A dual Beam Delivery System for two Interaction Regions at CLIC

Vera Cilento, Rogelio Tomás, Angeles Faus-Golfe, Benoit Cure, Barbara Dalena and Yngve Levinsen

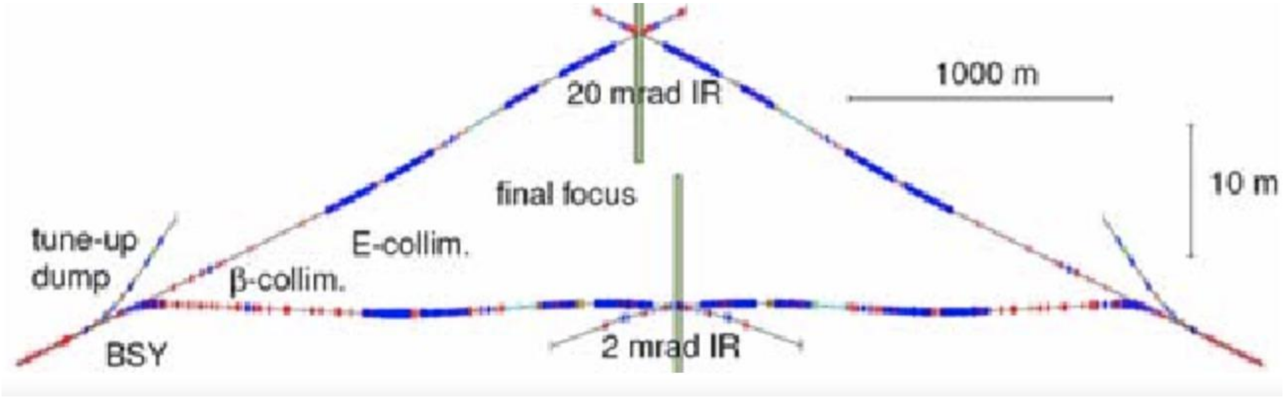
Outline

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

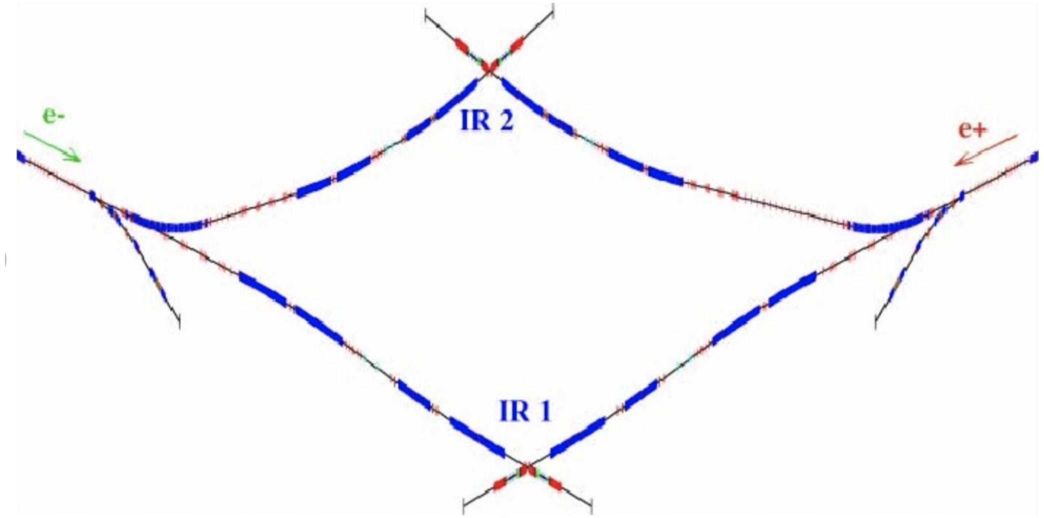
Motivation of the study

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

- ILC:



- NLC:

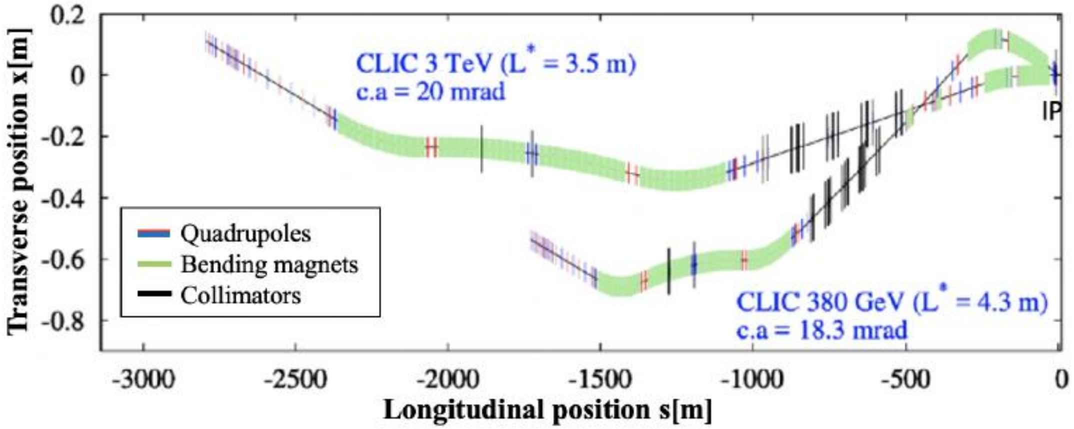


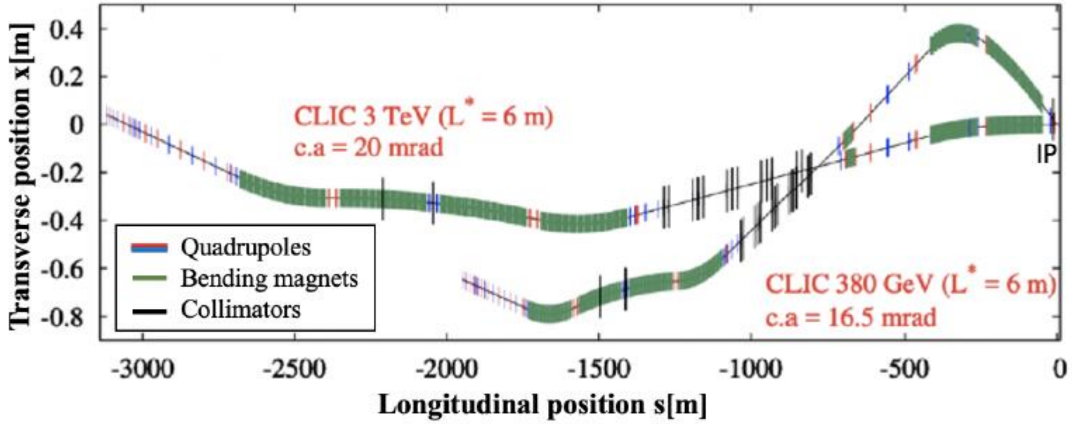
* BEAM DELIVERY SYSTEM IN ILC. G. A. Blair# , John Adams Institute at RHUL, London. TW20 0EX. UK. Proceedings of EPAC 2006, Edinburgh, Scotland.
* BEAM DELIVERY LAYOUT FOR THE NEXT LINEAR COLLIDER. Andrei Seryi , Yuri Nosochkov, Mark Woodley SLAC, Stanford, CA 94309, USA. Proceedings of EPAC 2004, Lucerne, 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	
	CDR	Current	CDR	Current
L* [m]	4.3	6	3.5	6
BDS length [m]	1728	1949	2795	3117
Norm. emittance $\gamma\epsilon_x$ [nm]	950	950	660	660
Norm. emittance $\gamma\epsilon_y$ [nm]	30	30	20	20
Beta function (IP) β_x^* [mm]	8	8	7	7
Beta function (IP) β_y^* [mm]	0.1	0.1	0.068	0.12
IP beam size σ_x^*[nm]	144	144	40	40
IP 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 [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
Crossing Angle [mrad]	18.3	16.5	20	20
Luminosity $\mathscr{L}_{TOT}$ [10^{34} cm^{-2}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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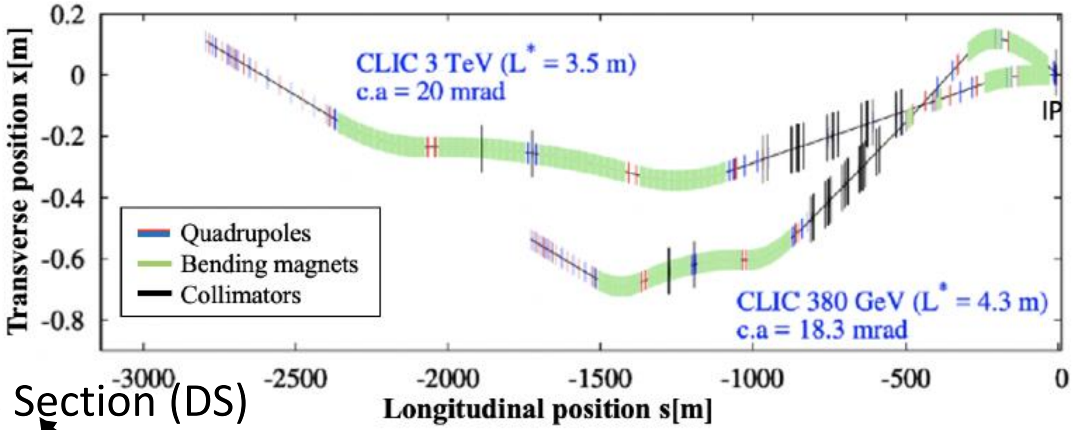
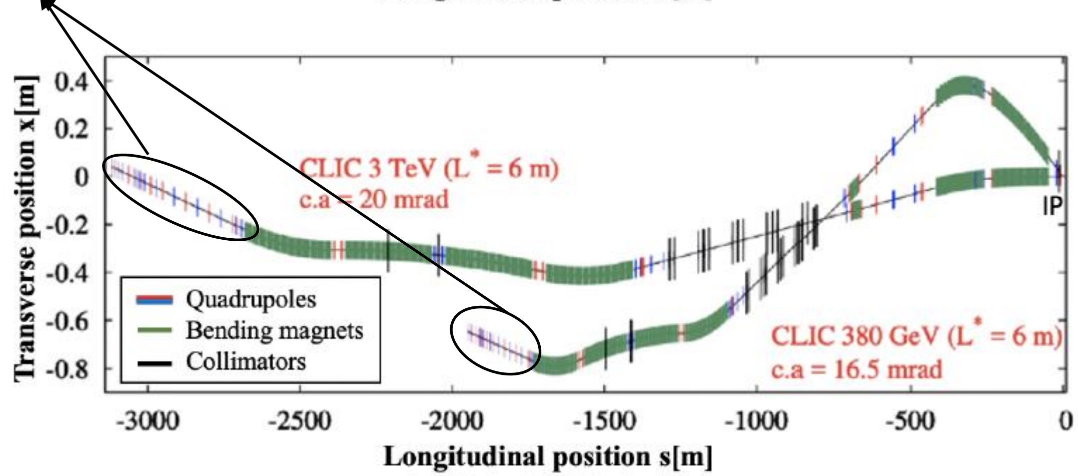


Diagnostics Section (DS)



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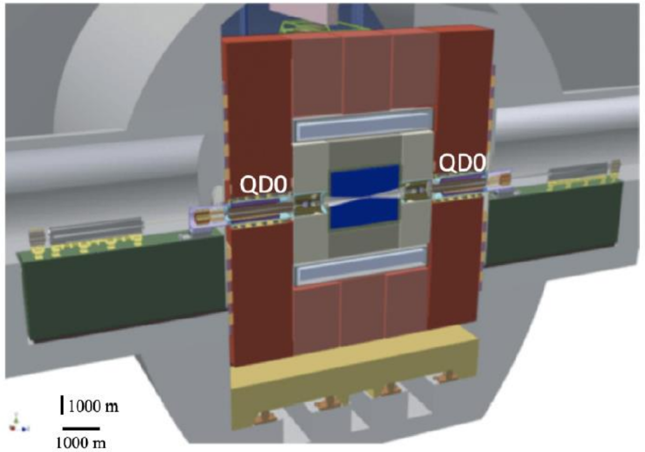
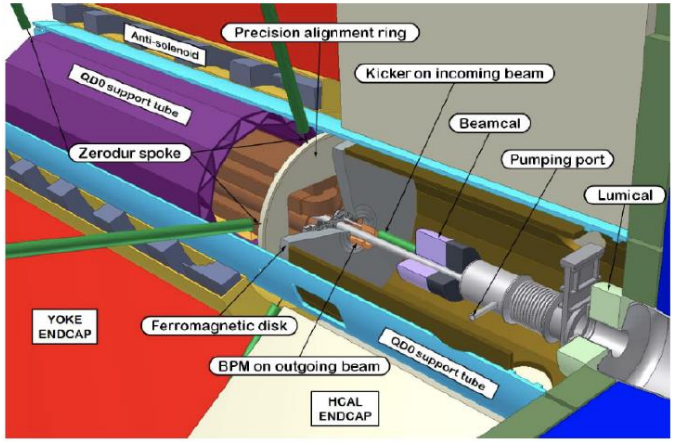
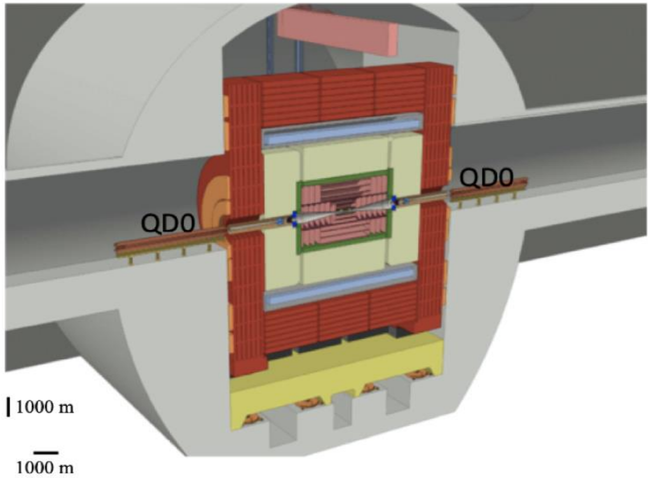
Introduction

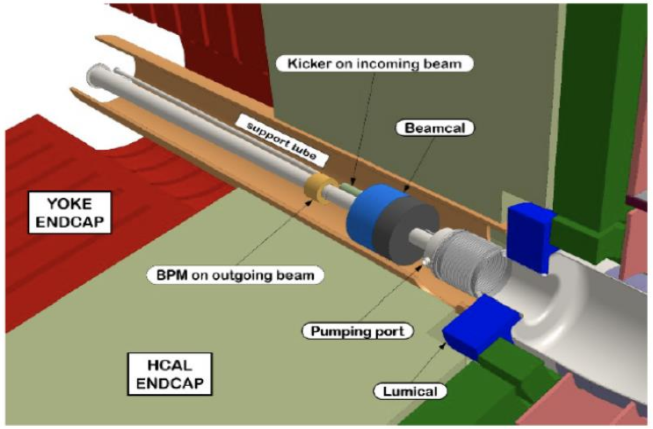
- CLIC MDI
  - SiD Detector (used in CLIC with L*= 3.5 m-CDR design)





