CLIC at 3 TeV

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Thanks to:

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Outline

- CLIC BDS at 3 TeV CM
  - Main lattice features
  - Incoherent synchrotron radiation
- CLIC MDI at 3 TeV CM
  - Interaction Region Solenoid effects and compensation
  - Hadronic background estimates

CLIC BDS

Energy Collimation

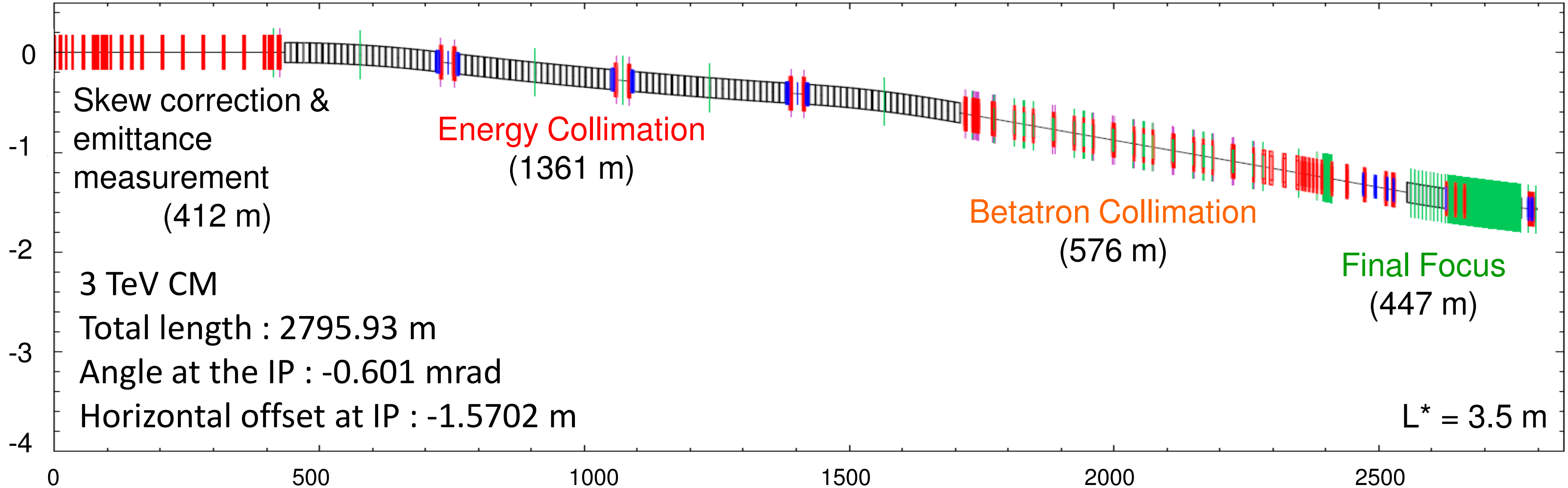
- Protection against mis-steered or errant beams with energy errors > 1.3%. Geometry and material under study.

Betatron Collimation

- New optimisation of collimation depths 15 σ_x & 55 σ_y .
  Wakefield and secondary particles produced at spoilers under study.

Final Focus

- Design to achieve the smallest beam size at IP (σ_y=1nm).
  Tuning strategy very challenging.



Luminosity Loss due to ISR in CLIC-BDS

Horizontal bending magnets and vertical strong focusing (Oide limit)
⇒ emission of Incoherent Synchrotron Radiation

ALL BDS	L/L0
ALL ISR OFF	1,00±0.02
ALL ISR ON	0,78±0.02
ISR QUAD ON/rest off	0,90±0.02
ISR MULTI ON/rest off	1,00±0.02
ISR SBEND ON/rest off	0,86±0.02
ISR FD off/rest on	0,87±0.02
ISR FD on/rest off	0,90±0.02
COLL ON/FFS OFF	0,98±0.02
COLL OFF/FFS ON	0,80±0.03

PLACET + GUINEA PIG

CLIC-BDS at 3 TeV CM:

-~**20%** of luminosity loss due to synchrotron radiation:

-~10% of luminosity loss due to Final Doublet.

-~10% of luminosity loss due to SBEND in the FFS.

CLIC-BDS at 0.5 TeV CM:
< 1%

CLIC PARAMETERS

Parameter	ILC	CLIC
Max. Center of Mass energy [GeV]	1000	3000
Luminosity $L_{99\%}$ [cm^{-2} sec^{-1}]	$2\ 10^{34}$	$2\ 10^{34}$
Bunch frequency [Hz]	5	50
Bunch spacing [ns]	369	0.5
# Particles per bunch	$2\ 10^{10}$	$3.7\ 10^{9}$
# Bunches per pulse	2670	312
Bunch train length [μs]	985	0.156
Beam power per beam [MW]	9	14
Bunch length [μm]	300	44
Crossing angle [mrad]	14	20
Core beam size at IP horizontal σ_x* [nm]	639	45
Core beam size at IP vertical σ_y* [nm]	5.7	0.9

CLIC-MDI

- Choice of the magnet technology for the FF magnets.
  QD0 design.
- Integration of FF magnets into the detectors, and required alignment
- Feasibility study of sub-nm active stabilization of QD0
- Luminosity instrumentation
- Post-Collision line
- **Beam background** direct and backsplash from the post-collision collimators and dumps into the detector
- Intrapulse-Beam feedback systems in the interaction region
- **Interaction Region Magnets and their interference**
- Other items (closer link with ILC)

Interaction Region magnets

Detector Solenoid

- It causes beams (incoming, spent) orbit deviation

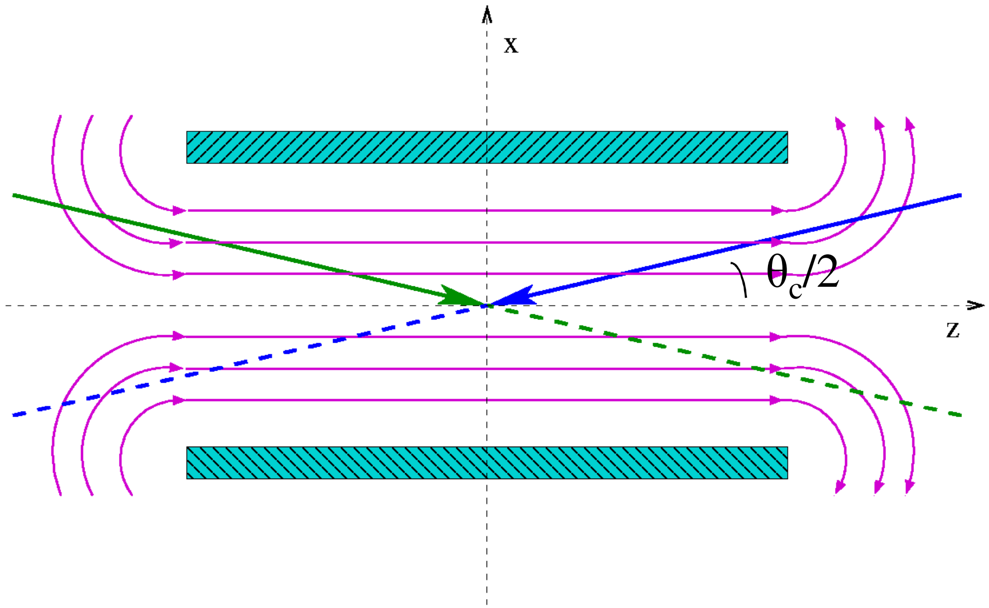
⇒ DiD-AntiDiD

- Due to short L*(3.5m) the detector solenoid field overlaps QD0 field, worsening beam orbit deviation, dispersion and coupling

⇒ Anti-Solenoid (compensating solenoid)

