DESIGN AND TEST OF C-BAND LINAC PROTOTYPES FOR ELECTRON FLASH RADIOTHERAPY

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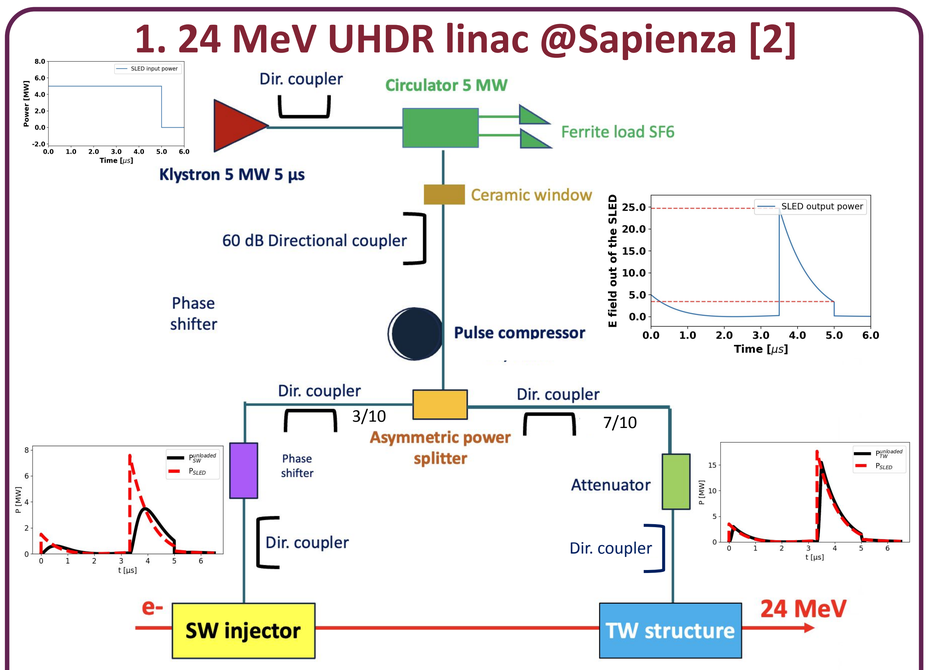
Abstract **FLASH Therapy [1]**,a novel cancer treatment technique, aims to control the tumor-grown sparing the healthy tissue from radiation damage increasing the therapeutic index. The translation of FLASH therapy into clinical practice, especially for treating deep-seated tumors, necessitates achieving Very High Electron Energy (VHEE) [3] levels within the 50-150 MeV range. In the framework of the SAFEST project, Sapienza University, in collaboration with INFN, is actively developing a compact C-band linac demonstrator at the energy of 24 MeV (loaded) with 100 mA peak current. This paper provides insights into the design strategy and electromagnetic characteristics, with a particular focus on prototype testing and tuning conducted at the Sapienza Accelerator Laboratory. The progress of this innovative linac represents a step toward realizing an advanced FLASH VHEE source in cancer treatment.

1. 24 MeV UHDR linac @Sapienza [2]



Parameters	Value
Frequency	5.712 GHz
RF pulse length	5 μs
Klystron Power	5 MW
Peak power with pulse compressor	24.4 MW (β = 3)
Linac length	~ 1.5 m
Nominal beam energy	**24 MeV**
Beam pulse current	**100 mA**

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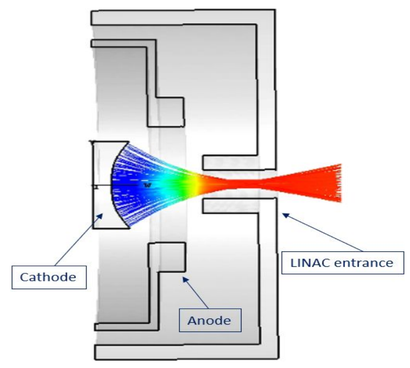
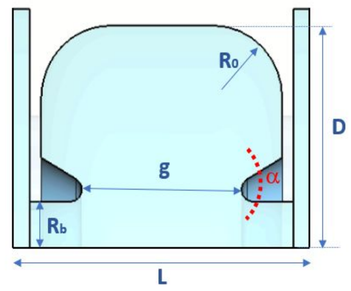
FLASH Radiotherapy with high Dose-rate particle beAms

2. Standing Wave Injector [3]

Electron source: **pulsed DC thermionic gun** at 15 kV.



