Very high gradient RF Guns operating in the C-band RF technology (Task 7.4)

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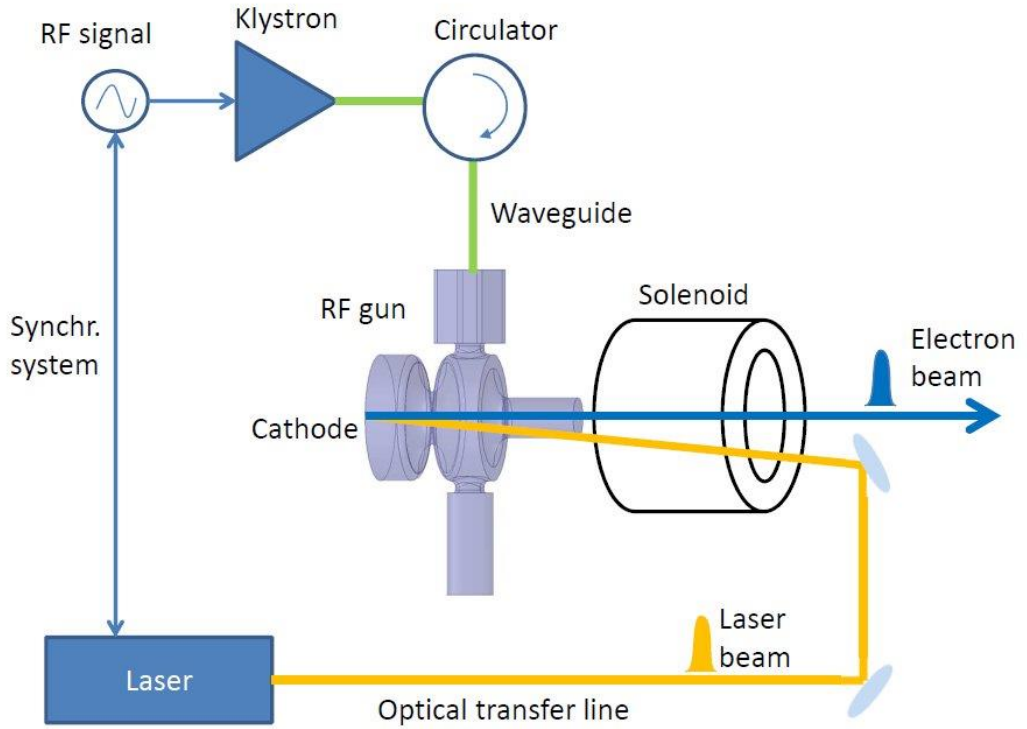
On behalf of the INFN-PSI Very High Gradient C band gun group

OUTLINE

1. **Recap. on Goals and Responsibilities**
2. Update on **SW GUN Activities**
3. Update on **TW GUN Activities**
4. **Bunker Status@PSI for high power test and timeschedule**

C BAND RF PHOTO-GUNS

- **RF Photo-injectors** are widely used in **FEL**, as very low-emittance and high-brightness electron sources.
- A **laser pulse** hits a cathode and the electrons are immediately accelerated by an intense RF E field (60-120 MV/m)
- **RF technology mostly used is the L or S-band** (f=1.3 or 3 GHz).
- The higher the **peak electric field on the cathode**, the better the quality of the beam emerging from the Gun.



- The frequency step-up from L/S-band to C-band can provide **higher achievable cathode peak field as high as 160-180 MV/m**.
- Because of its higher efficiency a C-band RF Gun is also suitable for **application requiring repetition rates in the 400 Hz÷1 kHz range**.

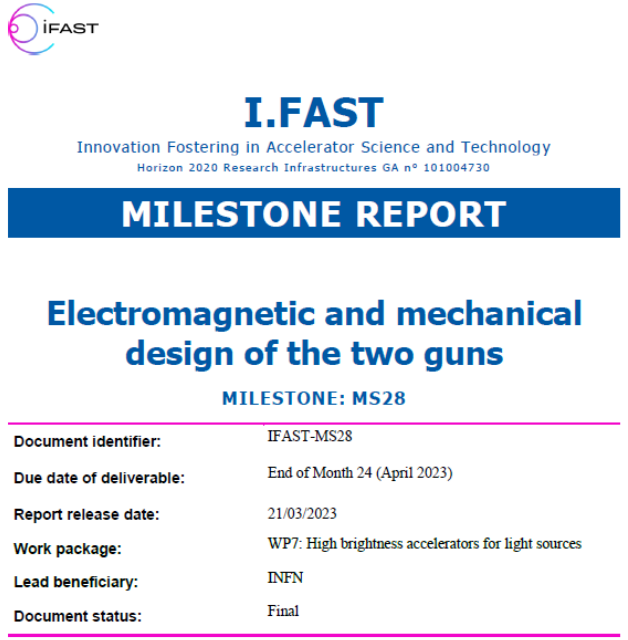
- The availability of a new state-of-the-art, electron injector would **bring benefits to a large accelerator user community, (FEL radiation sources, Thomson/Compton photon sources and plasma based accelerators)**

TASK 7.4 STRUCTURE AND OBJECTIVES

- **Design, realization and high power test of two different C-band (5.712 GHz) RF electron guns** operating at very high gradient cathode peak field (>160 MV/m):
  - ⇒ Standing Wave (**SW**) gun (**INFN** (IT), **COMEB** (IT))
  - ⇒ Travelling Wave (**TW**) gun (**PSI** (SW); **VLD** (NE))

