Measurement of the super-allowed branching ratio of ^{10}C

B. Blank, M. Aouadi, P. Ascher, M. Gerbaux, J. Giovinazzo, T. Goigoux, S. Grévy, T. Kurtukian Nieto, C. Magron
CEN Bordeaux-Gradignan, France

I. Matea
IPN Orsay, France

P. Delahaye, G.F. Grinyer, J. Grinyer
GANIL Caen, France

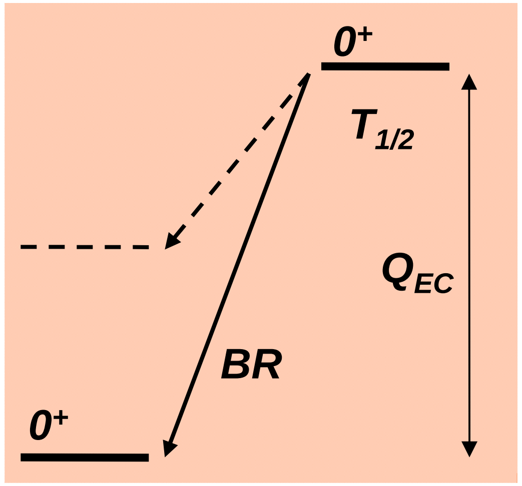
M.R. Dunlop, R. Dunlop, P.E. Garrett, A.T. Laffoley, C.E. Svensson
University of Guelph, Canada

G.C. Ball
TRIUMF, Vancouver, Canada

P. Finlay
K.U. Leuven, Belgium

Beam time accepted: 12 days for 3 types of measurements

Nuclear beta decay



$0^+ \rightarrow 0^+$:

$$Ft = ft\,(1 + \delta_R{}') \,(1 - \delta_c + \delta_{NS}) = \frac{K}{g_V^2\,(1 + \Delta_R)\,\langle M_F \rangle^2} = cnst$$

- $\delta_R{}'$: f(Z, Q_{EC}) ~ 1.5%
- δ_c, δ_{NS}: f(nucl. structure) ~ 0.3-1.5%
- Δ_R: f(weak interaction) ~ 2.4%

➔ ➔ $V_{ud} = g_V / g_\mu$

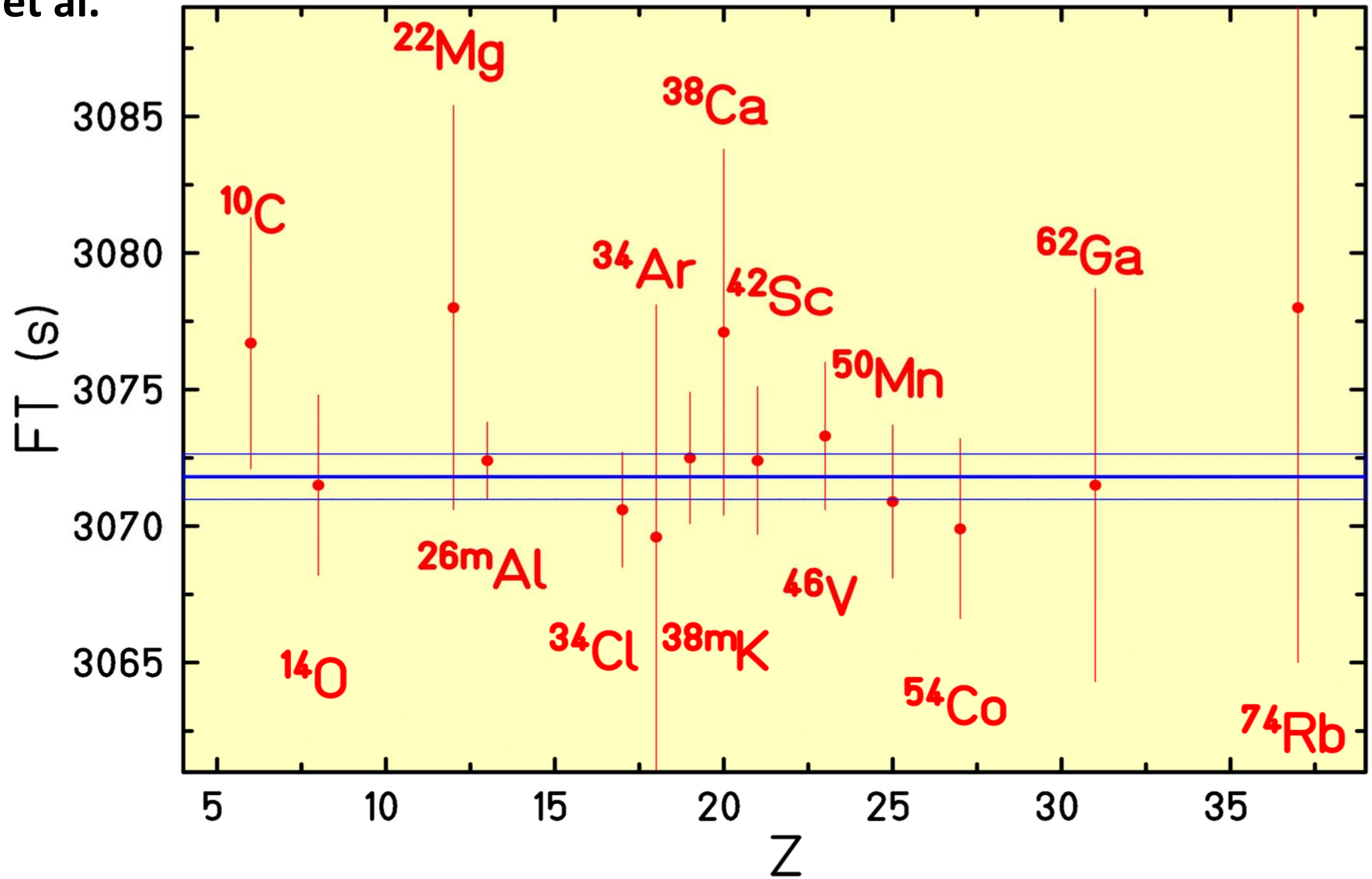
Precision measurements required: 10^{-3}

