PSI Center for Nuclear Engineering and Sciences

Target Activities at PSI

Isotope and Target Chemistry Group

Zeynep Talip

15 May 2025

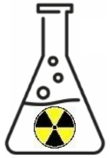
Lessons learnt

- The success of experiments depends on the **quality of the target**
- Preparing high-quality targets takes **time**.
- **A budget of target preparation** should be included in the proposals
- In case of a radioactive target preparation; **transport cost** and **waste disposal** should be planned.

Isotope and Target Chemistry Group

Research Topics

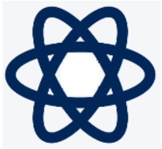
Separation Chemistry



Development of chemical separation methods

To isolate **exotic** and **medically relevant radionuclides** from irradiated materials produced at PSI or other facilities

Nuclear Data



Half-life determination

^{60}Fe, ^{146}Sm, ^{148}Gd, ^{154}Dy, ^{93}Mo, ^{53}Mn, ^{32}Si

Cross-section measurements

Target & Source Preparation

Target material

Preparation

Characterization

Emilio Andrea Maugeri

Liquid Metal Chemistry

Transpiration method

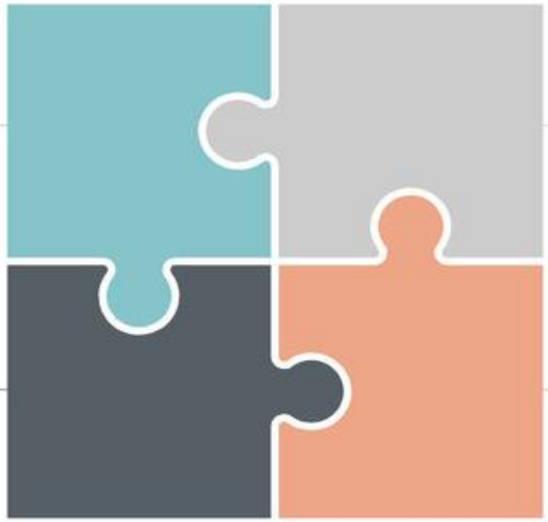
Thermochromatography

Isotope and Target Chemistry Group

Strengths

Unique radionuclide production facilities

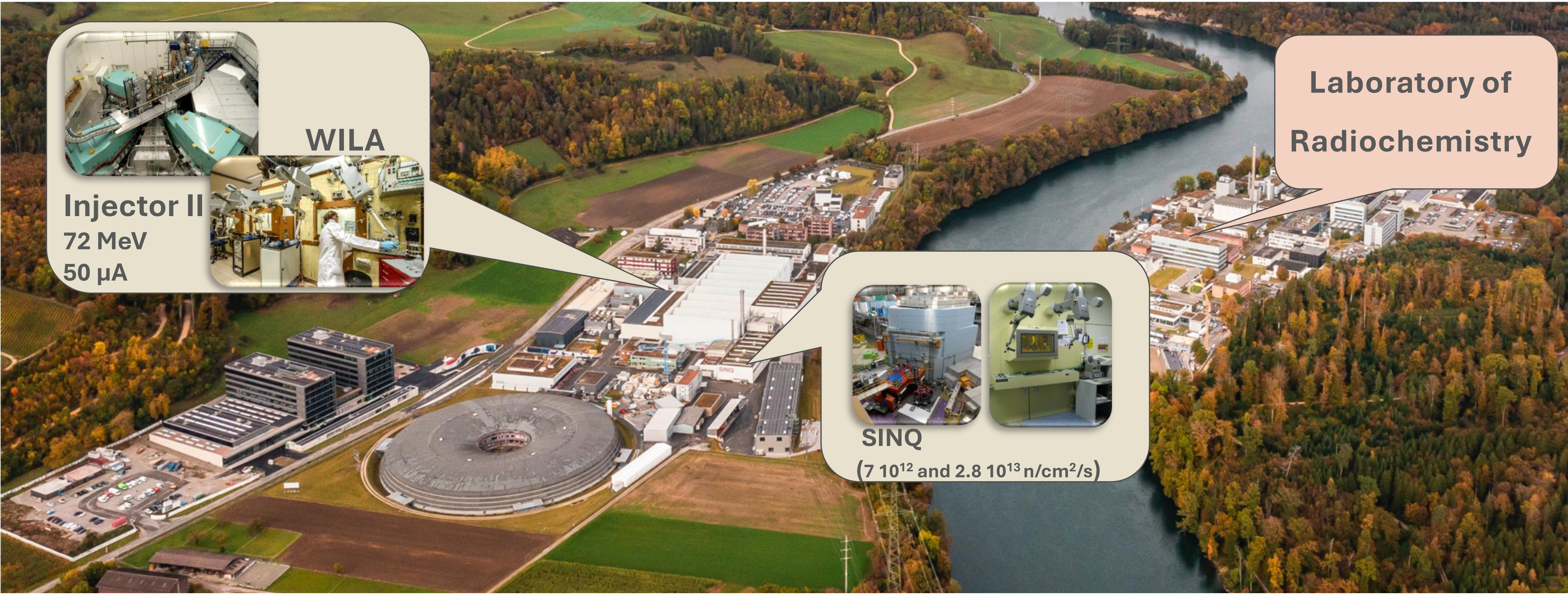
Infrastructure to handle high activities



