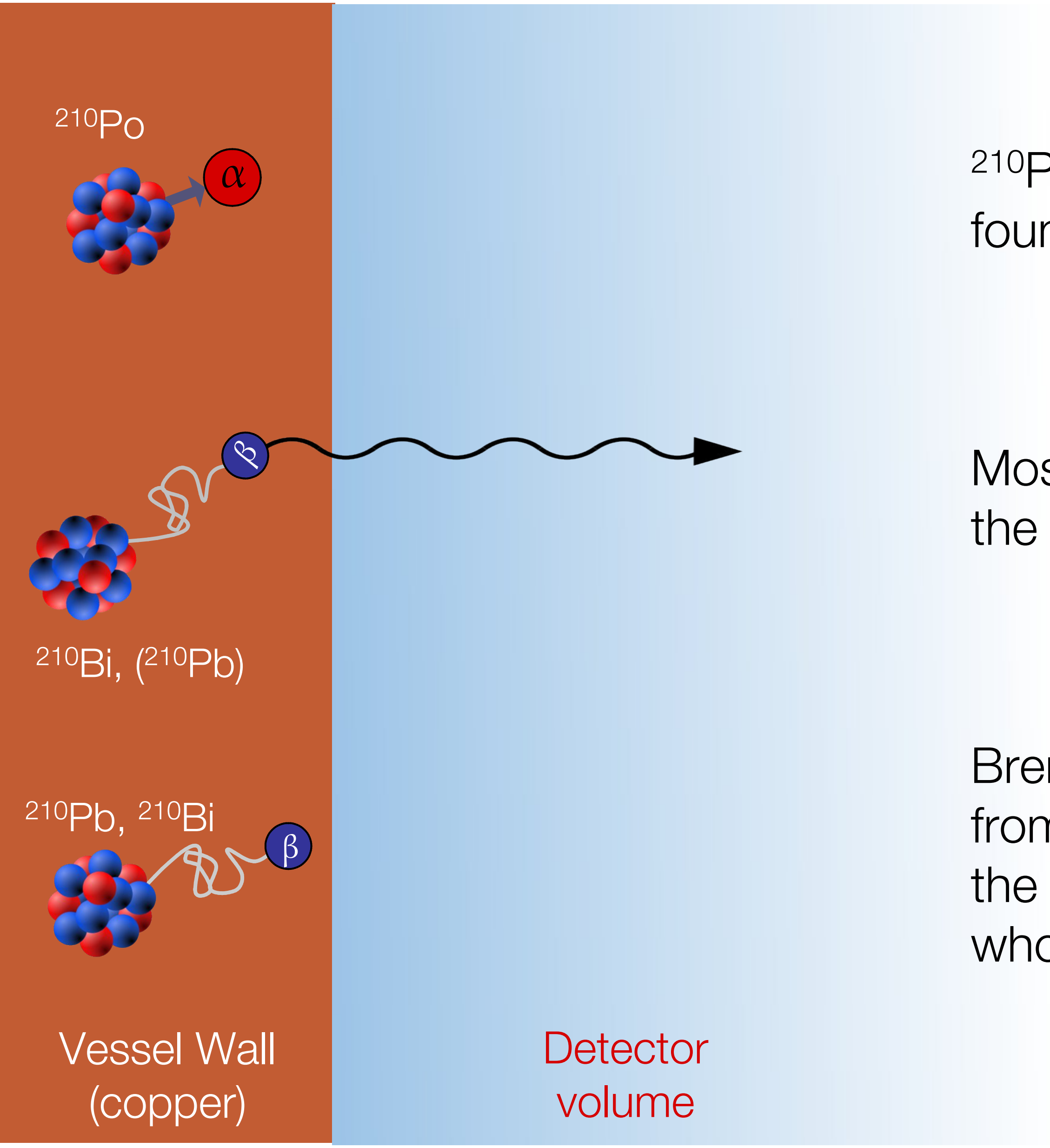
Status of ^{210}Pb Measurements

Daniel Durnford

June 11th 2019
NEWS-G Collaboration Meeting
Grenoble, France

Our worst background signal:



^{210}Pb is a long-lived radio-impurity found in copper

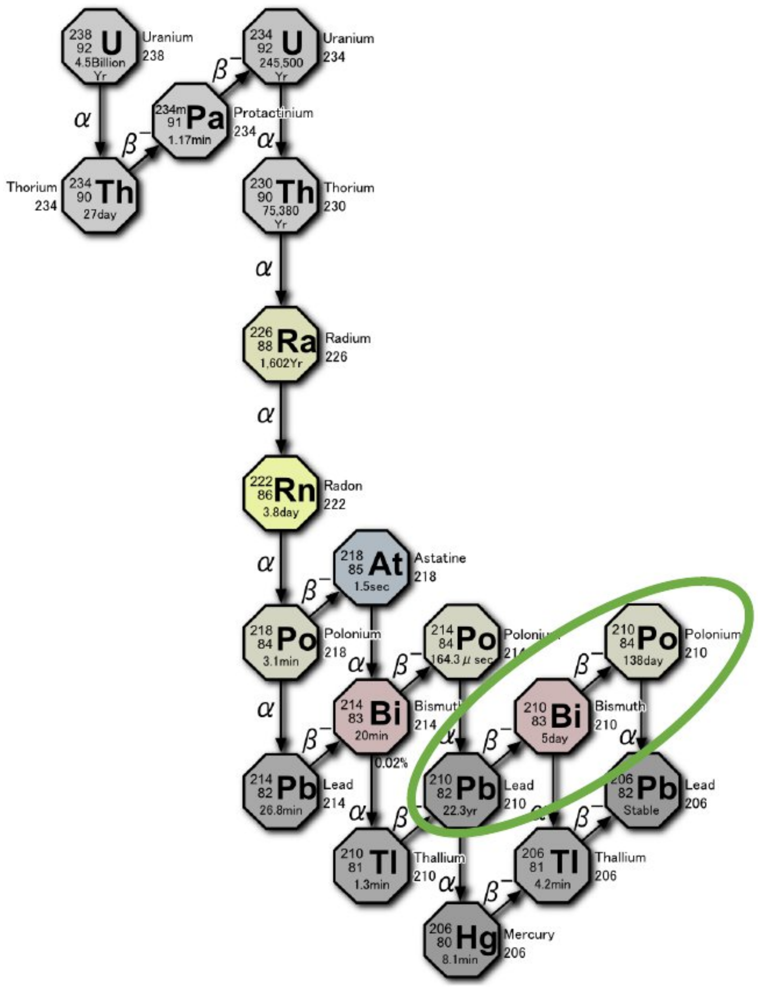
Most radiation is stopped inside the copper but...

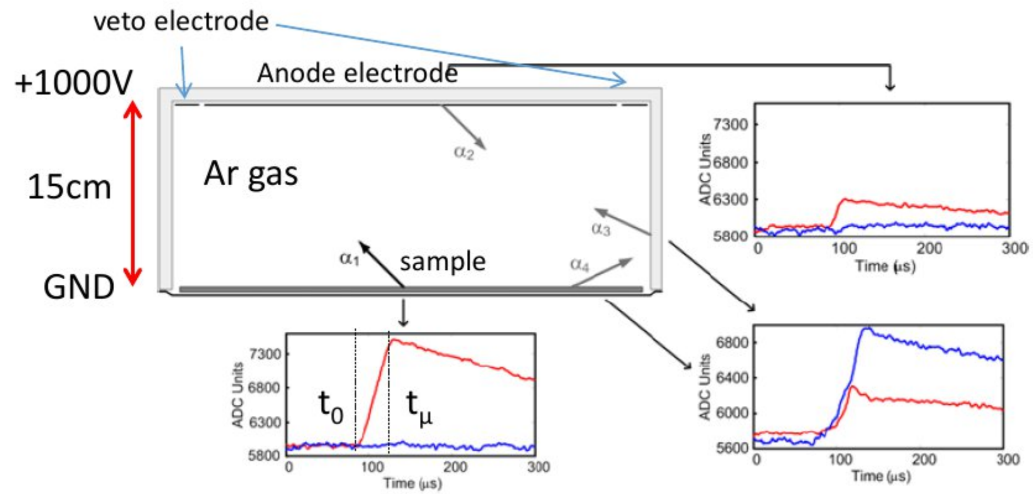
Bremsstrahlung x-rays (~keV) from ^{210}Pb and ^{210}Bi **β⁻** decay in the copper escape, travel through whole volume

XIA measurements of ^{210}Pb in copper

The XMASS collaboration from measures ^{210}Po alpha's with an XIA detector

The ^{210}Po activity can be used to calculate the concentration of ^{210}Pb





K Kobayashi (LRT 2017)

signal

veto signal

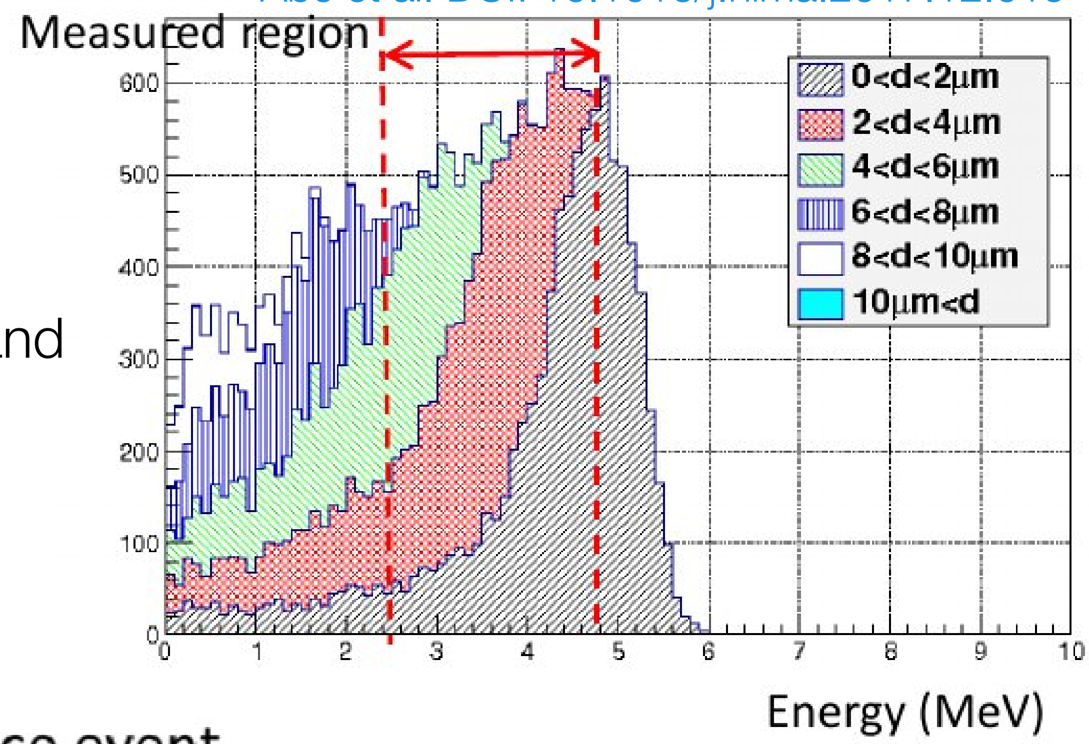
By measuring rise time (t_μ-t_0), surface event can be distinguished from event in Ar gas or ceiling.

