The Target Laboratory at INFN – LNS and the participation in the EURO-LABS project

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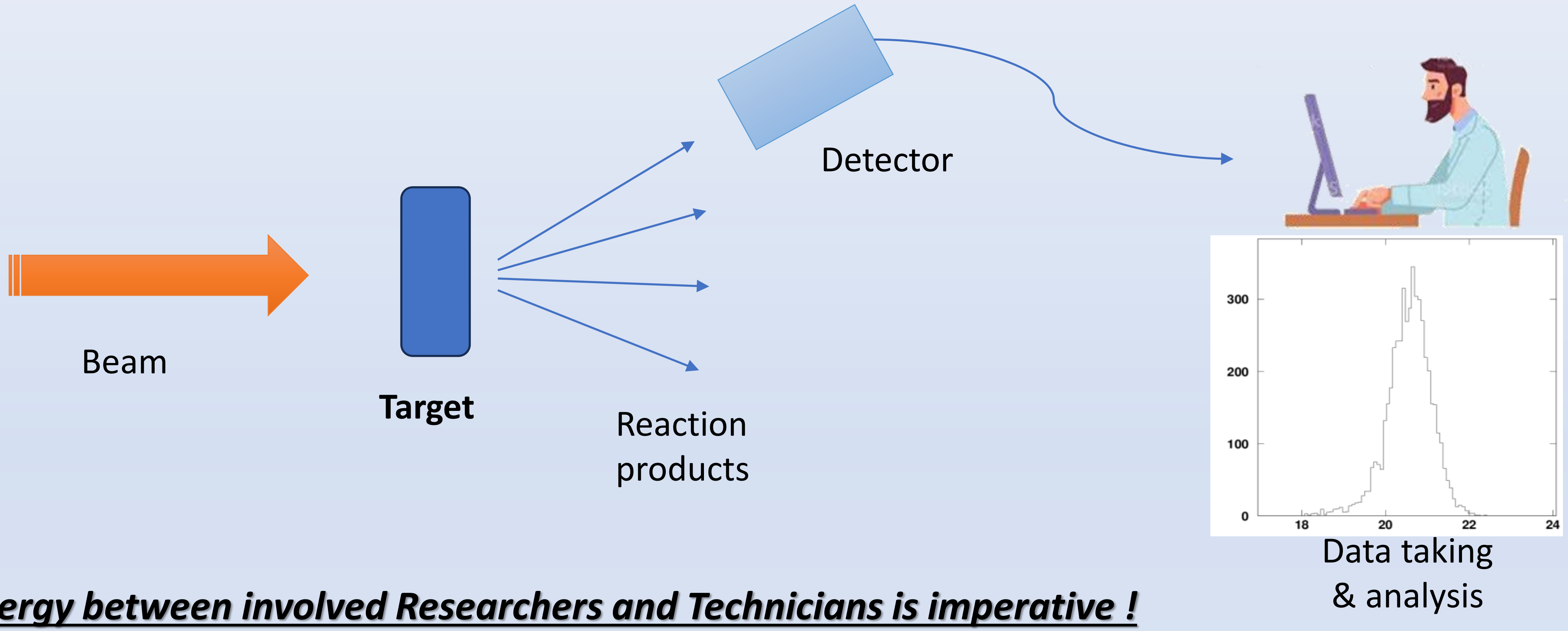
Second meeting on "Targets for Nuclear Physics"
GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany

Target: a key – ingredient for a Nuclear Physics experiment

- **A target is an essential ingredient for a nuclear physics experiment !**
  - ✓ Usually, a beam impinge on a target material, leading to a variety of reaction ejectiles to be measured



Synergy between involved Researchers and Technicians is imperative !

Targets for Nuclear Physics experiments: solid, gas or liquid ?

- Solid targets are the most common case

Why ? →

- ❖ Most elements and materials useful as targets are solid in standard conditions of pressure and temperature.
- ❖ Much simpler setup

- Gas and liquid targets may be used in some cases

Why ? →

- ❖ Need of an active target
- ❖ Specific properties of some targets

❑ *Here we focus:*

- *on solid targets developed and characterised at INFN –LNS*
- *on the participation in the EURO-LABS project* → *in collaboration with GANIL R. Rahali et al.*

The target lab at INFN – LNS: fabrication

- The target laboratory at INFN –LNS in Catania has over thirty years of experience in target preparation for nuclear physics experiments and interdisciplinary physics
- Users are not only local scientists but also researchers from other universities and laboratories worldwide

A. Massara et al., EPJ Web of Conferences 285, 06003 (2023)

Equipment for target production

- ✓ L300 Thermal Bell Jar (TBJ) evaporator
- ✓ L560 Leybold-Heraeus evaporator
- ✓ UNIVEX 400 Leybold evaporator
- ✓ Cold rolling mill

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L300 TBJ evaporator

- ➢ 2 resistive sources
- ➢ A probe to monitor the backing temperature
- ➢ A quartz crystal micro balances

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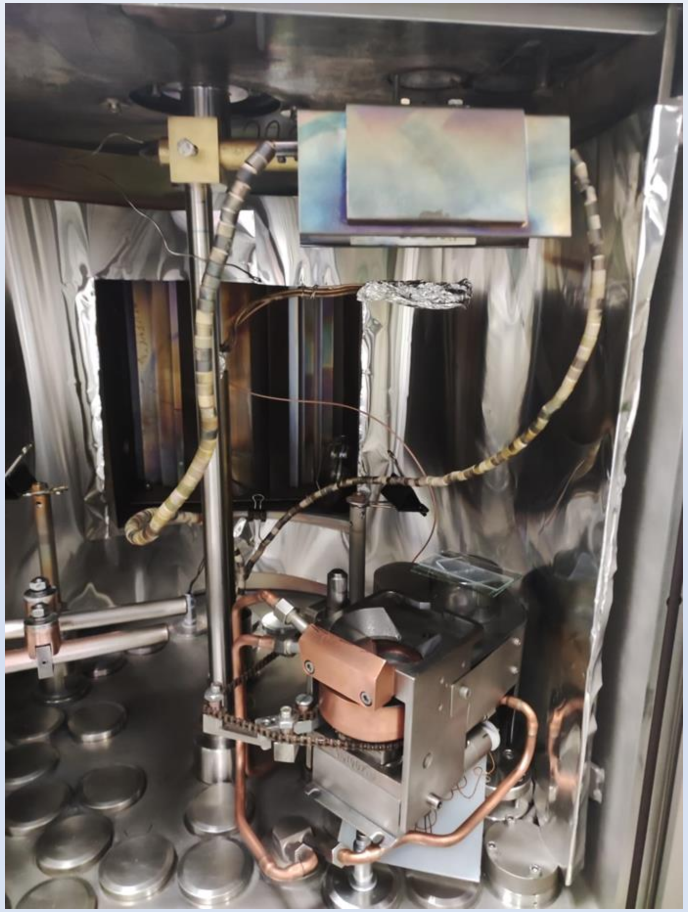
A. Massara et al., EPJ Web of Conferences 285, 06003 (2023)



