A New Algorithm for the Alignment of the CLIC BDS

An Update (preliminary results)

Andrea Latina, FNAL

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Alignment Procedure

- With the multipole magnets turned **OFF**
  1) Orbit Steering, 1-to-1
  2) Target Dispersion Steering

- With the multipole magnets turned **ON**
  3) Beam-based centering of the multipole magnets
  4) Target Dispersion Steering + Beta-Beating and Coupling Correction

The Systems of Equations

1) Target Dispersion Steering (step 2)

$$\begin{pmatrix} & & \mathbf{b} \\ \omega_1 & \cdot & (\boldsymbol{\eta} - \boldsymbol{\eta_0}) \\ & & \mathbf{0} \end{pmatrix} = \begin{pmatrix} & & \mathbf{R} \\ \omega_1 & \cdot & \mathbf{D} \\ \beta & \cdot & \mathbf{I} \end{pmatrix} \begin{pmatrix} \boldsymbol{\theta}_x \\ \boldsymbol{\theta}_y \end{pmatrix}$$

2) Coupling and Beta-Beating Steering (step 4)

$$\begin{pmatrix} & & \mathbf{b} \\ \omega_2 & \cdot & (\boldsymbol{\eta} - \boldsymbol{\eta_0}) \\ \omega_3 & \cdot & (\boldsymbol{\beta} - \boldsymbol{\beta}_0) \\ \omega_3 & \cdot & \mathbf{c} \\ & & \mathbf{0} \end{pmatrix} = \begin{pmatrix} & & \mathbf{R} \\ \omega_2 & \cdot & \mathbf{D} \\ \omega_3 & \cdot & \mathbf{B} \\ \omega_3 & \cdot & \mathbf{C} \\ \beta & \cdot & \mathbf{I} \end{pmatrix} \begin{pmatrix} \boldsymbol{\theta}_x \\ \boldsymbol{\theta}_y \end{pmatrix}$$

There are four free parameters to tune: $\boxed{\omega_1,\ \omega_2,\ \omega_3 \text{ and } \beta}$:

- the ω-terms, ie. the weights

- the SVD-term β to control and limit the amplitude of the correction

Simulation Setup

- CLIC BDS, $L^* = 3.5$ m

- Misalignment 10 μm RMS for:
  - quadrupoles: x and y
  - multipoles: x and y
  - bpms: x and y

- Added two BPMs:
  - one at the IP
  - one 3.5 meters downstream the IP (might this be the same used for the IP-Feedback?)

- Bpm resolutions:
  - 10 nm

- Synrad Emission has been taken into account

⇒ All simulations have been performed using placet-octave

Parameters Optimization (No Synrad)

- In my previous presentation, I had performed a scan of the weights $\boldsymbol{\beta}$, $\boldsymbol{\omega}_1$, $\boldsymbol{\omega}_2$ and $\boldsymbol{\omega}_3$ at the same time, finding the following resulting beamsizes:

$\boldsymbol{\beta}$	bpm res. [nm]	$\boldsymbol{\omega}_1$	$\boldsymbol{\omega}_2$	$\boldsymbol{\omega}_3$	vertical beam size @ IP [nm]
0.85	10	0.14	1.95	1.85	7.6
5.25	100	3.95	0.65	140.0	10.0

$\Rightarrow$ Best final emittance was 7.6 nm

- Now, I have rerun an optimization of these parameters, for different β, in two phases

