

BDS Alignment, Tuning,
Feedback update and Integrated
Simulation Plans
and Many Questions...

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Overview

- Current status of BDS beam dynamics studies:
 - Alignment & tuning
 - Intra-train feedback (single pulse studies)
 - 5 Hz feedback
- Integrated Uber-Simulation plans

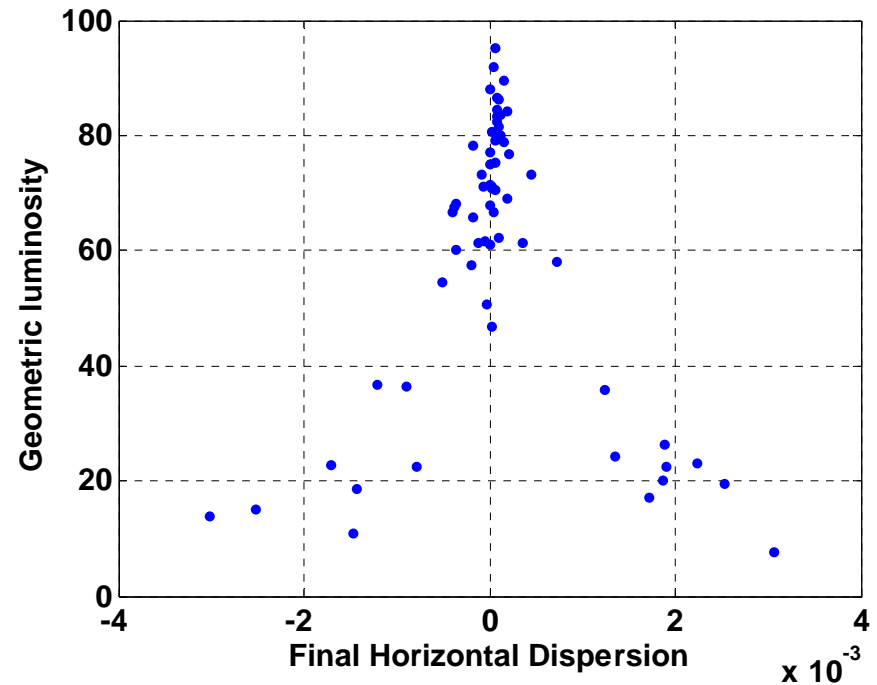
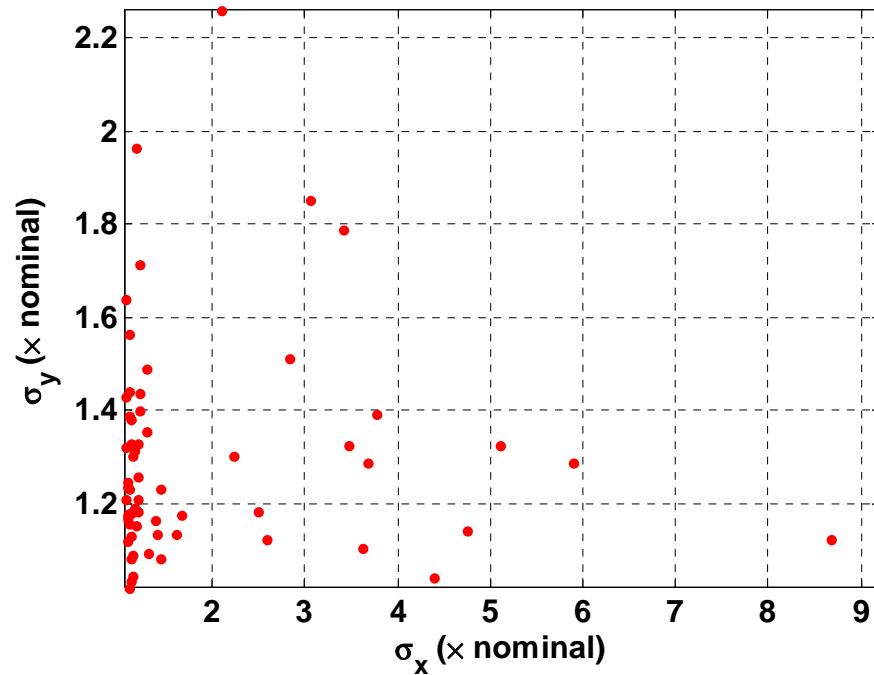
BDS Alignment & Tuning