Equipment for target production

- ✓ L300 Thermal Bell Jar (TBJ) evaporator
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- ✓ Cold rolling mill

L560 Leybold-Heraeus

- Evaporation by
  - ✓ e-beam heating source
  - ✓ resistive heating source
- Quartz crystal micro balance
- Halogen heating elements to fix temperature

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A. Massara et al., EPJ Web of Conferences 285, 06003 (2023)

UNIVEX 400 Leybold evaporator

- Commissioning tests almost completed!

New

Equipment for target production

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A. Massara et al., EPJ Web of Conferences 285, 06003 (2023)

Cold rolling mill

Equipment for target production

- ✓ L300 Thermal Bell Jar (TBJ) evaporator
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- ✓ Cold rolling mill

LNS Target lab website with some examples of targets produced in the lab: **https://www.lns.infn.it/en/targets.html**

The target lab at INFN – LNS: characterisation

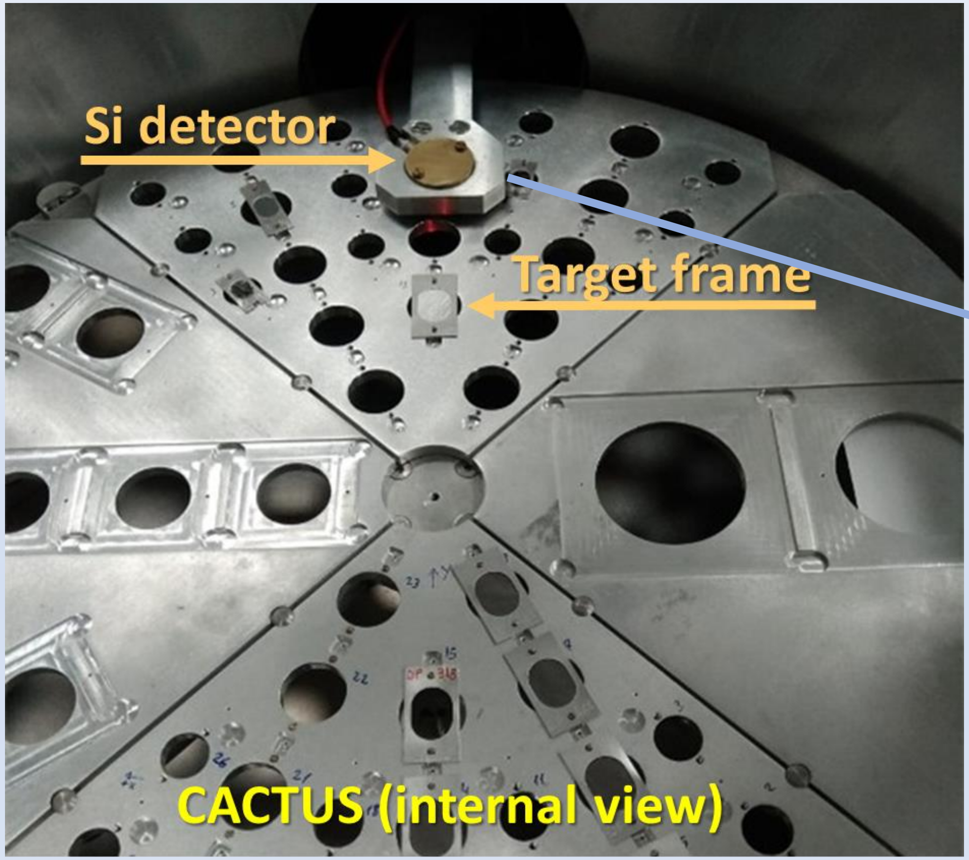
Equipment for target characterisation

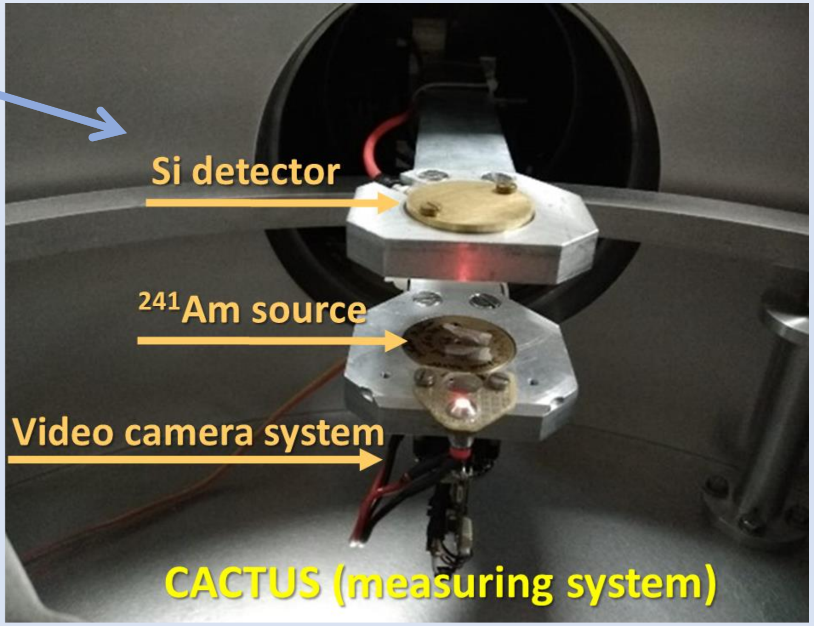
A. Massara et al., EPJ Web of Conferences 285, 06003 (2023)

✓ Chamber for Alpha-particle Characterisation of target Thickness and Uniformity by Scanning (CACTUS)

✓ CACTUS allows for the characterisation of the targets in terms of thickness, local and global non – uniformity.

