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Status of the TOP-IMPLART Proton Linac

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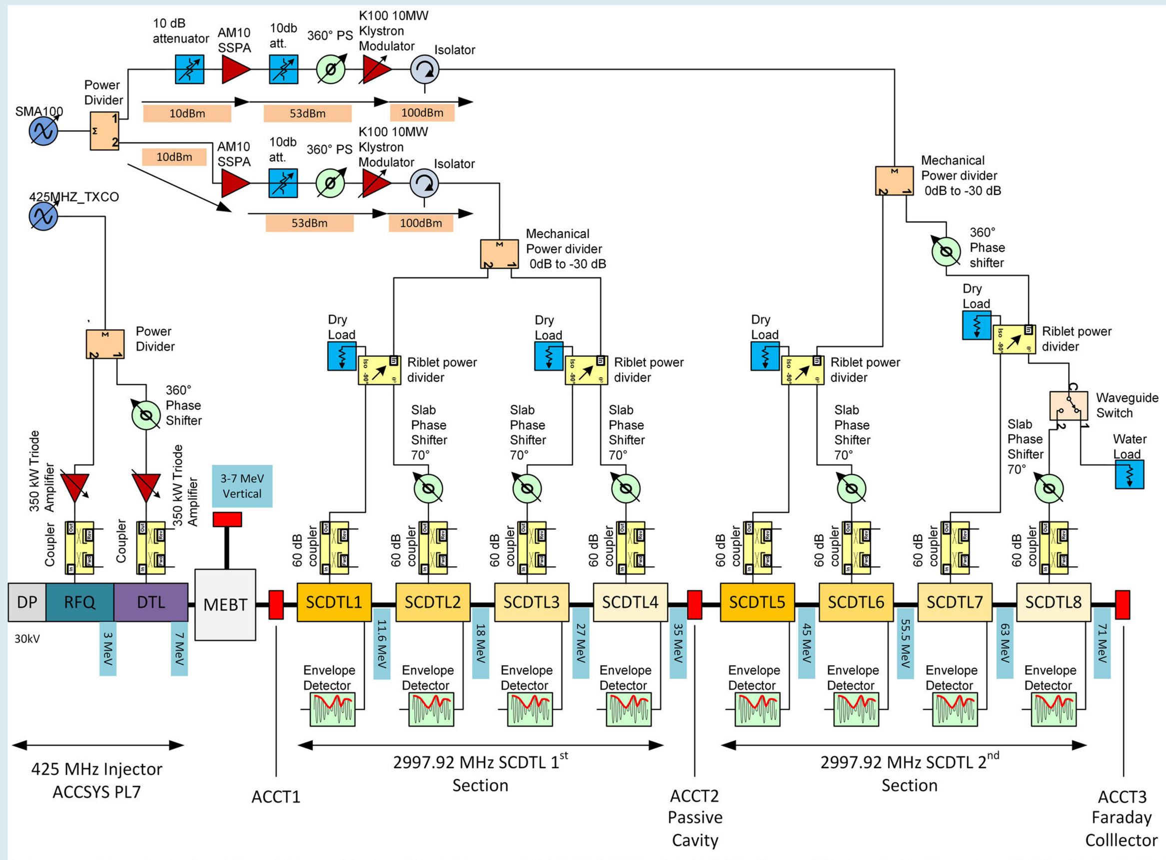
The TOP-IMPLART (Intensity Modulated Proton Linear Accelerator for Radio Therapy) proton linac, is a RF pulsed linac, designed for protontherapy consisting of a low frequency (425 MHz) 7 MeV injector followed by a sequence of accelerating modules operating at 3 GHz under construction, assembly and test at the ENEA Frascati Research Center. The accelerator features also a vertical low energy (3-7 MeV) line for irradiation of samples in horizontal position. The segment currently completed includes 8 SCDTL modules up to 71 MeV grouped in two sections each one powered by a 10 MW klystron driven by a SCANDINOVA K100 modulator with a variable pulse length (1-5 us) at a repetition frequency of 25 Hz. The output current can be varied up to 30 uA. The beam is mainly used for radiobiology experiments and dosimetry systems tests, but the flexibility in beam characteristics makes it suitable also for applications different from protontherapy, as the irradiation of electronics components to verify their behavior in the space environment. In this work, the current status of the accelerator and beam characteristics measurements are presented with an overview of the experiments carried on it.