✓ Q_{EC} ⟶ *mass measurements:* $f \sim Q_{EC}^5$

✓ $T_{1/2}$, BR ⟶ *β-decay studies:* $t = T_{1/2} / BR$

0⁺ → 0⁺ decays: status

Hardy et al.



B. Blank et al., EPJA 51 (2015) 8: $T_{1/2}$ & BR of ^{38}Ca

- **14 nuclei measured with precision of order 10^{-3}**
- **$V_{ud} = 0.97417 \pm 0.00021$, $\Sigma V_{ux} = 0.99978 \pm 0.00055$**

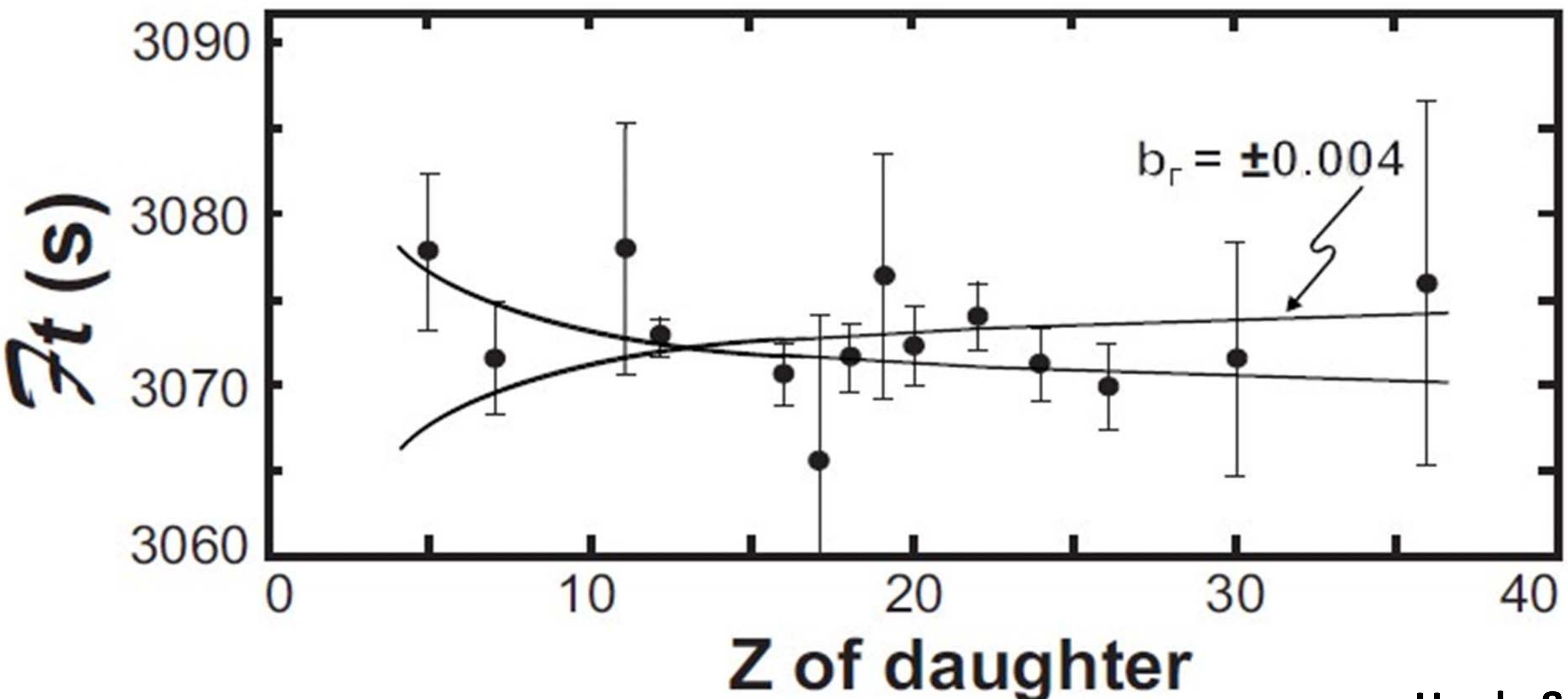
0⁺ → 0⁺ decays: limits on exotic currents

