Intensity-dependent effects in the ATF2, simulations and measurements

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Outline

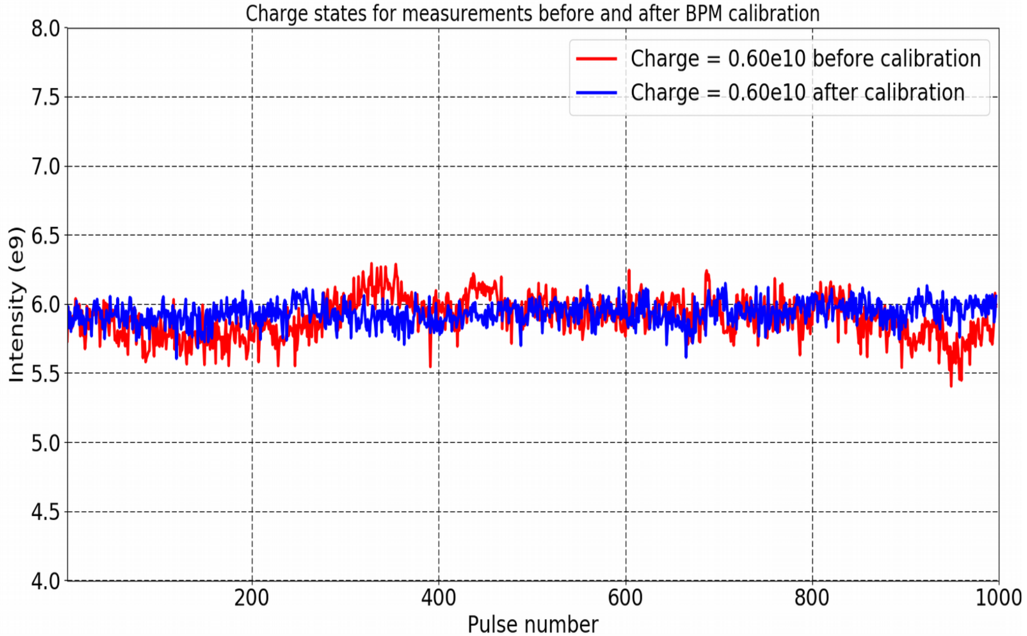
- **Experimental results:**
  - **- BPM calibration**
  - **- Dispersion Free Steering**
  - **- Intensity dependence studies using IPBMs**
  - **- Magnet roll/coupling correction**

- **Intensity dependence studies using Placet.**

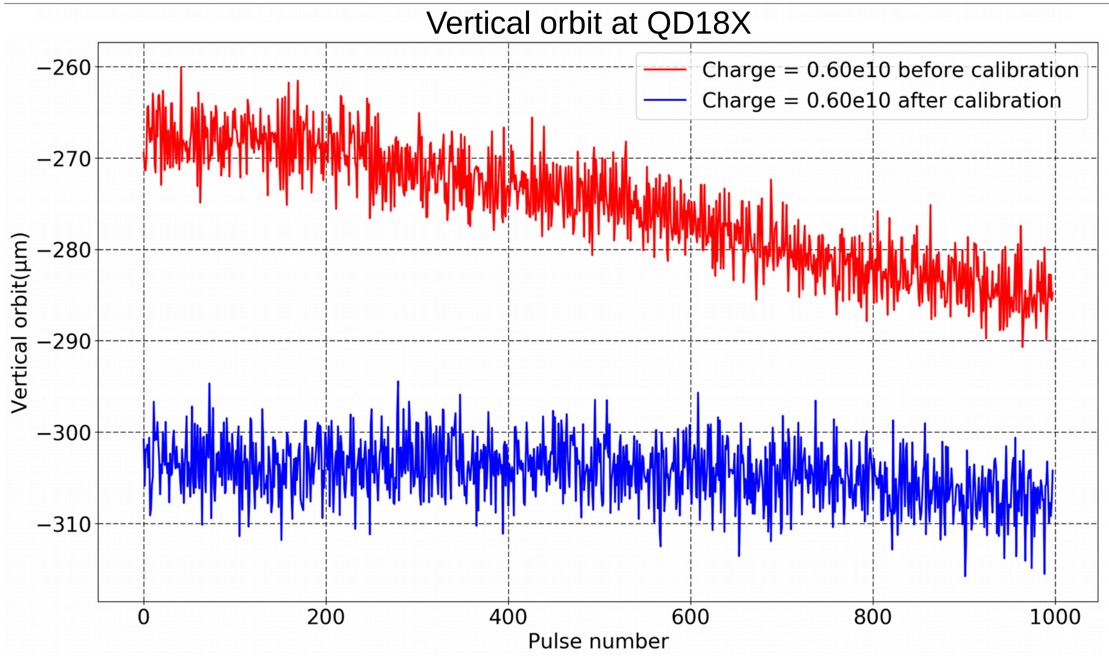
- **Plans for ATF2 run in December 2018.**

Experimental results
BPM calibration

BPM calibration



The charge is measured using an Integrated Current Transformer (ICT). The comparison of the evolution of the charges before and after BPM calibration shows that they have similar amplitudes and behaviors.



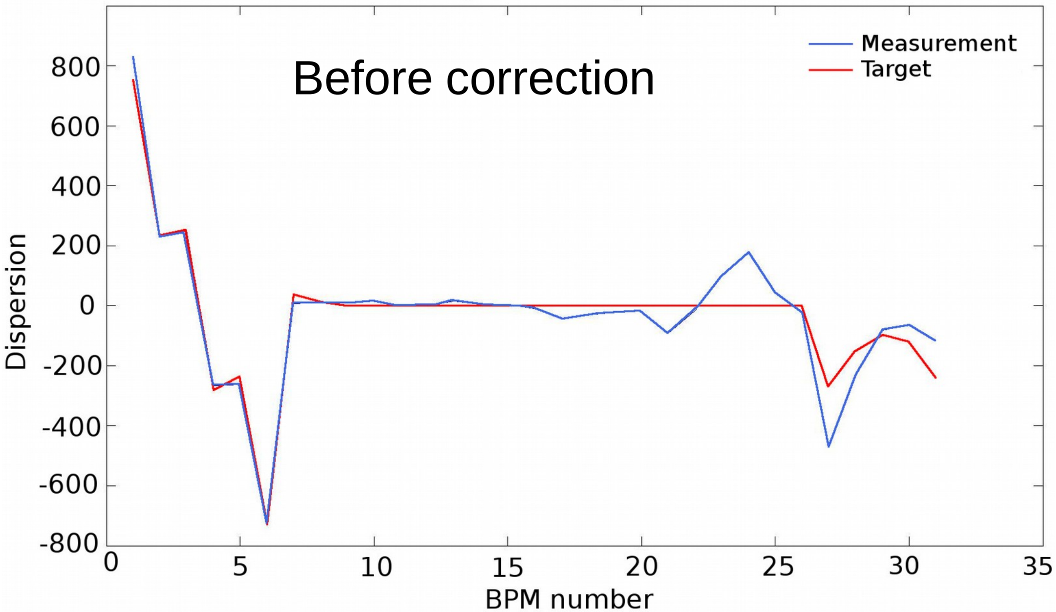
Before calibration, when observing the vertical orbit, on can see an unstable behavior of BPM QD18X (for instance) **in red**.
After calibration, for the same BPM, the vertical orbit is more stable, **(in blue)**.

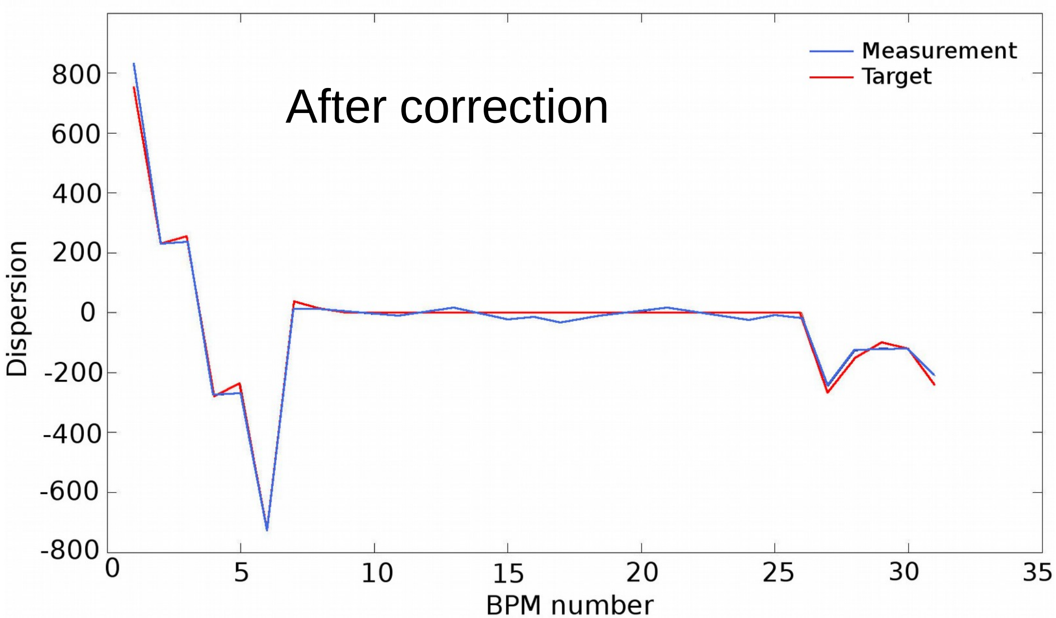
The BPM calibration is removing saturation in the signal making it more stable and reliable.

Raw plots of all BPMs showing the before/after calibration vertical orbits can be found here.

