

Trident Events in Beam-Beam Interactions and Update on Background Studies at CLIC

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1 Luminosity, Disruption and Beamstrahlung

2 Beam-Beam Background in a CLIC Detector

- Beam-Beam Background in CLIC_ILD
- Beam-Beam Background in CLIC_SiD

3 Summary

Acknowledgment

Information regarding the Trident Cascade courtesy of Jakob Esberg
(Aarhus, CERN-BE) See also his talk:

<http://indico.cern.ch/conferenceDisplay.py?confId=103216>

He also recently implemented this process into GUINEAPIG, release pending.

Luminosity

- Geometric Luminosity L

$$L \propto \frac{N^2}{\sigma_x \cdot \sigma_y} H_D$$

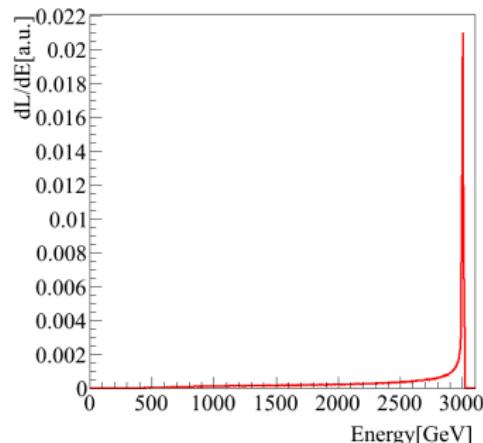
- ▶ Bunch charge: N
- ▶ Transverse beam sizes: σ_x, σ_y
- ▶ Enhancement Factor: $H_D \rightarrow$ Beamstrahlung
- Beam sizes on the order of few to tens of nanometer
- Have to take disruption of bunches into account. I.e. the size of the beams change during the collision
- Simulate luminosity with e.g. GUINEA PIG

Disruption and Beamstrahlung

- Attraction between bunches: Pinch effect and $H_D \approx 2$ (CLIC)
- Deflected particles produce synchrotron radiation: Beamstrahlung
- Reduced c.m.s. energy: Luminosity spectrum (right side)
- Qualitatively described by beamstrahlung parameter

$$\langle \gamma \rangle = \frac{5}{6} \frac{N r_e^2 \gamma}{\alpha \sigma_z (\sigma_x + \sigma_y)}$$

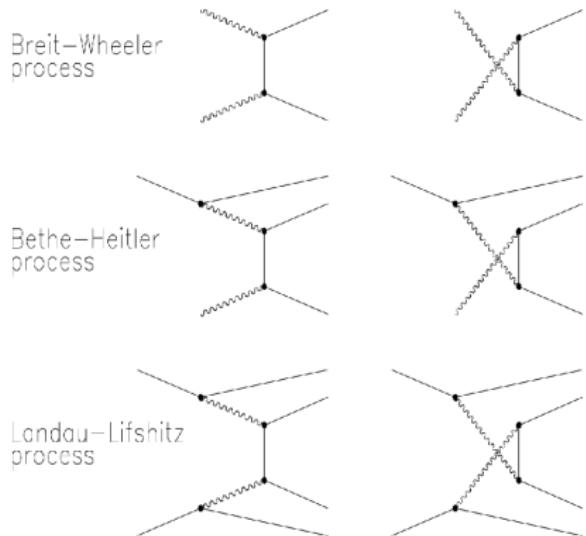
with the electron radius r_e and the fine-structure constant α



