CLIC FFS 2-beam Tuning with GM

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Outline

Tuning Set-up and Imperfections

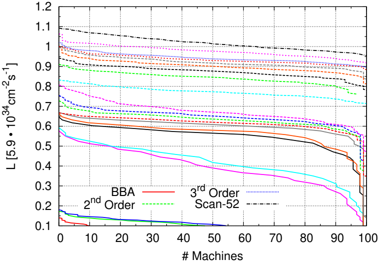
The tuning exams the ideal lattice design against realistic machine imperfections

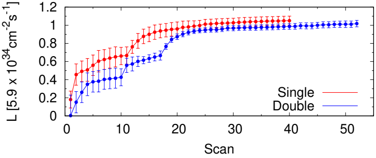
Error	Unit	σ_{error}
e^- & e^+ Treatment	-	Independently
BPM Transverse Alignment	[μm]	10
BPM Roll	[μrad]	300
BPM Resolution	[nm]	10
Magnet Transverse Alignment	[μm]	10
Magnet Roll	[μrad]	300
Magnet Strength	[%]	0.01
Ground Motion	[s]	0.02

Imperfections are randomly distributed on 100 different machines before applying the tuning algorithm⇒

- Beam-Based Alignment Techniques
- Linear Knobs (Transverse sextupole displacements)
- Non-linear Knobs (Strength variation sextupoles)
- Figures of merit: *Orbit* and *Luminosity*

Tuning w/ only Static Imperfections





90 % machines (e^-, e^+) reach 97 % of $\mathcal{L}_0$ after 15000 $\mathcal{L}$ meas
Slow convergence when $\mathcal{L} \geq 80\% \Rightarrow$

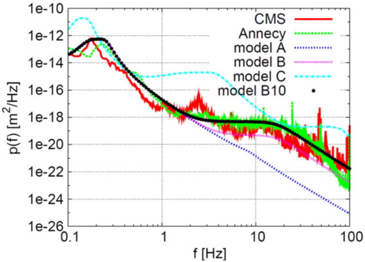
is there any interplay with dynamic imperfections?

* *https://journals.aps.org/prab/abstract/10.1103/PhysRevAccelBeams.21.011003*

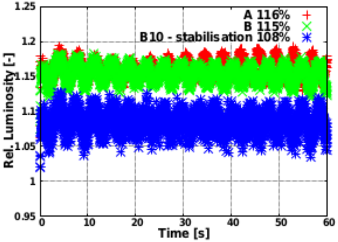
DYNAMIC STUDY
GROUND MOTION

CLIC Stability Requirements

GM models



$\mathcal{L}$ Stability

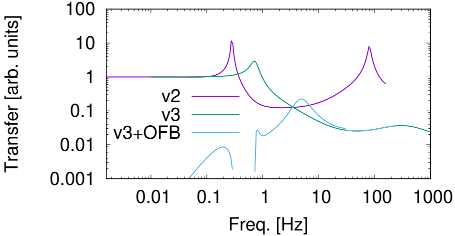


GM counter-measures:

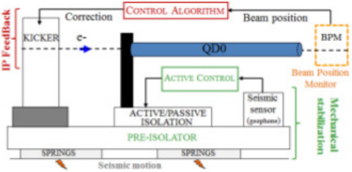
- Active Stabilization System
- Orbit Feed-Back
- Pre-isolator

Stabilization Systems

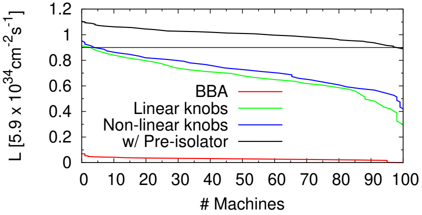
- Stabilization Filter type
  - v2
  - v3
  - v3+Orbit Feed-Back

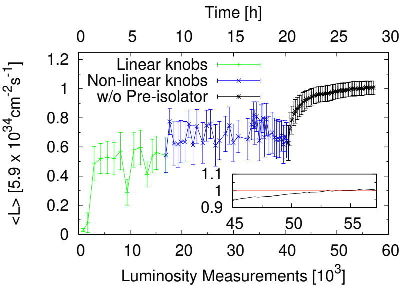


- Pre-isolator:
  - 1: simple version F. Ramos et al.
  - 2: mechanical feedback B. Caron et al.
  - 3: F. Ramos et al. including tilt motion



Results w/o Pre-isolator @ at IPAC18[†]



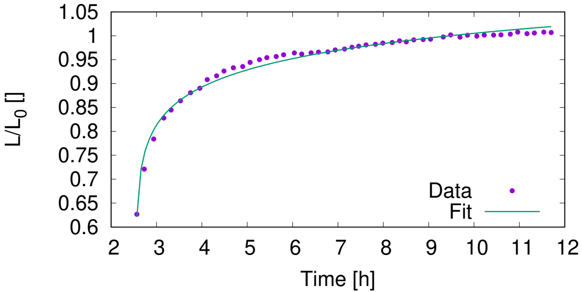


100 % machines $\geq$92 % of $\mathcal{L}_0$
58000 meas.

