Simulation results of the beam emittance using a flat-top and 3D ellipsoidal laser pulse shape for gun 4.2 at PITZ

- Introduction
- ASTRA Simulation setup
- Results
- Conclusions

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Simulation results
PITZ, 28.05.2015

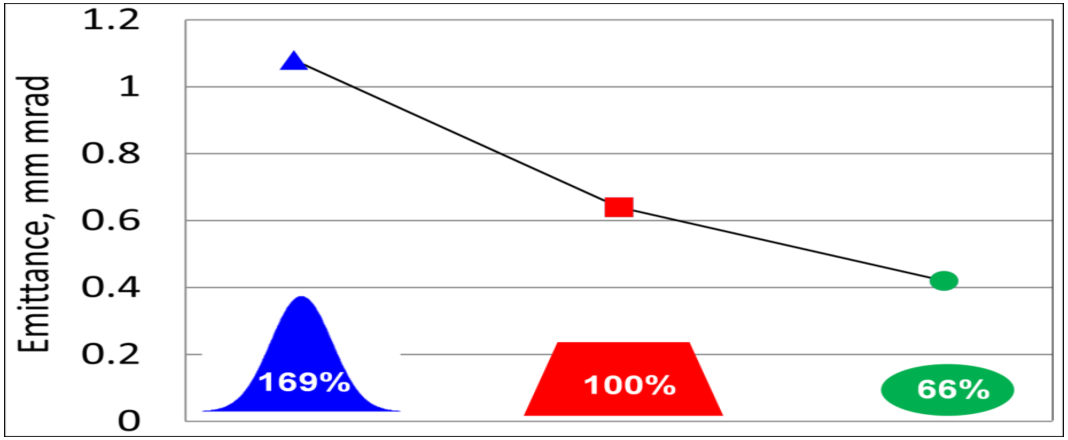
HELMHOLTZ | ASSOCIATION

DESY

Introduction

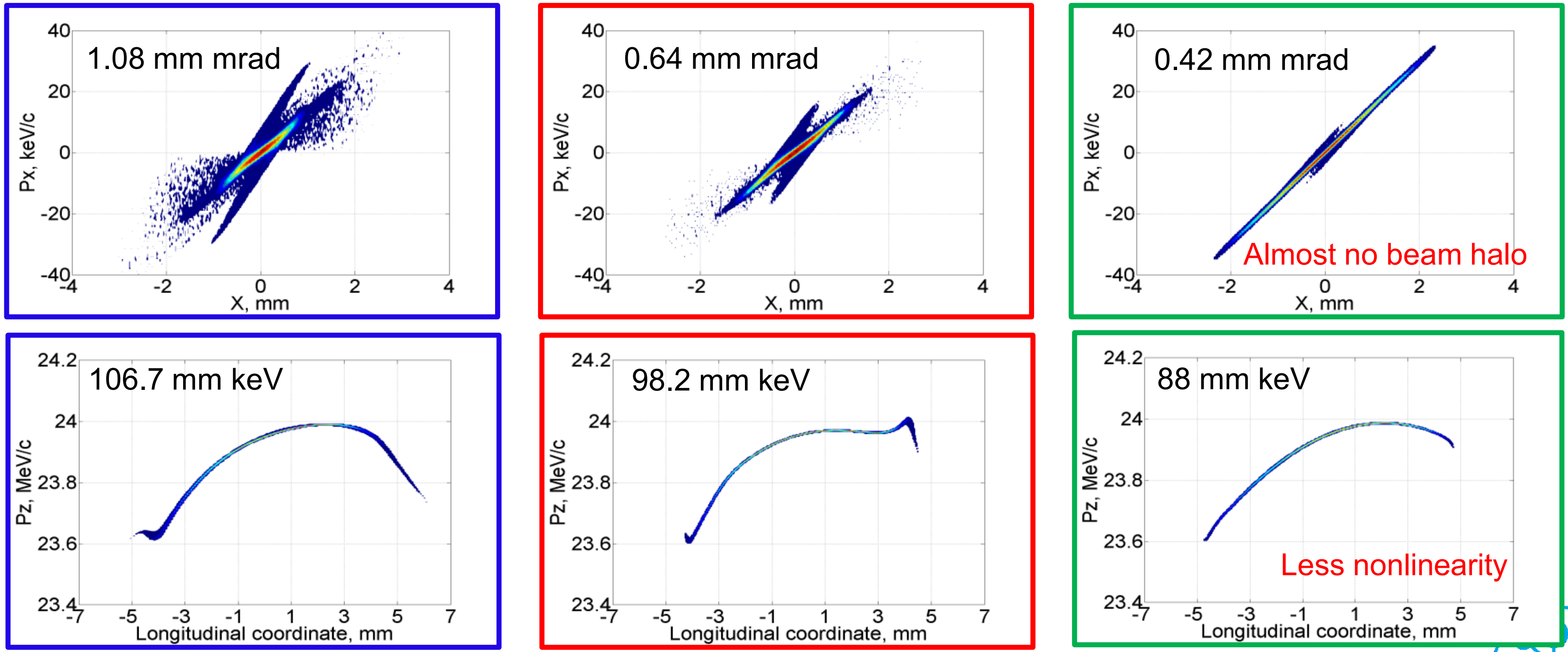
Transverse emittance for 3 different laser shapes (Zboo=2.7m)

For 1 nC at 6.7 MeV/c after the gun and 24 MeV/c after the booster. (Martin Khojoyan)



Using 3D ellipsoidal laser profile leads to:

a. More than **30% reduction** in slice emittance compared to the flat-top case
b. ~ **80%** contribution from the cathode emittance



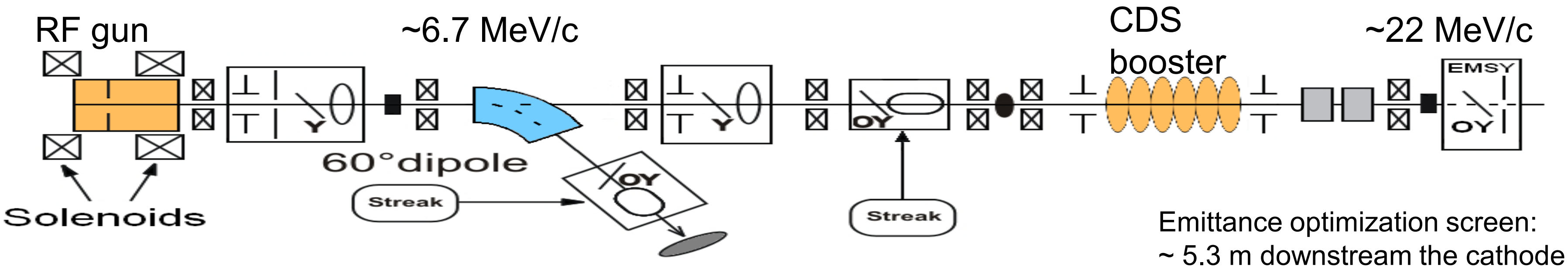
Introduction

- **Motivation:** Answer the next question

  → Does the other charges (20 pC ~2 nC) behave the same tendency like 1 nC?

