Delivery of SALAT Status and Plans

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PHYSICS WITH INTEGRATED CMOS SENSORS AND ELECTRON MACHINES

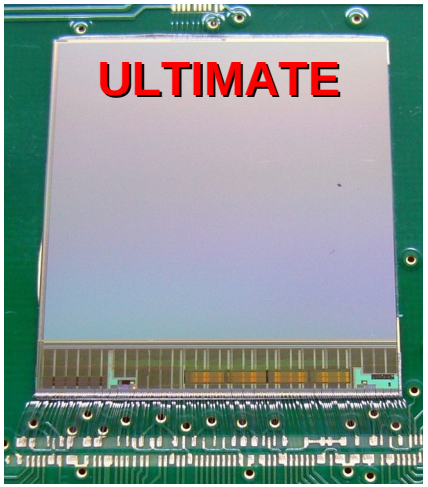
Outline

- Reminder on SALAT Prototype
- Preliminary results on SALAT Beam-Test @ DESY
- Plans for SALAT delivery
- Summary and outlook

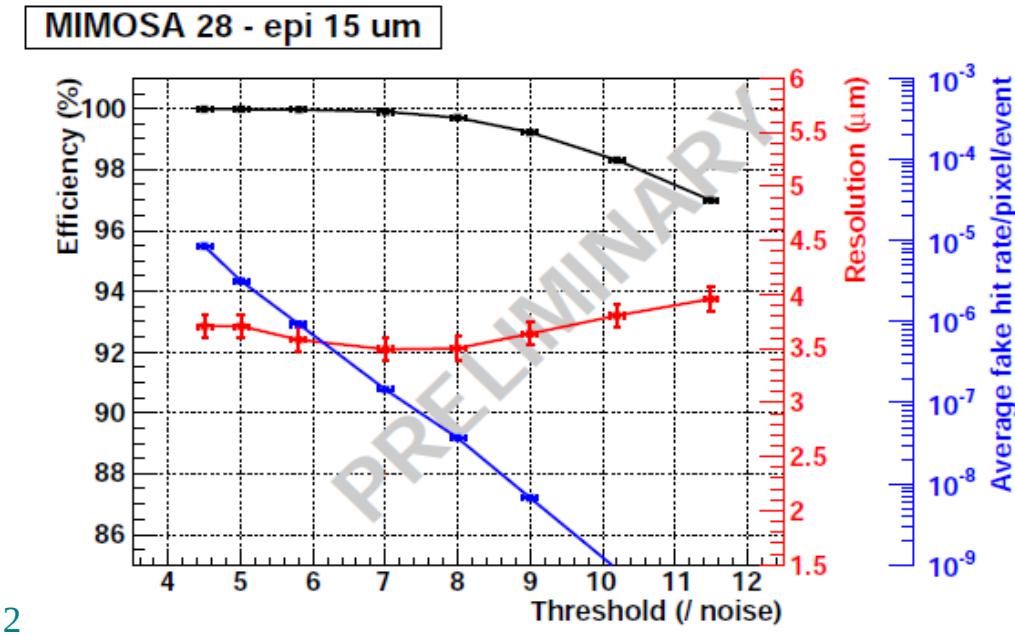
Reminder on SALAT prototype

The Sensors: ULTIMATE (MIMOSA-28)

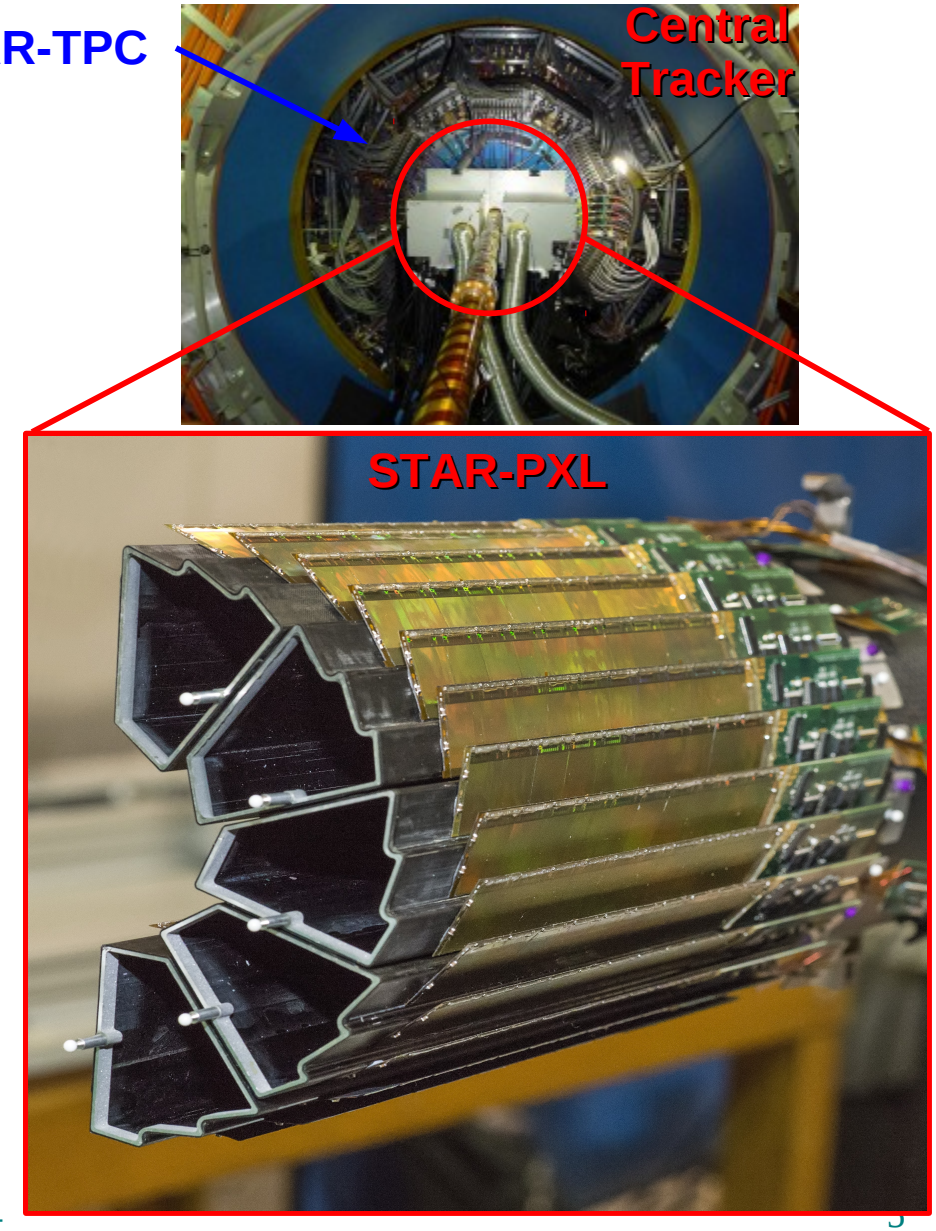
- **ULTIMATE main characteristics**
  - CMOS sensor (0.35µm AMS) high-resistive Epi-layer-15µm
    Sensor thinned to 50µm (total thickness)
  - Column || architecture with in-pixel CDS & amplification
  - End-of-column discriminator & binary charge encoding, followed by ∅-suppression
  - 960x928 (columns x rows): pitch 20.7µm (19.9x19.2 mm^2)
  - $t_{r.o.} \lesssim 200\mu s$ (~$5x10^3$ frames/s) ⇒ suited to > 10^6 part./cm^2/s
  - 2 outputs @ 160 MHz
  - Power consumption ~150mW/cm^2
  - Running at room temp. (T = 30C°)



- **ULTIMATE Performances**
  - $\sigma_{sp} \gtrsim 3.5\mu m$
  - Efficiency $\lesssim$ 99.9%
  - Fake rate $\lesssim 10^{-5}$



ULTIMATE @ STAR: STAR-PXL detector



- **STAR-PXL HALF-BARREL**
  - 2 layers: 20 ladders (0.37% X_0)
  - 200 sensors
  - 180×10^6 pixels
  - Air flow cooling: $T \lesssim 35^oC$
  - $\sigma_{sp} \lesssim 4\mu m$
  - Rad. Load 150kRad + 3×10^{12} n.e.q (Full life-time)
  - $t_{o.r.} \lesssim 200\mu s$
  - Currently commissioning with 200 GeV Au – Au collisions

LAT final plane

- **LAT motivations**
  - Big surface and thin reference planes

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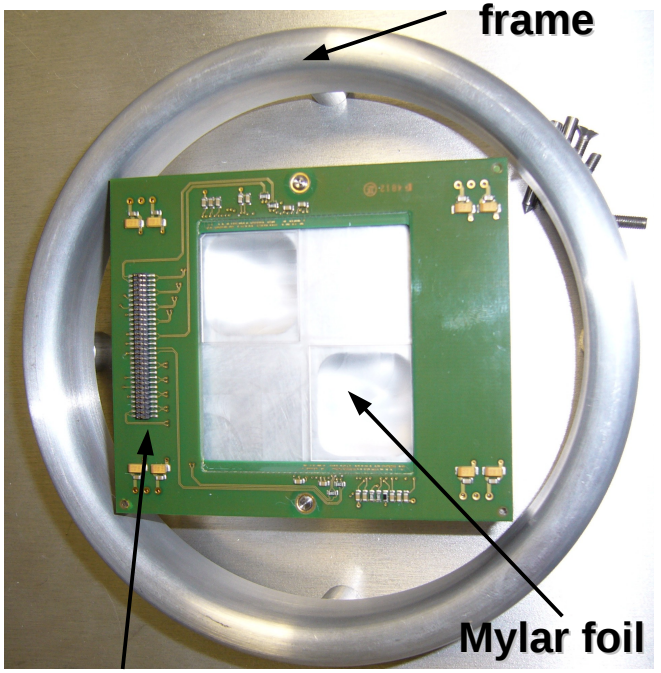
- **Assembly**
  - Stretched 50μm Mylar foil ($X_0^{Mylar} \sim 3 \times X^{Si}{}_0$)



