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

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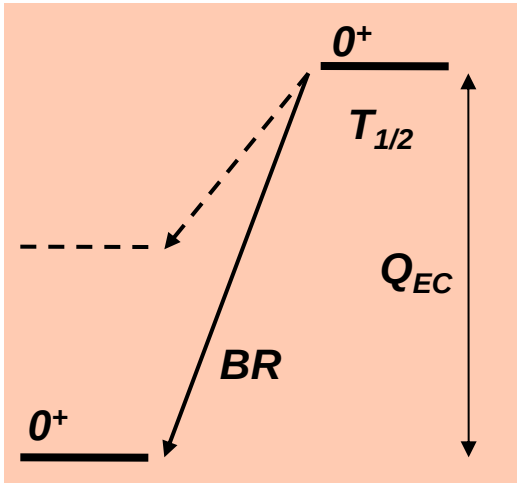
Beam time requested: 21 shifts on LA1

Nuclear beta decay



$0^+ \rightarrow 0^+$:

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

$f(Z, Q_{EC}) \sim 1.5\%$

f(nucl. structure) ~ 0.3-1.5%

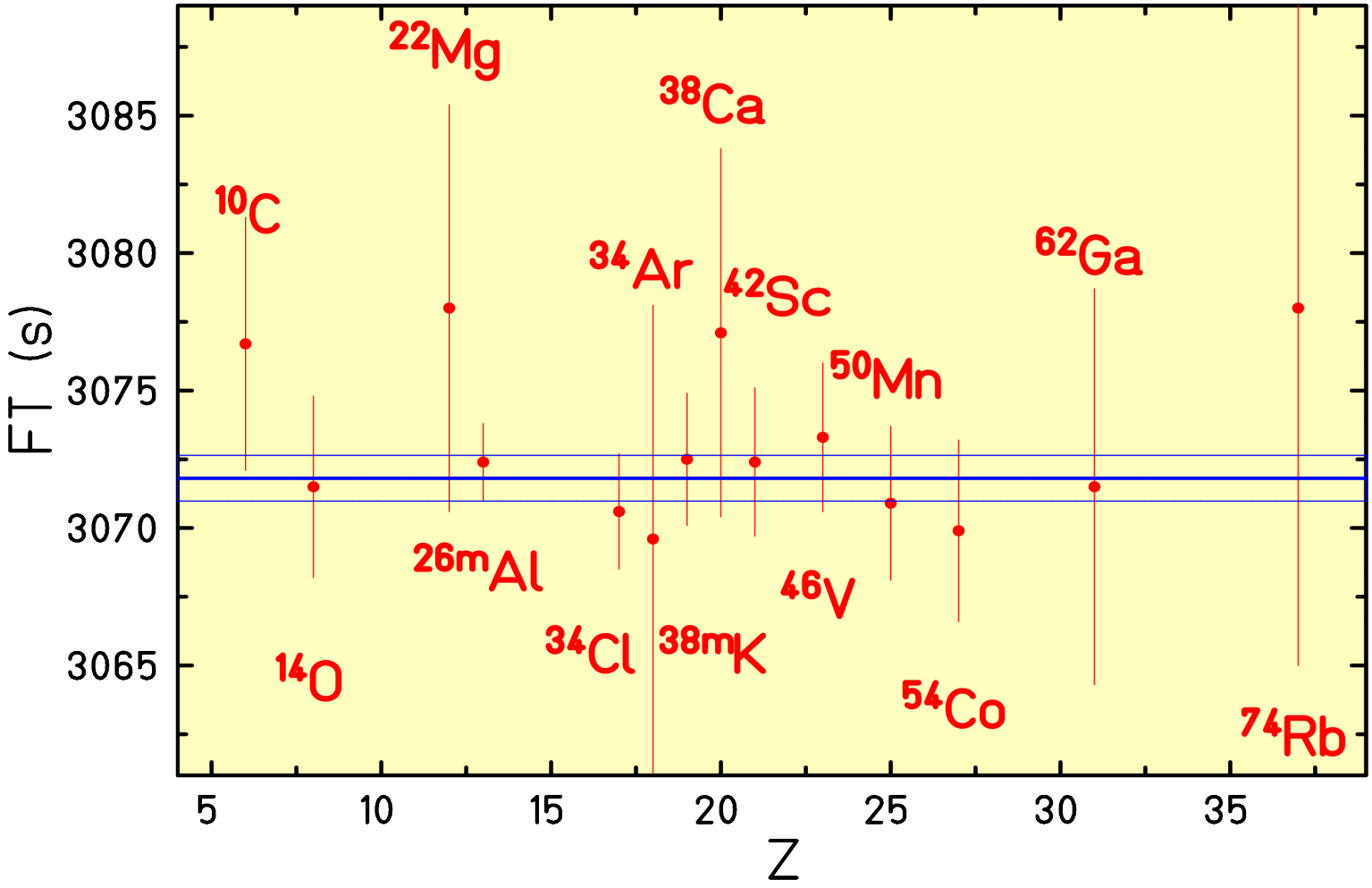
f(weak interaction) ~ 2.4%

➔ ➔ $V_{ud} = g_V / g_\mu$

Precision measurements required: 10^{-3}

- ✓ Q_{EC} → *mass measurements:* $f \sim Q_{EC}^5$
