PRECISION MEASUREMENTS

1. Motivation & Techniques

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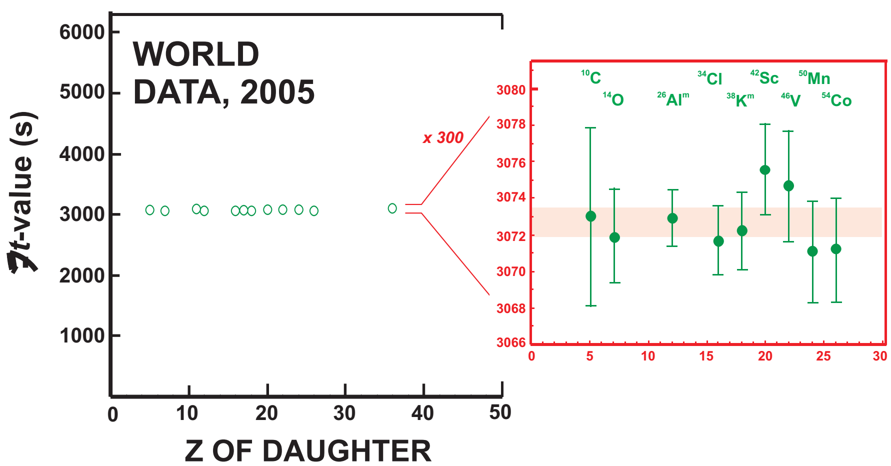

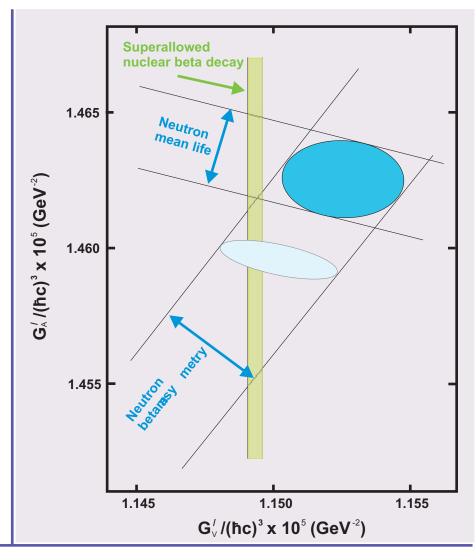

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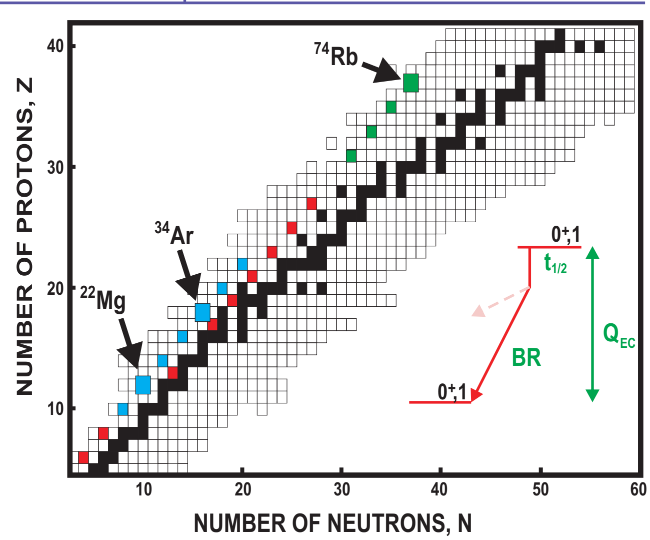


SUPERALLOWED $0^+ \rightarrow 0^+$ BETA DECAY

BASIC WEAK-DECAY EQUATION

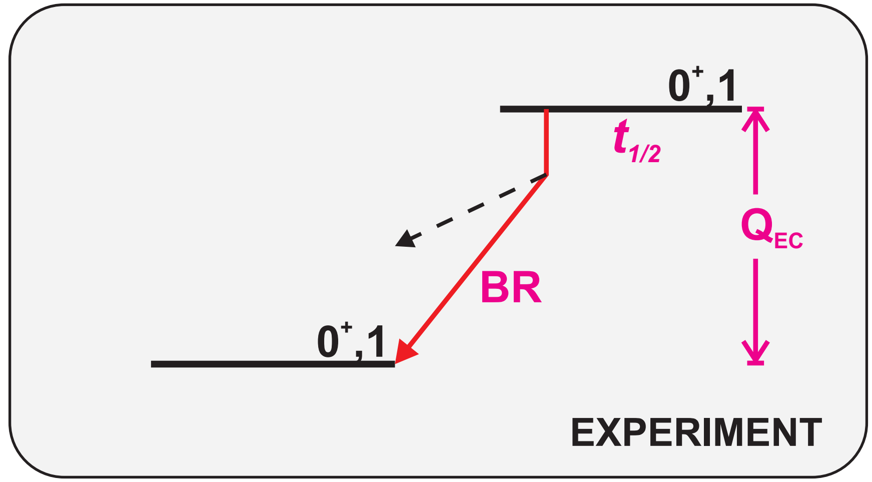
$$ft = \frac{K}{G_V^2 \langle \quad \rangle^2}$$