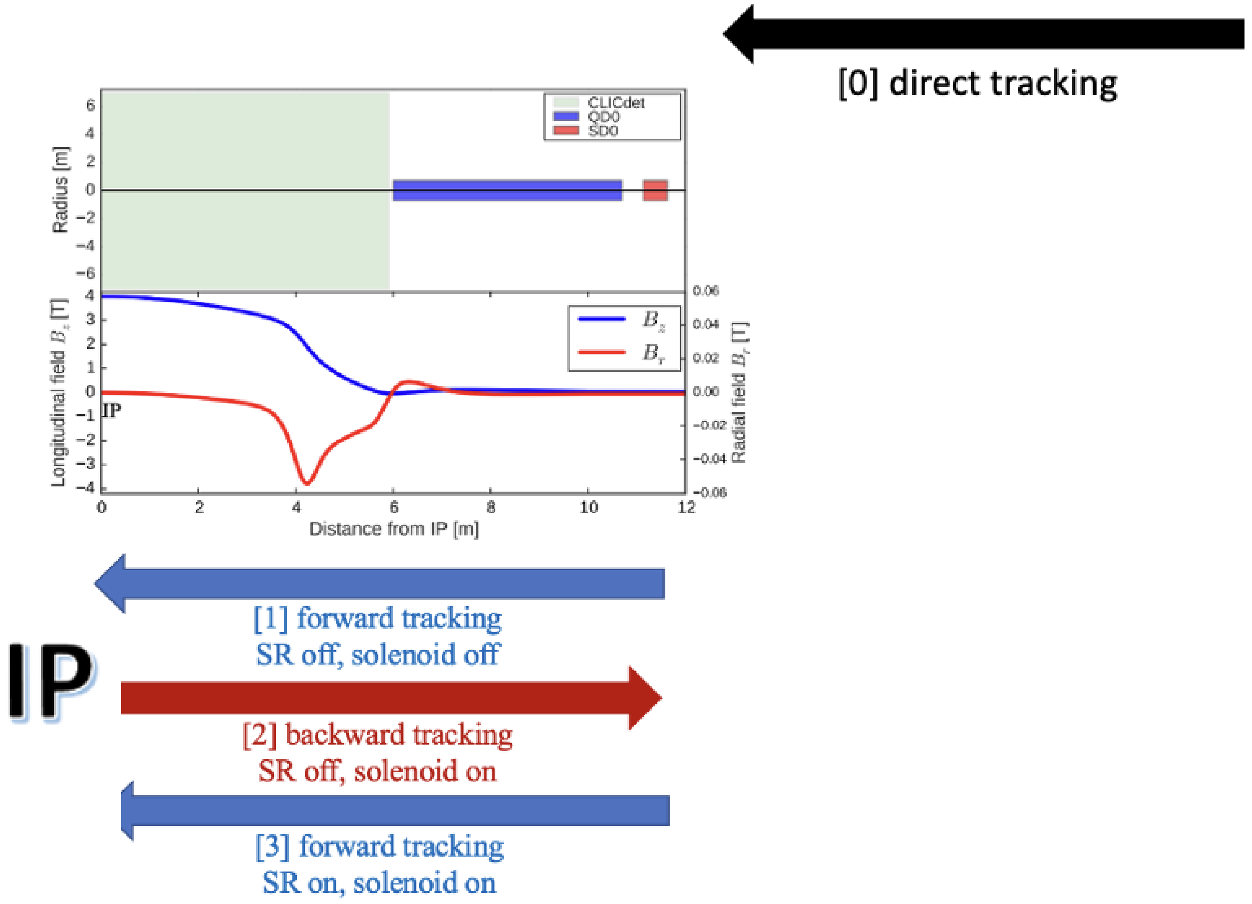
  - CLICdet (used in CLIC with L*= 6 m-current design)





Update of the CLIC 3 TeV performance including the detector solenoid effects

- Tracking procedure in PLACET* including the detector solenoid map



→ The beam is first tracked forward without SR, and without the solenoid field present (1).

→ The ideal IP beam distribution is tracked backwards through the beam line, with the solenoid field turned on but still without SR (2).

→ Finally, the SR is turned on, and the beam is tracked forward through the solenoid (3).

* Y. Inntjore Levinsen, B. Dalena, R. Tomás, and D. Schulte. «Impact of detector solenoid on the Compact Linear Collider luminosity performance». Phys. Rev. ST Accel. Beams **17**, 051002 – Published 27 May 2014; Erratum Phys. Rev. ST Accel. Beams **17**, 079901 (2014)

Update of the CLIC 3 TeV performance including the detector solenoid effects

- Results

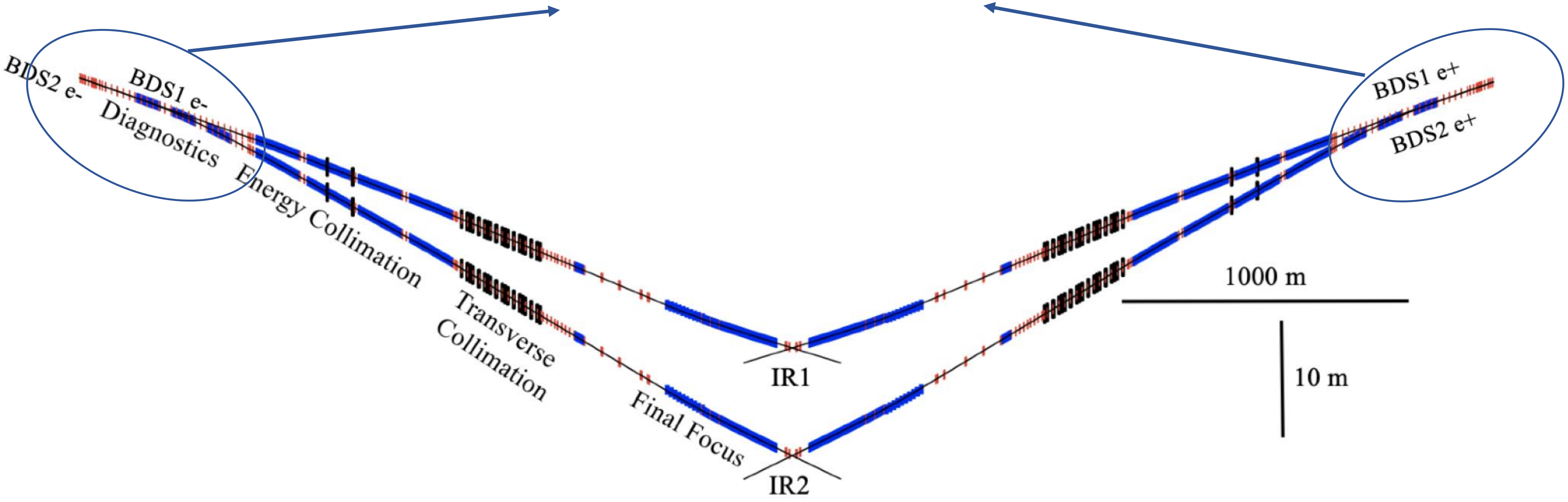
σ_x^* [nm]	ideal	w/ SR
baseline	41.4	50.3
σ_y^* [nm]	ideal	w/ SR
baseline	1.06	1.69

