Studies on emittance at long Gaussian laser pulses

Martin Khojoyan

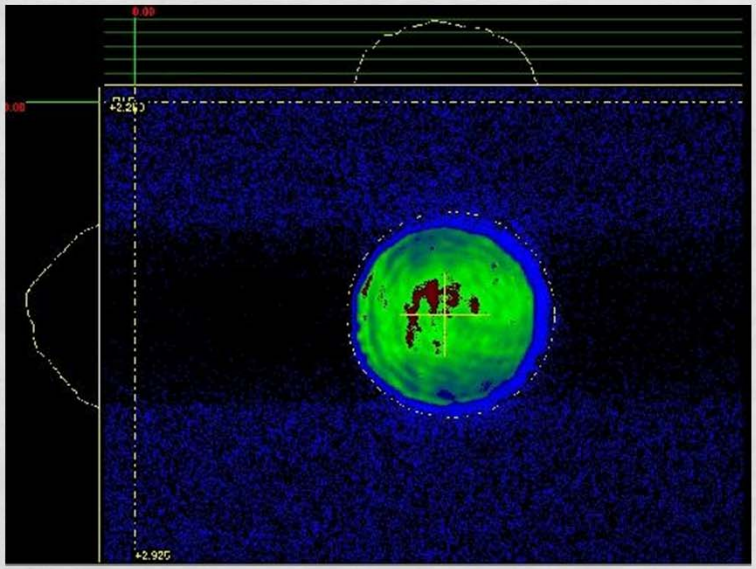
PITZ Physics Seminar, March 1th, Zeuthen

Content

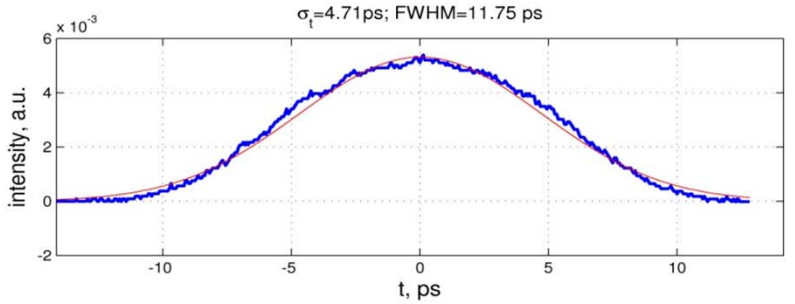
- Rough emittance “optimization” for long Gaussian laser pulses at 100pC
- Rough emittance “optimization” for long Gaussian laser pulses at 1nC
- Summary

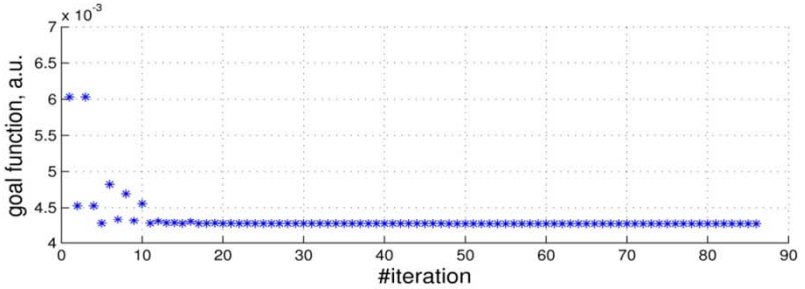
- Rough emittance “optimization” for long Gaussian laser pulses at 100pC
- Rough emittance “optimization” for long Gaussian laser pulses at 1nC
- Summary

Transverse and longitudinal laser profiles



$$\sigma_t \rightarrow [11-17]ps\,(FWHM)$$





$$\sigma_{xy} \rightarrow [60-320]\mu m\,(rms) \text{ for 100pC}$$

$$\sigma_{xy} \rightarrow [280-480]\mu m\,(rms) \text{ for 1nC}$$

Transverse and longitudinal laser profiles for the simulations.

Parameters of ASTRA simulations (100pC and 1nC)

Laser: Transverse rms size → [0.06:0.02:0.32]mm, Longitudinal: Gaussian → [11-17]ps (FWHM)

RF gun: Gradient → 63.5MV/m, gun phase → on-crest (MMMG phase) → ~6.99 MeV/c after the gun

CDS booster: Gradient → 24MV/m, booster phase → on-crest (~27.9 MeV/c after the booster)

Main solenoid current (scan with 2A step)→ min emittance at EMSY1 (5.74m downstream the gun)

Bunch charge → 100pC, 500kp used for the simulations

Laser: Transverse rms size → [0.28:0.04:0.48]mm, Longitudinal: Gaussian → [11-17]ps (FWHM)

RF gun: Gradient → 63.5MV/m, gun phase → on-crest (MMMG phase) → ~6.99 MeV/c after the gun

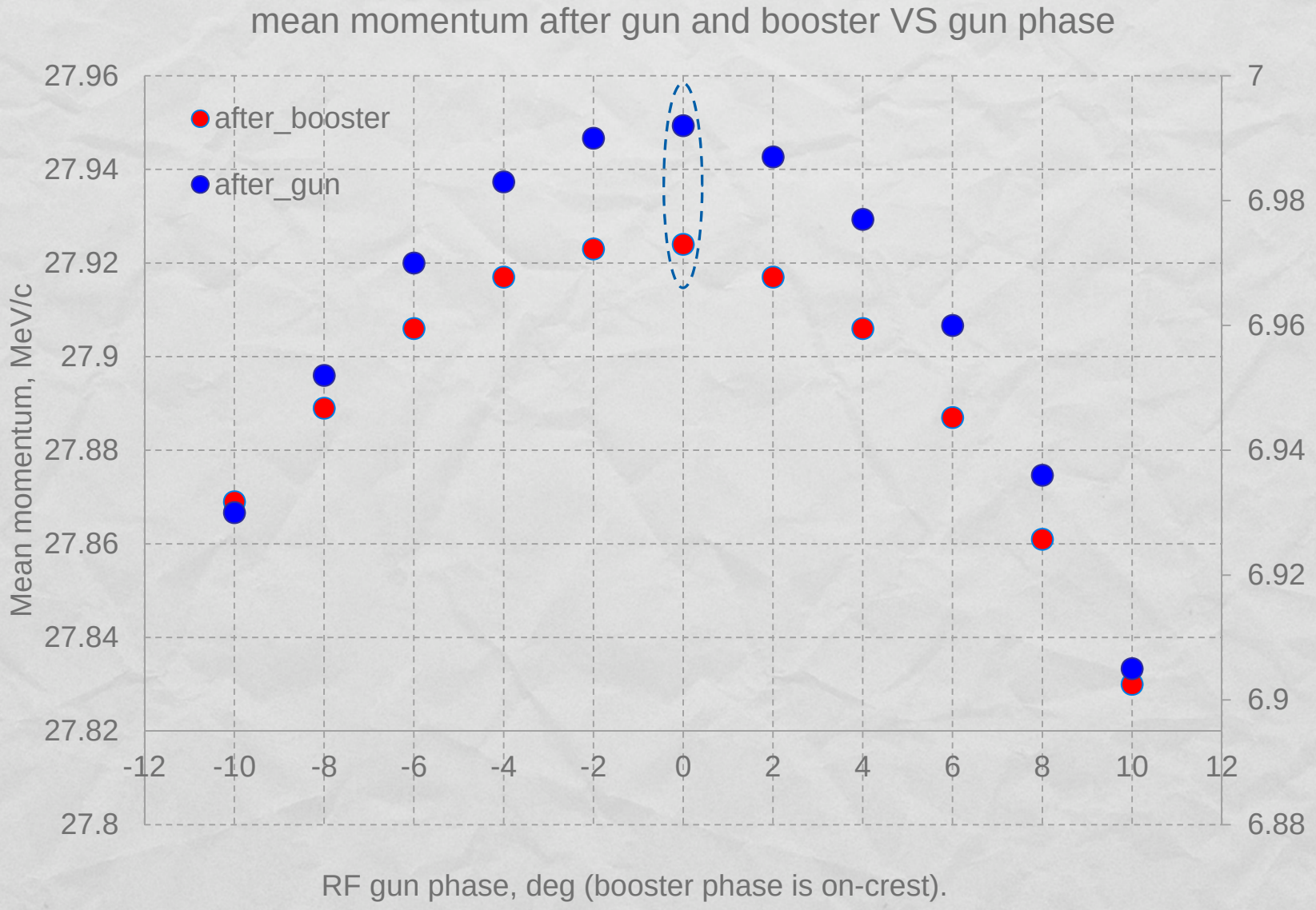
CDS booster: Gradient → 24MV/m, booster phase → on-crest (~27.9 MeV/c after the booster)

Main solenoid current (scan with 2A step)→ min emittance at EMSY1 (5.74m downstream the gun)

