The 8th International Conference
Charged & Neutral Particles Channeling Phenomena
CHANNELING 2018
September 23-28, 2018 Ischia (NA), Italy

INFN TTLab

VNIVERSITÀ DEGLI·STVDI DI·FERRARA

BIOMECCANICA

COMECER

TROPIC

Crystalline Target for Radioisotope Production via Anti-Channeling

G. Germogli, L. Bacci, E. Bagli, L. Bandiera, R. Camattari, S. M. Carturan, D. Casotti, D. De Salvador, F. Evangelisti, G. Guidi, V. Guidi, G. Maggioni, A. Mazzolari, M. Romagnoni, A. Sytov

Unione europea
Fondo europeo di sviluppo regionale

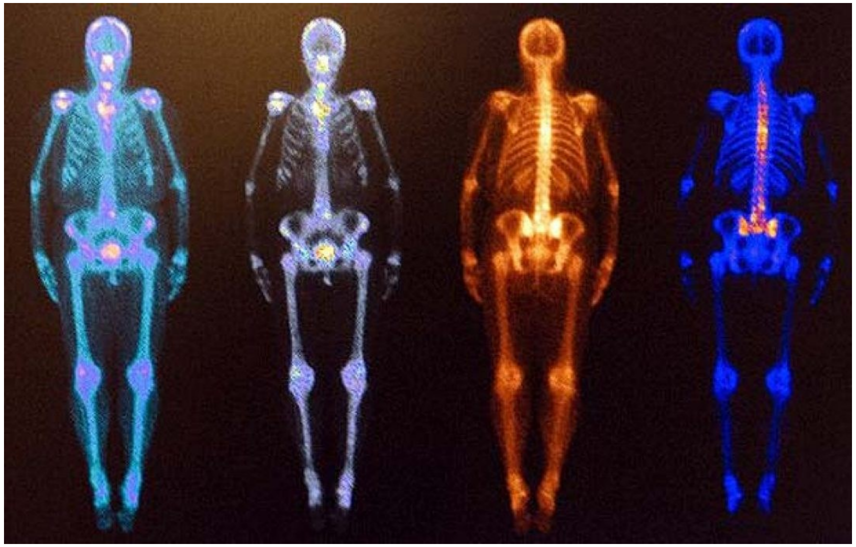
Regione Emilia-Romagna

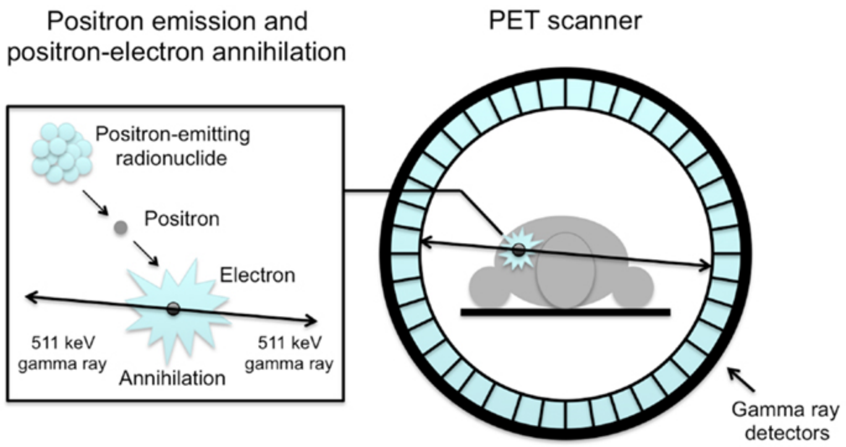
Outline

- Radionuclide productions in accelerators
- A benchmank for simulations: the GEKO project
- Searching for a crystalline target
- Validation in laboratory environment

Radioisotopes in Medicine

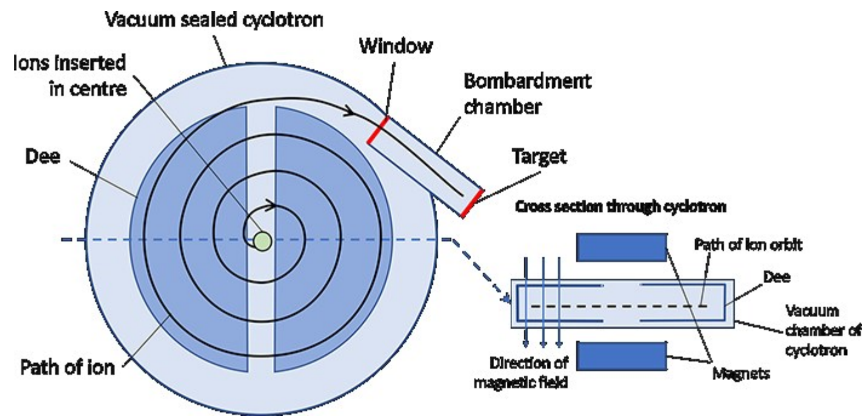
- Nuclear medicine uses radiation to provide diagnostic information about the functioning of a person's specific organs (SPECT, PET), or to treat them (Brachytherapy, target-therapy), especially for cancer. Diagnostic procedures using radioisotopes are now routine.
- Over 40 million nuclear medicine procedures are performed each year, and demand for radioisotopes is increasing at up to 5% annually.
- Radioisotopes for nuclear medicine are generated through various methods, i.e. particle accelerators, reactors facilities





