Intensity-dependent effects at ATF2

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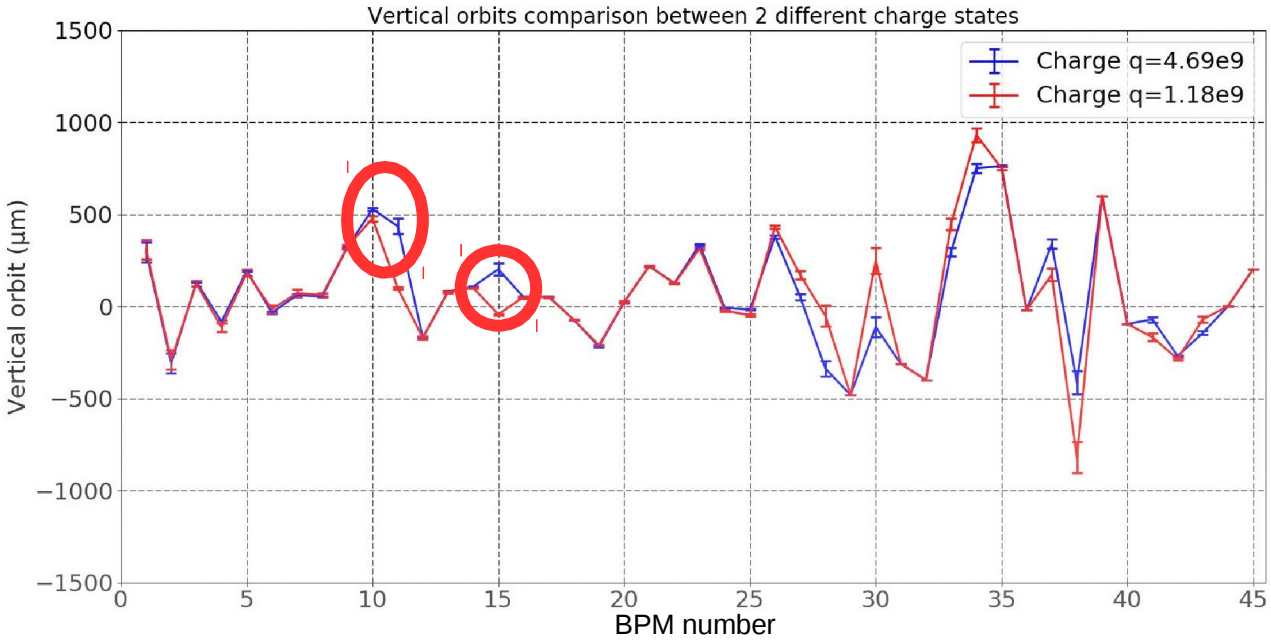
Acknowledgment: A. Latina, T. Okugi

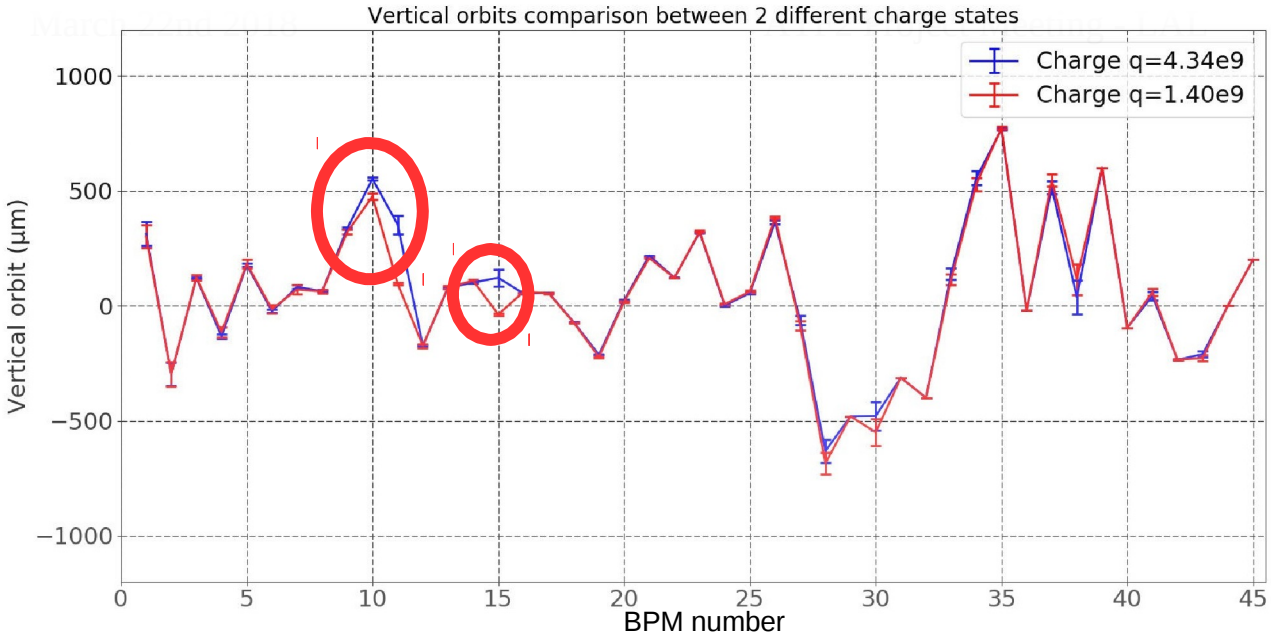
Outline

- **Previous intensity dependence results using BPMs.**
- **Intensity depedence studies using Placet.**
- **Dispersion Free Steering and Wakefield Free Steering first results.**
- **Plans for ATF2 run in June.**

Previous intensity dependence results using BPMs

Results from February 2018

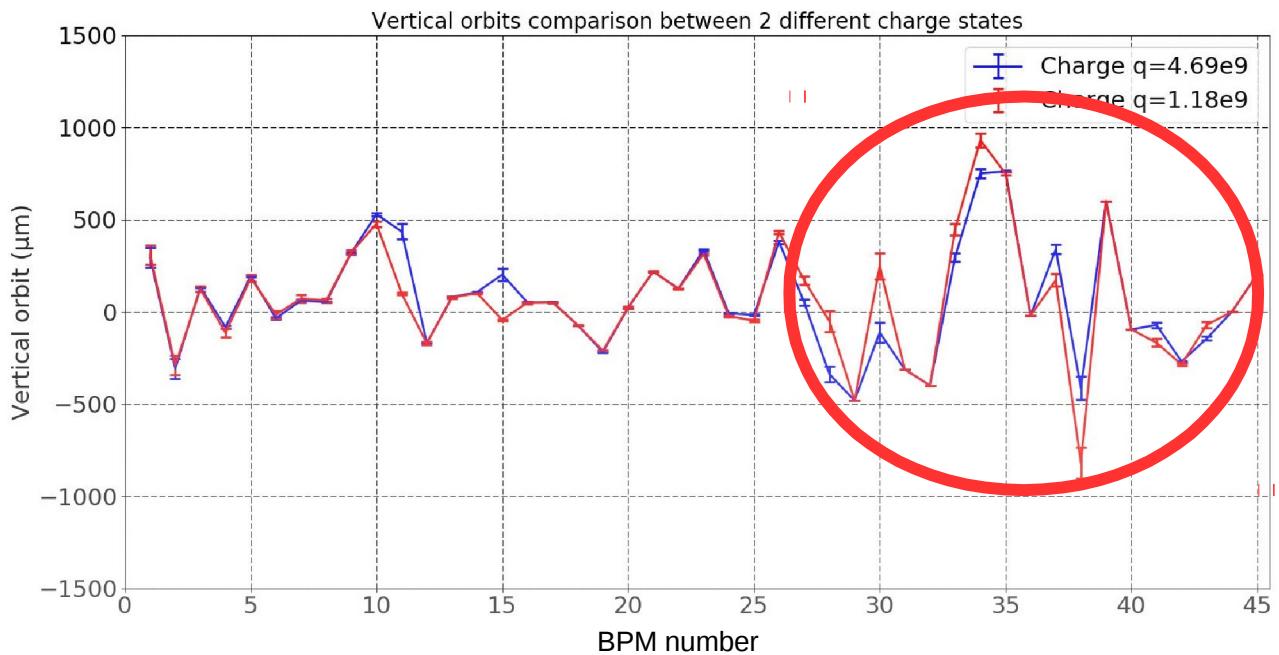




High intensity dependence observed at some BPMs, especially MQD8X (n°10), MQF9X (n°11) and MQF13X (n°15), all striplines.

Okugi-san told me that these striplines can't be trusted at high charge.

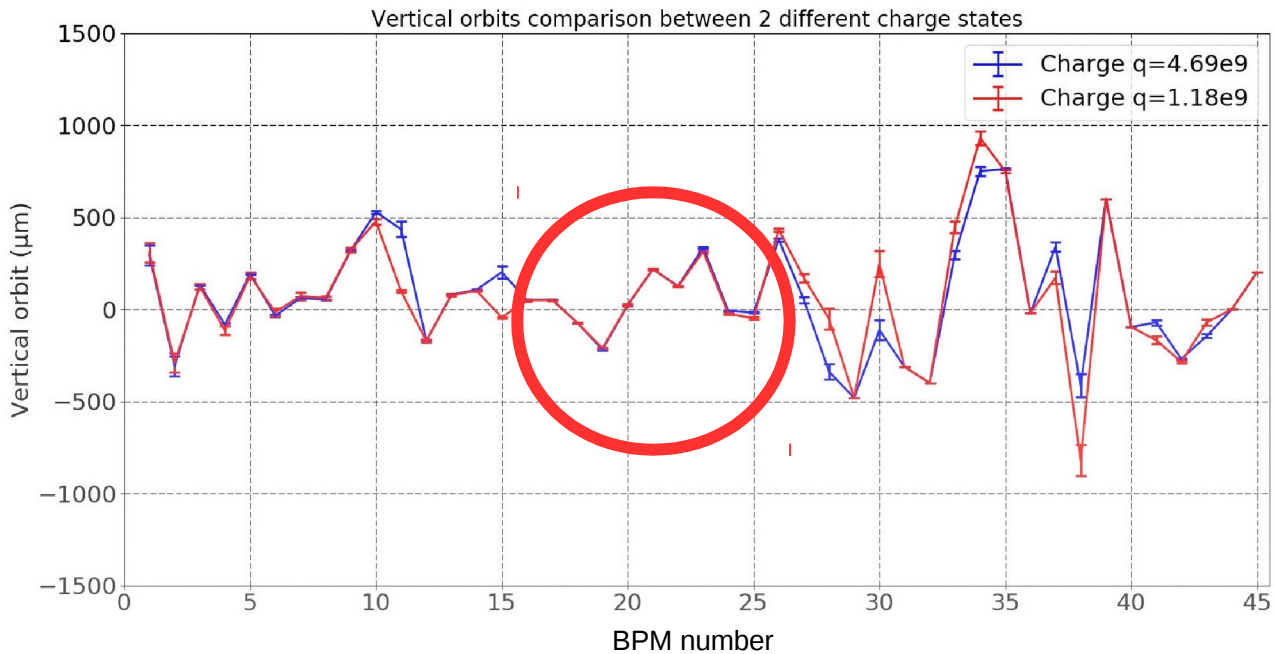
Results from February 2018



High intensity dependence also observed from cavBPM QM12FF (n°27) to the end.

A. Lyapin told me that these cavBPMs can't be trusted at high charge.

Results from February 2018



According to A. Lyapin only the first 10 cav BPMs are usabe for intensity dependence studies. From QD16X to QM13FF

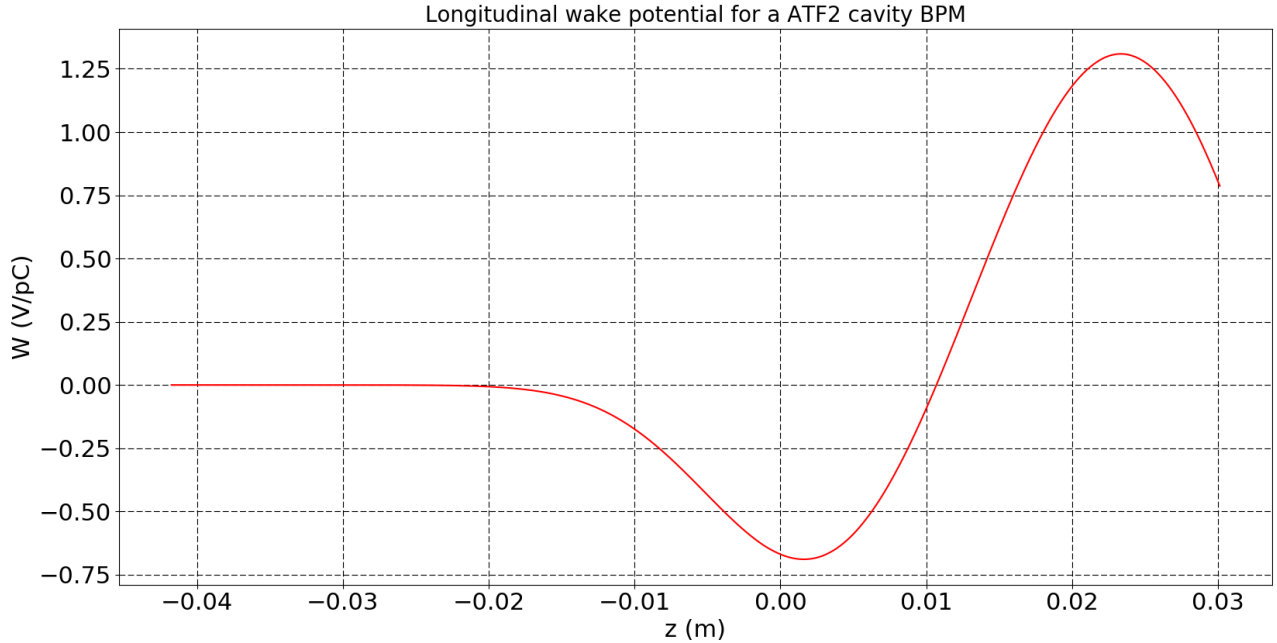
Intensity dependence studies using Placet

