New Tuning Techniques for CLIC

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Outline

1. Algorithm
2. Scan Method
3. Multi Scan
4. CONCLUSIONS

Algorithm

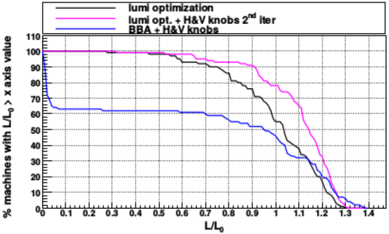
Tuning Results

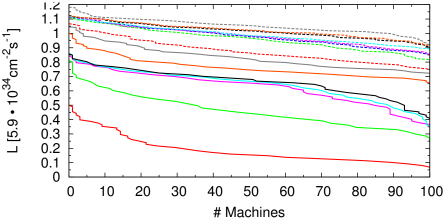
2012:

90% machines
90% $\mathcal{L}_0$
$\Downarrow$
100% $\mathcal{L}_0$

iter
18000
$\Downarrow$
6000

2016:



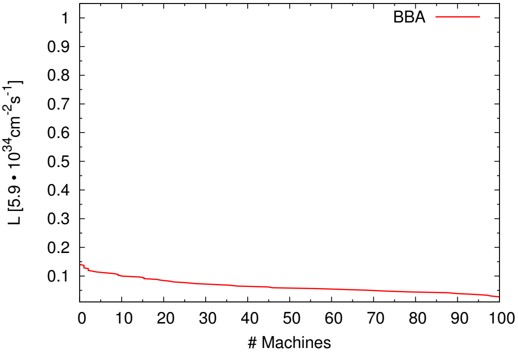


Strategy

Results

After applying;

- 1-to-1 Steering
- Dispersion Free Steering

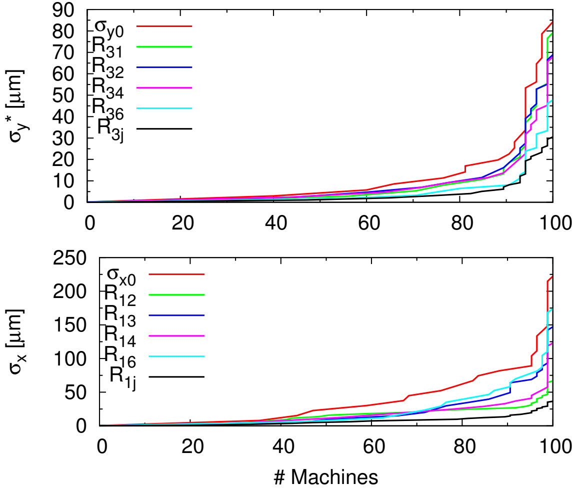


Aberrations

1^{st} order correlations are the most dominant e.g.;

$R_{12} \approx \alpha_x$

$R_{36} \approx \eta_y$



Linear Knobs-I

FFS Sextupoles SF6, SF5, SD4, SF1, SD0:
To construct knobs for α_x^*, α_y^* and η_x^* we use;

$$M_x = \begin{pmatrix} \frac{\partial\beta_x^*}{\partial x_{\mathrm{SF6}}} & \frac{\partial\beta_x^*}{\partial x_{\mathrm{SF5}}} & \frac{\partial\beta_x^*}{\partial x_{\mathrm{SD4}}} & \frac{\partial\beta_x^*}{\partial x_{\mathrm{SF1}}} & \frac{\partial\beta_x^*}{\partial x_{\mathrm{SD0}}} \\ \frac{\partial\alpha_x^*}{\partial x_{\mathrm{SF6}}} & \frac{\partial\alpha_x^*}{\partial x_{\mathrm{SF5}}} & \frac{\partial\alpha_x^*}{\partial x_{\mathrm{SD4}}} & \frac{\partial\alpha_x^*}{\partial x_{\mathrm{SF1}}} & \frac{\partial\alpha_x^*}{\partial x_{\mathrm{SD0}}} \\ \frac{\partial\beta_y^*}{\partial x_{\mathrm{SF6}}} & \frac{\partial\beta_y^*}{\partial x_{\mathrm{SF5}}} & \frac{\partial\beta_y^*}{\partial x_{\mathrm{SD4}}} & \frac{\partial\beta_y^*}{\partial x_{\mathrm{SF1}}} & \frac{\partial\beta_y^*}{\partial x_{\mathrm{SD0}}} \\ \frac{\partial\alpha_y^*}{\partial x_{\mathrm{SF6}}} & \frac{\partial\alpha_y^*}{\partial x_{\mathrm{SF5}}} & \frac{\partial\alpha_y^*}{\partial x_{\mathrm{SD4}}} & \frac{\partial\alpha_y^*}{\partial x_{\mathrm{SF1}}} & \frac{\partial\alpha_y^*}{\partial x_{\mathrm{SD0}}} \\ \frac{\partial\eta_x^*}{\partial x_{\mathrm{SF6}}} & \frac{\partial\eta_x^*}{\partial x_{\mathrm{SD0}}} & \frac{\partial\eta_x^*}{\partial x_{\mathrm{SD4}}} & \frac{\partial\eta_x^*}{\partial x_{\mathrm{SF1}}} & \frac{\partial\eta_x^*}{\partial x_{\mathrm{SD0}}} \end{pmatrix}$$