- **Main idea:** The reduction of the emittance using 3D ellipsoidal laser compared to Flat top laser is not constant but depends on the charge?

PITZ setup used in the simulations



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ASTRA Simulation setup

Two different photo cathode laser shapes have been considered in beam simulations:

- Longitudinal distribution: Flat-top. Transverse distribution: radial homogeneous
- Uniformly filled 3D ellipsoidal distribution

Fixed parameters during emittance optimization

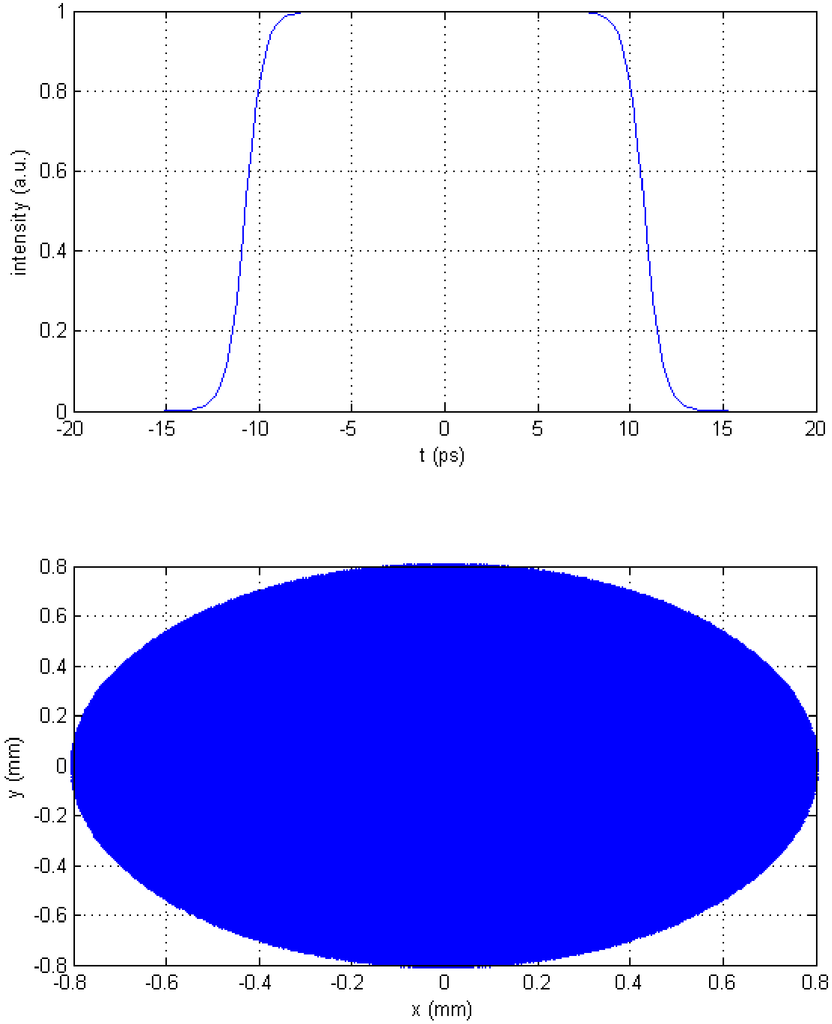
- Bunch charges: 20 pC ~ 2 nC,
- Electrons thermal kinetic energy at the cathode (0.55 eV),
- Gun gradient: 59.8 MV/m corresponding to Pz~6.7 MeV/c beam momentum after the gun
- CDS booster starting position: 2.73 m
- CDS booster gradient: 17.6 MV/m corresponding to Pz~22 MeV/c final beam momentum
- Reference point: EMSY1 (Z=5.125 m) → best emittance for 2 profiles with the same bunch length

The following parameters were optimized in the simulations:

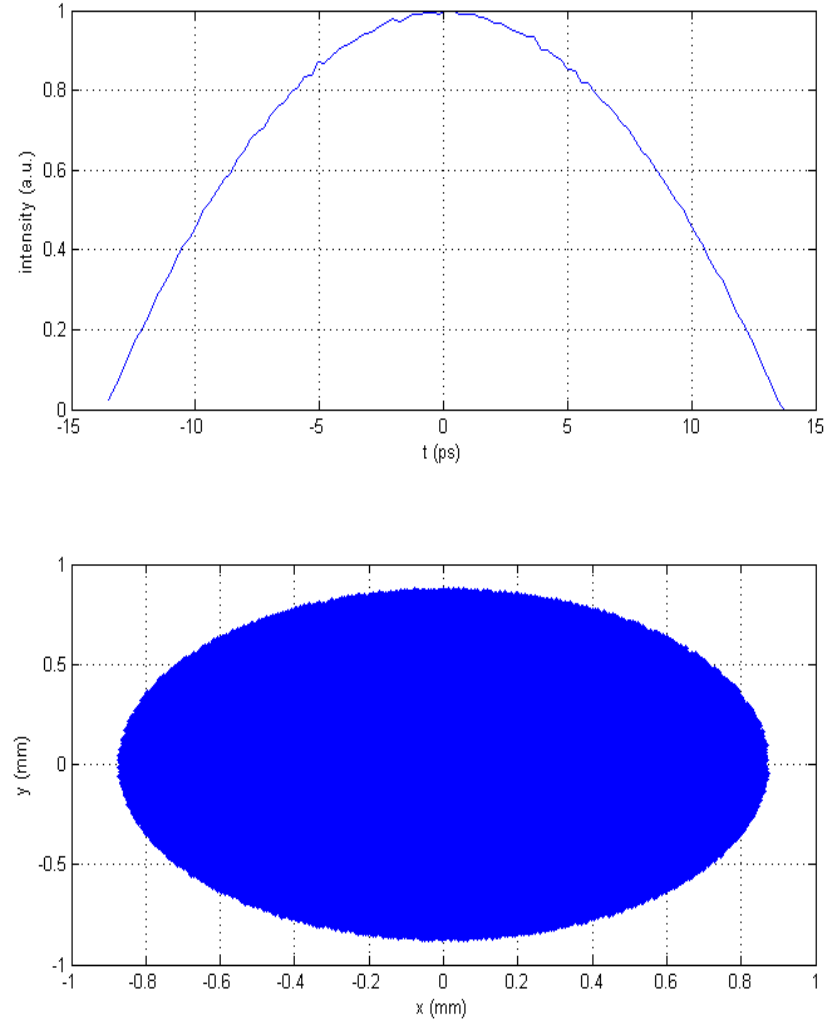
- Rms laser beam size,
- Gun Lunching phase,
- Solenoid current

Results:
Laser Longitudinal and transverse distribution:

Flat-top 2/21.5/2



3D Ellipsoidal



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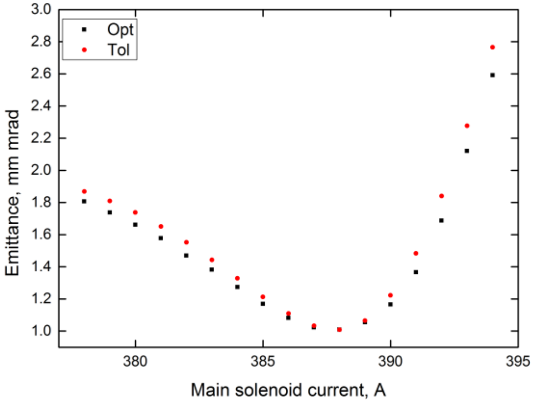
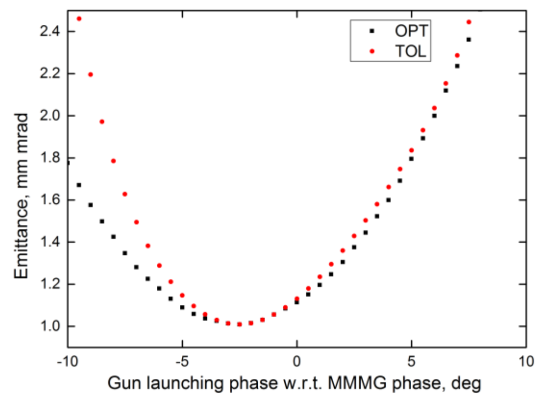
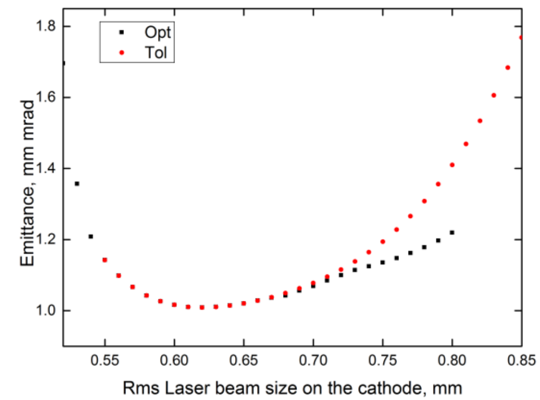
Results for 2 nC

flat-top laser

Opt. emittance 1.0089

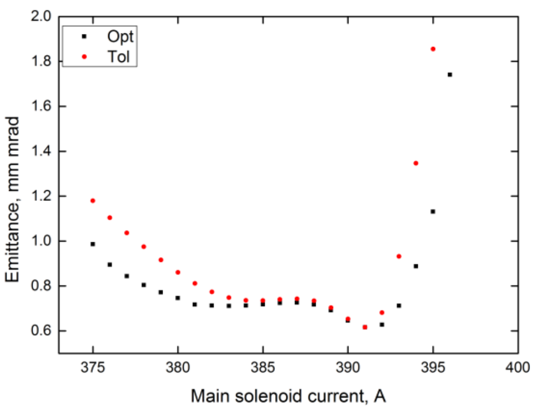


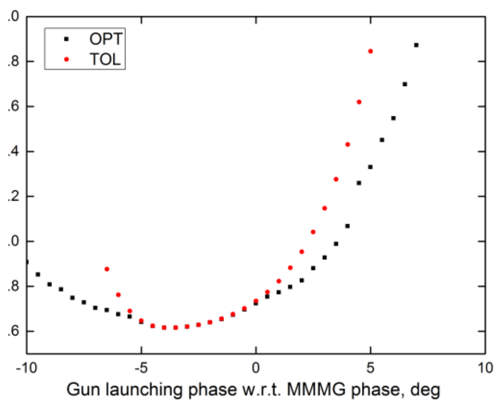


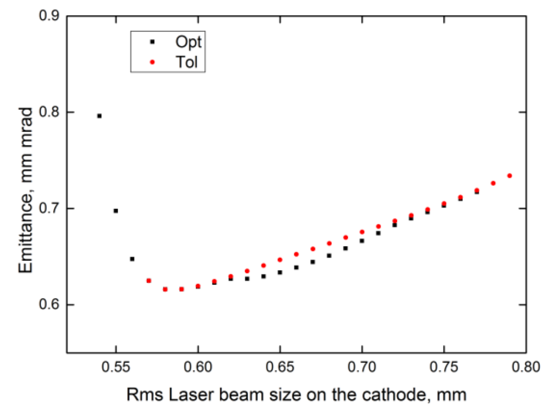


3D Ellipsoidal laser

Opt. emittance 0.6159





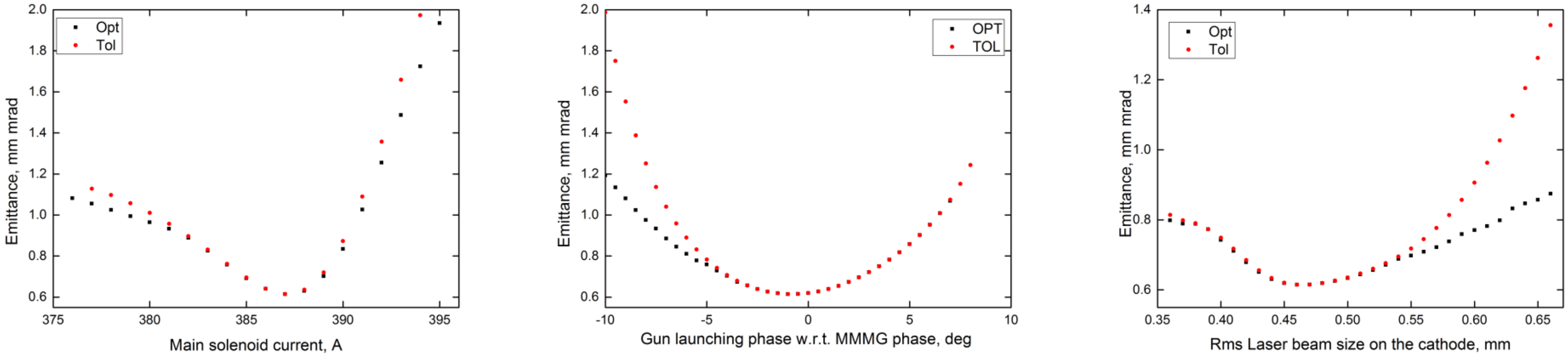


Opt → 3 parameters are changing simultaneously
Tol → 2 parameters fixed and only one changing

