Unione europea
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Regione Emilia-Romagna

TROPIC

Target for RadioisOtope Production
via antI-Channeling

INFN
TTLab

VNIVERSITÀ DEGLI·STVDI DI·FERRARA

BIOMECCANICA
Lavorazioni meccaniche di precisione

COMECER GROUP
ISOLATION TECHNOLOGY SOLUTIONS

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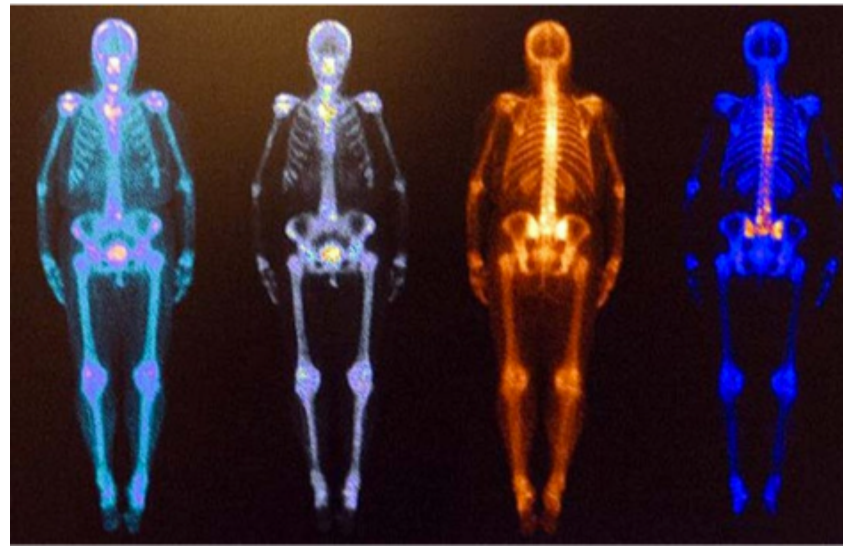
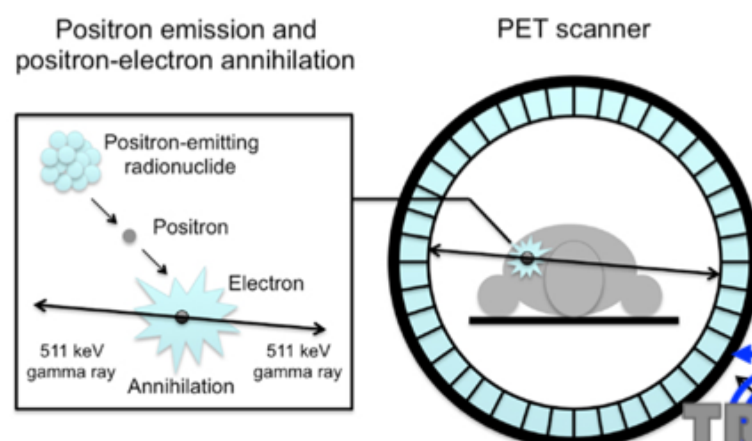
Radioisotopes in Medicine

