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Improving CKM Unitarity Limits via Low-Energy Nuclear Physics

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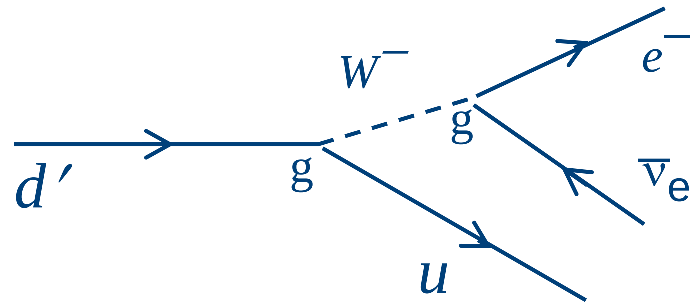
Capture Gamma-Ray Spectroscopy 2015

The Cabibbo-Kobayashi-Maskawa (CKM) matrix

- The CKM matrix plays a central role in the Standard Model

  and underpins all quark flavour-changing interactions:

→ weak interaction eigenstates ≠ quark mass eigenstates



$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

$$|d'\rangle = V_{ud}|d\rangle + V_{us}|s\rangle + V_{ub}|b\rangle$$

- In the Standard Model the CKM describes a unitary transformation.

$$V_{ud}^2 + V_{us}^2 + V_{ub}^2 = 1$$

The first row of the CKM matrix provides, by far, the most demanding experimental test of this unitarity condition.

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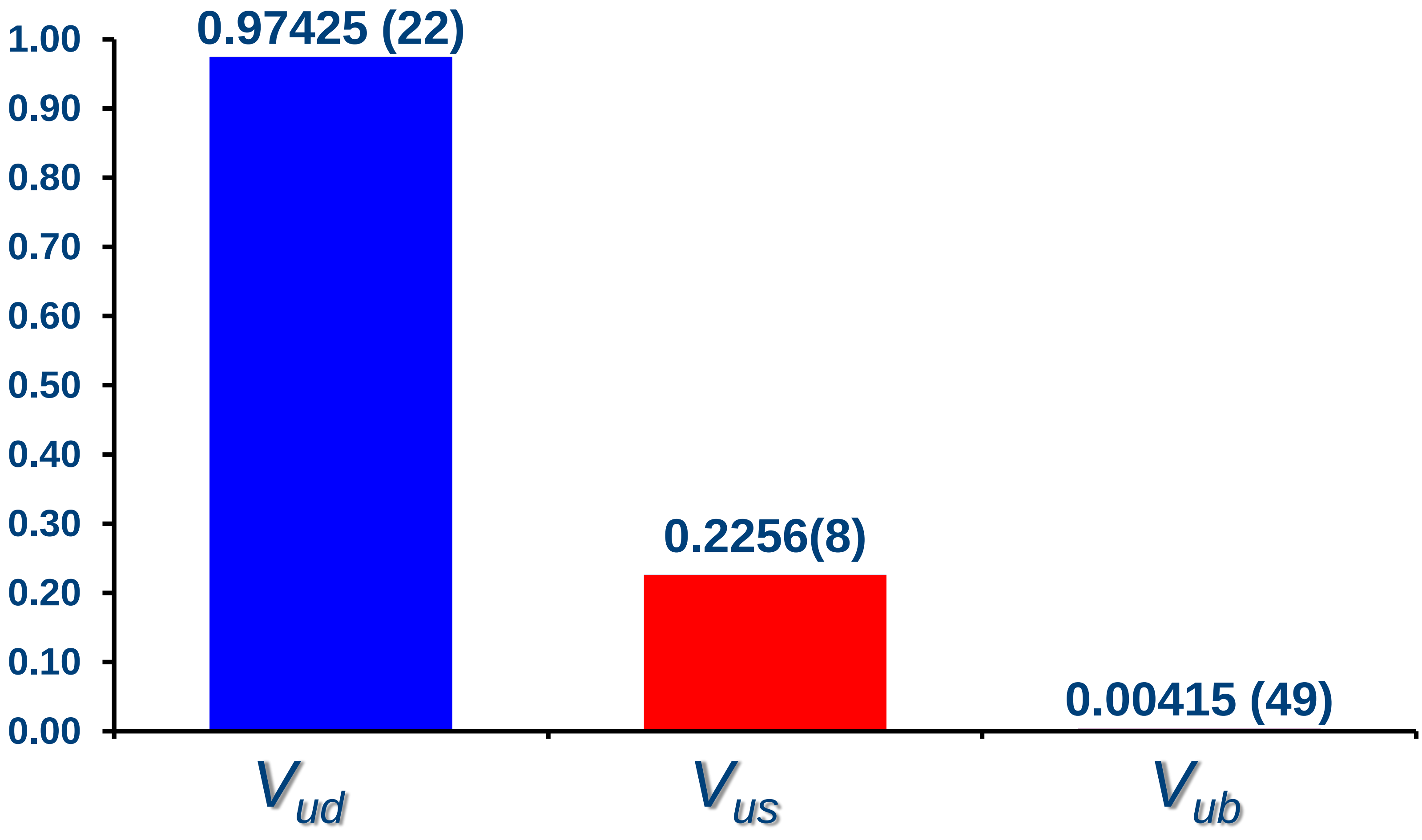
CKM Unitarity



J.C. Hardy and I.S. Towner, Ann. Phys. (Berlin) 525, 443 (2013).

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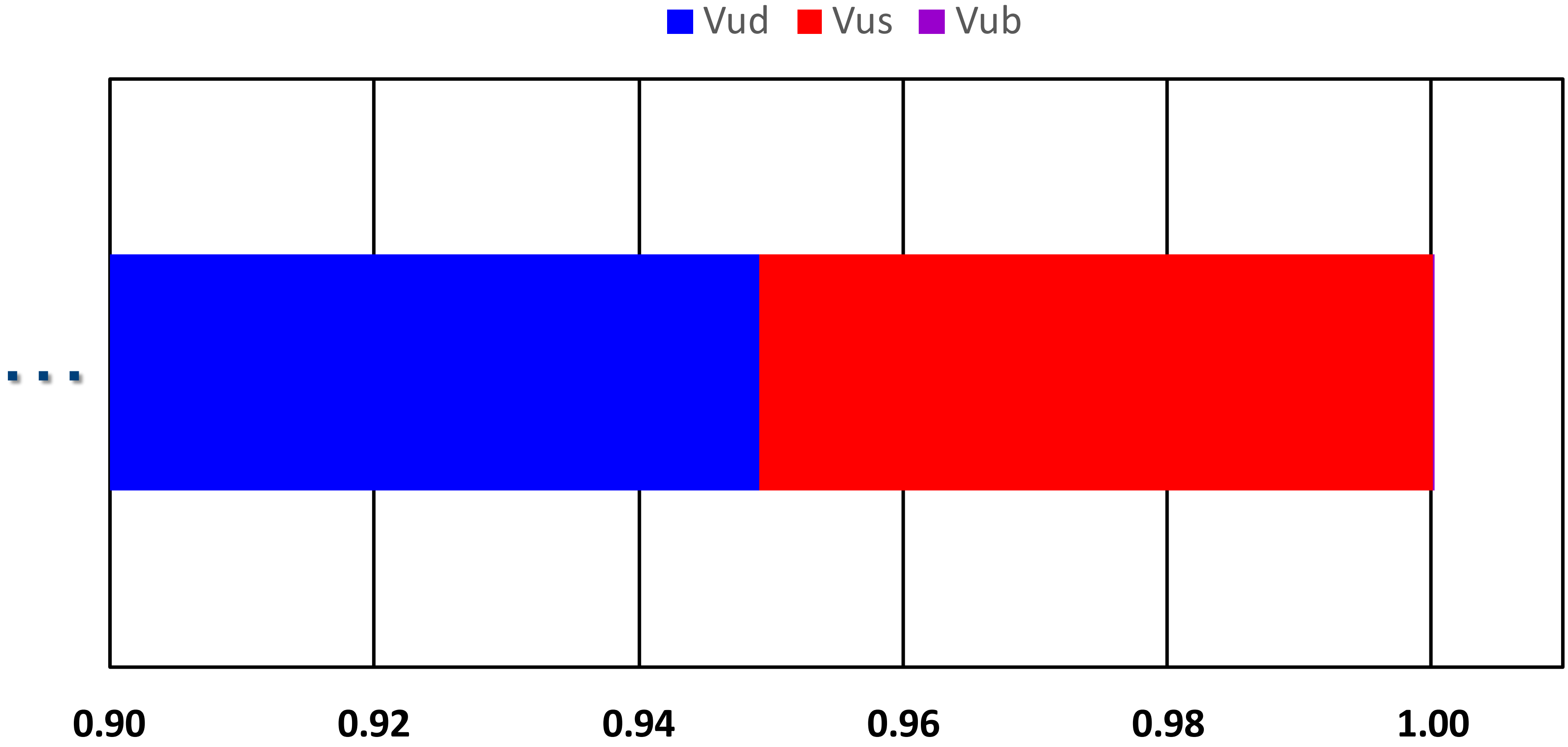
CKM Unitarity



$$|V_{ud}|^2 + |V_{us}|^2 + |V_{ub}|^2 = 1.00008(43)_{Vud}(36)_{Vus}$$

J.C. Hardy and I.S. Towner, Ann. Phys. (Berlin) 525, 443 (2013).

New Lattice QCD Form Factor Calculations for V_{us}

R.J. Dowdall et al., Phys. Rev. D 88, 074504 (2013)

$K^+ \to l\nu$ / $\pi^+ \to l\nu$ (HPQCD Collaboration)

$|V_{us}| = 0.22564(53)$

$$|V_{ud}|^2 + |V_{us}|^2 + |V_{ub}|^2 = 1.00009(43)_{Vud}(24)_{Vus}$$

A. Bazavov et al., Phys. Rev. Lett. 112, 112001 (2014)

$K^+ \to \pi^+ l\nu$ (Fermilab Lattice and MILC Collaborations)

$|V_{us}| = 0.22290(90)$

$$|V_{ud}|^2 + |V_{us}|^2 + |V_{ub}|^2 = 0.99885(43)_{Vud}(40)_{Vus}$$

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V_{ud} from Superallowed Fermi β Decay

To first order, β decay ft values can be expressed as:

$$ft = \frac{K}{|M_{fi}|^2 \, g^2}$$

- phase space (Q-value) → f
- half-life, branching ratio → t
- constants → K
- matrix element → $|M_{fi}|^2$
- Weak coupling strength → g^2

For the special case of $0^+ \rightarrow 0^+$ (pure Fermi) β decays between isobaric analogue states (superallowed) the matrix element is that of an isospin ladder operator:

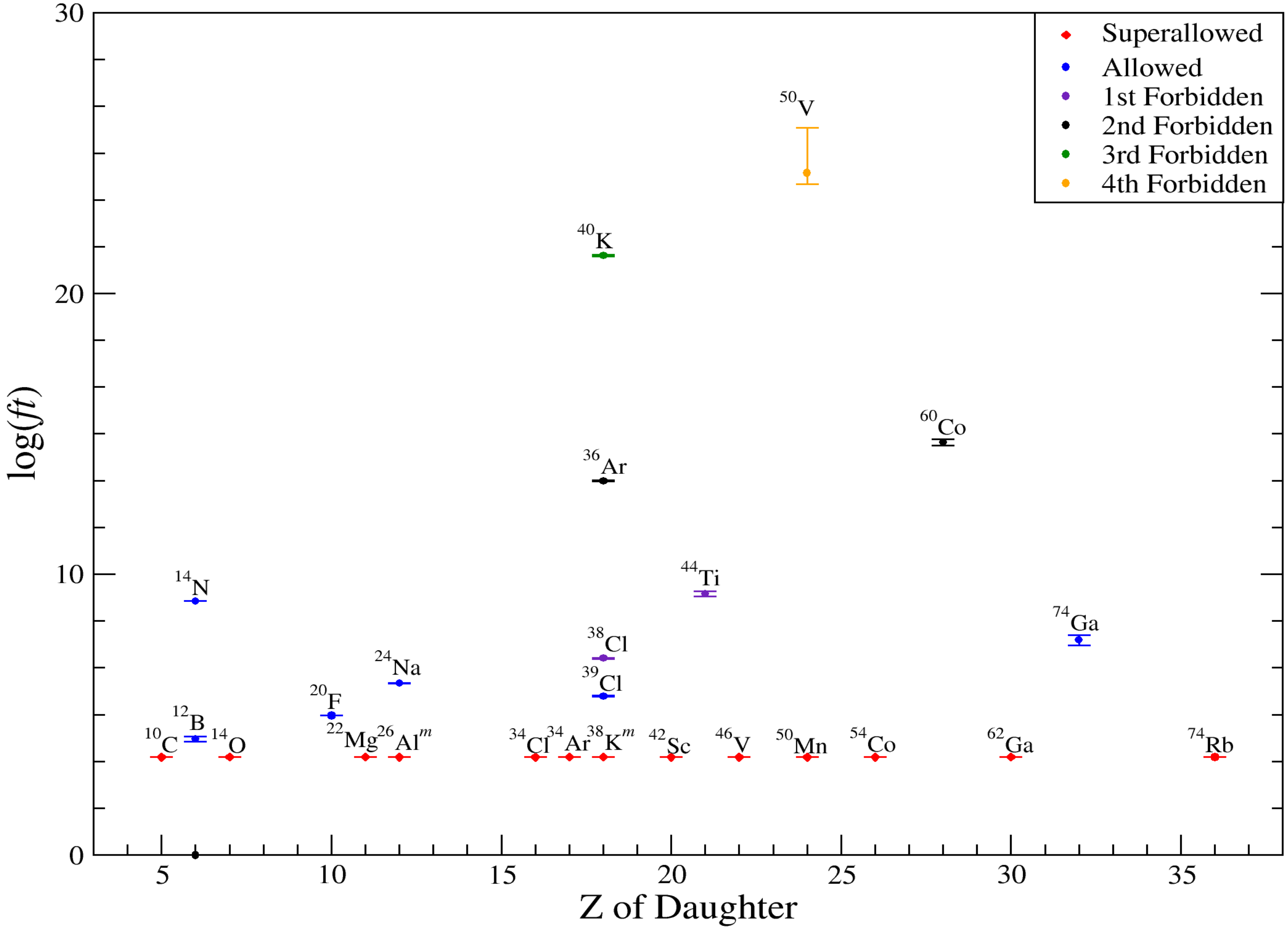
$$|M_{fi}|^2 = (T - T_Z)(T + T_Z + 1) = 2 \quad \text{(for T=1)}$$

Strategy: Measure superallowed ft-values, deduce G_V and V_{ud}:

Vector coupling constant → $$G_V^2 = \frac{K}{2\,ft}$$

$$|V_{ud}| = G_V / G_F$$ ← Fermi coupling constant

β decay *ft*-values



In general beta-decay *ft* values can span 20 orders of magnitude.