Experimental results
Dispersion Free Steering

Dispersion Free Steering
New results from June 2018



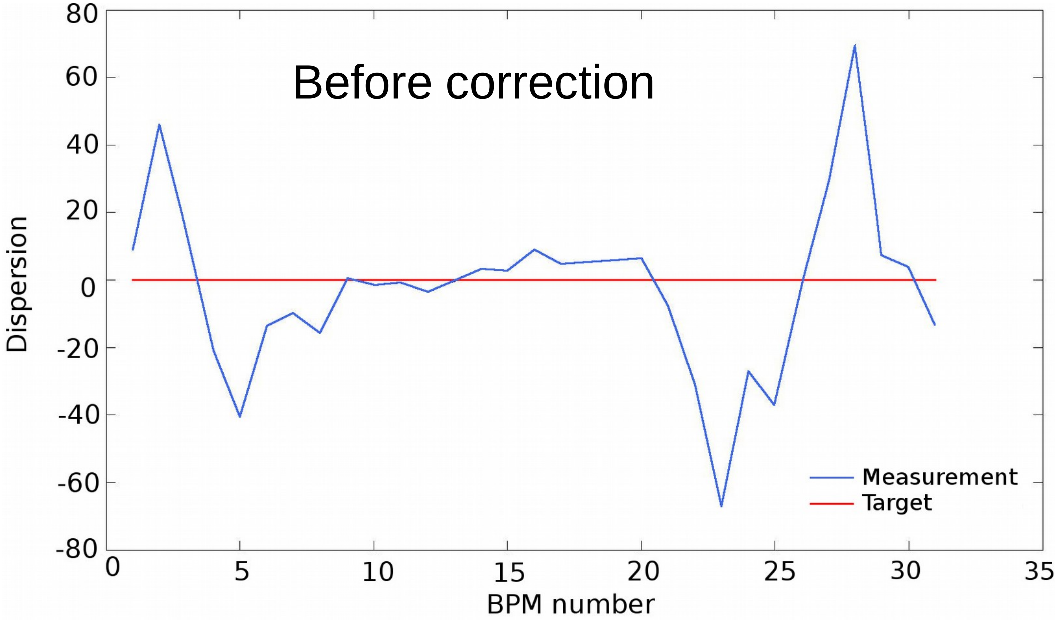


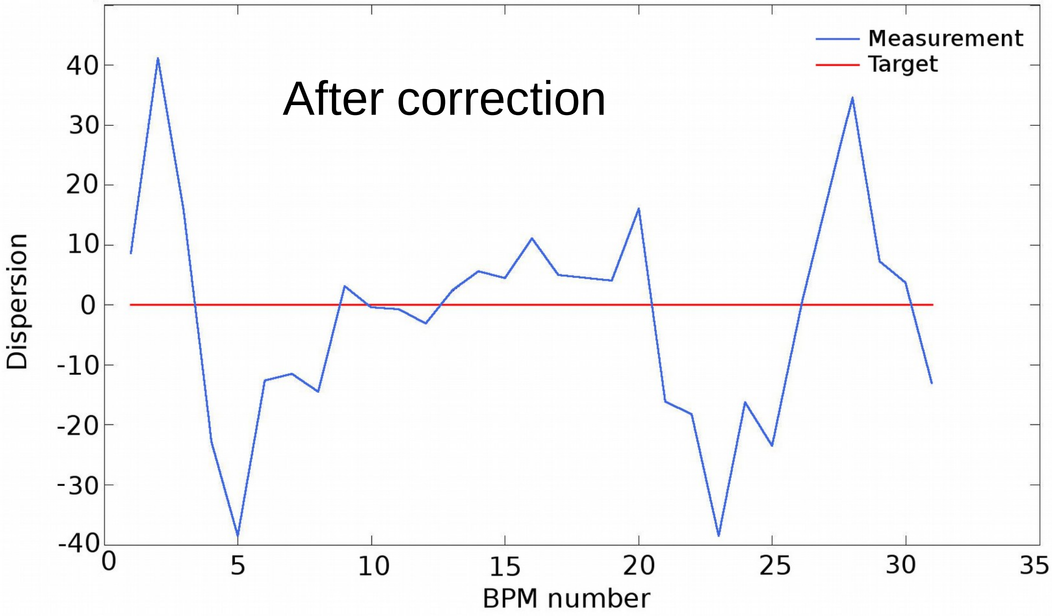
Horizontal plane

The dispersion is corrected using only the steering magnets in the extraction line.

The implemented code in the machine gives good results in the horizontal plane:
The measured dispersion fits really well the target.

Dispersion Free Steering
New results from June 2018





Vertical plane

The implemented code in the machine gives good results in the vertical plane as well:
Before correction: dispersion between -65mm and 65mm.
After correction: dispersion between -40 and 40mm.

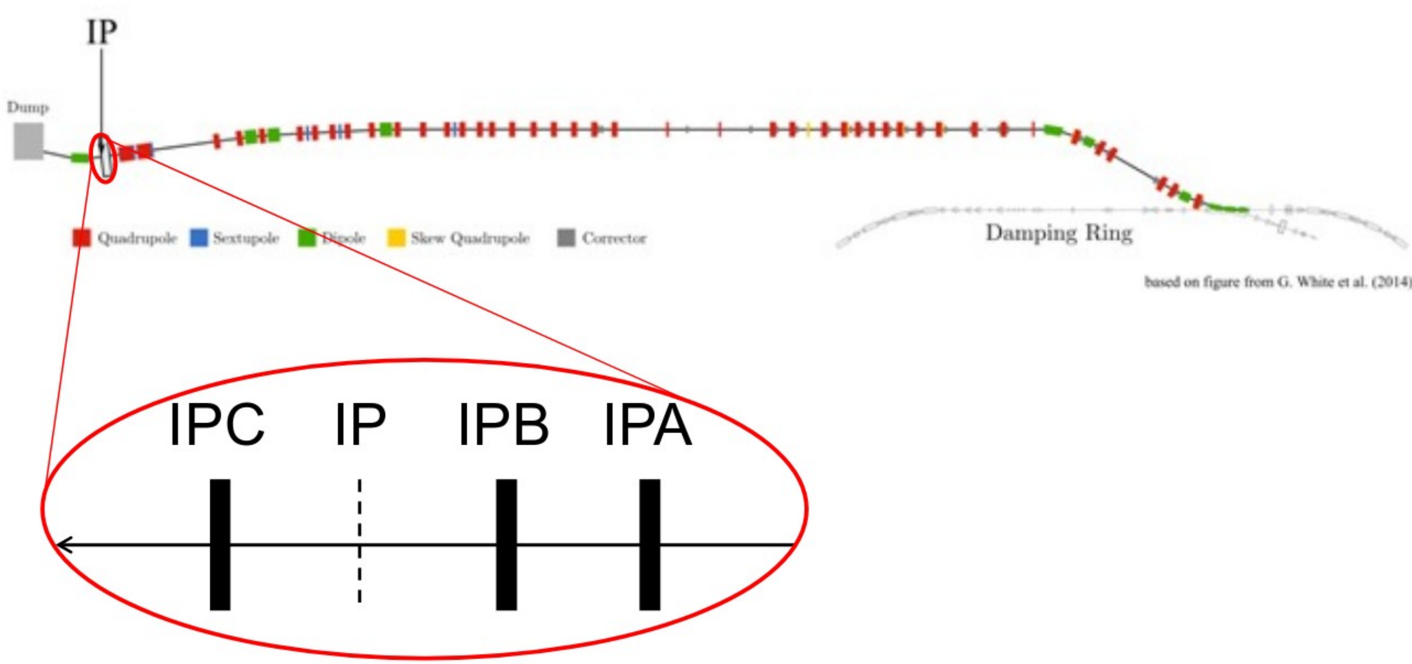
Decreases the vertical dispersion by a factor 1.6!

Experimental results
Intensity dependence studies using IPBPMs

Experimental results
Intensity dependence using IPBPMs

The goal was to measure the impact of an intensity increase on the beam jitter at IP.
For each intensity the IPBPMs were recalibrated. The attenuation on the dipole signals was 20dB. One should expect a resolution of [90-150] nm at the BPMs and a resolution of [90-150]/sqrt(2) = [65-105] nm at the waist.

Location of IP BPMs



Experimental results
Intensity dependence using IPBPMs

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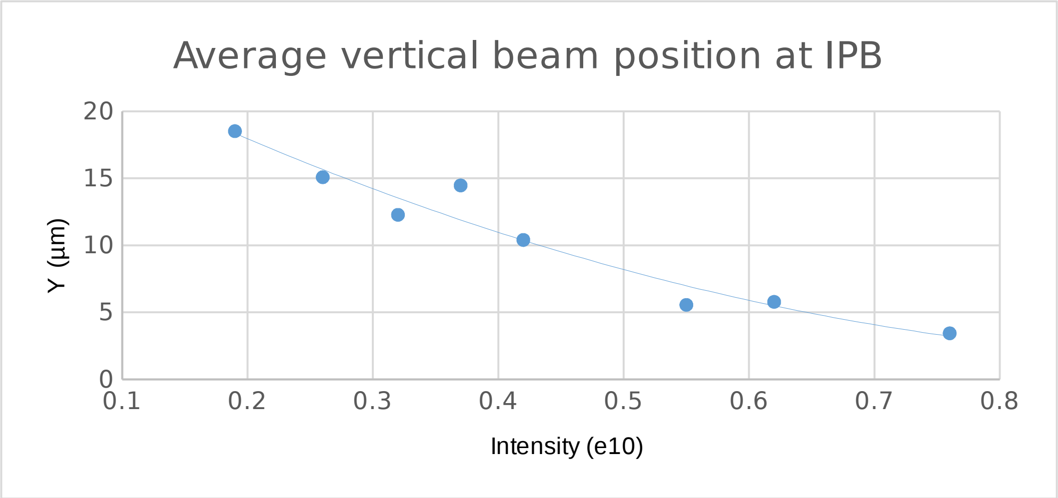

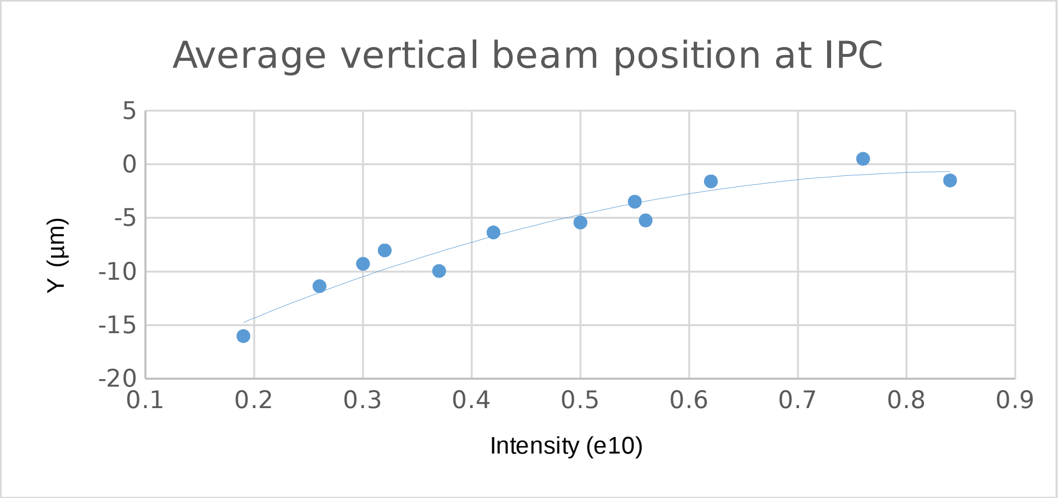

The average vertical beam position shows a quadratic correlation with the intensity at IPB and IPC.

This is not due to the known resolution dependence with the intensity.