Results for 1 nC

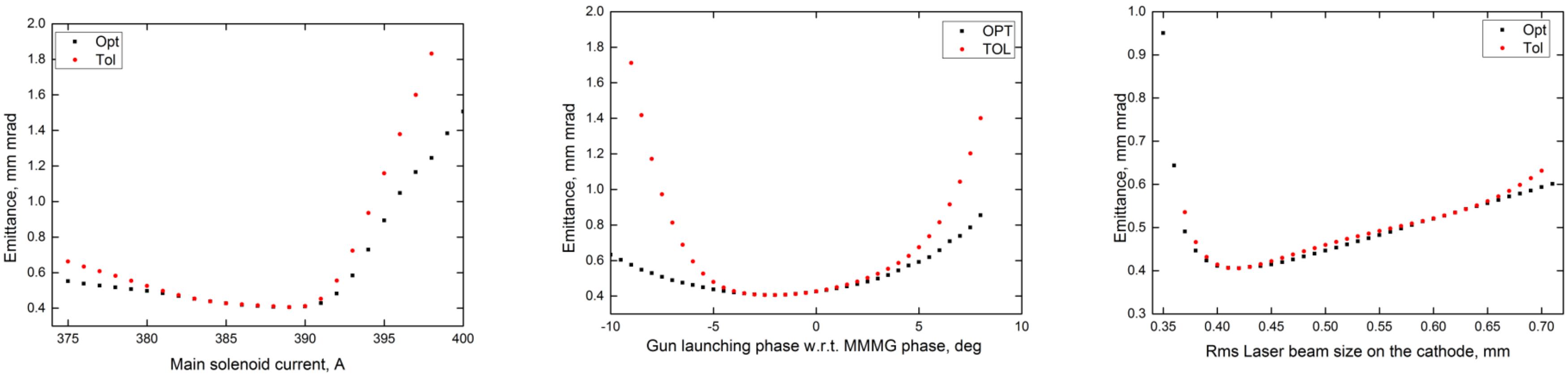
flat-top laser

Opt. emittance 0.6146



3D Ellipsoidal laser

Opt. emittance 0.4056

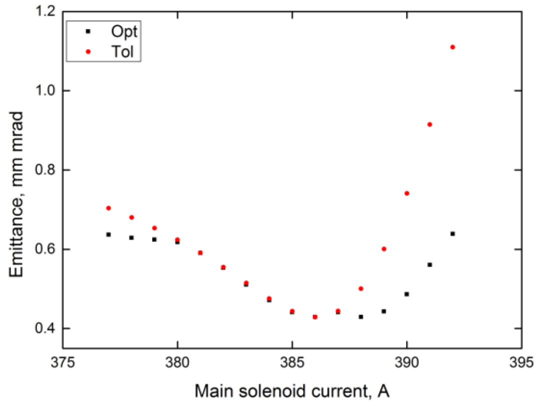


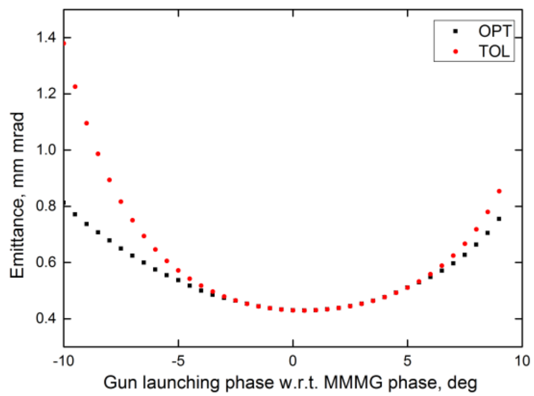
DESY

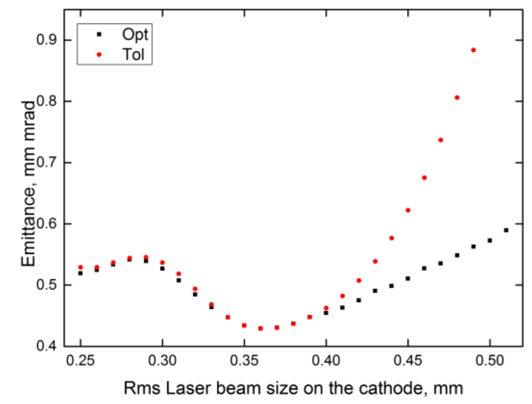
Results for 500 pC

flat-top laser

Opt. emittance 0.42896

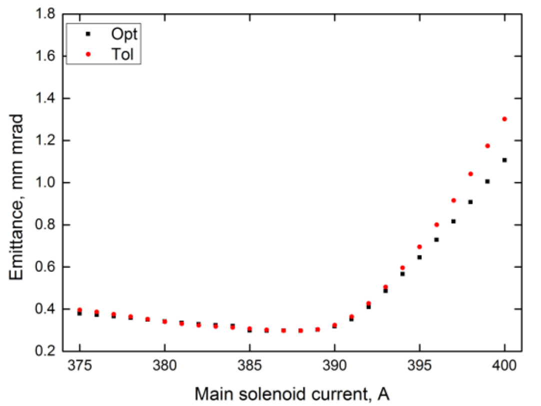


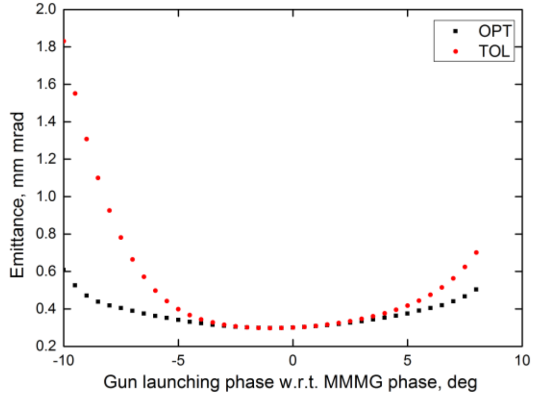


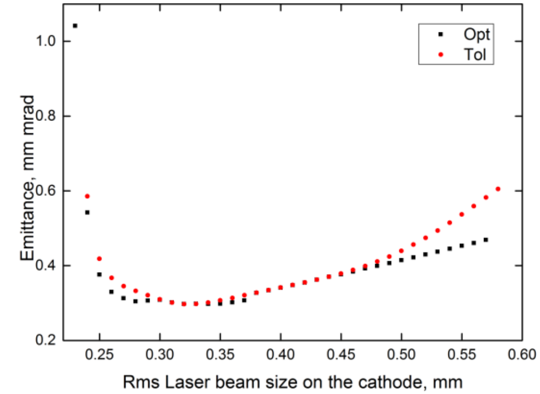


3D Ellipsoidal laser

Opt. emittance 0.2974







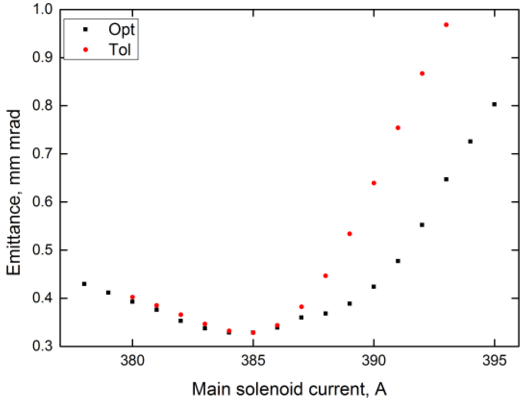
Opt → 3 parameters are changing simultaneously

