



# Background and Radiation Levels at CLIC

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Linear Collider Workshop 2011

Granada

September 28, 2011



- 1 Introduction
  - Very Brief Introduction to CLIC
  - Forward Region and Backgrounds at CLIC
- 2 Occupancies and Radiation Damage in Silicon Tracking Detectors
- 3 Calorimeter Endcaps
  - Energy and Time Distributions
  - ECal Endcap Occupancy
  - HCal Endcap Occupancy
- 4 Summary and Conclusion



## ■ Important for occupancies

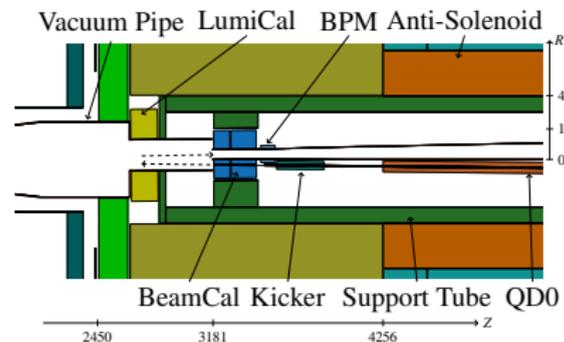
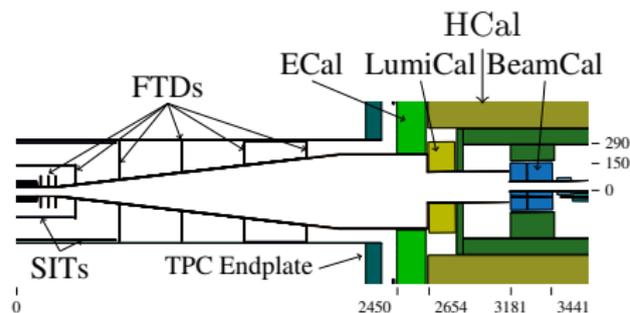
- ▶ Bunch spacing, number of bunches/train
- ▶ Amount of background

	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	$10^8$	$\approx 0$

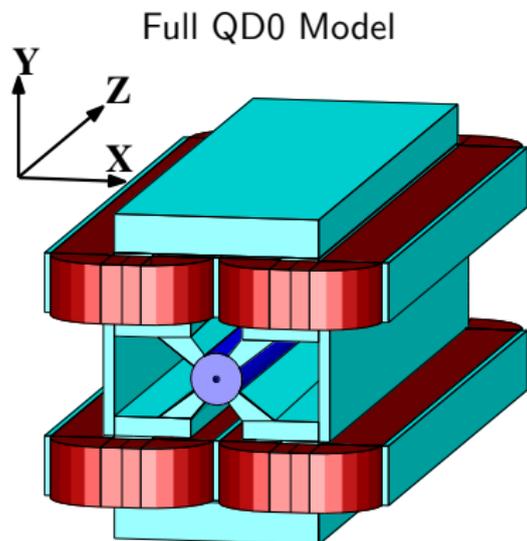
# Forward Region in CLIC\_ILD\_CDR Detector



- 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



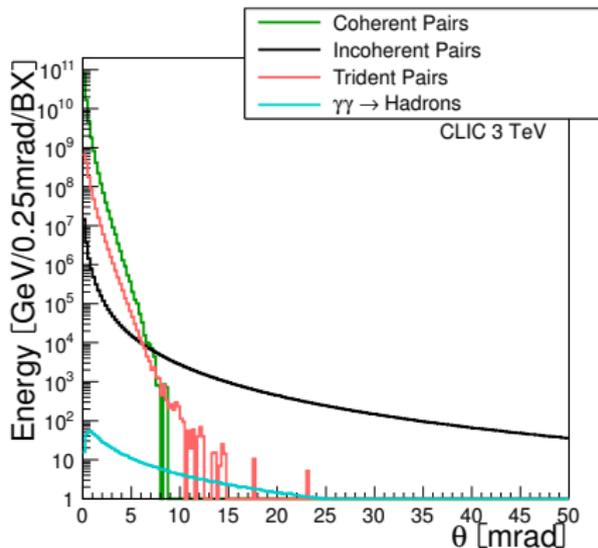
- CLIC\_ILD\_CDR model frozen
- LumiCal placed behind ECal
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- 4 mm thick, conical iron beam pipe reducing back-scatters
- QD0 only permanent magnet cylinder included



# (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 ( $\gamma\gamma \rightarrow \text{Hadrons}$ )
  - ▶ 3.2 events per BX
  - ▶ More central than pairs





