# Long $L^*$ FFS optimization status for CLIC and plans for ILC

Fabien Plassard

University Paris Sud, France
CERN, Switzerland

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# outline

1. CLIC FFS stages status L* = 6 m
   - BDS and MDI studies for CLIC 3 TeV c.o.m
2. ILC FFS long L* plans
   - FFS design strategy
3. Conclusions

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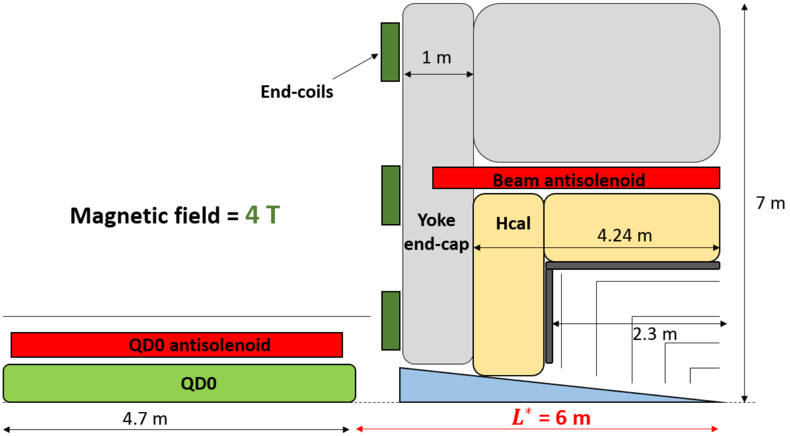
   - FFS design strategy
3. Conclusions

- New detector model with QD0 in the tunnel and without push-pull




- In order to remove QD0 from the detector $L^*$ have been estimated to be **6 m**

- An antisolenoid in the old QD0 region (to protect the beam) is needed
- The stray field towards the BDS (and therefore at QD0) can be significantly reduced by end coils, but the power consumption of those could become a limiting factor (2.2 MW). Depending on the outcome of this study, an outer antisolenoid protecting QD0 may have to be designed , but in this location space is no longer a major issue. This one is completely independent of the inner anti-solenoid.
- The impact of forward acceptance on the physics performance is currently study. However it was pointed that the gain in foward acceptance will be limited due to the sharp rise of backgrounds towards the beam axis.
- Position and support of the IP-feedback system. IP feedback does not necessarily move with QD0. On the contrary, the latency would increase by 7 ns per meter and therefore with 6 m distance to the IP the number of corrections would be reduced from 3 to 2. This in turn would lead to loss of luminosity.
- With all these inputs all MDI elements need to be positioned and supported.

- define parameters of QD0 (length, gradient, aperture) for anti-solenoid design and MDI elements position and support
- Then define performances: luminosity, tunability, prealignment constraints
- QD0 must remain light for reasons of stabilisation but length has been increased as the FFS length has been scaled for $L^* = 6$ m.
- QD0 is forseen to be divided in 3 parts to facilitate the magnet design, probably mounted on a common rigid support that will be prealigned and stabilised. Recent optimization have shown no difference in performance with QD0 divided in 3 parts separated by 10 cm.

## Current performances of CLIC 3 TeV FFS with $L^*$ = 6 m

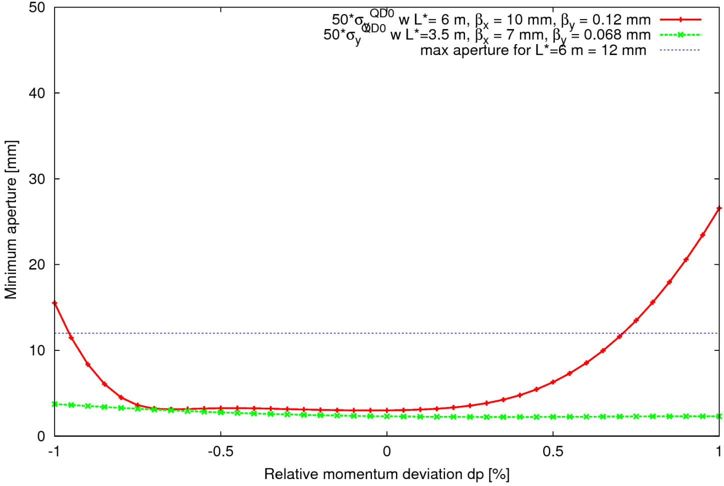
### (preliminary) QDO Parameters for CLIC 3 TeV & $L^*$=6 m

