Acceleratori - RF @ Sapienza/INFN-Roma1

Luigi Palumbo
Sapienza&INFN-Roma1

Team

L. Palumbo (PO), E. Chiadroni (PA), M. Migliorati (PA), A. Mostacci (PA), M. Petrarca (PA), L. Ficcadenti (INFN-Roma1) (+ L. Faillace now at LNF & B. Spataro)
& 4 PhD students (L. Giuliano, F. Bosco, M. Carillo, D. De Arcangelis).

.

Sapienza-INFN/Roma1 Accelerator Activity at glance

Main Activities

Participation in R&D effort @LNF (SPARC/Eupraxia@INFN-LNF - all)

Design of X-band hybrid photoinjector (Mostacci, Faillace, Ficcadenti, Spataro)

C-band cavity design for SPARC&ELI (mechanical workshop in SBAI + INF-Roma1) (all)

Design of compac hybrid high C- band gradient injectors for radiation sources (FEL, Compton) & beam dynamics studies (Migliorati, Mostacci, Faillace, Bosco, Carillo)

Novel medical linear accelerators for FLASH therapy (Migliorati, Mostacci, Faillace, Giuliano)

Collective effects and impedance budget for FCC-ee (M. Migliorati)
Transverse mode coupling instability for SuperKEKB (International Task Force, M.Migliorati)
THz Laser Laboratory (M. Petrarca)

Collaborations

Research institutes:
INFN, UCLA, CERN, LBNL, KEK

Industries:
SIT

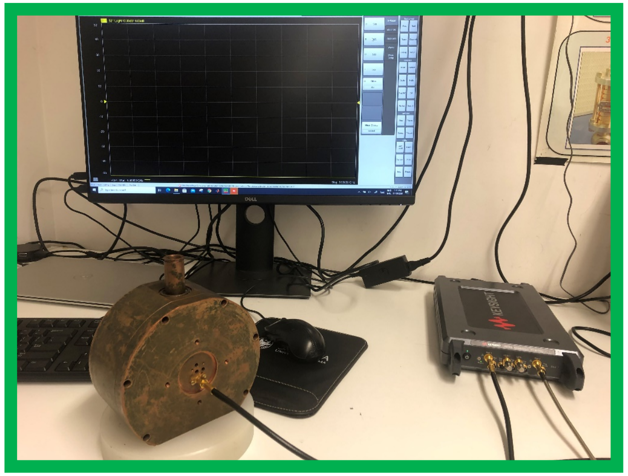
Synergies

EU projects: EuroFel, ELI, Eucard^2, EuroNNAc, EupraXia, FCC-IS, XLS-CompactLight

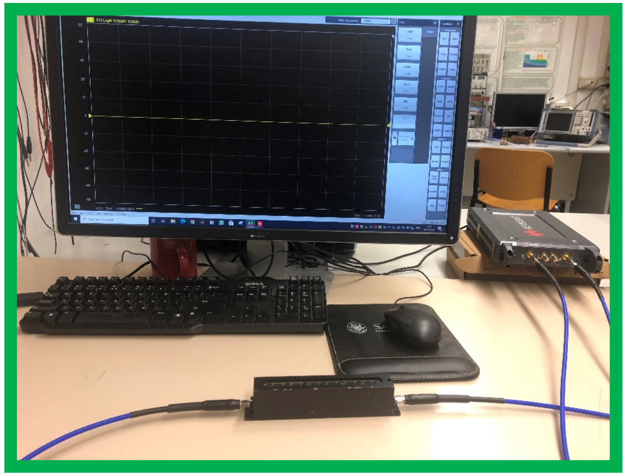
RF - ACCELERATORS- LABORATORY (Resp. Andrea Mostacci)

Vector Network Analyzers (VNA) and SPectrum Analyzers (SPA)