CLIC Luminosity profile: 30% of the events are inside 1% of the nominal energy

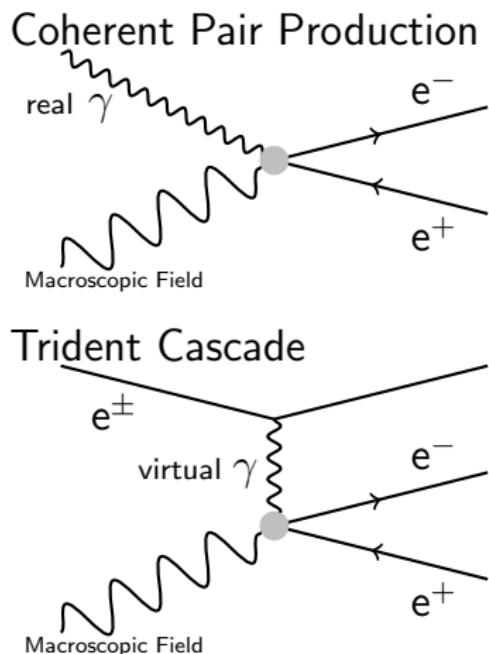
Incoherent Pairs

- Photons interacting with other electron/photon to produce an e^+e^- pair
- Photons can both be real or virtual
- A few 10^5 particles per bunch crossing

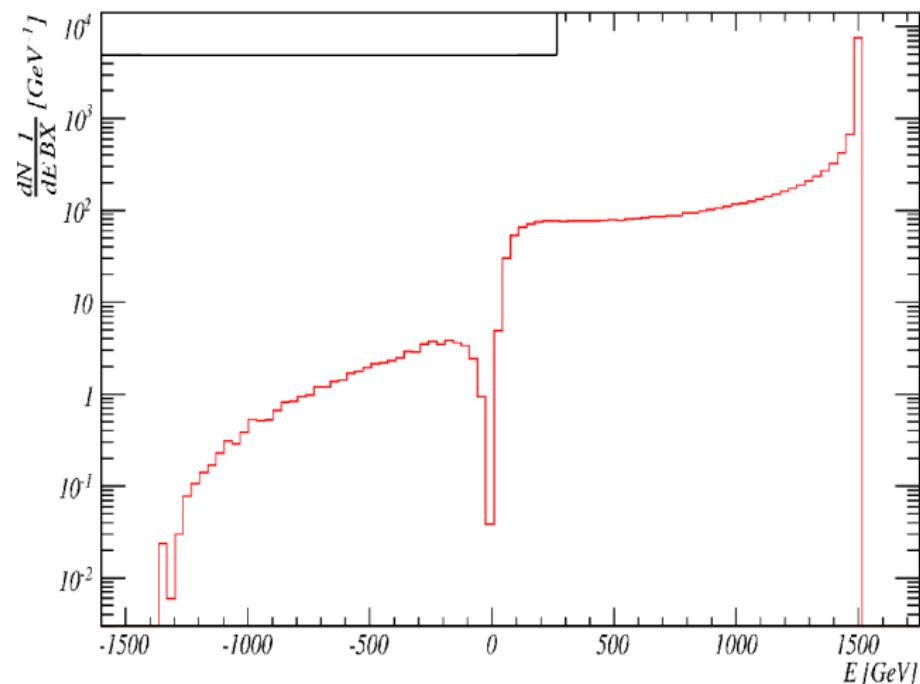


Coherent Pairs and Trident Cascade

- In very strong ($\Upsilon \geq 1$) fields (coherent effect of “all” bunch particles) photons can directly convert into e^+e^- pairs
- Possible both for *real* photons (“Coherent Pairs”)
- And *virtual* Photons (Trident Cascade)
- Coherent Pairs at CLIC are $\approx 0.1 \cdot N$, and give a correction to the luminosity spectrum (Tridents add small number as well)



Energy spectrum with Coherent Pairs



Energy spectrum of colliding particles, the negative part describes electron-electron and positron-positron events due to coherent pairs.