standard assumption: only vector current

- **limit on scalar current**

from β decay: $b_F = -0.0028 \pm 0.0026$ ← measure for scalar contributions

→→ improve on low-Z nuclei

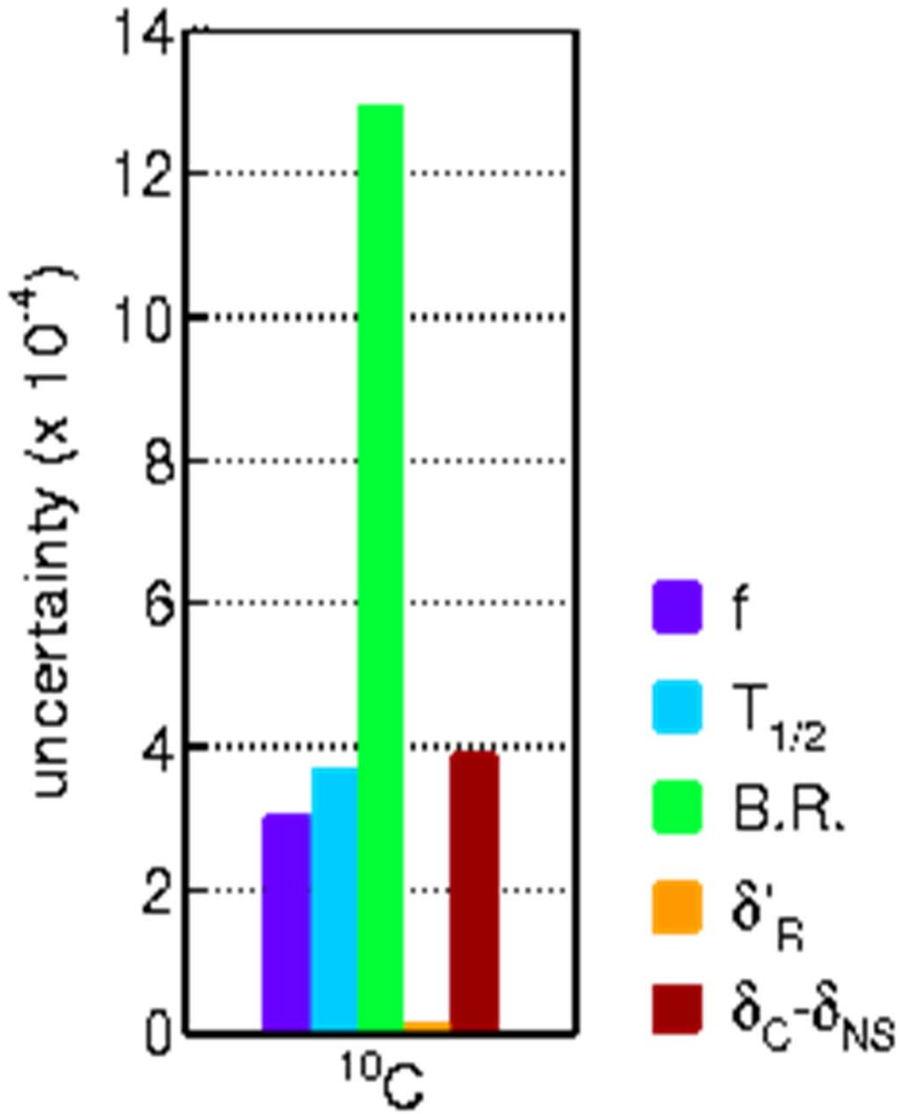


Hardy & Towner

• • • $0^+ \rightarrow 0^+$ decays: ^{10}C error budget

- BR by far largest error
- two precise measurements:
  - Savard et al.: 1.4625(25)%
    (PRL 74 (1995) 1521)
  - Fujikawa et al.: 1.4665(38)%
    (PLB 449 (1999) 6)