Fieldfox VNA/SPA - 14GHz



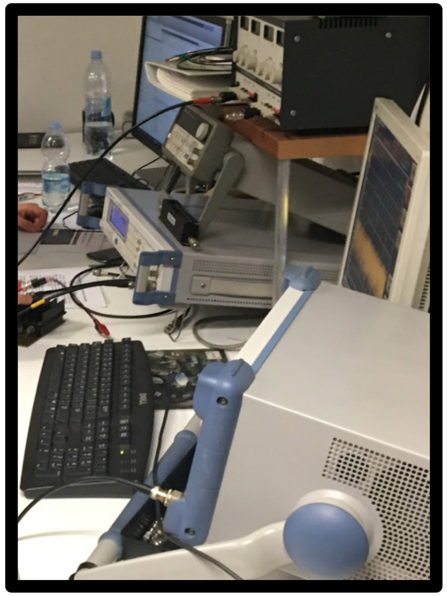
USB VNA - 20GHz



USB VNA - 6GHz

PNA VNA - 20GHz

VNA - 6GHz



SPA - 3GHz

Signal generator – 3GHz

Available Software

Instrument control
Data analysis

MATLAB

LabVIEW

Beam dynamics

GPT

Tstep

ASTRA

MAD

PyHEADTAIL

RF design

CST STUDIO SUITE
ELECTROMAGNETIC FIELD
SIMULATION SOFTWARE

Ansys HFSS

Coupling impedance

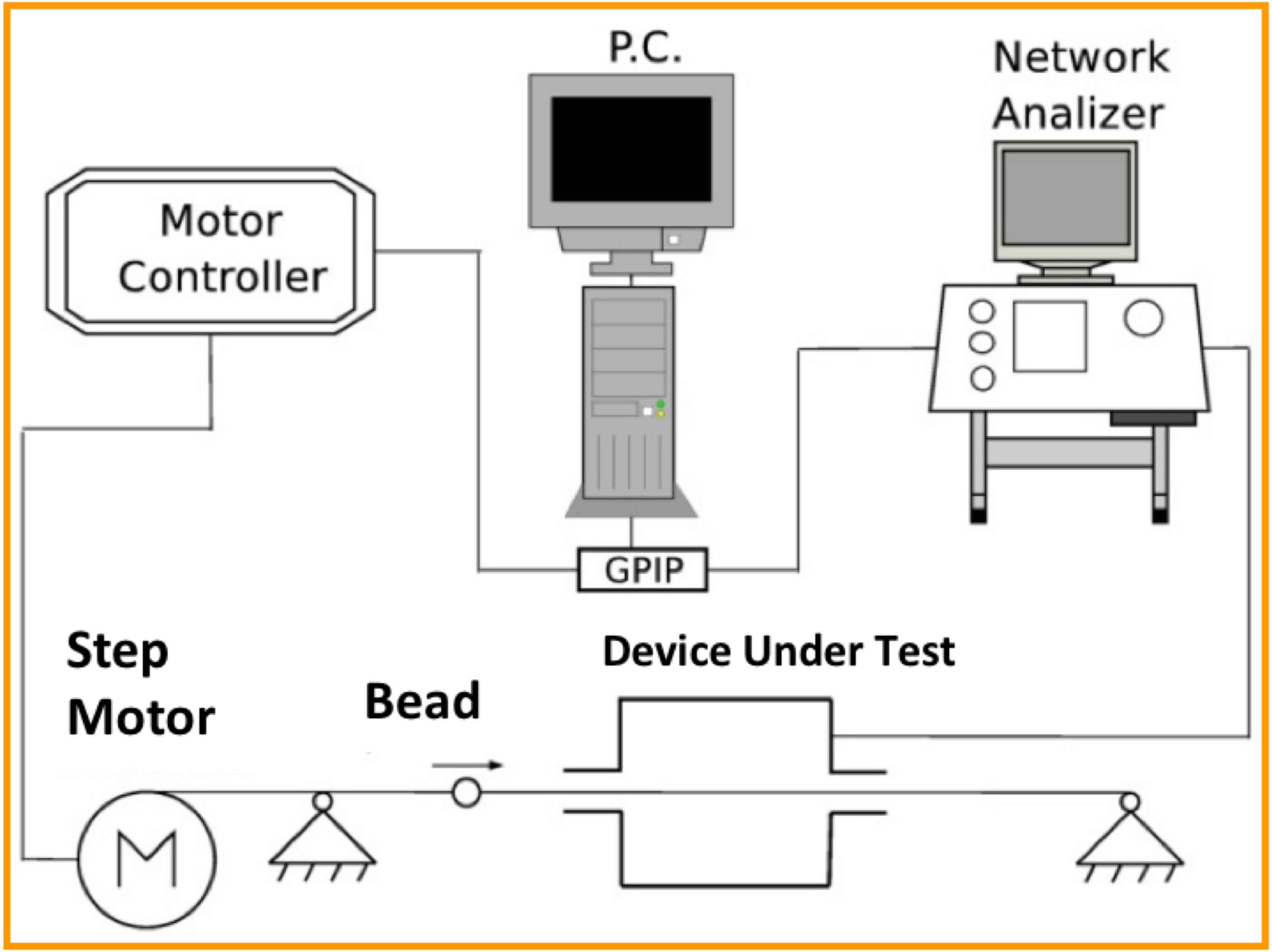
CST STUDIO SUITE
ELECTROMAGNETIC FIELD
SIMULATION SOFTWARE

ImpedanceWake2D

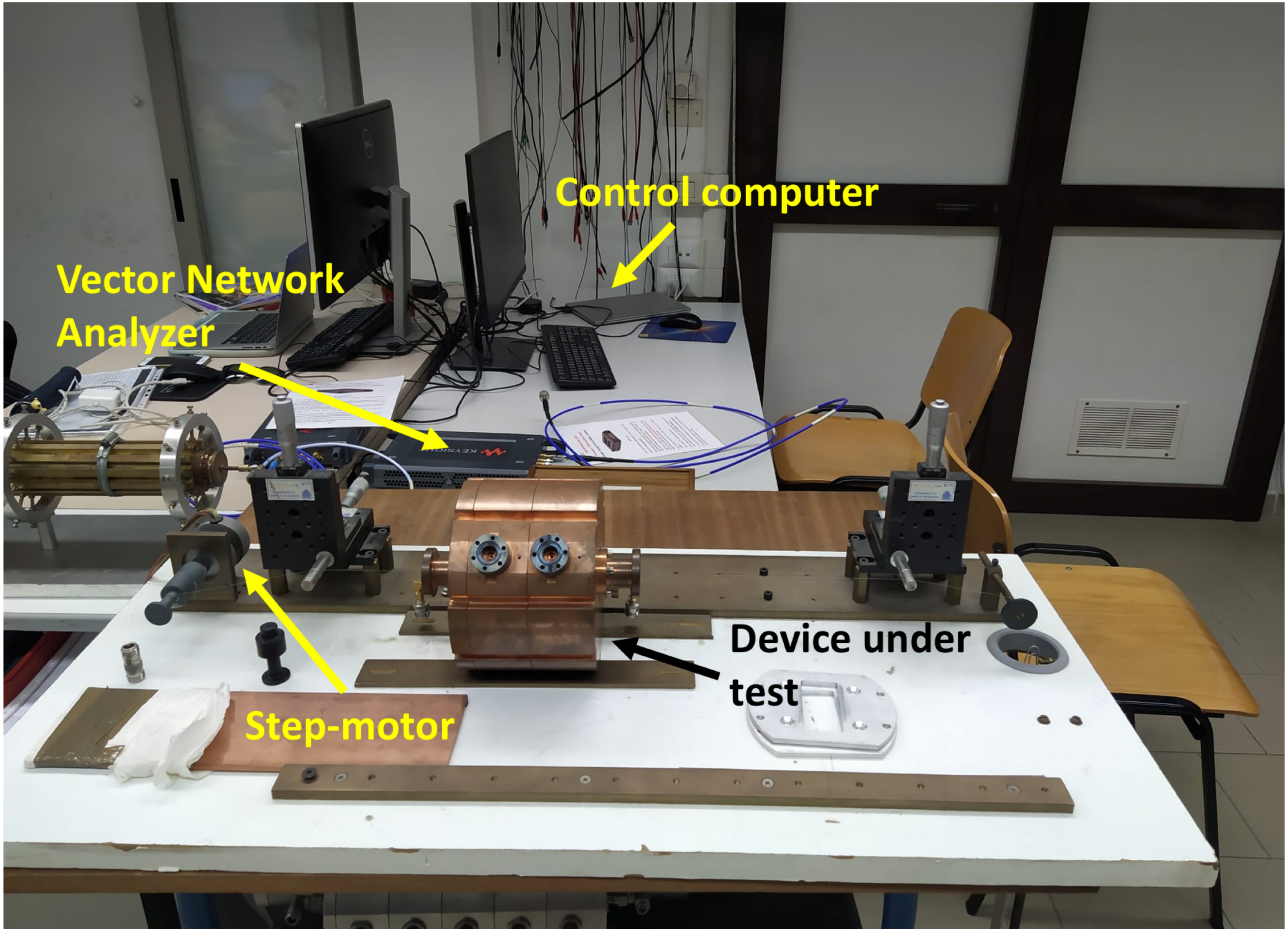
In house developed codes

- MILES: Modeling Instabilities for Linacs with Ellipsoidal Space Charge
- MuSiC: Multib-bunch/particle Simulation Code
- SBSC: Single Bunch Simulation Code

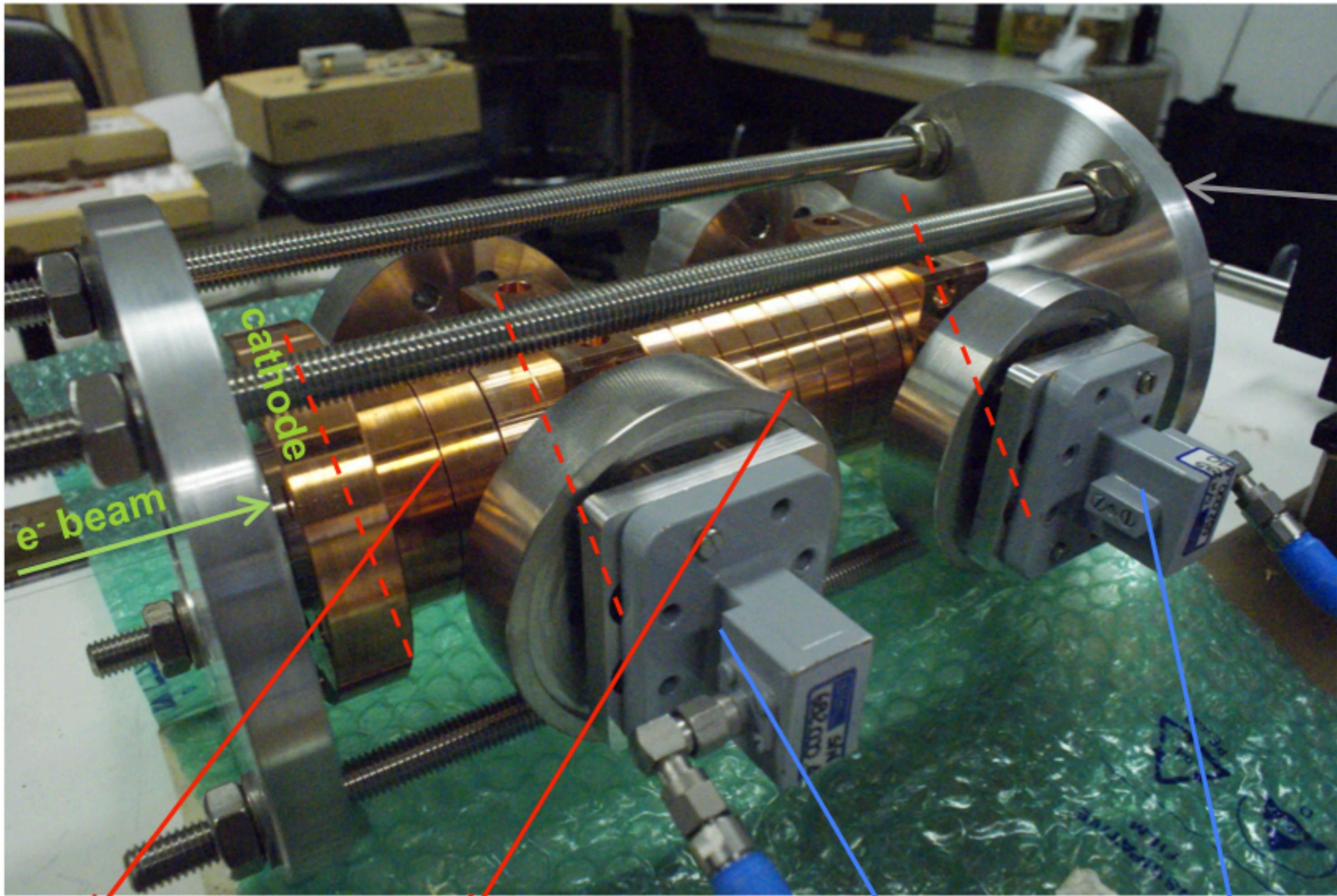
1st instrumentation : Bead pull bench measurements



Bead pull bench measurements: implementation



X-BAND HYBRID ELECTRON GUN (11.424 GHz)



