Very high gradient RF Guns (Task 7.4)

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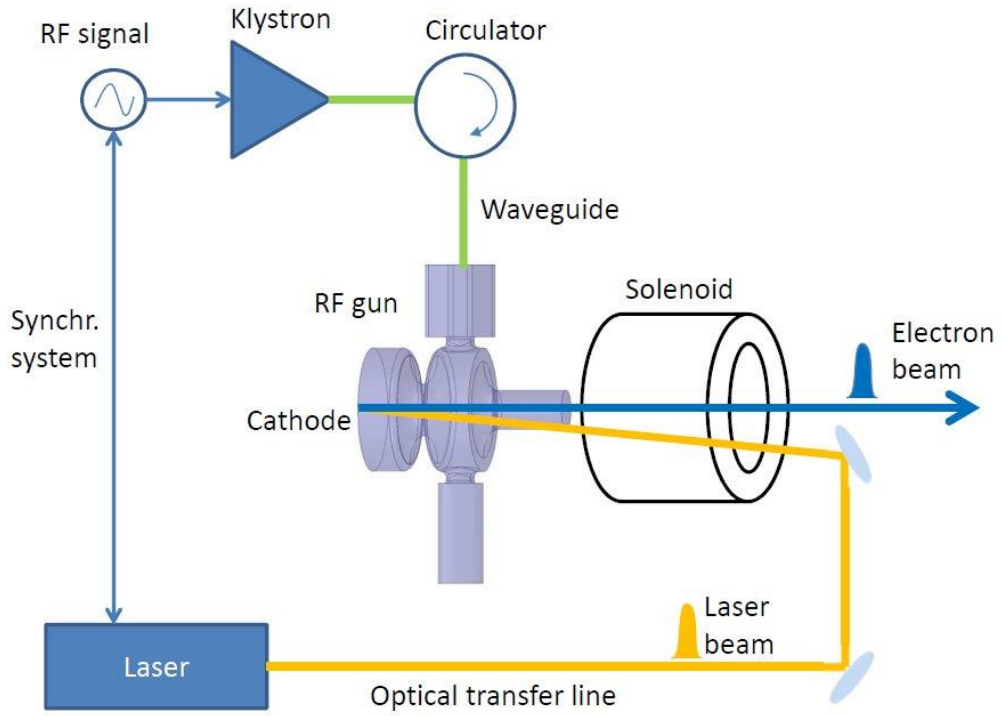
On behalf of the INFN-PSI Very High Gradient C band gun group

OUTLINE

1. **Goals, Responsibilities and Timeschedule** of task 7.4 on Very high gradient RF Guns
2. Update on **SW GUN Activities**
3. Update on **TW GUN Activities**
4. **Bunker Status@PSI for high power test**

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 200 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)**

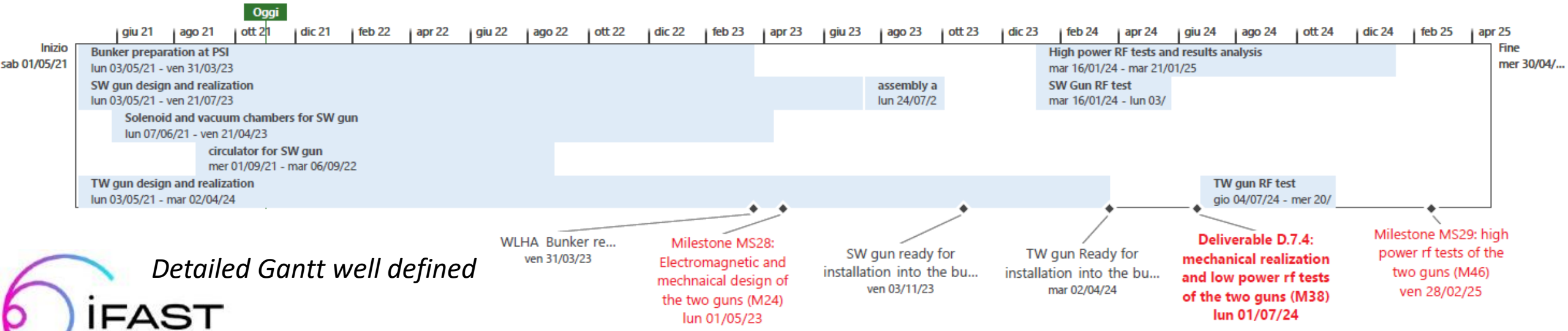
GOALS AND TIMSCHEDULE OF TASK 7.4

- **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): a Standing Wave (**SW**) gun and a Travelling Wave (**TW**) gun.
- **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)

