A ^{220}Rn source for internal calibration of next-generation low-background detectors

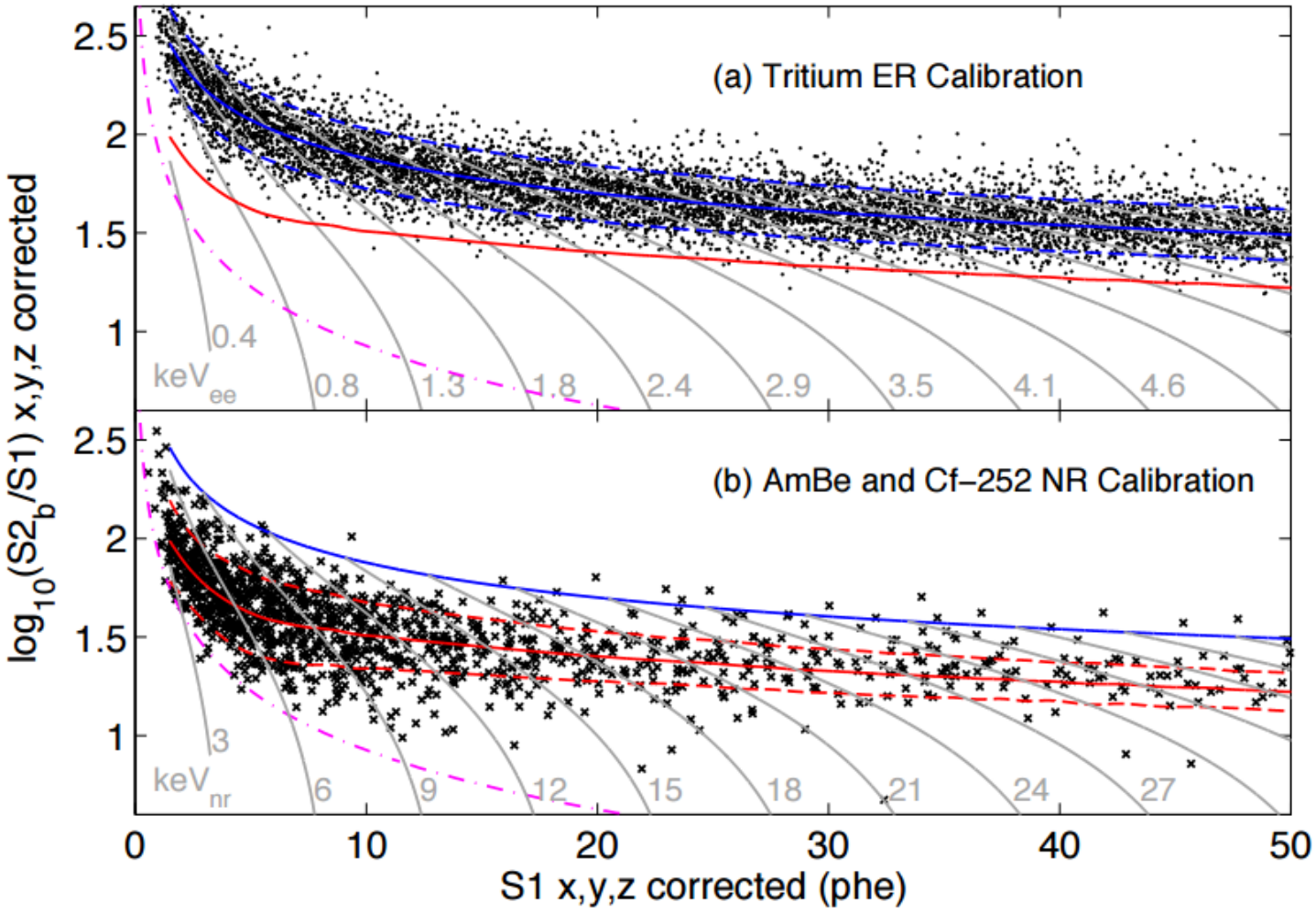
Darryl Masson, Purdue University

dmasson@purdue.edu

September 25, 2015. LOWECAL 2015

NR/ER band calibration

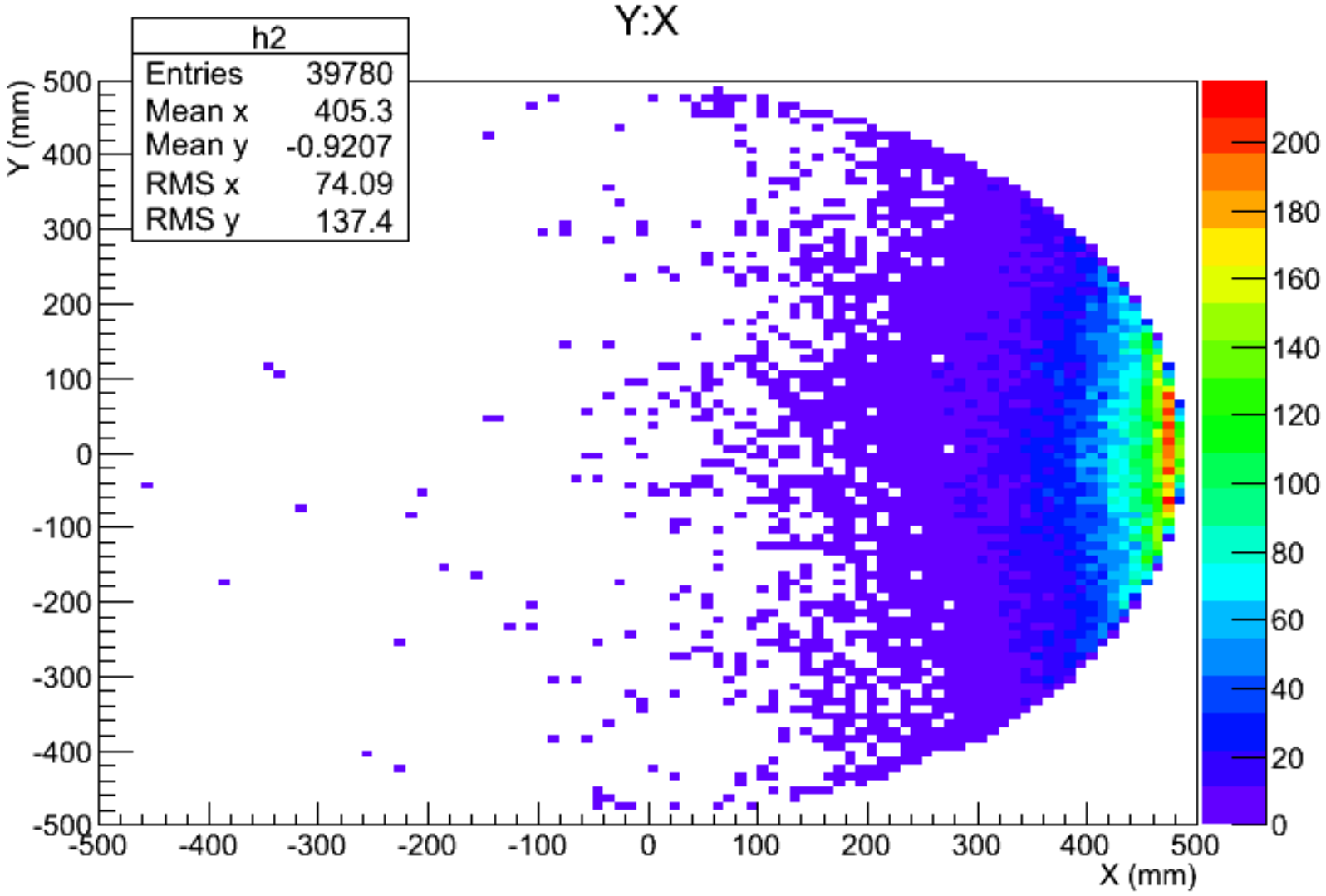
- Nuclear and electronic recoil discrimination necessary to pick signals out of backgrounds
- Need good statistics



LUX: 1310.8214

Out with the old…

