Lead materials and chemical reagents – What's their lead-210 background?

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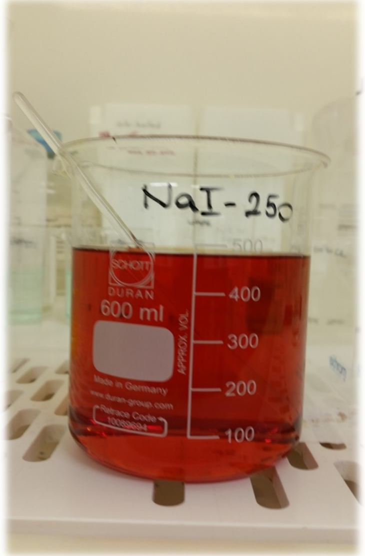
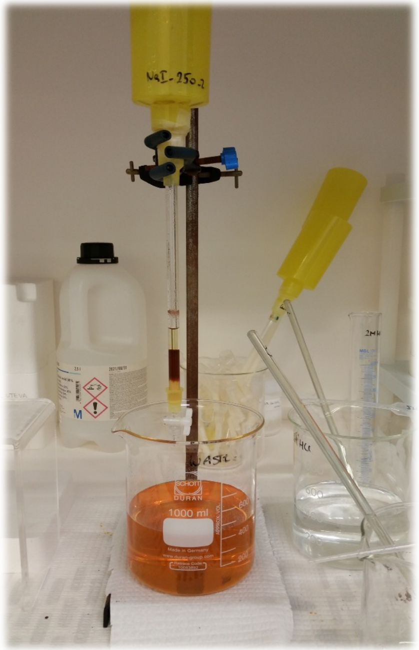
What do we want to do, why & how?

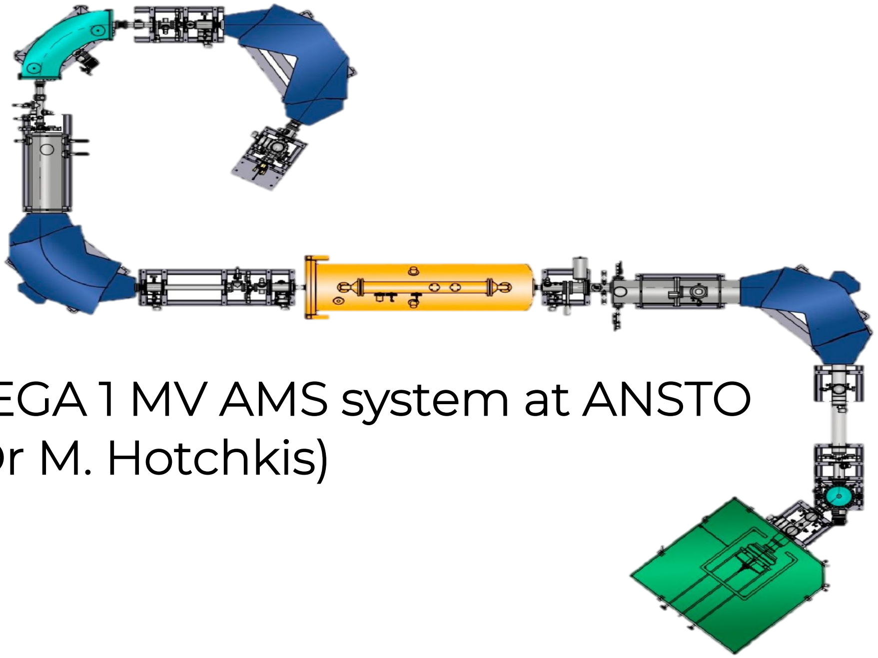
Goal: Characterise and quantify radioimpurities in detector material (NaI(Tl)) - ^{40}K, U & Th decay series, ^{210}Pb, ^{129}I, *etc.*

Why: Mimic signals in region of interest, limit sensitivity

How: Combination of analytical chemistry and Accelerator Mass Spectrometry.







