Emittance and Beam Size Measurements in the Injector

Current Status Report

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Hamburg, 28.04.2020

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

DESY.

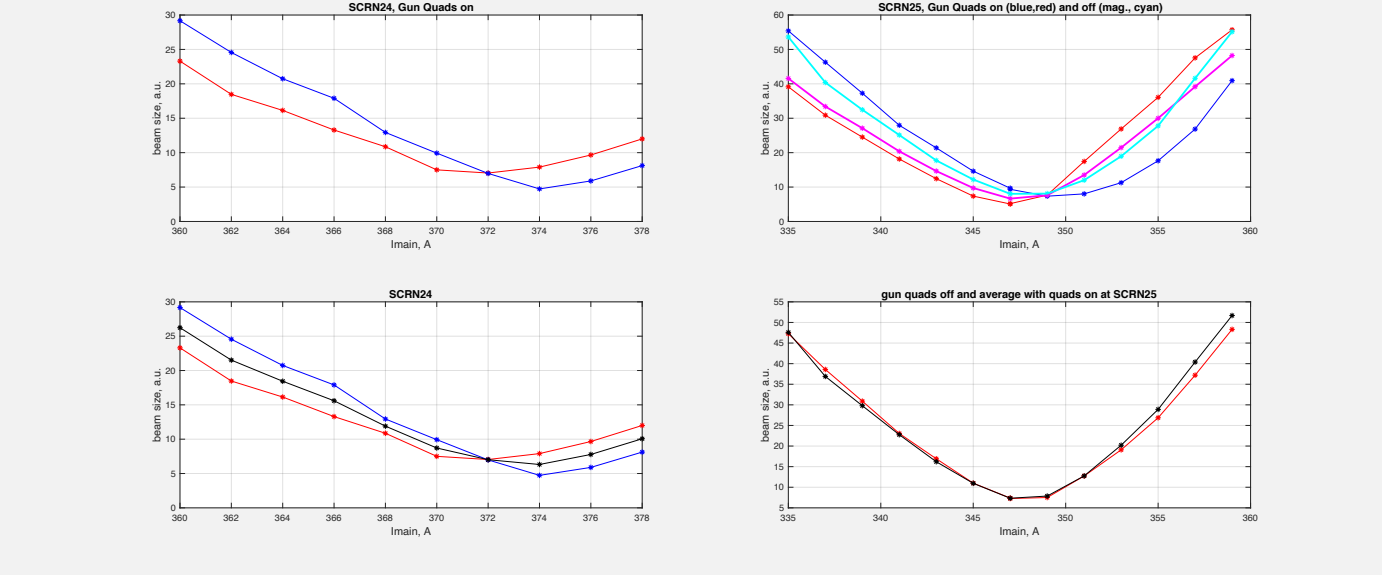
Outlook

Measurements on 29.10.2019 and 19.01.2020

Date		**29.10.2019**	**19.01.2020**
Parameters	Charge, pC	250	100, 250, 400
	BSA, mm	1.0	0.5 and 1.00
	Gun	55.6MV, -43 deg (MMMG phase)	
	Laser	Gauss, 3.119ps rms	
Measured	Beam size	yes	yes
	Emittance		for 250pC
Problems	Gun quads	on for SCRN24	off
	SCRN24	Noisy data, gun interlocks for high Imain	
	SCRN25	Saturation for small beam size	
Results		Solenoid calibration	Simulations running
		Effect of gun quads on beam size	

Beam size measurements

With and without gun quads. Measurements in October 2019



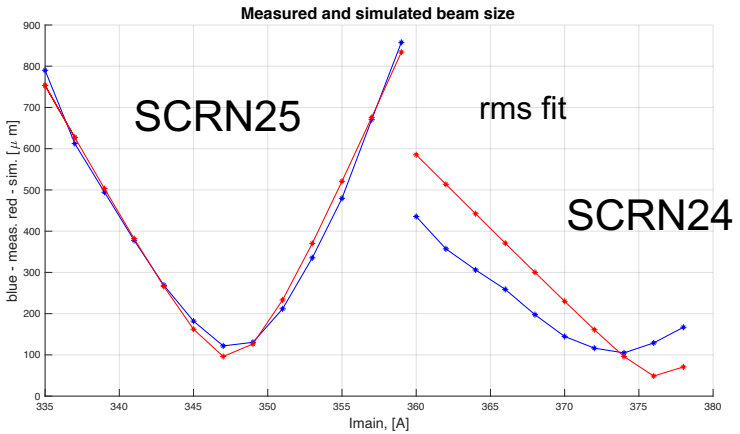
- Beam size measurements on SCRN24 with gun quads on only
- with and without gun quads on SCRN25
- Kick of QLN23 8.036mrad and of QLS23 3.675mrad
- Average (hor. and vert.) beam size at SCRN25 (plot 4) in good agreement with measurements without gun quads
- Average have been used for estimations at SCRN24

