CLIC BDS Tuning Study

Edu Marin
emarinla@cern.ch

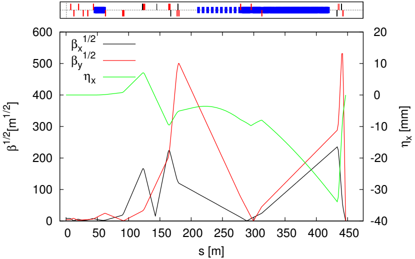
Tuesday, December 6^{th}, 2016
Beam Dynamics Session
LCWS 2016 Morioka

Outline

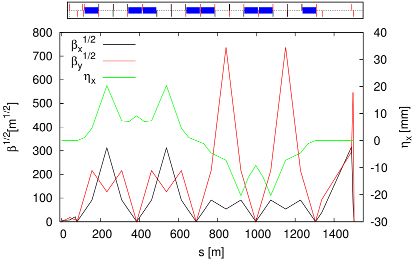
3 TeV Designs

FFS Options

- Local scheme
  ATF2, ILC
  CLIC Nominal



- Nonlocal scheme
  or traditional*
  FFTB,
  CLIC Alternative



* Traditional lattice obtained by H. Garcia Morales, published in Phys. Rev. ST Accel. Beams 17, 101001, 2014

CLIC BDS 3 TeV Design

CLIC CDR - physics and detectors published in 2012

Parameter	**Unit**	Value
Energy	[TeV]	3.0
Length FFS	[m]	447
Maximum energy/beam	[TeV]	1.5
Drift from IP to first quad, L^*	[m]	3.5
Crossing angle at the IP	[mrad]	20
Beta-function at IP, $\beta^*_{x,y}$	[mm]	10,0.07
Emittance @ BDS, $\gamma\epsilon_{x,y}$	[nm]	660,20
Core beam size at IP, $\sigma^*_{x,y}$	[nm]	45,1
Luminosity, $\mathcal{L}_0$	$[10^{34}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}]$	5.9

Lattice version *v_10_10_11.r*1187 available at;
https://svnweb.cern.ch/cern/wsvn/clicsim/trunk/CLIC/Lattices/MainBeam/BDS/v_10_10_11

Tuning Study

Errors

When errors are considered in our models, $\mathcal{L}$ drops by few orders of magnitude

Considered errors:

- Bpm reading error: 10 nm
- Transverse misalignment: 10 μm
- Roll misalignment: 300 μm
- Relative Strength: 10^{-3}

Tuning is the process of bringing the machine to recover the nominal $\mathcal{L}$

Algorithm

Tuning Procedure:

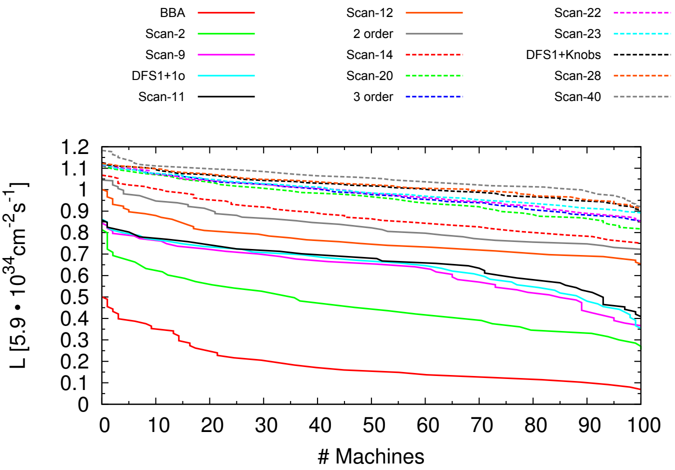
- Perform initial BBA (1-to-1 and DFS correction)
- Align non-linear magnets
- Perform second BBA (DFS correction)
- Scan DFS-knobs
  - 4-Knobs are constructed that correspond to the most important SVD values of the response matrix
- Scan 1^{st} order knobs: waist, coupling and dispersion

Further Steps:

- 2^{nd} & 3^{rd} order knobs are constructed by means of normal/skew sextupole and normal octupole magnets
- Linear and non-linear knobs are iteratively scanned
  - Individually (Parabola fit)
  - Simultaneously (Simplex)
- For machines with $\mathcal{L} \leq 0.8 \cdot \mathcal{L}_0$, DFS beam based alignment is repeated

1 Beam
Results

Tuning Results



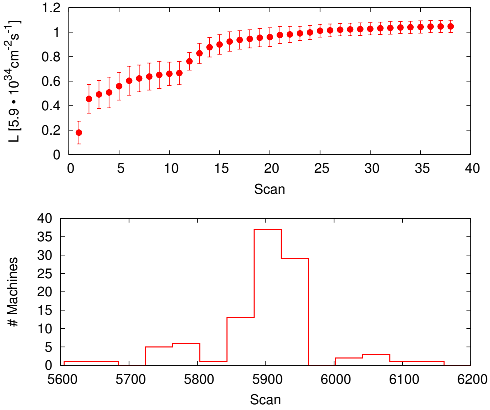
90% of machines reach $\mathcal{L}_0$

$\Downarrow$

Encouraging for the 2-beam tuning!