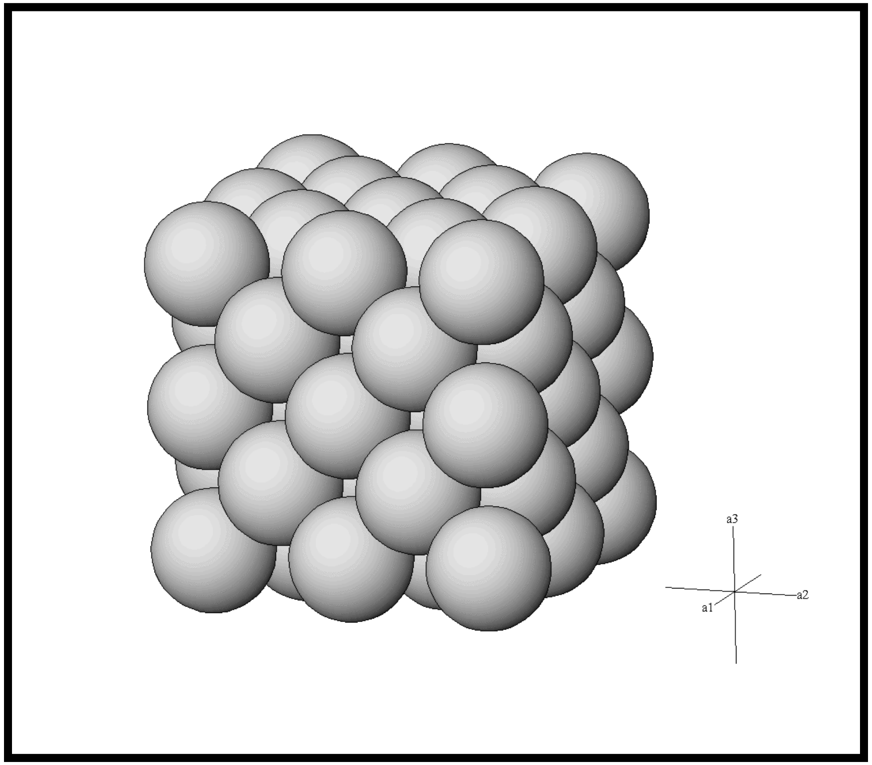
Accelerator produced radionuclides

- Current scenario:
  - Strong reduction of the production of Mo-99 (i.e. the parent daughter of TC-99m) in nuclear reactors
- Advantages of accelerators:
  - high specific activities can be obtained through charged particle induced reactions
  - few radioisotopic impurities by selecting the energy window
  - small amount of radioactive waste generated
  - access to accelerators is much easier than to reactors
- Major drawback:
  - in some cases an enriched (and expensive) target material must be used
  - <u>The overall production cost is still 3 to 10 times with respect to nuclear reactors</u>



Goal of TROPIC project

- Aim:
  - enhancement of the radio-isotopes production yield through cyclotron with minor modification of current instrumentations.
- How:
  - usage of microscopically ordered structures to force the particles to interact more frequently with nuclei.



History

- **2014/2015, collaboration with COMECER SpA:**
  - Anti-channeling idea
    - "*Exploiting Channeling of Charged Particles for the Enhancement of the Ni64->Cu64 Reaction Yield*", 7 June 2015, Society of Nuclear Medicine and Molecular Imaging Meeting 2015, Baltimore (US)

- **2016/2017, INFN-GeCO (Geant4 Crystal Objects) project:**
  - Integration of channeling simulations into Geant4
  - Anti-channeling experiments at INFN-Legnaro Laboratories
    - "*Crystalline targets for the enhancement of the nuclear interaction yield*", 15 November 2016, International Nuclear Target Development Society Meeting 2016, Cape Town (South Africa)
    - "*Experimental measurement of the enhancement of the nuclear interaction yield with crystalline targets*", 13 June 2017, International Conference on Applications of Nuclear Techniques, Crete (Greece)

- **2017/2019, POR-FESR TROPIC project**
  - Development of a target prototype for the production of radioisotopes for medical interest, to be tested in laboratory environment (TRL4) and in production environment (TRL5)

INFN TTLab

Radioisotope for medicine

- Radioactive isotopes used for diagnosys, therapy, or both (theragnostic)
- Lifetime of the order of biologial processes (few hours/days)
- Possibility to fix them to a functional molecule
- To be produced with a good yield by using particles at energies available at commercial cyclotron (~15-20 MeV)

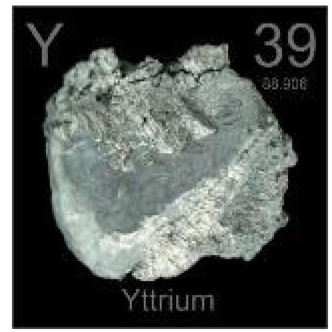
Target	Initial Isotope	Final Isotope
^{89}Y	^{89}Y	^{89}Zr
TeO_2	^{124}Te	^{124}I
TeO_2	^{123}Te	^{123}I
$SrCO_3$	^{86}Sr	^{86}Y
^{64}Ni	^{64}Ni	^{64}Cu
^{61}Ni	^{61}Ni	^{61}Cu
^{111}Cd	^{111}Cd	^{111}In
$CaCo_3$	^{44}Ca	^{44}Sc
^{67}Zn	^{67}Zn	^{67}Ga
^{68}Zn	^{68}Zn	^{68}Ga

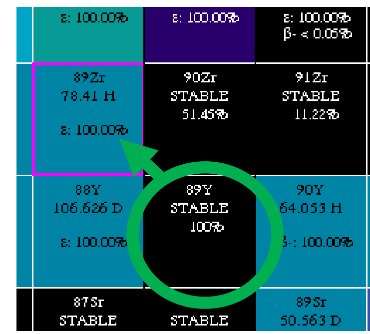
TROPIC

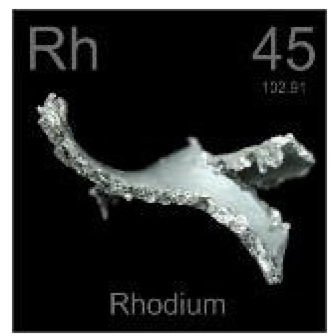
How to deal with crystals?