Simulation conditions

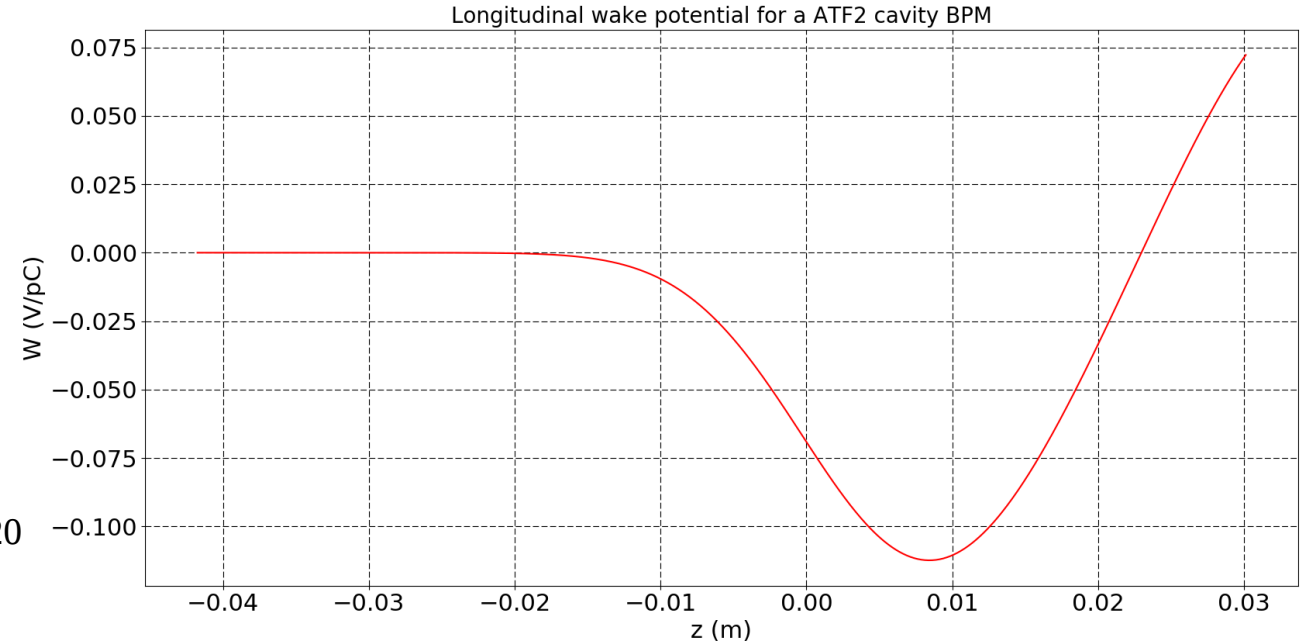
- **Wakefields used: GdfdL simulations from A. Lyapin.**

Wake potential of the cavity BPM

Longitudinal



Transverse



These wake potentials are used at every CavBPM.

Simulation conditions

- **Wakefields used: GdfdL simulations from A. Lyapin.**
- **Latest BPMs configuration with BPM resolution.**

Type	Resolution
Stripline	5.0μm
C-band BPM	1.0μm

ATF2 BPMs used in Placet simulations

BPM number	BPM name	s(m)	Type	BPM number	BPM name	s(m)	Type
1	MB1X	3.0851	STRIPLINE	24	QM15FF	53.3157	CBPM
2	MB2X	5.1001	STRIPLINE	25	QM14FF	54.8157	CBPM
3	MQF1X	7.2194	STRIPLINE	26	QM13FF	56.3157	CBPM
4	MQD2X	9.218	STRIPLINE	27	QM12FF	57.8157	CBPM
5	MQF3X	10.1891	STRIPLINE	28	QM11FF	59.4157	CBPM
6	MQF4X	14.4946	STRIPLINE	29	QD10BFF	60.9157	CBPM
7	MQD5X	15.2257	STRIPLINE	30	QD10AFF	61.8157	CBPM
8	MQF6X	17.2243	STRIPLINE	31	QF9BFF	63.1157	CBPM
9	MQF7X	20.6642	STRIPLINE	32	SF6FF	63.6757	CBPM
10	MQD8X	22.9347	STRIPLINE	33	QF9AFF	64.2357	CBPM
11	MQF9X	24.8416	STRIPLINE	34	QD8FF	66.0357	CBPM
12	QD10X	27.7434	CBPM	35	QF7FF	67.9357	CBPM
13	QF11X	29.1934	CBPM	36	QD6FF	69.8358	CBPM
14	QD12X	30.6434	CBPM	37	QF5BFF	71.6358	CBPM
15	MQF13X	31.6798	STRIPLINE	38	QD4BFF	74.0558	CBPM
16	MQD14X	32.7153	STRIPLINE	39	SD4FF	74.6158	CBPM
17	QD16X	34.7812	CBPM	40	QD4AFF	75.1758	CBPM
18	QF17X	36.2312	CBPM	41	QF3FF	77.9759	CBPM
19	QD18X	38.6137	CBPM	42	QD2BFF	79.676	CBPM
20	QF19X	40.0584	CBPM	43	QD2AFF	81.376	CBPM
21	QD20X	43.8237	CBPM	44	SF1FF	86.0509	CBPM
22	QF21X	47.8164	CBPM	45	QF1FF	86.999	CBPM
23	QM16FF	51.5817	CBPM	46	M-PIP	89.8417	CBPM

Simulation conditions

- **Wakefields used: GdfdL simulations from A. Lyapin.**
- **Latest BPMs configuration with BPM resolution.**
- **Misalignment of Quadrupoles, CavBPMs, Sextupoles of 100um RMS unless specified.**

Simulation conditions

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- **100 random seeds (machines) unless specified.**

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- **BBA correction applied: 1to1, DFS, WFS.**

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- **100 random seeds (machines) unless specified.**
- **BBA correction applied: 1to1, DFS, WFS.**
- **200 pulses – angle jitter between $0.1\sigma_{y'}$ and $0.5\sigma_{y'}$ With $\sigma_{y'}$ the angular divergence.** $\sigma_y' = \sqrt{\epsilon_y/\beta_y}$

Simulation conditions

- **Wakefields used: GdfdL simulations from A. Lyapin.**
- **Latest BPMs configuration with BPM resolution.**
- **Misalignment of Quadrupoles, CavBPMs, Sextupoles of 100um RMS unless specified.**
- **100 random seeds (machines) unless specified.**
- **BBA correction applied: 1to1, DFS, WFS.**
- **200 pulses – angle jitter between $0.1\sigma_{y'}$ and $0.5\sigma_{y'}$**
- **Following knobs used to correct the IP distribution: <y,x'>, <y,y'>, <y,E>, <y,x'²>, <y,x'*y'>, <y,x'*E>.**

Ideal knobs used

They always find the best correction for the beam distribution.

They work as the following:

First we define the knobs we are using as *Ay*. In this case we are using:
the following 1st order knobs: <y,x'>, <y,y'>, <y,E>
the following 2nd order knobs: <y,x'²>, <y,x'*y'>, <y,x'*E>.

$$Ay = [\, X' \; Y' \; E \; X' * Y' \; X' * E \,]$$

With X', Y', E respectiveley the particle horizontal angle, vertical angle, energy.

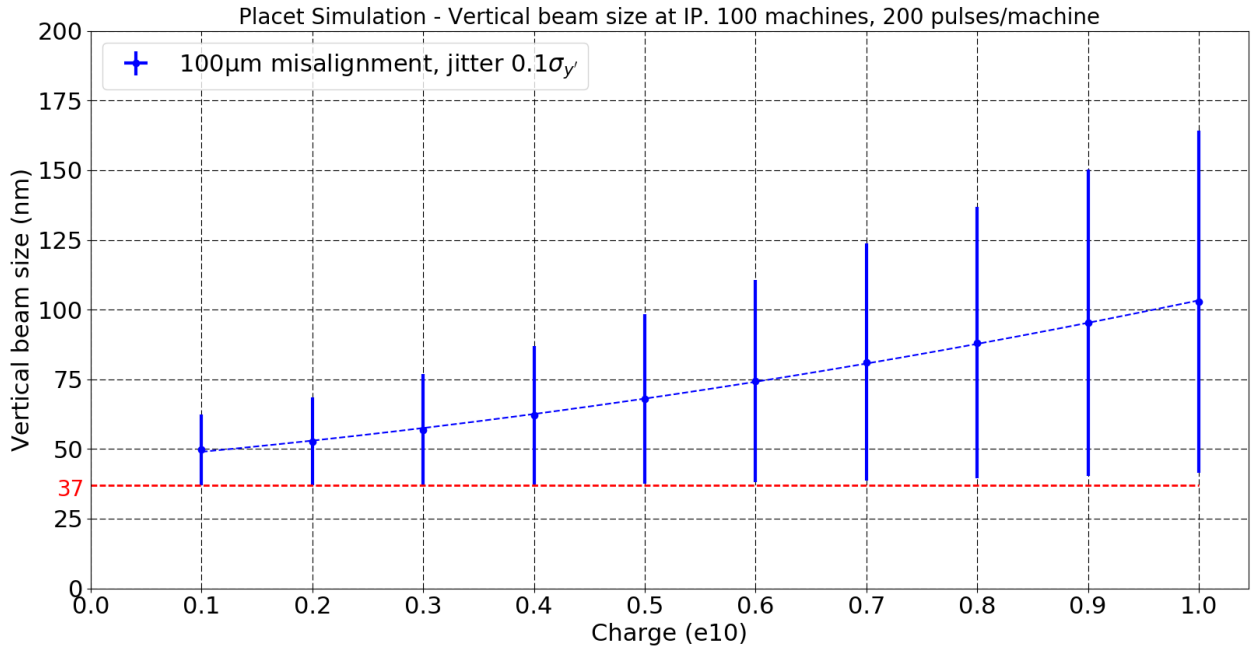
Then we calculate the correlations *Cy* between these parameters and *Y* as follow:

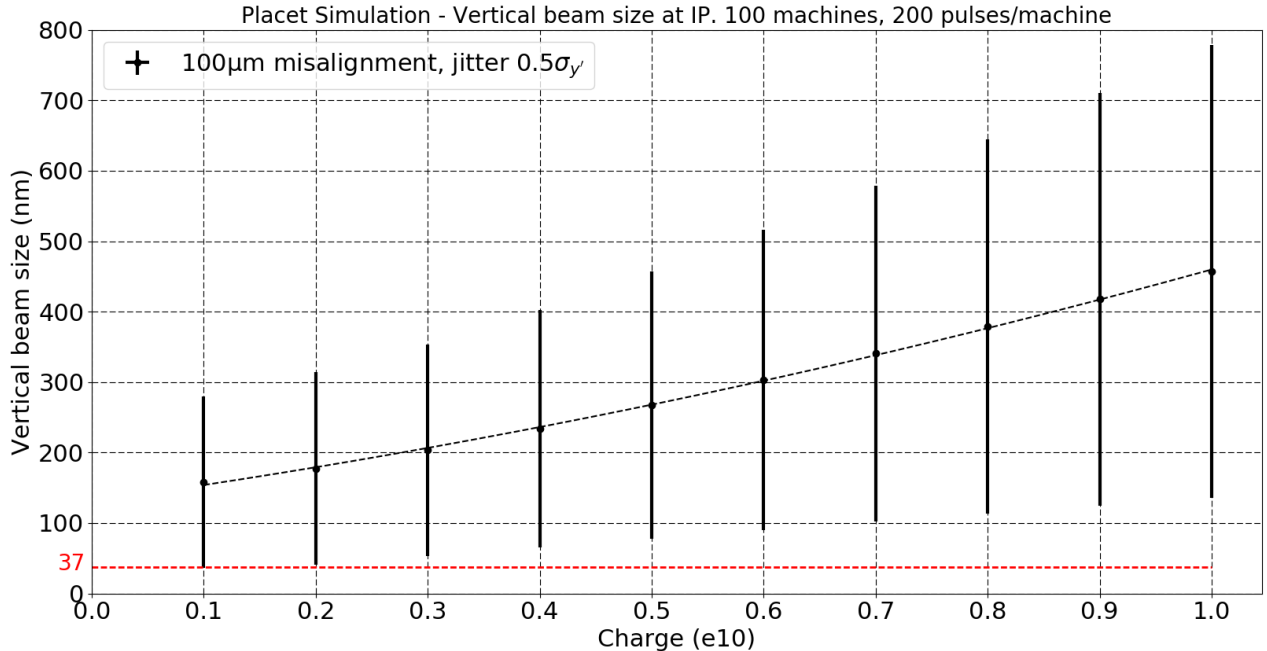
$$Cy = Ay^{-1} * Y$$

Finally you calculate the corrected *Y*, here called *Yc* by removing the correlations.

$$Yc = Y - Ay * Cy$$

Impact of the beam angle jitter





100 machines

200 pulses/machine

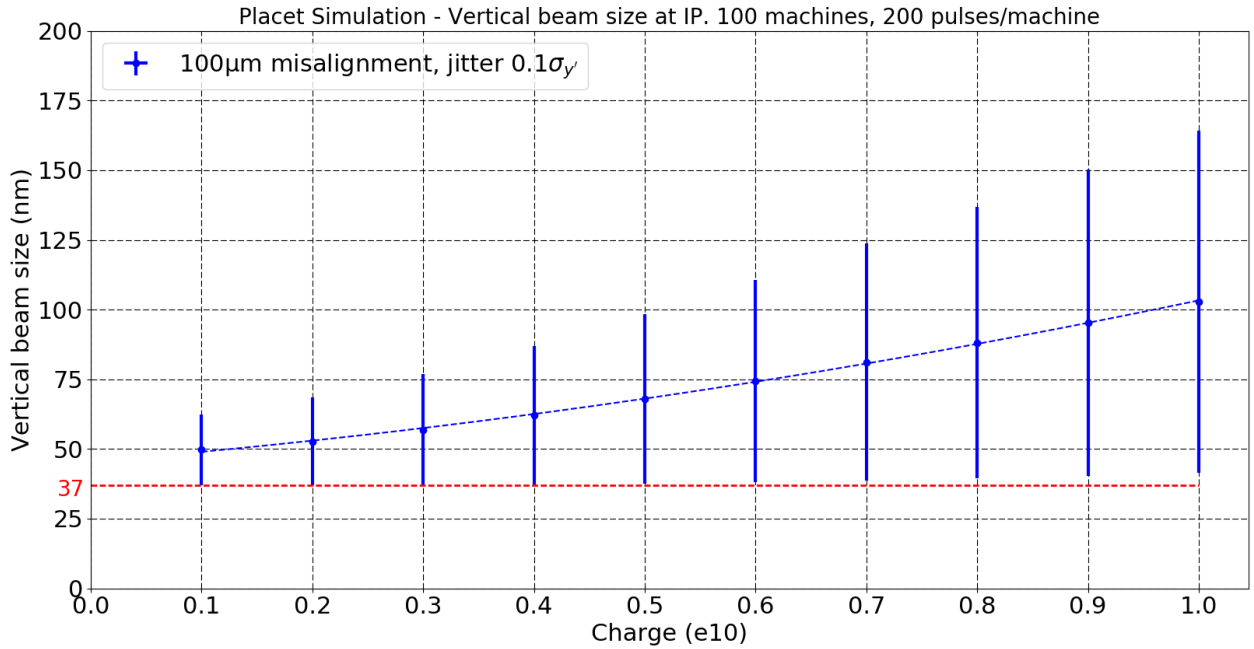
20.000 beam size measurements per charge state

