eurizon

European network
for developing new horizons for RIs

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WP4
Task 4.4

C. Vaccarezza

on behalf of the Task 4.4 Team:

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C. Vaccarezza

Outline

- The 4.4 task of the Eurizon project
- Previous scheme and update proposal
- LNF expertise
- To do list

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Task 4.4: Linac development [INFN, EuXFEL, DESY]

INFN has great experience in the development, construction and operation of high-energy high-brightness electron Linacs.

RF-guns with thermionic cathodes, photogun and regular accelerating structures in S-C band were developed in LNF INFN.

We plan a common study for a 6 GeV Linac based on S-C band technology to serve as an FEL driver and, potentially, as top-up injector for synchrotron X-ray storage rings

Simulations are planned to be carried out together with a virtual collaboration between INFN, DESY and the European XFEL.

A workshop including FEL developers and possible users will be organized by, and held at the European XFEL, where the study will be disseminated.

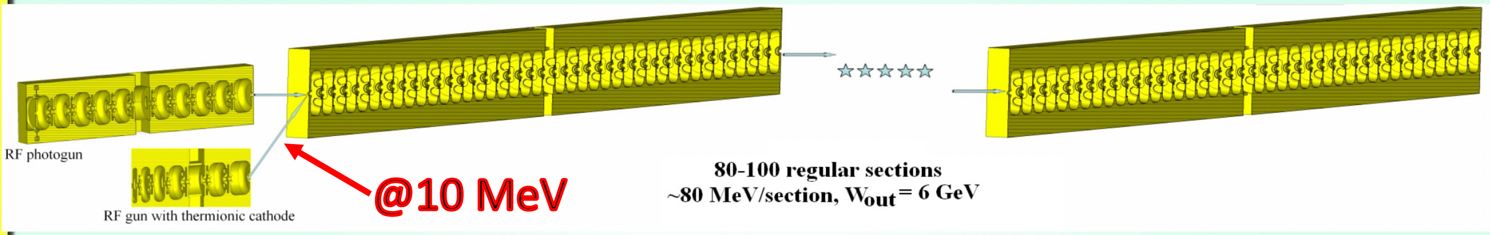
Ukrainian scientists from institutions that can profit from the project will be invited with special attention to young individuals.

- Deliverable 4.19 (D99) (M46, INFN) - Study report on a compact 6GeV high-brightness Linac (C-band) for top-up injection in storage rings and FEL applications
- Deliverable 4.20 (D101) (M48, EuXFEL) – Report from the workshop
- Milestone 58 (M40, INFN) – Simulation codes benchmark completed

The previous scheme:

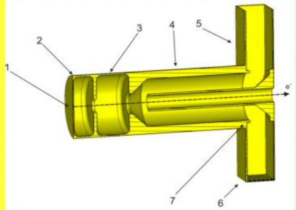
Top-up linac layout:

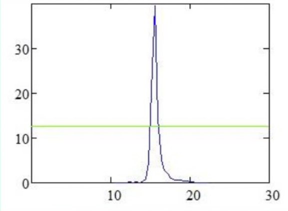
two RF-guns - photo-gun and thermionic gun (like Super-KEKB, MAX-IV, planned for *FCC-ee, Spring8-Upgr., PLS-Upgr.*) and 80-100 regular sections



Photogun:

1.5-, 3.5- or 5.5-cell design?



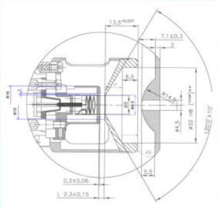


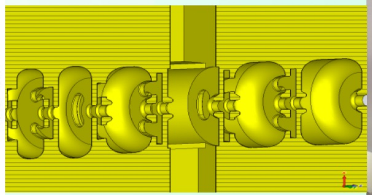
Cells	E, kV/cm	φ_{inj}	W_{max}, MeV	ΔW/W, %
3.5	600	2.0	6.2	1.8
5.5	600	2.7	8.1	0.9
5.5	700	2.8	8.2	1.2

