



AMS of ^{90}Sr at the sub-fg-level using laser photodetachment at VERA

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The long-lived fission product ^{90}Sr

- ^{90}Sr ($T_{1/2} \approx 29$ a) produced in nuclear fission with a yield of 4%
- Similarities to ^{137}Cs , but also major differences
- Established measuring method is decay counting → chemical separation of β -emitter and ingrowth of ^{90}Y (>2 weeks)
- With Accelerator Mass Spectrometry (AMS) the material, chemistry effort and measurement time can be significantly reduced

The long-lived fission product ^{90}Sr

- High radiotoxicity & $T_{1/2, \text{biolog.}} \approx 10\text{-}18 \text{ a}$
- Due to chemical similarities to Ca \rightarrow accumulation in bones or teeth
- Soluble and very mobile in the environment \rightarrow potential as tracer [1]

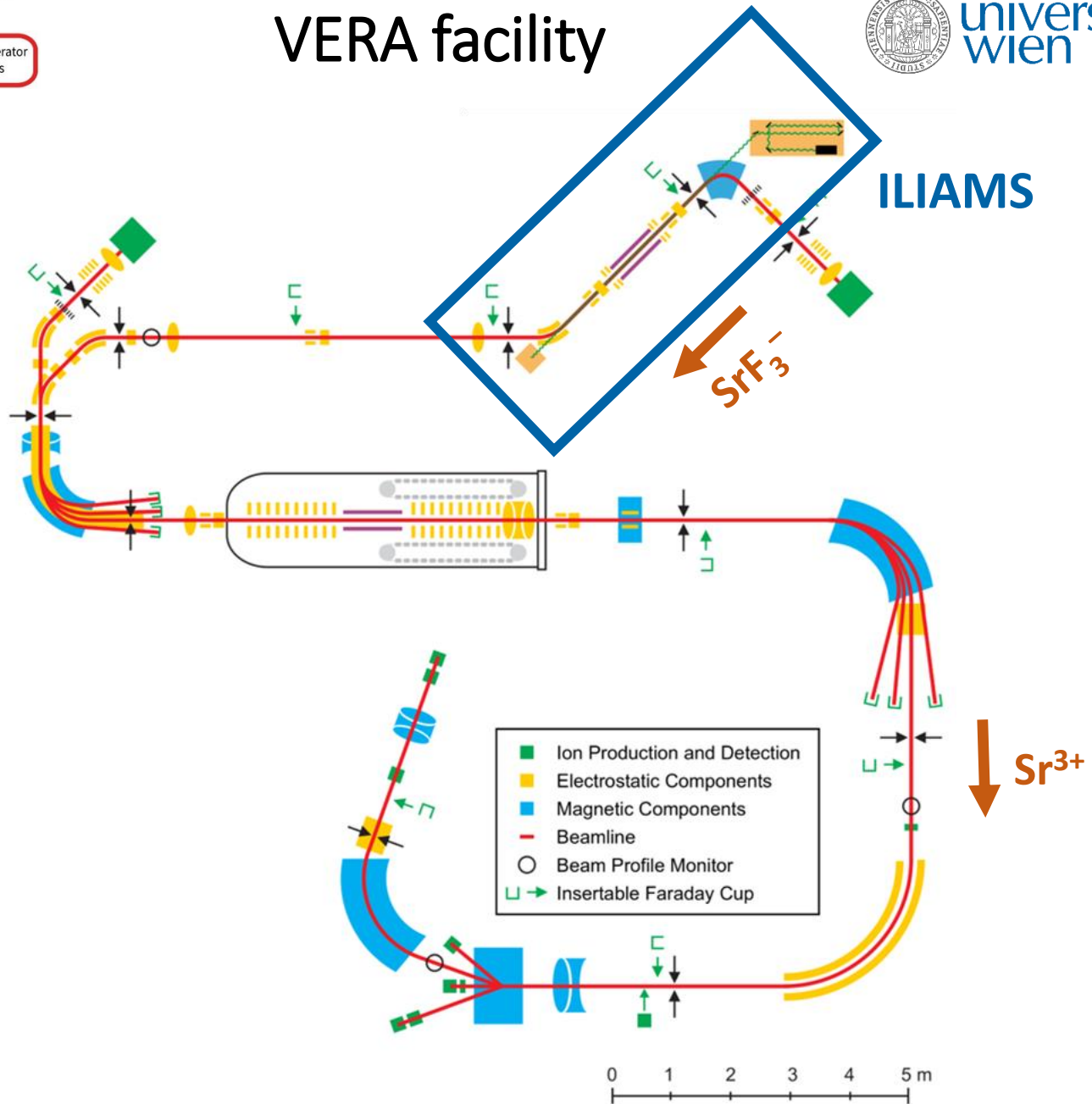
Nb 89 66 m β^+ 2.4; 2.9... γ 588; 507... m	Nb 90 2.0 h β^+ 3.3; γ 1627; 1833; 3093... g	Nb 91 18.8 s 14.6 h β^+ 1.5... γ 1129; 2319; 141... e ⁻	Nb 92 60.9 d 680 a β^+ (105) e ⁻ ϵ ; β^+ ... γ 1205	Nb 93 10.15 d 3.6 · 10 ⁷ a β^+ ... γ 561; 934	Nb 94 16.13 a 100 β^+ (31) α 0.86 + 0.29	Nb 94 6.26 m 2 · 10 ⁴ a β^- 0.5; γ 671; 703 e ⁻ α 0.6 + γ (671...) 14.4
