


Beam induced backgrounds and occupancies in CLICdet

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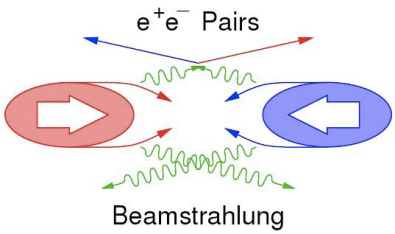
Overview

Motivation

- Obtain the beam-induced background yields and their distributions at all energy stages relevant to CLIC, as good knowledge of unwanted particles creation is required for a quality detector design and precise physics studies
- Estimate the arising occupancies in tracking detectors and calorimeters, if they are found to be too high it may trigger a change in the detector design
- Provide feedback information about luminosity spectra and their quality for different Beam Delivery System (BDS) designs required by physics studies, e.g. top quark mass measurement via threshold scan

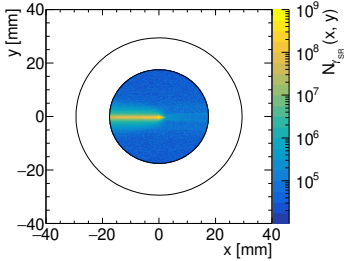
Background creation

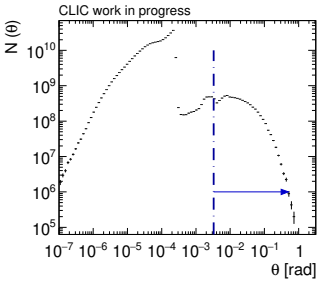


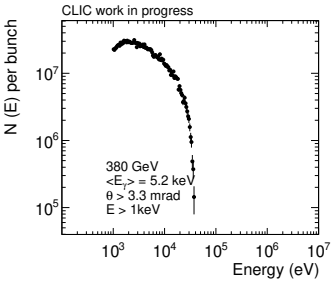
- Synchrotron radiation is created in strong focusing magnets of the Final Focus System and can travel downstream along the beam
- Beamstrahlung photons, another type of synchrotron radiation caused by charged particles' interactions with the electromagnetic field of the incoming beam, are produced in large quantities and with high energies

- This emission is the main cause of the lower energy tail in e^-e^+ luminosity spectrum
- Beamstrahlung interactions with e^-, e^+ or other photons lead to production of unwanted particles: incoherent pairs, hadrons, coherent pairs and trident cascades (for $\sqrt{s} > 1$ TeV)

Synchrotron radiation distributions

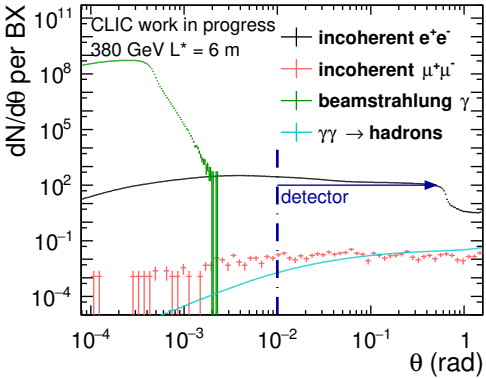


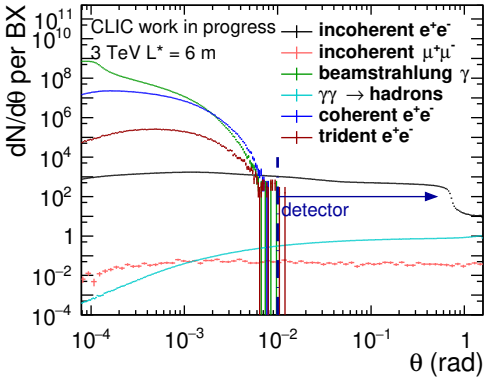




- Both direct and reflected photons coming from the Final Focus System are included
- The full impact on the detector's performance has not been fully assessed yet
- More information on reflected synchrotron radiation photons in my Monday talk

Background angular distributions





- Incoherent pairs and $\gamma\gamma \rightarrow$ hadron events are the only significant source of direct background at this energy stage
- Trident cascades and coherent pairs are boosted in the forward direction and do not cause any direct hit in the detector at 3 TeV