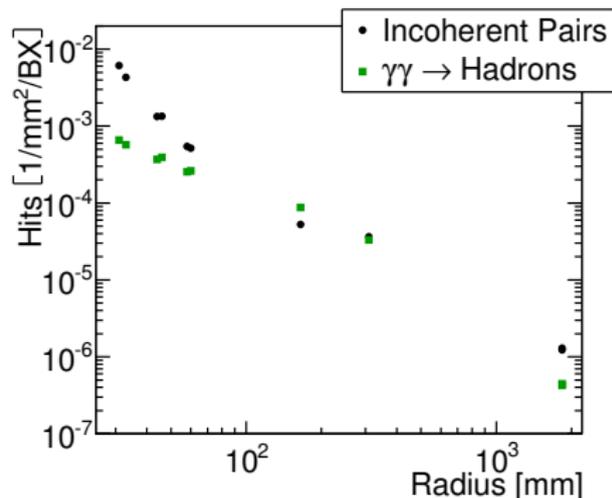
- CLIC\_ILD\_CDR with FieldMap instead of constant solenoid field
- QGSP\_BERT\_HP physics list
- 5  $\mu\text{m}$  range cut
- 64 bunch trains  $\gamma\gamma \rightarrow$  Hadrons
- Incoherent Pairs: 1 bunch train for trackers, 3 bunch trains for calorimeters
- Safety factors not included



# Occupancies and Radiation Damage in Silicon Tracking Detectors

- Ranges from  $6 \cdot 10^{-3}$  Hits/mm<sup>2</sup>/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

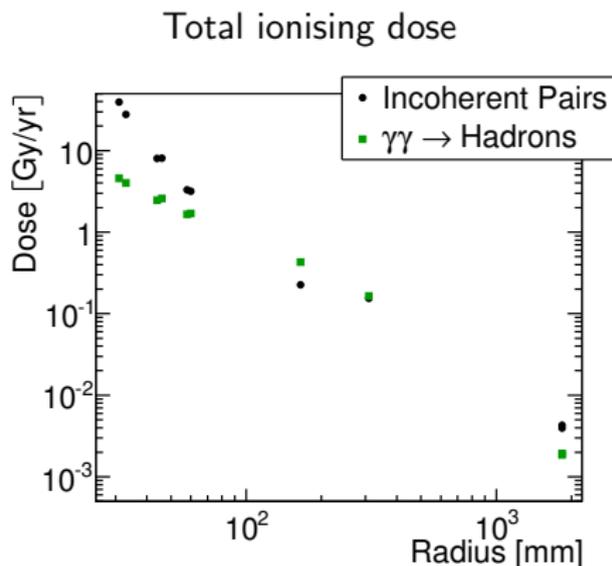
Hit densities in VXD, SIT, SET



# Total Ionising Dose

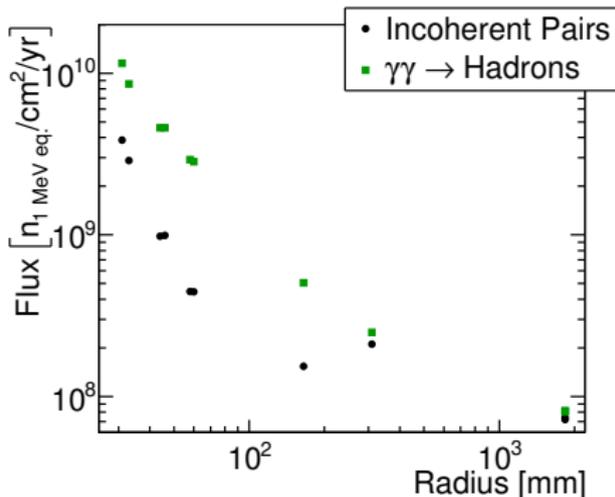


- About 50 Gy/yr in VXD
- Down to few mGy/yr in SET



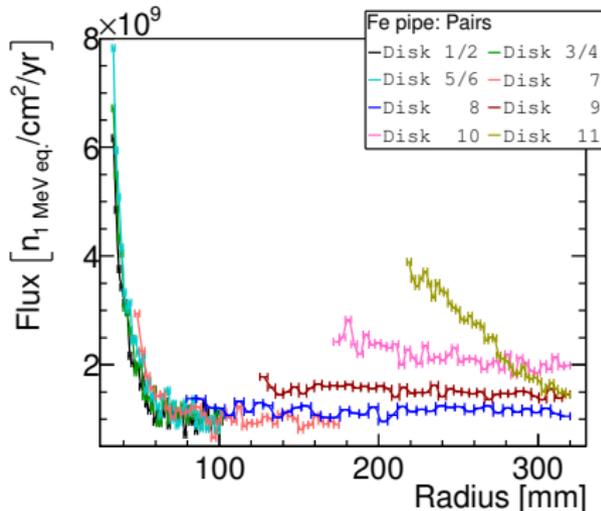
- 1 MeV-equivalent-neutron flux
- Passing particles weighted depending on momentum and type
- Few  $10^{10}$  n/cm<sup>2</sup>/yr
- At larger radius neutrons produced in BeamCal become important than direct part