Bunch charge → 1nC, 500kp used for the simulations

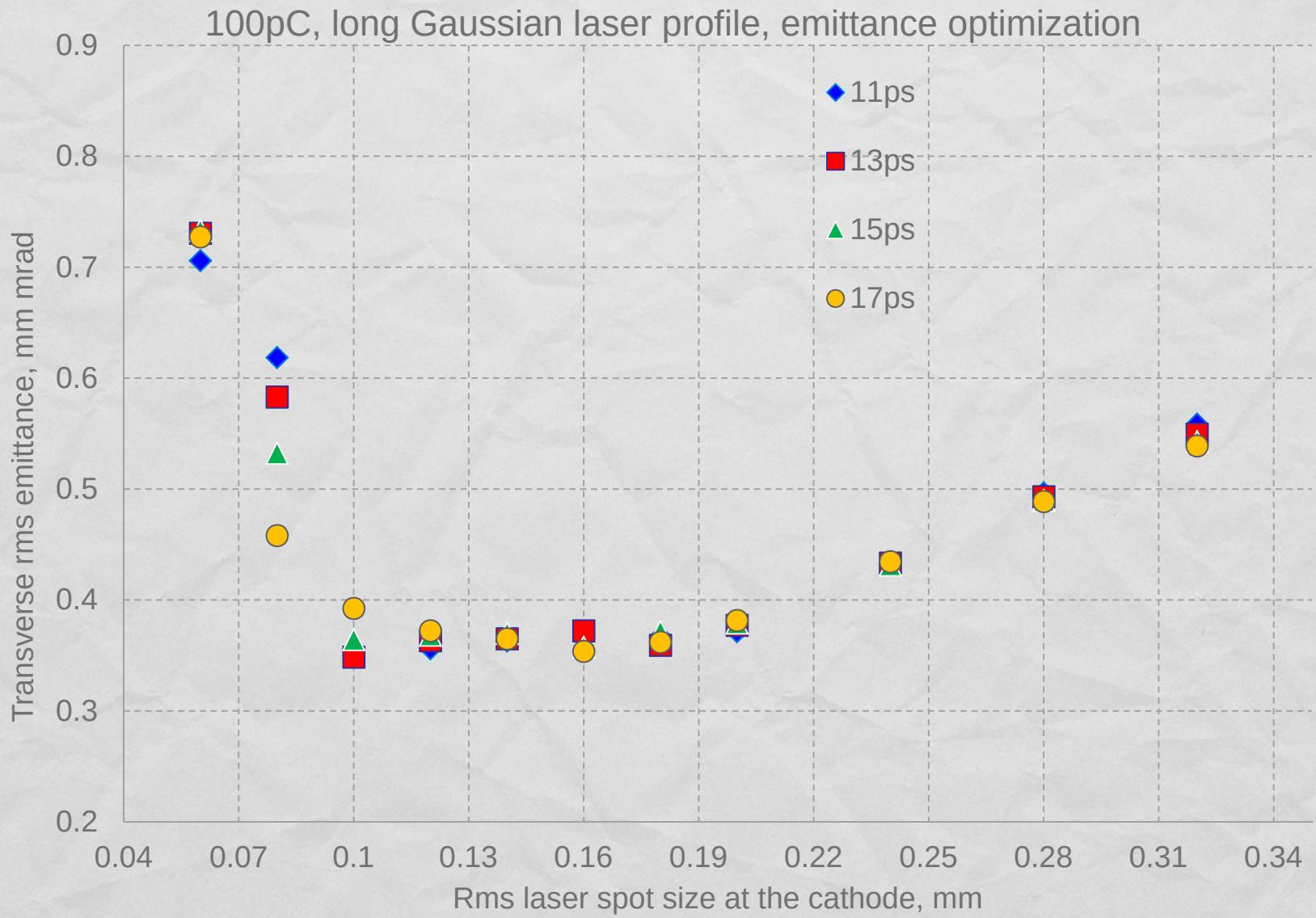
Setup and parameters for the simulations (100pC and 1nC).

Momenta after gun and booster



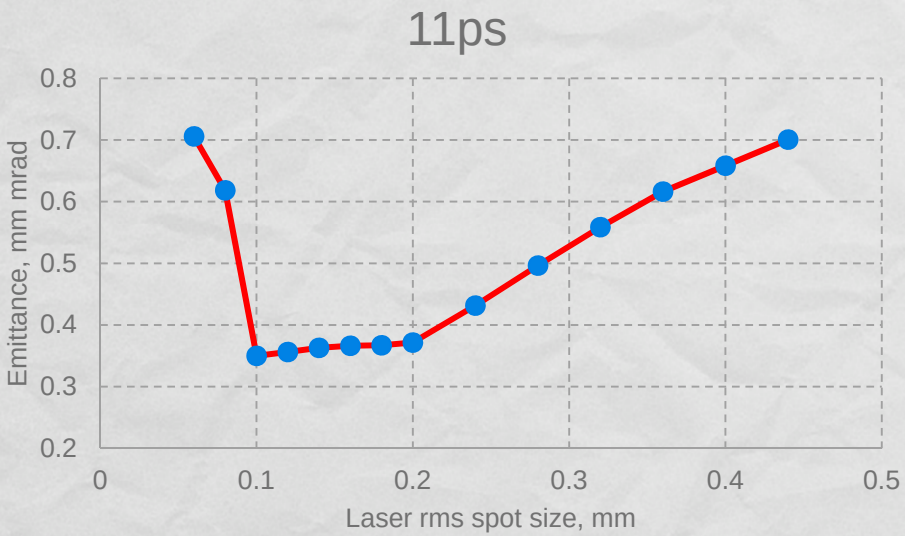
Mean momentum of the beam after the gun and the booster

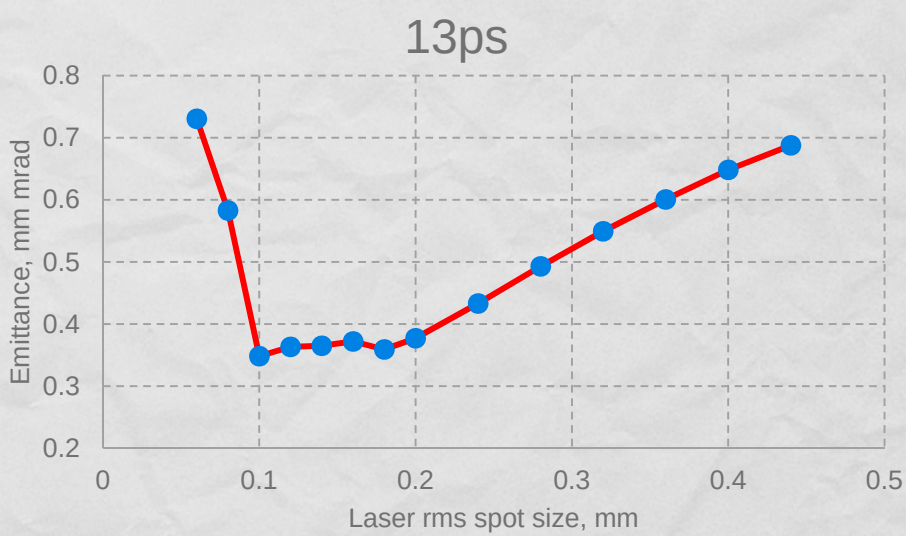
Emittance VS laser spot size

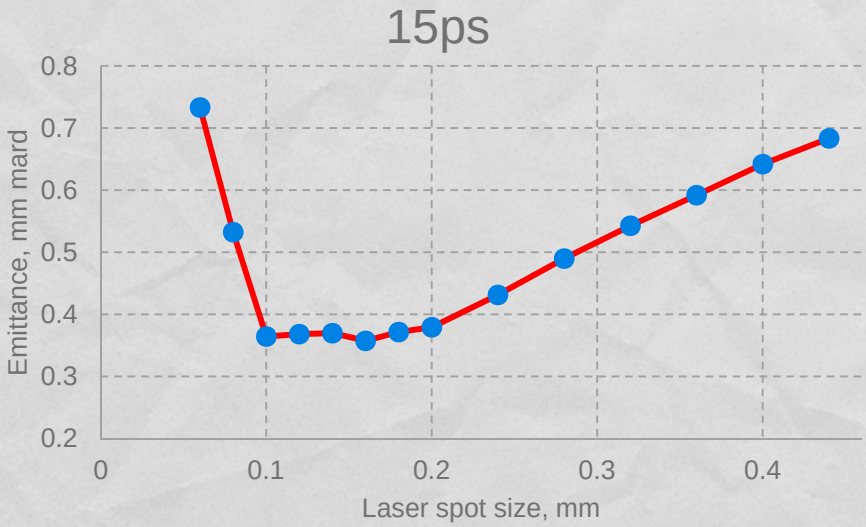


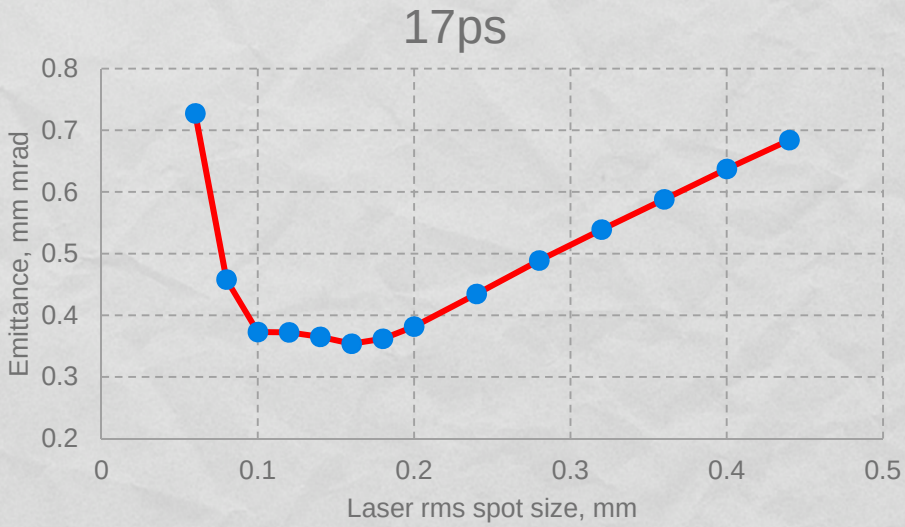
Emittance as a function of laser rms spot size for different laser pulse lengths.