- 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

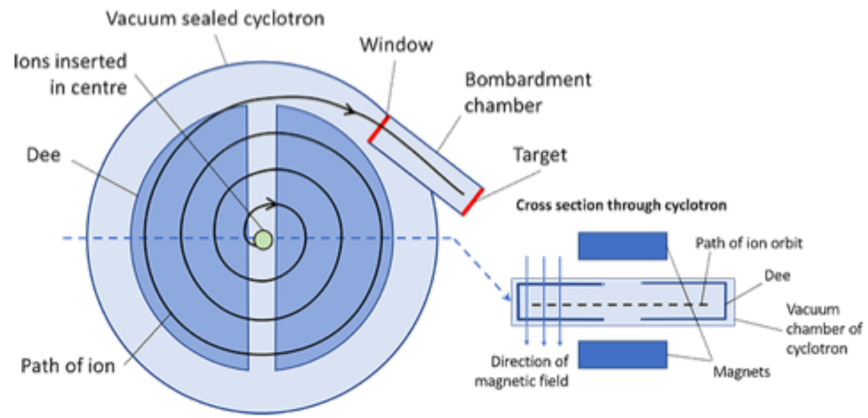




Accelerator produced radionuclides

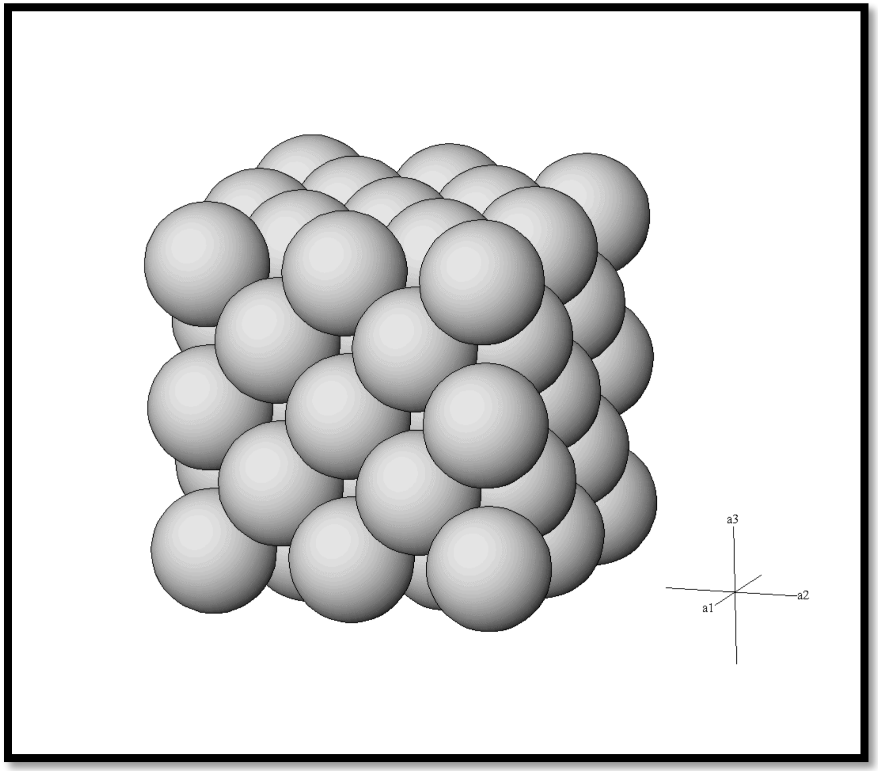
- Advantages:
  - high specific activities can be obtained through charged particle induced reactions
  - few radioisotopic impurities by selecting the energy window
  - small amount of radioactive waste generated
  - access to accelerators is much easier than to reactors

- Major drawback:
  - in some cases an enriched (and expensive) target material must be used



Introduction

- State of the art:
  - the availability of radio-isotopes is fundamental for diagnostic and therapeutic purposes in nuclear medicine.
- Aim:
  - enhancement of the radio-isotopes production yield through cyclotron with minor modification of current instrumentations.
- This project:
  - usage of microscopically ordered structures to force the particles to interact more frequently with nuclei.



