Latest measurements of intensity-dependent effects at ATF2

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Outline

- Bunch length studies in ATF2:

  - Measurements of the dependence of the ATF2 bunch length with the beam intensity.
  - Simulations of the impact of the bunch length incease in the ATF2 beam line on the vertical beam size at the IP.

- Wakefield knobs studies in ATF2:

  - Measurements of the impact of the wakefield knobs on the vertical beam size at the IP.
  - Simulations of the efficiency of the wakefield knobs.

ATF2 bunch length measurement with beam intensity

Bunch length measurement
Previous measurements (1/2)

Run	Horizontal ϵ_{0x} (10^{-9} m rad)	Horizontal r_{10x} [$= \epsilon(N = 10^{10})/\epsilon(N = 0)$]	Horizontal χ^2/ndf	Vertical ϵ_{0y} (10^{-12} m rad)	Vertical r_{10y} [$= \epsilon(N = 10^{10})/\epsilon(N = 0)$]	Vertical χ^2/ndf
A	$1.08 \pm 0.09 \pm 0.03$	$1.51 \pm 0.18 \pm 0.00$	1.26	$6.65 \pm 0.63 \pm 0.35$	$1.45 \pm 0.17 \pm 0.01$	0.195
B	$1.05 \pm 0.07 \pm 0.05$	$1.46 \pm 0.15 \pm 0.00$	1.09	$4.04 \pm 0.64 \pm 0.21$	$1.53 \pm 0.34 \pm 0.03$	3.64
C	$1.01 \pm 0.11 \pm 0.12$	$1.55 \pm 0.16 \pm 0.02$	0.215	$16.39 \pm 1.35 \pm 0.69$	$1.73 \pm 0.19 \pm 0.01$	1.44
D	$0.94 \pm 0.31 \pm 0.06$	$1.88 \pm 0.64 \pm 0.01$	/	$3.80 \pm 0.51 \pm 0.30$	$1.23 \pm 0.26 \pm 0.02$	2.21
E	$1.12 \pm 0.14 \pm 0.02$	$1.31 \pm 0.21 \pm 0.01$	1.49	$68.74 \pm 6.78 \pm 2.29$	$1.27 \pm 0.19 \pm 0.00$	0.721
F	$1.23 \pm 0.14 \pm 0.02$	$1.31 \pm 0.19 \pm 0.00$	0.181	$42.60 \pm 4.19 \pm 1.43$	$1.13 \pm 0.15 \pm 0.00$	1.22

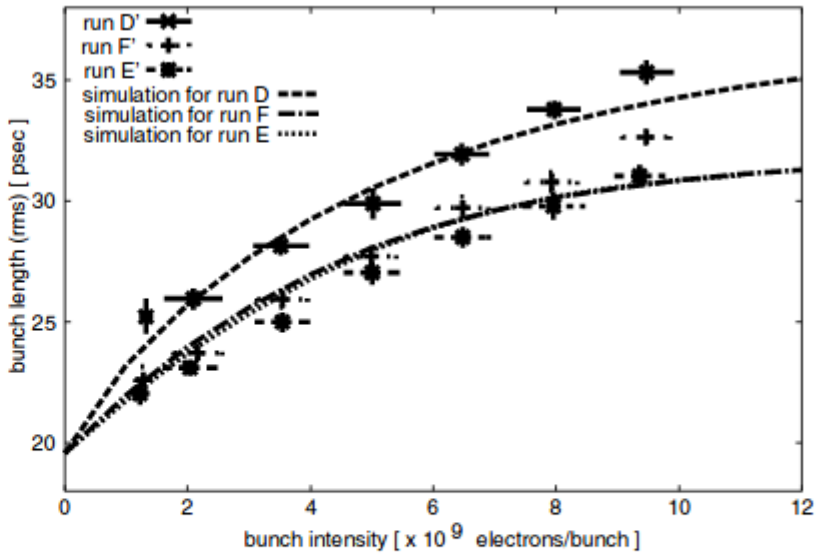


FIG. 5. Current dependence of the bunch length: Data are shown for the runs D', F', and E' (the symbols D', E', and F' indicate that the data were taken for the same condition as D, E, and F, but on another day.) The results of SAD simulations for 0.4%, 6%, and 3% coupling are superimposed.

References:

Y. Honda, et.al., “Achievement of Ultralow Emittance Beam in the Accelerator Test Facility Damping Ring”, Phys. Rev. Lett. 92, 054802 (2004)

K.L.F. Bane, et.al., “Impedance analysis of bunch length measurements at the ATF damping ring”, SLAC-PUB-8846

K.L.F. Bane, et.al., “Bunch length measurements at the ATF damping ring in April 2000”, SLAC-PUB-11608, SLAC-AAS-97, KEK-ATF-11

Bunch length measurement
Previous measurements (2/2)

Bunch length measurement from Nuria Fuster's thesis showing that the bunch length depends on the beam intensity (2016).

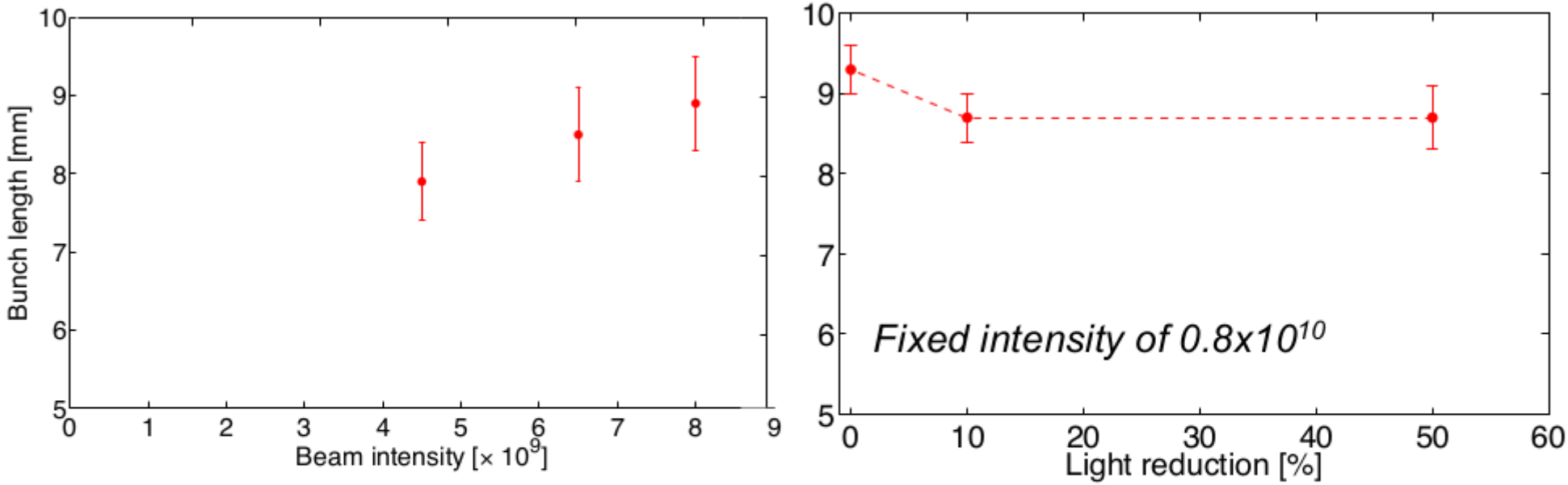
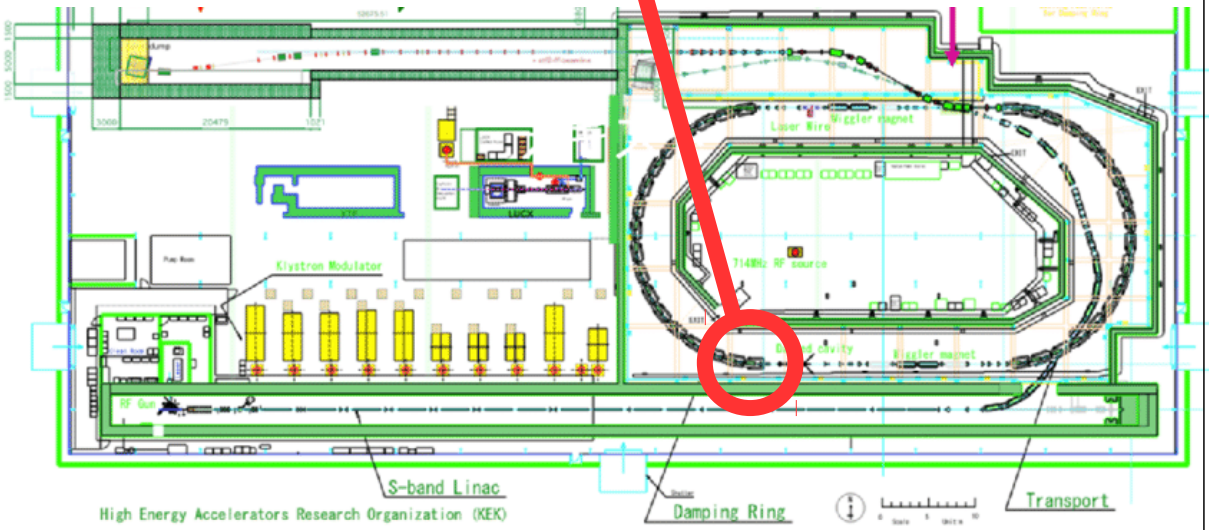


Figure 6.7: Bunch length measured in the DR with the Streak camera for different beam intensities (left) and Streak camera measurements for different filters absorption coefficient (right) for a fixed beam intensity of 0.8×10^{10}.