Emittance VS laser spot size



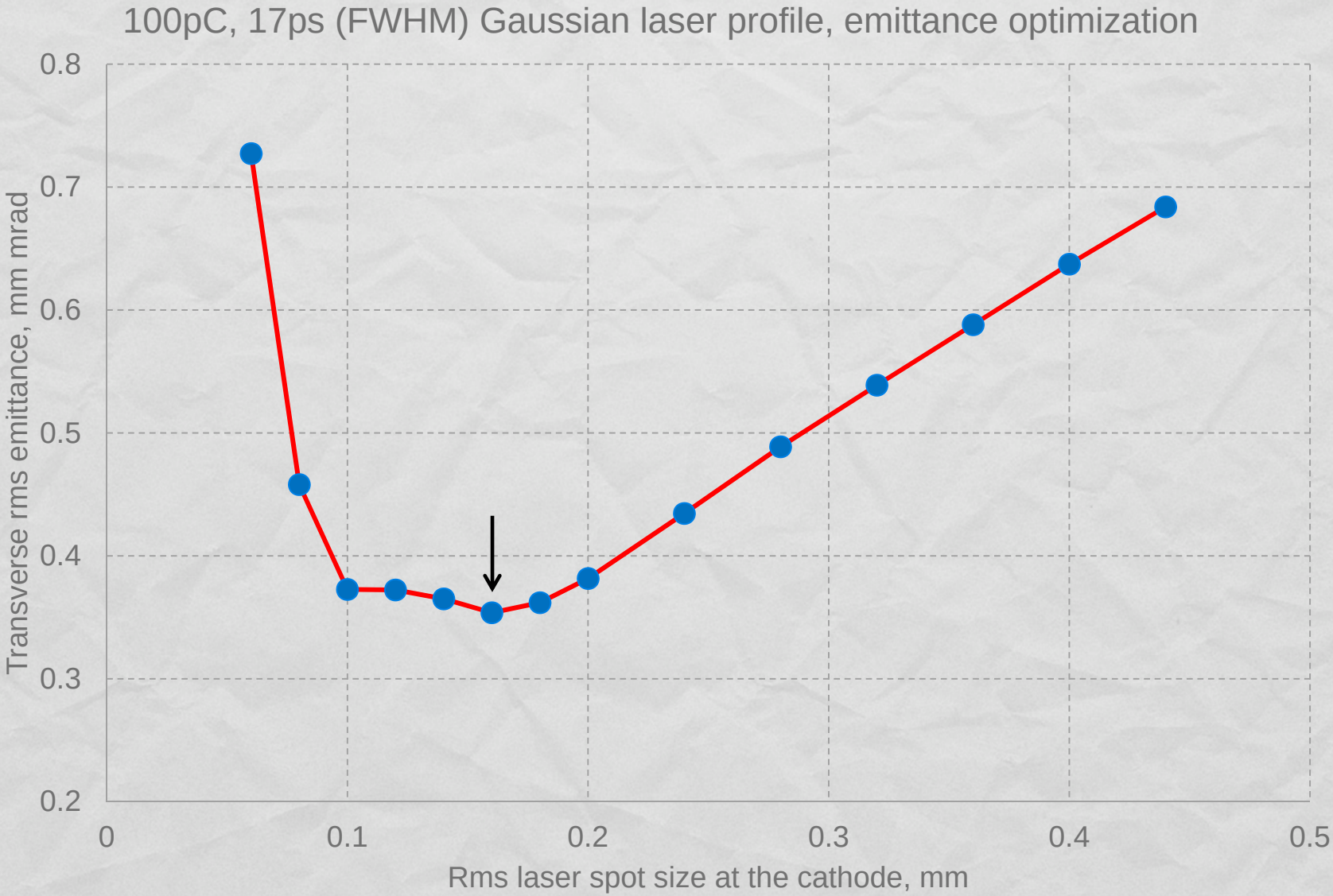






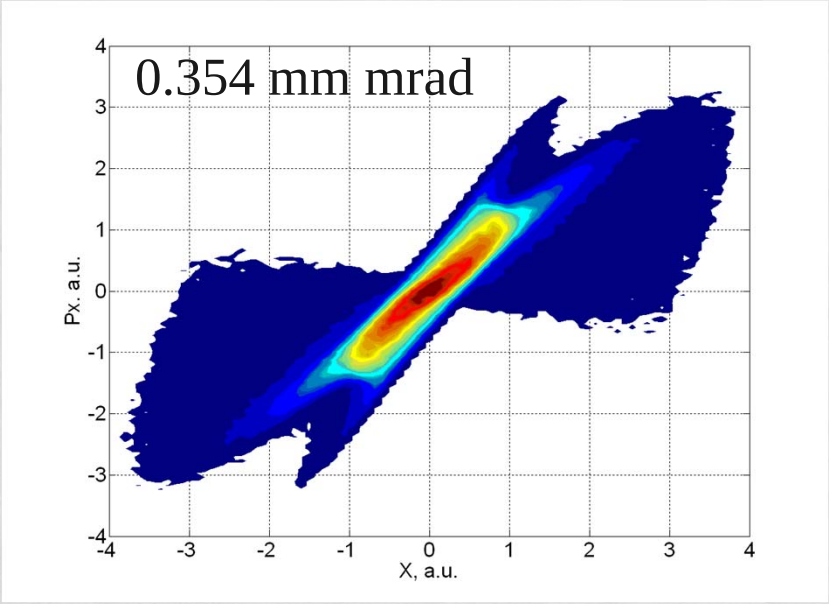
Separated pictures for each pulse length.

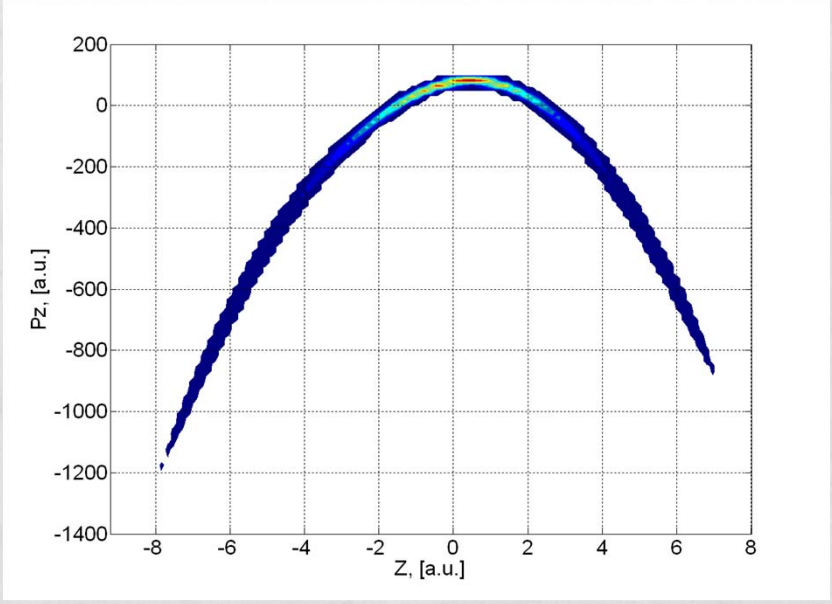
Emittance VS laser rms spot size → 17ps case

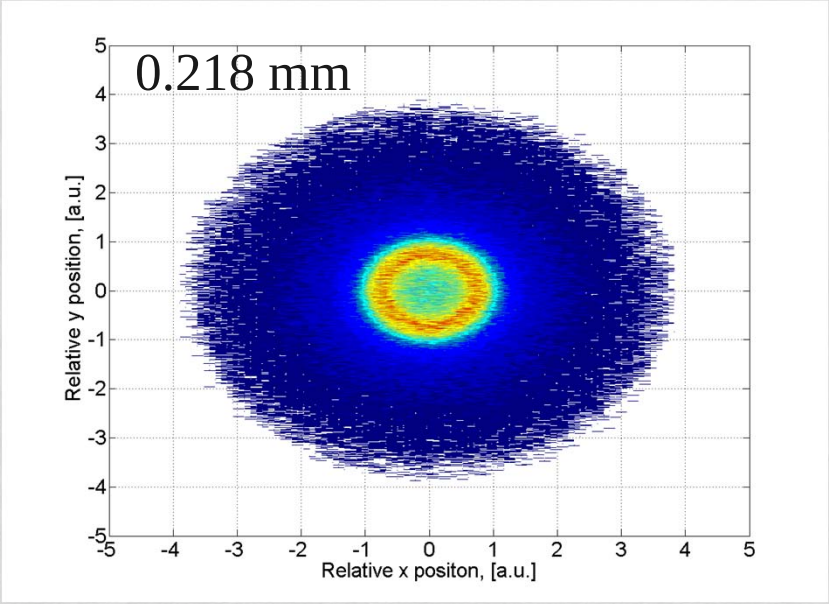


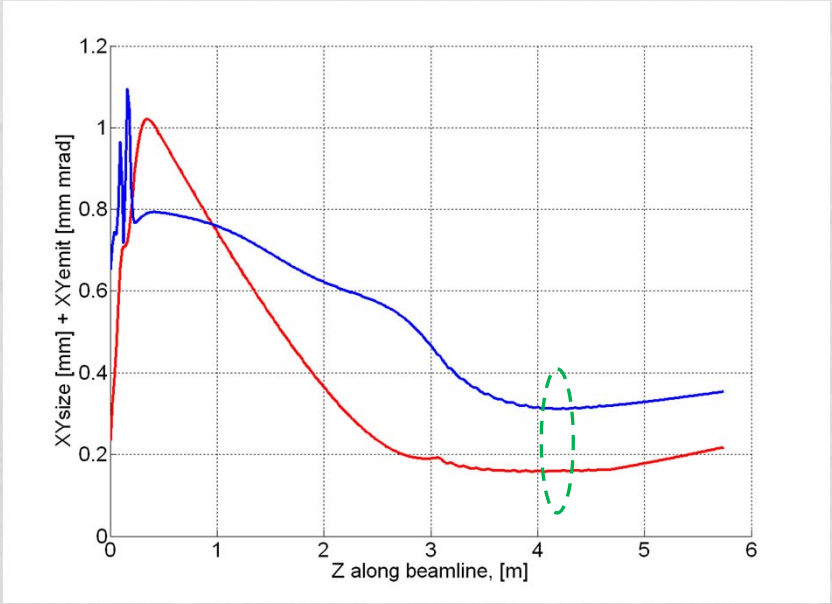
Emittance VS laser spot size, 17ps FWHM laser pulse length.