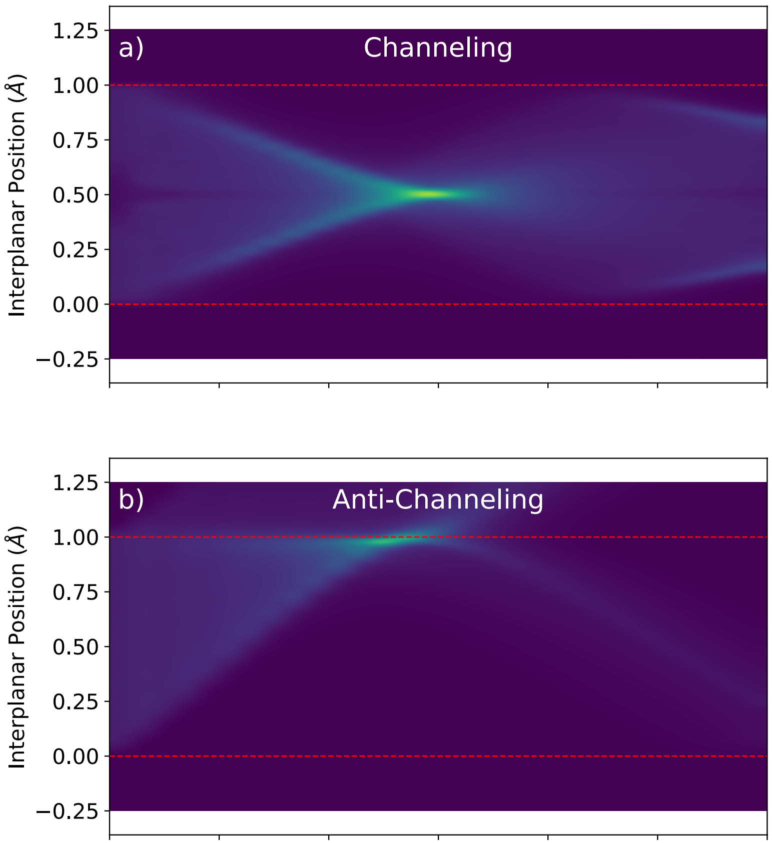
History

- **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**

Anti-Channeling Effect

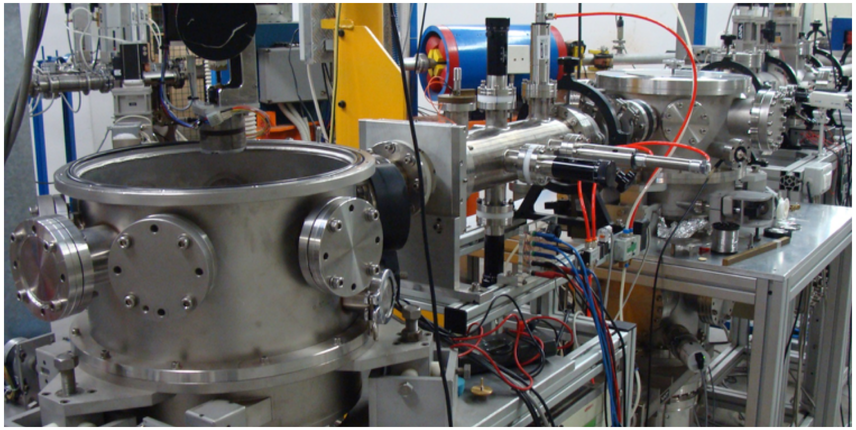


- Figures show the Geant4 simulated trajectories of channeled and anti-channeled 655 keV protons impinging on a Si (110) crystal.
- The particles with the angle close to the critical angle for channeling cross the crystal planes (red dashed line) and impinge close to atomic nuclei.
- At the opposite, a particle which enters parallel to the crystalline planes, bounces between them, in a region without nuclei.

RBS-Channeling at AN2000 INFN-LNL

AN2000 is an electrostatic-type accelerator with a maximum voltage terminal of 2 MV. At the RBS-Channeling line of AN2000 (CN) a high resolution goniometer (0.01° ~ 0.2 mrad) is present, which allows to align the crystal planes and axes with respect to the incoming beam within the critical channeling angle.

