

FoCal: Status of Pixel Layer R&D

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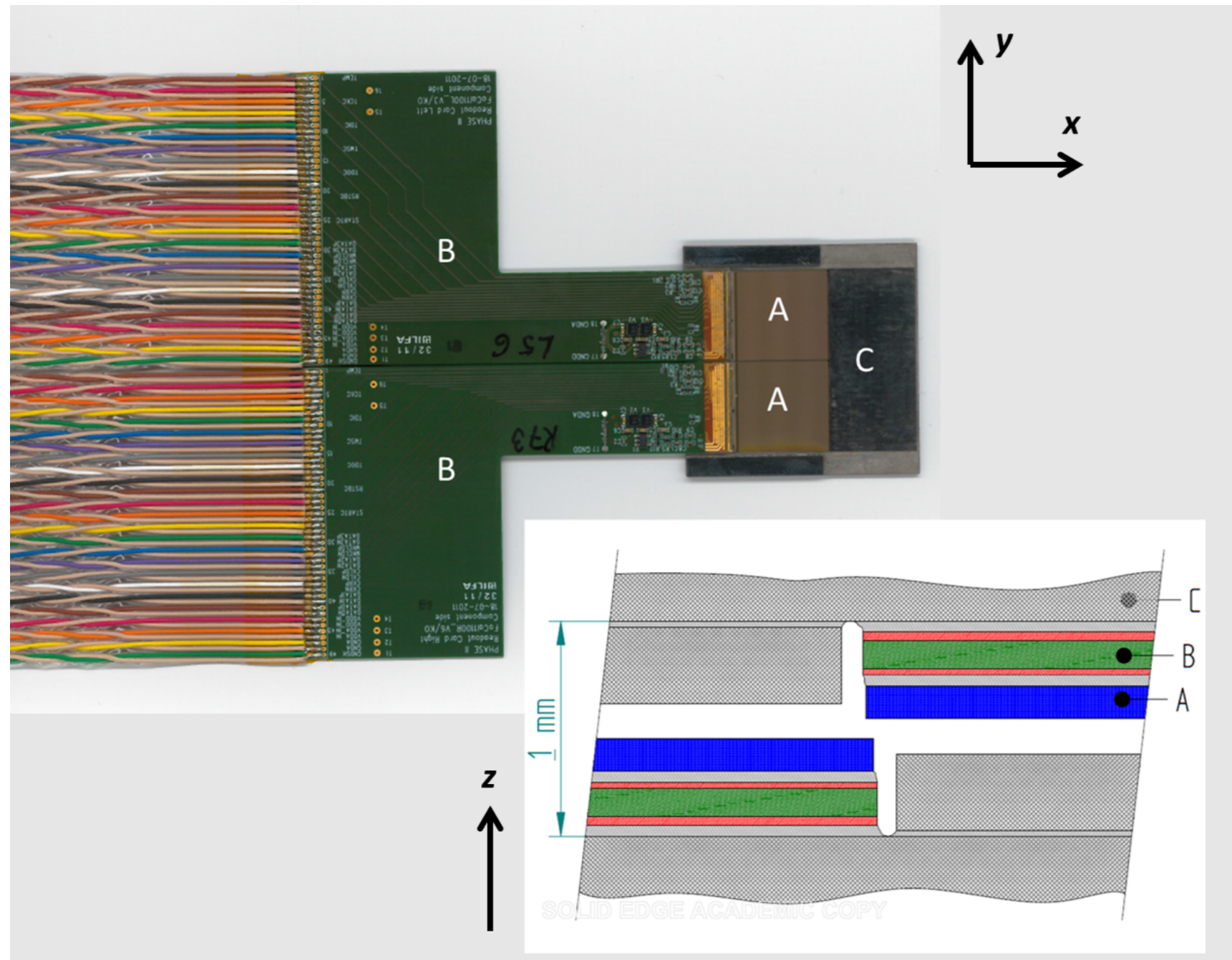
many slides thanks to N. van der Kolk

International Workshop on Forward Physics and Forward Calorimeter Upgrade in ALICE,
Tsukuba, 08.03.2019

Outline

- Results from MIMOSA prototype
- Current R&D
 - tests with Alpide
 - MiniFoCal in ALICE
- Summary

MIMOSA Prototype



calorimeter stack of 24x2 half layers equipped with MIMOSA CMOS pixel sensors

half layer with two sensors and 1.5mm W

two half layers mounted together with opposite orientation to minimise dead areas

total layer thickness $\approx 1 X_0$

full active layer with readout boards within 1mm

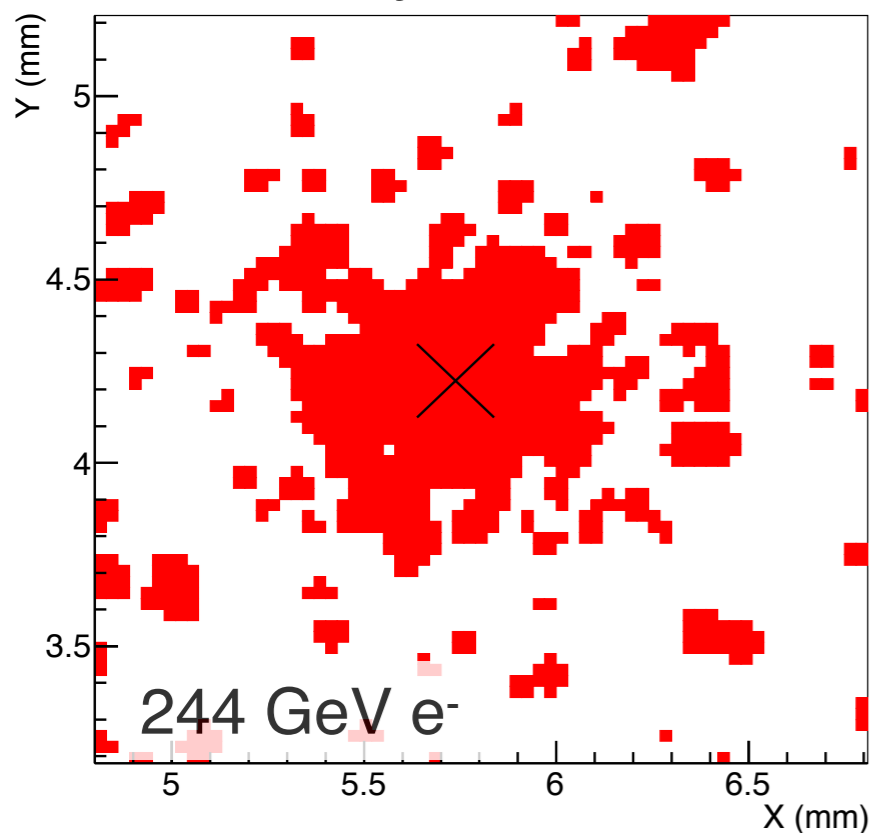
A: MIMOSA sensor
B: PCB
C: tungsten

extremely compact design

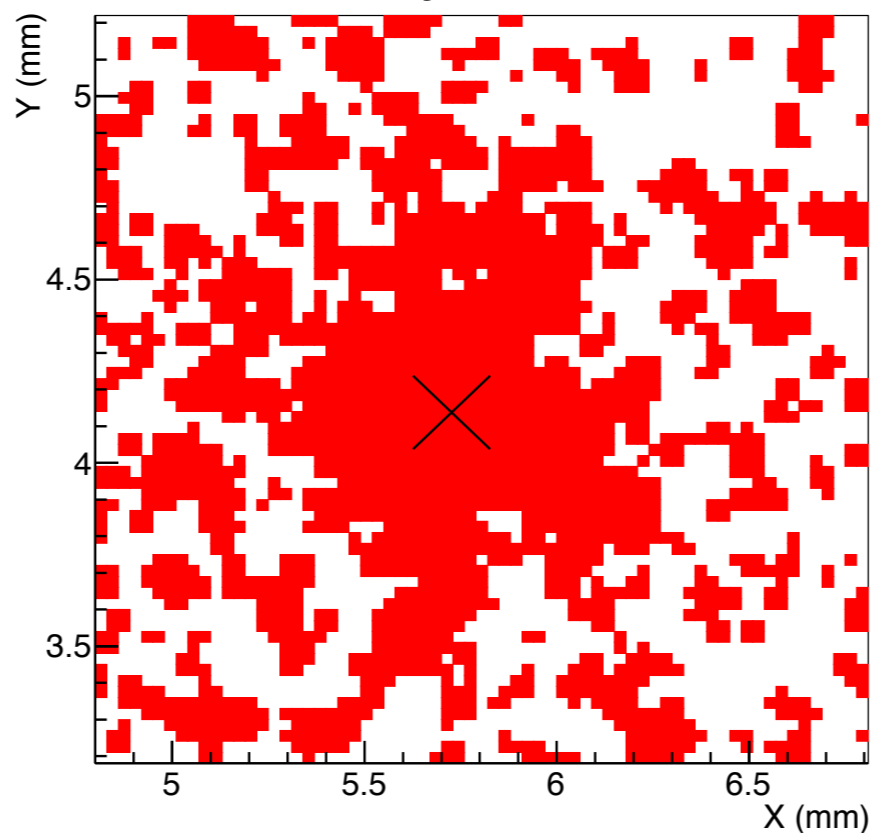
- allows for high pixel density and small Moliere radius