- **Comparison** of the performances, **beam dynamics** simulations to exploit the device potentialities
- **Research Institutions** involved: **INFN** (IT), **PSI** (SW);
- **Private Companies** involved: **VLD** (NE), **COMEB** (IT)

Parameter	SW GUN	TW GUN
Frequency [GHz]	5.712	
Number of cells	2.5	10+2 couplers
Phase adv. per cell	π	$2\pi/3$
Input power [MW]	18/25	37.5/82
Cathode field [MV/m]	160/180	138/200
Cathode type	copper	
Rep. rate [Hz]	100	
Filling time [ns]	166	90
RF pulse length [ns]	300	90
Output Energy [MeV]	5.7	13.1
Pulsed heating [°C]	16/20	14/30



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- Coordination
- Design and low power test of the SW Gun
- Solenoid design and procurement
- RF circulator procurement

COMEB

- mechanical construction and assembly of the SW gun

SW GUN

PAUL SCHERRER INSTITUT PSI

- design, brazing and low power characterization of the TW Gun
- hosting and setting up the facility to perform the high-power test

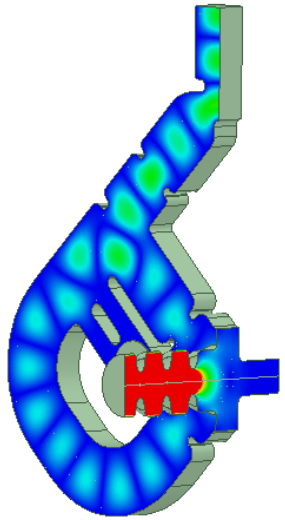
VDL

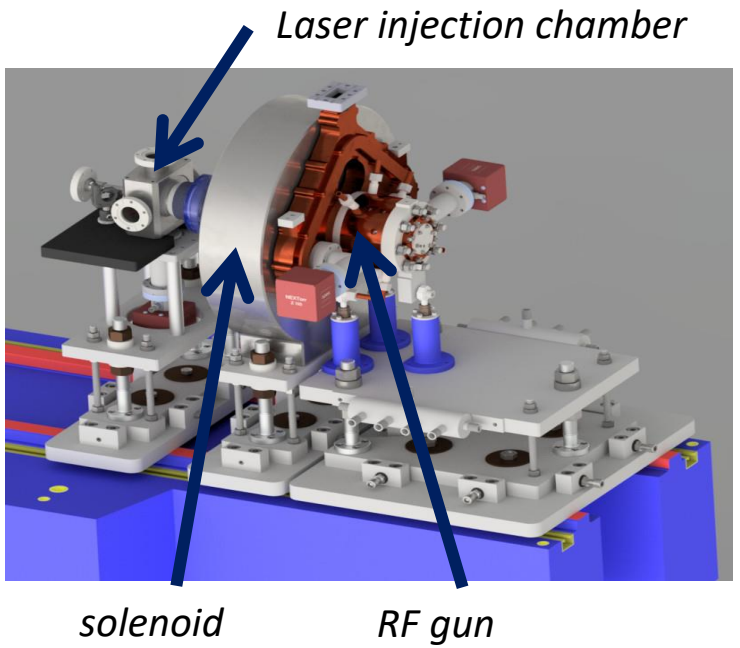
- mechanical construction of the TW gun components

TW GUN

SUMMARY OF ACTIVITIES: SW GUN

⇒ **Electromagnetic design of the gun:** completed
⇒ **Thermo-Mechanical design of the gun:** completed
⇒ **RF Measurements** of the alluminum prototype fabricated by COMEB
⇒ **Design of the solenoid and order**
⇒ **Design of the vacuum chambers and order**
⇒ **RF measurements and vacuum test of the final gun**
⇒ **Beam dynamics simulations to explore the capabilities of the gun**
(A. Giribono et al. Submitted to PRAB)