Solenoid Effects

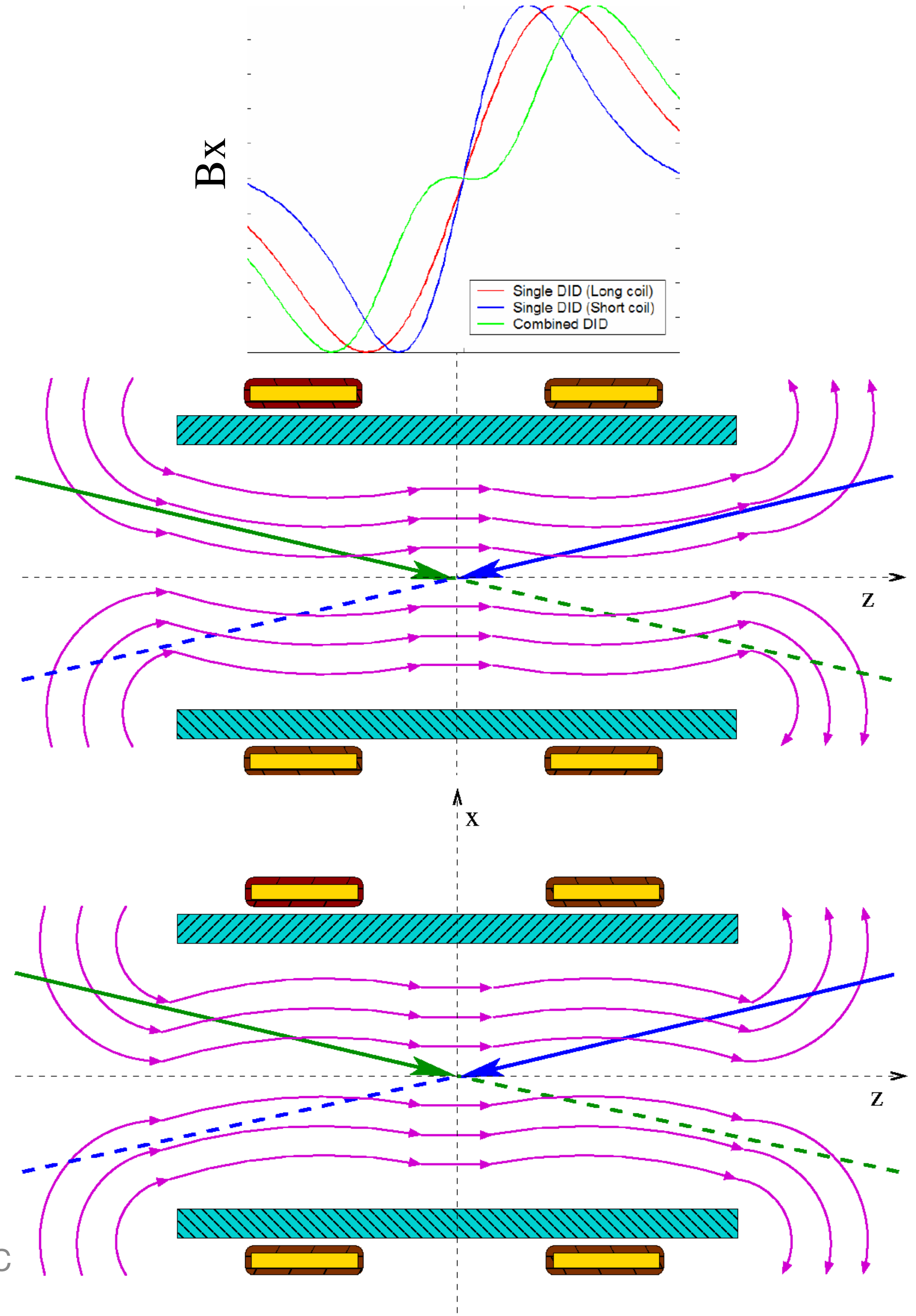
- *Weak focusing*: in the two transverse planes
- *Orbit deviation*: the beam is bent as it traverses the magnetic field
- *Coupling between x-y plane*: the particle position in one plane depends on the position in the other plane
- *Dispersion*: particles at lower energies experience a larger deflection 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.

