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4DPhantom: An innovative device for oncological proton treatment uncertainties minimization

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Introduction:
Beam hadron therapy of moving organs require dedicated measures to compensate the dosimetric influence target organs motion. In this talk will be described a novel device, called 4DPhantom (3D plus time) designed in the Trento Proton Therapy Center. The device goal is to realize a moving plane reproducing the breathing signal of oncological patients in order to perform hadronterapy dose measurement on a array of ionization chambers, which is the most widespread detector for patient specific quality assurance in modern hadronterapy facilities.

Talk Outline:

- The Trento Proton Therapy Center (TPTC)
- The TPTC Gantry rooms
- The treatment of moving organ problem in hadron therapy
- 4DPhantom Project Overview
- First Tested Prototype (only Y movement)
- Conclusion and Acknowledgment

The Trento Proton Therapy Center (TPTC)

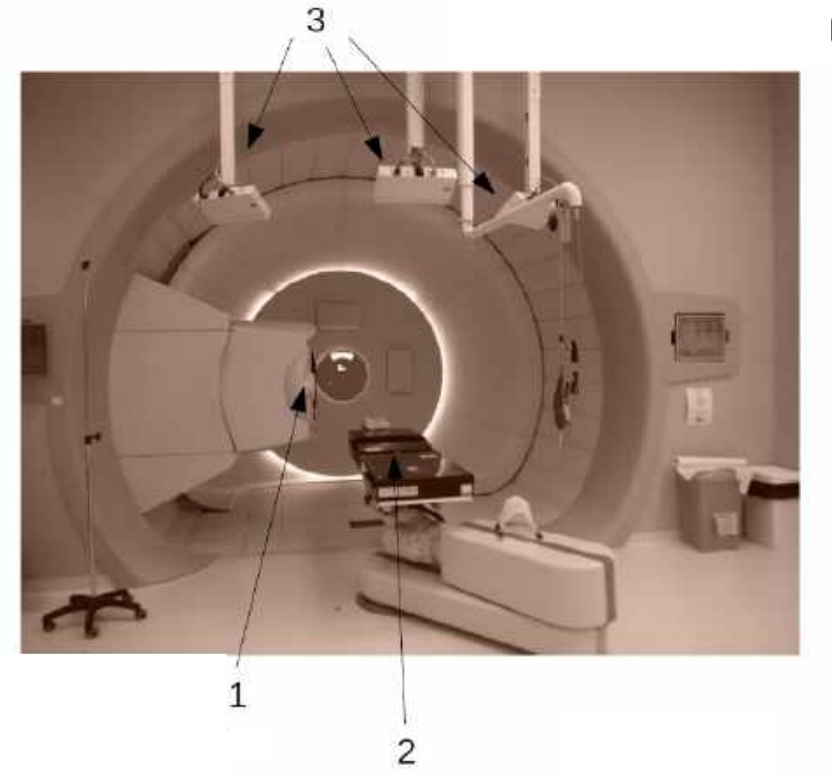
The Trento proton Therapy Center (TPTC)
Is a medical facility for hadron therapy
located in Trento, Italy.
It is operated by the *"Azienda Provinciale per i Servizi Sanitari"* (APSS).

https://protonterapia.provincia.tn.it/eng/?/switchlanguage/to/protonterapia_eng

The facility is equipped with two gantry rooms for patient treatment
and an experimental room for physics and biophysics experiments.
Clinical activity started in 2014.
In the first 5 years of activity more than one thousand patients were treated in the center.

(* Photo courtesy of the Trento Film Commission)

The TPTC Gantry rooms



The TPTC is equipped with the two gantry rooms realized by IBA (https://iba-worldwide.com/).

In each treatment room the gantry (1) can rotate 360 degrees, while the exact position of patient on the patient couch(2) can be monitored using non-invasive technique like infrared cameras (3).

