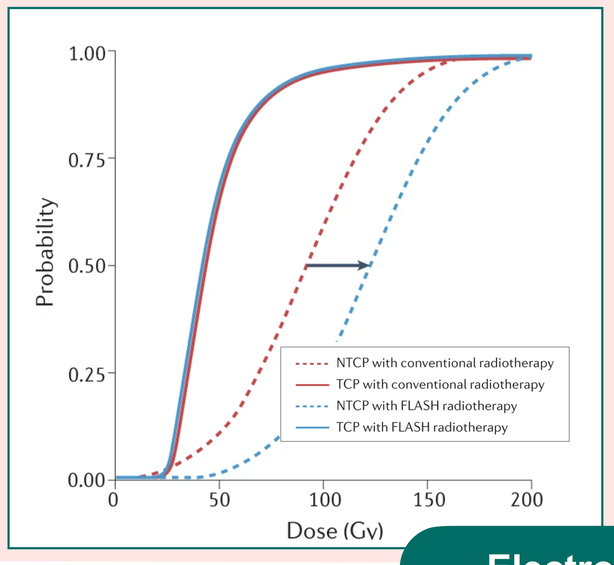
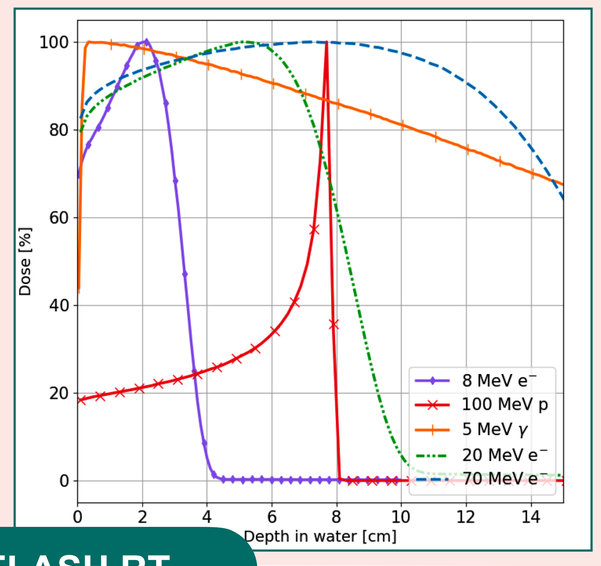
Physics Applied to Medicine: developing new tumor treatment therapy strategies (FLASH!) and enhancing the conventional ones

ARPG group https://arpg.sbai.uniroma1.it/

Radiotherapy makes use of radiation to destroy cancer cells, while trying to spare as much as possible the patient healty tissues. It is only curative in the therapeutic window, that is, the separation between the curves describing tumor control probability (TCP, that has to be maximized) and normal tissue complication probability (NTCP, that one wants to minimize). With FLASH radiotherapy, the TCP curve remains essentially the same but the NTCP curve is shifted to the right (black arrow) by a dose-modifying factor in the range 10–50% widening the therapeutic window.