Experimental results
Intensity dependence using IPBPMs

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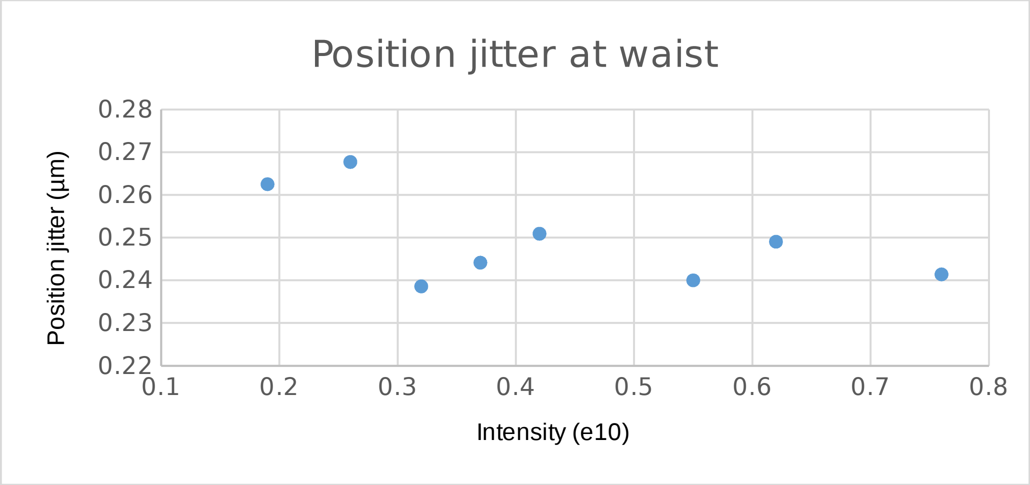
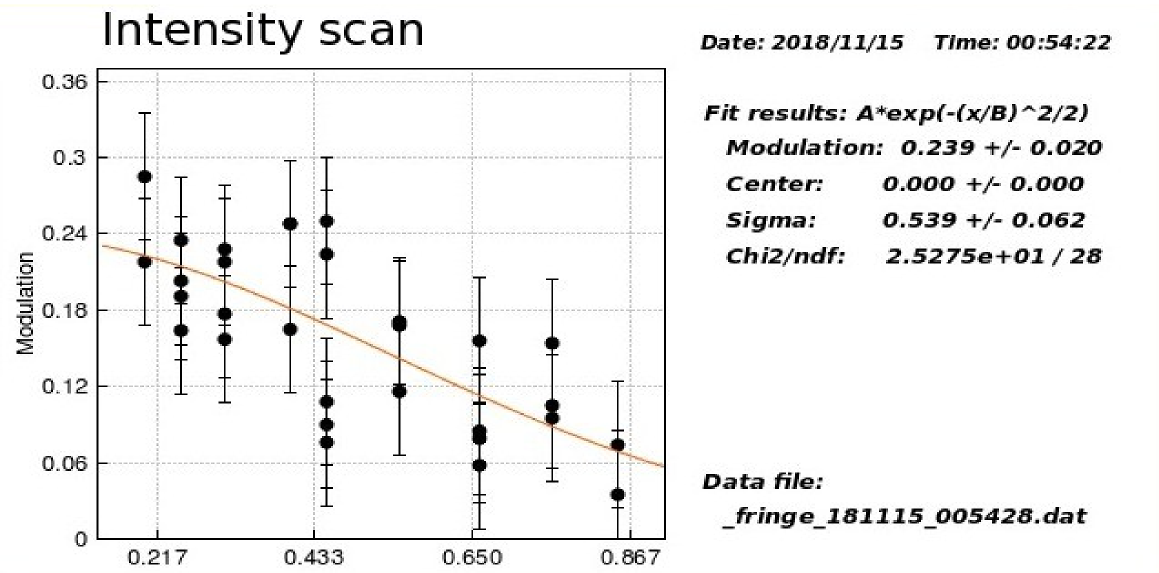


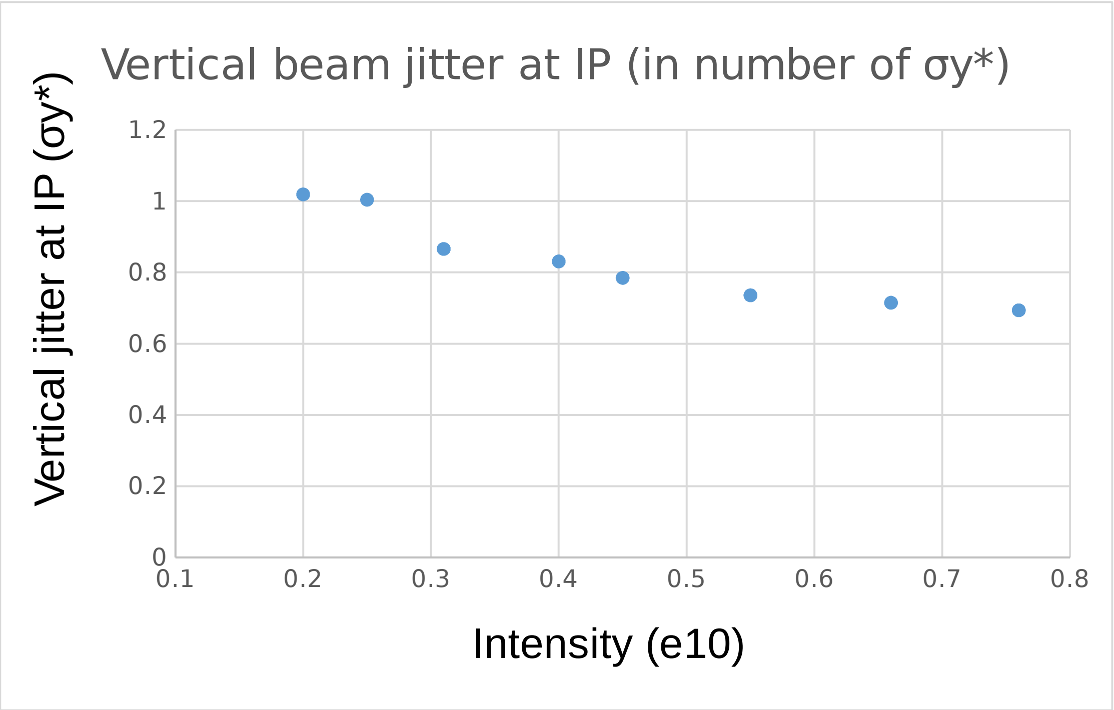
The jitters at the waist were calculated using an interpolation of the position and angle at the IPB and IPC.

The position and angle jitters at the waist don't seem to have a strong correlation with the intensity.

The effect is maybe too small compared to the **resolution of the IPBPMs**.

Experimental results
Intensity dependence using IPBSM



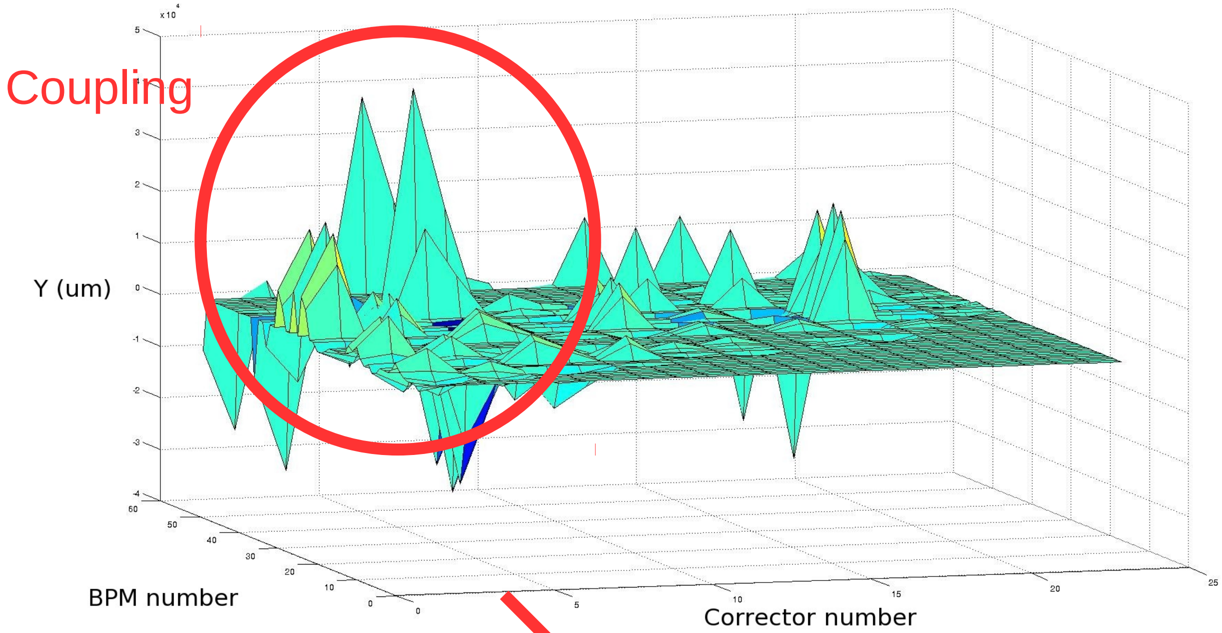


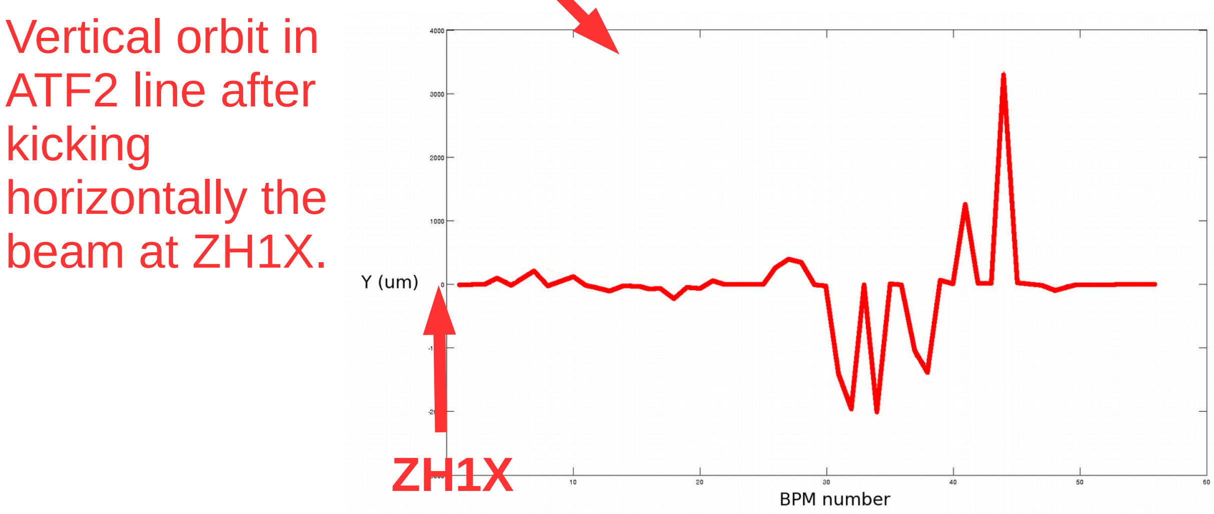
The vertical position jitter at IP corresponds to: $1.0\sigma_y^*$ at 0.2e10 and to $0.7\sigma_y^*$ at 0.76e10.

