Supporting Studies towards CLIC FFS Feasibility

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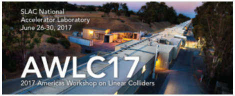
Session: MDI & BDS



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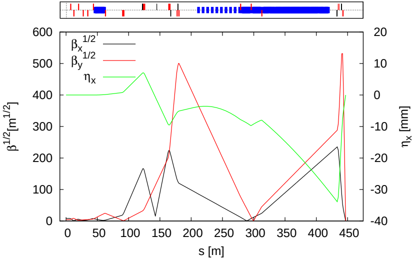
Outline

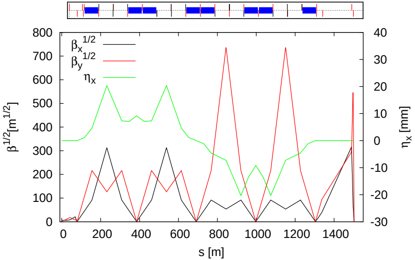
3 TeV Designs

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

Framework

$\mathcal{L}$ drops by few orders of magnitude when errors are included in our CLIC FFS model

Considered errors:

- Bpm reading error: 10 nm
- Transverse misalignment: 10 μm
- Roll misalignment: 300 μm
- Relative Strength: 10^{-4}

Tuning procedure is meant to recover the nominal $\mathcal{L}$

GOAL: **90%** machines reach **110%** $\mathcal{L}_0$

Algorithm

Tuning Procedure:

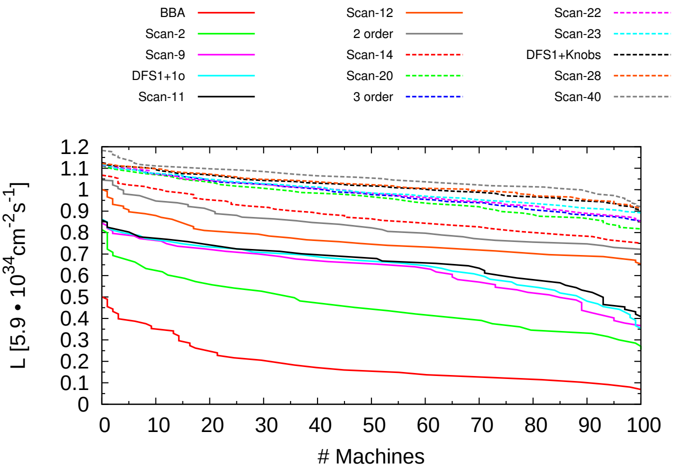
- Perform initial BBA (1-to-1 and DFS corrections)
- Align non-linear magnets
- Perform second BBA (DFS correction)
- Scan DFS-knobs
  - 4-Knobs are constructed that correspond to the most important SVD values of the response matrix
- Scan 1^{st} order knobs: waist, coupling and dispersion

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



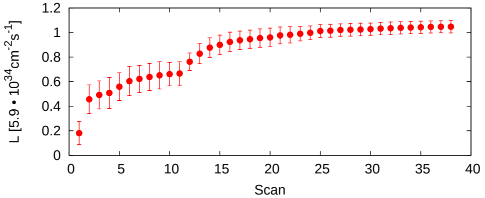
90% of machines reach 100% $\mathcal{L}_0$

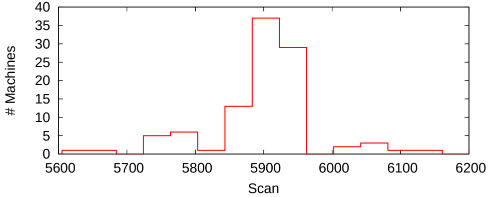
$\Downarrow$

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: $\approx$**5932** $\pm$ **416**

2 Beam Results

2 Beam Tuning

Tuning procedure modifications:

- e^- & e^+ FFS are rotated to bring beams into collision after applying BBA corrections
- Knob * is scanned first to e^- and after to e^+ beamlines before scanning to next knob
  - e^+ tuned beam is smaller than e^- tuned beam
- Beam-beam offset at the IP is removed before collisions (without modifying the angle accordingly)