➢ Technique: Alpha – particle spectroscopy (APS)





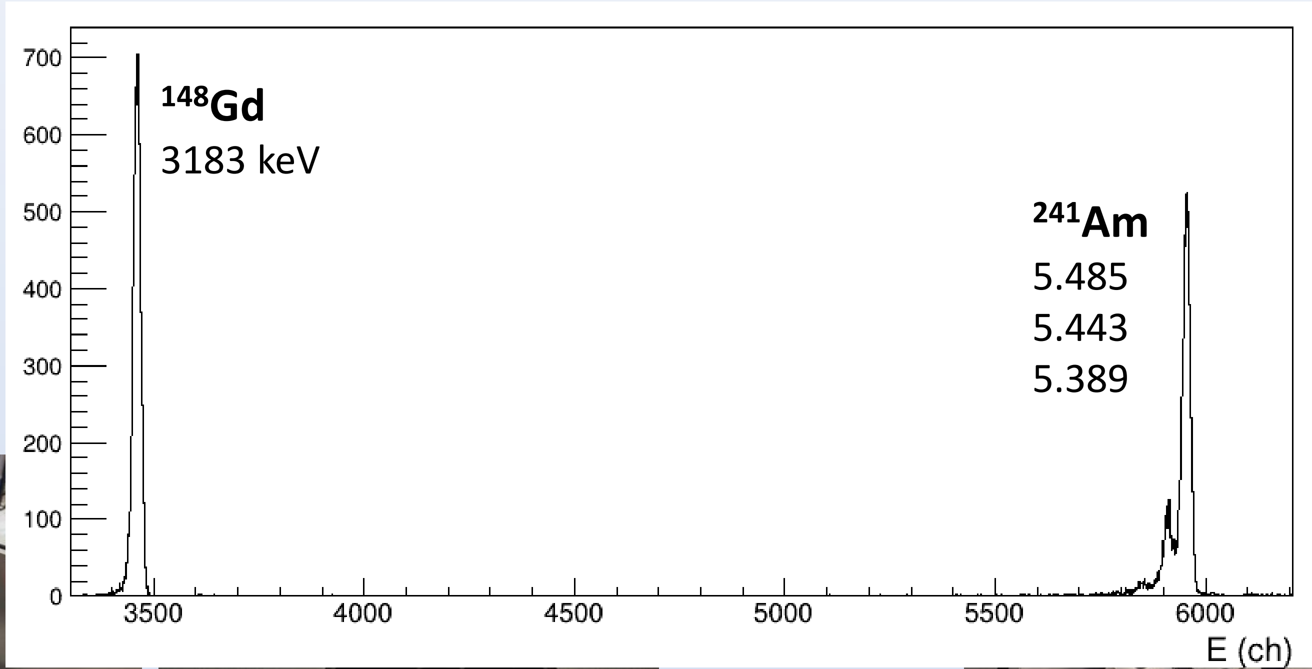
- ➢ Chamber diameter ~1m
- ➢ Host different types of target frame
- ➢ Scan different regions of the target surface with a **high precision** (1 mm) thanks to a rotational system and a video camera

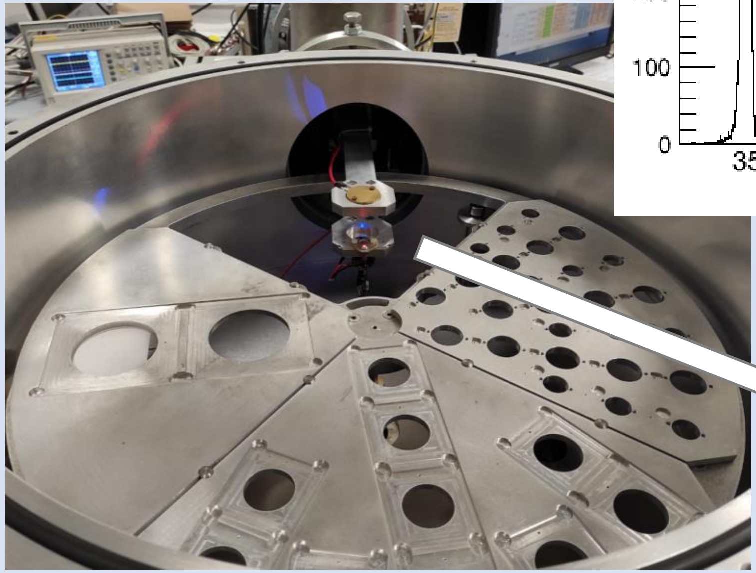
The target lab at INFN – LNS: characterisation