Single Event Hit Distribution - FoCal Pixel Prototype

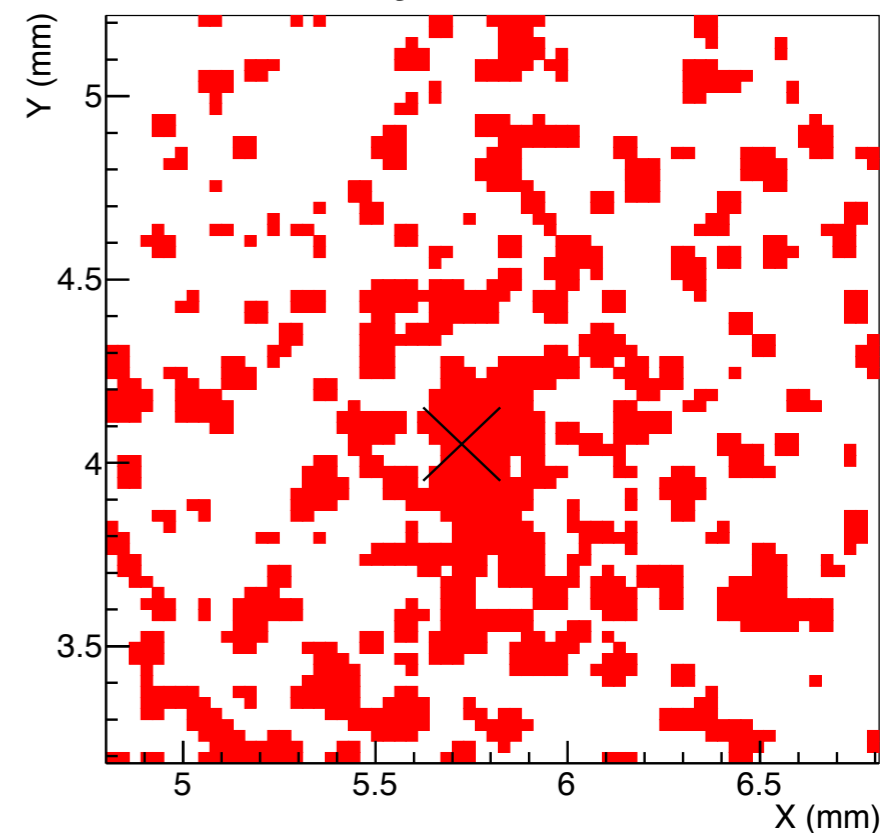
layer 4



layer 8



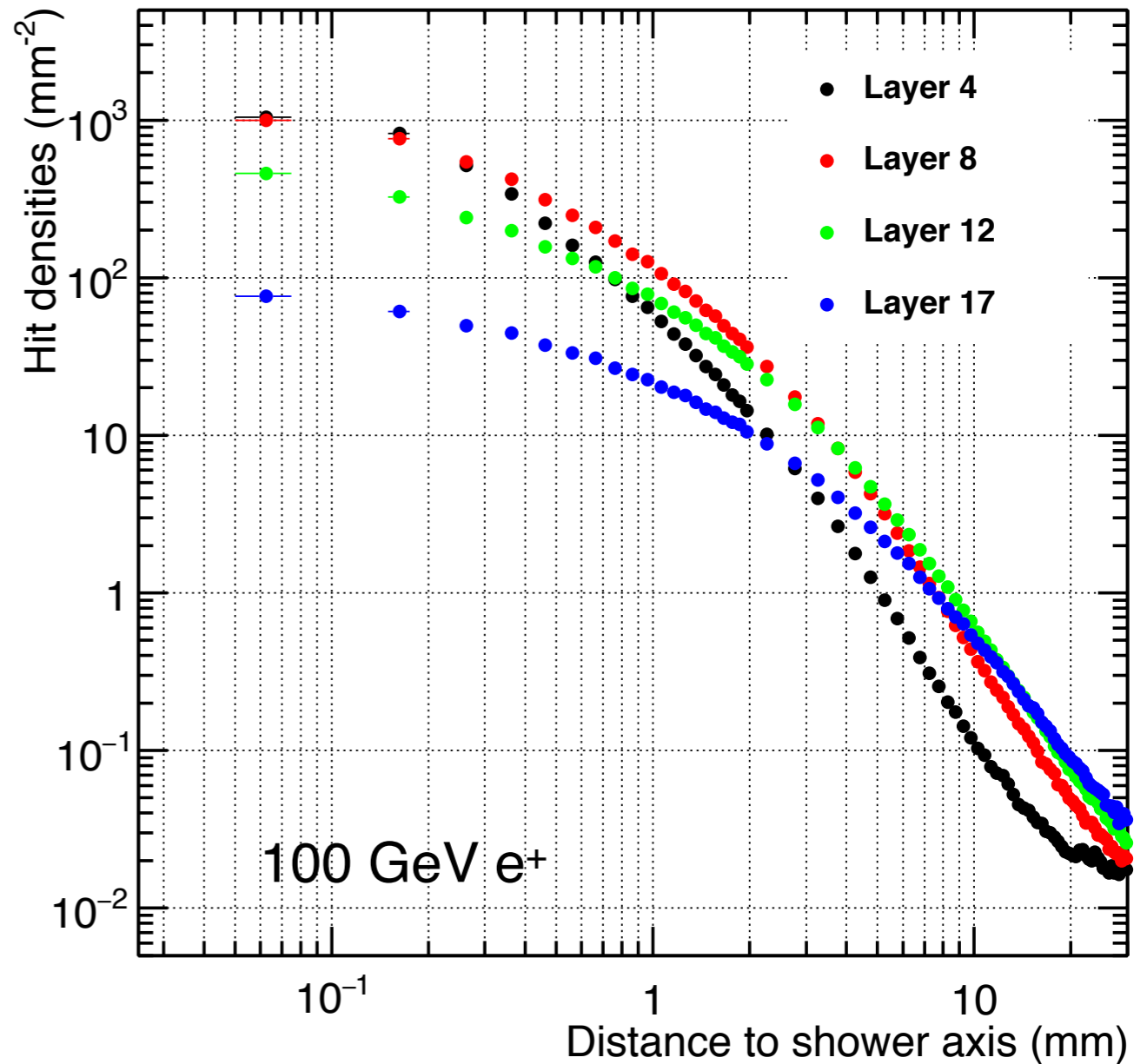
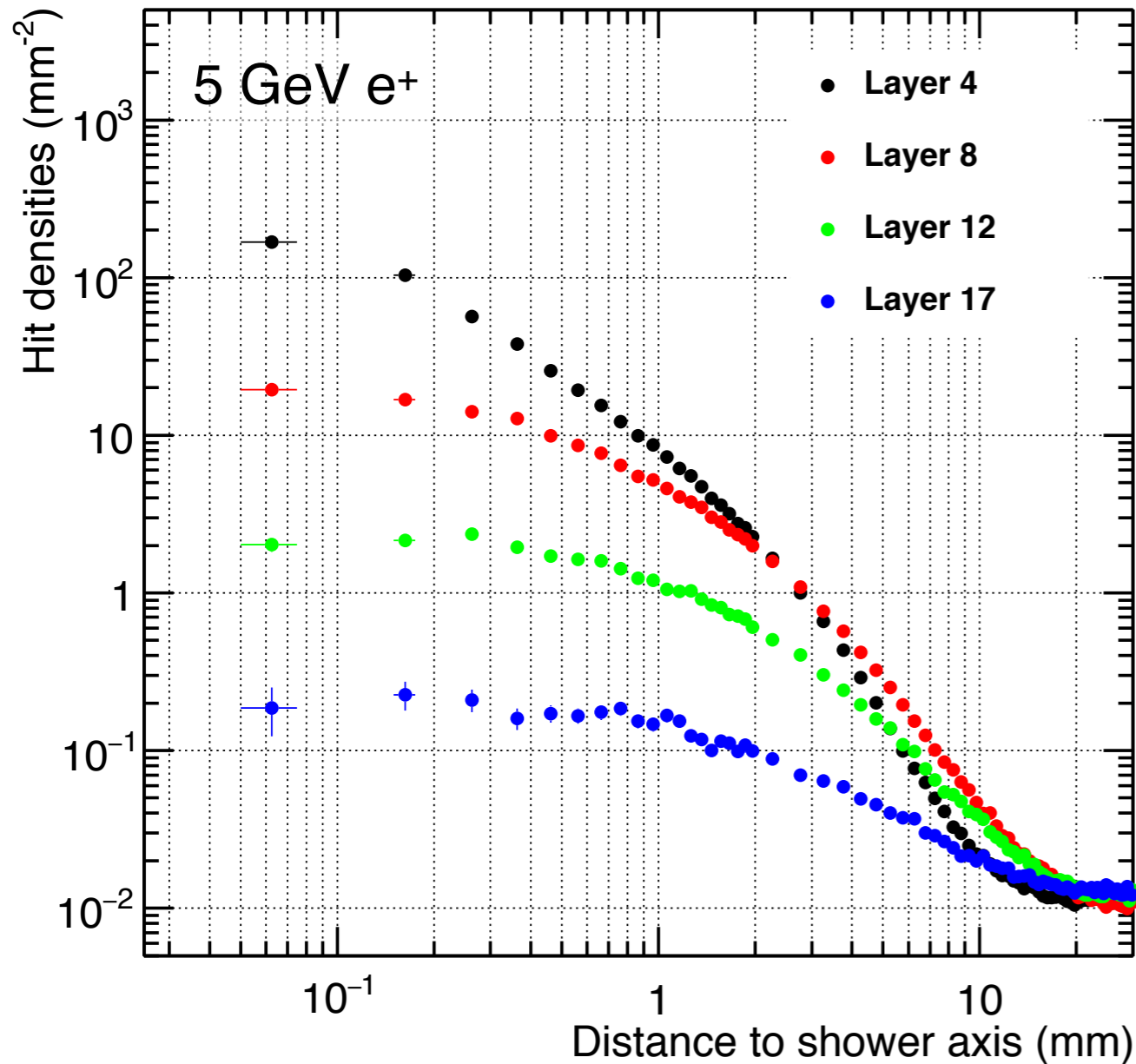
layer 12



very high hit density in shower core

- not possible to reconstruct single shower particles from pixel clusters
- have to use number of hits as response (not number of clusters)
- saturation (overlap of clusters) likely for very high energy

R&D - Lateral Profiles



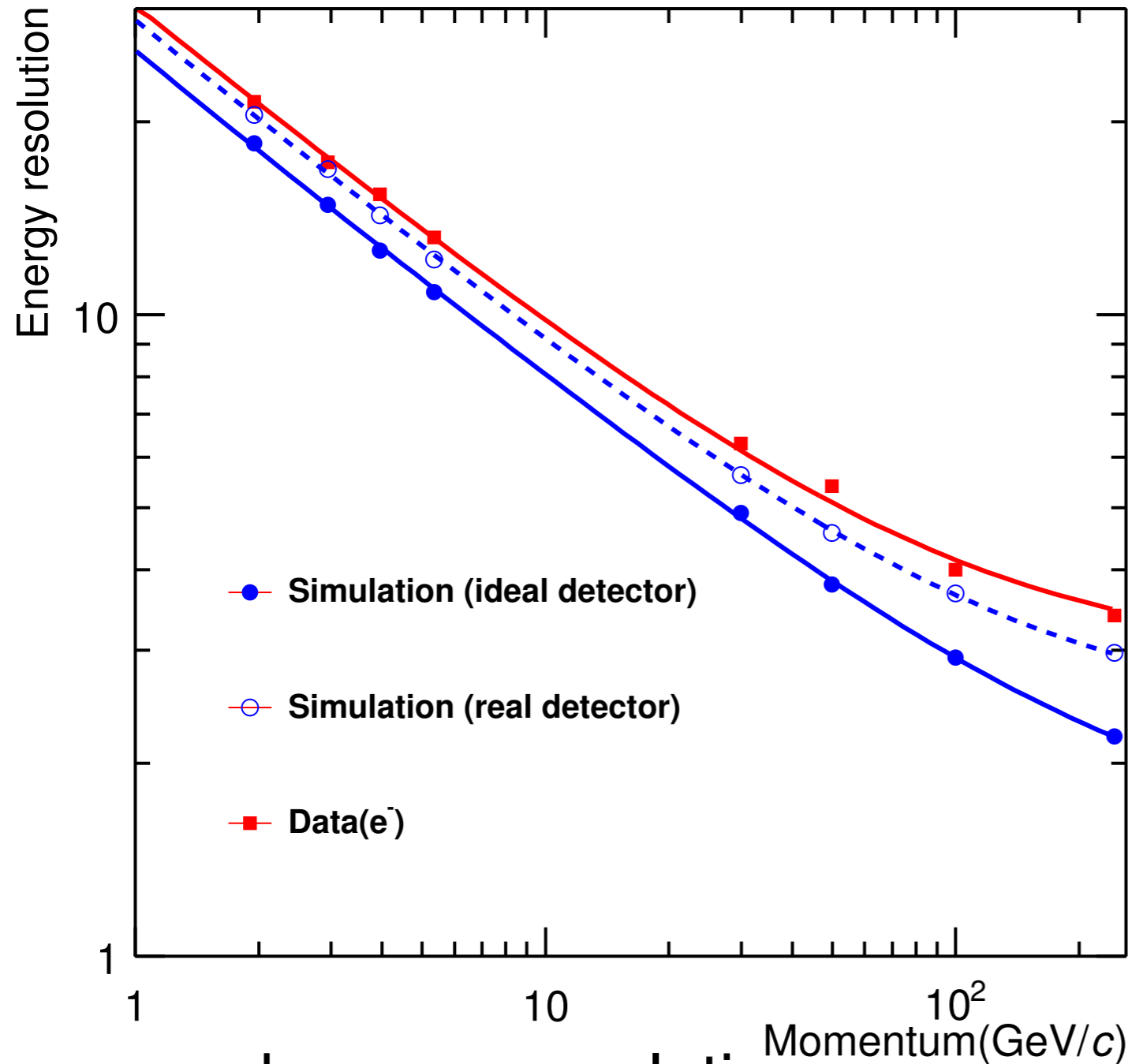
average hit densities as a function of radius
for different layers

$$\frac{dN_{\text{hit}}}{dA}(r)$$

- low energy: early shower maximum, profiles broaden and decay with depth
- high energy: profiles broaden with depth, increase up to shower maximum

shower measurements with unprecedented detail!

