An Ar-gas ionization chamber for alpha particle detection at the Yangyang underground laboratory.


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Motivation for a high sensitivity alpha counter

- Raw material assay via alpha counting, especially for NaI-Powder, CaMoO-Powder used in the dark matter (COSINE) and neutrinoless double beta decay (AMoRE) experiments.

  - Levels of radioactivies (U/Th/Pb) in your detector (grown crystal) often directly translate to the levels in the raw material (powder).

  - Detector components (Lead, Copper, and so on) need to be screened.

- Combined with other techniques such as ICP-MS (U/Th) and HPGe (K) measurements, a complete assay program can be established.

  - The alpha counter is crucial to understand the radio-purity for the Po-210 alpha decay (Pb-210).
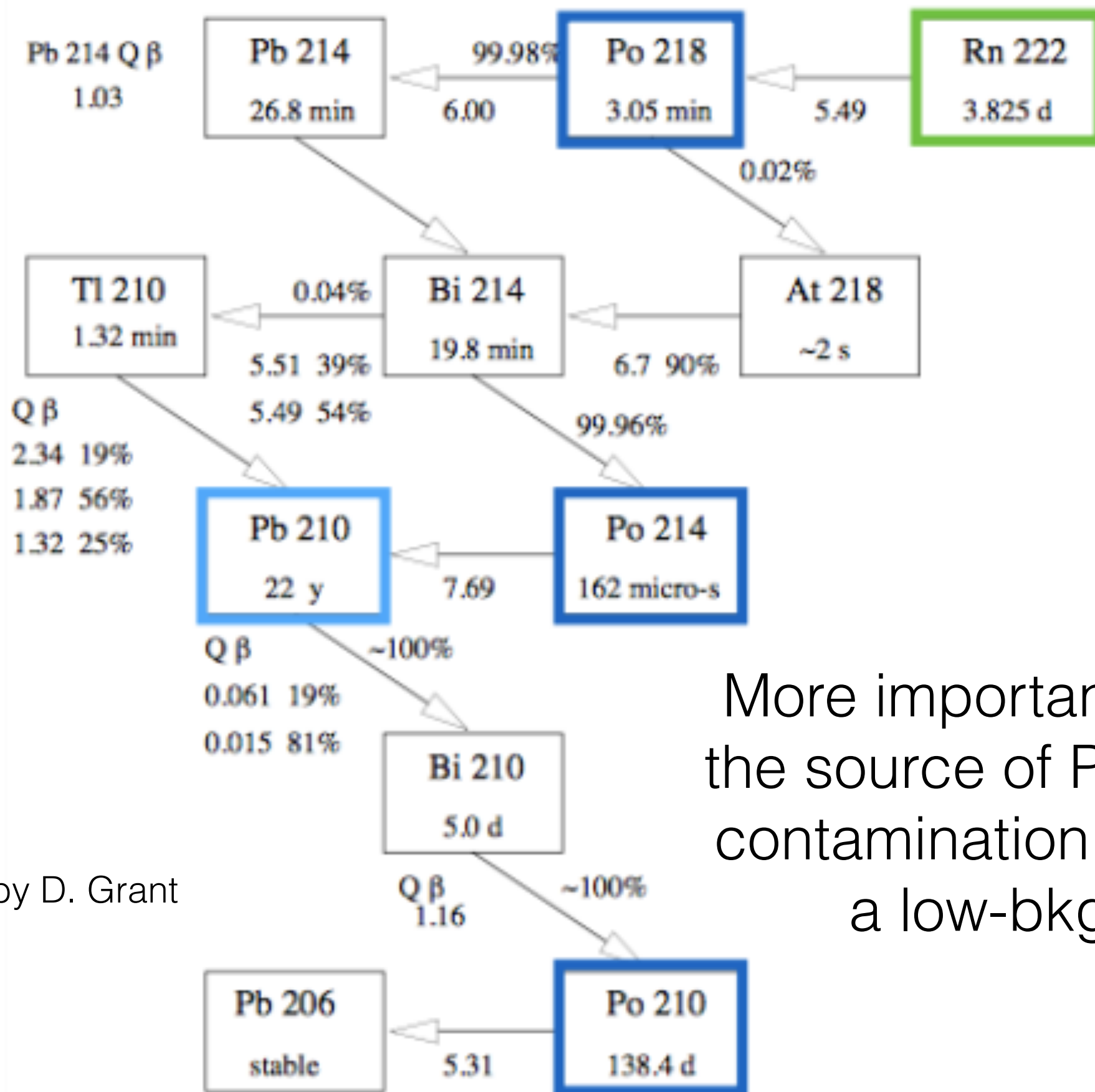
Trouble with Pb-210 …
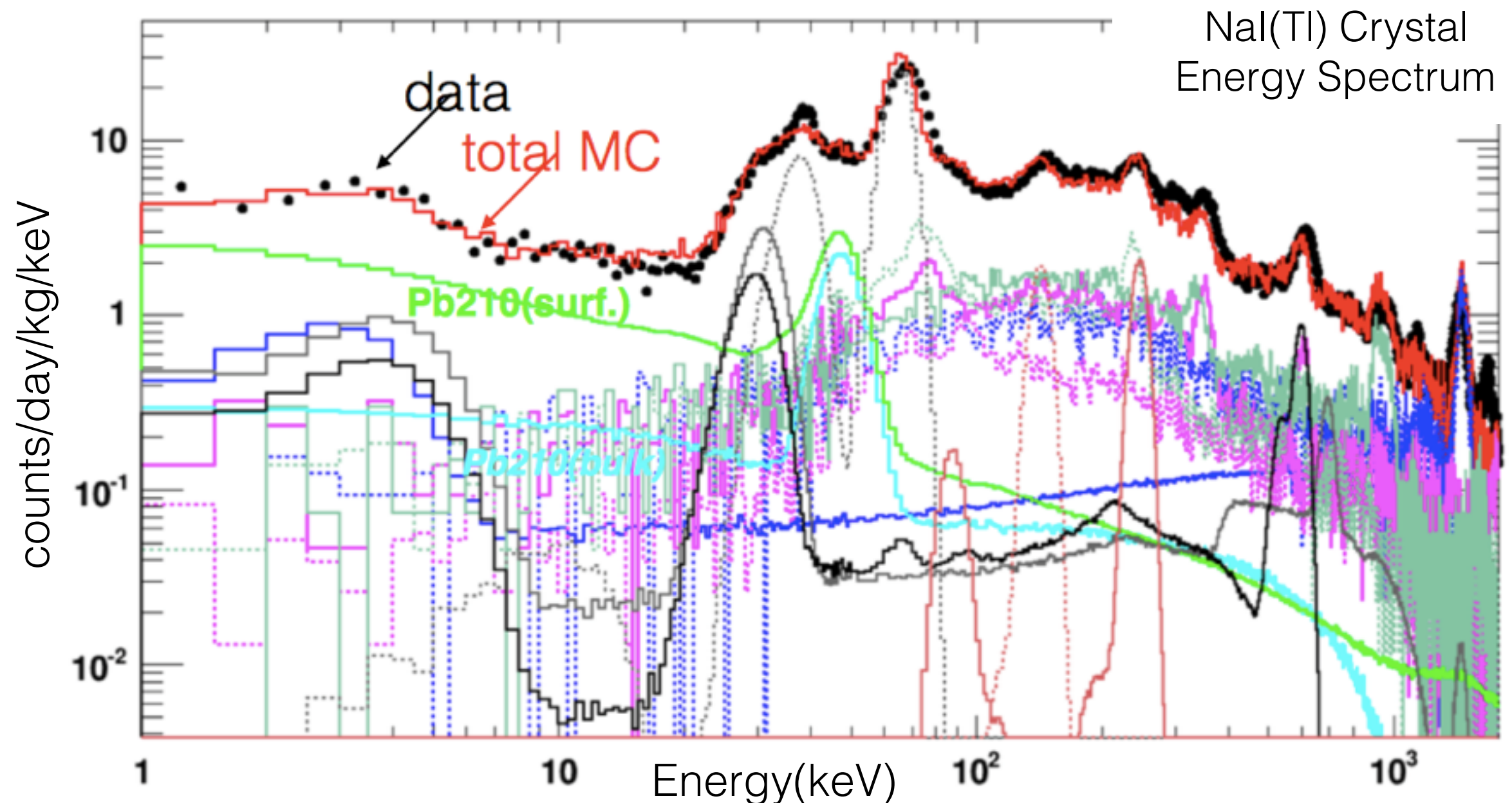
At lowest energies, Pb-210 bkg. is a main source.
Where the contamination is (bulk or surface) is also important.
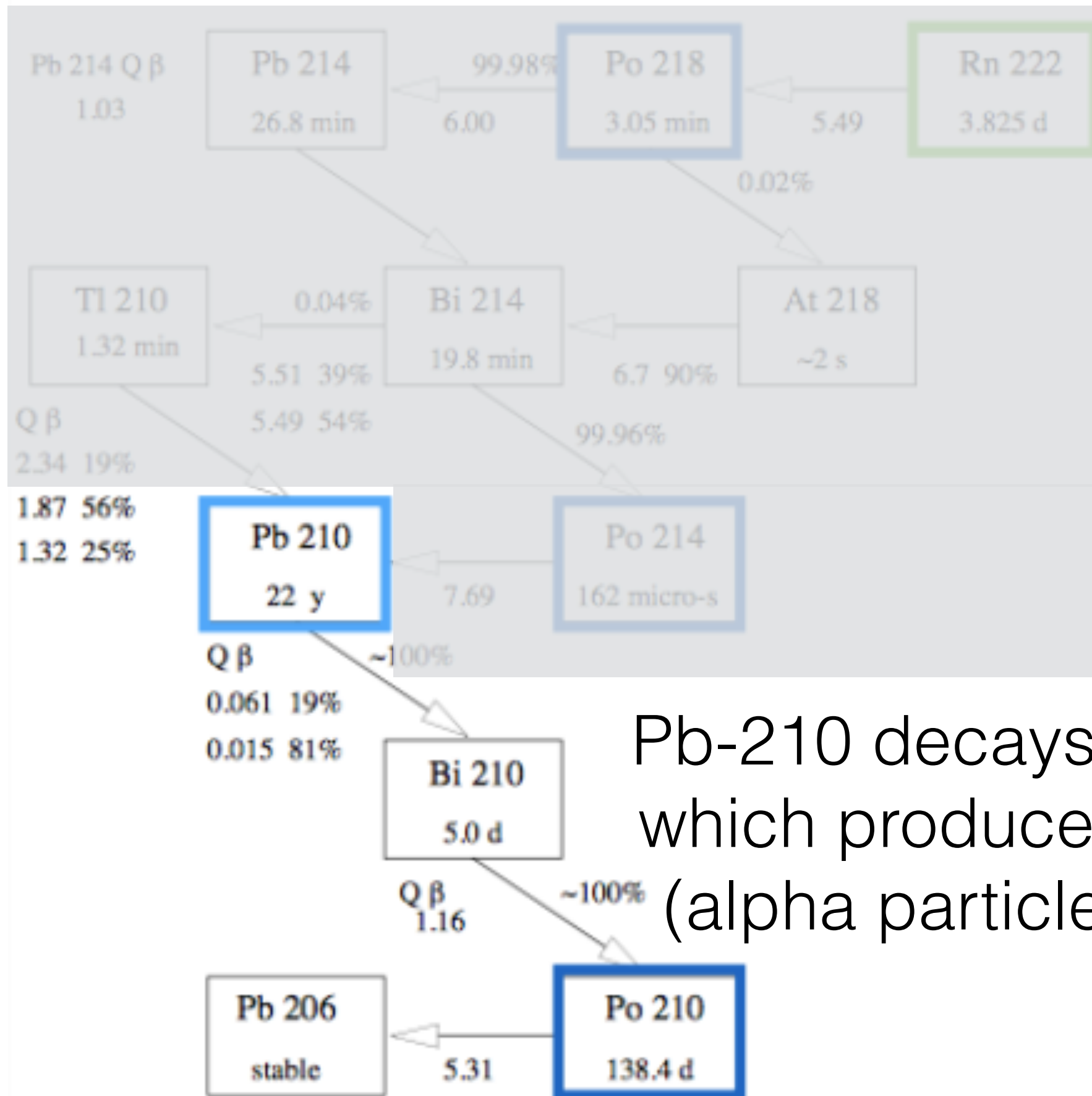
Pb-210 decays down to Po-210 which produces 5.3 MeV alpha (alpha particle measurement)

Pb 214 Q β
1.03

| Pb 214 | | Po 218 | | Rn 222 |
| 26.8 min | 6.00 | 3.05 min | 5.49 | 3.825 d |

99.98%

0.02%

Tl 210
1.32 min

Bi 214
19.8 min

At 218
~2 s

0.04%

6.7 90%

5.51 39%
5.49 54%

Q β
2.34 19%
1.87 56%
1.32 25%

99.96%

Pb 210
22 y

Po 214
162 micro-s

7.69

Q β
0.061 19%
0.015 81%

~100%

Bi 210
5.0 d

Q β
1.16

~100%

Pb 206
stable

Po 210
138.4 d

5.31

by D. Grant

More importantly, understanding the source of Pb-210, e.g. Rn-222 contamination, is often critical for a low-bkg. experiment.

