Intensity-dependent effects in the ILC BDS

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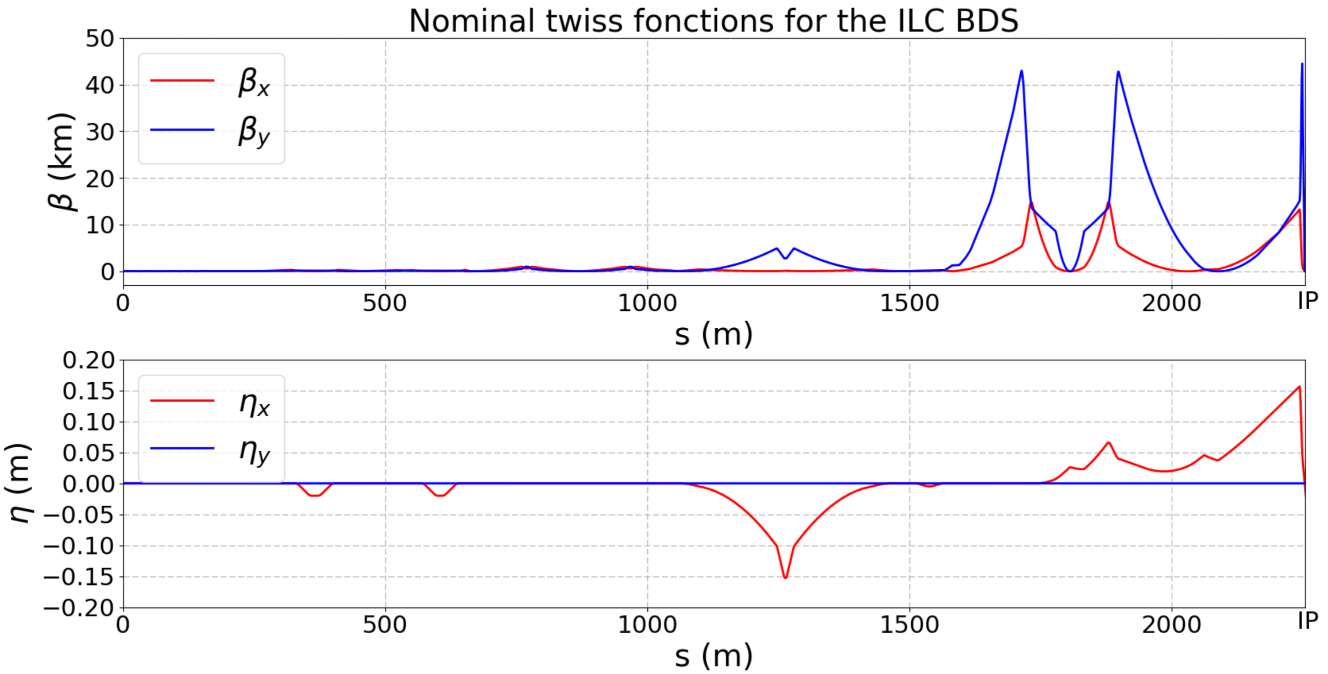
Outline

- **Presentation of resistive walls.**

- **Beam Based Alignment (BBA) + knobs studies in the ILC BDS.**

- **Intensity dependent effects in the BDS for a bunch train.**

Introduction
ILC BDS 250GeV beam energy



Centre-of-mass energy	E_{CM}	500	GeV
Number of bunches	n_b	1312	
Bunch population	N	2.0×10^{10}	
RMS bunch length	σ_z	0.3	mm
Beta functions at the entrance of the BDS	β_x/β_y	51.3/9.40	m
Emittances at the entrance of the BDS	$\varepsilon_x/\varepsilon_y$	10/0.04	μm
IP beta functions	β_x^*/β_y^*	21/0.4	mm
IP RMS beam sizes	σ_x^*/σ_y^*	655/5.7	nm

Resistive walls

Resistive walls wakefield

- Electrons going through the pipe interacts with the surrounding structure and generates a wake field.

- This wake field produces a transverse kick for the following particles inside the same bunch (short range) but also for the following bunches (long range).

  The following model is used for the transverse wake function:

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

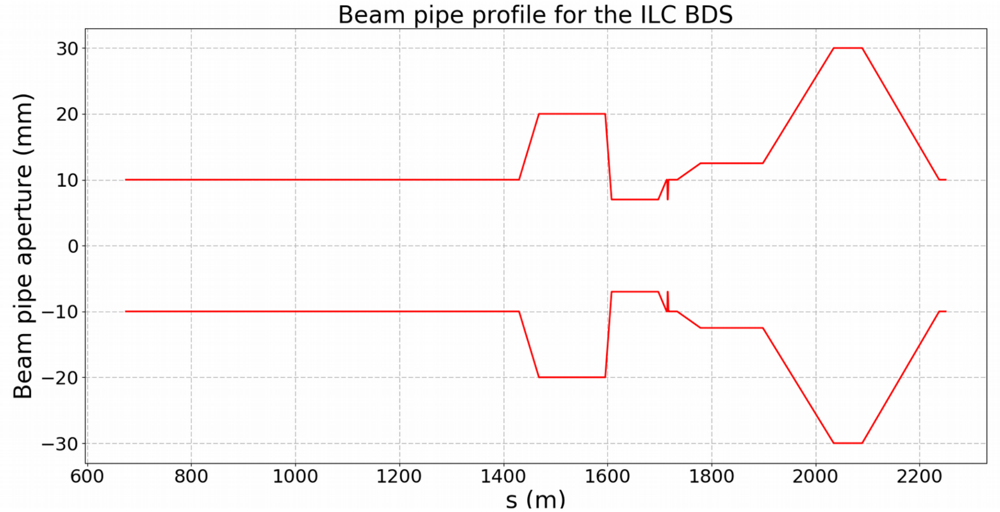
With *b* the radius of the beam pipe, Z_0 the impedance of the vacuum, σ_r the conductivity of the pipe and *L* the length of the beam line element