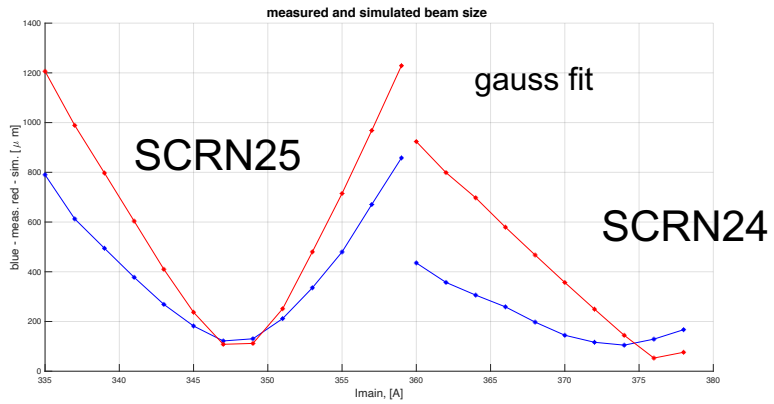
Beam size measurements

250pC. October 2019

Problems

- Screen calibration is unknown: 16.6μm/pxl assumed to fit rms measurements
- Gauss or rms beam size?
- Noisy data for SCRN24
- Gun interlocks for $I_{main} > 376A$ (and Vgun=56MV)
- Calibration of the solenoid described by $B = a_0 + a_1 \cdot I_{main}$ → first guess PITZ value for $a_1 = 5.8541 \cdot 10^{-4}$
- PITZ choice for a_1 leads to rather high value for $a_0 = 0.02$ in order to meet the minimum at SCRN25
- Doesn't fit the measurements at SCRN24



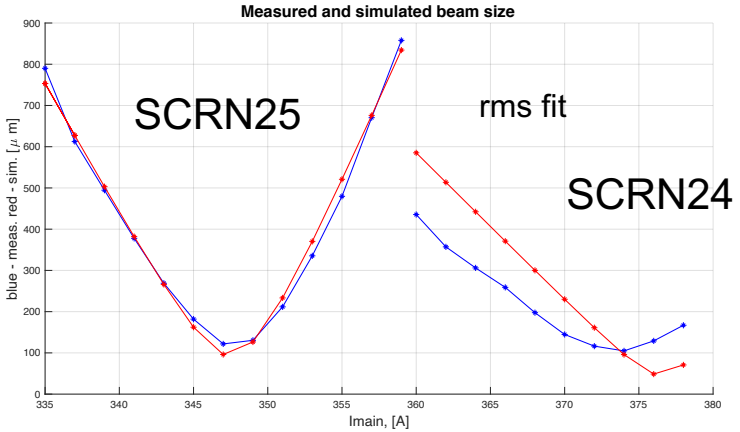


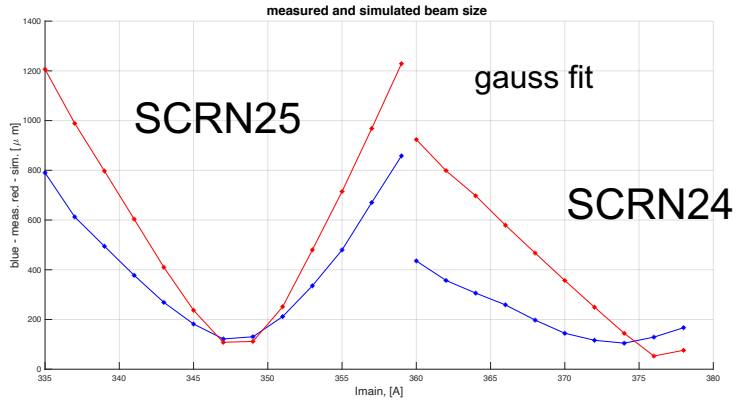
Solenoid Calibration

PITZ calibration

Method:

- Calibration of the solenoid:
  $B = a_0 + a_1 \cdot I_{main}$
- Once I_{main} for minimum beam size (maximum focussing) at two different points measured:
- $a_1 = \frac{B_2 - B_1}{I_2 - I_1}$;
- $a_0 = \frac{1}{2}\left(B_1 + B_2 - a_1(I_1 + I_2)\right)$
- Corresponding B_1 and B_2 to be found out from simulations
- PITZ calibration
  $a_1 = 5.8541 \cdot 10^{-4} \rightarrow a_0 = 0.02$