Beam properties for the point 100pC@17ps@160um



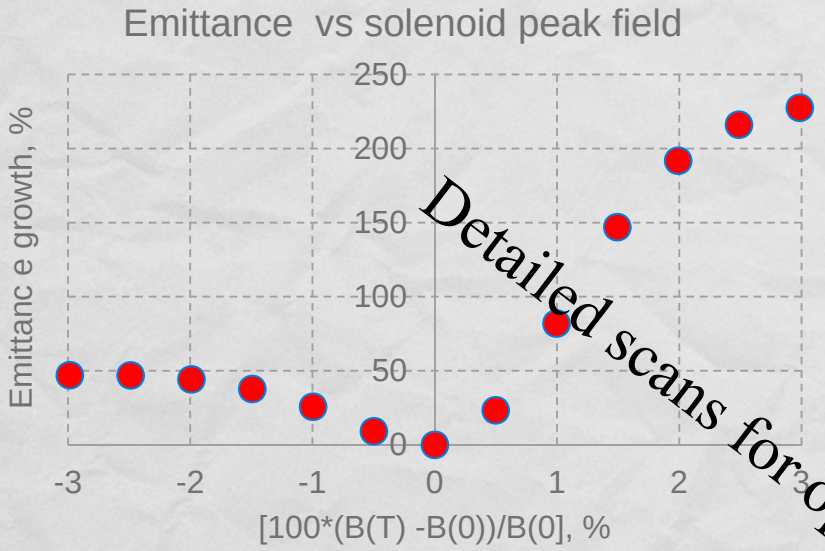


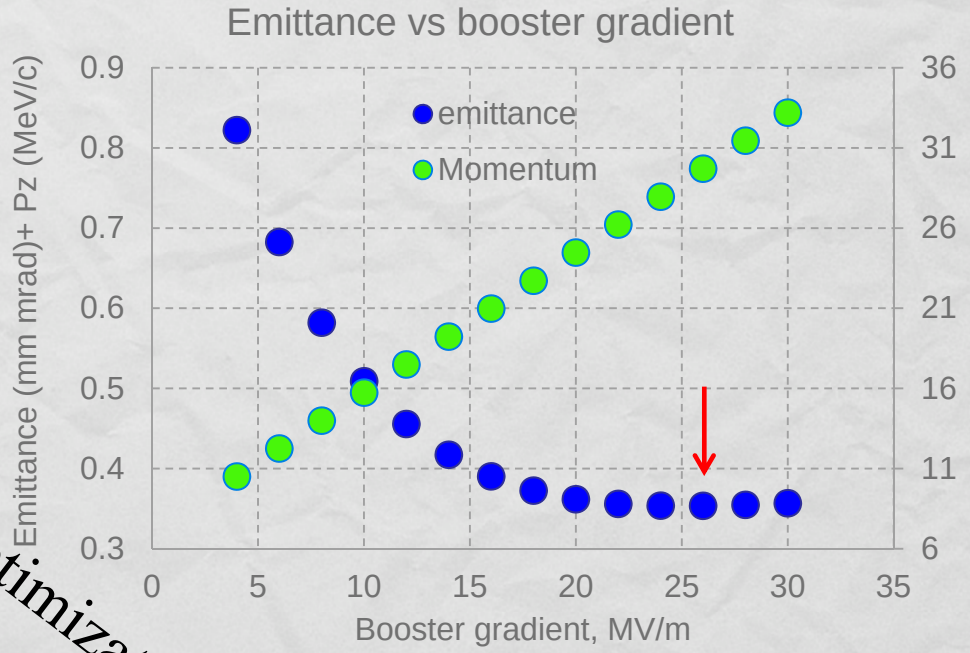




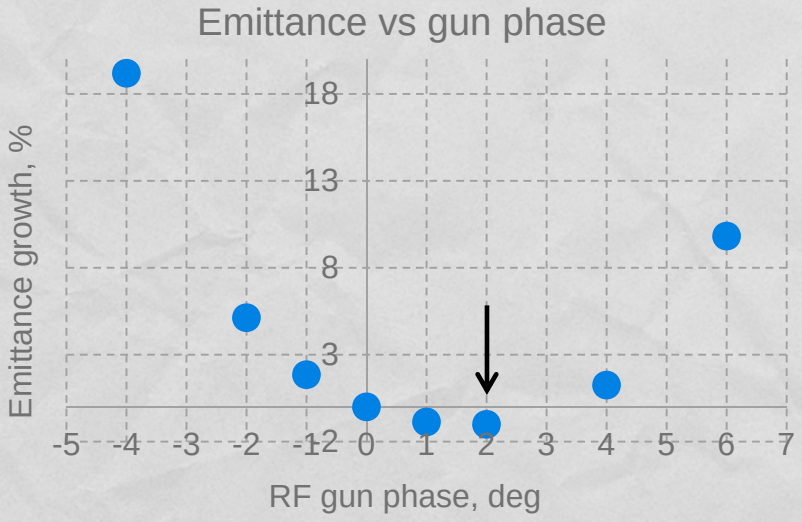
Emittances and beam sizes for 100pC charge and 160um laser rms spot size.

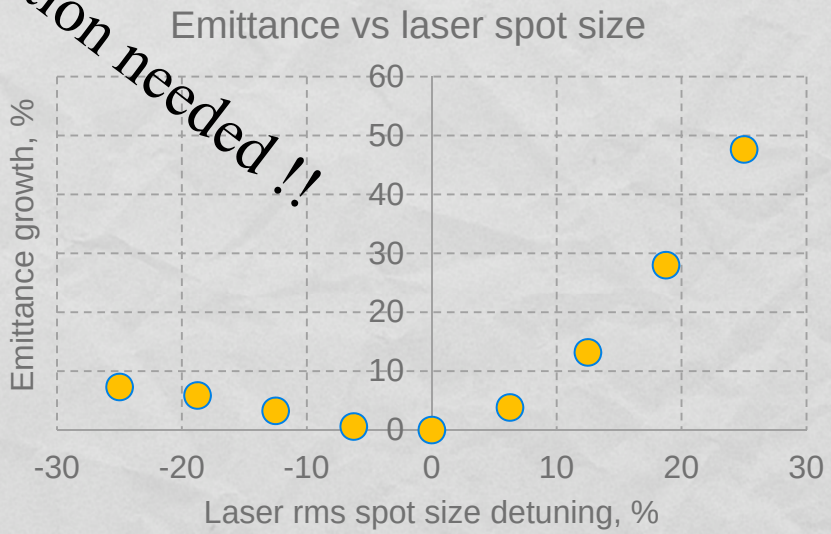
Tolerance studies for the point 100pC@17ps@160um)





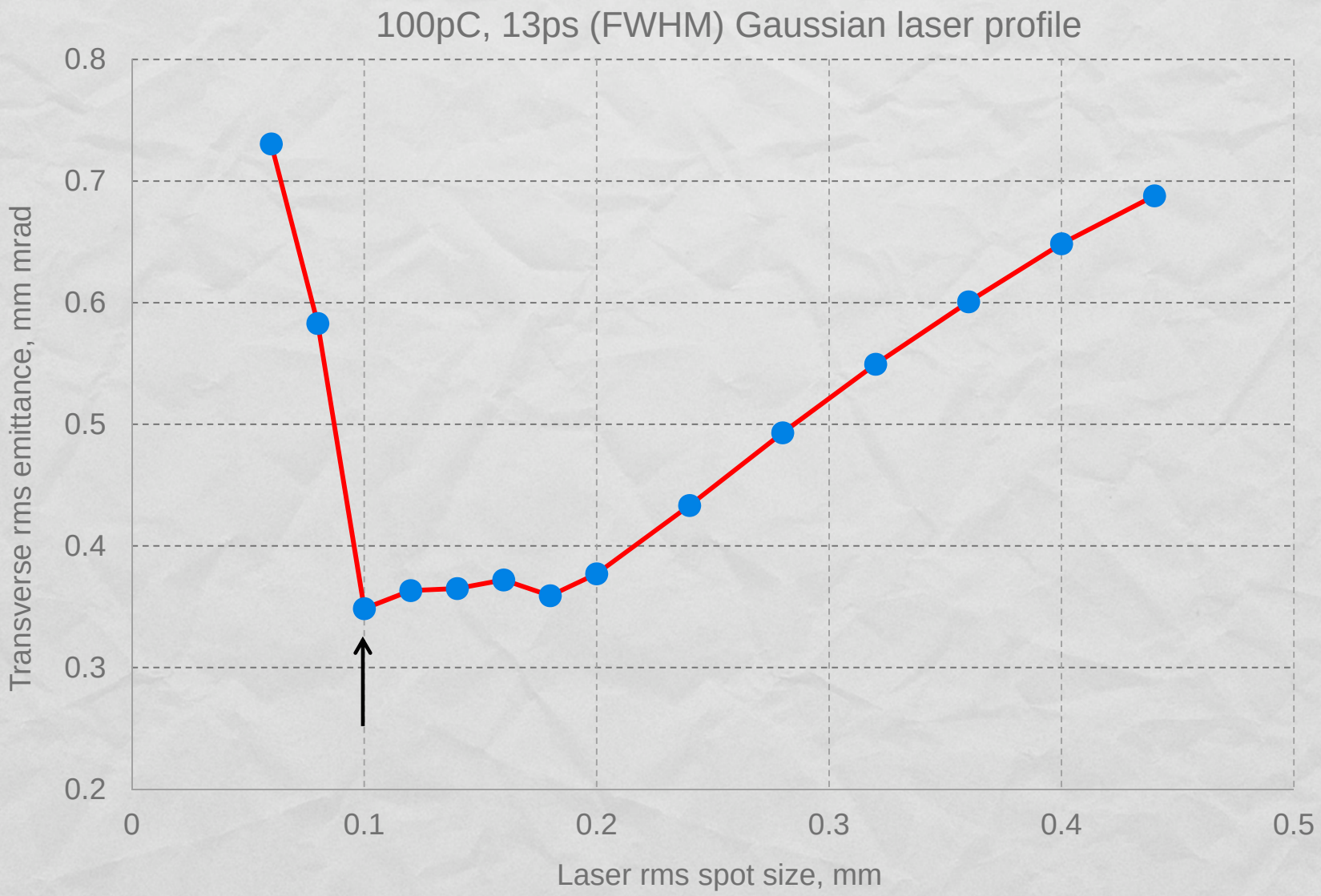
Detailed scans for optimization needed !!