VEGA 1 MV AMS system at ANSTO (Dr M. Hotchkis)

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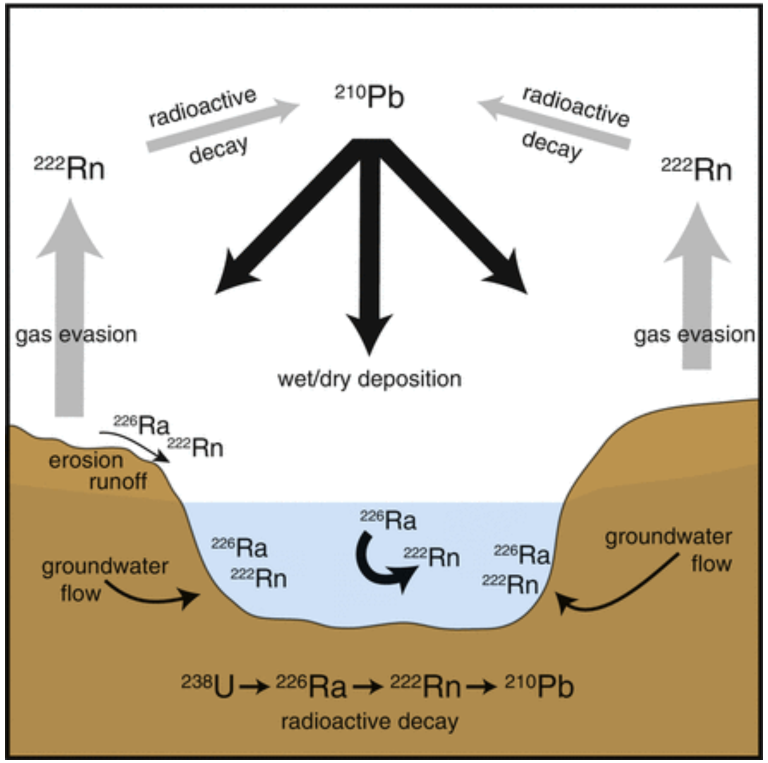
Challenges & Strengths

AMS: is a relative measurement (isotopic ratio, $^{210}Pb/^{208}Pb$), carrier.
Pb-210: decay product of U-238 → omnipresent.
NaI: Expected $^{210}Pb < 3.0\times10^{-2}$ mBq/kg ($^{210}Pb/^{208}Pb = 1.33\times10^{-14}$) [1].

We need to: Screen potential Pb carriers and chemicals/reagents to be used.



Currently, we are able to measure $^{210}Pb/^{208}Pb$ ratios down to 1×10^{-14} [2].

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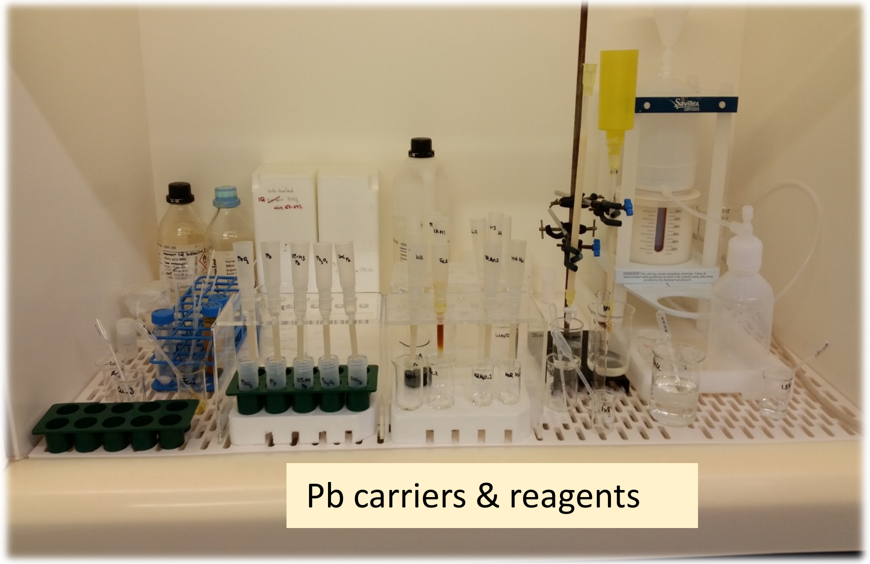
[1] Antonello et *al*., Astroparticle Physics, 2019; 106:1-9.
[2] Froehlich et *al*., Nucl Instrum Methods Phys Res B, 2022; 529:18-23.

