A Novel CLIC Dual Beam Delivery System for two Interaction Regions

Vera Cilento, Rogelio Tomás and Angeles Faus-Golfe

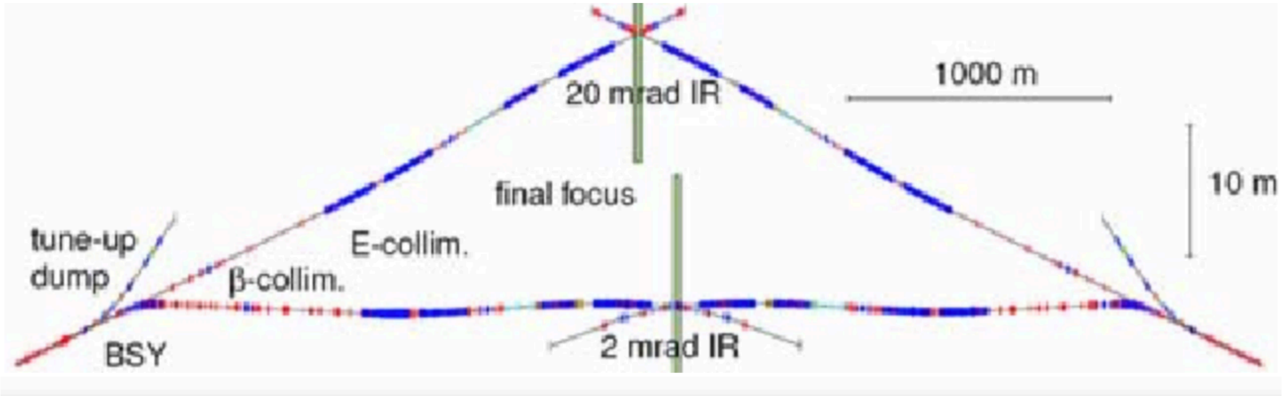
Outline

- Motivation of the study
- Introduction
- Update of the performance of CLIC 3 TeV including detector solenoid effects
- Development of the Model to construct the Dual BDS for CLIC
    - CLIC 380 GeV
    - CLIC 3 TeV
- Simulation Results
    - Beam size and Luminosity
    - Detector Solenoid Effects
- Conclusions and Outlook

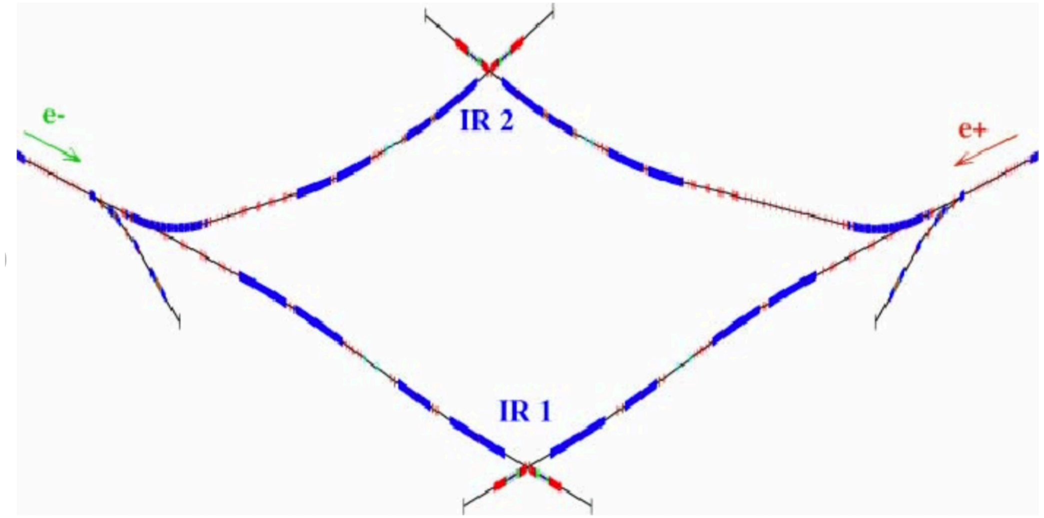
Motivation of the study

- Two Interaction Regions (IRs) would make CLIC design more comparable with other future accelerator projects
- The two IRs possibility was studied already in ILC* and NLC*

- ILC:



- NLC:

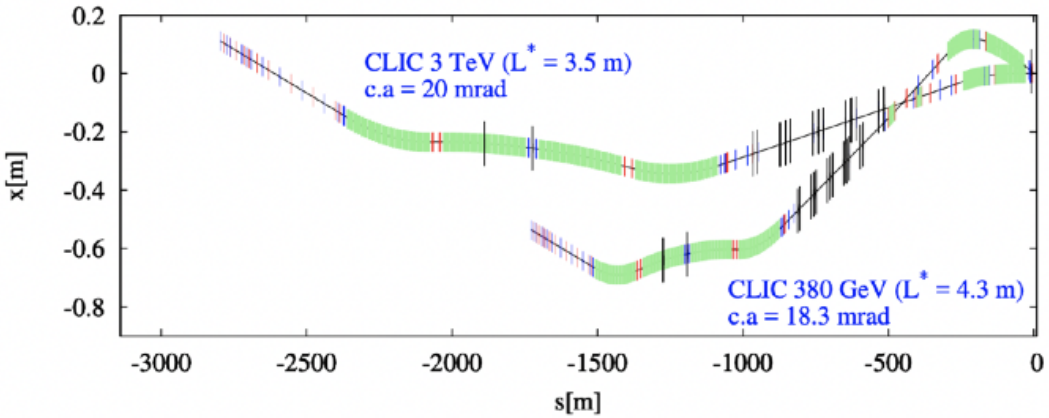


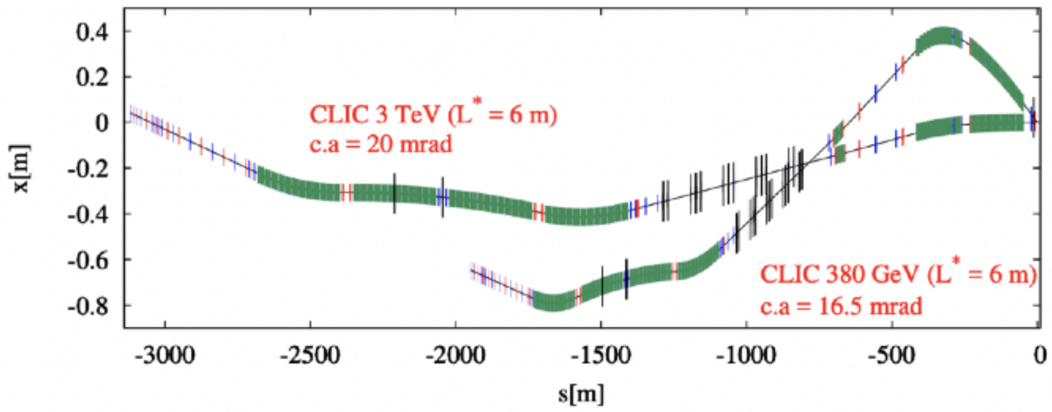
* BEAM DELIVERY SYSTEM IN ILC. G. A. Blair# , John Adams Institute at RHUL, London. TW20 0EX. UK. Proceedings of EPAC 2006, Edinburgh, Scotland.
* BEAM DELIVERY LAYOUT FOR THE NEXT LINEAR COLLIDER. Andrei Seryi , Yuri Nosochkov, Mark Woodley SLAC, Stanford, CA 94309, USA. Proceedings of EPAC 2004, Lucerne, Switzerland.

Introduction

- The BDS* design taken into account are the
  - CLIC 380 GeV with L*= 6 m
  - CLIC 3 TeV with L*= 6 m

CLIC	380 GeV		3 TeV	
L* [m]	4.3	6	3.5	6
BDS length [m]	1728	1949	2795	3117
Norm. emittance (IR) $\gamma\epsilon_x$ [nm]	950	950	660	660
Norm. emittance (IR) $\gamma\epsilon_y$ [nm]	30	30	20	20
Beta function (IR) β_x^* [mm]	8	8	7	7
Beta function (IR) β_y^* [mm]	0.1	0.1	0.068	0.12
IR beam size σ_x^*[nm]	144	144	40	40
IR beam size σ_y^*[nm]	2.9	2.9	0.7	0.9
Bunch length σ_z[μm]	70	70	44	44
rms energy spread δ_p[%]	0.3	0.3	0.3	0.3
Bunch population N_e [$\times 10^9$]	5.2	5.2	3.72	3.72
Number of bunches n_b	352	352	312	312
Repetition rate f_{rep} [Hz]	50	50	50	50
Luminosity $\mathcal{L}_{TOT}$ [$10^{34}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$]	1.5	1.5	5.9	5.9





* Optics optimization of longer L* Beam Delivery System designs for CLIC and tuning of the ATF2 final focus system at ultra-low β* using octupoles. Fabien Plassard. CERN-THESIS-2018-223. PhD : U. Paris-Saclay : 2018-06-06.

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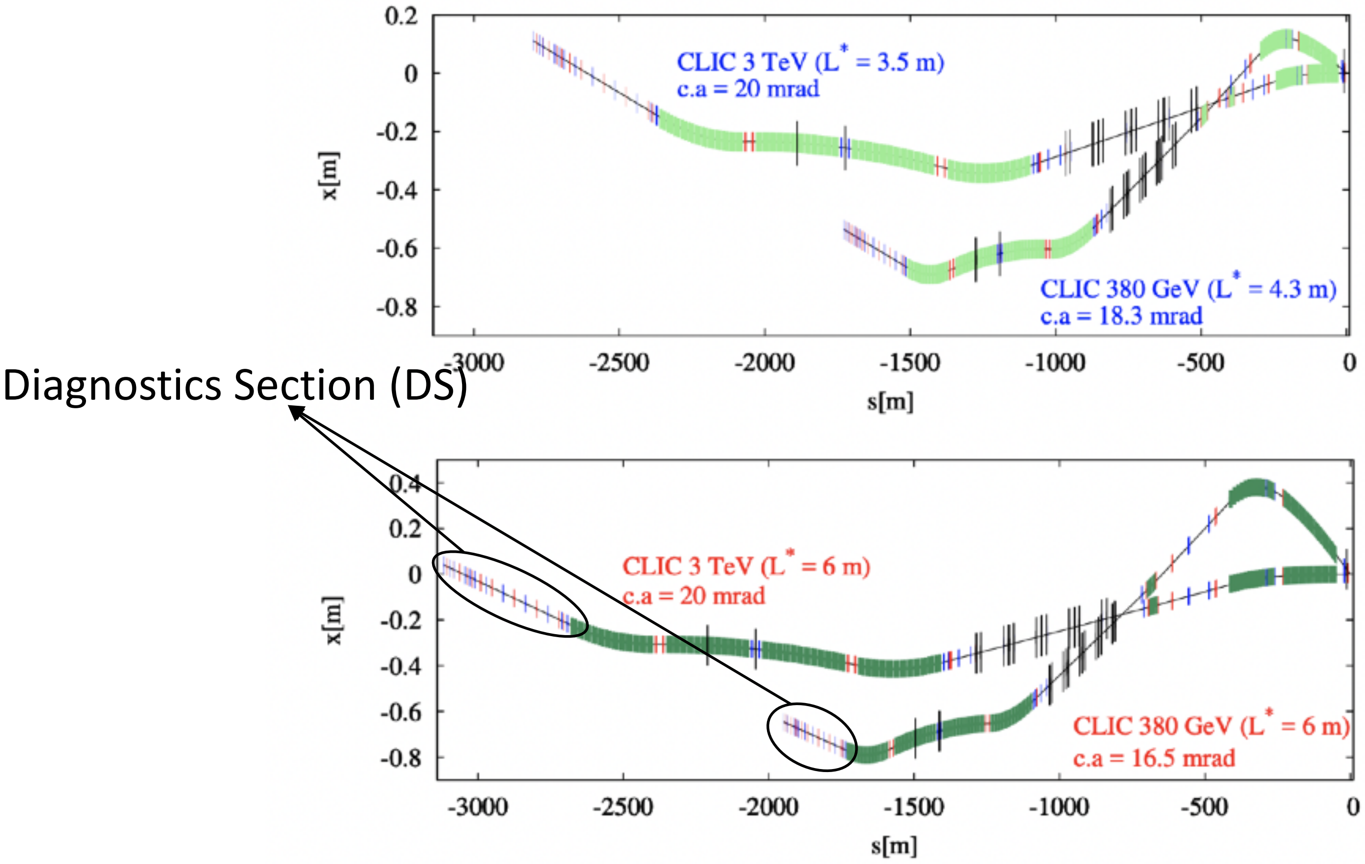

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Update of the performance of CLIC 3 TeV

	ideal	w/ SR
σ_x^* [nm]	41.4	50.3
σ_y^* [nm]	1.06	1.69

	Ideal case	w/ solenoid	w/ SR	w/ solenoid+SR
Luminosity [10^{34} cm^{-2} s^{-1}]	9.40	8.65	6.50	6.22

- The detector solenoid effects was never evaluated for the CLIC with L*= 6 m, while for the L*= 3.5 m was ~ 4%.
- The evaluation of the beam size and the luminosity (ideal and w/ SR) has been done with the direct PLACET tracking procedure.
- The evaluation of the luminosity including the detector solenoid effects has been done with the forward-backward-forward PLACET tracking procedure (ideal, w/ sol, w/ sol+ SR).
- The luminosity loss from the solenoid field for the the current baseline with L*= 6 m is about 4%.