D. De Salvador



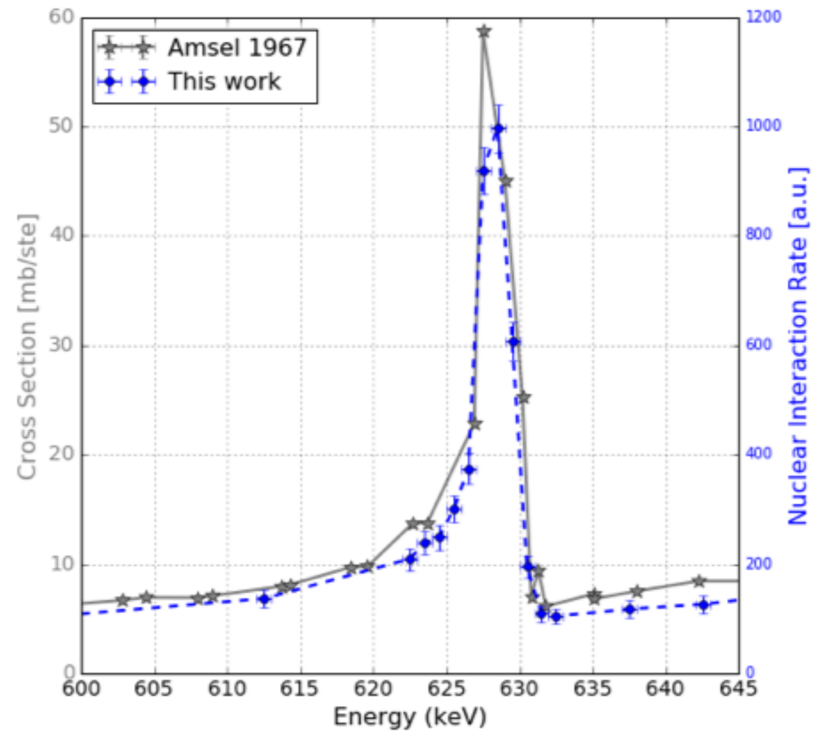
- Two Silicon detectors are mounted in the chamber, one for the RBS and one for the nuclear resonance analysis (NRA), to allows for the simultaneous measurement of the two quantities. Optionallym a gamma-ray detector can be mounted instead of the NRA detector.

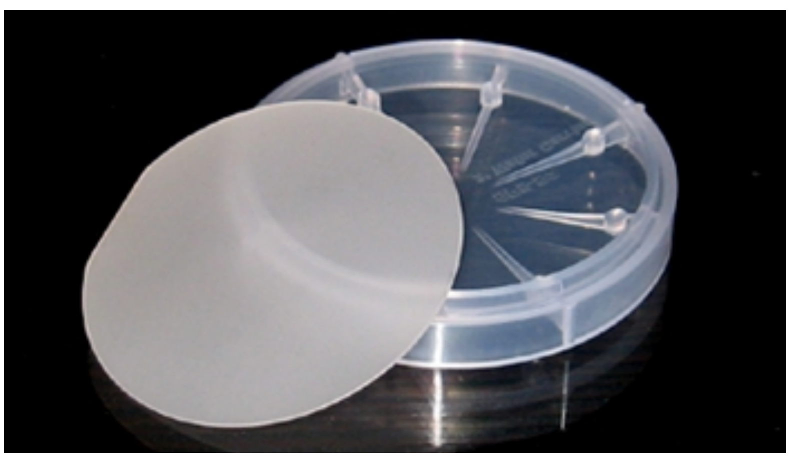
Al_2O_3 crystal

We decided to use a nuclear reaction with a resonance at energy accessible by the AN2000 accelerator. The chosen reaction is the

$^{18}O\ (p,\alpha)\ ^{15}N$

reaction at ~627 KeV[1] with a Q-value of ~4.0 MeV.