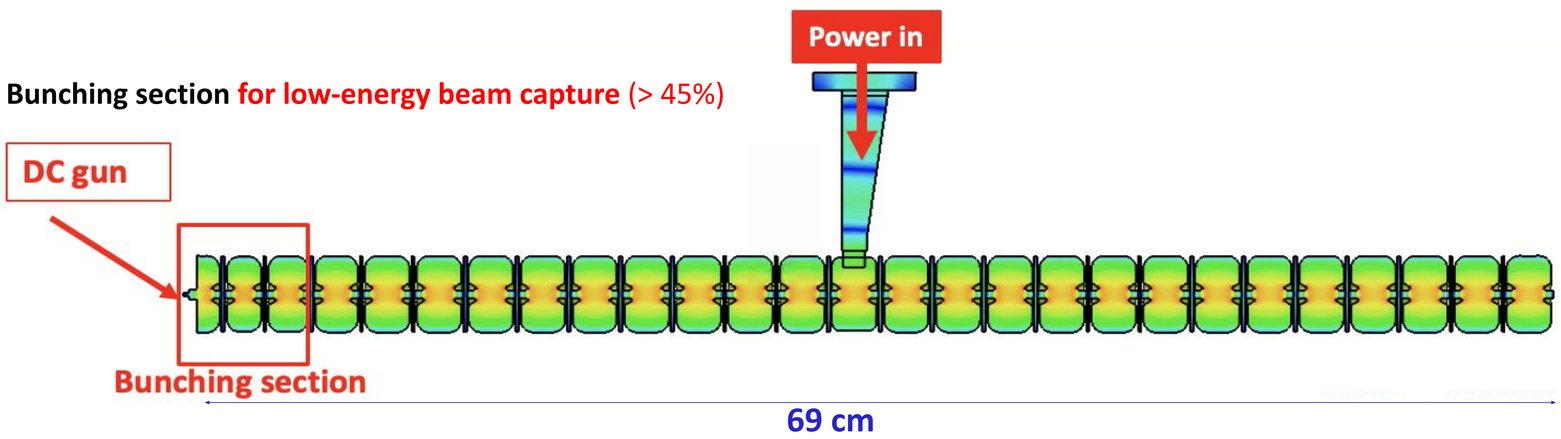
Parameters	Value
Mode of operation	Bi-periodic π/2
N of cells	27
Shunt Impedance	103 MΩ/m
Quality factor	10178
Coupling coefficient	1.58
Beam capture	45%
Filling Time	0.220 μs
Beam output energy	**10 MeV**
Beam pulse current	**100 mA**



