Second Meeting on "Targets for Nuclear Physics" within EURO-LABS
18–19 May 2026 GSI lab, Darmstadt (Germany)

Target manufacturing activities at INFN-LNL

J. Esposito, on behalf of INFN- Legnaro National labs (LNL) targets group- *juan.esposito@lnl.infn.it*

A quick review of techniques focused on different topics

"Target production" for nuclear physics (NP) experiments

"Target production" for applied NP (radioisotopes production)

"Quality Control techniques: nuclear targets characterization "

Target production at LNL

Nuclear Physics (NP) studies

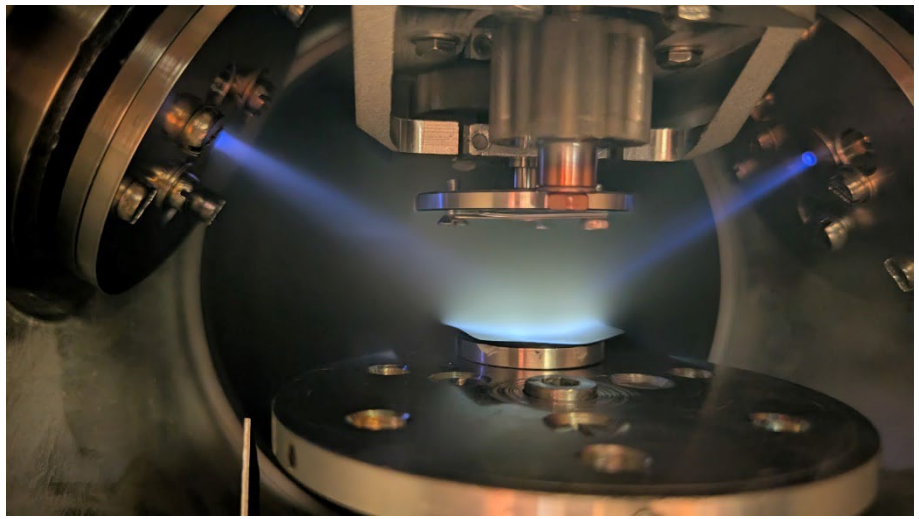
Target production at LNL NP studies

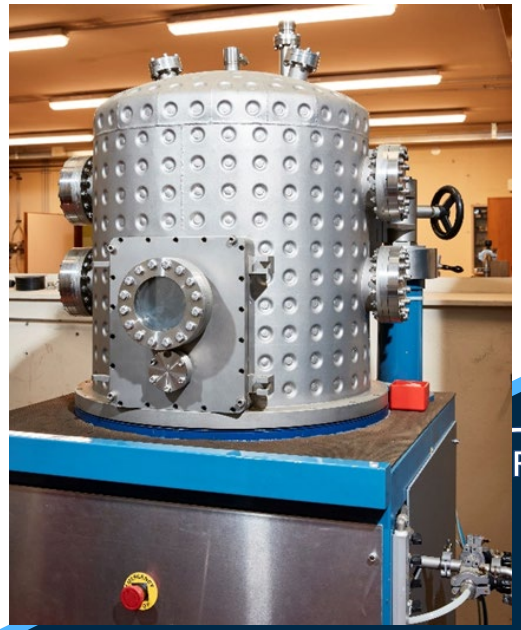
Targets for nuclear physics experiments typically are thin films of isotope-enriched materials obtained by various techniques:

- lamination (few mg/cm²)
- vacuum evaporation (few tens - few hundred µg/cm²)
- Ion beam sputtering

There are different types of fabrication:

- self supporting
- with backing
- strip-targets
- sandwich-target
- plunger – target

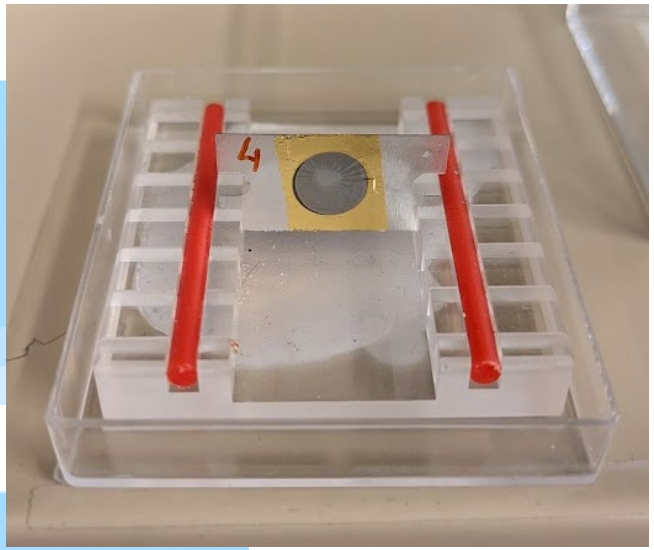




Some examples

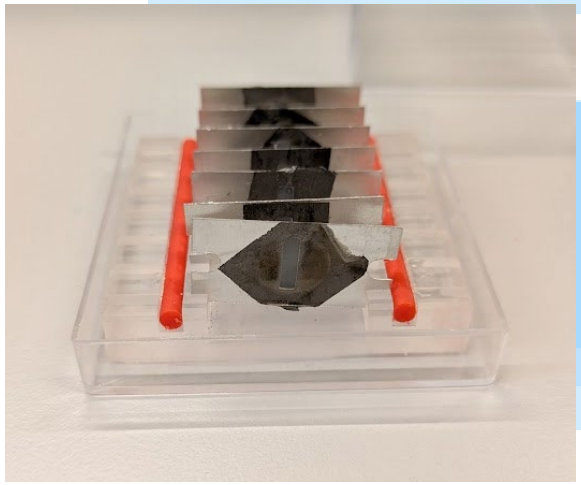
Self supporting **target of C_2D_4** produced by **thermal evaporation** (2mg/cm²)

Very fragile film; difficult to peel away from the glass substrate



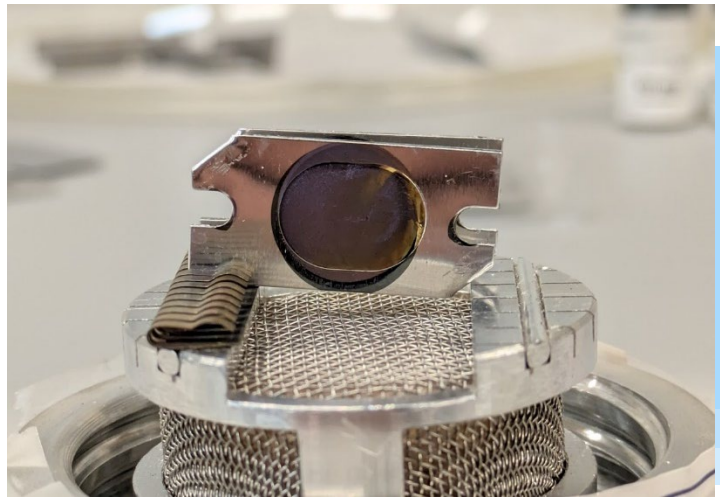
Target of ^{130}Te, thickness 500 µg/cm², on Au backing of 500 µg/cm² obtained by **thermal evaporation (Thermal-based PVD)** in vacuum.

Adhesion improved by special heat treatment on the Au backing



Target of ^{124}Sn, thickness 300 µg /cm², on C backing of 20 µg/cm² and C shield of 15 µg/cm².

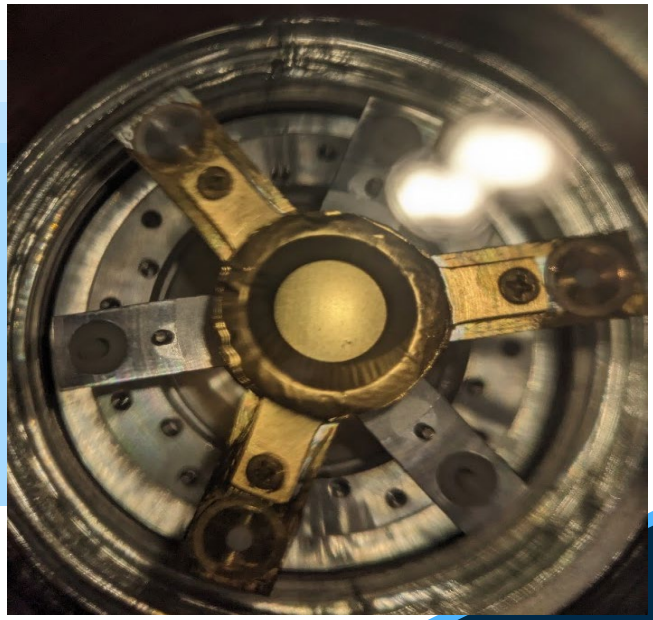
(Sandwich target – Strip target)



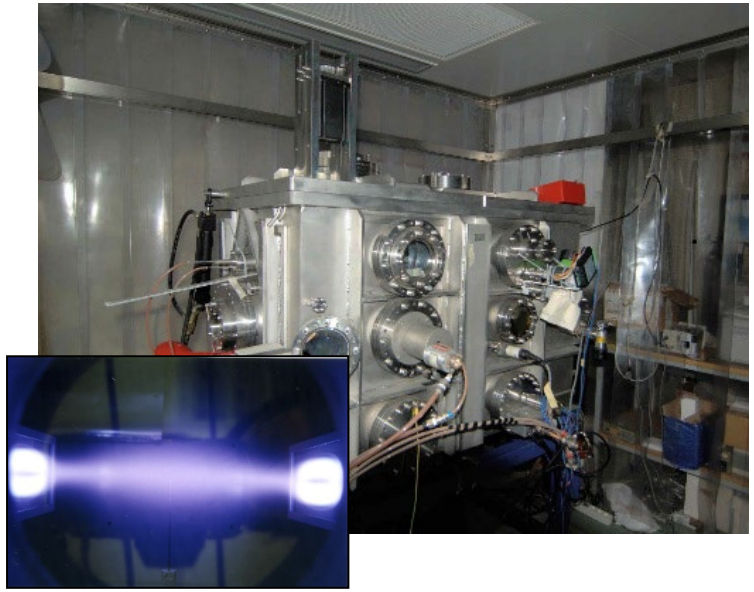
Target of ^{10}B, thickness 500 µg/cm², on Au backing of 4mg/cm². The Au backing was previously prepared by **rolling**.

