UNIVERSITY OF LATVIA
Institute of Chemical Physics

MED-015
Sc radionuclide extraction and mass-separation at MEDICIS

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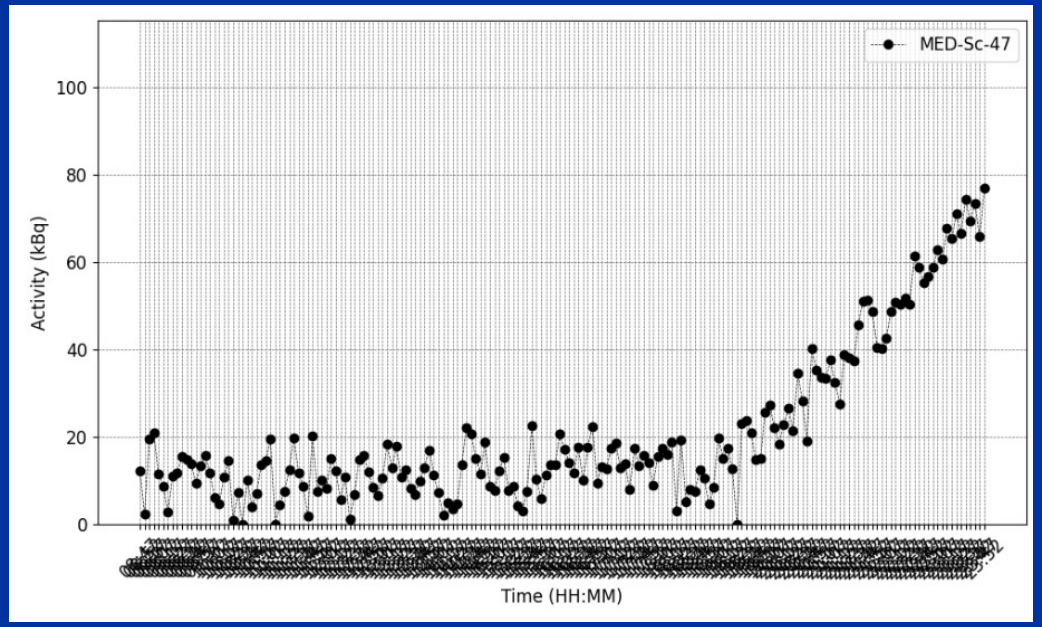
SY-STI-RBS

06/12/2023

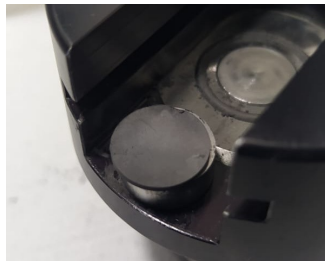


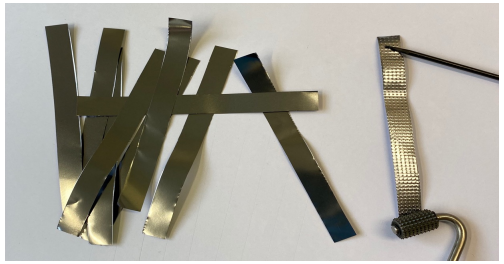
Structure

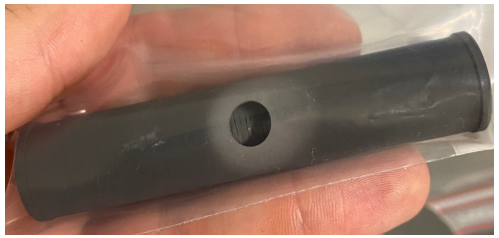
1. Target development
2. Sc release studies
3. Molecular beams
4. Mass-seaparation results from experiments
5. Conclusions and outlook

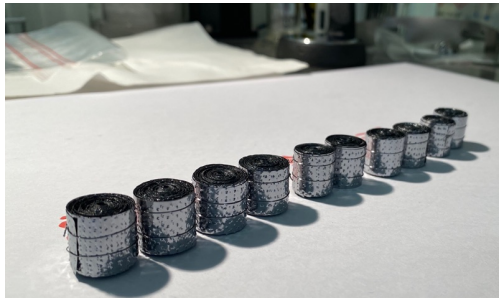
Ti and V foil Target material development

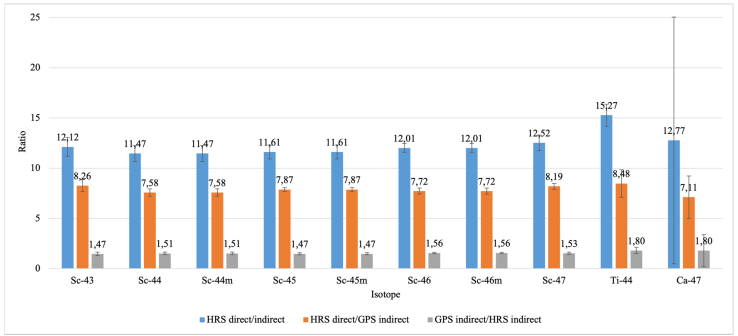
- Target temperature cap **1550 ºC (Ti), 1800 ºC (V) and 2900 ºC (TiC),**
- **Embosed rolls to reduce sinthering and help reduce readsorption**
- **Titanium foils**
  - **1st try – Double rolls: 74.8 g**
  - **2nd try – Double rolls: 96.3 g**
- **Vanadium foils**
  - **1st try – heavily oxidized V foil: 44.8 g**
  - **2nd try – std. V foils: 61.7 g**
  - **3rd try – higher purity V foils: 34.4 g**
- **Macrometric TiC**
  - **1st try – TiC pellets: 14.7 g**