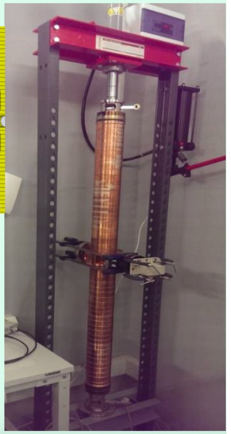
Microsoft Teams

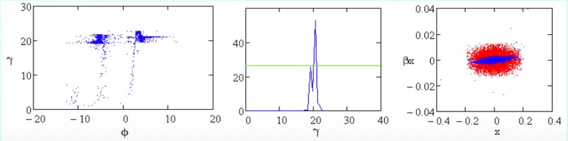
Thermogun:

We need to control the transverse emittance on low energies



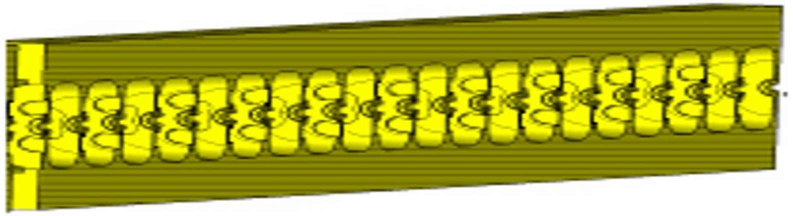






N.B. The previous Task 4.4 team was based on 15 people, now on 7.

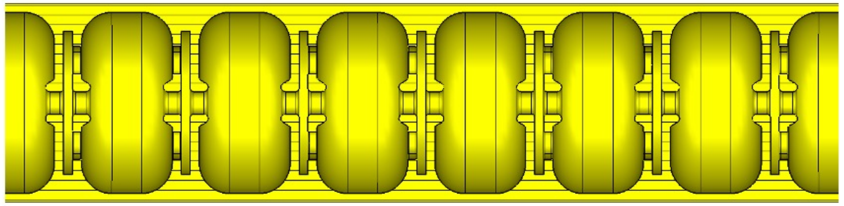
Previous scheme was based on S-band Accelerating structure



SLAC-type TW DLW:
3-m-length for 80MV/sec

-Low coupling coefficient
-Long RF pulse necessary
-High beam loading effect
-Wide spectrum

-*Compression is possible!*



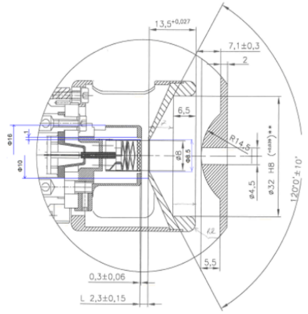
Biperiodic Accelerating Structure (BAS) SW:
2-m-length for 75 MeV/sec

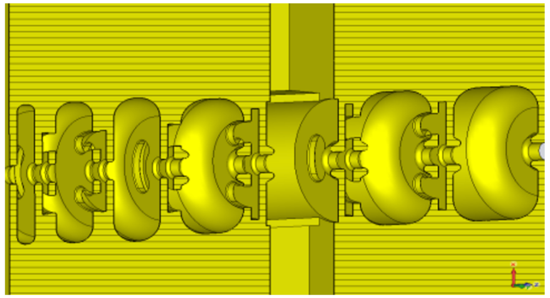
-High coupling coefficient
-Shorter RF pulse is necessary
-Lower beam loading effect
-Narrow spectrum