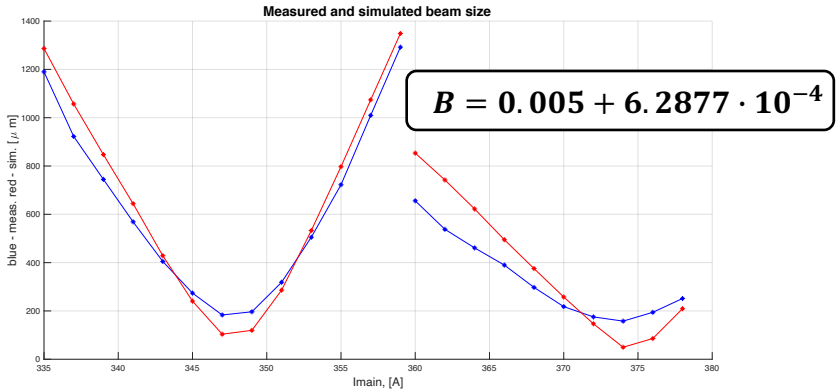
Solenoid Calibration

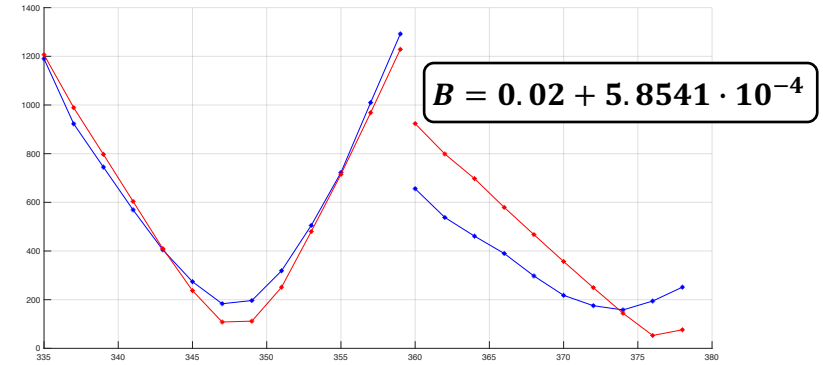
Fit the minima at SCRN24 and SCRN25. Measurements October 2019

Summary

- Screen calibration of 25μm/pxl assumed in order to fit the measurements at SCRN25
- Poor agreement between measurements at SCRN24 and SCRN25 → beam sizes do not increase with a predicted rate
- Measurement at SCRN24 too noisy and thus less truthworthy
- Probably saturation effects for small beam sizes, leading to overestimating of the beam size there
- Beam size behaviour at SCRN24 for higher solenoid currents missing (gun interlocks)

fit for gaussian beam size measurement





Improvements

Measurements in January 2020

Goal/Plan

- Take more accurate care of saturation and noisy effects during measurements
- Accomplish with the emittance measurements
- Measure with gun quads off
- Take data for other charges

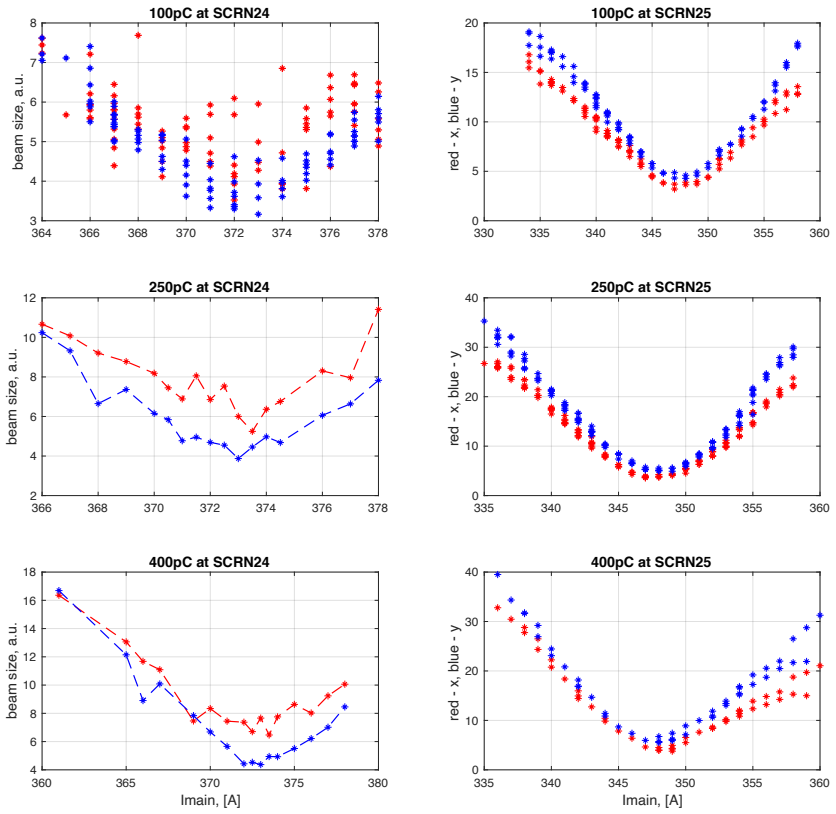
Measured Beam Sizes in Injector

January 2020

Summary:

- Smooth measurement for SCRN25
- Noisy data at SCRN24
- Gun interlock for Imain > 378A

Q, pC	100	250	400
BSA, mm	1.0	1.0	1.0
Gun V, MV	55.6	55.6	55.6
Gun Phi, deg	-43	-43	-43
$I(\sigma_x=min)_{SCRN24}$, A	372	373.5	373
$I(\sigma_y=min)_{SCRN24}$, A	373	373	372.5
$I(\sigma_x=min)_{SCRN25}$, A	347	347	348
$I(\sigma_y=min)_{SCRN25}$, A	348	348	348