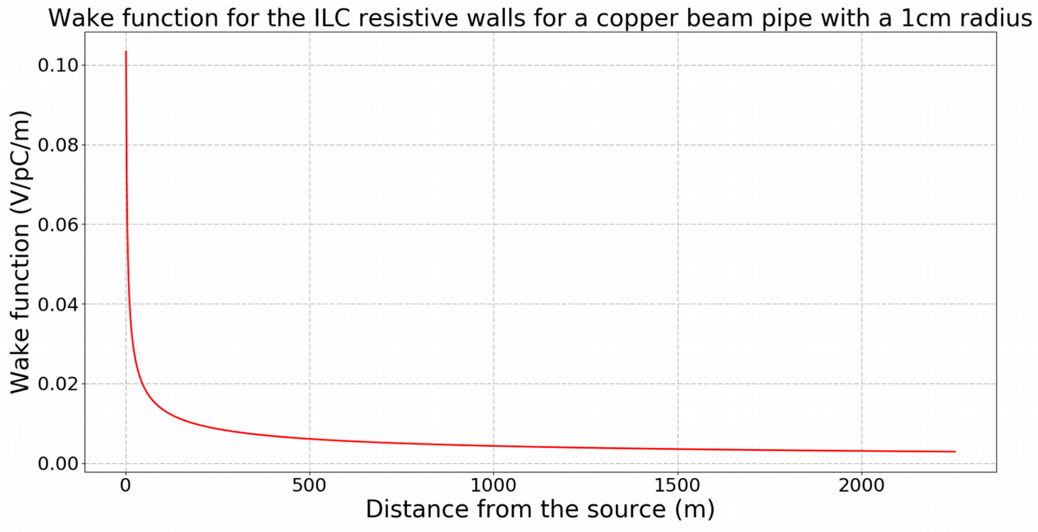
Resistive walls wakefield

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

Beam pipe profile

Material used: copper





Beam Based Alignment + knobs studies in the ILC BDS

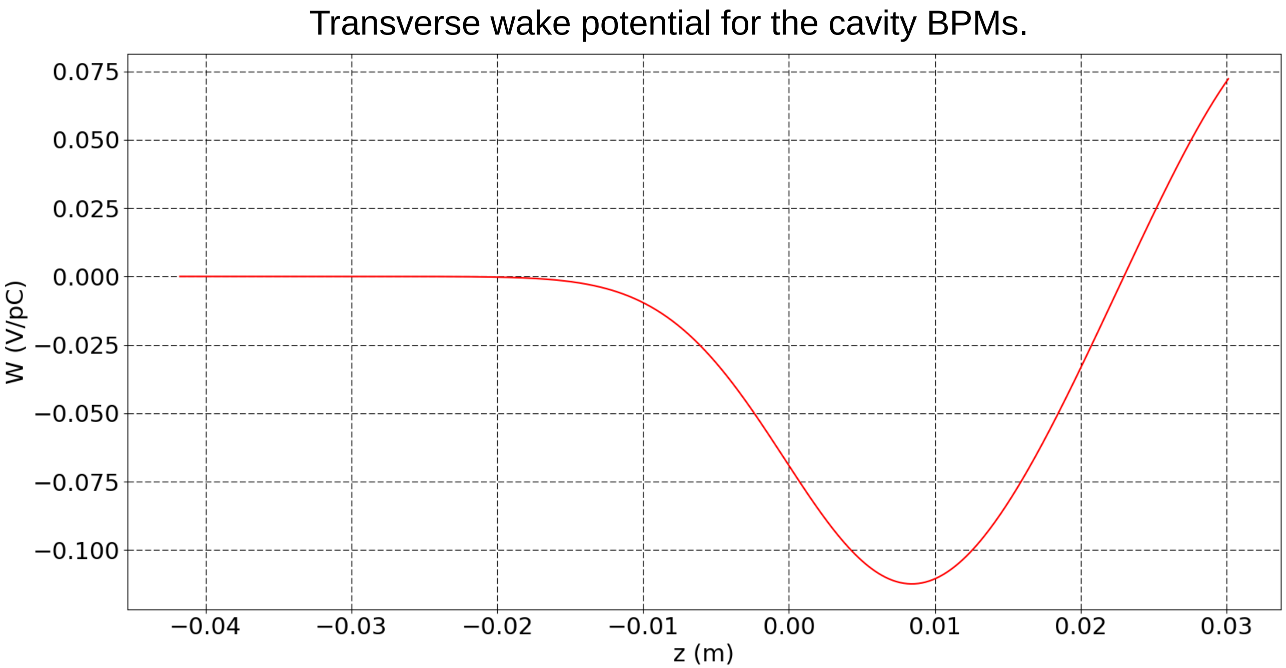
Simulation conditions for the BBA

- $N = 2.0\times10^{10}$ electrons.
- 100 random seeds (machines).
- BBA correction applied: 1to1, Dispersion Free Steering, Wakefield Free Steering. For DFS, E = 2.5GeV, for WFS, q = 1e10.
- Perfect knobs used to correct the IP distribution: <y,x’>, <y,y’>, <y,E>, <y,x’²>, <y,x’*y’>, <y,x’*E>.
- The following errors:

Type of error	Amplitude
Misalignment of quads, CBPMs and sextupoles	50µm RMS
BPM resolution	1.0µm
Roll errors	200µrad RMS
Strength error	1.0×10^{-4}

Simulation conditions for the BBA

- Wakefields used: GdfdL simulations from A. Lyapin for cavity BPMs.

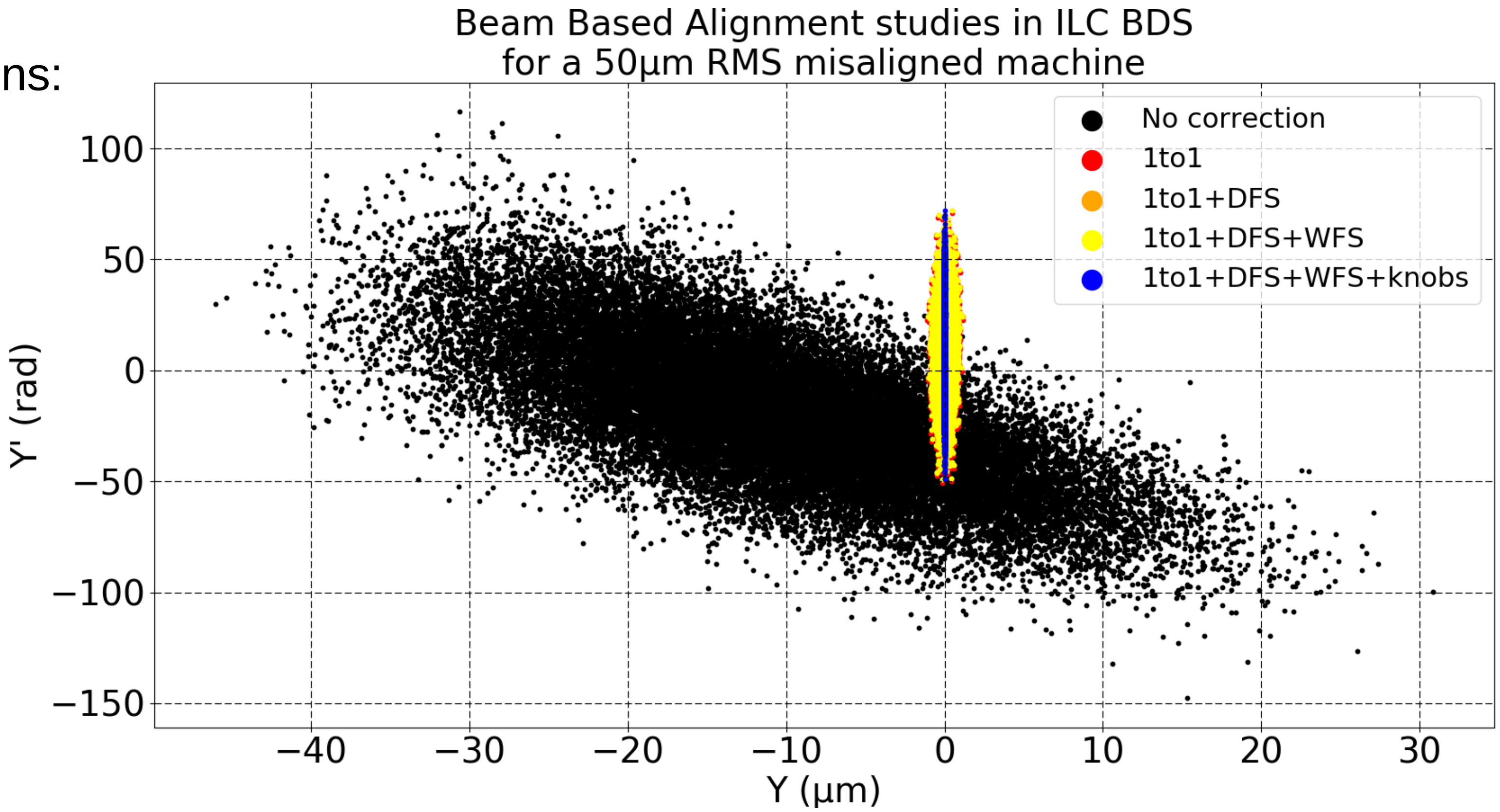


This wake potential is used at every Cavity BPM in the BDS.

+ Resistive walls calculated earlier.