$\approx$35000 effective measurements
20 hours (2s)

[†] E. Marin et al, "Tuning of CLIC-Final Focus System 3 TeV Baseline Design Under Static and Dynamic Imperfections", IPAC18 - MOPMF043

Tuning Convergence Speed

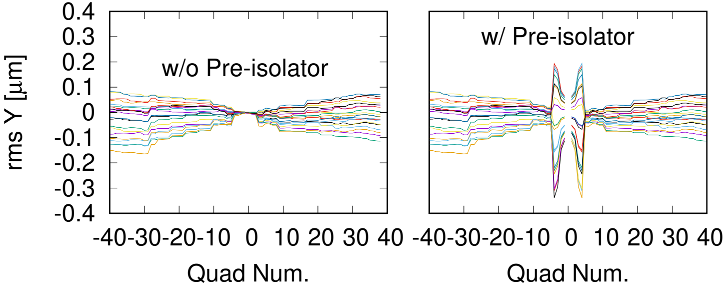


Fitted function: $\mathcal{L}[\mathcal{L}_0](t) = a_0 * log(c_0 * t[h]) + x_0$

$$a_0 = 0.069 \pm 0.002$$
$$c_0 = 7.09 \pm 0.02$$
$$x_0 = 0.731 \pm 0.006$$

Pre-isolator

Motion of the FD quadrupoles un-correlated to the rest of the beamlines



⇓

$\mathcal{L}$-signal jitter is larger than knob improvements

A bug was recently found in the lattice definition (girders definition not compatible with pre-isolator) by C. Gohil

Machine Learning Approach

Latterly we have started a collaboration with Univ. of Malta to use a different approach to tackle the tuning study, **Machine Learning**

- Data containing 100 machines and $\approx$ 1500 parameters/machine
- Neural network with 2 different layers
- Data is split into 80% training and 20% testing
- Five categories
  - Correctors
  - Bending
  - Quadrupoles
  - Multipoles
  - Quads& Mults

First Results: $D_L = \mathcal{L}_{pred} - \mathcal{L}_{tuned}$

Category	$< D_L >$ $[10^{32} cm^{-2} s^{-1}]$	δD_L $[10^{33} cm^{-2} s^{-1}]$
Dipoles	4.19	2.2
Bendings	6.43	2.3
Quadrupoles	2.32	2.3
Multipoles	2.59	2.1
Quads& Mults	2.61	1.8

CONCLUSIONS

Conclusions

CLIC FFS Tuning study has made a notable progress since CDR (2012)

- Imperfections:
  - item Most static imperfections included
  - Ground motion model for first time in tuning
- Procedure: Implementation of second order knobs
- Performance: x3 faster and slightly larger $\mathcal{L}$

90% of machines reached a $\mathcal{L} \geq 92\%\mathcal{L}_0$‡

- The evolution of $\mathcal{L}$ over the range [60% to 100%] has been obtained
- Machine learning approach has been initiated but data set needs to be extended to few (tens) thousands machines

‡Convergence almost achieved

FUTURE WORK

Improvements

- Correct implementation of the pre-isolator

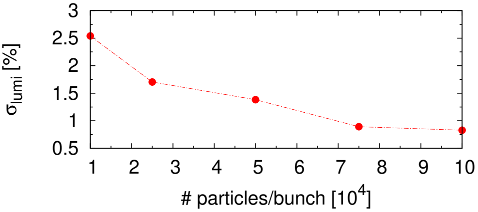
  $\Downarrow$

  Reduce jitter on lumi signal $\Rightarrow$ improve performance
- Increase time lapse between luminosity measurements to few seconds (*0.02s at the moment*)
- Realistic luminosity signal
- Additional imperfections
- Knobs (orthogonality and/or non-effective)
- Tuning procedure: target smallest $\sigma^*_{e^+,e^-}$, IP feed-back
- Need to reduce the computational time
  - Particle tracking
  - Ground Motion evaluation
  - Luminosity calculation
- Machine learning output? could be of use at initial/intermediate/final tuning stages

BACK UP

Computational Time

- $< \mathcal{L} >$ should be computed as the average of $\mathcal{L}$ over Δt
- Bunch Population is linked to $\mathcal{L}$ precision
  - Minimum 10^5 particles/beam required for last tuning scans



