State of the art of Targets activities at GANIL and perspectives

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WP2 – Research Infrastructures for Nuclear Physics
Task 2.5 – Service Improvements
Subtask C2 – Targets for high intense beams

Outline

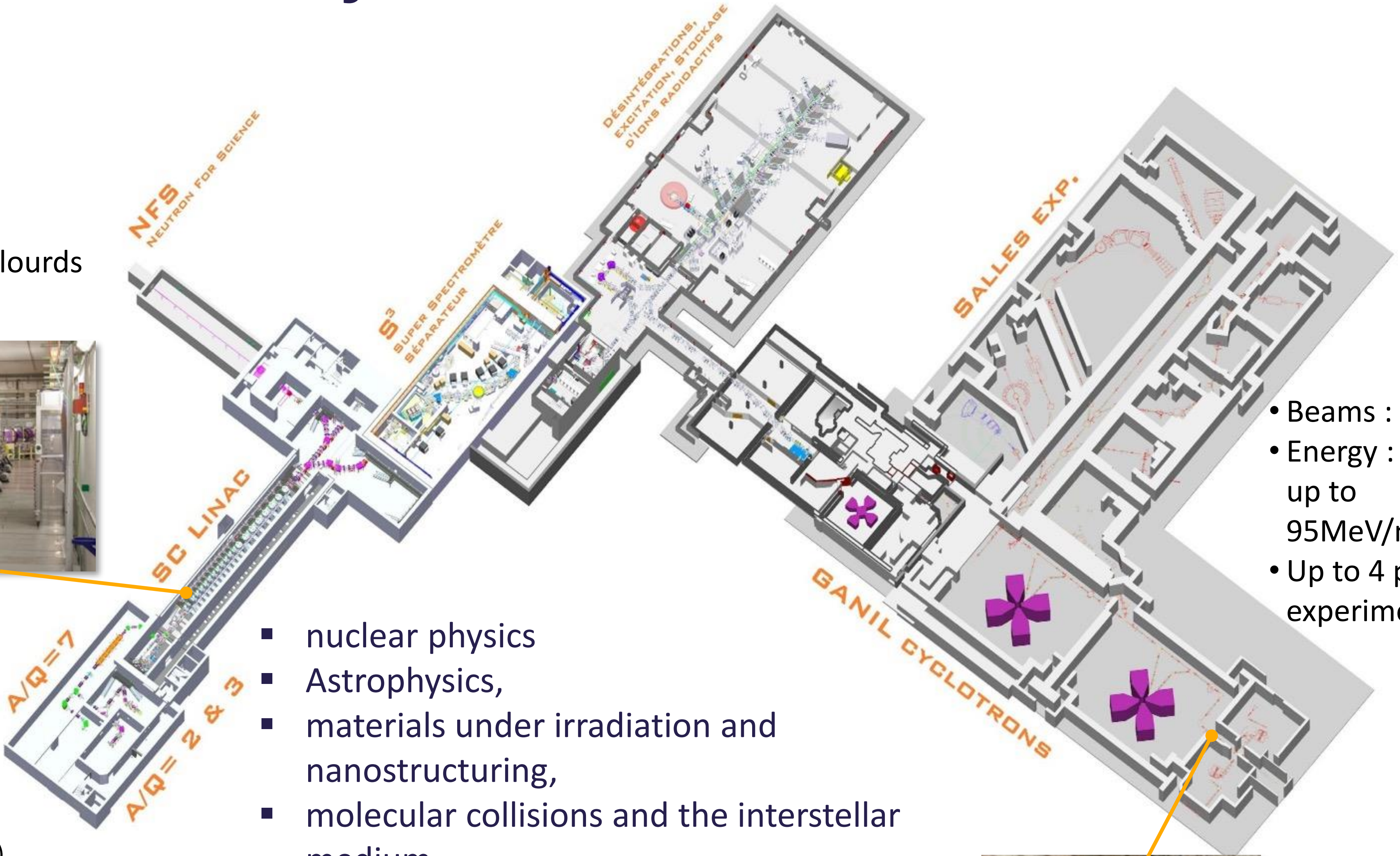
1. GANIL/SPIRAL2 Facility
   - Accelerators.
2. Target needs at GANIL
3. GANIL target laboratory
   - Examples of Targets Fabricated at GANIL
4. PALAIS project
5. Grand PALAIS (ATLAS) project
6. Conclusions

GANIL/SPIRAL2 Facility

Accelerator & Experimental areas

GANIL/SPIRAL2 Facility

Beams :
33 MeV protons
40 MeV deutons
<14,5 MeV/nucleon ions lourds



- Beams : ^{12}C à U
- Energy : from <1 MeV up to 95MeV/nucleon
- Up to 4 parallel experiments

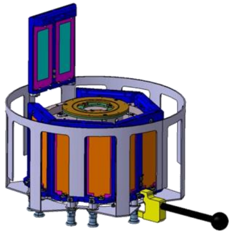
- nuclear physics
- Astrophysics,
- materials under irradiation and nanostructuring,
- molecular collisions and the interstellar medium,
- radiobiology and innovative techniques for imaging and therapy of certain cancers.

LINAC beams : He to U
- 1 mA, < 14,5 MeV/A (A/Q=3)
- 1 mA, < 7,5 MeV/A (A/Q=7)

targets of different thicknesses, geometries and materials are required

- **n + Ce, ^{A}Pb, ^{A}Sn, Ni, C : ~ cylinder of 4 cm diameter, weight = 250 g, thickness = 3 cm**
- **n + actinides**

- **Activation targets**
- **Radioisotopes: ~ 70 µm Bi**

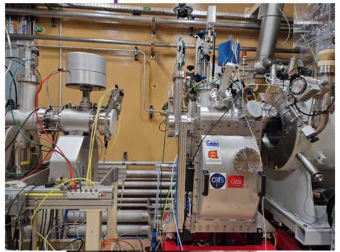


REPARE system, M. Michel

Courtesy J.C. Foy, M. Michel

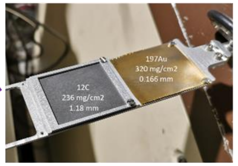
Low Energy Branch (0,5 – 1 mg/cm²)
^{50}Cr , ^{58}Ni, ^{175}Lu, ^{180}Hf, ^{208}Pb, ^{238}U, ^{116}Sn, ^{144,148}Sm, ^{160,164}Dy, ^{60}Ni, ^{45}Sc, ^{170}Er, ^{174}Yb, ^{160}Gd, ^{184,186}W & ^{181}Ta

SIRIUS – 300-500 µg/cm²
$^{204/207/208}$Pb, ^{209}Bi, ^{238}U
Future: actinide targets



Liquid H 7 mg/cm²

CD_2/CH_2
1- 2 mg/cm²



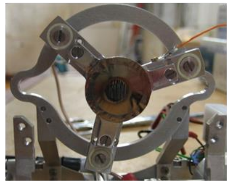
C 236 mg/cm²
Au 320mg/cm²

C, Ni, Sn, Ta, Au, Ca… 0,02-10 mg/cm²

Pb, Bi, Sn, Yb 0,3-0,6 mg/cm²
+ C 30-50 µg/cm²

Courtesy V. Watt-Morel, JC Thomas, Q. Delignac, N. Leneindre, T. Roger

Mg, Ti, Ni, Au
2-5 mg/cm²



Au, Fe 200-600 µg/cm²…

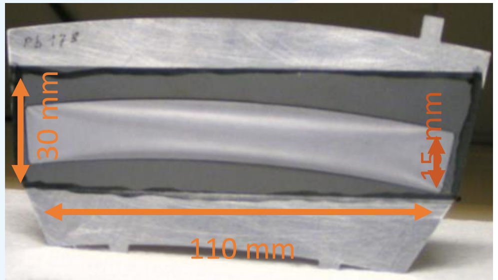
Au 90 µg/cm²

Targets needs at GANIL

Targets Needs

- **Stable** Targets @ S3 > 2025, 0,2-1 mg/cm² ± 5% ≈ 22 cm² - 1 wheel = 18 targets
  - Equilibrium charge states foils + backings: C @ 30 µg/cm²
  - Commissioning: ^{116}Sn, ^{174}Yb, ^{180}Hf, ^{175}Lu, ^{58}Ni, ^{197}Au, ^{206}Pb, ^{209}Bi,
  - Low Energy Branch : ^{50}Cr, ^{58}Ni, ^{nat}Zn, ^{96}Mo, ^{175}Lu, ^{178,180}Hf, $^{206\text{-}208}$Pb, ^{209}Bi, ^{208}Pb, ^{238}U,
  - SIRIUS: ^{58}Ni, ^{174}Yb/^{170}Er, ^{96}Ru, ^{92}Mo, ^{206}Pb, ^{209}Bi, $^{204,\,207,\,208}$Pb (PbS), ^{209}Bi (Bi203), ^{232}Th,^{238}U
  - ^{45}Sc, ^{170}Er, ^{160}Gd, ^{184,186}W, ^{181}Ta, ^{144,148}Sm, $^{160,\,164}$Dy, …….