Development of the Model to construct the Dual BDS for CLIC

- CLIC 380 GeV
  - The novel dual BDS includes a new bending magnet to separate the two beamlines
  - The design of the dual BDS has been done starting from the Diagnostics Section (DS)
  - The FODO cell structure of the DS has been increased with 8 more cells with a μ of 45°
  - The total additional length of the dual BDS is 300 m
  - The FODO cells have been filled with a Dipole + Dispersion Suppressor for the separation of the two BDS
  - The Twiss functions and the horizontal Dispersion have been matched at the design values
  - The new DS has been connected to the rest of the BDS in order to get the beam to two different IRs
  - We need different lengths of the DS because the new layout involves four different beamlines in order to provide the desired longitudinal and transverse separation (BDS1/IR1 (short and long) BDS2/IR2 (short and long))

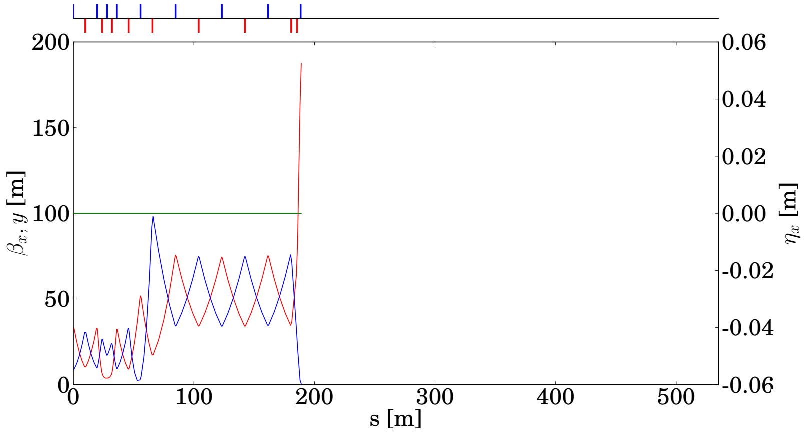
CLIC 380 GeV

	BDS1 (short)	**BDS1** (long)	**BDS2** (short)	**BDS2** (long)
θ [mrad]	-	-	4.83	4.83
L_{dipole}[m]	-	-	218.11	218.11
L_{FODO} [m]	38.36	38.36	38.36	38.36
L_{DS}[m]	512.89	551.24	512.89	551.24
L_{BDS} [m]	2255.95	2294.3	2255.95	2294.3
c.a. [mrad]	-16.5	-16.5	-26	-26

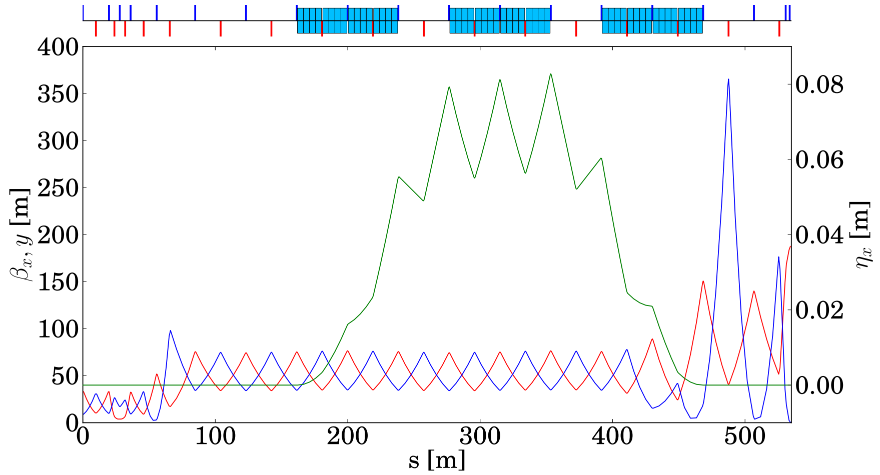
Development of the Model to construct the Dual BDS for CLIC

- Twiss Functions and Horizontal Dispersion for CLIC 380 GeV

DS for the single IR (baseline design with long L*)



