C-BAND GUN DESIGN AND HIGH REPETITION RATE CHALLENGES

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on behalf of the C-band gun study group

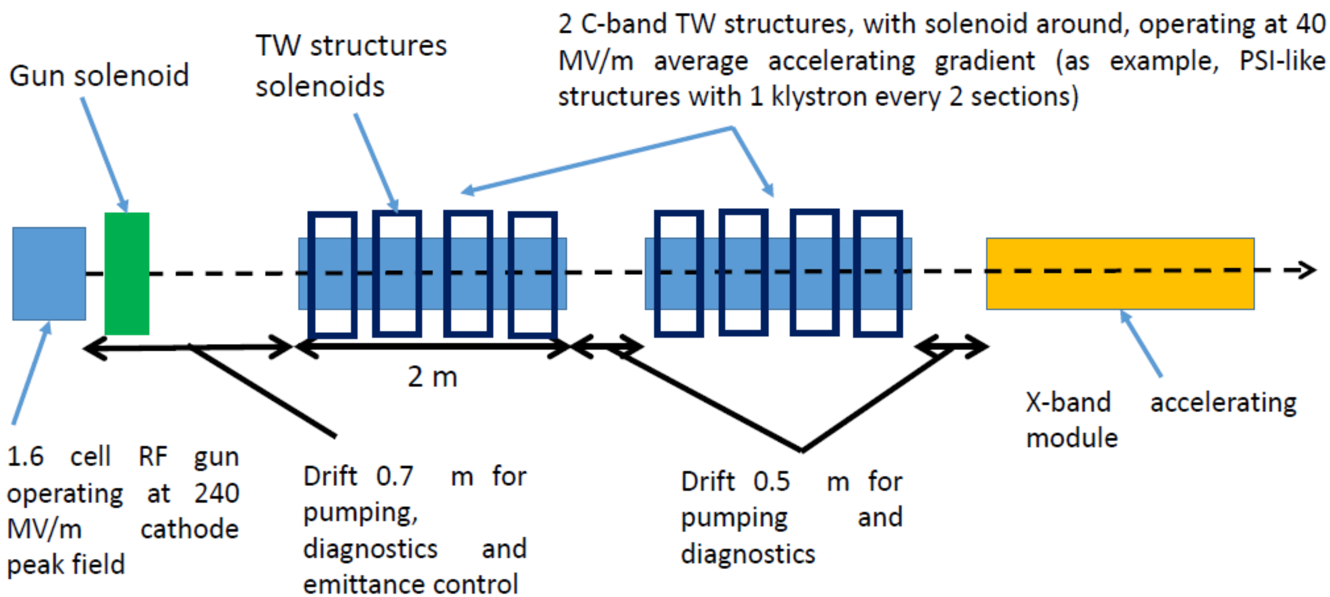
XLS Midterm Meeting, Helsinki, Finland, 1-4 July 2019

C-BAND RF INJECTOR FOR COMPACT LIGHT

⇒ The **schematic layout of the full C-band injector** we are proposing is given in the figure. The C-band gun is followed by two 2 m long C-band TW structures (operating mode $2\pi/3$) fed by a single klystron and a pulse compressor able to achieve E_{acc}=40 MV/m.

⇒ The **solenoids** after the gun and around the TW structures allow to keep under control the beam emittance increase also in case of longitudinal compression by velocity bunching.

⇒ The **correct scaling laws for the cathode field**, indicate that, in order to have a very high gain in term of emittance and brightness one has to scale $E_{cath} \propto \lambda_{RF}^{-1}$. This drives to the conclusion that, in C-band, if we want to scale the working points of the S band guns we have to reach a cathode peak field of 220-240 MV/m (**BD simulations in progress**).