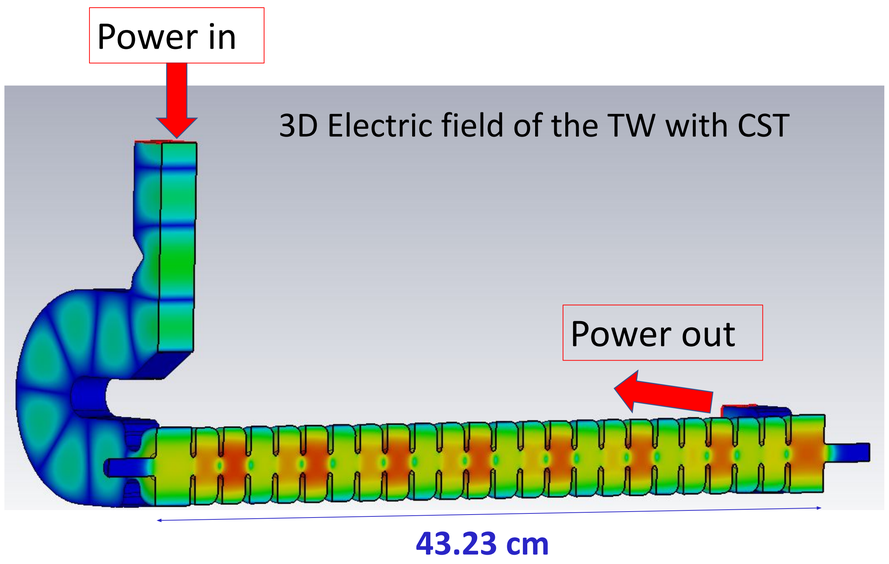
Single cell parameters [mm]

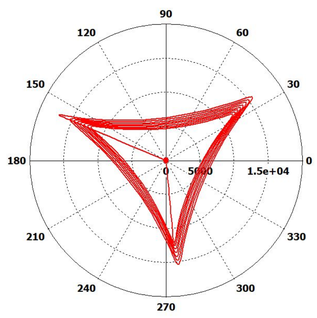
D	g	L	Rb	R0	α
38.25	15.6	24.4	3	6	30°

Bunching section for low-energy beam capture (> 45%)



3. Traveling Wave design [3]

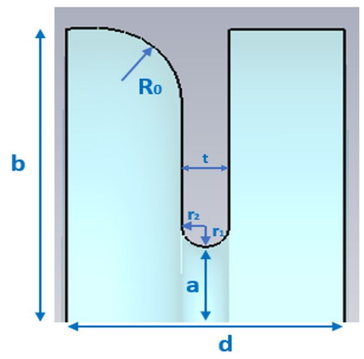




Electric field polar plot with 2π/3cell-to-cell phase advance

Parameters	Value
Structure type	Constant Impedance
Shunt impedance	107 MΩ/m
Quality factor	10127
Filling time	0.143 μs
Group velocity	0.01c
Mode of operation	$2/3\pi$
Final beam energy	**24 MeV**
Beam pulse current	**100 mA**

Single Cell design

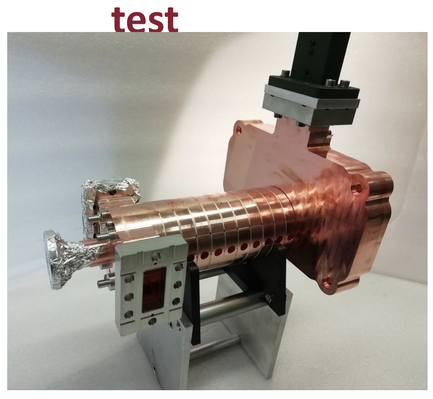


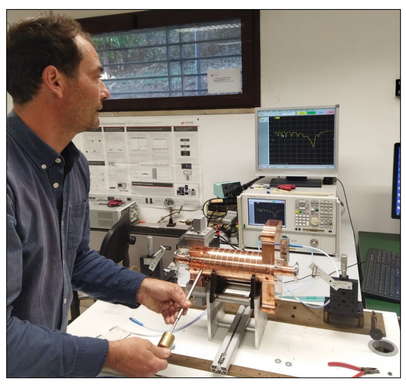
Asymmetric cell to facilitate in house realization.

