High-precision studies of the superallowed β decay of heavy odd-odd T_z=0 and even-even T_z=-1 nuclei

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β-decay as a test of the Standard Model

- Standard Model : very succesful but includes numerous free parameters

- g_v can be measured in several ways... (see A. Bacquias' talk just after)

... but highest precision achieved through the study of superallowed $0^+ \rightarrow 0^+$ β decays

β decays
- Allowed: $\Delta J = J_i - J_f = 0, \pm 1$; $\pi_i \pi_f = +1$; $L_{leptons} = 0$
  - Fermi ($S_{leptons} = 0$)
  - Gamow-Teller ($S_{leptons} = 1$)
- ~~Forbidden ($L_{leptons} \neq 0$)~~

Compared half-life:

$$ft = \frac{K}{g_V^2 \langle M_F \rangle^2 + g_A^2 \langle M_{GT} \rangle^2}$$

$\langle M_F \rangle^2 = T(T+1) - T_{Zi} T_{Zf}$ =2 for T=1 nuclei

For $0^+ \rightarrow 0^+$ decays:

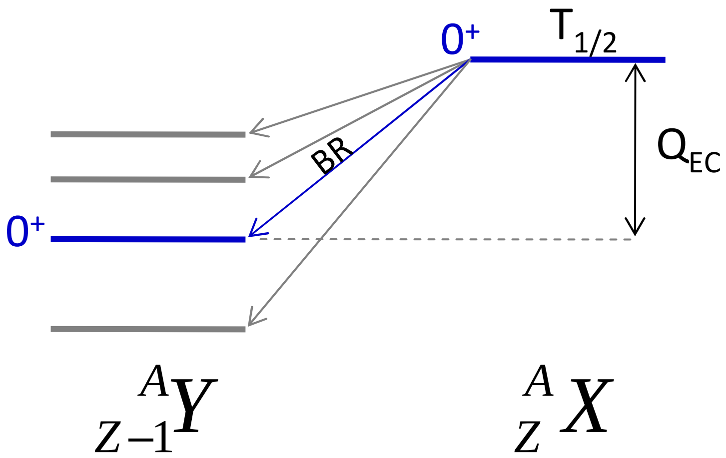
$$ft = \frac{K}{2 g_V^2}$$

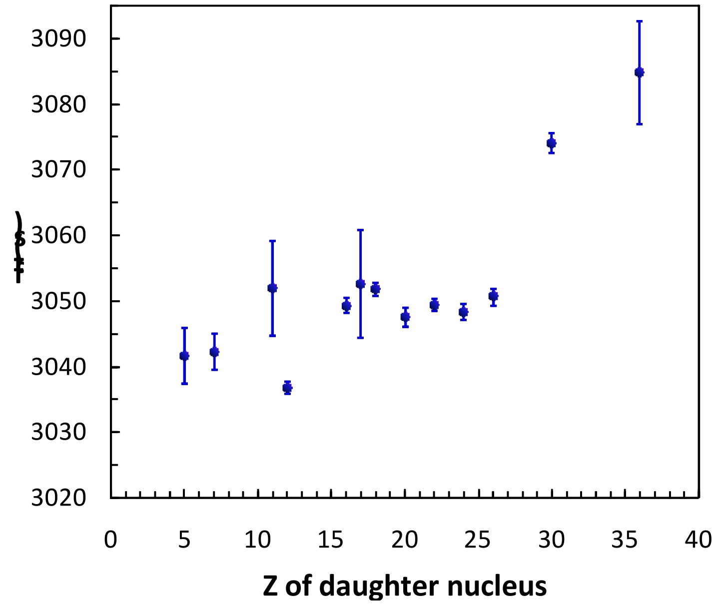
nucleus-independent

(consistent with CVC hypothesis)