Expertise in separation chemistry

Expertise in activity measurements

Radionuclide Production at the Paul Scherrer Institute

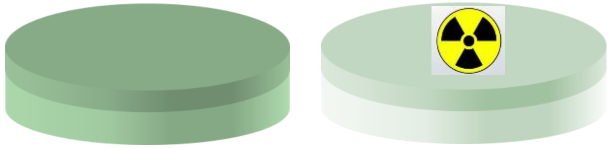


Infrastructure for the separation of radionuclides

Separation Modules

Target and Sources

Targets



Cross section Measurements

Nuclear Structure

Synthesis of Super Heavy Elements

Production of Medical Radionuclides

Sources

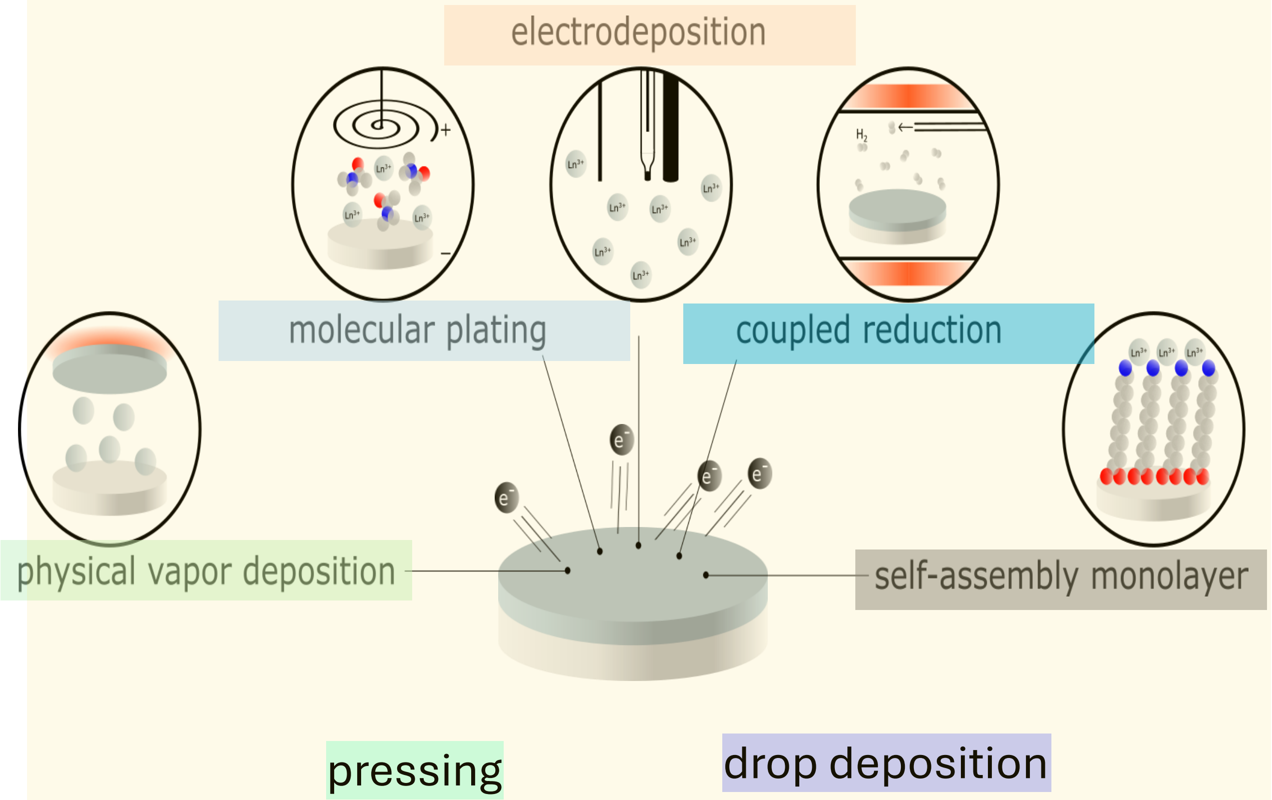
Calibration Standards

Nuclear Data Measurements

Interaction of Radiation with Matter

Uniform and Radioactive Thin Films

Preparation



Characterization

- Gamma and alpha spectroscopy
- Radiography
- SEM, EDX,
- XPS, XRD,
- RAMAN, IR,
- SIMS, AFM/STM
- Profilometry
- ICP-MS

Courtesy: N. Cerboni

Production of targets for (n,γ) cross-section measurement

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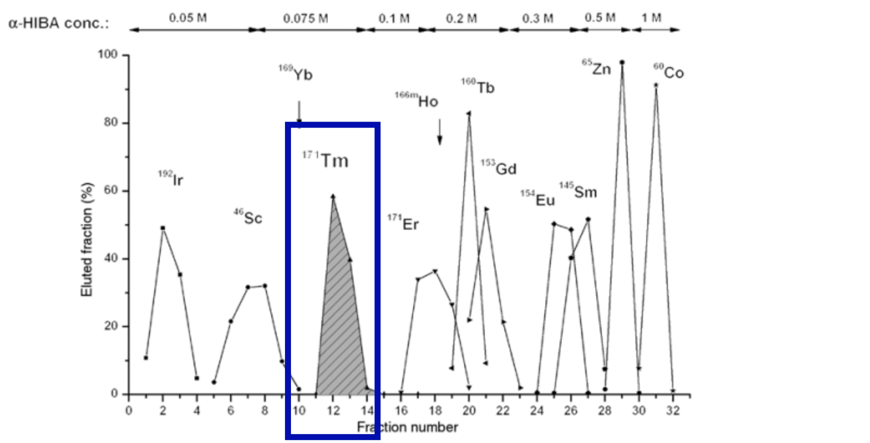
… targets that must be homogeneous



Separation profile of ^{171}Tm on the Aminex HPX87H cation resin. The gradual elution of different radioisotopes with increasing α-HIBA concentration is shown.