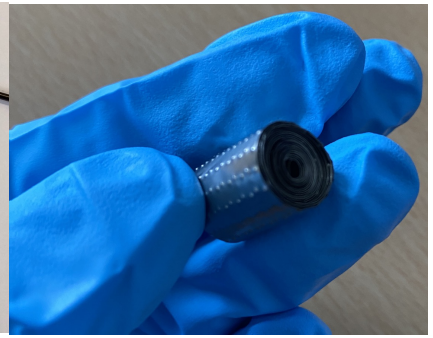


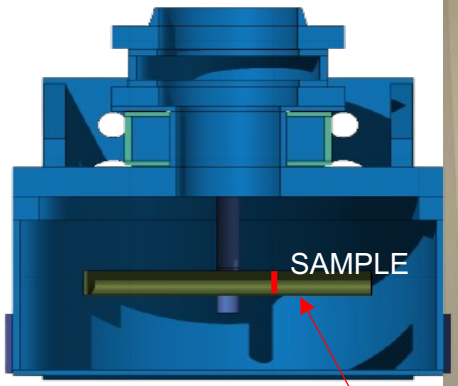




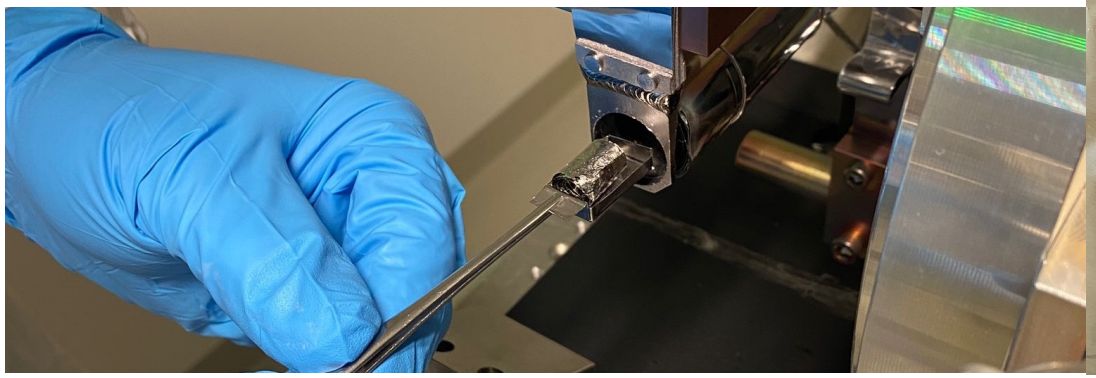


Sc thermal release studies from activated foils

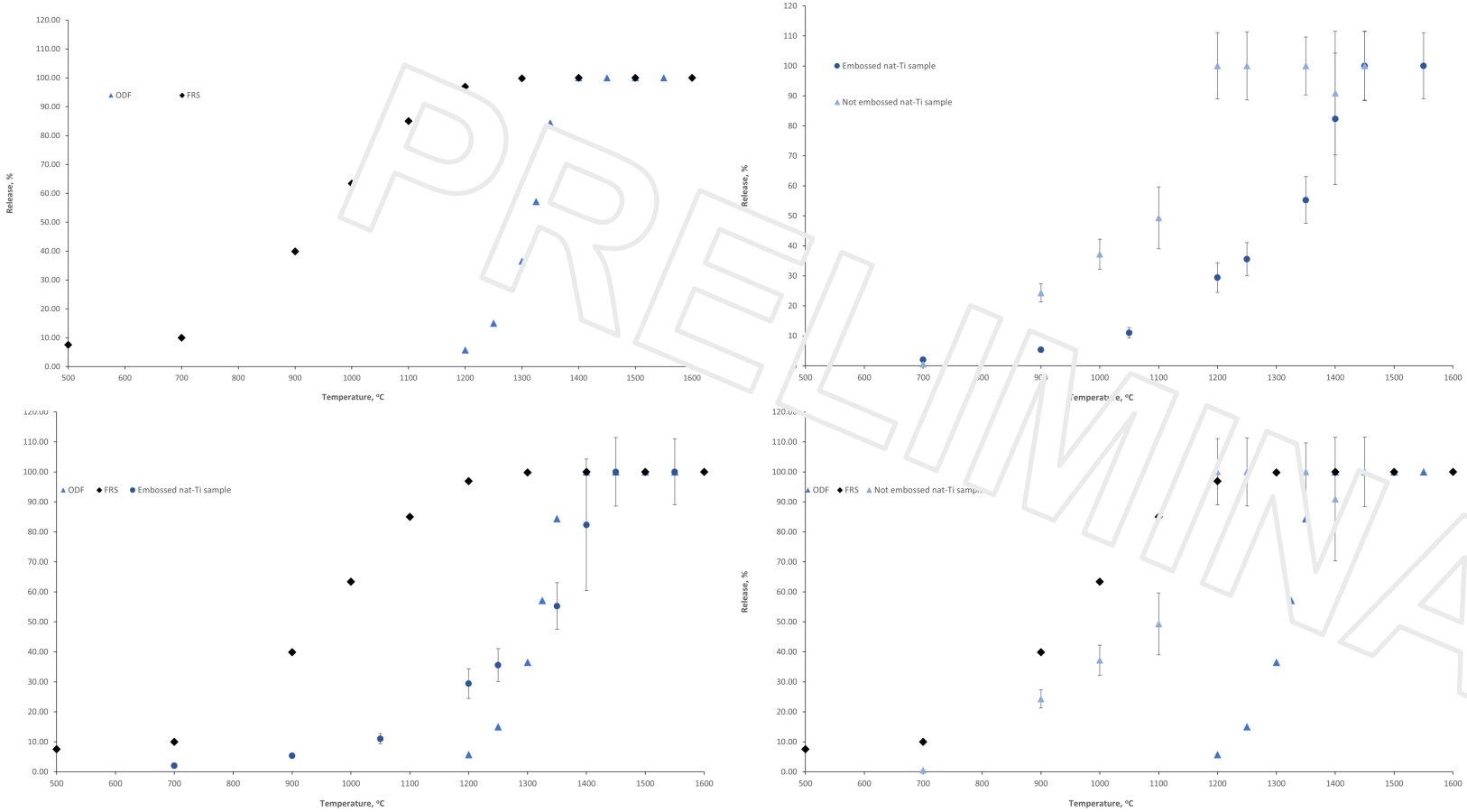




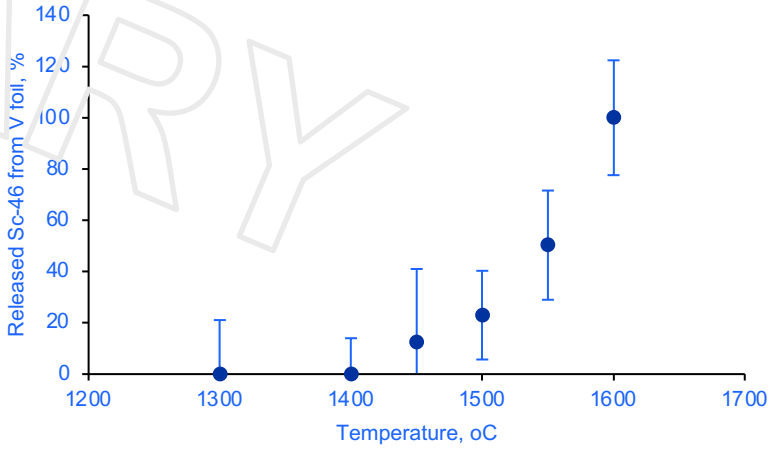
Samples were placed on a tantalum boat to avoid sample melting/sticking in target container



Preliminary release results



- Sc from Ti rolls in Ta environment is fully released at 1200-1500 °C within an hour.
- Sc is released from V foil rolls fully at 1600 oC within an hour and there is no release at 1400 °C.
- 27 consecutive sample handlings with RP



