First look at CLIC 2-beam tuning

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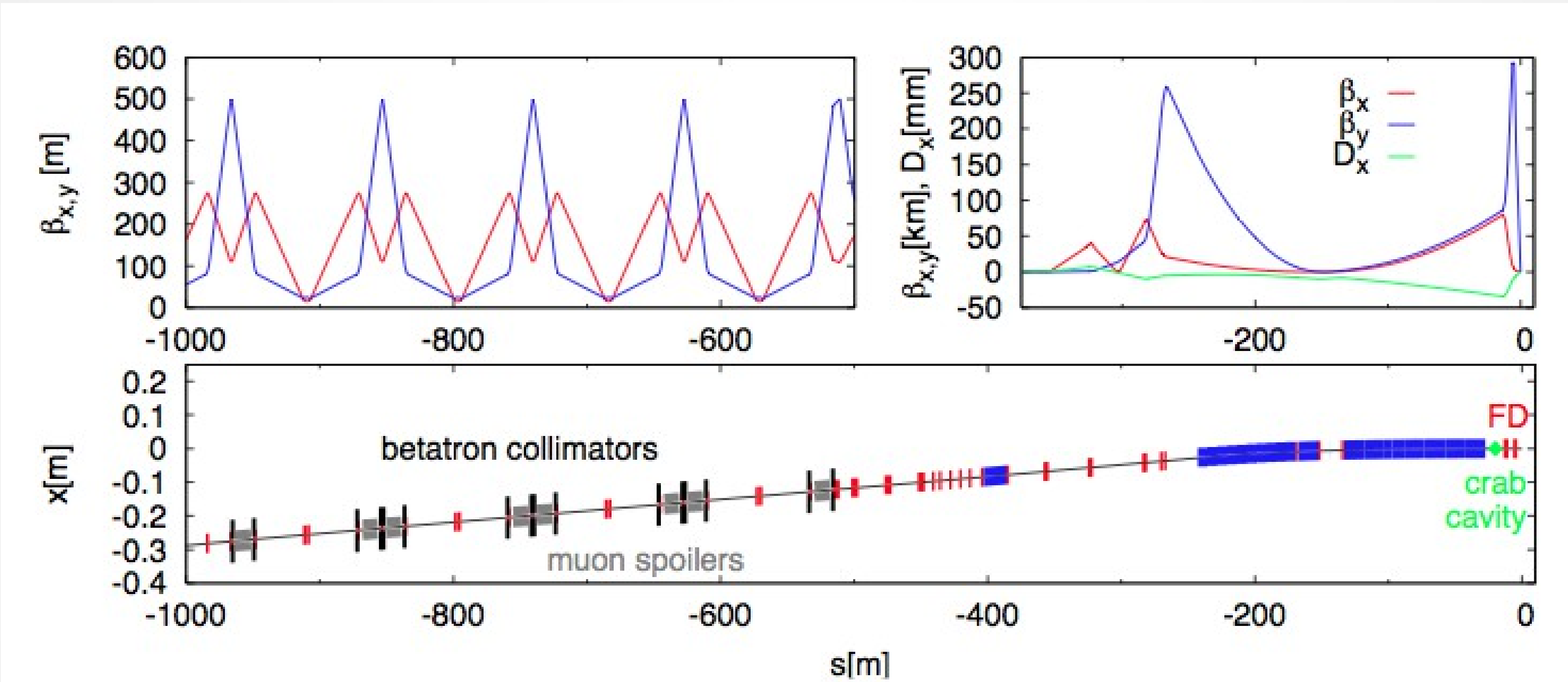
Outline

- Current status CLIC 1-beam tuning
- Summary ILC 1 and 2-beam tuning
- Thoughts / Future Plan

