Occupancies from Beam-Related Backgrounds in SiD at ILC and CLIC

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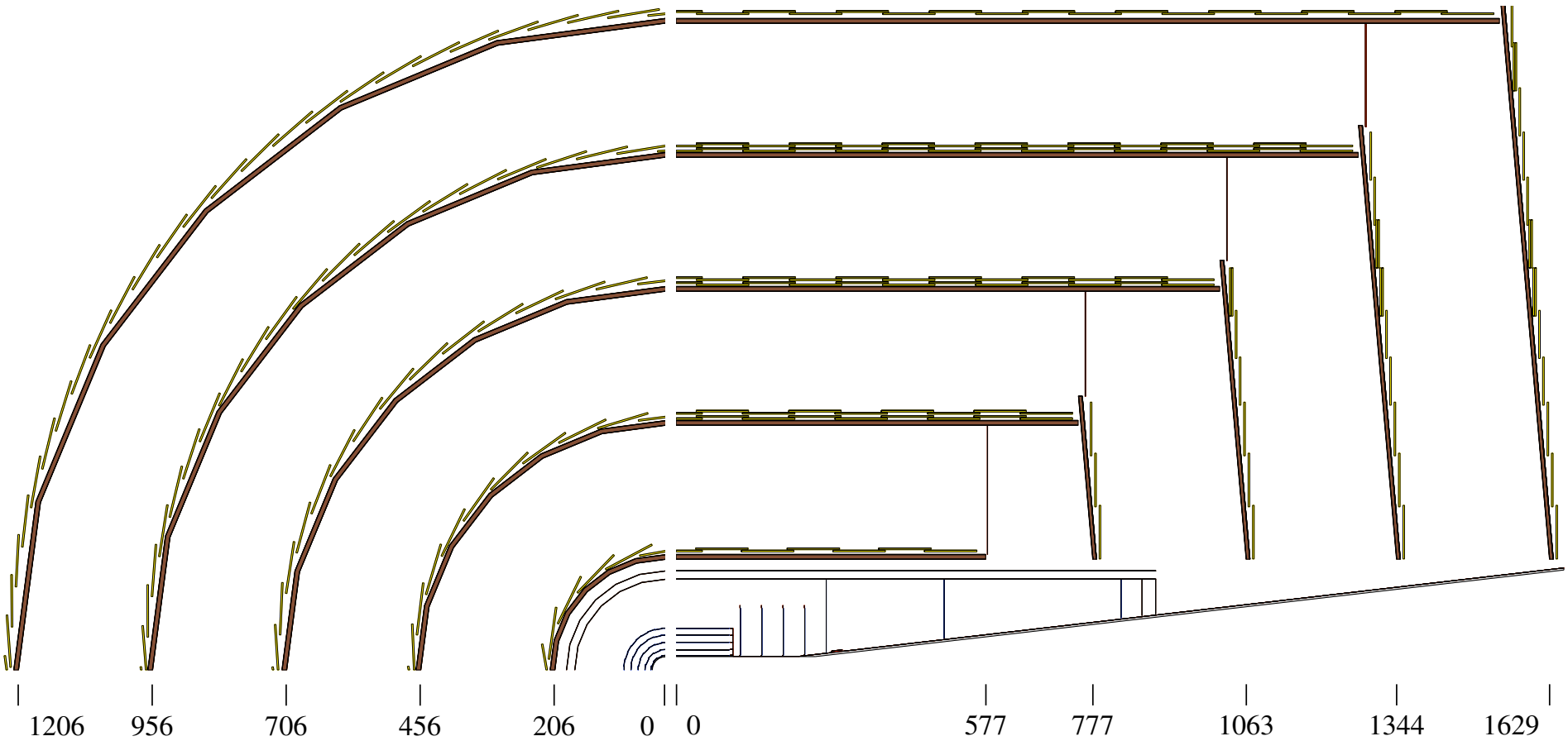
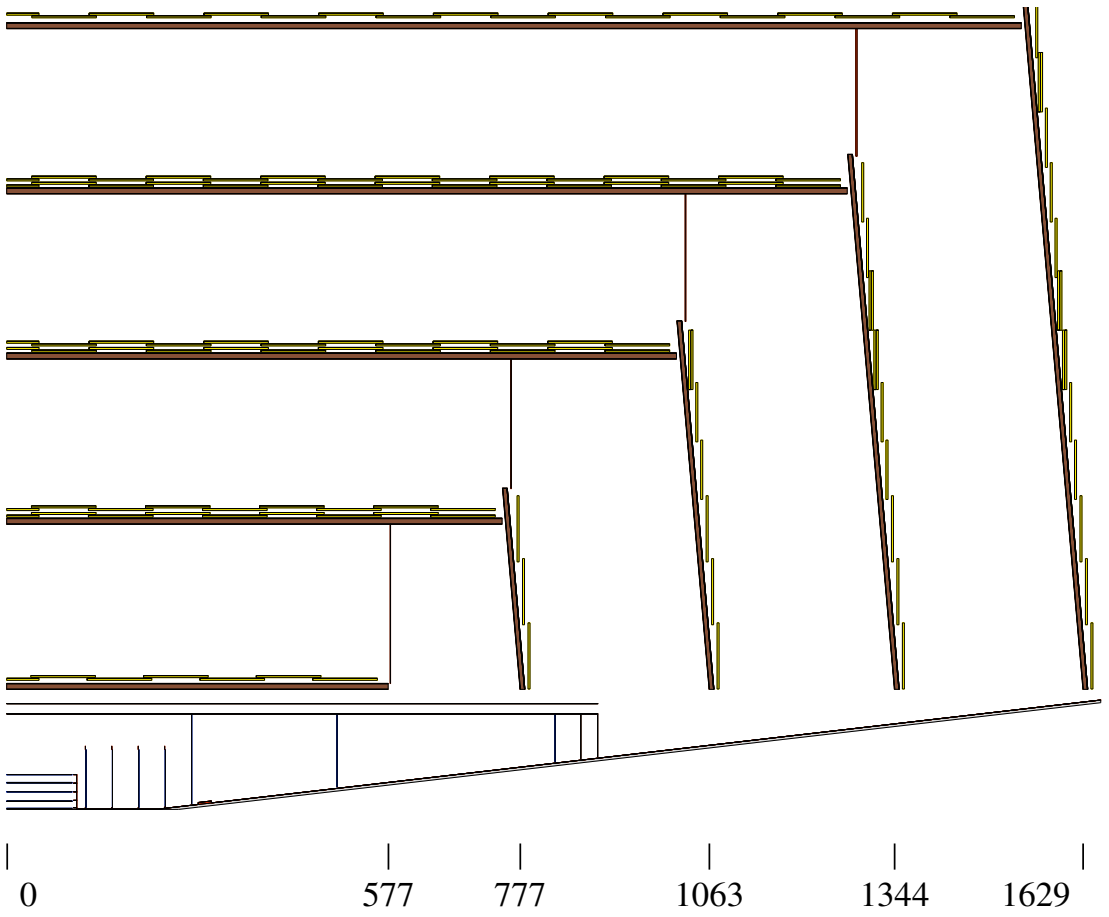
Tracker Layout (CLIC_SiD)



