Mokka Studies of AHCAL Tiles Gaps and Non-uniformities

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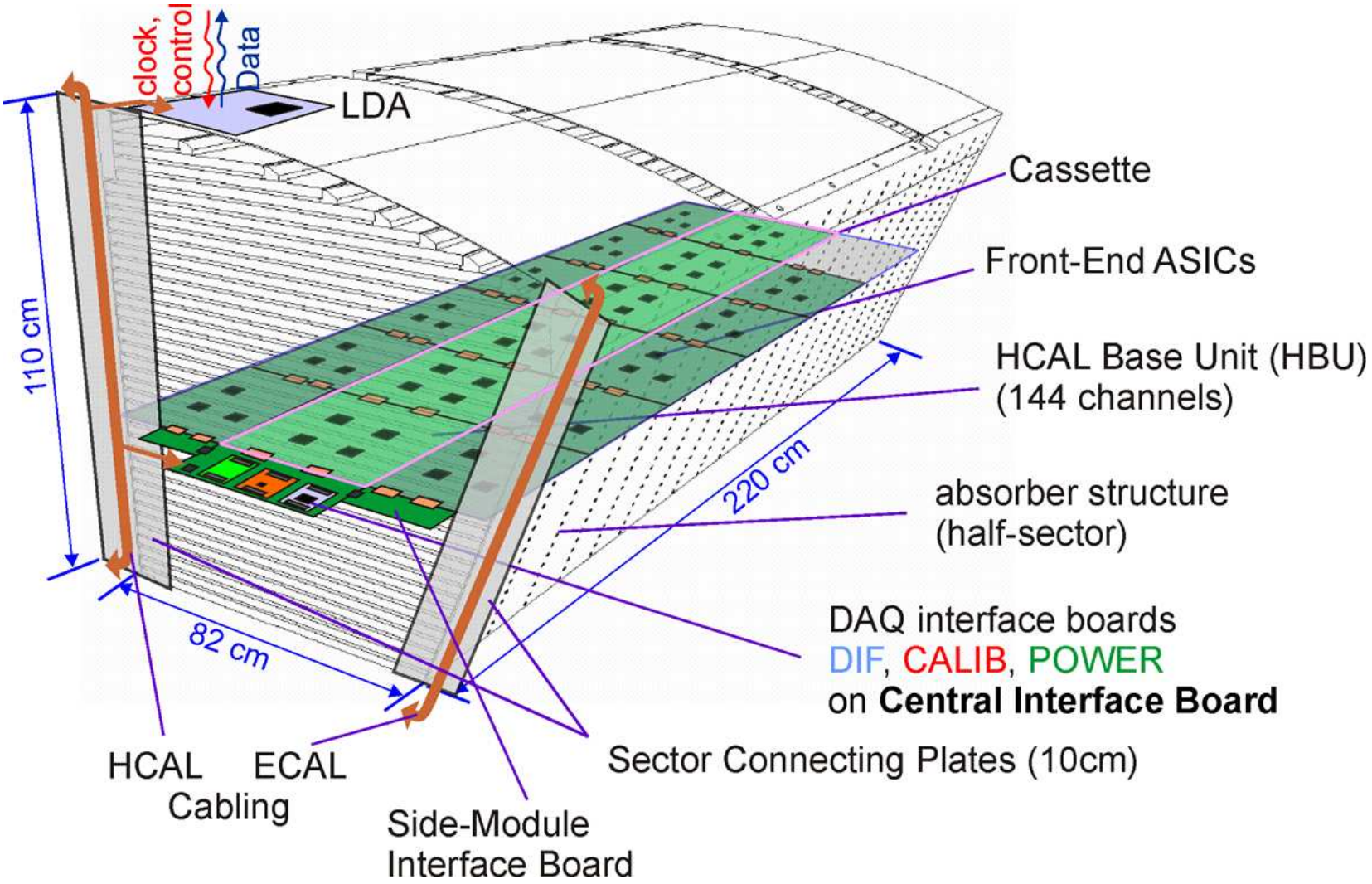
Overview

Introduction

- **Problem**: scintillator AHCAL driver for ILD has
  - virtual tiles (i.e. no separate volumes)
  - no gaps between tiles
  - no gaps between HBUs (HCAL electronic base units)
  - no simulation of tile non-uniformity
- **Theorem**:
  - Virtual vs real tiles:
    - no significant impact on physics
    - from the technical point of view, difficult to implement for the ILD AHCAL (millions of tiles, assymmetry, GEANT4 limitations)
  - Gaps between tiles and HBUs: no significant impact on physics
- (Partial) **proof**: this talk

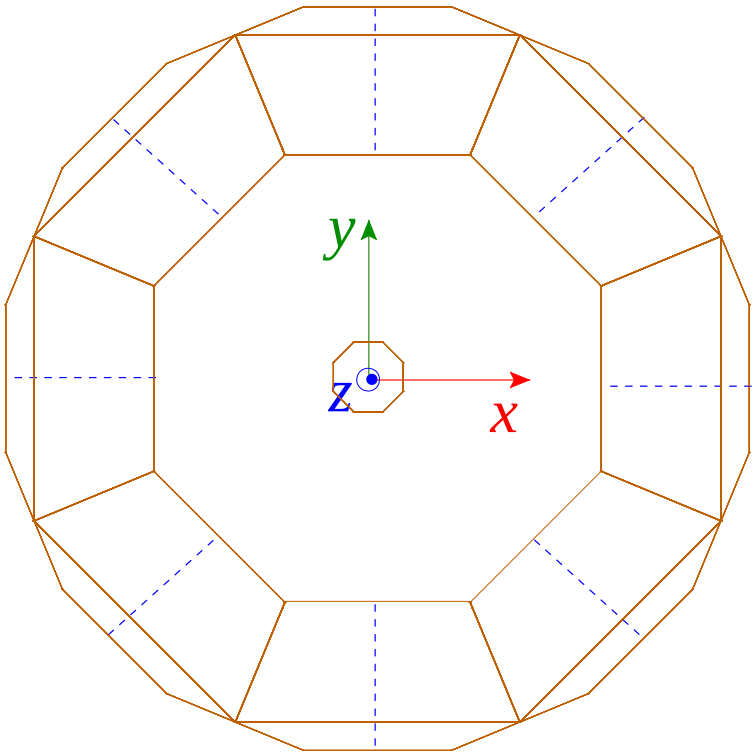
ILD Design

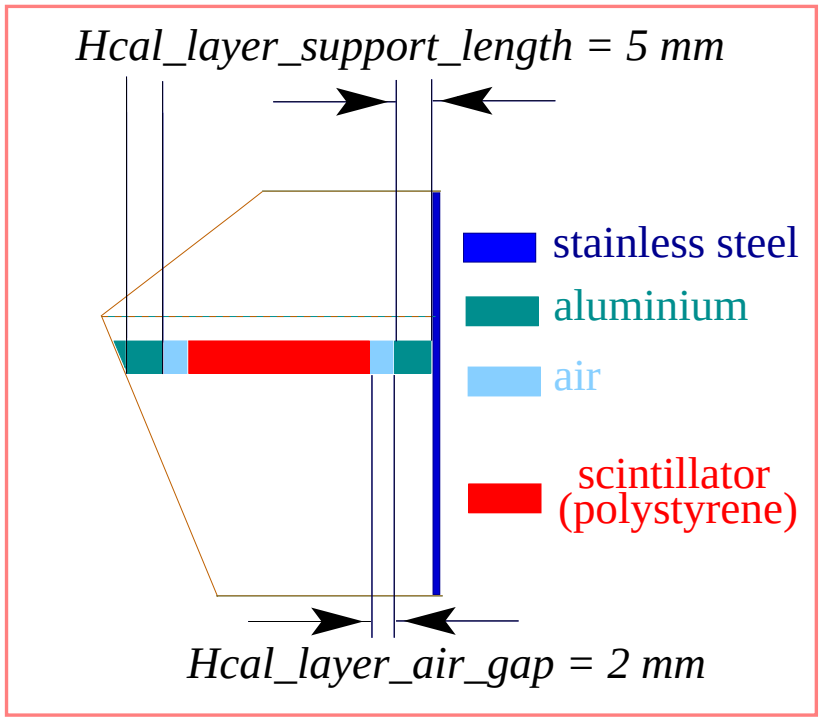
- Electronics integrated into absorber structure
- Basic eletronic unit (HBU): 36 $\times$ 36 cm^2 (144 tiles)

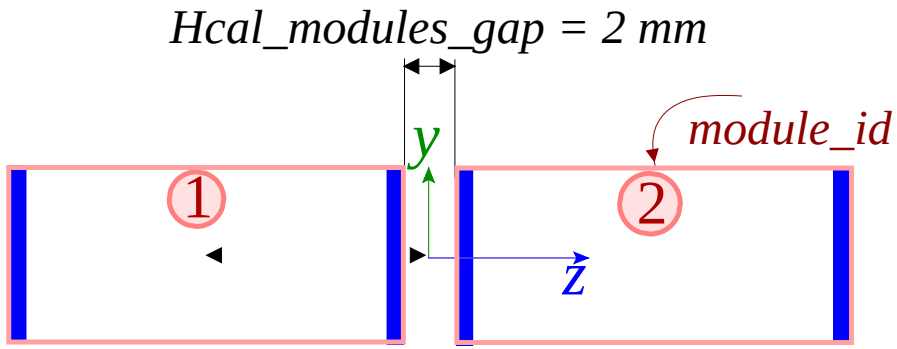


AHCAL Implementation in Mokka

- 2×8 staves, each divided in two halves in the$(x,\ y)$ plane
- Implemented: gaps between staves, gaps between modules (along z), layer support structure, air gap

