Background Strategy in SuperCDMS SNOLAB

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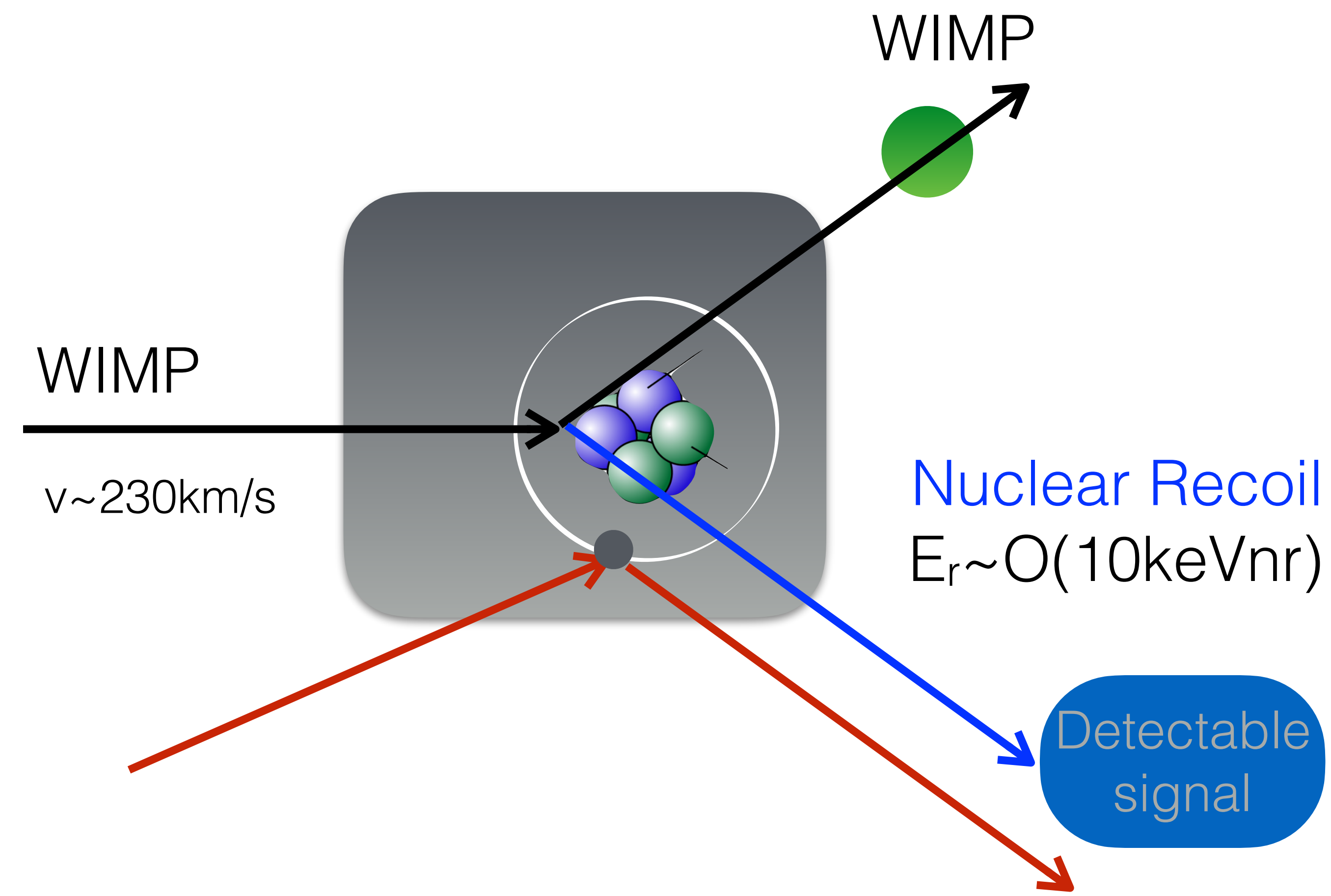
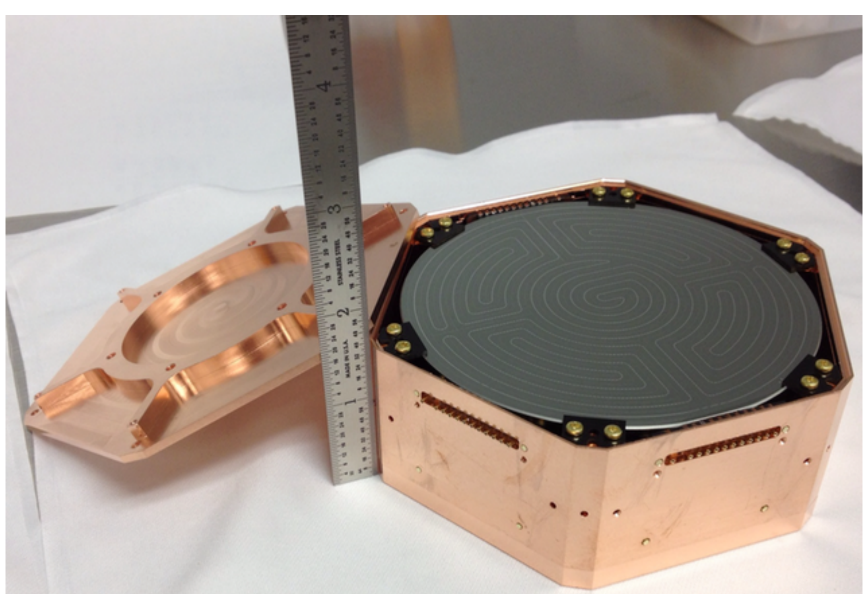
Signal vs Backgrounds

Elastic Scattering of WIMPs off target nuclei
→ Nuclear Recoil (signal)

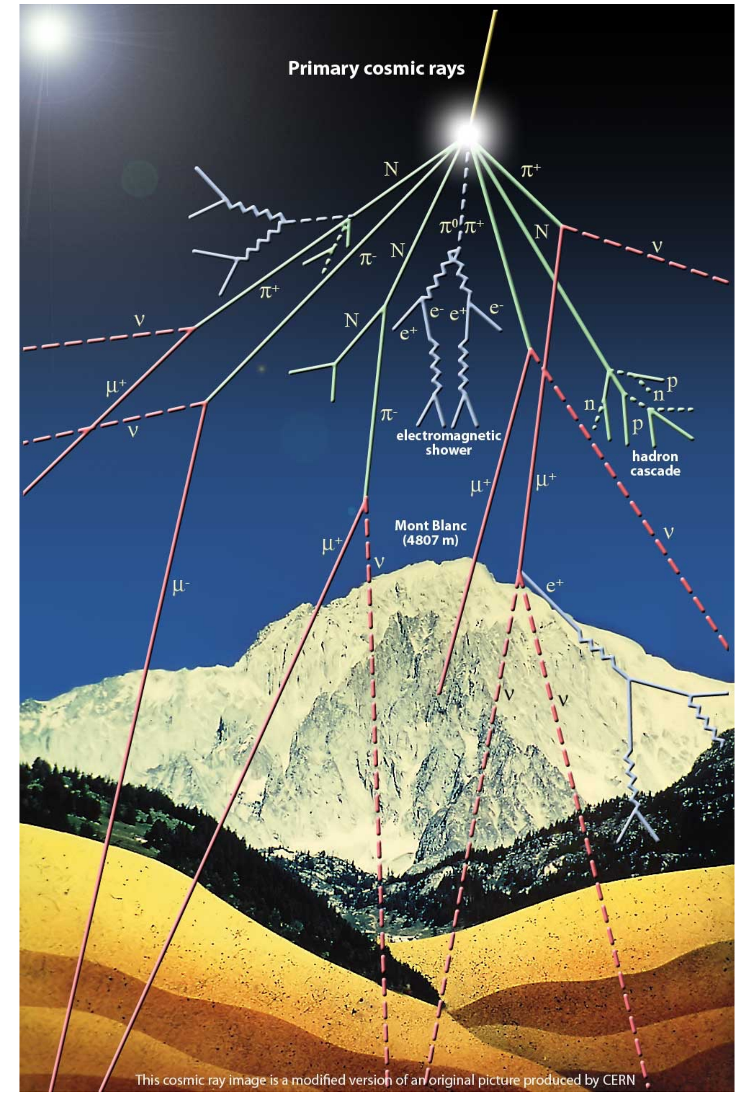




Gamma- and beta- particles interacting with the atomic electron
→ Electronic Recoil (background)

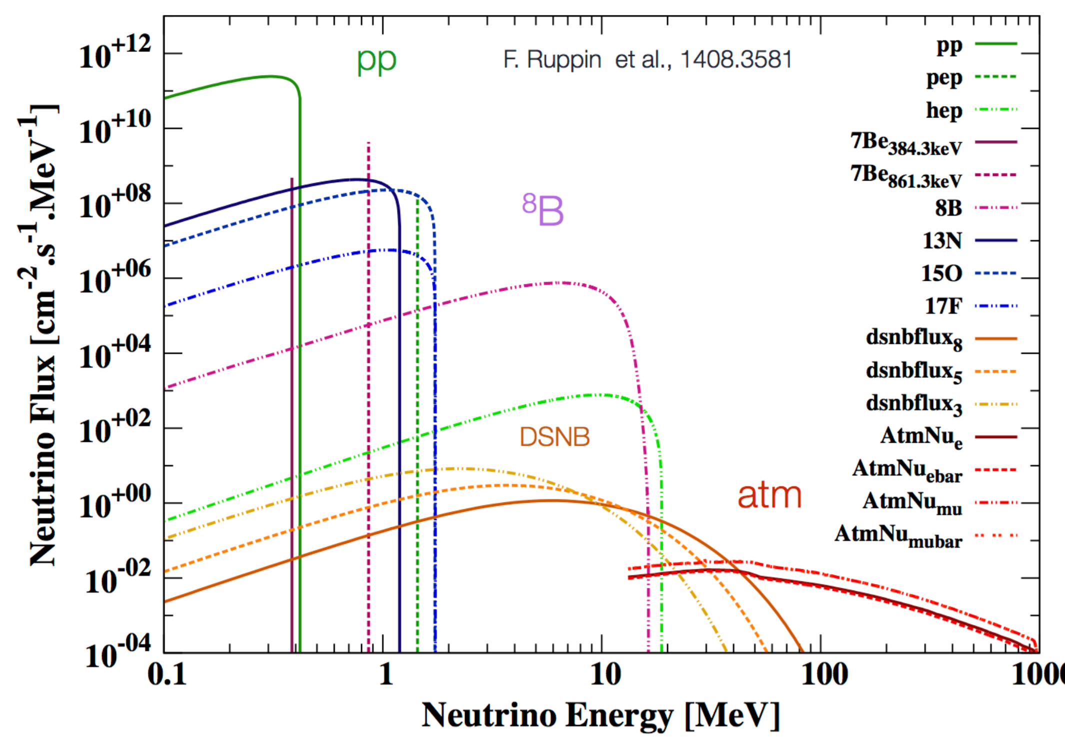
What Background?