New DS for the dual IRs in the case of the longer DS



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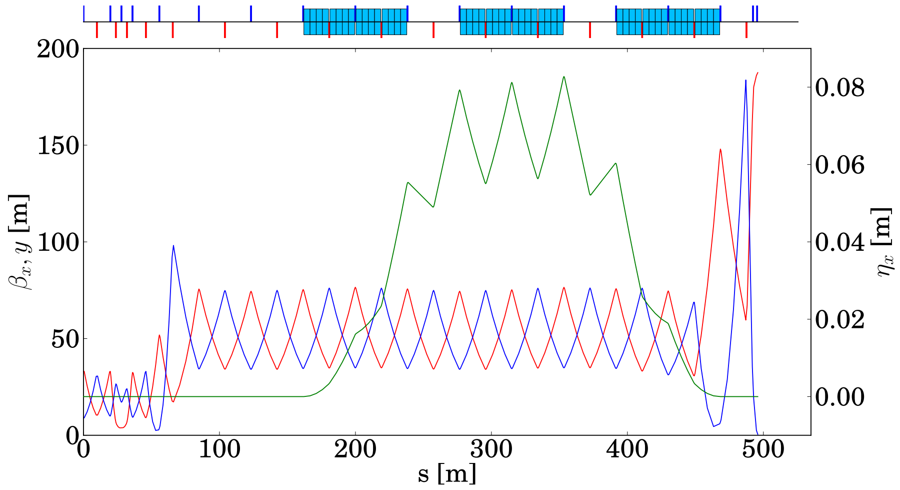
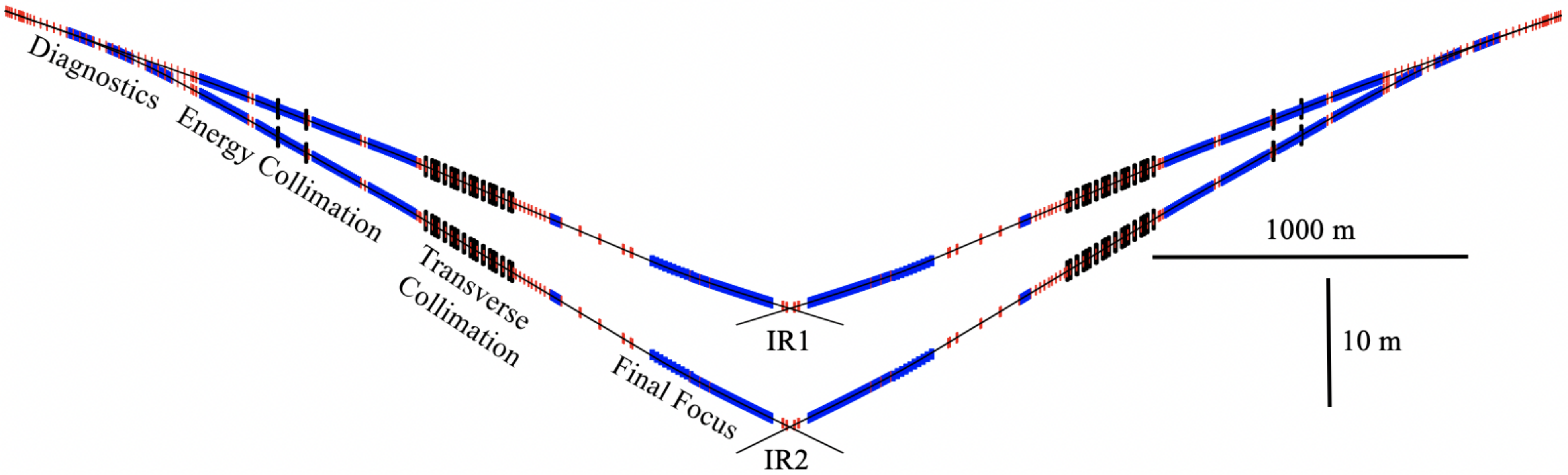


Novel Layout of the Dual BDS for CLIC 380 GeV



- Four different beam lines have been constructed to provide:
  - Longitudinal separation of ~ 40 m
  - Transverse separation of 10 m
- The θ in the DS of the BDS2 is 4.83 mrad
- The crossing angles are at IR1 and IR2 respectively -16.5 mrad and -26 mrad

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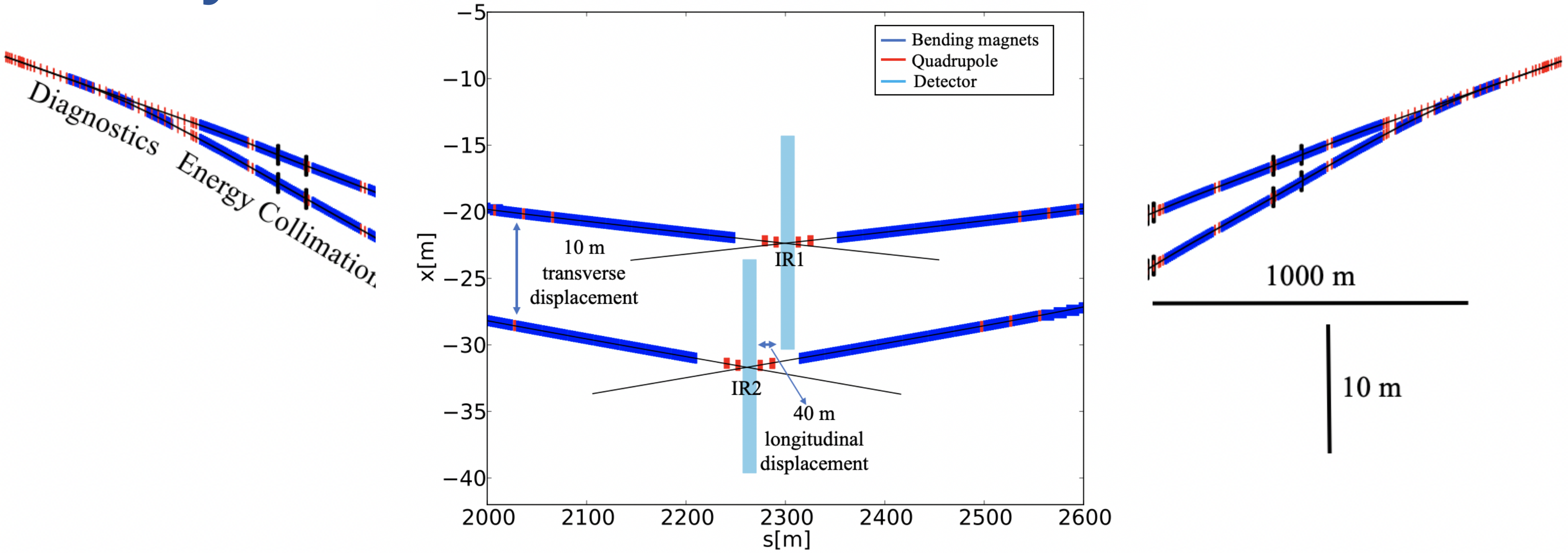

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- The θ in the DS of the BDS2 is 4.83 mrad
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Development of the Model to construct the Dual BDS for CLIC

- CLIC 3 TeV

  - ➢ The procedure to make the new DS has been the same
    - The longitudinal separation displacement is ~ 80 m (one FODO cell in the DS)
    - The transverse separation displacement between the two detectors is 10 m

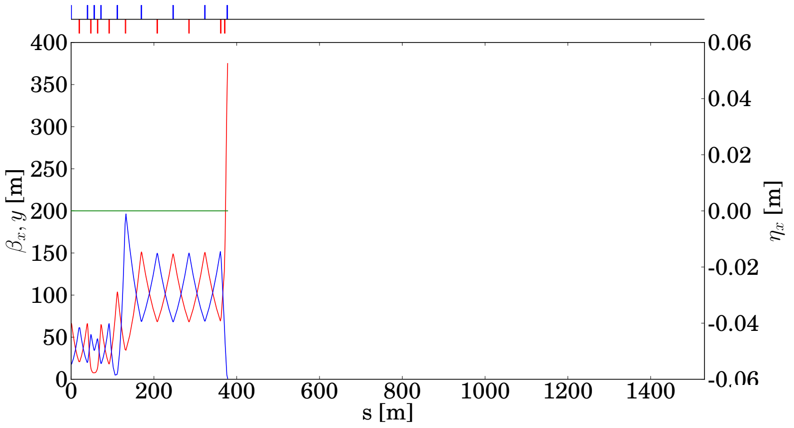
    - Additional length of 1.2 km
      → total length of the DS is ~ 1.5 km
      → in this case the θ is 2.75 mrad