Non-ionising energy loss: Barrels



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

## Non-ionising energy loss: FTDs

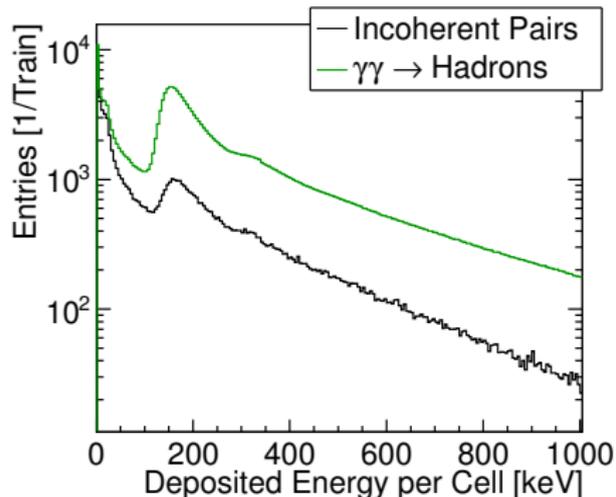




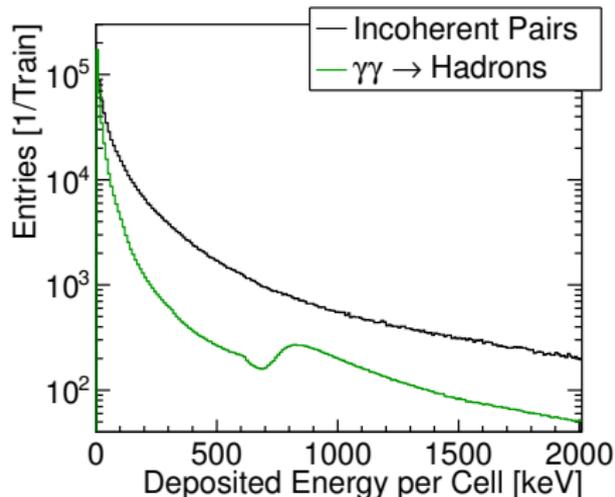
# Calorimeter Endcaps

# Energy Deposits

## Ecal Endcap



## HCal Endcap



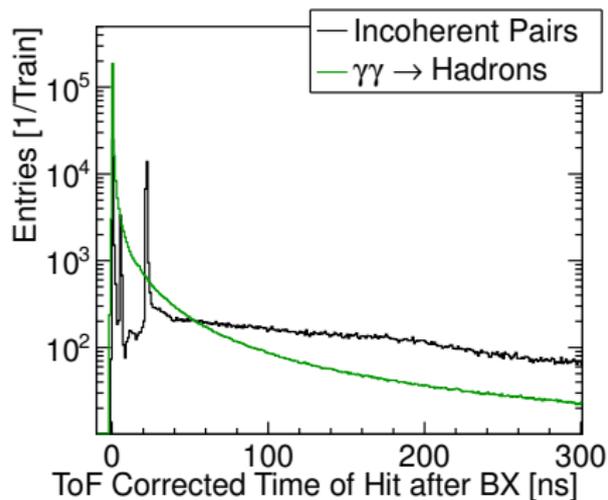
■ Chosen thresholds ( $\approx 0.3$  MIP)

- ▶ 40 keV in ECal
- ▶ 300 keV in HCal

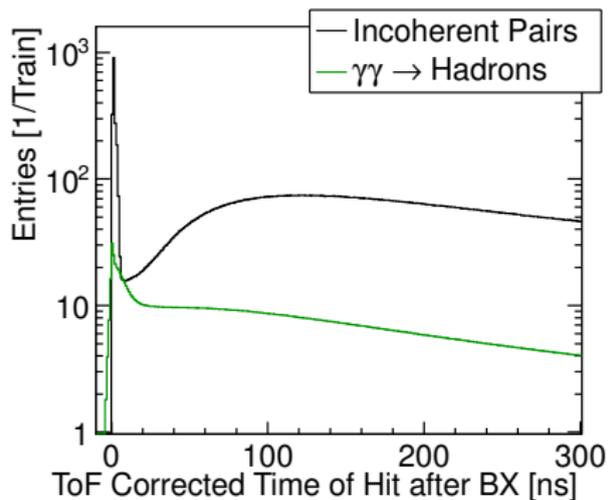
### Total Reconstructed Energy [TeV/Train]

	Pairs	GG
ECal	1.7	10.5
HCal	16.2	5.6

## 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



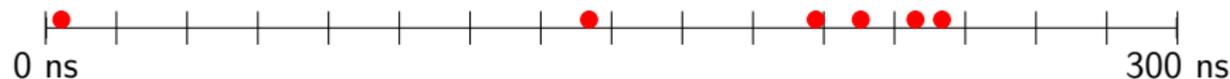
- Divided 300 ns after first bunch crossing into  $12 \times 25$  ns time windows
  - ▶ Could use shorter total time (but hadronic showers take time to develop)
  - ▶ Readout window harder to decrease
  - ▶ HCal: Plateau from pairs reached after 100 ns