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

- The detector solenoid effect 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 design with L*= 6 m is about 4%.**

Novel Layout of the Dual BDS for CLIC 380 GeV

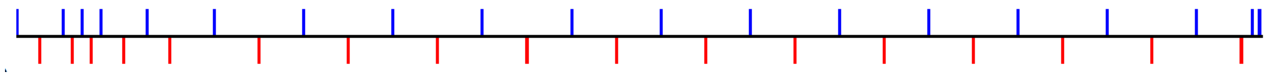
New DS for the dual BDS configuration



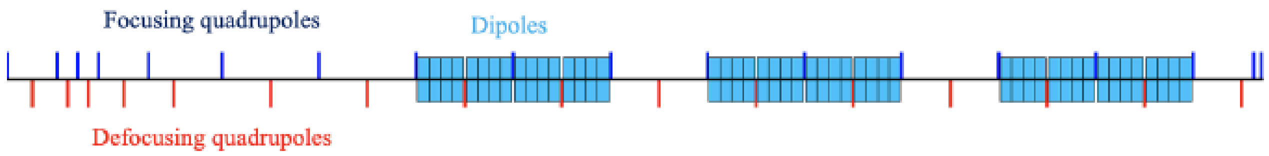
Development of the Model to construct the Dual BDS for CLI

1. The novel optics design have been done in MAD-X starting from the current BDS with one IR
2. 8 more cells with a μ of 45° → **additional length of 300 m**
3. The FODO cells have been **filled with Dipoles + Dispersion Suppressor** for the separation of the two BDS
4. We have different lengths of the DS → **the new layout involves four different beamlines** in order to provide the desired longitudinal and transverse separation at the IP

- BDS1:



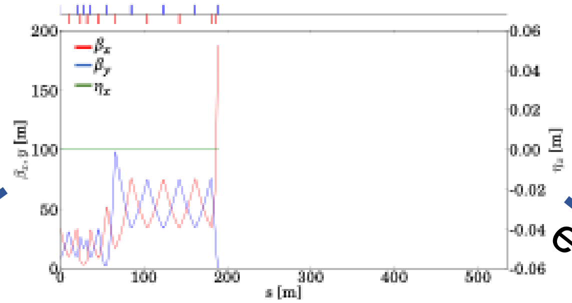
- BDS2:



CLIC 380 GeV				
	IR1		IR2	
	BDS1 e^+ (short)	BDS1 e^- (long)	BDS2 e^- (short)	BDS2 e^+ (long)
θ [mrad]	0	0	4.83	4.83
L_{dipole}[m]	0	0	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