[1] D. Alesini et al., TUPTS024, IPAC 19

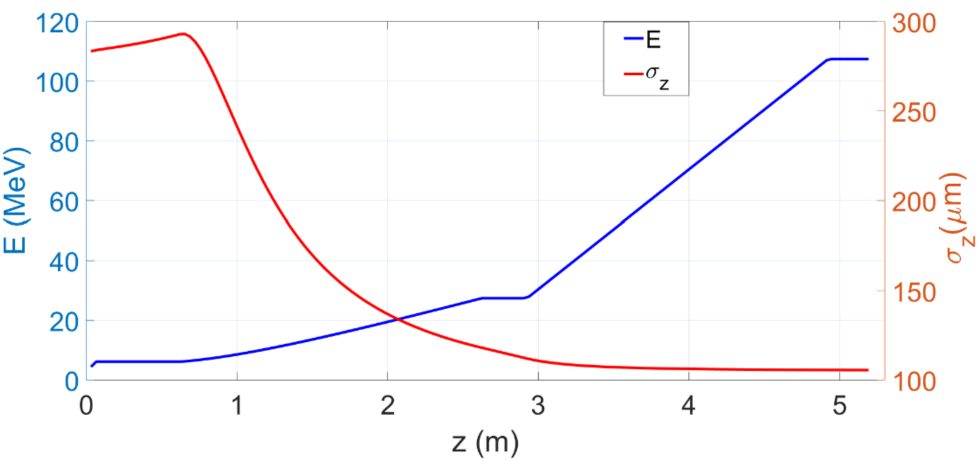
BEAM DYNAMICS SIMULATIONS

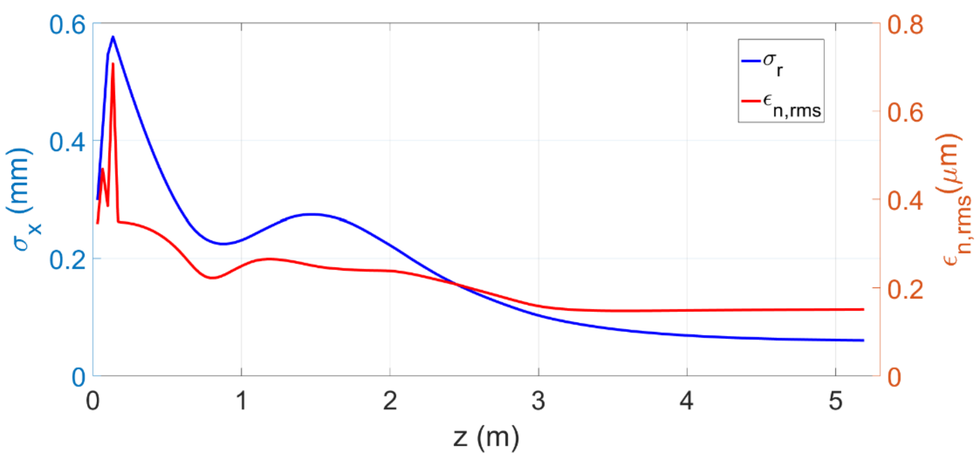
⇒ Working point of the injector **scaled from the S-band injector**.

⇒ Simulations with **GPT** code have been also compared with Tstep and Astra.

⇒ The **intrinsic emittance** has been calculated, for the copper cathode, considering the ideal case of a flat cathode giving $\epsilon_{int} \approx 0.8\ \mu m/mm$.

⇒ We have analysed the **two cases of on crest acceleration and longitudinal compression (BC) using the velocity bunching technique**. The final normalized emittance on crest and in the compression case are the same and equal to $\boldsymbol{\epsilon_{n,rms} \approx 0.15\ \mu m}$.





Parameter	w/o BC	with BC
Laser spot size [μm]	294 (uniform)	
Laser rms length [ps]	3.4	
Rise time laser pulse [fs]	600	
Bunch charge [pC]	75	
Beam emittance [mm·mrad]	0.15	
Bunch length [μm]	295	105
Beam Energy [MeV]	170	107
Peak current [A]	22	60
Beam energy spread [%]	0.6	1.4