Cosmic rays & cosmogenic activation of detector and materials



Natural radioactivity (^{238}U, ^{232}Th, ^{40}K): γ, e^-, n, β, α

Ultimately: neutrino-nucleus scattering (solar, atmospheric and supernovae neutrinos)



How to Minimize Backgrounds?

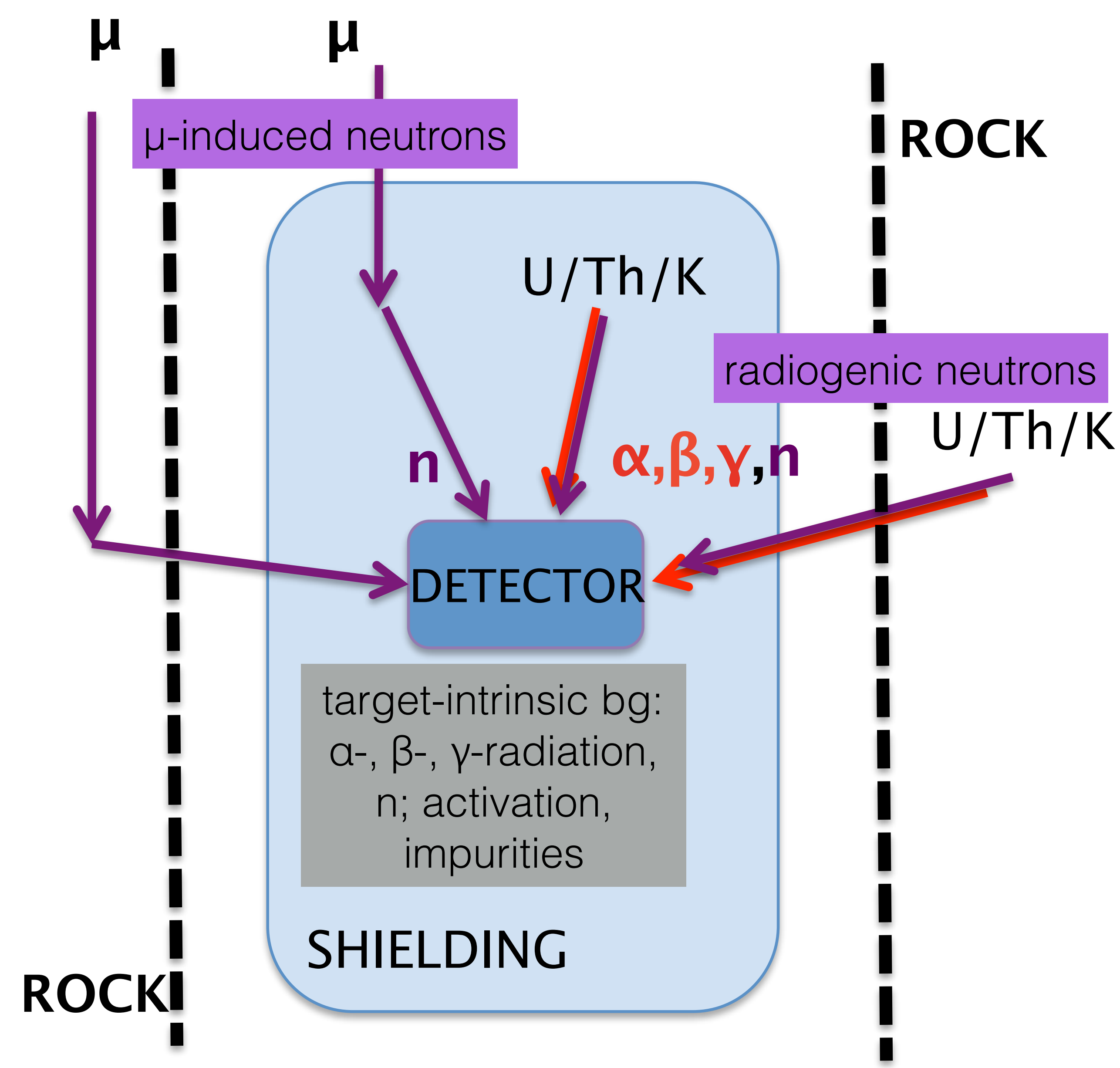
Minimize time at surface
+ go deep underground
Limit cosmogenic activation, and fewer cosmic rays to produce neutrons (neutrons produce nuclear recoils as WIMPs)

Passive/Active shielding
Reduce backgrounds from environmental radioactivity (^{238}U, ^{232}Th, ^{40}K)

Surface cleaning and radon-reduced cleanroom to minimize surface backgrounds

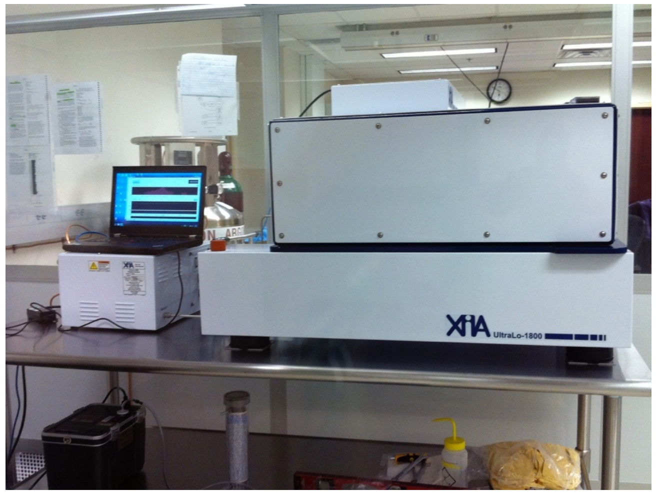
Material screening
(alpha / beta / gamma spectroscopy, chemical trace analysis)

Select LowRad materials



PE to moderate neutrons
Cu, Pb for betas and gammas

How to Minimize Backgrounds?