Novel Layout of the Dual BDS for CLIC 380 GeV

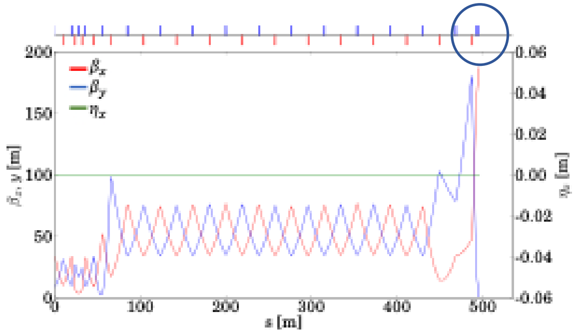
DS of the BDS with one IR



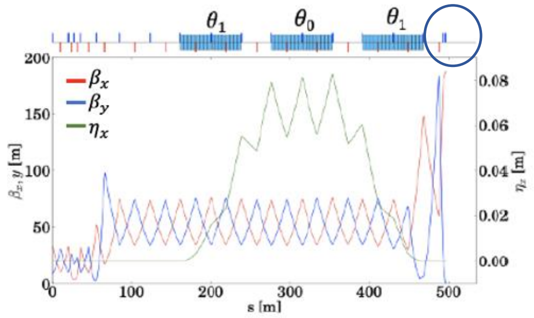
BDS1 e+/e-

BDS2 e+/e-

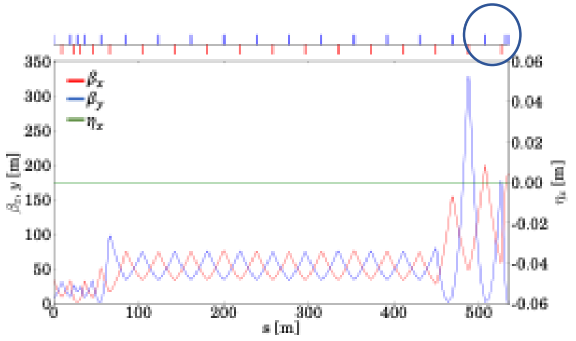
New DS of the BDS1 e+



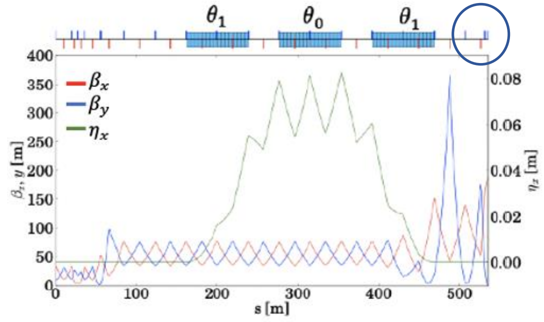
New DS of the BDS2 e-



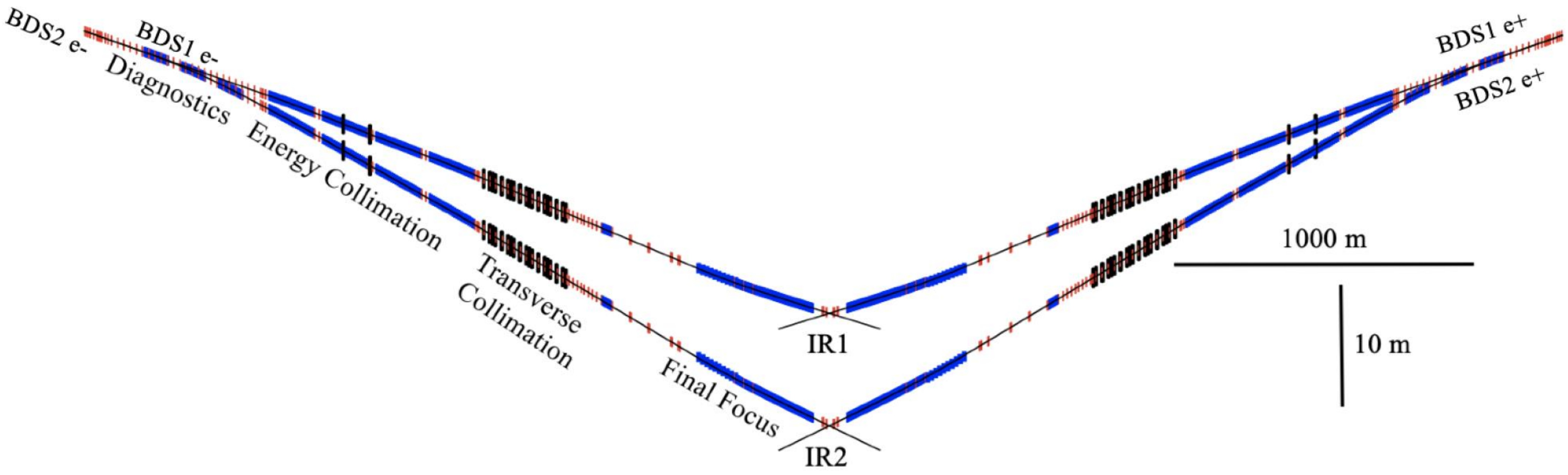
New DS of the BDS1 e-



New DS of the BDS2 e+

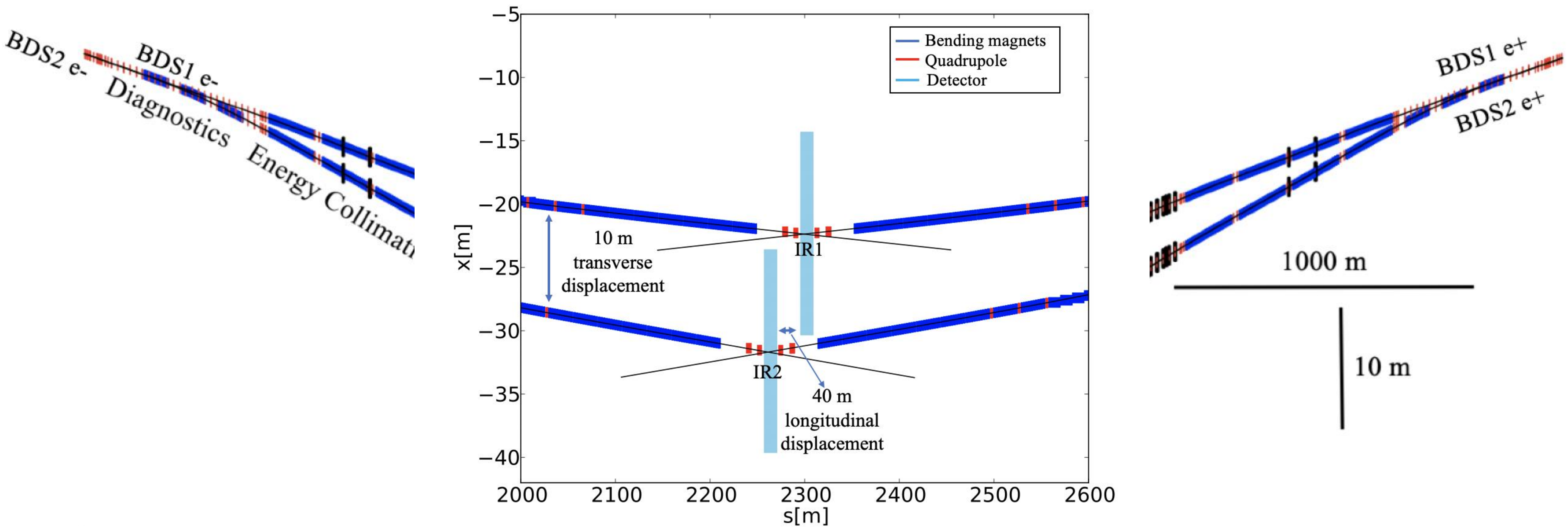


Novel Layout of the Dual BDS for CLIC 380 GeV



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

Novel Layout of the Dual BDS for CLIC 380 GeV



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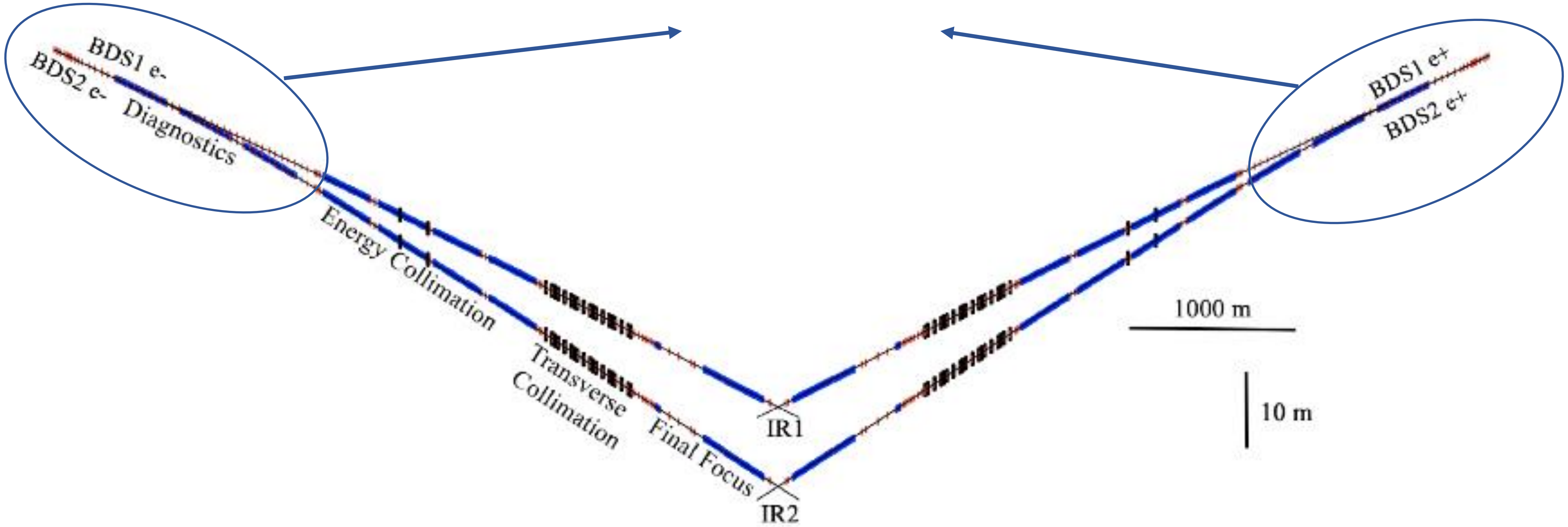
Novel Layout of the Dual BDS for CLIC 3 TeV

New DS for the dual BDS configuration



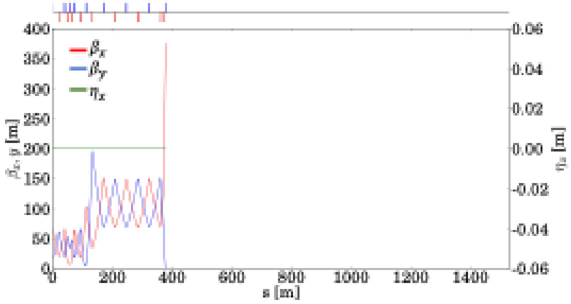
Development of the Model to construct the Dual BDS for CLI

1. The procedure to make the new DS has been the same: **Additional length of 1.2 km →** total length of the DS is ~ 1.5 km (longer dipoles to avoid large SR)
2. In order to have the IRs at the exact same locations as in the CLIC 380 GeV case → ***θ* in the DS of the BDS2 is 2.75 mrad**
3. Same longitudinal and transverse dispalcement at the IP as in the case of the 380 GeV

CLIC 3 TeV				
	IR1		IR2	
	BDS1 e^+ (short)	BDS1 e^- (long)	BDS2 e^- (short)	BDS2 e^+ (long)
θ [mrad]	0	0	2.75	2.75
L_{dipole}[m]	0	0	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

