

Beta-asymmetry parameter of ^{67}Cu for tensor current search

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Physics motivation

The general structure of the Weak Interaction Hamiltonian:

$$H_\beta = H_V(C_V, C'_V) + H_A(C_A, C'_A) + H_T(C_T, C'_T) + H_S(C_S, C'_S) + H_P(C_P, C'_P)$$

Standard Model:

$$H_\beta = H_V(C_V, C'_V) + H_A(C_A, C'_A)$$

Experimental limits:

$$\begin{aligned} |C_S/C_V| &< 0.070 & |C_T/C_A| &< 0.090 \\ |C'_S/C_V| &< 0.067 & |C'_T/C_A| &< 0.089 \end{aligned}$$

β asymmetry parameter A

$$\tilde{A}_{GT}^{\beta\mp} \simeq A_{SM} \left[1 \pm \frac{\gamma m C_T + C'_T}{E_e / C_A} \right]^{-1}$$

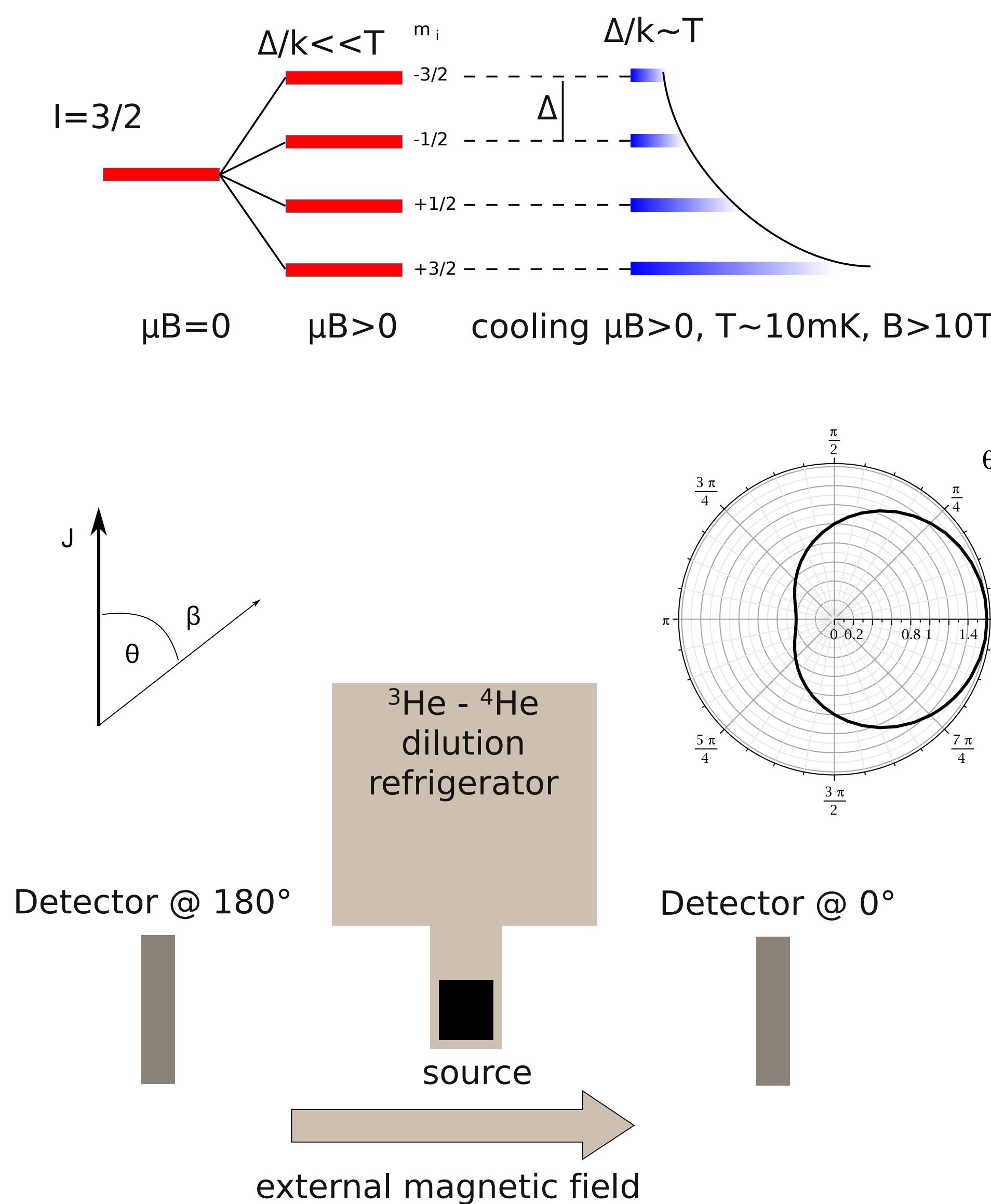
Experimental observable:

$$W(\Theta) = 1 + \tilde{A} \frac{\langle J \rangle p_e}{J E_e}$$

To measure this parameter we need oriented nuclei!

N. Severijns, M. Beck, O. Naviliat-Cuncic, RMP 78 (2006) 991
N. Severijns and O. Naviliat-Cuncic, Annu Rev Nucl Sci 61 (2011) 23

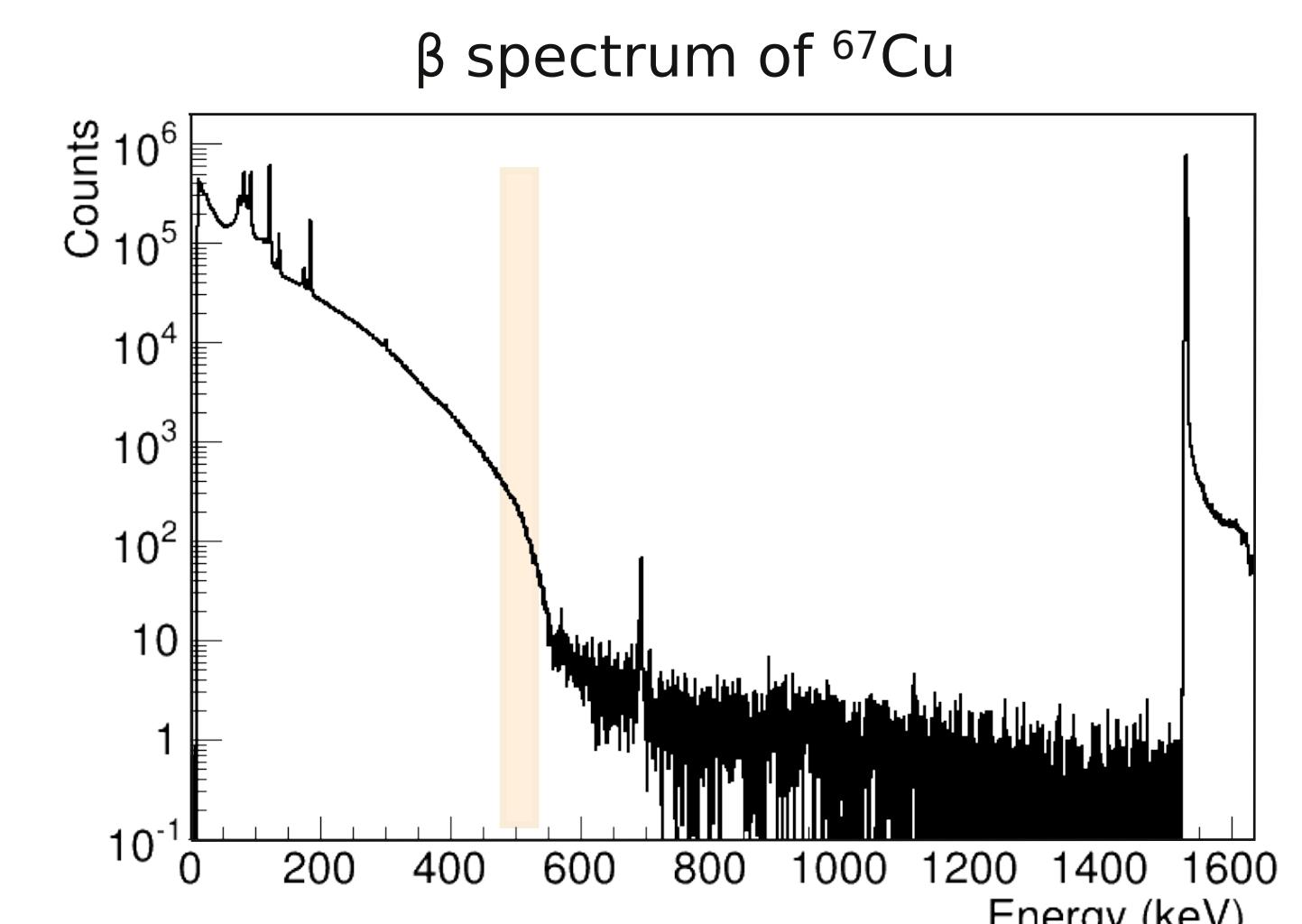