Ultra low background Materials
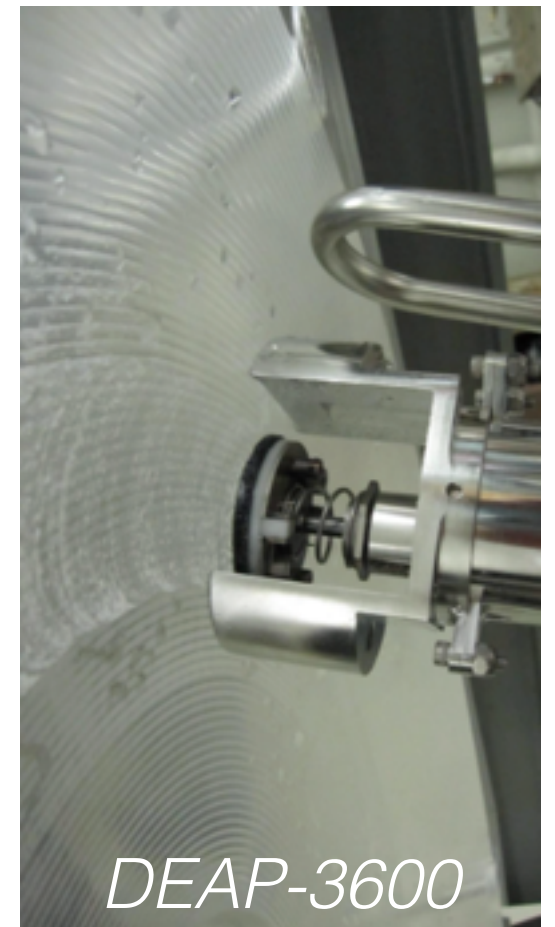

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Underground Cu forming

Ph.D. thesis A. Fard
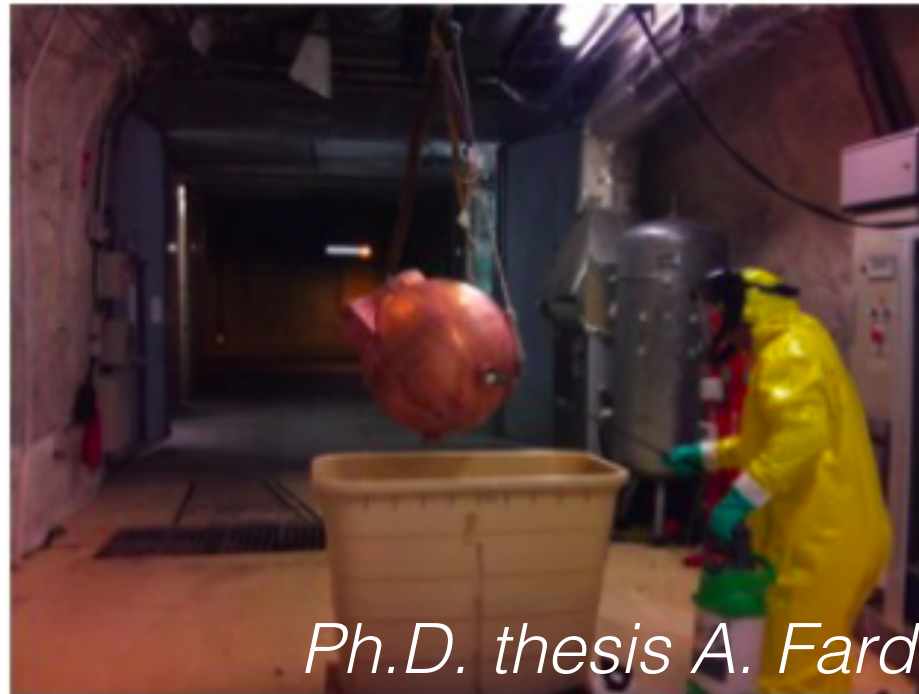
Chemical Cleaning

DEAP-3600

Mechanical Surfacing

D. Grant (IDM16)
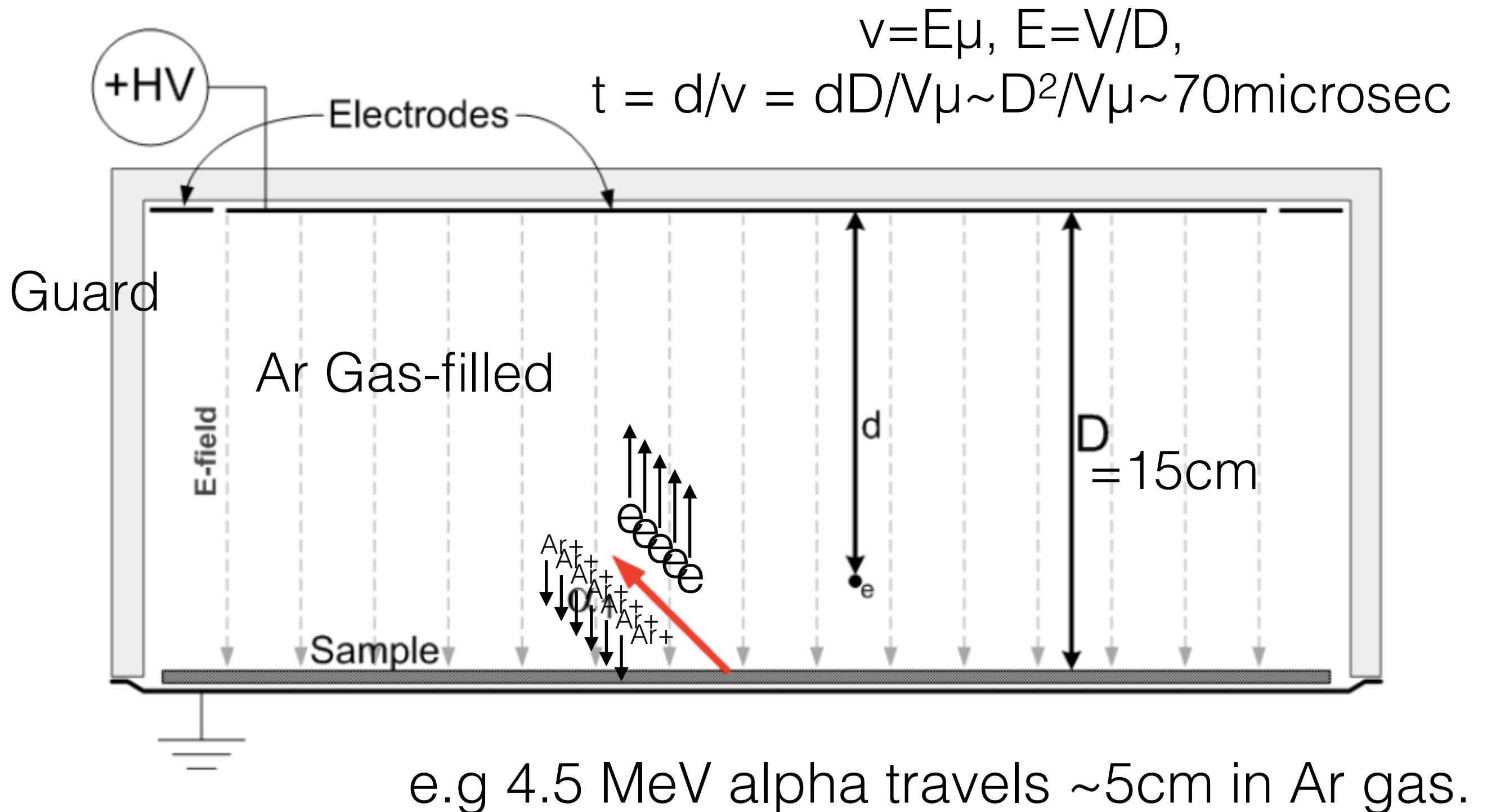
Rn-reduced clean room

- Selecting/Fabricating Low-bkg. materials

- Chemical/Mechanical cleaning of the materials

- Measurement of the materials

    - (HPGe, Rn monitor, alpha counter, ICP-MS …)
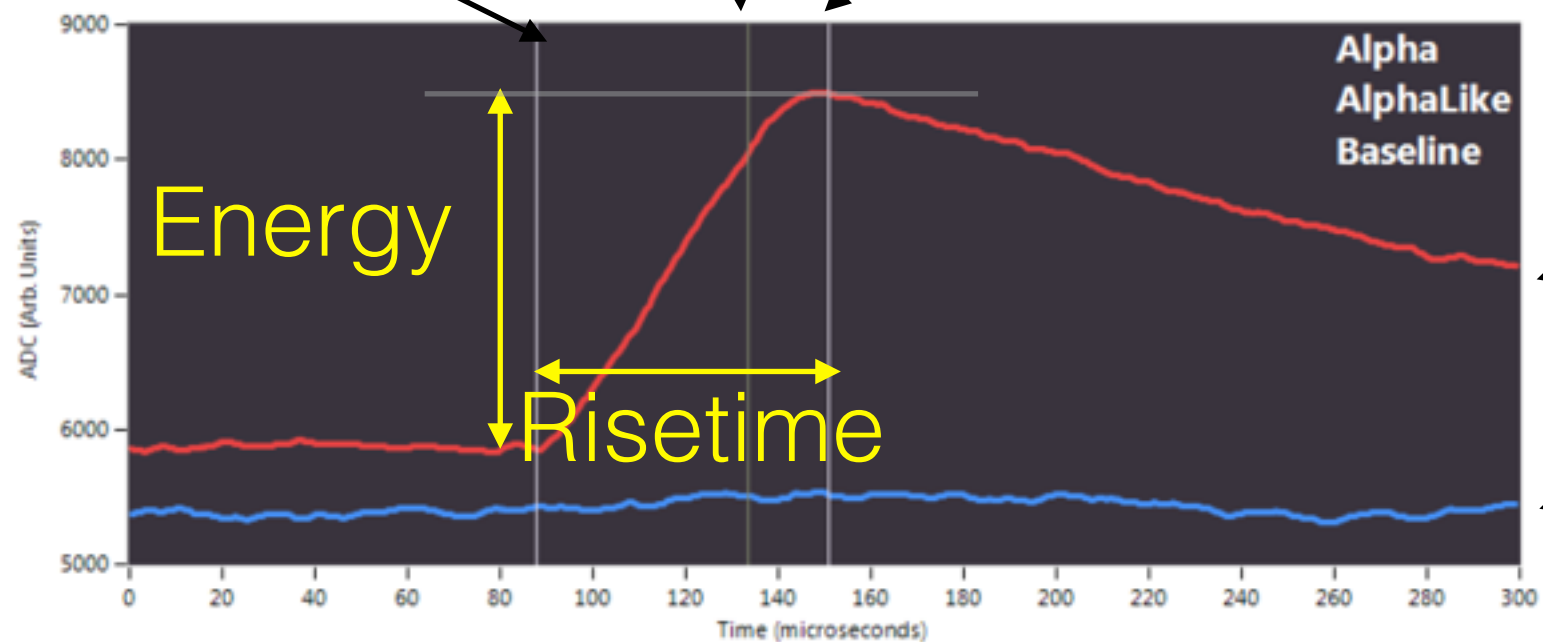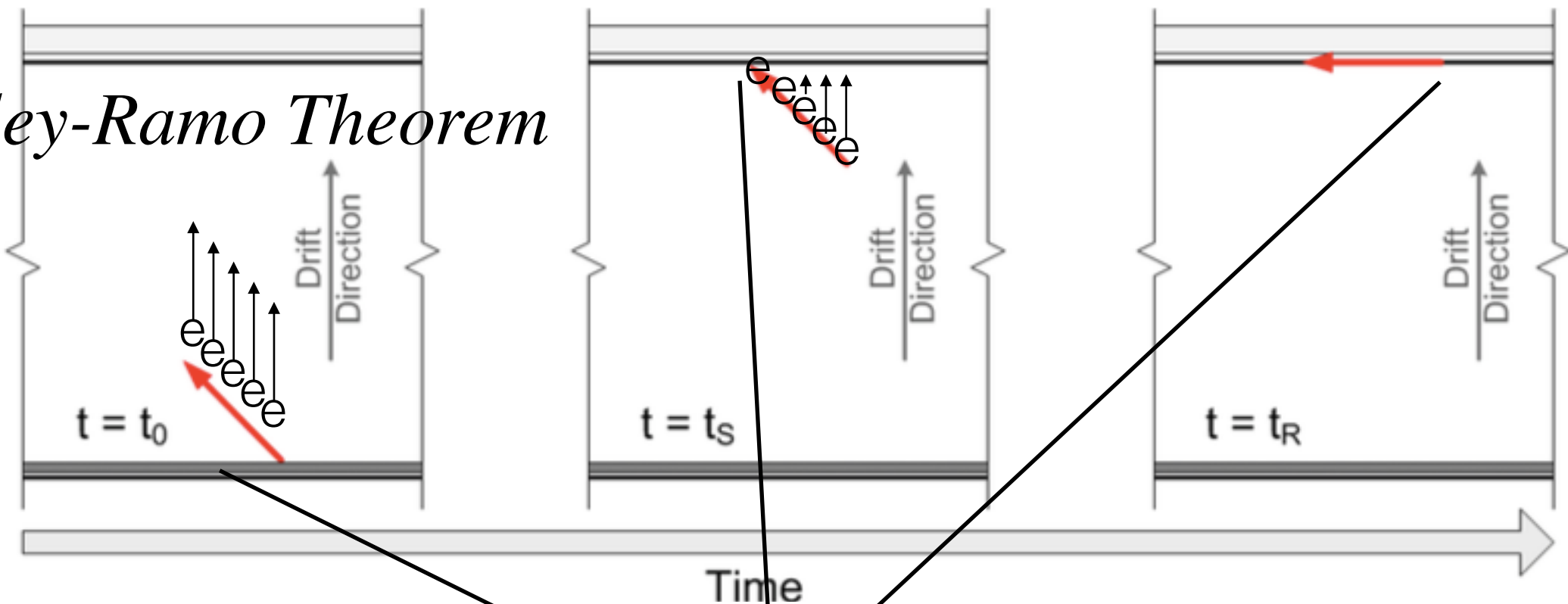
Ionization Chamber Overview