(a) xy (b) zx

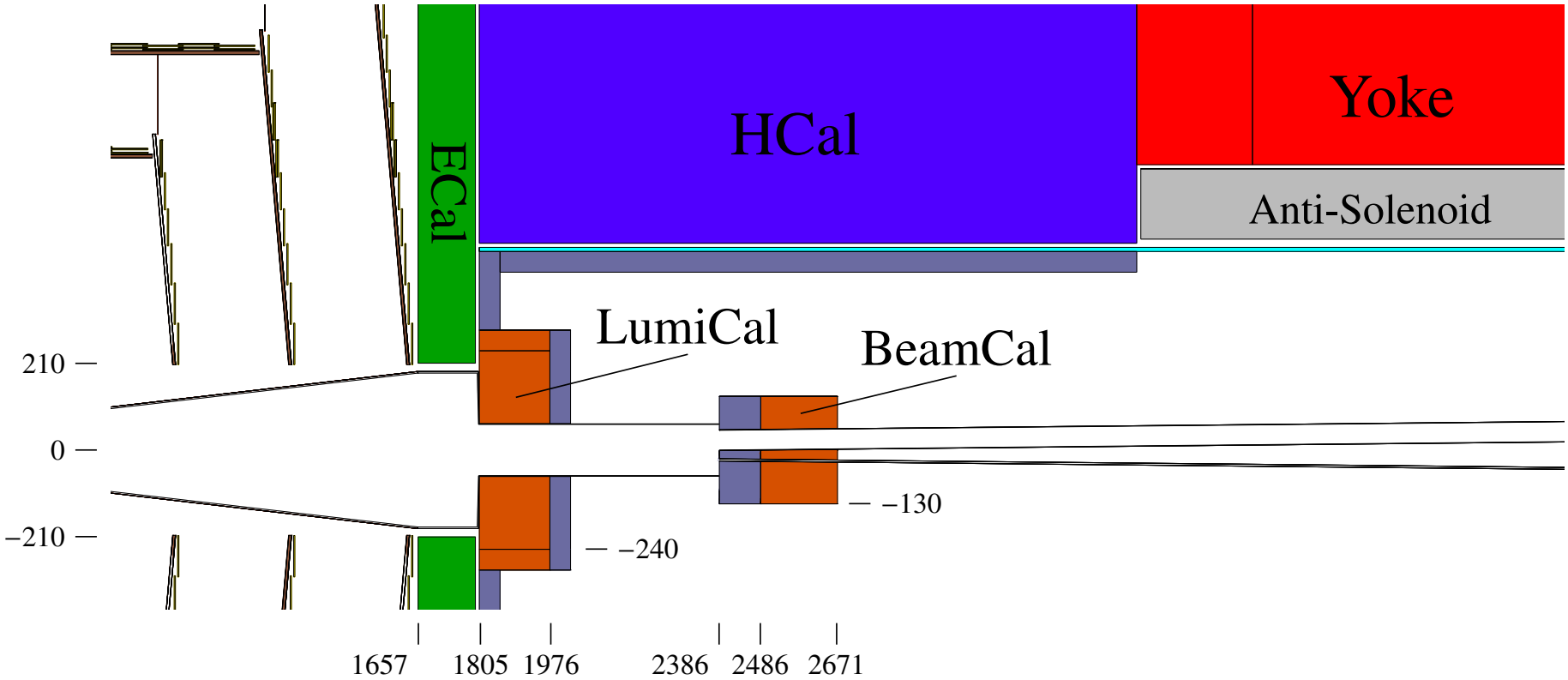
Tracker Layout (CLIC_SiD)

- Based on sidloi3
- All-silicon tracker
- Pixelized vertex detector
  - 5 barrel layers + 7 disk layers
  - 20 µm pitch
- Main tracking detector
  - 5 barrel layers + 4 disk layers (stereo strips)
  - 25 µm strip pitch
  - 50 µm read-out pitch
  - 100 mm strip length



(b) zx

Forward Region (CLIC_SiD)



- Forward region not optimized in CLIC_SiD and sidloi3
- Beam pipe in very forward region not conical

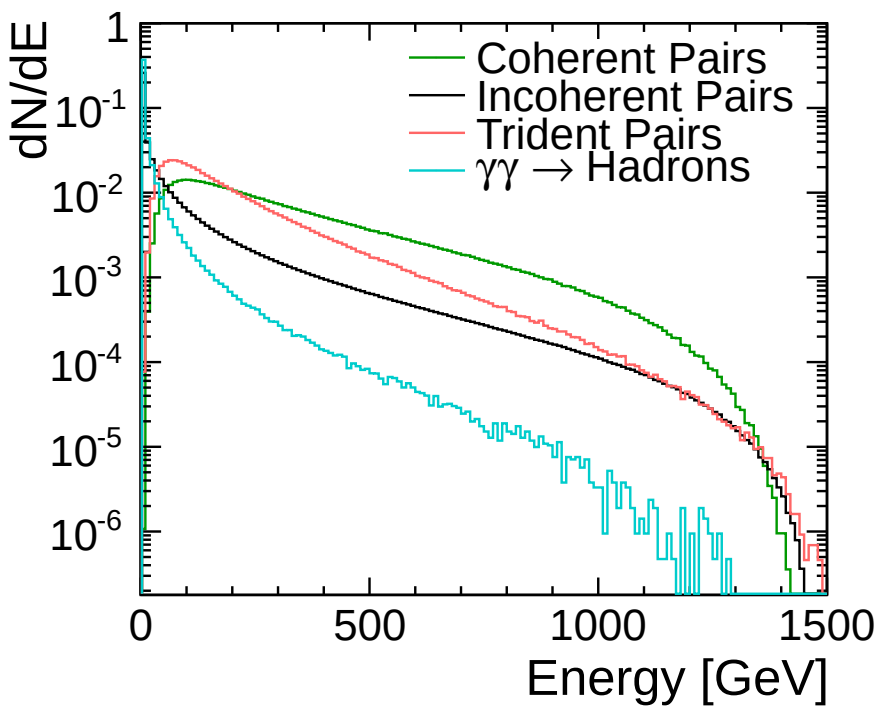
Differences between sidloi3 and CLIC_SiD