R&D - Energy Resolution



$$\frac{\sigma_E}{E} = a \oplus \frac{b}{\sqrt{E/\text{GeV}}} \oplus \frac{c}{E/\text{GeV}}$$

$$a = (2.95 \pm 1.65)\%$$

$$b = (28.5 \pm 3.8)\%$$

$$c = 6.3\%$$

noise term c compatible
with pedestal width (fixed in fit)

recent work on improved calibration

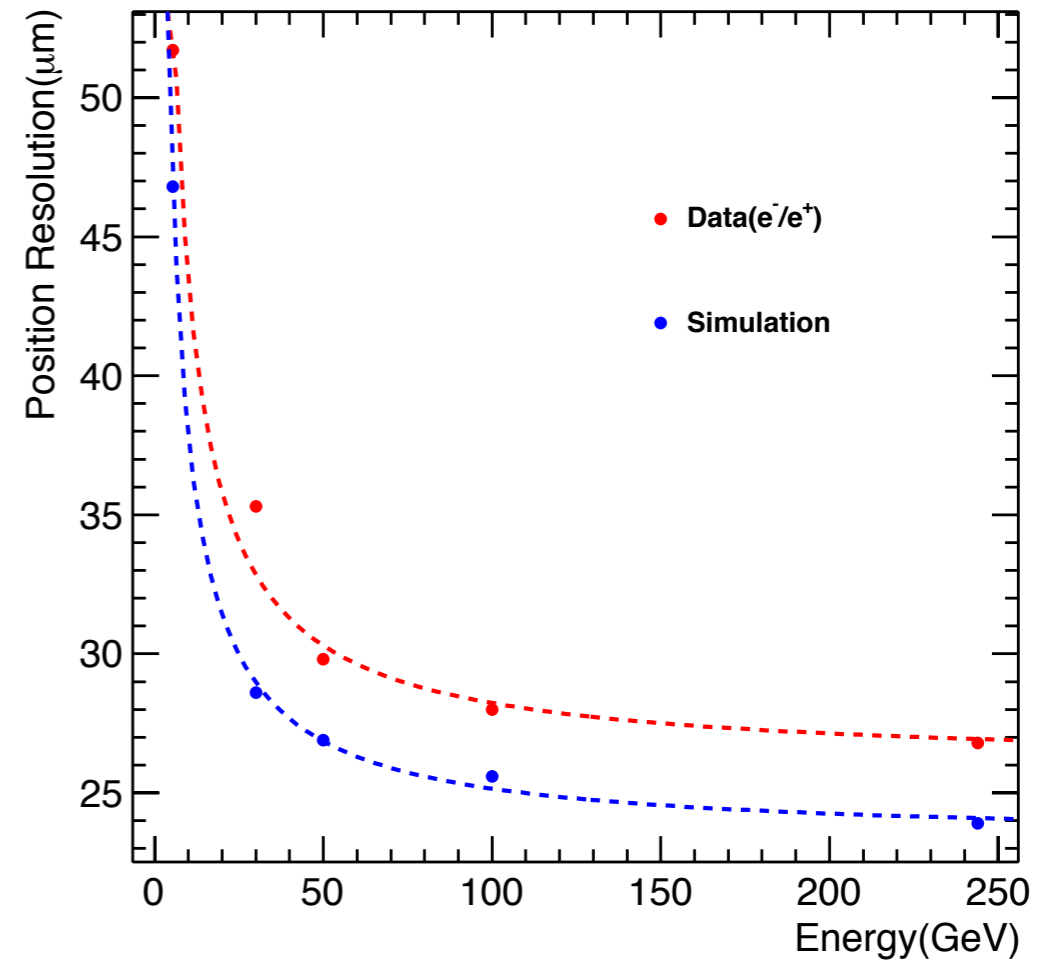
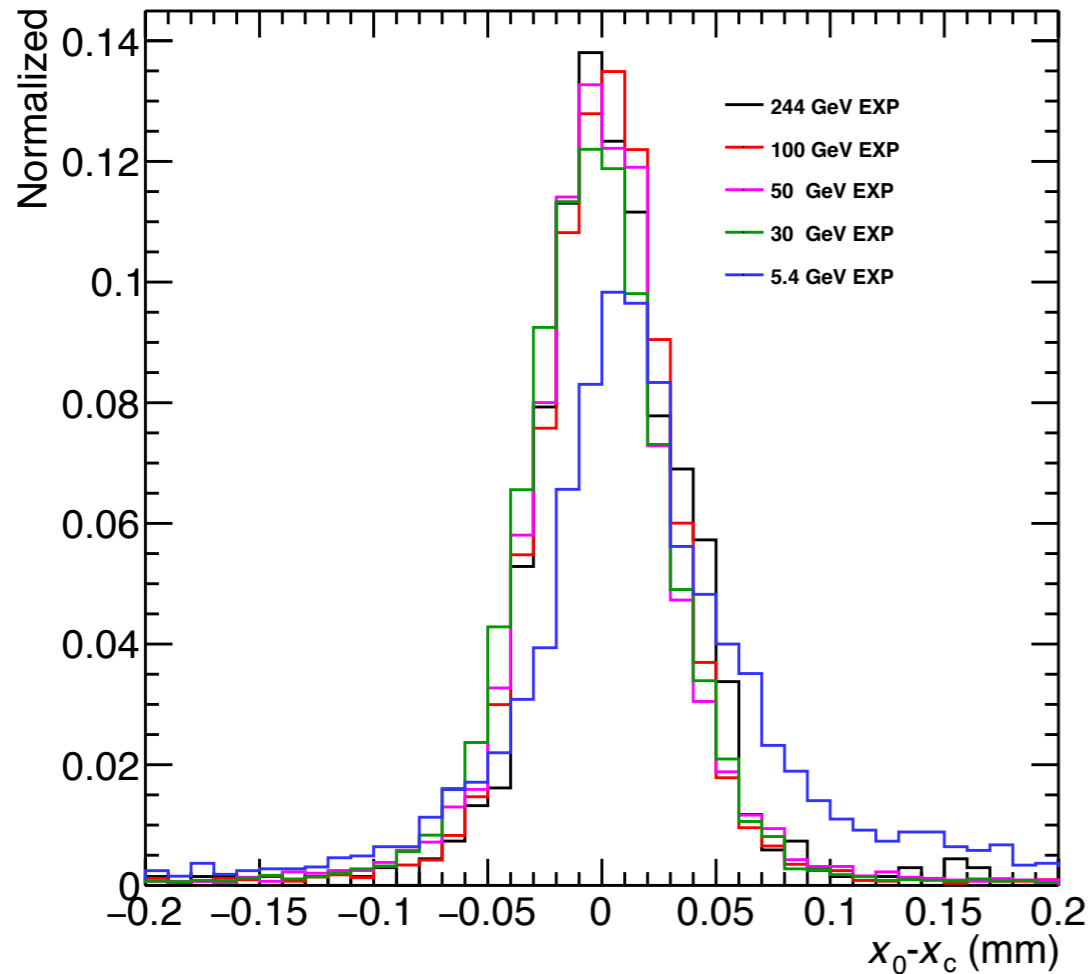
slightly worse than MC simulation,
not unexpected

good energy resolution

- certainly sufficient for forward detector
- note: sampling fraction $< 1/1000$
- possibly still improve calibration, better sensor (ALPIDE) in the future

proof of principle of digital calorimetry

R&D - Position Resolution



calculate difference of position from

- cluster in layer 0 and
- center of gravity of shower in layers 1 - 23

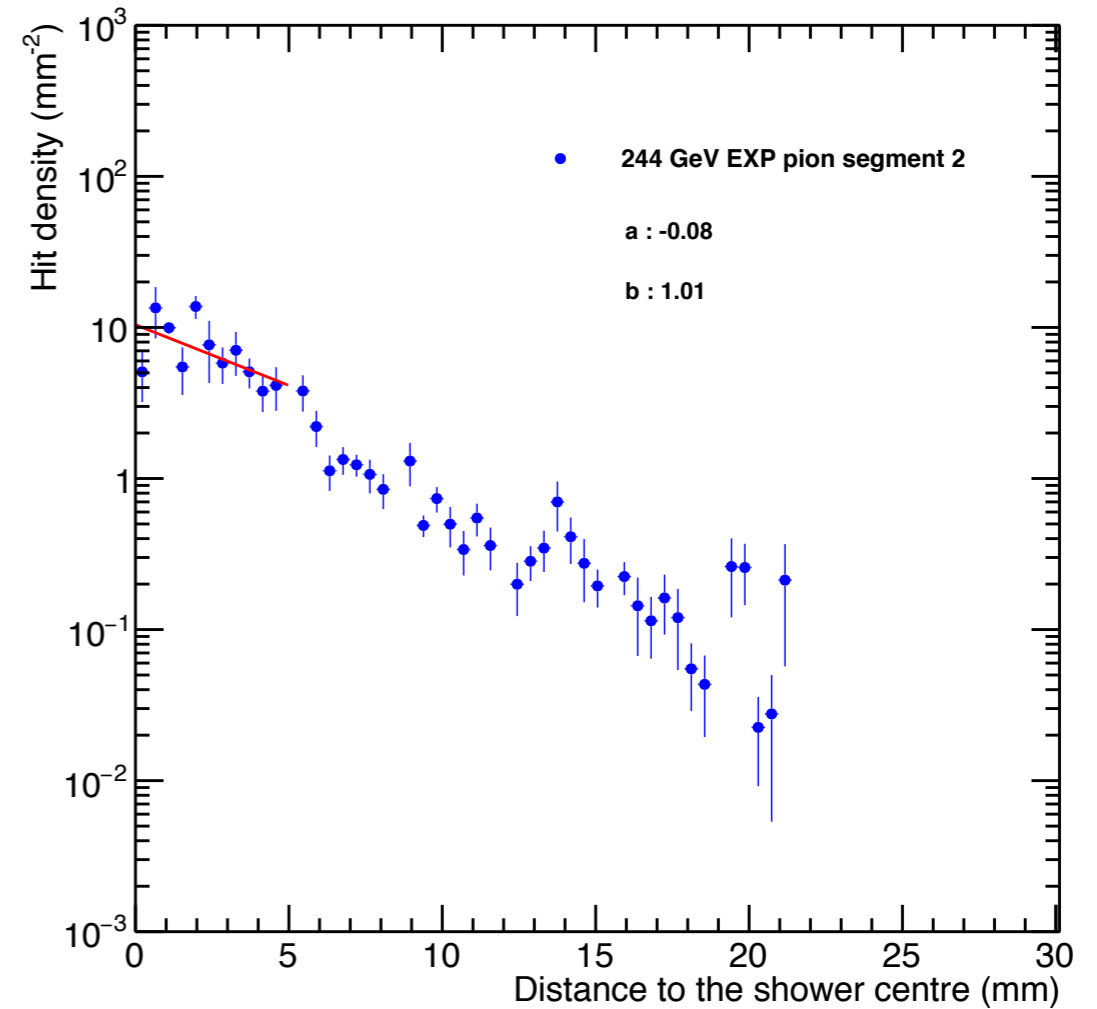
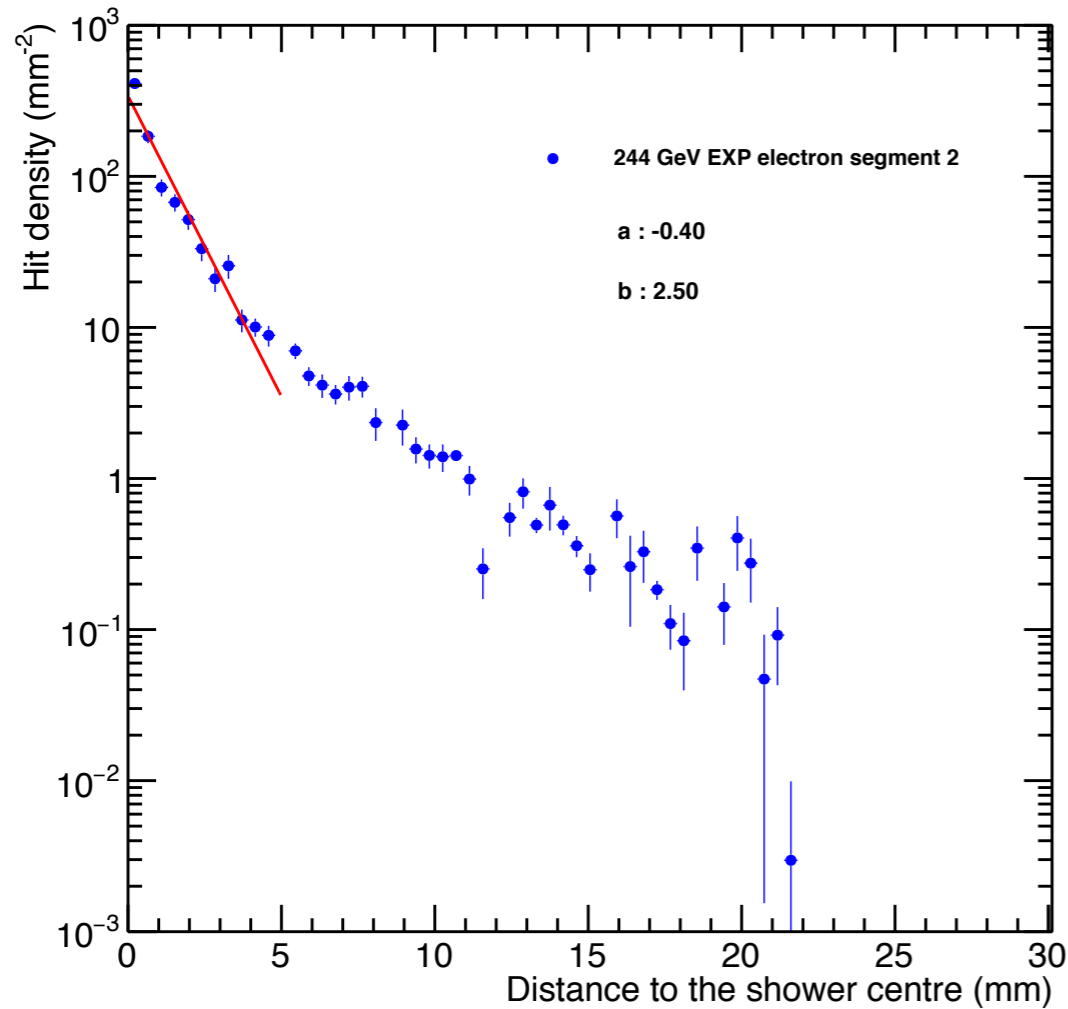
single shower position resolution obtained from width of residuals

