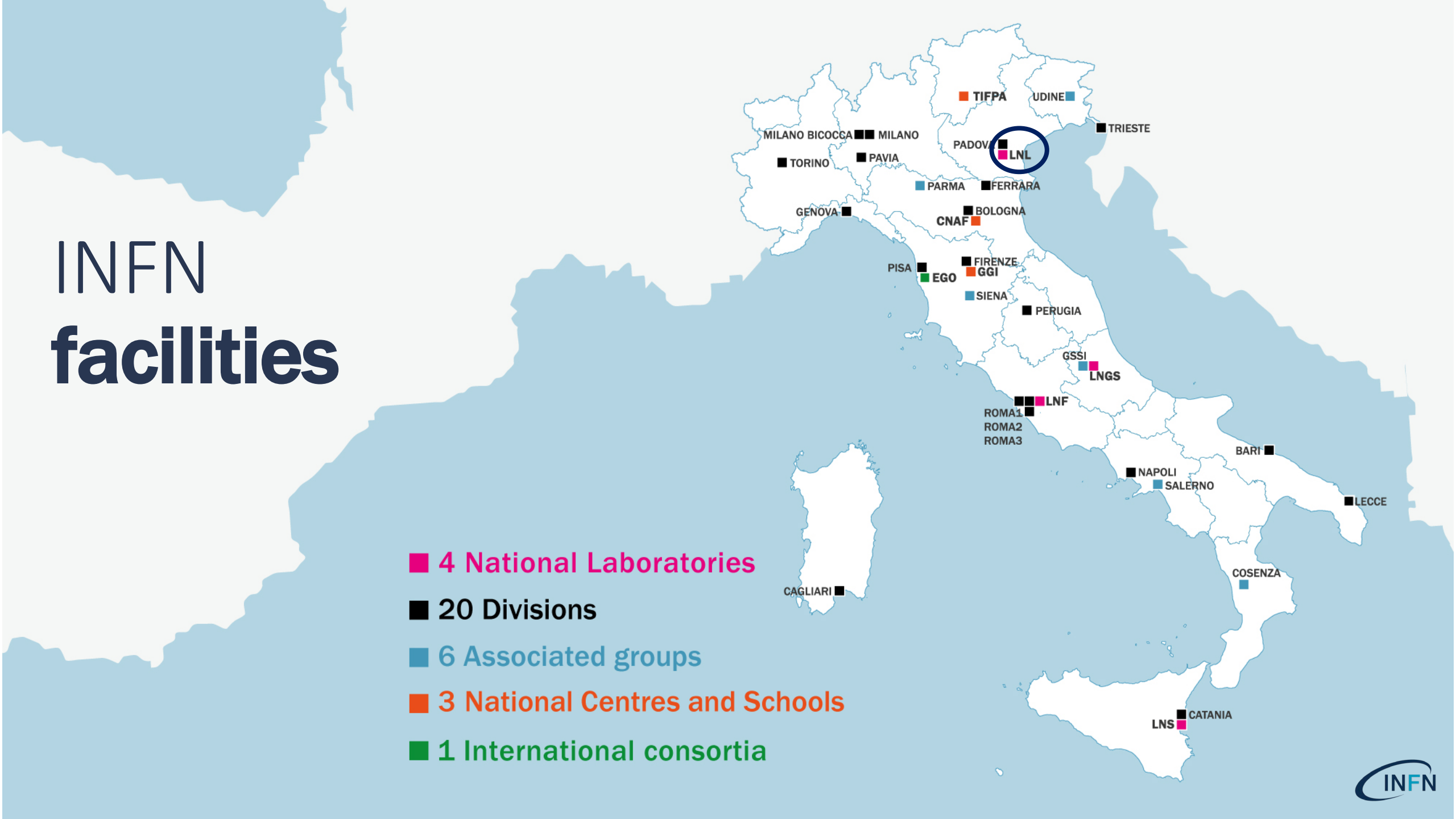