M. Croia

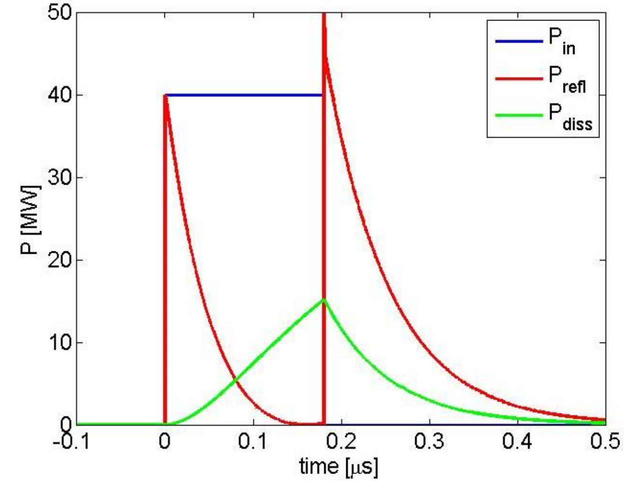
C-BAND GUN DESIGN CRITERIA AND POWERING SCHEMES

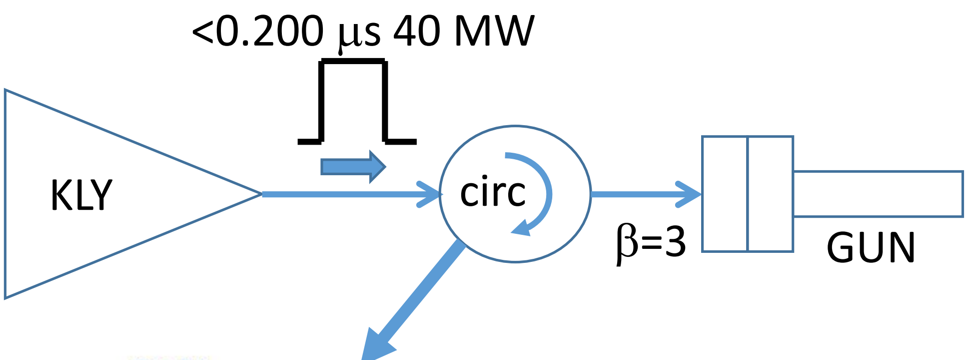
There are **three main quantities** that play a role in the BDR control: **peak E field**, **modified Poynting vector (S_c), RF pulse length (t_p)** and **Pulsed Heating (ΔT)**. The control of these quantities in an RF structure allows to control and predict the final BDR. The scaling law are **frequency-independent**.

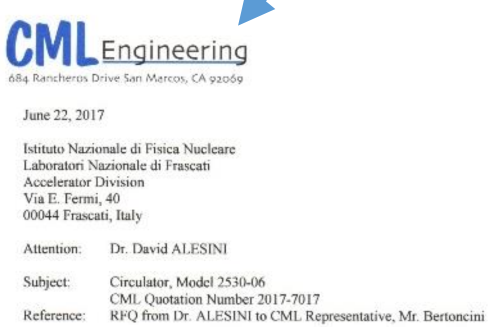
According to the previous considerations the gun has been designed in ordeer to:

1. **Be powered with extremely short RF pulses** (< 200 ns)

