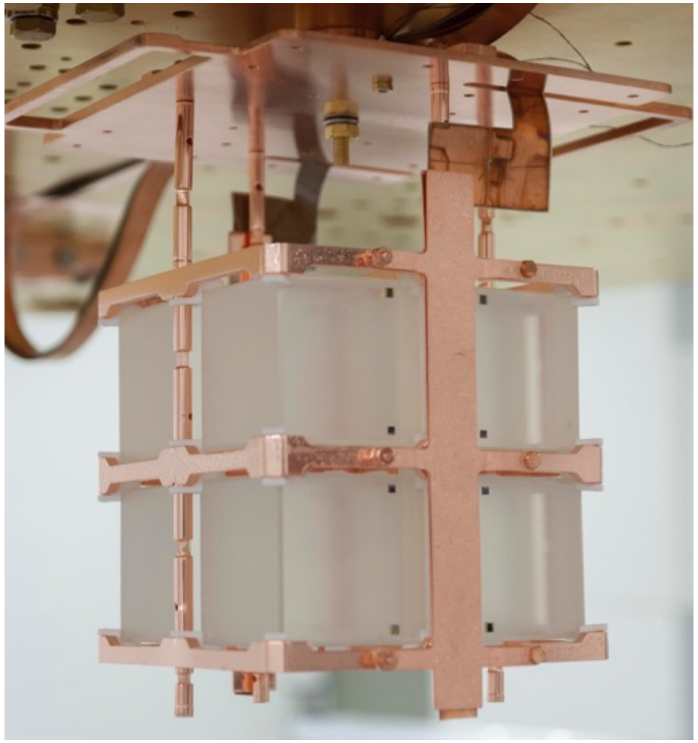
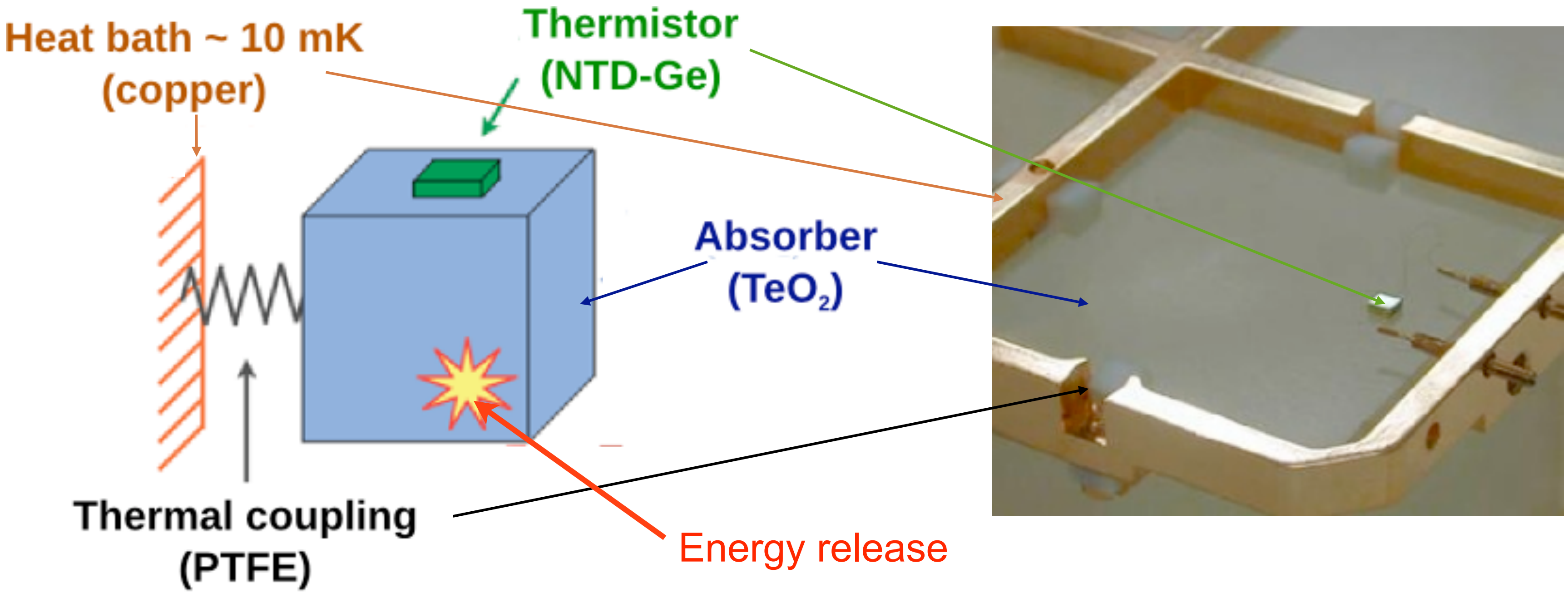
49th Meeting of the ISOLDE and Neutron Time-of-Flight Committee
CERN, February 11-12, 2015

An implanted ^{228}Ra source for response characterization of bolometers



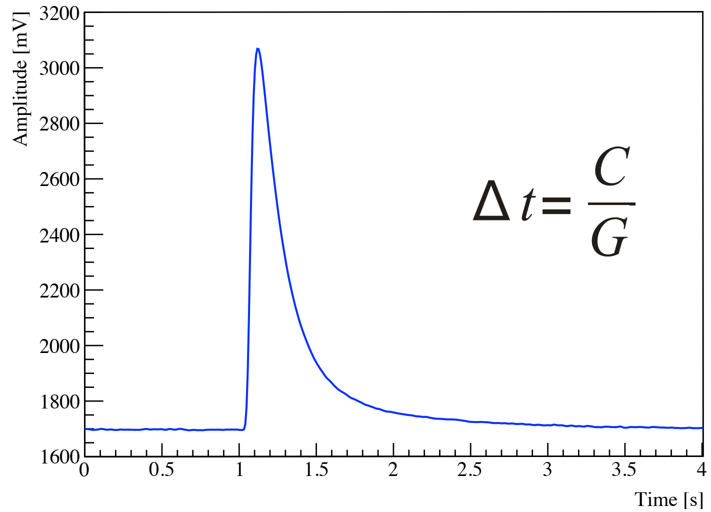
C. Brofferio
University of Milano Bicocca
and INFN, Sezione di Milano Bicocca

