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C-band photoinjector beam dynamics

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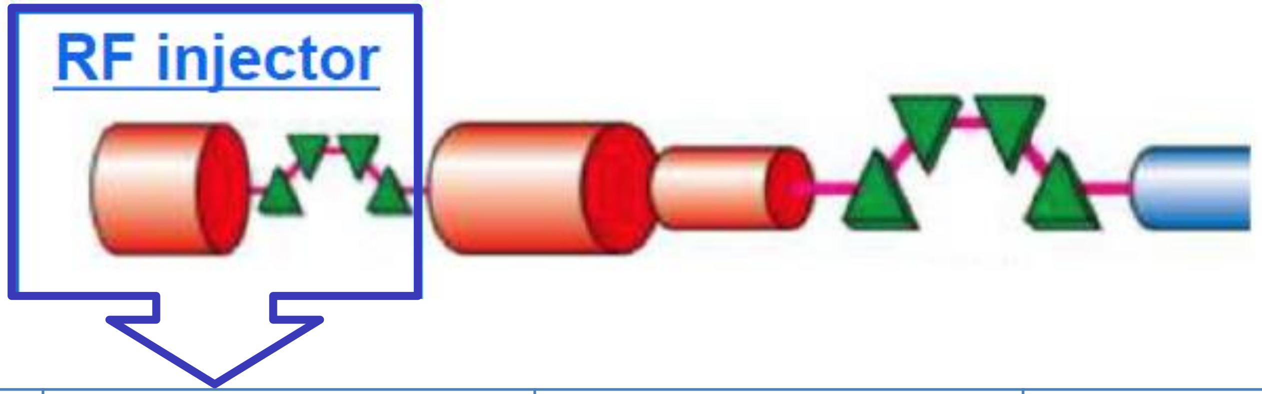
On behalf of the WP3 XLS team

Outline

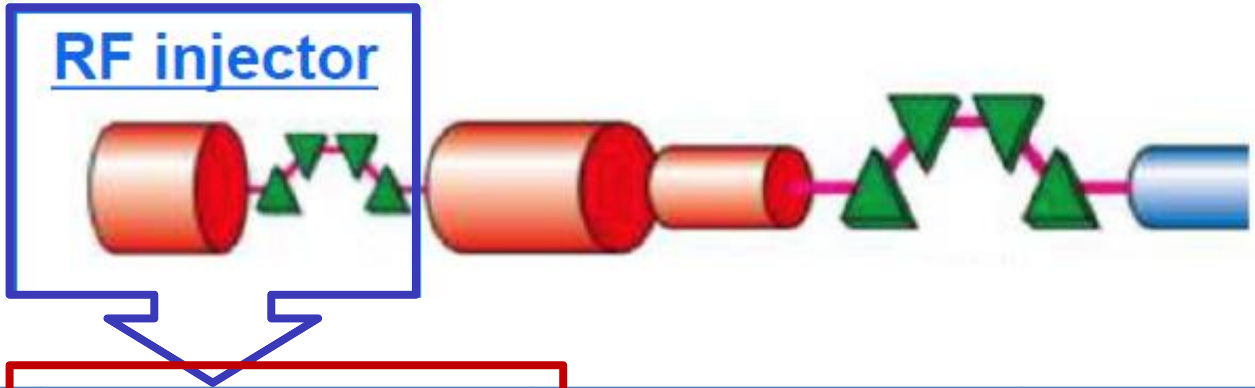
- The target parameter list
- The C-band photoinjector proposal
  - Layout description
  - Beam dynamics studies
  - Space charge effects up to injector exit
- Conclusions and hints for next future

The target parameter list



Parameters	Before BC1	After BC1	units
Q	75		pC
Rep. rate	100 – 1000		Hz
E	125	300	MeV
σ_E/E	0.5	0.5	%
$\epsilon_{n,rms}$	0.15		μm
σ_z	380	30	μm
I_{peak}	20	300	A

The target parameter list



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The C-band photoinjector proposal

- We propose a **C-band** photoinjector relying on a **2.5 cell gun** followed by *n* 2 m long TW structures
- The **C-band technology** could represent a good compromise between the S and X-band ones

✓ it still allows for exploring a wide range in terms of beam charge and length

✓ it allows for a more compact beamline compared to S-band solution

✓ it enables high repetition rate operation with higher field compered to S-band solution

→ up to 160 MV/m peak field on cathode in the gun

→15 MV/m average field in TW sections

- The **2.5 cell gun** allows to at least double the space for *beam characterization after the gun → 150 cm drfit*