Tracking detector occupancies

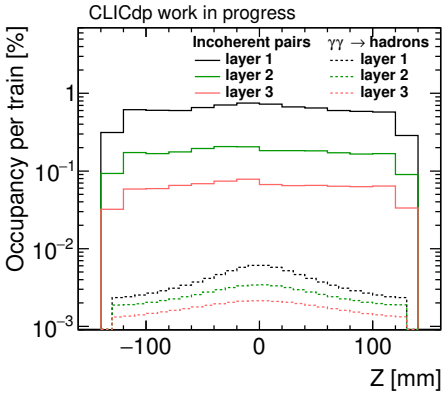
Tracking detectors read-out occupancy definition used in this analysis:

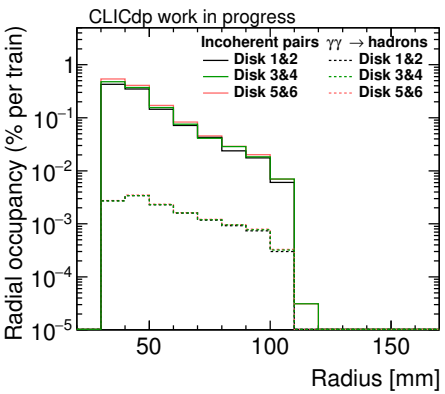
$$Occupancy/train = \sum_{proc} Hits_{proc}/(mm^2 \cdot n_{BX}) \cdot n_{bunches/train} \cdot p \cdot l \cdot cs \cdot sf_{proc} \ , \qquad (1)$$

where:

- p is granularity in the transverse direction (pitch)
- l is sensitive element's length (pixel's or strixel's)
- cs is the average number of readout cells responding to each hit (cluster size), used 5 for vertex and 3 for tracker
- sf are safety factors for uncertainty of simulation results: 5 for incoherent pairs, 2 for $\gamma\gamma \rightarrow$ hadrons events
- Cut-off energy deposition are 6.4 keV for tracker's sensors and 3.2 keV for vertex pixels

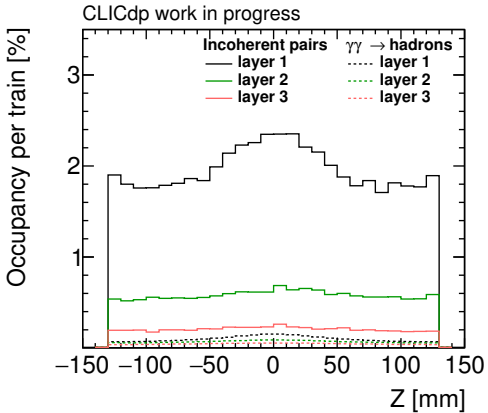
Vertex detector occupancies - 380 GeV

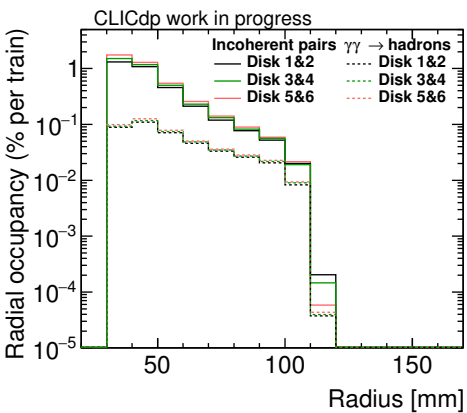




- The highest occupancies are present in the first layer of Vertex detector
- Half of the irradiation in the Vertex endcaps comes from backscattered particles from BeamCal and LumiCal
- All detector layers are well below the maximum readout occupancy of 3%

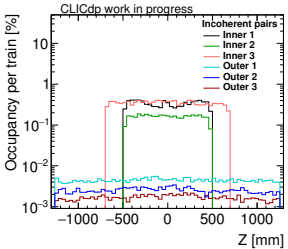
Vertex detector occupancies - 3 TeV

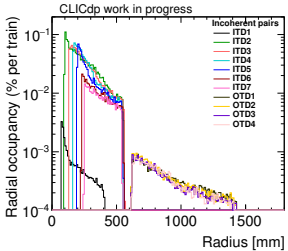


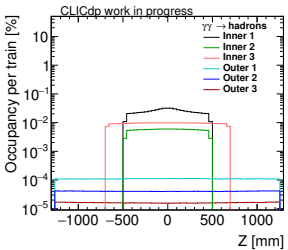


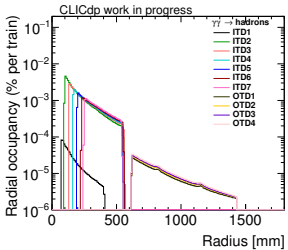
- The highest occupancies are present in the first layer of Vertex detector
- Combined effect of incoherent pairs and $\gamma\gamma \rightarrow$ hadrons give rise to high occupancies, close to the read out limit of 3%