Low Temperature Nuclear Orientation



Data taking & Analysis

Measure the countrate in the particle detectors:

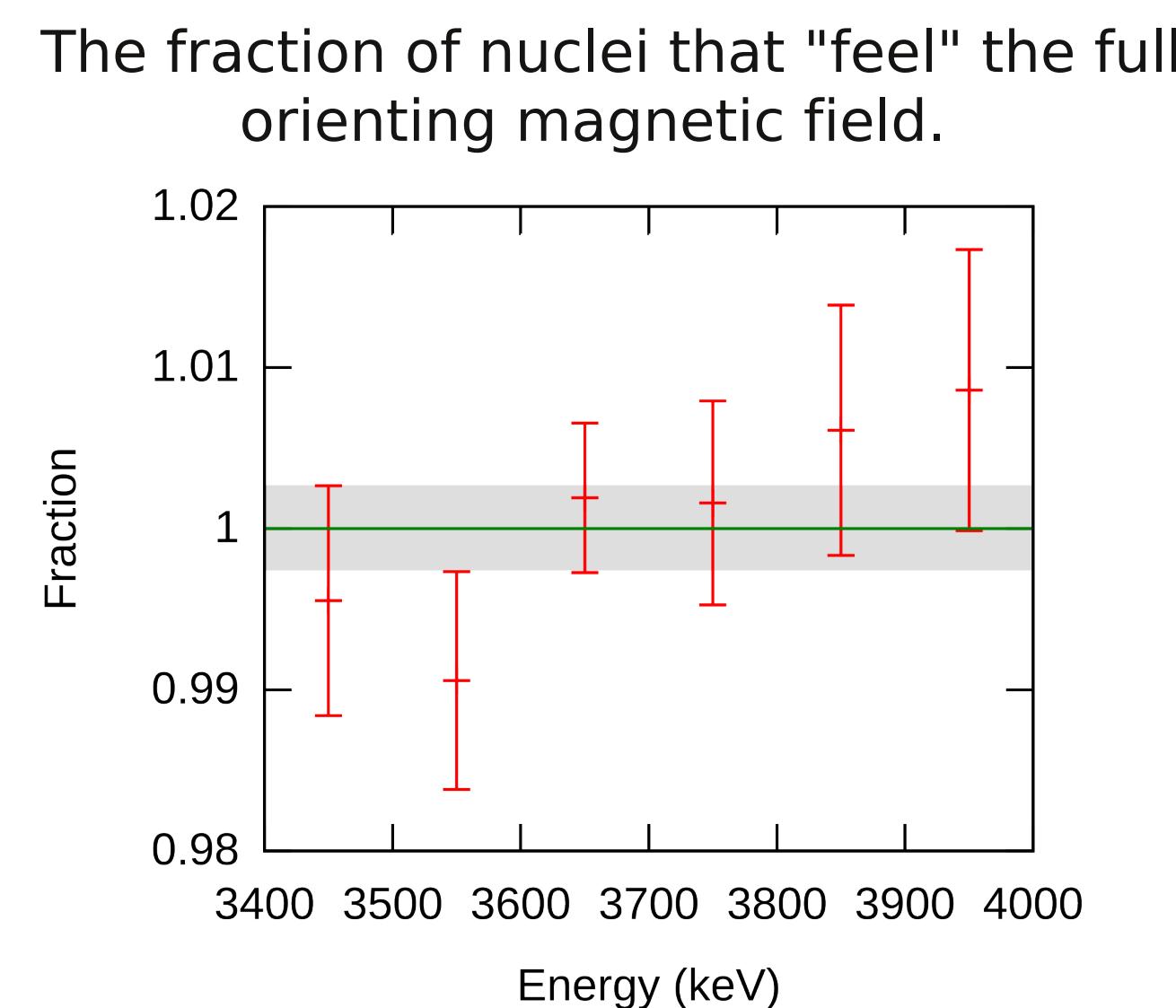
- for an oriented sample (milliKelvin region): $N(\Theta)_{COLD}$
- for an unoriented sample (4K region): $N(\Theta)_{WARM}$



