CLIC Background Studies for Vertex and FTD Optimisation

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September - 2011

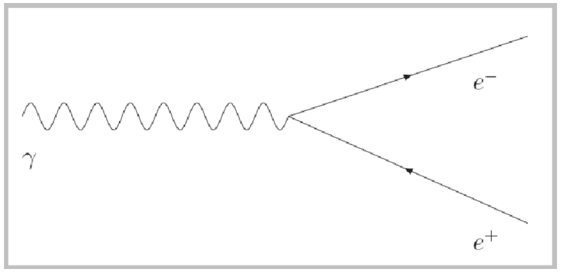
Outline

- Layout Simulation studies for the vertex and tracking region.
  - Previous studies of background with ILC configuration in a CLIC concept showed the need of redesign the vertex and tracking region.
- Background studies for high sensitive detectors.
  - Background studies were performed to obtain variations in occupancies due to the characteristics of the different technologies.

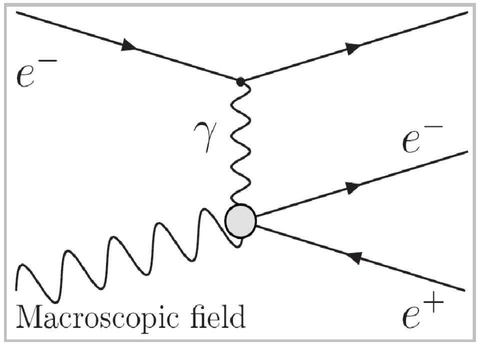
Sources

- Background sources
  - ✗ Coherent pair production: Higly boosted along the beam axis.
  - ✗ Trident Cascade: Higly boosted, run away to the beam pipe.
  - ✓ **Incoherent pair production: dominant in Vertex and FTD.**
  - ✗ $\gamma\gamma \rightarrow$ hadrons: dominant in outer detectors.

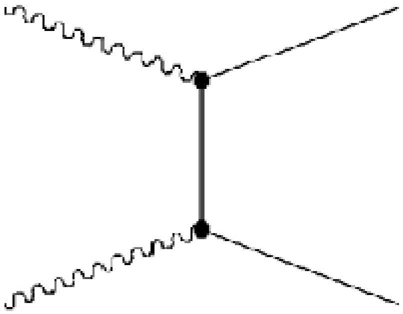
- Coherent pair production: Real photons emitted from one of the beams can turn into electron-positron loops.
- Trident cascade: Virtual photons emitted from one of the beams can convert to electron-positron pairs.
- Incoherent pair production: Electron-positron pairs can be produced in the collision of two photons emitted from the electron/positron beams.



Coherent pairs.

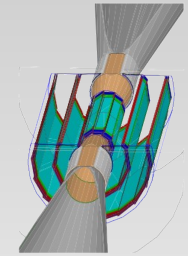


Trident Cascade.

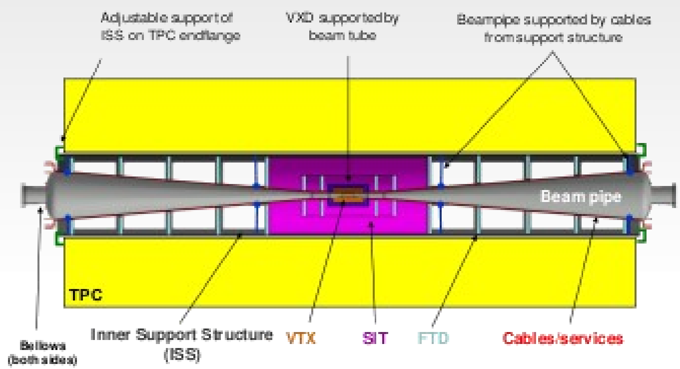


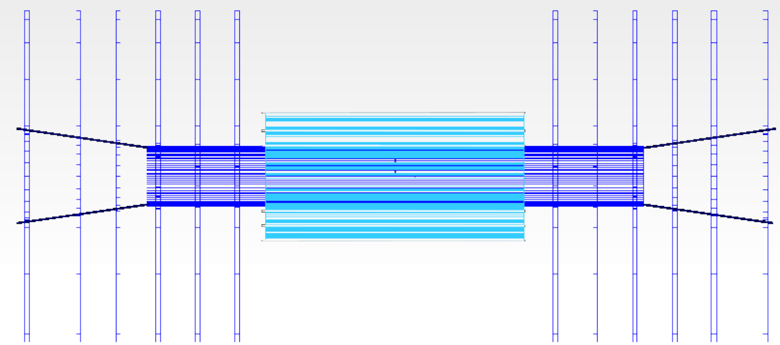
Incoherent pairs

CLIC-ILC Vertex and FTD layout



- VERTEX in ILC and CLIC: 3 double layer.
- FTD
  - In ILC: 7 disks
  - In CLIC:11 disks, 3 innermost double disks and 5 extern disks.





ILC				
VERTEX		FTD		
Radius [mm]	Ladder Length [mm]	Inner Radius [mm]	Outer Radius [mm]	Z [mm]
16,00	125,00	39,00	164,00	220,00
18,00	125,00	49,60	164,00	371,30
37,00	250,00	70,10	308,00	644,90
39,00	250,00	100,30	309,00	1046,10
58,00	250,00	130,40	309,00	1447,30
60,00	250,00	160,50	309,00	1848,50
		190,50	309,00	2250,00

CLIC				
VERTEX		FTD		
Radius [mm]	Ladder Length [mm]	Inner Radius [mm]	Outer Radius [mm]	Z [mm]
31,00	130,00	32,70	102,00	159,99
32,93	130,00	32,70	102,00	162,01
44,00	130,00	32,70	102,00	207,01
45,93	130,00	32,70	102,00	208,99
58,00	130,00	32,70	102,00	255,00
59,93	130,00	32,70	102,00	257,00
		46,89	175,00	382,11
		79,42	320,00	665,05
		125,53	320,00	1065,96
		171,66	320,00	1467,11
		217,77	320,00	1868,00