Bunch length measurement
Experimental setup (1/2)

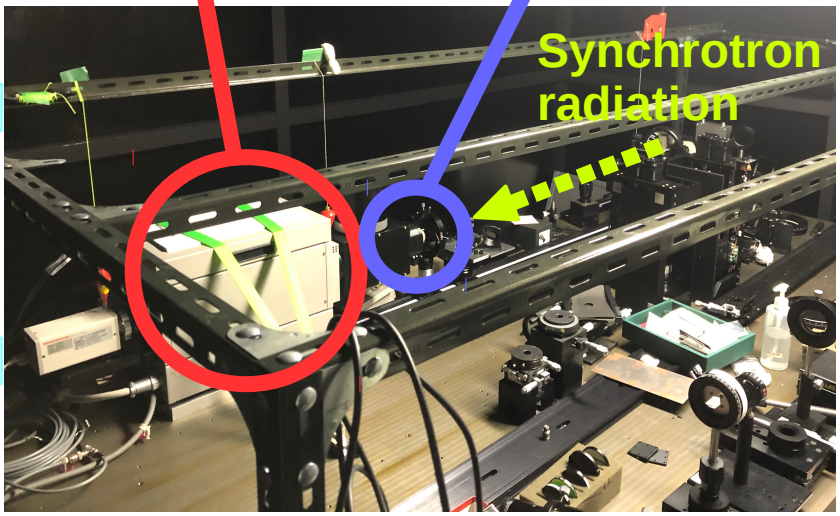
Synchrotron radation from this bending magnet



ATF scheme

Streak camera

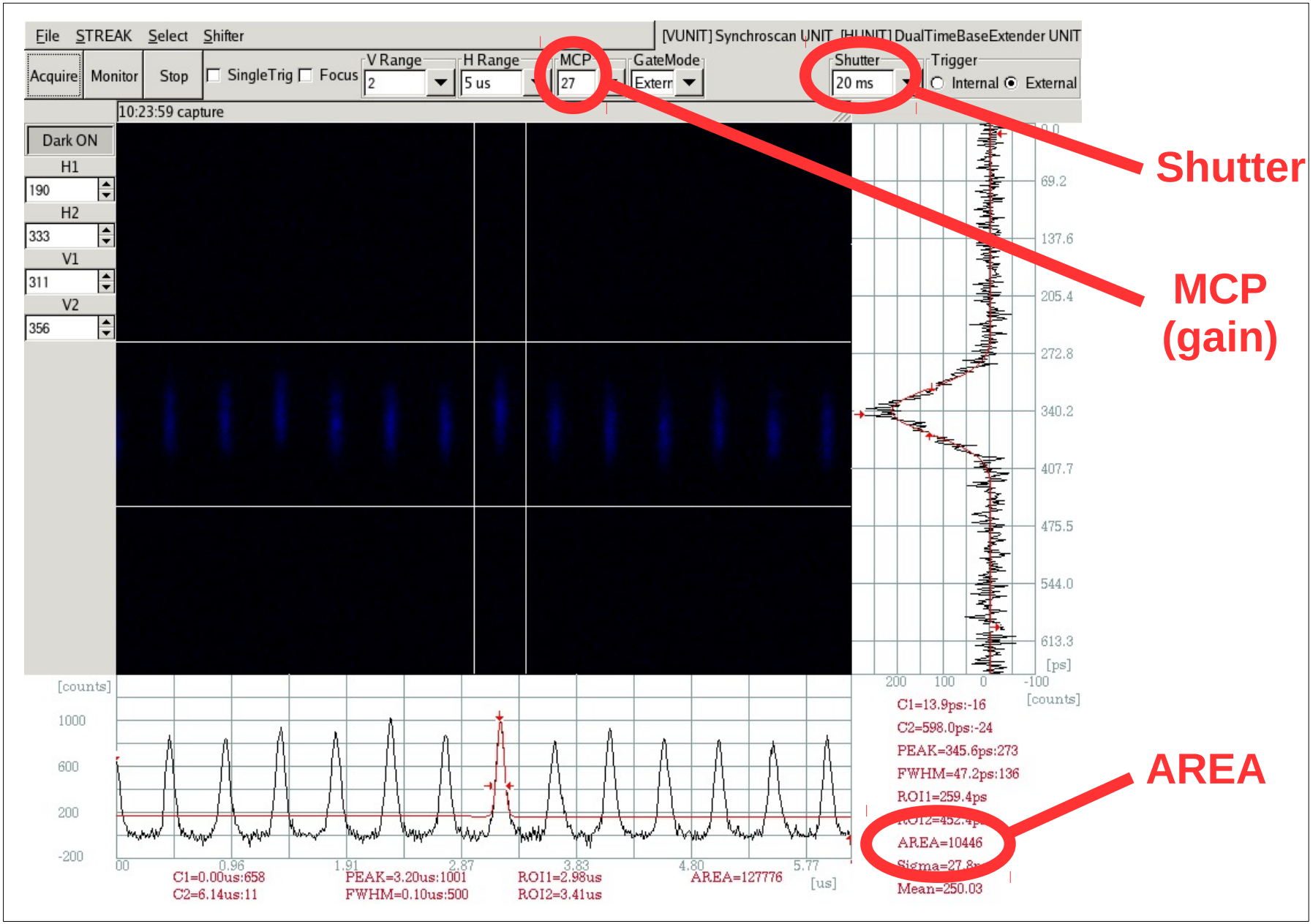
Rotating filter



Bunch length experimental setup

The bunch length of the beam was obtained by using a streak camera to measure the time structure of the synchrotron radiation from one of the bending magnets in the arcs. The images obtained by thestreak camera were fitted with a Gaussian function.

Bunch length measurement
Experimental setup (2/2)



Bunch length measurement
Experimental results (1/6)

Measurement - 2019/12/05:

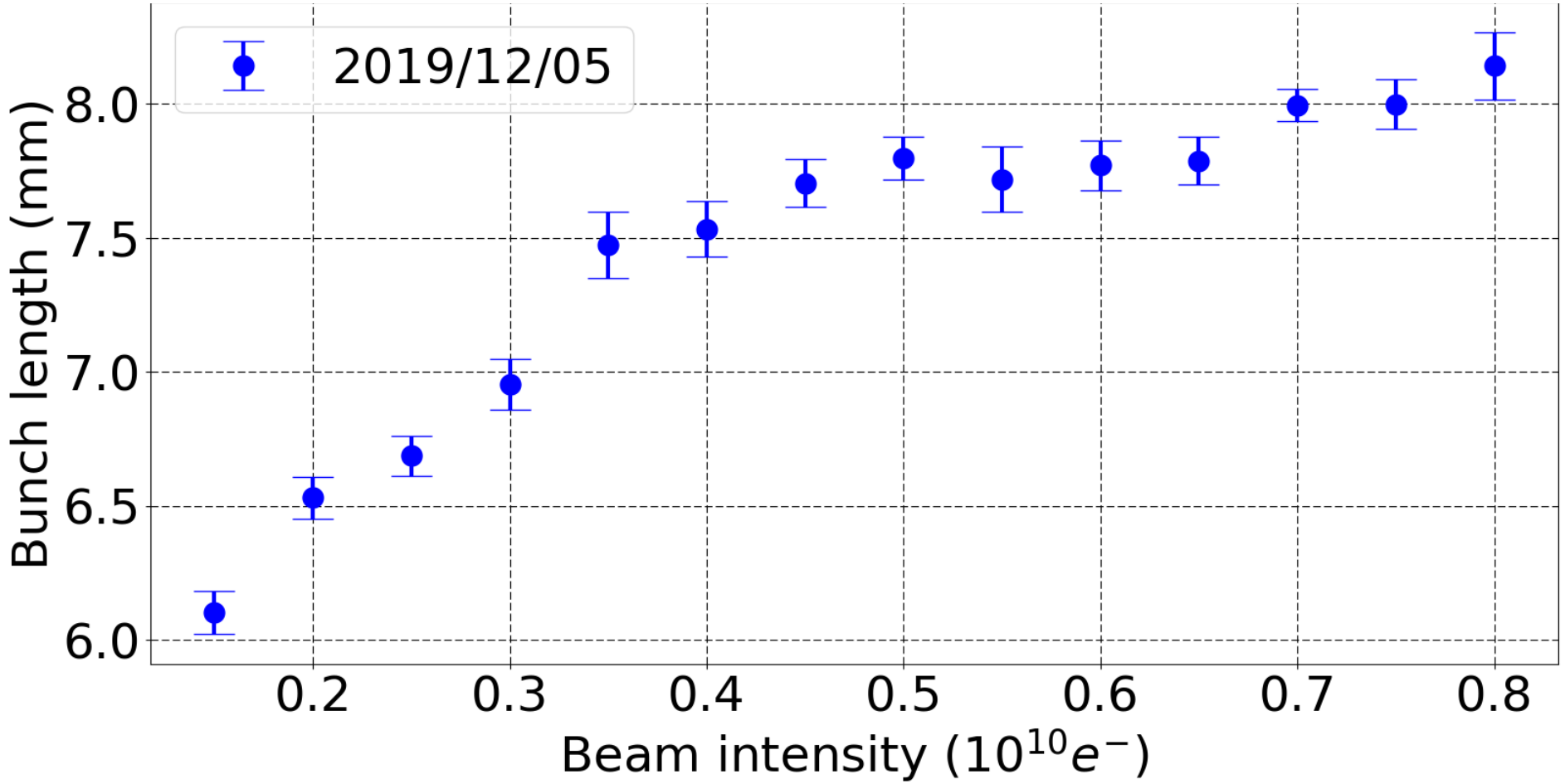
Parameters used for the streak camera:

- Shutter: 20ms
- MCP: **27**
- H Range: 5 µs
- V range: 2
- AREA: always around **10000**

Goal: keep a constant **AREA** of around 10000 for all beam intensities only by changing the opacity of the rotating filter (and keep MCP=27).

