ILC BDS Tuning and Beam-Based Alignment

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- **Tuning and alignment strategy for the BDS**
- **Preliminary results and progress report**
- **Future plans**

BDS Alignment and Tuning Simulations

- Using most recent (pre-Snowmass) 20mrad BDS deck from MW with FF9 final-focus optics plus extraction line.
- Start with expected post-survey magnet and BPM alignment tolerances, magnet errors and BPM resolutions.
- Simulate BPM-Magnet alignment using Quad-shunting technique and fits to higher-order magnet moves (Sexts, Octs, Decs).
- Steer/move to BPM readings with measured alignment.
- Generate orthogonal knobs for correction of IP waists, dispersion (x & y) and x-y coupling.
- Simulation tool used: Lucretia.

Initial Parameter Assumptions

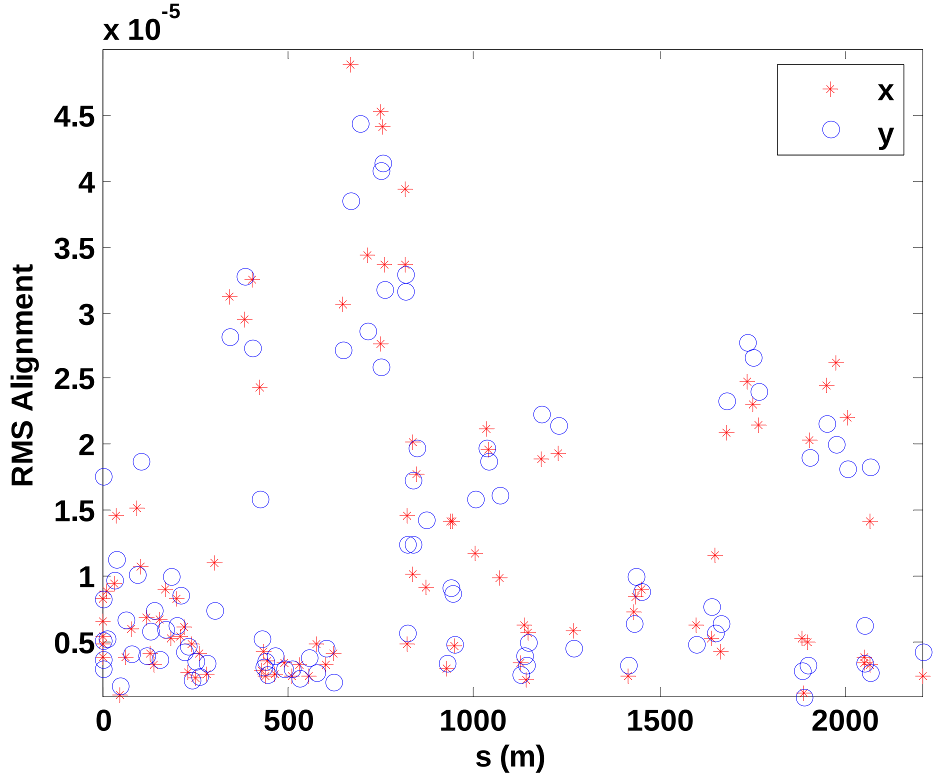
- Magnet and BPM RMS mis-alignment: 200um.
- Magnet rotation: 300urad.
- RMS relative magnetic strength error: 0.1%.
- Magnet mover resolution (x & y): 50nm.
- BPM resolution: 1um.
- Assume incoming beam centered with respect to 1st quad to within BPM res.
- Each magnet modeled as split thick-lens magnet with BPM and x,y correctors at centre.
- Use TESLA bunch parameters (ideal gaussian) with 10^{-4} E uncorl. E spread.
- Track 1000 macro-particles per bunch.

