Intensity-dependent effects in the ATF2, simulations and measurements

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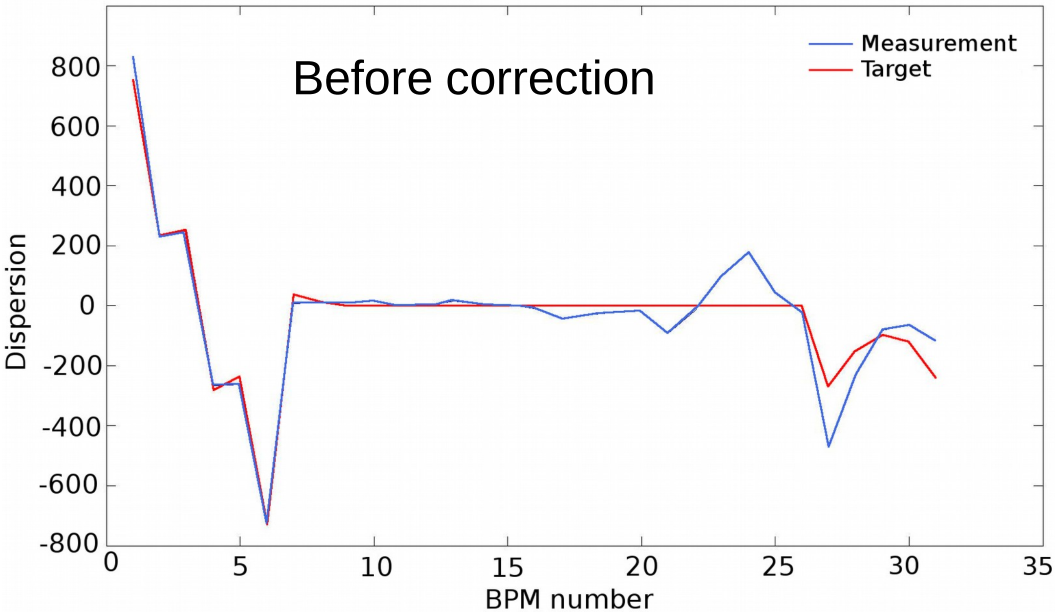
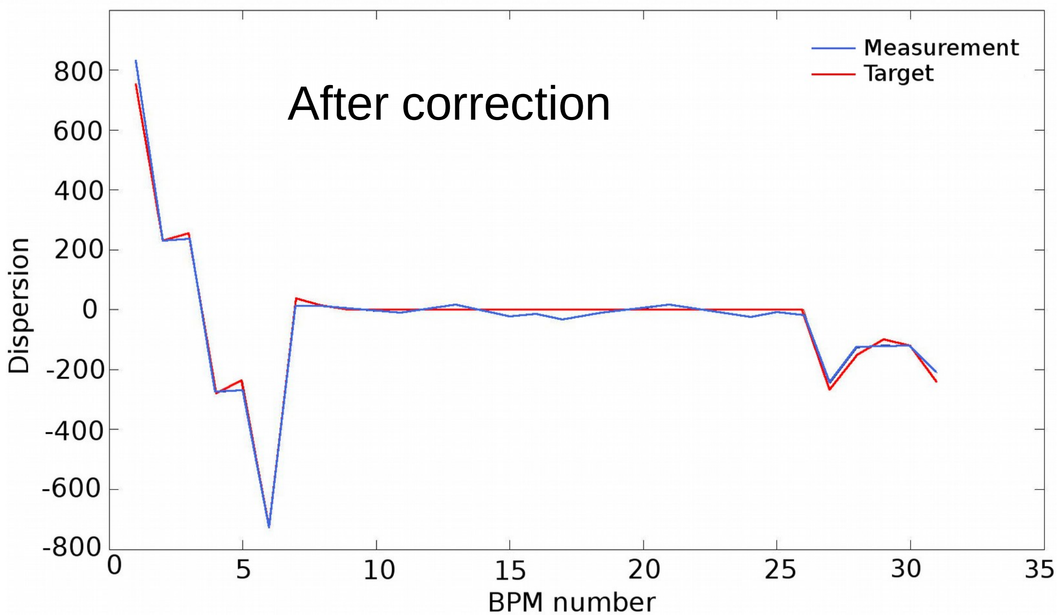
Outline

- Experimental results:
  - Dispersion Free Steering.
  - Wakefield Free Steering.
  - Intensity dependence studies using upstream BPMs and IPBMs.
  - Magnet roll/coupling correction.
- Intensity dependence studies with Placet.
- Plans for ATF2 run in March 2019.

Experimental results
Dispersion Free Steering

Dispersion Free Steering measurements
Horizontal plane

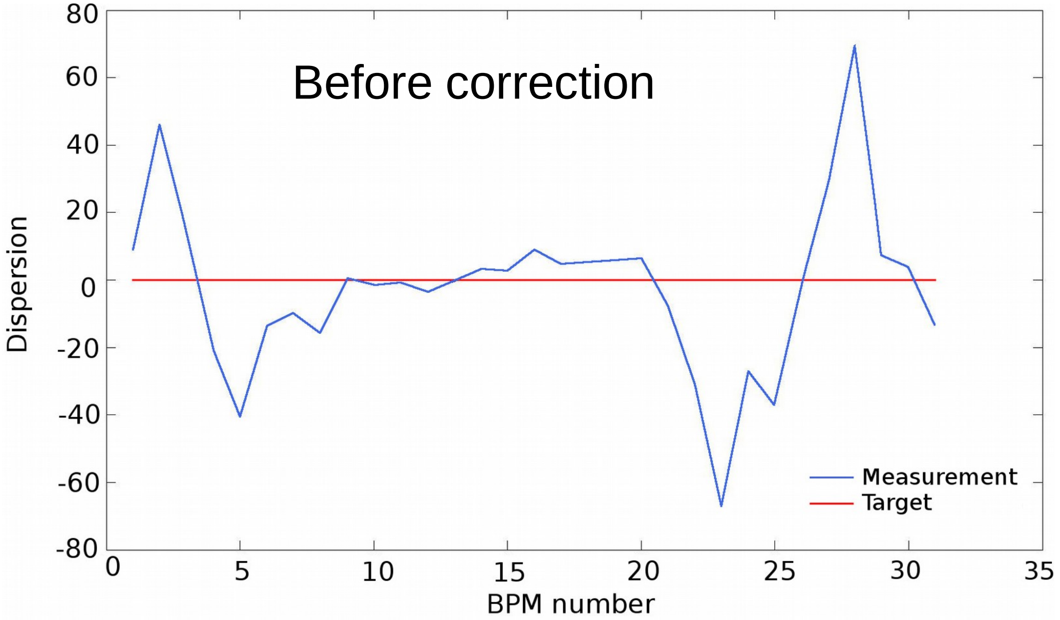


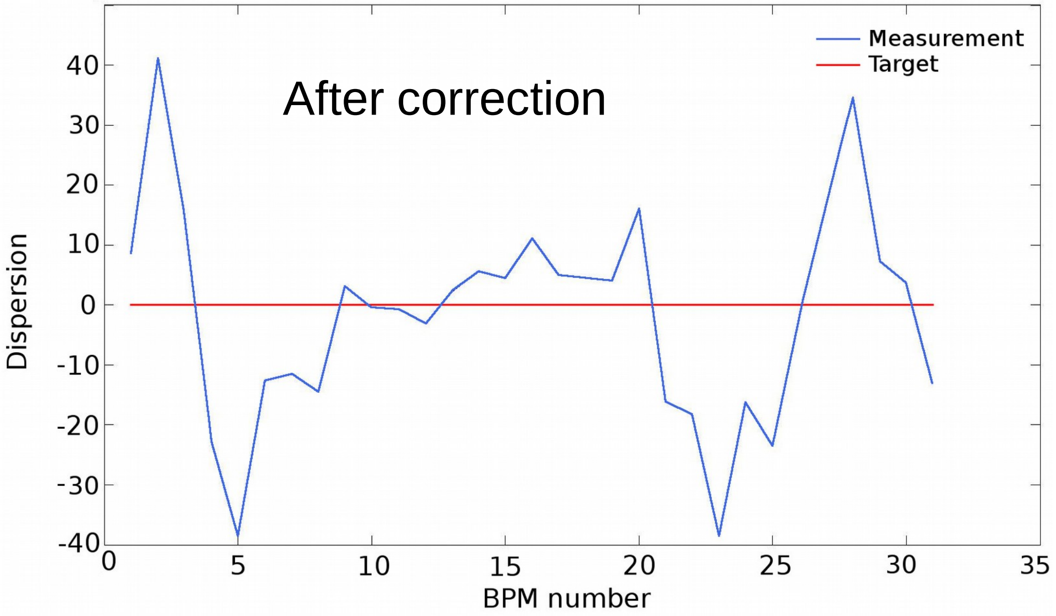


Goal: Correct the dispersion using only the steering magnets in the ATF2 beamline.

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

Dispersion Free Steering measurements
Vertical plane





Goal: Correct the dispersion using only the steering magnets in the ATF2 beamline.