- External gamma sources no longer probe the entire fiducial volume of larger detectors



… In with the new

Internal β^- source provides an equivalent spectrum to Compton scatters from an external source

Requirements:

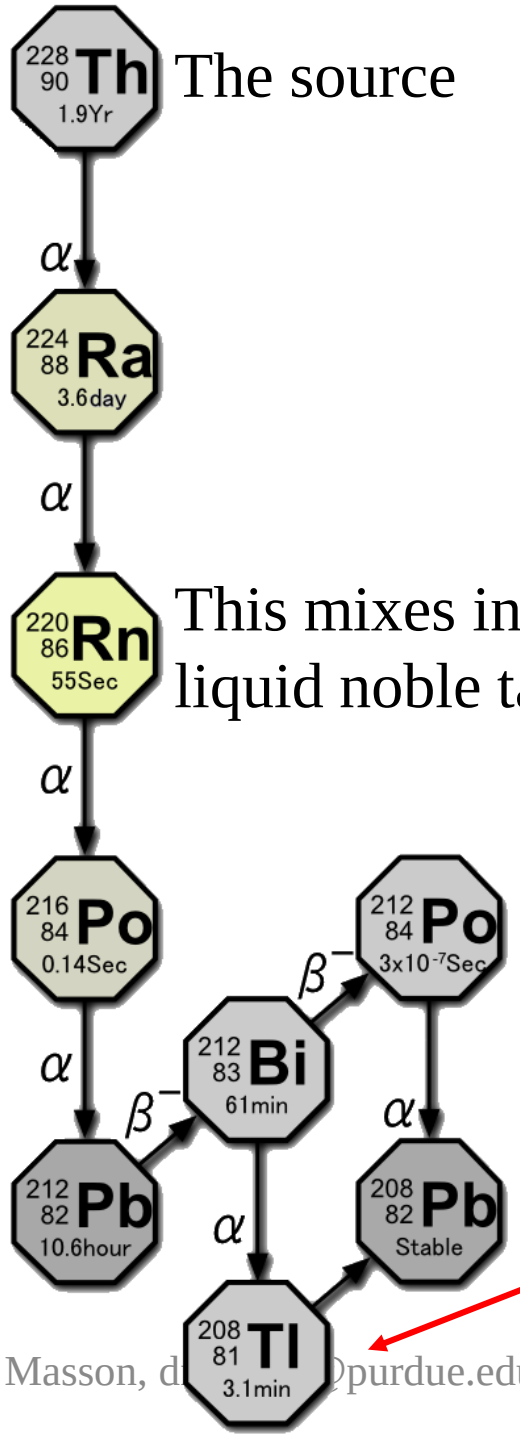
- Get it in
  - Noble element
  - Hitchhike on contaminant
- Do something useful
  - β decays to ground state
- Get it out
  - Decay
  - Purification

Which one, which one?