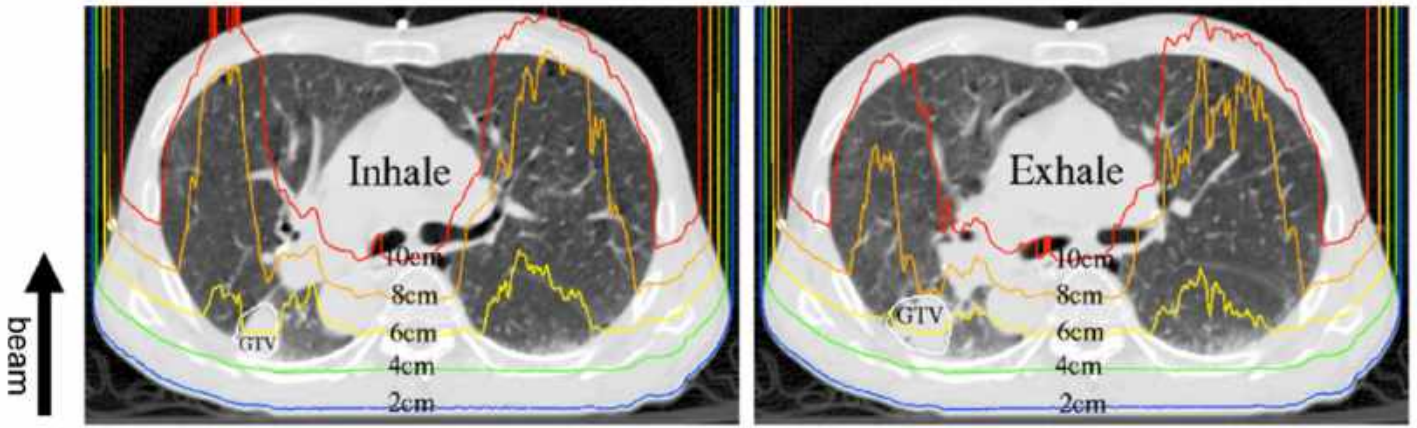
Each gantry room includes a patient positioning system featuring a robot-controlled patient couch.

Proton beam energy can be tuned from 70 MeV up to 226 MeV.

(* Photo by the author)

The treatment of moving organ problem in hadron therapy

In hadron therapy, treatments of moving organs (like lug) require dedicated measures to compensate for the dosimetric influence of inter- and intra-fractional target organs motion.

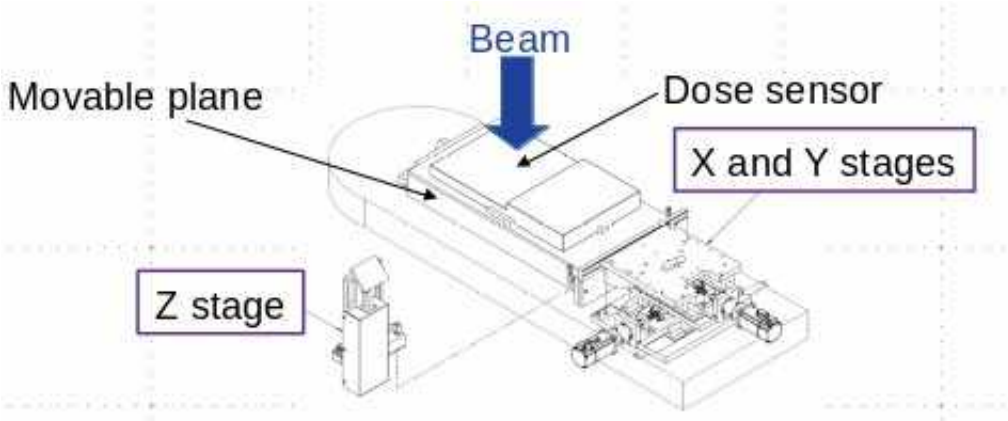


(*Courtesy from *C. Bert and M. Durante 2011 Phys. Med. Biol. 56 R113)*

(*) Intra-fractional motion not only changes the geometrical position of the tumor but also causes changes in the radiological depth. In this example, respiratory motion moves a lung tumor in and out of the displayed axial slice. Due to a high difference in density between tumor mass and surrounding lung tissue, the displayed iso-range lines that also reflect the position of a Bragg peak are strongly influenced when comparing inhale versus exhale.