2. With a **cell profile and coupler to take under control E_{peak}, S_c and the pulsed heating**





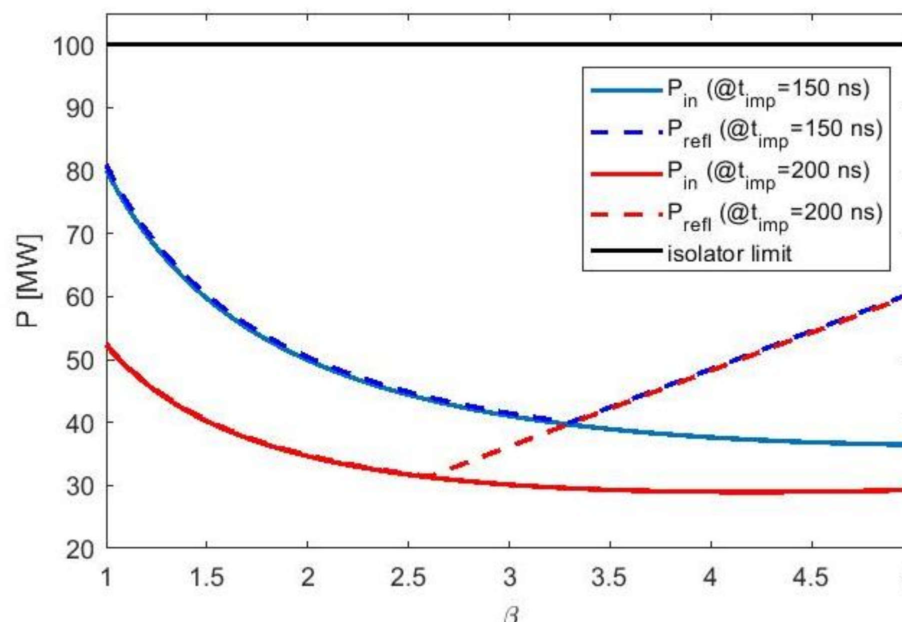

CML Engineering
684 Rancheros Drive San Marcos, CA 92069

June 22, 2017

Istituto Nazionale di Fisica Nucleare
Laboratori Nazionale di Frascati
Accelerator Division
Via E. Fermi, 40
00044 Frascati, Italy