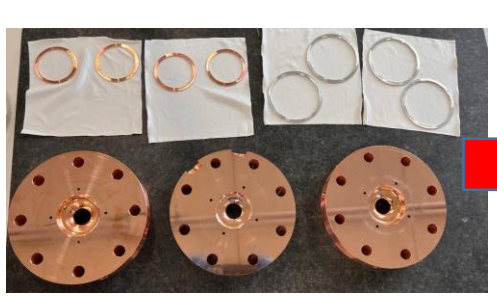


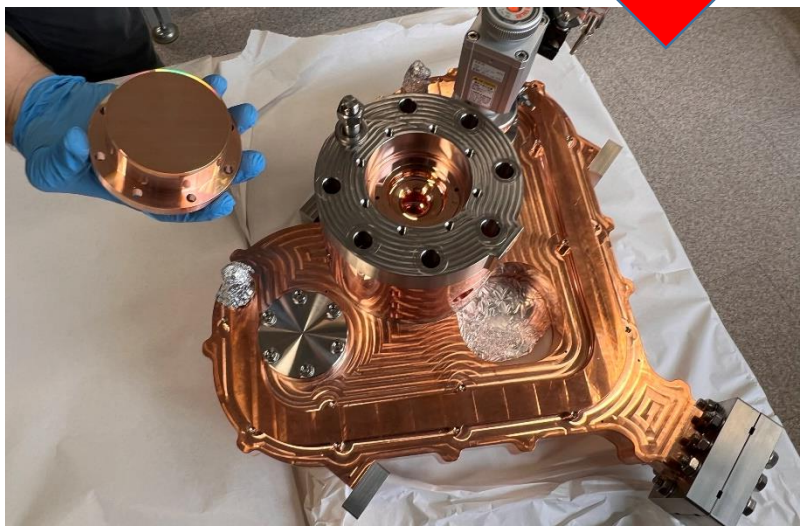


⇒ **Realization of the alluminum prototype**
⇒ **Realization of the final gun**

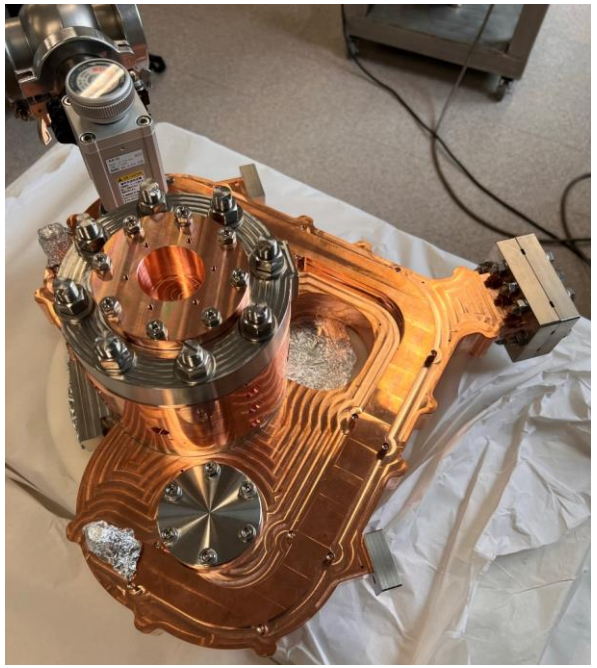
VACUUM AND RF TESTS OF THE GUN

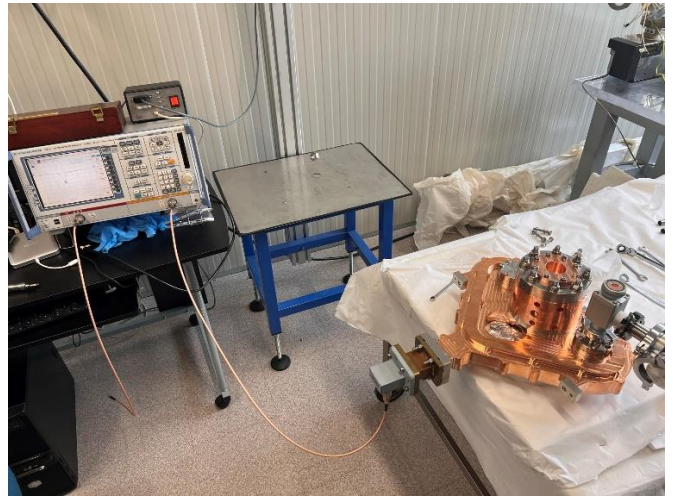
The **cells have been clamped** and finally also the cathode is mounted. The assembly has been vacuum tested and then mechanically characterized and **rf tested**.





