Background and Radiation Levels at CLIC

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Content

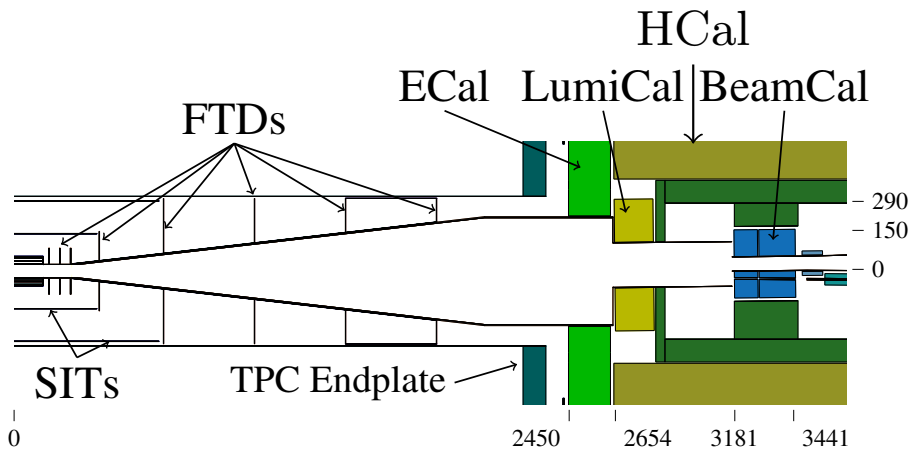
CLIC Parameters

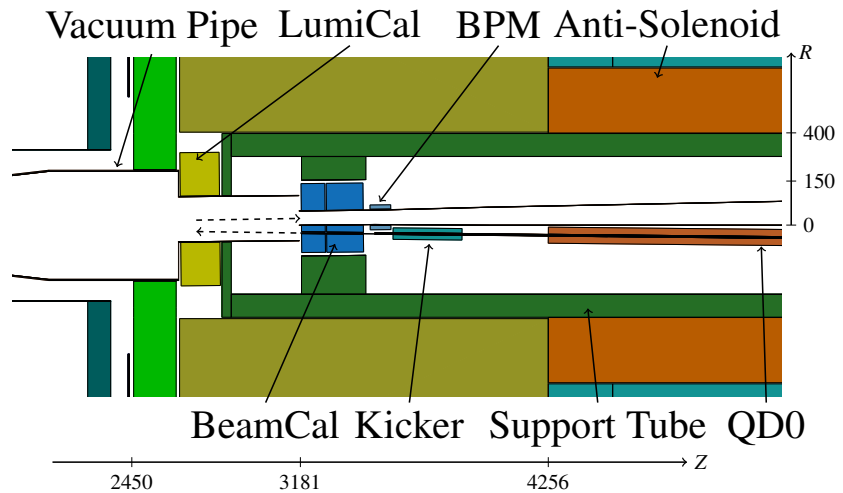
- Important for occupancies
  - Bunch spacing, number of bunches/train
  - Amount of background

	CLIC 3 TeV	CLIC 500 GeV
Bunch Spacing	0.5 ns	0.5 ns
Bunches/Train	312	354
Trains/Second	50	50
$\gamma\gamma \rightarrow$ 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

Forward Region in CLIC_ILD_CDR Detector

- CLIC_ILD_CDR model frozen
- LumiCal placed behind ECal
- BeamCal about 30 cm behind LumiCal
- 4 mm thick, conical iron beam pipe reducing back-scatters





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- CLIC_ILD_CDR model frozen
- LumiCal placed behind ECal
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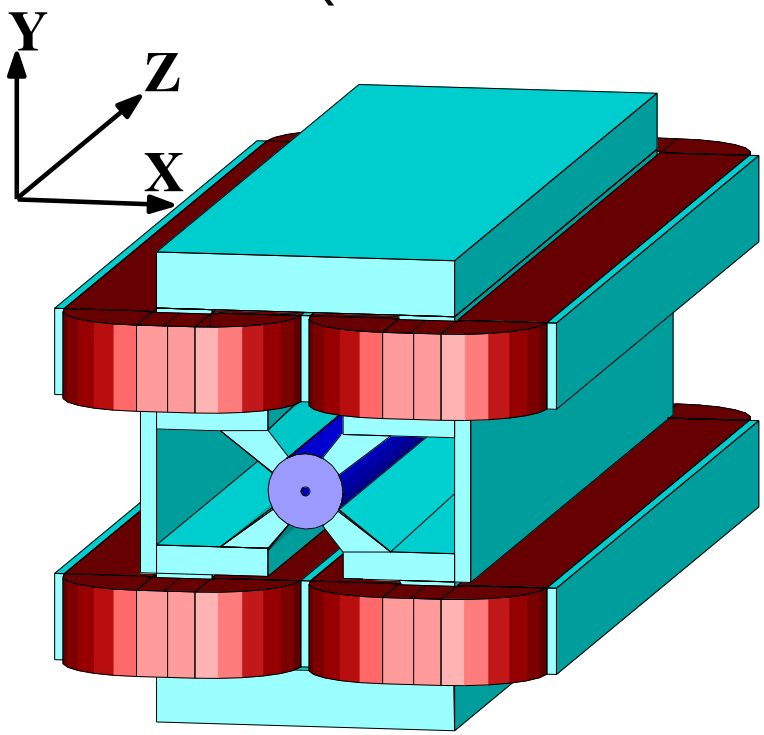
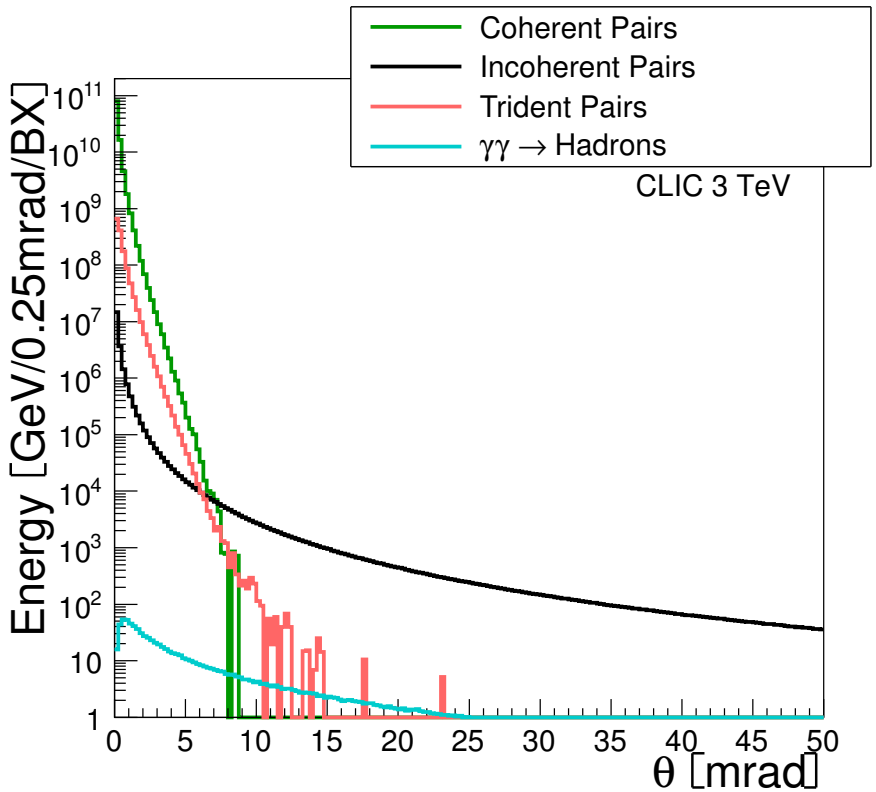
- 4 mm thick, conical iron beam pipe reducing back-scatters
- QD0 only permanent magnet cylinder included

Full QD0 Model



(Some) Backgrounds at CLIC

- More details: See Barbara's talk
- Coherent/Trident pairs
  - Leaving the detector inside beam pipe
- Incoherent pairs
  - 300k particles per BX
  - Large number in detector acceptance
- Two-photon events producing hadrons ($\gamma\gamma \rightarrow$ Hadrons)
  - 3.2 events per BX
  - More central than pairs



Simulation Parameters

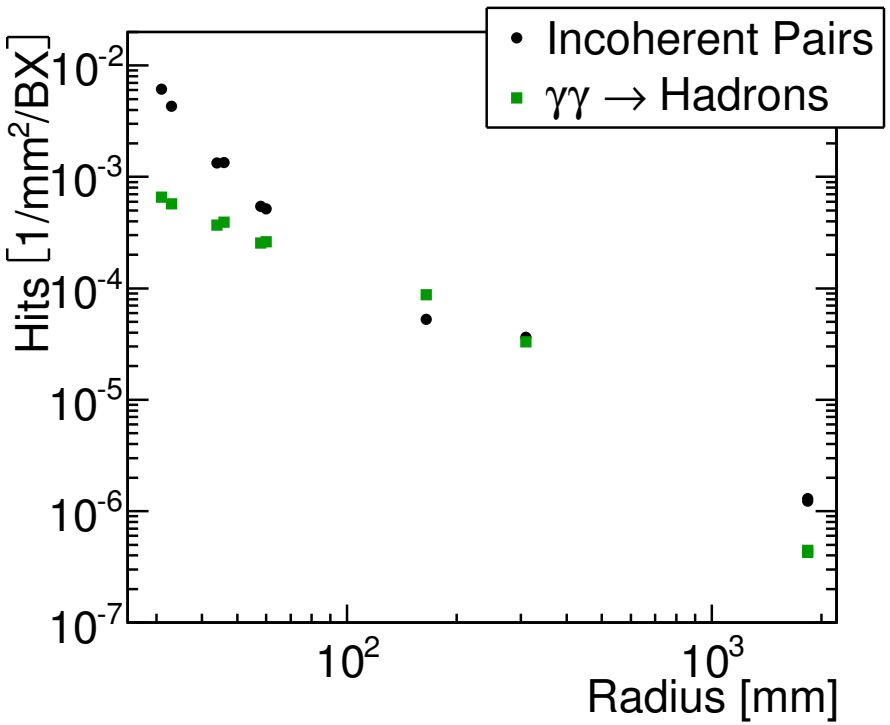
- CLIC_ILD_CDR with FieldMap instead of constant solenoid field
- QGSP_BERT_HP physics list
- 5 μm range cut
- 64 bunch trains $\gamma\gamma \rightarrow$ Hadrons
- Incoherent Pairs: 1 bunch train for trackers, 3 bunch trains for calorimeters
- Safety factors not included

