Instruments and methods for theranostic radioisotope production at the Bern medical cyclotron

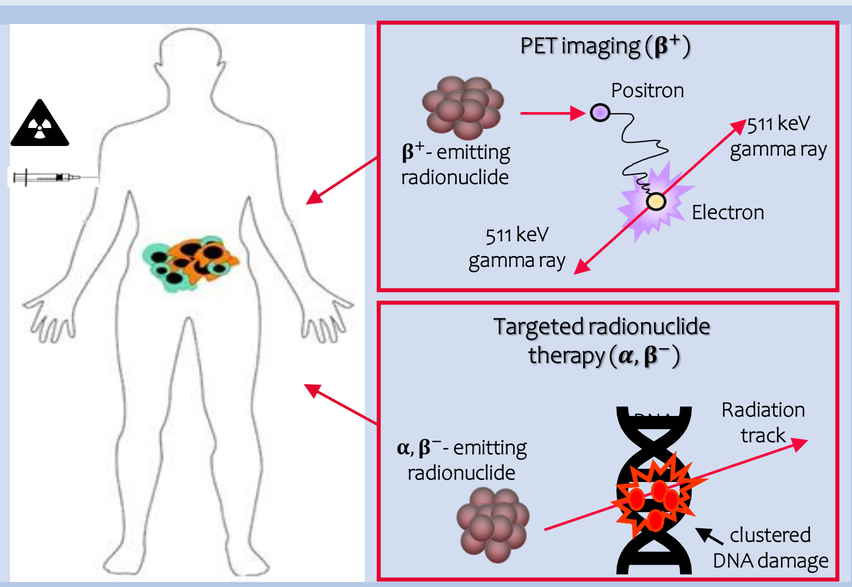
Dellepiane G.*, Casolaro P., Häffner P.D., Mateu I., Scampoli P., Voeten N., Zyaee E., Braccini S.

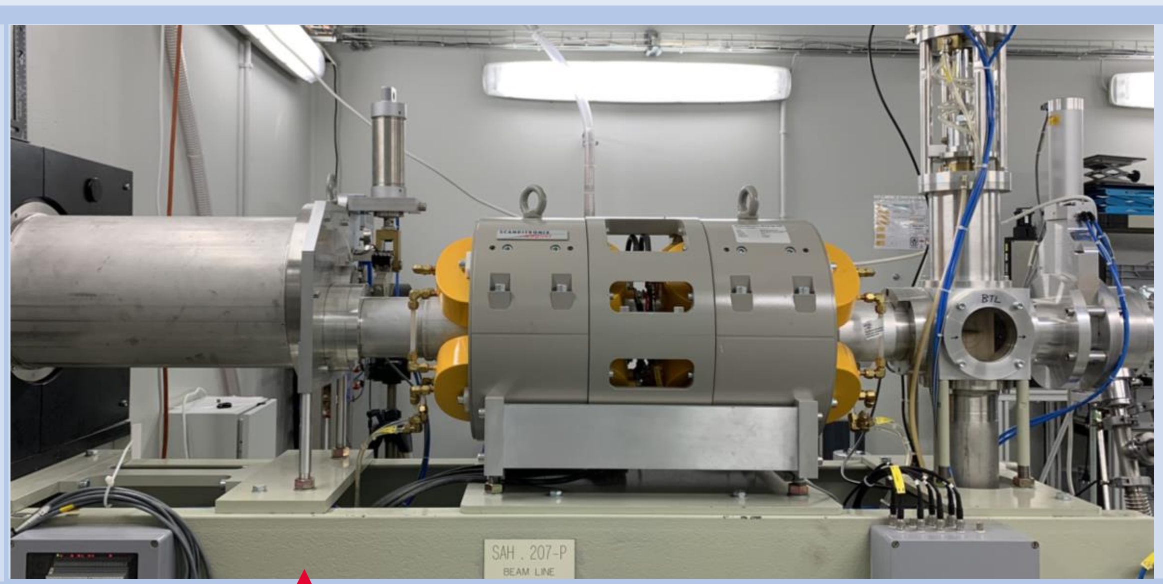
Theranostics in nuclear medicine

Theranostics is based on a pair of radioisotopes with very similar or identical chemical properties, one for diagnosis and one for therapy.
They are used to label biomolecules that undergo the same metabolic processes within the patient body, allowing at the same time to treat the disease and to follow the therapy evolution.

