# Intensity-dependent effects in ATF2 and ILC

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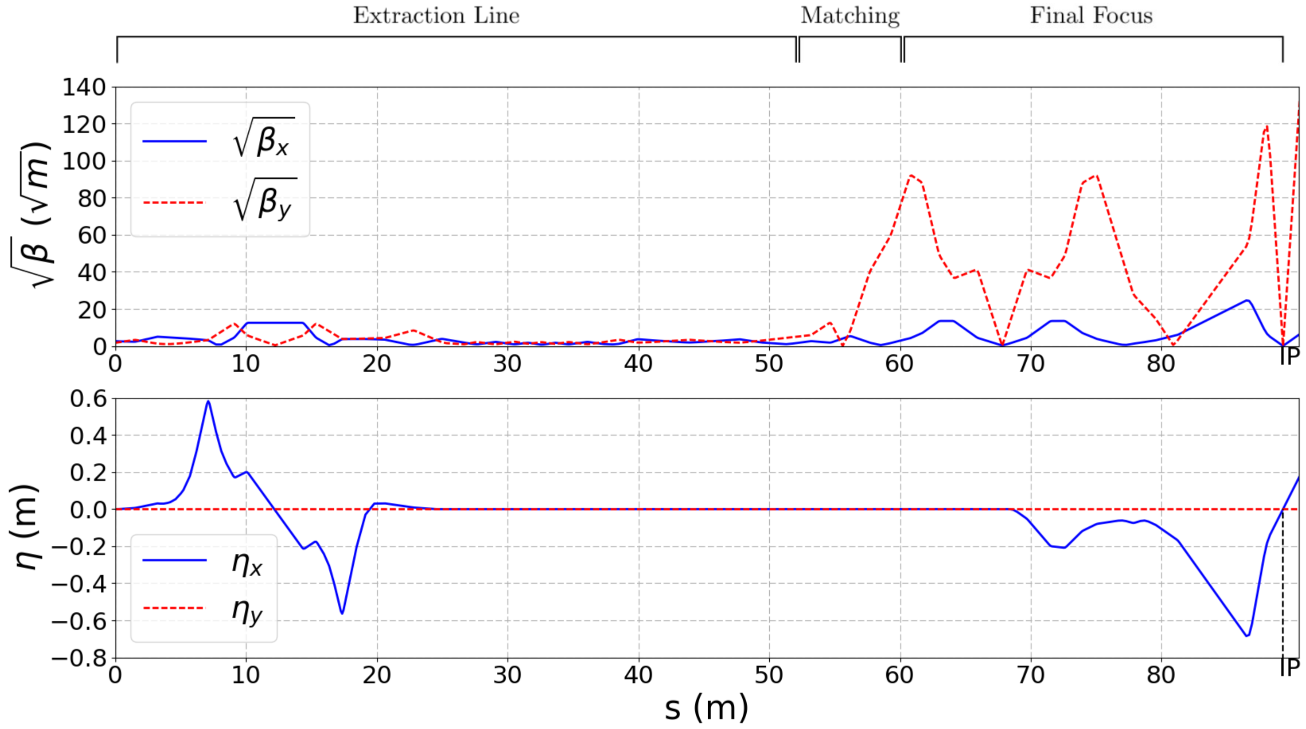
# Outline

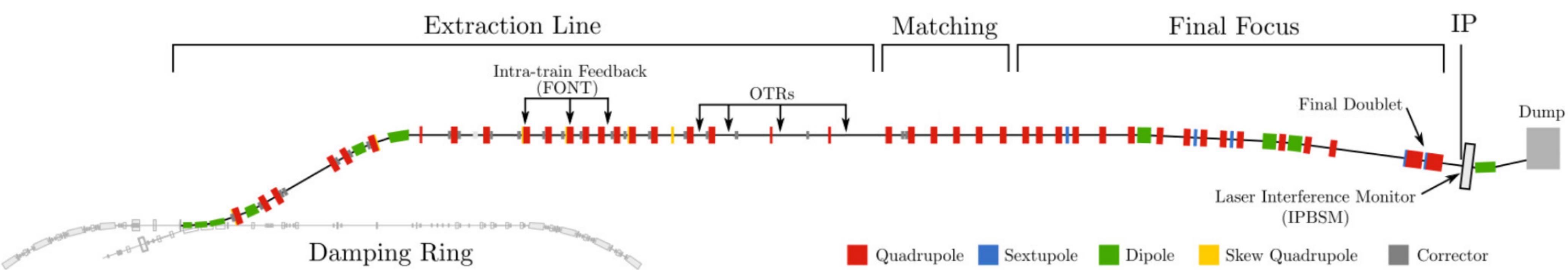
- Intensity-dependent effects in ATF2.
  Simulations of the impact of short-range wakefields in ATF2 with static and dynamic imperfections and with corrections.

- Intensity-dependent effects in ILC.
  Simulations of the impact of short-range and long-range wakefields in the ILC BDS with static imperfections and with corrections.

# ATF2 Parameters and Optics



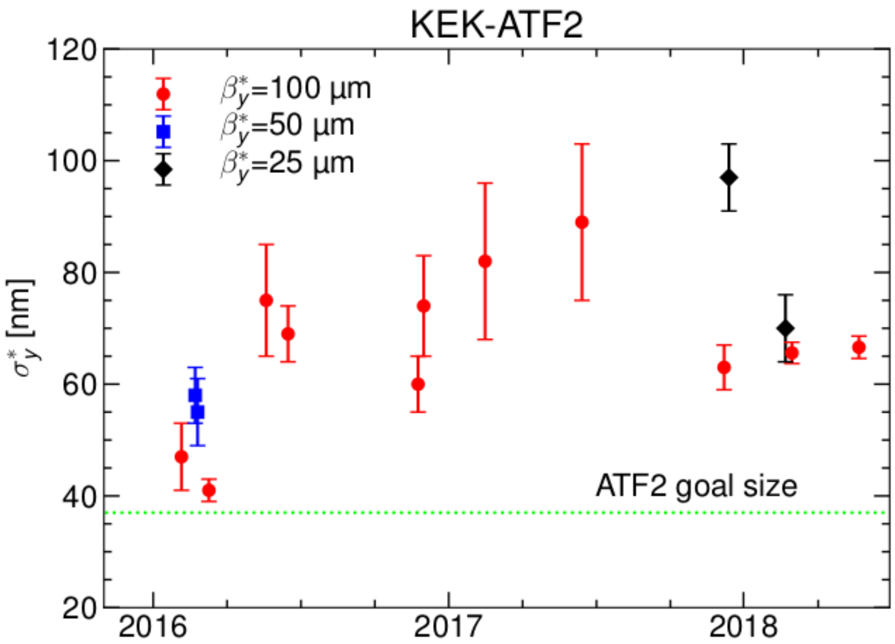

| Parameter | Symbol | Value |
|---|---|---|
| Length of ATF2 | $L$ | 90 m |
| Beam energy | $E$ | 1.3 GeV |
| Nominal bunch population | $N_e$ | $1.0 \times 10^{10} e^-$ |
| Nominal beam sizes at IP | $\sigma_x^*/\sigma_y^*$ | 8.9 µm/37 nm |
| Bunch length | $\sigma_z$ | 7 mm |



# Goals of ATF2

**Goal 1**: Obtain a small beam size at the IP ($\sigma_y^*$ = 37 nm). Demonstrate the performance of the Final Focus System based on local chromaticity correction.

**Goal 2**: Control the beam position. Demonstrate the performance of the beam orbit's stabilisation with a nanometer precision at the IP.