Tracking detector occupancies - 380 GeV



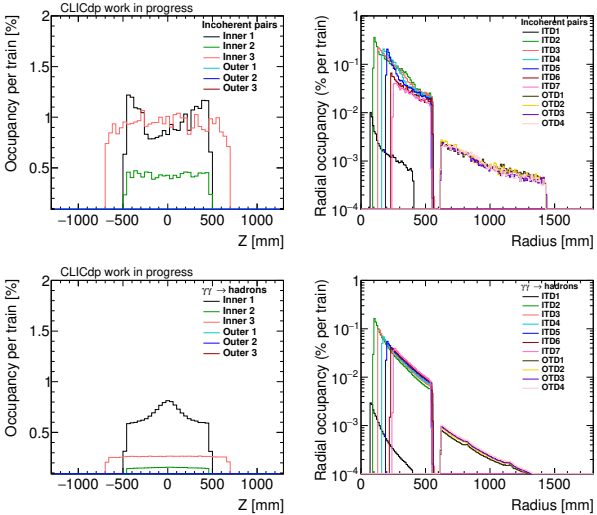






- All detector layers are well below the maximum readout occupancy of 3%
- At this energy stage incoherent pairs dominate the observed occupancies
- Occupancies and irradiation of outer tracker layers are negligible
- First tracker disk sees much lower occupancies thanks to its high granularity 25x25 μm^2

Tracking detector occupancies - 3 TeV

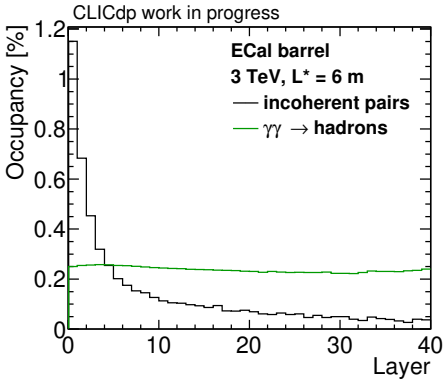


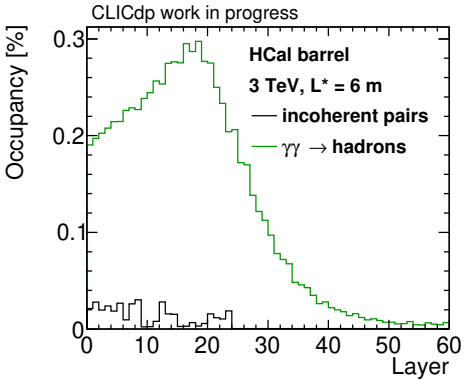
- All detector layers are below the maximum readout occupancy of 3%, although the inner tracker approaches the required limit
- $\gamma\gamma \rightarrow$ hadrons events have much higher impact at this energy stage
- Occupancies and irradiation of outer tracker layers are very low and are not going to impact the detector's performance significantly

Calorimeteres occupancies

- Initial assumption: calorimeter readout time per bunch train is separated into 8 windows, each 25 ns long, totaling 200 ns from the beggining of a train
- Occupancy of a cell is defined as a number of time windows with energy deposition above threshold
- Threshold energy is 0.5 MIP (40 keV) for ECal and 0.3 MIP (300 keV) for HCal
- ECal cell size is 5x5 mm^2 and HCal is 30x30 mm^2
- Occupancy of a detector is defined as an average number of saturated cells over full integration time
- Radial distribution will present the average occupancy among cells at given radius

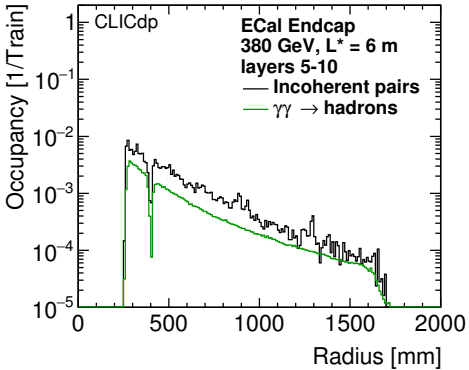
Central barrel calorimeters occupancies at 3 TeV