Bunch length measurement
Experimental results (2/6)

Measurement from 2019/12/05:



Bunch length measurement
Experimental results (3/6)

Measurement - 2019/12/10:

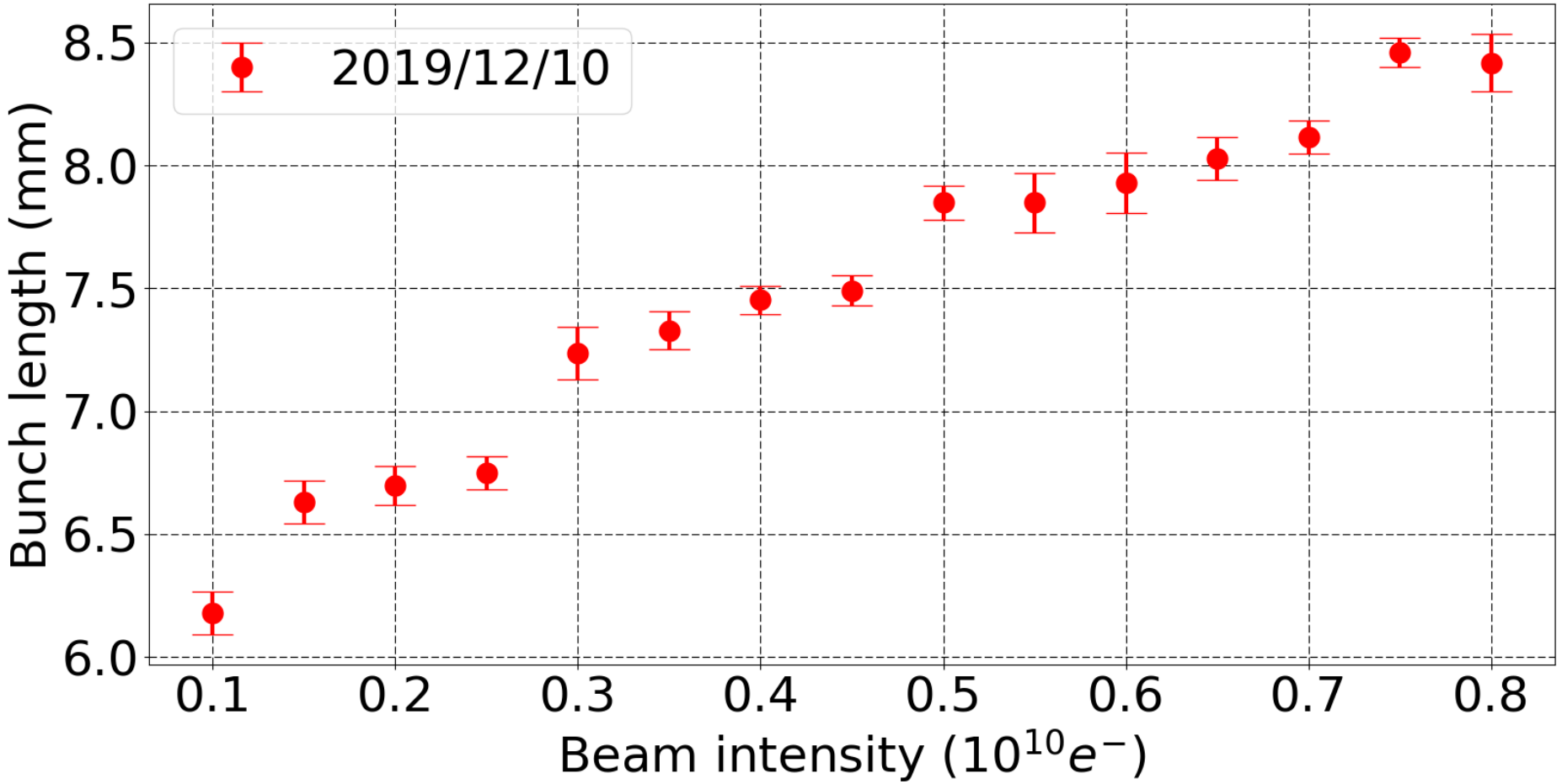
Parameters used for the streak camera:

- Shutter: 20ms
- MCP: **27**
- H Range: 5 µs
- V range: 2
- AREA: always around **10000**

Goal: keep a constant **AREA** of around 10000 for all beam intensities only by changing the opacity of the rotating filter (and keep MCP=27).

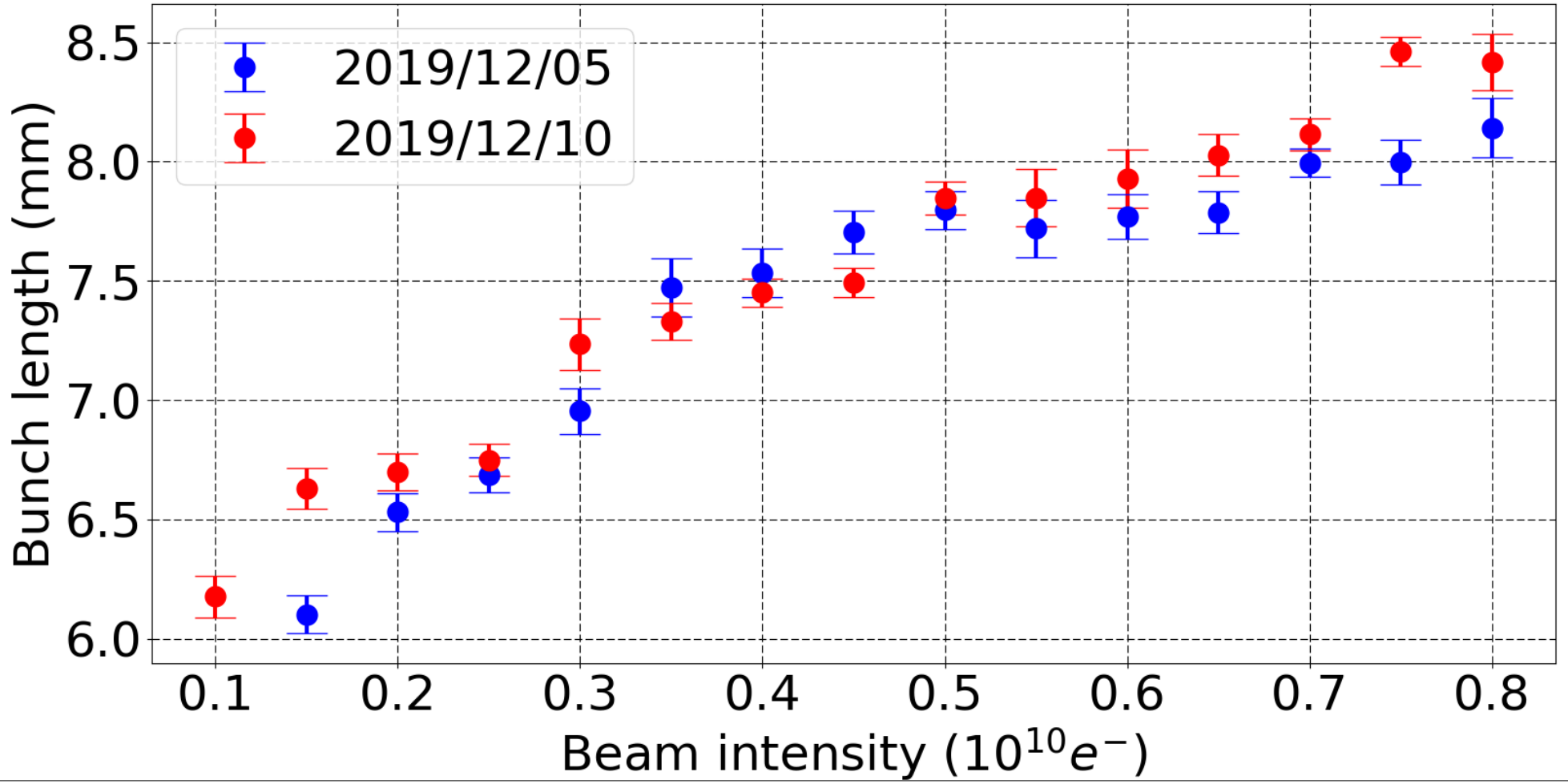
Bunch length measurement
Experimental results (4/6)

Measurement from 2019/12/10:



Bunch length measurement
Experimental results (5/6)

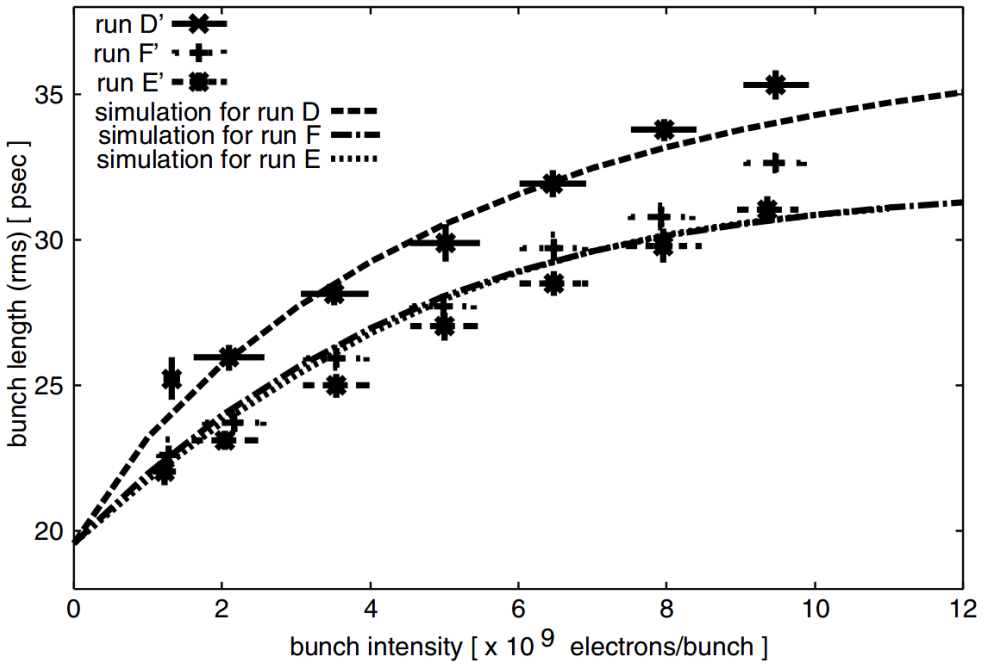
Measurement from both 2019/12/05 and 2019/12/10:

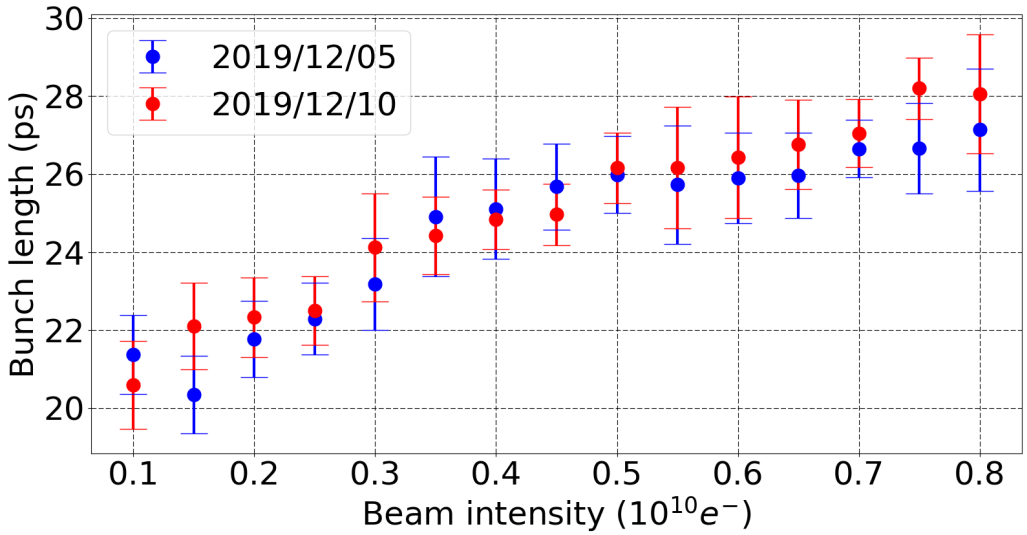


Link to log.