XIA Alpha Counter LUMINA Lab @SMU

Gopher HPGe detector @SNOLAB

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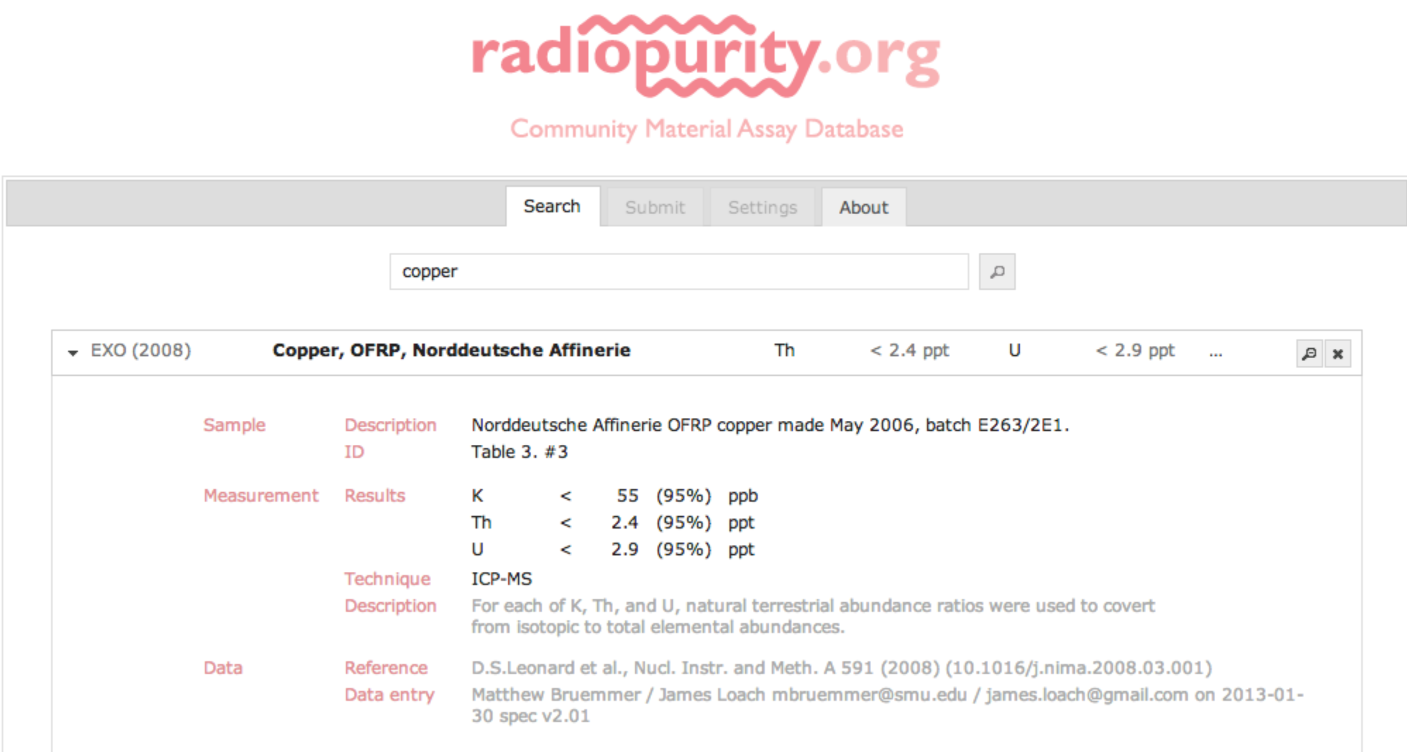
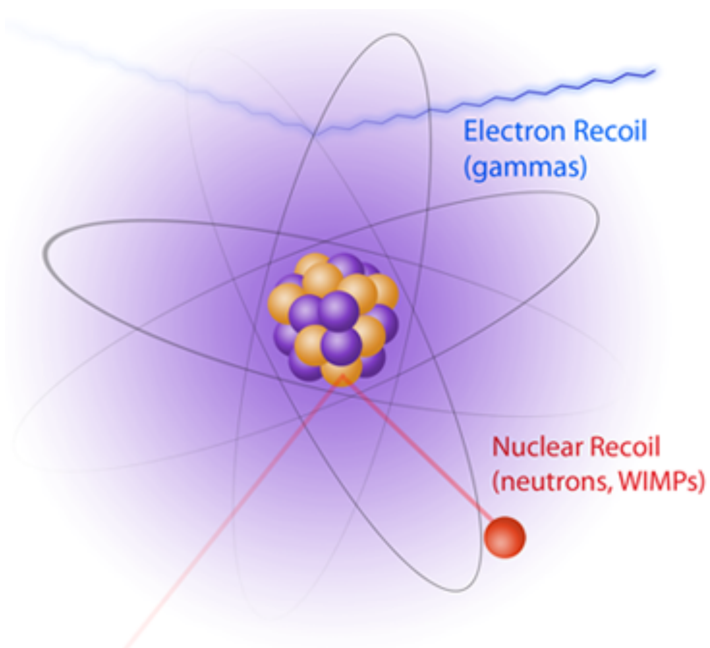
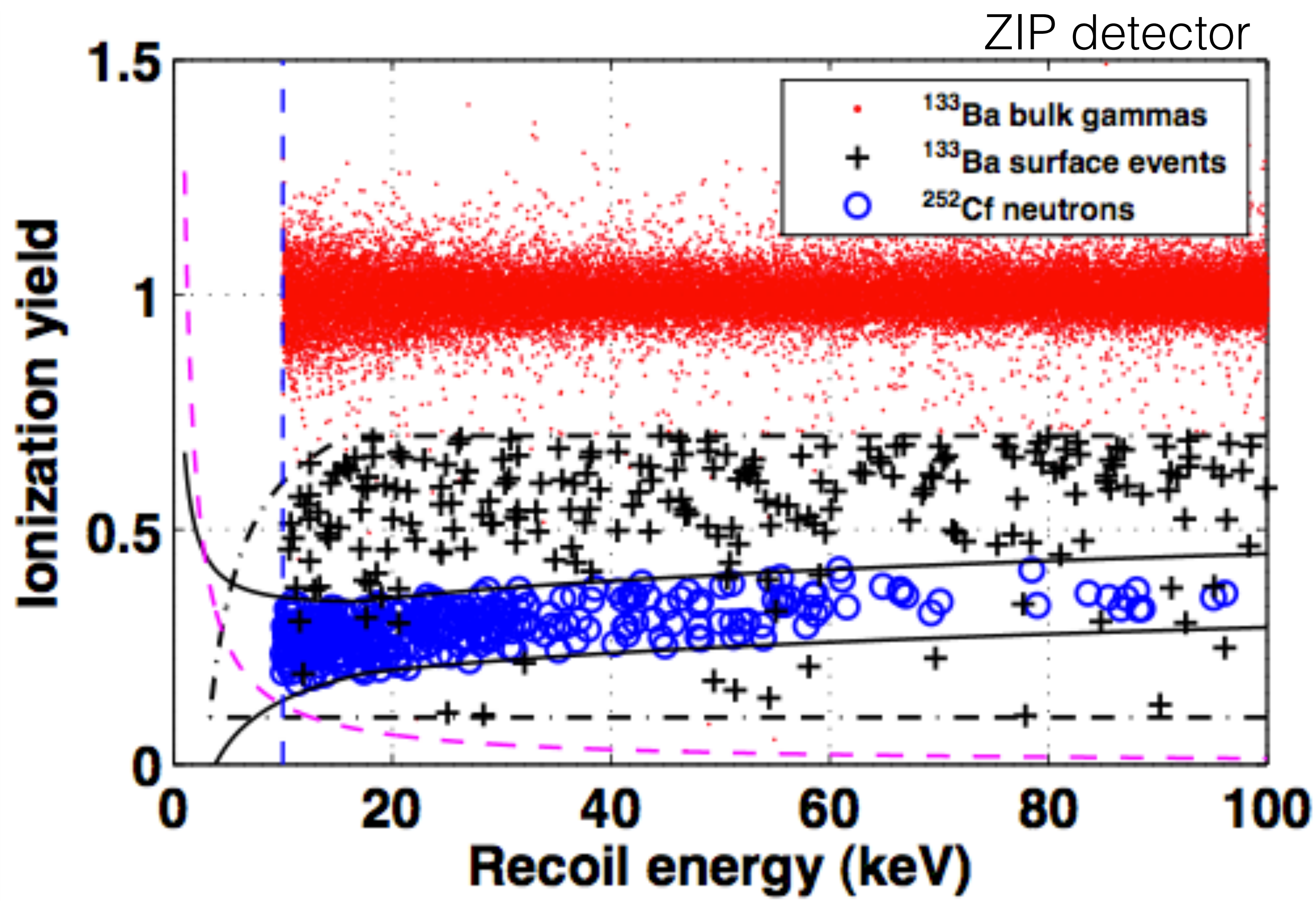


How to Identify Backgrounds?

Ge/Si crystal: event ID from measurements of charge and phonon signals





Discrimination

Fiducialization

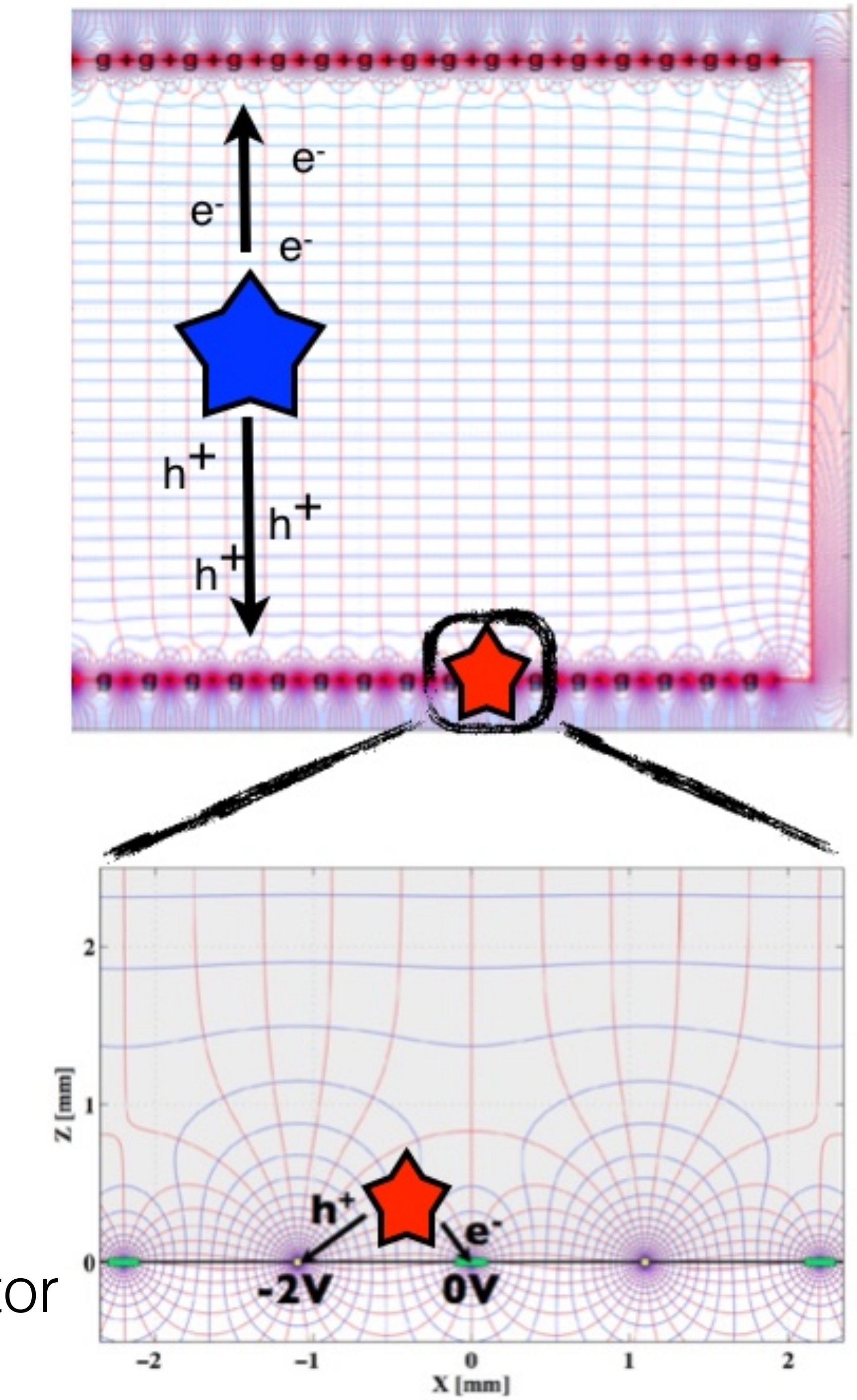
Rejection of bulk electron recoils better than 4.7 x 10^{-6} (90%C.L.)