Novel Layout of the Dual BDS for CLIC 380 GeV

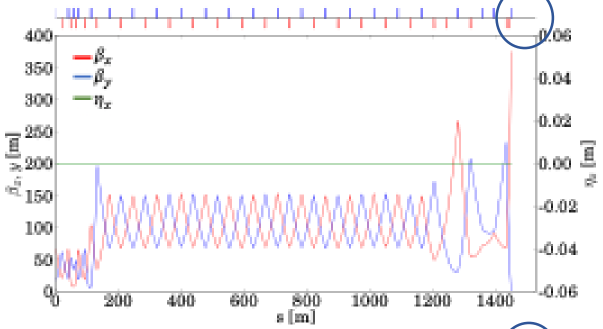
DS of the BDS with one IR



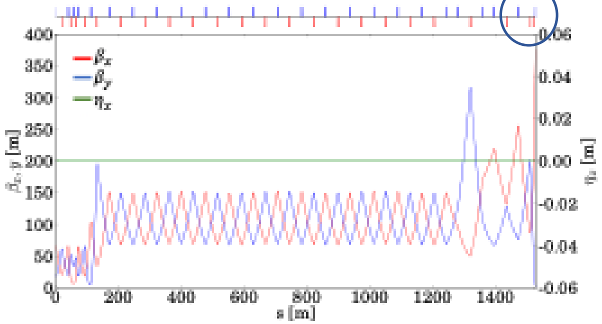
BDS1 e+/e-

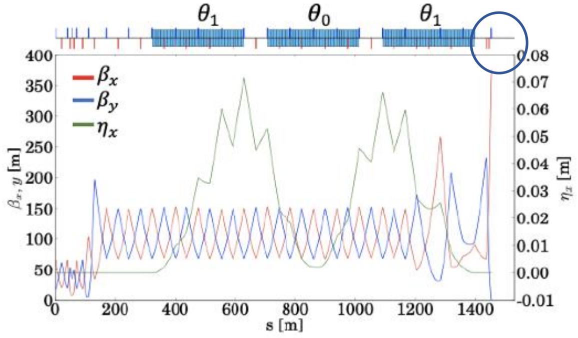
BDS2 e+/e-

New DS of the BDS1 e+

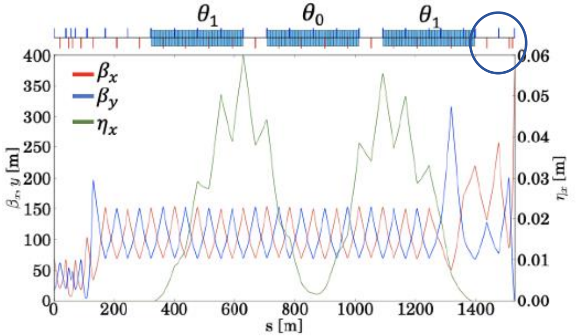


New DS of the BDS1 e-



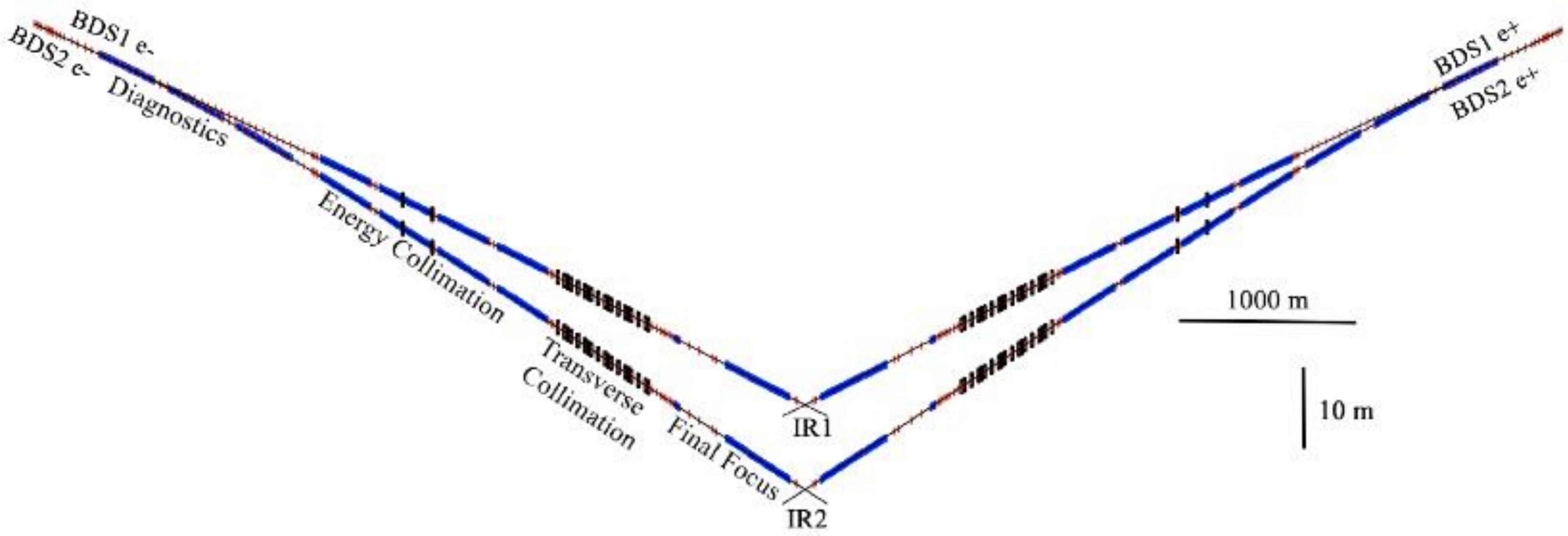


New DS of the BDS2 e-



New DS of the BDS2 e+

Novel Layout of the Dual BDS for CLIC 3 TeV

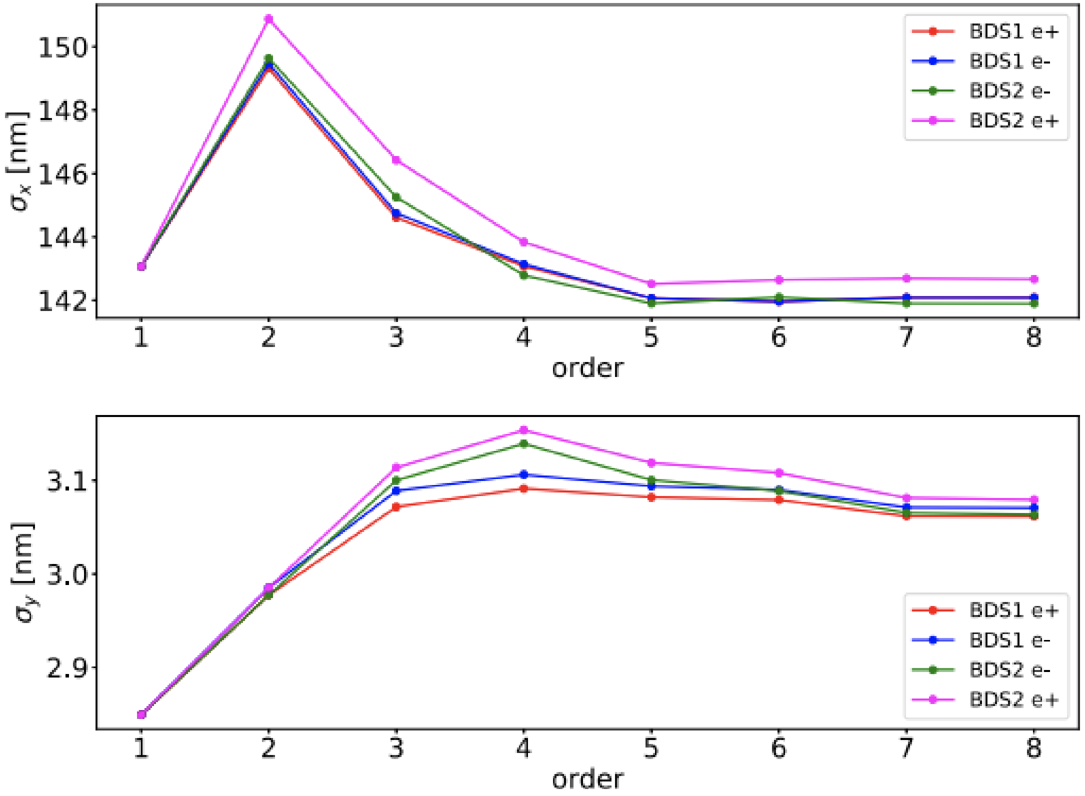


- **The crossing angles at IR1 and IR2 are respectively 20 mrad and 25.5 mrad**.