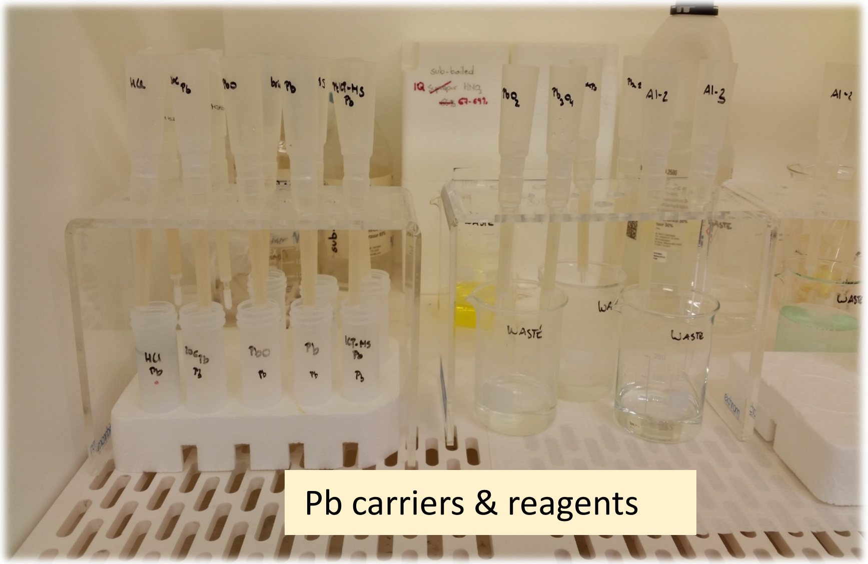
Pb carriers and chemical reagents

Pb compound	Pb compound	Chemical reagent	Reagent
Pb (metal powder)	Pb_20001 (roof)	AE resin (1-X8, 100-200 mesh, Cl^- form)	Ag (Ag powder)
PbO	^{204}Pb & ^{206}Pb	HCl (Suprapur®)	NaI-250
PbO_2	ICP-MS Pb	Fe (Fe wire)	Chemical blank
Pb_3O_4	brick	Al (Al cathodes)	Ag, AgF & AgF_2*
PbF_2	LNGS material	Milli-Q water	SbF_3*
U. Chicago Spanish lead	Hampton Court Palace roof	Sub-boiled Milli-Q water	
PNNL ancient lead	LANL stock & Chicago stock	Cu (Cu cathodes)	

