Backgrounds in CLIC

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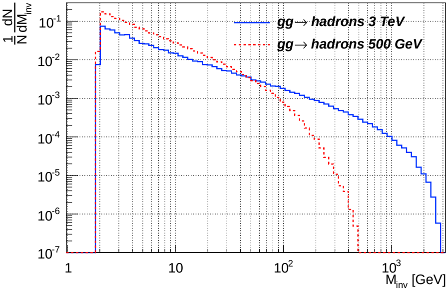
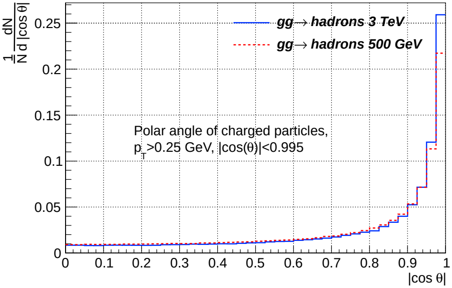
Contents

Some relevant CLIC Parameters

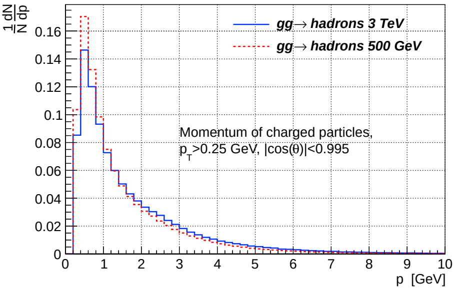
	3 TeV	500 GeV
Bunch Spacing	0.5 ns	0.5 ns
Bunches/Train	312	312
Trains/Second	50	50
$\gamma\gamma \to$ Hadron events/BX	3.2	0.3
Incoherent pairs/BX	$3 \cdot 10^5$	$0.7 \cdot 10^5$
Coherent Pairs/BX	10^8	≈ 0

$\gamma\gamma \to$ Hadrons





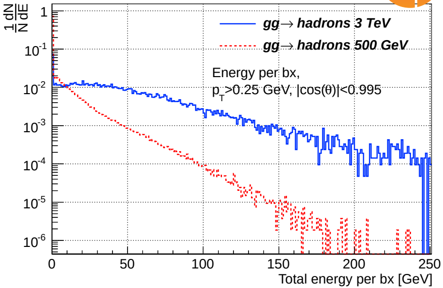
- Effective cross-section depends on Beamstrahlung and virtual photon spectra
- 500 and 3000 GeV final state particles similarly distributed (but rates differ)

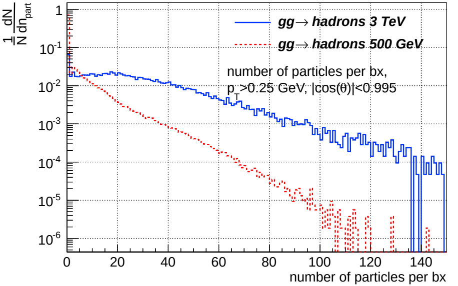


(D. Dannheim)

$\gamma\gamma \to$ Hadrons

- CLIC 3 TeV
  - 3.2 $\gamma\gamma \to$ Hadron events/BX
  - Energy/BX: 1300 GeV ($\theta > 7.3^{\circ}$: 49 GeV)
  - Tracks/BX: 50 ($\theta > 7.3^{\circ}$: 25.6)
- CLIC 500 GeV
  - 0.3 $\gamma\gamma \to$ Hadron events/BX
  - Energy/BX: 13 GeV ($\theta > 7.3^{\circ}$: 2.9 GeV)
  - Tracks/ BX: 2.4 ($\theta > 7.3^{\circ}$: 1.8)

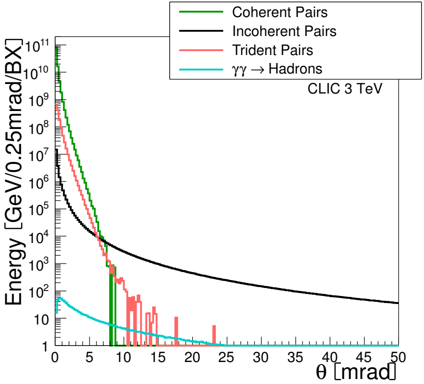


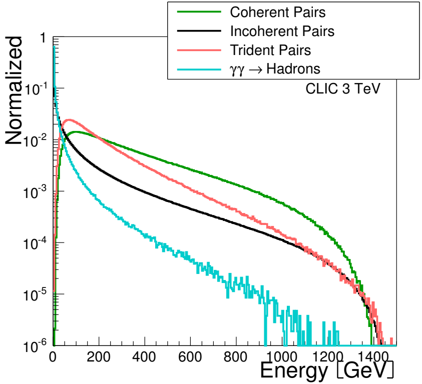


(D. Dannheim)

