# A COMPACT AND MOBILE SYSTEM FOR BREAST IRRADIATION IN PRONE POSITION

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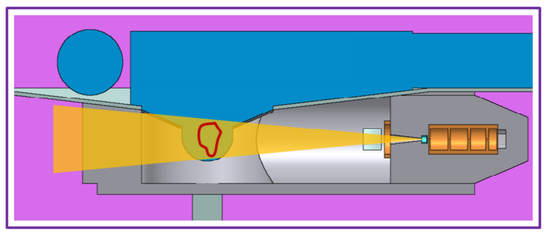
## *Abstract*

The APAM (Accelerators of Particles for Medical Application) Laboratory in the ENEA-Frascati Research Center developed a prototype of a self-shielded device dedicated to the treatment of breast cancer with the patient in prone position. It consists of a rotating X-ray source, based on a compact 3 MeV electron accelerator, placed under the patient bed which is provided with a circular opening through which the breast hangs down and can be irradiated. The system has been designed to suitably screen the patient body from the underlying accelerator. This setup improves target coverage and gives a valuable advantage in sparing healthy tissues: prone position increases the separation of the target and critical organs and in addition minimizes target motion caused by breathing. The prototype has been developed in the framework of the TECHEA (TEChnology for HEAlth) Project aimed to the realization and validation of prototype systems for applications to health protection. The paper describes the apparatus and reports the results of the experimental characterization of the X-ray source done in collaboration with the Laboratory of Medical Physics and Expert Systems of Regina Elena Hospital.

## *TECHEA Project*

The TECHEA (**TECHnology for HEAlth**) Project launched by ENEA aims to create a technological infrastructure for the development, construction and validation of system prototypes, based on physical technologies, for applications to protect citizens' health.

The Project is divided in three WPs. **WP2 is devoted to the development of a rotating and low-stray radiation X-ray source for prone breast treatment based on a compact electron accelerator.**



Conceptual layout of the TECHEA Prone Breast Irradiation System.

## *TECHEA-PBS (Prone Breast System)*

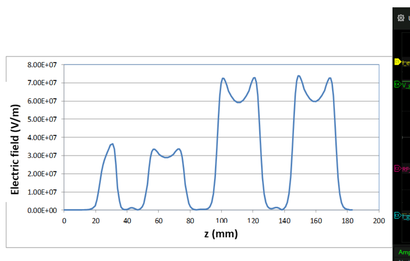
The TECHEA PBS prototype in the test bunker at ENEA-Frascati

| Parameter | Value |
|---|---|
| Rotation angle of the beam source | 270° |
| Source-isocenter distance | 60 cm |
| Treatment couch position | fixed |
| Electron beam energy | 3 MeV |
| Dose rate at isocenter | 1.5 Gy/min |
| TPR20/10 | 0.524 |
| Maximum spot diameter | 14 cm |

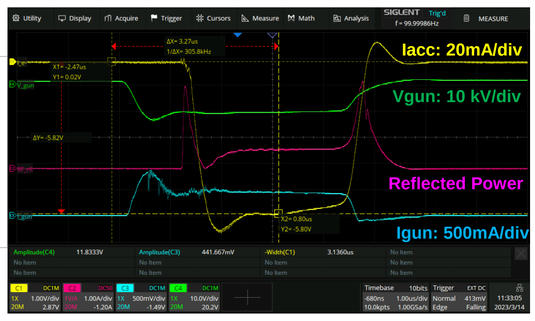
Aims:
- Improve Target coverage
- Sparing of OAR
- Reduce of the overall treatment time
- Simplify of installation
- Reduce of undesired integral dose to patient
- Reduce of the overall costs of the Breast RT

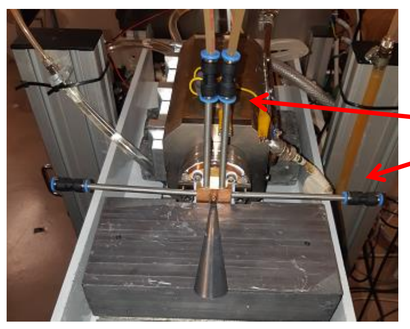
## *Electron Linear accelerator and e-X converter*

| Parameter | Value |
|---|---|
| Accelerating structure length | 20.8 cm |
| RF frequency | 2998 MHz |
| Number of accelerating cavities | 4 |
| Length of accelerating cavities | 22,44,48,48 mm |
| Bore hole diameter | 6 mm |
| Injection energy | 12-15 KeV |
| Output energy (max.) | 3 MeV |
| Output pulse current | 120 mA |
| Pulse duration | 3.4 μsec |
| Repetition frequency | 10-100 Hz |



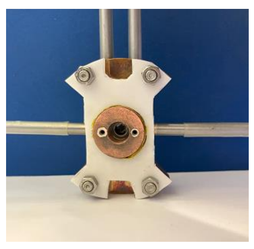

Design accelerating electric field



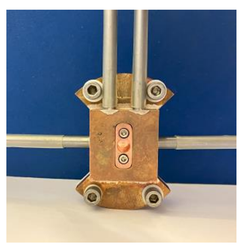




Front view of the linac (without external shielding) followed by the first shielding (open).