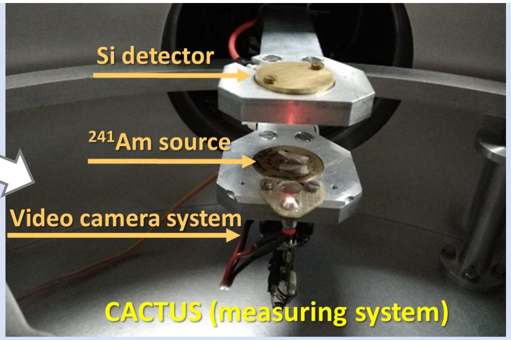
Equipment for target characterisation

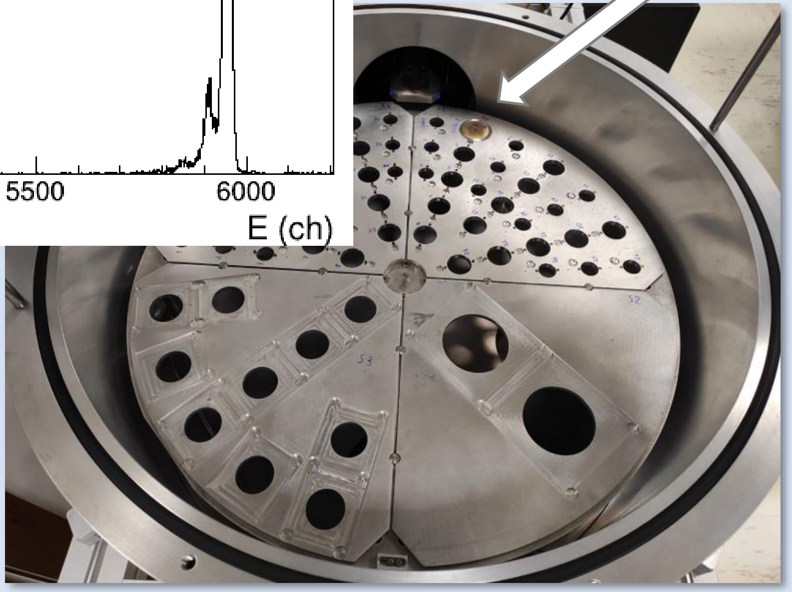
A. Massara et al., EPJ Web of Conferences 285, 06003 (2023)

✓ **Energy calibration** based on **2 α-sources** (**^{148}Gd** & **^{241}Am**) covering a broad energy range









Target characterisation at INFN – LNS

Why characterisation ?

- ✓ measure the average thickness
- ✓ determine the non – uniformity of the samples

Characterisation is essential towards the selection of the most suitable manufacturing procedure !

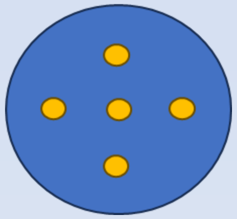
How ?

- Alpha Particle Spectroscopy (APS) technique using the CACTUS facility
- Comparison with simulations to determine the **local non – uniformity** in a specific irradiated area of the sample. The thickness deviation (σ_t/t) is related to the non – uniformity as follows:

$$\frac{\sigma_t}{t} = \frac{\sigma_{non-unif}}{\Delta E} = \frac{\sqrt{\sigma_{meas}^2 - \sigma_{sim}^2}}{\Delta E}$$

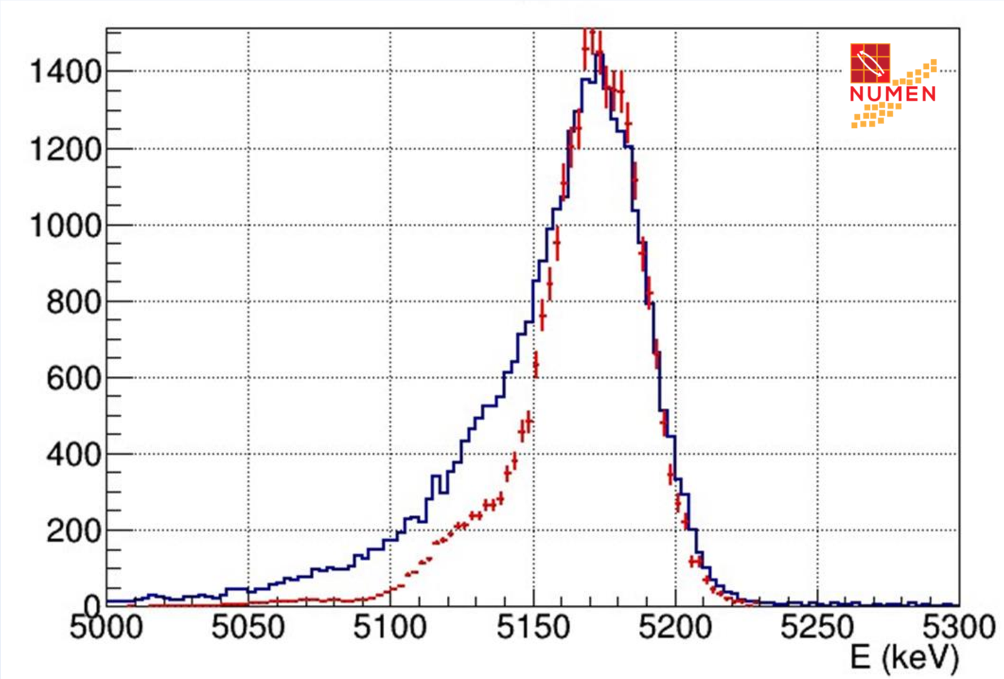
M. Fisichella et al., Eur. Phys. J. A 61, 144 (2025)

- Irradiation of different areas of the sample to determine the **global non – uniformity**