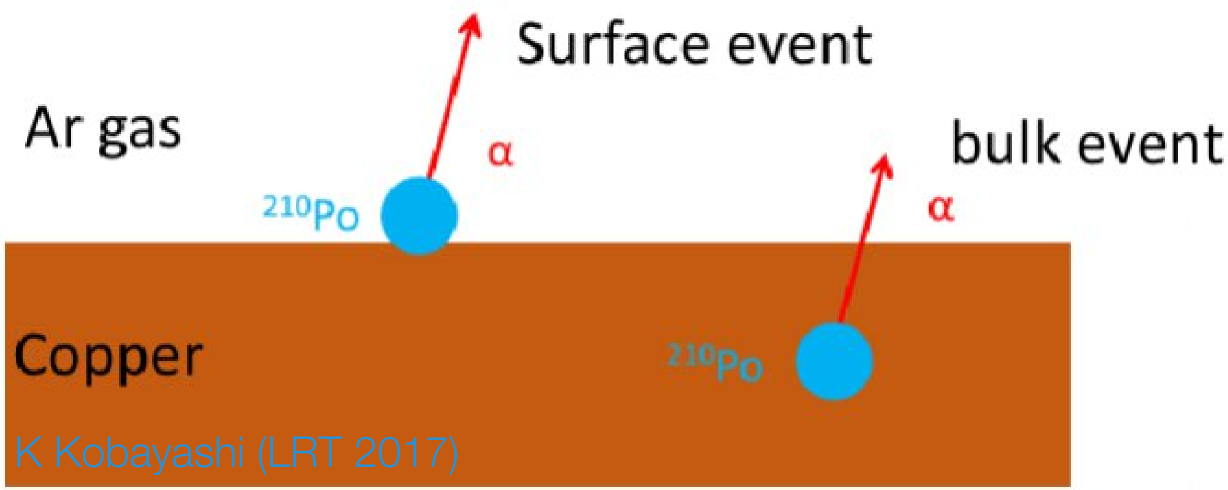
7

Bulk alpha's lose energy as they leave the copper

An energy ROI of 2.5 -> 4.8 MeV to select bulk alpha's, and a coefficient relating bulk contamination to ROI activity are based on a Geant4 simulation

Abe et al. DOI: 10.1016/j.nima.2017.12.015





A joint likelihood fit of all measurements using an extended un-binned likelihood with a Gaussian prior on the background:

$$\mathcal{L}\left(\{c, t_1, t_2\} \,|A_{\mathrm{Pb}}, A_{\mathrm{Po}}, A_{\mathrm{B}}\right) = \prod_{i=1} \frac{\mu_{\mathrm{i}} e^{-\mu_{\mathrm{i}}}}{c_{\mathrm{i}}!} \times \mathcal{L}_{\mathrm{B}}$$

$$\mu_i = \int_{t_{1_i}}^{t_{2_i}} A_{Po}\left(t|A^0_{Pb}, A^0_{Po}\right) dt + N_B \qquad \mathcal{L}_B = \frac{1}{\sqrt{2\pi\sigma_B^2}} e^{-\frac{(N_B-\mu_B)^2}{2\sigma_B^2}}$$

Choices/Assumptions:

- Profile likelihood to extract uncertainties on parameters
- A Gaussian uncertainty on the ROI background they gave us (5.6×10^{-6} $\alpha/\mathrm{cm}^2/\mathrm{hr}$)
- No uncertainty on emissivity to activity conversion factors, quality cuts...

Current analysis results

Date	Measurement ($\alpha/cm^2/hr$)	Counts
July 2 - 25, 2018	2.33×10^{-4}	70.01
Oct. 5 - 17, 2018	2.20×10^{-4}	40.54
Dec. 28, 2018 - Jan. 9, 2019	1.44×10^{-4}	28.51
April 19 - May 7, 2019	1.41×10^{-4}	34.93

After 3rd measurement:

^{210}Pb results:

1σ confidence Window:

11.2 - 40.3 mBq/kg

Best fit value: 25.4 mBq/kg

Other parameters:

A_{Po} = 159 mBq/kg

$A_B = 5.60 \times 10^{-6}\ \alpha/cm^2/hr$

Current analysis results

Date	Measurement ($\alpha/cm^2/hr$)	Counts
July 2 - 25, 2018	2.33×10^{-4}	70.01
Oct. 5 - 17, 2018	2.20×10^{-4}	40.54
Dec. 28, 2018 - Jan. 9, 2019	1.44×10^{-4}	28.51
April 19 - May 7, 2019	1.41×10^{-4}	34.93

