Ground Motion + Vibration Transfer Function for Final QD0/SD0 Cryomodule System at ILC

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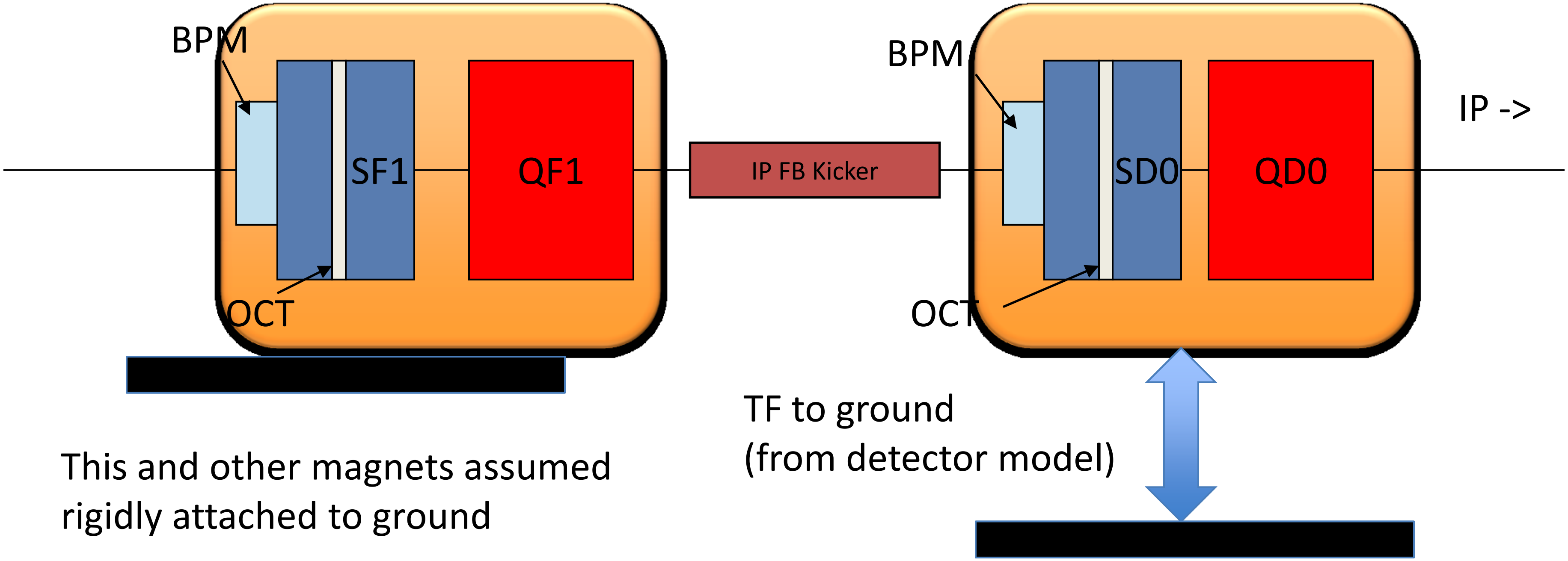
Simulation Overview

- Lucretia simulation of ILC BDS
  - ILC2006e (RDR) lattice and beam parameters
  - Reduce Nb 2625 -> 1320 for luminosity calculation with fast feedback to more closely mimic SB2009 parameter set
  - Electron and positron beamlines
- Ground motion applied to all ILC elements plus transfer function (TF) between ground and QD0/SD0/OC0 system.
- 50 consecutive pulses (10s) modelled with ground motion + pulse-pulse feedback.
  - Results shown for GM models ‘A’, ‘B’ and ‘C’
  - QD0 system TF calculation for SiD “rigid support from platform” (Marco).
- Fast IP position feedback for tolerance estimates.
- Simplifications
  - RTML and Linac excluded from tracking simulation
  - Incoming beam perfectly aligned with first element (upstream FFB)
  - No intra-pulse misalignments
  - No other mechanical noise model of magnets applied

Simulation Parameters

- Initially perfect lattice.
- BPMs
  - Cavity systems throughout BDS
    - Resolution = 100nm
    - Scale factor error = 1%
  - Stripline BPMs for fast feedback
    - Resolution = 2um
    - Scale factor error = 1%
  - Corrector magnet field errors 0.1%
- 5 Hz feedback
  - Simple gain feedback, convergence 50 pulses
- Intra-pulse feedback
  - Based on detection of beam-beam kick at IP for small offsets using downstream stripline BPM and correction using stripline kicker system between QF1 & QD0 cryomodule systems
  - Feedback is PID controller using linearised look-up of beam-beam kick to IP beam offset model (up to turn-over point). Feedback convergence ~20 bunches for offsets left of turn-over point.