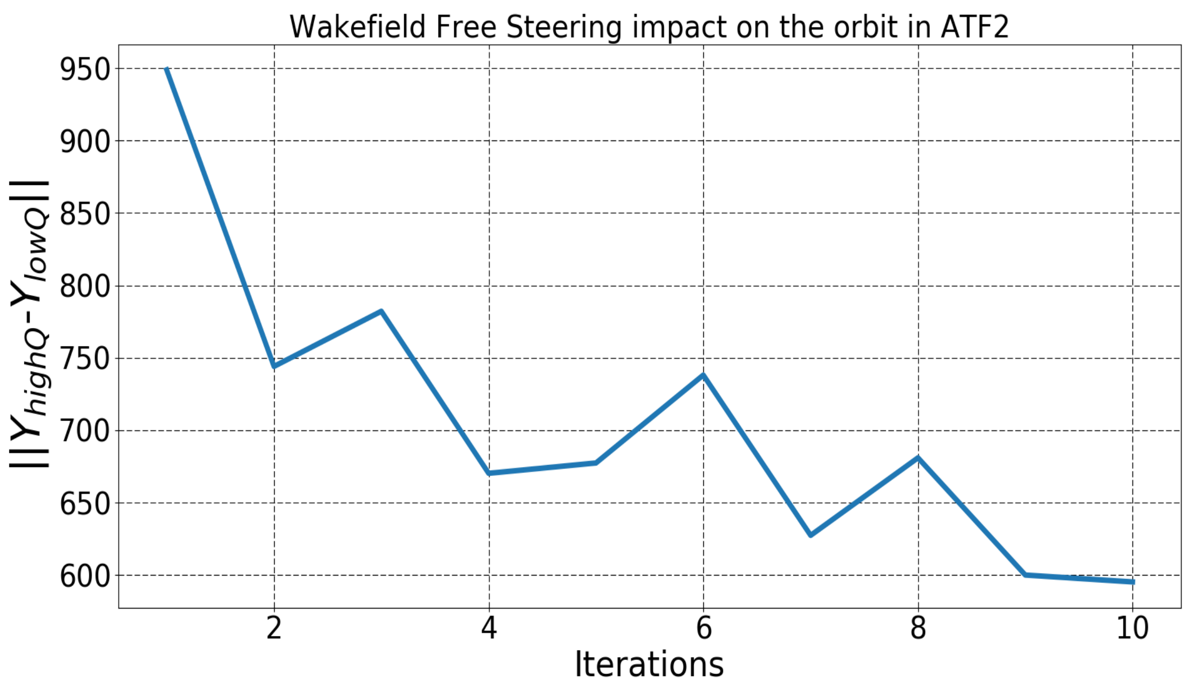
The implemented code in the machine gives good results in the vertical plane as well:
Before correction: dispersion between -65mm and 65mm.
After correction: dispersion between -40 and 40mm.

Decreases the vertical dispersion by a factor 1.6!

Experimental results
Wakefield Free Steering

Wakefield Free Steering measurements
Results from December 2018 run.

Goal: Correct the difference in orbit due to wakefields using only the steering magnets in ATF2 beamline.



$$With \, ||Y_{highQ}-Y_{lowQ}|| = \sqrt{\sum |Y_{highQ}-Y_{lowQ}|^2}$$

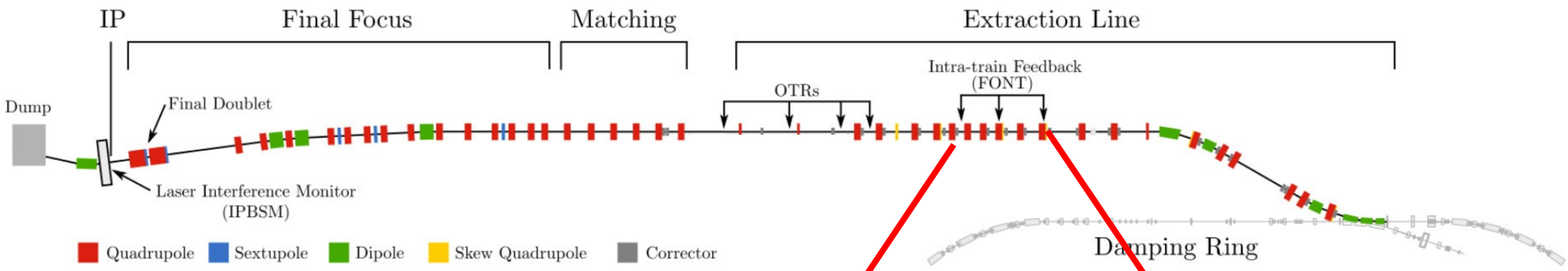
Y_{highQ} *the vertical orbit at high charge*

Y_{lowQ} *the vertical orbit at low charge*

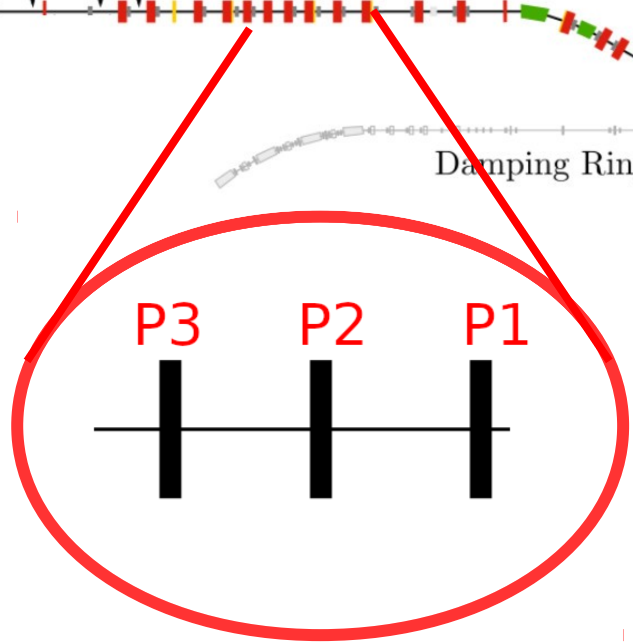
After applying DFS, the WFS code corrects the impact of the wakefields on the orbit in the actual ATF2 beamline (measurements).

Experimental results
Upstream BPMs

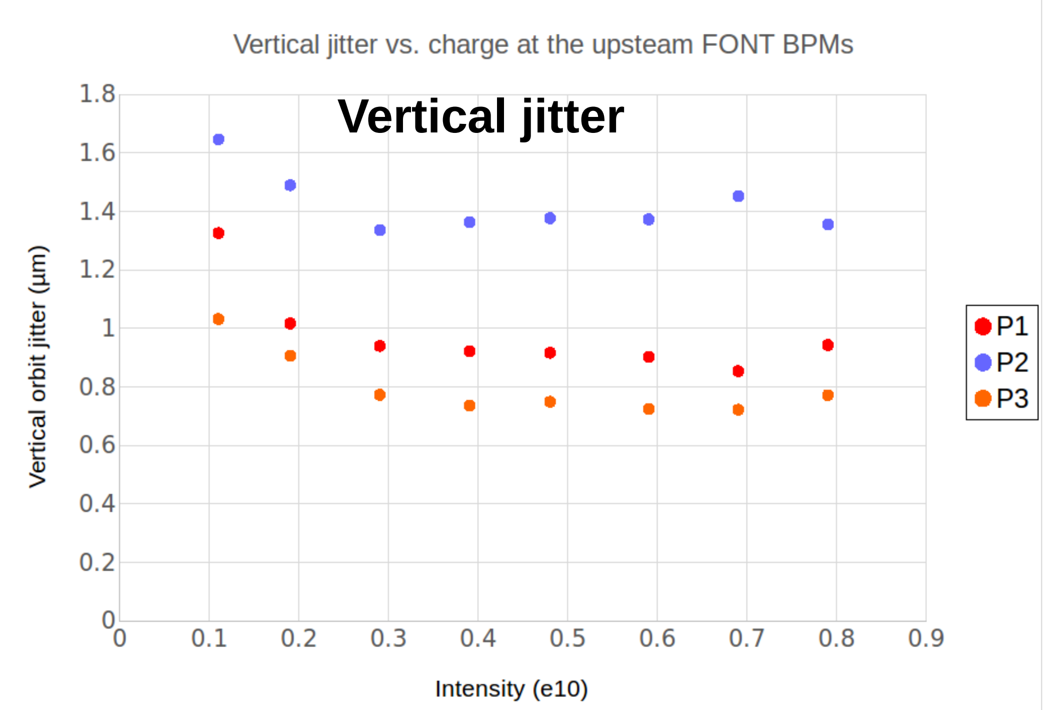
Upstream BPMs
Results from December 2018 run.

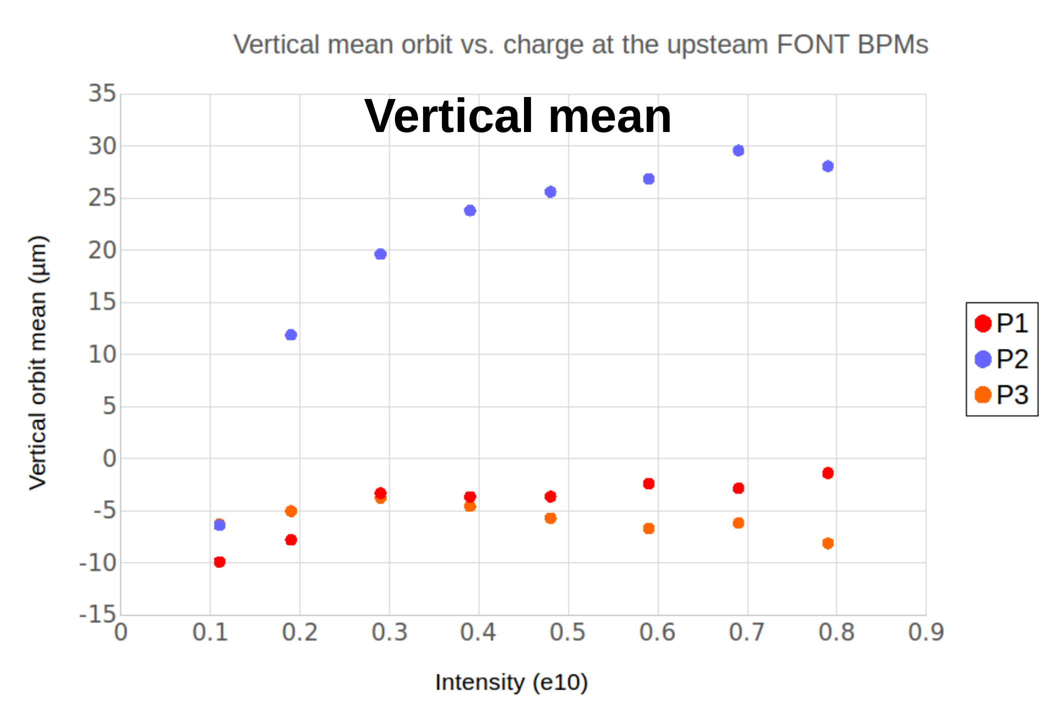


The 3 upstream FONT BPMs are located between MQF9X and MQD16X



Upstream BPMs
Results from December 2018 run.