f = statistical rate function: $f(Z, Q_{EC})$

t = partial half-life: $f(t_{1/2}, BR)$

G_V = vector coupling constant

$\langle \quad \rangle$ = Fermi matrix element



Reference: Hardy & Towner, Phys. Rev. C71, 055501 (2005).

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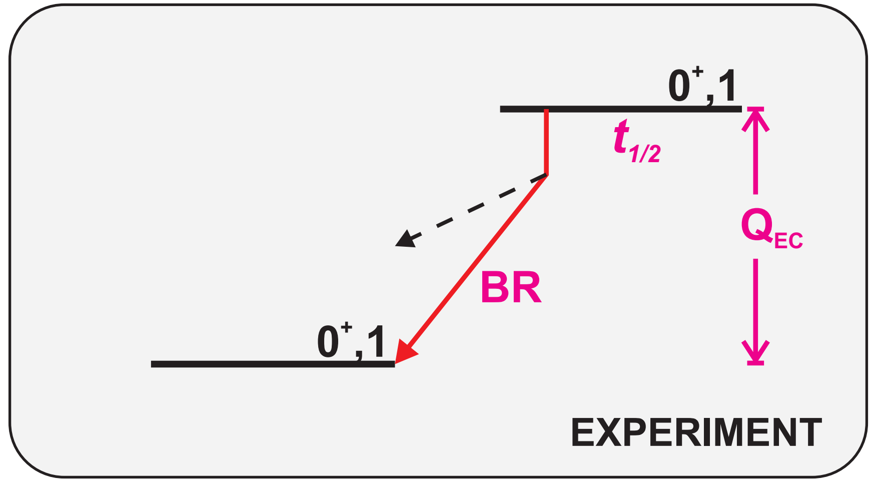

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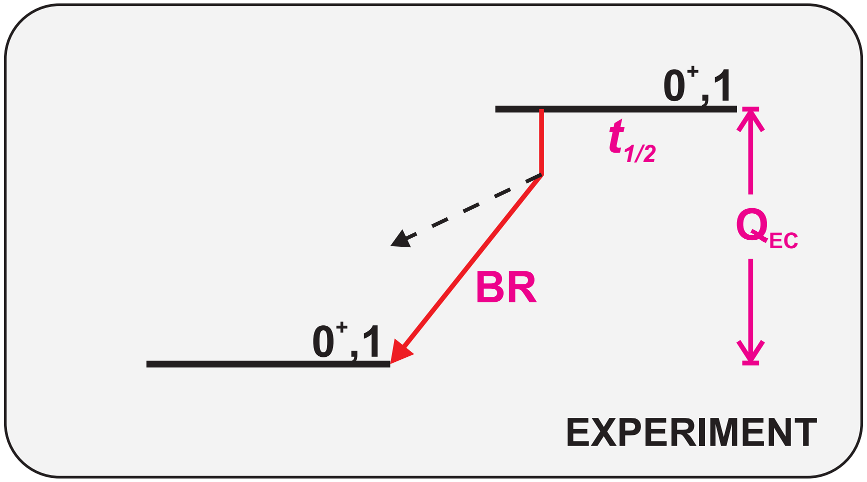

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f(nuclear structure) 0.3-0.7%

f(interaction) ~2.4%

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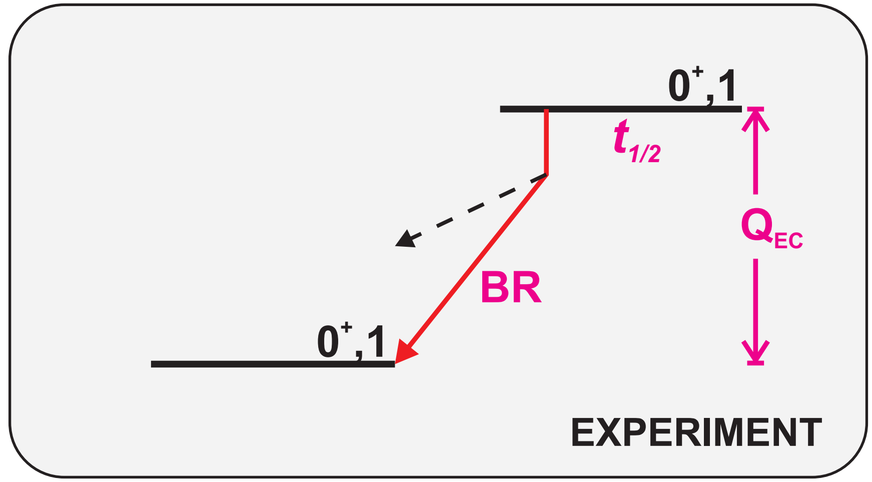