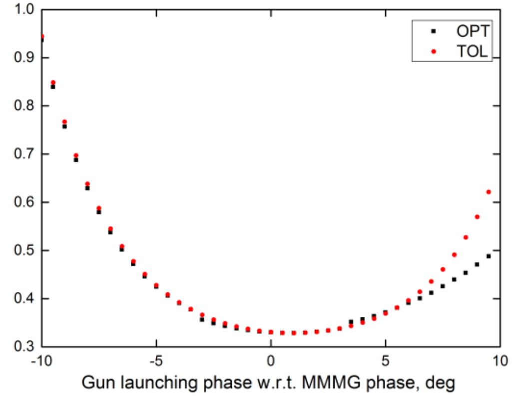
Tol → 2 parameters fixed and only one changing

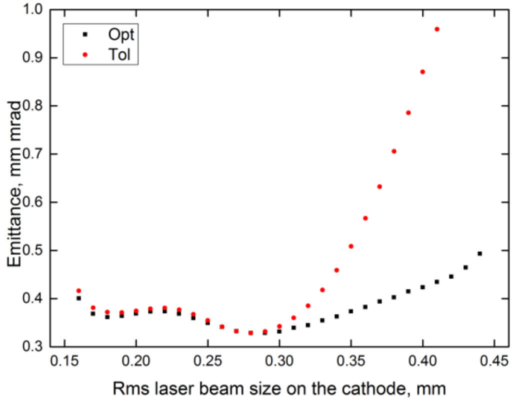
Results for 250 pC

flat-top laser

Opt. emittance 0.3286

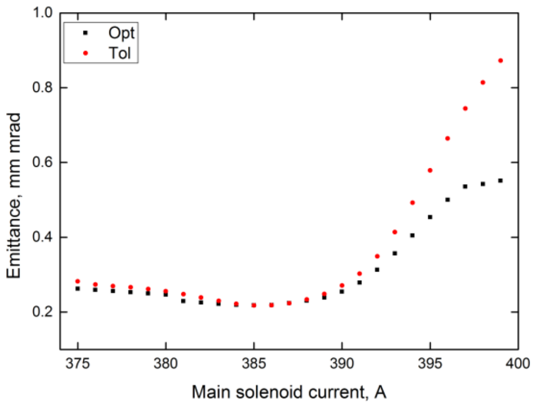


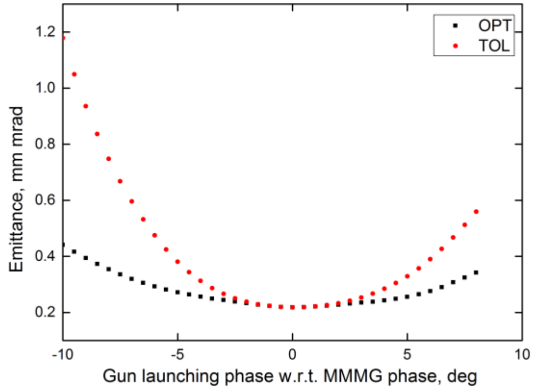


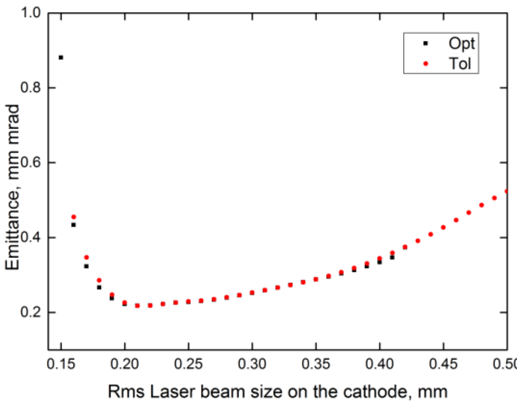


3D Ellipsoidal laser

Opt. emittance 0.2178



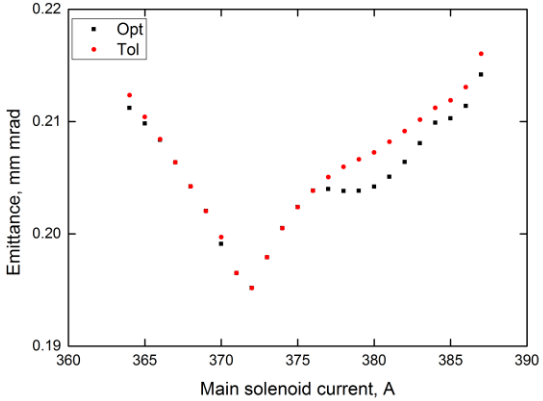


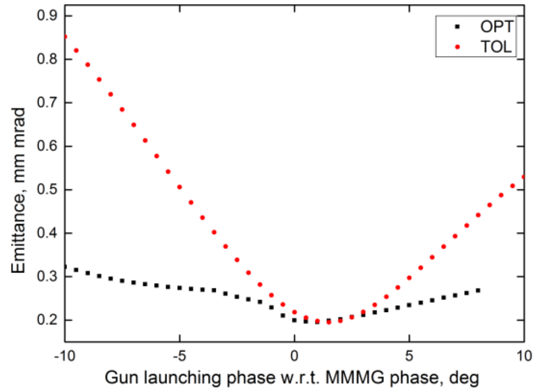


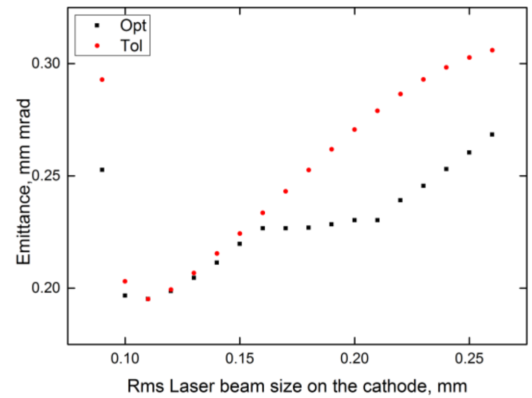
Results for 100 pC

flat-top laser

Opt. emittance 0.1952

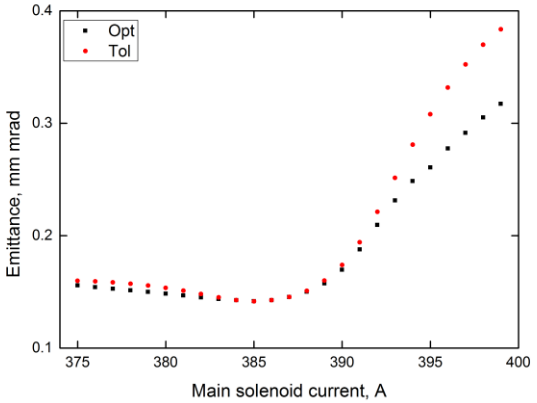


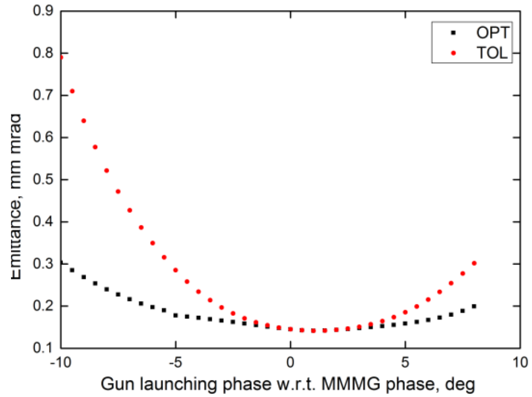


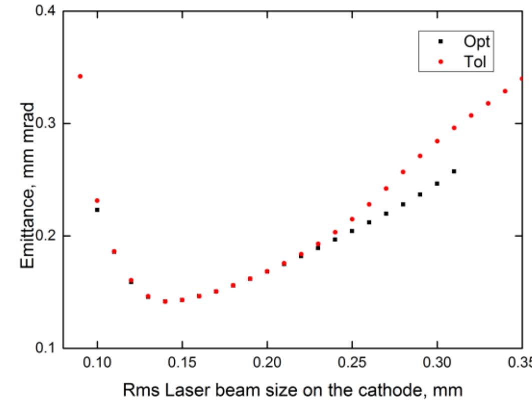


3D Ellipsoidal laser

Opt. emittance 0.1415







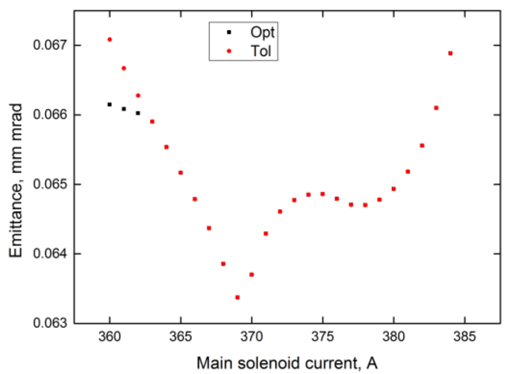
Opt → 3 parameters are changing simultaneously

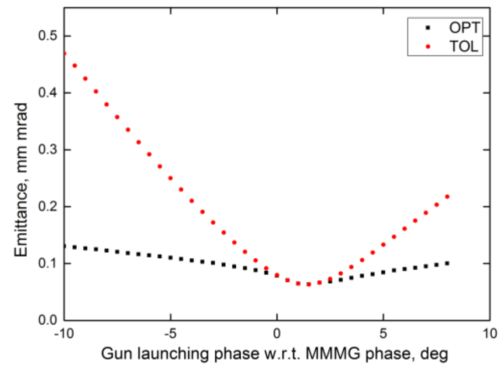
Tol → 2 parameters fixed and only one changing