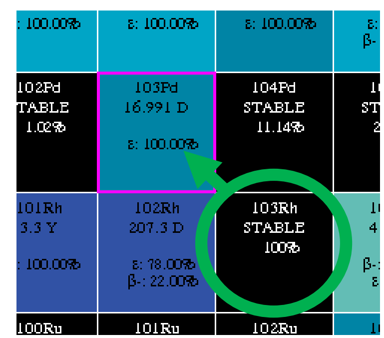
- Isotopic purity needed to obtain a good yield of production without contaminants.
- A crystalline quality sufficiently high to observe the anti-channeling effect

- **Yttrium** and **Rhodium** have only one isotope, they can be found as crystalline material, and are useful materials for nuclear medicine:
  - Pros: No need to be enriched
  - Cons: to be found as a pure monocrystal (expensive/not trivial)
- First Y (2x2x0,5 mm) and Rh (3x3x0,5mm) already purchased, characterized and polished are the first candidates as a target.



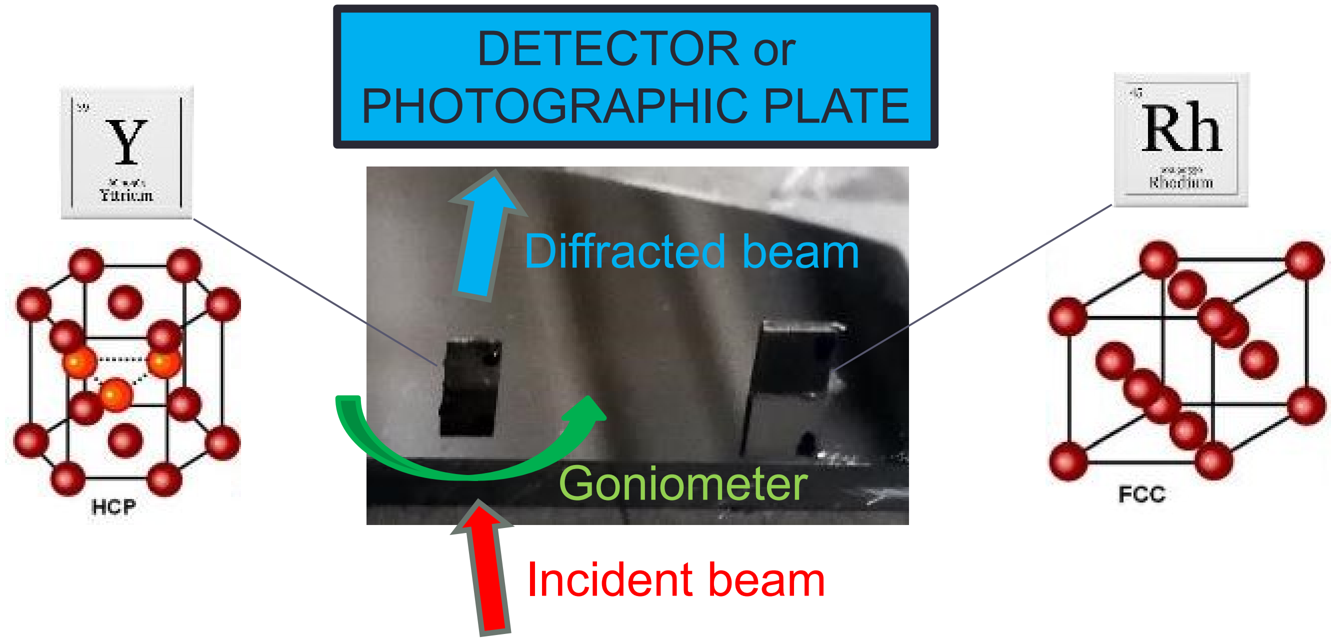






Crystal Bulk Characterization @ ESRF ID11

Photon energy	140 keV
divergence	Negligible
DE/E	10^{-3}
Beam dimension	From 50x50 to 500x500 micron



Y (0001)

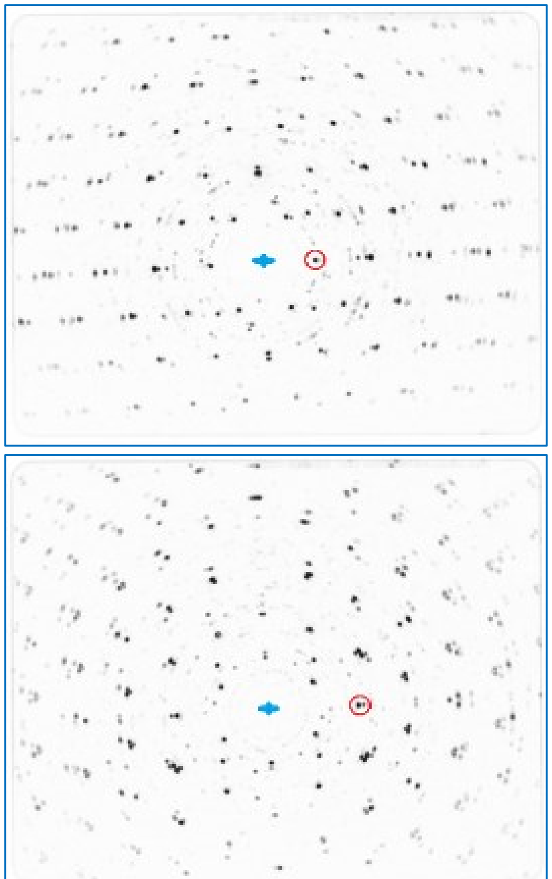
Sample dimensions	2x2x0,5 mm
Traversed thickness	0,5 mm