IP Region Final Doublet



BPM

SF1

QF1

OCT

IP FB Kicker

BPM

SD0

QD0

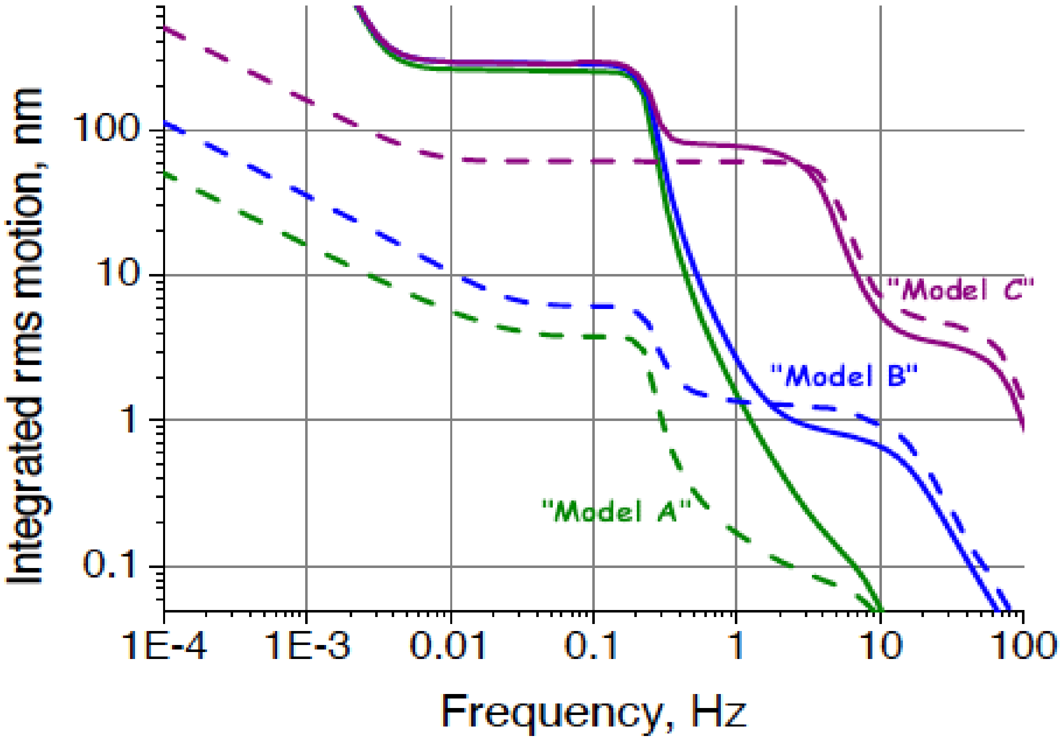
OCT

IP ->

This and other magnets assumed
rigidly attached to ground

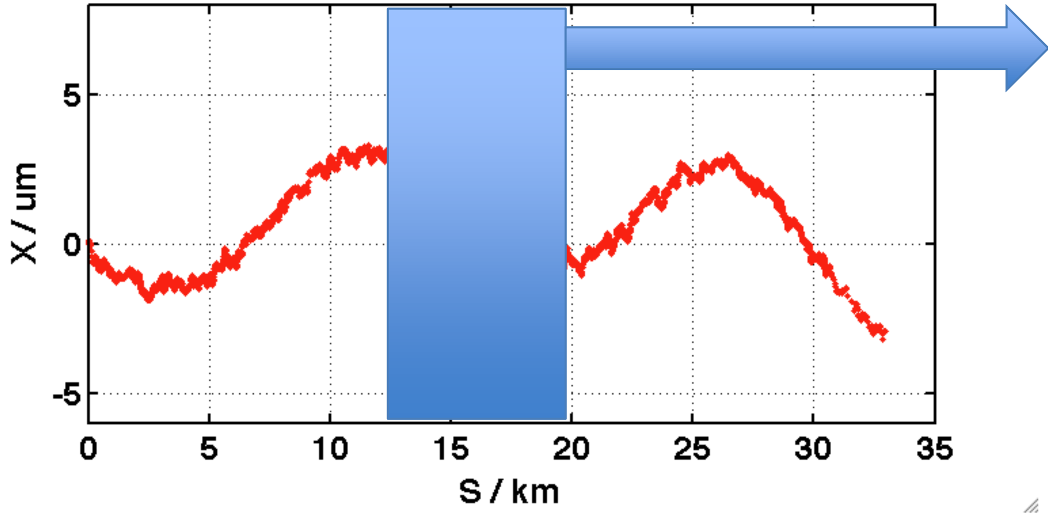
TF to ground
(from detector model)