$v = E\mu$, $E = V/D$,
$t = d/v = dD/V\mu \sim D^2/V\mu \sim 70$ microsec

+HV

Electrodes

Guard

Ar Gas-filled

E-field

d

D = 15cm

$Ar+$

Sample

e.g 4.5 MeV alpha travels ~5cm in Ar gas.

Shockley-Ramo Theorem

-Induced current is proportional to speed of drift electrons

Shockley-Ramo Theorem

$i=Eqv$

t = t₀ → $t = t_0$

Drift Direction

t = tₛ → $t = t_S$

Drift Direction

t = tᵣ → $t = t_R$

Drift Direction

Time

Energy

Risetime

Alpha
AlphaLike
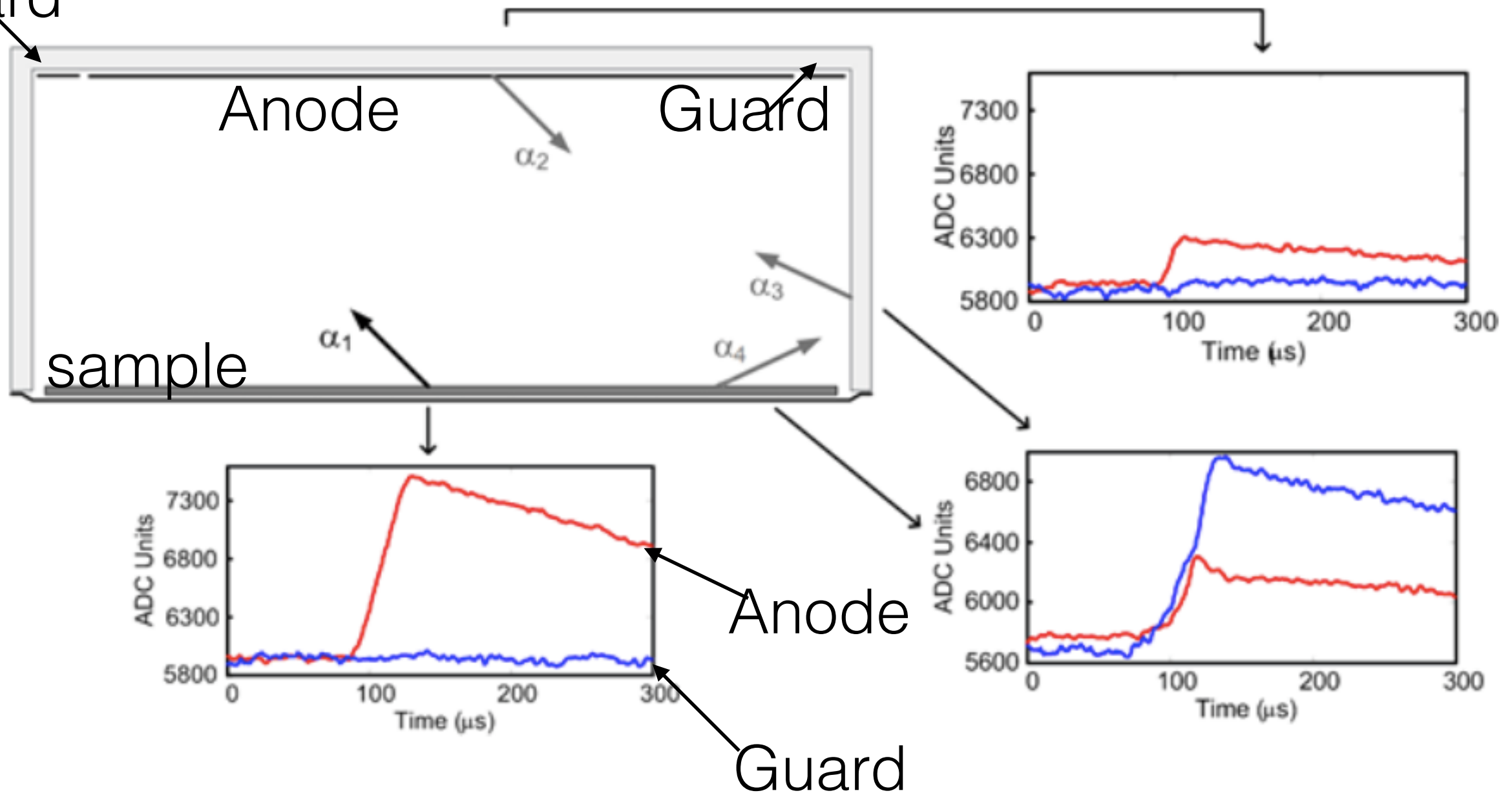Baseline

Anode
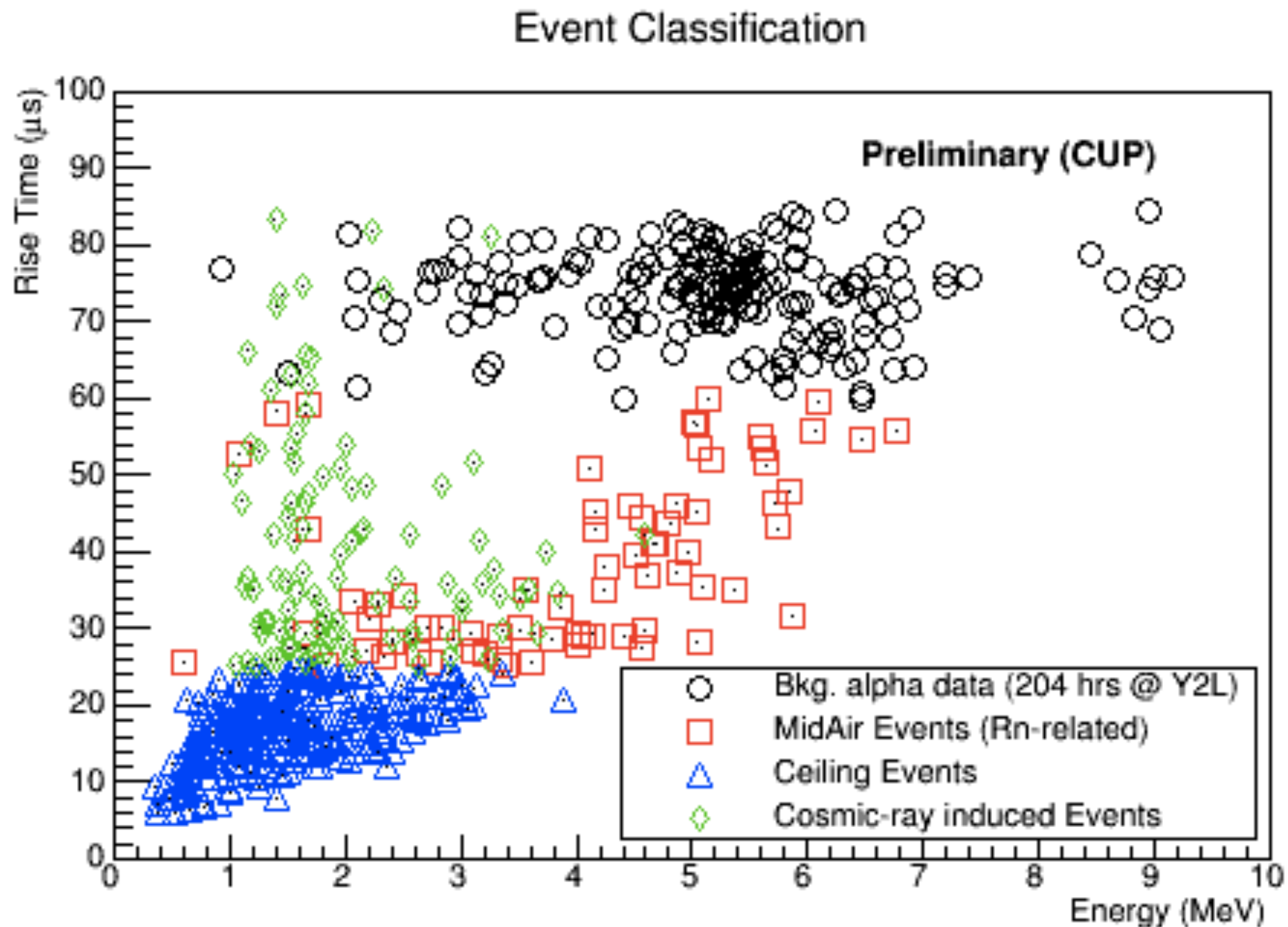
Guard

ADC (Arb. Units)

Time (microseconds)

Secondary Veto Channel
=How big is the blue line (Guard readout) ?

