# Intensity-dependent effects at ATF2, KEK


P. Korysko[1,2], P.N. Burrows[2], A. Latina[1], K. Kubo[3], T. Okugi[3], A. Faus-Golfe[4]

[1]CERN, Meyrin, Switzerland
[2]University of Oxford, Oxford, UK
[3]KEK, Tsukuba, Japan
[4]LAL, Orsay, France



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## Abstract

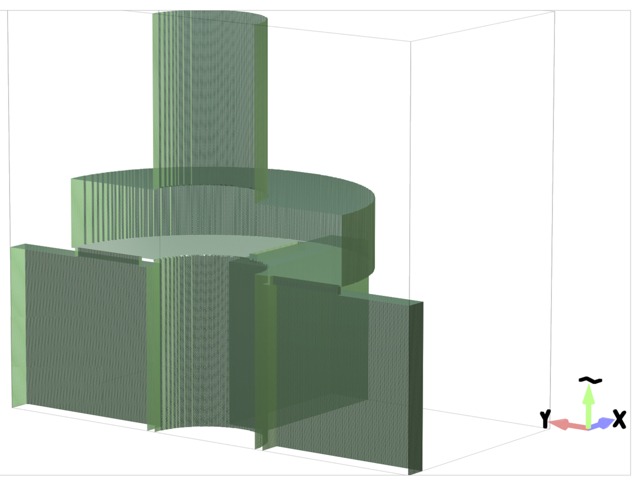
The Accelerator Test Facility 2 (ATF2) at KEK is a prototype for the Final Focus Systems of the future e+e- linear colliders, the International Linear Collider (ILC) and the Compact Linear Collider (CLIC). In this paper both simulation and experimental results are presented with special emphasis on intensity-dependent effects. The importance of these effects is shown using the PLACET code and realistic ATF2 machine simulations (including beam jitter, misalignment, wakefield, Beam Based Alignment (BBA) correction). The latest experimental results are also presented, in particular the impact of the beam intensity on the beam size at the IP.