BDS Final Focus



- CLIC 3 TeV
- L* = 3.5 m

CLIC: 1 vs 2 beam tuning

- So far only “1 beam tuning” has been simulated
  - Optimise one BDS beamline from static errors
  - Collide beam with “itself” to measure luminosity
  - CPU-less intensive
  - Two methods
- 2 beam tuning will be at least twice as long (except for BBA)
  - How much longer?
  - Luminosity measurement less precise for lower lumi.
  - Additional luminosity loss is expected as self-collision is often optimal
  - After BBA, are the beams aligned wrt each other?
    - Additional constraint on BBA
    - Final Doublets alignment of both lines needs to be good enough

1 beam tuning - errors

- Misalignment in two planes:
  - 10 μm std normal distribution (CLIC prealignment)
- BPM resolution 10 nm

Luminosity optimisation method

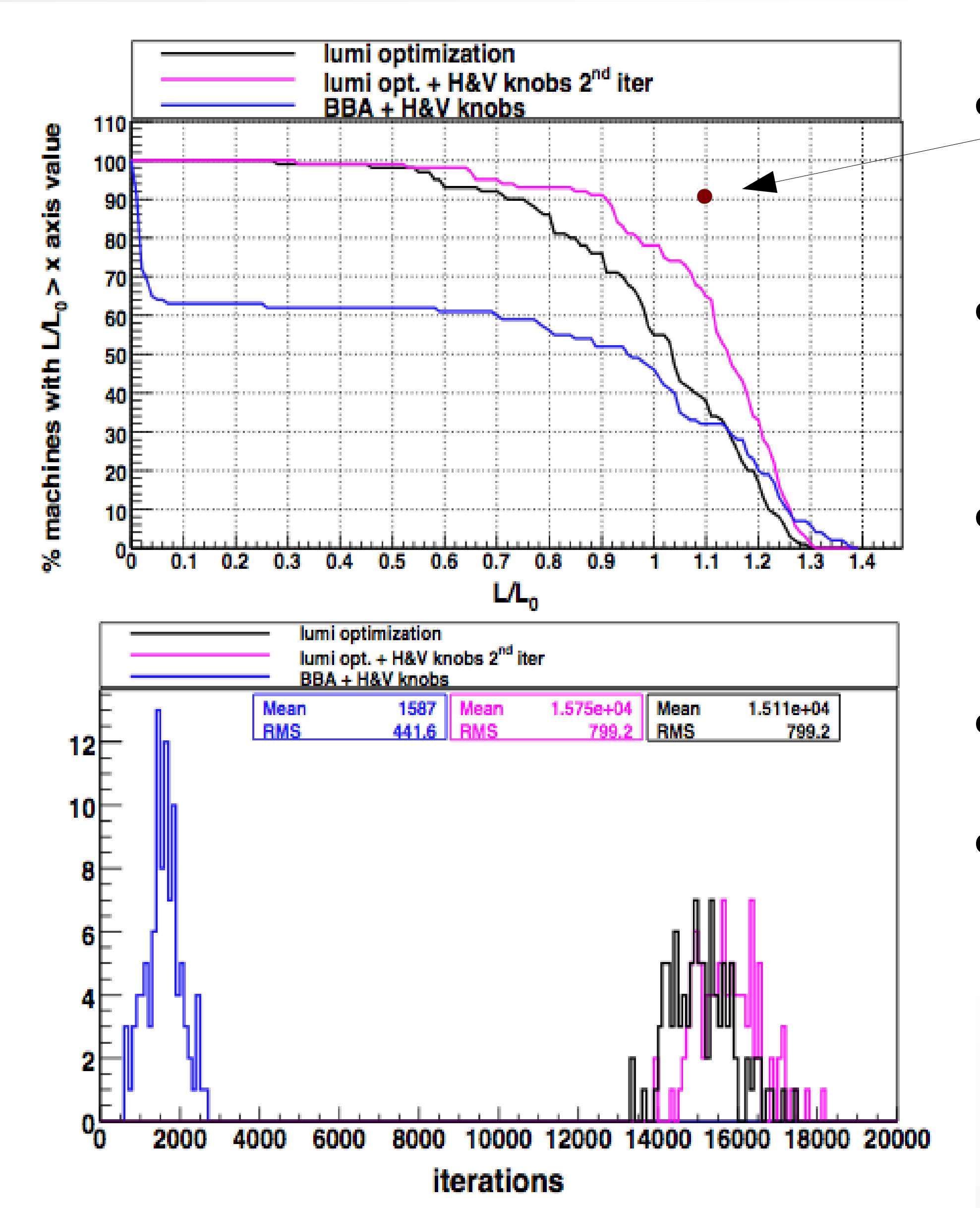
- Large optimisation with simplex method
- Move all elements of the Final Focus system
  - 2 iterations
- Can be combined with sextupole knobs afterwards
- B. Dalena et al.: http://prst-ab.aps.org/abstract/PRSTAB/v15/i5/e051006

