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# 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



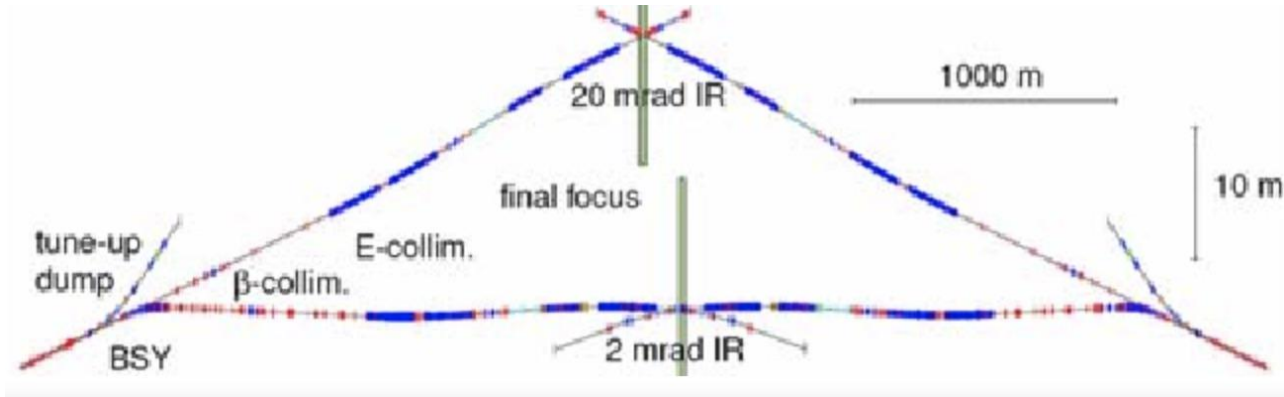
# Outline

- 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

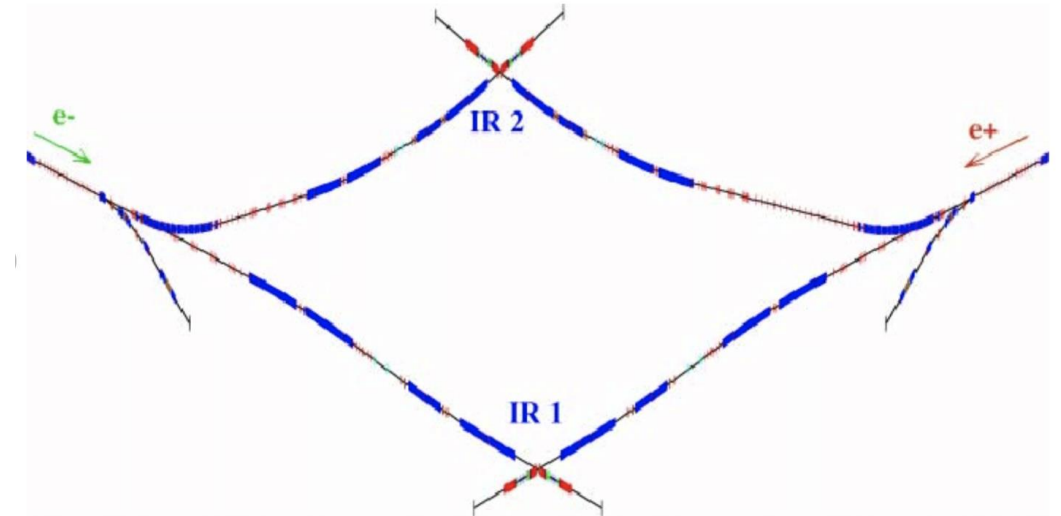
# Motivation of the study

- **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:



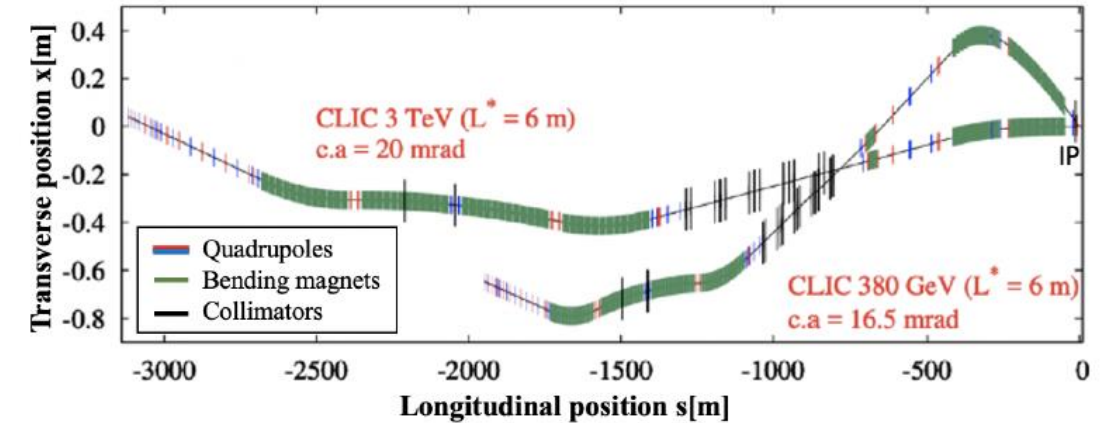
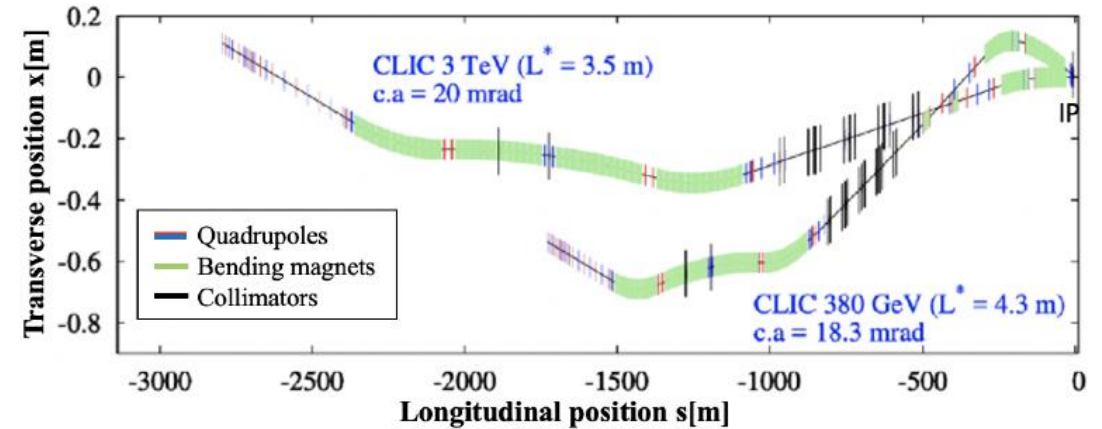
\* BEAM DELIVERY SYSTEM IN ILC. G. A. Blair# , John Adams Institute at RHUL, London. TW20 0EX. UK. Proceedings of EPAC 2006, Edinburgh, Scotland.