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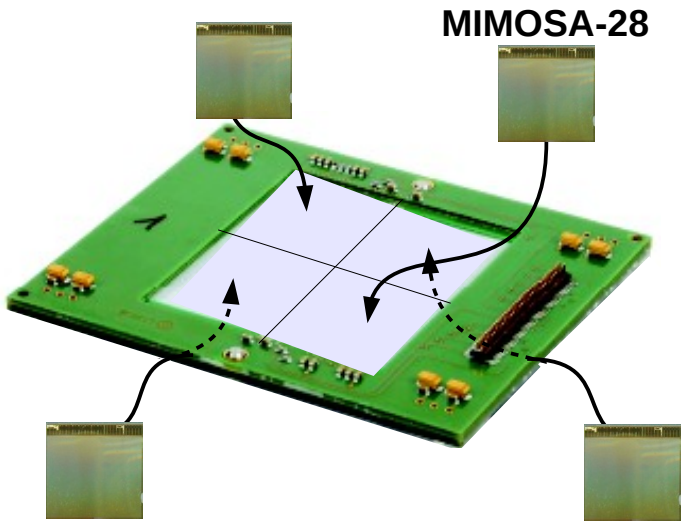

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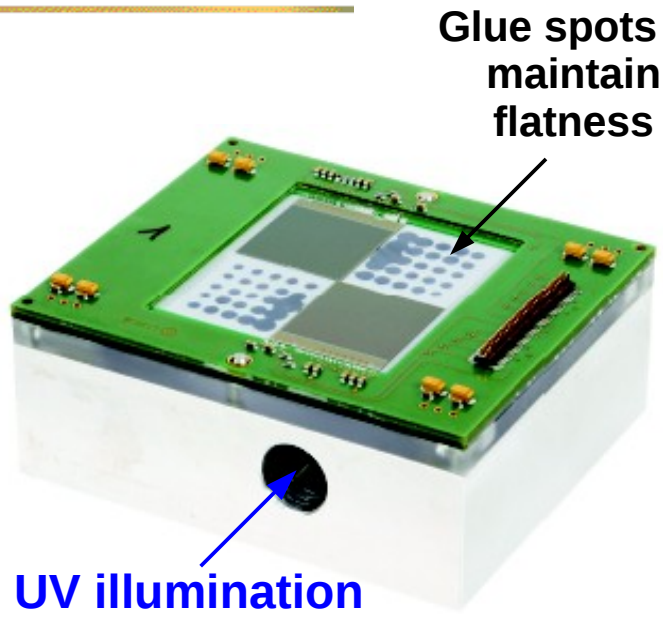

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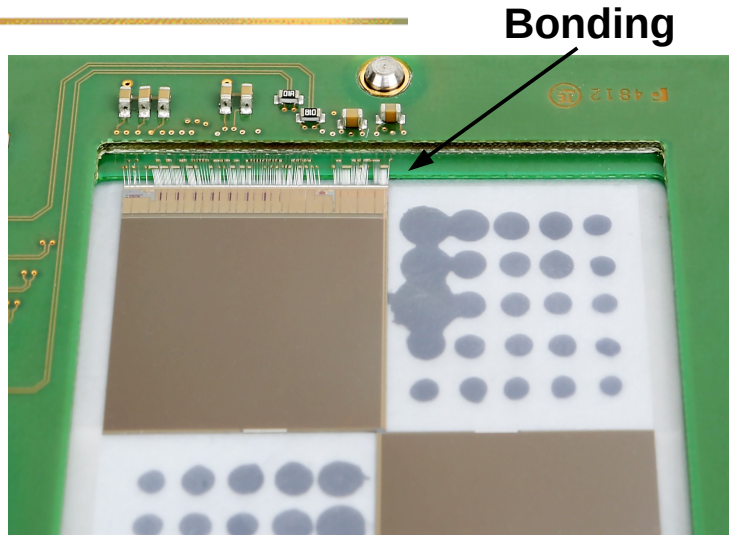

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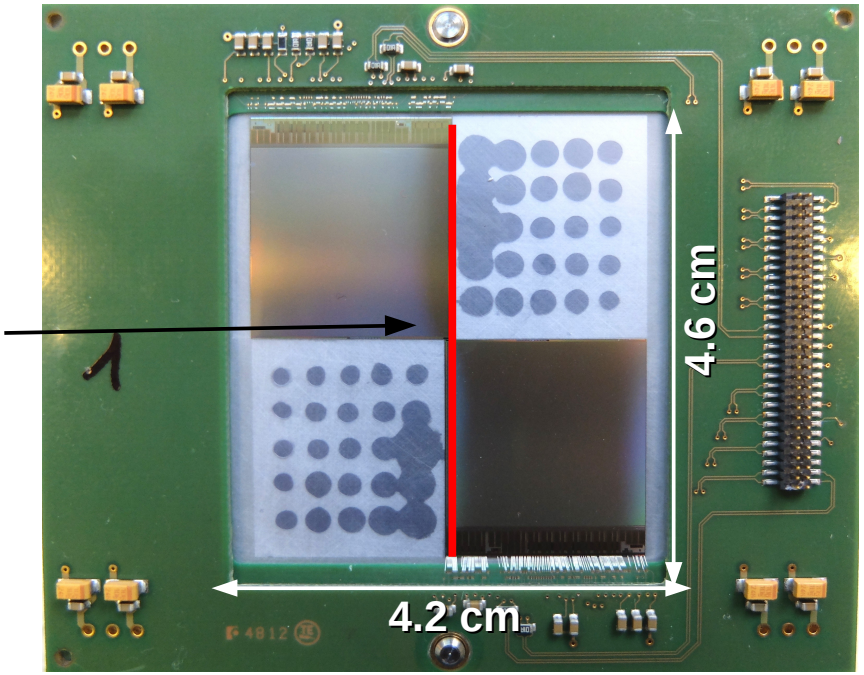
- **Basic numbers**
  - 3.6 M-pixels over 15.3 cm^2
  - $\lesssim$ 200µs integration time
  - Insensitive areas ~100µm

Sensing area = 4 x 3.8cm^2



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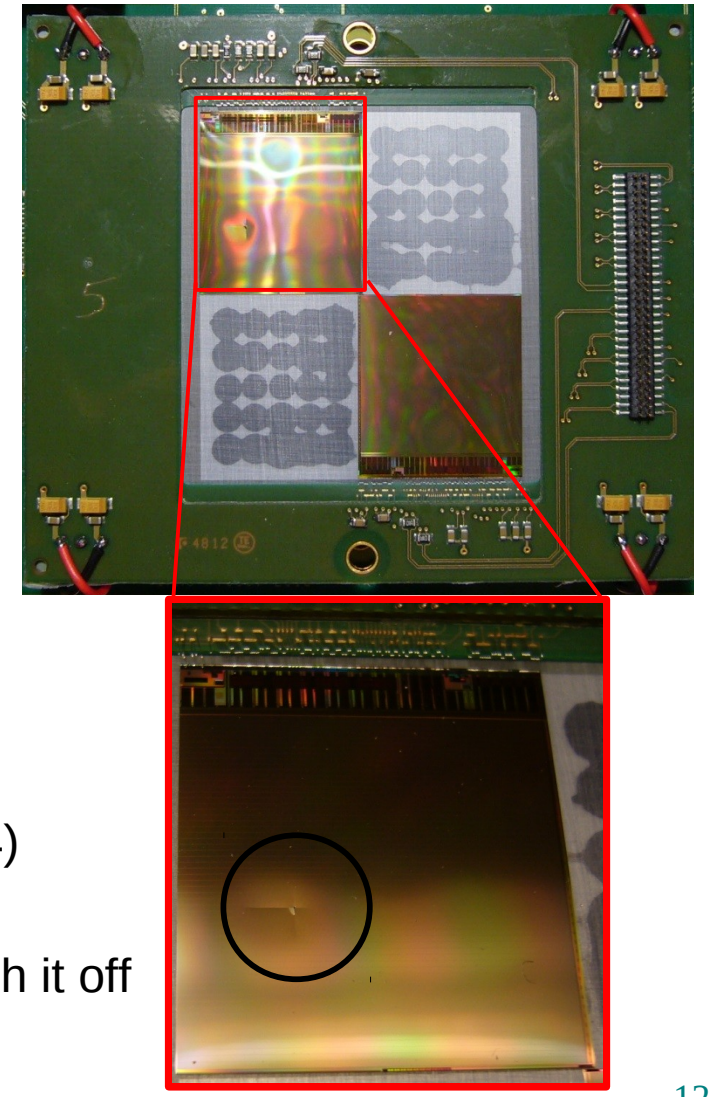
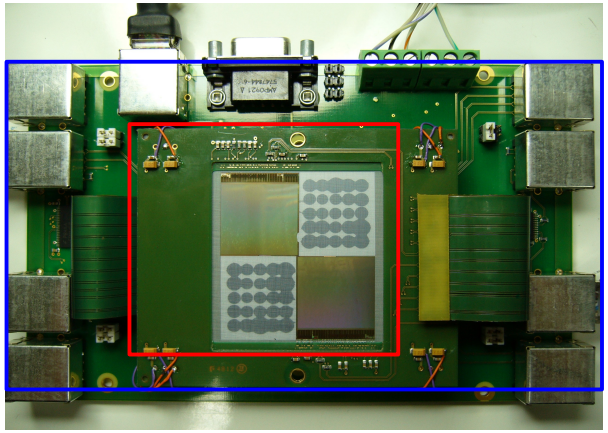
- **Production**
  - 2 SALAT planes fully operational (Mod-3 and 4)
  - One crack on sensor of Mod-3 during gluing
  - Even if sensor still operational decided to switch it off