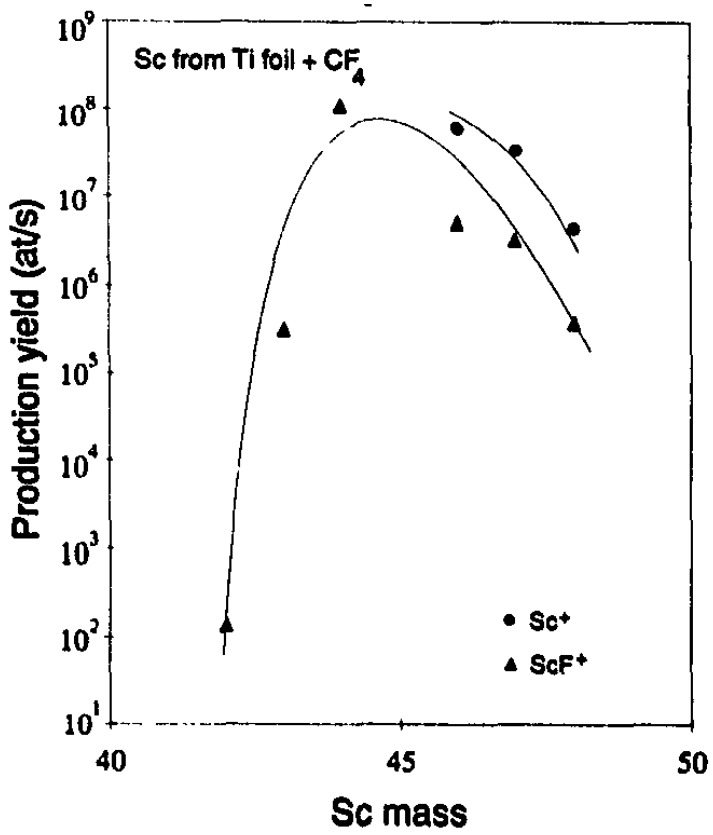
- Sc radionuclide production by neutron activationof nat-Ti corresponds well to Actiwiz code developed by CERN RP
- Embossing rolls shift the release to higher temperatures

Sc^+ and ScF_x^+ molecular beams at ISOLDE

- Sc extraction from irradiated ^{nat}Ti rolls as molecular halide beams was previously reported with W surface ion source at ISOLDE (1991);
  - Sc^+ and ScF^+ beams were observed, but no ScF_2^+ molecular ions alongside evaporation of Ti target

Note: Ti^+ beam current rose from 0.1 to 5 μA when fluorinating gas was added (Ti ionization efficiency is up to 1 % with surface source);

Intact (left) and molten (right) Ti roll target material.



Production yields of Sc^+ and ScF^+ ions from a 40 g/cm2 Ti foil target with a W surface ionizer. Irradiation 600 MeV protons.
R. Eder, et al. The production yields of radioactive ion-beams from fluorinated targets at the ISOLDE on-line mass separator, *Nuclear Instruments and Methods in Physics Research B62 (1992) 535-540, North-Holland*

ScF_x^+ sidebands (F saturated environment CF_4)

ScF_3^+ / **ScF_2^+** / ScF^+ / Sc^+ : 0 / **10** / 1 / 1

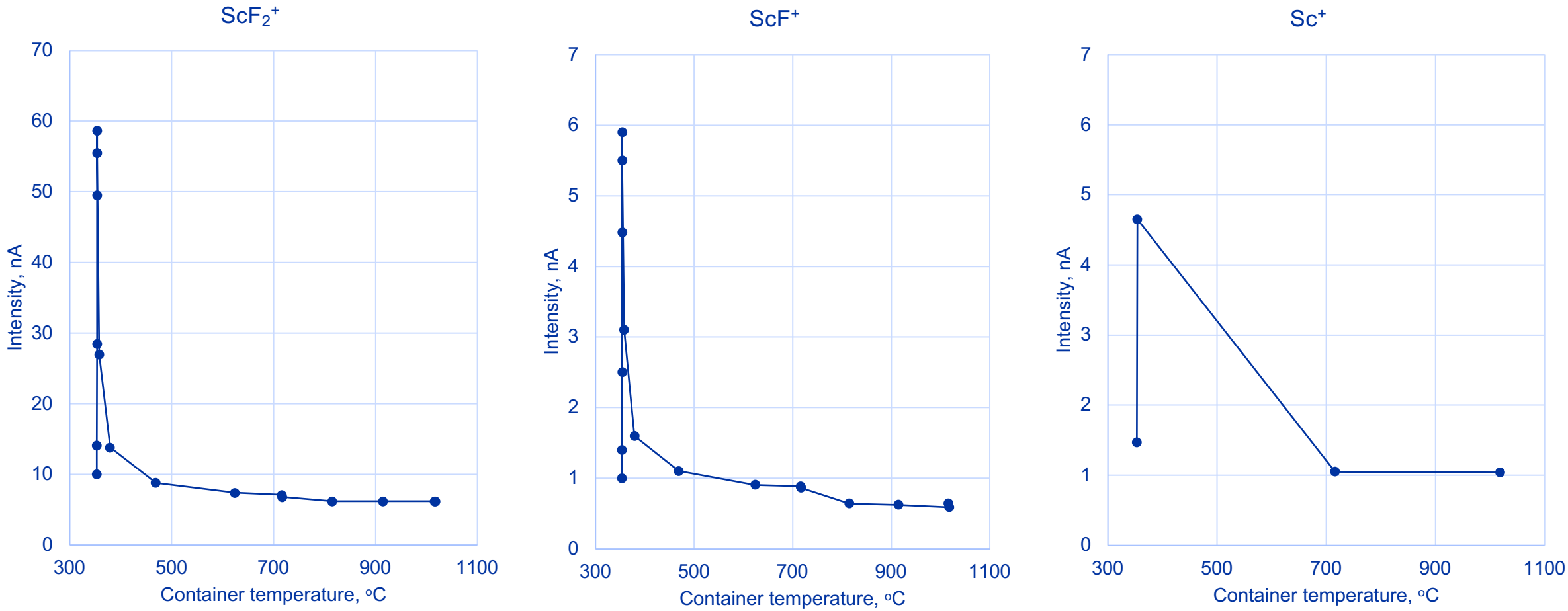


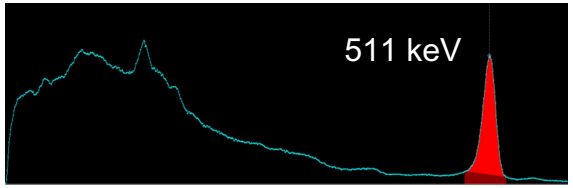
Fig. 19. V ScFx+ ion species current ratio in the total beam from target unit £731