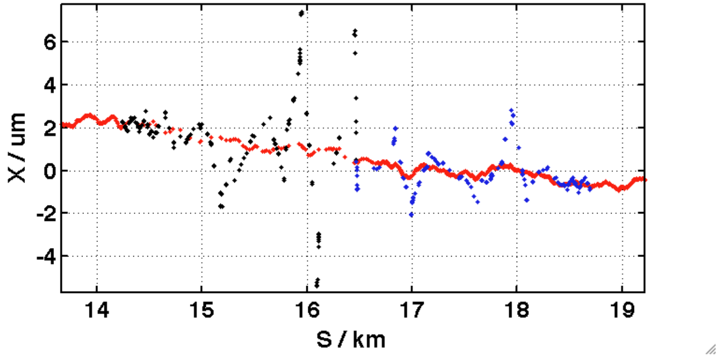
Ground Motion Spectra



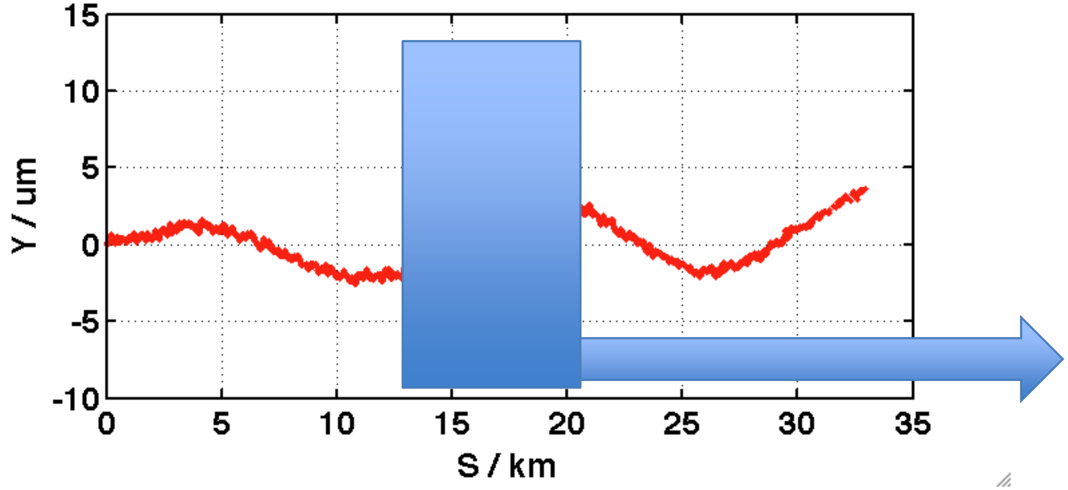
- The simulation applies offsets due to ground motion according to Model ‘A’, ‘B’ or ‘C’
- The spectra for these models indicative of ‘quiet’, ‘average’ and ‘noisy’ sites, mainly in terms of the magnitude of high frequency noise, are shown above

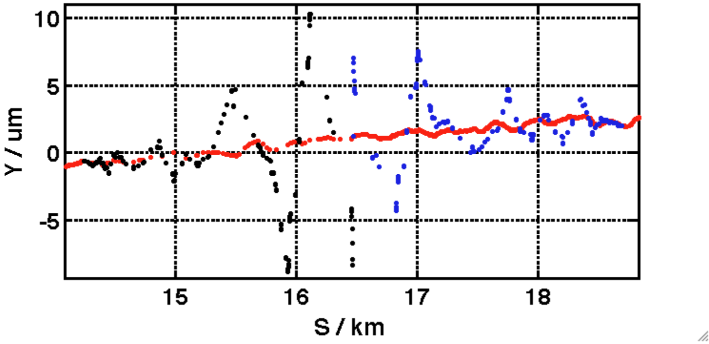
Simulated GM Example (‘C’)