Obtained from the beta-asymmetry measurement of ^{68}Cu .

$$W(\Theta) = \frac{N(\Theta)_{COLD}}{N(\Theta)_{WARM}} = 1 + f \tilde{A} P \frac{\nu}{c} Q \cos(\Theta)$$

Fraction



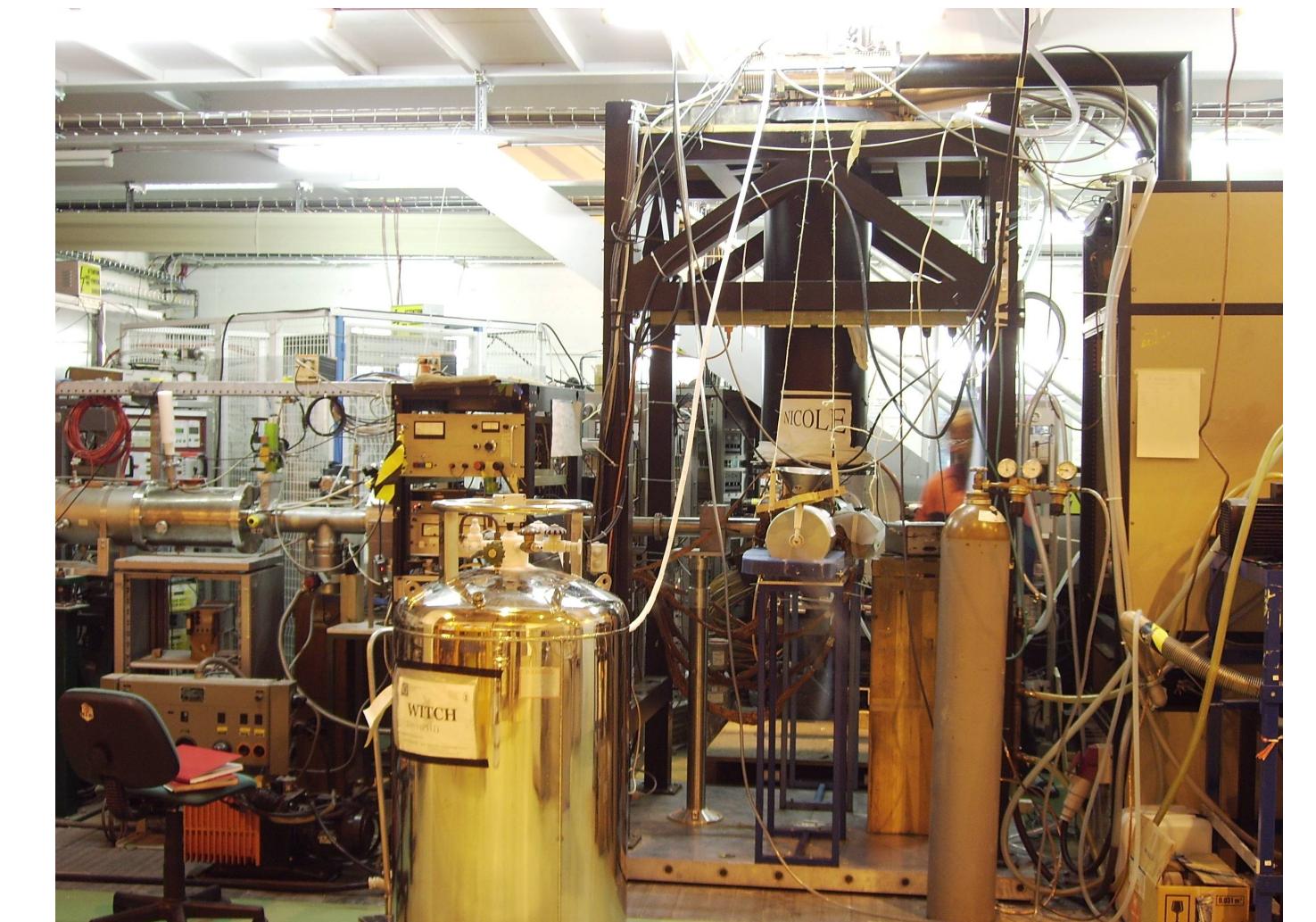
Polarization

Purely temperature dependent term. In the experiments ^{60}Co , ^{57}Co and ^{54}Mn nuclear thermometers were used

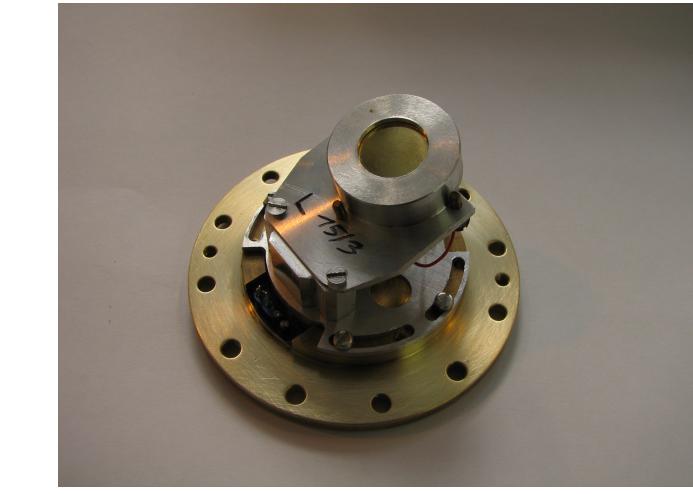
Beta asymmetry parameter

$A_{SM} + \text{corr.}$
Recoil: effect of the strong interaction
B. R. Holstein, RMP 46 (1974) 789
Radiative
Y. Yokoo, PTP 50 (1973) 1894
 $A_{SM} = 0.5993(2)$

