Trento Institute for
Fundamental Physics
and Applications

Istituto Nazionale di Fisica Nucleare

Physics and Radiobiology Experimental Beam Tests at the Trento Proton Therapy Center

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Talk Outline:

- Trento Proton Therapy Center description
- The Accelerator
- The gantry rooms
- The experimental area description
- A specific tool for proton irradiation: the dual ring set-up
- Conclusion
- Documentation and References

The Trento Proton Therapy Center

The Trento Proton Therapy Center (TPTC) is a medical facility for hadron therapy specialized in the treatment of pediatric patients, located in Trento, Italy.

The facility is operated by the the *“Azienda Provinciale per i Servizi Sanitari”* (APSS), clinical activity started in 2014. The medical area is equipped with two gantry rooms for patient treatment. There is also a experimental area (experimental cave and multidisciplinary laboratory) reserved for non medical activities (physics and biophysics experiments) operated by the TIFPA-INFN and Trento University.

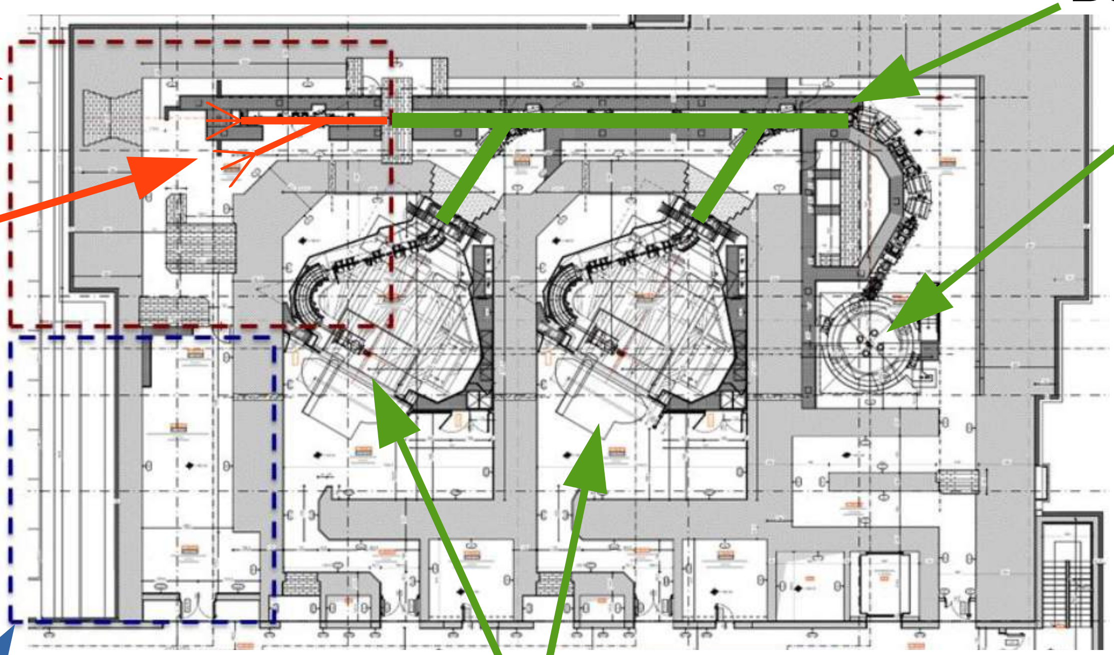
The Trento Proton Therapy Center

Experimental cave

Beam distribution line

Isochronous Cyclotron

Experimental beamlines



Remote control area
and
multidisciplinary laboratory

Gantry rooms
for patients treatment

The Accelerator

The accelerator and the beam system distribution was realized and is operated by the Ion Beam Accelerator Company (IBA).

The proton accelerator is a IBA Proteus 235 cyclotron working at 106 MHz.

Beam current (nominal, at cyclotron exit) can be tuned from ~200 p/s up to 320 nA (***)

The proton energy at the accelerator exit is 230 MeV, before the entrance of the distribution line can be lowered down until 70 MeV using a passive degrader on user request.