\* 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) $\beta_x^*$ [mm]	8	8	7	7
Beta function (IP) $\beta_y^*$ [mm]	0.1	0.1	0.068	0.12
IP beam size $\sigma_x^*$ [nm]	144	144	40	40
IP beam size $\sigma_y^*$ [nm]	2.9	2.9	0.7	0.9
Bunch length $\sigma_z$ [ $\mu\text{m}$ ]	70	70	44	44
rms energy spread $\delta_p$ [%]	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 $\mathcal{L}_{TOT}$ [ $10^{34} \text{ cm}^{-2} \text{ s}^{-1}$ ]	1.5	1.5	5.9	5.9

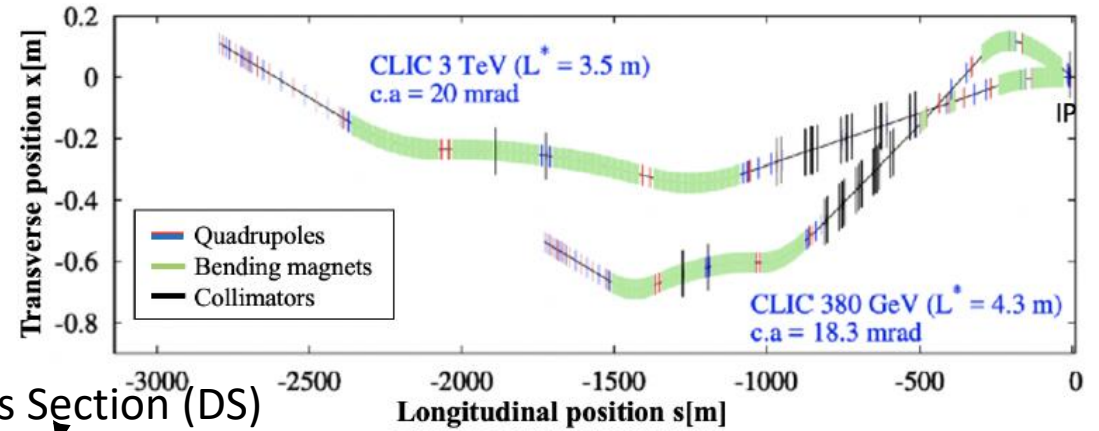


\* Optics optimization of longer  $L^*$  Beam Delivery System designs for CLIC and tuning of the ATF2 final focus system at ultra-low  $\beta^*$  using octupoles. Fabien Plassard. CERN-THESIS-2018-223. PhD : U. Paris-Saclay : 2018-06-06.

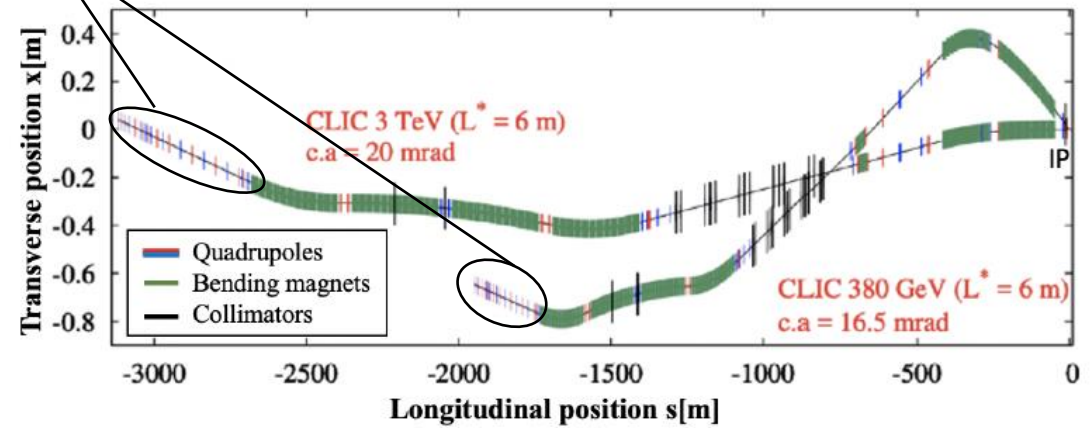
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Diagnostics Section (DS)

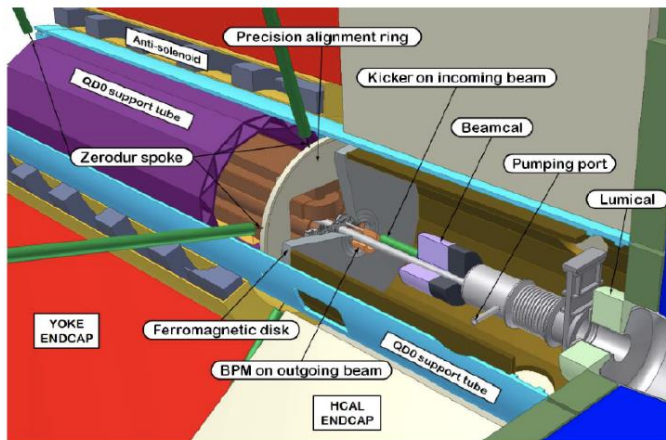
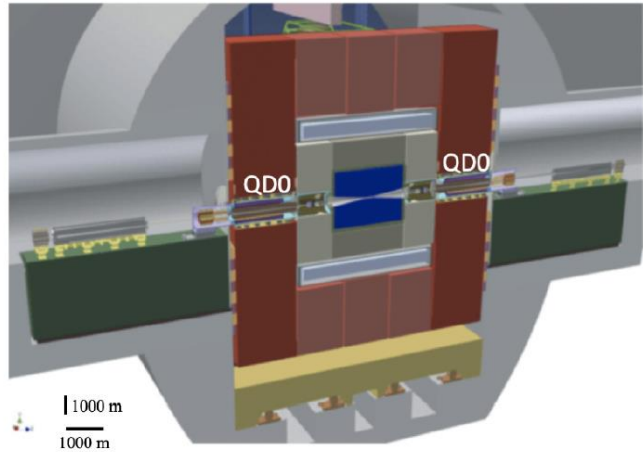


\* Optics optimization of longer  $L^*$  Beam Delivery System designs for CLIC and tuning of the ATF2 final focus system at ultra-low  $\beta^*$  using octupoles. Fabien Plassard. CERN-THESIS-2018-223. PhD : U. Paris-Saclay : 2018-06-06.

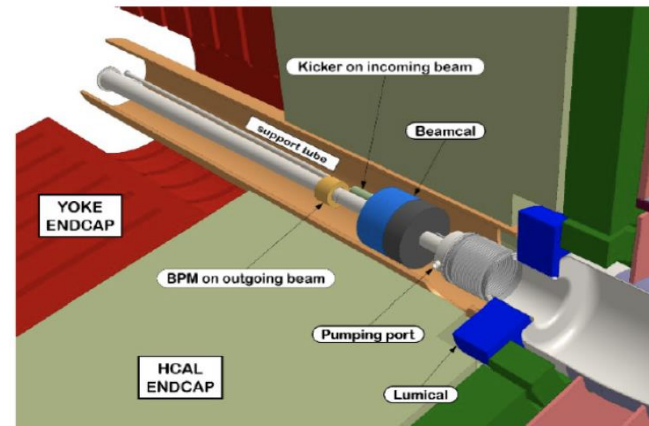
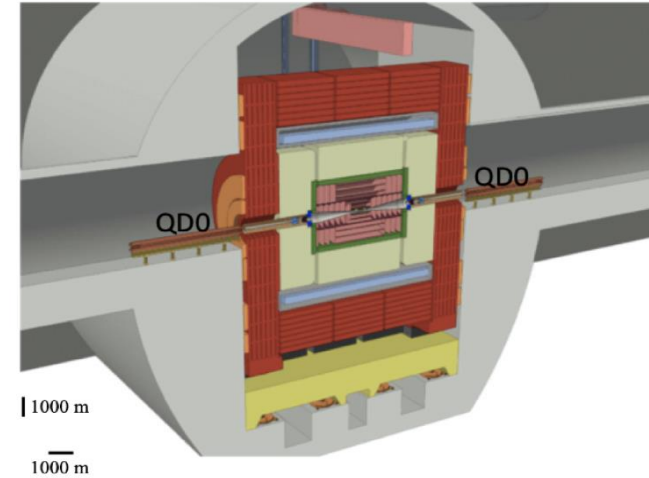
# Introduction

