Comb-like configuration studies

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On behalf of SPARC_LAB collaboration

OUTLINE

- Introduction
- Witness working point optimisation
- Comb beam transport and optimisation

Introduction

- A "comb-like" configuration for the electron beam, consisting of a 200 pC driver followed by a 30 pC witness bunch, has been explored.

- Computational studies have been devoted to provide
  - 0.55 ps beam spaced, corresponding to $\lambda_p/2$ (for $n_p = 10^{16}$ cm^{-3}), i.e. the accelerating and focusing region in the plasma bubble.
  - 3 μm (fwhm) witness length, and so 3 kA-fwhm peak current, minimising as much as possible the degradation of the transverse normalised emittance, that occurs because of the witness-driver crossing.
  - driver and witness transversally matched to the plasma (2 and 4 μm)

- First results have been obtained by
  - using the laser-comb technique, experimentally demonstrated at SPARC_LAB
  - appropriate shaping and relative spacing of the laser-comb pulses at the cathode surface
  - a fine tuning of phases of accelerating cavities and of magnetic fields of solenoids *starting from an optimised witness working point*

Witness working point optimisation

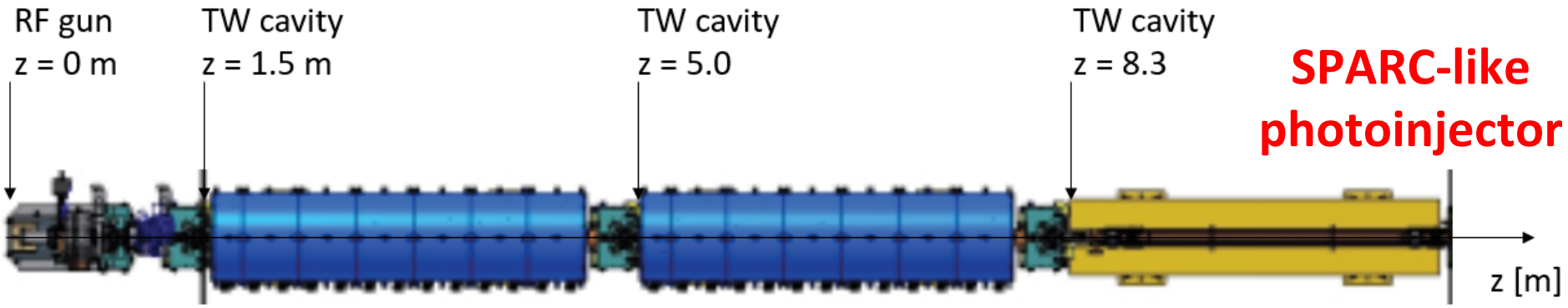
An injector scheme able to satisfy the high-quality, 3 kA witness request has been studied

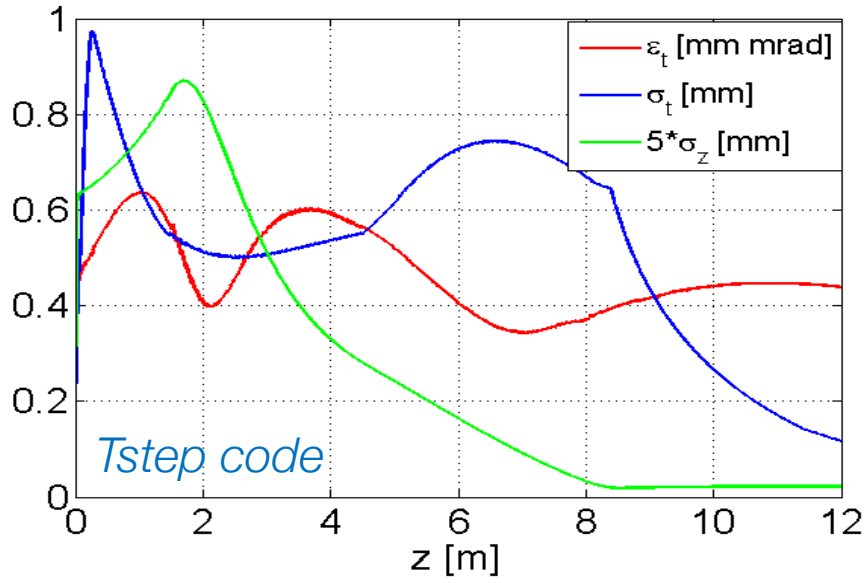
- The successful operation of a plasma-based user facility should not introduce any degradation of the beam quality but only boost of the energy.
- The beam parameters, except for the energy, requested at the undulator are those at the plasma entrance, independently by the driving mechanism.
- The study is focused on a witness beam at plasma entrance suitable for LWFA and PWFA: 30 pC, 3 kA, 500 MeV, 1 - 3 μm transverse spot size
- The Injector is composed of *
  - S-band photoinjector to generate 3 kA beam current (*TSTEP*)
  - X-band linac to boost the beam up to 500 MeV (*Elegant*)
  - Focusing region to match the beam transversally at the plasma entrance (*Elegant,TSTEP)*

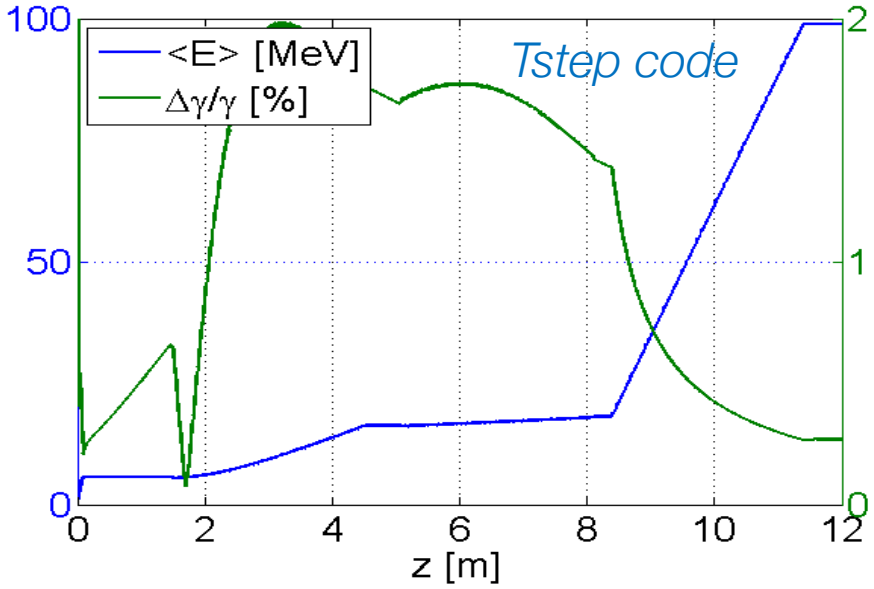
* *Used codes: Tstep, Elegant,Trace 3D*

Resume: BD in photoinjector

- BD and photoinjector layout optimised for the 30 pC witness beam in order to reach a peak current of ~3kA