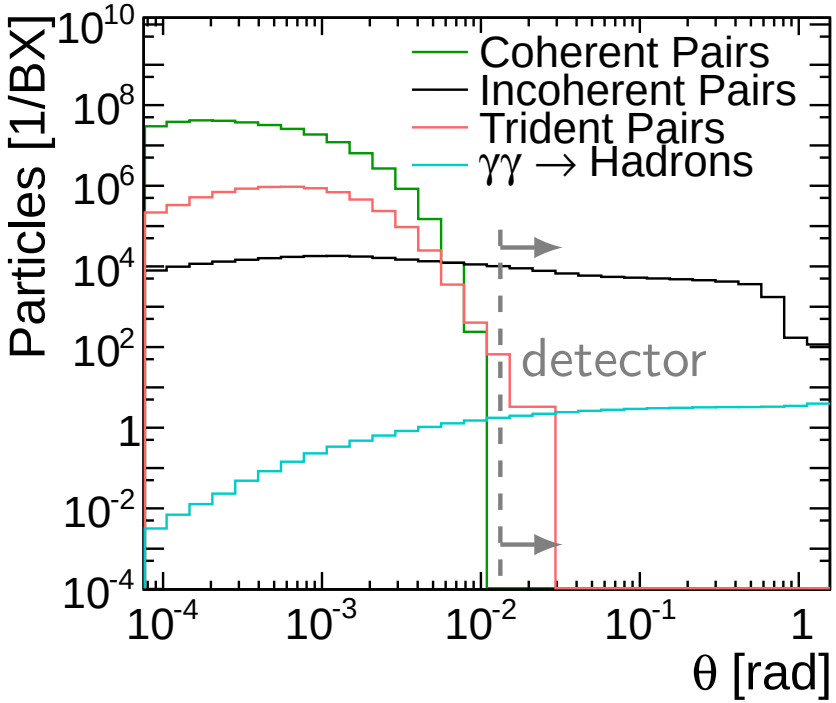
- Vertex Detector
  - Inner radius: $1.4\,\mathrm{mm} \Rightarrow 2.7\,\mathrm{mm}$
  - Half length: $60\,\mathrm{mm} \Rightarrow 100\,\mathrm{mm}$
  - Disk placement
- Forward region
  - Crossing angle: $14\,\mathrm{mrad} \Rightarrow 20\,\mathrm{mrad}$
  - LumiCal position and radius
  - BeamCal position and radius
  - Larger support tube for QD0 at CLIC ($r = 50\,\mathrm{mm}$)
- Beam pipe
  - Conical part pointing in CLIC_SiD, increased thickness to 4 mm

Beam-Related Backgrounds

- Coherent pairs almost co-linear
- Determine opening in forward calorimeters and crossing angle
- Only incoherent pairs and $\gamma\gamma \rightarrow$ hadrons relevant to central detector
- Solenoid field confines (charged) particles at low radii

CLIC @ 3 TeV





Background Samples

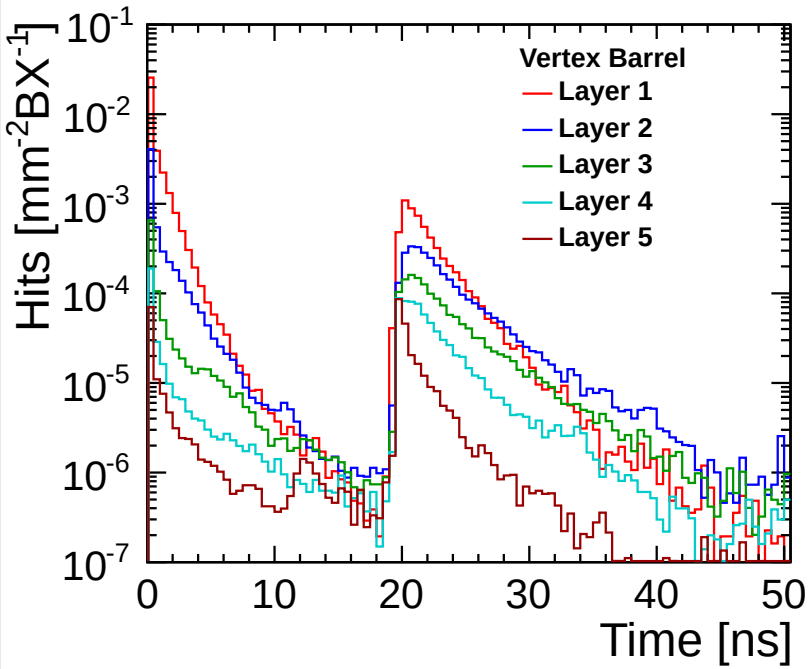
- Incoherent pair samples generated by GuineaPig
- $\gamma\gamma \rightarrow$ hadrons generated by WHIZARD (photon spectrum from GuineaPig)
- Hadronization of $\gamma\gamma \rightarrow$ hadrons in PYTHIA
- Studied beam configurations with highest occupancies
  - ILC DBD @ 1 TeV
  - CLIC CDR @ 3 TeV

Simulation & Digitization

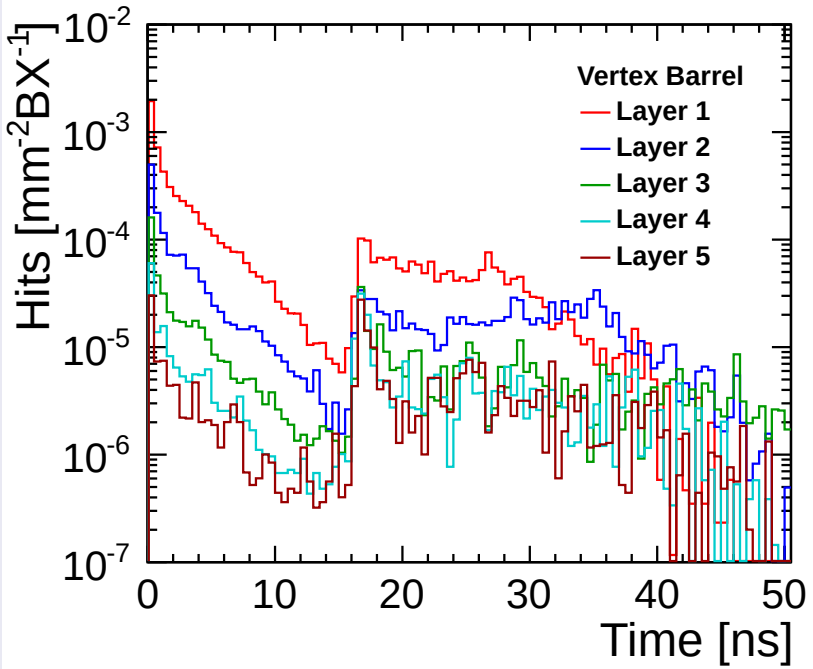
- Full detector simulation using SLIC (GEANT4)
  - Incoherent pairs: single particle per simulated event
    ILC: $\sim$ 400k / BX, CLIC: $\sim$ 300k / BX
  - $\gamma\gamma \rightarrow$ hadrons: one interaction per event
    ILC: 4.1 / BX, CLIC: 3.2 / BX
- Merge events to represent 1 BX in `org.lcsim`
  - Dedicated driver in `org.lcsim` creating deep copies of merged objects to allow efficient garbage collection
- Run standard tracker hit digitization in `org.lcsim` (SiSim)
- Nearest neighbor clustering to form TrackerHits