- ✓ $T_{1/2}$, BR → *β-decay studies:* $t = T_{1/2} / BR$

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



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

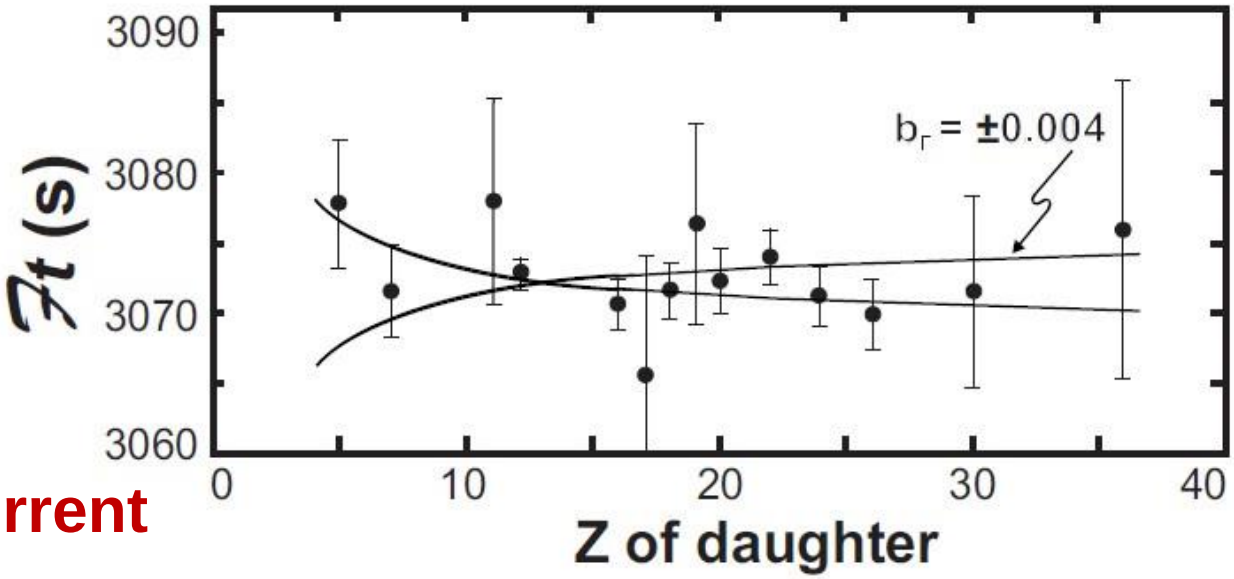
- 14 nuclei measured with precision of order 10^{-3}
- $V_{ud} = 0.97417 \pm 0.00021$, $\Sigma V_{ux} = 0.99978 \pm 0.00055$

$0^+ \rightarrow 0^+$ decays: limits on exotic currents

- assumption: only vector current
- limit on scalar currents:

  $b_F = Re((C_s + C'_s) / C_v) = 0.0026(42)$ (90% CL)

Severijns et al.



- limit on scalar current from β decay:

  $|C_s / C_v| \leq 0.065$

Hardy & Towner

➔➔ improve on low-Z nuclei

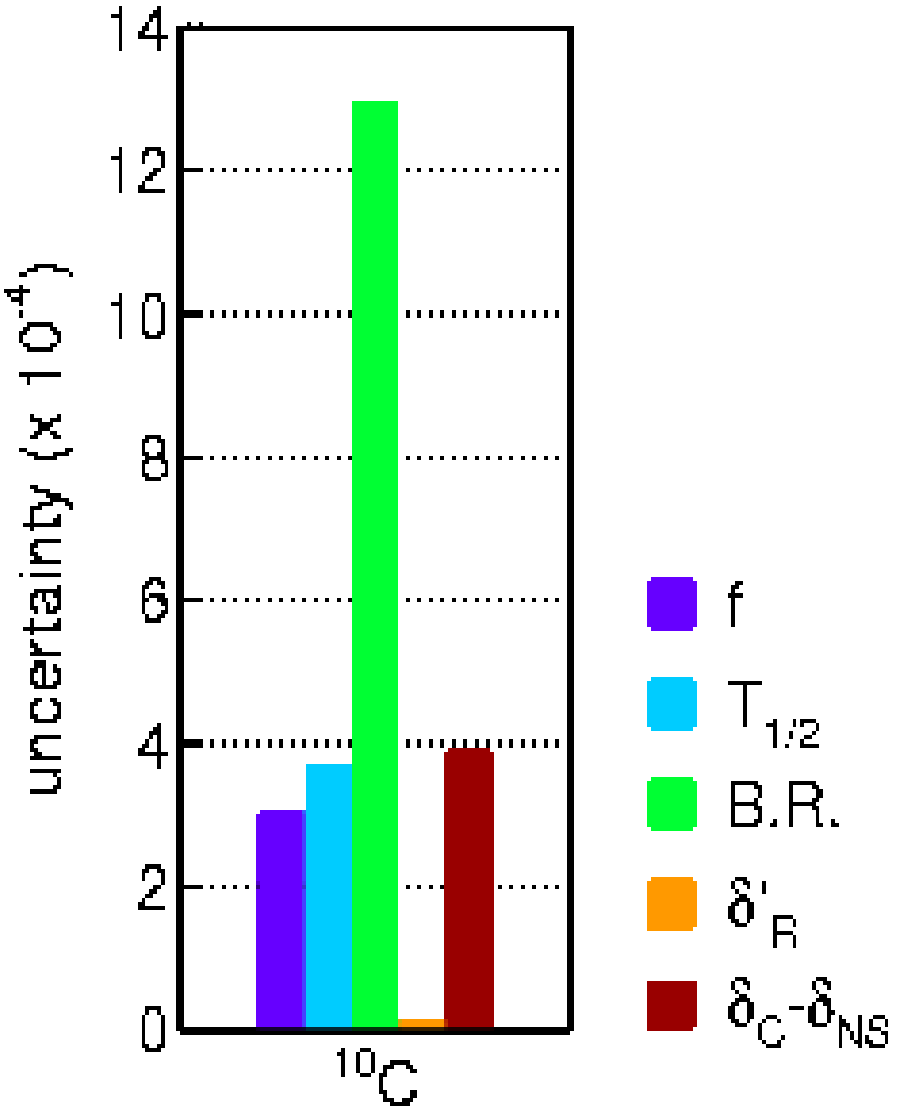
$0^+ \rightarrow 0^+$ decays: ^{10}C error budget

- 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)

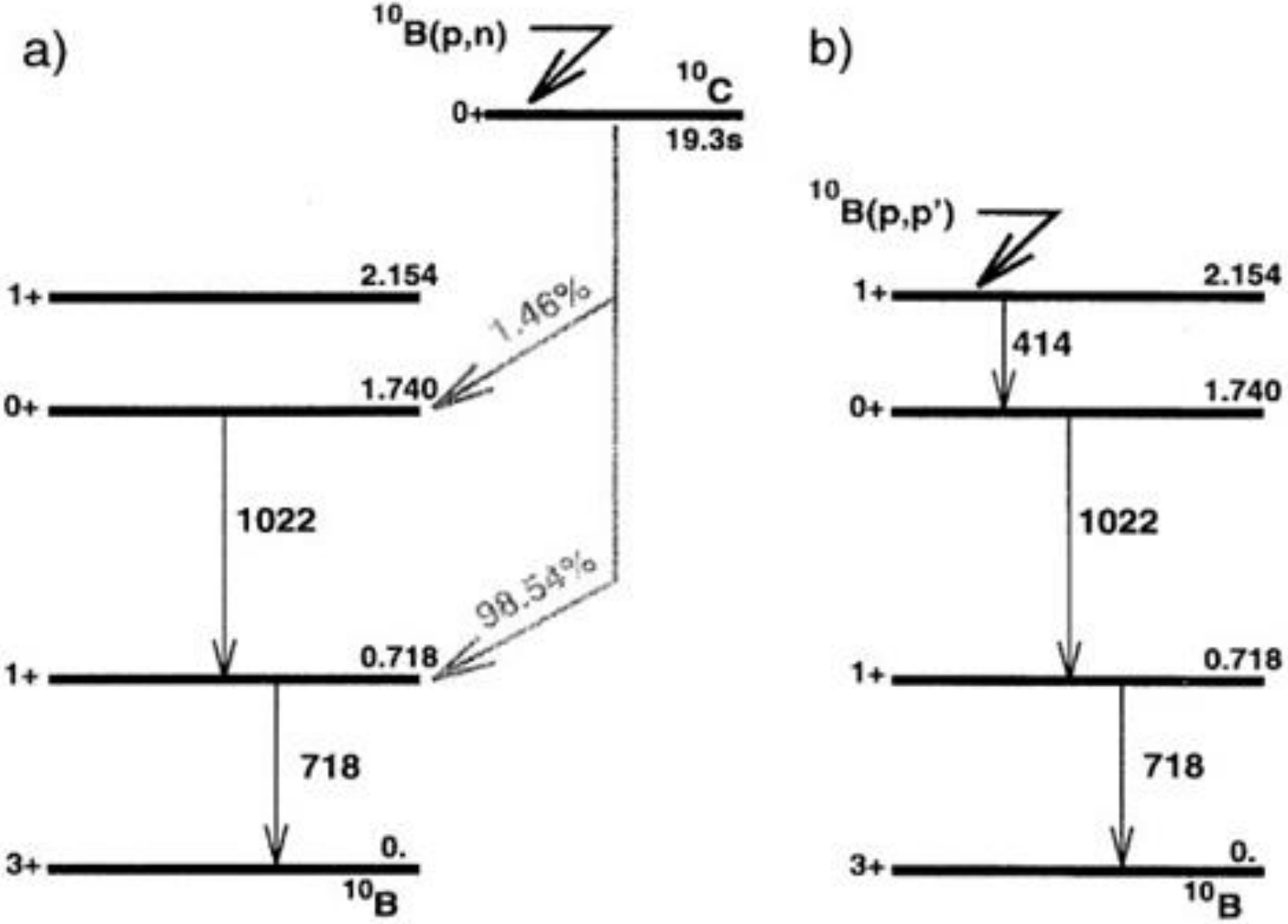
➔measurements with Ge multi-detector array