can also provide excellent two-shower separation

R&D: Single Event Shower Profiles

electron

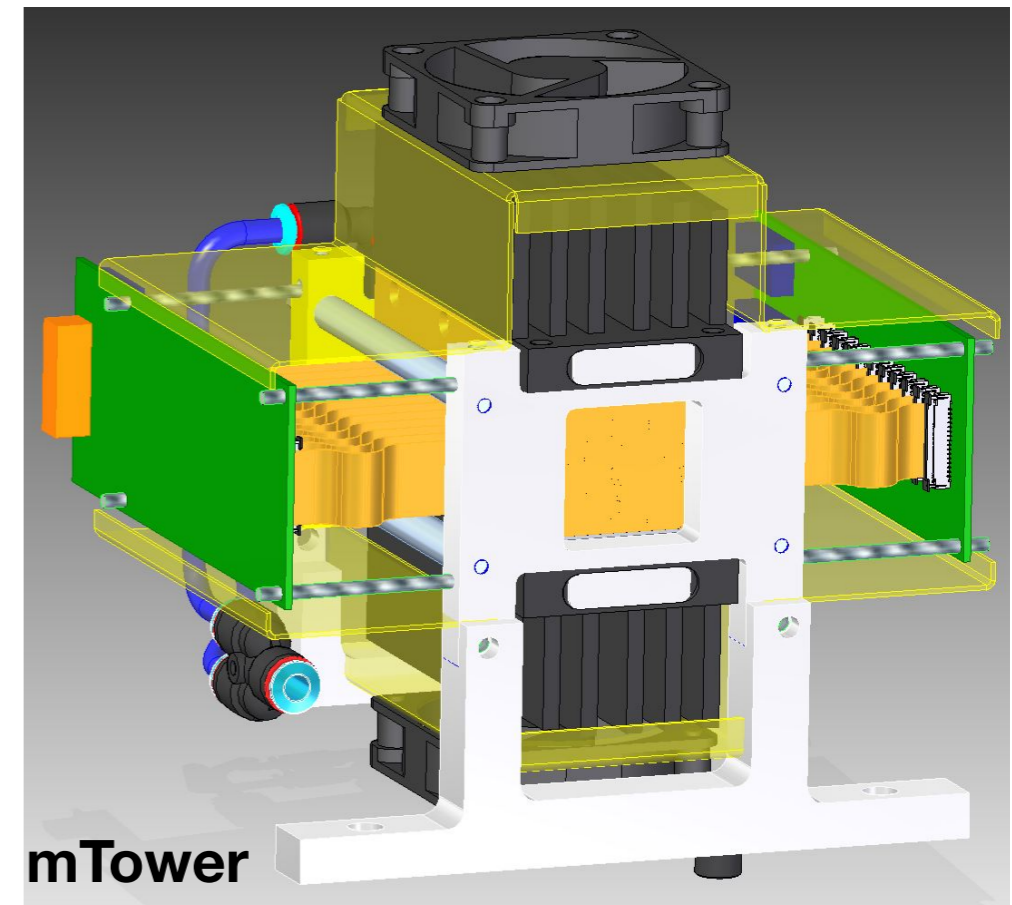
pion



electron showers have well defined profile, very narrow shower core
pion showers show much larger fluctuation, often much wider

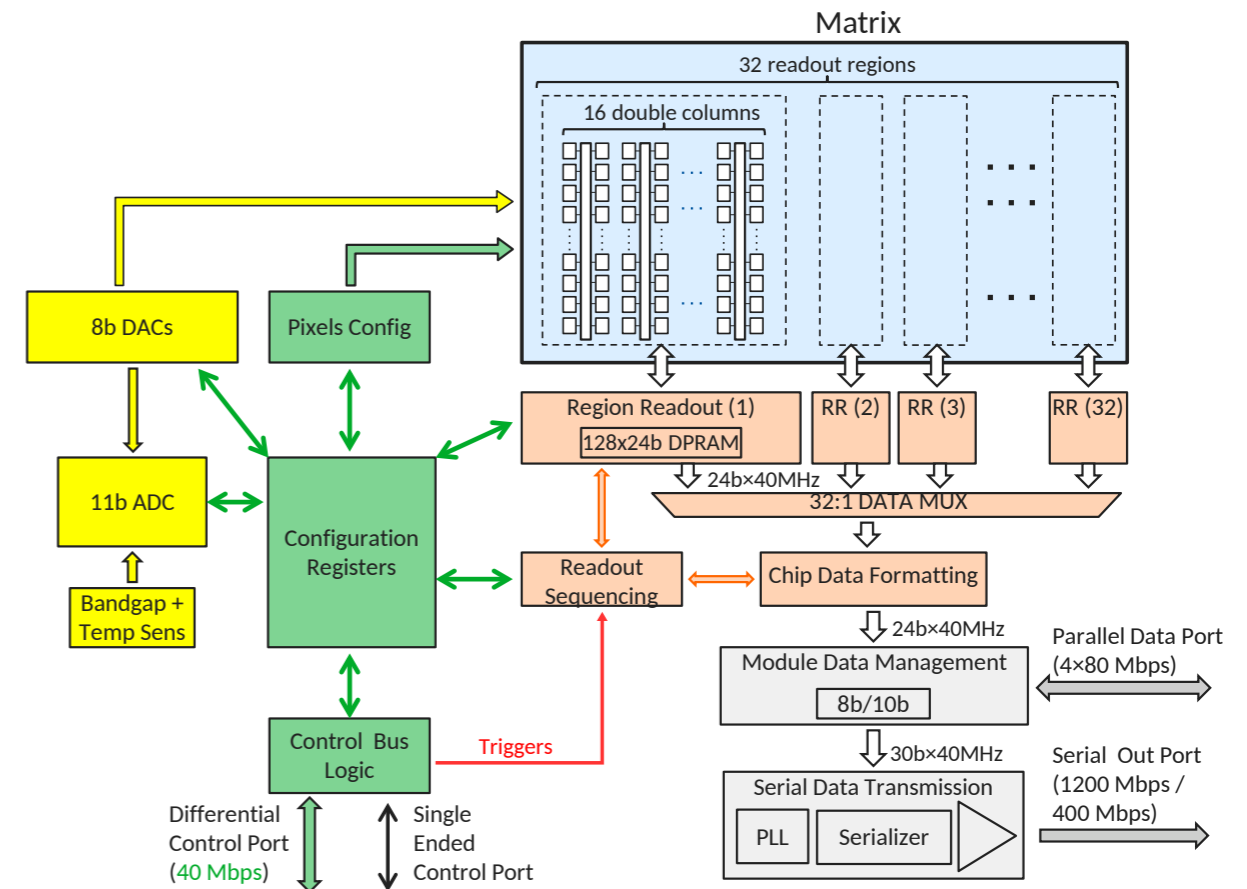
New Prototype: mTower

- Currently building new prototypes based on the **ALPIDE MAPS sensor** that is developed for the new ALICE Inner Tracking System
- New prototype **mTower**
 - Small digital calorimeter ($3 \times 3 \text{ cm}^2$) with 24 layers of 2 ALPIDE sensors and 3 mm W
 - Allows to test the performance of the ALPIDE in a calorimeter
 - Provides input into the FoCal design parameters
 - Allows to study particle showers in detail



