Measurement of the super-allowed branching ratio of ^{22}Mg

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

A. De Roubin
MPIK Heidelberg, Germany & CEN Bordeaux-Gradignan, France

P. Delahaye, G.F. Grinyer, J. Grinyer, A.T. Laffoley, J.-C. Thomas
GANIL Caen, France

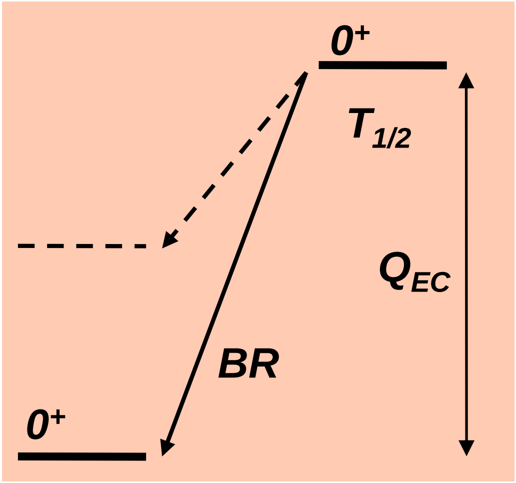
M.R. Dunlop, R. Dunlop, P.E. Garrett, C.E. Svensson
University of Guelph, Canada

