Fast Feedback Performance Studies for ILC

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GDE/ALCPG Workshop Sept. 2009

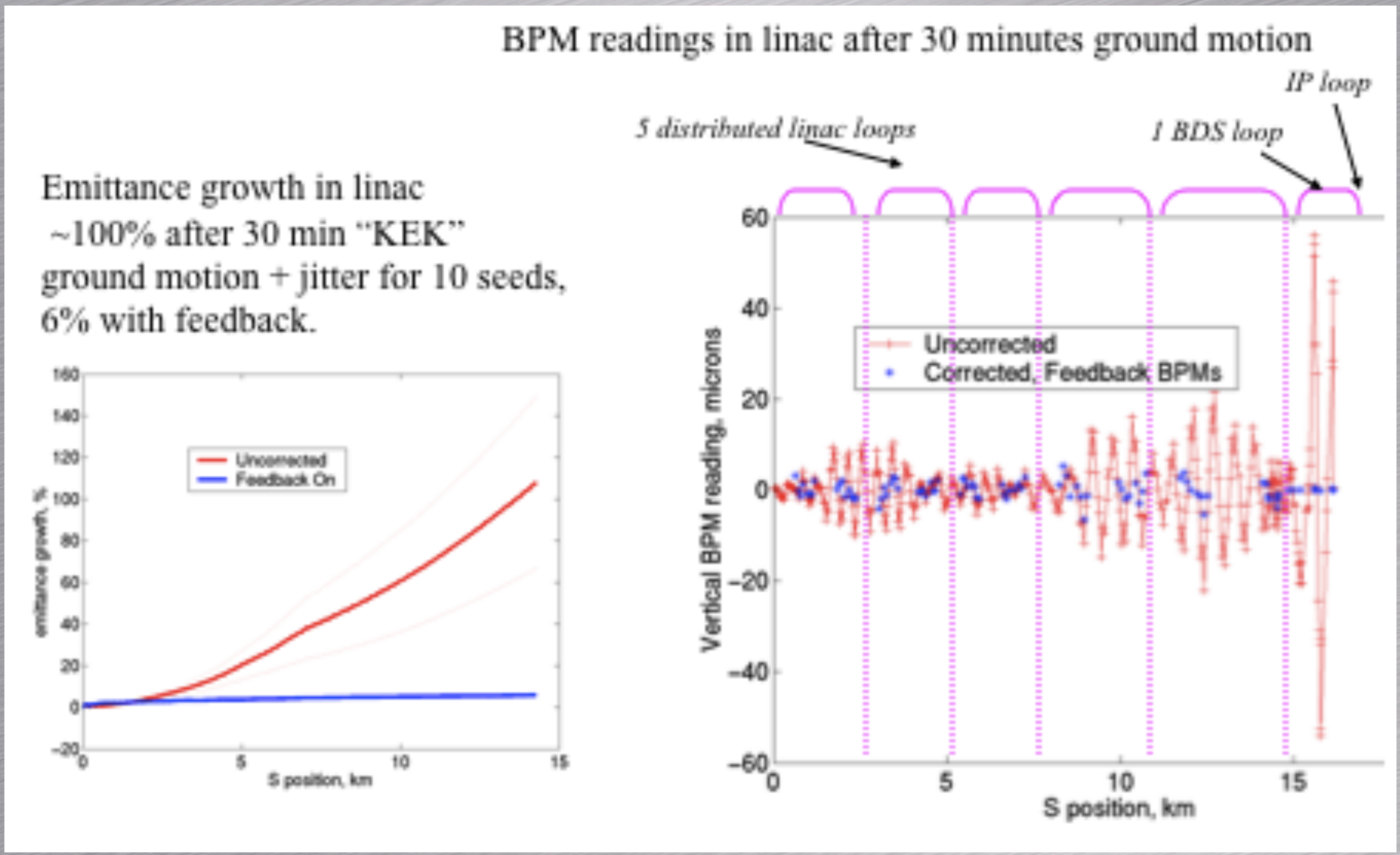
Overview

- Review of simulation work done ~< RDR publication time by Glen.
- Work continued by Javier with more up-to-date design parameters.
- Beam-beam dynamics @ IP with different parameter sets.
- Feedback system components and specs.
- Estimated performance from simulations.