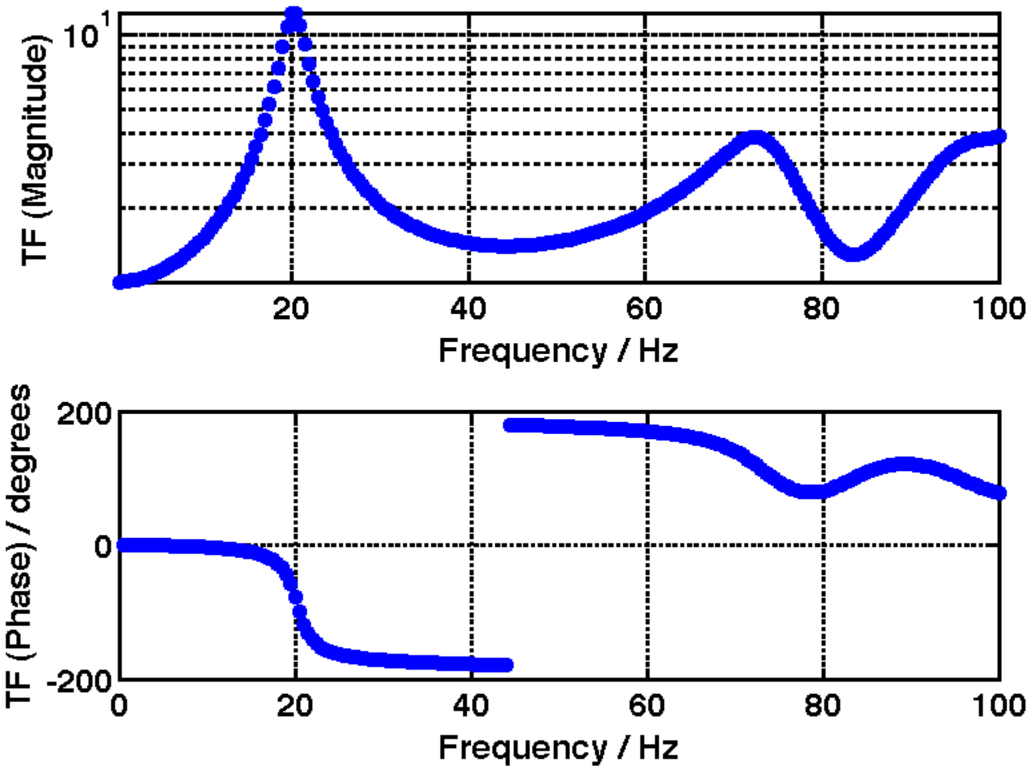


- 10s of ‘C’ GM showing ground position change and beam orbits
- Tracking studies focused on BDS section