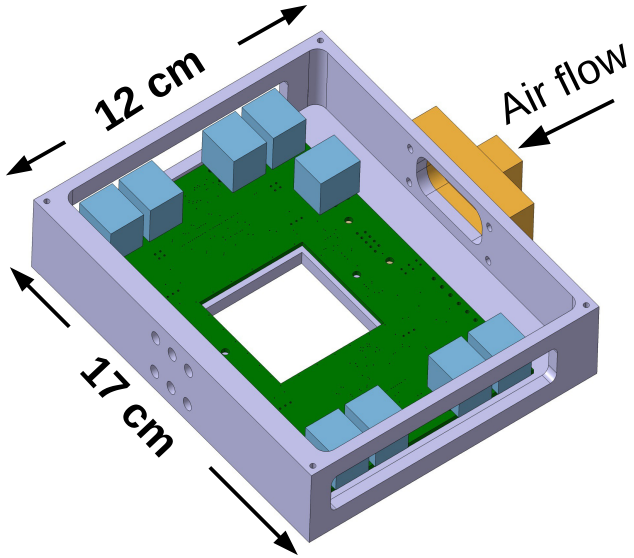
Module-3



SALAT PCB, Mechanics and Cooling

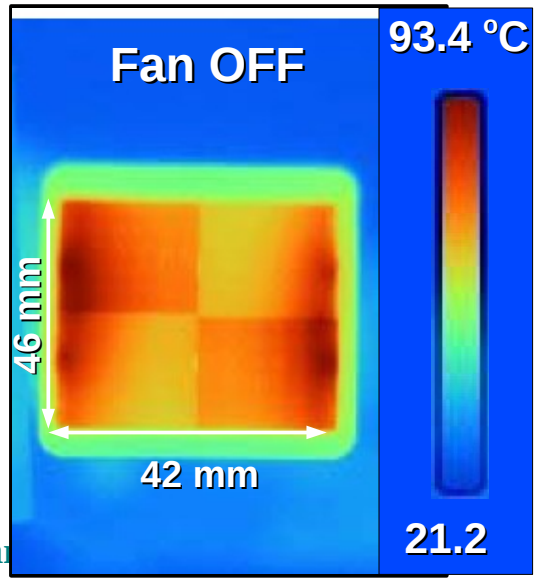


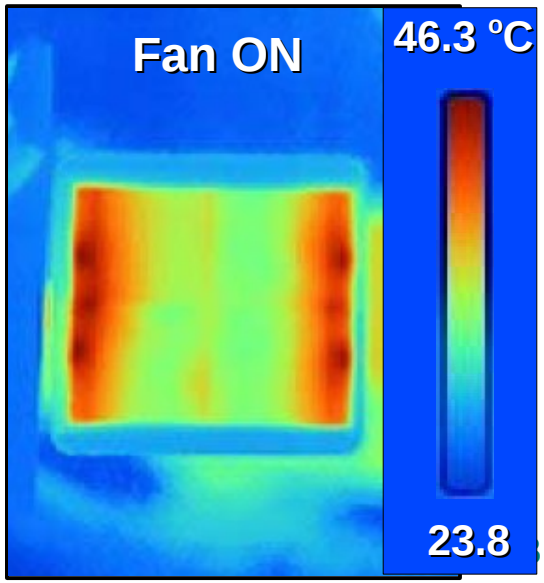
- **PCB design**
  - Mother (10x16 cm^2) and daughter (7x8 cm^2) design and production at IPHC micro-tech group



- **Mechanical structure**
  - Design and production at IPHC mechanical workshop

- **Cooling system**
  - Chip works with no cooling (relatively high noise)
  - Modest cooling required
  - Few m/s of ambient air



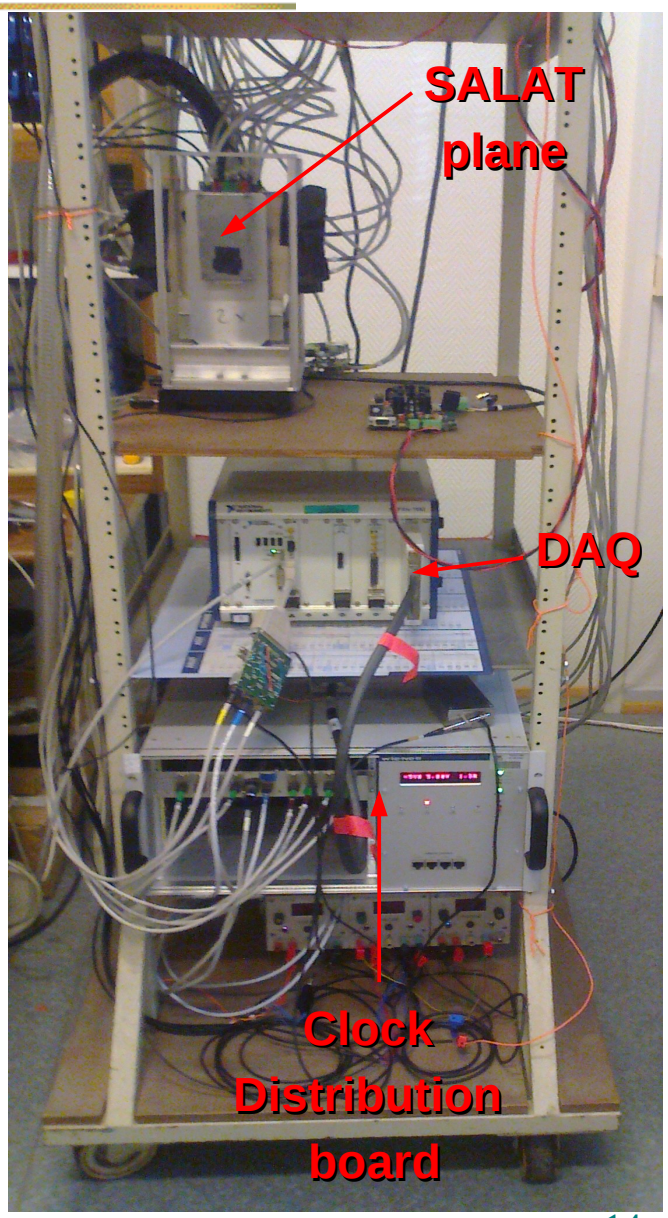


SALAT Data Acquisition System

- **DAQ package for Mimosa-28 beam-test**
  - DAQ developed for IPHC
  - Limited to 2 SALAT planes (8xMi28 sensors)
  - Need clock distribution board

    ⇒ prototype version used

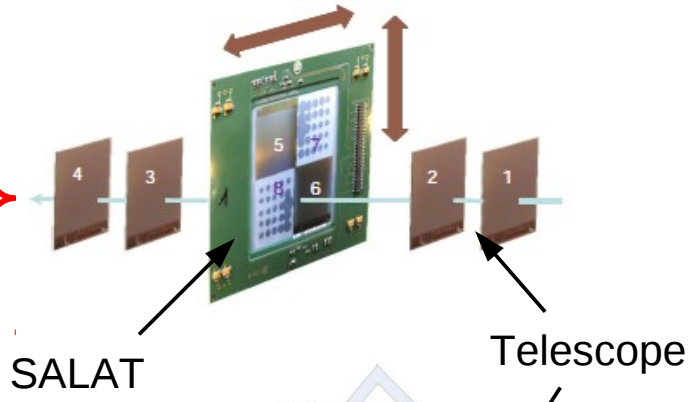
- **DAQ in a nut shell**
  - Based on NI FlexRIO acquisition board hosted in a PXIe crate
  - Acquire 16 links (8 x Mi28 x 2 links) @ 160MB/s
  - Continuous readout – Data bandwidth 220 MB/s
  - No dead-time up to 8 x Mi28 = 2 x SALAT planes
  - Data Storage on a RAID system
  - Particles flux up to 10^6 hits/cm^2/s



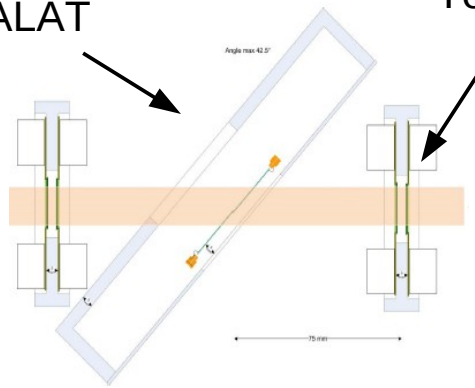
SALAT beam test @ DESY
Preliminary results

February test beam @ DESY: overview

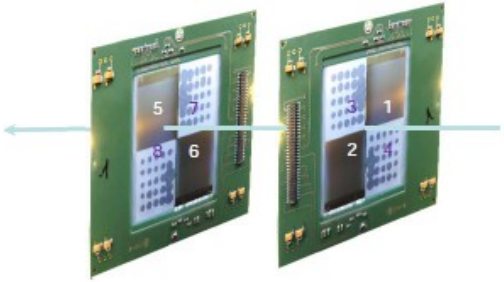
- **Conditions @ DESY**
  - e^- beam with energy from 3.0 up to 6 GeV
  - Air cooling
- **Uniformity study**
  - Scan SALAT surface with e^--beam & telescope
  - Study uniformity of sensor performances (efficiency & resolution)



- **Studies of planarity assessment**
  (Not reported in this talk)
  - SALAT @ sizeable angles (20, 40º)
  - Ongoing analysis