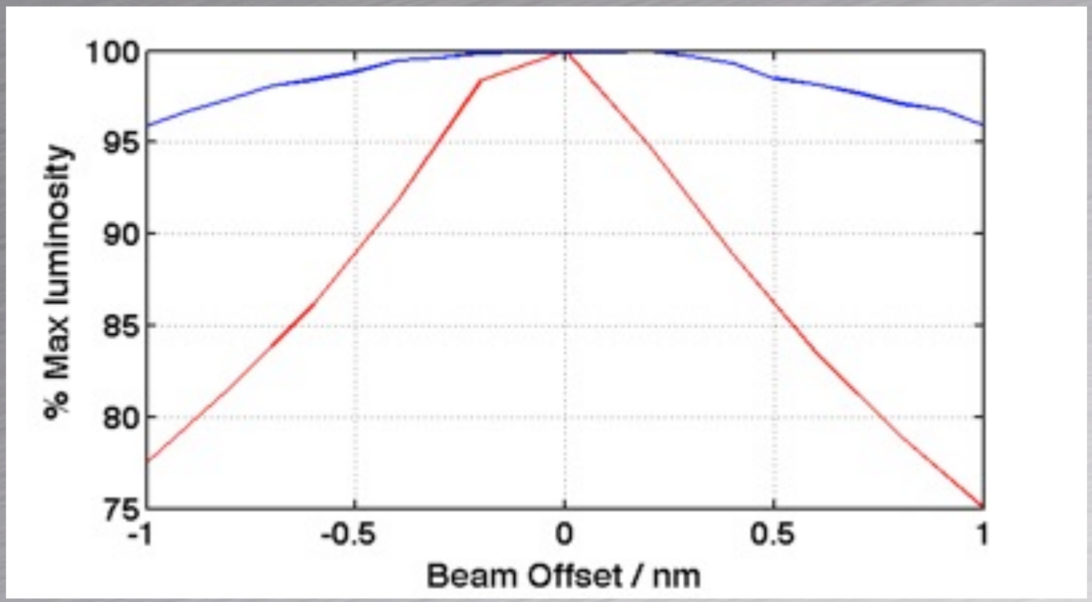
Luminosity Loss

- Luminosity lost through many ‘static’ and ‘dynamic’ effects causing beam misalignment in magnetic components and at IP, emittance dilution and bunch shape distortion.
  - Naturally occurring ground motion
  - Mechanical vibration sources
  - Wakefield effects in accelerating cavities and small apertures (collimation systems).
- Most acute luminosity loss mechanism due to relative jitter of final focusing magnet elements.
  - Need mechanical stabilization at <1nm-level of magnets (difficult) or active feedback based on beam trajectory after collision (baseline design).

Emittance Growth Constrained by 5Hz Feedback

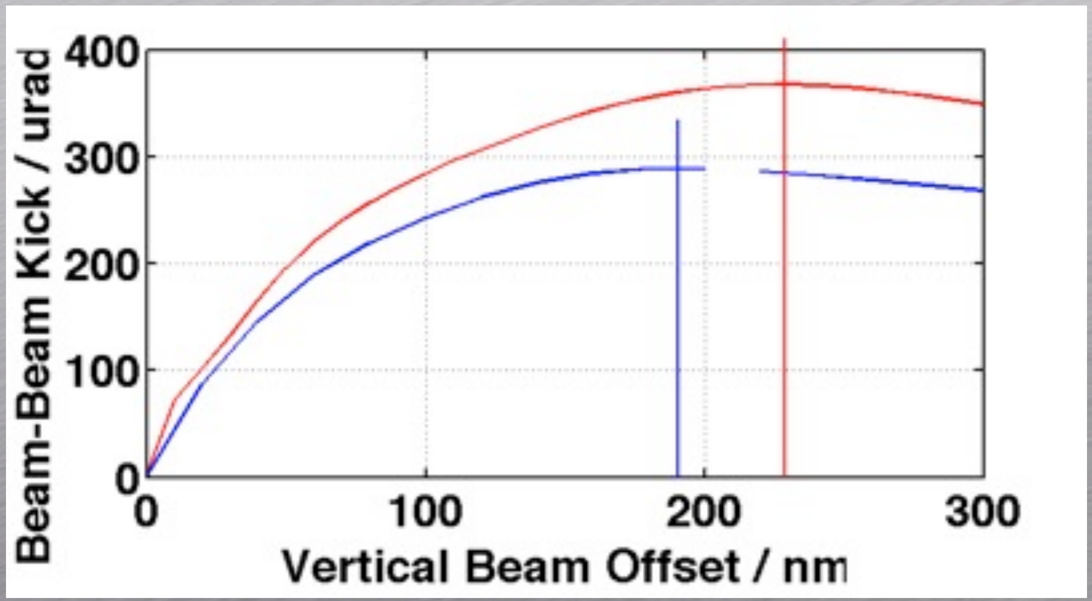


IP Beam-Beam Dynamics



SB2009 (lowP with trav focus)

Nominal Parameter Set



GUINEA-PIG Simulations

- IP vertical position feedback based on beam-beam kick
- "turn over" point of kick sets desired dynamic range
- SB2009 more sensitive
- Vertical beam offset must be kept <200pm for <5% lumi loss
- SB2009 parameter set gives slightly larger dynamic range for FFB system