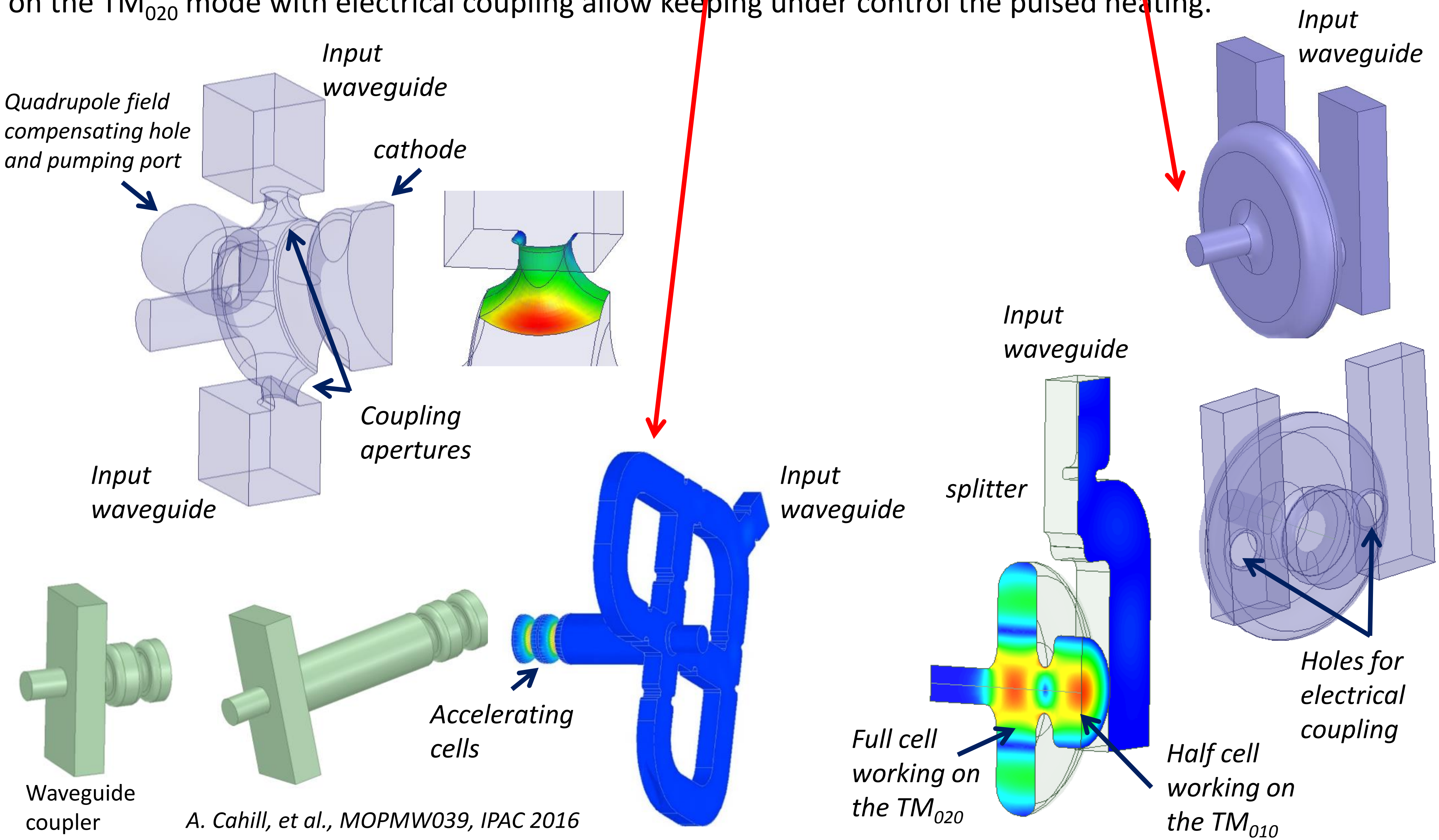
Attention: Dr. David ALESINI

Subject: Circulator, Model 2530-06
CML Quotation Number 2017-7017
Reference: RFQ from Dr. ALESINI to CML Representative, Mr. Bertoncini



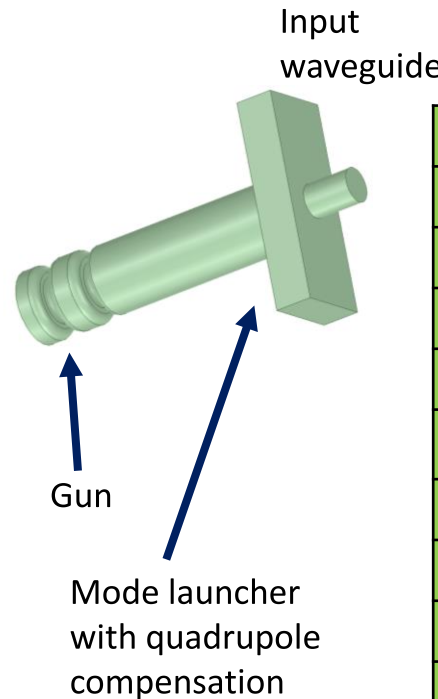
LOW PULSED HEATING COUPLERS

"Standard" coupling slots on the full cell cannot be used because of **the high magnetic field** even considering strongly rounded holes. **Mode launcher based couplers** or **the new proposed couplers** working on the TM_{020} mode with electrical coupling allow keeping under control the pulsed heating.

