Ion Beam Analysis for Materials Characterization

G. Maggioni

➢Laboratory of Materials Physics for Nuclear Physics at INFN-LNL (MatLab-LNL)

INFN Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Legnaro

➢University of Padua

Università degli Studi di Padova

Personnel involved

- Dr. G. Maggioni
- Dr. S. M. Carturan
- Dr. W. Raniero
- Dr. S. Bertoldo
- Dr. C. Carraro
- Prof. D. De Salvador
- Dr. F. Sgarbossa
- Dr. V. Rigato
- Dr. M. Campostrini

<u>MatLab-LNL</u>

- Since 1992
- Radiation detectors: gamma detectors and plastic scintillators
- Nuclear targets

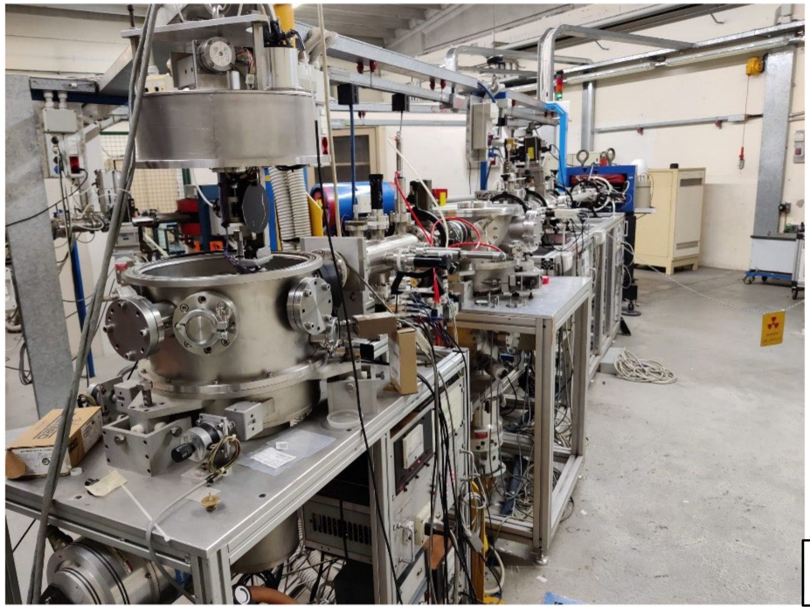
<u>Activity at the AN2000 accelerator</u>

Materials characterization in the frame of R&D projects

Analytical techniques

- Rutherford Backscattering Spectrometry (RBS, ^{4}He up to 2 MeV)
- Channelling RBS (^{4}He up to 2 MeV)
- Elastic Recoil Detection Analysis (ERDA ^{4}He 1.6 MeV)
- Nuclear Reaction Analysis (NRA ^{1}H 1.6 MeV, 660 keV, ….)

Analysis Chamber



AN2000 - 60° Beam Line

- Elemental composition: qualitative and quantitative
- Contamination
- Film thickness (down to a monolayer)
- Hydrogen measurement
- Materials structure

Analytical techniques

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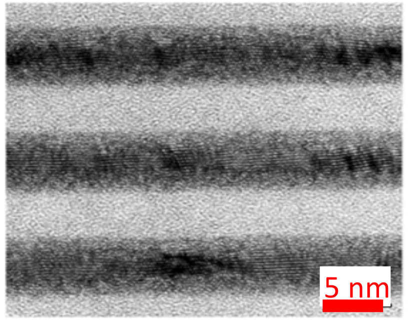
- Channelling RBS (^4He up to 2 MeV)
- Elastic Recoil Detection Analysis (ERDA ^4He 1.6 MeV)
- Nuclear Reaction Analysis (NRA ^1H 1.6 MeV, 660 keV, ...)