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THEORETICAL UNCERTAINTIES

0.05 – 0.10%

CKM MATRIX AND UNITARITY

CABIBBO-KOBAYASHI-MASKAWA QUARK-MIXING MATRIX

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

weak eigenstates — mass eigenstates

THREE-GENERATION UNITARITY

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

Reference: S. Eidelman *et al.*, Phys. Lett. B592, 1 (2004): Section 11

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$V_{ud}^2 = G_V^2 / G^2$

nuclear (n &) decays

muon decay

$K^{+} \longrightarrow {}^{0} e^{+} {}_{e}$

$K_L^{0} \longrightarrow {}^{\pm} e^{\mp} {}_{e}$

0.0507(9)

B decays

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WHAT PRECISION IS NEEDED?

$$1 - V_{us}^2 - V_{ub}^2 = 0.9493(9)$$

< 0.1%

PRECISION REQUIRED FROM EXPERIMENT

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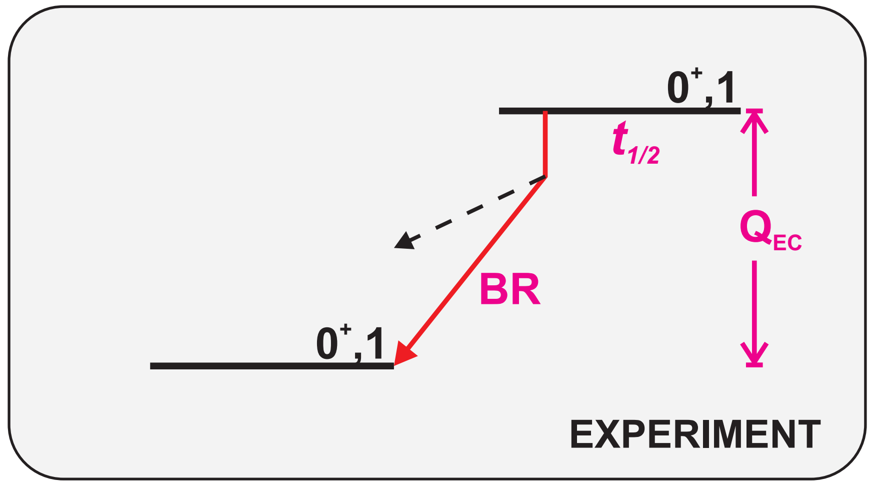

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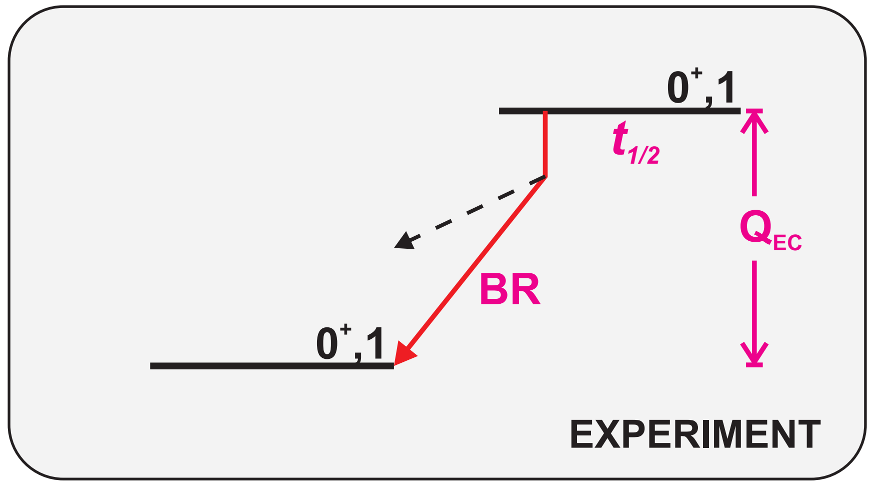