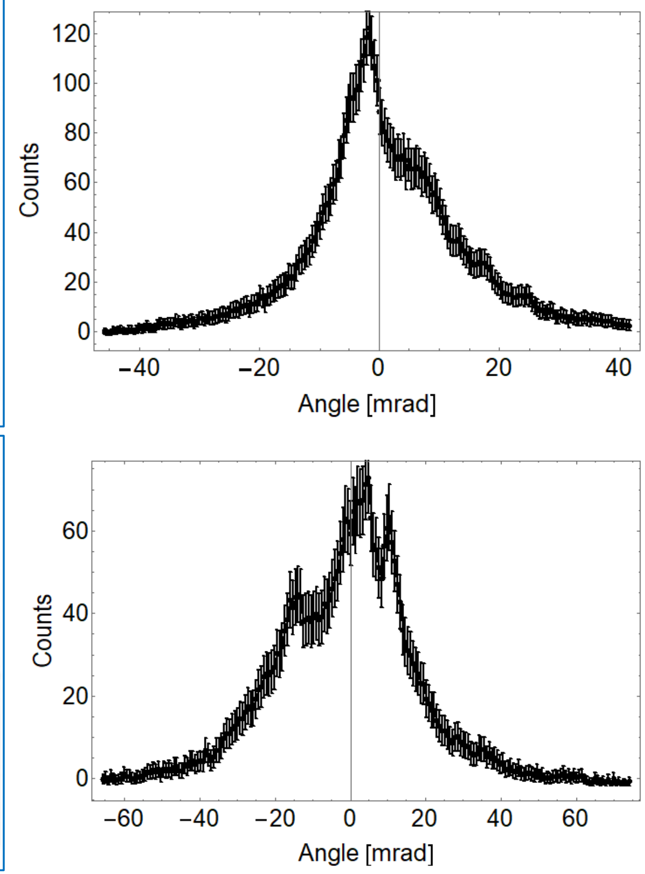
Photographic plate

Rocking curve on selected point

Horizontal direction

Vertical direction

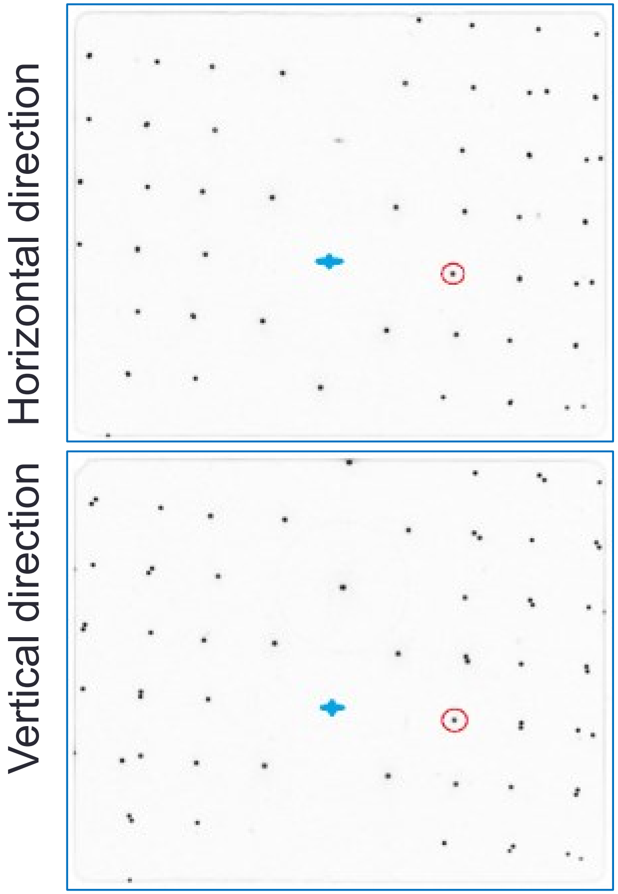




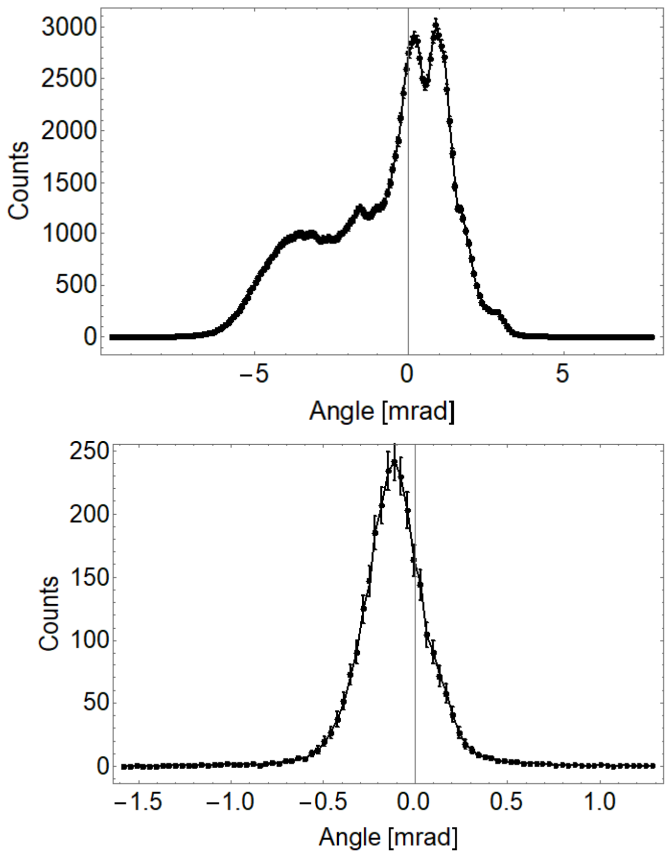
Rh (100)