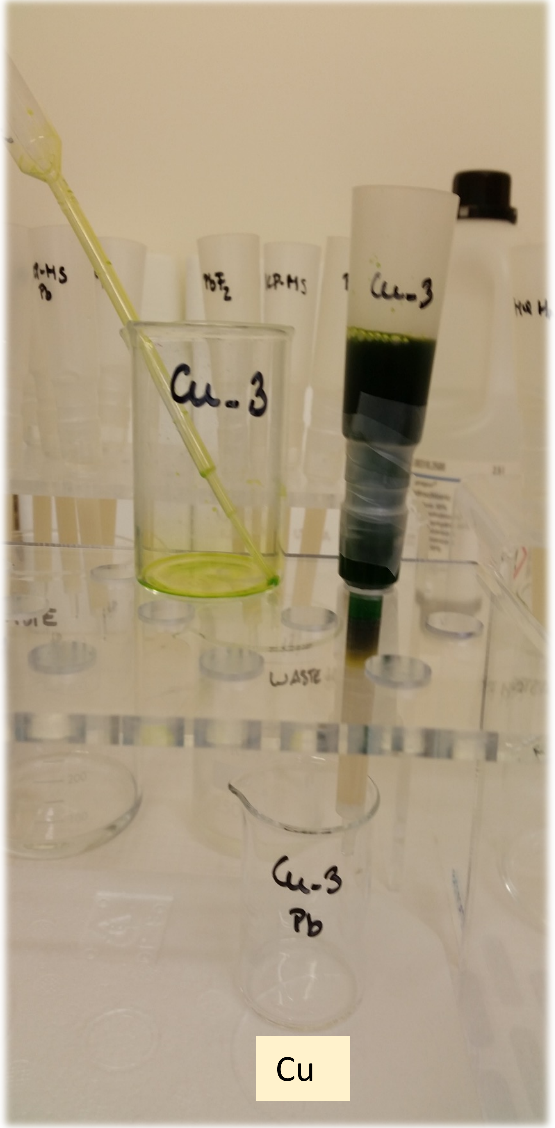
*No chemistry



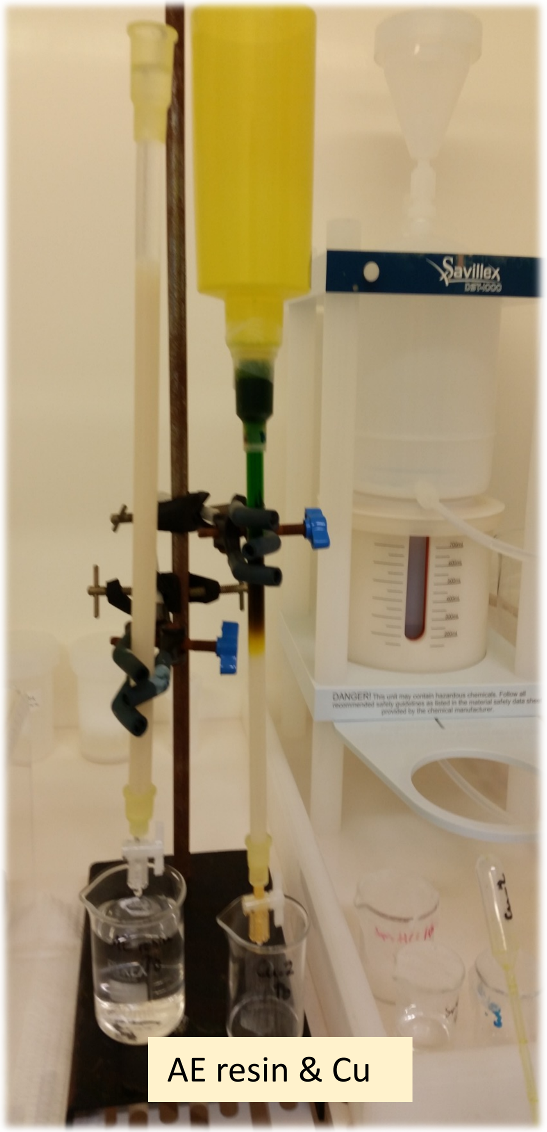
Pb carriers & reagents



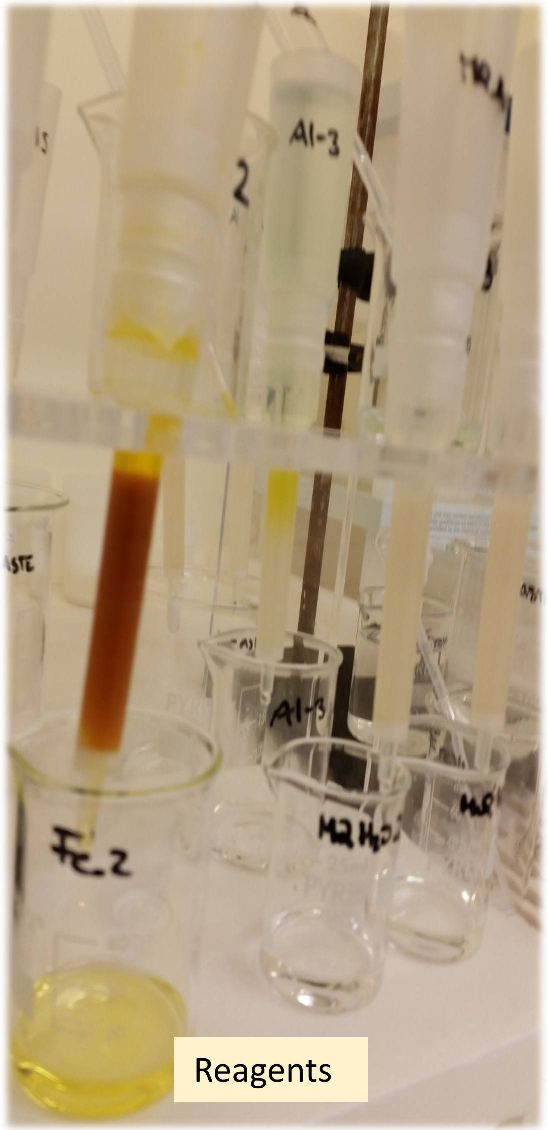
Pb carriers & reagents



Cu



AE resin & Cu



Reagents

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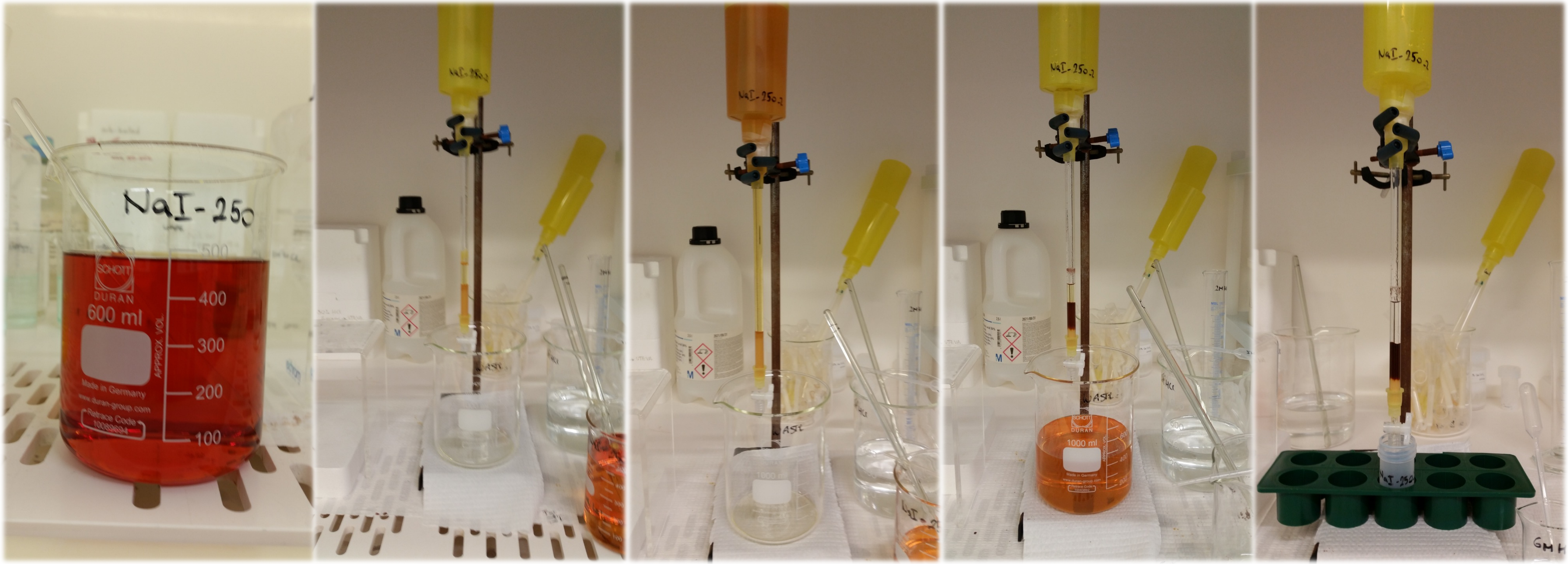

250 g NaI in 2M HCl

6M HCl ⟶ Pb

Results – Pb carriers

Pb compound	^{210}Pb [cts]	^{210}Pb/Pb	Pb compound	^{210}Pb [cts]	^{210}Pb/Pb
Pb (metal powder)	0		ICP-MS Pb	$7^{+3.30}_{-2.75}$	9.6×10^{-14}
PbO	$1^{+1.75}_{-0.63}$	1.2×10^{-14}	brick	0	
PbO_2	$1^{+1.75}_{-0.63}$	1.1×10^{-14}	LNGS	0	
Pb_3O_4	$4^{+2.78}_{-1.66}$	4.8×10^{-14}	U. Chicago Spanish lead	$4^{+2.78}_{-1.66}$	9.1×10^{-15}
PbF_2	$4^{+2.78}_{-1.66}$	3.9×10^{-14}	PNNL ancient lead	$3^{+2.30}_{-1.90}$	2.7×10^{-15}
Pb_20001 (roof)	$1^{+1.75}_{-0.63}$	7.3×10^{-15}	Hampton Court Palace roof	$4^{+2.78}_{-1.66}$	2.5×10^{-15}
^{204}Pb	0		LANL stock	$3^{+2.30}_{-1.90}$	1.7×10^{-15}
^{206}Pb	$1^{+1.75}_{-0.63}$	9.1×10^{-15}	U. Chicago stock	33±6	2.3×10^{-14}

NaI: Expected ^{210}Pb < 3.0×10^{-2} mBq/kg → ^{210}Pb/^{208}Pb = 1.33×10^{-14} [1]

→ ^{210}Pb/Pb = 7.0×10^{-15}.