our approach:

high-precision
single-crystal
germanium detector

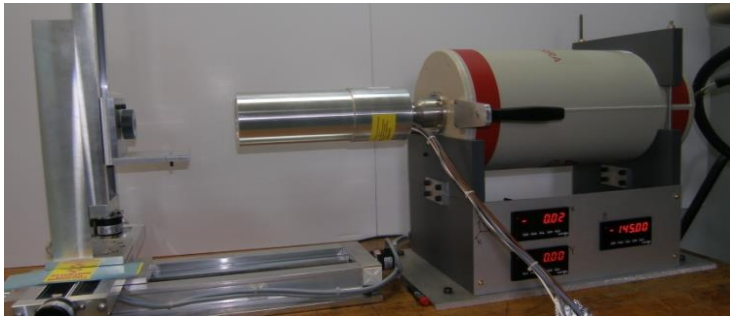


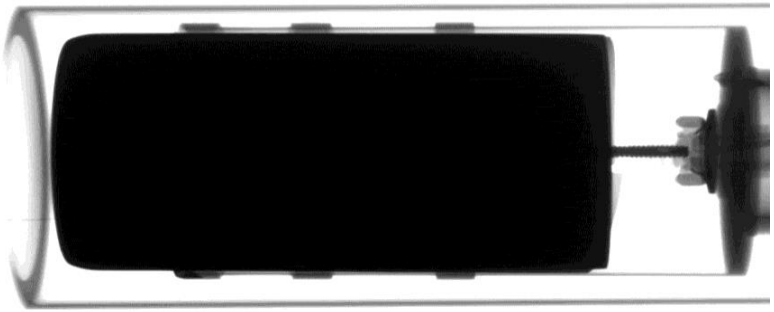
^{10}C decay scheme



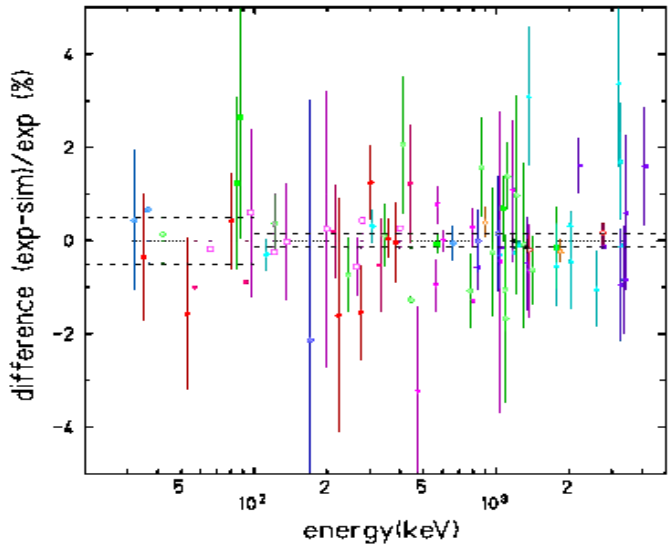
Calibration of germanium detector

- $\Delta\varepsilon_{rel}$ = 0.1%, $\Delta\varepsilon_{abs}$ = 0.15%
- calibration programme of a HP Ge detector:
  - x-ray photography of detector
  - scan of the crystal at CSNSM
  - source measurements
  - MC simulations: CYLTRAN, GEANT4