CLIC 3 TeV				
	BDS1 (short)	**BDS1** (long)	**BDS2** (short)	**BDS2** (long)
θ [mrad]	-	-	2.75	2.75
L_{dipole}[m]	-	-	872.45	872.45
L_{FODO} [m]	76.72	76.72	76.72	76.72
L_{DS}[m]	1486	1562.75	1486	1562.75
L_{BDS} [m]	4190.66	4267.37	4190.66	4267.37
c.a. [mrad]	-20	-20	-25.5	-25.5

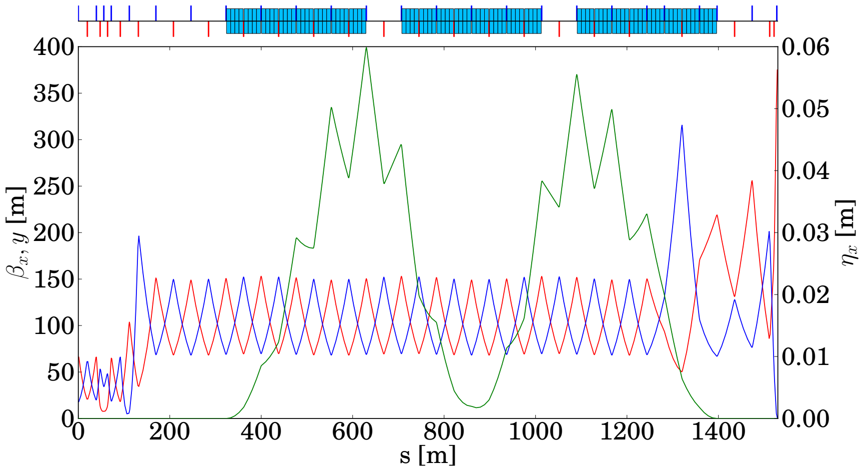
Development of the Model to construct the Dual BDS for CLIC

- Twiss Functions and Horizontal Dispersion for CLIC 3 TeV

DS for the single IR (baseline design with long L*)



New DS for the dual IRs in the case of the longer DS



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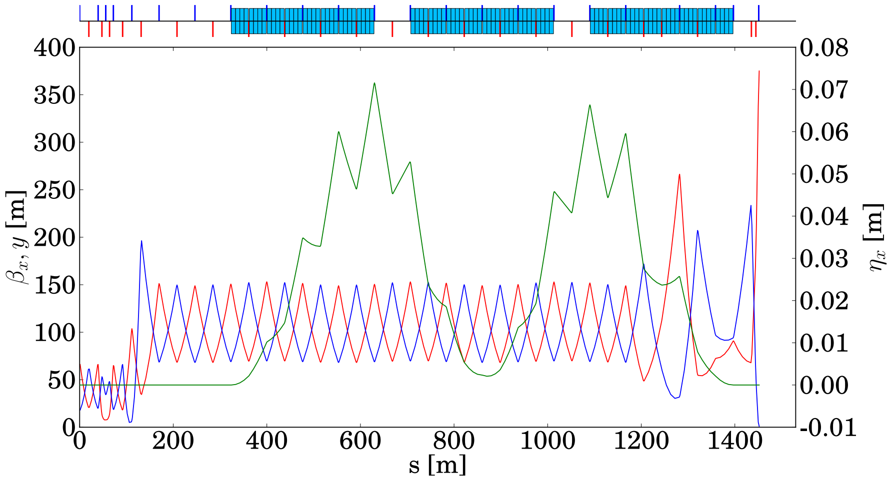
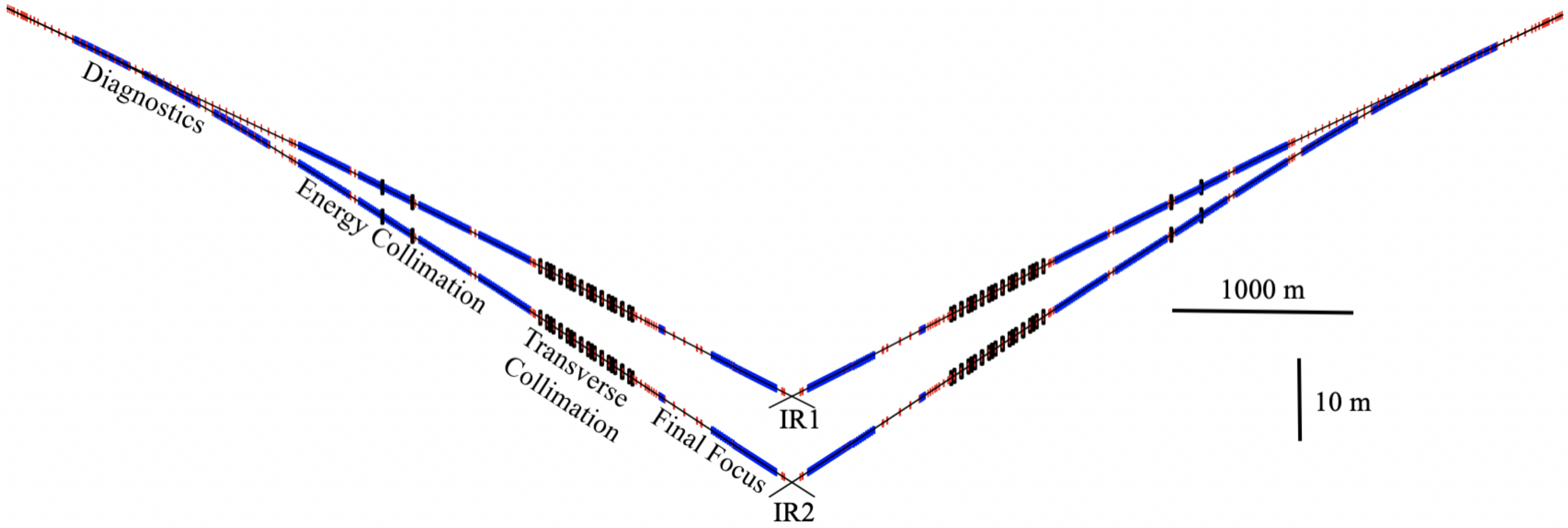