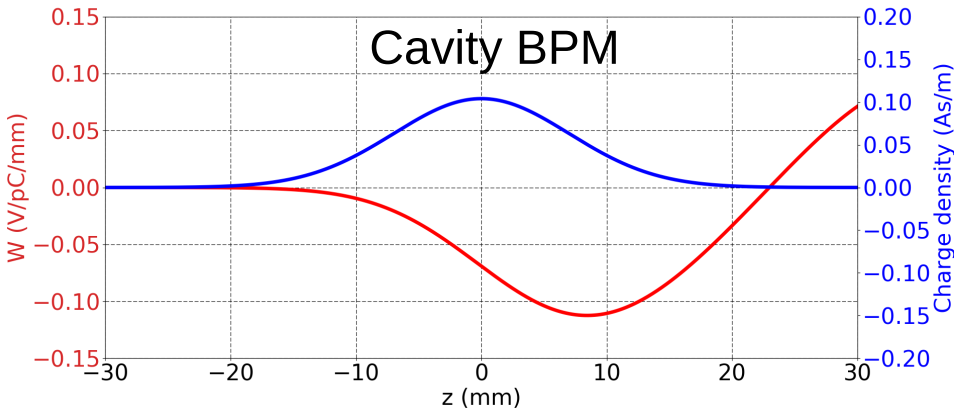

Minimum of **$\sigma_y$* = 42 nm** measured in 2016.
All these measurements were done at around **10% of the nominal beam intensity** (1.0 x $10^9$ $e^-$).

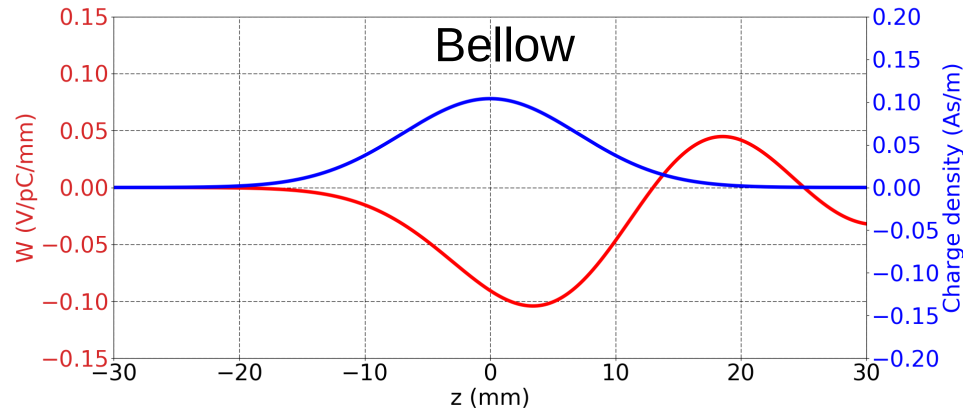
# Intensity-dependent effects in ATF2

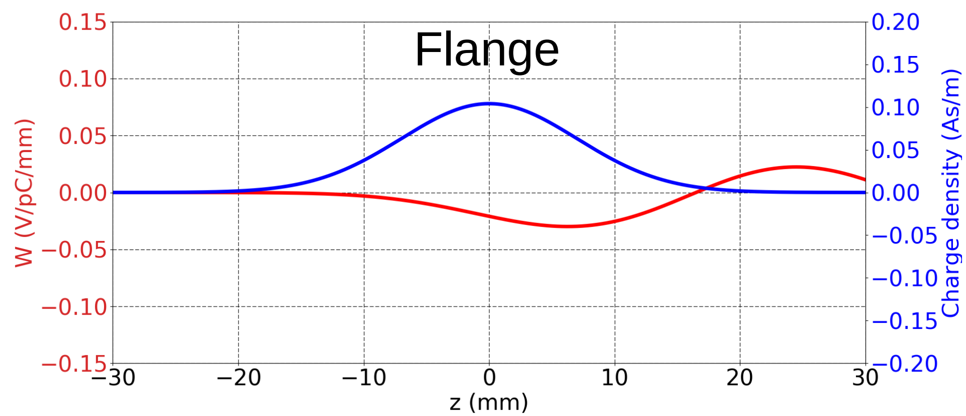
# Simulation conditions

## Wakefields:

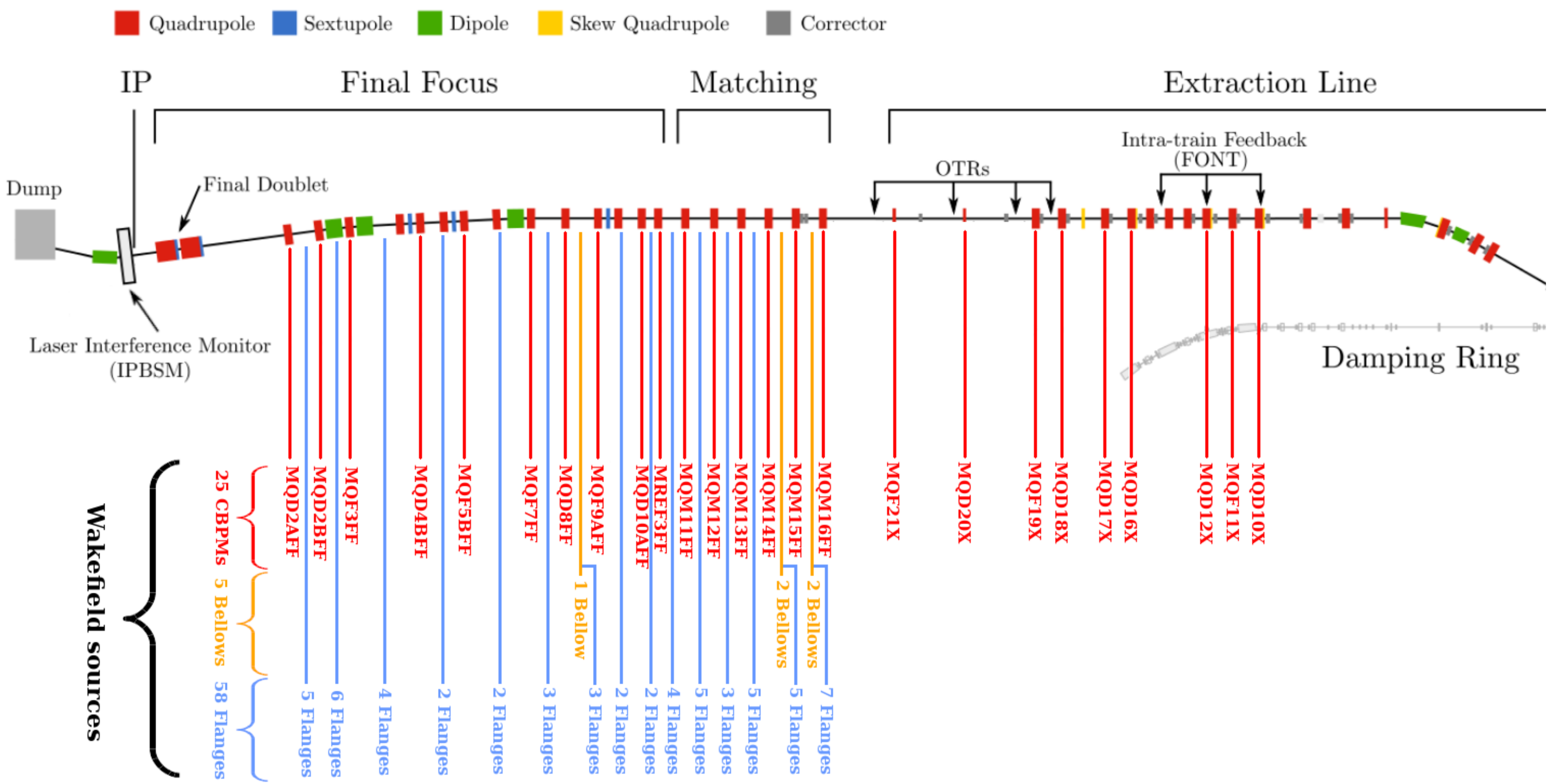
- Simulations were done with PLACET, a code developped at CERN, which simulates the dynamics of a beam in the main accelerating or deccelerating part of a linac in the presence of wakefields.
- Wakefield sources: Cavity BPMs, bellows and flanges (wakepotentials calcultated with GdfdL ).



# Simulation conditions
# Positions of wakefield sources



# Simulation conditions

## Static imperfections:

- Misalignment of Quadrupoles, CavBPMs, Sextupoles of 100 µm RMS.
- Strength error of Quadrupoles and Sextupoles of $1\times10^{-3}$ RMS.
- Roll error of Quadrupoles, CavBPMs and Sextupoles of 200 µrad RMS.
- 100 random machines.