A word about bolometers

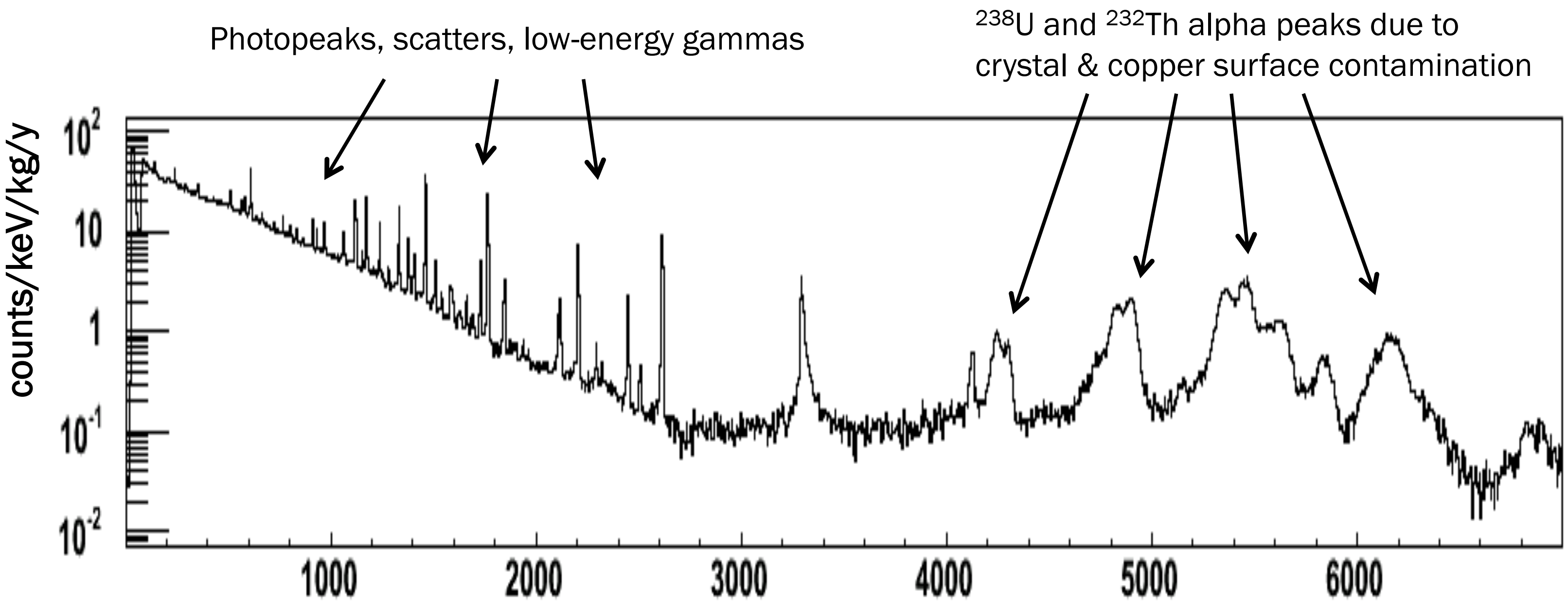


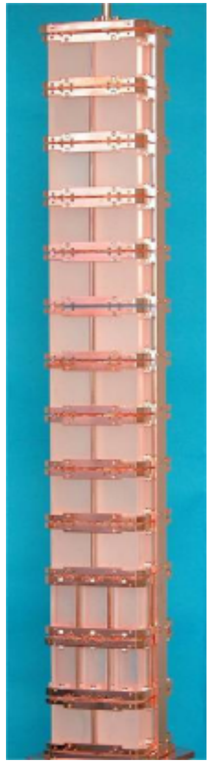
- Energy deposit in absorber results in temperature rise
- For TeO_2 crystals configured for CUORE at ~10mK, ΔT = 0.1mK per MeV
- Temperature change read out with Ge-NTD
- Energy response ~~can~~ must be calibrated with sources