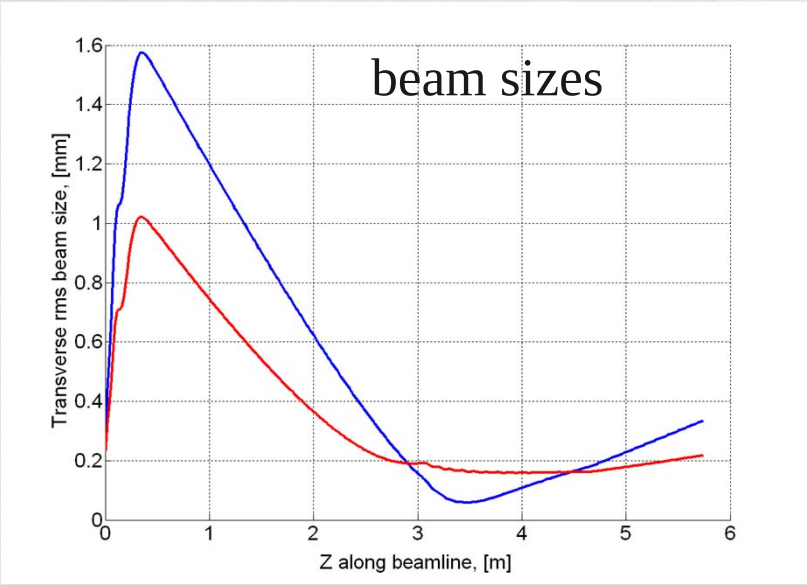
Reference point → 160um, 0.2365T, on-crest, 24MV/m.

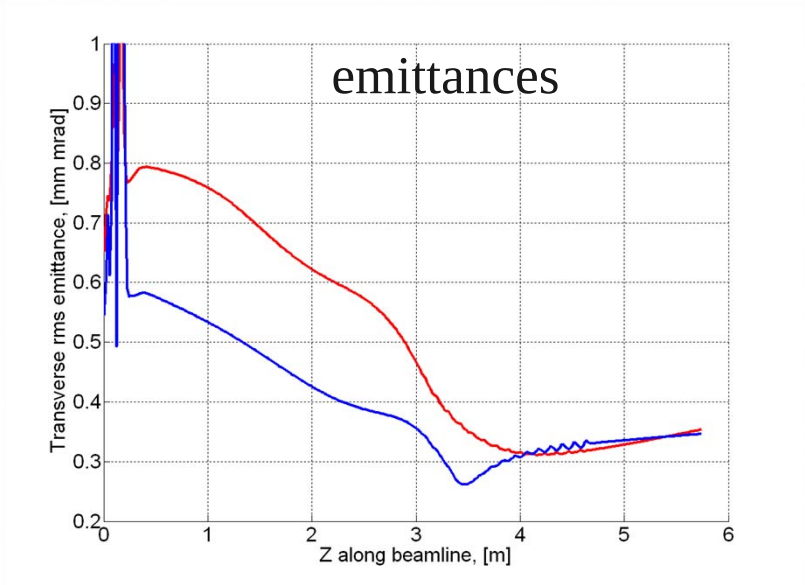
Emittance VS laser rms spot size → 13ps case

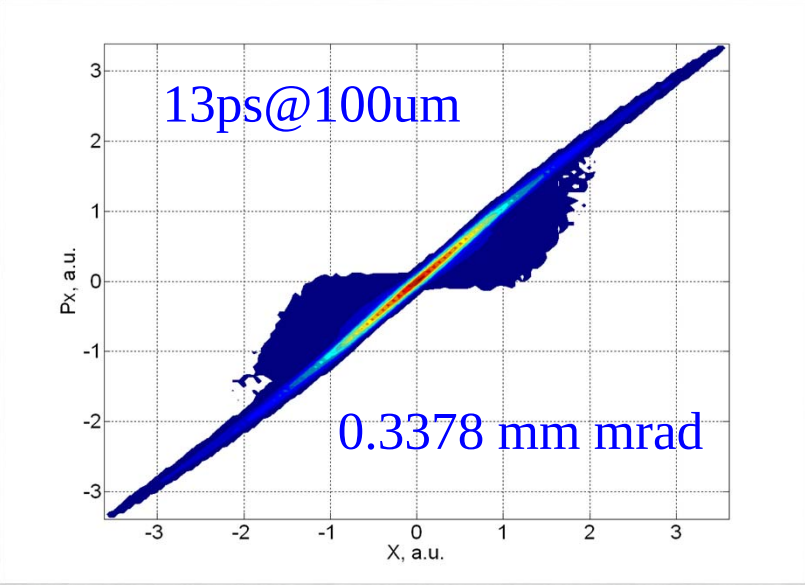


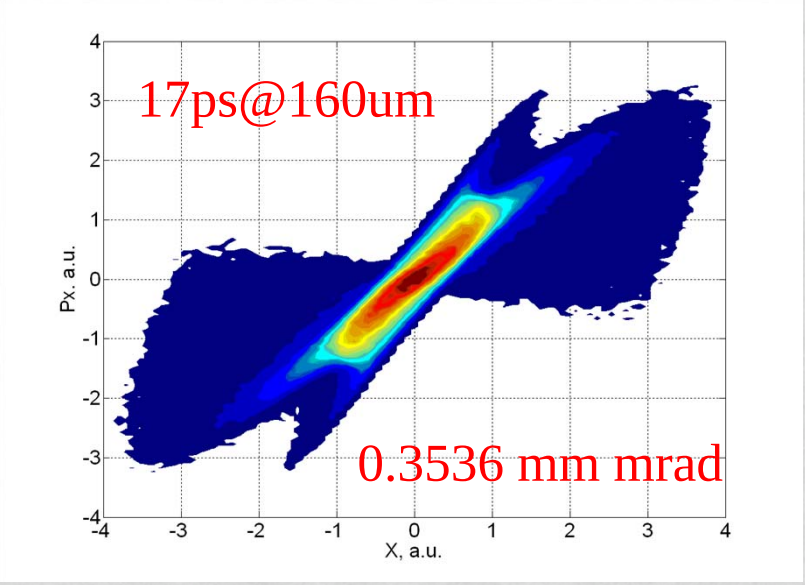
Emittance VS laser spot size, 13ps FWHM laser pulse length.

Comparison 100pC → 17ps@160um and 13ps@100um









Summary plots for 17ps@160um and 13ps@100um.

Summary of observed results for 100pC and two different laser pulses

	parameter	unit	value
cathode laser	temporal	profile	Gaussian
	transverse	distribution	rad. hom.
	FWHM	ps	17
	XYrms	mm	0.16
	Ek	eV	0.55
	th. emit	mm mrad	0.136
RF gun	Ecath	MV/m	63.5
	phase	deg	2
	maxBz	T	0.2365
CDS	maxE	MV/m	24
	phase	deg	0
beam @ EMSY1	charge	pC	100
	momentum	MeV/c	28
	proj. emit	mm mrad	0.354
	th./proj. em.	%	38.5
	av.sl. emit	mm mrad	0.242

	parameter	unit	value
cathode laser	temporal	profile	flat-top
	transverse	distribution	rad. hom.
	rt/FWHM\ft	ps	2/20\2
	XYrms	mm	0.154
	Ek	eV	0.55
	th. emit	mm mrad	0.13
RF gun	Ecath	MV/m	60
	phase	deg	1.4
	maxBz	T	0.225
CDS	maxE	MV/m	21.3
	phase	deg	0
beam @ EMSY1	charge	pC	100
	momentum	MeV/c	24.7
	proj. emit	mm mrad	0.182
	th./proj. em.	%	42
	av.sl. emit	mm mrad	0.14

Summary for 100pC charge and two different laser profiles (Gaussian and flat-top).