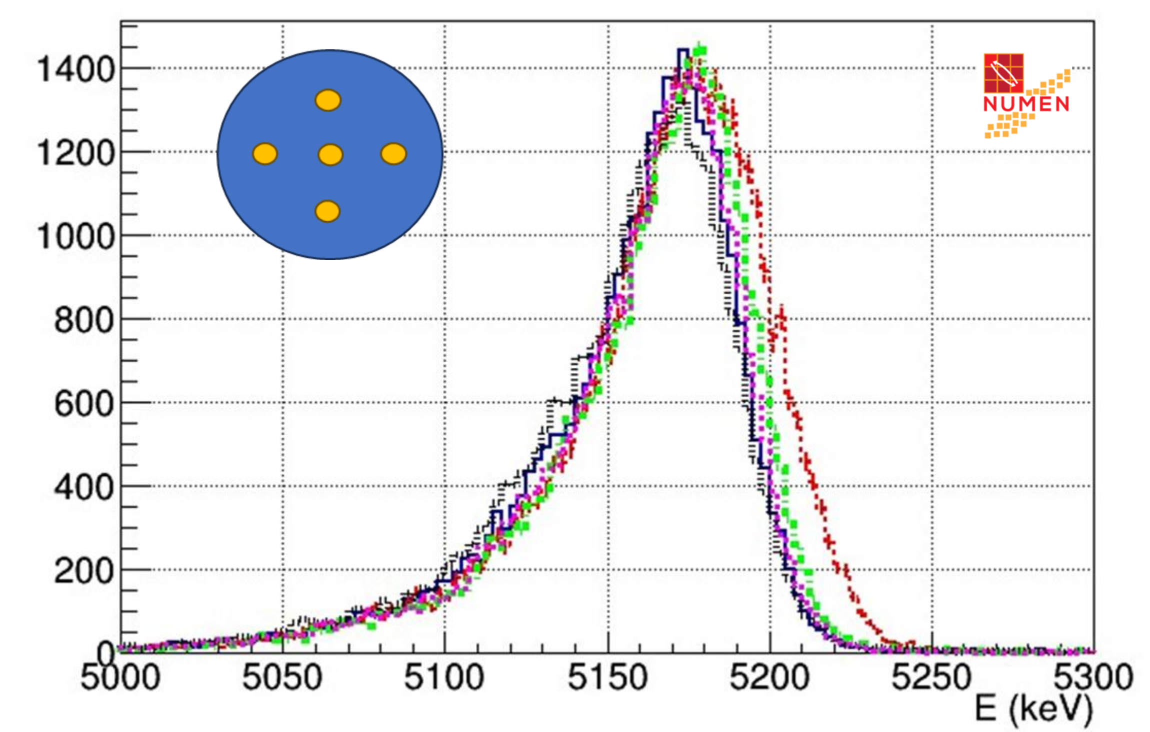
Global non – uniformity ≡ deviation thickness between the different irradiation points

Target characterisation at INFN – LNS:
characterisation of a multilayer graphene sample



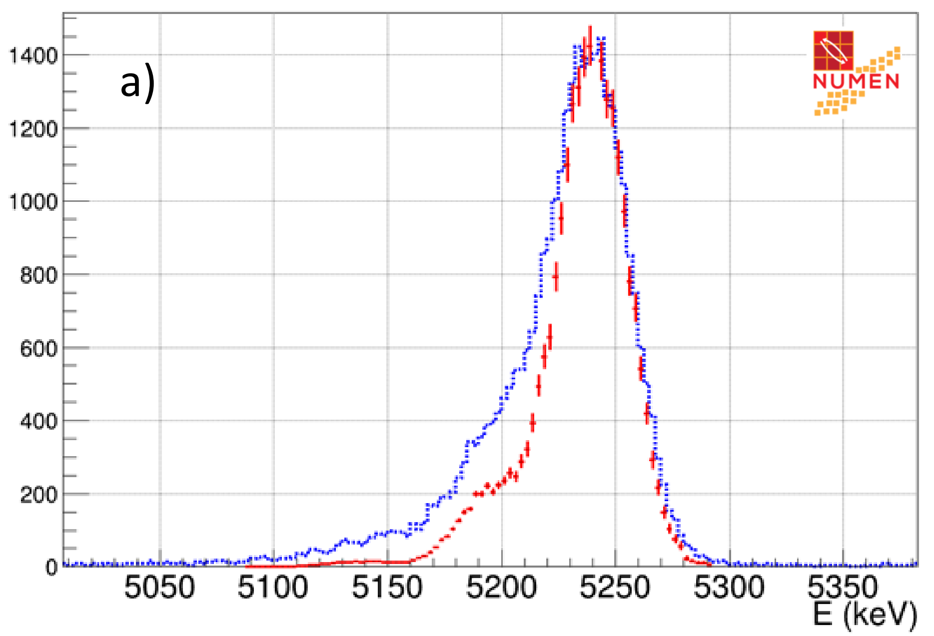
Experimental α – spectrum presented in blue in comparison with the simulated one presented in red. From the σ_{meas} and σ_{sim} we can determine the $\sigma_{non\text{-}unif}$

Typical experimental α – spectra in 5 different irradiated points of the same sample

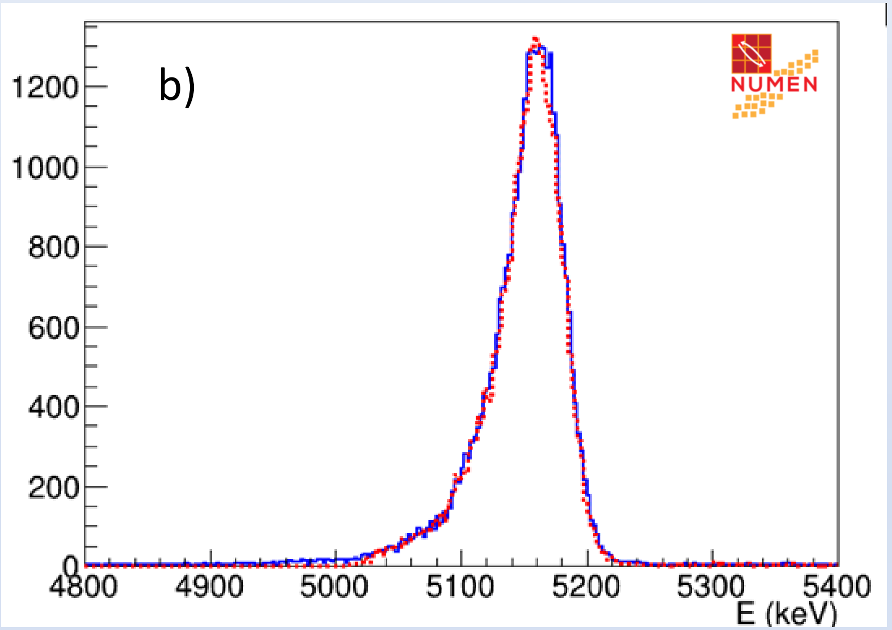


Target characterisation at INFN – LNS:
characterisation of a target evaporated onto a substrate

1) APS and characterisation of the substrate
2) Evaporation of the target material onto the substrate
3) APS using (target + substrate) and characterisation of the target