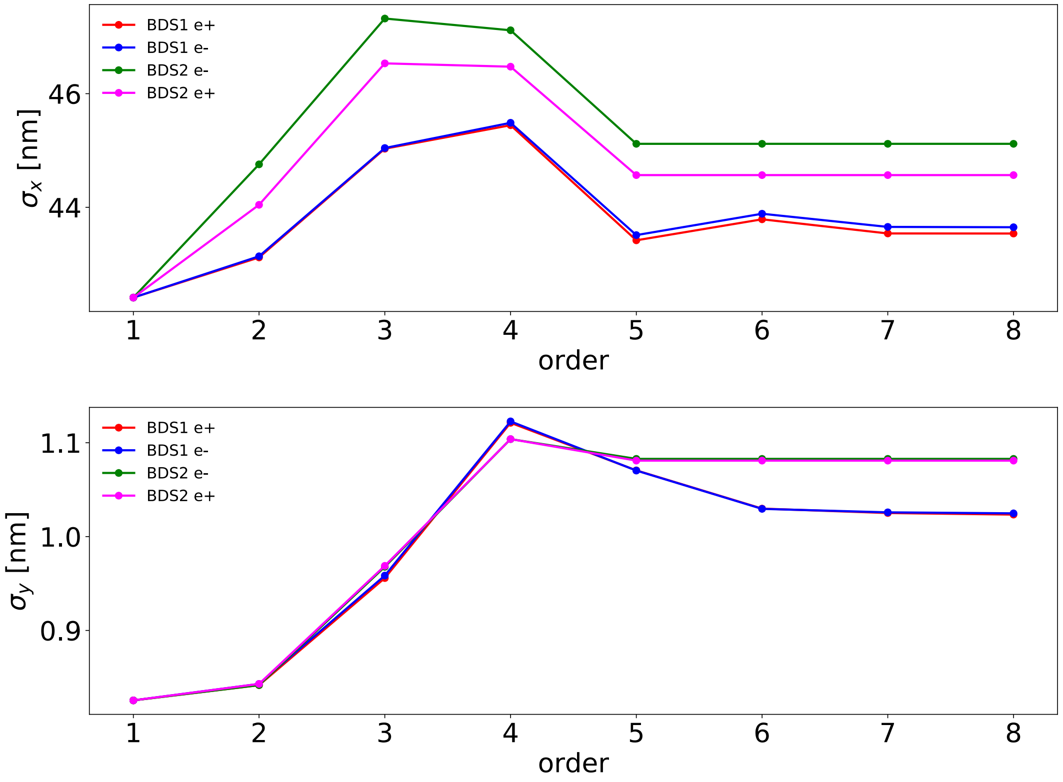
Simulation Results for the dual CLIC BDS

