DRAFT: Summary of Standard Errors and Simulation Results

v4, 201005

K. Kubo, A. Latina, D. Schulte, N. Solyak, N. Walker, G. White

List of Standard errors

Local Alignment Error. Cold section

Error	RTML and ML Cold	with respect to
Quad Offset	300 µm	cryo-module
Quad roll	300 µrad	design
RF Cavity Offset	300 µm	cryo-module
RF Cavity tilt	300 µrad	cryo-module
BPM Offset (initial)	300 µm	cryo-module
Cryomoduloe Offset	200 µm	design
Cryomodule Pitch	20 µrad	design

Local Alignment Error. Warm section

Error	RTML Warm	BDS Warm	with respect to
Quad Offset	150 µm	200 µm	design
Quad roll	300 µrad	300 µrad	design
BPM Offset (initial)	100 µm	100 µm	attached magnet
(after BBA)	7 µm	?	attached magnet
Bend offset	300 µm	200 µm	design
Bend Roll	300 µrad	300 µrad	design

Mechanical fast movement (vibration)

	Cold Sections	RTML Warm	BDS Warm
Quad, Sext.	100 nm	10 nm	10 nm
Cavity tilt	3 urad	---	---

RTML Return line: Orbit change at the entrance of turn-around

Quad 10 nm → 0.02-sigma orbit: no problem

(0.75-sigma orbit in turn-around increase emittance by 5%)

RTML down stream:

Quad 10 nm should be OK ?

ML: Orbit change at linac end

Quad 80 nm → 1-sigma orbit.

Cavity tilt 3.6 urad → 1-sigma orbit.

Magnet Strength Stability

Magnet to magnet independent, random

	Cold Sections	RTML Warm	BDS Warm
Quad	1E-4	1E-5	1E-5
Bend Strength	---	1E-5	1E-5
Corrector	1E-4	1E-3	1E-3
Sext.	---	---	1E-5
Oct.	---	---	1E-5

Quad 1E-5 in warm sections:

Assuming typical misalignment 100 um, equivalent to 1 nm vibration.

Should be no problem.

ML: Orbit change at linac end 1E-4 → 1 sigma.

RF dynamic errors

		Amplitude	Phase
BC Correlated		0.5%	0.24 deg.
Klystron-to-klystron Uncorrelated		1.6%	0.48 deg.
ML Correlated		0.07%	0.35 deg
Klystron-to-klystron Uncorrelated		1.05%	5.6 deg
Cavity-to-cavity Uncorrelated	Flatness	?	---
	Jitter	1%	---
Crab e+e- Relative			0.015 deg

Correlated :same for all klystrons
Klystron-to-klystron random : klystron to klystron independent, random

What determines the tolerance?
BC: Timing at IP
ML Correlated and kly-to-kly uncorrelated: Energy jitter at the end.
ML Cavity-to-cavity un correlated: Vertical orbit change and emittance growth.
If fixed cavity tilt is 300 urad, 1.2% amplitude change will cause 1-sigma orbit change.
And 5% amplitude change increases emittance by 12 nm.
Crab: Horizontal offset at IP

Magnet Strength fixed Error

	Cold Sections	RTML Warm	BDS
Quad	0.25%	0.25%	1 E-4
Bend Strength	---	0.25%	1E-4
Corrector	?	?	?
Sext.	---	---	1E-4
Oct.	---	---	1E-4

It is not clear what determines these tolerances in RTML and ML.

1E-4 in BDS may be too tight. (?)
In BDS, this error will affect the convergence time of the tuning algorithm .

Error of beam monitors

	Cold Sections	RTML Warm	BDS
BPM Resolution	1 μm	1 μm	0.1 μm
BPM Dynamic range	3 mm ?	3 mm ?	3 mm ?
BPM Scale error	5~10% (?)	---	---
Beam size monitor resolution	1 μm		
Pair monitor (single pulse)	---		1%

Stability of stray fields

	Requirement
RTML Long return line	< 2 nT (may be 5 nT)

depends on time and space structures

Simulation Results
Static tuning

Results of static tuning (RTML and ML)

	Emittance increase (nm)		Corrections
	average	90% CL	
Return line	2.15	?	Kick minimization without coupling correction
Turn-around and spin rotator	1.9	?	Kick minimization and skew coupling correction
Bunch compressor	3.3	?	DFS and dispersion bumps
Main linac*	4.5	8.0	DFS (DMS) without coupling correction

* BPM scale error was not included here.