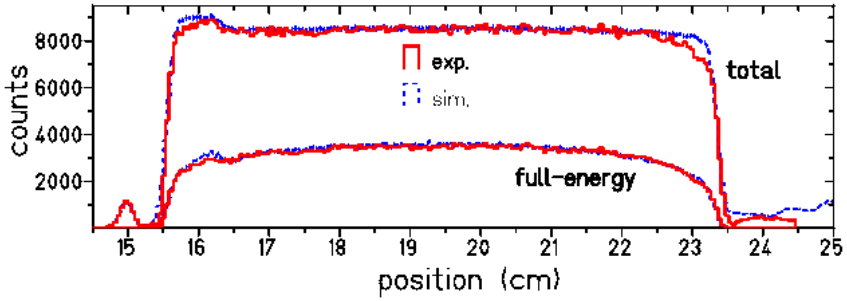




X-ray photography



Scan at CSNSM

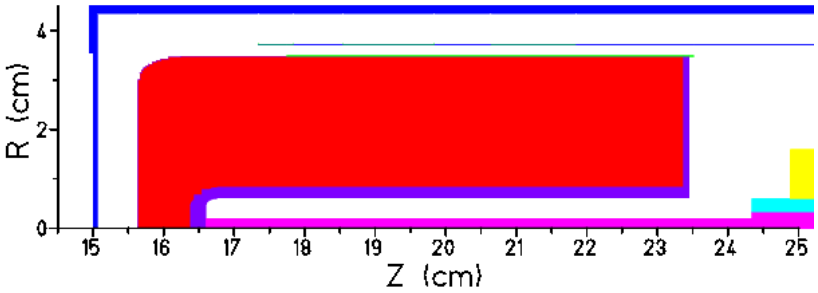


B. Blank et al., NIMA776 (2015) 34

Branching ratios:

^{24}Na, ^{27}Mg, ^{48}Cr, ^{56}Co, ^{60}Co, ^{66}Ga, ^{75}Se, ^{88}Y, ^{133}Ba, ^{134}Cs, ^{137}Ce, ^{152}Eu, ^{180}Hf, ^{207}Bi