Occupancies and Radiation Damage in Silicon Tracking Detectors

Occupancies in the Barrel-like Si Tracking Detectors

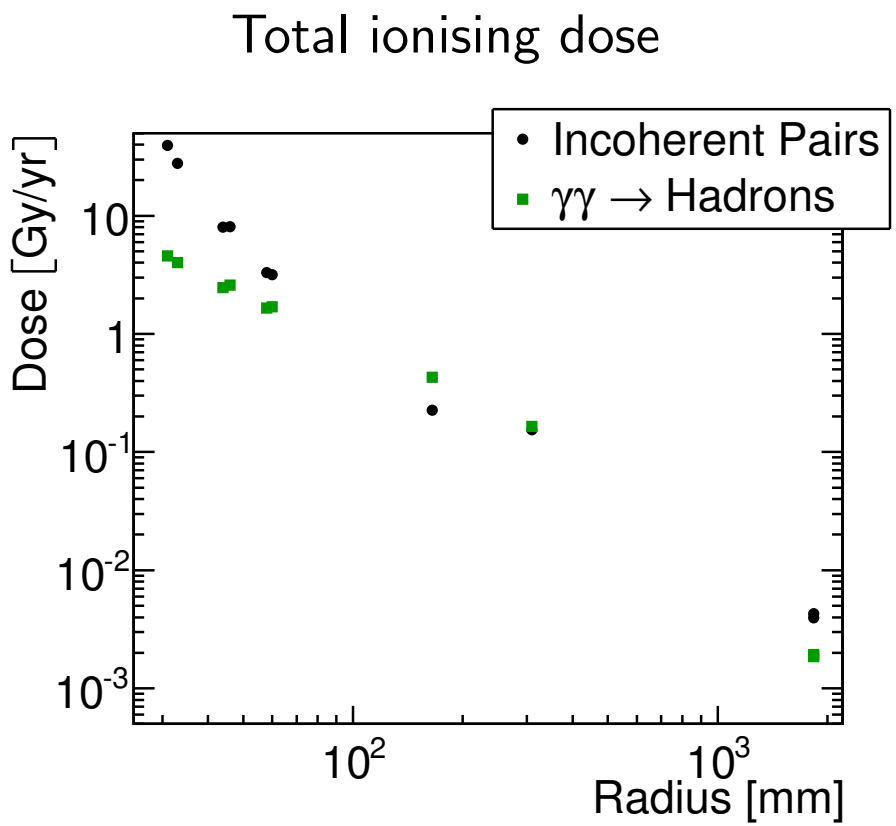
- Ranges from $6 \cdot 10^{-3}$ Hits/mm^2/BX in VXD to 10^{-6} in SET
- incoherent pairs higher than $\gamma\gamma \rightarrow$ Hadrons
  - Back-scattering important effect
- Occupancies depend on sensor size
  - Few percent in pixel VXD
  - Need short strips in SIT to keep at few percent level
- FTD/ETD behave similarly

Hit densities in VXD, SIT, SET



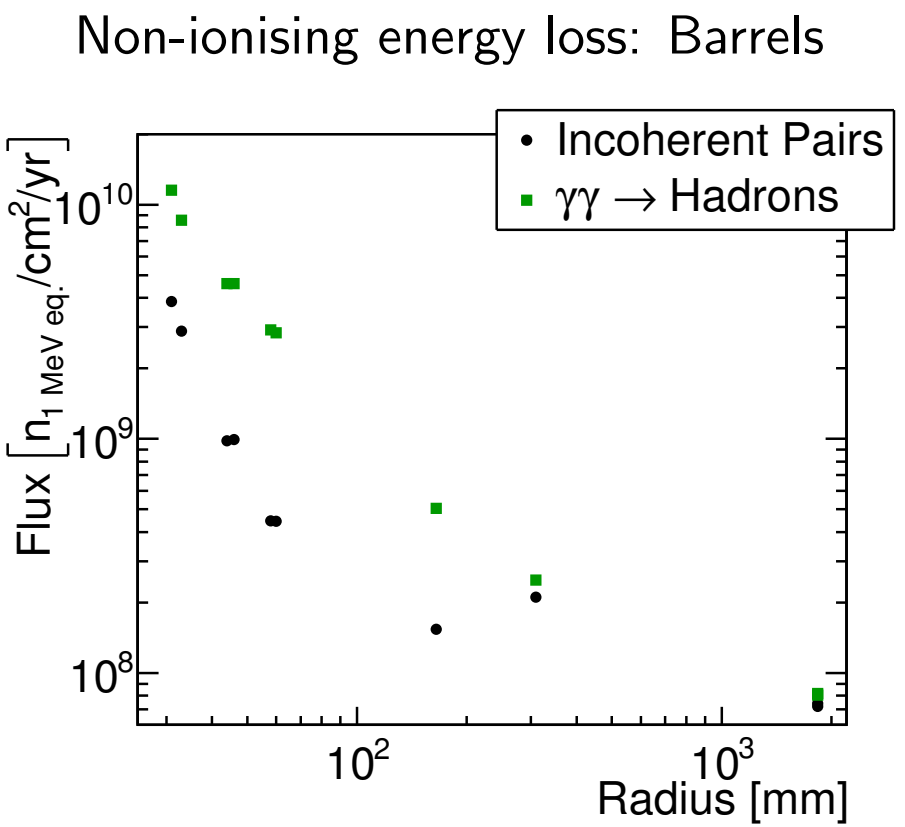
Total Ionising Dose

- About 50 Gy/yr in VXD
- Down to few mGy/yr in SET



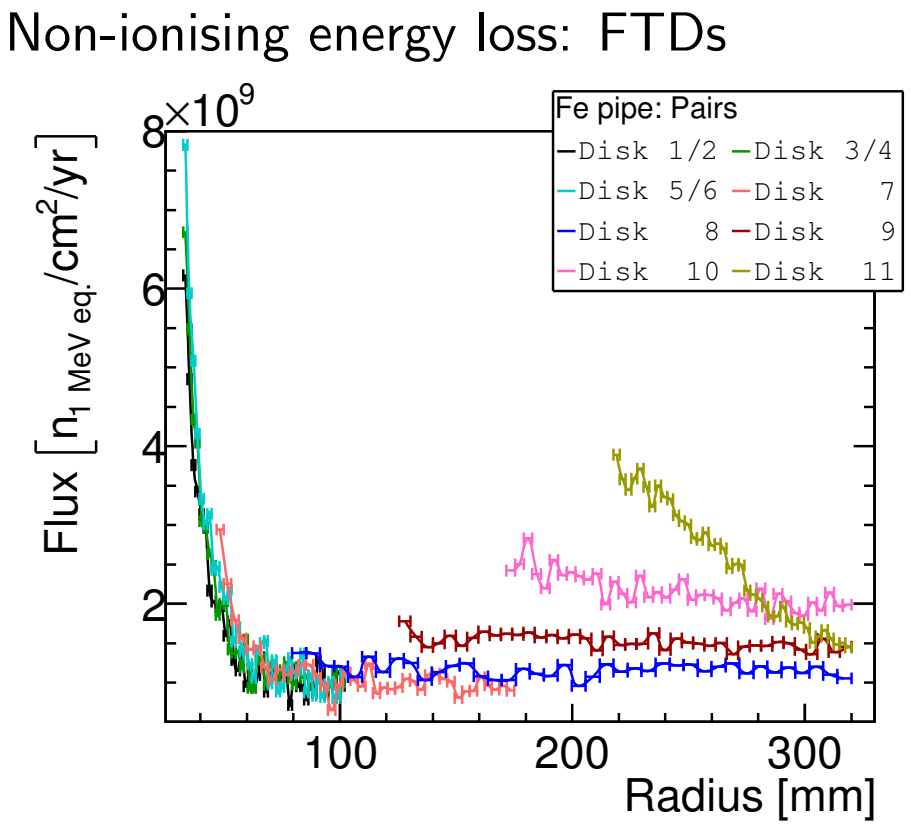
Non-Ionising Energy Loss (NIEL)

- 1 MeV-equivalent-neutron flux
- Passing particles weighted depending on momentum and type
- Few 10^{10} n/cm^2/yr
- At larger radius neutrons produced in BeamCal become important than direct part



