ARC CENTRE OF EXCELLENCE FOR DARK MATTER PARTICLE PHYSICS

Metrology Update

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Australian Government
Australian Research Council

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Metrology Team at ANU

Steve Tims

Michaela Froehlich

Zuzana Slavkovská

Metrology Team at ANU

Development of ultra-sensitive techniques to measure radionuclides


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SABRE: Impurity estimation

Low-background needed

How much radioactivity present?

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1. Chemistry

- procedures
- chemicals

2. AMS (Accelerator Mass Spectrometry)

ANU + ANSTO

- ultra-sensitive atom counting
- radio-/ stable nuclide ratios down to 10^{-12}-10^{-17}
- limited to isobaric interference

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SABRE: Impurity estimation

Low-background needed

How much radioactivity present? - **^{129}I, ^{40}K, ^{210}Pb**, ^{232}Th, ^{238}U

Radioimpurities in Detector Materials

^{129}I

- $t_{1/2}$ (^{129}I) = 15.7 Ma
- From nuclear activities
- Routine AMS isotope, ^{129}I/^{127}I

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How much radioactivity present?

Type of NaI Powder	$^{129}I/^{127}I$ ($x10^{-15}$)	Activity µBq/g
Growth Grade (2016)	189 +/- 13	1.10
Astro Grade (2016)	161 +/- 11	0.91
Commercial NaI (2016)	154 +/- 14	0.87

Radioimpurities in Detector Materials

^{40}K

- $t_{1/2}$ (^{40}K) = 1.25 Ga, primordial origin, $^{40}K/^{39}K = 1.255 \times 10^{-4}$
- Collaboration with **Research School of Earth Sciences at ANU** (ICP-MS) – Gabriel Enge

Radioimpurities in Detector Materials

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Type of NaI Powder	^{39}K Content ug/g	Activity
Growth Grade (2016)	340	10 mBq/g
Astro Grade (2016)	0.140	4.4 µBq/g
New material (2021)	?	?

Radioimpurities in Detector Materials

^{210}Pb

- $t_{1/2}$ (^{210}Pb) = 22.2 a, naturally occurring in environment
- Not enough Pb to produce AMS sample after extraction from NaI
- **Optimal carrier,** as low ^{210}Pb content as possible

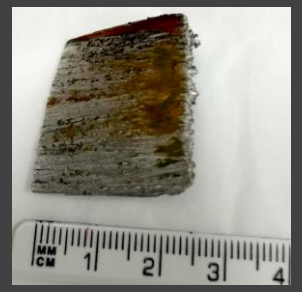
Radioimpurities in Detector Materials

^{210}Pb

- $t_{1/2}$ (^{210}Pb) = 22.2 a, naturally occurring in environment
- Not enough Pb to produce AMS sample after extraction from NaI
- **Optimal carrier,** as low ^{210}Pb content as possible

Examine old lead: **16th century church roof**

Detector shielding



Radioimpurities in Detector Materials

^{210}Pb

Idea: Leach the material several times

Remove environmental ^{210}Pb from surface

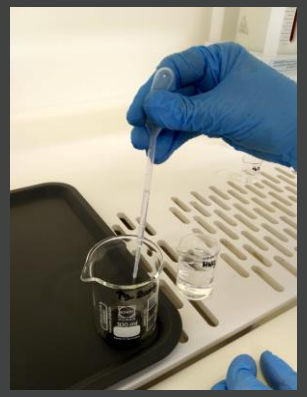
1. Chemistry
2. Pressing AMS samples
3. Measurement of samples

Radioimpurities in Detector Materials

^{210}Pb

1. **Chemistry**

a) Leach in HNO_3



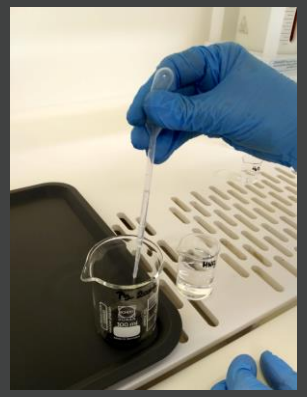
Radioimpurities in Detector Materials

^{210}Pb

1. **Chemistry**

a) Leach in HNO_3

b) Dry on hot plate (70°C) – **$Pb(NO_3)_2$**



Radioimpurities in Detector Materials

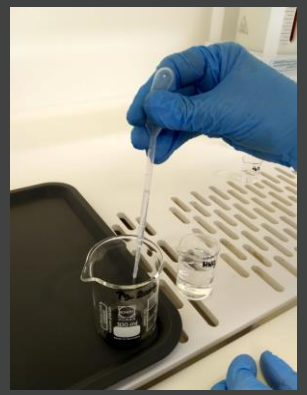
^{210}Pb

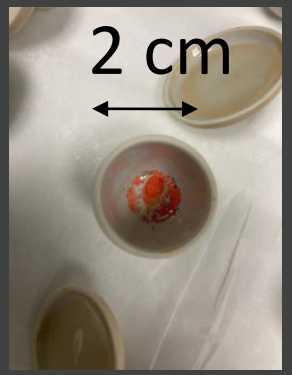
1. **Chemistry**

a) Leach in HNO_3

b) Dry on hot plate (70°C) – **$Pb(NO_3)_2$**

c) Transform to **PbO** in muffle furnace (500°C)