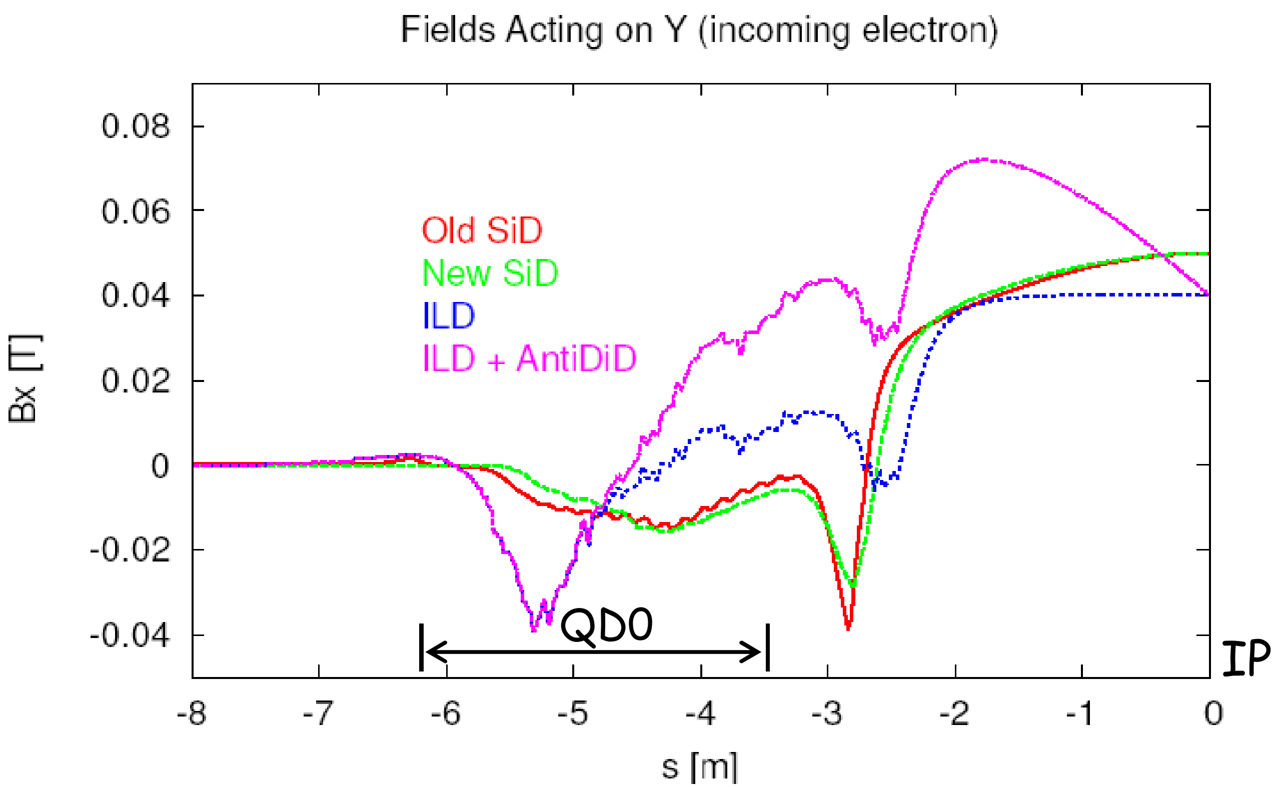
DiD - AntiDiD

- 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



A. Seryi

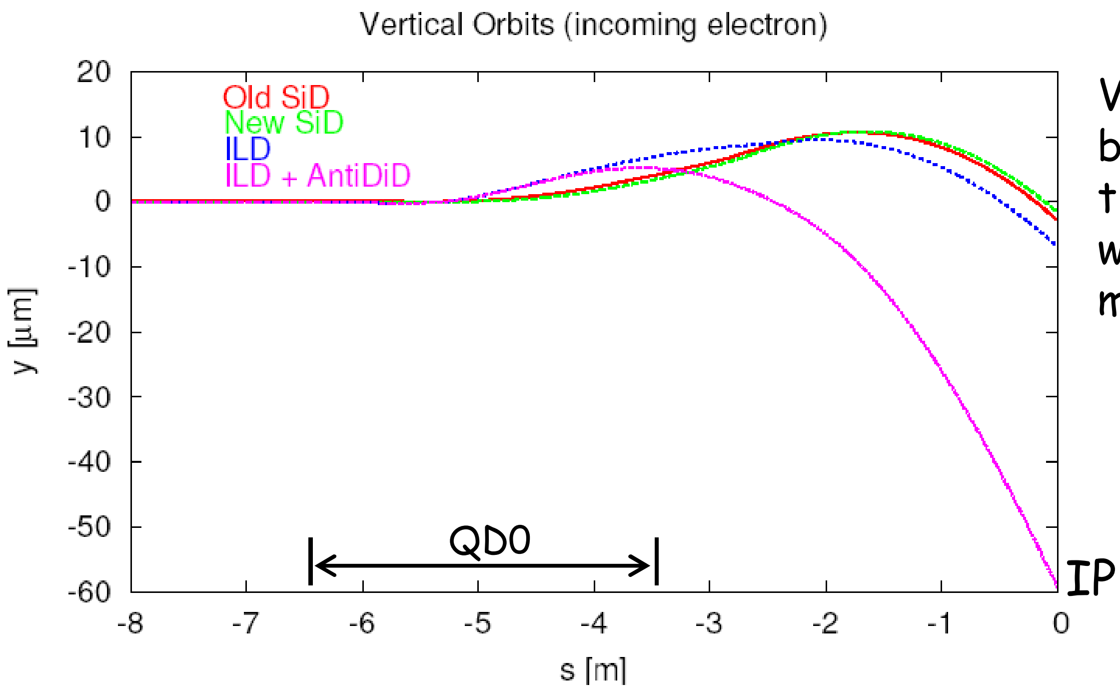
Detector Solenoid magnetic fields



B_x component of solenoid fields in the beamline reference system

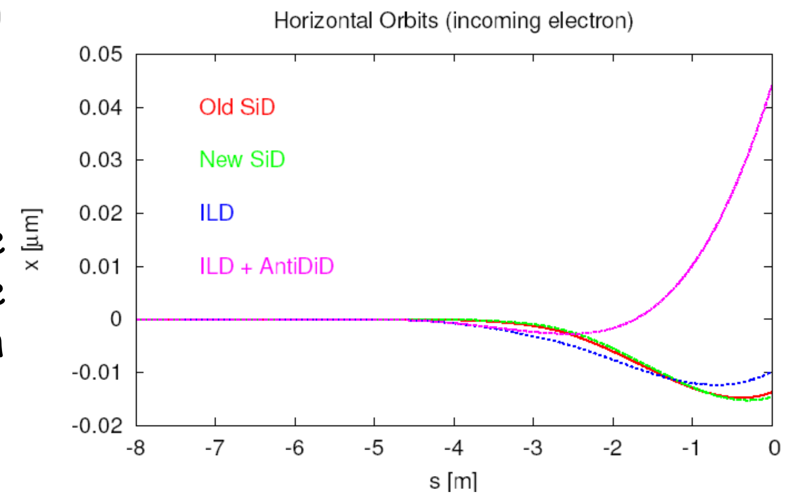
Old SiD: http://www-project.slac.stanford.edu/lc/bdir/Meetings/beamdelivery/2005-10-04/index.htm
New SiD: Kurt Krempetz (FNAL)
ILD (AntiDiD): A. P. Sailer (CERN) Mokka database

Orbits



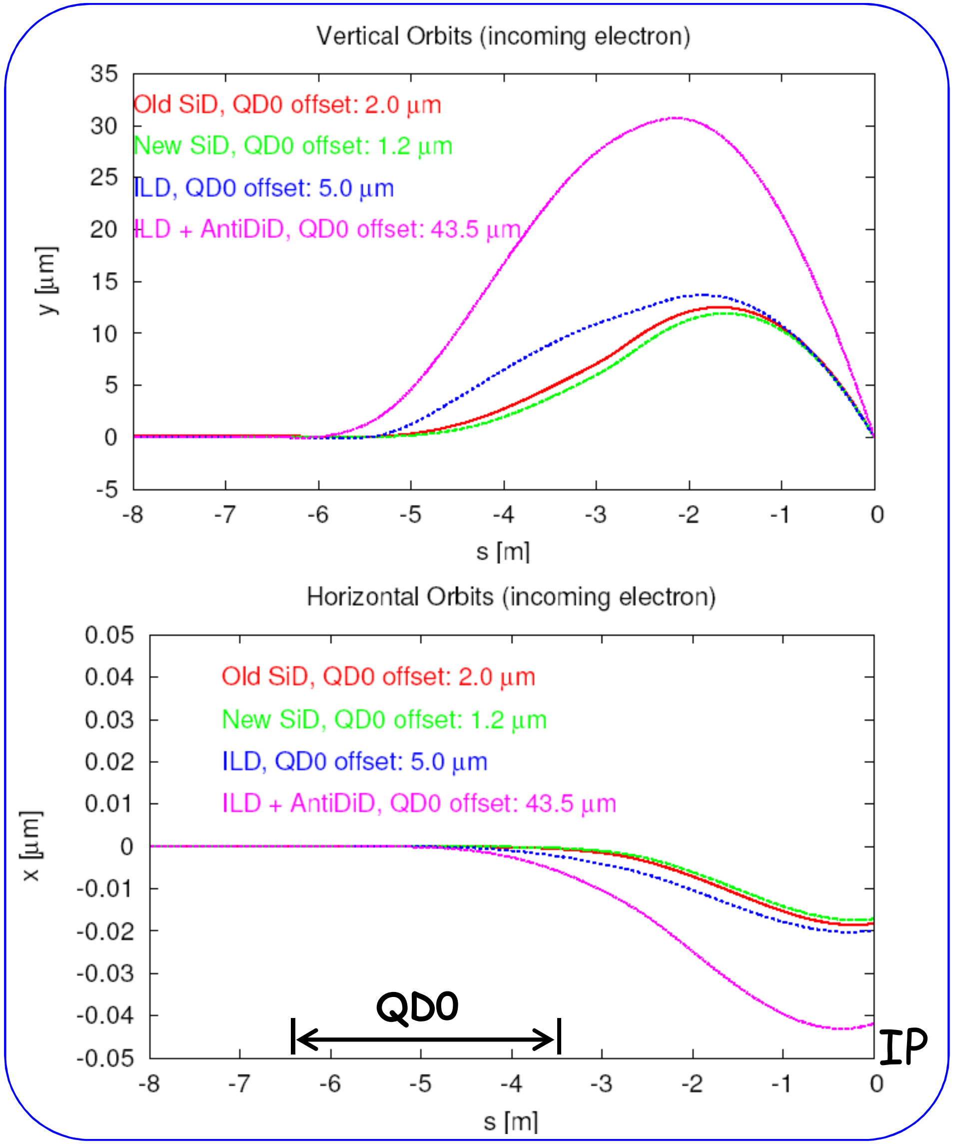
Vertical orbits deviation in the beamline reference system due to the Solenoid field and its overlap with QD0 (and the other FF magnets).

Horizontal orbits deviation in the beamline reference system due to the Solenoid field and its overlap with QD0(and the other FF magnets).



Vertical offset correction (1/2)

- Compensation of detector solenoid effects:
  - J.J. Murray, SLAC-CN-237
  - Y. Nosochkov and A. Seryi, PRST-AB 8, 021001 (2005)
  - B.Parker and A. Seryi, LCC-0143



- The vertical offset at IP can be compensated with QD0 offset.