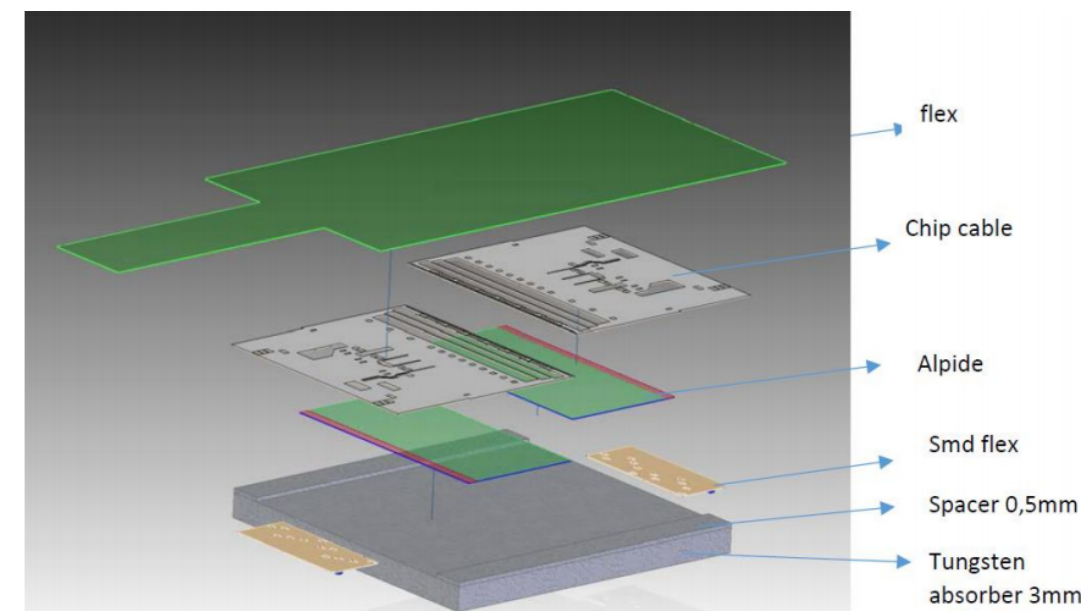
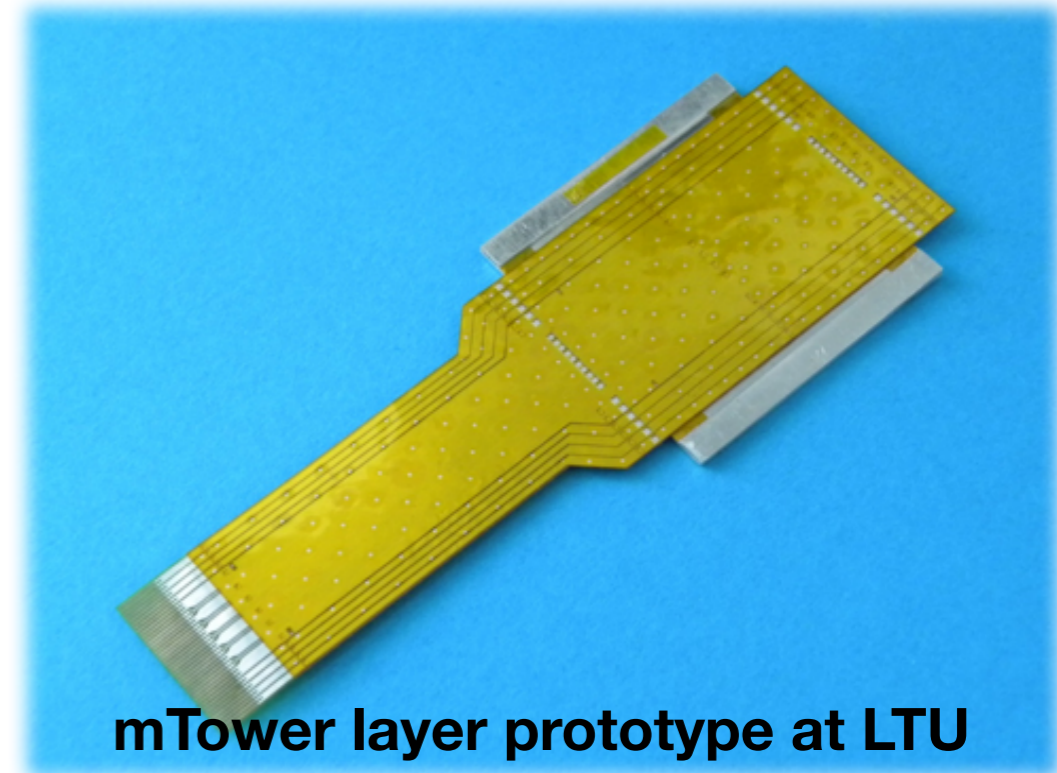
ALPIDE

- Monolithic Active Pixel Sensor
- Chip size: 30.00 mm x 15.00 mm
- Pixel matrix: 1024 x 512 (=524288 pixels / chip)
- Active area: 29.94 mm x 13.76 mm
- Pixel size: 29.24 μm x 26.88 μm
- Hit driven readout
- Readout speed: 400 Mb/s - 1.2 Gb/s
- Power consumption proportional to the occupancy.



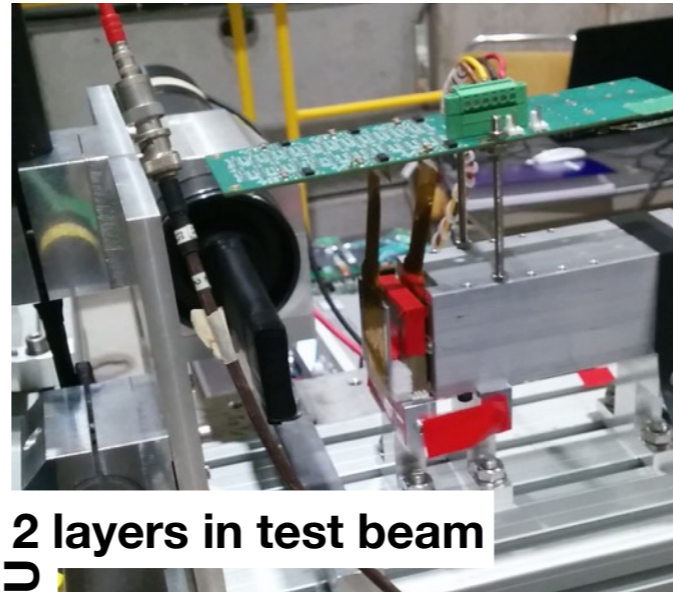
mTower Layers

- Layer: W absorber and two ALPIDE chips
- Thin, compact cabling to keep small Molière radius
 - Chip-cable and multilayered flex for connection (LTU Charkov)

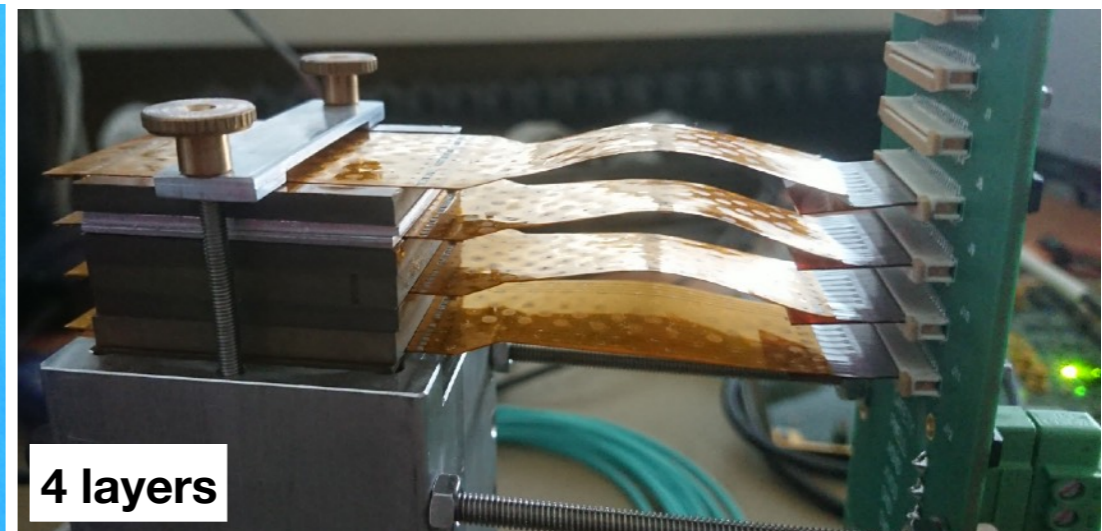
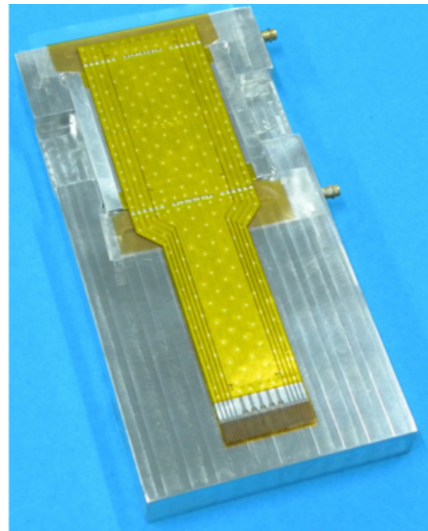


mTower Status

- Design ready
- 2 layers tested at PS and SPS
- Performance tests with 4 layers ongoing, at Utrecht and Bergen: some issues when pixel matrix active
- Same readout boards as ALICE ITS upgrade

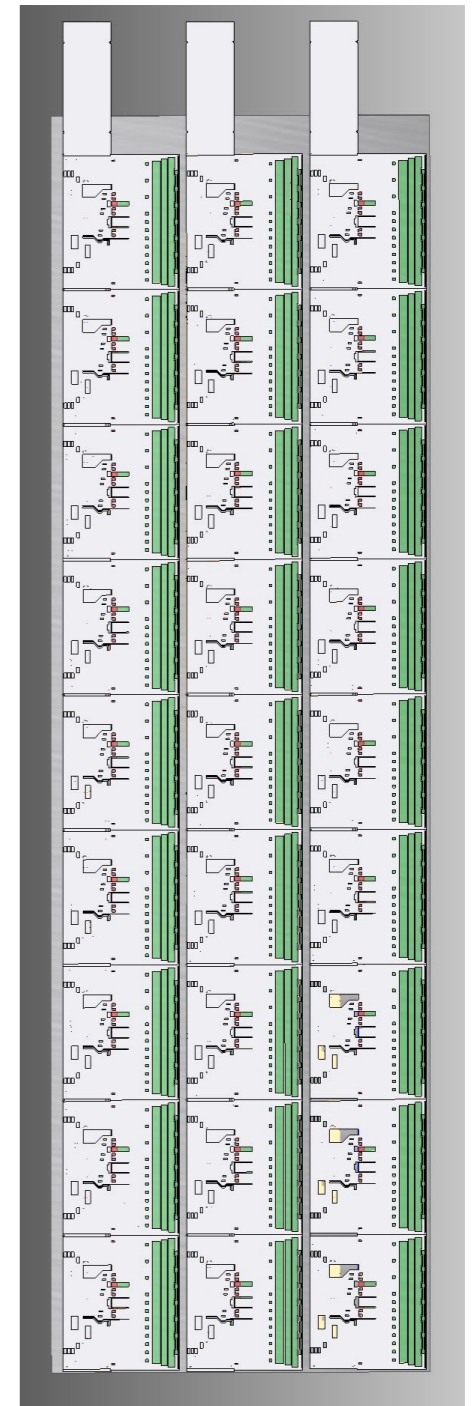
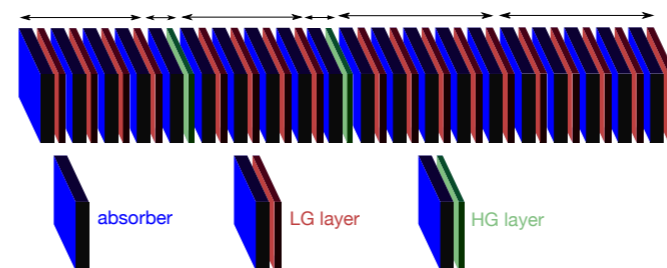


layer in assembly jig at LTU

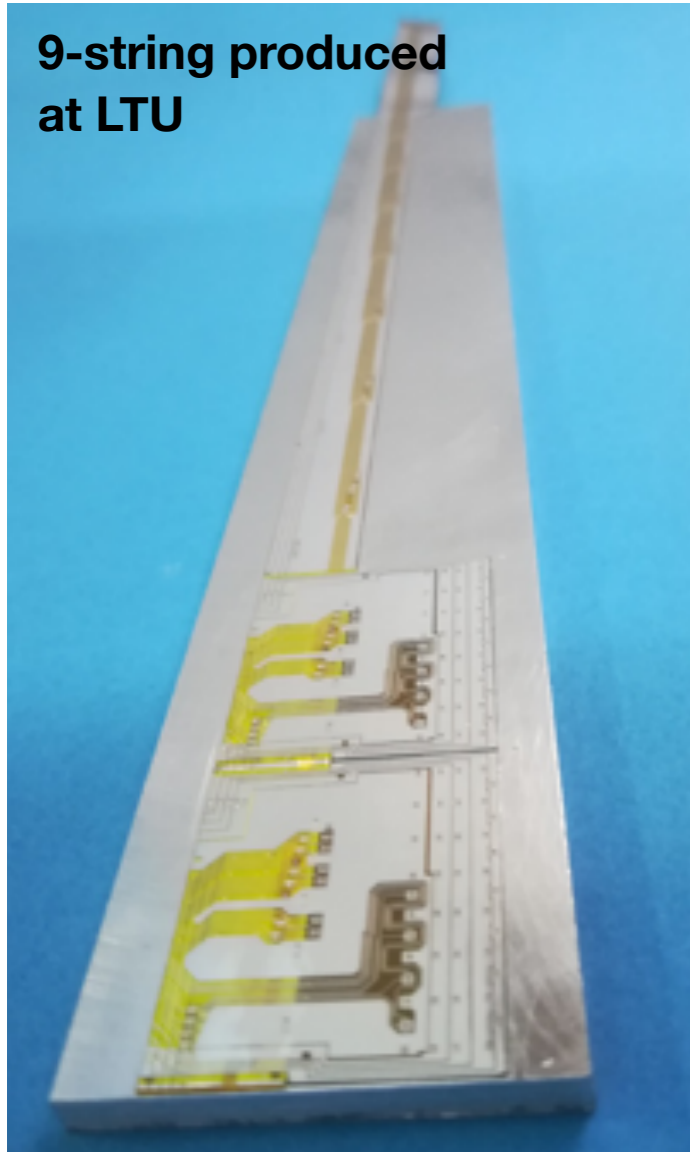


MiniFoCal

- New prototype **MiniFoCal**
 - Combine ALPIDE layers (HG) with PAD layers (LG)
 - 3 slabs of 3x9 ALPIDE sensors on each side (54 sensors/slab)
 - Allows to test FoCal design (mechanical integration, cabling, cooling, readout synchronisation, scalability to full detector)
 - Allows to test performance of FoCal-E