Tm 171
1.92 a
β^- 0.1…
γ (67), e^-
σ ~160

DE GRUYTER — Radiochim. Acta 2017; 105(10): 801–811

Stephan Heinitz*, Emilio A. Maugeri, Dorothea Schumann, Rugard Dressler, Niko Kivel, Carlos Guerrero, Ullrich Köster, Moshe Tessler, Michael Paul, Shlomi Halfon and the n_TOF Collaboration[a]

Production, separation and target preparation of ^{171}Tm and ^{147}Pm for neutron cross section measurements

Molecular plating technique

The final deposition efficiency for the ^{171}Tm target of **93.6 ± 0.4 %**

The final arrangement of the ^{171}Tm target provided to n_TOF CERN.

140 GBq ^{171}Tm

PHYSICAL REVIEW LETTERS **125,** 142701 (2020)

Neutron Capture on the *s*-Process Branching Point ^{171}Tm via Time-of-Flight and Activation

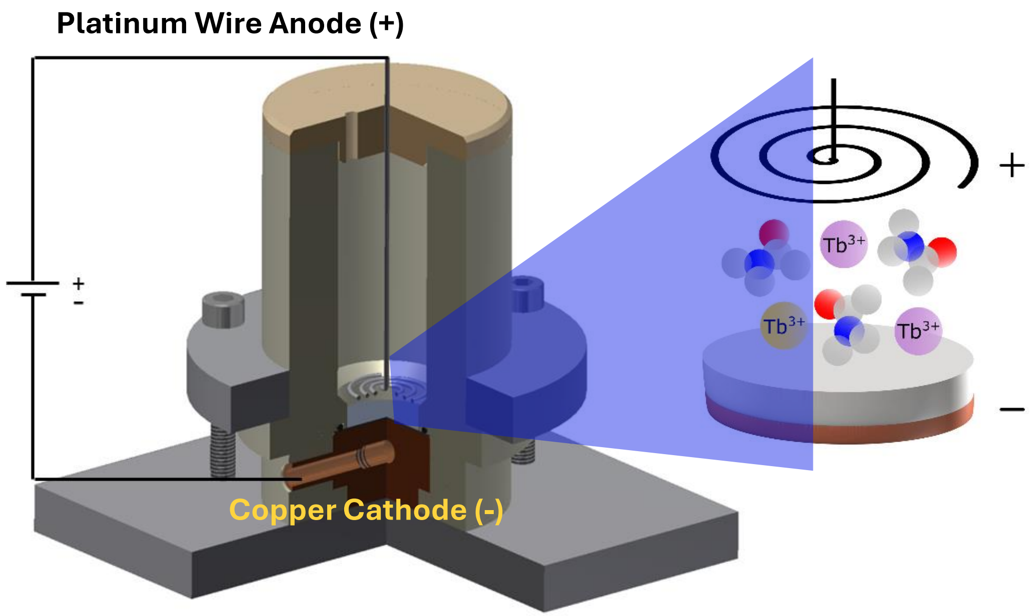
C. Guerrero,[1,2,*] J. Lerendegui-Marco,[1] M. Paul,[3] M. Tessler,[4] S. Heinitz,[5] C. Domingo-Pardo,[6] S. Cristallo,[7,8] R. Dressler,[5] S. Halfon,[4] N. Kivel,[5] U. Köster,[9] E. A. Maugeri,[5] T. Palchan-Hazan,[3] J. M. Quesada,[1] D. Rochman,[5] D. Schumann,[5] L. Weissman,[4] O. Aberle,[10] S. Amaducci,[26] J. Andrzejewski,[11] L. Audouin,[12] V. Bécares,[13] M. Bacak,[14] J. Balibrea,[13]

PHYSICAL REVIEW LETTERS **125,** 142701 (2020)

illustrative example, Neyskens *et al.* [3] have recently been able to determine an upper limit of 2.5×10^8 K for the *s*-process temperature in low-mass asymptotic giant branch (AGB) stars (see also Ref. [4]). This result has been possible thanks to a combination of the HERMES spectrograph observations [5] of the Zr/Nb abundance ratio in red giants and the availability of the new experimental Maxwellian-

The quality of the ^{171}Tm sample has been key to the success of the experiments presented herein. In the context of a larger project involving the production of ^{79}Se, ^{147}Pm, ^{163}Ho, and ^{204}Tl as well, a pellet of 240 mg $^{170}Er_2O_3$ enriched to 98.1% was irradiated for 55 days at the high-flux reactor Institut Laue-Langevin (ILL) in France, where neutron capture on stable ^{170}Er produced sizable quantities of ^{171}Er (7.516 h) that decayed into ^{171}Tm (2.92 y).

Molecular Plating Technique



- Organic solvent
- Starting material: neutral salt, such as $Me(NO_3)_x$
- high voltage (100–600 V), low current (few mA)

$$2\,H_2O_{(l)} + 2e^- \rightarrow H_{2(g)} + 2\,OH^-_{(aq)}$$

$$x\,OH^-_{(aq)} + Me^{x+}_{(aq)} \rightarrow Me(OH)_{x\,(aq)} \downarrow$$

- Rapid process with low-cost setup
- **90-95% yield**

but...