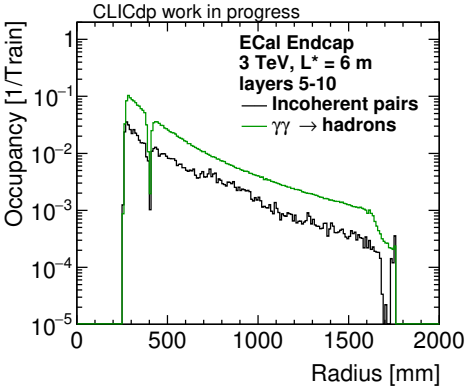




- Occupancies generally low - should not create too high data rates
- First layers of ECal barrel most impacted by incoherent pairs, constant rate for $\gamma\gamma \rightarrow$ hadrons

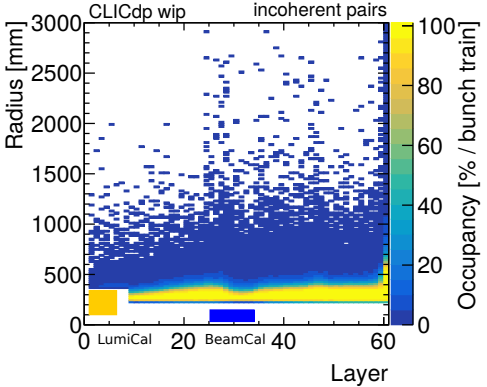
ECal endcap occupancies

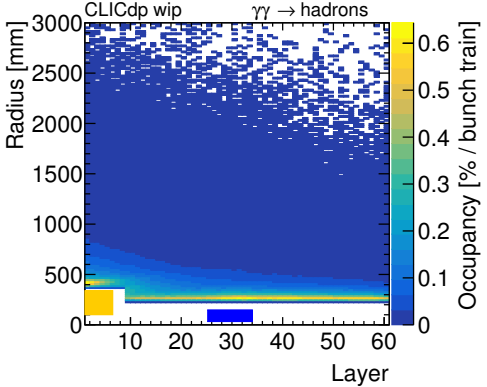




- Occupancies at 380 GeV are an order of magnitude below the 3 TeV level
- $\gamma\gamma \rightarrow$ hadrons events are more prominent at the higher energy stage
- Occupancies below 1% level – shouldn't yield too high data rates

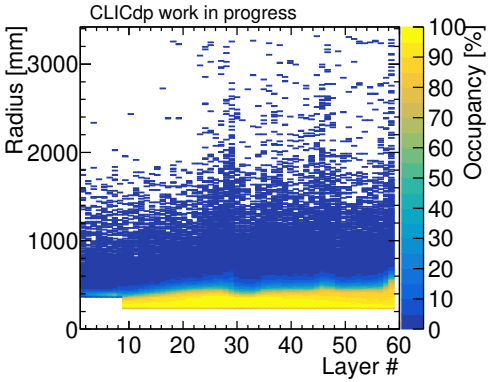
HCal endcap occupancies – 380 GeV

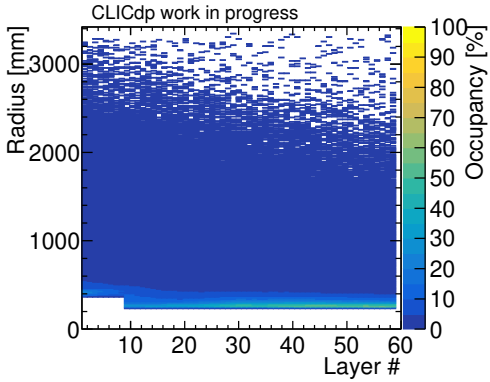




- HCal suffers from higher occupancies than ECal and is fully saturated in the lowest radius region
- Visible gap between ECal Endcap and ECal Plug in $\gamma\gamma \rightarrow$ hadrons occupancies
- Layers 20-25 and 35-60 at lowest radii have the highest background yield, especially coming from incoherent pairs' interactions with BeamCal material