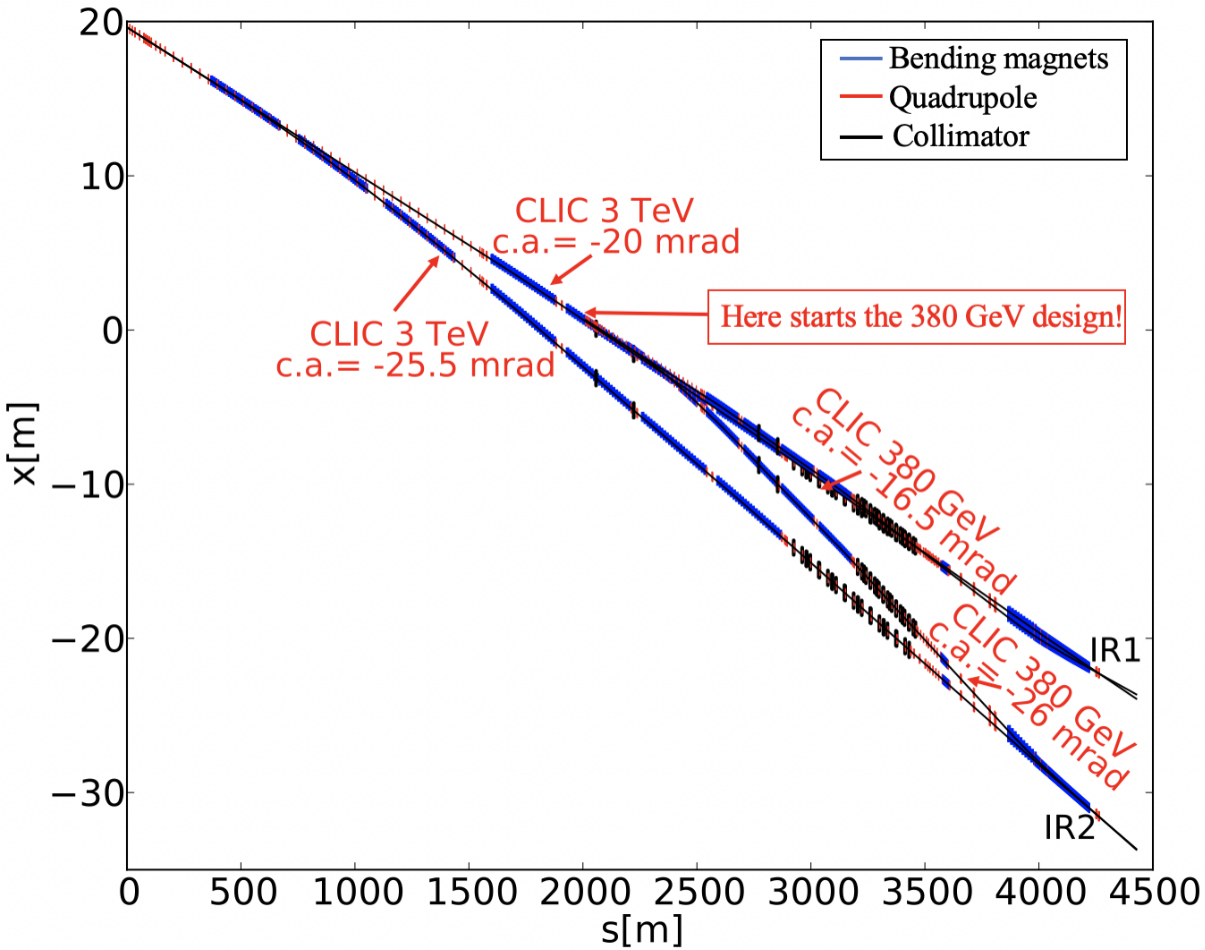
Novel Layout of the Dual BDS for CLIC 3 TeV



- In order to have the IRs at the exact same locations as in the CLIC 380 GeV case:
  - The θ in the DS of the BDS2 is 2.75 mrad
  - The crossing angles are at IR1 and IR2 respectively -20 mrad and -25.5 mrad