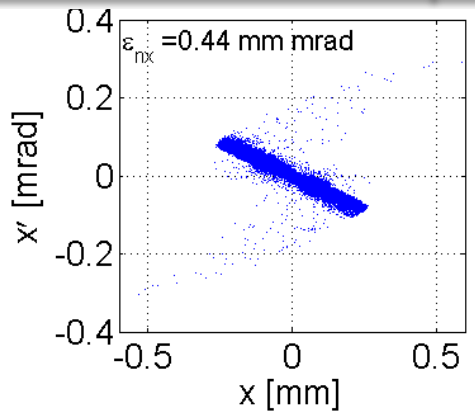


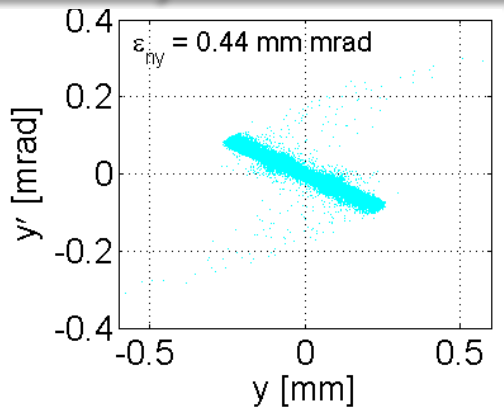


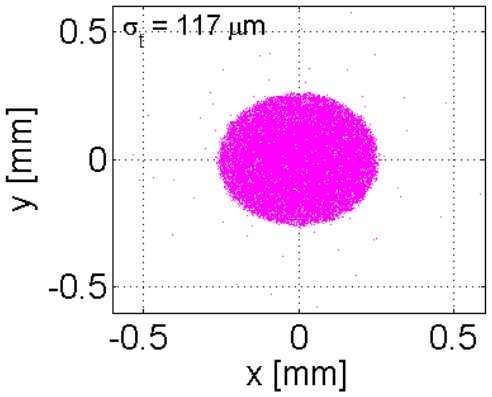
➢ WP optimisation for the photoinjector

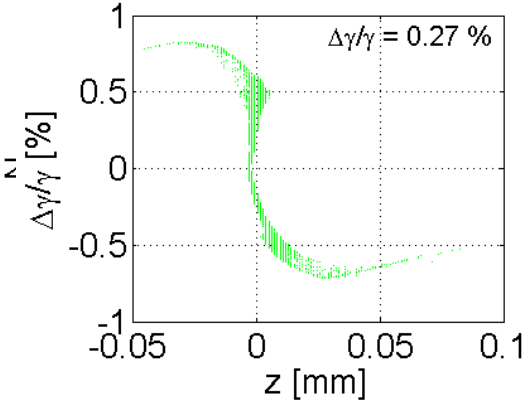
The beam dynamics in the photoinjector has been optimised for the witness beam with particular regard to the transverse normalised emittance

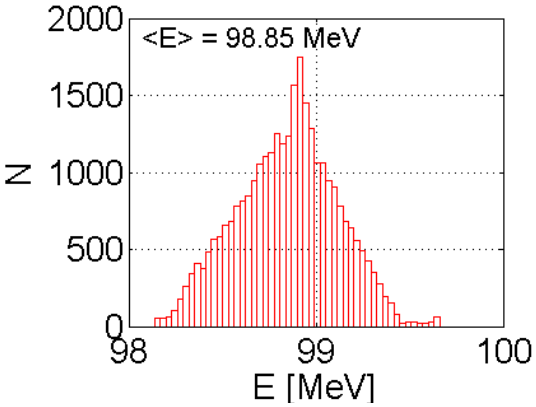
Beam parameters @Photoinj.Exit	
	Optimised
E [MeV]	**98.85**
$\varepsilon_{x,y}$ [mm mrad]	**0.44**
$\sigma_{z\text{-FWHM}}$ [μm]	**~ 3.0**
$\sigma_{z\text{-rms}}$ [μm]	**5.6**
ΔE/E [%]	**0.27**
$\sigma_{x\text{-rms}}$ [μm]	**117**
$\beta_{x,y}$ [m]	**6.1**
$\alpha_{x,y}$	**2.1**
$I_{peak\ [FWHM]}$ [kA]	**3**