Wall, Ceiling, and Sample events using Guard readout

Event Classification

Event Classification

Events are pre-selected by hardware veto. Of those, events with risetime above 60µs are classified as alpha events
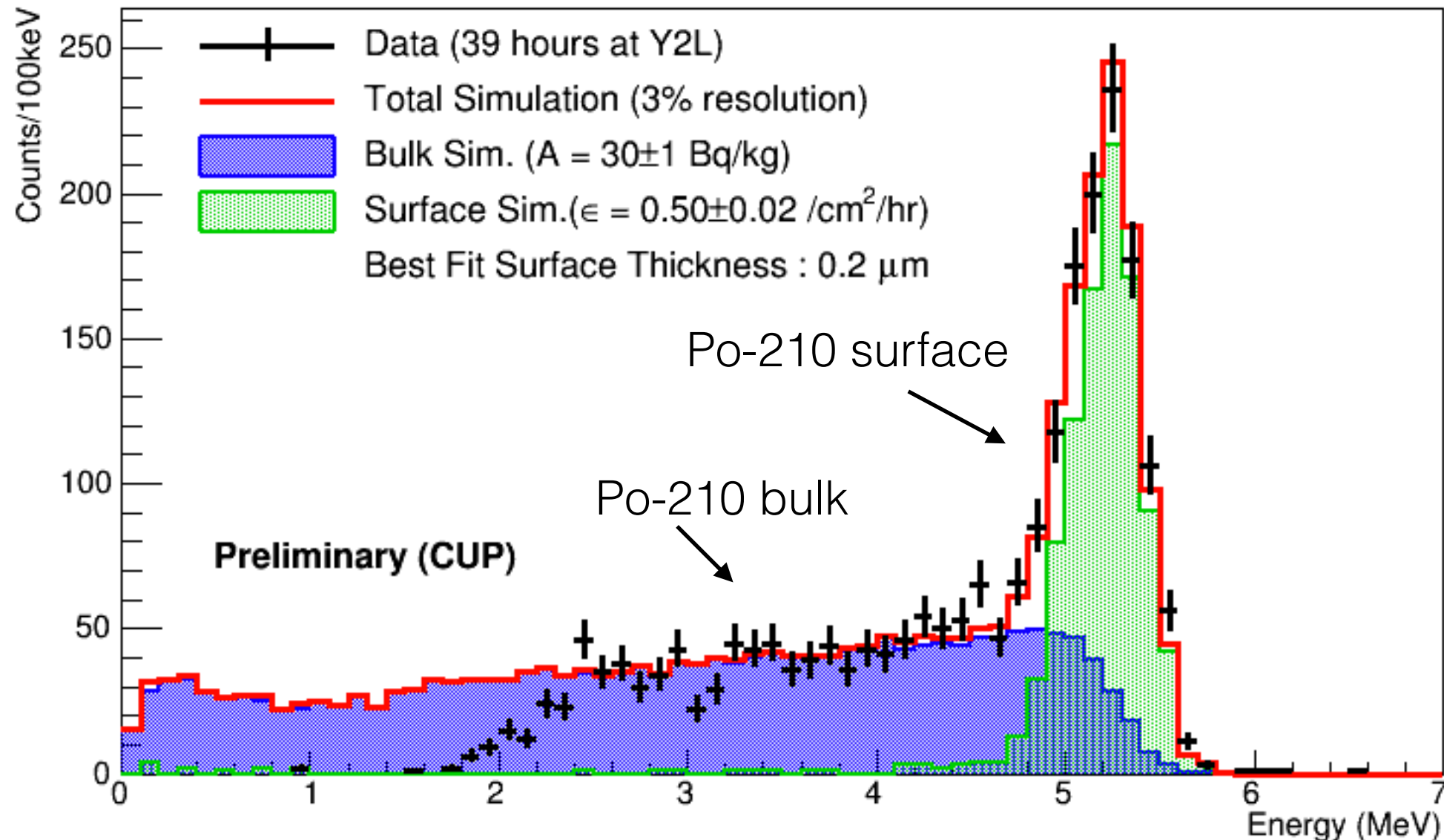
Calibration with Am-241 source (5.5 MeV alpha) (+ 10μm Mylar layer)
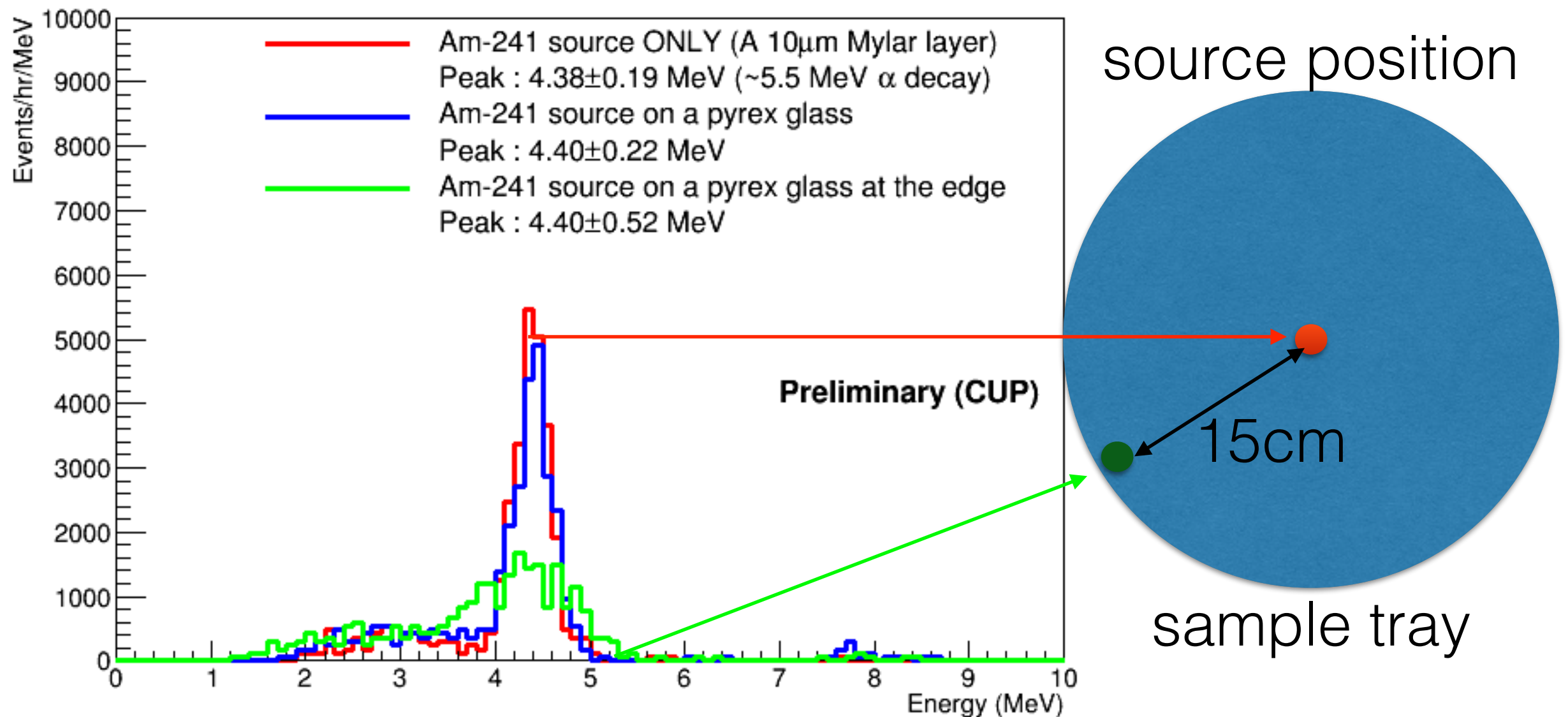
Dielectric material can be measured too.
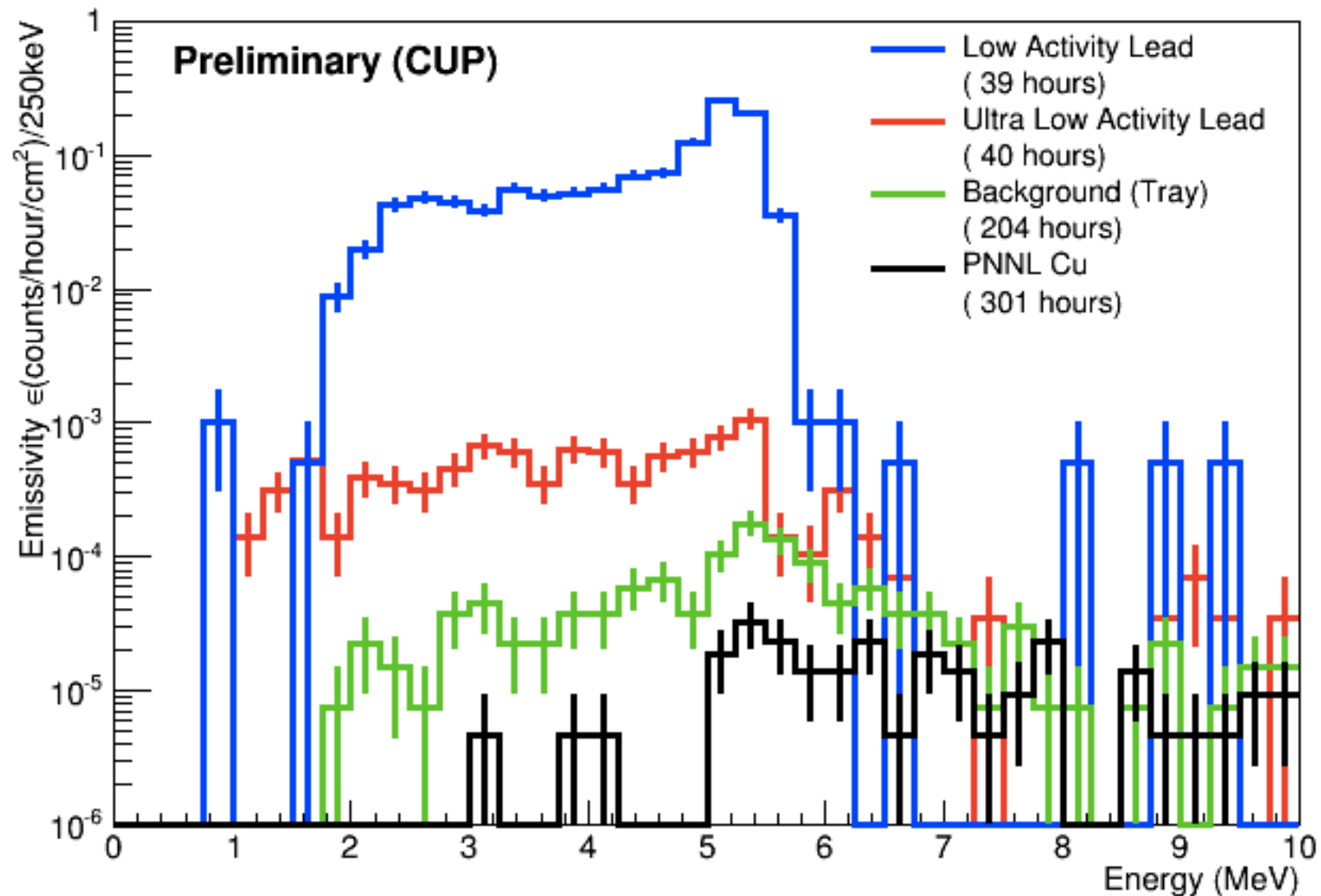Energy Resolution degrades close to the edge of the detection area.

