Rebaselining and long L* study for CLIC and ATF2

BDS designs optimization from 380 GeV to 3 TeV with L*=6 m for CLIC

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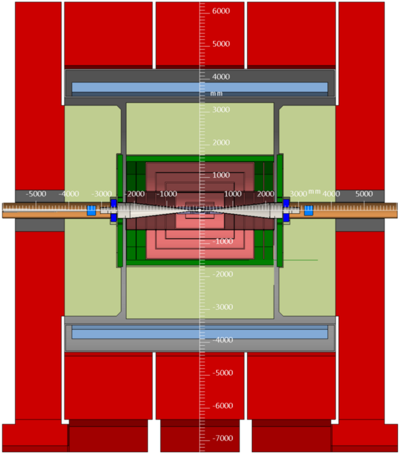
OUTLINES

Long L* design and new CLIC detector design

Motivations : Remove QD0 from the influence of the detector vibrations and solenoid field and increase space inside the experiment ⇒ No interplays between QD0 and solenoid fields, reduce QD0 vibrations, ease stabilization and design of the IR (No integration of QD0) and increase forward acceptance

picture from N. Siegrist



- New detector model under development by the detector and MDI teams ⇒ **CLICdet-2015**
- Length of the detector has been reduced allowing the location of QD0 in the tunnel with a minimal L^* of **6**m ⇒ re-optimization of the BDS with longer L^* for all stages
- FFS optimization is more challenging as the chromaticity generated at the IP increase with L^* leading to an unrecoverable loss of luminosity compared to shorter L^* option
- **Goal :** Identify the potential performances (loss of luminosity compared to the nominal L^*), pre-alignment, tuning performance and impact of the detector field on luminosity

Rebaselining : optimizing the CLIC first stage (380 GeV c.o.m)

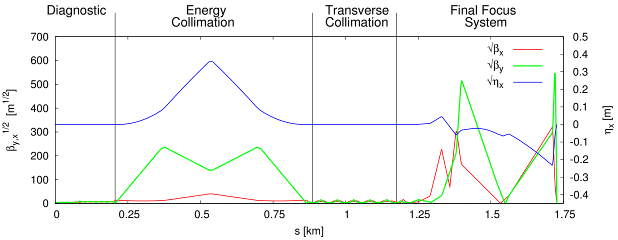
- Optimization of the BDS optics based on the CLIC 500 GeV baseline (For L^*= 4.3 m and L^*= 6 m)
- FFS scheme based on the Local Chromaticity Correction
- Definition of the machine parameters at 380 GeV
- Dispersion optimization in the FFS for both options (nominal and long L^*) in order to improve chromaticity correction
- Energy transition from CLIC 380 GeV to 3 TeV c.o.m :
  - Alignment of the CLIC 380 GeV Linac with the CLIC 3 TeV Linac in the tunnel $\Rightarrow$ Changes of the angles of the energy collimation bending magnets and crossing angle
  - Re-optimization of the final lattice and comparative study between both options

Design parameters

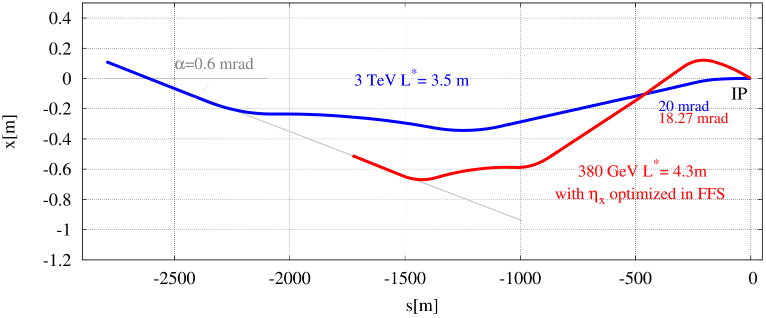
CLIC	380 GeV	380 GeV
L^* (m)	**4.3**	**6**
FFS length (m)	553	770
$\epsilon_{Nx}/\epsilon_{Ny}$ (nm)	950 / 20	950 / 20
β_x^*/β_y^* (mm)	8.2 / 0.1	8.2 / 0.1
σ_x^*/σ_y^* design (nm)	145 / 2.32	145 / 2.32
σ_z (μm)	70	70
δ_p (%)	0.3	0.3
particles/bunch N ($\times 10^9$)	5.2	5.2
Number of bunches n_b	352	352
f_{rep} (Hz)	50	50
L_{tot} ($10^{34} cm^{-2} s^{-1}$)	**1.5**	**1.5**
$L_{1\%}$ ($10^{34} cm^{-2} s^{-1}$)	**0.9**	**0.9**
Chromaticity ξ_y (L^*/β_y^*)	43000	60000