Vacuum test



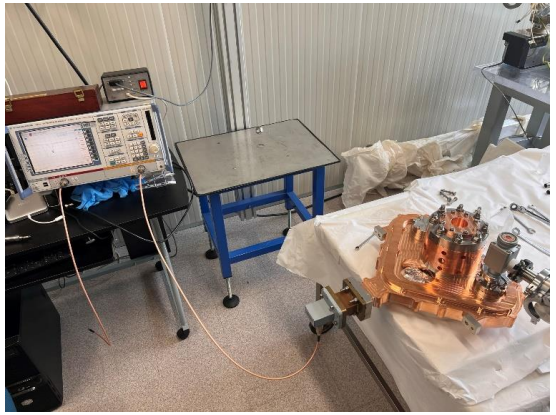


RF test

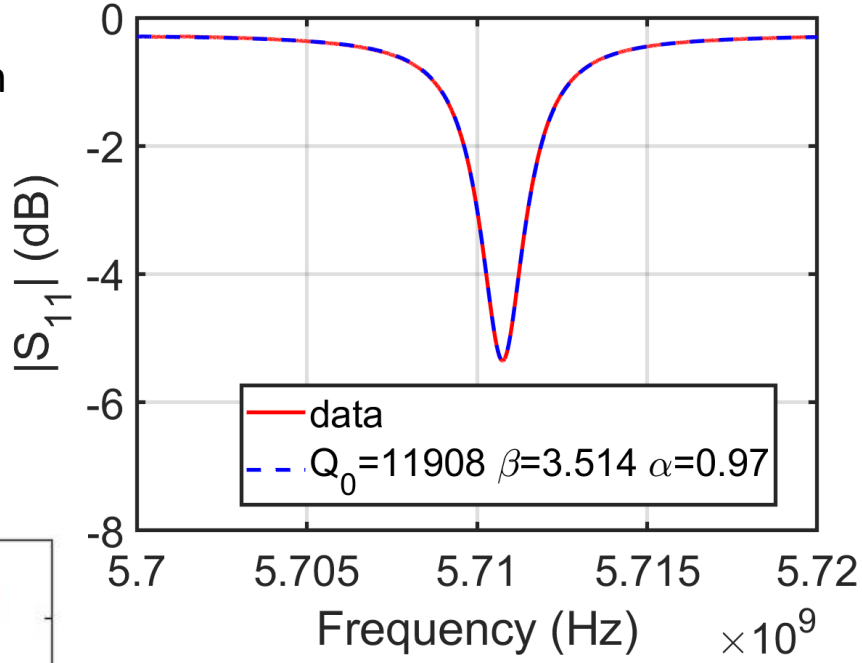
CMC test

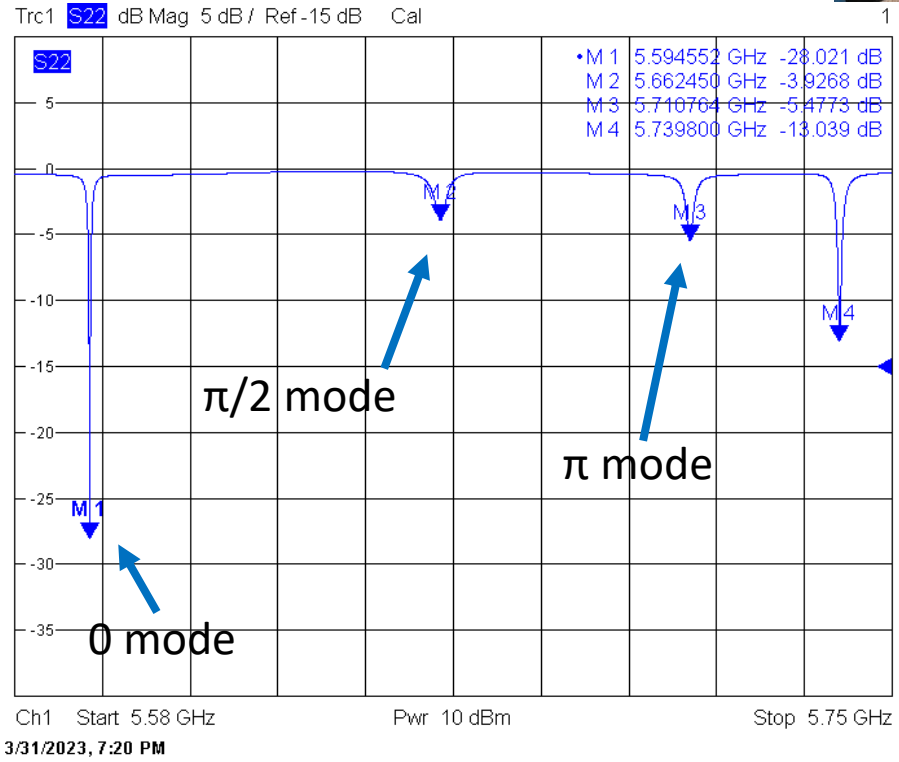
GUN RF TEST RESULTS

Cavity temperature during measurement = 23°C
f_0 = 5.7107 GHz in Nitrogen

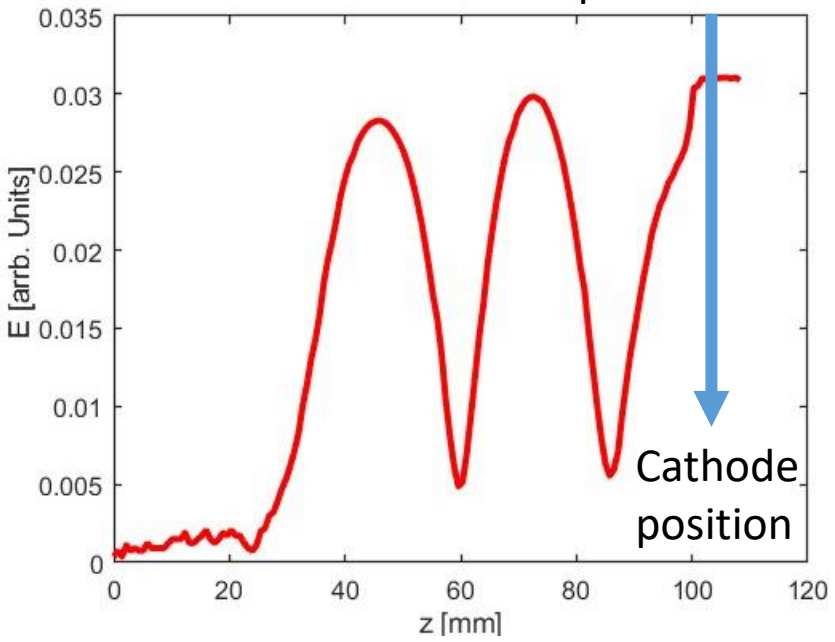


Reflection





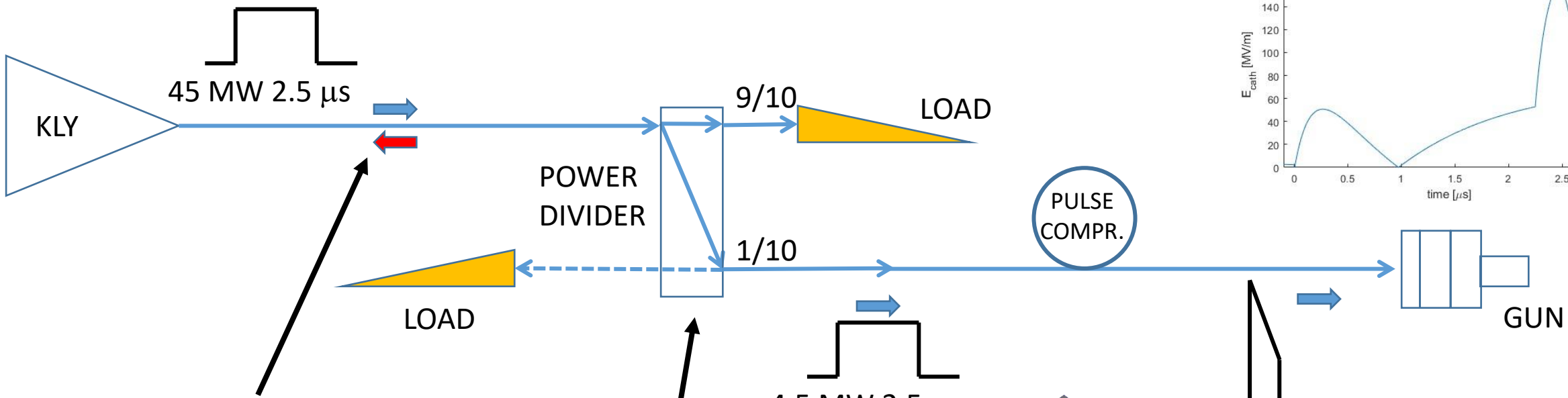
E field: bead drop

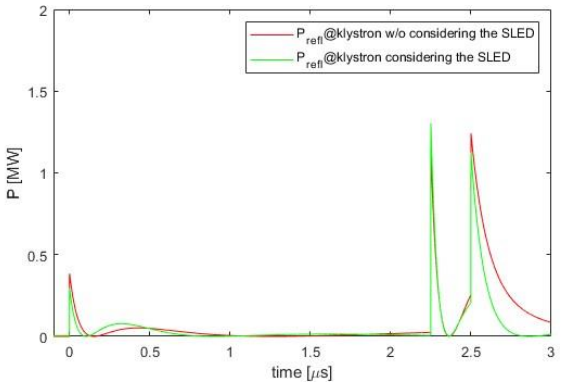


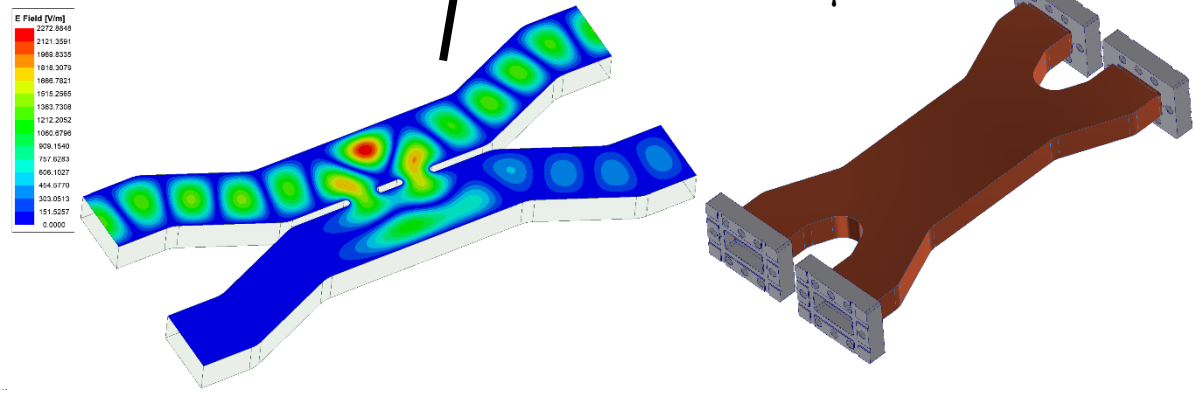