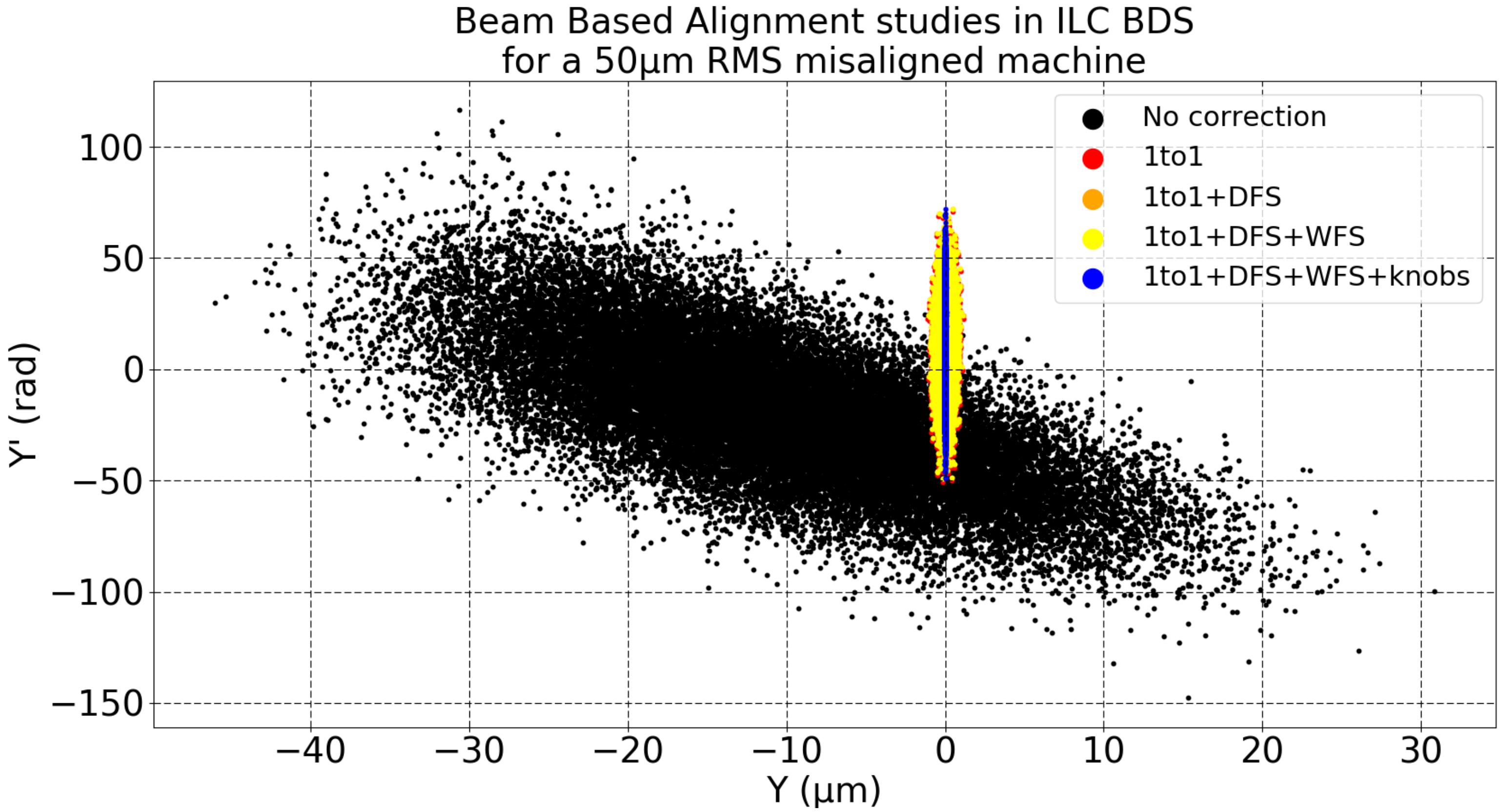
Results of Beam Based Alignment + knobs in ILC BDS for one machine

IP distributions:



	Vertical beam size at IP σ_y^*
No correction	10400 nm
1to1	280 nm
1to1 + DFS	272 nm
1to1 + DFS + WFS	268 nm
1to1 + DFS + WFS + knobs	7.05 nm

Results of Beam Based Alignment + knobs in ILC BDS for one machine



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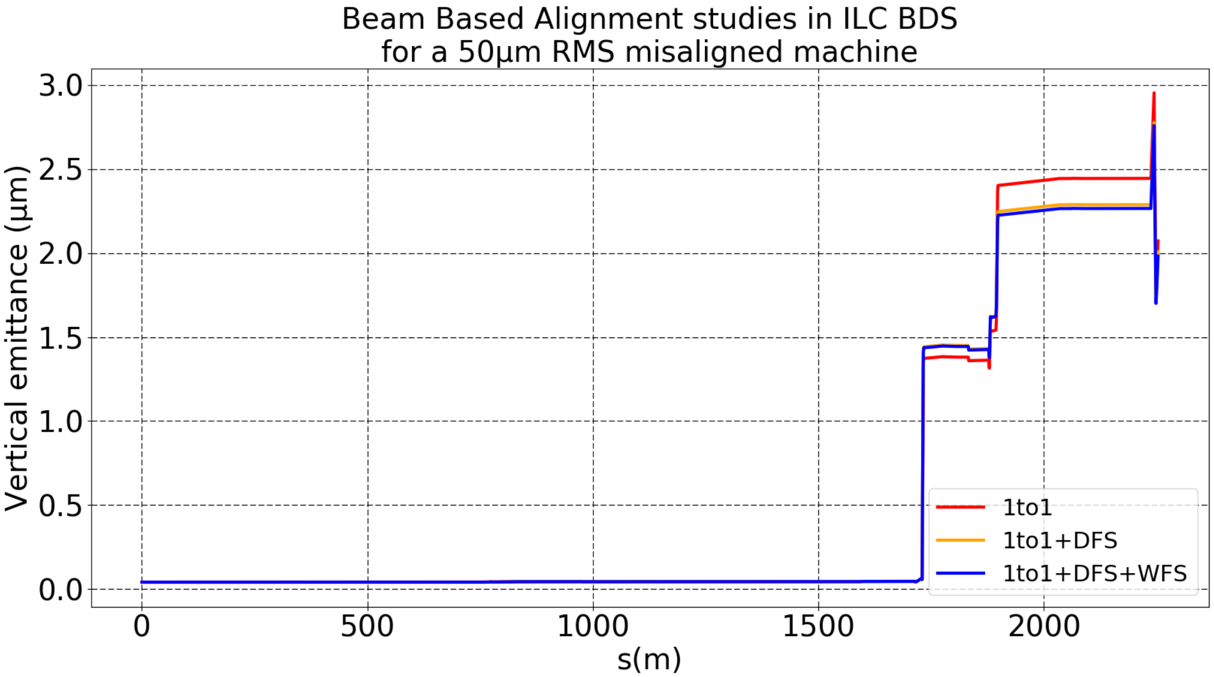
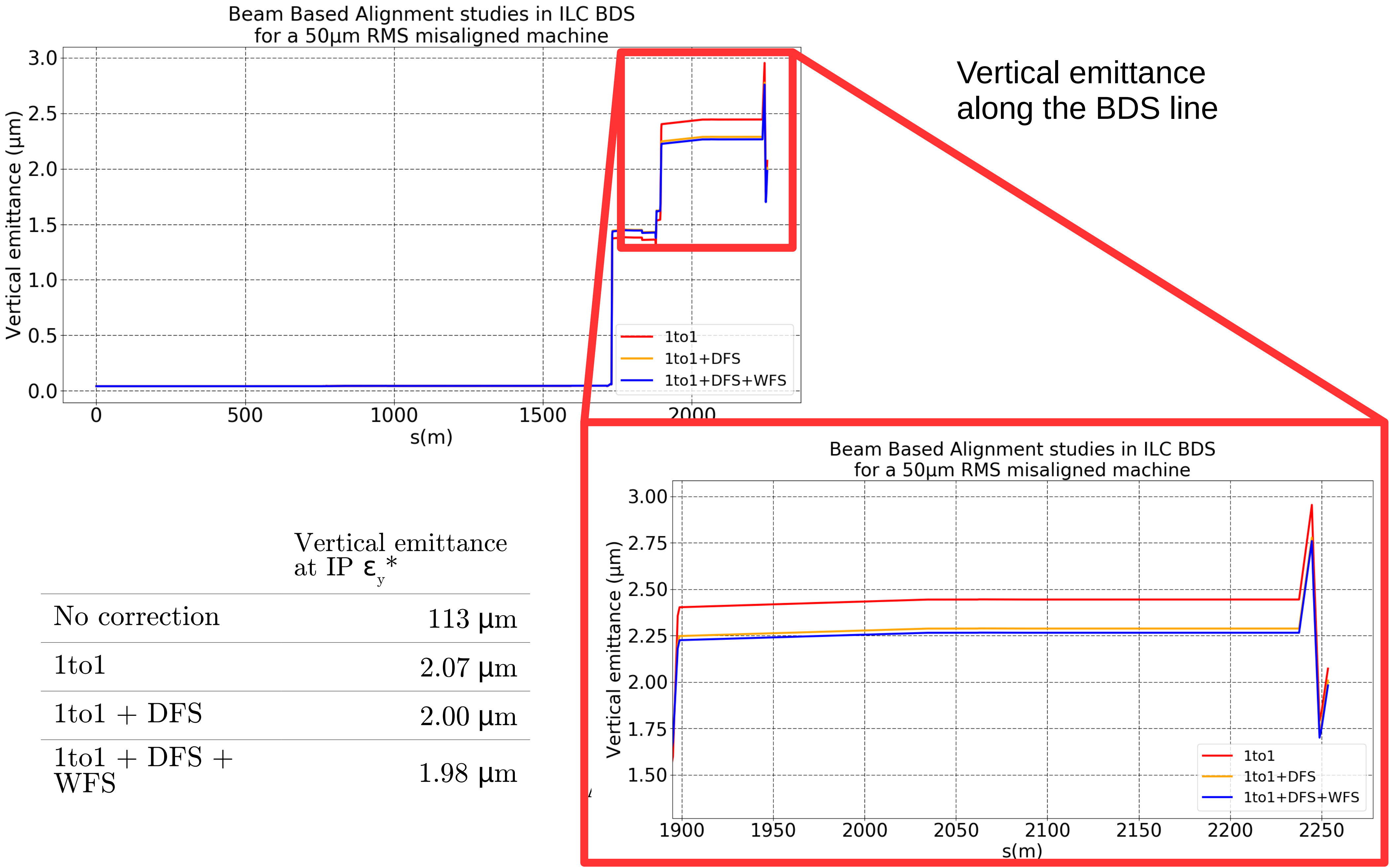
The correction manages to squeeze the beam from 10μm to 7nm.