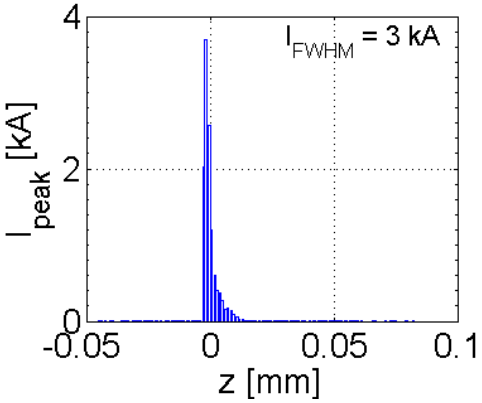






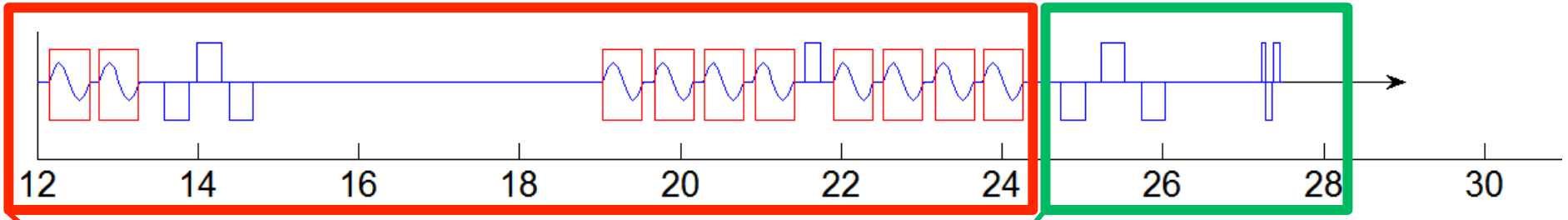


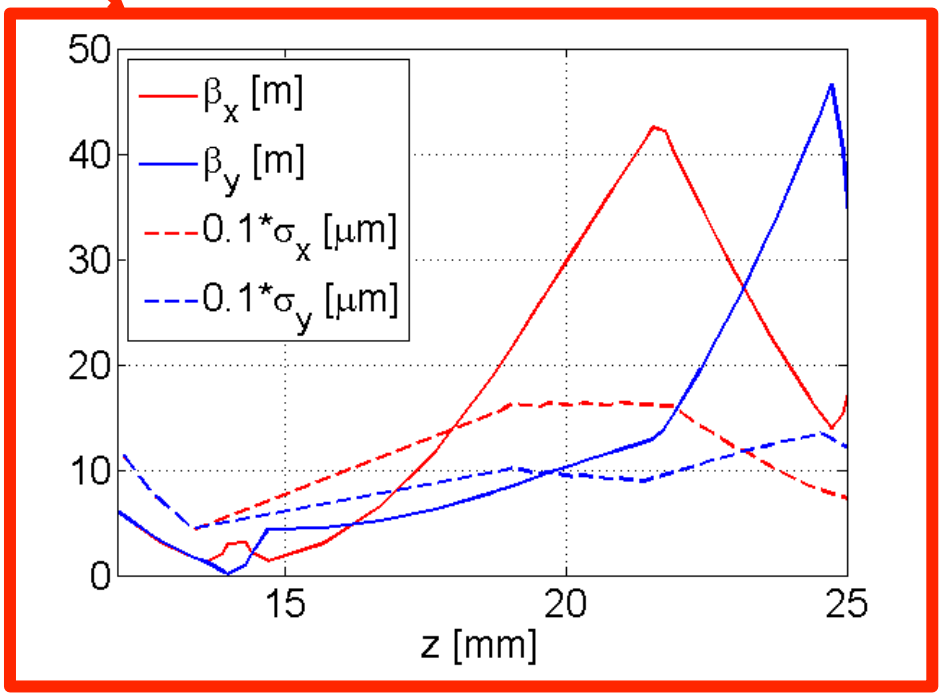


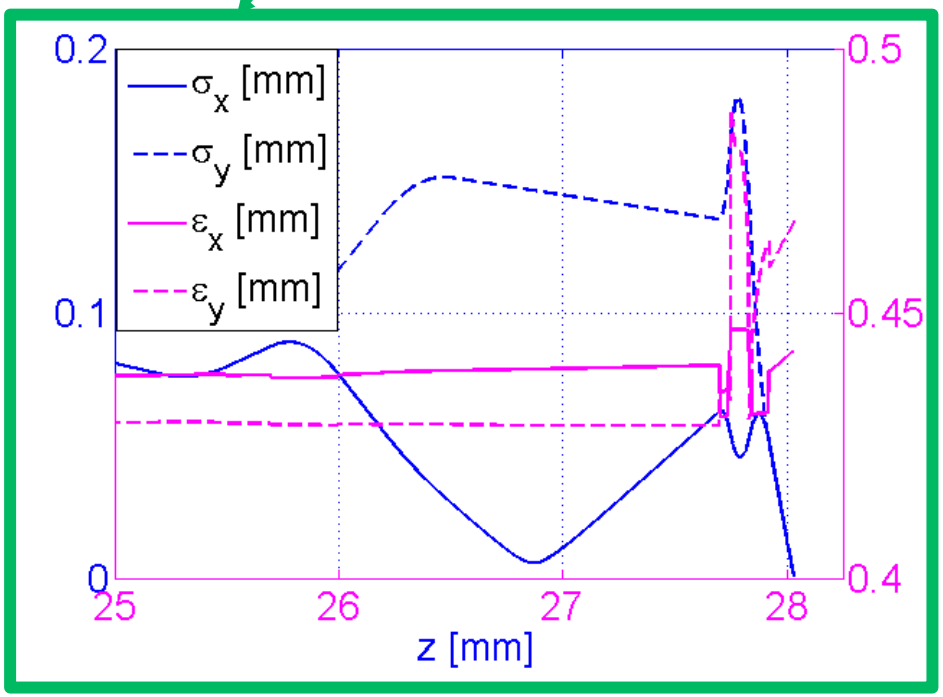


X-band linac optimisation studies

- BD and X-band linac layout optimised for the 30 pC witness beam in order to boost the energy and preserve the beam quality.



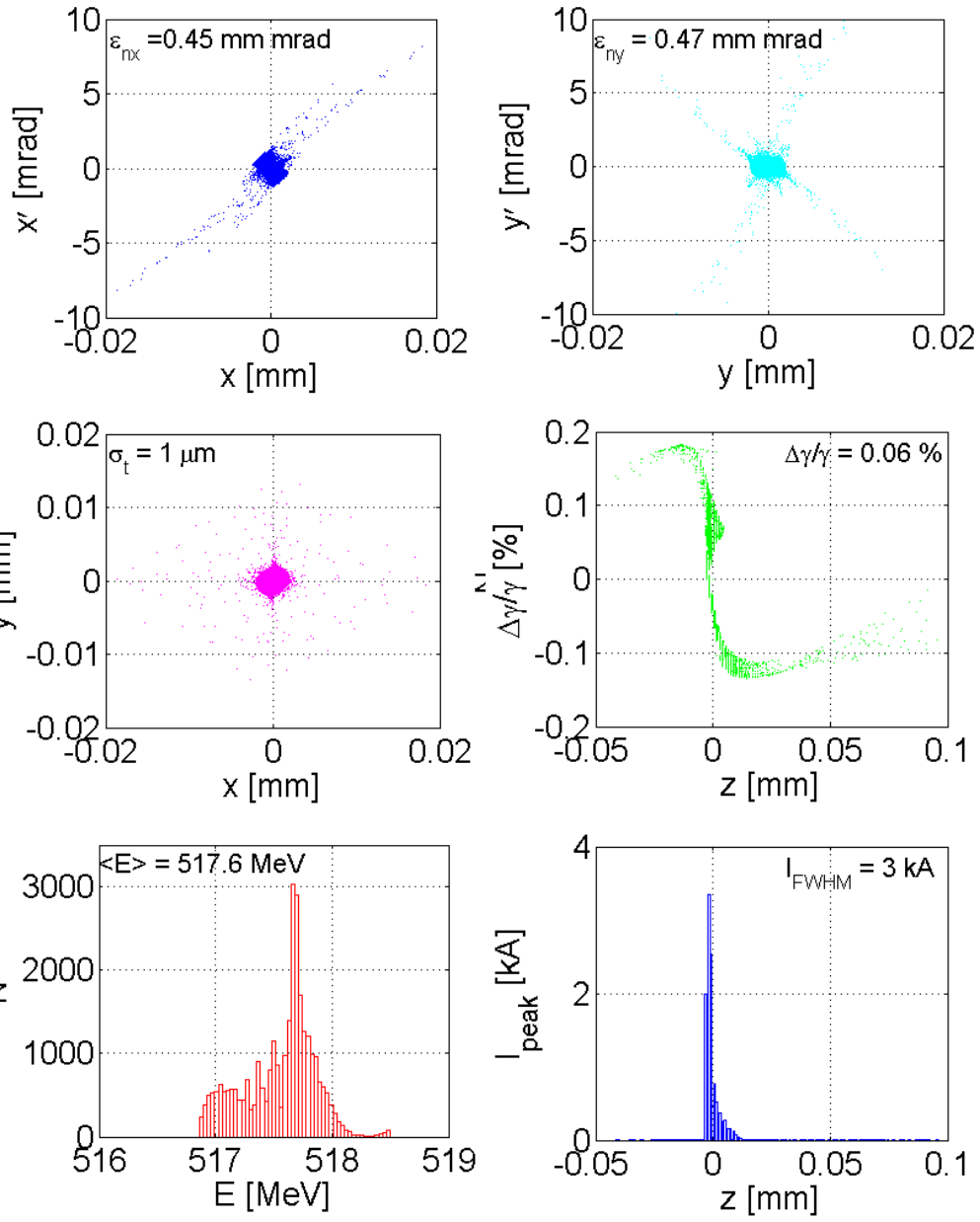




X-band linac optimisation studies

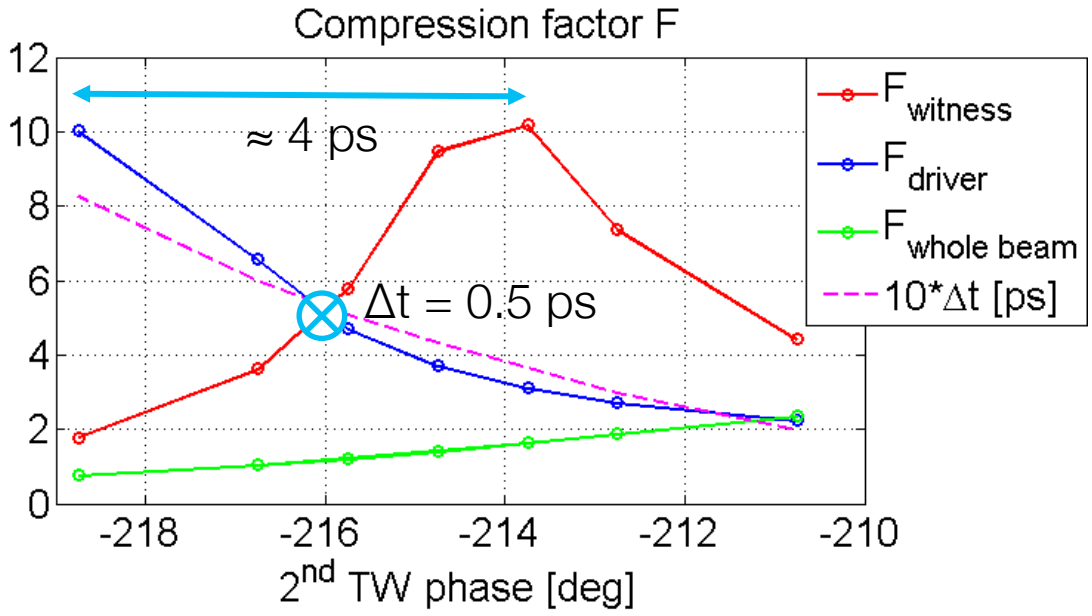
Phase space at plasma entrance

Beam parameters @Plasma Entrance	
	Optimised
E [MeV]	**517.6**
$\varepsilon_{x,y}$ [mm mrad]	**0.45 – 0.47**
$\sigma_{z\text{-FWHM}}$ [μm]	**~ 3.0**
$\sigma_{z\text{-rms}}$ [μm]	**6.0**
ΔE/E [%]	**0.06**
$\sigma_{x\text{-rms}}$ [μm]	**1.0**
$\beta_{x,y}$ [mm]	**2.0**
$\alpha_{x,y}$	**~ 0.0**
$I_{peak\ [FWHM]}$ [kA]	**3**