After 3rd measurement:

^{210}Pb results:

1σ confidence Window:

11.2 - 40.3 mBq/kg

Best fit value: 25.4 mBq/kg

Other parameters:

A_{Po} = 159 mBq/kg

$A_B = 5.60 \times 10^{-6}\ \alpha/cm^2/hr$

After 4th measurement:

^{210}Pb results:

1σ confidence Window:

20.6 - 36.8 mBq/kg

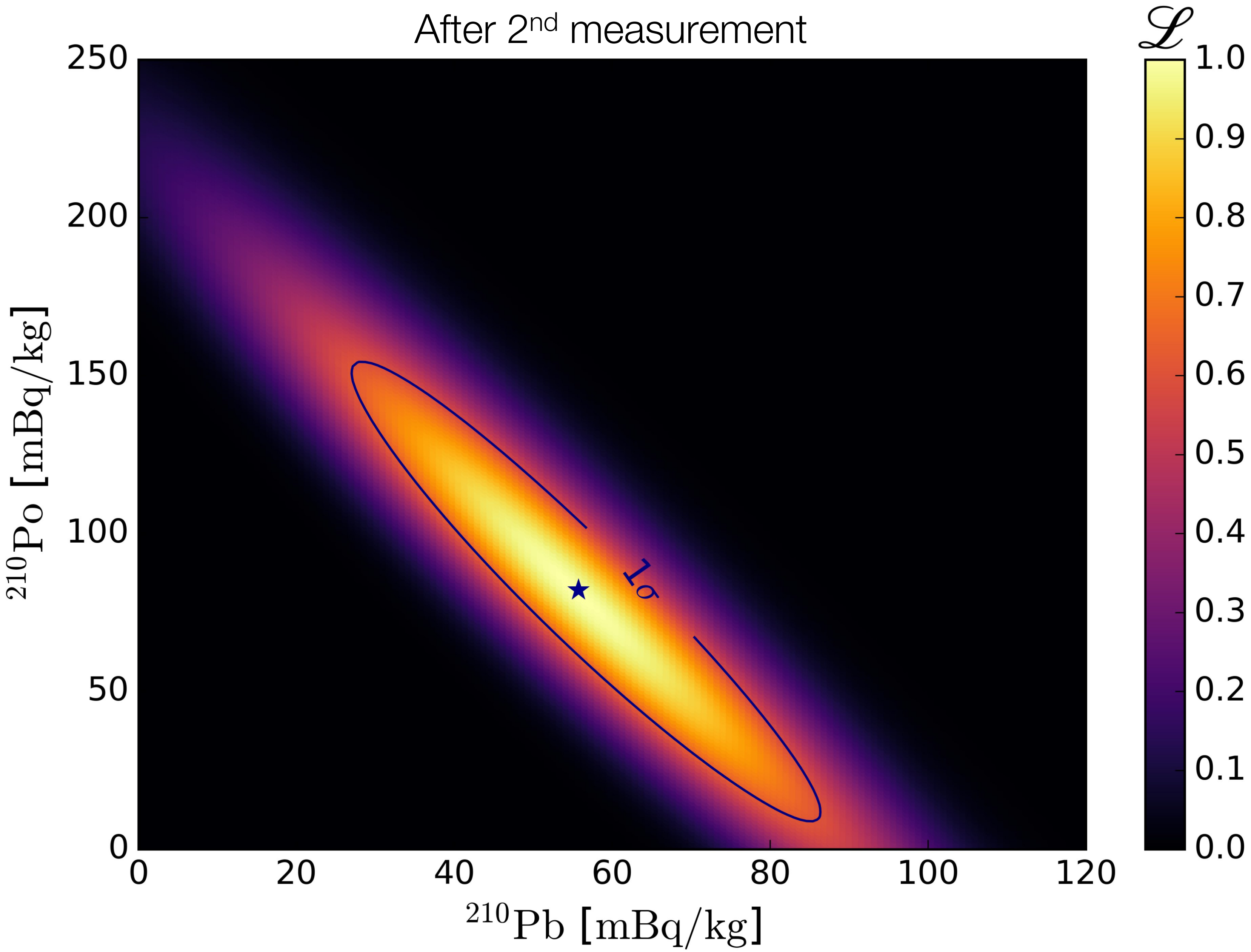
Best fit value: 28.5 mBq/kg

Other parameters:

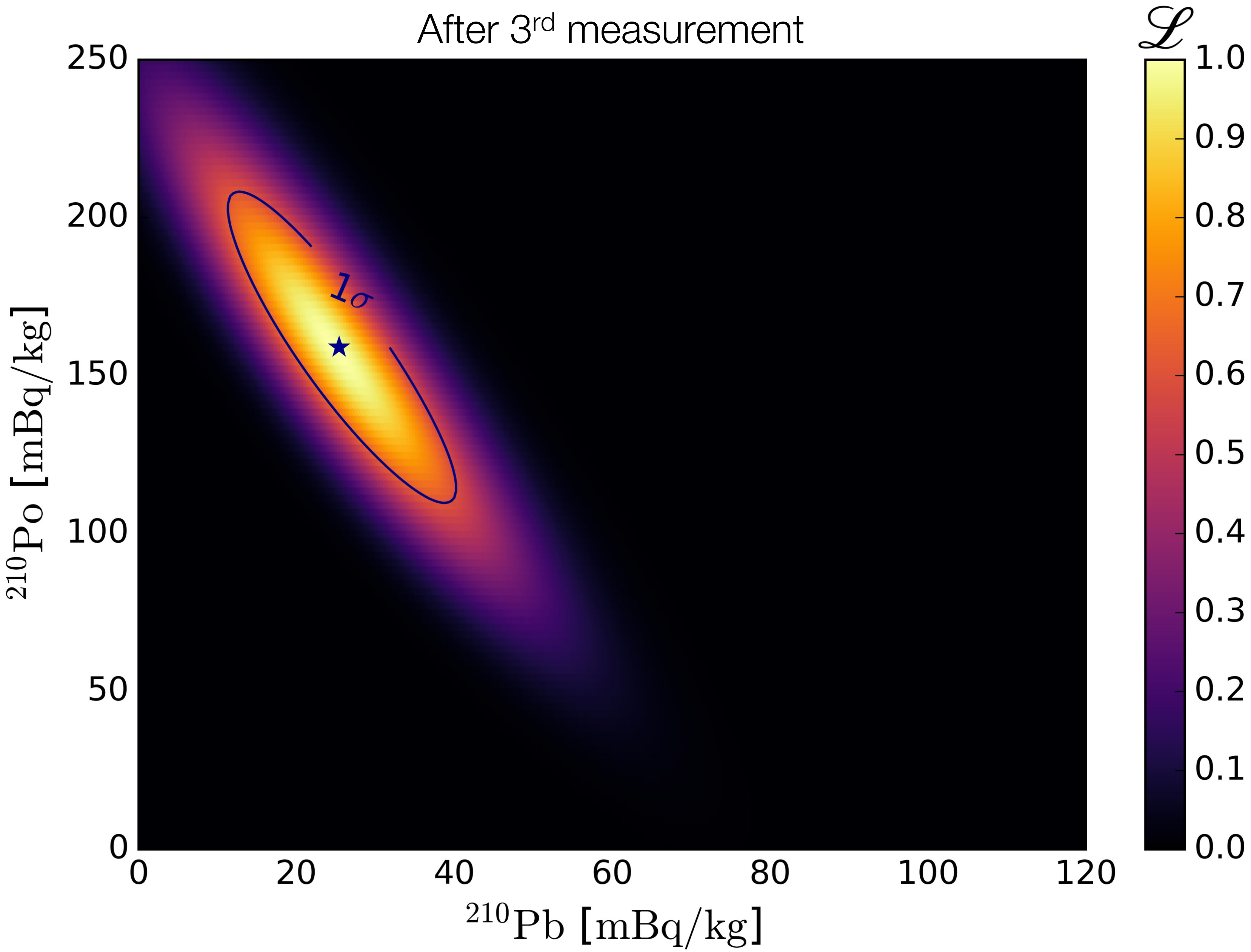
A_{Po} = 143 mBq/kg

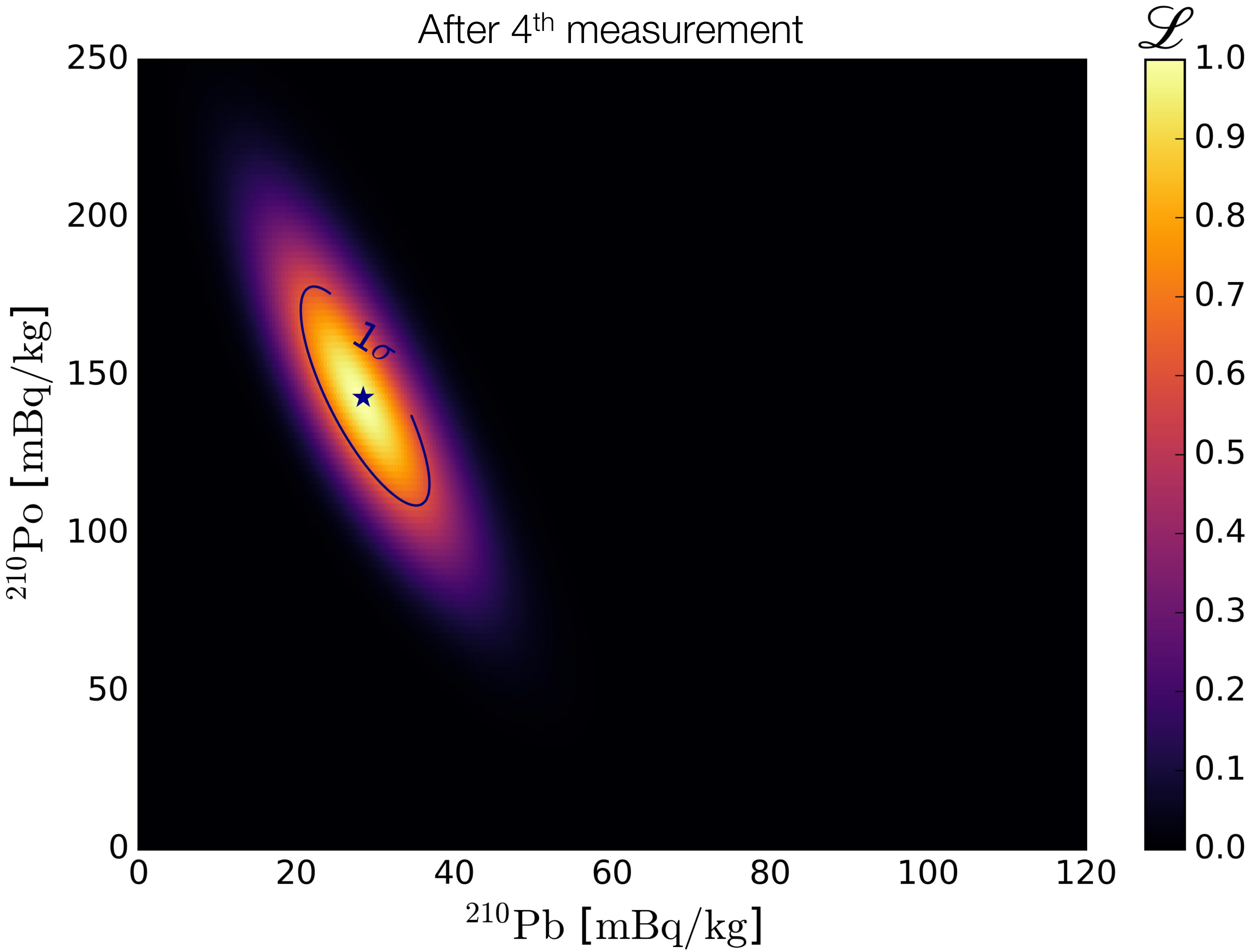
$A_B = 5.60 \times 10^{-6}\ \alpha/cm^2/hr$