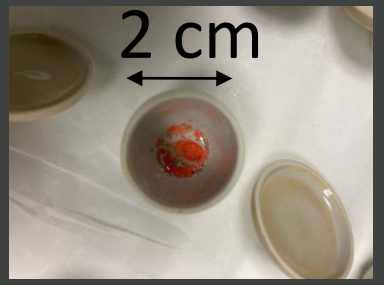




Radioimpurities in Detector Materials

^{210}Pb

1. Chemistry
2. **AMS sample preparation**

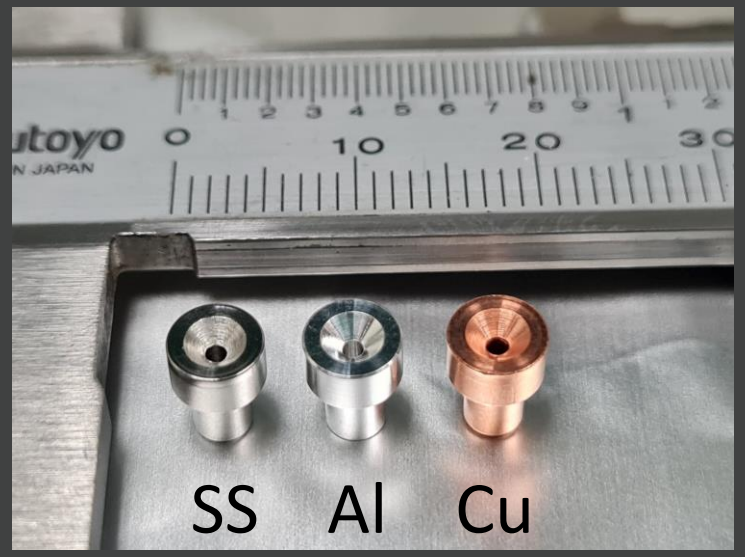


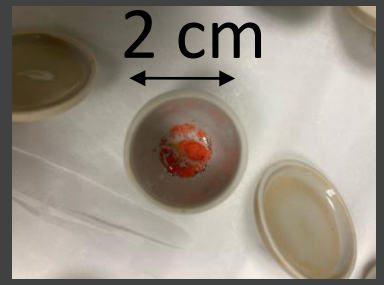
Radioimpurities in Detector Materials

^{210}Pb

1. Chemistry
2. **AMS sample preparation**

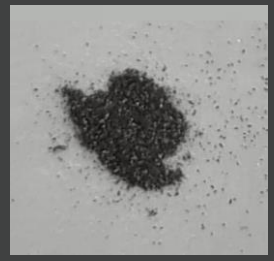
a) Different holder materials
b) Different additives
c) Different additive amount



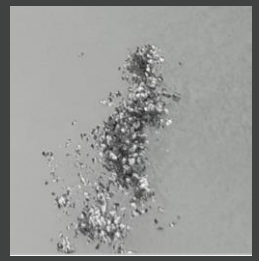


Ag

Nb



Al



Radioimpurities in Detector Materials

^{210}Pb

1. Chemistry
2. AMS sample preparation
3. **AMS Measurement**

ANSTO 8-9 January 2021

collaboration with M. Hotchkis

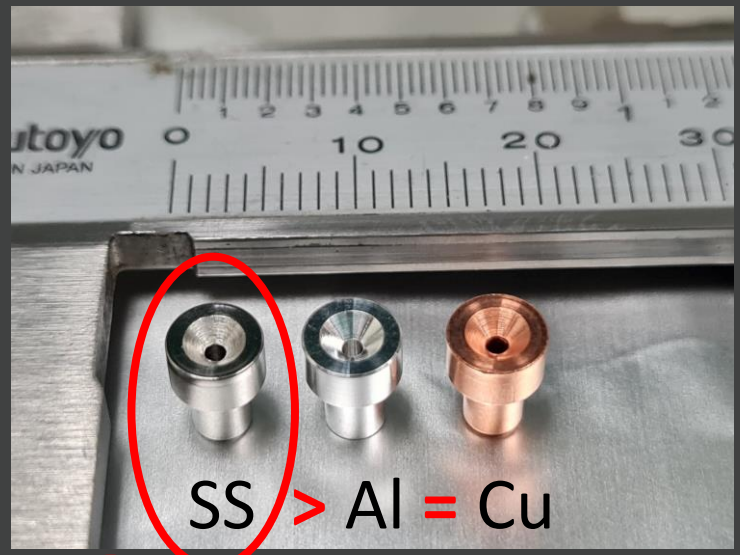
VEGA at ANSTO

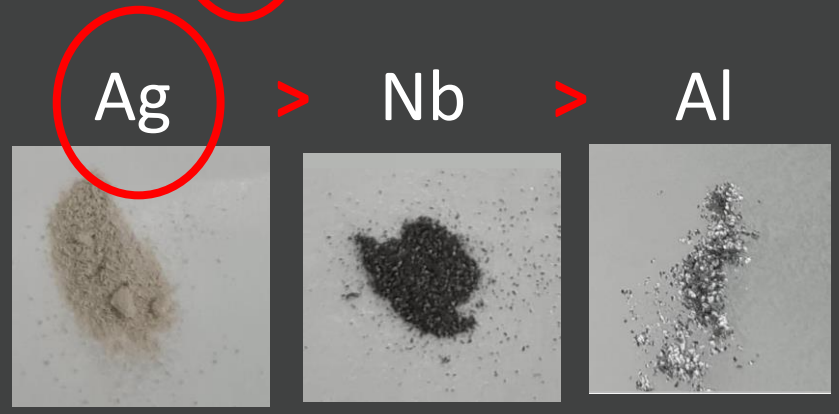
Radioimpurities in Detector Materials

^{210}Pb

3. AMS Measurement: Results

- SS: 50% more output than Cu and Al
- Poor output with Nb and Al
- Ratios 1:2 – 1:4 similar





Radioimpurities in Detector Materials
^{210}Pb

Outlook:

- PbO vs. **PbF_2** - Better performance?
- **Alternative materials** as carrier
- Improve the method sensitivity
- **Further beamtimes planned at ANSTO in 2021**

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Thank you for your attention!

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