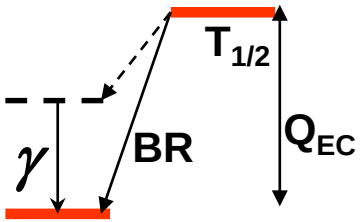
Precision measurement of the half-life and branching ratio of T=1/2 mirror β decay of ^{37}K

T. Kurtukian-Nieto[1], B. Blank[1], P. Ascher[1], G. Benzoni[2], A. De Roubin[1], X. Fléchard[3], M. Gerbaux[1], J. Giovinazzo[1], S. Grévy[1], G. Grinyer[4], A. Husson[1], E. Liénard[3], J. Liendo[5], J. Michaud[1], M. Pomorski[1], G. Quéméner[3], J.C.Thomas[6], M. Versteegen[1]

[1] CENBG, IN2P3/CNRS/Université Bordeaux 1, BP120 F-33175 Gradignan, France
[2] INFN, Sezione di Milano, via Celoria 16, I-20133 Milano, Italy
[3] LPC CAEN-ENSICAEN, 6 Boulevard du Marechal Juin, 14050 Caen Cedex, France
[4]Department of Physics, University of Regina, Regina, SK S4S 0A2, Canada
[5] Universidad Simon Bolivar, Baruta. AP 89000, Caracas,Venezuela.
[6] GANIL, CEA/DRF-CNRS/IN2P3, Bvd Henri Becquerel, 14076 Caen, France

62th Meeting of the INTC. CERN, November 6-7, 2019

Superallowed Mixed Mirror β decay



Measurements needed :

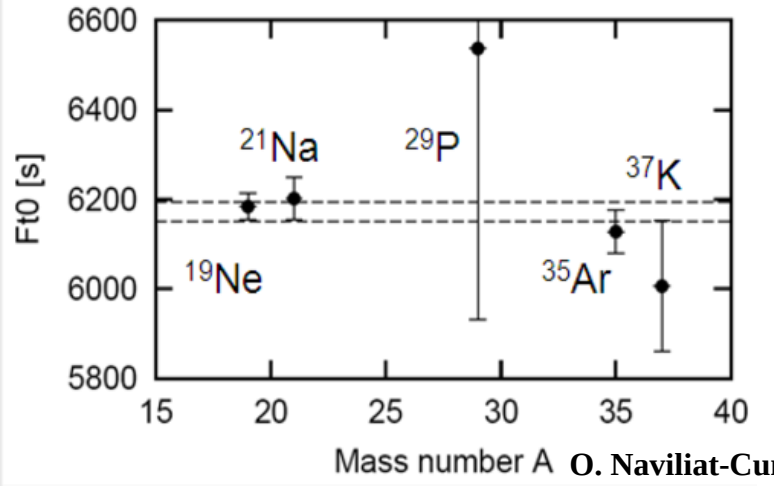
- Q_β value
- Branching ratio of super-allowed transition
- β-decay half-life
- GT-to-F mixing ratio: $a_{\beta\nu}$, A_β

$$ft = f(Q_{ec}) * T_{1/2} / BR$$

$$\mathcal{F}t^{\text{mirror}} \equiv f_V t\left(1+\delta'_R\right)\left(1+\delta^V_{\text{NS}}-\delta^V_C\right) = \frac{2\mathcal{F}t^{0^+\to 0^+}}{\left(1+\frac{f_A}{f_V}\rho^2\right)}$$

with $\rho = G_A M_{GT} / G_V M_F$

$$Ft_0 = Ft^{\text{mirror}}\left(1+\frac{f_A}{f_V}\rho^2\right) = 2Ft^{0^+\to 0^+} = \frac{K}{G_F^2 V_{ud}^2 (1+\Delta_R^V)}$$



First consistent test of CVC from a set of nuclear transitions other than super-allowed pure Fermi