Non-Ionising Energy Loss (NIEL): FTDs

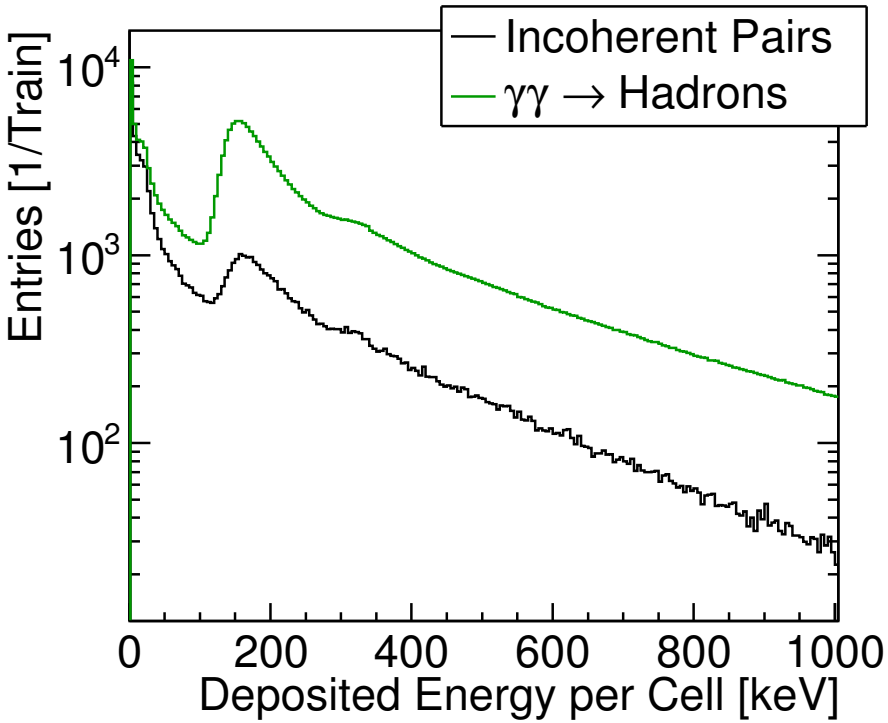
- For later disks back-scattering neutrons
- Isotropically produced in e.m. showers in the BeamCal
- NIEL falls with distance to the BeamCal



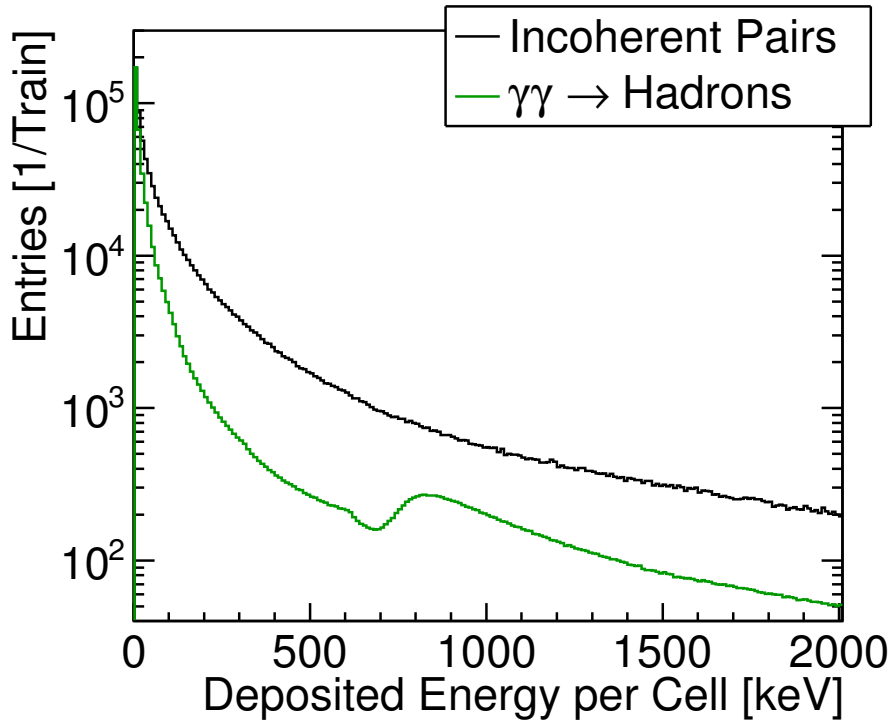
Calorimeter Endcaps

Energy Deposits

ECal Endcap



HCal Endcap



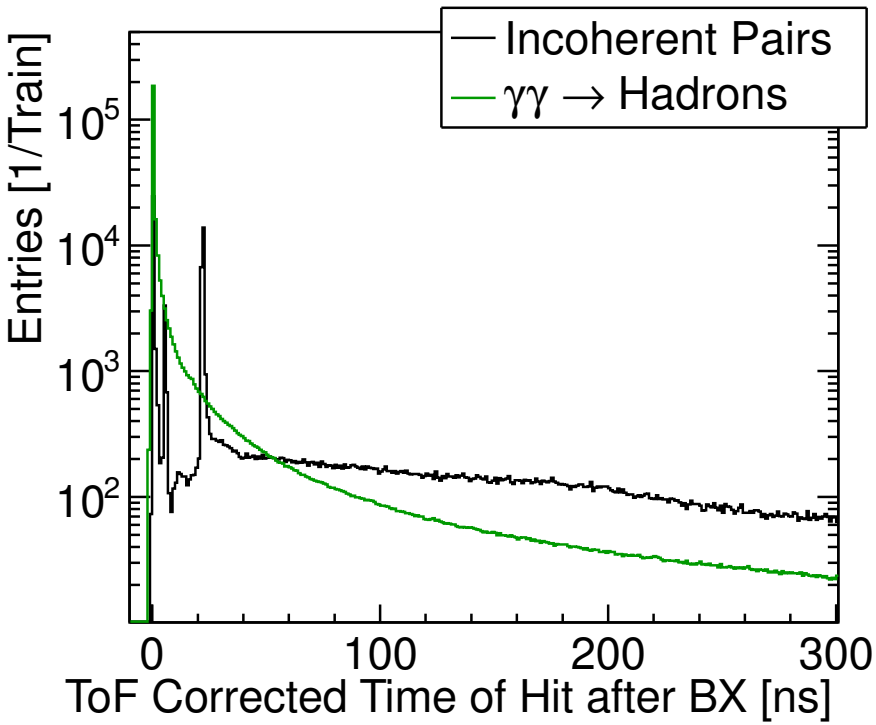
- Chosen thresholds ($\approx$ 0.3 MIP)
  - 40 keV in ECal
  - 300 keV in HCal

Total Reconstructed Energy [TeV/Train]

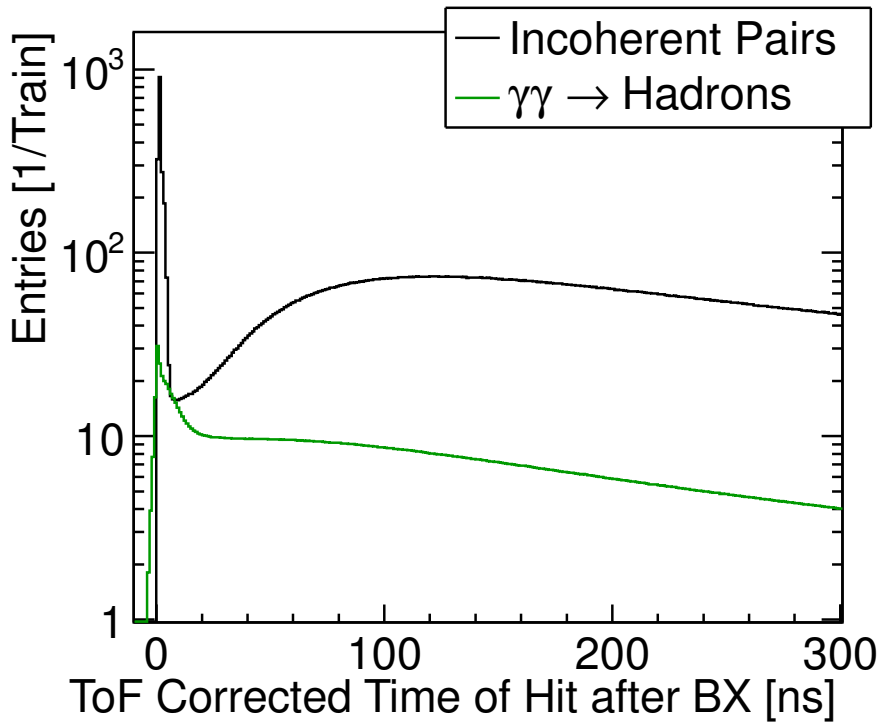
	Pairs	GG
ECal	1.7	10.5
HCal	16.2	5.6

Time of Hits

ECal Endcap



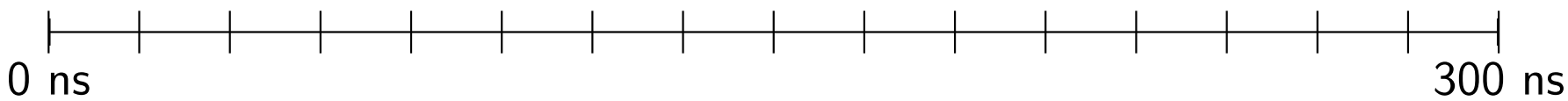
HCal Endcap



- Peaks for the pairs in ECal:
  - Direct hits
  - Back-scatters into back of ECal on same side
  - Back-scatters into front of opposite ECal

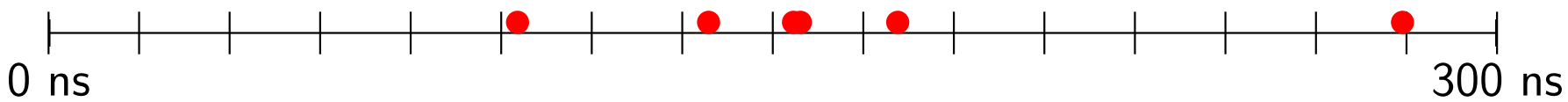
Occupancy Calculations

- Divided 300 ns after first bunch crossing into 12×25 ns time windows
  - Could use shorter total time (but hadronic showers take time to develop)
  - Readout window harder to decrease
  - HCal: Plateau from pairs reached after 100 ns