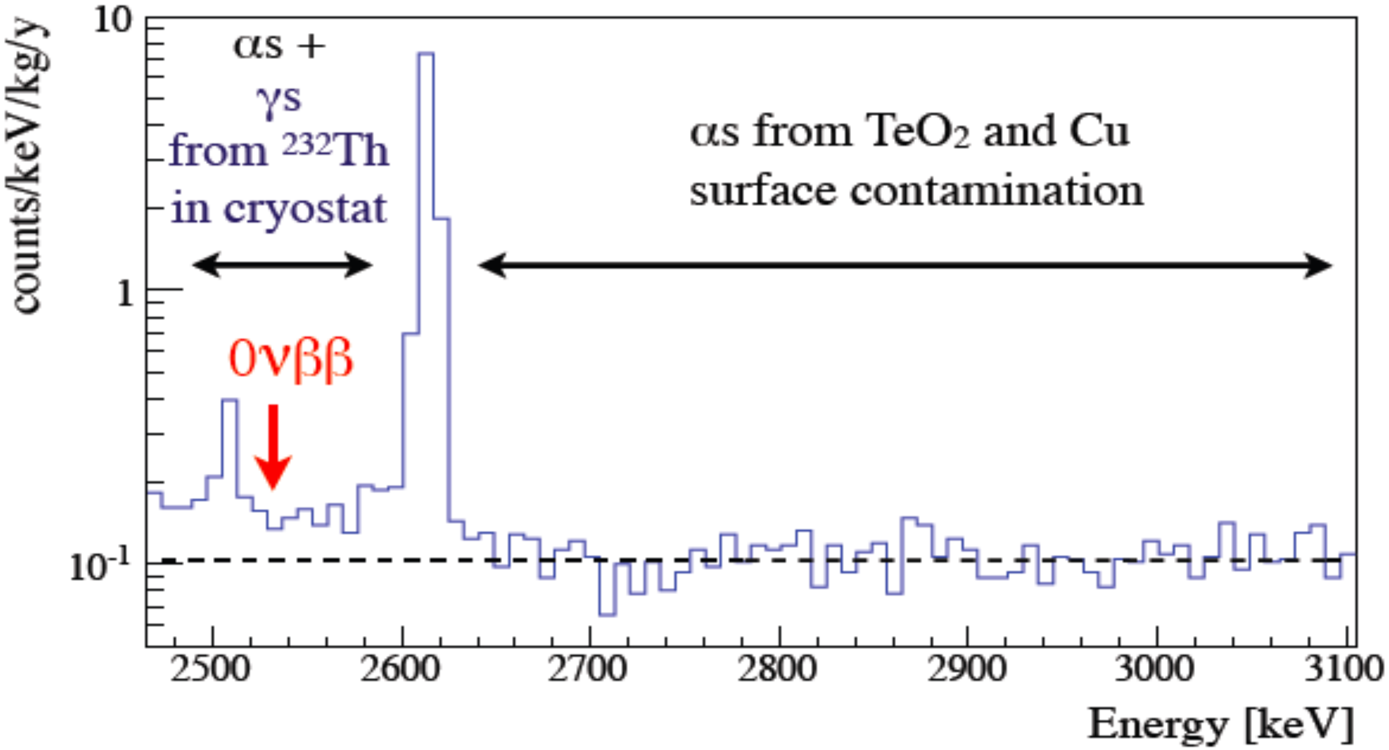
Sample Particle Pulse from NTD

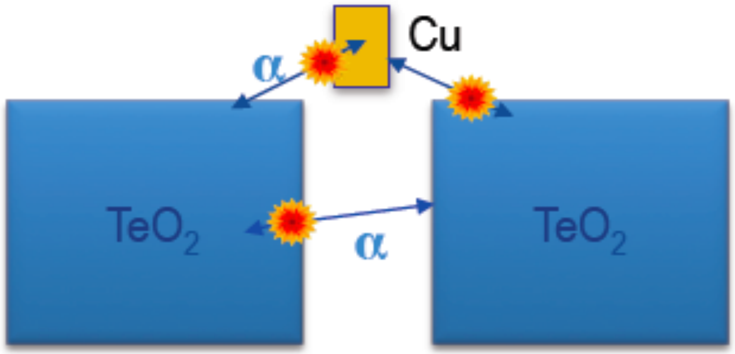


Cuoricino Lesson: The Bkg origin

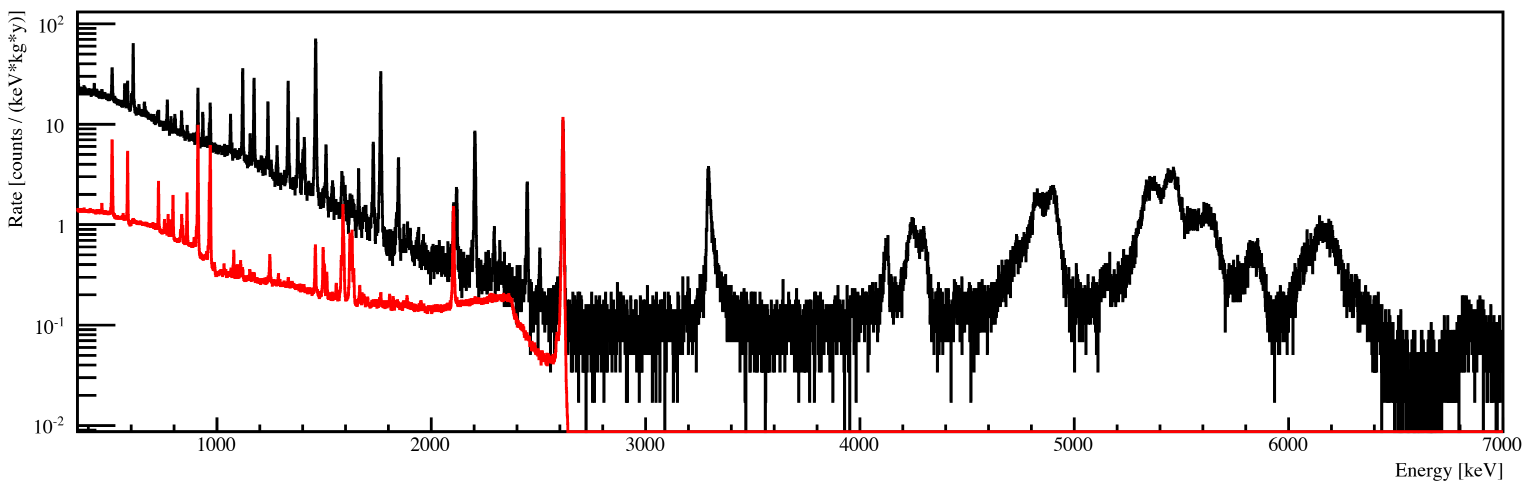




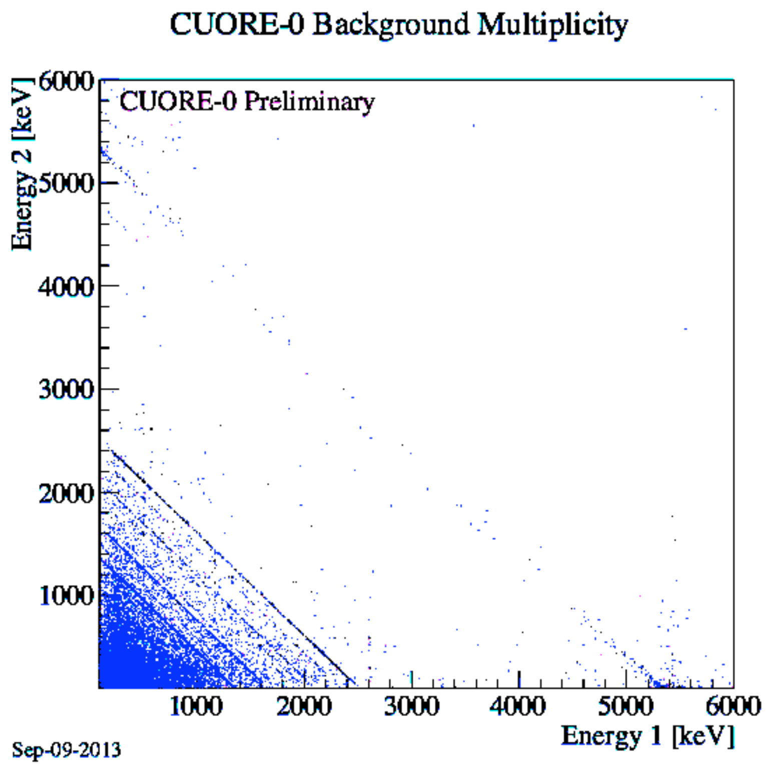


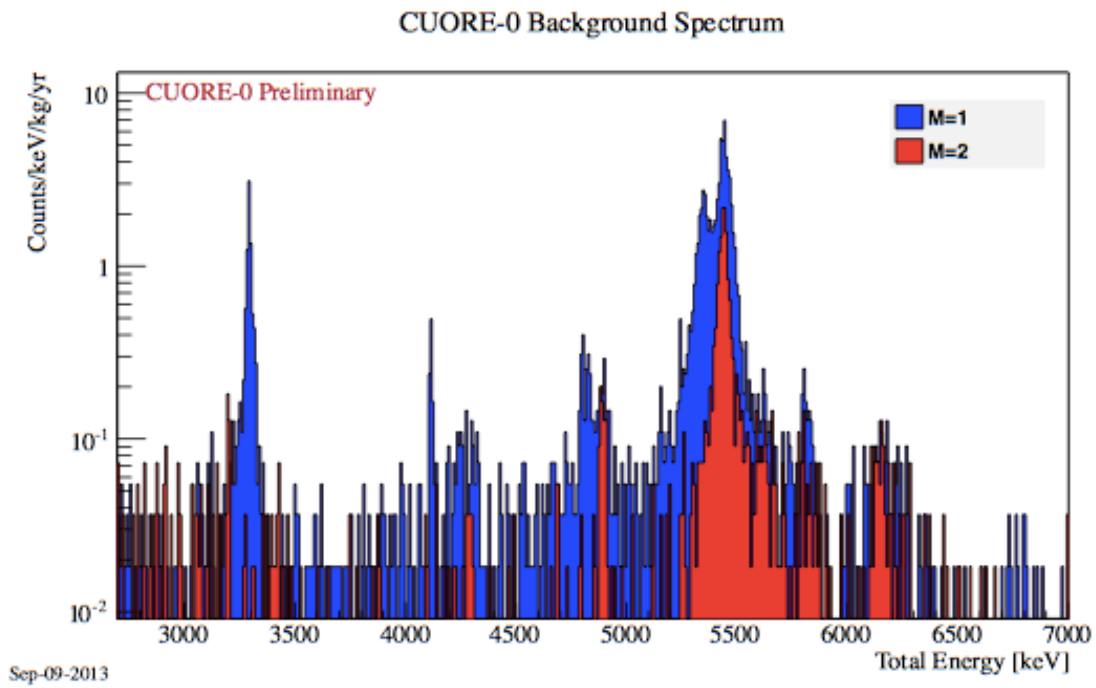


Why are calibration sources so critical



- The only info from TeO_2 bolometers is energy: knowing that energy very well is essential for event identification
  - Region-of-interest: finding the 0νββ peak
  - Whole spectrum: reliable identification of backgrounds