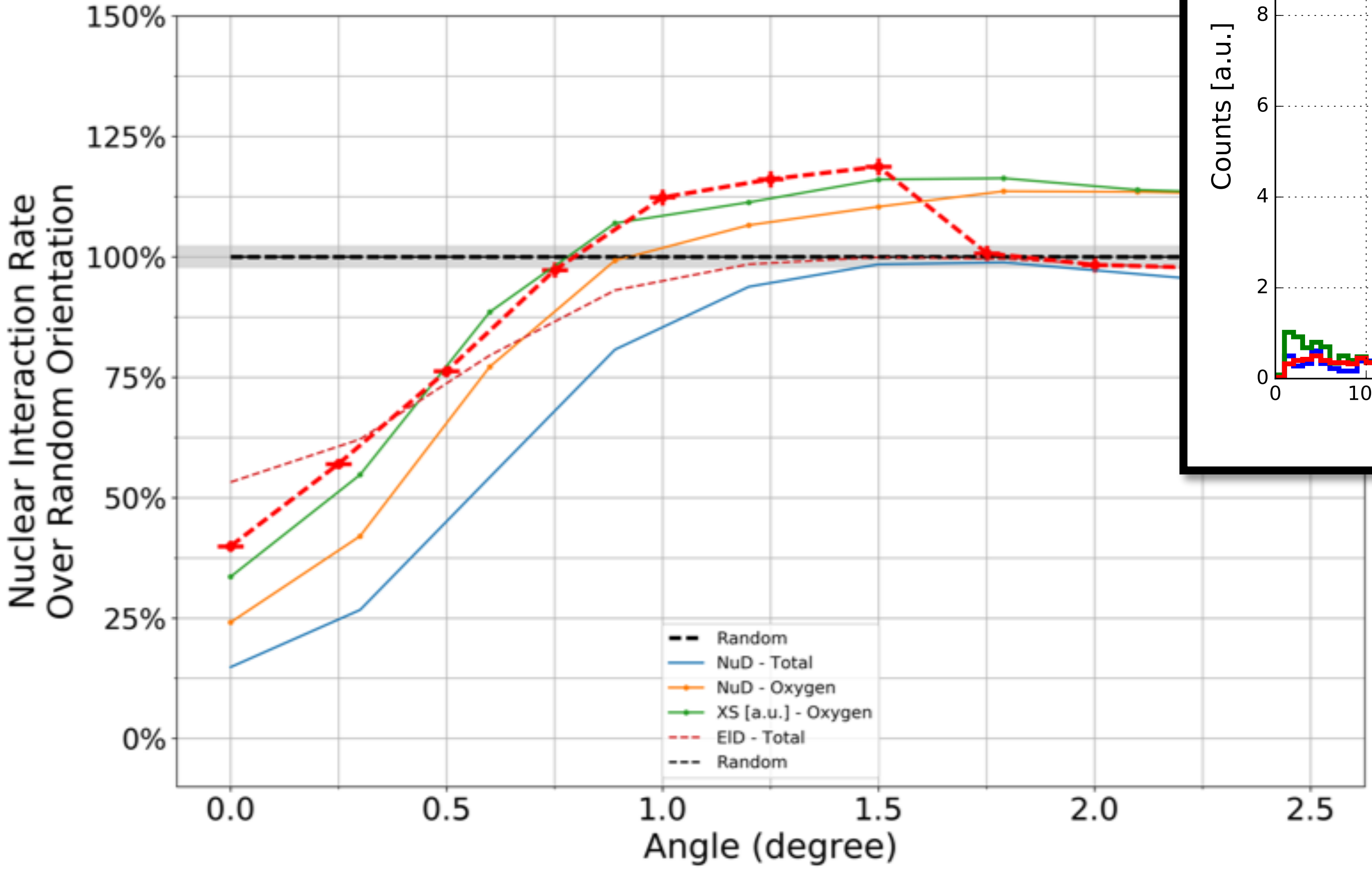


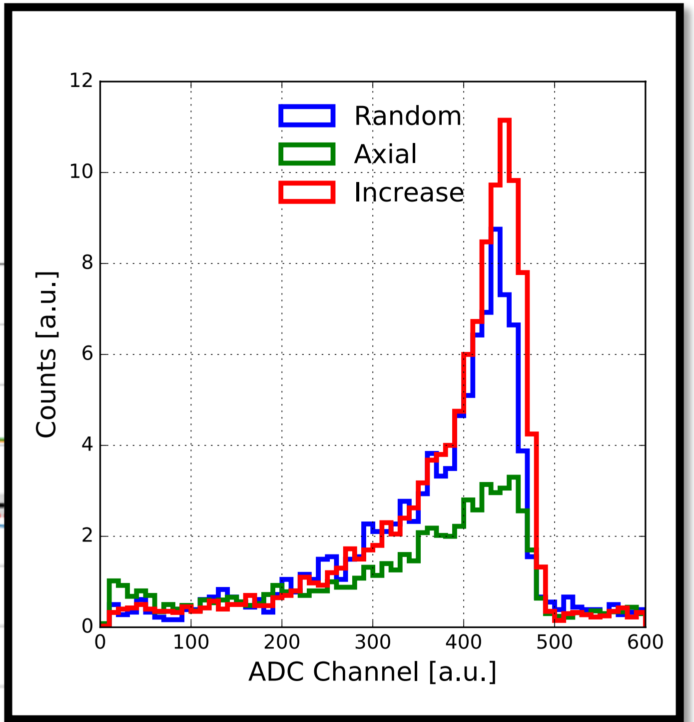


- We choose the Al_2O_3 aluminum oxide C-plane wafer for the experiment, i.e. the <0001> direction, that has an hexagonal crystal structure.

Al_2O_3 crystal - NRA

Al_2O_3 substrates, <0001> axis, $^{18}O(p,\alpha)\,^{15}N$ reaction





CSN5 Grant for young researchers

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)

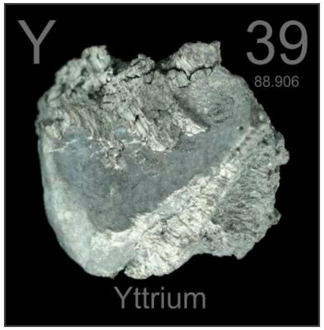
Target	Initial Isotope	Final Isotope
^{89}Y	^{89}Y	^{89}Zr
TeO_2	^{124}Te	^{124}I
TeO_2	^{123}Te	^{123}I
$SrCO_3$	^{86}Sr	^{86}Y
^{64}Ni	^{64}Ni	^{64}Cu
^{61}Ni	^{61}Ni	^{61}Cu
^{111}Cd	^{111}Cd	^{111}In
$CaCo_3$	^{44}Ca	^{44}Sc
^{67}Zn	^{67}Zn	^{67}Ga