Single cell RF parameters in mm

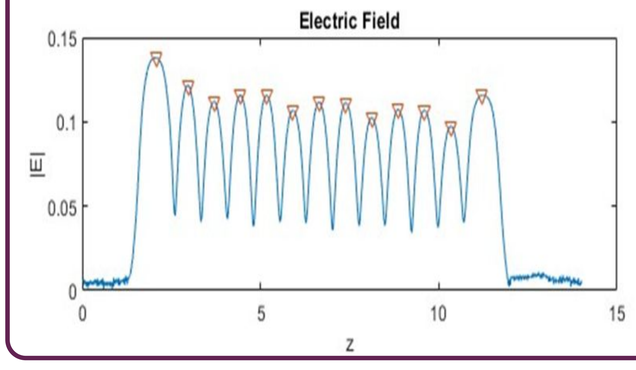
a	b	d	R_0	t	r_1/r_2
5	21.03	17.5	6	3	1.25

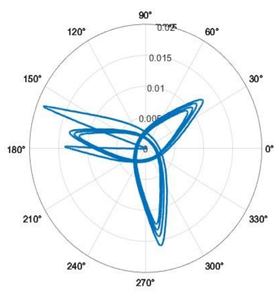
4. TW first prototype: tuning test



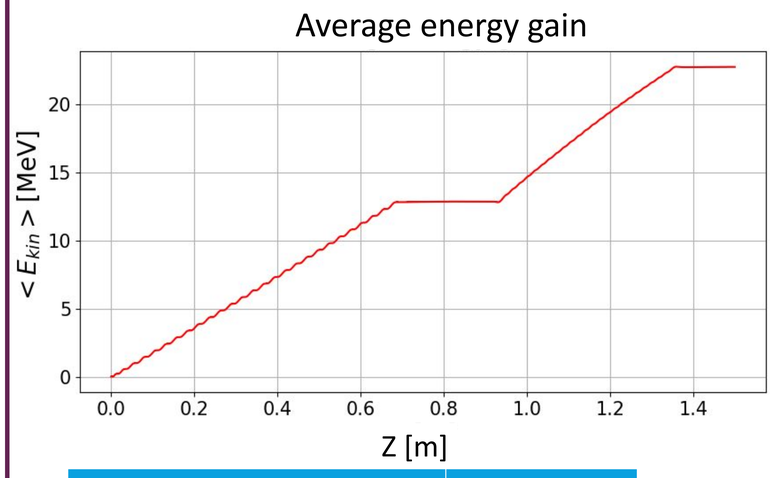


In house realization of the TW structure @ La Sapienza & INFN

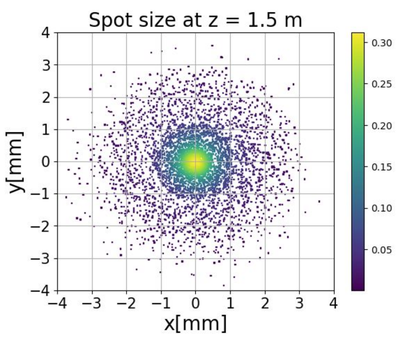


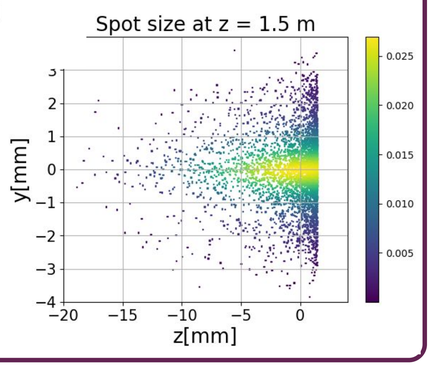


5. ASTRA beam dynamics simulations



Parameters	Value
Bunch charge	18 pC
Bunch length (rms)	23 ps
Bunch train charge in 1 μs	100 nC
Transverse spot size (rms)	1.2 mm





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Reference

[1] V. Favaudon et al., Ultrahigh dose-rate FLASH irradiation increases the differential response between normal and tumor tissue in mice, Sci Transl Med. 6, 245ra293, 2014.

[2] L. Palumbo et al. Safest: A Compact C-band Linear Accelerator for VHEE-FLASH Radiotherapy, *14th International Particle Accelerator Conference, 2023*

[3] L. Faillace Perspectives in linear accelerator for FLASH VHEE: Study of a compact C-band system *Phys Med. 2022 104:149-159.*