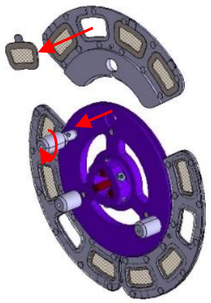
2025 – 2027 ≈ 600/year (15g)



- **Actinide** Targets @ S3, > 2027-2028 Experiments **+ for NFS**

1 isotope per year

^{226}Ra*, (^{237}Np), ^{243}Am*, ^{248}Cm*, $^{239/242/244}$Pu* (≈ 25 mg ≈ 10^2 –10^8 Bq)



0,3 - 0,5 mg/cm² ; 1 wheel ≈ 12 targets of ≈ 3 cm² or 6 targets of ≈ 6 cm² ≈ 36 cm²

≈ **20 mg** ≈ 10^2 –10^8 Bq < 1 GBq

Isotopic enrichment >≈ 97%

Preparation of 3 wheels (30-40 targets) per year

GANIL Target Laboratory

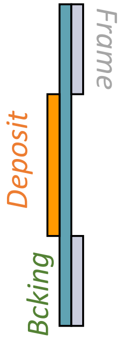
G. Frémont, expert Cibles

F. Pérocheau, chef du projet & Ch. Stodel, pilote stratégique

M. Bourges

R. Rahali

The existing target laboratory



Different Deposition Techniques Available:

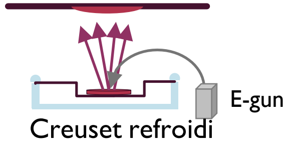
- **Physical Vapour Deposition (PVD)**
- **Sublimation**
- **Mechanical Shaping**: Tablet pressing, rolling
- **Chemical Techniques**: Electrodeposition/Molecular Plating, Polymerization

Resistive heating

H.A.F. Muggleton, Vacuum 37 (1987) 785-817.

e-bombardement

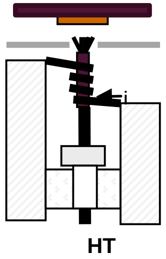
electron gun

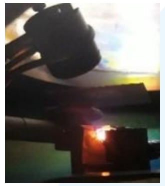


Electron Heating of the material

G.E. Thomas et al., Nucl. Instr. and Meth. A 303 (1991) 162-164.

Electrostatic focused electrons (EFe-)





Electronic bombardment of the crucible

L. Westgaard et al, Nucl. Inst. Meth. 42 (1966) 77-81
A. Stolarz, *Journal of Radioanalytical and Nuclear Chemistry* vol. 299, pages 913–931 (2014)

Sublimtion

Tech-Evap Carbone : sublimation

10-100 µg/cm2

P. Maier-Komor, NIM 102 (1972) 485-486
W. Thalheimer et al, Cryst. Res. Technol. 34 (1999) 175-179.

Evaporator large dimension (diamètre 700 x1500)

Metallisation of thin foils for detectors

Electro-deposition

Preparation of osmium targets with carbon backing

^{68}Zn, ^{60}Ni

Georges Fremont, et al, AIP Conf. Proc. 1962, 030002-1–030002-4; doi: 10.1063/1.5035519

Mechanical techniques

Two Rolling machine

0.5 mg/cm^2 → g/cm^2

Tablet pressing

~20 mg/cm² → g/cm²

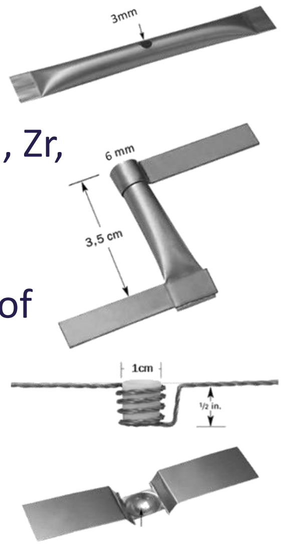
Targets development – Recent results

Process optimization

Optimizing the deposition process and making it reproducible—this is achieved through extensive testing and fine-tuning of key parameters

Variable parameters :

- Substrate (backing) : Carbon, Aluminium
- Different currents (step by step or not)
- **Different Evaporation boat (**Crucibles) (Ta, Zr, Al_2O_3) – different forms/shapes, different diameters, different depths.
- Amount of material used (20mg, 100 mg of Gd_2O_3)
- Reducing agent (Zr, Hf, La)
- Different distance crucible- substrat
- With and without rotating frame techniques
- The temperature & deposition time



Characterization development

Developing the characterization and analysis workflow — setting up reliable methods to assess thickness, homogeneity, composition, and other target properties

- **microbalance:** Used to evaluate target thickness.
- **Alpha source:** assess thickness, check homogeneity, and detect potential defects.
- **XRF (X-ray fluorescence):** Chemical composition analysis.
- **SEM/EDS (Scanning Electron Microscopy / Energy Dispersive Spectroscopy):** For surface and elemental analysis.

Targets development – Recent results

Optimizi
reproduc
testing a

Variable

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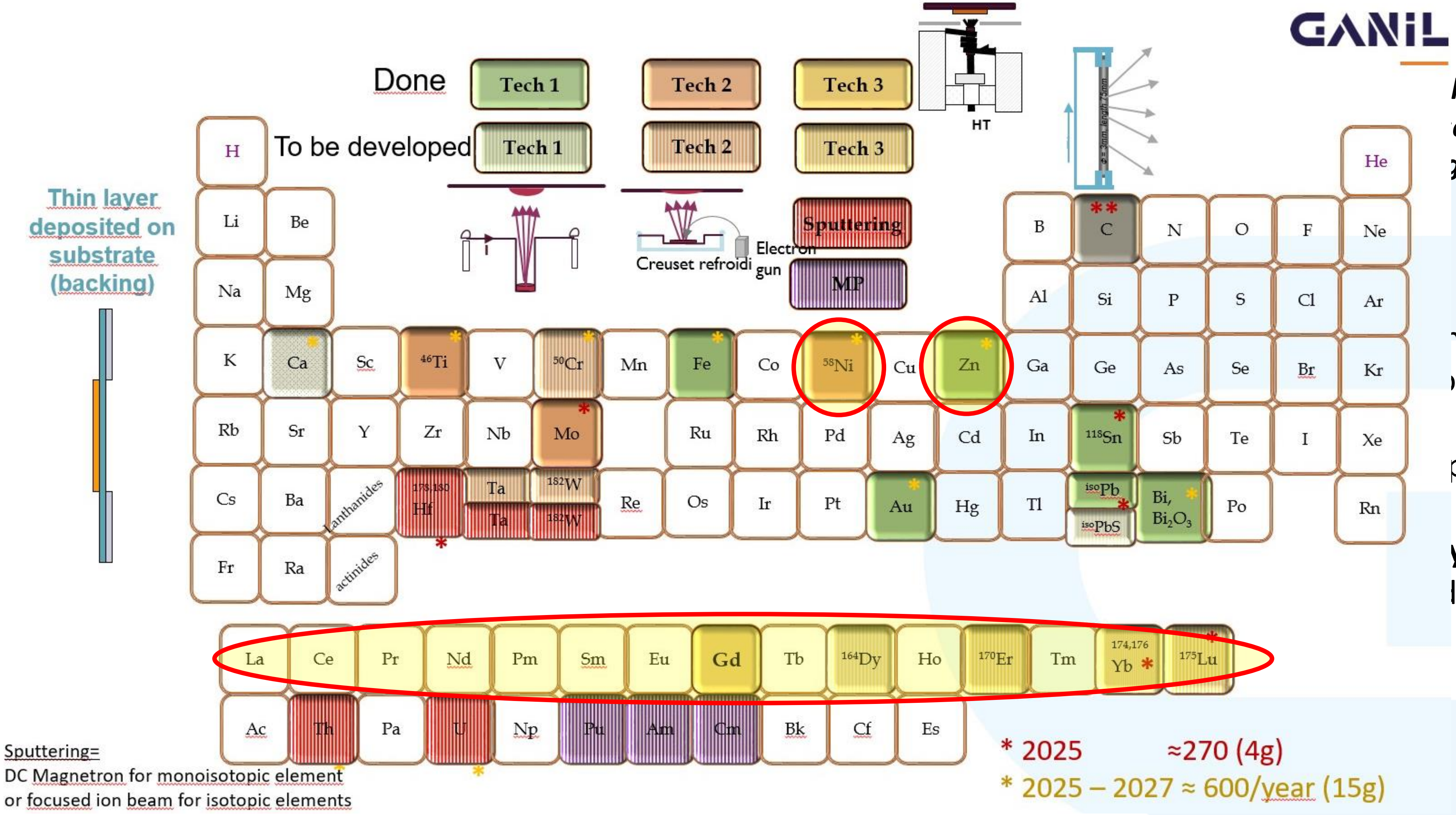
- Diffe
- **Diff** Al_2C dian
- Amo $Gd_2($
- Red
- Diffe
- With



lysis workflow
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get properties