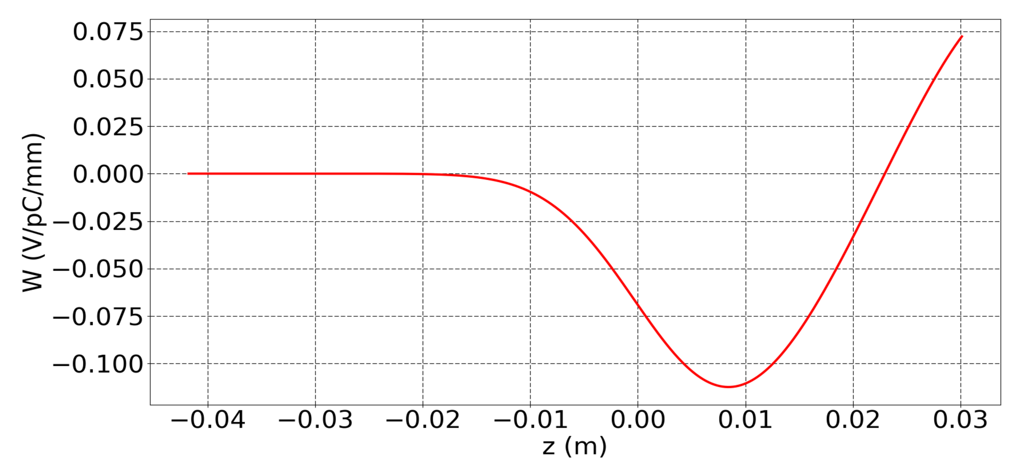

## ATF2 parameters

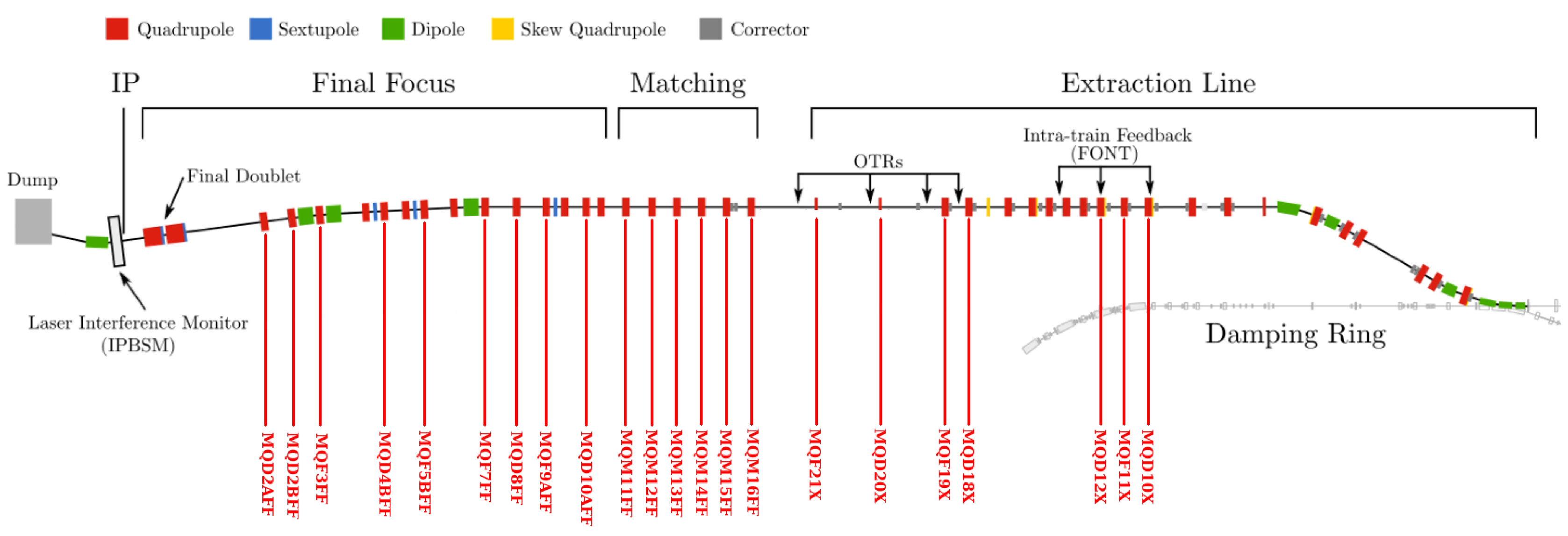
| Parameter | Symbol | Value |
|---|---|---|
| Length of ATF2 | $L$ | 90 m |
| Beam energy | $E$ | 1.3 GeV |
| Nominal bunch population | $N_e$ | $1.0 \times 10^{10} e^-$ |
| Nominal beam sizes at IP | $\sigma_x^* / \sigma_y^*$ | 8.9 μm/37 nm |
| Bunch length | $\sigma_z$ | 7 mm |

## Wakefield sources and simulation conditions

- The study of the intensity-dependent effects as done with PLACET, a tracking code developped at CERN.
- **Simulation conditions**:
  - **Misalignment** and **roll error** of quadrupoles, Cavity BPMs and sextupoles by respectively 100 μm rms and 200 μrad rms and quadrupoles, sextupoles **strength error** of 1.0 x $10^{-3}$ rms.
  - 100 random seeds.
  - **Short range wakefield**: multiple wakefield sources (wakepotentials calculated with GdfidL).
  - 200 pulses – incoming angle/position jitter of 0.5σy' /0.5σy
- **Corrections applied**:
  - **One-to-one correction** that steers the beam and minimizes the transverse displacements measured by BPMs.
  - **Dispersion-Free Steering,** to cancel the unwanted dispersion introduced by misaligned quadrupoles. This correction steers the beam through the center of the BPMs and simultaneously minimizes the difference between the trajectories of two beams with different energies.
  - **Wakefield Free Steering** correction, which minimizes the difference of orbits between beams with different charges.
  - **Tuning knobs** are applied at the IP. These knobs remove the correlations between the following pairs: <y,x'>, <y,y' >, <y,E> and <y,xx'>, <y,x'y'> <y, x'E>.