- CLIC 380 GeV emittances $\epsilon_{x,y}$ were chosen according to the emittances calculated at the exit of the Main Linac

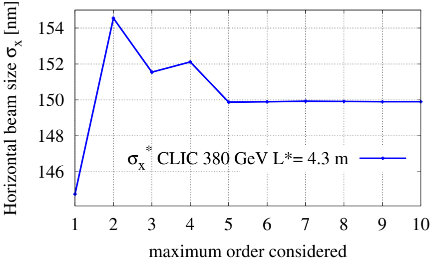
CLIC 380 GeV BDS with L*=4.3 m

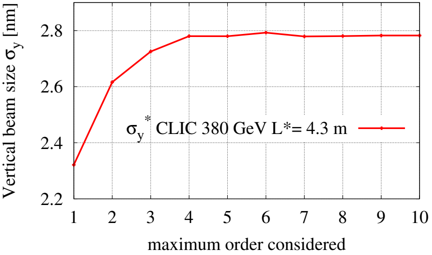


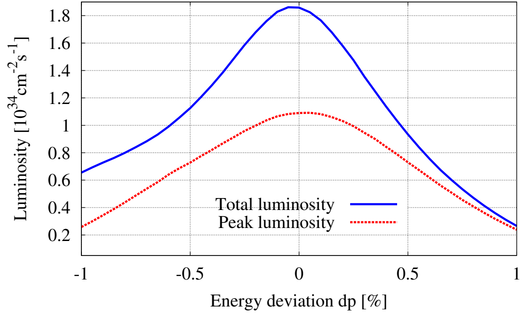
- Scan of the dispersion performed ⇒ no change in the FFS bending magnets was needed
- Linacs alignment performed only by reducing the crossing angle from 20mrad to **18.27 mrad**
- No change in the energy collimation bending magnets was needed



CLIC 380 GeV BDS with L*=4.3 m





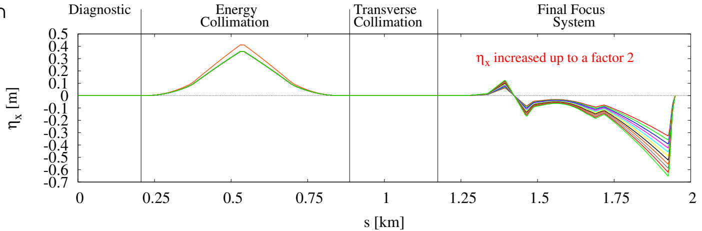


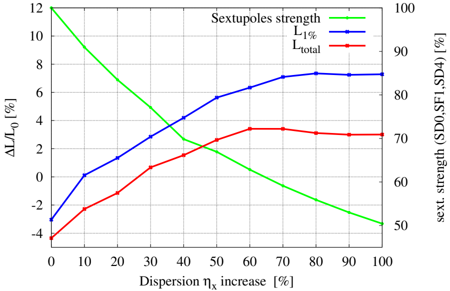
σ_x^*/σ_x^*(SR) (nm)	149.5 / **150**
σ_y^*/σ_y^*(SR) (nm)	2.78 / **2.7**
L_{tot} $(10^{34} cm^{-2} s^{-1})$	**1.86**
$L_{1\%}$ $(10^{34} cm^{-2} s^{-1})$	**1.09**

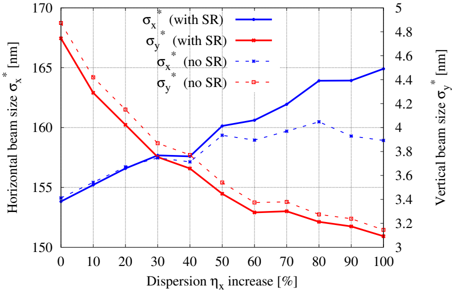
- The total luminosity achieved is **24%** higher than the design luminosity and **21%** for the peak luminosity
- Very small impact of synchrotron radiation at low energy