Hit Time Structure (Incoherent Pairs)

sidloi3

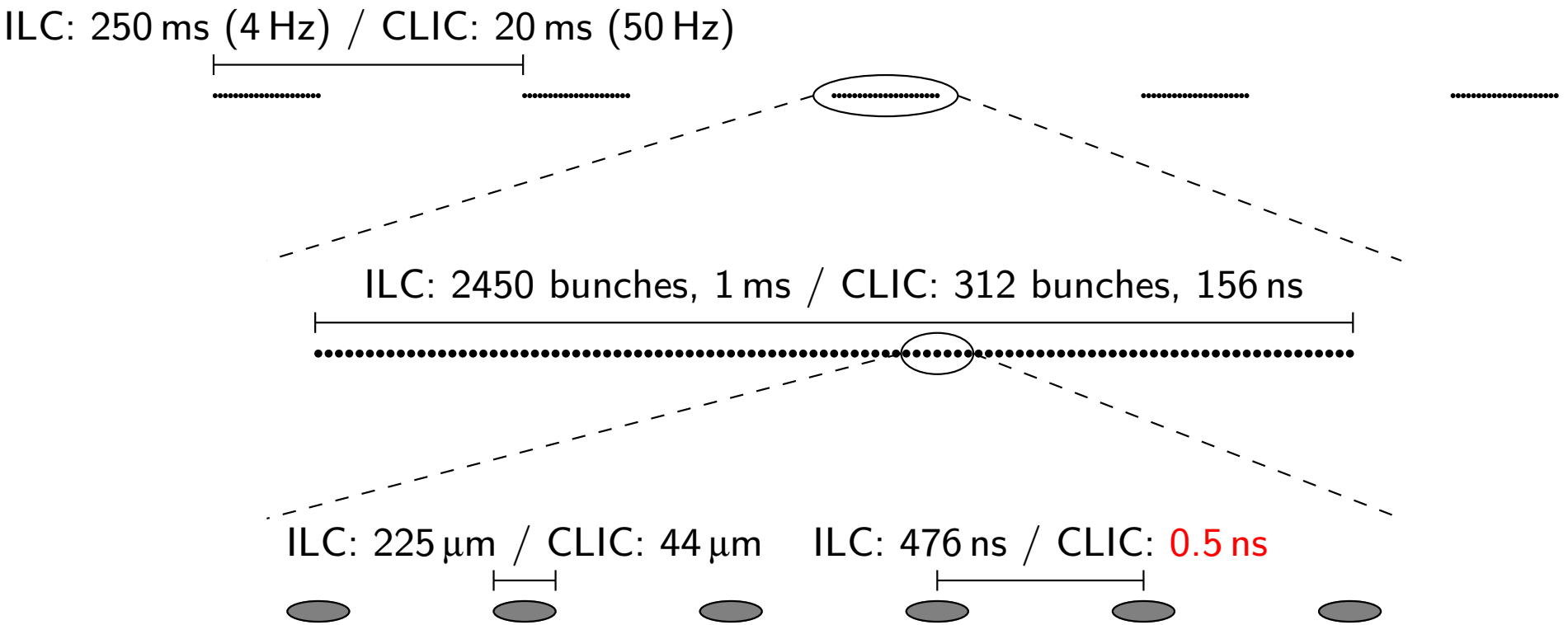


CLIC_SiD



- Back-scattered particles create indirect hits
- Time delay given by time of flight from the IP to the BeamCal
- Less pronounced in CLIC_SiD due to thicker conical beam pipe

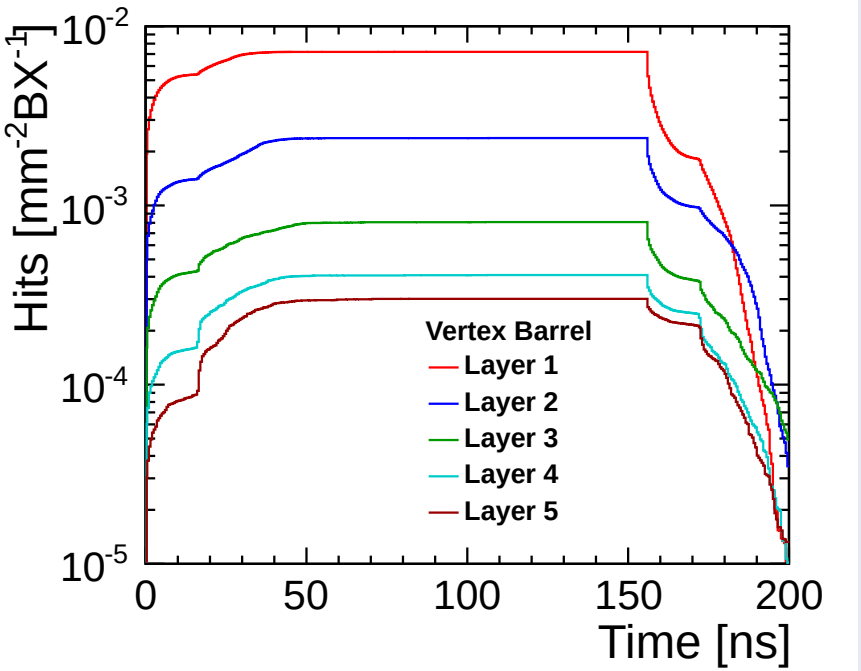
Beam Structure at ILC (1 TeV) and CLIC (3 TeV)



Hit Time Structure in (Incoherent Pairs)

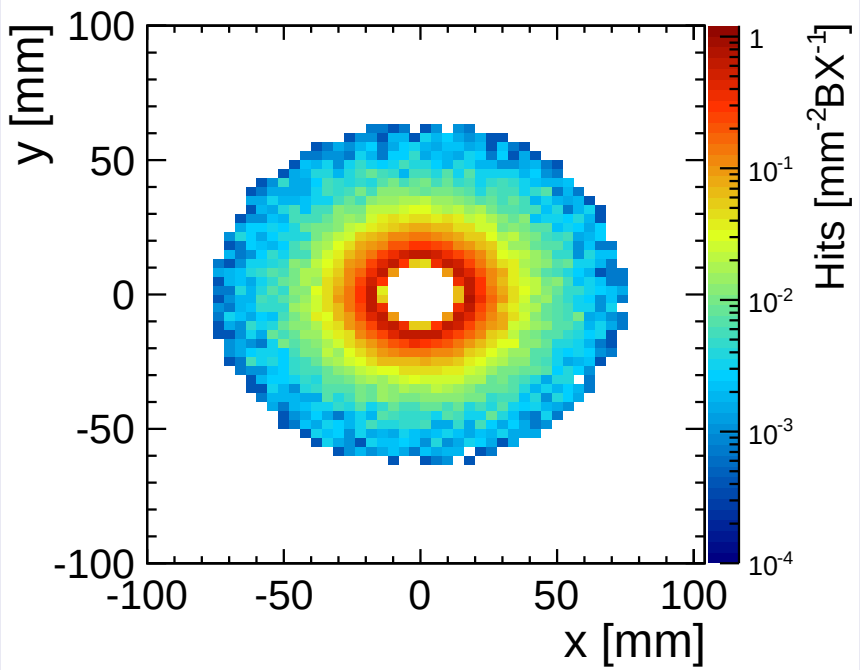
- Back-scatters dominating contribution from incoherent pairs at CLIC
- Conical beam pipe can be used to shield inner detector
  - 4 mm steel in CLIC_SiD
- Careful design of forward region more important at CLIC
- Detailed studies of forward region layout still to be done (have been performed in CLIC_ILD)