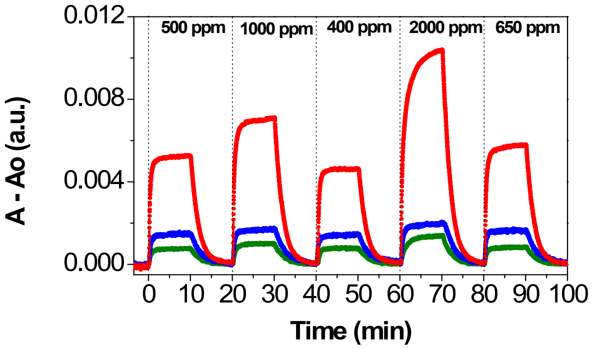
Past R&D Activities

Multilayer Technology

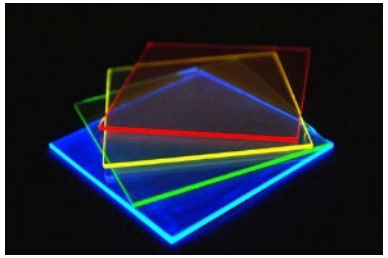


EUV Multilayer Mirrors

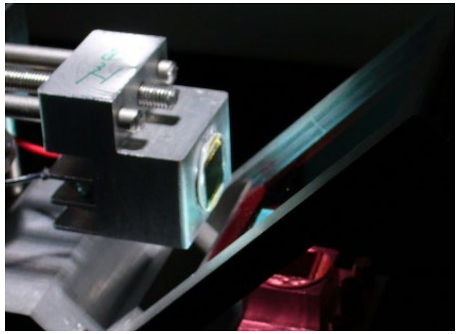
Methanol vapour



Optical gas/VOC sensors



Luminescent Solar Concentrators



Dichroic filters for photovoltaic applications

Analytical techniques

- Rutherford Backscattering Spectrometry (RBS, ^{4}He up to 2 MeV)
- Channelling RBS (^{4}He up to 2 MeV)
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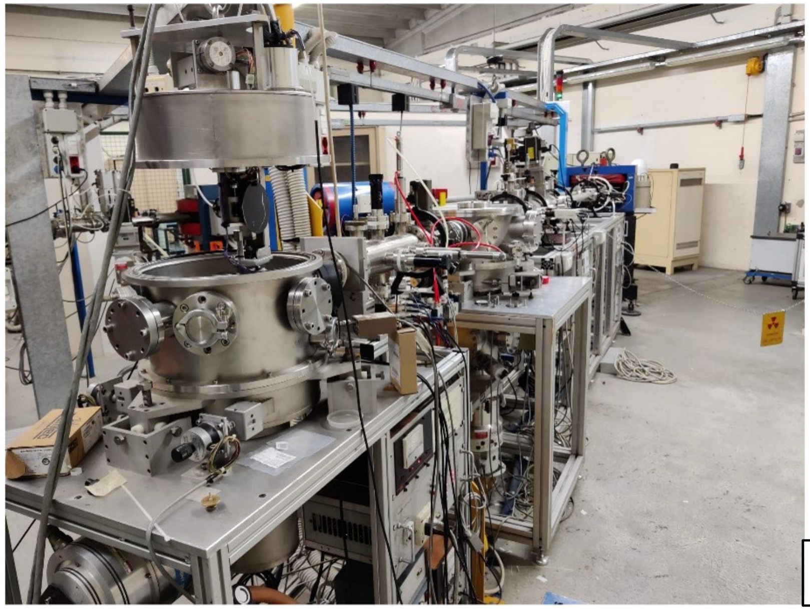
- Nuclear Reaction Analysis (NRA ^{1}H 1.6 MeV, 660 keV, ….)

Analysis Chamber



AN2000 - 60° Beam Line

Current R&D Projects

- **N3G** (CSN 5 INFN)
- **VIRGO** (CSN 2 INFN)
- **OREO** (CSN 5 INFN)
- **BEYOND** (CSN 5 INFN)
- **PLUS** (CNR-IFN Padua)
- **LUNA3** (CSN 3 INFN)
- **GAMMA** (CSN 3 INFN)
- **SPES**
- **…..**

N3G - Next Generation Germanium Gamma Detectors

Call of 5th INFN Commission – 2021/2024

PI: Prof. D. De Salvador (UniPD)

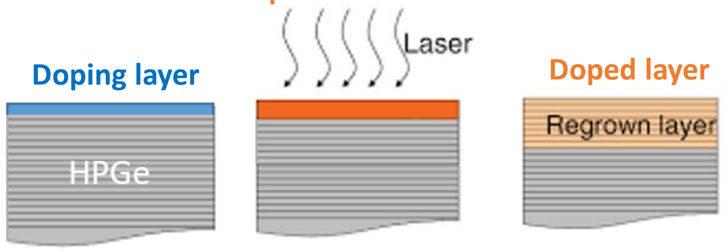
Research Units: LNL, PD, FE, MI

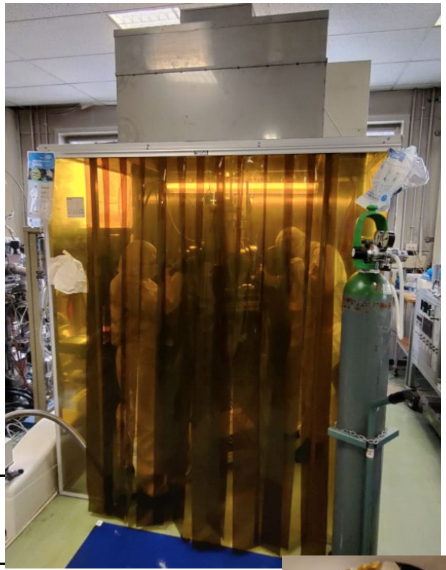
AIM

To implement Pulsed Laser Melting technology for the production of complex segmented HPGe coaxial detectors

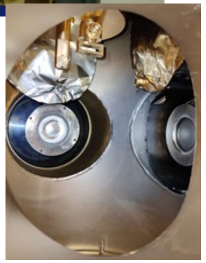
Pulsed Laser Melting (PLM)

pulse < 100 ns

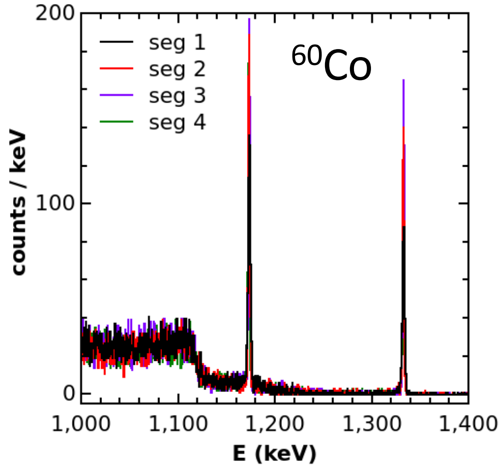


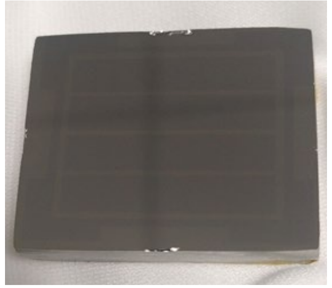


Clean sputtering deposition chamber

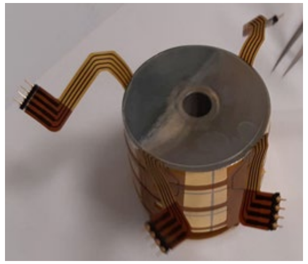


FWHM (1332.50KeV) < 1.8 KeV

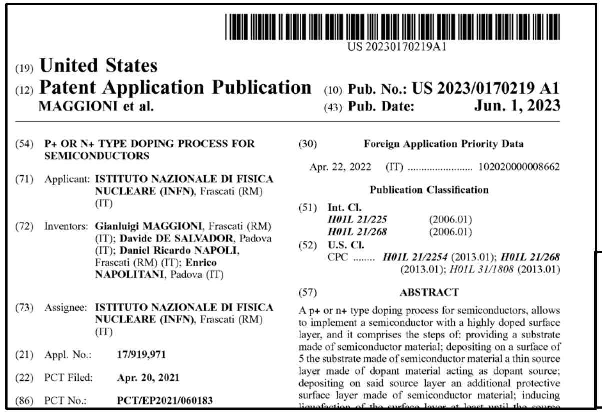




Planar segmented detector



Coaxial segmented detector



US 20230170219A1

(19) **United States**
(12) **Patent Application Publication** (10) **Pub. No.: US 2023/0170219 A1**
MAGGIONI et al. (43) **Pub. Date: Jun. 1, 2023**