G.C. Ball
TRIUMF, Vancouver, Canada

P. Finlay
K.U. Leuven, Belgium

Beam time requested: 10 shifts on LA1 and LA2

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}) ~ 1.5%

f(nucl. structure) ~ 0.3-1.5%

f(weak interaction) ~ 2.4%

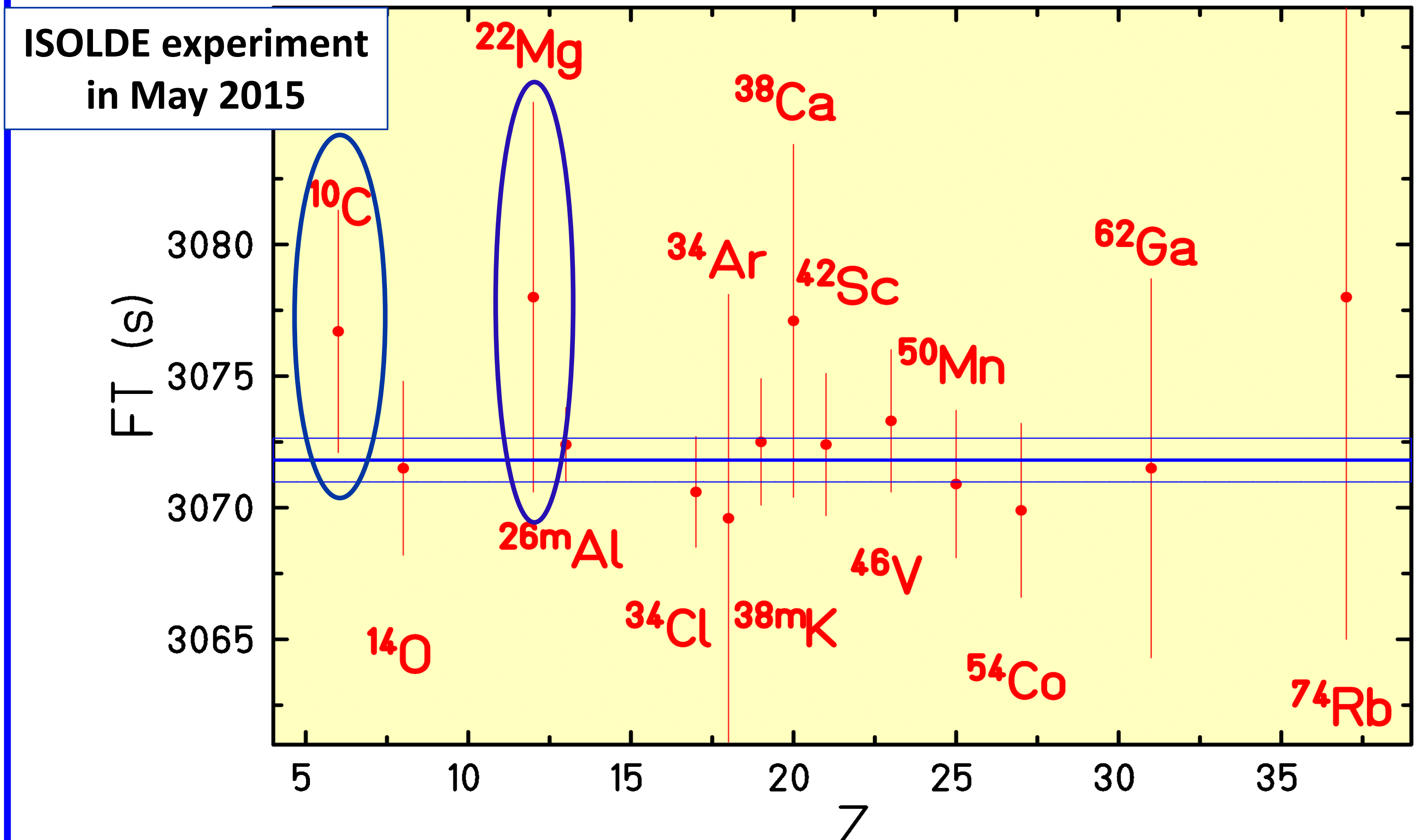
➔ ➔ $V_{ud} = g_V / g_\mu$

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

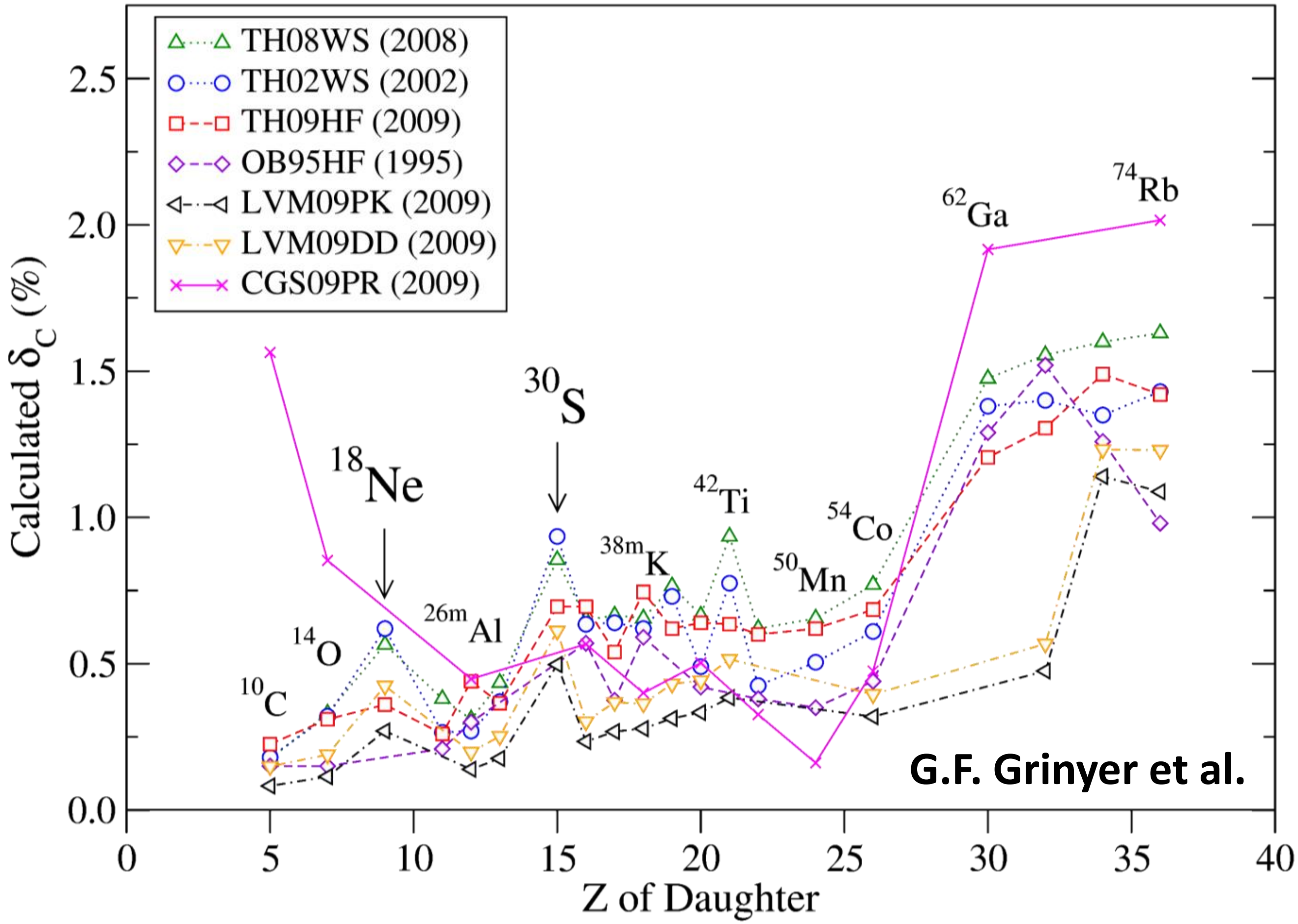


- 14 nuclei measured with precision of order 10^{-3}
- Ft = [3072.27 ± 0.62 (stat) ±0.36 (δ_R')]s
- V_{ud} = 0.97417 ± 0.00021, ΣV_{ux} = 0.99978 ± 0.00055

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

0⁺ → 0⁺ decays: problems with δ_c corrections

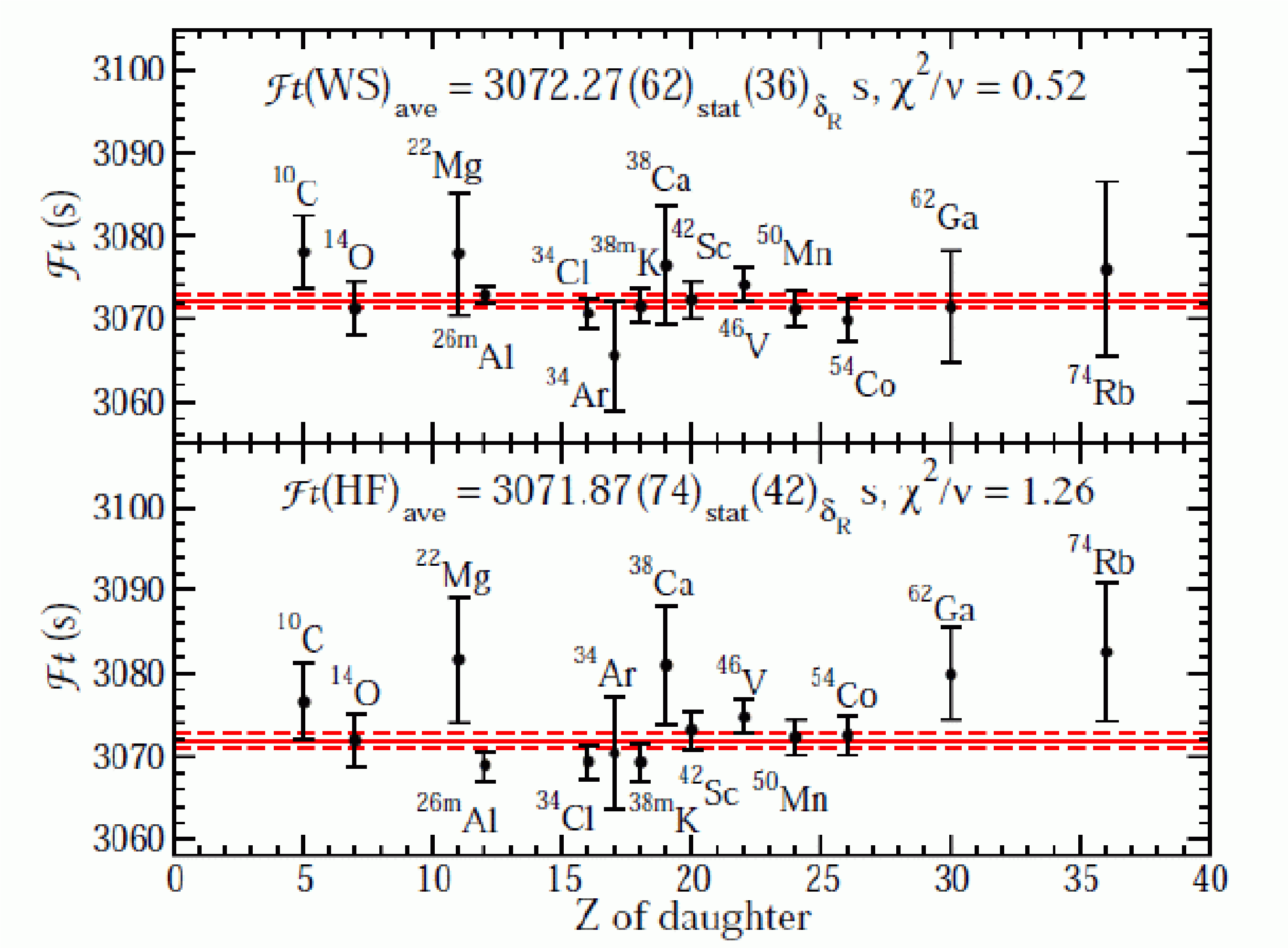
- different models give different δ_c corrections