“BBA” method

1. Multipoles off, Beam Based Alignment
    1. 1-1 correction
    2. “Target Dispersion Steering” (DFS-like method)
2. Multipole shunting:
    1. vary position to centre the multipoles
3. Multipole knobs
4. Target Dispersion Steering
5. Multipole knobs

A. Latina, P. Raimondi:
http://accelconf.web.cern.ch/AccelConf/LINAC2010/papers/mop026.pdf

Results

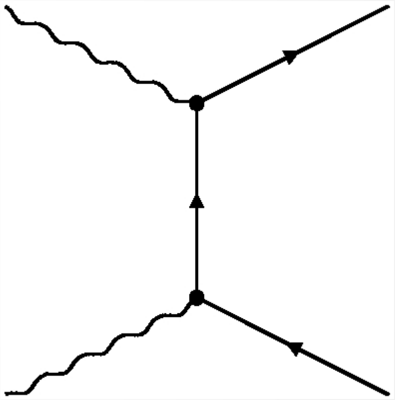


- Goal: 90% of machines to 110% Lumi
- Remaining 10% for dynamic imperfections
- 16,000 Lumi meas. for method 1
- 2,000 for method 2
- Method 2 seems to suffer from simulation problems in 30-40% of cases
  - Should be possible to improve

Luminosity measurement

- Fast luminosity measurement is essential
  - Depending GM model, CLIC loses up to 10% of lumi in 1h
- Traditional e^+e^- methods (Bhabha scattering counting) take 7 to 70 minutes in CLIC
- Solution: look at hadronic pair production with detector
- 1% precision luminosity measurement

  needs 20 trains ≈ 0.5 s
- Method 1: 2 hours Method 2: 15 min.



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ILC tuning experience
2 beam tuning

- Valuable discussions and slides from Glen White
- e.g. http://indico.cern.ch/conferenceDisplay.py?confId=98683

ILC 2 beam tuning experience (Glen White)

Alignment and Tuning Steps

- Switch off Sextupoles and Octupoles.
- Perform initial BBA using Quad movers and BPMs -> beam through to IP.
- Quadrupole BPM alignment. → Quad shunting
- Perform Quadrupole BBA (DFS). → Mover minimisation
- Align Sextupole BPMs.
- Move FCMS to minimize FCMS BPM readings.
- Align tail-folding Octupole BPMs.
- Activate and align sextupole and octupole magnets.
- Rotate whole BDS about first quadrupole to pass beam through nominal IP position.
- Apply sextupole multiknobs to tune-out IP aberrations and maximise luminosity. → Higher order corrections (sextupole strengths and tilts)
- 5-Hz feedback system used throughout to maintain orbit whilst tuning.