  1) β fixed, optimization of ω_1

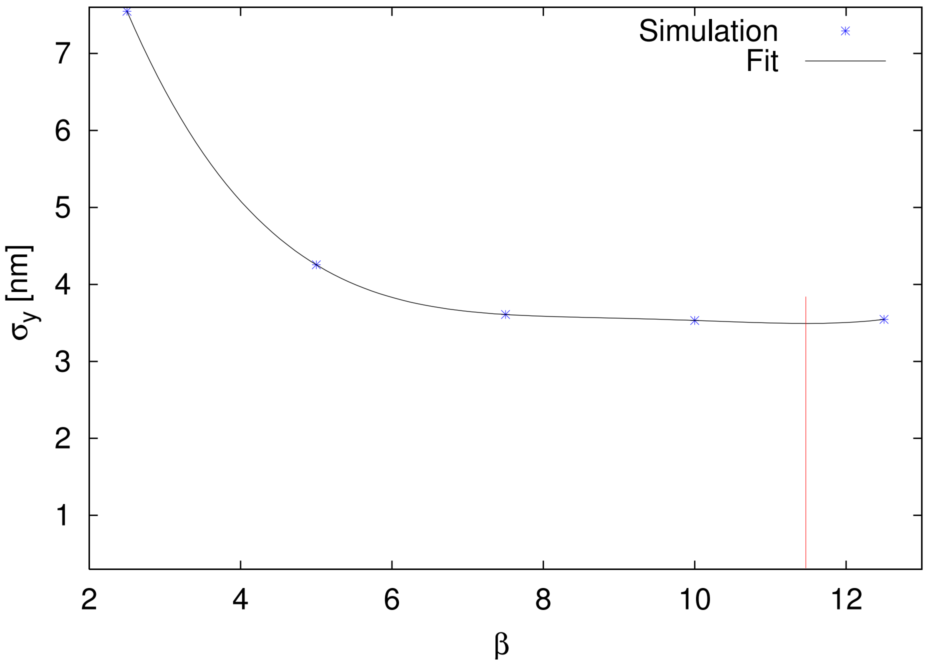
  2) β fixed, optimization of ω_2 and ω_3

- Then I have fit the resulting vertical beamsize to find the optimal β

$\Rightarrow$ Results are in the followind slide

Parameters Optimization (No Synrad)

- Each point is the average of 100 seeds; $\sigma_{\text{bpm}} = 10$ nm

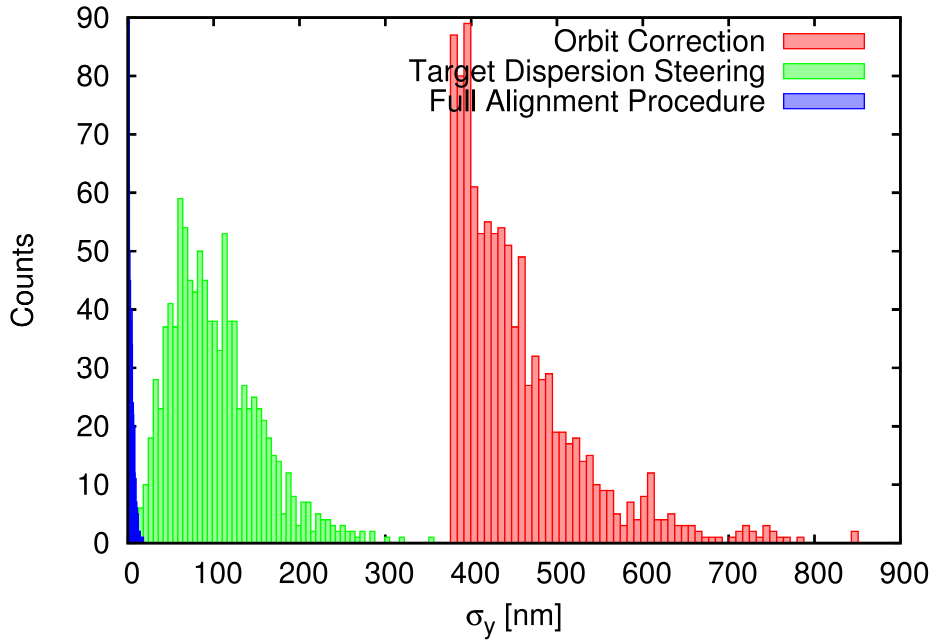


$\Rightarrow$ The minimum is for $\beta = 11.45$ at $\boxed{\sigma_y = 3.49}$ nm

$\Rightarrow$ The omegas are: $\omega_1 = 9.5$, $\omega_2 = 1.0$, $\omega_3 = 1370.0$