After 2nd measurement

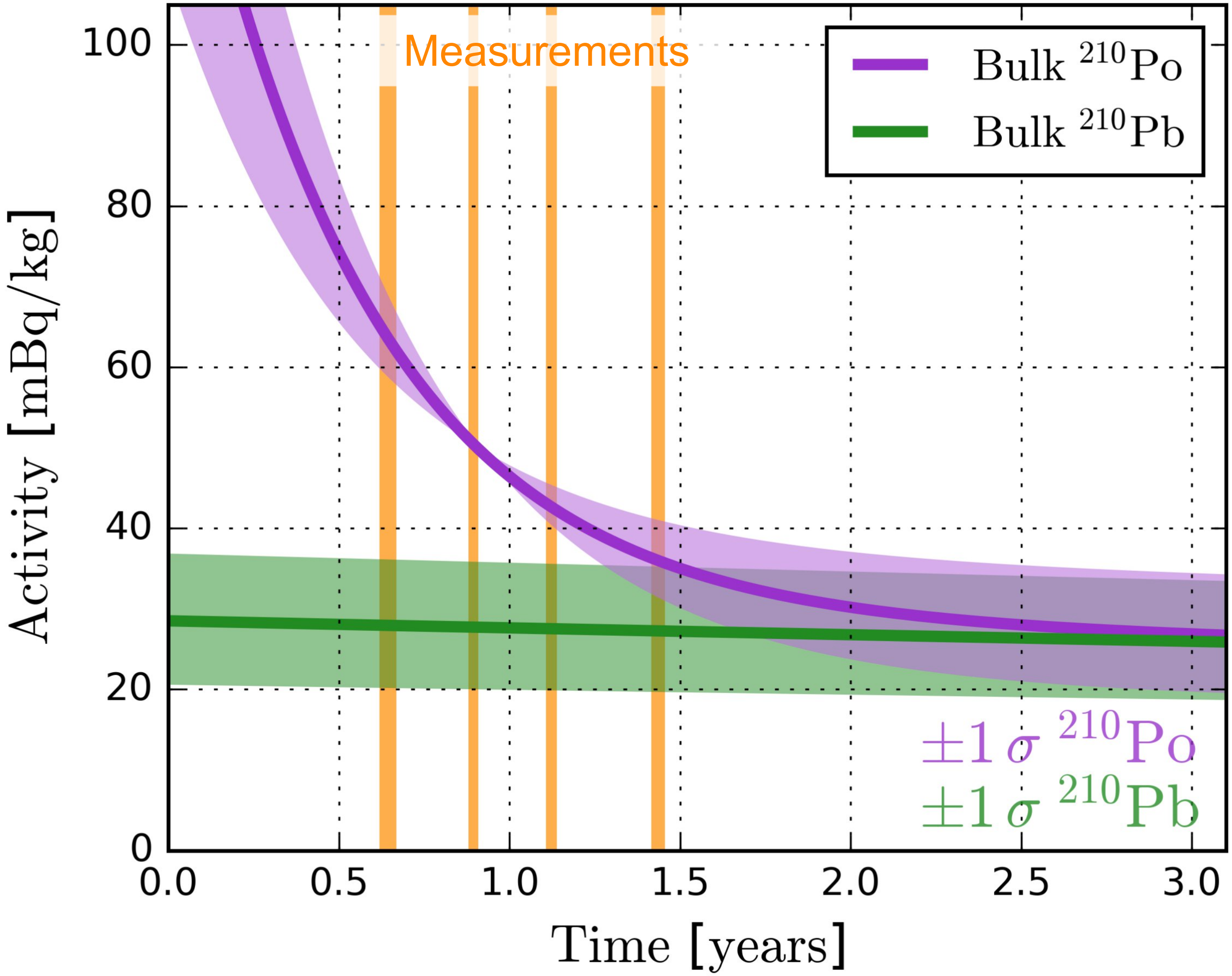


Current analysis results




After 4th measurement
$\mathscr{L}$
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
250
200
150
100
50
0
0
20
40
60
80
100
120
1σ
^{210}Po [mBq/kg]
^{210}Pb [mBq/kg]

How is the sample evolving over time?