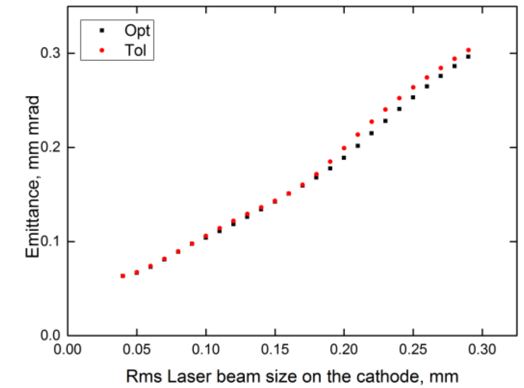
Results for 20 pC

flat-top laser

Opt. emittance 0.0634

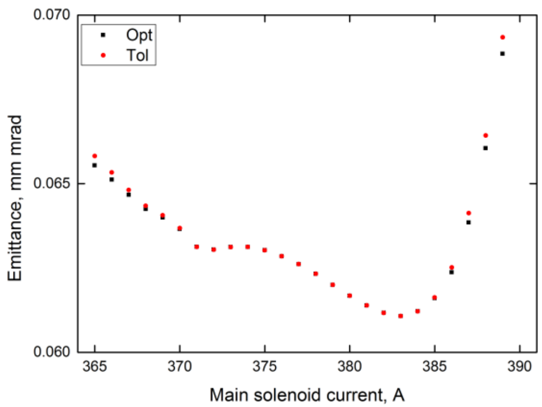


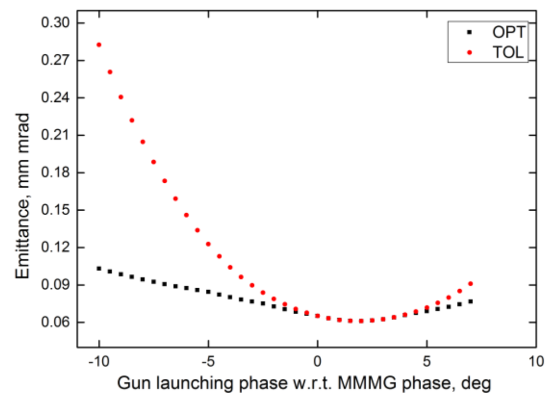


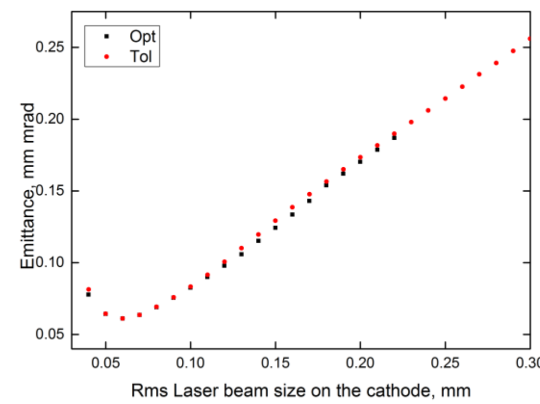


3D Ellipsoidal laser

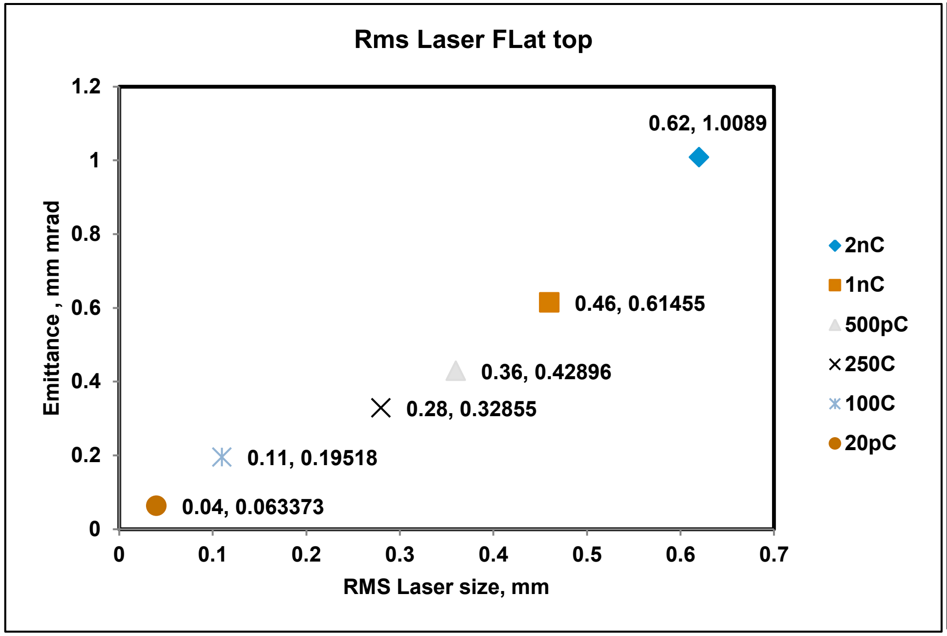
Opt. emittance 0.0611

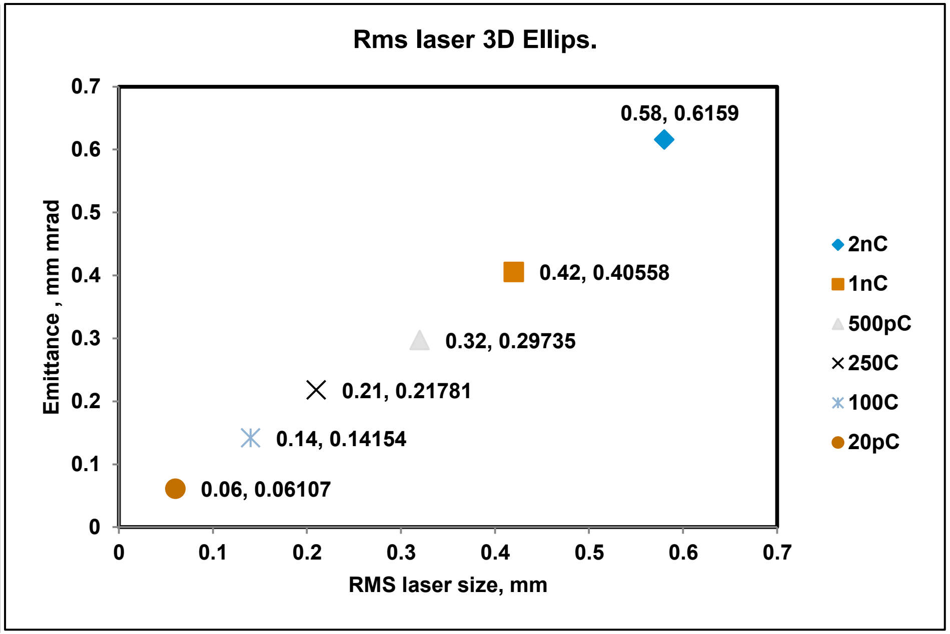


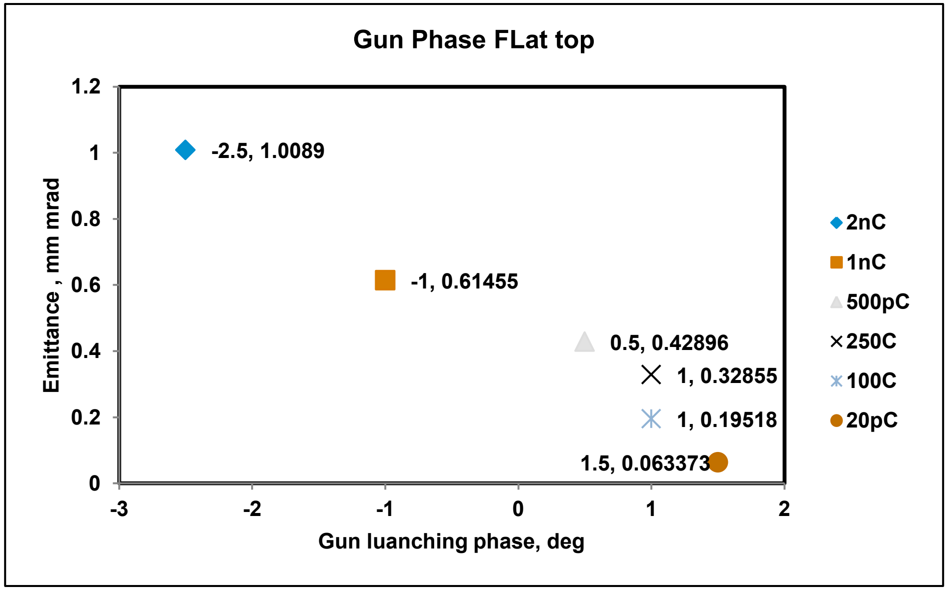


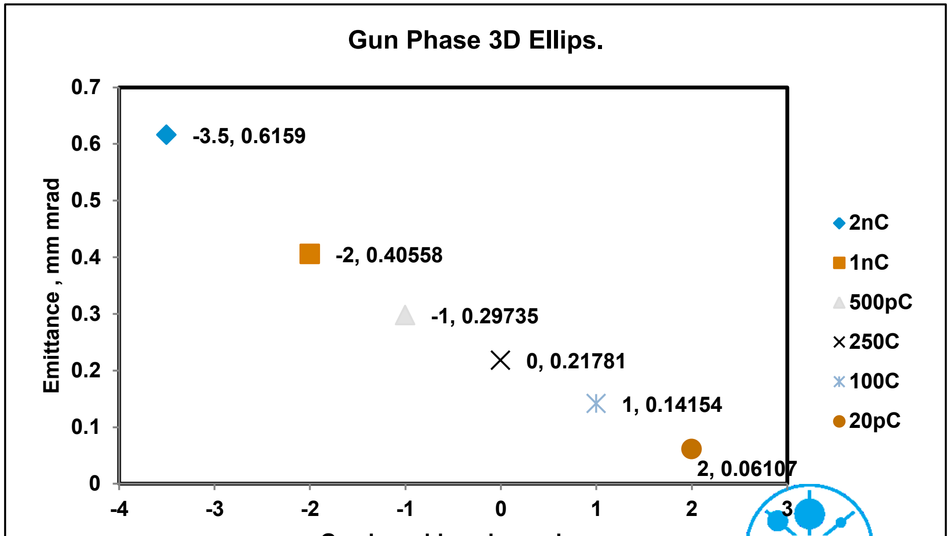


General conclusions

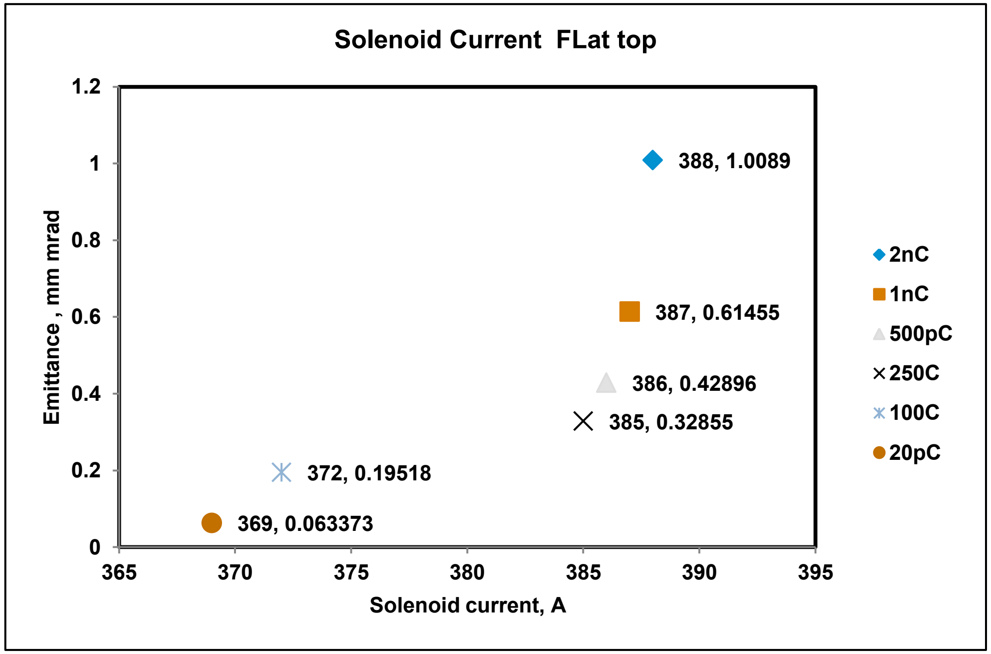


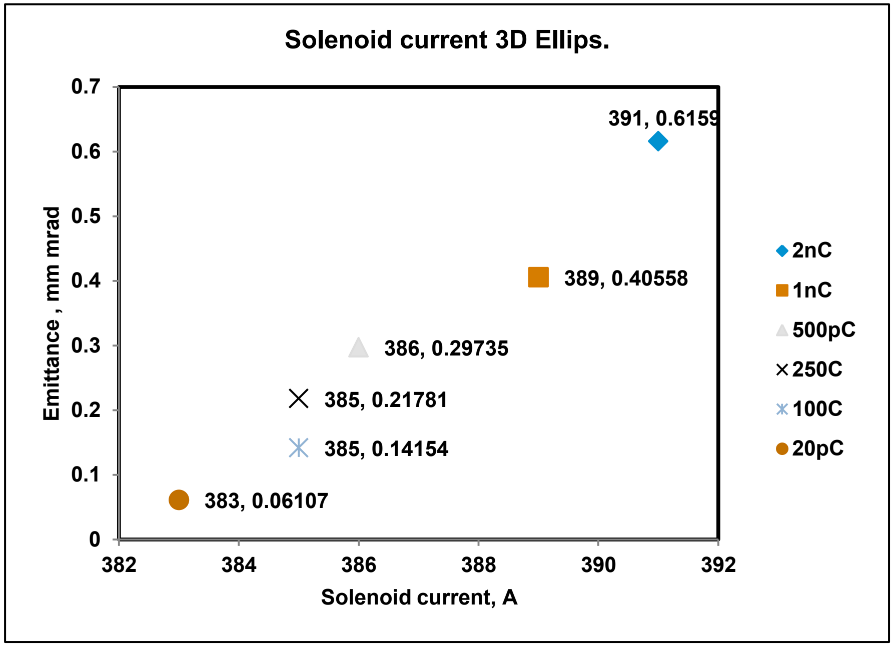




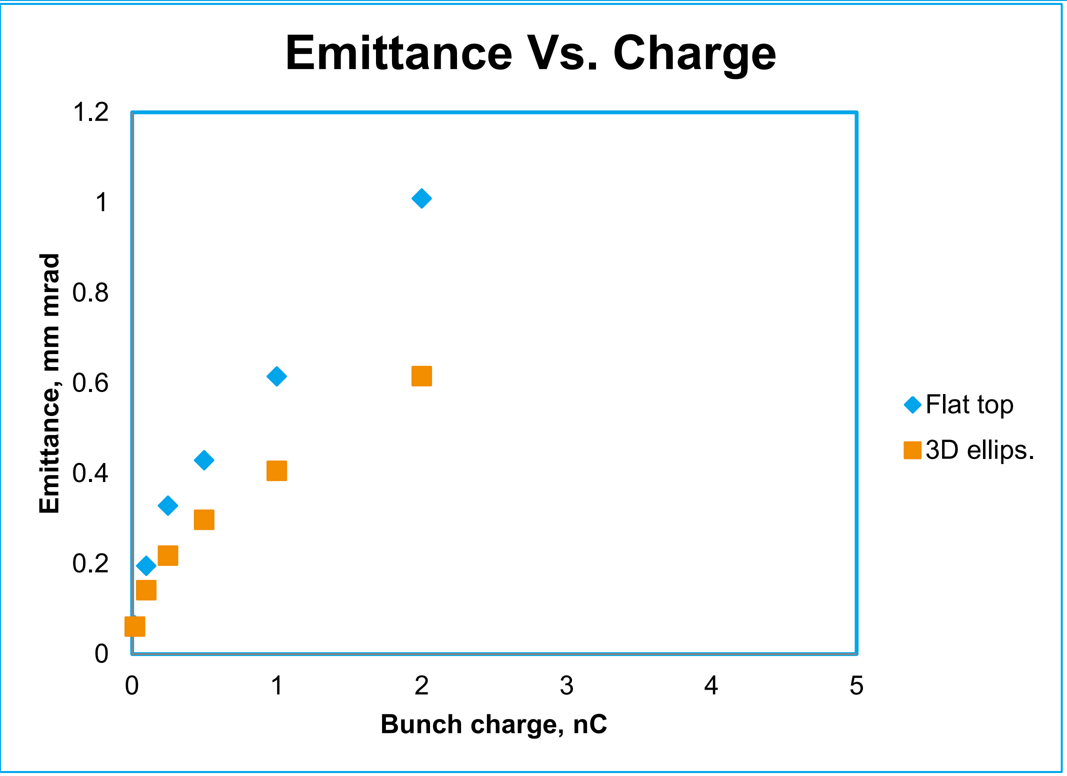


General conclusions





Summery & future plan