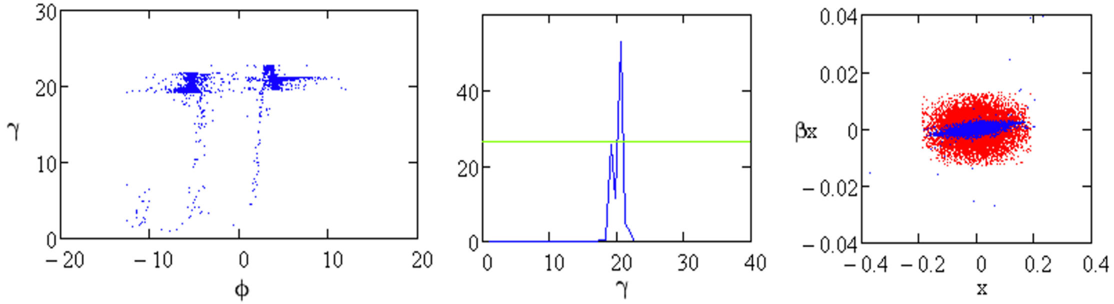
-*Compression is theoretically possible but not realized!*

and Thermionic gun beam dynamics

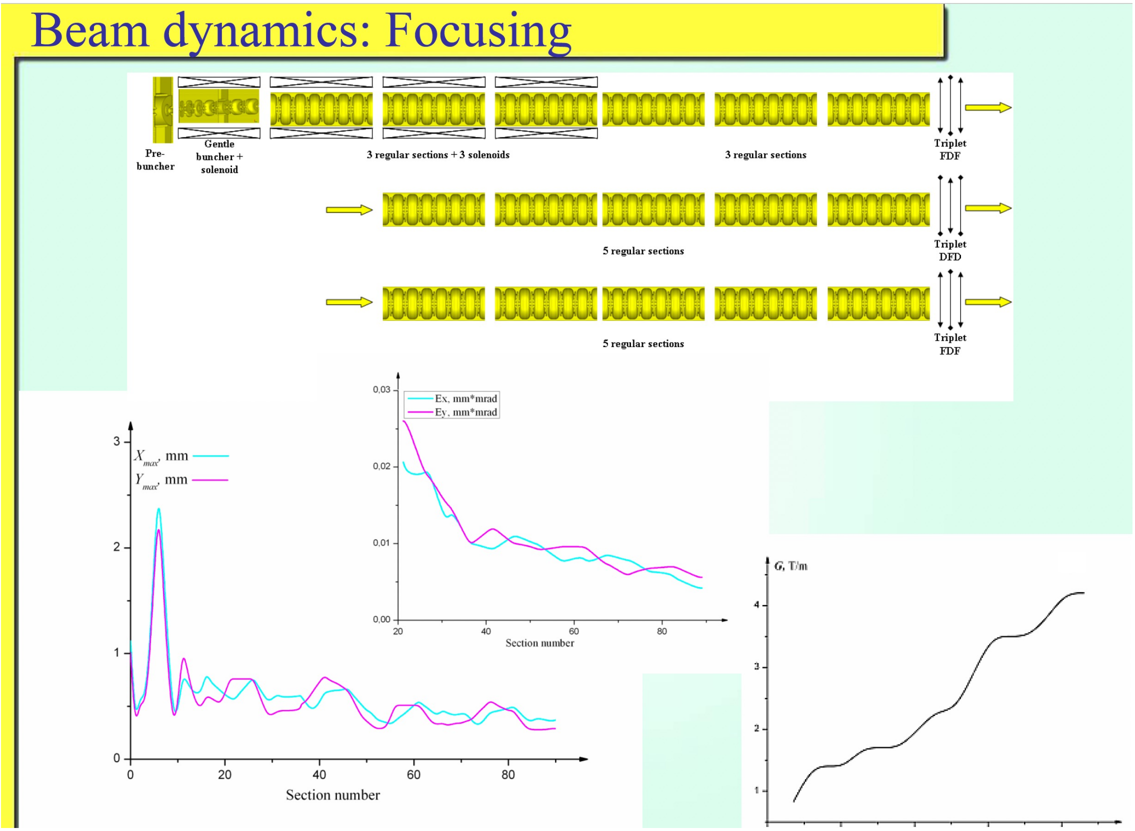
RF gun with thermionic cathode







S. Polozov, V.Rashchikov,

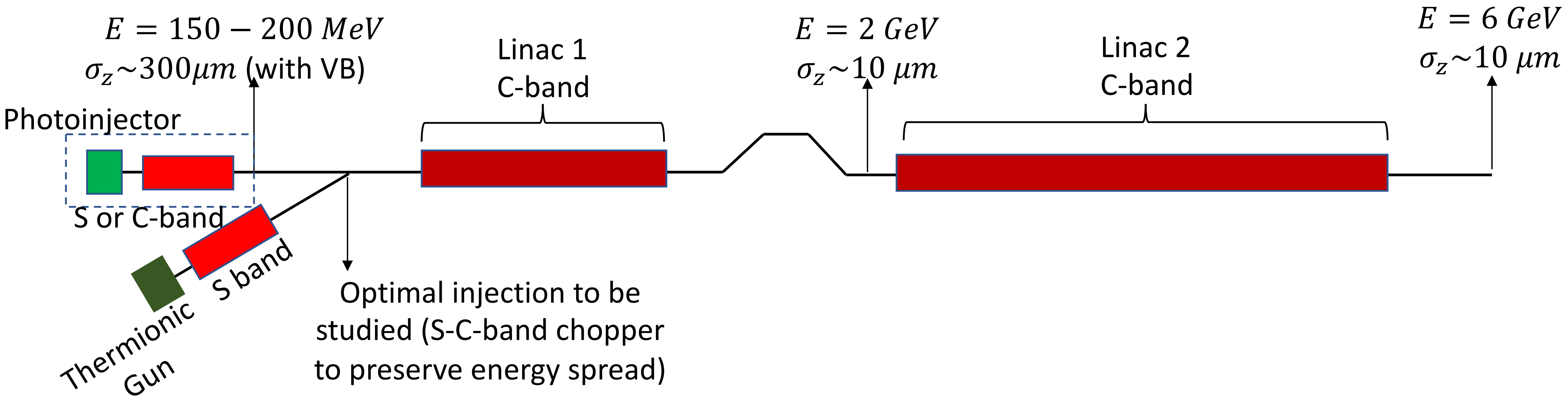


Updated layout proposal

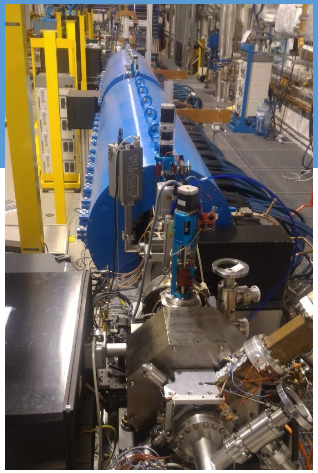
LNF previous option

- Emittance Compensation Scheme in the Photoinjector
- C-band accelerating structures, 2 m long, with $E_{acc} \sim 35\ \mathrm{MV/m}$ (transition energy to be studied)