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position

y / Energy
l elemental

Targets development – Recent results

Resistive heating technique

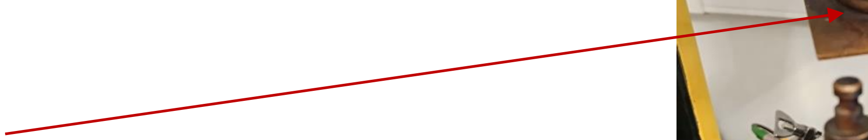
Crucible : Zirconium of 0.7 x 0.7 mm diameter

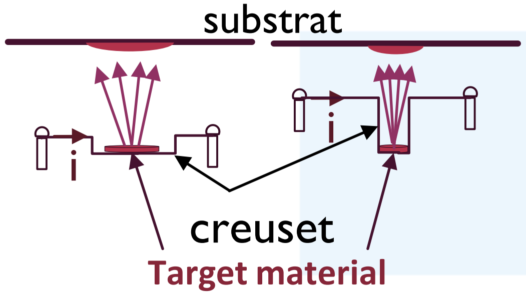
Deposition without rotation.

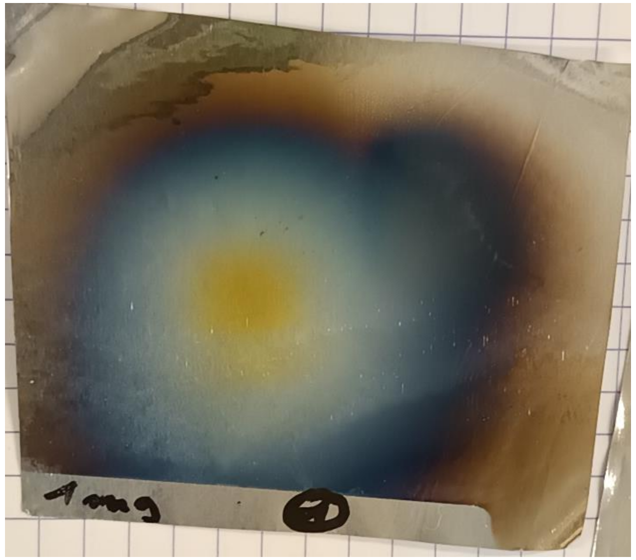
Deposition on aluminum foil attached to a copper plate cooled throughout the deposition.