Extremely slow evaporation of Boron using an electron-beam

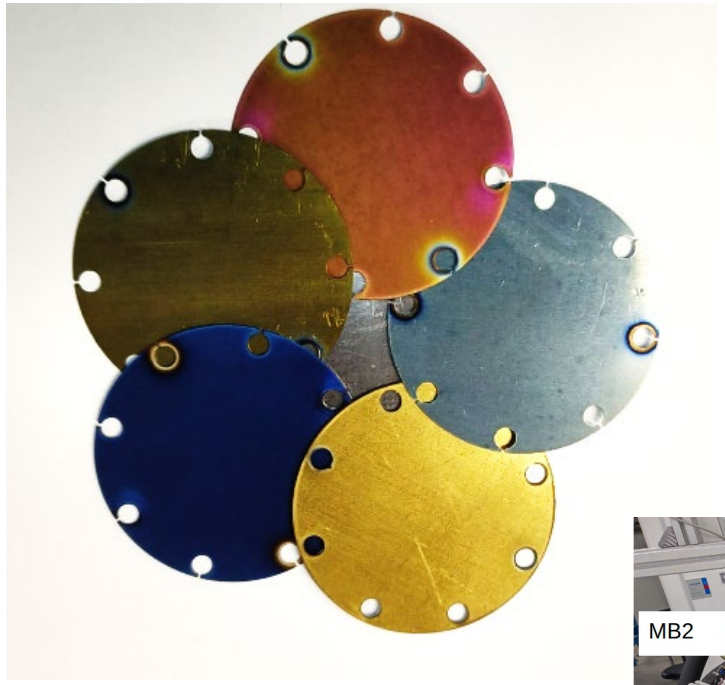
Target Plunger of ^{40}Ca (800 µg/cm²), on Au 4 mg/cm² and Au shield of 150 µg cm². Chemical reduction and simultaneous evaporation of calcium metal in vacuum.



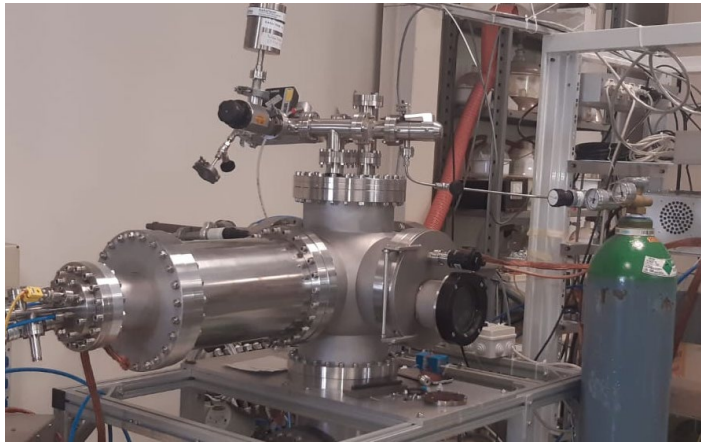
Solid target development by PVD magnetron sputtering technology

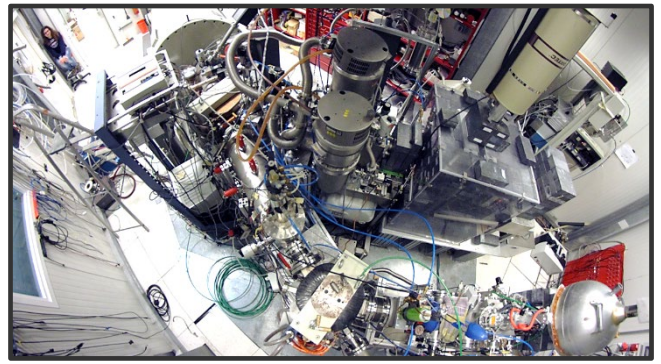


Solid targets for nuclear physics experiments



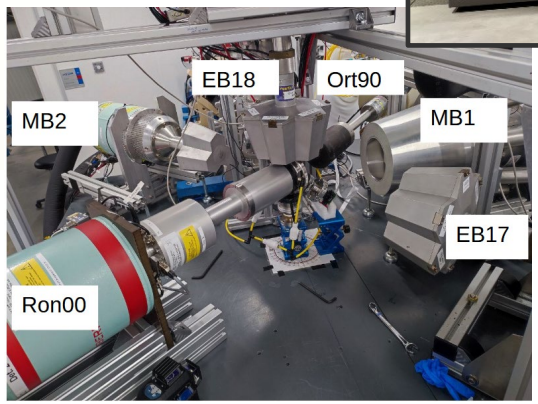
- ✓ High Purity
- ✓ Enriched compound
- ✓ Alkali compound





LUNA 400 kV (LNGS)

Bellotti IBF (LNGS)

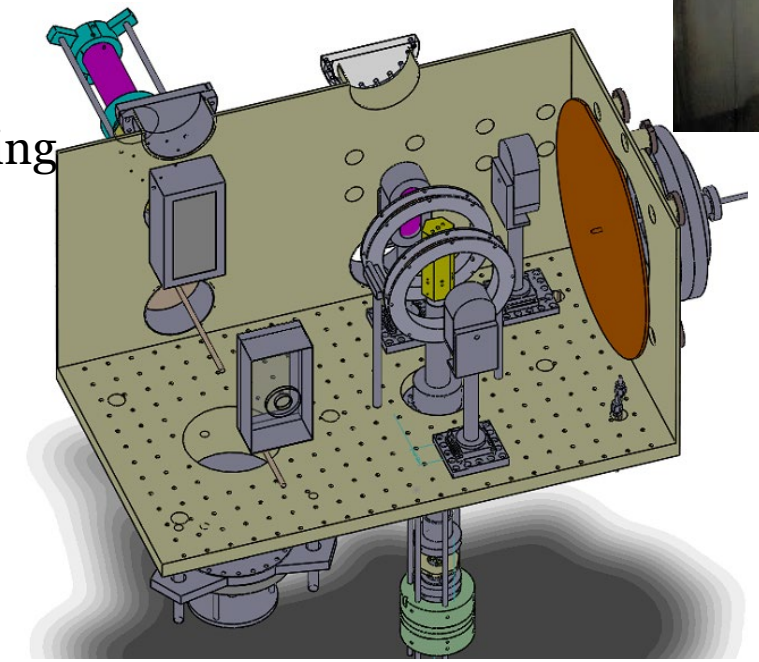


HZDR Felsenkeller Laboratory

LNL Sputtering chamber and design

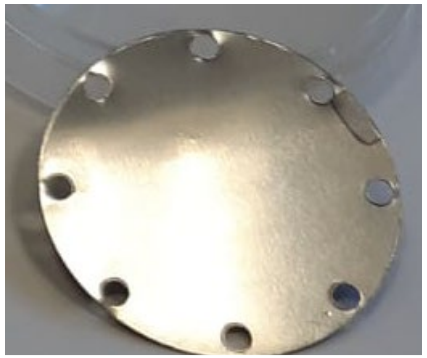
Characteristics:

- 3 sputtering source (50mm x 140mm)
- 2 sputtering source (150mm x 230mm)
- Active gettering system (porous Ti /Ba/Al)
- Optical emission plasma diagnostics for reactive processes (deposition of compound layers
- Different power supply technologies: High-power Impulse Magnetron Sputtering (HiPIMS, DC, pulsed-DC, or RF)
- 2 different sample holder

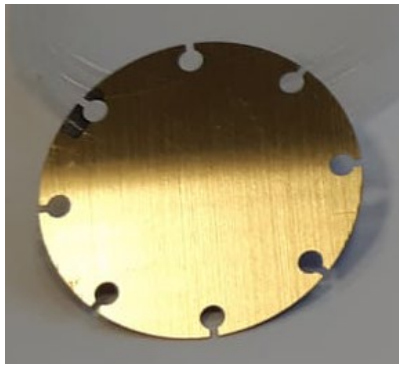


LUNA solid target development by PVD magnetron sputtering technology

- **Targets preparation for LUNA experiments (INFN Gran Sasso Laboratory): Nitrides ($Ta^{nat}N$, $Zr^{nat}N$, $Ti^{nat}N$)**
- High-Z metals nitrides for reduction of neutrons production for LUNA-MV
- TaN target produced by PVD techniques using ^{14}N enriched gas

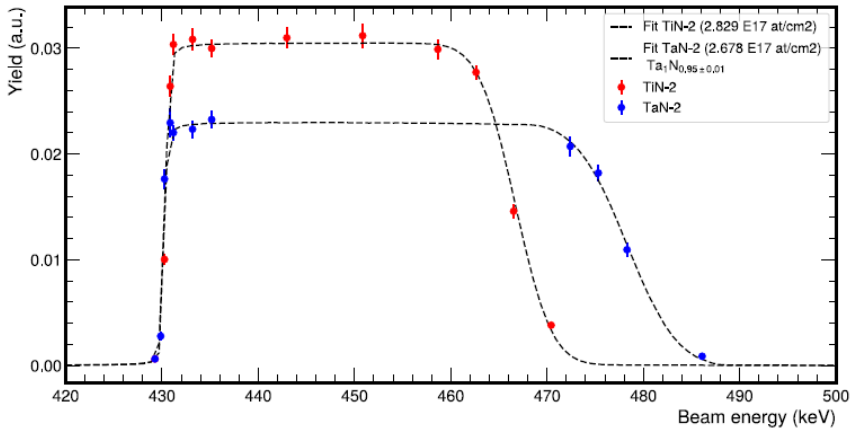


TaN 2.8*10^{18} atoms/cm^2 deposited on 7.8*10^{17} atoms/cm^2 of high purity Ta interlayer Tantalum substrate