Promising theranostic pairs:

- ^{64}Cu/^{67}Cu;
- ^{68}Ga/^{177}Lu;
- ^{155}Tb/^{161}Tb
- ^{43}Sc/^{47}Sc and ^{44}Sc/^{47}Sc





Beam Transfer Line (BTL)

The BTL brings the beam in a bunker with independent access, allowing to perform multi-disciplinary research in parallel with daily clinical radioisotope production.

The BTL is equipped with two horizontal-vertical quadrupole doublets, capable of focusing the beam down to a millimiter.

An XY steering magnet can be used to bend the beam of maximum ±7 mrad horizontally and vertically.

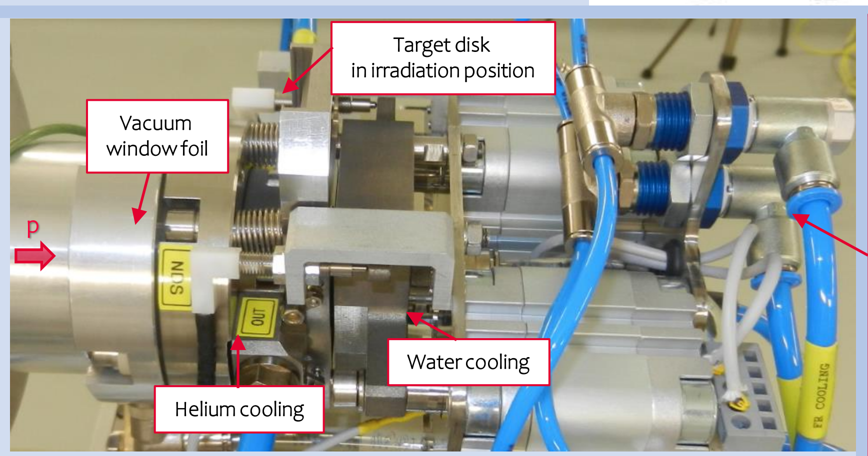
The extracted beam energy was measured to be (18.3 ±0.4) MeV.

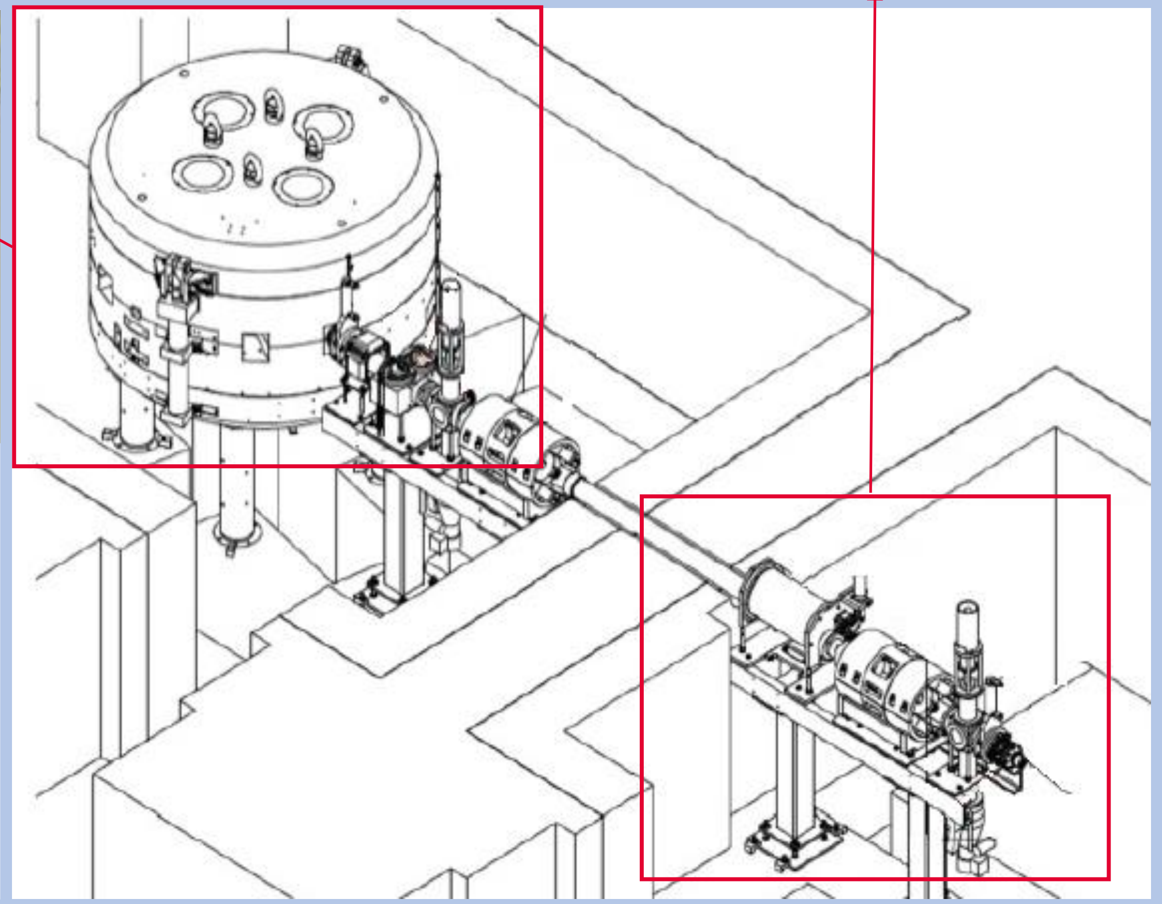
Solid Target Station (STS)