Zr 88 83.4 d ϵ γ 393	Zr 89 4.16 m 78.4 h β^+ 0.9; γ 1507; g m	Zr 90 51.45 α ~0.014	Zr 91 11.22 α 1.2	Zr 92 17.15 α 0.2	Zr 93 1.5 · 10 ⁶ a β^- 0.06... m α <4	
Y 87 13 h β^+ ... γ 381	Y 88 80.3 h 106.6 d β^+ ... γ 485 m	Y 89 16.0 s 100 β^+ ... γ 909 m	Y 90 3.19 h 64.1 h β^- 2.3... γ (2186...) α <6.5	Y 91 49.7 m 58.5 d β^- 1.5... γ (1205) α 1.4	Y 92 3.54 h β^- 3.6... γ 934; 1405; 561; 449...	
Sr 86 9.86 α 0.81 + 0.23	Sr 87 2.81 h 7.00 β^- 1.8... γ 1077 α <20	Sr 88 82.58 α 0.0058	Sr 89 50.5 d β^- 1.5... γ (909) g α 0.42	Sr 90 28.64 a β^- 0.5 no γ g α 0.010	Sr 91 9.5 h β^- 1.1; 2.7... γ 1024; 750; 653... m; g	
Rb 85 72.17 α 0.06 + 0.38	Rb 86 1.02 m 18.7 d β^- 1.8... γ 1077 α <20	Rb 87 27.83 4.8 · 10 ¹⁰ a β^- 0.3 no γ ; g α 0.10	Rb 88 17.8 m β^- 5.3... γ 1836; 898... α 1.2	Rb 89 15.2 m β^- 1.3; 4.5... γ 1032; 1248; 2196...	Rb 90 4.3 m 2.6 m β^- 5.9... γ 802; 1375; 3317... β^- 6.6... γ 632; 1061; 4366... h γ 107; e ⁻ 4136...	

Karlsruhe chart of the nuclides 7th edition

Achievements

- ILIAMS achieves Zr suppression of 10^7 → access to ^{90}Sr at VERA
- Overall ^{90}Sr detection efficiency of 0.4‰
- More than tenfold improved AMS detection limit of 0.1 mBq
- First successful measurements of environmental samples