Experimental determination of ft

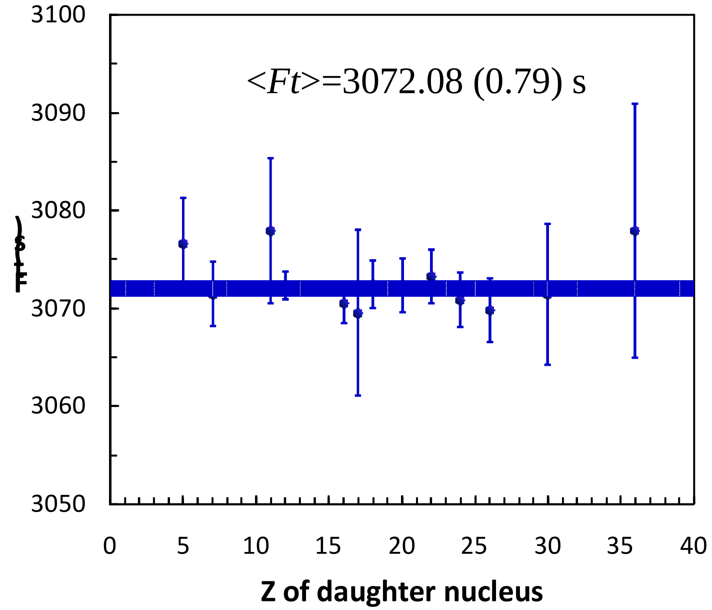
- f is a function of Q_{EC}
- t is a function of both $T_{1/2}$ and the transition branching ratio (BR)





A few corrections (≈%) must be applied to obtain a truly nucleus-independent value Ft :

$$Ft = ft\left(1+\delta_R'\right)\left(1+\delta_{NS}-\delta_C\right)$$



Precision reached (13 best cases) : 2.6×10^{-4}

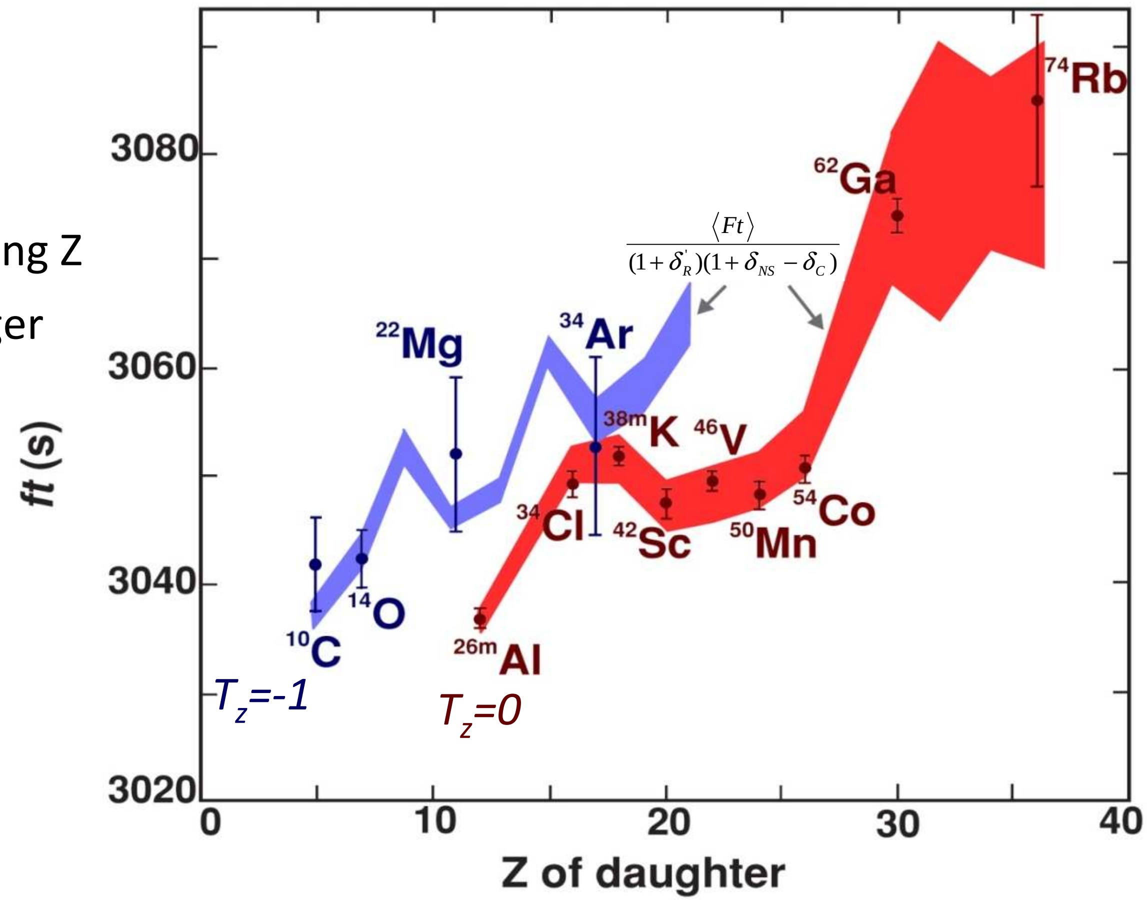
How to push the test further ?