Isotope	Q-value [keV]	% to GS	Half-life	Advantages	Disadvantages
^{37}Ar (ec)	814	100	35 d	2 keV X-ray, Auger e^-	Line source
^{83m}Kr (IT)	41.6	-	1.83 hr	Decays away, 32.2 & 9.4 keV γ	Line source
^{3}H	18.6	100	12.3 yr	Every decay useful	Long half-life
^{14}C	156	100	5700 yr		Very long half-life
^{39}Ar	565	100	269 yr		Large Q, long half-life
^{85}Kr	687	>99	10.7 yr		Large Q, long half-life
^{212}Pb (^{220}Rn)	560	12	10.66 hr	Decays away, decays from daughters	Large Q, low BR, decays from daughters

^{228}Th chain

Whole chain after ^{220}Rn dominated by half-life of ^{212}Pb (10.66 hr); introduced activity decays in a week



The source

Picture from Wikipedia

This mixes into the liquid noble target

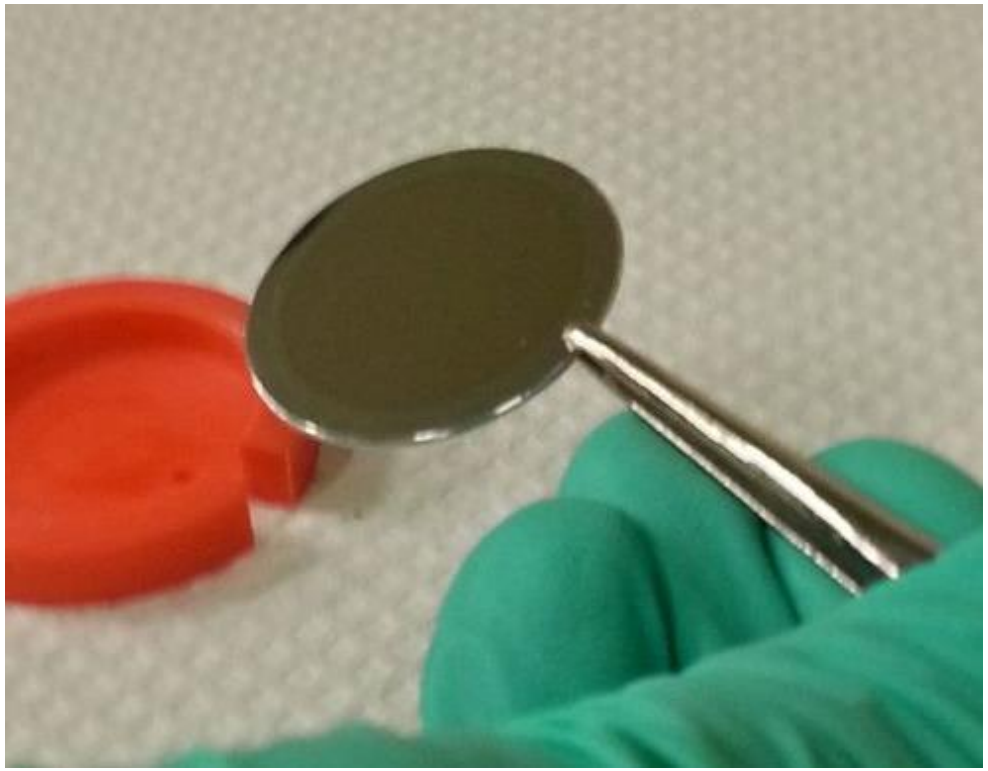
Background-free way of measuring activity