## Dynamic imperfections:

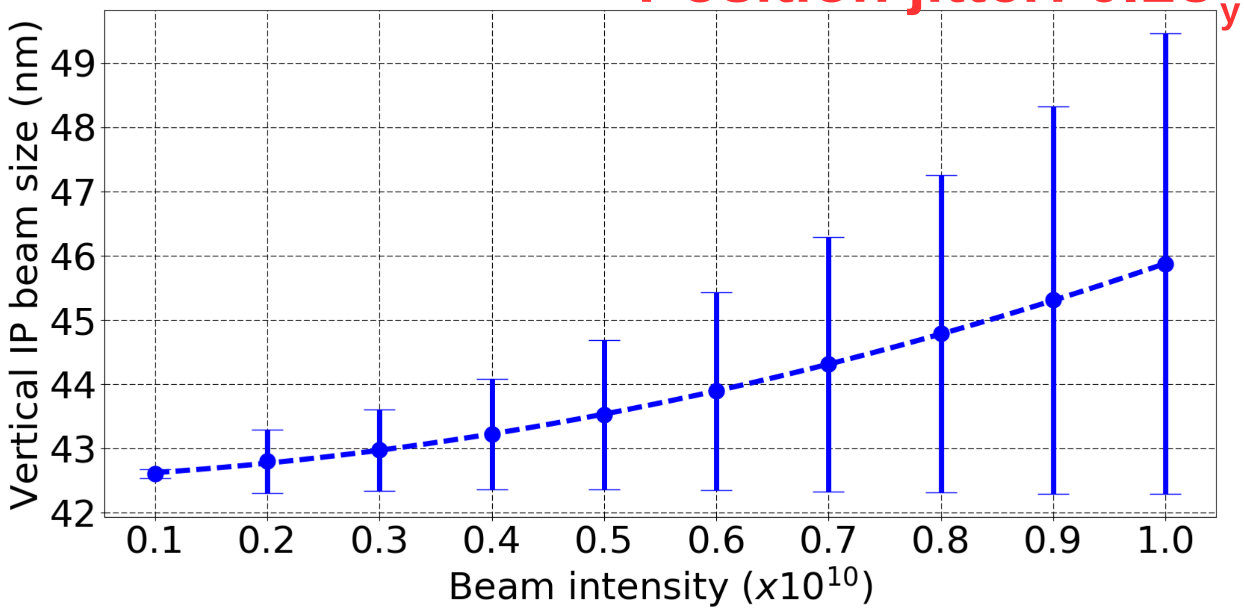
- 200 pulses: initial position jitter of $[0.1\sigma_y - 0.5\sigma_y]$ RMS or angle jitter of $[0.1\sigma_{y'} - 0.5\sigma_{y'}]$ RMS. (With $\sigma_{y'}$ the angular divergence: $\sigma_{y'} = \sqrt{\epsilon_y / \beta_y}$ )

## Corrections:

- 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>.

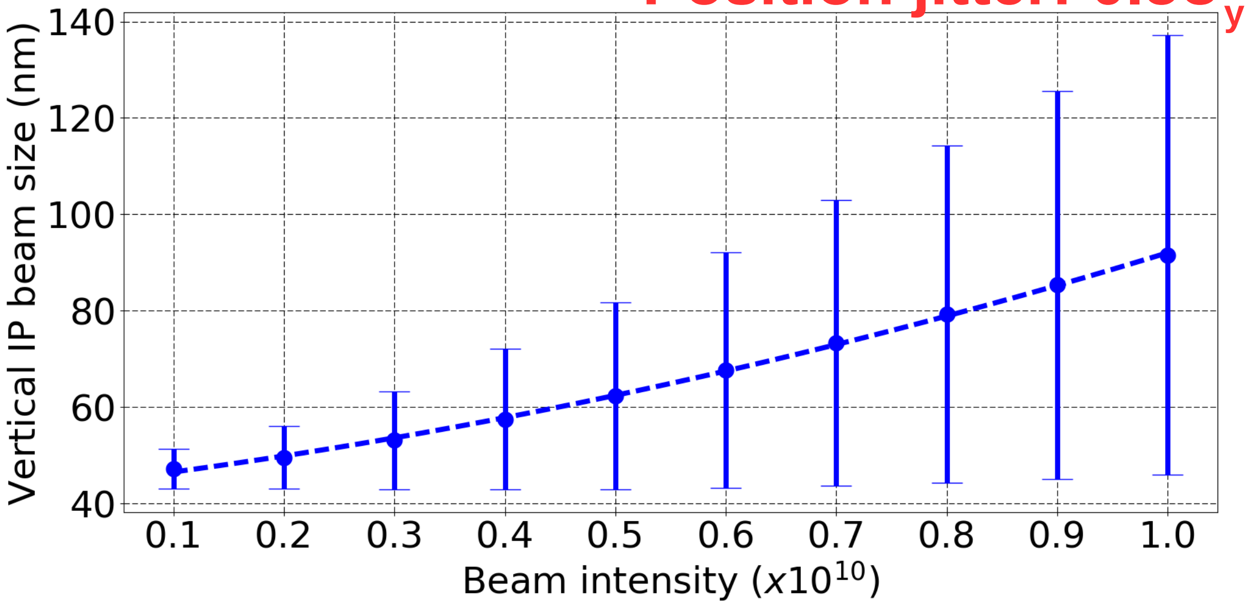
# ATF2 Intensity-dependent effects simulations
# Impact of position jitter

## Position jitter: 0.1$\sigma_y$




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

## Position jitter: 0.5$\sigma_y$



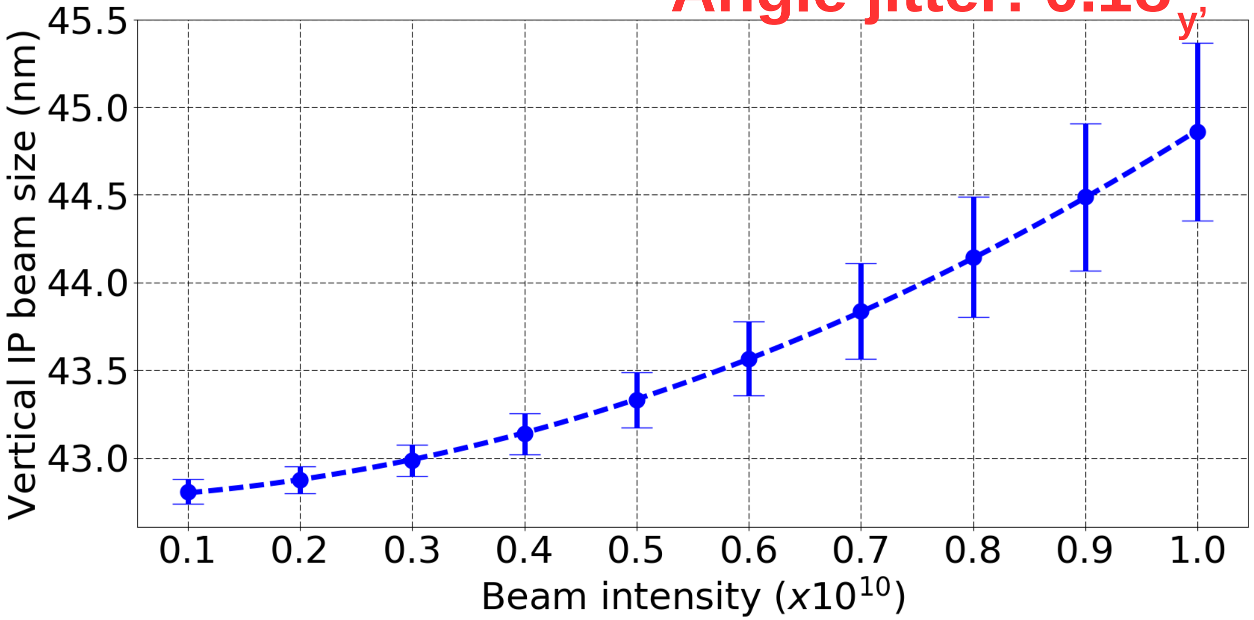

| Intensity | Average $\sigma_{y,ip}$ | 90th percentile* |
|---|---|---|
| $N=1.0x10^9$ | 46.69nm | 57.18nm |
| $N=10x10^9$ | 91.42nm | 159.93nm |