^{68}Zn	^{68}Zn	^{68}Ga

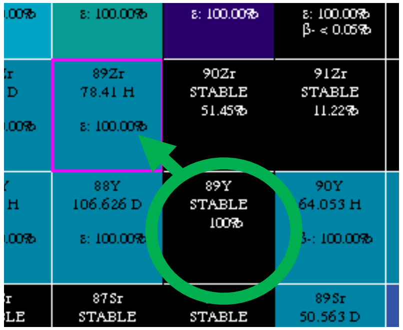
How to deal with crystals?

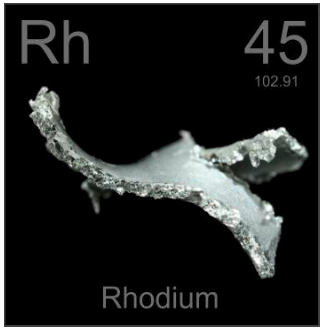
- Isotopic purity needed to obtain a good yield of production without contaminants. For instance, Ge is a perfect mono-crystal but has several stable isotopes.

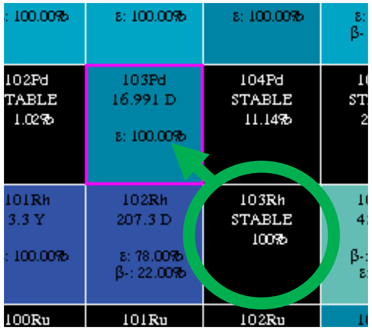
- **Yttrium** and **Rhodium** can be found as crystalline material, have only one isotope, and are useful materials for nuclear medicine:
  - Pros: No need to be enriched
  - Cons: to be found as a pure monocrystal (expensive/not trivial)

- First Y (2x2x0,5 mm) and Rh (3x3x0,5mm) already purchased and ready to be characterized and are the ideal targets to be used as a first test bench.