4DPhantom Project Overview

4DPhantom gantry set-up



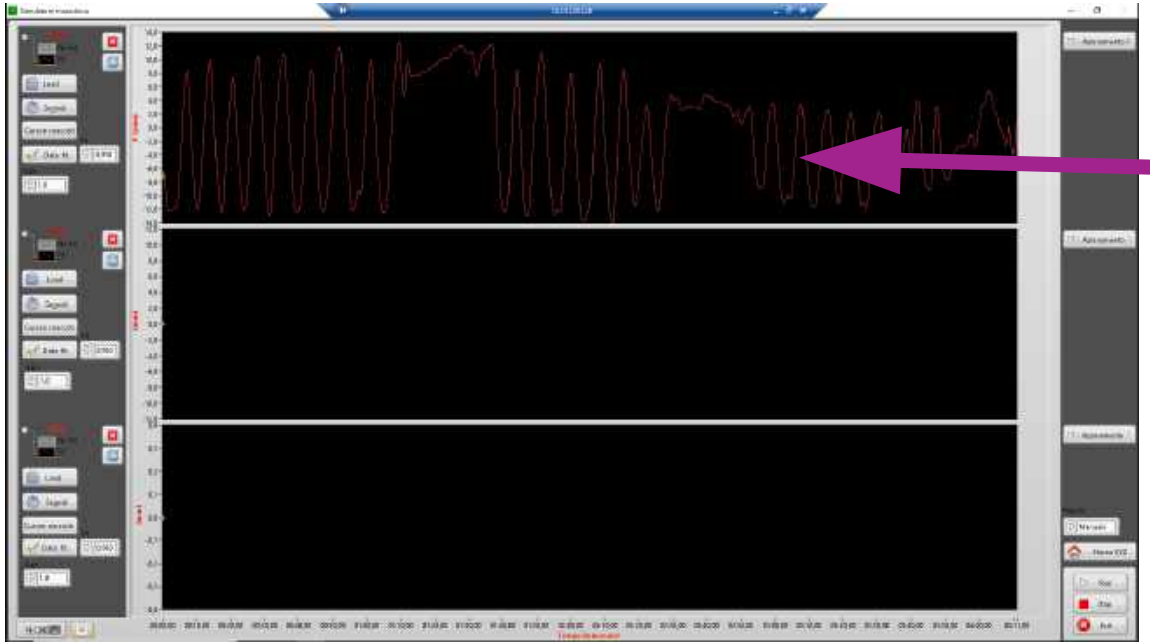
The movement in each direction will be realized using three motors remotely controlled by a dedicated LabVIEW program.

The software is able to reproduce analytical curves (such as $\sin(t)$,$\cos^4(t)$) to simulate a breathing signal and also real breathing patterns of patients acquired via infrared cameras during the radiotherapy treatment.

This plane will reproduce the 3D time dependent movement oscillation of an internal organ of a patient (e.g. lung or pancreas) during breathing.