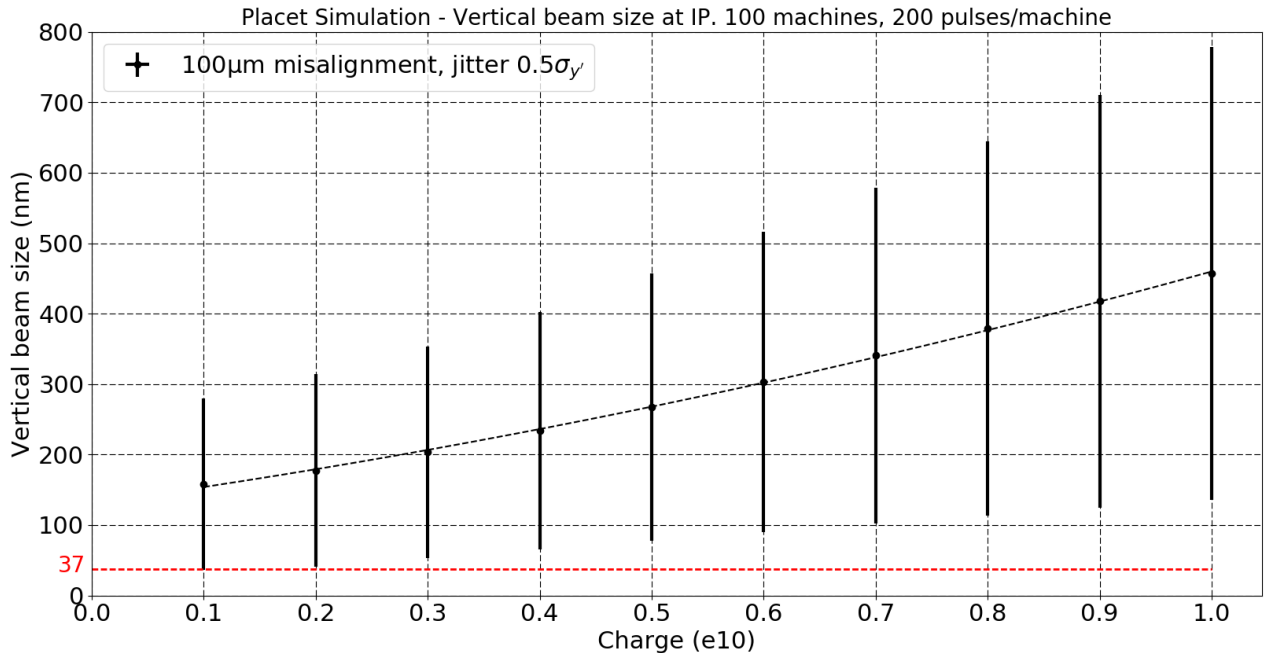
The error bars are representing the standard deviation of the sample:

$$std = \frac{\sqrt{\Sigma\left(\sigma_y - \overline{\sigma_y}\right)^2}}{N}$$

With $\overline{\sigma}_y$ the average vertical beam size and N the number of measurements.

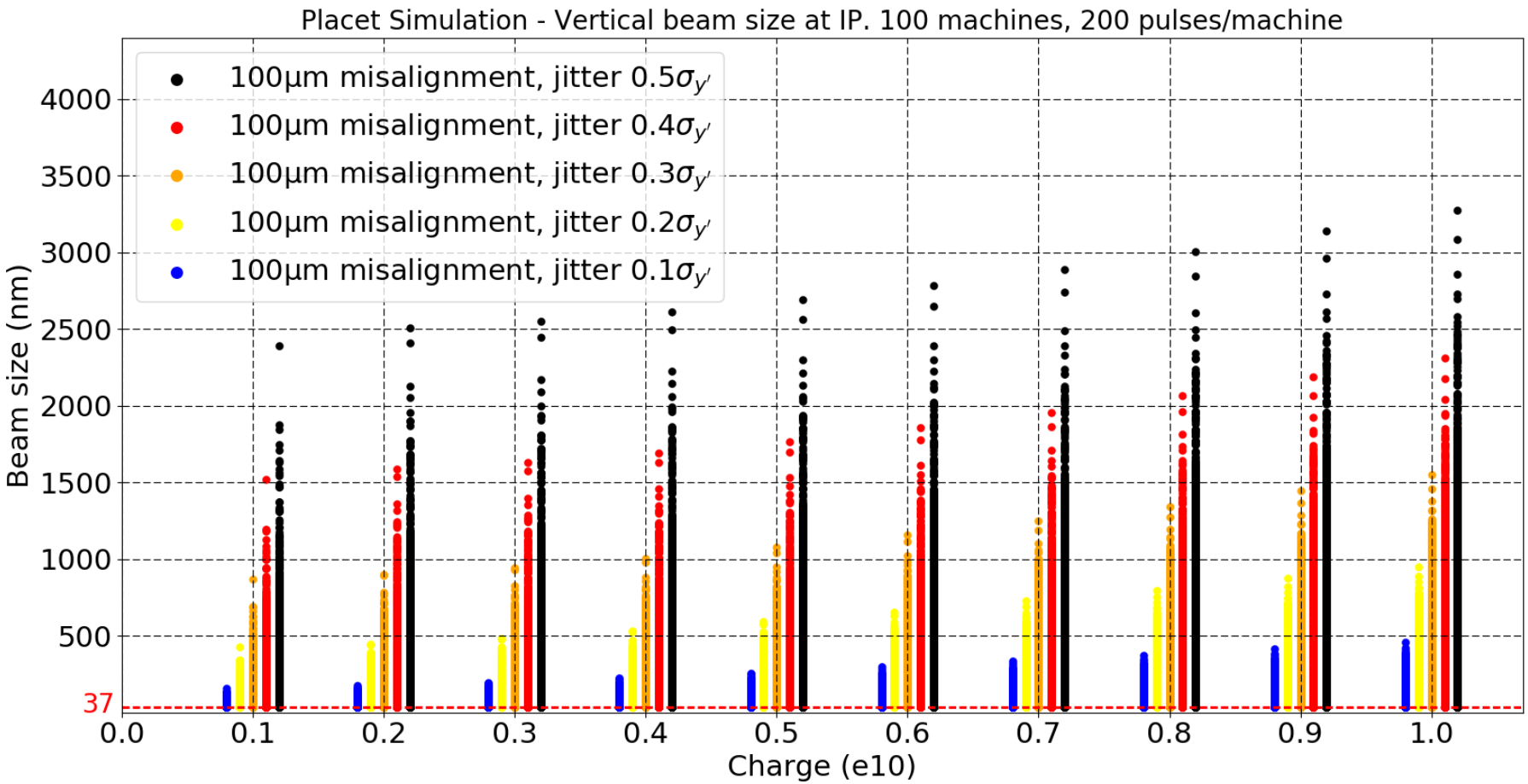
Impact of the beam angle jitter





The beam size seems to scale linearly with the jitter and to scale quadratically with the beam charge.

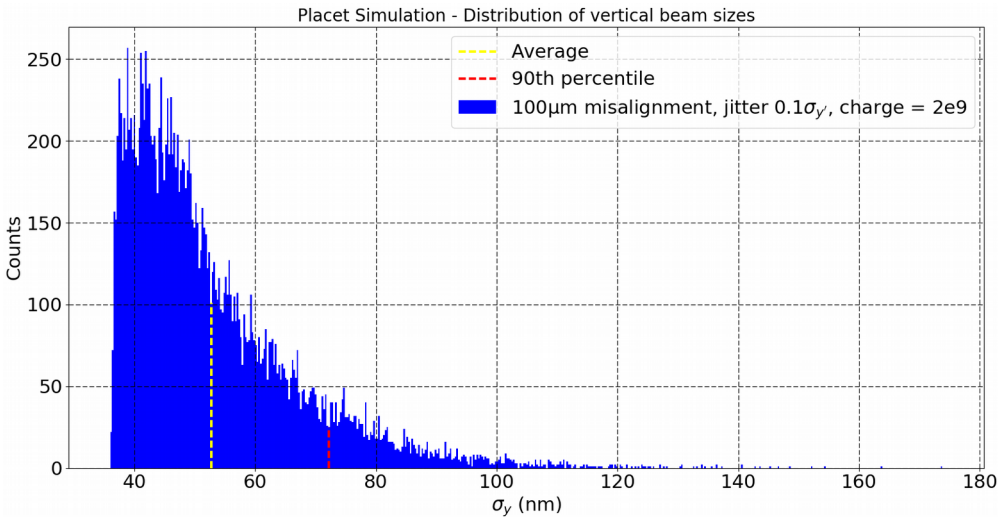
Impact of the beam angle jitter – All pulses

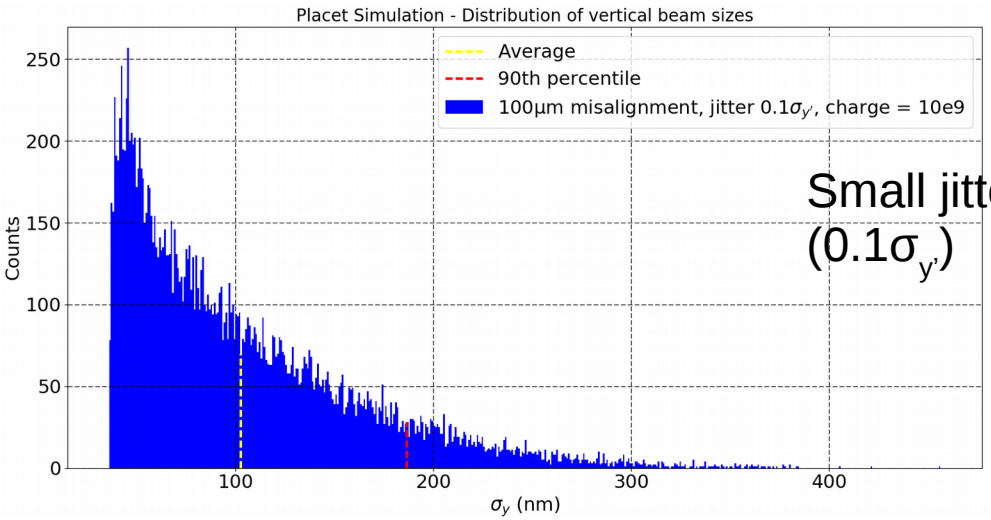


Impact of the beam angle jitter – All pulses

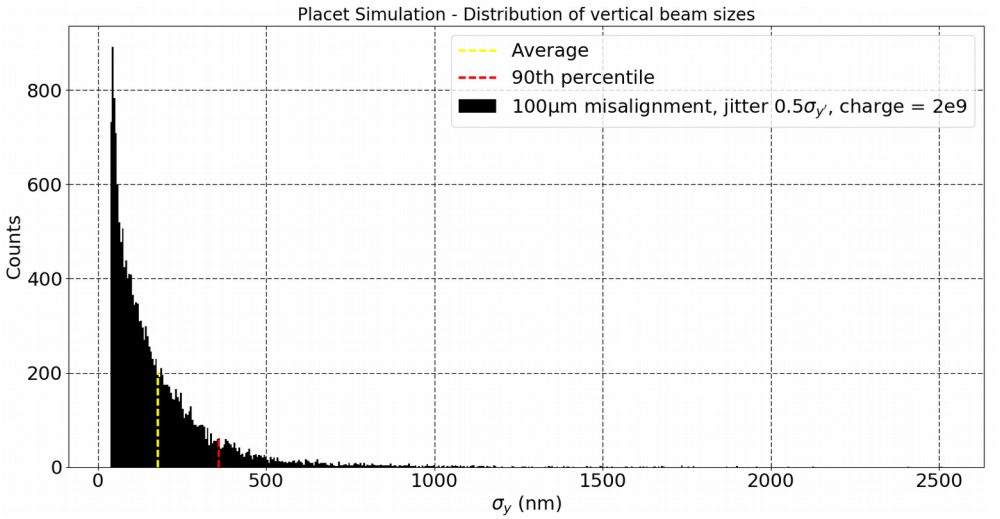
Low charge (2e9)

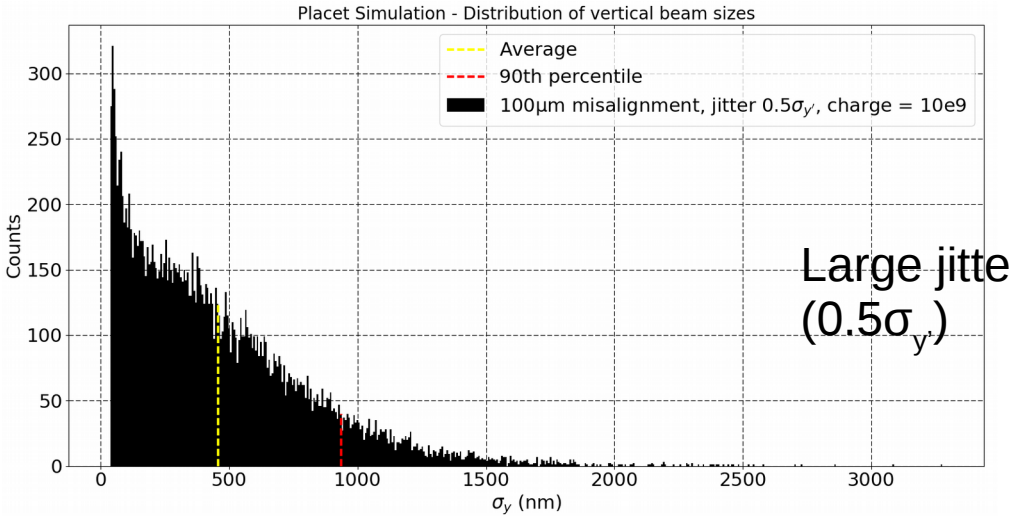
High charge (10e9)