Current 104 A

ANR TTRIP

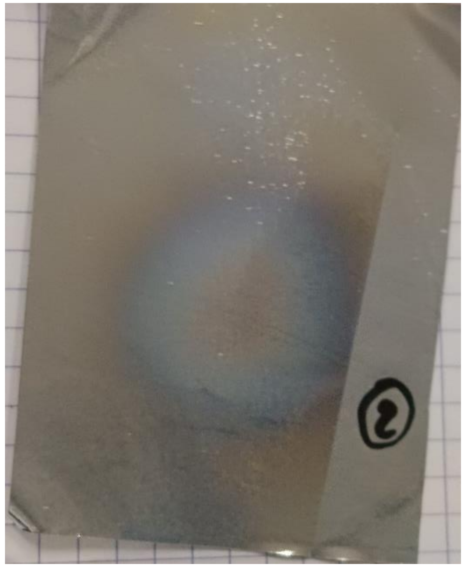




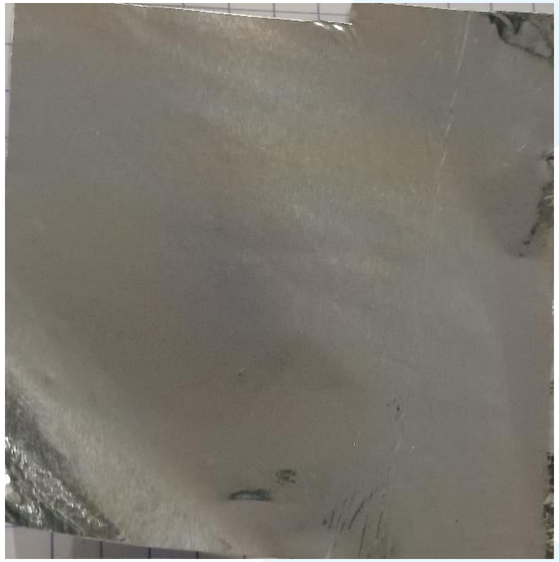


100 mg Gd_2O_3
100 Zr

Yield ~ 1%



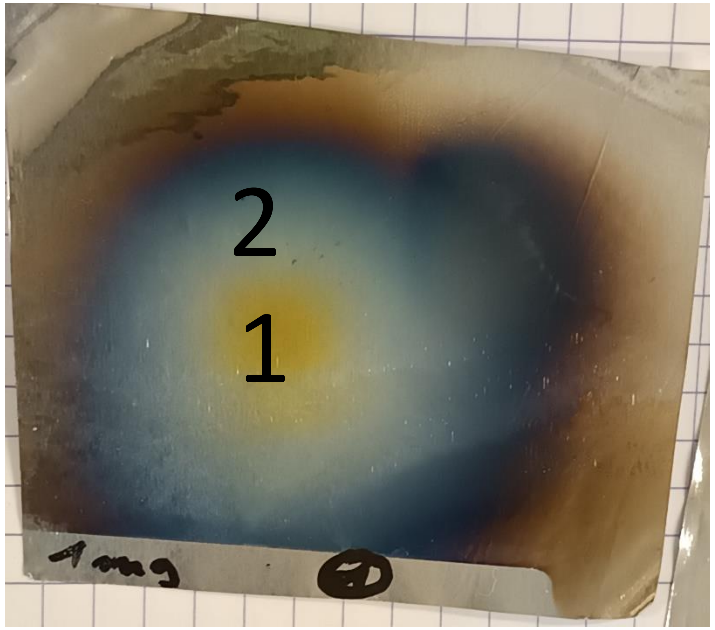
100 mg Gd_2O_3
200 Zr



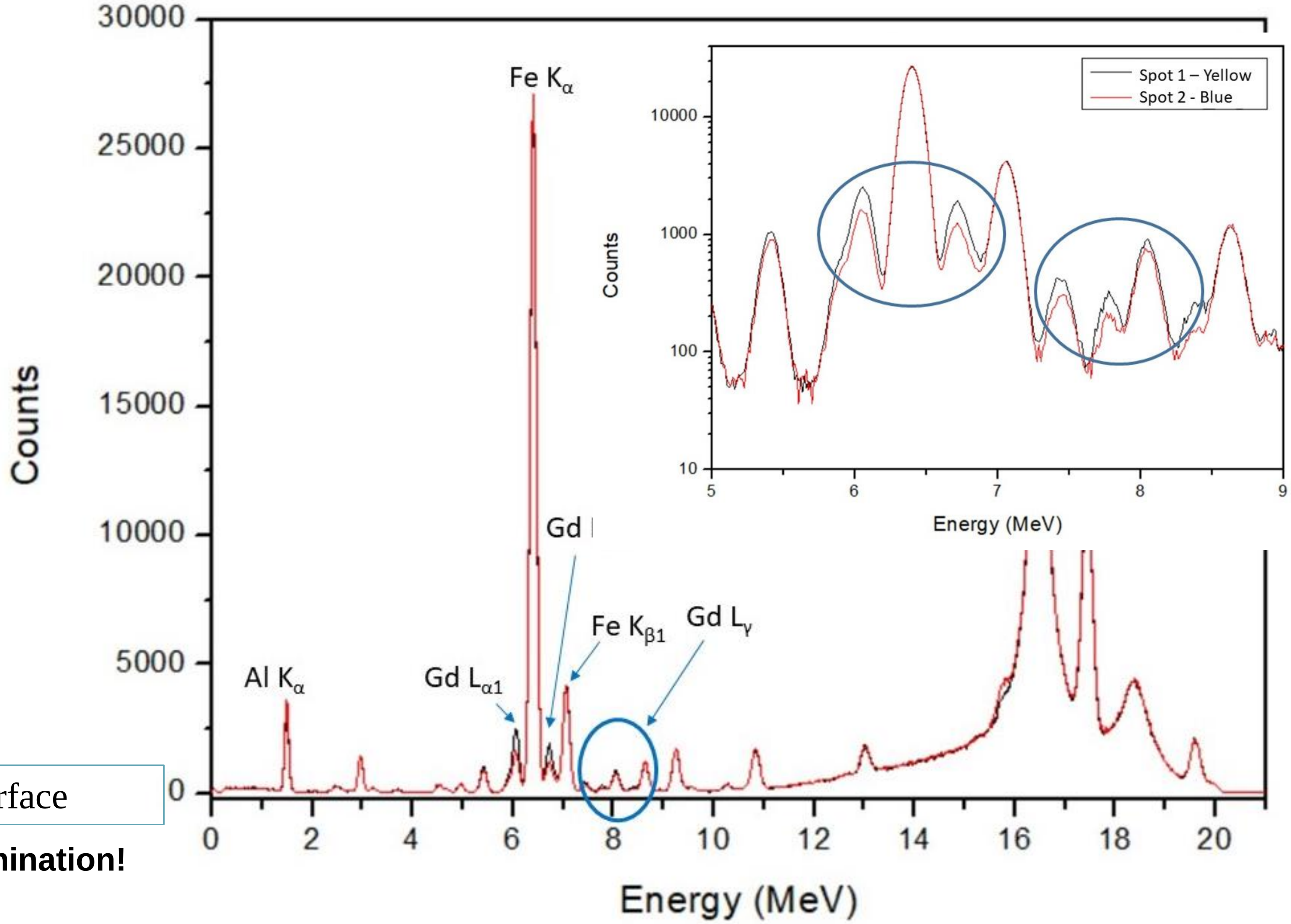
120 mg Gd_2O_3
Zr 50mg

Non-homogeneous distribution over the surface → Different thickness

Targets development – Recent results



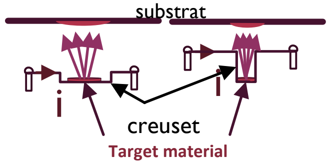
100 mg Gd_2O_3
100 Zr



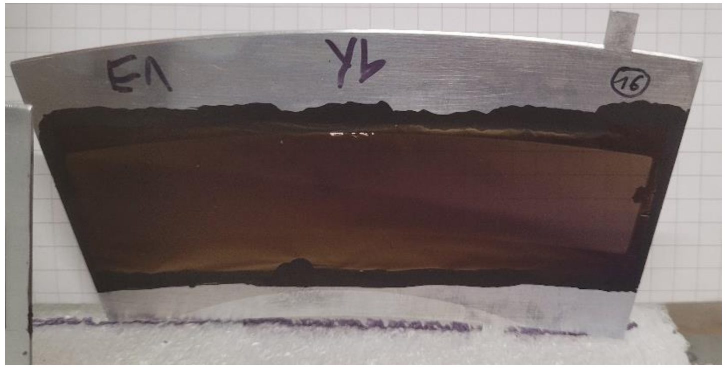
Different thickness distribution over the surface

Crucible (Zr) destroyed but no comtamination!

Targets development – Recent results



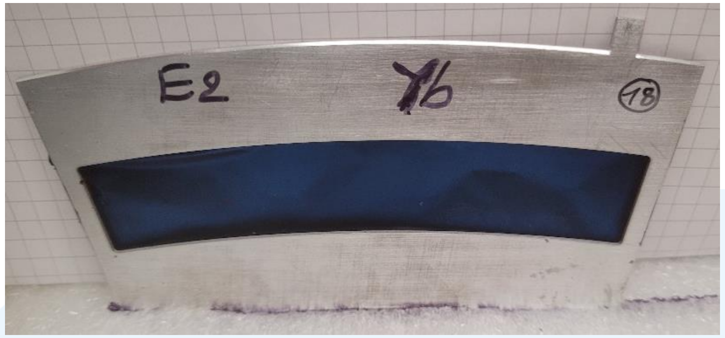
Yb/C → from 50 µg/cm² to 4 mg/cm²



^{174}Yb ~ 115 µg/cm²

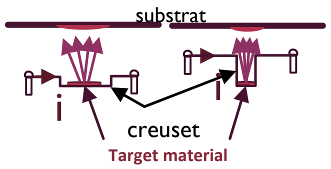
- 1 Frame with carbon foils of ~ 35 µg/cm² and a mask rotating at 50 rpm
- Yb_2O_3+ Hf or La (reductant agent)
- Crucible : Tantalum
- Current ~ 60 – 85 A *T < 1600° C*
- High vacuum condition: 10^{-5} mbar

Rotating wheel → Homogeneous distribution over a large surface

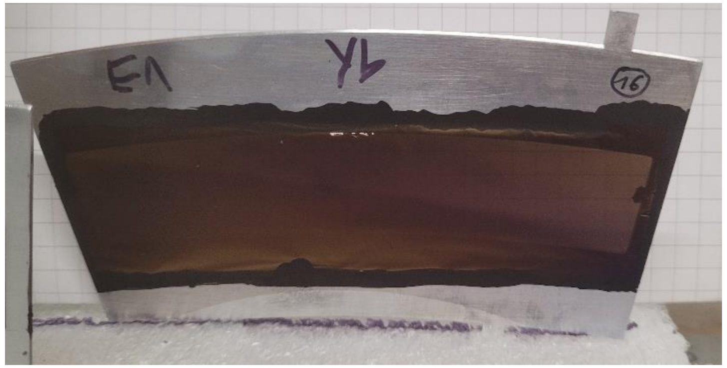


^{174}Yb ~ 4 mg/cm²

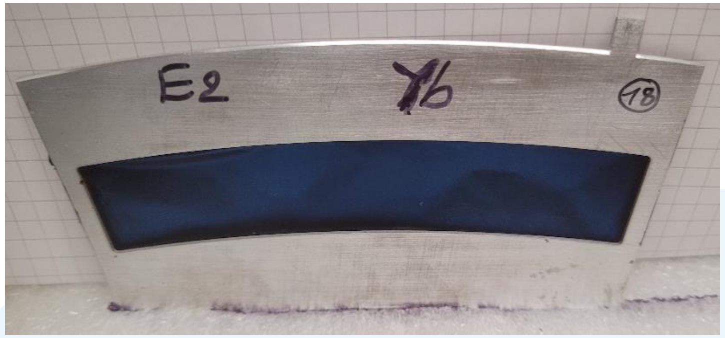
Targets development – Recent results



Yb/C → from 50 µg/cm² to 4 mg/cm²



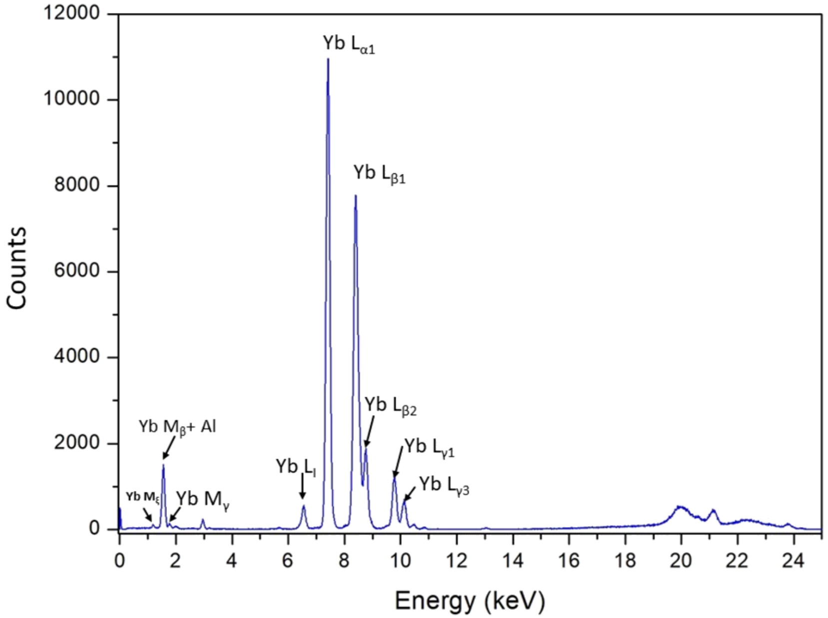
- 1 Frame with carbon foils of ~ 35 µg/cm² and a mask rotating at 50 rpm
- Yb_2O_3+ Hf or La (reductant agent)
- Crucible : Tantalum
- Current ~ 60 – 85 A *T < 1600° C*
- High vacuum condition: 10^{-5} mbar



^{174}Yb ~ 115 µg/cm²

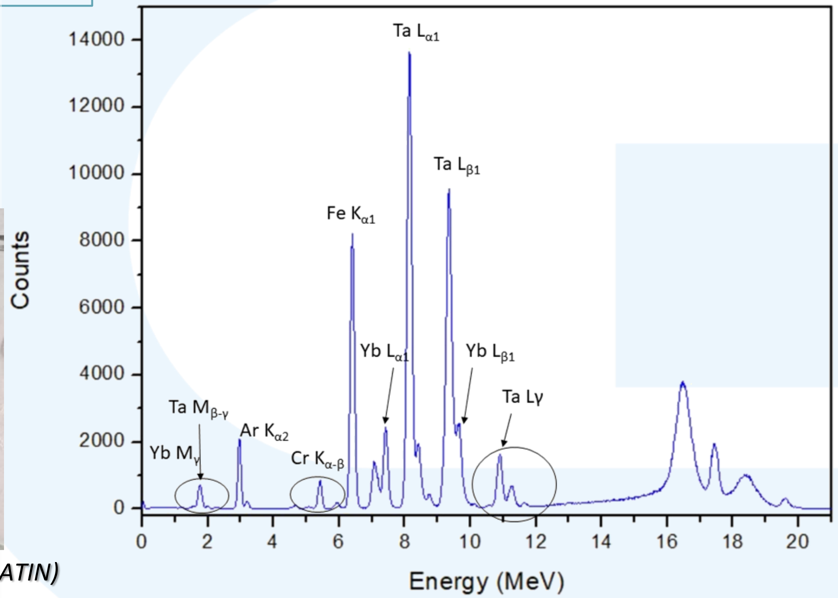
Rotating wheel → Homogeneous distribution over a large surface