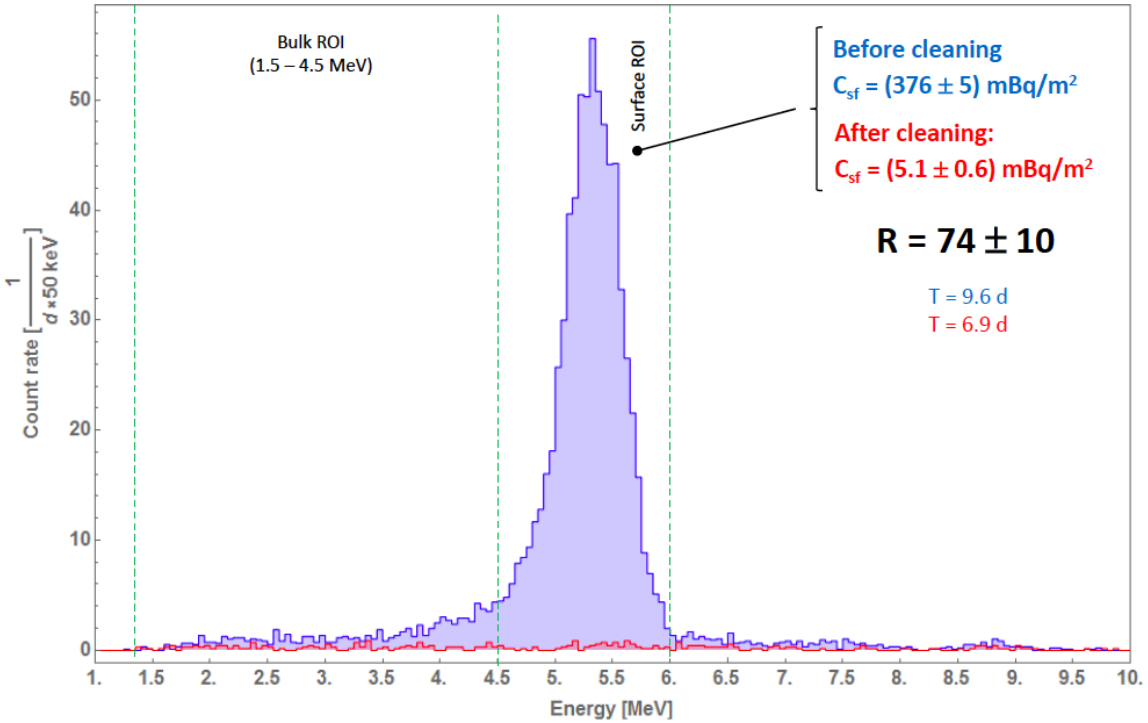
INFN **facilities**