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

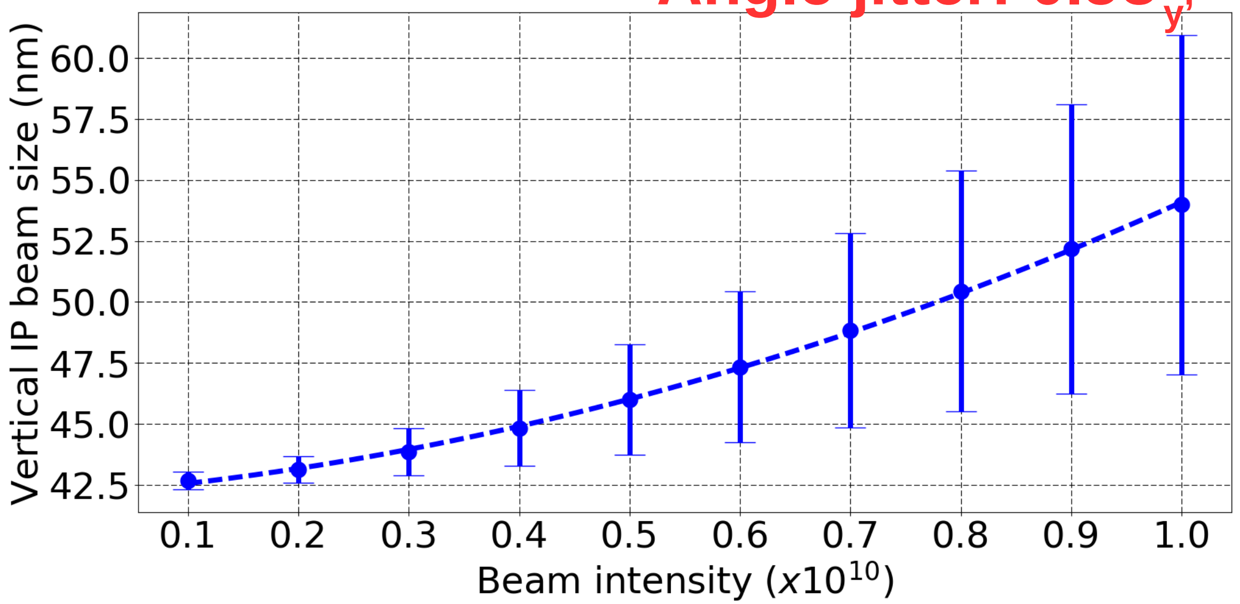
# ATF2 Intensity-dependent effects simulations
# Impact of angle jitter

## Angle jitter: 0.1$\sigma_{y'}$




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

## Angle jitter: 0.5$\sigma_{y'}$

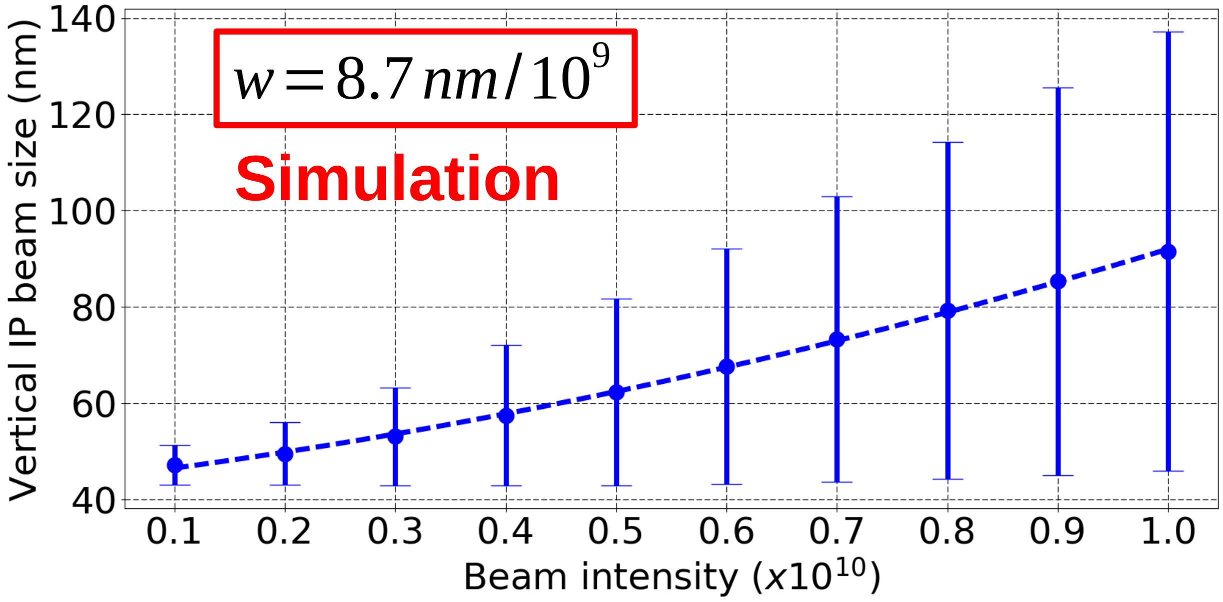



| Intensity | Average $\sigma_{y,ip}$ | 90th percentile* |
|---|---|---|
| N=1.0x10$^9$ | 42.79nm | 51.26nm |
| N=10x10$^9$ | 54.08nm | 78.18nm |