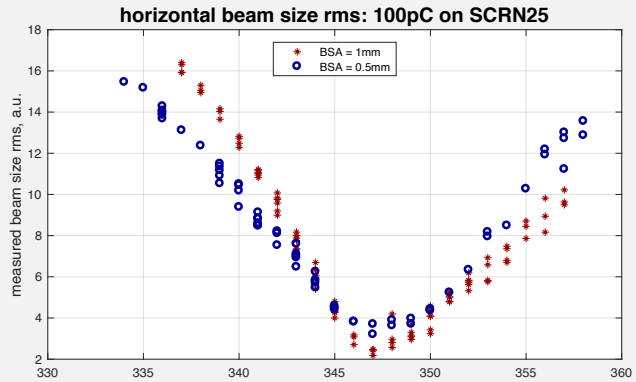
Beam Size Measurements for 100pC

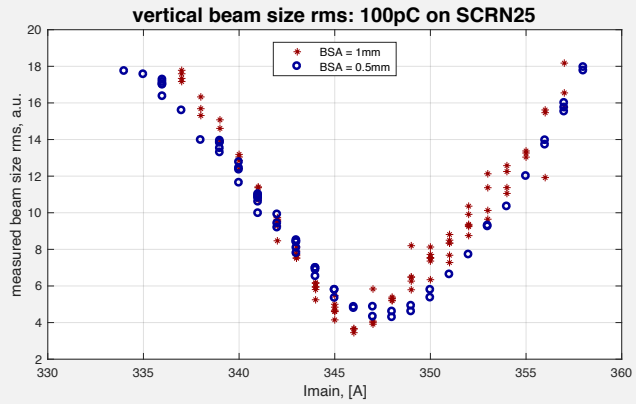
On SCRN25

Summary

- Almost no difference between 0.5mm and 1.0mm BSA
- Horizontally: stronger focussing for 1mm BSA
- Vertically: less prominent difference between 0.5mm and 1mm BSA

BSA, mm	0.5	1.0
Gun V, MV	55.6	55.6
Gun Phi, deg	-43	-43
I(σ_x=min), A	347	347
σ_{xmin}, a.u.	3.7	2.5
I(σ_y=min), A	347.5	346
σ_{ymin}, a.u.	4.3	3.5





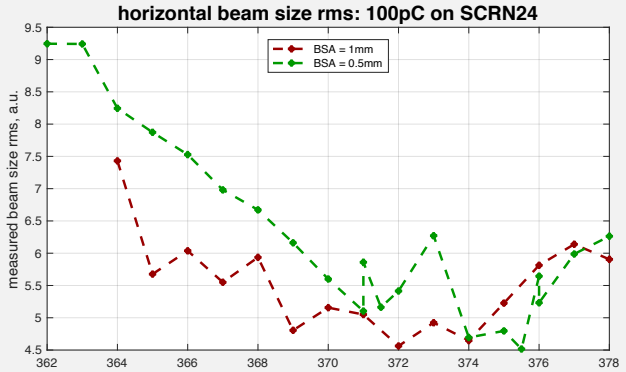
Beam Size Measurements for 100pC

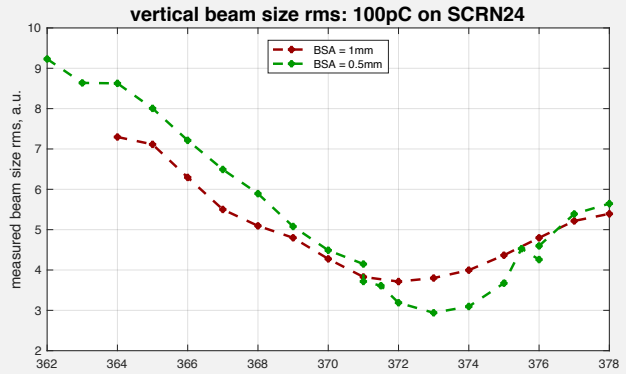
On SCRN24

Summary

- Beam size for smaller BSA tends to grow faster
- Stronger field needed to get maximum focusing for smaller BSA

BSA, mm	0.5	1.0
Gun V, MV	55.6	55.6
Gun Phi, deg	-43	-43
I(σ_x=min), A	375	372
σ_{xmin}, a.u.	4.51	4.56
I(σ_y=min), A	373	372
σ_{ymin}, a.u.	2.94	3.71