- Rough emittance “optimization” for long Gaussian laser pulses at 100pC
- Rough emittance “optimization” for long Gaussian laser pulses at 1nC
- Summary

Parameters of ASTRA simulations (100pC and 1nC)

Laser: Transverse rms size → [0.06:0.02:0.32]mm, Longitudinal: Gaussian → [11-17]ps (FWHM)

RF gun: Gradient → 63.5MV/m, gun phase → on-crest (MMMG phase) → ~6.99 MeV/c after the gun

CDS booster: Gradient → 24MV/m, booster phase → on-crest (~27.9 MeV/c after the booster)

Main solenoid current (scan with 2A step)→ min emittance at EMSY1 (5.74m downstream the gun)

Bunch charge → 100pC, 500kp used for the simulations

Laser: Transverse rms size → [0.28:0.04:0.48]mm, Longitudinal: Gaussian → [11-17]ps (FWHM)

RF gun: Gradient → 63.5MV/m, gun phase → on-crest (MMMG phase) → ~6.99 MeV/c after the gun

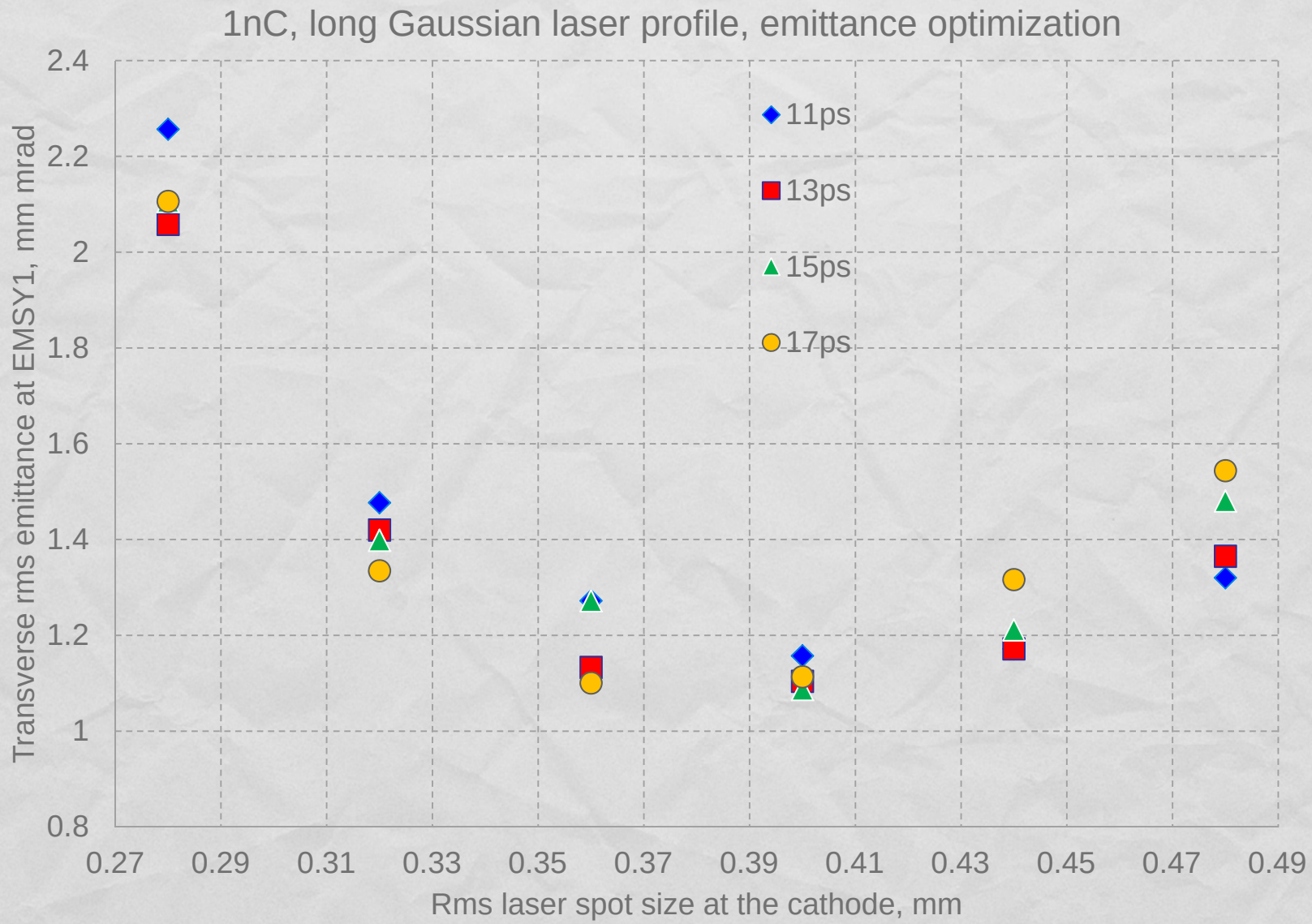
CDS booster: Gradient → 24MV/m, booster phase → on-crest (~27.9 MeV/c after the booster)

Main solenoid current (scan with 2A step)→ min emittance at EMSY1 (5.74m downstream the gun)

Bunch charge → 1nC, 500kp used for the simulations

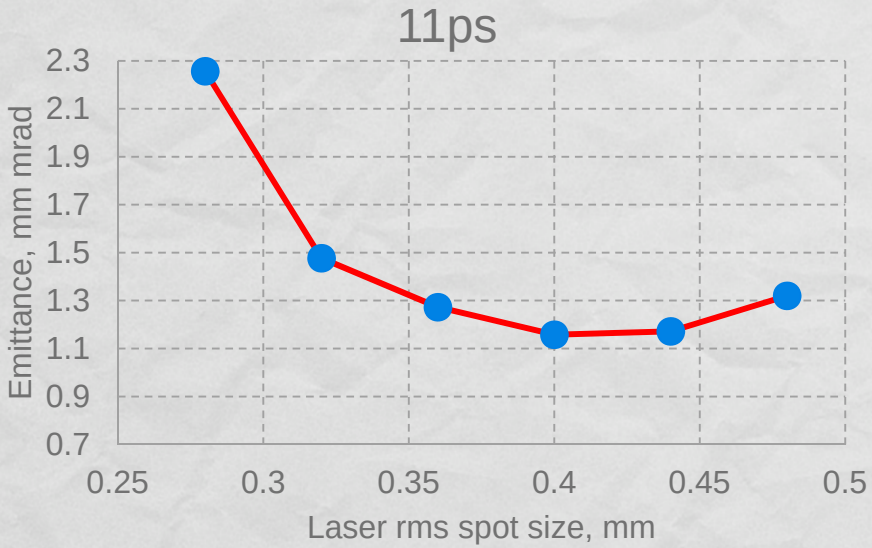
Setup and parameters for the simulations (100pC and 1nC).

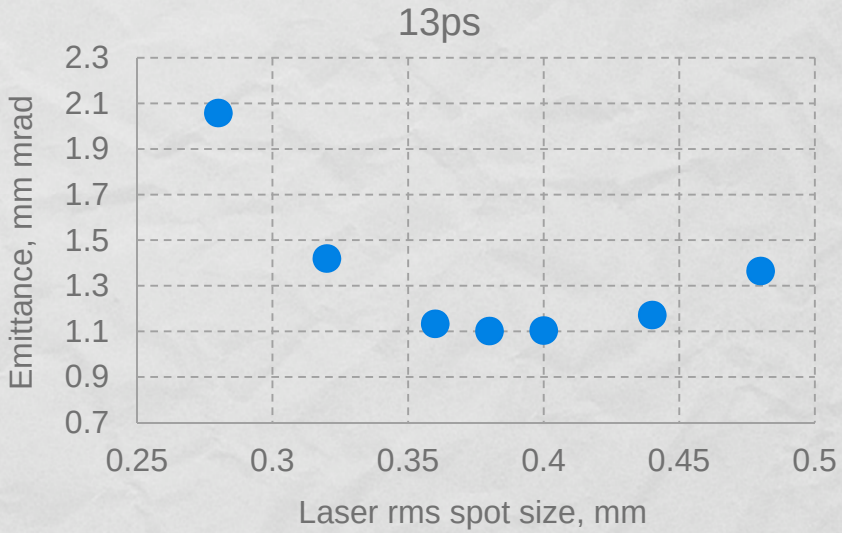
Emittance VS laser spot size

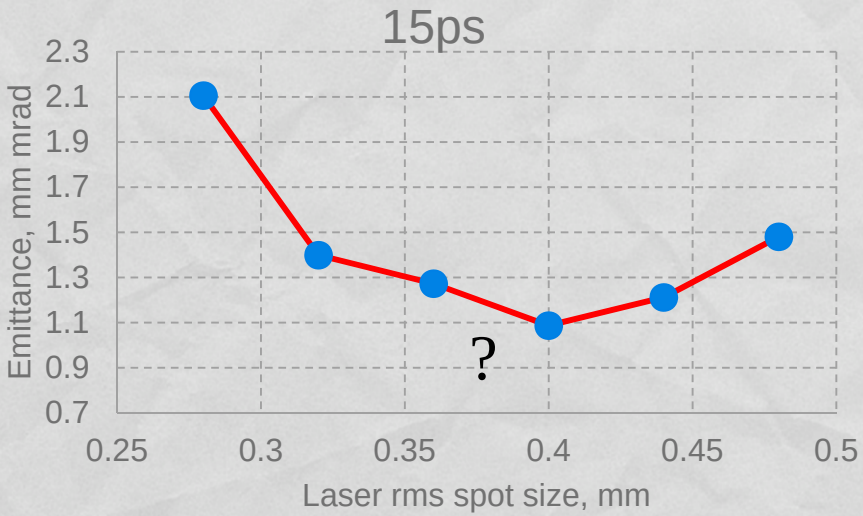


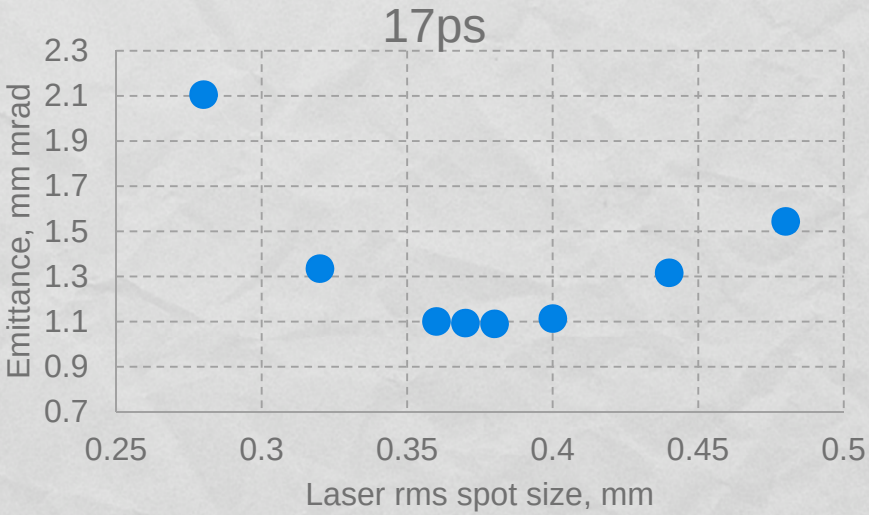
Emittance as a function of laser rms spot size for different laser pulse lengths.