Sample dimensions	3x3x0,5 mm
Traversed thickness	0,5 mm

Photographic plate



Rocking curve on selected point

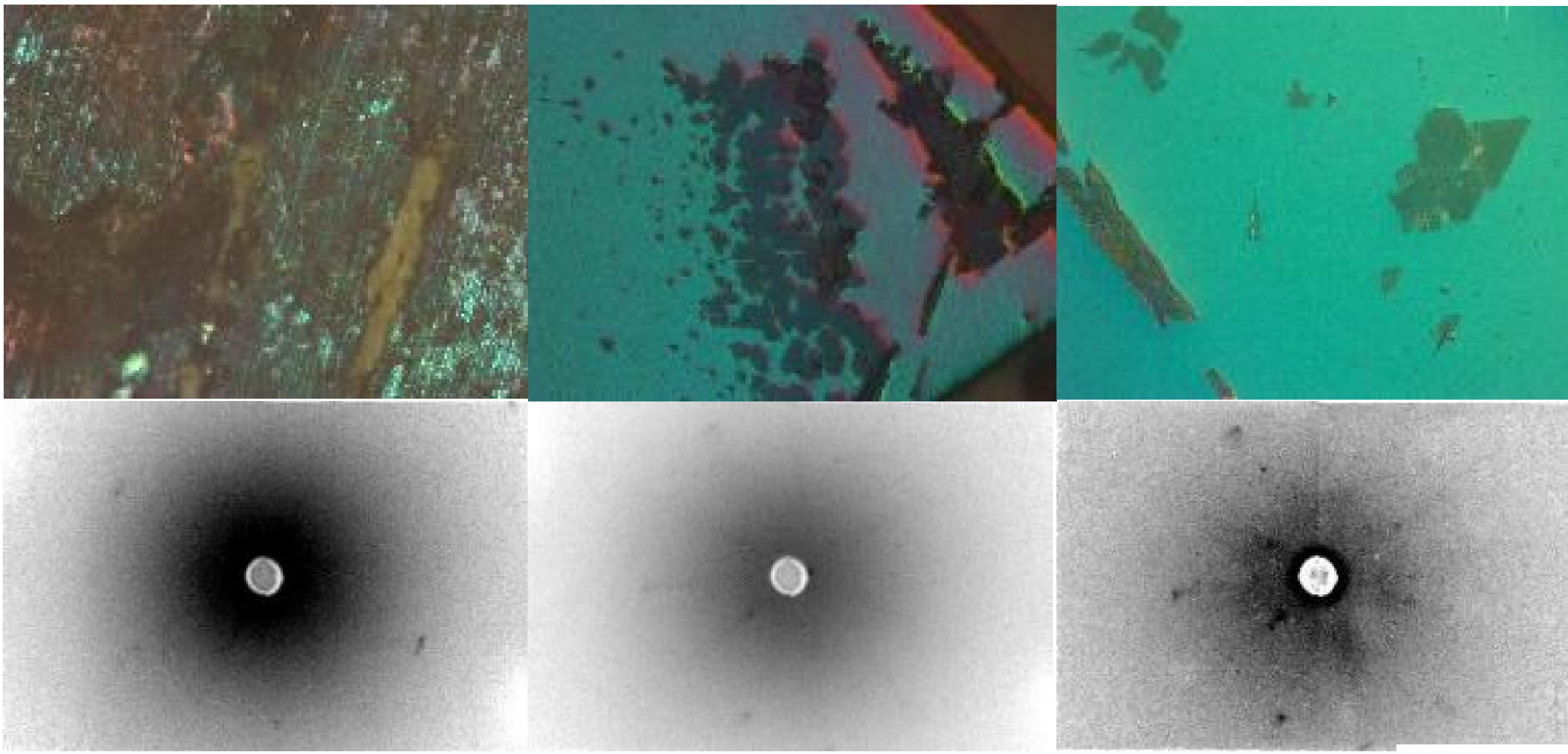


Surface realignment and polishing
Surface Preparation Laboratory (Netherlands)