How to Identify Backgrounds?

Ge/Si crystal: event ID from measurements of charge and phonon signals

Bulk Events:
Equal but opposite ionization signal appears on both sides of each detector (symmetric)

Surface Events:
Ionization signal appears on one detector side (asymmetric)



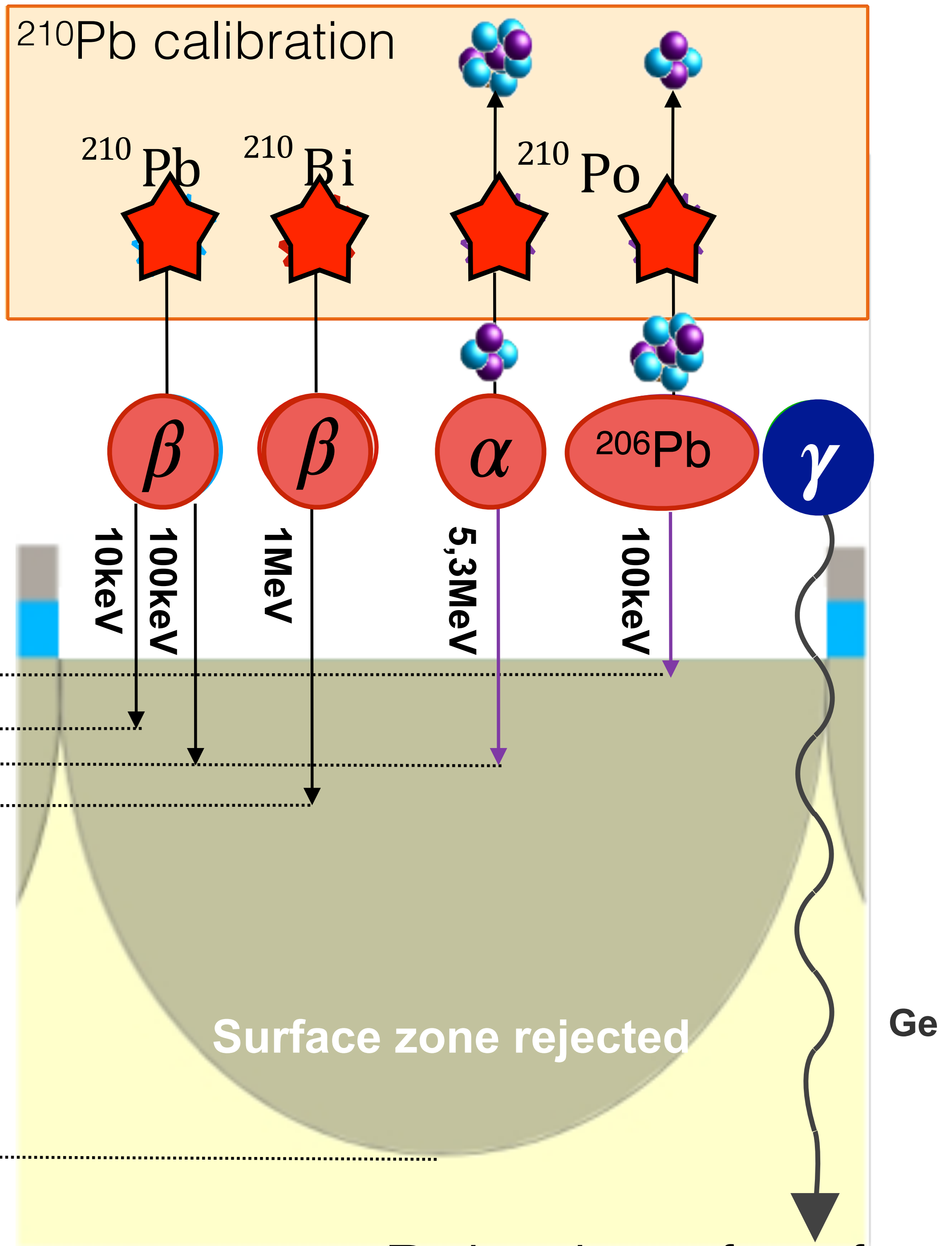
Discrimination

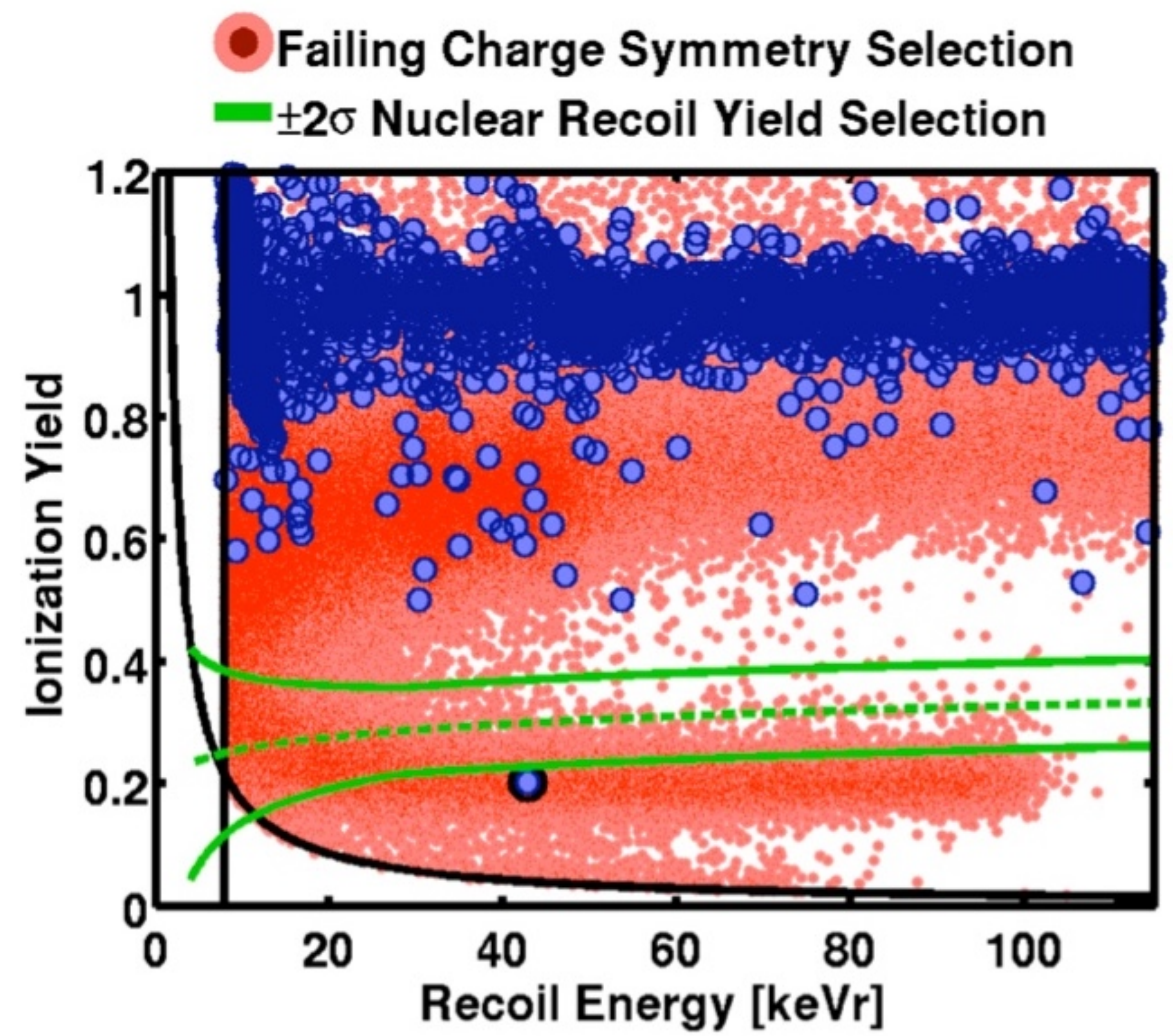
Fiducialization

iZIP detector

Surface Events

Incomplete charge collection → low yield