## ➤ CLIC MDI

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

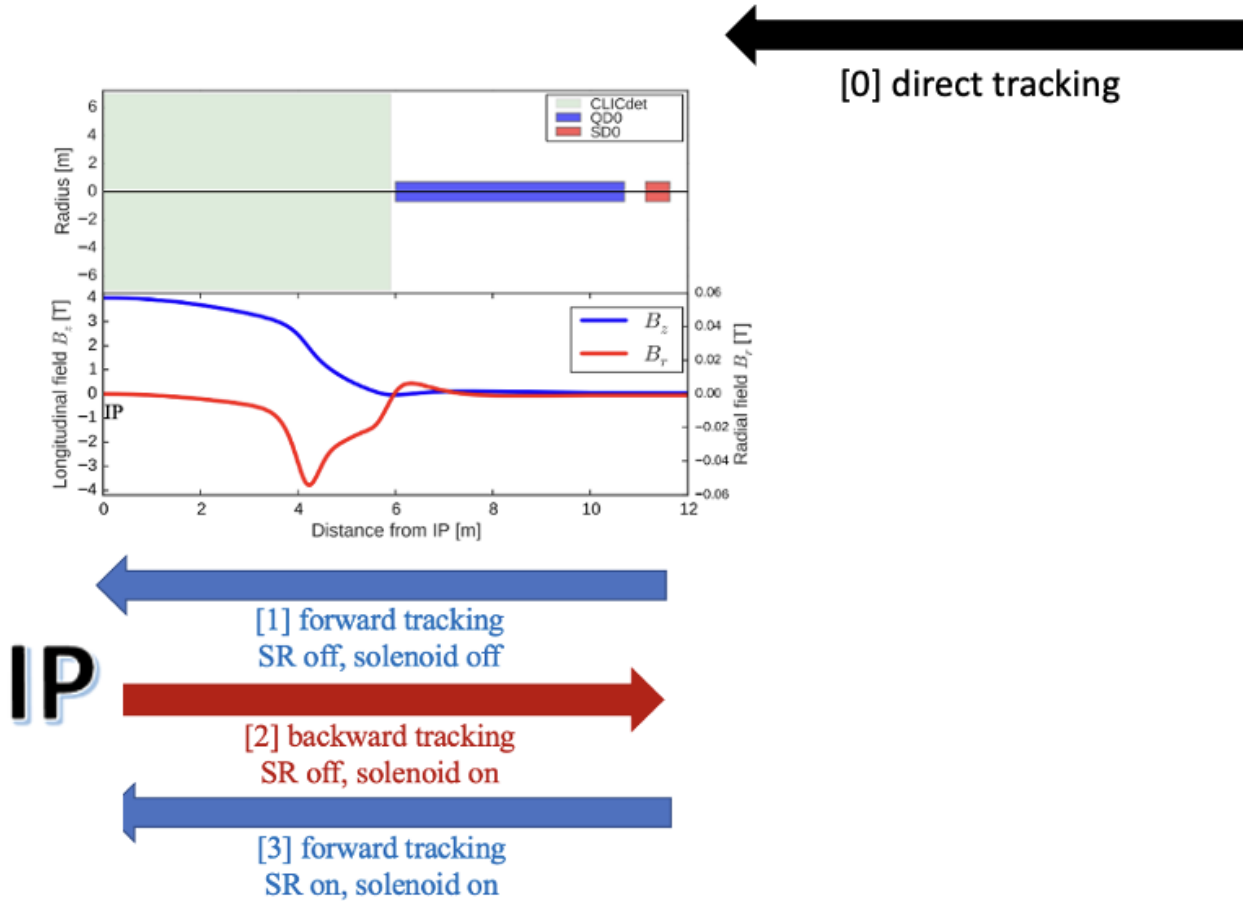


- CLICdet (used in CLIC with  $L^* = 6$  m-current design)



# 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

$\sigma_x^*$ [nm]	ideal	w/ SR
baseline	41.4	50.3
$\sigma_y^*$ [nm]	ideal	w/ SR
baseline	1.06	1.69

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

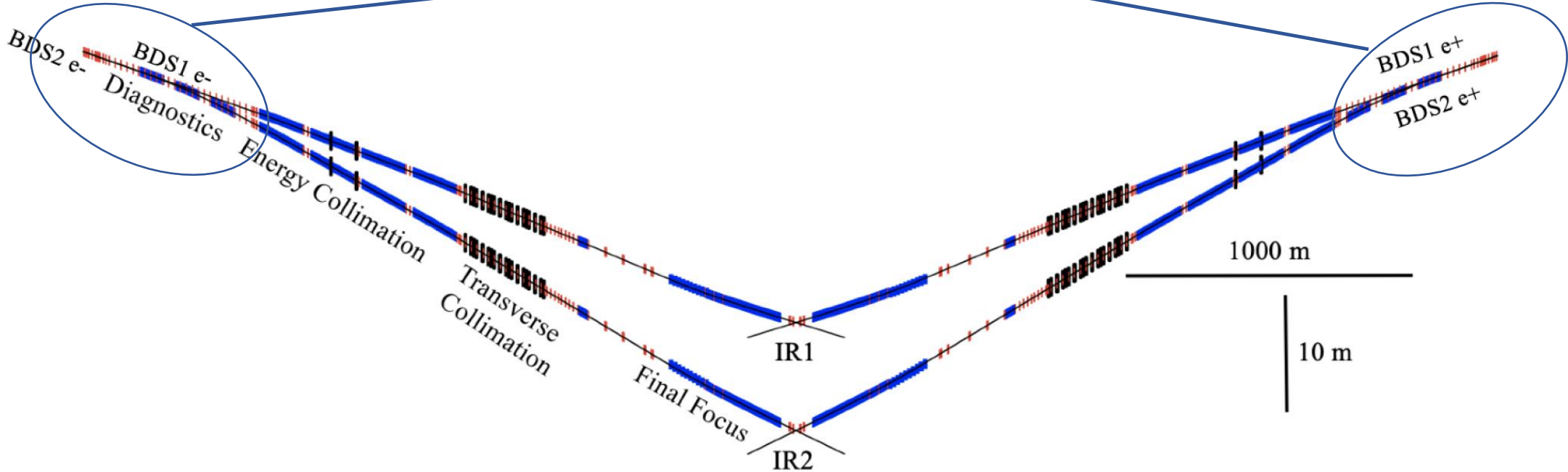
- The detector solenoid effect was never evaluated for the CLIC with  $L^* = 6 \text{ m}$ , while for the  $L^* = 3.5 \text{ m}$  was  $\sim 4\%$ .
- The evaluation of the beam size and the luminosity (ideal and w/ SR) has been done with the direct PLACET tracking procedure.
- The evaluation of the luminosity 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  $L^* = 6 \text{ m}$  is about 4%.**