Pair Particle Energy Distribution

All numbers for nominal 3 TeV
CLIC

■ Incoherent Pairs

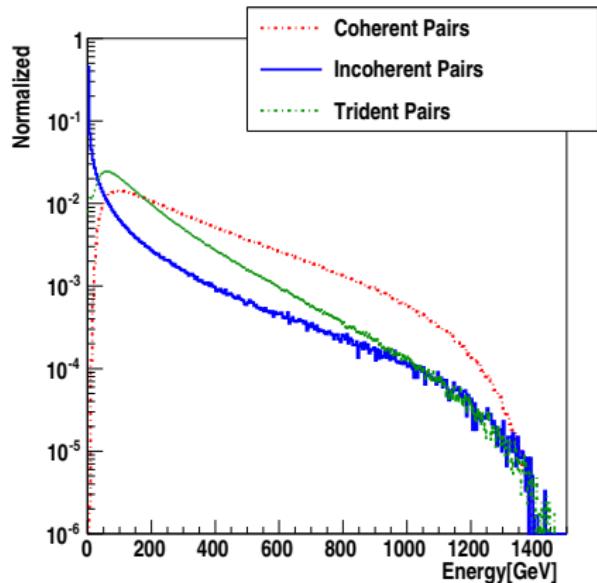
- ▶ Peak at lowest Energies
- ▶ few 10^5 particles/BX

■ Trident Pairs

- ▶ Suppressed at lower energies
- ▶ 10^6 particles/BX

■ Coherent pairs

- ▶ Cutoff at several GeV
- ▶ 10^8 particles/BX

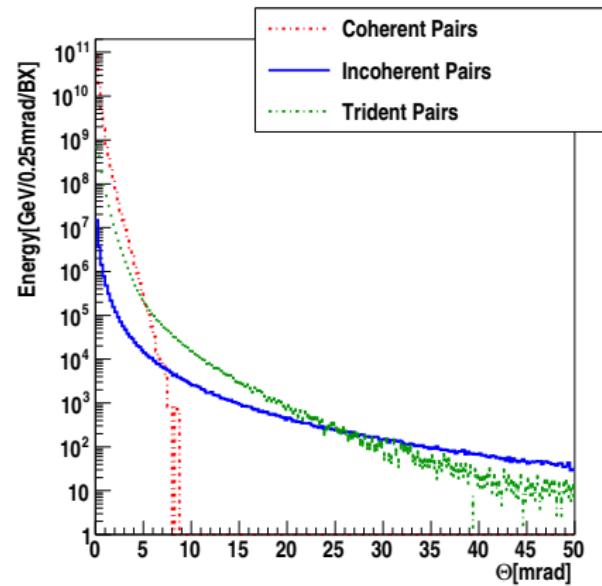


Angular Distribution

Maximum angle after disruption is related to the energy

- For small angles: Trident Pairs order of magnitude above incoherent pairs.
- Masking (BeamCal) starts at 10 mrad, coherent pairs leaving detector

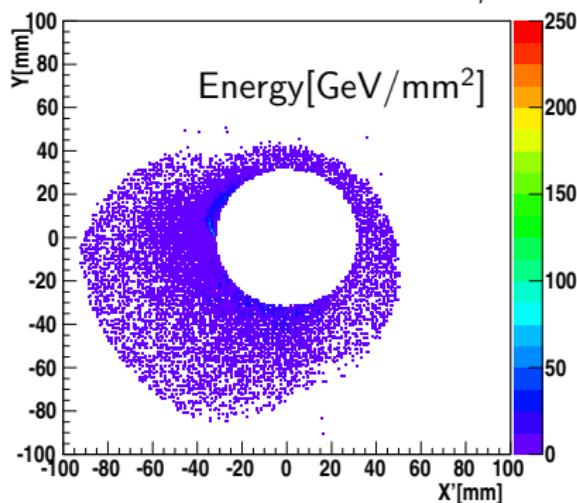
Angular distribution of background pairs after beam-beam effects