Linear Knobs-II

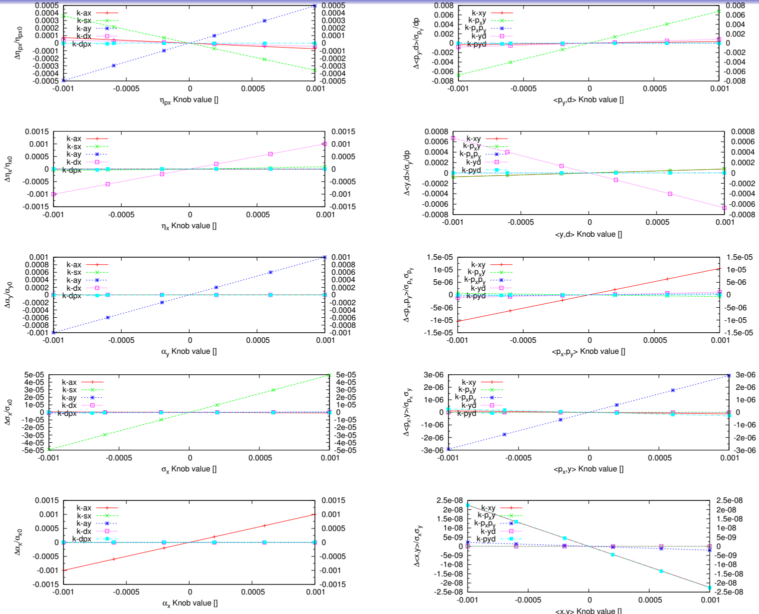
FFS Sextupoles SF6, SF5, SD4, SF1, SD0:

To construct knobs for we use;

$< x, y >$, $< p_x, y >$, $< p_x, p_y >$, η_y^* and $\eta_y^{*'}$

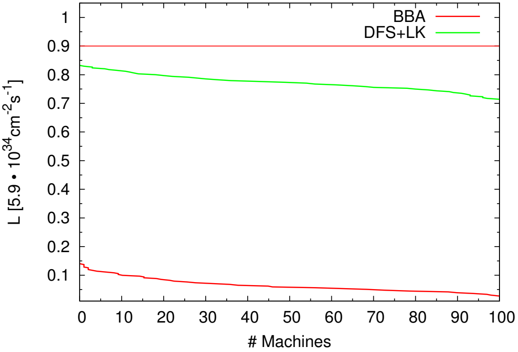
$$M_y = \begin{pmatrix} \frac{\partial <x,y>}{\partial y_{\mathrm{SF6}}} & \frac{\partial <x,y>}{\partial y_{\mathrm{SF5}}} & \frac{\partial <x,y>}{\partial y_{\mathrm{SD4}}} & \frac{\partial <x,y>}{\partial y_{\mathrm{SF1}}} & \frac{\partial <x,y>}{\partial y_{\mathrm{SD0}}} \\ \frac{\partial <p_x,y>}{\partial y_{\mathrm{SF6}}} & \frac{\partial <p_x,y>}{\partial y_{\mathrm{SF5}}} & \frac{\partial <p_x,y>}{\partial y_{\mathrm{SD4}}} & \frac{\partial <p_x,y>}{\partial y_{\mathrm{SF1}}} & \frac{\partial <p_x,y>}{\partial y_{\mathrm{SD0}}} \\ \frac{\partial <p_x,p_y>}{\partial y_{\mathrm{SF6}}} & \frac{\partial <p_x,p_y>}{\partial y_{\mathrm{SF5}}} & \frac{\partial <p_x,p_y>}{\partial y_{\mathrm{SD4}}} & \frac{\partial <p_x,p_y>}{\partial y_{\mathrm{SF1}}} & \frac{\partial <p_x,p_y>}{\partial y_{\mathrm{SD0}}} \\ \frac{\partial \eta_y^*}{\partial y_{\mathrm{SF6}}} & \frac{\partial \eta_y^*}{\partial y_{\mathrm{SF5}}} & \frac{\partial \eta_y^*}{\partial y_{\mathrm{SD4}}} & \frac{\partial \eta_y^*}{\partial y_{\mathrm{SF1}}} & \frac{\partial \eta_y^*}{\partial y_{\mathrm{SD0}}} \\ \frac{\partial \eta_y^{*'}}{\partial y_{\mathrm{SF6}}} & \frac{\partial \eta_y^{*'}}{\partial y_{\mathrm{SF5}}} & \frac{\partial \eta_y^{*'}}{\partial y_{\mathrm{SD4}}} & \frac{\partial \eta_y^{*'}}{\partial y_{\mathrm{SF1}}} & \frac{\partial \eta_y^{*'}}{\partial y_{\mathrm{SD0}}} \end{pmatrix}.$$