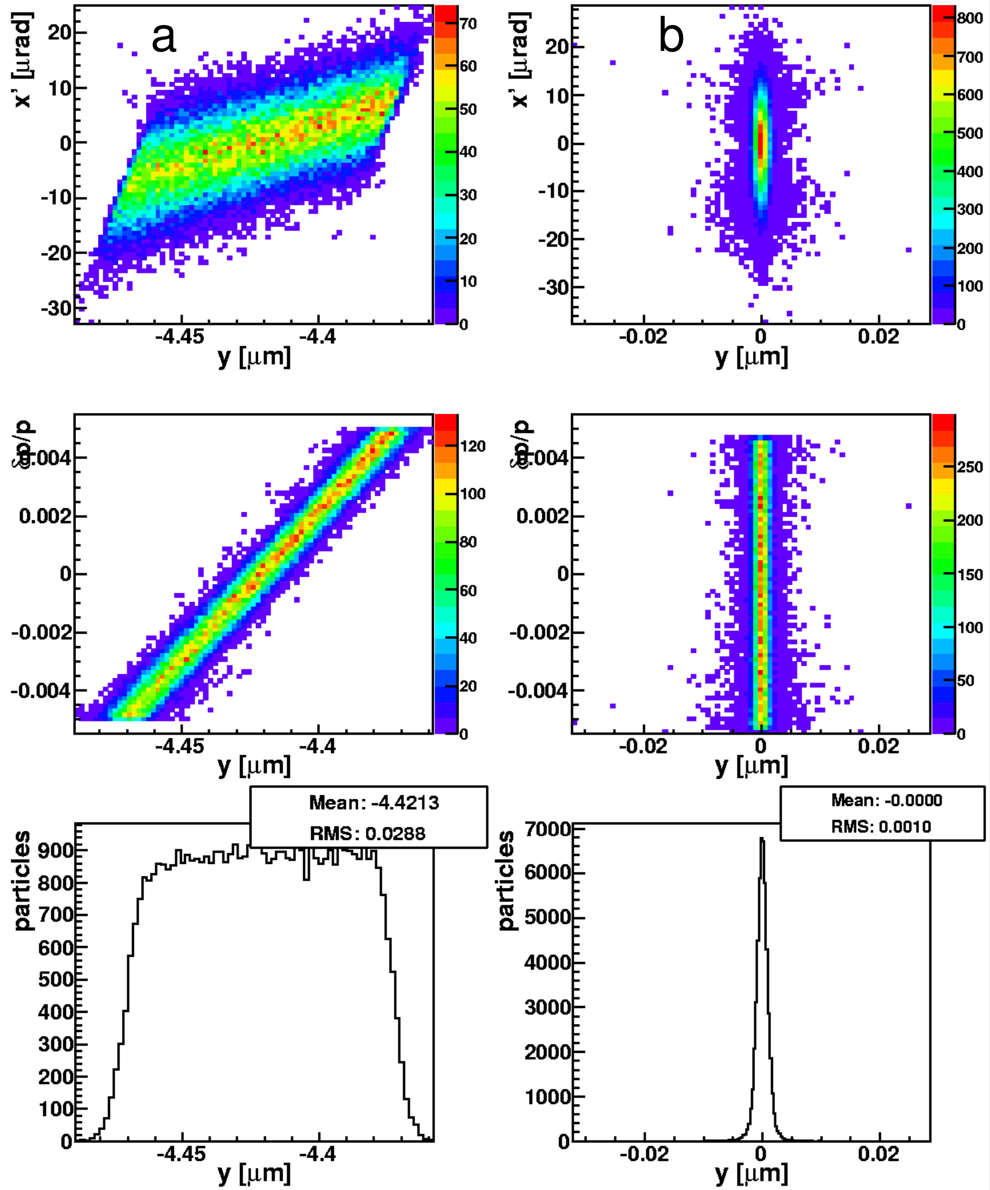
Solenoid and QD0 overlap

Beam sizes increase at IP

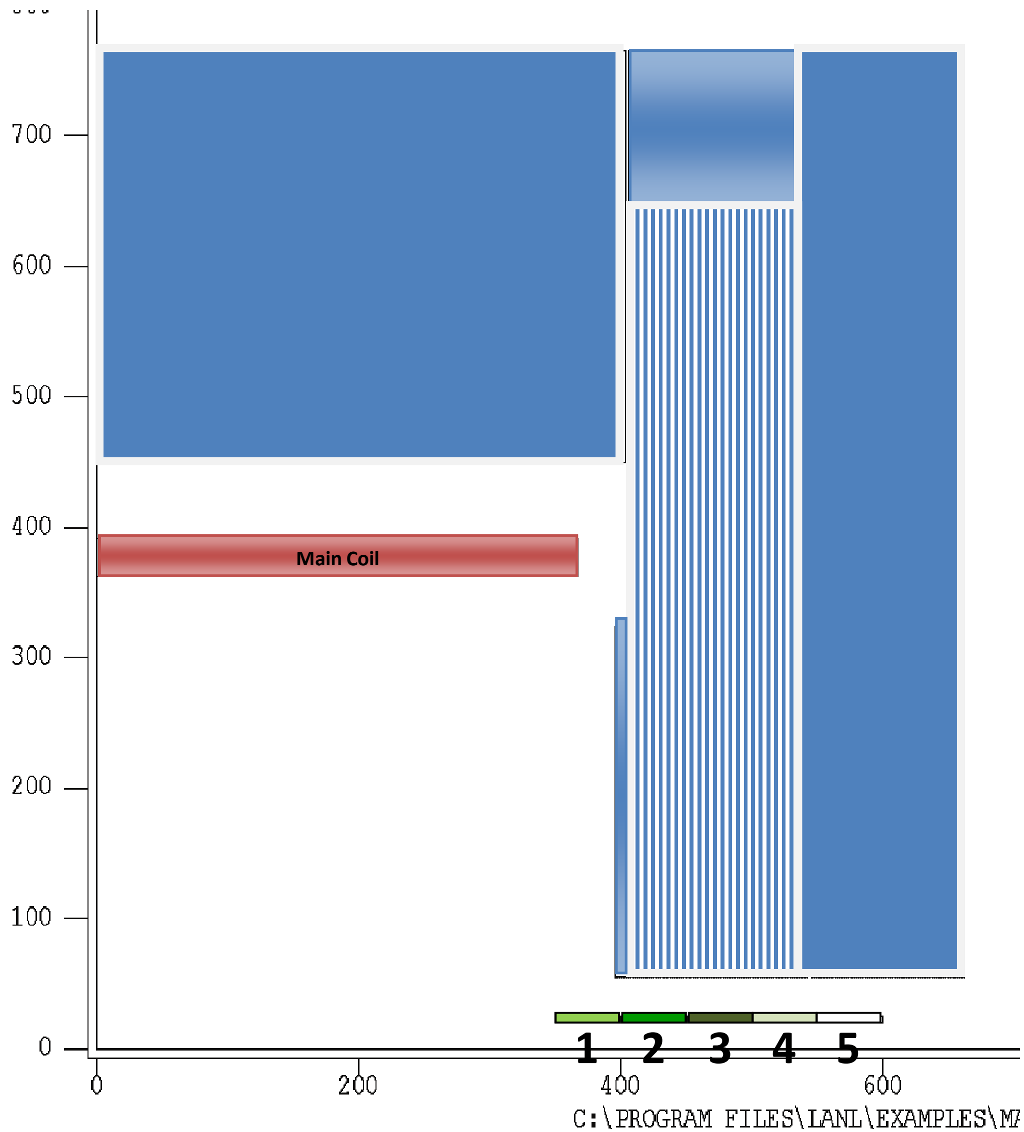
< x′,y > coupling and
vertical dispersion at IP