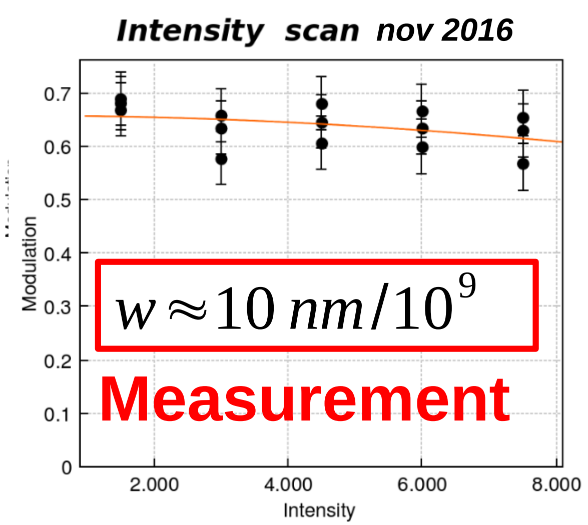


* 90% of the beam sizes are smaller than this value

# Dynamic effects
# Comparison simulation/measurement




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




*Date: 2016/11/23*

*Fit results: A*exp(-(x/B)^2*

*Modulation: 0.658 +/- 0.021*

*Center: 0.000 +/- 0.000*

*Sigma: 20.482 +/- 9.037*

*Chi2/ndf: 6.6394e+00 / 13*

*Data file:*

*Intensity_fringe_*

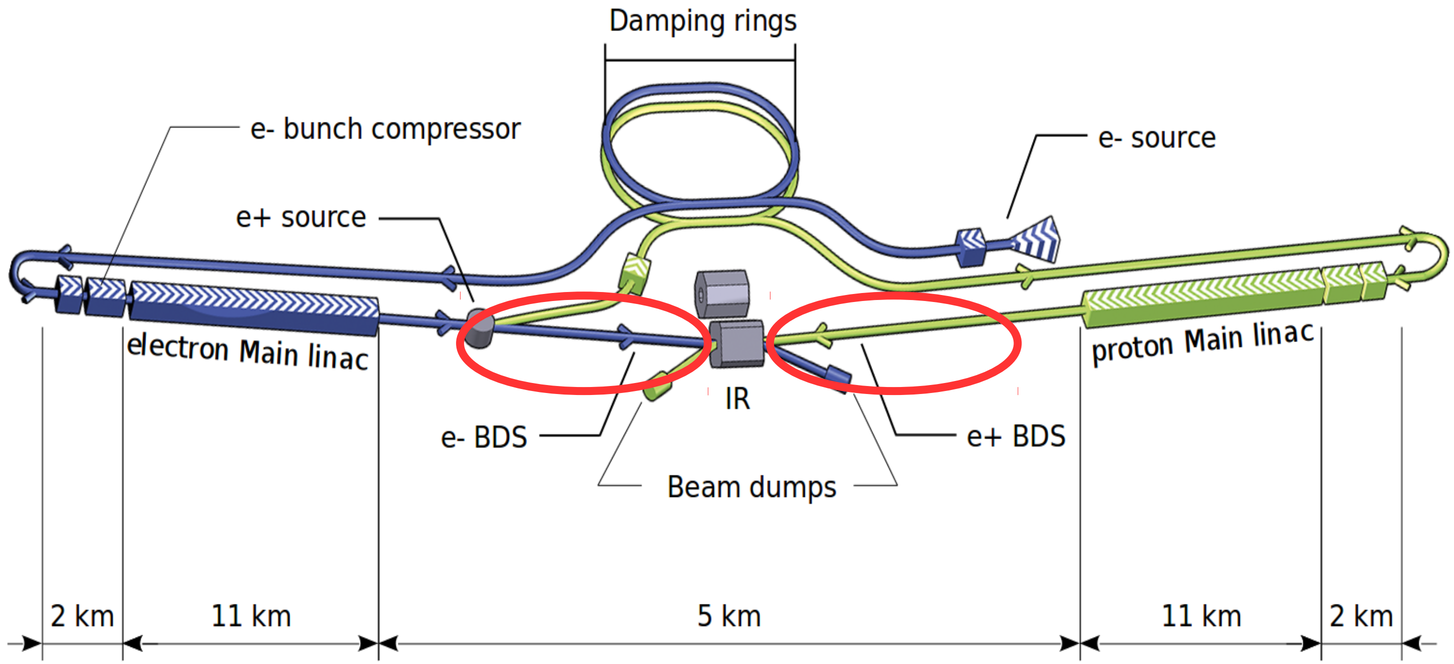
*161123_203036.dat*

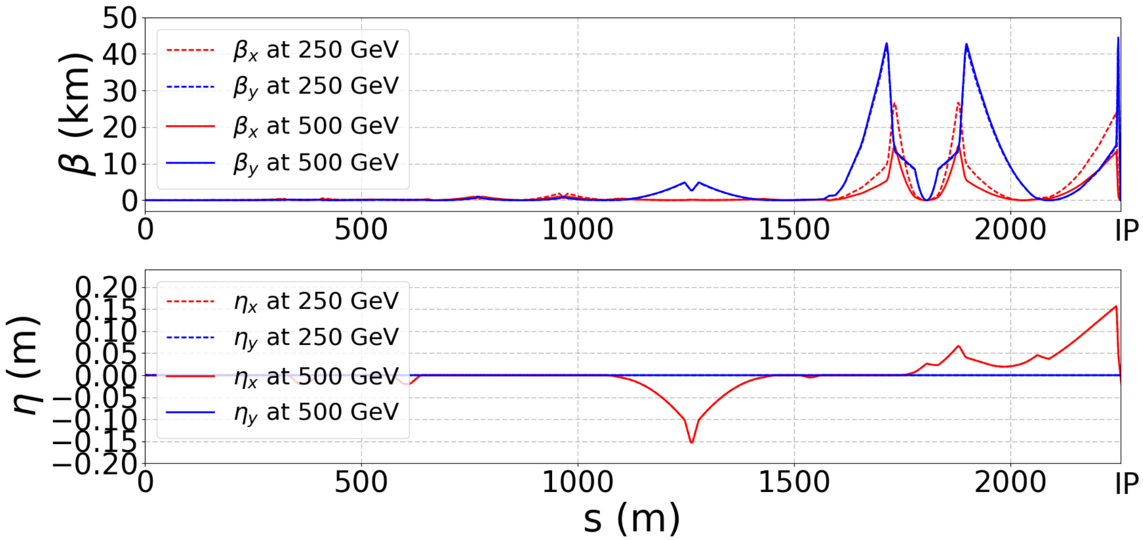
Intensity dependence parameter:

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

# Intensity-dependent effects in ILC BDS

# ILC BDS
# Parameters and optics



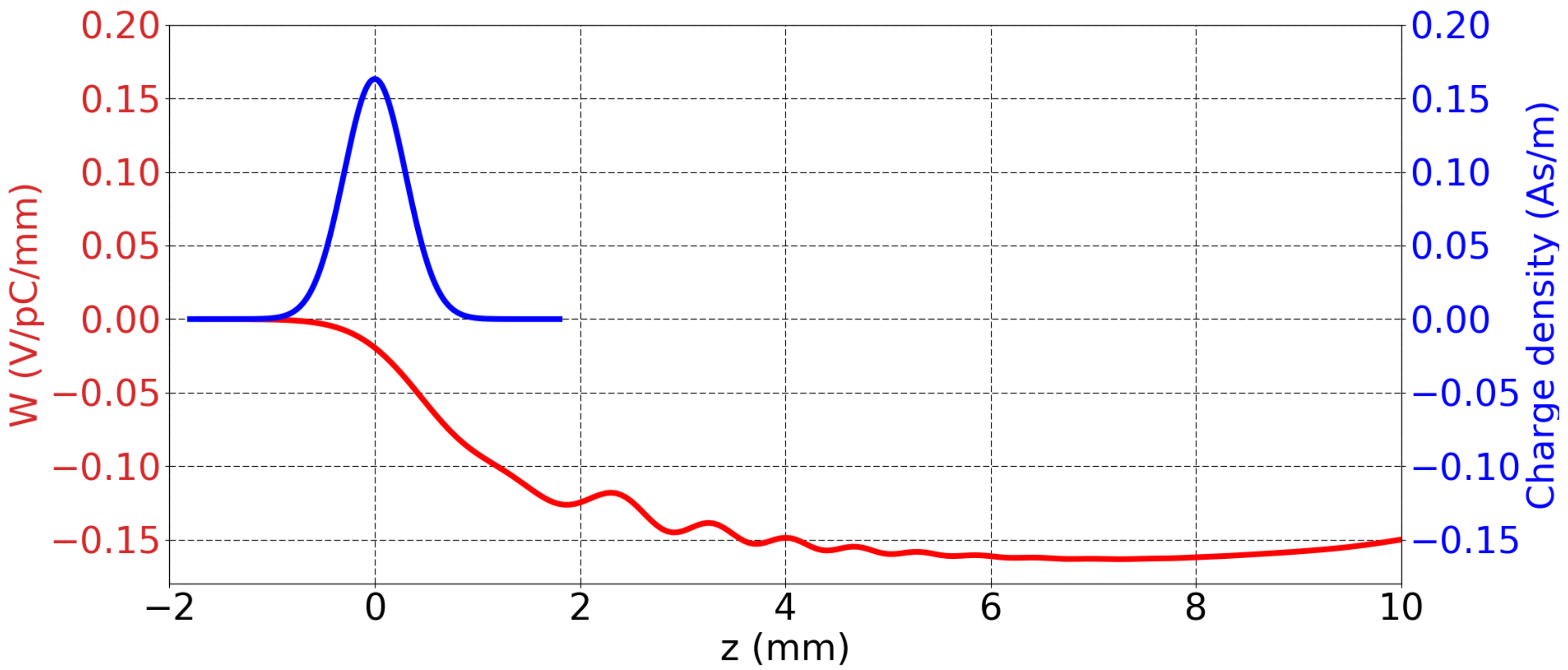




| **Parameter** | | Initial | Upgrade |
|---|---|---|---|
| Centre-of-mass energy | $E_{CM}$ [GeV] | 250 | 500 |
| Number of bunches | $n_b$ | 1312 | 1312 |
| Bunch population | $N \times 10^{10}$ | 2.0 | 2.0 |
| rms bunch length | $\sigma_z$ [mm] | 0.3 | 0.3 |
| Bunch separation | $\Delta t_b$ [ns] | 554 | 554 |
| IP rms beam sizes | $\sigma_x^*/\sigma_y^*$ [nm] | 729/7.7 | 474/5.9 |

# Intensity-dependent effects in ILC BDS for a single bunch
# Simulation conditions

## Wakefields:

- Short-range wakefield sources: Cavity BPMs (masked bellows and flanges).