  ➔ measurements with Ge multi-detector array

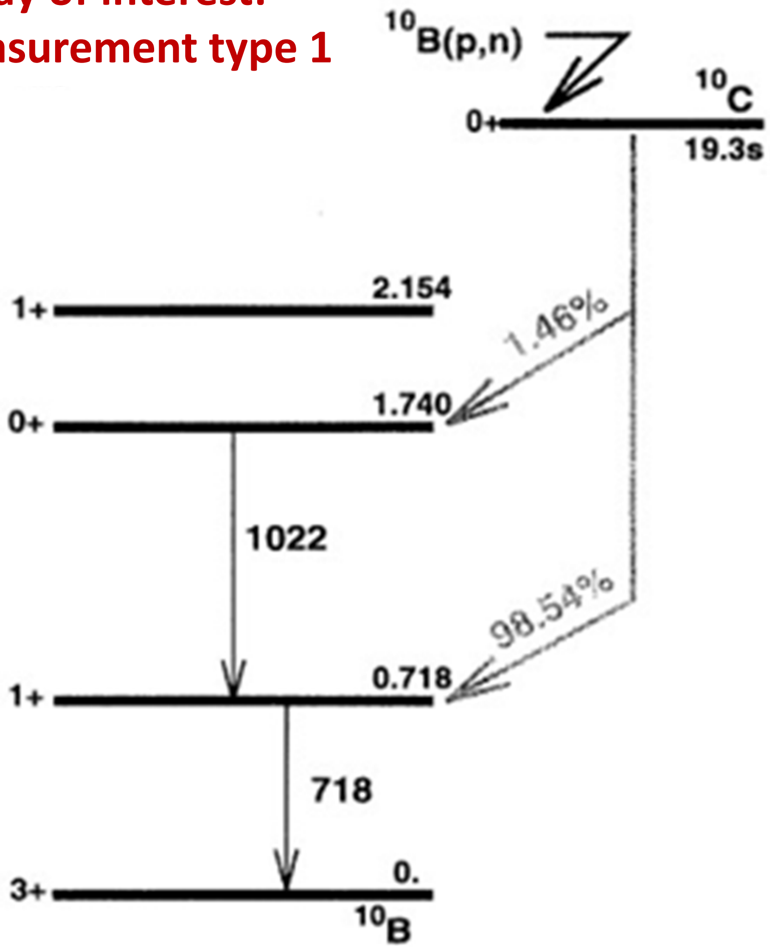


our approach:

re-doing the Fujikawa experiment by improving on the systematic errors and with Ge and LaBr3 detectors