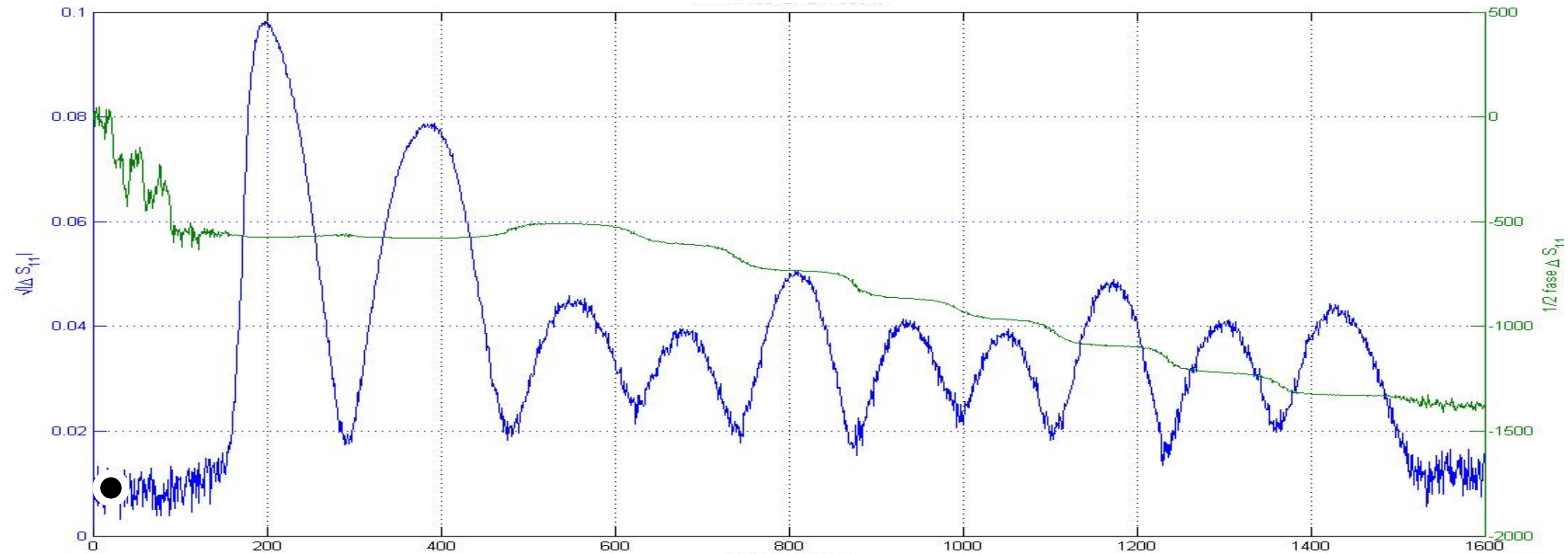
2,5 cells SW part

TW part

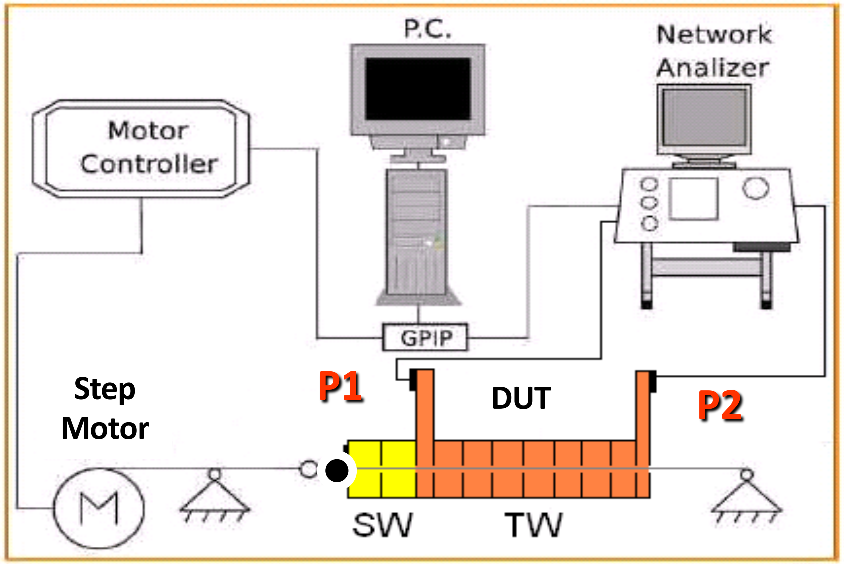
Input Power coupler

Output Power Coupler

BEAD PULL MEASUREMENTS

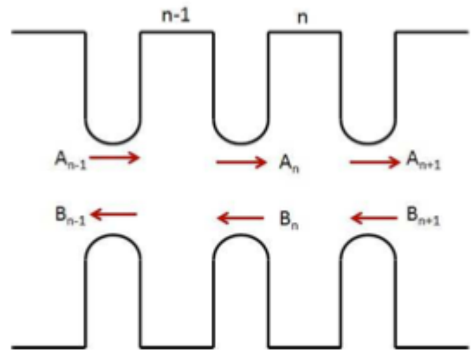


$$\Gamma_p - \Gamma_u = j\omega k_{steele} \frac{E_z^2}{2P_{in}}$$



TUNING OF C BAND TW STRUCTURE (coll. LNF)

Goal **Accelerating field flatness along the cells with proper phase advance per cell.**



1. measure the complex field distribution In at working frequency (bead-pull);

2. calculate the local reflection coefficients Γn of each regular cell;

$$\Gamma_n = \frac{-I_{n-1} + 2I_n \cos\varphi - I_{n+1}}{I_{n-1} - I_n \exp(-j\varphi)}.$$

3. predict the deformation to be applied to the cells;

$$\Gamma_n = jQ'_{0,n}\frac{\Delta f_n}{f_{RF}},$$

4. tune the cells looking at the variation of the modulus of the global reflection coefficient |ΔΓglobal|;

$$|\Delta\Gamma_{\text{global}}| = e^{-2\alpha(n)}|\Delta\Gamma_n|$$

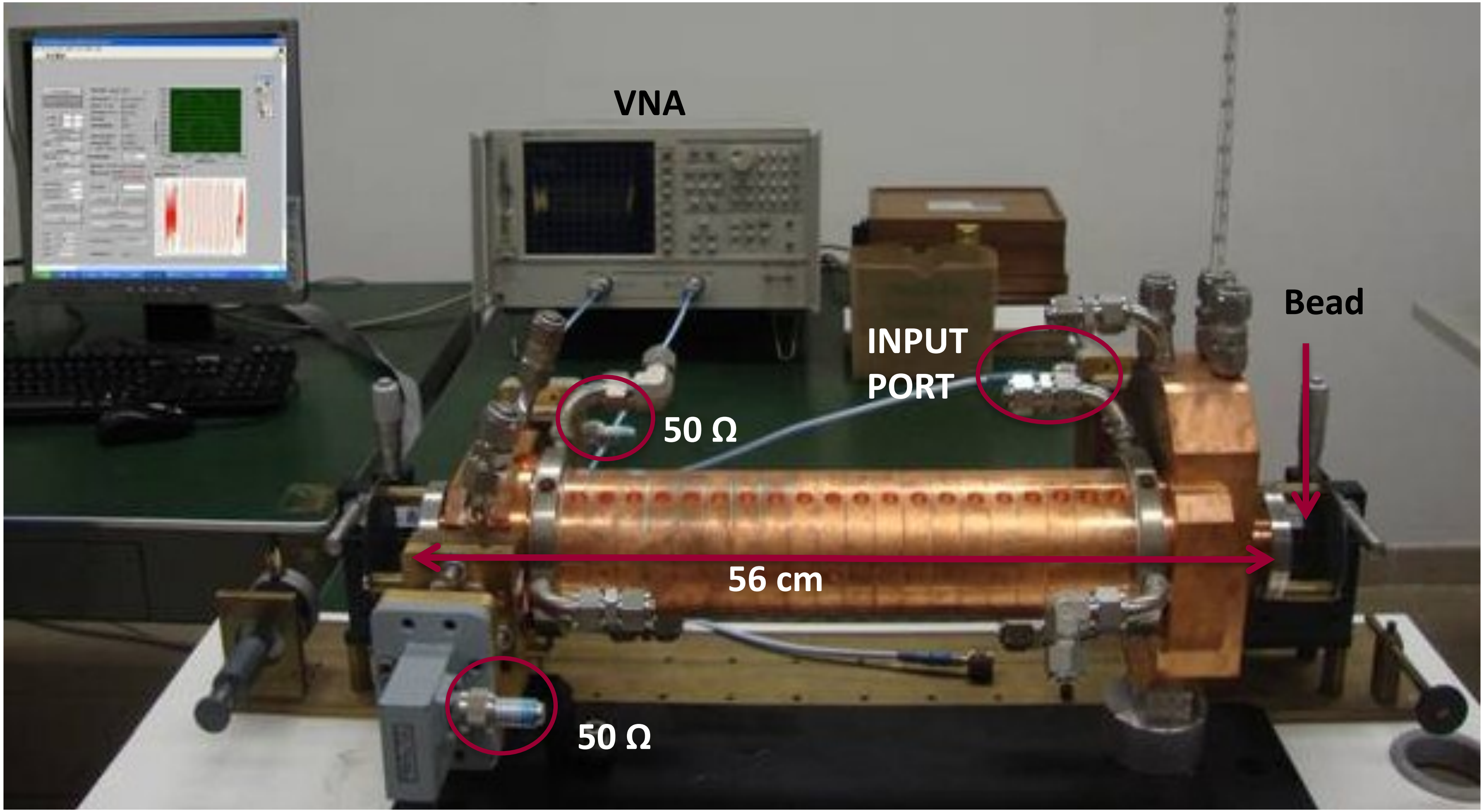
5. repeat such procedure until the Γn is smaller of the desired value (~|Γn| < 0.005)

D. Alesini et al., Tuning procedure for travelling wave structures and its application to the C-Band cavities for SPARC photo injector energy upgrade, Journal of Instrumentation, 2013.

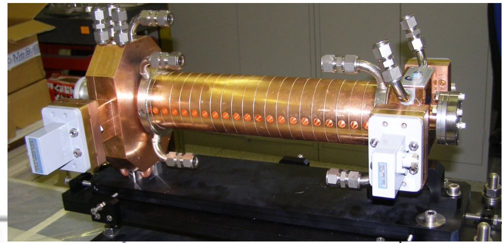
J. Shi, A. Grudiev, A. Olyunin, Tuning of CLIC accelerating structure prototypes at CERN, CERN, 2010

BEAD PULL MEASUREMENT SET-UP

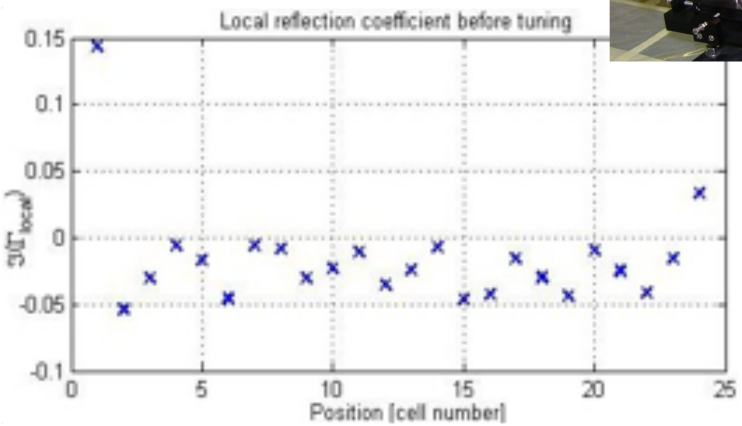
Steele formula $$\Gamma_p - \Gamma_u = j\omega k_{bead}\frac{E_z^2}{2P_{in}}$$