Numbers from:
RTML: Jeff Smith, LET Workshop at SLAC, Dec. 2007.
ML: K. Kubo.

Results of static tuning (BDS)

- Assuming incoming emittance 34 nm,
  - Design luminosity was achieved for all (100) seeds (1-sided simulation)
  - Design luminosity was achieved for 75% of seeds. (2-sided simulation)
    - 2-sided simulations show increased convergence time for tuning, improvements are expected by letting the simulation run longer.
  - The convergence time of the tuning algorithm is slower than desired and work is currently ongoing to find ways to shorten it

Simulation Results
Dynamic errors

Dynamic sources of orbit jitter and emittance growth

	Source	Assumption	Induced orbit	Induced emittance growth
RTML Return Line	Quad vibration (offset change)	10 nm	0.02 sigma	small
RTML Return Line	Stray field	2 nT (5 nT)	0.2 sigma (0.5 sigma)	0.15 nm (1 nm) in turnaround
ML	Quad vibration (offset change)	100 nm	1.5 sigma	0.2 nm
ML	Quad+steering strength jitter	1E-4	1 sigma	0.1 nm
ML	Cavity tilt change	3 urad	0.8 sigma	0.5 nm
ML	Cavity to cavity strength change, assuming 300 urad fixed tilt	1%	0.8 sigma	0.5 nm
Warm sections	Quad strength jitter	1E-5	small	small

sigma: nominal beam size assuming $\gamma\varepsilon = 20$ nm.

Longitudinal effects of RF Dynamic errors

	For 2% luminosity reduction by arrival time jitter	
	Amplitude	Phase
BC RF, Correlated	0.5%	0.24 deg.
BC RF, Uncorrelated (kly-to-kly)	1.6%	0.48 deg.

	For 0.07% Energy jitter	
	Amplitude	Phase
ML RF, Correlated	0.07%	0.35 deg.
ML RF, Uncorrelated (kly-to-kly)	1.05%	5.6 deg.

(from RDR)

Mechanical fast movement (vibration)

RTML Return line: Orbit change at the entrance of turn-around

Quad 10 nm → 0.02-sigma orbit: no problem

(0.75-sigma orbit in turn-around increase emittance by 1 nm)

ML: Orbit change at linac end

Quad 80 nm → 1-sigma orbit and 0.1 nm emittance.

Cavity tilt 3 urad → 0.8-sigma orbit and 0.5 nm emittance.

Magnet Strength jitter, Magnet to magnet independent, random

Quad 1E-5 change in warm sections:

Assuming typical misalignment 100 um, it is equivalent to 1 nm vibration and should be tolerable.

ML Quads and dipole steerings:

1E-4 strength change → 1 sigma orbit and 0.1 nm emittance.

RF dynamic errors

BC:

Each of correlated amplitude jitter 0.5%, phase jitter 0.24 deg, uncorrelated amplitude jitter 1.6% and phase jitter 0.48 deg causes bunch arrival timing jitter at IP reducing luminosity by 2%.

ML (correlated and klystron-to-klystron uncorrelated)

Each of correlated amplitude 0.07%, phase 0.35 deg, klystron-to-klystron 1.05% and phase 0.35 deg jitter causes 0.07% beam energy jitter. Effect to transverse motion is small.

ML Cavity-to-cavity uncorrelated:

Assuming fixed cavity tilt 300 urad random,

1% amplitude change cause 1-sigma orbit change.

5% amplitude change cause 12 nm emittance.

Stray field

RTML Long return line:

7.5 nT random (independent for each section between two quad magnets), fast changing (no feed-back/feed-forward) stray magnetic field in the long return line cause 2 nm emittance increase in the following turn-around.