Using pair production meas. in simulation

FCMS = Final Doublet (Final Cryomodule String)

Higher order corrections (Glen White)

INTERNATIONAL LINEAR COLLIDER

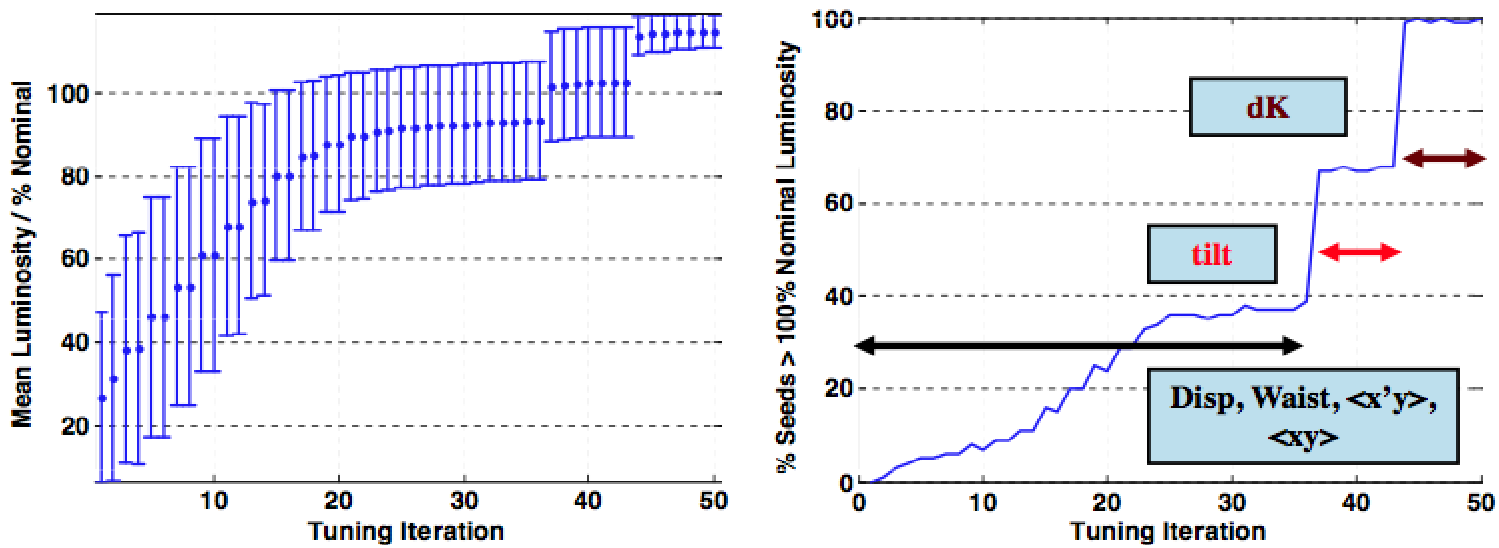
Higher-Order Sextupole Multi-Knobs

- Due to sextupole tilt and strength errors, and due to non-linear fields as the beam passes off-center in the sextupoles, higher-order aberrations also exist at the IP.
- These are corrected for by iterating through sextupoles 1-3 using the tilt dof. on the movers to maximise luminosity after the linear knobs have converged.
- The strengths of the 5 sextupoles are also scanned.

Results
(Glen White)

INTERNATIONAL LINEAR COLLIDER

Application of Multi-Knobs



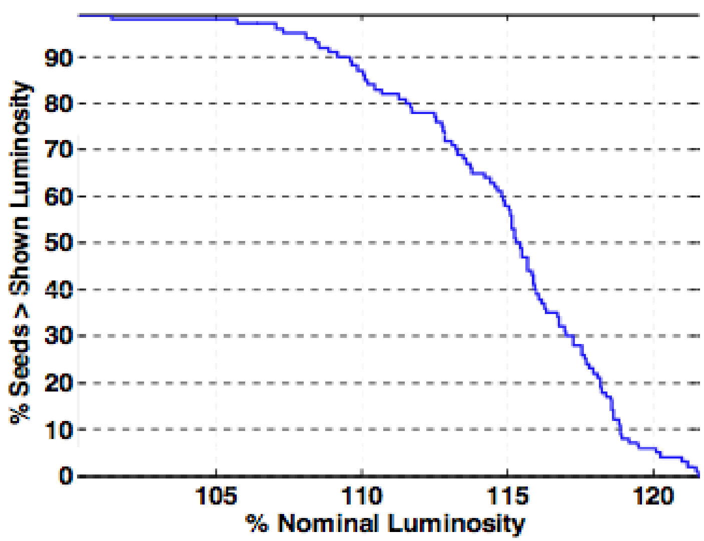
- Single-sided simulation (100 seeds).
- The linear sextupole knobs are applied until convergence, then the sextupole tilts and strengths are tuned on.