MiniFoCal Status



carrier with cooling tube



- MAPS layers design ready
- Mechanical tests ongoing (gluing, cooling, etc.)
- First functional 9-string (2 chips mounted) tested, some performance issues, revision of chip cable design ongoing
- PADS have been tested in ALICE cavern

Test Beam August 2018

- 2 layers of 2 ALPIDE chips at PS and SPS
- Most of the time positioned behind the FoCal PADS, but also some time directly in the beam
- Readout with RUV1 for ITS
 - No external trigger input possible -> Blind data taking -> At most 20% of SPS data recorded could coincide with the beam
 - Could read out only maximally 2 chips at the same time
- Data analysis still ongoing...

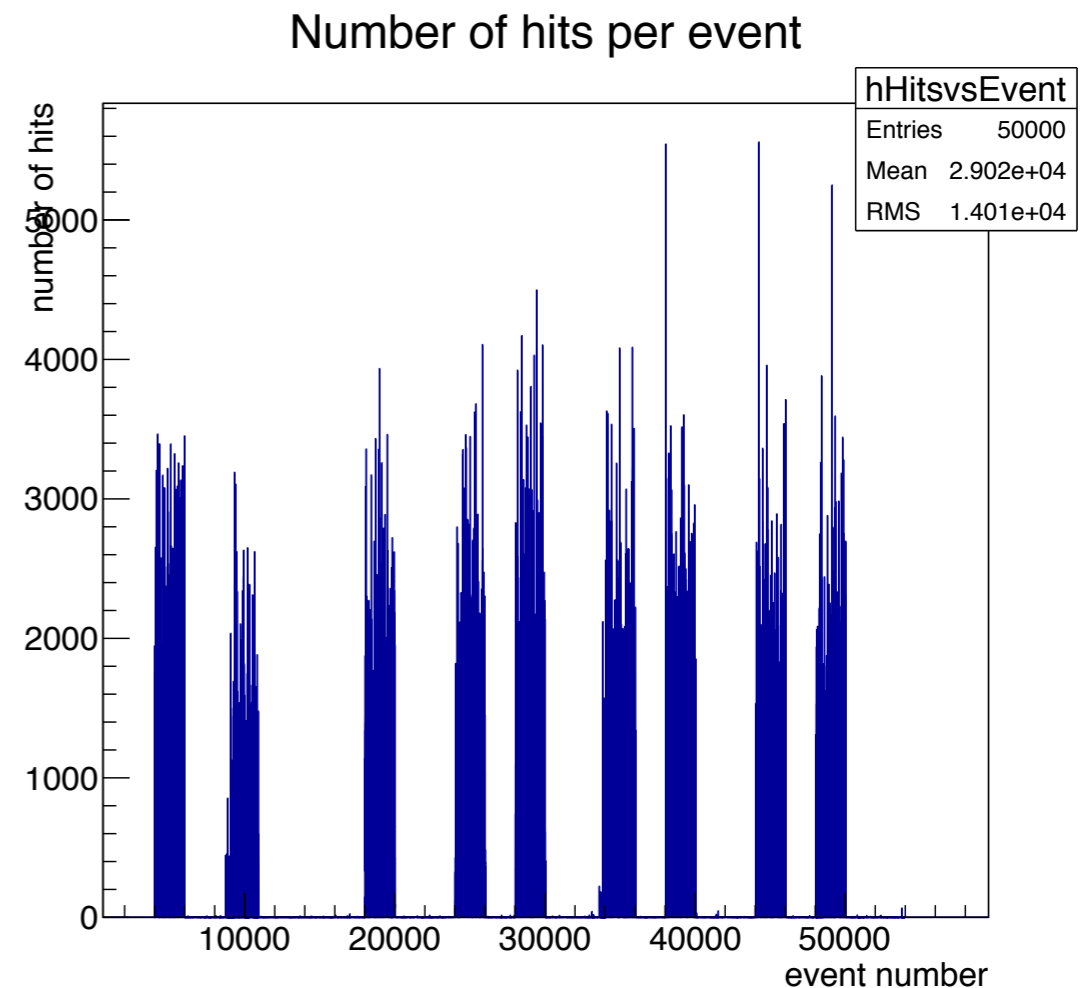
Data Sets SPS

- Electron beam
- Two Setups
 - Behind PADS (effectively 66.5 mm W $\sim 19 X_0$)
50, 100, 110, 120, 150, 180, 250 GeV
 - Directly in beam with 0, 20 ($\sim 5.7 X_0$), 28 ($\sim 8 X_0$) mm W in front
50, 100, 150 GeV
- Total of **580 Million events** recorded at SPS, but only small (still unknown) number of events with beam particles

Event Selection

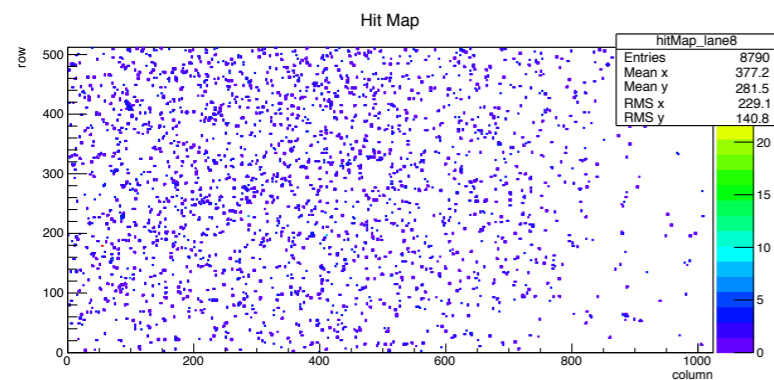
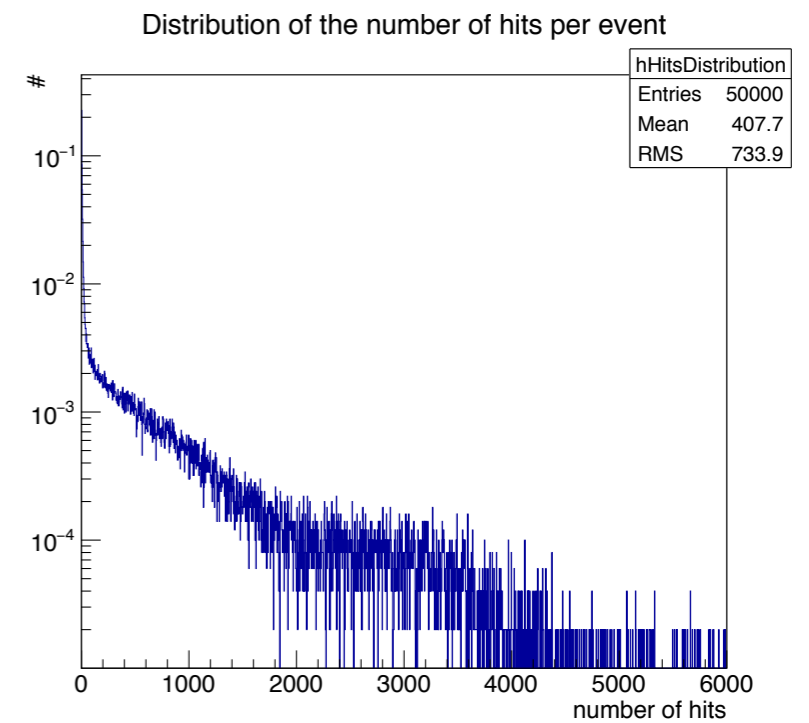
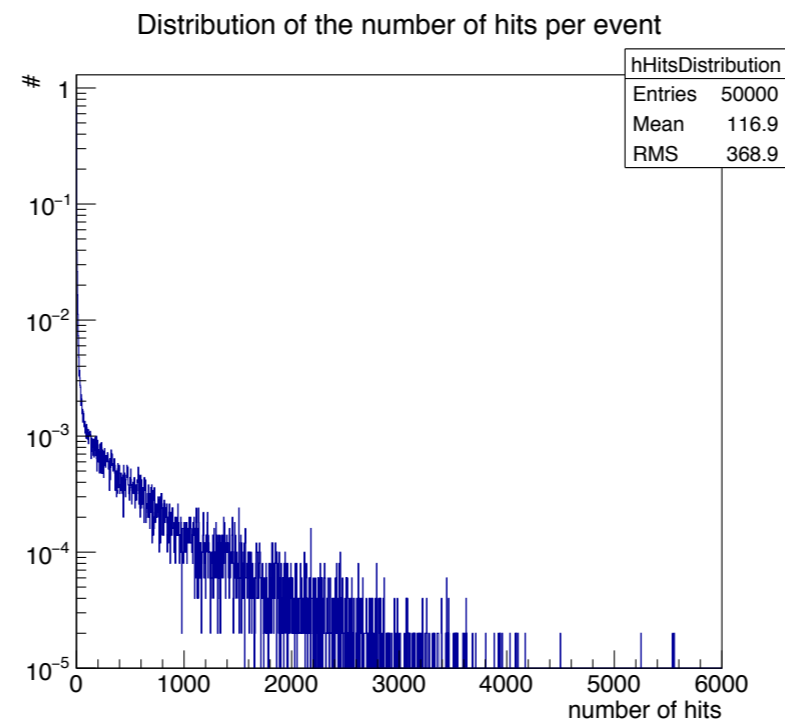
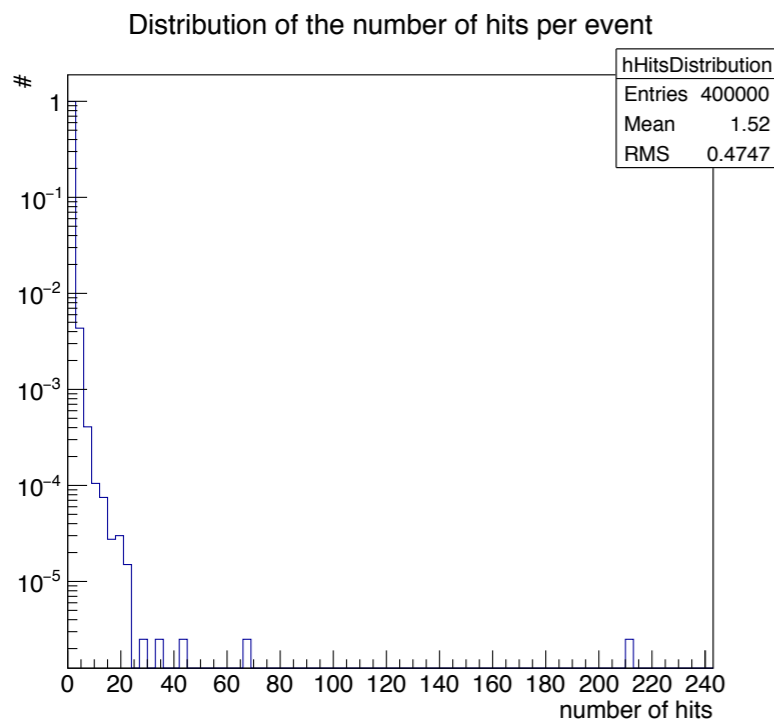
Work in
Progress