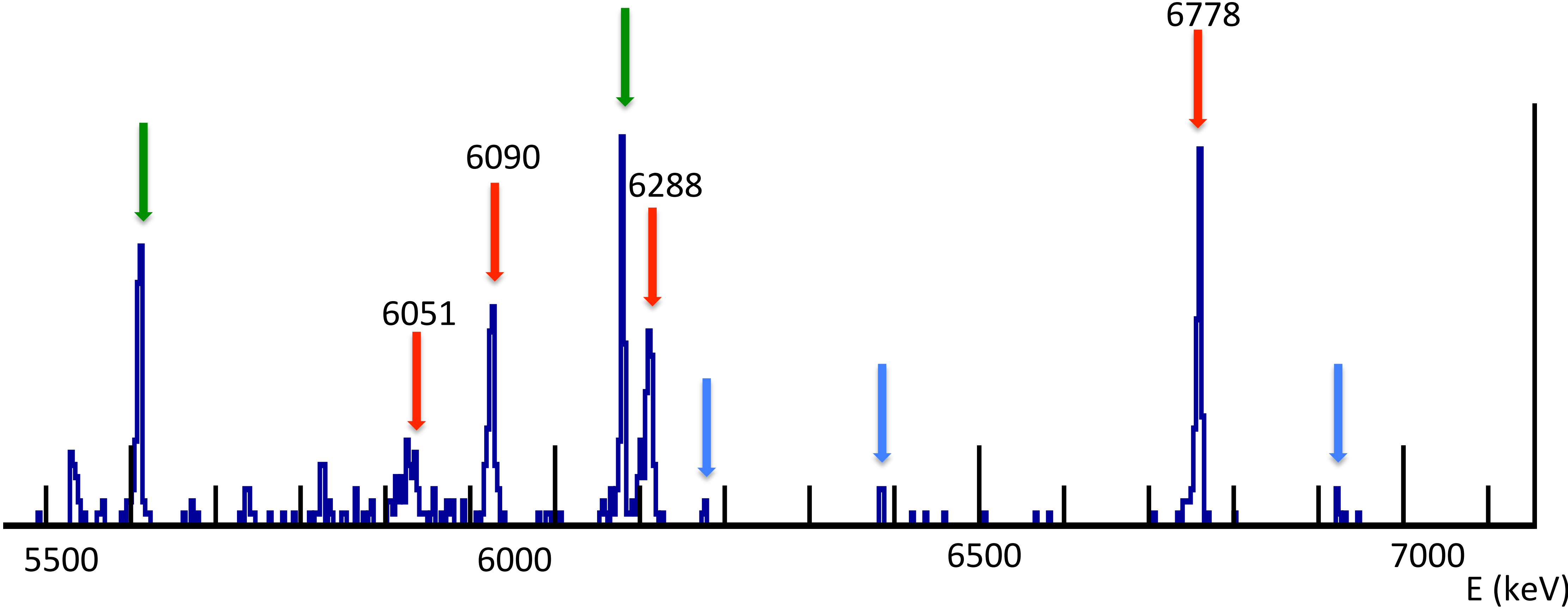




Detector response to α: the need of a HQ source

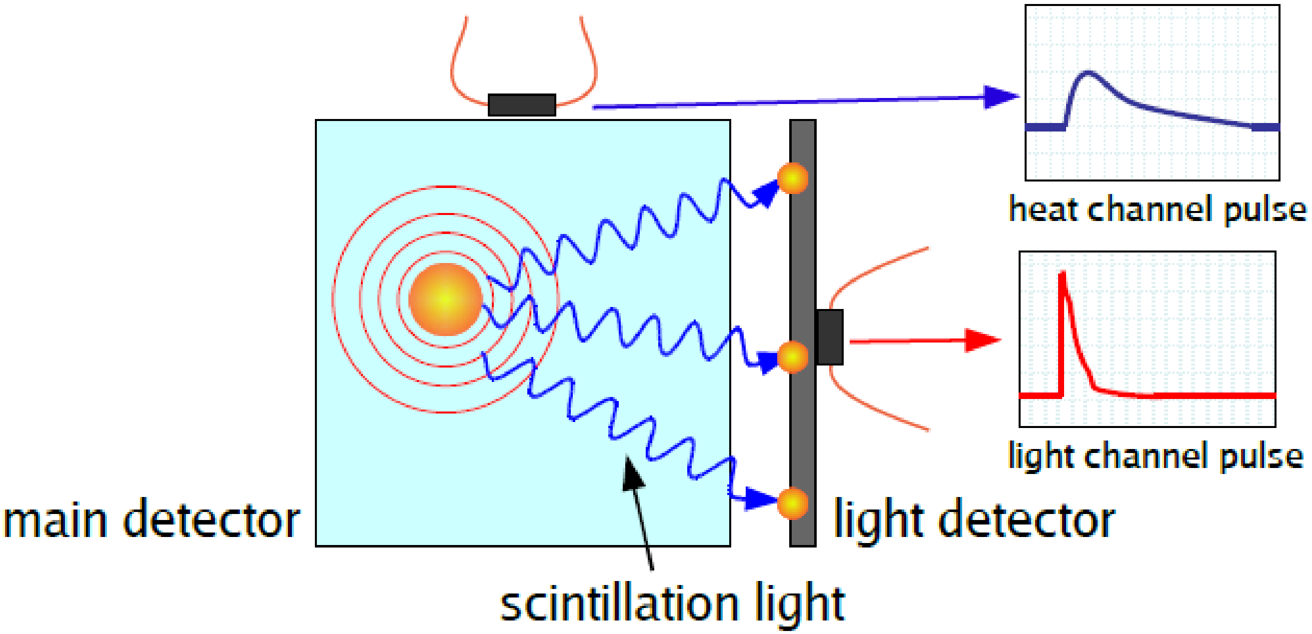
Bolometers do not respond in the same way to α, β/γ or nuclear recoils ⟹ Q. F.

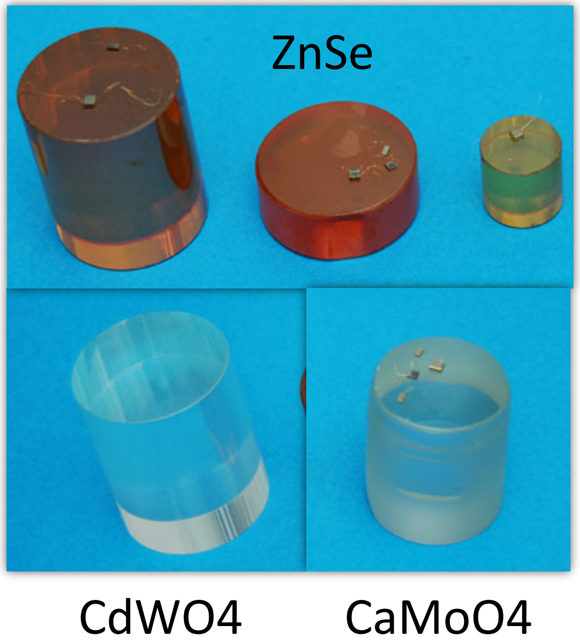
To calibrate the spectrum for the different species it is fundamental to have a very good intrinsic energy resolution gamma and (much more difficult!) alpha source