BPM-Magnet Alignment

- Switch off Sexts, Octs, Decs initially.
- Apply 1-1 steering to centre beam in Quad BPMs with initial alignment tolerances.
- Use ‘Quad Shunting’ technique to get BPM-Quad offsets using shift in downstream 20 Quad BPMs for each Quad being aligned when switching off Quads power (using ext. line BPMs for last few Quads).
  - i.e. use weighted-fit to:

$$x_{Quad} = \Delta x_{BPM} / \left(\Delta R_Q(1,1) * R(1,1) + \Delta R_Q(2,1) * R(1,2) \right)$$

Quadrupole Alignment Results

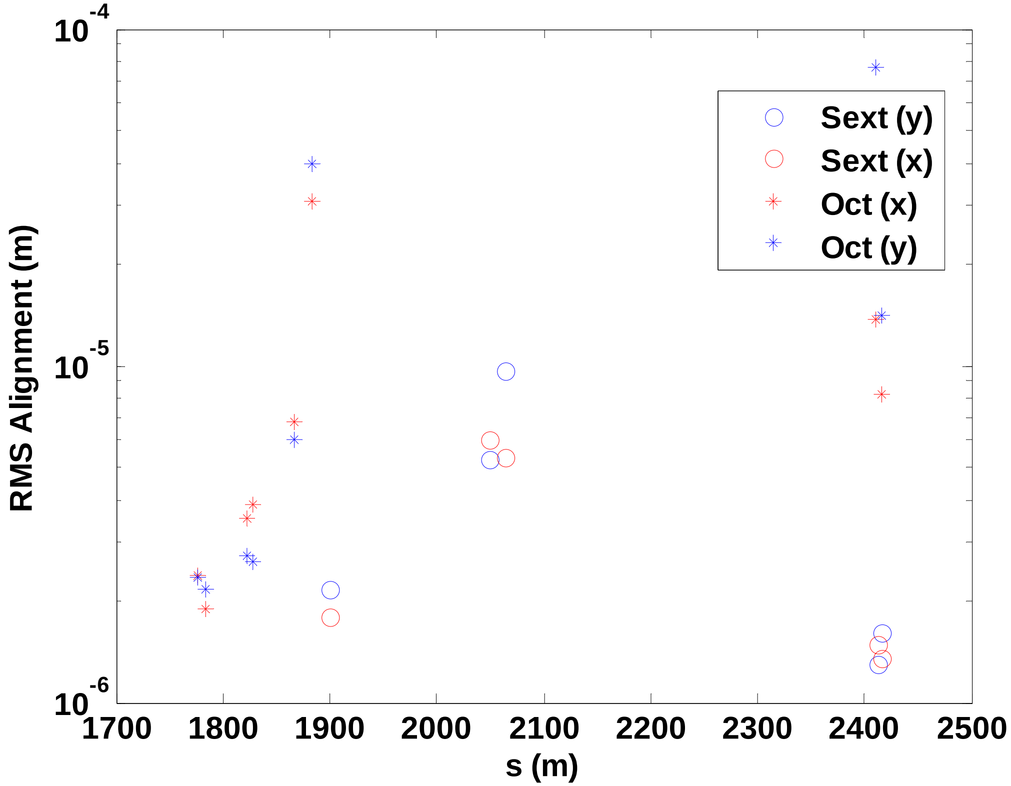


- BPM-Quad alignments (RMS mis-alignment from 50 seeds).

Sextupole, Octupole, Decupole Alignment

- Use x-, y-movers on higher-order magnets and fit 2nd, 3rd and 4th order polynomials to downstream BPM response (for Sext, Oct and Dec respectively). Use BPM with largest response for alignment measurement (alignment is where 2nd, 3rd, 4th derivitive is 0 from fits).
- Sextupoles:
  - 20 moves +/- 1mm in x and y.
- Octupoles:
  - 20 moves +/- 2.5 mm in x and y.
  - Need to increase strength of Octs # 6,7 and 8 by a factor of 10 to get reasonable fits (not fully optimised yet).
- Decupoles:
  - 20 moves +/- 4 mm in x and y.
  - Increase strength by factor 10 to try to get good fits.
  - Fails- left with initial alignment errors.