There is a correlation between the vertical orbit jitter and the intensity.

There is a correlation between the average vertical orbit and the intensity.

The upstream measured vertical position jitter corresponds to around 0.29 times the vertical beam size.

$$Jitter\ upstream : J_{upstream} \approx 0.29\,\sigma_y$$

Experimental results
Intensity dependence studies using IPBPMs

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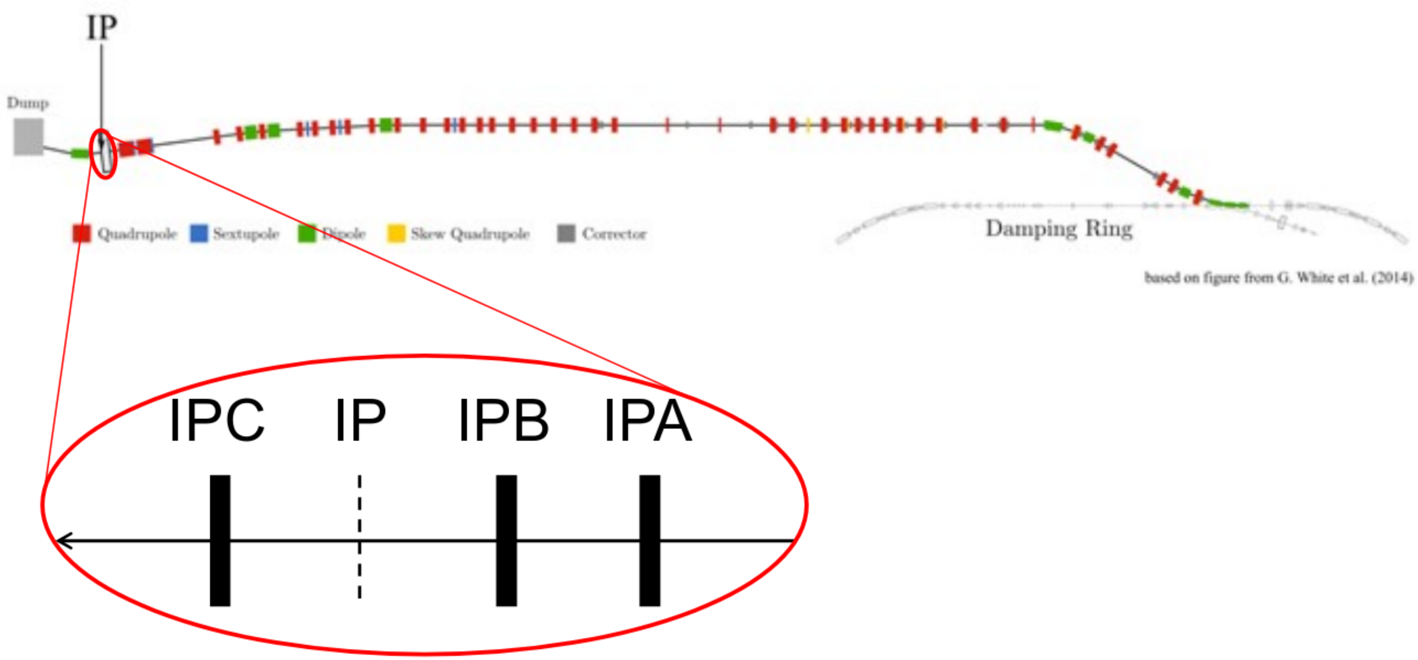
The goal was to measure the impact of an intensity increase on the beam jitter at IP.
For each intensity the IPBPMs were recalibrated. The attenuation on the dipole signals was 20dB. One should expect a resolution of [90-150] nm at the BPMs and a resolution of [90-150]/sqrt(2) = [65-105] nm at the waist.

Location of IP BPMs



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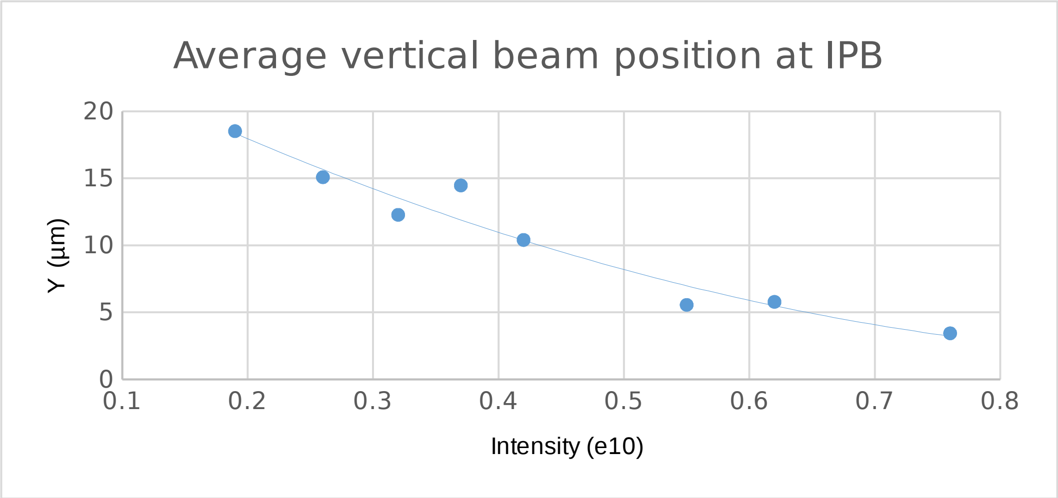

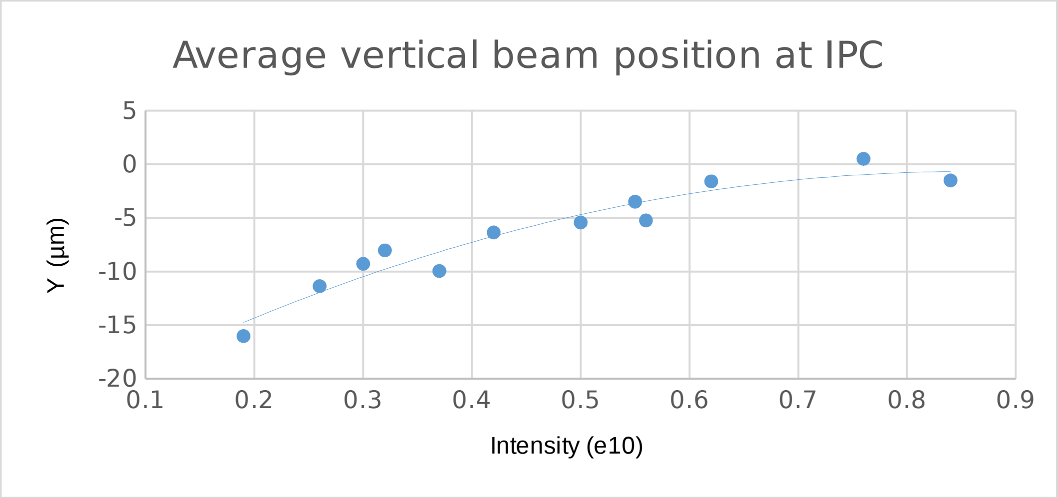

The average vertical beam position shows a quadratic correlation with the intensity at IPB and IPC.

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

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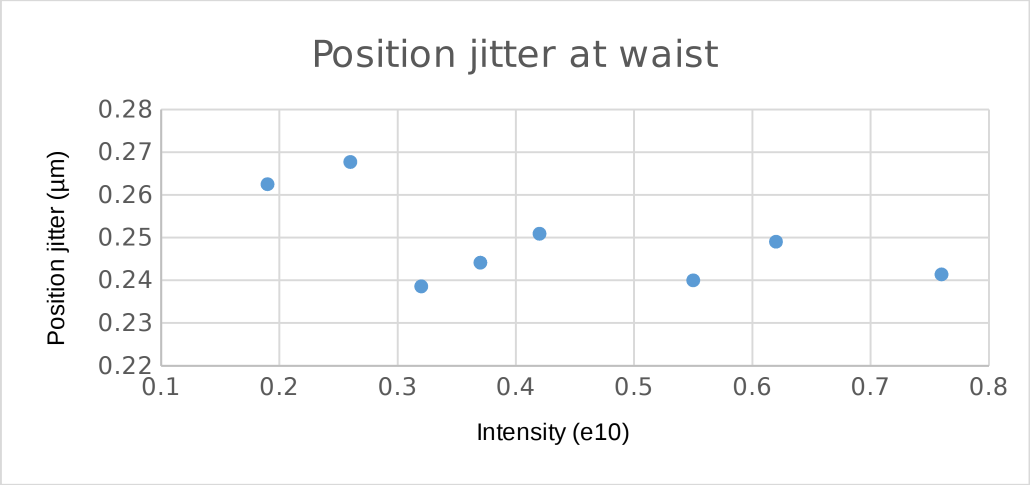
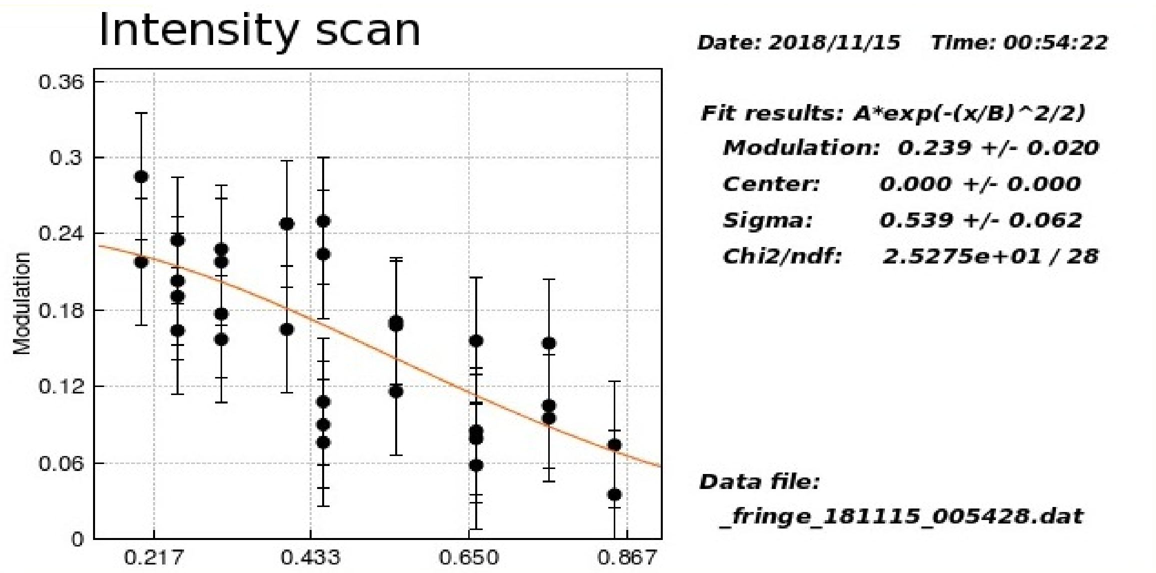