ILC FTD covers θ=5-36 deg, CLIC covers θ=6.6-32.5 deg

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ILC – CLIC Occupancies

ILC Occupancies

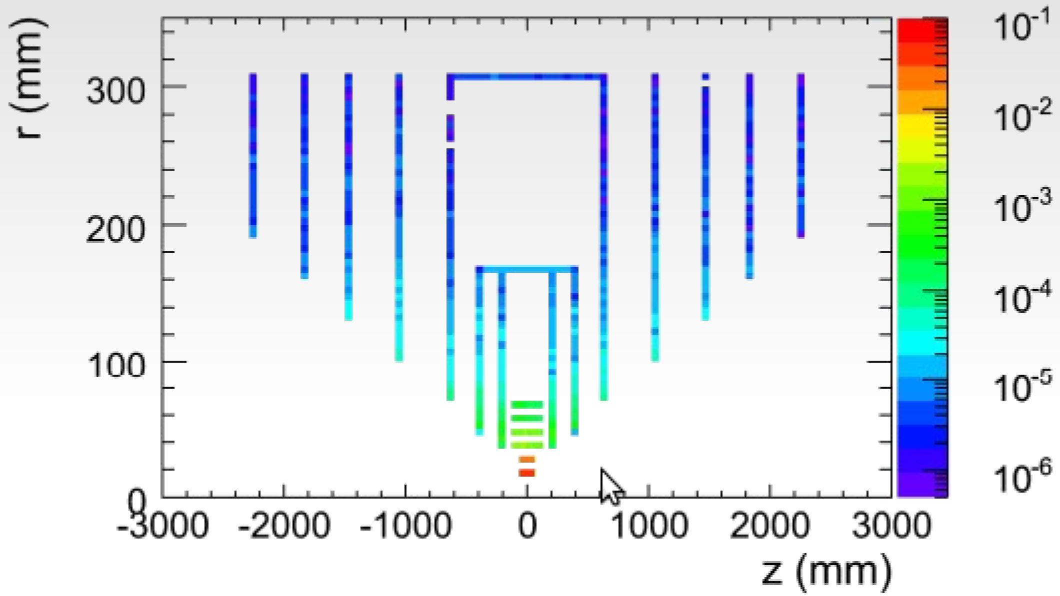
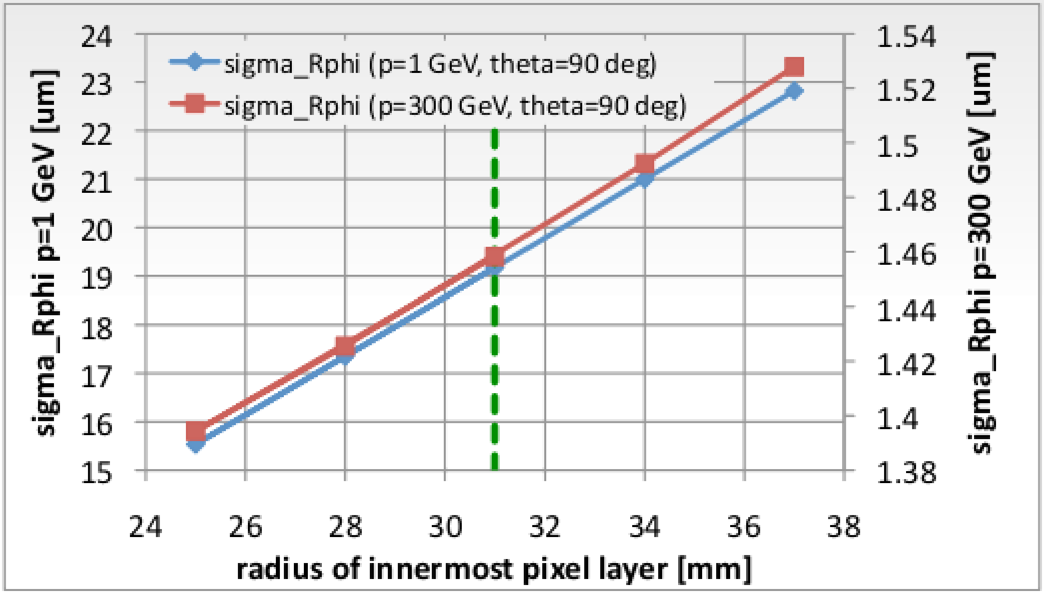


FIGURE 6.7-10. Distribution of the background hit densities on the inner silicon detectors (VTX, SIT, FTD) in units of [hits/mm^2/BX].

CLIC VXD Occupancy: $3.3 \cdot 10^{-2}$ hits/mm^2 in the first double layer. Moving to 31mm the first layer we recover the same occupancy than ILC.