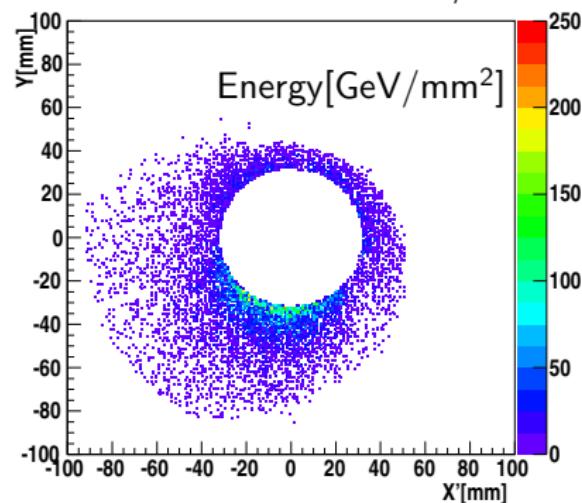
Energy at front Face of BeamCal*

Simple GEANT4 propagation to plane with $Z=2.8$ meters. Takes crossing angle and magnetic field (4T, noDID) into account.

Incoherent Pairs: 27 TeV/BX



Trident Pairs: 75 TeV/BX



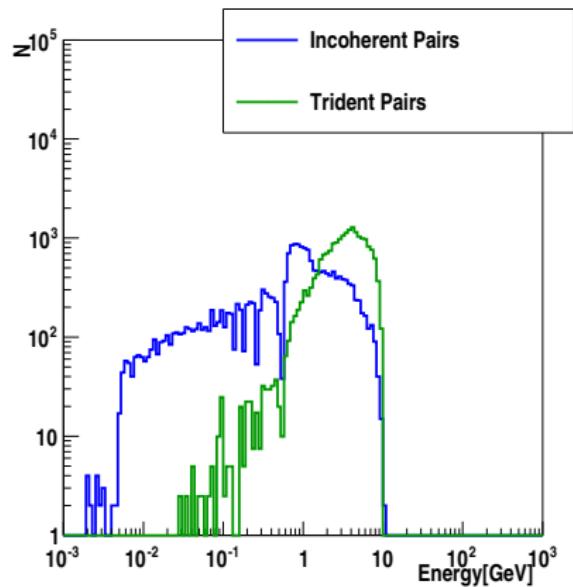
Trident pairs deposit three times the energy of incoherent pairs.

*Only on one side

Energy at front Face of BeamCal

- More incoherent pairs hit BeamCal
- But Trident pairs contain more higher energetic particles.
- The cutoff is due to kinematics, transverse momentum and maximal deflection from beam-beam interaction.

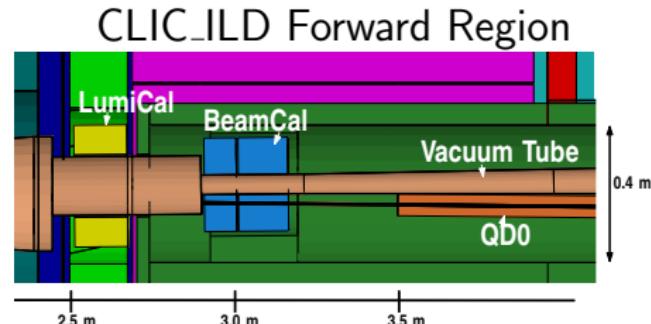
Energy distribution of particles hitting BeamCal



CLIC_ILD Detector Simulation

- GEANT4 9.2,
QGSP_BERT_HP,
 $5 \mu\text{m}$ rangeCut
- CLIC_ILD with forward region
- 4 Tesla field map
- Vertex Detector (VXD)
 - ▶ Inner Radius: 31 mm
 - ▶ Count particle passing as hit
 - ▶ $50 \mu\text{m}$ silicon, 3.4 keV threshold

Simulate beam-beam pairs to estimate background in the detector.