(54) **P+ OR N+ TYPE DOPING PROCESS FOR SEMICONDUCTORS**

(71) Applicant: **ISTITUTO NAZIONALE DI FISICA NUCLEARE (INFN)**, Frascati (RM) (IT)

(72) Inventors: **Gianluigi MAGGIONI**, Frascati (RM) (IT); **Davide DE SALVADOR**, Padova (IT); **Daniel Ricardo NAPOLI**, Frascati (RM) (IT); **Enrico NAPOLITANI**, Padova (IT)

(73) Assignee: **ISTITUTO NAZIONALE DI FISICA NUCLEARE (INFN)**, Frascati (RM) (IT)

(21) Appl. No.: **17/919,971**

(22) PCT Filed: **Apr. 20, 2021**

(86) PCT No.: **PCT/EP2021/060183**

(30) **Foreign Application Priority Data**

Apr. 22, 2022 (IT) 102020000008662

Publication Classification

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H01L 21/268 (2006.01)

(52) **U.S. Cl.**
CPC *H01L 21/2254* (2013.01); *H01L 21/268* (2013.01); *H01L 31/1808* (2013.01)

(57) **ABSTRACT**

A p+ or n+ type doping process for semiconductors, allows to implement a semiconductor with a highly doped surface layer, and it comprises the steps of: providing a substrate made of semiconductor material; depositing on a surface of 5 the substrate made of semiconductor material a thin source layer made of dopant material acting as dopant source; depositing on said source layer an additional protective surface layer made of semiconductor material; inducing

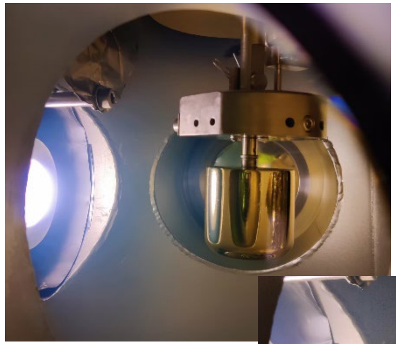
International patent application

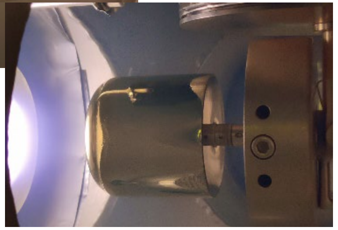
N3G - Next Generation Germanium Gamma Detectors

Doping elements: - Al, Ga (p+ dopant), Sb, P, Li (n+ dopant)
[- Ge codeposited or cap layer]

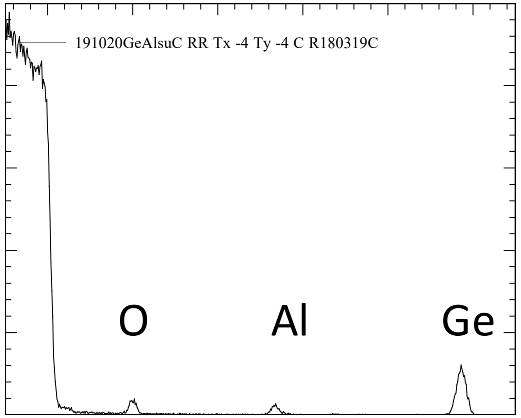
- As-deposited doping layers: characterization of film thickness, composition, presence of contaminants, thickness homogeneity (RBS, channelling RBS, NRA)
- Laser annealed layers: study of the dopant diffusion (RBS, channelling RBS, NRA)