e^+e^- Pairs

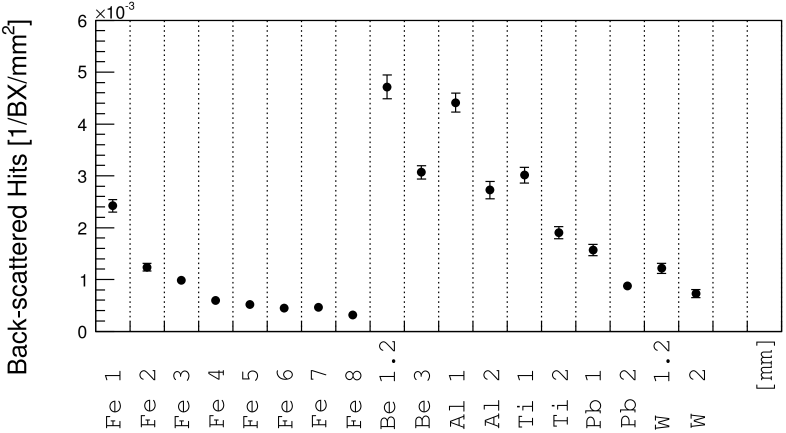
- Several production processes for e^+e^- pairs, coherent processes suppressed below 1 TeV
- **Coherent pairs** define outgoing beam pipes (10 mrad), ‘all’ coherent pairs leave detector
- For ‘larger’ angles trident pairs orders of magnitude below incoherent pairs
- Simulating only incoherent pairs to estimate background/radiation dose





e^+e^- Pairs and Geometry optimisation

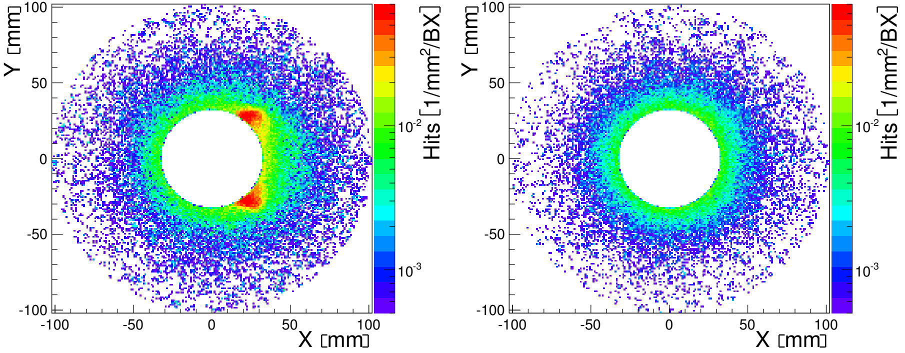
- Reducing back-scatters by using a pointing beam pipe as a mask
- With 4 mm iron, back-scatters factor 10 below direct hits
- LCD-Note in preparation
- Engineering design still needed



Hit density from back-scattering particles ($t_{\mathrm{Hit}} > 15$ ns) w.r.t. beam pipe thickness and material.

e^+e^- Pairs and Geometry optimisation

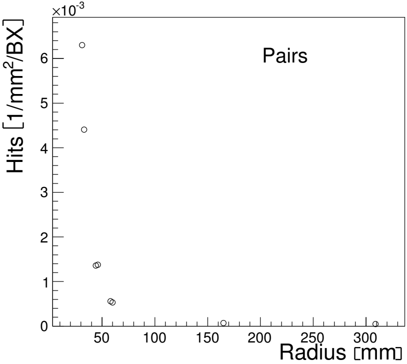
- Without back-scatters hit distribution no longer phi dependent (CLIC_ILD_CDR without Anti-DID field, large amount of back-scatters from beam pipe inside BeamCal)

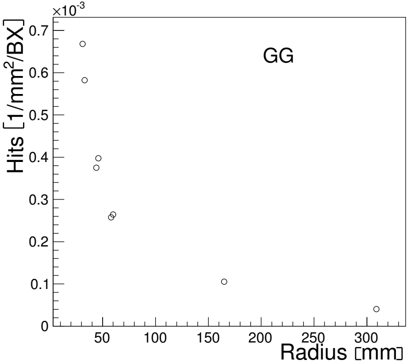


Hit density from incoherent pairs in the inner FTDs with thin and thick beam pipe.