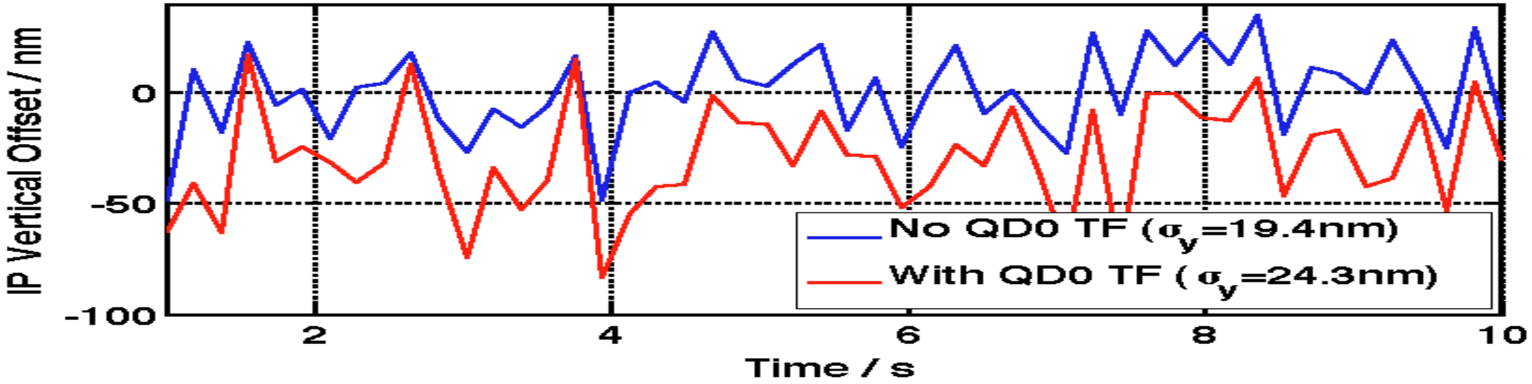


QD0 TF

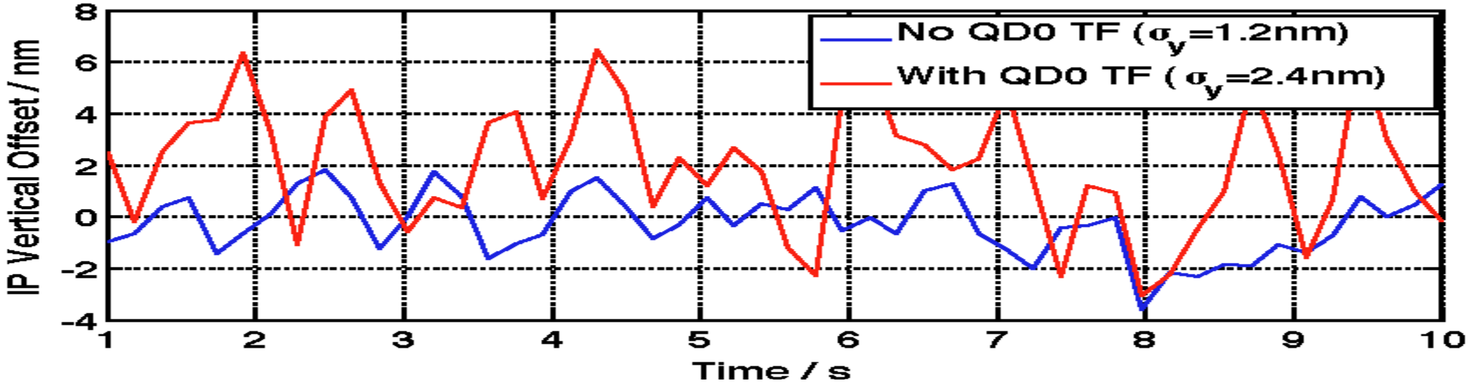


- “Rigid support structure” model from SiD group (Marco). QD0 rigidly attached to detector platform.
- Apply to simulation girder element attached to SD0/OC0/QD0 cryomodule.

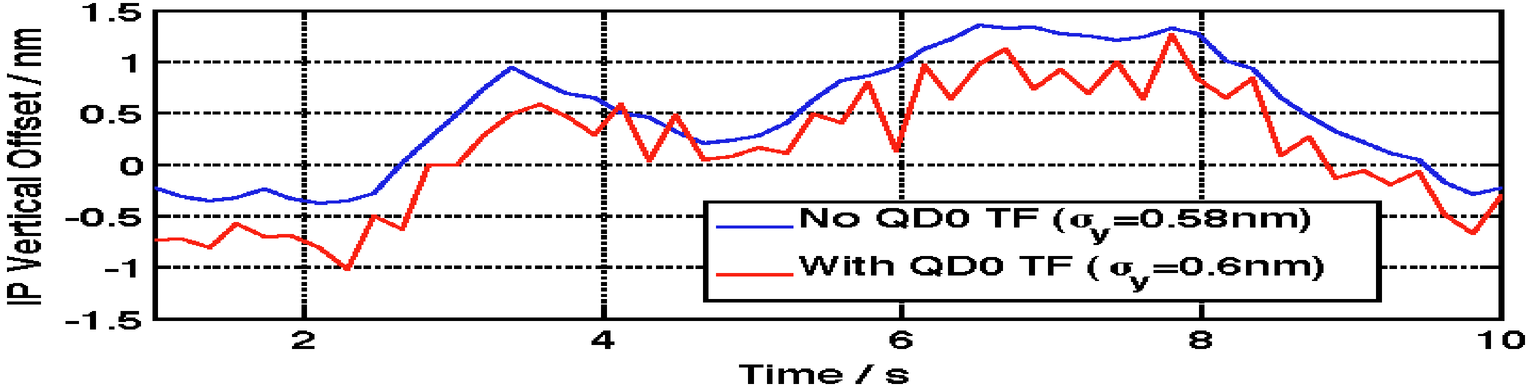
GM Induced Jitter @ IP (Vertical Offset between e- and e+ beams at IP) with and without QD0 TF



GM ‘C’



GM ‘B’