# Novel Layout of the Dual BDS for CLIC 380 GeV

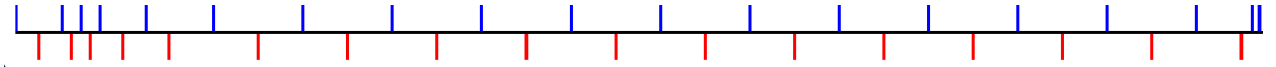
New DS for the dual BDS configuration



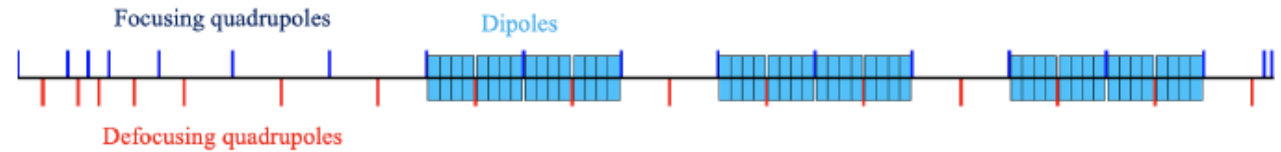
# Development of the Model to construct the Dual BDS for CLIC

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  $\mu$  of  $45^\circ$  → **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

- BDS1:



- BDS2:

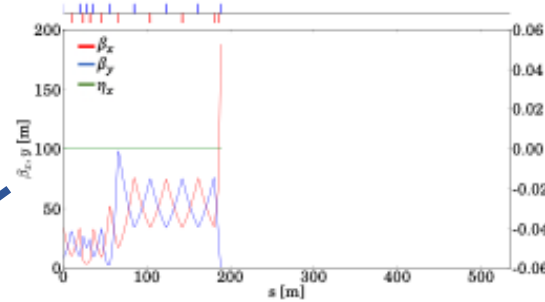


CLIC 380 GeV				
	IR1		IR2	
	BDS1 e <sup>+</sup> (short)	BDS1 e <sup>-</sup> (long)	BDS2 e <sup>-</sup> (short)	BDS2 e <sup>+</sup> (long)
$\theta$ [mrad]	0	0	4.83	4.83
$L_{dipole}$ [m]	0	0	218.11	218.11
$L_{FODO}$ [m]	38.36	38.36	38.36	38.36
$L_{DS}$ [m]	512.89	551.24	512.89	551.24
$L_{BDS}$ [m]	2255.95	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