a) Tracking trough FFs and IP Solenoid
b) Tracking trough FFs only

Nominal CLIC beam 3 TeV CM

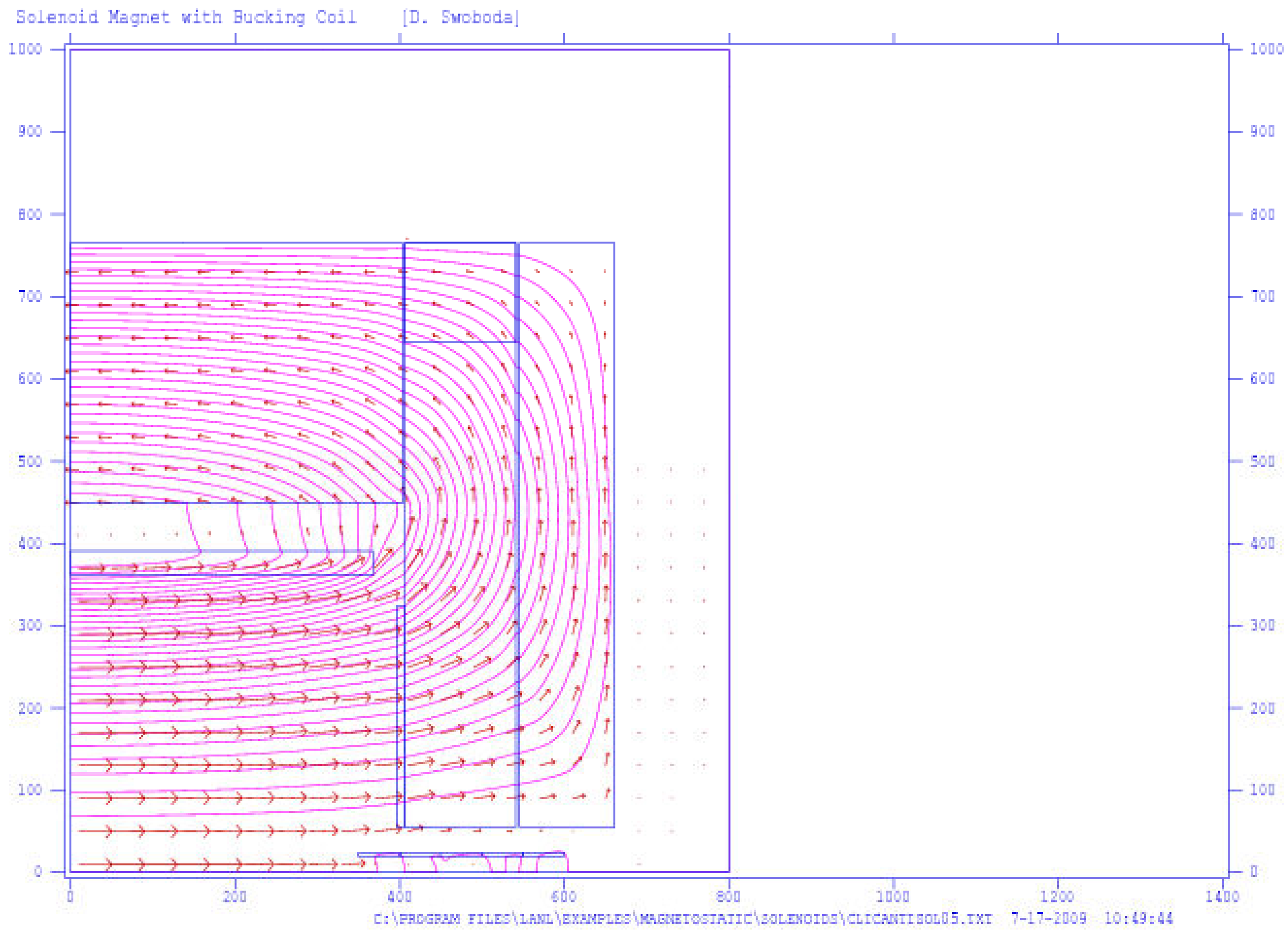


FE model



D. Swoboda

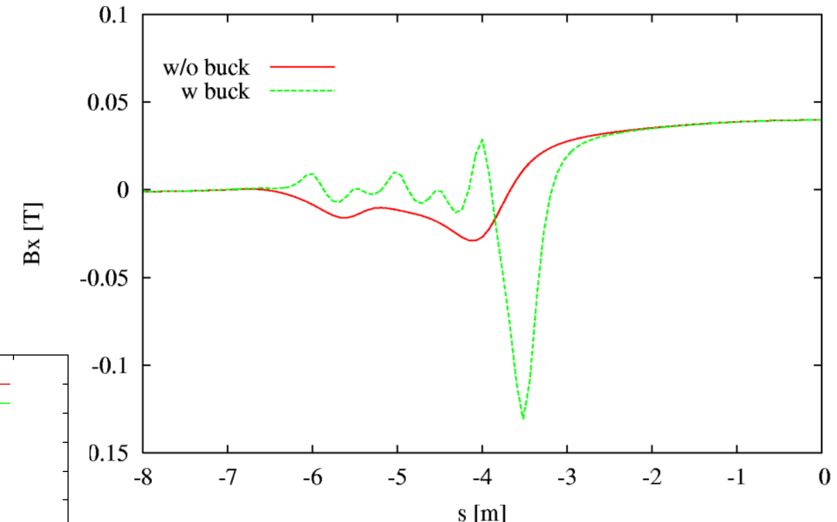
Field Plot with bucking coils

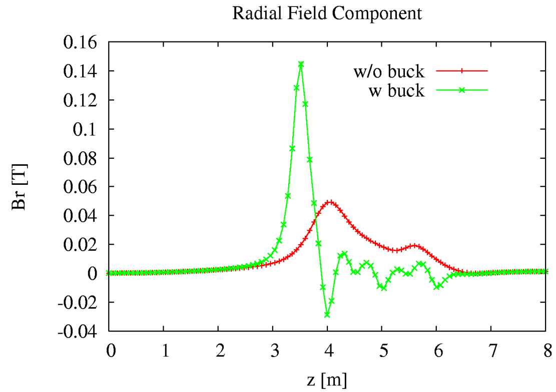


D. Swoboda

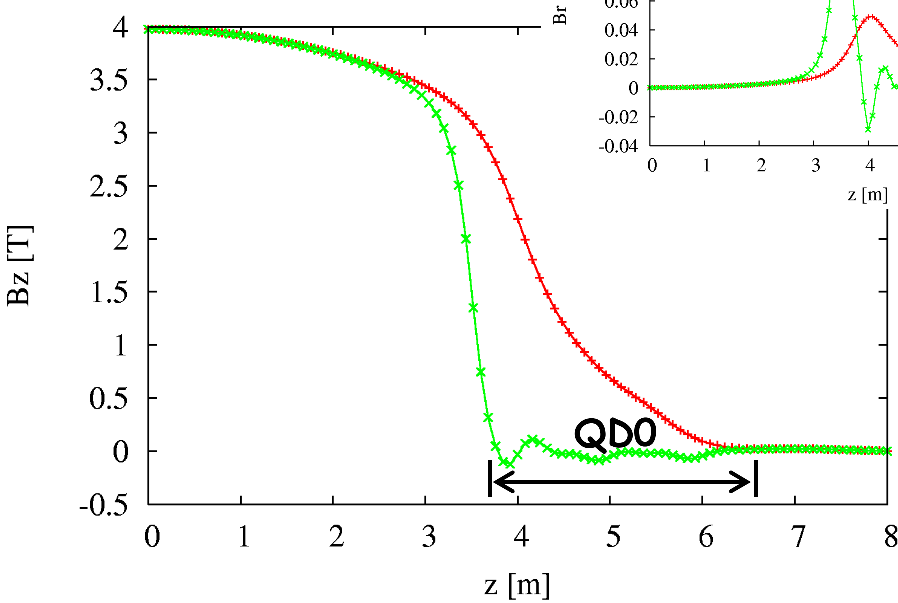
Vertical offset correction (2/2)

- "anti-solenoids" (bucking coils covering QD0), cancelling the main solenoid magnetic field component, can also reduce offset at IP (z=s=0).