BDS Fast Feedback System

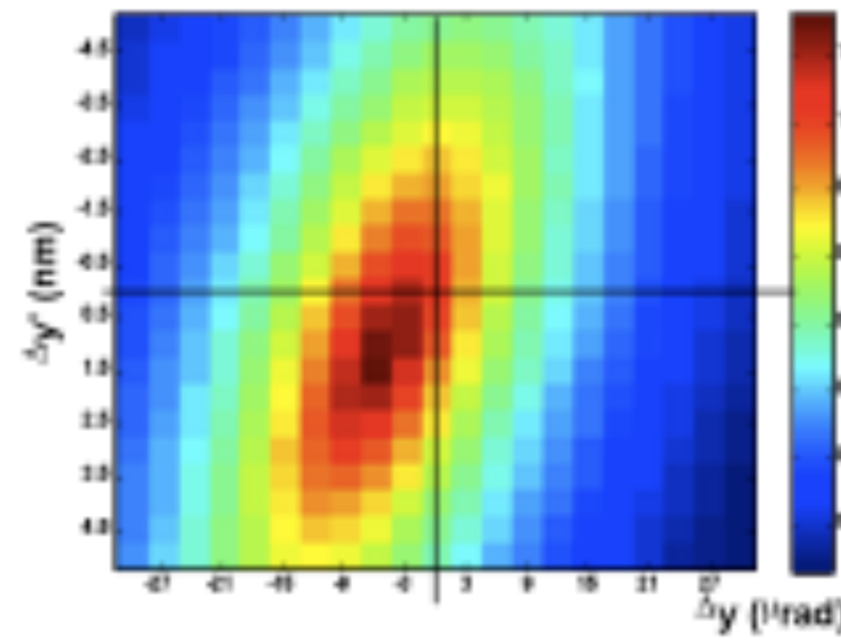
- 3 independent bunch-bunch beam-based FB systems in BDS:
  - **post-LINAC Fast Feeback**
    - 2 pairs of kickers/BPMs at different phases
    - Strong kickers (~100 times Voltage of other 2 FB kickers if same type)
    - Need ~100nm resolution on BPM's
    - Corrects static & dynamic HOM-driven initial wiggle in train + any other systematic intra-train effects.
    - Separates BDS and LINAC 5-Hz feedback systems.
    - Not much simulation done with this, makes negligible difference to luminosity performance with studies done if keep gain low.

BDS Fast Feedback System

- **IP-ANGLE Fast Feedback**
  - Corrects and optimises collision angle of bunches
  - 3 1m Stripline kickers at IP phase at start of FFS with same drive requirements as IP FFB.
  - BPM 90^o downstream.
  - BPM res. Required ~ 2um (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
- **IP-POSITION Fast Feedback**
  - Based on beam-beam kick signal calculated with GP.
  - BPM just upstream of BeamCal, ~10um res required (stripline)
  - Kicker in the ~1m gap between SD0 and 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).

Luminosity-Feedback

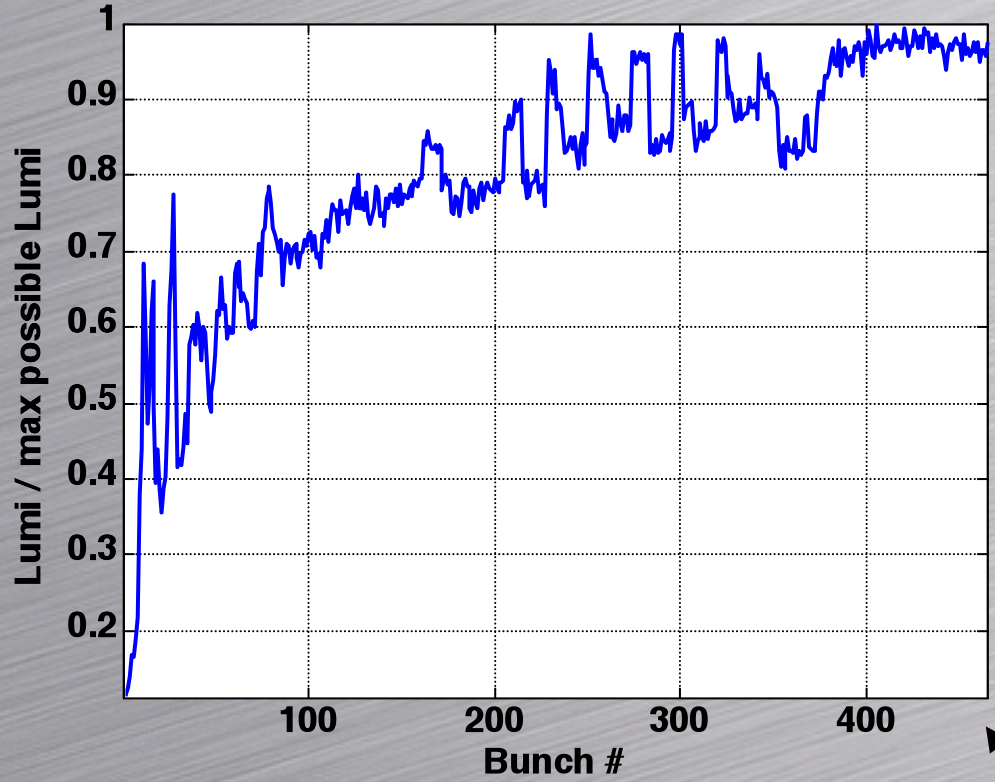
- Lumi Feedback
  - After some number of bunches (~150) when effects like HOM's have damped and beam-based FFB's have settled, optimize IP collision parameters using lumi-based signal.
  - Require prompt signal from 1st layer of BeamCal (integral of incident pairs), which although not directly proportional 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
  - Bunch-bunch system essential if optimal collision parameters change pulse-pulse (20% lumi-loss otherwise).