Experimental results
Magnet roll/coupling
(early results)

Experimental results
Magnet roll/coupling

The goal was to measure and correct the coupling due to quadrupole rolls.



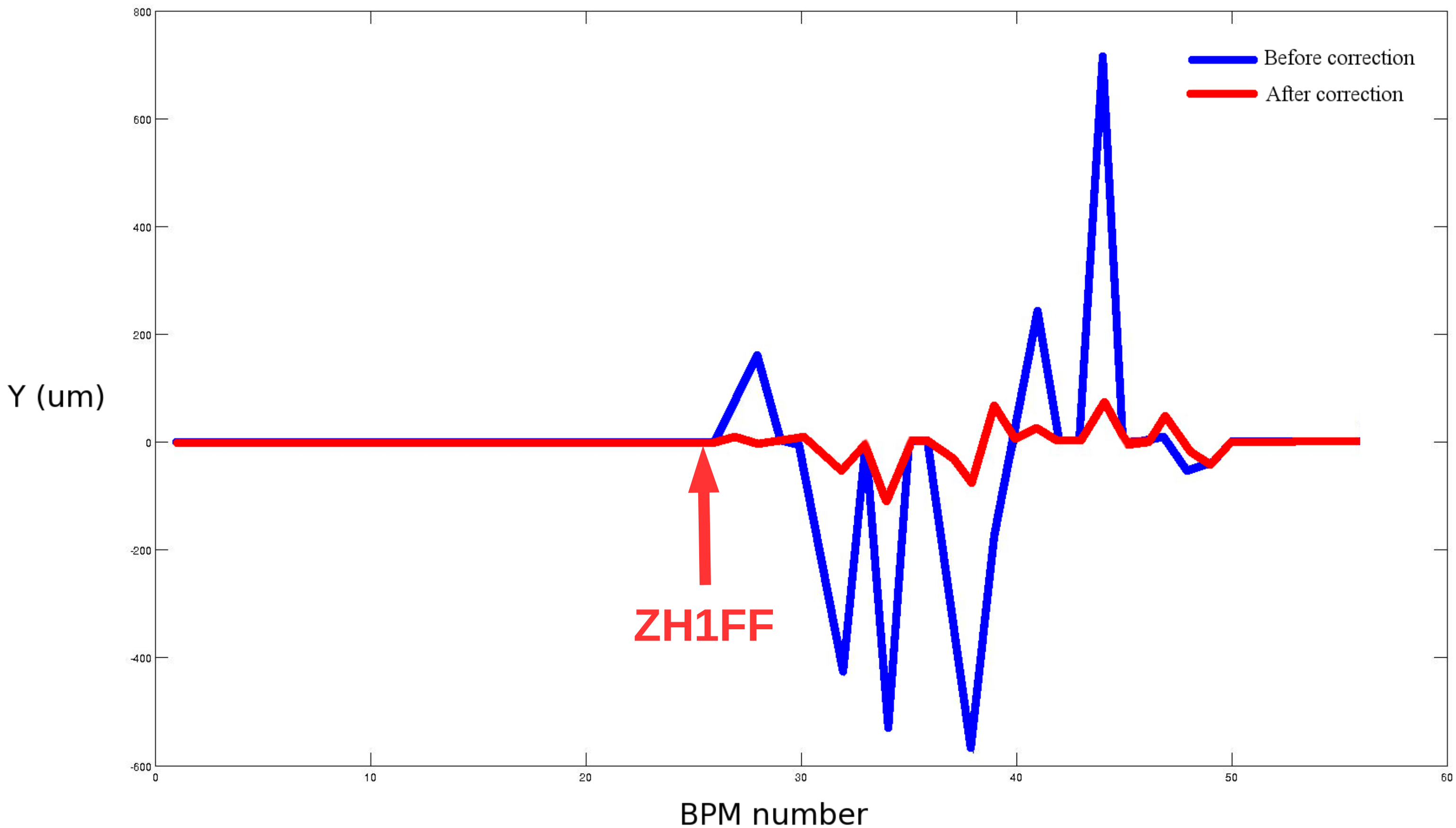


Corrector number	Corrector name	Comment
1	ZV1X	Good
2	ZV2X	Good
3	ZH1X	Good
4	ZV3X	Good
5	ZH2X	Good
6	ZV4X	Good
7	ZV5X	Good
8	ZH3X	Good
9	ZV6X	Good
10	ZH4X	Good
11	ZV7X	Good
12	ZH5X	Good
13	ZV8X	Good
14	ZH6X	Good
15	ZH7X	Good
16	ZV9X	Good
17	ZH8X	Good
18	ZV10X	Good
19	ZH9X	Good
20	ZV11X	Good
21	ZH10X	Offline
22	ZH1FF	Good
23	ZV1FF	Good

Experimental results
Magnet roll/coupling

The effect of a kick at ZH1FF (last steering magnet in ATF2, s=52.56m) on the vertical orbit is shown on the following figure. The correction consists of finding the best combinaison of the following magnets rolls (AQM13FF and AQM16FF in this case).

The best correction was obtained by rolling AQM16FF by +250μrad and AQM13FF by -100μrad.



This correction reduced the average vertical orbit (generated by kicking horizontally at ZH1FF) by a factor 20.

The goal is to apply this correction in an automatic way.

Intensity dependence studies using Placet

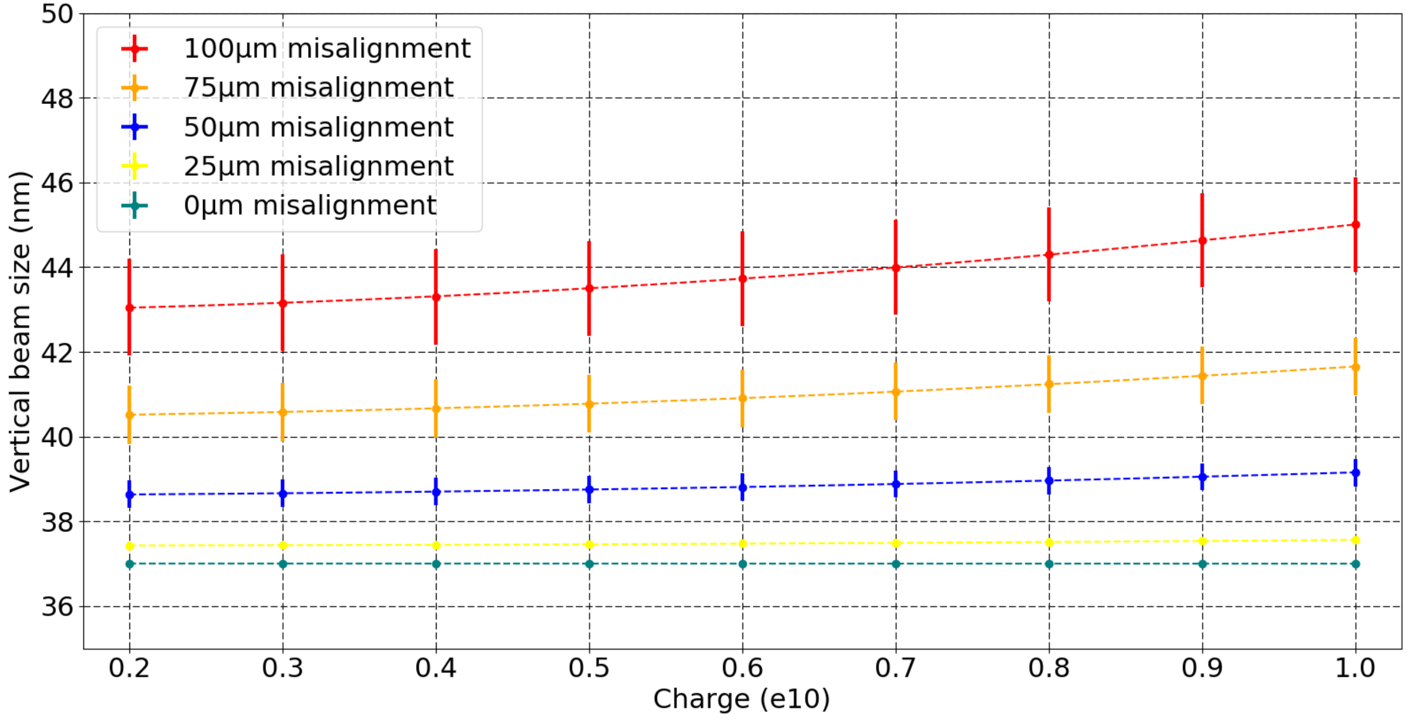
Static effects
Simulation conditions

- Wakefields used: GdfdL simulations from A. Lyapin.
- Latest BPMs configuration with BPM resolution (5µm for striplines, 1µm for CavBPMs).
- 100 random seeds (machines).
- BBA correction applied: 1to1, DFS, WFS.
- Ideal knobs used to correct the IP distribution: <y,x’>, <y,y’>, <y,E>, <y,x’^{2}>, <y,x’*y’>, <y,x’*E>.

Static effects
Impact of misalignments

Simulations conditions:

- Conditions from slide 17.
  + Misalignment of Quadrupoles, CavBPMs, Sextupoles.