# Occupancy Calculations



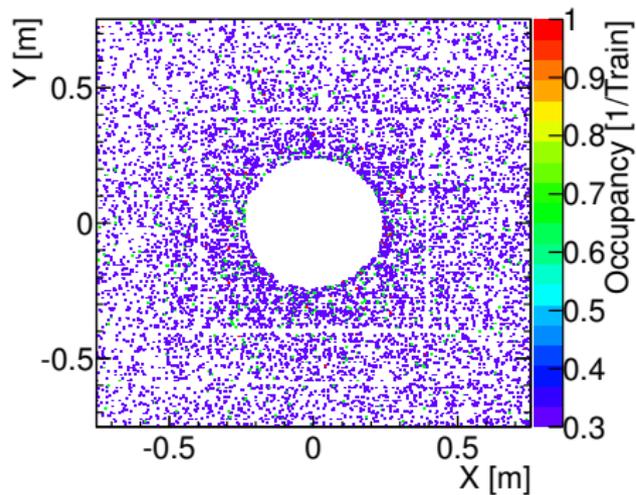
- Divided 300 ns after first bunch crossing into  $12 \times 25$  ns time windows
  - ▶ Could use shorter total time (but hadronic showers take time to develop)
  - ▶ Readout window harder to decrease
  - ▶ HCal: Plateau from pairs reached after 100 ns
- Distribute hits in window (with BX offset)
- Sum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



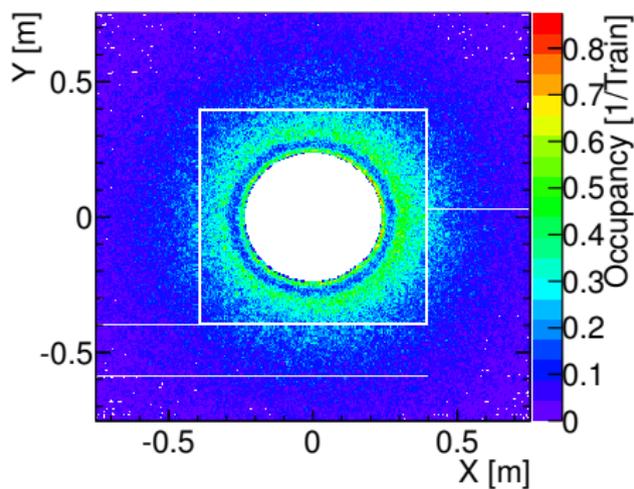


# ECal Endcap Occupancy

## Pairs (Layer 1)

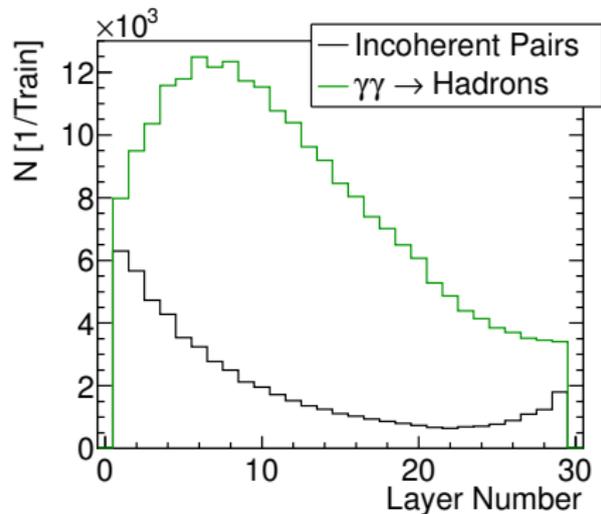


## $\gamma\gamma \rightarrow$ Hadrons (Layer 6)

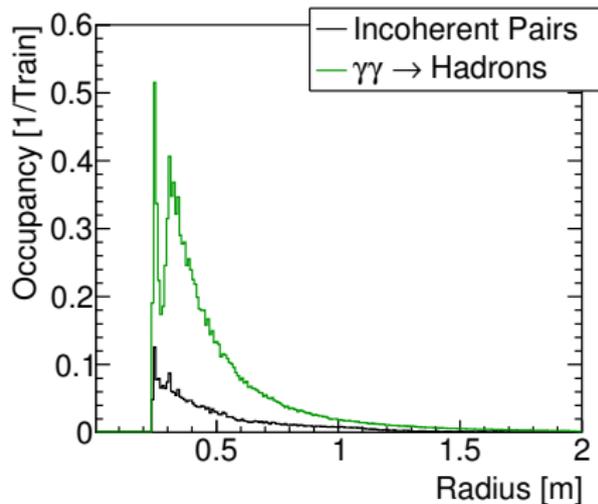


- Low statistics visible for pair sample
- Dip in radial distribution caused by thick conical beam pipe