THE TOP-IMPLART LINAC

Layout of the TOP-IMPLART Linac situated at the ENEA Frascati Research Center:

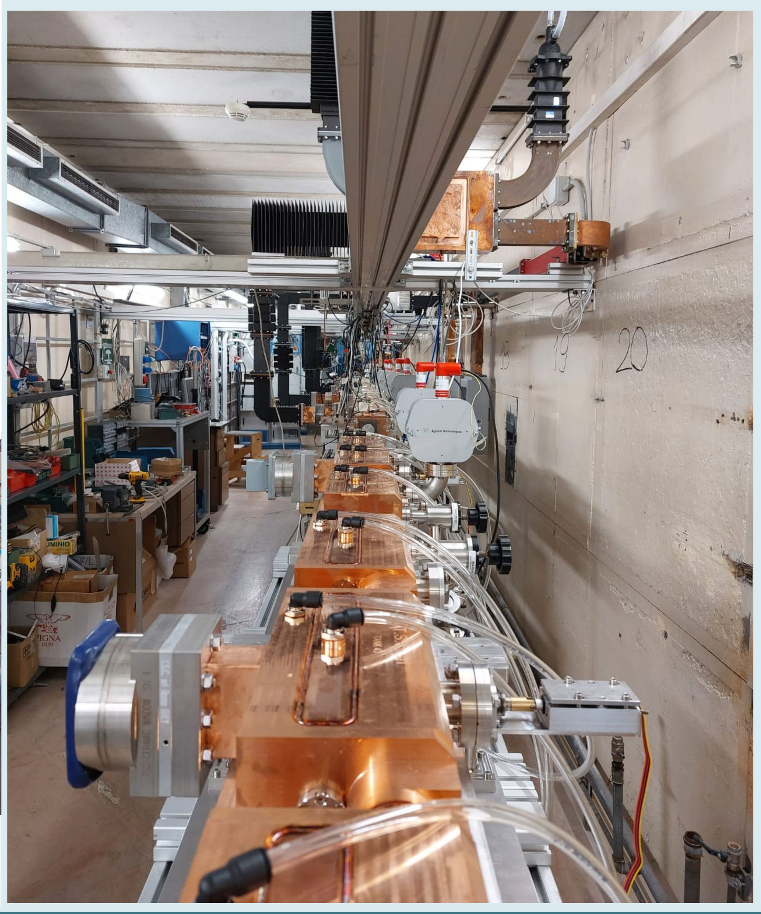
- Injector: model PL-7 manufactured by AccSys Hitachi consisting of a 3 MeV RFQ and a 7 MeV DTL, operating at 425 MHz.
- 1st section: 4 SCDTL structures (ENEA design), 35 MeV output energy, powered by a 10MW klystron tube (Canon E37325, 2998.5 MHz).
- 2nd section: 4 SCDTL structures (ENEA design), 71 MeV output energy, powered 10MW klystron tube (Canon E37325, 2998.5 MHz).
- 3rd section: 3 CCL structures (ENEA design), 110 MeV output energy to be constructed powered by a 10MW klystron.