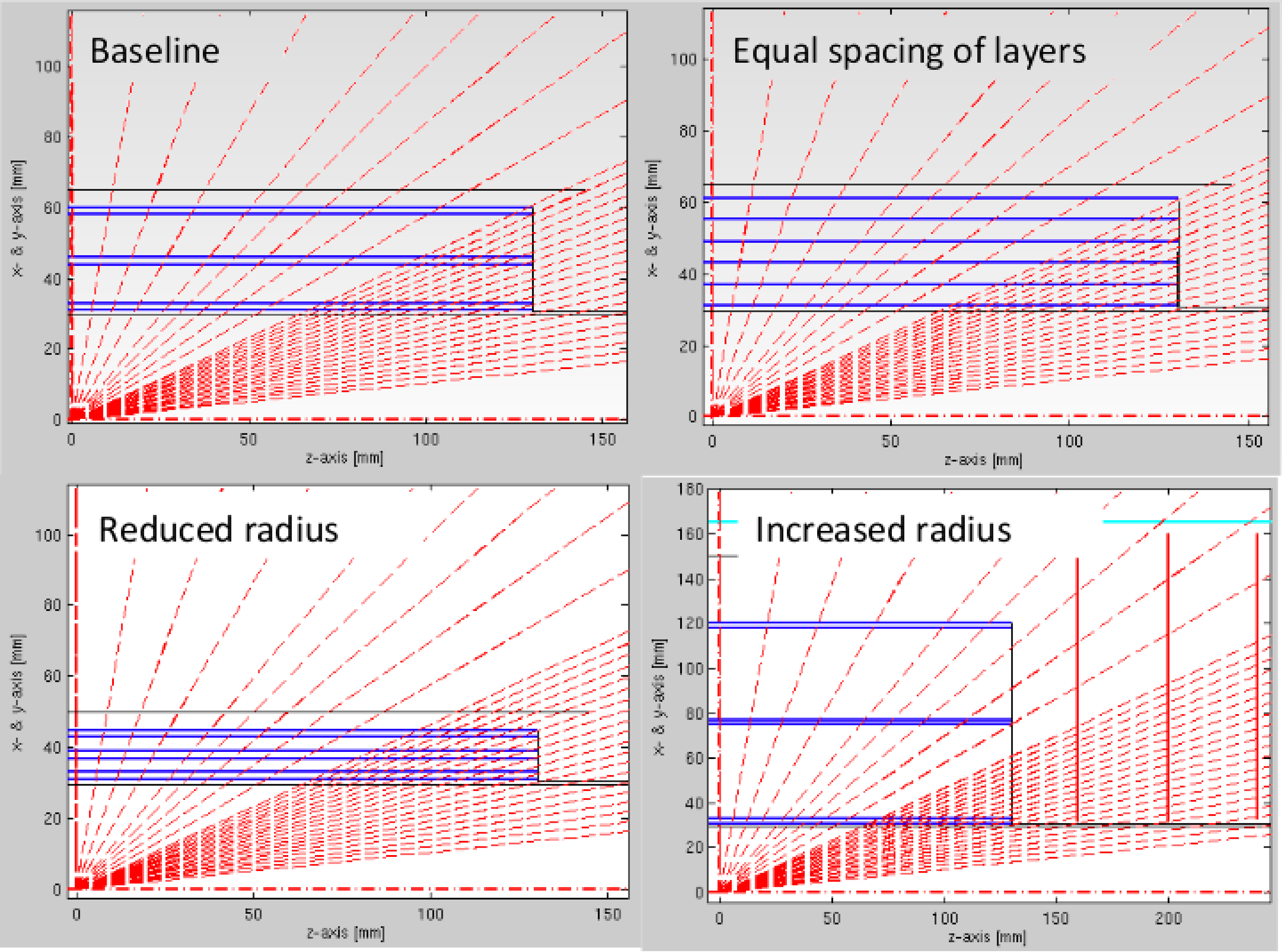
Distance to IP

Impact parameter resolution $\sigma_{R\phi} = \sqrt{a^2 + \frac{b^2 \mathrm{GeV}^2 \sin^3\theta}{p_T^2}}$, with $a \approx 5\mu\mathrm{m}$ and $b \approx 10\mu\mathrm{m}$.



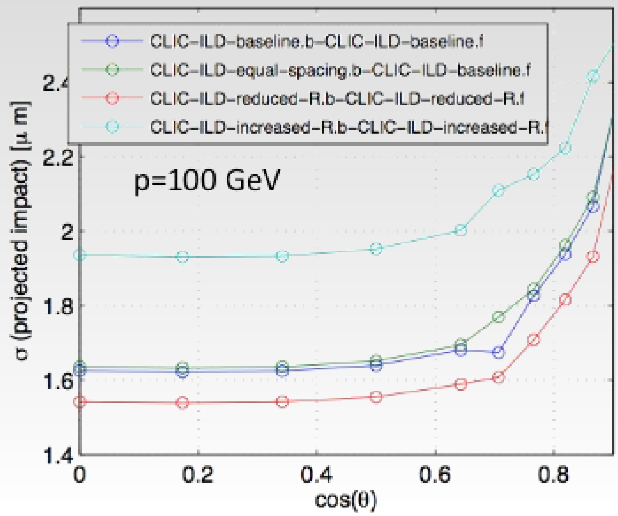
With the first layer of vertex detector at 31mm, *b*=20um and *a*=1.46um.
a is inside the requirements but b is almost doubling the value.

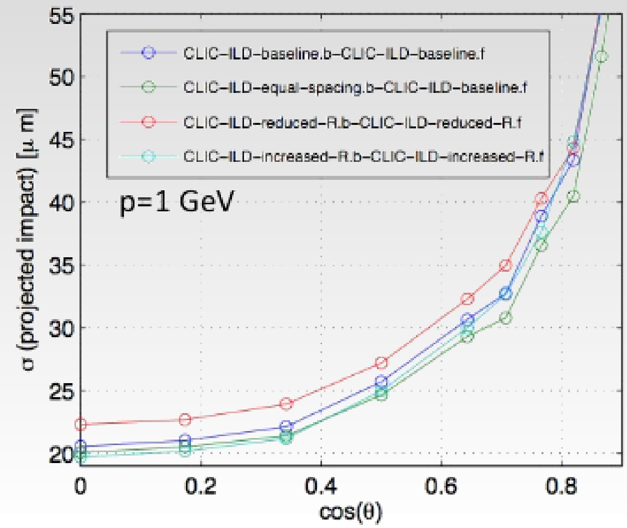
Radial arrengements for radial barrels



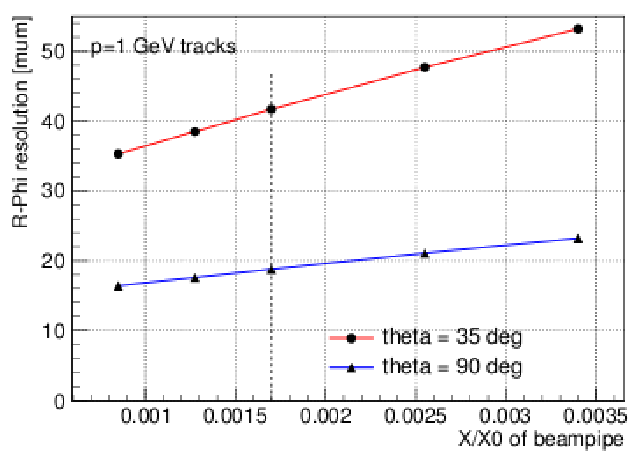
Transverse impact paramenter resolution

Varying the radial arrengements of the vertex layer barrel.

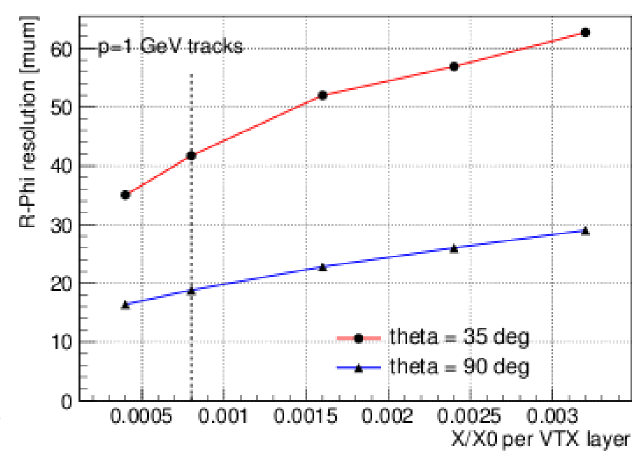




Varying the material inside a) the beam pipe and b) the vertex barrel pixel layers.