NICOLE: Online dilution refrigerator @ ISOLDE, CERN



Planar HPGe detector operating at ~10 K directly facing the radioactive sample



D. Venos, NIM A 365 (1995) 419
D. Venos, NIM A 454 (2000) 403
G. Soti, NIM A 728 (2013) 11

Geant4 simulations

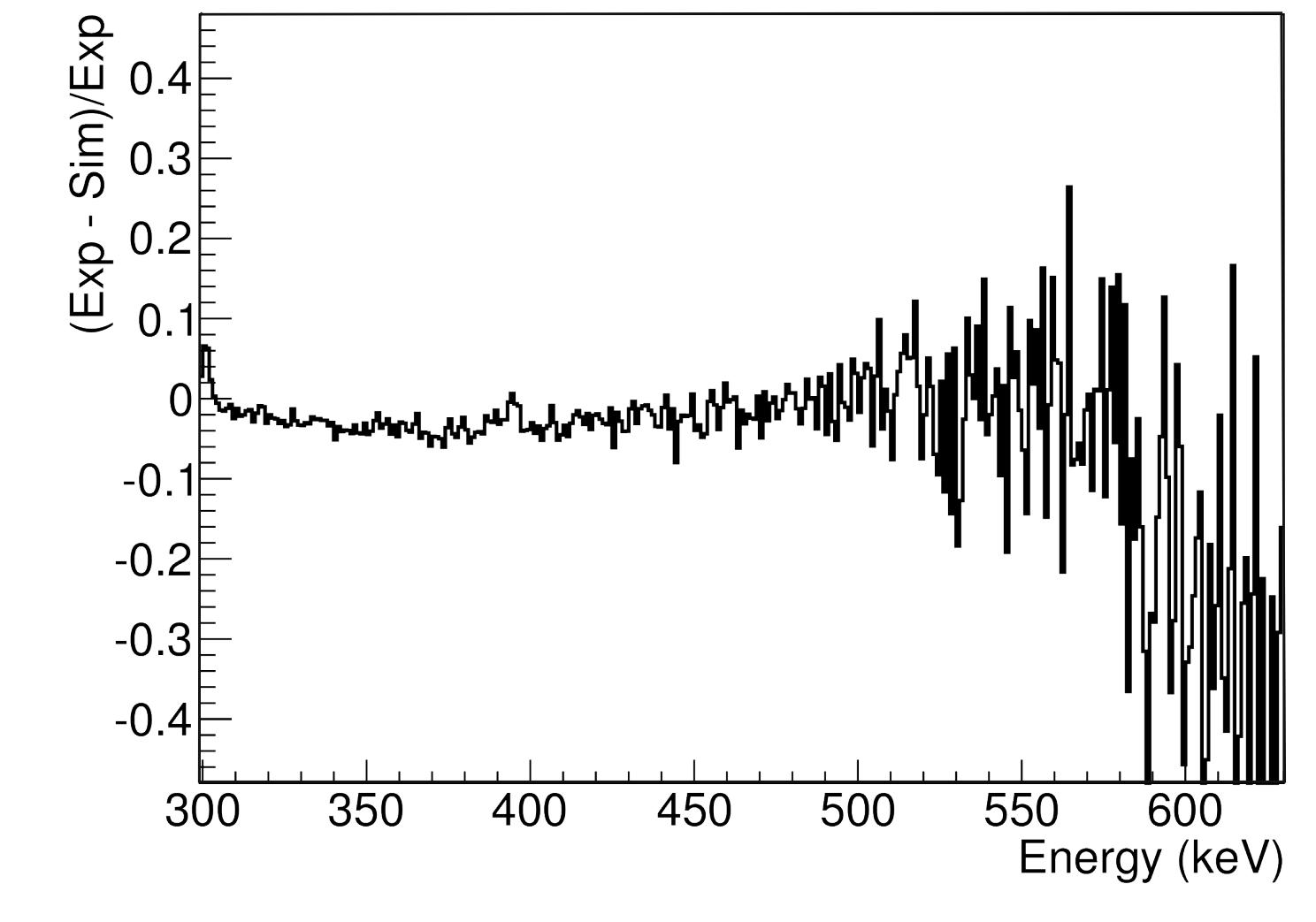
Our Geant4 based simulation code takes into account the effects that modify the experimentally observed anisotropy:

- electron scattering in the source and backscattering from the detector
- electron trajectories in the magnetic field of the dilution refrigerator
- simulating the Compton background
- solid angle
- initial velocity of the electrons

F. Wauters, NIM A 609 (2009) 156

Quality of the Geant4 simulations

Difference plot of the beta spectrum of ^{67}Cu , isotropic emission.