ALTERNATIVE FEEDING SCHEME W/O ISOLATOR

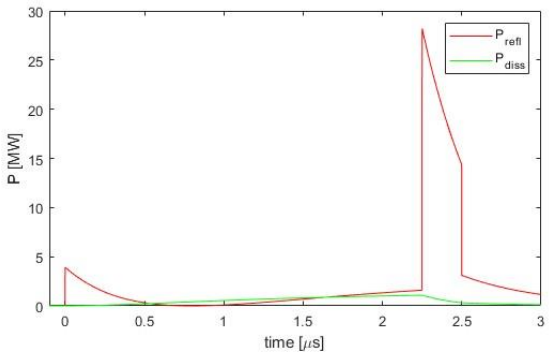
Delays in delivery the C-band Isolator.

Plan B with an **alternative feeding scheme** for the gun based on a power divider









SUMMARY OF ACTIVITIES: TW GUN

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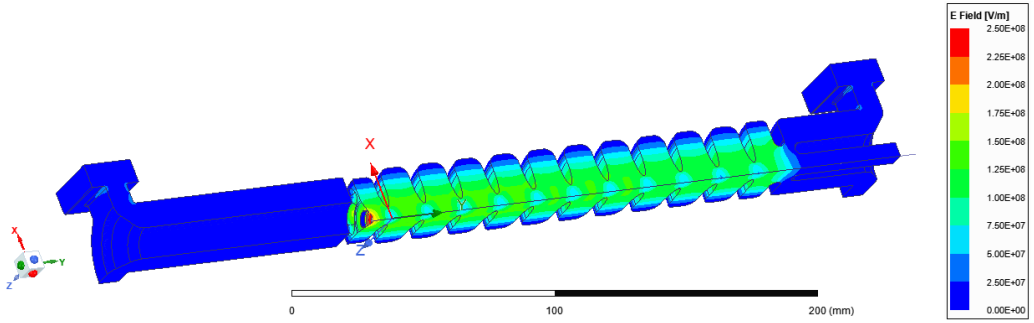
⇒**RF and thermo-mechanical design has been completed**. It was then sent to VDL for machining of the individual components.