Dopant film sputter deposition on coaxial crystal



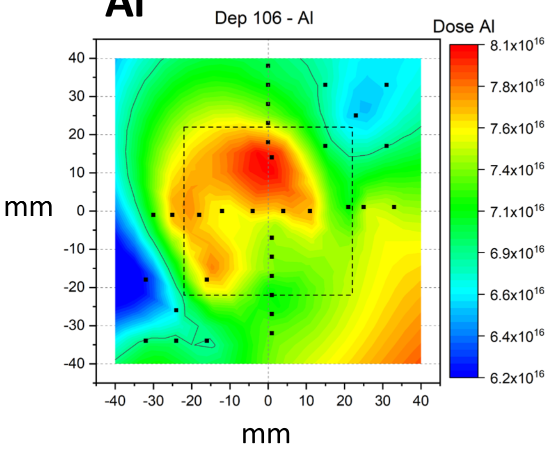


RBS

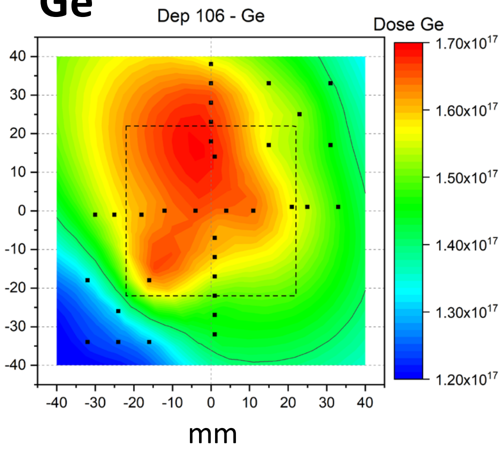


Film thickness homogeneity

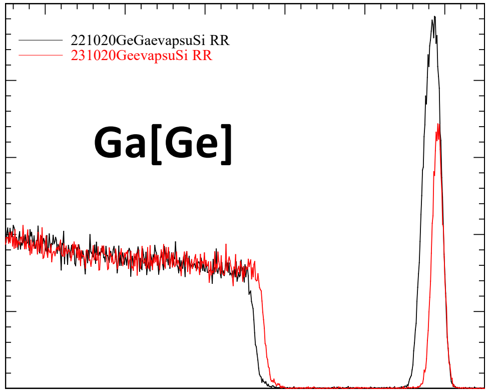
Al



Ge



RBS



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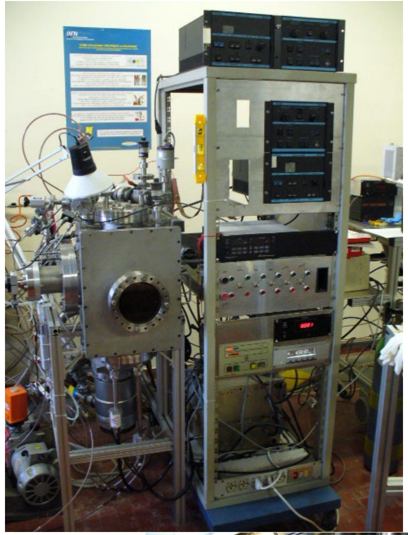
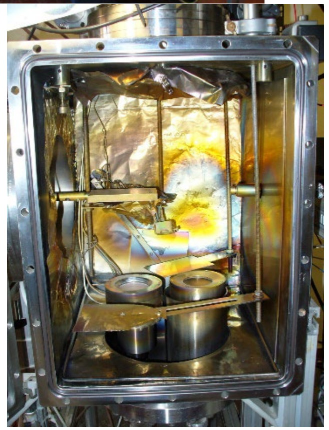
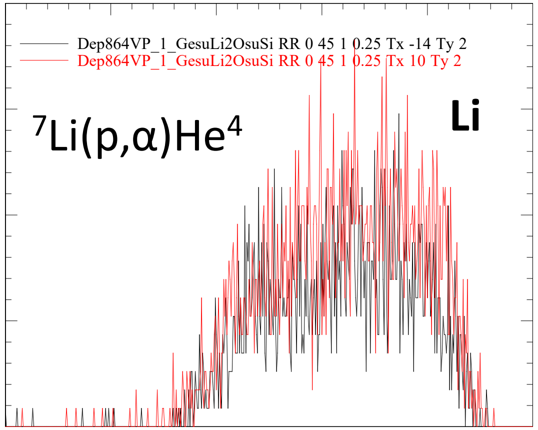
Sputtering chamber

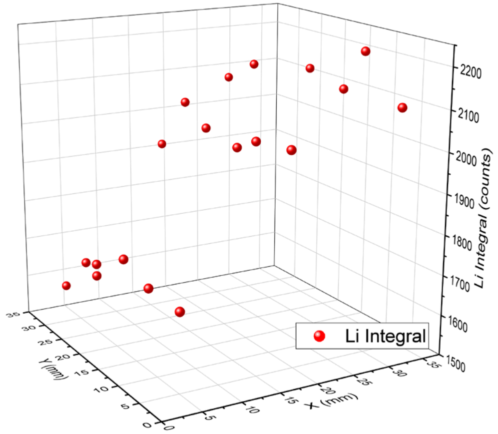




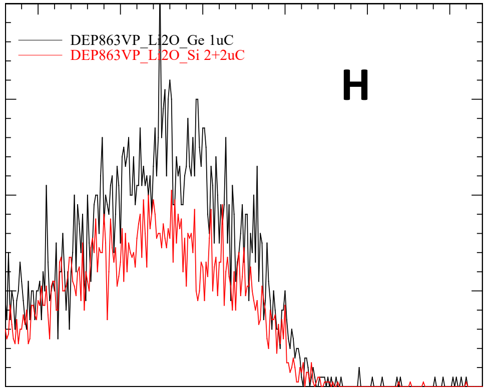
NRA



Film thickness homogeneity



ERDA



N3G - Next Generation Germanium Gamma Detectors

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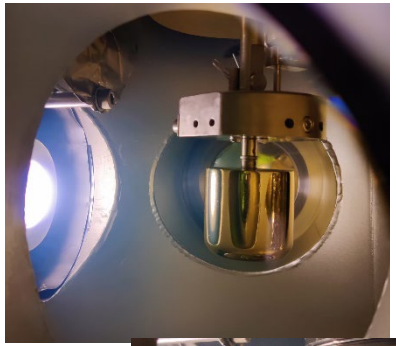

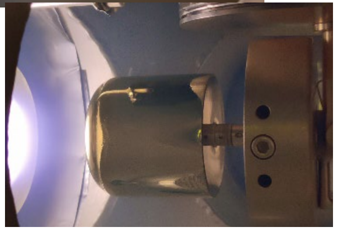

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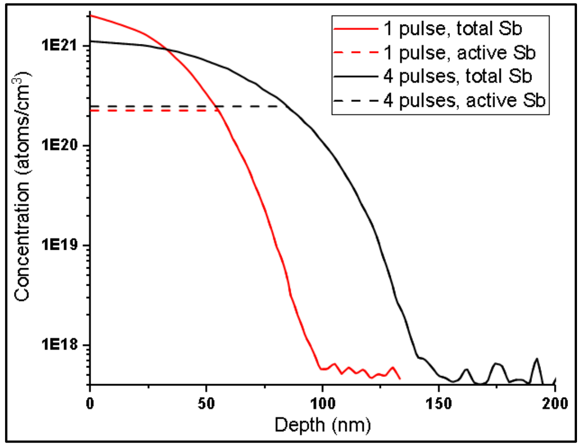
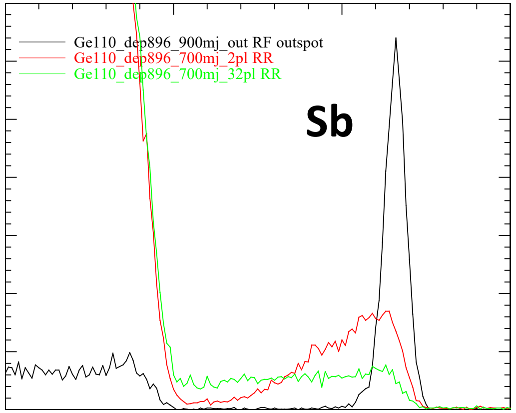
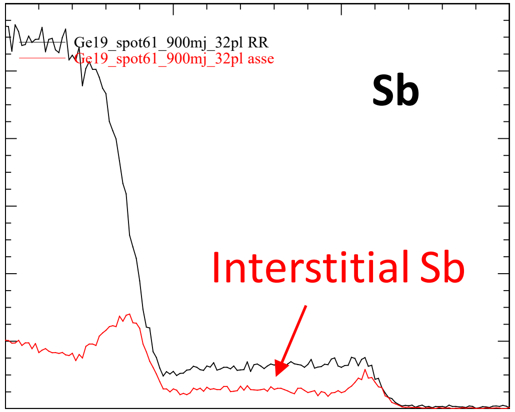
SIMS