Alignment Results (Sextupoles and Octupoles)

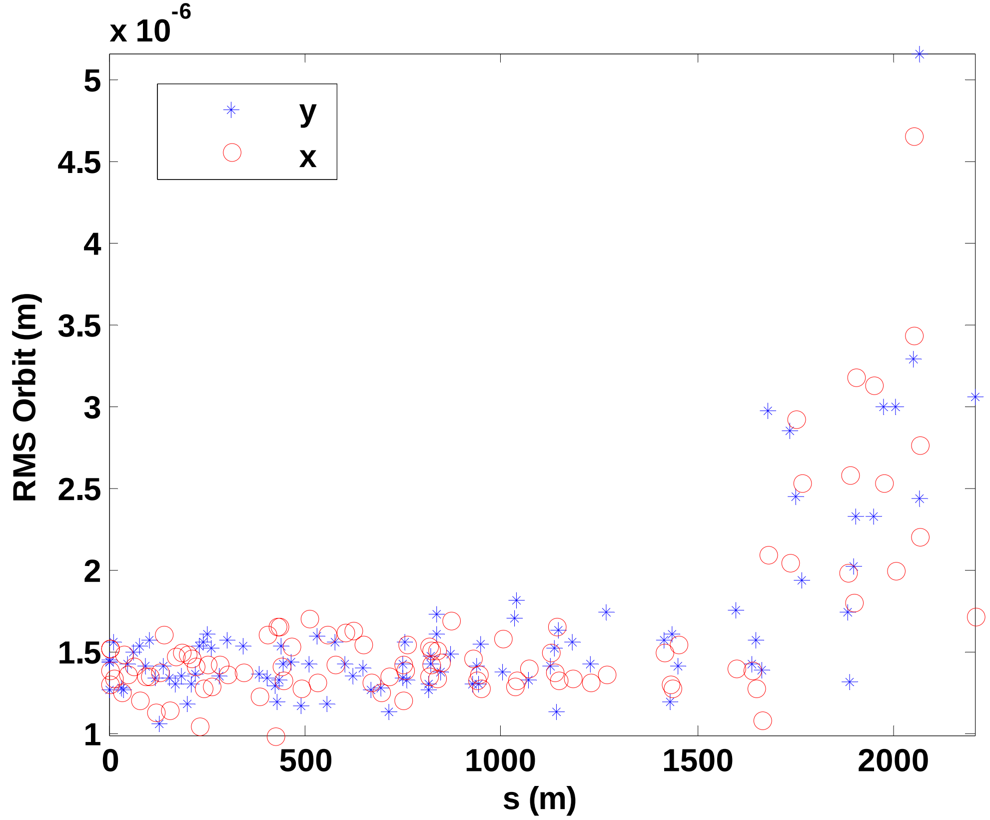


- BPM-Sext,Oct alignments (RMS mis-alignment from 50 seeds).

Post-BPM Aligment Steering

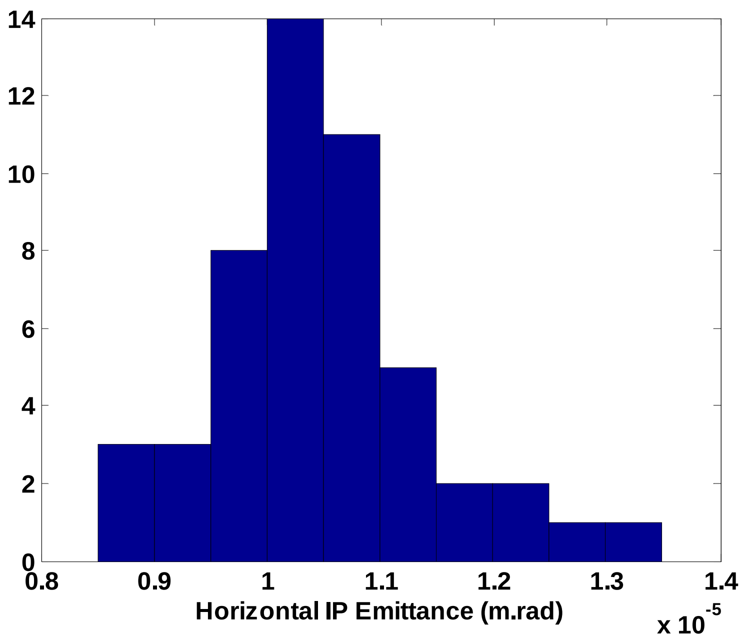
- After getting BPM-Magnet alignment:
  - Steer to Quad centres with Sexts etc off.
  - Move Sexts, Octs, Decs on-orbit with movers.
  - Switch on all magnets.
- Ideally use Quad movers to move quads onto alignment, minimising dispersive kicks- still under study, for now use 1-1 steering.