^{174}Yb ~ 4 mg/cm²



Different results :
Variable deposition time
different distances (crucible- substrate)
Different type of crucible

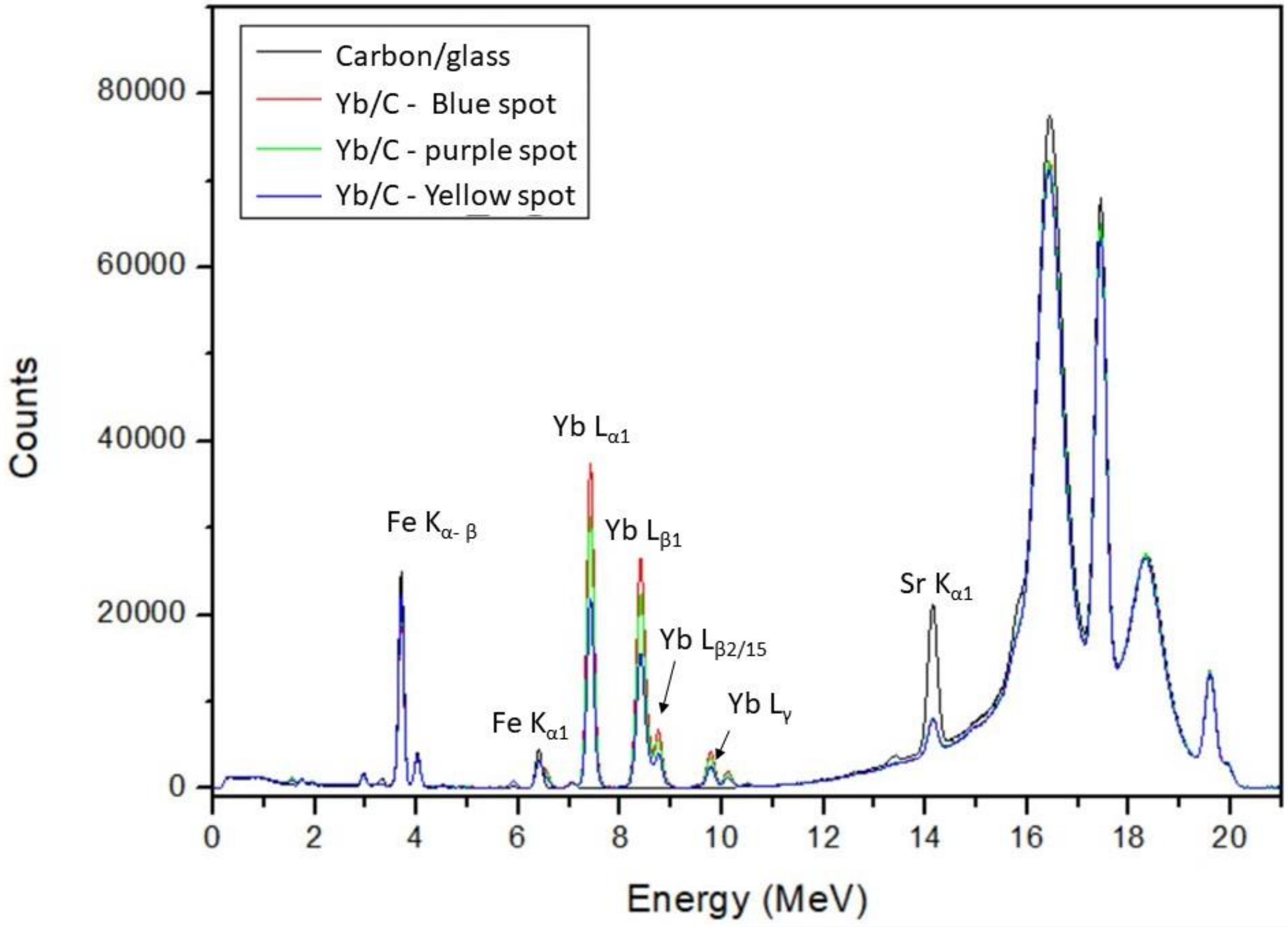
XRF device (courtesy of PLATIN)



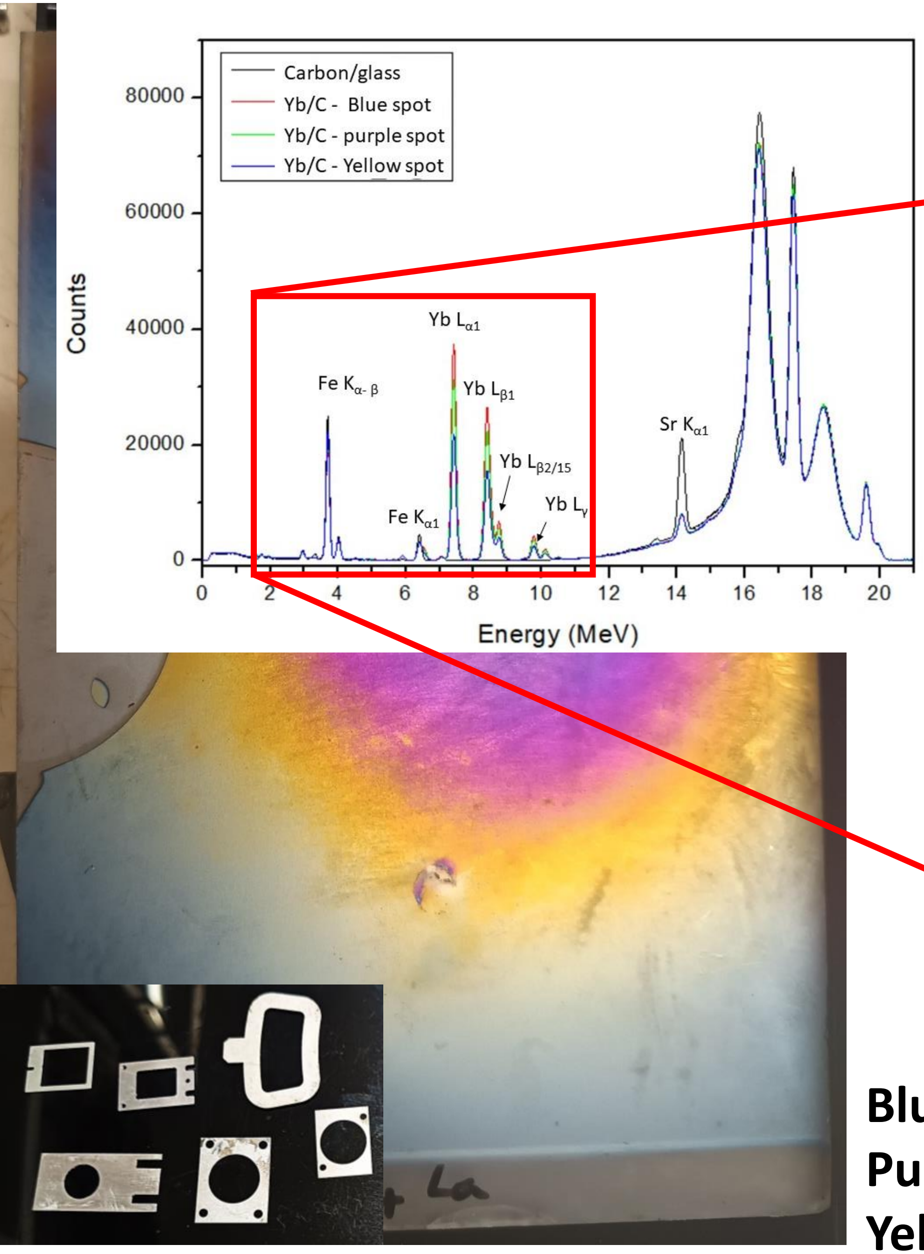
- **Long deposition time → Possible contamination of the crucible**

