CLIC main detector solenoid and anti-solenoid impact

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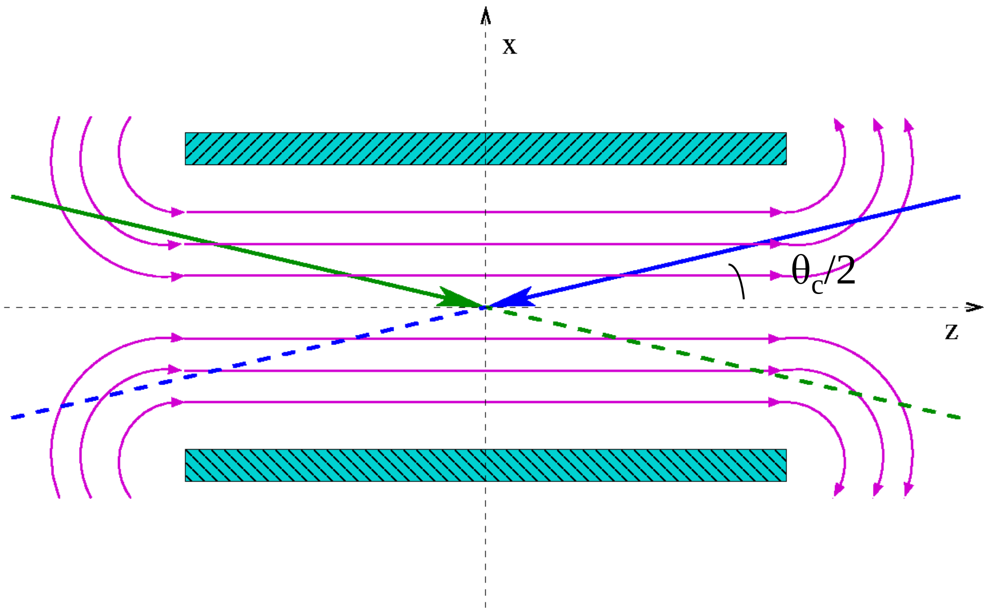
Outline

- Detector solenoid and QD0 overlap effects
- Anti-solenoid impact and design
- Incoherent synchrotron radiation effects in CLIC
- Conclusions and outlook

Solenoid and QD0 overlap Effects

Due to crossing angle:

- ***Weak focusing***: in the two transverse planes
- ***Orbit deviation***: the beam is bent as it traverses the magnetic field
- ***Coupling between x-y plane***: the particle position in one plane depends on the position in the other plane
- ***Dispersion***: particles at lower energies experience a larger deflection than those at higher energies
- The beam emits ***Incoherent Synchrotron Radiation*** (ISR) as it is deflected



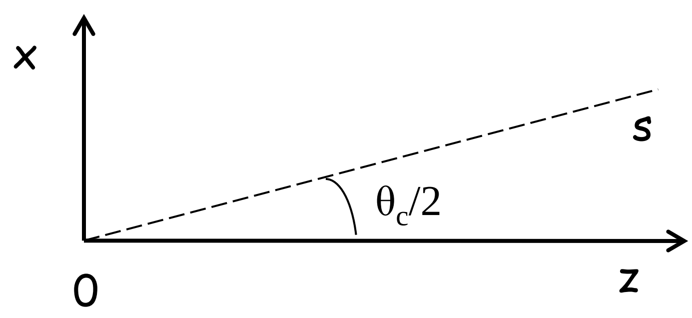
Schematic view of the two beam colliding with a crossing angle in the detector solenoid.

Detector solenoid and beamline magnets interference

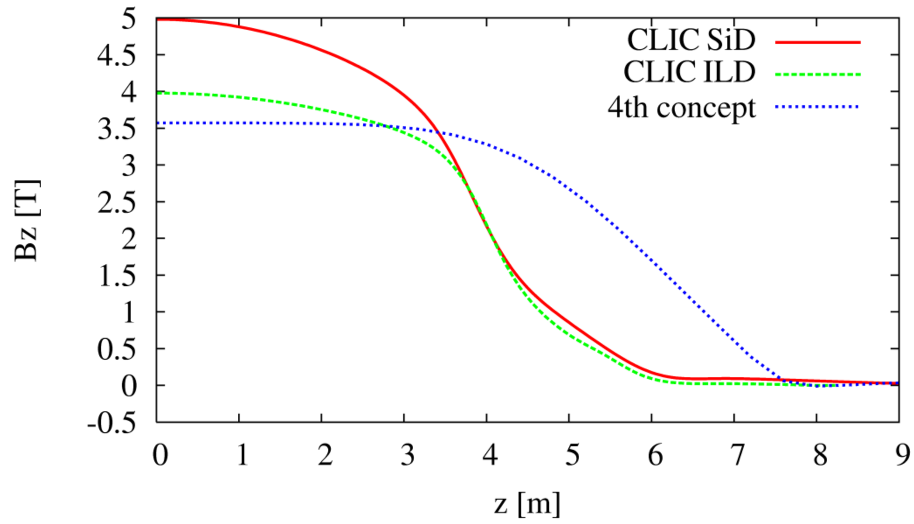
- Worse **vertical dispersion** and **<x',y> coupling** at the IP of the main solenoid
- **vertical offset** at the IP

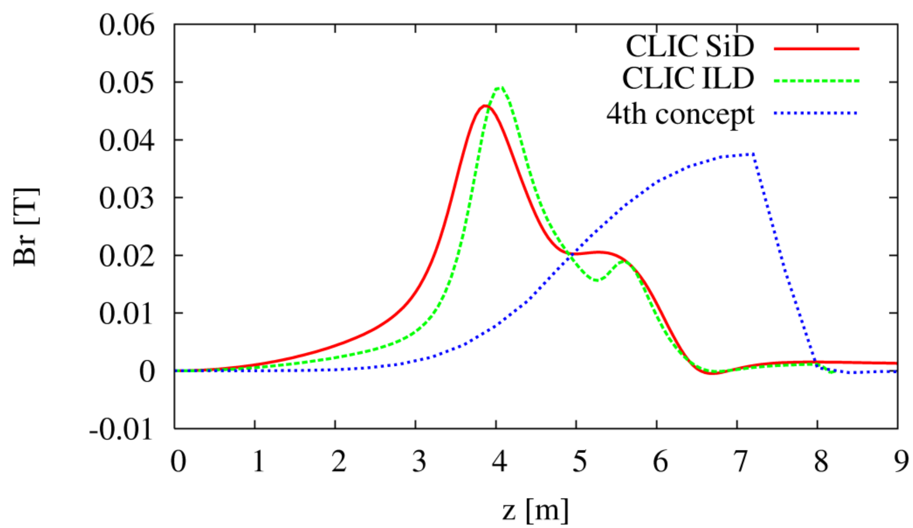
Y. Nosochkov and A. Seryi, PRST-AB 8, 021001 (2005)