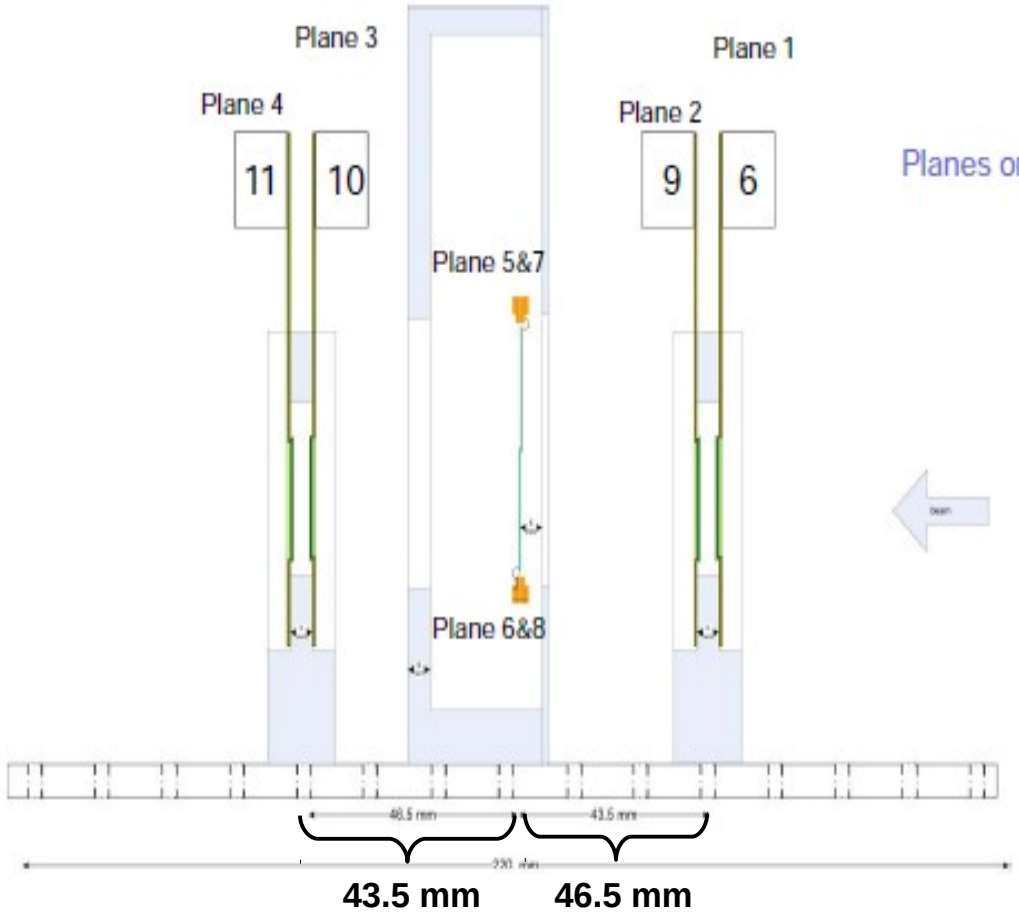


- **Proto-Telescope**
  - Only 2 SALAT planes available



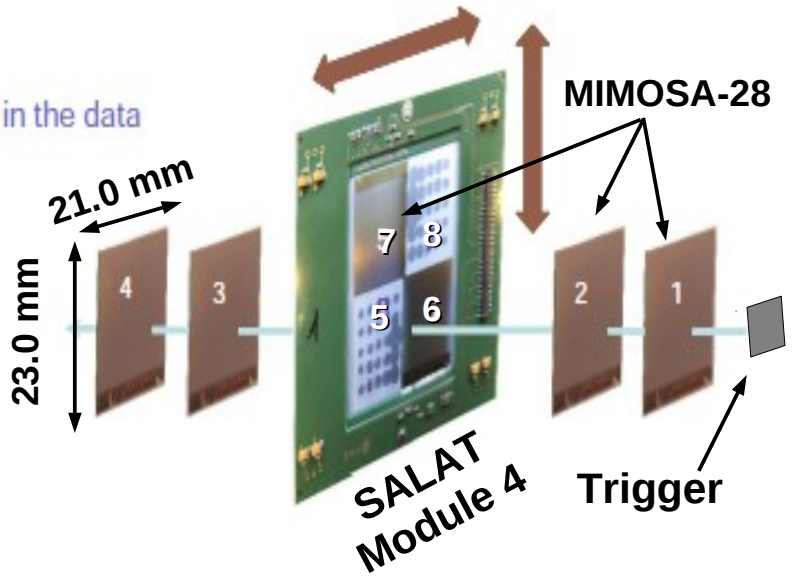
Uniformity Studies: Set-up

- **Configuration:** 4 reference planes (Telescope) and one SALAT module
  - Homogeneity scan: efficiency and resolution



Planes order in the data

5.0 – 5.4 GeV e^- beam



Collimator: 2x2 cm^2

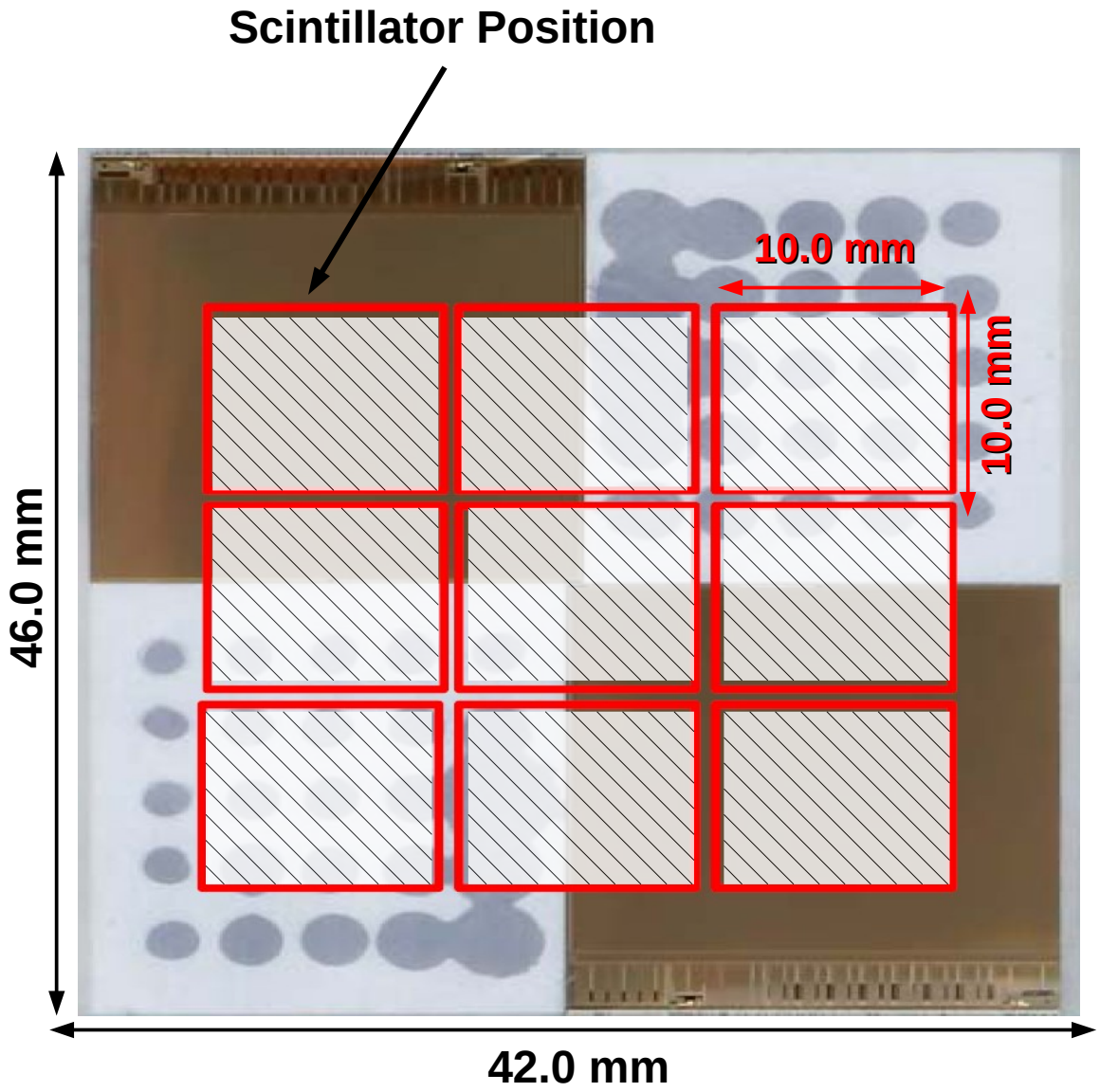
Trigger: 1x1 cm^2 Scintillator

Uniformity Studies: The Data

- Scan over the SALAT surface
- 9 regions, several thresholds:

  5, 6, 8 and 10 x noise

  (Not all the thresholds for all regions)