Comb-like operation

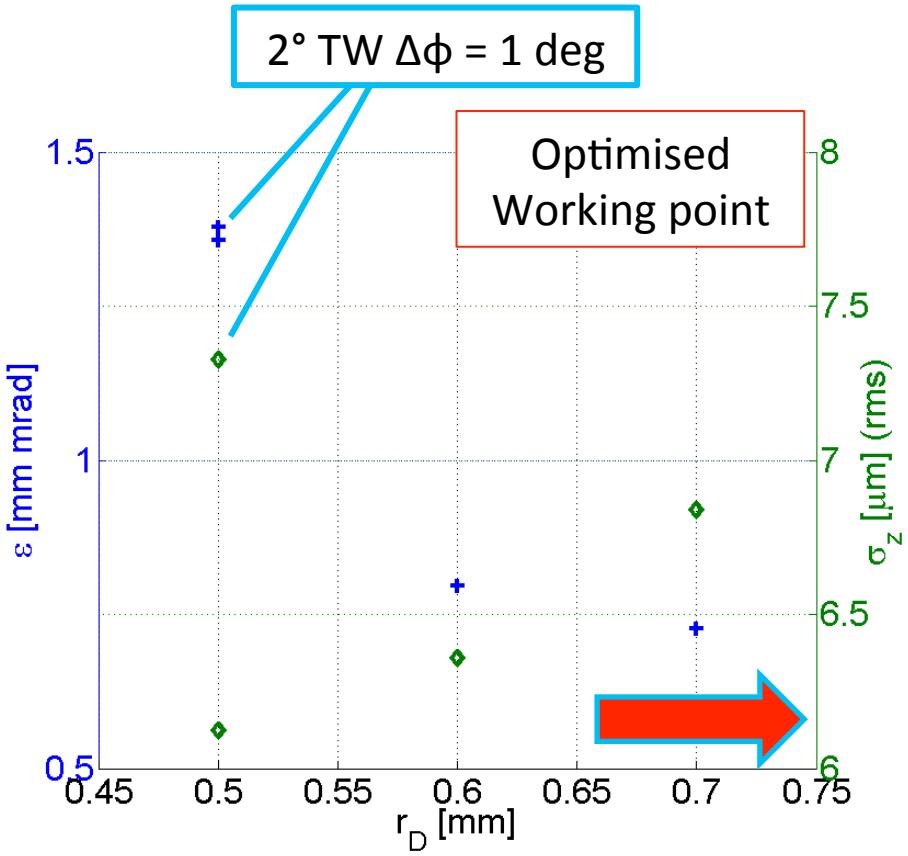
- Laser comb configuration with two laser pulses spaced of 4 ps
- The studies started from the witness point optimisation …

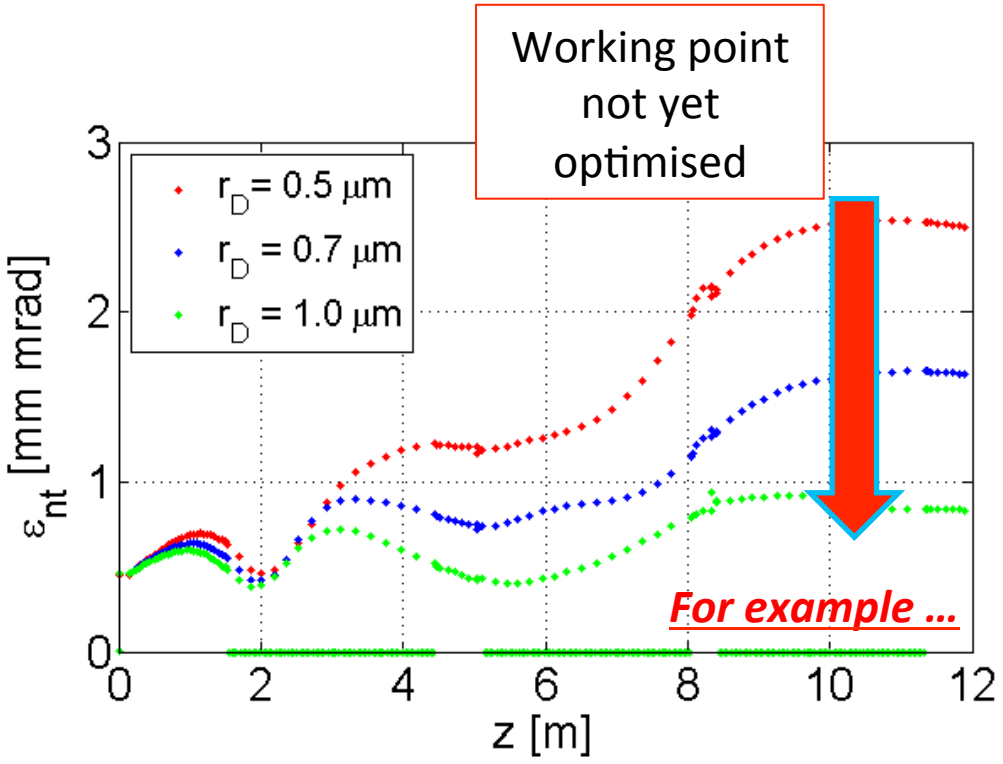


Beam parameters on the cathode		
	Driver	Witness
Charge [pC]	200	30
# of macroparticles	200k	30k
Transverse profile	Uniform	Uniform
Radius [μm]	500 -700	350
Longitudinal profile	Gaussian	Gaussian
σ_z [μm]	120	120