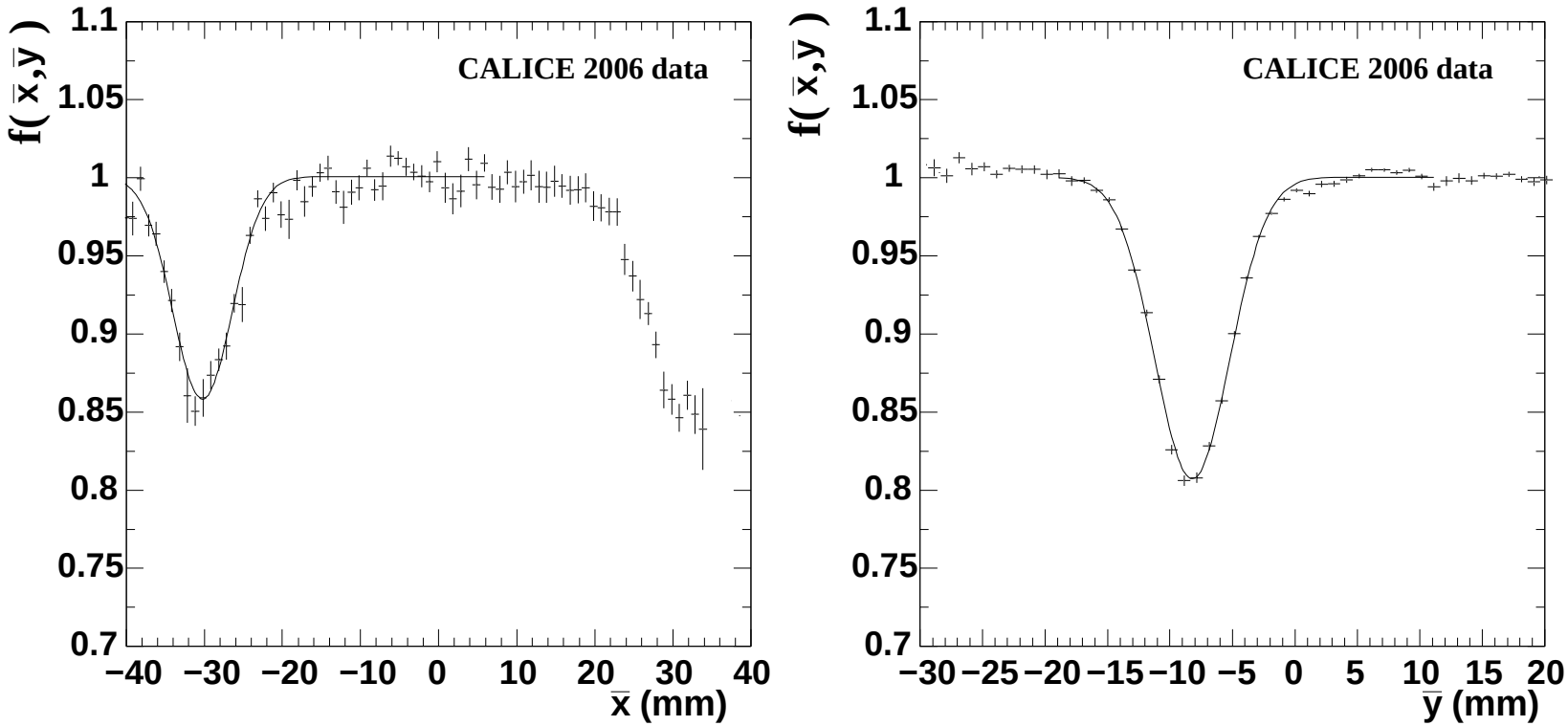






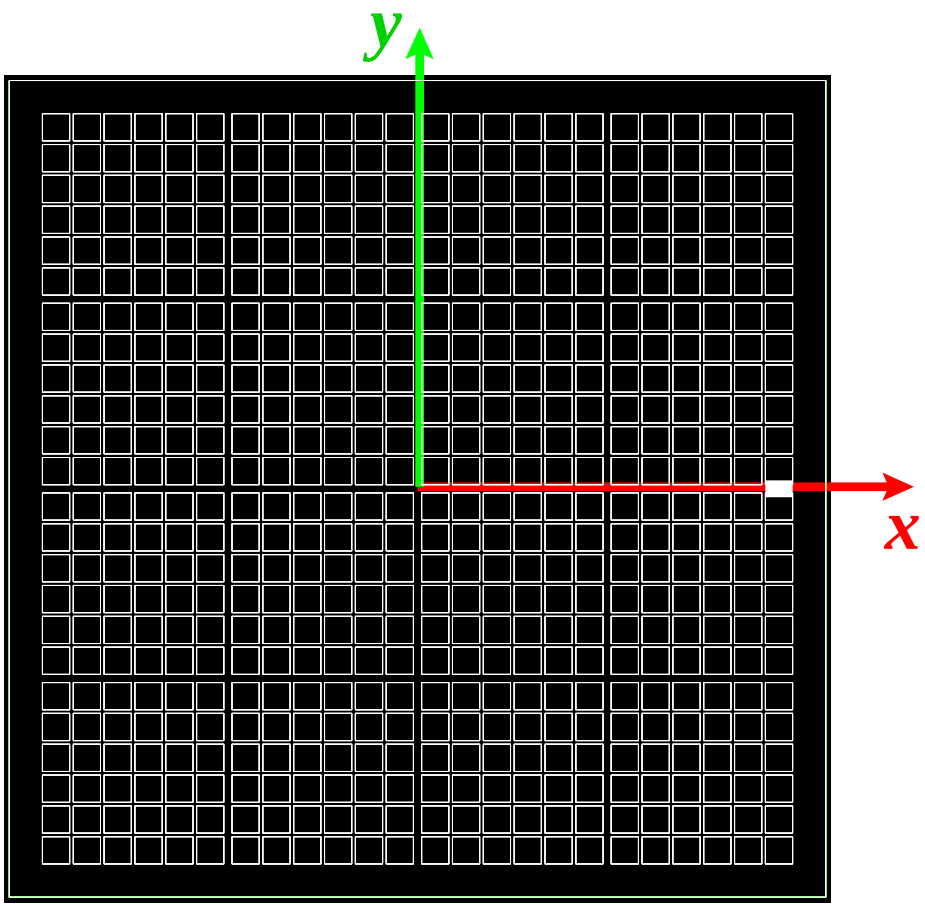
Counter-argument

- Response of CALICE Si-W ECAL to e^-:
  - inter-wafer gaps (2 mm) significant compared to transverse shower size $\Rightarrow$ degradation of detector response
  - figure: normalized response function (for a combined sample of 10, 15 and 20 GeV e^-) vs shower barycenter coordinates



- Inter-wafer gaps corrections possible on average, but not for individual events

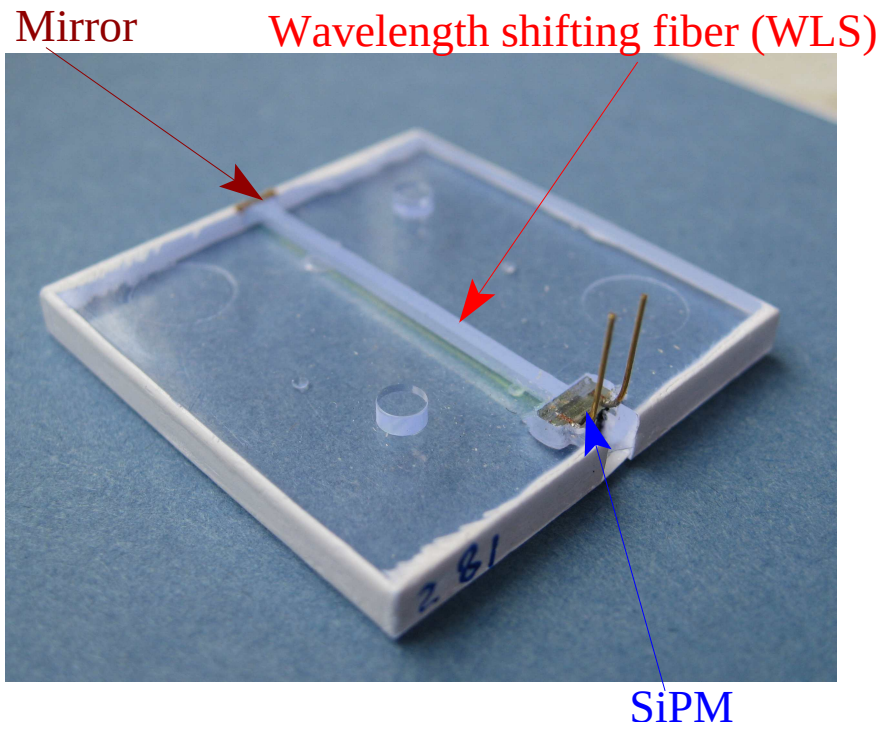
Gaps and Tiles with Wavelength Shifting Fiber (WLS): Strategy



- New Mokka driver, similar to the **test beam** AHCAL, i.e. (38 layers, 20 mm Fe absorber), but with 3×3 cm^2 tiles
- 6×6 tiles grouped to an electronic unit (HBU=HCAL base unit)
- Studies done with simulated hits only: no digitisation, no ECAL in front

Strategy - continued

- Tile and HBUs gaps: 2 sets, unrealistic (1.5 and 5 mm), and realistic (0.15 and 0.5 mm, respectively)
- Particle type: e^-, π^-, with energies 5 and 50 GeV
- Beam position scan: 30 points
- Each combination: 10000 events $\Rightarrow$ Long live NAF (batch system available for German institutes)