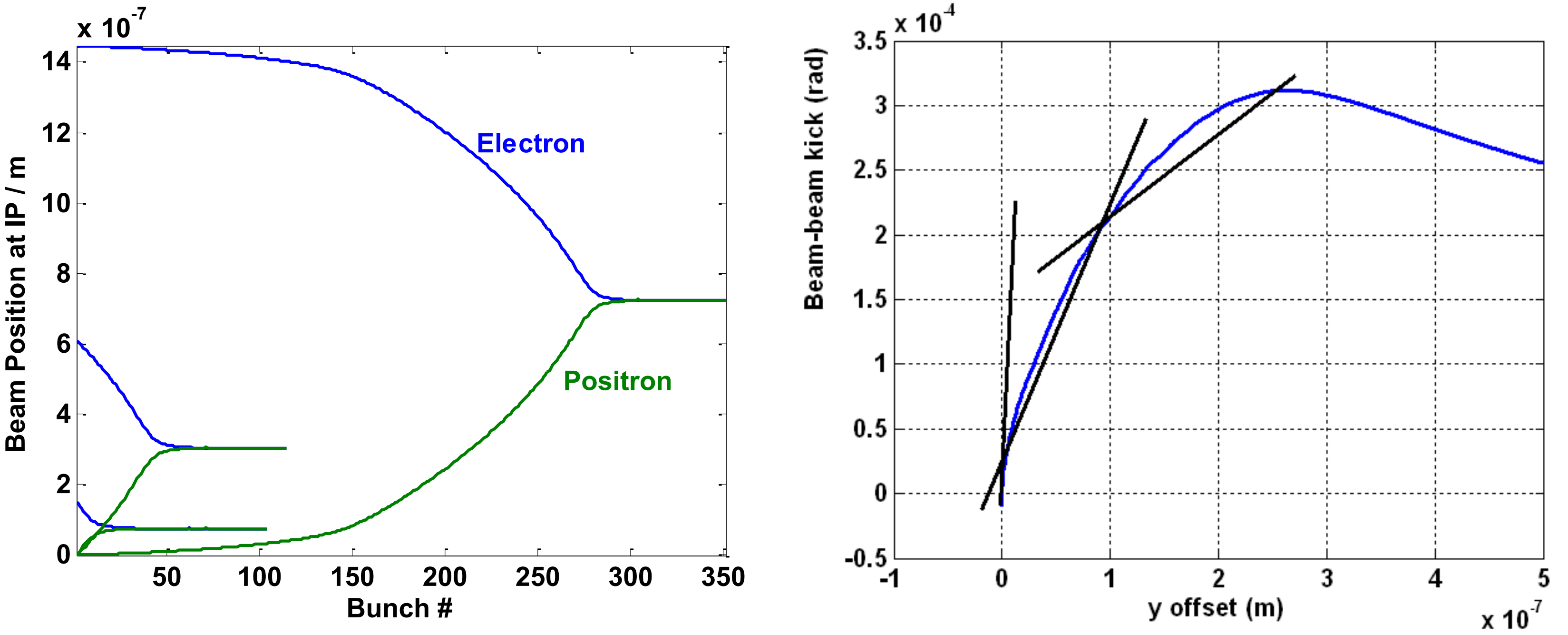
GM ‘A’