INFN Istituto Nazionale di Fisica Nucleare — COMEB

PAUL SCHERRER INSTITUT PSI — VDL

SW GUN ***TW GUN***



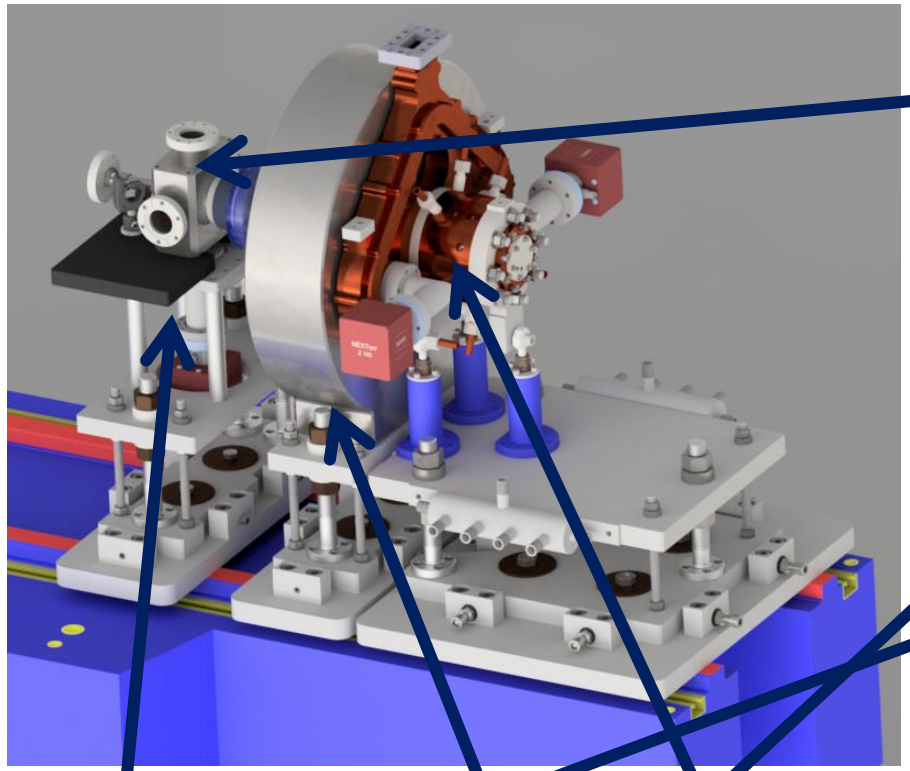
Detailed Gantt well defined

iFAST

SW GUN STATUS

⇒ **e.m. design** completed

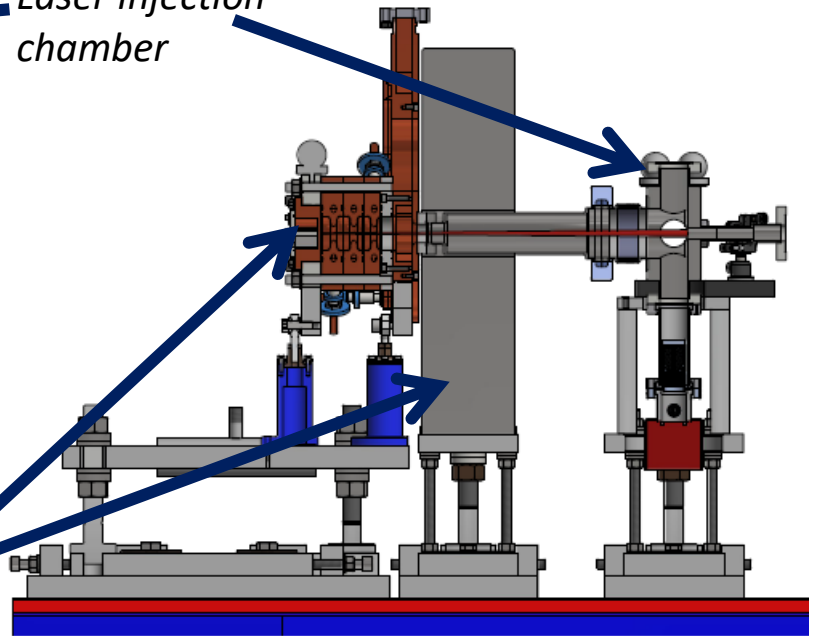
⇒ **Mechanical design:** almost completed