The 100µm RMS misalignments increase the average beam size
by 16.35% at $N=2.0\times10^{9}$ and by 21.64% at $N=1\times10^{10}$

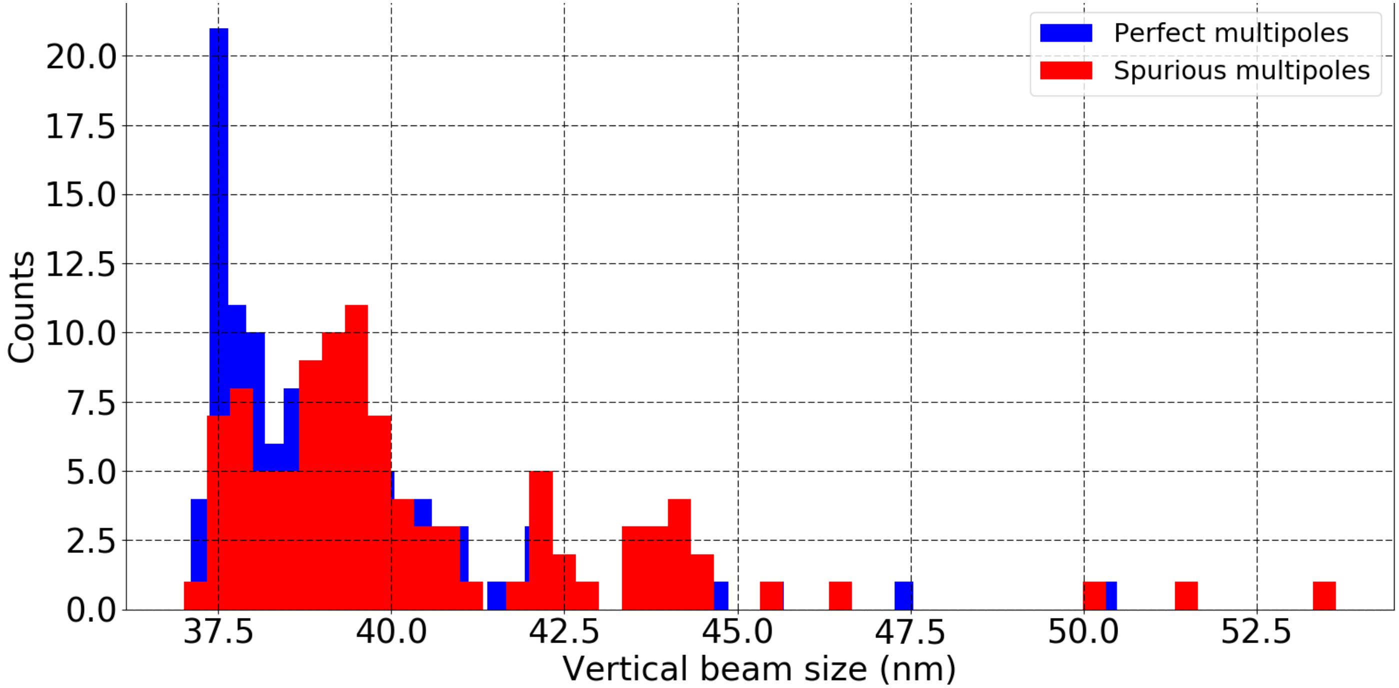
Static effects
Impact of spurious multipoles

Simulations conditions:

- Conditions from slide 17.

  + Misalignment of Quadrupoles, CavBPMs, Sextupoles of 50µm RMS.

  + Errors in the Quadrupoles and Sextupoles strengths of $1x10^{-4}$.

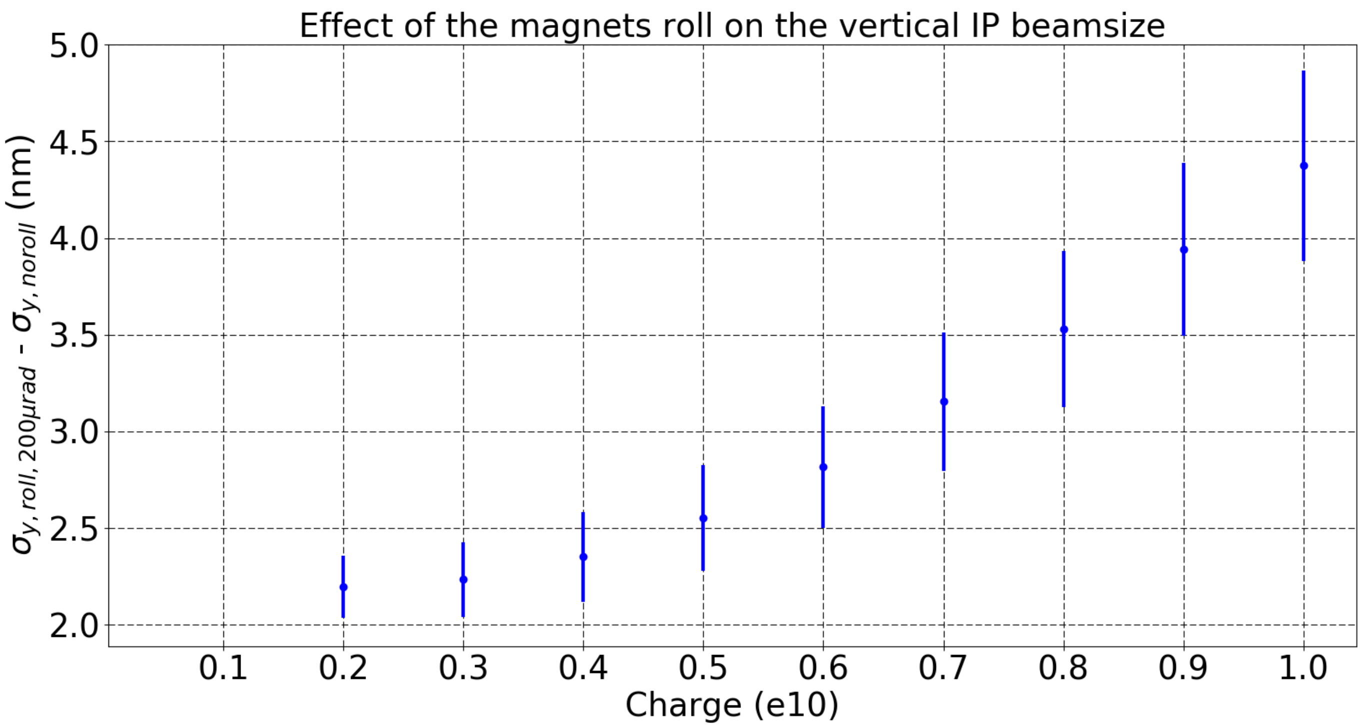


38 perfect machines provide a vertical beam size of at most 38nm against 15 machines for the spurious multipoles case.

Static effects
Impact of magnet rolls

Simulations conditions:

- Conditions from slide 17.
  + Roll error of 200µrad RMS for BPMs, quadrupoles, sextupoles.



The roll error increases the average beam size by 5.94% at $N=1.0x10^{9}$ and by 11.82% at $N=1.0x10^{10}$

Static effects
Summary

Static error type	Misalignment	Strength error	Roll error
Error's amplitude	100µm	1.0×10^{-4} (and 50µm misalignment)	200µrad
$\sigma_{y,ip}$ growth at $N=2.0 \times 10^{9}$	16.35%*	4.33%	5.94%
$\sigma_{y,ip}$ growth at $N=1.0 \times 10^{10}$	21.64%	14.62%	11.82%

$*\sigma_{y,ip,\ nominal} + 16.35\% \times \sigma_{y,ip,\ nominal} = \sigma_{y,ip,\ 100\mu m,\ 2.0e9}$

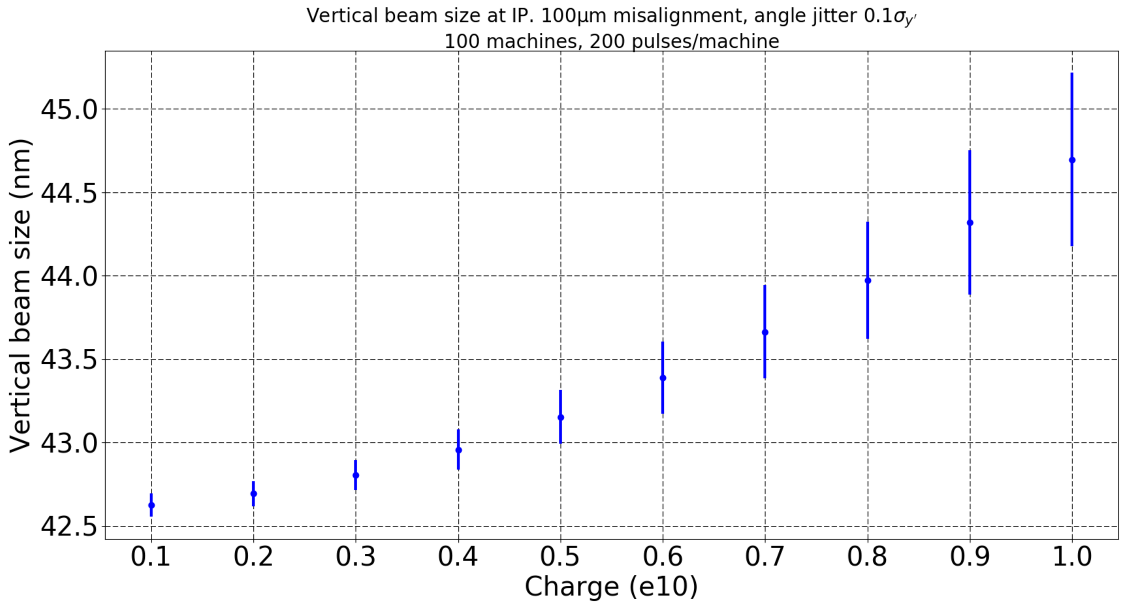
with $\sigma_{y,ip,\ nominal} = 37nm$

Dynamic effects
Simulation conditions

- Wakefields used: GdfdL simulations from A. Lyapin.
- Latest BPMs configuration with BPM resolution.
- Misalignment of Quadrupoles, CavBPMs, Sextupoles of 100um RMS.
- 100 random seeds (machines).
- BBA correction applied: 1to1, DFS, WFS.
- 200 pulses: initial position jitter of $0.1\sigma_y$ or angle jitter of $0.1\sigma_{y'}$
  (With $\sigma_{y'}$ the angular divergence: $\sigma_{y'}=\sqrt{\epsilon_y/\beta_y}$)
- Ideal knobs used to correct the IP distribution:
  <y,x'>, <y,y'>, <y,E>, <y,x'²>, <y,x'*y'>, <y,x'*E>.

Dynamic effects
Angle jitter

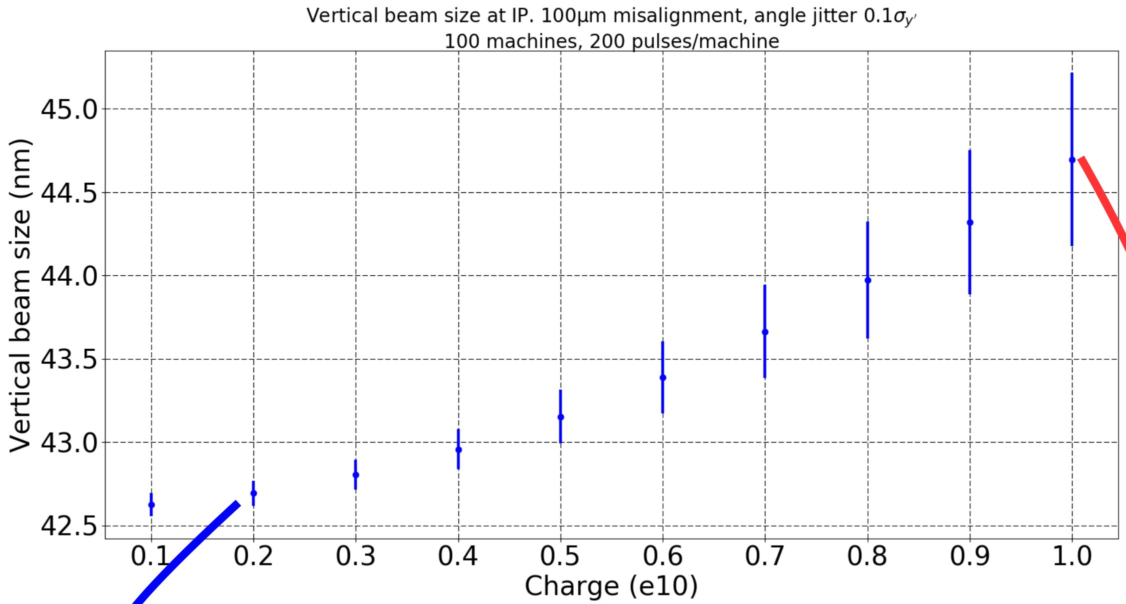
In this case, there are 100 machines with a 100µm RMS misalignment and 200 pulses/machine.