Detector Solenoid magnetic fields



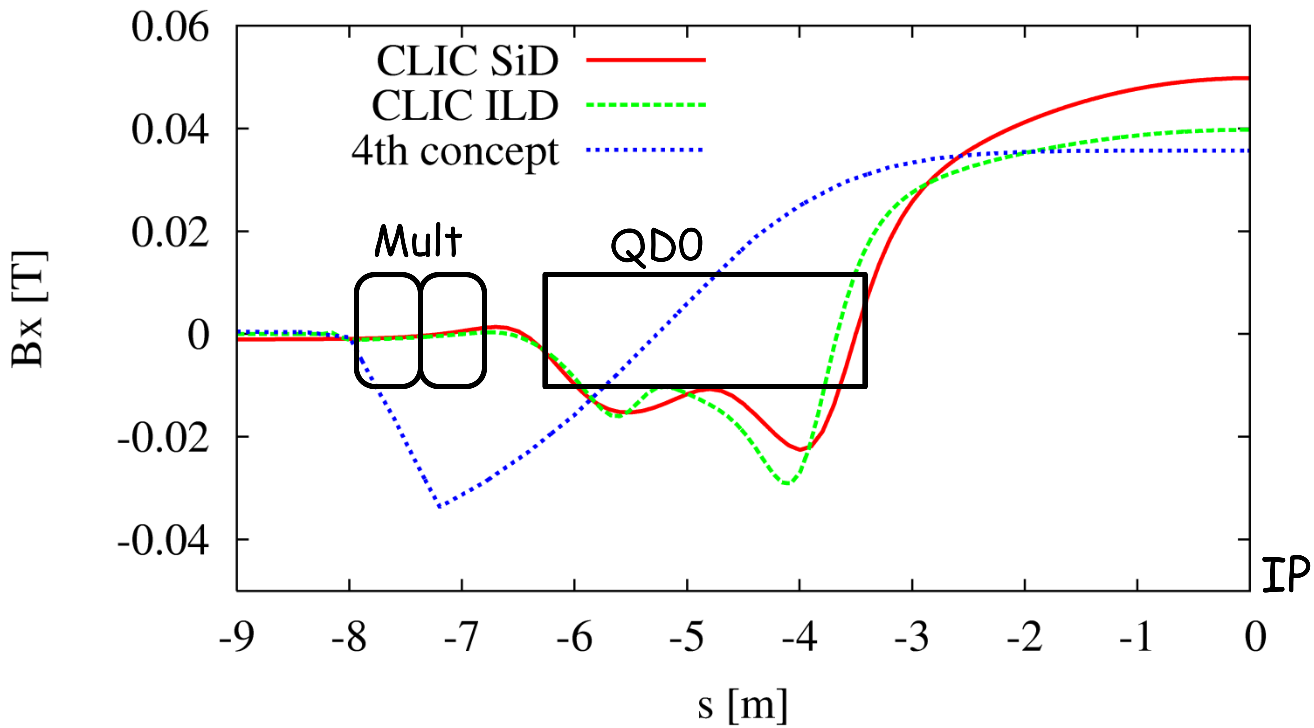
- x, z solenoid axises
- s beam line longitudinal axis