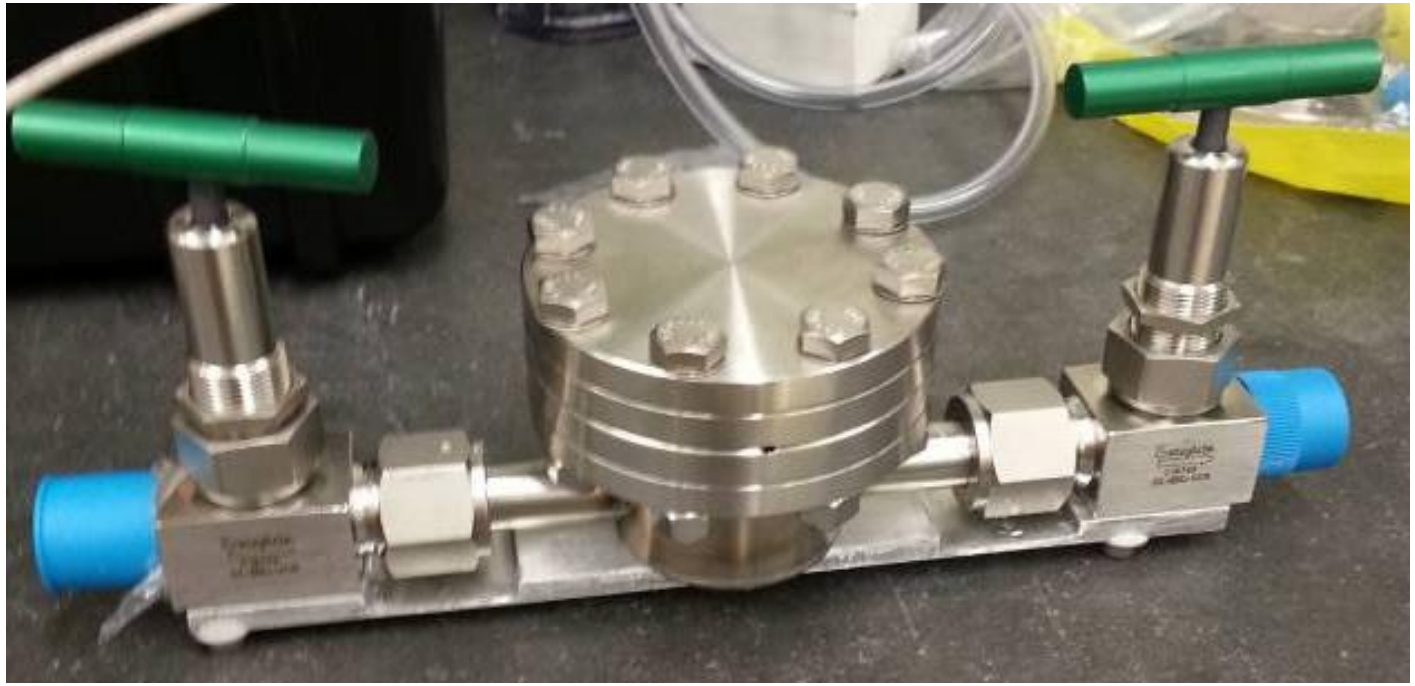
GS β decays for DM detector calibration

2.6 MeV γ line, useful for calibrating Q-value for ^{136}Xe ββ (2458 keV) (e.g. EXO)

^{228}Th Source

- Electroplated $Th(NO_3)_4$ onto a 30mm SS disk.
- ~70 kBq when produced at PTB

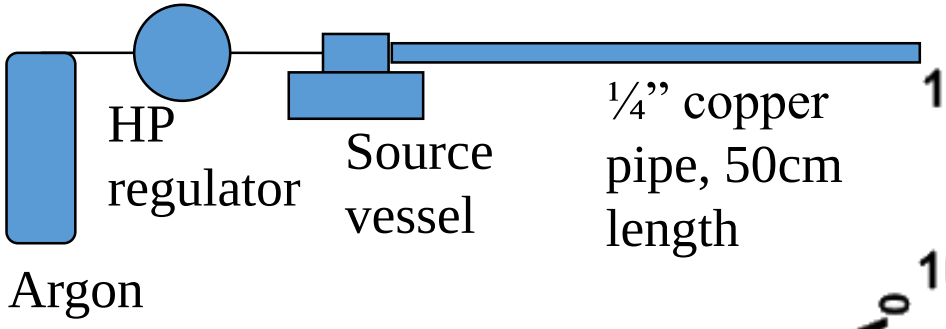




Emanation test: TÜV, Germany

- Nitrogen recirculation for 96 hours through a filter
- Filter paper tested for gamma activity with Ge counter immediately after exposure and again a week later
- Emanation limits:
- $^{228}Th < 19\ s^{-1}$ ($< 0.22\ \mu Bq/s$)
- $^{224}Ra < 0.4\ s^{-1}$ ($< 0.88\ \mu Bq/s$)