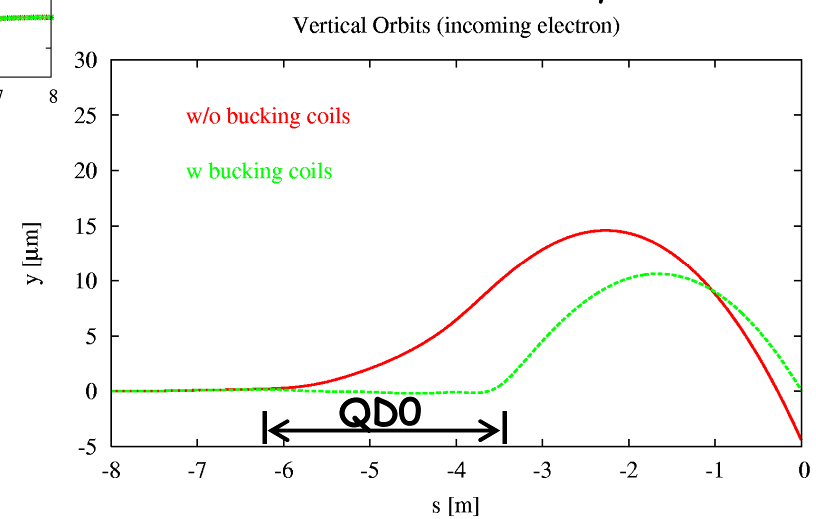




solenoid reference system



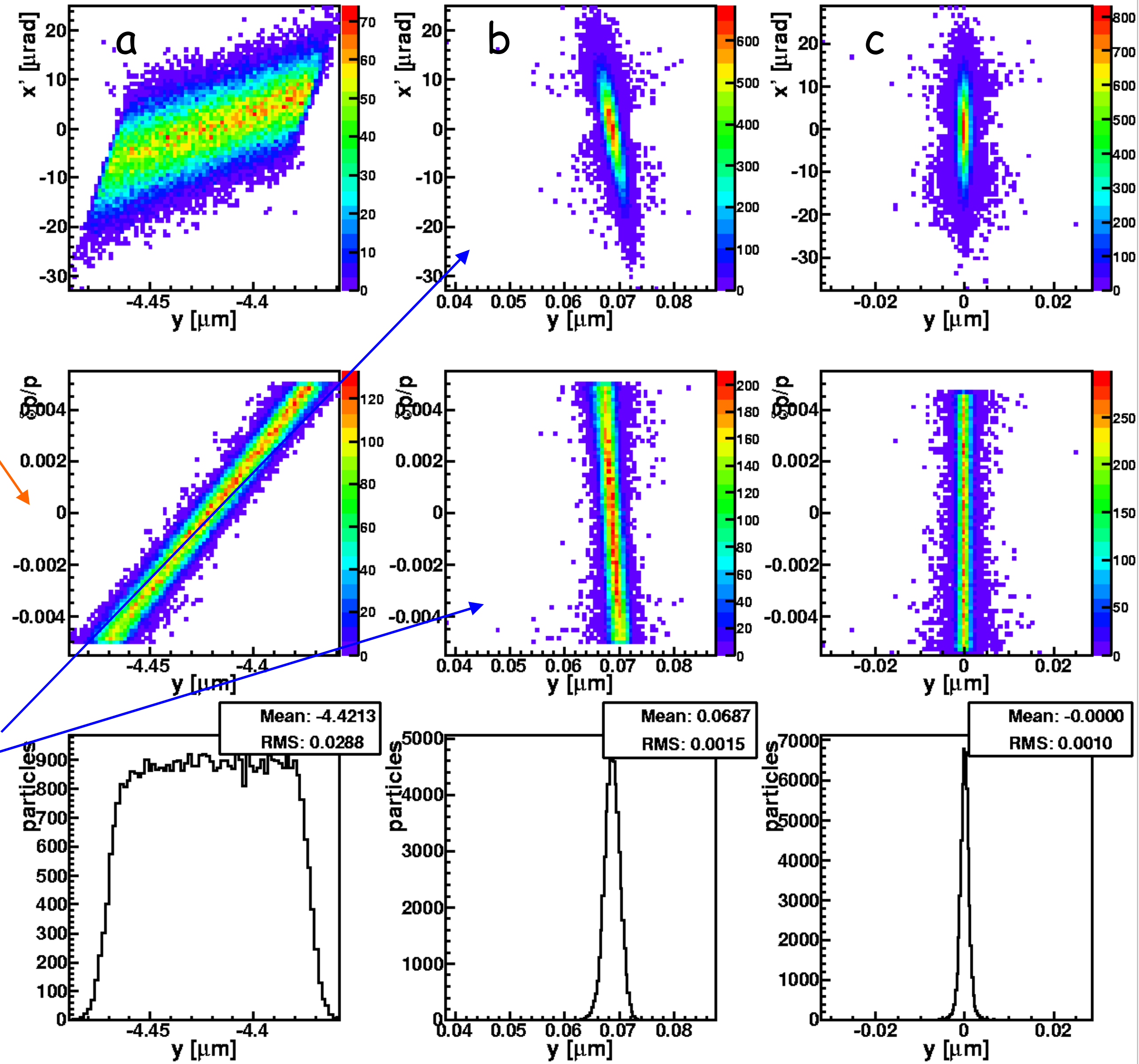
beamline reference system



Vertical dispersion and <x',y> coupling

< x',y > coupling and vertical dispersion at IP

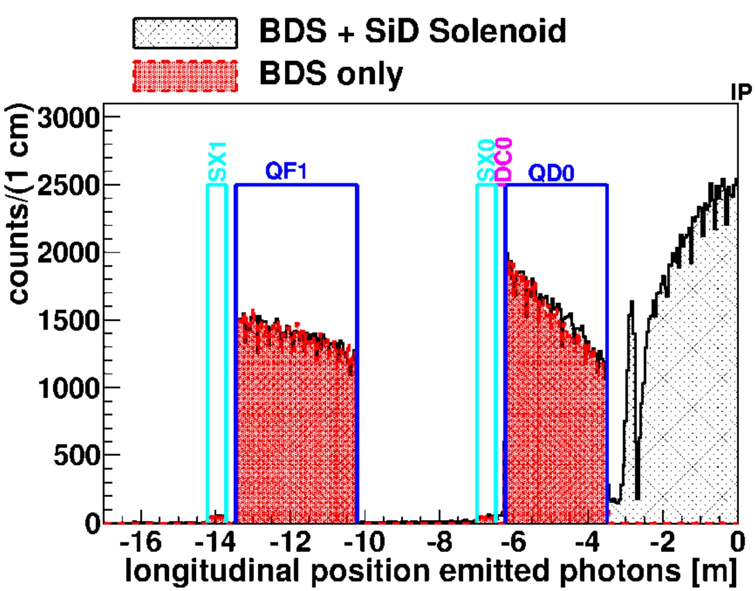
a) Tracking trough FFs and IP Solenoid
b) Tracking trough FFs and IP Solenoid + anti-solenoids covering QD0
c) Tracking trough FFs only

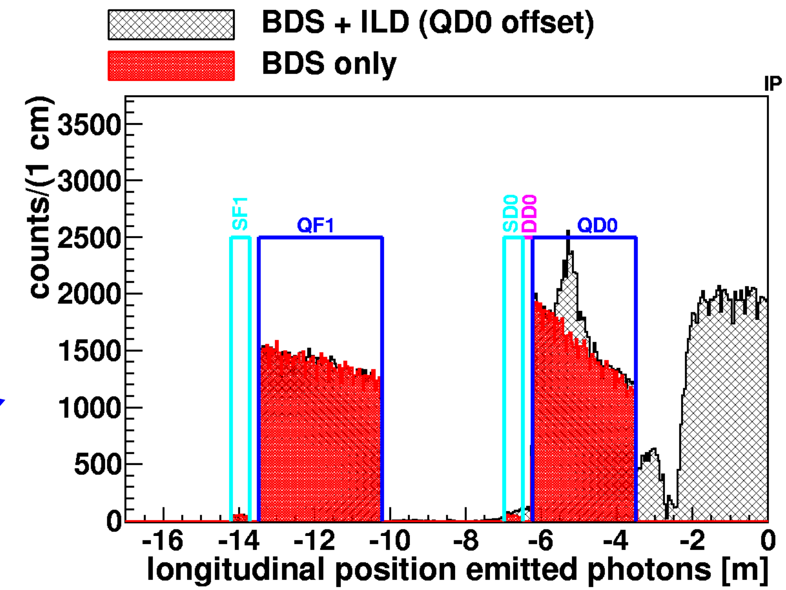


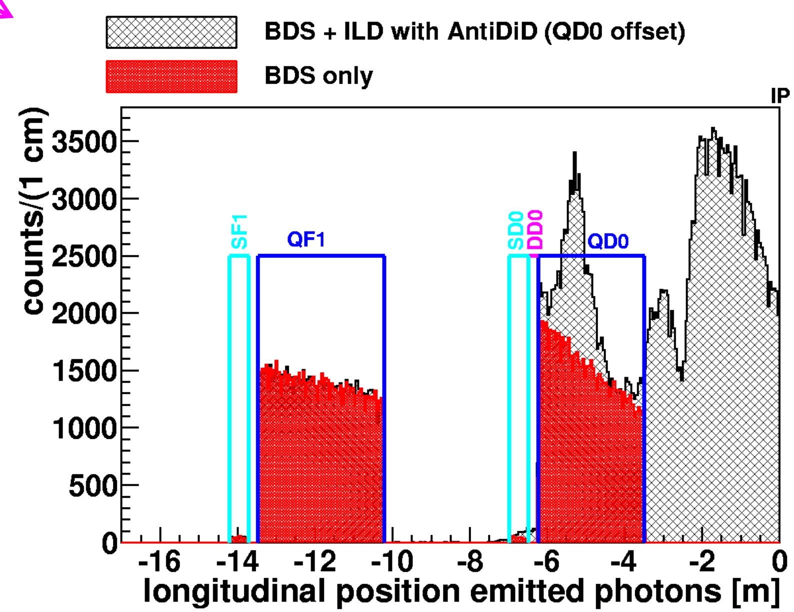
Residual <x',y> coupling and dispersion can be compensated using the other FFs magnets

Synchrotron Radiation photons

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







Luminosity Loss

Map	Bz [T]	Lumi loss [%]
Old SiD	5	~4.0
New SiD	5	~3.0
ILD	4	~4.0
ILD + AntiDiD	4	~25.0

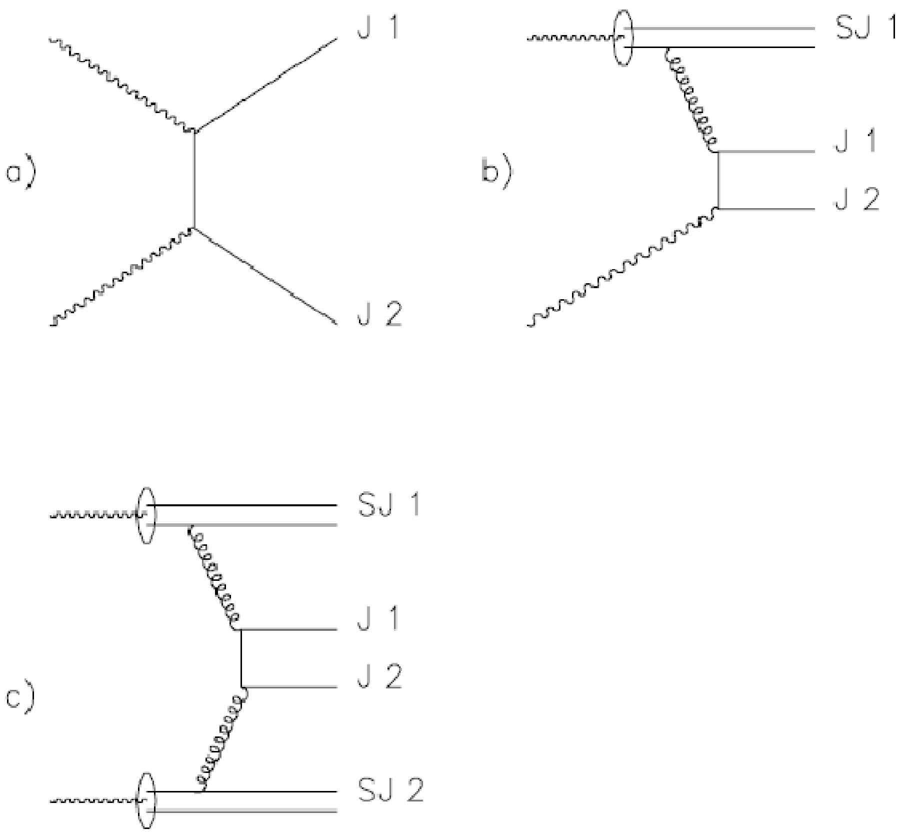
- luminosity calculation by GUINEA-PIG
- CLIC half horizontal crossing angle 10 mrad
- ILD values are computed with QD0 offset: 5μm (ILD), 43.5μm (ILD+AntiDiD)

Beam-Beam background

Beam-Beam Backgrounds at CLIC:

- Beam particles
- Beamstrahlung photons
- Coherent Pairs
- Incoherent Pairs
  - See A. Sailer talks
- $\gamma\gamma \rightarrow$ hadrons
  - beam tracked trough Main Linac and BDS before collision
  - w and w/o machine imperfections