Occupancy Calculations

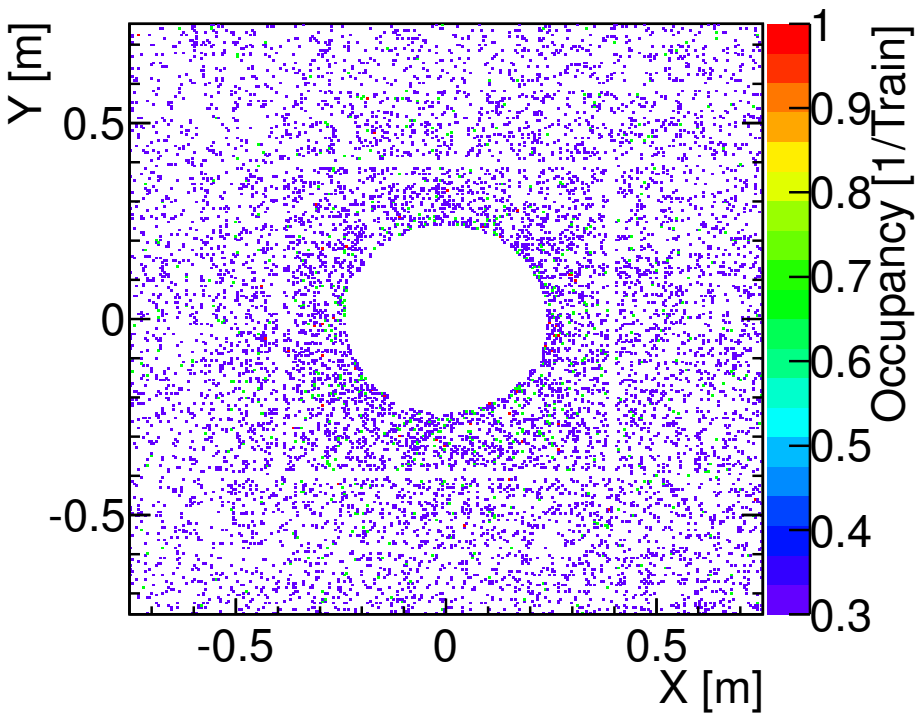
- Divided 300 ns after first bunch crossing into 12×25 ns time windows
  - Could use shorter total time (but hadronic showers take time to develop)
  - Readout window harder to decrease
  - HCal: Plateau from pairs reached after 100 ns
- Distribute hits in window (with BX offset)
- Sum deposited energy in these time windows
- Apply threshold
- Occupancy given as: Number of time windows with energy deposit above threshold



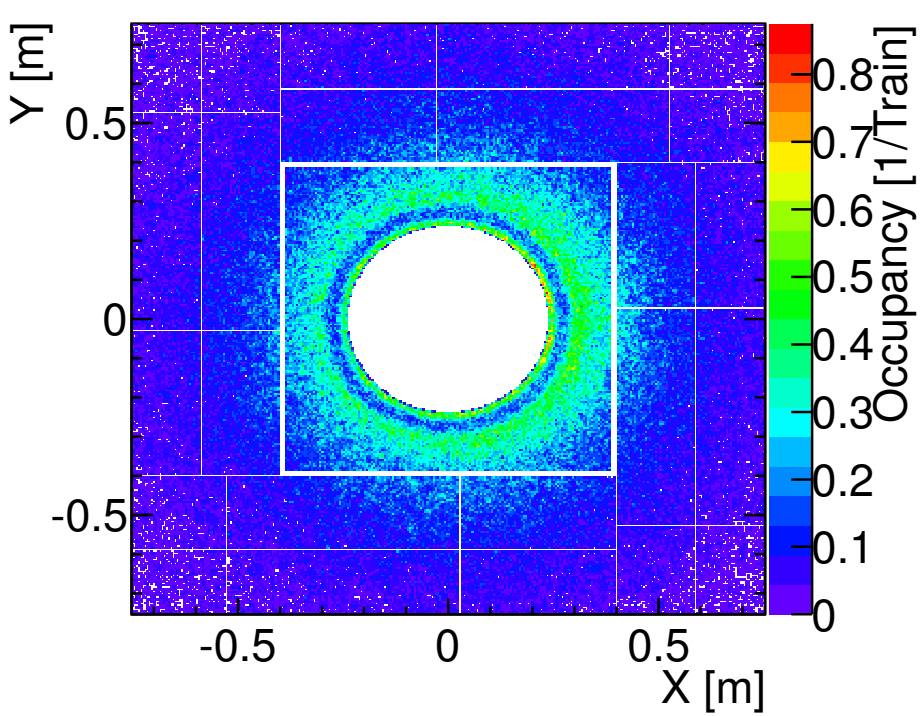
ECal Endcap Occupancy

ECal Endcap: *XY* Distributions

Pairs (Layer 1)



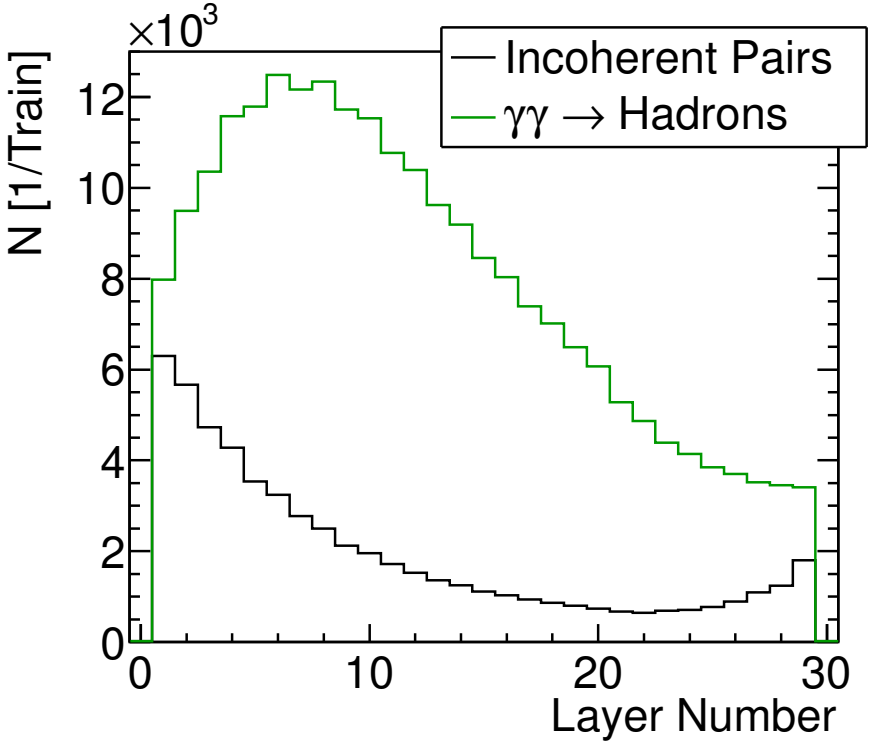
$\gamma\gamma \rightarrow$ Hadrons(Layer 6)



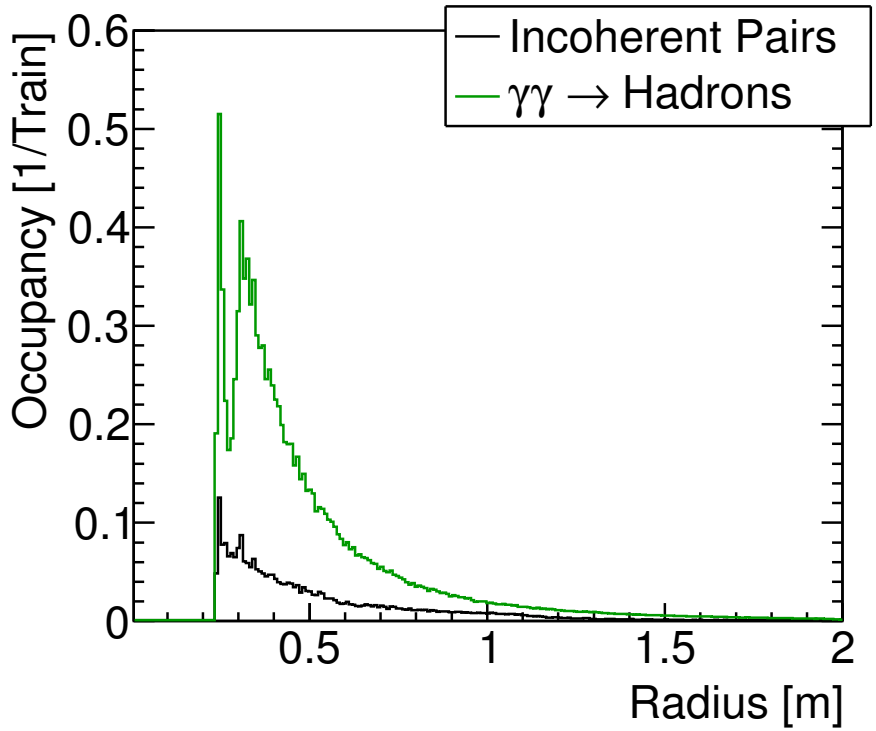
- Low statistics visible for pair sample
- Dip in radial distribution caused by thick conical beam pipe