Update for Eurizon

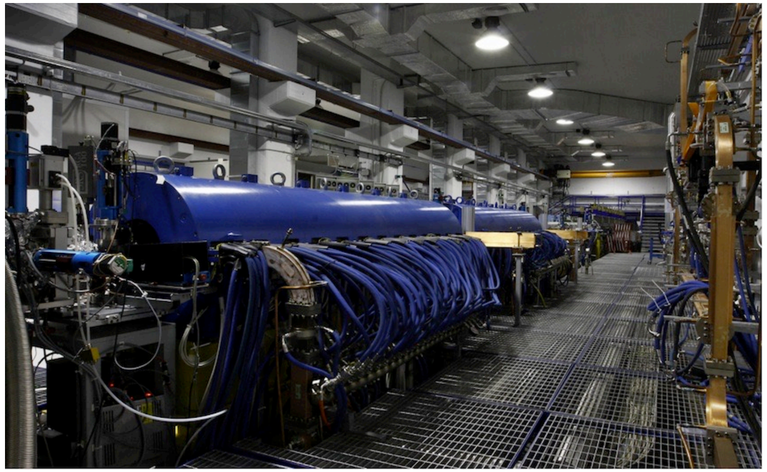


LNF expertise on Photoinjector: S and C band



The Photoinjector

The SPARC_LAB photoinjector is based on a 1.6 cell S-band RF gun which operates at ~120 MV/m peak on cathode. At the gun exit a solenoid is located for the emittance compensation and downstram two 3 m long S-band accelerating structures plus a 1.5 m C-band, are located providing a total energy of ~200 MeV on crest.