- Investigating the nature of the events: noise or electron?
- Exclude “hot” pixels (only 2 for this chip)
- Cut on a minimum number of hits
- Some examples of electrons @ 150 GeV on the next slides

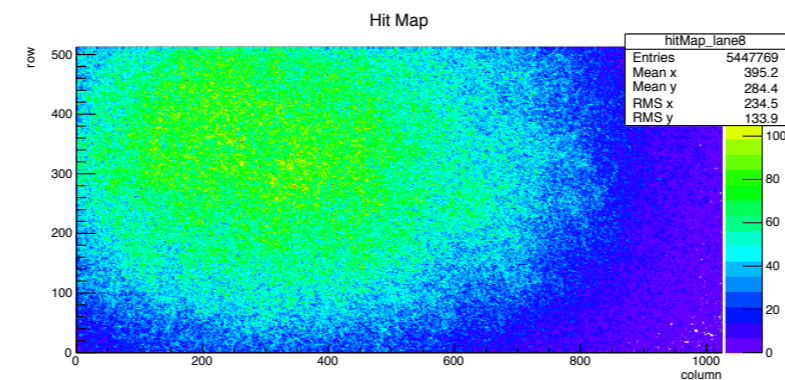


Number of Hits and Hit Maps

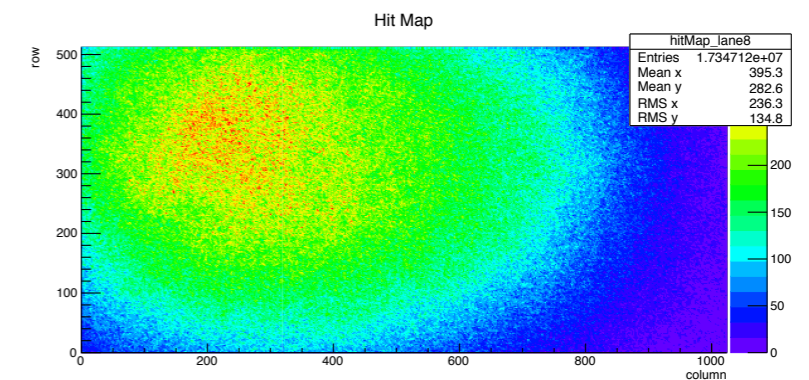
Work in Progress



0 mm W



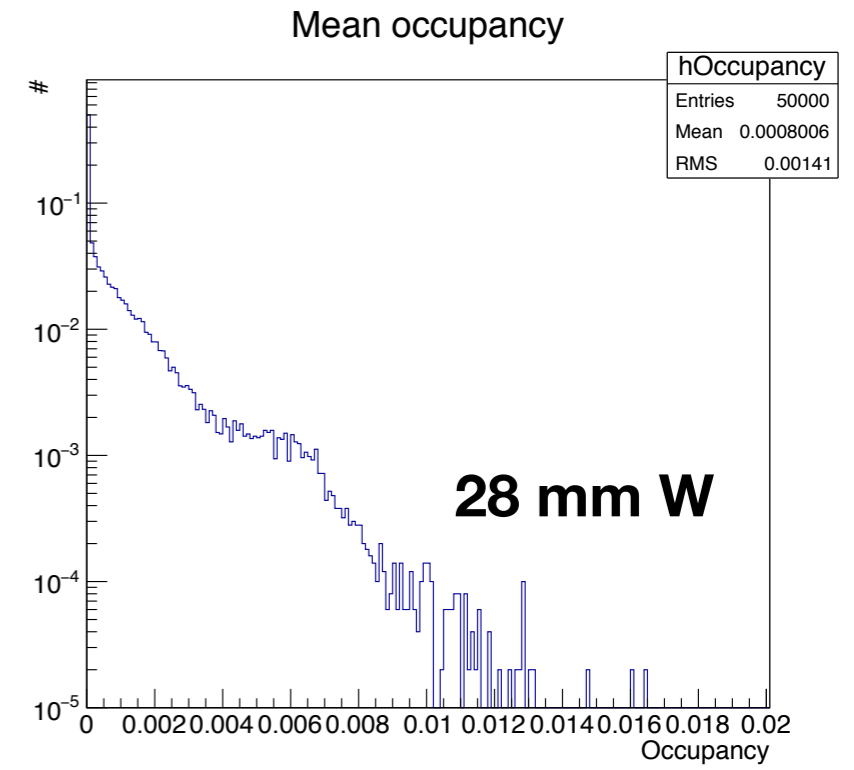
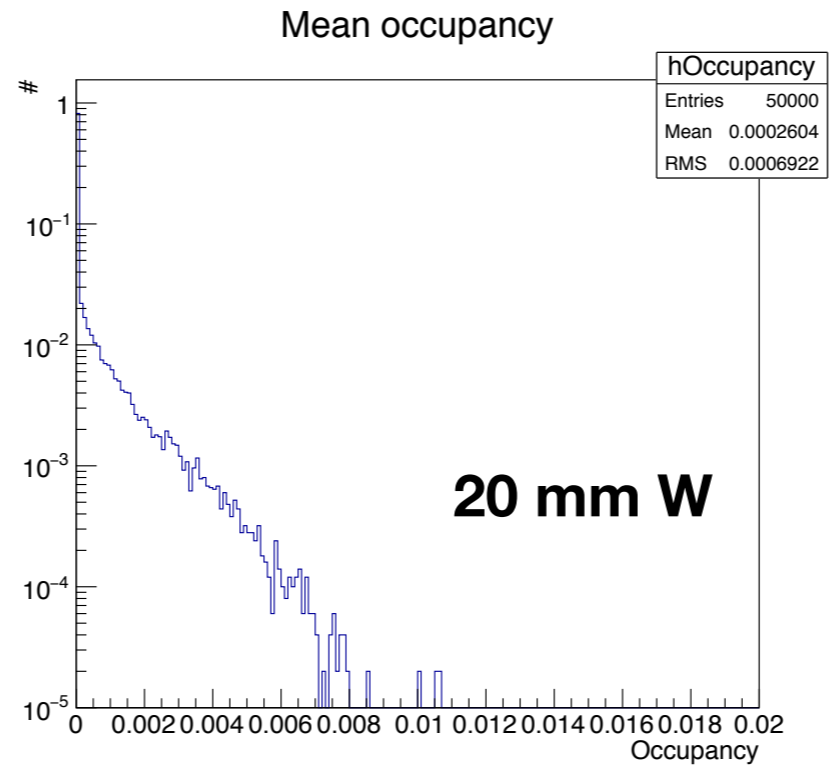
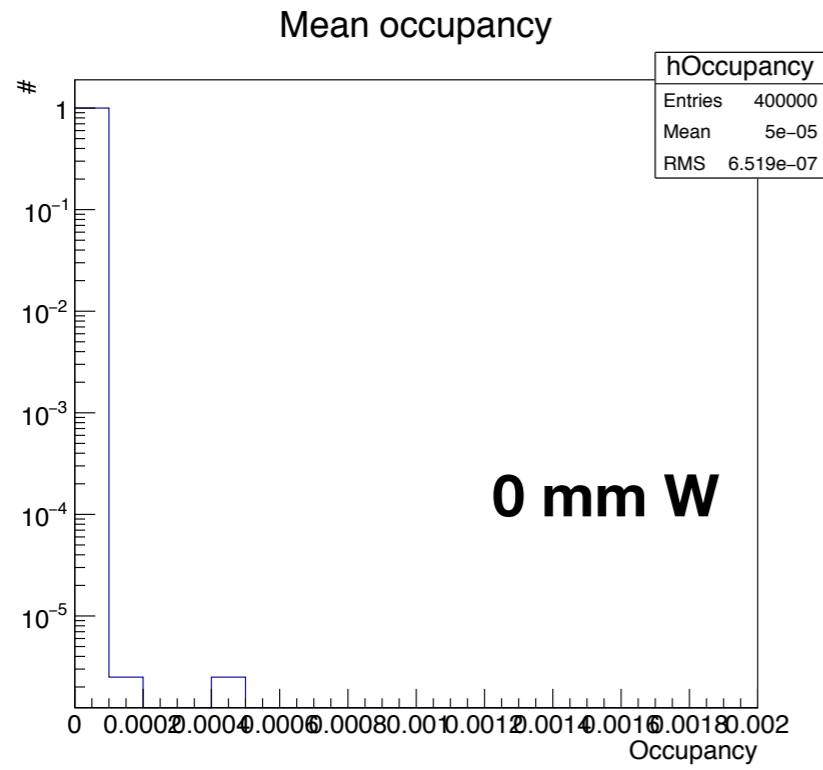
20 mm W