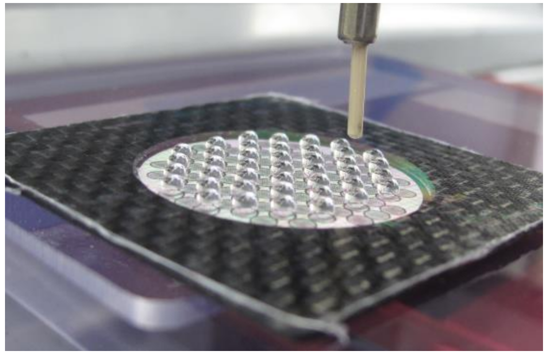
Me^{3+} can also interact with anionic and radical by-products formed during electrolysis of the organic solvent, leading to complex speciation.

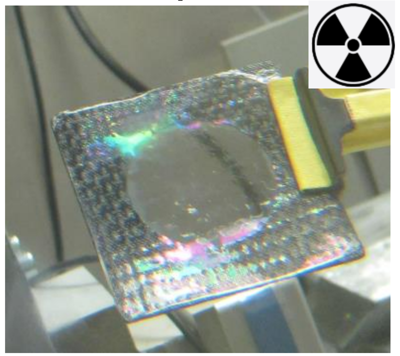
- Co-deposition of other species
- Poor adhesion to substrate
- Amorphous film limits thermal/electrical conductivity

Production of targets for (n,α) cross-section measurement

....targets that must be thin (nm – µm scale)

Drop deposition tehnique

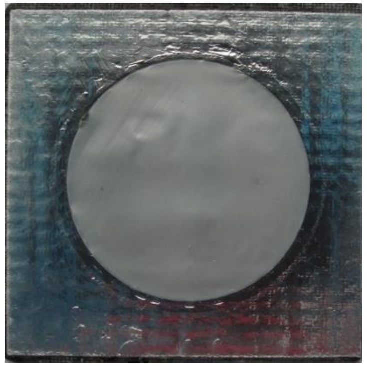


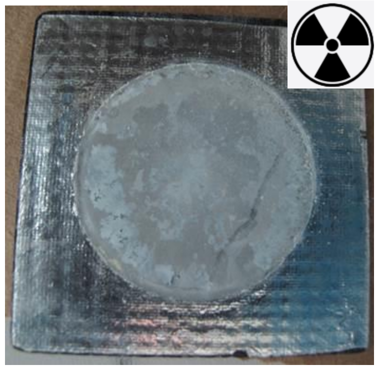


0.36 µm, 25 GBq ^{7}Be

Be 7
53.22 d
ε
γ 478
$\sigma_{n,\alpha}$ < 0.1
$\sigma_{n,p}$ 38820

Molecular plating





5.25 µm, 25 GBq ^{7}Be

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Preparation of ^{7}Be targets for nuclear astrophysics research

E.A. Maugeri,[a,1] S. Heinitz,[a] R. Dressler,[a] M. Barbagallo,[b] N. Kivel,[a] D. Schumann,[a] M. Ayranov,[c] A. Musumarra,[d] M. Gai,[e] N. Colonna,[b] M. Paul,[f] S. Halfon,[g] L. Cosentino,[d] P. Finocchiaro,[d] A. Pappalardo[d,h] and the n_TOF collaboration

PRL 117, 152701 (2016) PHYSICAL REVIEW LETTERS week ending 7 OCTOBER 2016

^{7}Be$(n,\alpha)^{4}$He Reaction and the Cosmological Lithium Problem: Measurement of the Cross Section in a Wide Energy Range at n_TOF at CERN

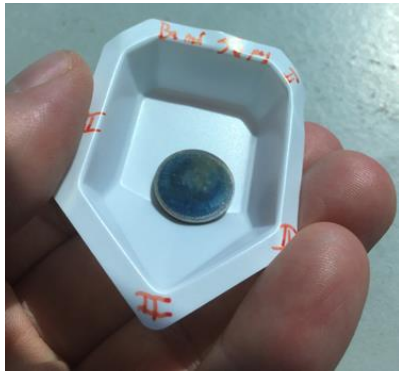
M. Barbagallo,[1] A. Musumarra,[2,3] L. Cosentino,[3] E. Maugeri,[4] S. Heinitz,[4] A. Mengoni,[5] R. Dressler,[4] D. Schumann,[4] F. Käppeler,[6] N. Colonna,[1,*] P. Finocchiaro,[3] M. Ayranov,[7] L. Damone,[1] N. Kivel,[4] O. Aberle,[8] S. Altstadt,[9]

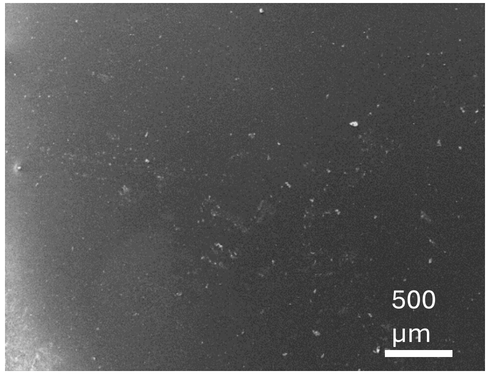
Production of targets for Muonic Atom Spectroscopy