The beam delivered in the experimental area has a gaussian transverse intensity profile with sigma and peak value depending on the beam energy.

Parameters of the proton beam in the Experimental Area

Energy(*) [MeV]	**Average sigma (gaussian profile)** [mm]	**Flux(**)** [p/s]
70.2	6.92	3.8x10^6
100.0	5.68	1.2x10^7
142.9	4.56	3.6x10^7
169.4	4.00	7.4x10^7
202.4	3.48	1.4x10^8
228.2	2.73	2.3x10^8

(*) Nominal energy at the beamline window

(**) Nominal flux evaluated for 1 nA current

(See **REF1** for details)

(***) Due to beam transportation losses only ~10% of this nominal current is available in the experimental area

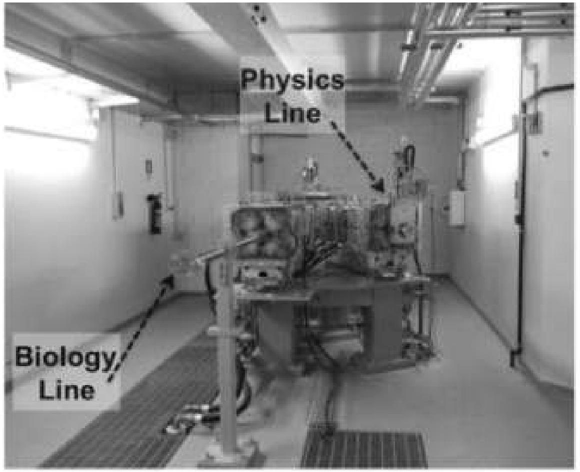
The gantry rooms

The center is equipped with two gantry rooms realized by the IBA corporation.
Each gantry can rotate 370 degree around the patient coach.

According to patients treatments requests, the gantry rooms are used also for beam QA experiments and Treatment Plan System (TPS) optimization tests. See **Talk3** for details

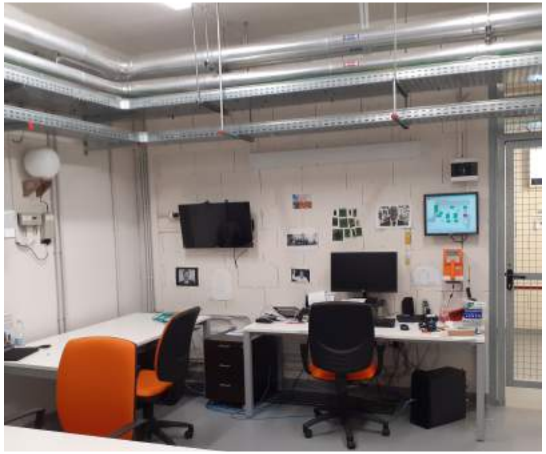
The Experimental Area

For ~3 hours every working day after the patient treatments and on Saturday morning, the beam is used for non medical experiments in the experimental area. Beam time is assigned by a PAC Committee after a experiment proposals evaluation. See here for details: https://www.tifpa.infn.it/sc-init/med-tech/p-beam-research

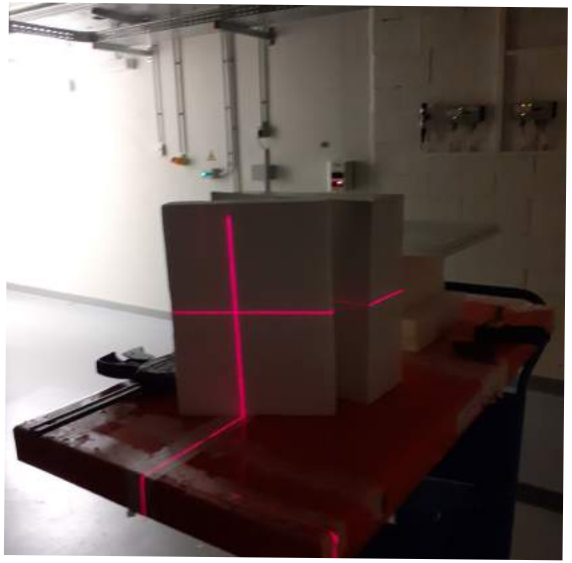


The experimental area is composed by a experimental cave (left) where irradiations are performed and the contiguous room (down) used for instruments remote control and as multidisciplinary laboratory for electronic set-up or cells preparation.