Yttrium as received | after 6 µm polishing | final result

microscope images

Laue diffraction

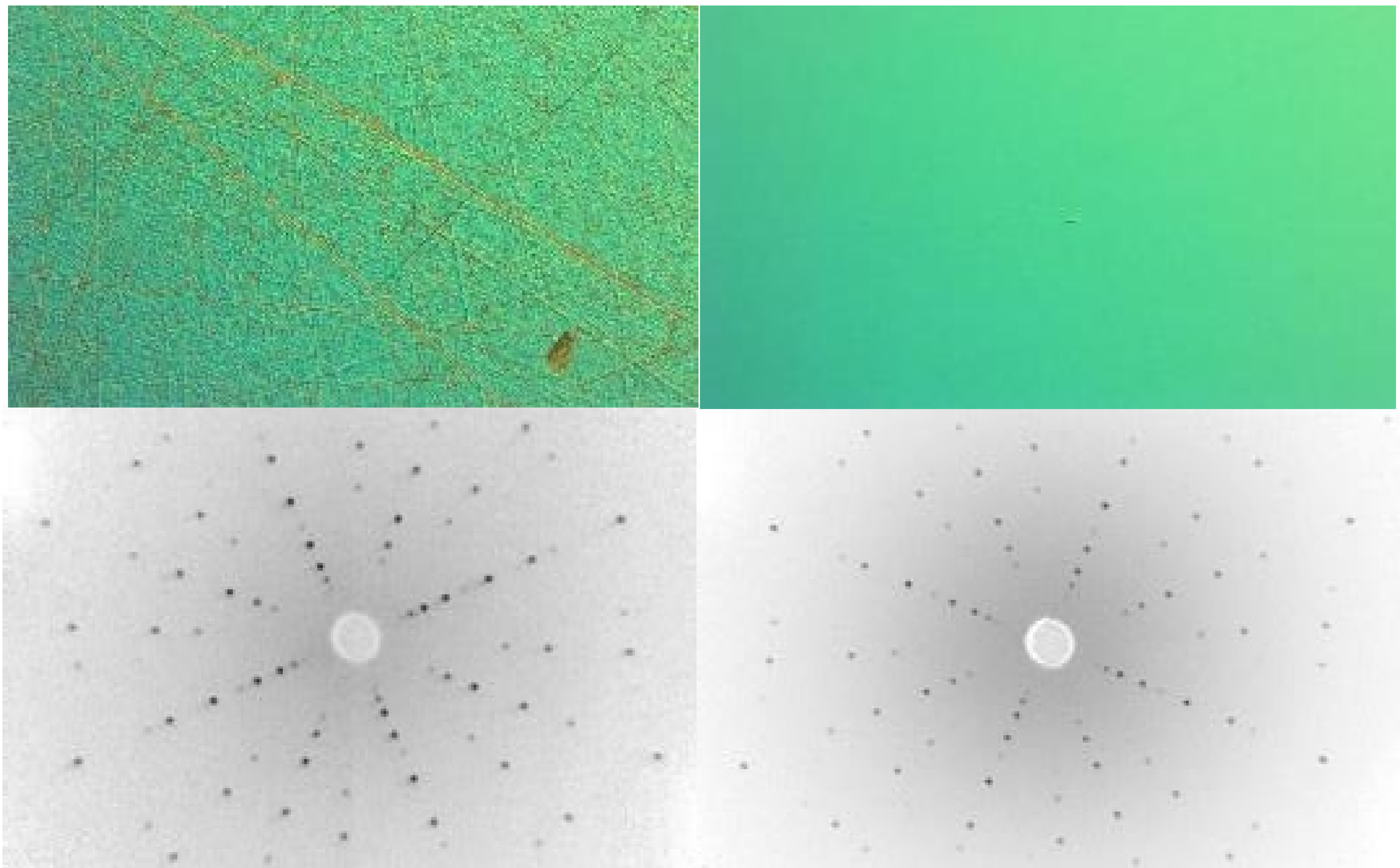


Surface realignment and polishing
Surface preparation laboratory (Netherlands)