In this context superallowed *ft* values are comparatively constant

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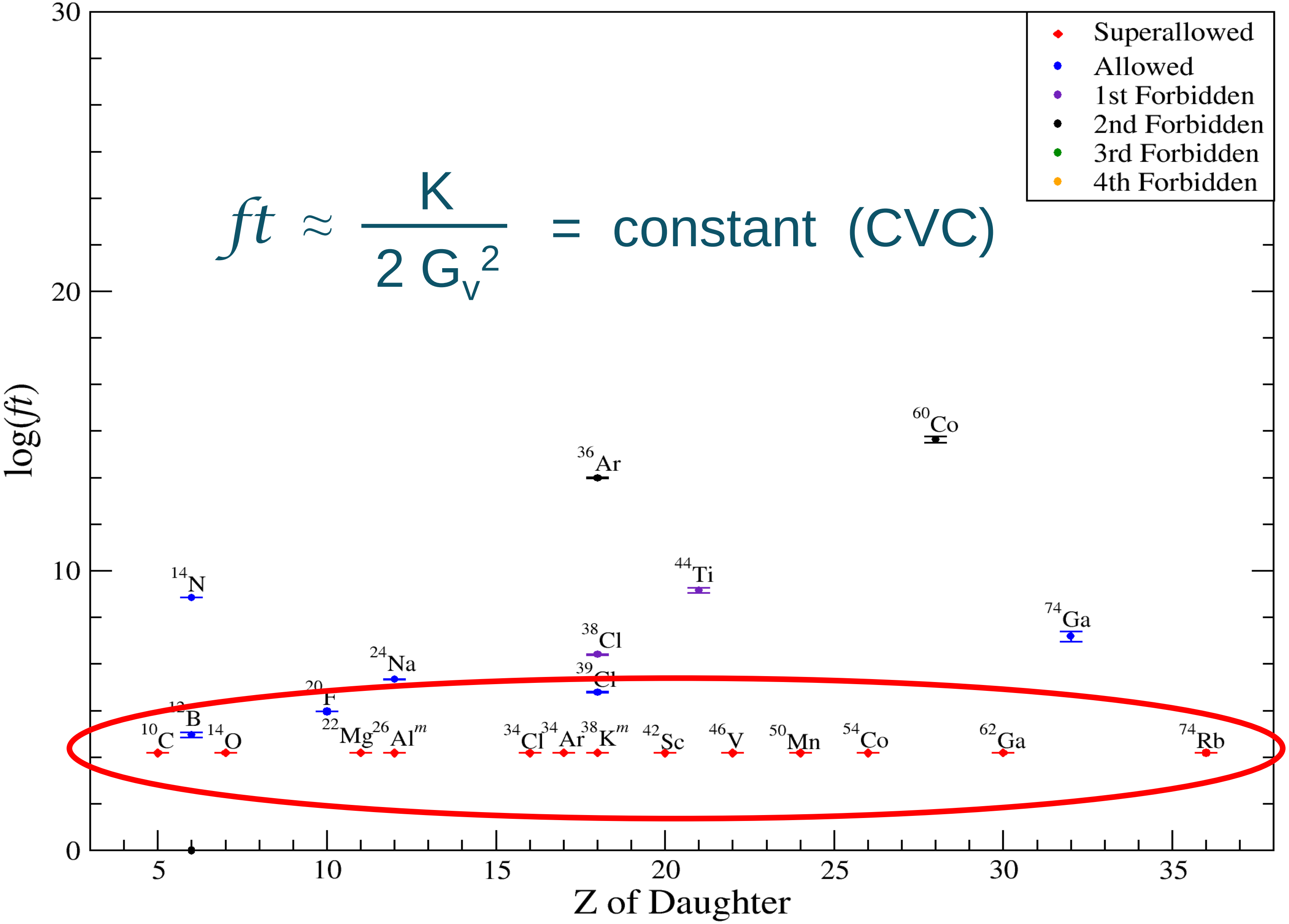
β decay ft-values



In general beta-decay ft values can span 20 orders of magnitude.

In this context superallowed ft values are comparatively constant

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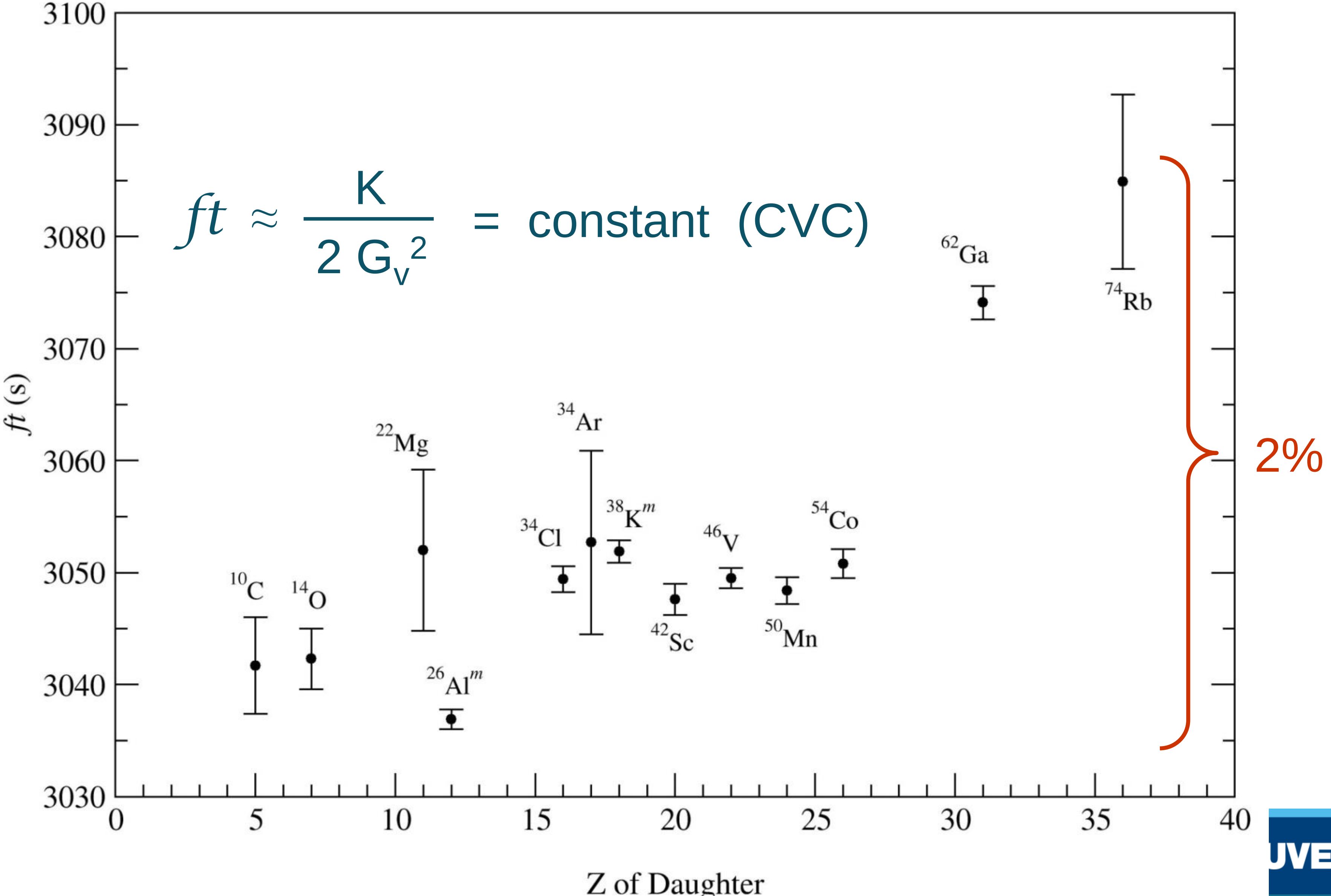
Superallowed ft-values



$$ft \approx \frac{K}{2\,G_V^2} = \text{constant (CVC)}$$

Superallowed Fermi β Decay: Corrections

$$\mathcal{F}t = ft(1+\delta'_R)(1+\delta_{NS}-\delta_C) = \frac{K}{2G_V^2(1+\Delta_R^V)} = \text{constant}$$

"Corrected" *ft* value

Experiment

Calculated corrections (~1%)
(nucleus dependent)

Inner radiative correction (~2.4%)
(nucleus independent)

CVC Hypothesis

Δ_R^V = nucleus independent inner radiative correction: 2.361(38)%

δ'_R = nucleus dependent radiative correction to order $Z^2\alpha^3$: ~1.4%
- depends on electron's energy and *Z* of nucleus

δ_{NS} = nuclear structure dependent radiative correction: -0.3% – 0.03%

δ_C = nucleus dependent isospin-symmetry-breaking correction: 0.2% – 1.5%
- strong nuclear structure dependence

$\delta_C = \delta_{C1} + \delta_{C2}$ (isospin mixing plus radial overlap)

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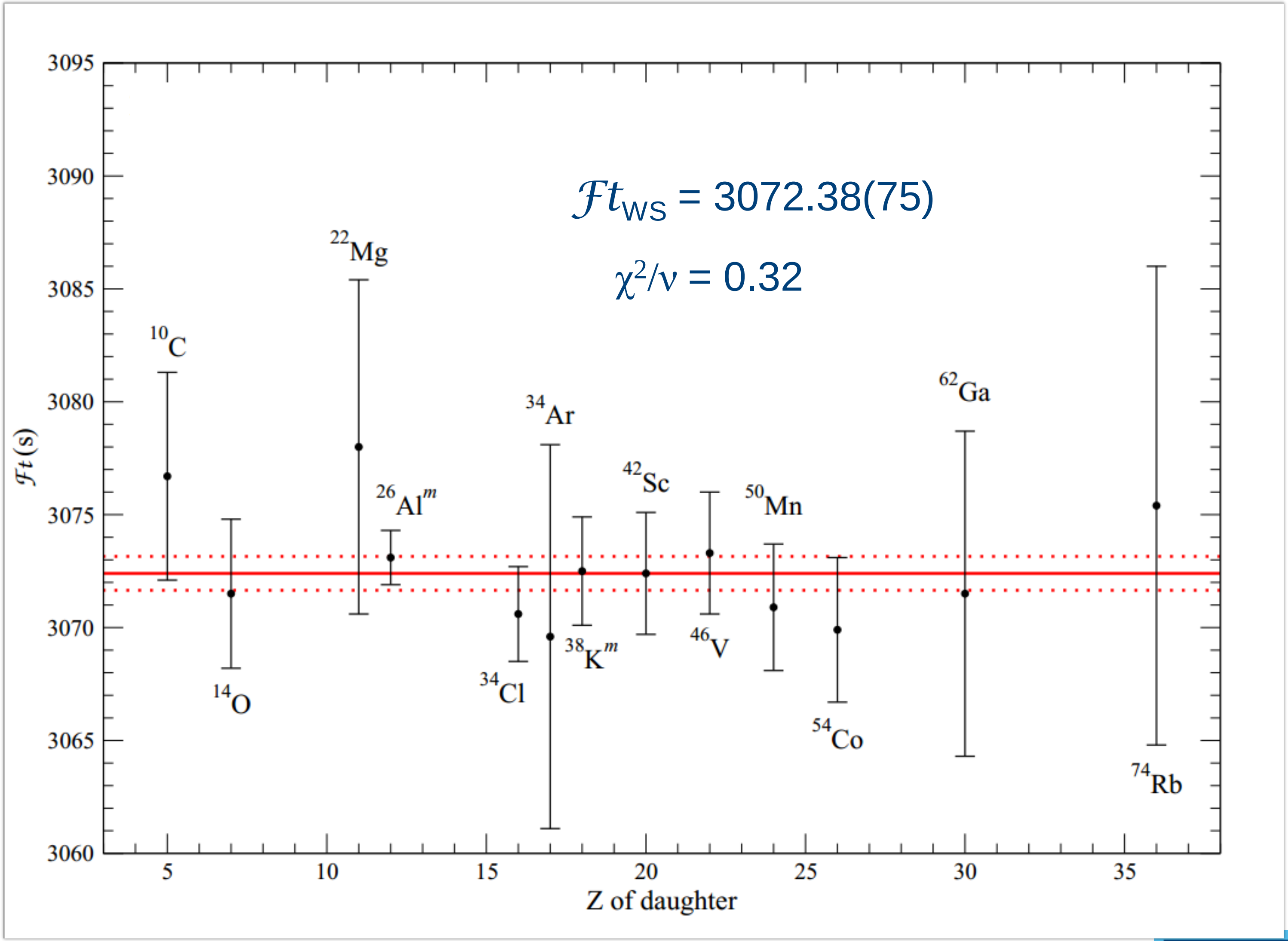
Corrected Superallowed $\mathcal{F}t$ Values



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P. Finlay, *et al.*, Phys. Rev. Lett. 106, 032501 (2011)
R. Dunlop, *et al.*, Phys. Rev. C 88, 045501 (2013)

Theoretical Treatment of δ_C

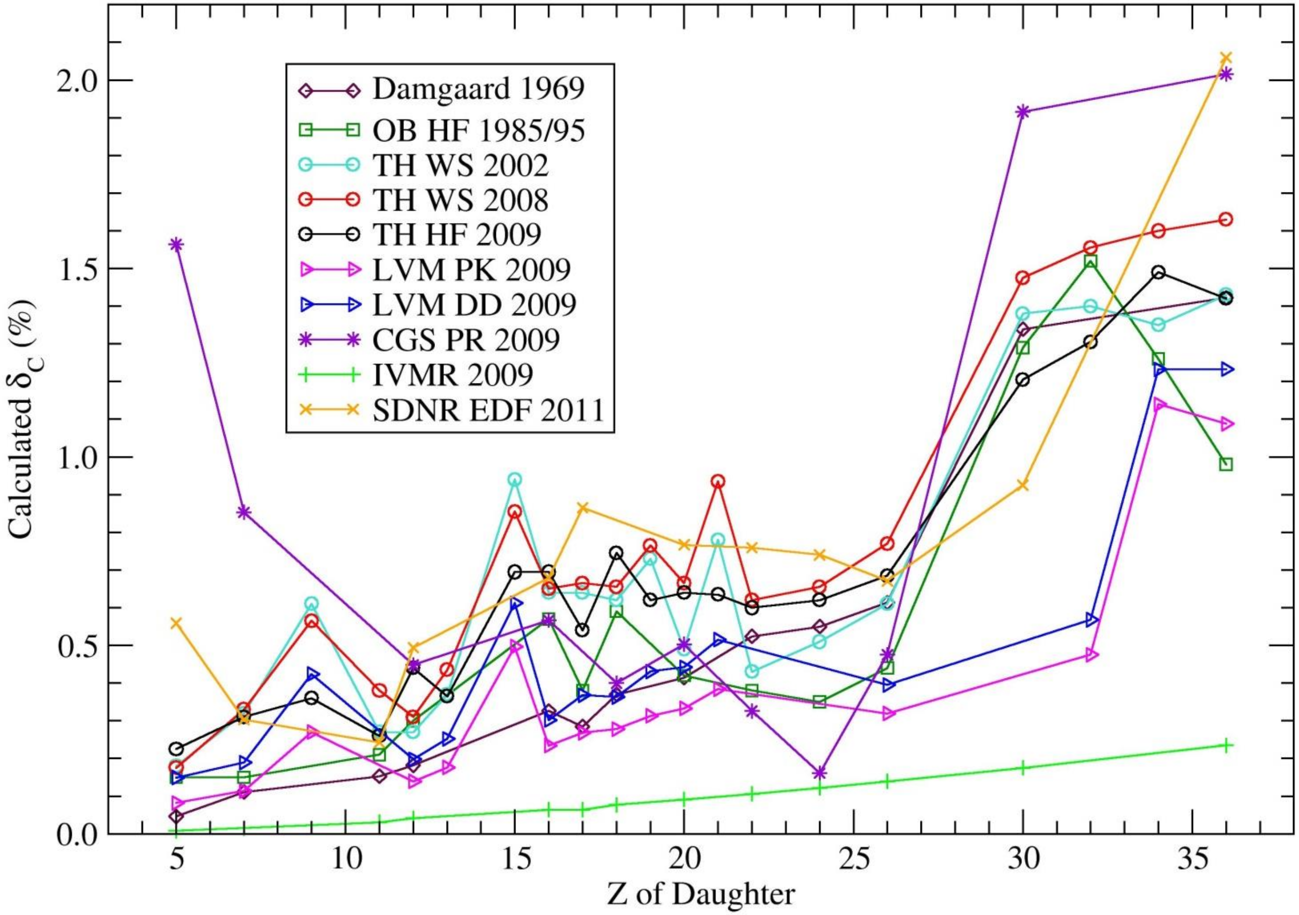
Many recent approaches to ISB corrections

→ Nuclear Shell Model

→ Relativistic Hartree-Fock

→ Random Phase Approximation

→ Energy Density Functional



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Superallowed β Decay Studies at TRIUMF

^{74}Rb: $T_{1/2}$, G.C. Ball *et al*, PRL 86 1454 (2001)
BR, A. Piechaczek et al, PRC 67, 051305 (2003)
BR, R. Dunlop et al, PRC 88, 045501 (2013)
Q: S. Ettenauer et al., PRL 107, 272501 (2011)
CR: E. Mané et al, PRL 107, 212502 (2011)

^{62}Ga: $T_{1/2}$, G.F. Grinyer, PRC 77, 201501 (2008)
BR, B.H. Hyland, PRL 97, 102501 (2006)
BR, P. Finlay PRC 78, 044321 (2008)

^{54}Co, ^{50}Mn: $T_{1/2}$ and BR

^{38m}K: BR, K.G. Leach et al., PRL 100, 192504 (2008)
$T_{1/2}$, G.C. Ball *et al*, PRC 82, 045501 (2010)