- Assumptions for hardware:
 - All quads, sext's and oct's on x and y movers with 50nm resolution. (Maybe also roll needed for some sext's)
 - All quads, sext, oct's have x and y dipole corrector windings for steering.
- Reminder of current strategy:
 - Align quads with sext/oct's deactivated
 - Use nulling quad-shunting to get BPM alignment.
 - Use global steering algorithm using movers to align to BPM readouts.
 - Get Sext/oct -> BPM alignment by fits to x and y moves.
 - Switch on sext/oct's, moved to established orbit.
 - Use 1-1 steering to maintain orbit with low gain, tuned to keep beam within IP feedback capture range ($\sim < 200\mu\text{m}$).
 - Use orthogonal sext moves and skew quad k changes to tune out linear IP aberrations.
 - Need FFS SQ3FF (Is this in 'official' deck?)
 - Need to tune out higher-order aberrations? Need more study...

BDS Tuning Issues

- Initially tried to use multi-knobs to tune solely based on luminosity
 - Worked for the seed I developed the algorithm on, poor results from multi-seed run.

Multi-Seed Results



- Final tuned spot-sizes (left)
- Results dominated by horizontal dispersion achieved (right).

BDS Tuning Issues

- Initially tried to use multi-knobs to tune solely based on luminosity
 - Worked for the seed I developed the algorithm on, poor results from multi-seed run.
- Changed algorithm to assume measurement of x,y dispersion and all coupling terms possible to see if this improves things- currently re-running multi-seeds. Will need sensible errors to fix to these...
- Seems from limited studies that sext strength errors (default assumed, like quads to be at 10^{-3} level) might become limiting factor on achievable results as this ruins orthogonality of knobs.
 - Need to study effect of different errors
 - Current specs on expected errors here? Do I need to provide?

BDS Tuning Questions

- What results do I aim for, what do I need to show (for RDR)?
 - Show X % of seeds perform better than Y?
 - What is X? 100%? ...
 - What is Y? ie figure of merit
 - Luminosity? Geometric, or real using Guinea-Pig (integrated simulations...)
 - Emittance? What is the emittance budget for BDS system? Me to provide, or given from LINAC people?
- For RDR, need to demonstrate performance on all parameter sets, both BCD beamlines?? Or enough to show, e.g. nominal parameter set with IR-1 (20mrad crossing angle)?
- Can I assume getting movers and dipoles on all magnets or need to prove that I require these?

BDS Tuning Future Directions

- Immediately, need to get better multi-seed results.
- From then depends upon suggested priorities between this, feedback and integrated simulation construction. ie:
 - Make more dynamic, including GM, component jitter etc...
 - May need better 5 Hz feedback
 - Include other beam, and lumi simulations (guinea-pig)
 - Put more effort into eeking out every last drop of lumi, better FB, higher-order knobs etc...

BDS Intra-Train Feedback Layout

- 3 independent bunch-bunch beam-based FB systems in BDS:
 - **post-LINAC Fast Feedback**
 - 2 pairs of kickers/BPMs at different phases
 - With current optics, need strong kickers (~100 times Voltage of other 2 FB kickers if same type)
 - Also, need ~100nm resolution on BPM's, ie. Need cavities
 - Live with this, or request optics re-design to provide larger beta-functions?
 - Corrects static & dynamic HOM-driven initial wiggle in train + any other systematic intra-train effects.
 - Separates BDS and LINAC 5-Hz feedback systems.
 - Not much simulation done with this, makes little difference to luminosity performance with the single pulse studies done if keep gain low.

BDS Intra-Train Feedback Layout

– IP-ANGLE Fast Feedback

- Corrects and optimises collision angle of bunches
- 3 1m Stripline kickers at -1 IP phase at start of FFS with same drive requirements as IP FFB.
- BPM 90° downstream.
- BPM res. Required $\sim 2\mu\text{m}$ (stripline)
- If not at correct location, or if lattice errors present, cross-talk to IP-POSITION FFB possible. Can mitigate by reducing gain, or interleaving- how to spec?
- Assuming this and not a vertical crab-cavity to do angle correction, can't see a very good reason that a crab-cavity solution would be worth the extra complexity even if it were plausible... or.....?