# Intensity-dependent effects in ILC BDS for a single bunch
# Simulation conditions

## Wakefields:

- Short-range wakefield sources: Cavity BPMs (masked bellows and flanges).

## Static imperfections:

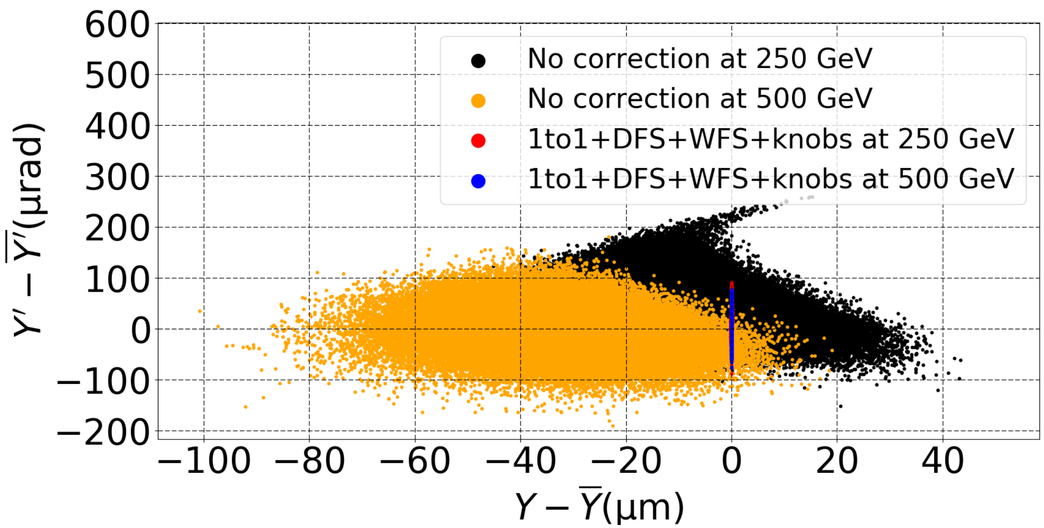
- Misalignment of Quadrupoles, CavBPMs, Sextupoles of 50 µm RMS.
- Strength error of Quadrupoles and Sextupoles of $1\times10^{-4}$ RMS.
- Roll error of Quadrupoles, CavBPMs and Sextupoles of 200 µrad RMS.
- 100 random machines.

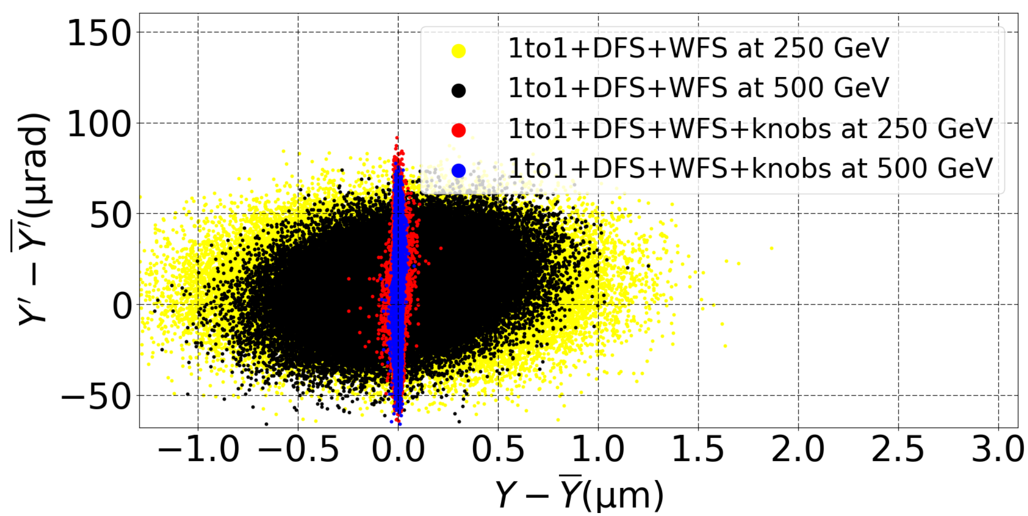
## Corrections:

- BBA correction applied: 1to1, DFS, WFS.
- Ideal knobs used to correct the IP distribution:
  $\langle y,x'\rangle$, $\langle y,y'\rangle$, $\langle y,E\rangle$, $\langle y,x'^2\rangle$, $\langle y,x'*y'\rangle$, $\langle y,x'*E\rangle$.

# Intensity-dependent effects in ILC BDS for a single bunch
# Correction impact

**For one machine:**



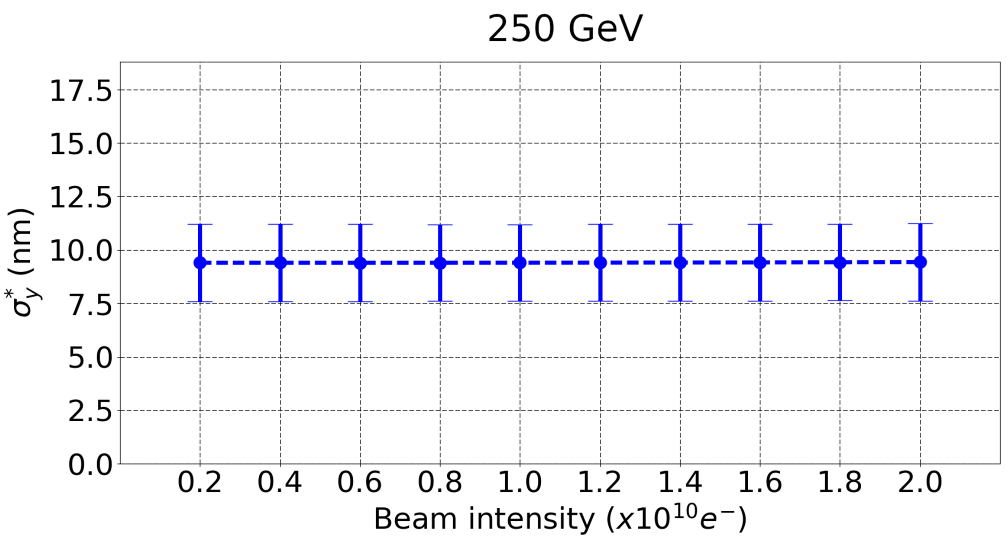

**For 100 machines:**

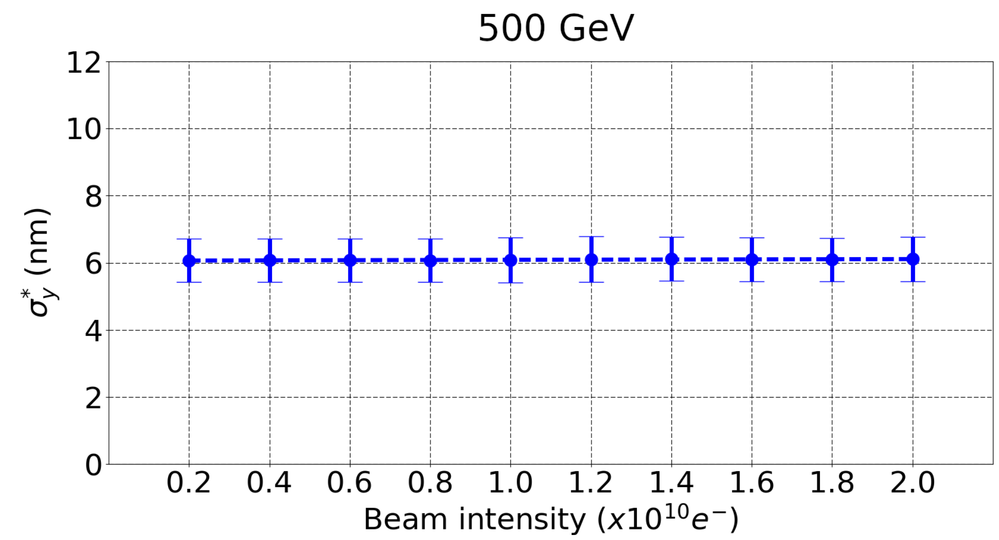
| CM energy (GeV) | 250 | | 500 | |
|---|---|---|---|---|
| Intensity ($e^-$) | $2.0\times10^9$ | $2.0\times10^{10}$ | $2.0\times10^9$ | $2.0\times10^{10}$ |
| Correction | Average $\sigma_y^*$ [nm] | | Average $\sigma_y^*$ [nm] | |
| No correction | 21120 | 22001 | 12669 | 12882 |
| 1to1 | 752 | 783 | 451 | 458 |
| 1to1+DFS | 590 | 614 | 354 | 367 |
| 1to1+DFS+WFS | 587 | 611 | 352 | 365 |
| 1to1+DFS+WFS+knobs | 9.40 | 9.43 | 6.07 | 6.11 |