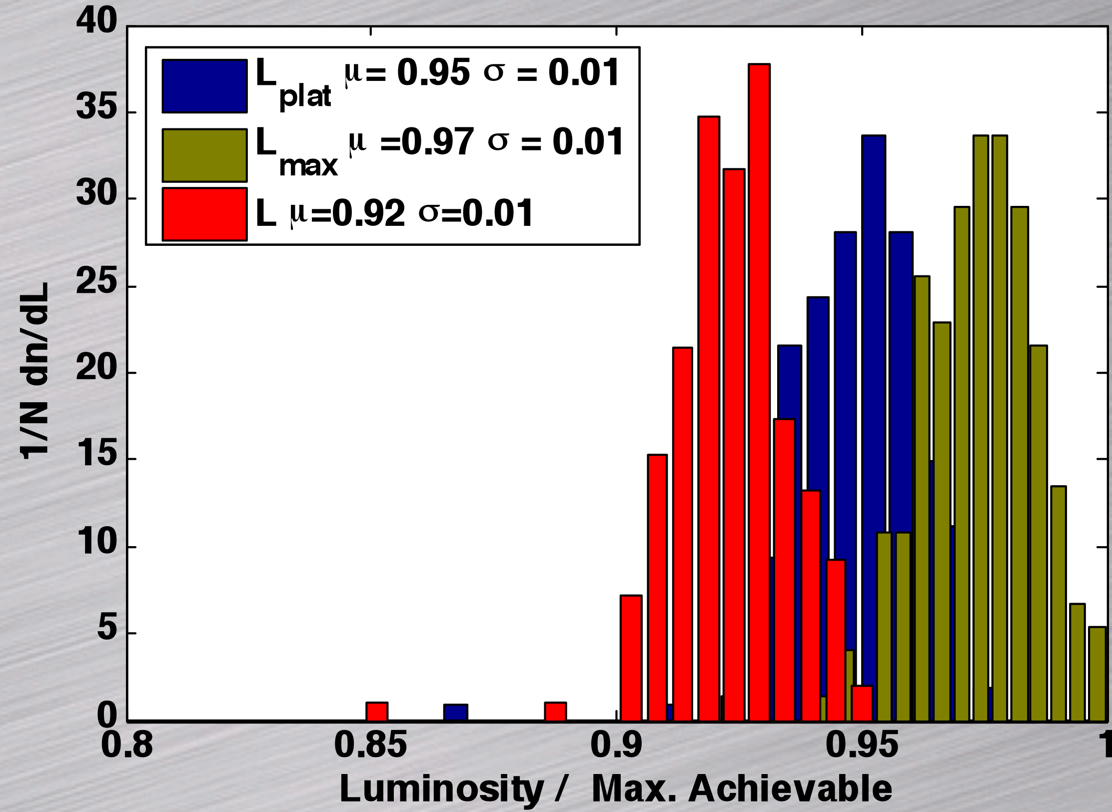


GW (pre-RDR) Simulation

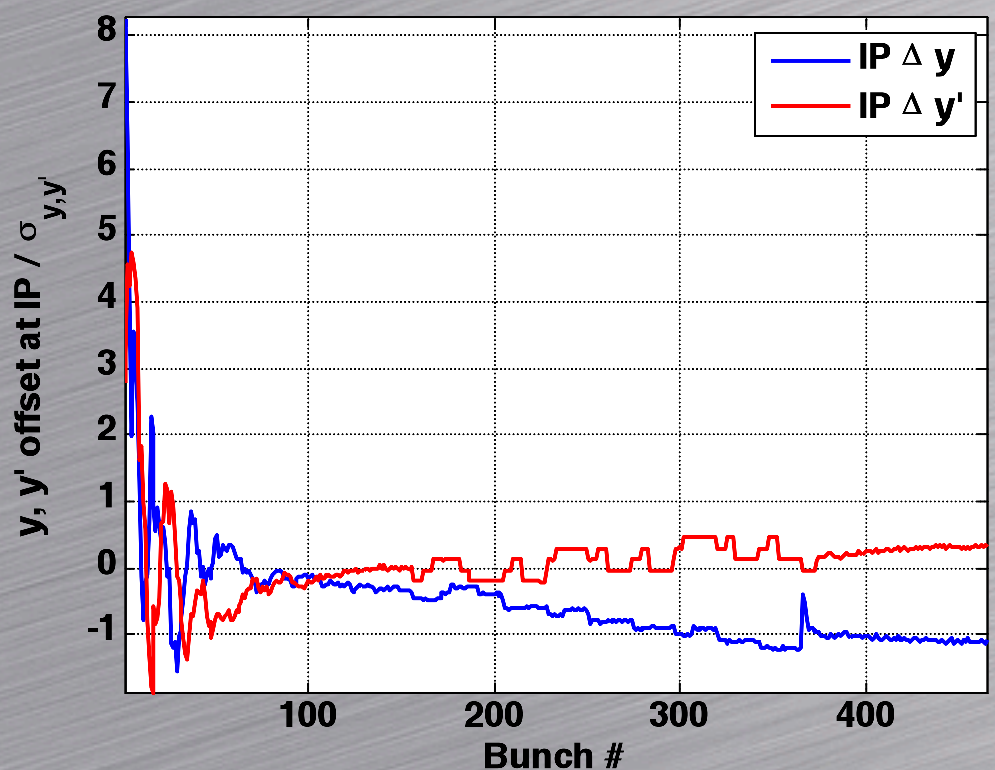
- 200-seed study, including tracking through LINAC, BDS and IP. Using Placet, MatMerlin and GUINEA-PIG.
- Study response and performance of FFB's as described given initially tuned beamline that delivers target emittances and lumi. Then add inter-pulse effects of GM (K model) + component jitter including SR + LR WF's in Linac cavities.
- TESLA beam parameters used in simulation with Snowmass 2005 lattice (20 + 2mrad IP crossings).