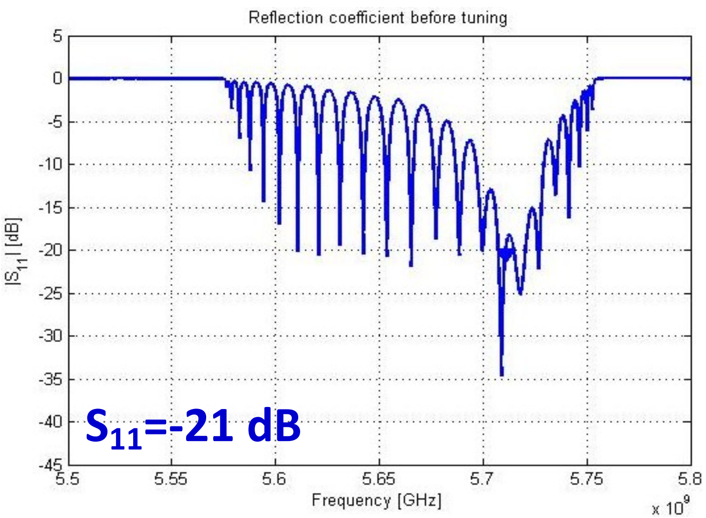


REFLECTION MEASUREMENTS

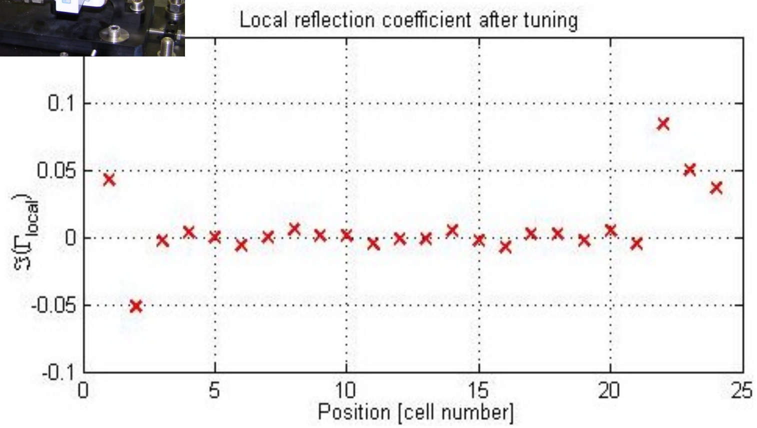


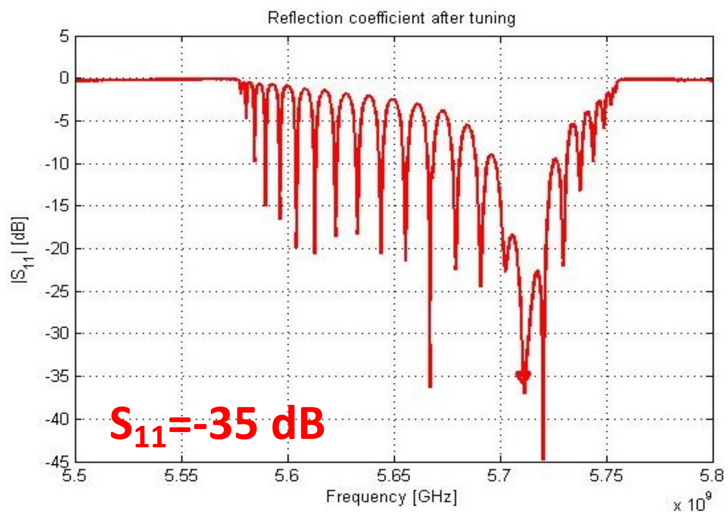
Before tuning





After tuning

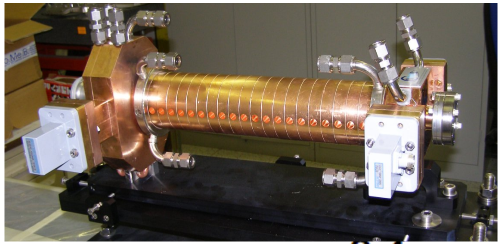




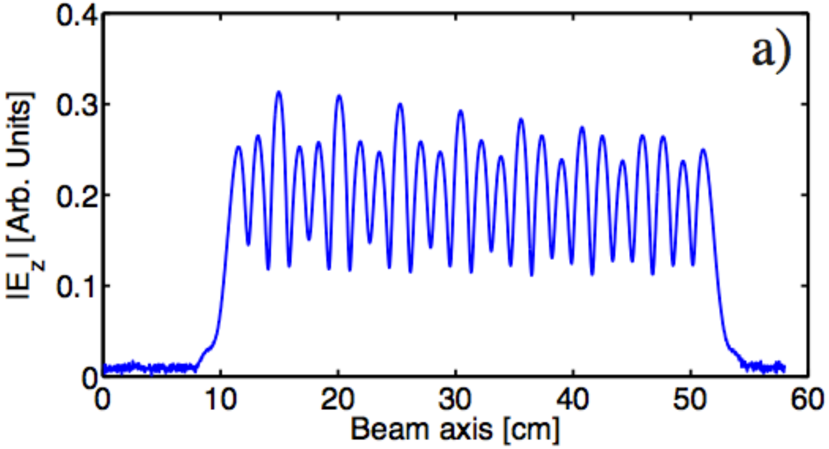
D. Alesini et al., JINST 2013

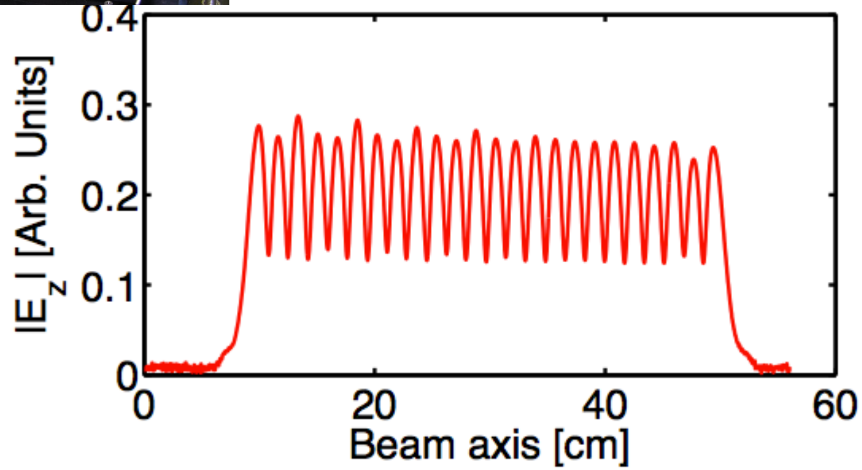
FIELD MEASUREMENTS

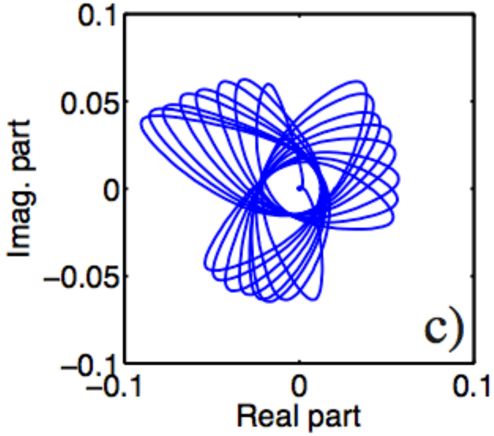
Before tuning



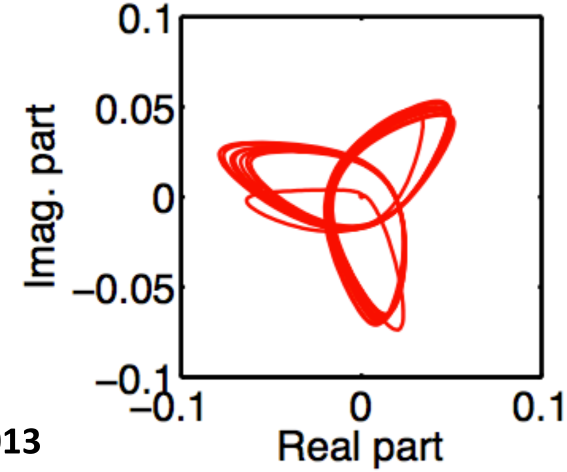
After tuning



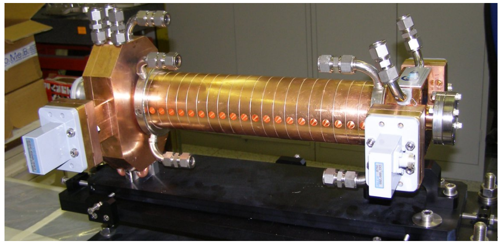




D. Alesini et al., JINST 2013

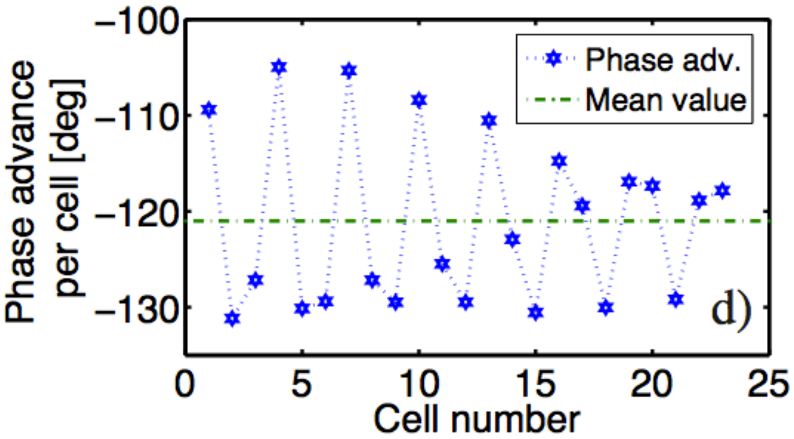


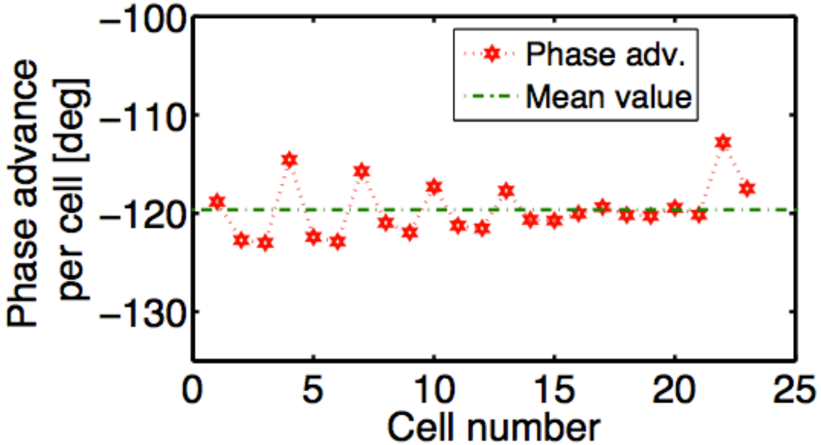
FIELD MEASUREMENTS

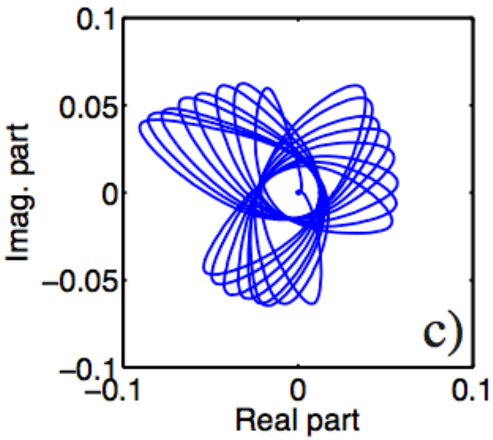


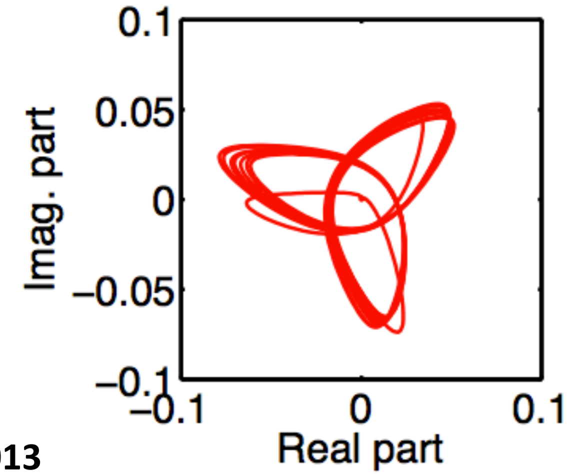
Before tuning

After tuning









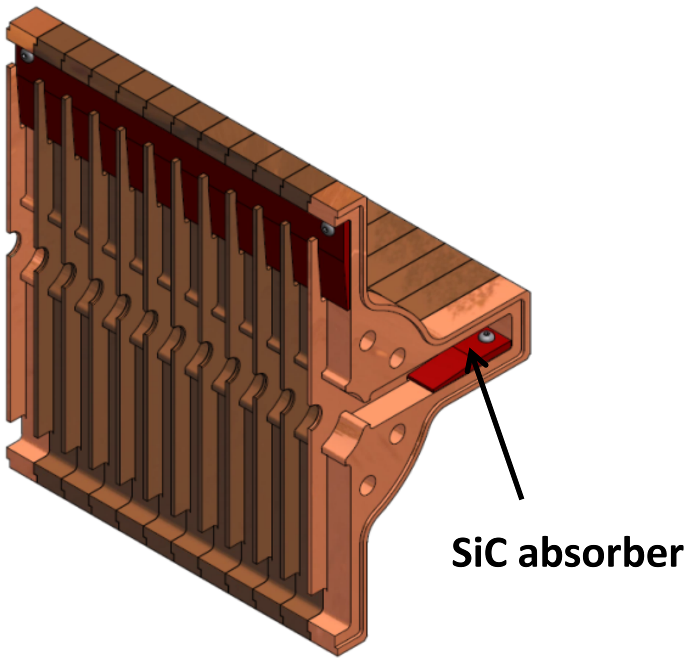
D. Alesini et al., JINST 2013

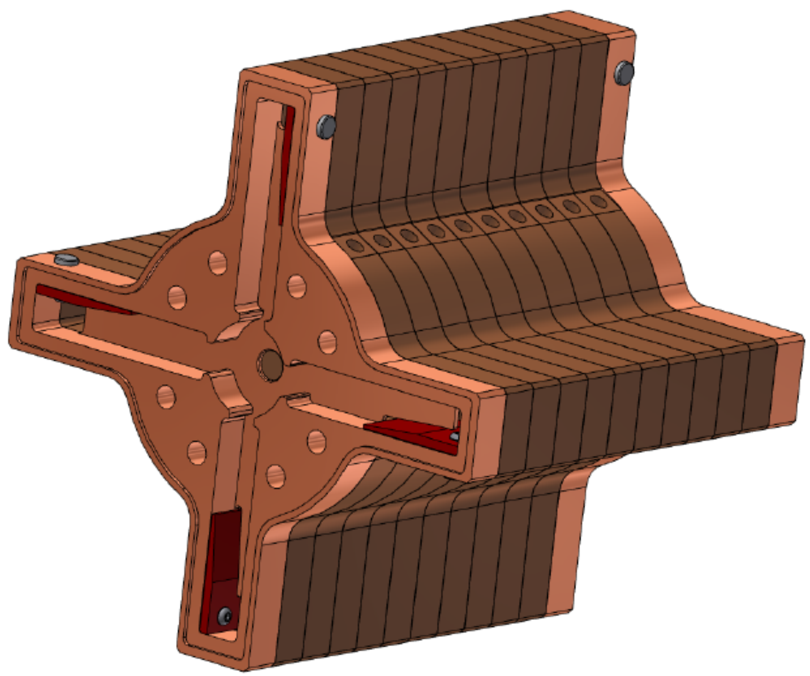
DAMPED STRUCTURE SiC ABSORBERS (ELI)

Each cell of the structure has four waveguides that allows the excited HOMs to propagate and dissipate into silicon-carbide (SiC) RF loads.