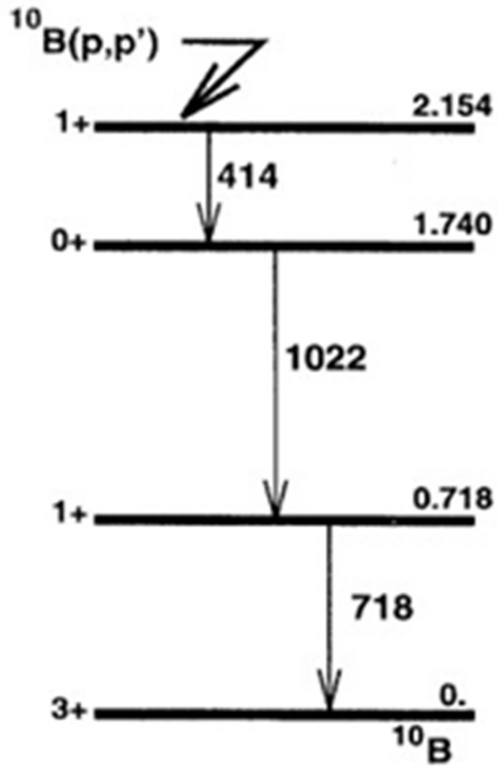
^{10}C decay scheme

Decay of interest:
Measurement type 1



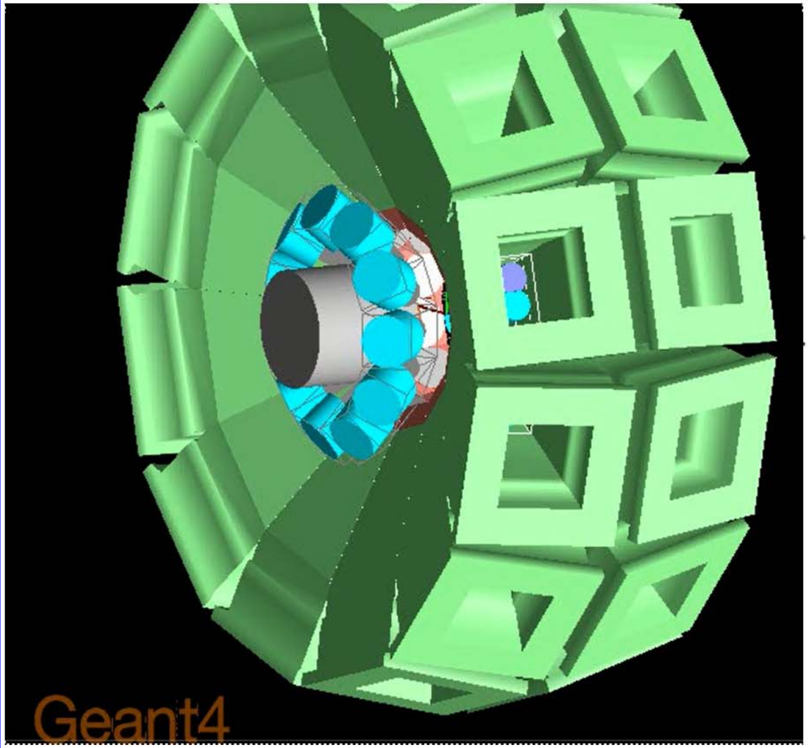
100% BR of 718 keV γ ray
➔ only relative efficiency needed

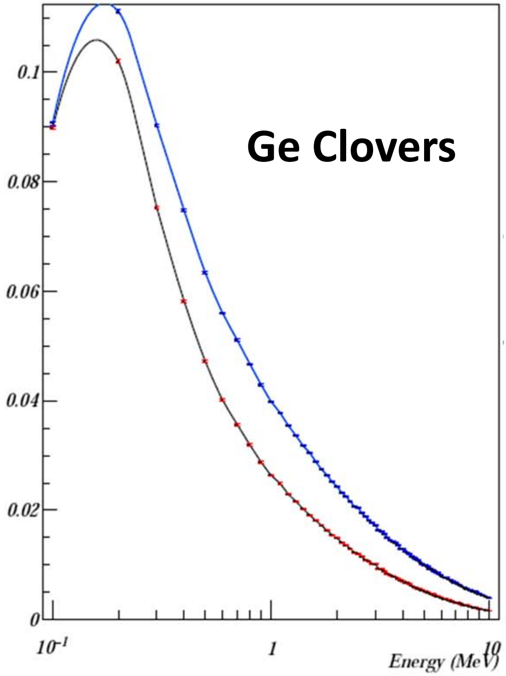
Efficiency calibration reaction:
Measurement type 2

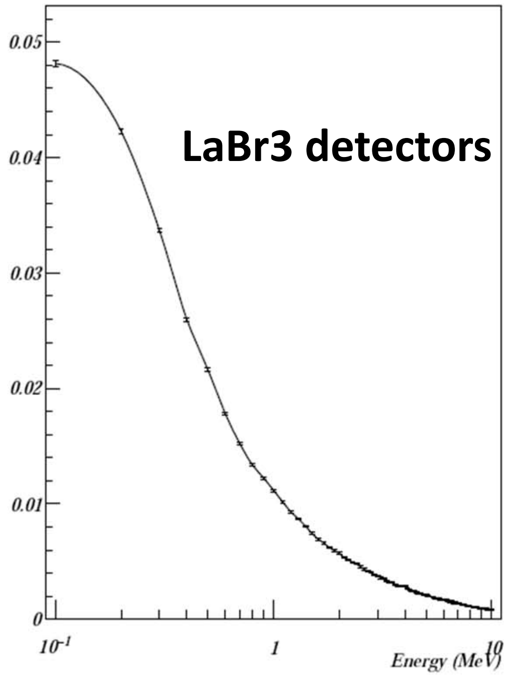


Gate on 414 keV in one detector
➔ 100% BR for two other γ rays
➔ relative γ ray efficiency for the two γ's