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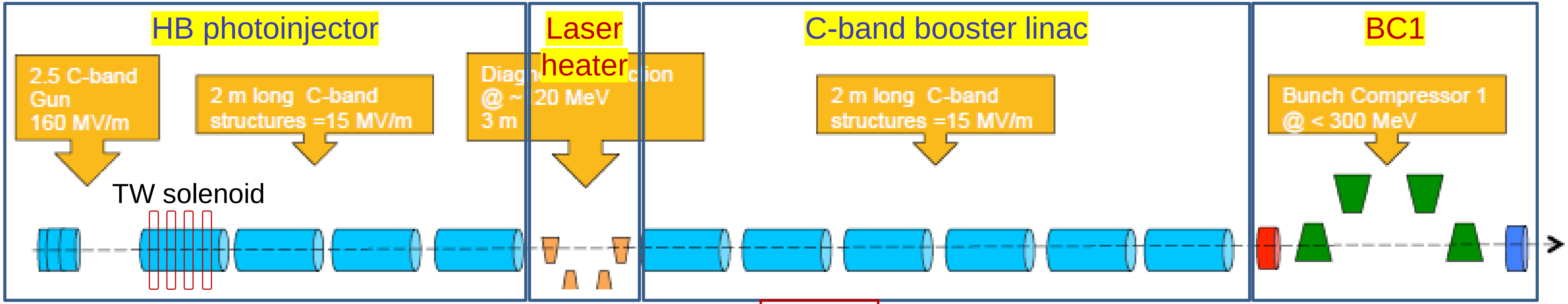
Layout description

*Courtesy of
Massimo Ferrario*



News:

1. 2.5 cell gun + solenoid → M. Diomede's talk
2. The choice of the on crest operation as baseline
3. Space for diagnostics has been addressed → A. Cianchi's talk