Luminosity Loss Mechanisms and Preventative Feedbacks

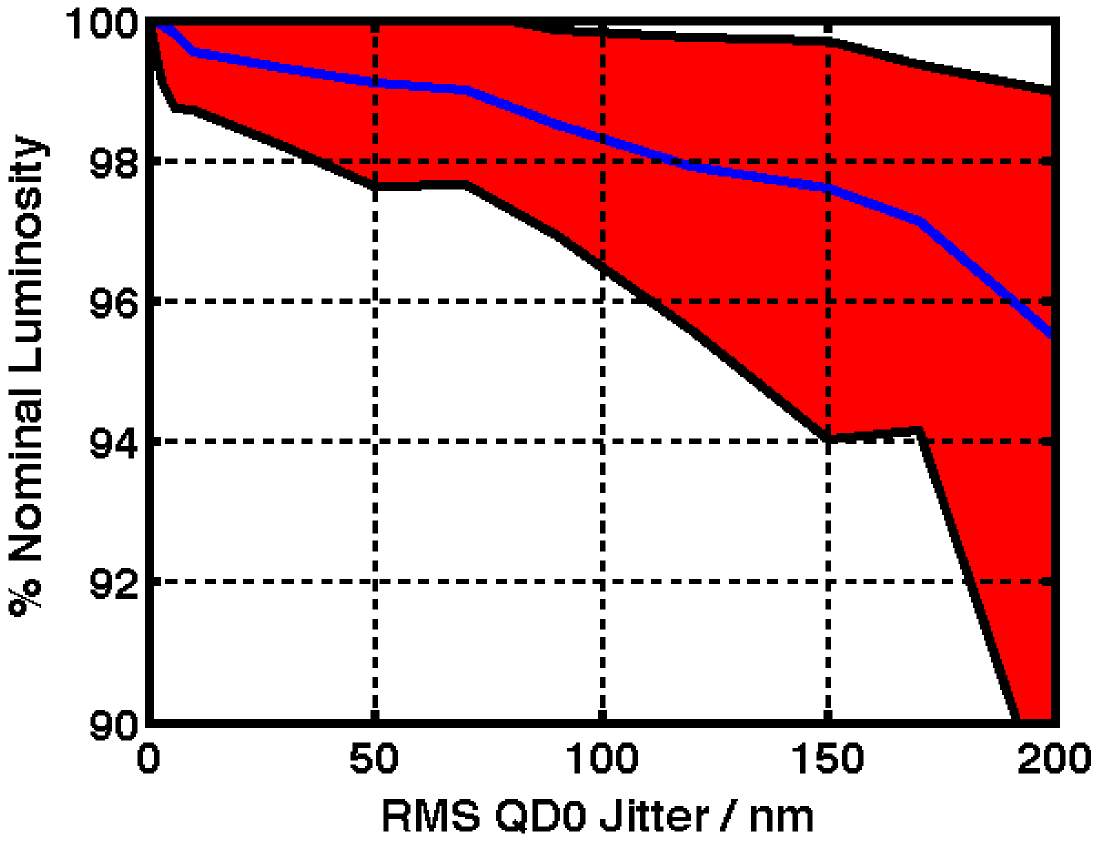
- Ground motion causes misalignment of all BDS magnets, causing growth of beam orbit over time
- 2 mechanisms for Luminosity loss
  - Beamsize growth at IP
    - Orbit generates emittance growth due to dispersive kicks along the beamline
    - Offsets in non-linear elements cause larger beamsize at IP through introduction of linear and higher order aberations (mainly waist offset, dispersion and coupling)
  - Beams move out of collision in position and angle at IP
- Slow orbit feedbacks keep beamsize effects from becoming too large
  - Still residual pulse-pulse jitter at IP, this must keep within the tolerances of the intra-pulse feedback system (ideally ~<200nm)
- Intra-pulse feedbacks keep beams in collision.
  - Depends on shape of pulse train, incoming conditions etc which are hard to model. Model a conservative case tuned to deal with harsh conditions.
  - Performance limited by speed of convergence (governed by intra-pulse jitter conditions and pulse shape reproducibility) and beamsize growth due to correction kick induced offset through SD0 (depends on the size of the required correction (IP offset)).

Intra-Pulse IP Feedback

- Use ILC IP FFB, tuned for ‘noisy’ conditions (like those simulated for TESLA)
- Assume BDS-entrance FFB has perfectly flattened beam train (flat trajectory into Final Doublet).
- No systematic or random intra-pulse distortions.
- Calculate Luminosity from measured bunches, with mean of last 50 weighted to account for the rest of the beam train (1320 bunches).