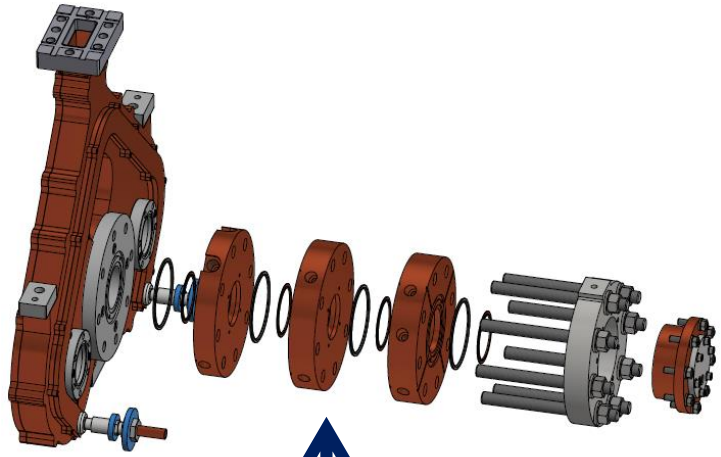


Laser injection chamber

solenoid

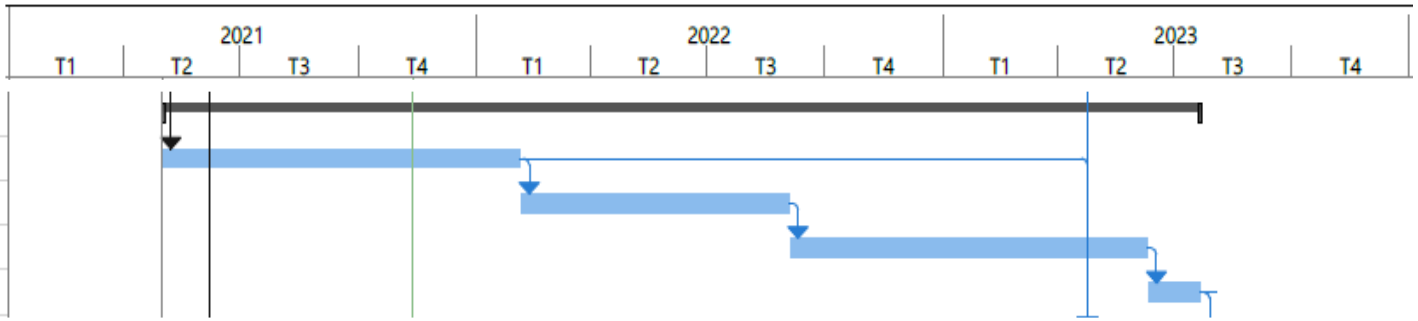
RF gun





***New technology** w/o brazing for RF gun realization (clamping and special gaskets)*

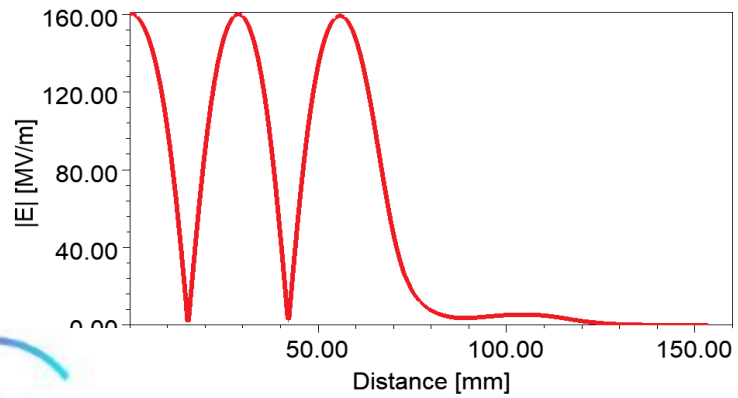
SW gun design and realization
Design of the SW gun
realization of the alluminum prototype
realization of the final copper gun and vacuum test
low power rf measurements