4. Laser heater studies in the C-band linac → S. Di Mitri's talk
5. Space charge up to BC1 → C.Vaccarezza's talk

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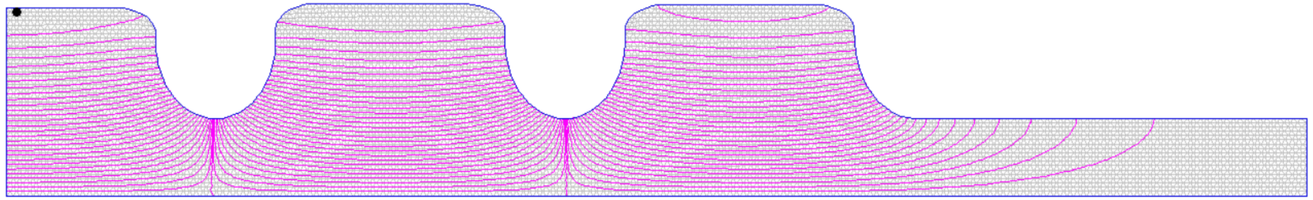
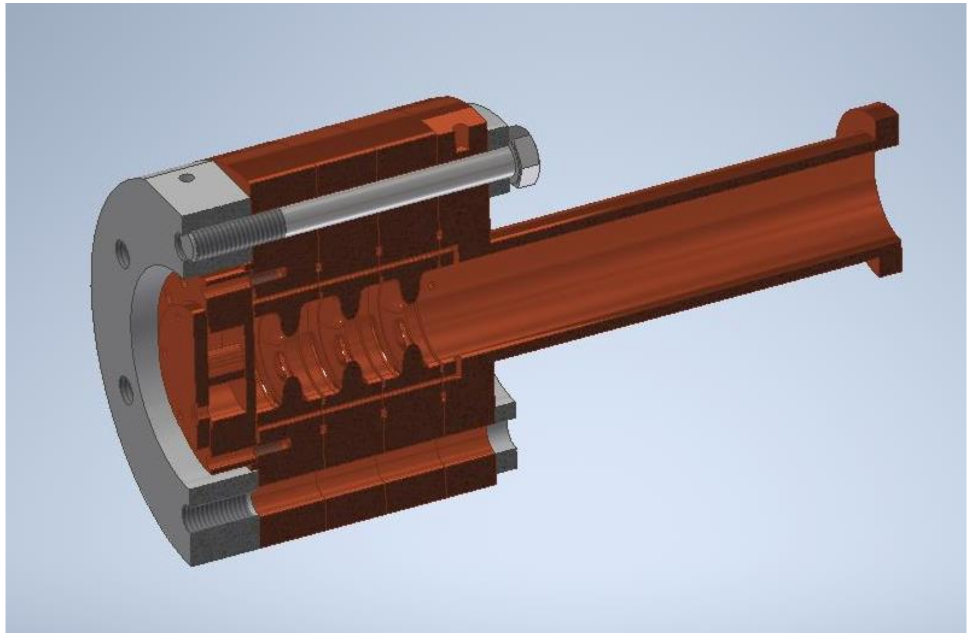
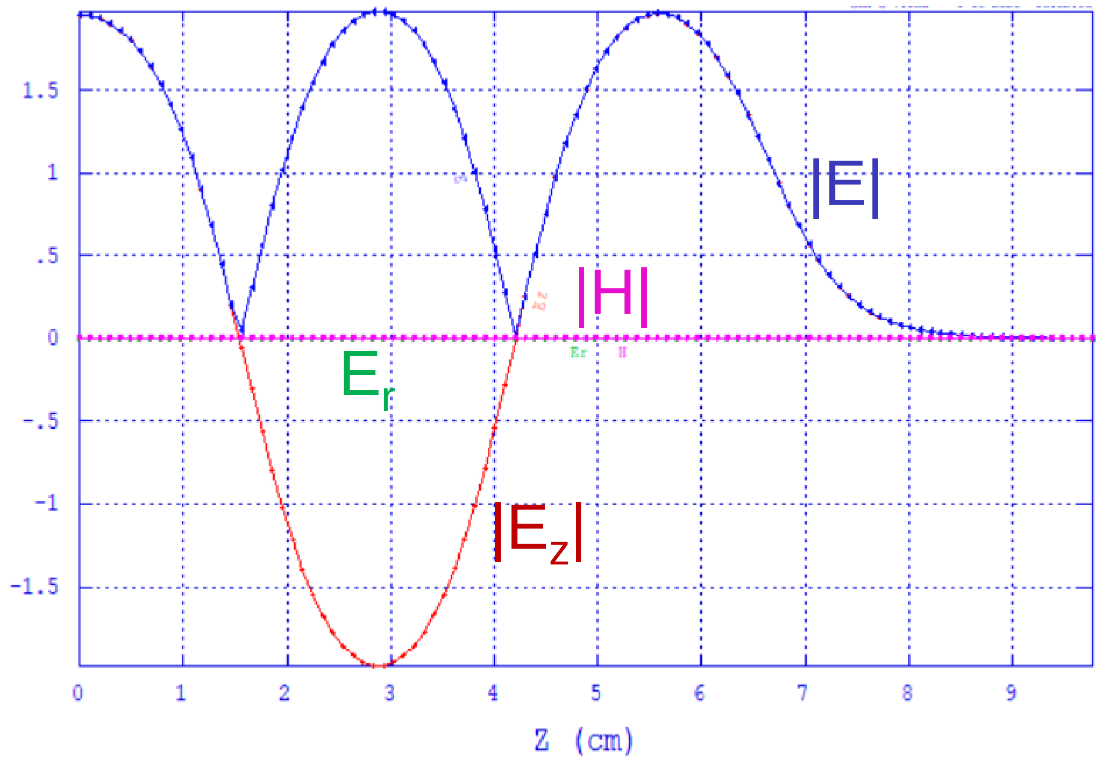
The 2.5 cell C-band gun