Linear Knobs-III



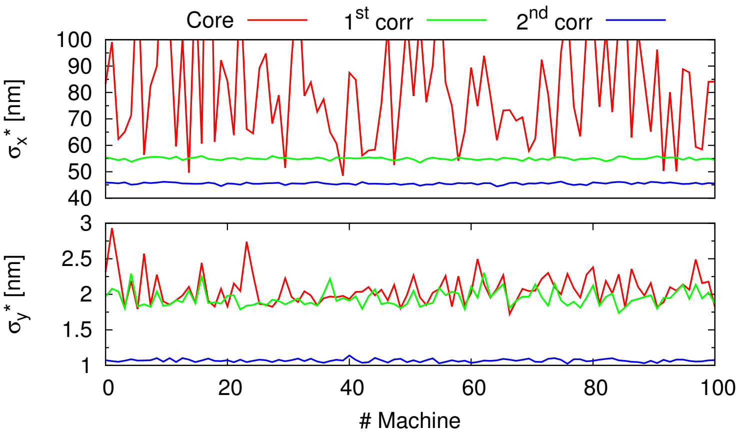
Results

After Scanning linear knobs iteratively;



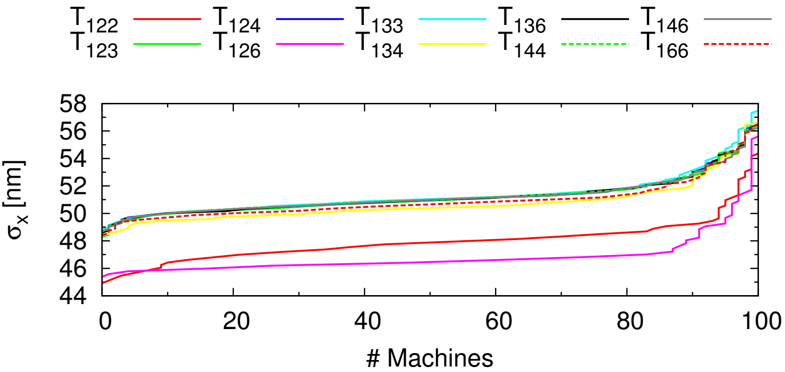
Beam sizes

IP beam size orders



Aberrations

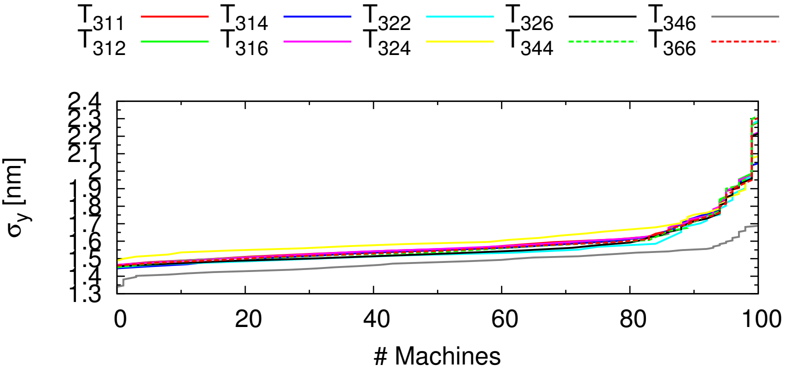
Most dominant aberrations in σ_y^*



Most important aberrations : T_{126} and T_{122}

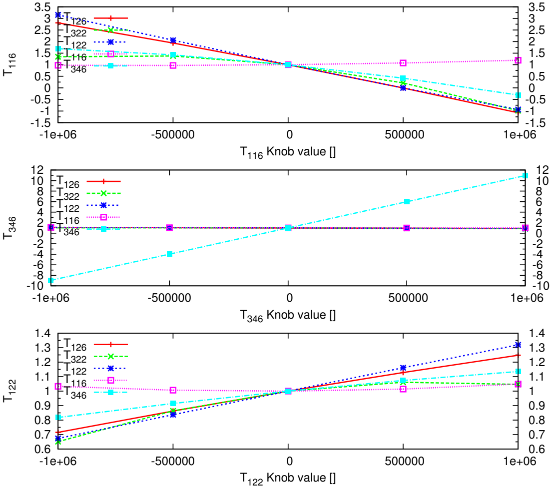
Aberrations