The rooms are equipped with two cable connected patch-panels (BNC, SHV, ethernet) for remote control of the instrumentation.



The Experimental Area



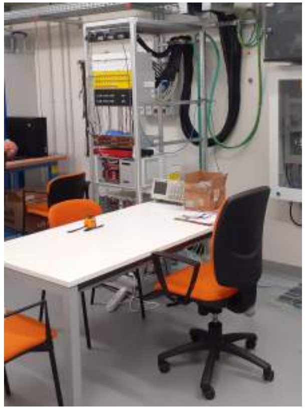
In the experimental cave two almost identical beamlines are present for “in air” irradiation of biological targets (cells), biophysics measurement or particle physics test-beam:

- the “0 degree” or biological line
- the “30 degree” or physics line

Both of them are equipped with a laser system for beam alignment.

All the experimental cave can be monitored with a remote movable camera system.

In order to have a “almost flat” intensity beam profile instead of the gaussian one, a specific set-up can be assembled on the biological line: the dual ring. Using a passive scattering system this set-up allows to have a flat irradiation fields of 6 and 16 cm diameter starting from a fix pencil beam at 148 MeV.



(remote control room patch-panel)

The Experimental Area

Beam restrictions

Due to administrative limitations every day only a
total charge of **0.5 mC** can be delivered in the experimental cave.

Working for example with a 200 nA beam, this limit is achieved
in 2500 seconds (~41 minutes) irradiation time.

The accelerator can work in two modalities:

- dark current mode
  - from 200 p/s up to ~20 p/s
- high current mode
  - from fraction of nA up to 320 nA

Due to interlock restrictions, when working in high current mode, every 5 minutes of irradiation the accelerator have to stop for 5-2 minutes (depending on the irradiation current).

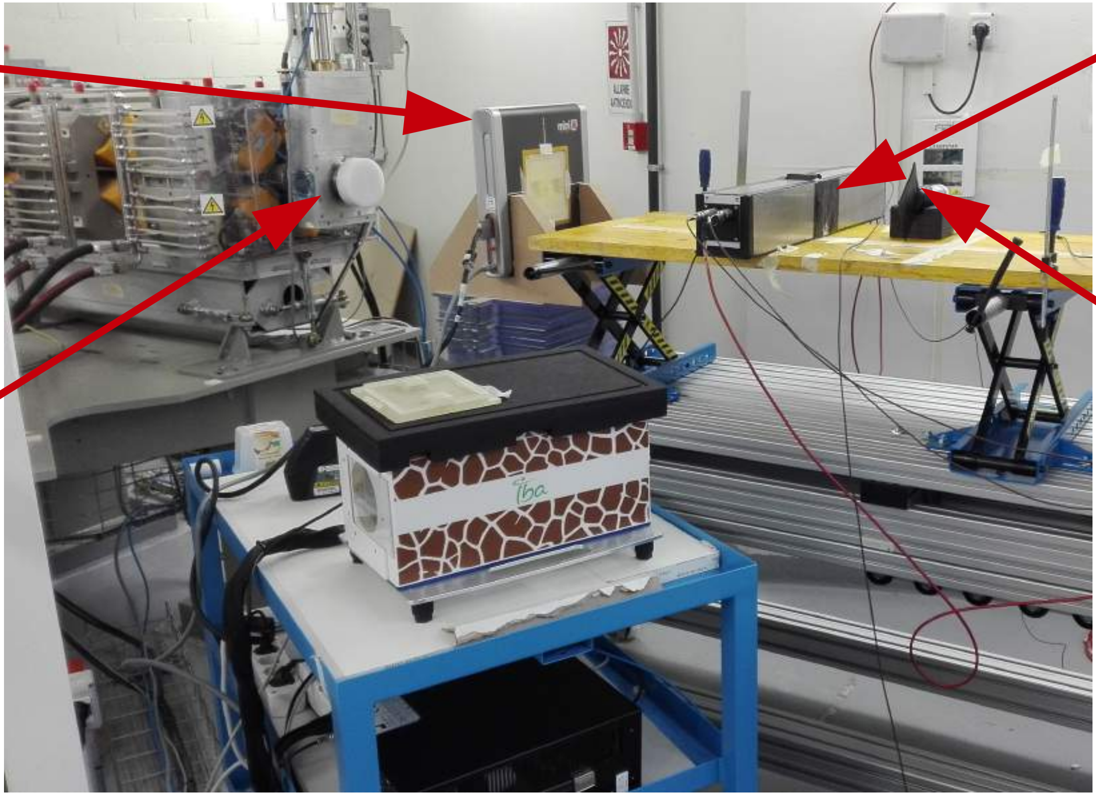
A refund of about 1Keuros/day is asked to the users for the facility maintenance, it is lower for multiple irradiation days. See here for details https://www.tifpa.infn.it/sc-init/med-tech/p-beam-research