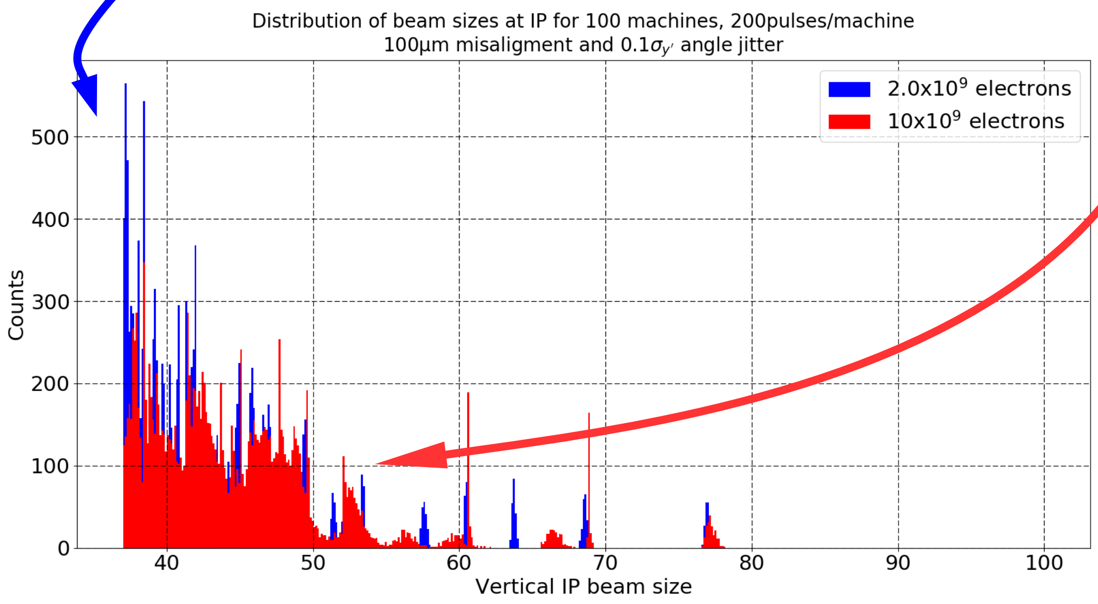


Each point of the plot represents the average of 100 machines and 200 pulses per machine.

Dynamic effects
Angle jitter

In this case, there are 100 machines with a 100µm RMS misalignment and 200 pulses/machine.





Each point of the plot represents the average of 100 machines and 200 pulses per machine.

The distribution of all beam sizes at high charge shows that are some misalignment seeds giving large beamsizes for all pulses even with this good correction schemes.

K

Dynamic effects
Angle jitter

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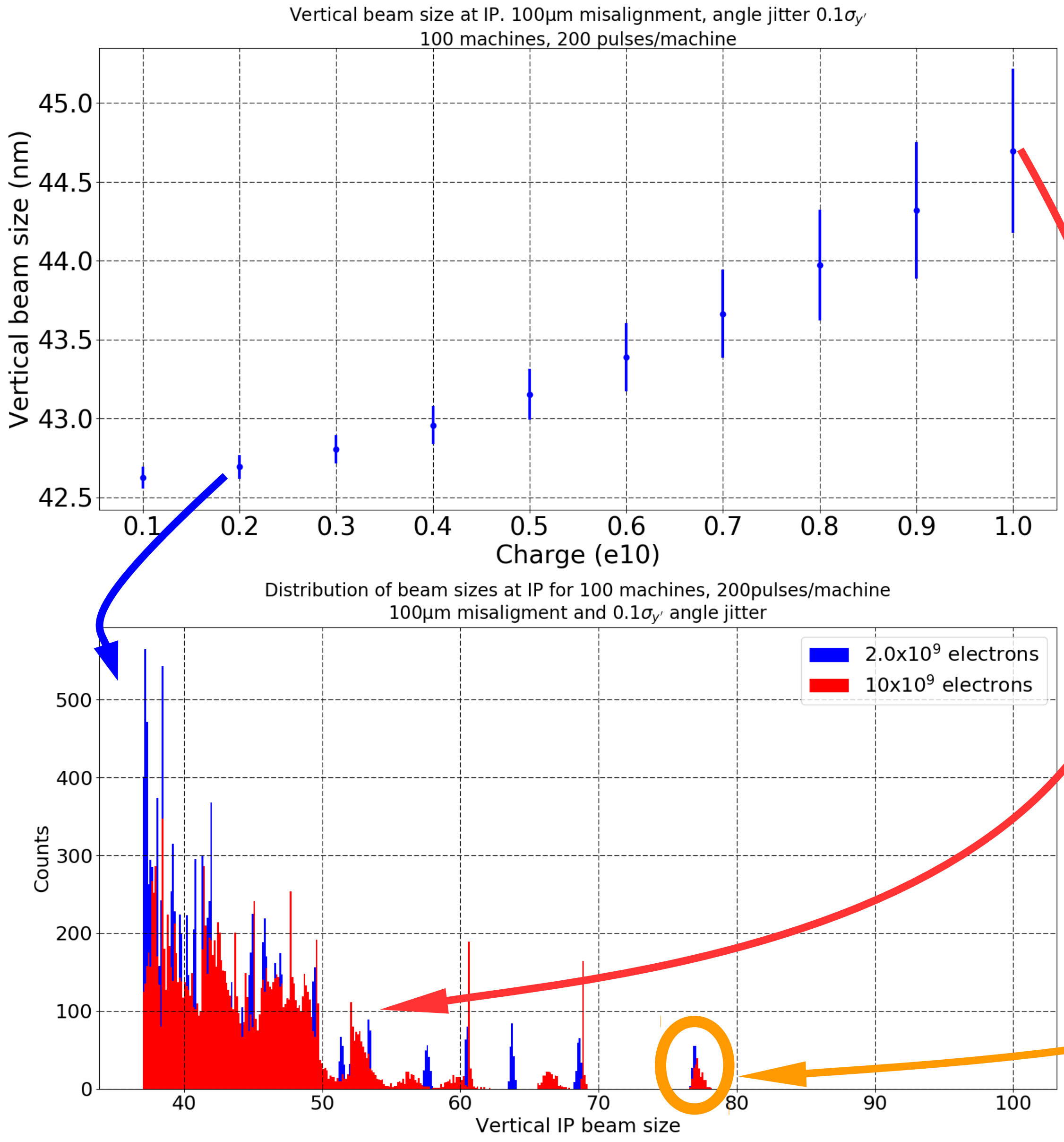

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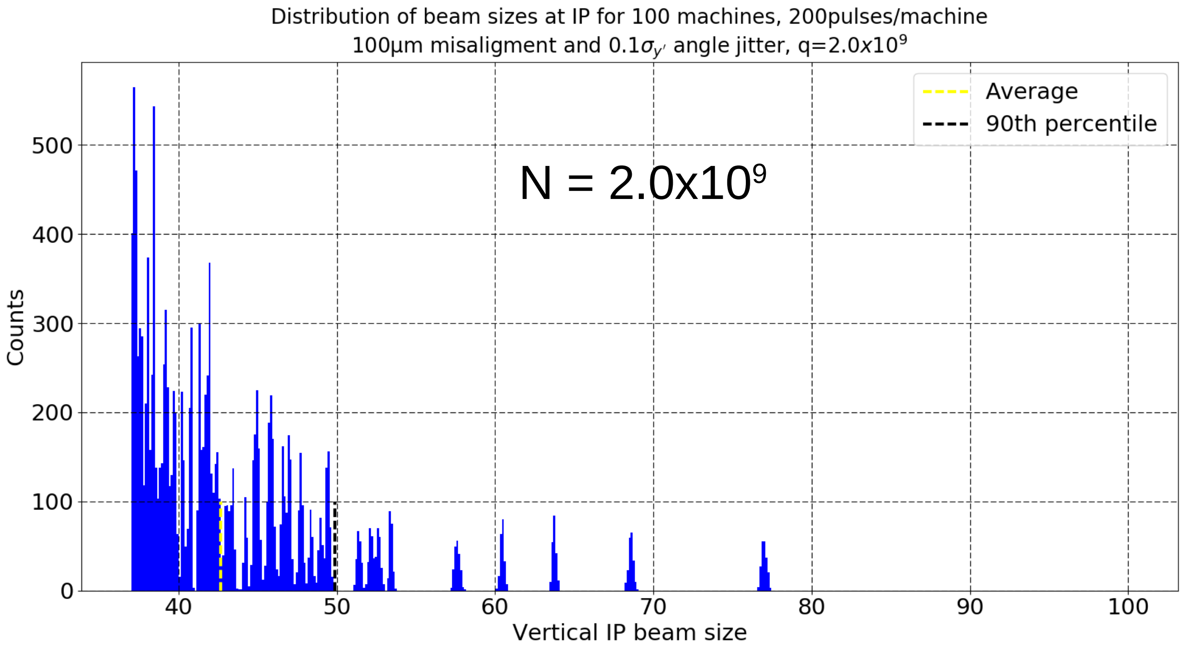
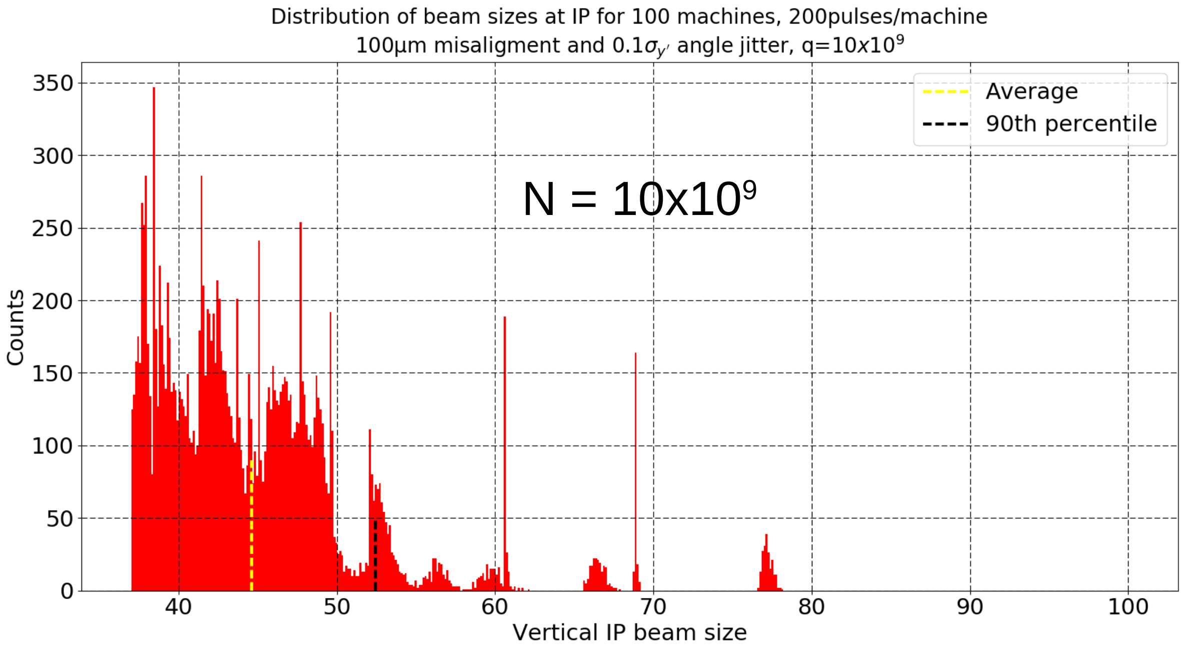
Dynamic effects
Angle jitter - Summary