- different detector designs generate different field along the beamline

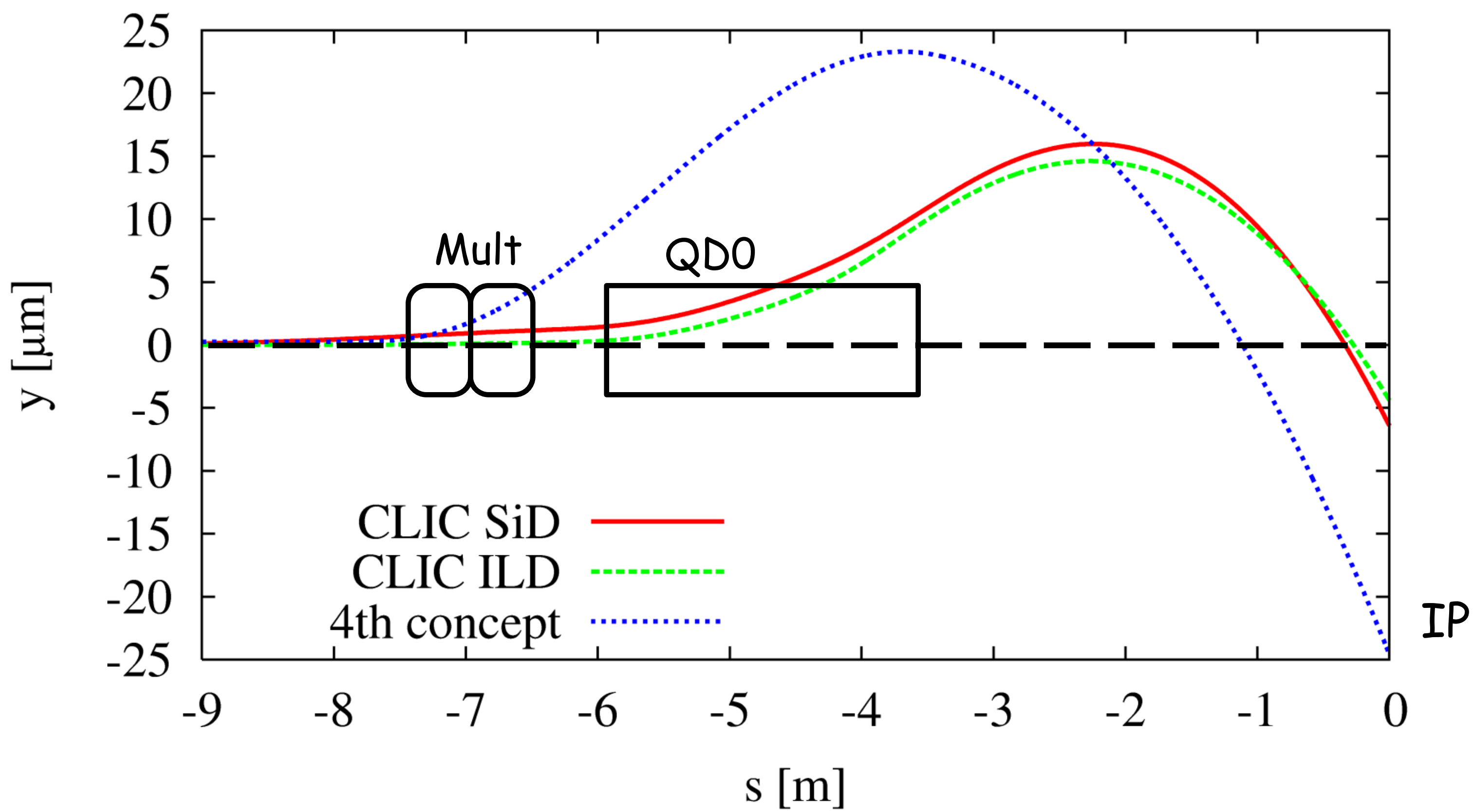
Main field component acting on the beam



B_X component of solenoid fields in the beamline reference system

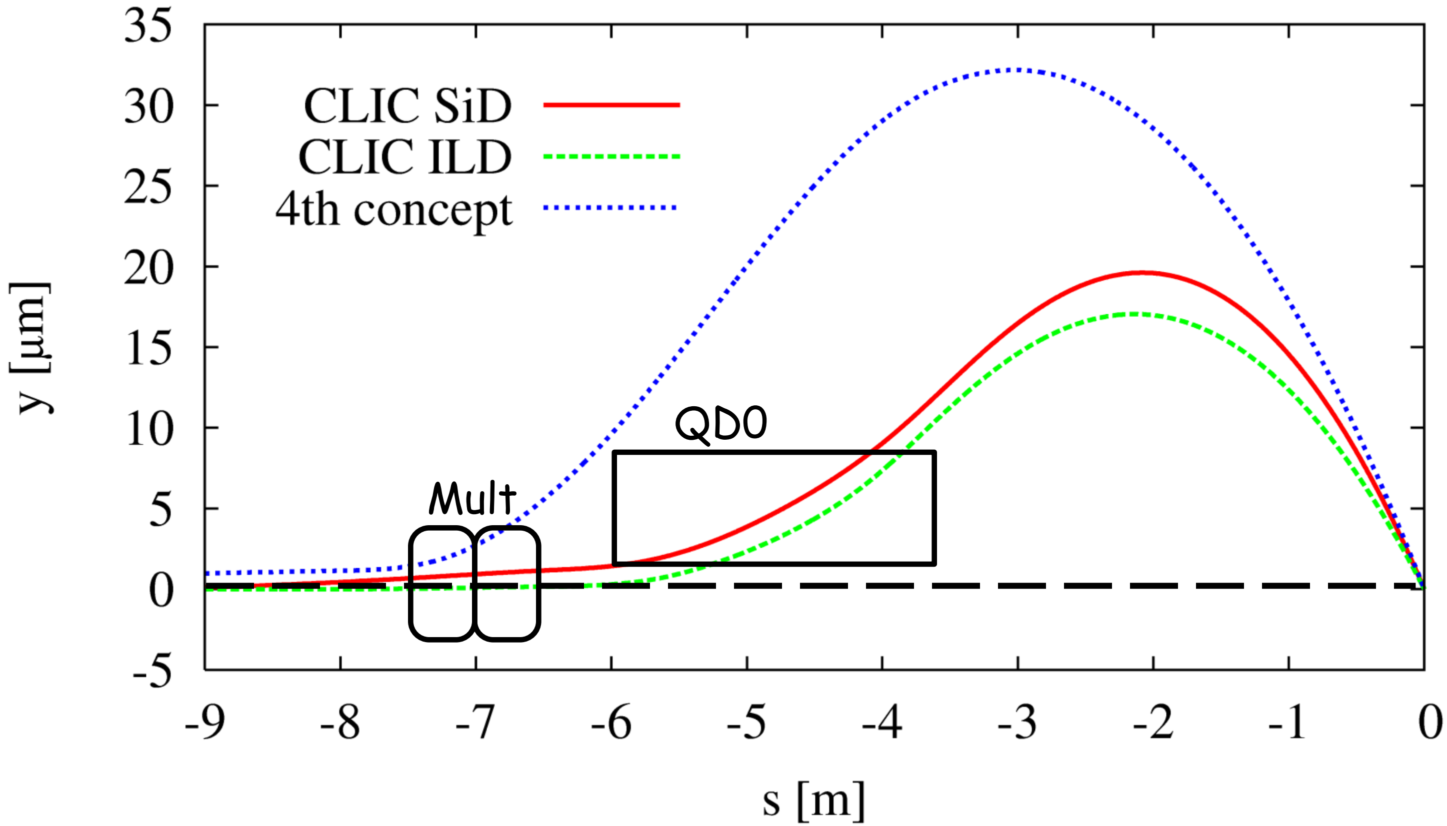
— CLIC_SiD H. Gerwig (CERN)
— CLIC_ILD D. Swoboda (CERN)
— ILD_4th concept J. Hauptman (Iowa State University)

Orbit deviations



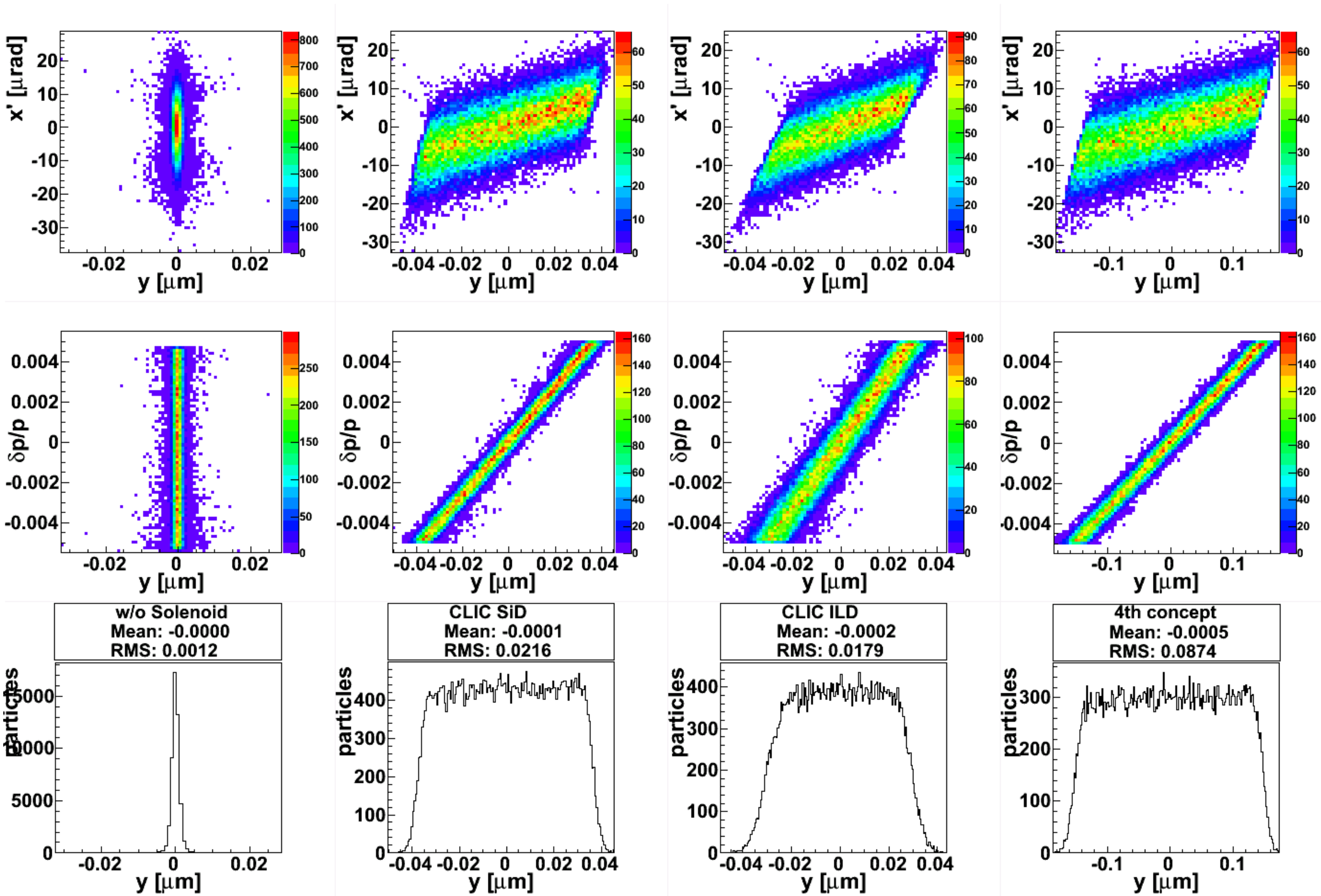
Vertical orbits deviation due to the detector solenoid field and its overlap with QD0 (and the other FF magnets)