Simulation Results



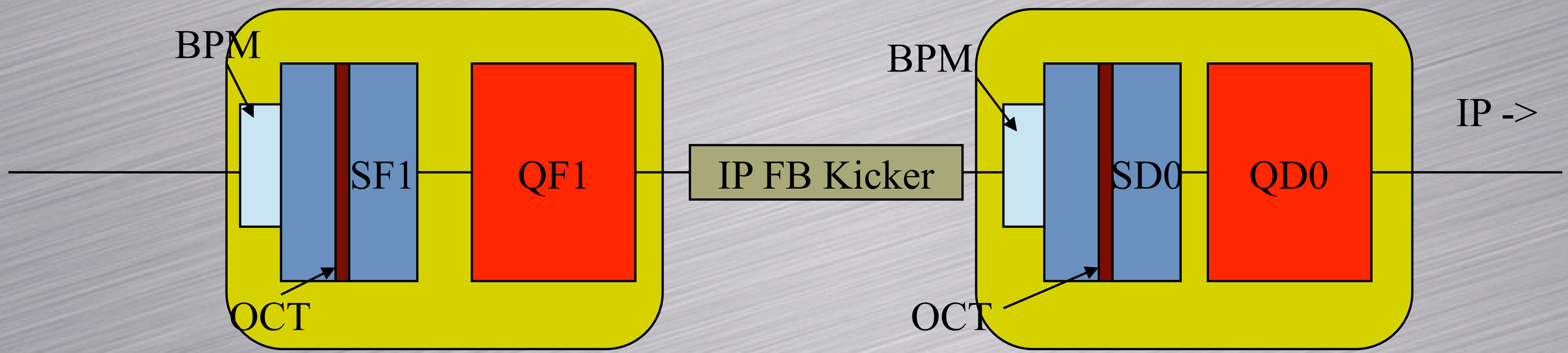


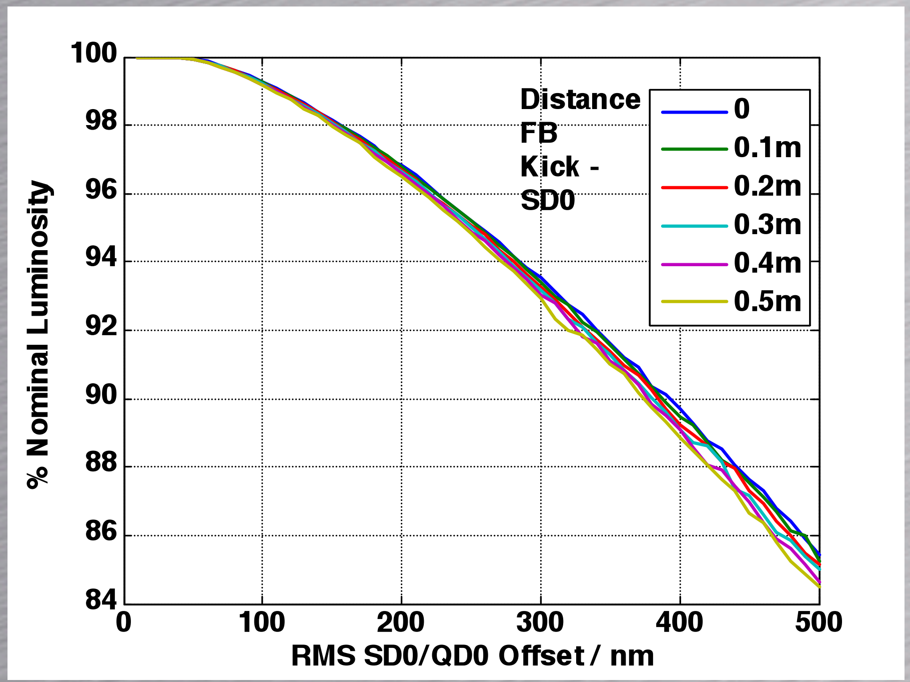
200 Seeds

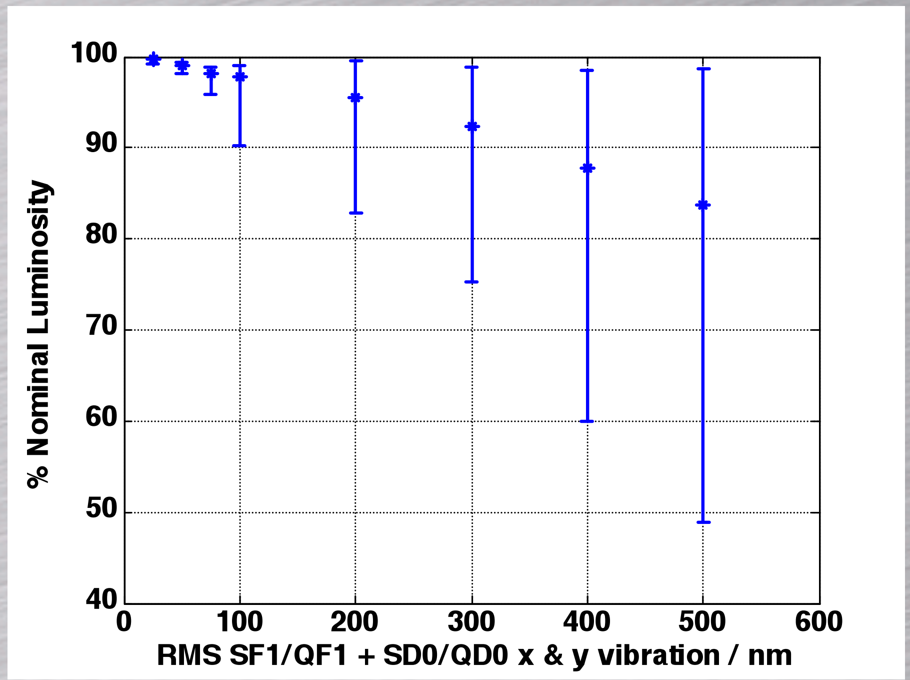