TOP IMPLART LINAC (@ 71MeV) – RF and main parameters

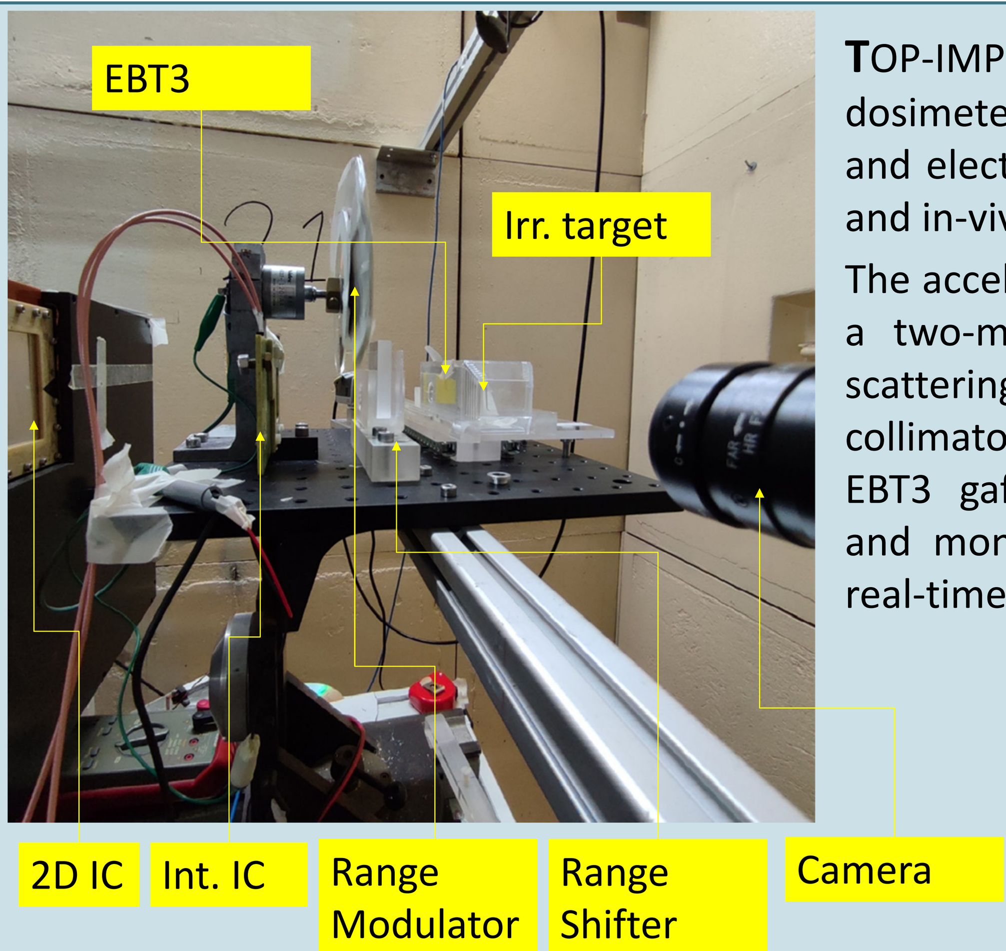


Parameter	Value
Pulse width	1 - 4 (µs)
Pulse Repetition Frequency	10-100 (Hz)
Maximum pulse current	30 (uA)
Spot size (exit window)	<3 (mm)
Maximum pulse charge	70 (pC)
Number of proton per pulse	4.3x10^8
Commissioned maximum energy	63 (MeV)

RF modulators area: (Scandinova K1) with Thales TH751A klystron and two Scandinova K100 with Canon E37325 klystrons.