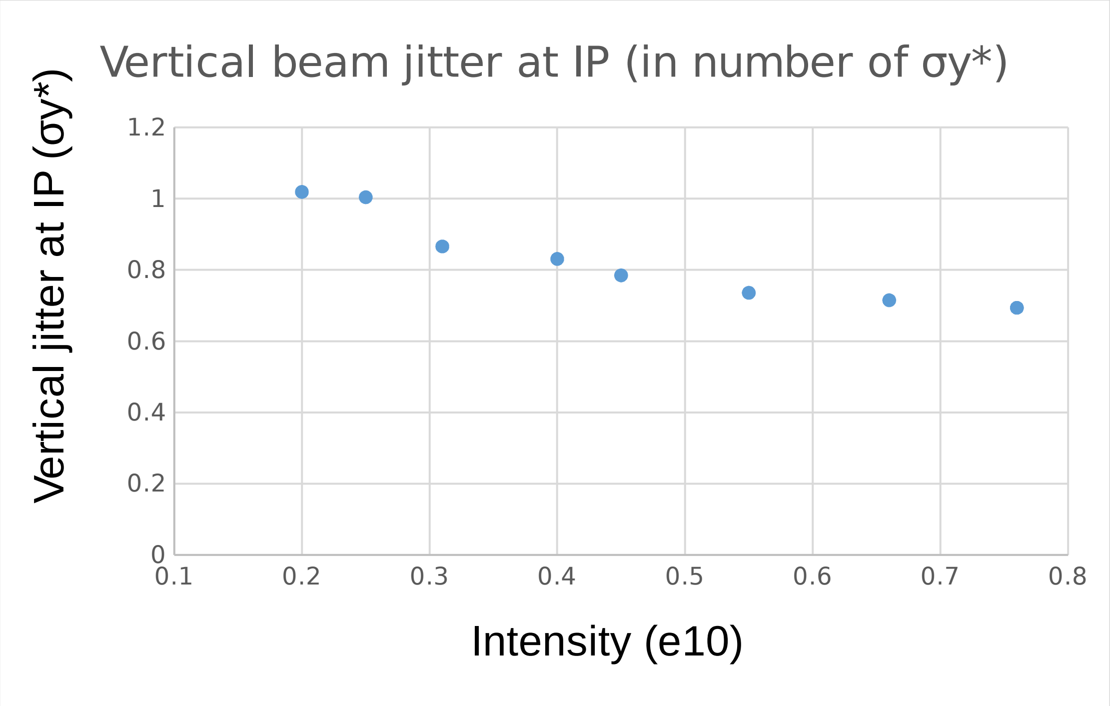
The jitters at the waist were calculated using an interpolation of the position and angle at the IPB and IPC.

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



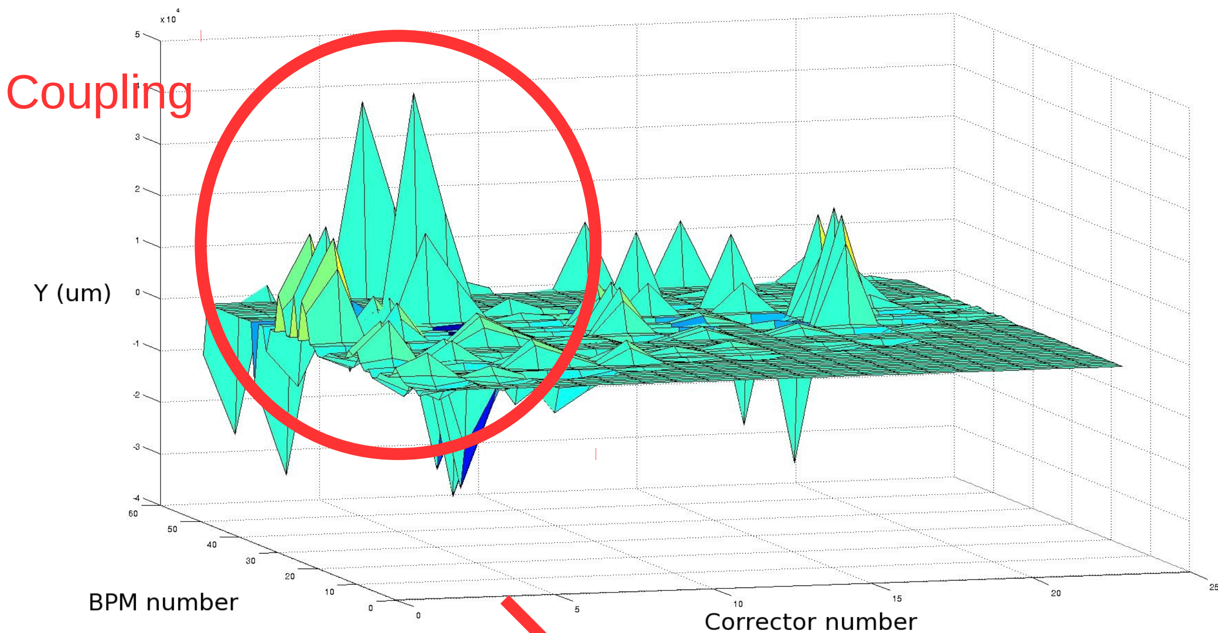


The vertical position jitter at IP corresponds to: $1.0\sigma_y^*$ at 0.2e10 and to $0.7\sigma_y^*$ at 0.76e10.

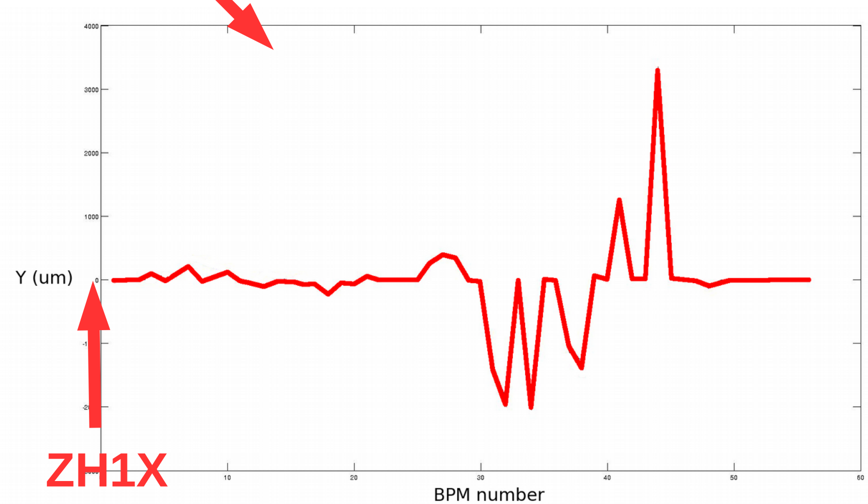
Experimental results
Magnet roll/coupling
(early results)

Experimental results
Magnet roll/coupling

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



Vertical orbit in ATF2 line after kicking horizontally the beam at ZH1X.