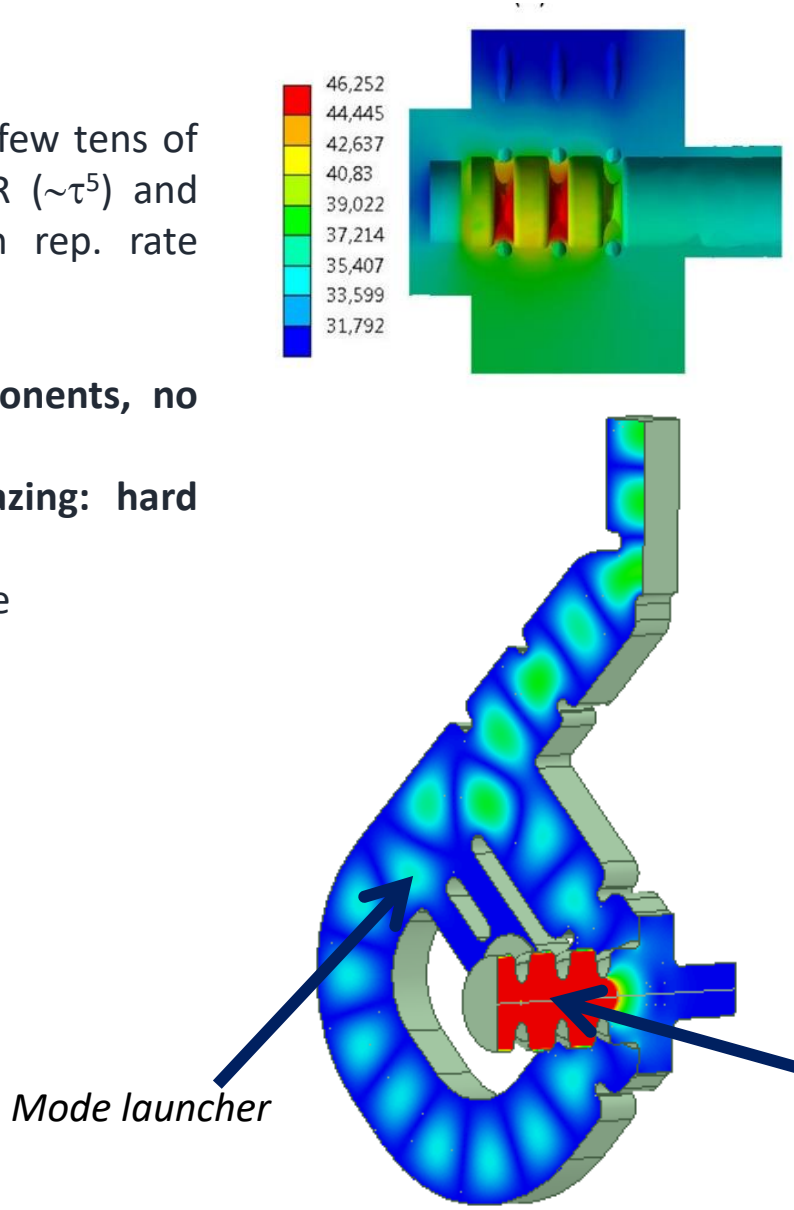


SW GUN: STRATEGY, PARAMETERS

- ⇒ **2.5** cell
- ⇒ Powered with very **short rf pulses** (300 ns) of few tens of MW to reduce the pulsed heating ($\sim\sqrt{\tau}$), BDR ($\sim\tau^5$) and average dissipated power (allowing the high rep. rate operation);
- ⇒ **Cathode peak field (E_{cath})> 160 MV/m**
- ⇒ **4-port mode launcher (no quadrupole components, no pulsed heating)**
- ⇒ **New technology for its realization w/o brazing: hard copper**
- ⇒ (Commercial) **circulator is necessary**: order done
- ⇒ Design compatible with **1 kHz rep. rate**;

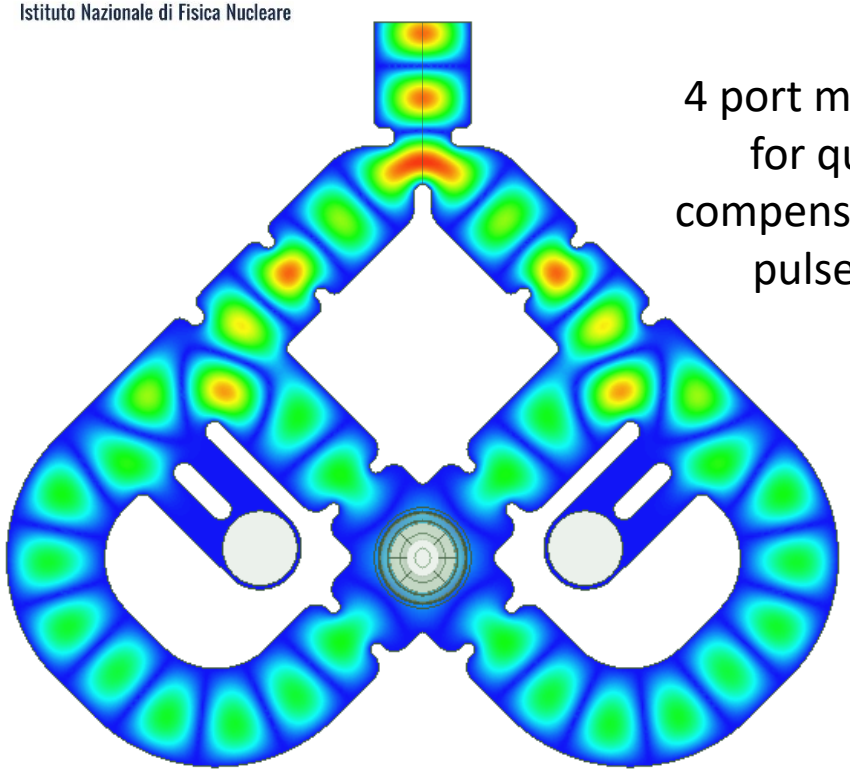
Longitudinal electric field profile





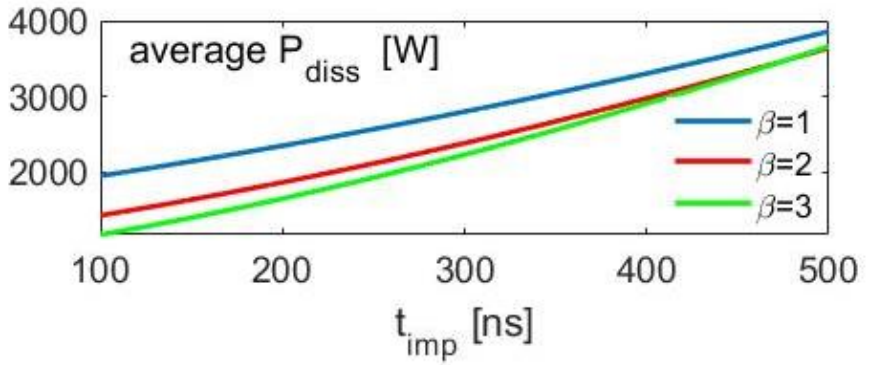
Parameter	value	
Frequency [GHz]	5.712	
$E_{cath}/\sqrt{P_{diss}}$ [MV/(m·MW$^{0.5}$)]	51.4	
Peak input power [MW]	18	23
Cathode field [MV/m]	160	180
Cathode type	copper	
Rep. rate [Hz]	1000	100
Quality factor	11900	
Filling time [ns]	166	
Coupling coefficient	3	
RF pulse length [ns]	300	
E_{surf}/E_{cath}	0.96	
Mod. Poy. Vect. [W/μm^2]	2.5	3.1
Pulsed heating [°C]	16	20
Av.diss. Power [W]	2300	300