Results: 1 vs 2 beam (Glen White)

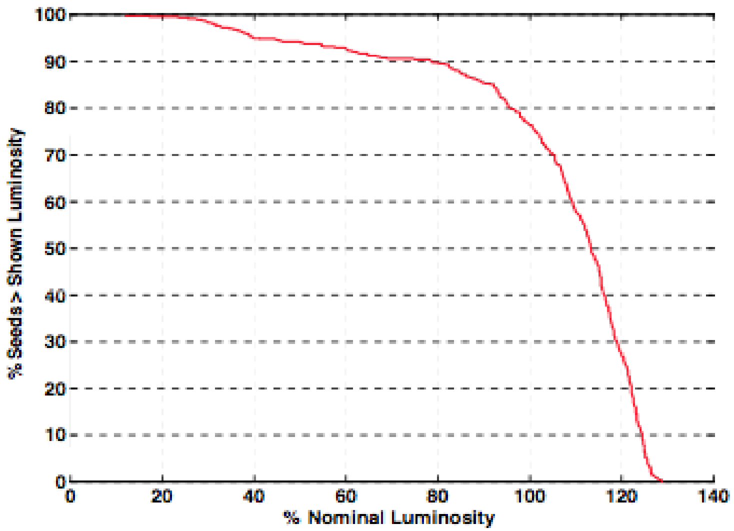
INTERNATIONAL LINEAR COLLIDER

Achieved Luminosity

Single-Sided Sim



2-Sided Sim

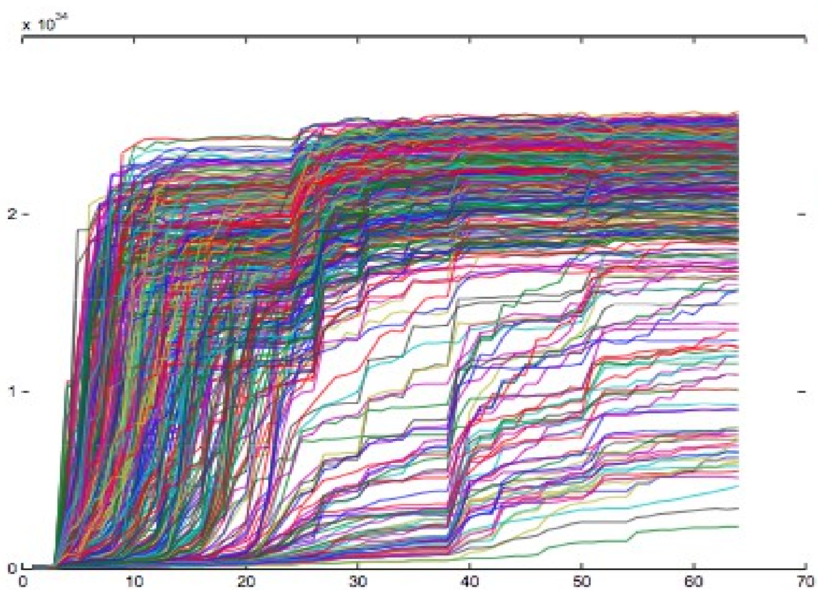


- Median lumi overhead ~15% in both cases
- When simulating both sides 25% of seeds fail to meet design luminosity.