Experimental set-up: nu-ball







	Ge Clovers	LaBr3 detectors
ε(414 keV):	5%	2.5 %
ε(718 keV):	3%	1.5 %
ε(1022 keV):	2%	1.0 %

- 24 Germanium detectors
- 32 LaBr3 detectors

Rate estimates: ^{10}B part

- continuous beam (8 MeV protons with 10nA intensity)
- limitation is 3000 pps per Ge crystal
- peak/total: ≈ 0.4
- 3 γ's per cascade
- 50 % γ's of interest
- multiplicity 2 trigger

- 3000 γ's / s * 0.4 (P/T) / 3 (γ's per cascade) * 0.5 (γ's of interest) = 200 γ's / s in each peak
- With 414 keV coincidence: 200 * 5% = 10 pps per crystal

➔ 20h * 3 days:

- 414 keV + second γ: peak = 2.4 * 10^6 counts per crystal

➔ Good efficiency calibration

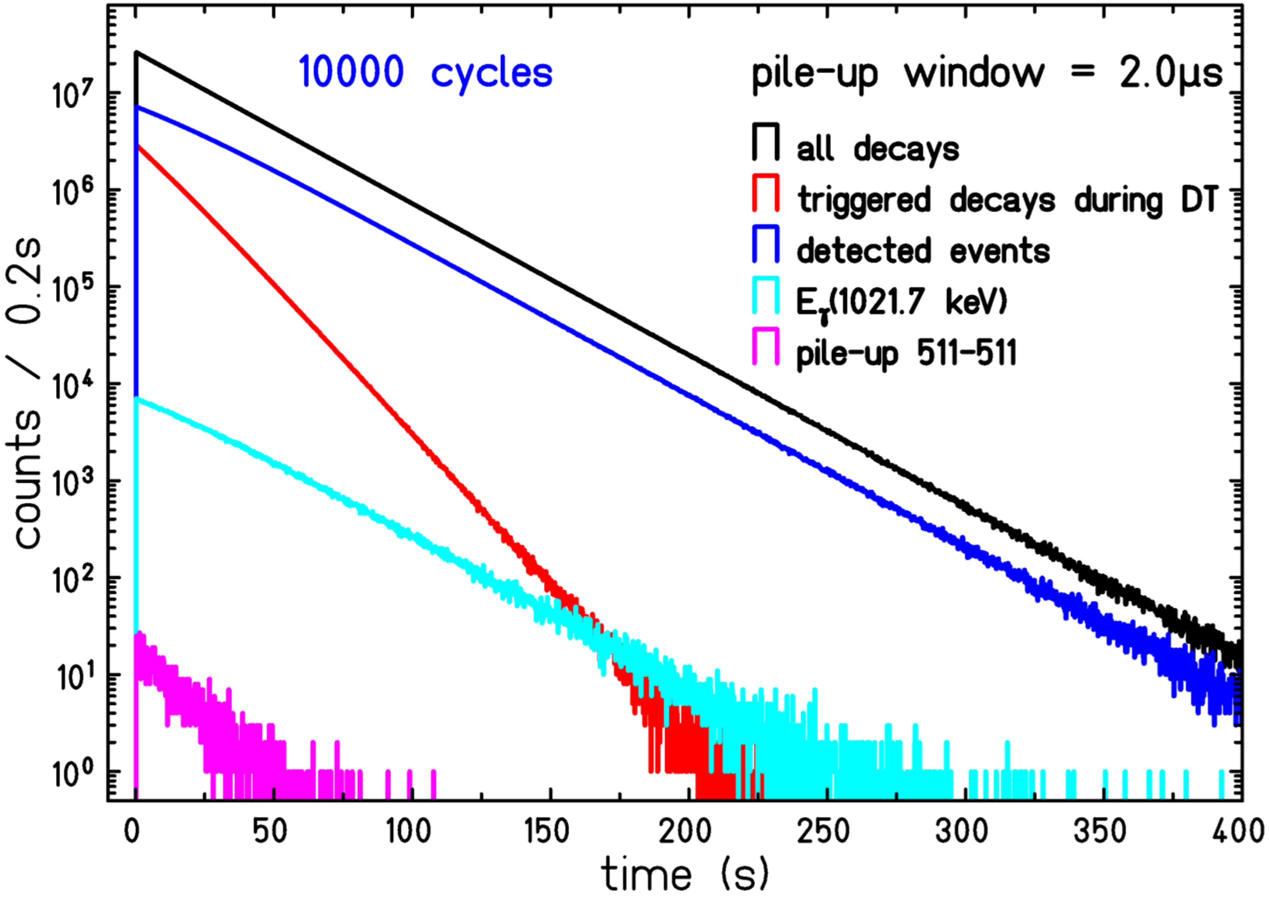
Half efficiency for LaBr3 detectors: ➔ 1.2 * 10^6 counts per detector