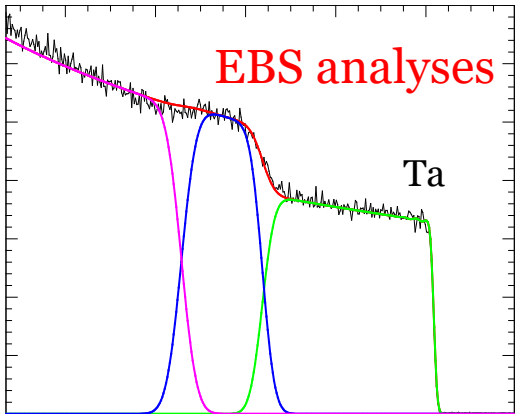


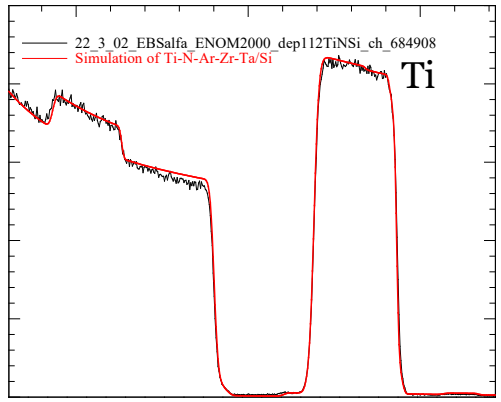
TiN 2.7*10^{18} atoms/cm^2 deposited Tantalum substrate and Silicon substrate (for EBS analysis)

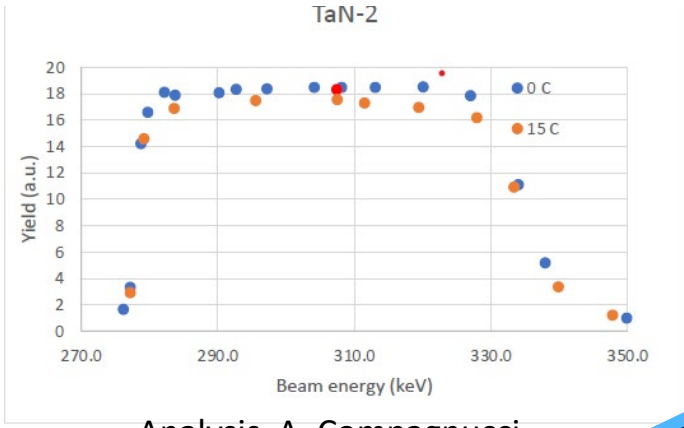
- Production and EBS characterization performed @ LNL (AN2000)
- Low energy resonance scan and endurance test performed @ LNGS (LUNA400)



429 keV ^{15}N resonance scan of TaN and TiN







278 keV ^{14}N resonance scan of TaN After an irradiation of 15 C

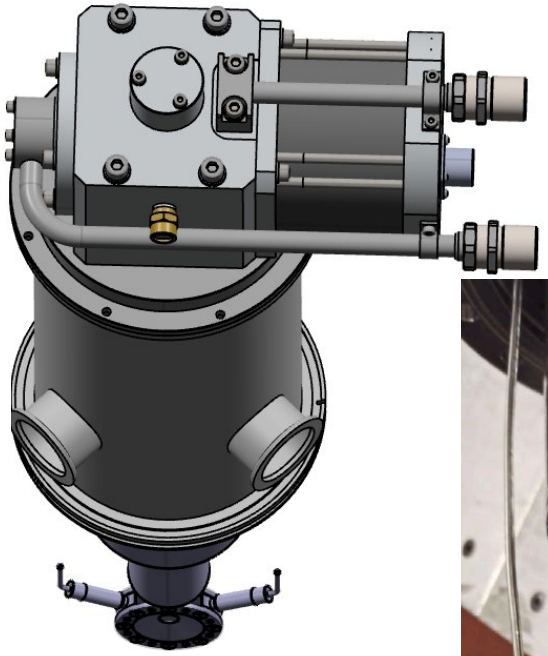
Analysis A. Compagnucci

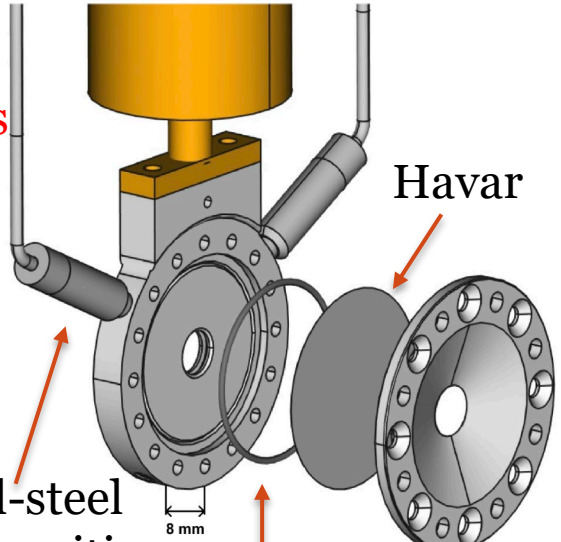
CTADIR: design, construction and commissioning of the prototype of a ^{3,4}He cryogenic target for direct reactions in inverse kinematics.

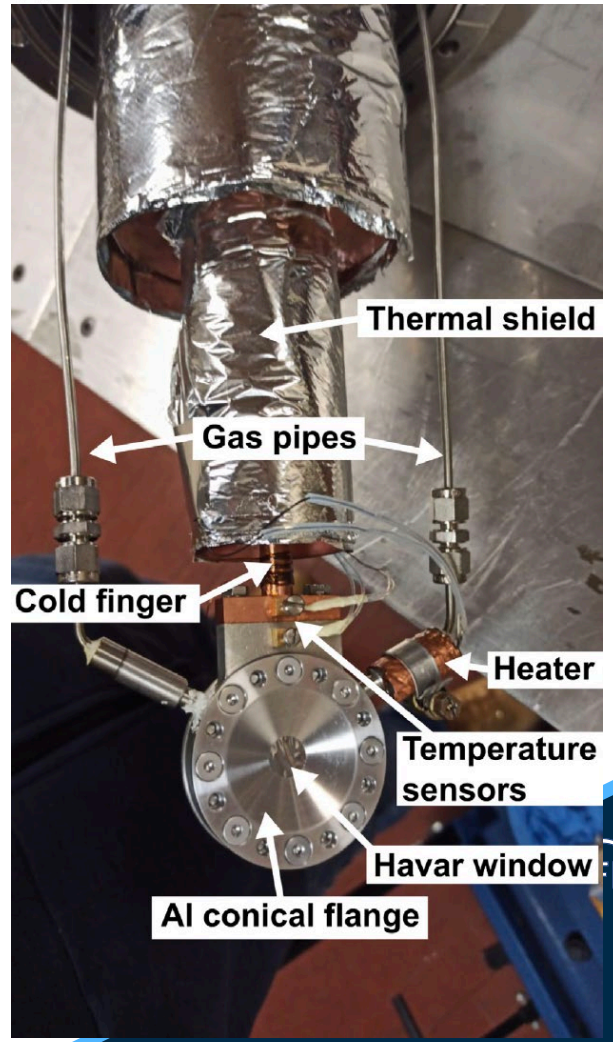
Y. Peinnaud, P. Rosier, C. Soulet

CTADIR

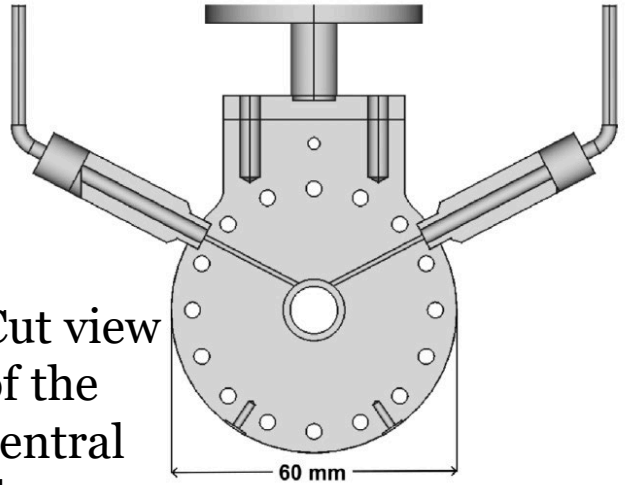
Next RIB's @ SPES have opened the opportunity to perform direct reactions with unstable beams in inverse kinematics.







- GM (Sumitomo) cryogenic source (2W @ 4K) – free orientation
- 4 mm gas cell
- Aluminum body to reduce γ-ray absorption and scattering
- As modular as possible for portability
- Temperature kept constant by a temperature controller feedback
- Havar windows 3.8 or 2.5 μm thickness
- At 1 bar, 10 K, ^{4}He $3 \cdot 10^{20}$ at/cm^2



Cut view of the central flange

CTADIR in-beam commissioning (I)