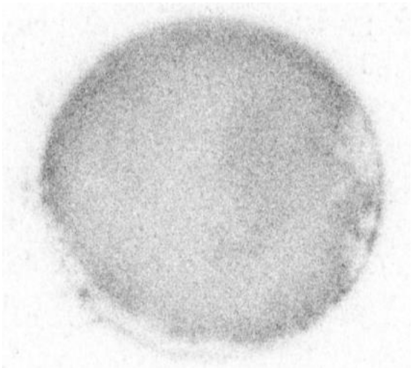
....targets that must be very thin (nm-scale)

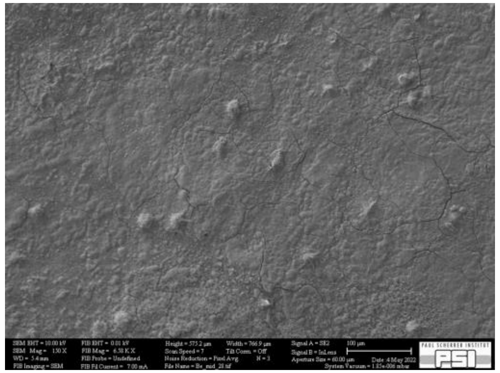
^{nat}Ba target and ^{133}Ba target (lighter homologous of ^{226}Ra)

Solvent: N,N-Dimethylacetamide; **backing:** Glassy carbon; **Quantity of Ba plated:** ~ 50 µg; **Area plated:** 3.14 cm^2



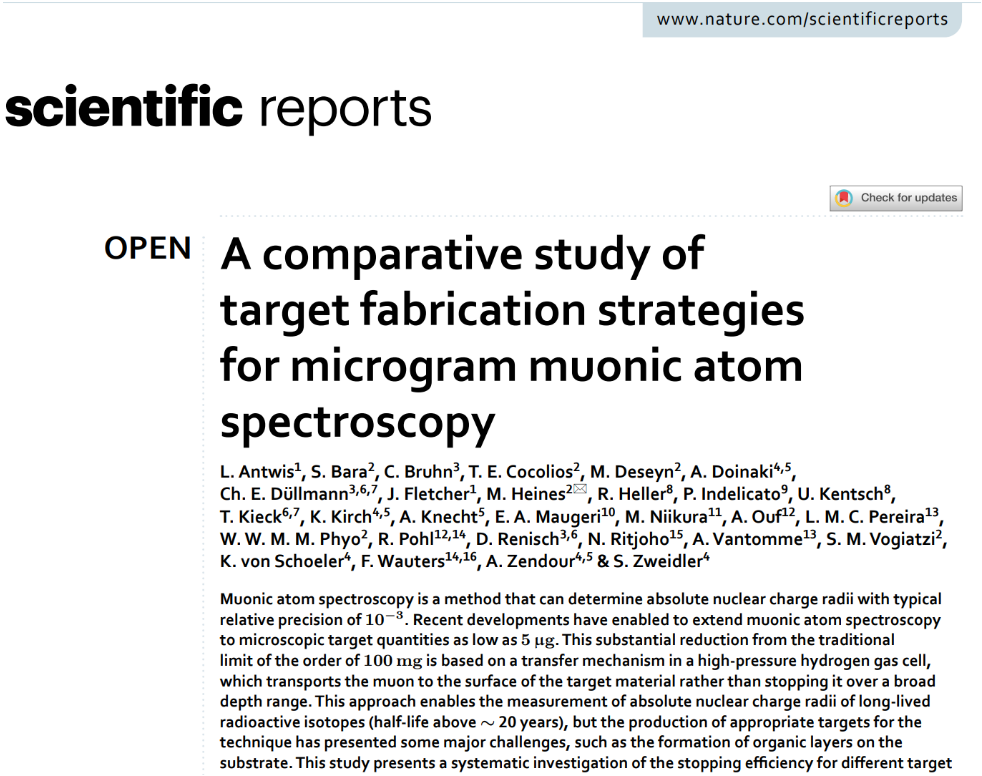






Deposition yield: 99%, Uniform barium target

Ba 133	
38.93 h	10.551 a
IT 276...	
e⁻	ε
γ 12, e⁻	γ 356, 81
ε	303..., e⁻
γ (633)	σ 3.0



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A comparative study of target fabrication strategies for microgram muonic atom spectroscopy

L. Antwis[1], S. Bara[2], C. Bruhn[3], T. E. Cocolios[2], M. Deseyn[2], A. Doinaki[4,5], Ch. E. Düllmann[3,6,7], J. Fletcher[1], M. Heines[2]✉, R. Heller[8], P. Indelicato[9], U. Kentsch[8], T. Kieck[6,7], K. Kirch[4,5], A. Knecht[5], E. A. Maugeri[10], M. Niikura[11], A. Ouf[12], L. M. C. Pereira[13], W. W. M. M. Phyo[2], R. Pohl[12,14], D. Renisch[3,6], N. Ritjoho[15], A. Vantomme[13], S. M. Vogiatzi[2], K. von Schoeler[4], F. Wauters[14,16], A. Zendour[4,5] & S. Zweidler[4]