The SPARC_LAB photocathode laser system is based on a Titanium-Sapphire laser at 800 nm, the laser system is synchronized with the RF system with a compressed pulse energy of about 50 mJ. We split the laser pulses from the oscillator to two CPA systems, one used for the photocathode and one for FEL seeding and diagnostics

Funded by the European Union

Compact

XLS-Report-2021-010
22 December 2021

XLS Deliverable D2.3

Conceptual Design Report of the CompactLight X-ray FEL

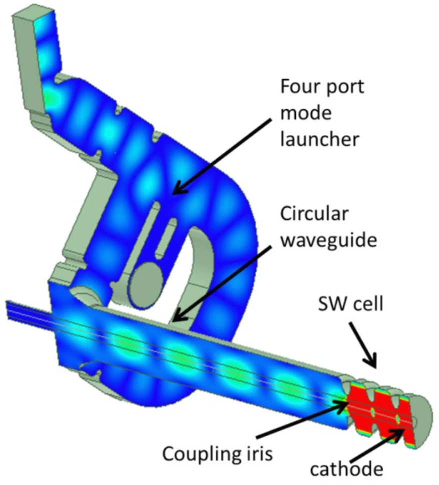


Figure 5.2.: Gun geometry simulated by ANSYS-HFSS

Table 5.2.: Main parameters of the C-band gun.

Parameter	Unit	Value
Working frequency	GHz	5.996
$E_{cath}/P_{diss}^{1/2}$	MV/(mMW$^{1/2}$)	52
RF input power	MW	18
Cathode peak field	MV/m	160
Cathode type		copper
Rep. rate	Hz	1000
Quality factor		11800
Filling time	ns	164
Coupling coefficient		3
RF pulse-length	ns	300
E_{surf}/E_{cath}		0.9
Modified Poynting vector	W/μm^2	2.5
Pulsed heating	$^\circ$C	<20
Average diss. Power	W	2300

C-band structures at LNF

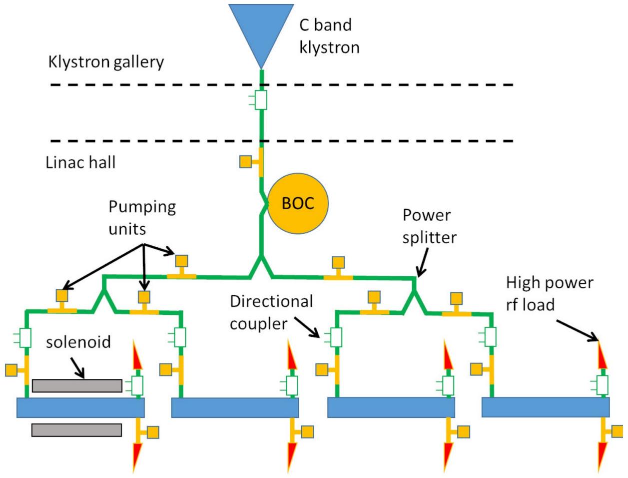


Figure 5.11.: Schematic layout of the C-band booster feeding system

Table 5.5.: Main parameters of the C-band structures.