| Parameter | Unit | CLIC 3 TeV ($L^*$=3.5 m) | CLIC 3 TeV ($L^*$= 6 m) |
|---|---|---|---|
| *Bunches per train* | | 312 | 312 |
| *Bunch population* | $10^9$ | 3.72 | 3.72 |
| *Repetition rate* | Hz | 50 | 50 |
| *Hor. Norm. emittance* | µm | 0.66 | 0.66 |
| *Ver. Norm. emittance* | nm | 20 | 20 |
| *Hor. Beta at IP* | mm | **7** | **10** |
| *Vert. Beta at IP* | mm | **0.07** | **0.12** |
| *Hor. beam size at IP* | nm | **40** | **47.4** |
| *Ver. Beam size at IP* | nm | **0.7** | **0.9** |
| *Bunch length* | µm | 44 | 44 |
| *Energy spread (rms)* | % | 1 | 1 |
| *Total Luminosity* | $10^{34}\mathrm{cm^{-2}s^{-1}}$ | **5.9** | **5.9** |

| Parameter calculated | Unit | CLIC 3 TeV ($L^*$=3.5 m) | CLIC 3 TeV ($L^*$= 6 m) |
|---|---|---|---|
| $\sigma_x^*$ *(10th order)* | nm | 40 | **49** |
| $\sigma_y^*$ *(10th order)* | nm | 1 | **1.06** |
| *Total Luminosity (SR)* | $10^{34}\mathrm{cm^{-2}s^{-1}}$ | 6.9 | **5** |
| *Peak Luminosity (SR)* | $10^{34}\mathrm{cm^{-2}s^{-1}}$ | 2.5 | **2.1** |

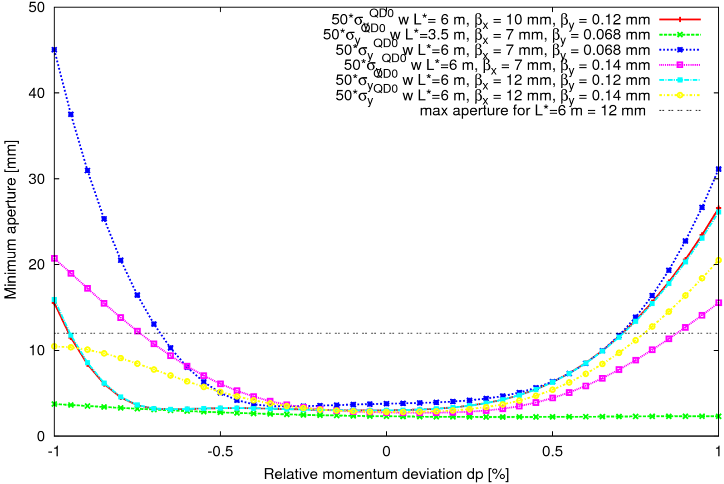
**QDO with $L^*$ = 6 m**

- Minimum aperture needed = max($14\sigma_x^{QD0}$; $55\sigma_y^{QD0}$)
  ⇨ Ap = 3.5 mm (radius w/o beam pipe) **(dp=0)**
- For **dp=-1%,** Ap < 10 mm but for **dp=+1%,** Ap = 25 mm — *Must be relaxed*
- $k_1$ = -0.0394 $\mathrm{m^{-2}}$
- Gradient = -196,77 T/m
- **Bmax = 1.97 T** with **Ap = 10 mm**
  **Bmax = 5 T** with **Ap = 25 mm**
- The FFS needs further optimization to keep QD0 aperture around 10 mm




The current main issue for CLIC FFS with $L^* = 6$ m is the blow up of the beam at QD0 while considering beam energy deviation up to ± 1%. beam size increases rapidly with increasing momentum deviation. Keeping 50 $\sigma$ aperture this leads to a large aperture for QD0. This limits the possible gradient. Increasing the beta function at the IP helps a bit, but further optimisation is required, keeping in mind also the cost in luminosity.