CLIC_SiD

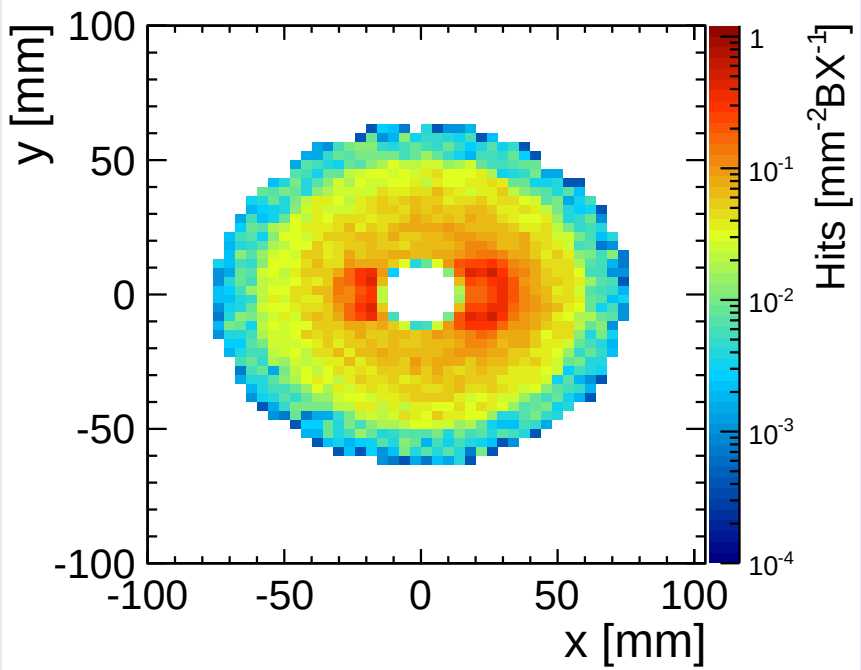


Direct and Indirect Hits (sidloi3 Vertex Disk)

Direct Hits ($t < 15\,\mathrm{ns}$)



Indirect Hits ($t > 15\,\mathrm{ns}$)



- Back-scattered particles not symmetric in ϕ
- Hot spots projection of openings in BeamCal

Occupancy Estimation

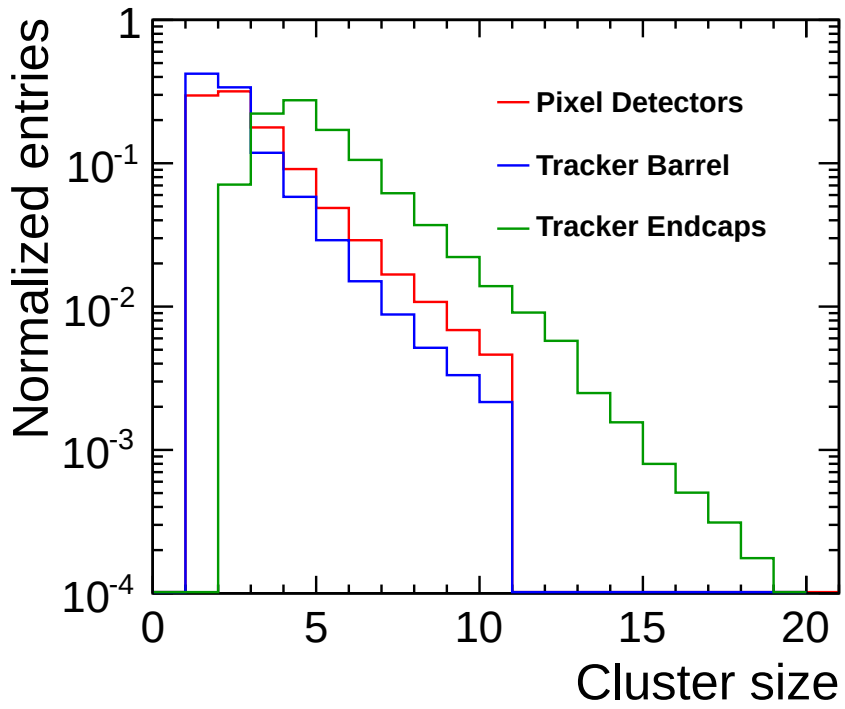
- Start from hit rates
- Take into account segmentation
- Take into account average cluster size
- Assume reading out full train (2450 BX / 312 BX)
- Add safety factors
  - Incoherent pairs: 5 (large uncertainty in amount of back scatters)
  - $\gamma\gamma \rightarrow$ hadrons: 2
- Digitized single BX: underestimate ghost hits in stereo strips