Hadronic background

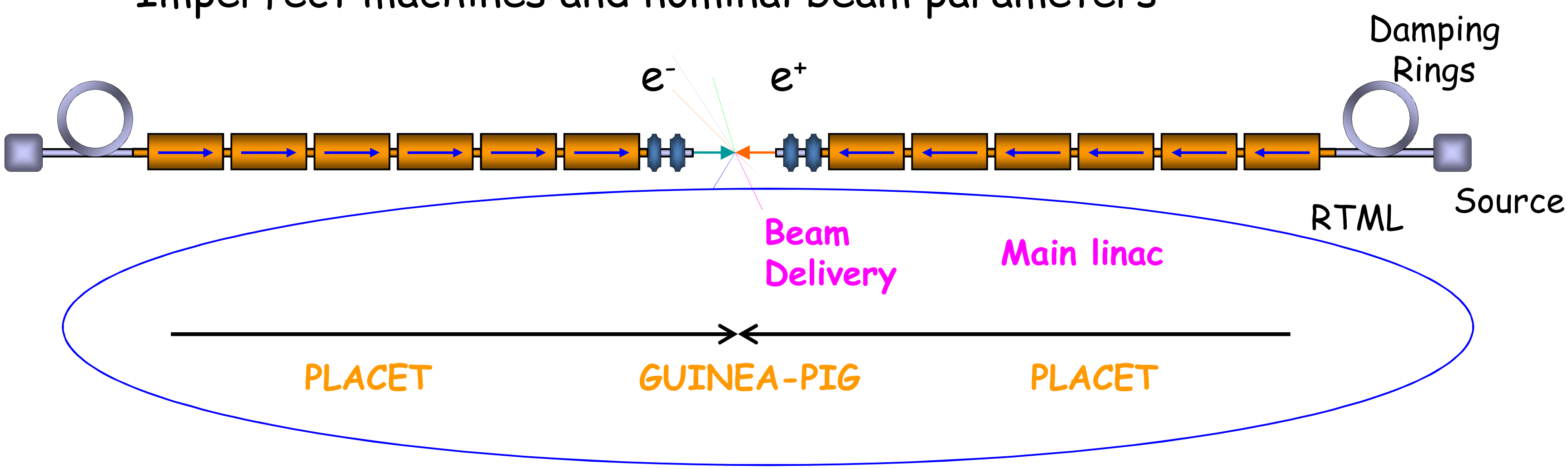


- G.A.Schuler and T.Sjostrand, CERN-TH/96-119 (1996) parametrization of cross section used in GUINEA-PIG
- Cross section slightly increase with CM energy

- Most energy is in the forward/backward direction
  - Evis ≈ 450 GeV per hadronic event for no cut
  - Evis ≈ 23 GeV for $\theta > 0.1$
  - Evis ≈ 12 GeV for $\theta > 0.2$

Hadronic background estimates

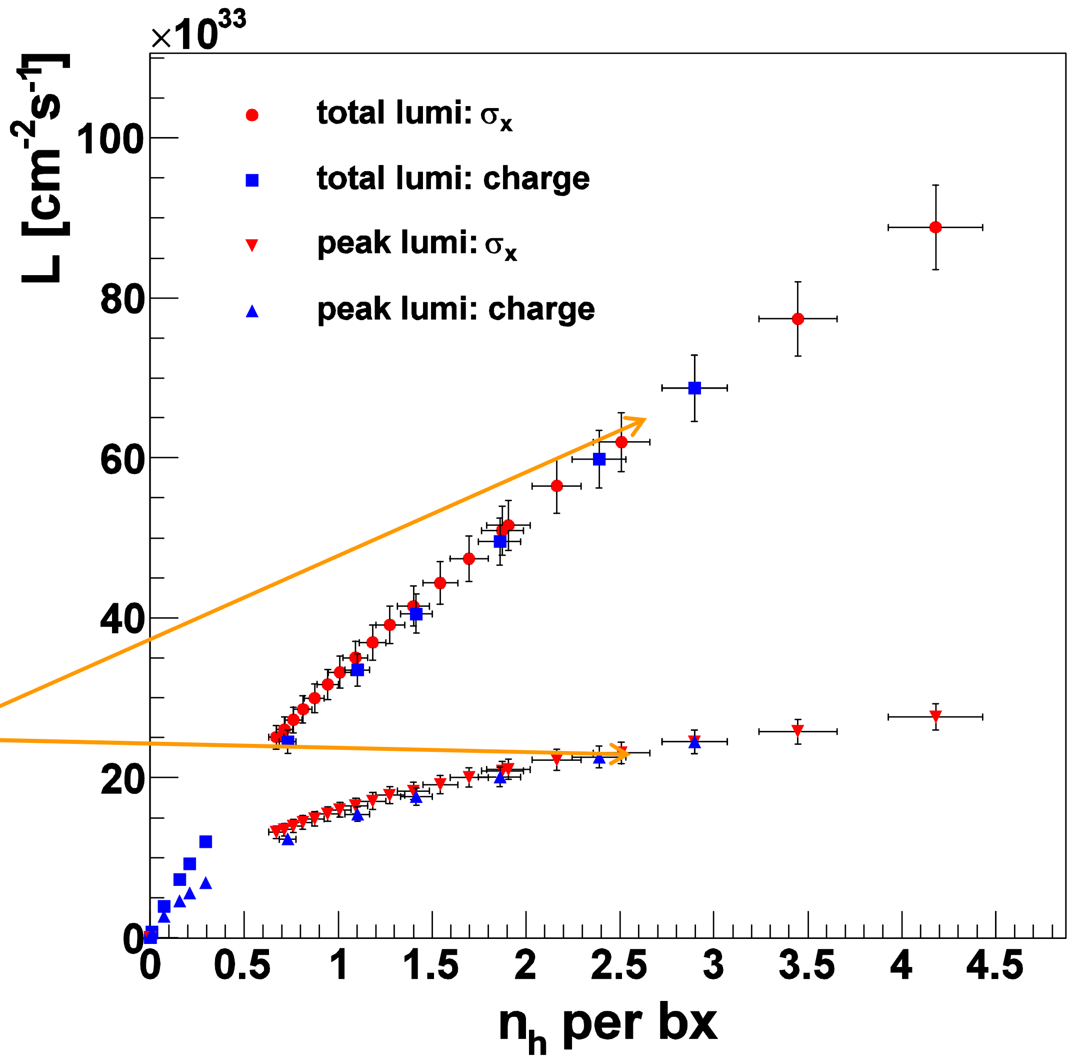
- Beam tracking with PLACET trough LINACs and BDSs
- Beam-Beam ($\gamma\gamma \rightarrow$ hadrons) calculation with GUINEA-PIG
- Aim $\rightarrow$ study BB background at different machine parameters/conditions
  - Perfect machines and non-nominal beam parameters
  - Imperfect machines and nominal beam parameters