Surface Contamination





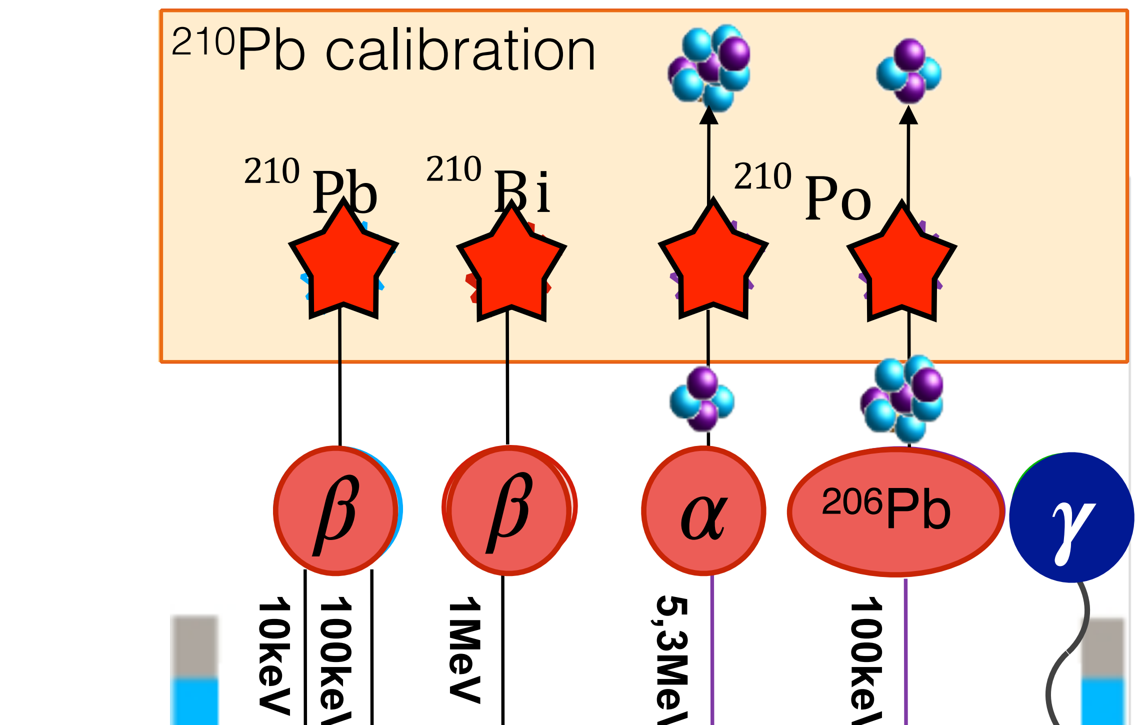
iZIP detector

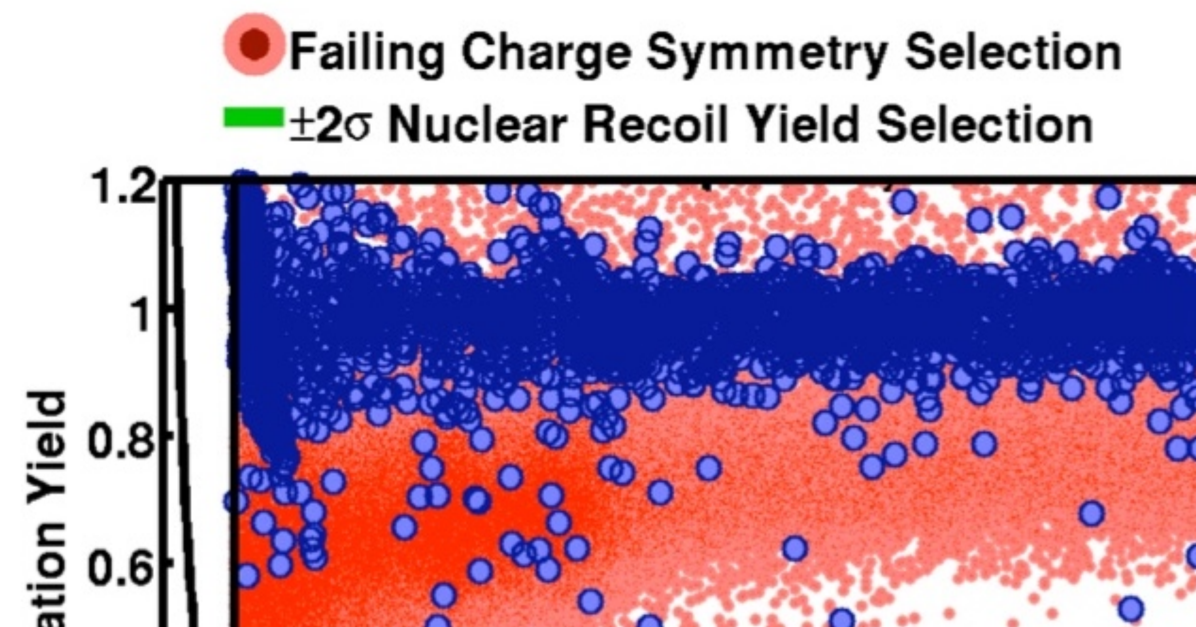
Rejection of surface events better than 1.26 x 10^{-5} (90% C.L.)

Surface Events

Incomplete charge collection → low yield

Surface Contamination





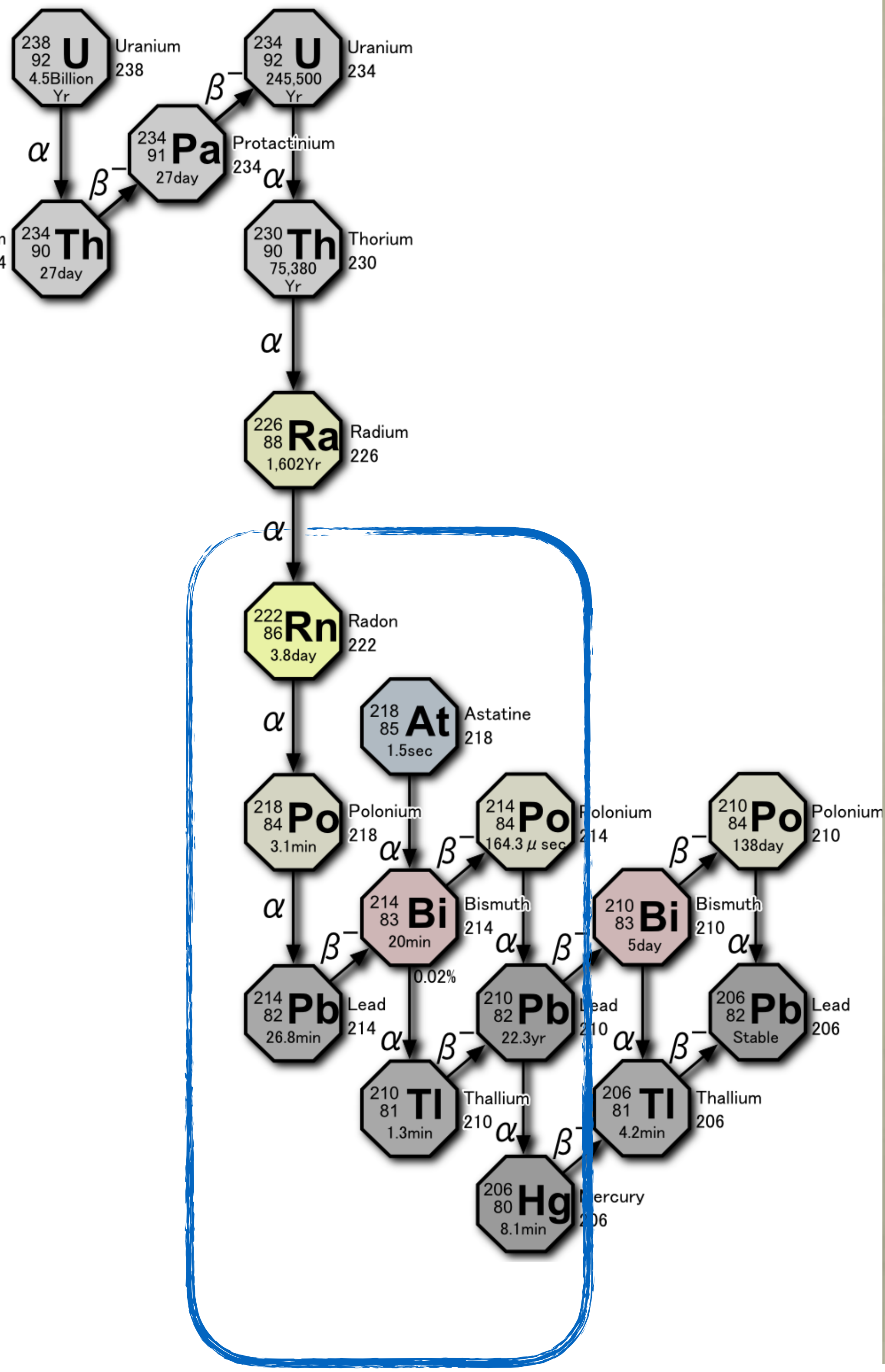
^{210}Pb from Rn exposure and U, Th, K in dust

- Detectors, housing interiors, clamps, DIBs, ...
- High rate from low-penetration emissions (alphas, betas, x-rays)