ECal Endcap Occupancies

Entries per Layer



Layer 6

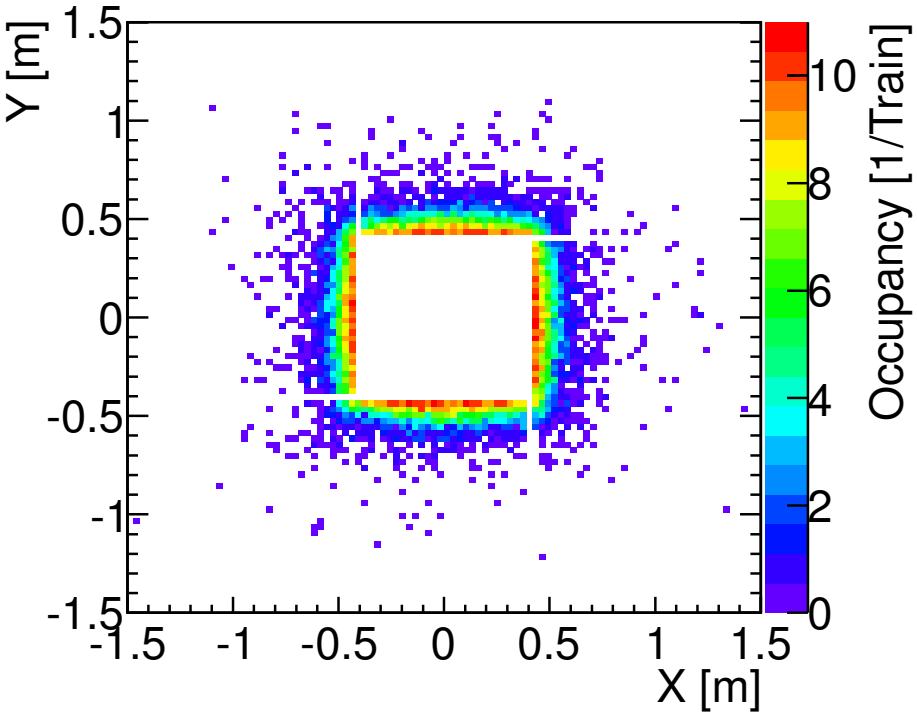


- For $\gamma\gamma \rightarrow$ Hadrons shower maximum in layer 6
- Some back-scattering into ECal for pairs
- Dip in radial distribution caused by thick conical beam pipe

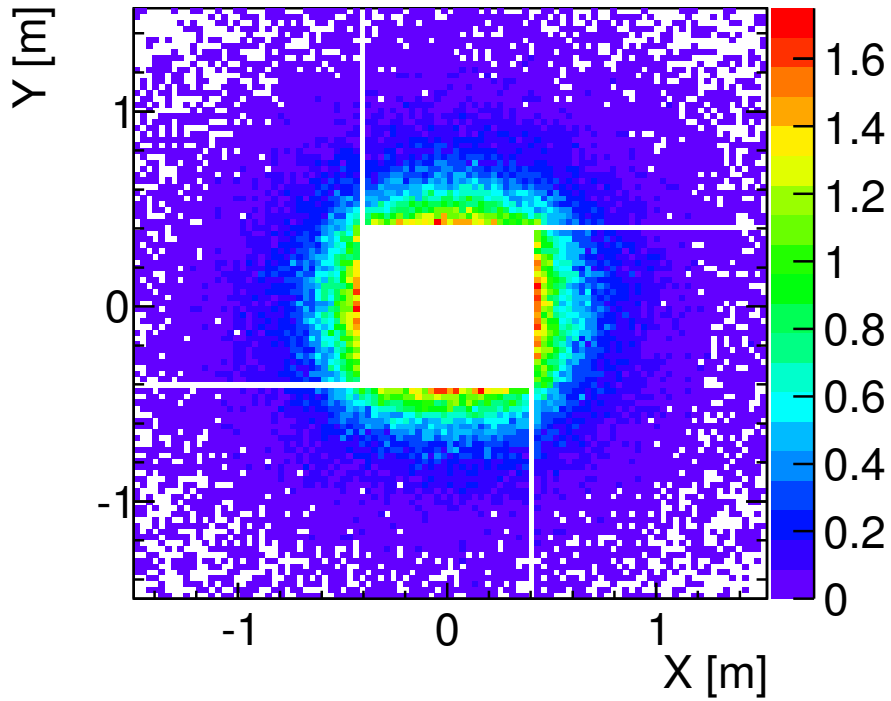
HCal Endcap Occupancy

HCal Endcap: XY Distributions

Pairs (Layer 40)



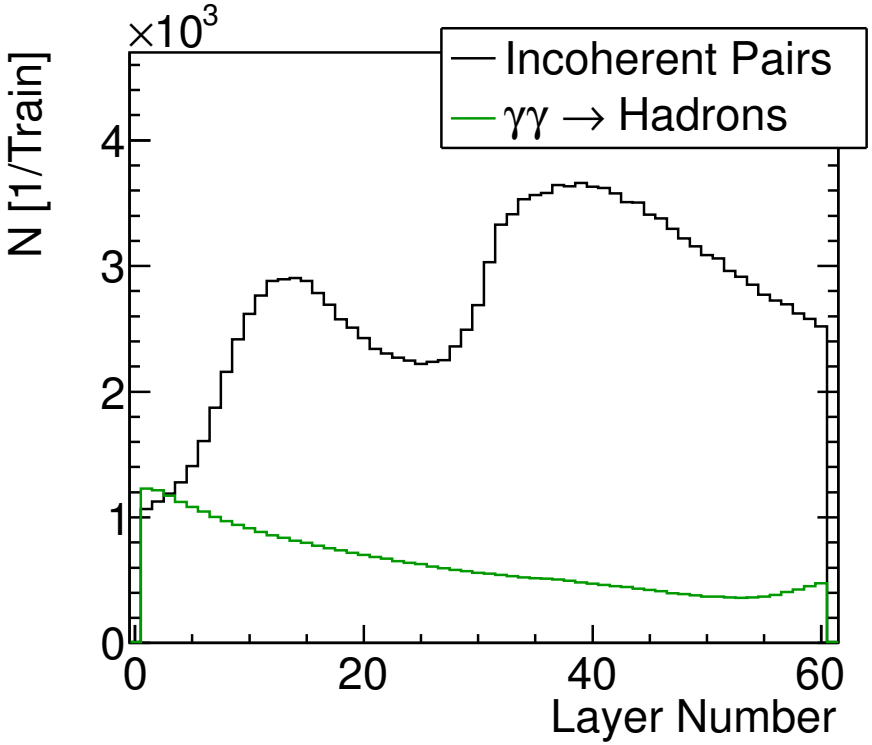
$\gamma\gamma \rightarrow$ Hadrons(Layer 1)



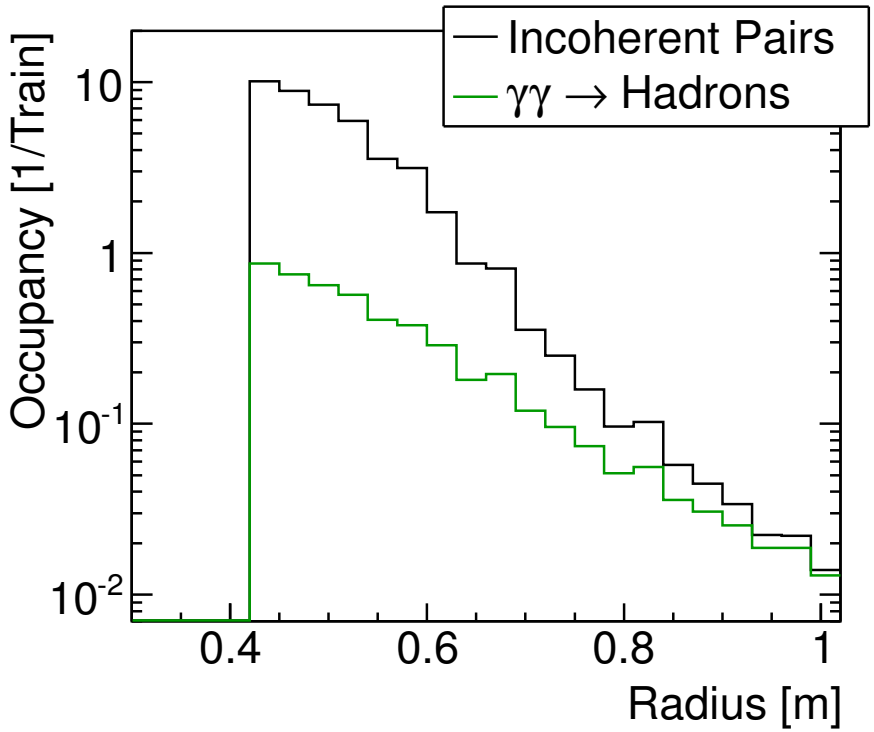
- Very large occupancy for pairs for the innermost cells
  - Neutrons produced in BeamCal passing through support tube
- Occupancy for $\gamma\gamma \rightarrow$ Hadrons below 2.