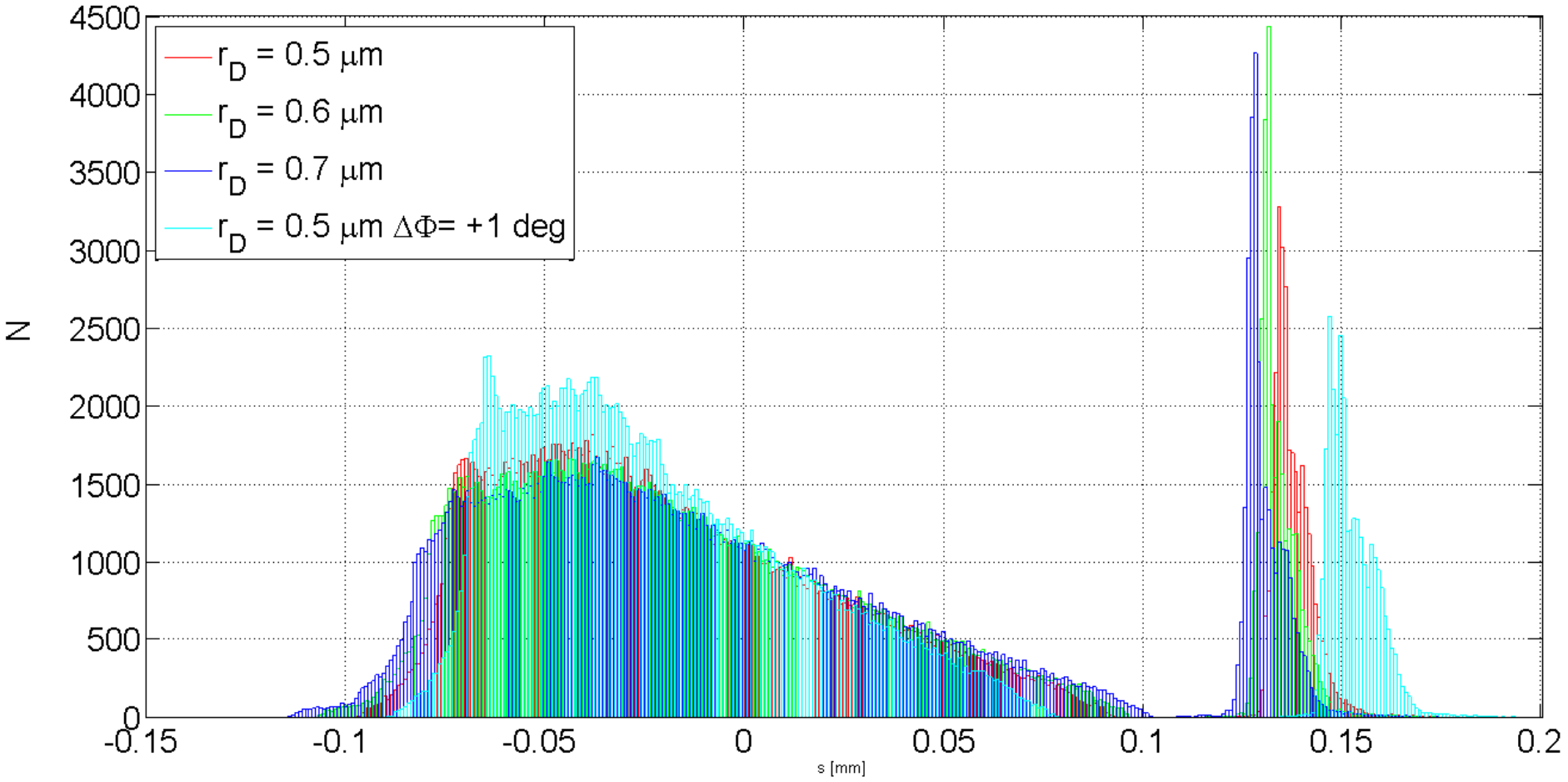
Transverse emittance optimisation

- The driver spot size on the cathode is crucial for the control of
  - the witness emittance growth
  - the longitudinal distribution
  - the behavior of the transverse normalised emittance and bunch length as function of the driver spot radius indicates σ_t = 350 μm as the optimal value for the driver spot size at the cathode surface

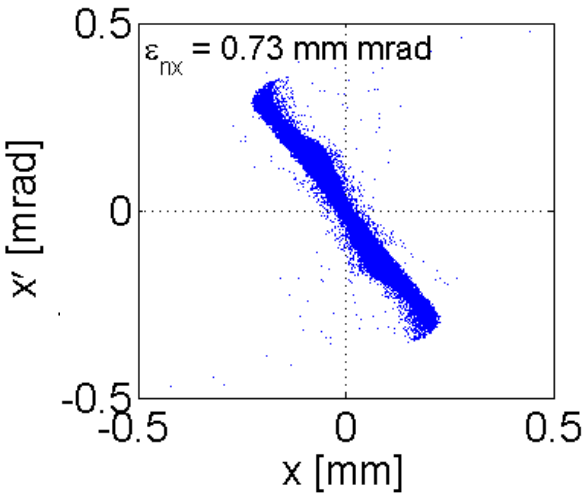


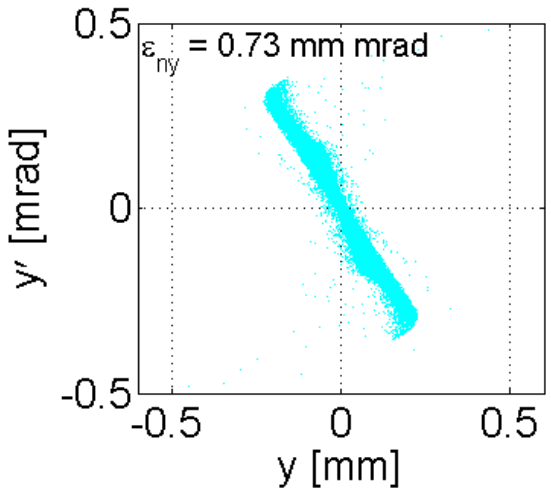


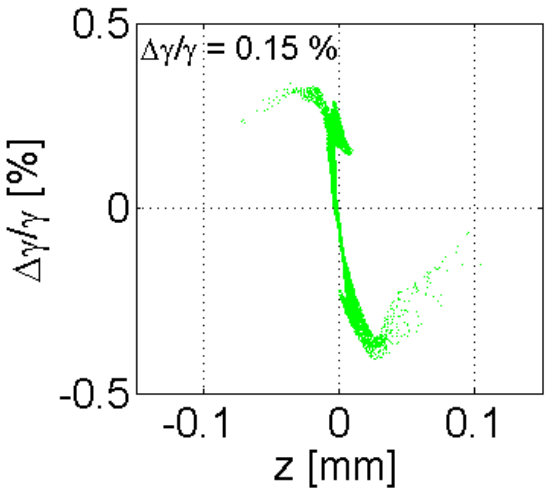
Comb-like operation

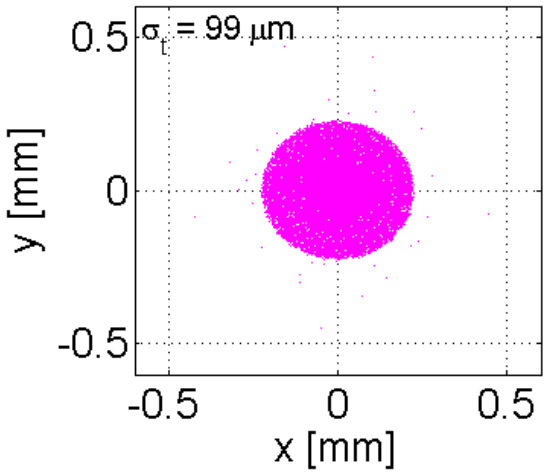


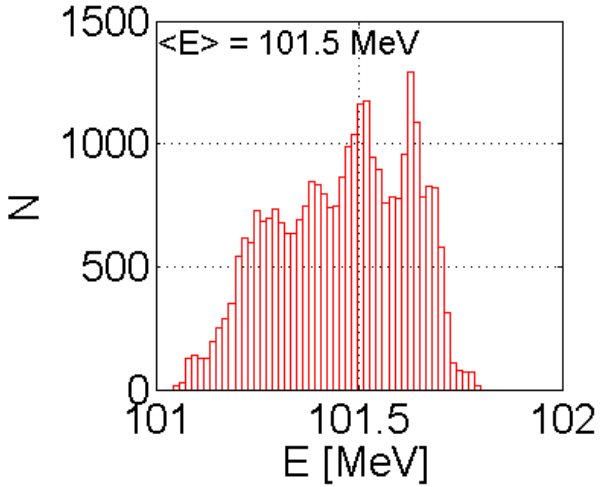
Phase space at photoinjector exit: *the witness*