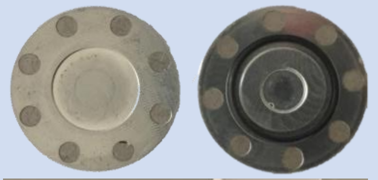
The STS allows to produce novel radioisotopes by irradiating solid materials.

It is connected to the cyclotron by means of a vacuum window foil, which safeguards the cyclotron vacuum.

Since the beam decreases its energy in the foil, the thickness and material of the vacuum window can be choosen according to the radionuclide to be produced.







To irradiate compressed 6 mm diameter powder pellets, a new target coin was developed.
It is composed of two halves kept together by small permanent magnets.

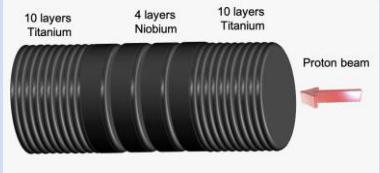
- The front window is used to adjust the proton energy reaching the target material;
- The back part hosts the pellet and an o-ring to prevent the escape of molten material or any gas produced during the irradiation. It also stops the protons.

The front window of the coin is cooled by helium, the back part by water.
To minimize the dose to the personnel, a mechanical transfer system was developed to load the target station.

The STS was customized with a pneumatic transfer system.
The irradiated coin falls into a shuttle, which is sent to a lead-pot in a receiving station in the BTL bunker through a delivery tube.
An automatic system allows to open the tube and place the cap on the lead-pot.
The process can be followed by remote thanks to a video camera.
A CZT detector was mounted to assess the produced activity.

Beam energy measurement

The measurement of the beam energy is ongoing with a method based on the stacked-foils technique, using the well known monitor reaction $^{48}\mathrm{Ti}(p,n)^{48}\mathrm{V}$.
Two stacks composed of natural Ti thin foils, separated by an energy degrader of Nb, are positioned in the coin pocket and irradiated.
The resulting activities of ^{48}V are assessed by an HPGe detector.

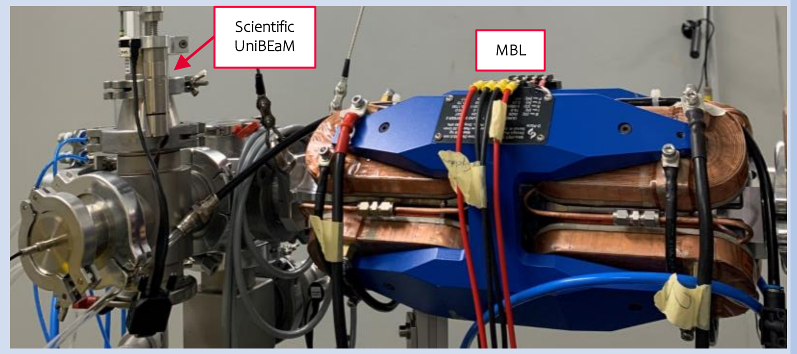


Automatic Focusing System (AFS)

The AFS was developed to enhance the irradiation performance. It allows to control the size and position of the beam and correct its characteristics, steering and focusing it on target.
It is made of two components:

- the Mini-PET Beamline (MBL): an innovative compact (~50 cm) magnet embedding two quadrupoles and two steering magnets;
- a scientific UniBEaM: a non-destructive two-dimensional beam profiler.