Muonic atom spectroscopy is a method that can determine absolute nuclear charge radii with typical relative precision of 10^{-3}. Recent developments have enabled to extend muonic atom spectroscopy to microscopic target quantities as low as 5 µg. This substantial reduction from the traditional limit of the order of 100 mg is based on a transfer mechanism in a high-pressure hydrogen gas cell, which transports the muon to the surface of the target material rather than stopping it over a broad depth range. This approach enables the measurement of absolute nuclear charge radii of long-lived radioactive isotopes (half-life above ~ 20 years), but the production of appropriate targets for the technique has presented some major challenges, such as the formation of organic layers on the substrate. This study presents a systematic investigation of the stopping efficiency for different target

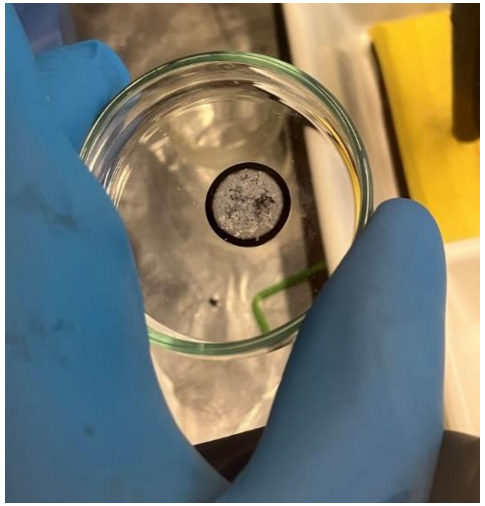
Production of targets for Muonic Atom Spectroscopy

....targets that must be very thin (nm-scale)

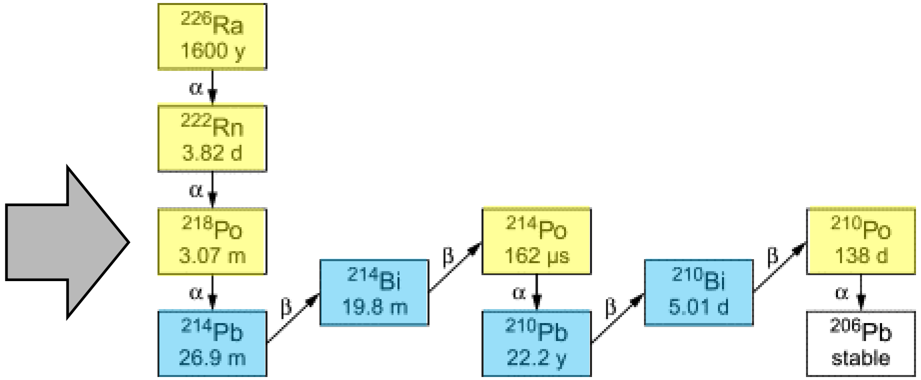
Isotope	Half-life	Max. Activity	Max. Mass	Density
^{226}Ra	1600 y	200 kBq	5 µg	~ 1 µg/cm^2

Ra 226
1600 a
α 4.7843, 4.601...
γ 186...
C14
σ 13.7, σ_f <5E-5

Solvent: N,N-Dimethylacetamide; **backing:** Glassy carbon; **Quantity of Ba plated:** ~ 5 µg; **Area plated:** 3.14 cm^2