- Single Seed:
  - Luminosity
  - IP Position/Angle

Final Doublet Jitter Tolerance

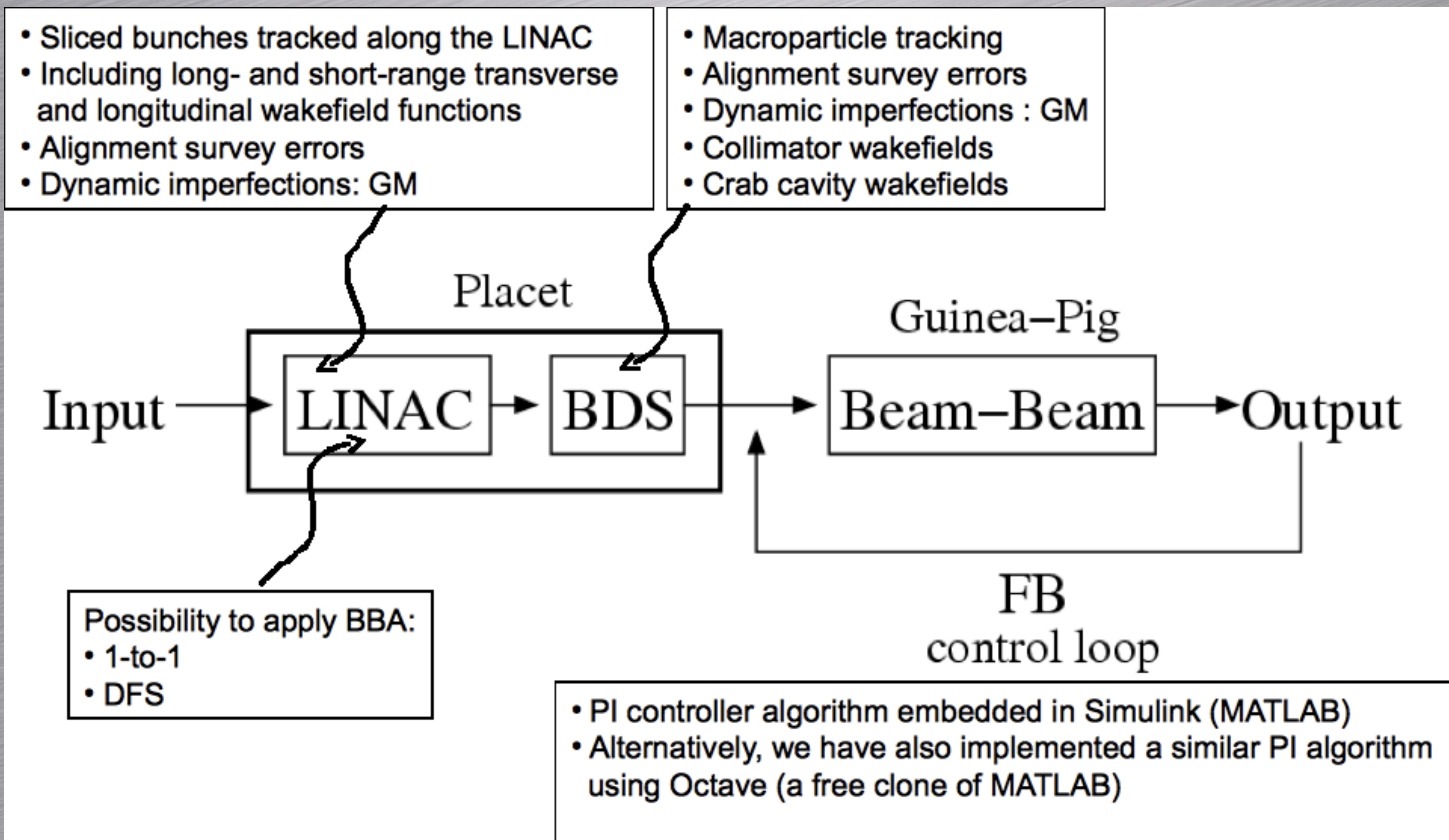