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

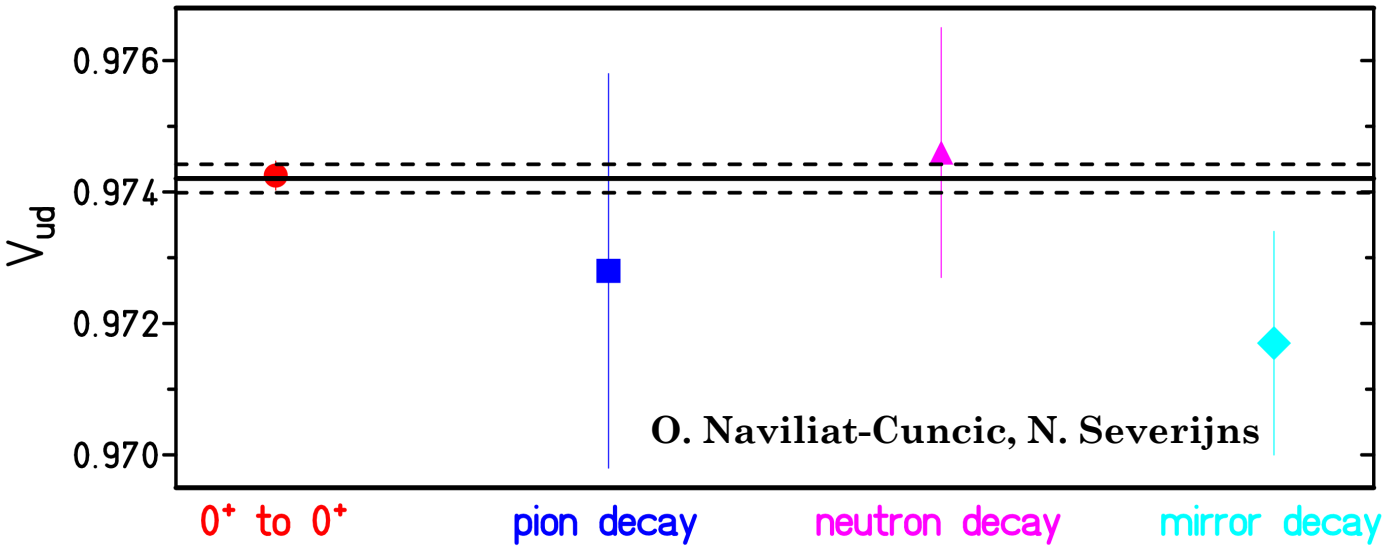
Introduction: quark-mixing matrix CKM

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

➔

unitarity condition:

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

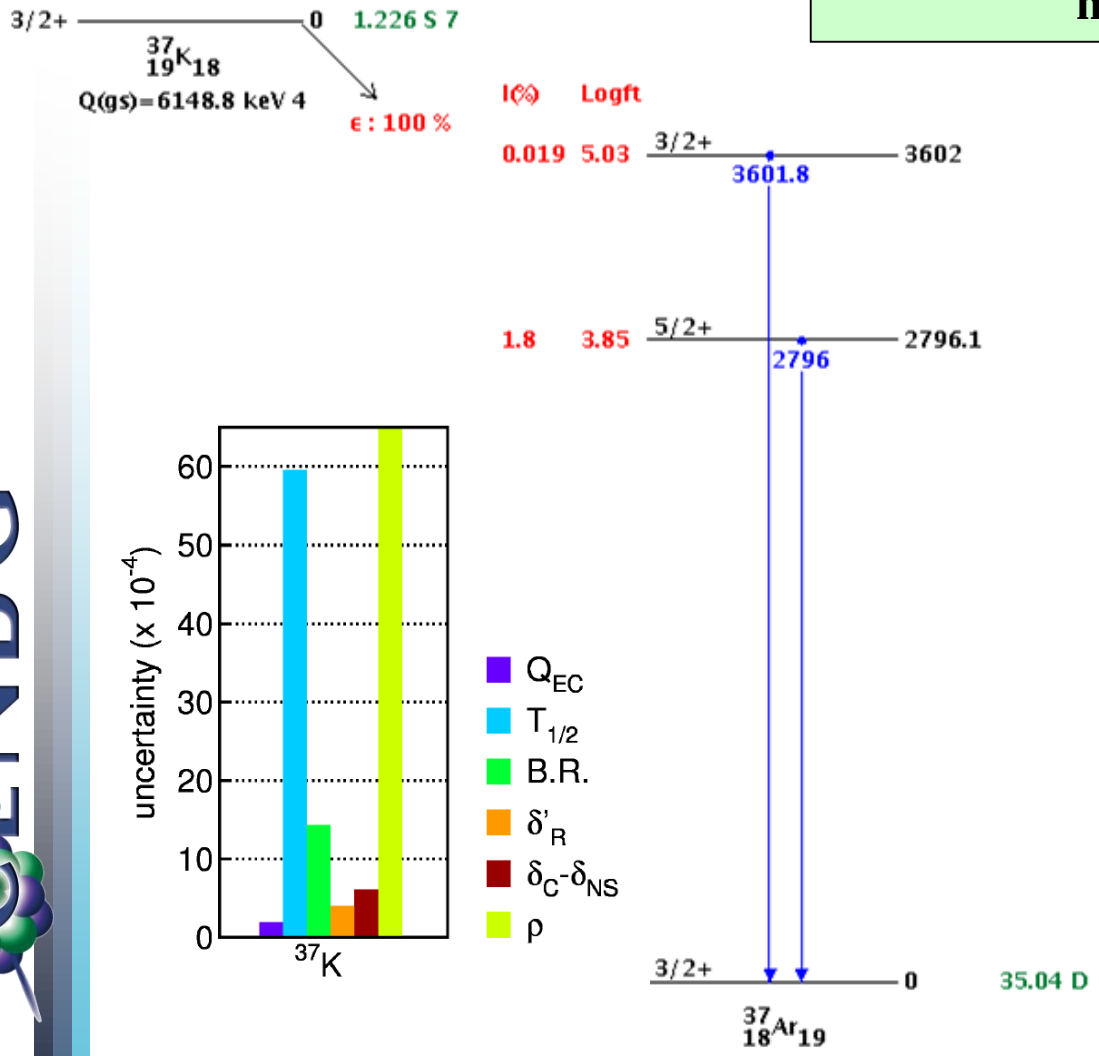


Improvements require:

- new and precise measurements of correlation coefficients,
  (e.g. βν-correlation coefficient *a* and beta asymmetry parameter *A*)
- improved corrected Ft-values for T=1/2 mirror transitions

Why to re-measure ^{37}K ?