C (graphene) 0.321 mg/cm² (1.59 um)
dE=247keV



Te evaporated on a) with a thickness of 0.253 mg/cm²
dE=77keV

Targets for high – intense beams

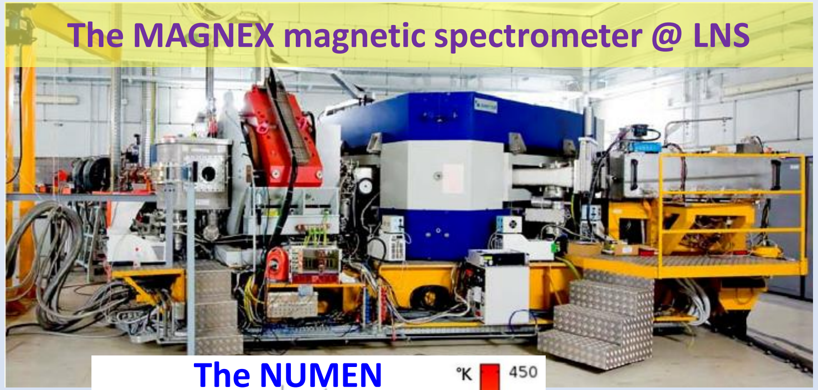
- Experimental campaigns with high – intensity beams are planned at INFN – LNS

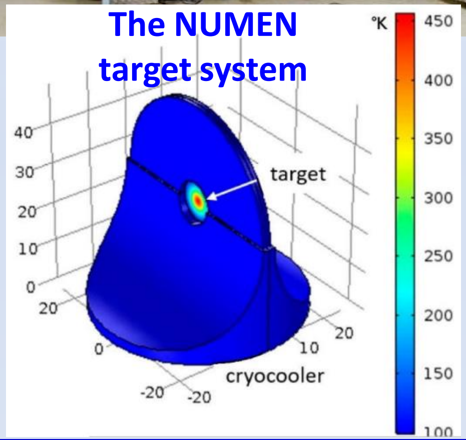
- The case of NUMEN experimental campaign:
  - ^{18}O and ^{20}Ne beams at energies >15MeV/u, beam intensity up to **10^{13} ions/sec** → deposition of **several W/cm² in the target**
  - Isotopically enriched target will be deposited on a **highly thermally conductive foil of graphene**
  - A **cooling system** for the target will be used
  - Target materials: Ca, Ge, Se, Zr, Mo, Cd, Pd, Sn, Te, Sm, Pt and many other with a **typical thickness of ~ 250 – 500 µg/cm²**
  - Both target and substrate should be as uniform as possible to maintain **high energy resolution**
  - If possible, we should **avoid buffer materials**

- Intense activity on target development and characterisation is ongoing in collaboration with INFN-Torino, INFN-Genova, University of Genova, INFN-LNL and University of Catania

See also talk by Daniela Calvo this afternoon !

F. Cappuzzello et al., Int. J. Mod. Phys. A 36, 2130018 (2021)





Target production of NUMEN interest: evaporation in standard conditions

Standard evaporation conditions:

1. Low evaporation rate
2. No backing heating
3. No buffer

Standard evaporation conditions

	Tellurium	Germanium	Selenium	Molybdenum
Evaporator	L300 resistive source	L560 resistive source	L300 resistive source	L560 e-beam
Used material	0.4 g	0.6 g	0.5 g	0.6 g
Distance source – backing	210 mm	250 mm	250 mm	200 mm
Heating substrate	NO	NO	NO	**300 ºC**
Buffer	NO	NO	NO	NO
Evaporation rate	0.2 Å/s	0.2 Å/s	1 Å/s	0.3 - 0.4 Å/s

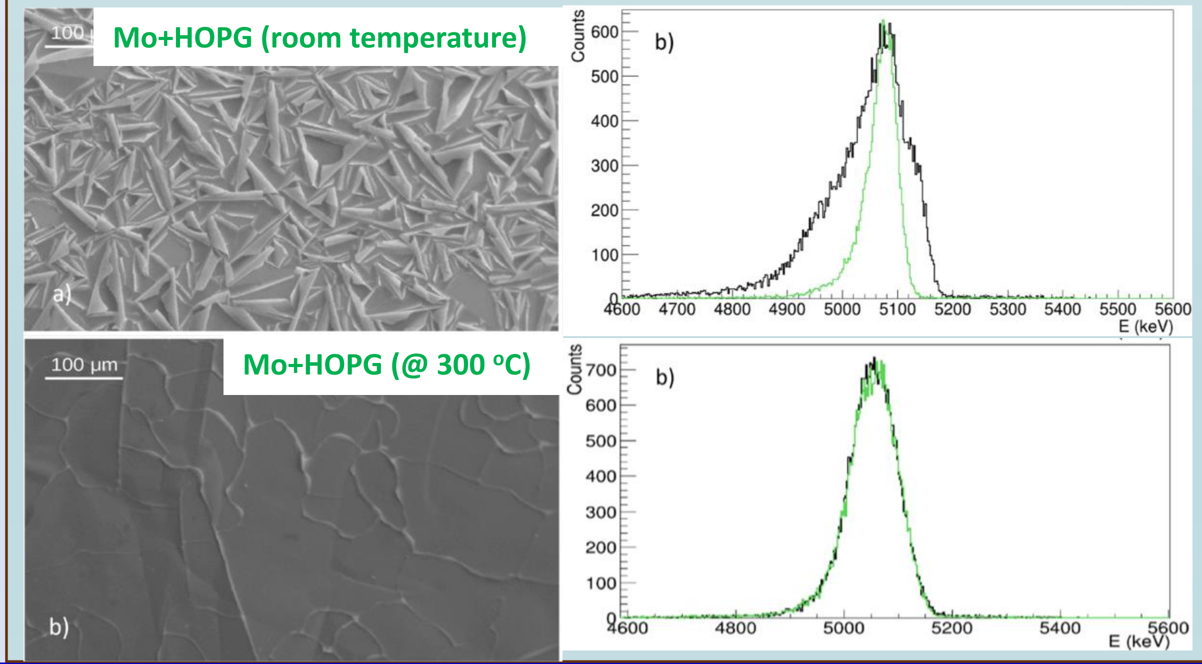
M. Fisichella et al., Eur. Phys. J. A 61, 144 (2025)