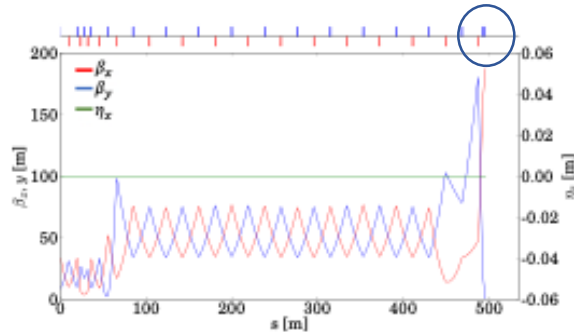
DS of the BDS with one IR

BDS1 e+/e-

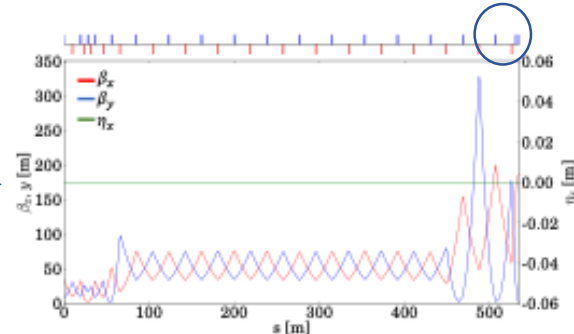


BDS2 e+/e-

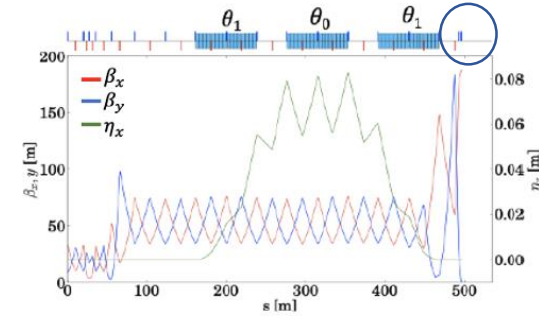
New DS of the BDS1 e+



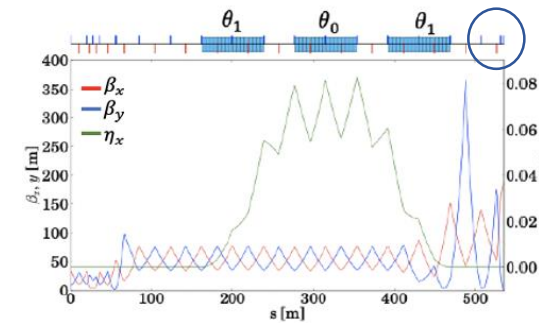
New DS of the BDS1 e-



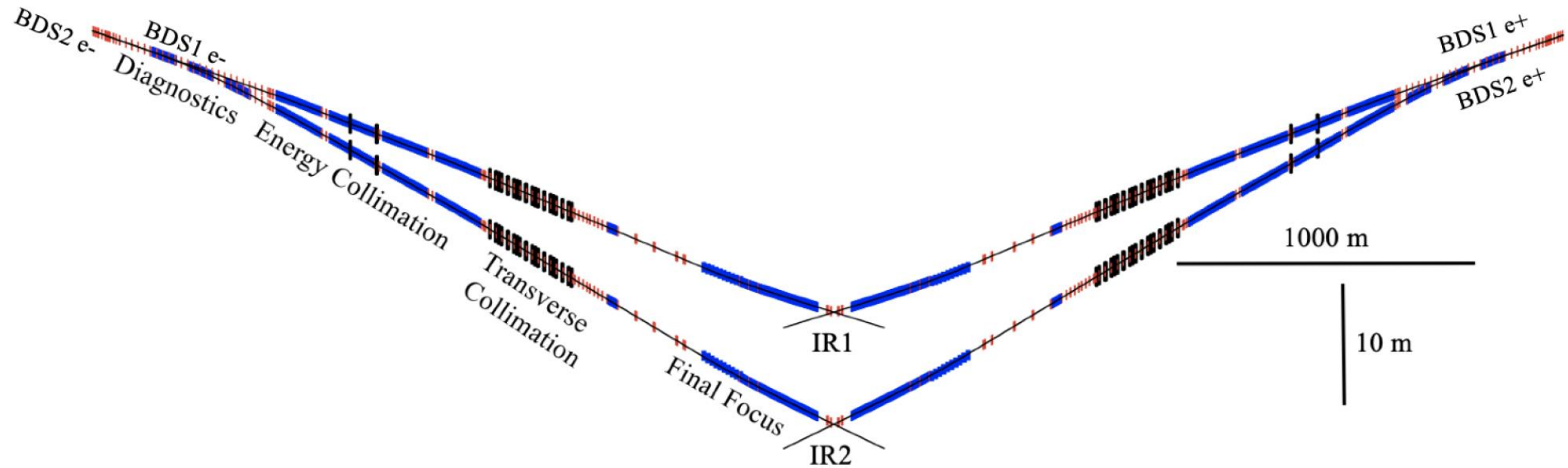
New DS of the BDS2 e-



New DS of the BDS2 e+



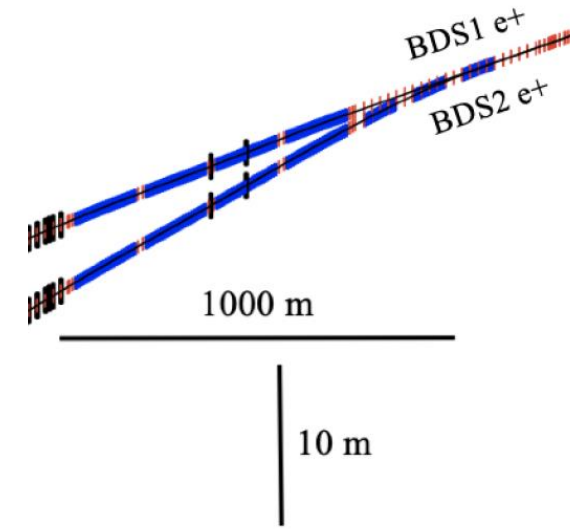
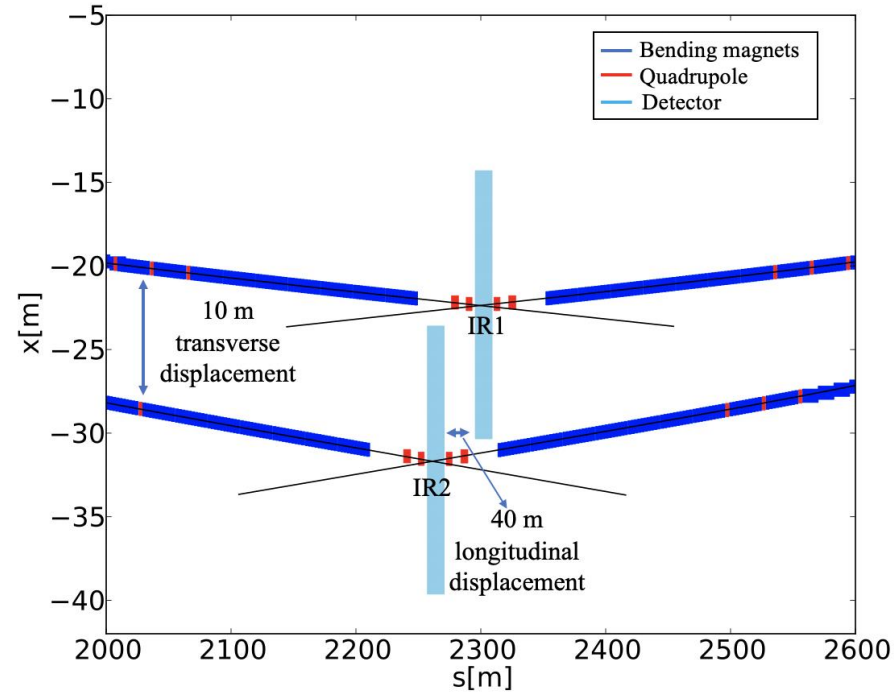
# Novel Layout of the Dual BDS for CLIC 380 GeV



- Four different beam lines have been constructed to provide:
  - Longitudinal separation of  $\sim 40$  m at IP.
  - Transverse separation of 10 m at IP.
- The  $\theta$  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

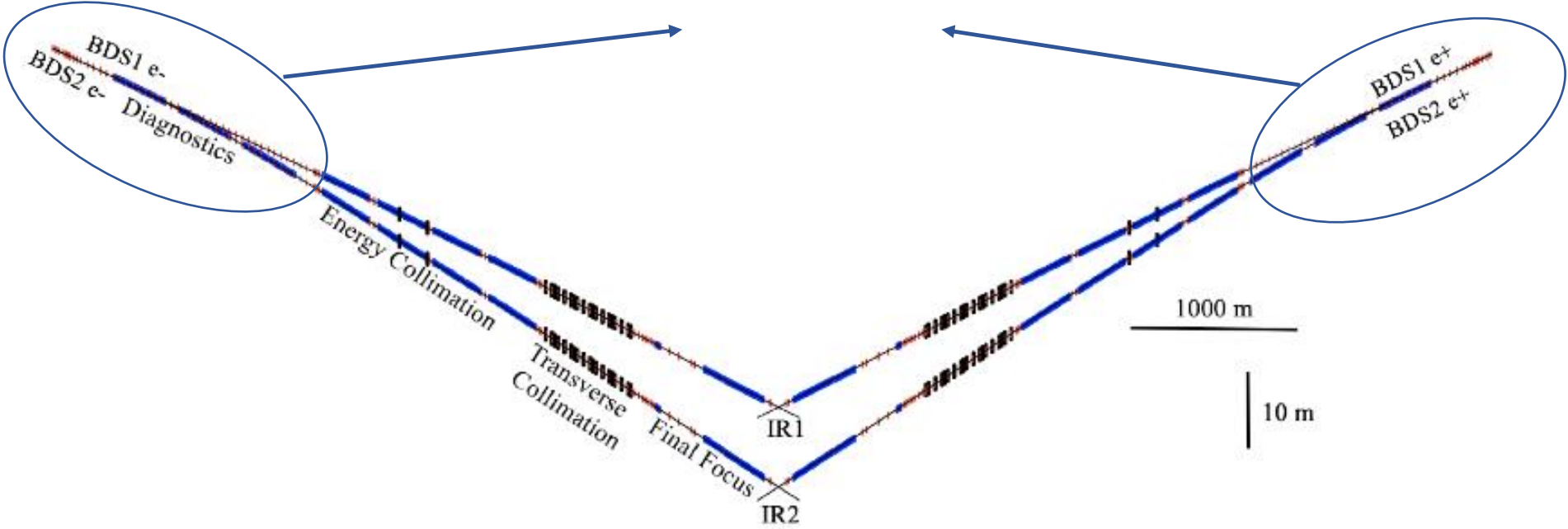
BDS2 e-  
BDS1 e-  
Diagnostics  
Energy Collimat



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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 CLIC

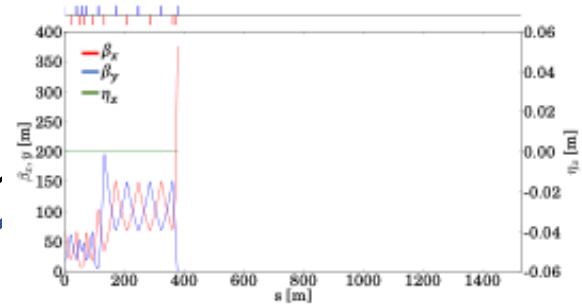
1. The procedure to make the new DS has been the same:  
**Additional length of 1.2 km** → total length of the DS is  $\sim 1.5$  km (longer dipoles to avoid large SR)
2. In order to have the IRs at the exact same locations as in the CLIC 380 GeV case →  $\theta$  in the **DS of the BDS2 is 2.75 mrad**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

CLIC 3 TeV				
	IR1		IR2	
	BDS1 e <sup>+</sup> (short)	BDS1 e <sup>-</sup> (long)	BDS2 e <sup>-</sup> (short)	BDS2 e <sup>+</sup> (long)
$\theta$ [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