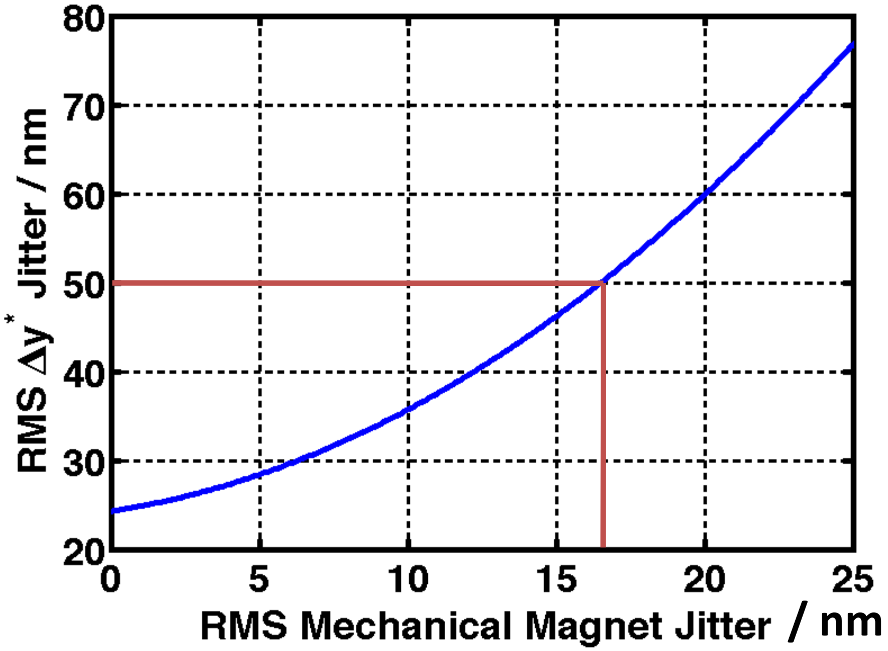


Luminosity Loss vs. QD0 Jitter



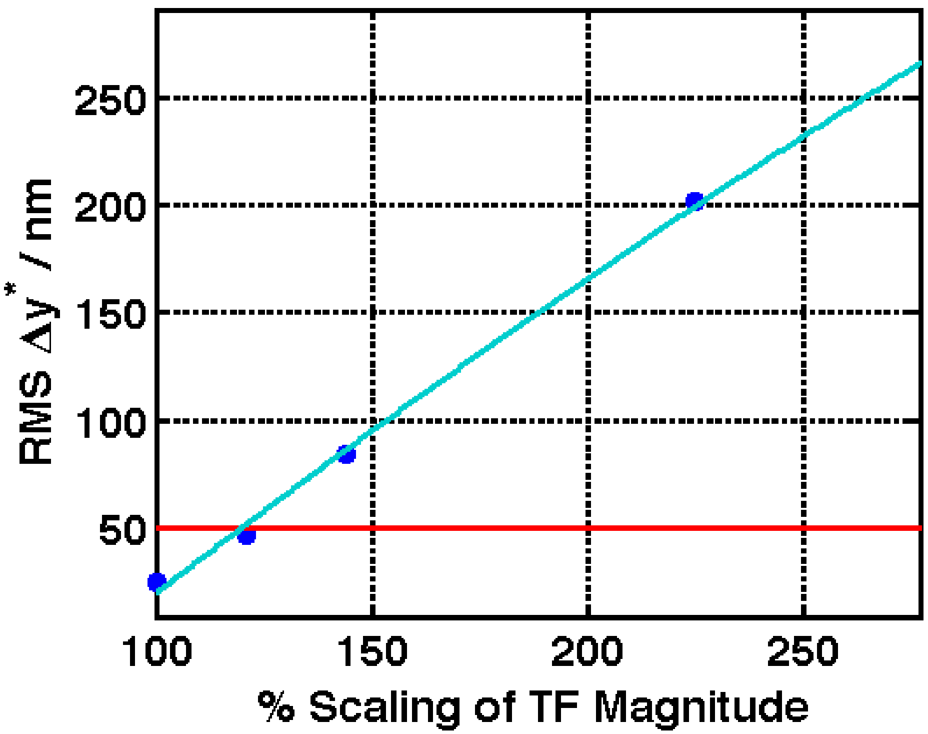
- Data shown gives % nominal luminosity for different levels of uncorrelated QD0 jitter.
  - 100 pulses simulated per jitter cases with FFB
  - Mean, 10% & 90% CL results shown for each jitter point from 100 pulse simulations
- **Tolerance to keep luminosity loss <1% is <50nm RMS QD0 jitter.**

Mechanical Jitter of Magnets



- GM ‘C’ + QD0 TF + mechanical jitter added to all BDS magnets
- Could tolerate -> 17nm RMS additional mechanical magnet jitter.

Scaling of TF Magnitude



- Scale magnitude of TF attached to QD0
- Can be scaled by -> 120% before required 50nm RMS IP offset jitter exceeded.

Conclusions

- In the worst GM model considered (‘C’), the QD0 TF studied increases expected jitter of QD0 magnet from 19.4 -> 24.3 nm
  - The effect in GM Models ‘A’ and ‘B’ is negligible.
- The jitter tolerance to keep luminosity loss <1% is <50nm RMS
  - The TF studied meets this requirement in the worst studied GM case.
  - Can scale magnitude of provided TF up to 120% before exceeding tolerance.
- This assumes no other mechanical vibration
  - For GM ‘C’ and the studied TF, up to a further 17nm RMS jitter can be tolerated whilst keeping within the 50nm tolerance.