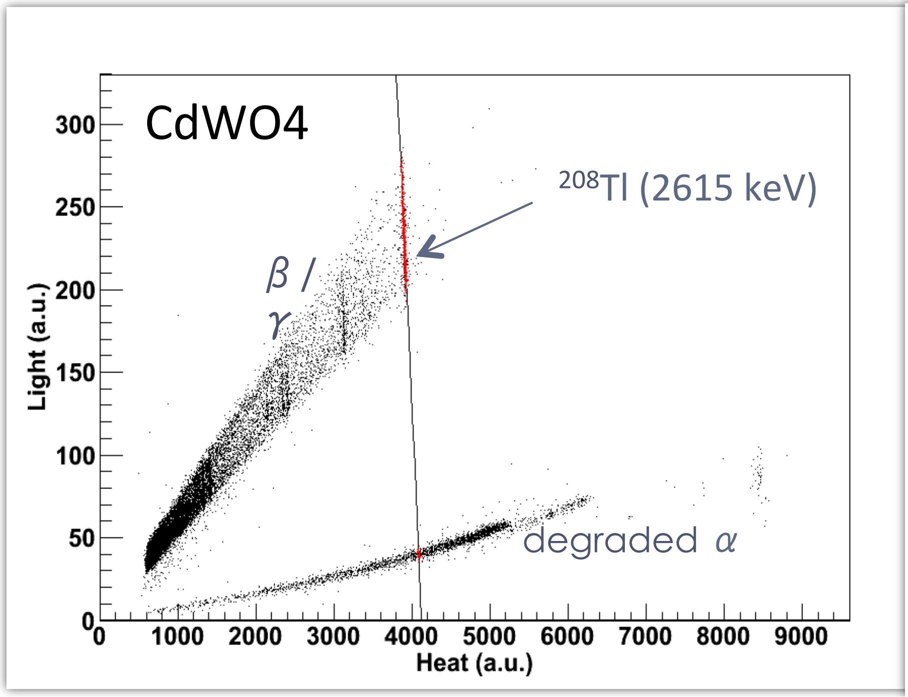


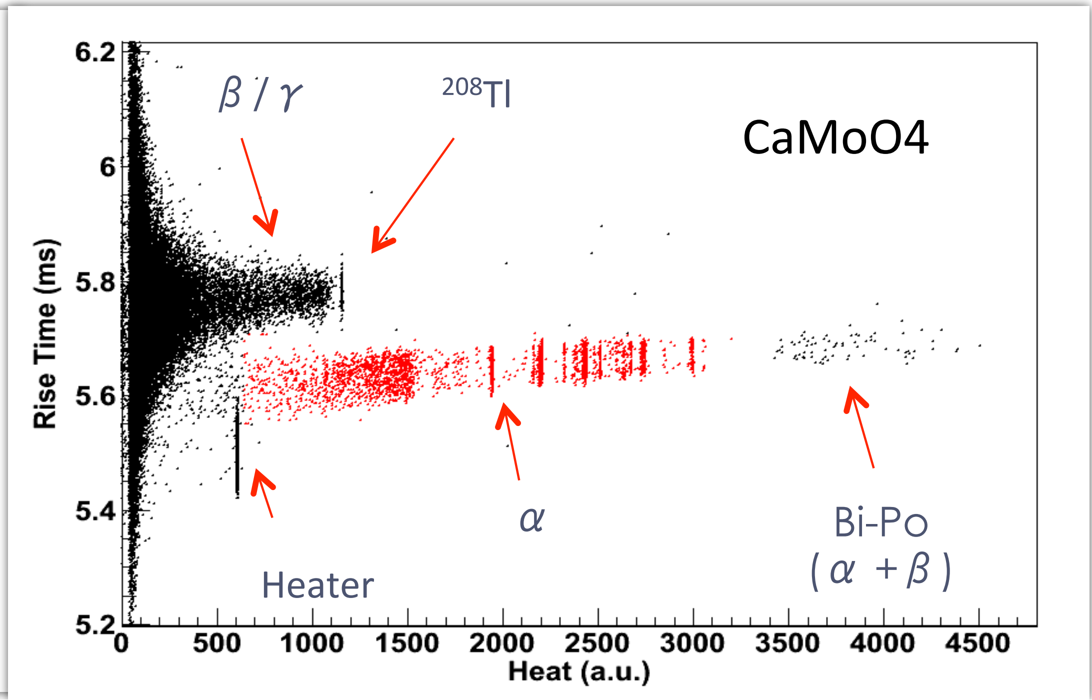
γ : $y = x$ α_{int} : $y = 1.05\,x - 360$ α_{ext} : $y = 0.95\,x + 380$

Beyond CUORE: double read-out





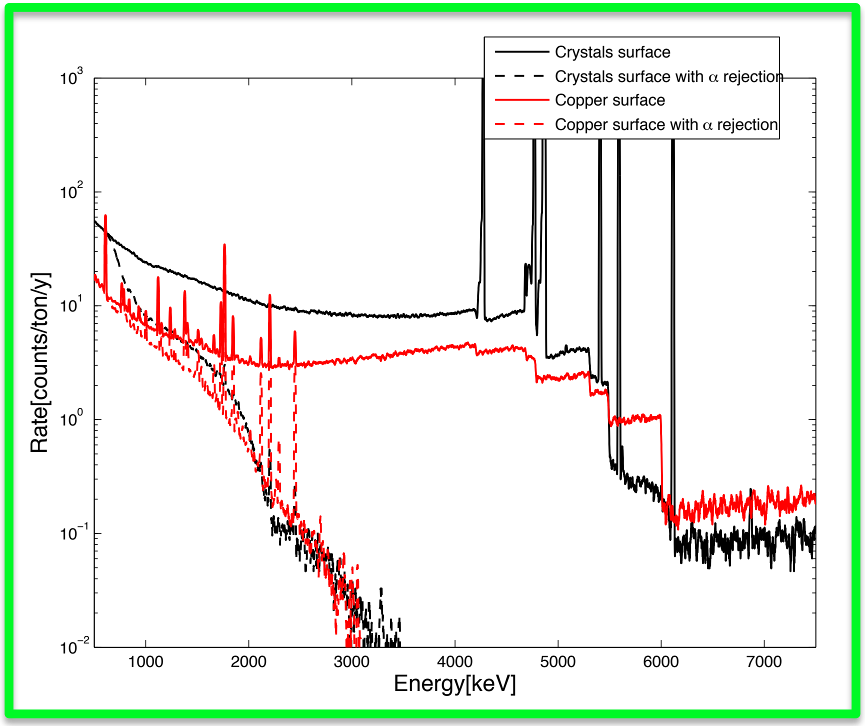


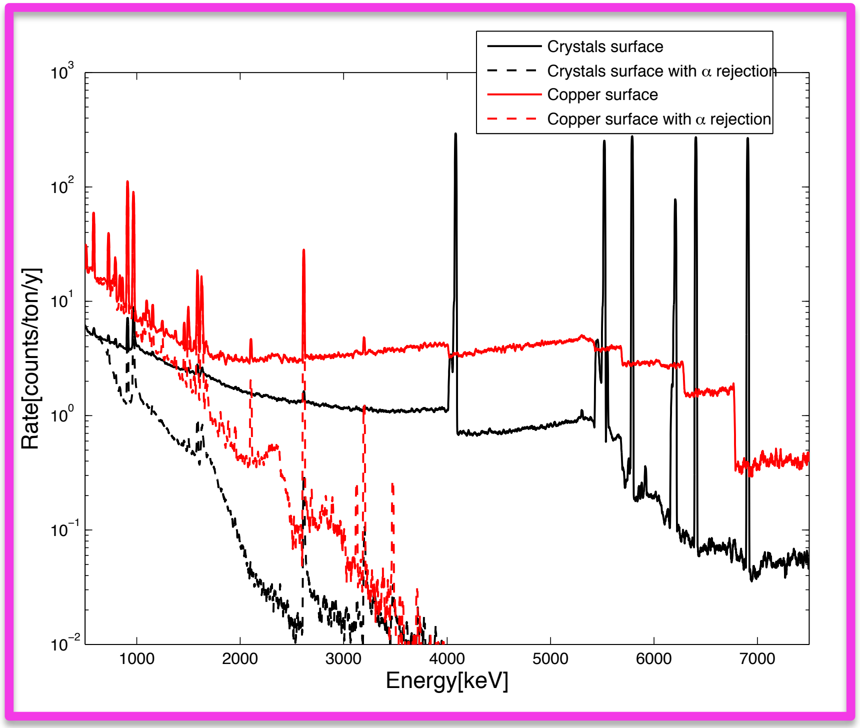


Background: α contributions

Simulations of **crystals** or surrounding **Cu** contamination

- in ^{238}U without (_____) or
- in ^{232} Th with (--------) alpha rejection

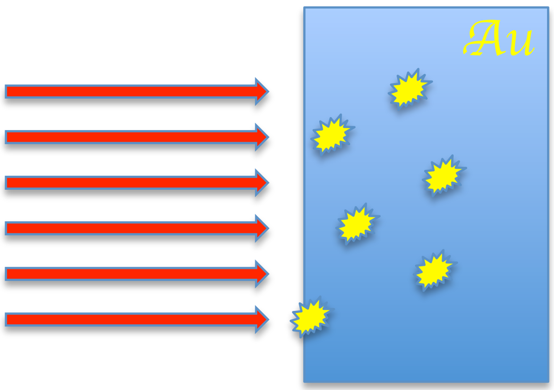




A gain of 2 orders of magnitude at 2.5 MeV (DBD RoI)