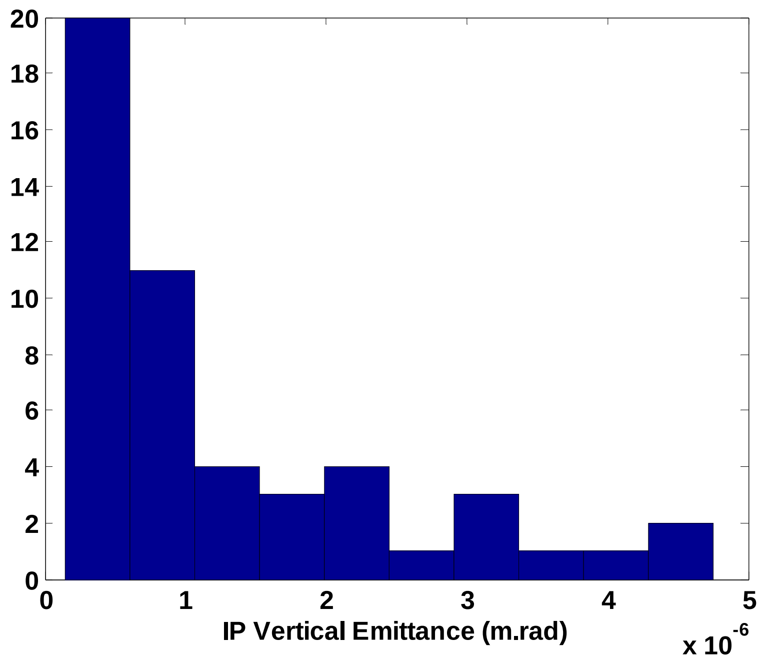
Post-Alignment and Steering Results



- **RMS beam orbit after alignment and steering (50 seeds).**

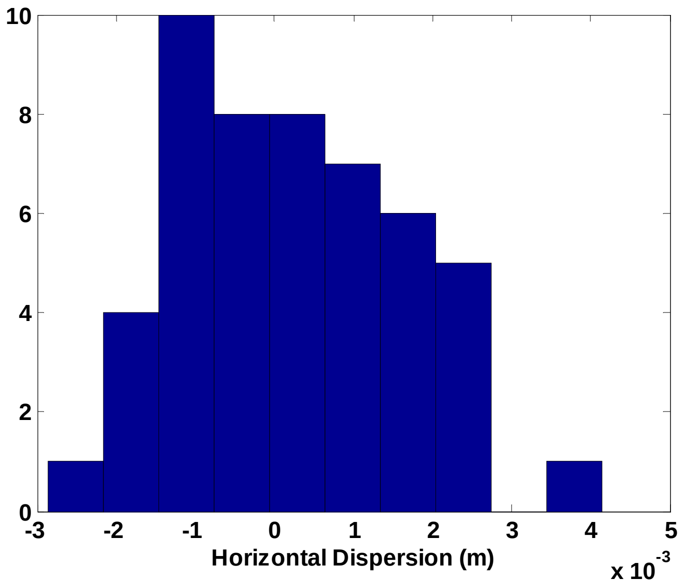
Post-Alignment and Steering Results

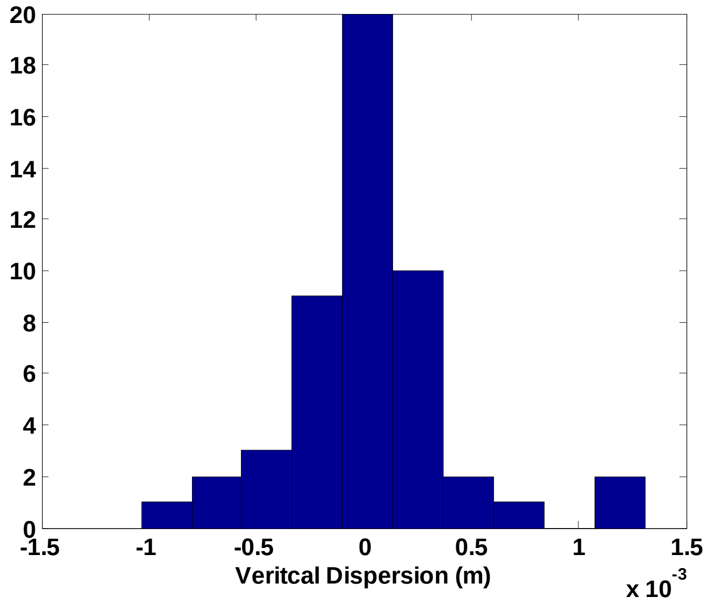




- **IP x- and y- (normalised) emittances (50 seeds).**
- **Mean= 10.5 um (x) 1.3 um (y).**
- **Initial= 10 um (x) 30nm (y).**