Nuclear Instruments and Methods in Physics Research A 1080 (2025) 170626

Contents lists available at ScienceDirect

Nuclear Inst. and Methods in Physics Research, A

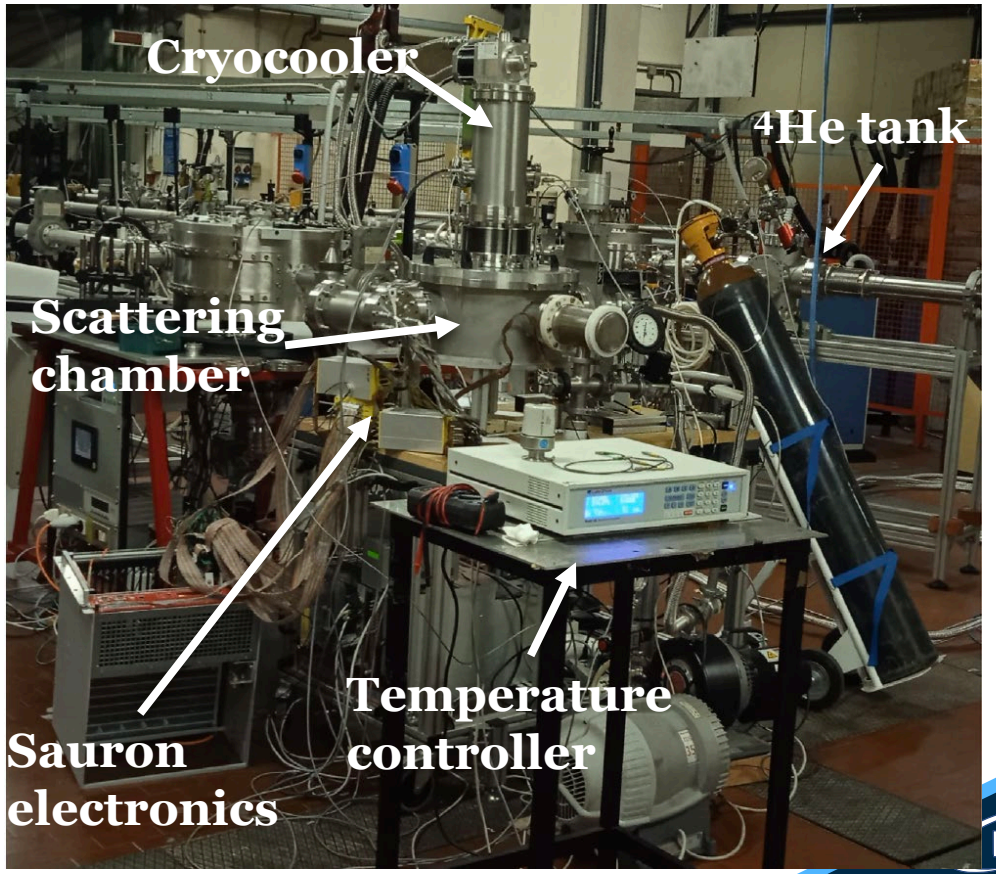
journal homepage: www.elsevier.com/locate/nima

Full Length Article

CTADIR: A ^{3,4}He Cryogenic TArget for DIrect Reactions at low energy

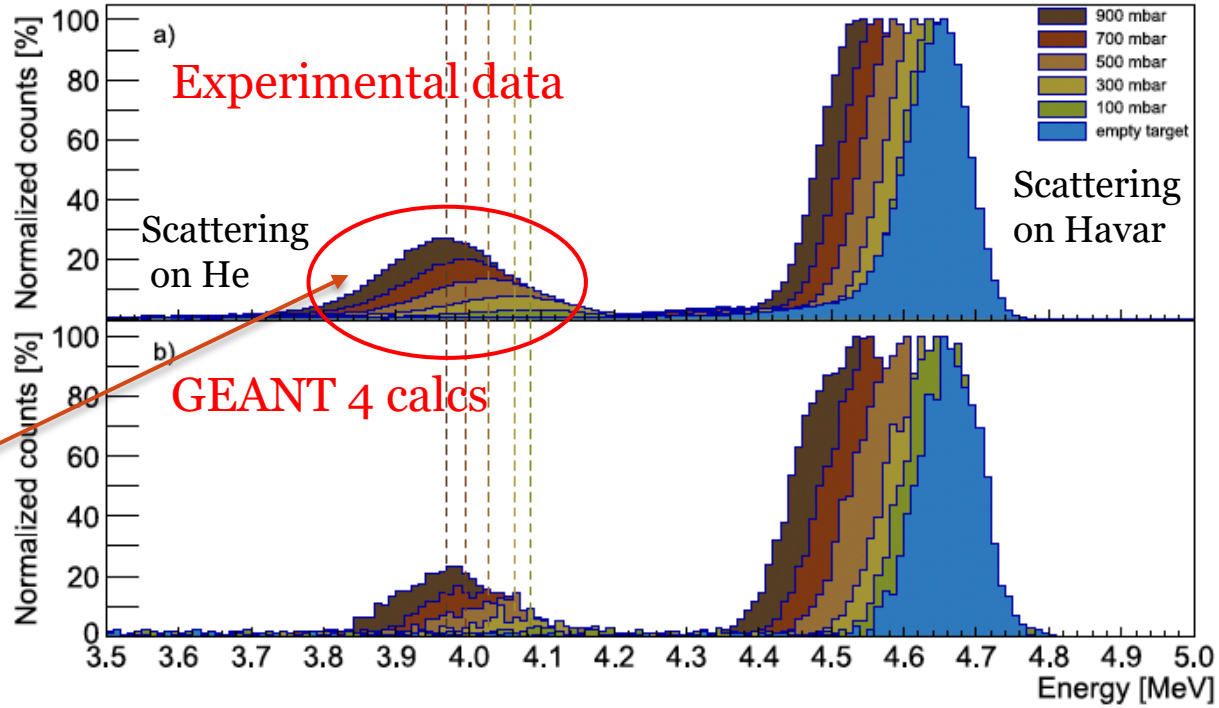
M. Sedlák [a,b,*], A. Gottardo [a], R. Pengo [a], A. Goasduff [a], I. Zanon [a,1], A. Cobo Zarzuelo [a,d,2], M. Balogh [a], D. Brugnara [a], G. Andreetta [a,d], F. Angelini [a,d], R. Nicolás del Álamo [a,d], F. Galtarossa [d], B. Góngora Servín [a,e], T. Grečnárová [b], I. Lombardo [g,f], D. Mengoni [c,d], J. Pellumaj [a,e], S. Pigliapoco [c,d], E. Pilotto [a,d], F. Recchia [c,d], J.J. Valiente-Dobón [a], L. Zago [a,d]

- Commissioning at CN accelerator with 5 MeV protons
- Manual filling ^{4}He gas system
- Micron S1 detectors in front and back of the target



CTADIR in-beam commissioning (II)

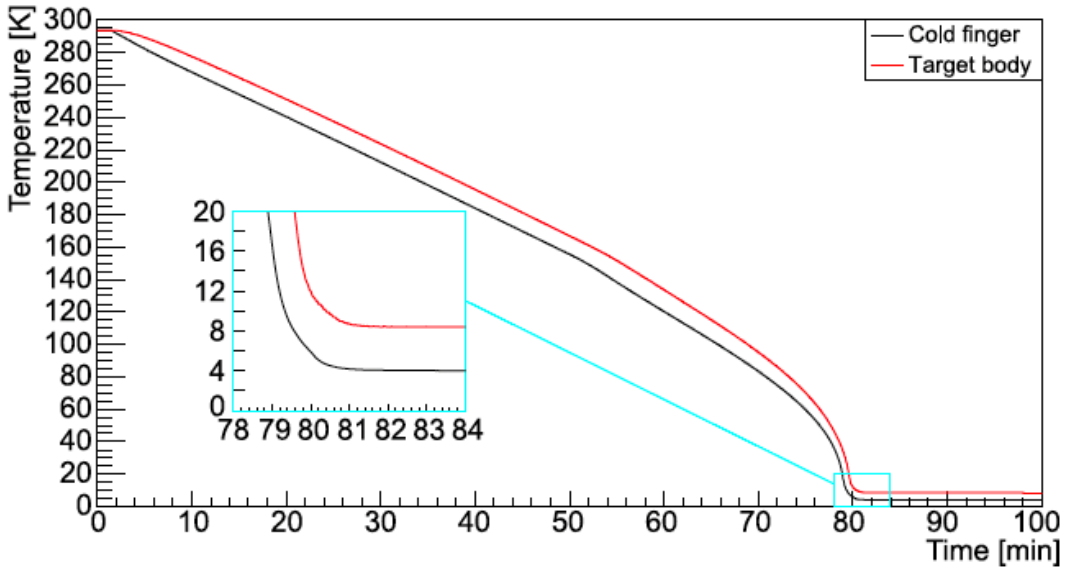
- 5 MeV proton scattering on Havar 3.8 μm windows
- Test at different He gas pressures
- Temperature kept at 12 K to limit density
- Proton energy spread behavior on ^{4}He gas target compatible with thickness of few 10^{20} at/cm^2



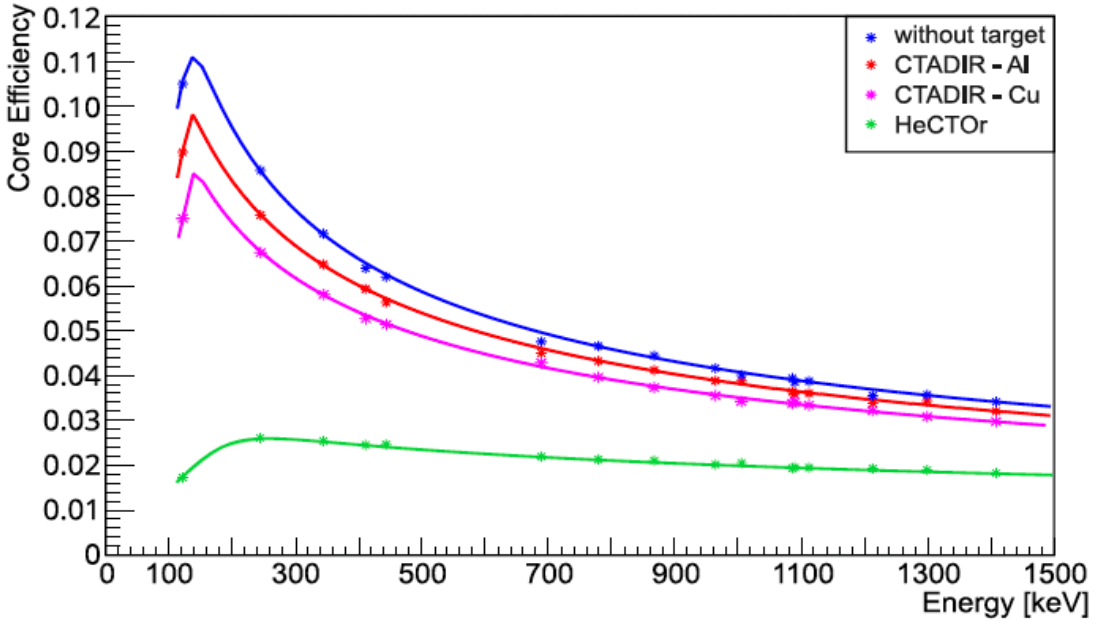
The peak at higher energy represents the protons scattered on the Havar® foil window at the exit of the target. The peak with lower energy is due to protons scattered on the ^{4}He gas filling the target.