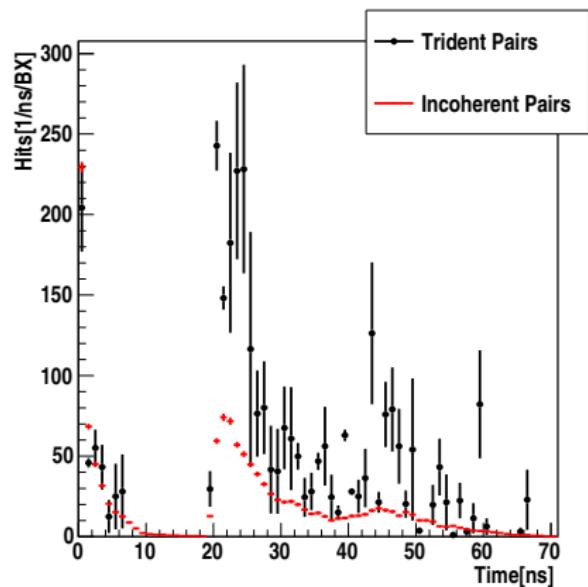
■ BeamCal

- ▶ 10 cm Graphite
- ▶ Inner radius: 32 mm
- ▶ Z-Position: 2.86 m
- ▶ New Absorber Structure (Graphite and Tungsten)

Back-Scatters I

- Incoherent pairs
 - ▶ Input Files: 312 BX, each simulated once
 - ▶ 4 Hits/mm²/Train
- Trident Pairs:
 - ▶ Input Files: 15900 GP Runs \approx 2/3 BX
 - ▶ Simulated 3 times in Mokka
 - ▶ 10 Hits/mm²/Train
- Direct hits similar in numbers
- larger number of indirect hits comes from Tridents

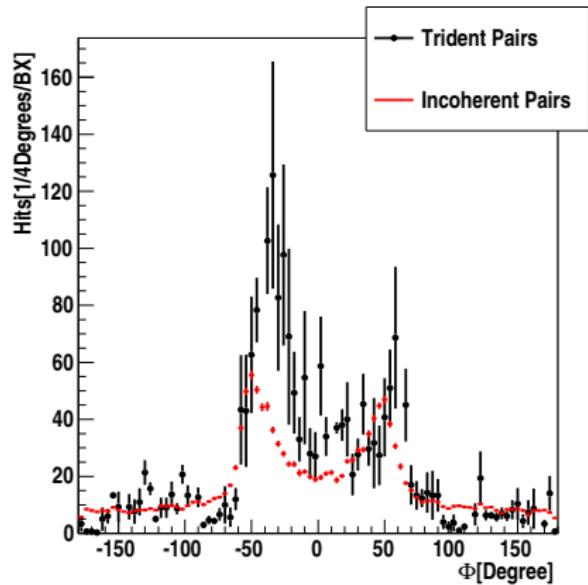
Time of Hits in first Layer of VXD



Back-Scatters II

Angular Distribution of Hits in the first layer of VXD

- Large azimuthal inhomogeneity in both cases
- Increased local hit density



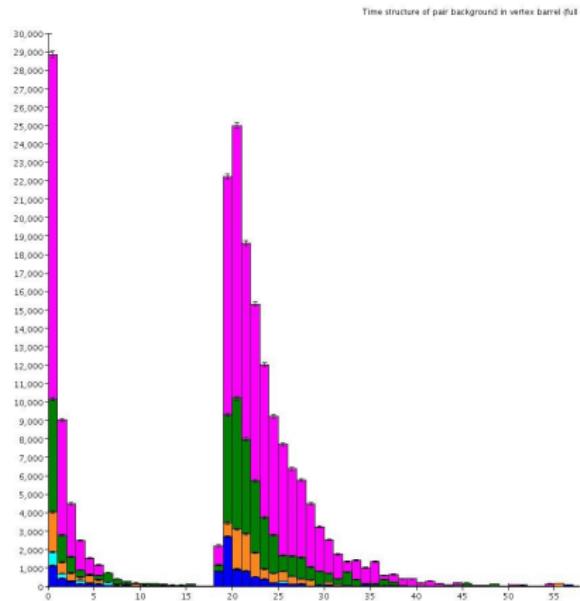
CLIC_SiD Vertex Detector and Forward Region