HCal Endcap Occupancy

Entries per Layer



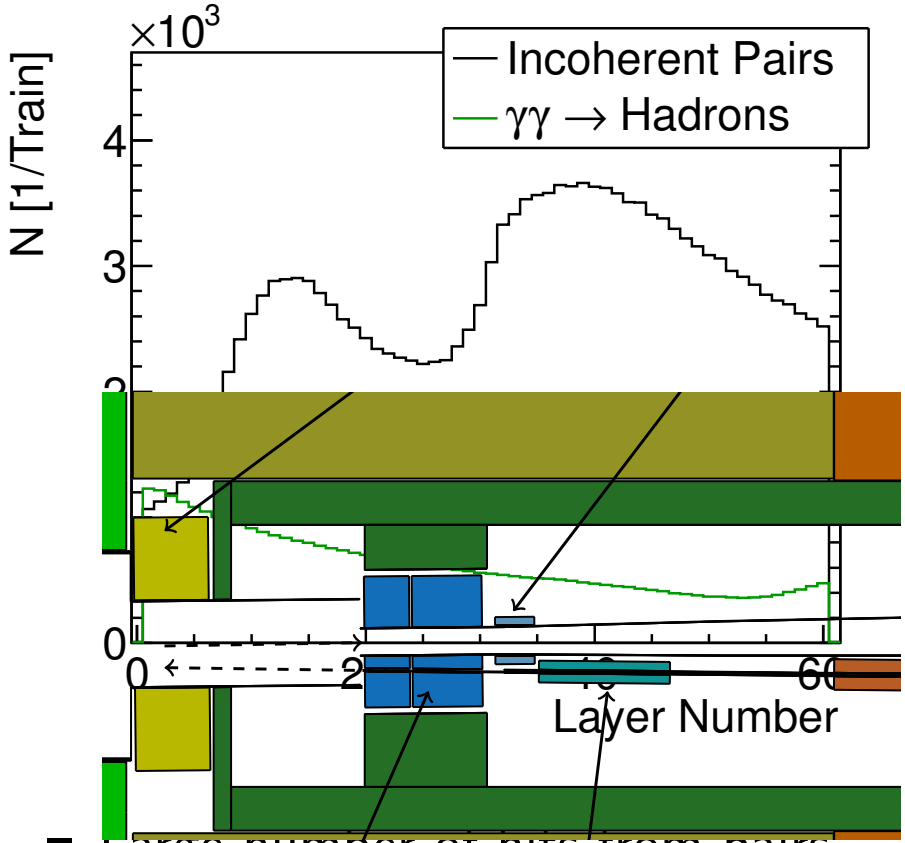
Radius (Layer 35–45)



- Large number of hits from pairs
- Very high occupancy: 10 out of 12 time windows see energy deposit

HCal Endcap Occupancy

Entries per Layer



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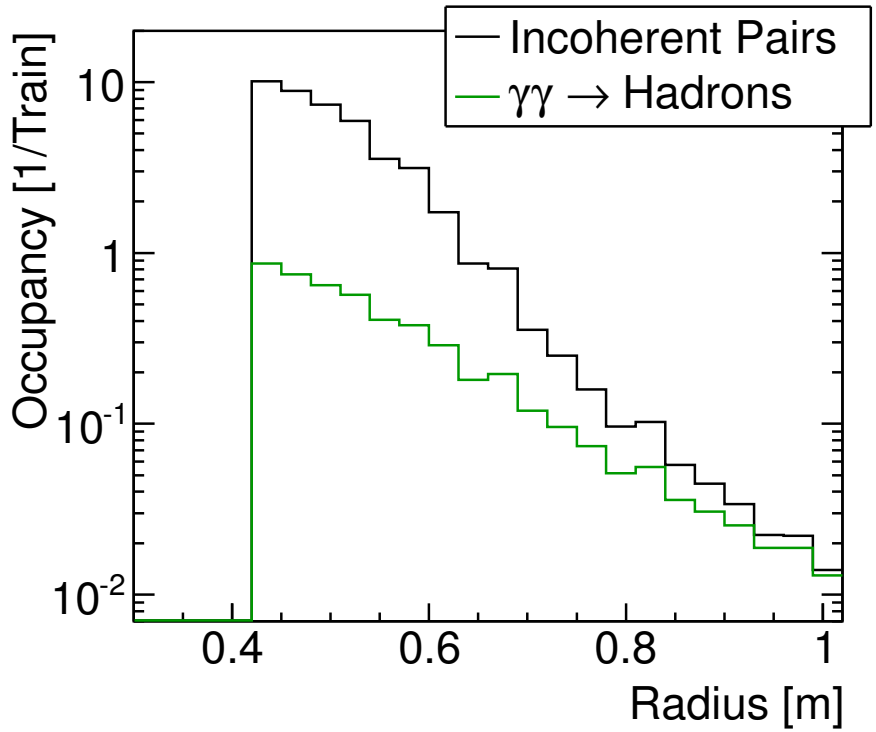
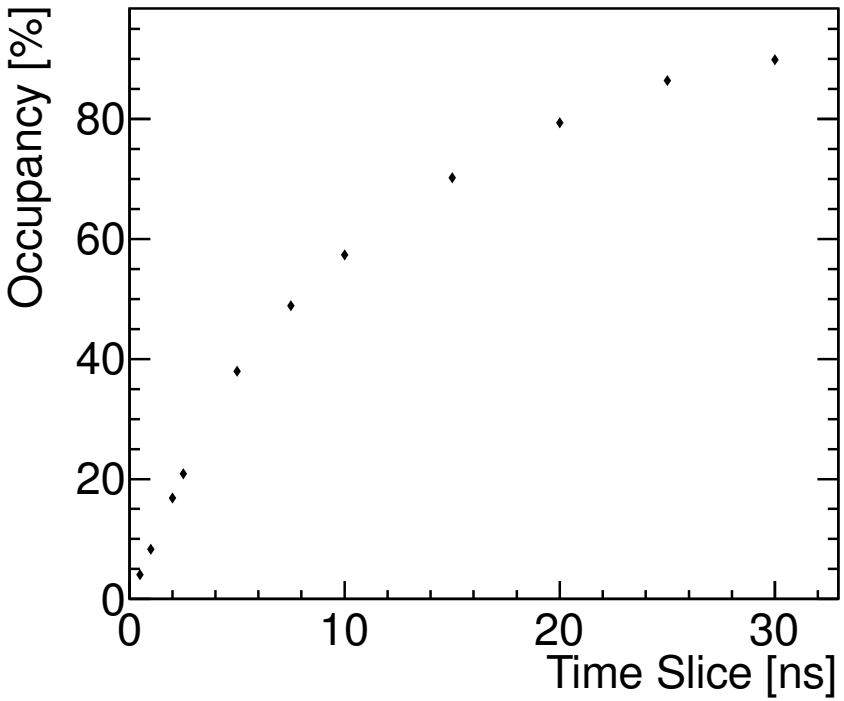


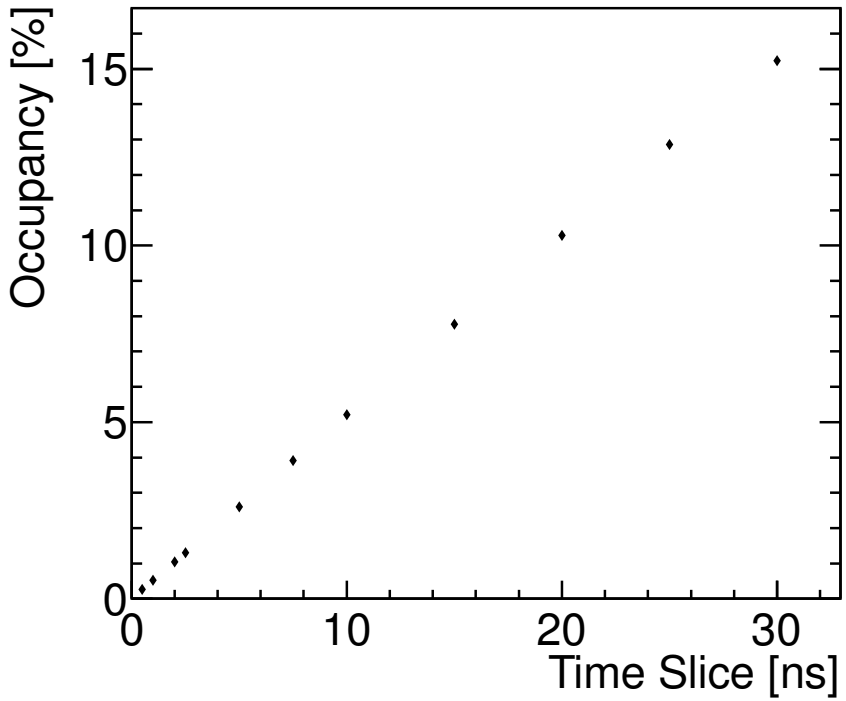
- Large number of hits from pairs
- Very high occupancy: 10 out of 12 time windows see energy deposit
- Structure caused by "BeamCal Support" inside support tube

HCal Endcap: Occupancy vs. Time Window

Pairs



$\gamma\gamma \rightarrow$ Hadrons



- Easier to change size of time windows than simulating with smaller pad size
- 10 times higher granularity (in time) gives 20% instead of 80% occupancy for pairs

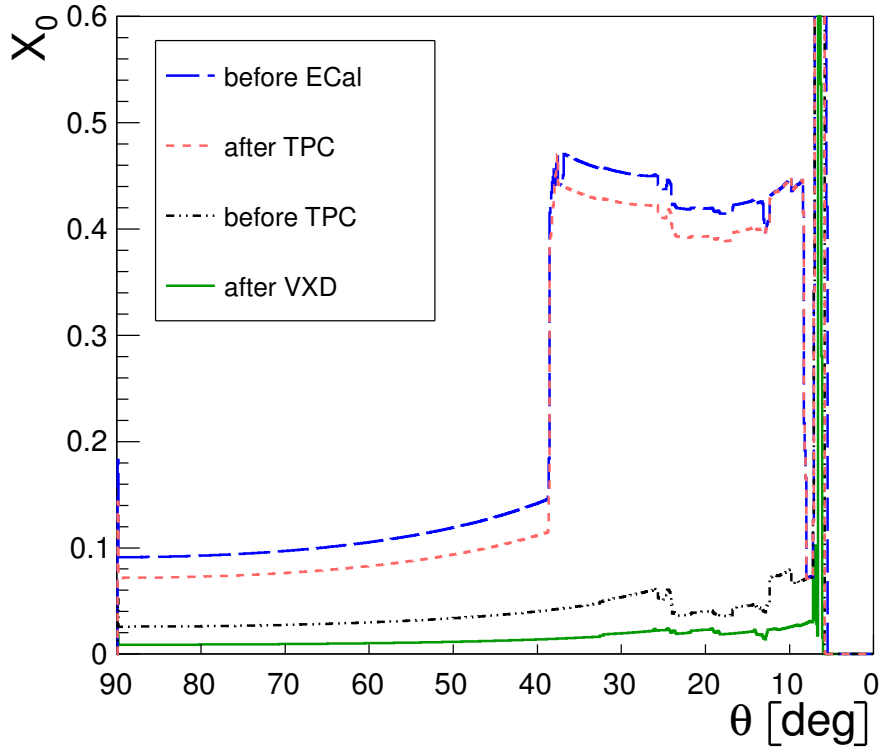
Summary and Conclusions

- Occupancy and radiation levels in Si trackers
  - Occupancy few per cent in VXD
  - Might have to optimize spatial and temporal granularity of strip detectors
  - maximal eq. neutron 10^{10} n/cm^2/yr
  - Impact from neutrons produced in the BeamCal
- Occupancies in the calo endcaps
  - Large energy deposits from secondary neutrons produced in the BeamCal
  - Need optimisation
    - ⋆ BeamCal position
    - ⋆ Support tube
    - ⋆ HCal granularity at small radii
- More details in soon to be released LCD-Note-2011-021
  `http://lcd.web.cern.ch/lcd/Documents/Documents.html`