Beam delivery



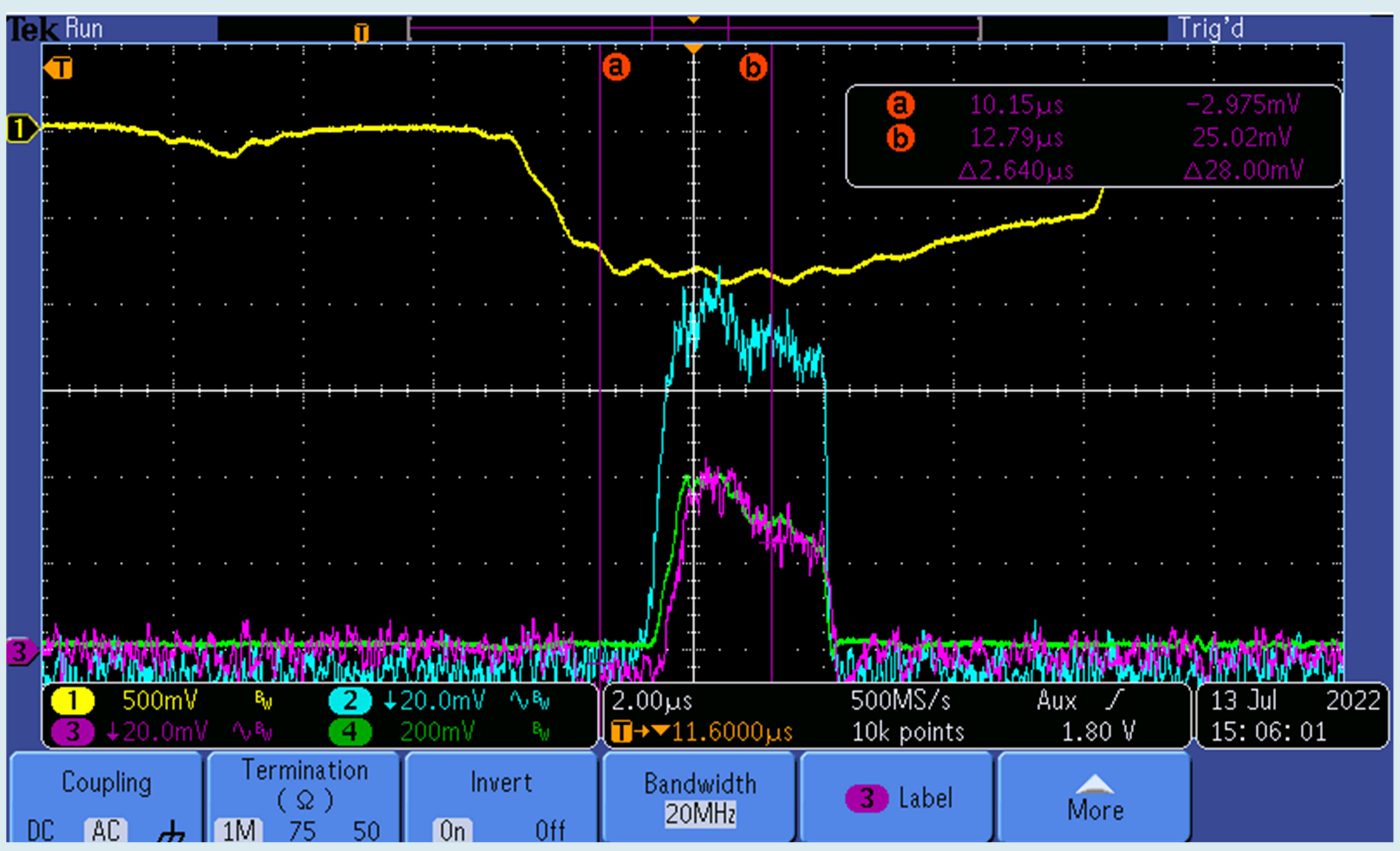
TOP-IMPLART beam is used to characterize dosimeters, perform experiments on material and electronics components, and for in-vitro and in-vivo (mice) radiobiology experiments.

The accelerated beam is expanded in air over a two-meter long beam line, featuring a scattering foil, beam current diagnostics, collimators, dosimetric systems (based on EBT3 gafchromic films), diamond detector and monitor ionization chambers providing real-time control of delivered dose.

The photo above shows the terminating part of the irradiation beam line equipped with a setup designed to irradiate thick biological samples (placed inside the plastic box) using a SOBP (Spread Out Bragg Peak). The SOBP is obtained by rotating the range modulator during irradiation. The range shifter allows to further degrade the beam energy and, thus define the irradiation depth. The two ionization chambers allow dose control during irradiation.