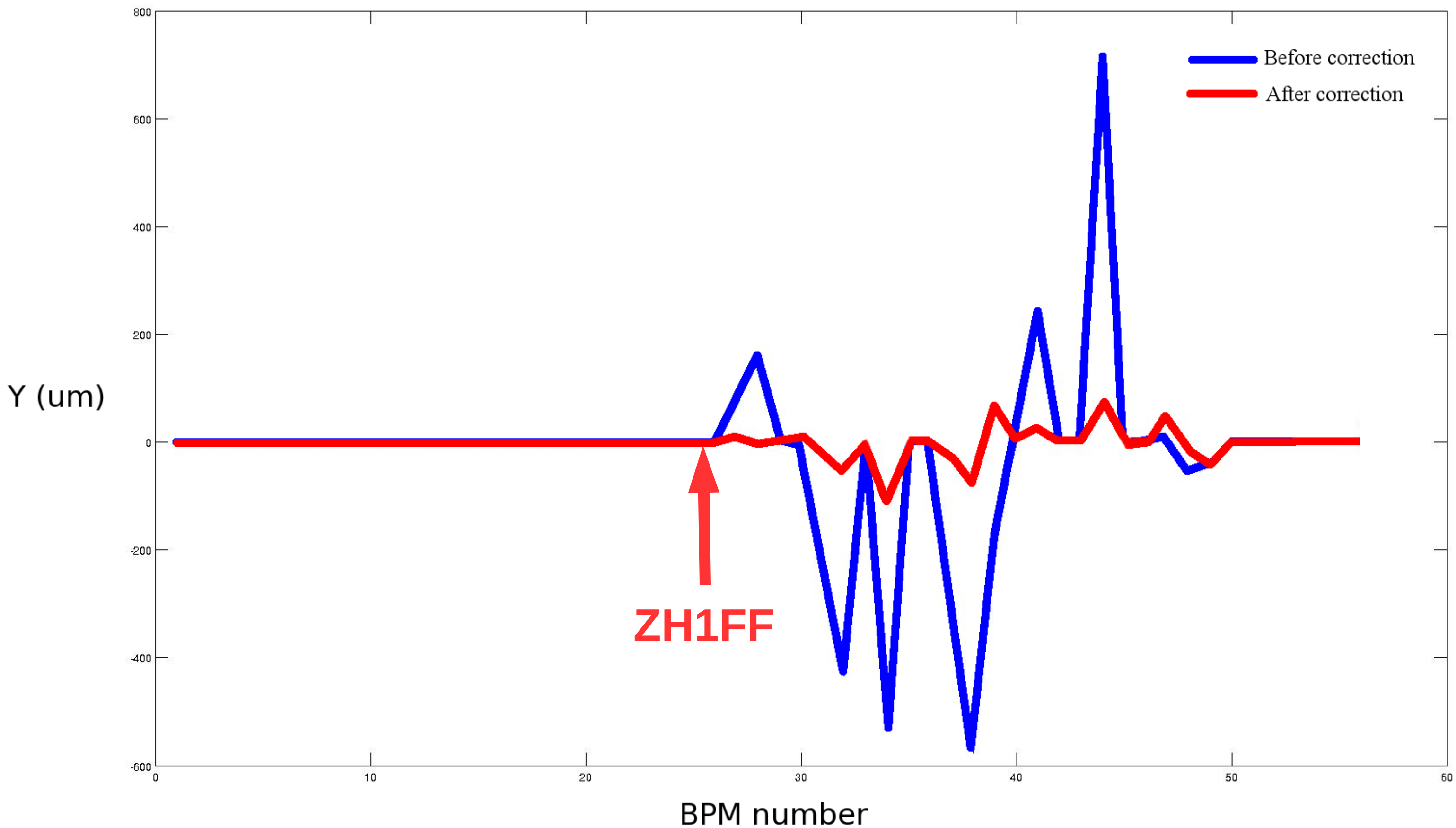


Corrector number	Corrector name	Comment
1	ZV1X	Good
2	ZV2X	Good
3	ZH1X	Good
4	ZV3X	Good
5	ZH2X	Good
6	ZV4X	Good
7	ZV5X	Good
8	ZH3X	Good
9	ZV6X	Good
10	ZH4X	Good
11	ZV7X	Good
12	ZH5X	Good
13	ZV8X	Good
14	ZH6X	Good
15	ZH7X	Good
16	ZV9X	Good
17	ZH8X	Good
18	ZV10X	Good
19	ZH9X	Good
20	ZV11X	Good
21	ZH10X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

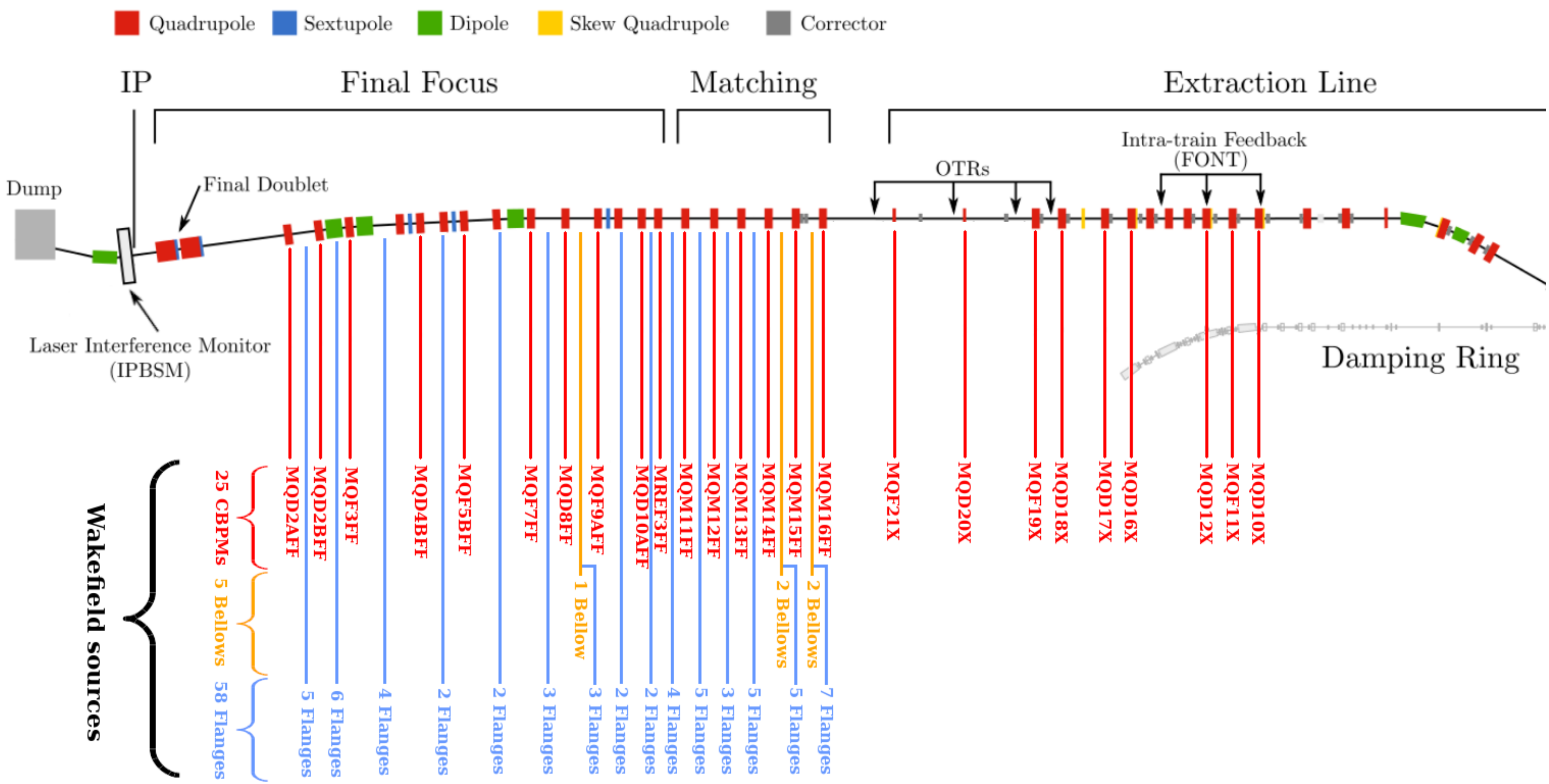
The goal is to apply this correction in an automatic way.

Intensity dependence studies using Placet

Simulation conditions

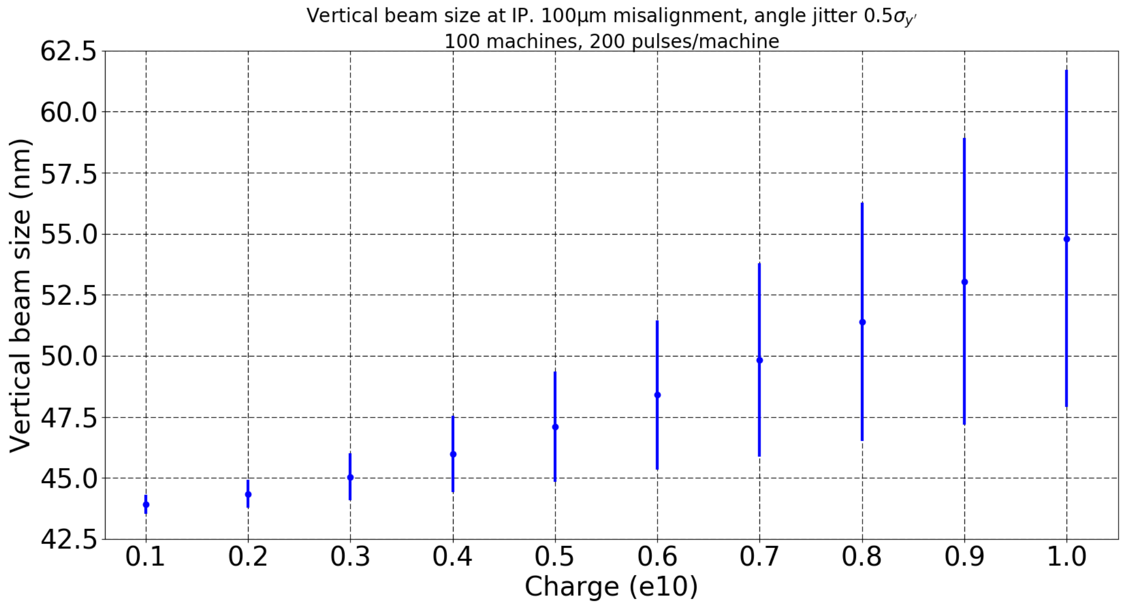
- Wakefields used: Cavity BPMs, bellows and flanges (GdfdL wakepotentials).
- Misalignment of Quadrupoles, CavBPMs, Sextupoles of 100um RMS.
- Strength error of Quadrupoles and Sextupoles of 1e-3.
- Roll error of Quadrupoles, CavBPMs and Sextupoles of 200urad.
- 100 random machines.
- BBA correction applied: 1to1, DFS, WFS.
- 200 pulses: initial position jitter of $0.5\sigma_y$ or angle jitter of $0.5\sigma_{y'}$
  (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>.