Cluster Sizes

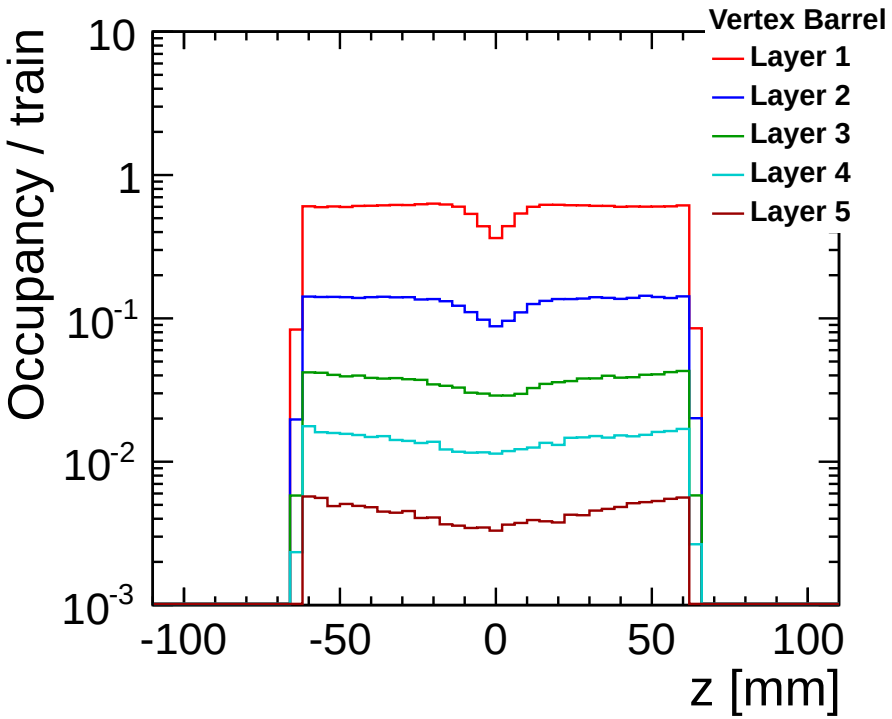
Mean values

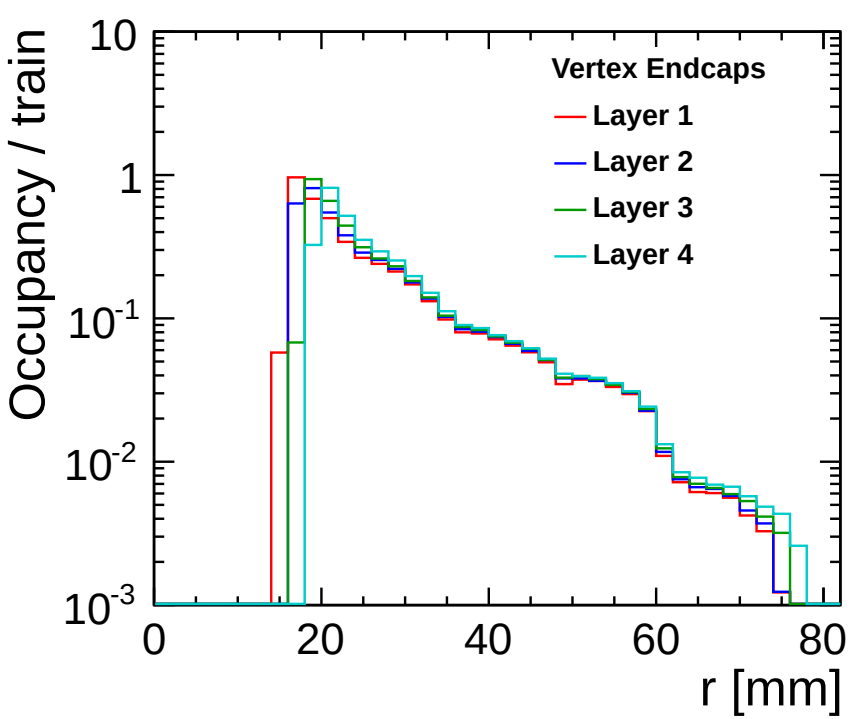
- Pixel detectors: 3.0
- Strip detectors: 2.6
- Stereo strip: 5.2 (two strips hit)

sidloi3



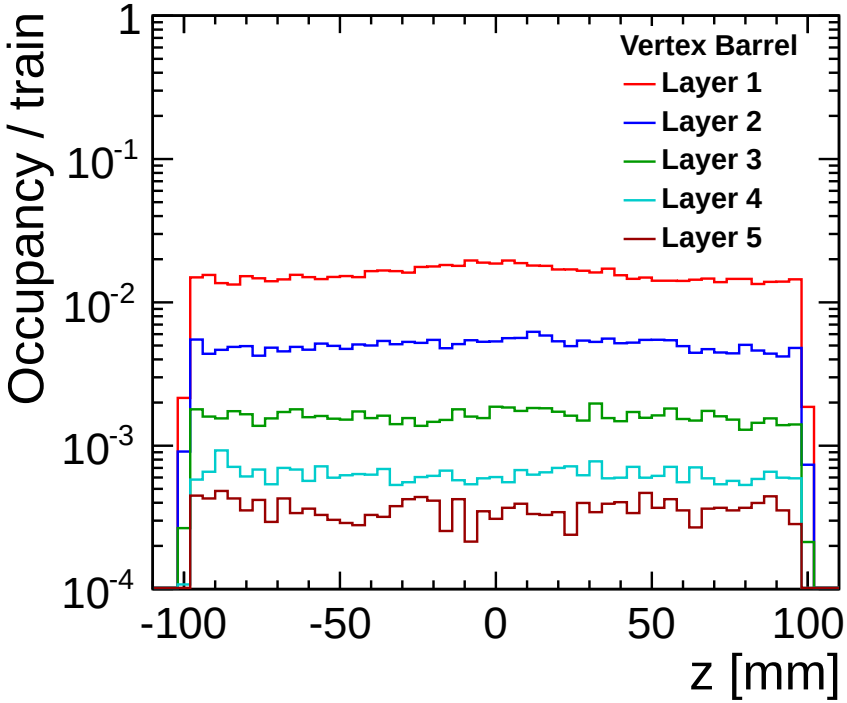
Vertex Detector (sidloi3, Incoherent Pairs)