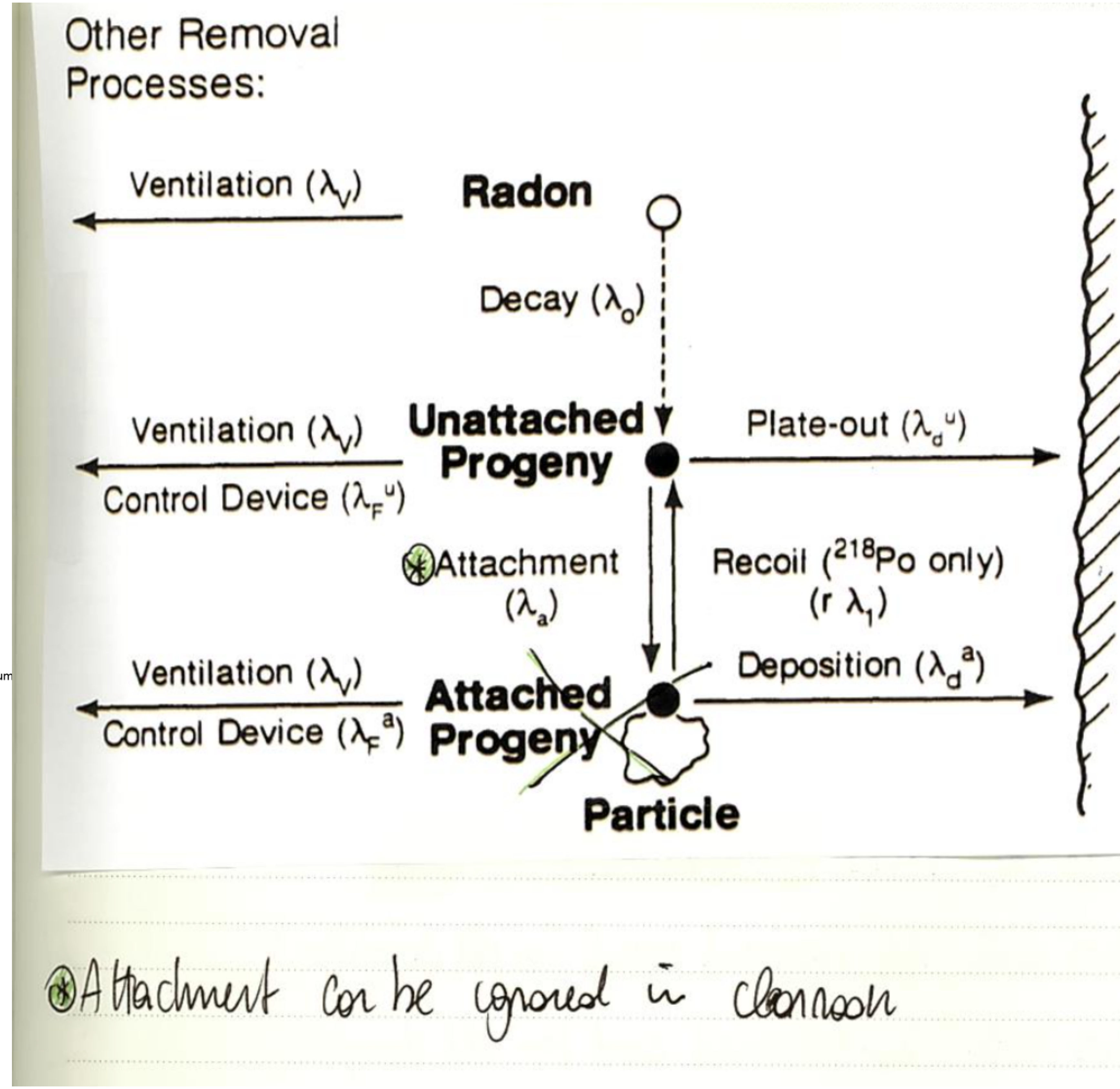
Average radon activity @SNOLAB ≈ 135 Bq/m^3

^{210}Pb plate-out is a concern during installation

Plate-out

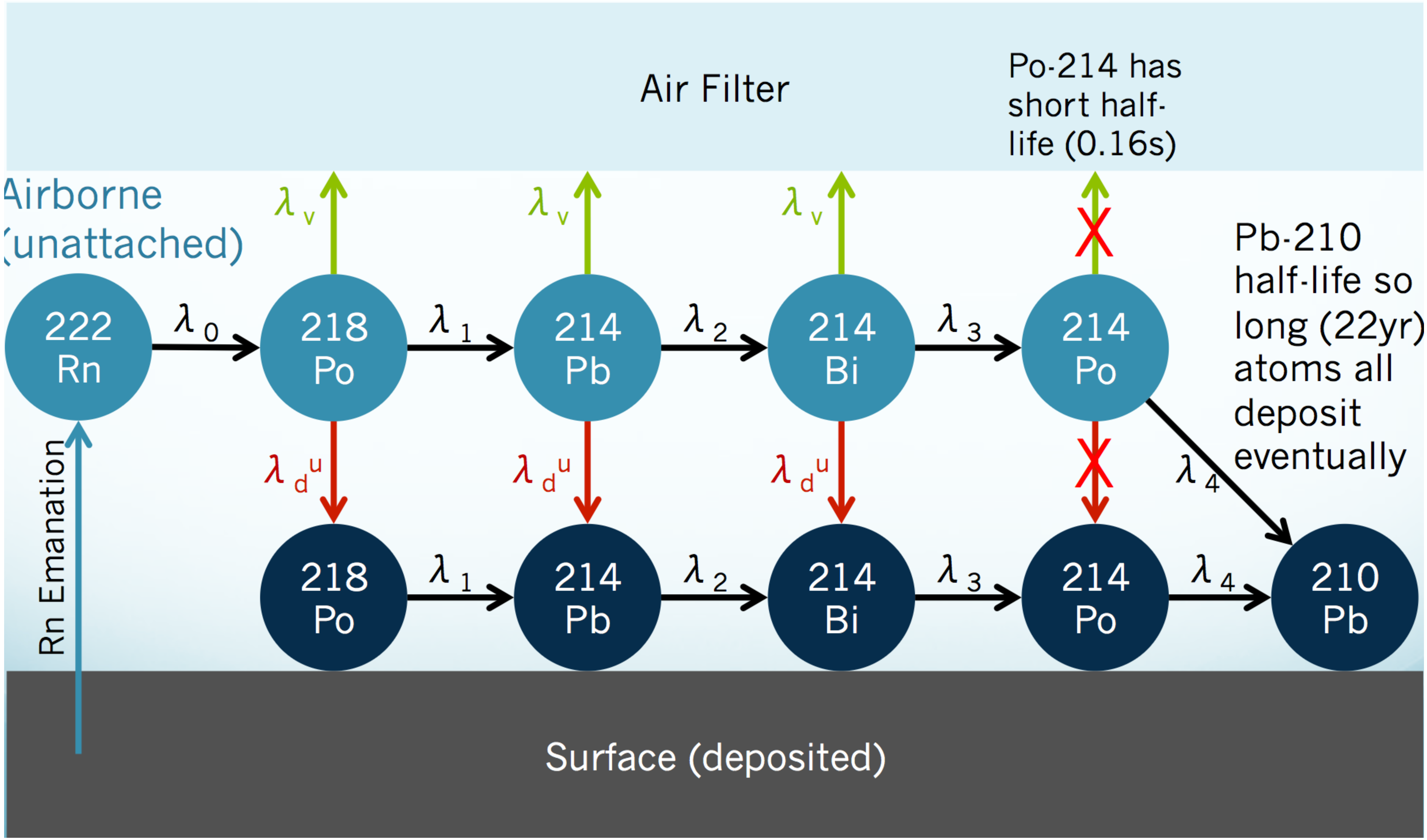


238 92 U 4.5Billion Yr
Uranium 238
234 92 U 245,500 Yr
Uranium 234
234 91 Pa 27day
Protactinium 234
234 90 Th 27day
230 90 Th 75,380 Yr
Thorium 230
226 88 Ra 1,602Yr
Radium 226
222 86 Rn 3.8day
Radon 222
218 85 At 1.5sec
Astatine 218
218 84 Po 3.1min
Polonium 218
214 84 Po 164.3 μ sec
Polonium 214
210 84 Po 138day
Polonium 210
214 83 Bi 20min
Bismuth 214
210 83 Bi 5day
Bismuth 210
0.02%
214 82 Pb 26.8min
Lead 214
210 82 Pb 22.3yr
Lead 210
206 82 Pb Stable
Lead 206
210 81 Tl 1.3min
Thallium 210
206 81 Tl 4.2min
Thallium 206
206 80 Hg 8.1min
Mercury 206
α
β⁻



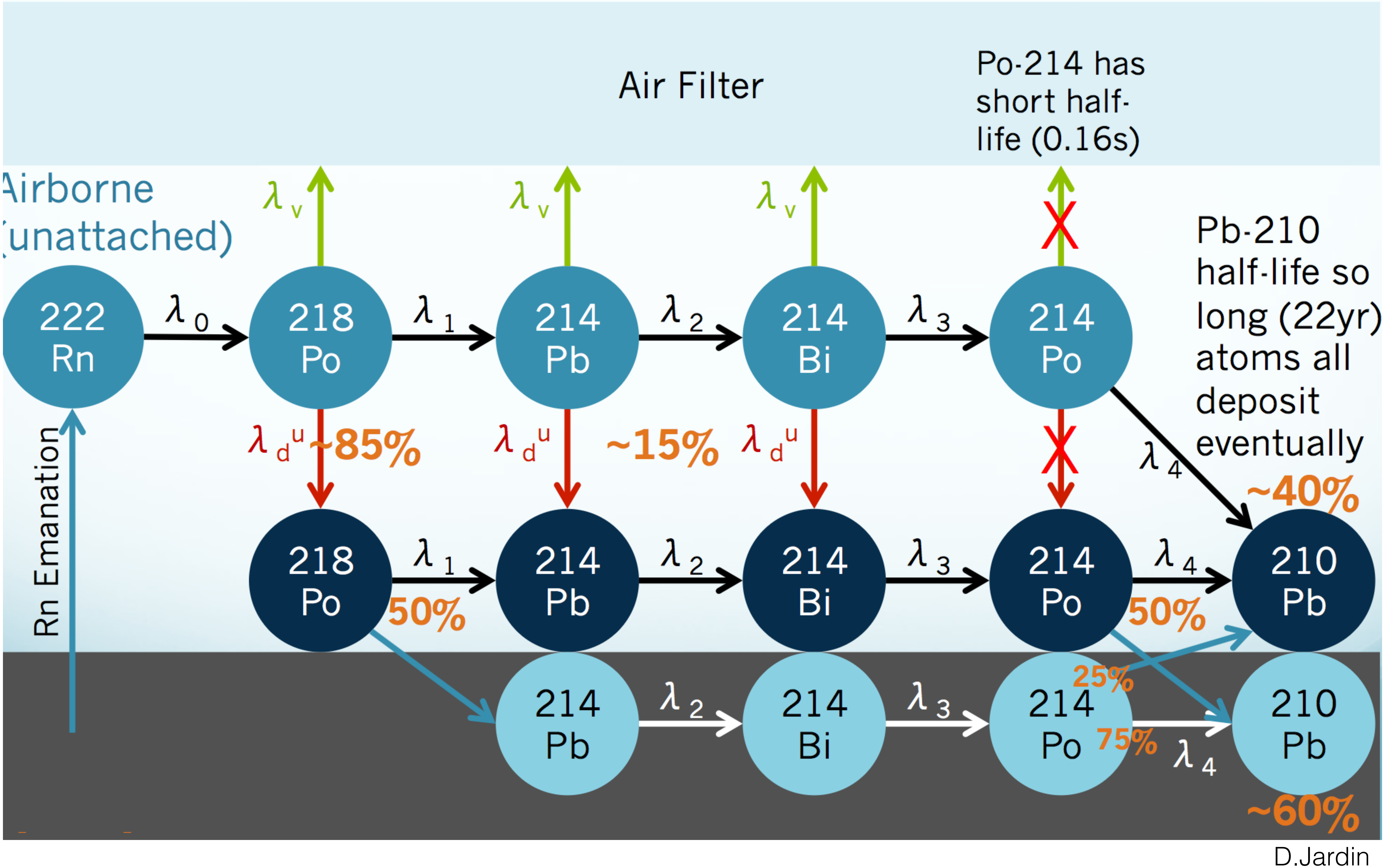
Other Removal Processes:
Ventilation (λV)
Radon
Decay (λo)
Ventilation (λV)
Control Device (λFu)
Unattached Progeny
Plate-out (λdu)
Attachment (λa)
Recoil (218Po only) (r λ1)
Ventilation (λV)
Control Device (λFa)
Attached Progeny
Deposition (λda)
Particle
Attachment can be ignored in cleanroom