⇒**Beam dynamics simulations** have been completed and have illustrated a five-fold increase in the 5D brightness when compared to the SwissFEL S-band Photogun.

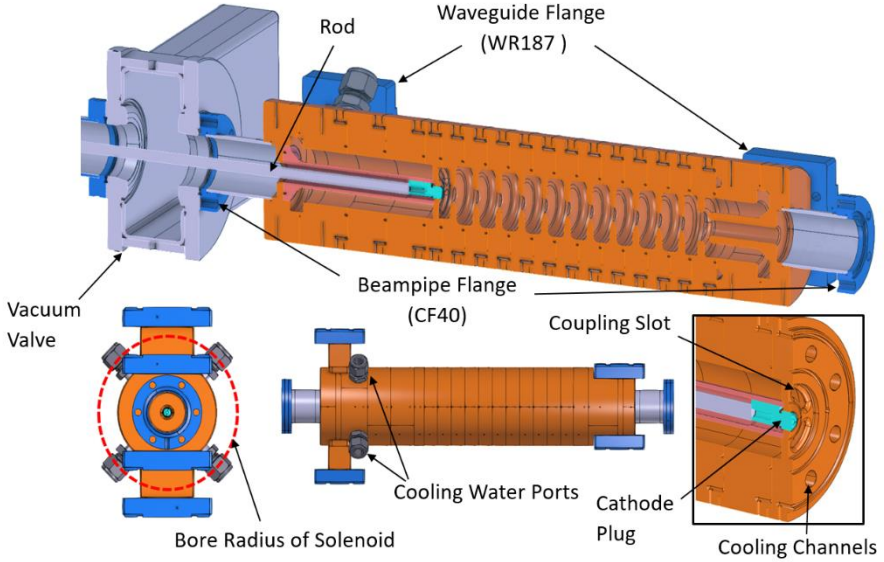


⇒The **bunker has been refurbished** with the addition of a new wall and preparation for the high power tests of the gun have begun (authorizations, …).

⇒The **waveguide network** for the testing of the C-band isolator has been installed.

Courtesy T. Lucas

I.FAST Innovation Fund *to the test a* ***field emission*** *cathode in the TW gun for applications realted to* ***medicine and industrial irradiation facilities*** *(PSI & VDL project, PI Prof. Dr. Mike Seidel). Friday morning T. Lucas Talk*