The SiC tiles have been optimized to avoid reflections and are integrated into the structure.

In each stack of 12 cells there are four SiC long absorbers, each stack is brazed and all stacks are finally assembled and brazed with the input and output couplers.



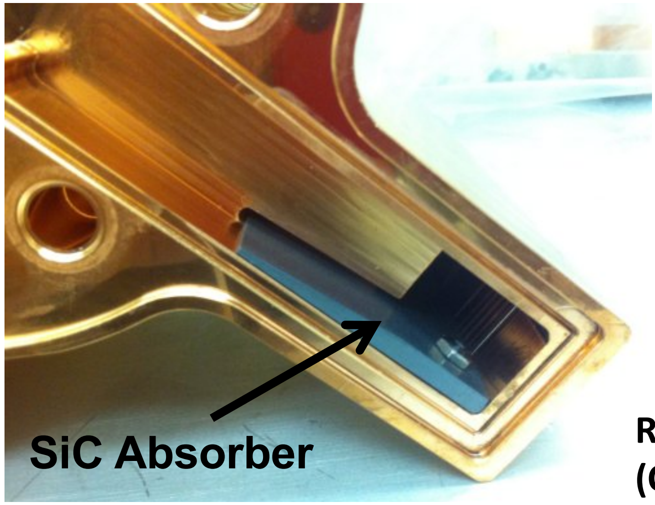


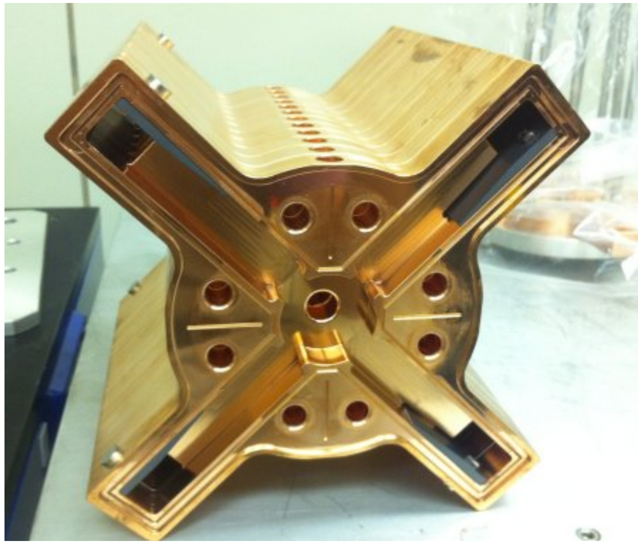
DAMPED STRUCTURE PROTOTYPES

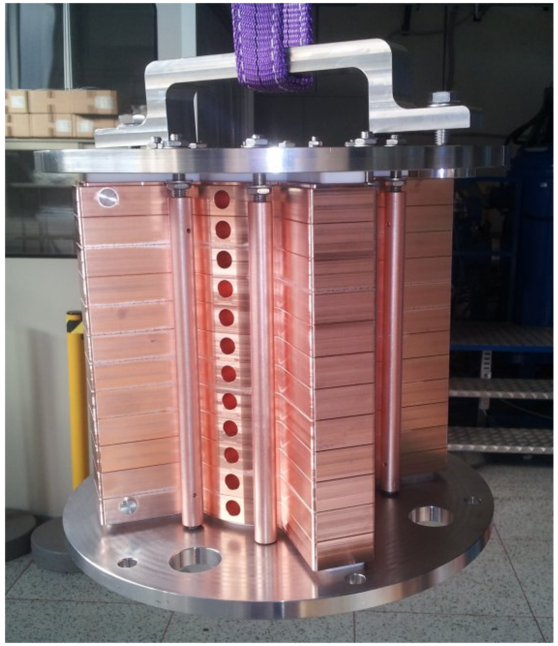
Intense activity of prototyping to verify both feasibility of copper cells machining and effectiveness of brazing process.

Mechanical prototype: full scale device, without precise internal dimensions and with SiC absorbers, to test the brazing process, structure deformations and vacuum leaks.

RF prototype: device with reduced number of cells with precise internal dimensions with tuners and SiC absorbers, to test the RF properties of the structure at low and high power.







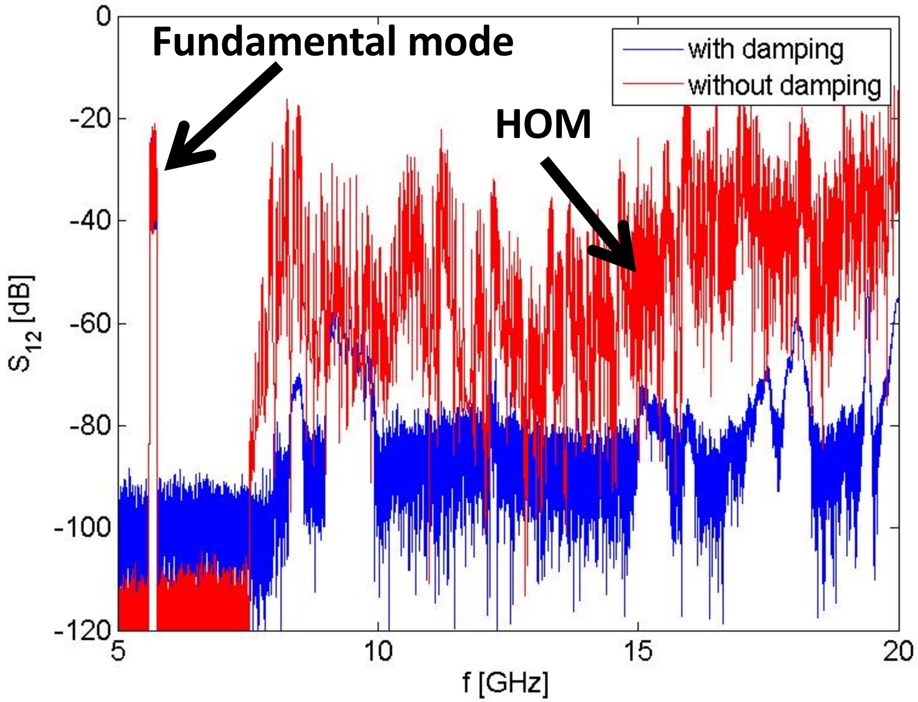
R&D program in close collaboration with Italian Companies (COMEB, CERINCO, ANDALO GIANNI, TSC)