T=1/2 decay is predominantly 3/2+ to 3/2$^+$ mixed Fermi/GT decay

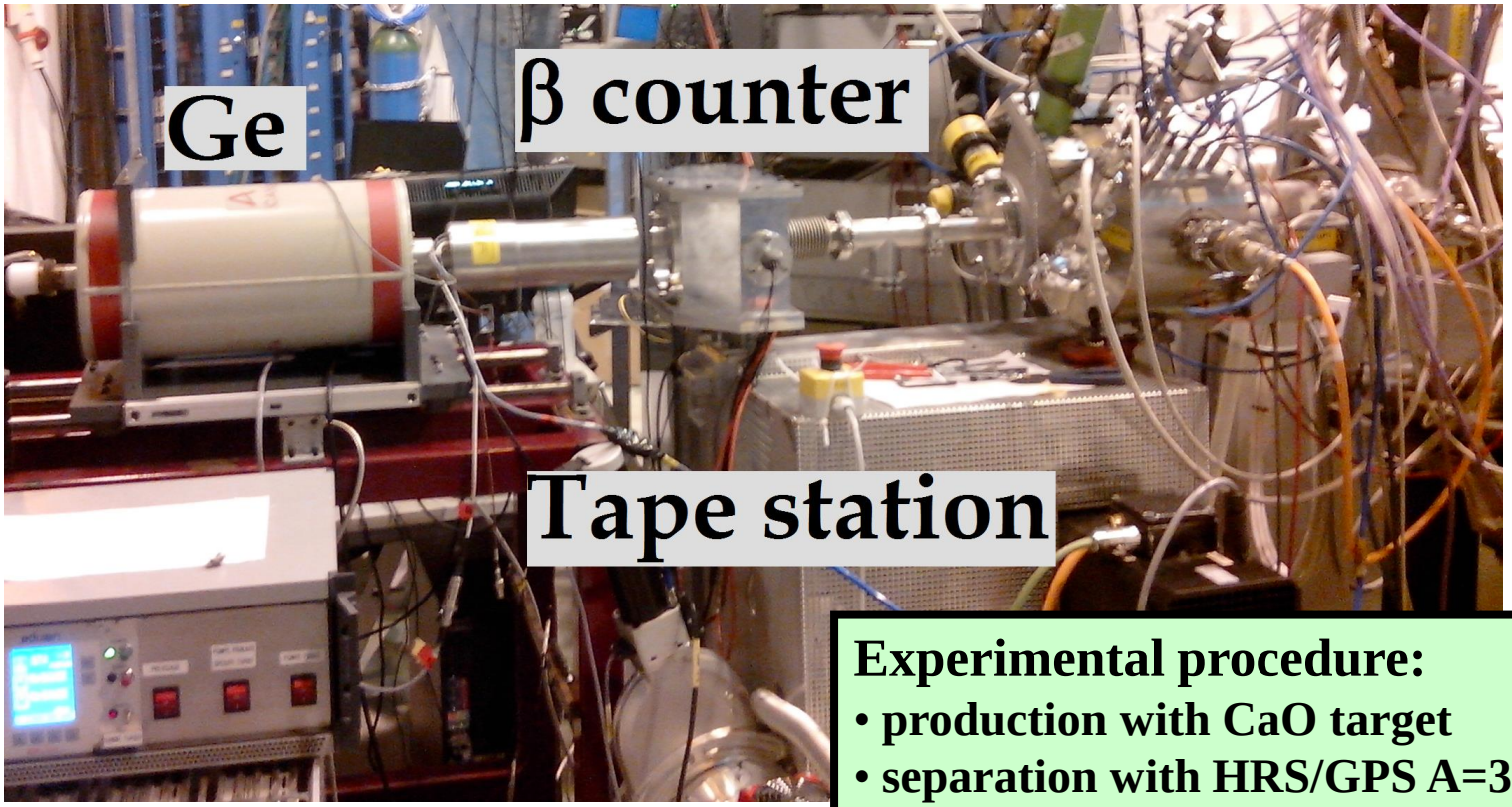


Aim:

- $\Delta T_{1/2}$ ~ 0.1 %
- ΔB.R. ~ 0.1 %

Half-life and BR measurement of ^{37}K

Detection setup at LA1 beamline



Experimental procedure:

- production with CaO target
- separation with HRS/GPS A=37
- accumulation on tape
- tape transport into setup
- measurement for 3-20$T_{1/2}$
- background
- tape move and new cycle start