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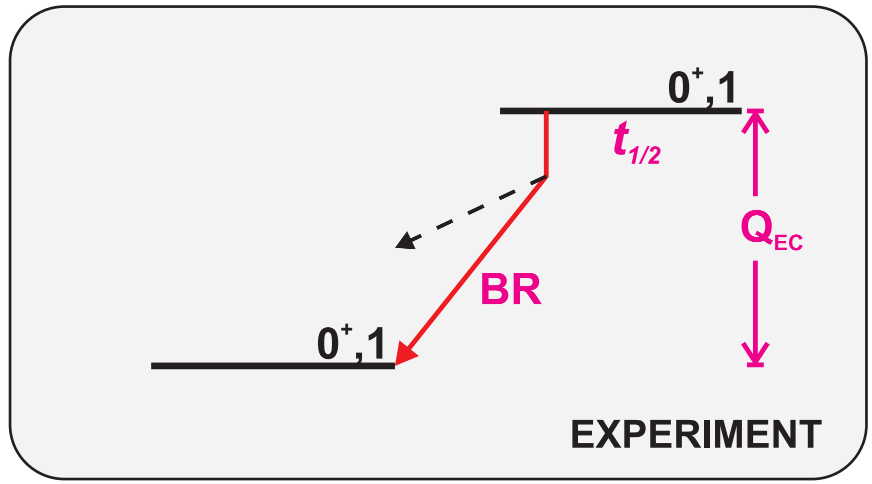

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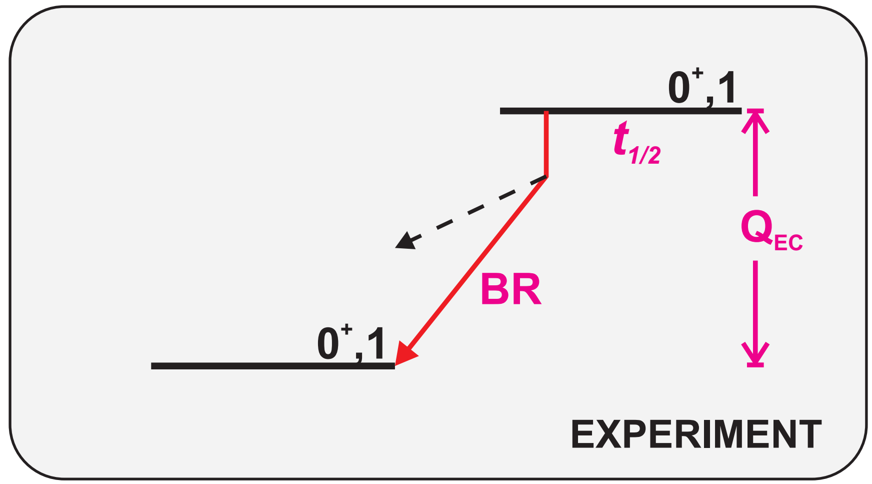

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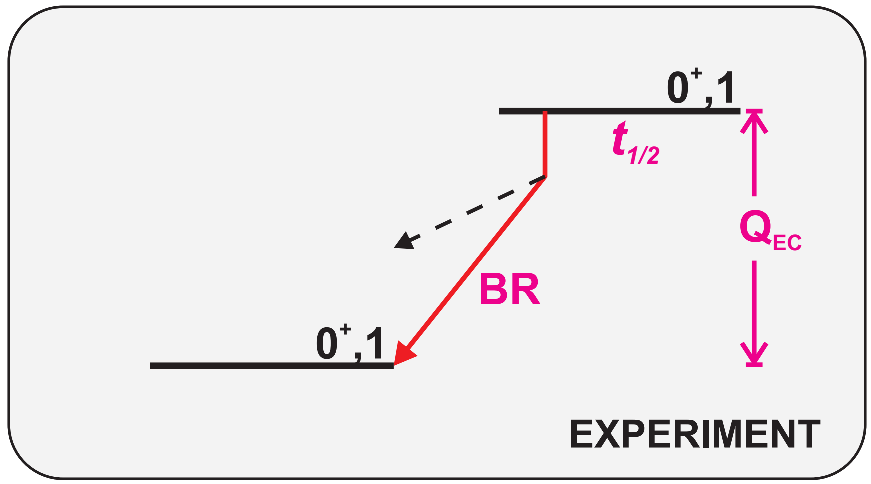
$f = f(Z, Q_{EC}) \propto Q^5$