Most dominant aberrations in σ_y^*

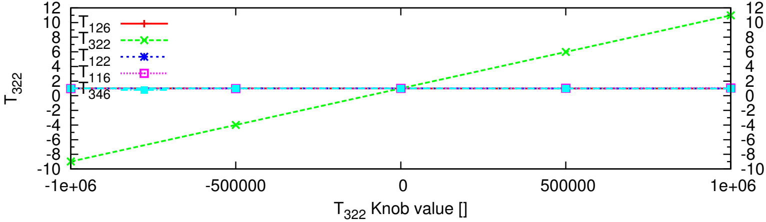


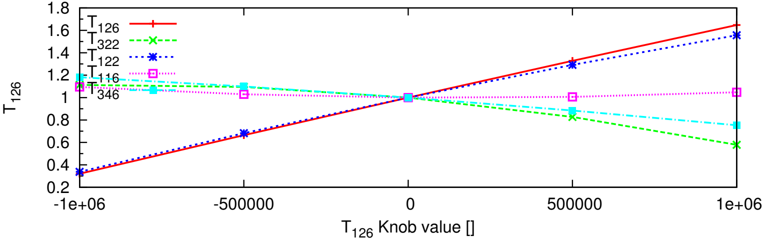
Most important aberrations : T_{346} and T_{322}

CLIC 2 Order Knobs



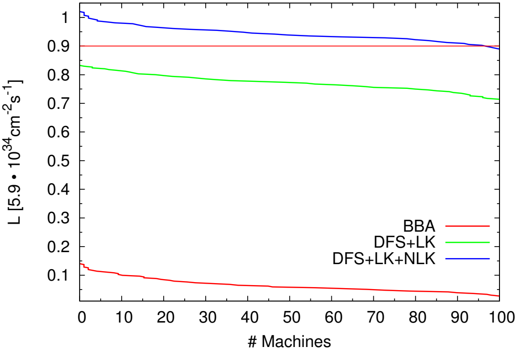
CLIC 2 Order Knobs-II





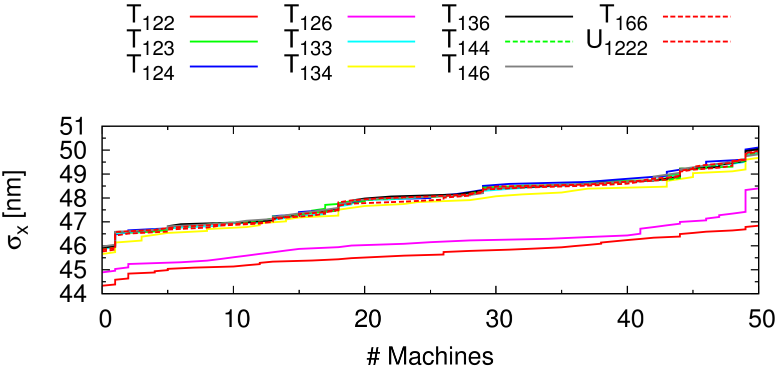
Results

After Scanning linear, second and third order knobs iteratively;