➔ different Ft values…………

0⁺ → 0⁺ decays: different Ft values

- Ft values with different δ_c corrections (T&H: WS and HF)



→ In particular T_z=1 are off the systematics for HF corrections

→ BR of ^{22}Mg is measured only once with precision!

0⁺ → 0⁺ decays: ^{22}Mg error budget

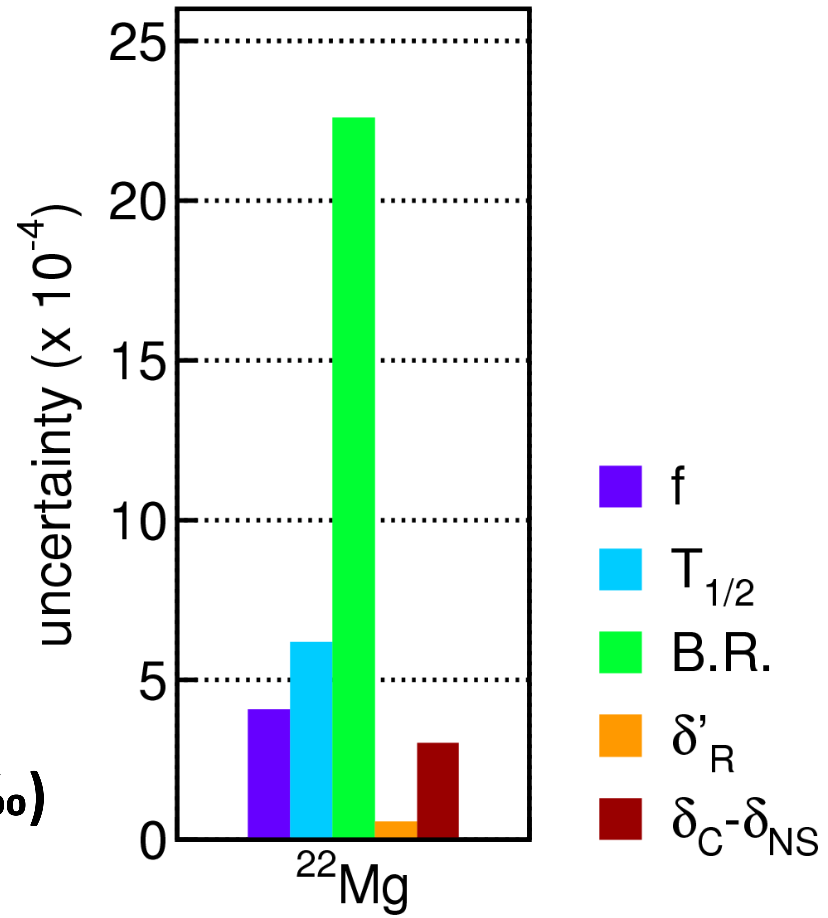
- BR by far largest error
- one precise measurement
  - Hardy et al.: 53.15(12)%
    (PRL 91 (2003) 082501)

our approach:

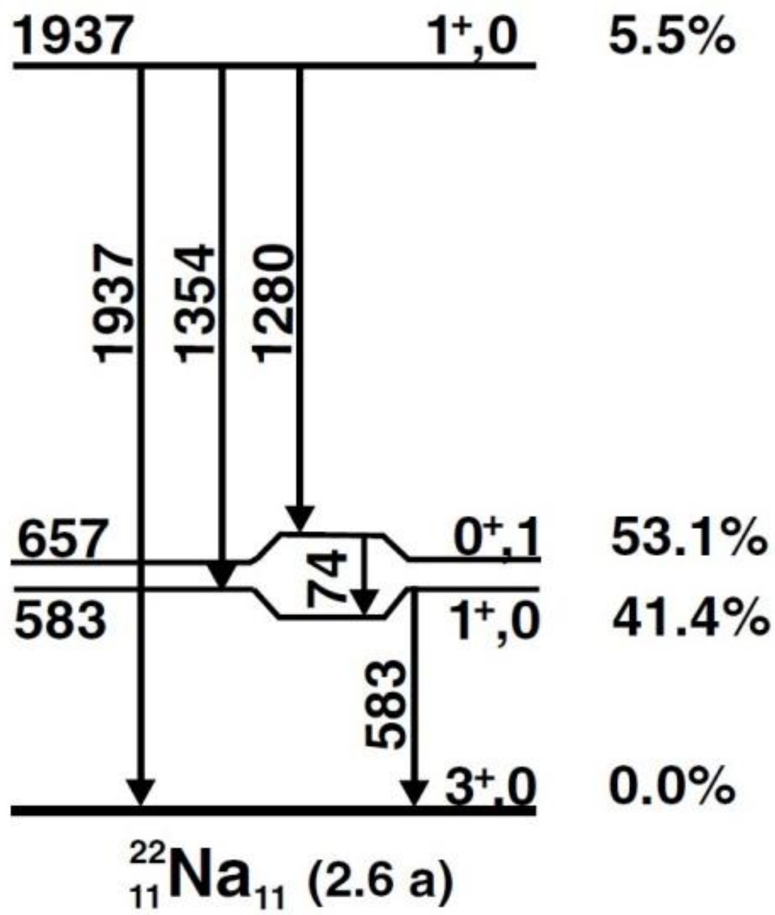
high-precision
single-crystal
germanium detector

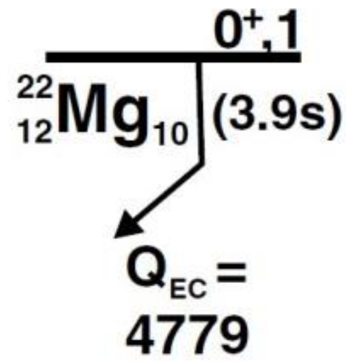
our goal:

statistical error
< systematic error (1‰)



^{22}Mg decay scheme

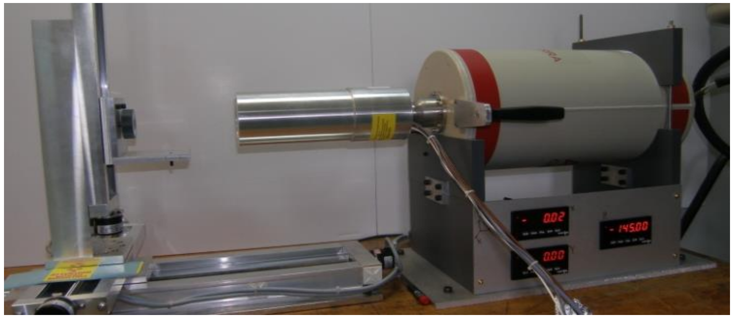


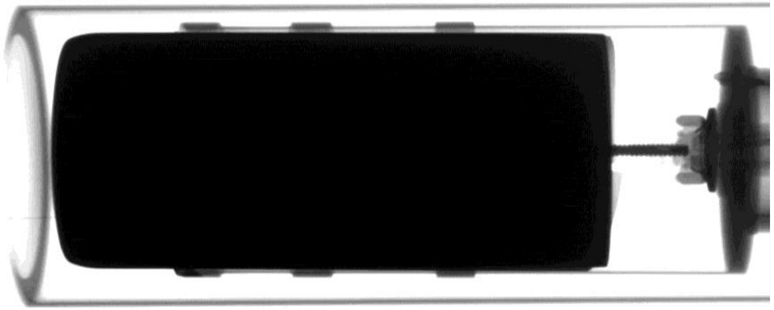


E_γ (keV)	BR_γ (keV)
74	58.36(6)
583	100.00(19)
1280	5.40(7)
1354	0.015(3)
1937	0.032(3)