For perfect machine: $\sigma_{y,250\ GeV}$* = 7.7 nm, $\sigma_{y,500\ GeV}$* = 5.9 nm

# Intensity-dependent effects in ILC BDS for a single bunch Results

| CM energy (GeV) | 250 | | 500 | |
|---|---|---|---|---|
| Intensity ($e^-$) | $2.0\times10^{9}$ | $2.0\times10^{10}$ | $2.0\times10^{9}$ | $2.0\times10^{10}$ |
| Correction | Average $\sigma_y^*$ [nm] | | Average $\sigma_y^*$ [nm] | |
| 1to1+DFS+WFS+knobs | 9.40 | 9.43 | 6.07 | 6.11 |



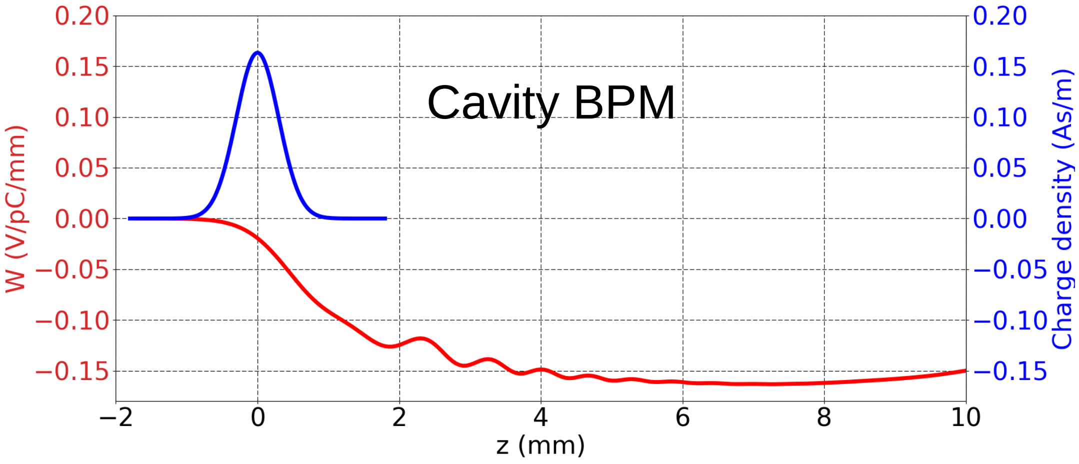

**The intensity-dependent effects in the ILC BDS due to short-range wakefields are relatively small if one takes into account the cited imperfections and corrections.**

# Intensity-dependent effects in ILC BDS for train of bunches
# Simulation conditions

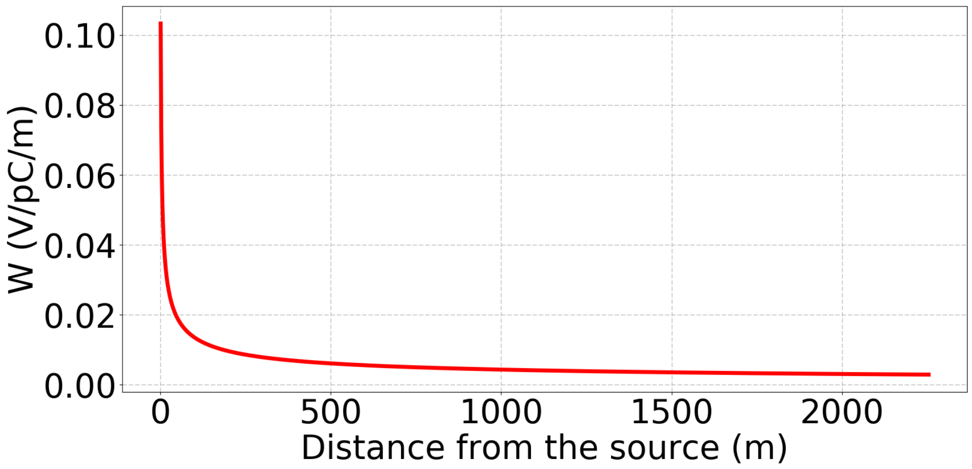
## Wakefields:

- Short-range wakefield sources: Cavity BPMs (masked bellows and flanges).
- Long-range wakefield sources: resistive walls.

**Short range**




**Long range**




$$W(z) = \frac{c}{\pi b^3} \sqrt{\left(\frac{Z_0}{\sigma_r \pi z}\right)} L$$

# Intensity-dependent effects in ILC BDS for train of bunches
# Simulation conditions

**Wakefields:**

- Short-range wakefield sources: Cavity BPMs (masked bellows and flanges).
- Long-range wakefield sources: resistive walls.