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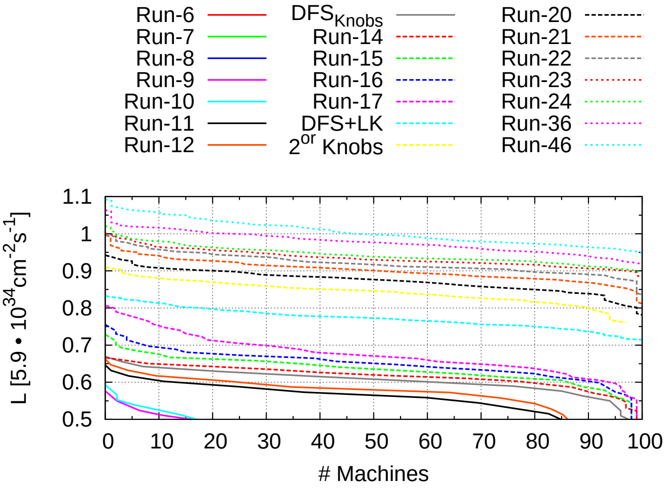
*Same linear and non-linear tuning knobs are scanned

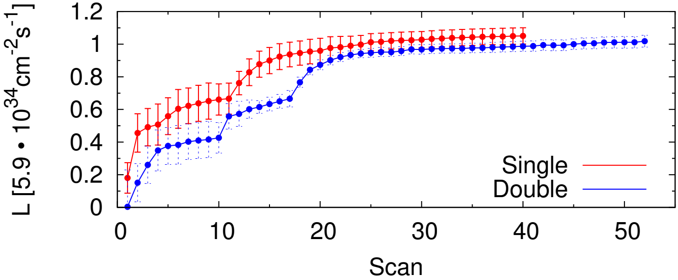
2 Beams Tuning Results

- 90% of the systems reach 97% of $\mathcal{L}_0$
- 2-Beams tuning can be treated as a perturbation



Tuning Comparison

Tuning Comparison



# of iterations (2-beams) is **2.5 times** $\geq$ # iterations (1-beam)

$\Downarrow$

Tuning convergence is ≈ 25 % slower than when treating the $e^- - e^+$ beamlines independently

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

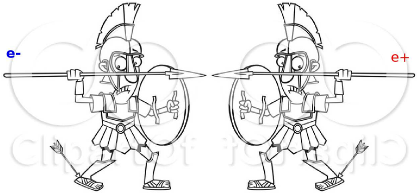
Single beam: 90 of machines reach 100% $\mathcal{L}_0$

Double beam: 90 of machines reach 97% $\mathcal{L}_0$

Outlook

- Complete 2 beam study
- Improve tuning efficiency
  - remove non efficient knobs
  - improve knobs orthogonality
- Include dynamic errors
  - IP feedback (orbit)
  - Ground motion
  - ...
- Tolerance evaluation

Is the FFS Tuning no longer the Achilles heel of CLIC



Thank you for your attention!

BACK-UP

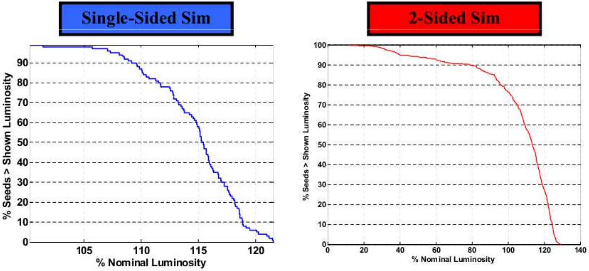
ILC Tuning Study

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

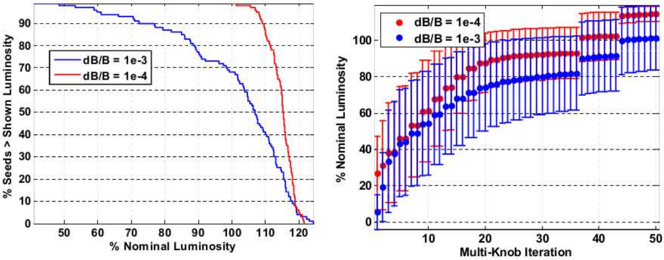


- When simulating both sides 25% of seeds fail to meet design luminosity
- 2-Beam tuning can be treated as a perturbation