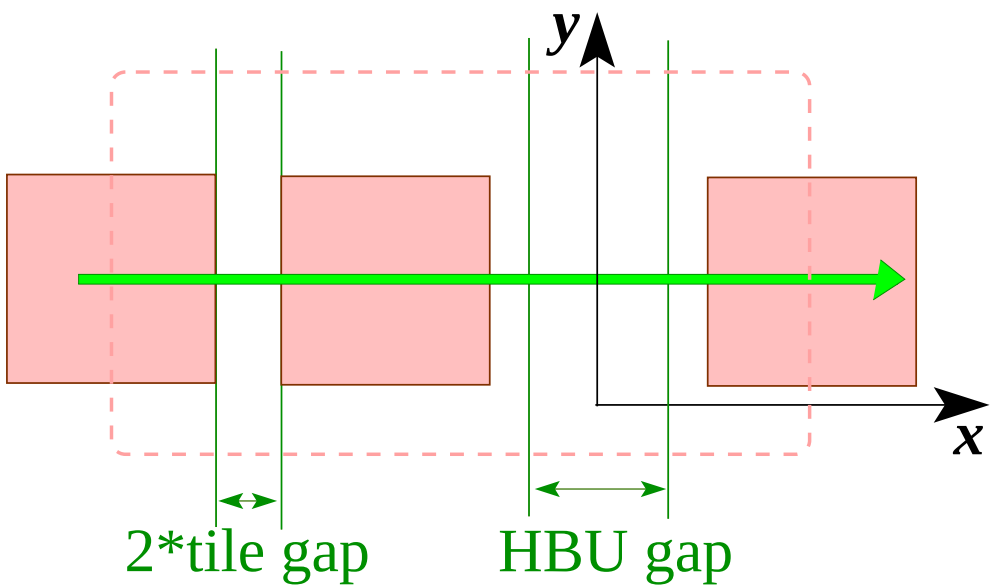


Dead regions

- Dead regions (due to mirror and SiPM cut-outs): OFF/ON
- Approximately 80% energy loss in the WLS area, according to measurements done by our Russian colleagues

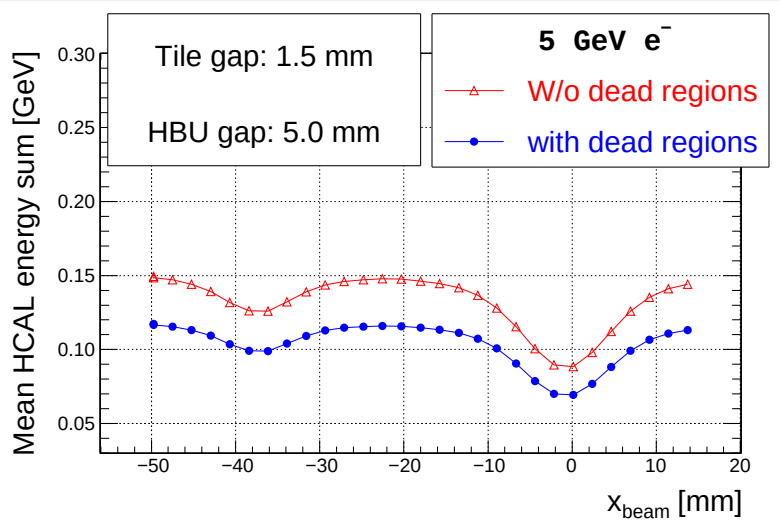
How to read the next plots

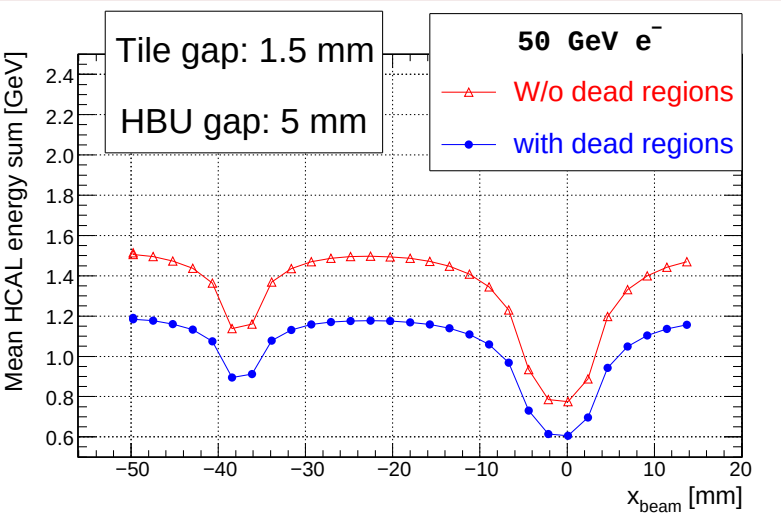
- Beam with no spread
- y_{beam}: **in the middle of the tile**
- x_{beam} from the middle of the second left tile, to the center of the first right tile (relative to the AHCAL center)
- Look at the AHCAL summed energy distribution
- Plot the mean of the histogram (no fit)