RBS



RBS+Channelling RBS



VIRGO

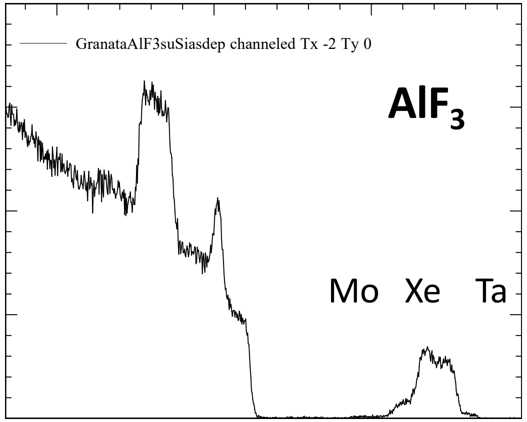
(CSN 2 INFN)

Low Noise mirror coatings for Gravitational Waves (GW) Interferometers

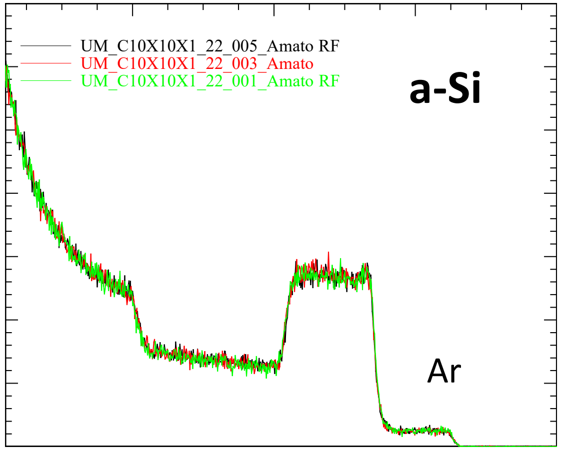
- <u>Deposition and characterization of a-Si and SiC</u>: film thickness, composition, presence of contaminants (RBS, ERDA)
- <u>Characterization of a-Si, AlF_3, SiO_2, Si_3N_4 e $TiGe_xO_y$ films produced in the collaboration</u>: film thickness, composition, presence of contaminants (RBS, channeling RBS, ERDA)

Sputtering chamber ES

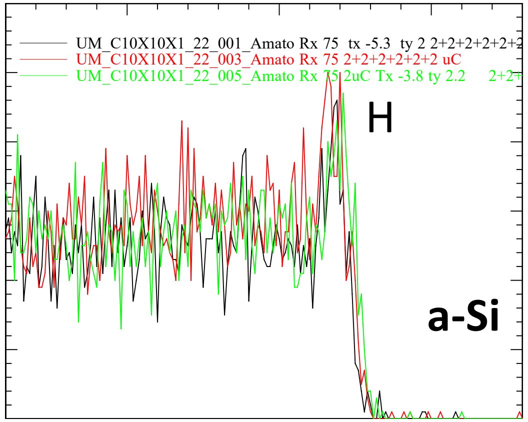
Channelling RBS



RBS



ERDA



SiC-coated sample

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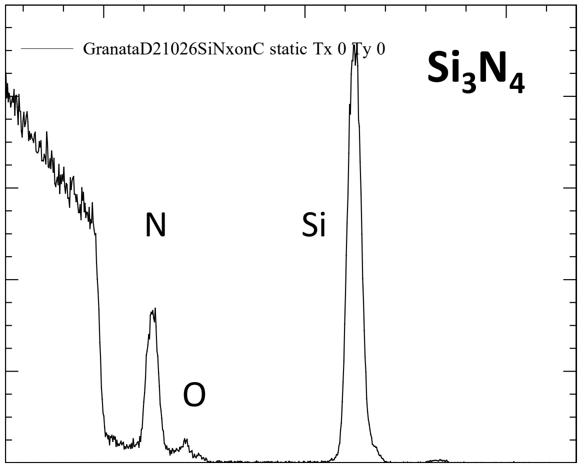
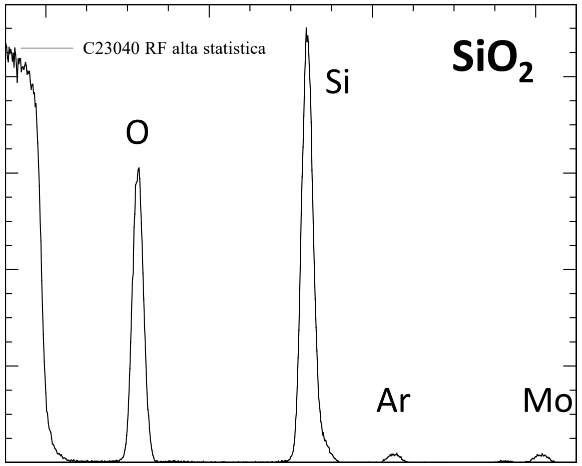
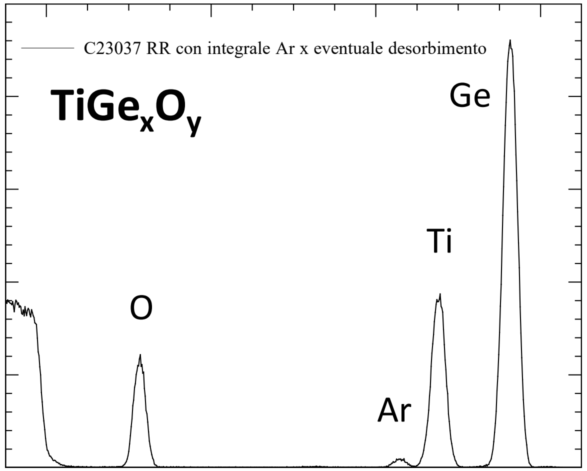
RBS