Results for 1000 seeds (No Synrad)

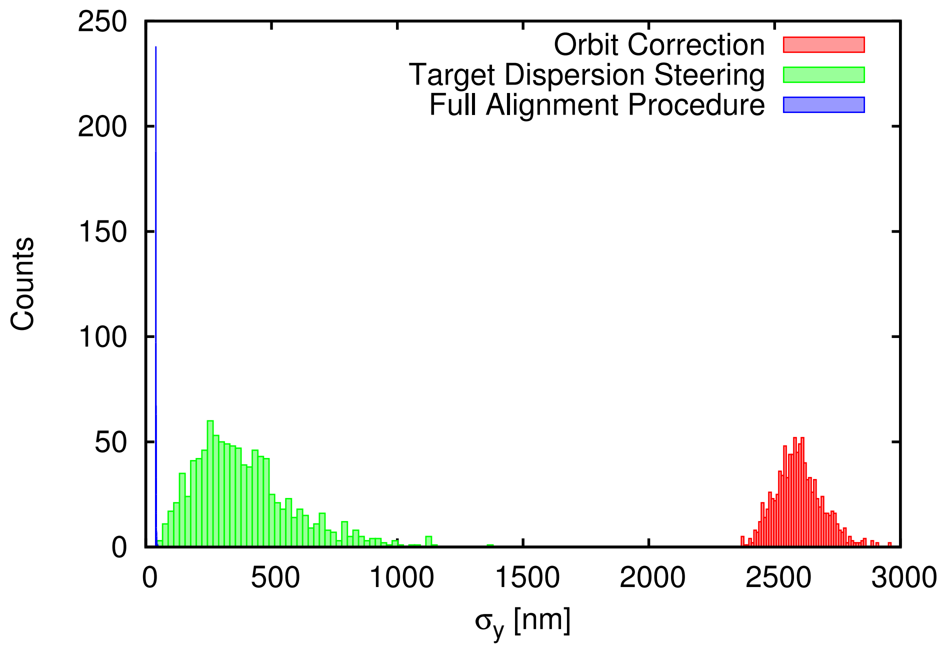
- Histograms of final vertical beamsizes for a 1000 seeds, $\sigma_{\text{bpm}} = 10$ nm



- **Final beamsize** after each stage of optimization:
  - Orbit Correction = 455.2 nm
  - Target Dispersion Steering = 102.0 nm
  - Full Alignment Procedure = 4.38 nm

Results for 1000 seeds (No Synrad)

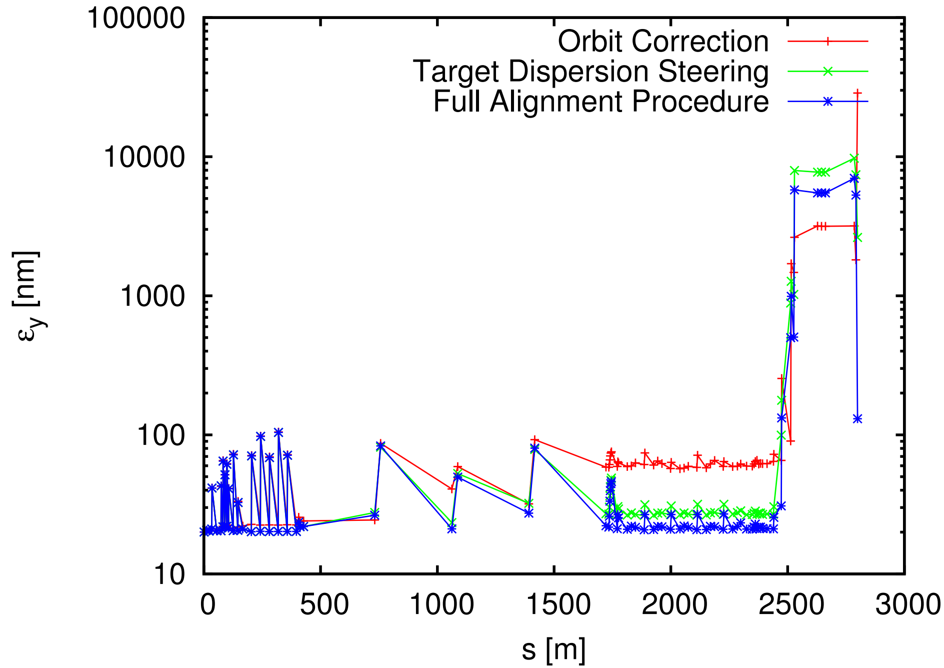
- Histograms of final horizontal beamsizes for a 1000 seeds, $\sigma_{\text{bpm}} = 10$ nm