Solid lines: evolution of isotopes assuming best fit values

Shaded bands: possible evolution assuming $\pm 1\sigma$ values

Currently our estimation of the bulk ^{210}Pb is 28.5 mBq/kg, which is in-line with expectations from other samples measured by Abe et al.

The way in which these results are disseminated could determine how much effort is put into "polishing" this analysis. We could:

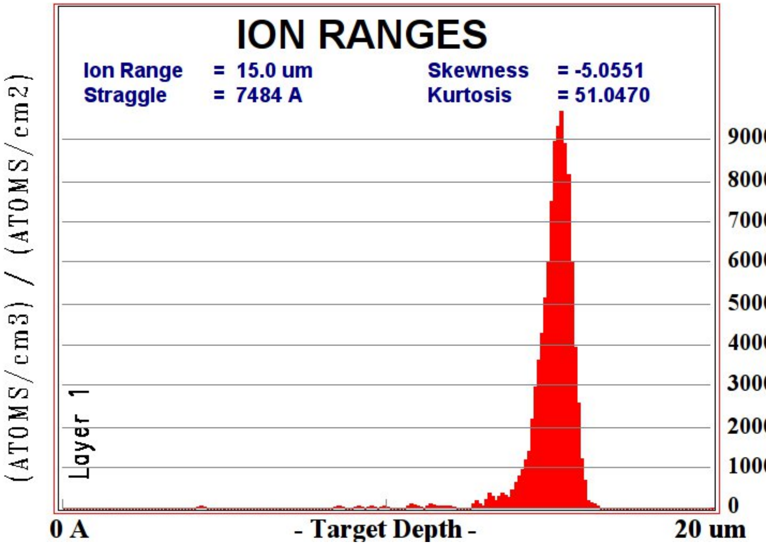
- Try to replicate Geant4 simulation
- Re-visit fit model allowing for surface roughness

Future work

It may also be possible to measure the Pb-210 contamination of lead (i.e. the arhaeological lead)

Po-210 alpha's have a similar range in lead, so the measurements should be feasible

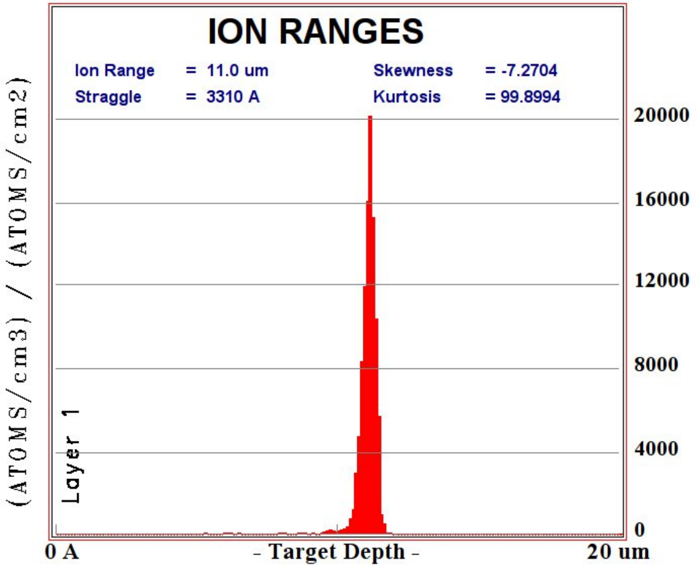
Advantage over Germanium measurements of Pb-210 gamma's because of greater attenuation in lead



Lead

vs.

Copper

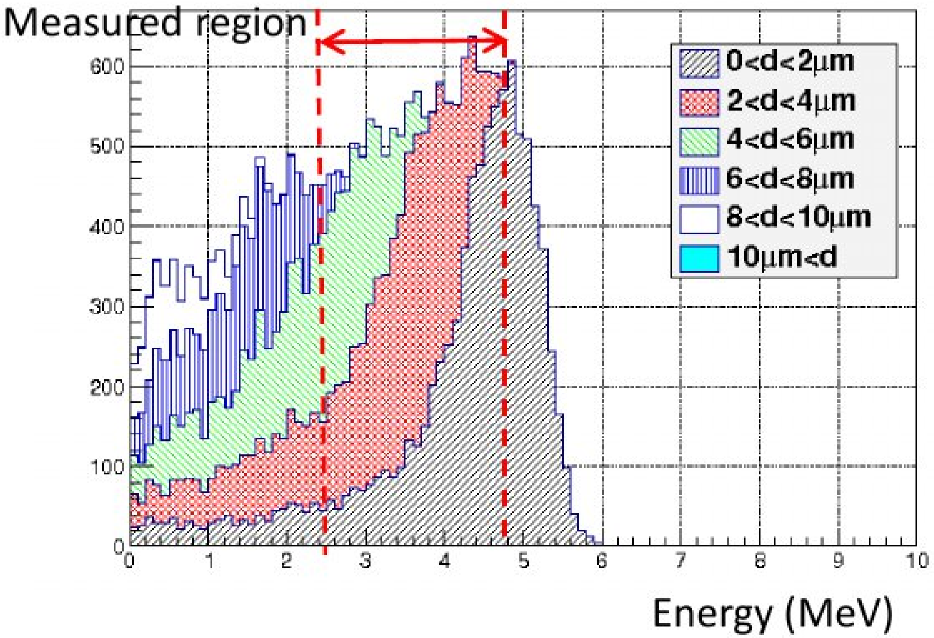


It may also be possible to measure the Pb-210 contamination of lead (i.e. the arhaeological lead)