Onset of release

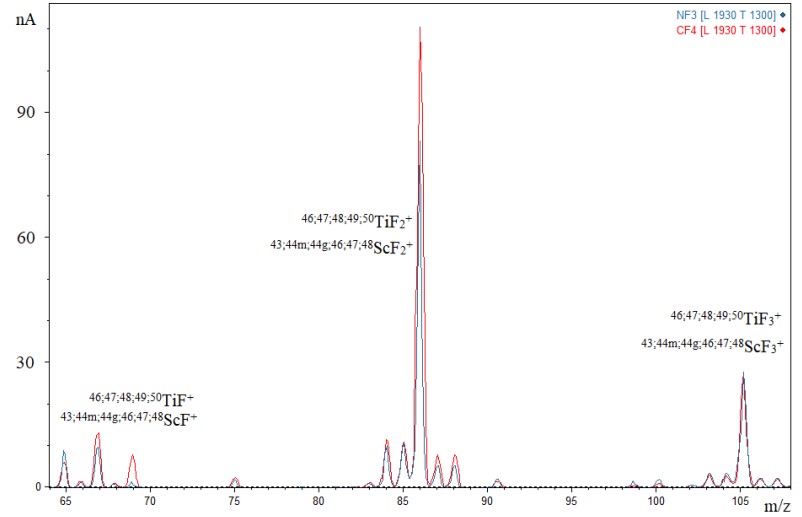
Nr.	Target Nr.	Target material	Ion source	Max operated target T, oC	Sc radionuclides collected	Appearance temperature of target	Species monitored
1	723M	Titanium foil, double layer (embossed)	VD-5	1600	44Sc, 47Sc 47Ca	**1200** **1100**	44mSc+ 47ScF2+
2	741M	Titanium foil, double layer (embossed)	VD-5	1600	44Sc, 46Sc, 47Sc	**1550*** **1400** **1180**	44gScF2+ 46ScF2+ 47ScF2+
3	766M	V foil (embossed, oxidized)	VD-5	1850	47Sc	**1650**	47ScF2+
4	790M	V foil (embossed)	VD-5	1700	47Sc 47Ca	**1500 -1650**	47ScF2+, 47ScCl+
5	801M	Externally irradiated Ca-43	VD-5	2000	43Sc, 44Sc	**1550 oC ???**	43ScF2+ 44ScF2+
6	805M	V foil (embossed, >98% purity)	VD-5	1750	44Sc, 47Sc	**1540 (hottest part - line)** **#2: ~1500 (hottest part - line)**	44ScF2+ 47ScF2+
7	805M	V foil (embossed, >98% purity)	Laser	1750	-	**1570 (at the coldest part)** **1700 (hottest part)**	44-47Sc+
8	702M	TiC (1-2 um)	VD-5	2000	47Sc 46Sc	**1525**	47ScF2+ 47ScF+ 46ScF2+

^{44m,44g}Sc and ^{47}Sc collection from Ti

- ScF_x molecular beams are suppressed by TiF_x isobars;
- Identified strong 511 keV (from positron annihilation) line in on-line gamma spectroscopy
- Collected Sc-44 radionuclide activity in range of **few kBq;**
- Ca-47 extraction as Sc-47 generator without reactive gas



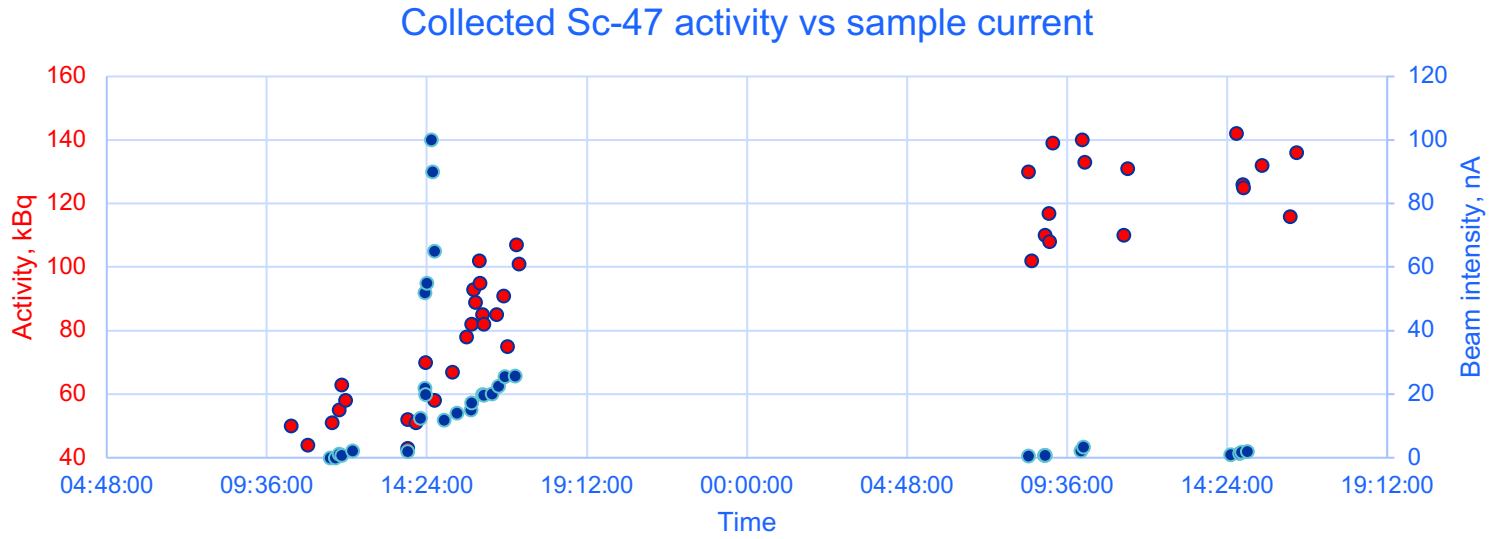
Kromek γ-spectra during $^{44}ScF_2^+$ collection at MEDICIS (target 741M)



Mass scan fragments from medical Sc extraction by different fluorinating gases at same operation conditions, identifying strong TiF_x beams

Nuclide Name	*Half Life*	*Conf.*	*Energy (keV)*	*Yield(%)*	*Activity (Bq/units)*
Ca-47	4.54 d	0.99	489.23 *	6.20	1.62E+04
			807.86 *	6.20	1.69E+04
			1297.09 *	71.00	1.46E+04
Sc-47	3.35 d	0.99	159.38 *	68.30	8.78E+03

Gamma spectroscopy results for Ca-47 collection from nat-Ti target



V foils target - molecular

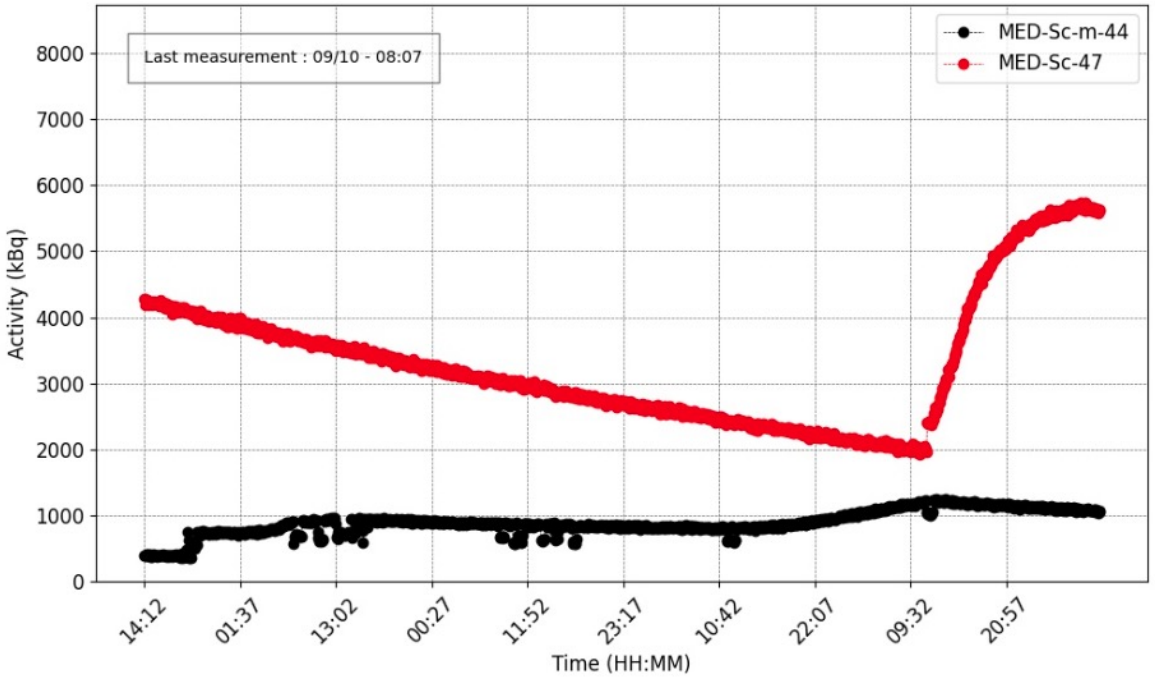
Collection 09.2023

- The collection onset was with cold container (but hot middle part where the line is attached ~1540 ^{o}C)