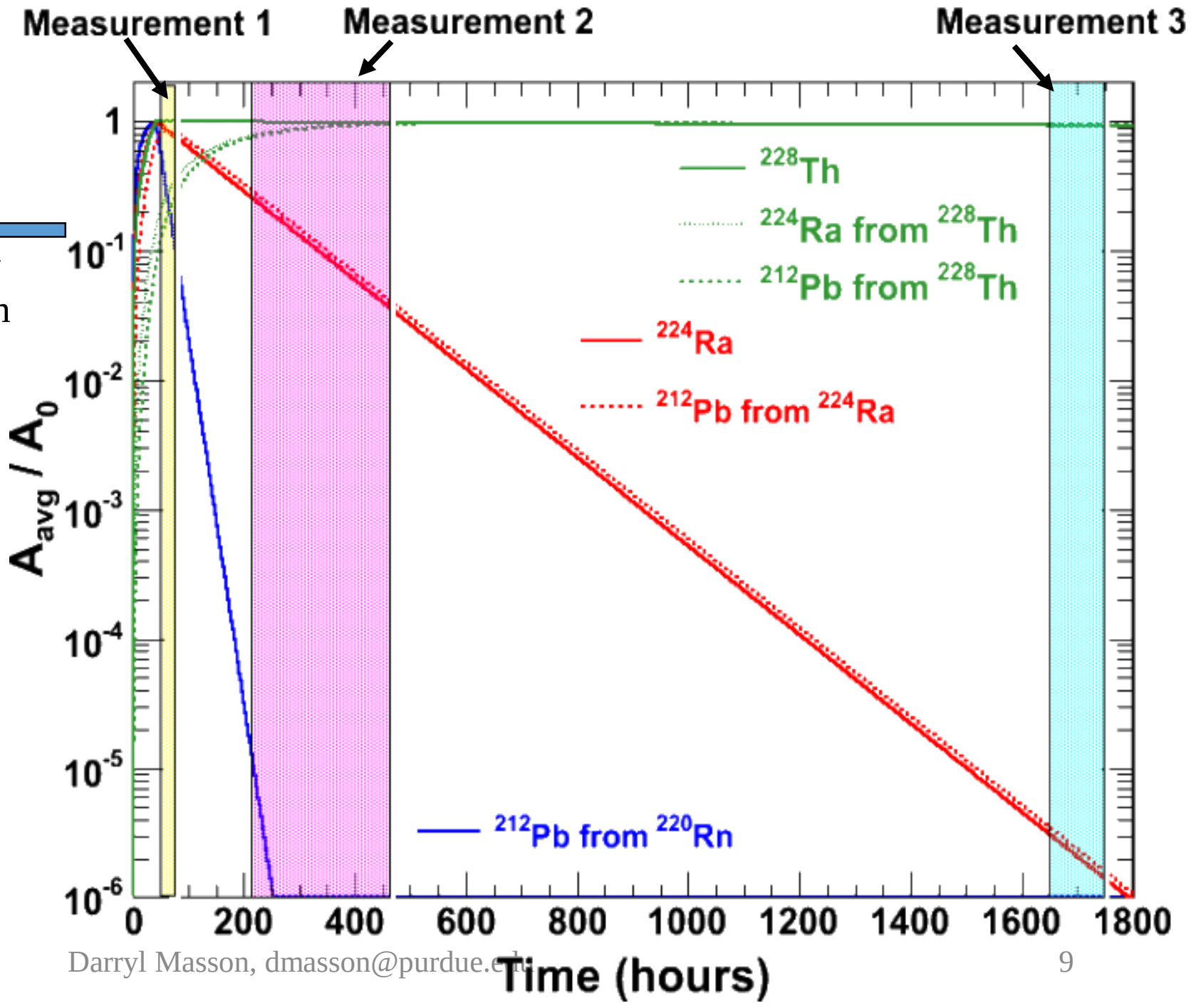
Plate-out test



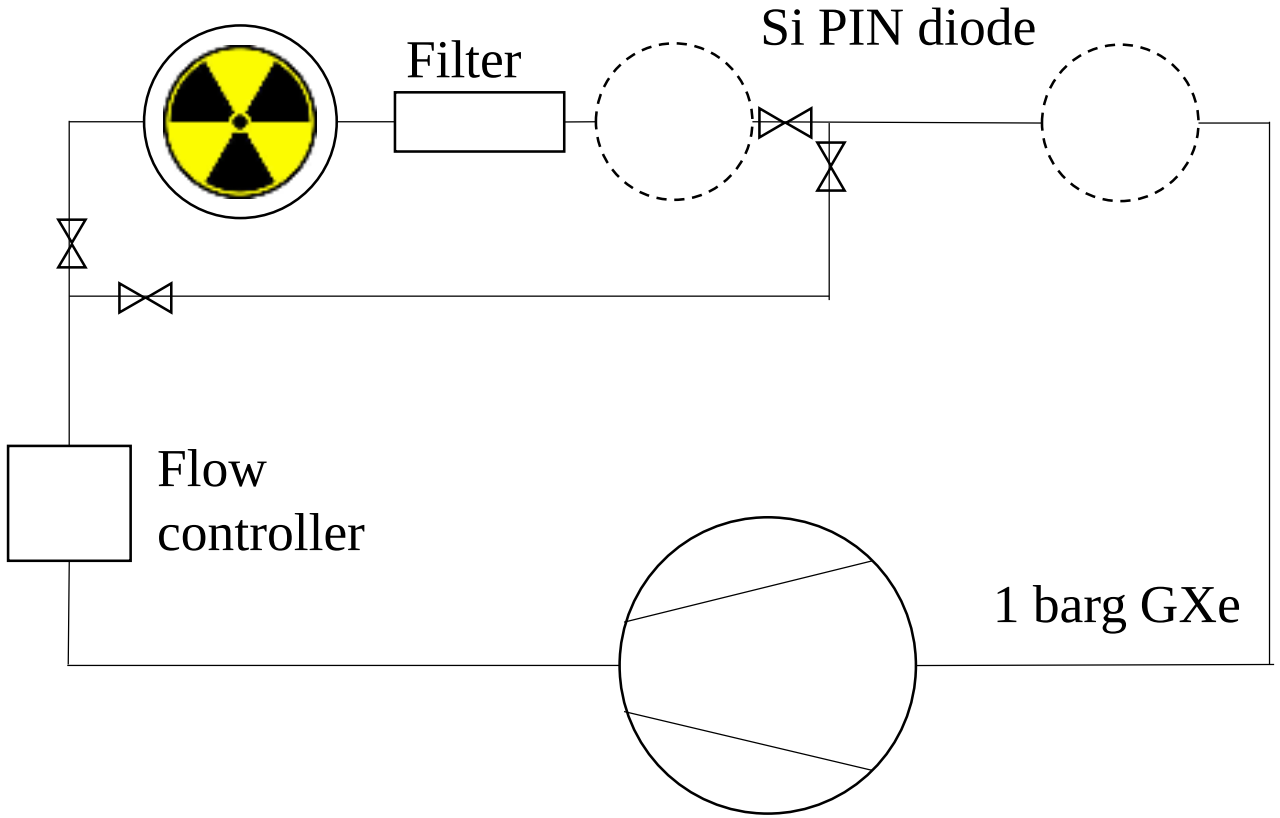
41 hours flushing, ~6 slpm
Measurements done with
Heidelberg’s Ge detectors

^{228}Th < 54 s^{-1} (0.61 μBq/s)
^{224}Ra = 8(1) s^{-1} (14.7 μBq/s)