Experimental details

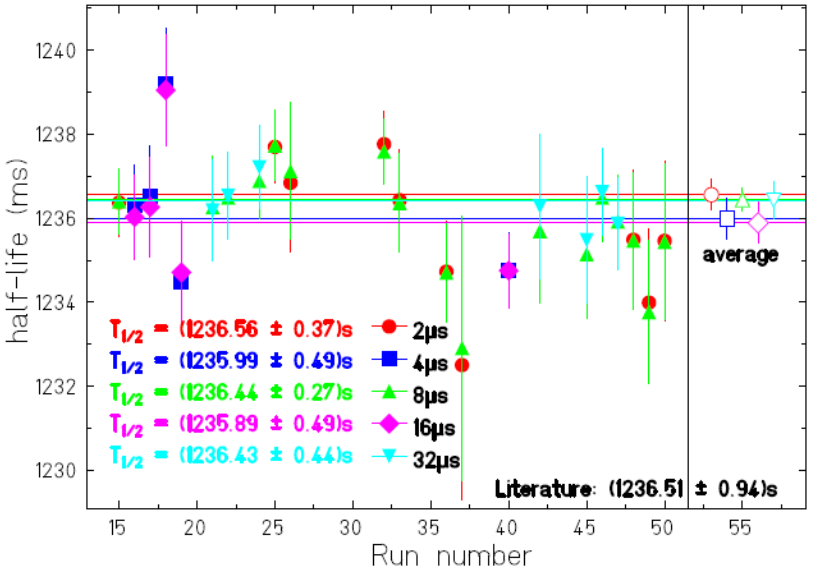
Measurements with

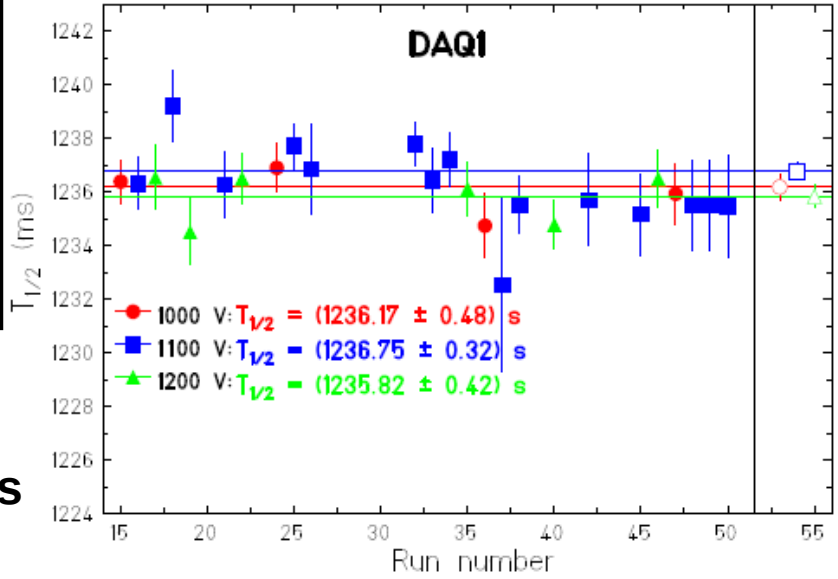
- **a fast DAQ system**
  - **two electronic chains:**
    2, 4, 8, 16 and 32 µs fixed dead-time

- **a listmode DAQ system**
  - **half-life measurement with 200µs DT**
  - **γ-ray measurement for branching ratio**

search for systematic errors:

- **different CFD thresholds**
- **different detector HV**
- **different cycle times**