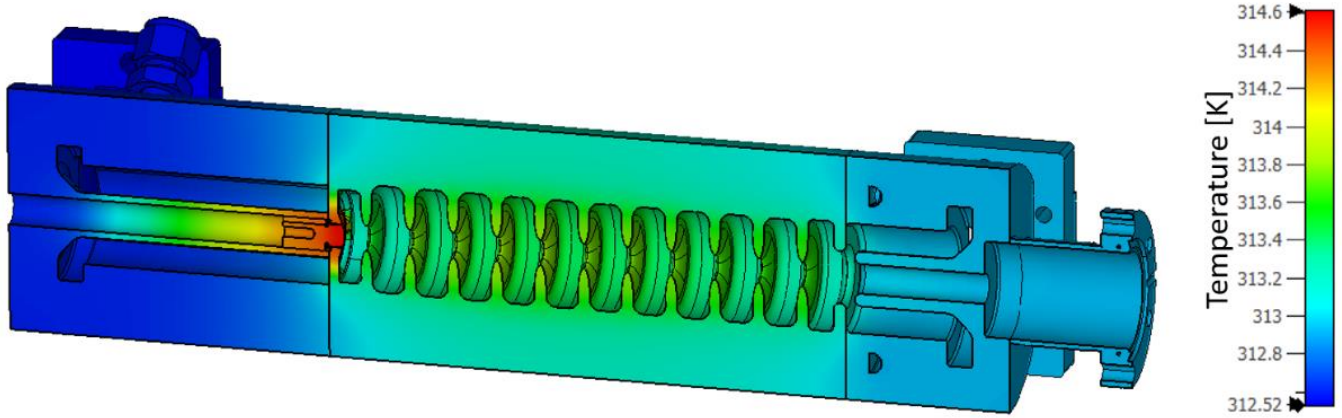


VDL

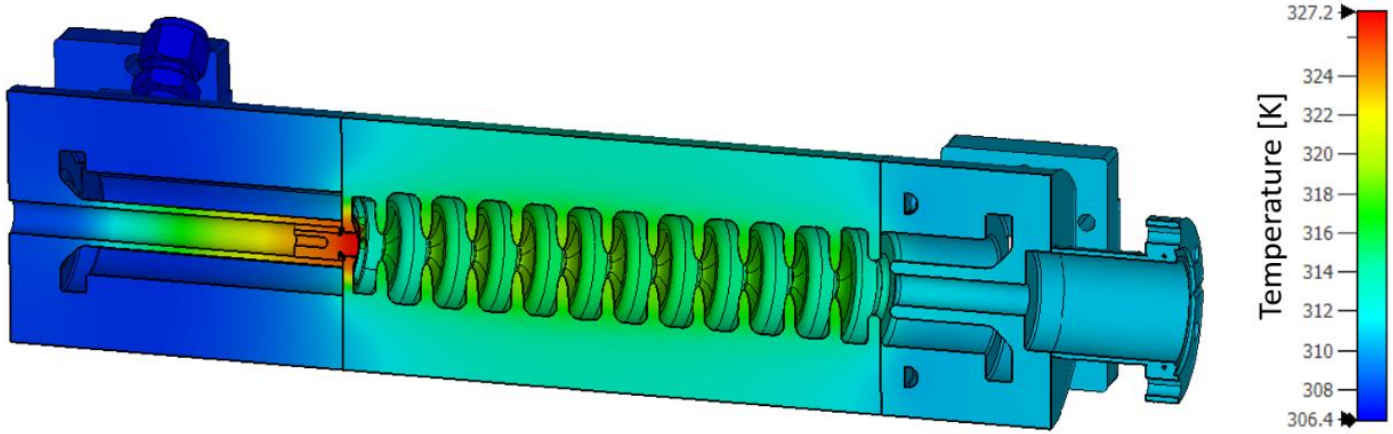
Is starting the mechanical realization of the different components

THERMAL SIMULATIONS

- Thermal simulations performed to understand the possibilities of **high repetition rate operation**.
- The TW photogun has a short filling time and low **attenuation of 28%.**
- Operation at **repetition rates up to 1 kHz** foreseeable given the temperature distributions.



100 Hz

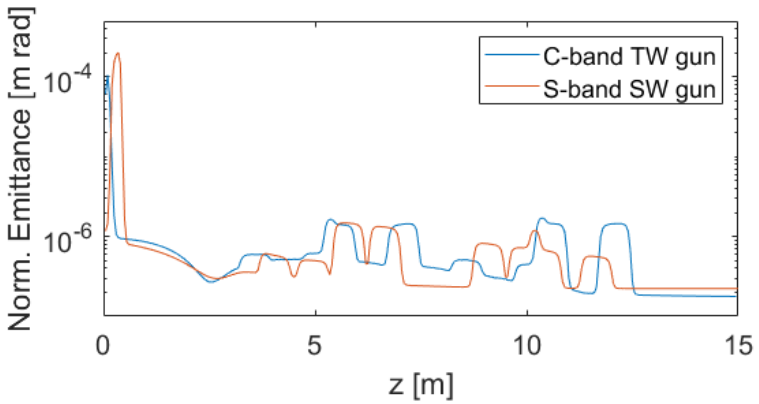


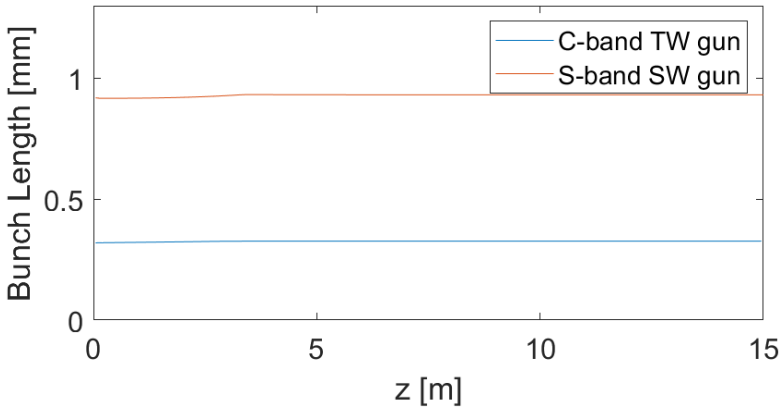
1000 Hz

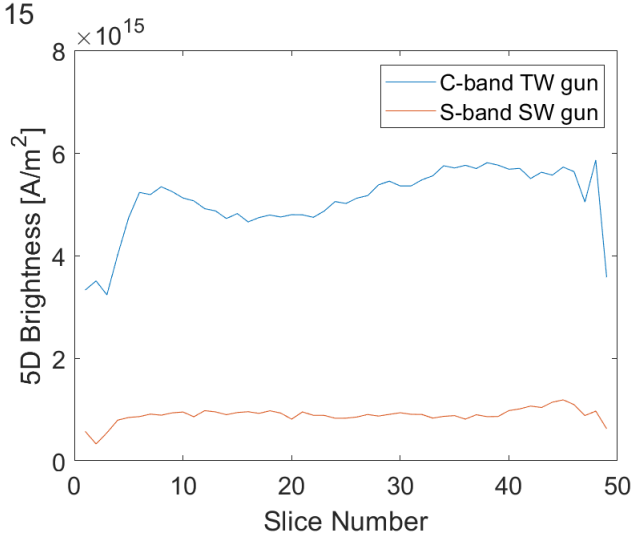
Lucas. T.G., et al. Towards a Brightness Upgrade to the SwissFEL: A High Gradient Traveling-Wave RF Photogun, Submitted March 2023 to Phys. Rev. Accel Beams.

BEAM DYNAMICS SIMULATIONS

- **Beam dynamics simulations** performed in General Particle Tracer (GPT).
- Simulations consist of RF gun and two S-band accelerating structures.
- **Comparison between current SwissFEL photogun and new TW gun design** illustrate that the brightness can be increase by a factor of 5.