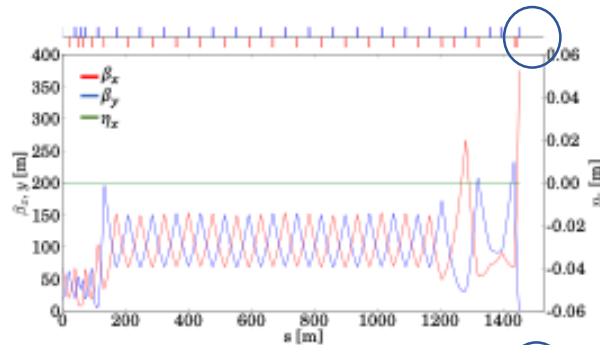
DS of the BDS with one IR

BDS1 e+/e-

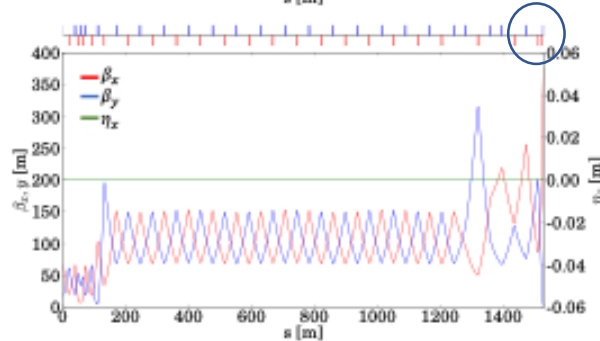


BDS2 e+/e-

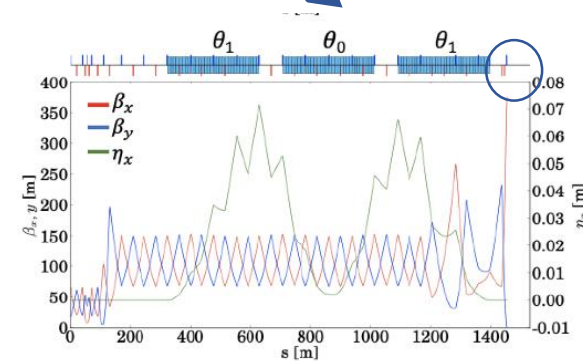
New DS of the BDS1 e+



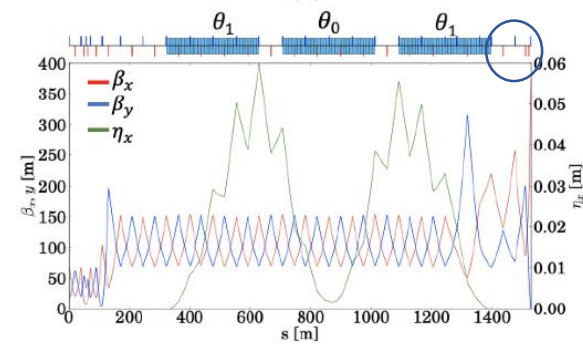
New DS of the BDS1 e-



New DS of the BDS2 e-

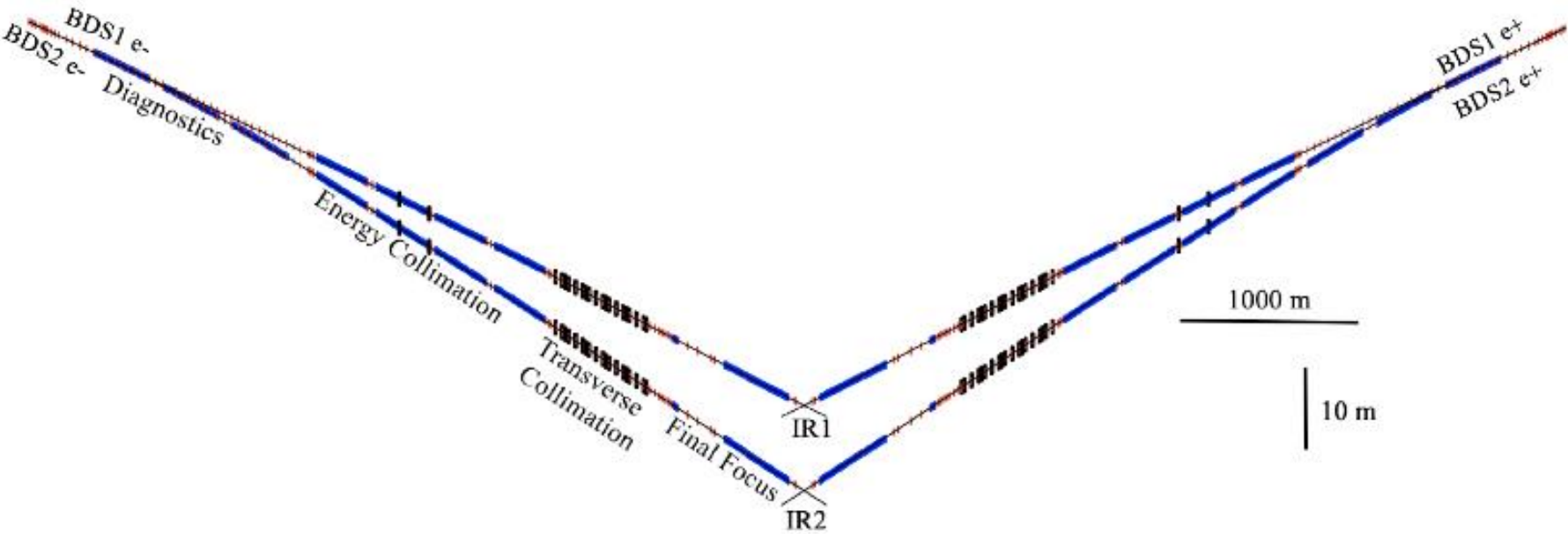


New DS of the BDS2 e+





# Novel Layout of the Dual BDS for CLIC 3 TeV

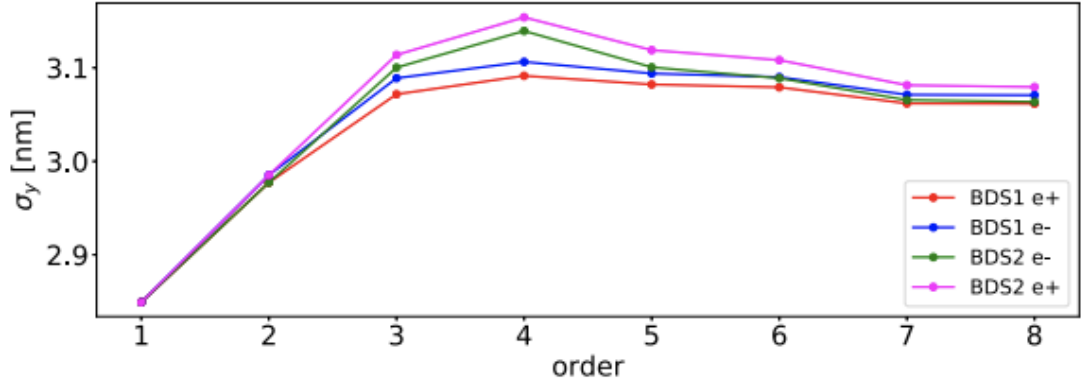
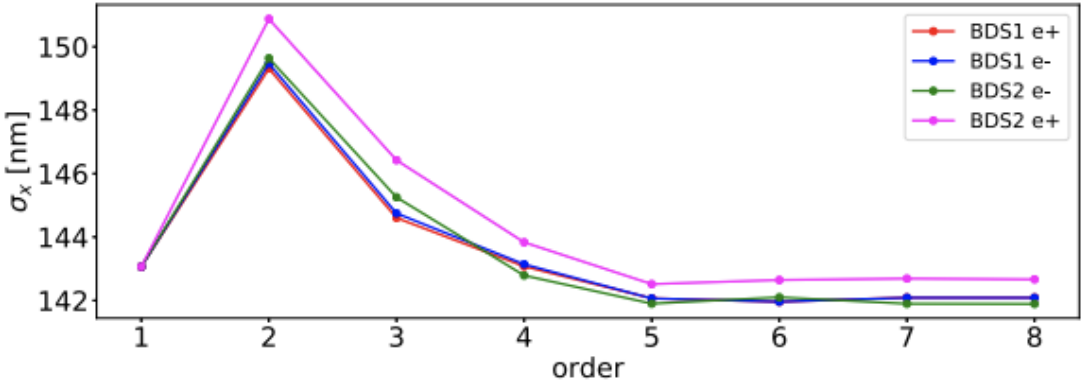


➤ The crossing angles at IR1 and IR2 are respectively 20 mrad and 25.5 mrad.