Results of Beam Based Alignment in ILC BDS for one machine



Vertical emittance along the BDS line

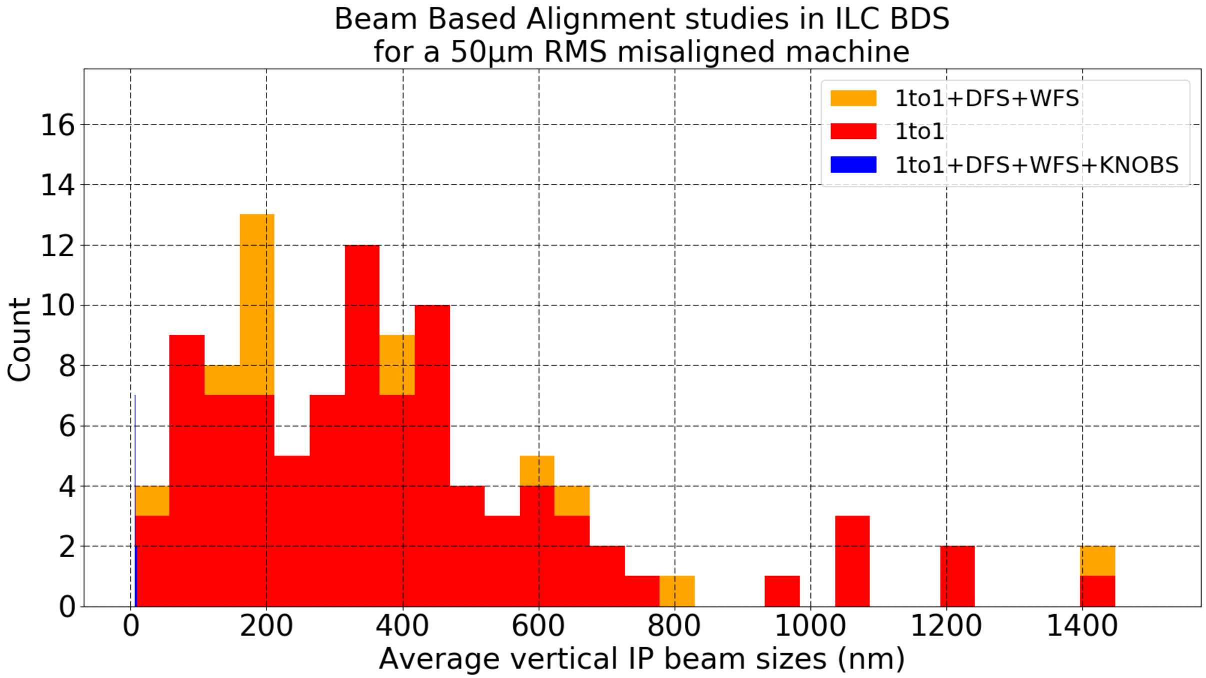
Results of Beam Based Alignment in ILC BDS for one machine



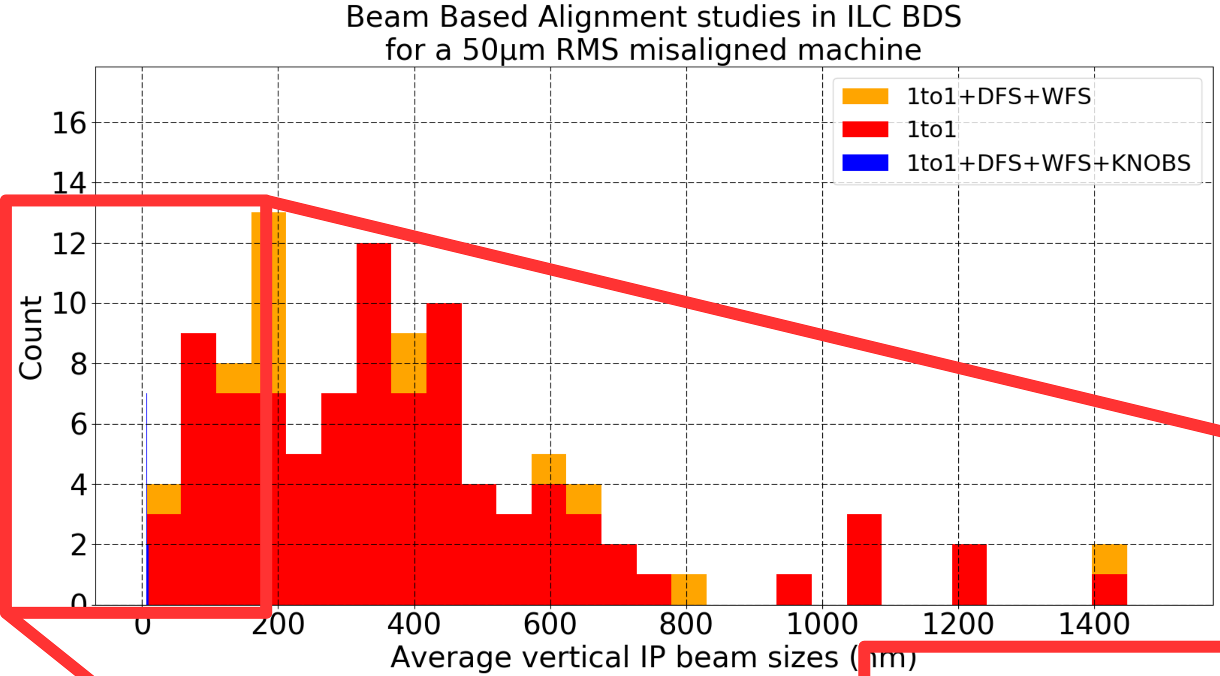
Vertical emittance along the BDS line

	Vertical emittance at IP ε_y^*
No correction	113 µm
1to1	2.07 µm
1to1 + DFS	2.00 µm
1to1 + DFS + WFS	1.98 µm