RBS



RBS



OREO

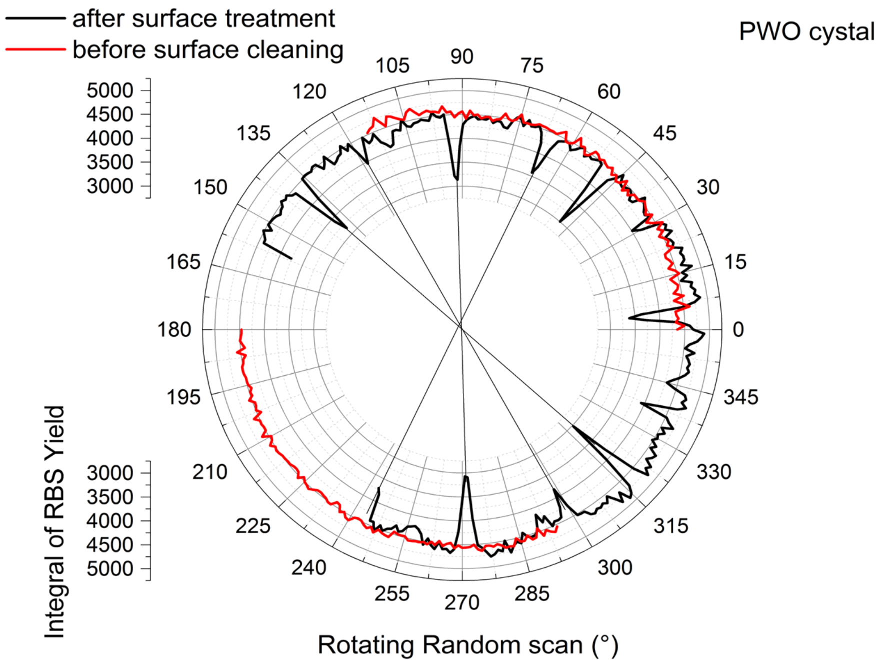
(CSN 5 INFN)

PI: L. Bandiera (FE)

Research Units: Fe, LNL, MIB

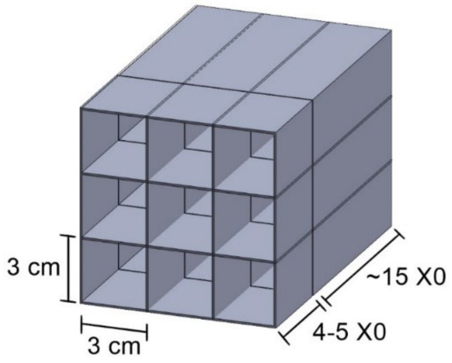
Ultra-compact calorimeters for ultra-relativistic particles based on oriented crystals

- **Ultrafast PWO scintillator (PWO-UF*)**: good crystallographic properties; scintillation decay with a time constant of 640 ps at a light yield of 7 phe/MeV and a high radiation tolerance to the electromagnetic component of ionizing radiation. *It is considered a candidate for dual readout of scintillation and Cherenkov photons in electromagnetic calorimetry at future collider*.



- Crystal quality TEST by XRD (FE), **RBS-Channeling (AN & CN) (LNL),** photoelastic conoscopic method (FE)

- Prototype construction: realization of a 3x3x2 matrix of oriented PWO-UF crystals. Mechanics and precise mounting (FE), SiPM based readout system (MI), **with the development of a technology applicable to large calorimeters**;



BEYOND

PI: Ilaria Fratelli, INFN-BO

Research Units: BO, LNL, PD

– flexiBlE hYbrid neutrON Detectors –

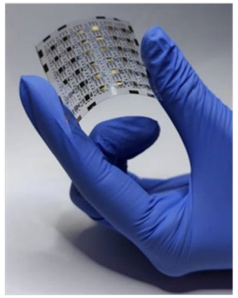
INFN - Grant Giovani Ricercatori e Ricercatrici

CSN 5 INFN – 2023/24

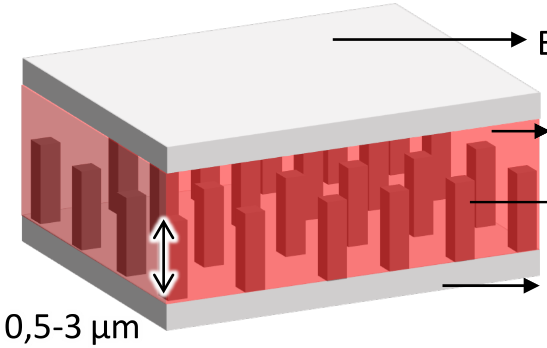
AIM

Realization and characterization of flexible and scalable, large area devices based on perovskite (PVK) and organic materials (OP) for the detection of thermal and fast neutrons

Flexible detectors

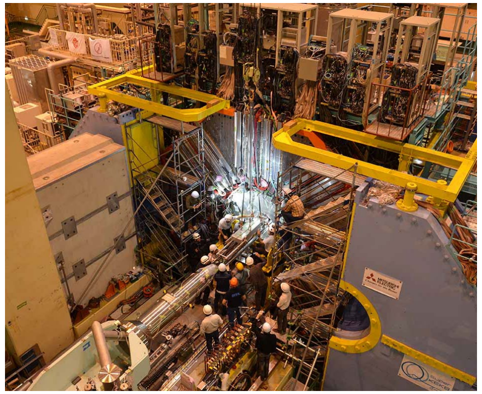


TND THERMAL NEUTRON DETECTION

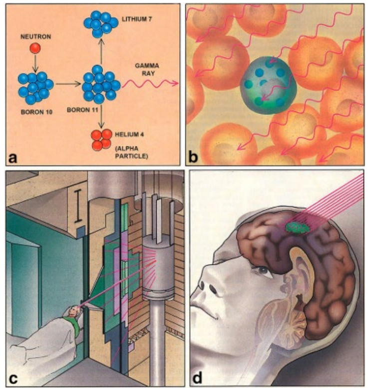


Applications

AMBIENT MONITOR

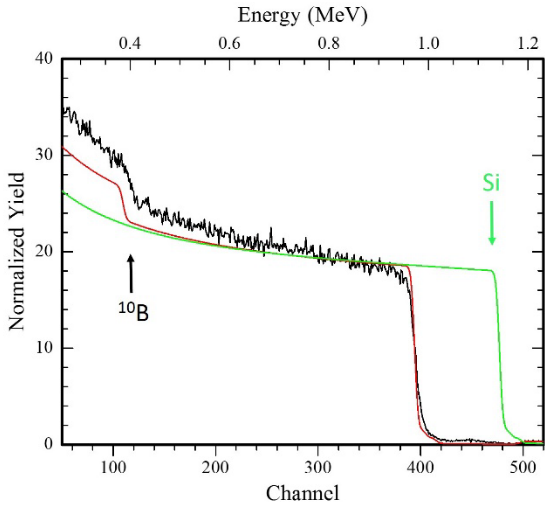


PERSONAL DOSIMETRY



Deposition and characterization of ^{10}B and $^{10}B_4C$: film thickness, composition, presence of contaminants (RBS)