Unfortunately, ILC development has been drastically reduced

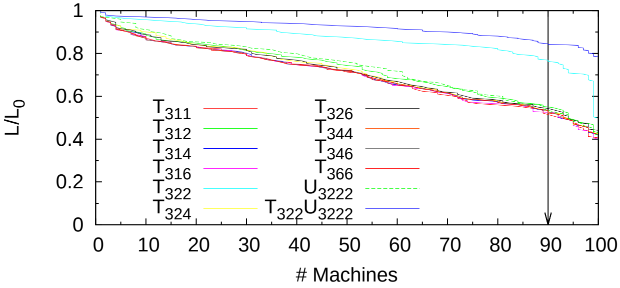
ILC Magnet Strength Error

- 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 @ $E_{\rm cm}$=500 GeV (TDR design)
- Confidence level obtained by "artificially" removing the correlations from the beam distributions

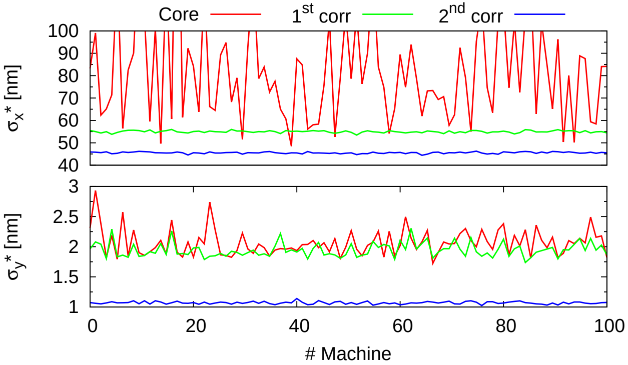


Most present high order aberrations:

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

CLIC Partial Tuning Results

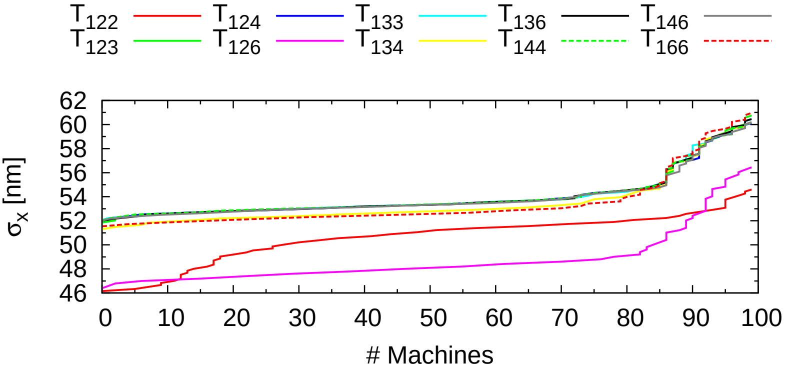
Tuning results obtained after applying the tuning procedure previously described (3 iterations of the linear set of knobs)



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

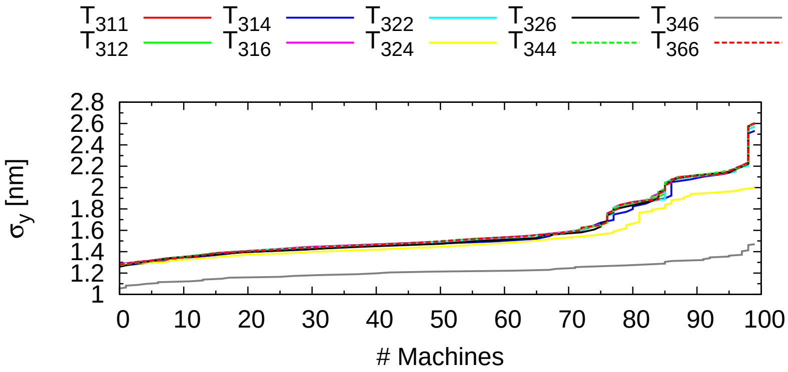
CLIC High order aberrations

Which 2[nd] order aberrations are the most dominant?