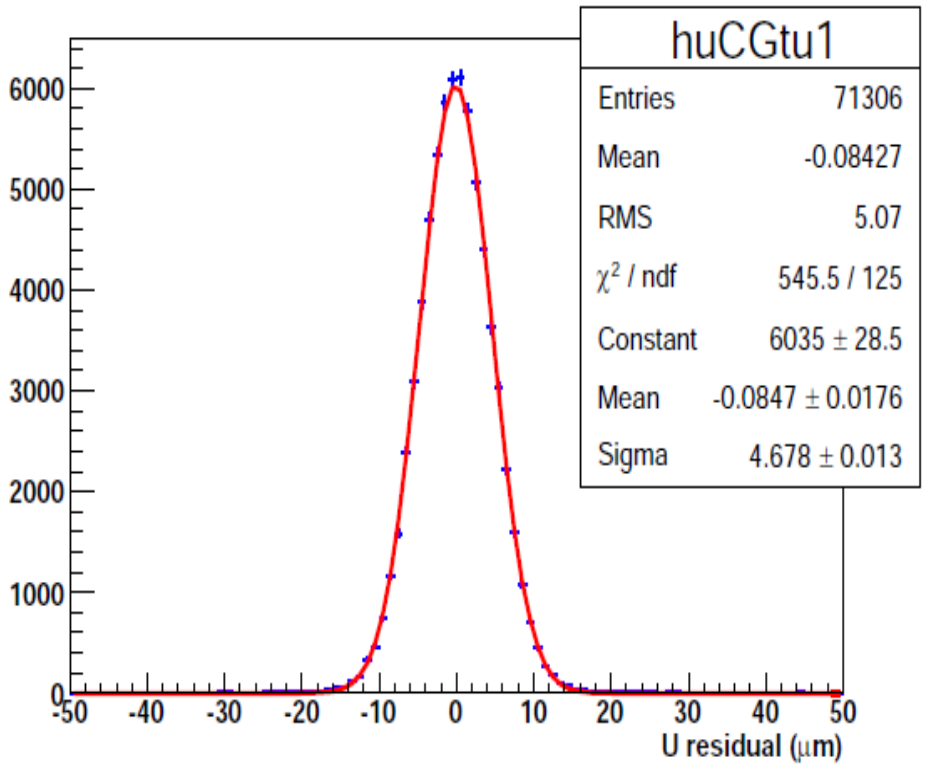


Uniformity Studies: Alignment and Residuals

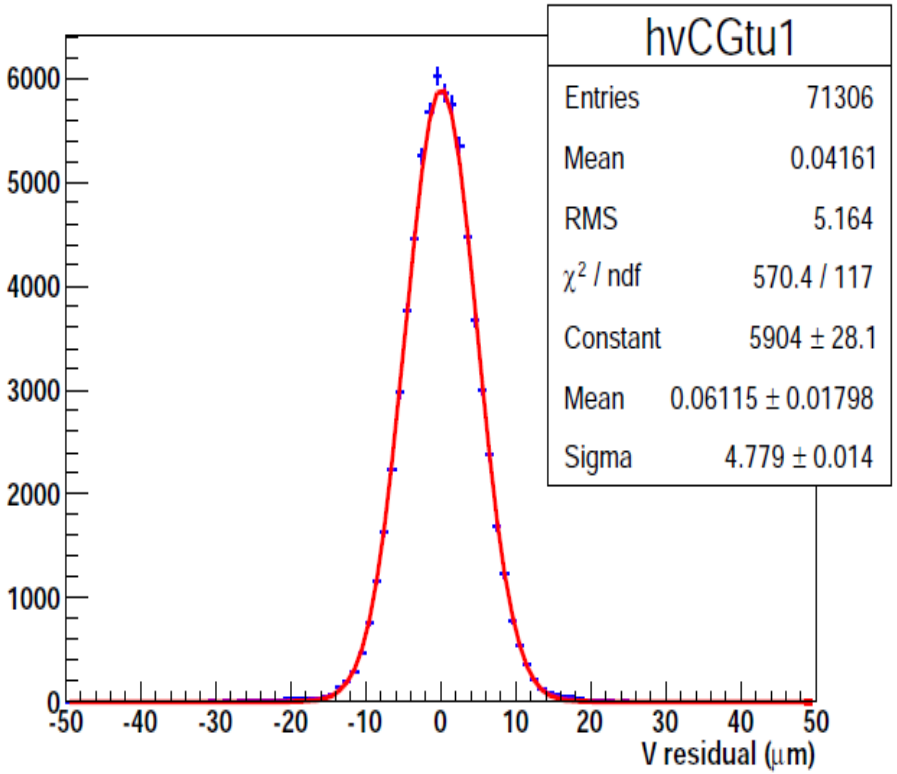
Sensor 5 of module 4

THR @ 6x noise

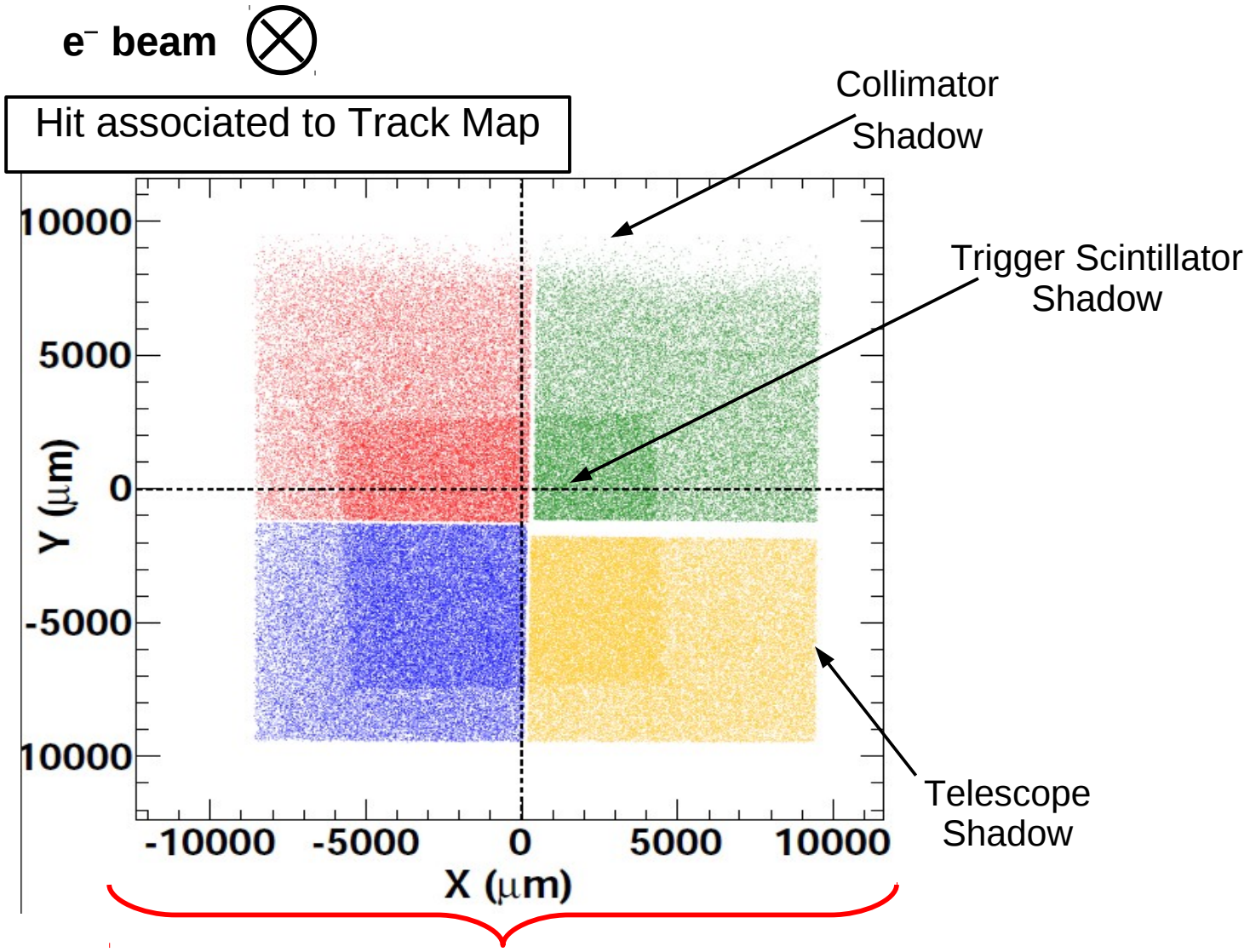
Residual U



Residual V



Uniformity Studies: SALAT Insensitive Zones

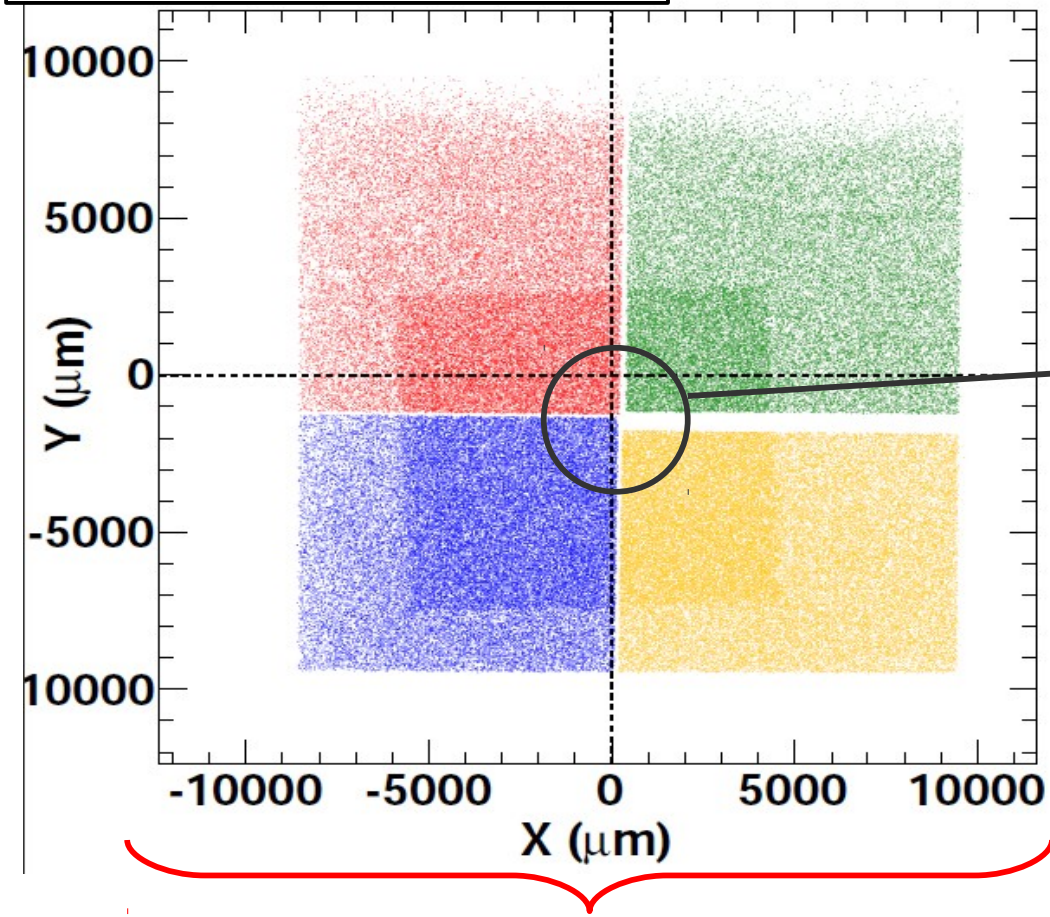