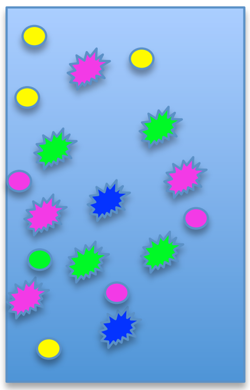
How we prepare our high quality source

^{228}Ra implant at ISOLDE

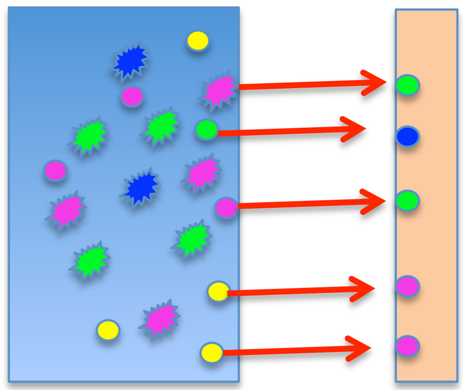


@ 10 kV 545 Å ± 253 Å (SRIM)

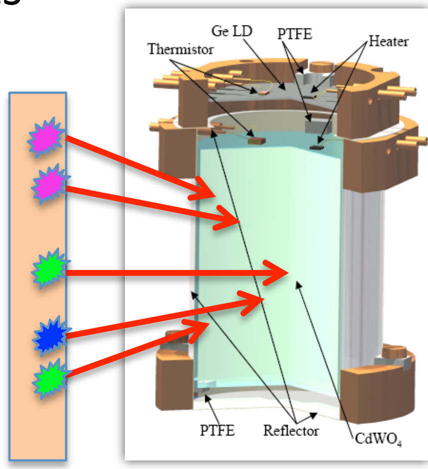
^{228}Ra chain



NR from α decays implants ^{224}Ra et al. on Cu foil



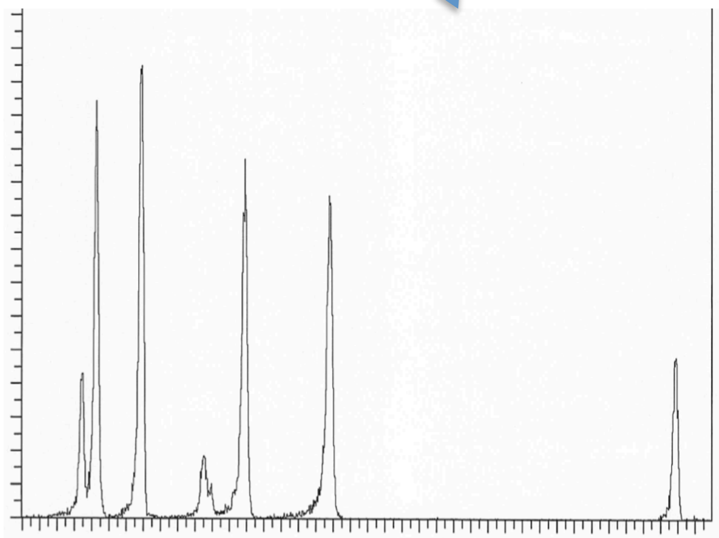
@ 100 keV: 100 Å ± 60 Å
difficult to escape, but possible

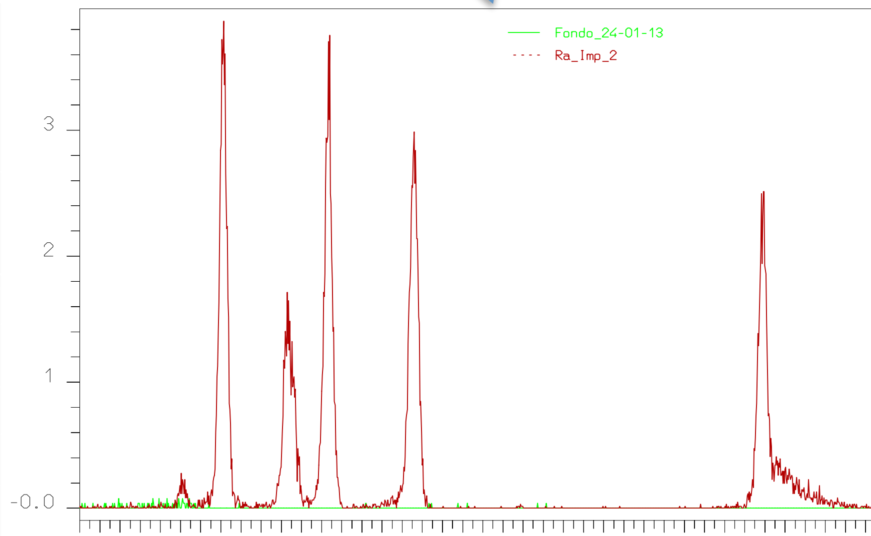


Result: a very shallow depth alpha source!

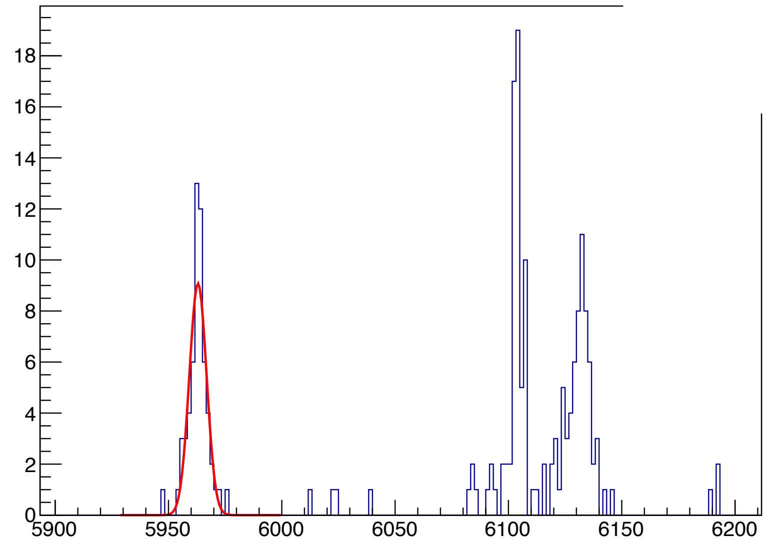
Spectra taken with Si barrier detector: resolution dominated by it

35 keV FWHM @ 5 MeV





Conclusions



On the market: very best intrinsic peak broadening of 20 keV

OUR source: 8.8 keV vs 5.0 keV for internal contamination peaks

DEFINITELY MUCH BETTER!

BUT... WE NEED THE ISOLDE PARENT SOURCE...

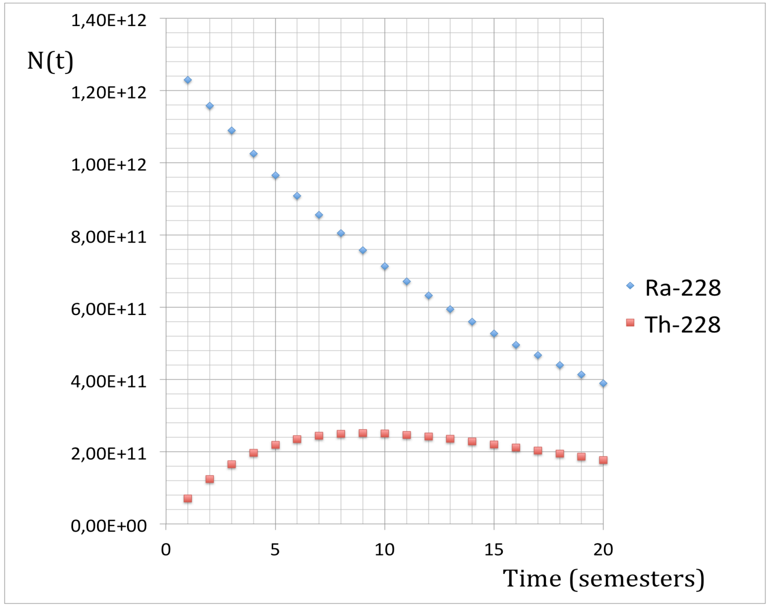
TO CONCLUDE

To produce a 5 kBq ^{228}Ra source, we ask for a UCx target with surface ionizer. The yield should be (ISOLDE database) 1.8e7 ions/μC and we assume here to get the proton current of at least 1μA.