RBS



PLUS Planetary Ultraviolet Spectrometer

Consiglio Nazionale delle Ricerche

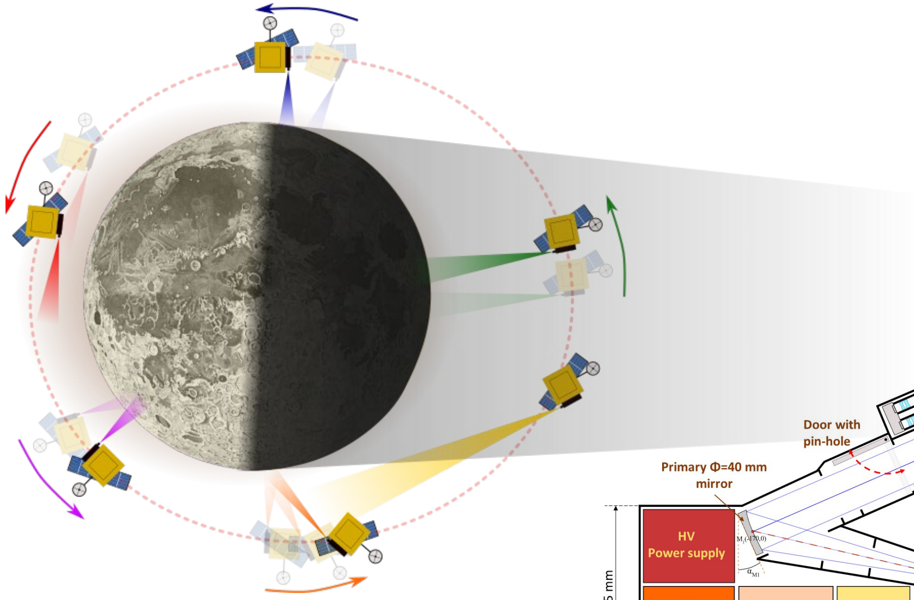
POLITECNICO MILANO 1863

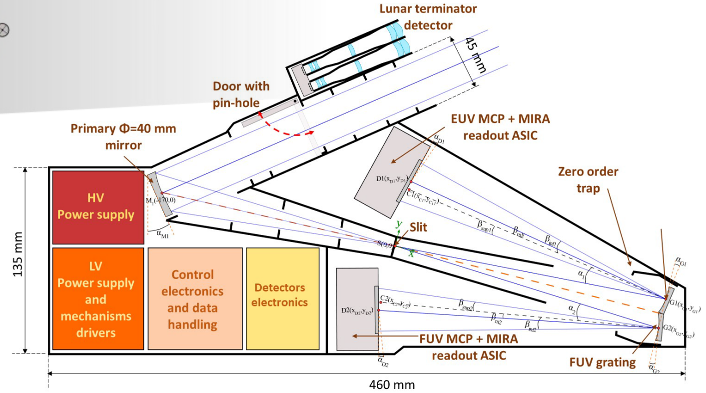
INAF ISTITUTO NAZIONALE DI ASTROFISICA NATIONAL INSTITUTE FOR ASTROPHYSICS

Università degli Studi di Padova

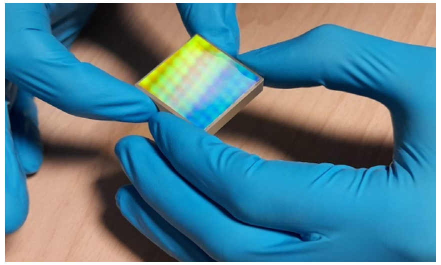
AIM

Spectrometer for observations in the far and extreme ultraviolet (FUV/EUV) region to probe the lunar exosphere

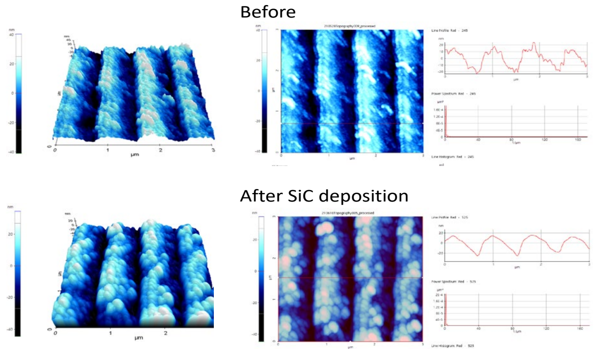




UV Grating



SiC thickness: 70 nm (RBS and profilomter).
Grooves density: 1190 lines/mm (AFM)
Average blaze angle: 4.55° (AFM)



OUR CONTRIBUTION

Deposition of SiC_x films on optical gratings to increase their reflectivity

https://doi.org/10.1117/12.2596137

PLUS Planetary Ultraviolet Spectrometer

Consiglio Nazionale delle Ricerche

POLITECNICO MILANO 1863

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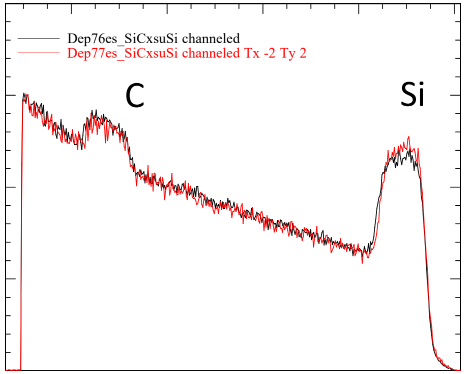
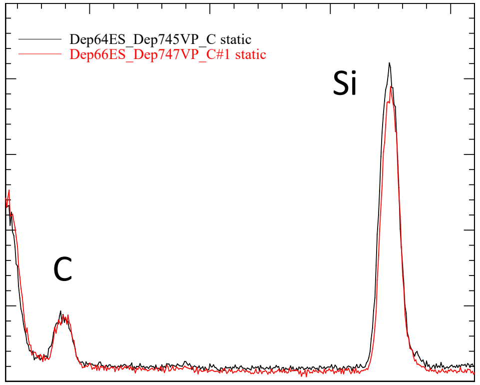
Sputtering chamber ES