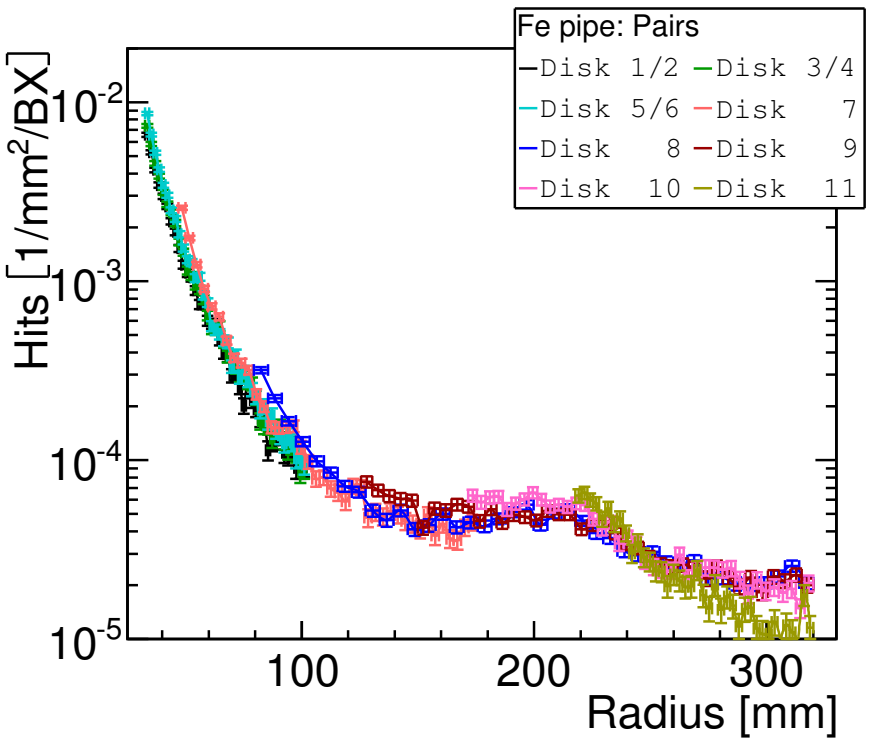
Backup Slides

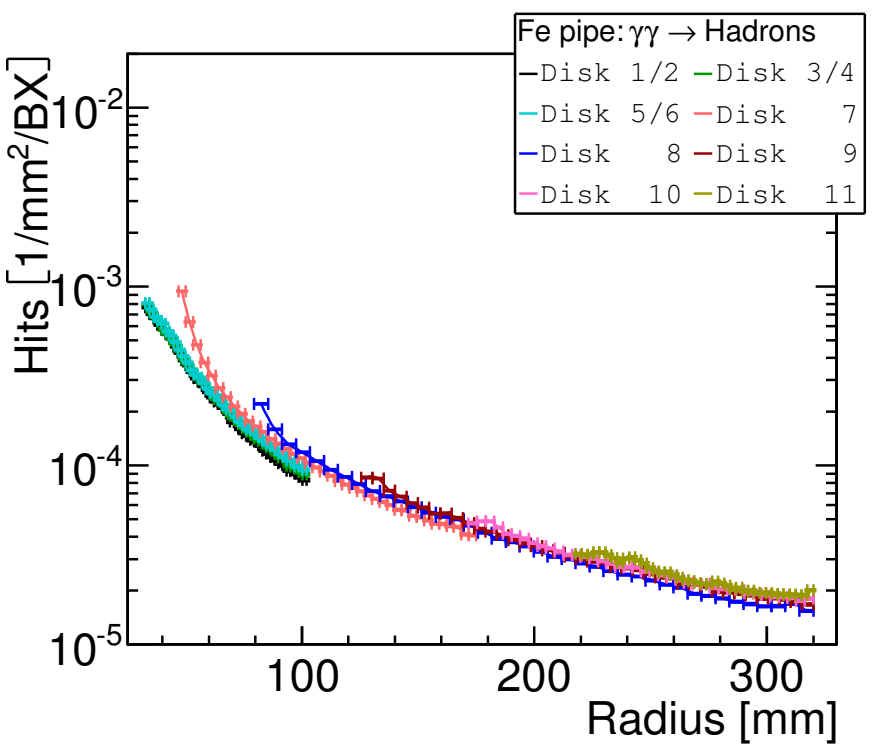
CLIC_ILD_CDR Material Budget

- Material Budget before the VXD, TPC and ECal
- TPC Endcap from 40° to 10°
- Peak at 7° from beam pipe



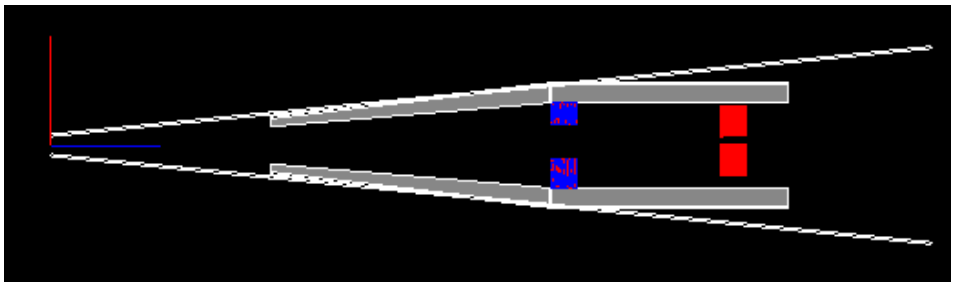
Occupancies in the Disk-like Si Tracking Detectors



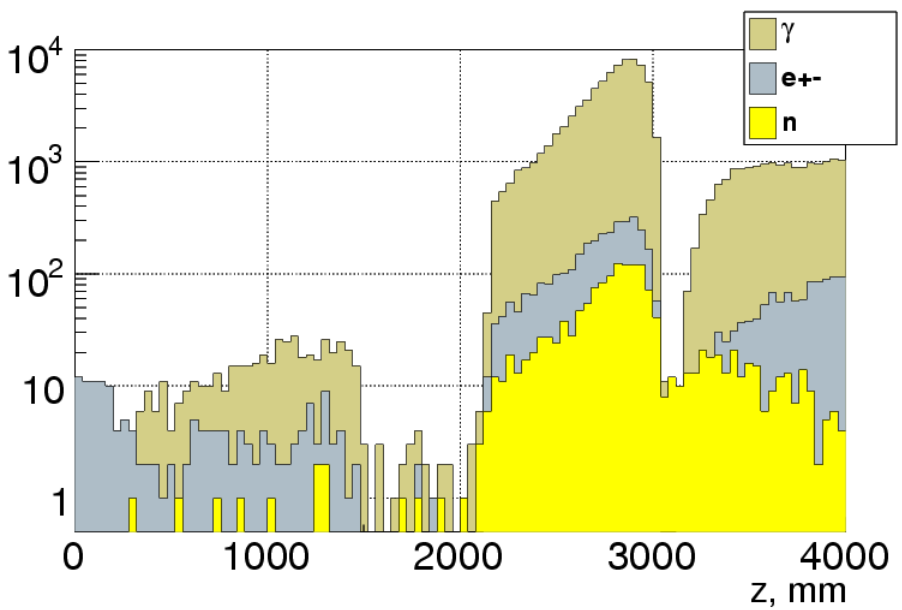


Particles Reaching HCal

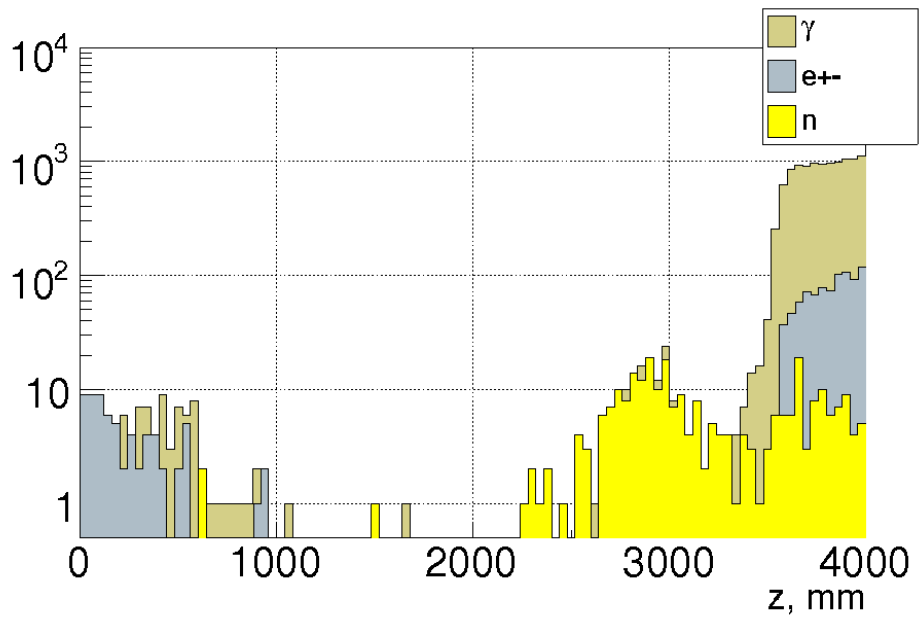
- Study by Andrei Sapronov (2008)
- Looking at incoherent pairs
- Particle spectrum with and without tungsten mask
- Only neutrons pass through the mask
- N.b. mask length limited