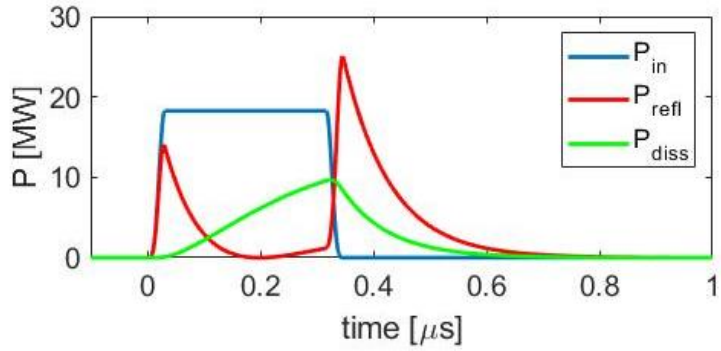
SW GUN: MAIN FEATURES

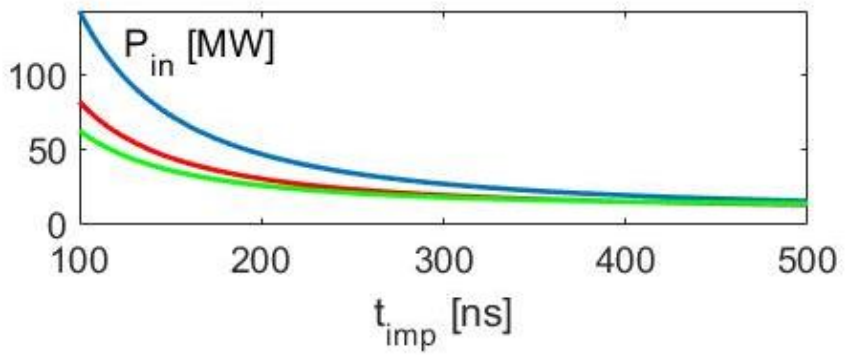


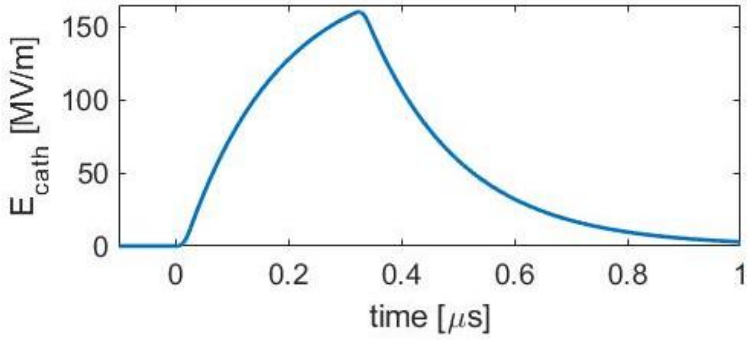
4 port mode launcher for quadrupole compensation and low pulsed heating

Coupling coefficient for short rf pulses







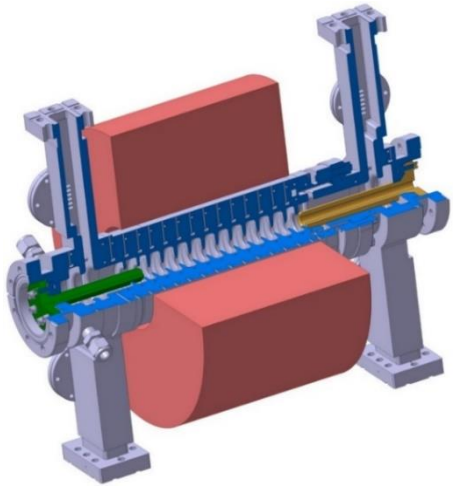


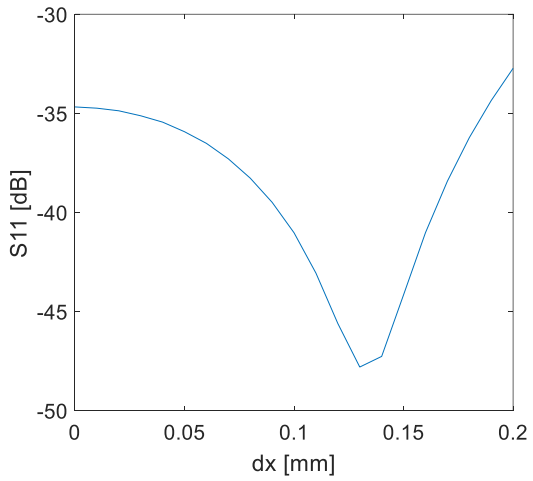
⇒ **Dark current studies in progress;**

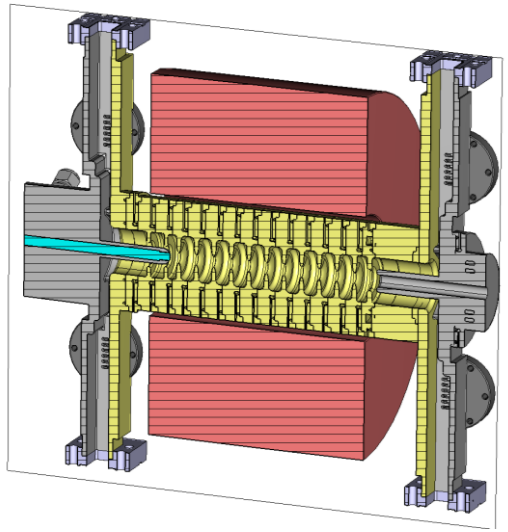
TW GUN RF GUN DESIGN: NEW DESIGN

- Started with the design by M Schaer (PR-AB19, 072001 (2016)).
- **Tolerance Studies** demonstrated **tight tolerance requirements** for the cathode.
- Concerns over chokes for the possibility of multipacting.
- A **new design was conceived based on tolerance studies**.
- **A rigid (brazed) inner conductor** on the coaxial couplers and a cathode threaded through the inner conductor which is removable.
- **All chokes were removed to prevent multipacting**.
- Misalignment in brazing can be fixed with a phase shift and adjustment of the cathode in z.