VERA facility

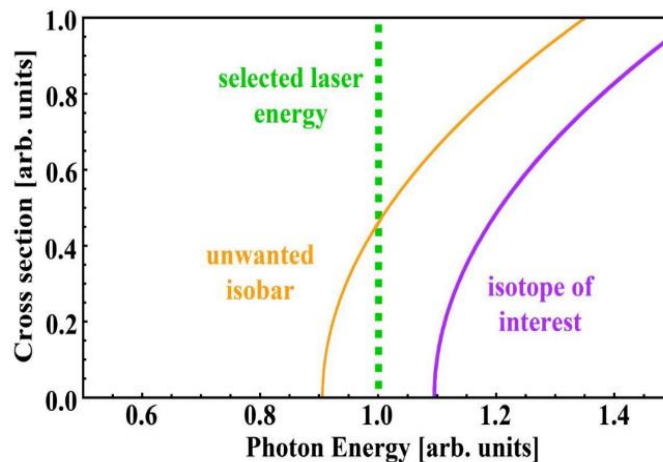


- Ion Production and Detection
- Electrostatic Components
- Magnetic Components
- Beamline
- Beam Profile Monitor
- U → Insertable Faraday Cup

0 1 2 3 4 5 m

- Exploitation in differences in the electron affinity (EA) → isobar suppression
- EAs for atomic anions reversed → not suitable
- $\text{SrF}_3^- - \text{ZrF}_3^-$ – system has right properties

Anion	EA (eV)
Sr^-	0.05206 ± 0.00006 [2]
Zr^-	0.427 ± 0.014 [3]
SrF_3^-	> 3.6 [4]
ZrF_3^-	< 2.3 [4]

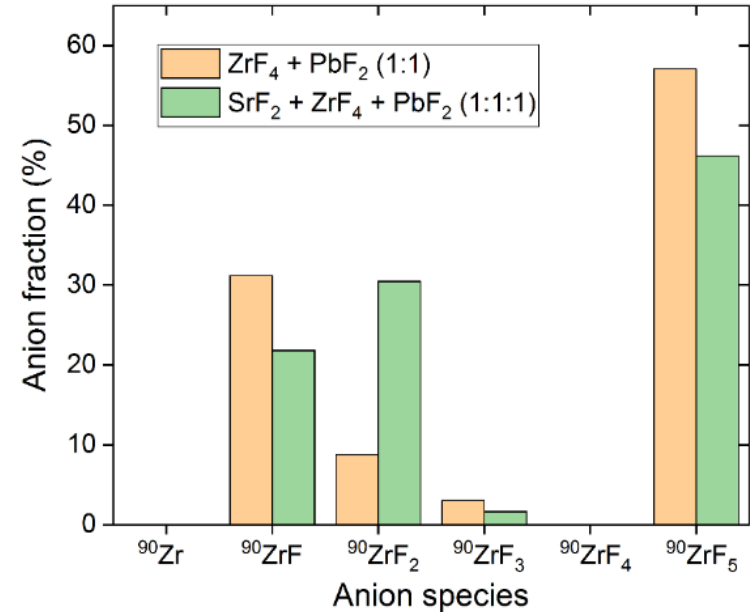
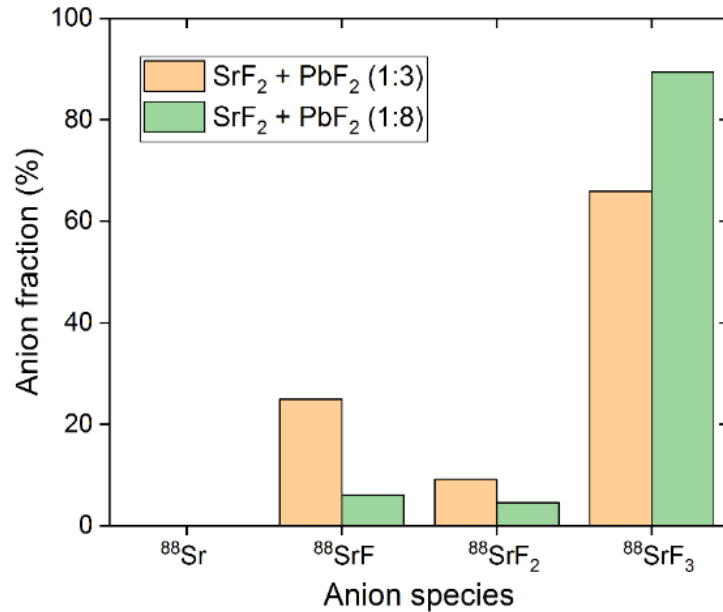