Without Mask

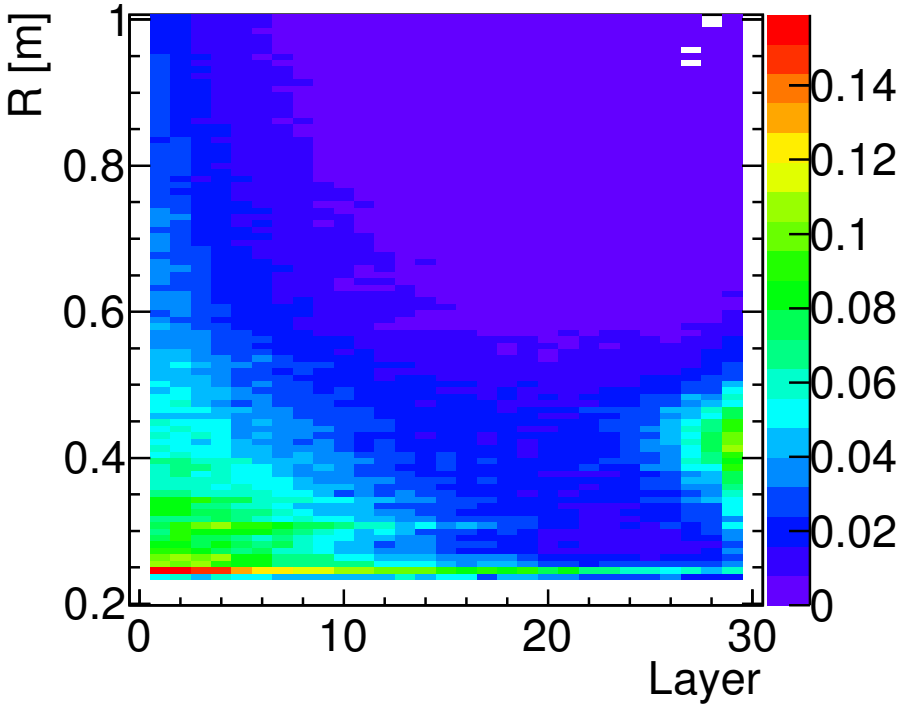


With Mask

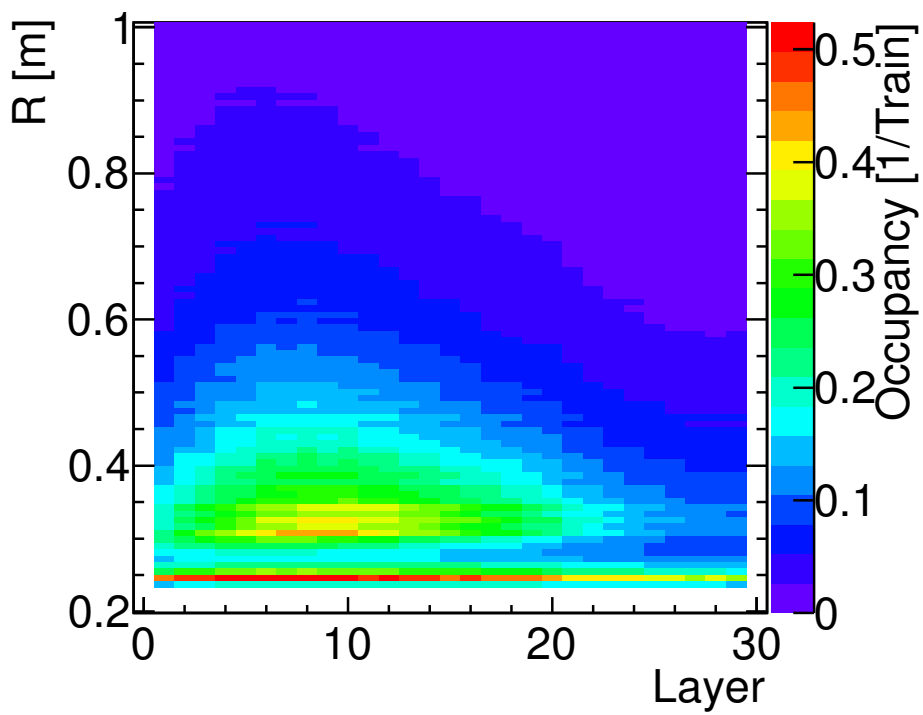


ECal: Radial Distributions

Pairs



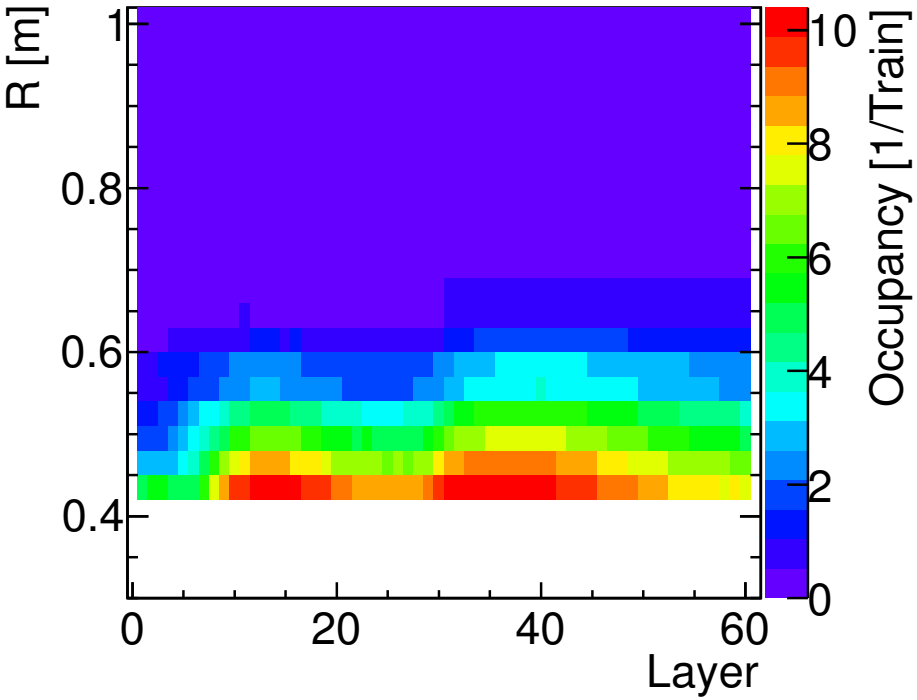
$\gamma\gamma \rightarrow$ Hadrons



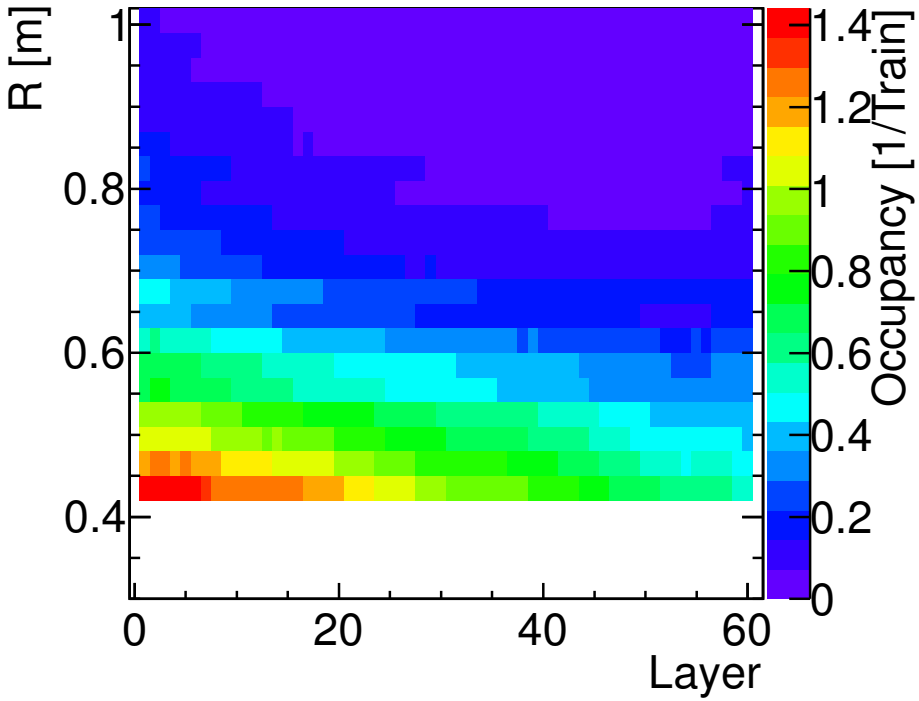
- Occupancies below 0.5: Less than one hit per pad and train

HCal: Radial Distributions

Pairs



$\gamma\gamma \rightarrow$ Hadrons



- Up to 10/12 time windows hit for pairs
- (N.b.: Radius vs. X/Y distance)
- Beyond 1.5 m only few per cent