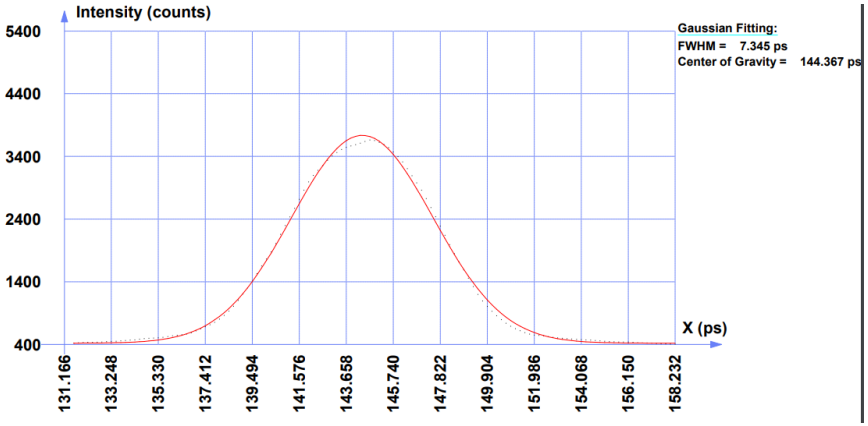


Longitudinal profile

Data from diagnostics

Longitudinal

- Gaussian approximation used
- FWHM=7.345ps → σ=3.125ps

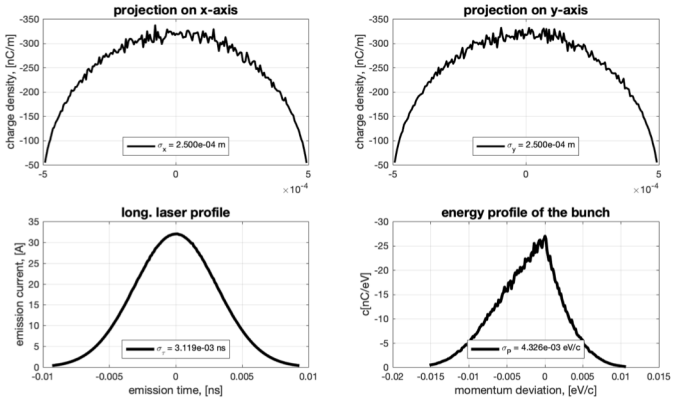


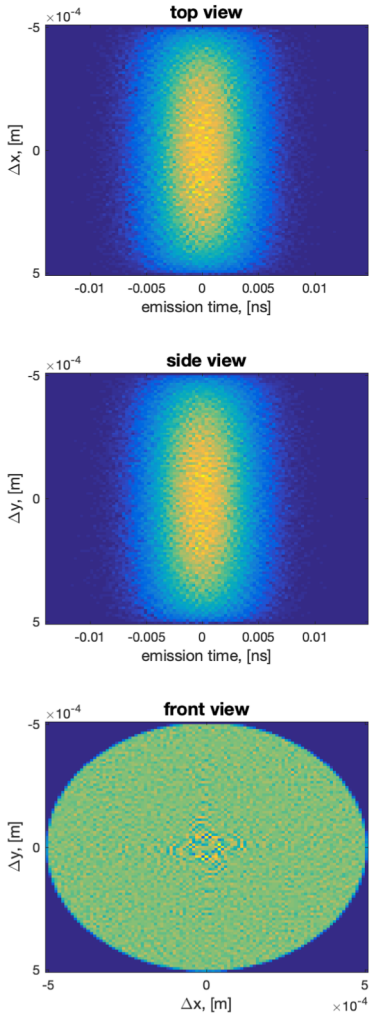
Transverse profile

Radial uniform distribution

Create ASTRA Distribution first with:

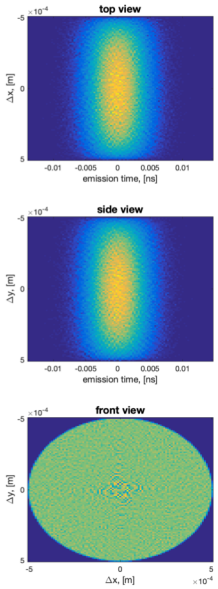
- 1mm (or 0.5mm) diameter BSA
- Transverse: radial uniform distribution
- Longitudinal: gaussian with 3.11ps rms
- Here: 200k particles