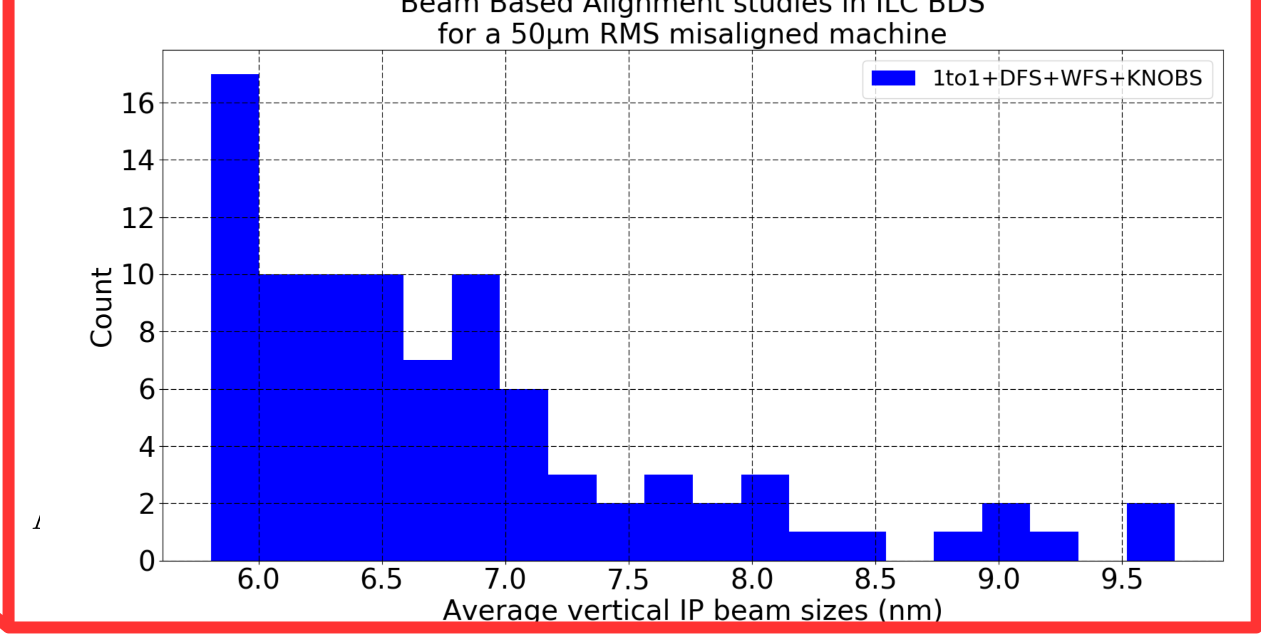
Results of Beam Based Alignment in ILC BDS for 100 machines



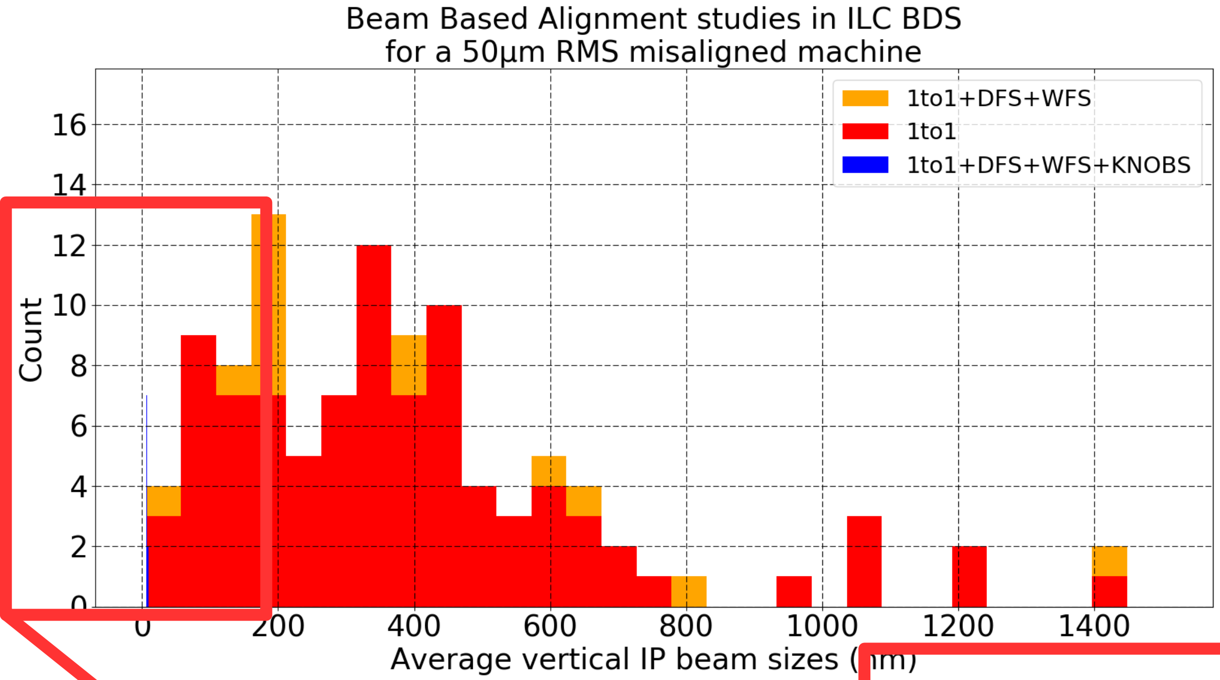
Results of Beam Based Alignment in ILC BDS for 100 machines



	Average beam size at IP σ_y^*
1to1	458nm
1to1 + DFS	367nm
1to1 + DFS + WFS	365nm
1to1 + DFS + WFS + KNOBS	6.8nm