Bunch length measurement
Experimental results (6/6)

Comparison between the measurements from PhysRevLett.92.054802 (2004) and the latest ones (Dec 2019):





Both measurements (2004 and 2019) agree: the bunch length is varying from 20 ps at 0.1x10^{10} e$^-$ to around 30 ps at 0.9x10^{10} e$^-$.

ATF2 bunch length simulation with beam intensity

Bunch length variation's impact on the IP beam size
Simulation conditions (1/2)

Simulated errors:

- Static errors:
  - Misalignement of quads, sexts, bpms of 100 µm RMS
  - Strength error of quads, sexts of 0.1%
  - Roll error for quads and sexts of 200 µrad
- Dynamic errors:
  - Incoming position jitter of $0.3\sigma_y$

Corrections applied:

- One-to-one
- DFS
- WFS
- Knobs (<Y, YP D XP XP.*XP XP.*YP XP.*D>)

First order Second order

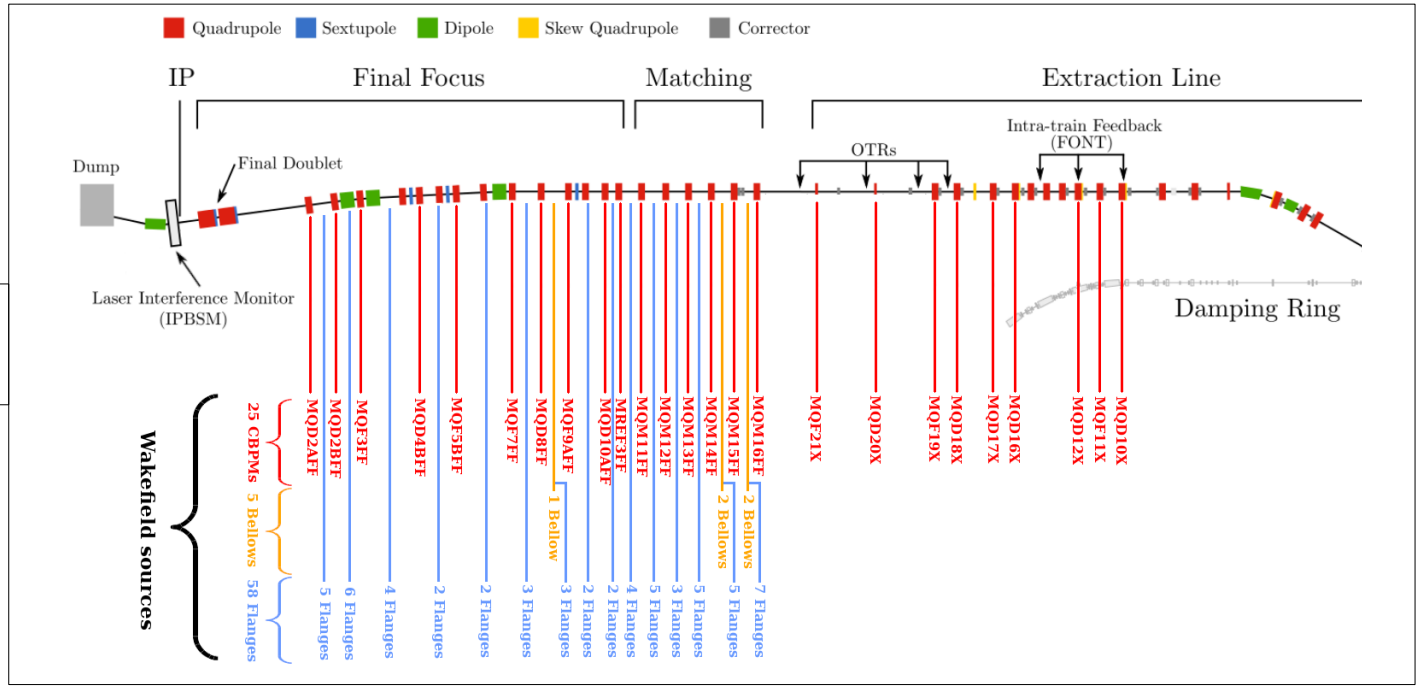
Simulation procedure:

- Tracking 200 bunches per machine from the ATF extraction line to the IP.
- 100 machines with the previously cited static imperfections.
- Apply the cited corrections and the knobs on the distribution at the IP.
- Run these simulations for beam intensities varying from $0.1\text{x}10^{10}$ e^-/bunch to $0.8\text{x}10^{10}$ e^-/bunch using the measured bunch length for each of them (eg: σ_z = 8.3 mm at $0.8\text{x}10^{10}$ e^-)

Bunch length variation's impact on the IP beam size
Simulation conditions (2/2)

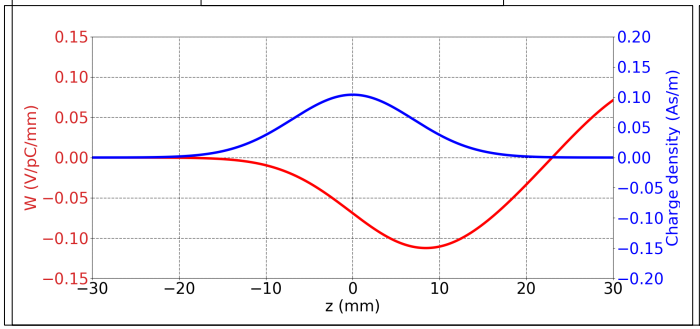
- Wakefield sources: Cavity BPMs, bellows and flanges (wakepotentials calcultated with GdfdL).

Position of wakefield sources

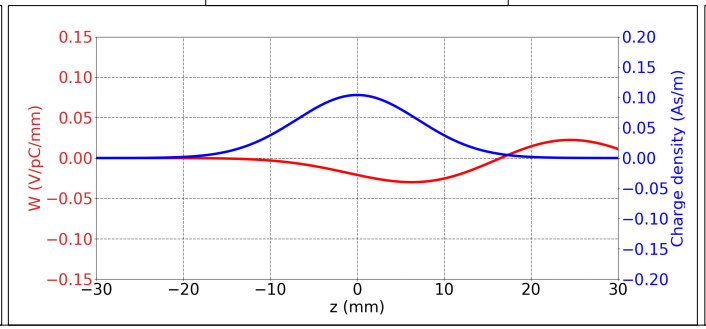


Wakefield sources wakepotentials (V/pC/mm)