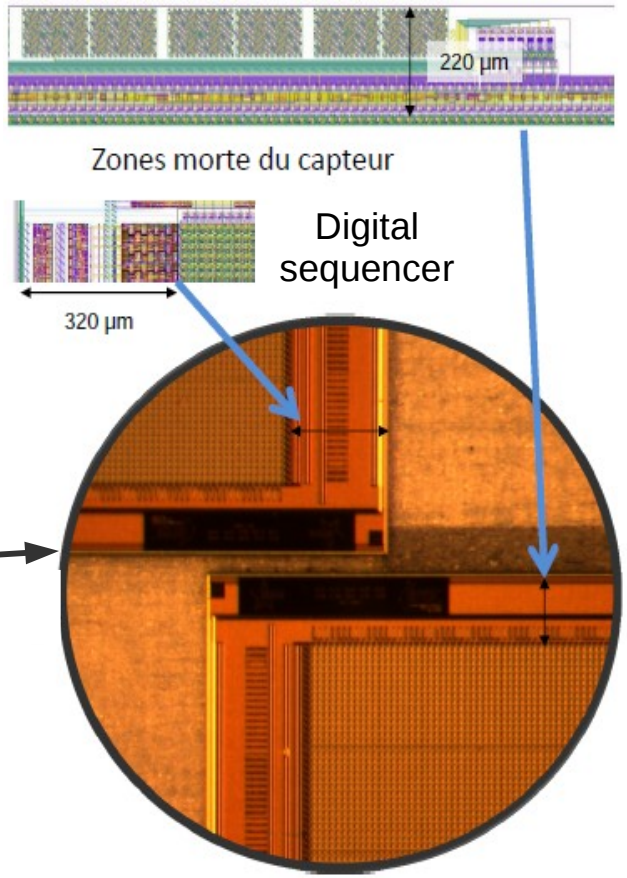
Each Quadrant = one MIMOSA-28 Corner

Uniformity Studies: SALAT Insensitive Zones

e^- beam ⊗

Hit associated to Track Map

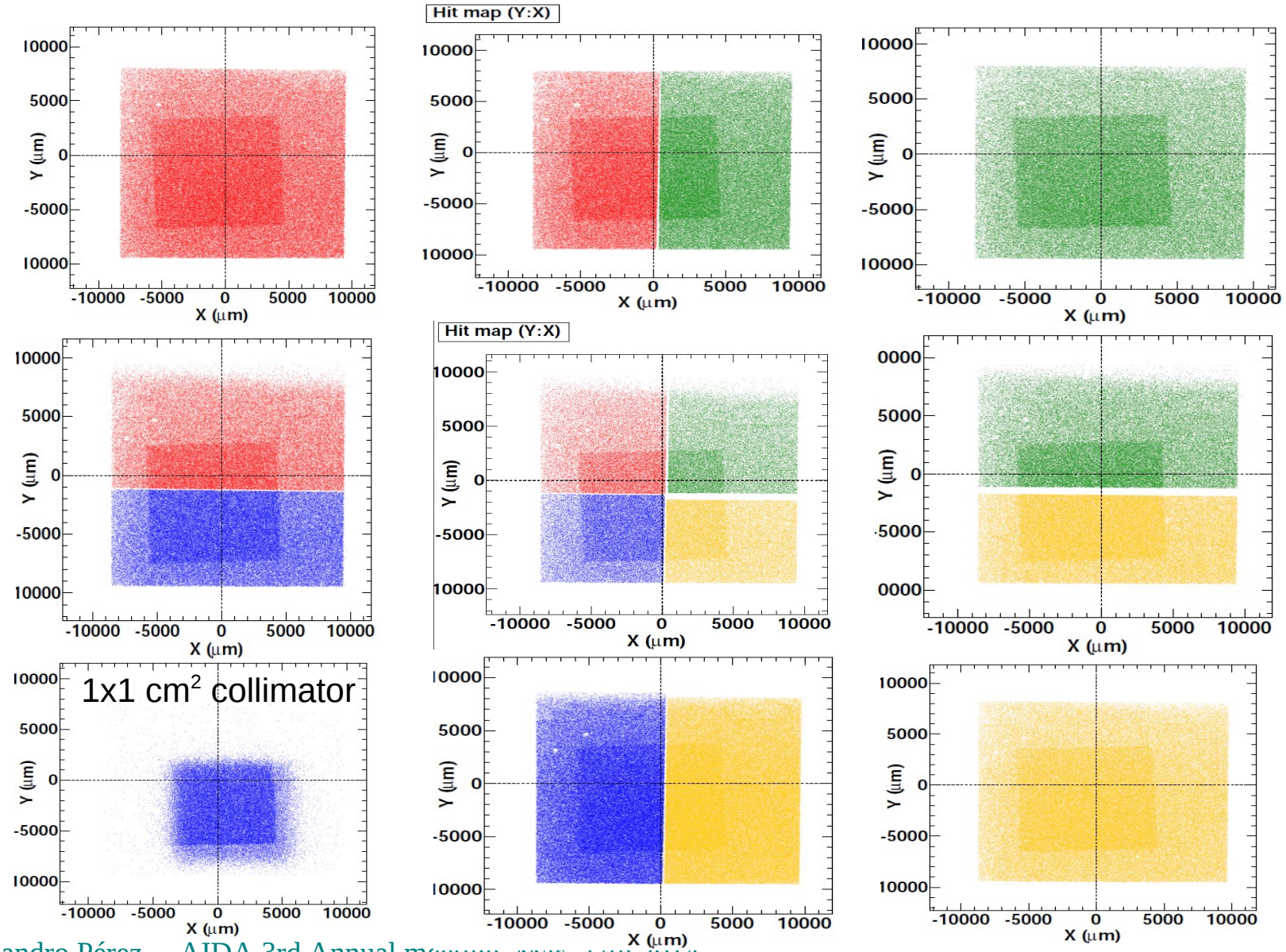




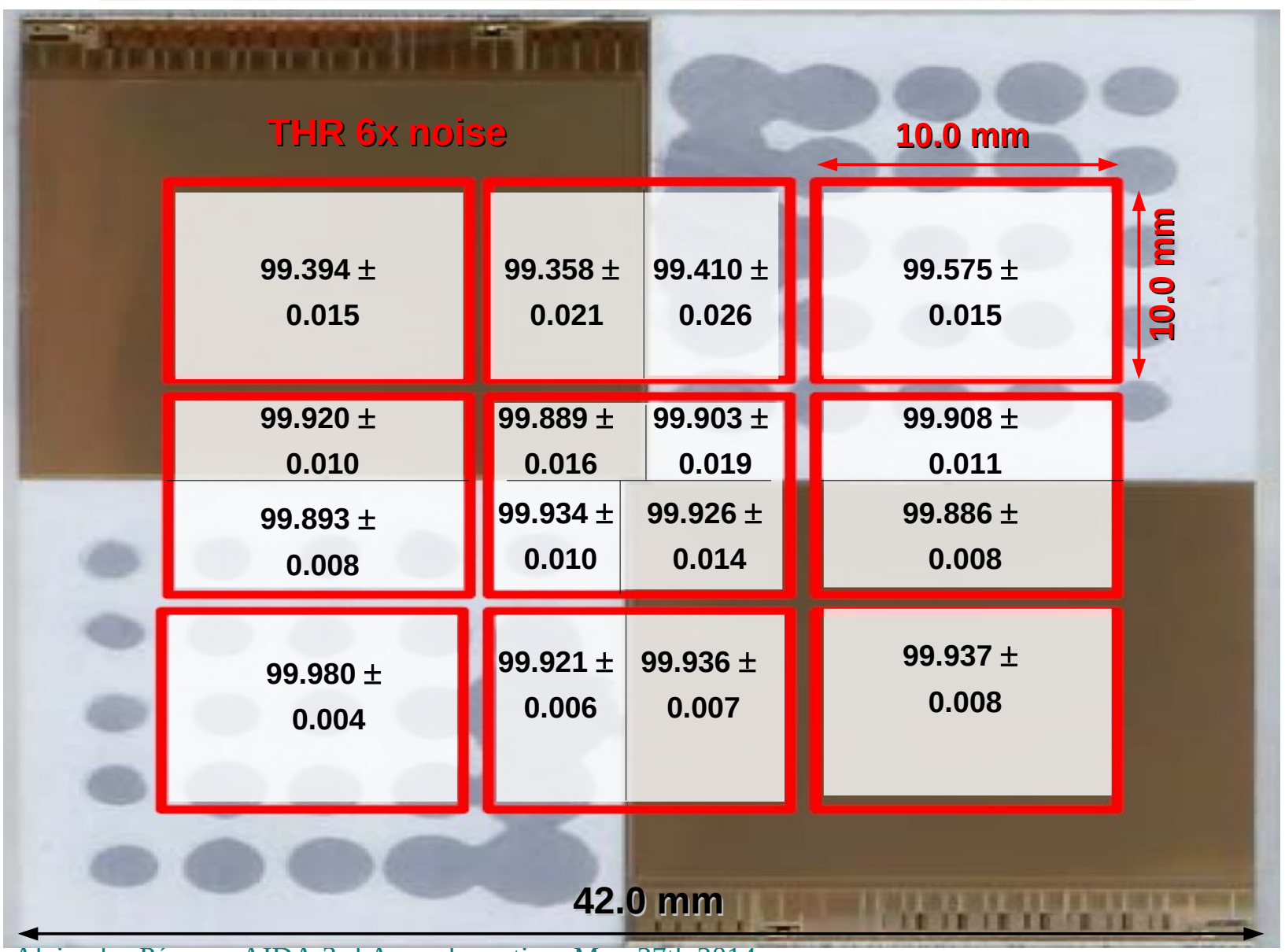
- Final version no horizontal gap
- Vertical gap ~100µm