Low Activity Lead Measurement
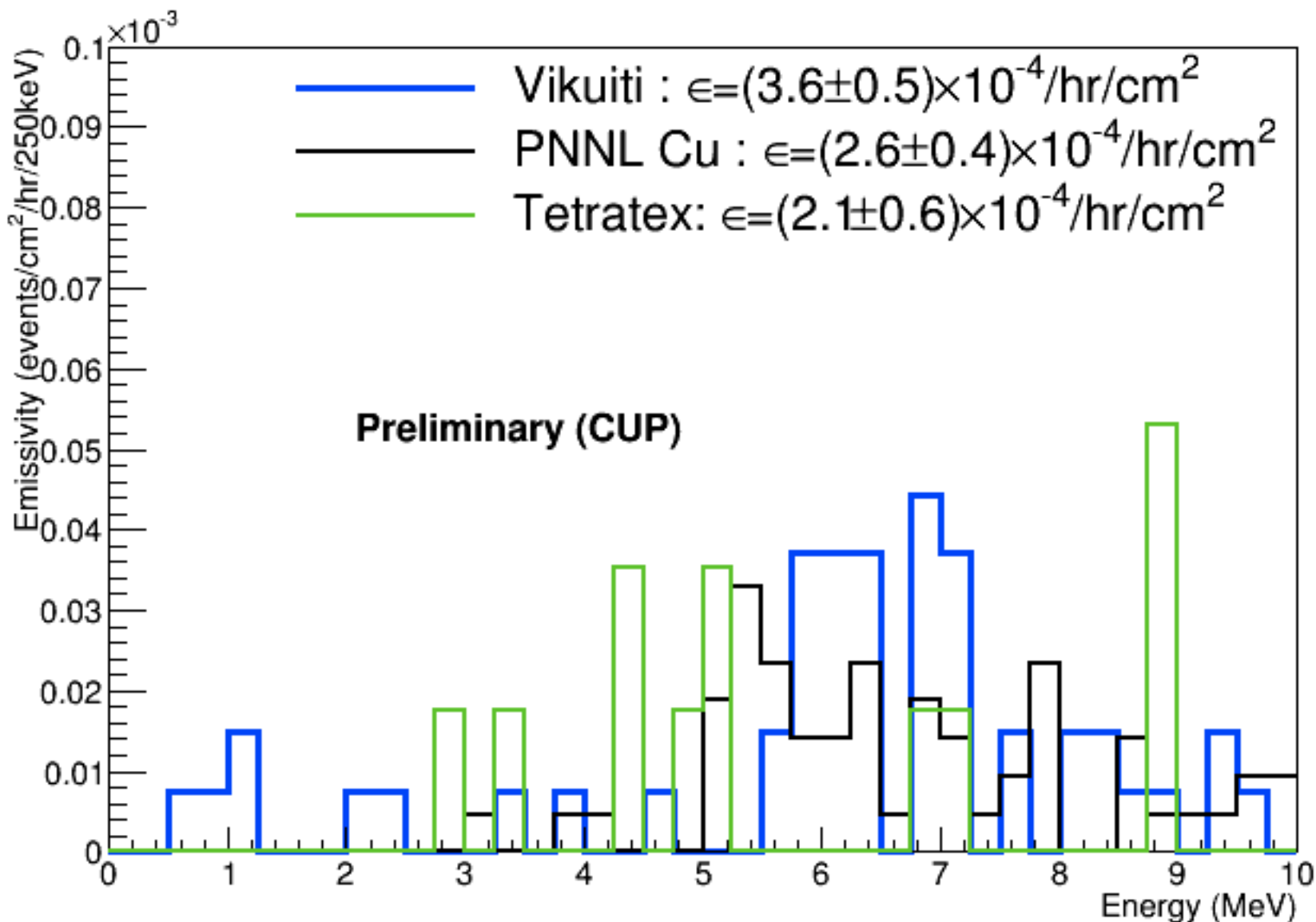
Lead Bar Dimension : 10cm x 5cm x 0.5cm

We can separate bulk component from the surface component with simulation and fit

Emissivity Comparison

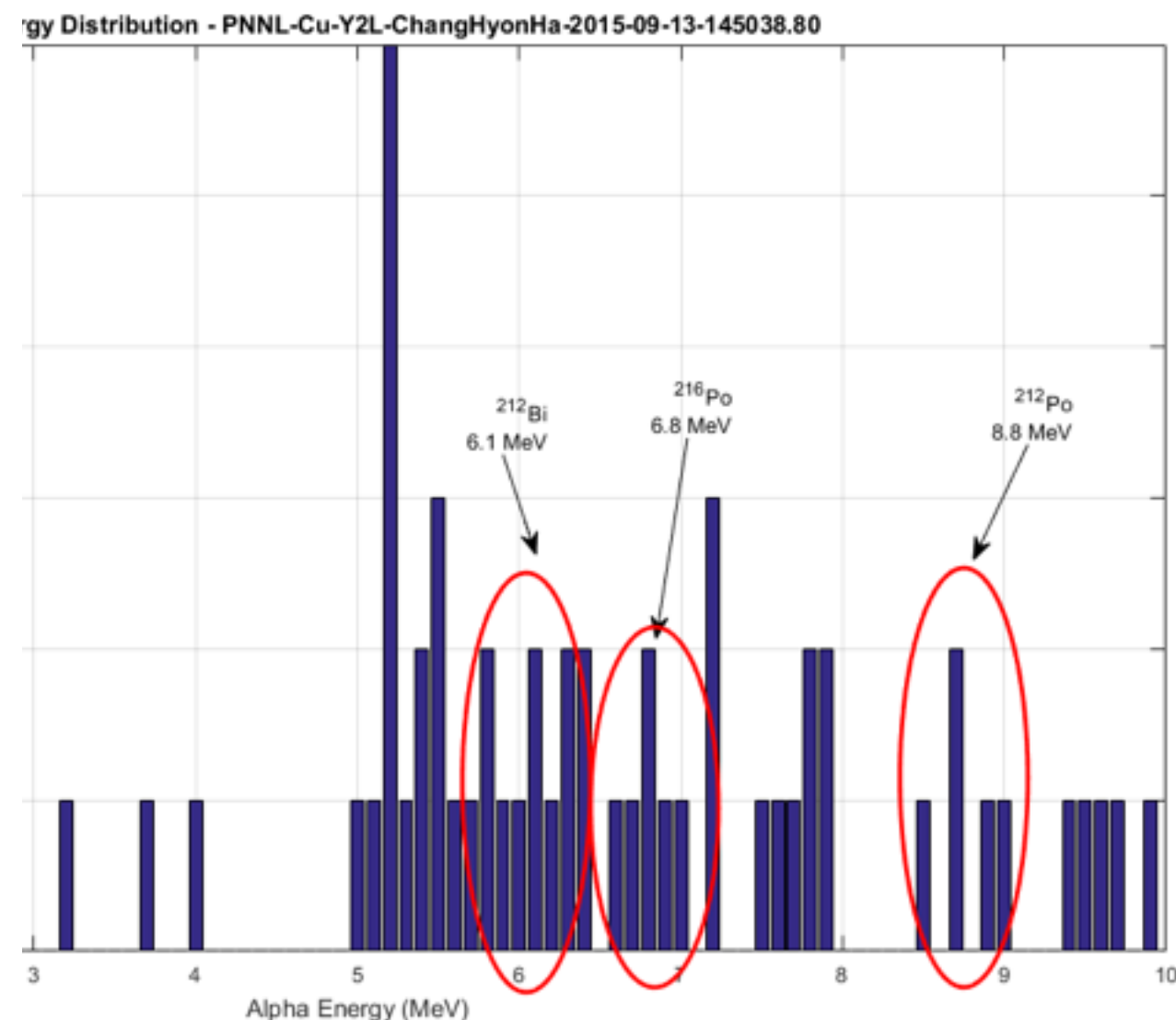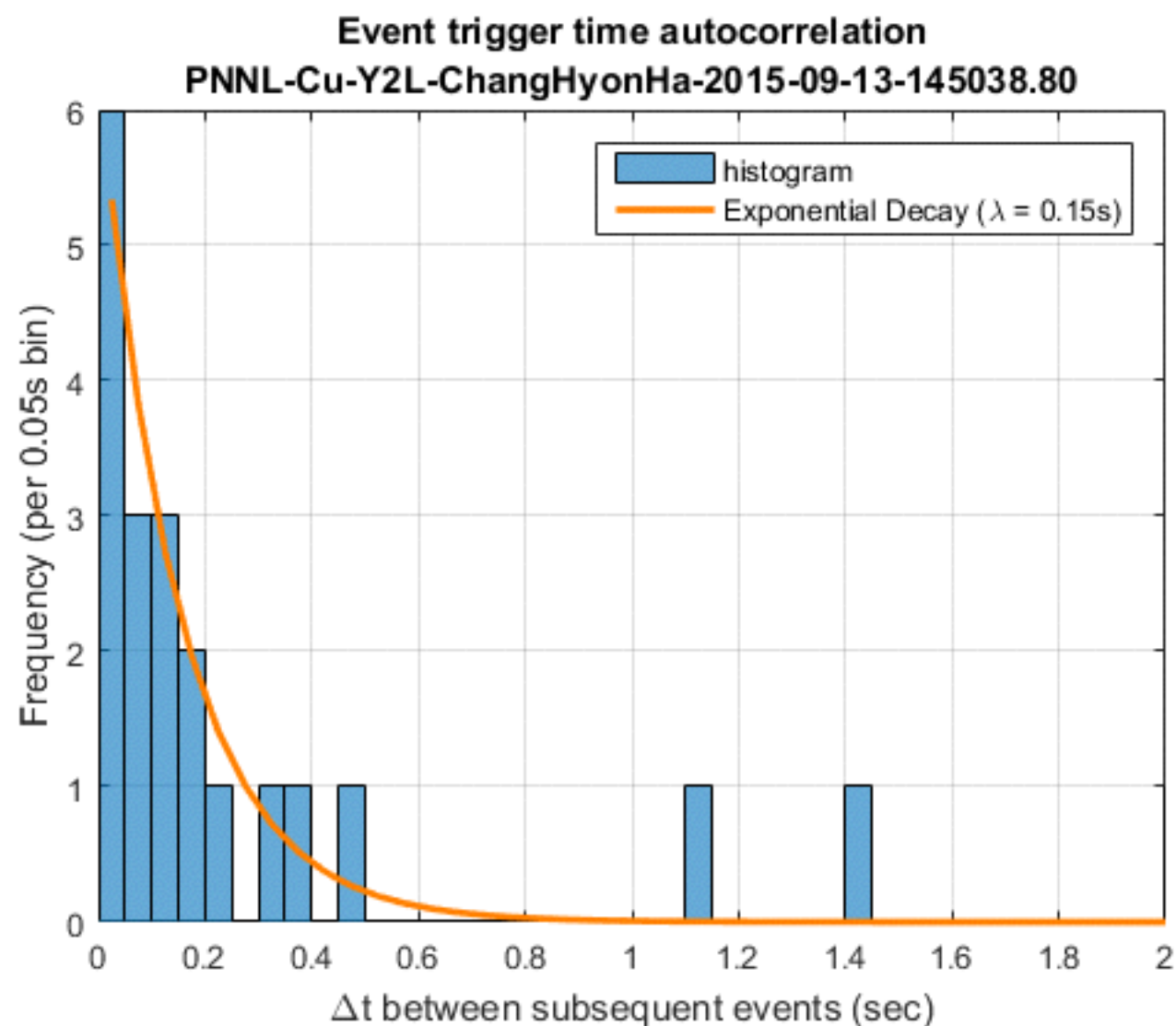The Alpha counter is sensitive enough to measure ultra-low background (bulk sensitivity of $^{210}Pb \sim 1mBq/kg$)

Ultra Low Activity Sample Comparison

Preliminary (CUP)

Vikuiti : $\epsilon=(3.6\pm0.5)\times10^{-4}/hr/cm^2$
PNNL Cu : $\epsilon=(2.6\pm0.4)\times10^{-4}/hr/cm^2$
Tetratex: $\epsilon=(2.1\pm0.6)\times10^{-4}/hr/cm^2$