➢ **Successful separation from long lived ^{46}Sc and ^{48}Sc contaminants was achieved**

Collection 10.2023:

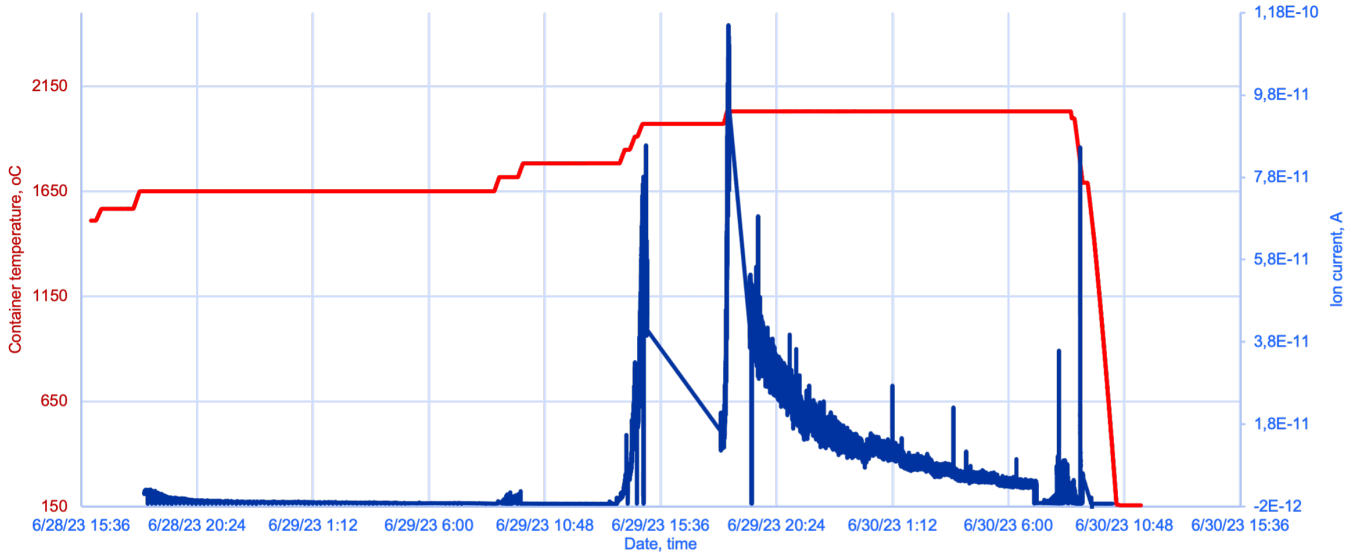
- **Collected of foil**
  - ~300 kBq of Sc-44m ***Eff. = 0.20 %***
  - ~ 780 kBq of Sc-47. ***Eff. = 0.18 %***



Laser ionization efficency of elemental $^{45}Sc^{+}$

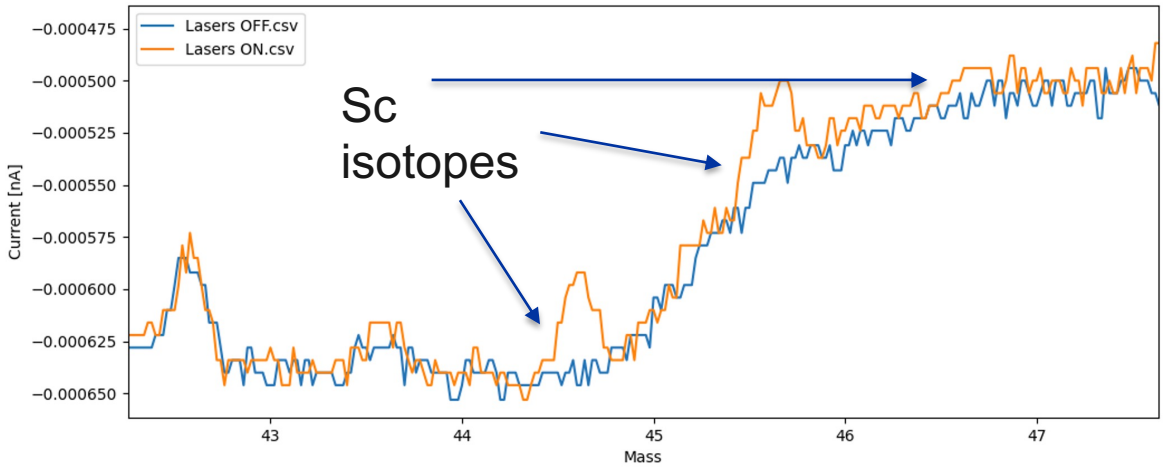
Stable beam tests 26-30.06.2023

- **W and Re surface source**
- **Sc_2O_3 in 0.1M HNO_3**
  - W source: 600 nAh Enhancement factor ~96x
  - Re source: 11800 nAh and enhancement factor of 193.5x
- **Efficiency: 0.06% (from 11 800 nAh)**



Radioactive beams from V foils

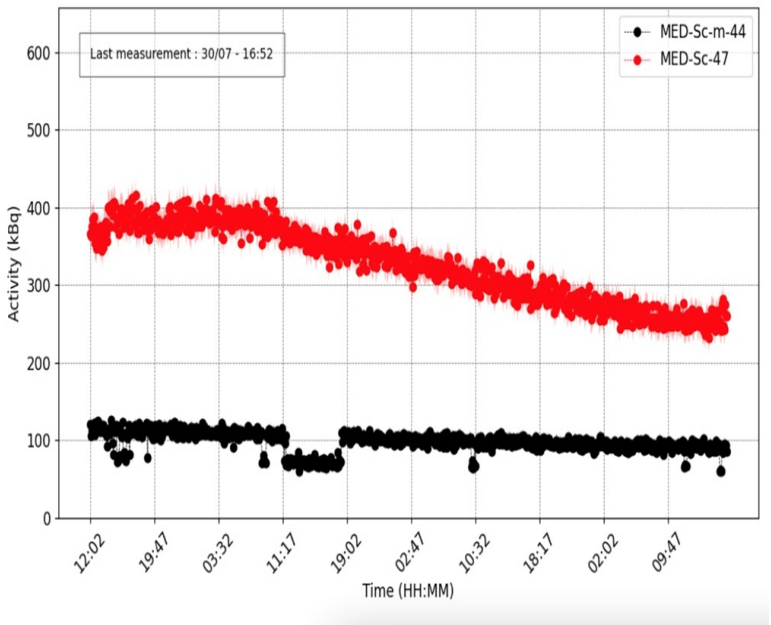
- **No fluorinating gas added.**
- **When molecules were formed no laser enhancent ever observed.**
- **Laser ionisation dissapeared in 1 day – full release?**