Number of Iterations

Tuning becomes very slow when $\mathcal{L} \geq 0.8 \cdot \mathcal{L}_0$



Number of luminosity measurements: ≈**5932** ± **416**

2 Beams Results

2 Beams Tuning

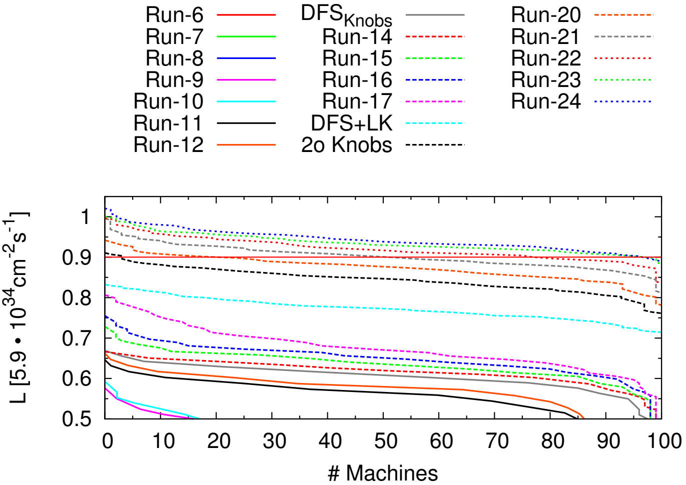
Same tuning knobs are scanned to both systems

The tuning procedure has been slightly modified:

- e^- & e^+ FFS rotated to bring beams into collision
- Same knob is scanned to both beamlines before moving to next knob
- Beam-beam offset is artificially removed (without modifying the angle accordingly)

2 Beam Tuning

- 90% of the systems reach 92% of $\mathcal{L}_0$
- 2-Beam tuning can be treated as a perturbation



CONCLUSIONS
&
PROSPECTS

Conclusions

- 3 TeV local beam tuning has significantly improved since CDR
  - Algorithm
  - Realistic study
  - Better performance in less measurements
  - 2-beam tuning studies at 3 TeV are still ongoing and promising

Single beam: 90 of machines reach $1.0 \cdot \mathcal{L}_0$

Double beam: 90 of machines reach $0.91 \cdot \mathcal{L}_0$

Outlook

- Complete 2 beam study
- Include dynamic errors
  - IP feedback (orbit)
  - Ground motion
  - ...
- Tolerance evaluation

BACK-UP

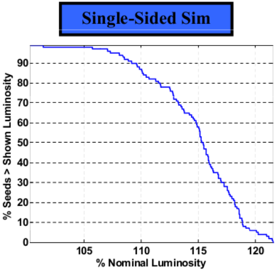
ILC Tuning Study

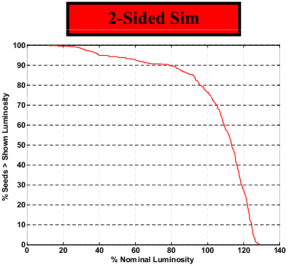
ILC Lattice	L^*	$\gamma\epsilon_x$	β_x^*	σ_x^*	$\gamma\epsilon_y$	β_y^*	σ_y^*
	[m]	[μm]	[mm]	[nm]	[nm]	[mm]	[nm]
RDR	3.5	10	20	639	10	0.4	5.7
TDR	4.1	10	11	474	10	0.48	5.9

Error	Unit	Value
Quad, Sext, Oct xy transverse alignment	μm	200
Quad, Sext, Oct roll alignment	μrad	300
Initial BPM-magnet field center alignment	μm	30
dB/B for Quad, Sext, Octs (RMS)		10^{-4}
Mover resolution	nm	50
BPM resolutions (Quads)	μm	1
BPM resolutions (Sexts)	μm	100
FCMS: Assembly alignment	μm / μrad	200 / 300
FCMS: Relative internal magnet alignment	μm / μrad	10 / 100
FCMS: BPM-magnet initial alignment	μm	30
Corrector magnet field stability (x & y)	%	0.1
Luminosity (pairs measurement or x/y IP sigma measurements)	%	1