Based on Forstner et.al., NIMB, 2015

- [2] Andersen et.al., Phys.Rev. A.,1997
 [3] Feigerle et.al., J. Chem. Phys., 1981
 [4] Eliades et.al.,NIMB, 2015

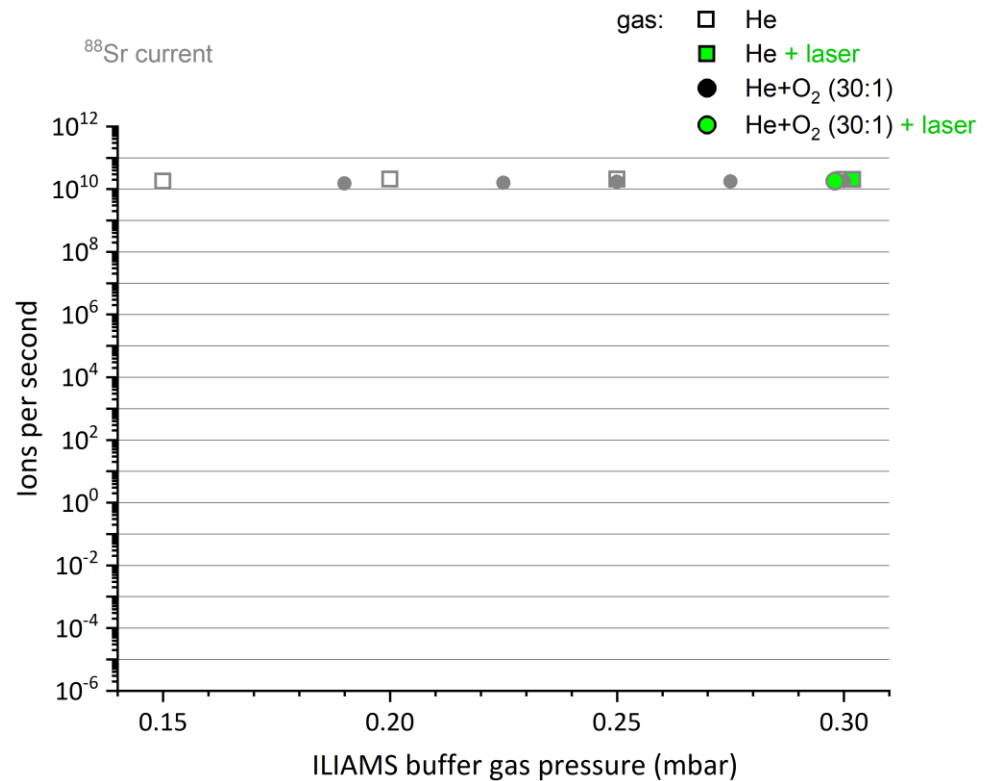
SrF₃⁻ molecule performance

- Added PbF₂ by weight to sample material of SrF₂
- Excellent SrF₃⁻ and poor ZrF₃⁻ formation [5] → isobar suppression
- SrF₃⁻ ionization yield of 0.9% for samples with higher PbF₂ content