Horizontal beam size and charge

- perfect machines
- scan of horizontal beam size and of the charge in bunches

$15 < \sigma_x < 85$ nm
$0.3e^{-6} <$ charge $< 3.72e^{-9}$

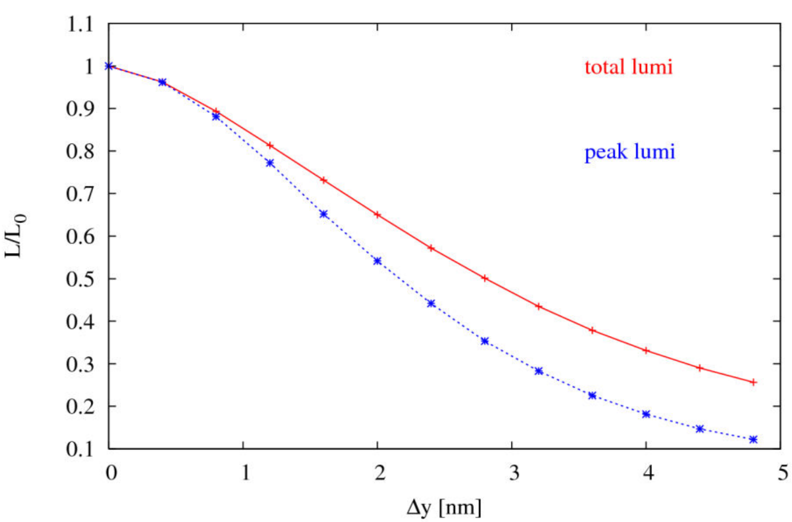


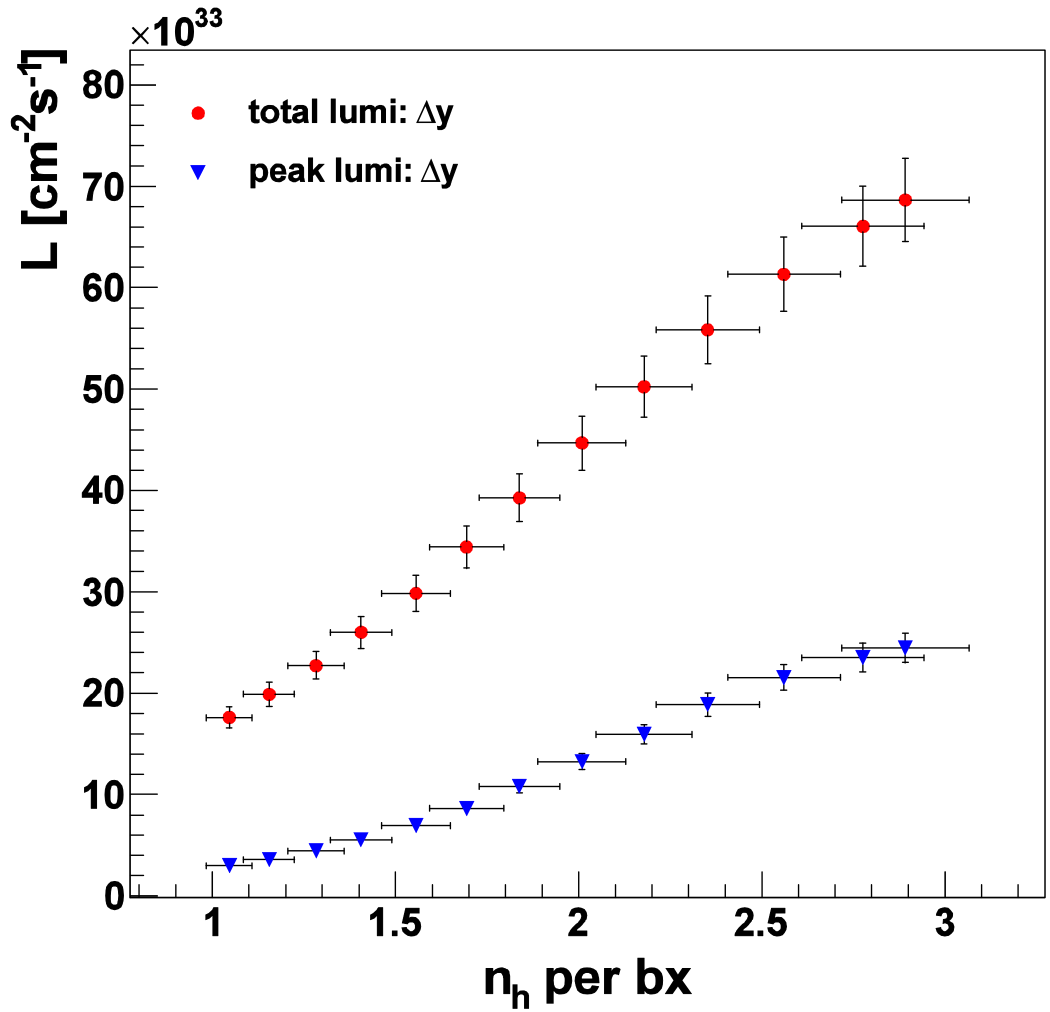
CLIC nominal 3TeV CM

- CLIC 3 TeV: n_{hadr} 2.9 bx
- ILC 0.5 TeV: n_{hadr} 0.12 bx

Vertical offset

- "perfect machines"
- scan of vertical offset at IP



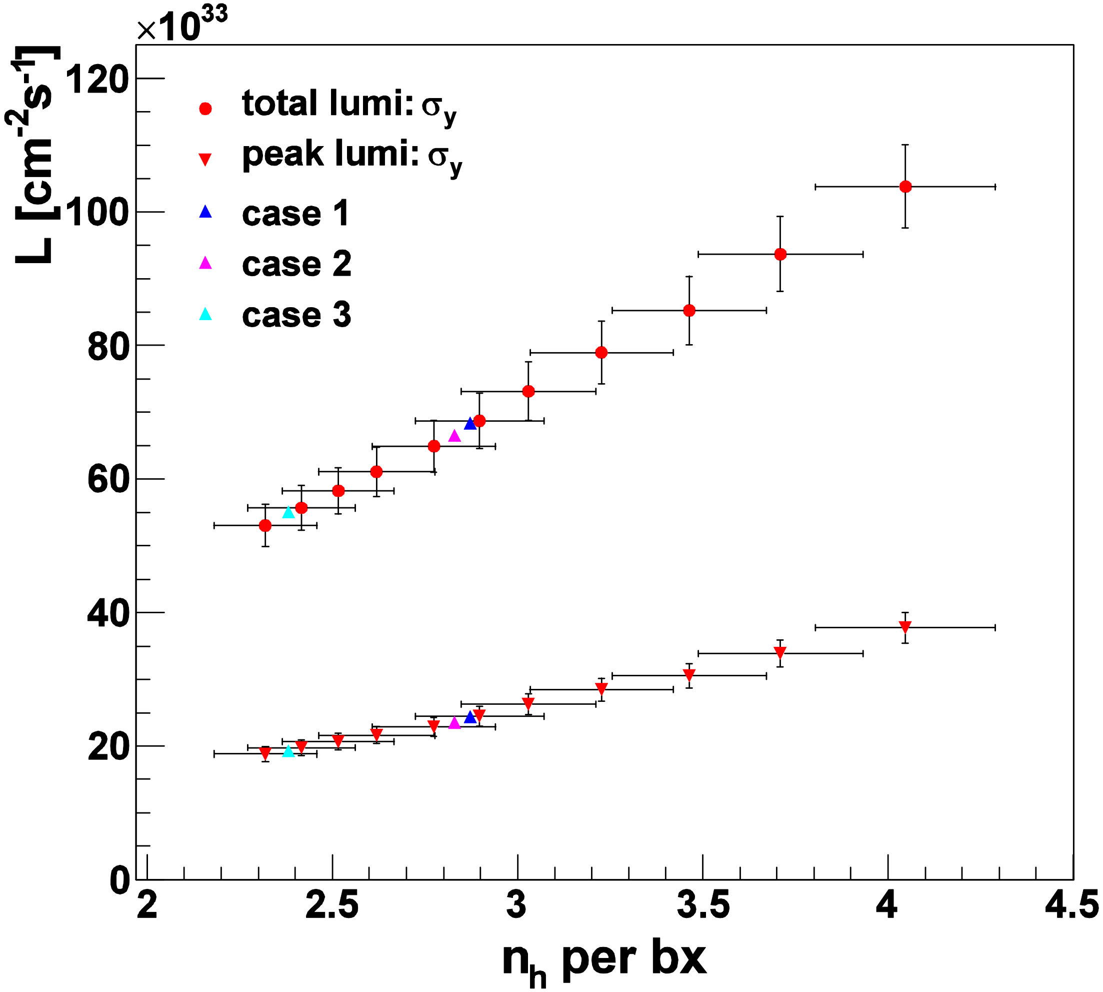


Vertical emittance growth

- perfect machines
- scan of vertical beam size:
  $0.1 < \varepsilon_y < 0.3 \times 10^{-7}$ m rad
- static imperfections:
  case 1
  - quadrupole offset and rotation in the main linac
  - perfect bds
  - 1-to-1 steering in linac and bds

  case 2
  - quadrupole offset and rotation + cavity misalignment
  - perfect bds
  - 1-to-1 steering in linac and bds

  case 3
  - quadrupole and cavity misalignment + cavity phase and gradient errors
  - perfect bds
  - 1-to-1 steering in linac and bds



Conclusion and Outlook

- Incoherent Synchrotron Radiation in CLIC-BDS at 3TeV CM
  - ~ 20% luminosity loss
- Compensation of detector solenoid effects on the beam size
  - AntiDiD increases the luminosity loss due to Synchrotron Radiation up to 25%
  - Anti-Solenoid (bucking coils covering QD0) reduces (> 90%) the optical distortions at IP but still to be evaluated/considered:
    - Interference with QD0
    - Radiation
    - Main Solenoid field distortion in the forward tracking region
- Hadronic background
  - ~ 3 $\gamma\gamma \rightarrow$ hadronic events for CLIC nominal parameter 3 TeV CM
  - considering different beam parameter and machine conditions

  $\Rightarrow$ background increase with luminosity
  - to do… realistic beam-beam background simulation
    - Static and dynamic machine imperfections + their corrections (alignment-tuning-feedback) all along the machine

Incoherent Synchrotron Radiation

- In order to evaluate ISR effect (O(nm)) we need to consider fully compensated optical effects (O(μm))

- Incoherent synchrotron radiation due to detector solenoid is evaluated by tracking, a compensated beam (from backtracking), taking into account the Monte Carlo synchrotron radiation implemented in PLACET

IP beam distributions