CLIC 380 GeV BDS with L*=6 m

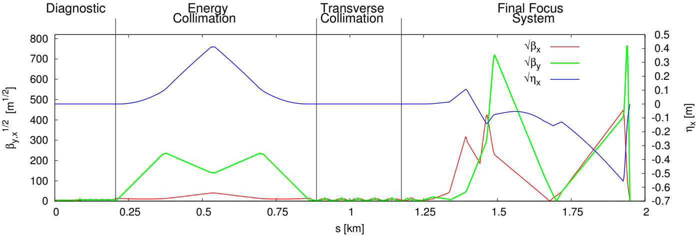
- The optimal dispersion η_x was found by **increasing the dipole angles by 70%**
- With the optimal dipole angles the average sextupole strength has been reduced by 40%



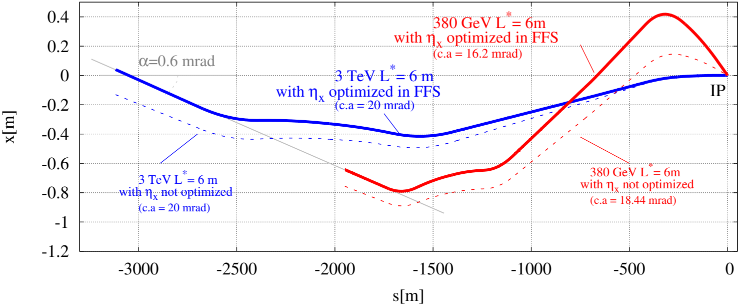




CLIC 380 GeV BDS with L*=6 m

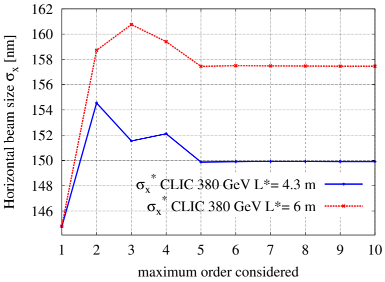


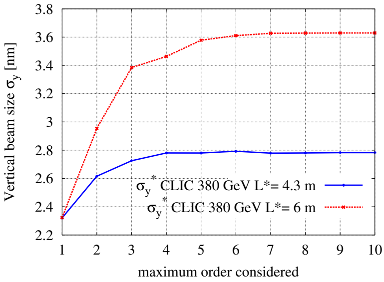
- Functions $\beta_{x,y}$ and η_x with FFS bendings increased by 70% and EC bendings modified
- Alignment of the Linacs performed by reducing c.a to **16.2 mrad** and increasing EC bendings by 15%

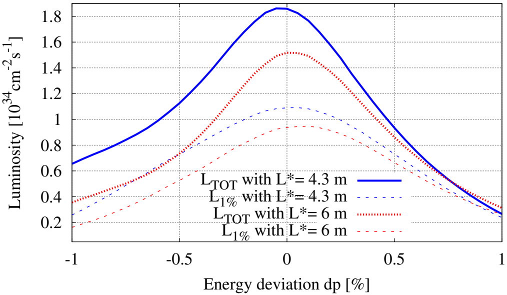


- The optimized CLIC 380 GeV BDS ($L^* = 6$m) is aligned in the tunnel with the optimized CLIC 3 TeV BDS with $L^* = 6$m (shown in the next slides)

Performances : L* = 4.3 m vs L* = 6 m







σ_x^*/σ_x^*(SR) (nm)	157 / **160**
σ_y^*/σ_y^*(SR) (nm)	3.6 / **3.5**
L_{tot} $(10^{34}cm^{-2}s^{-1})$	**1.52**
$L_{1\%}$ $(10^{34}cm^{-2}s^{-1})$	**0.94**

- Luminosity of the optimized and aligned system
- **1.5%** in L_{tot} and **4.5%** in $L_{1\%}$ of luminosity budgets
- The changes in EC bendings leads to 2% of L_{tot} loss and 3.2% of $L_{1\%}$

TUNING : Alignment procedure applied

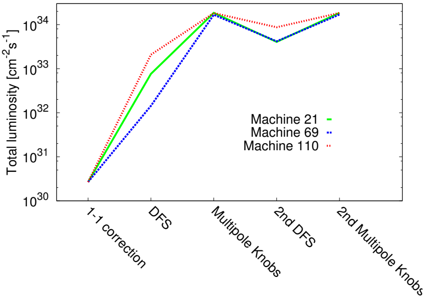
- The tuning of the Final Focus System aims to **mitigate the static imperfections** (misalignment, magnet strength errors) by means of **BPM readings, magnet movers and dipole correctors** in order to recover the luminosity loss from these imperfections
- The alignment procedure consists of 2 iterations of **Beam Based Alignment (BBA)**, for the correction of the **orbit** using steering magnets, followed by a **sextupole knobs tuning**, for the correction of the **beam parameters at the IP** using sextupole movers :