Targets development – Recent results

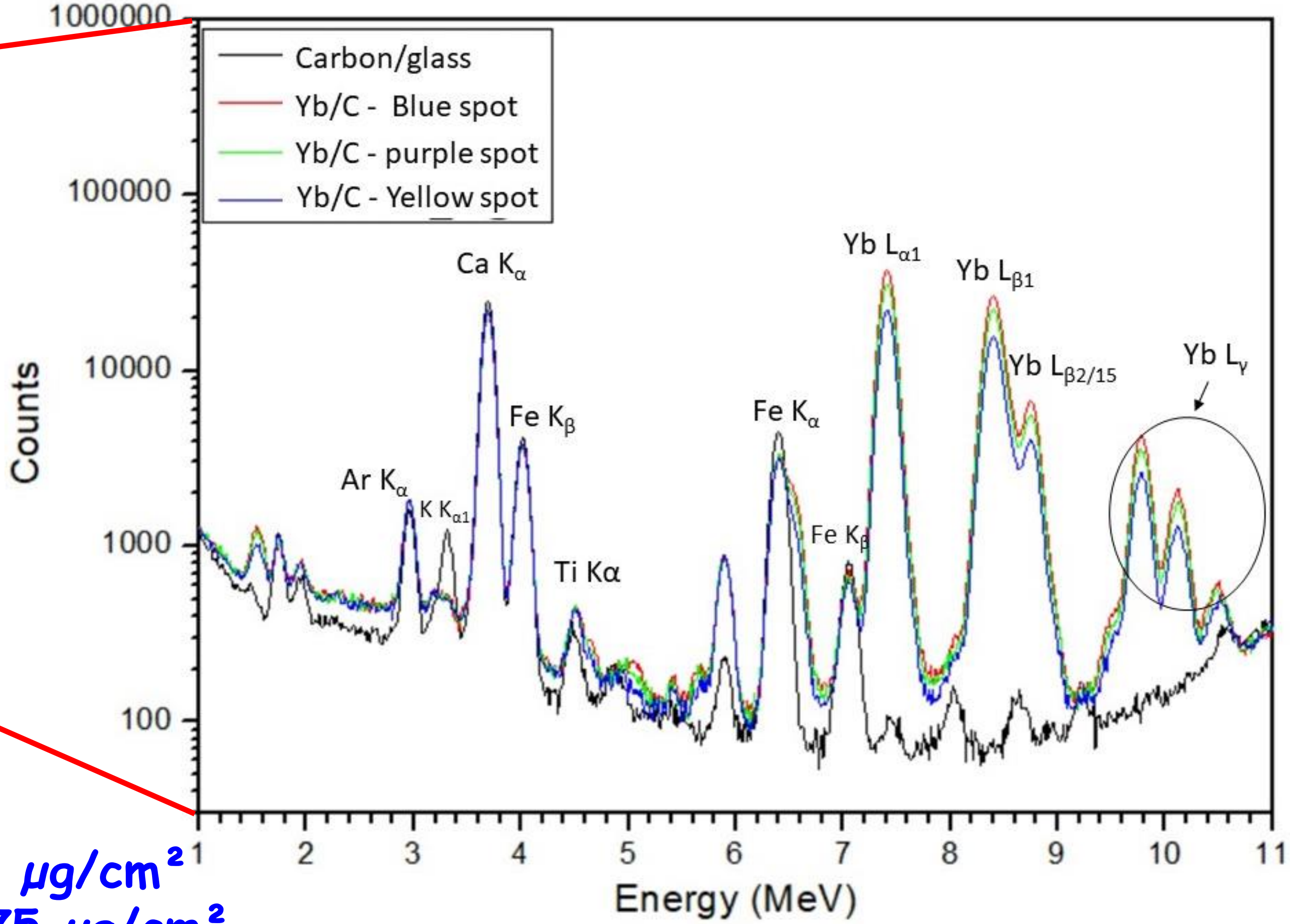
Yb on Carbon caking



Targets development – Recent results

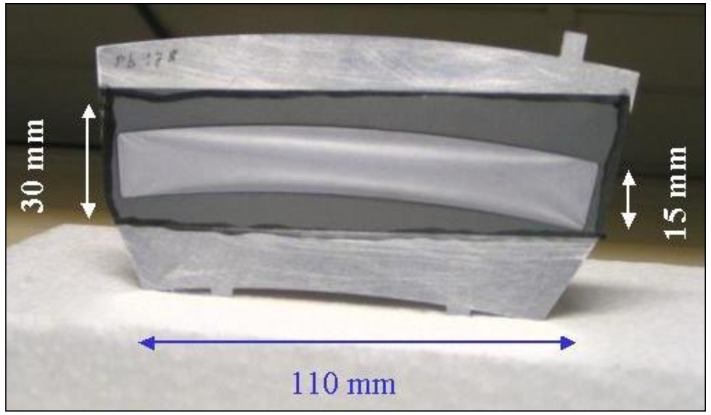


Yb on Carbon caking

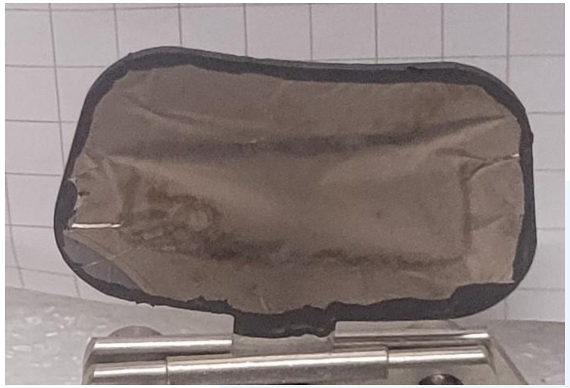


Blue ~ 90 $\mu g/cm^2$
Purple ~ 75 $\mu g/cm^2$
Yellow ~ 52 $\mu g/cm^2$

Targets development – Recent results



Enriched ^{208}Pb target of 350 µg/cm²
sandwiched between C 35 µg/cm² and C 5 µg/cm².
PVD

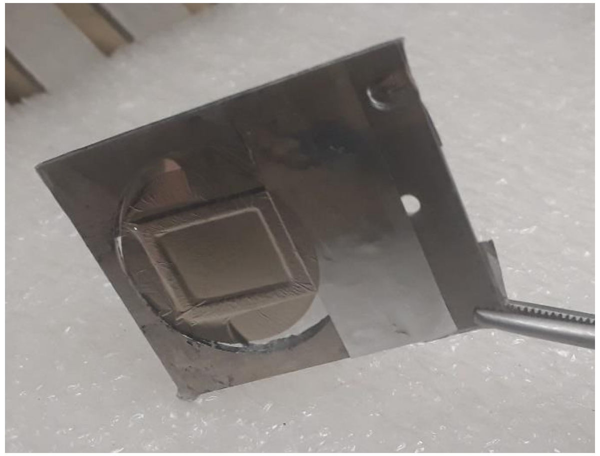


^{208} Bi ~ 150 µg/cm²
On carbone backing of 35 µg/cm²
Resistive heating

CD2 ~ 135 µg/cm²
Ni backing
polymerisation

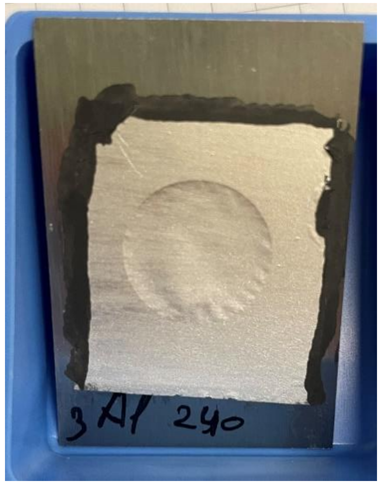
Sn ~ 150 µg/cm²
On carbone backing of 35 µg/cm²
Resistive heating

Targets development – Recent results



^{60}Ni
150 et 250 µg/cm²
Self supported
Electrodeposition

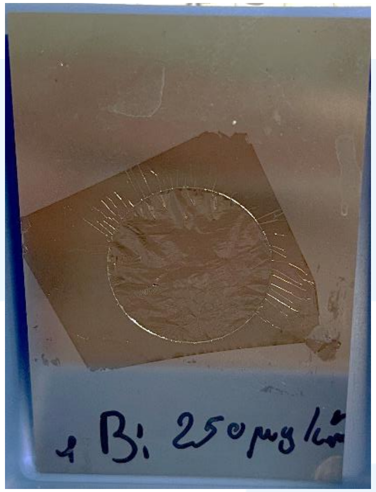
Au ~ 70 µg/cm²
Self supported



Al natural ~ 240 µg/cm²
Self supported
PVD (resistive heating)

^{70}Zn ~ 480 µg/cm²
Self supported
PVD (resistive heating)

CD2 ~ 10 to …. µg/cm²
Self supported



Bi natural ~ 250 µg/cm²
Self supported
PVD (resistive heating)

GANIL Beamtime 2024

Deposition size:	10 mm diameter
Backing:	2.1 µm Ti
Areal weight:	**1650(40) µg/cm²**

Irradiation

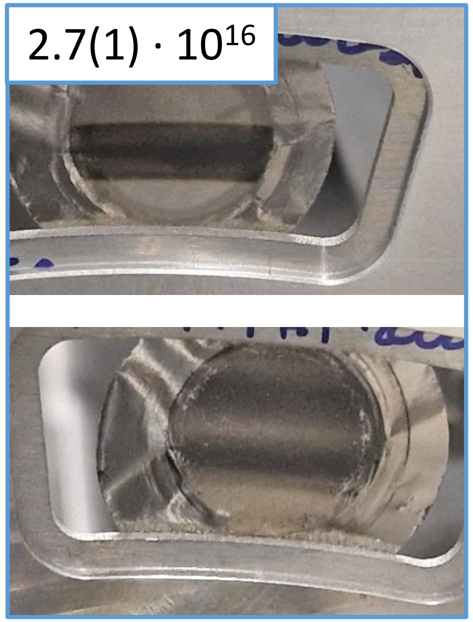
Projectile:	$^{40}Ar^{6+}$ with
Beam intensity:	3.25 ·
Beam dose:	7

Fluence: 5.