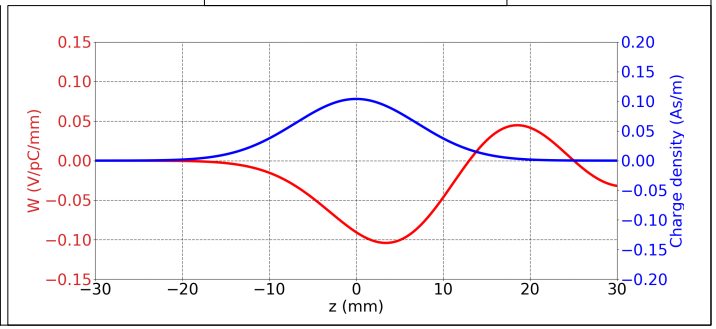
Cavity BPM



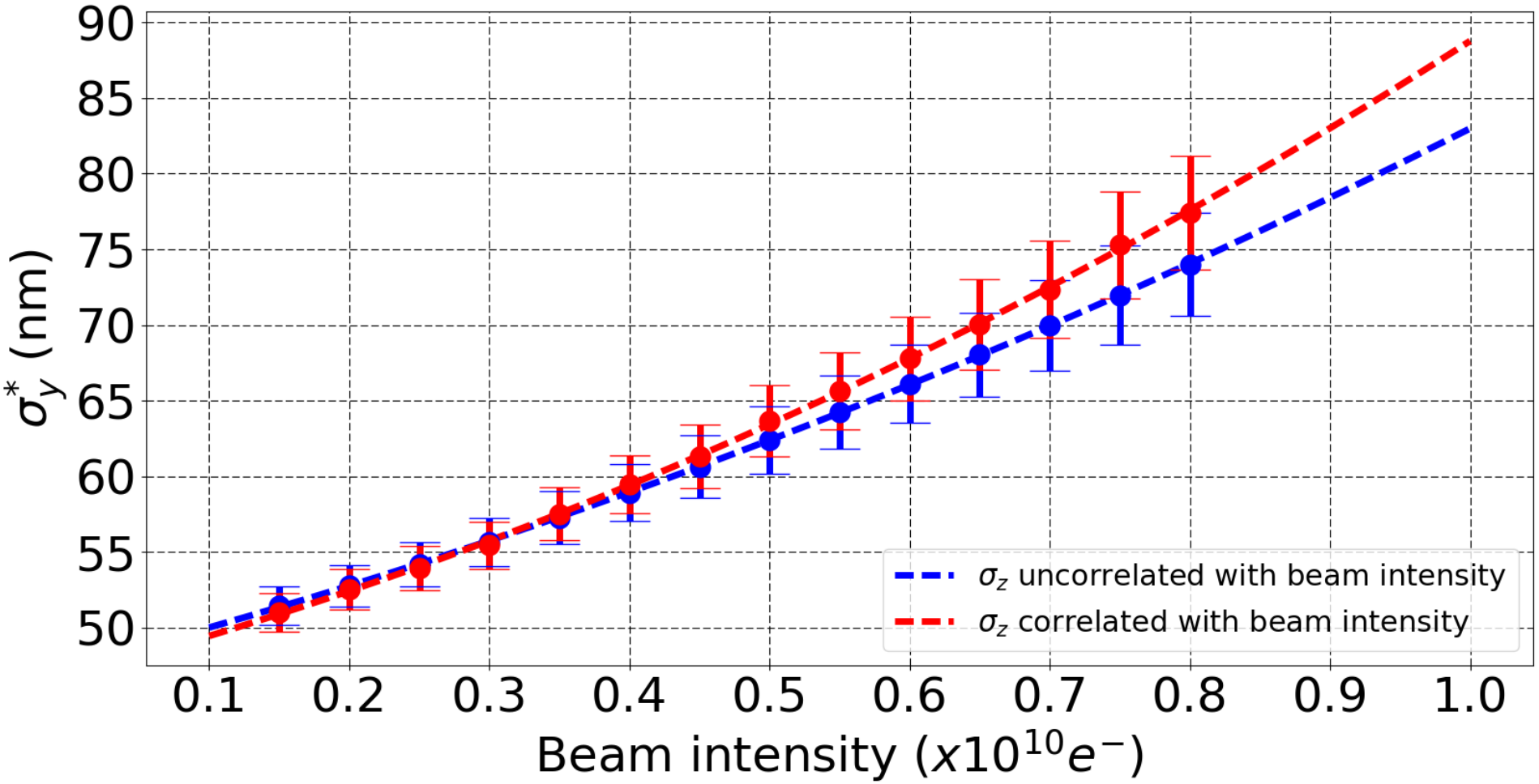
Bellow



Flange



Bunch length impact on the IP beam size
Simulation results

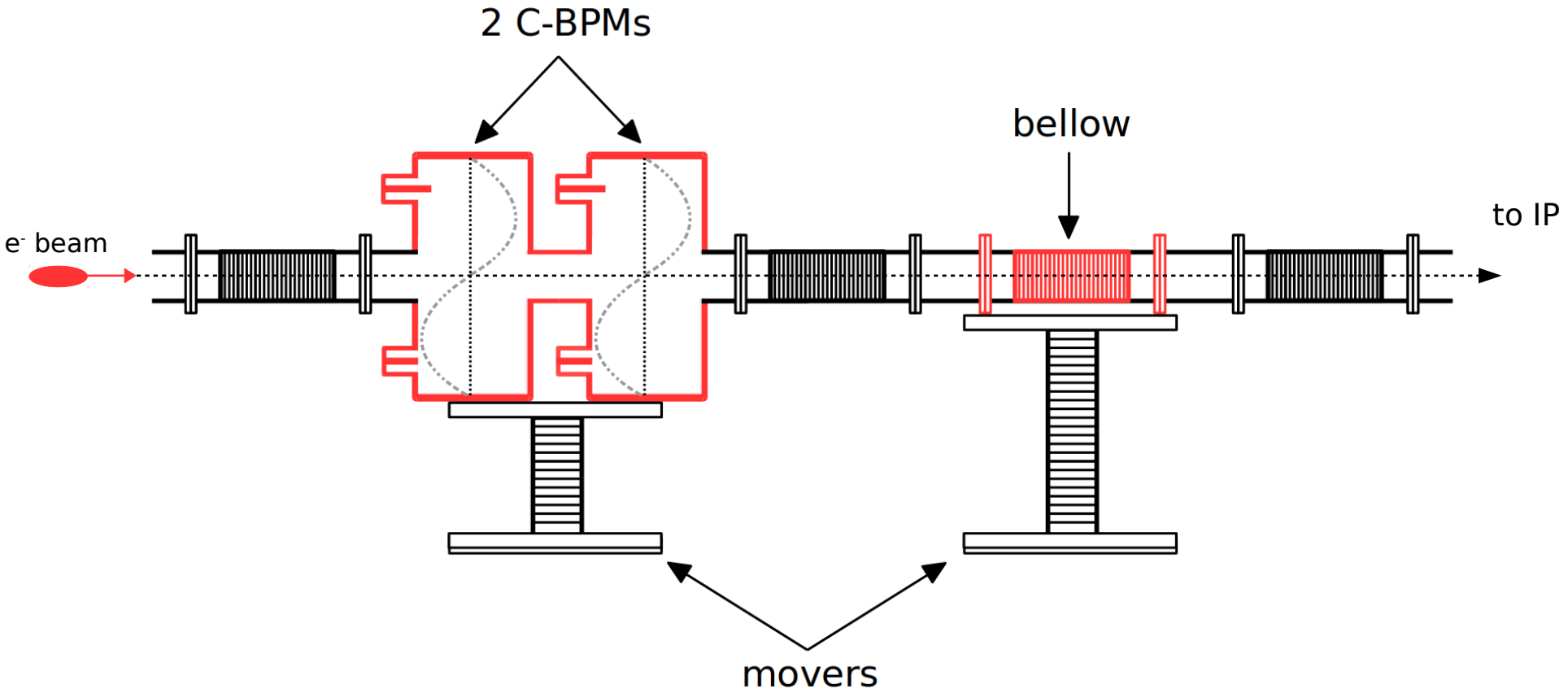


The impact of the **bunch length's variation** with the beam intensity has a **significant impact** on the vertical beam size at the IP: the **average difference** is around **3.4 nm at 0.8 x 10^{10} e^-, which represents more than 4.4%**

Wakefield knobs in ATF2 Measurement

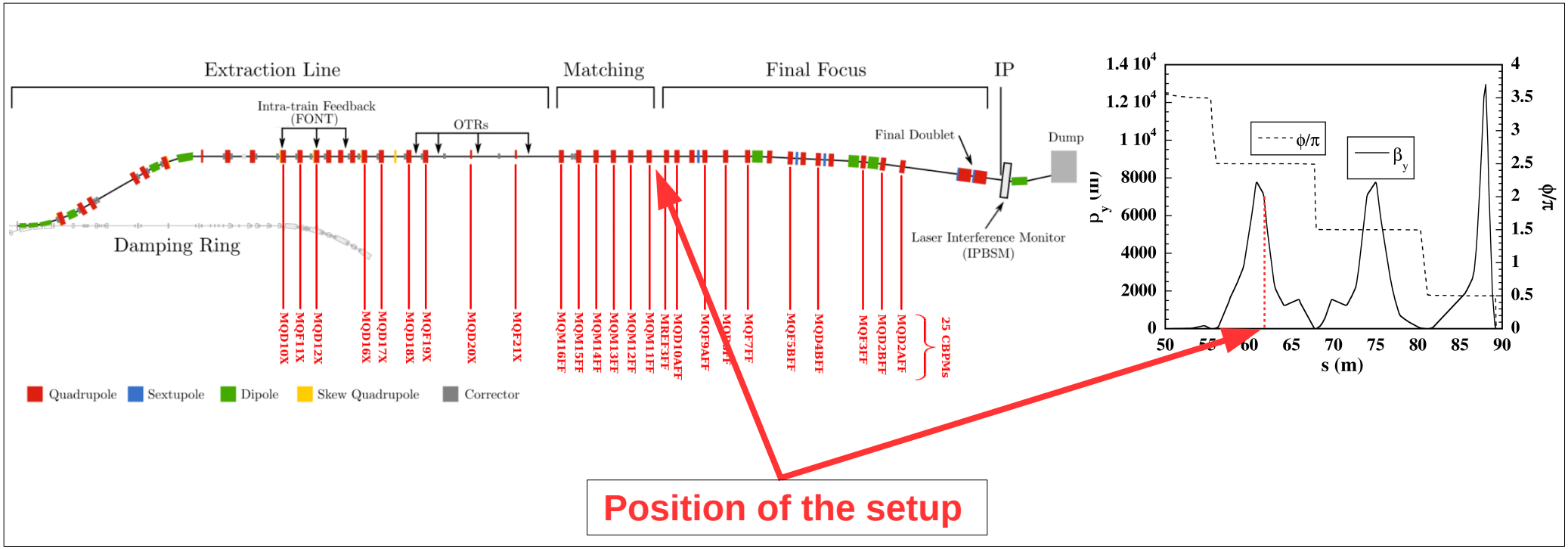
Wakefield knobs
Experimental setup (1/2)

Goal: Use two well known wakefield sources on movers in the ATF2 extraction line to compensate the intensity-dependent effects.
Setup: Made of two movers, the first one carries two C-BPMs and the second one carries a bellow.



Wakefield knobs
Experimental setup (2/2)

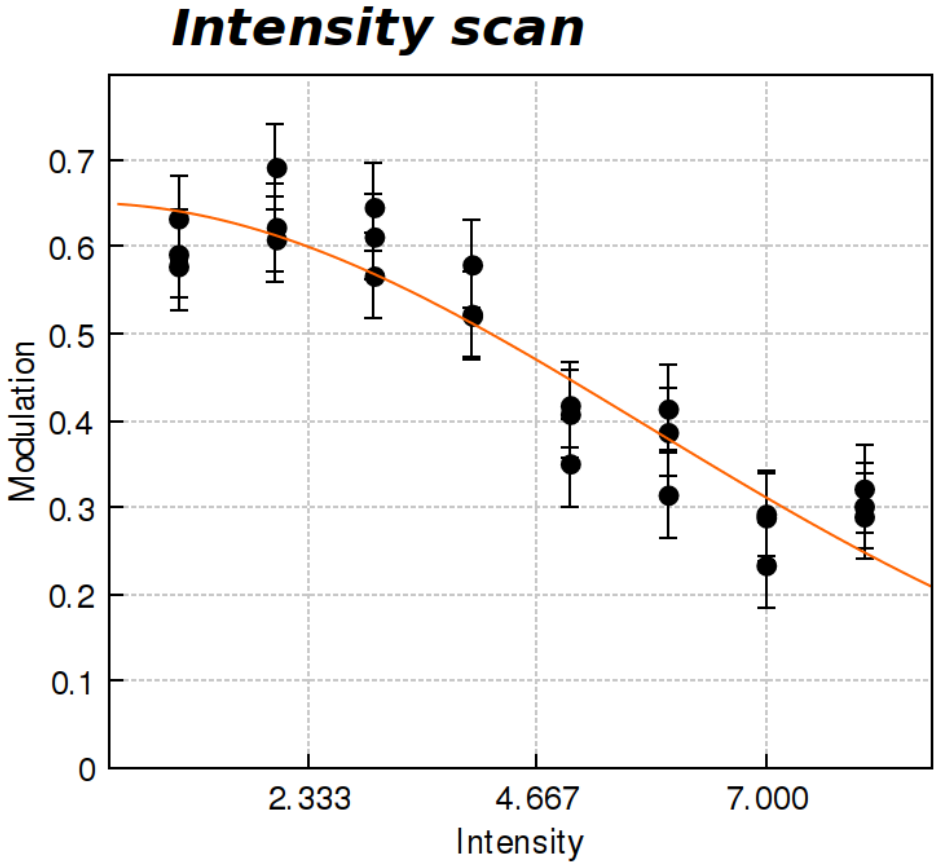
Position: The setup was installed in the the ATF2 extraction line between QD10BFF and QD10AFF. The phase between the setup and the IP is around 2.5π. Thus, the kicks generated by the setup translate into a position offset at IP.