Deposition yield: 86%, Thick, non-uniform with poor adhesion

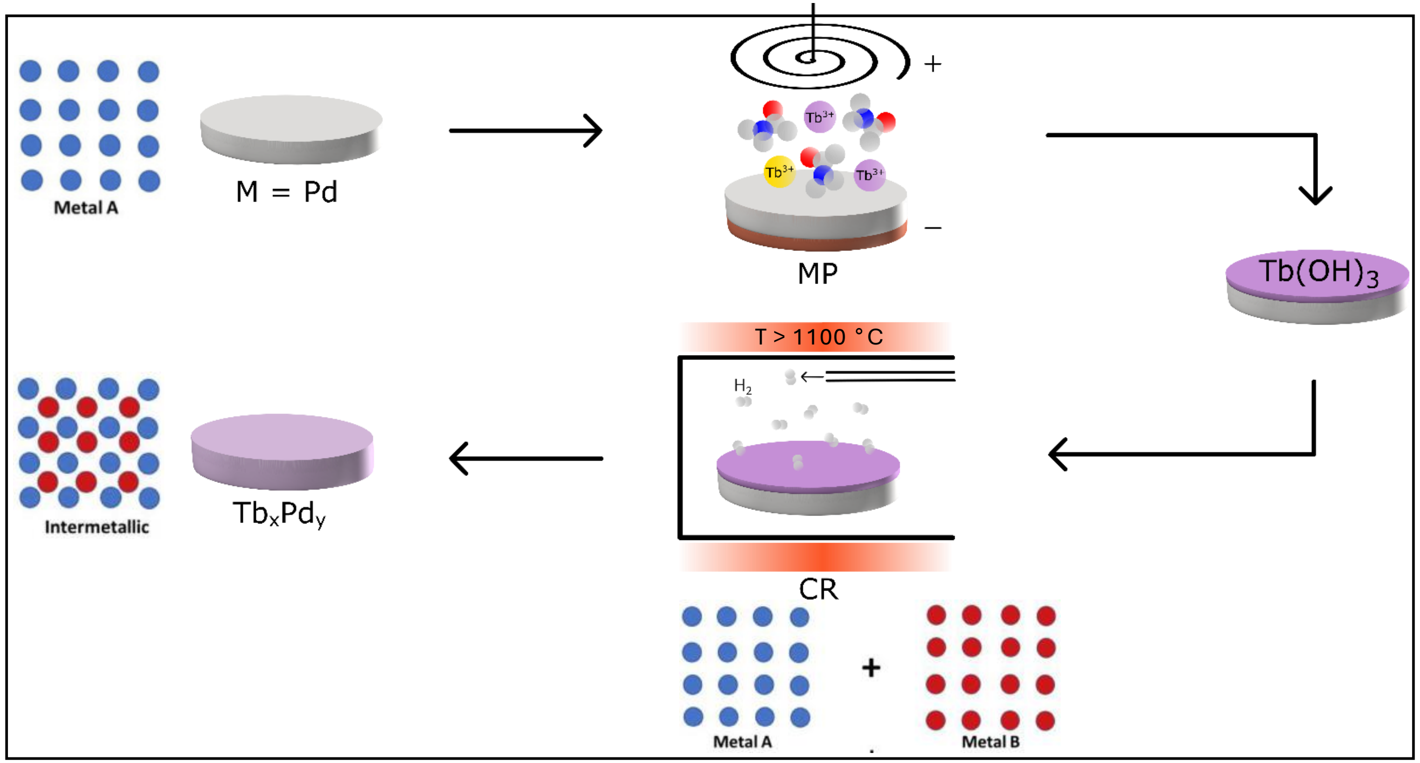


Co deposition of the undesired materials induced by **radiolysis of the organic solvent**

Production of targets for superheavy elements

PSI

....targets that need to withstand high stress level



$$x\,Pd + y\,Ln(OH)_3 + 3y\,H_2 \rightarrow Ln_yPd_x + 6y\,H_2O$$

Many advantages over only molecular plated samples

- High thermal and electrical conductivity
- High chemical and mechanical stability

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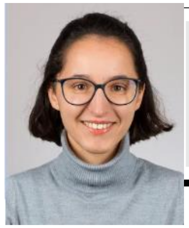
Contents lists available at ScienceDirect

Journal of Alloys and Compounds

journal homepage: www.elsevier.com/locate/jalcom



Unraveling the formation of Tb/Pd films by coupled reduction as targets for heavy ion-beam irradiation

Noemi Cerboni [a,b], Balazs Székér [b], Rugard Dressler [b], Michael Wörle [a], Robert Eichler [b,c], Thomas A. Jung [d,e], Dominik Herrmann [b], Colin C. Hillhouse [b], Pascal V. Grundler [f], Nick P. van der Meulen [b,f], Patrick Steinegger [a,b], Emilio A. Maugeri [b,*]

[a] Department of Chemistry and Applied Biosciences, Eidgenössische Technische Hochschule Zürich, Vladimir-Prelog-Weg 1, Zurich CH-8093, Switzerland
[b] Laboratory of Radiochemistry, Paul Scherrer Institut, PSI, Forschungsstrasse 111, Villigen CH-5232, Switzerland
[c] Department of Chemistry, Biochemistry and Pharmaceutical Sciences, University of Bern, Hochschulstrasse 6, Bern CH-3012, Switzerland
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Materials & Design 253 (2025) 113954

Contents lists available at ScienceDirect

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journal homepage: www.elsevier.com/locate/matdes

Elemental distribution and phase composition of Pd-Gd thin films

Xuandong Kou [a,b], Noemi Cerboni [a,c], Robert Eichler [a,b], Malgorzata Makowska [a], Elisabeth Müller [d], Matthias Muntwiler [e], Patrick Steinegger [a,c], Emilio A. Maugeri [a,*]

[a] PSI Center for Nuclear Engineering and Sciences, 5232 Villigen PSI, Switzerland
[b] Department of Chemistry, Biochemistry and Pharmaceutical Sciences, University of Bern, 3012 Bern, Switzerland
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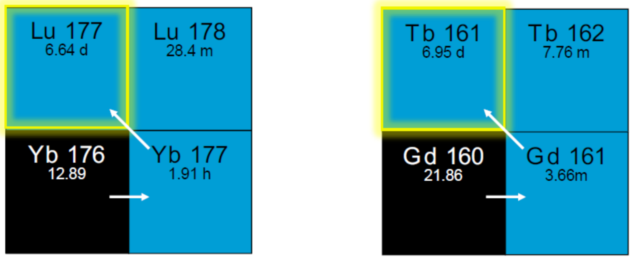
Production of targets for nuclear medicine

RAdiolanthanide Production In Core (RAPIC)

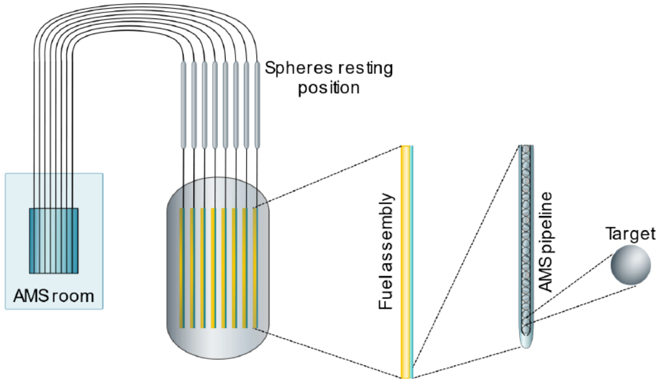
Motivation

^{177}**Lu** ($E_{ave\beta}$134 keV) and ^{161}**Tb** ($E_{ave\beta}$156 keV) have shown promising results for cancer treatment with Targeted Radionuclide Therapy. Current production methods depend solely **on the availability of research reactors**, which **restricts the supply** and consequently their widespread therapeutic use.