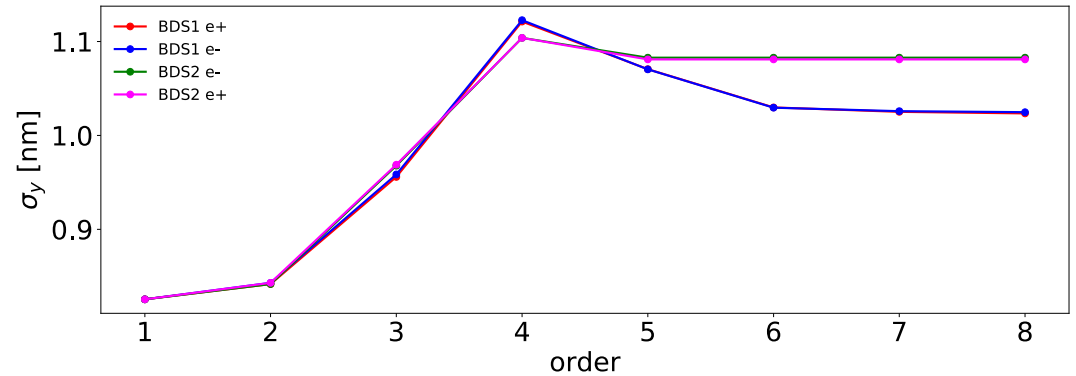
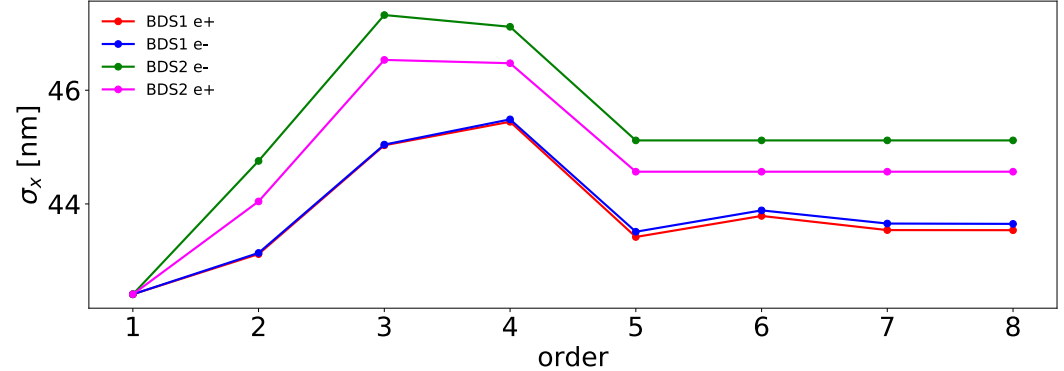
# Simulation Results for the dual CLIC BDS

- Beam Size with MAPCLASS and PTC

- CLIC 380 GeV

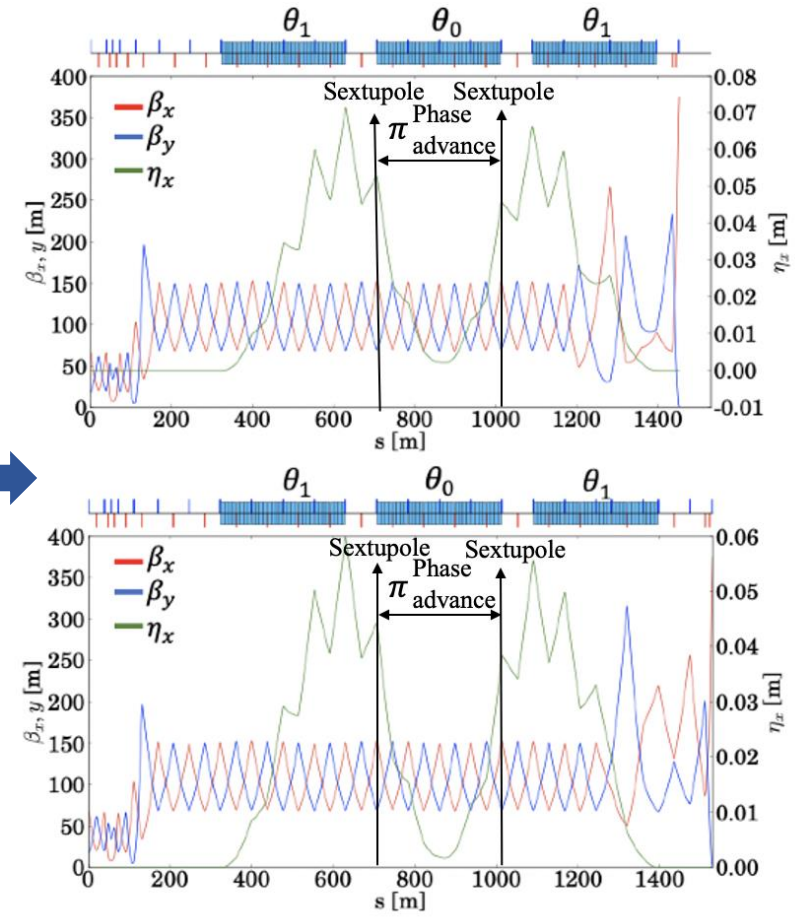
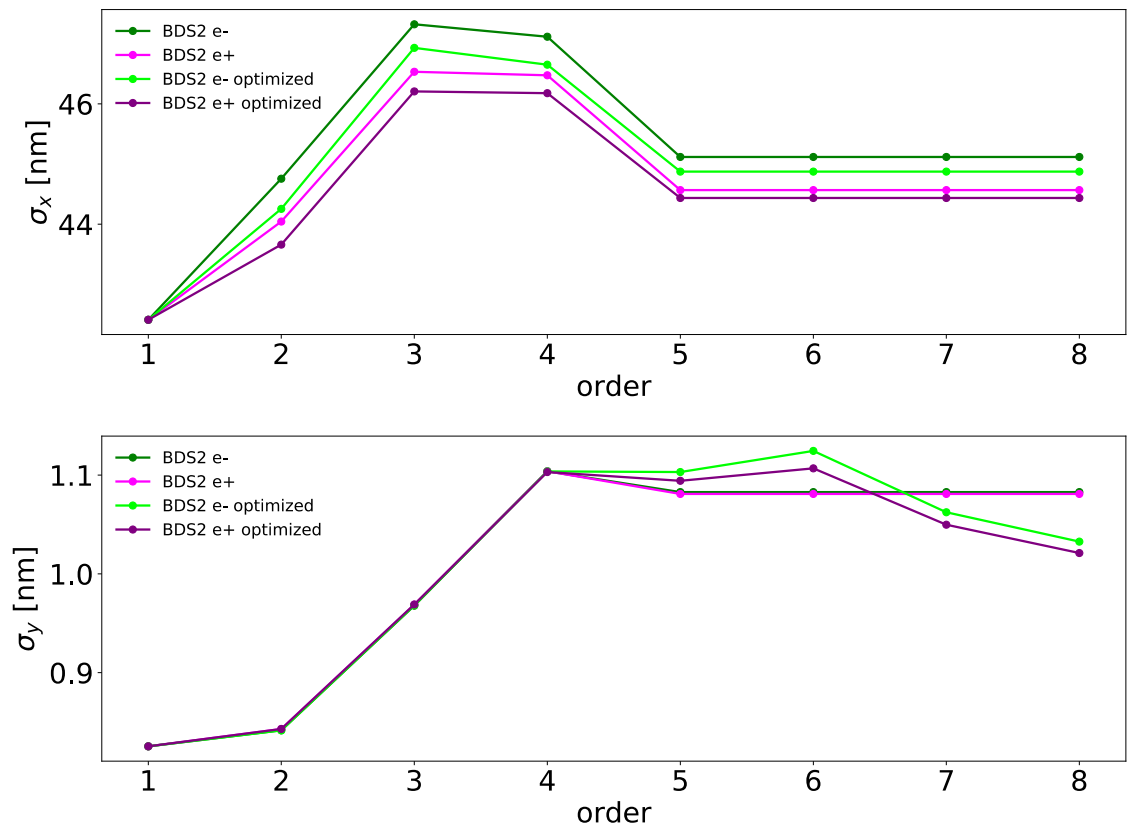


