ML Modeling of Luminosity for FFS Tuning

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CLIC Week 2019 - Accelerator Session

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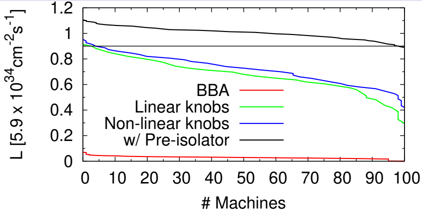
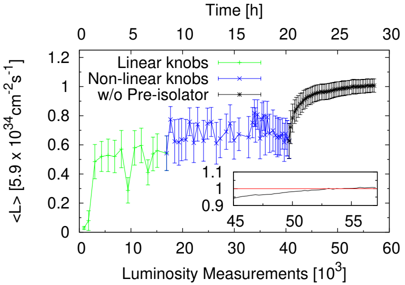
Outline

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





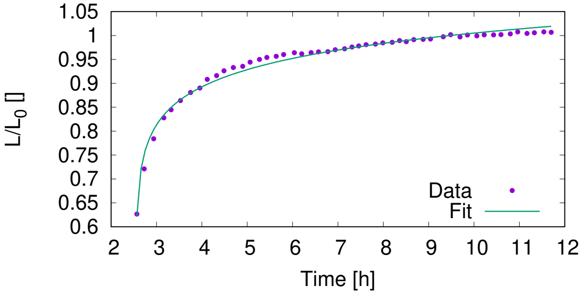
Tuning algorithm is based on knobs (dfs, linear and non-linear)

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

$\approx$35000 effective measurements

[†] "Tuning of CLIC-Final Focus System 3 TeV Baseline Design Under Static and Dynamic Imperfections", *IOP Conf. Series: Journal of Physics: Conf. Series 1067 (2018) 022014.*

Tuning Speed



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

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

$\Delta\mathcal{L} \approx \frac{1}{t}$ $\Rightarrow$ slow when approaching $\mathcal{L}_0$

Strategy

How can we reduce the number of measurements?

- Improve the knobs orthogonality (continue with the current procedure)
- Obtain "advanced knobs" based on patter recognition

In this sense **Machine Learning** has a great potential to be applied on tuned machines to identify relevant system features that could drastically shortcut the tuning procedure
It is currently being applied in different fields, being accelerators one of the most popular...

- So far only 100 colliders tuned at a level of $\mathcal{L}_0$
- Machine imperfections add up to $\approx$ 1500 parameters/machine

Machine Learning Approach

- Data is split into 80% training and 20% testing
- Neural network with 2 different layers
- 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 $[10^{33} cm^{-2} s^{-1}]$
Correctors	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

Prospect

The current CLIC FFS 3 TeV Tuning study considers a 2-beam system under static and dynamic imperfections, most CLIC realistic scenario studied so far

The implemented tuning algorithm is

- satisfactory in terms of final luminosity
  90% of machines reached a $\mathcal{L} \geq 92\%\mathcal{L}_0$
- but convergence speed is to slow
  $\approx$ 35000 measurements

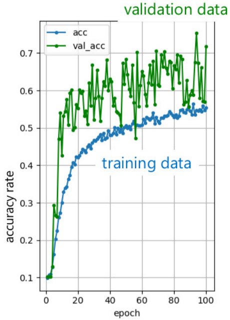
Machine learning approach has been initiated

- preliminary results have been obtained but
- data needs to be extended to few (tens) thousands machines

Further Collaboration

Y. Kobayashi *et al*. from Tohoku Univ. are studying the feasibility of a **pair-production monitor for the ILC using Deep Learning** ‡

- 500 hit distributions (images of σ_y^*)
- Machine Learning (NN) and Deep Learning (DNN) are considered
- accuracy 60%-70%



They are interested in collaborating with us

‡ https://agenda.linearcollider.org/event/7889/timetable/

BACK UP

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$\Rightarrow$

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