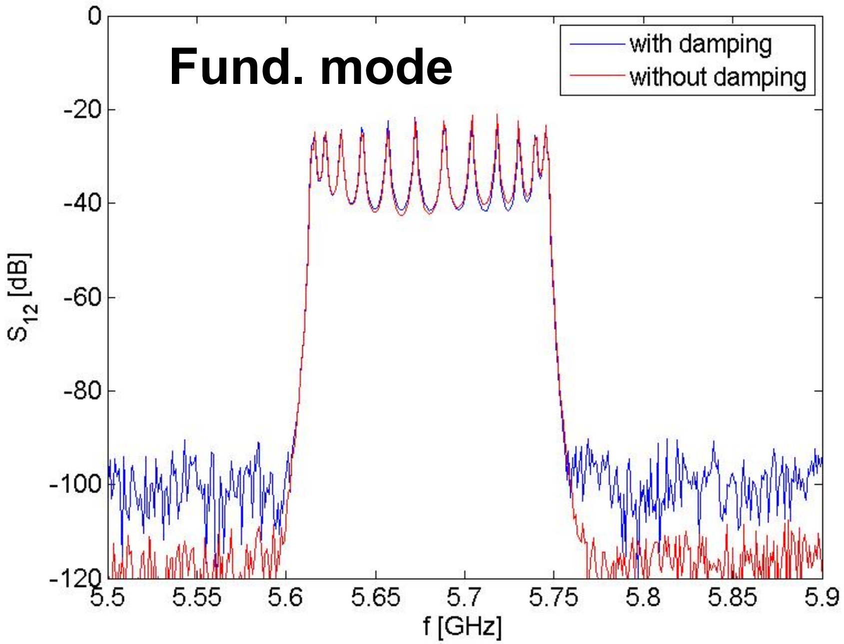
RF TEST OF 12 CELLS PROTOTYPE

Low power RF test in the 12 cells module with and without the SiC absorbers (antenna coupling).

No dumpers: HOM Q factor of few 1000s

With dumpers: HOM hardly measurable.



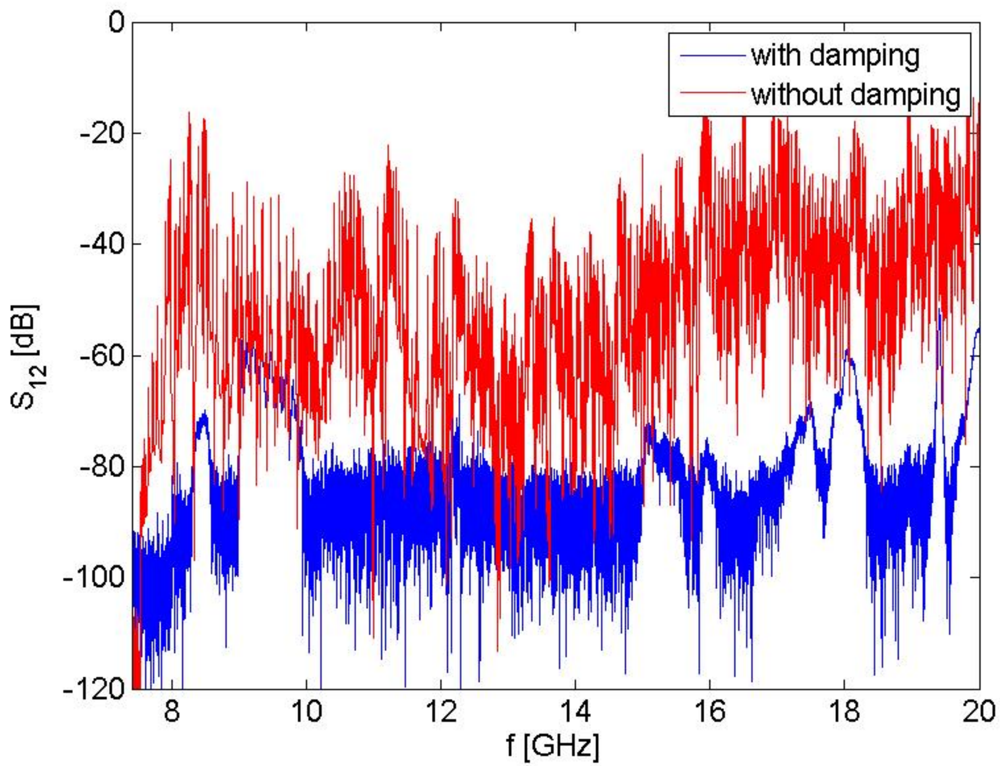


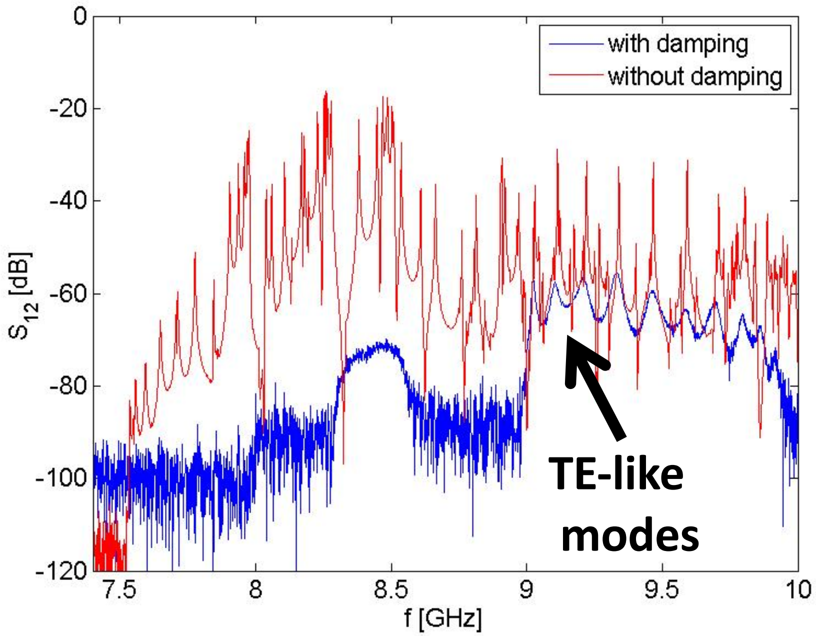
RF TEST OF 12 CELLS PROTOTYPE

Low power RF test in the 12 cells module with and without the SiC absorbers (antenna coupling).

TE modes: Q factor of few hundreds.

Negligible transverse impedance.