Vertical offset correction



Vertical offset at IP compensated by QD0 offset

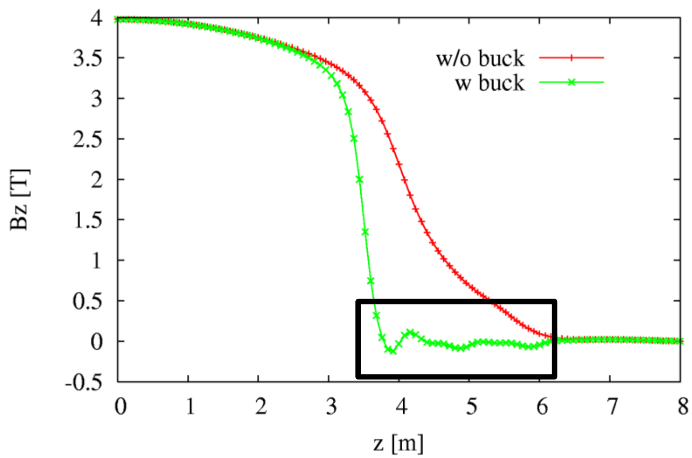
Vertical dispersion and <x',y> coupling at the IP

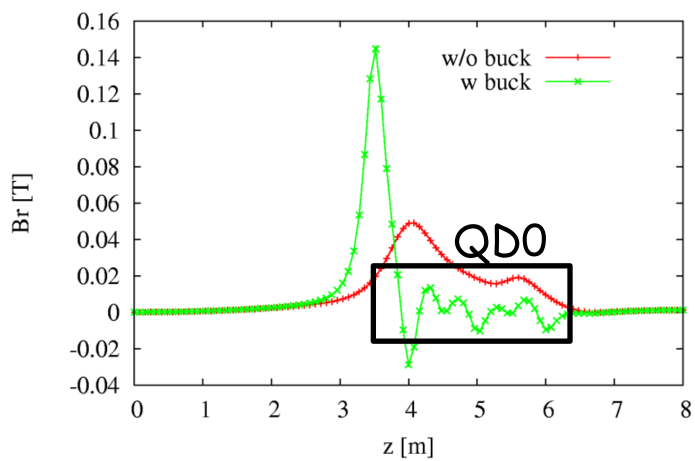


Compensation of the optical distortions

Bucking coils that cancel the main solenoid field in the magnets region

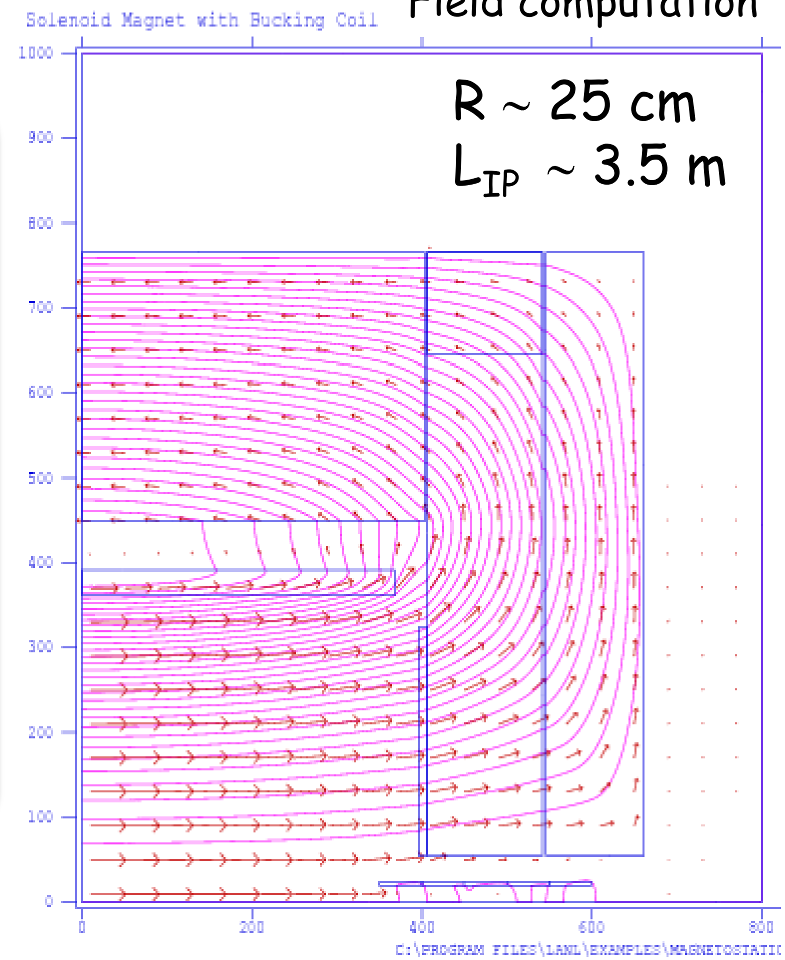
- reduce the beam distortions at the IP
- QD0 shielding from the main solenoid field