CTADIR performances

- Cool down in about 80 minutes
- Significant de-icing already at 40 K: de-icing procedure feasible in 2 hours (including gas removal/refilling)



- Gamma-ray transparency greatly enhanced compared to Hector, thanks to lower material budget and Al body



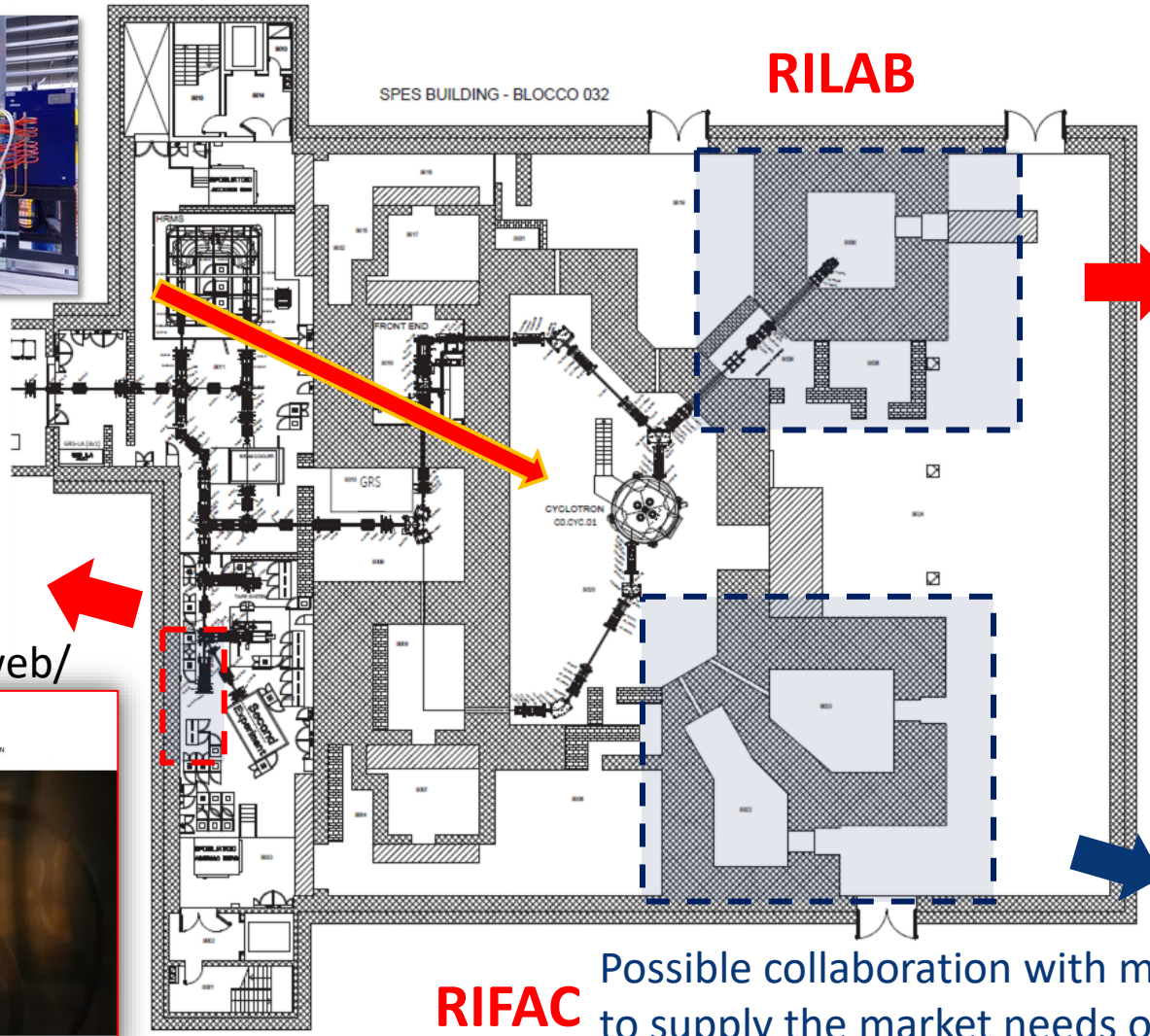
Exploiting the intense radioactive beams from existing and upcoming ISOL facilities (for instance ISOLDE, TRIUMF, SPES, RAON) the CTADIR target will allow one to perform proton adding (^{3}He,d) and neutron stripping (^{3}He, ^{4}He) reactions around the **key doubly-magic nuclei ^{78}Ni and ^{132}Sn** combining the AGATA energy resolution with the granularity of GRIT.

M. Sedlak

Target production at LNL

Applied NP studies (emerging radioisotopes production for thenanostics radiopharmaceuticals)

Study and production of novel/emerging medical radionuclides feasible at SPES facility

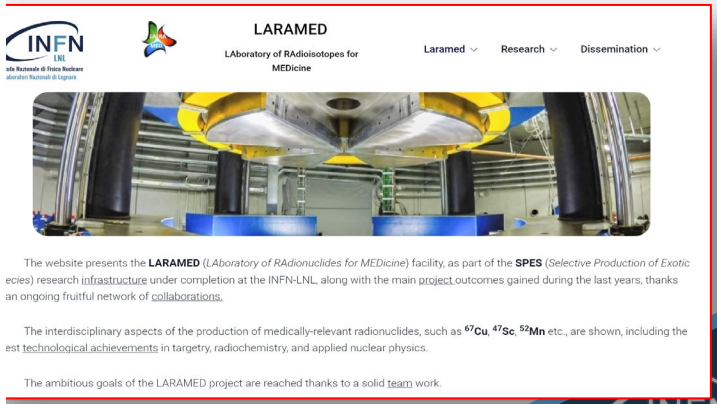


RILAB

DIRECT technology

LAboratory of RAdionuclides for MEDicine

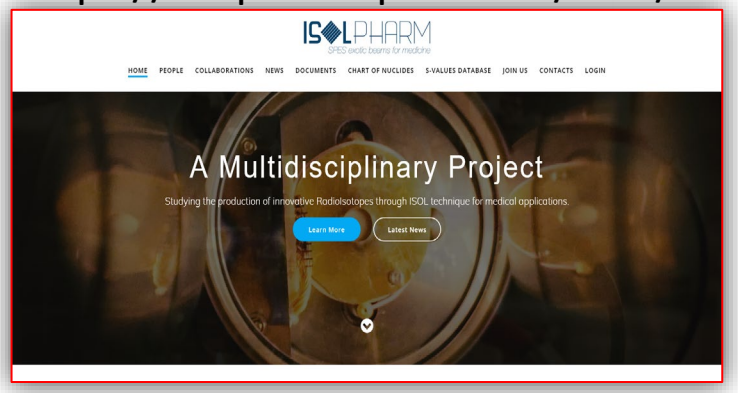
https://web.infn.it/LARAMED/



ISOL technology

ISOLPHARM – SPES exotic beams for medicine

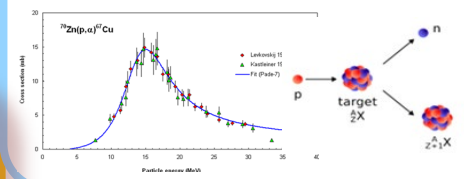
https://isolpharm.pd.infn.it/web/



RIFAC Possible collaboration with multinationals to supply the market needs of RIs

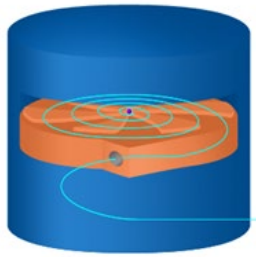
Cyclotron production cycle

Nuclear physics studies



Target preparation

Cyclotron irradiation



Radioisotope of Interest

Contaminants

Target activation

Radiochemistry process

Dissolution

Extraction/ separation

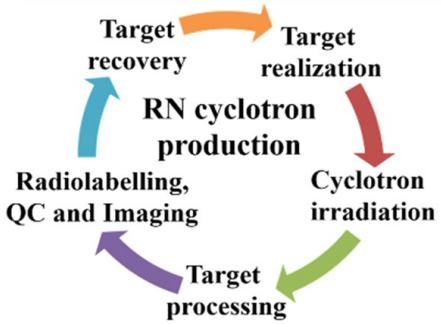
Purification

Quality Control

Pure radioisotope

Radio-pharmaceutical preparation

Target recovery



Fore more details, follow Sara Cisternino's presentation right after this one.