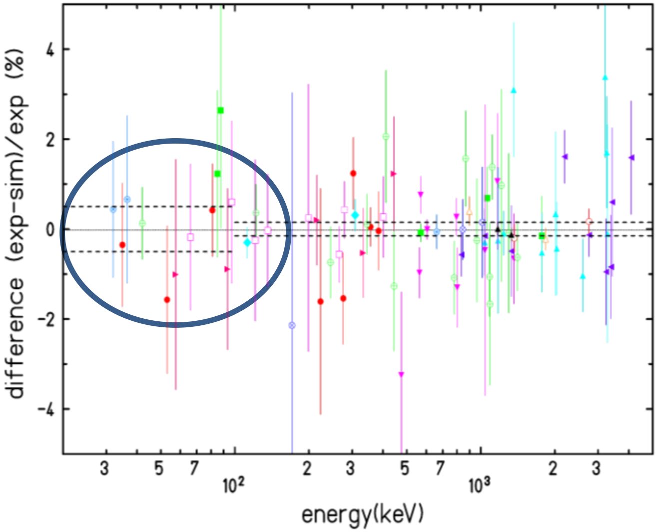
Calibration of germanium detector

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

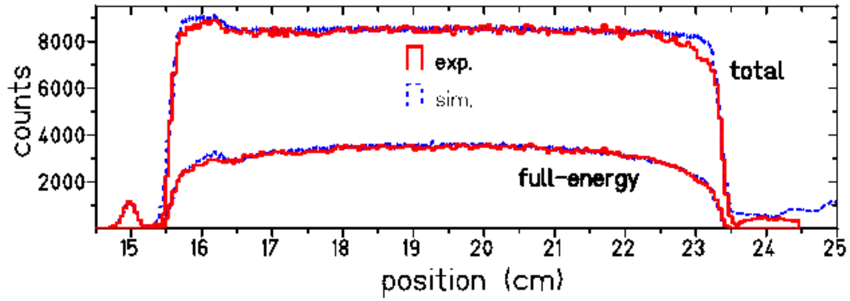


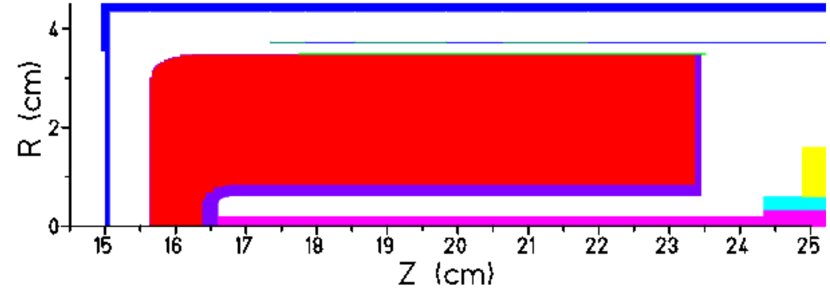


X-ray photography



Scan at CSNSM





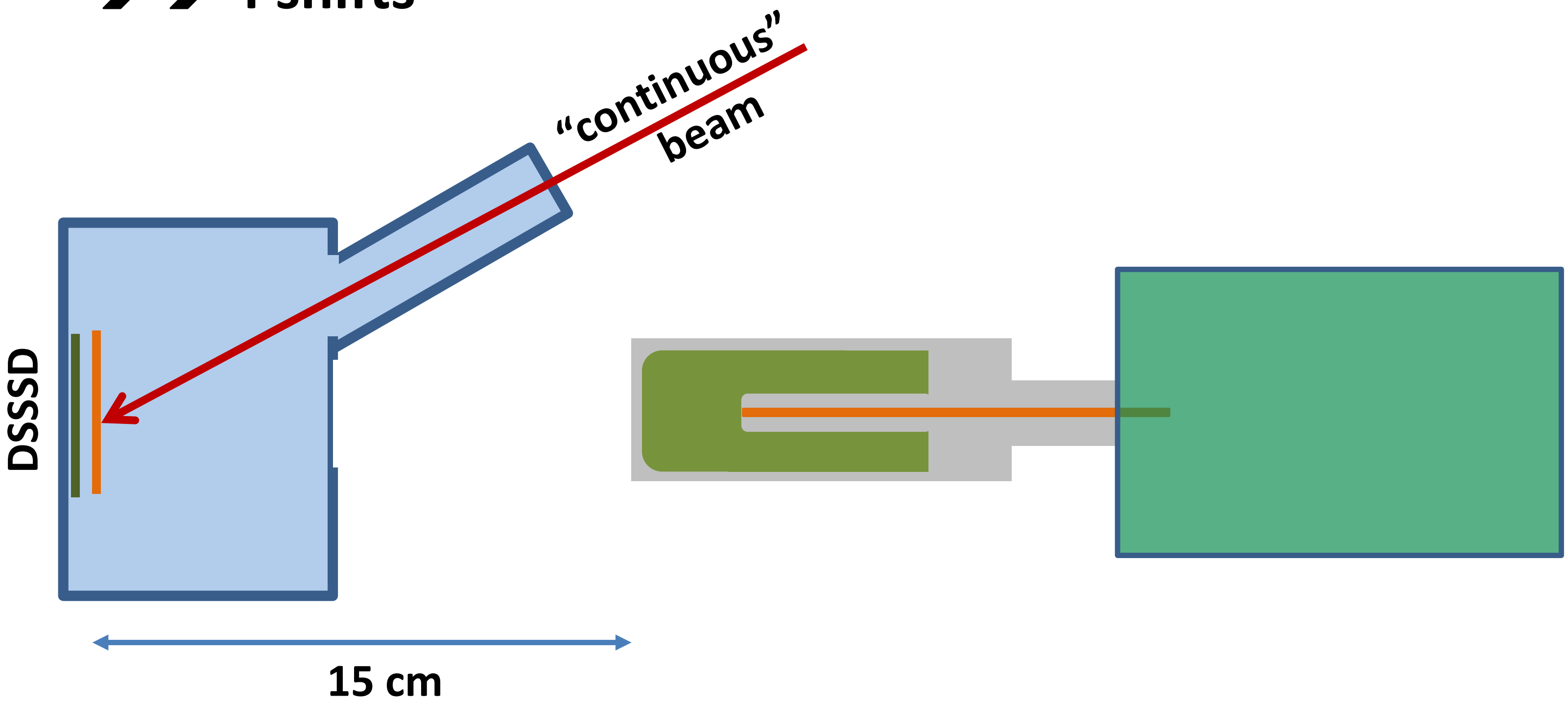
Branching ratios:
^{24}Na, ^{27}Mg, ^{48}Cr, ^{56}Co, ^{60}Co, ^{66}Ga, ^{75}Se, ^{88}Y, ^{133}Ba, ^{134}Cs, ^{137}Ce, ^{152}Eu, ^{180}Hf, ^{207}Bi