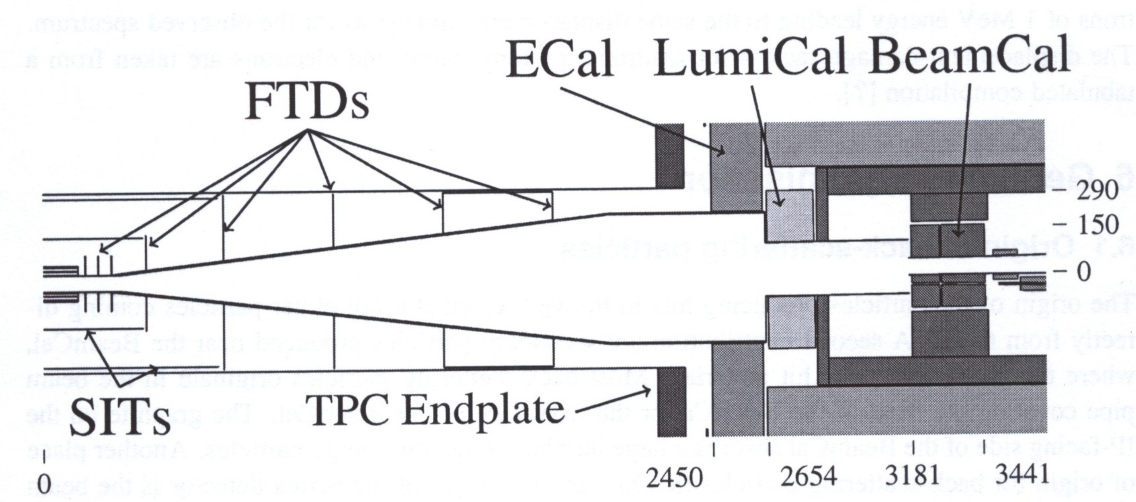
a)



b)

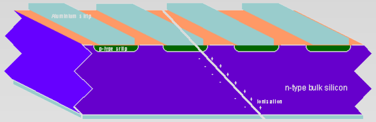
Setup

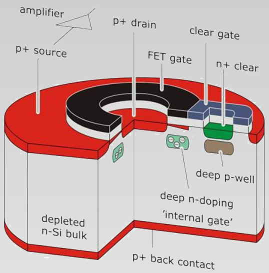
- Studies performedusing Andre Sailer studies as starting point. ilcsoft version used: v01-11. Mokka: v07-06-p02. Marlin: v01-00.
  - Geant4-based full Detector Simulation
  - Geometry: CLIC_ILD_CDR
    - FTD composed by 3 double disks and 5 single disks far from the vertex detector. The 3 innermost disks with pixels, the other 5 with Si-strips.
  - Physics List: presents results with QGSP_BERT_HP, but another physycs list were used.
  - Incoherent Pairs/BX: 3.1e5 particles
  - Threshold energy for Hit: 0eV-3.6KeV
  - RangeCut: 5um-1um



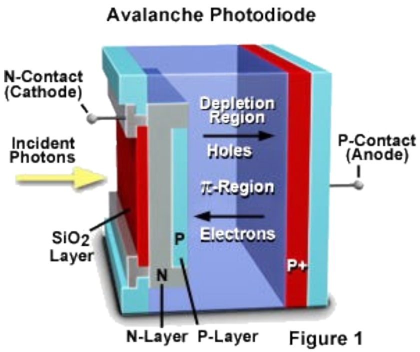
Andre Sailer talk. Radiation Levels and Occupancies. Wednesday in the session about Simulation / Detector Performance / Reconstruction + Detector Integration

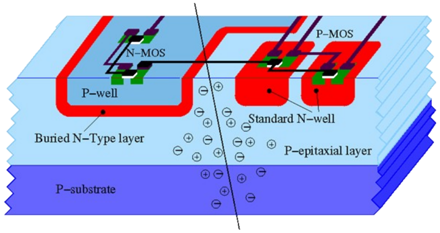
Technology dependence





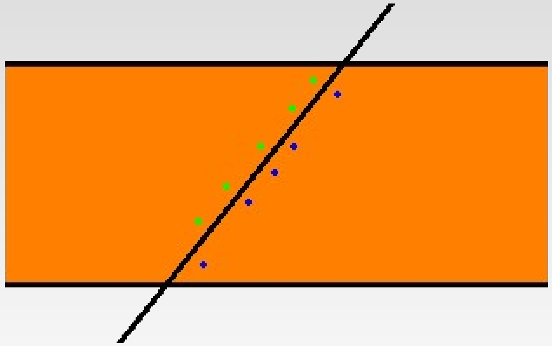
- Studies of background to know the occupancy of the detectors don't take into account any special technology.
- Different types of technology present different energy threshold. From single electron to 400e.
- Different technologies present different sensitive thickness. From 1um to 200um.
- Different detection threshold and sensitive thicknes could mean different occupancies in the detector.
  - ↑ Sensitive thickness → ↑ Hit Density by clustering.
  - ↑ Detection threshold → ↓ Hit Density by losting hits without enough energy deposition.





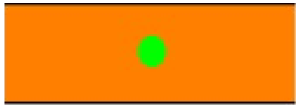
Mokka Simulations

- In standard simulations in Mokka every particle leaves a single hit

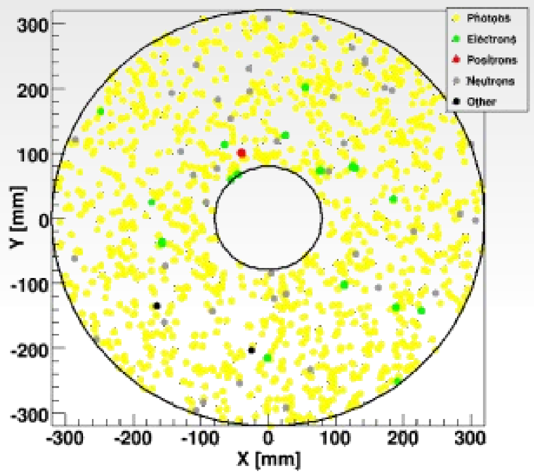


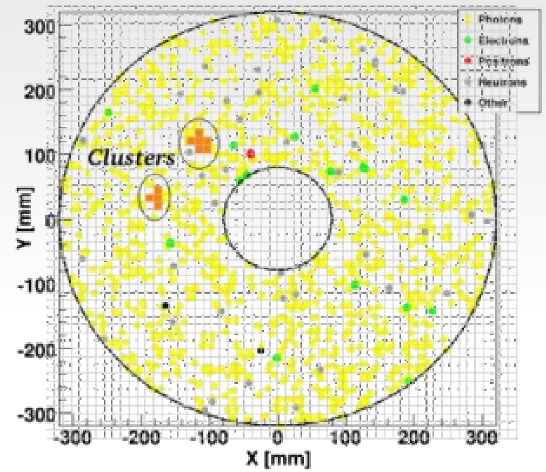
Mokka normally integrate the whole track inside the layer in one hit