- Improve accuracy on the existing experimental data or the corrections
- Additionnal measurements (at higher Z)

All the more interesting as…

- Corrections get larger with increasing Z
- Their relative uncertainties get larger too !

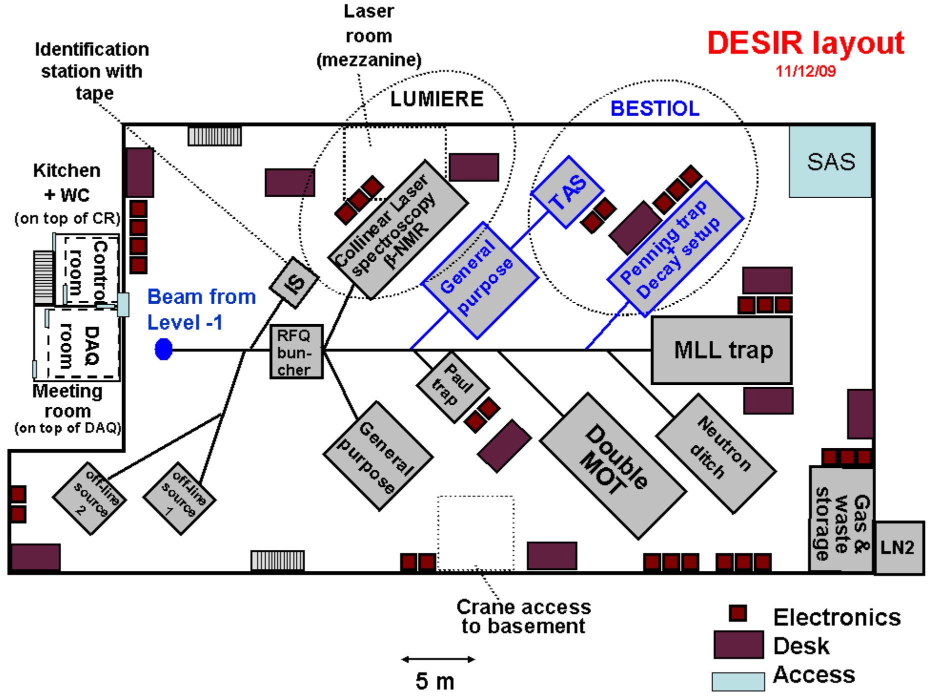
⇒ Stronger experimental test of the corrections (assuming CVC is valid).