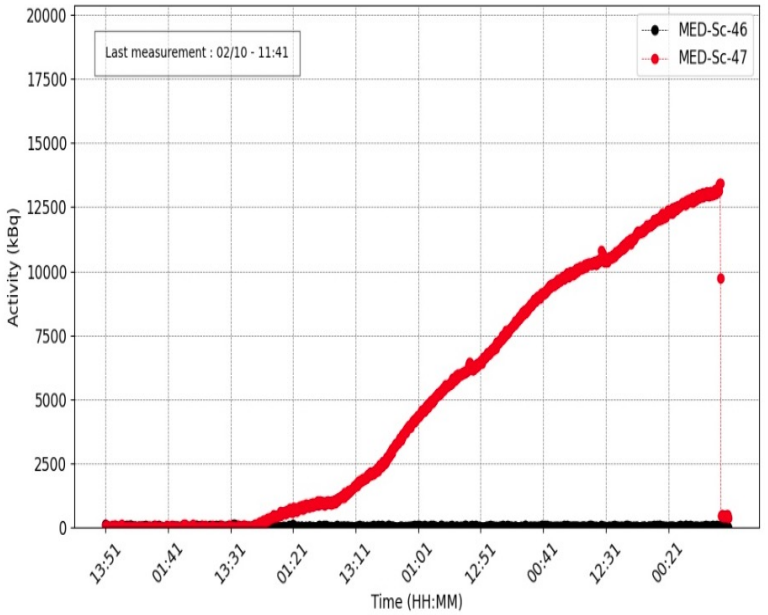
TiC

- **Onset of release 4x consistent 1550 °C**
- Collected of foil 09-10.2023
  - **MS-032 = 3.4Bq (02.10) and MS-034 = 860 kBq (09.10) of Sc-47. *Total eff. = 0.62 %***
  - ***MS-032 was collected without CF4, MS-034 with CF4. Both correspond to 12 MBq at End of Irradiation***

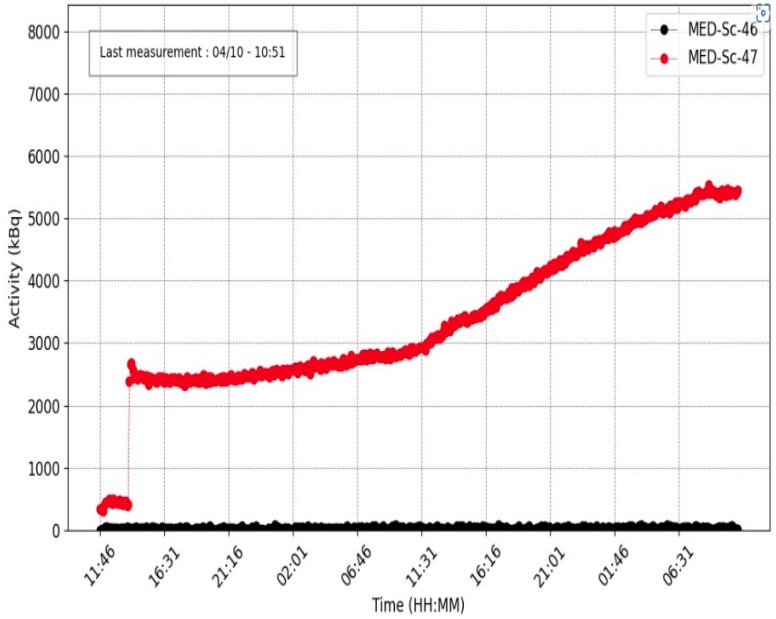
Collection in 08.2023



Collection on MS-032 09.2023



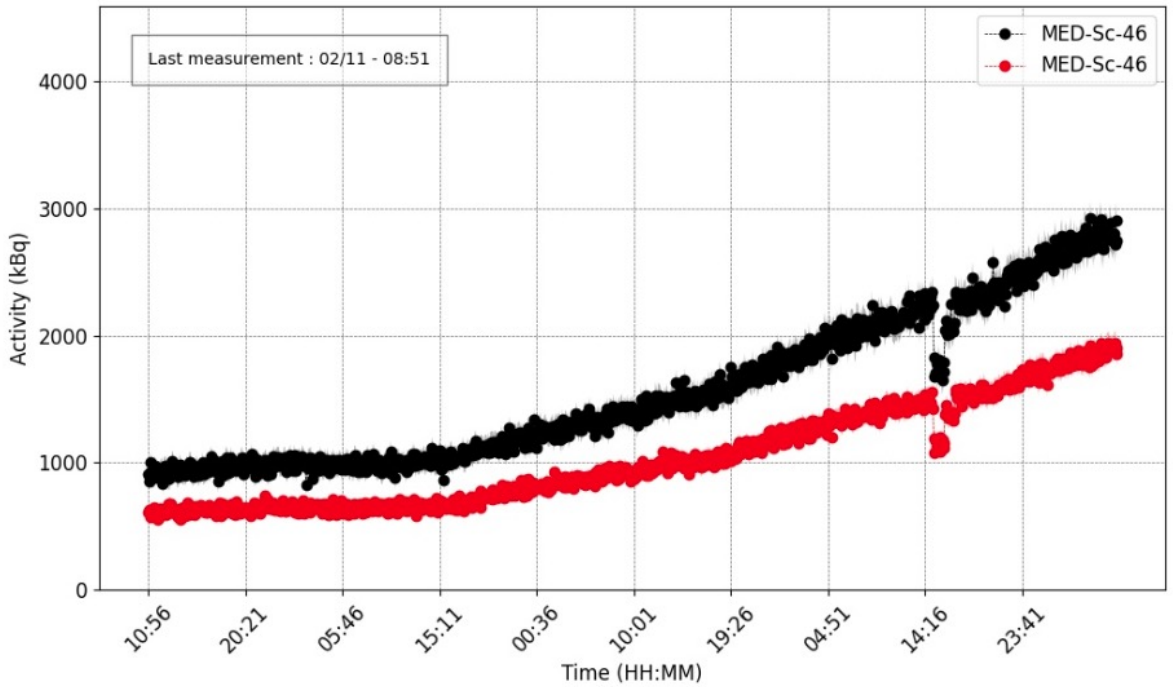
Collection on MS-034 09.2023 After previous foil retrieval