Physics beam line

Typical experiment configuration in dark current mode,
used for test on silicon pixel, strips, lgad etc.

Beam monitor

DUT



Beamline
exit window

Event trigger
(plastic scintillator)

(photo courtesy of the **HERMES** collaboration https://www.hermes-sp.eu)

Dual ring set-up

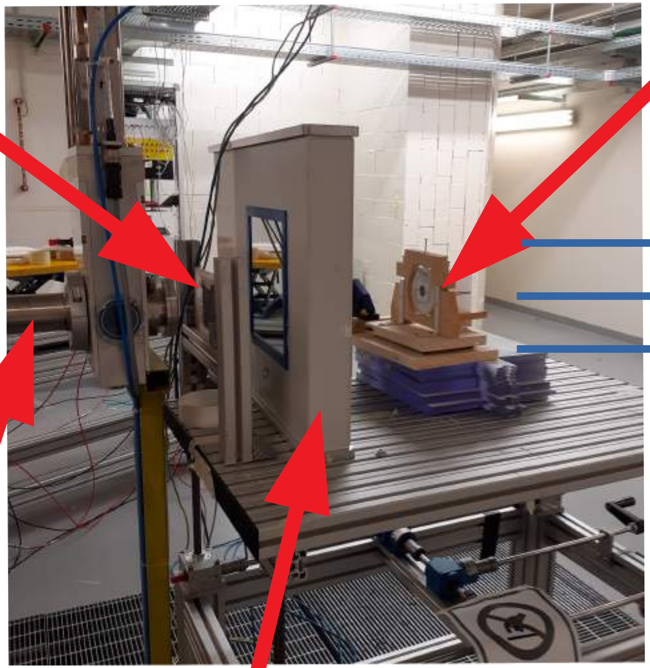
First foil

Dual ring

incoming proton beam
(gaussian profile, 148MeV)

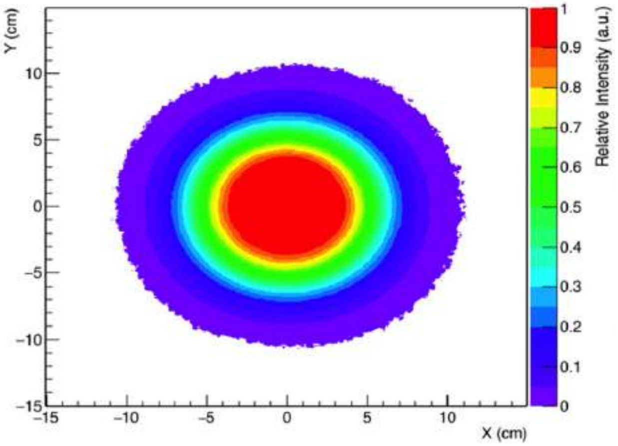
scattered proton beam
(flat profile, ~140 MeV)

Target
area



beampipe

Monitor drift chamber



Small dual ring intensity profile

(See **REF2** for details)

Dual ring irradiation

The dual ring set-up can be assembled in two configurations:

- small dual ring ==> circumference of ~3 cm radius with flat intensity profile
- large dual ring ==> circumference of ~8 cm radius with flat intensity profile

The intensity peck is different in the two configurations.
(See **REF2** for details)

This configuration is commonly used for large area irradiations on cells culture or radiation damage studies on electronic devices and silicon sensors.