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

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

Experimental setup: BR measurement

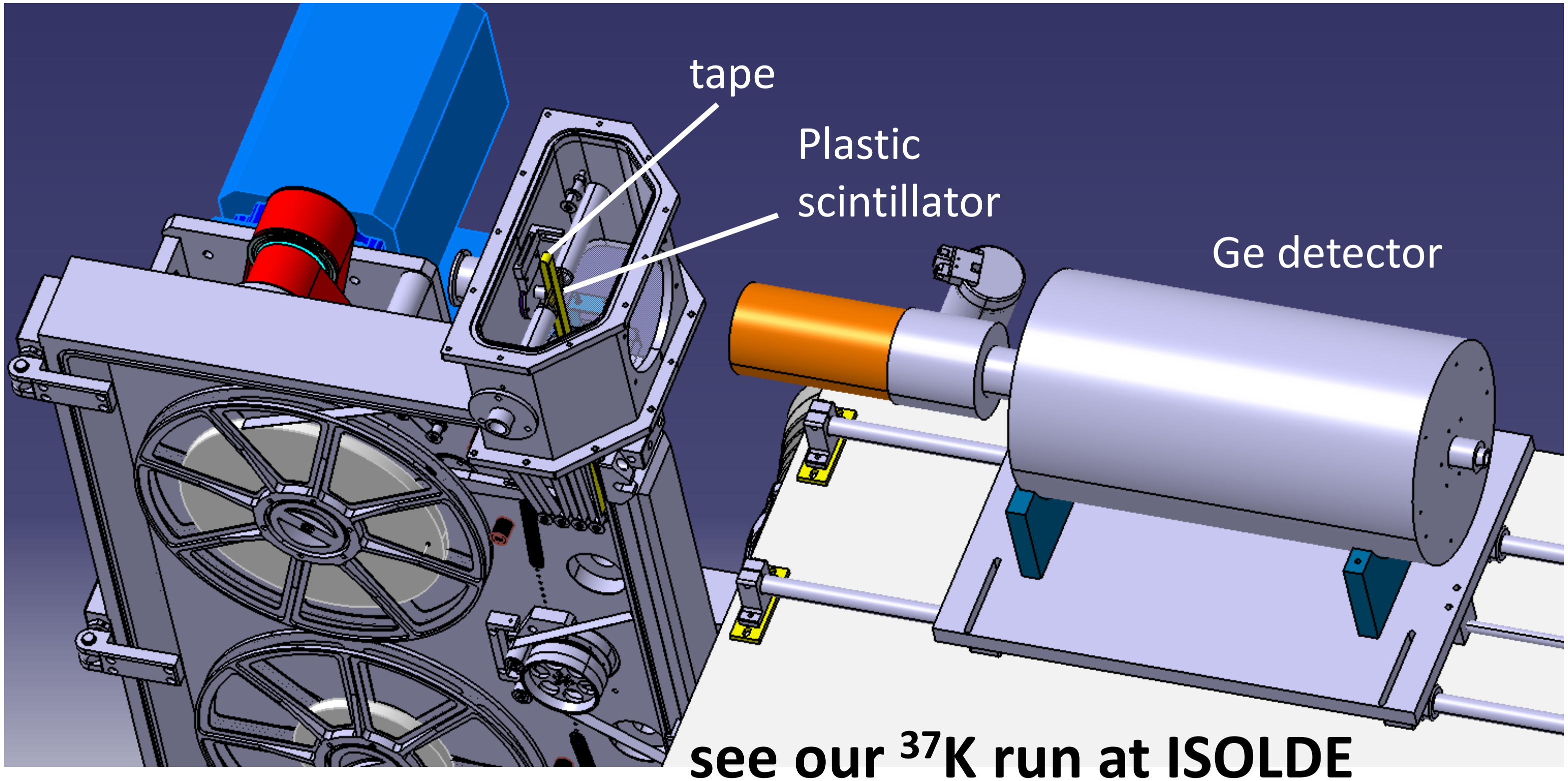
- limitation: 1000 counts per second in Ge
- 1.6 γ rays + two 511 keV rays per decay + 1.4 background
  ➔ 5 γ rays per decay ➔ 200 ^{22}Mg decays per second detected
- 1 % total efficiency of Ge detector
  ➔ 20000 decays per second in setup
  ➔➔ 10^5 s to achieve < 0.1% statistical error for all peaks
  ➔➔ 4 shifts



Experimental setup: $T_{1/2}$ measurement

- limitation: dead time correction < 20 %
  ➔ 10^5 ^{22}Mg decays per cycle (2s + 0.5 s + 77.2 s + 0.5 s ≈ 80 s)
- to reach 10^8 decays
  ➔ 1000 cycles

➔➔ 4 shifts



see our ^{37}K run at ISOLDE

Summary

- 2 shifts for tuning and optimizing
- 4 shifts for branching ratio measurement
- 4 shifts for half-life measurement

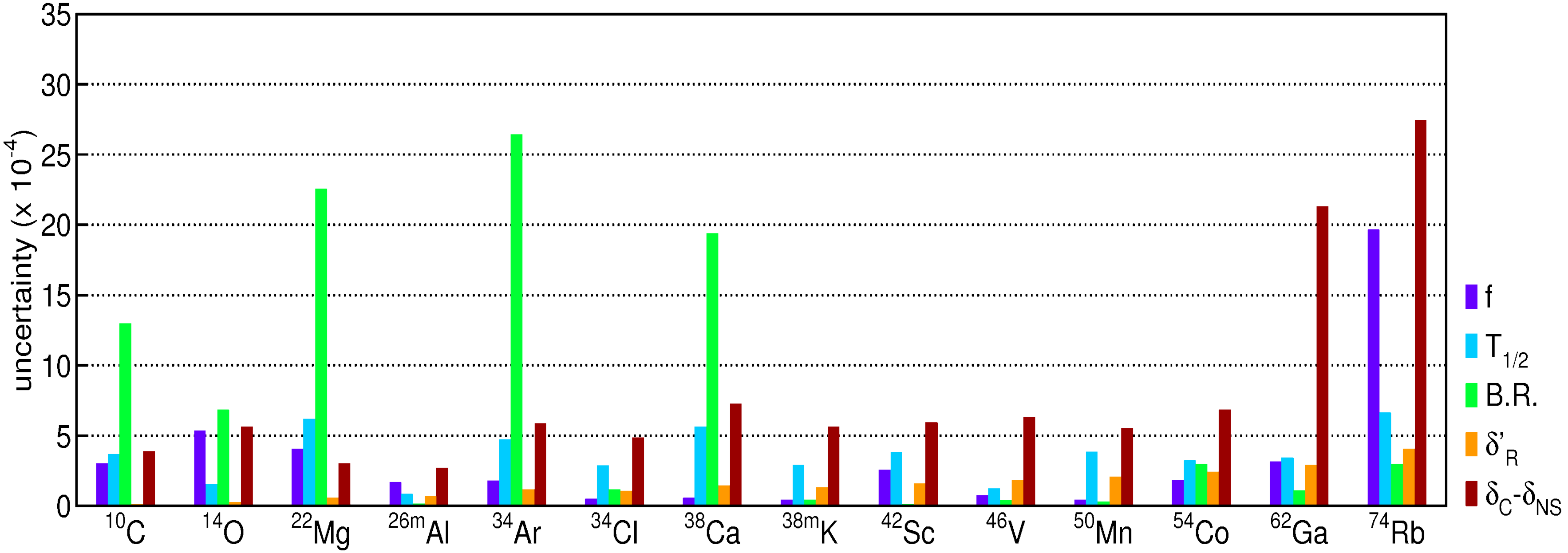
➔ total: 10 shifts

TAC:
do we need laser ionisation: yes/no
- either reduce ^{22}Na (and ^{22}O, ^{22}F) by laser ionisation
- or by a good tune of the HRS ($m/\Delta m = 4400$ for $^{22}Na/^{22}Mg$)