28 mm W

Occupancy

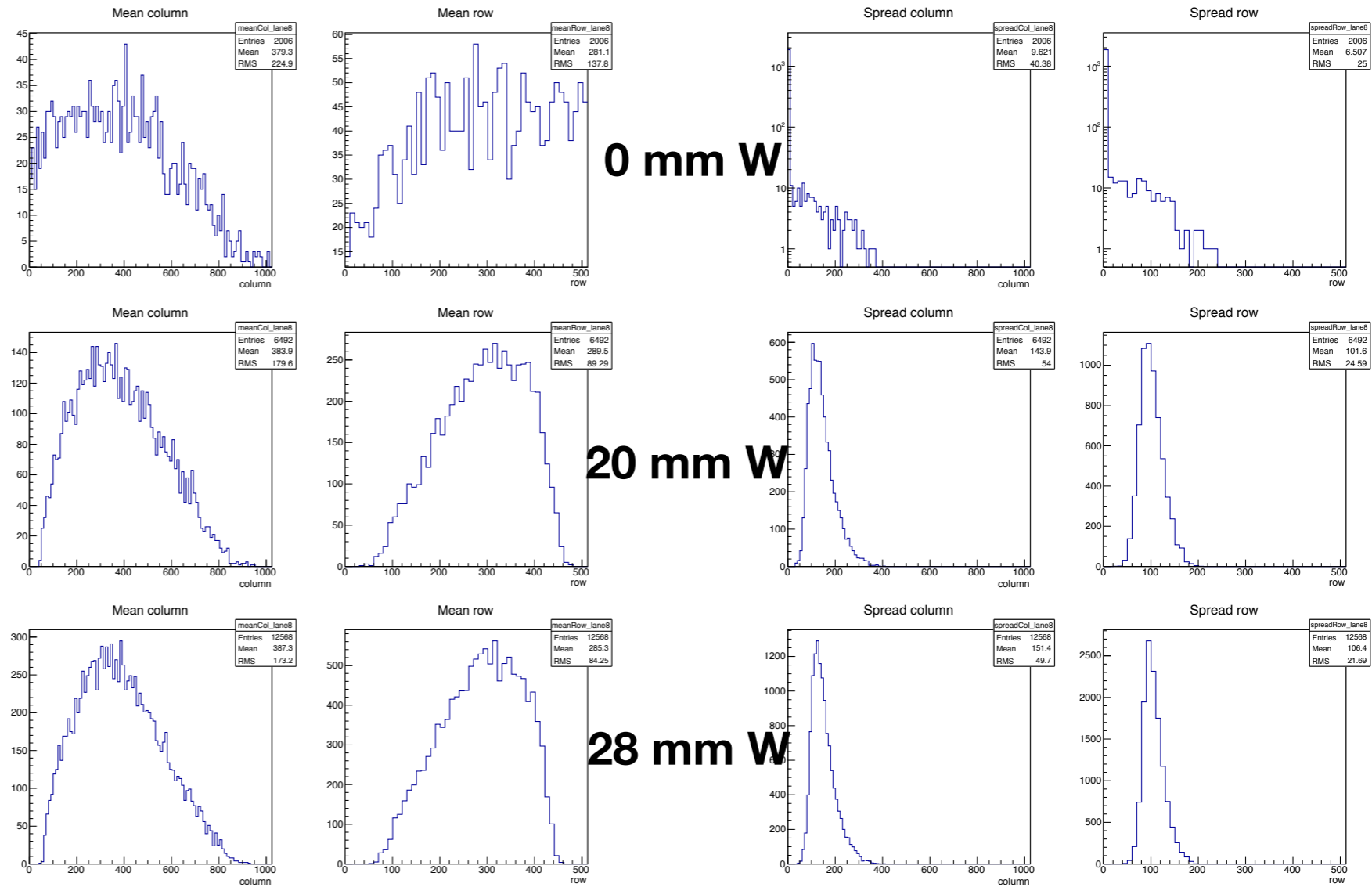
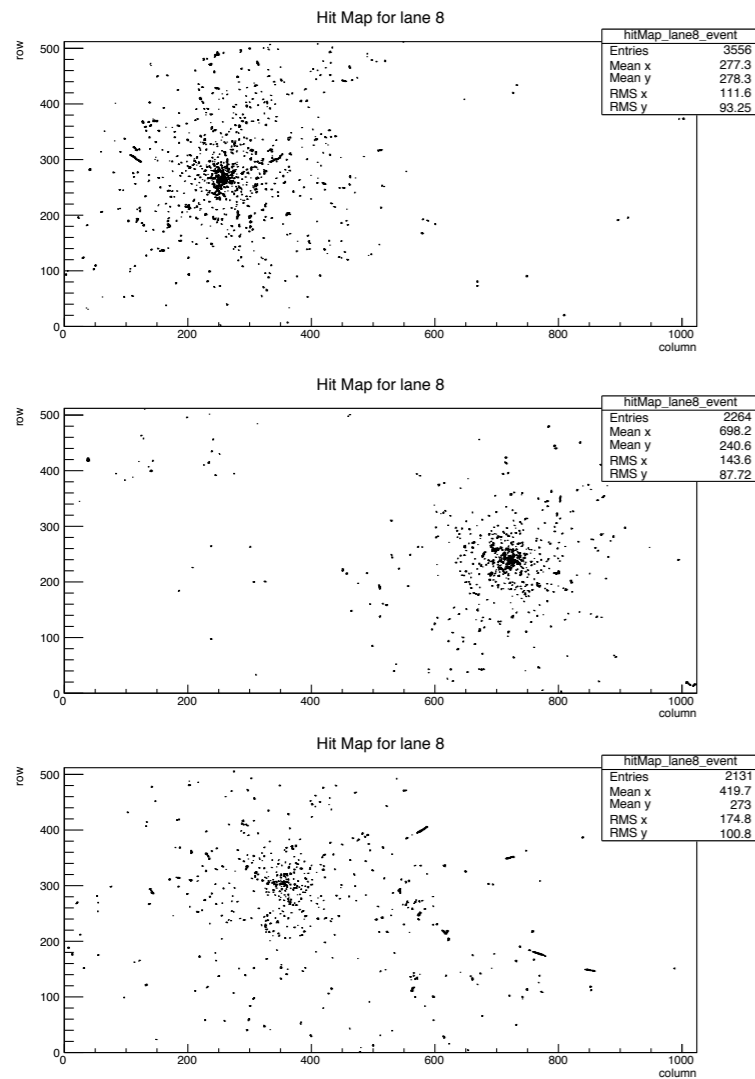
Work in Progress



Mean and Width of Hit Distribution

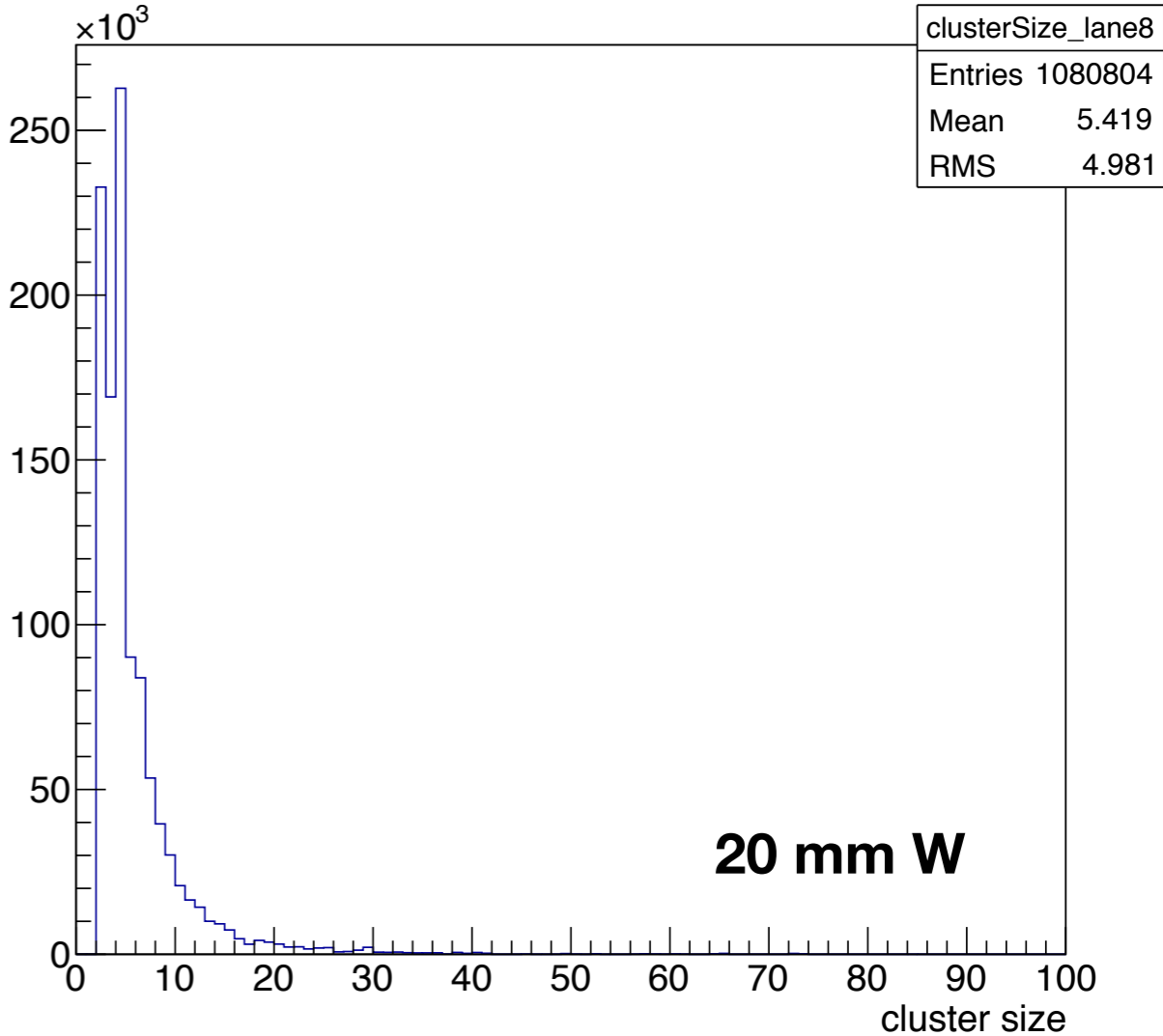
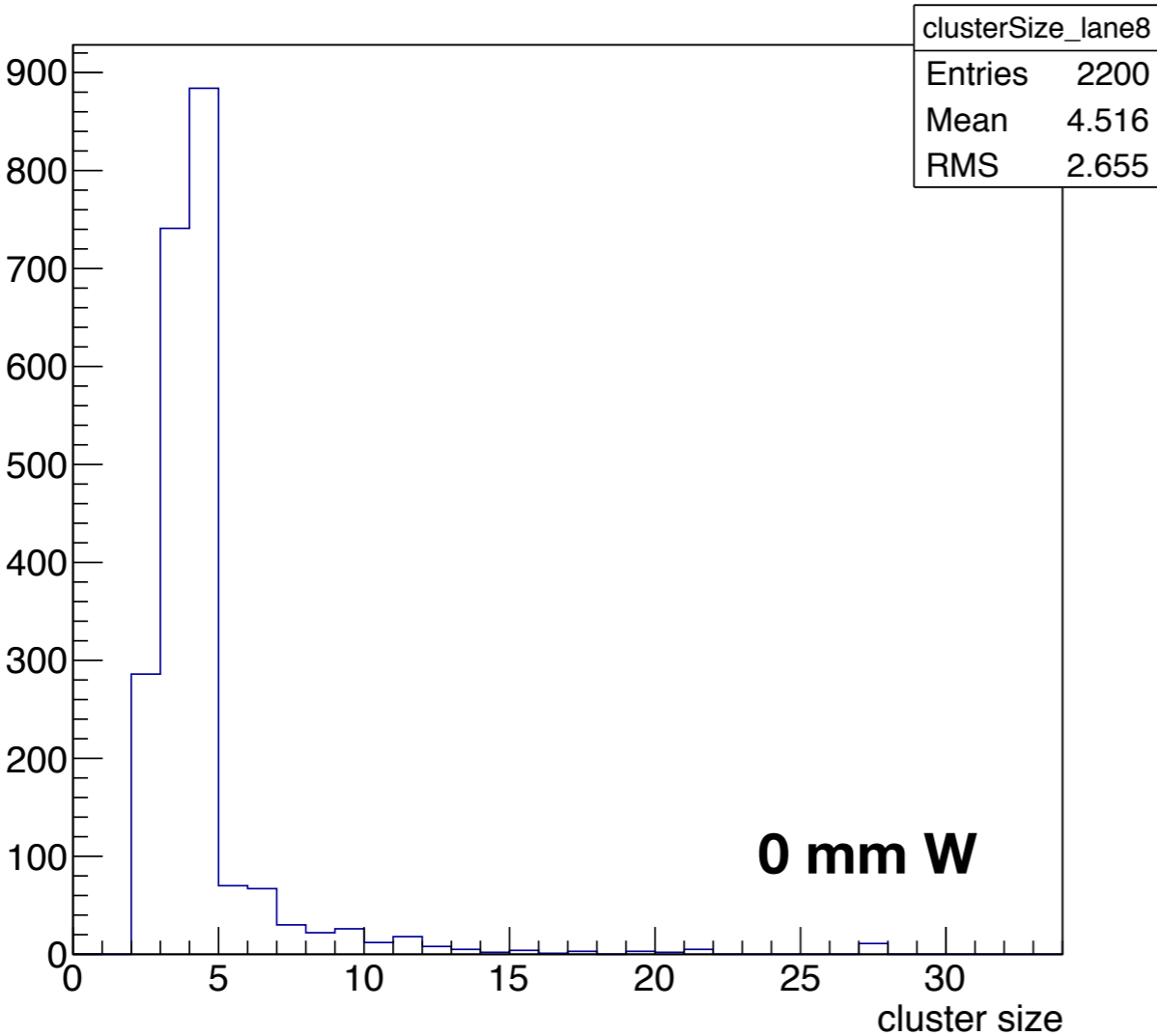
Work in Progress

Single events 28 mm W



Cluster size

Work in Progress



Conclusion

- **Proof of principle from MIMOSA prototype**
 - detailed information on working principle of digital pixel calorimeter, shower development
 - basis for reconstruction algorithms
- **Current R&D**
 - tests with ALPIDE ongoing, full prototype being built
 - working on full functionality of RU
 - MiniFocal in ALICE
 - complement with pixel layers?