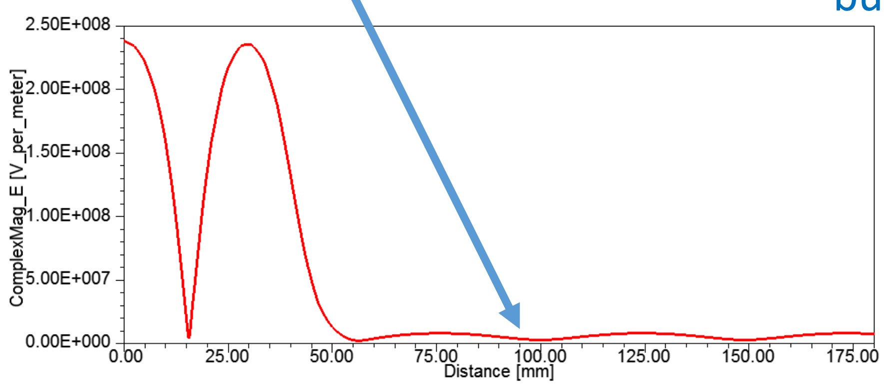


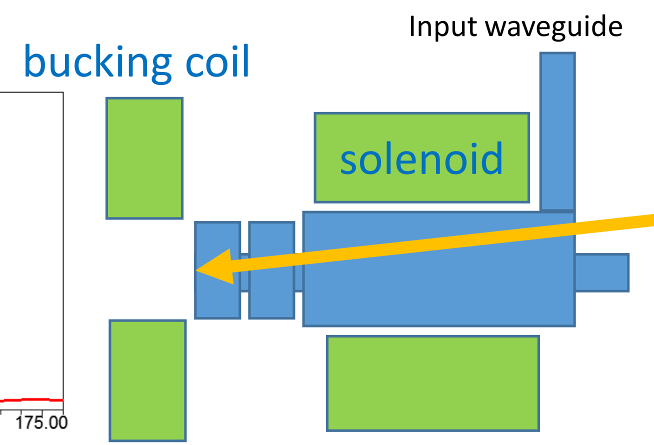
MODE LAUNCHER COUPLER

PROS	CONS
Perfect 2D profile: **no multipole components in the cell**	**Pumping ports**: Pumping from waveguides could be too far form the accelerating cells
Pulsed heating: No pulsed heating on the input coupler	**Solenoid**: Large bore for gun insertion and bucking coil necessary
Cooling: easy due to the 2D profile	**Residual field on the circular waveguide**: impact on beam dynamics to be evaluated
Fabrication: lathe	
High ratio $E_{CAT}/\sqrt{P_{diss}}$	
Relatively easy laser injection	



E_{cath}	240 MV/m
$\Delta f_{0\text{-}\pi}$	≈ 100 MHz
Q_0	11000
β	3
P_{diss} @240MV/m	12 MW
$E_{CAT}/\sqrt{P_{diss}}$	67 [MV/mMW$^{0.5}$]
P_{IN} @240MV/m	31 MW
ΔT @ 200 ns	<30 °C
RF pulse length	200 ns
Av diss power	200 W
Rep. Rate	100 Hz

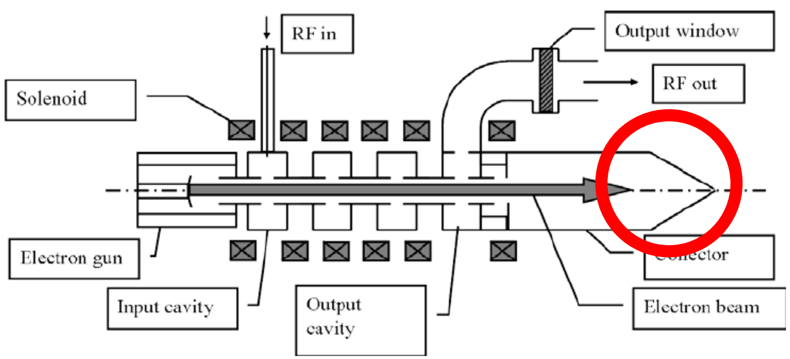




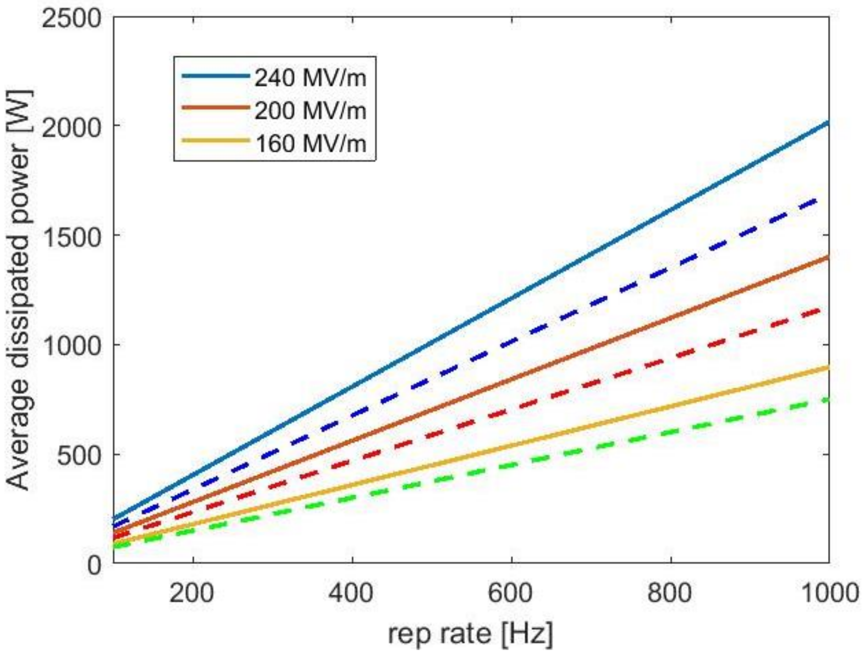
kHz REPETITION RATE OPERATION

The high repetition rate operation is limited by two effects:

The klystron power available at high rep. Rate. This is the **real limitation** and it is due to the **maximum power can be released on the collector**



The **average dissipate power in the structure**. This power because of the short pulses **can be managed**, in principle, even at extremely high gradients of 240 MV/m

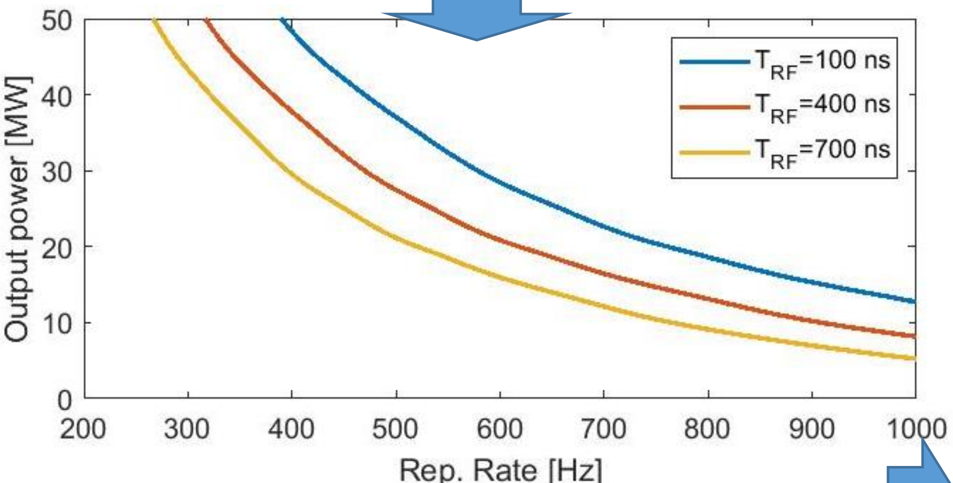


Cont. Line: t_p=200 ns
Dashed Line: t_p=100 ns

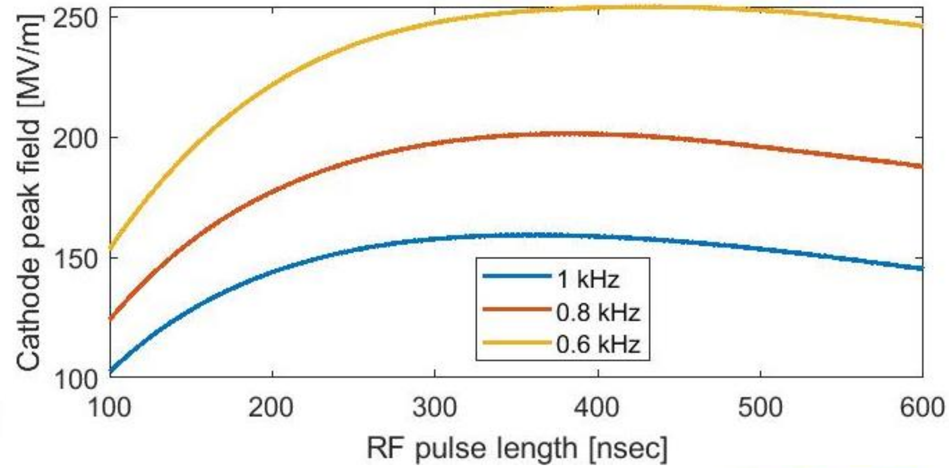
REP RATE INCREASE REDUCING THE RF PULSE DURATION

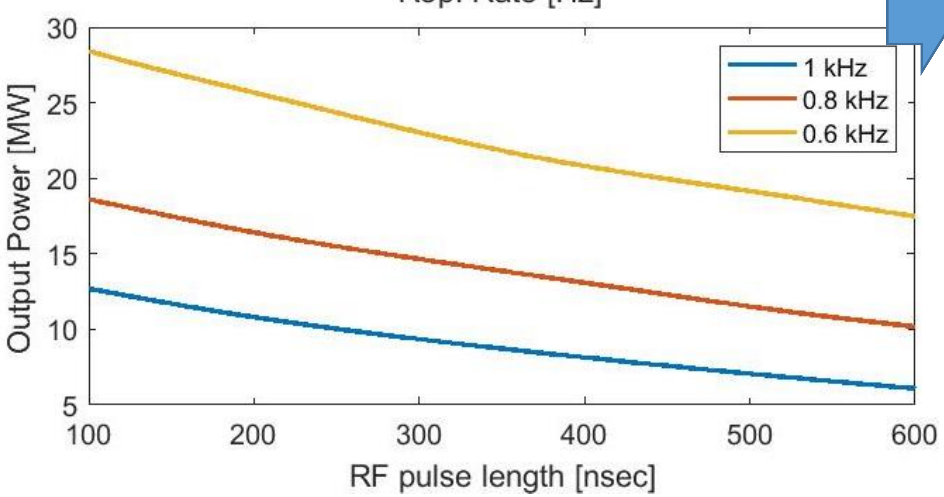
In this case **we reduce the RF pulse but we are dominated by the modulator transients**. Looking at the values of the high power C-band klystron Canon (Toshiba) E37212 that are specified for 100 Hz, 50 MW, t_{RF_MAX}=2.5 μs, t_{trans}=2.5 μs, we obtain **P_{coll_MAX}≅58kW.**