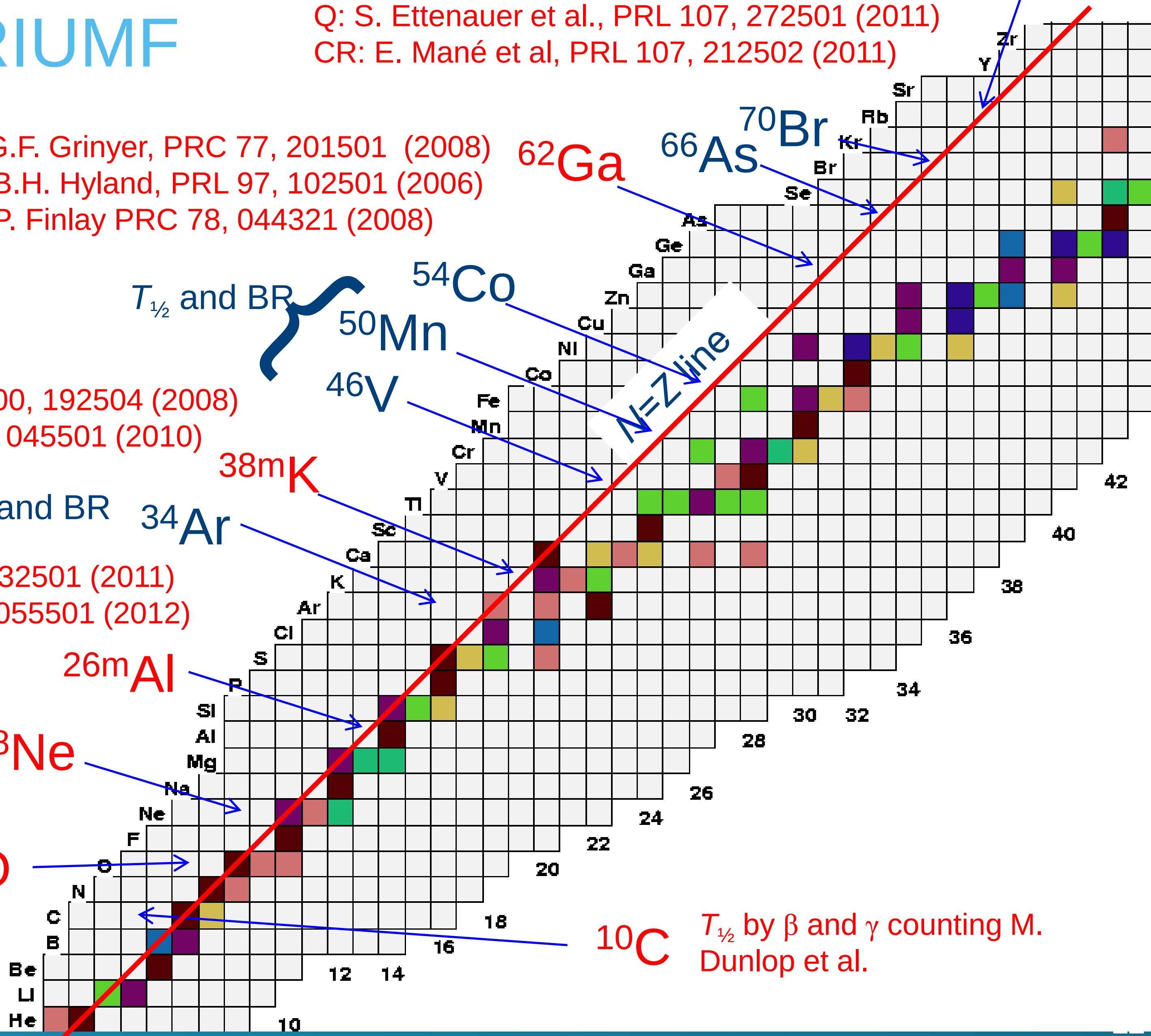
^{34}Ar: $T_{1/2}$ and BR

^{26m}Al: $T_{1/2}$ P. Finlay et al, PRL 106, 032501 (2011)
BR, P. Finlay et al, PRC 85, 055501 (2012)

^{18}Ne: $T_{1/2}$, G.F. Grinyer et al,
PRC 76, 025503 (2007)
PRC 87, 045502 (2013)

^{14}O: $T_{1/2}$, A.T. Laffoley et al,
PRC 88, 015501 (2013)

^{10}C: $T_{1/2}$ by β and γ counting M. Dunlop et al.



Superallowed β Decay Studies at TRIUMF

Large ISB corrections

$T_{1/2}$, G.C. Ball *et al*, PRL 86 1454 (2001)
BR, A. Piechaczek et al, PRC 67, 051305 (2003)
BR, R. Dunlop et al, PRC 88, 045501 (2013)
Q: S. Ettenauer et al., PRL 107, 272501 (2011)
. Mané et al, PRL 107, 212502 (2011)

(2008)
(2006)
BR, P. Finlay PRC 78, 044321 (2008)

$T_{½}$ and BR

BR, K.G. Leach et al., PRL 100, 192504 (2008)
$T_{1/2}$, G.C. Ball *et al*, PRC 82, 045501 (2010)

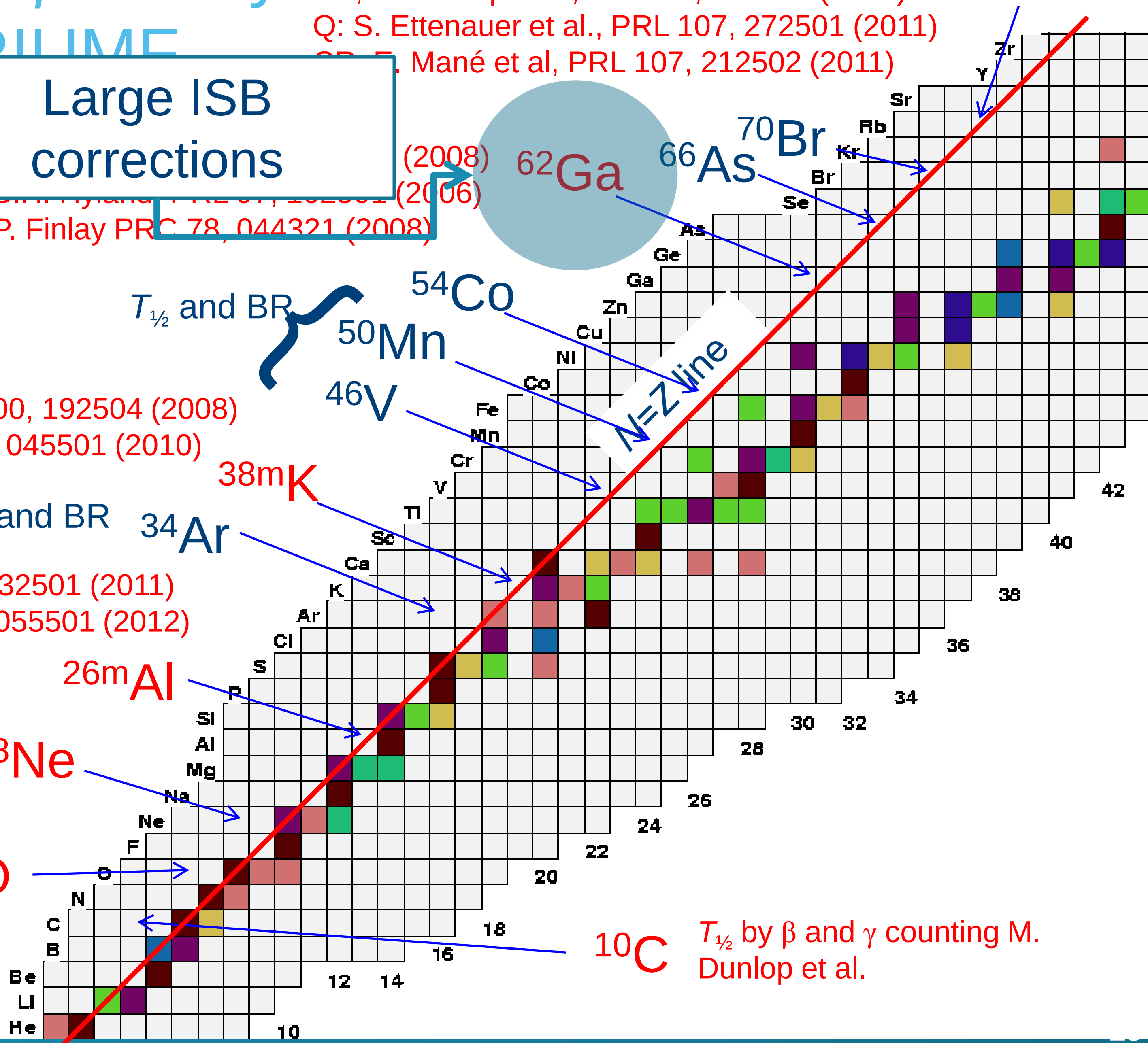
$T_{½}$ and BR

$T_{½}$ P. Finlay et al, PRL 106, 032501 (2011)
BR, P. Finlay et al, PRC 85, 055501 (2012)

$T_{½}$, G.F. Grinyer et al,
PRC 76, 025503 (2007)
PRC 87, 045502 (2013)

$T_{½}$, A.T. Laffoley et al,
PRC 88, 015501 (2013)

$T_{½}$ by β and γ counting M. Dunlop et al.



Superallowed β Branching Ratios for A ≥ 62 and the Pandemonium Effect

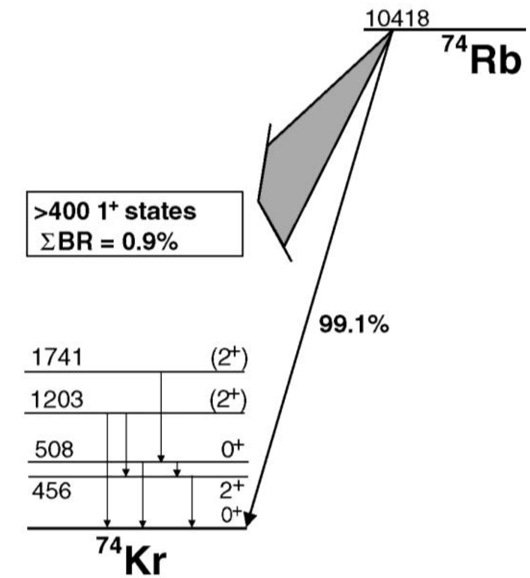
VOLUME 88, NUMBER 25 PHYSICAL REVIEW LETTERS 24 JUNE 2002

Superallowed Beta Decay of Nuclei with $A \geq 62$: The Limiting Effect of Weak Gamow-Teller Branches

J. C. Hardy and I. S. Towner*
Cyclotron Institute, Texas A & M University, College Station, Texas 77843
(Received 16 January 2002; published 6 June 2002)

The most precise value of V_{ud}, which is obtained from superallowed nuclear β decay, leads to a violation of Cabibbo-Kobayashi-Maskawa unitarity by 2.2σ. Experiments are underway on two continents to test and improve this result through decay studies of odd-odd $N = Z$ nuclei with $A \geq 62$. We show, in a series of illustrative shell-model calculations, that numerous weak Gamow-Teller branches are expected to compete with the superallowed branch in each of these nuclei. Though the total Gamow-Teller strength is significant, many of the individual branches will be unobservably weak. Thus, new techniques must be developed if reliable ft values are to be obtained with 0.1% precision for the superallowed branches.

DOI: 10.1103/PhysRevLett.88.252501 PACS numbers: 23.40.Hc, 21.60.Cs, 27.50.+e



- For large Q-value β decays, there are generally many weak β branches to the large number of daughter states within the Q-value window.
- In the subsequent γ decay, many individual γ-rays may be too weak to identify.
- The sum of these unobserved γ intensities will, however, generally be sufficient to prevent precision determination of β decay branching ratios through γ-ray spectroscopy.

Controlling Pandemonium via 2^+ "Collector" States

I_{gs} = 0.1338(26)%

Direct β feeding of 2^+ states is negligible

I'_{2+} = 0.0199(29) %

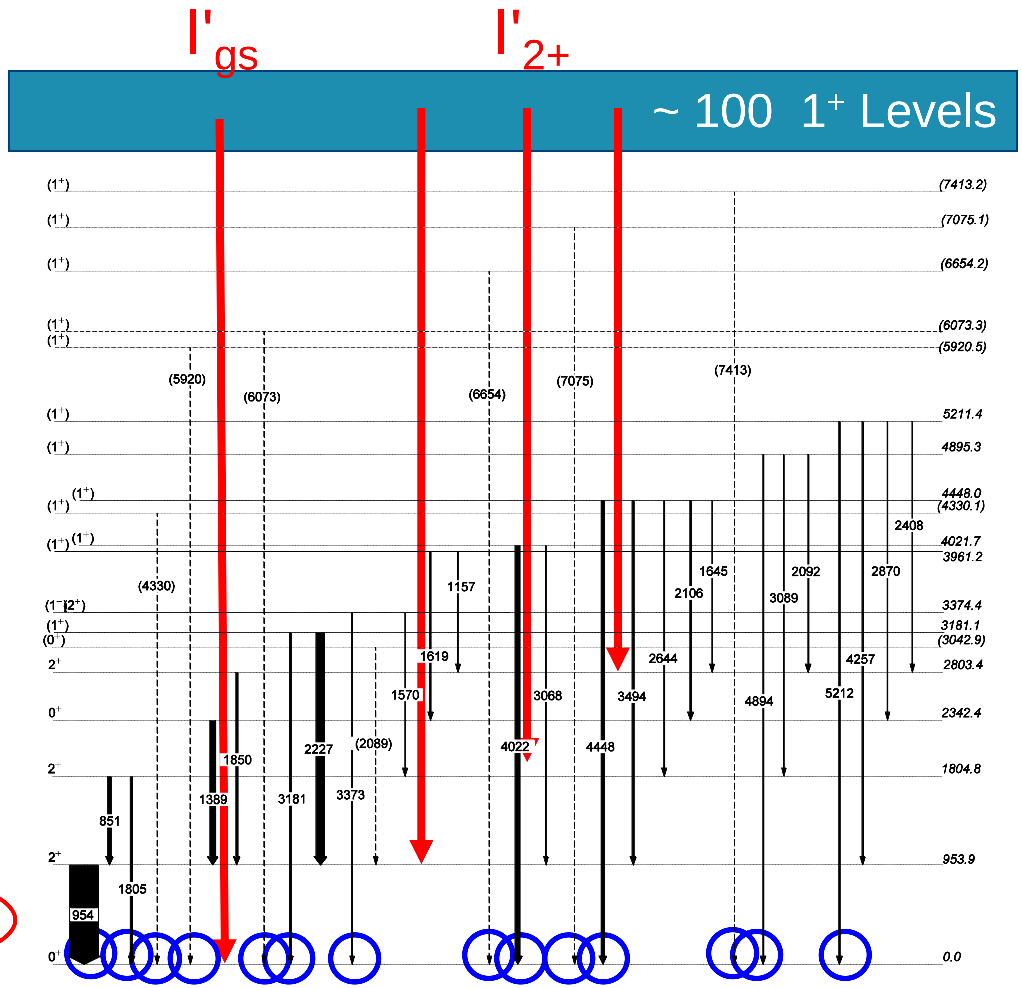
$B_{gs} = I'_{gs} / (I'_{gs} + I'_{2+})$

Expt + Shell Model:

B_{gs} = 0.20(20)

I'_{gs} = 0.008(8) %

SBR = *99.859(8) %*



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Isospin-Symmetry-Breaking Corrections for ^{62}Ga

$\overline{\mathcal{F}t} = 3071.6(8)$

$$\delta_C = 1 - \frac{\overline{\mathcal{F}t}}{ft(1+\delta_R)} = \mathbf{1.48(5)_{ft\text{-}\mathcal{F}t}(9)_{\delta_R}\ \%}$$

✓ $\delta_C = \mathbf{1.48(16)\ \%}$

I.S. Towner and J.C. Hardy, Phys. Rev. C **66**, 035501 (2002)

$\overline{\mathcal{F}t} = 3075.6(8)$

$$\delta_C = 1 - \frac{\overline{\mathcal{F}t}}{ft(1+\delta_R)}$$

✓ $\delta_C = \mathbf{1.26\% - 1.32\%}$ (Hartree-Fock)

✗ $\delta_C = \mathbf{1.60\% - 1.70\%}$ (Woods-Saxon)

W.E. Ormand and B.A. Brown, Phys. Rev. C **52**, 2455 (1995)

$$= \mathbf{1.35(5)_{ft\text{-}\mathcal{F}t}(9)_{\delta_R}\ \%}$$

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Isospin Mixing Components δ^{n}_{C1}