Position of the setup

Wakefield knobs
Experimental results (1/4)

First, set both **CBPMs and bellow movers** position to **zero** and measure the intensity-dependent effects **before** applying the wakefield knobs:



Date: 2019/12/05 Time: 14:51:43

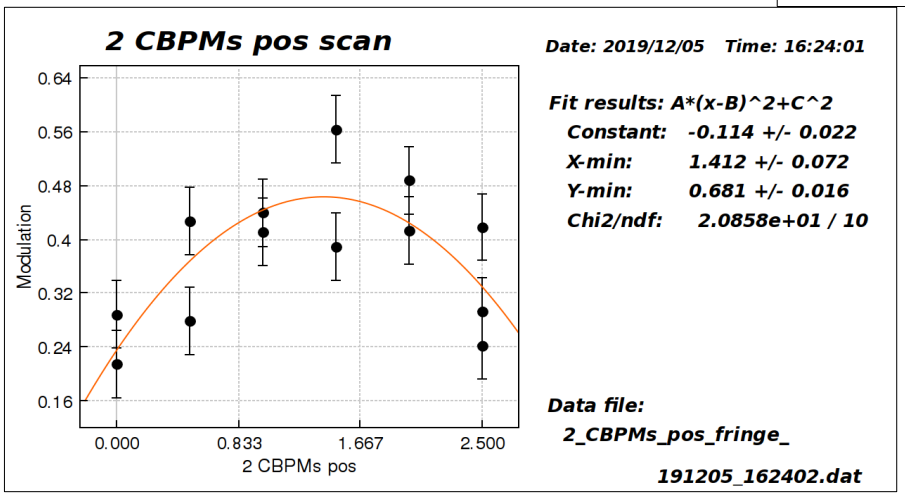
Fit results: A*exp(-(x/B)^2/2)
Modulation: 0.652 +/- 0.019
Center: 0.000 +/- 0.000
Sigma: 5.772 +/- 0.255
Chi2/ndf: 2.3737e+01 / 22

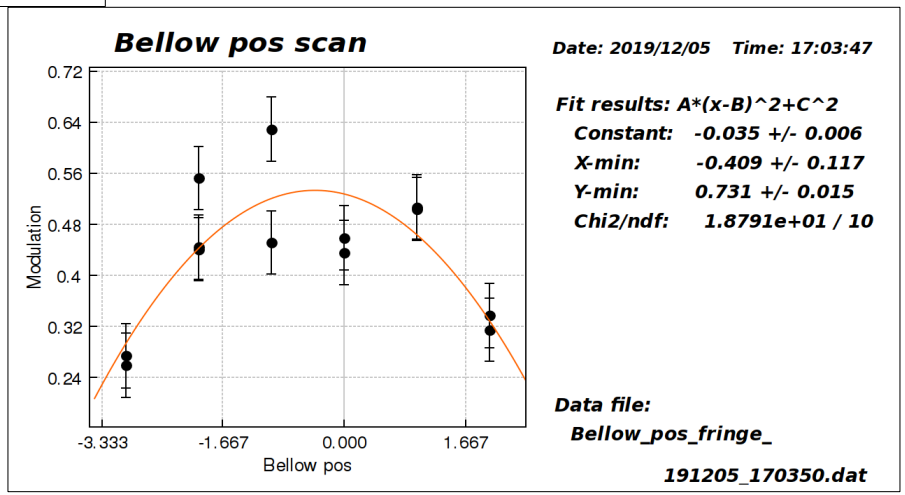
Data file:
Intensity_fringe_
191205_145146.dat

Wakefield knobs
Experimental results (2/4)

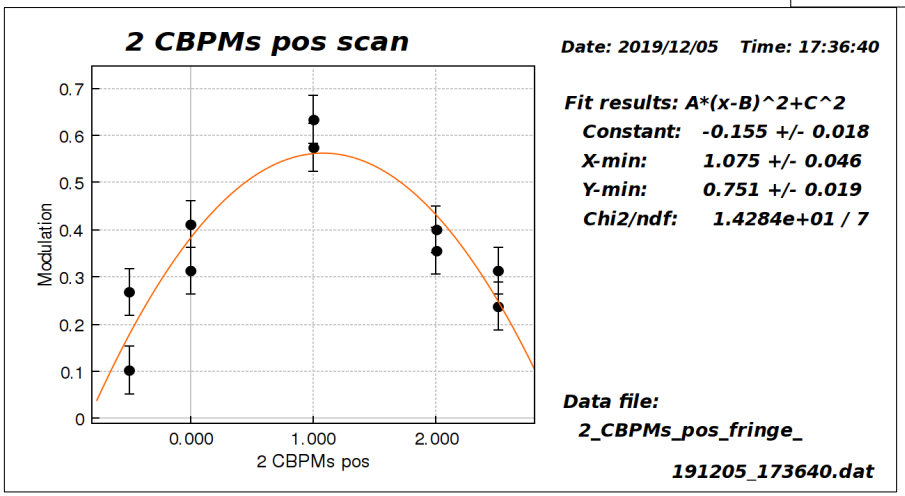
Then, **iteratively** find the minimum beam size (maximum modulation) by moving the CBPMs and the bellow.

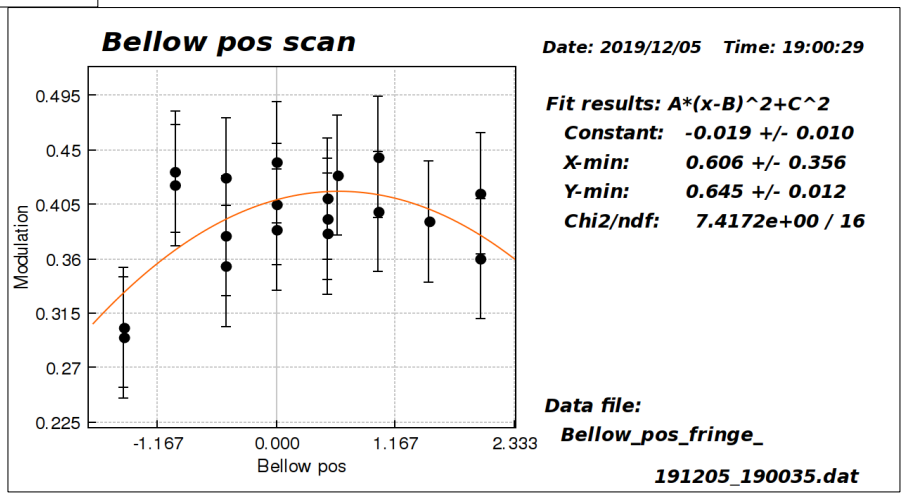
1st iteration:





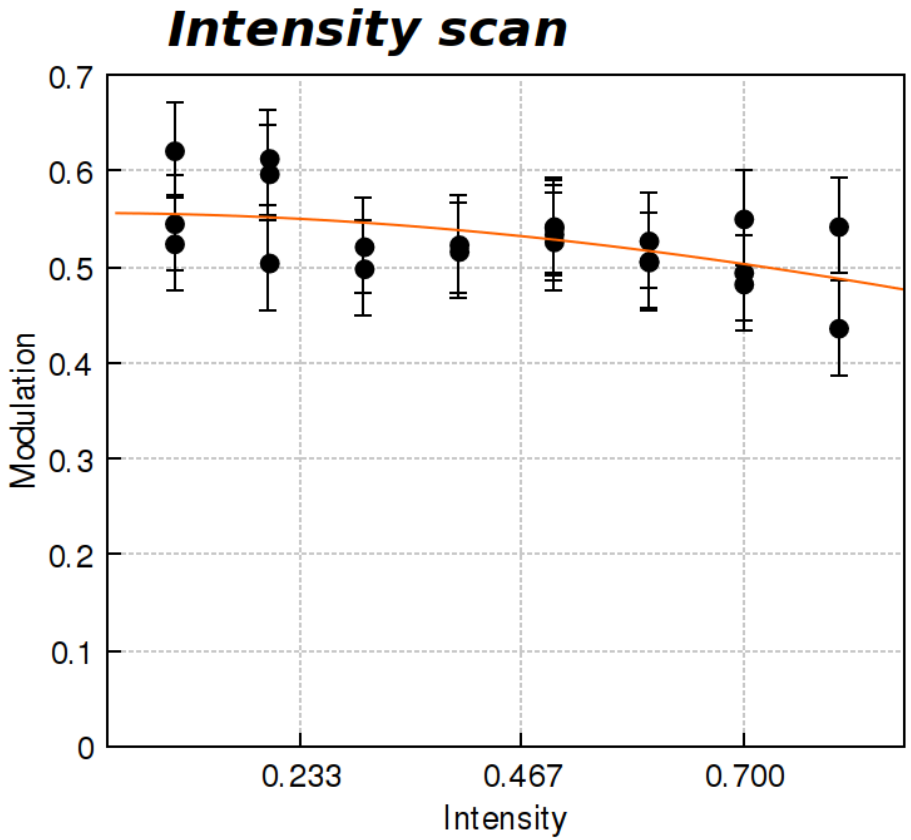
2nd iteration:





Wakefield knobs
Experimental results (3/4)

Intensity-dependent effects **after applying** the wakefield knobs:
Final CBPMs mover position: +1.075 mm,
Final bellow mover position: +0.606 mm