Simulation conditions
Positions of wakefield sources



Dynamic effects
Angle jitter

Considering the previous simulation conditions but with an intial angle jitter of $0.5\sigma_{y'}$



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

Dynamic effects
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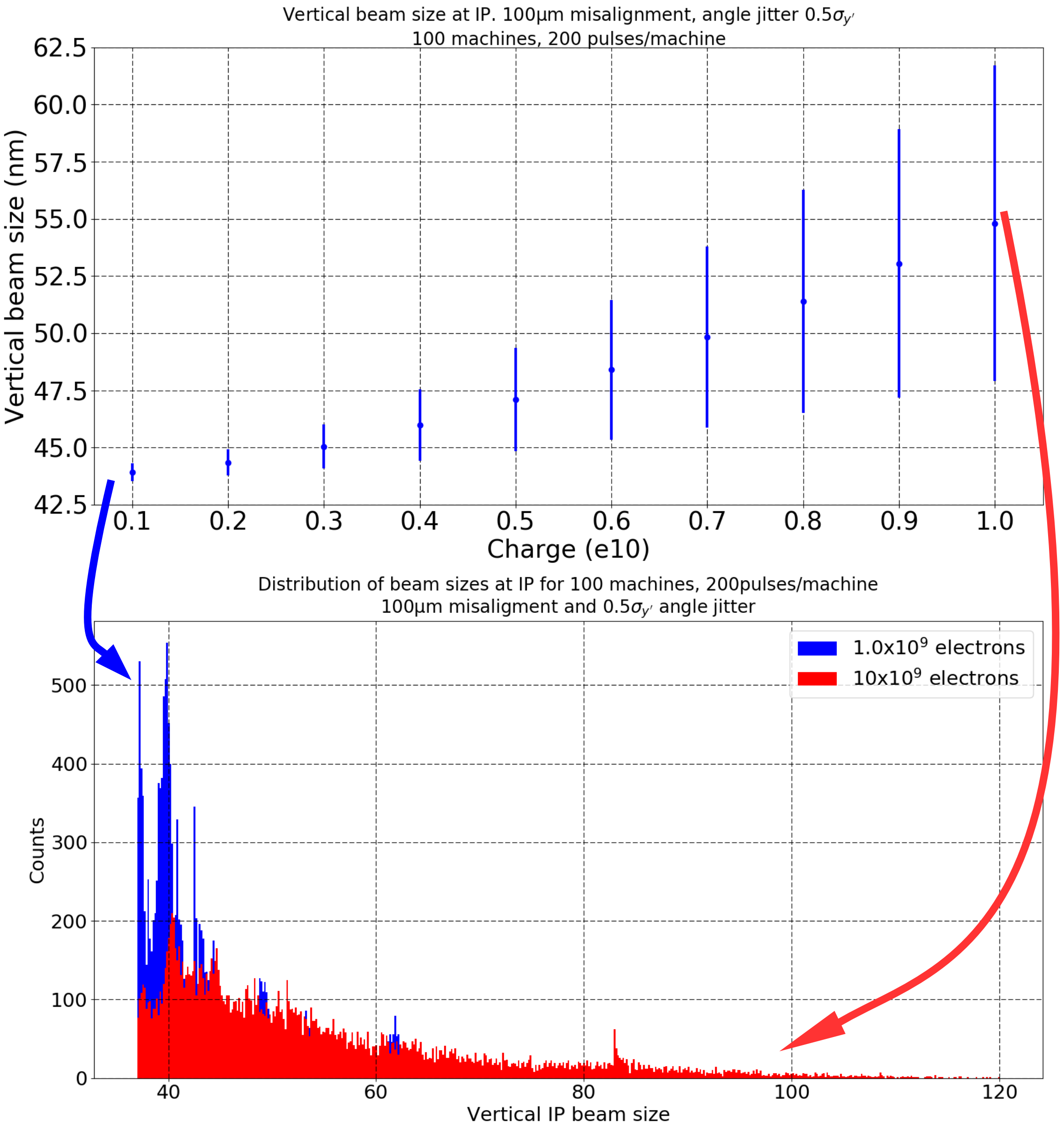
Considering the previous simulation conditions but with an intial angle jitter of $0.5\sigma_{y'}$



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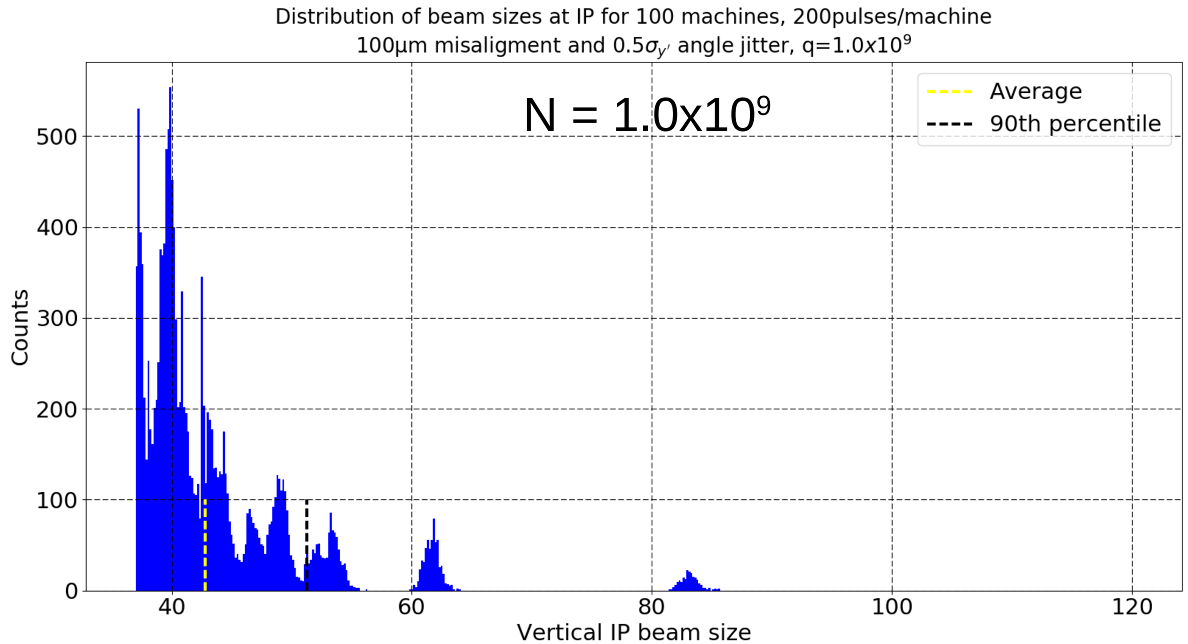
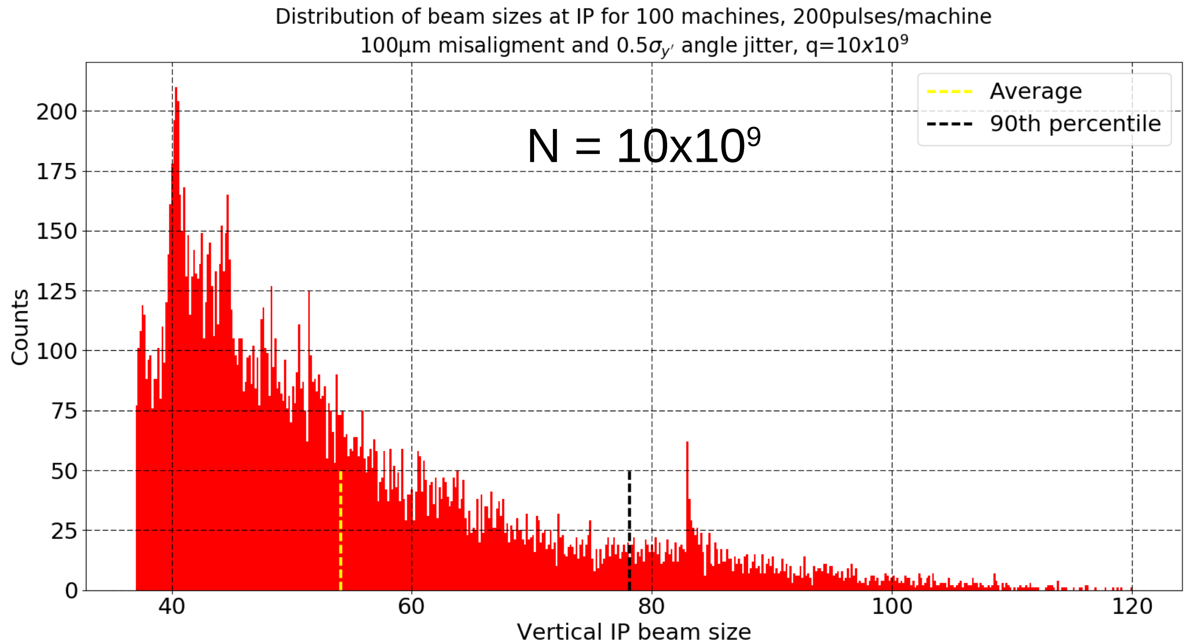
Dynamic effects
Angle jitter - Summary