The AFS was recently installed on the cyclotron

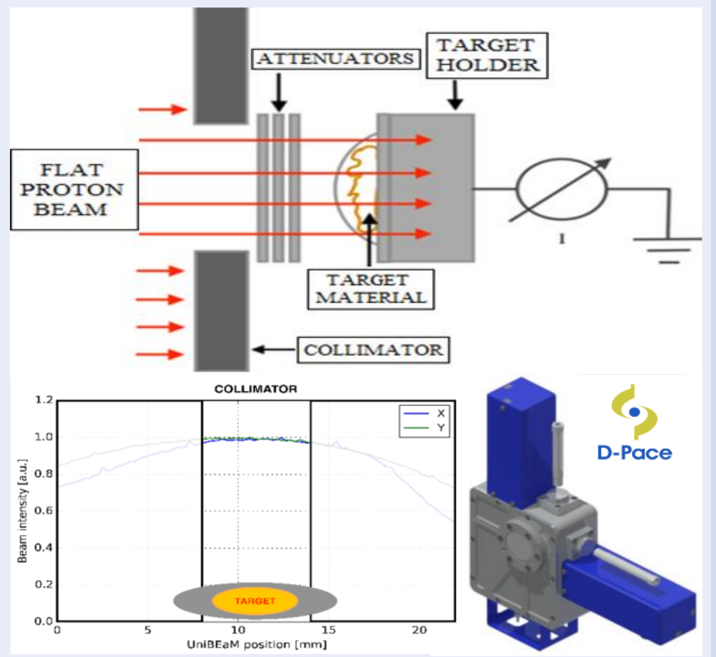


Cross section measurements

The knowledge of the cross sections is fundamental to optimize the radioisotope production.

The new procedure is based on the irradiation of the full target mass by means of a known flat beam current surface density.

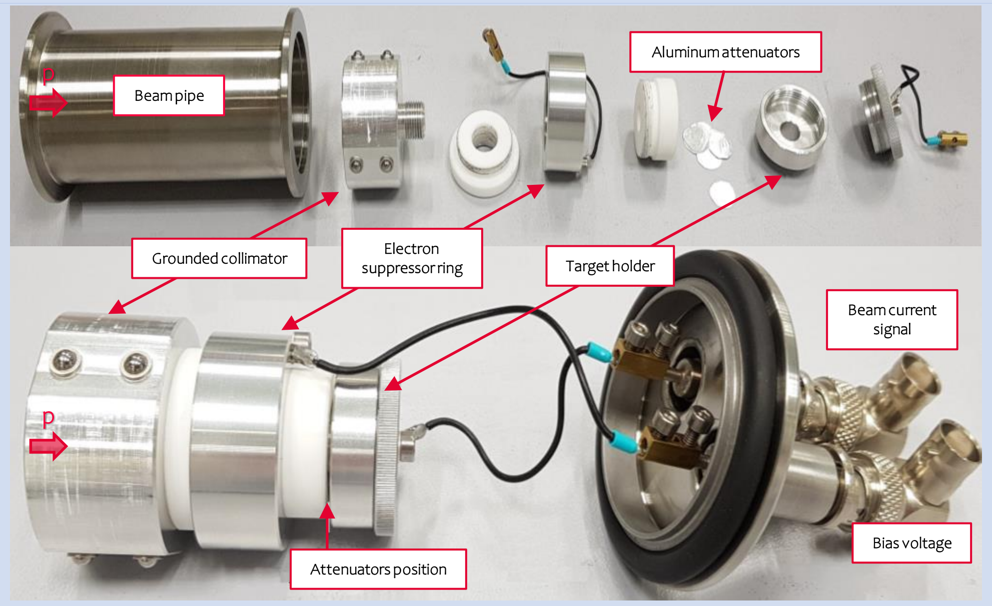
The beam flatness is controlled by a non-distructive UniBEaM detector, based on two scintillating fibers passing vertically and horizontally through the beam.



The number of protons per unit area hitting the target is determined by measuring the current in real time during the irradiation, thanks to a customized target station.

The station hosts:

- a 6 mm diameter collimator connected to ground;
- an electron suppressor ring connected to a negative bias voltage, used to repel secondary electrons;
- a target holder, connected to an ammeter to measure the current.



Aluminum attenuator discs can be located in front of the target to modulate the energy of the impinging protons.

With this method, the production cross section of ^{47}Ca, ^{43}Sc, ^{44}Sc, ^{44m}Sc, ^{47}Sc, ^{48}Sc, ^{48}V, ^{61}Cu, ^{66}Ga, ^{67}Ga, ^{68}Ga, ^{154}Tb, ^{155}Tb, ^{156}Tb, ^{165}Tm, ^{166}Tm and ^{167}Tm were measured.

*gaia.dellepiane@lhep.unibe.ch