e-X converter

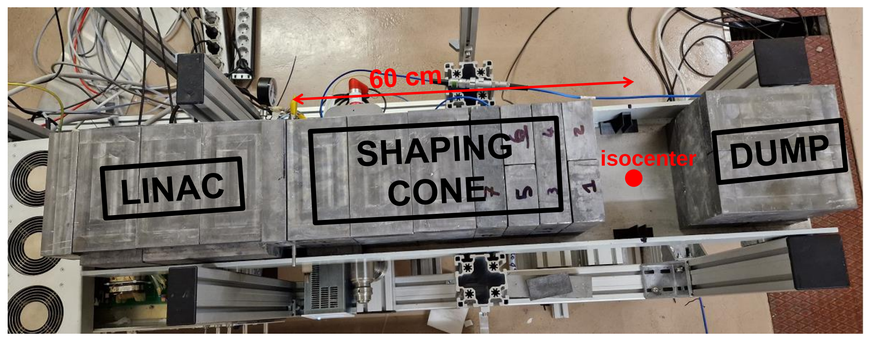


side W (400 μm thick)



side Cu (1.6 mm thick)

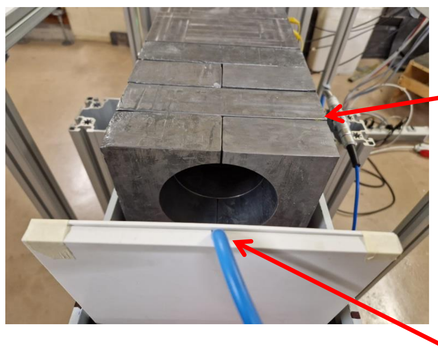
## *Pb collimator and shielding*




Top view

The photon beam is collimated by a Pb conical collimator having an aperture of 13 degrees. A lead block (“dump”) is positioned behind the nominal irradiation position (isocenter) to shield the x-rays traversing the target.

## *Dosimetry*



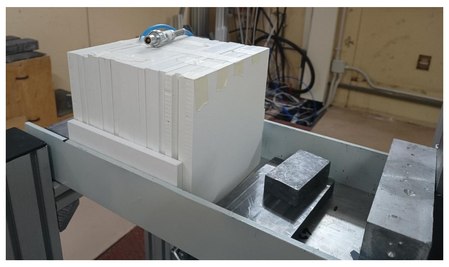
**Monitor Chamber (MC)**

(Transmission chamber, PTW TM7862 model , 95 mm diameter)

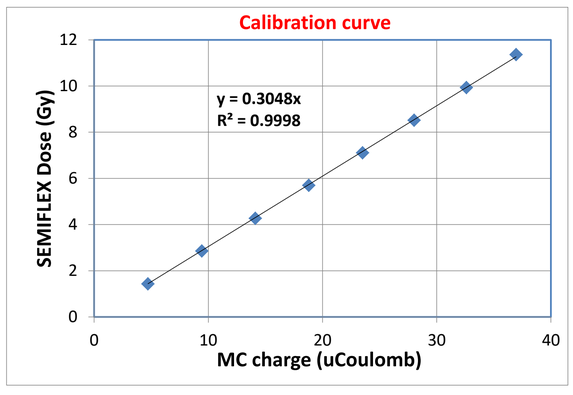
Front view of the setup during the dosimetric inter-calibration measurements

**Reference dosimeter**

(PTW TM31010 Semiflex chamber Sensitive volume 0.125 cm$^3$, Radius 2.75 mm)

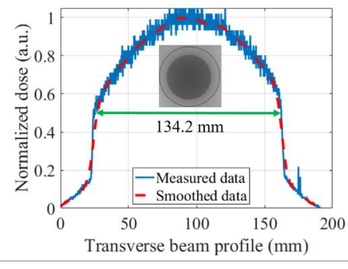


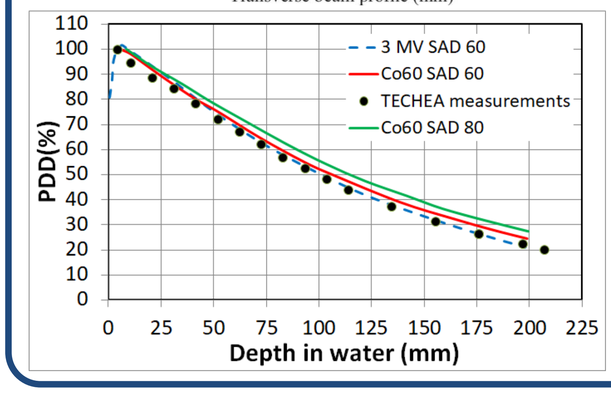
**Solid Water Phantom**
density=1.035 g/cm$^3$
20x20x1 cm$^3$ slabs



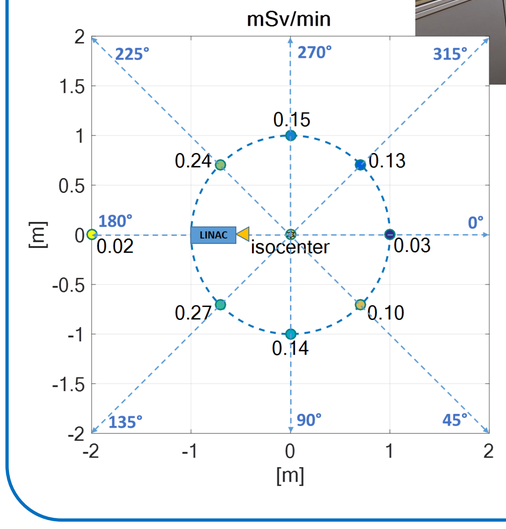

## *X-ray characterization*

The X-rays characteristics were investigated with EBT3 films, and the Semiflex ionization chamber respectively for lateral distribution measurements and PDD (Percentage Dose Depth) curves acquisition. A LUDLUM chamber (model 9DP) was used for environmental radiation measurements.




**Environmental Radiation Measurements**




## *From the prototype to the final device*

The TECHEA prototype demonstrated the main features of a compact dedicated system for PB Irradiation. For an upgrade to an engineered clinical device:
- Fiber carbon couch
- Multileaf collimator
- Improving the shielding