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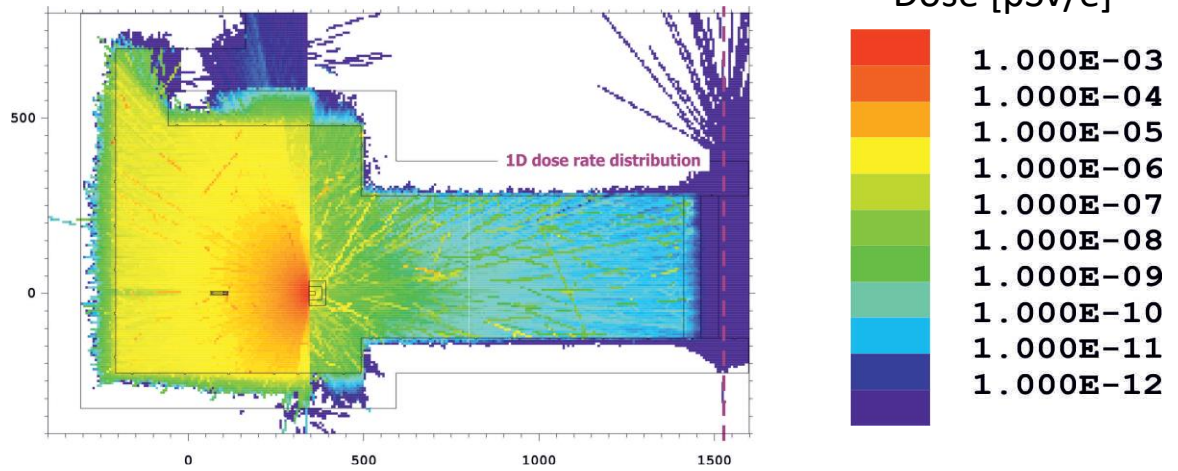
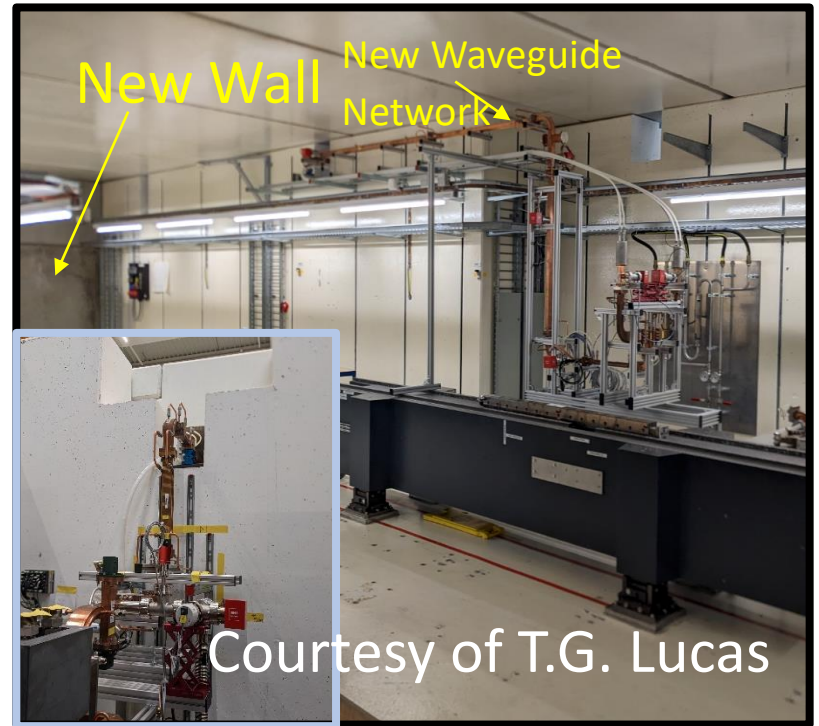
RADIATION SIMULATIONS AND HIGH POWER TESTING FACILITY

- **Radiation simulations performed** to understand whether current bunker is suitable for high power testing.
- Simulations illustrate that **radiation dose is dominated by X-rays**.
- The **new one-meter wall** downstream illustrated to be sufficiently thick for test stand.
- The **bunker has been refurbished** with the addition of a new wall and preparation for the high power tests of the gun have begun.
- The **waveguide network for the testing of the C-band isolator** has been installed.



Talanov, V. Internal PSI (TM-81-22-1103)



PLANNING FOR NEXT PERIOD

STANDING WAVE GUN

Now to 15 June: gun setup with support, cooling system and vacuum system
15 June: shipment to PSI
30 July: complete installation for RF test
September-end of the year: high power RF test

TRAVELLING WAVE GUN

Now to September 2023 – Machining of the TW gun components at VDL.
September 2023 – Arrival of individual components at PSI.
November 2023 – Brazing of the TW gun.
December 2023 – Low power testing.
January 2024 – Installation in the high power test-stand.

CONCLUSIONS

- **SW GUN: realized now in the final setup phase. All other components fabricated or under fabrication**
- **TW GUN: design activity** concluded, fabrication will start soon
- **BUNKER: ready to host the RF test**

THANK YOU FOR YOUR ATTENTION

MAIN CONTRIBUTORS

INFN-LNF: F. Cardelli, G. Di Raddo, A. Vannozzi, A. Giribono, L. Faillace, A.Gallo, L. Pellegrino (support on project management tools)
INFN-ROMA1: L. Ficcadenti, G. Pedrocchi, G. Castorina
PSI: T. Lucas, P. Craievich, R. Fortunati, R. Zennaro, M. Pedrozzi, F. Marcellini, J-Y Raguin, M. Schaer

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