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Results – chemical reagents

Chemical reagent	^{210}Pb [cts]	$^{210}Pb/Pb$	Chemical reagent	^{210}Pb [cts]	$^{210}Pb/Pb$
AE resin (1-X8, 100-200 mesh, Cl^- form)	0		Sub-boiled Milli-Q water (1 L)	0	
HCl (Suprapur®)	$2^{+2.25}_{-1.26}$	5.4×10−1^{4}	Sub-boiled Milli-Q water (10 L)	$1^{+1.75}_{-0.63}$	1.7×10−1^{3}
Fe (Fe wire)	$1^{+1.75}_{-0.63}$	7.7×10−1^{4}	Ag (Goodfellow 99.99%)	$2^{+2.25}_{-1.26}$	1.3×10−1^{4}
Al (Al cathodes)	$2^{+2.25}_{-1.26}$	1.1×10−1^{2}	NaI-250	-	-
Cu (Cu cathodes)	-	-	Chemical Blank	$2^{+2.25}_{-1.26}$	2.6×10−1^{3}
Milli-Q water (1 L)	0		PbF_2 + Ag (1:10)	27±5	4.1×10−1^{4}
Milli-Q water (5 L)	$5^{+2.81}_{-2.25}$	2.6×10−1^{3}	PbF_2 + AgF (1:10)	$15^{+4.32}_{-3.68}$	1.9×10−1^{4}
Milli-Q water (10 L)	22±5	7.4×10−1^{3}	PbF_2 + AgF_2 (1:10)	29±5	2.0×10−1^{4}
Milli-Q water (20 L)	$6^{+3.28}_{-2.18}$	3.6×10−1^{3}	PbF_2 + SbF_3 (1:10)	$4^{+2.78}_{-1.66}$	2.9×10−1^{4}

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Milli-Q water: ~0.2 mBq/L
Sub-boiled water: ~0.09 mBq/L

Optimising the chemical procedure

Large mass of NaI is challenging for chemical extraction of Pb (85 % is I).

Tests using **Anion Exchange resin 1-X8** (100-200 mesh, Cl^- form, 2 ml) and **Sr resin** (100-150 μm, 2 ml).

Anion Exchange resin → poor retention, i.e., pre-concentration (Fe/Pb co-ppt)

Sr resin → high retention for Pb but resin is bleeding.

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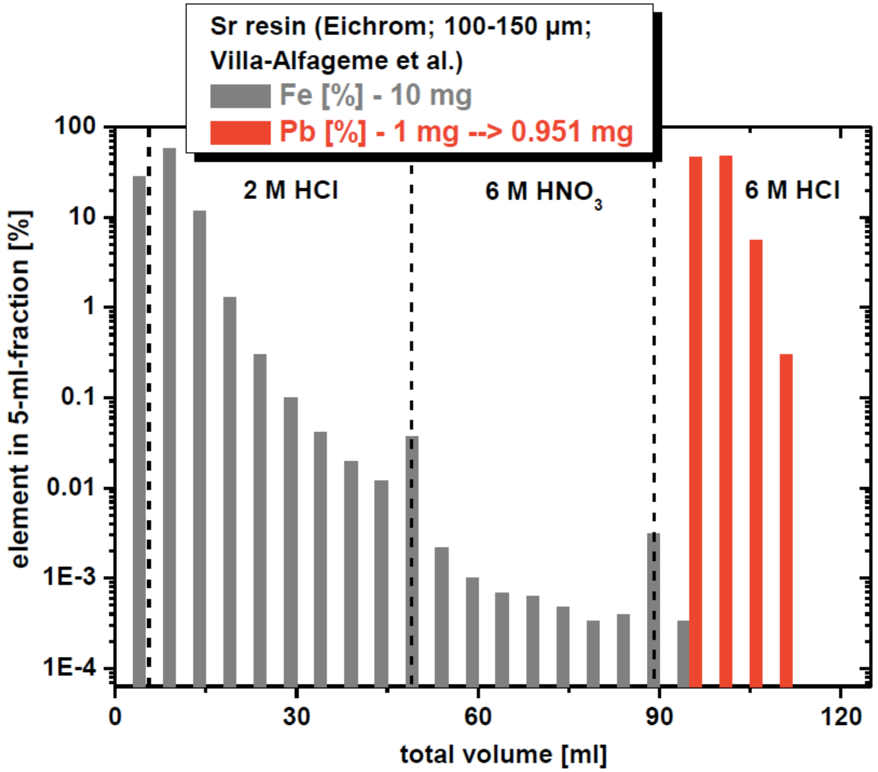

Anion Exchange resin → poor retention, i.e., pre-concentration (Fe/Pb co-ppt)
Sr resin → high retention for Pb but resin is bleeding.