Plate-out



D.Jardin

Implantation



Radon Plate-out

26 Oct 2016 - 18 Jan 2017 (83d)

XIA LLC alpha counter measurement of ^{210}Po alphas (5.3 MeV)

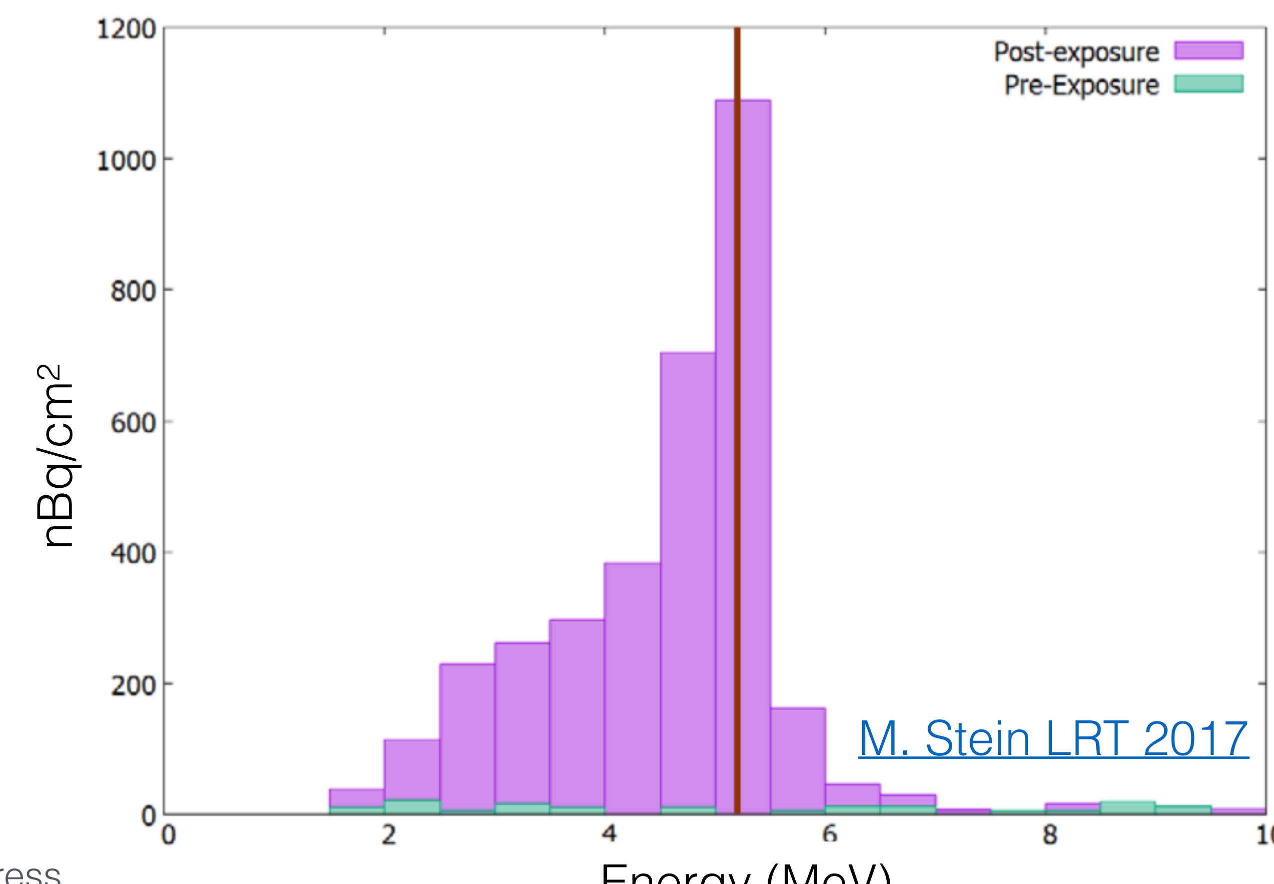
SuperCDMS group at SMU (Dallas, TX)

Pre-exposure assays performed

96 ± 18 nBq/cm^2 for HDPE

394 ± 62 nBq/cm^2 for Cu

Two post-exposure measurements per sample



- Cu and HDPE samples exposed in SNOLAB
- Predict alpha activity over time
- Inform exposure limits for installation of SuperCDMS SNOLAB
- Inform future background estimates
- Be useful for other projects/experiments

Analytical Model
^{210}Po Activity

$$Total\ Activity = {}^{210}Pb\ Activity + (Dust\ Activity)$$

$^{210}Pb \rightarrow {}^{210}Po$ ($t_{1/2}$138d)

^{210}Po activity **increases** with time, after exposure

U and Th chains activity,
constant in time

Analytical Model ^{210}Po Activity

$$Total\ Activity = R_{Pb}K_{Pb} + S_{dust}K_{dust}$$

Two measurements of activity:

- two unknown variables
- ingrowth of ^{210}Po

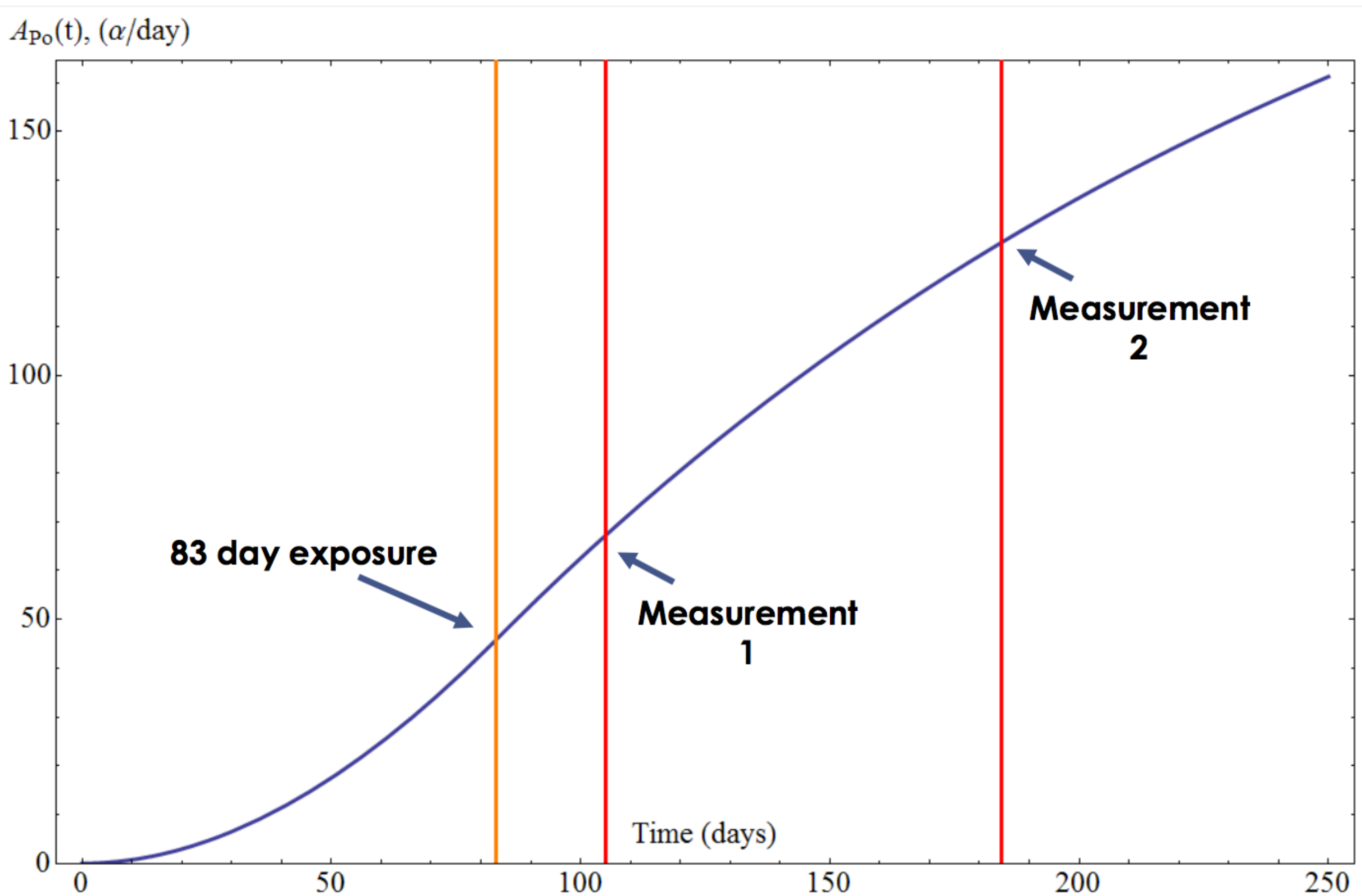


Plate-out rate: ~278(423) ^{210}Pb atoms per day per cm^2 for HDPE(Cu)