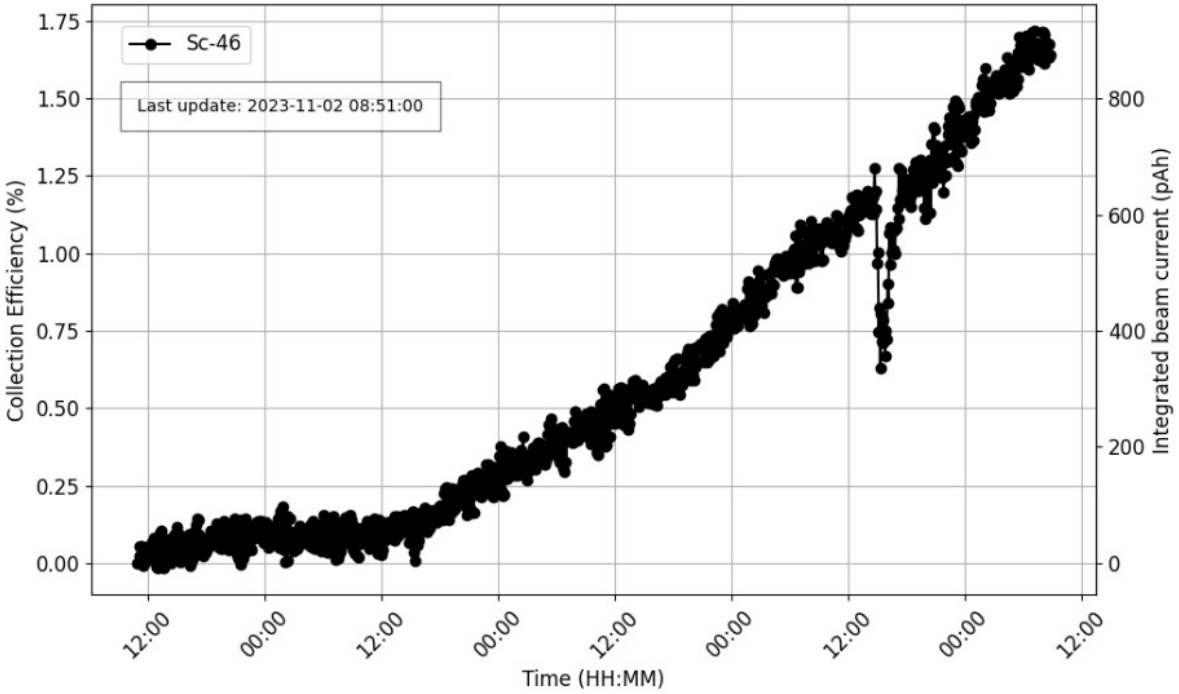


Special thanks to R. Hernandez

TiC continued $^{46}ScF_2^+$ molecular beam extraction

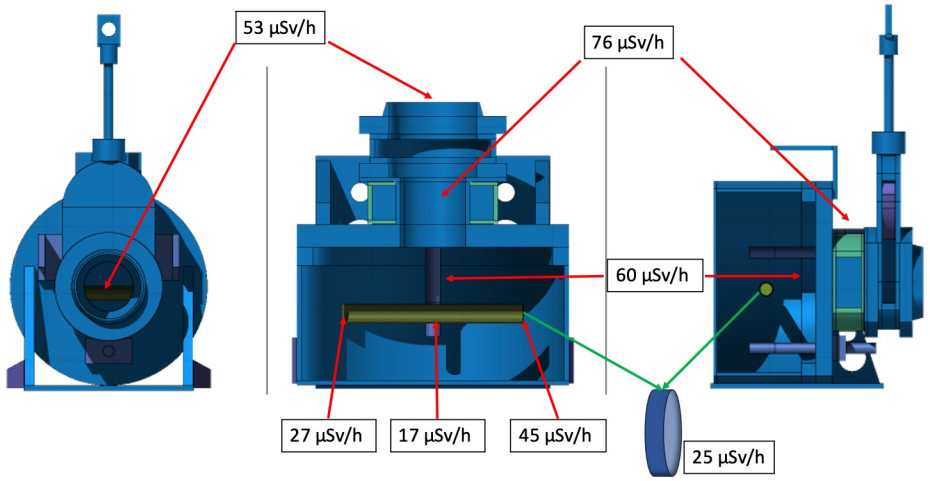
- **Target was <u>not irradiated again</u> – continuation of previous collection**
- **Additional fluorination**
- Collected 2.2 MBq 02.11.2023 = ~2% efficiency
- ***Total efficiency = 2.6 % from half charge TiC target***
- ***Target unit still operational***

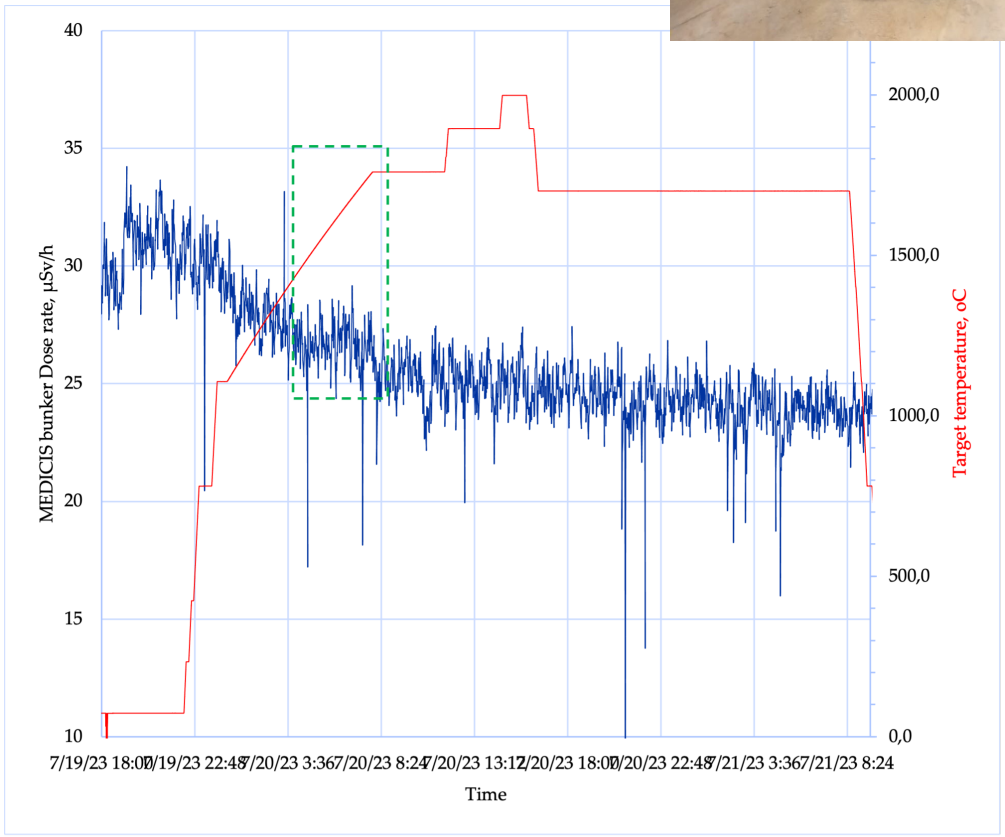




External $^{43/44}ScCl_3$ sample (PSI)

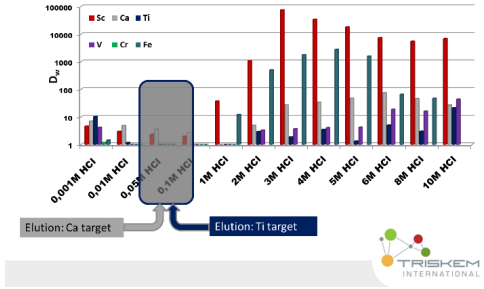
- $ScCl_3 \cdot 6H_20$ upon heating above 60 °C starts to lose water and above 275 °C begins to decompose rapidly forming Sc_2O_3
- No activity collected of fluoride sideband.
- Sample was released from target container at temperatures of 1500-1760 °C either as elemental or different molecule other than ScF_2^+.
  - Possibly Sc(II)O or $ScCl_x$ (*x=1-2*)