Slower convergence (Glen White)

INTERNATIONAL LINEAR COLLIDER

2-beam Simulation



- Some seeds slower to converge in 2-sided simulation case. (450 seeds simulated).
- In 2 beam-simulation:
  - Rotate 2 beamlines to bring beams into collision
  - Added tuning iterations – perform a tuning scan on e-, then e+ beam – in 1-beam simulation, effectively colliding beam with self- here against a larger beam- effects pair stats.

Slower convergence presumably due to reduced performance of the pair production detector

2 beam tuning

- ILC results encouraging
  - # iterations: more than a factor 2 needed wrt 1 beam, but maintainable
  - Increased luminosity losses for 30% worst performing seeds
    - More iterations were needed?

(personal) ATF2 experience

- Optimise beamlines as best as possible before starting with sextupole knob tuning
  - Knob tuning either works or not, going back to BBA and DFS needs retuning of knobs
- Higher order knobs important
- Maybe add OTR measurement for emittance measurement in simulation
- Monitor IP image point

Thoughts / Questions

- How to know which beam needs tuning?
  - Asymmetric background process available (Jakob Esberg):
    - Low energy photons at large angles from incoherent pairs
- Optimisation parameter (luminosity) measurement is very slow (several trains)
  - What is the optimal luminosity error needed?
    - Will depend on optimisation stage
    - First round of knobs could tolerate larger error than subsequent rounds
      - Can be easily simulated with less particles
  - Can other beam instrumentation be used?
- Beam deflection angle can be used to correct lumi meas.
  - Better knob tuning?
- Add additional tuning possibilities to beamline?
  - Skew sextupoles / octupoles
  - Variable magnet coils

Dynamic imperfections

- Dynamic imperfections
  - Ground motion
  - (Intra-train) IP feedback
  - Orbit feedback
- This will affect the luminosity measurement correlation wrt beam size at IP
  - Slower tuning
- (Keep in mind, but forget about dynamic problems for the moment)

Plan of Attack

- (Due to extended work at ATF2 no preliminary results yet)
- Apply current 1 beam tuning (BBA) with the current setup for two beams
- Verify all intermediate tuning steps and try to optimise them
- Add higher order corrections
- Add more static imperfections
  - Extend BBA procedure accordingly
- Suggestions / discussions welcome