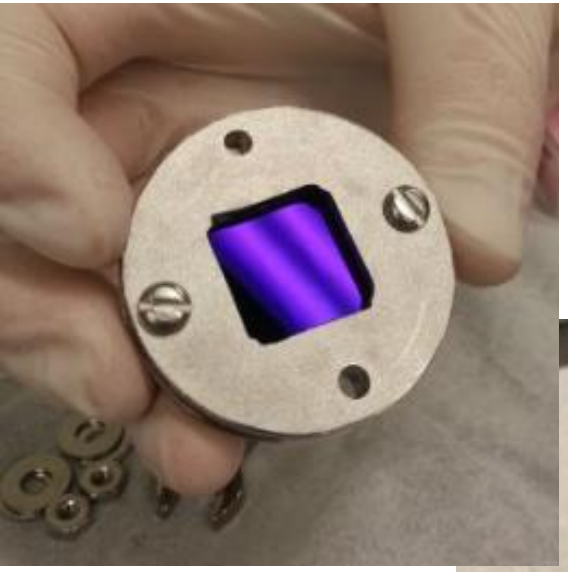
=> Some filtration necessary

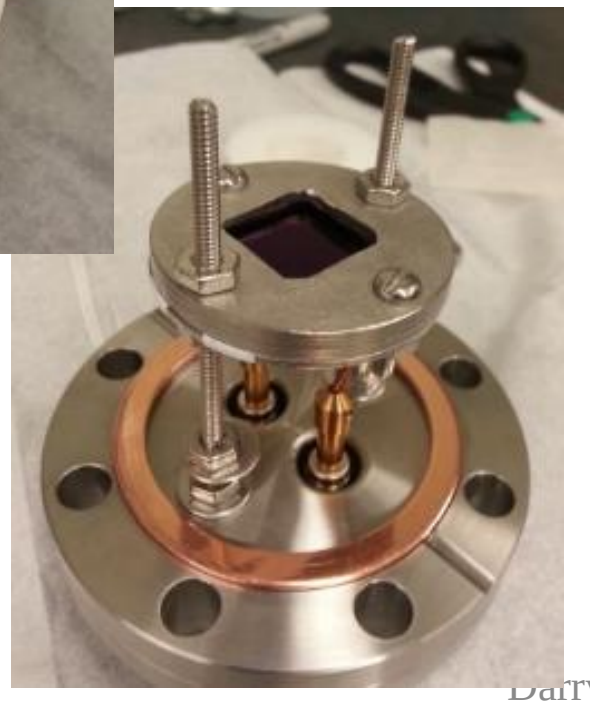


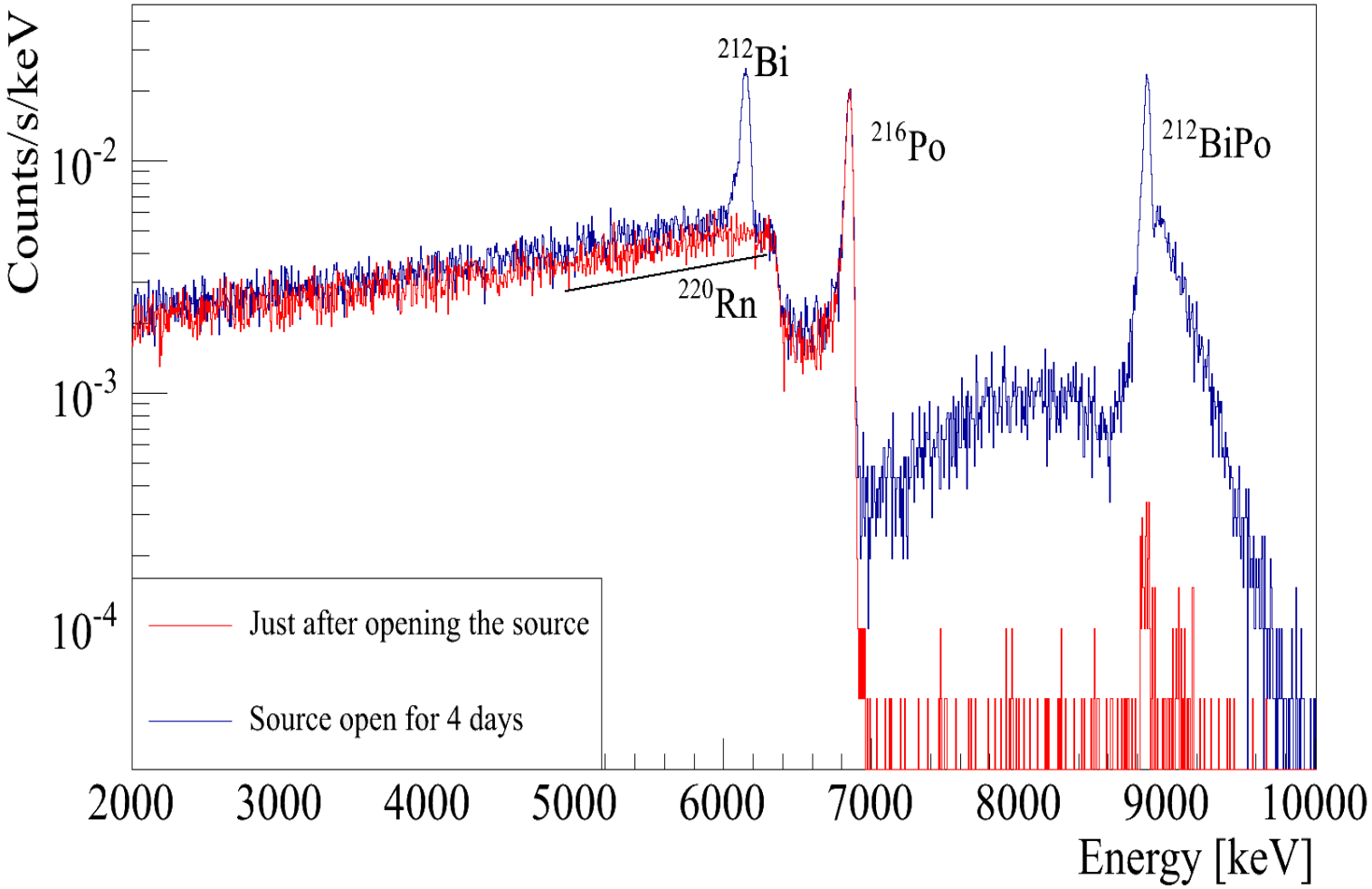
Filter efficacy: setup



Si PIN Diode

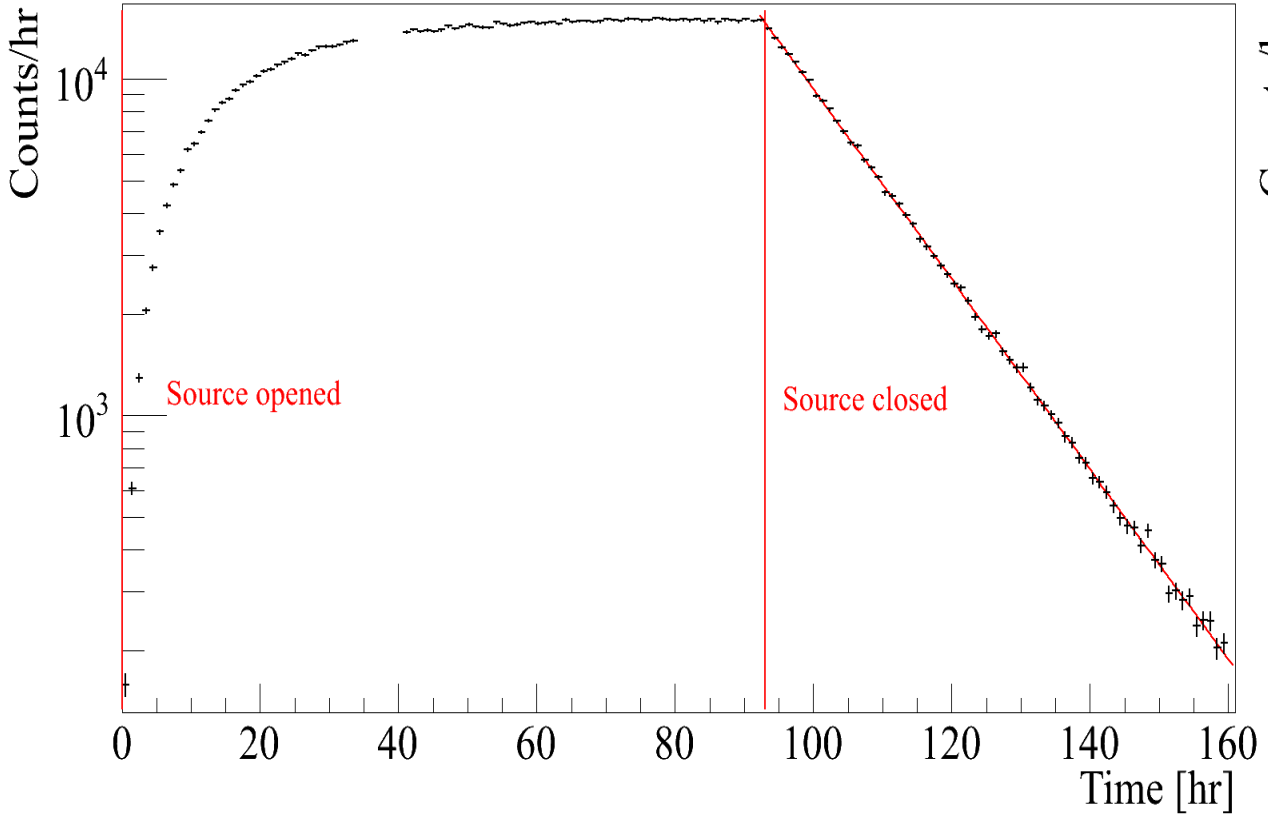


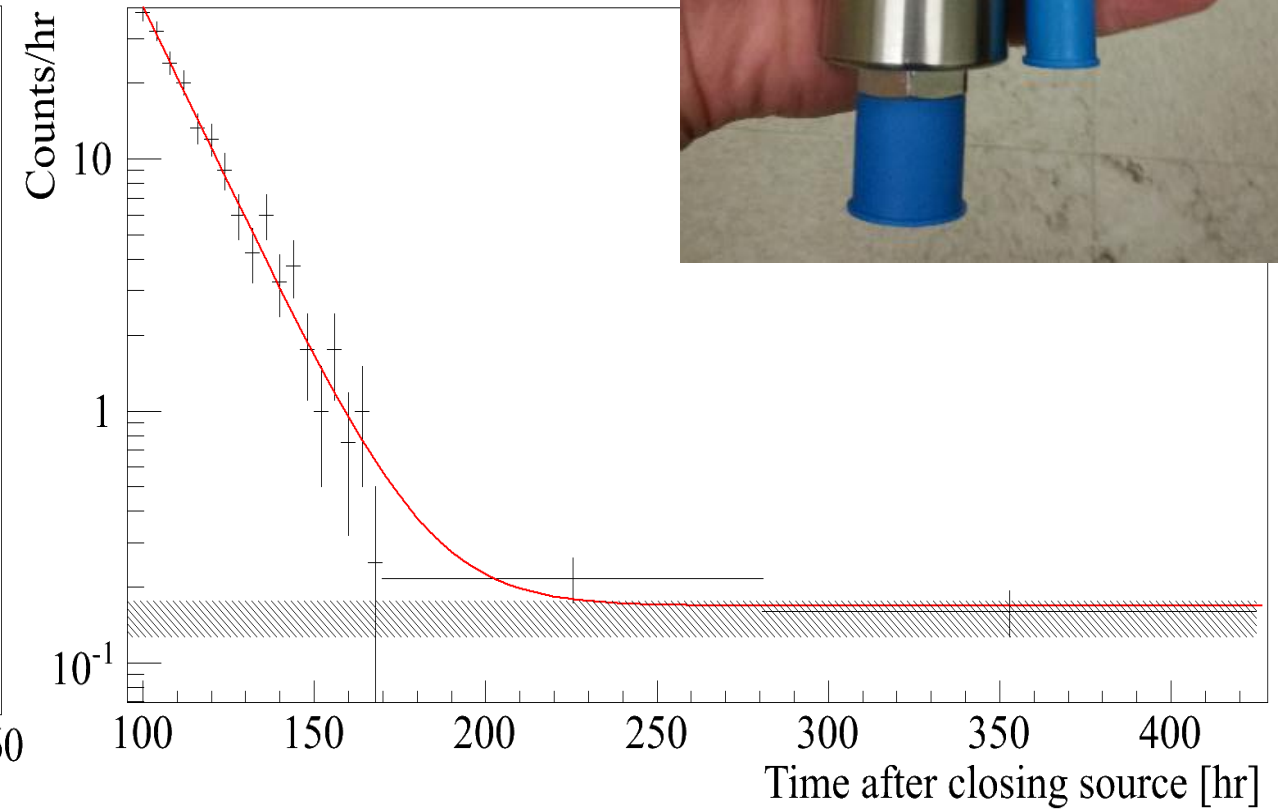



Counts/s/keV
10^{-2}
10^{-3}
10^{-4}
^{212}Bi
^{216}Po
^{212}BiPo
^{220}Rn