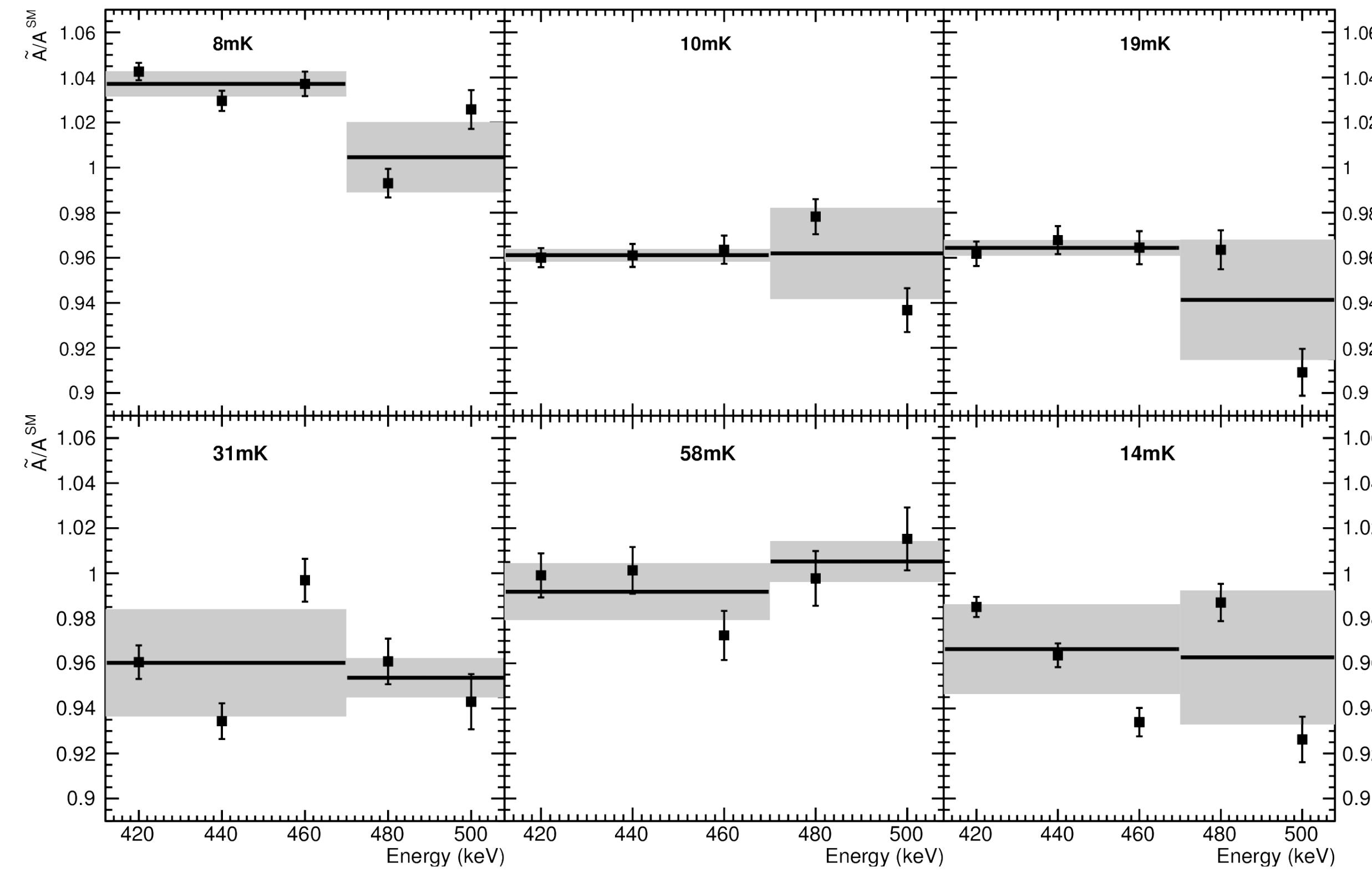


G. Soti, NIM A 728 (2013)

Results

Divide experimental and simulated spectra

$$\frac{W_{exp}-1}{W_{sim}-1} = \frac{\tilde{A}}{A_{SM}}$$

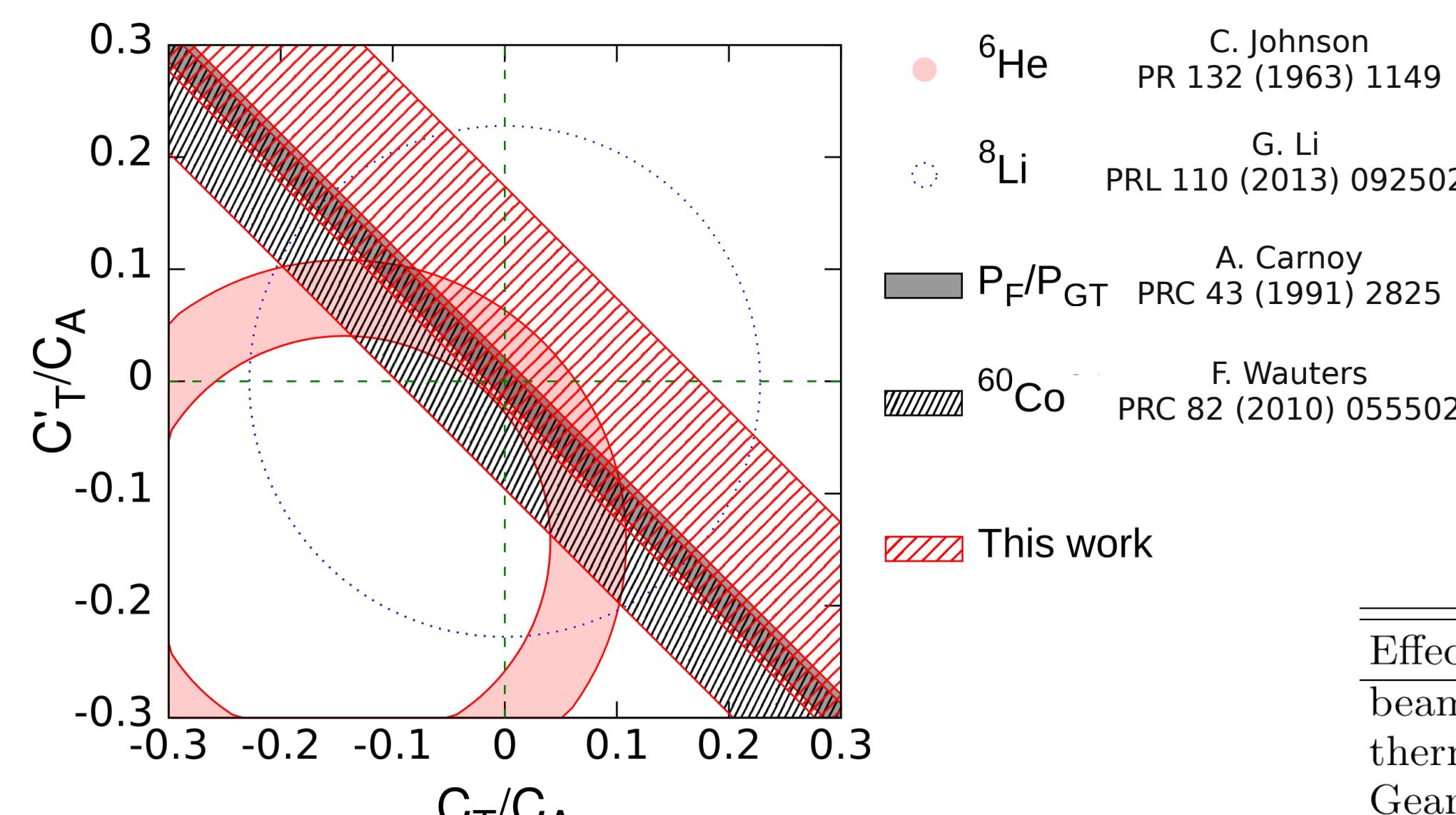


$$\tilde{A} = 0.584(13)$$

Obtained limits

$$\frac{\tilde{A}}{A_{SM}} = 0.974(10)_{stat}(18)_{syst}$$

$$-0.023 < (C_T + C'_T)/C_A < 0.174 \text{ (90% C.L.)}$$



Largest contributions to the error budget:

- thermometry
- ^{67}Cu half life
- ^{68}Cu relaxation

Effect	Value
beam spot position	0.0027
thermometry	0.0087
Geant4	—
pile-up	0.0028
half-life of ^{67}Cu	0.0068
geometry	0.0032
hyperfine interaction μB	0.0006
recoil corrections (Sec. VII)	0.0002
fraction from ^{68}Cu	0.0130
Total:	0.0178

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