Precision for Q **0.01%**



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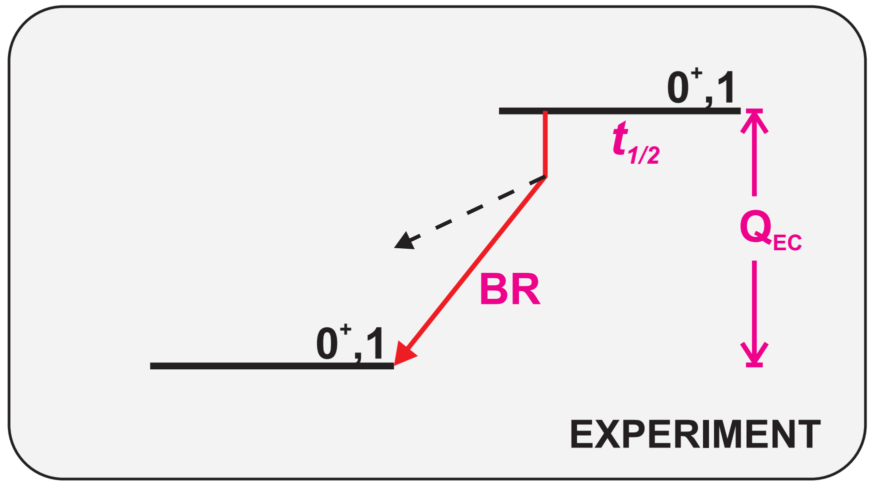

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200eV – 1keV

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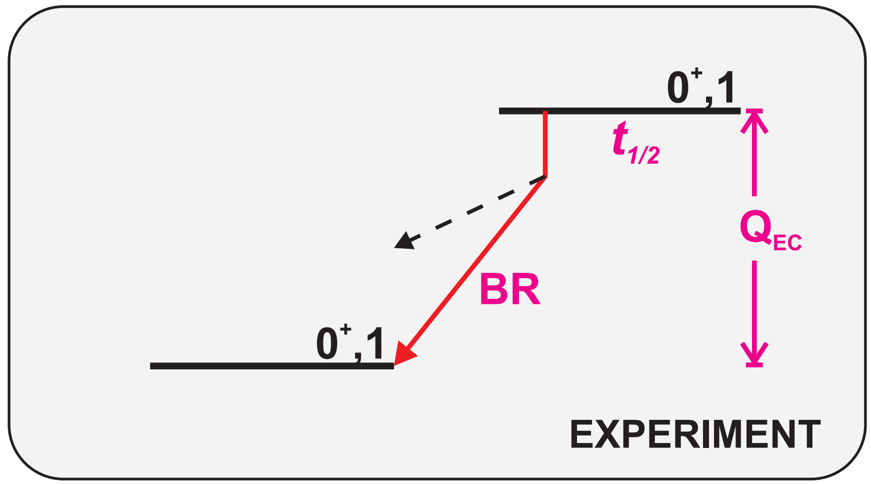

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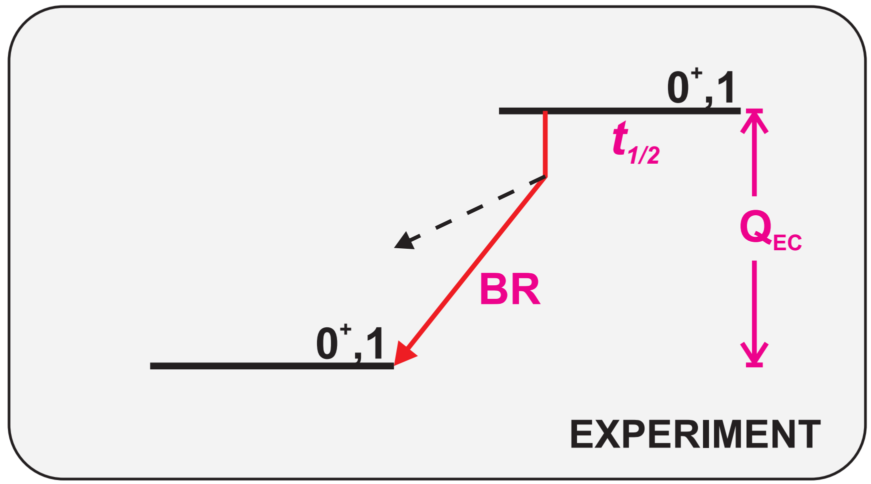

By the usual nuclear physics standards, these are very challenging requirements!

GUIDELINES FOR PRECISION MEASUREMENTS

- Experimental apparatus should be as simple as possible.
- All experimental parameters must be under control and testable.
- Experimental equipment should be dedicated only to this measurement.
- Calibration is often the most important part of the measurement.
- Tests for sources of systematic error must dominate data acquisition.
- Redundancy is desirable in both measurement and analysis.
- No inconsistencies can be overlooked.
- A complete error budget is the most important part of the result.