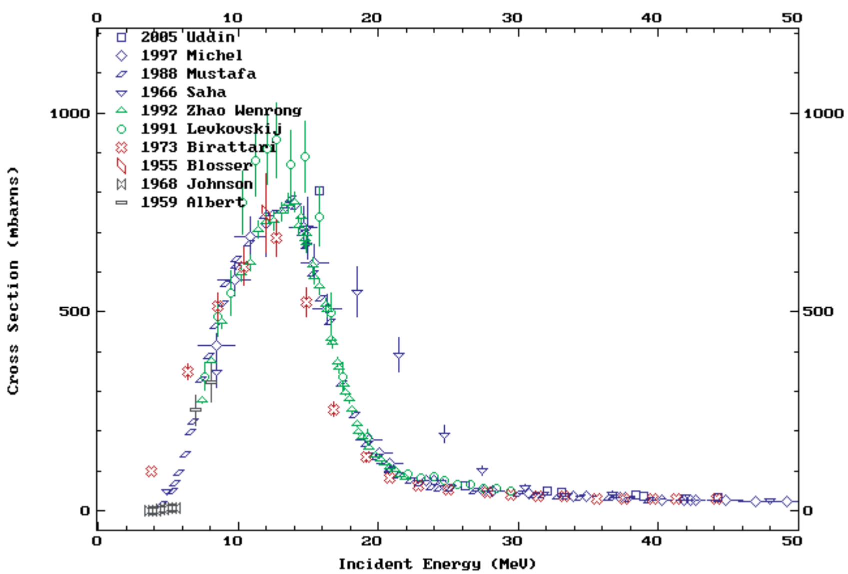


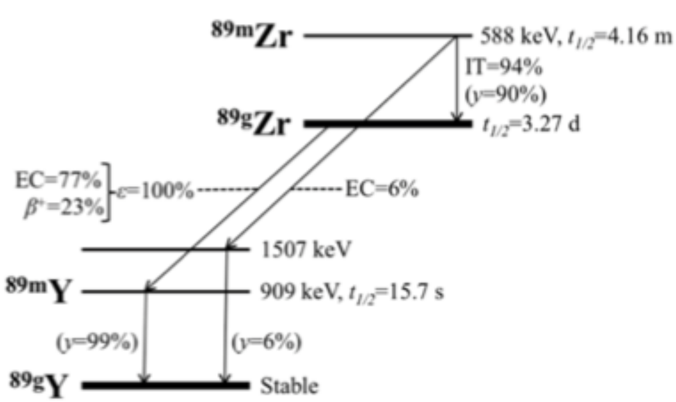






^{89}Y (p,n) ^{89}Zr production





- ^{89}Zr has a relatively long half-life (3.3 d) and decays 23% by positron emission and 77% by electron capture. The end point energy of the positron is 0.9 MeV.
- ^{89}Zr is employed in specialized diagnostic applications using PET imaging, for example, with ^{89}Zr labeled antibodies (immuno-PET).
- One of the most promising radioisotope for theragnostic usage.

Crystal Characterization & Holder

- The crystalline quality of the samples will be characterized at INFN-Fe (X-ray, white- and red-light interferometers, autocollimator) and INFN-LNL (RBS).

- In collaboration with company partners the prototypes of nozzles compatible with the available accelerators will be designed. Two solutions will be investigated:
  - fixed support at the anti-channeling angle
  - an online angular controller to remotely adjust angular position

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Possible accelerator facilities

- Experiments can be carried out in two different environments, accelerator facilities and commercial cyclotrons.
- Accelerator facilities for fundamental physics research for *"validation in lab"* (TRL4):
  - INFN-LNL, PD, Italy
  - INFN-LNS, Catania, Italy
- Cyclotrons in hospitals for *"validation in relevant environment"* (TRL5), e.g.:
  - Sacro Cuore Don Calabria, VR, Italy
  - Policlinico di Milano, MI, Italy
  - …

Project schedule