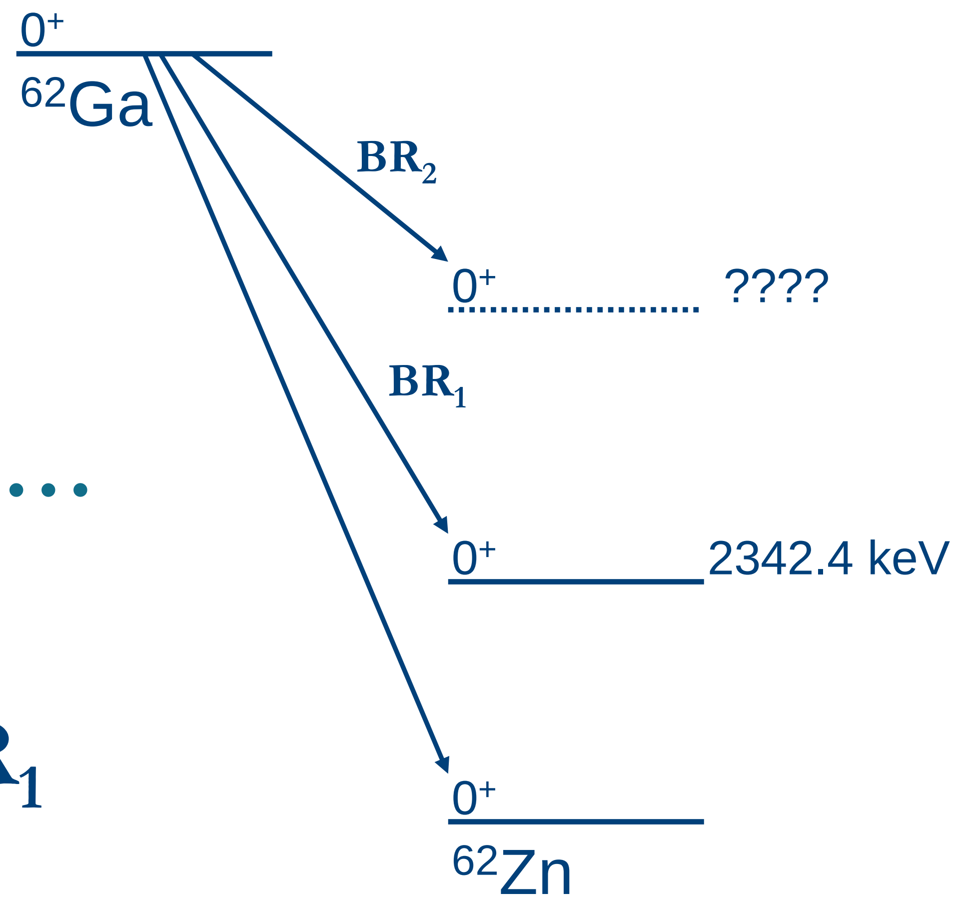
configuration mixing

radial overlap

$$\delta_c = \delta_{c1} + \delta_{c2}$$

$$\delta_{c1} = \delta^{1}_{c1} + \delta^{2}_{c1} + \ldots$$

$$\delta^{1}_{c1} = (f_0/f_1)BR_1$$



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Isospin Mixing Components

$BR_1 = 77(12)\ ppm$ $(f_o/f_1) = 4.91$

$$\delta^1_{C_1} = (f_o/f_1)BR_1$$

$$\leq \mathbf{0.038(6)\ \%}$$

- ✘ $\delta^1_{C_1} = \mathbf{0.085(20)\ \%}$
- ✘ $\delta^1_{C_1} = \mathbf{0.079\ \%}$ (FPVH)
- ✘ $\delta^1_{C_1} = \mathbf{0.169\ \%}$ (FPD6)

$BR_3 = 12(5)\ ppm$ $(f_o/f_3) = 8.92$

$$\delta^3_{C_1} = (f_o/f_3)BR_3$$

$$\leq \mathbf{0.011(4)\ \%}$$

✘ $BR_3 = 217\ ppm$
$\delta^3_{C_1} = \mathbf{0.193\ \%}$

I.S. Towner and J.C. Hardy, Phys. Rev. C **66**, 035501 (2002)
W.E. Ormand and B.A. Brown, Phys. Rev. C **52**, 2455 (1995)

Recent ^{64}Zn(p,t)^{62}Zn – Where is the 0_1^+?

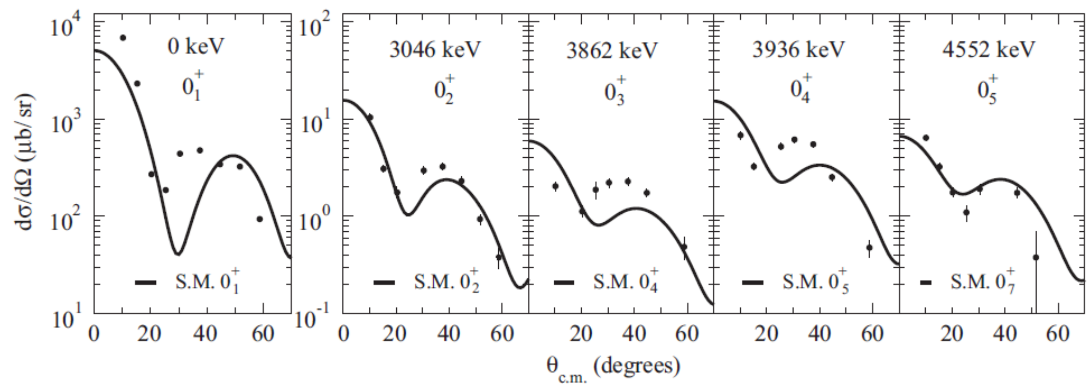

FIG. 1. Experimental angular distributions for the five observed 0+ states in ^{62}Zn from this work. The data are compared to one- + two-step DWBA calculations using shell-model wave functions for each respective final state, and in most cases the experimental uncertainties are smaller than the data points. Due to the large cross-section disparity between the ground state and the excited states, the 0_1^+ state is displayed on a different scale. The curves are normalized to the data in order to provide a better shape comparison. A discussion on the assignment of each state and a comparison with previous experimental data are given in the text.

K.G. Leach *et al.*, Phys. Rev. C **88**, 031306 (2013)

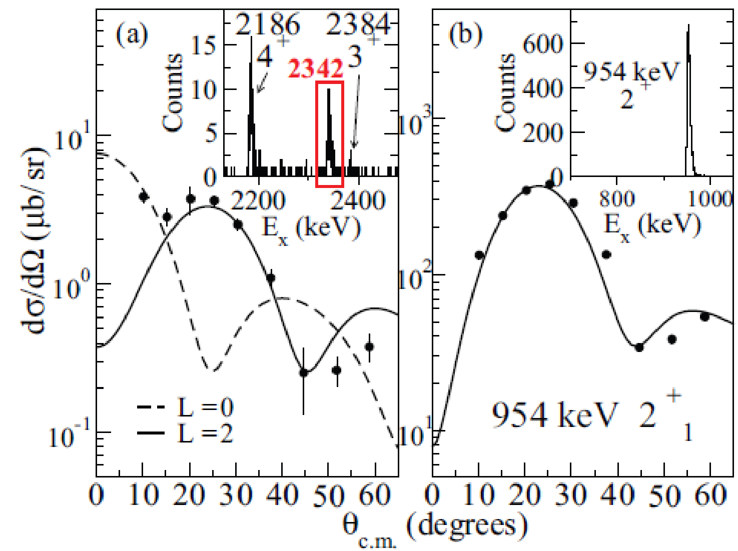

FIG. 2. (Color online) (a) Experimental angular-distribution data for the 2342-keV state, shown with calculated DWBA prediction for $L = 0$ and $L = 2$ transfers. With the exception of the 10° cross section, the 2342-keV state exhibits a nearly identical angular-distribution shape to the well-known 954-keV 2_1^+ state, shown in panel (b) for comparison. The focal-plane position spectrum region of interest for the respective states at 30° are displayed as an inset in the top right corner, where the listed energies are in keV. The assignment of the 2342-keV state is discussed further in the text.

Recent ^{64}Zn(p,t)^{62}Zn calls into question the validity of the 0^+ assignment for the 2.3 MeV state in ^{62}Zn.

The assignment of the first 0^+ state at 3 MeV has ***consequences for the ISB corrections*** in this nucleus.

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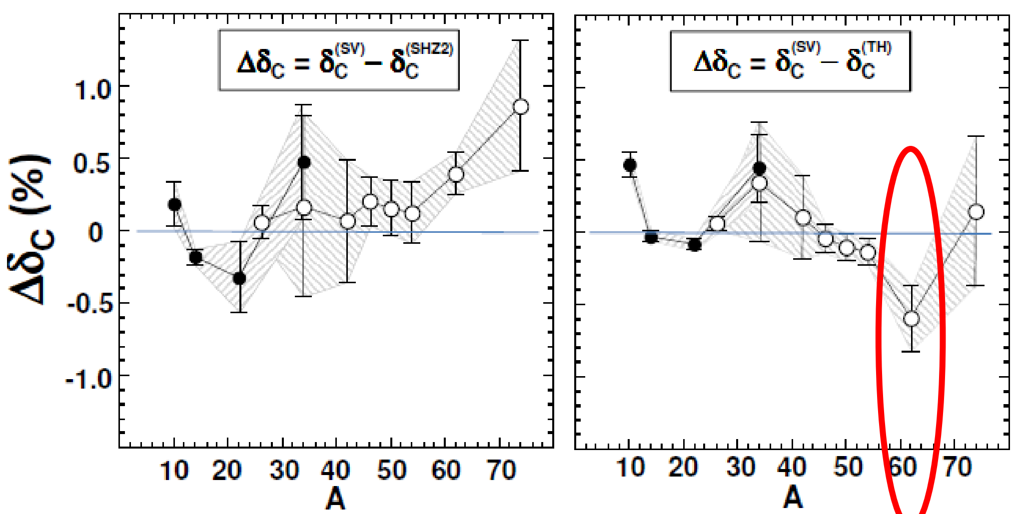
Consequences of state (mis)assignment

K. G. LEACH *et al.* PHYSICAL REVIEW C **88**, 031306(R) (2013)

TABLE II. A comparison of the unscaled and scaled isospin-mixing correction terms for ^{62}Ga, using both the previous 0_2^+ excitation energy from Ref. [27] and the value presented here. The result of the new energy scaling lowers the δ_{C1} central value by nearly a factor of two. The adopted values in each case are shown in bold and result from the average of the MSDI3 and GXPF1 calculations. The uncertainties used for the adopted values are described further in the text.

Shell model		Unscaled		Ref. [27]	Previous scaling		This work	New scaling	
Interaction	$E_x(0_2^+)$ (MeV)	δ_{C1}^1 (%)	δ_{C1} (%)	$E_x(0_2^+)$ (MeV)	δ_{C1}^1 (%)	δ_{C1} (%)	$E_x(0_2^+)$ (MeV)	δ_{C1}^1 (%)	δ_{C1} (%)
MSDI3	2.263	0.089	0.350	2.342	0.084	0.329	3.045	0.049	0.193
GXPF1	2.320	0.160	0.221		0.159	0.219		0.093	0.128
		Adopted value			**0.120(40)**	**0.275(55)**		**0.070(35)**	**0.160(70)**

2σ shift in TH δ_{C1}



DFT calculations for ISB corrections, compared with TH δ_C.
New scaling would reduce this discrepancy if energy of first excited 0^+ is verified.

W. Satula *et al.*, Phys. Rev. C **86**, 054316 (2012)

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Gamma

Ray

Infrastructure

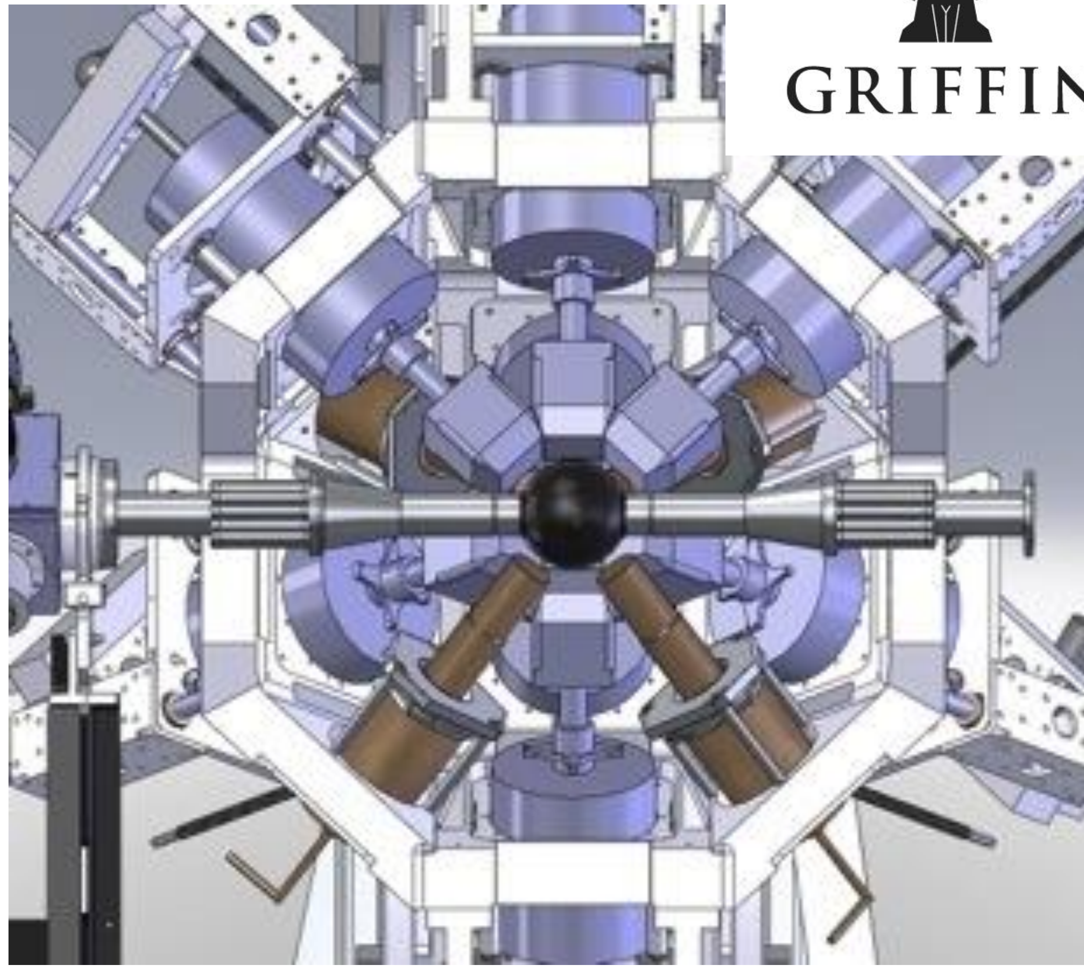
For

Fundamental

Investigations

of

Nuclei



GRIFFIN

New high-efficiency decay spectroscopy facility for ISAC-1

S1518 – Isospin-symmetry breaking in ^{62}Ga scheduled for October 2014, the first experiment with GRIFFIN!