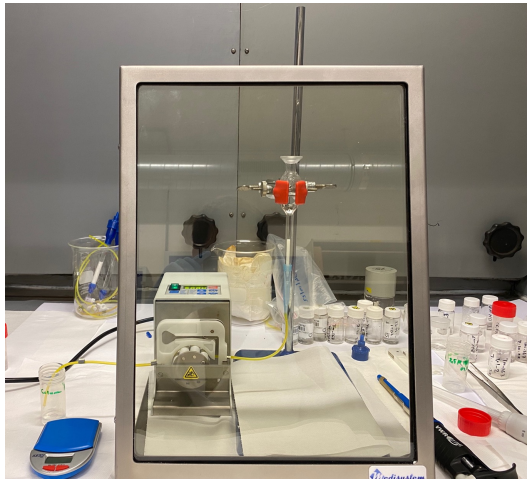


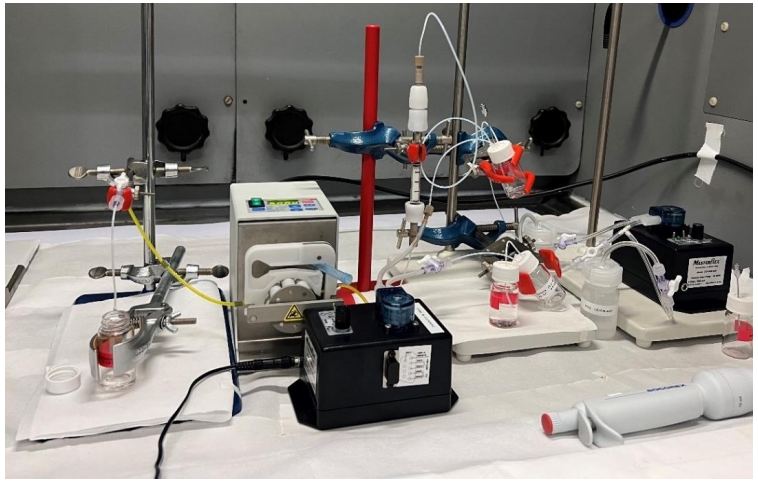


Special thanks to N. Van Der Meulen and PSI

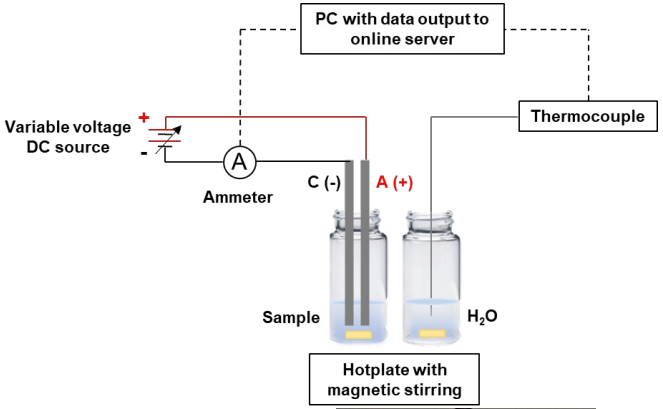
Radiochemical separation

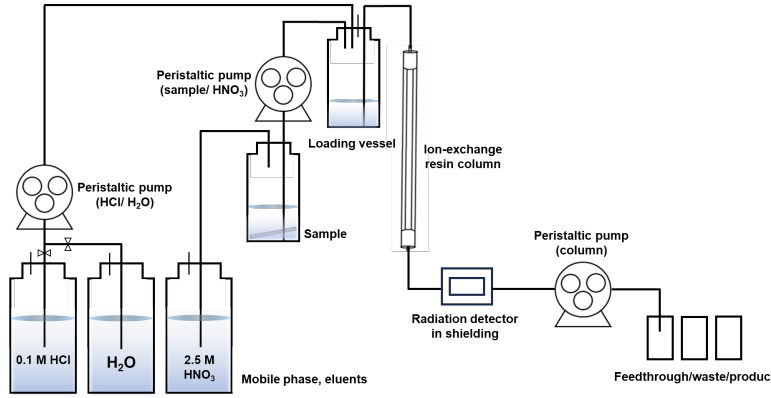


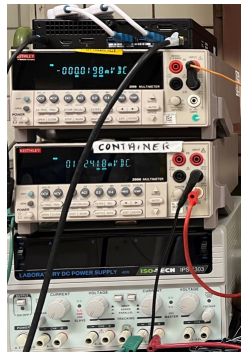


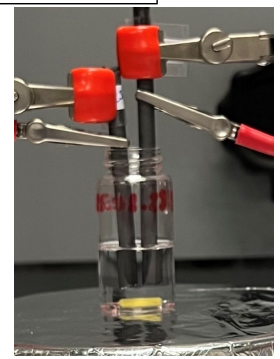


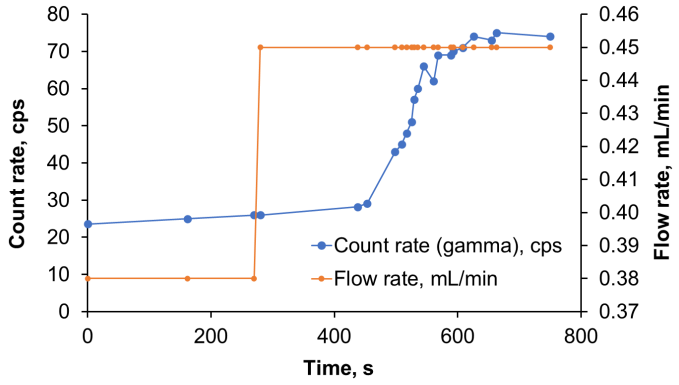
- Optimized radiochemical separation from Zn and Al coating with ion exchange
- Semi-automated setup – reduced exposure
- Electrochemical deposition tested and still ongoing
- Radiochemical Yield > 98%, Recovery >95 %
- First chemical (stable) samples shipped to Riga, Latvia for analysis
- Most thanks to R.J. Zabolockis and P. Kalniņa







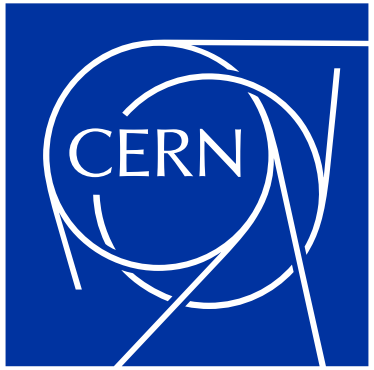




Conclusion and outlook

- **Sc radionuclides can be produced and mass-separated in sufficienct quantities to be shipped back to Latvia.**
- **High radiochemical purity.**

- **Improove on sputtering and beam purity.**
- **More radiochemical processing is studied in Riga, Latvia**
- **Ship first radioactive samples to Latvia**



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