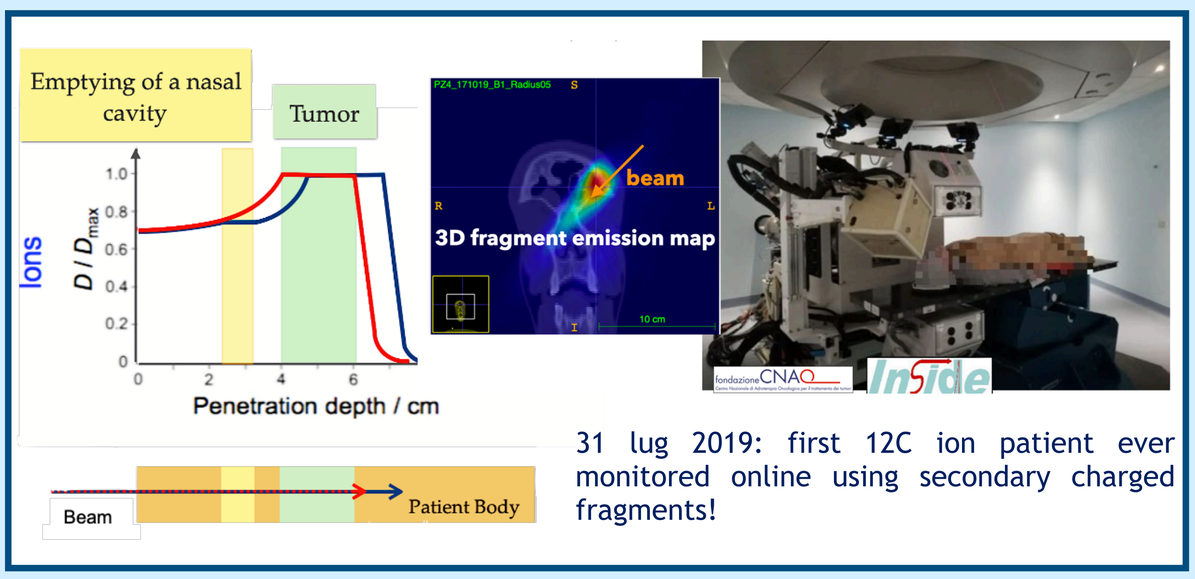


Particle Therapy

In Particle Therapy (PT) solid tumors are treated exploiting charged ions beams, mainly proton and ^{12}C ions. High precision in the dose released in the target volume is combined with a great efficacy in damaging the cancerous cells. However PT is highly sensible to range variations, typically due to CT scan mis-calibration, uncertainties on the CT Hounsfield number conversion, inter-fraction morphological changes (organ motion, Tumour regression, weight loss) or patient mis-positioning.

Clinical Trial @ CNAO

A clinical trial (ClinicalTrials.gov Identifier: NCT03662373) is carried on since 2019 from the INSIDE collaboration to evaluate the Dose Profiler capability and sensitivity in detecting morphological changes arising in pathologies of the neck-head district. At present, the monitoring data obtained from a sample of 10 patients affected by Adenoid Cystic Carcinoma, Clival Chroma and Intestinal-type adenocarcinoma has been collected.



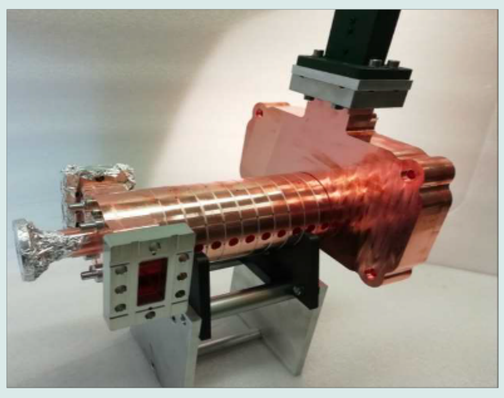
31 lug 2019: first 12C ion patient ever monitored online using secondary charged fragments!

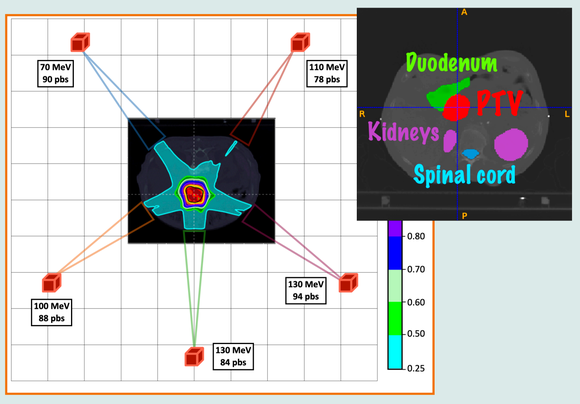
2. VHEE

The INFN - Sapienza way towards FLASH VHEE:

SAFEST project:

1. C-band accelerator capable of delivering FLASH electrons for therapeutic purposes. Now being built in synergy with Laboratori Nazionali di Frascati —> will be installed in Sapienza!

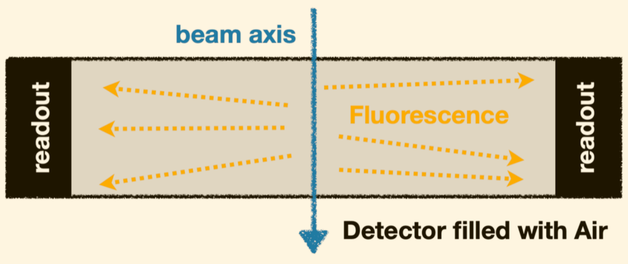




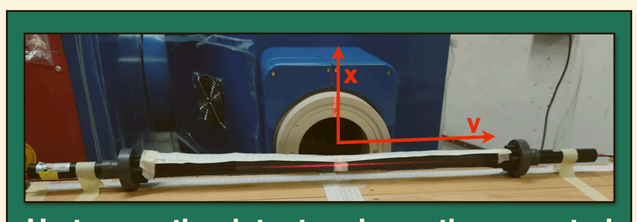
2. feasibility study of VHEE potential in well-identified clinical cases.