- The **2.5 cell gun** allows to double the space for *beam characterization after the gun*
- It is based on the PSI-like S-band one
- In case of 1 kHz repetition rate it will operate at 160 MV/m peak field at cathode surface → (M. Diomede's talk)







D. Alesini, G. Di Raddo, A. Giribono

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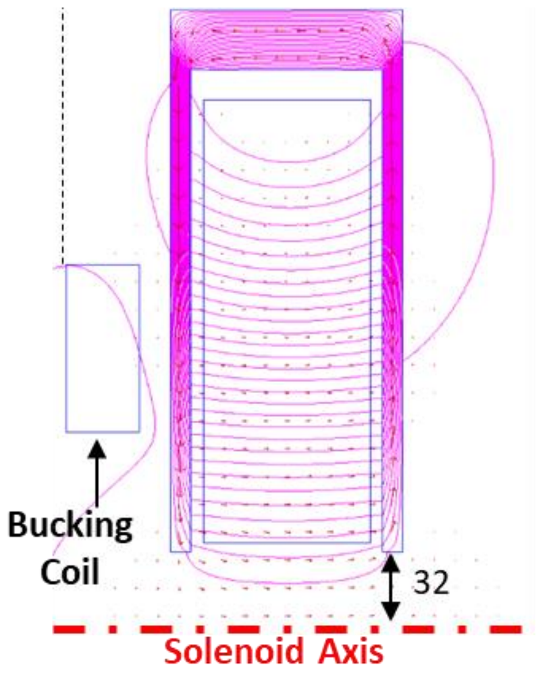
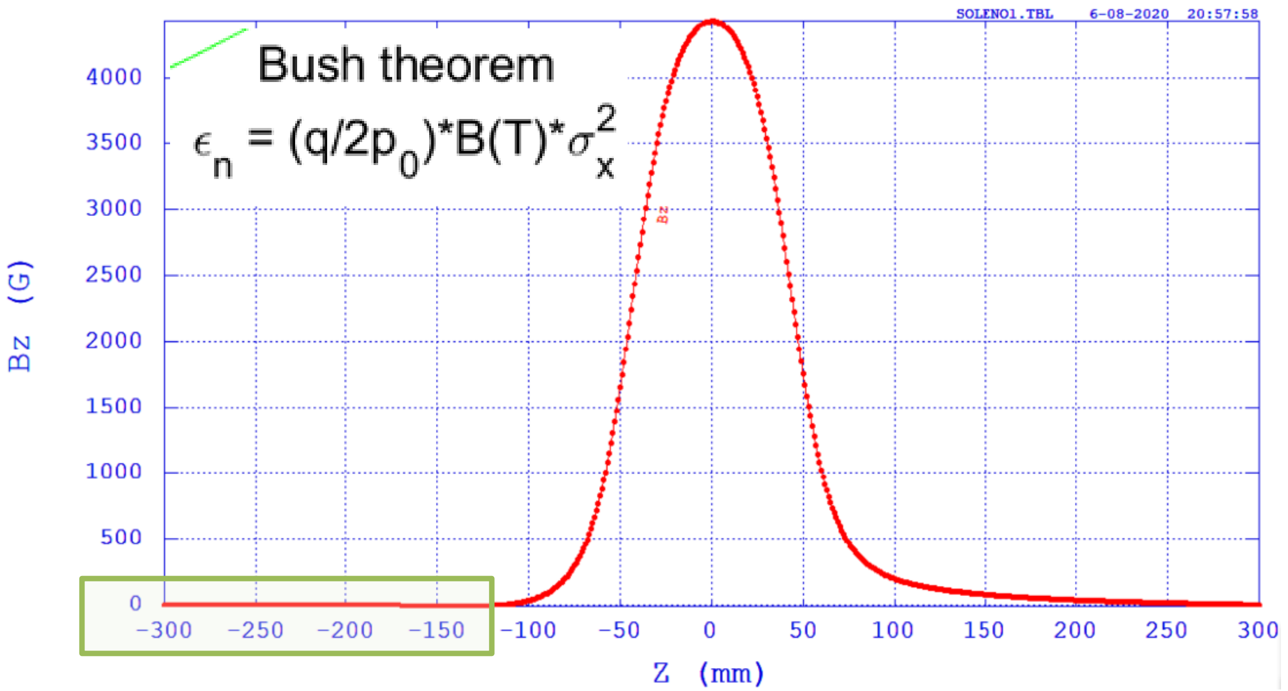
Solenoid for the 2.5 cell C-band gun

- Axial symmetric 2D simulations have been performed with **Poisson Superfish.**
- **Integrated field** allows to have a 150 cm focal length.
- **Bucking coil** for the cancellation of the field on cathode, let to have a magnetic field less than 10 G from 11 cm of the solenoid centre (green box in the picture) → see Bush theorem
- Design will be finalized with a mechanical integration final review.

SOLENOID SPECIFICATIONS	
Bmax	4430 G
Yoke Material	Low Carbon Steel
Integrated Field	42,05 Tmm
Good Field Radius	10 mm
Integrated Field Quality	3E-5
COIL SPECIFICATIONS	
Number of Turns	192
Conductor Dimensions	5,6x5,6 / bore 3,6 mm
ELECTRICAL INTERFACE	
Nominal Current	190 A
Nominal Voltage	81 V
Inductance	3 mH
Resistance	124 mΩ





*Courtesy of
A. Vannozzi*

Beam dynamics studies

- The beam dynamics in the C-band photoinjector has been studied by means of TStep simulations (ASTRA benchmark will come soon) nearly according to the *M. Ferrario's WP*

- The baseline relies on the on crest operation with the working point optimisation coming from the scaling with the RF frequency of the S-band injector WP as suggested in [1]

$$\sigma_x \propto \lambda_{RF},\ \sigma_z \propto \lambda_{RF},\ Q \propto \lambda_{RF}$$
$$(A = \sigma_x/\sigma_z \text{ constant})$$

- In the photoinjector the beam is generated at the cathode in the RF gun with its own intrinsic emittance, that represents the lowest possible emittance. For the working point we are going to it is of the order of 0.09 mm-mrad.