Mokka



Taking into account the technology

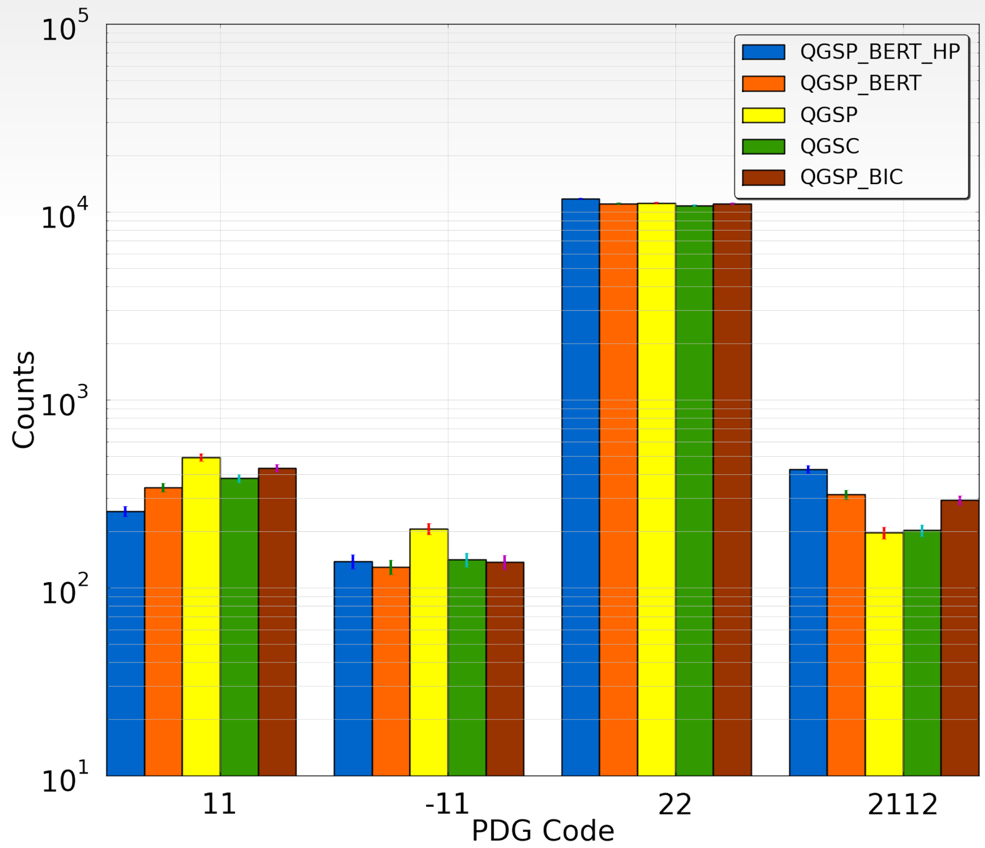




- DetailHitStoring permits store a detailed simulation with each matter-radiation interaction in the different layers.
  - Posterior data processing to integrate energy in each pixel/cell
  - Divide the disk in channels of 25x25μm^2
  - Vary sensitive depth (1-200 um) and threshold (single-400 electrons).
  - Hit density calculated by energy threshold and sensitive thickness.

Particles/BX

- Studies carried out using different physics list: QGSP, QGSC, QGSP_BERT, QGSP_BIC, QGSP_BERT_HP
- Threshold energy for Hit: 0eV; Range Cut:5um