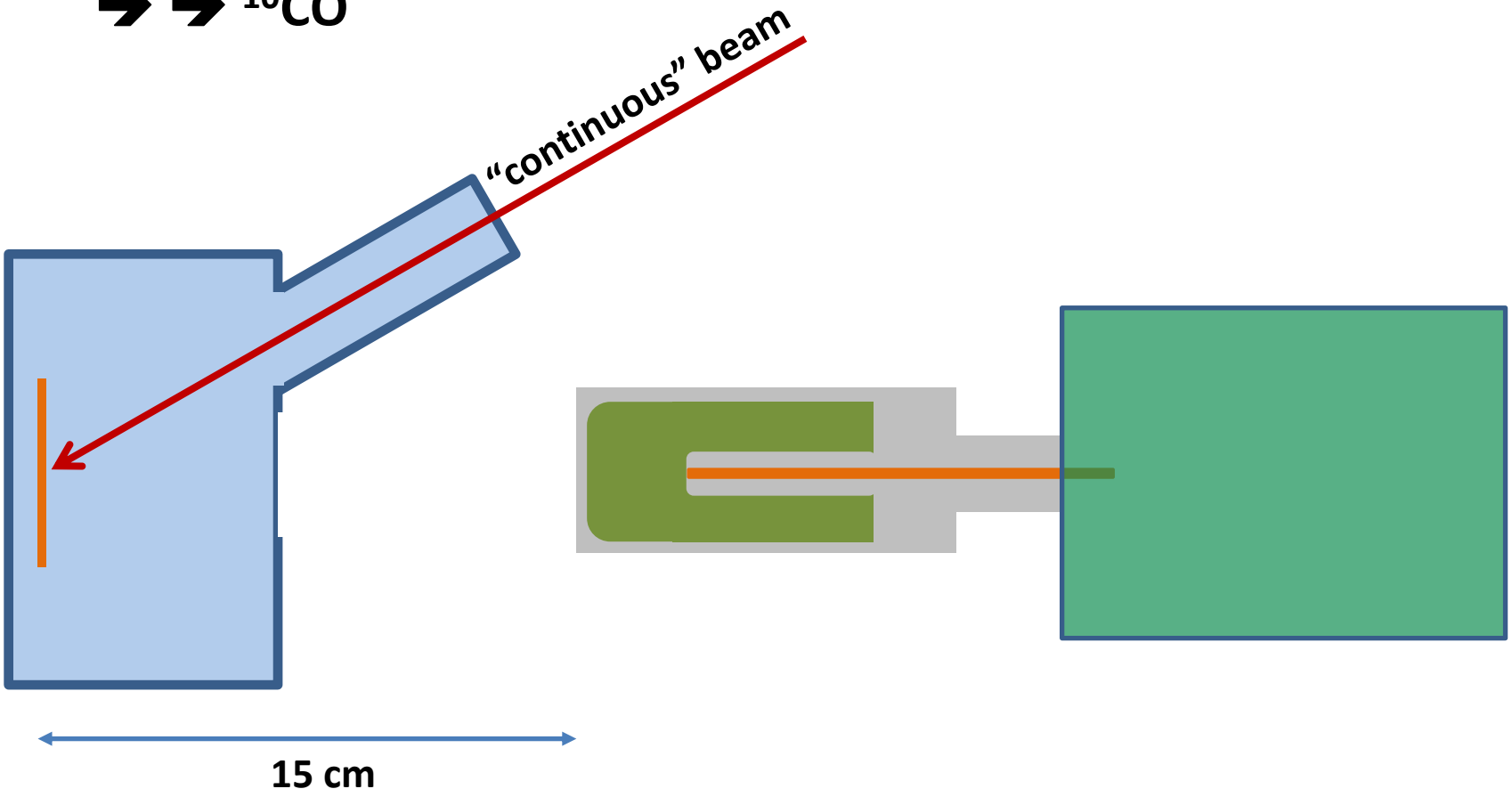
Peak/total: ^{22}Na, ^{41}Ar, ^{51}Cr, ^{54}Mn, ^{57}Co, ^{58}Co, ^{65}Zn, ^{85}Sr …ISOLDE sources



Experimental setup

- 15 proton pulses per minute (30%)
- nanoCaO + VD7 or molten NaF:LiF salt targets + VD7
- GPS or HRS to LA1

➔ ➔ ^{10}CO



Rate estimates: ^{10}C

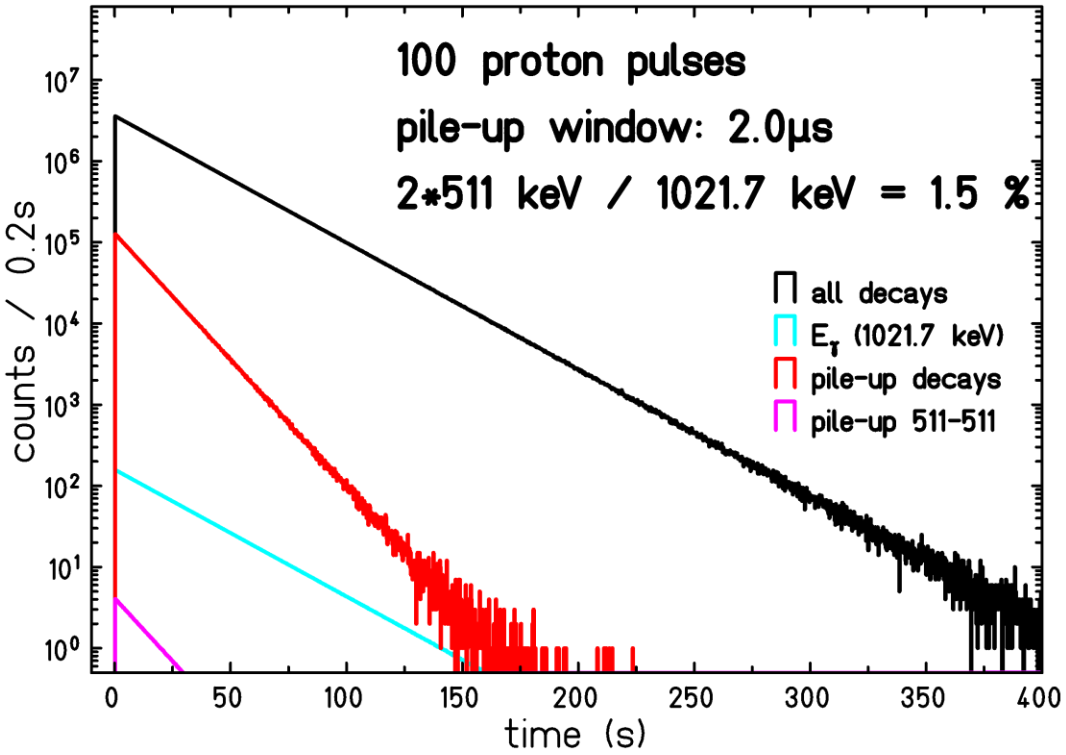
Count rate for 1021.7 keV γ ray:

- $5*10^5$ ^{10}C per pulse * 15 pulses/min * 60 min * 20 h * 3 d = $2.7*10^{10}$ ^{10}C decays * 0.0146 (BR) * 0.0028 (ε(1022keV)) = $1.1*10^6$ γ's at 1022 keV

  ➔ statistical precision of 0.1%

511 keV – 511 keV pile-up:

- ε(511 keV) = 0.4 %, pile-up window: 2μs, $5*10^5$ ^{10}C produced instantaneously



➔ 1.5 % of 1.022 MeV peak from 511 – 511 pileup

➔➔ 3 days

Rate estimates: ^{19}Ne

^{19}Ne decay - 511 keV – 511 keV pile-up:

- ε(511 keV) = 0.4 %, pile-up window: 2μs, 5*10^5 ^{19}Ne produced instantaneously

- 5*10^5 ^{19}Ne per pulse * 15 pulses/min * 60 min * 20 h = 0.9*10^{10} ^{19}Ne decays * 2 (511) * 0.004^2 (ε(511 keV)) * 2μs (pile-up window) = 5400 counts at 1022 keV
  ➔ statistical precision of 1.3 %

➔➔ 1 day

2 days:

^{10}C measurement at different distances

1 day:

debugging, setting-up, optimisation

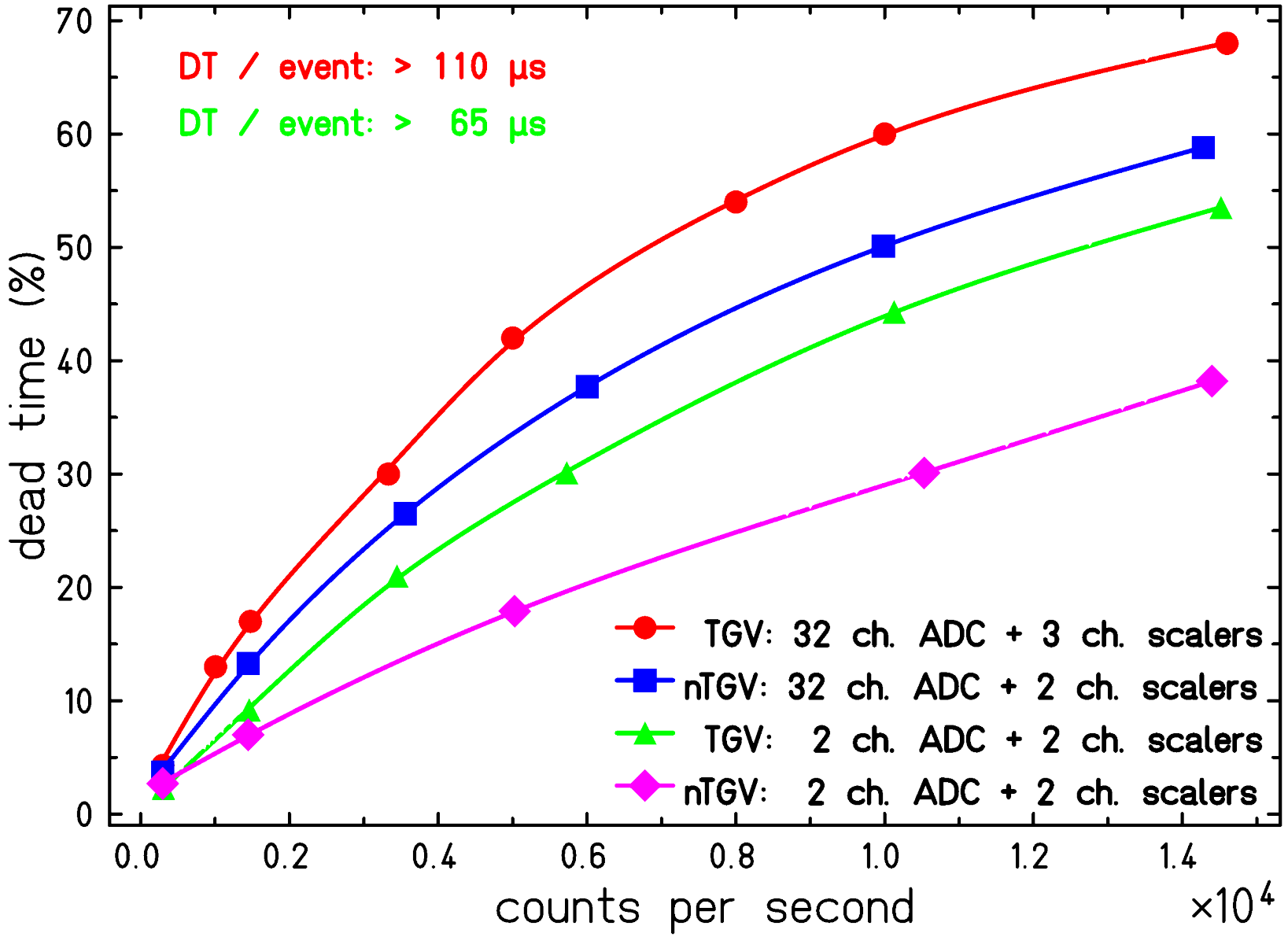
Summary of request

- starting the experiment, setting-up separator and experimental setup: 1 day
- measurement with ^{10}C in optimal conditions: 3 days
- measurement with ^{19}Ne: 1 day
- ^{10}C measurement at a different distances: 2 days

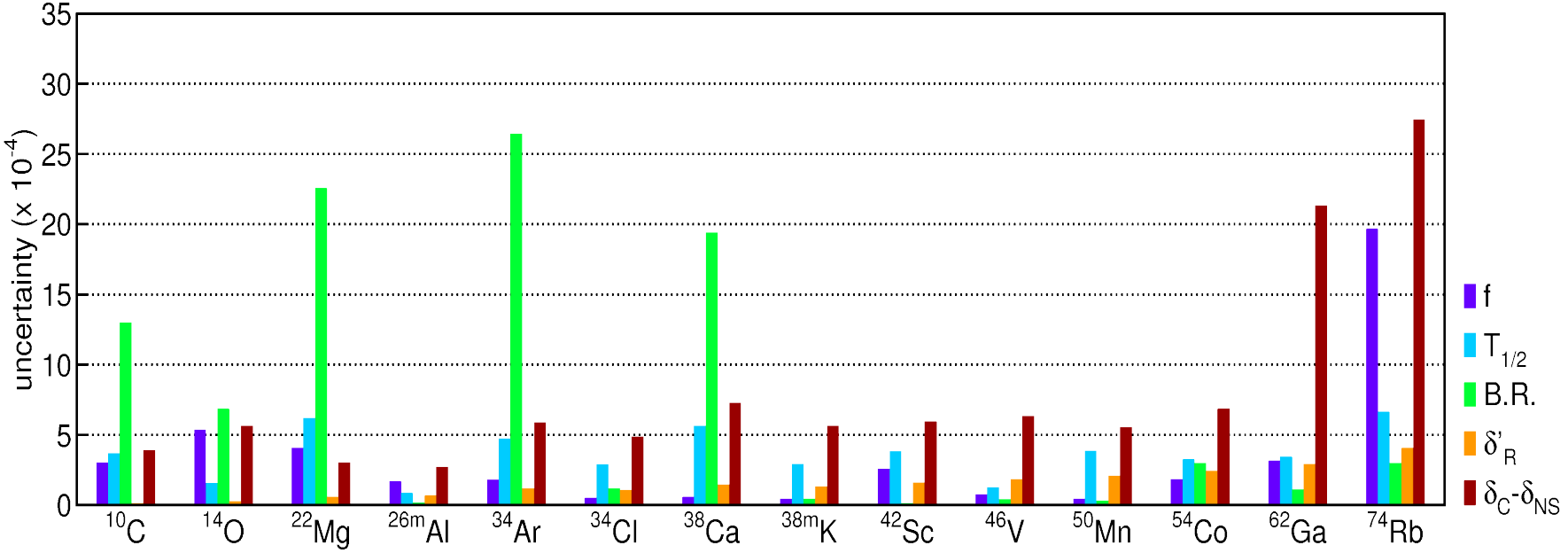
Total: 7 days

Thanks for your attention

DAQ dead-time



$0^+ \rightarrow 0^+$ uncertainties



Fierz term b_F

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

➔ ➔ largest sensitivity for small Z