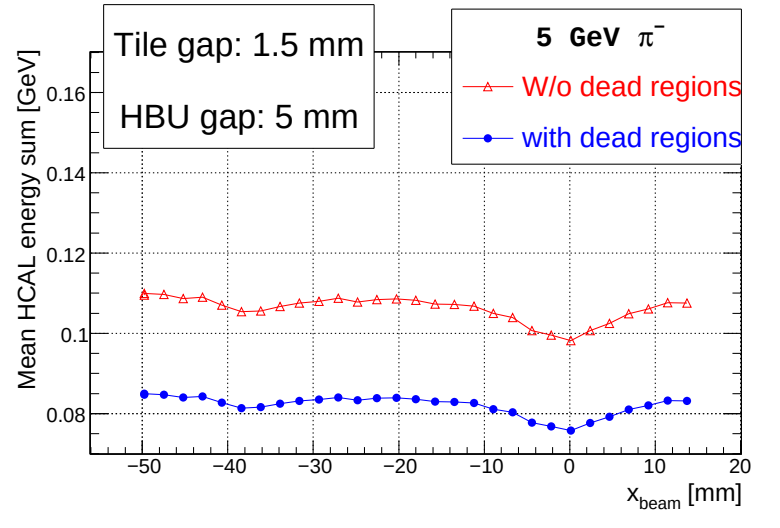
Results: UNREALISTIC gaps

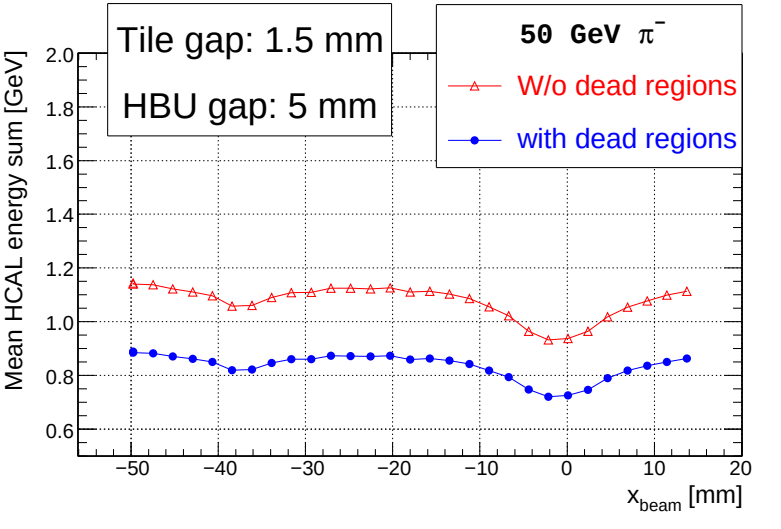
Electrons





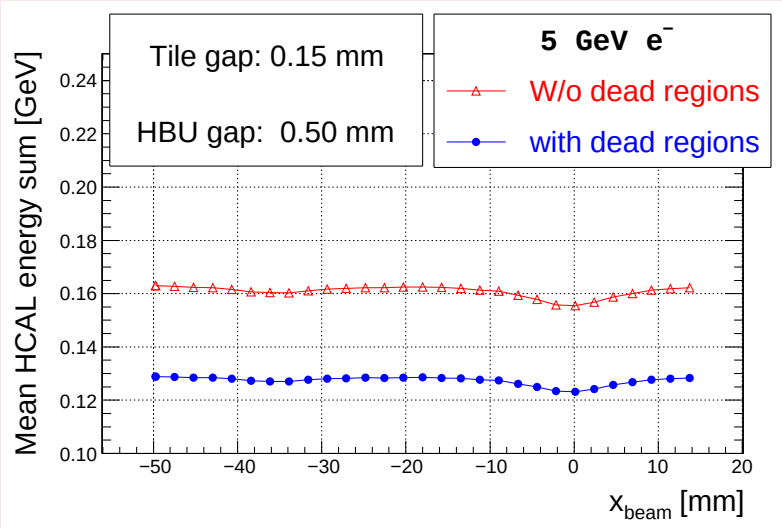
Pions

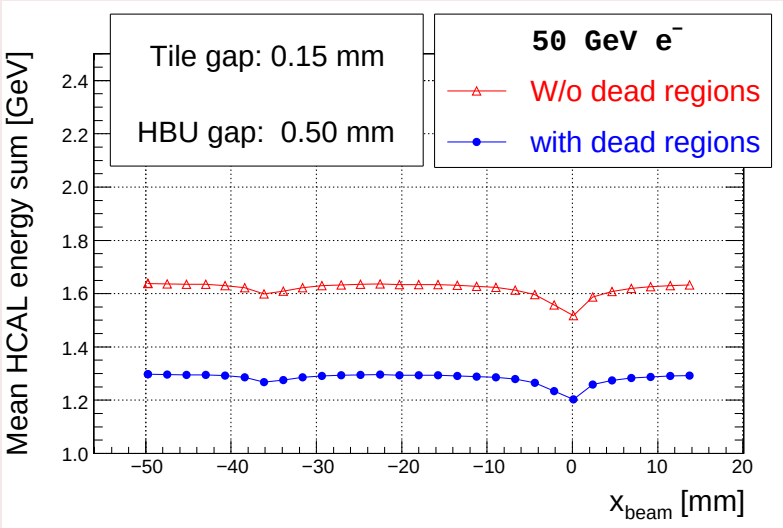




Results: realistic gaps

Electrons





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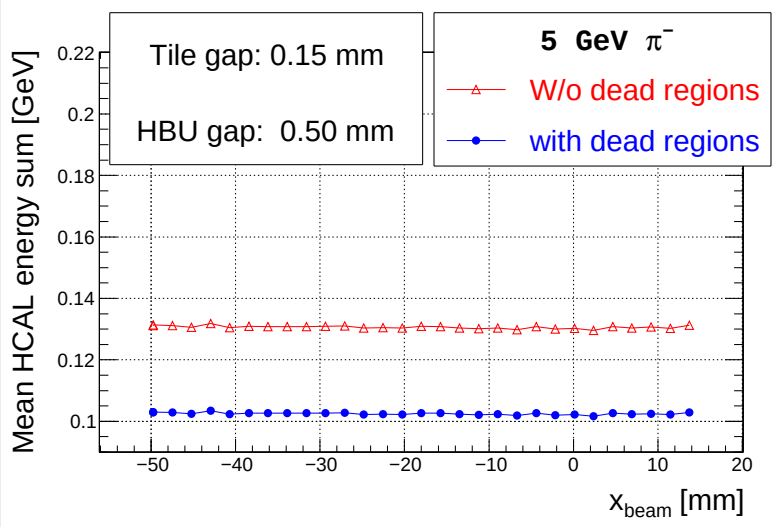
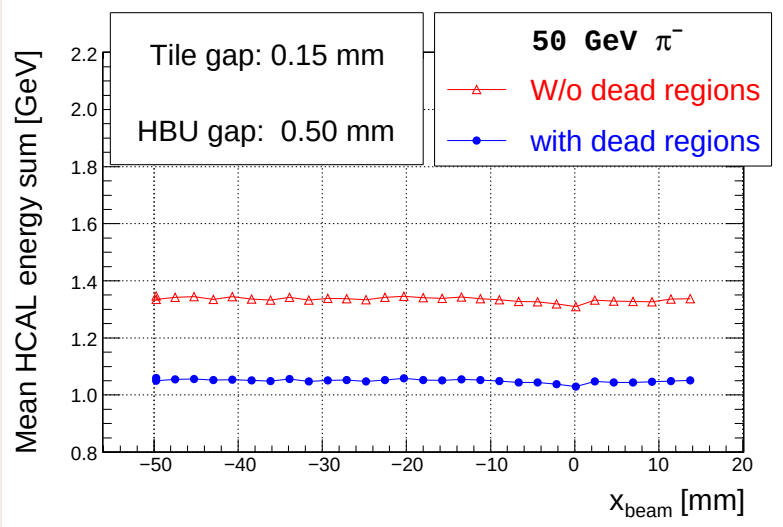
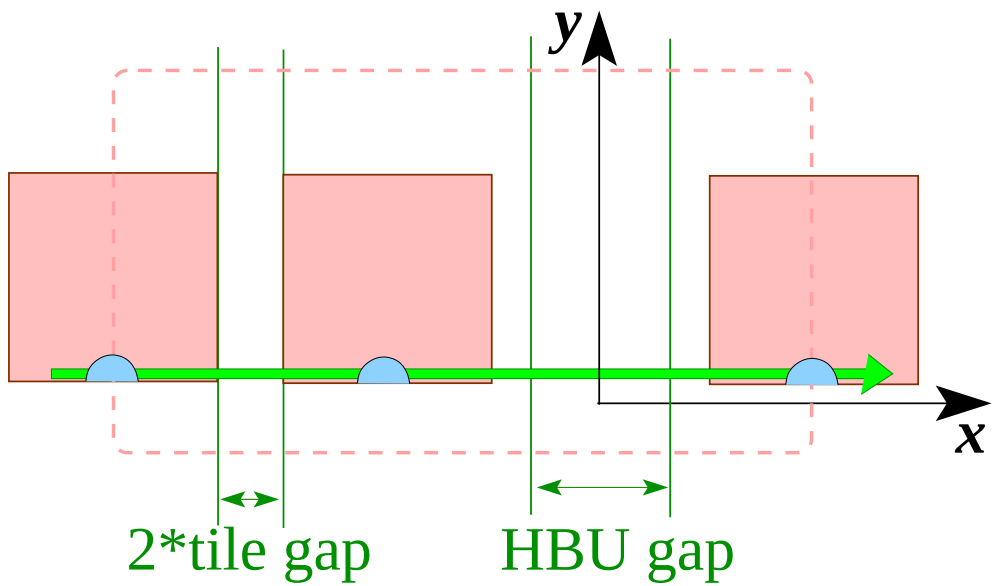




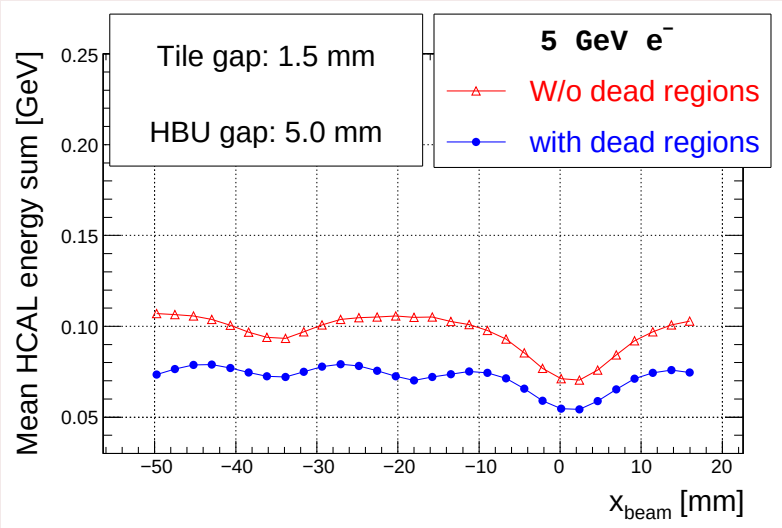
How to read the next plots

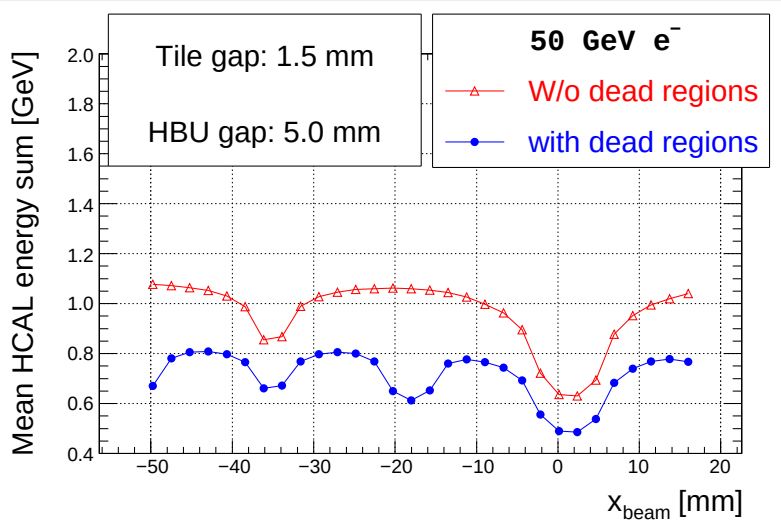
- Beam with no spread
- **SiPM cut out: 3 mm radius semi-circle**
- y_{beam}: **1 mm from the center of SiPM**
- x_{beam} from the middle of the second left tile, to the center of the first right tile (relative to the AHCAL center)
- Look at the AHCAL summed energy distribution
- Plot the mean of the histogram (no fit)