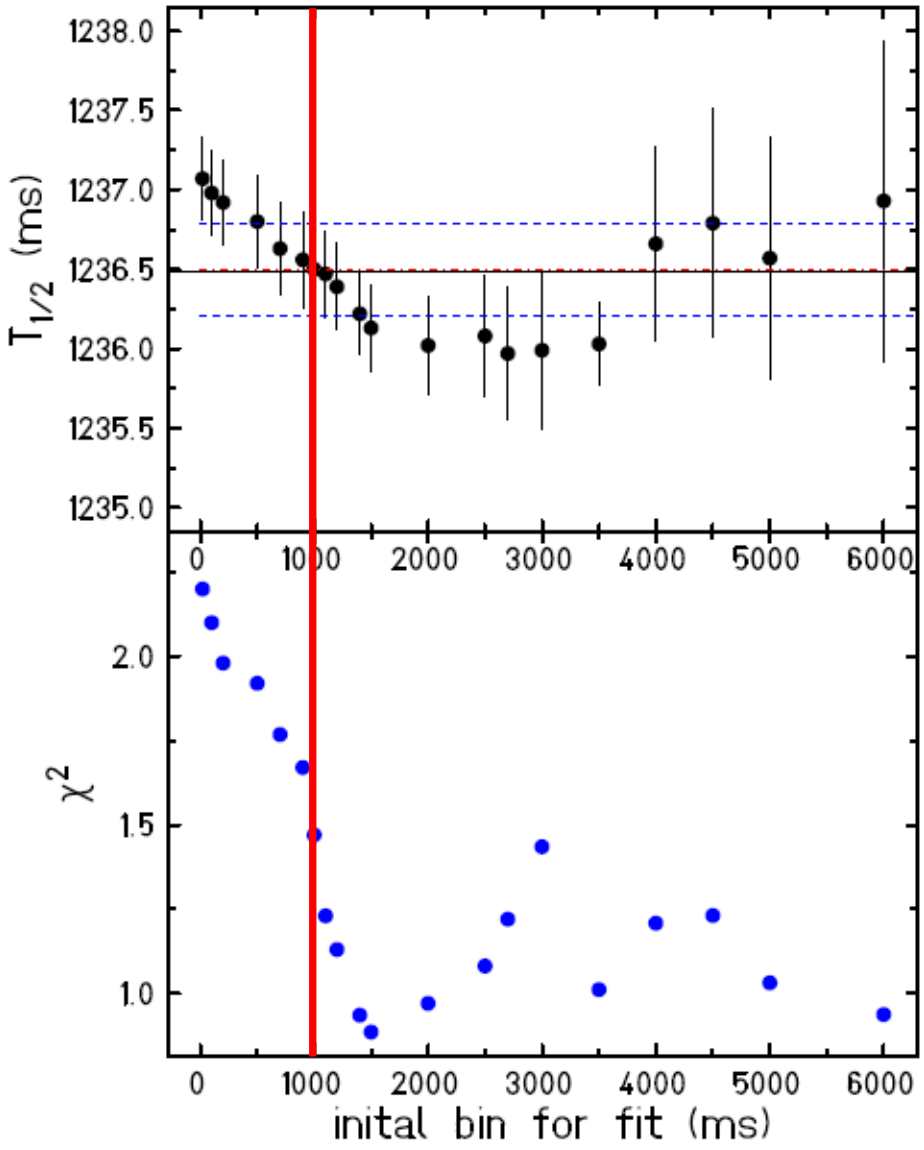




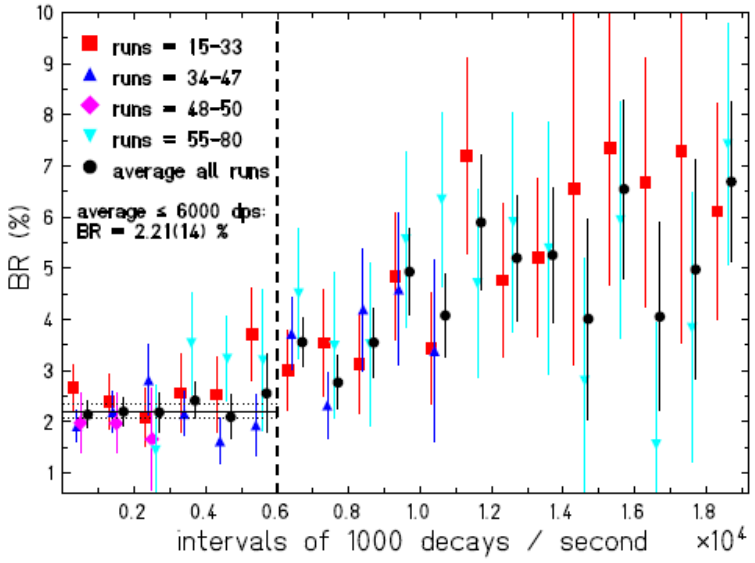
$T_{1/2}$ = (1236.35 ± 0.23 (stat) ± 0.85 (sys)) ms