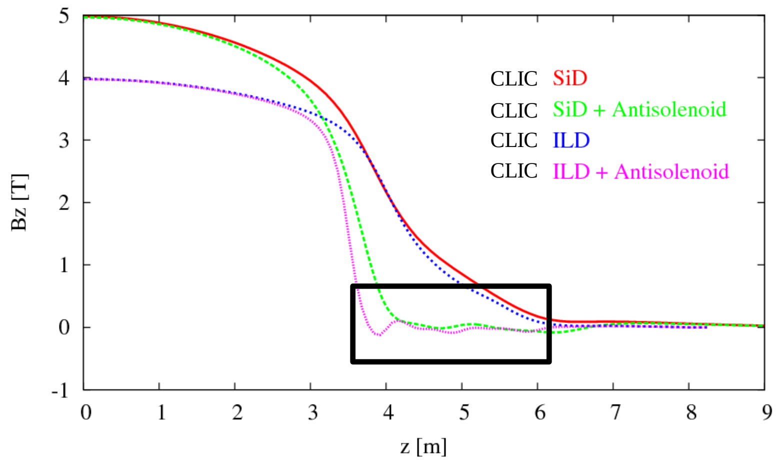
D.Swoboda, BD, R. Tomas
CLIC-Note-815

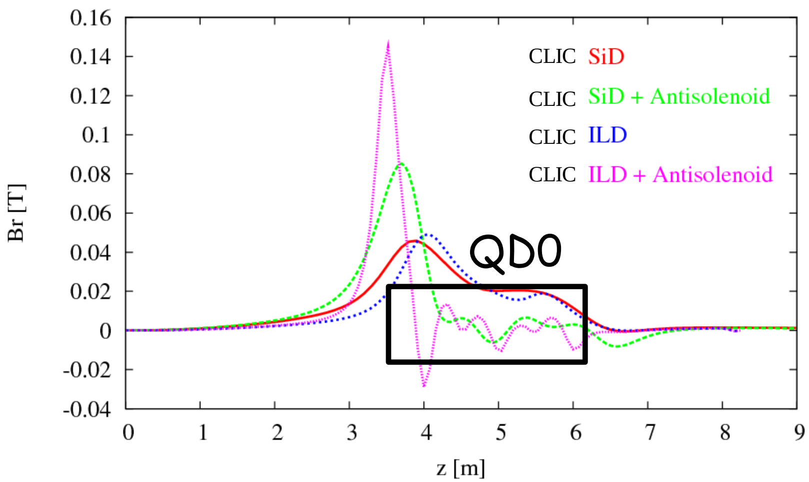
Field computation

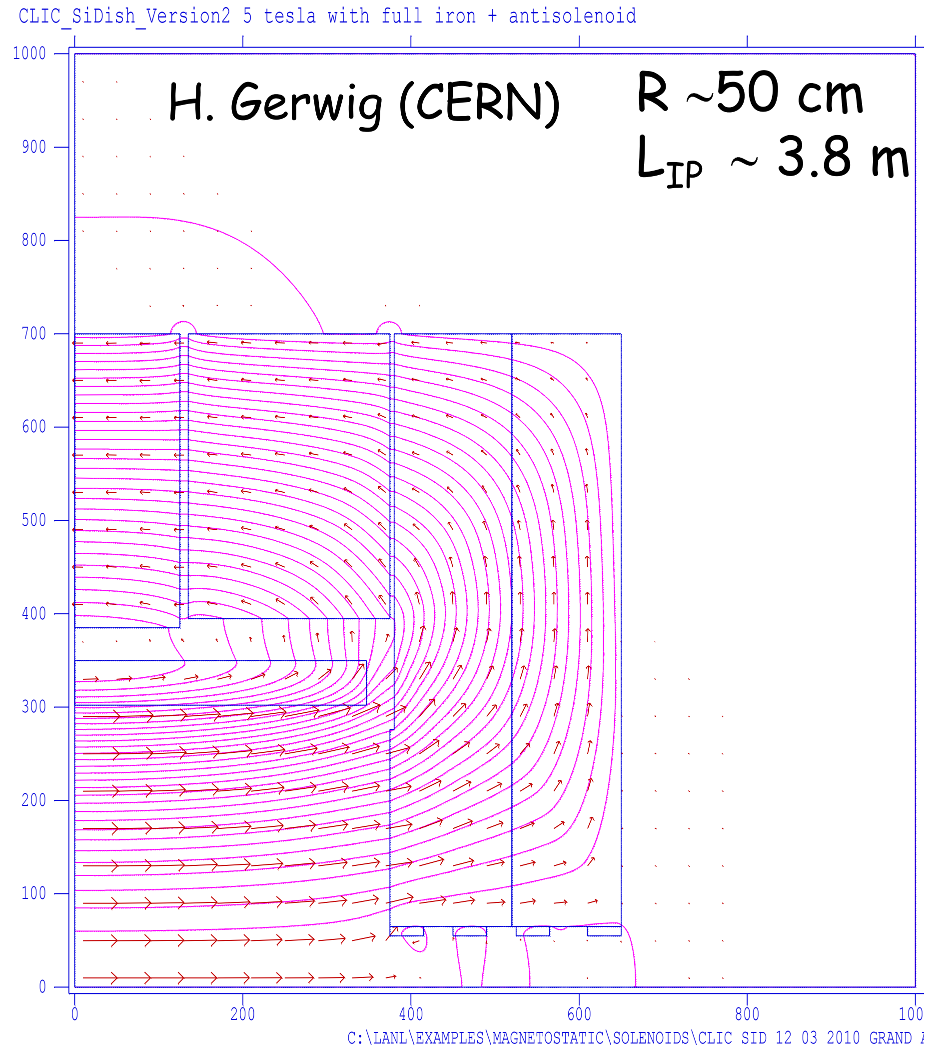


Anti-solenoid design

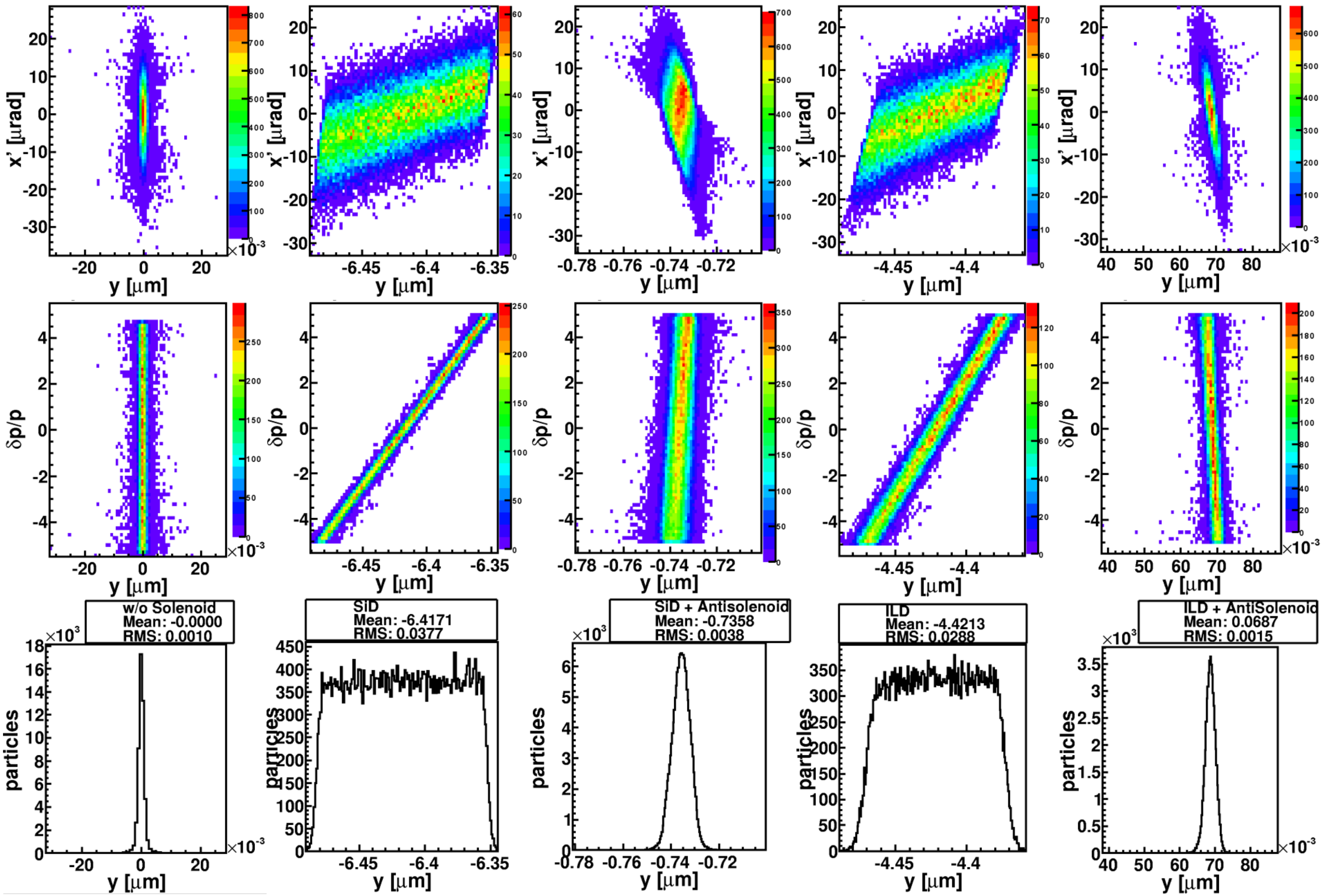
- Anti-solenoid integration:
  - 4 bucking coils of same length and equally spaced