Gamma
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Q: S. Ettenauer et al., PRL 107, 272501 (2011)
CR: E. Mané et al, PRL 107, 212502 (2011)

$T_{½}$, G.F. Grinyer, PRC 77, 201501 (2008)
BR, B.H. Hyland, PRL 97, 102501 (2006)
BR, P. Finlay PRC 78, 044321 (2008)

$T_{½}$ and BR

BR ... 04 (2008)
T_1 ... (2010)

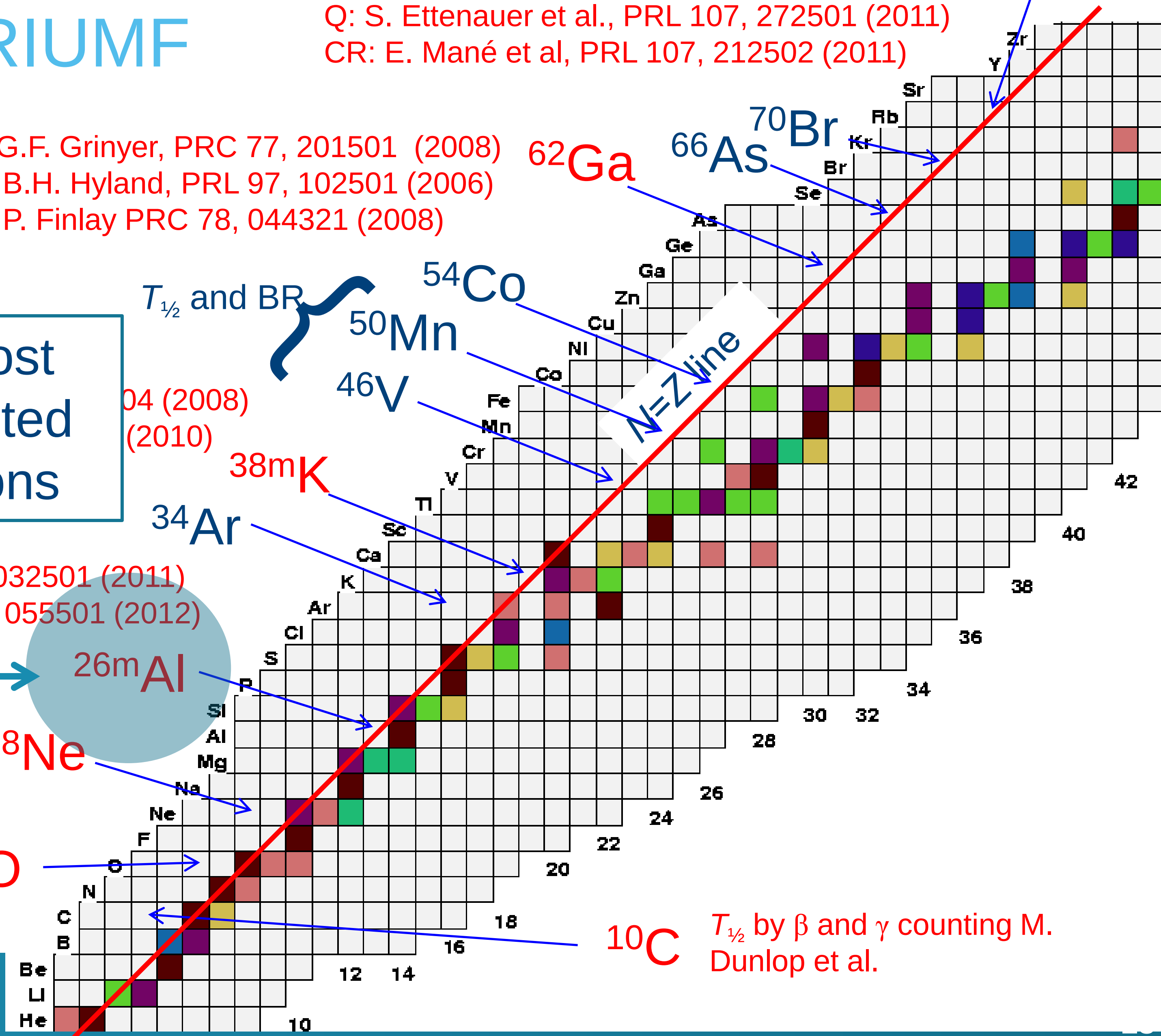
Smallest, most precisely quoted ISB corrections

$T_{½}$ P. Finlay et al, PRL 106, 032501 (2011)
BR, P. Finlay et al, PRC 85, 055501 (2012)

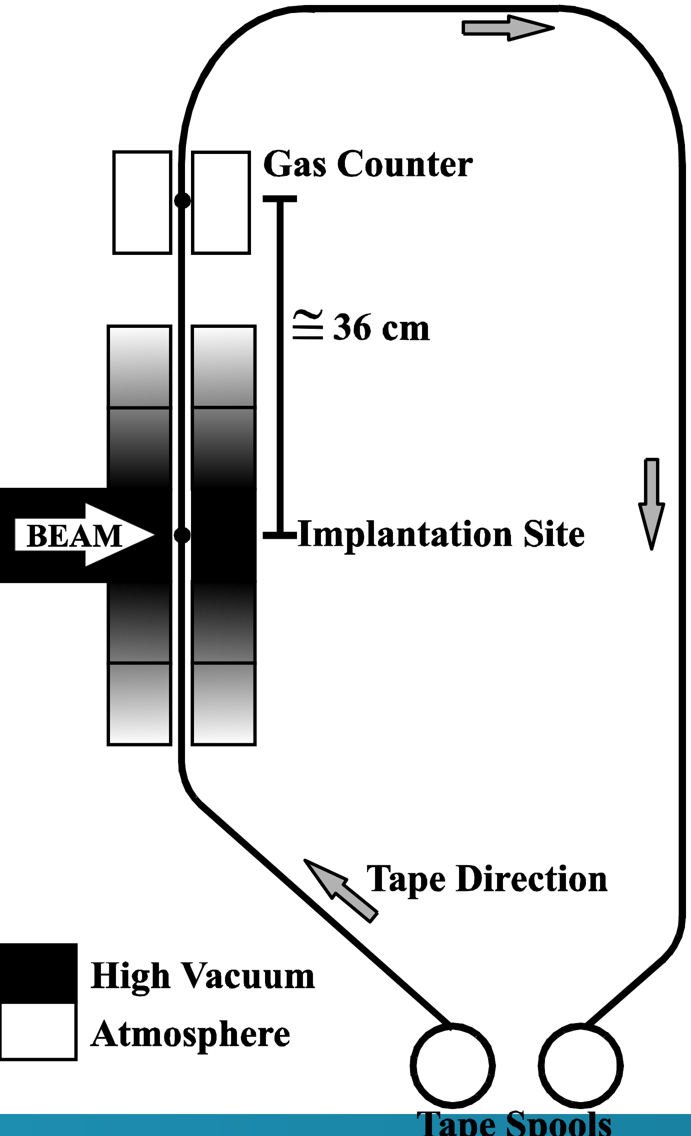
$T_{½}$, G.F. Grinyer et al,
PRC 76, 025503 (2007)
PRC 87, 045502 (2013)

$T_{½}$, A.T. Laffoley et al,
PRC 88, 015501 (2013)

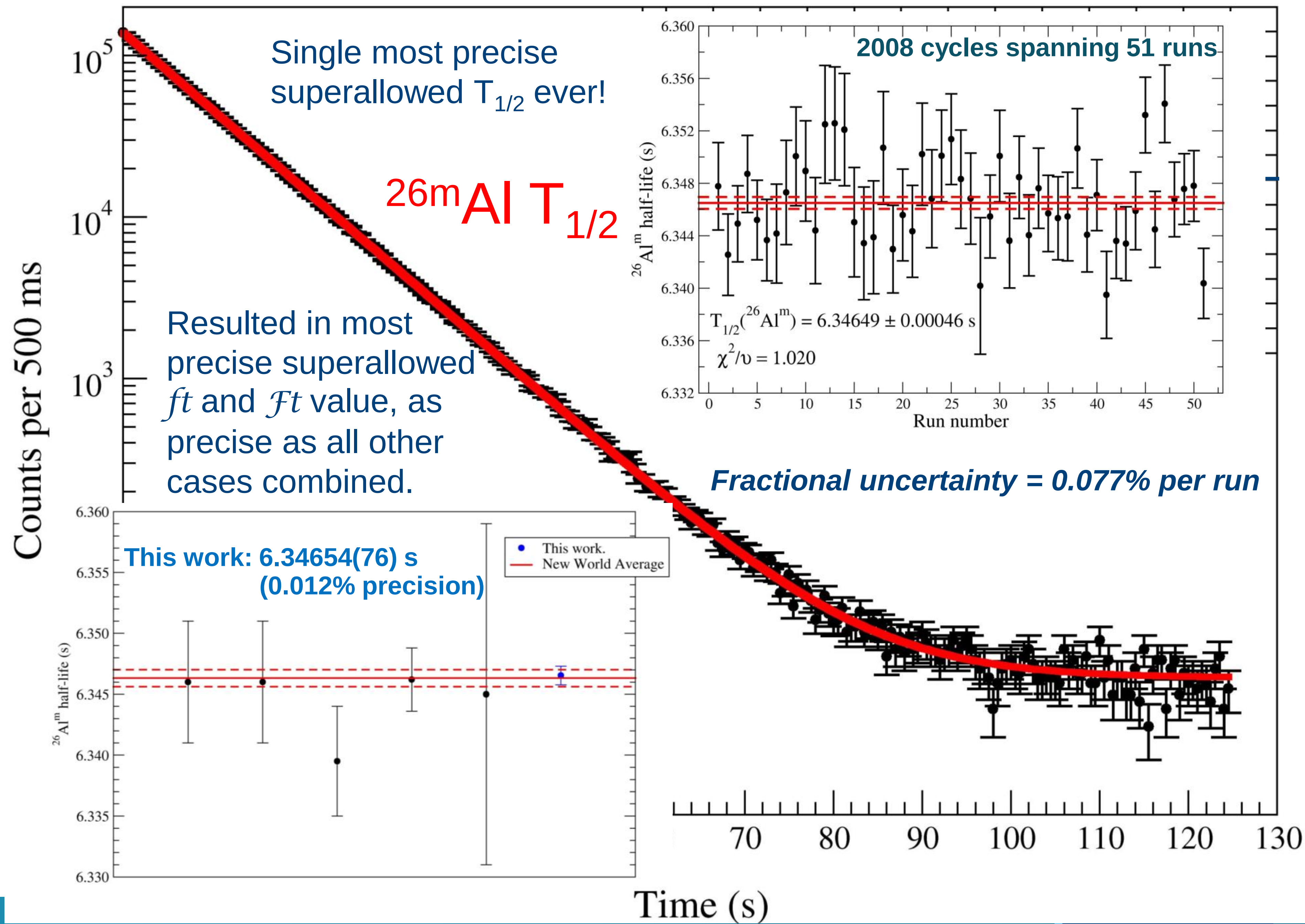
$T_{½}$ by β and γ counting M. Dunlop et al.



High-precision Half-Life Measurements



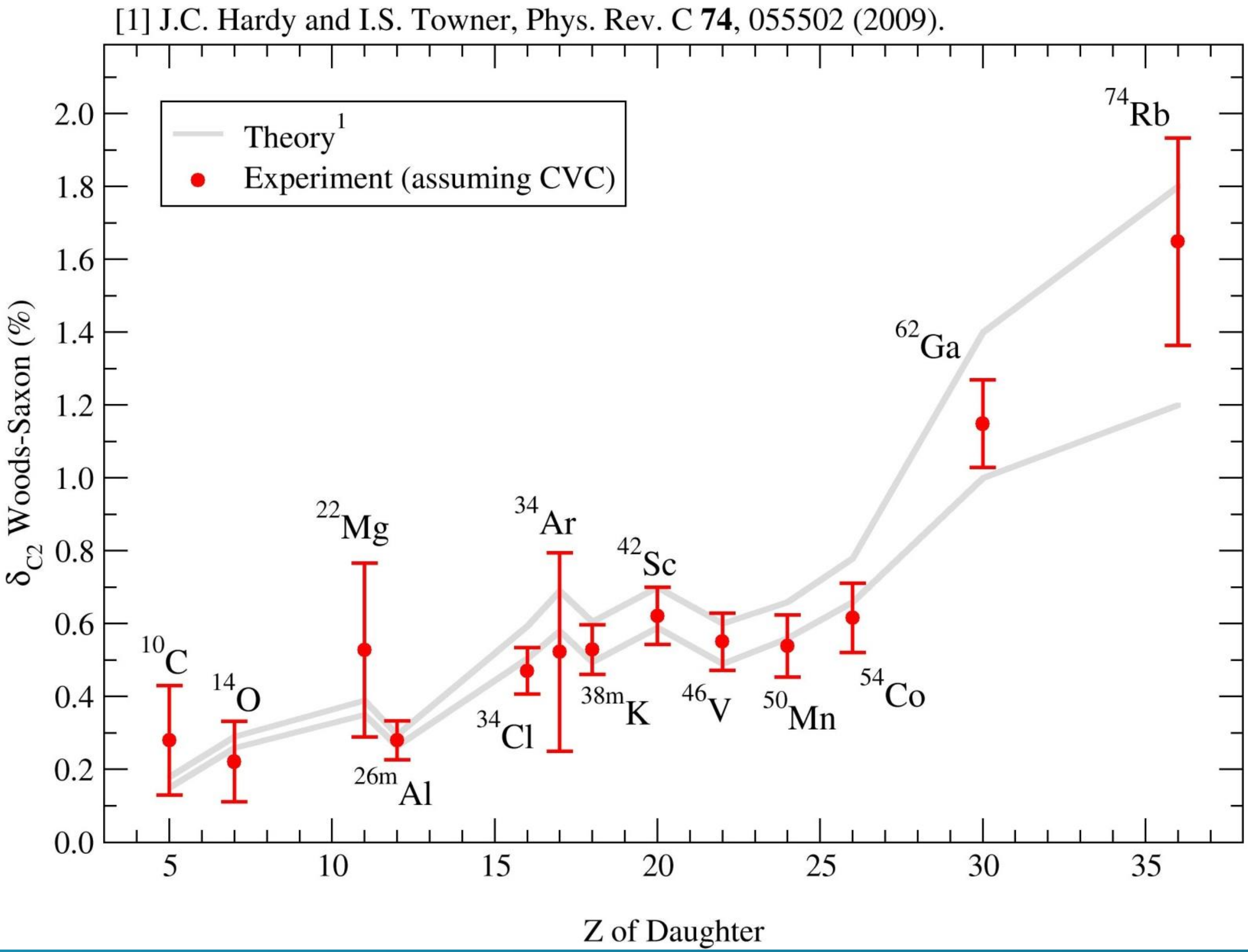
4π continuous-flow gas-proportional counter and fast tape transport system


Single most precise superallowed $T_{1/2}$ ever!
^{26m}Al $T_{1/2}$
Resulted in most precise superallowed ft and $\mathcal{F}t$ value, as precise as all other cases combined.
2008 cycles spanning 51 runs
$T_{1/2}(^{26}Al^{m}) = 6.34649 \pm 0.00046$ s
$\chi^2/\upsilon = 1.020$
Run number
$^{26}Al^{m}$ half-life (s)
Fractional uncertainty = 0.077% per run
This work: 6.34654(76) s
(0.012% precision)
This work.
New World Average
Counts per 500 ms
Time (s)

Experimentally determined δ_{C2}

Woods-Saxon ISB Calculations

$$\delta_{C2} = 1 + \delta_{NS} - \delta_{C1} - \frac{\mathcal{F}t^{WS}_{^{26}\mathrm{Al}^m}}{ft_{\mathrm{exp.}}(1+\delta'_R)}$$



Excellent overall agreement.

The Woods-Saxon calculations by Towner and Hardy appear self-consistent

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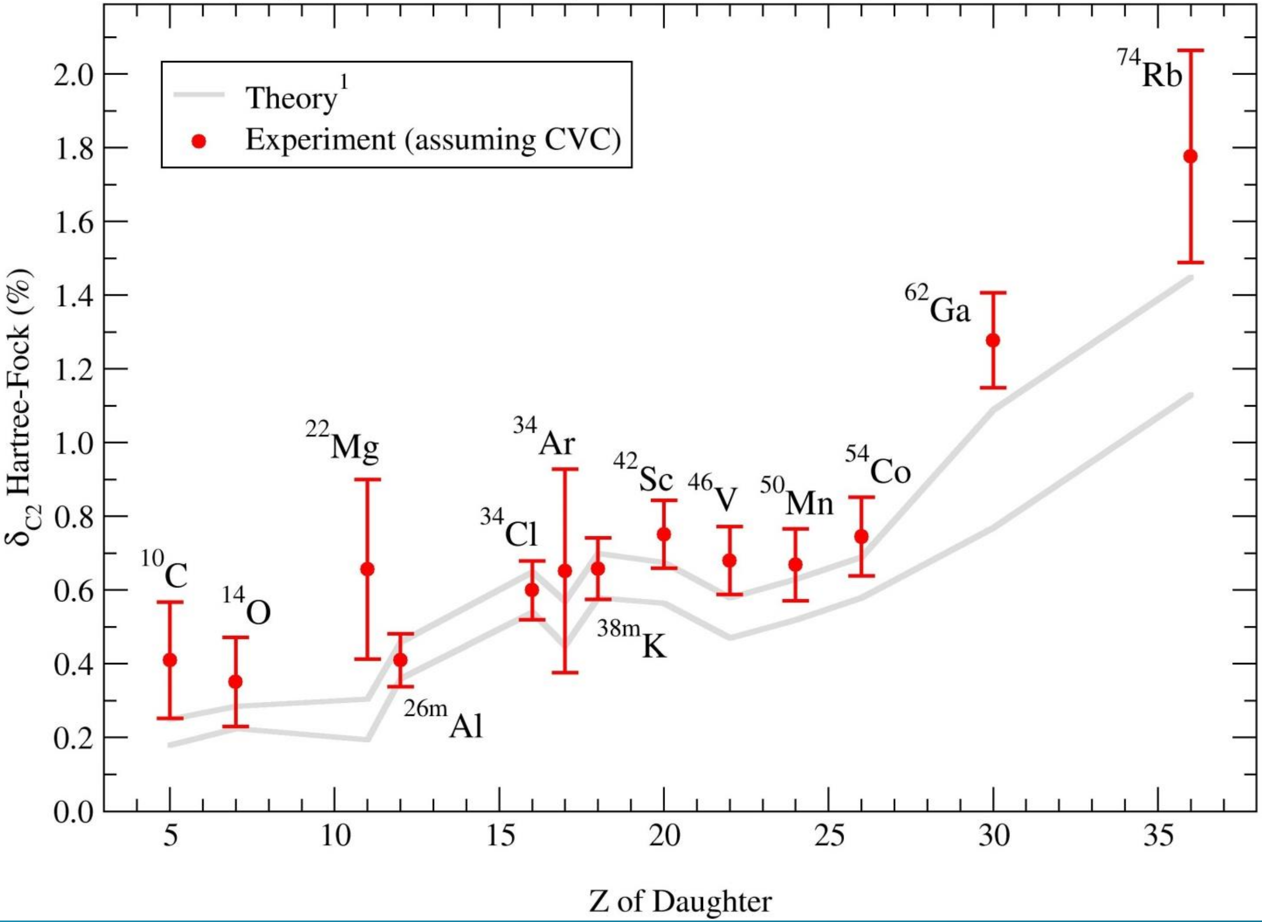
Experimentally determined δ_{C2}

Hartree-Fock ISB Calculations

$$\delta_{C2} = 1 + \delta_{NS} - \delta_{C1} - \frac{\mathcal{F}t^{HF}_{^{26}\mathrm{Al}^m}}{ft_{\mathrm{exp.}}(1+\delta'_R)}$$

[1] J.C. Hardy and I.S. Towner, Phys. Rev. C **74**, 055502 (2009).