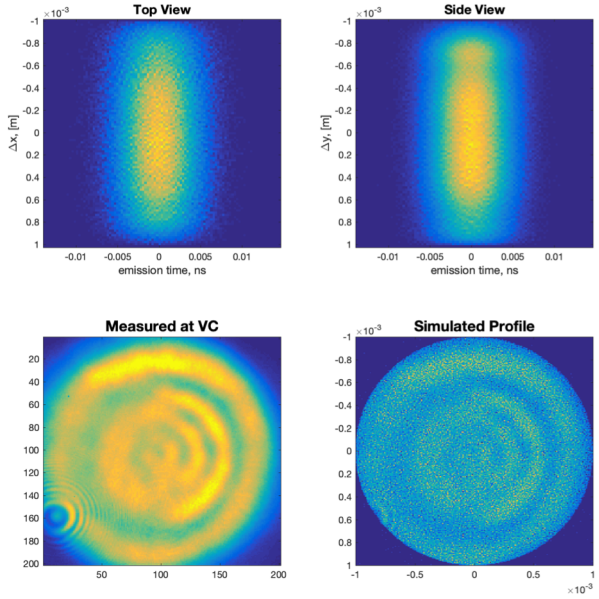


Transverse profile

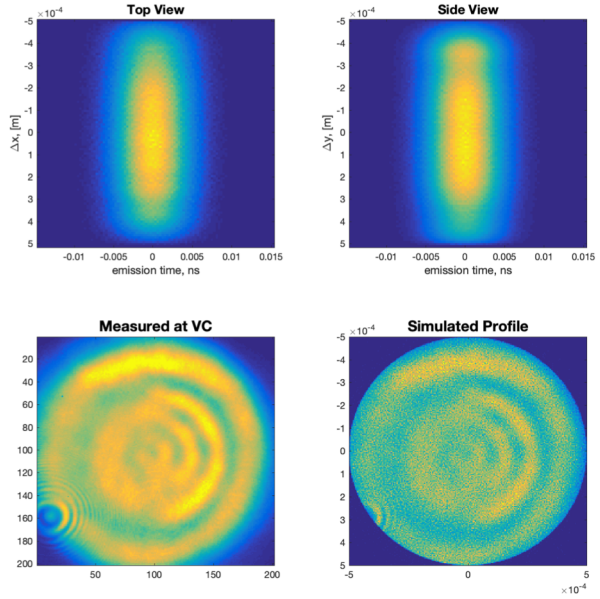
Imprint measured laser profile from VC



Initial radial uniform distribution



Imprint with 200k particles



Imprint with 1M particles

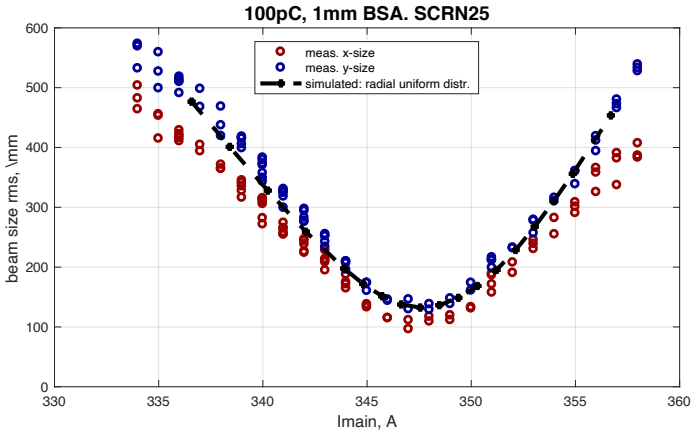
Measurements and Simulations for 100pC

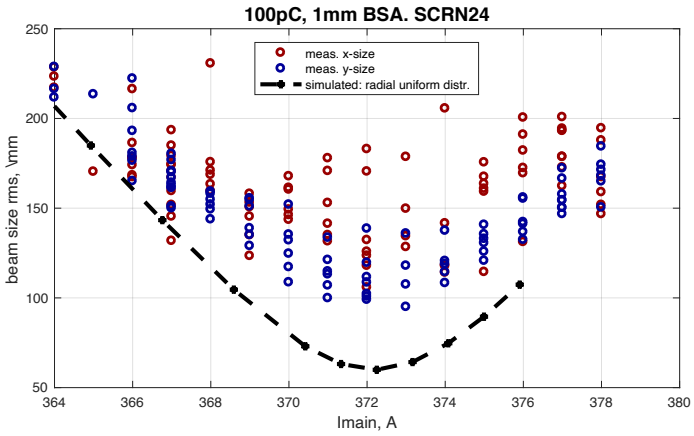
Solenoid Calibration. 1mm BSA

Summary

- Screen calibration 30μm/pxl assumed
- Noisy data for SCRN24. Further filtering of measurements data to be carry out
- Overestimated size for focused beam on SCRN24
- Probably good agreement for SCRN25

	SCRN24	SCRN25
BSA	1.0mm	
GunV	55.6 MV	
GunPhi	-43 deg (MMMG)	
OTR Calibration	30μm/pxl	
Sol.Calibration	6.8340e-4*I – 0.0155	
$I_{main_{min}}$ (meas.)	372.2	347.5





Solenoid Calibration: $B = a_1 I + a_0$

Summary for measurements with 100pC

Model	Measured		Simulated		Calibration	
	I_{24}	I_{25}	B_{24}	B_{25}	a_1	a_0
Q=100pC BSA=0.5mm Gun: 55.6MV/m, 0deg Radial uniform	374.0	347.25	0.24050	0.22310	7.0303e-4	-0.0210
Q=100pC BSA=1.0mm Gun: 55.6MV/m, 0 deg Radial uniform	372.2	347.5	0.23888	0.22200	6.8340e-4	-0.0155
Q=100pC BSA=0.5mm Gun: 55.6MV/m, 0 deg VC distribution	374.0	347.25	0.24020	0.22281	7.0100e-4	-0.0206
Q=100pC BSA=1.0mm Gun: 55.6MV/m, 0 deg VC distribution	372.2	347.5		0.22193	*Simulations ongoing*	
PITZ first guess					*5.8541e-4*	*?*
Data Base					*6.0000e-4*	*0*