- CLIC 3 TeV



# 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

$\sigma_x^*$ [nm]	ideal	w/ SR
IR1	141	144
IR2	141	144

$\sigma_y^*$ [nm]	ideal	w/ SR
IR1	3.07	3.08
IR2	3.06	3.07

Luminosity [ $10^{34} \text{ cm}^{-2} \text{ s}^{-1}$ ]	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

$\sigma_x^*$ [nm]	ideal	w/ SR
IR1	43.5	51.5
IR2	44.9	64.8

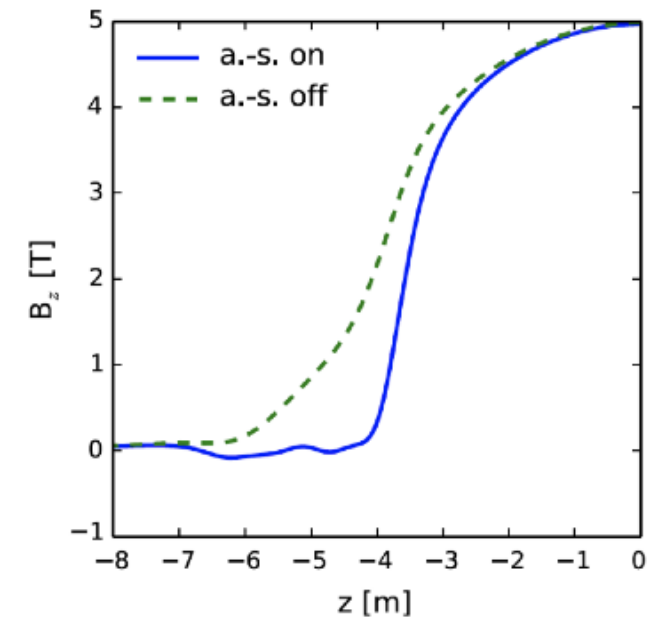
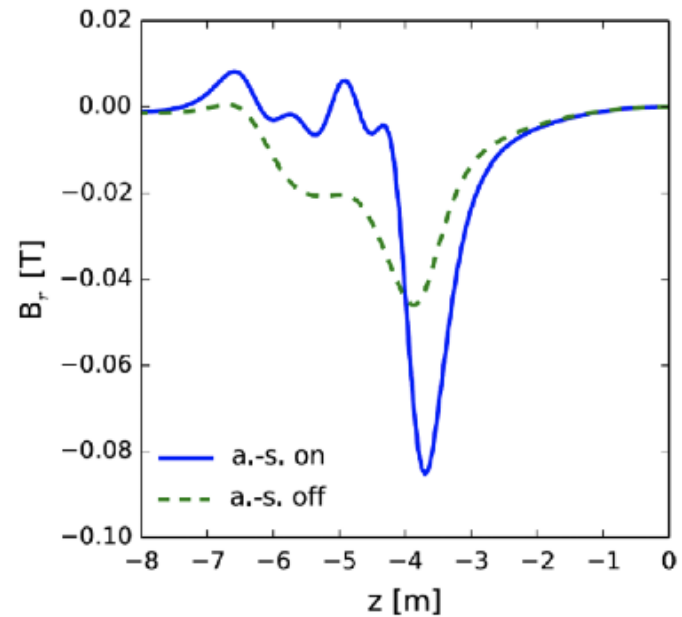
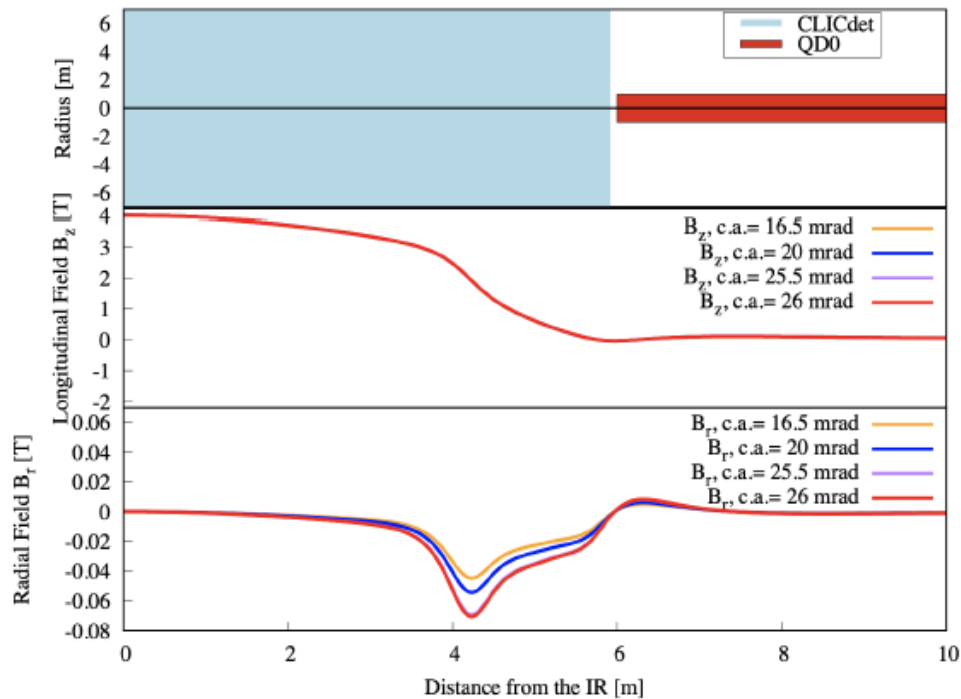
$\sigma_y^*$ [nm]	ideal	w/ SR
IR1	1.02	1.71
IR2	1.02	1.92

Luminosity [ $10^{34} \text{ cm}^{-2} \text{ s}^{-1}$ ]	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!