Emittance VS laser spot size



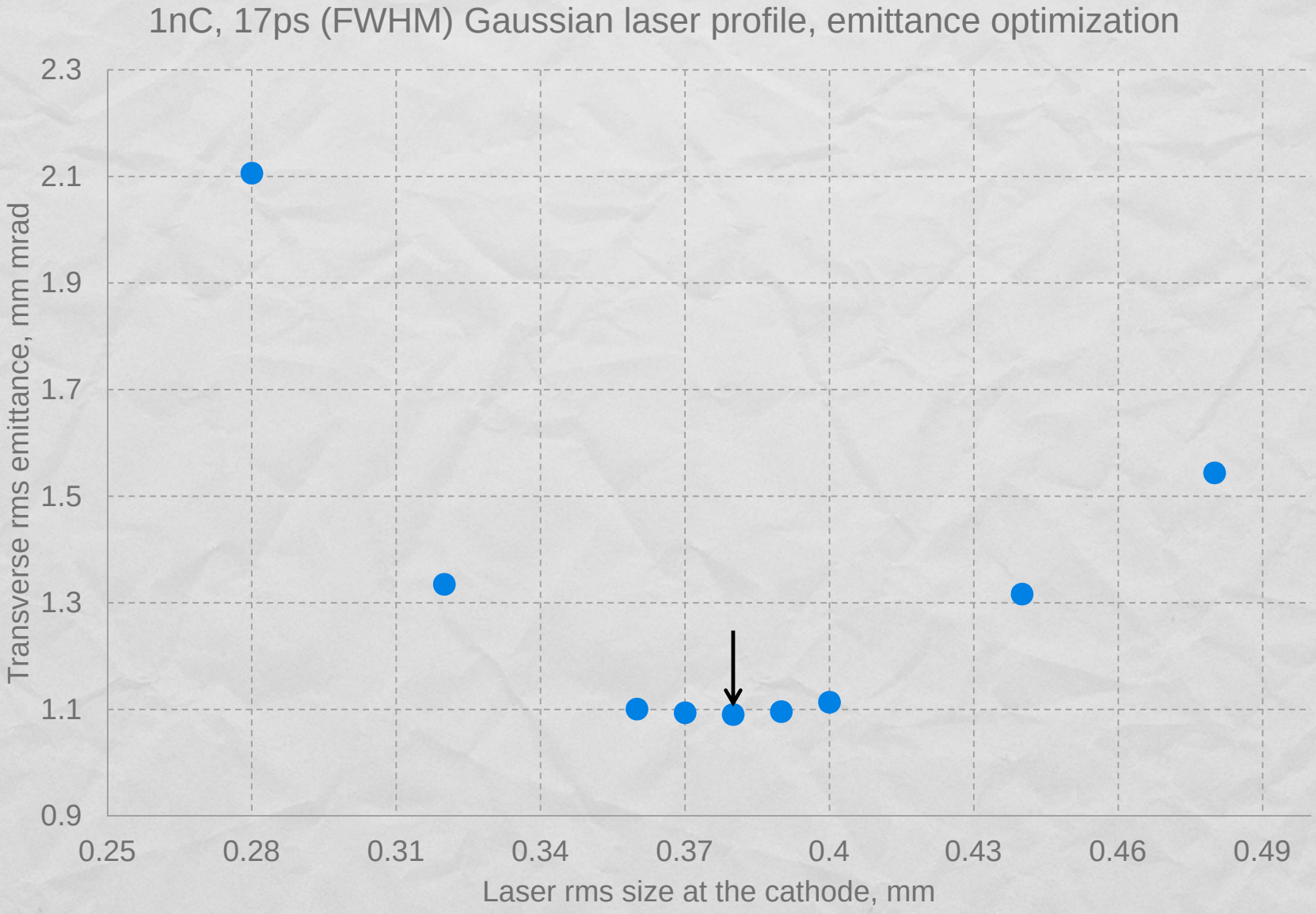






Separated pictures for each laser pulse length.

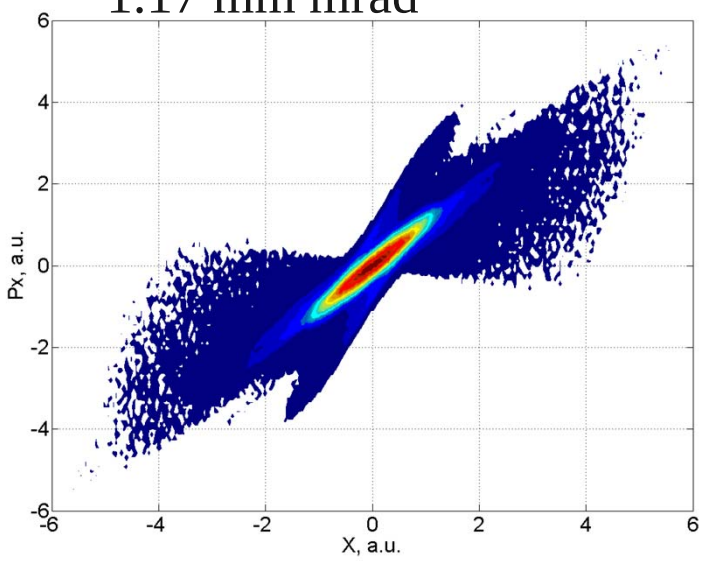
Emittance VS laser rms spot size → 17ps case

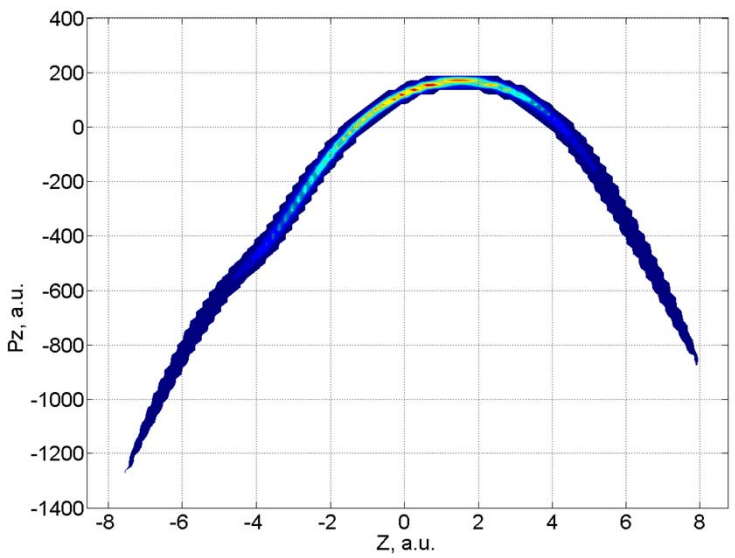


Emittance VS laser spot size, 17ps FWHM laser pulse length.

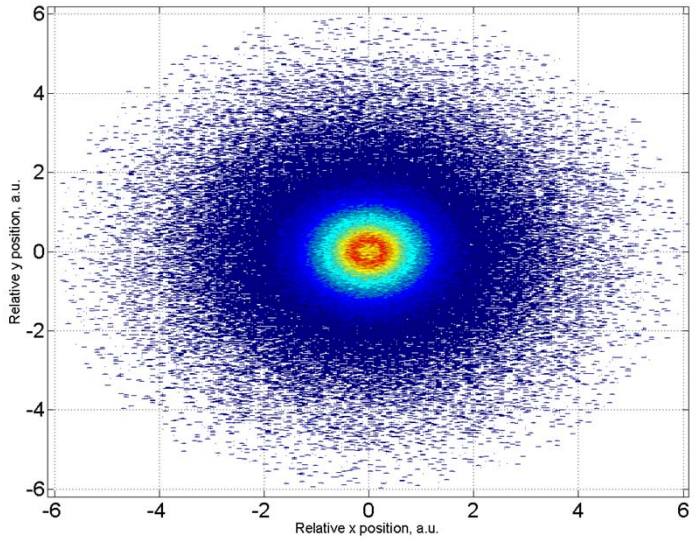
Beam properties for the point 1nC@17ps@380um