4DPhantom Project Overview

4DPhantom control interface panel

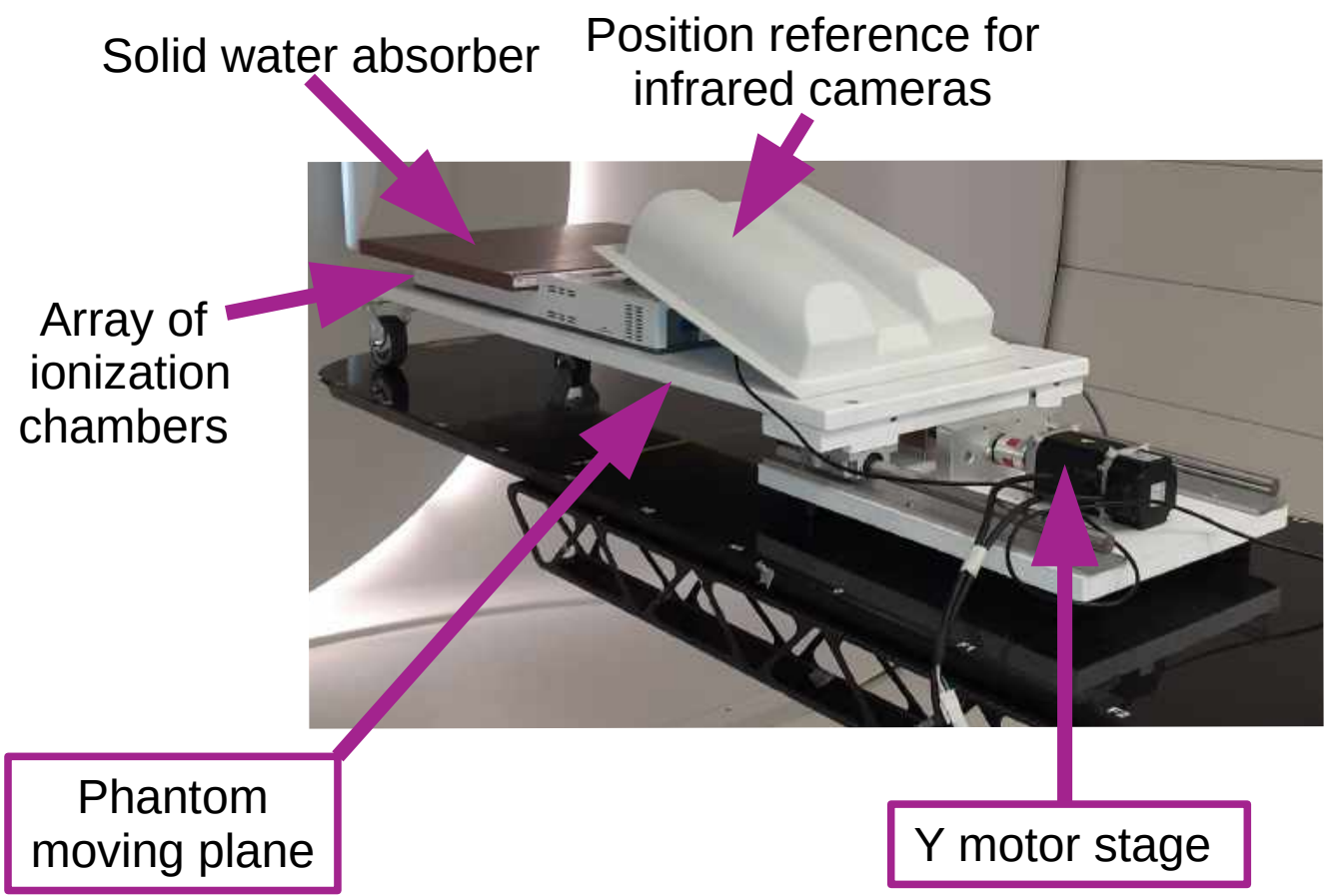


real patient breathing Y signal stored using the gantry infrared tracking system (apnea condition)

To speed up movement controls in the three independent directions a FPGA was added as stages control.

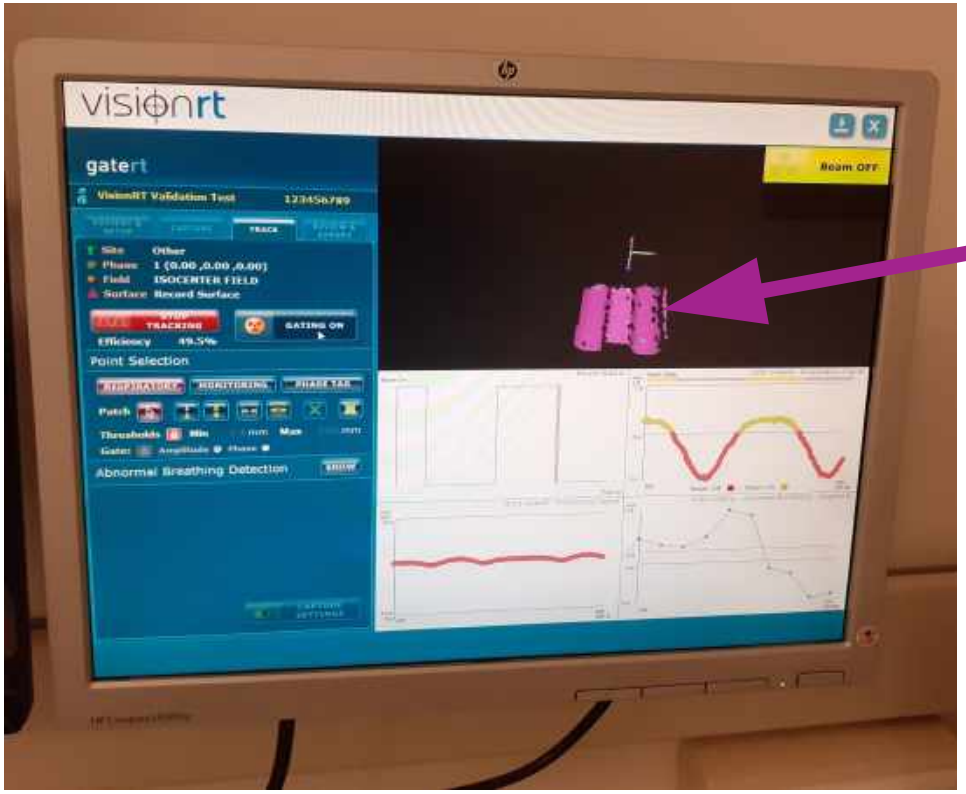
First Tested Prototype (only Y movement)

Prototype 4DPhantom set-up in the gantry room during the test



First Tested Prototype (only Y movement)