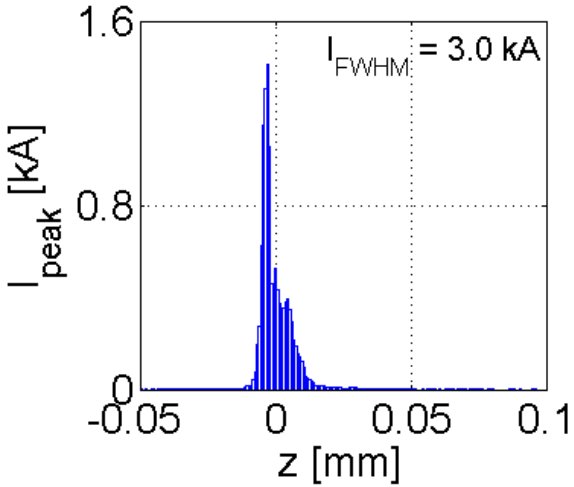




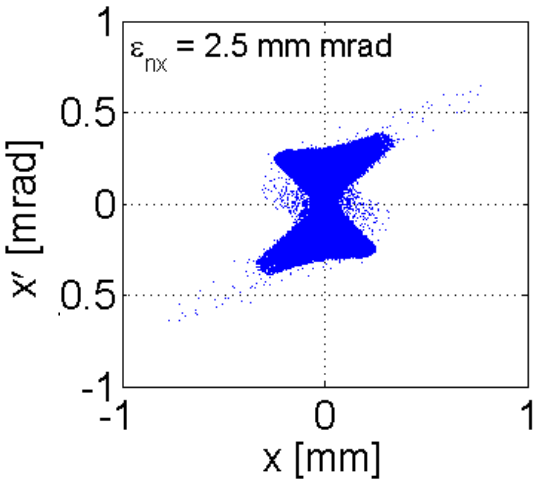


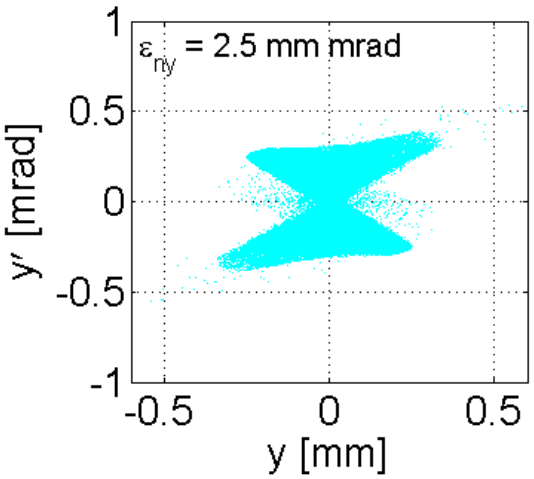


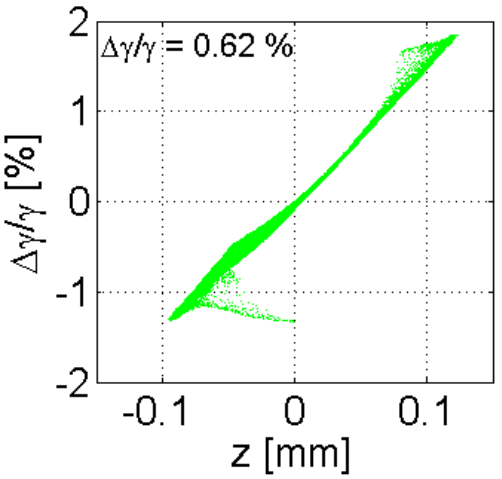


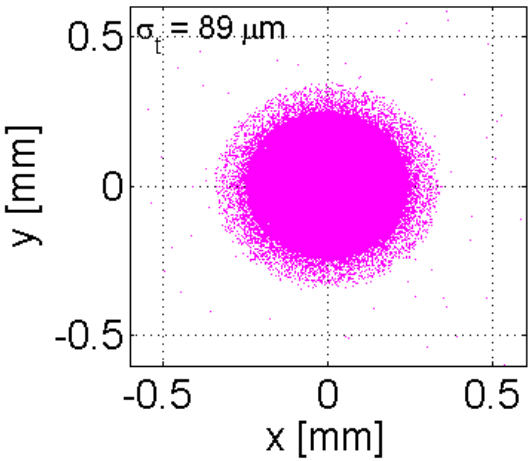


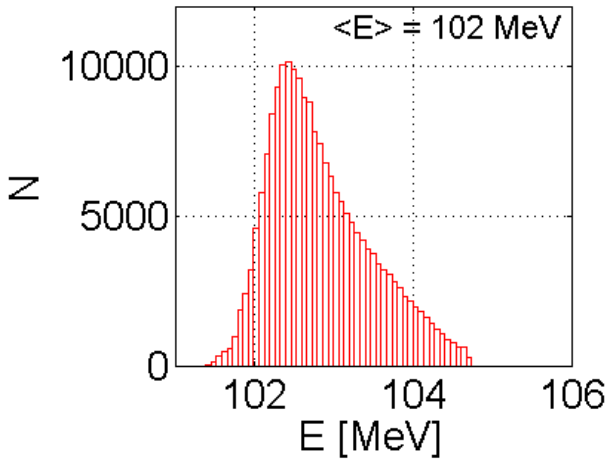
Phase space at photoinjector exit: *the driver*

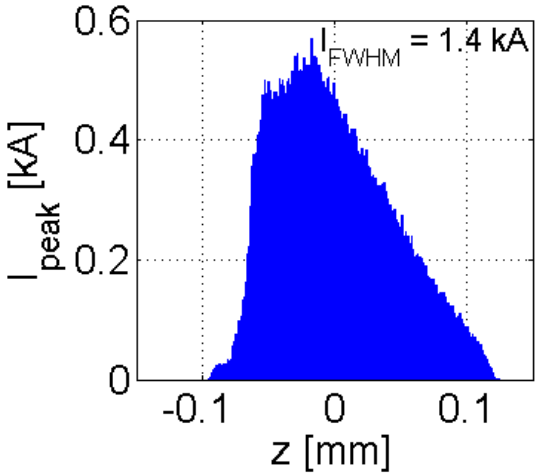




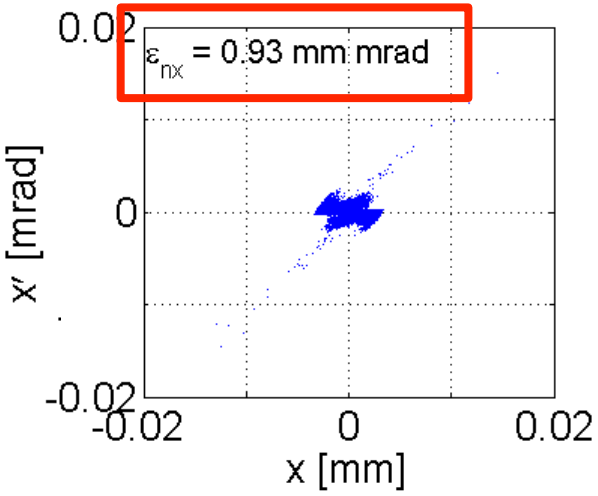


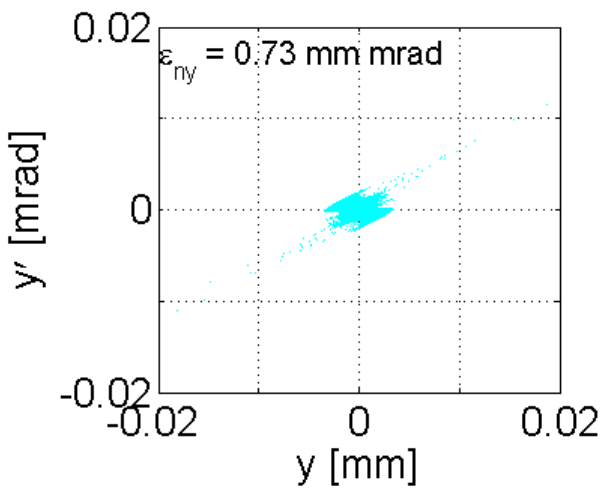


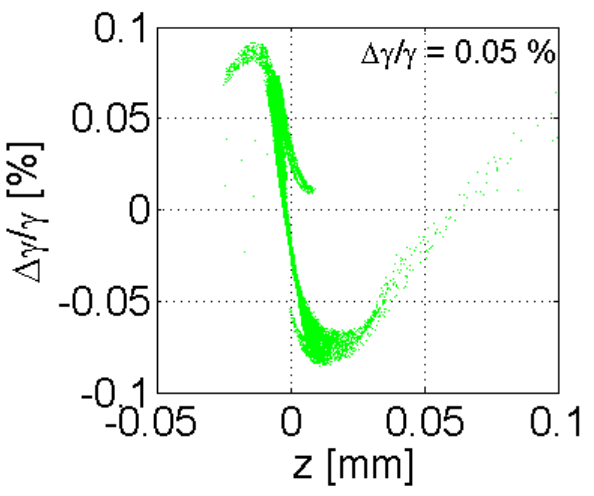


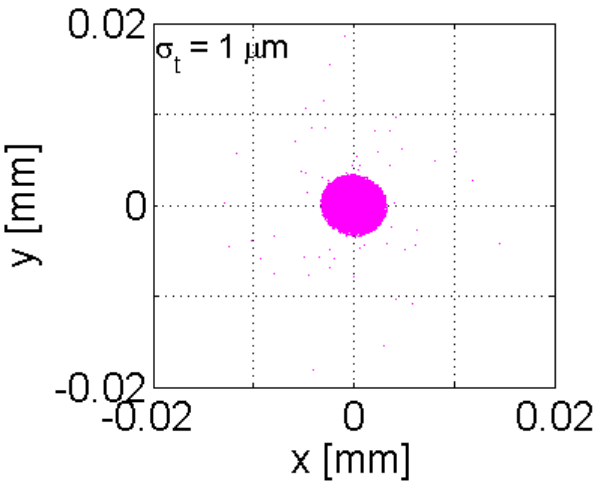


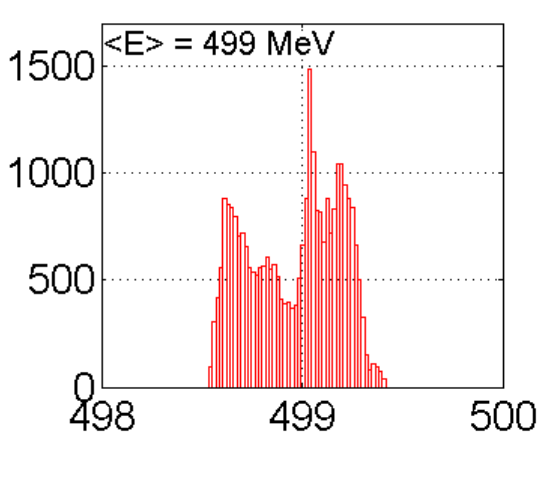
Phase space at plasma entrance: *the witness*