FLASH Beam Monitor with Air Fluorescence

- Beam monitoring is a cornerstone of FLASH effect studies, that must provide the reliable assessment of the beam parameters (most importantly, the **rate of impinging particles per pulse**).
- Standard devices such as transmission ionization chambers undergo substantial energy dependencies due to **volume recombination**.
- We need *new monitoring devices!!!*



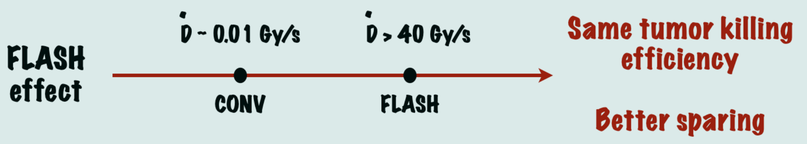
Objective: develop a monitor for FLASH-RT capable to simultaneously provide online the instantaneous rate of impinging particles per pulse and beam position, exploding the FLUORESCENCE !!

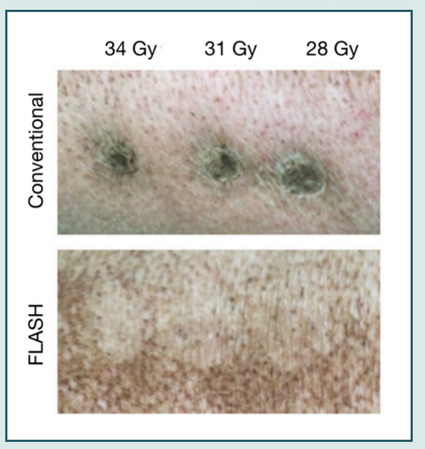


Up to now the detector shows the expected linear response.. Still more tests are needed

Electron FLASH RT

Today there is a renewed interest ob both low and Very High Energy Electron (VHEE) beams especially due to the possibility to deliver them at FLASH intensities.
The specific characteristics of the electron's interaction with matter can be exploited to provide effective alternatives to standard RT and PT treatments and, among the three, can be provided by the technology that is most easily adaptable for **FLASH** treatment deliveries.





E < 20 MeV

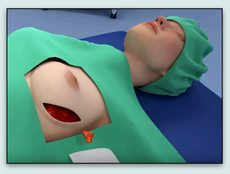
Mainly adapted for **Intra Operative Radio Therapy-IORT** and **superficial tumor treatments**

E > 50 MeV

VHEE beams have been considered already in the past but due to cost, complexity and space encumbrance they have not yet reached the clinical stage. Today the X and C band technology have changed the game.

1. IOeRT

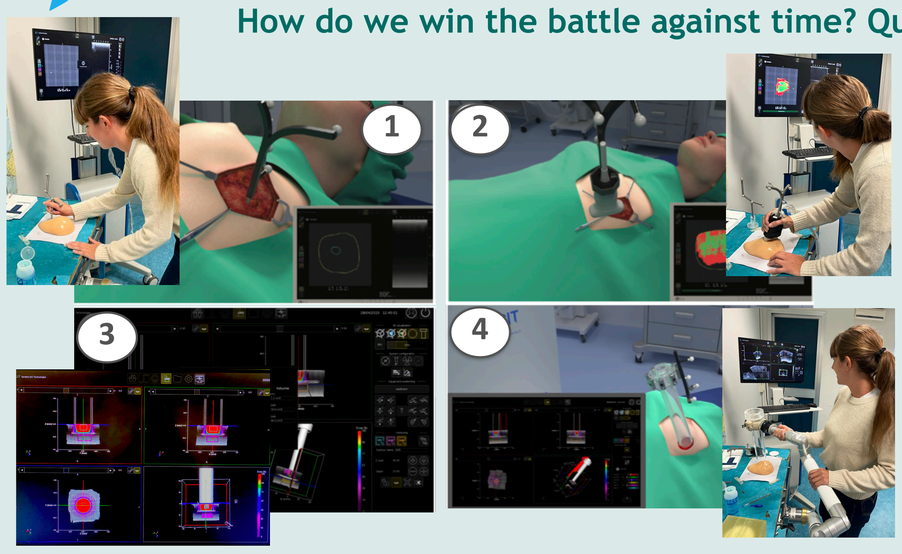
IOeRT is a technique that, after the surgical tumor removal, delivers a dose of ionizing radiation directly to the surgery bed. The goal is to eradicate the microscopic residual tumor cells that surgery was not able to remove completely.



The patient is surgically treated. The surgeon identifies and prepares the Planning Target Volume (**PTV**) that has to be treated. A **protective disk** is applied in order to preserve the organs from the undesired dose. The **thickness** of the target volume is identified by means of a **needle** and thus the electron **beam energy** is chosen. The beam is passively collimated by means of a **PMMA applicator**, whose **dimension** is chosen according to the volume of the surgical breach using a uniform electron beam irradiation (4-12 MeV)

The lack of adequate imaging, treatment planning, and position verification, which are currently absent due to time constraints, is directly associated with underdosage or geographical misses of the PTV

How do we win the battle against time? Quick planning



1. Identification of the regions of interest;
2. US **imaging acquisition;**
3. Treatment **simulation** and optimization
4. **Image guided docking** to deliver the treatment exactly as it was planned in point 3.