Anti-solenoids impact on the beams



Beam covariances at the IP

	$D_y \propto cov(Y,E)$ µm ILD	D_y / $D_{y\ main\ solenoid}$ %	$D_y \propto cov(Y,E)$ µm SiD	D_y / $D_{y\ main\ solenoid}$ %	IP Offset µm ILD	IP Offset µm SiD
Main Solenoid	9.853	100	13.047	100	-4.421	-6.417
Solenoid + Antisolenoid	-0.304	3	0.587	4.5	+0.069	-0.736
w/o Solenoid	0.000		0.000		0.000	0.000

Both anti-solenoids cancel > 95% of the vertical dispersion due to the main detector solenoid and QD0 overlap.

	$cov(y,x')$ µm rad ILD	$cov(y,x')$ / $cov(y,x')_{main\ solenoid}$ %	$cov(y,x')$ µm rad SiD	$cov(y,x')$ / $cov(y,x')_{main\ solenoid}$ %	IP offset µm ILD	IP offset µm SiD
Main Solenoid	0.146	100	0.171	100	-4.421	-6.417
Solenoid + Antisolenoid	-0.008	5	-0.011	6.5	+0.069	-0.736
w/o Solenoid	0.000		0.000		0.000	0.000

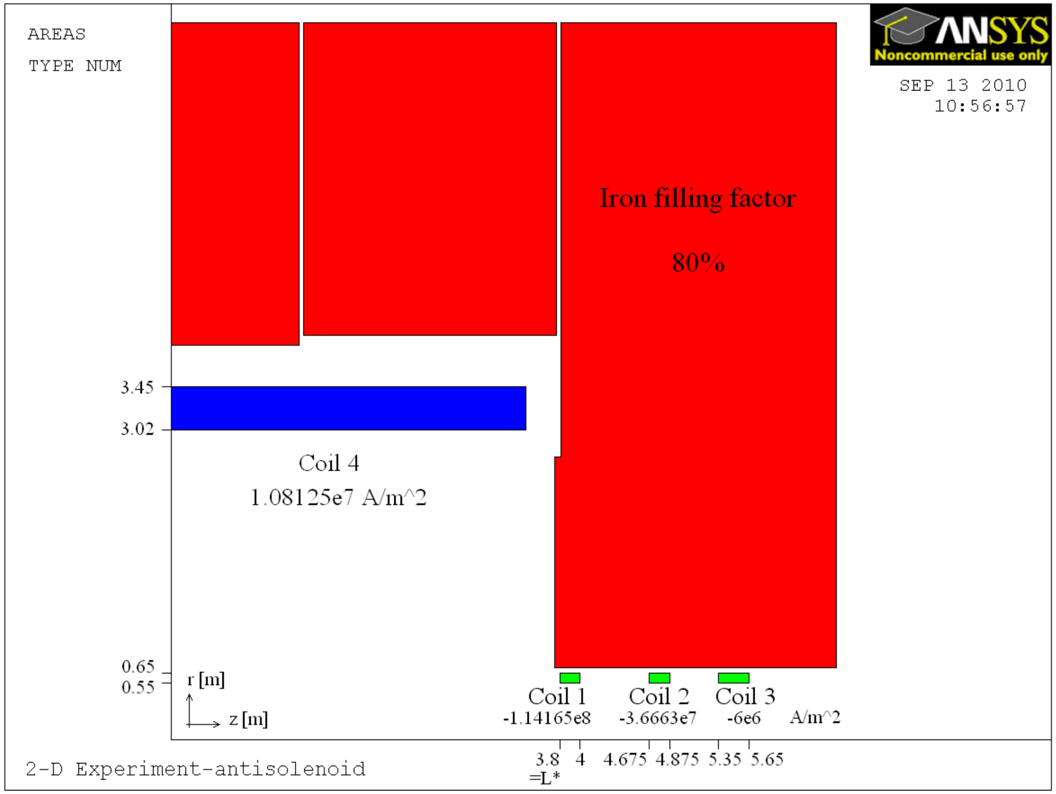
Both anti-solenoids cancel ~ 90% of the $\langle x', y \rangle$ coupling due to the main detector solenoid and QD0 overlap.

Magnetic and mechanical analysis
(A. Bartalesi, CERN)

-The magnet (superconducting technology) dimensioning seems feasible. Stresses and global forces are quite relevant though.

- Structural integration with MDI area to be checked

- Residual main solenoid field is important for QD0 achievable gradient



see M. Modena talk on CLIC QD0 status

From optical distortions correction to synchrotron radiation impact

- Anti-solenoid effectively reduces the optical distortions due to detector solenoid and QD0 overlap at the IP
- Full compensation is needed to achieve nominal luminosity
  - Optimization of anti-solenoid
  - tuning knobs
  - …
- Even if full correction of the optical distortions is achieved luminosity loss due to incoherent synchrotron radiation still expected
  - Full compensated beam used to evaluate synchrotron radiation effects…

Luminosity Loss due to incoherent synchrotron radiation

Field Map	Bz [T]	Lumi loss [%]
CLIC_SiD	5	~14.0
CLIC_SiD + Antisolenoid	5	~10.0
CLIC_ILD	4	~10.0
CLIC_ILD + Antisolenoid	4	~10.0
ILC_ILD at 3 TeV + AntiDiD	4	~25.0
ILC_4th at 3TeV concept	3.5	~20.0

- Luminosity calculation by GUINEA-PIG
- CLIC half horizontal crossing angle 10 mrad
- $\Delta\sigma^*_y \propto (\mathbf{B}\theta_c\mathbf{L})^{5/2}$ P.Tenembaum et al., PRST-AB 6, 061001 (2003)
- CLIC-BDS budget: 20% luminosity loss