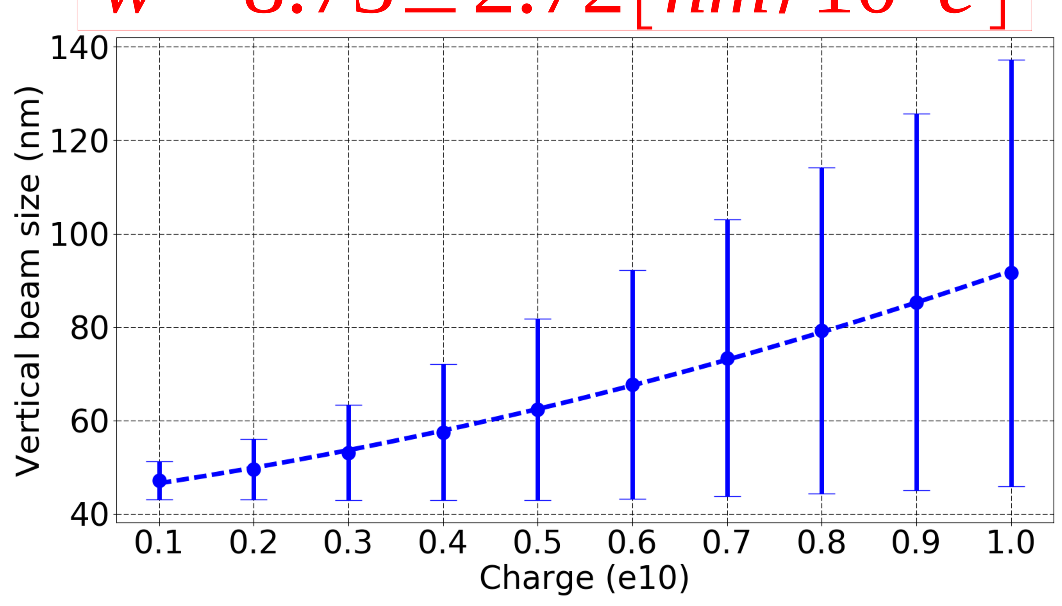



## Simulation results

The vertical IP beam sizes are shown for 100 machines, 200 pulses per machine and for 10 different beam intensities considering the previous simulation conditions and an incoming position jitter of $0.5\sigma_y$. The beam size evolves quadratically with the beam intensity. The evolution of the vertical beam size at the IP is following the same behaviour as observed in the ATF2 machine.

$$w = 8.73 \pm 2.72 [nm/10^9 e]$$




At 0.1 x $10^{10}$ $e^-$, an average beam size of 47.2 nm is measured compared to 91.6 nm at the nominal beam intensity of 1.0 x $10^{10}$ $e^-$.
In order to quantify this correlation, one can define the intensity dependence parameter w as follows:

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

| Case | $\overline{\sigma_y^*}$ | 90th percentile |
|---|---|---|
| **Angle jitter** | | |
| Jitter $0.5\sigma_{y'}$, $1 \times 10^9 e^-$ | 43 ± 0.4 nm | 51 nm |
| Jitter $0.5\sigma_{y'}$, $10 \times 10^9 e^-$ | 54 ± 7.0 nm | 78 nm |
| **Position jitter** | | |
| Jitter $0.5\sigma_y$, $1 \times 10^9 e^-$ | 47 ± 4.1 nm | 57 nm |
| Jitter $0.5\sigma_y$, $10 \times 10^9 e^-$ | 91 ± 46 nm | 160 nm |

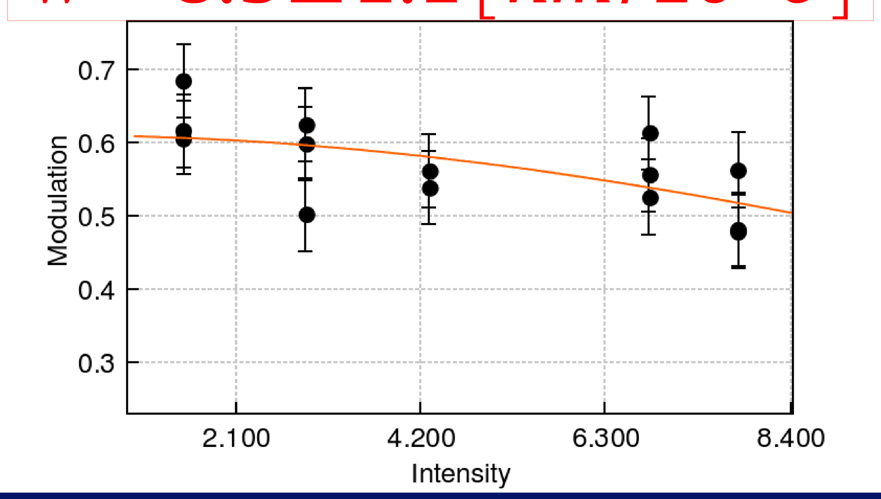
## Experimental results

In ATF2, the beam size at the IP is measured using the Shintake IP Beam Size Monitor (IPBSM). The monitor is made of two laser beams that intersect at the IP with the electron beam. Compton scattered photons are generated when the electron beam passes through the interference pattern of the two laser beams and the signal is recorded by a Compton photon detector.
The modulation of the Compton signal is measured. It is expressed as

$$M = \frac{N_+ - N_-}{N_+ + N_-}$$

$N_+$ and $N_-$ are the maximum and minimum Compton signal intensities during a scan.

$$w = 8.5 \pm 1.1 [nm/10^9 e]$$




## Conclusion

The simulations with realistic imperfections, showed that the impact of dynamic errors is significant even after full correction. The simulated correction was similar to what is used experimentally in the ATF2 beam line, just more effective. The agreement between simulations and measurements at ATF2 makes the PLACET simulations on the intensity dependent effects in future linear collider ILC and CLIC more reliable.


pierre.korysko@cern.ch



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