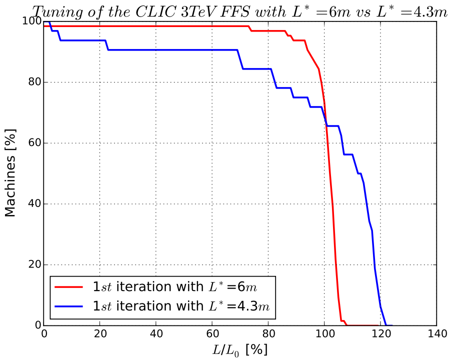
1. 1-1 correction
2. 1st Target Free Steering (TFS)
3. 1st Sextupole Knobs tuning
4. 2nd TFS
5. 2nd Sextupole Knobs tuning

TUNING SETUP assumed for the simulations :

Static imperfections considered	transverse misalignment only
Elements misaligned	QUADRUPOLES, SEXTUPOLES, BPMs
Pre-alignment	$\sigma = 10\mu$m
BPM resolution	10 nm
Number of machines randomly misaligned	110
Goal	90 % of machines recover 90% of L_0

TUNING : Preliminary results : L*=4.3m vs L*=6m





- The design total luminosity is L_0 **= 1.5** $10^{34} cm^{-2} s^{-1}$
- For L^* = 4.3m : **75% of the machines recover 90% of** L_0
- For L^* = 6m : **91% of the machines recover 90% of** L_0 $\Rightarrow$ Goal achieved
- For both L^* options **70% of the machines achieve 100% of** L_0
- The fact that the sextupoles strengths have been reduced by 40% for L^*= 6m compare the short L^* may have helped for the tuning performance
- In both cases, the tuning performance seems very promising and almost fulfills the requirements at the 1st iteration

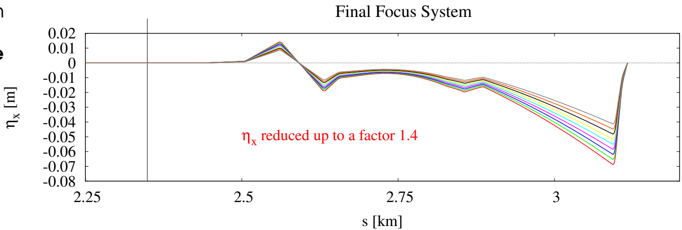
Design parameters CLIC 3 TeV

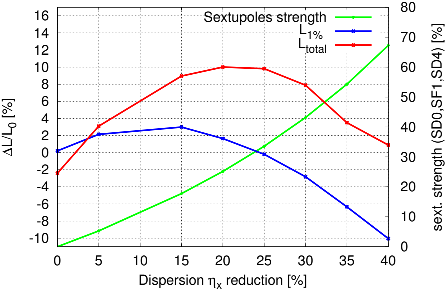
CLIC	3 TeV	3 TeV
L^* (m)	**3.5**	**6**
FFS length (m)	553	770
$\epsilon_{Nx}/\epsilon_{Ny}$ (nm)	660 / 20	660 / 20
β_x^*/β_y^* (mm)	**7 / 0.068**	**7 / 0.1**
σ_x^*/σ_y^* design (nm)	40 / 0.7	40 / 1
σ_z (μm)	44	44
δ_p (%)	0.3	0.3
particles/bunch N ($\times 10^9$)	3.72	3.72
Number of bunches n_b	312	312
f_{rep} (Hz)	50	50
L_{tot} ($10^{34} cm^{-2} s^{-1}$)	**5.9**	**5.9**
$L_{1\%}$ ($10^{34} cm^{-2} s^{-1}$)	**2**	**2**
Chromaticity ξ_y (L^*/β_y^*)	51500	60000