Solenoid Calibration: $B = a_1 I + a_0$

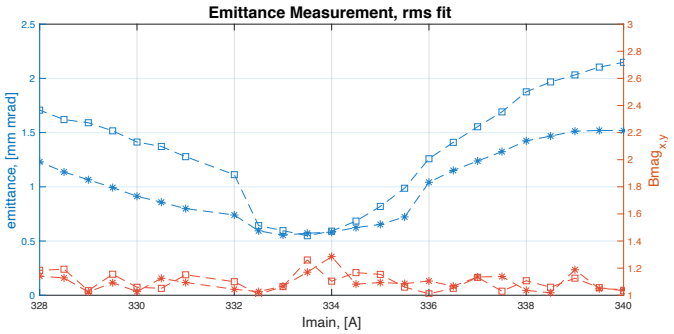
Summary for measurements with 250 and 400pC

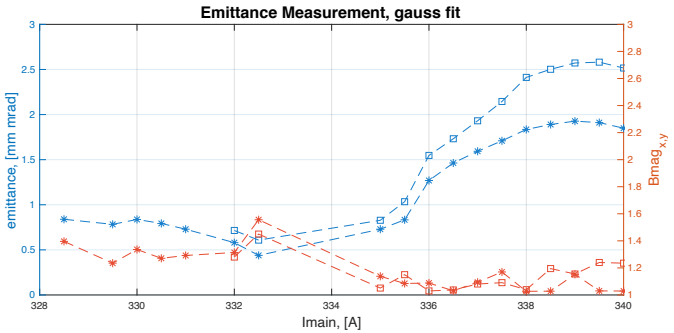
Model	Measured		Simulated		Calibration	
	I_{24}	I_{25}	B_{24}	B_{25}	a_1	a_0
Q=250pC BSA=1.0mm Gun: 55.6MV/m, 0deg Radial uniform	373.25	347.5	0.24025	0.22322	6.6136e-4	-0.0066
Q=250pC BSA=1.0mm Gun: 55.6MV/m, 0 deg VC distribution	373.25	347.5	0.24026	0.22340	6.5476e-4	-0.0041
Q=250pC BSA=1.0mm Gun: 58.0MV/m, 4 deg VC distribution	373.25	347.5	0.24949	0.23190	6.8311e-4	-0.0055
Q=400pC BSA=1.0mm Gun: 55.6MV/m, 0 deg Radial uniform	372.75	348	0.24065	0.22322	7.0424e-4	-0.0219
Q=250pC, October 2019					6.2877e-4	0.0050
PITZ first guess					*5.8541e-4*	*?*
Data Base					*6.000e-4*	*0*

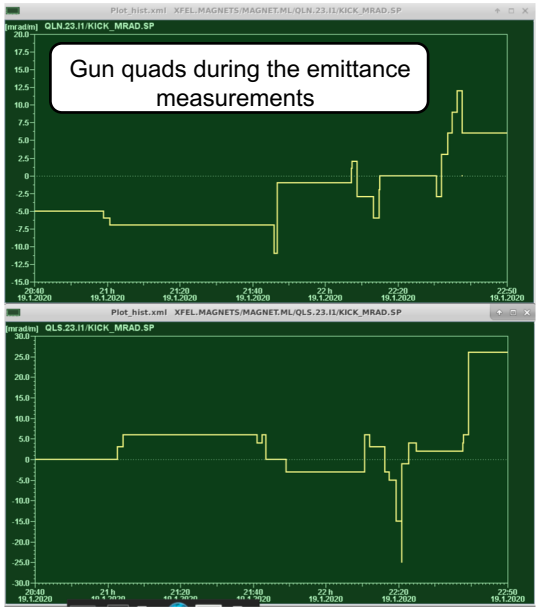
Emittance measurements

250pC. January 2020

- Detailed measurement row for the rms fit for solenoid current from 328 to 340A
- Gaussian fit: different behaviour for $I_{main} < I_{main}(\varepsilon = min)$. No match was found for minimum emittance
- Corresponding simulations ongoing







Matching with the help of gun quads

- vary gun quads in the range of $\pm 20 mrad$ in order to get matching for different solenoid current
- Mismatch well below 1.2 for solenoid current in the range of 12A

Summary

- Beam size measurement series have been done for 100, 250 and 400pC
- Emittance measurements for 250pC and well matched beam for a wide range of solenoid current
- Gun quads proved to be a powerful tool to get matched beam.
- Simulations to reconstruct the beam sizes and emittance in the injector are running/ongoing.
- First iteration for solenoid calibration done. To be improved after analysis of further data.