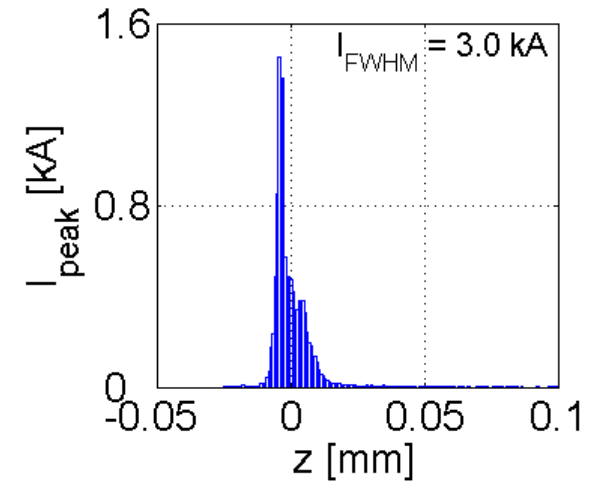






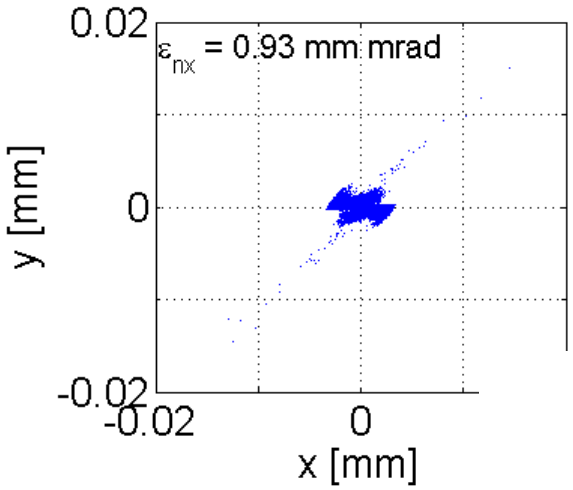


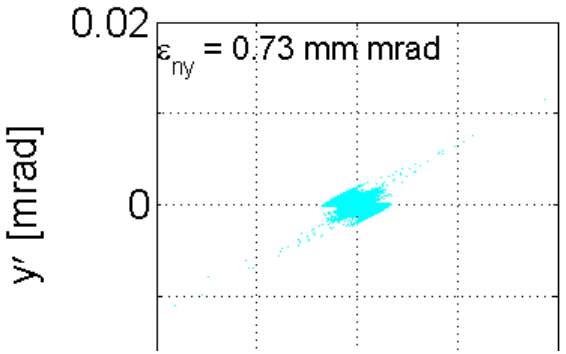


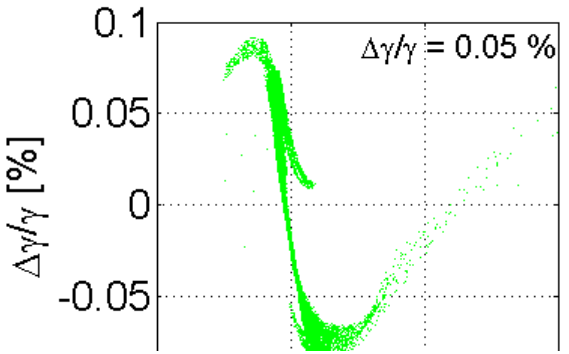


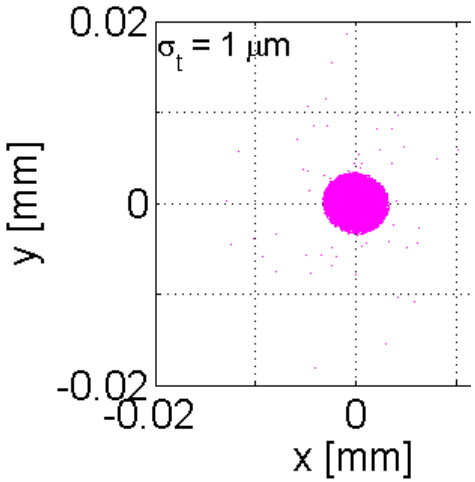
Phase space at plasma entrance: *the witness*