- Beam Size with MAPCLASS and PTC

  - CLIC 380 GeV



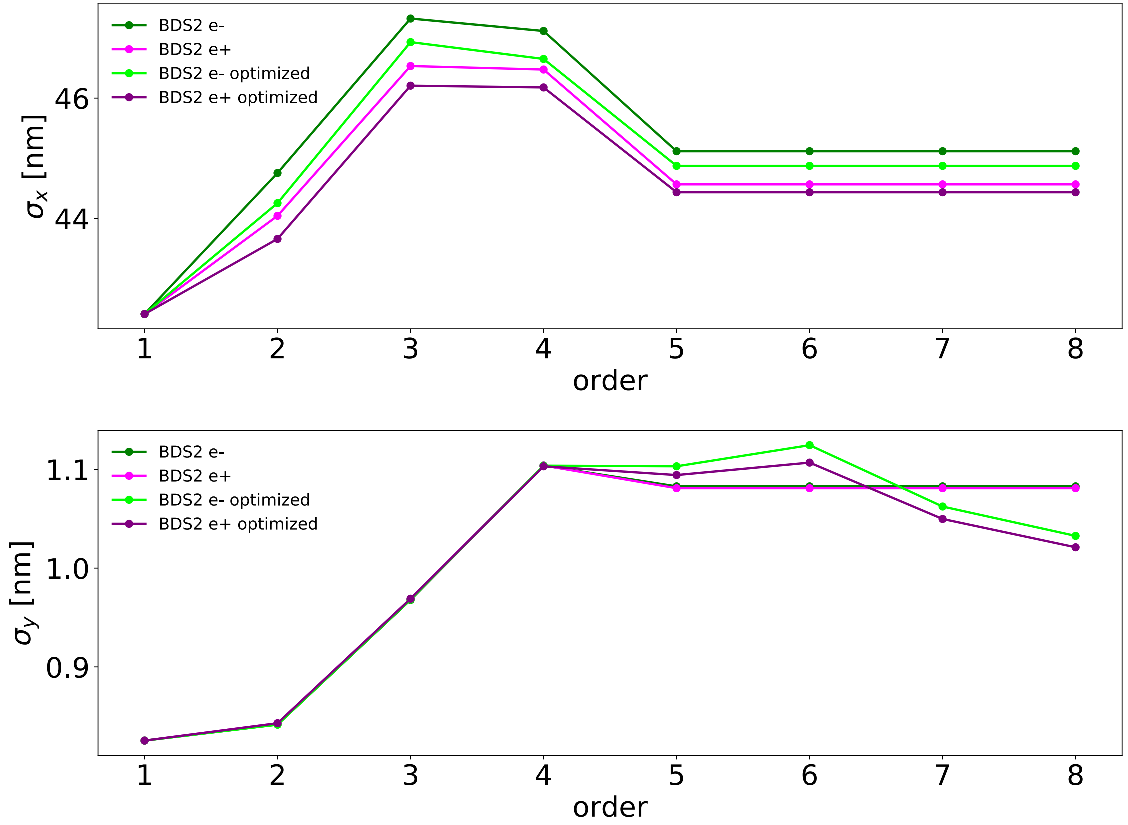
  - CLIC 3 TeV

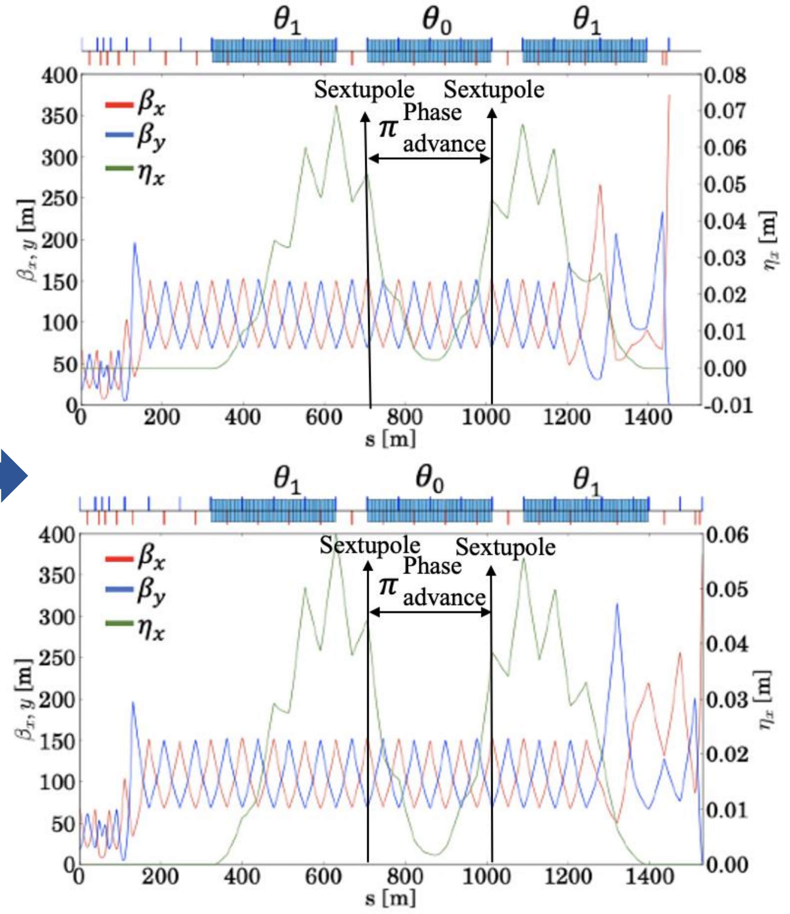


Simulation Results for the dual CLIC BDS

- Beam Size with MAPCLASS and PTC

  - CLIC 3 TeV-BDS2 optimized





Simulation Results for the dual CLIC BDS

- 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 for the dual CLIC BDS

- 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	44.9	64.8

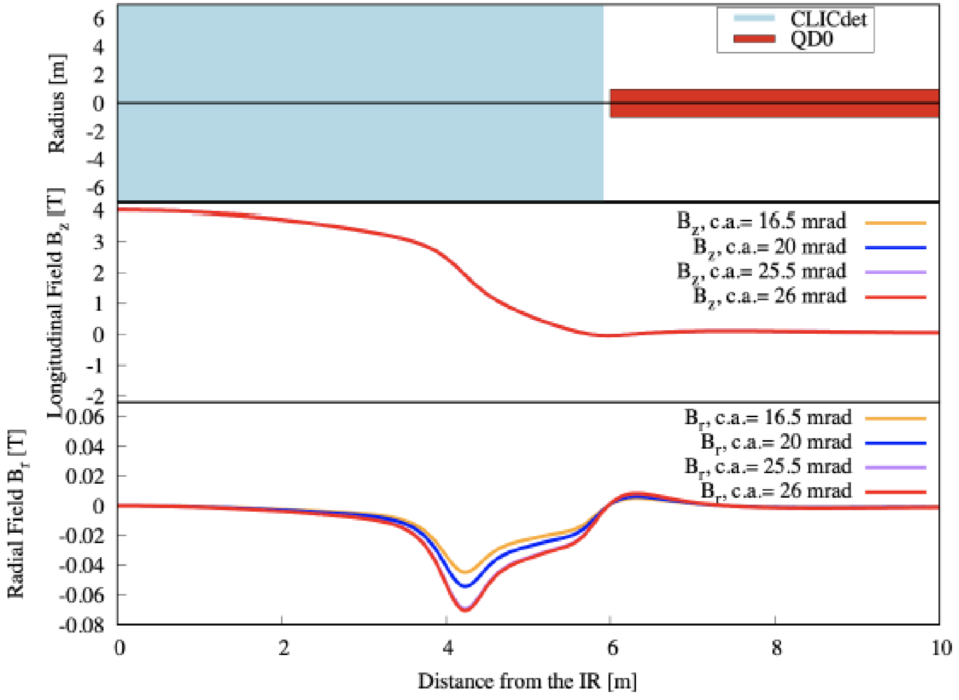
σ_y^* [nm]	ideal	w/ SR
IR1	1.02	1.71
IR2	1.02	1.92

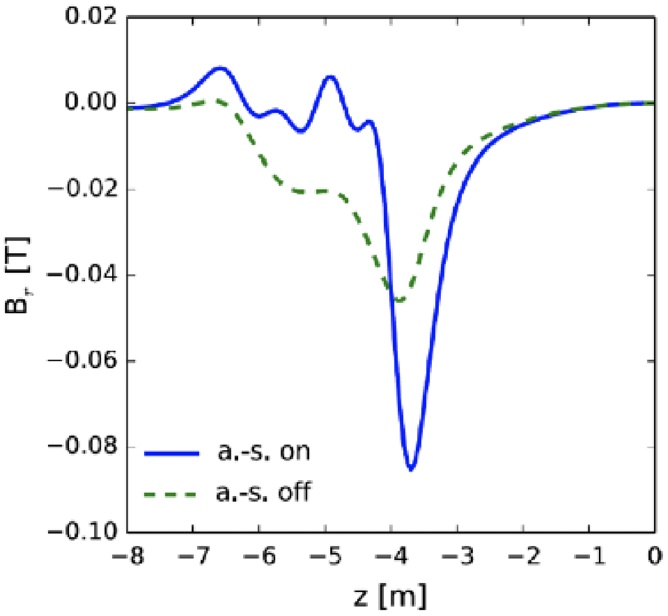
Luminosity [10^{34} cm^{-2} s^{-1}]	ideal	w/ solenoid	w/ SR	w/ sol+ SR
IR1	9.0	8.21	6.30	6.09
IR2	8.33	7.59	5.14	4.17

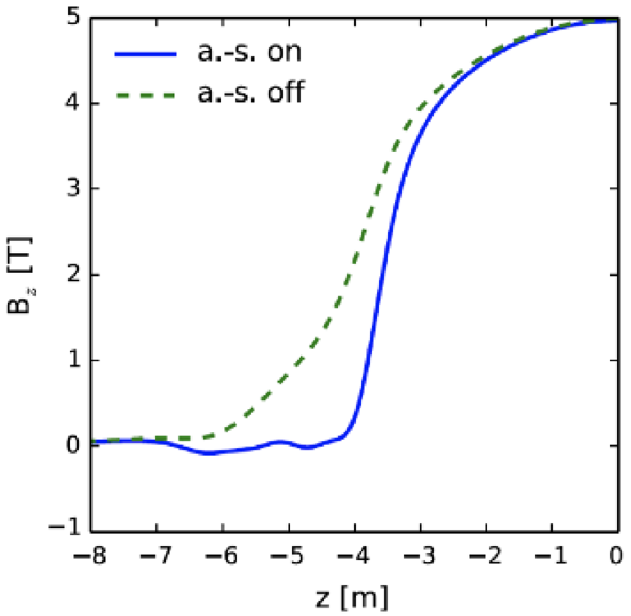
- The beam size simulations with the different codes (MAPCLASS and PLACET) show consistency of the results.
- **The impact on the luminosity performance of CLIC 3 TeV for the solenoid field is ~ 4% for the IR1 and ~ 19% for IR2.**

Simulation Results for the dual CLIC BDS

- Mitigation of the Detector Solenoid Effects: Anti-solenoid







- Different crossing angles imply different magnetic field near the IP. In fact, the transverse solenoid magnetic field increases with the increase of the design crossing angle.
- A simulation with the new baseline design but with the SiD configuration has been done.
- **Adding an anti-solenoid to the CLIC configuration could reduce luminosity loss from 4% to 1%.**

Conclusions and Outlook

- **The dual BDS design is competitive up to 3 TeV** with a total luminosity loss of about 30% for the extra line with larger crossing angle.

- The impact on the luminosity performance of CLIC 3 TeV for the detector solenoid field is about 4% for the baseline and for IR1 and about 19% for IR2 → **adding the antisolenoid reduces the luminosity losses of at least 3%.**

- 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
  → make a longer BDS to reduce the SR effects.

Thank you for the attention!