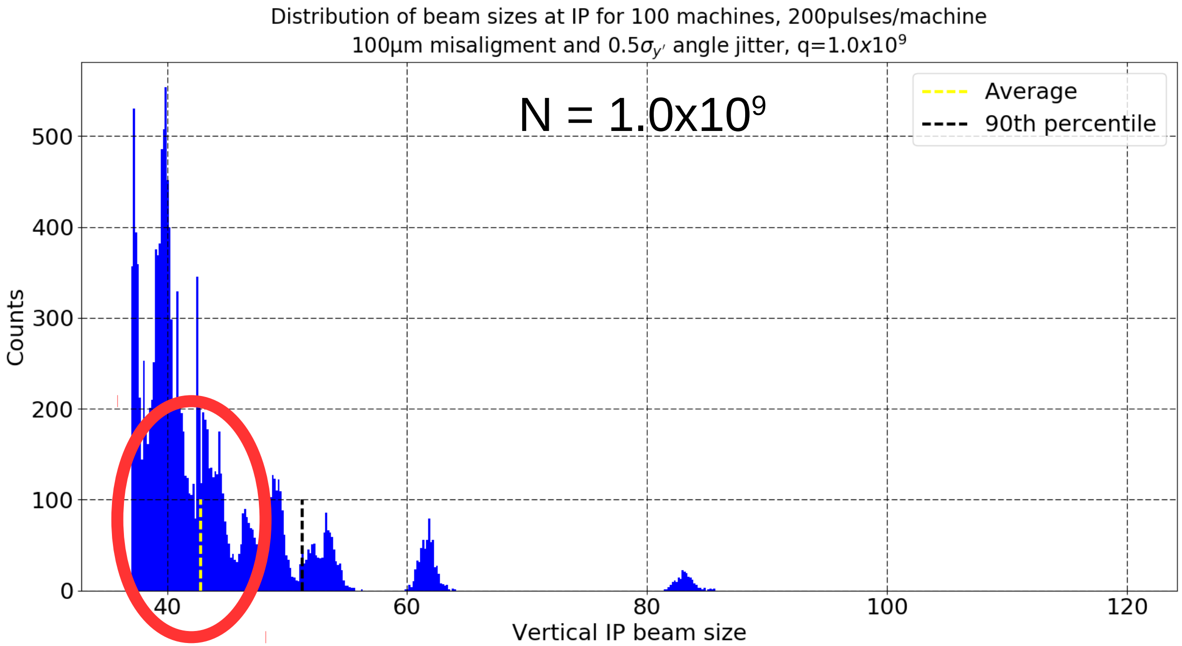


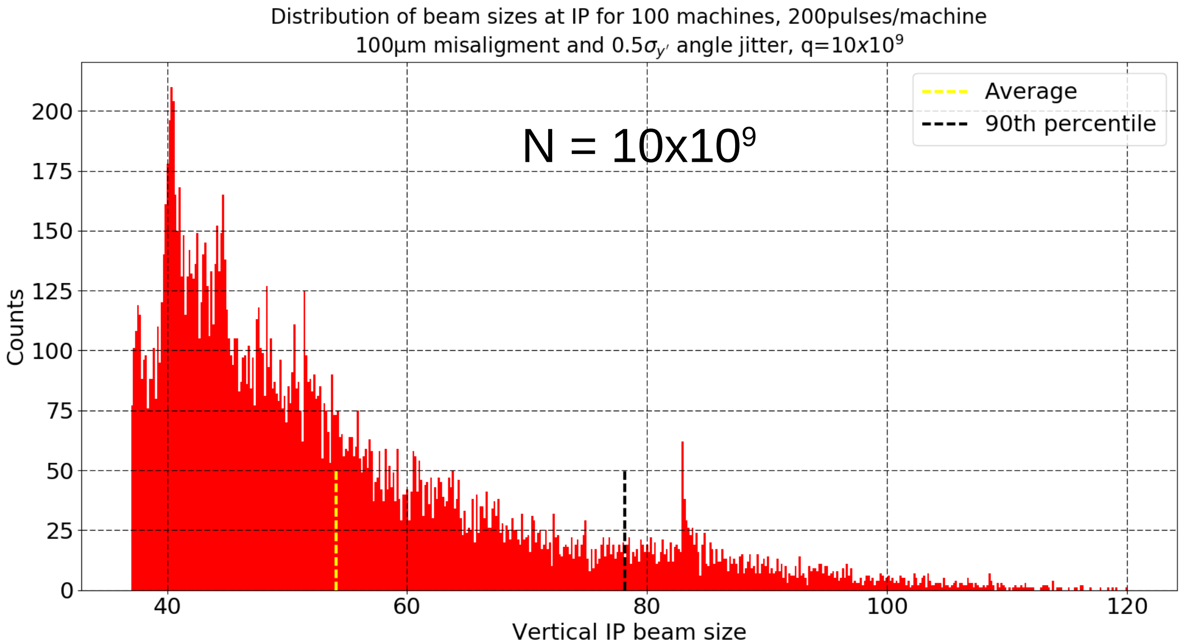
For 100 machines with a 100µm RMS misalignment and 200 pulses with an initial angle jitter of $0.5\sigma_{y'}$
The results are as follows:

Charge	Average $\sigma_{y,ip}$	90th percentile*
N=1.0x10^9	42.79nm	51.26nm
N=10x10^9	54.08nm	78.18nm

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

Dynamic effects
Angle jitter - Summary





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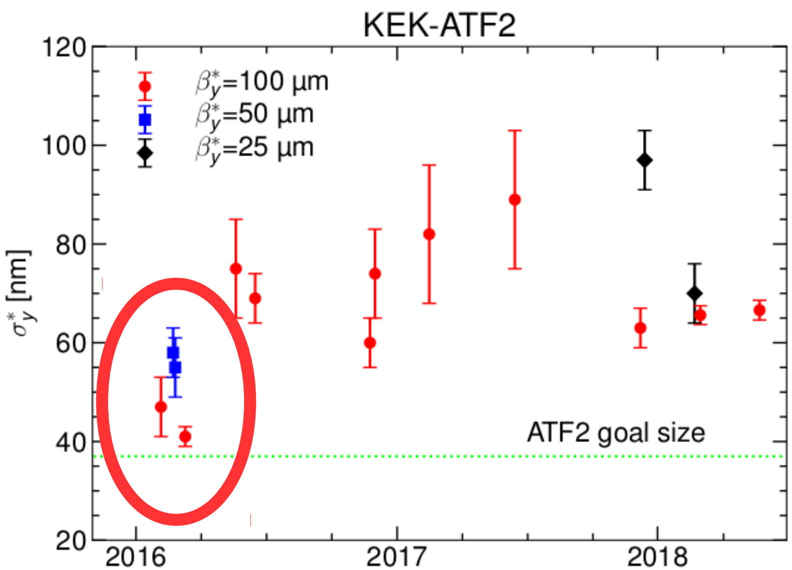
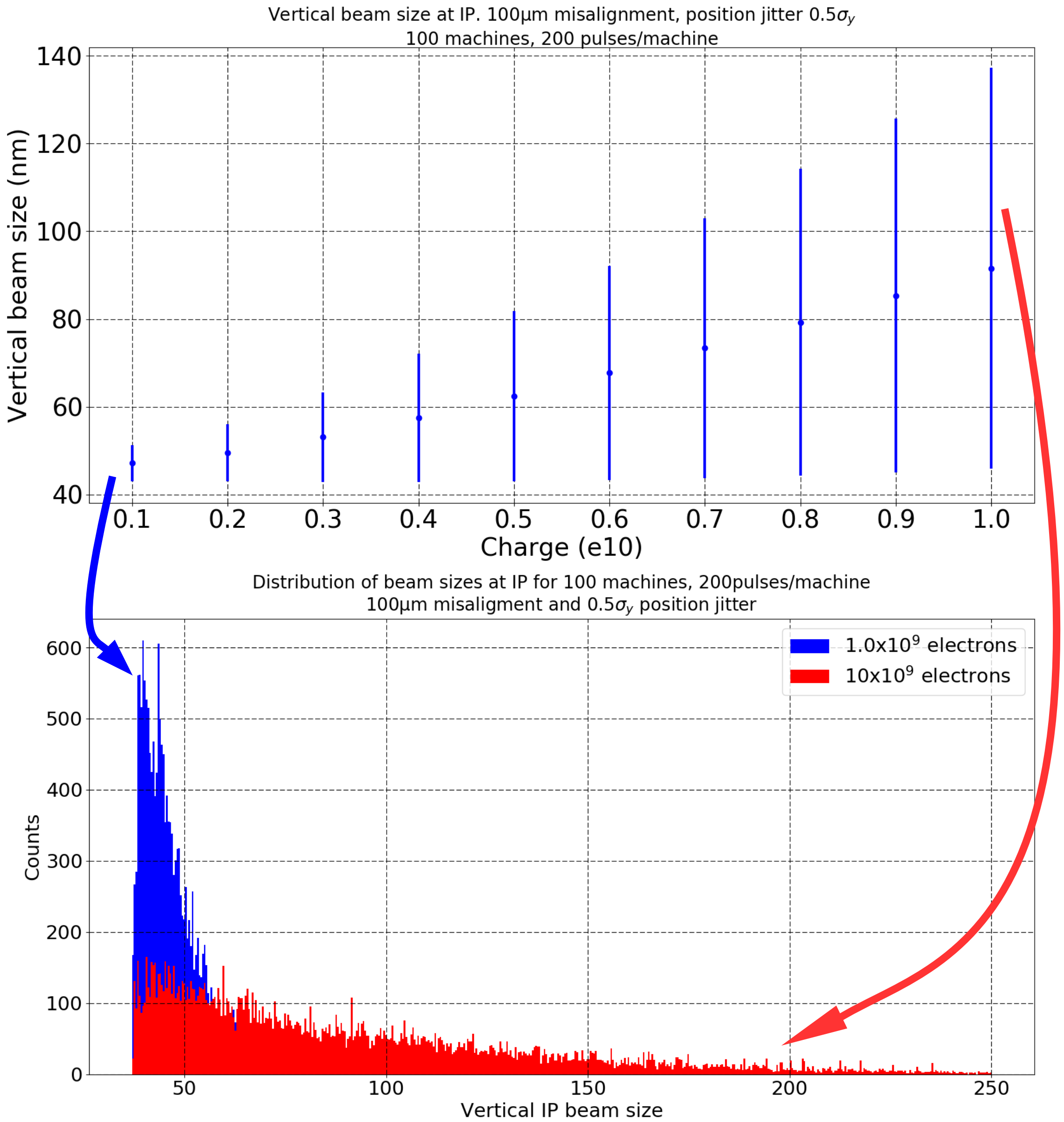


Dynamic effects
Position jitter

Considering the same simulation conditions (slide 20) but with an intial position jitter of $0.5\sigma_y$