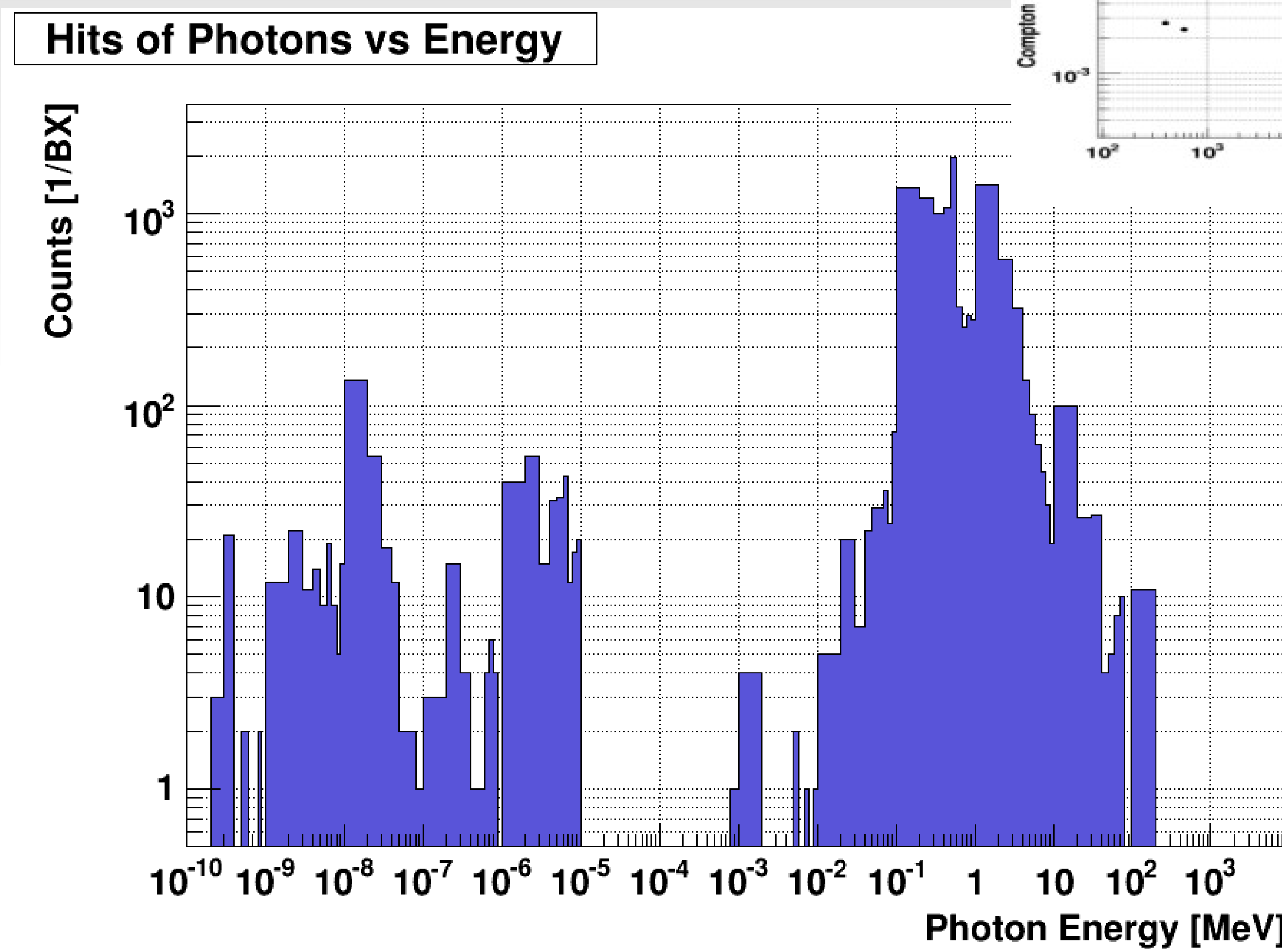


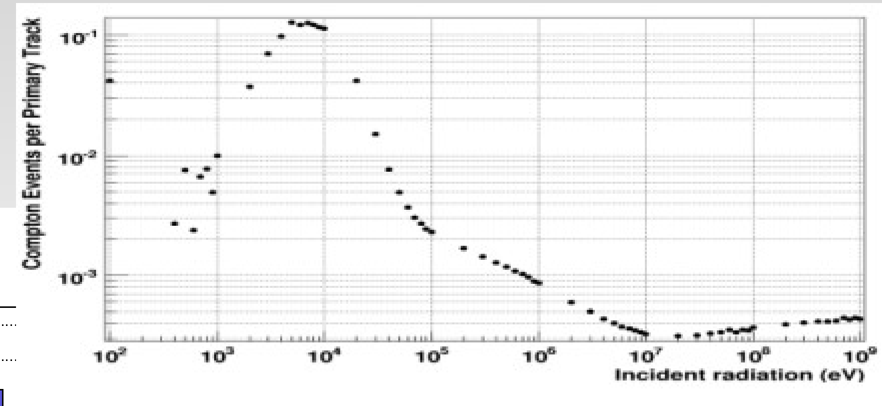
PDG Code	
11	Electrons
-11	Positrons
22	Photons
2112	Neutrons

~10^4 photons
~10^2 charged particles

Photon distribution. Interaction with the FTD.

Looking for a possible problematic radiation source for detectors with low energy threshold.



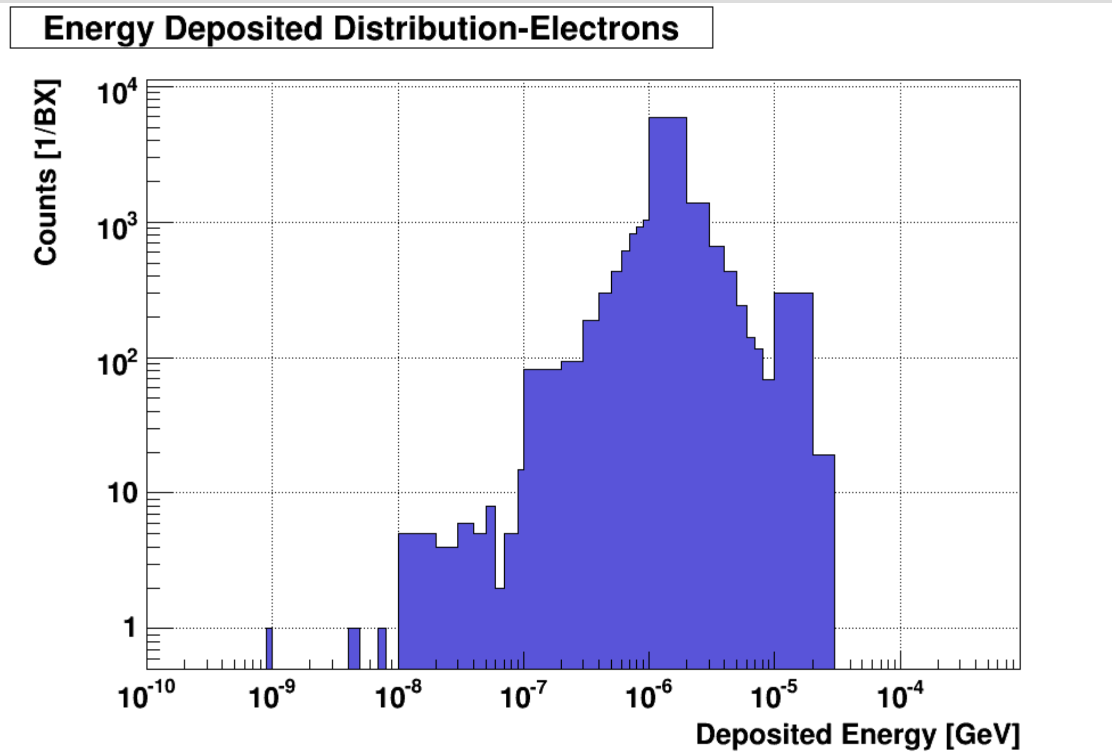


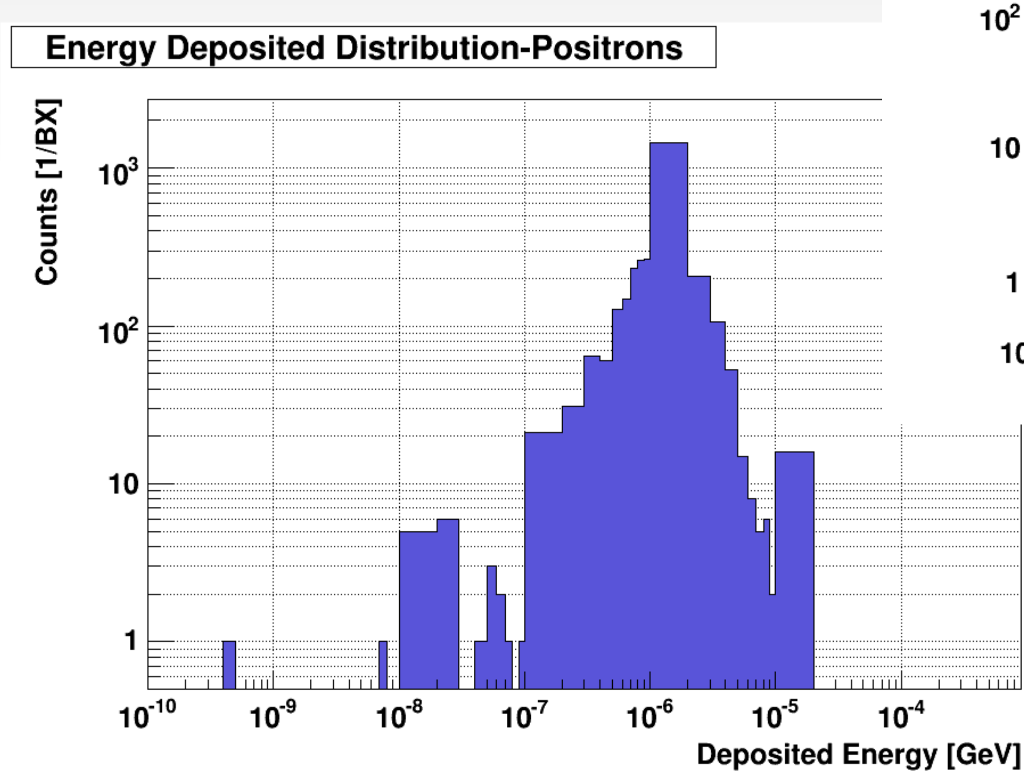
- **10 photons of 10^4 hit the FTD releasing ~1keV**

Detectors in FTD are transparent for photons.