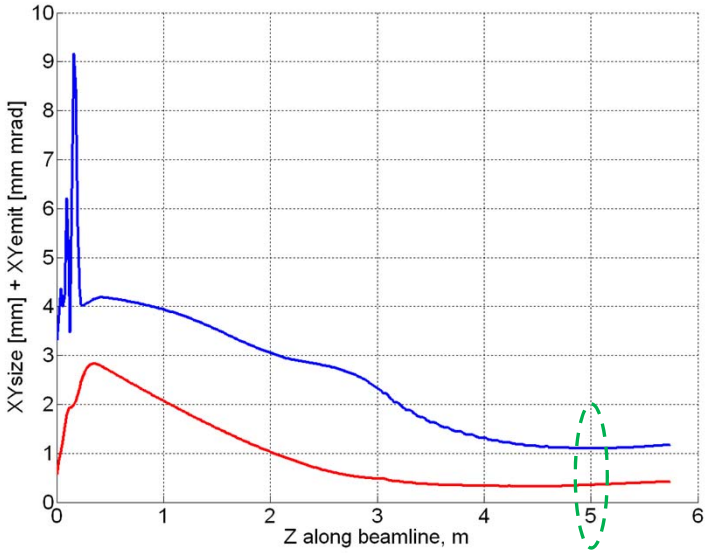
1.17 mm mrad





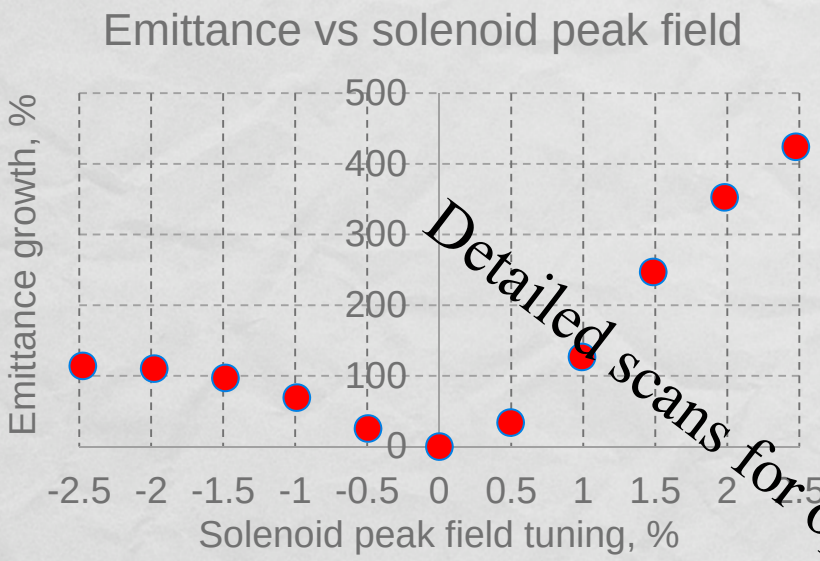
0.423 mm

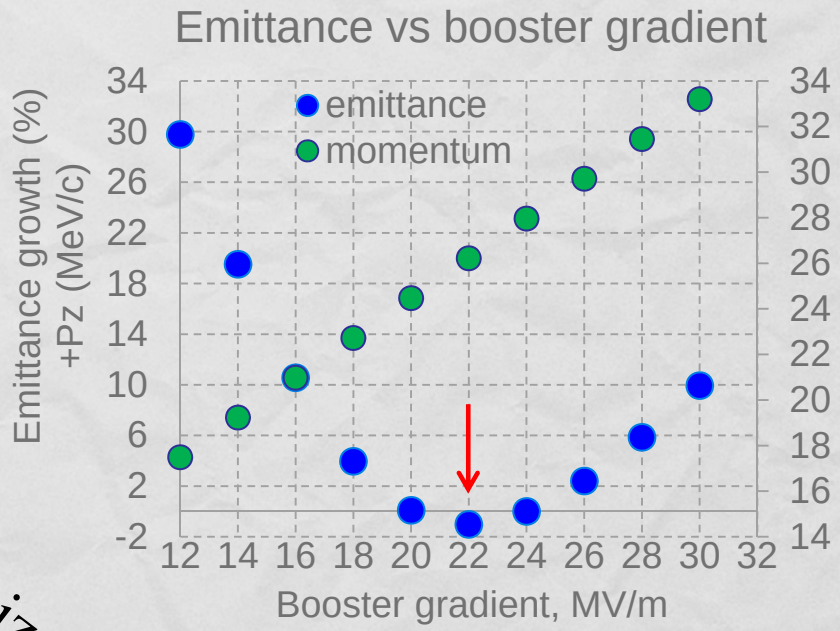




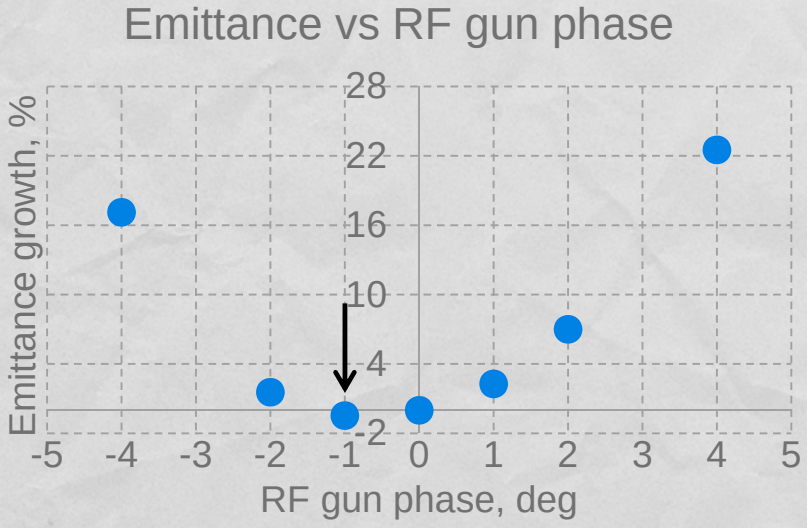
Emittances and beam sizes for 100pC charge and 160um laser rms spot size.

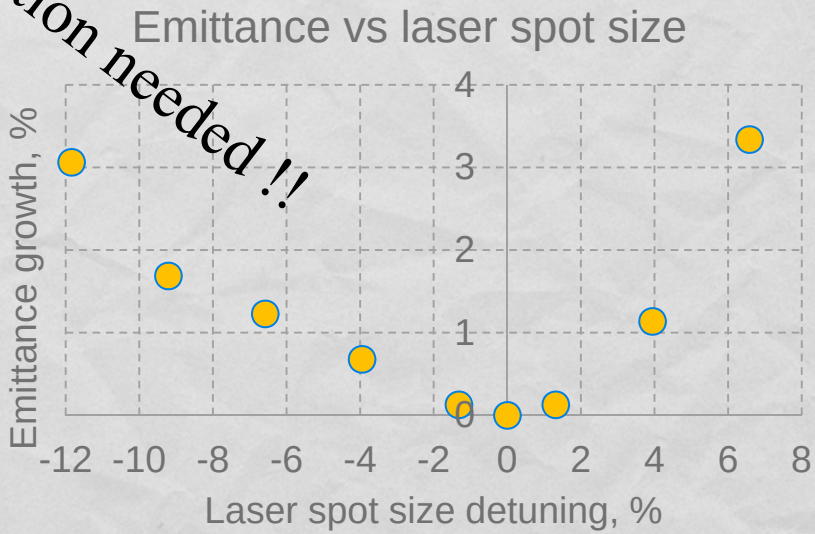
Tolerance studies for the point (1nC@17ps@380um)





Detailed scans for optimization needed !!





Reference point → 380um, 0.2377T, on-crest, 24MV/m

Summary table for 1nC and two different laser profiles

	parameter	unit	value
cathode laser	temporal	profile	Gaussian
	transverse	distribution	rad. hom.
	FWHM	ps	17
	XYrms	mm	0.38
	Ek	eV	0.55
	th. emit	mm mrad	0.322
RF gun	Ecath	MV/m	63.5
	phase	deg	-1
	maxBz	T	0.2377
CDS	maxE	MV/m	22
	phase	deg	0
beam @ EMSY1	charge	nC	1
	momentum	MeV/c	26.2
	proj. emit	mm mrad	1.168
	th./proj. em.	%	27.5
	av.sl. emit	mm mrad	0.98

	parameter	unit	value
cathode laser	temporal	profile	flat-top
	transverse	distribution	rad. hom.
	rt/FWHM\ft	ps	2/22\2
	XYrms	mm	0.401
	Ek	eV	0.55
	th. emit	mm mrad	0.34
RF gun	Ecath	MV/m	60.58
	phase	deg	-1.116
	maxBz	T	0.22808
CDS	maxE	MV/m	20.6
	phase	deg	0
beam @ EMSY1	charge	nC	1
	momentum	MeV/c	24.64
	proj. emit	mm mrad	0.6
	th./proj. em.	%	57
	av.sl. emit	mm mrad	0.53

Summary of optimized emittances at 1nC and two different laser temporal shapes.

- Rough emittance “optimization” for long Gaussian laser pulses at 100pC
- Rough emittance “optimization” for long Gaussian laser pulses at 1nC
- Summary

Summary

- Hard to make an emittance optimization for long Gaussian laser profile
- Only 27-38% contribution from thermal emittance (poor slice emittance)
- For 100pC@13ps@100um → XYemit=0.338mm (open questions…)
- For 100pC@17ps@100um → XYemit=0.354mm
- For 1nC@17ps@380um →XYemit=1.17mm mrad

Still to be done…

- Precise calculations to study the tolerances for 100pC and 1nC
- More detailed look on observed results (simulations for 1nC@15ps and laser rms spot size between [0.35-0.4]mm)
- RF gun gradient scan ?
- Change the optimization point from EMSY1 to EMSY2?

Thank you for attention !