## Entries per Layer



## Layer 6

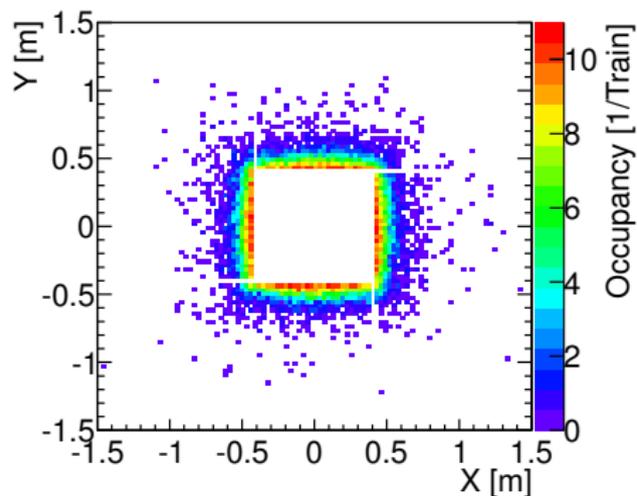


- For  $\gamma\gamma \rightarrow$  Hadrons shower maximum in layer 6
- Some back-scattering into ECal for pairs
- Dip in radial distribution caused by thick conical beam pipe

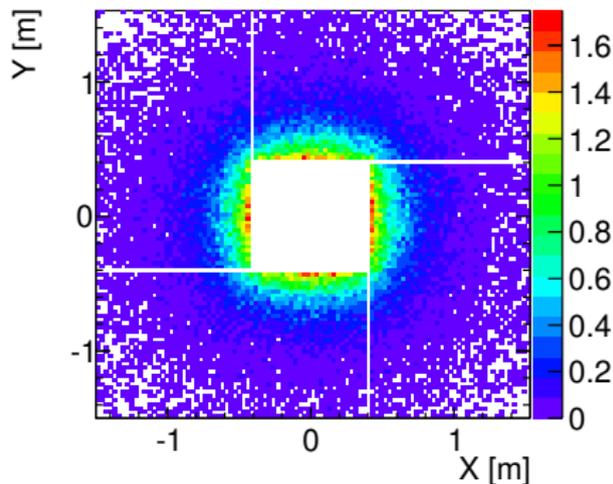


# HCal Endcap Occupancy

## Pairs (Layer 40)

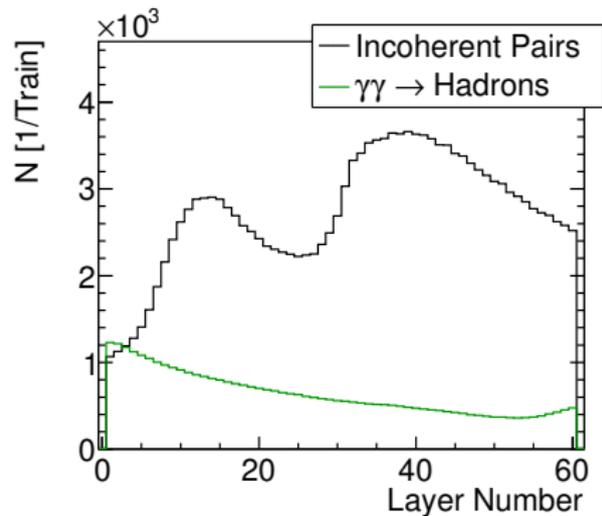


## $\gamma\gamma \rightarrow$ Hadrons(Layer 1)

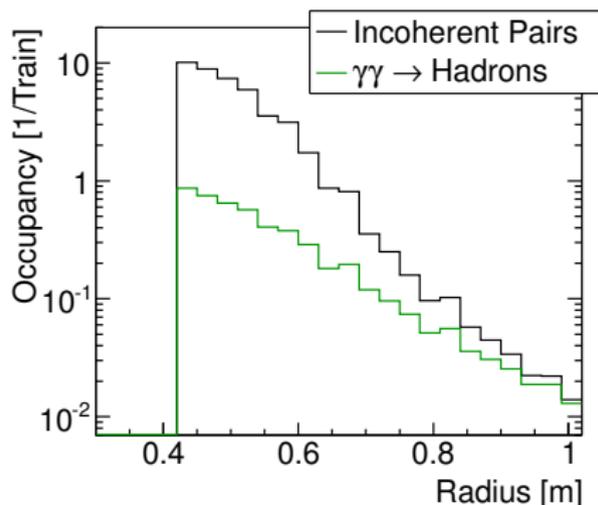


- Very large occupancy for pairs for the innermost cells
  - ▶ Neutrons produced in BeamCal passing through support tube
- Occupancy for  $\gamma\gamma \rightarrow$  Hadrons below 2.