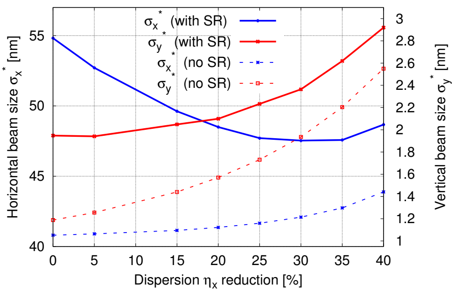
- For the L^* = 6 m option an optimization study of the $\beta^*_{x,y}$ has been performed in order to optimize the luminosity
- The β_y^* has been increased from 0.068 mm to 0.1 mm allowing to reduce the chromaticity at the IP and reduce the β_y function at the Final Doublet

Optimisation of the beamline with L*=6 m

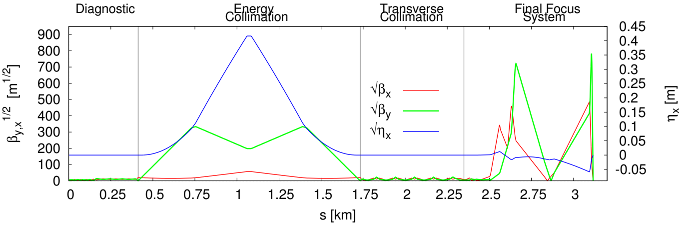
- The optimal dispersion η_x was found by **decreasing the dipole angles by 15%**
- With the optimal dipole angles the average sextupole strength has been increased by 18%



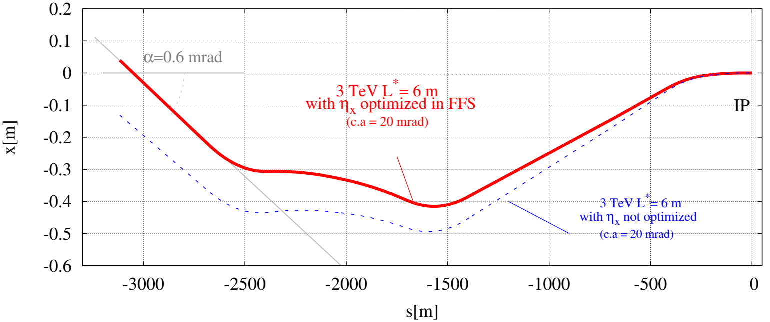




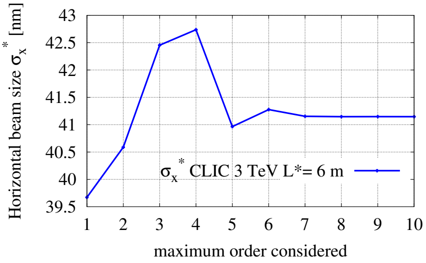
Optimisation of the beamline with L*=6 m

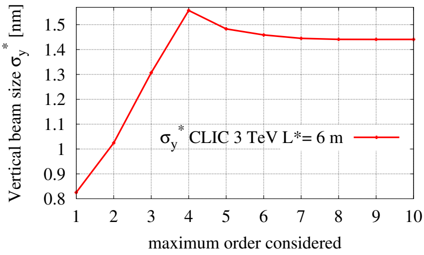


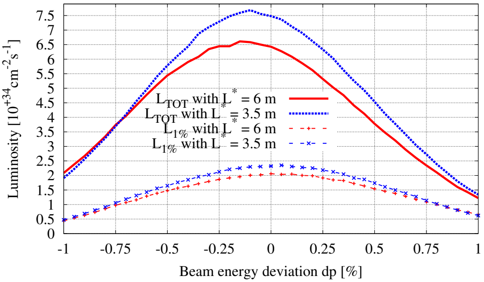
- Functions $\beta_{x,y}$ and η_x with FFS bendings decreased by 15%
- Footprint of the BDS in the tunnel for L^*=6m before and after η_x optimization in the FFS