… a similar experiment accepted at TRIUMF with GRIFFIN

Thanks for your attention

$0^+ \rightarrow 0^+$ uncertainties



$0^+ \rightarrow 0^+$ uncertainties: ^{22}Mg

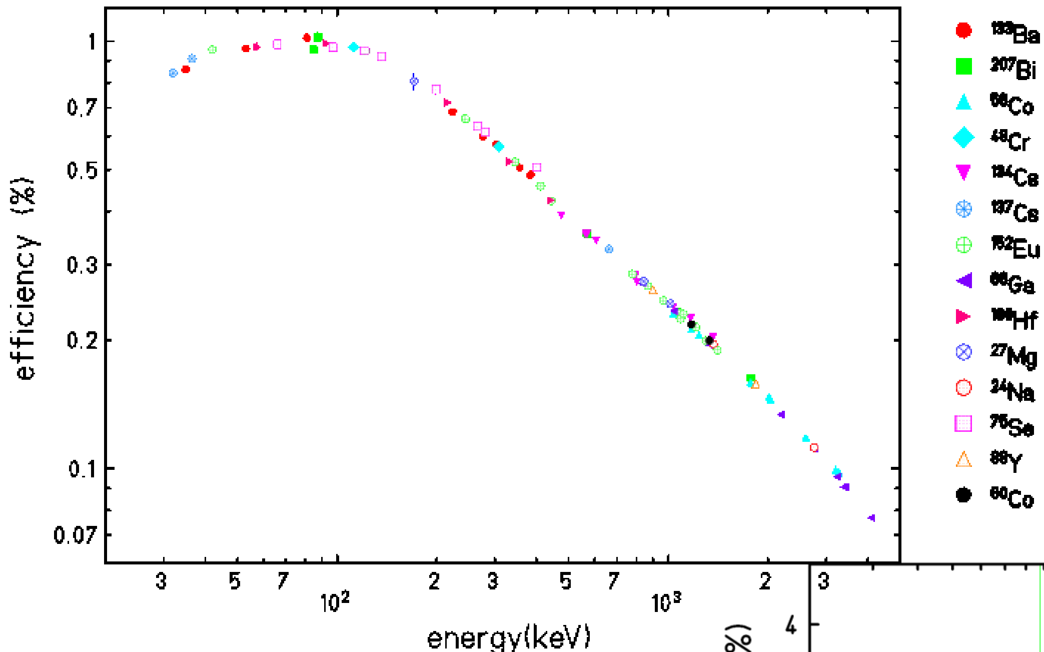
	δ_{NS}	δ_{C1}	δ_{C2}	δ_C
T&H&H 1977				**0.350(30)**
T&H 2002 (WS)	**-0.240(20)**	**0.010(10)**	**0.255(10)**	**0.270(20)**
T&H 2008 (HF)	**-0.225(20)**	**0.010(10)**	**0.250(55)**	**0.260(56)**
T&H 2008 (WS)	**-0.225(20)**	**0.010(10)**	**0.370(20)**	**0.380(22)**