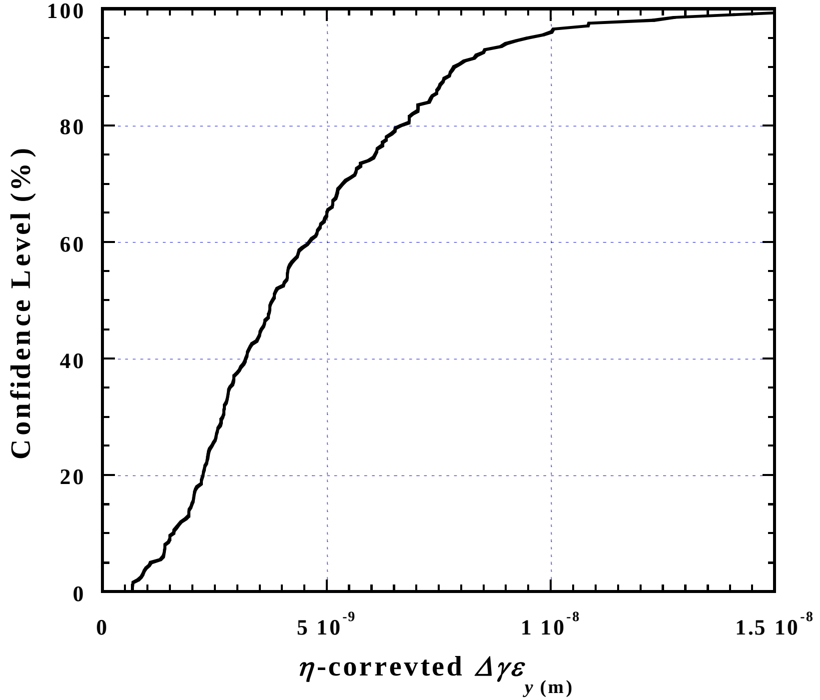
Other areas:

Effects are assumed to be negligible.

Reference figures

ML, Static tuning simulation

“Standard” set of errors. No BPM scale error.
DMS (test beam energy 90% of nominal, weight factor 30000) .

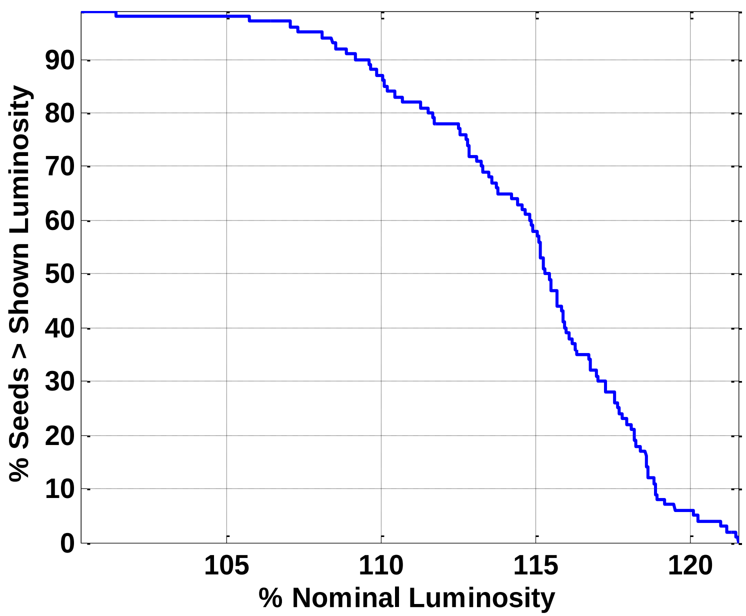


Confidence Level: Ratio of random seeds which give smaller emittance growth than the horizontal axis.