Target production at LNL

Quality Control (QC) techniques: nuclear targets characterization

IBA facilities for nuclear target characterization @ LNL

- **quantitative determination of composition**
- **thickness measurements in terms of dose (at/cm²)**
- **depth profiles analysis**

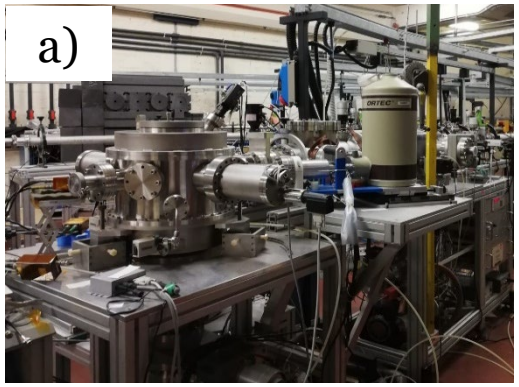
✓ non-destructive

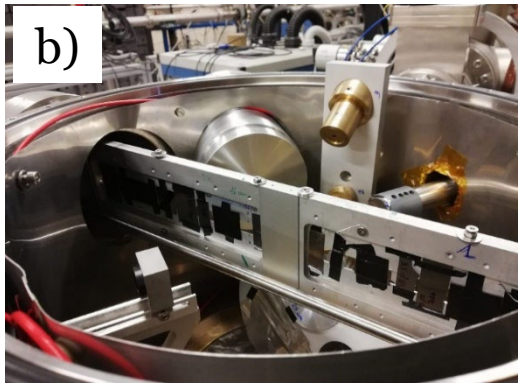
✓ High accuracy and resolution

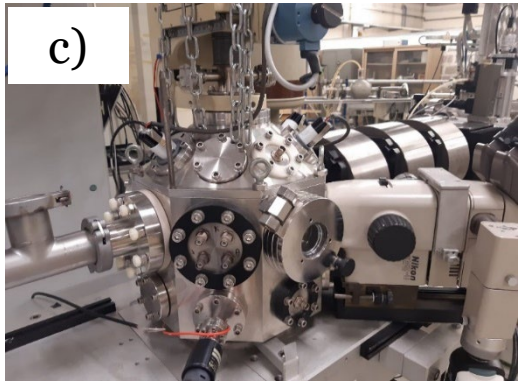
-15° beam line at CN facility [a), b)]
- EBS analysis
- PIXE analysis
- PIGE analysis

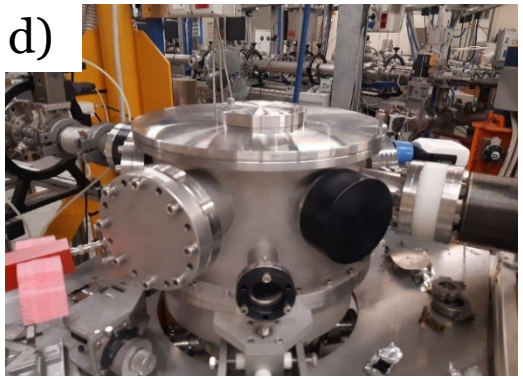
0° beam line (μ-beam) at AN2000 facility [c)]
- EBS analysis
- PIXE analysis

60° beam line at AN2000 facility [d)]
- EBS analysis
- ERDA analysis









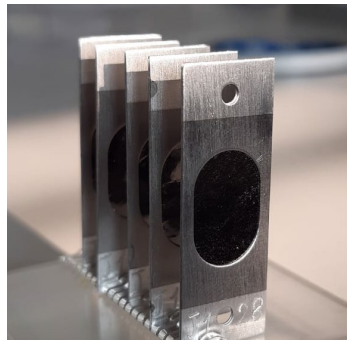
INFN
INFN LNL Istituto Nazionale di Fisica Nucleare Laboratori Nazionali di Legnaro
EURO-LABS EUROPEAN LABORATORIES FOR ACCELERATOR BASED SCIENCES

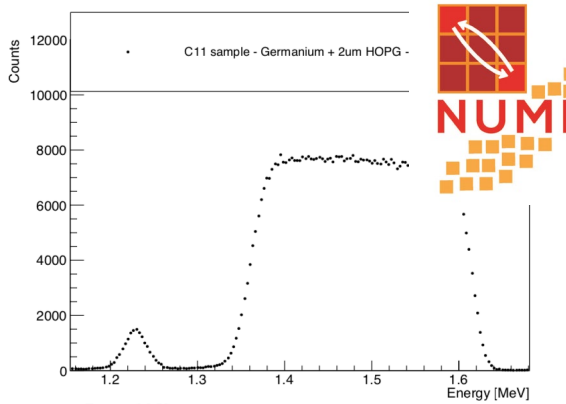
IBA facilities for nuclear target characterization @ LNL

Dedicated experiments in nuclear target analysis:

Deposition of Elements on Substrates (DES) involved in NUMEN project

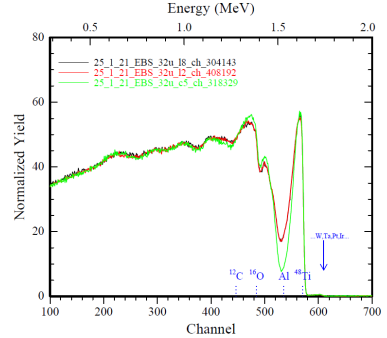
- Elastic backscattering spectrometry (EBS)





Characterization of HIVIPP targets for REMIX project (HIX) involved in LARAMED project

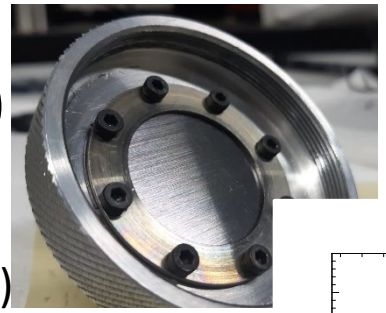
- Elastic backscattering spectrometry (EBS)

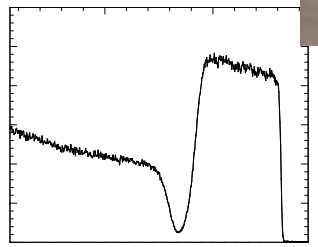


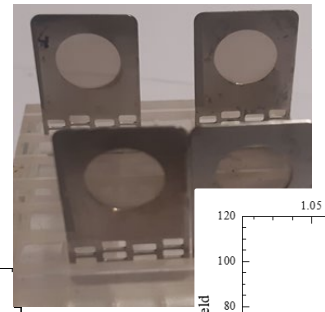
Advances Nuclear Target (ANT)

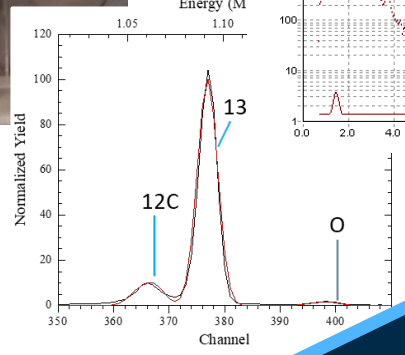
involved in SALVIA project, LUNA collaboration (target development) and LNL target service (target characterization)

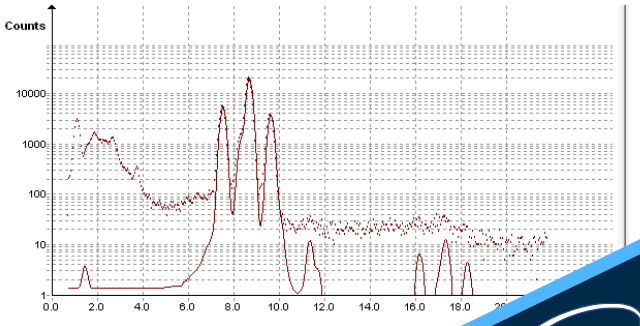
- Elastic backscattering spectrometry (EBS)
- Nuclear Reaction Analysis (NRA)
- particle induced X-ray emission (PIXE)
- particle induced γ-ray emission (PIGE)





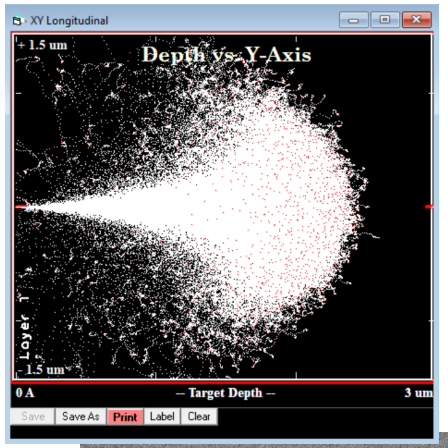




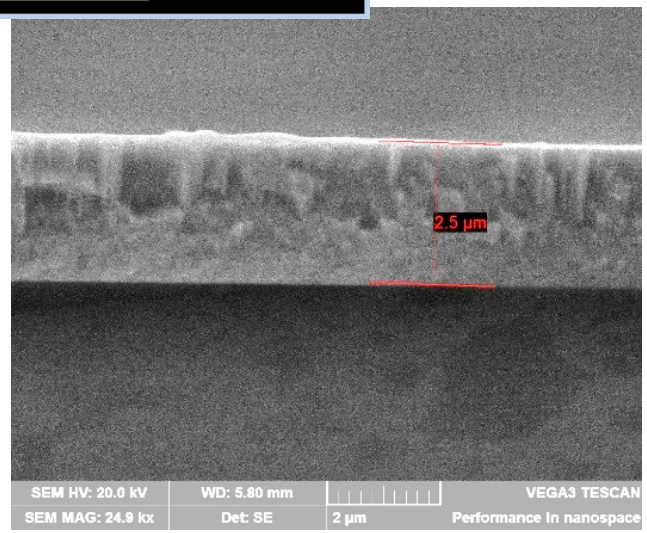


IBA characterization of nuclear target @ LNL

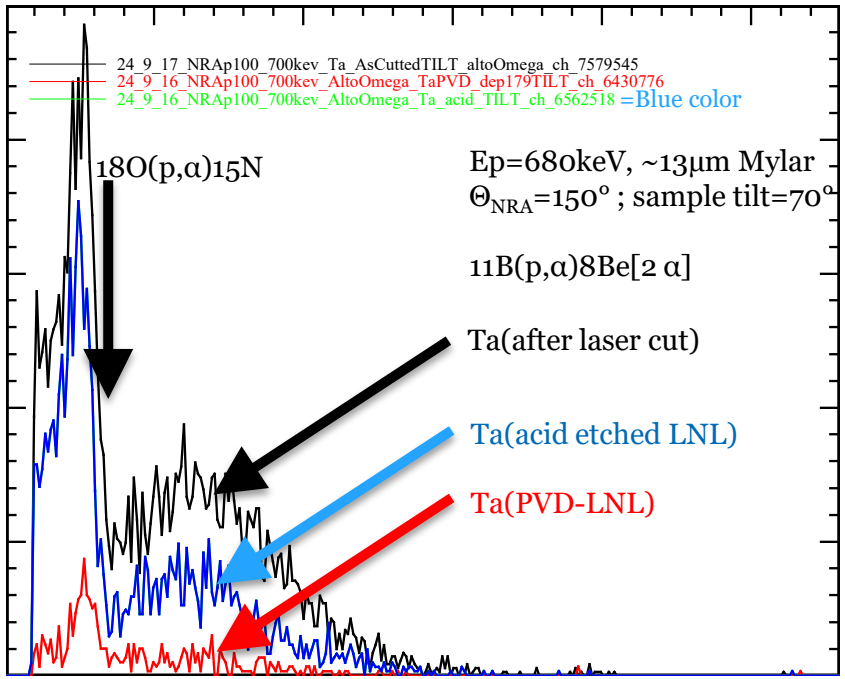
- **Boron contamination reduction using High Purity PVD Tantalum deposited on tantalum backing**
- **Beam induced background reduction**