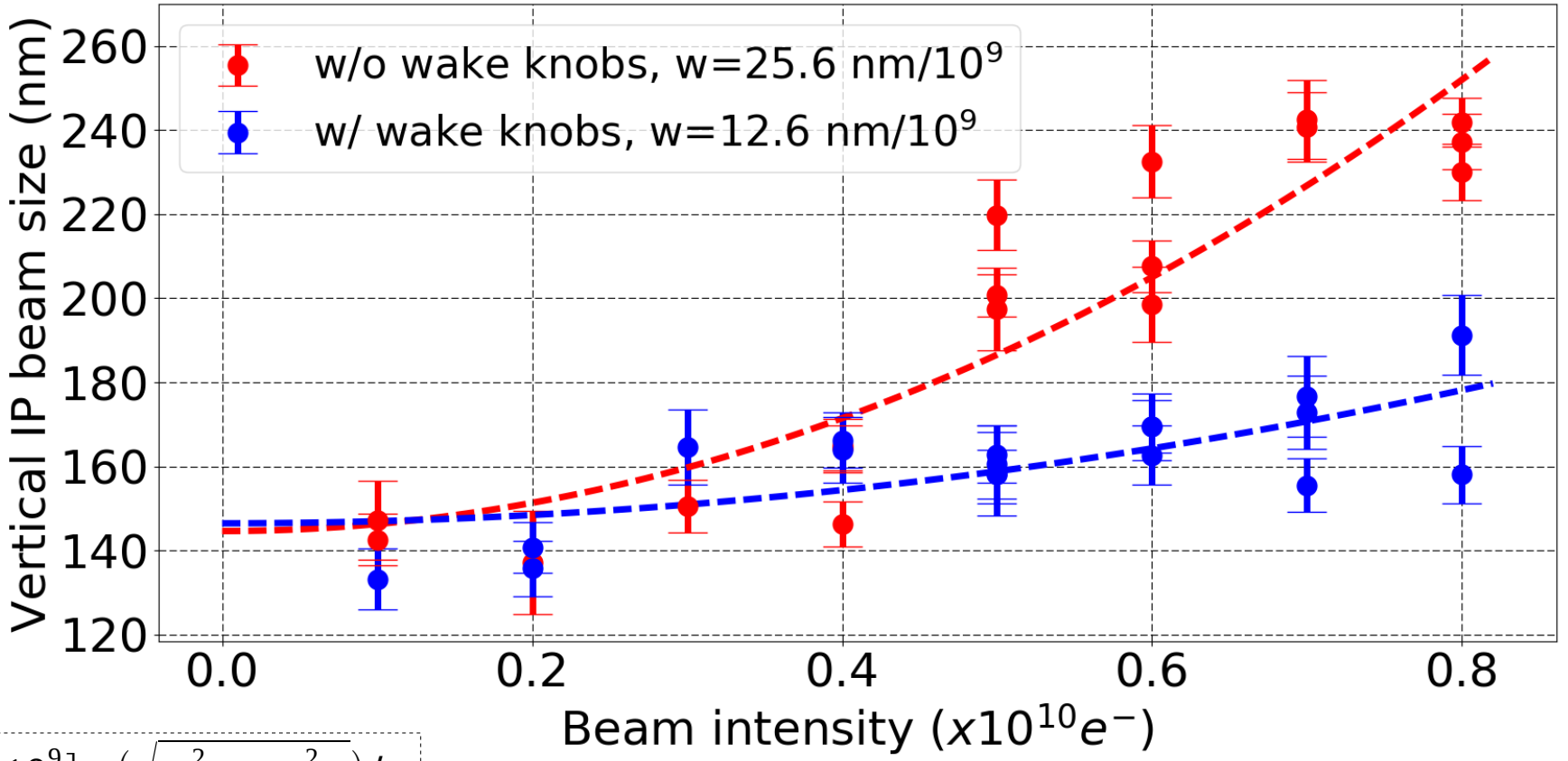
Date: 2019/12/05 Time: 21:46:46

Fit results: A*exp(-(x/B)^2/2)
Modulation: 0.558 +/- 0.017
Center: 0.000 +/- 0.000
Sigma: 1.563 +/- 0.391
Chi2/ndf: 1.0499e+01 / 20

Data file:
Intensity_fringe_
191205_214646.dat

Link to log.

Wakefield knobs
Experimental results* (4/4)



$$w\left[nm/10^9\right]=\left(\sqrt{\sigma_{y,q}^2-\sigma_{y,0}^2}\right)/q$$

*Using the IPBSM 30° mode

The wakefield knobs reduced the intensity dependence parameter from **25.6 nm/10⁹** to **12.6 nm/10⁹**. (The **IP angle jitter** was **~70 μrad**).

Wakefield knobs in ATF2 Simulation

Wakefield knobs
Simulation conditions (1/2)

Simulated errors:

- Static errors:
  - Misalignement of quads, sexts, bpms of 100 µm RMS
  - Strength error of quads, sexts of 0.1%
  - Roll error for quads and sexts of 200 µrad

Corrections applied:

- One-to-one
- DFS
- WFS
- Knobs (<Y, YP D XP XP.*XP XP.*YP XP.*D>)

First order Second order

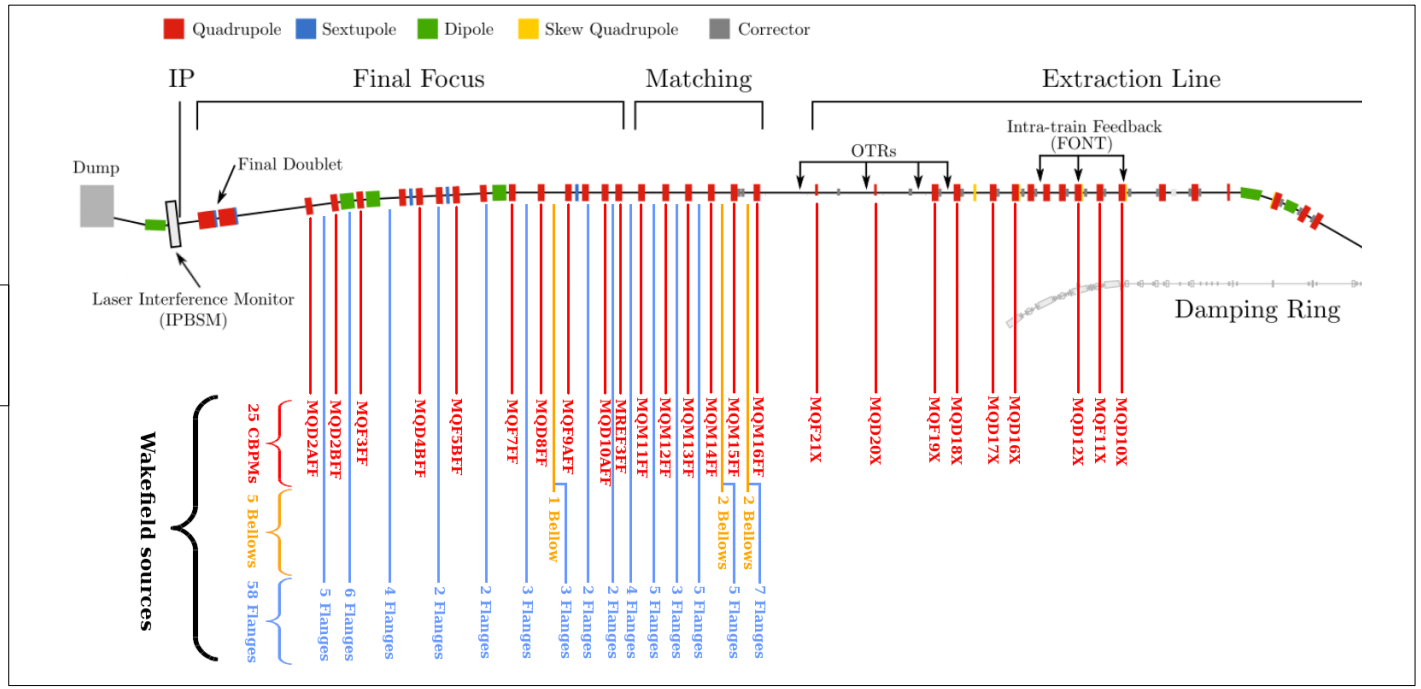
Simulation procedure:

- Tracking 200 bunches per machine from the ATF extraction line to the IP.
- 100 machines with the previously cited static imperfections.
- Apply the cited corrections and the knobs on the distribution at the IP.
- The position of both movers is scanned from -3 mm to +3 mm with a step of 300 µm. The minimum beam size of this 2D scan is calculated for each pulse of each machine.

Wakefield knobs
Simulation conditions (2/2)

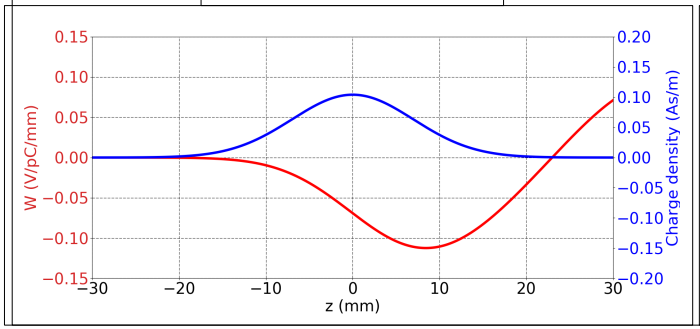
- Wakefield sources: Cavity BPMs, bellows and flanges (wakepotentials calcultated with GdfdL).

Position of wakefield sources

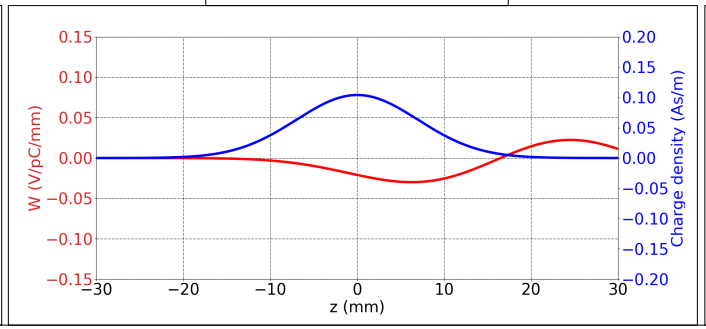


Wakefield sources wakepotentials (V/pC/mm)