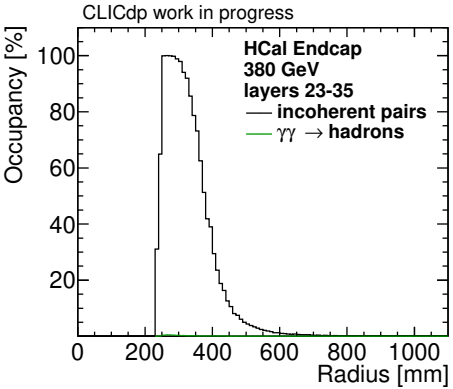
HCal endcap occupancies - 3 TeV

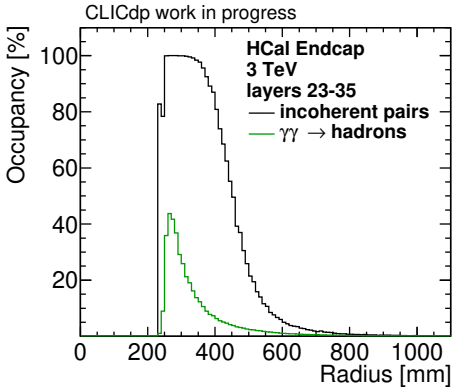




- HCal suffers from almost full saturation in radii below 400 mm
- $\gamma\gamma \rightarrow$ hadrons irradiation significant at this stage, has to be mitigated along with incoherent pairs

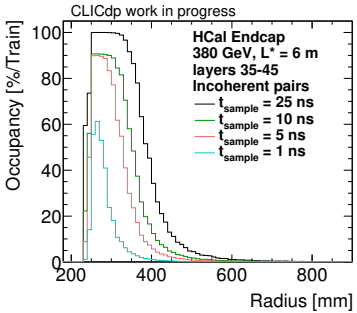
HCal endcap radial occupancies

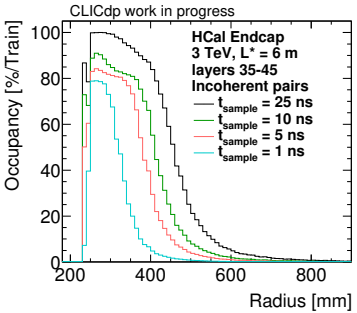


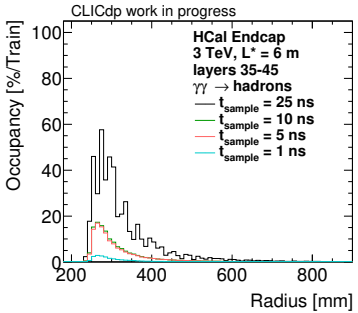


- The most irradiated regions are fully saturated with background particles, especially as a result of incoherent pairs interactions
- At 3 TeV $\gamma\gamma \rightarrow$ hadrons events also become relevant

HCal endcap occupancies - time sampling

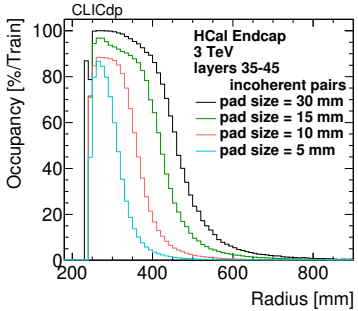


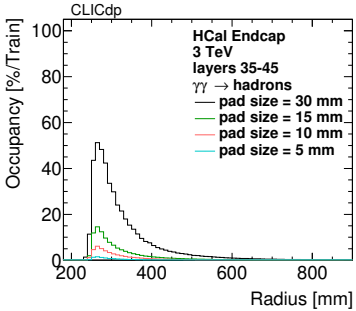




- High occupancy levels in the low radii region can be addressed through varying the calorimeter granularity, integration time of clusters, and shielding
- Varying cluster integration time lowers the occupancy while there is still a fully saturated region; the same technique used in ECal lowers occupancy $\propto N_{time\ windows}$
- Shielding with tungsten and polyethylene may strongly reduce the observed occupancy levels, at the cost of reduced acceptancy, more about shielding in: CLICdp-Note-2014-004