Charged particle distribution and neutrons. Interaction with the FTD.

Number of hits using detailed hit storing.



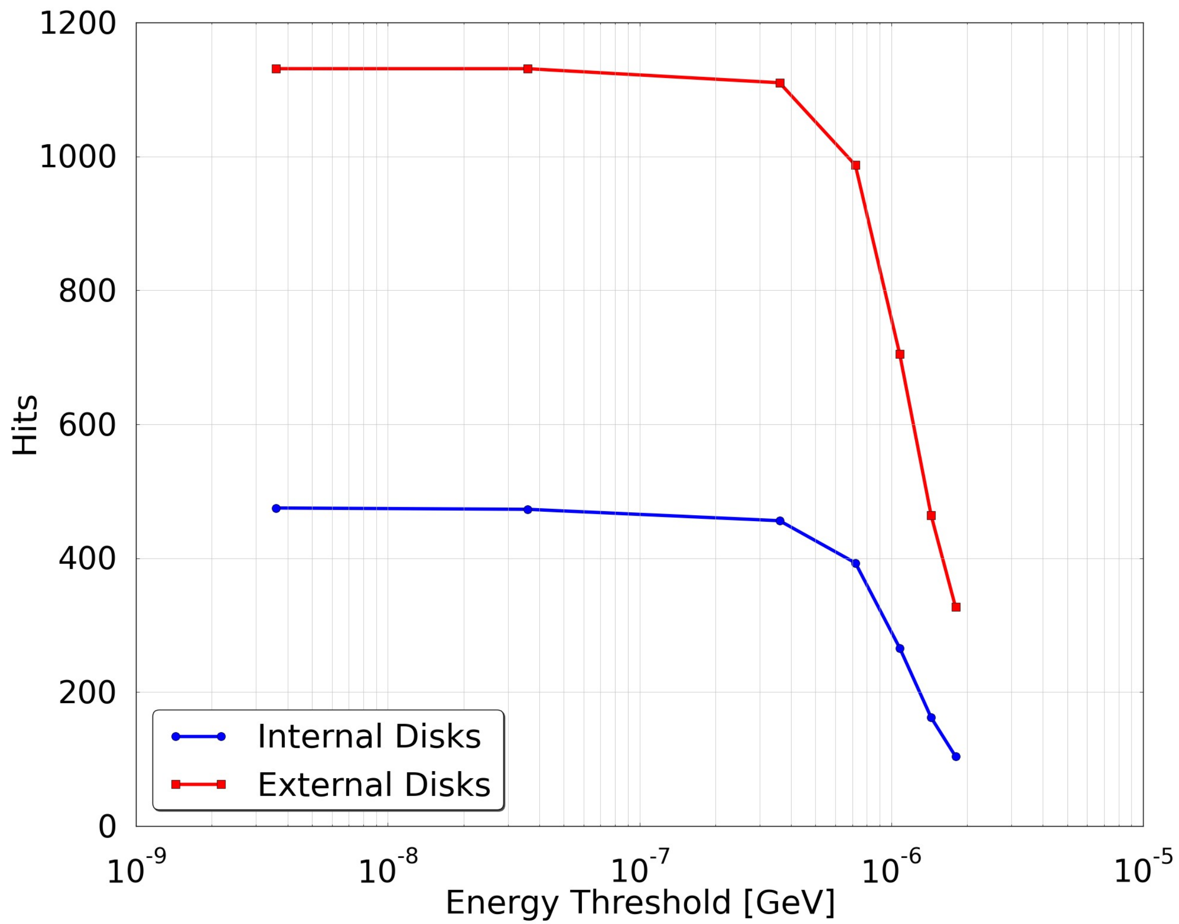


- **Maximum Step for simulation used: 5μm.**
- **Typical deposition: ~1keV**

- **Typical deposition by neutrons: 0eV.**

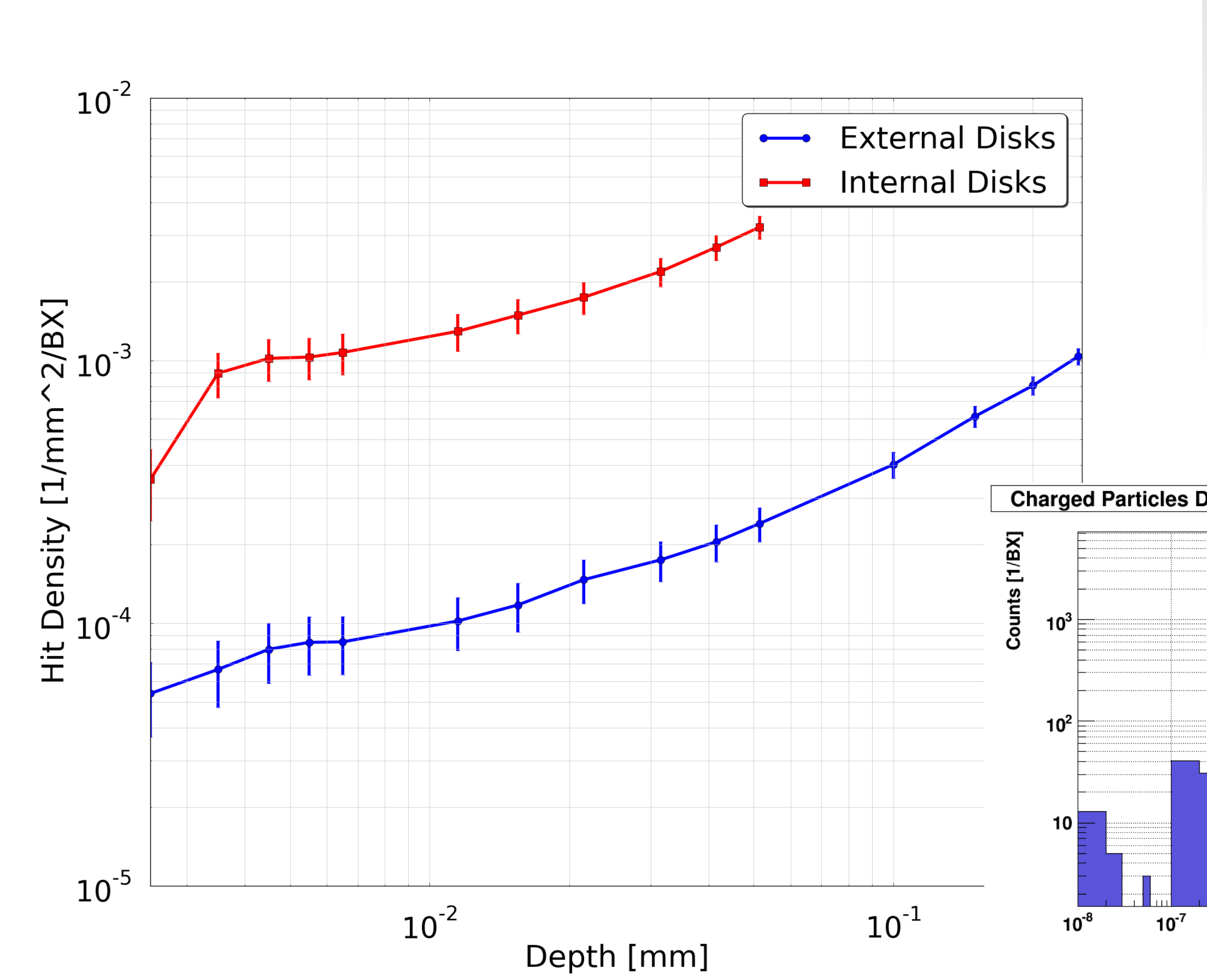
Hit vs Energy Threshold

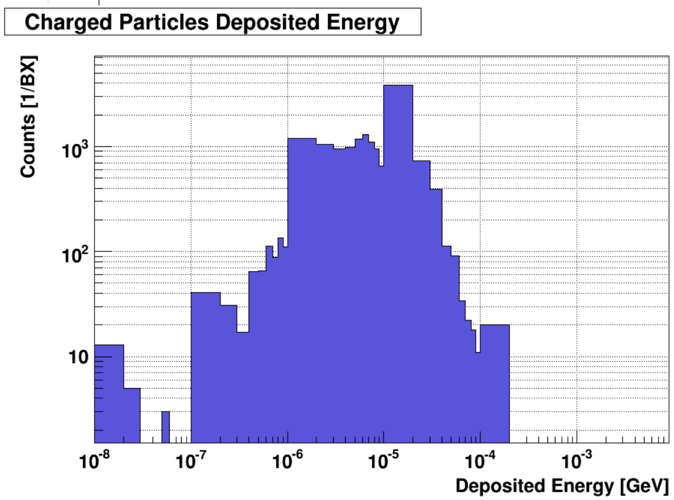
- Mean value of energy hits for internal and external disks, by its energy deposition



Varying the sensitive depth.

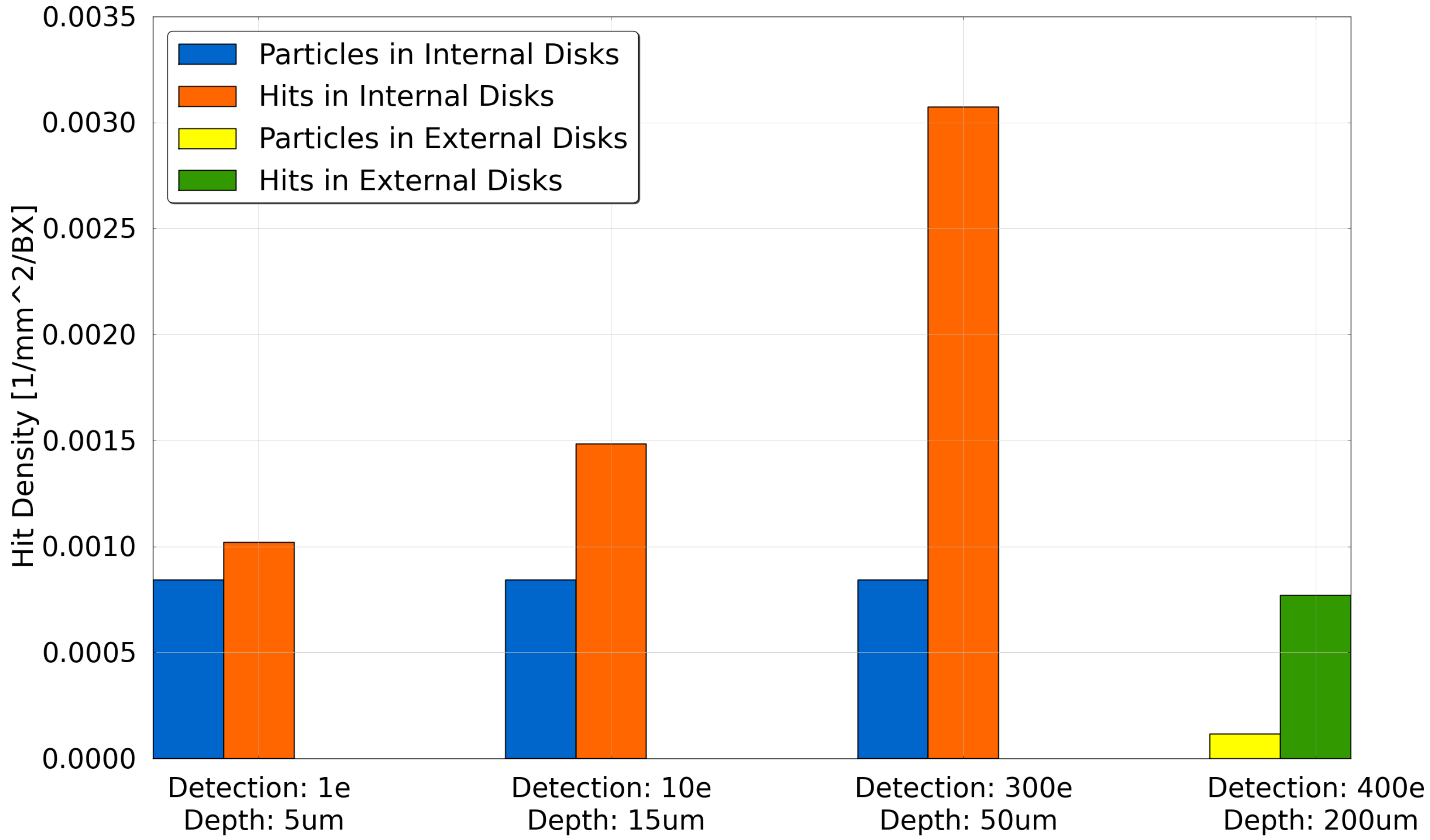
Number of hit 25x25 um² pixels increases strongly with increasing thickness of the active layer.





Some example combinations of depth and threshold.

- Thickness is more important than threshold



Conclusions

- Background studies in ILC detector with CLIC conditions were performed. To recover the same occupancies as in ILC, the CLIC vertex and tracking regions had to be move.
- As a result, the geometry part of the impact parameter resolution is inside the requirements, but the multiple scattering term increase to 20 um.
- Using the new layout, background studies to take into account technology were performed.
- Particular properties of each technology, as sensitive thickness and threshold, can cause an important variation in occupancies.
- Simulations don't show any radiation source capable of ”blinding” technologies sensitive to single electron.

Backup.

- Photon Spectrum. Hit Time vs Energy of photon.