Parameter	Unit	
Working Frequency	GHz	5.996
Phase advance per cell	rad	$2\pi/3$
Average iris radius $< a >$	mm	6.6
Iris radius **a**	mm	6.94-6.26
Number of cells per structure		120
Accelerating cell length	mm	16.67
Structure length $\mathbf{L_s}$	m	2
Shunt impedance **R**	MΩ/m	71 - 77
Effective shunt impedance $\mathbf{R_s}$	MΩ/m	190
Group velocity v_g/c	%	2.4-1.6
Filling time	ns	336
Average acceleration gradient	MV/m	15
Required input power per module	MW	9
Number of structure in the module		4

Table 5.6.: Main Parameters of the C-band Klystr

Parameter	Unit	Value
Operating frequency	GHz	5.996
Klystron pulse-length	μs	2
Klystron peak power	MW	15
Repetition Rate	Hz	1000
Q_0 of BOC		216000
Q_E of BOC		19100

ELI-NP Gamma beam System

Technical Design Report

Final version

July 14th 2014

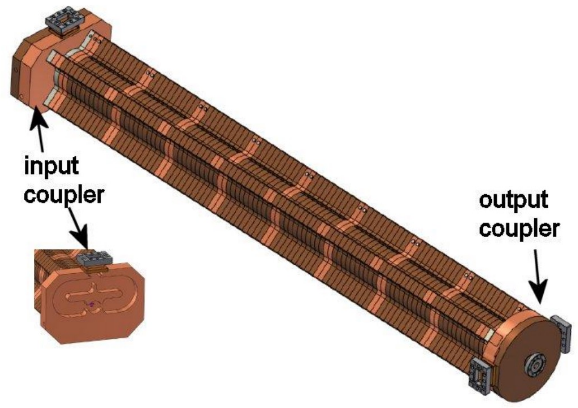


Fig. 66. Mechanical drawings of the C-band structure with details of couplers

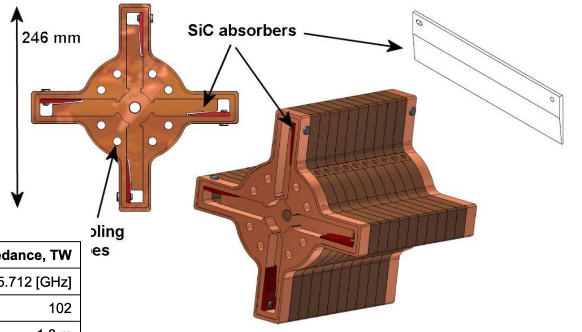


Fig. 67. Detail of the TW cell with absorbers

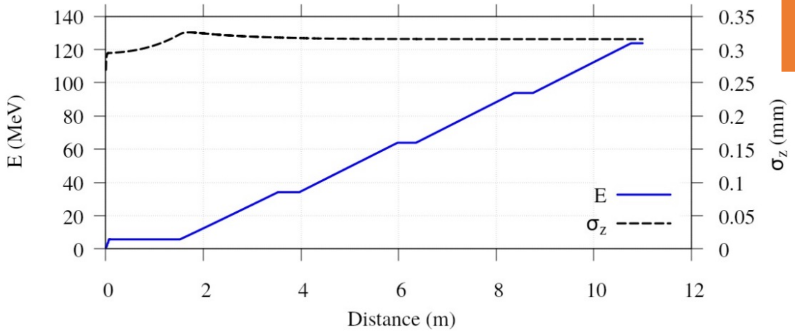
Table 16. Main parameters of the C-Band TW accelerating structures