Results: UNREALISTIC gaps

Electrons





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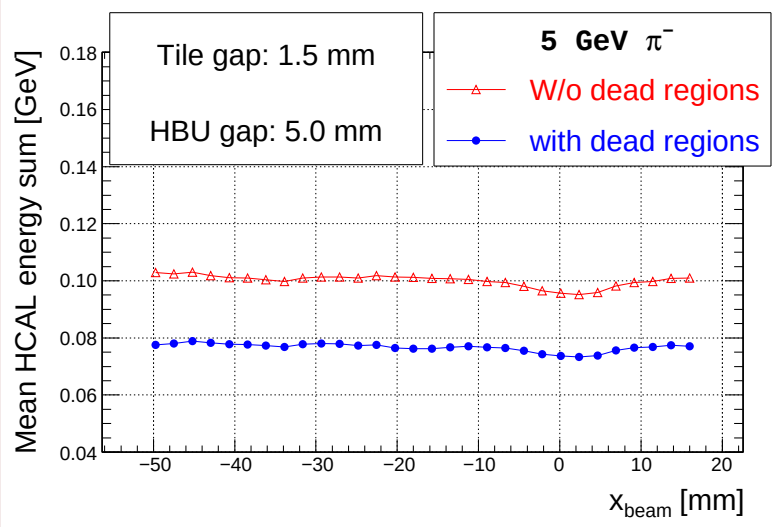
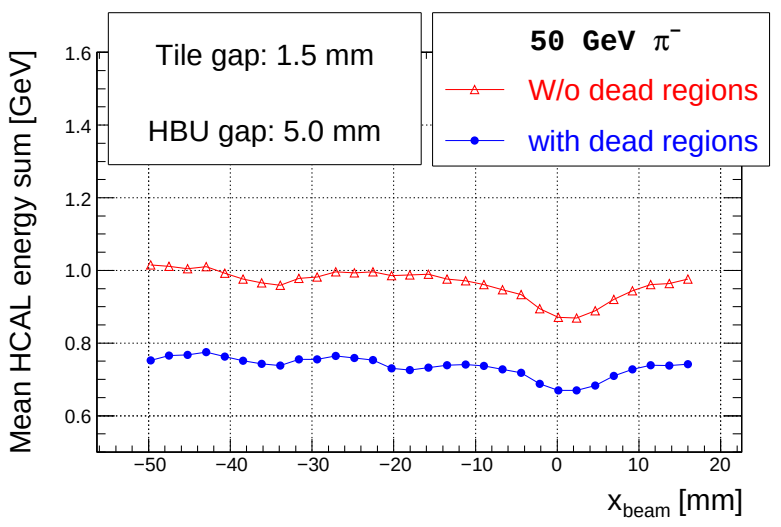
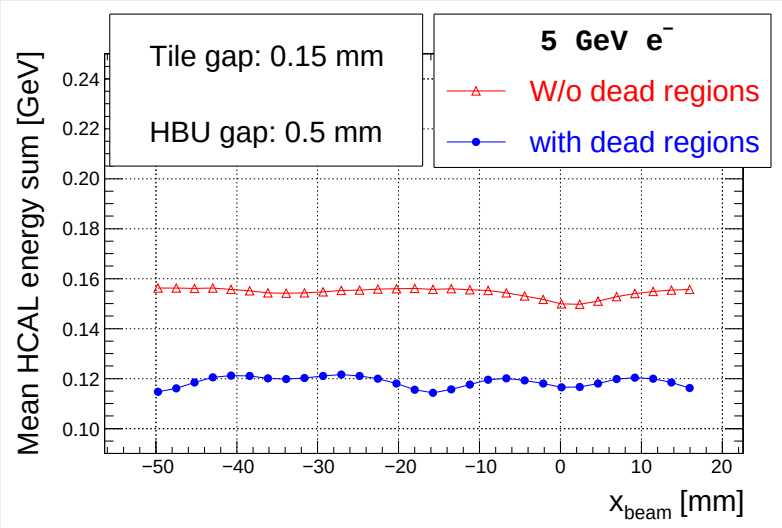
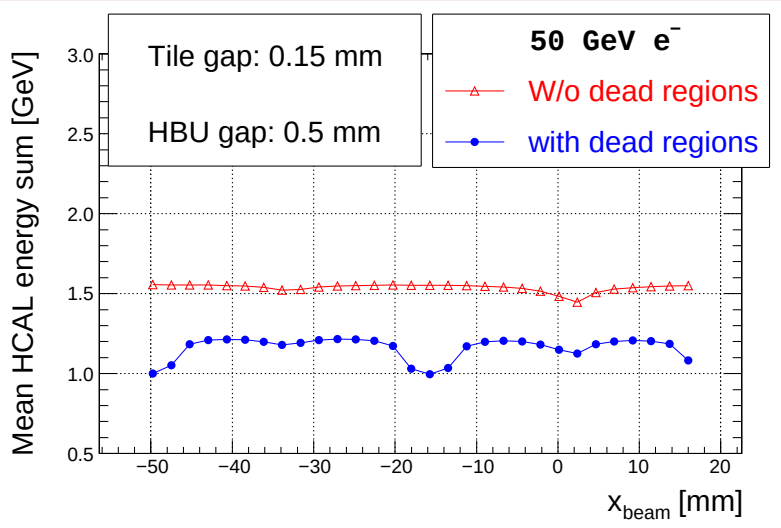




Results: realistic gaps

Electrons





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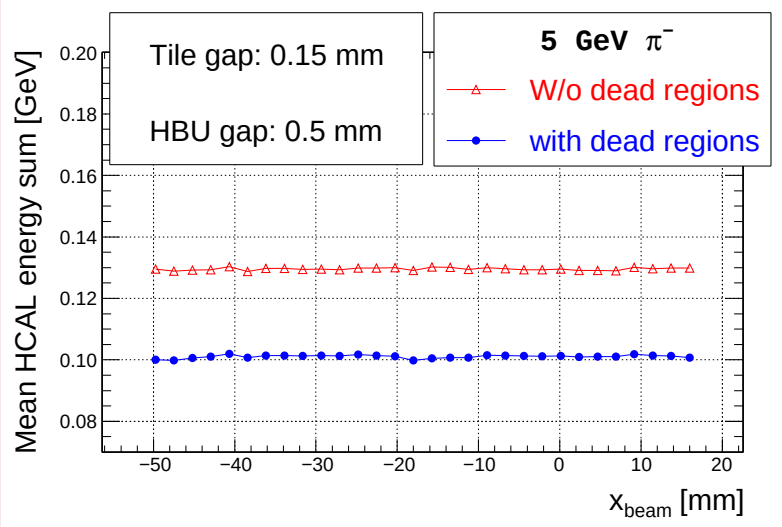
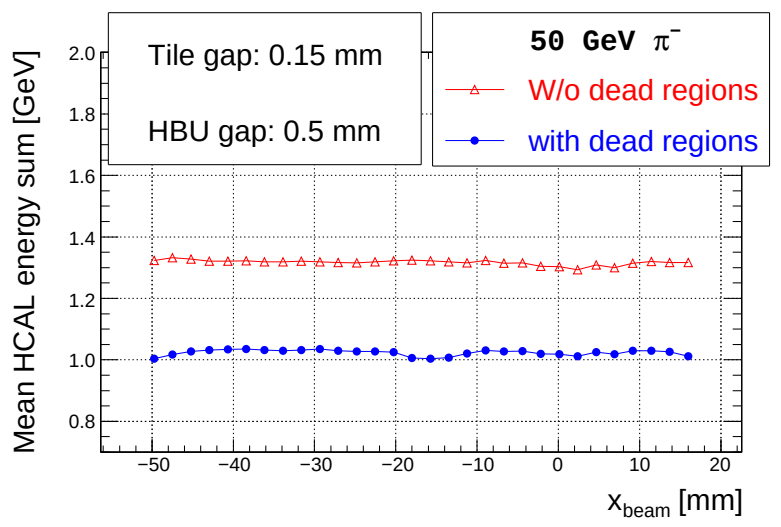


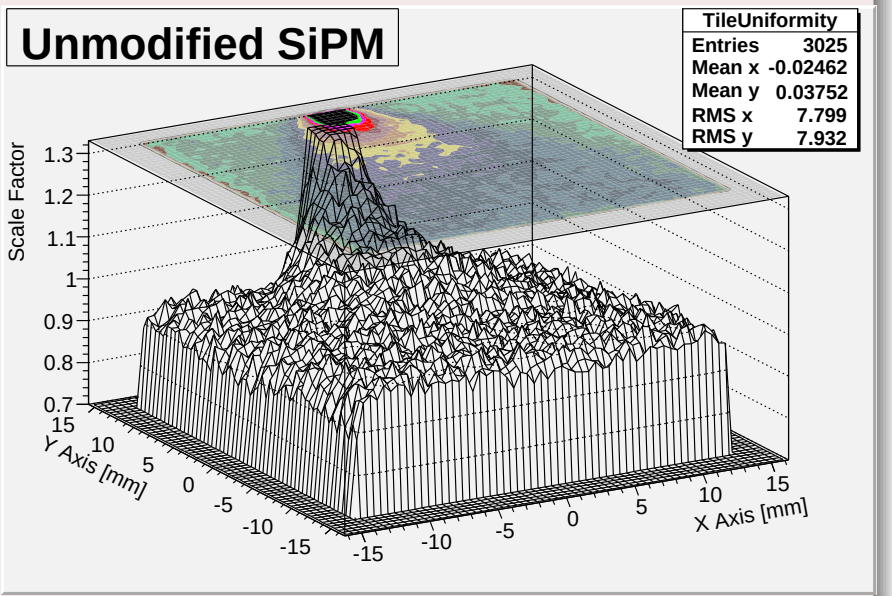


Gaps and Tiles with Direct Coupling of SiPM

- Based on non-uniformity measurements done by Christian Soldner (MPI, Munich) in his diploma thesis
- 2 cases chosen: unmodified SiPM (worst) and mini-SiPM (best)

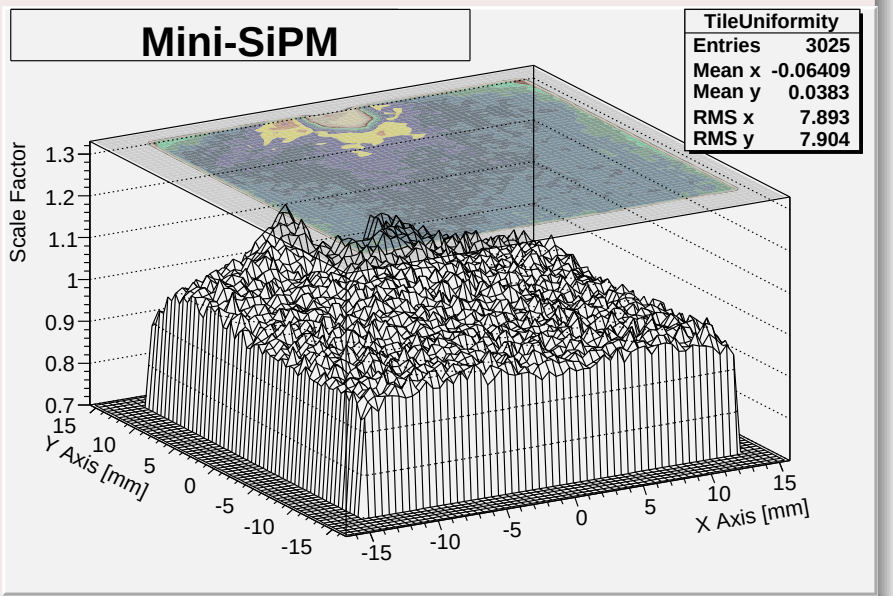
Unmodified tile (worst)

- SiPM directly coupled to the tile



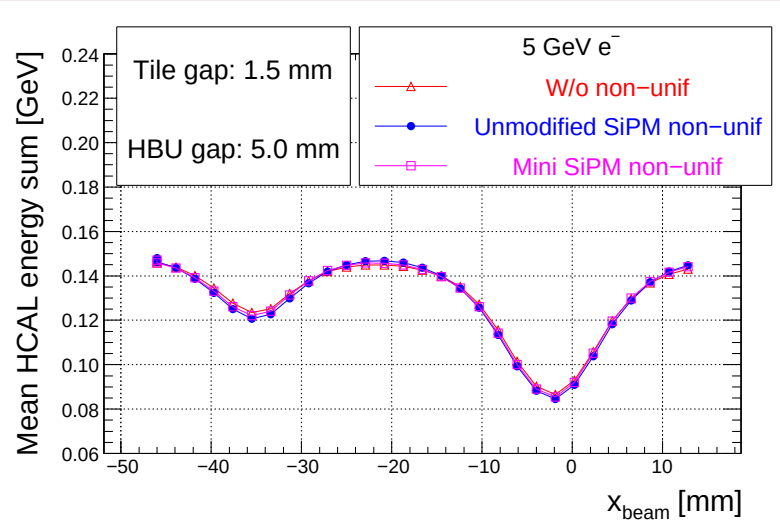
Mini-SiPM (best)