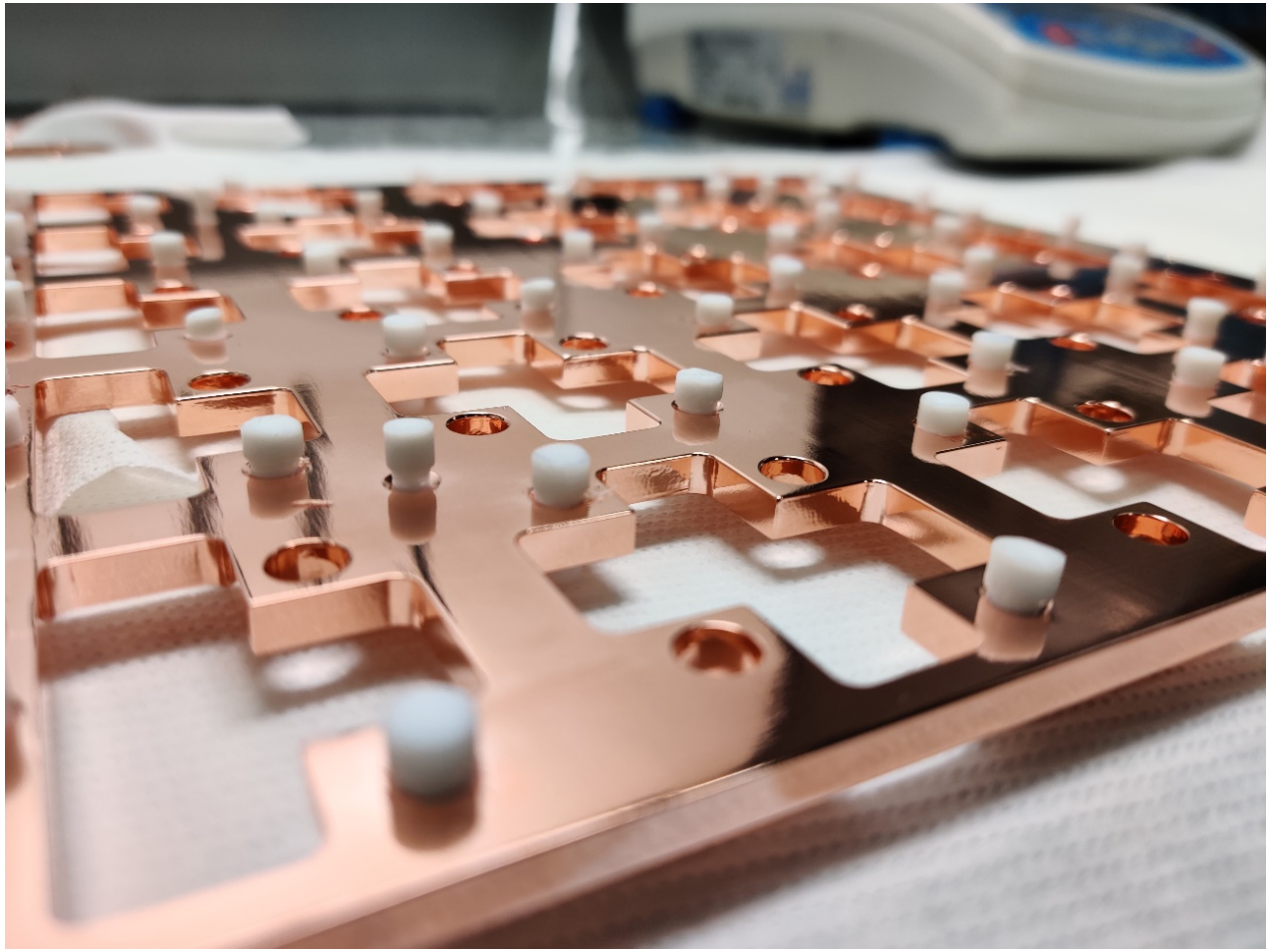


LNL Competencies (knowHow)

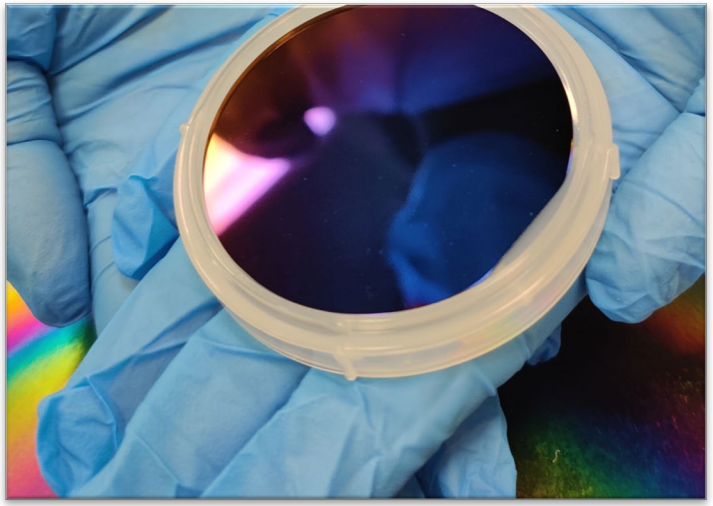
- **Surface Cleaning and Preparation of Materials:**
  - *Physical Treatments: ex. Barrel Polishing*
  - *Chemical and Electrochemical Treatments: ex. Electropolishing, SUBU5*
- **Surface modification of Materials:**
  - *Physical Vapor Deposition (PVD)*
  - *Plasma Enhanced Chemical Vapor Deposition (PECVD)*
- ***Vacuum Generation**: ex. surfaces preparations, materials for vacuum applications, pumping units and procedure of handling and manipulations of vacuum components*