Po-210 alpha's have a similar range in lead, so the measurements should be feasible

Advantage over Germanium measurements of Pb-210 gamma's because of greater attenuation in lead

First step is to repeat this calculation for lead



Thank you

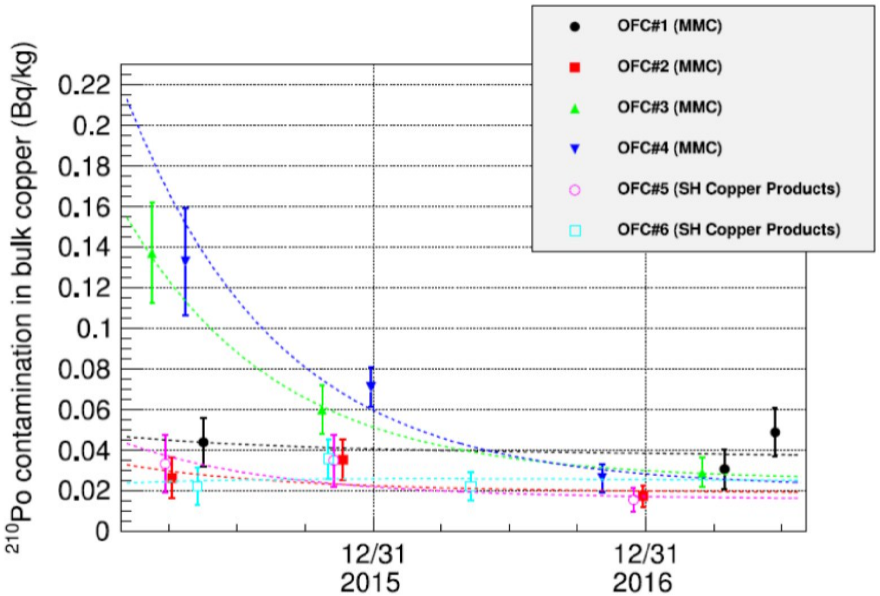
Extra Slides

The results of Abe et al.

They demonstrated that the equilibrium between ^{210}Pb and ^{210}Po in copper is broken during the casting process.

The overall ^{210}Po activity has contributions from the initial amount of ^{210}Po and ^{210}Pb after casting

Multiple measurements over time are required to disentangle the two contributions



Sample	^{210}Pb contamination (mBq/kg)	^{210}Po contamination (mBq/kg)
OFC#1 (C1020) (MMC)	40±8	47±21
OFC#2 (C1020) (MMC)	20±6	33±14
OFC#3 (C1020) (MMC)	27±7	$(1.6\pm0.3)\times10^2$
OFC#4 (C1020) (MMC)	23±8	$(2.2\pm0.4)\times10^2$
OFC#5 (C1020) (SH copper products)	17±6	44±18
OFC#6 (C1020) (SH copper products)	27±8	24±17
OFC (class1) (SH copper products)	36±13	38±3
Coarse copper (MMC)	$(57\pm1)\times10^3$	$(16\pm2)\times10^3$
Bare copper (MMC)	8.4±4.0	$(1.1\pm0.2)\times10^2$
OFC (MMC)	23±8	$(1.3\pm0.3)\times10^2$
6N copper (MMC)	<4.1	<4.8
Electroformed copper (Asahi-Kinzoku)	<5.3	<18

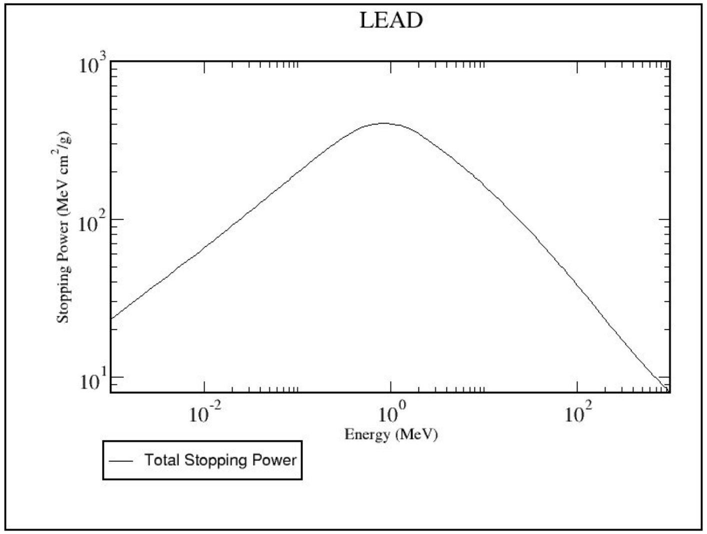
Abe et al. DOI: 10.1016/j.nima.2017.12.015

Future work

It may also be possible to measure the Pb-210 contamination of lead (i.e. the arhaeological lead)

Po-210 alpha's have a similar range in lead, so the measurements should be feasible

Advantage over Germanium measurements of Pb-210 gamma's because of greater attenuation in lead



Lead

vs.

Copper