## Entries per Layer

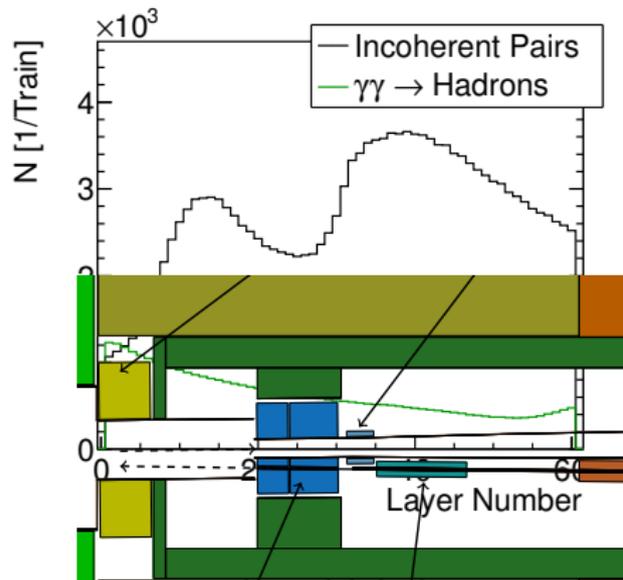


## Radius (Layer 35–45)

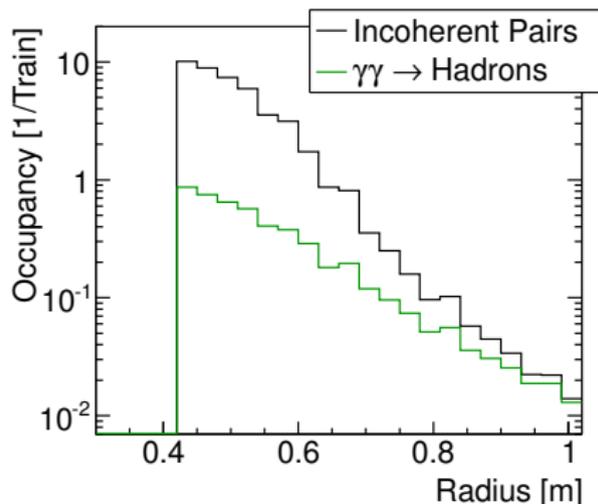


- Large number of hits from pairs
- Very high occupancy: 10 out of 12 time windows see energy deposit

## Entries per Layer



## Radius (Layer 35–45)

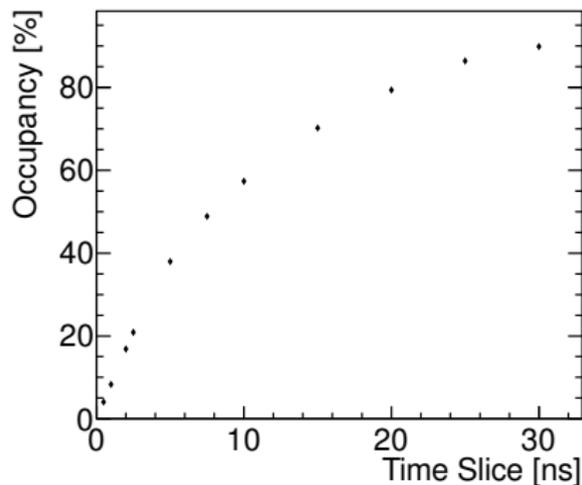


- Large number of hits from pairs
- Very high occupancy: 10 out of 12 time windows see energy deposit
- Structure caused by “BeamCal Support” inside support tube

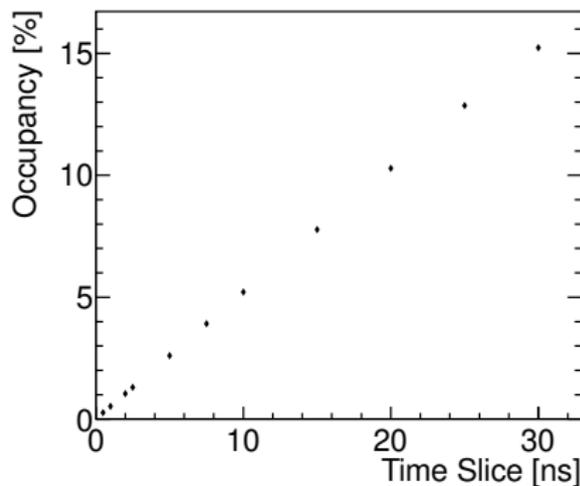
# HCal Endcap: Occupancy vs. Time Window



Pairs



$\gamma\gamma \rightarrow$  Hadrons



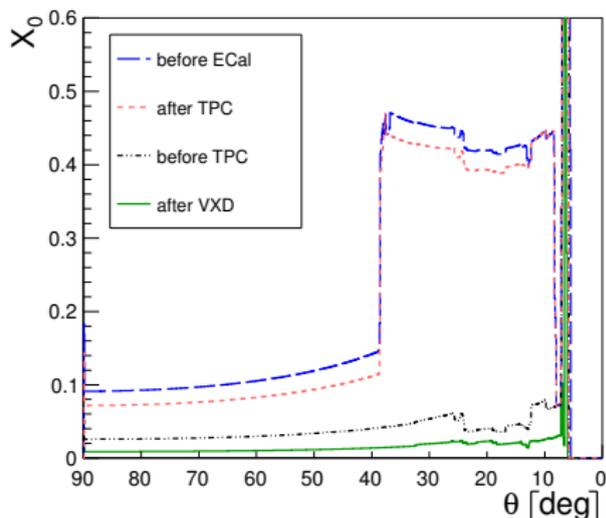
- Easier to change size of time windows than simulating with smaller pad size
- 10 times higher granularity (in time) gives 20% instead of 80% occupancy for pairs