Small jitter ($0.1\sigma_{y'}$)





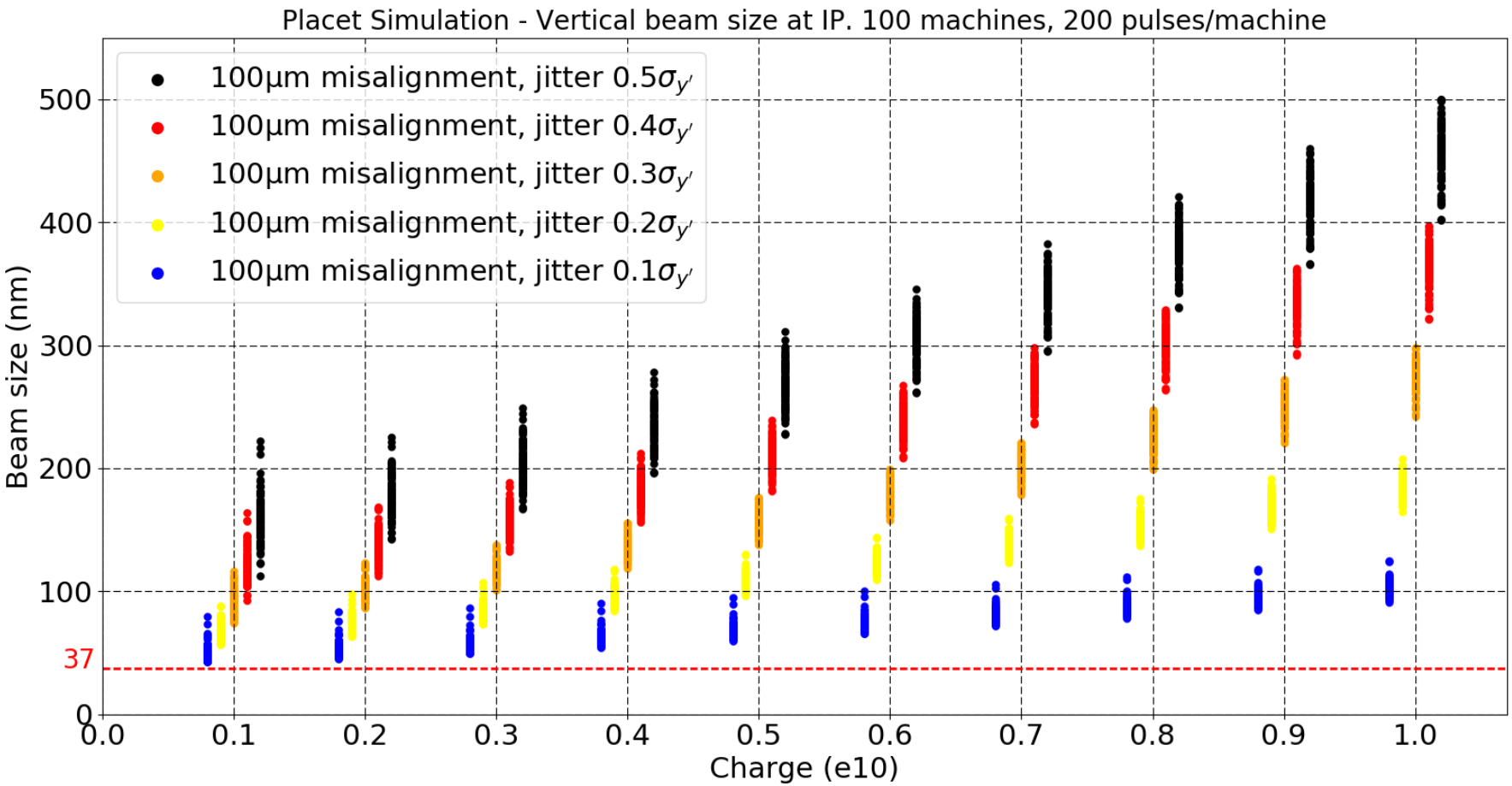
Large jitter ($0.5\sigma_{y'}$)

Impact of the beam angle jitter – All pulses

	Average beam size (nm)	90th percentile* (nm)
Jitter $0.1\sigma_{y'}$ Charge 2e9	52.68	72.23
Jitter $0.1\sigma_{y'}$ Charge 10e9	102.77	186.53
Jitter $0.5\sigma_{y'}$ Charge 2e9	177.19	359.39
Jitter $0.5\sigma_{y'}$ Charge 10e9	456.95	934.64

* 90% of the beam sizes are smaller than this value.

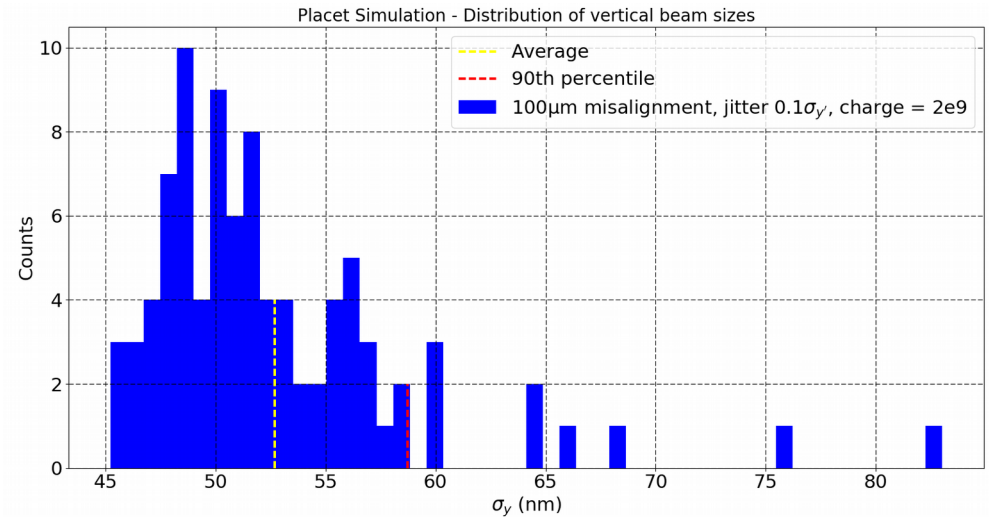
Impact of the beam angle jitter
1 beam size measurement every 200 pulses

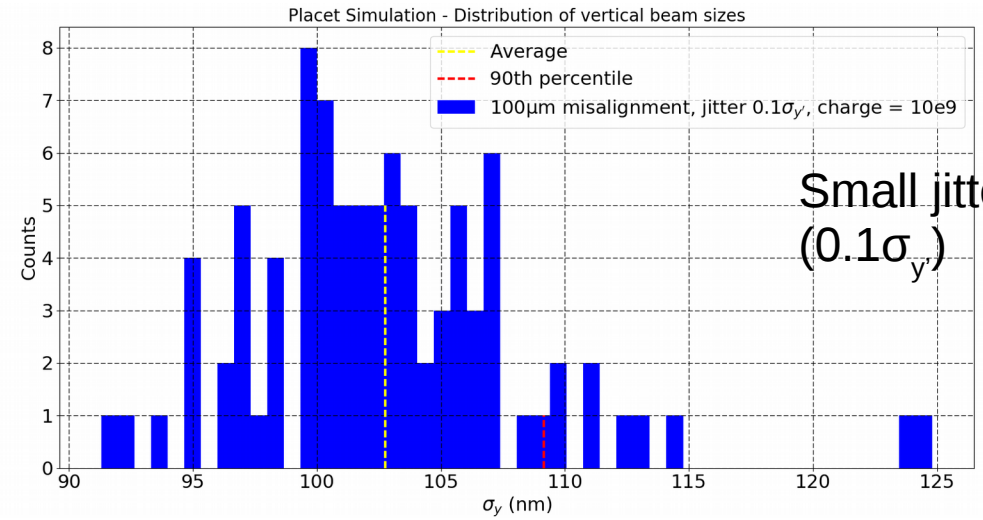


Impact of the beam angle jitter
1 beam size measurement every 200 pulses

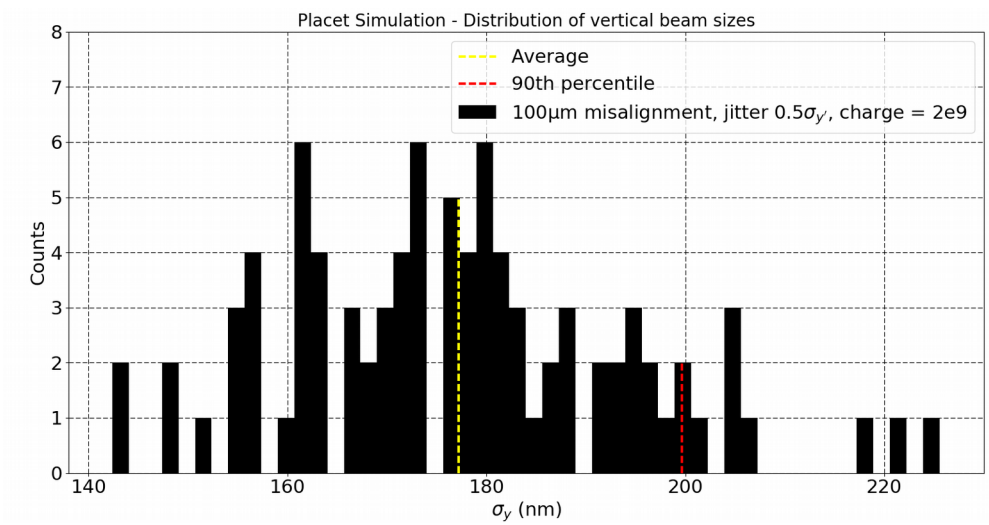
Low charge (2e9)

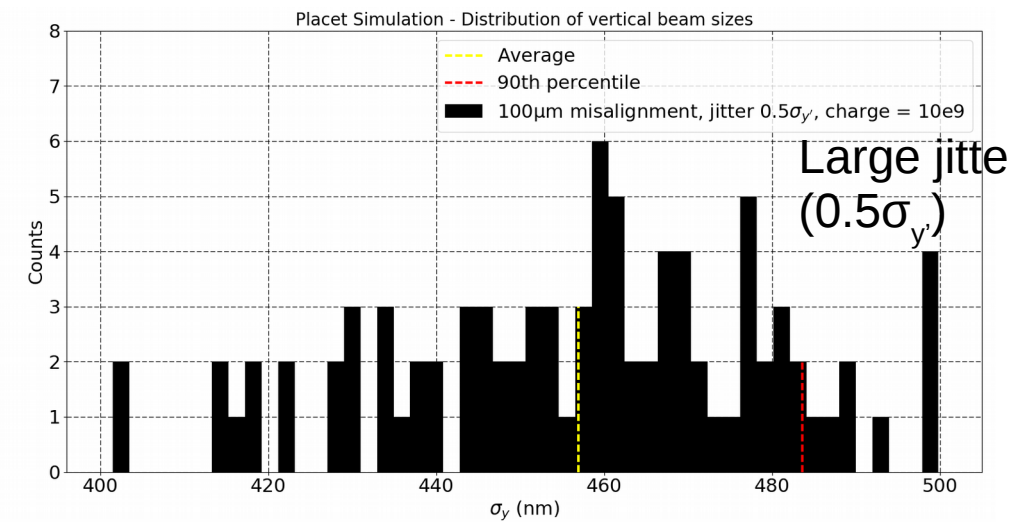
High charge (10e9)





Small jitter ($0.1\sigma_{y'}$)





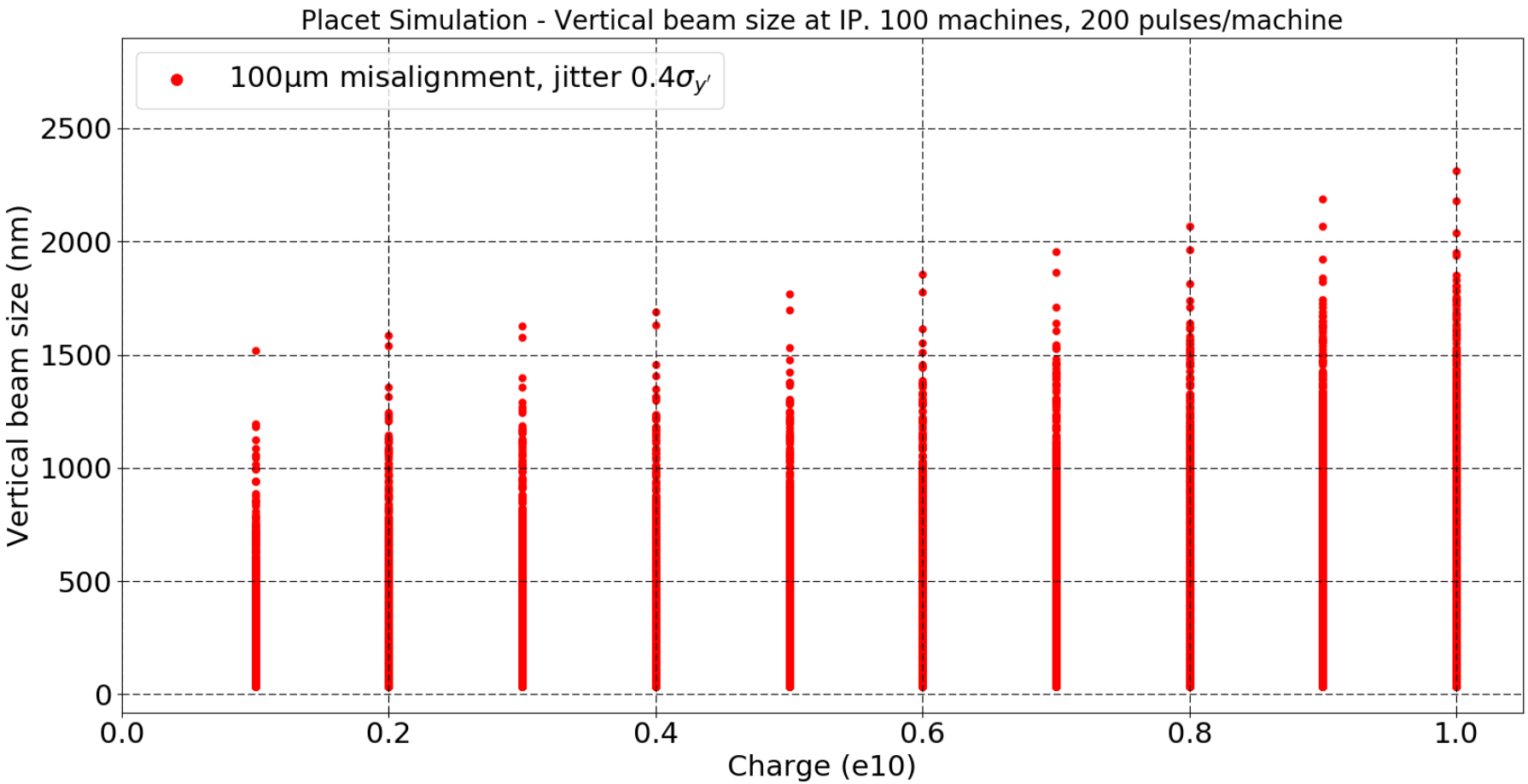
Large jitter ($0.5\sigma_{y'}$)