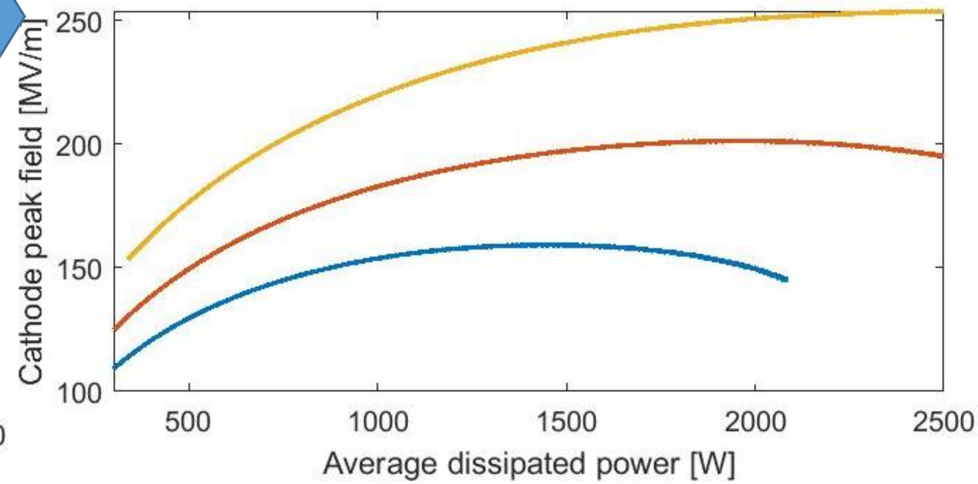
Assuming equivalent transients given by solid state modulators similar to that measured on **SPARC C-band klystrons** (t_{trans}~1.2 μs) we obtain:



Mode launcher case







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NEXT STEPS

1) **Final electromagnetic optimized design of the gun with quadrupole compensation on the mode launcher**

2) Design of the **solenoids** (in progress)

3) **BD simulations** for lower cathode peak field (high rep. rate case) considering also the case of 2.5 cell (in progress)

4) **High repetition rate options for the TW C band structures**

5) Preliminary **3D model of the injector**

...THANK YOU FOR YOUR ATTENTION!

With the contribution of:

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