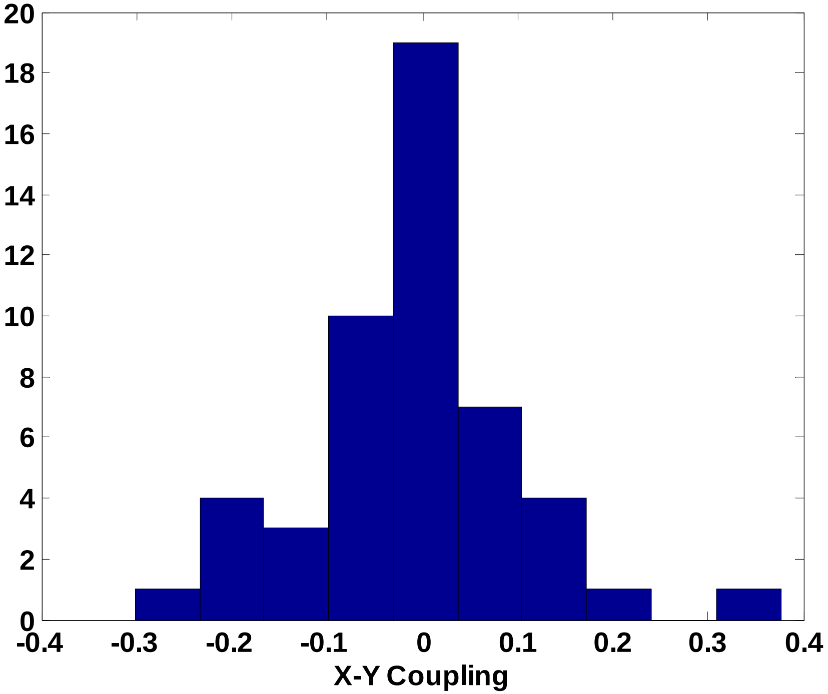
Post-Alignment and Steering Results





- **IP x- and y-Dispersion (50 seeds).**
- **RMS= 1.5mm (x) 0.4mm (y)**

Post-Alignment and Steering Results

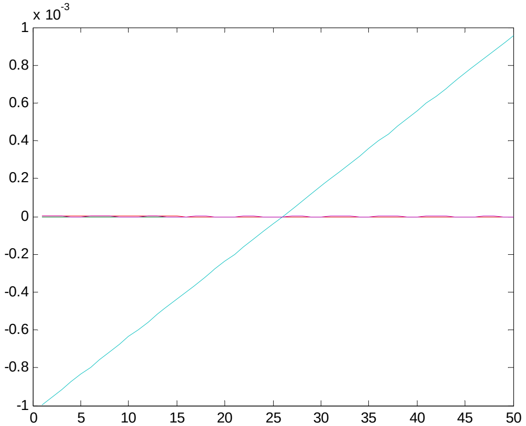


- **IP X-Y coupling (50 seeds).**
- **RMS= 0.11.**

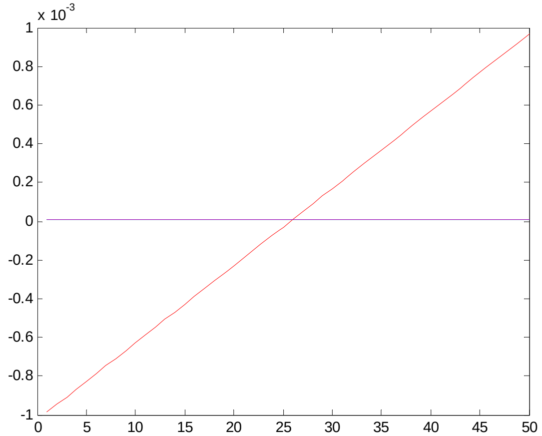
Generating IP Tuning Knobs

- Use x- and y-moves of 5 Sextupole magnets to generate IP x- and y-dispersion and waist tuning knobs and x-y coupling knobs.
- Generate response matrix to map Sextupole movements to IP parameters.
- Use SVD matrix inversion to get tuning knobs.
- Best results seen over wider range if use all 10 movement parameters.