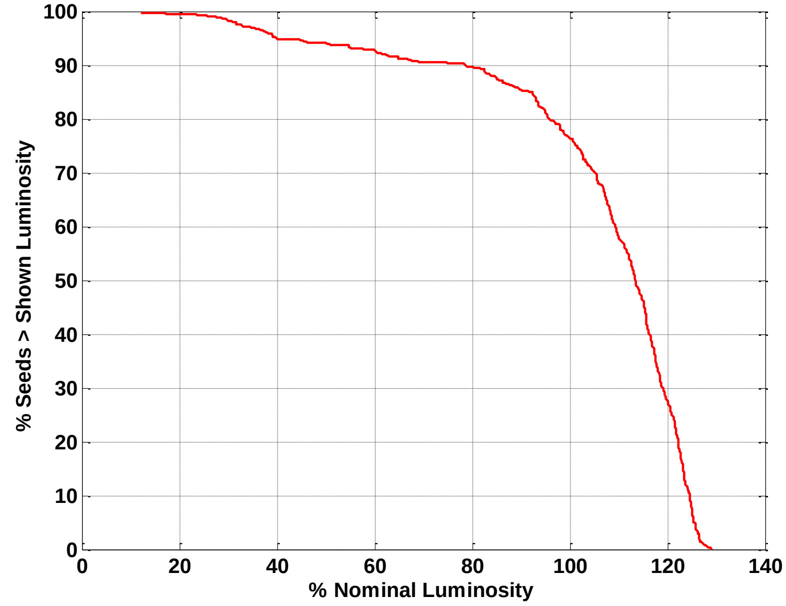
K. Kubo

BDS, Static tuning simulation
Achieved Luminosity

Single-Sided Sim



2-Sided Sim

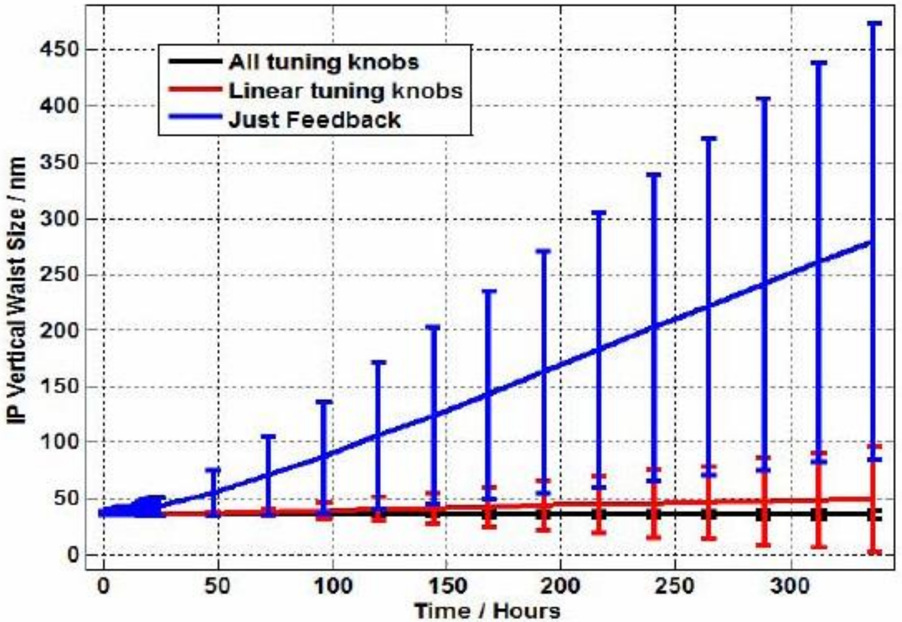


- Median lumi overhead ~15% in both cases
- When simulating both sides 25% of seeds fail to meet design luminosity.

G.White, ILC-LET WS, SLAC, Dec 2007

BDS Dynamic Effect Simulation

Long-Timescale Performance



At each point, none, linear (waist, dispersion and coupling) and full tuning knobs (include sextupole strength and tilt scans) applied. For blue, red and black respectively.

- Vertical IP beam size over 2 week period
- Mean and +/- 1 sigma RMS from 100 seeds shown at each point

G.White, ILC-LET WS, SLAC, Dec 2007