Characterization of 63 MeV beam

Current measurement

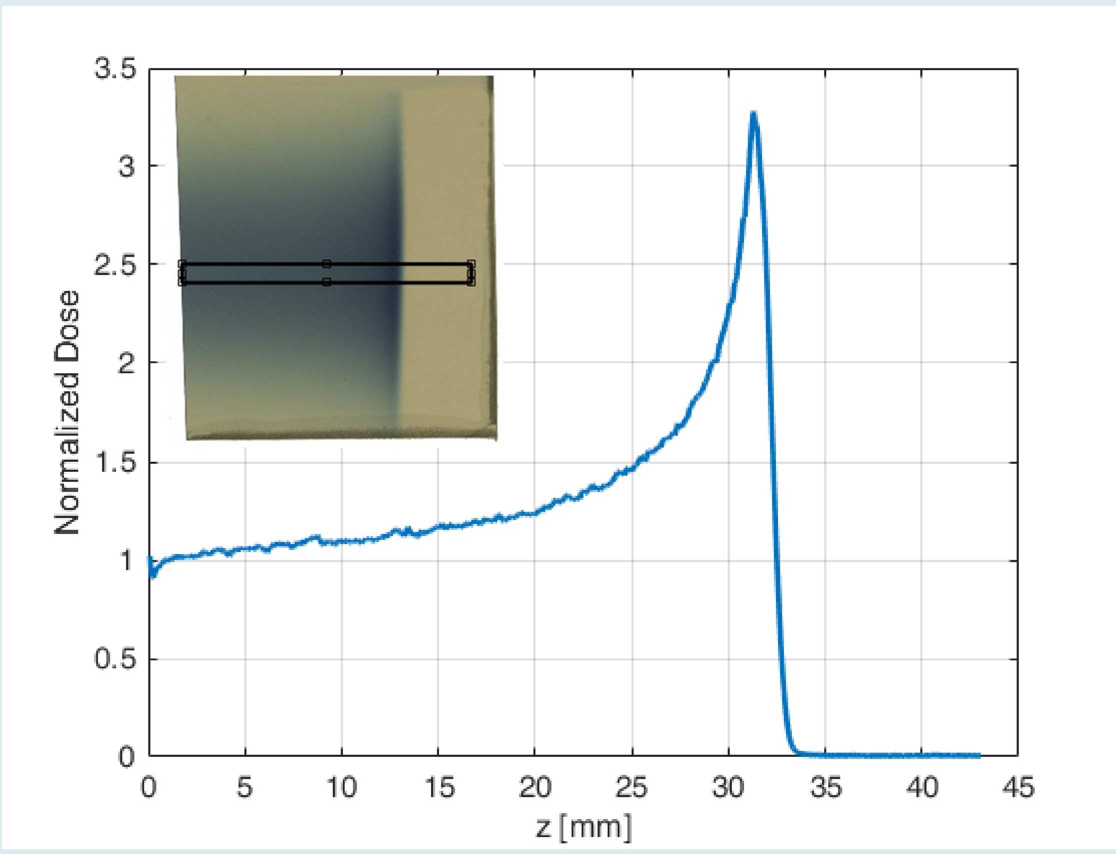


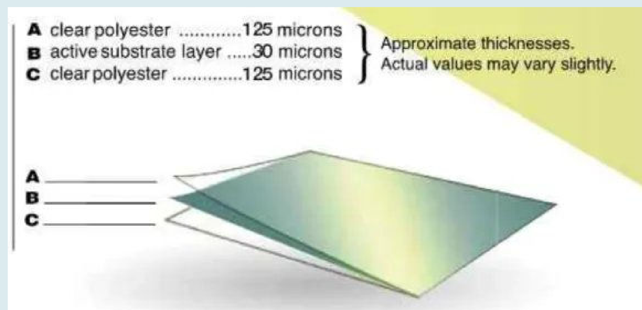
Beam current measured along the linac.

- Yellow trace: injected current measured at ACCT1 (500uA/div),
- Cyan trace: beam current at SCDTL4 output (35 MeV) measured at ACCT2 (9uA/div)
- Magenta trace: beam current at SCDTL7 output (63 MeV) measured at ACCT3 (10uA/div). The ACCT3 is placed after 1 mm of Aluminium to suppress secondary electrons.
- Green trace: beam current (10uA/div) measured by a Faraday Collector placed after a 15.3 mm total Aluminium thickness.

Energy Measurement (Bragg peak @ 63MeV)

Beam energy is extracted by measuring the particle range in an EBT3 radiochromic film placed in a custom-designed solid phantom positioned at beam output window, parallel to the beam propagation axis.





Bragg peak analysis. Dose integrated in the selected ROI (see inset). The dose value is normalized to the entrance level (left). Beam penetration depth is scaled to water density. (Inset) Irradiated EBT3 as acquired from the scanner showing ROI used to extract the curve. (Right) Solid phantom with EBT3 sandwiched between two plastic materials of the density of radiochromic external layers.

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