We will ask for access to the SSC-GLM chamber and a beam energy of 10 kV

Requests/Suggestions from INTC-TAC

^{228}Th activity after irradiation



Some numbers...

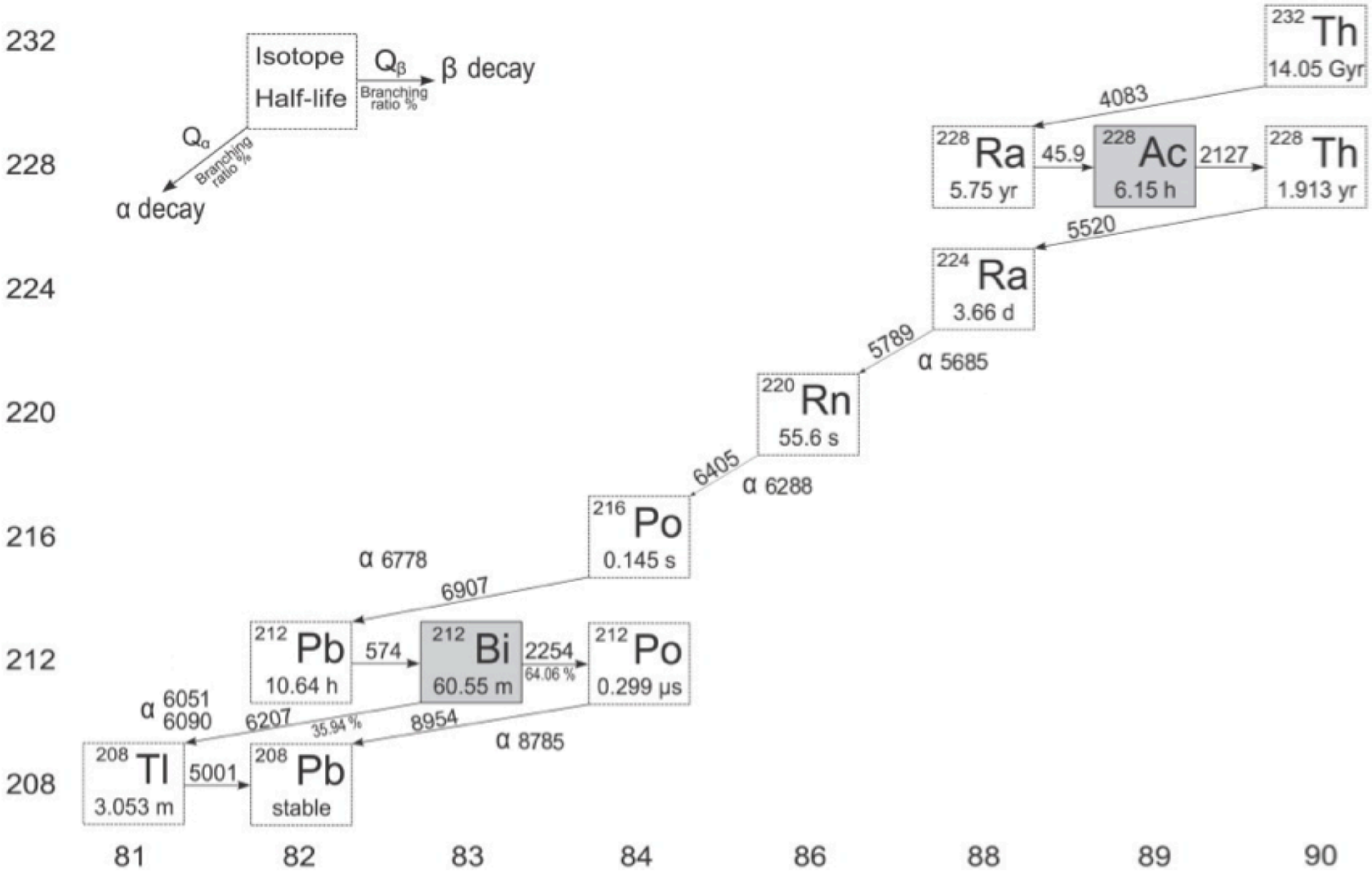
	Ra-228	Th-228	
At start time:	5 kBq	0 kBq	
After 1 month:	4.9 kBq	150 Bq	
After 6 months:	4.7 kBq	0.8 kBq	
After 2 years	3.9 kBq	2.3 kBq	← MAX tot activity
At max (4.5 y)	2.9 kBq	2.9 kBq	
After 16 y	0.7 kBq	1.0 kBq	