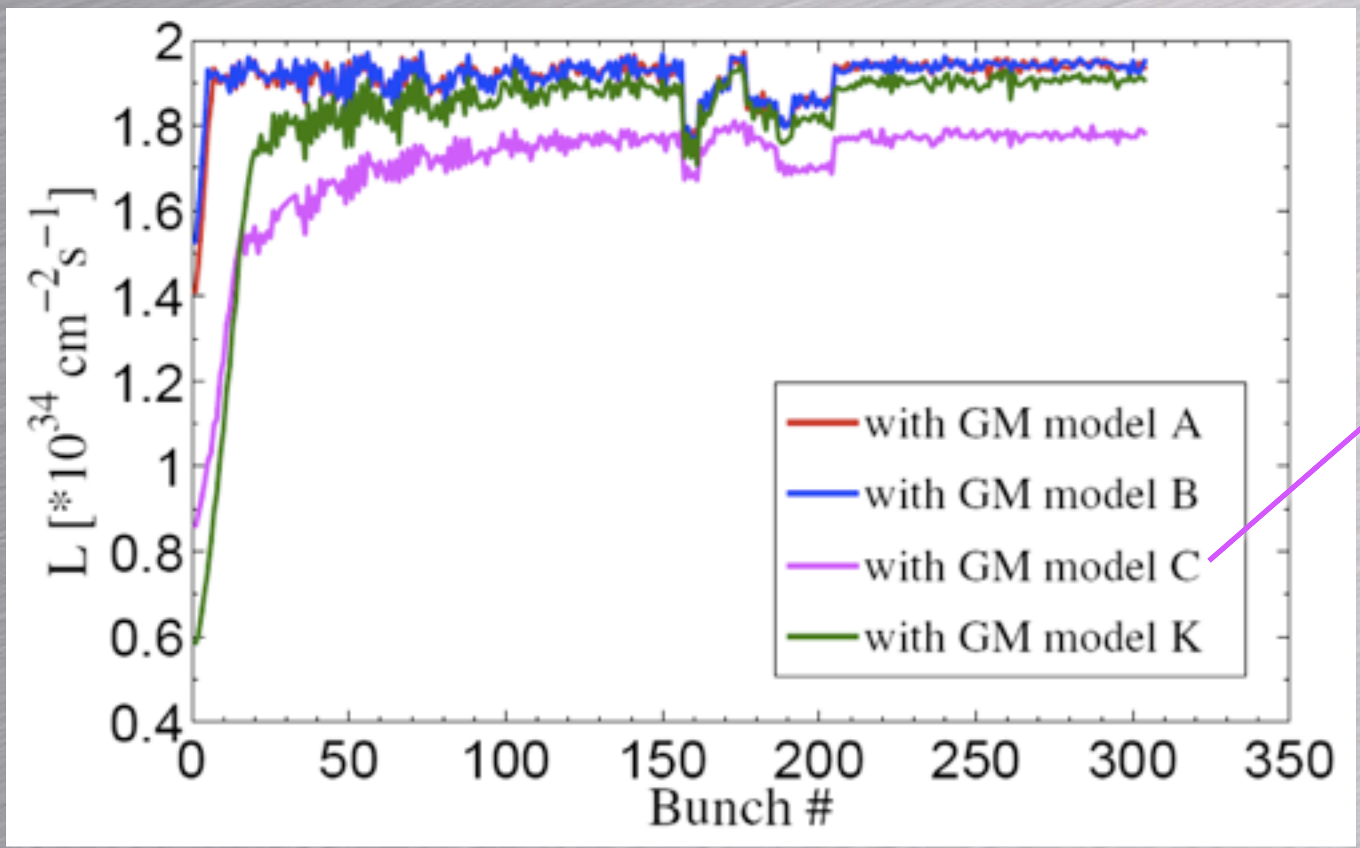


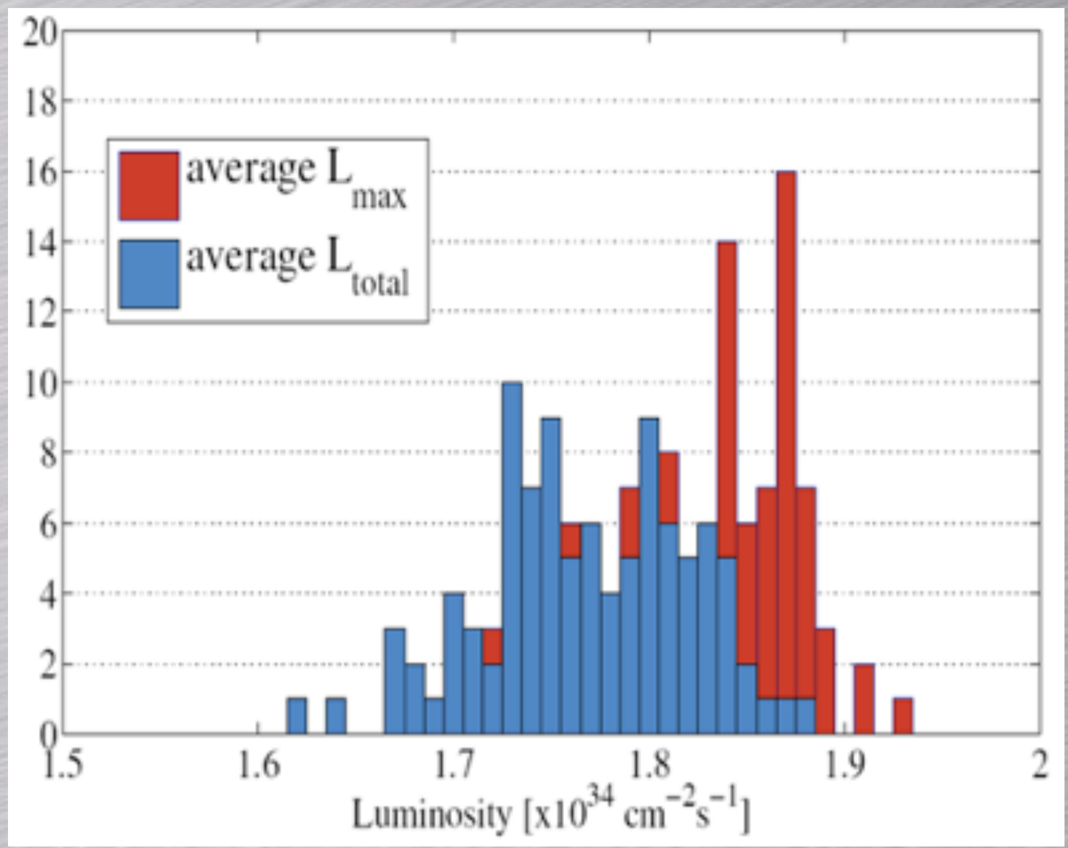
- Lumi loss due to beam offset in SD0 (beamsize growth) and IP misalignment of beams