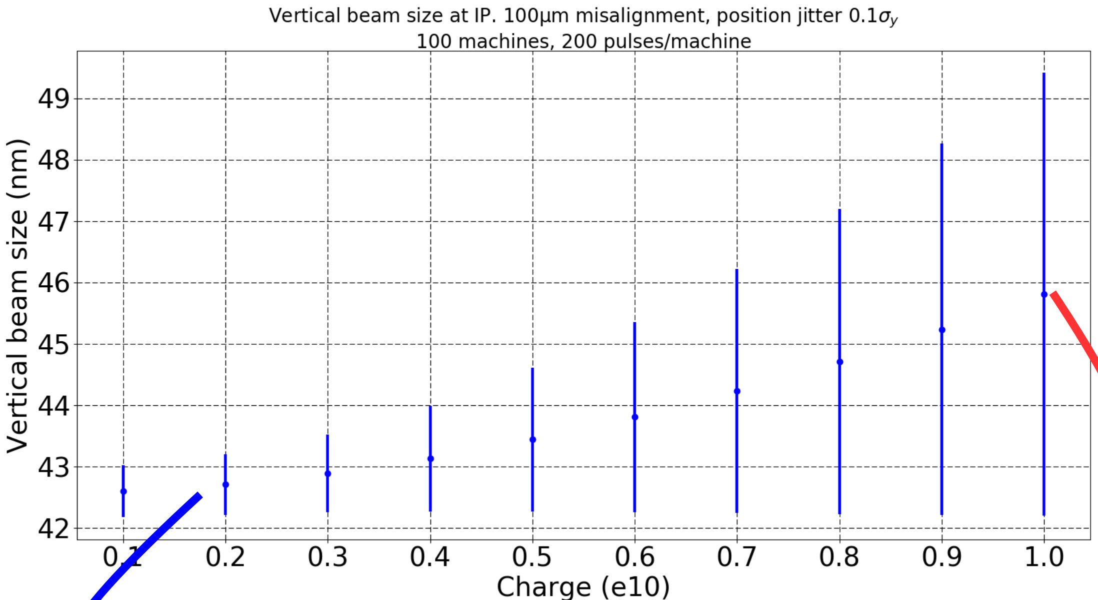
For 100 machines with a 100µm RMS misalignment and 200 pulses with an initial angle jitter of 0.1$\sigma_{y'}$
The results are as follows:

Charge	Average $\sigma_{y,ip}$	90th percentile*
N=2.0x10^9	42.56nm	49.89nm
N=10x10^9	44.63nm	52.85nm

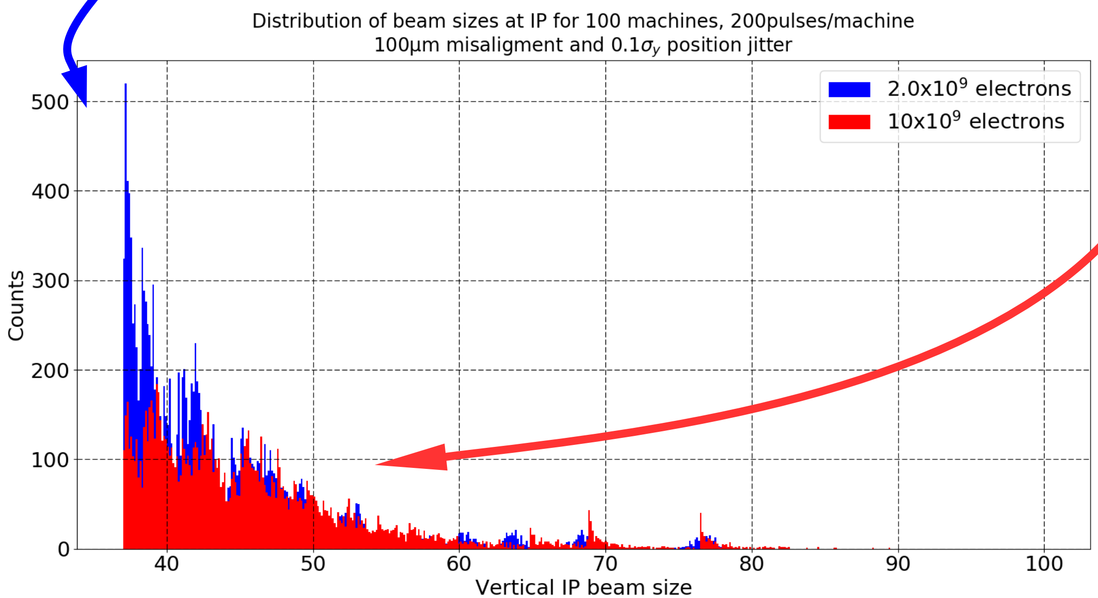
* 90% of the beam sizes are smaller than this value

Dynamic effects
Position jitter

Considering the same simulation conditions but with an intial position jitter of $0.1\sigma_y$



Each point of the plot represents the average of 100 machines and 200 pulses per machine.



The distribution of all beam sizes at high charge shows that are some misalignment seeds giving large beamsizes for all pulses even with this good correction schemes.

K

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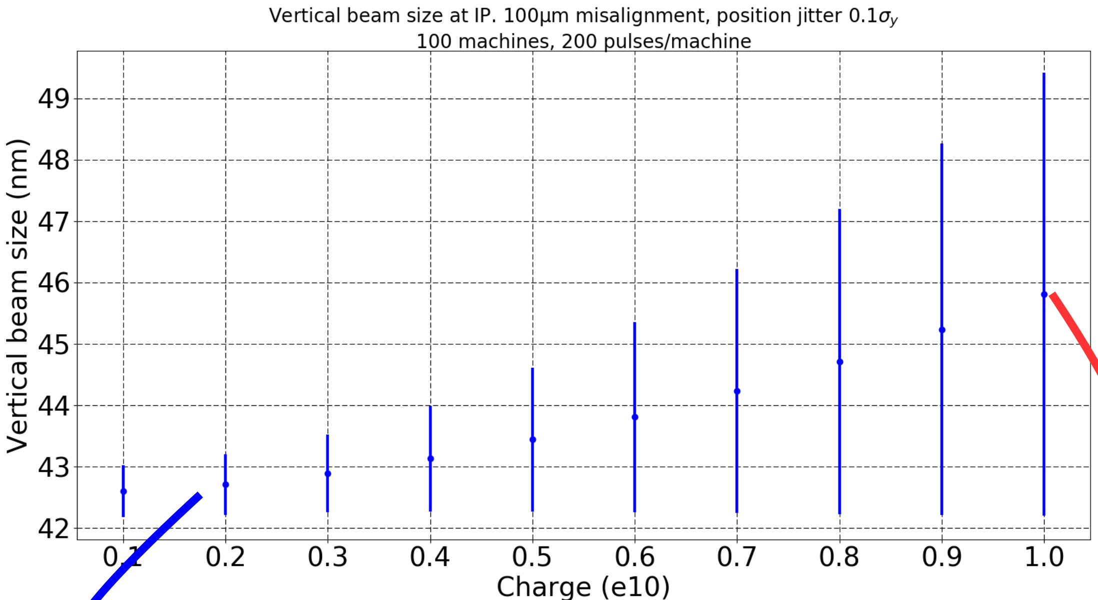

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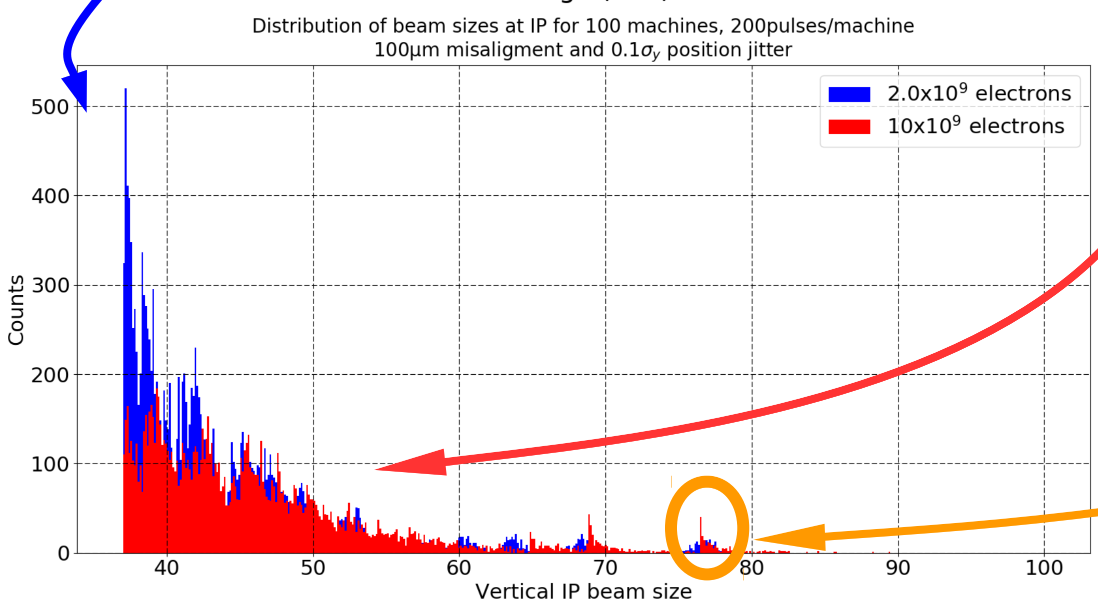