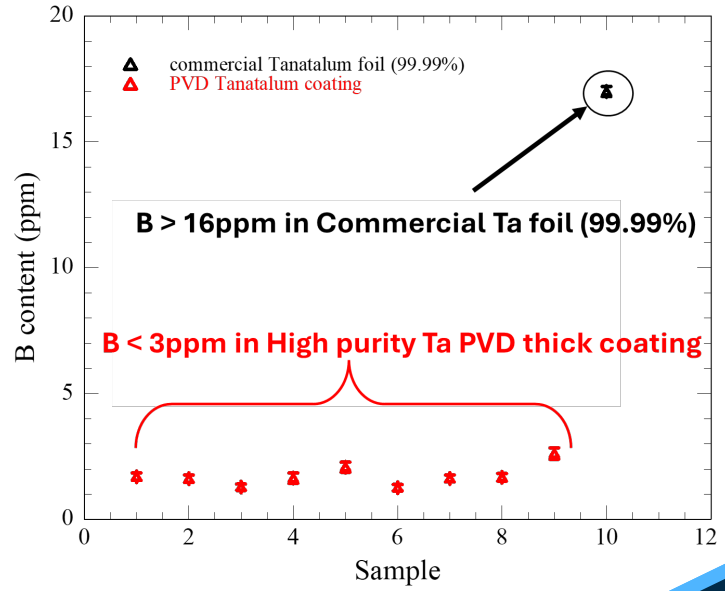


PVD Ta thickness > 2.5µm
(E_{pmax}=400keV)



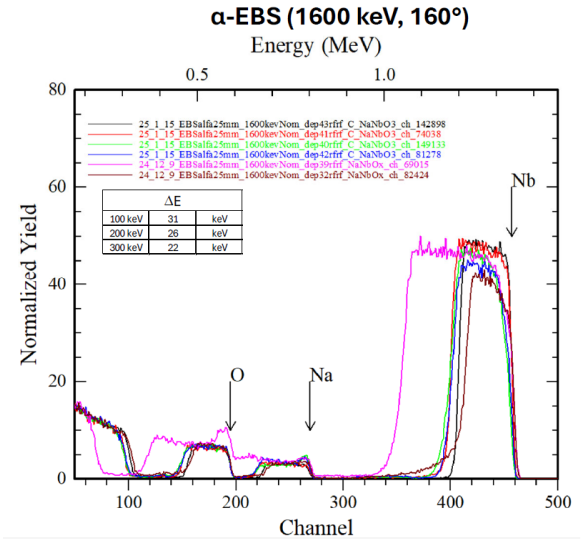
SAMPLE TILTED 70°

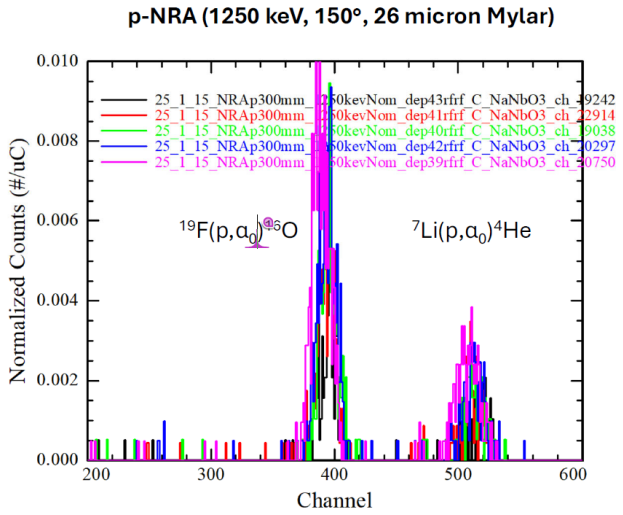




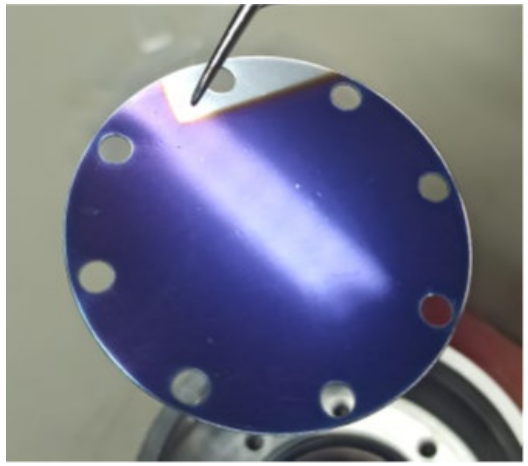
IBA characterization of nuclear target @ LNL

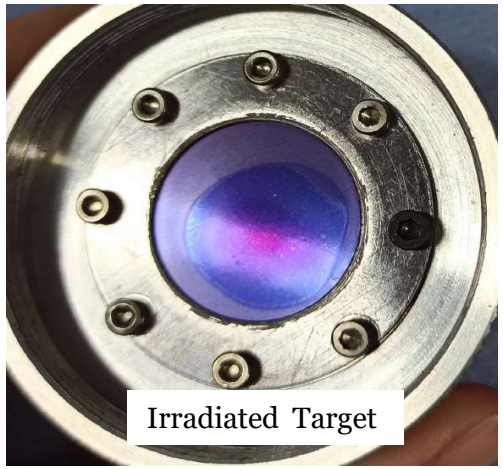
- **Targets preparation for : $^{23}Na(p,\alpha)^{20}Ne$ experiment (LNGS)**
  Alkali targets produced by PVD technics and contaminants reduction



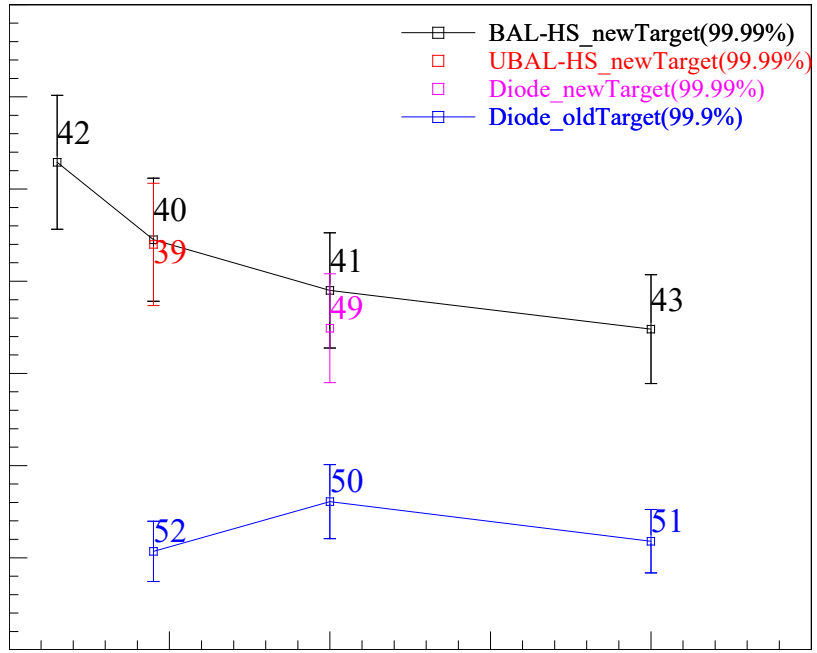


Sodium Niobate Nuclear Target



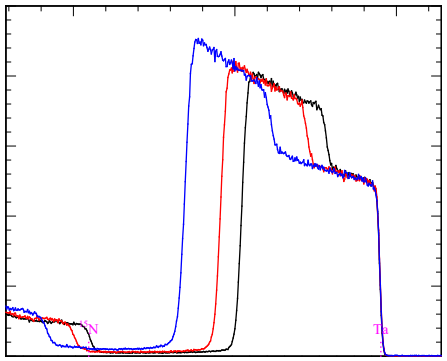


^{7}Li content (ppm) in different deposition process setup

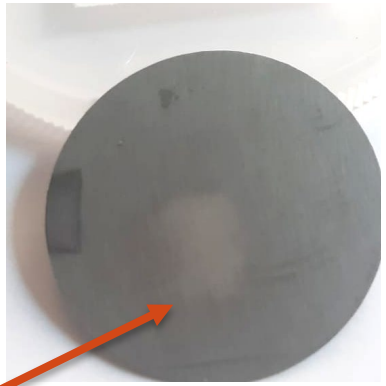


IBA characterization of nuclear target @ LNL

- **Targets for : $^{15}N(\alpha,\gamma)^{19}F$ experiment (Felsenkeller Laboratories)**
  TaN target produced by PVD technics using **^{15}N enriched gas**