3 different studies are under invesyigation to solve the QD0 aperture problem:




- $\beta^*$ optimization $\rightarrow$ varying $\beta^*$ in order to relaxe $\beta^{QD0}$ and thus QD0 beam size

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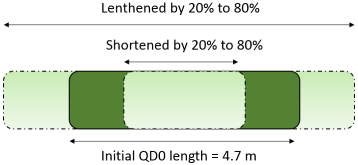
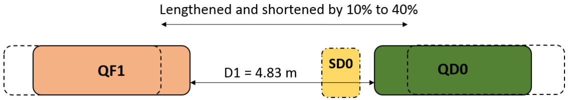



- Optimizing QD0 length (initially = 4.7 m for $L^*$ = 6 m) by shortened and lengthened the magnet and see the impact on QD0 beam size. 8 different lattices are being optimized in parallel with QD0 shortened and lengthened by 20%, 40%, 60% and 80%




- Optimization of QF1 $L^*$ or the distance between QF1 and QD0 can have an impact on chromaticity generated by the FD but also on the beam size at QD0 and thus on QD0 aperture. 8 different lattices are being optimized with the distance between QD0 and QF1 shortened and lengthened by 10%, 20%, 30% and 40%

# outline

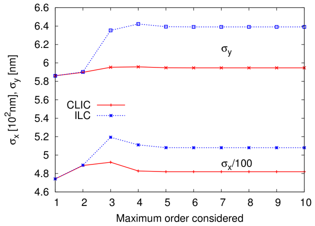
- Long $L^*$ studies have started for ILC FFS based on the traditional design and must be deepened in further optimizations

- The plan is now to focus on the local scheme with $L^* = 6$ m for ILC with the same current design optimization strategy applied for CLIC

- Profit from the studies currently performed for CLIC long $L^*$ option from the MDI side (detector layout, MDI elements positions, stray field calculation, IP feedback study, etc.) and from BDS side ($L^* = 6$ m FFS optimizations) as the interaction region for CLIC and ILC are similiar

- What would be the impact (on the minimal $L^*$, stray fields and MDI layout) of moving QD0 in the tunnel assuming that we keep the current push-pull system with ILD and SiD detectors?

- Previous studies from Hector Garcia Morales[1] on ILC FFS optimization have shown that a CLIC-based FFS using ILC parameters gives better performances (for $L^* = 3.5m$) with a shorter FFS.




| Parameter | ILC | CLIC-based |
|---|---|---|
| Length [m] | 735 | 553 |
| $\beta_x^*/\beta_y^*$ [mm] | 11/0.48 | 11/0.48 |
| $\sigma_x^{core}$ [nm] | 503.0 | 483.7 |
| $\sigma_y^{core}$ [nm] | 6.09 | 5.89 |
| $\mathcal{L}_T$ $[10^{34}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}]$ | 1.38 | 1.47 |
| $\mathcal{L}_{1\%}$ $[10^{34}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}]$ | 0.86 | 0.89 |

- As CLIC 500 GeV with $L^* = 6m$ has not been optimized yet, the same comparison study is forseen for ILC with both local FFS lattices

[1] *"Comparative study of Final Focus Systems for CLIC and other luminosity ehancement studies for future linear colliders"* CERN-THESIS-2014-230

# Summary

- A working group actively studying the design of a new detector model for CLIC with QD0 in tunnel in order to evaluate the benefits and drawbacks of this configuration and estimate the gain in forward acceptance and the loss of luminosity
- This study takes into account the impact of the main solenoid field on QD0 in the tunnel and on the beam inside the detector in order to design two independent anti-solenoid, the impact and the limit of foward acdceptance on physics performance, the impact on IP-feedback performance and also position and support of the MDI elements
- From a BDS point of view the goal is to optimize the luminosity with $L^*$ = 6 m taking into account the constraints on the optics in terms of maximum B-field, aperture, stabilisation and tunability to avoid additional loss of luminosity
- Many optimization are currently running in order to reduce QD0 aperture as a blow-up on the beam size has been observed at this location for high beam energy deviation (± 1%) $\longrightarrow$ evaluation of the optimal $\beta^*$, optimal QF1 $L^*$ and optimal QD0 length with the aim to provide feasible optics while keeping the luminosity close to the design performances
- All these studies on CLIC long $L^*$ from detector and BDS sides will **profit to a possible long $L^*$ option feasibility study for ILC** as the interaction regions of both colliders are similar
- In parallel with CLIC FFS study, the ILC 500 GeV FFS will be optimized for $L^* = 6m$ based on local design with a comparison between ILC FFS and CLIC-based FFS performances. Then further optimizations are forseen for the traditional design.