Thank you for your attention!

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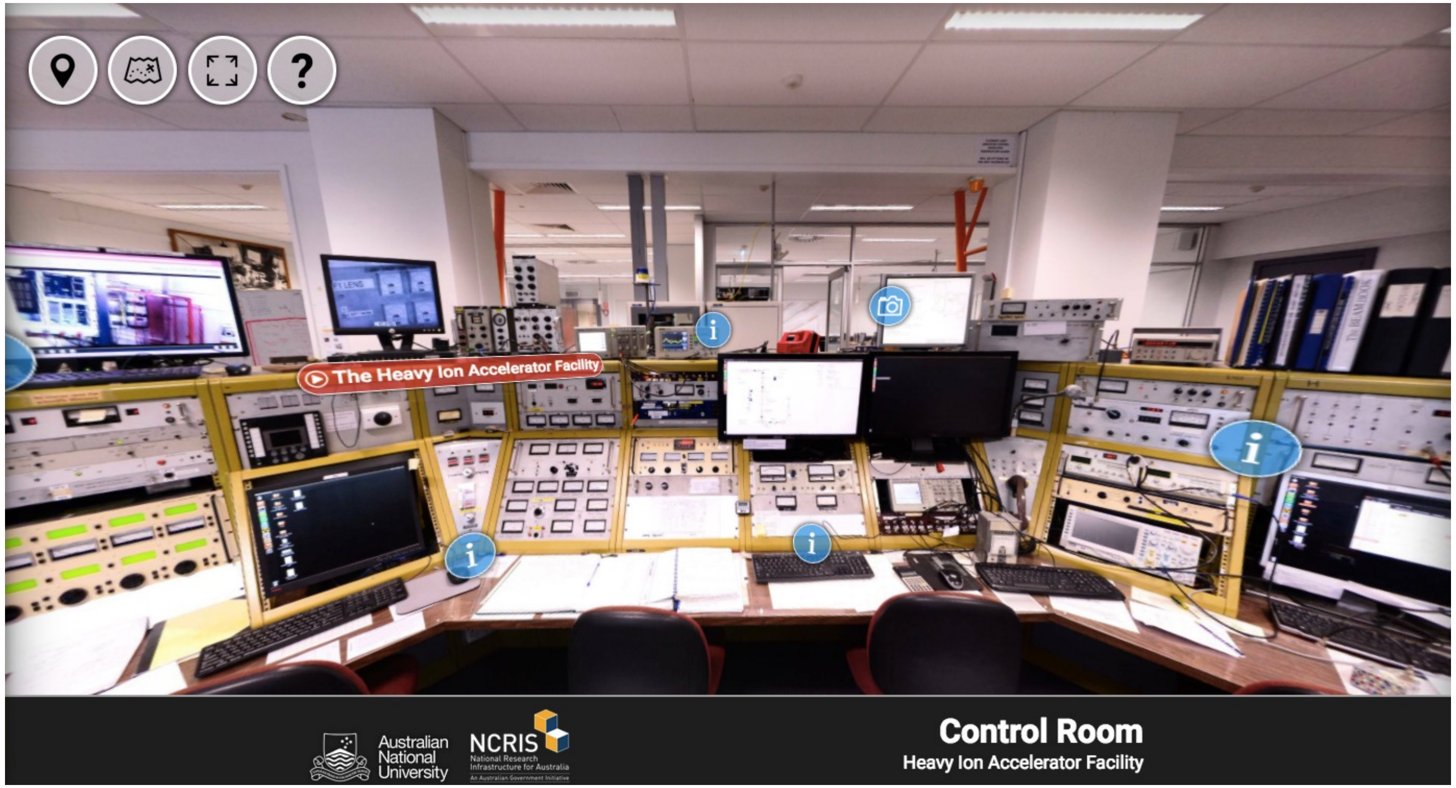

Any questions?

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