Rhodium as received | after polishing

microscope images

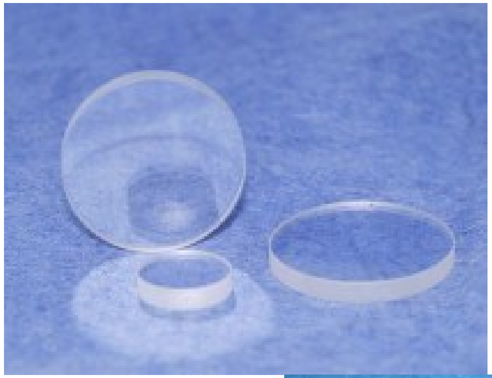
Laue diffraction



Alternative ionic/oxide crystals

- KBr

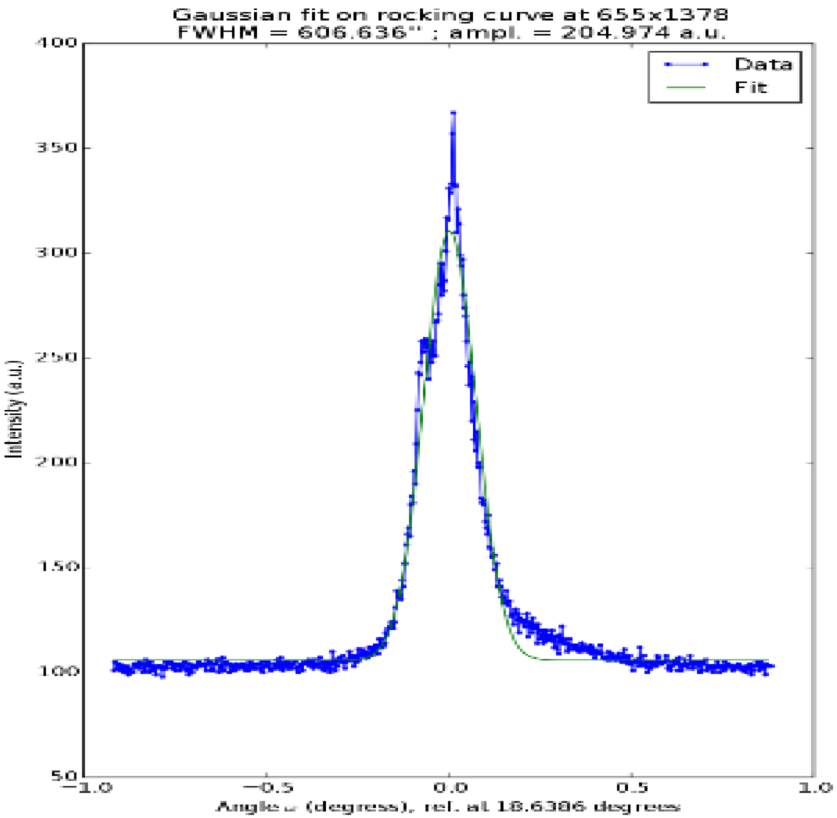
- YAG, $YAlO_3$, YVO_4

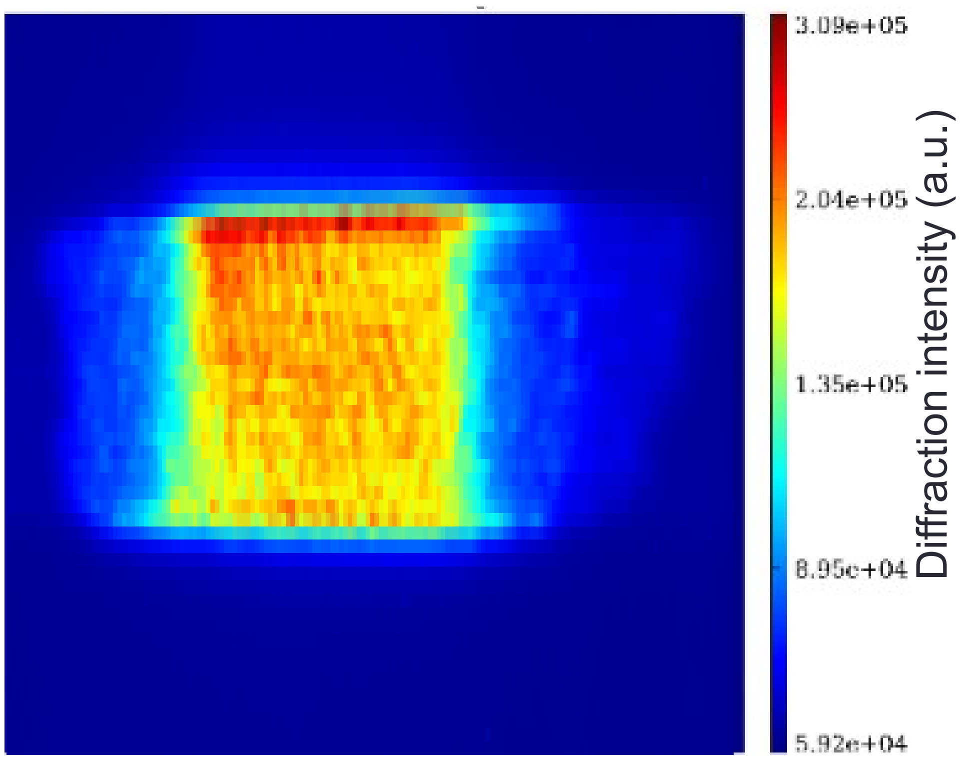


Crystal surface @ ESRF BM05

- Rh (100) - PRELIMINARY

Photon energy	20 keV
Divergence	Negligible
Beam dimension	10x10 mm

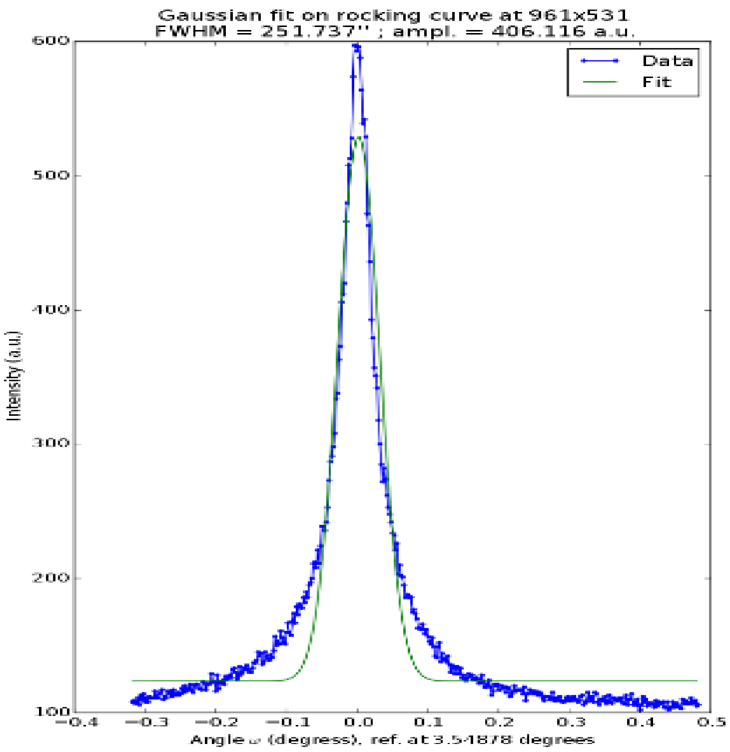


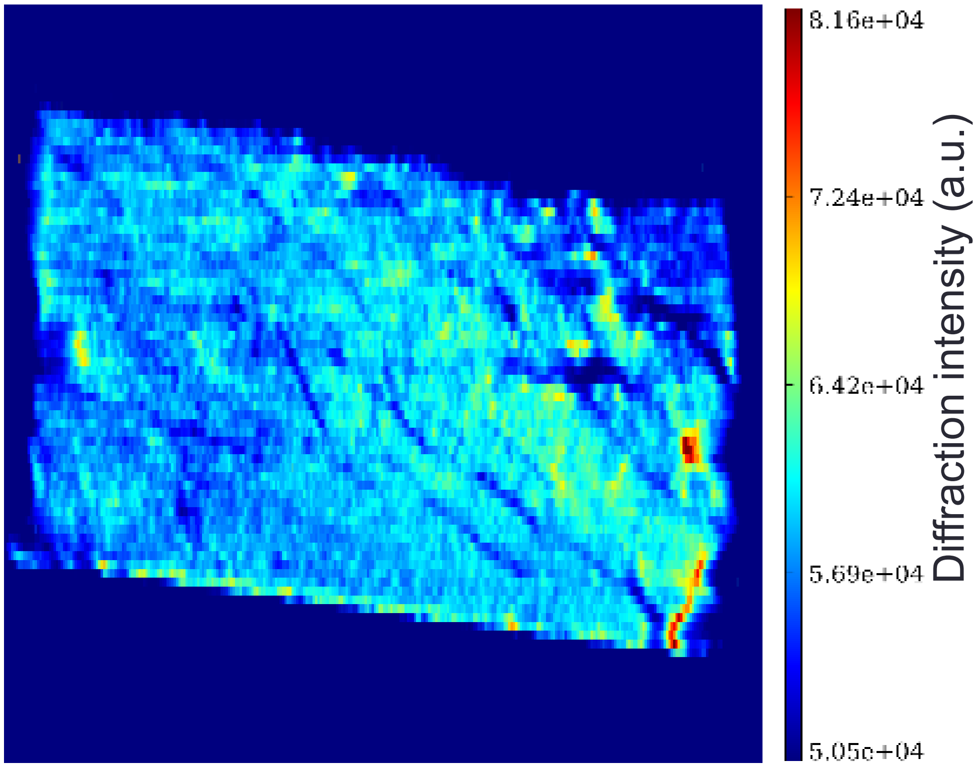


Crystal surface @ ESRF BM05

- KBr (110) - PRELIMINARY