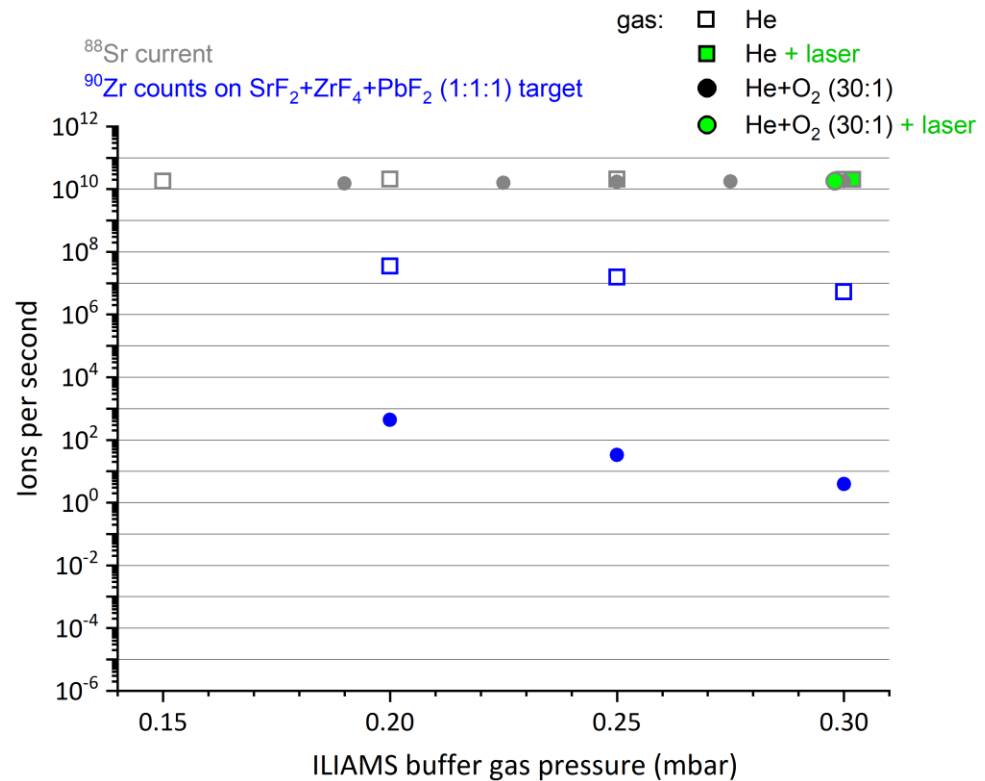
ILIAMS suppression and transmissions

- He+O₂ buffer gas without laser → suppression of 10⁵
- He+O₂ combined with 532 nm laser → Zr suppression of 10⁷
- Transmissions:
 - i) ILIAMS: 35%
 - ii) Accelerator: 23% (+3, 3 MV)