- 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<sup>2</sup>/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



# Backup Slides

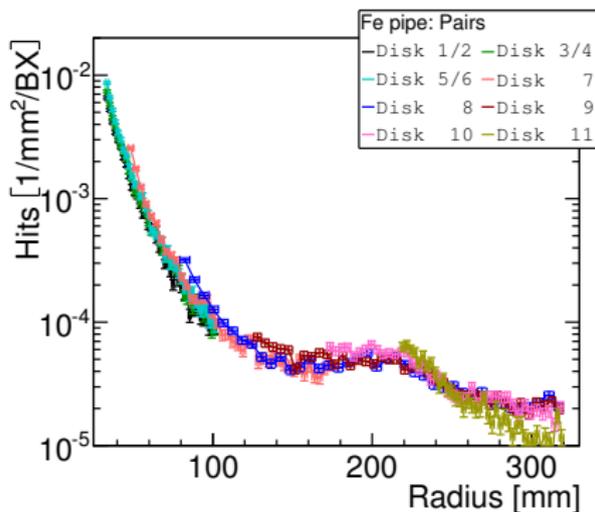
- Material Budget before the VXD, TPC and ECal
- TPC Endcap from  $40^\circ$  to  $10^\circ$
- Peak at  $7^\circ$  from beam pipe



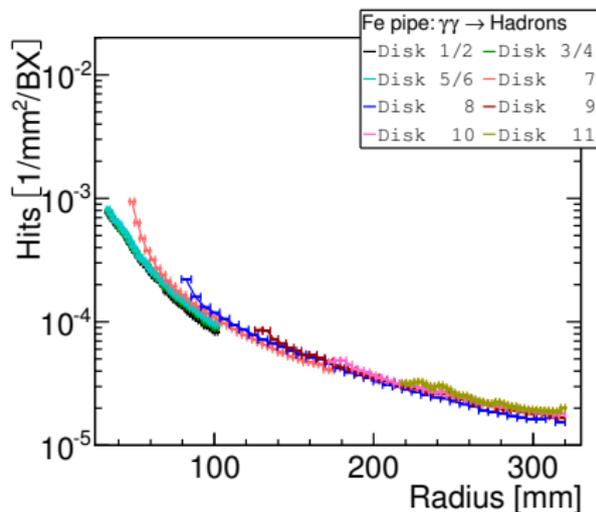
# Occupancies in the Disk-like Si Tracking Detectors



## Incoherent Pairs

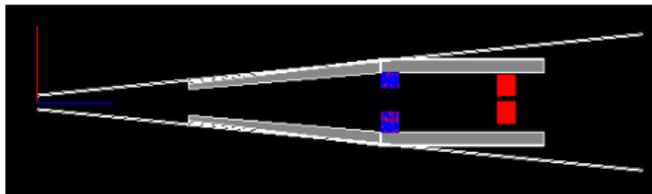


## $\gamma\gamma \rightarrow$ Hadrons

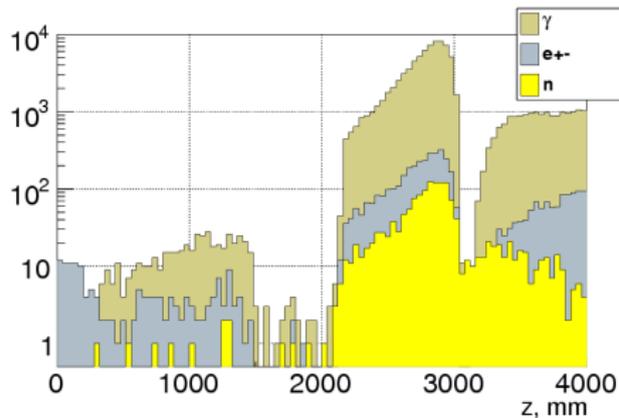


# Particles Reaching HCal

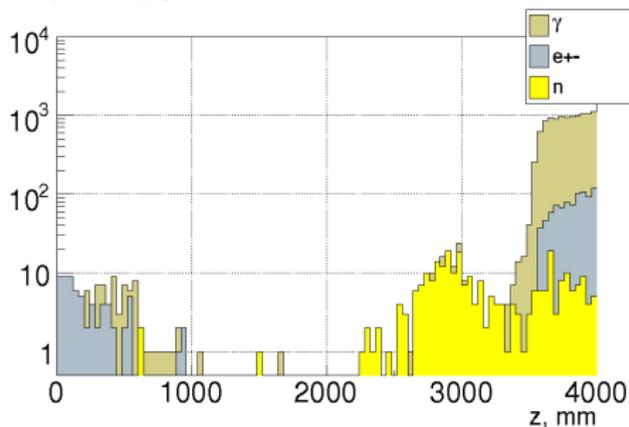
- Study by Andrei Sapronov (2008)
- Looking at incoherent pairs
- Particle spectrum with and without tungsten mask
- Only neutrons pass through the mask
- N.b. mask length limited