Each Quadrant = one MIMOSA-28 Corner

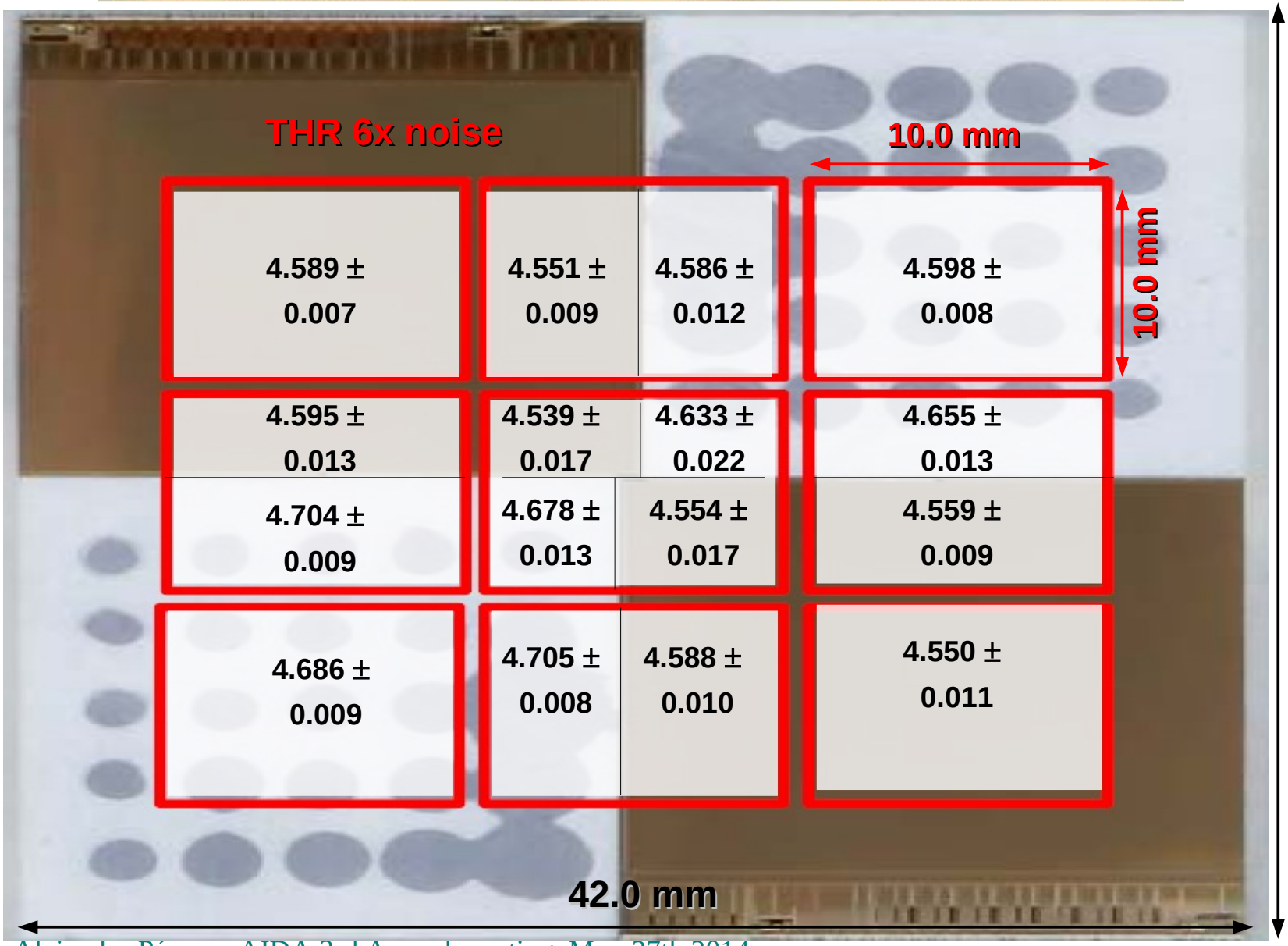
Uniformity Studies: SALAT Image of beam scan



Uniformity Studies: Detection Efficiency (%)

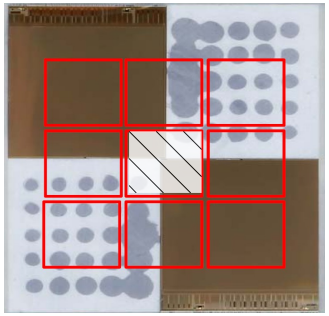


Uniformity Studies: Residual-U (µm)

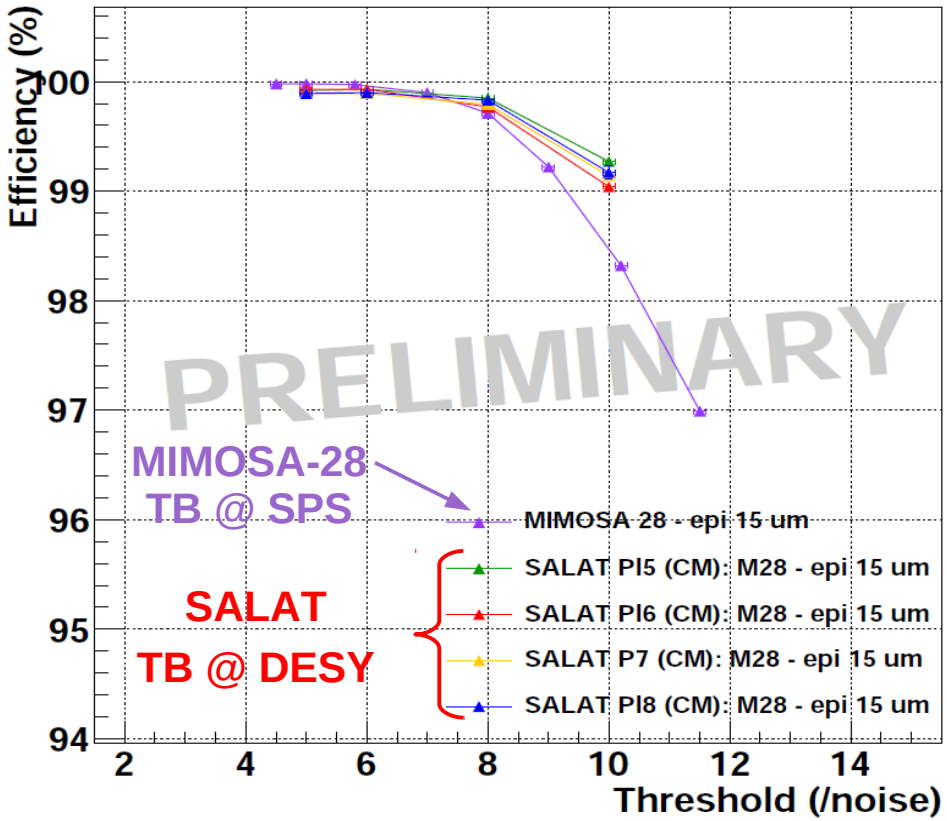


Uniformity Studies: Sensor performances vs THR

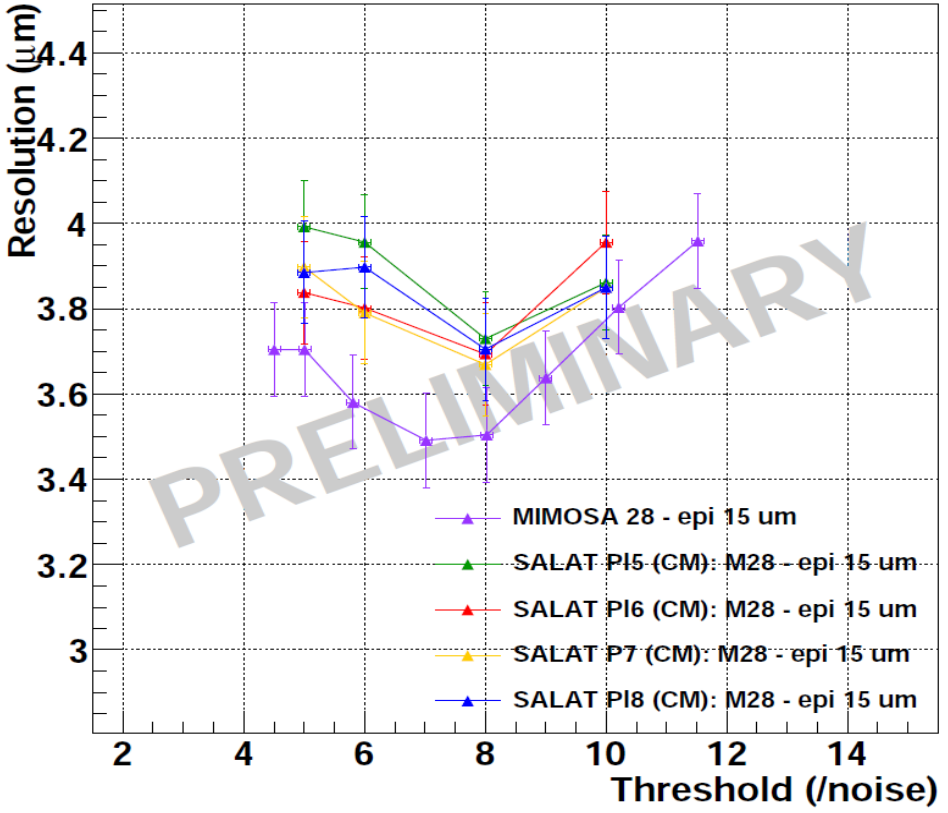
- Estimated Telescope resolution + multiple scattering ~ (2.2 ± 0.2)µm
- Same performances as MIMOSA-28 beam-test @ SPS (~100GeV π^+)