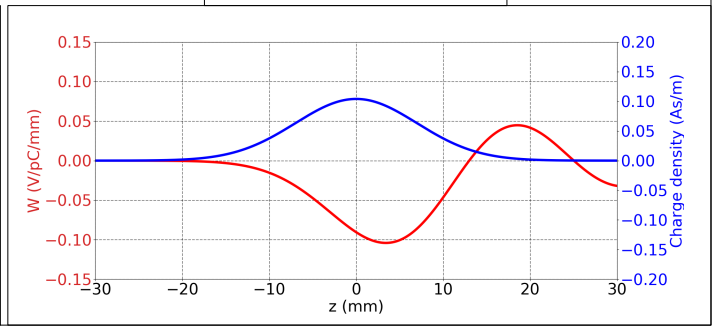
Cavity BPM



Bellow

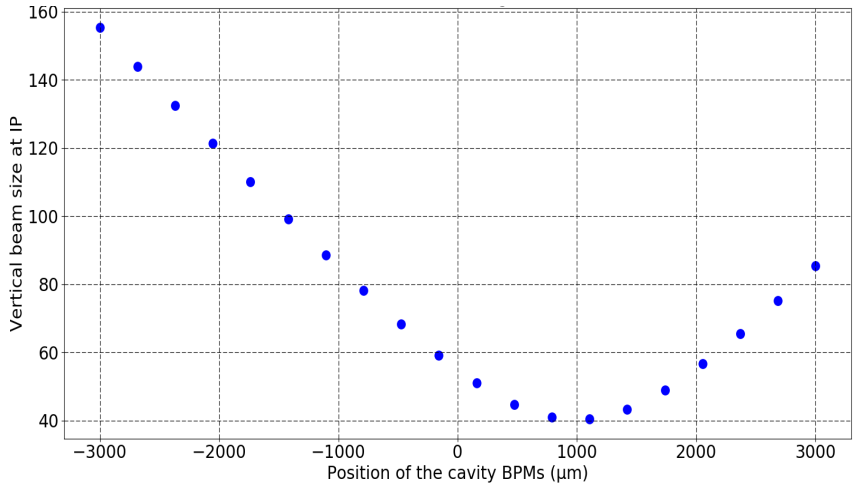


Flange

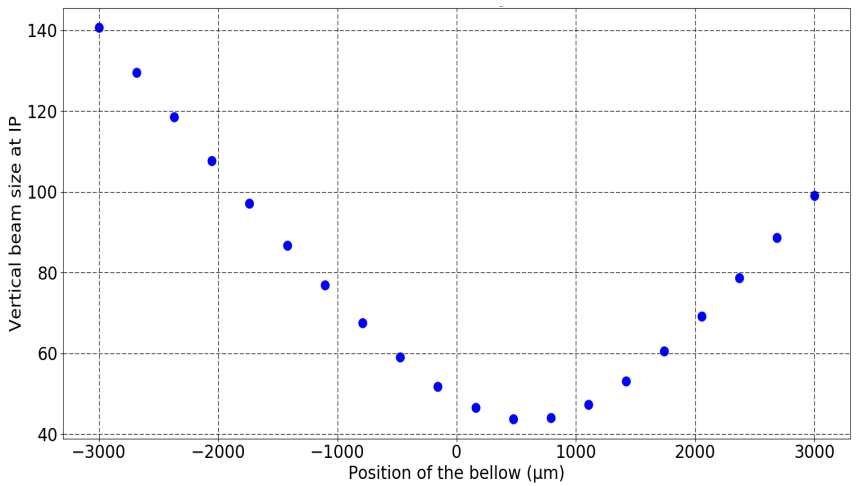


Wakefield knobs
Simulation results (1/2)

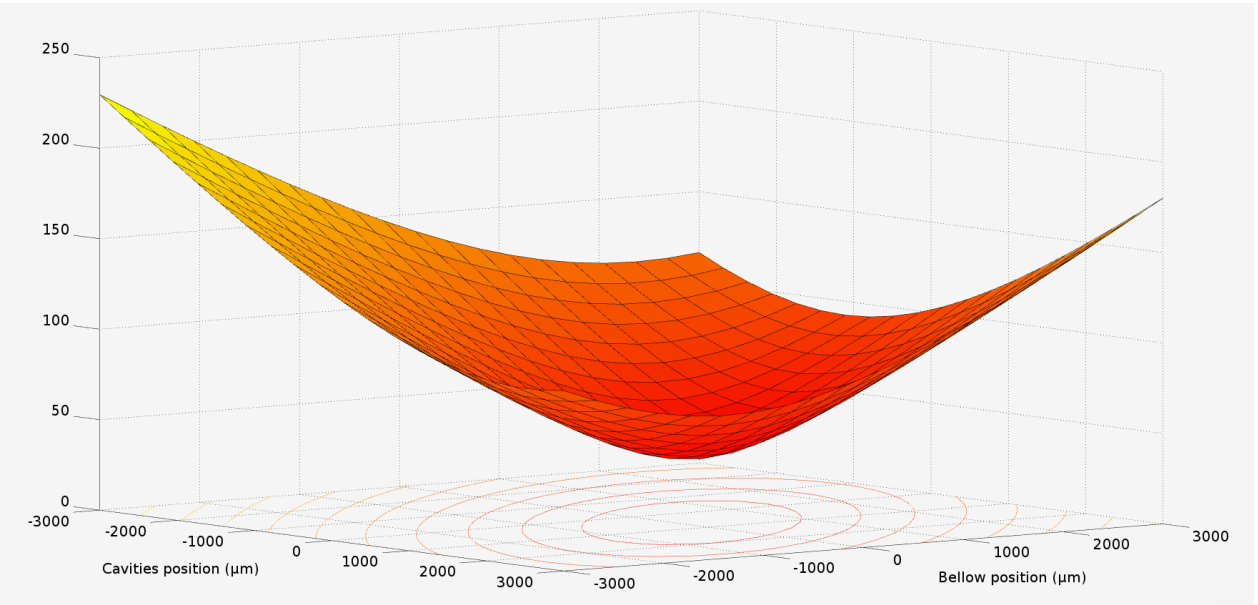
Position of CBPMs scan for one machine.



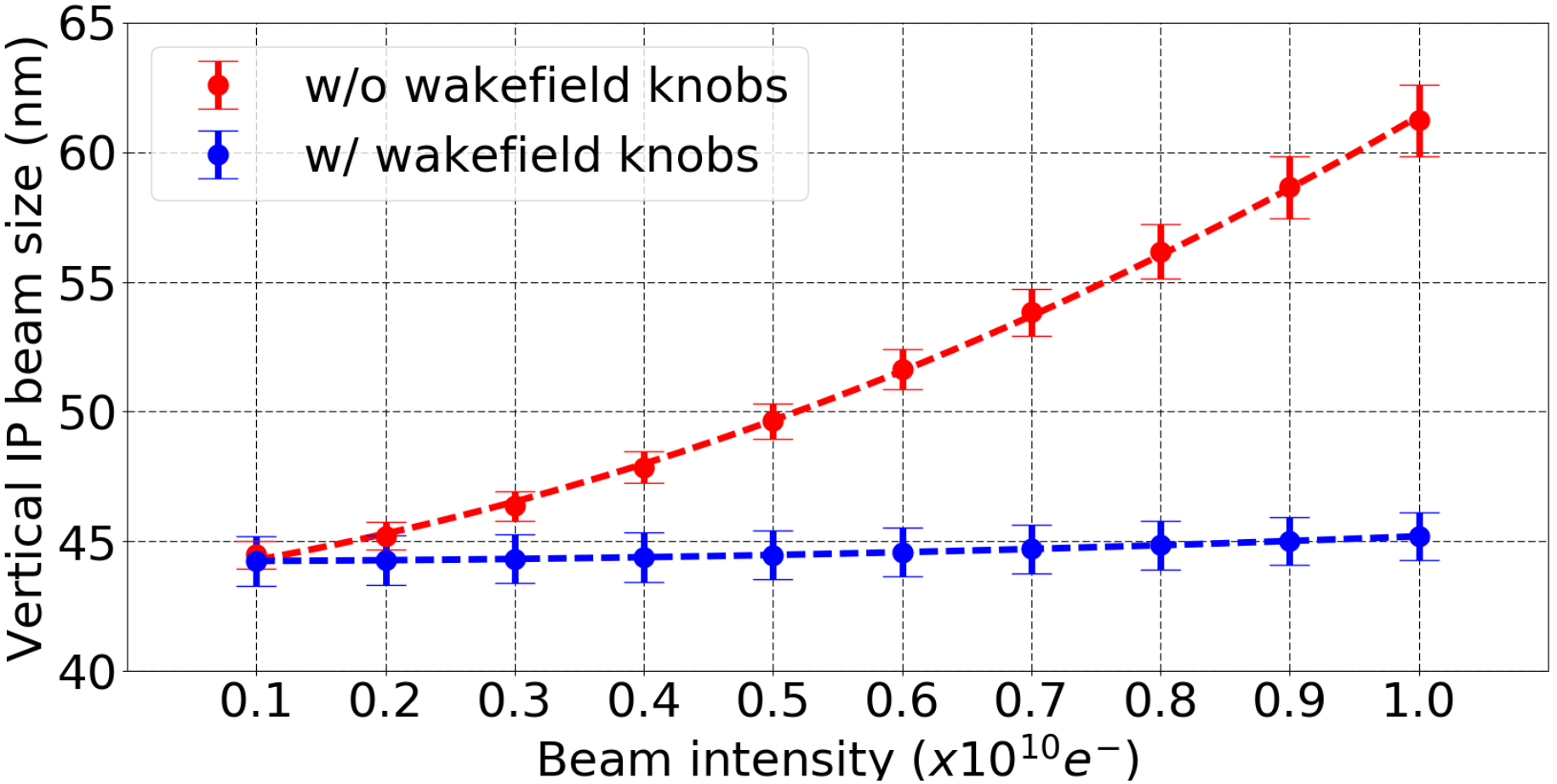
Position of bellow scan for one machine.



2D scan for one machine



Wakefield knobs
Simulation results (2/2)



The simulated wakefield knobs reduce the intensity-dependent effects really efficiently at the IP. The resulting intensity-dependent parameter is really small: **w ~ 0.2 nm/10^9 e^-**.

Conclusions

- The **bunch length's variation with the beam intensity** was measured in the ATF damping ring. It is varying from around **6 mm at 0.1x10^{10} e-/bunch** to around **8.5 mm at 0.8x10^{10} e$^-$/bunch**.

- The impact of such variation was **simulated** taking into account several types of imperfections and corrections. The **average difference** between a beam which does have a bunch length correlated with the beam intensity and a beam which doesn't is around **0.2 nm**. This seems to be a **negligible** effect.

- The **measured** wakefield knobs correction gave really good results for the nominal optics and at 30° mode in December 2019. The intensity parameter was decreased from **25.6 nm/10^9 e$^-$/bunch** to **12.6 nm/10^9 e$^-$/bunch** (with an **IP angle jitter** of **~70 µrad**).

- The **simulated** wakefield knobs correction is **really efficient**. It decreases by more than a **factor 10** the intensity-dependent parameter.

Thank you