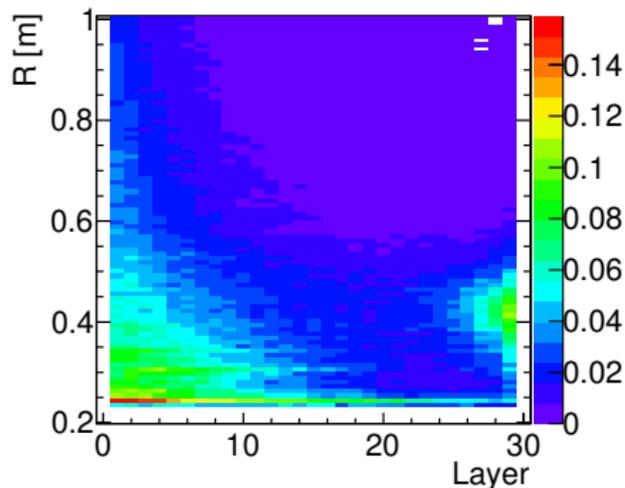
## Without Mask



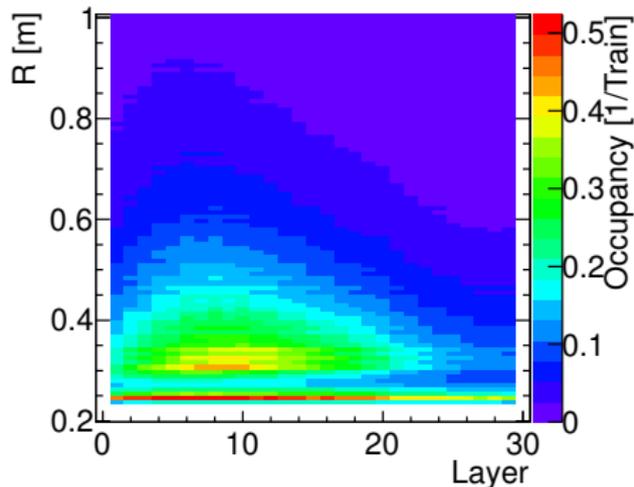
## With Mask



## Pairs

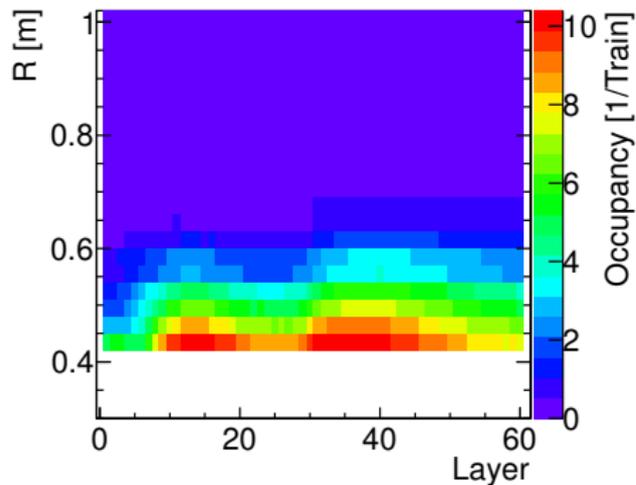


## $\gamma\gamma \rightarrow$ Hadrons

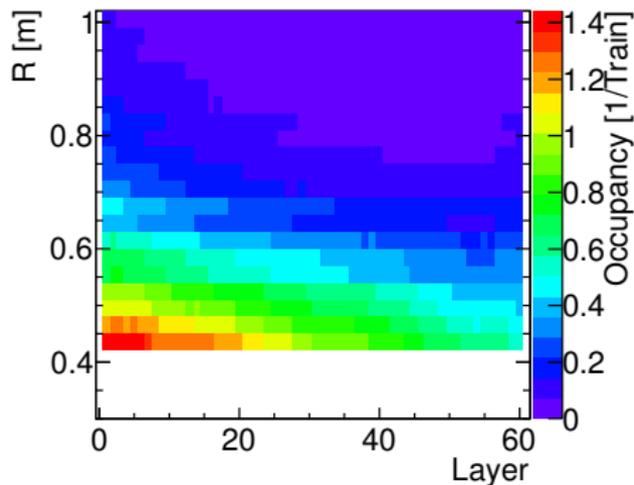


- Occupancies below 0.5: Less than one hit per pad and train

## 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