Photon energy	20 keV
divergence	Negligible
Beam dimension	10x10 mm

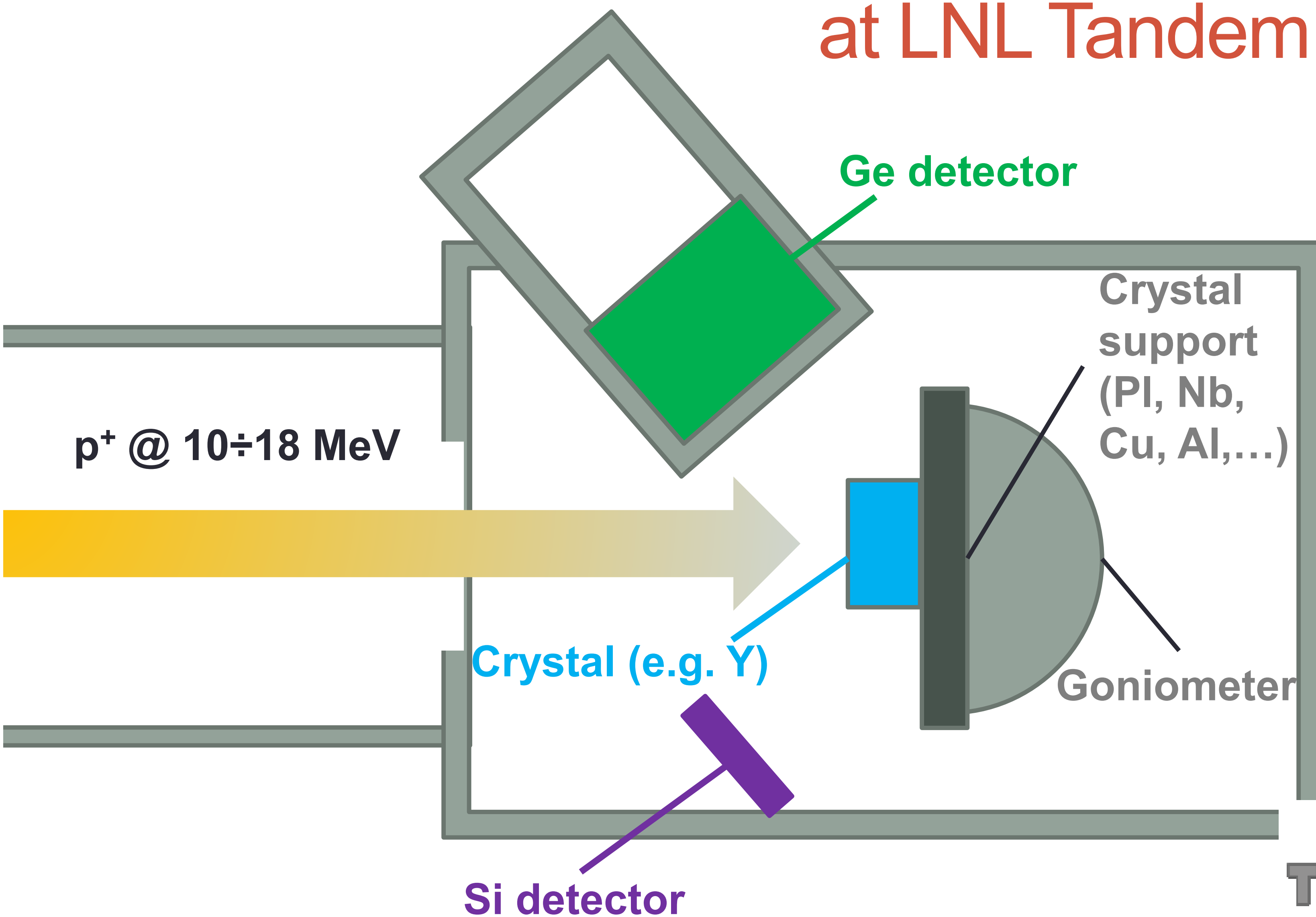


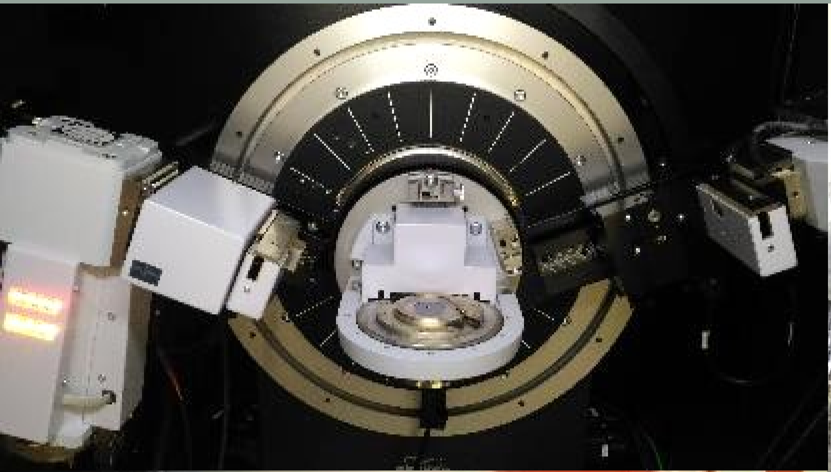


Tests with proton beam

- Experiments can be carried out in accelerators facilities
- The proposal for the TROPIC experiment at the Tandem accelerator of the INFN Legnaro National Laboratories, PD, Italy was **accepted by the USIP**. This represents the *"validation in lab"* (TRL4)

Setup scheme for laboratory validation at LNL Tandem





Thank you for your attention !