ELECTRON LINAC FLASH RADIOTHERAPY

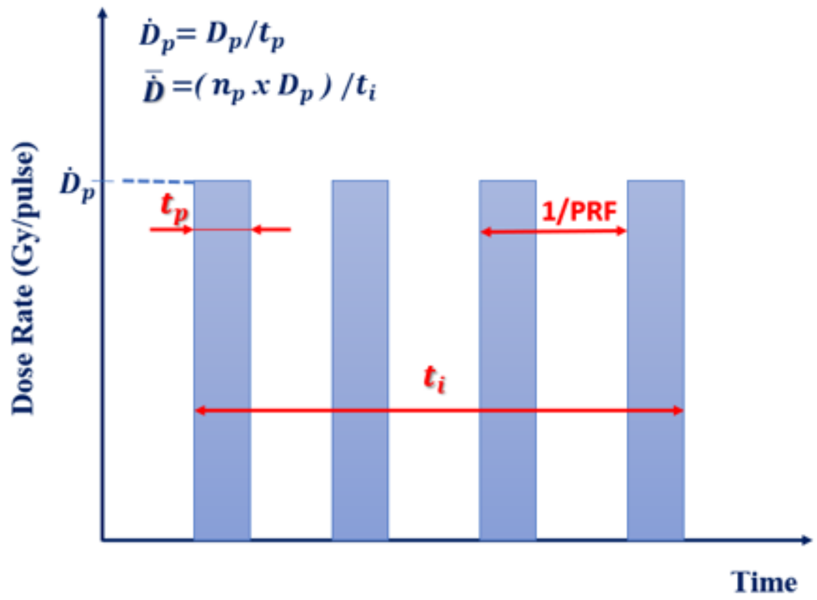
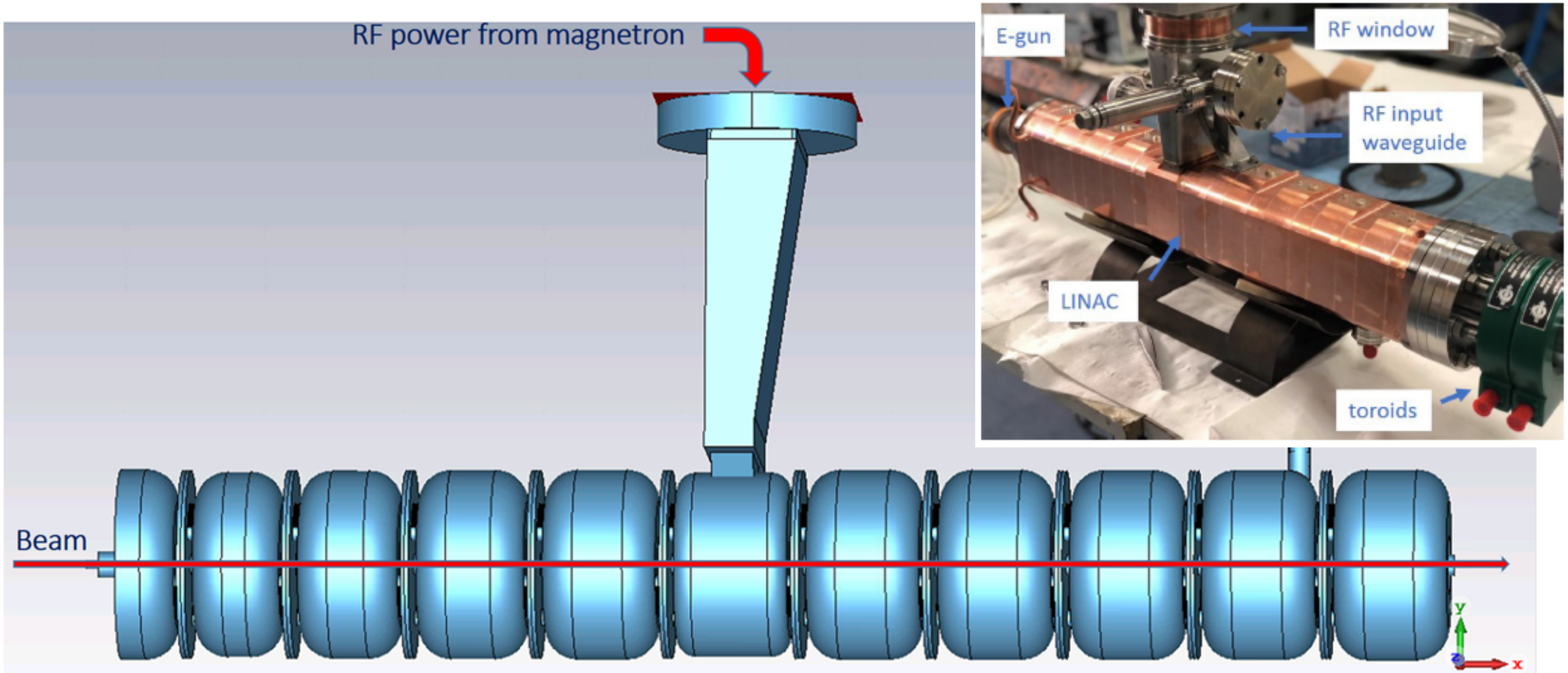
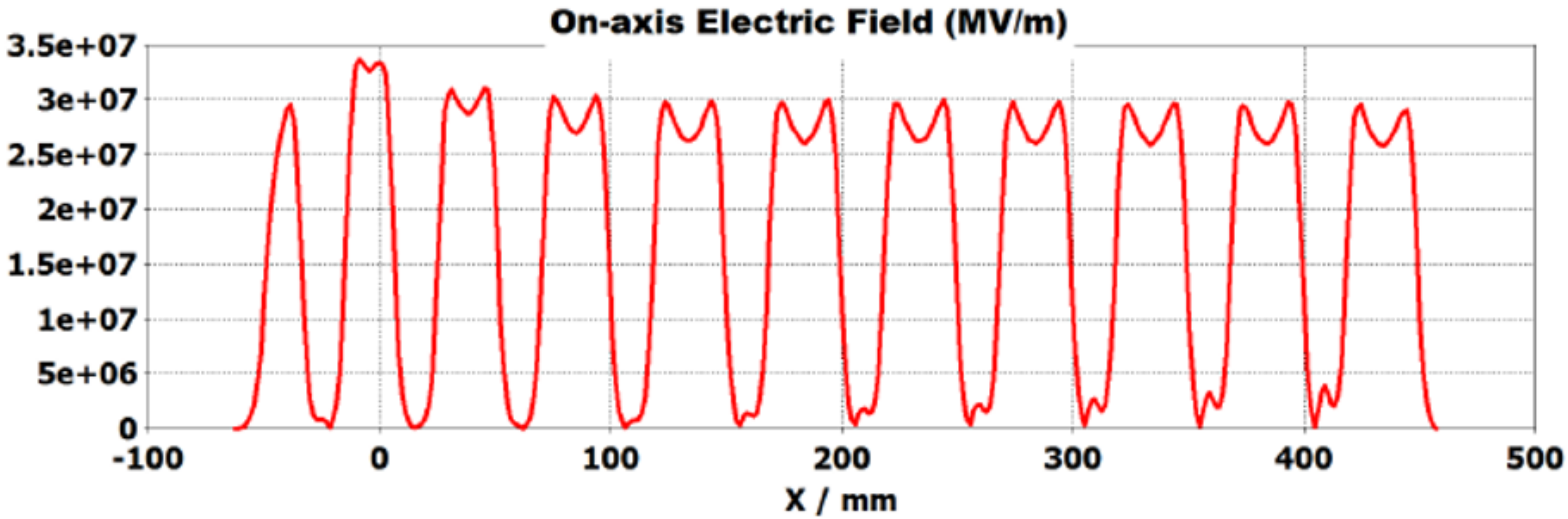


Table 1: Main FLASH parameters for the irradiations.

Parameter	Description	Value
PRF	Pulse repetition frequency	> 100 Hz
t_p	Pulse width	0.1-4.0 μs
t_i	Total irradiation time	< 100 ms
$\overline{\dot{D}}$	Time-averaged dose rate	> 100 Gy/s
$\dot{D}_p$	Dose-rate in a single pulse	$> 10^6$ Gy/s
D_p	Dose in a single pulse	> 1 Gy


RF power from magnetron
Beam
y
x
E-gun
RF window
RF input
waveguide
LINAC
toroids


On-axis Electric Field (MV/m)
3.5e+07
3e+07
2.5e+07
2e+07
1.5e+07
1e+07
5e+06
0
-100
0
100
200
300
400
500
X / mm

PROGETTO LINAC-FLASH 7 MeV – realizzato dalla SIT – primo esemplare al CURIE Parigi

Table 2: Main characteristics of the EF4000

Characteristics EF4000	Value
Output energy	5 - 7 MeV
Pulse repetition frequency	1 - 250 Hz
Pulse width	0.5 - 4 μs
Maximum peak beam current	120 mA
Dose rate per pulse	$> 10^6$ Gy/s
Mean Dose rate	1000 Gy/s
Max Dose per pulse	30 Gy in a surface of ⌀ 10 mm

PHYSICAL REVIEW ACCELERATORS AND BEAMS **24,** 050102 (2021)

Compact *S*-band linear accelerator system for ultrafast, ultrahigh dose-rate radiotherapy

L. Faillace,[1,6,*] S. Barone,[2] G. Battistoni,[3] M. Di Francesco,[2] G. Felici,[2] L. Ficcadenti,[4] G. Franciosini,[4,5] F. Galante,[2] L. Giuliano,[1,4] L. Grasso,[2] A. Mostacci,[1,4] S. Muraro,[3] M. Pacitti,[2] L. Palumbo,[1,4] V. Patera,[1,4] and M. Migliorati[1,4]