2 Beam Tuning

- Added tuning iterations to perform a tuning scan on e^-, then e^+ beam in 1-beam simulation



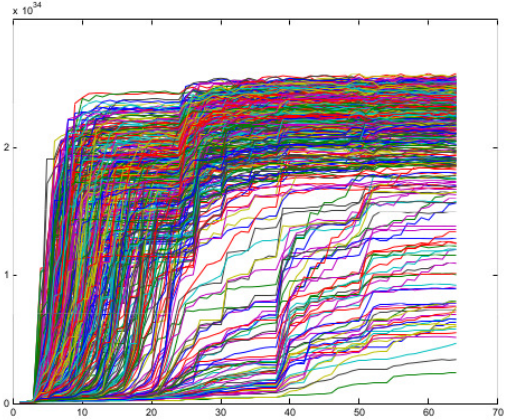


- When simulating both sides 25% of seeds fail to meet design luminosity
- 2-Beam tuning can be treated as a perturbation

Unfortunately, ILC development has been drastically reduced

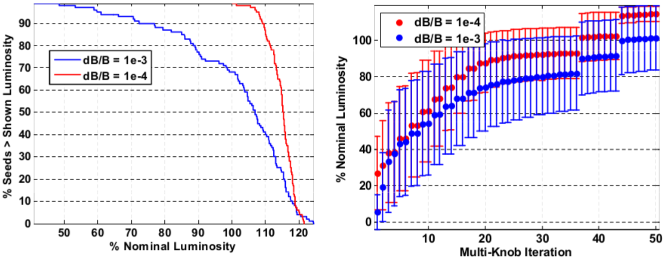
ILC 2-Beam Simulation

- Slower to converge in 2-sided simulation case
- Computation requirements becomes more challenging



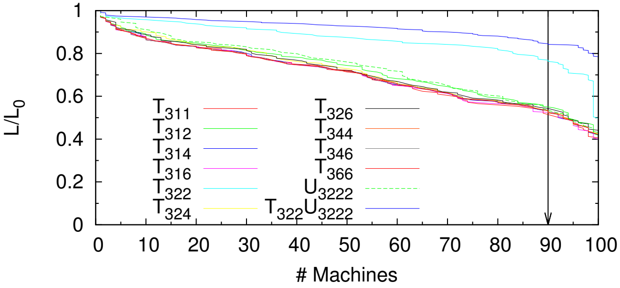
ILC Magnet Strength Error

- Comparison of results with relative absolute RMS errors on all magnets of 10^{-3} and 10^{-4}



ILC High order aberrations

- ILC BDS L*=4 m @ E_{cm}=500 GeV (TDR design)
- Confidence level obtained by "artificially" removing the correlations from the beam distributions

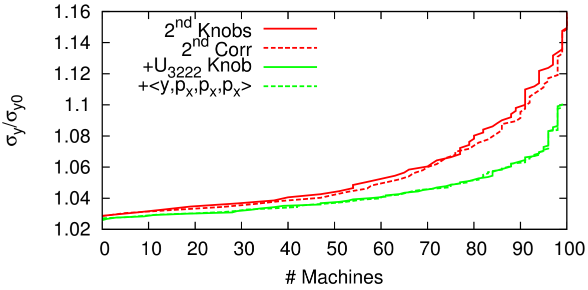


Most present high order aberrations:

$$T_{312},\ T_{322},\ T_{324},\ T_{326} \text{ and } U_{3222}$$

ILC 2^{nd} & 3^{rd} Knobs

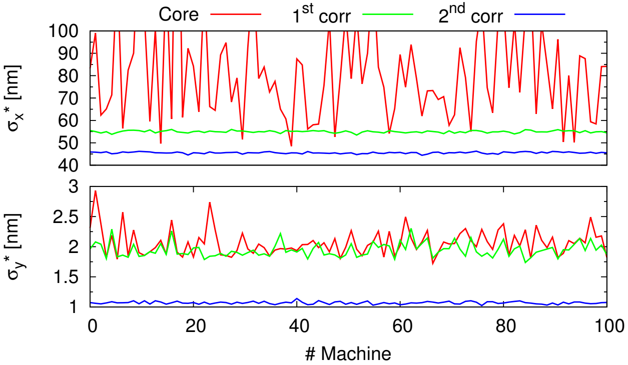
- 2^{nd} order knobs T_{312}, T_{324}, T_{322} and T_{326} are constructed by means of 4 skew sextupoles
- U_{3222} knob is obtained by adding the octupole (OCM10) to the skew sextupoles