The Hartree-Fock calculations by Towner and Hardy do not show the same degree of self consistency.

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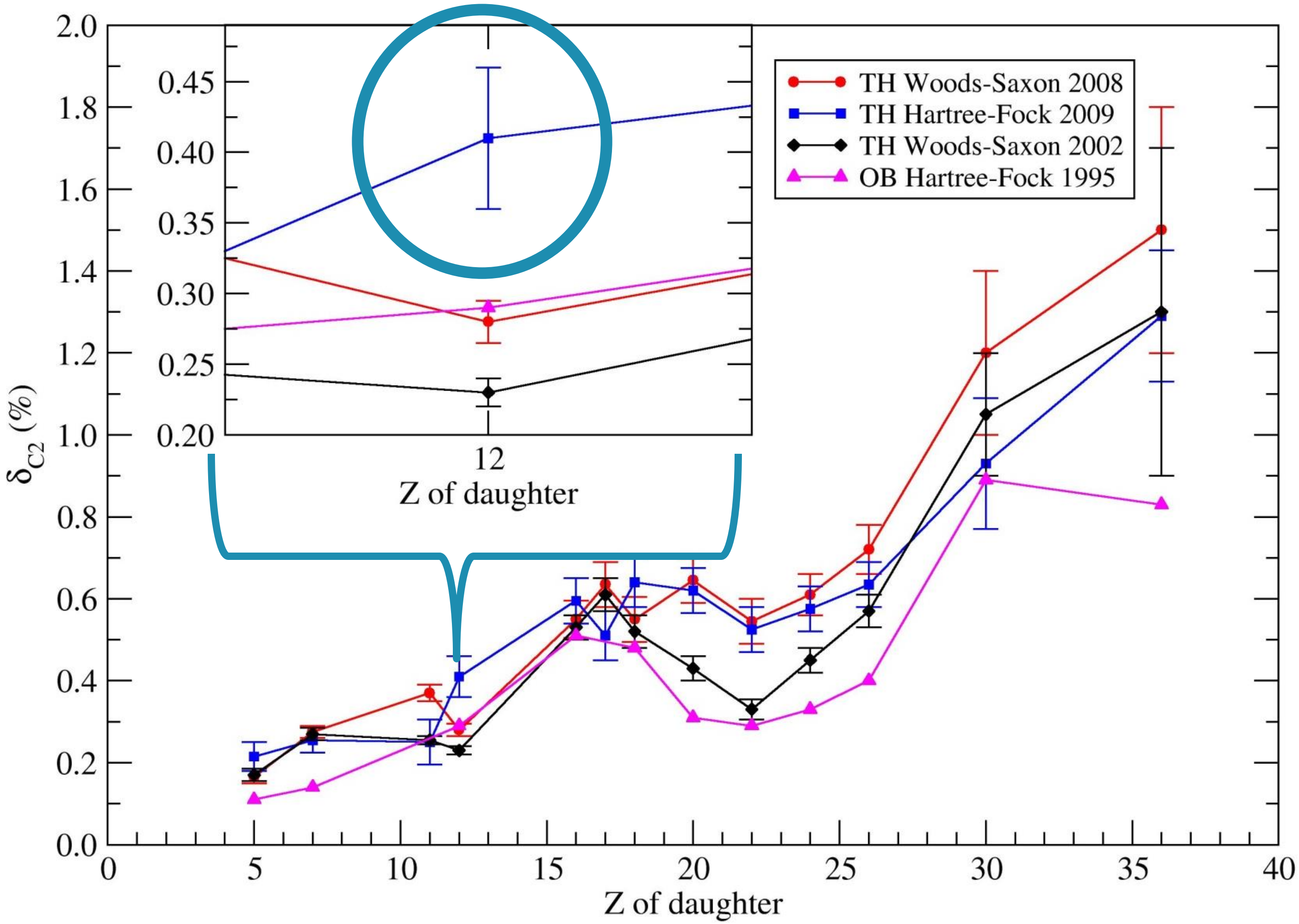
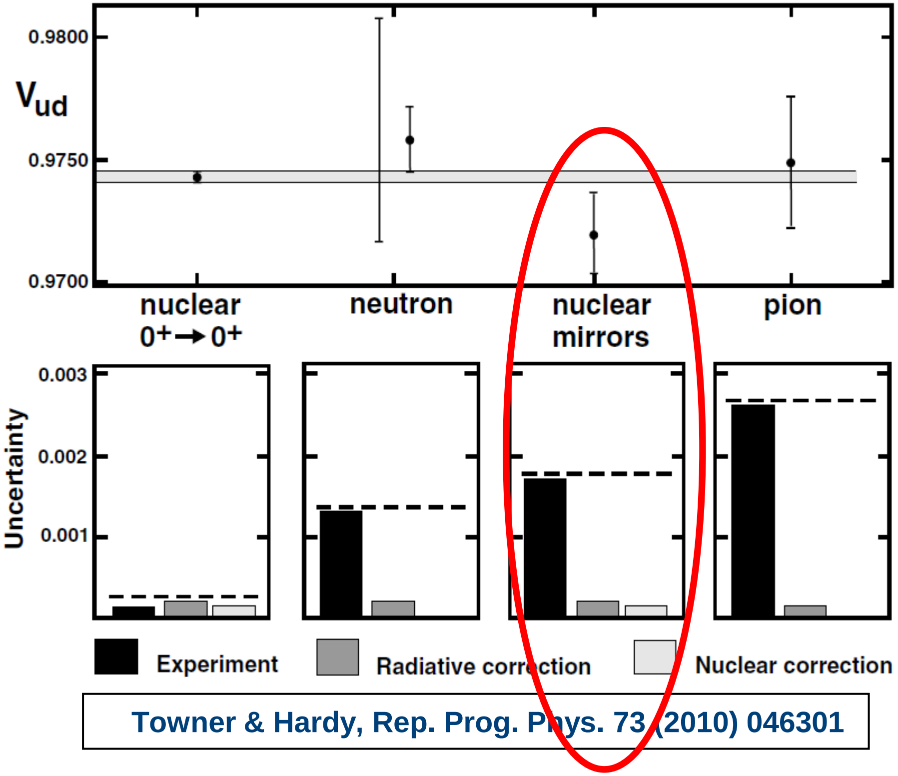
The Radial Overlap Correction: δ_{C2}



W.E. Ormand and B.A. Brown, Physical Review C **52**, 2455 (1995)
I.S. Towner and J.C. Hardy, Physical Review C **66**, 035501 (2002)
I.S. Towner and J.C. Hardy, Physical Review C **77**, 025501 (2008)
J.C. Hardy and I.S. Towner, Physical Review C **79**, 055502 (2009)

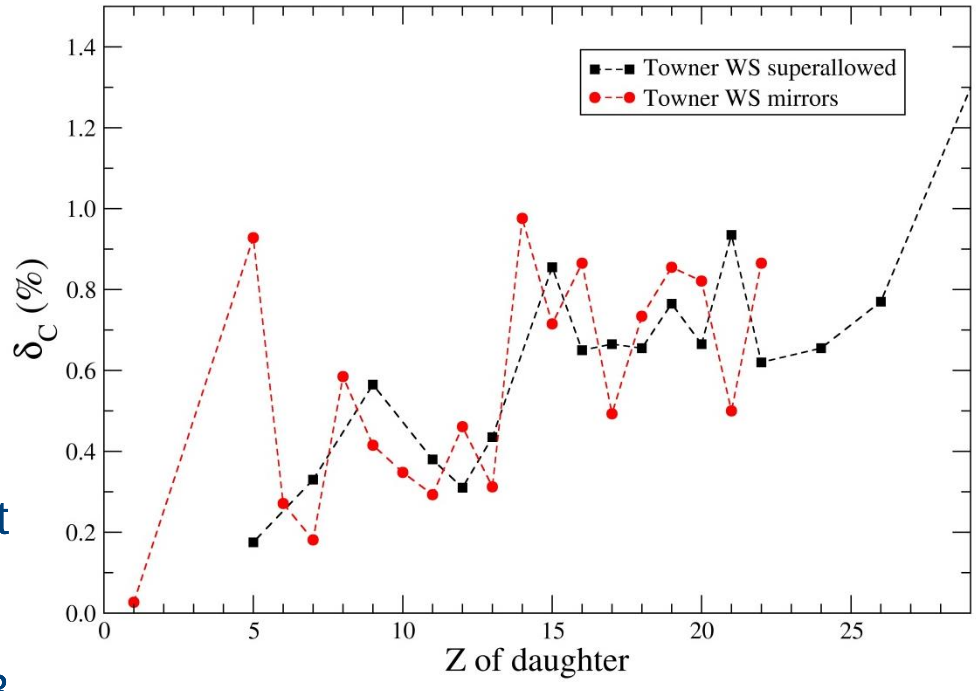
V_{ud} from $\mathcal{F}t$ values of the mirror β transitions



^{19}Ne, ^{21}Na, ^{29}P, ^{35}Ar and ^{37}K

$|V_{ud}| = 0.9719(17)$

O. Naviliat-Cuncic & N. Severijns
PRL 102 (2009) 142302



- Completely independent set with different nuclear-structure dependent corrections
- Ideal to test the machinery of the ISB calculations

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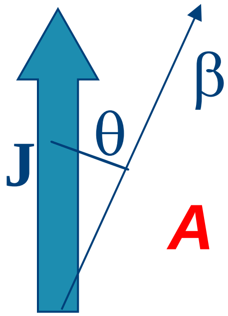
V_{ud} from $\mathcal{F}t$ values of the mirror β transitions

correcting Ft values of mirror β transitions for GT/F mixing ratio yields V_{ud}:

$$Ft^{mirror}\left(1+\frac{f_A}{f_V}\rho^2\right) = 2Ft^{0^+\to 0^+} = \frac{K}{G_F^2 V_{ud}^2 (1+\Delta_R^V)}$$

correlation coefficients depend on GT/F mixing ratio $\rho = \frac{C_A M_{GT}}{C_V M_F}$

e.g. $a_{SM} = \frac{1-\rho^2/3}{1+\rho^2}$ **and** $A_{SM} = \frac{\mp\lambda_{J'J}\rho^2 - 2\delta_{J'J}\sqrt{J/(J+1)}\rho}{1+\rho^2}$



V_{ud} from $\mathcal{F}t$ values of the mirror β transitions

N.Severijns & O. Naviliat-Cuncic, Physica Scripta T152 (2013) 014018

New beta decay correlation measurements with mirror nuclei:

ΔV_{ud} for relative precision of 0.5% on $a_{\beta\nu}$ or A_β :

$a(^{19}Ne)$ → ΔV_{ud} = 0.0011 (data from GANIL-LIRAT being analysed)

$a(^{35}Ar)$ → ΔV_{ud} = 0.0019 (data from GANIL-LIRAT being analysed)

$A_\beta(^{35}Ar)$ is most sensitive to V_{ud} :

$A(^{35}Ar)$ → ΔV_{ud} = 0.0007 with present Ft value

$A(^{35}Ar)$ → ΔV_{ud} = 0.0004 if Ft value is improved by factor 4.8

(requires Q_{EC}, $T_{1/2}$ and BR)

only factor of 2 !!

(Note: ΔV_{ud} (0+ → 0+) = 0.00022)

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V_{ud} quark mixing matrix element from β asymmetry parameter and Ft value of ^{35}Ar

- Avoid need for precise determination of nucl. polar. *J* of ^{35}Ar in host lattice by relative measurement of β asymmetry for mixed mirror transition and pure GT transition to excited state

  Experimental asymmetry:

  $$\mathcal{A} = \left\langle \frac{v}{c} \cos(\theta) \right\rangle J A = \frac{R-1}{R+1} \quad \text{where} \quad R = \sqrt{\frac{N(0,+J)N(\pi,-J)}{N(0,-J)N(\pi,+J)}}$$

  After experimental corrections and evaluation of the phase space and geometrical acceptances $\langle (v/c)\cos(\theta)\rangle$ the asymmetry parameter ratio is obtained as:

  $$\frac{A_{gs}}{A_{ex}} = \frac{\langle (v/c)\cos(\theta)\rangle_{ex} \mathcal{A}_{gs}}{\langle (v/c)\cos(\theta)\rangle_{gs} \mathcal{A}_{ex}}$$

- Use ^{21}Na and/or ^{23}Mg to optimize method.

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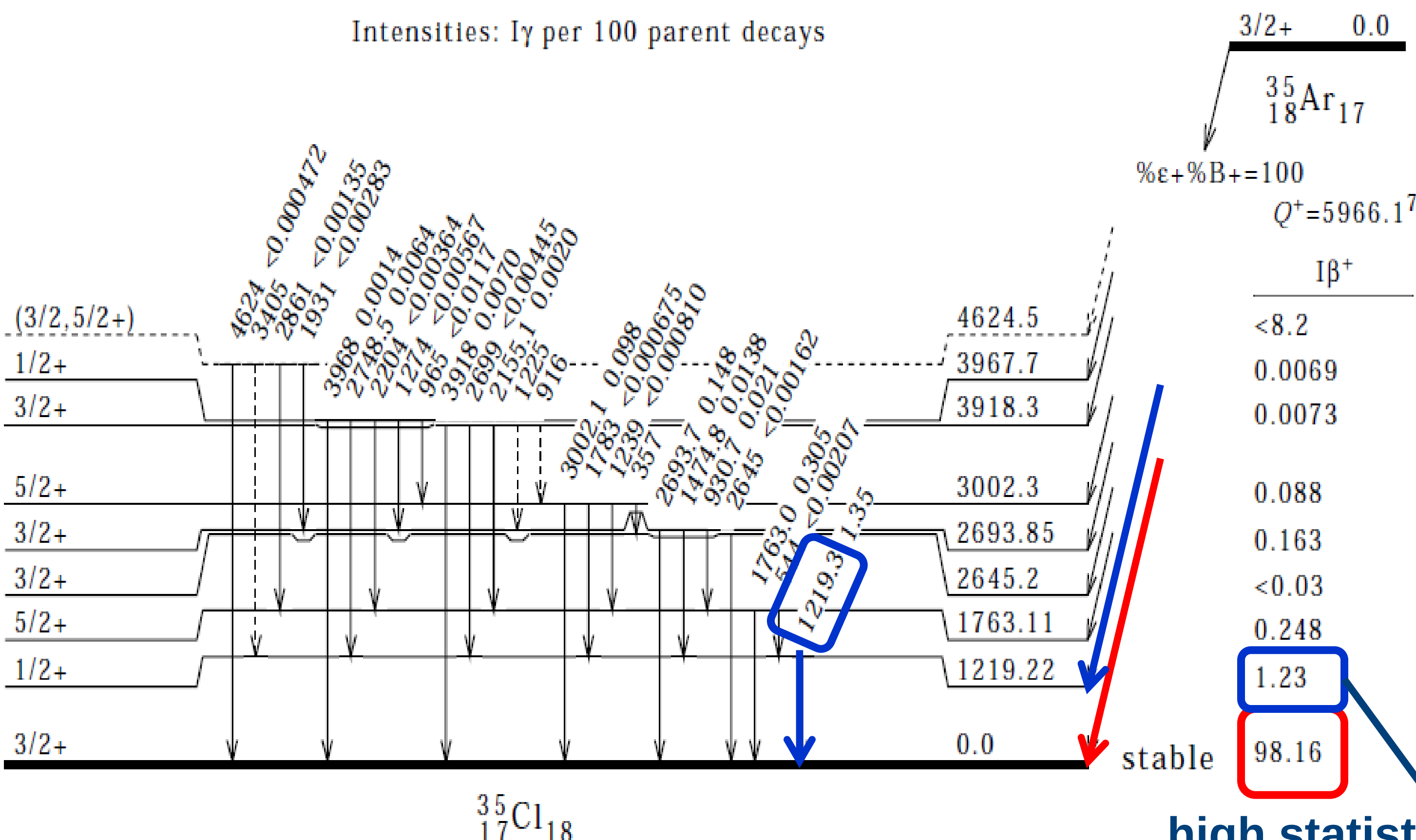
V_{ud} quark mixing matrix element from β asymmetry parameter and Ft value of ^{35}Ar

- Beta-gamma coincidences required to distinguish mirror beta transition to g.s. from GT transition to excited state



Iβ+	Iε	Log ft
<8.2	<0.00036	>4.8
0.0069	0.00070	4.81
0.0073	0.00063	4.88
0.088	0.00105	4.973
0.163	0.00123	4.989
<0.03	<0.0002	>5.8
0.248	0.00067	5.475
1.23	0.00205	5.091
98.16	0.0708	3.7520

high statistics required !!