Impact of the beam angle jitter
1 beam size measurement every 200 pulses

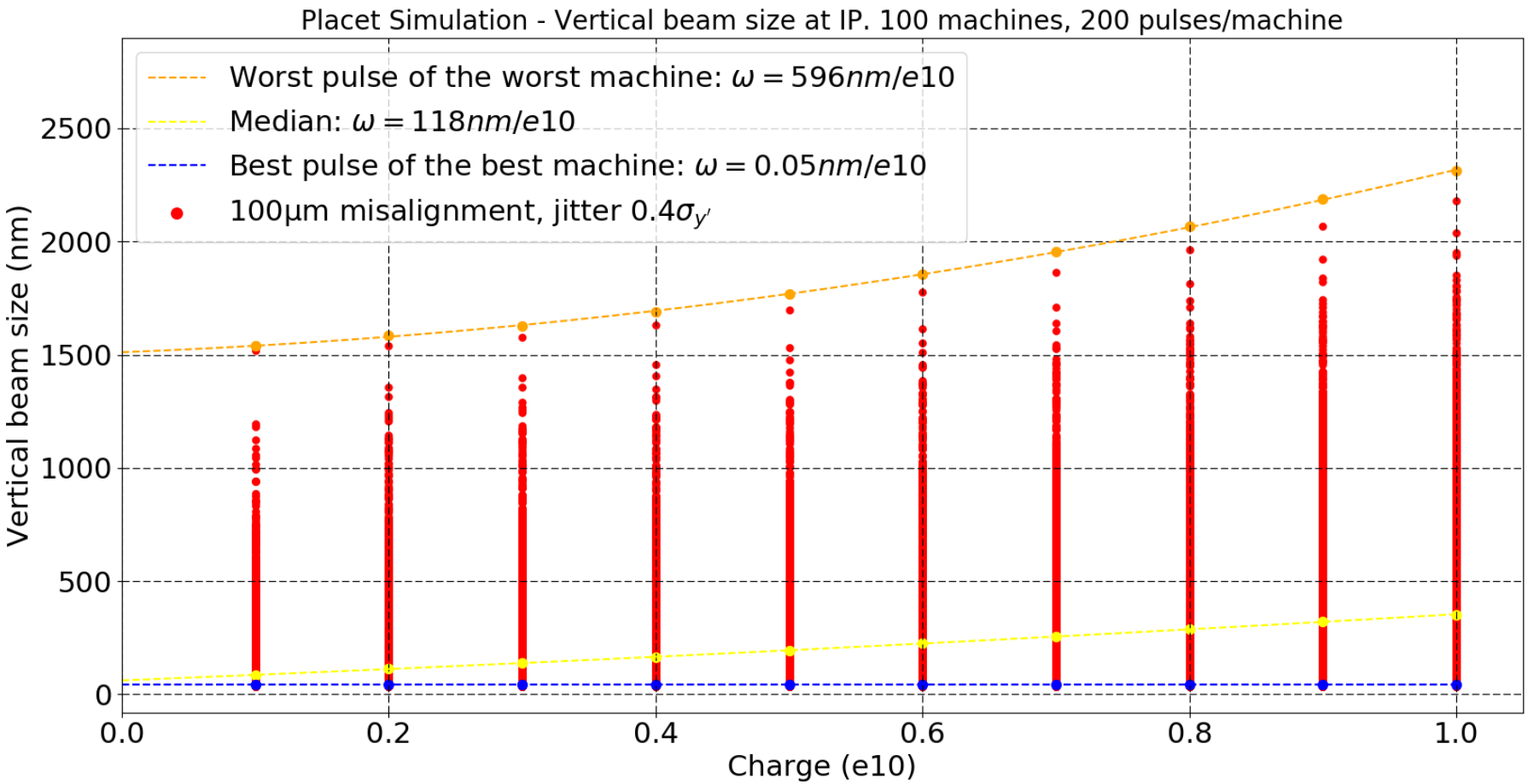
	Average beam size (nm)	90th percentile* (nm)
Jitter $0.1\sigma_{y'}$ Charge 2e9	52.68	58.72
Jitter $0.1\sigma_{y'}$ Charge 10e9	102.77	109.15
Jitter $0.5\sigma_{y'}$ Charge 2e9	177.19	199.62
Jitter $0.5\sigma_{y'}$ Charge 10e9	456.95	483.58

* 90% of the beam sizes are smaller than this value.

Impact of the beam angle jitter – All pulses



Introducing the intensity dependence parameter



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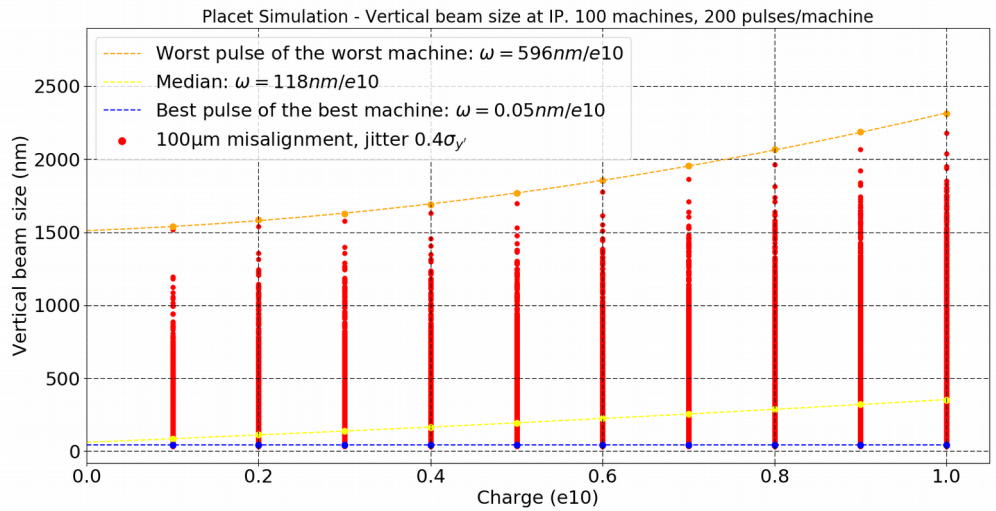


The orange, yellow and blue lines of the figure are obtained using the following fit

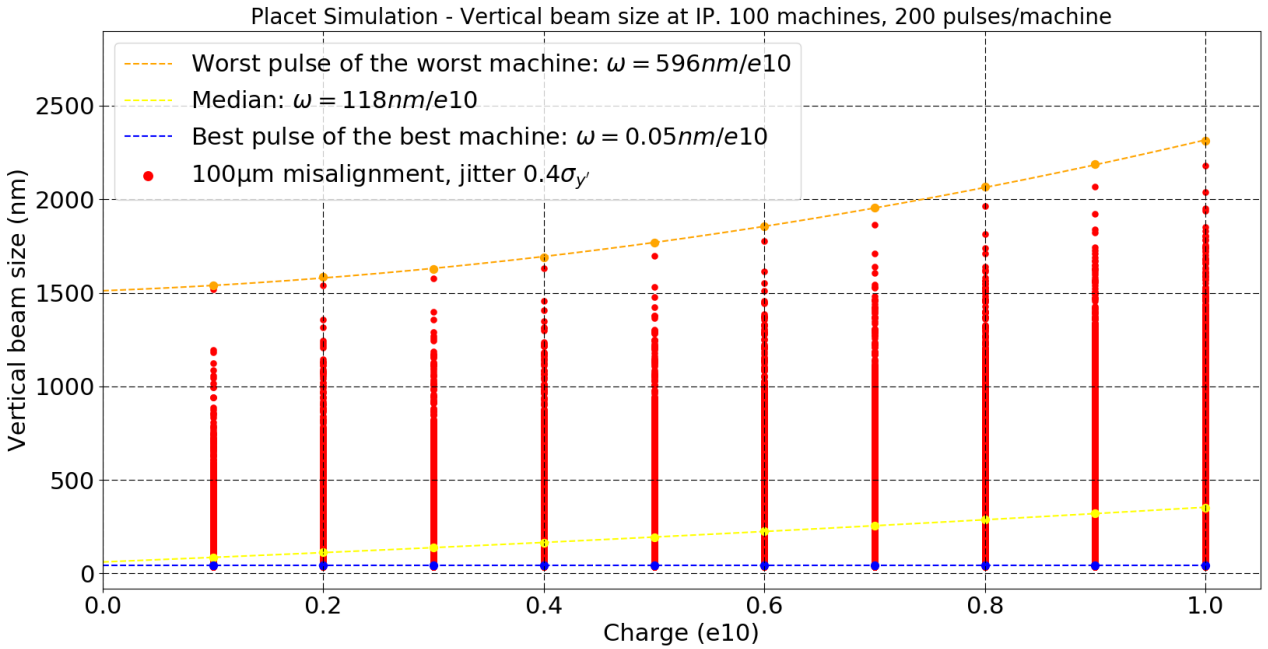
$$\sigma_y^2 = \sigma_{y,0}^2 + \omega^2 N^2$$

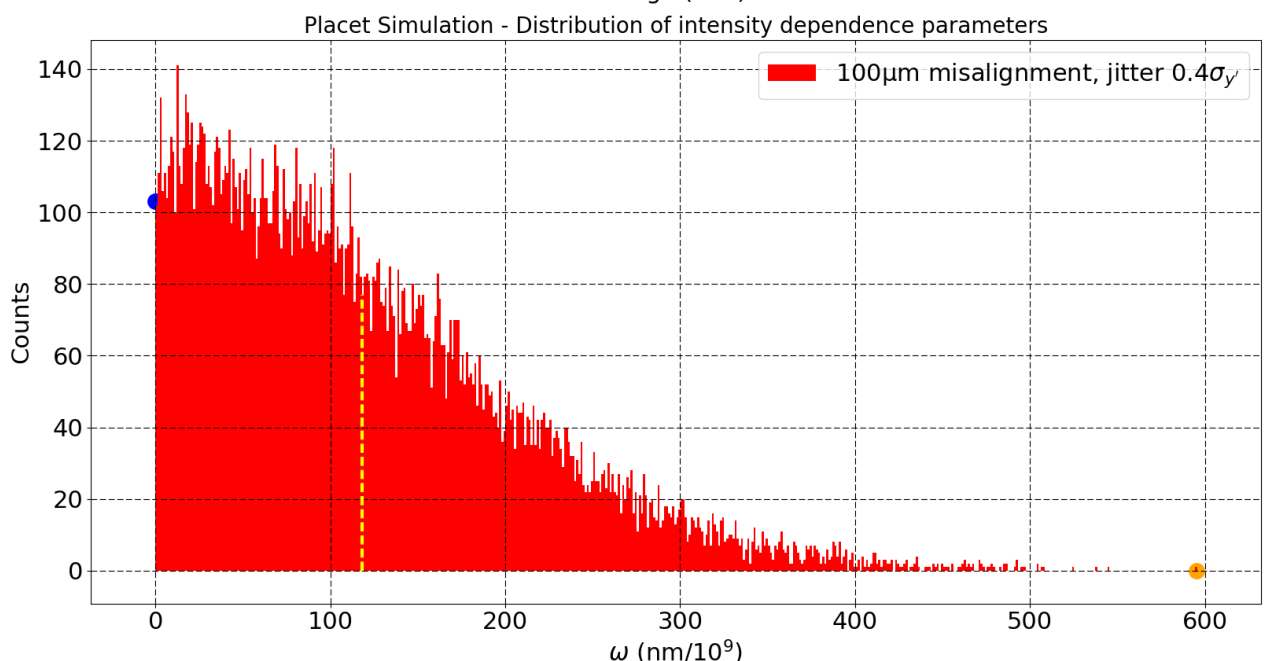
With *N* the bunch population and $\sigma_{y,0}$ and ω are two fitting parameters.
Then, one can define ω, the intensity dependence parameter as:

$$\omega\,[nm/10^9] = \sqrt{\sigma_y^2 - \sigma_{y,0}^2}/q$$

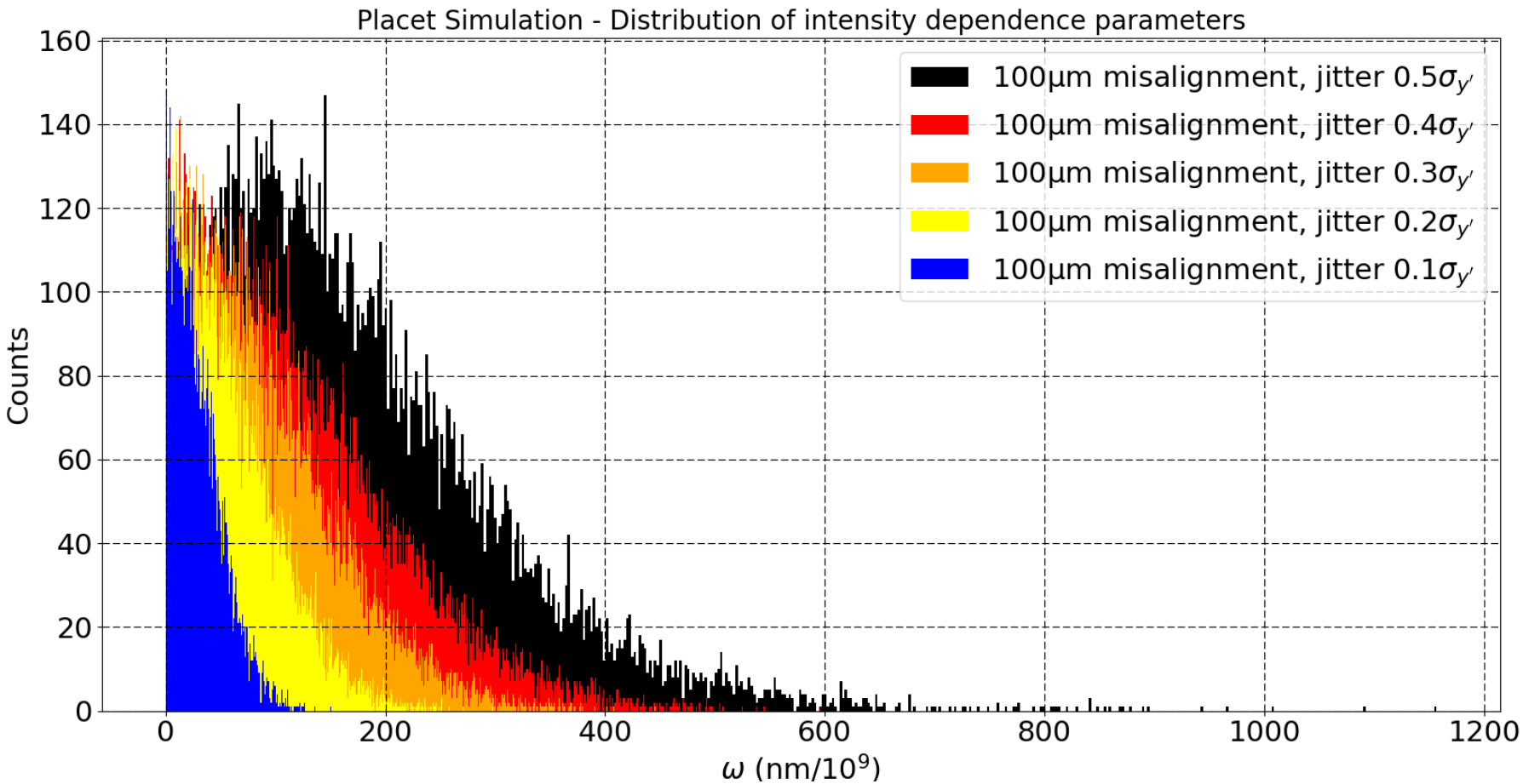
With *q* the bunch population divided by 10^9.

Intensity dependence parameter distribution





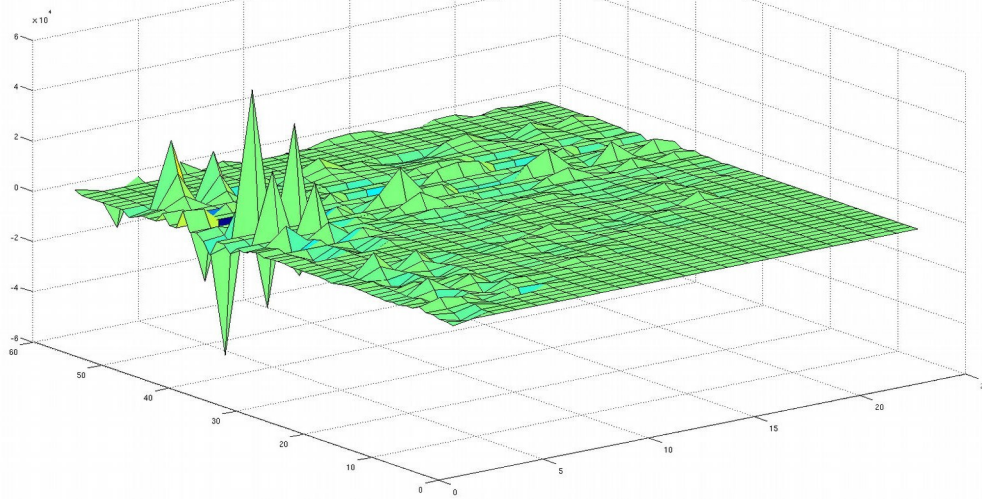
Intensity dependence parameter distribution



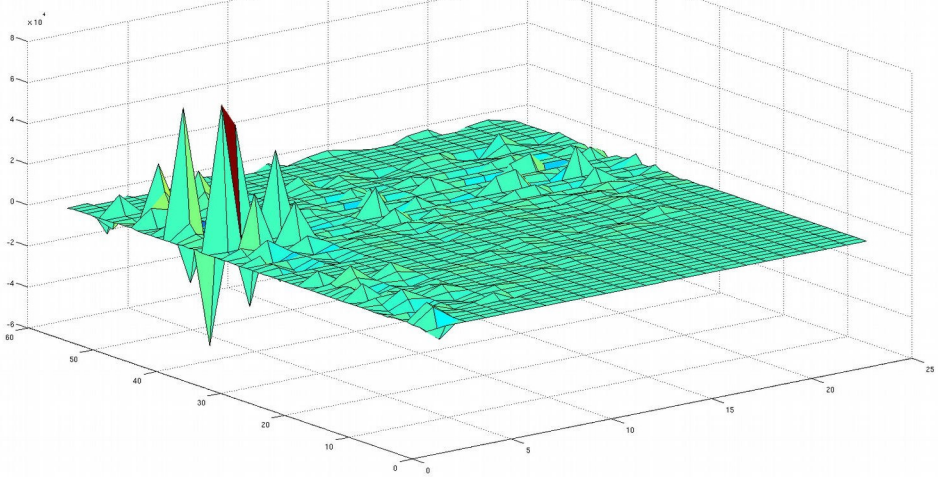
Dispersion Free Steering and Wakefield Free Steering first results

Dispersion Free Steering
Response matrices (February 2018)

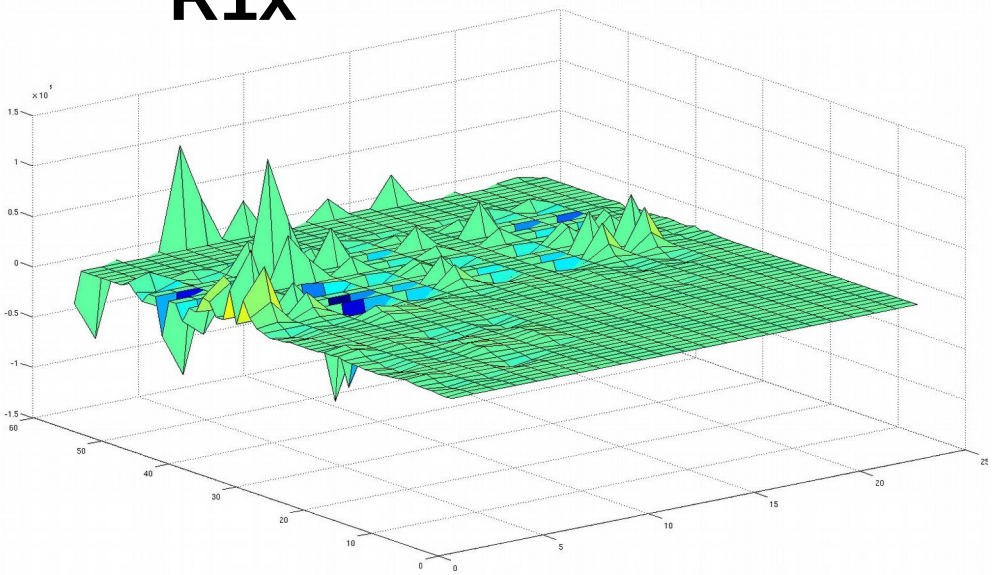
R0x



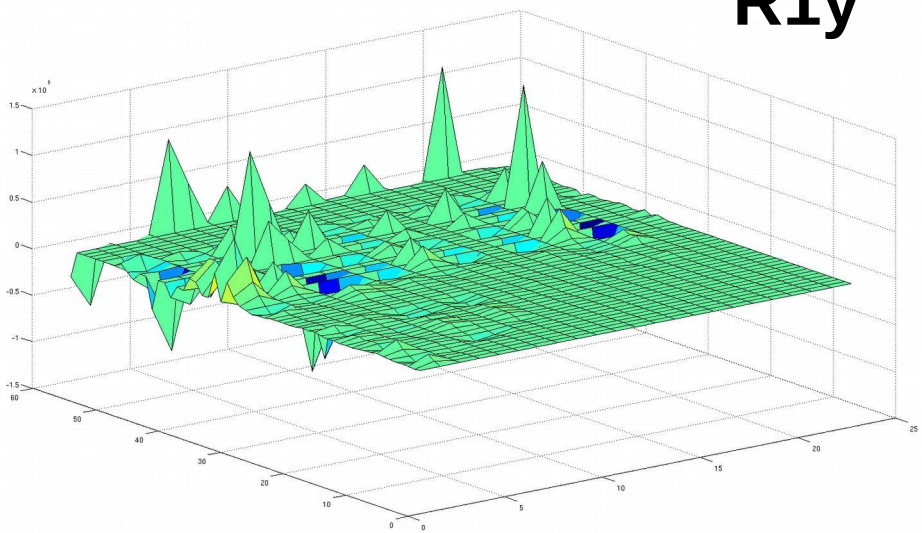
R0y



R1x

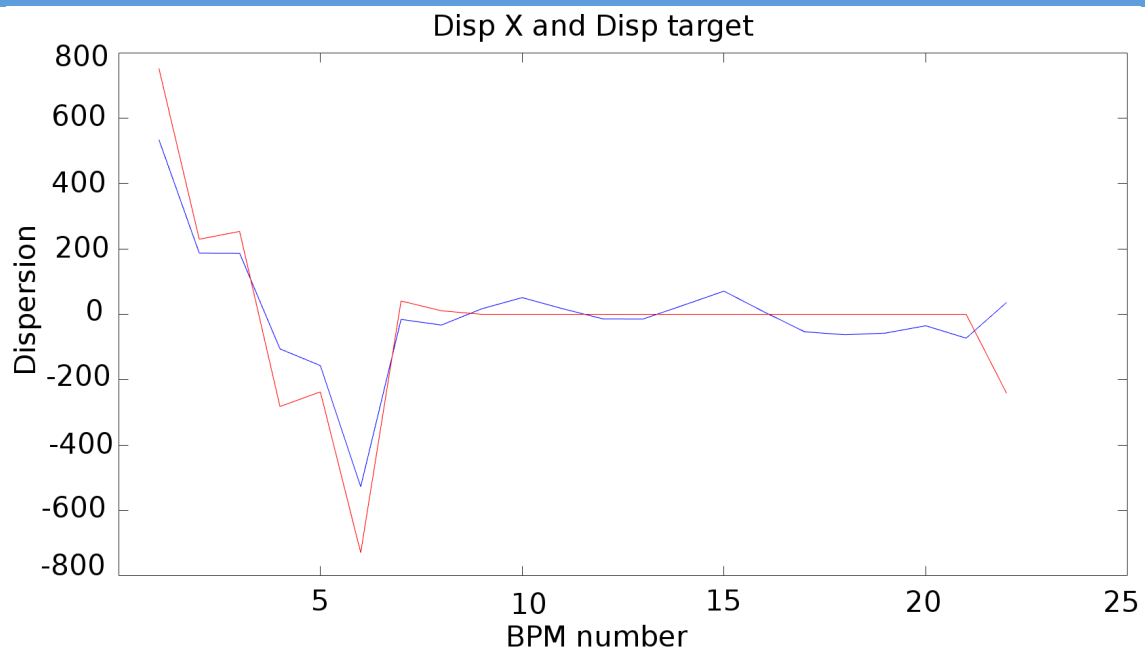


R1y

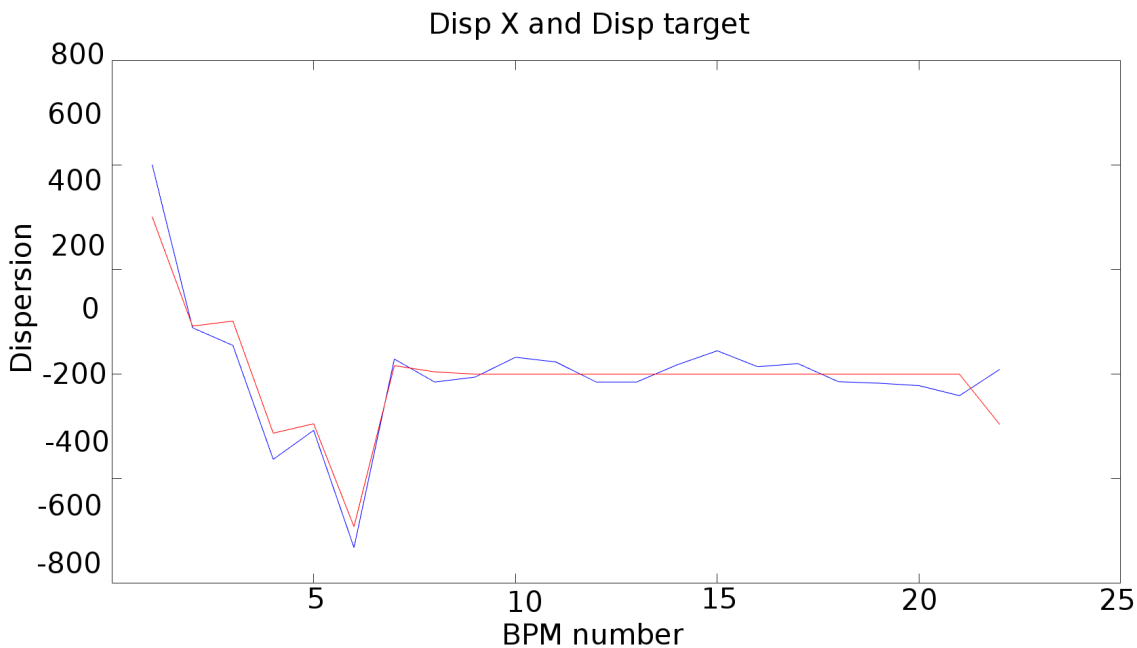


Dispersion Free Steering
First results (February 2018)