Results of Beam Based Alignment in ILC BDS for 100 machines


Beam Based Alignment studies in ILC BDS
for a 50µm RMS misaligned machine

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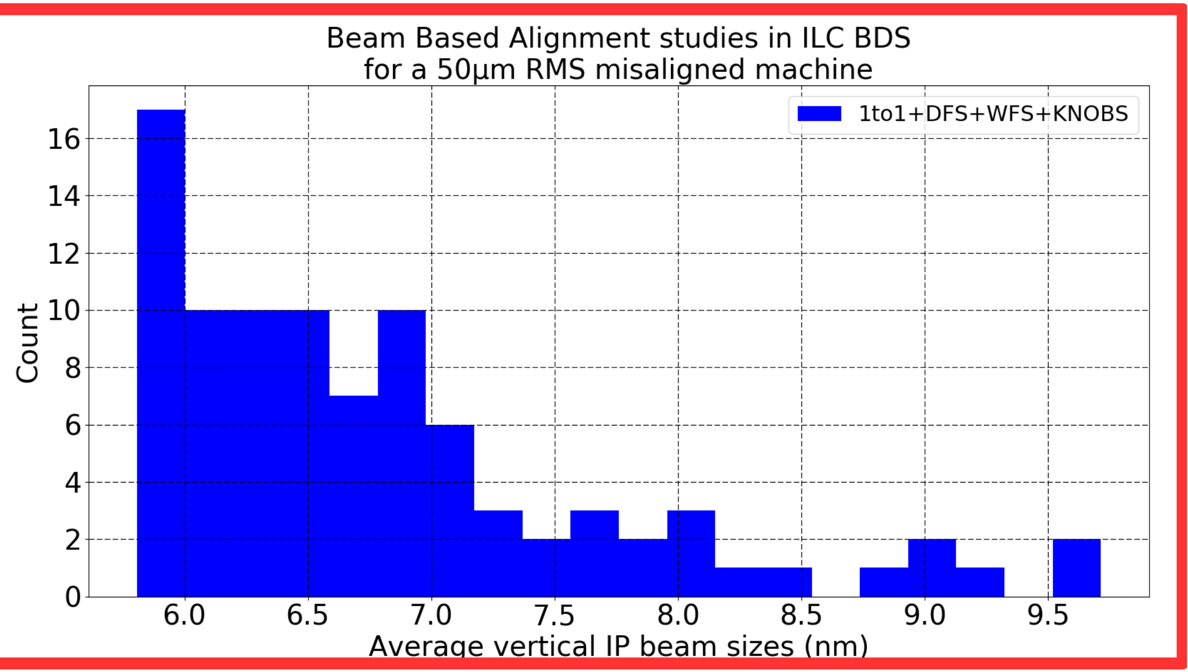
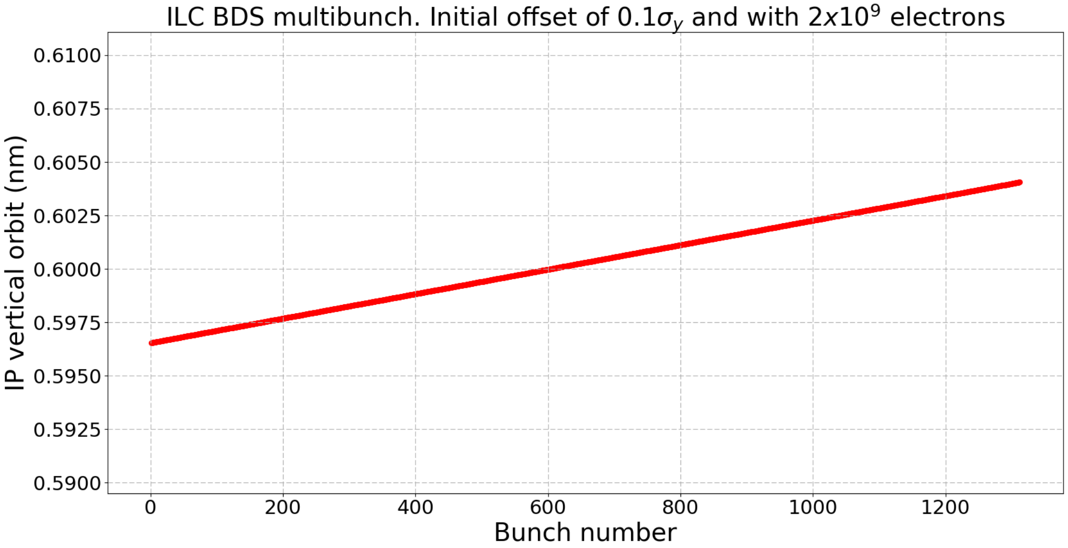
The correction is significantly decreasding the beam size!

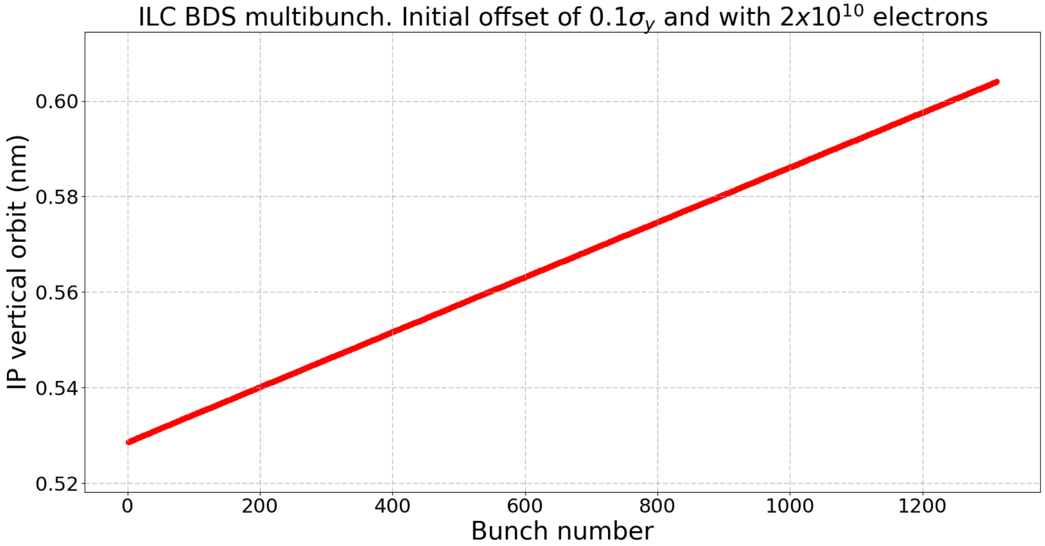

Beam Based Alignment studies in ILC BDS
for a 50µm RMS misaligned machine

Intensity dependent effects in the BDS for a bunch train

Multi bunch simulations in ILC BDS
Orbit studies – Effect of the initial position offset

In order to study the impact of the long range wakefield with Placet, one considers each bunch to be one macro particle. 1312 consecutive macroparticles are tracked through the BDS. They are all injected with the same initial offset and one studies the vertical orbit at the IP.





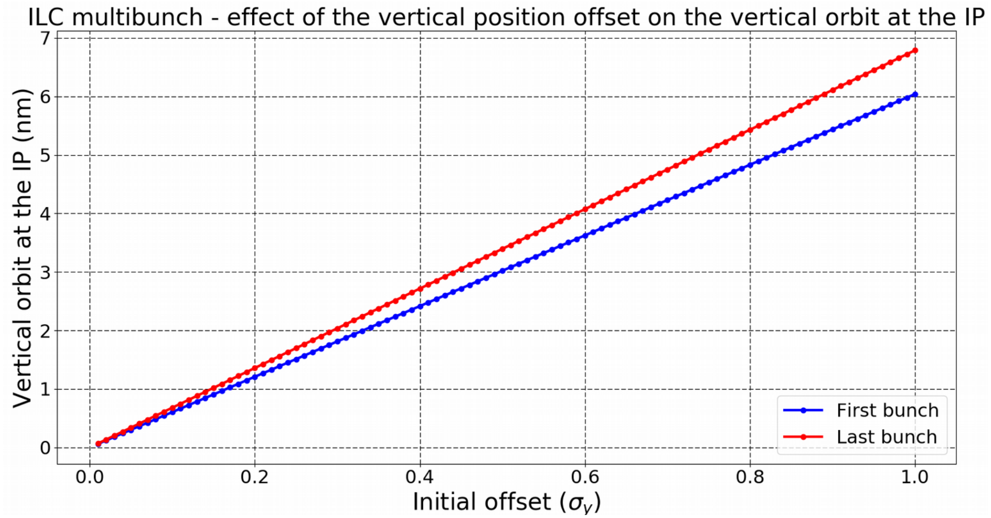
Here is show the IP vertical orbit at the IP with an initial position offset of $0.1\sigma_y$ at low and at high charge.