Conclusion

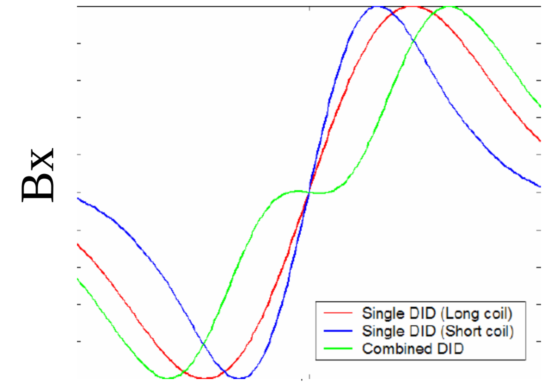
- Detector Solenoid design has a big impact on the beam dynamics in the interaction region
  - **Anti-Solenoid** (bucking coils covering QD0) reduces (> 90%) the optical distortions at IP
  - **AntiDiD** excluded in CLIC at 3 TeV, due to luminosity loss for incoherent synchrotron radiation
  - ILC_**4th concept** disfavored in CLIC at 3 TeV, due to high luminosity loss for incoherent synchrotron radiation
  - CLIC_**ILD** and CLIC_**SiD** design give about 10% luminosity loss due to synchrotron radiation

… and outlook

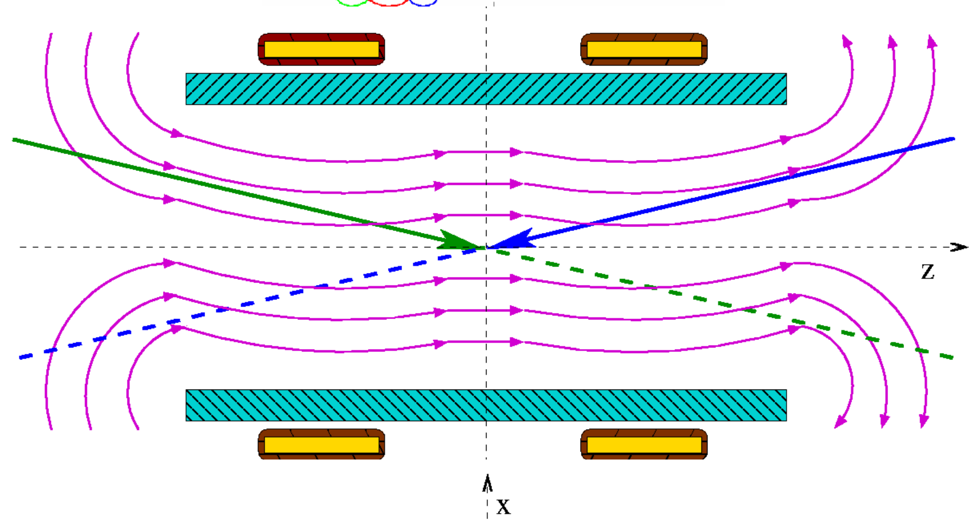
- Further optimization in the anti-solenoid design to improve beam distortions at the IP and QD0 shielding
- New detector length (shorter) can improve the luminosity loss due to incoherent synchrotron radiation
  - ILC_"like" detector designs give ~4% luminosity loss at 3 TeV

SPARES

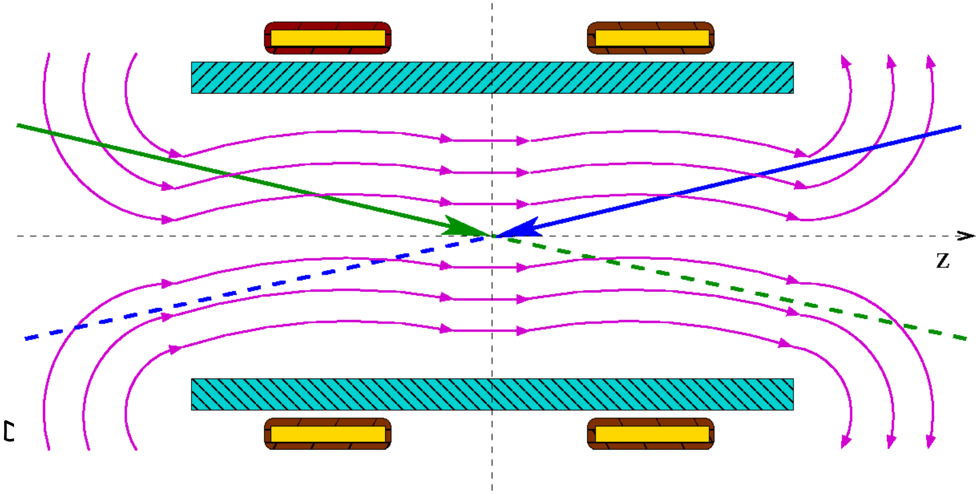
DiD - AntiDiD



- DiD
  - Coil wound on detector solenoid giving transverse field (Bx)
  - It can zero y and y' at IP
  - But the field acting on the outgoing beam is bigger than solenoid detector alone ⇒ pairs diffuse in the detector



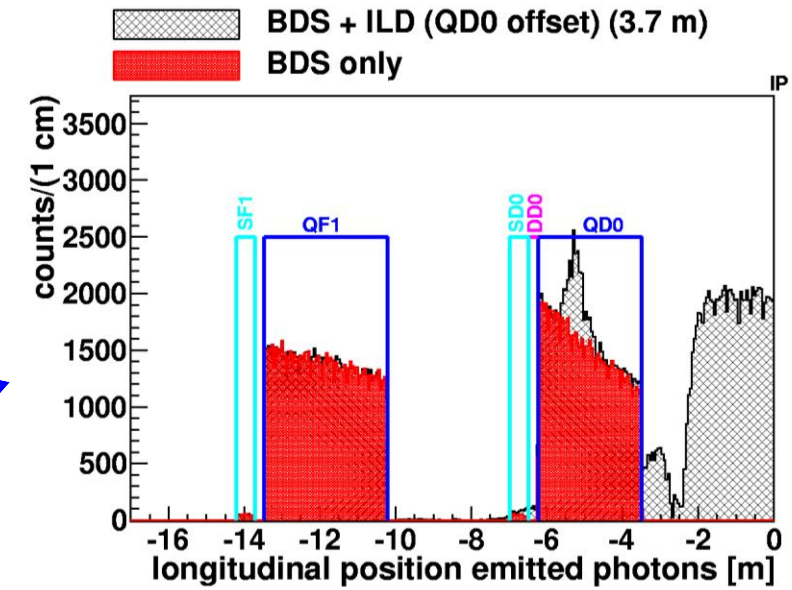
- AntiDiD
  - Reversing DiD's polarity and optimizing the strength, more than 50% of the pairs are redirected to the extraction apertures