J.C. Hardy & I.S. Towner, Phys. Rev. C 79, 055502 (2009)

Experiments at DESIR

Production by fusion–evaporation in S^3 then measurement at the BESTIOL facility



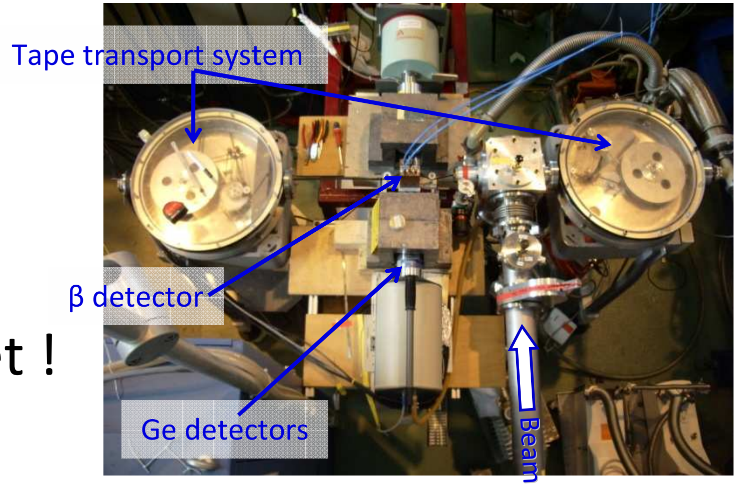
Masses: not our business ☺ (MLL trap)

Half-lives: In principle not too difficult provided $T_{daughter}$ is not too close to T_{parent}.

Branching ratios: 2 kinds of measurements

- Global measurements with the TAS
- Precise spectrometry with HPGe detector(s)

10^{-3} precision needed !!!



Ultra-pure samples would be a decisive asset !

→ Double Penning trap needed

Expected cross section for odd-odd T_z=0 nuclei

Nucleus	Reaction	σ (mb)	Intensity needed* (pps)
^{66}As	^{40}Ca(^{28}Si,pn)^{66}As	10	~ 10^{10}
^{70}Br	^{40}Ca(^{36}Ar,αpn)^{70}Br	5	~ 2×10^{10}
^{74}Rb	^{40}Ca(^{36}Ar,pn)^{74}Rb	0.2	~ 6×10^{11}
^{78}Y	^{40}Ca(^{40}Ca,pn)^{78}Y	0.1	~ 10^{12}
^{82}Nb	^{40}Ca(^{46}Ti,p3n)^{82}Nb	0.1	~ 10^{12}
^{86}Tc	^{40}Ca(^{50}Cr,p3n)^{86}Tc	0.1	~ 10^{12}
^{90}Rh	^{40}Ca(^{58}Ni,αp3n)^{90}Rh	0.02	~ 7×10^{12}
^{94}Ag	^{40}Ca(^{58}Ni,p3n)^{94}Ag	0.007	~ 2×10^{13}
^{98}In	^{40}Ca(^{64}Zn,p5n)^{98}In	0.0005	~ 3×10^{14}

* For 100 pps at the end of the line and assuming 5% total efficiency from the target to BESTIOL

Expected cross section for even-even T_z=-1 nuclei

Nucleus	Reaction	σ (mb)	Intensity needed* (pps)
^{46}Cr	$^{20}Ne(^{28}Si,2n)^{46}Cr$	0.5	~ 10^{11}
^{50}Fe	$^{24}Mg(^{28}Si,2n)\ ^{50}Fe$	0.2	~4×10^{11}
^{54}Ni	$^{32}S(^{24}Mg,2n)\ ^{54}Ni$	0.2	~ 5×10^{11}
^{58}Zn	$^{32}S\ (^{28}Si,2n)\ ^{58}Zn$	0.05	~ 2×10^{12}

* For 100 pps at the end of the line and assuming 5% total efficiency from the target to BESTIOL

Conclusion

DESIR will bring great opportunities for the study of superallowed $0^+ \rightarrow 0^+$ transitions

- Thanks to the coupling with the low energy branch of S^3, high production rate should be available for many of our nuclei of interest including refractory elements that couldn't be studied at ISOL facility.
- This open the possibility to test the theoretical corrections in a more demanding way
- The Total Absorption Spectrometer will allow precision study of nuclei with decay having large non-analogue branches.
- The double Penning trap will allow the measurement of isotopically pure sample provided their half-life is not too short.

Thanks for your attention !