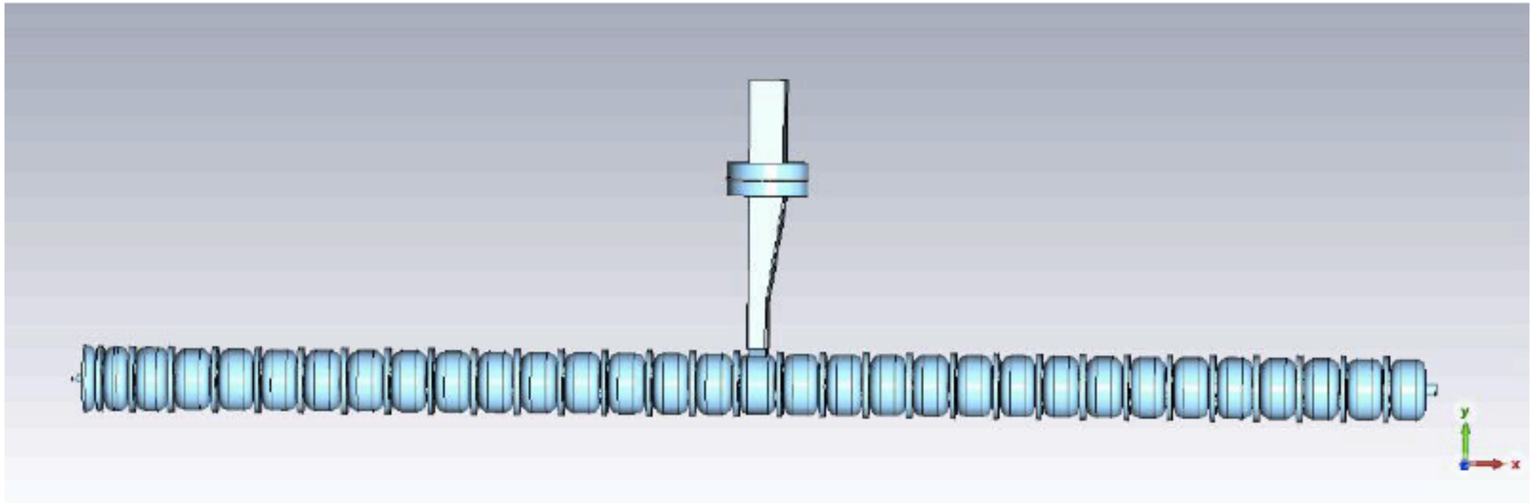
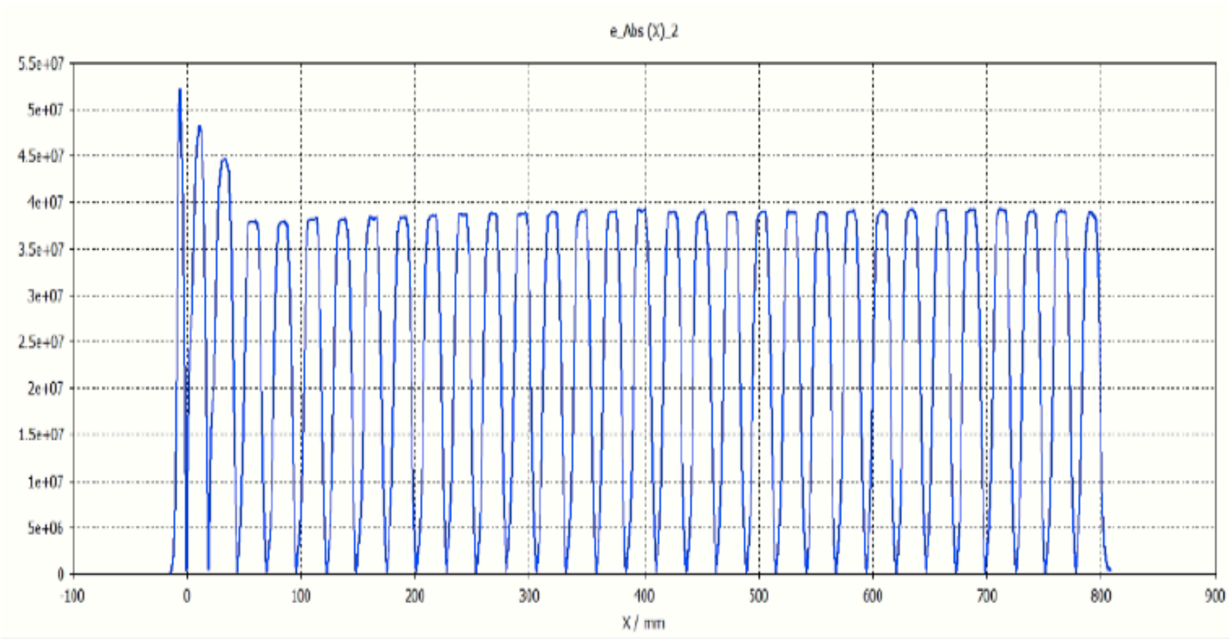
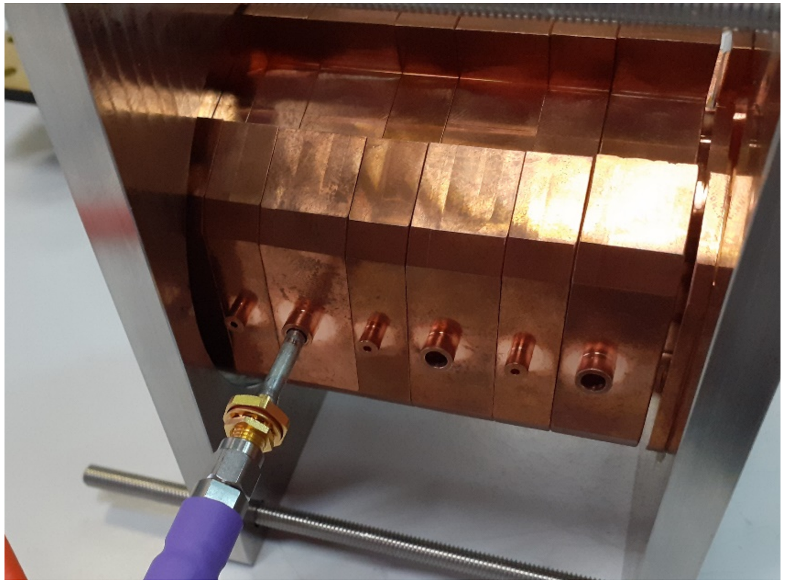
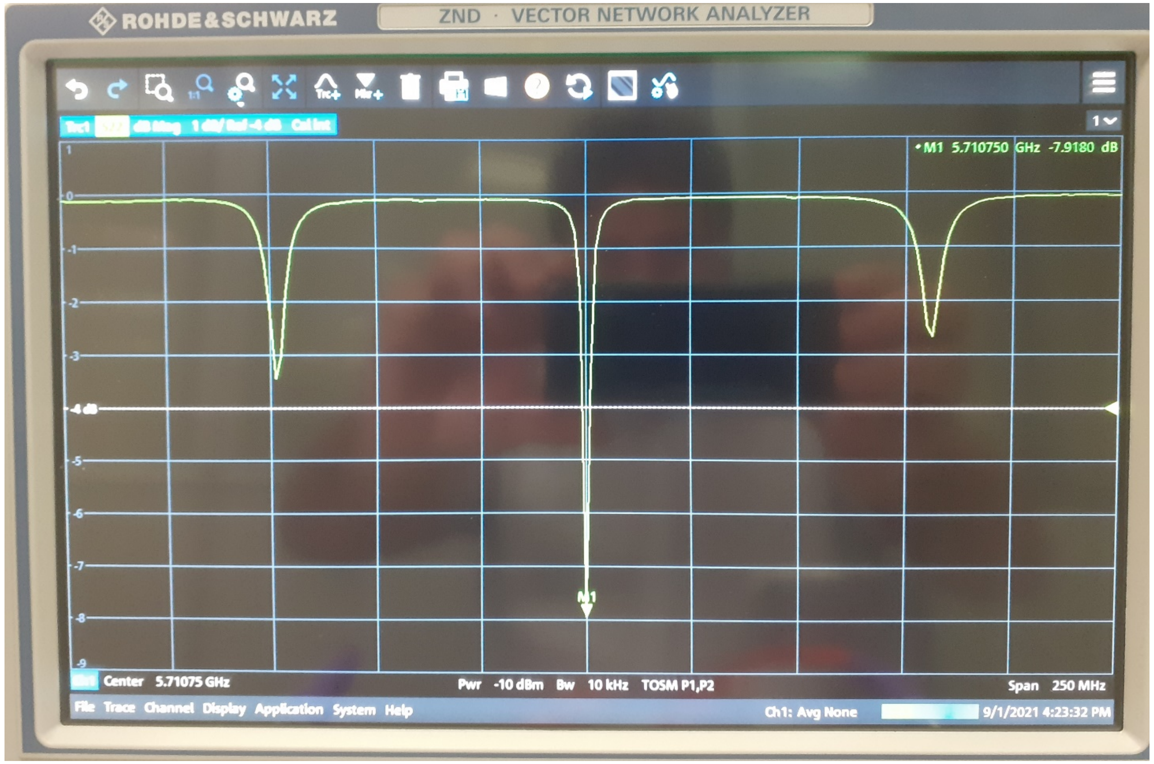


Fig. 1: Modello 3D da CST del linac in banda C composto da 32 celle acceleranti



3. simulazione con la guida d'onda e la RF window per la sintonizzazione del linac completo;




ROHDE&SCHWARZ
ZND · VECTOR NETWORK ANALYZER
M1 5.710750 GHz -7.9180 dB
M1
Center 5.71075 GHz
Pwr -10 dBm Bw 10 kHz TOSM P1,P2
Span 250 MHz
File Trace Channel Display Application System Help
Ch1: Avg None
9/1/2021 4:23:32 PM

VHEE Very High Energy Electrons (50-250 MeV) for deep tumors

The discovery of FLASH effect and the technology innovation in accelerator physics are freeing the VHEE RT from the limbo.

Very High Energy Electron Radiotherapy Workshop (VHEE'2020)

5-7 October 2020
CERN
Europe/Zurich timezone

Search...

- Overview
- Timetable
- Contribution List
- Registration
- Scientific Advisory Committee
- Local Organising Committee
- Videoconference instructions
- VHEE 2017

CLIC Project Office
clic.project.office@cern.ch

VHEE2020

Establishing innovative treatment modalities for cancer is a major 21st century health challenge. Although accelerated electrons are widely used to generate X-rays for radiotherapy, electrons are less frequently used directly because low energy electrons have limited penetration range and are mostly for the treatment of superficial tumours and thus limiting their clinical applicability.

The investment (man power, funding, infrastructure) in the field are mainly driven by the fundamental research (but also companies are active) and a clear example is a new initiative is starting at CERN/SLAC

VHEE & the FRIDA project: a CSN5 call

Goal of FRIDA is aCSN5 interdisciplinary call proposal addressing all the crucial areas related with FLASH therapy. 4 work-packages

- ✓ mechanism modelling & rad-bio experiments;
- ✓ beam delivery techniques ;
- ✓ Detectors for beam monitoring;
- ✓ treatment planning development

- ✓ Explore the time scales at which the FLASH effect occurs
- ✓ Develop compact, high intensity sources and delivery solutions for EBRT with e and p
- ✓ Explore novel detection strategies both for dosimetry and beam monitoring applications
- ✓ Explore clinical potential of FLASH EBRT

Personnel - Sections

A community of 80 researchers distributed in 7 INFN sections & Labs: CT, LNS, Milano, Pisa, Roma1, TIFPA, Torino.

- CT: Amato, Bartolotta, Borgese, D'Oca, Italiano, Marrale, Romano, Tomarchio (3.8 FTE)
- LNS: Bravatà, Calvaruso, Cammarata, Catalano, Cirrone, Cuttone, Forte, Guarrera, Mauro, Ficarra, Milluzzo, Minafra, Petringa, Russo, Sorbello, Torrisi (FTE: 4.7)
- Milano: Bortolussi - Bacci - Dong - Drebot - Giove - Mattei - Muraro - Massa - Mattei - Mettiver - Russo - Sarnu - Serafini (2 FTE)
- Pisa: Belcari, Bisogni, Costa, Del Sarto, Di Martino, Gizzi, Kraan, Labate, Marasciulli, Morrocchi, Paiar, Rosso, Sportelli, Strettoi, Ursino, Vannini, Zanacchi (2.8 FTE)
- Roma1: Faillace, Ficcadenti, Franciosini, Giuliano, Marafini, Migliorati, Mostacci, Palumbo, Patera, Sarti, Schiavi, Toppi, Traini, Trigilio (2.5 FTE)
- TIFPA: Attili, Bellinzona, Bisio, Boscolo, Cordoni, Croci, Fuss, Manghi, La Tessa, Scifoni, Schwarz, Tommasino (4.0 FTE)
- Torino : Abujami, Aprà, Cirio, Martì Villarreal, Monti, Picollo, Vignati (4.3 FTE)

GRUPPO LAVORO SAPIENZA-INFN, FLASH-VHEE-RT

PRECEDENTI: INCONTRO RETTRICE POLIMENI CON PRESIDENTE ZOCCOLI
INCONTRO CON PRORETTICE ALLA RICERCA SARTO E VICEPRESIDENTE BETTONI
+ riunioni separate con la Rettrice e con il Presidente INFN

SAPIENZA

Cardinale Vincenzo
Cenci Giovanni
Giuliano Lucia (& INFN)
Marampon Francesco
Migliorati Mauro (& INFN)
Mostacci Andrea (& INFN)
Patera Vincenzo (& INFN)
Palumbo Luigi (& INFN)
Sarti Alessio (& INFN)
Tombolini Vincenzo

INFN

Alesini David
Bisogni Maria Giuseppina
Cuttone Giacomo (Resp. INFN for Life Science)
Faillace Luigi
Gallo Alessandro
Pablo Cirrone
Torrisi Giuseppe

GOAL: STUDIO FATTIBILITA' ENTRO 2021