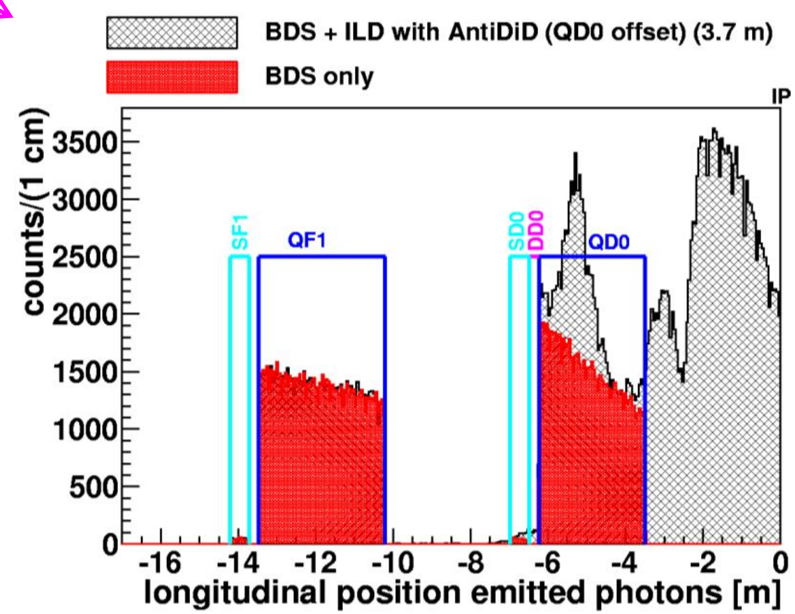


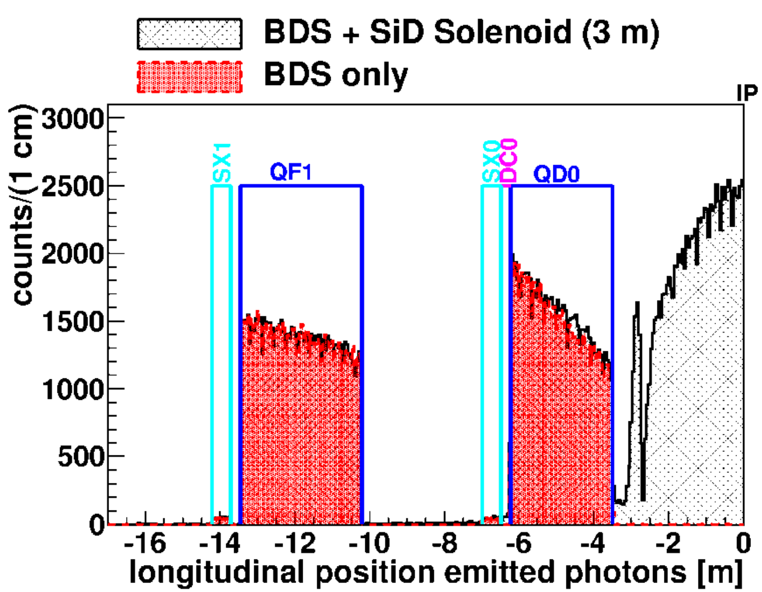
<u>A. Seryi</u>

Synchrotron Radiation photons

- Optic distortion compensated
- CLIC nominal beam tracked trough BDS and BDS + Solenoid considering Synchrotron Radiation
- Longitudinal position of emitted photons shown
  - ILD (ILD + AntiDiD)
  - SiD







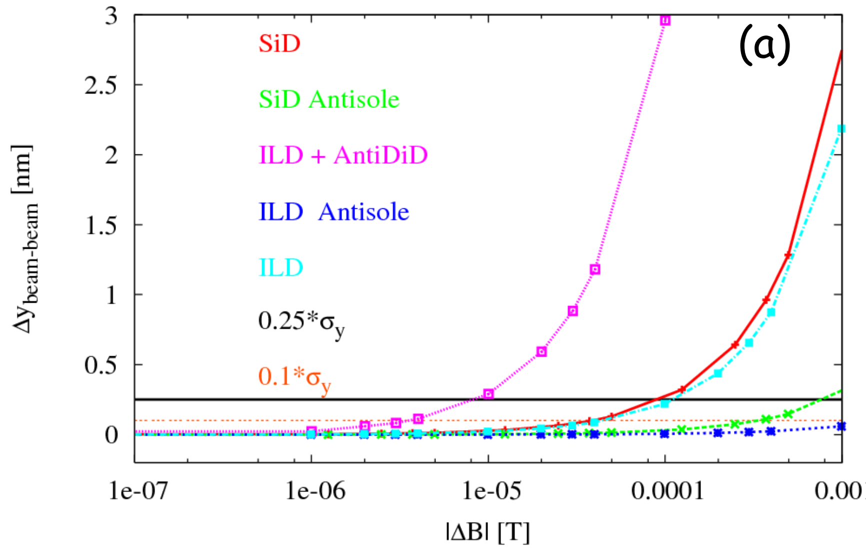
Solenoid field stability

Rivalutarle con solo anti-sole e/o due solenoidi non assieme

Tolerances are defined using the beam-beam offset at the IP.

Two cases:

- perfect aligned solenoid (a)
- horizontally misaligned solenoid (b)

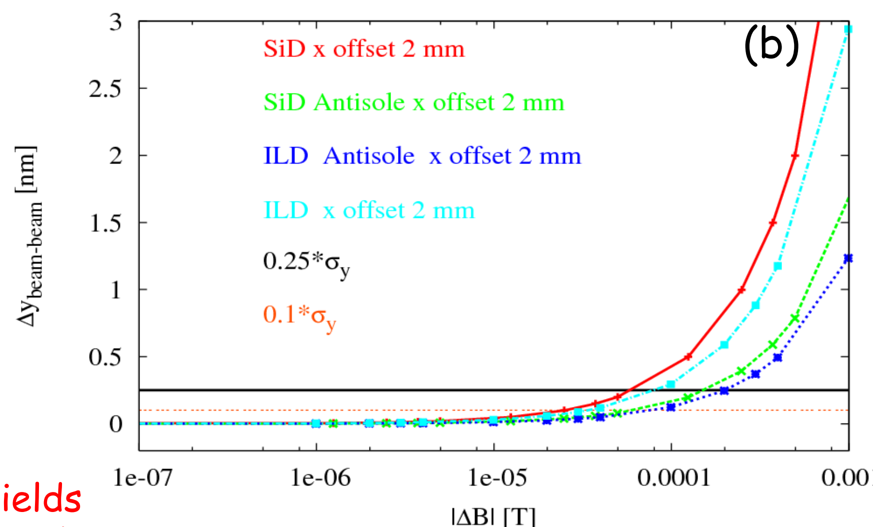


(a) perfect aligned solenoid ($0.25\sigma_y$)

- $\Delta B \cong [8.65\text{-}10.0]$ e-5
- $\Delta B \geq 10.$ e-5 + Antisolenoid
- $\Delta B \cong 0.8$ e-5 + AntiDiD

(b) horizontally misaligned solenoid

- $\Delta B \cong [5.7\text{-}7.9]$ e-5
- $\Delta B \cong 10.0$ e-5 + Antisolenoid



N.B. assumptions:

- linear and homogeneous (along z) scaling of the fields
- main solenoid and compensating solenoid scale together