Just after opening the source
Source open for 4 days
2000
3000
4000
5000
6000
7000
8000
9000
10000
Energy [keV]

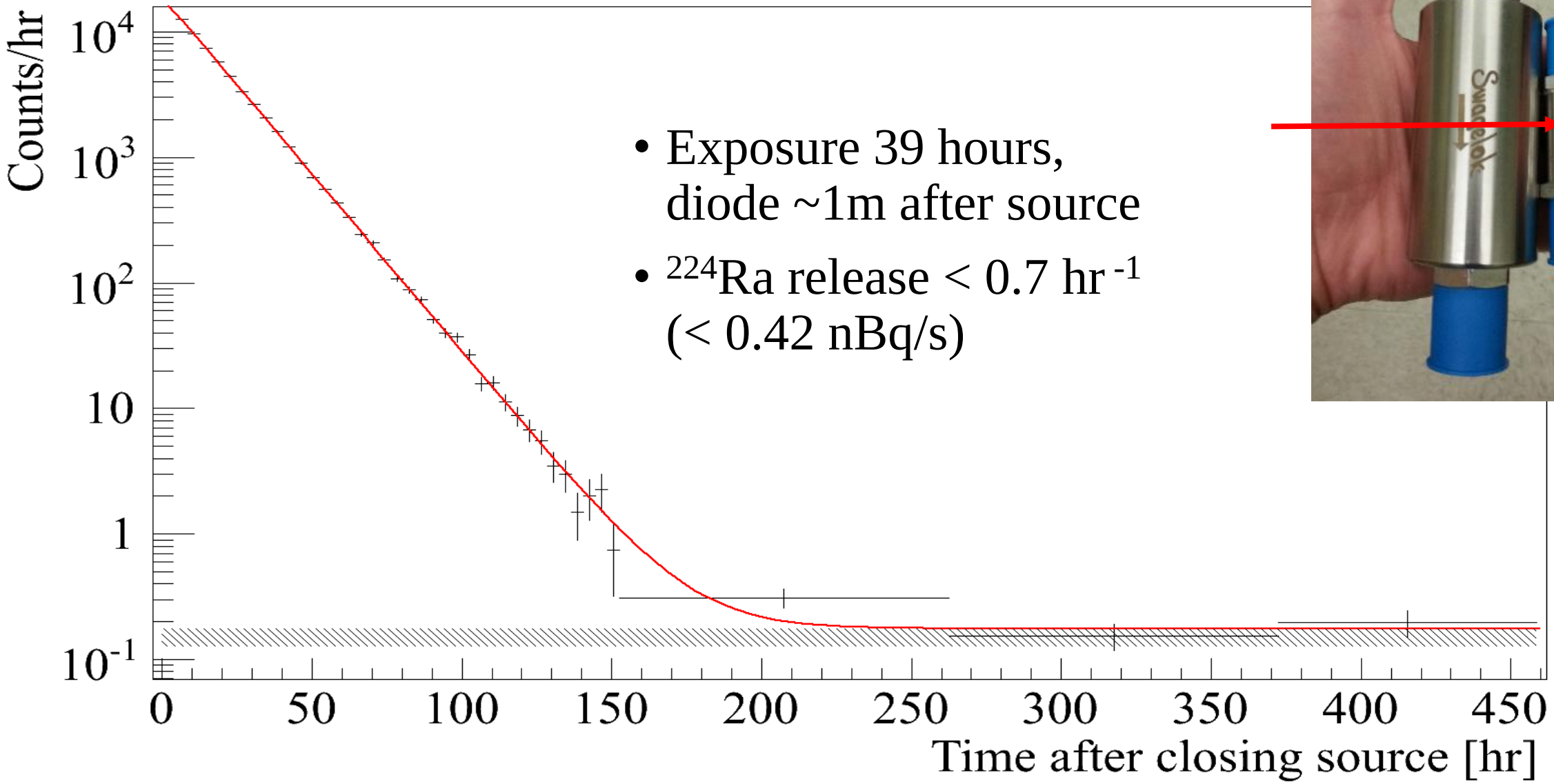
Ceramic filter

- Exposure 93 hours, diode immediately after source
- ^{224}Ra release < 0.2 hr^{-1} (< 0.12 nBq/s)





Sintered filter



- Exposure 39 hours, diode ~1m after source
- ^{224}Ra release < 0.7 hr $^{-1}$ (< 0.42 nBq/s)

In Summary

- ^{212}Pb works for ER band calibration
- ^{220}Rn mixes readily with noble gas stream
- < 12 hour half-life means it goes away in a week, assuming you filter out the long-lived parent isotopes

Backup

^{212}Pb β spectrum

- Events < 20 keV of interest (~1% of total)
- All events contribute to trigger rate, DAQ saturation possible