**No static or dynamic imperfections.**

**1312 consecutive bunches in a train.**

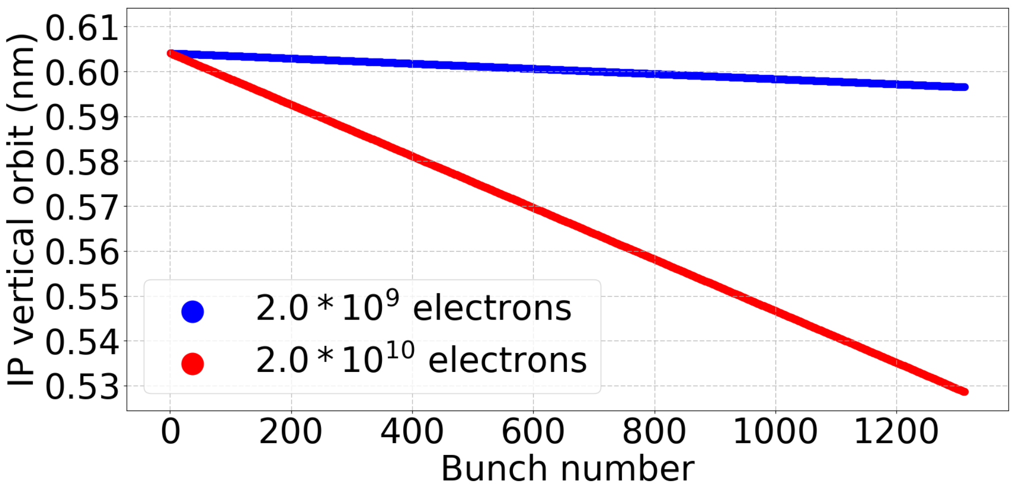
**One macroparticle per bunch.**

**Initial position offset of the train of [$0.1\sigma_y$ – $1.0\sigma_y$].**

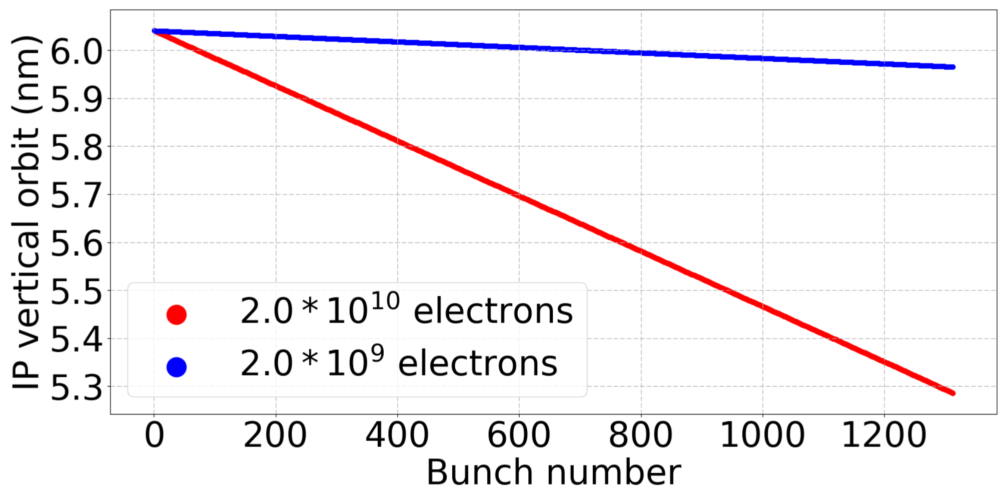
**Initial angle offset of the train of [$0.1\sigma_{y'}$ – $1.0\sigma_{y'}$].**

# Intensity-dependent effects in ILC BDS for train of bunches
# Results for 500 GeV

Intial position offset of $0.1\sigma_y$:




Intial position offset of $1.0\sigma_y$:




| **Incoming Y** | **Intensity** | **$\Delta_y$ at IP** |
|---|---|---|
| $0.1\sigma_y$ | $2.0\times10^9e^-$ | 0.008 nm |
| $0.1\sigma_y$ | $2.0\times10^{10}e^-$ | 0.076 nm |
| $1.0\sigma_y$ | $2.0\times10^9e^-$ | 0.075 nm |
| $1.0\sigma_y$ | $2.0\times10^{10}e^-$ | 0.755 nm |
| **Incoming Y'** | **Intensity** | **$\Delta_y$ at IP** |
| $0.1\sigma_{y'}$ | $2.0\times10^9e^-$ | 0.019 nm |
| $0.1\sigma_{y'}$ | $2.0\times10^{10}e^-$ | 0.20 nm |
| $1.0\sigma_{y'}$ | $2.0\times10^9e^-$ | 0.19 nm |
| $1.0\sigma_{y'}$ | $2.0\times10^{10}e^-$ | 2.03 nm |

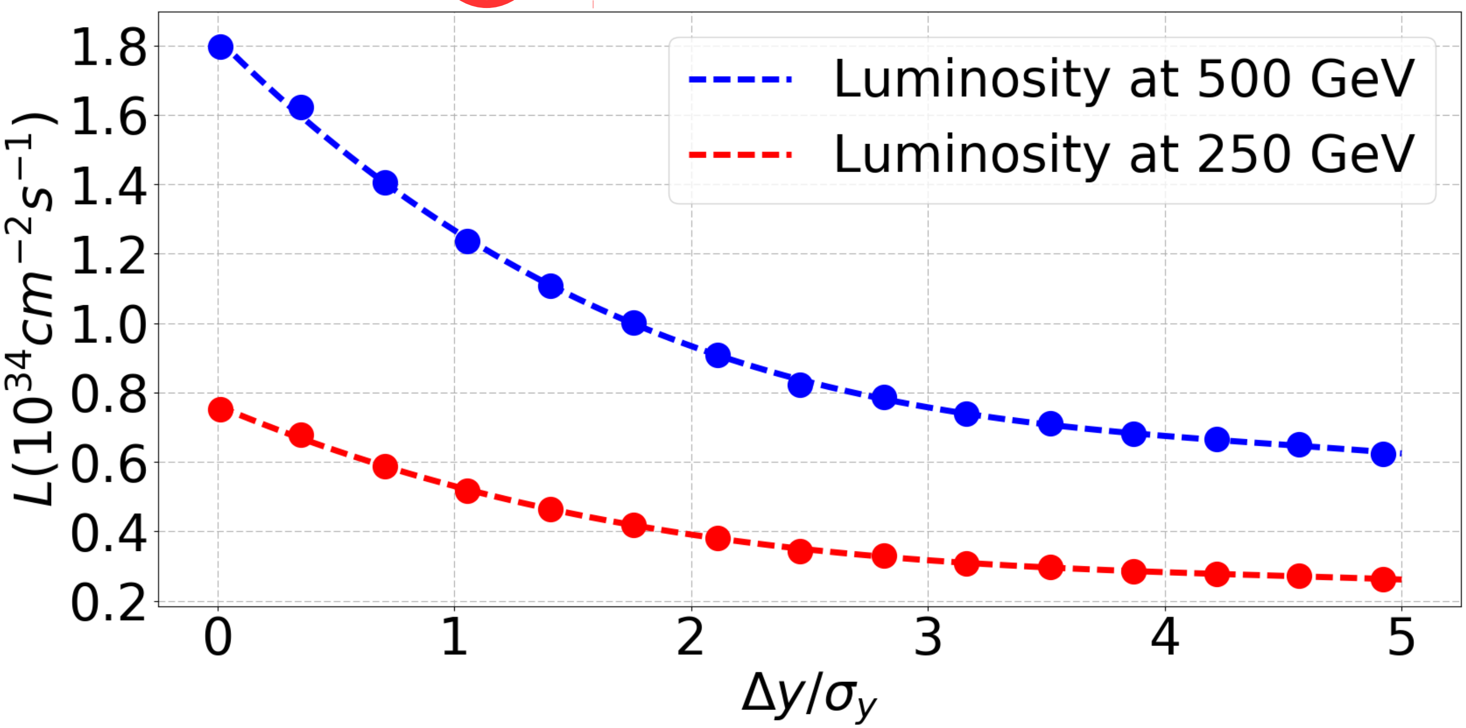
# Intensity-dependent effects in ILC BDS for train of bunches
# Impact on the luminosity

| Incoming Y | Intensity | $\Delta_y$ at IP | $L / L_0$ |
|---|---|---|---|
| $0.1\sigma_y$ | $2.0 \times 10^9 e^-$ | 0.008 nm | $\sim 1.0$ |
| $0.1\sigma_y$ | $2.0 \times 10^{10} e^-$ | 0.076 nm | 0.998 |
| $1.0\sigma_y$ | $2.0 \times 10^9 e^-$ | 0.075 nm | 0.998 |
| $1.0\sigma_y$ | $2.0 \times 10^{10} e^-$ | 0.755 nm | 0.964 |
| **Incoming Y'** | **Intensity** | **$\Delta_y$ at IP** | **$L / L_0$** |
| $0.1\sigma_{y'}$ | $2.0 \times 10^9 e^-$ | 0.019 nm | $\sim 1.0$ |
| $0.1\sigma_{y'}$ | $2.0 \times 10^{10} e^-$ | 0.20 nm | 0.992 |
| $1.0\sigma_{y'}$ | $2.0 \times 10^9 e^-$ | 0.19 nm | 0.996 |
| $1.0\sigma_{y'}$ | $2.0 \times 10^{10} e^-$ | 2.03 nm | 0.901 |

**Luminosity loss at 500 GeV:**

**3.6% at $2\text{x}10^{10}$ $e^-$ with an incoming position offset of $1.0\sigma_y$**

**9.9% at $2\text{x}10^{10}$ $e^-$ with an incoming angle offset of $1.0\sigma_{y'}$**



# Conclusions

- The impact of static and dynamic effects has been analyzed and quantified in ATF2. 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.

- The same beam-based correction procedure used in ATF2 gives very good results in the ILC BDS. This procedure decreases the vertical IP beam size to nearly nominal. Therefore, these simulations proved that the intensity-dependent effects of short-range wakefields on the IP beam size are negligible in the ILC BDS.

- Simulations of long-range wakefields due to resistive walls, in a perfect machine, showed that they induce a significant vertical offset at the IP and thus a luminosity degradation in both the 250 and 500 GeV ILC designs. However, one expects that this luminosity loss can be effectively compensated with appropriate IP intra-train feedback.

Thank you