Surface Cleaning: ex.
DS Copper Motherboard

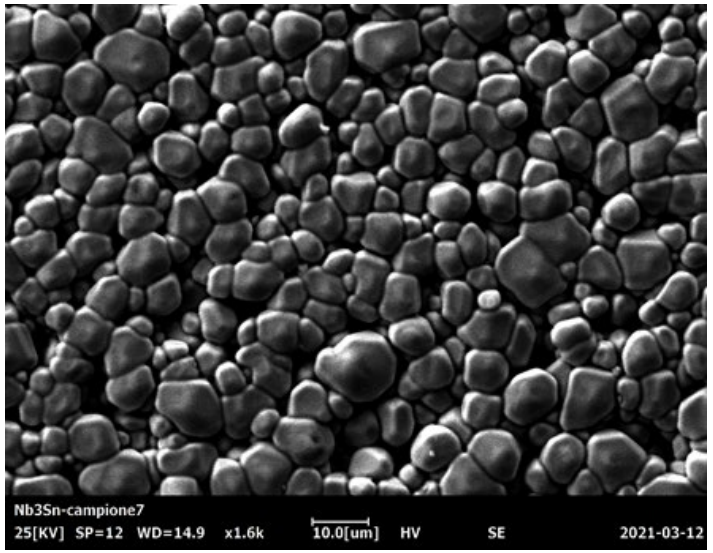




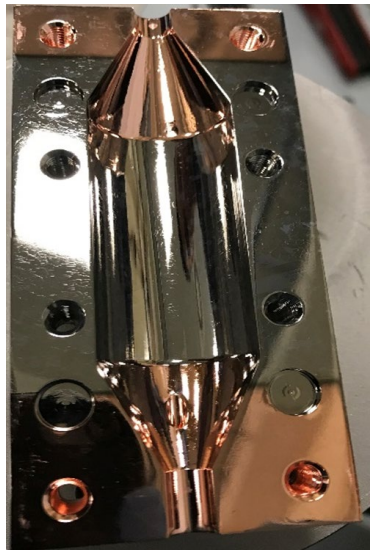
Surface Modifications: Thin films (less than 5 μm thick)



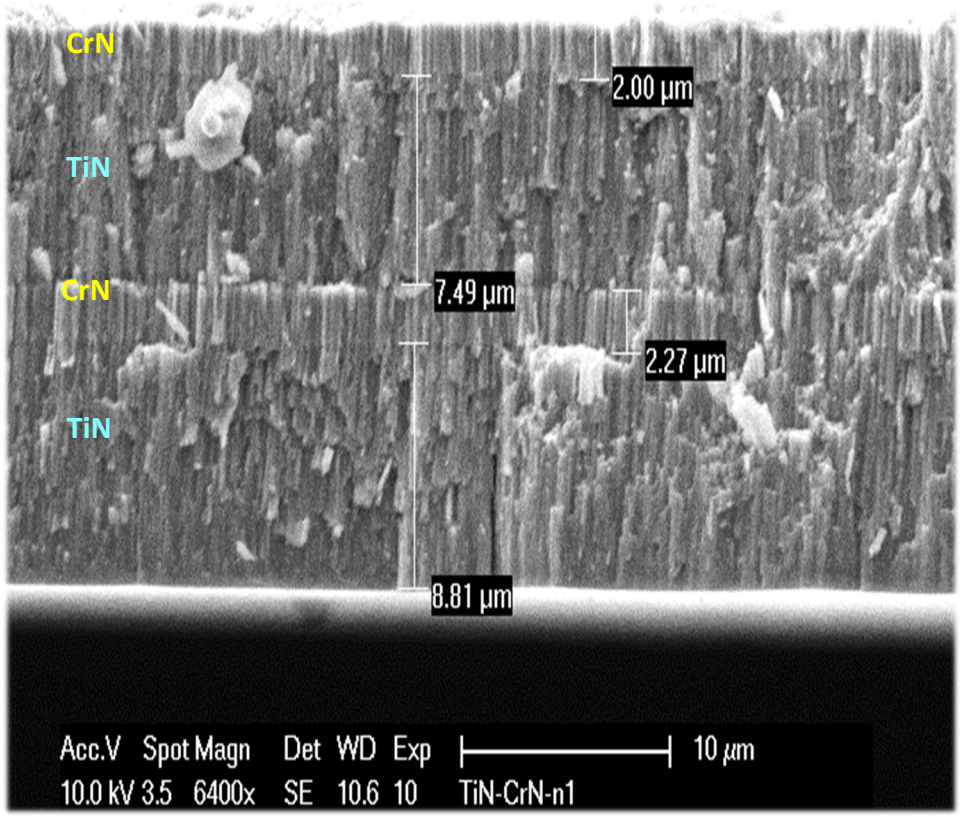
Antireflective Coatings as Nb_2O_5 or SiO_2