Conclusions

In the Experimental Area of the Trento Proton Therapy Center a proton beam with energy between 70-228 MeV is available for experiments.
This beam allows to a variety of physics, silicon sensors and biological experiments for medical, electronic or space applications.
We are waiting your experiment applications!

Thanks for your attention!

Fell free to contact me for questions!
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References

TIFPA-INFN: www.tifpa.infn.it
APSS: https://protonterapia.provincia.tn.it/eng
Physics UniTN: https://www.physics.unitn.it/en
Biology UniTN: https://www.cibio.unitn.it
IBA: https://iba-worldwide.com

Trento Proton Therapy Center:
Experimental Area info and Beam Time applications:
http://www.tifpa.infn.it/sc-init/med-tech/p-beam-research

TIFPA Activity Reports:
https://www.tifpa.infn.it/contacts/downloads

Experimental area beam characterization:

REF1 – *Proton beam characterization in the experimental room of the Trento Proton Therapy facility*
F. Tommasino et al. NIM A 869 (2017) 15–20.
DOI: http://dx.doi.org/10.1016/j.nima.2017.06.017

REF2 – *A new facility for proton radiobiology at the Trento proton therapy centre: Design and implementation*
F. Tommasino et al. Physica Medica 58 (2019) 99–106
DOI: https://doi.org/10.1016/j.ejmp.2019.02.001

Documentation

Other TPTC description talks:

TALK1 - *Proton and x-ray irradiation of silicon devices at the TIFPA-INFN facilities in Trento (Italy)*
B. Di Ruzza, ICHEP 2020
https://indico.cern.ch/event/868940/contributions/3815732

TALK2 - *Education initiatives in the experimental area of the Trento Proton Therapy Center (Italy)*
B. Di Ruzza, ICHEP 2020
https://indico.cern.ch/event/868940/contributions/3814048

TALK3 - *4DPhantom: An innovative device for oncological proton treatment uncertainties minimization*
B. Di Ruzza, 106 Congress of the Italian Physical Society SIF2020
https://agenda.infn.it/event/23656/contributions/120640

Review on accelerators for medical applications:

REV1 - Yves Jongen, *REVIEW ON CYCLOTRONS FOR CANCER THERAPY*
Proceedings of CYCLOTRONS 2010, Lanzhou, China
https://accelconf.web.cern.ch/Cyclotrons2010/papers/frm1cio01.pdf

Back-up slides

Abstract:

The Trento Proton Therapy Center is a cyclotron based proton therapy center located in Trento (Italy) where proton beams with energies from 70 MeV up to 228 MeV are used for cancer treatment. The Center started clinical operations in 2015 and since then more than 1300 patients were treated.
The facility features not only two patient rooms, both equipped with 360 degree rotating gantries, but also a unique experimental room equipped with two beam lines used exclusively for non-clinical research.
The two non-clinical beamlines are used for a variety of physics, radiobiological or biological experiments and they can provide proton beams with energies between 70-228 MeV where particle rate can be tuned from 200 Hz up to 10^10 Hz. This flexibility allows a variety of measurements and tests such as characterization of solid state silicon based (pixel, drift and microstrip) tracking systems, new crystal scintillator calorimetric tests for high energy physics and space applications, development of innovative microdosimetry instruments and also high rate proton irradiation studies.
One of the two beamlines is also equipped with a unique passive beam modulator system, called double ring, used for large area proton irradiation effect studies on biological cells, silicon sensors and electronic devices.

This contribution will describe the Trento Proton Therapy Center, the Experimental Room of the Center and the instruments used for beam quality monitoring during the experiments. An overview of the experiments performed in the experimental room will be also given.