Second irradiat

later

Fluence: 2.7(4) · 10



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

Full Length Article

Preparation of lanthanide thin films for ion beam experiments and post irradiation characterization

E. Artes [a,b,c,*], D. Ackermann [d], Ch.E. Düllmann [a,b,c], T. Häger [e], B. Kindler [c], T. Lefrou [d], B. Lommel [c], A.T. Loria Basto [a,b], C.-C. Meyer [a,b], C. Mokry [a,b], F. Munnik [f], J. Piot [d], L.E. Reed [a], D. Renisch [a,b], H. Rothard [g], J. Runke [a,c], H. Savajols [d], C. Stodel [d], T. Madi [g], V. Urbanova [a], V. Watt-Morel [d], A. Yakushev [c]

Development of actinide targets for SHE production and assessment of their performance in intense heavy-ion beams

Ernst Artes[1,2,3], Ch. E. Düllmann[1,2,3], B. Kindler[2], B. Lommel[2], T. Loria Basto[1], A. Mery[4], C.-C. Meyer[1,3], J. Piot[4], L. E. Reed[1,3], D. Renisch[1,3], H. Rothard[4], H. Savajols[4], C. Stodel[4], V. Urbanova[1]

[1] *Department of Chemistry – TRIGA Site, Johannes Gutenberg University, Mainz, Germany*

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[3] *Helmholtz Institute Mainz, Mainz, Germany*

[4] *GANIL, Caen, France*

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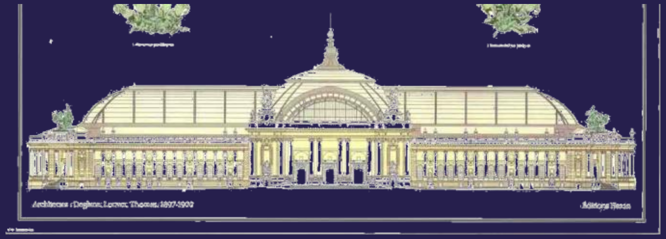
INTDS Conference, Knoxville Tennessee

18-23 August 2024



PALAIS Project

Plateforme Cibles pour GANIL/SPIRAL2

G. Frémont, Targets Expert

F. Pérocheau, Project Manager & Ch. Stodel, Strategic Pilot

Projet PALAIS Plateforme Cibles pour GANIL/SPIRAL2

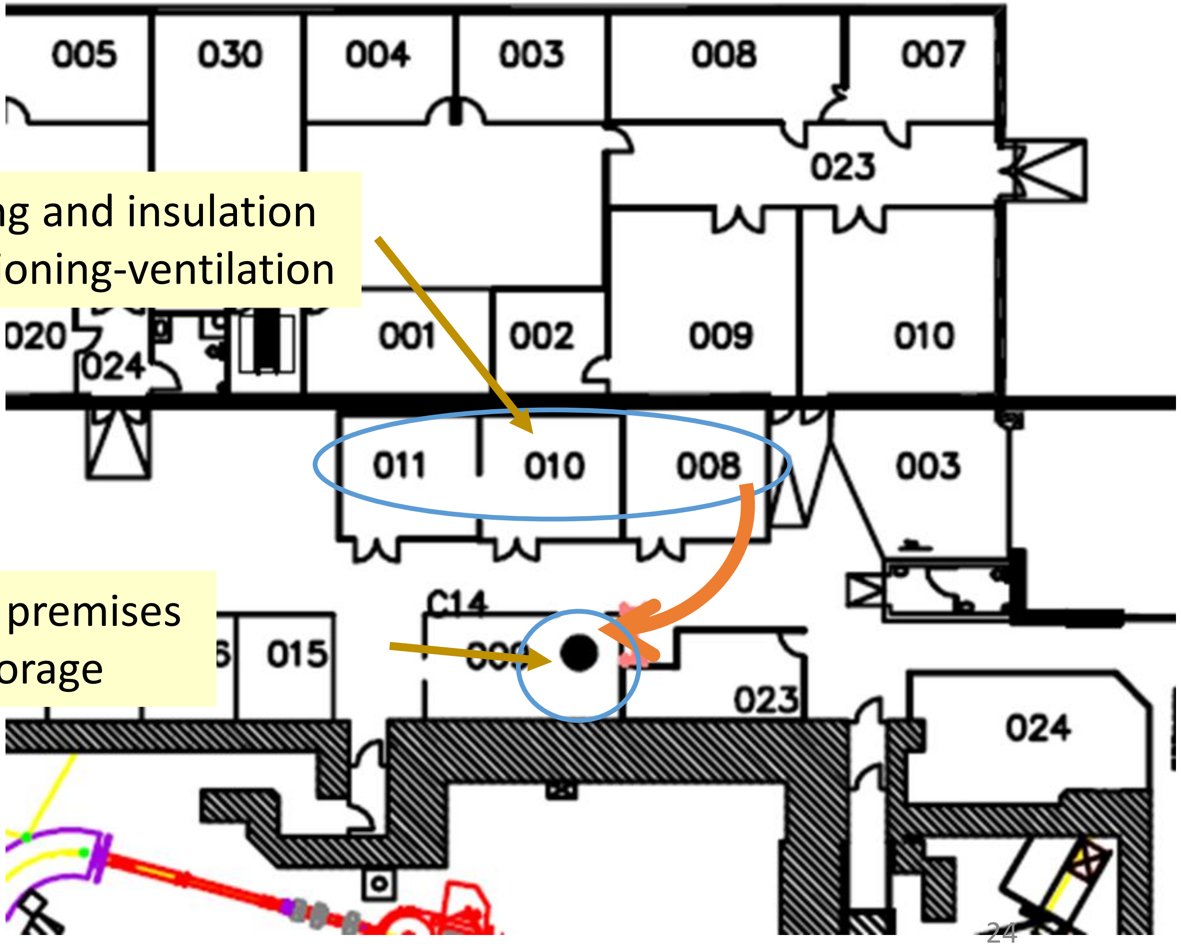
- Need of a lot of targets (**stables**, ^{238}U & actinides)
- → increase the production capacity, including development and caracterization

G. Frémont, M. Bourges, R. Rahali

- **2023-2025 Funding from Région Normandie**
  - **4 Systems for Target Fabrication:**
    - Evaporators for carbone et metals
    - Evaporator with magnetron sputttering for ^{238}U and mono-isotopic elements
    - Evaporator with resistive heating & EFe- heating method
  - **Characterization system**
    - X-ray fluorescence spectrometer for the chemical composition analysis of thin films
- **PHASE1 (2023-2025) :**
  - Equipment purchase (in progress) and installation
  - Expansion of existing space: from **3 x 25 m² to ~ 100 m²** (summer 2025)
  - 2 years Post-doc: R&D lanthanides & characterization.