Before correction



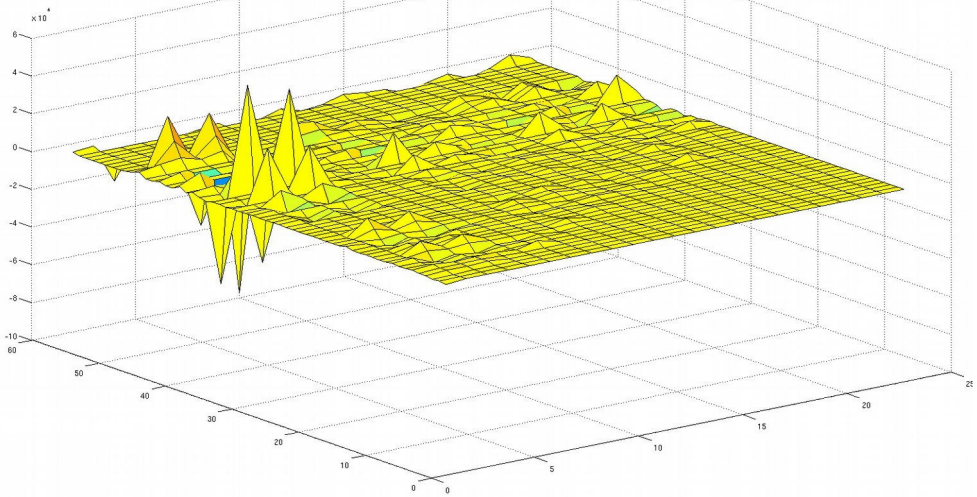
After correction



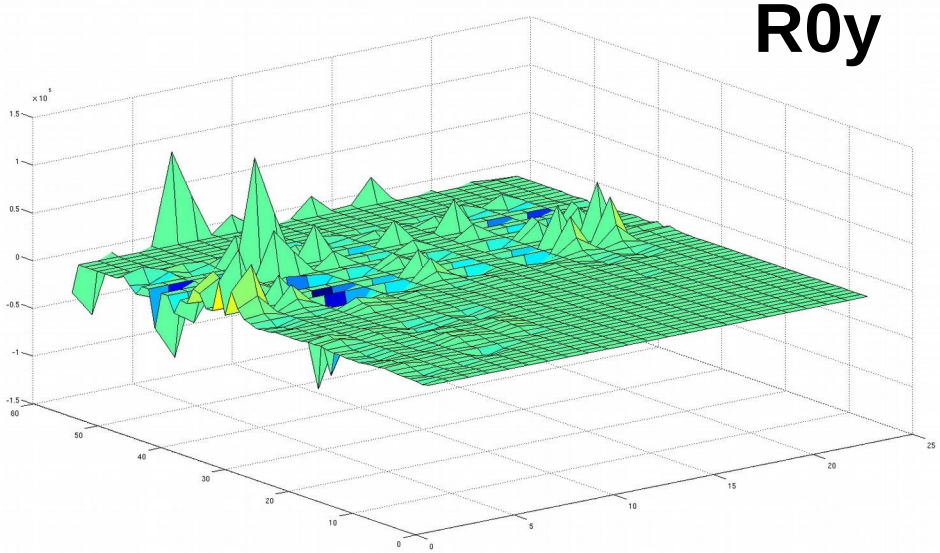
Script running and working. It needs a little more tuning to have better results. For example use more or less BPMs, remove the ones with wrong orbit, change the DFS parameters (gain, weights, number of singular values, …).

Wakefield Free Steering
Response matrices (February 2018)

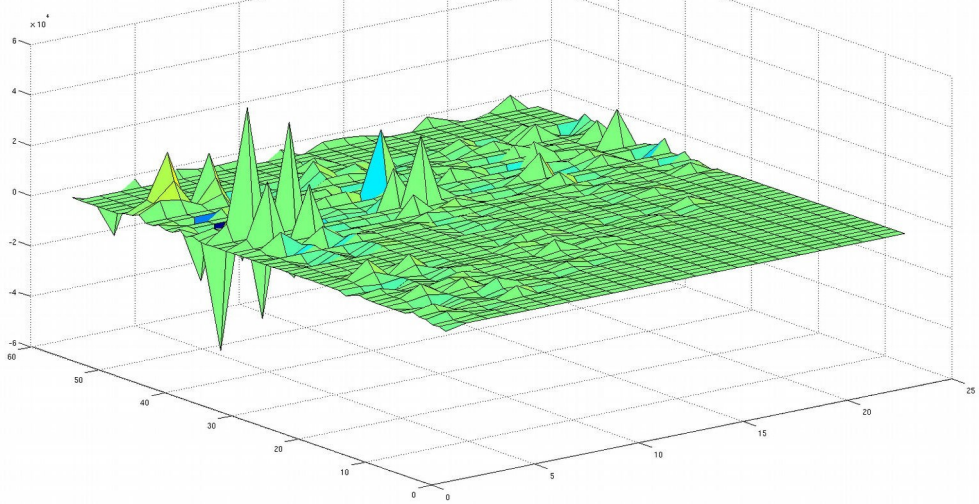
R0x



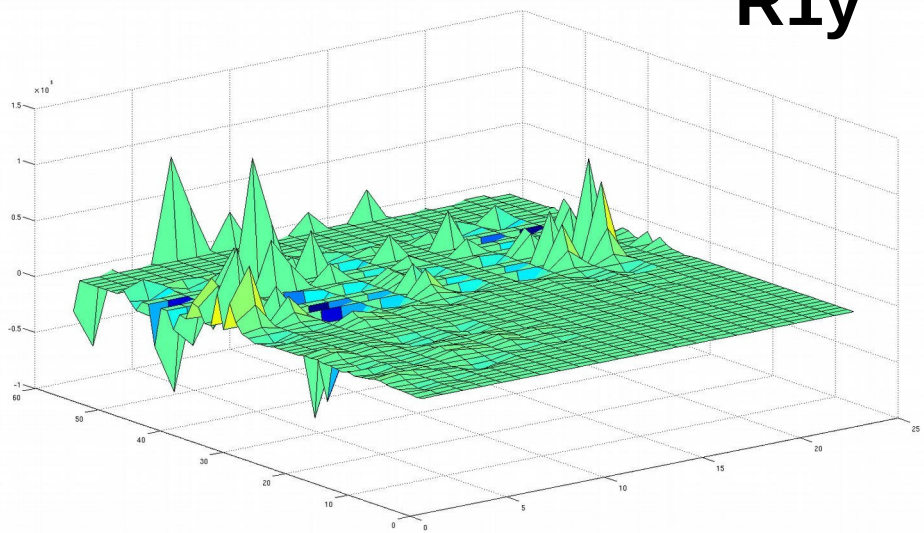
R0y



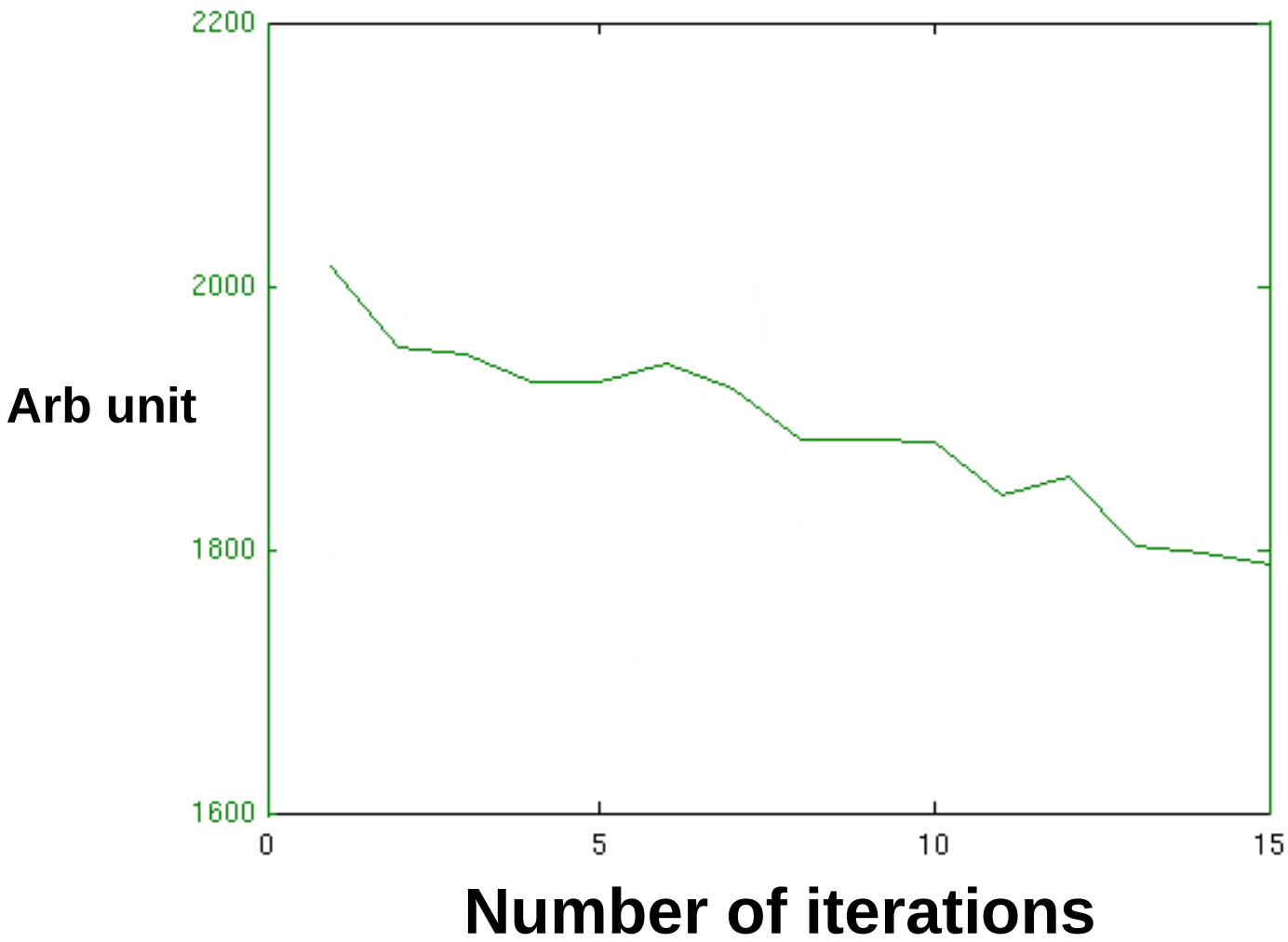
R1x



R1y



Wakefield Free Steering
First results (February 2018)



Script running and working. It needs a little more tuning to have better results. For example use more or less BPMs, remove the ones with wrong orbits...

Proposal for tuning procedure

Tuning procedure to achieve goal 1:

- Calibrating BPMs
- OTR screens (emittance measurement)
- DFS
- WFS
- First order knobs
- Second order knobs

Plans for ATF2 run in June

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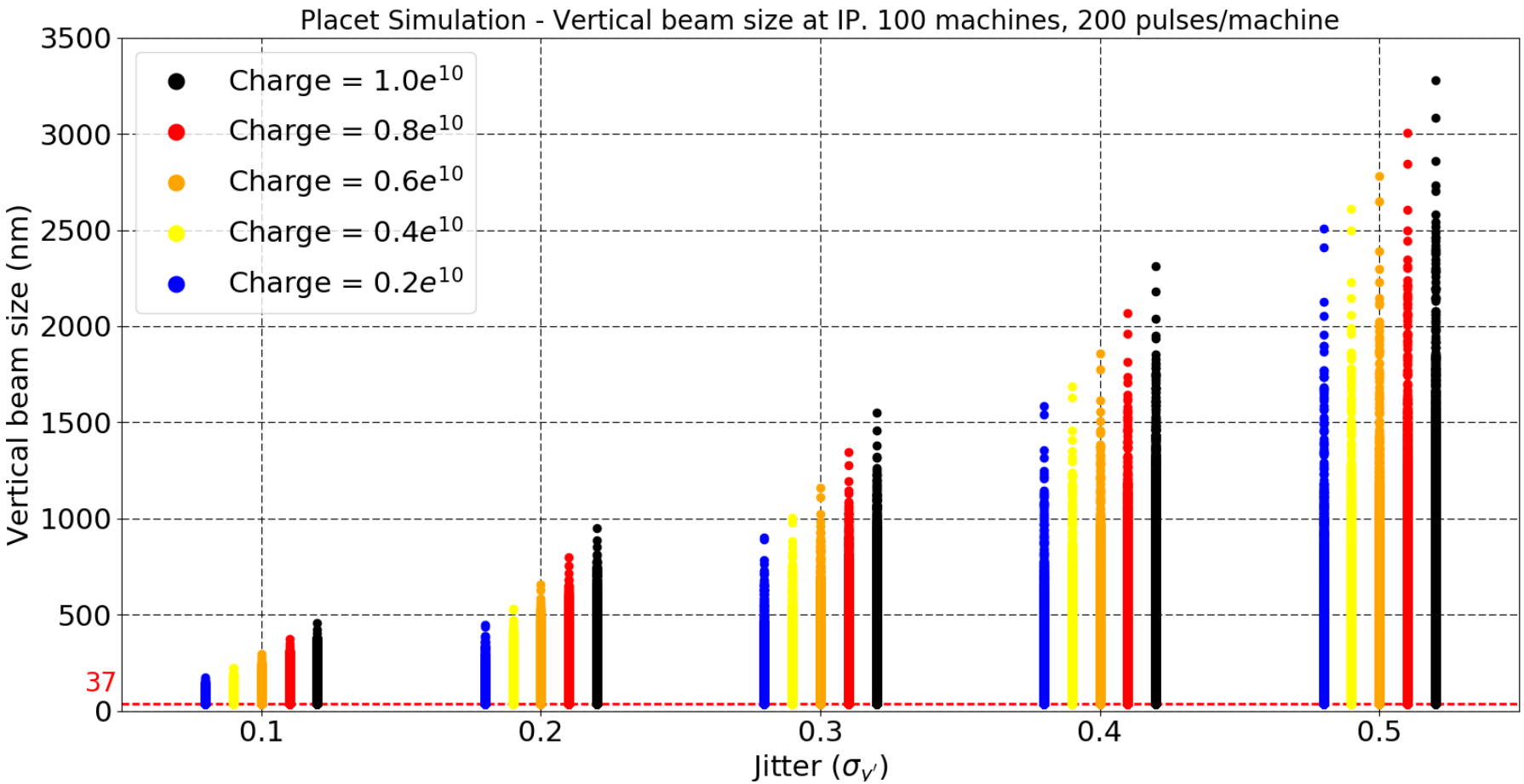
- **Spend some time calibrating the BPMs.**
- **Use Dispersion Free Steering correction code in order to have a dispersion free machine. Find the best parameters (number of BPM used, gain, weights, number of singular values, …) in order to have the best results.**
- **Use Wakefield Free Steering correction code in order correct the charge impact on the orbit. Find the best parameters (number of BPM used, gain, weights, number of singular values, …) in order to have the best results.**
- **Use the 4 OTR screens in the machine in order to study the intensity dependence effect on the beam distribution at different positions in the machine before and after applying WFS.**
- **Use the IPBSM in order to study the intensity dependence effect on the beam at the IP before and after applying WFS.**