Rate estimates for Ge clovers: ^{10}C

10000 cycle:

1.5/min * 60 min * 22 h * 7 d = 13860 cycles

limitation:
singles trigger rate ≈ 5000 trig/s



^{10}C decay:

- **$5*10^5$ ^{10}C produced "instantaneously" (short time with respect to half-life)**
- **1021.7 keV: $5*10^5$ decays / cycle * 10000 (cycles) * 1.5 % (BR) * 2% (ε): $1.5*10^6$ counts**
- **511 keV: $5*10^5$ decays / cycle * 10000 (cycles) * 2 (BR) * 4% (ε) * 0.1% (pile-up prob.) / 100 (detectors): 4000 counts**

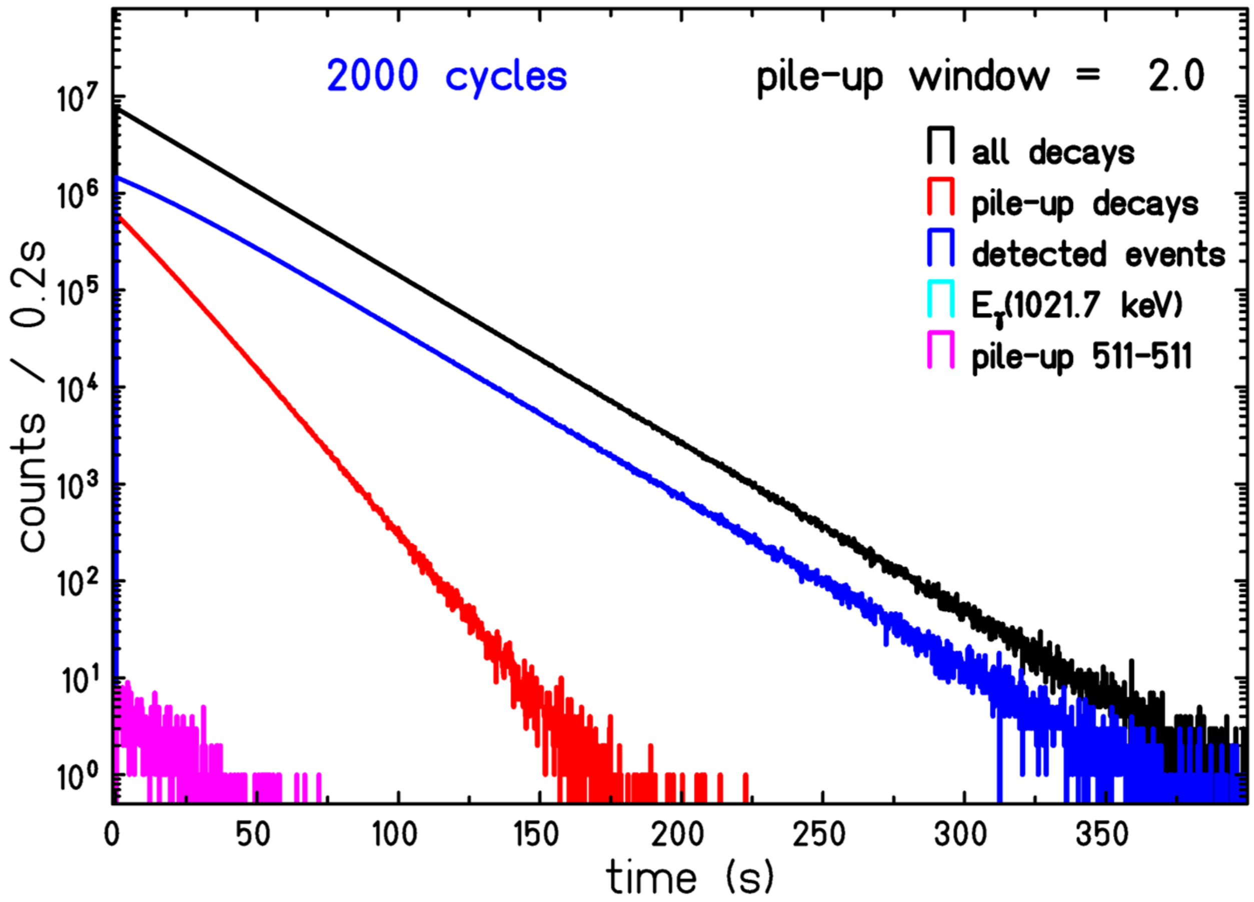
  ➔ 511keV – 511keV pile-up compared to 1021.7 keV peak: 2 – 3 ‰