Occupancy in VXD/SIT

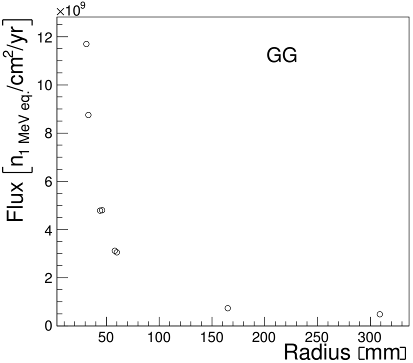
- With 4 mm iron beam pipe, direct hits from incoherent pairs dominant: $6 \cdot 10^{-3}$ Hits/mm^2/BX
- $\gamma\gamma \rightarrow$ Hadrons is factor 10 below background from pairs, falling less steeply, dominating in TPC (see below)





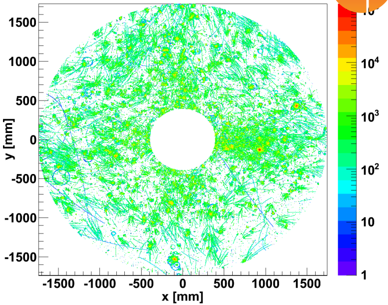
NIEL in Silicon Tracking Detectors

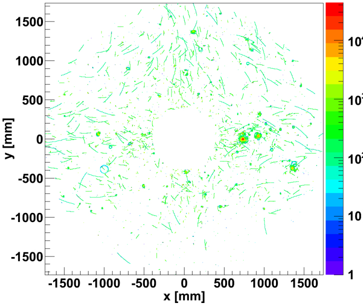
- Non Ionising Energy Loss / Displacement Damage
- Simulating without thresholds in tracking detectors
- Weight particles passing sensitive detectors with displacement damage factor relative to 1 MeV Neutrons
  (Values from: `http://sesam.desy.de/members/gunnar/Si-dfuncs.html`)
- Eq. neutron flux around $10^{10}/\mathrm{cm}^2/\mathrm{year}$
  (Atlas Vertex $10^{14}/\mathrm{cm}^2/\mathrm{year}$)



Beam Halo Muons

- Muon pair production from interaction of beam particles with beam gas/halo scrapers
- Initial estimate from Accelerator: $\approx 80/\mathrm{BX}$
- Large impact on detector
  - Showers and tracks in the calorimeters and TPC
- Beam Halo muon rate will be reduced by magnetised shielding in the BDS
- Now assuming $5/\mathrm{BX}$ including safety factor
- Right side: Hits in the TPC from a bunch train of beam halo muons, without (top) and with (bottom) magnetised shielding

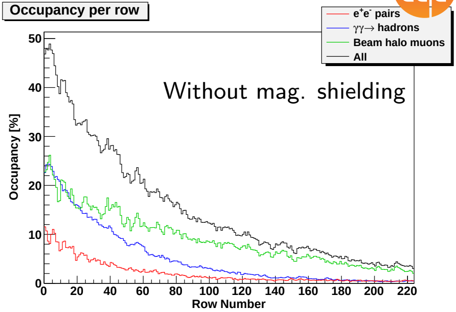


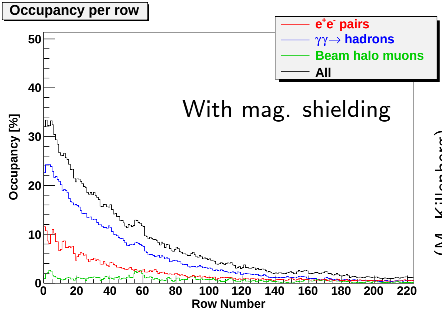


(M. Killenberg)

Occupancy in the TPC

- Plots on the right give the percentage of voxels occupied for each pad-row during one bunch train without and with magnetised shielding
- Without beam halo muons, $\gamma\gamma \rightarrow$ Hadrons dominate TPC occupancy with pairs close behind





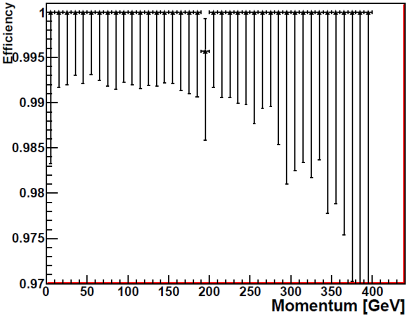
(M. Killenberg)