Charge nC	Flat top mm mrad	3D ellips. mm mrad	Reduction
4	???	????	????
2	1.0089	0.6159	39%
1	0.61455	0.40558	34%
0.5	0.42896	0.29735	31%
0.25	0.32855	0.21781	34%
0.1	0.19518	0.14154	27%
0.02	0.063373	0.06107	4%

Using 3D ellipsoidal laser profile leads to:

a. For charges > **0.25 nC** more than **30% reduction** in emittance compared to the flat-top case
b. For charges < 100 pC the emittance reduction is dramatically decrees and reach to 4% only for 20 pC?????

To be done soon:

1- Simulate 4 nC and 50 pC to check the tendency.
2- Continue the analysis of the electron beam properties at the optimized emittance parameters.
3- Write report about the simulation.

Thanks

Introduction

- **Motivation:** Further improvement of the electron beam quality by reduction of the transverse projected beam emittance.
- **Main idea:** Optimization of the cathode laser pulse shape in order for to minimize the impact of the space charge on the transverse emittance.

$$\varepsilon = \sqrt{\varepsilon_{cath}^2 + \varepsilon_{RF}^2 + \varepsilon_{SpCh}^2}$$

$$\text{cathode laser shape}: \varepsilon_{SpCh} \rightarrow \min$$

- Minimum SC influence on beam emittance
- Better longitudinal compression
- Reduced beam halo
- Less sensitivity to the machine settings