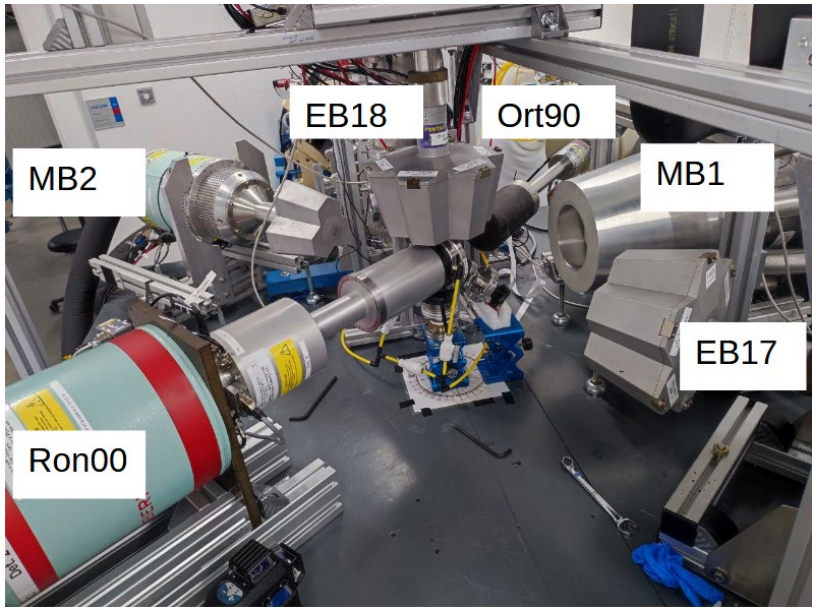


RBS spectrum α
beam
1.6MeV(AN2000)
witness samples

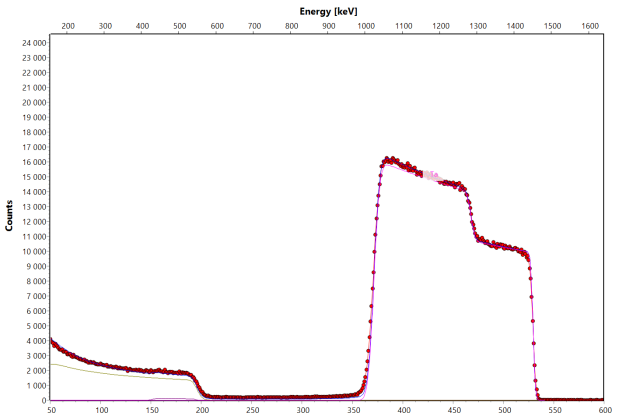


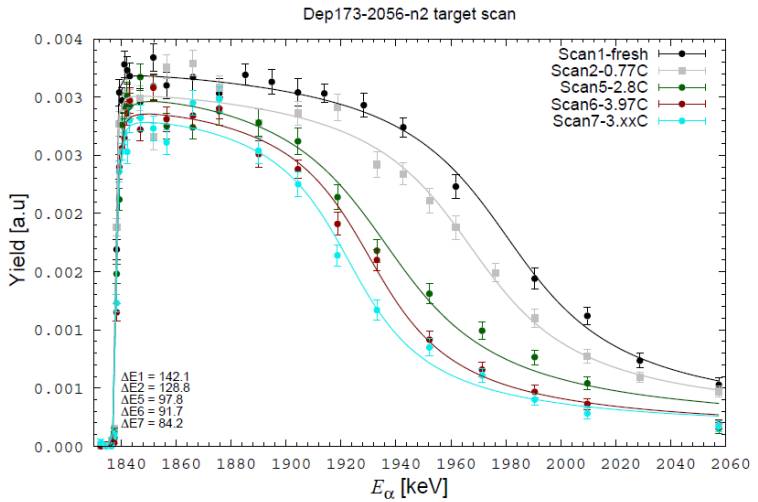
TaN 0.8-1.2-2.4*10^{18} atoms/cm^2
deposited on 1.1*10^{18} atoms/cm^2 of high purity Ta interlayer Tantalum substrate

Irradiated target
Ta^{15}N @ HZDR



Felsenkeller experimental setup

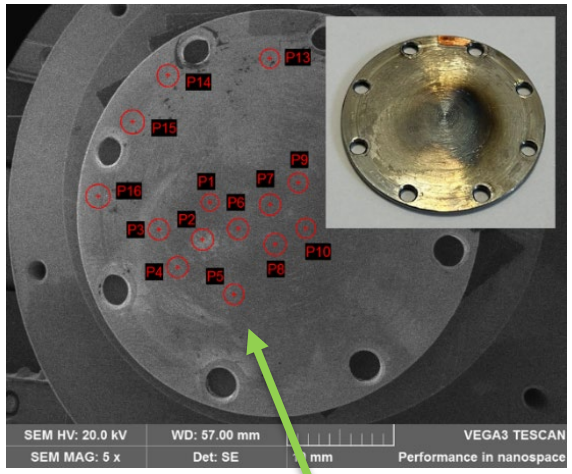


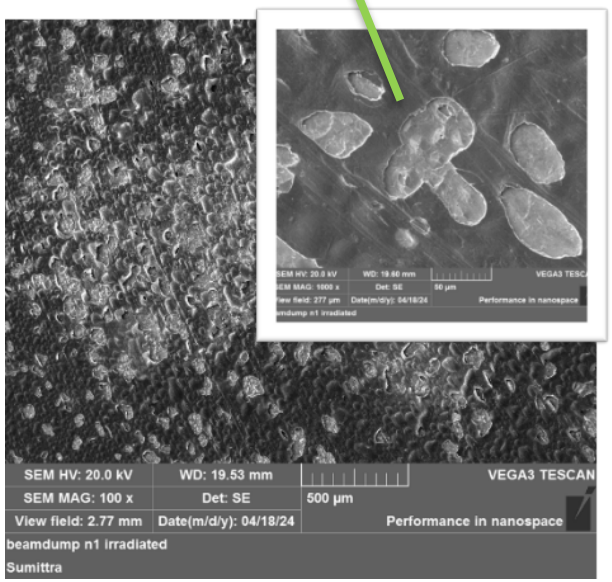


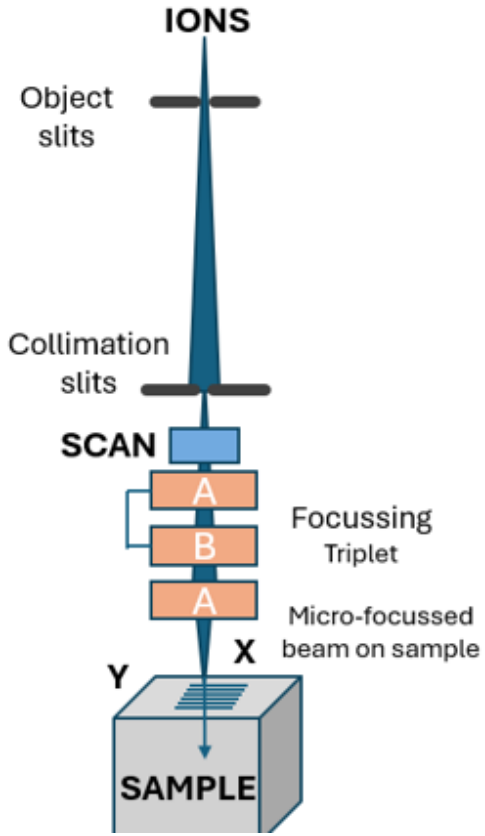
Target degradation under intense He^+ beam
Thanks E. Masha

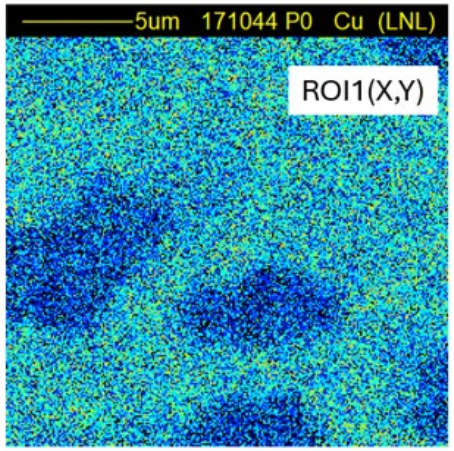
IBA characterization of nuclear target @ LNL

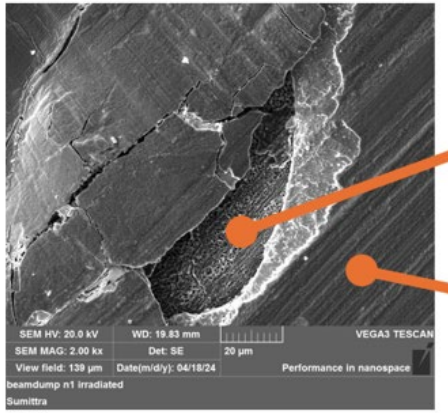
- **Target degradation induced by blistering (intense He+ beam)**
- **<u>μ-RBS analysis and 2-D maps using AN2000 μ-beam probe</u>**





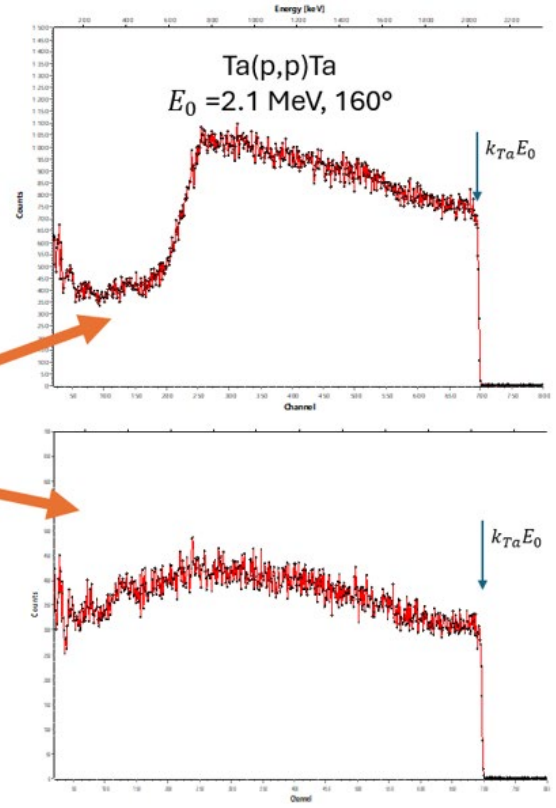






He bubbles are created at a depth of about 2.4 μm and cause surface blisters.

<u>Thickness evaluation using μ-RBS 2-D maps</u>



EURO-LABS WP2.5.2 Collaboration meeting
May 18th, 2026 GSI lab, Darmstadt (Germany)

Thank you from target makers group @LNL

- Massimo Loriggiola
- Lorenzo Loriggiola
- Matteo Campostrini
- Valentino Rigato
- Andrea Gottardo
- Sara Cisternino
- Alisa Kotliarenko
- Gaja Piteo (PhD UNIPD)
- Stefano Corradetti
- me