Optical tracking system (VisionRT) control interface panel during the test



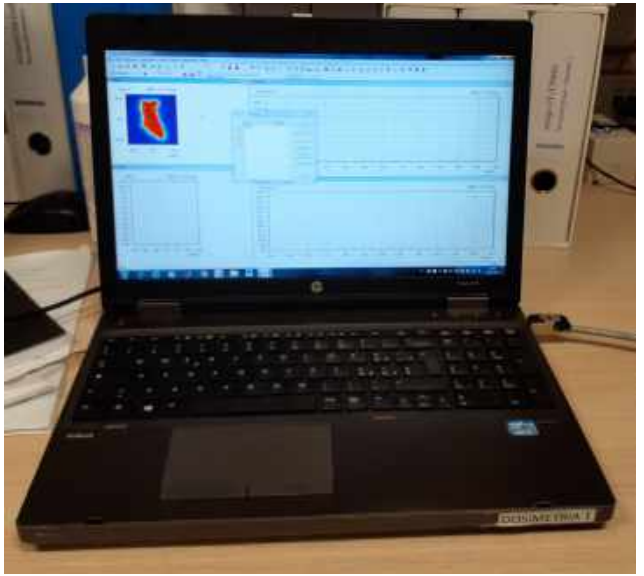
position reference as seen by the tracking system

The 4DPhantom is designed for not requiring any direct hardware or software connection to the therapy room controls.

First Tested Prototype (only Y movement)

Gantry therapy control room during the test

The 4DPhanthom is designed to be be completely remote controlled from the control room during the operations.



Dose measurement system during the test

Conclusions

A 4DPhantom was designed in the Trento Proton Therapy Center in order to emulate the 3D time dependent movement oscillation of an internal organ of a patient (e.g. lung or pancreas) during breathing. All the device is designed in order to be used easily during quality assurance measurement without interfering in any way with the patient treatment system even if is integrated in the system itself: the 4DPhantom control panel is completely independent from all the others dose, beam and gantry controls.

In February 2020, just before the lock-down the first tests were performed successfully on a prototype able to reproduce only the Y movement. Tests were resumed in June 2020.

After this second successfully test session, the construction of the final device started. The final device will be able to reproduce organ motion during breathing in both X and Y directions and is equipped also with a plane for the Z oscillation.

Measurements with this device will be used for minimization of treatment uncertainties due to organ motion during breathing.

Thanks for your attention
an stay tuned for new interesting medical results

For questions and comments write to: **benedetto.diruzza@tifpa.infn.it**

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https://www.fondazionecaritro.it/risorse/bandi/
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(5)Azienda Provinciale per i Servizi Sanitari della (APSS), Provincia Autonoma di Trento.

Back-up slides

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- TIFPA-INFN
www.tifpa.infn.it

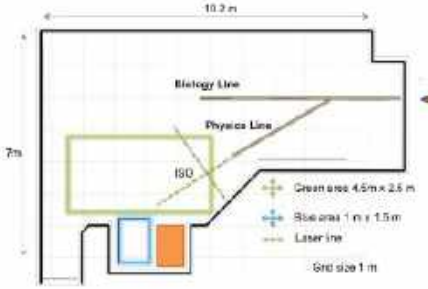
- Trento Proton Therapy Center Experimental Area
http://www.tifpa.infn.it/sc-init/med-tech/p-beam-research/

Abstract

Societa' Italiana di Fisica, 106 Congresso Nazionale
Sezione V: Biofisica e fisica medica
id comunicazione: atticon12893
TITOLO:
4DPhantom: An innovative device for oncological proton treatment uncertainties minimization

Proton therapy (PT) exploits the Bragg peak depth-dose profile to obtain conformal treatments, while sparing healthy tissues surrounding the tumor. Despite the high physical selectivity, PT is very sensitive to treatment-related uncertainties. Among these uncertainties, organ motion acquires increasing importance for pencil beam scanning PT. We will describe a novel device, called 4DPhantom (3D plus time), which is able to reproduce the real breathing signal of oncological patients during proton therapy treatment and can be combined with dosimetric devices for quality assurance purposes. The results of the first successful tests, performed at the Centro di Protonterapia di Trento, will also be shown.

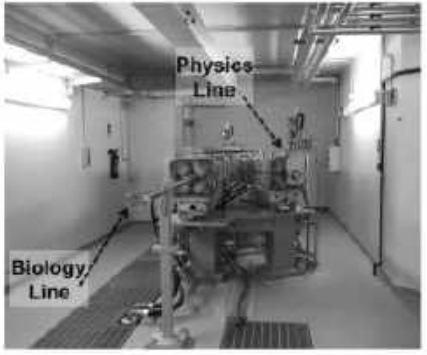
The TPTC experimental room



Proton Beam

In the facility experimental room, operated by TIFPA-INFN, there are two identical beamlines for “in air” exposition of biological targets (cells), biophysics measurement or particle physics test-beam

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



Experimental set-up in the physics line

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