Performances : L* = 3.5 m vs L* = 6 m



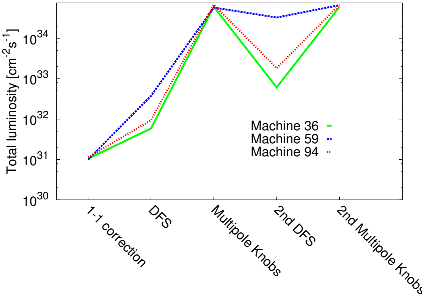


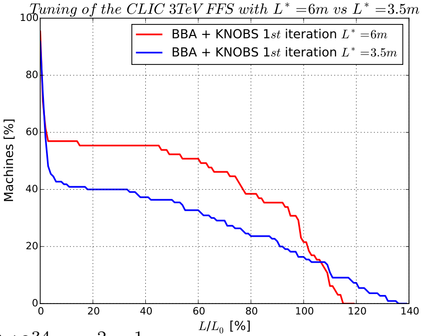


L^* (m)	**6**	**3.5**
σ_x^*/σ_x^*(SR) (nm)	41.2 / **49.7**	40 / **47.7**
σ_y^*/σ_y^*(SR) (nm)	1.44 / **2**	1 / **2.5**
L_{tot} $(10^{34}cm^{-2}s^{-1})$	**6.43**	**7.5**
$L_{1\%}$ $(10^{34}cm^{-2}s^{-1})$	**2.06**	**2.3**
Budget $L_{tot}/\ L_{1\%}$ (%)	9 / 3	27 / 15

- The luminosity loss by increasing L^* from 3.5 m to 6 m is **14%** in L_{tot} and **10%** in $L_{1\%}$
- No octupoles were inserted in the L^* = 6 m beamline

Preliminary tuning results : L*=3.5m vs L*=6m

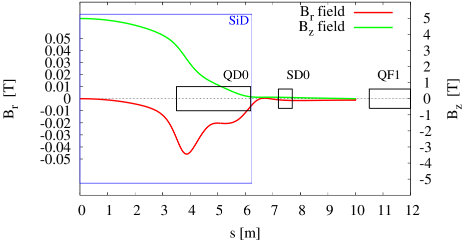


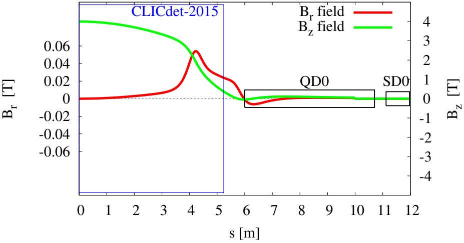


- The design total luminosity is L_0 **= 5.9** $10^{34} cm^{-2} s^{-1}$
- For L^* = 3.5m : **22% of the machines recover 90% of** L_0 (Simulation of Barbara Dalena)
- For L^* = 6m : **35% of the machines recover 90% of** L_0
- The longer L^* scenario seems to not degrade the tuning performance at the first iteration !
- More iterations of the BBA+KNOBS algorithm can significantly improve the tuning performance
- Tuning feasibility has not yet been proven but improvement of the tuning procedure is ongoing

Impact on CLIC 3 TeV luminosity

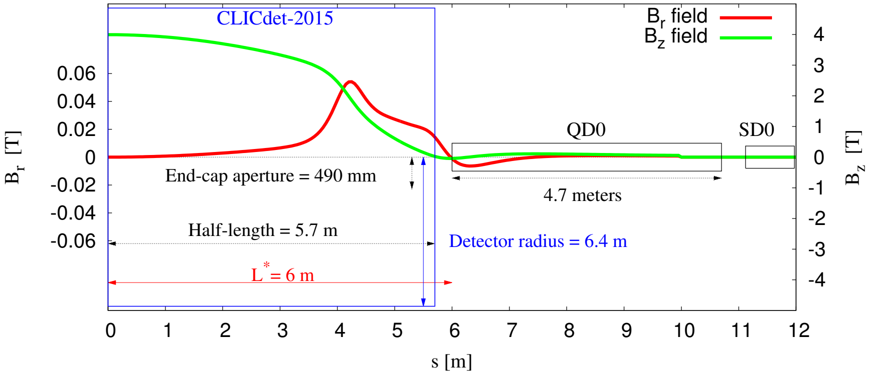
(B_z and B_r fields evaluated along the beamline (20mrad crossing angle) in the solenoid reference frame)





- B_z and B_r fields of the SiD solenoid with the last magnets of the L^*=3.5m lattice (left plot) and of the new detector model CLICdet-2015 simulated by *B. Curé* with the last magnets of the L^*=6m lattice (right plot)
- The simulation approach has been implemented and applied on the nominal 3 TeV BDS with the SiD detector by *B. Dalena* and *Y. Levinsen* (***Phys. Rev. ST Accel. Beams 17, 051002 (2014)***)
- The same simulation process using PLACET and GUINEA-PIG have been applied on the L^* = 6 m lattices with the field of the CLICdet-2015
- The simulation procedure evaluates the **luminosity loss due to ISR** in the interaction region