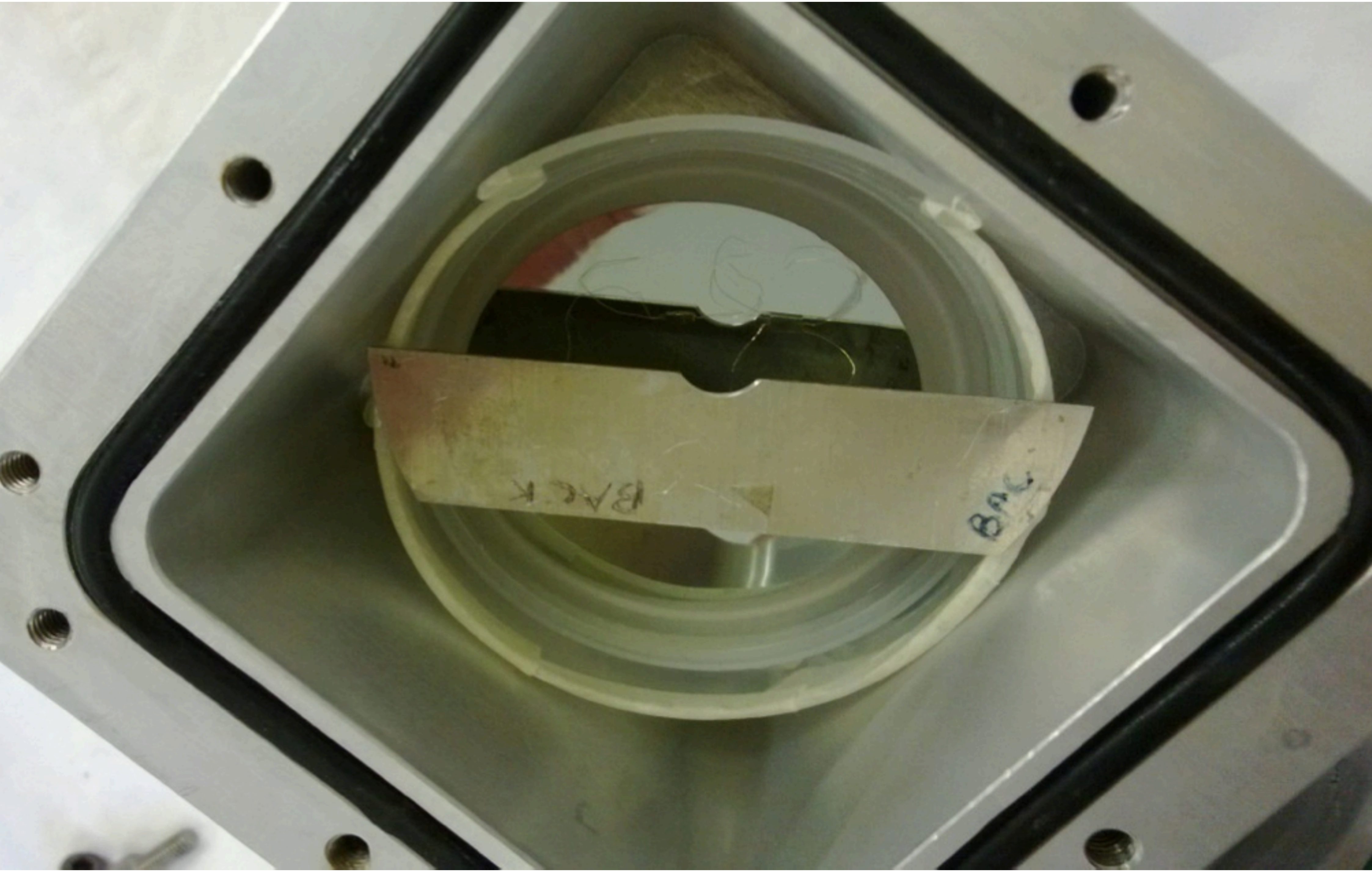
Consider ^{228}Fr

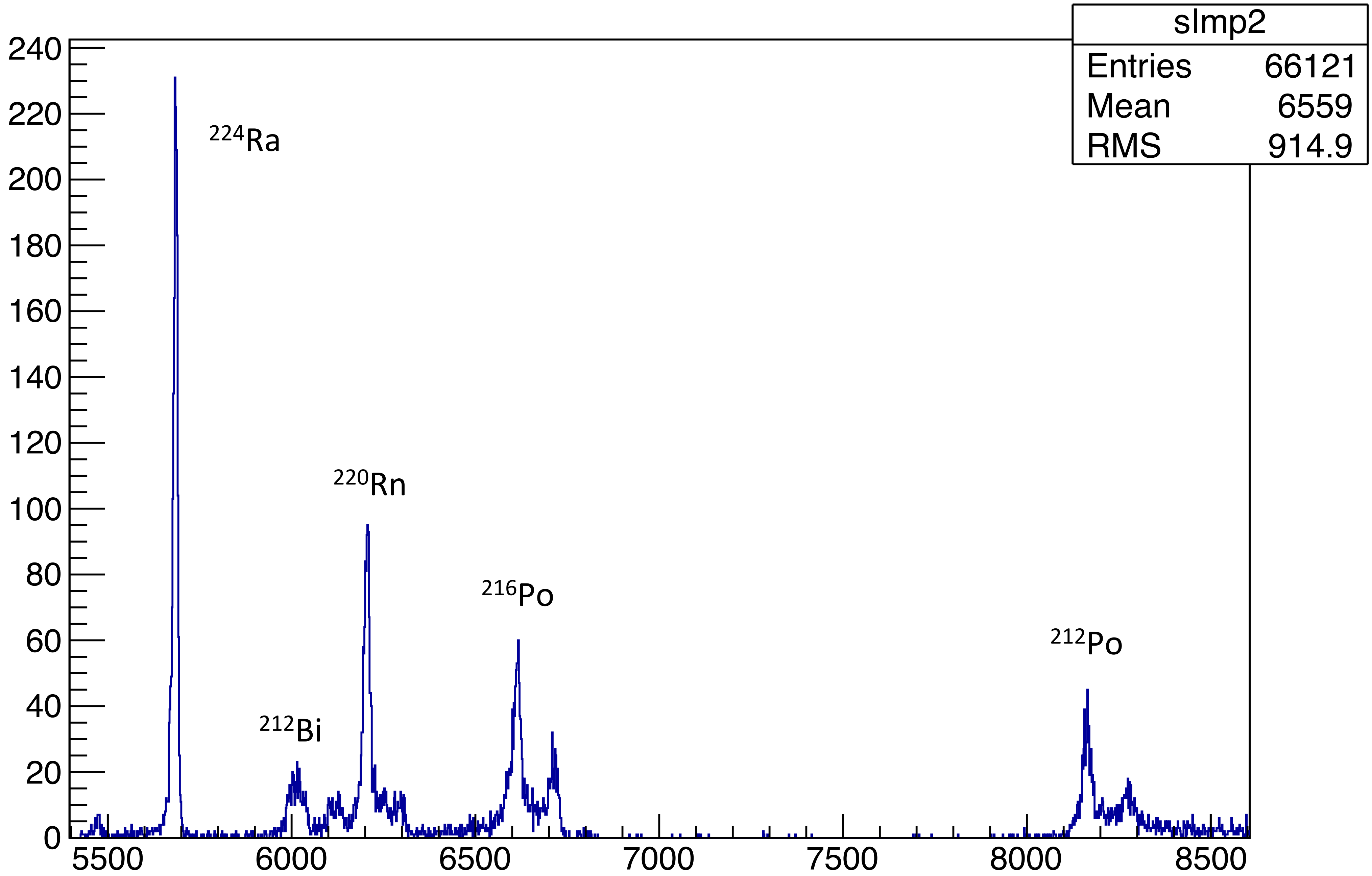
Taking into account that ^{228}Fr decays 100% pure β^- on ^{228}Ra with a halflife of 38 s and that the yield available in the ISOLDE database for it is 2e8 ions/μC (from SC data), instead of 1.8e7 ions/μC quoted for ^{228}Ra, we should be able to reduce consistently the required time of exposure. The target will be chosen consequently.

1 SHIFT WILL BE ENOUGH

Back-up slides


232
228
224
220
216
212
208
Isotope
Half-life
Qβ
Branching ratio %
β decay
Qα
Branching ratio %
α decay
232 Th
14.05 Gyr
4083
228 Ra
5.75 yr
45.9
228 Ac
6.15 h
2127
228 Th
1.913 yr
5520
224 Ra
3.66 d
5789
α 5685
220 Rn
55.6 s
6405
α 6288
216 Po
0.145 s
α 6778
6907
212 Pb
10.64 h
574
212 Bi
60.55 m
2254
64.06 %
212 Po
0.299 μs
α 6051
6090
6207
35.94 %
8954
α 8785
208 Tl
3.053 m
5001
208 Pb
stable
81
82
83
84
86
88
89
90


BACK
BAC



sImp2
Entries 66121
Mean 6559
RMS 914.9
224Ra
220Rn
216Po
212Bi
212Po
0
20
40
60
80
100
120
140
160
180
200
220
240
5500
6000
6500
7000
7500
8000
8500

TeO_2 bolometer parameters

Detector working temperature: T ~ 10 mK

Mixing chamber temperature: T_{MC} ~ 5 mK

Heat capacity of crystal: C ~ 2 x 10^{-9} J/K

Thermal conductance of thermal coupling to heat bath: G ~ 2 x 10^{-9} W/K

Time constant of bolometer: t ~ C/G ~ 1 s

Rise time of pulse: ~ 50 ms

Decay time of pulse: ~ 200 ms

Resistance of thermistor: R ~ 100 MΩ

$$R(T) = R_0 \cdot \exp[(T_0/T)_\gamma]$$

R_0: nominal values ~0.9-1.2 Ω

T_0: nominal values ~3-4 K

γ is considered to be = 0.5

A representative set of reasonable parameters that reproduces R ~ 100 MΩ is: R_0 ~ 1.1 Ω, T_0 ~ 3.35 K, γ = 0.5

Detector Response:

$\Delta V_{thermistor}$ ~ 0.3 mV/MeV

$\Delta R_{thermistor}$ ~ 3 MΩ/MeV

$\Delta T_{thermistor}$ ~ 0.03 mK/MeV

$\Delta T_{crystal}$ ~ 0.1 mK/MeV