Algorithm

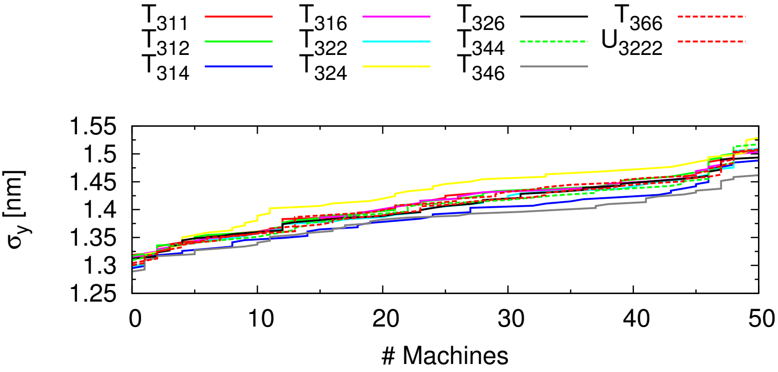
Remaining aberrations in σ_x^*



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

Algorithm

Remaining aberrations in σ_y^*



Dominant correlations T_{314}, T_{346}

Knobs Optimization

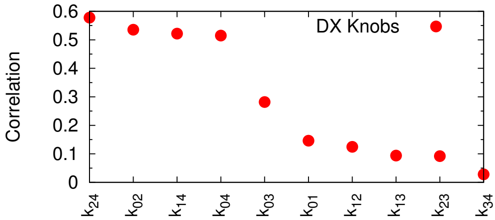
Multiple Knob Scan

- Instead of scanning the knobs 1 by 1, knobs are scanned simultaneously
- Advantageous for non fully orthogonal knobs
- Scanning time reduction over a few iterations

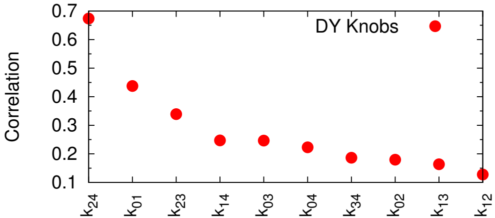
Knobs Correlations-I

Linear knobs

- x-displacements: R_{12}, R_{34}, R_{16}, R_{11}, R_{33}



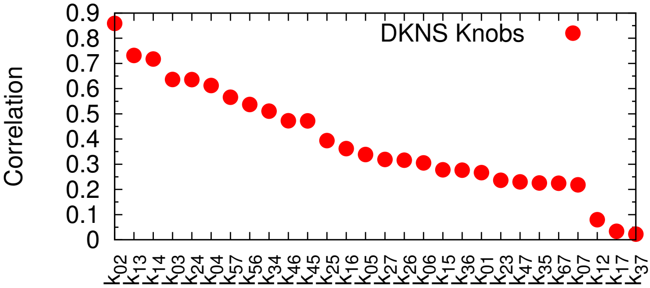
- y-displacements: R_{13}, R_{24}, R_{23}, R_{36}, R_{46}



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}



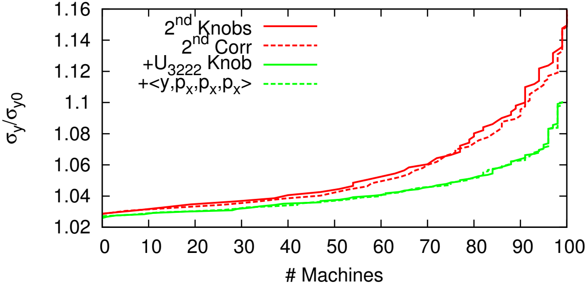
CONCLUSIONS

Conclusions

- Tuning results strongly depend on implemented algorithm
- Simplex
  - For large number of variables it does not provide best results
    - Luminosity
    - Iterations
  - It is a partial blind approach
- Knobs
  - For large number of variables it has provided best results
  - Target effective if suitable magnets are available
  - Knobs may be non-fully orthogonal
    - Scan of multiple knobs can provide some inside regarding correlations
    - Multi-knob may be constructed, if strong correlations are found
    - Which may lead to a tuning time reduction

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 Tuning Results