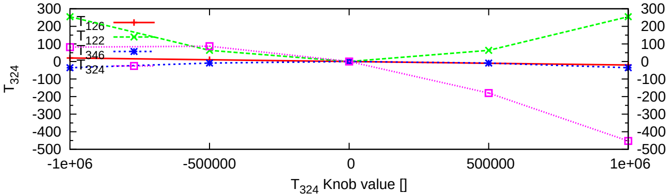
Target aberrations: T_{126} T_{122}

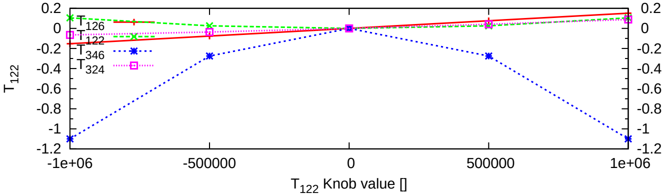
CLIC High order aberrations-II



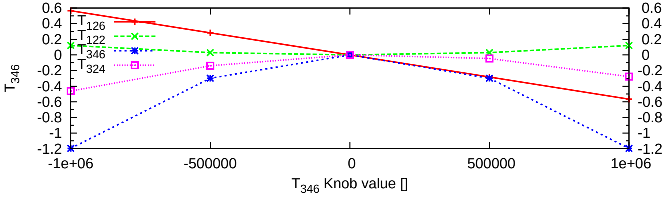
Target aberrations: T_{126} T_{346}

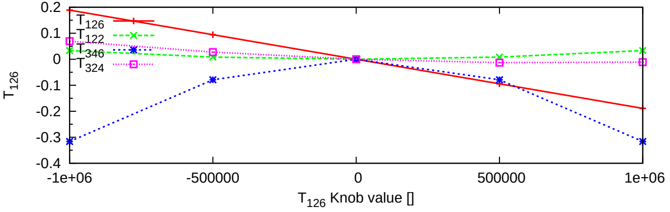
CLIC 2 Order Knobs





CLIC 2 Order Knobs-II

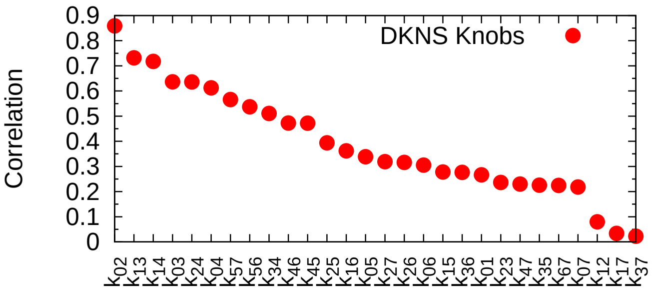




Knobs Correlations-II

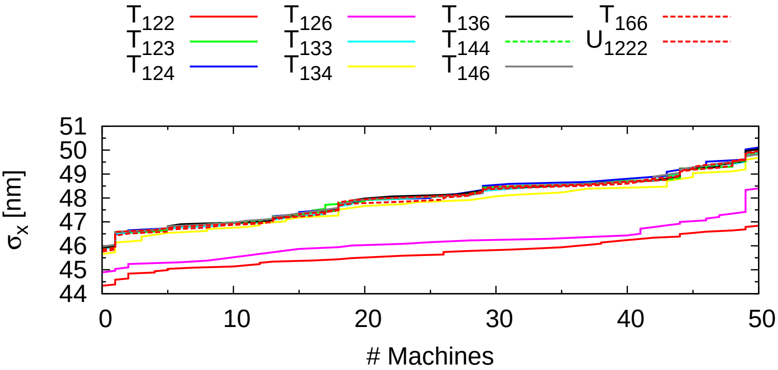
Non-Linear knobs

- Normal sextupoles: T_{126}, T_{122}, T_{116}, T_{346}, T_{166}
- Skew sextupoles : T_{322}, T_{326}, T_{146}



Aberrations

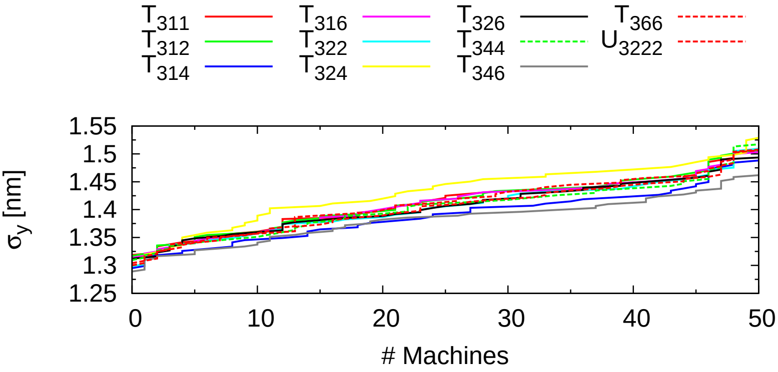
Remaining aberrations in σ_x^* after Run-24$^{\mathrm{th}}$



Still some dominant correlations T_{126}, T_{122}

Aberrations

Remaining aberrations in σ_y^* after Run-24$^{\text{th}}$



Dominant correlations T_{314}, T_{346}