- Initial test of knobs- move all 5 knobs and measure dispersion, waist and coupling changes.

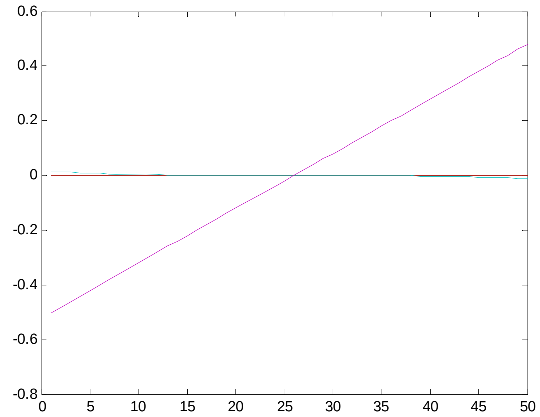
Test of IP Multi-Knobs



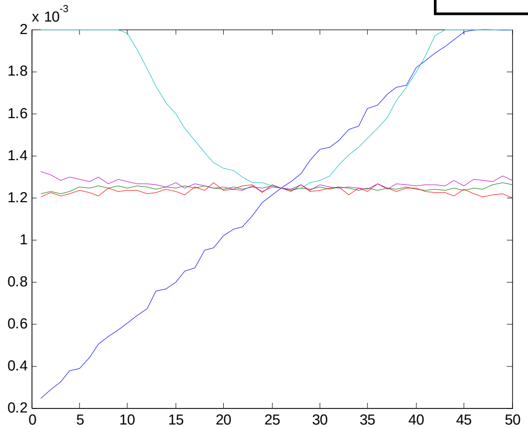
Y DISP



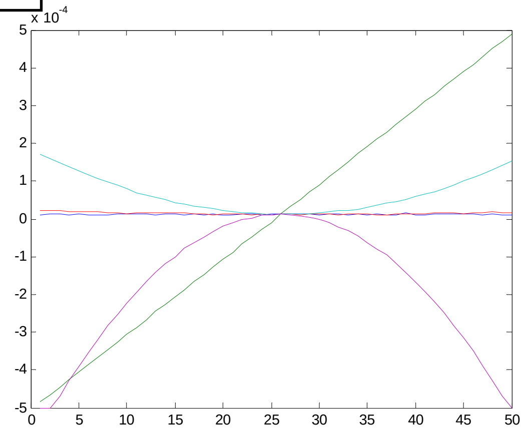
X DISP



X-Y COUPLING



X WAIST



Y WAIST

Future Plans

- Implement Quad mover steering.
- Get IP multi-knobs working after alignment + steering phase.
- Simulate 2 beams- tune on luminosity (pair signals).
- Include LINAC to get real bunch shapes.
- Include GM.
- Integrated time-evolved simulation with initial tuning + pulse-pulse FB + intra-bunch FB.
  - Provides information on how often re-tuning necessary and most detailed luminosity performance estimate.