BDS Intra-Train Feedback Layout

– IP-POSITION Fast Feedback

- Essential- puts beams into collision at IP.
- Based on beam-beam kick signal calculated with GP.
- BPM just upstream of BeamCal, ~10um res required (stripline)
- Kicker probably needs to be in the 1m gap between SD0 and QF1, otherwise is limiting aperture in magnet.
- Stripline kicker in cold a problem??
- A.S. looked at effect of putting kick upstream of SD0: no effect up to a 70 sigma kick at upstream face of SD0, or up to 10 sigma at QF1 downstream-face. 2% vertical beam size growth at 150 sigma kick at SD0 and 50 sigma at QF1.
- Kick voltage requirements: 600 V/m for 70 sigma kick for 20 mrad crossing or 3 KV/m for 2 mrad due to larger aperture.
- IP FFB sets tolerance for 5-Hz feedback- must keep beam in IP FFB dynamic range. Tail of beam-beam vs. offset curve goes out to 100's of nm, but prefer to be on left-side of peak for fastest convergence. For nominal beam parameter set, this is ~100nm, most constricting is low Q parameter set (~35nm).

BDS Intra-Train Feedback Layout

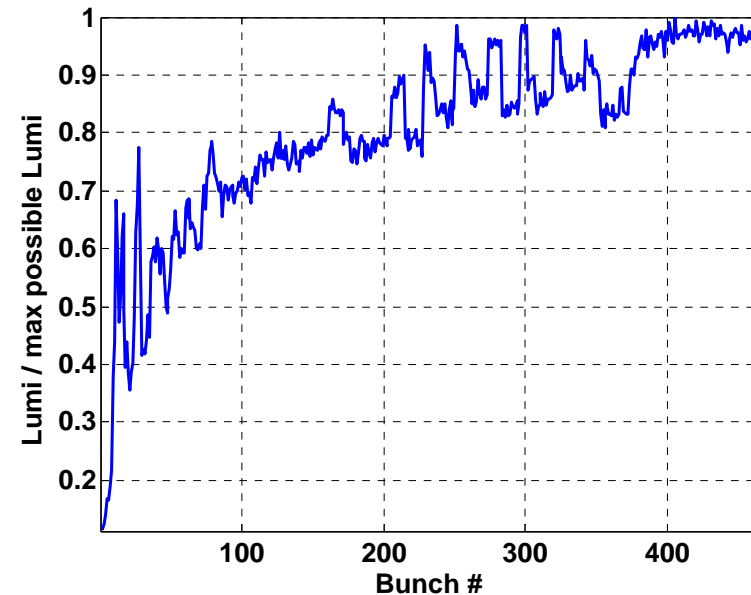
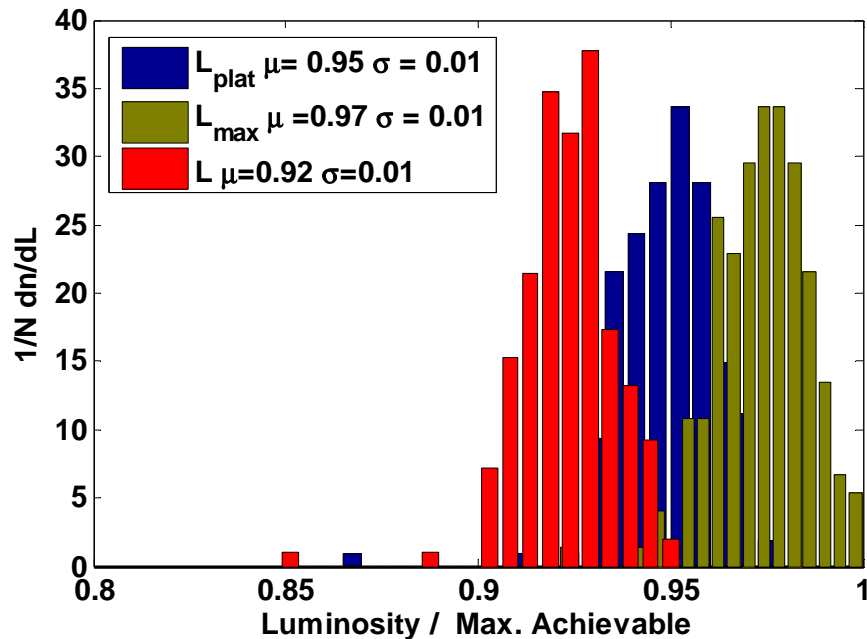
- Lumi Feedback
 - After some number of bunches (~150) when effects like HOM's have damped and beam-based FFB's have settled, optimize IP collision parameters using lumi-based signal.
 - Require prompt signal from 1st layer of BeamCal (integral of incident pairs), which although not directly proportional to lumi, are maximal at lumi max.
 - Need to perform 2D scan in y, y' space to find optimal collision parameters, 2 1D scans doesn't give best performance.
 - Variables are; size of 2D 'pixel' when scanning and number of bunches to average lumi signal over for each scan point. These depend upon noise in lumi signal and noise characteristics of incoming beam