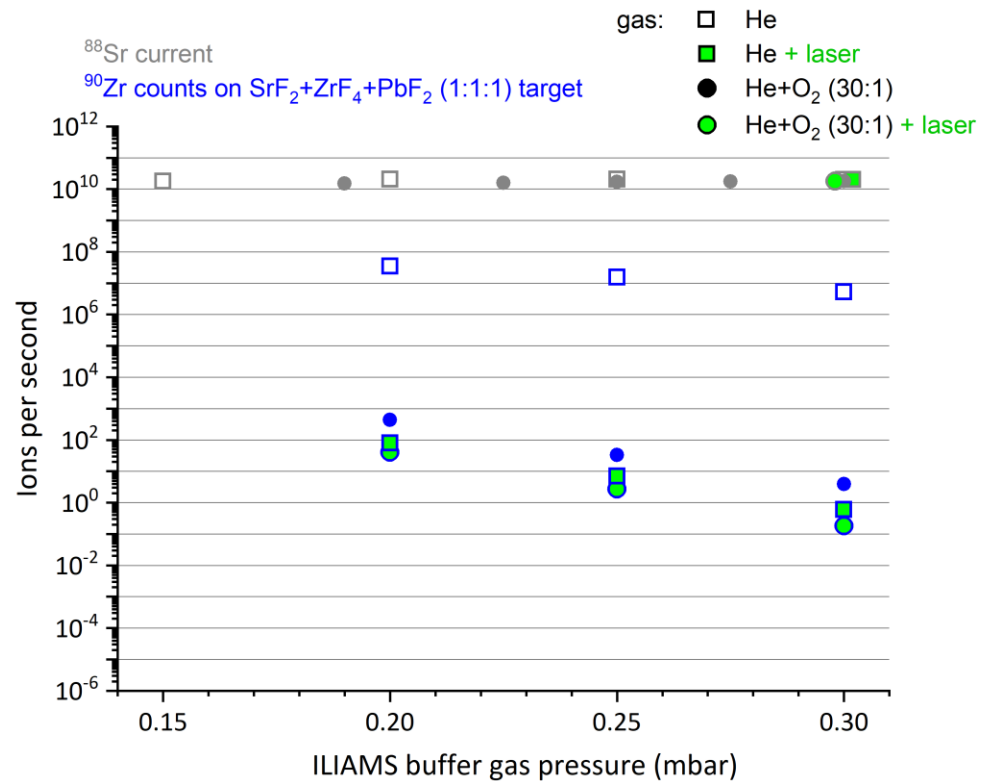
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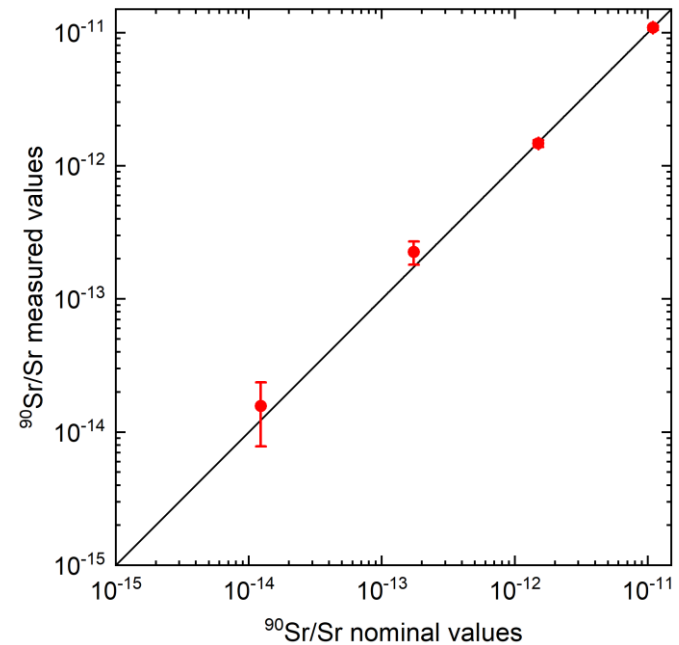
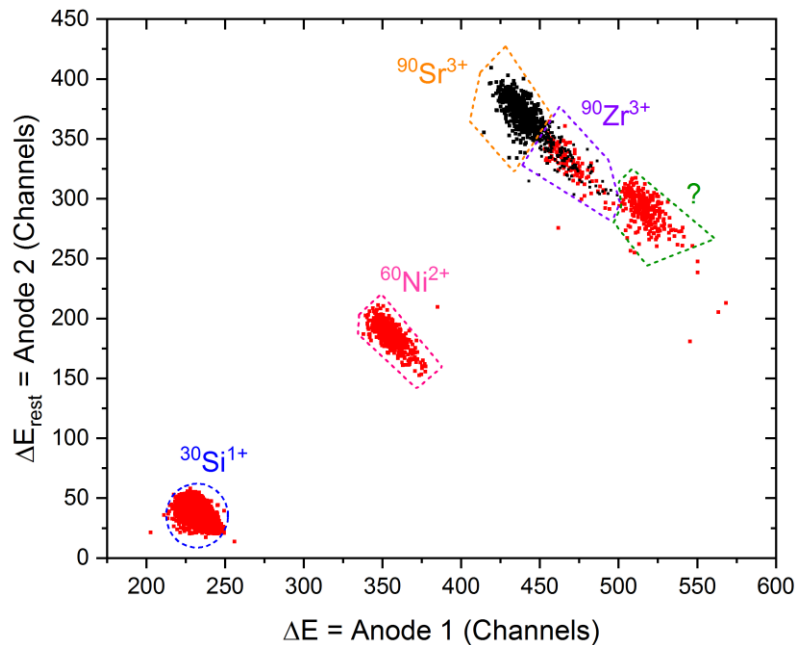