Courtesy T. Lucas







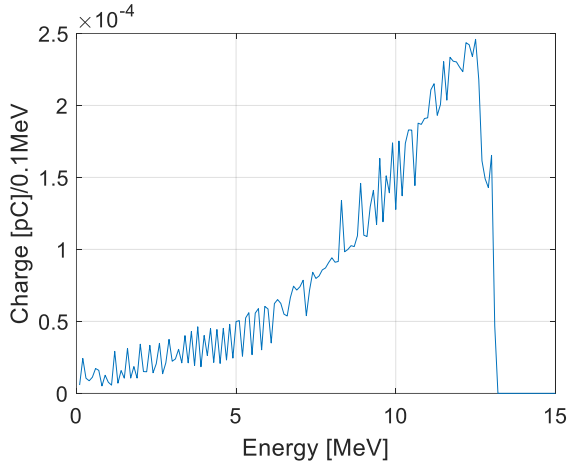
Parameter	Value	Unit
Frequency	5712	MHz
Phase advance	120	deg
Repetion rate	100	Hz
Group velocity	0.0079	
Q	10000	
R/Q	8268	W/m
Regular cell	10	
RF length	220	mm
Filling time	90	ns

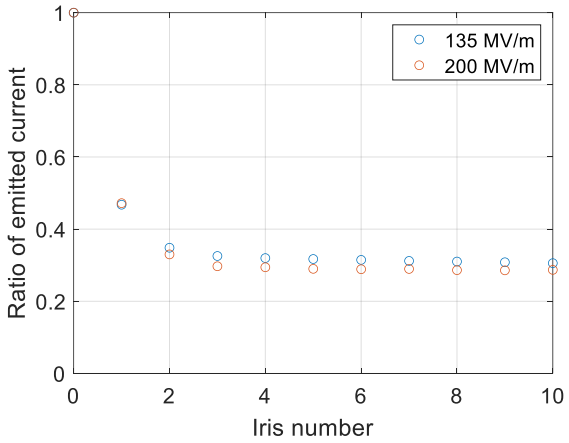
Gradient at cathode	135	MV/m
Gun output energy	12.7	MeV

Gradient at cathode	200	MV/m
Gun output energy	13.9	MeV

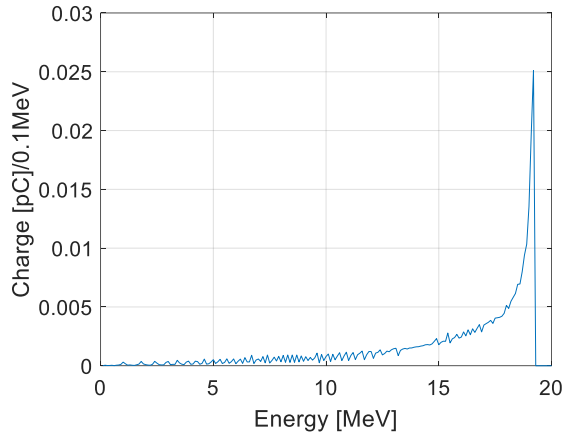
TW GUN: DARK CURRENT SIMULATIONS

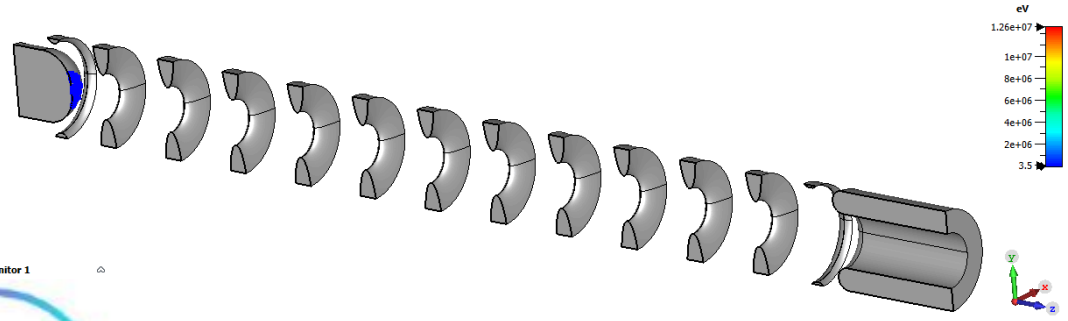
- Simulations of **dark current performed in CST.**
- Values of A_e and β taken from measurements of SwissFEL gun.
- **Dark current production less than 1 nC per RF pulse at 200 MV/m**.
- New design not expected to change this.