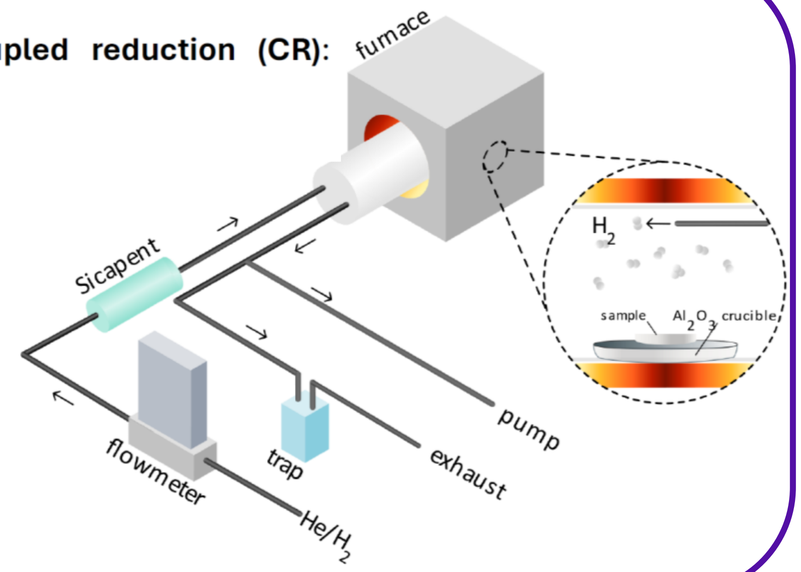


Aim of the project

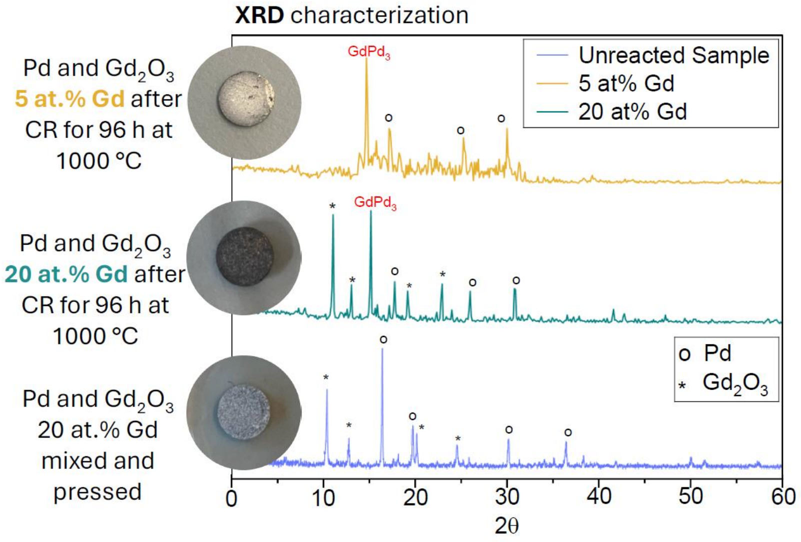
Implementation of a **reliable** and **sustainable** ^{177}Lu and ^{161}Tb **supply** employing the **existing Aeroball Measuring System (AMS) in KKG.**



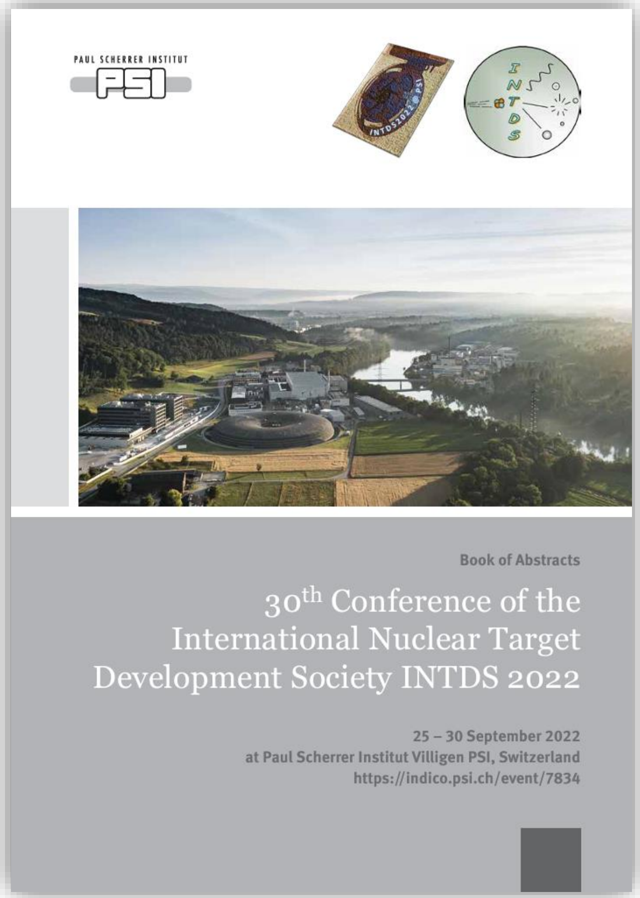
Coupled reduction (CR):



Preliminary results



INTDS 2022 (International Nuclear Target Development Society)



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