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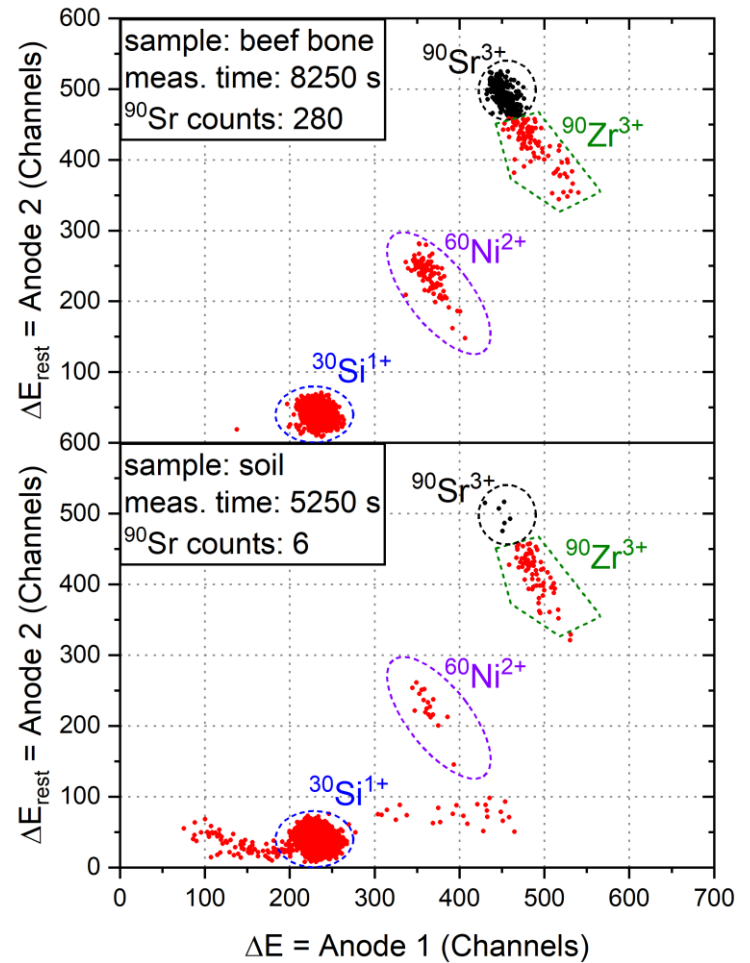
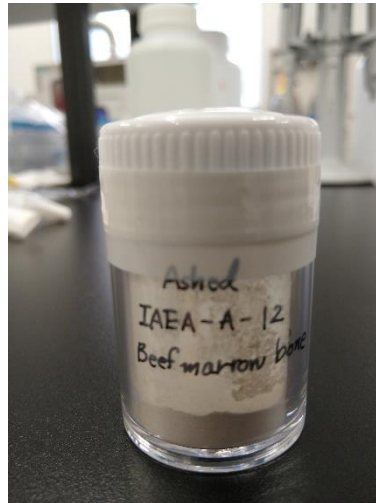
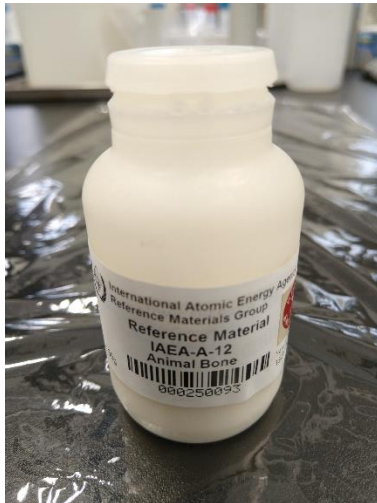
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- Overall ^{90}Sr detection efficiency is 0.4‰
- Blank level $^{90}\text{Sr}/\text{Sr} = (4.5 \pm 3.2) \times 10^{-15}$ \rightarrow detection limit of < 0.1 mBq
- Improvement of previous AMS detection limit of 3 mBq [6]



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