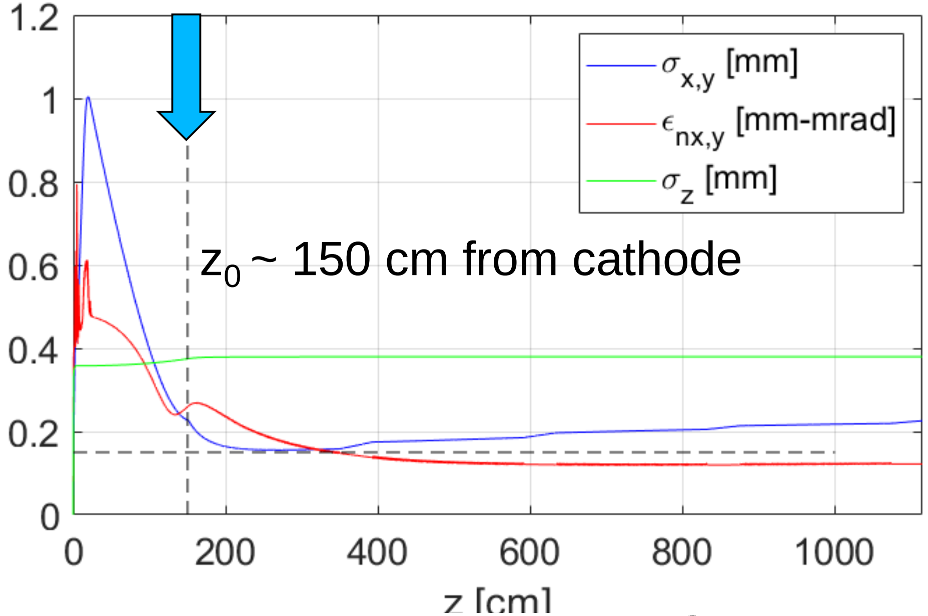
Cathode material	E_{RF}^{peak}[MV/m]		σ_{rms} [mm]	$\varepsilon_{n,int}$ [μm]	QE
Cu	160	0.73	0.23	0.16	~ 10^{-5} -10^{-4}
	240	0.82	0.17	0.12	

Courtesy of J. Scifo Athens XLS meeting

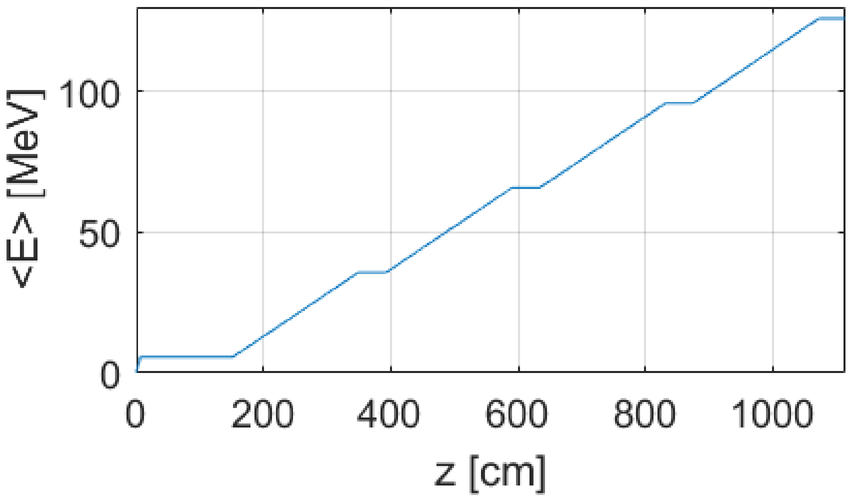
- ***In the following we report on the on crest - high repetition rate operation resulting in a 75 pC beam with 0.12 mm-mrad emittance and 0.380 mm length before entering the laser heater.***

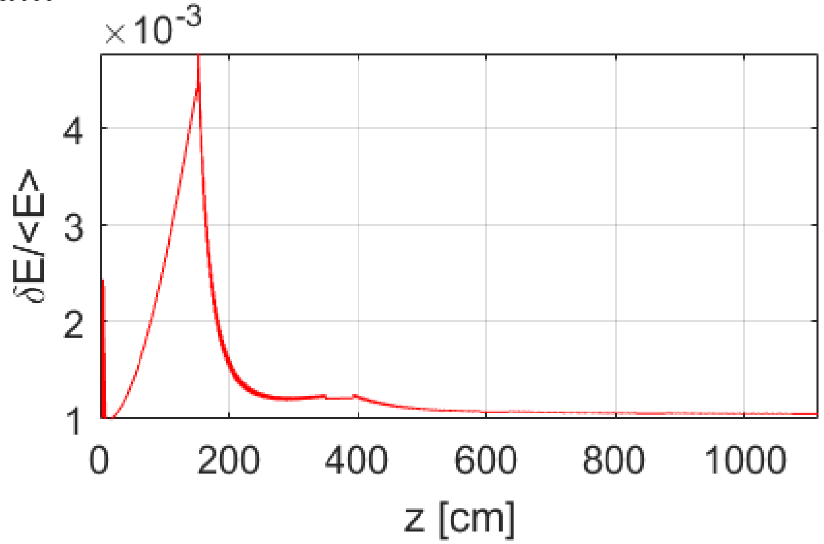
- [1] J. Rosenzweig, E. Colby - Charge and Wavelength Scaling of RF Photoinjector Designs (1994)

BD studies: high repetition rate case *(conservative)*



Parameters before BC1	Sim. results	Target	units
Q	75		pC
Rep. rate	1000		Hz
E	126	125	MeV
σ_E/E	0.11	0.5	%
$\epsilon_{n,rms}$	**0.12**	**0.15**	**µm**
σ_z	380	380	μm
I_{peak}	20	20	A