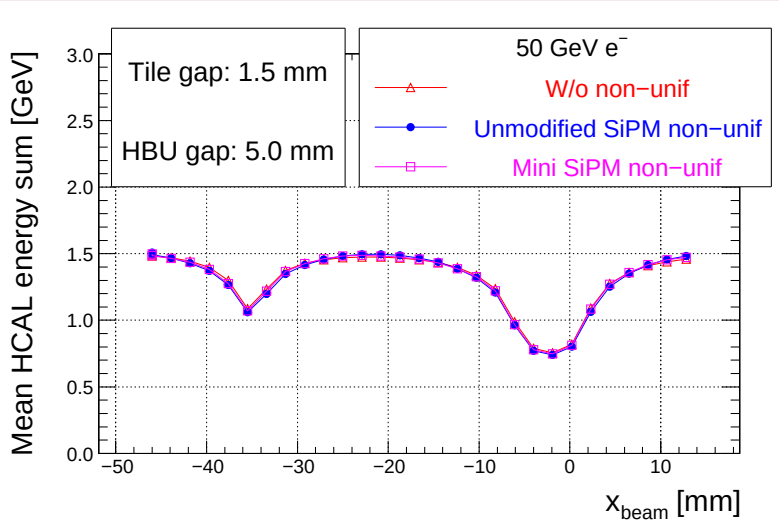
- SiPM integrated into the tile, into a deep slit



Results: UNREALISTIC gaps, step along *x*

Electrons





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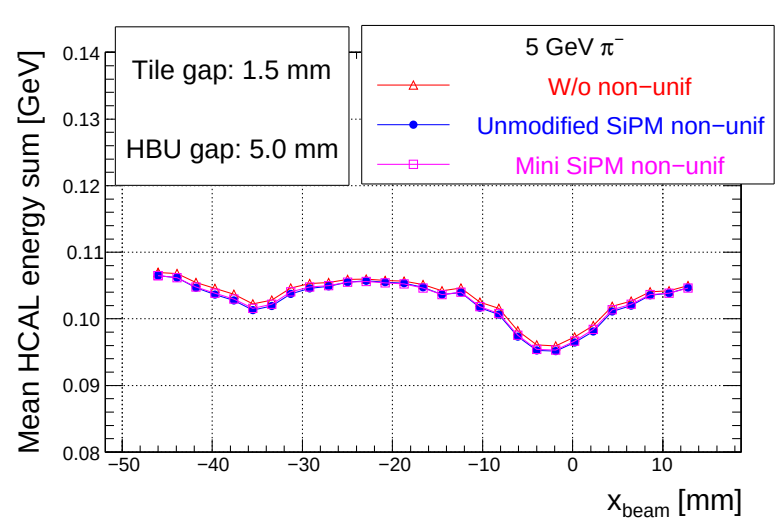
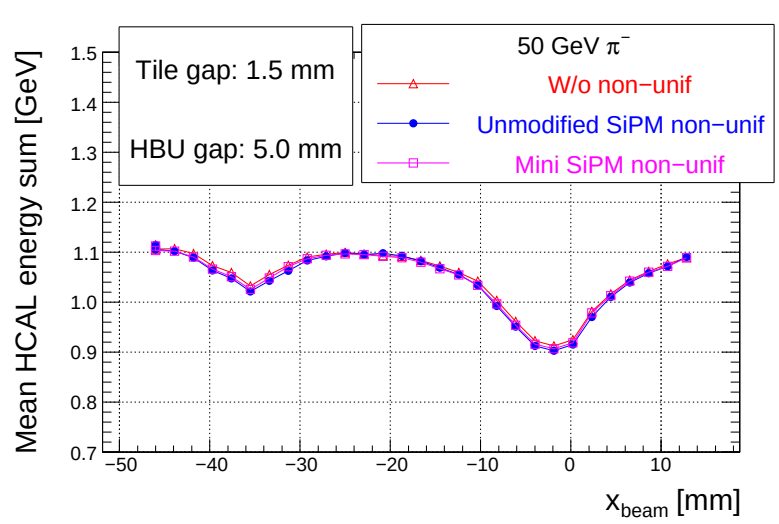
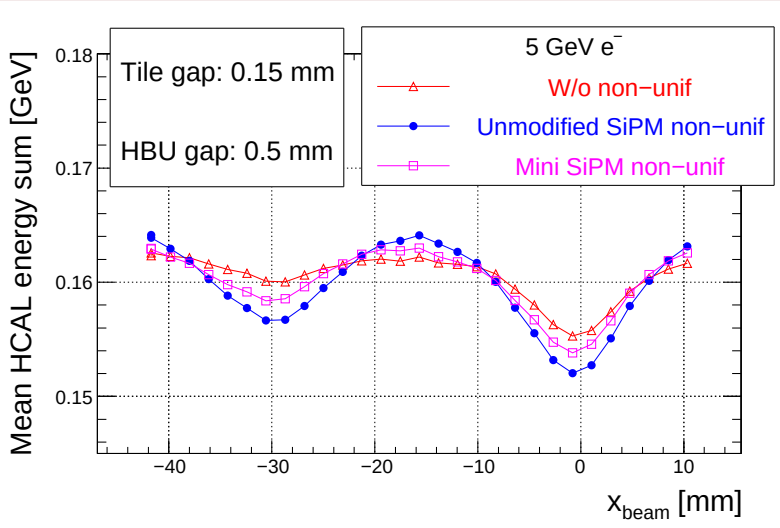
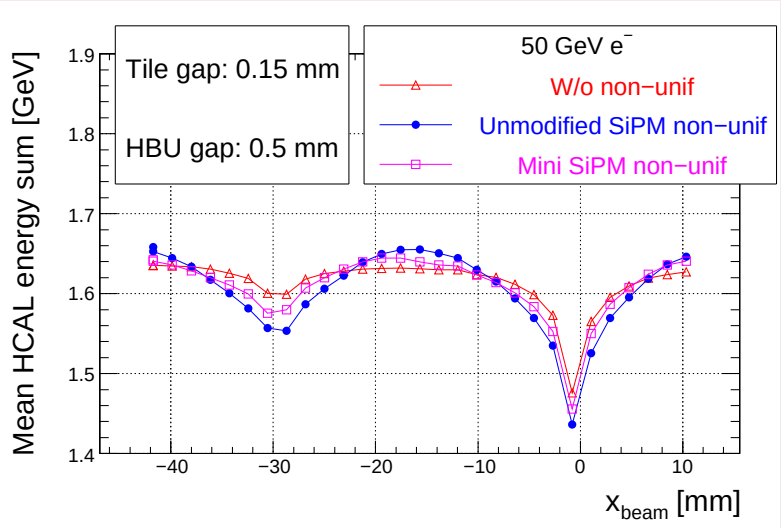