Specular Reflective Flim

Teflon sheets

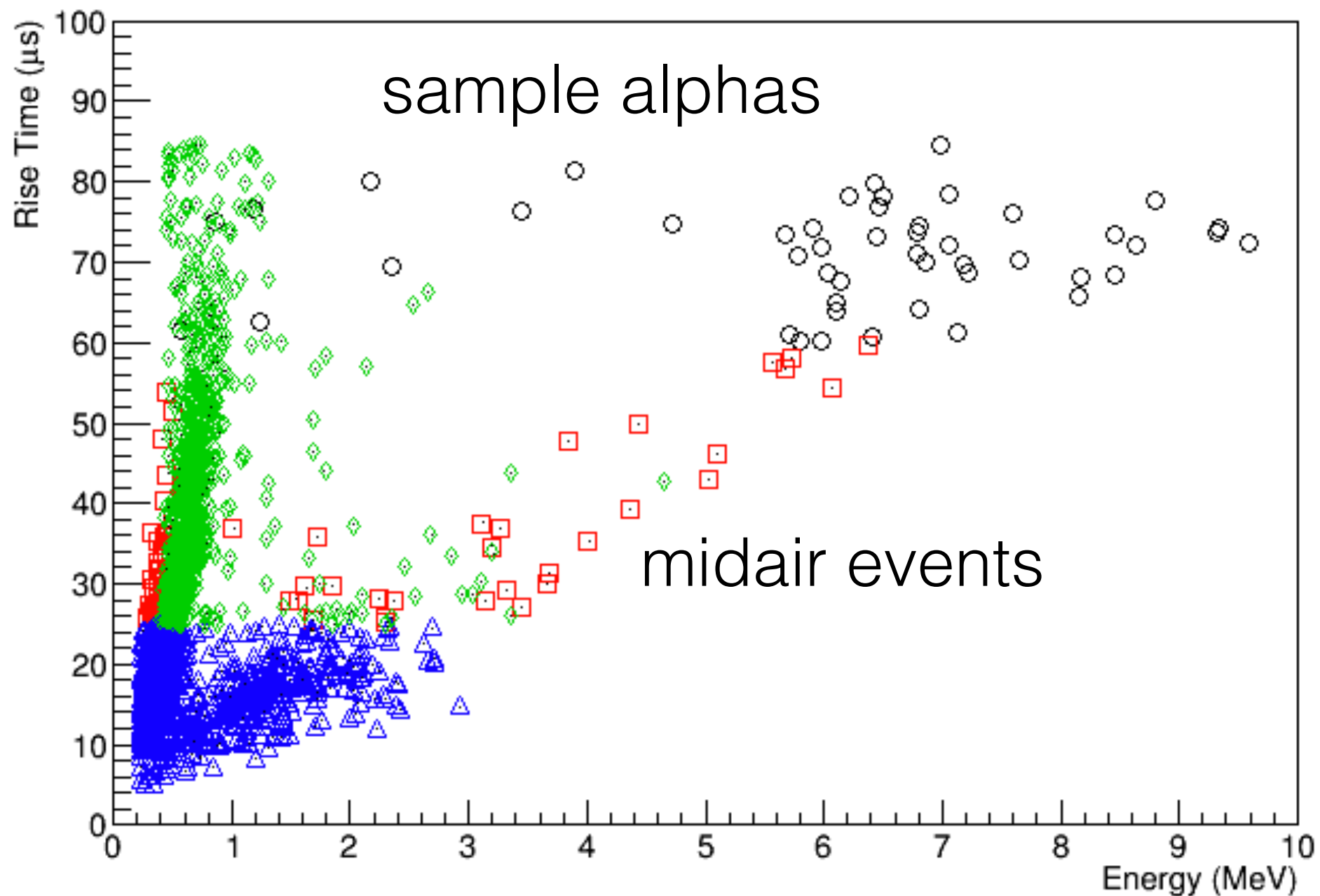Several ultra low activity samples have been measured.

Low Activity Background (e.g. PNNL Cu)

Rn-220 is coming through the gas tubing. Need to figure out where they are from.

# Low activity Backgrounds (e.g. specular reflector)

At the detector limit, midair background shows up. They are suspected to be from outside, e.g. Ar-gas, or gas plumbing materials. A cold trap to filter this Radon contamination is under development
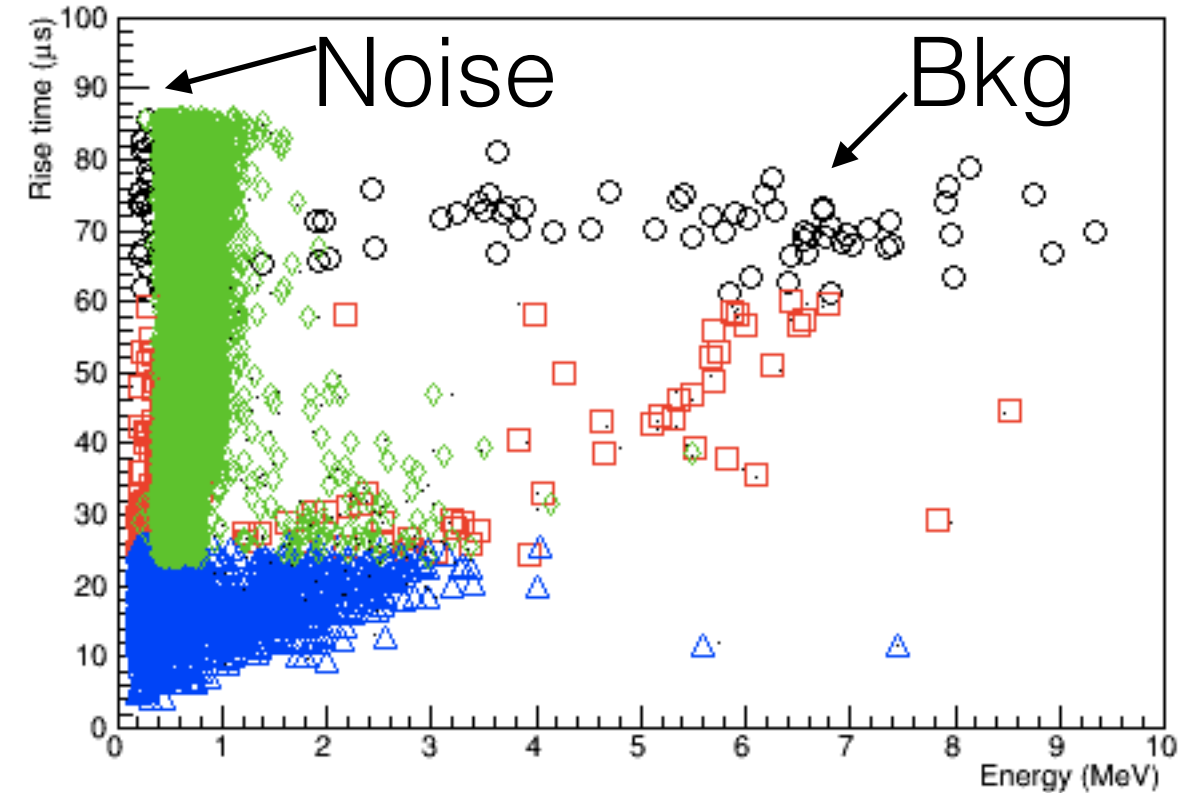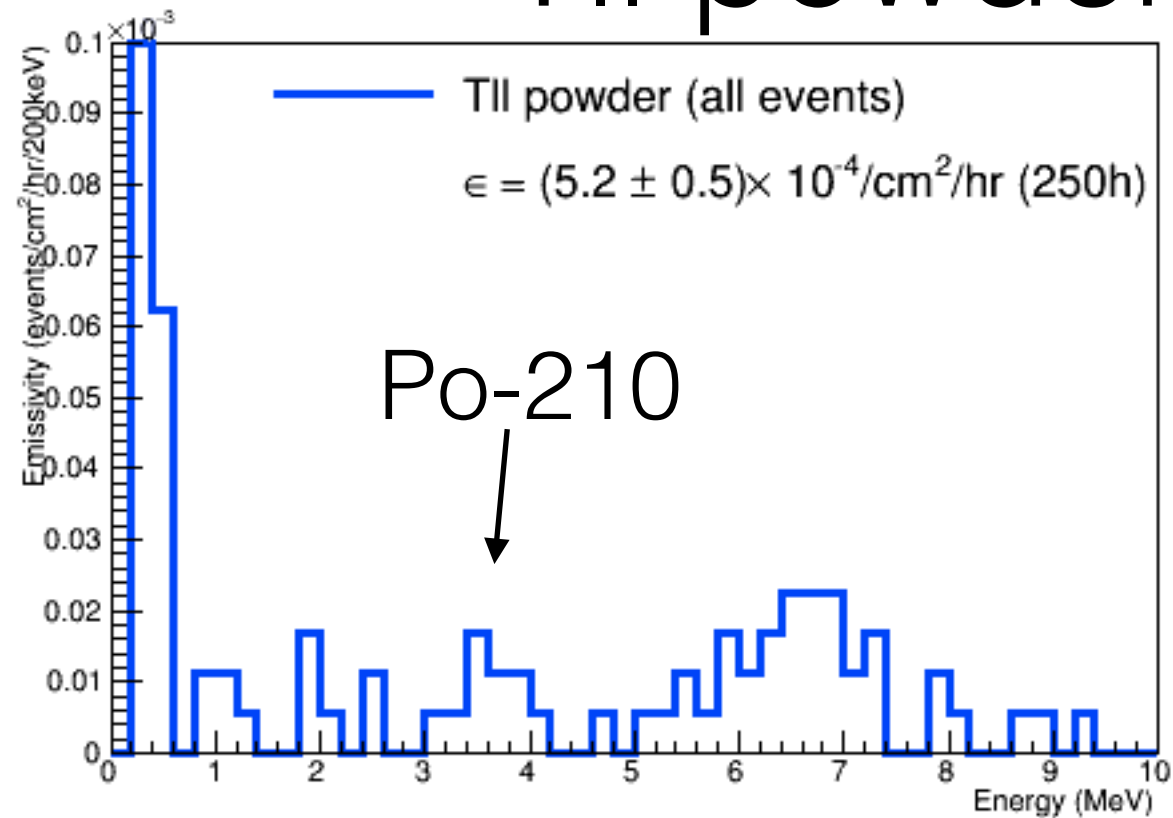
Rn-exposed Copper Measurement
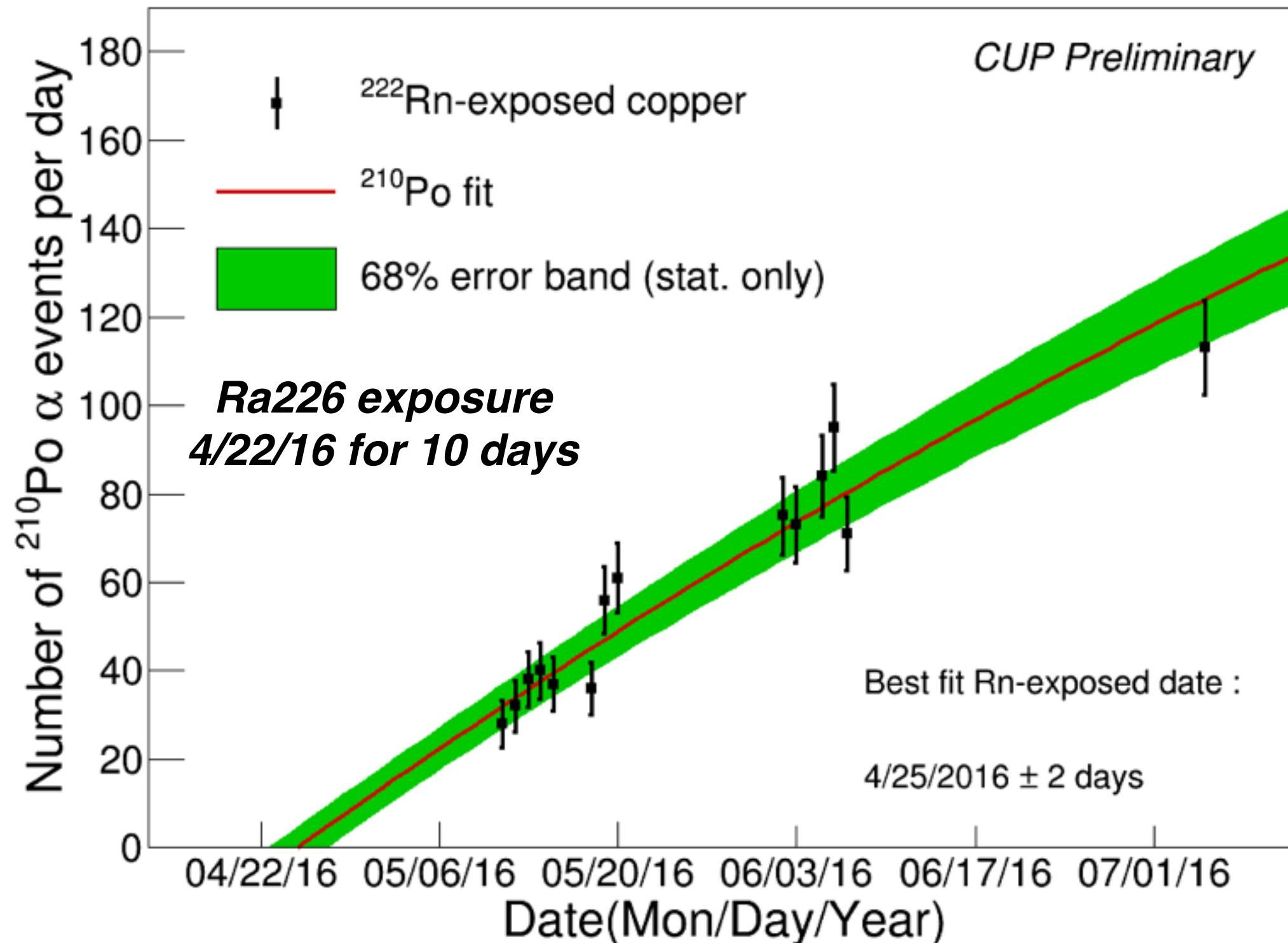
Radon contamination date can be pinpointed with data