Rate estimates for Ge clovers: ^{19}Ne

2000 cycle:

1.5/min * 60 min * 22 h * 1 d = 1980 cycles

limitation:
singles trigger rate ≈ 5000 trig/s



^{19}Ne decay:

- **$5*10^5$ ^{19}Ne produced "instantaneously" (short time with respect to half-life)**
- **511 keV: $5*10^5$ decays / cycle * 2000 (cycles) * 2 (BR) * 4% (ε) * 0.1% (pile-up prob.) / 100 (detectors): 800 counts**

➔ Good enough to test coincidence probability

Summary

- similar estimates possible for LaBr3
- beam intensity is “free” parameter depending on count rates

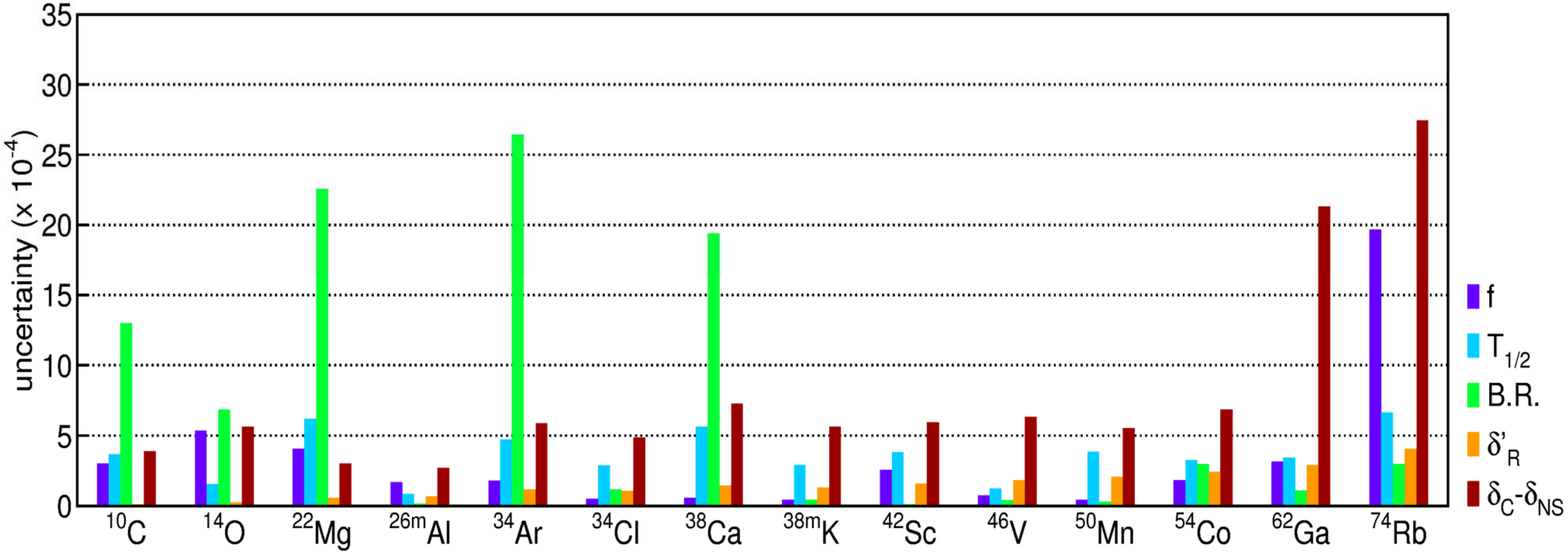
- all in all: experiment more than feasible with nu-ball

- ideally:
  two independent DAQs for Ge clovers and LaBr3 detectors

- need of multiplicity-2 trigger

- what is DAQ dead time?
- maximum event rate?
- when available?

$0^+ \rightarrow 0^+$ uncertainties



• • • Fierz term b_F

- additional term in statistical rate function f: $(1+b_f * \gamma_1 / W)$
- $\gamma_1 = \mathrm{sqrt}(1 - (\alpha * Z)^2)$
- W increases with Z

➔ ➔ largest sensitivity for small Z