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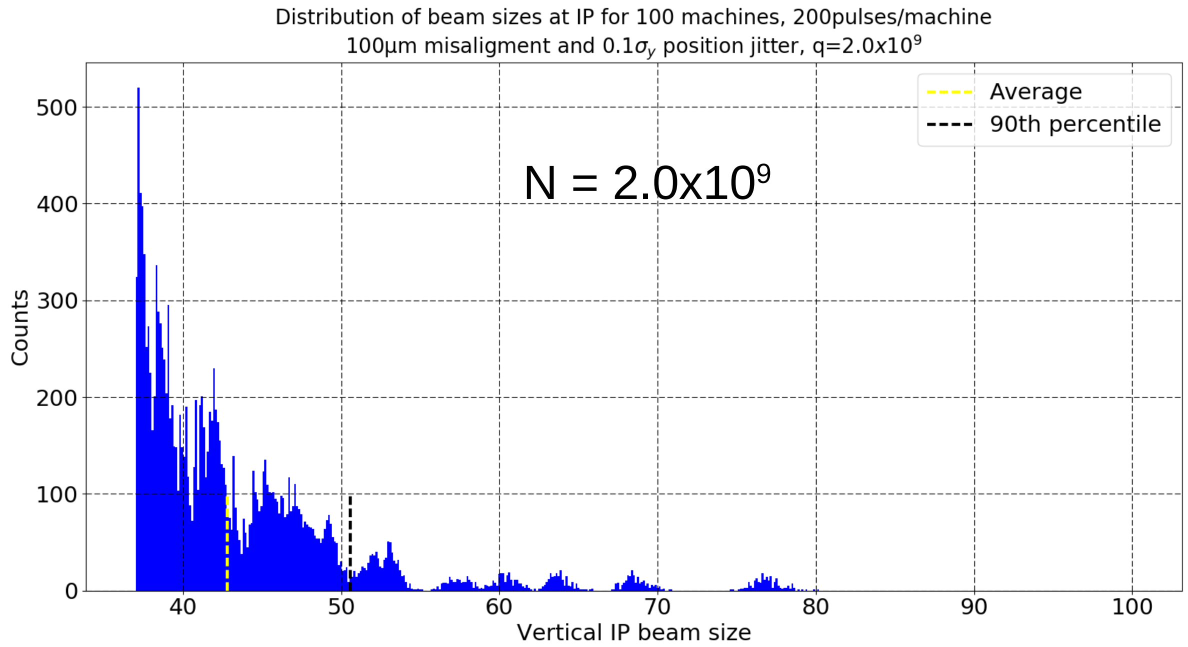
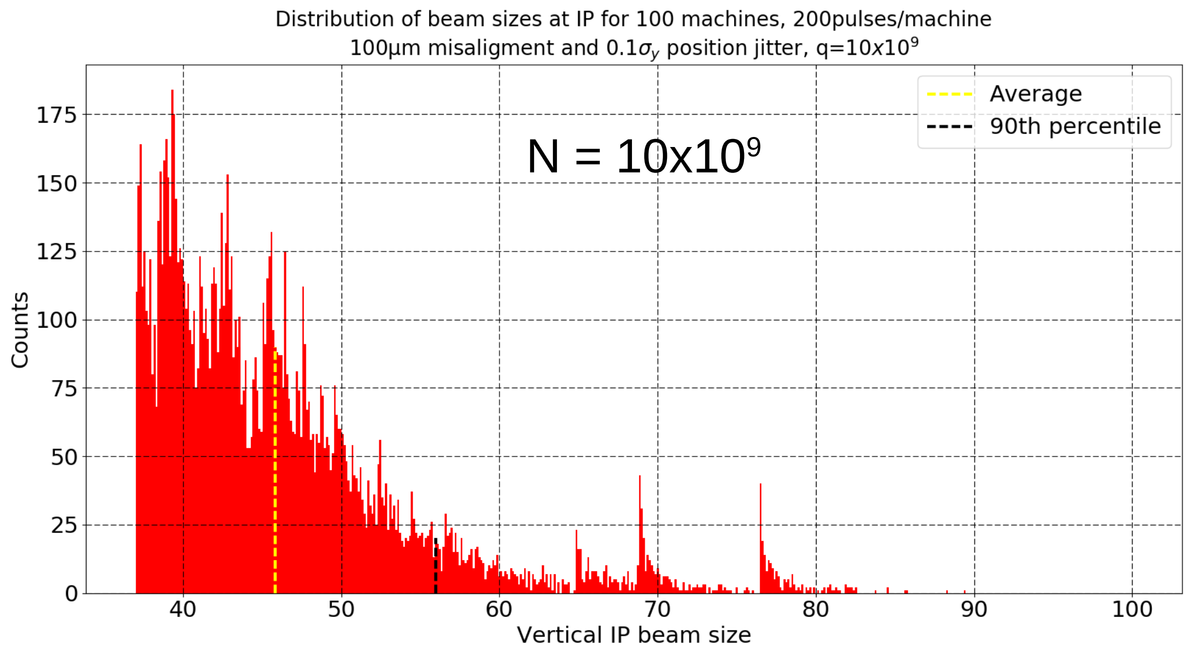
Dynamic effects
Position jitter - Summary





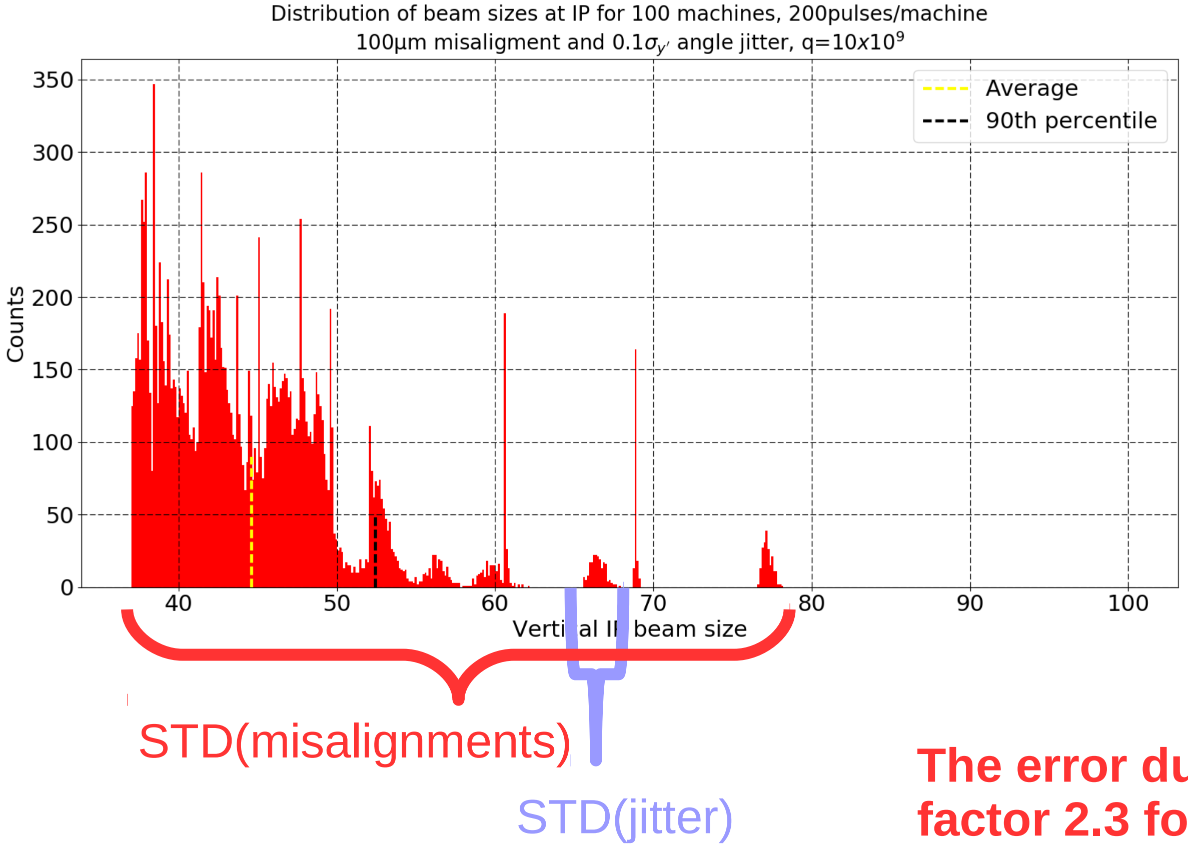
For 100 machines with a 100µm RMS misalignment and 200 pulses with an initial position jitter of $0.1\sigma_y$
The results are as follows:

Charge	Average $\sigma_{y,ip}$	90^{th} percentile*
$N=2.0x10^9$	42.79nm	50.56nm
$N=10x10^9$	45.81nm	55.98nm

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

Dynamic effects
Angle and position jitter

Comparing the standard deviation of the beam sizes due to the misalignment or due to the jitter:



Case	STD(misalignment)	STD(jitter)
Position jitter $0.1\sigma_y$ $N = 2.0x10^9$	7.21nm	0.42nm
Position jitter $0.1\sigma_y$ $N = 10x10^9$	8.34nm	3.61nm
Angle jitter $0.1\sigma_{yp}$ $N = 2.0x10^9$	7.20nm	0.08nm
Angle jitter $0.1\sigma_{yp}$ $N = 10x10^9$	7.22nm	0.52nm

The error due to the misalignment is larger by a factor 2.3 for the position jitter case at $N = 10x10^9$ and by a factor 13 for the angle jitter at $N = 10x10^9$.

Plans for December 2018 operations

- Work on the Dispersion Free Steering code implementation and try it on the ultra low beta optics during the CERN tuning week.
- Implement and work on the Wakefield Free Steering code.
- Pursue the study of the wakefield sources on movers
- (Trying to assess the intial jitter of the ATF2 extraction line using the beam orbit?).

Conclusion and outlook

- The BPMs calibration permits to have a more stable and reliable orbit.
- The Dispersion Free Steering correction scheme gives good results in the ATF2 extraction line.
- The IPBPMs show some intensity dependence in the vertical position of the beam at the IP.
- Coupling downstream ATF2 was corrected by tilting quadrupoles. The goal would be to do that in an automatic way.
- The impact of static and dynamic effects has been analyzed and quantified. Misalignments, incoming beam angle and position jitters have a large impact on the beam size.

Outlook:

- Simulate the effect of resistive walls in ATF2.
- Measuring the incoming position and angle jitter in the ATF2.

Thank you