^{35}Ar beta asymmetry program at KU Leuven

- Grant "KU Leuven-GOA/15/010" awarded Dec. 2013 for ^{35}Ar beta asymmetry measurement program.
- Design studies of optimal geometry, anticipated counting rates, etc. ongoing at KU Leuven.
- MOT for beta asymmetry of trapped ^{35}Ar, complimentary experiment with separate systematics at University of Liège.
- VITO beamline at ISOLDE for polarized isotopes, plan to take first beam October 2014.

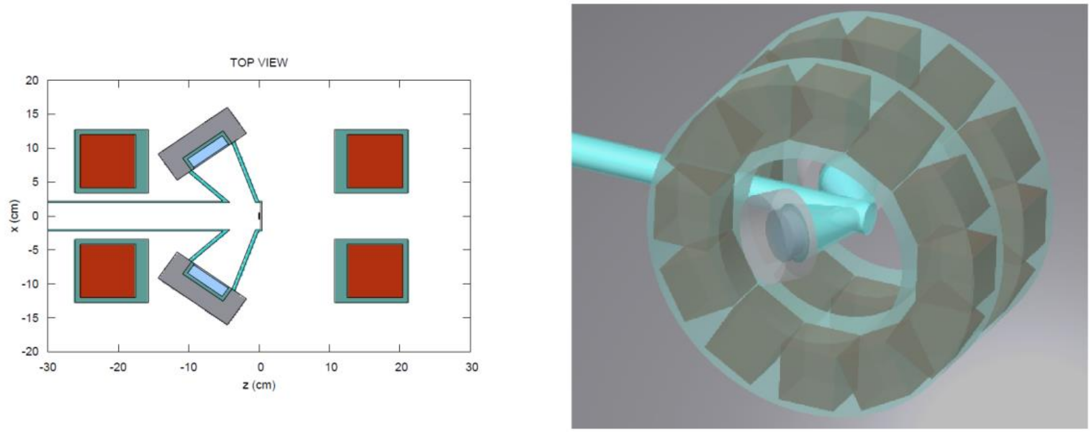
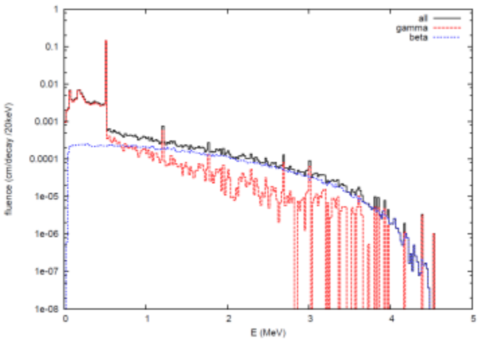


Figure 3: Overview of the detection system.



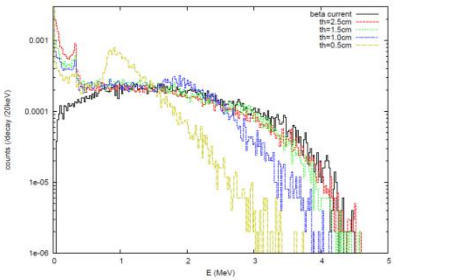


Figure 5: Energy spectrum in the E-detector for different scintillator thickness.

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^{35}Ar beta asymmetry program at KU Leuven

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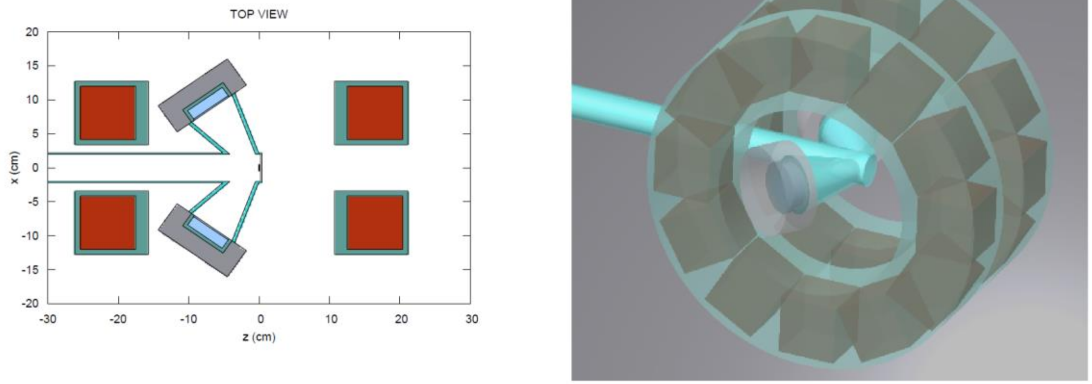
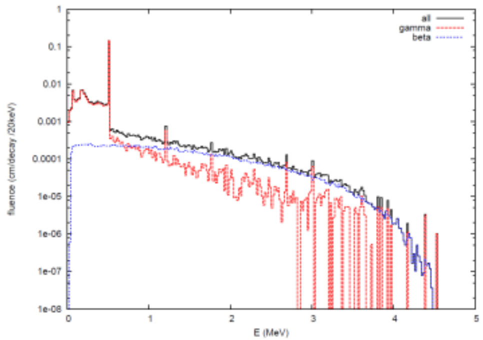


Figure 3: Overview of the detection system.



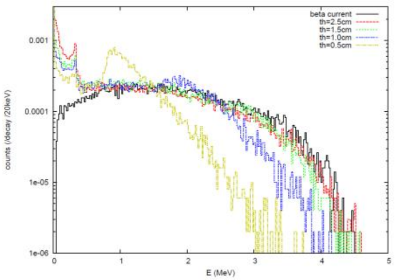


Figure 5: Energy spectrum in the E-detector for different scintillator thickness.

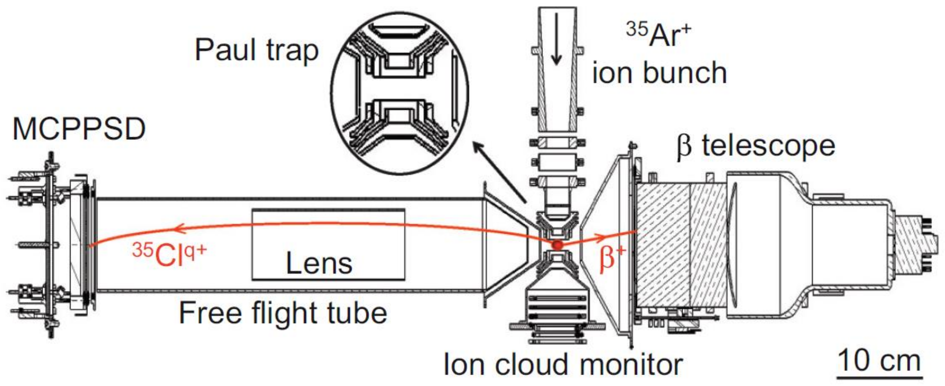
Session 29, talk by R. Garcia Ruiz

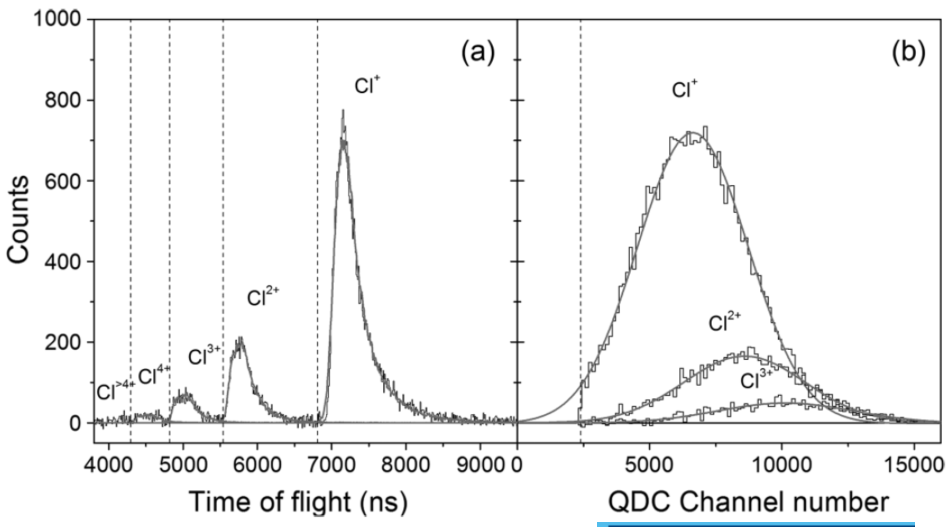
KU LEUVEN

Beta-neutrino angular correlation, $a_{\beta\nu}$

- LPCTrap: Paul trap with beta telescope and MCP detector. Established setup with well-controlled systematics.

- LPCTrap has recently carried out high-precision $a_{\beta\nu}$ measurements for ^{35}Ar and ^{19}Ne in 2012/2013, which are currently being analyzed.



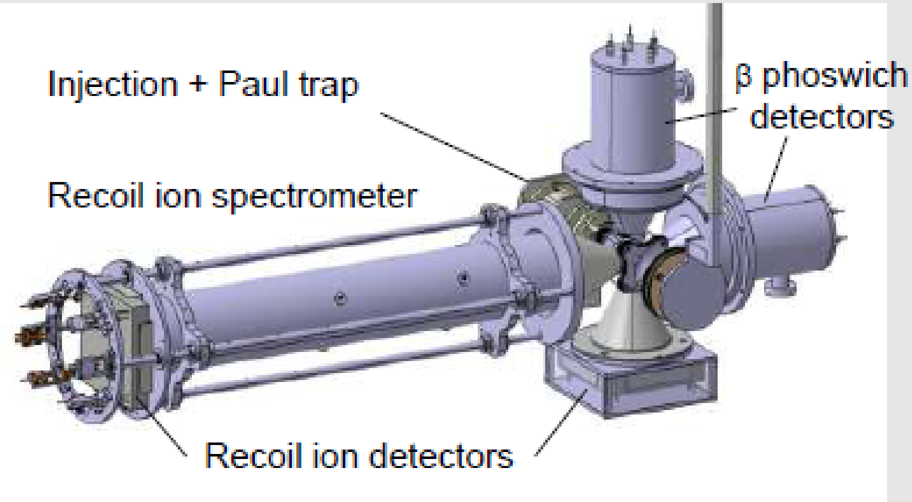


What can we expect from *a* measurements ?

- Ion with rate > 1E+06 pps (from *Spiral_beam.pdf* in DESIR W-S website)

Ion	$T_{1/2}$ (s)	Expected rate (pps)	Expected nb of coinc.	Estimated $a \pm \sigma_a$	New $\rho \pm \sigma_\rho$	Gain factor
^{21}Na	22.49	1.8E+08	1.7E+06	0.5587(24)	-0.7034(29)	2.7
^{23}Mg	11.32	4.3E+07	8.1E+05	0.6967(35)	0.5426(40)	new
^{33}Cl	2.51	1.8E+07	1.5E+06	0.8848(25)	0.3075(37)	new
^{37}K	1.22	1.1E+07	1.9E+06	0.6580(16)	0.5874(26)	10.5

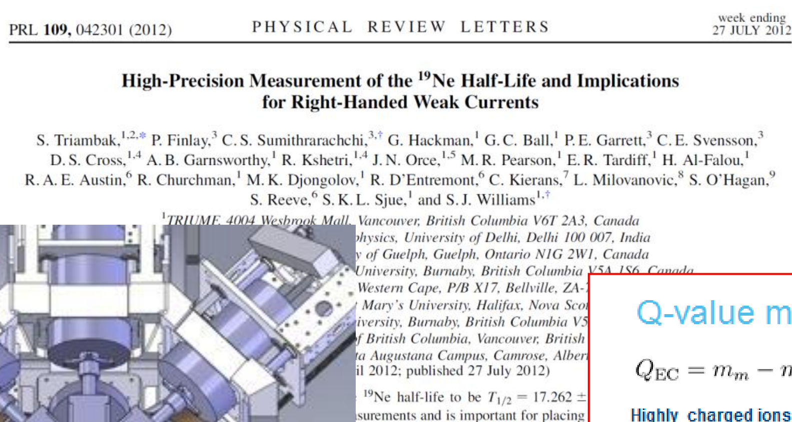
- Estimation of coinc. (1 week):
  - Based on ^{35}Ar experiment
  - $T_{1/2}$ taken into account
  - LPCTrap → LPCTrap2
    - phoswich for β detection
    - detectors number X 2
    - FASTER DAQ system



➡ Gain in stat: factor of ~ 4

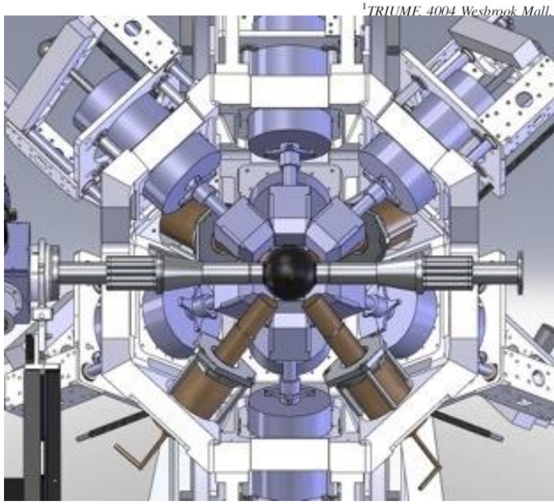
Mirror *ft* values at TRIUMF

Approved Experiments	Status
S1192 – $T_{1/2}$, BR for ^{19}Ne	Completed
S1385 – $T_{1/2}$ for ^{21}Na	Scheduled, Nov. 2014
S1517 – $T_{1/2}$, Q-value for ^{35}Ar	Pending

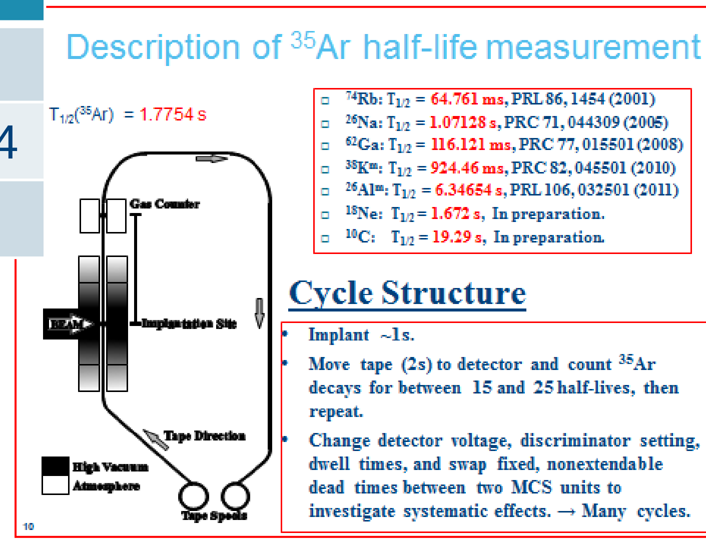

PRL 109, 042301 (2012) PHYSICAL REVIEW LETTERS week ending 27 JULY 2012

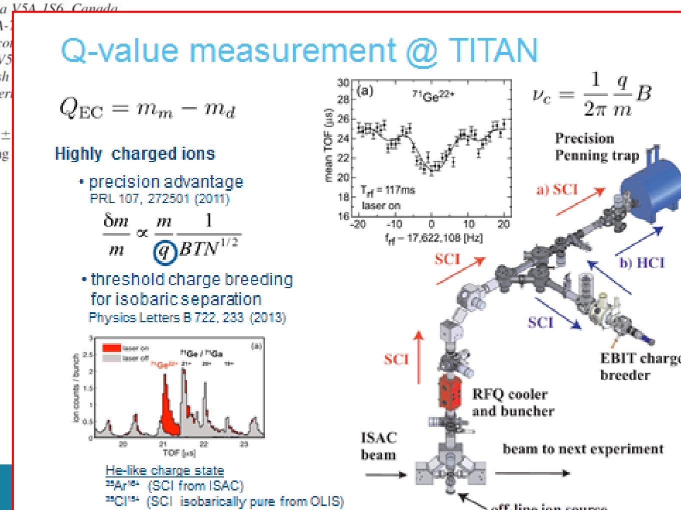
High-Precision Measurement of the ^{19}Ne Half-Life and Implications for Right-Handed Weak Currents

S. Triambak,[1,2,*] P. Finlay,[3] C. S. Sumithrarachchi,[3,†] G. Hackman,[1] G. C. Ball,[1] P. E. Garrett,[3] C. E. Svensson,[3] D. S. Cross,[1,4] A. B. Garnsworthy,[1] R. Kshetri,[1,4] J. N. Orce,[1,5] M. R. Pearson,[1] E. R. Tardiff,[1] H. Al-Falou,[1] R. A. E. Austin,[6] R. Churchman,[1] M. K. Djongolov,[1] R. D'Entremont,[6] C. Kierans,[7] L. Milovanovic,[8] S. O'Hagan,[9] S. Reeve,[6] S. K. L. Sjue,[1] and S. J. Williams[1,†]



GRIFFIN





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Summary and Conclusions

- Superallowed Fermi beta decays currently provide the most precise value for the CKM matrix element V_{ud}, which is itself limited in precision due to theoretical, rather than experimental, uncertainties.