SiC target

RBS



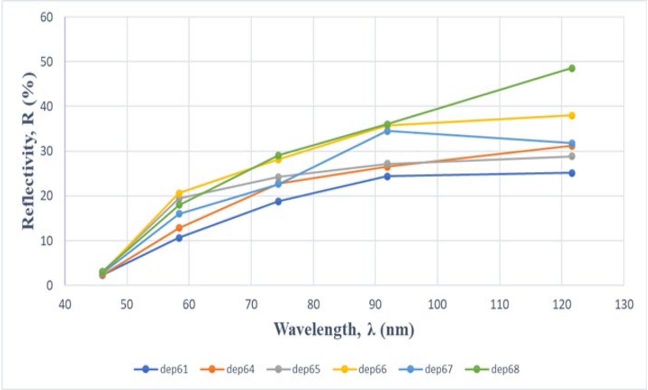
RBS



Film stoichiometry

Deposition nr.	Nr. of Si pieces	Dose Si ($x10^{15}$ at/cm^2)	Dose C ($x10^{15}$ at/cm^2)	Si/C
56	0			0.74
64	4	297.3	259	1.15
65	3	281	274	1.04
66	2	266.5	255	1.07

UV Reflectance of SiC_x films

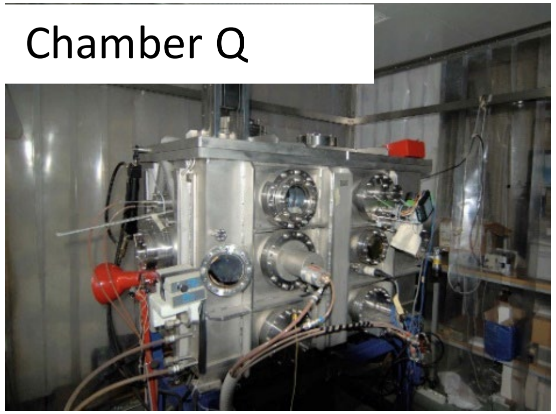


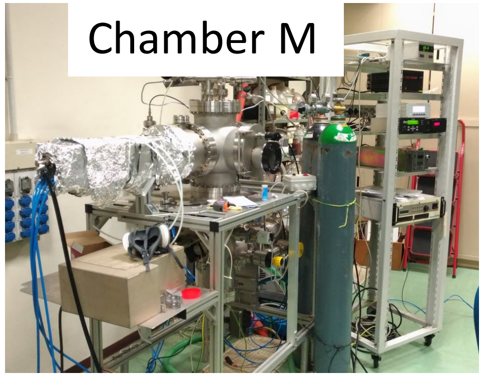
LUNA3 (CSN 3)

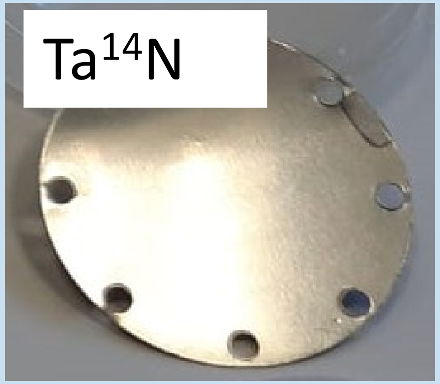
PI: G. Imbriani (NA)

Research Units: BA, GE, LNGS, LNL, MI, NA, PD, ROMA1, TO

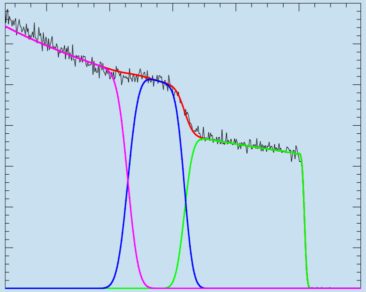
- **Nuclear target synthesis (Nitrides, Oxides and Hydride)** with reactive magnetron sputtering technologies using also enriched gasses
- **Engineered thick coating as substrate**, high purity and low contaminants content target substrate development for beam induced background reduction
- **Characterization** of targets and thick coatings by IBA, SEM-EDS, AFM and other techniques

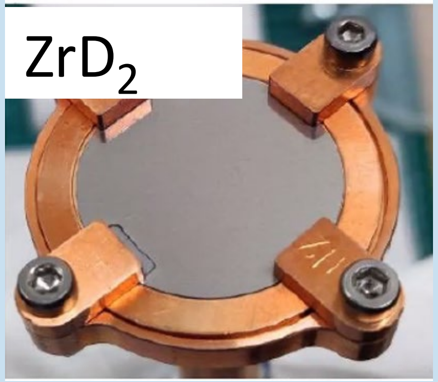




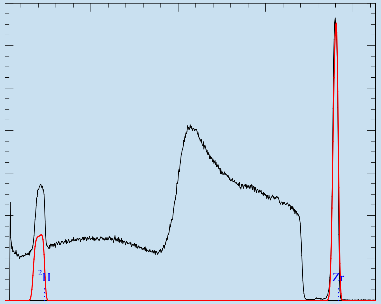


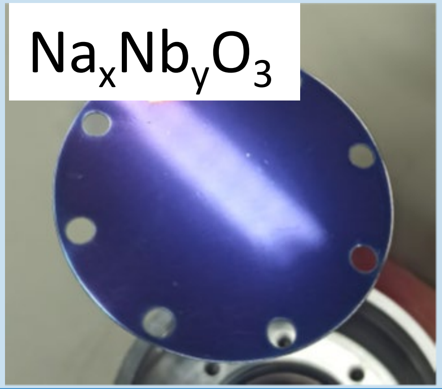
$^{14}N(p,\gamma)^{15}O$ experiment, the first shift is ongoing at Bellotti facility (LNGS)





2H(p,γ)3He reaction above 300 keV at Felsenkeller using ZrD2 targets





Sodium Niobate target deposited on tantalum backing for $^{23}Na(p,\alpha)^{20}Ne$ experiment

First test performered at LUNA400 facility (LNGS) in June 2023

Deposition process under investigation

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THANK YOU!