Results: realistic gaps, step along *x*

Electrons





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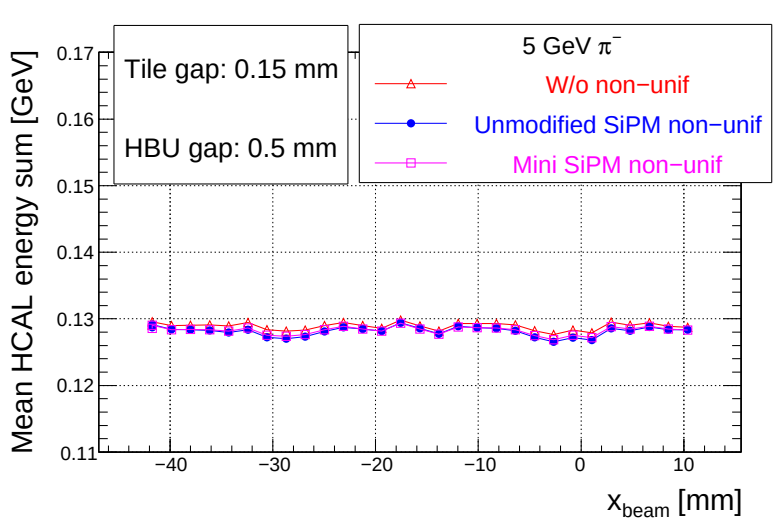
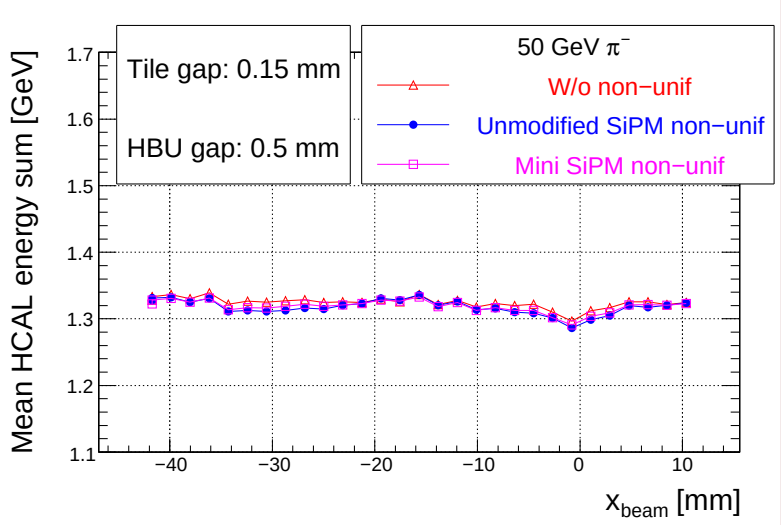
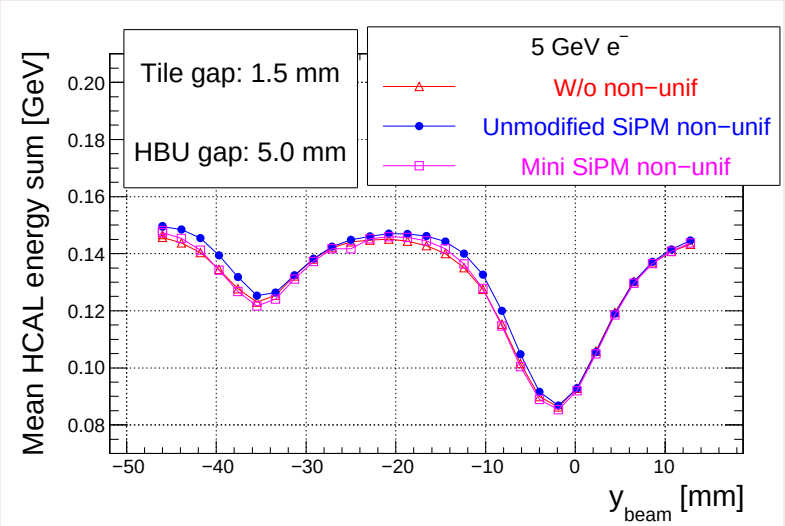
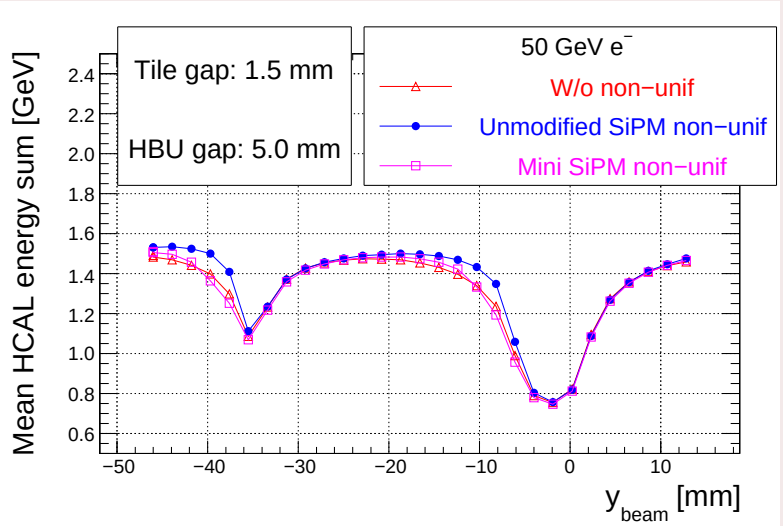




Results: UNREALISTIC gaps, step along *y*

Electrons





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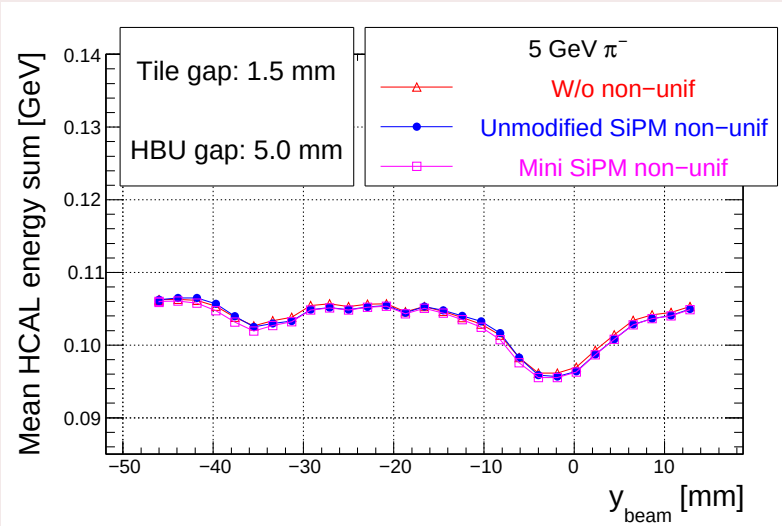
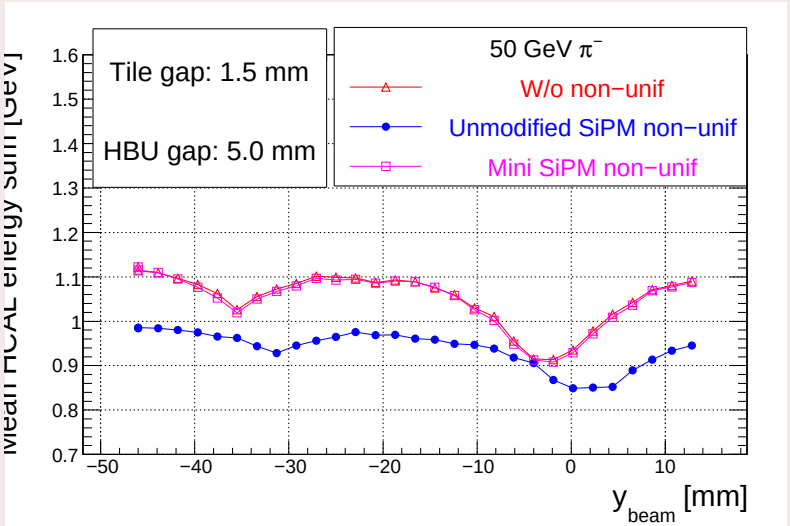
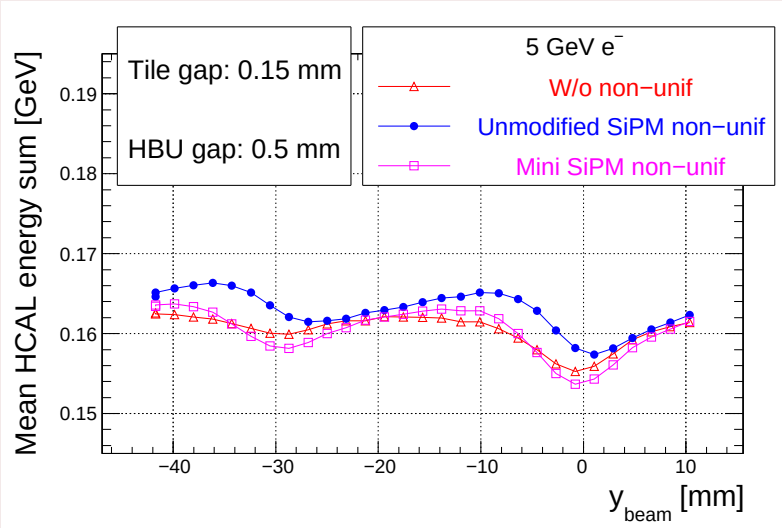
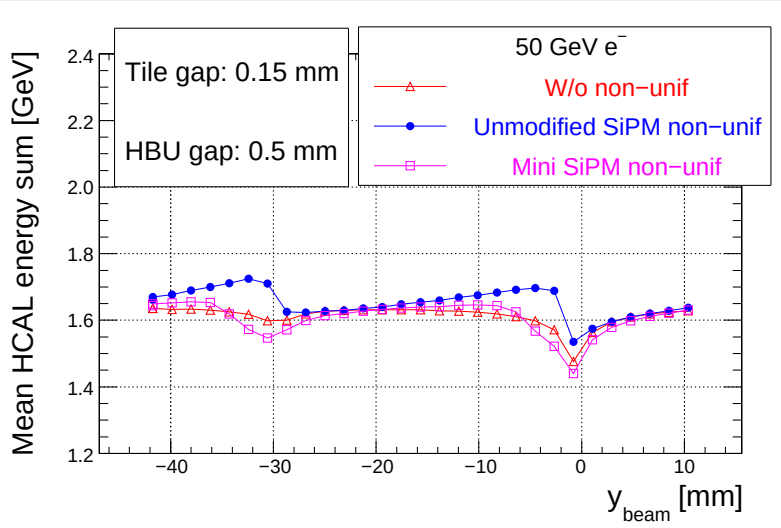




Results: realistic gaps, step along *y*

Electrons





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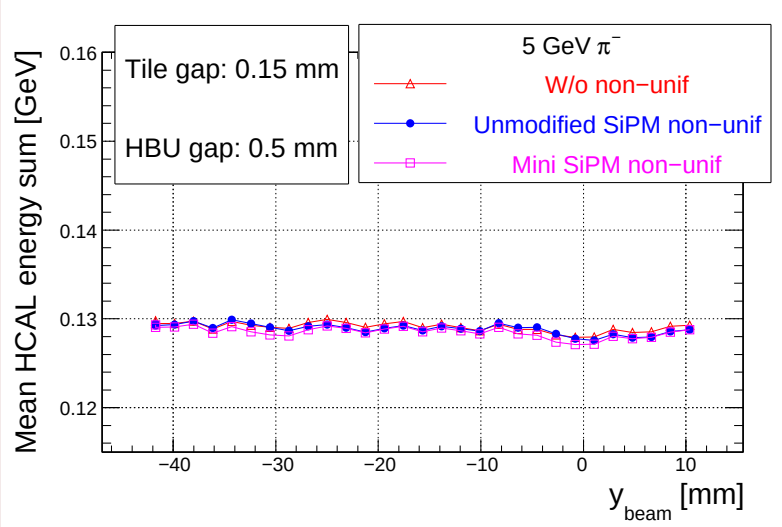
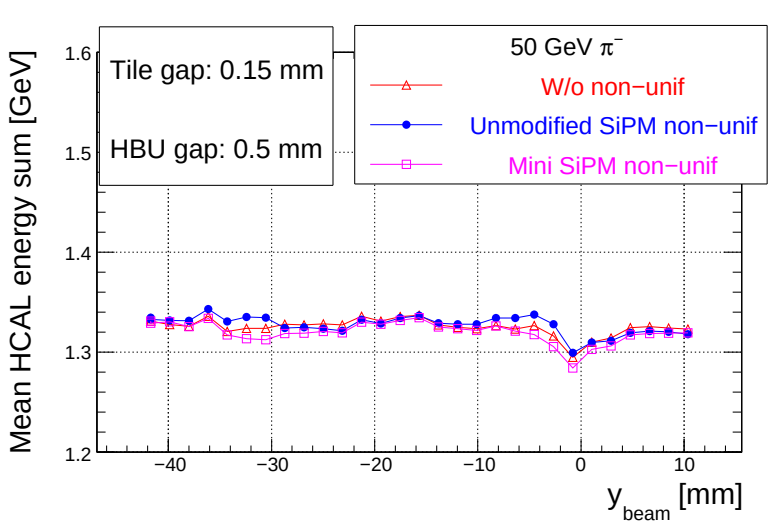