JRL Simulation



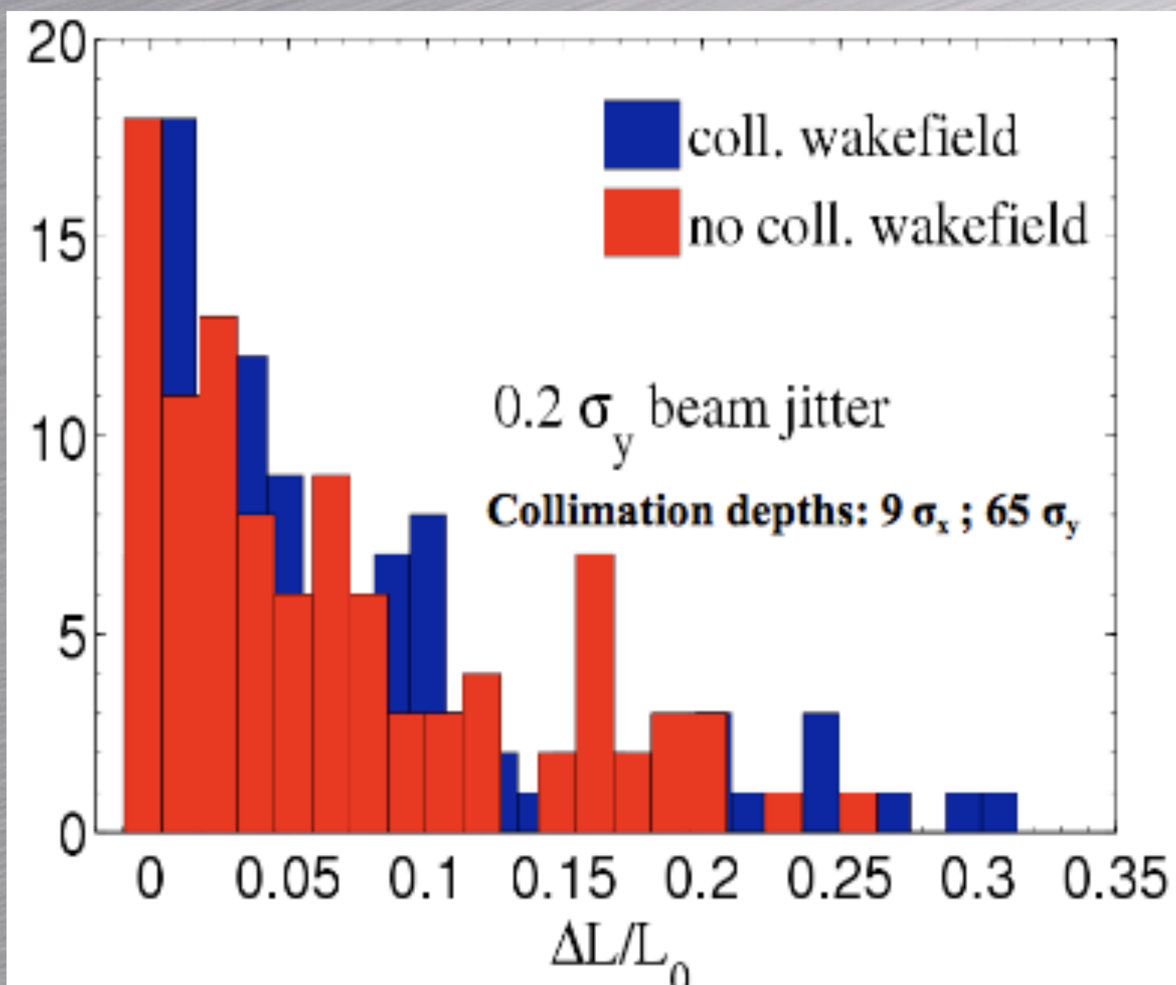
Simulation Results





- Banana effect negligible here
- Mean L_{max} = 92%, L_{total} = 88%

Collimator Wakefields



- Luminosity-loss distribution from 100 simulated seeds including collimator wakefield effects.

Summary

- Integrated simulations of ILC from Linac through to IP performed with static and dynamic effects added.
- The use of 3 fast feedbacks in the BDS as described is adequate when used in conjunction with a slower distributed FB to keep luminosity >~90% of max achievable.
- This should be factored in to design when considering emittance growth budgets for BDS.