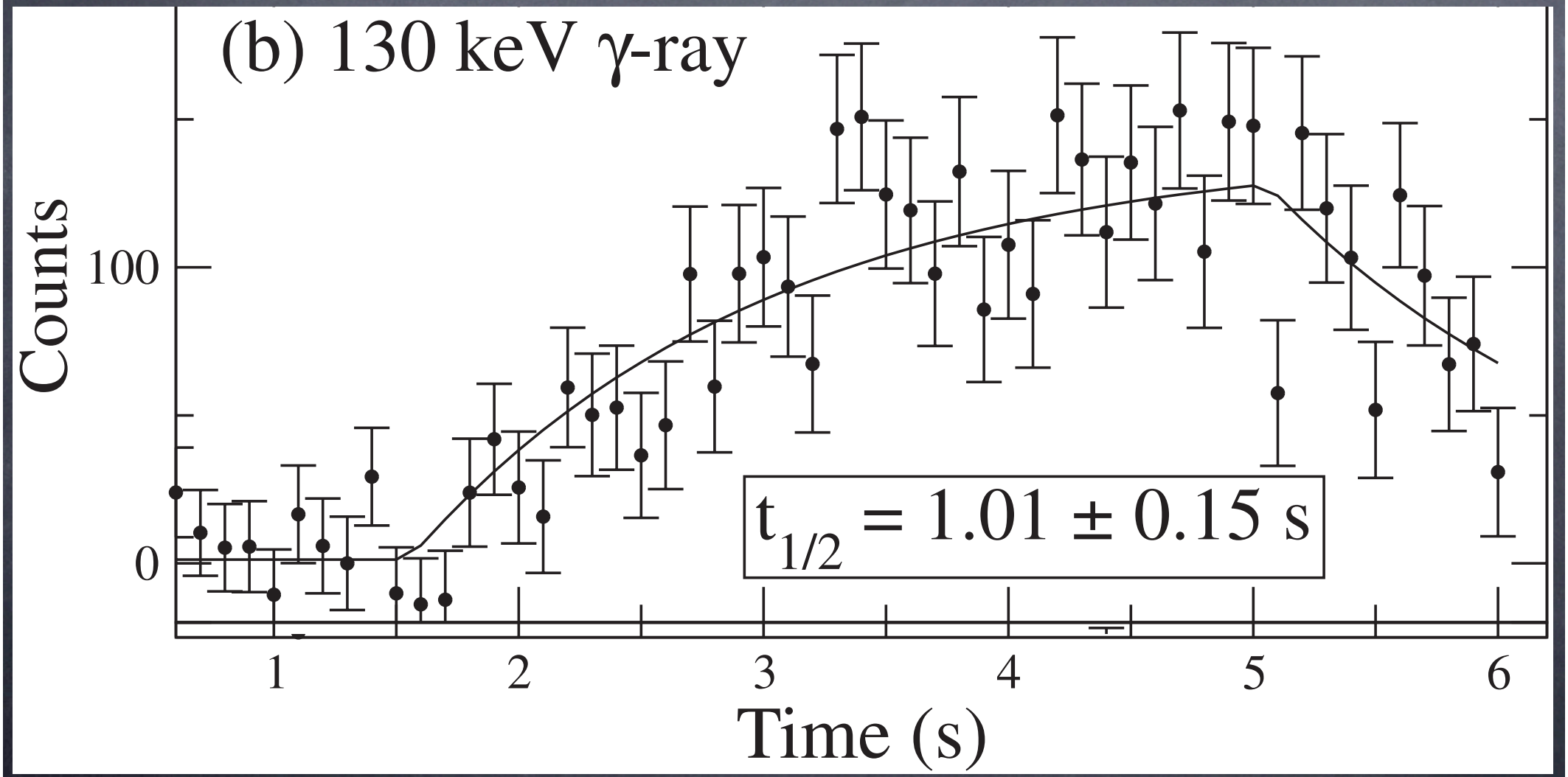
Results

Enlarged low-energy section of the βγ anti-coincidence spectrum



Results

Projection of the 130 keV peak with time, showing half-life of state



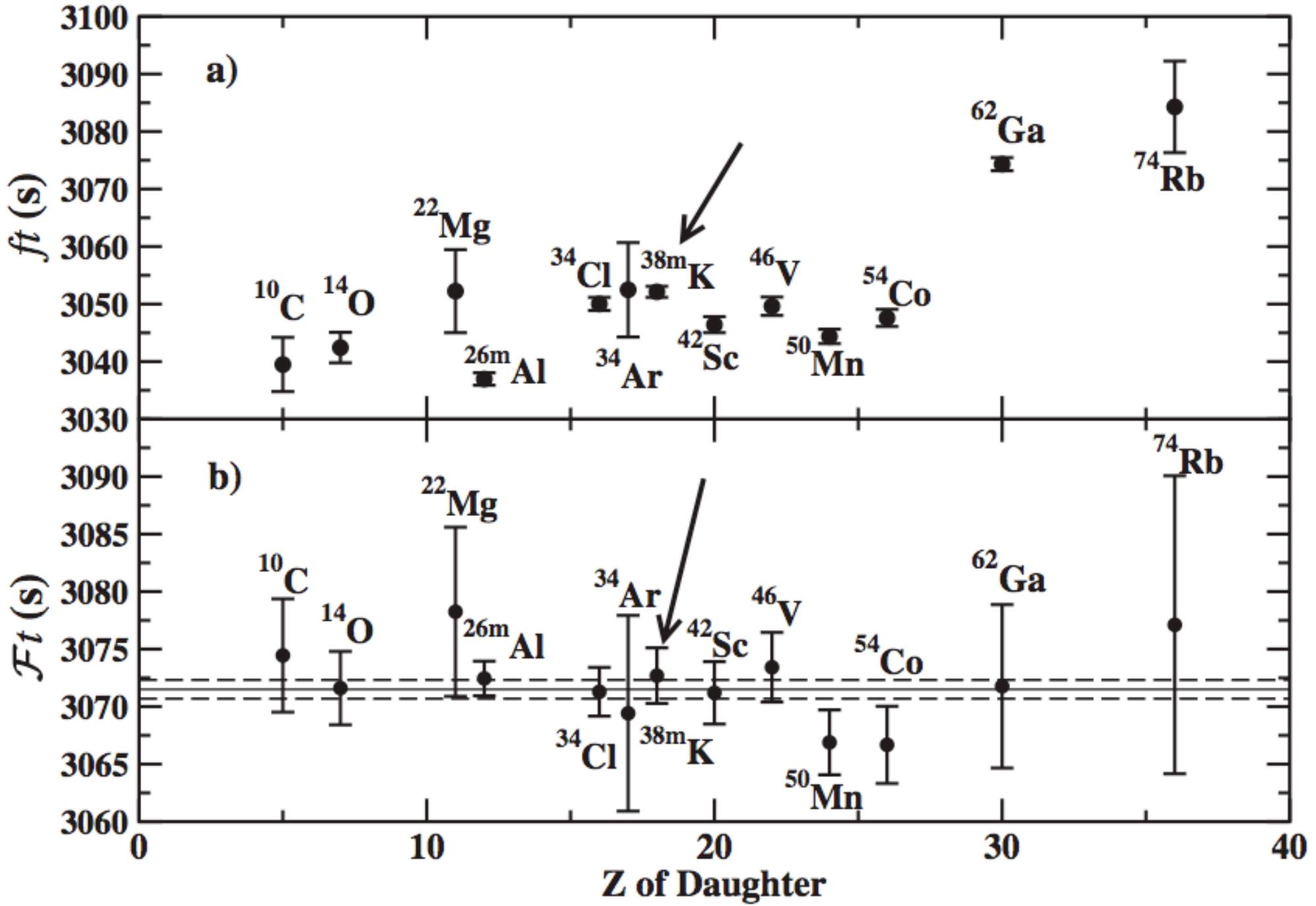
Literature value: $t_{1/2}$ = 0.92433(27) [1]

Experimental Results

- Yields M3 branching ratio of 237(31) ppm
- B(M3) value of 0.21(3) W.u. Shell model predicts 1.2×10^{-4} W.u.
- Total internal decay **b.r. = 330(43) ppm**
- Revised superallowed branching ratio of 99.967(4)%
- Alters the partial half life to t = 0.92542(57) s
  from total half life of $^{38}K^{m}$: $t_{1/2}$ = 0.92433(27) s [1]
- Together with f = 3298.10(33)[1] ft = 3052.1(10) s
- Applying corrections from ref [2] Ft = 3072.7(24) s
- Increases world average Ft by 0.12 s to 3071.5(8) s

[1] J. C. Hardy, and I.S. Towner Phys. Rev. C **71**, 055501 (2005)
[2] I.S. Towner and J. C. Hardy, Phys. Rev. C **77**, 025501 (2008)

ft and Ft values shown with average Ft = 3071.5(8)



Conclusion

- Revised superallowed branching ratio in $^{38}K^{m}$ of 99.967(4)%
- Revised ft and Ft values, as well as revised world average Ft
- Shift in the central value of up-down element of the CKM matrix
- From V_{ud} = 0.97418(13)(14)(18) this paper reports a revised value

$$V_{ud} = 0.97416(26)$$