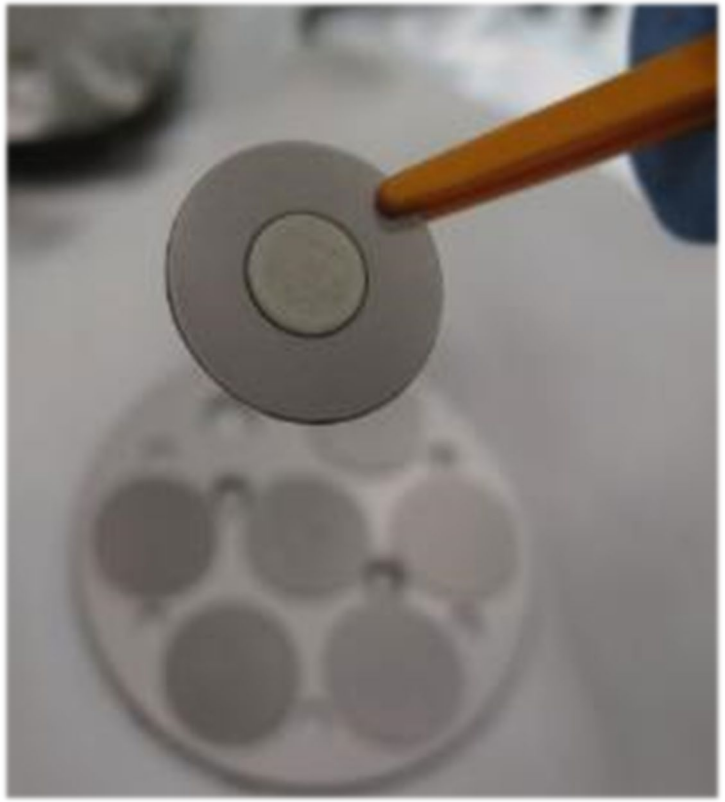
Superconductive Materials as Nb, NbTi or Nb_3Sn



Surface modifications: Thick films (until 100 μm thick)



Multilayared Hard Coatings as TiN/CrN



Yttrium thick film (more than 100 μm) for radiophatrmaceutical applications

LNL for VACRET (R&D for ET)

Call Gr V - VACRET

R&D on VAcuum and CRyogenic for *Einstein Telescope*

INFN RESEARCH UNITS: **INFN ROMA, NAPOLI, LNF, LNL, LNGS**

National Representative: Ettore Majorana
Local PI@LNL: Giorgio Keppel

INFN Section	Surname Name	FTE
LNL	Keppel Giorgio	0,1
LNL	Azzolini Oscar	0,1
LNL	Pira Cristian	0,1
LNL	ADR - senior (research fellow)	1
	Total FTE	**1,30**