Novel Layout of the Dual BDS for CLIC 3 TeV

- BDS tunnel compatibility between the 380 GeV and 3 TeV layouts

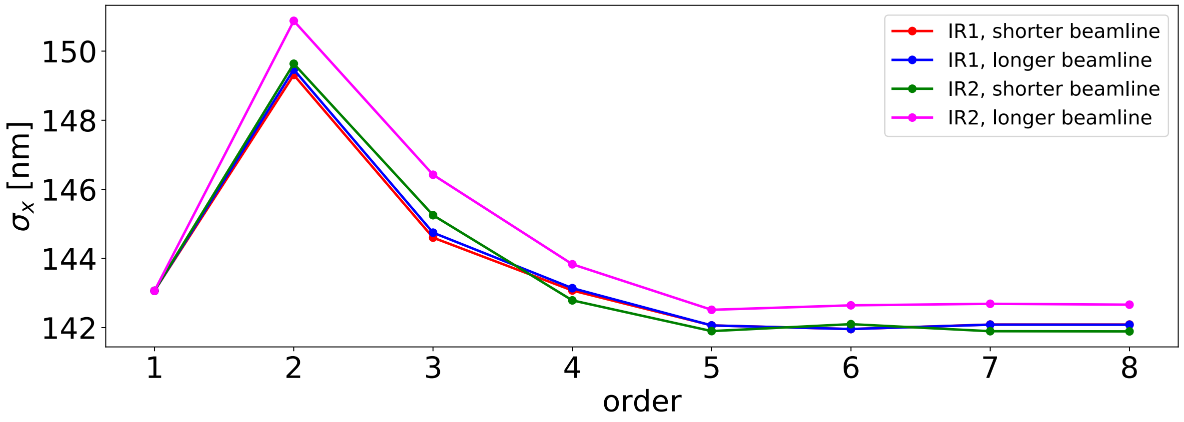


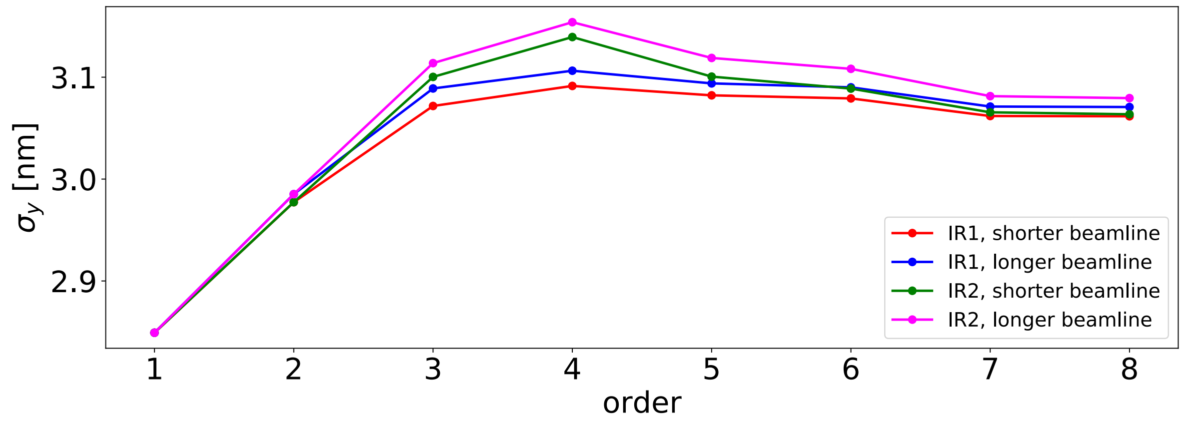
These results indicate the tunnel construction stages of the dual CLIC BDS, starting from the first energy stage of 380 GeV and going to the 3 TeV stage.

Simulation Results

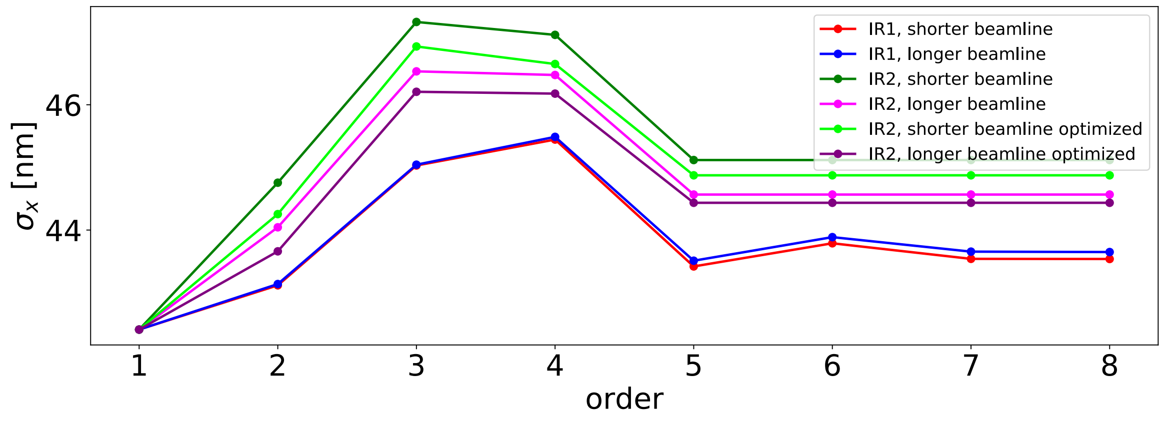
- Beam Size with MAPCLASS and PTC

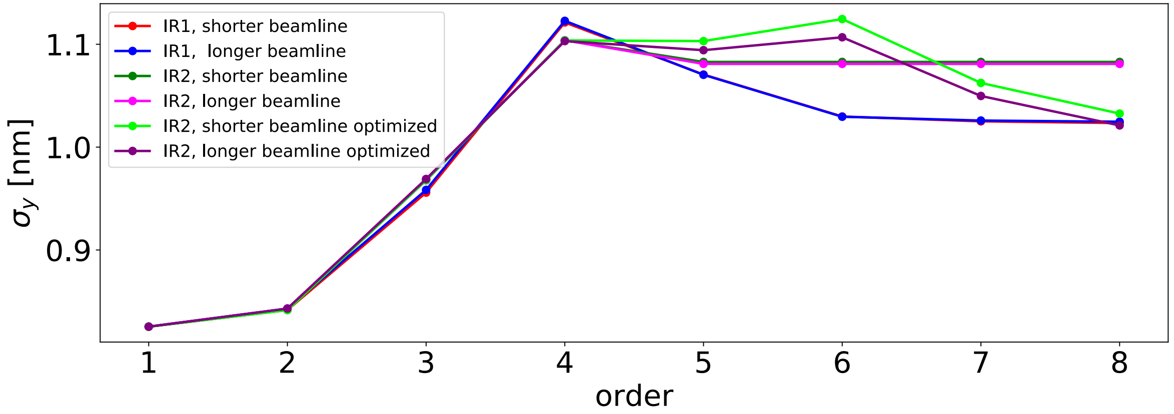
  - CLIC 380 GeV





  - CLIC 3 TeV





Simulation Results

- Beam Size and Luminosity with PLACET and GUINEA-PIG for CLIC 380 GeV including detector solenoid effects

σ_x^* [nm]	ideal	w/ SR
IR1	141	144
IR2	141	144

σ_y^* [nm]	ideal	w/ SR
IR1	3.07	3.08
IR2	3.06	3.07

Luminosity [10^{34} cm^{-2} s^{-1}]	ideal	w/ solenoid	w/ SR	w/ sol+ SR
IR1	1.515	1.512	1.492	1.412
IR2	1.491	1.475	1.466	1.392

- The beam size simulations with the different codes (MAPCLASS and PLACET) show consistency of the results
- The luminosity loss can be considered negligible for the CLIC 380 GeV case

Simulation Results

- Beam Size and Luminosity with PLACET and GUINEA-PIG for CLIC 3 TeV including detector solenoid effects

σ_x^* [nm]	ideal	w/ SR
IR1	43.5	51.5
IR2	47.5	64.8

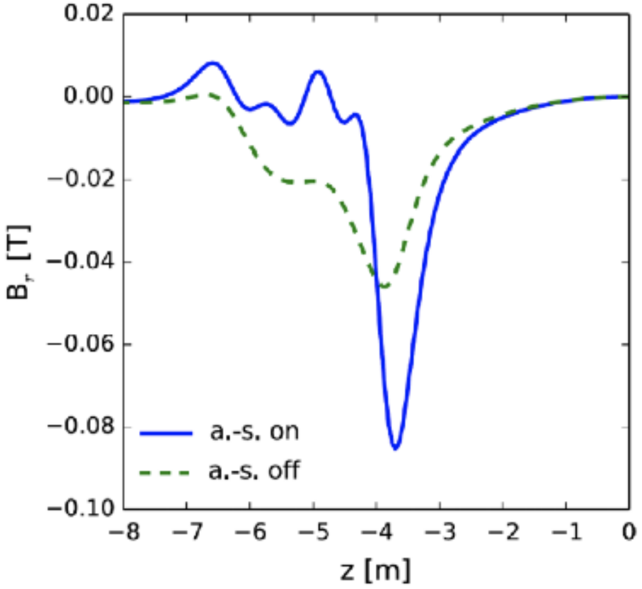
σ_y^* [nm]	ideal	w/ SR
IR1	1.02	1.71
IR2	1.02	1.92