Conclusions

- Gaps and tiles with WLS:
  - Effect of realistic gaps between AHCAL tiles and HBU's visible for electromagnetic showers, but minimal for hadrons
  - Dead regions $\Rightarrow$ less energy deposited
- Gaps and tiles with directly coupled SiPM:
  - Non-uniformity relevant for realistic gaps and for electrons, smaller effect for hadrons
  - Effect increases with increasing energy, because the shower is boosted; possible solution: rotate position of SiPM in cells in subsequent layers by 90° (see diploma of Christian Soldner)

In the ILD case:

- ECAL in front of AHCAL $\Rightarrow$ most of the electrons will not reach AHCAL
- Tiles are staggered $\Rightarrow$ gaps will not be aligned

Acknowledgements

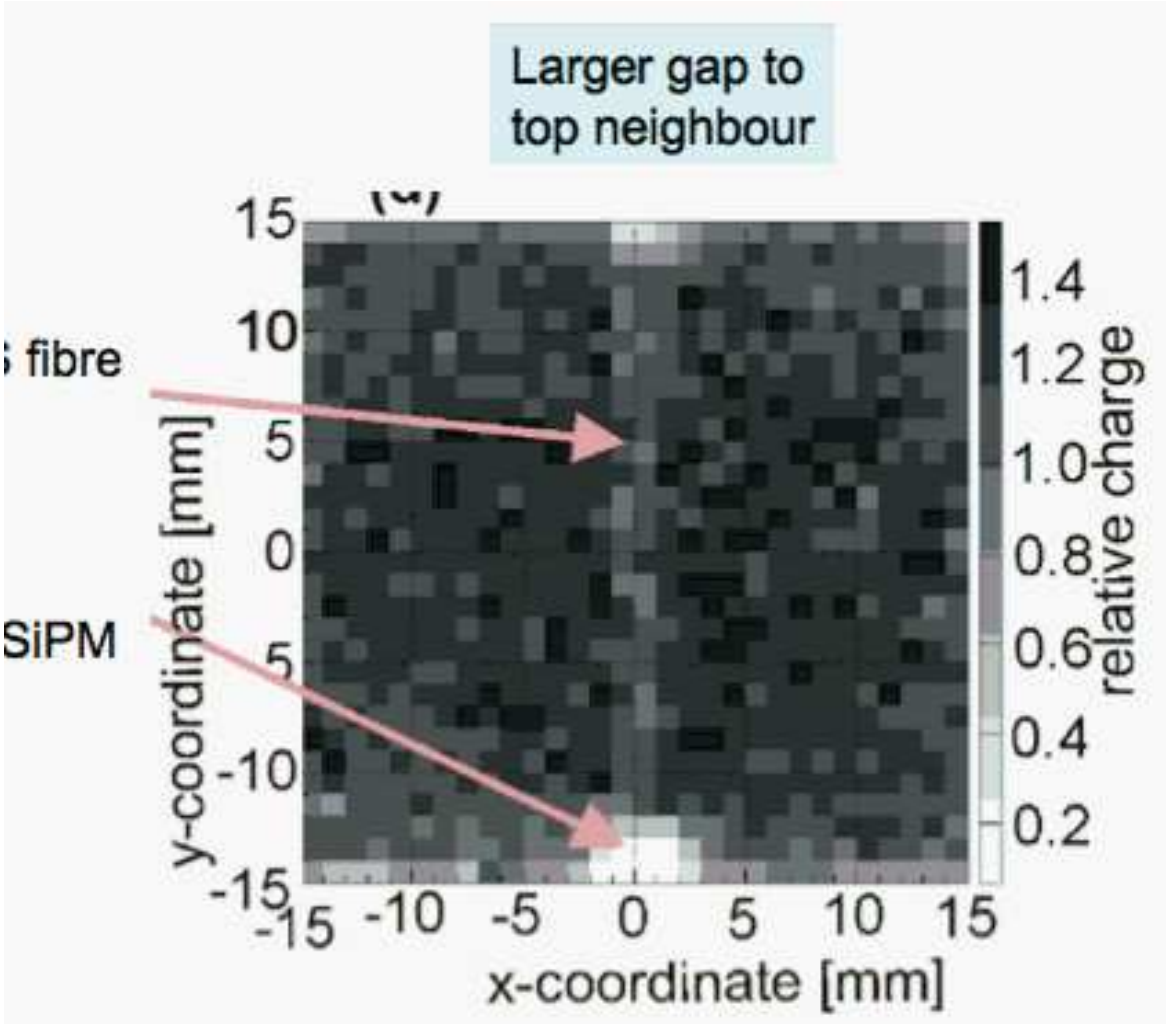
Many thanks to Christian for providing the non-uniformity measurements

BACK-UP SLIDES

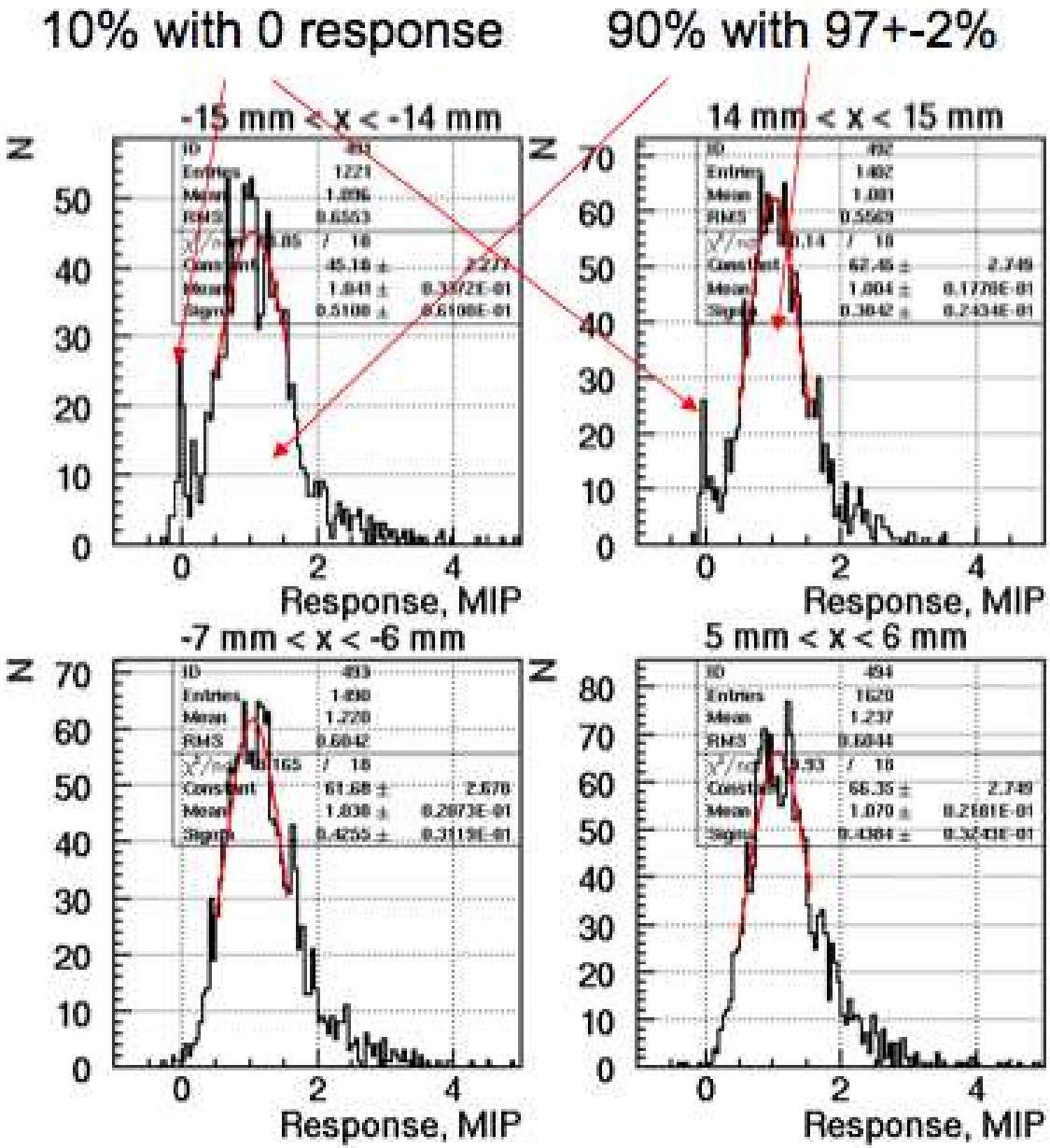
ITEP Measurements

- Measurements performed at ITEP (Russia) in hadron test beam, using a wire chamber tracking system ($\sigma \approx 1$ mm)

- Results: mean response in 1×1 mm^2
- Left and right edges: 10% less response
- Fibre: 20% less response
- Mirror and SiPM: very low response



ITEP Measurements: EDGES



ITEP Measurements: FIBRE

- 20% lower response