Fast Feedback Study Results

- 200-seed study, including tracking through LINAC, BDS and IP. Using Placet, MatMerlin and GUINEA-PIG.
- Study response and performance of FFB's as described given initially tuned beamline that delivers target emittances and lumi. Then add inter-pulse effects of GM + component jitter including SR + LR WF's in Linac cavities.
- TESLA beam parameters used in simulation as high vertical IP disruption provides most challenging case for Fast Feedback.

Fast Feedback Study Results

- Irreducible 3% loss due to bunch-shape and emittance growth.
- 2 % loss due to gain of FB amplifying random bunch-bunch jitter. Can be mitigated by reducing gain after lumi-optimisation if expect no further intra-train dynamics after this point.
- Further 3% loss due to initial HOM-driven instability, settling time of feedbacks and time taken to perform collision optimisations. Can look into partially mitigating this loss by using more aggressive initial feedback technique, reducing number of sample per lumi scan point (here, 5) or increasing pixel size of 2D scan. These are greatly dependent on the precise noise characteristics of the incoming beam however.



Fast Feedback Questions

- Assume the 3 beam-based FFB's operate independently. If conditions prevail that makes this not the case, can improve independence by reducing gains, or interleaving. Has lumi consequences- will be an operational optimization at time of ILC running. Any numbers required now on trade-offs on different schemes?
- Want to look into any other fast feedbacks?
- What other effects important to put into simulation?
 - Collimator wakes.
 - Fast RF instabilities.
 - Bunch charge fluctuations.
 - More intra-train dynamics, e.g. from DR extraction (currently assuming flat-insertion). -> model turn-around FFB? Include RTML studies -> integrated simulations...
 - Again, need to study all parameter sets/crossing schemes etc. ?

5-Hz Feedback

- Requirements- keep emittance growth small and beam within IP FFB capture range.
- For alignment study purposes, 1-1 correction with every magnet corrector and BPM and 'IP BPM' (beam-beam kick) with low gain (50-bunch convergence) seems adequate.
- Is this still adequate with ground motion? Is a more complex modern dynamic state-vector optimal feedback algorithm etc going to make much difference? Want simplest thing possible to meet requirements above, or need a control-system enthusiast?
- At least probably want to make informed selection of correctors/BPM's to use, especially when considering E errors...

The Mother of all Simulations

- Integrated feedback plans.
- Construct framework to include all beam dynamics simulations from DR exit -> RTML -> LINAC -> BDS -> IP -> extraction.
- I'm using Lucretia.
- Goal to produce multi-seed averaged luminosity vs. time plot including all alignment, tuning and feedbacks.

Integrated Feedback Strategy

- Doing everything, linearly with multi-bunches the whole way will be way too slow.
- One approach:
 - Produce ~100 seeds of aligned & tuned RTML, LINAC and BDS files.
 - Randomly load one in of each for each seed (and wakes etc...).
 - With single seed tracking, advance N pulses including 5-Hz feedback applied and every Mth pulse throughout.
 - Then track multi-bunch and get Lumi estimate.
 - Repeat for desired length of time, perform retuning where necessary.
- Estimate of CPU requirements:
 - ~10 mins per single bunch track, ~30 hours per multi-bunch simulation with lumi estimate on the newest type of CPU's currently found in compute clusters.
 - Assuming from TESLA TDR studies, need to re-tune on 10-day type timescales-want to study ~30 days of ILC-time.
 - If choose N= once per day and M=every 30 mins and want 100 seeds, this is 475 **days** of cpu time! (for one machine configuration and one of the beam parameter sets).
 - Assume availability of 100 cpu's for this task- just over a month of time to complete (checkpointing of simulation important as each parallel task to run longer than the wall-time limit on cluster schedulers).
 - To get it done faster than this will require parts of the simulation to be internally parallelized (parallel tracking algorithms, parallel GUINEA-PIG). Even then, not clear that running 100 parallelized simulations sequentially will be better than 100 simultaneous runs of the whole simulation, unless we get LOADS of CPU's and do both!