Courtesy T. Lucas

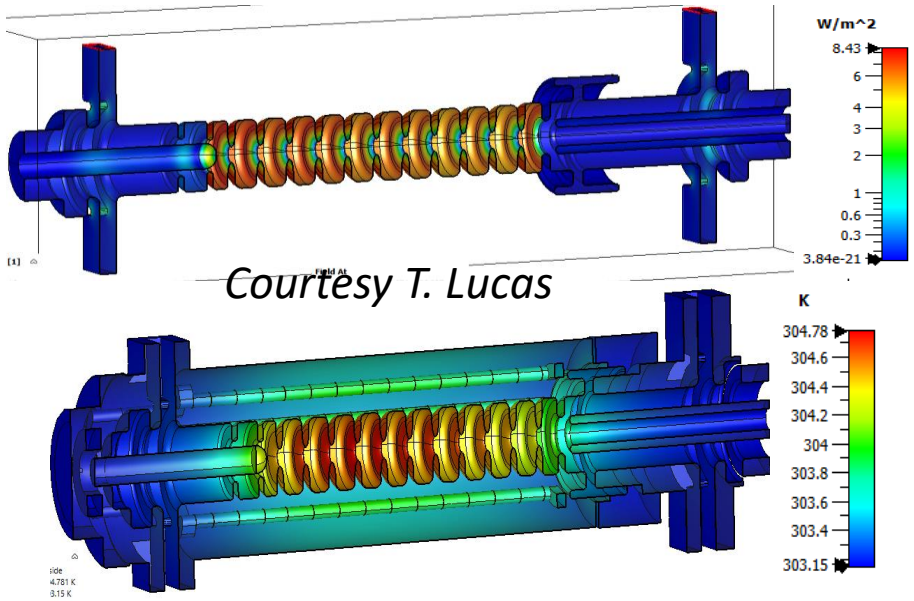




Field Enhance-ment Factor (β)	Effective area (A_e) [um^2]	Cathode Gradient [MV/m]	Charge arriving downstream (per 90ns RF pulse) [pC]	Capture Ratio	Total Field emitted charge (per 90ns RF pulse) [pC]	Peak Energy [MeV]
70	0.01	135	5.9	0.31	19.0	13.0
70	0.01	200	160.3	0.29	552.8	19.2
70	0.1	135	65.8	0.31	212.3	13.0

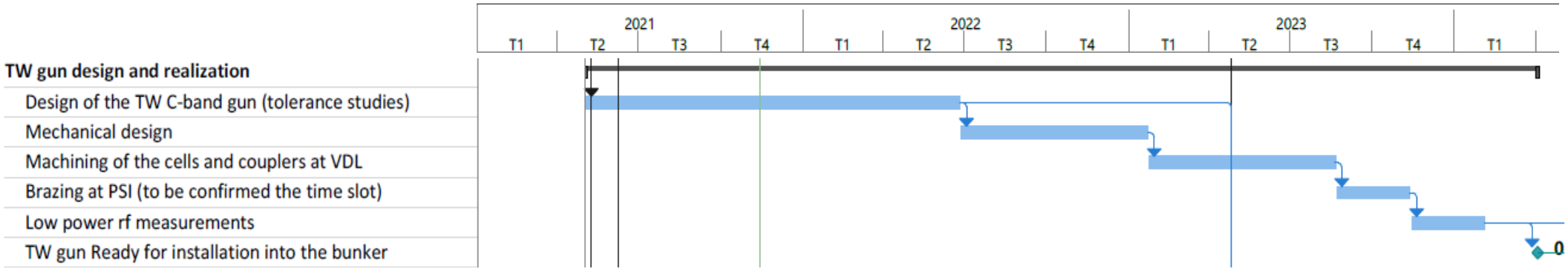
TW GUN: THERMAL SIMULATIONS

- **Thermal Simulations performed in CST** by coupling EM solver to Thermal Solver.
- Heating from surface currents.
- Convection coefficient for cooling water applied using empirical model.
- **No significant heating issues observed**.
- New design expected to perform better with a better thermal connection between end of cathode and cooling channels.