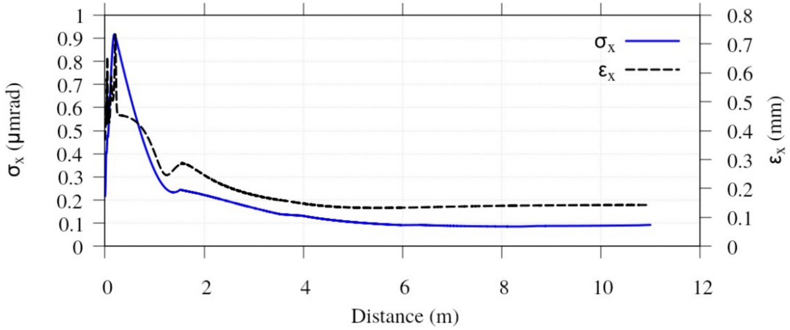
Structure type	Constant impedance, TW
Working frequency (f_{RF})	5.712 [GHz]
Number of cells	102
Structure length	1.8 m
Working mode	TM_{01}-like
Phase advance between cells	c
Nominal RF input power (P_{IN})	40 MW
Average accelerating (E_{acc})	33 MV/m
Quality factor (Q_0)	8800
Shunt Impedance per unit length	67-73 MΩ/m
Phase velocity	c
Normalized group velocity	0.025-0.014 (v_g/c)
Filling time (τ)	310 ns
Structure attenuation constant	0.58 neper
Operating vacuum pressure (typical)	10^{-8}-10^{-9} mbar
Max RF input pulse length (τ_{IMP})	0.8 μs
Pulse duration for beam acceleration (τ_{BEAM})	<500 ns
Iris half aperture (a)	6.8-5.8 mm
Rep. Rate (f_{rep})	100 Hz
Average dissipated power	2.3 kW

Beam Dynamics w C-band

Compact-Light
2.5 cell C-band Photoinjector

Astra & Tstep codes for collective effects

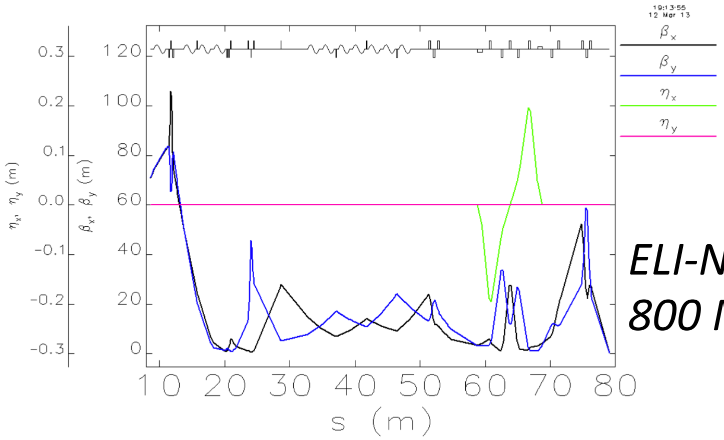




Evolution of:

(a) the RMS bunch length and energy gain

(b) the transverse normalized emittance and transverse spot size along the photo-cathode RF gun and first C-Band section of the injector.



ELI-NP Gamma beam System
800 MeV C-band Linac

Fig. 21. **Twiss parameters of the high energy beamline from the photoinjector exit down to the high energy Compton Interaction point**

Elegant and CSRtrack codes for CSR, Wakefields & LSC effects

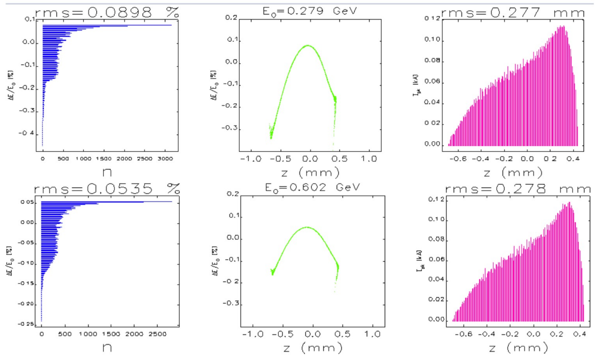


Fig. 25. **Energy spread, energy and current distribution of the reference working point electron beam at the low (above) and high (bottom) energy interaction point**

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To do List:

- Codes Benchmark (1st milestone)
- Fel Parameters list for 6 GeV Linac + 250 pC beam ($\sigma_z \leq 10\mu m$) - discussion already started
- 250 mA beam optimal insertion in C-band linac for top-up operation
- Final 6 GeV linac layout and report (2nd Milestone)
- Workshop preparation & report (3rd milestone

Thanks for your attention