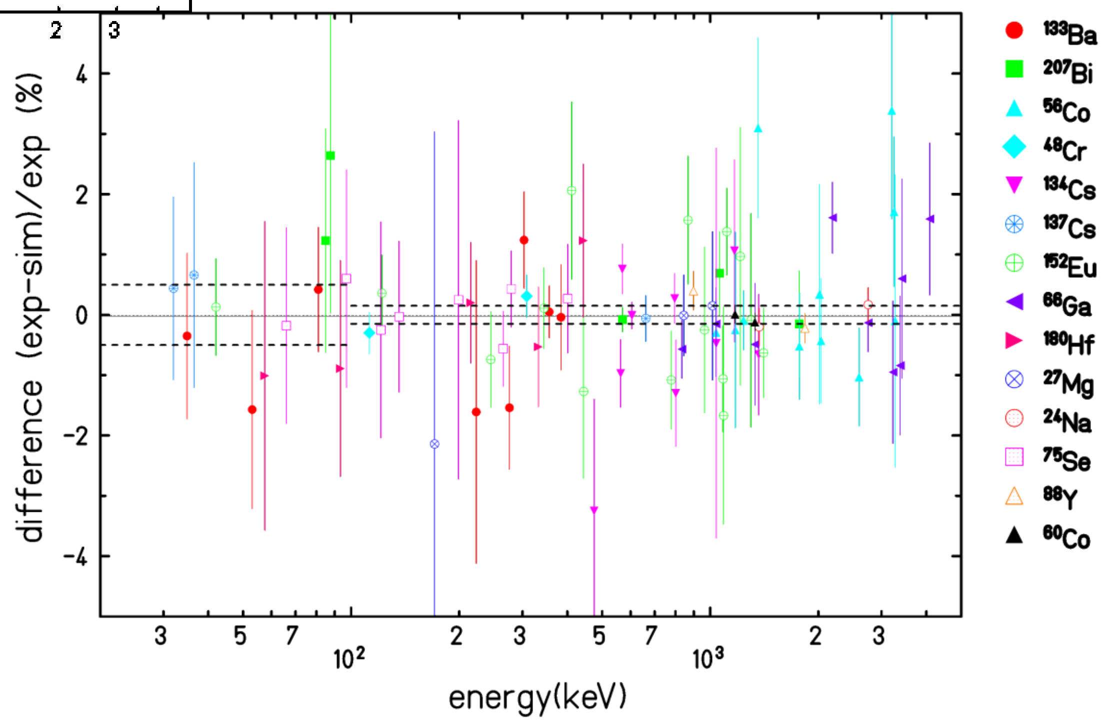
additonal sources

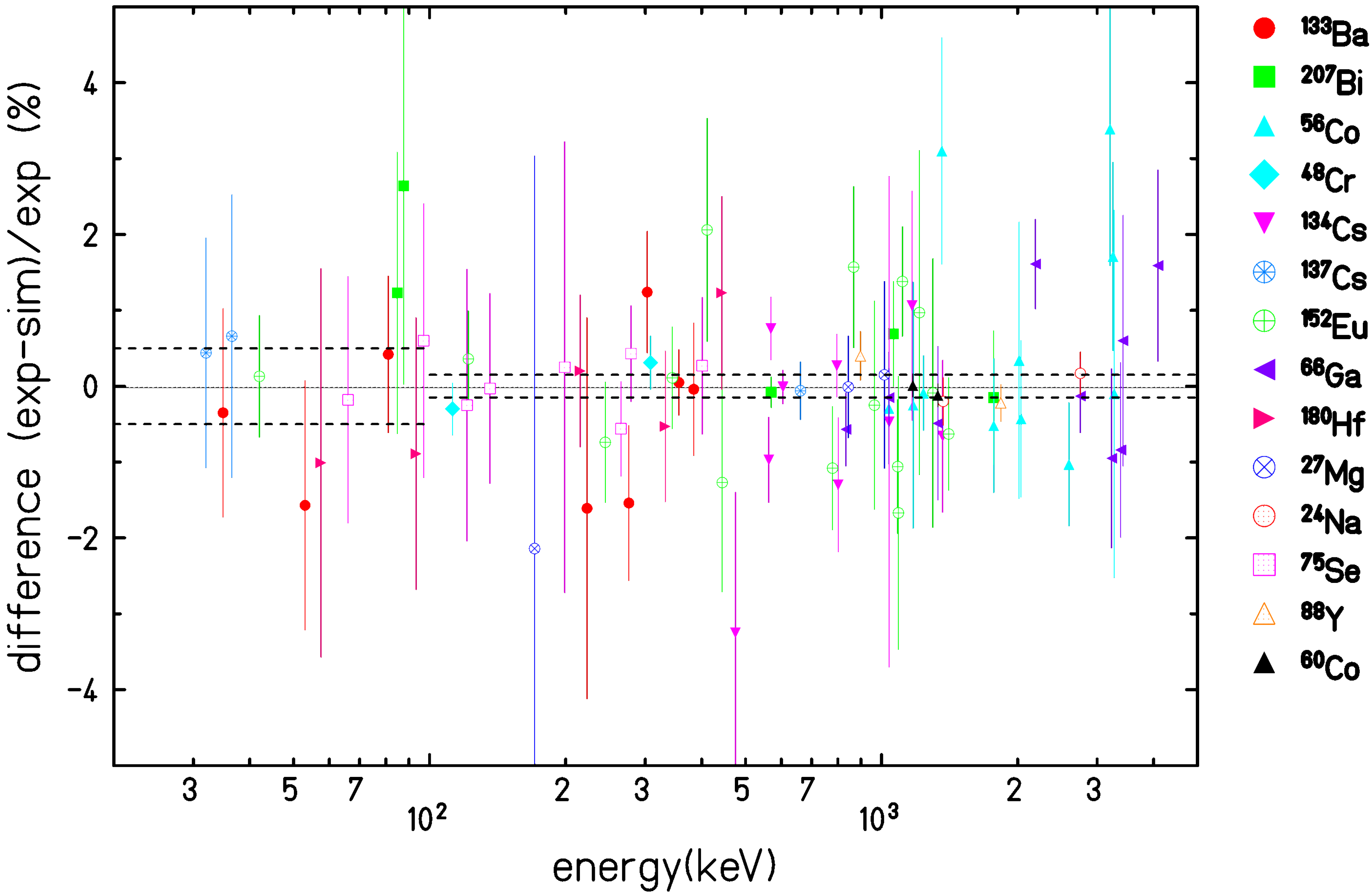
	Eγ (keV)	BR(%)	ISOLDE / μC	other isotopes
^{48}Cr	112, 308	98.34(4), 99.473(5)	10^7 pps	
^{109}Cd	22, 25, 88	82.1(9), 17.3(3), 3.63(2)	source	
^{75}Se	66, 97, 121, 136, 199, 265, 279, 303	1.112(12), 3.42(3), 17.2(3), 58.2(7), 1.48(4), 58.9(3), 24.99(13), 1.316(8)	?	10^6 - 10^7
^{120m}Sb	90, 197, 1023, 1171	79.57(16), 87.22(11), 99.057(10), 99.908(1)	?	10^7
^{133}Ba	53, 81, 276, 303, 356, 384	2.161(18), 34.11(28), 7.247(30), 18.30(6), 61.94(14), 8.905(29)	source	
^{180m}Hf	93, 215, 332, 443	17.51(14), 81.50(15), 94.43(5), 81.8(13)	3*10^6 pps	

already used...

Germanium efficiency







difference (exp-sim)/exp (%)
4
2
0
-2
-4
3
5
7
10^2
2
3
5
7
10^3
2
3
energy(keV)
^{133}Ba
^{207}Bi
^{56}Co
^{48}Cr
^{134}Cs
^{137}Cs
^{152}Eu
^{66}Ga
^{180}Hf
^{27}Mg
^{24}Na
^{75}Se
^{88}Y
^{60}Co