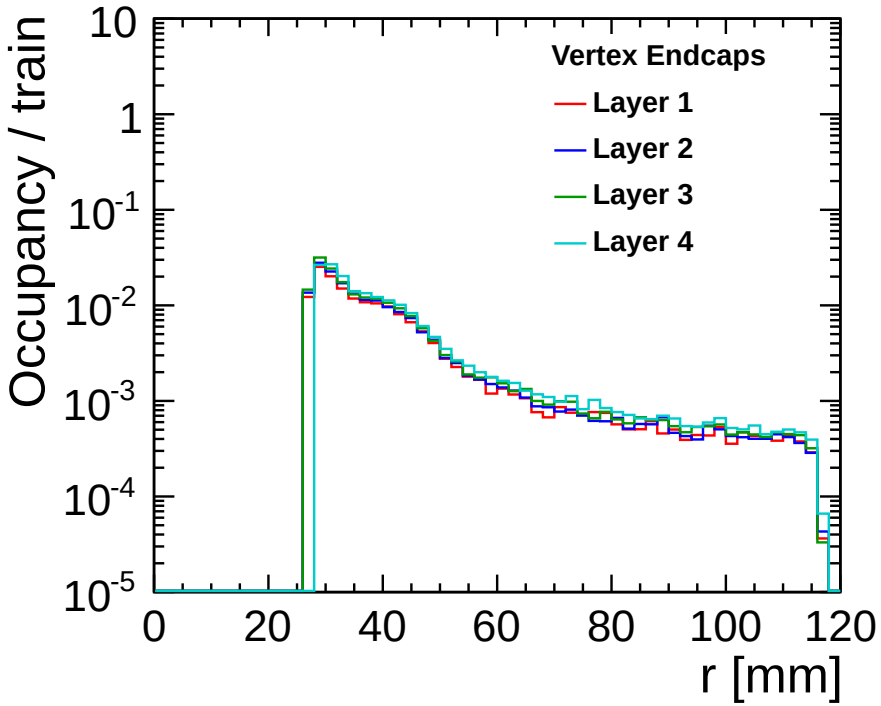




- Occupancies reach up to 100% over full train

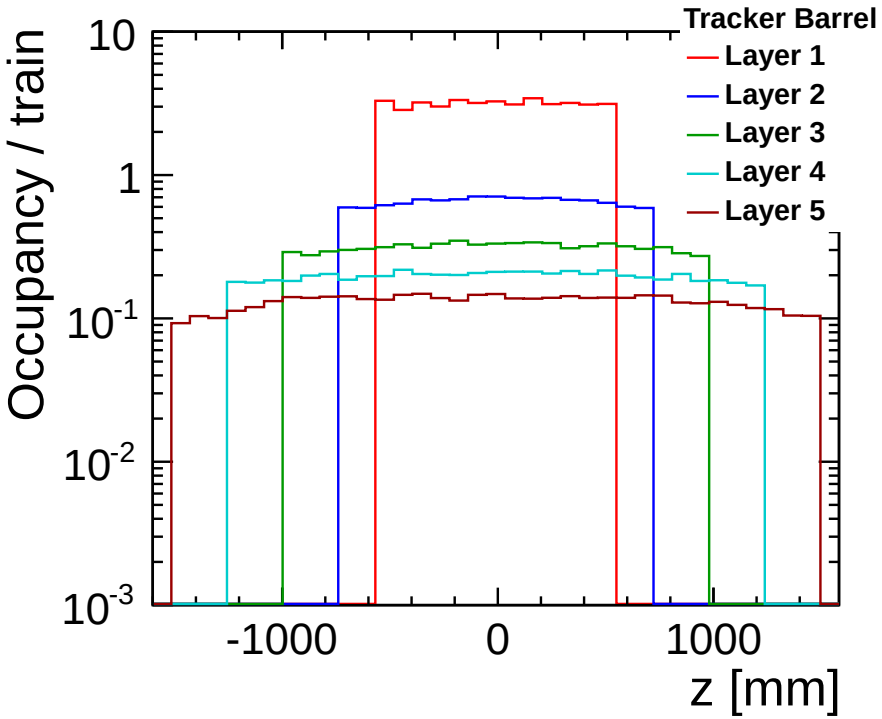
Vertex Detector (CLIC_SiD, Incoherent Pairs)

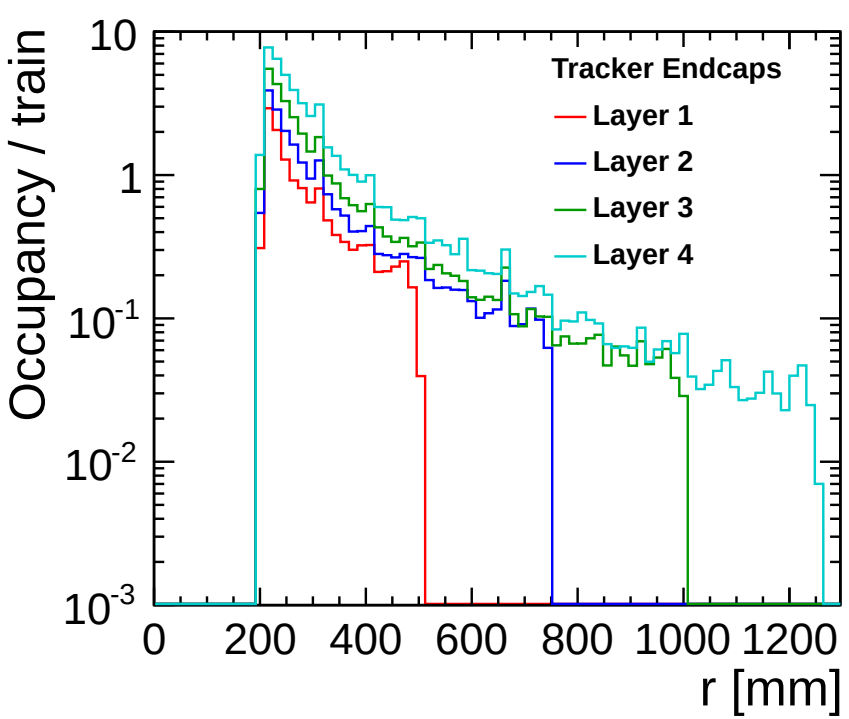




- Occupancies reach up to 3% over full train

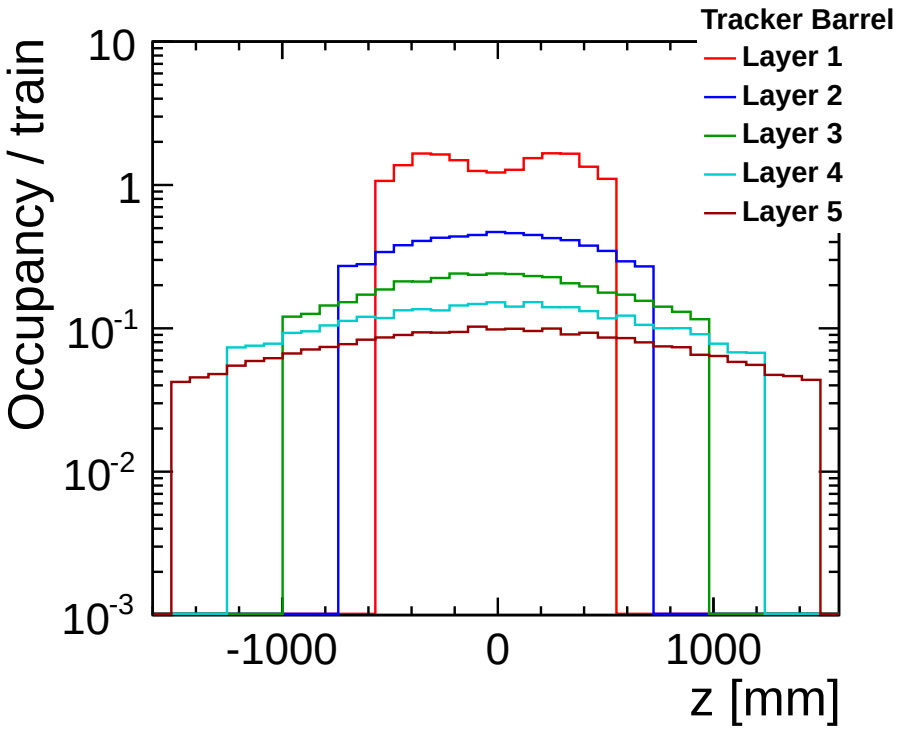
Main Tracker (sidloi3, Incoherent Pairs)