Need to reduce computing time

- Particle tracking
- Ground Motion evaluation
- Luminosity calculation

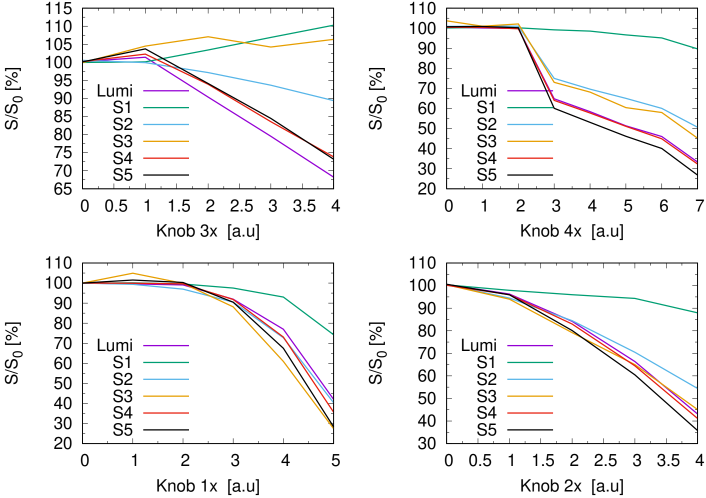
Considered Signals

Signals generated by Guinea-Pig through collision of 10^6 particles per beam

- Luminosity
- Number of Photons (beam1)
- Number of Photons (beam2)
- Number of Coherent
- Number of Pairs
- Number of Hadrons

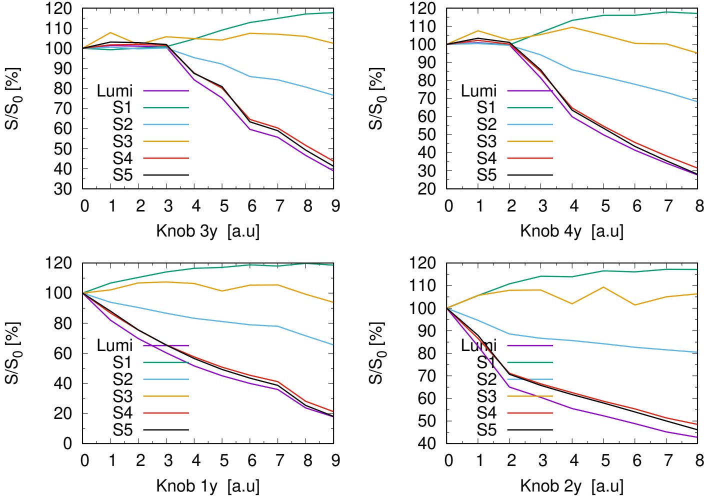
Considered Signals

X - Linear Knobs (Mapclass)



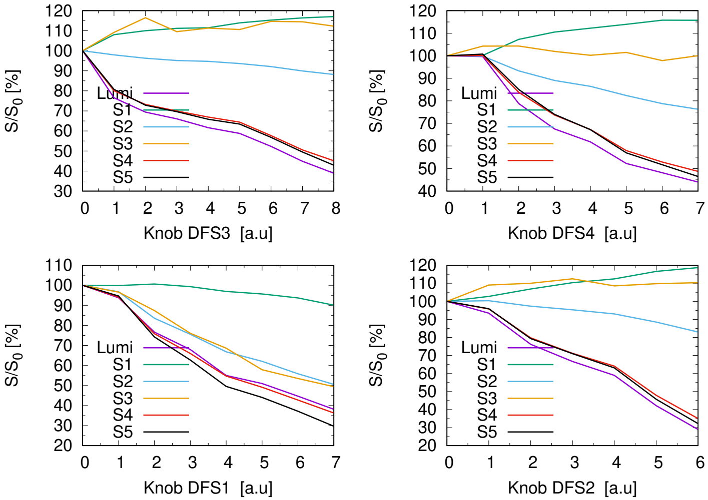
Considered Signals

Y - Linear Knobs (Mapclass)



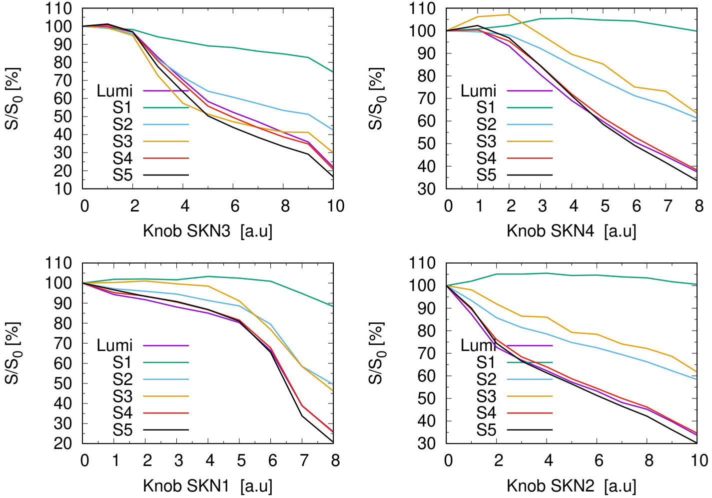
Considered Signals

Dispersion-Free-Steering Knobs - Octave



Considered Signals

Normal Sextupoles - Non-Linear Knobs - Mapclass



Considered Signals

Skew Sextupoles - Non-Linear Knobs - Mapclass