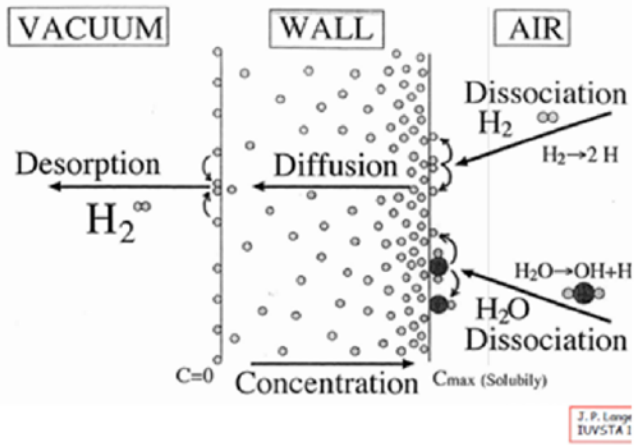
Objective of LNL R&D: H_2 Outgassing reduction

The methods used for the **reduction of H_2 outgassing** (bulk effect, permeation effect) from stainless steel are mainly:

1. **Ex situ heating at high temperature** in vacuum furnace (vacuum firing 950°C): coupled with Glow Discharge of inert gases (bulk effect)

2. **Passive coatings** also defined as Hydrogen Permeation Barrier (HPB): Thin or thick film deposition (SiO_2, Al_2O_3,TiN, TiAlN) (Permeation effect)

Below, Hydrogen permeability scheme
P. Michelato, Vacuum technology advanced lessons, December 12 - 14, 2016



Right, R.A. Causey, R.A. Karnesky, C. San Marchi, "Tritium Barriers and Tritium Diffusion in Fusion Reactors", Chapter in: R.J.M. Konings (Ed.) Comprehensive Nuclear Materials, Elsevier, Oxford, 2012, pp. 511-549.

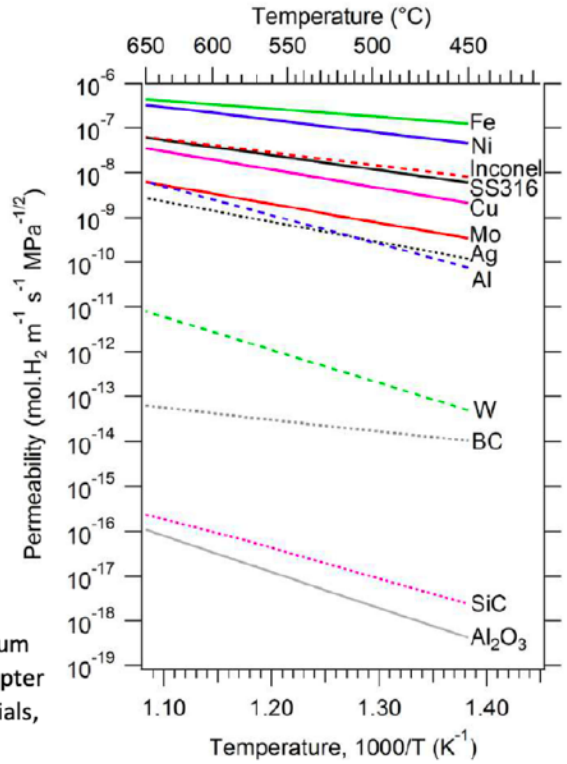


Fig. 3 Hydrogen permeability

LNL Research Program for HPB Coatings

Material Identification

Material	H_2 permeability [mol H_2/m/s/$Pa^{0.5}$]	T [°C]
Molybdenum	1.2E-11	500
Tungsten	4.3E-15	500
TiN	2.2E-17	400
TiAlN	6.5E-18	400
ZrN	7.9E-18	400
Cr_2O_3	0.7E-18	400

Coating Technique Identification

1. Magnetron Sputtering
2. Cathodic Vacuum Arc
3. Plasma Spray

Research Goal

Combination of **material** and coating **technique** scalable for the dimensions of the ET vacuum pipe and suitable for the vacuum limit of the Experiment.