RÉGION NORMANDIE

Space planning



Partitioning and insulation
Air conditioning-ventilation

Recovery of premises
for target storage

Projet PALAIS Plateforme Cibles pour GANIL/SPIRAL2

Need of a lot of targets (stables, ^{238}**U** & actinides)

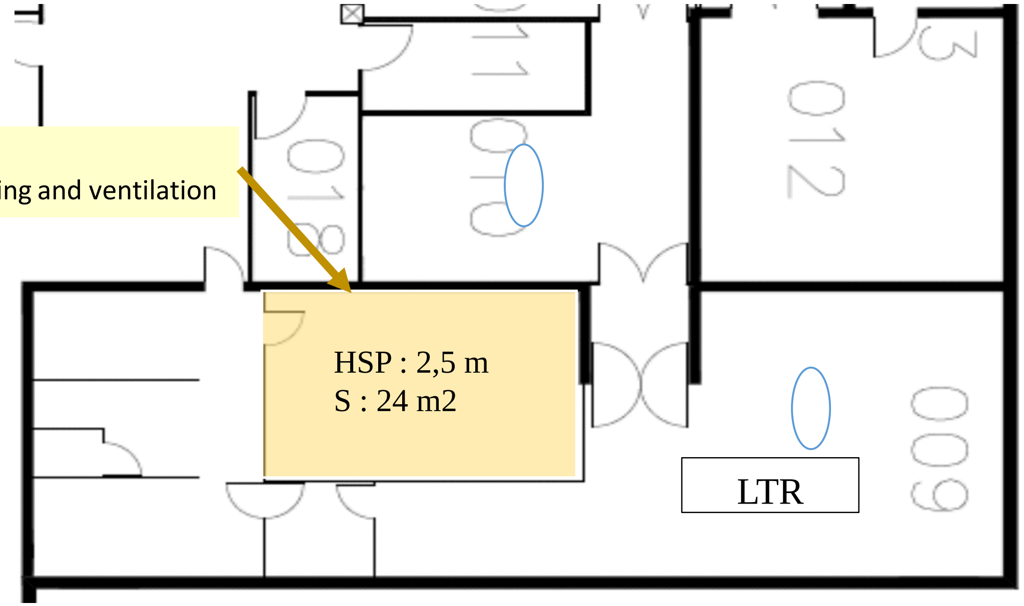
→ increase the production capacity, including development and caracterisation

RÉGION NORMANDIE

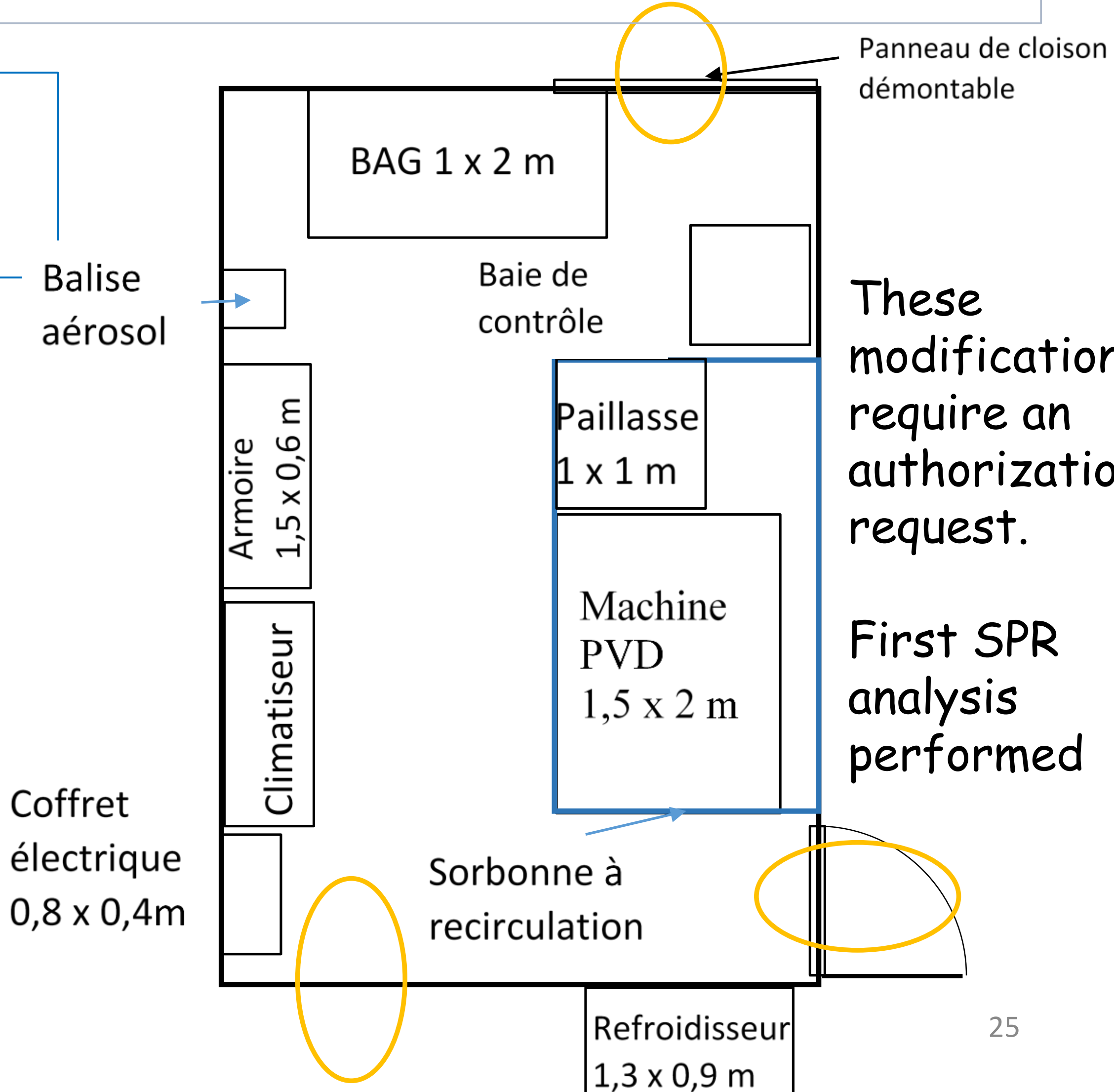
- **PHASE 2 (2024-2026):**
  - Fitting out of one « radiation working zone » (LTR) for ^{238}U and maybe ^{232}Th targets

Modification and development of the LTR waste room

Partitioning
Air conditioning and ventilation

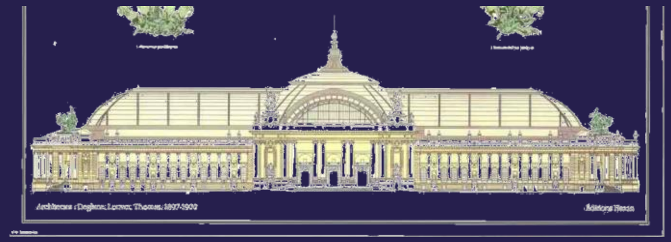


Courtesy of F. Pérocheau



These modifications require an authorization request.

First SPR analysis performed



Grand PALAIS (ATLAS) Project

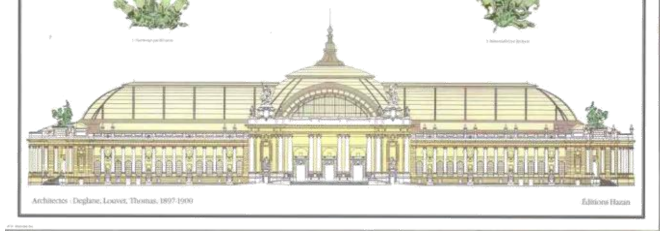
Plateforme Cibles pour GANIL/SPIRAL2

Actinide Target Laboratory and Associated Services

G. Frémont, Targets Expert

F. Pérocheau, Project Manager & Ch. Stodel, Strategic Pilot

Project Grand PALAIS (ATLAS)



Goal → Increase the target developments capabilities (standard, actinide)

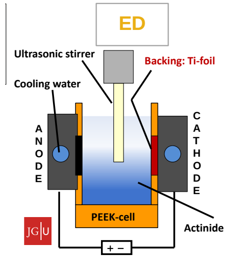
- **PHASE 3 (2023-202x) : Production of Actinide Targets**

Manufacturing processes and characterization of actinide targets

→ Skills

→ New building & Identification of material requirements

→ Authorizations/licences….



- **Infrastructure dedicated to target manufacturing (F. Pérocheau)**
  - **New building**
  - **Equipement:**
    - Glove boxes / Fume hoods
    - Shielding / Monitoring systems
    - MP Cells
    - Caracterization Systems
    - Storage
  - Preliminary layout Diagrams & plans
  - Cost evaluation
  - Project management / implementation

- **Authorizations and licenses :**
  - Mnα transformation
  - Handling procedures…
  - MN possession and management,
  - Waste management stream..
  - Material transportation

Conclusion & Take-home messages

- An ambitious scientific program is planned for the coming years, involving both accelerators → this will require a large number of high-quality targets.
- Rare isotopes / targets:
  - ✓Production of thin ytterbium (Yb) targets deposited on carbon backing, self-supported isotopically enriched zinc, and nickel…
  - ✓Renovation of the stable target laboratory and modernization with new tools and equipment to meet the growing demand and upcoming experimental needs → ***PALAIS project.***
- A future actinide target laboratory is under discussion and pending validation → ***GRAND PALAIS (ATLAS) project*** → A postdoctoral position in radiochemistry will soon open.
- Ongoing development of target characterization techniques, including the acquisition of an XRF spectrometer and expanded collaborations for advanced analyses such as SEM and XPS.
- We remain open to new collaborations for complementary or innovative characterization methods, as well as the exchange of ideas and knowledge.


Thank you for your attention
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