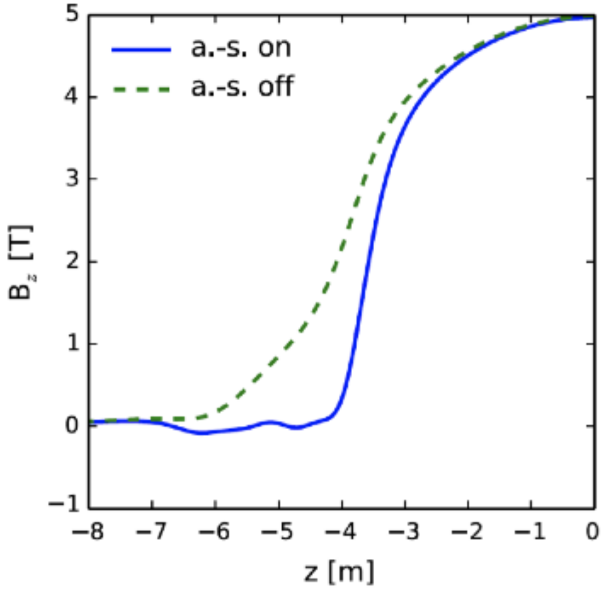
Luminosity [10^{34} cm^{-2} s^{-1}]	ideal	w/ solenoid	w/ SR	w/ sol+ SR
IR1	9.0	8.21	6.30	6.09
IR2	8.33	7.59	5.14	4.17

- The beam size simulations with the different codes (MAPCLASS and PLACET) show consistency of the results
- The % of irrecoverable SR in the new dipole is ≈ 10%
- Further work to optimize aberrations ≈ the 6% could be possible → reducing the SR loss would require to make a longer system, extra cost
- The impact on the luminosity performance of CLIC 3 TeV for the solenoid field is ~ 3.5% for IR1 and ~ 19% for IR2.

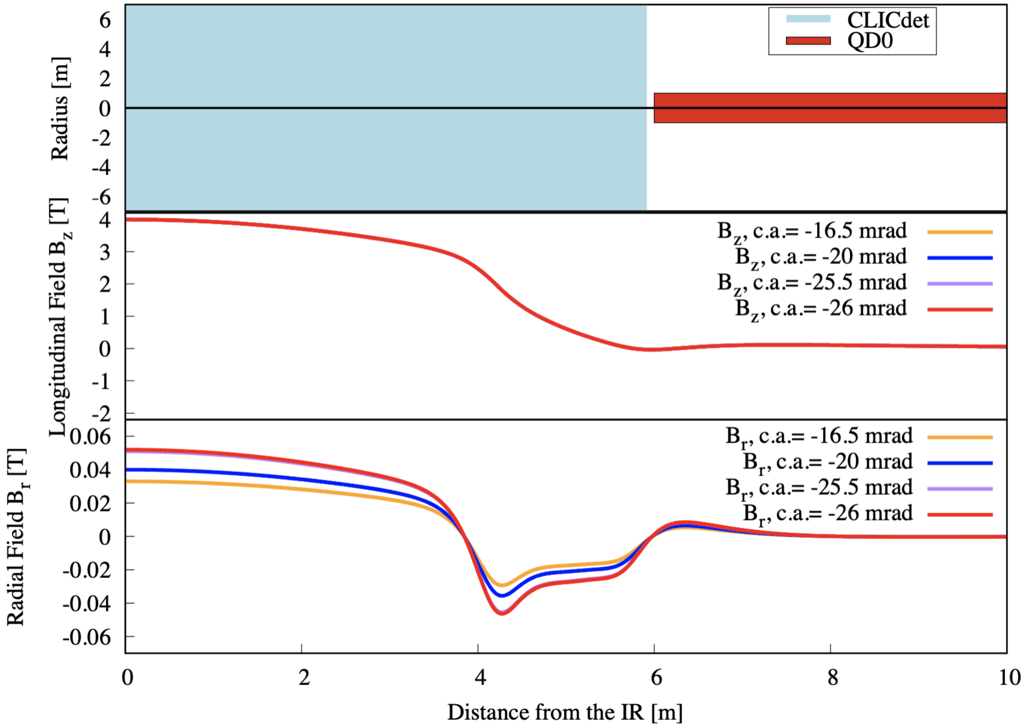
Simulation Results

- Detector Solenoid Effects





- The impact of solenoid on luminosity depends on the crossing angles → particles with large angles at the IR have a large displacement from the beam orbit in the region close to the last magnet, where the radial solenoid field is strongest.



- A simulation with the new baseline design but with the SiD experiment configuration, that includes the antisolenoid, has been done (central field is 5 T while in the new configuration is 4 T so the comparison is pessimistic).
- From the simulations we can see that adding an antisolenoid to the CLIC configuration should reduce luminosity loss by at least 3% → bringing the CLIC baseline design and the dual CLIC BDS1 design at the same luminosity value.

Conclusions and Outlook

- Considering the detector solenoid effects there is in total a luminosity performance loss from the baseline design for the CLIC 3 TeV of about 2% at the IR1 and about 33% of luminosity performance loss at the IR2 both with respect to the previous design but including the solenoid, 6.22 $\times 10^{34}$ cm^{-2} s^{-1}.

- The luminosity loss for the CLIC 380 GeV case can be considered negligible, considering all the effects.

- The impact on the luminosity performance of CLIC 3 TeV for the detector solenoid field is about 3.5% for IR1 (as in the case of the baseline design → about 4%) and about 19% for IR2 and this represents the total luminosity loss that cannot be corrected once the design is fixed.

- The possibility to add the antisolenoid reduces the luminosity losses of at least 3% and leads the luminosity performance of the CLIC dual BDS of the IR1 design comparable to the baseline design. For the IR2 instead we could not estimate the potential since the magnetic design of the solenoid does not exist for now.

- Further improvements can still be performed for the dual BDS layout in order to recover part of the luminosity performance mostly due to optic aberrations → put half of the bends (with opposite angle) in IR1 and half in IR2 (this will reduce lumi loss in IR2 and increase it in IR1); Make a longer BDS to reduce the SR effects.

Thank you for the attention!