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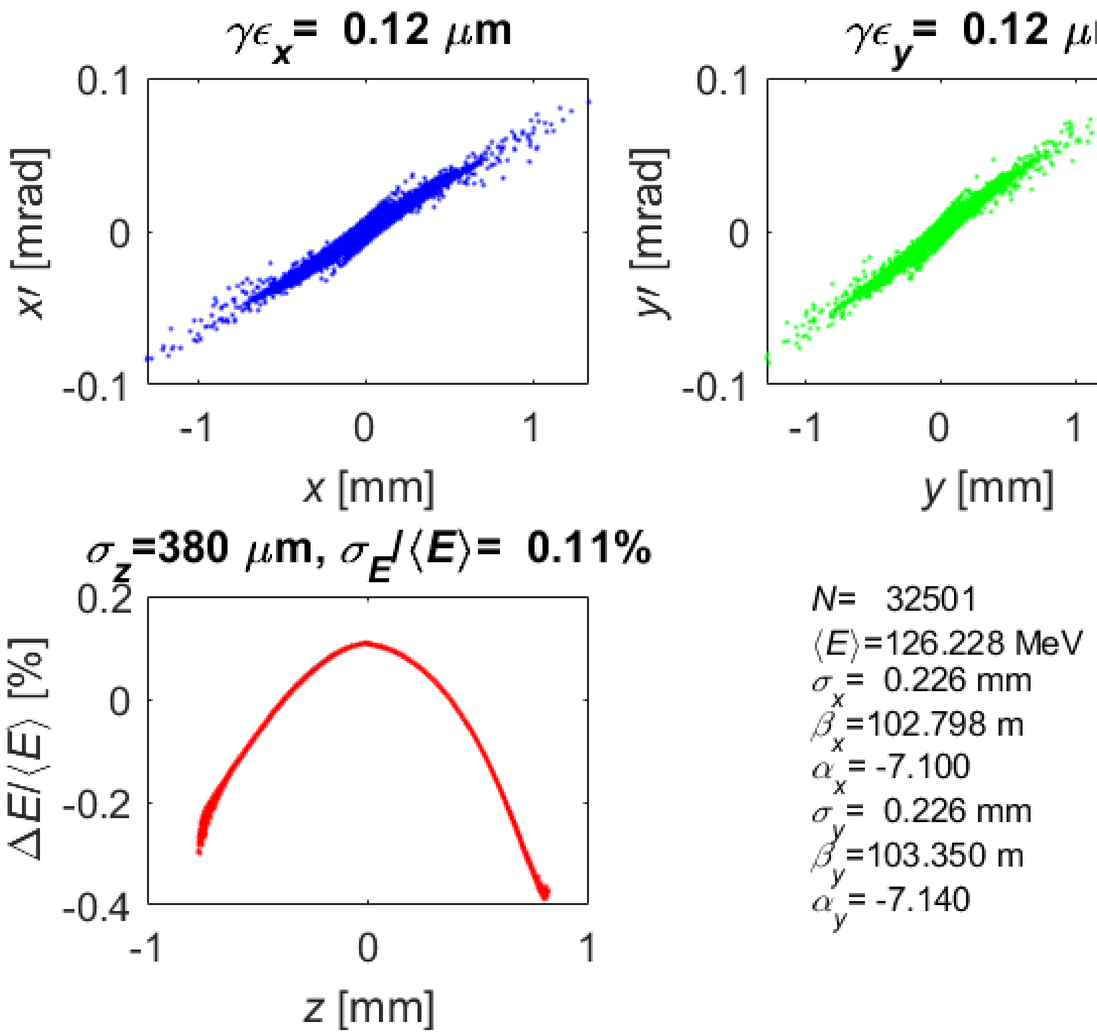
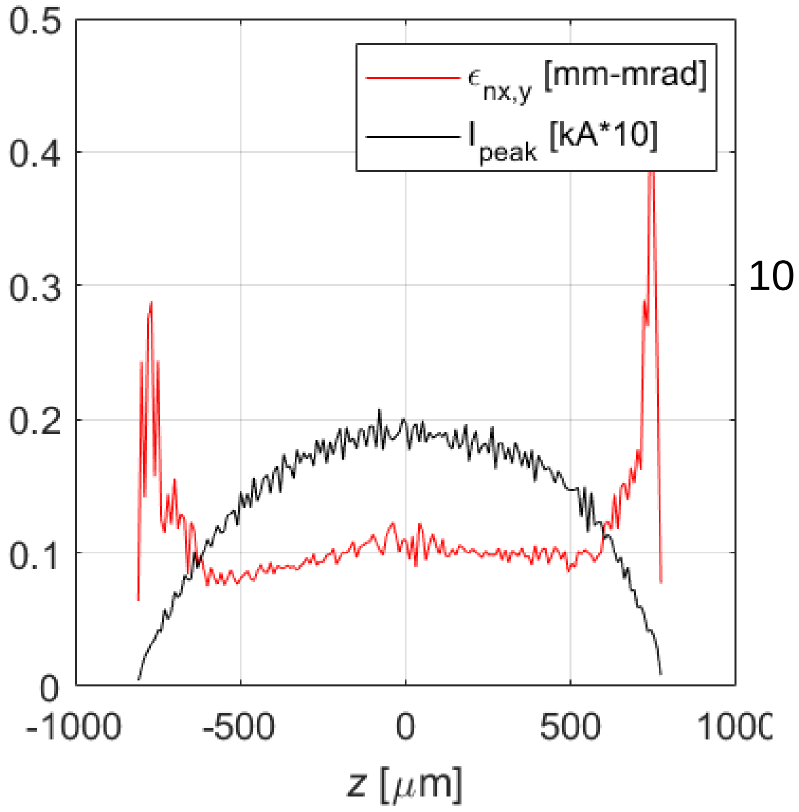
BD studies: high repetition rate case *(conservative)*