Comparable performance is obtained by applying the knobs or "artificially" removing the correlations

CLIC Partial Tuning Results

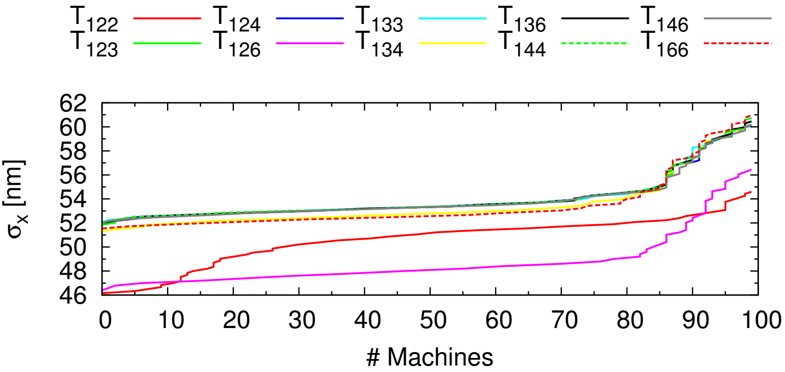
Tuning results obtained after applying the tuning procedure previously described (3 iterations of the linear set of knobs)



- More iterations of the linear knobs are needed for correcting σ_x^*
- Need to design 2$^{\mathrm{nd}}$ order knobs

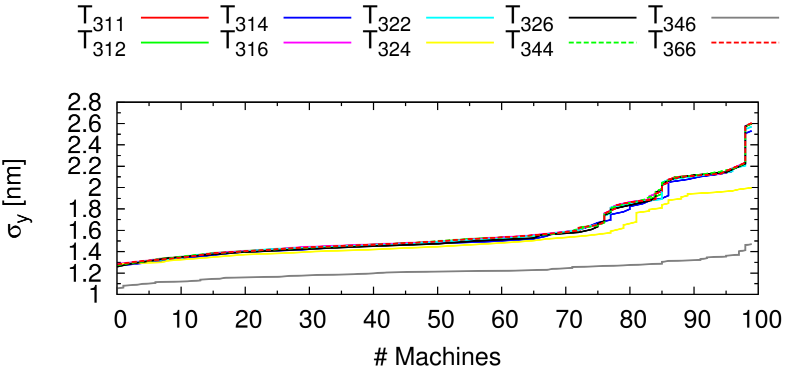
CLIC High order aberrations

Which 2nd order aberrations are the most dominant?



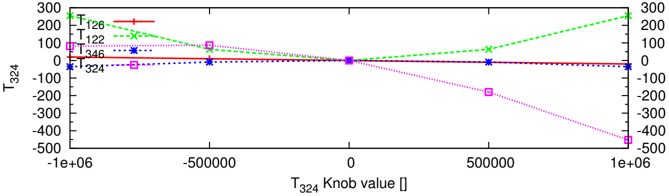
Target aberrations: T_{126} T_{122}

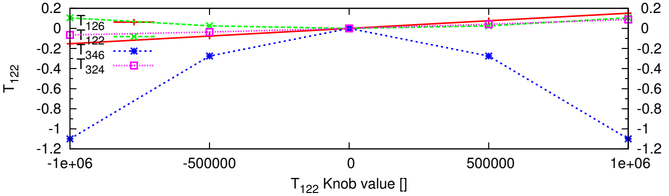
CLIC High order aberrations-II



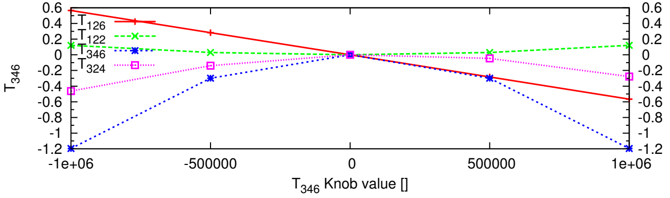
Target aberrations: T_{126} T_{346}

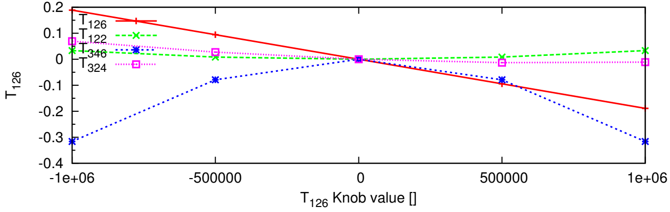
CLIC 2 Order Knobs





CLIC 2 Order Knobs-II





CLIC Tuning Results