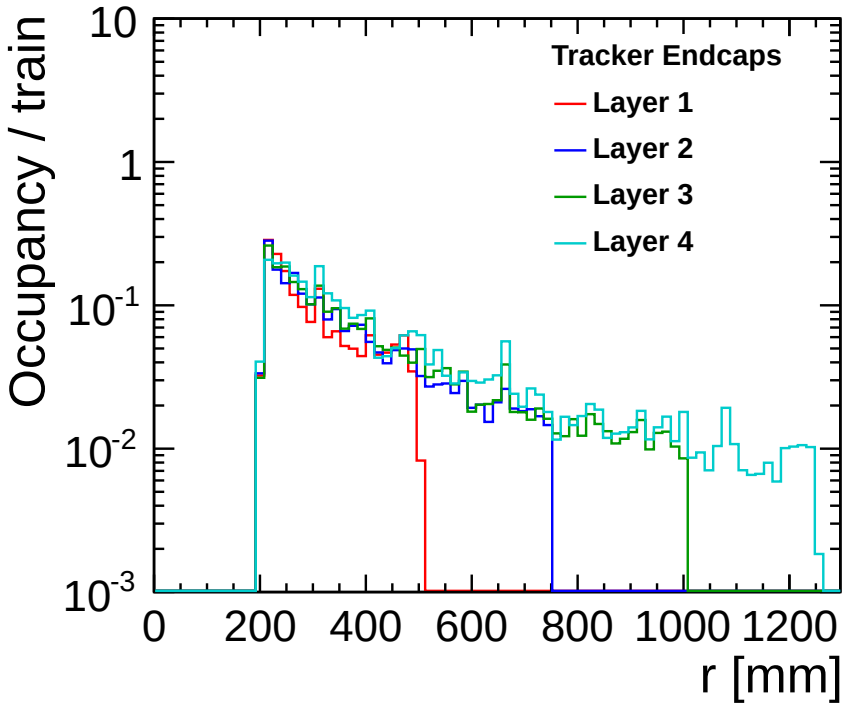




- Occupancies reach up to 300% in strip detectors
- Occupancies reach up to 900% in stereo strip detectors

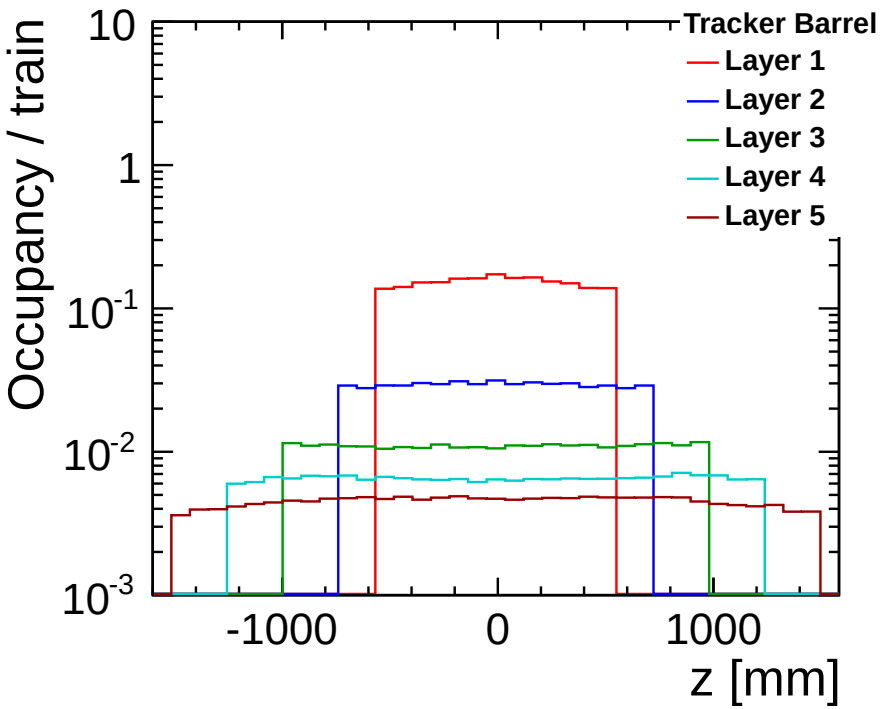
Main Tracker (CLIC_SiD, Incoherent Pairs)

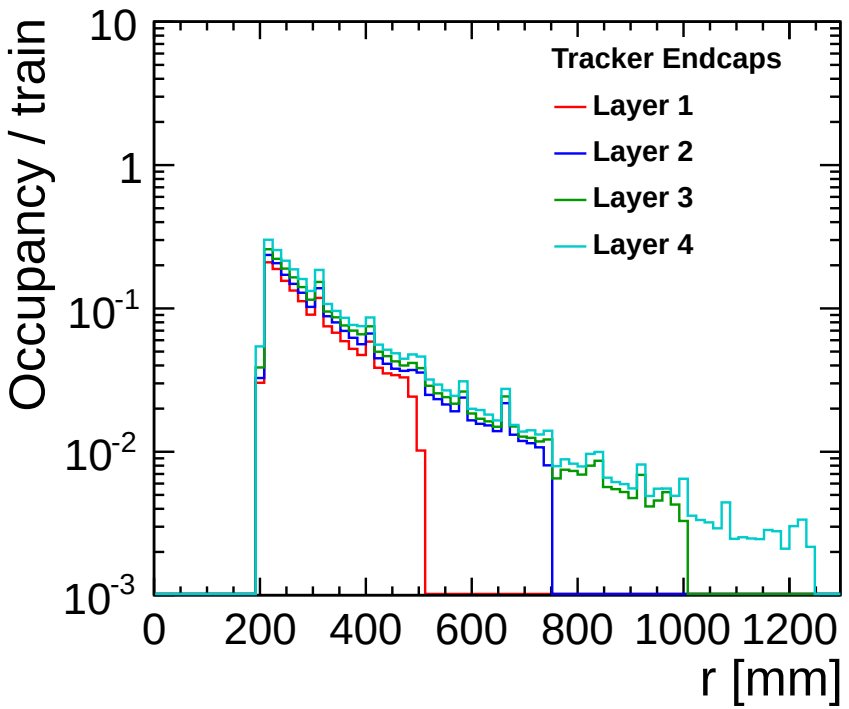




- Occupancies reach up to 200% in strip detectors
- Occupancies reach up to 30% in stereo strip detectors
- Thick conical beam pipe effectively reduces amount of back-scatters in inner detector

Main Tracker (CLIC_SiD, $\gamma\gamma \rightarrow$ hadrons)





- Occupancies reach up to 20% in strip detectors
- Occupancies reach up to 30% in stereo strip detectors
- Only problematic in endcap region

Conclusion and Outlook

- Occupancies in central detectors are challenging at ILC and CLIC
- Innermost barrel strip layer most critical
  - Multi-hit capability
  - Shorter strips
  - Read out multiple times per train at ILC
- Stereo strip detectors at low radii problematic
- Pixel detector occupancies critical at ILC (if reading once per train)
- Optimization studies of forward region and beam pipe required to reduce amount of back scattered particles