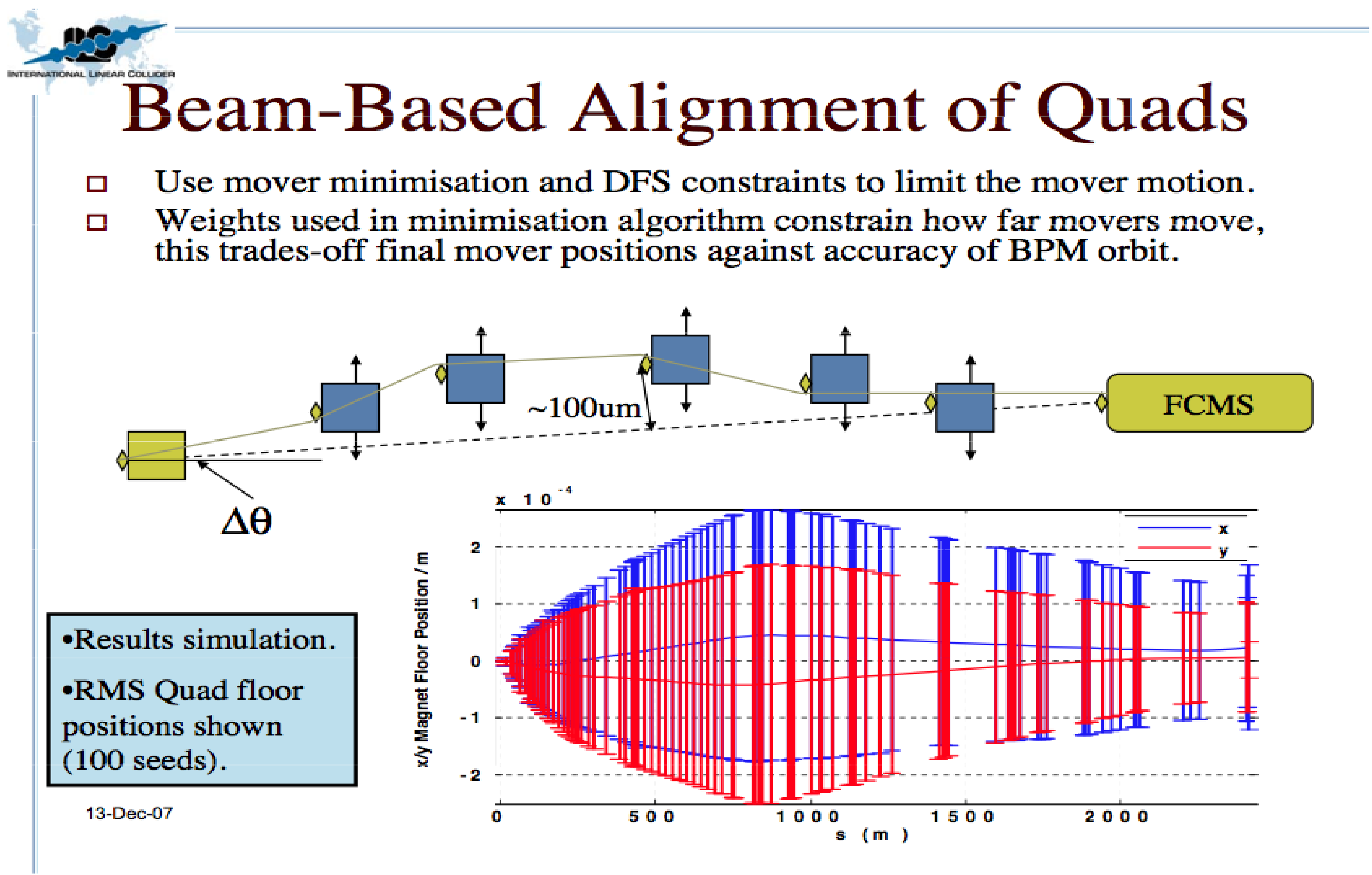
Backup

ILC Error Parameters (Glen White)

Error Parameters

Initial Quad, Sext, Oct x/y transverse alignment	200 um
Quad, Sext, Oct roll alignment	300 urad
Initial BPM-magnet field center alignment	30 um
dB/B for Quad, Sext, Octs (RMS)	1e-4
Mover resolution (x & y)	50 nm
BPM resolutions (Quads)	1 um
BPM resolutions (Sexts)	100 nm
Power supply resolution	14 - bit
FCMS: Assembly alignment	200 um / 300urad
FCMS: Relative internal magnet alignment	10um / 100 urad
FCMS: BPM-magnet initial alignment (i.e. BPM-FCMS Sext field centers)	30 um
FCMS: Oct – Sext co-wound field center relative offsets and rotations	10um / 100urad
Corrector magnet field stability (x & y)	0.1 %
Luminosity (pairs measurement or x/y IP sigma measurements)	1 % (ATF2 SM ~5%)

ILC BBA method (Glen White)



ILC Quad Shunting (Glen White)

Quadrupole BPM Alignment

- Nulling Quad-Shunting technique:
  - To get BPM-Quad offsets, use downstream 10 Quad BPMs for each Quad being aligned (using ext. line BPMs for last few Quads).
  - Quad dK 100-80 %, use change in downstream BPM readouts to get Quad offset.
  - Move Quad and repeat until detect zero-crossing.
  - For offset measurement, use fit to downstream BPM readings based on model transfer functions:

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