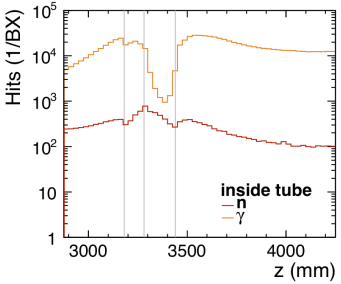
HCal endcap occupancies - cell sizes

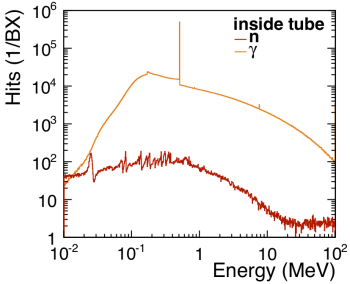




- Decreasing the sizes of pads for HCal helps improve the high occupancy at low radii
- The occupancy vanishes if pad size is smaller than 10x10 mm for $\gamma\gamma \rightarrow$ hadrons
- It cannot be a stand-alone solution - it has to be combined with other mitigation techniques in the case of incoherent pairs

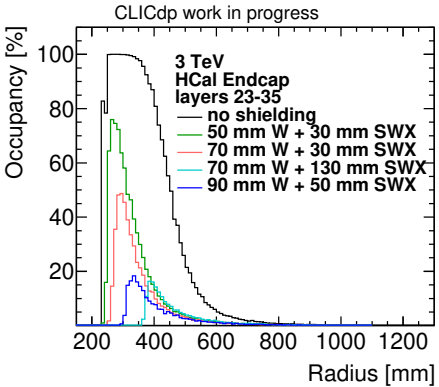
Backgrounds' spectra in HCal endcap

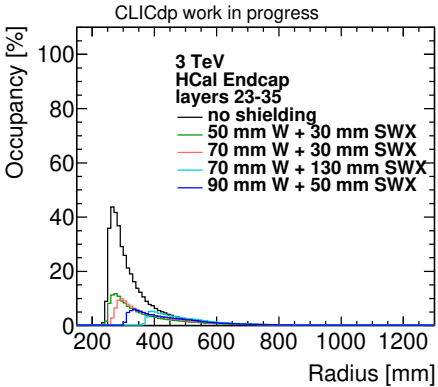




- From CLICdp-Note-2014-004, slightly different detector layout but the source of backgrounds remains unchanged
- The biggest issue is a high flux of high energy photons, although neutrons have to be contained as well
- Best choice is a composite shield with a short radiation length material and a neutron absorber

HCal endcap occupancies - shielding





- Significant occupancy reduction possible without an excessive detriment in detector's acceptance
- Tungsten more efficient per length but has to be combined with a neutron absorbing material - SWX (95% polyethylene, 5% boron carbide)
- Combine shield with other mitigation methods for maximum efficiency

Summary and outlook

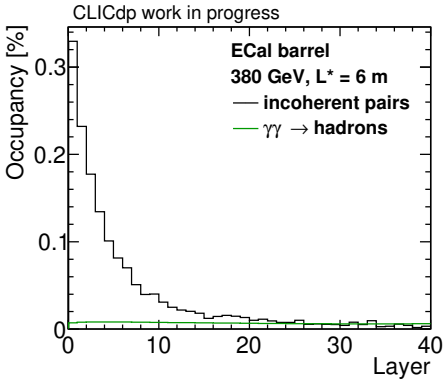
- Occupancies in tracker detectors are below the required 3% mark per bunch train and do not pose a limiting factor on detector's performance
- ECal occupancies are generally low thanks to high granularity and limited secondary irradiation
- HCal endcap occupancies are high in the region close to beam pipe; this can be addressed with a combination of shielding, time sampling and changes in granularity
- More about backgrounds and their distributions in CLIC can be found on CLIC Beam-beam webpage

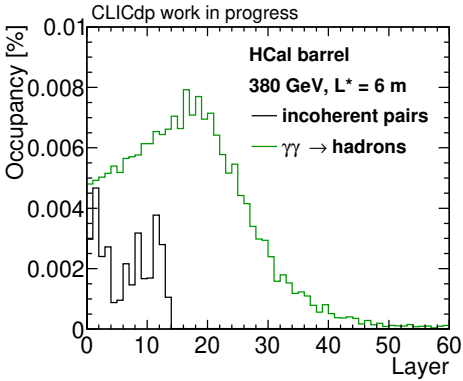
Future and ongoing works:

- Assess the full impact of reflected synchrotron radiation photons on CLICdet
- Study the CLICdet muon identification system

Additional material

Central barrel calorimeters occupancies at 380 GeV





- Occupancies factor of 4 lower than at 3 TeV - should not create too high data rates
- First layers of ECal barrel most impacted by incoherent pairs, constant rate for $\gamma\gamma \rightarrow$ hadrons