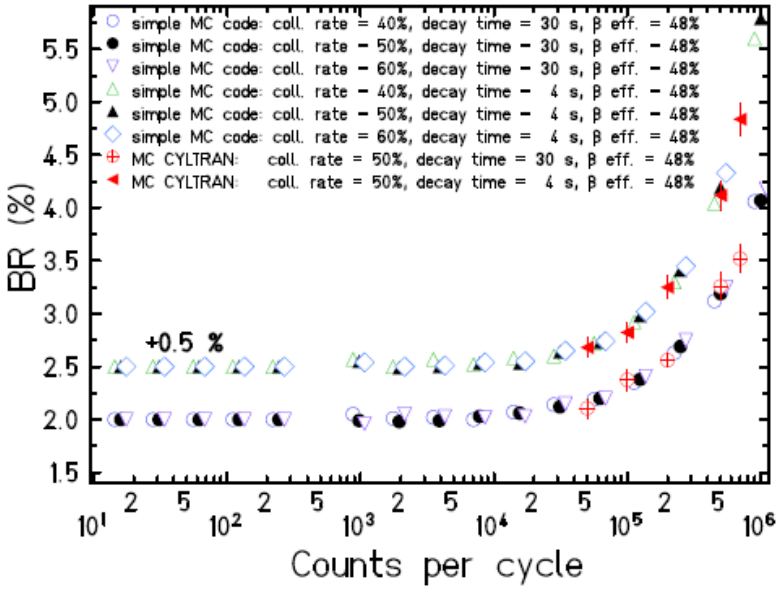
➔ 0.7 ‰, **but…**

Problems encountered in 2014

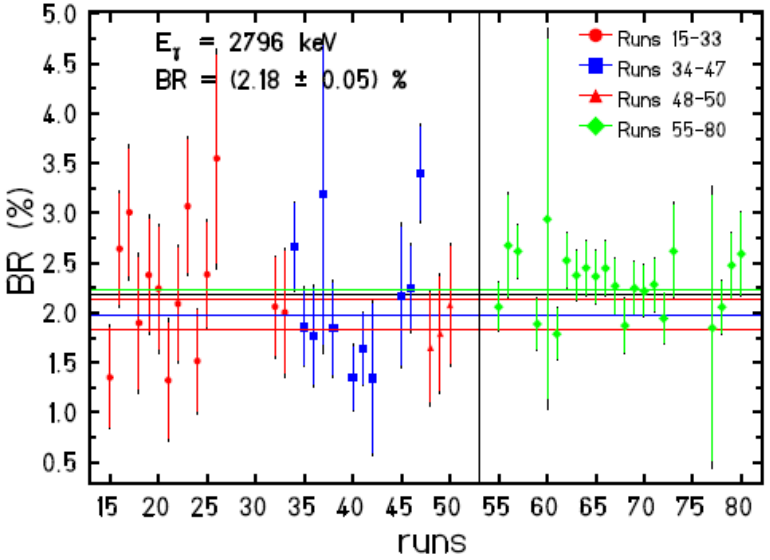


Problems encountered in 2014





Count rate limit:
BR = 2.21(19) %



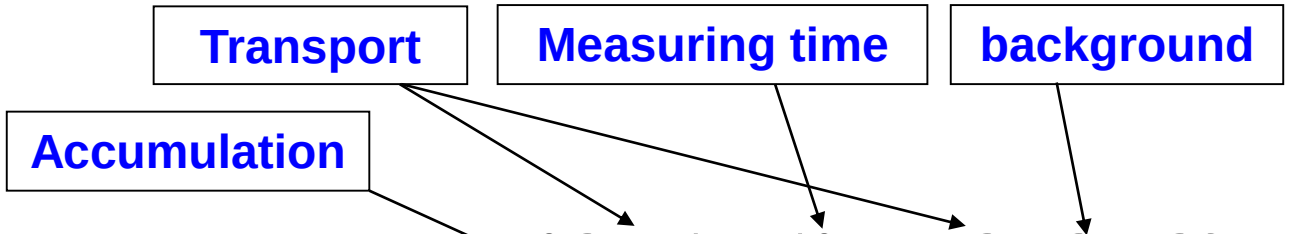
MC simulations:
BR = 2.30(16) %

Final result:
2.20(17) %
BR(s.a.) = 97.96(14)%
➔ 1.4 ‰

Scaler analysis:
BR = 2.18(7) %

Beam request

Aim:
- $\Delta T_{1/2}$ ~ 0.1 %
- ΔBR ~ 0.1 %



- long cycles: 0.3s + 1s + $10T_{1/2}$ + 3s +2s ~ 36 s
- effective rate: 2000 ^{37}K decays detected/cycle

- 7 shifts of effective counting: ~ 9 million ^{37}K decays
- 1 shift for systematic errors (high count rate) ~ 2 million ^{37}K decays

$\Delta T_{1/2} < 0.1$ %

- with 8 long cycle shifts + 3 short cycle shifts
  ~ 1000 β-γ for 2796 keV (ε_γ=0.2%)

$\Delta BR < 0.1$ %

- 1 shift to optimise production

➔Total request: 12 shifts

Improvements

- limit counting rate to 2000 cps
- improve beam focusing on catcher
- improve collimation in front of setup and further from the setup
- use TDC between β signal and γ signal
- use FASTER DAQ in addition to standard DAQ

Measurements performed since our measurement:

- **P. D. Shidling *et al.*, Phys. Rev. C 90, 032501 (2014) ➔ $T_{1/2}$ = 1.2365(9) s**
- **B. Fenker *et al.*, PRL 120, 062502 (2018) ➔ ρ = 0.576(6)**

Foreseen in future: ρ measurement with LPCTRAP

Existing measurements

- ✓ least known quantity: Gamow-Teller / Fermi
- ✓ second least known quantity: half-life