Problems/Tasks

- Noisy data for the first screen (SCRN24).
- Screen resolution is not known

Thank you

Back Slides

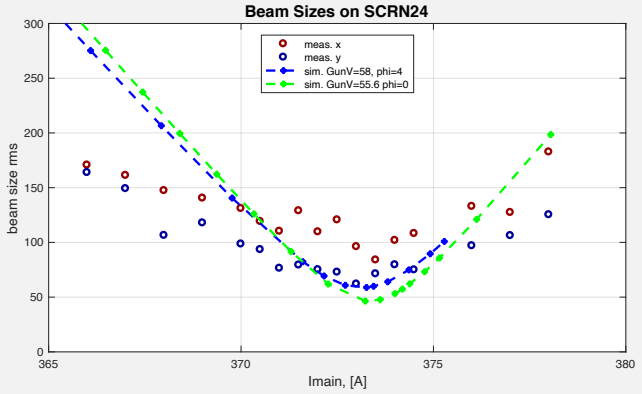
Beam sizes for 250pC

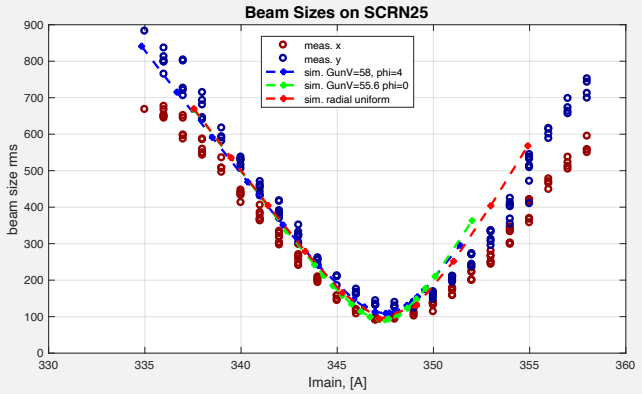
Measurements and simulations

Results

- Noisy data for SCRN24 – no agreement between measurements and simulations
- Good agreement for SCRN25
- Doesn't matter which model to use
- Slightly better agreement for radial uniform model, most probably due to initially larger beam size

	Solenoid calibration
GunV=58.0MV, phi=4, VC transv. data	B=6.8388e-4*I-0.0058
GunV=55.6MV, phi=0, VC transv. data	B=6.5204e-4*I-0.0032
GunV=55.6MV, phi=0, rad.uniform distribution	
PITZ Calibration	





	SCRN24	SCRN25
BSA	1.0mm	
Screen Cal., μm/pxl	16	25
$I_{main_{min}}$ (meas.)	372.5	346.5

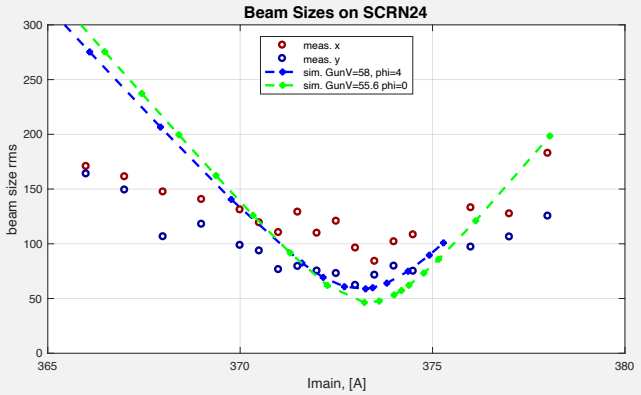
Simulations

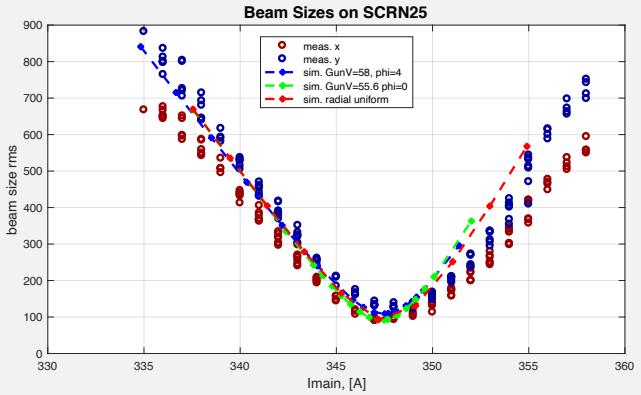
Description

Results

- Solenoid calibration differs from 250pC: Discrepancy at SCRN25
- Noisy data for SCRN24

	SCRN24	SCRN25
BSA	1.0mm	
GunV	55.6 MV	
GunPhi	-43 deg (MMMG)	
OTR Calibration	30μm/pxl	
Sol.Calibration	6.2877e-4*I+0.005	
$I_{main_{min}}$ (meas.)	372-?	346/347
$I_{main_{min}}$ (sim.)	372	345





Measurements and Simulations for 100pC

0.5mm BSA. Radial uniform distribution in simulations

Results

- Solenoid calibration results in a fair fit for SCRN25
- Noisy data for SCRN24

	SCRN24	SCRN25
BSA	0.5 mm	
GunV	55.6 MV	
GunPhi	-43 deg (MMMG)	
OTR Calibration	40μm/pxl	
Sol.Calibration	6.2877e-4*I+0.005	
$Imain_{min}$ (meas.)	370-375	347/348
$Imain_{min}$ (sim.)	374	347