- **Final beamsize** after each stage of optimization:
  - Orbit Correction $=$ 2.5 mm
  - Target Dispersion Steering $=$ 392.0 nm
  - Full Alignment Procedure $=$ $\boxed{40.0}$ nm

Results for 1000 seeds (No Synrad)

- Average final vertical emittance along the line for a 1000 seeds, $\sigma_{\text{bpm}} = 10$ nm



- **Final emittances** after each stage of optimization:
  - Orbit Correction = 28.7 μm
  - Target Dispersion Steering = 2.6 μm
  - Full Alignment Procedure = 130.6 nm

Synchrotron Radiation Emission

- I have used the parameters β, ω_1, ω_2 and ω_3 previously found

- Synchotron radiation emission has been taken into account for all magnets

- Precautions to stabilize the simulation

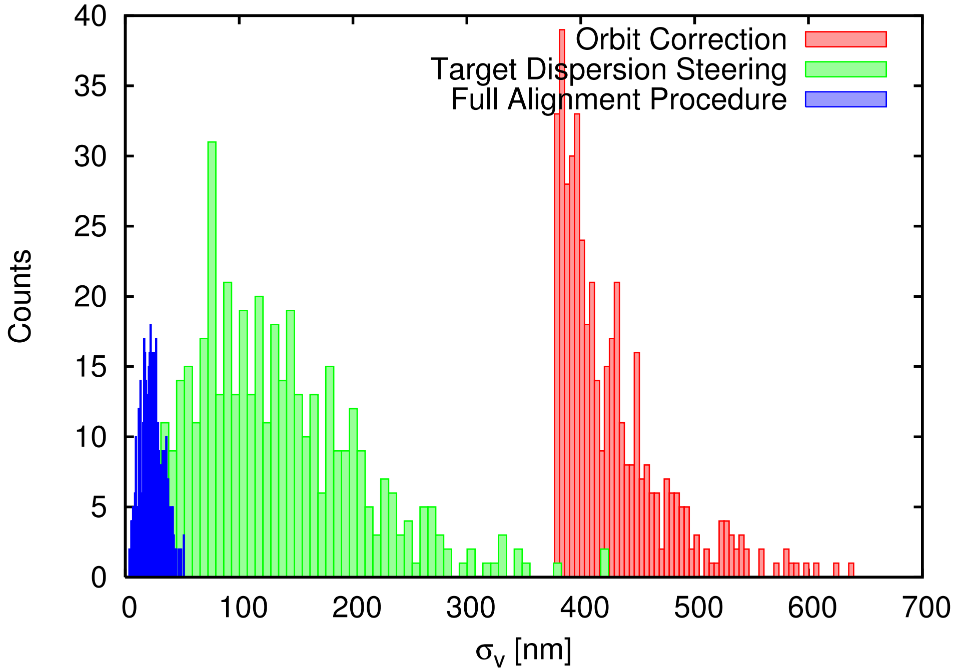
  $\Rightarrow$ increase the statistics: bunches of 100'000 particles have been simulated