- While high-precision ft value measurements for select superallowed emitters, such as $^{26}Al^{m}$ and ^{62}Ga, have provided some of the most rigorous self-consistency checks of the leading ISB calculations, in order to continue to improve the limits on the CKM unitarity sum from low-energy nuclear physics further, and more comprehensive, checks need to be developed.

- The isospin T=1/2 mirror beta transitions offer an independent system in which to test the machinery of the ISB calculations, with the potential of not only refining the ISB corrections in superallowed decay, but ultimately contributing directly to an improved determination of V_{ud} in conjunction with the superallowed data.

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X. Fabian

GANIL

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G.F. Grinyer

Rez

D. Zákoucký

University of the Western Cape

S. Triambak

FWO VLAANDEREN

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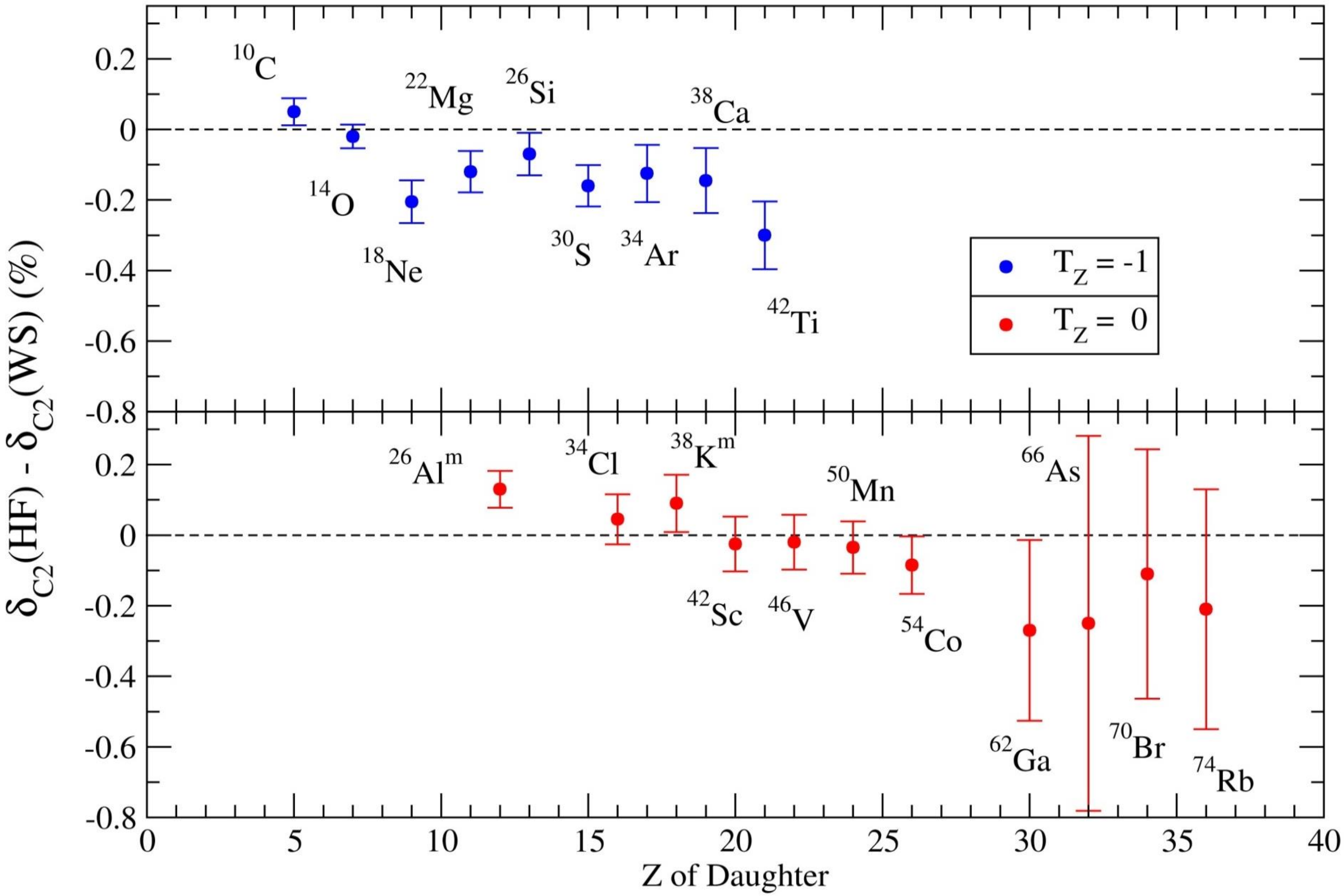
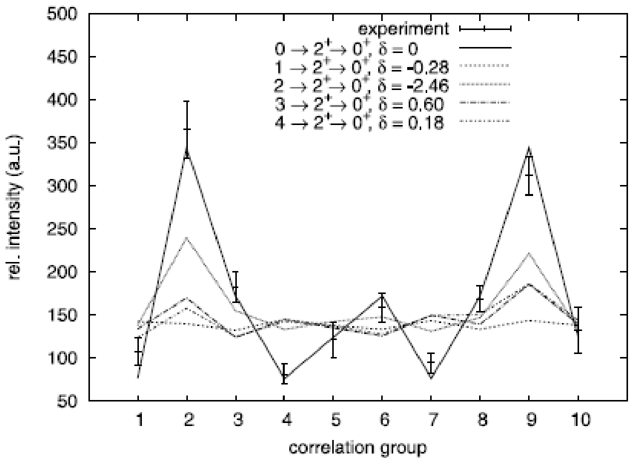
Difference between Woods-Saxon and Hartree-Fock Radial Overlap Corrections



Previous spectroscopic data for ^{62}Ga and the 1st excited 0^+

Gamma-gamma correlations

M. Albers et al. / Nuclear Physics A 847 (2010) 180–206



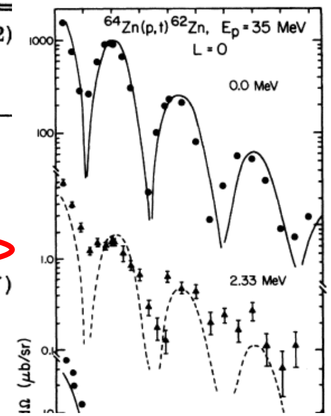
E_{level} [keV]	J_i^π	$E_{level,Lit}$ [keV]	$J_{i,Lit}^\pi$
953.8(1)	2_1^+	953.92(17)	2^+
1804.7(2)	2_2^+	1804.88(20)	2^+
2186.0(1)	4_1^+	2186.1(5)	4^+
2342.0(4)	0_2^+	2342.45(33)	0^+
2384.4(1)	3_1^+	2384.5(4)	3^+

M. Albers *et al.*, Nucl. Phys. A **847**, 180 (2010)

Transfer reactions

TABLE I. Levels in ^{62}Zn.

Peak No.	Present work E (MeV)	J^π	$d\sigma_{max}/d\Omega$ (μb/sr)	N	(p,t) (Ref. 1) E (MeV)	J^π	(p,t) (Ref. 2) E (MeV)	J^π
1	0.0	0^+	911	490	0.0	0^+	0.0	0^+
2	0.957	2^+	150	197	0.957	2^+	0.95	2^+
3	1.801	2^+	19	23	1.801	2^+	1.80	2^+
4	2.18 ± 0.01	4^+	2.6	15	2.17 ± 0.01	4^+	2.18	4^+
5	2.33 ± 0.01	0^+	1.5	0.7	2.34 ± 0.02		2.38	0^+
6	2.75 ± 0.01	4^+	23	130	2.74 ± 0.02	3	2.75	$(3^-, 4^+)$



R.A. Hinrichs and D.M. Patterson, Phys. Rev. C **10**, 1381 (1974)

Previous work on ^{62}Zn → first excited 0^+ state at 2.3 MeV.

This provides scaling for δ_{C1} BR meas. $\delta_{C1,1}$

R.R. Betts *et al.*, Phys. Lett. B **76**, 47 (1978)

^{62}Zn

E_x (MeV)	J^π	S_α Exp.	S_α Calc.
0.00	0^+	1.0 a)	1.0 a)
0.95	2^+	0.23 b)	0.23 b)
1.81	2^+	0.004	0.002
2.17	4^+	0.04	0.004
2.33	0^+	<0.10	0.02
3.22	3^-	0.27 b)	0.27 b)

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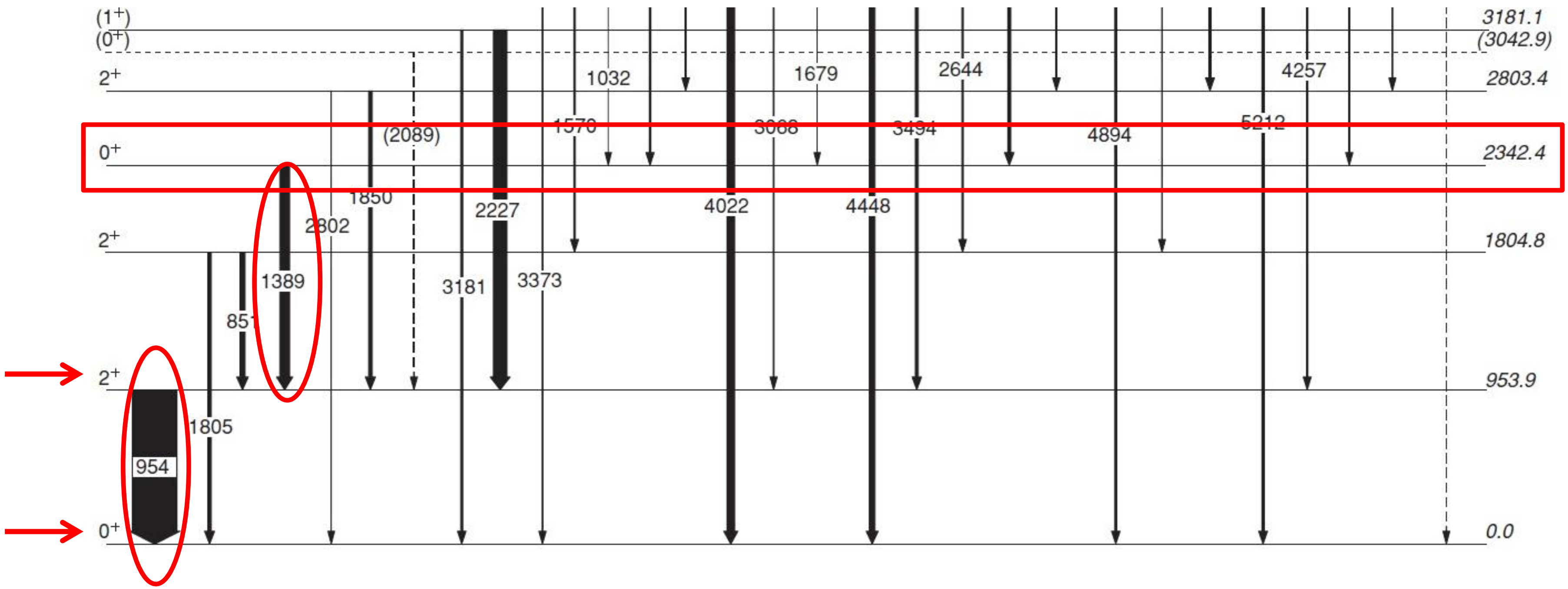
Low-lying levels in ^{62}Zn



Identify spin of 2342-keV state via angular distribution of 1389 keV gamma ray detected in coincidence with pure E2 954 keV gamma.

A 2^+ or 0^+ spin for the 2342-keV state will result in different distribution of opening angles between these two subsequently emitted gammas.

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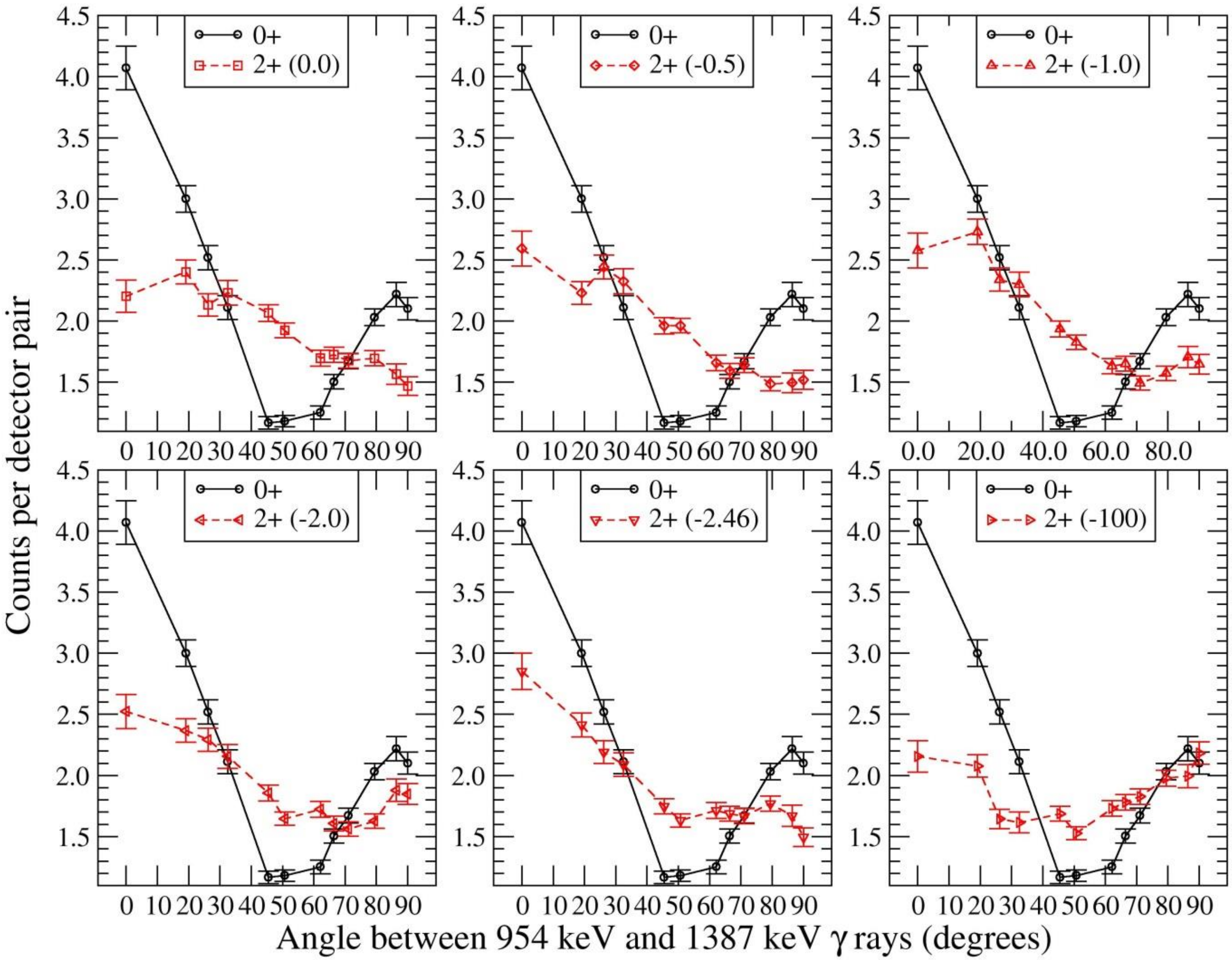
γγ coincidences for the 954 keV and 1387 keV γ rays



Individual GRIFFIN crystal combinations give 12 distinct angular pairs for detecting 954 keV and 1387 keV gammas.

12 shifts necessary for clear distinction between 0^+ and 2^+ assignment, even under a wide range of assumptions for the M1/E2 mixing ratio if 2^+

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