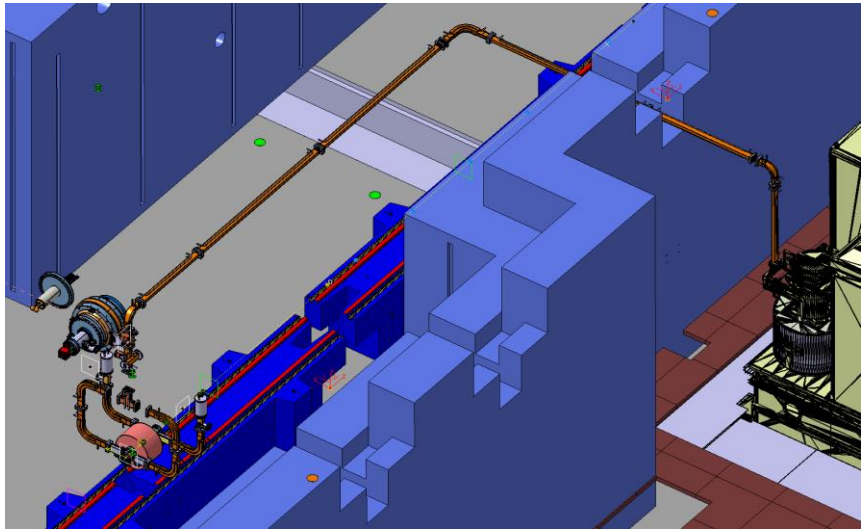
Courtesy T. Lucas

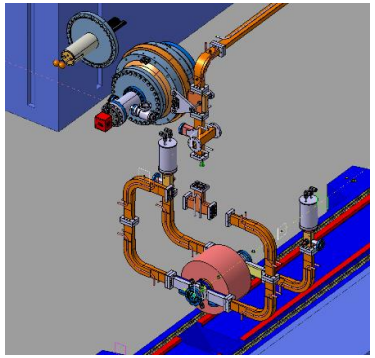
TW GUN: SHORT TERM TIMELINE



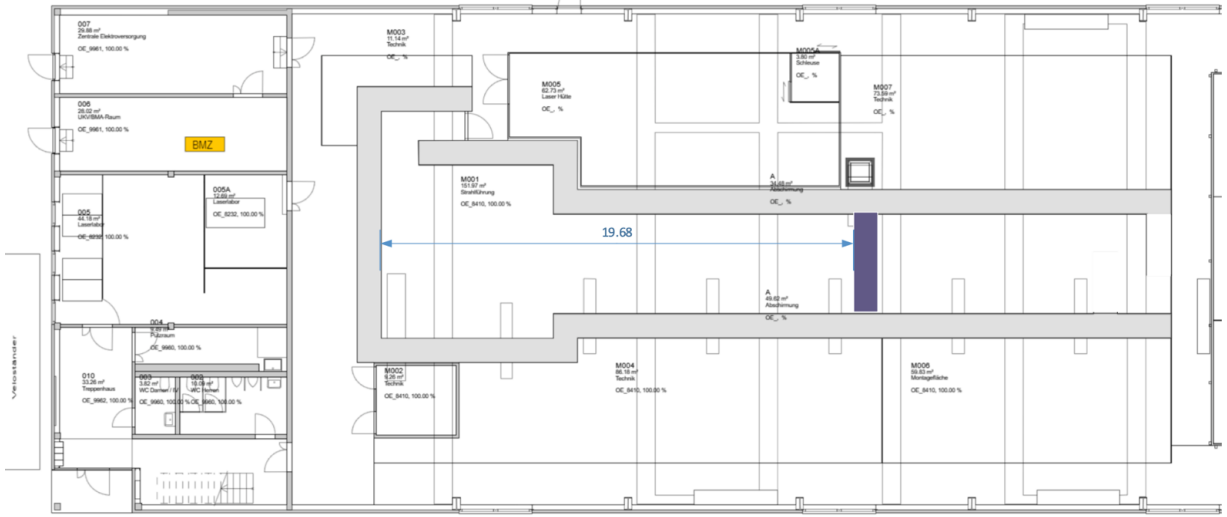
BUNKER@PSI: STATUS

- **HV klystron modulator is routinely running** on C-band PSI loads (max power 50 MW)
- **Closure of the bunker**: documents under preparation to get permission from BAG
- **Waveguide network:** C-BOC and most of the RF components **already at PSI**



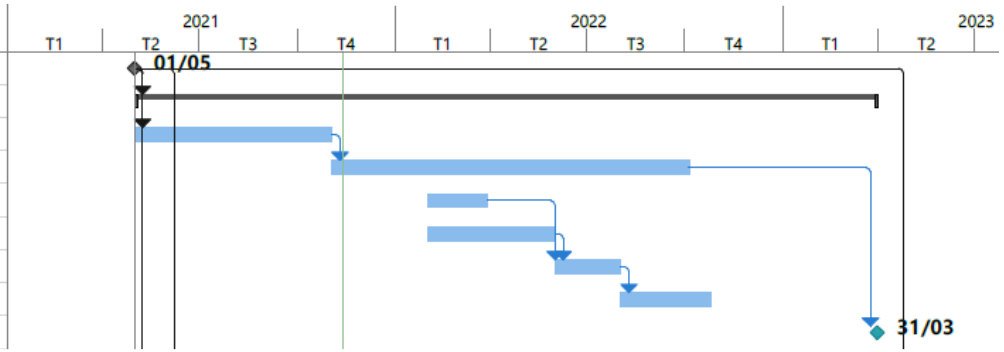


Courtesy P. Craievich



The bunker will be closed approximately at 19 m from the wall to ensure that he bunker meets safety standards with respect to emergency exits.
The bunker already has all water and electrical facilities installed

Nome attività
Project Start
Bunker preparation at PSI
Drafting documents for BAG authorizhation
BAG Decision
Wall construction
Installation control access systems
Beamline setup
Waveguide network installation
WLHA Bunker ready



CONCLUSION

- **TIMESCHEDULE for SW, TW and BUNKER preparation well defined**
- **DESIGN activities** on both SW and TW guns started according to the established GANTT
- **NEXT STEPS**:
    - SW GUN: Concluding the mechanical design, solenoid design and its order
    - TW GUN: Concluding the e.m. design and proceed with the mechanical one
    - BUNKER: waiting for the authorizations (BAG) and work in parallel on control access, waveguides, etc…

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
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