	CLIC_SiD	CLIC_ILD
VXD Layout	5 Single	3 Double
Innermost VXD Radius	27 mm	31 mm
B-Field	5 T	4 T
LumiCal Z_{Start}	1.8 m	2.5 m
LumiCal R_{Inner}	64 mm	100 mm
BeamCal Z_{Start}	2.8 m	2.9 m
BeamCal R_{Inner}	28 mm	32 mm

Coverage of very forward calorimeters very similar by design

Background in the CLIC_SiD Vertex Detector

- Incoherent Pairs only
(remember $\times 4$ for tridents)
- Backscatters arrive earlier due to smaller distance between IP and BeamCal
- Background rates and distributions similar to CLICILD

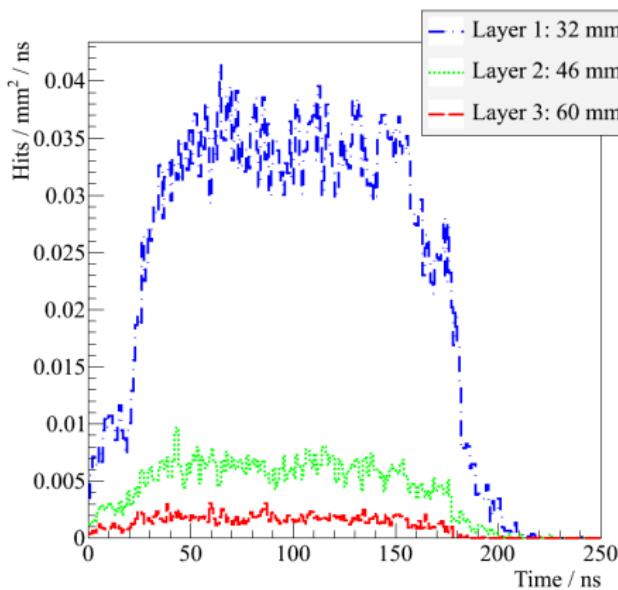


(Courtesy of C. Grefe, CERN)
Number of Hits vs. Time of hit in nanoseconds (histogram not stacked; sum of 312 BX)

Background during one Bunch train

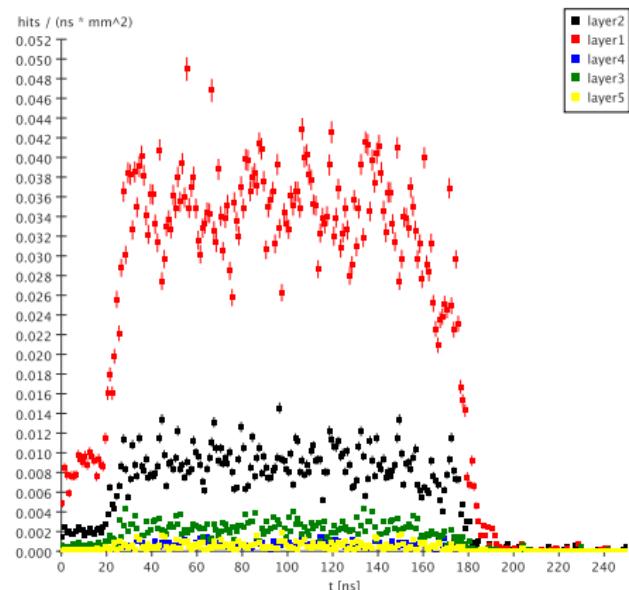
Background hit densities from incoherent pairs in the vertex detector.

CLIC_ILD



CLIC_SiD

Occupancy in Vertex Barrel



Summary

- Coherent processes affect luminosity spectrum through “generation” of charge
- Trident Process added to GUINEAPIG (by J. Esberg)
- Tridents deposit significant amount of Energy in BeamCal
- Increases background in the detector
- Background simulations also for CLIC_SiD (C. Grefe) with similar results as for CLIC_ILD