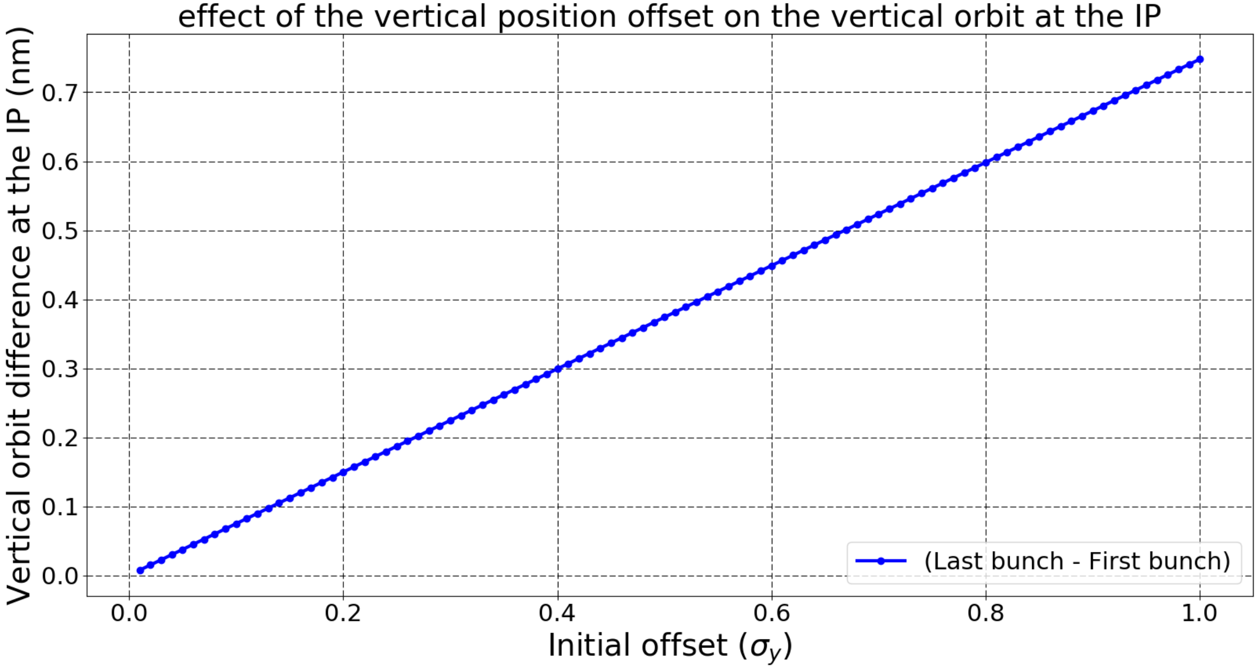
The impact of this initial vertical position offset is negligible at low charge.

At high charge, with an initial vertical offset of $0.1\sigma_y$ the last bunch is deflected by 0.075nm compared to the first one, which corresponds to 1.32% of the vertical IP beam size (5.7nm).

Multi bunch simulations in ILC BDS
Orbit studies – Effect of the initial position offset

The same simulations were done for initial offsets between 0 and 1.0σ_y at N=2.0x10^{10}



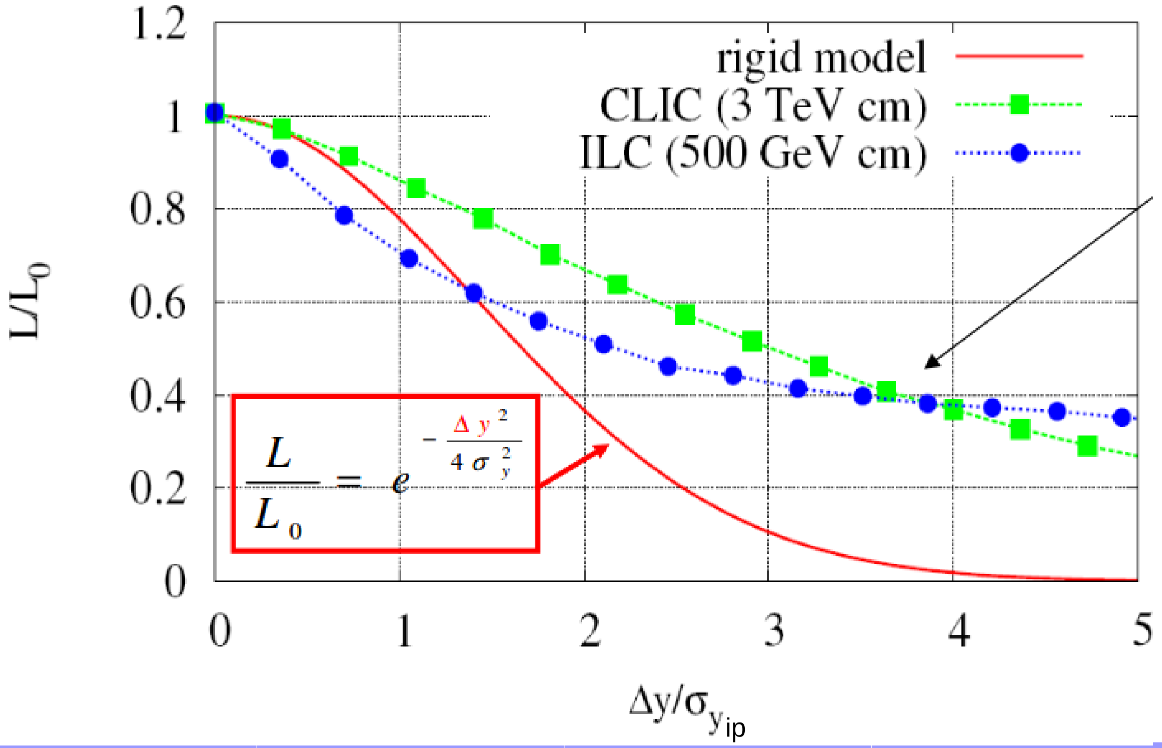


The impact of an initial vertical position offset on the vertical orbit at the IP is summarized in the following table:

Initial vertical position offset	Vertical orbit offset at the IP
0.1σ_y	0.075nm
0.2σ_y	0.150nm
0.3σ_y	0.225nm
0.4σ_y	0.300nm
0.5σ_y	0.375nm
0.6σ_y	0.450nm
0.7σ_y	0.525nm
0.8σ_y	0.600nm
0.9σ_y	0.675nm
1.0σ_y	0.750nm

Multi bunch simulations in ILC BDS
Impact of initial position offset in the luminosity

The impact of the vertical offset at the IP on the luminosity has been simulated by Javier Resta Lopez:



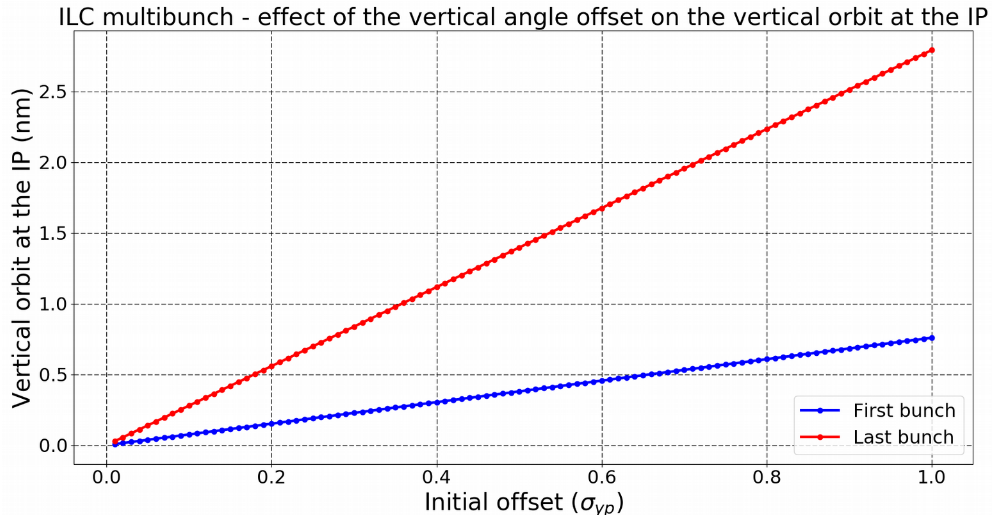
GUINEA-PIG simulations

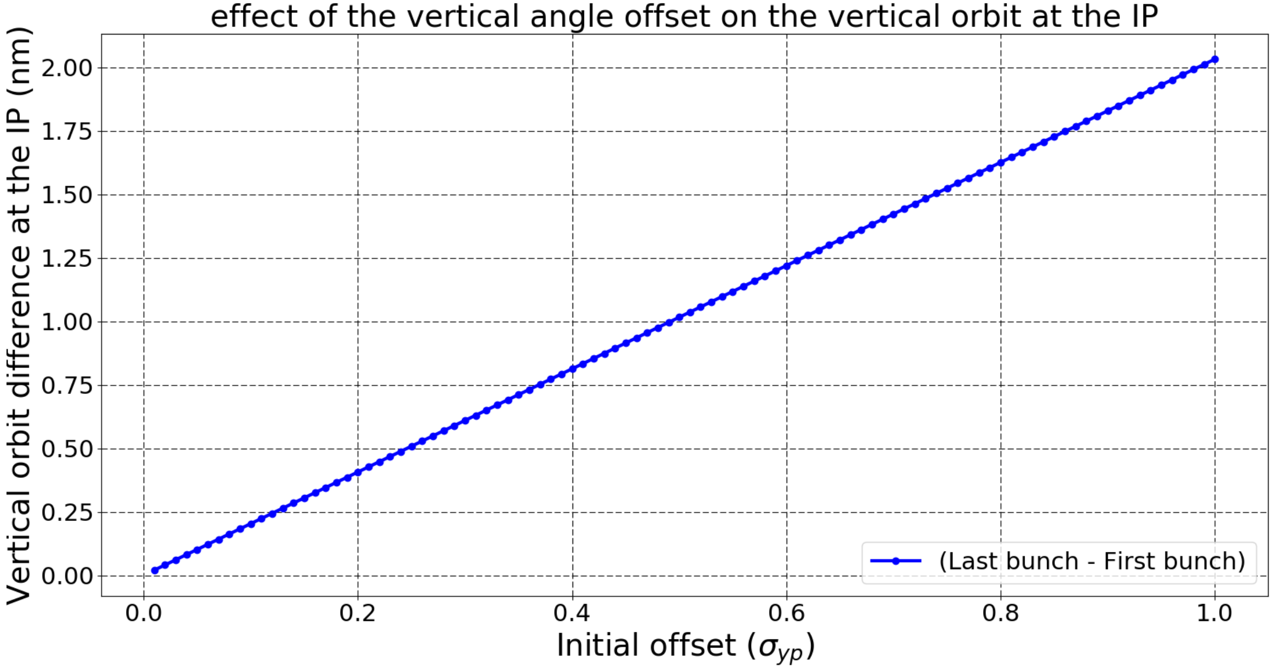
Initial vertical position offset	Vertical orbit offset at the IP	$\Delta y/\sigma_{y\ ip}$	L/L_0
$0.1\sigma_y$	0.075nm	0.01	0.998
$0.5\sigma_y$	0.375nm	0.07	0.986
$1.0\sigma_y$	0.750nm	0.13	0.974

Losing 2.6% of luminosity at $N=2.0\times10^{10}$ with an initial position offset of $1.0\sigma_y$

Multi bunch simulations in ILC BDS
Orbit studies – Effect of the initial angle offset

The same simulations were done for initial offsets between 0 and 1.0σ_{yp} at N=2.0x10^{10}


ILC multibunch - effect of the vertical angle offset on the vertical orbit at the IP


effect of the vertical angle offset on the vertical orbit at the IP

The impact of an initial angle vertical offset on the vertical orbit at the IP is summarized in the following table:

Initial vertical angle offset	Vertical orbit offset at the IP
0.1σ_{yp}	0.20nm
0.2σ_{yp}	0.41nm
0.3σ_{yp}	0.61nm
0.4σ_{yp}	0.81nm
0.5σ_{yp}	1.01nm
0.6σ_{yp}	1.22nm
0.7σ_{yp}	1.42nm
0.8σ_{yp}	1.63nm
0.9σ_{yp}	1.83nm
1.0σ_{yp}	2.03nm

Multi bunch simulations in ILC BDS
Impact of initial angle offset in the luminosity

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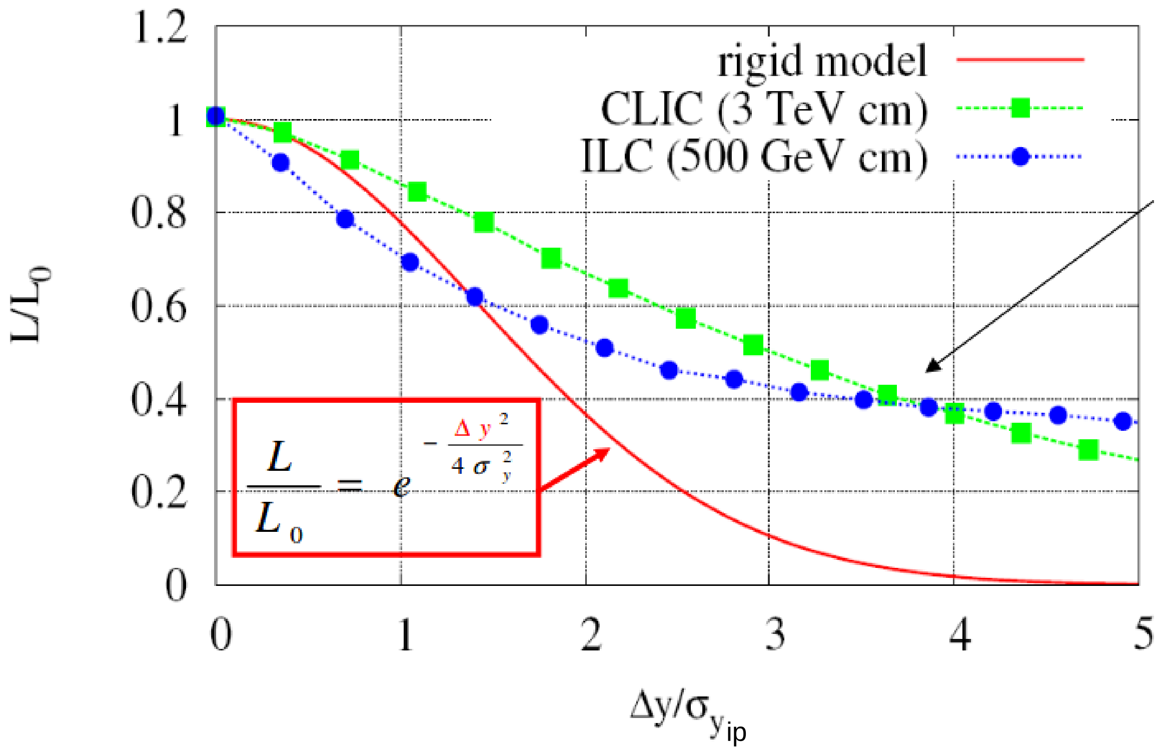

$$\frac{L}{L_0} = e^{-\frac{\Delta y^2}{4\sigma_y^2}}$$

GUINEA-PIG simulations

Initial vertical angle offset	Vertical orbit offset at the IP	$\Delta y/\sigma_{y\ ip}$	L/L_0
$0.1\sigma_y$	0.20nm	0.04	0.992
$0.5\sigma_y$	1.01nm	0.18	0.964
$1.0\sigma_y$	2.03nm	0.36	0.926

Losing 7.4% of luminosity at $N=2.0\times10^{10}$ with an initial angle offset of $1.0\sigma_{yp}$

Conclusion and outlook

- **The Beam Based Alignment in the ILC BDS shows good results taking into account different types of errors.**
- **The implementation of resistive walls in Placet shows that an initial offset has a significant impact on the vertical orbit at the IP and thus on the luminosity.**

Outlooks:

- **Studying the multi bunch intensity effects using full distributions of particles.**
- **Studying the impact of the incoming jitter.**

Thank you