Fit with Rn-exposed Cu for the Po-210 diffusion depth
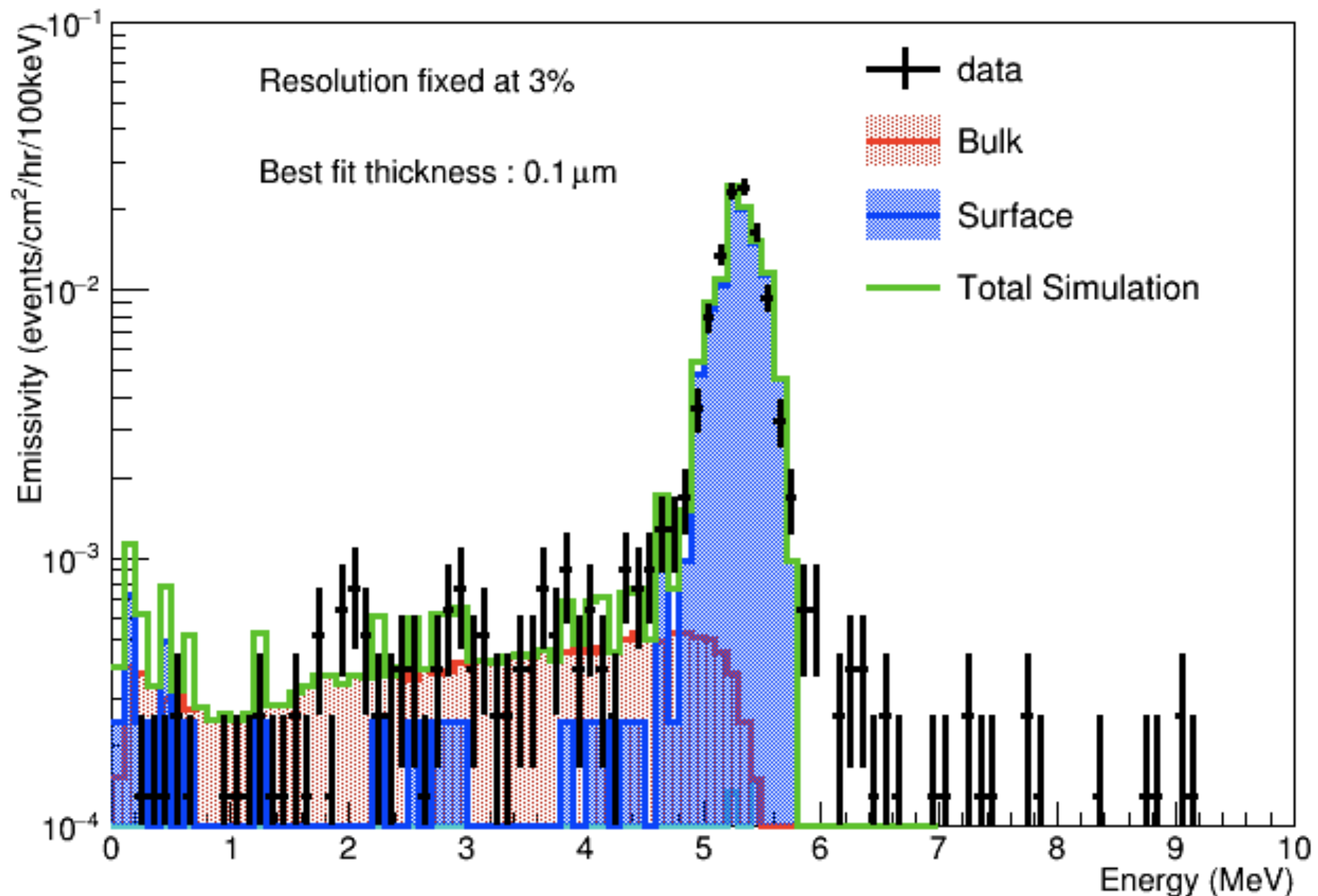
The best fit thickness of the bulk component shows the Po-210 diffusion depth is shallow for this particular sample.

TlI powder measurement

$\epsilon = (5.2 \pm 0.5) \times 10^{-4}/cm^2/hr$ (250h)

TlI powder (all events)

Po-210

Noise   Bkg

Total Po-210 activity is estimated to be

1.1×10^{-4} counts/cm^2/hr
(< 4 mBq/kg)

Summary

- Ionization chamber alpha counter at Yangyang is running smoothly.

- We have several measurements that reached to $\sim 10^{-4}$ counts/hr/cm^2

- Interesting measurements e.g. Rn-exposed sample, and measurements with thin Mylar cover.

- We plan to improve the counter using better plumbing or a charcoal-based cold trap to lower the residual background.

  - Rn-free air is supplied in the detector room now.

- We have started powder measurements for assaying the raw material of the crystals.
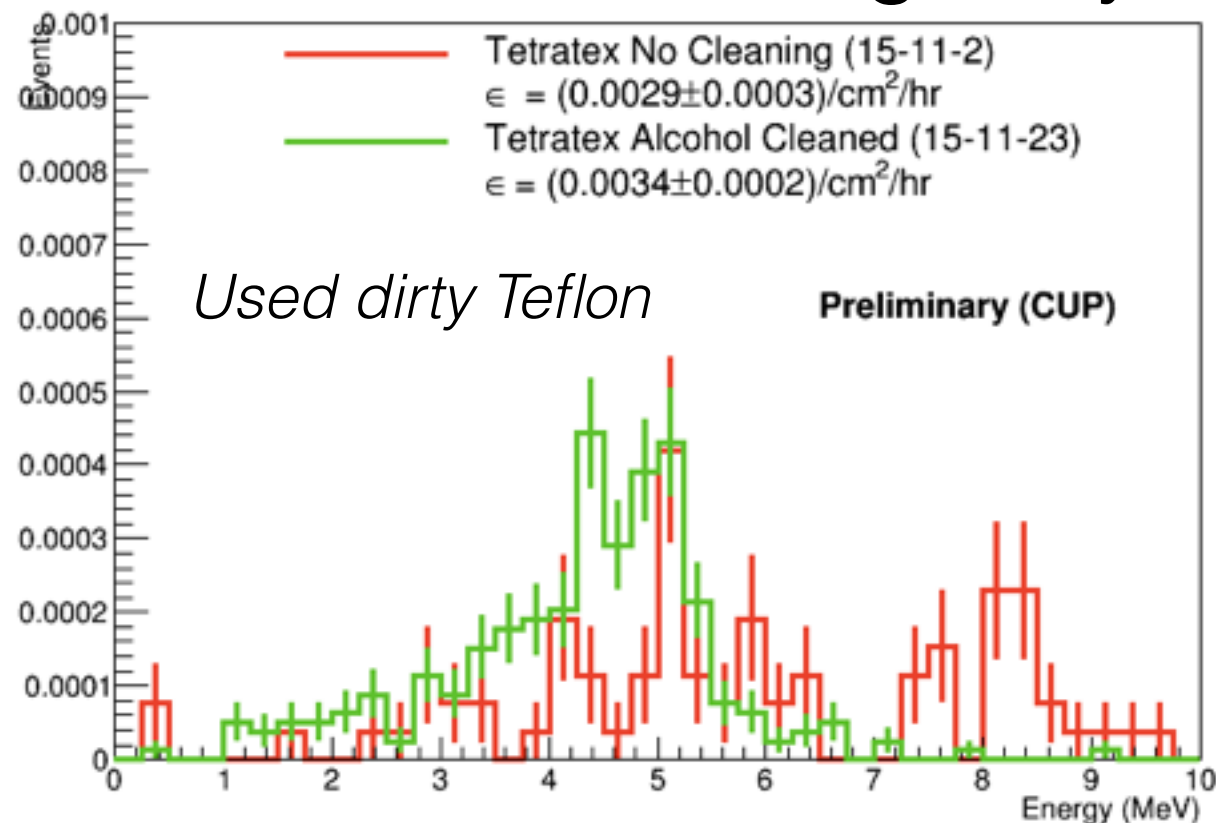
Backup

Detector Threshold & Efficiency
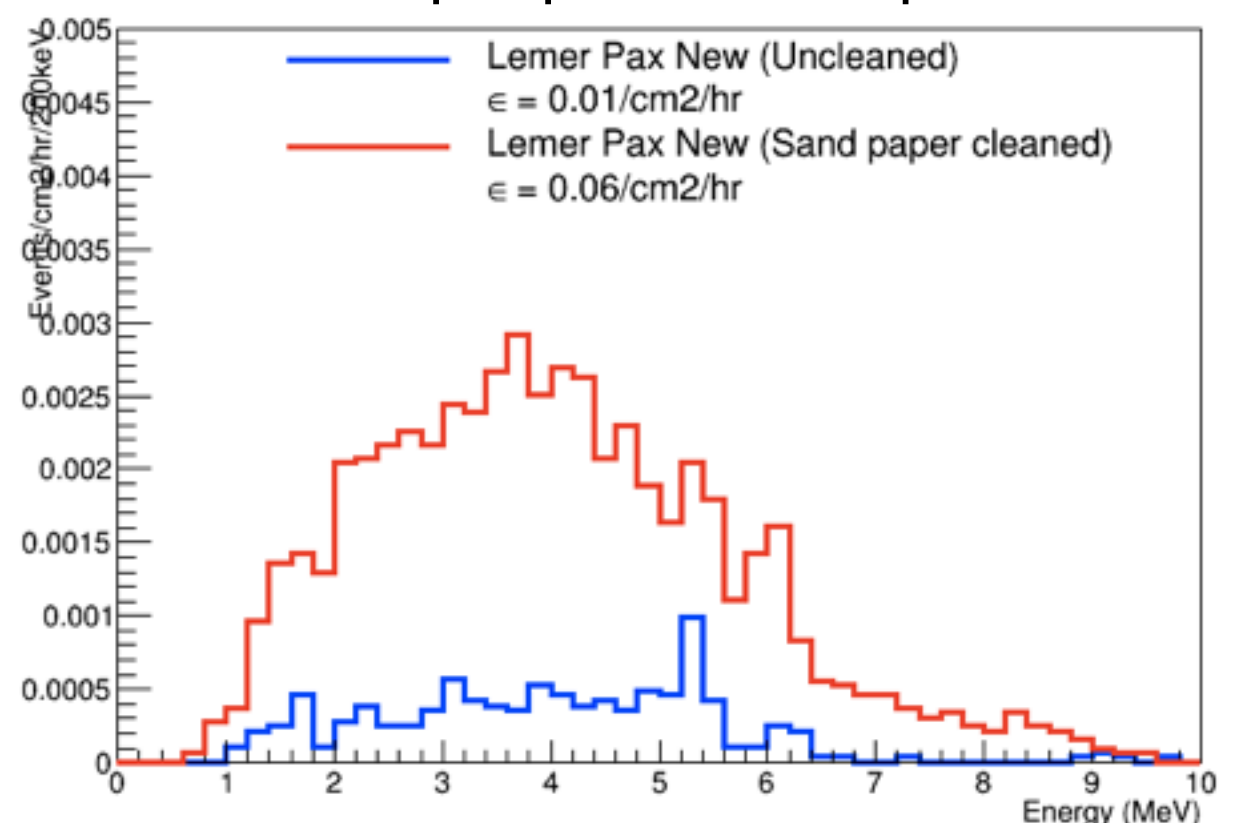
Data to Best fit simulation
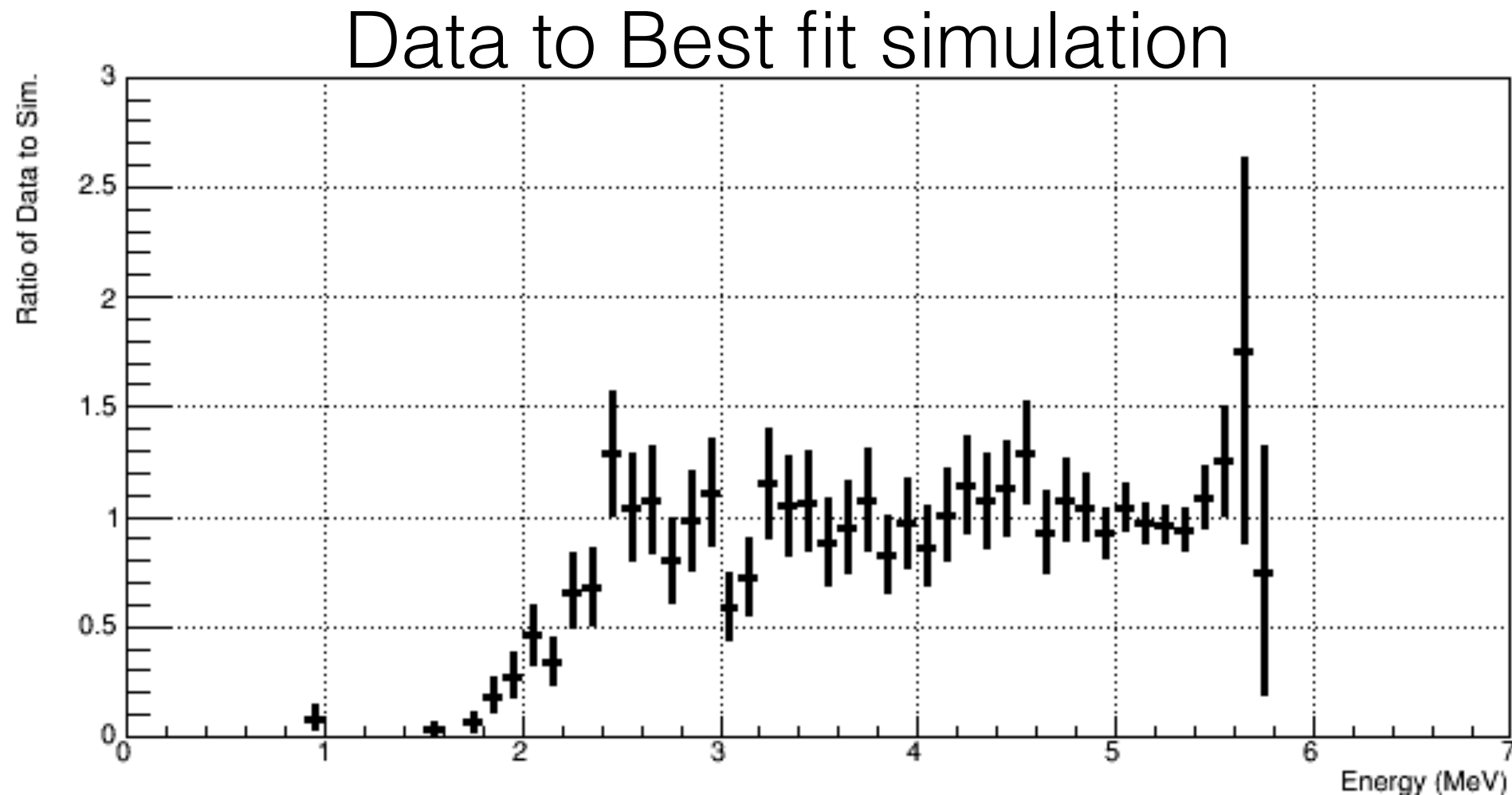
Preset trigger threshold : 1.5 MeV. Above 2.4 MeV 100% efficient
The threshold has been lowered by about 1 MeV