Conclusion

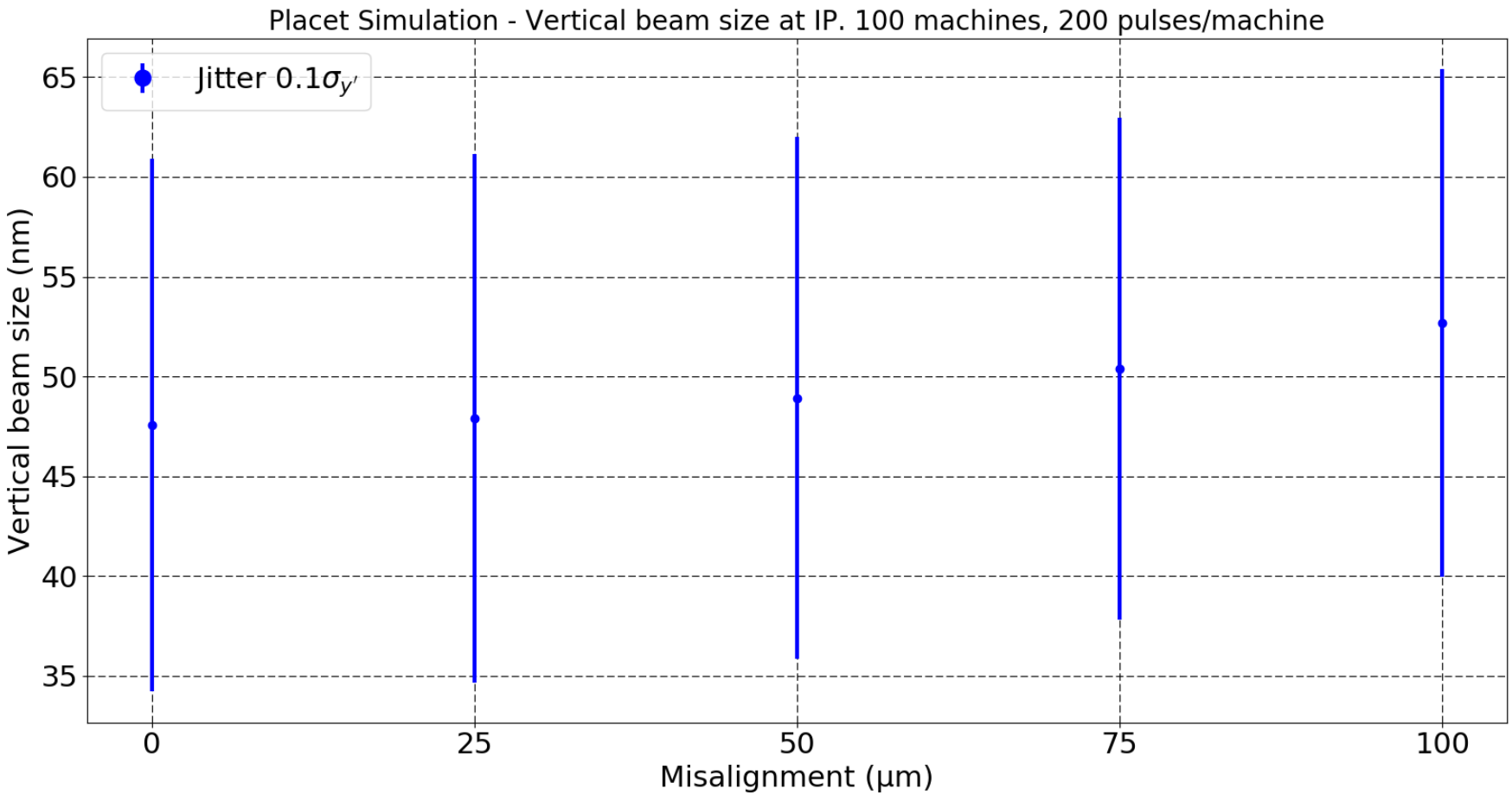
- **Using ATF2 BPMs for intensity dependence studies seems to be a complicated task since only 10 of them provide the required stability and resolution.**
- **Simulations in Placet show that the vertical angle jitter has a significant impact on the beam size at the IP. And it seems complicated to achieve goal 1 with a jitter greater than $0.1\sigma_{y'}$.**
- **Previous results of WFS and DFS were promising. Further work will be done in order to refine the results.**
- **Measurements using the OTR screens and IPBMS are part of the plans for the future ATF2 run in June.**

Thank you

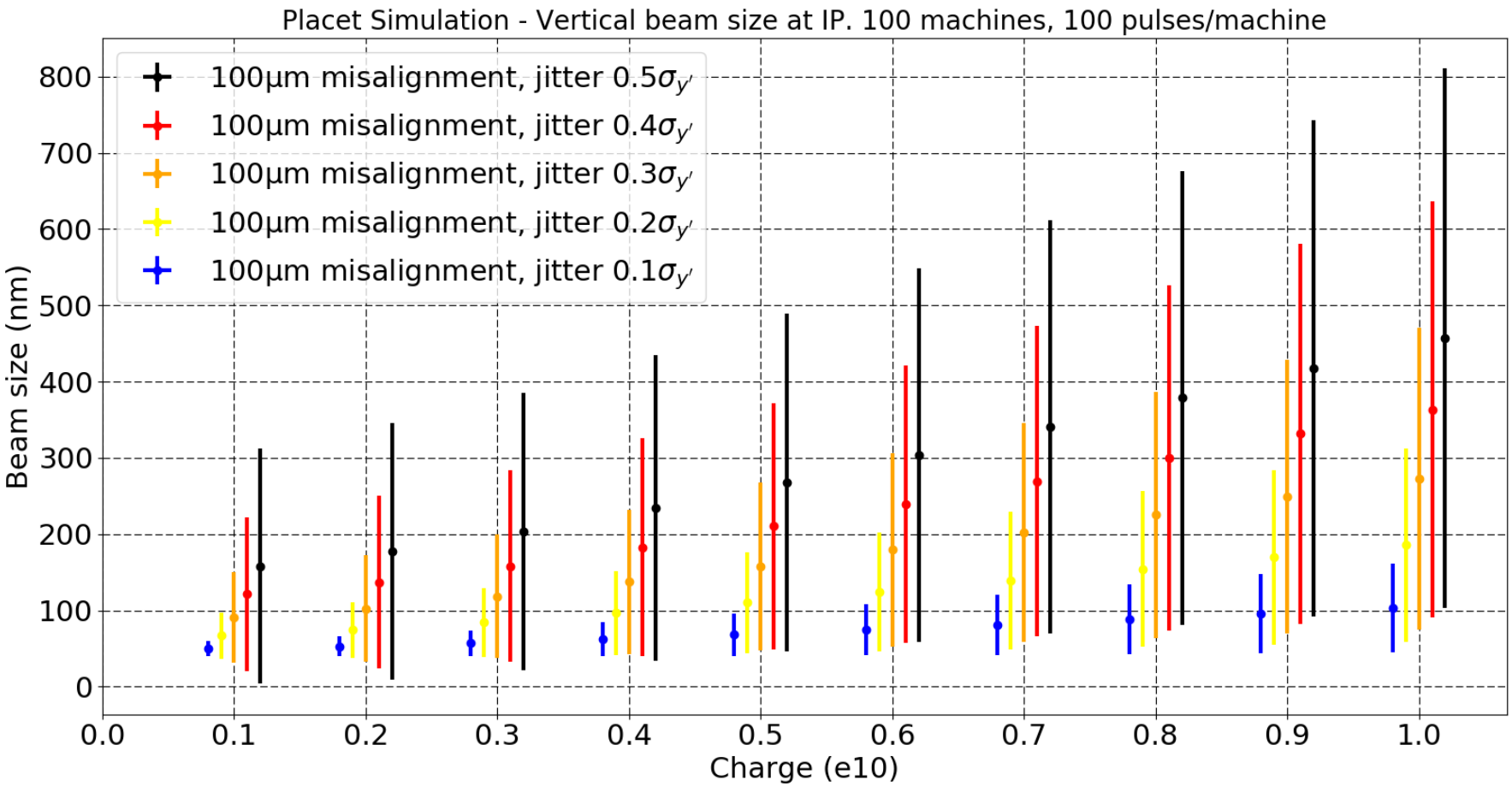
Extra slides



Extra slides

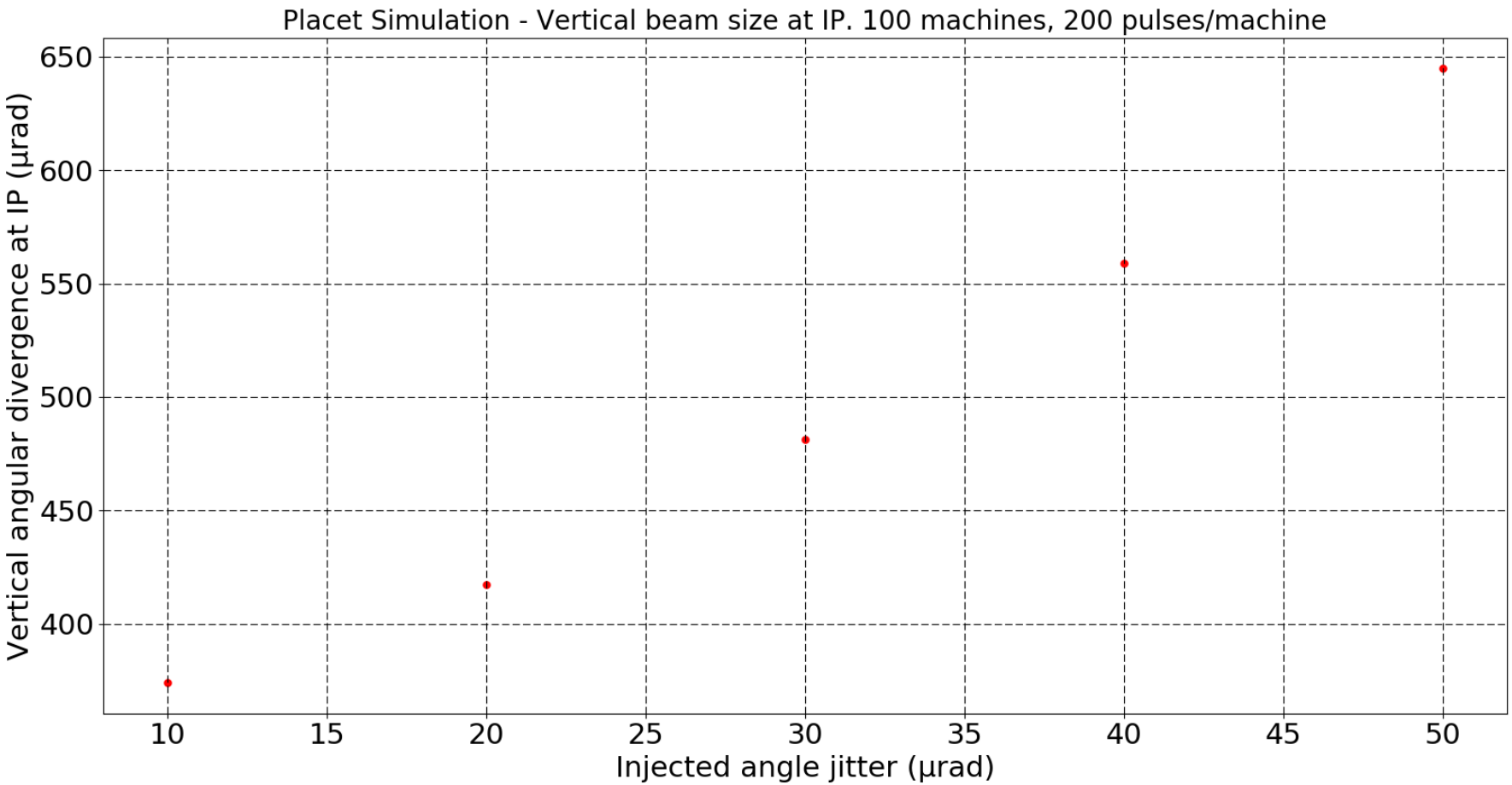


Extra slides



Extra slides

The nominal vertical angular divergence at IP
$\sigma_{y',IP}$ = 350μm



$0.1\sigma_{y'}$ $0.2\sigma_{y'}$ $0.3\sigma_{y'}$ $0.4\sigma_{y'}$ $0.5\sigma_{y'}$