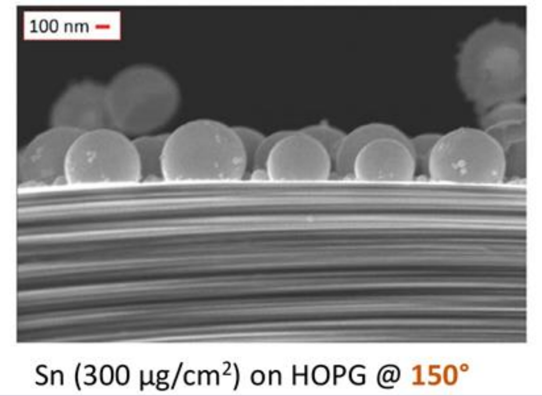
Target production of NUMEN interest: some challenging cases

➢There are several materials on which the application of standard evaporation conditions did not provide satisfactory results.

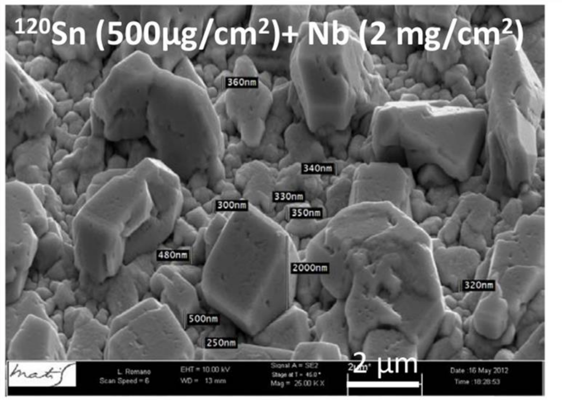
➢Depending on our needs, the conditions may be modified accordingly (e.g. the **Mo** case) with satisfactory results *Protocol published in: Eur. Phys. J. A 61, 144 (2025)*

➢One of the special cases is the **Sn** : development of Sn targets at standard or even at non-standard conditions is a difficult task!





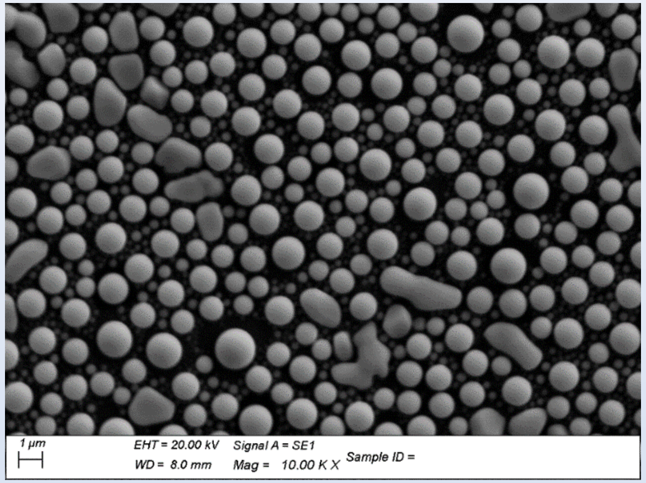
@ TRUSTECH, F. Pinna, PhD thesis

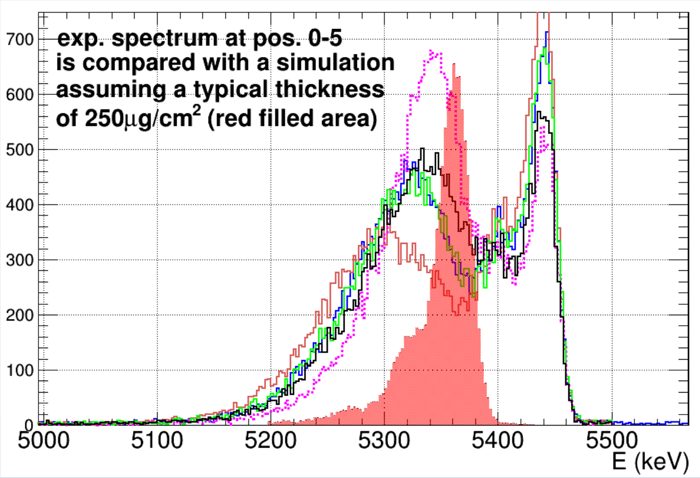


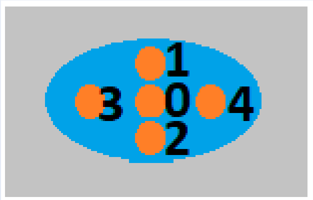
@ LNS, M. Fisichella, PhD thesis (standard evaporation conditions)

Target production : the case of Sn

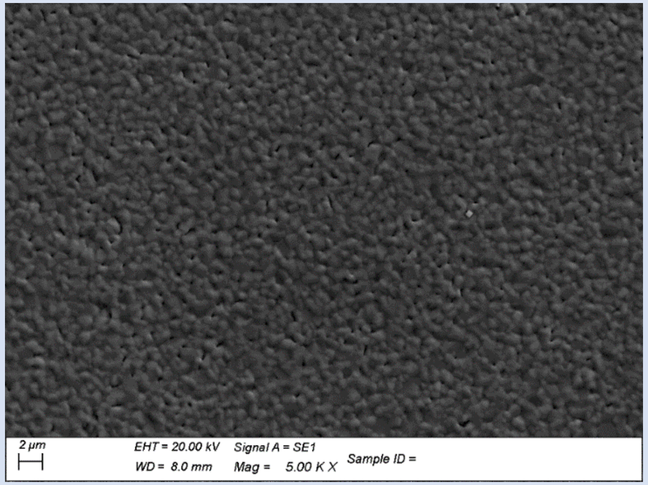
➢ One of the special cases is the **Sn** : development of Sn targets at standard or even at non-standard conditions is a difficult task!