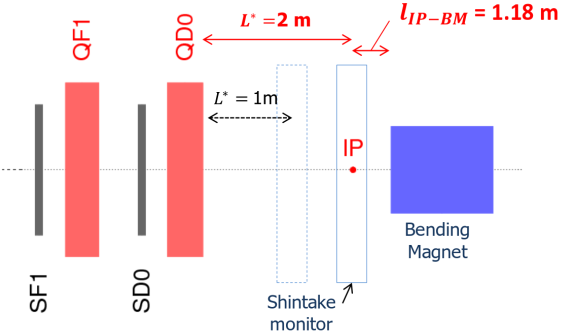
Impact on CLIC 3 TeV luminosity



CLIC 3 TeV	Impact on L_{TOT} (%)	Impact on L_{peak} (%)
L^*= **6 m** NO Antisol	**3.7**	**4.6**
L^*= **3.5 m** NO Antisol	**7.8**	**8.2**
L^*= **3.5 m** WITH Antisol	**6.25**	**6.7**

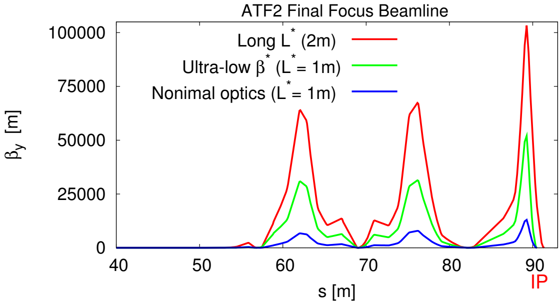
Proposal for experimental long L* study at ATF2

- The long L^* design should make the machine more challenging to operate therefore several points need to be proved experimentally to check its feasibility (Chromaticity correction at the IP, tuning, stabilization, influence of wakefields, impact of ground motion)
- **In the scenario where all the Goals of ATF2 are achieved soon , long L^* study could be considered in the future**
- Increase the L^* of ATF2 **from 1m to 2m** is the main technical challenge for ATF2 $\Rightarrow$ move the Shintake monitor by 1m



Proposal for experimental long L* study at ATF2

- The optimization of the ATF2 beamline has to be done by simulation
- The linear optics (quadrupoles) have been done and the optimization of the sextupoles (and octupoles) for the chromaticity correction is ongoing



- Long L^* option allows also the demonstration of the feasibility of the CLIC chromaticity level with larger $\beta_y^* \Rightarrow (\xi_y = \frac{L^*}{\beta_y^*})$
- The lattice for this configuration still needs to be proved by simulation and many other technical considerations have to be studied during the next years in order to check the feasibility of this project

Summary

CLIC	380 GeV	380 GeV	3 TeV	3 TeV
L^* (m)	**4.3**	**6**	**3.5**	**6**
σ_x^* (SR) (nm)	150	160	47.7	49.7
σ_y^* (SR) (nm)	2.7	3.5	2.5	2
L_{tot} (design) / L_{tot} $(10^{34}cm^{-2}s^{-1})$	1.5 / **1.86**	1.5 / **1.52**	5.9 / **7.5**	5.9 / **6.43**
$L_{1\%}$ (design) / $L_{1\%}$ $(10^{34}cm^{-2}s^{-1})$	0.9 / **1.09**	0.9 / **0.94**	2 / **2.3**	2 / **2.06**
Chromaticity ξ_y (computed)	68464	95697	82637	93017
Budget L_{tot}/ $L_{1\%}$ (%)	24 / 21	1.5 / 4.5	27 / 15	9 / 3
Impact of solenoid on L_{tot}/ $L_{1\%}$ (%)	-	-	**7.8 / 8.2**	**3.7 / 4.6**
Tuning : Machines achieving 90% of L_0	**75%**	**91%**	**22%**	**35%**

- BDS Designs have been optimized and are consistent with the energy transition in the CLIC tunnel between stages
- Luminosity requirements for CLIC are achieved for the first and final stages with smaller luminosity budget (for static and dynamic imperfections) in the case of the long L^*
- A preliminary study on the tuning performance has shown promising results for the first stage (380 GeV) at the first iteration
- At top energy (3 TeV) the tuning feasibility has not yet been proven for both L^* options ⇒ improvement of the tuning algorithm will be needed to achieve this goal
- If the tuning at top energy does not improve, the traditional FFS scheme will be considered for future linear colliders
- The impact of the solenoid on the luminosity is lower for the long L^* option and should not require anti-solenoid