# Sample Preparation/Cleaning Studies

Alcohol submerge/dry

Used dirty Teflon

Legend:
- Tetratex No Cleaning (15-11-2) $\epsilon = (0.0029 \pm 0.0003)/cm^2/hr$
- Tetratex Alcohol Cleaned (15-11-23) $\epsilon = (0.0034 \pm 0.0002)/cm^2/hr$

Preliminary (CUP)

Alcohol cleaning did not improve the quality. We suspect drying process was not controlled properly.

Sand paper scraped

Legend:
- Lemer Pax New (Uncleaned) $\epsilon = 0.01/cm2/hr$
- Lemer Pax New (Sand paper cleaned) $\epsilon = 0.06/cm2/hr$

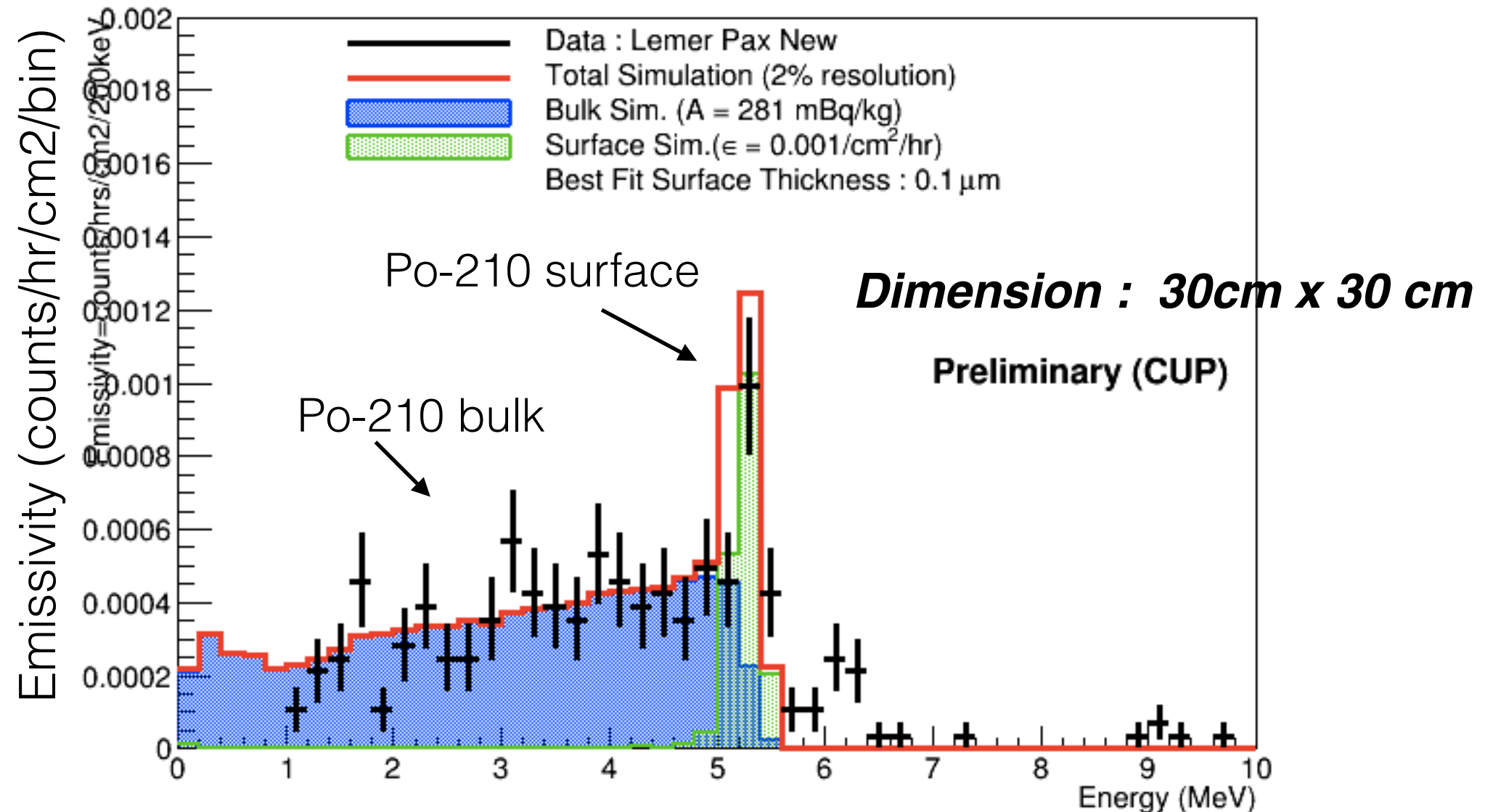We suspect the sand paper left residue after cleaning.

Samples need to be prepared in a controlled environment, e.g. N2-supplied glove box.

Tray Background Measurements
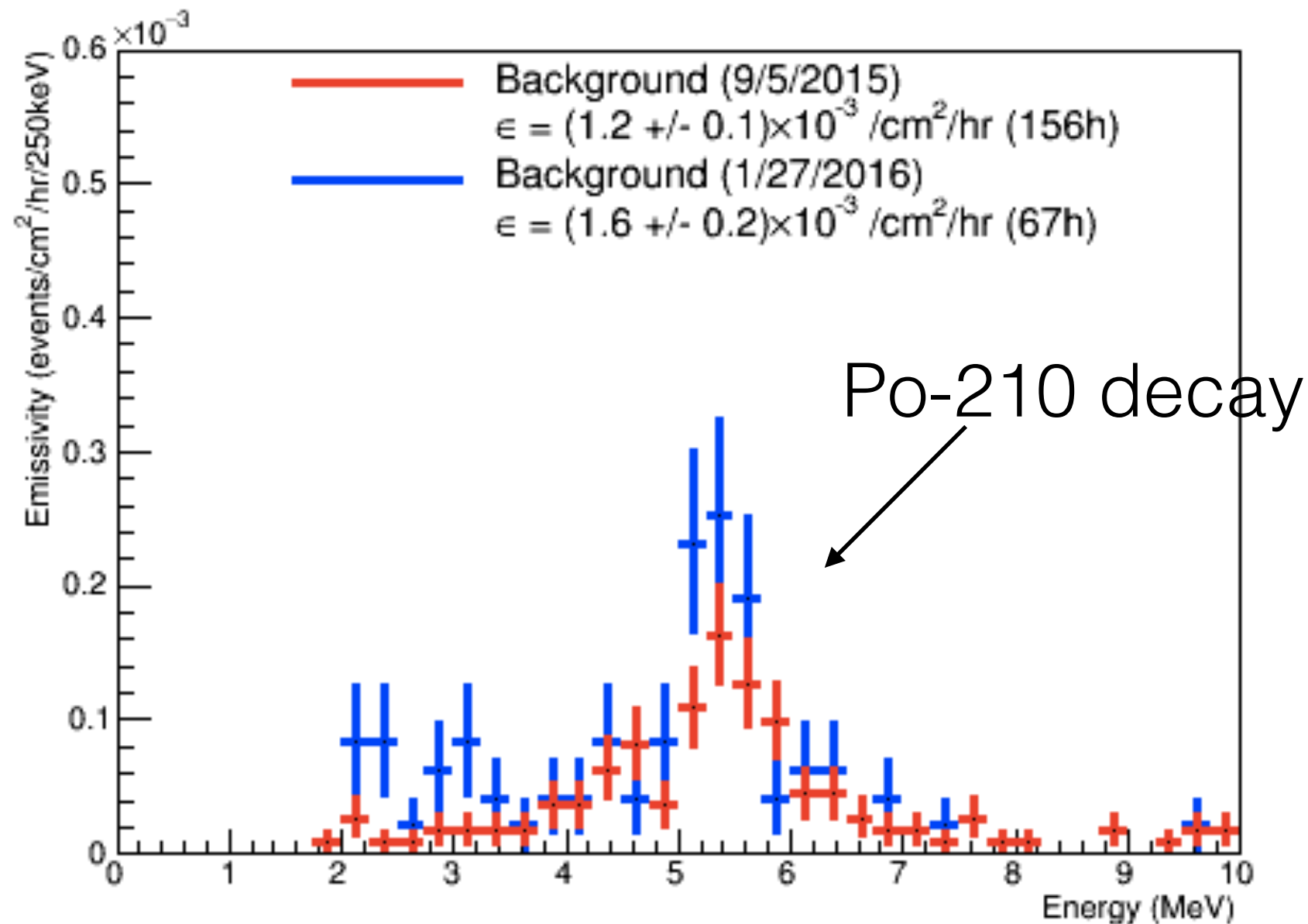
Tray background measurements between 5 months
seem to be consistent.

Ultra Low Activity Lead Measurement

We can separate bulk component from the surface component with simulation and fit