Beam-induced Background in the MC Mass Production

- Pairs mostly significant for inner tracker
- Tracking software not able to handle too many hits (same SW as LoI)
- Overlap of background and signal showers in the calorimeter are the bigger problem
- Assuming 10 ns integration times in most sub detectors
- Exceptions:
  - TPC would integrate a full bunch train (156 ns)
  - HCal Barrel: According to GEANT4, shower development slower $\rightarrow$100 ns integration time (W-AHCal test beam campaign underway)
- Conclusion: Overlay 60 BX $\gamma\gamma \rightarrow$ Hadron events

Track Reconstruction

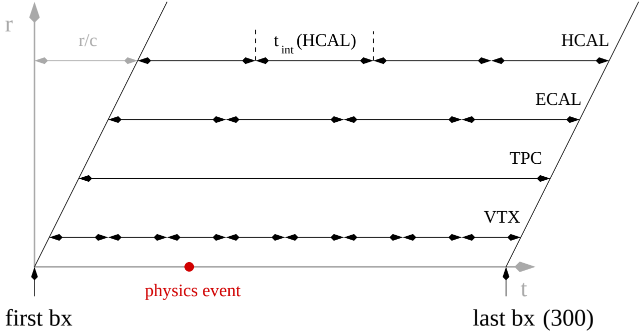
- See talk by J. Nardulli in SW pre-meeting
- Efficient track reconstruction, even in presence of backgrounds
- LCD note in preparation



Efficiency for the reconstruction of single muons with overlaid background (J. Nardulli)

OverlayTiming Processor

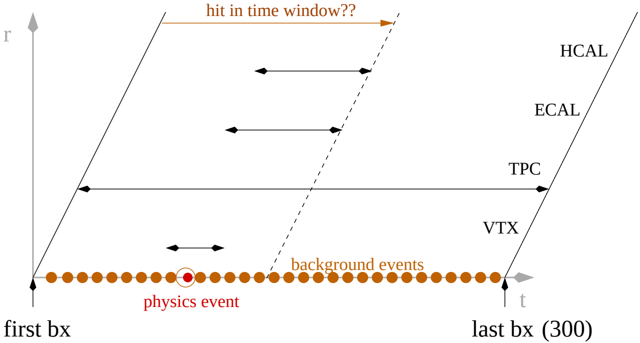
- Different integration times in the sub-detectors
- For calorimeters the hit time resolution can be a lot faster
- E.g. because of slower shower development, longer integration time in HCal Barrel (tungsten absorber)



(P. Schade)

OverlayTiming Processor

- The physics and background events are placed in the train
- All entries in the collections inside the time windows are merged



(P. Schade)

LCD-Note-2011-006 (to be released).

Reconstruction with Background

- Overlay Processor seems to be mature, no memory leaks, no bugs (anymore)
- Amount of overlaid background limited by tracking software
- Reconstruction time grows quickly with amount of background
- We overlay 60 BX of $\gamma\gamma \rightarrow$ Hadron events
- Contributions to software (e.g. see my talk in the SW pre-meeting).

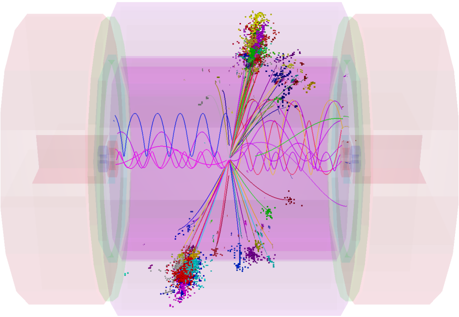
Separating Physics and Background

- Reconstruct tracks, clusters and PFOs
- Select PFOs based on cluster and track time, p and p_T
- We are using several levels of cuts (and store all different PFO sub-collections)

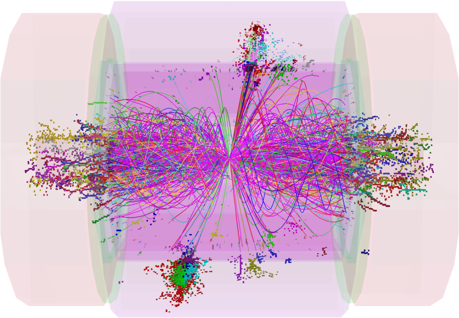
Event and Background before Cuts

Shown are the reconstructed PFOs

Two Jet Event:



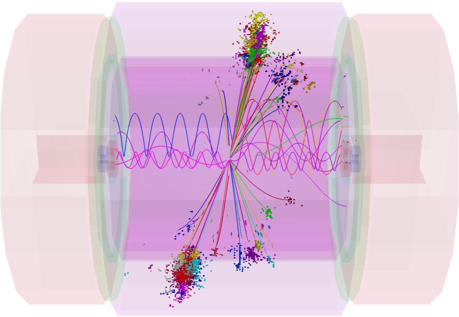
Event overlaid with $\gamma\gamma \to$ Hadron background



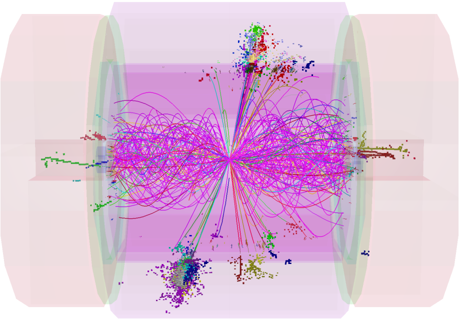
(M.Thomson)

Event and Background with Loose Cuts

Two Jet Event:



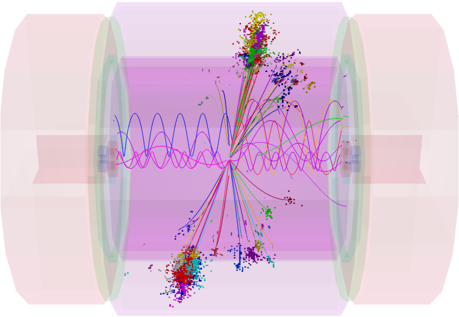
Loose Selection Cuts:



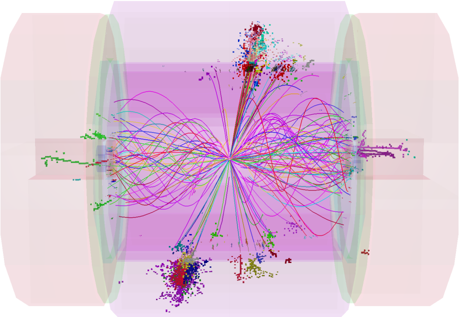
(M.Thomson)

Event and Background with Default Cuts

Two Jet Event:



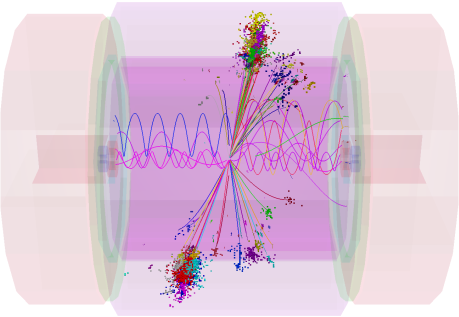
Default Selection Cuts:



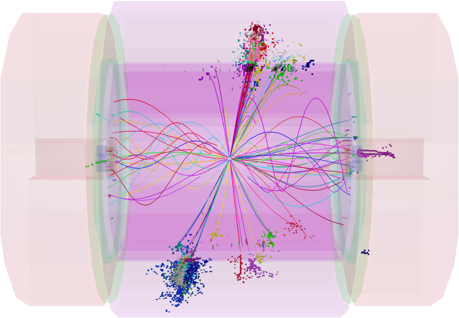
(M.Thomson)

Event and Background with Tight Cuts

Two Jet Event:



Tight Selection Cuts:



(M.Thomson)

Benchmark Studies for CDR

- For the CDR several benchmark channels are being studied
- Taking into account the $\gamma\gamma \rightarrow$ Hadron background
- Not all events are going be reconstructed with overlay
- About 500k events to be reconstructed with Overlay in CLIC_ILD

Summary

- Studied main sources of beam-induced backgrounds in the CLIC_ILD_CDR model
- Found ways to reduce backgrounds in the detector
- Routinely overlaying and reconstructing $\gamma\gamma \rightarrow$ Hadron backgrounds for CDR Mass Production

Links

- LCD Notes etc.: `http://lcd.web.cern.ch`
- CLIC CDR WG6, many interesting presentations:
  `https://indico.cern.ch/categoryDisplay.py?categId=3222`
- $\gamma\gamma \rightarrow$ Hadron Working group
  `http://indico.cern.ch/categoryDisplay.py?categId=3395`