Dust activity increases ~27(5) nBq per day per cm^2 for HDPE(Cu)

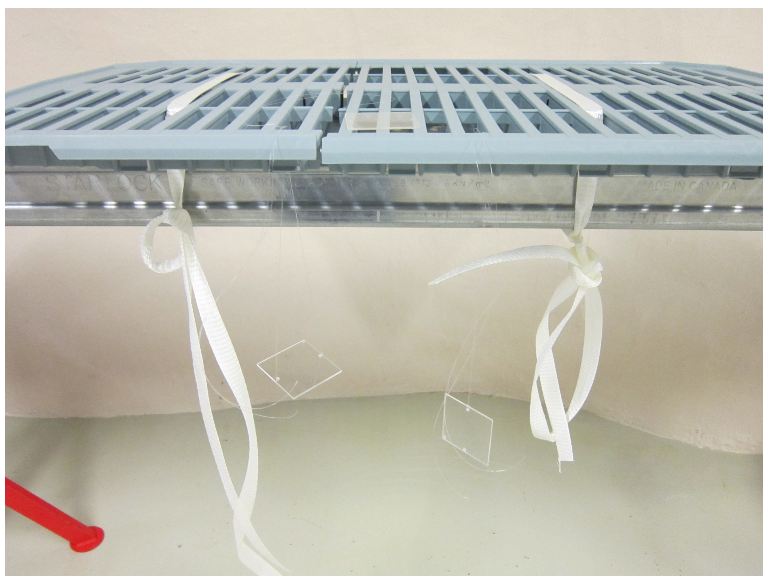
Compatible with SNOLAB TR
S_{dust} = [3.6-28.8]

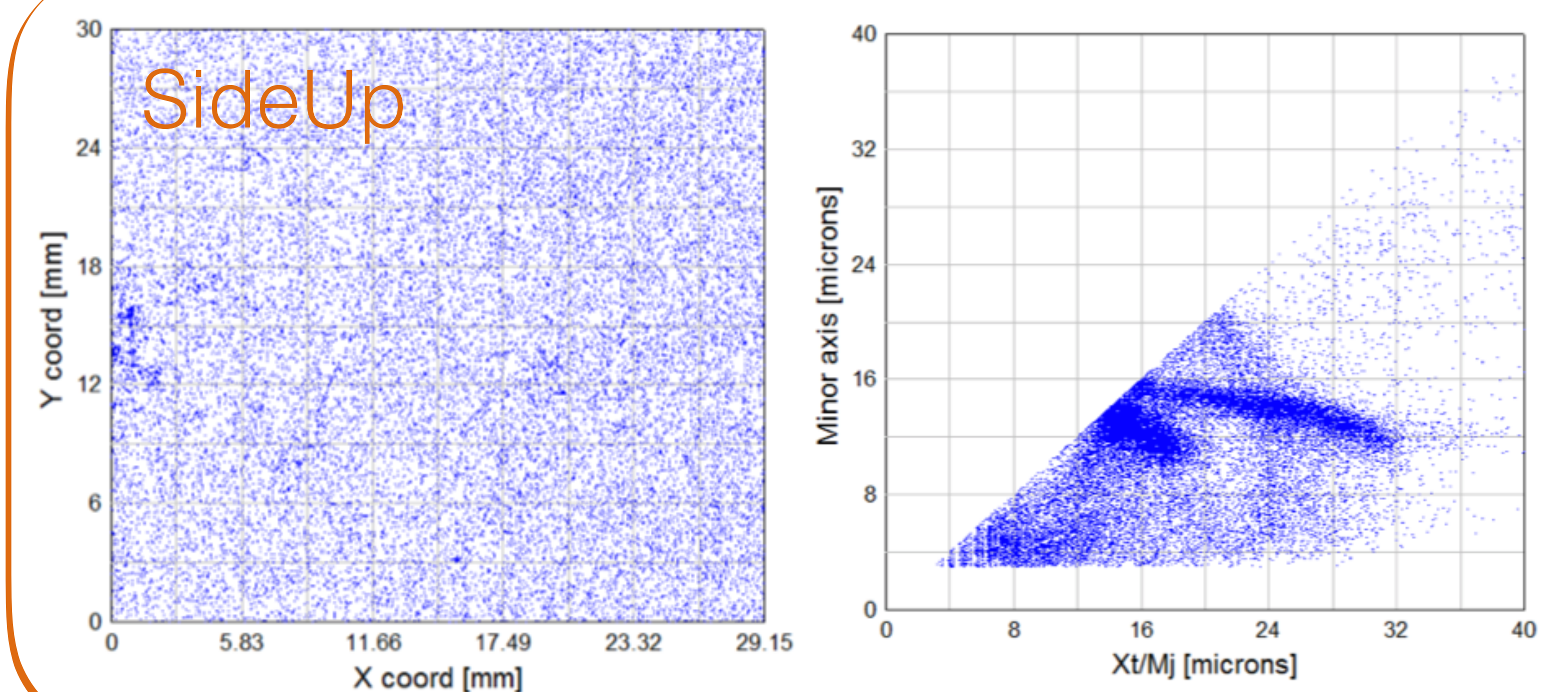
Constraint for installation:

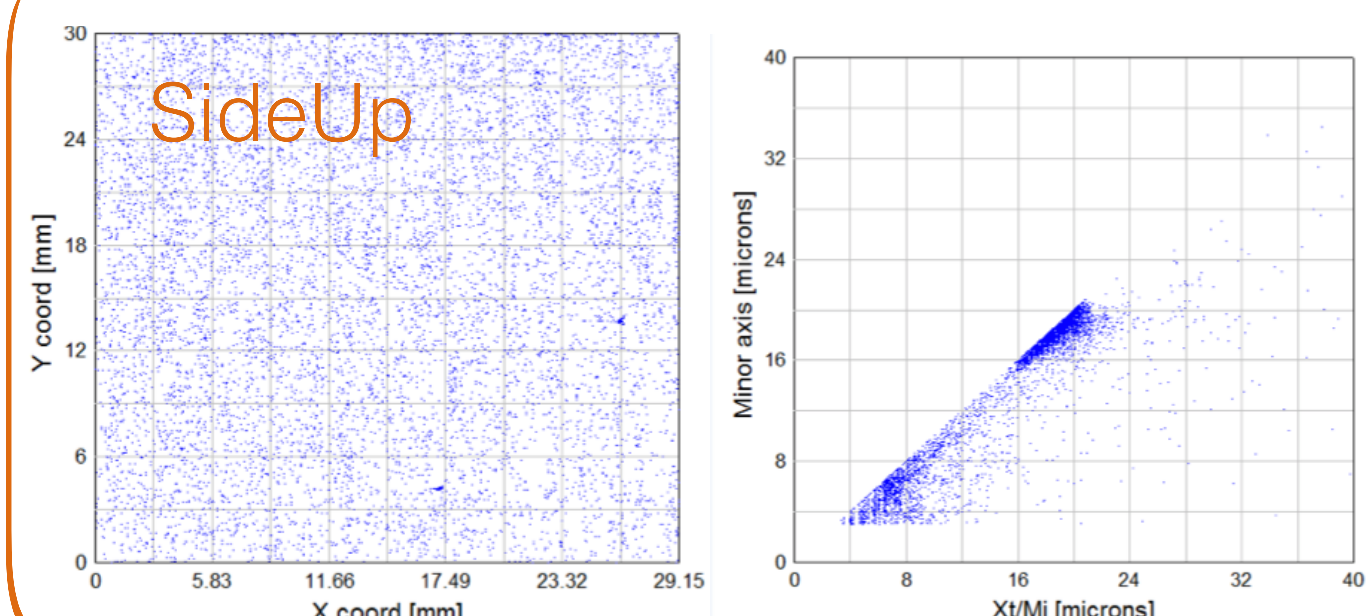
~39 days to limit ^{210}Pb to 10 µBq/cm^2
~60 days to limit dust activity

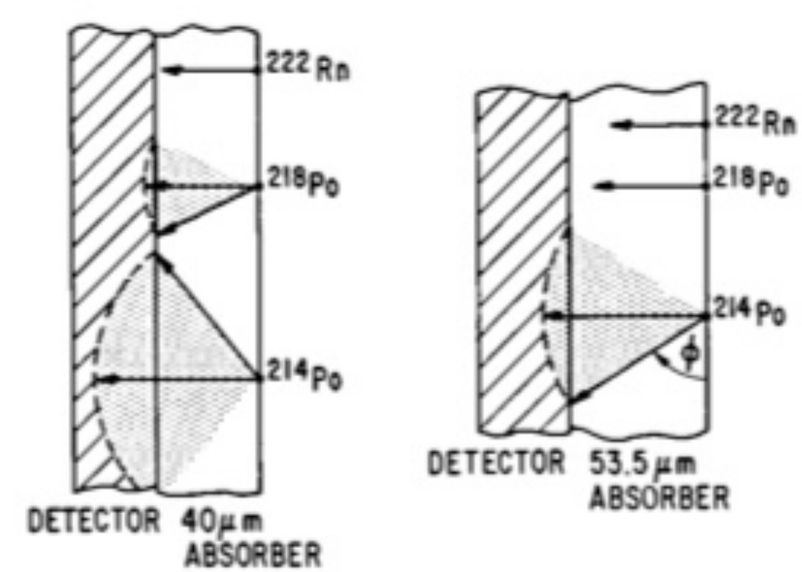
Cross Measurements

[TASL]









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thank you!