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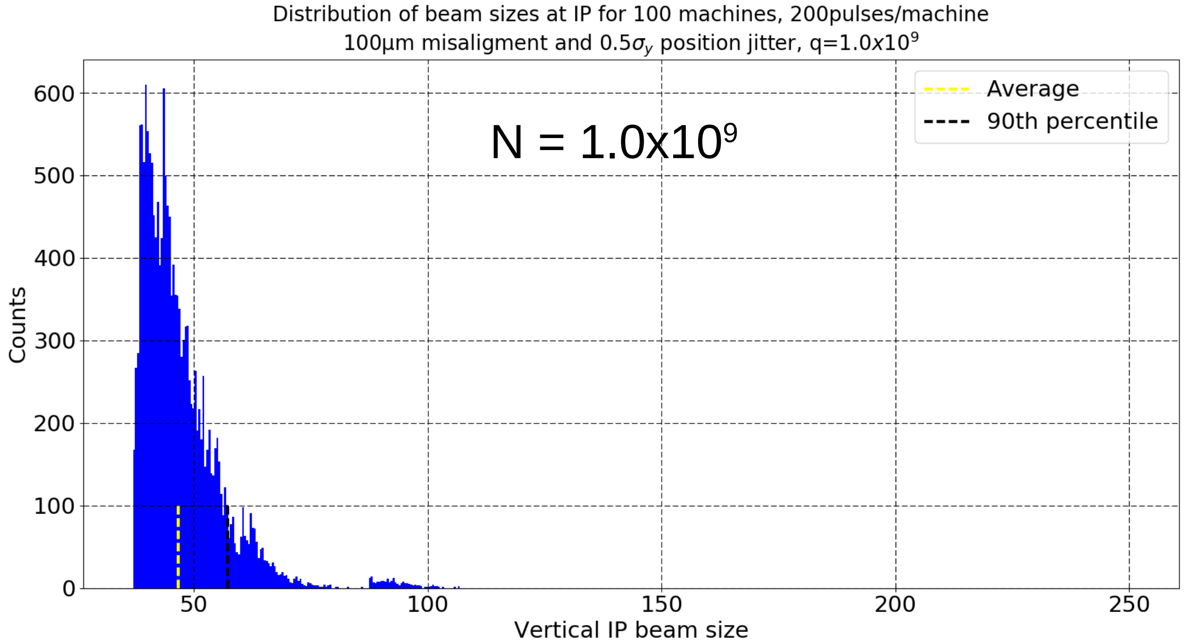
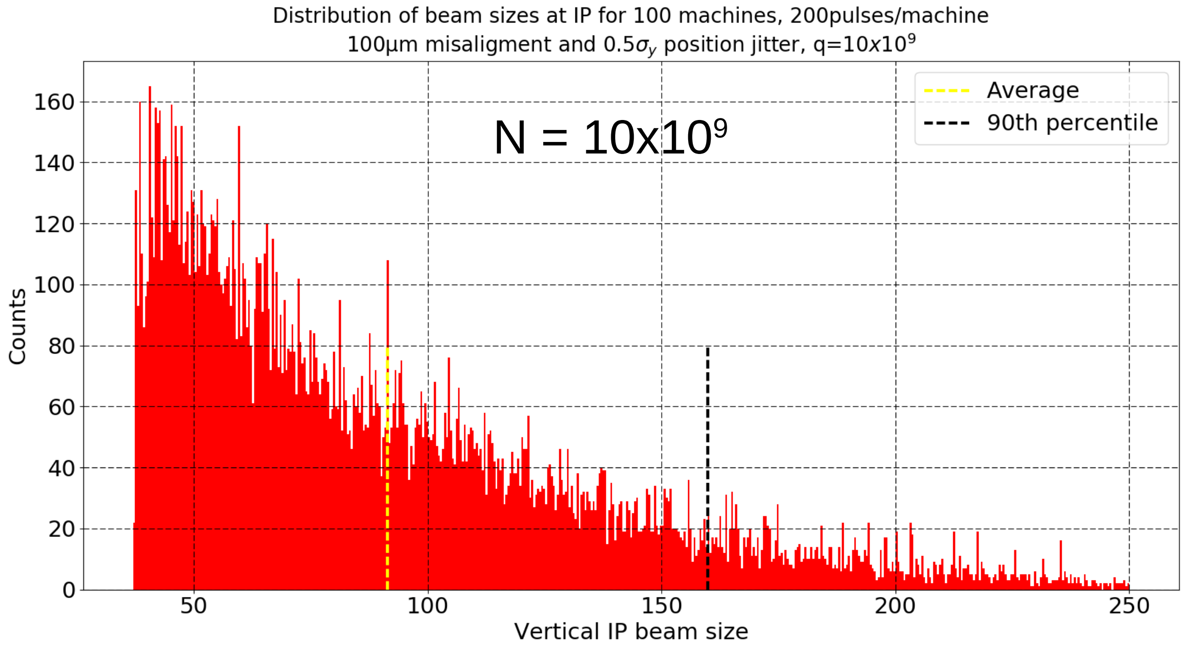
Dynamic effects
Position jitter - Summary





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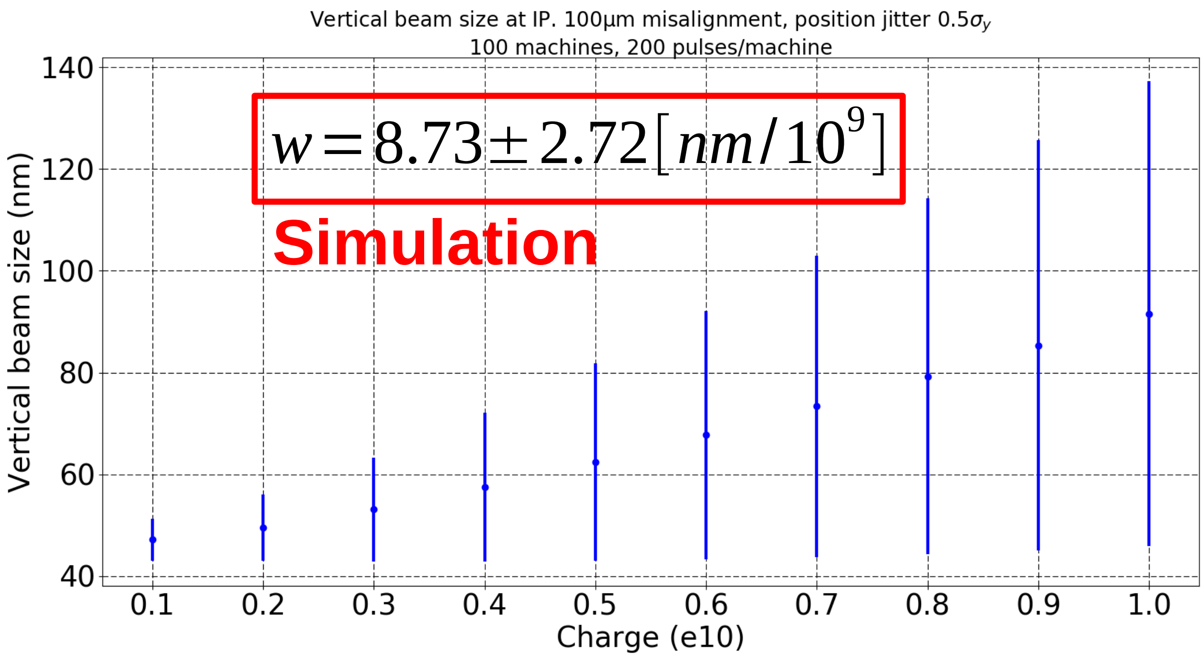
Charge	Average $\sigma_{y,ip}$	90^{th} percentile*
$N=1.0x10^9$	46.69nm	57.18nm
$N=10x10^9$	91.42nm	159.93nm

Dynamic effects
Comparison simulation/measurement



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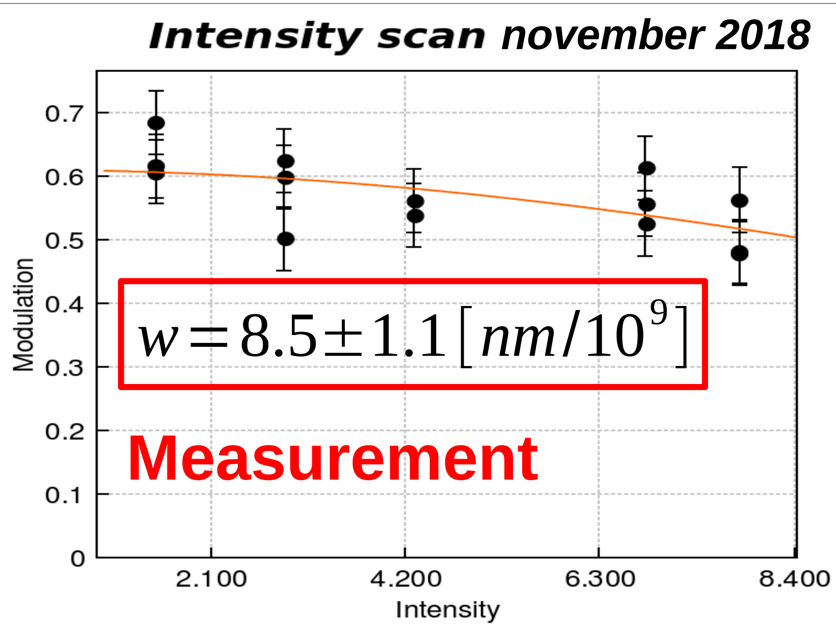

Intensity dependence parameter:

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

Plans for March 2019 operations

- Pursue the study of the wakefield sources on movers.
- Work on the WFS code to make it more accessible.
- Pursue the studies on quadrupoles rolls correction.

Conclusions

- The Dispersion Free Steering and the Wakefield Free Steering correction schemes give good results in the ATF2 extraction line.
- The upstream BPMs and IPBPMs show some intensity dependence in the vertical position. The upstream BPMs show a vertical position jitter of the order of $0.3\sigma_y$
- Coupling downstream ATF2 was corrected by tilting quadrupoles. The goal would be to do that in an automatic way with the sextupoles switched off.
- 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. The intensity dependence parameter calculated with Placet simulations seems to agree with experimental data.

Thank you