  $\Rightarrow$ improve the tracking: sbends and multipoles have been simulated in thin lens approximation: 50 thin lenses per magnet (the default, for multipoles, is 5)

$\Rightarrow$ No tracking of the core: each single step of the simulation is based on 100'000 particle bunches (very cpu intensive, computing time is about 2 days per seed)

Results with Synrad Emission

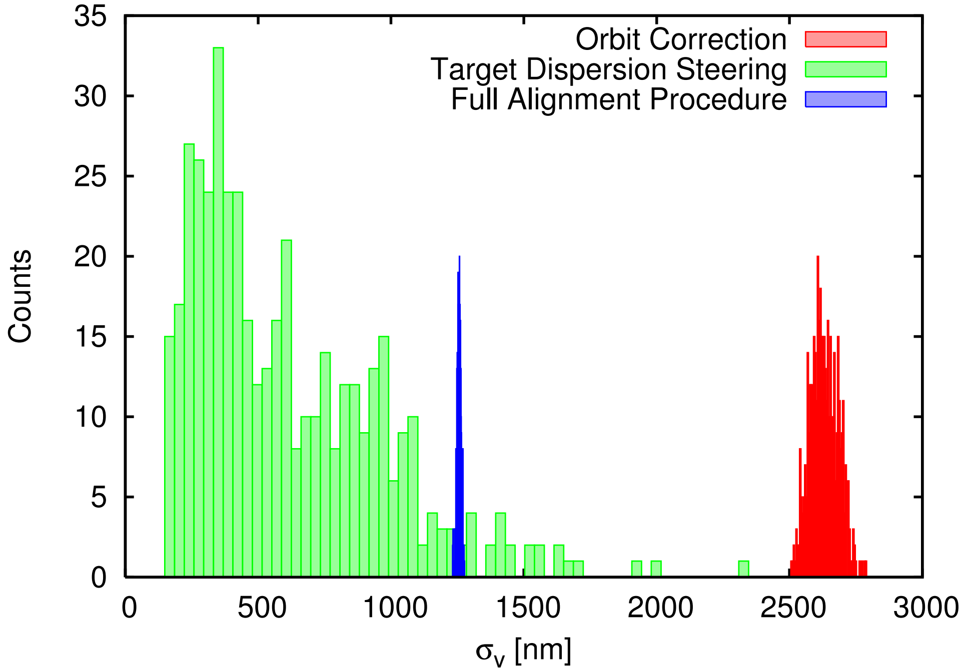
- Histograms of final vertical beamsizes for a 500 seeds, $\sigma_{\text{bpm}} = 10$ nm



- **Final emittances** after each stage of optimization:
  - Orbit Correction = 426.4 nm
  - Target Dispersion Steering = 131.3 nm
  - Full Alignment Procedure = 23.4 nm

Results with Synrad Emission

- Histograms of final horizontal beamsizes for a 500 seeds, $\sigma_{\text{bpm}} = 10$ nm



- **Final emittances** after each stage of optimization:
  - Orbit Correction = 2630.1 nm
  - Target Dispersion Steering = 607.4 nm
  - Full Alignment Procedure = 1256.0 nm

Conclusions and Next Steps

Results with synchrotron radiation emission have been presented.

Convergence is 100% also when synrad emission is taken into account

Average final vertical beamsize is 23 nm, when synrad is considered.

Results are promising, but something more needs to be understood: in presence of synrad, the X axis converges to $\approx$1250 nm beamsize

Next steps:

- Misaligned multipoles induce: 1) a dipole kick to the beam centroid; 2) a quadrupolar kick
- Multipoles are aligned using a technique similar to quad-shunting (i.e. beam centroid measurement)

  $\Rightarrow$ this corrects only for the dipole kick, but not for the quadrupolar component of the kick

  $\Rightarrow$ taking into account a beamsize measurements might help to correct for the quadrupolar kick