10 μm length slilce

Almost uniform longitudinal distribution → no need of K-band structures after the gun

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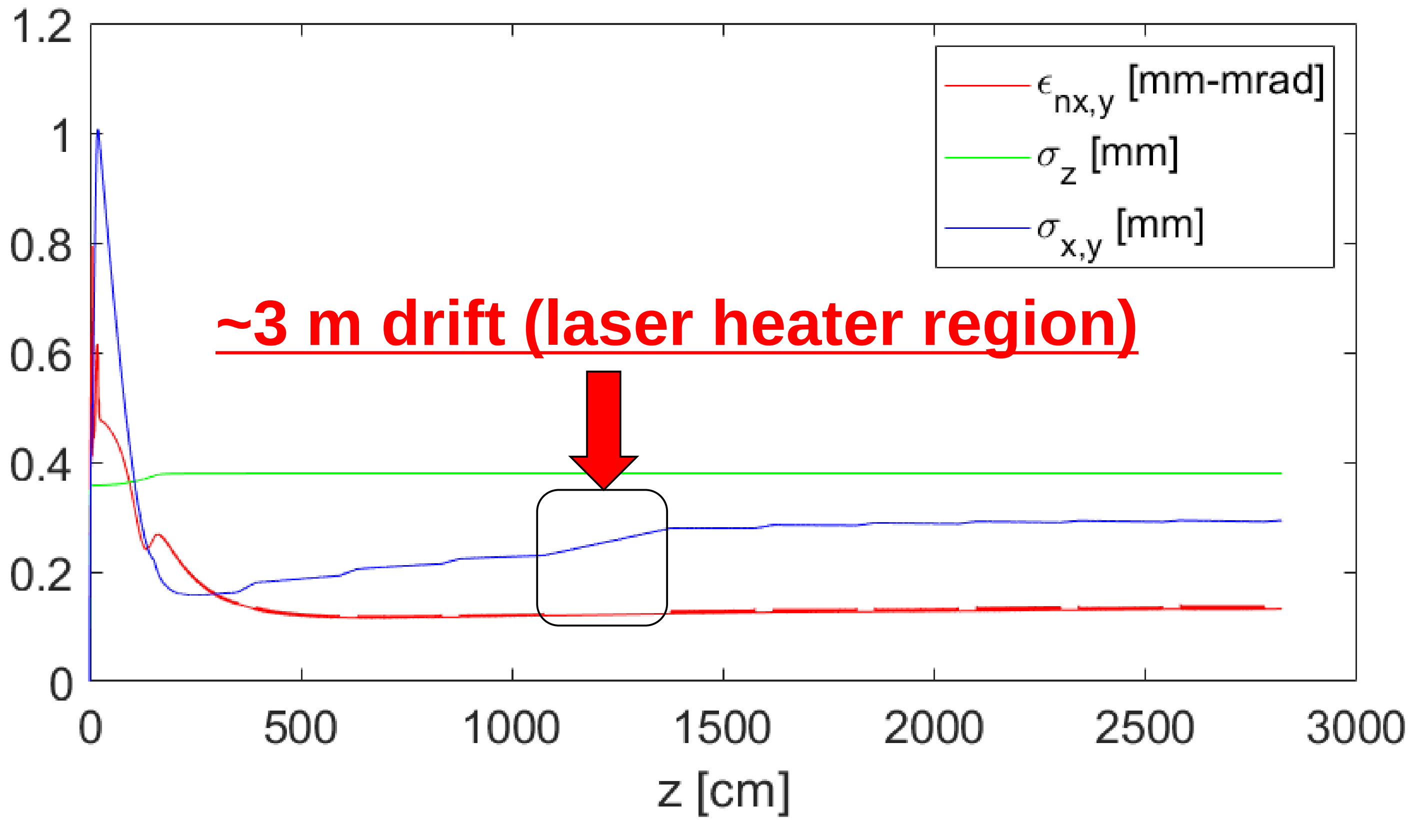
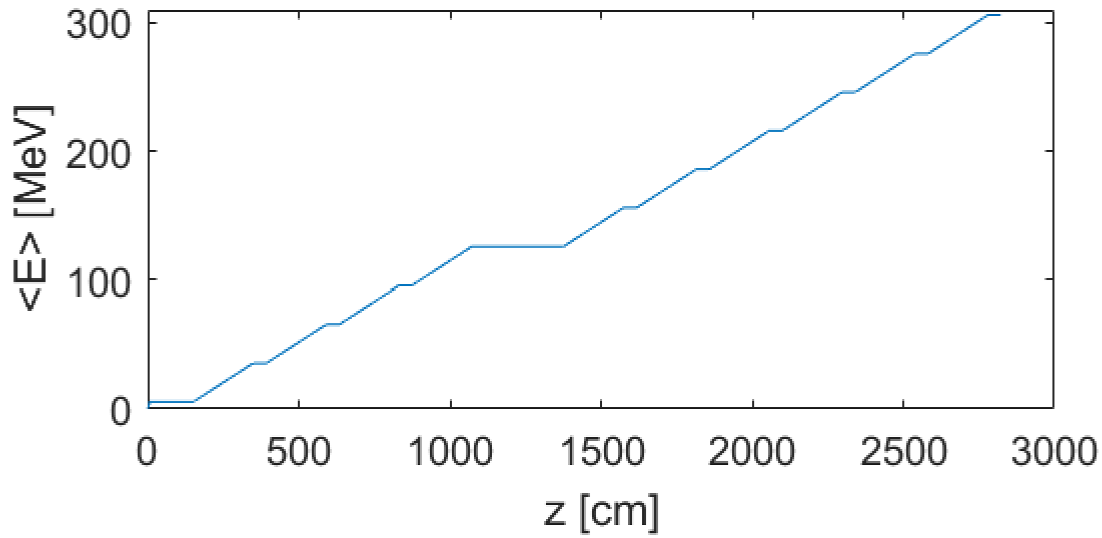
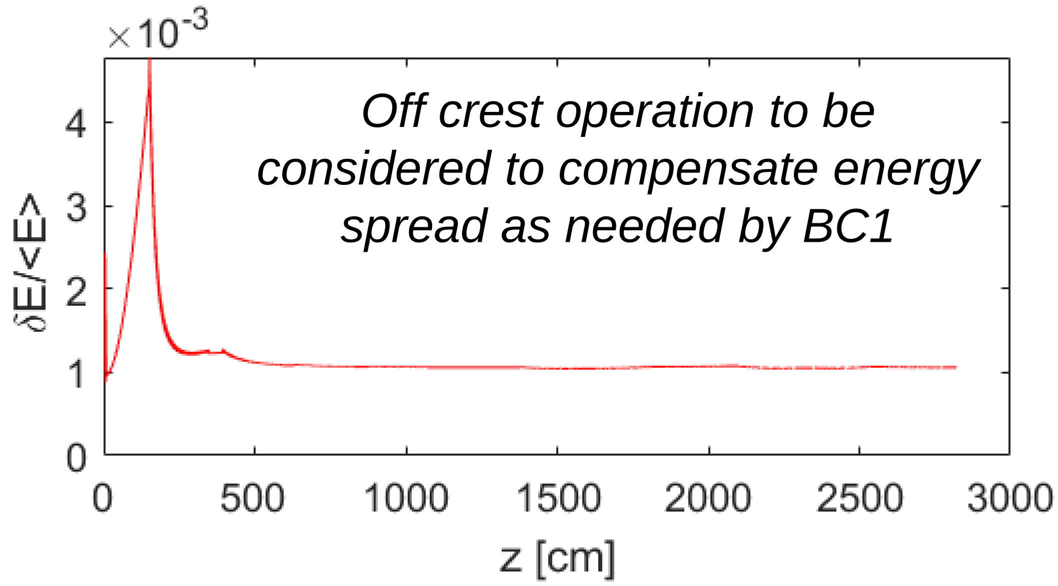
Space charge effects up to injector exit

- Space charge effects along the overall C-band linac have been investigated by means of beam dynamics simulations → matching to be addressed (see C. Vaccarezza's talk)







Conclusions and some hints for next future

- *Beam dynamics have been investigated in the on crest– high repetition rate operation*

- *It has been shown that it is possible to generate an high brightness beam with 75 pC charge, 0.12 mm-mrad emittance, 0.390 mm length - turning in a 20 A peak current and almost uniform longitudinal distribution at laser heater entrance → no need of the k-band structure after the gun*

- *The new gun region configuration allows for 150 cm drift for allocating beam characterization as required by WP8 → longer drift will be investigated*

- Space charge effects along the overall C-band linac have been investigated by means of beam dynamics simulations with promising results

- *The mode launcher for the C-band gun presents "field tails" whose effect on the beam dynamics is ongoing*

- *In the next future the study will be enlarged to the low repetition rate operation*