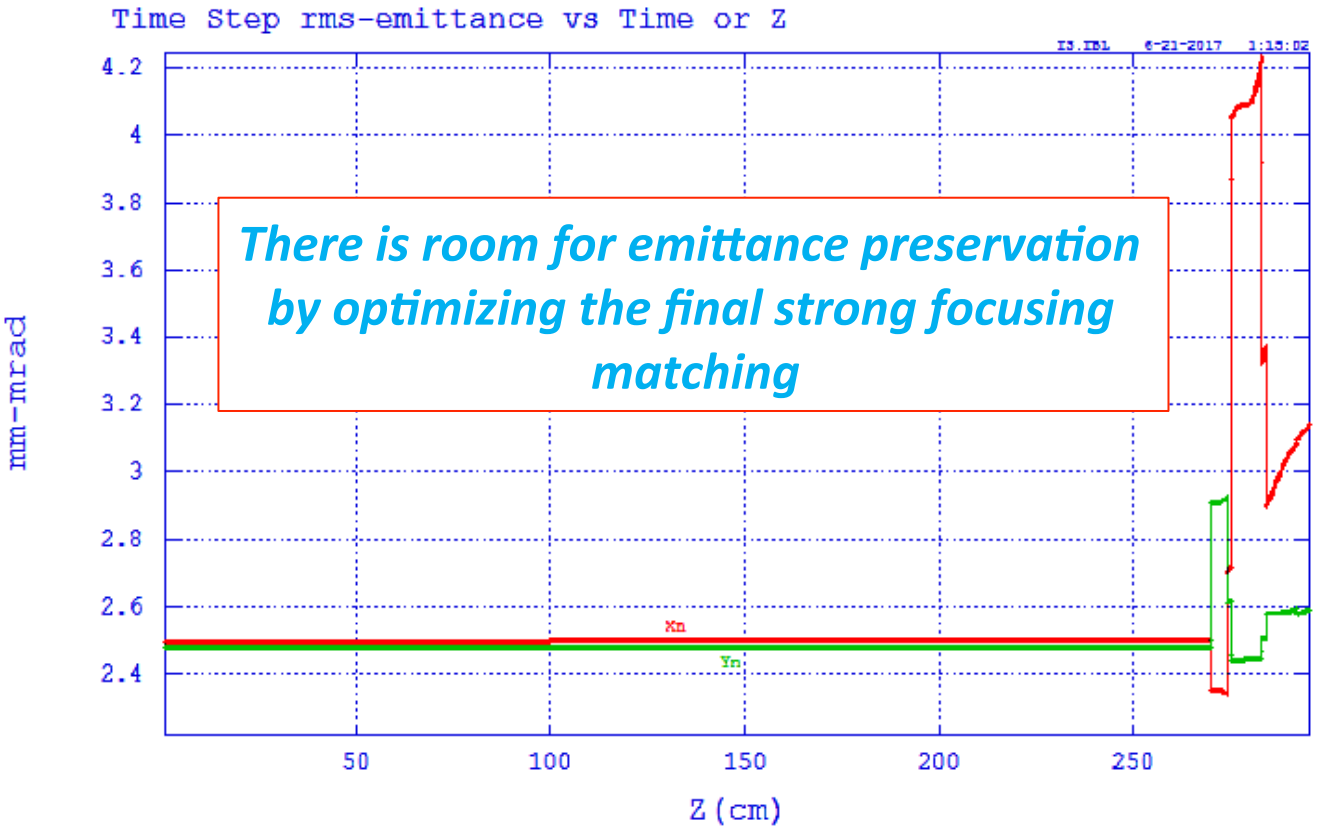
Very first results





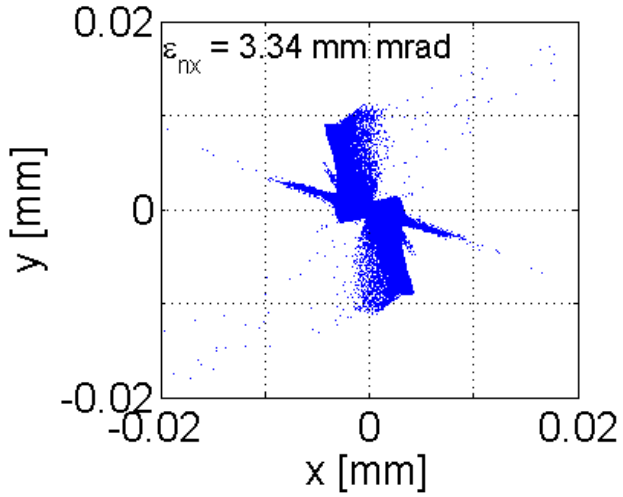


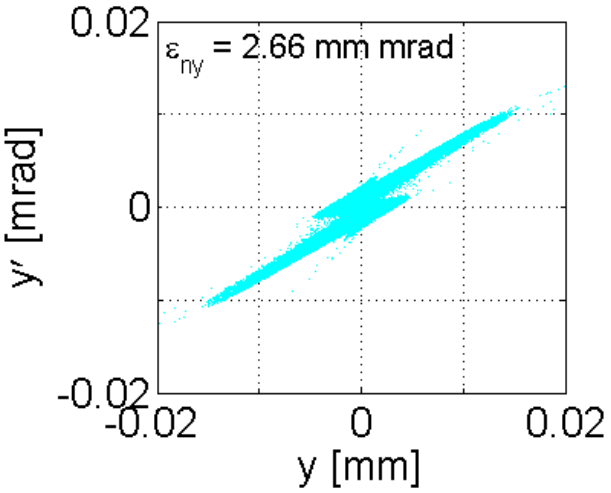


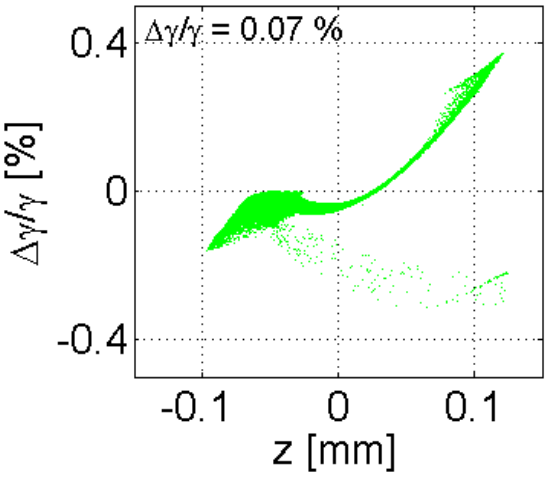


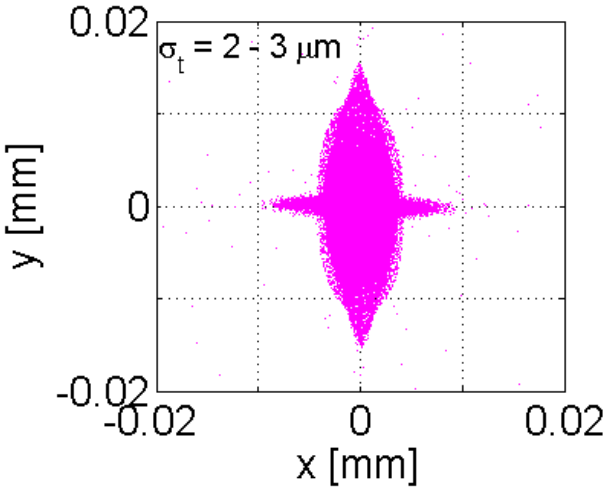
There is room for emittance preservation by optimizing the final strong focusing matching

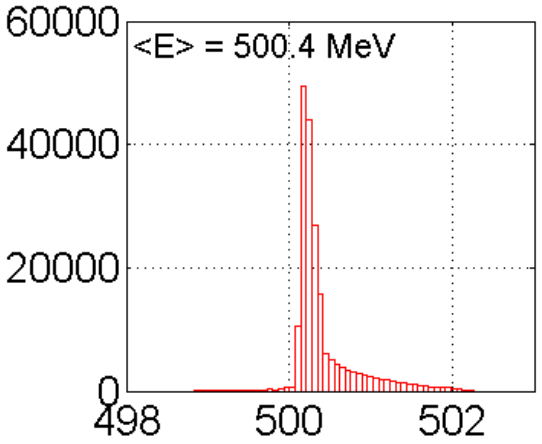
Phase space at plasma entrance: *the driver*

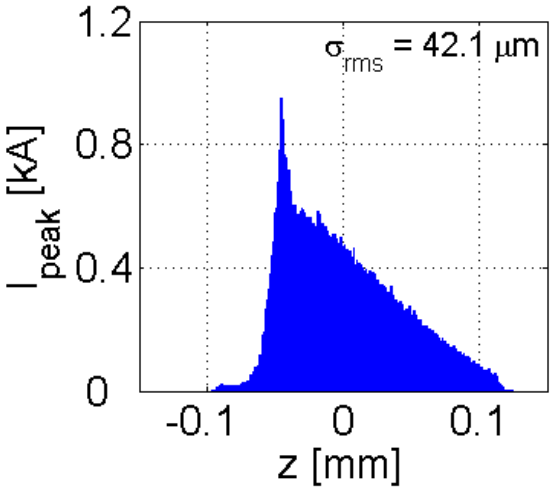












Beam parameters at plasma entrance

Beam parameters @Plasma Entrance			
	Witness (Single bunch)	**Witness (Comb beam)**	**Driver (Comb beam)**
E [MeV]	517.6	**499**	**500.4**
$\varepsilon_{x,y}$ [mm mrad]	0.45 – 0.47	**0.73 – 0.93**	**2.6 - 3.3**
$\sigma_{z\text{-FWHM}}$ [μm]	~ 3.0	**~ 3.0**	**-**
$\sigma_{z\text{-rms}}$ [μm]	6.0	**6.0**	**42.1**
ΔE/E [%]	0.06	**0.05**	**0.07**
$\sigma_{x\text{-rms}}$ [μm]	1.0	**1.1**	**2 - 3**
$\beta_{x,y}$ [mm]	2.0	**2.0**	**-**
$\alpha_{x,y}$	~ 0.0	**~ 0.0**	**-**
$I_{peak\ [FWHM]}$ [kA]	3	**3**	**-**

CONCLUSIONS

- Injector scheme to provide a 3 kA witness beam at plasma injection has been optimised for a 30 pC electron beam.
- BD in the injector has been described with particular attention to the longitudinal beam quality at the plasma injection.
- The phase space quality has been optimised preserving the high beam current at the plasma entrance.

THANK YOU!!!

X-band linac optimisation studies

- X-band cavity radius, r , ranges between 2.4 – 3.5 mm

- A check on the beam envelope along the X-band linac is mandatory due to the X-band cell iris radius