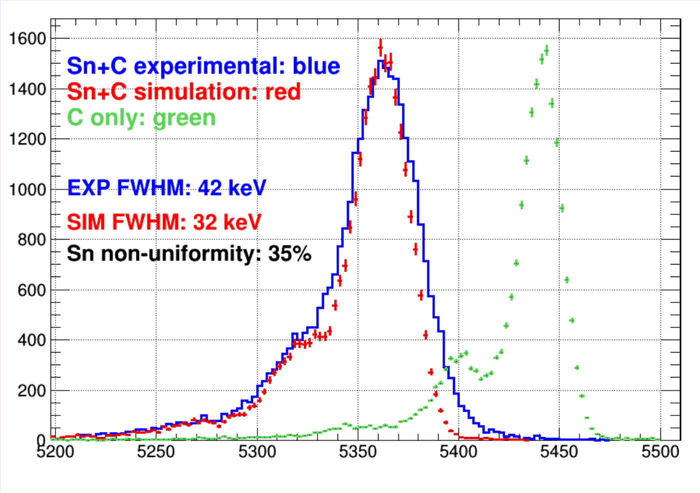






- ❑ **Sn (250 µg/cm²) + C (40 µg/cm²)**
- ❑ ***Evaporation at standard conditions***
- ❑ *Similar behaviour for all 5 samples of the same evaporation*

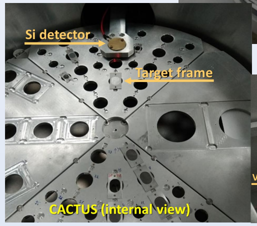


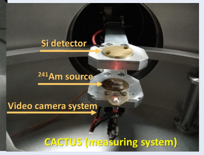


- ❑ **Sn (250 µg/cm²) + Bi (100 Å) + C (40 µg/cm²)**
- ❑ *Similar behaviour for all 6 samples of the same evaporation*
- ❑ ***Evaporation with and without Bi buffer to be performed with the new UNIVEX 400 evaporator***

Summary and future perspectives

- ❑ The development of the appropriate target is essential for the success of nuclear physics experiments
- ❑ The target characterisation:
  - ✓ Provide a tool to examine if the target produced is indeed suitable for the experiment
  - ✓ is of great importance towards the selection of the most suitable manufacturing procedure





- ❑ Target development and characterisation are essential towards the success of large – scale experimental campaigns with high – intensity beams, scheduled in the near future at INFN – LNS
- ❑ A protocol was established for the characterisation of both self – supported and (target + substrate) samples by means of the determination of local and global non – uniformity
  - ➢ To be extended in more elements / isotopes

- ❑ New opportunities with the new evaporator recently installed at INFN – LNS

- ❑ Turbulences in the global market may seriously affect the target production and therefore, the timely schedule of nuclear physics experiments

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

Targets database within the EURO-LABS project

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[2]Istituto Nazionale di Fisica Nucleare – Laboratori Nazionali del Sud (INFN – LNS), Catania, Italy

[3]University of Catania, Catania, Italy

[4]Istituto Nazionale di Fisica Nucleare – Laboratori Nazionali di Legnaro (INFN – LNL), Legnaro, Italy

Second meeting on "Targets for Nuclear Physics"
GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany

Targets for Nuclear Physics

❑What are the main properties of a target that we are interested in ?

- ✓ Thickness
- ✓ Homogeneity / Uniformity
- ✓ Purity
- ✓ Isotopic or natural material
- ✓ Possible existence of buffer or substrate material

Strongly depends on the experiment !

Why a new target database is important ?

- Find a target not available in – home & facilitate collaboration and target sharing
- Improve fabrication techniques
- Improve characterisation techniques
- Exchange valuable information on target properties, manufacturing and characterisation among different scientific communities that use the same materials.
- Collect and centralize data on target production and properties, including both existing and newly developed targets across laboratories.

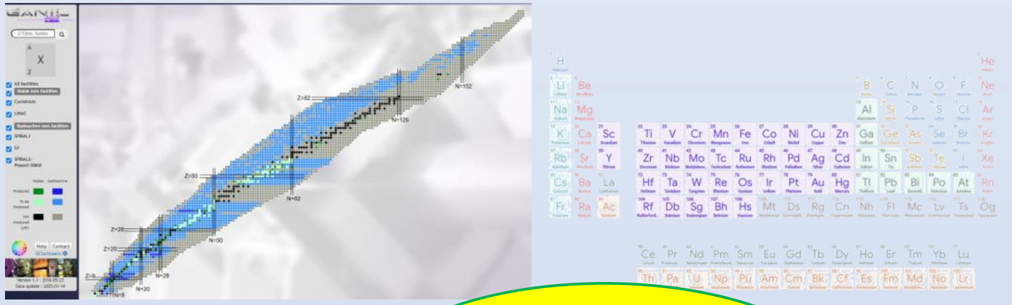
Final goal: **a significant improvement in service to the nuclear physics community - strengthening our knowledge and relationships, and facilitating exchange, collaboration, and knowledge transfer at the European level.**

What is the status of the database ?

❖Database (continuously updated) is already available in excel file including:

- ➢**Target material (with Z, A)**
- ➢**Isotopic or natural material**
- ➢**Thickness**
- ➢**Chemical form (e.g. metal)**
- ➢**Substrate (if exists)**
- ➢**Manufacturing technique**
- ➢**Laboratory**
- ➢**Characterisation technique (if exists)**
- ➢**Status (already done or in R&D)**
- ➢**Applications (medical, nuclear physics, industry, material science, …)**
- ➢**Publications / references**

❖**Final goal:** database to be publicly accessible to the scientific research community as an online interactive chart



Why It is so important

-Target preparation is a key step toward successful nuclear physics experiments

-A shared database ensures **reproducibility**, **efficiency**, **traceability**, and **quality**

-The laboratories will be able to **contribute**, **consult**, and **collaborate** through a digital hub, **expanding** the database

See also talk by Christelle Stodel this afternoon !