Efficiency vs Threshold

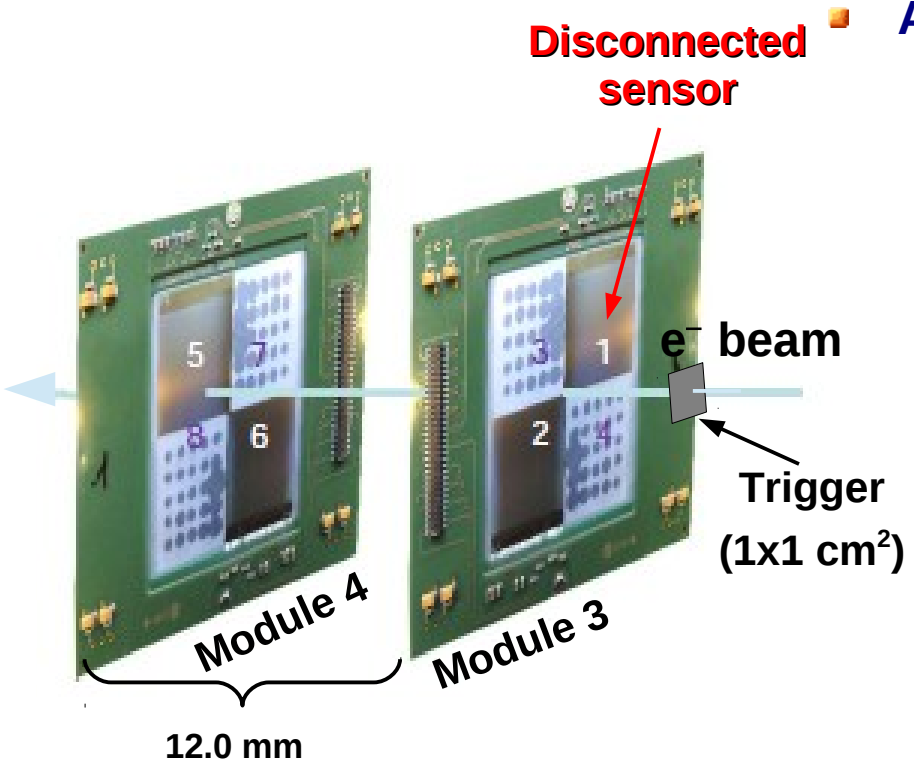


Resolution vs Threshold

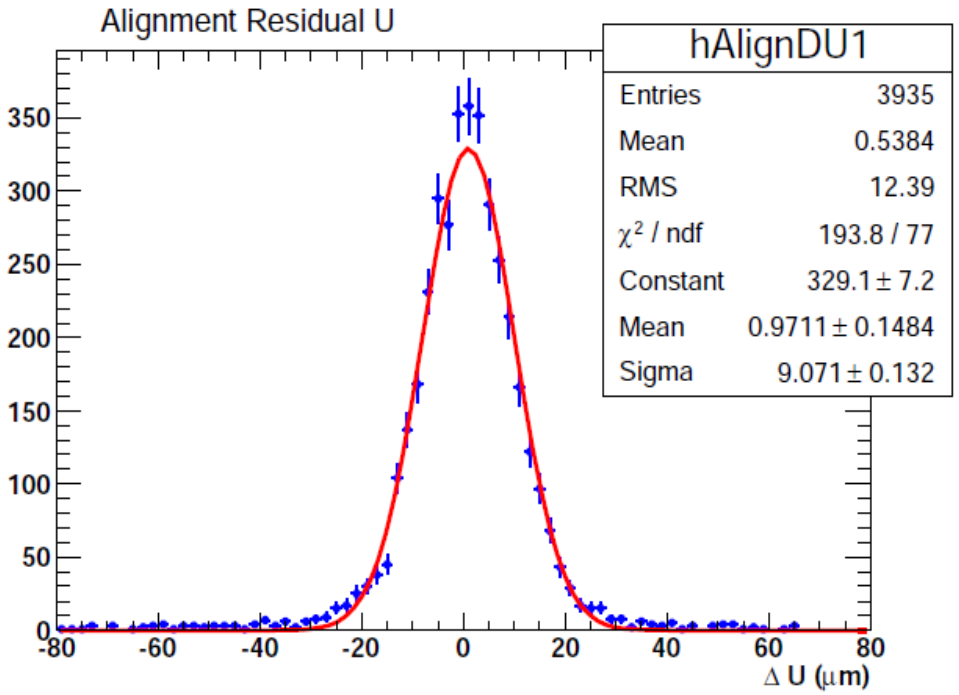


Proto-Telescope: Set-up and Alignment

- **Configuration:** 2 SALAT planes ⇒ Proto-Telescope
  - Data: different energies (3 – 6 GeV) with/without collimator



- **Alignment**
  - Mod-4: use previous relative alignment of 4 MIMOSA-28 sensors
  - Mod-4 used as reference
  - Assume straight tracks: align independently the 3 sensors of Mod-3



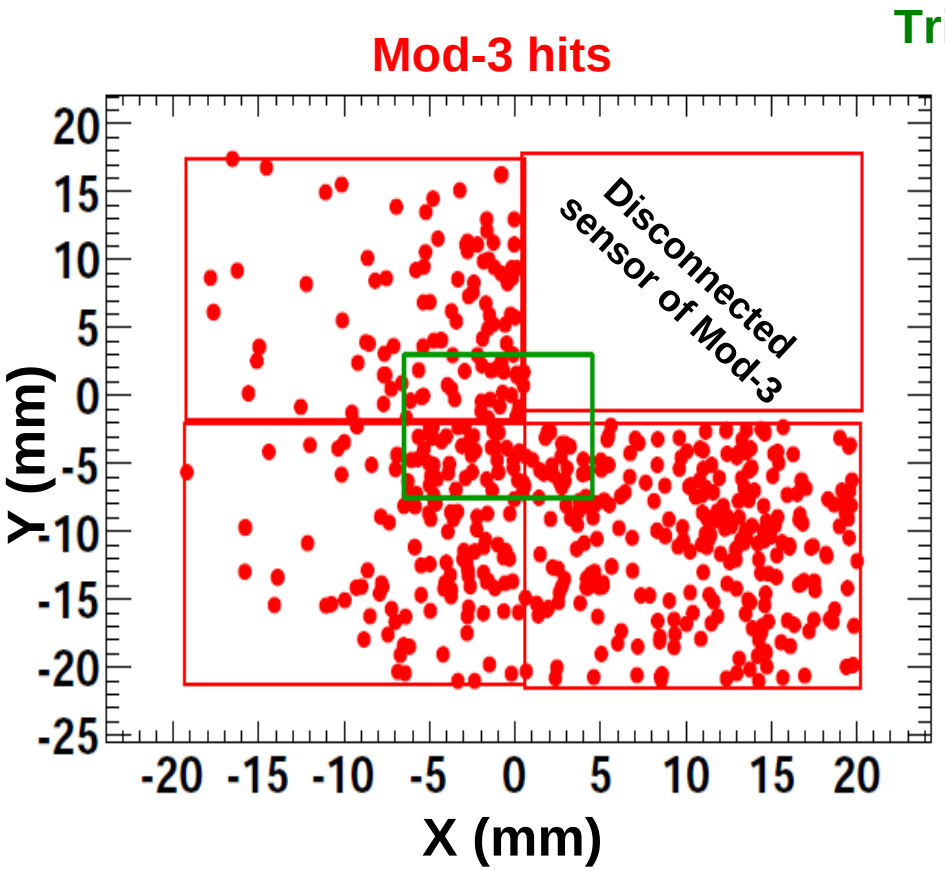
Alignment precision = 9μm/√N$_{evts}$

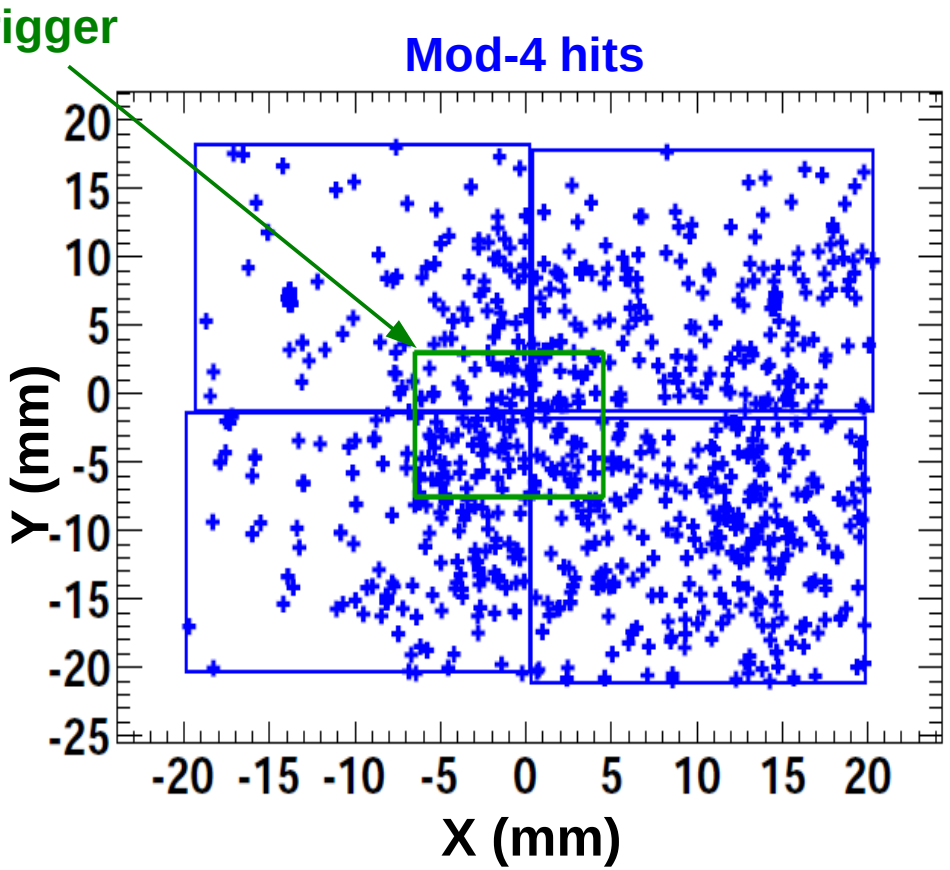
Proto-Telescope: Some preliminary results

- No real tracking possible ⇒ only 2 SALAT planes
- Can study the correlations of hits in one plane w.r.t. the hits on the other

Accumulation of 50 events

(~12 Tracks/evt)





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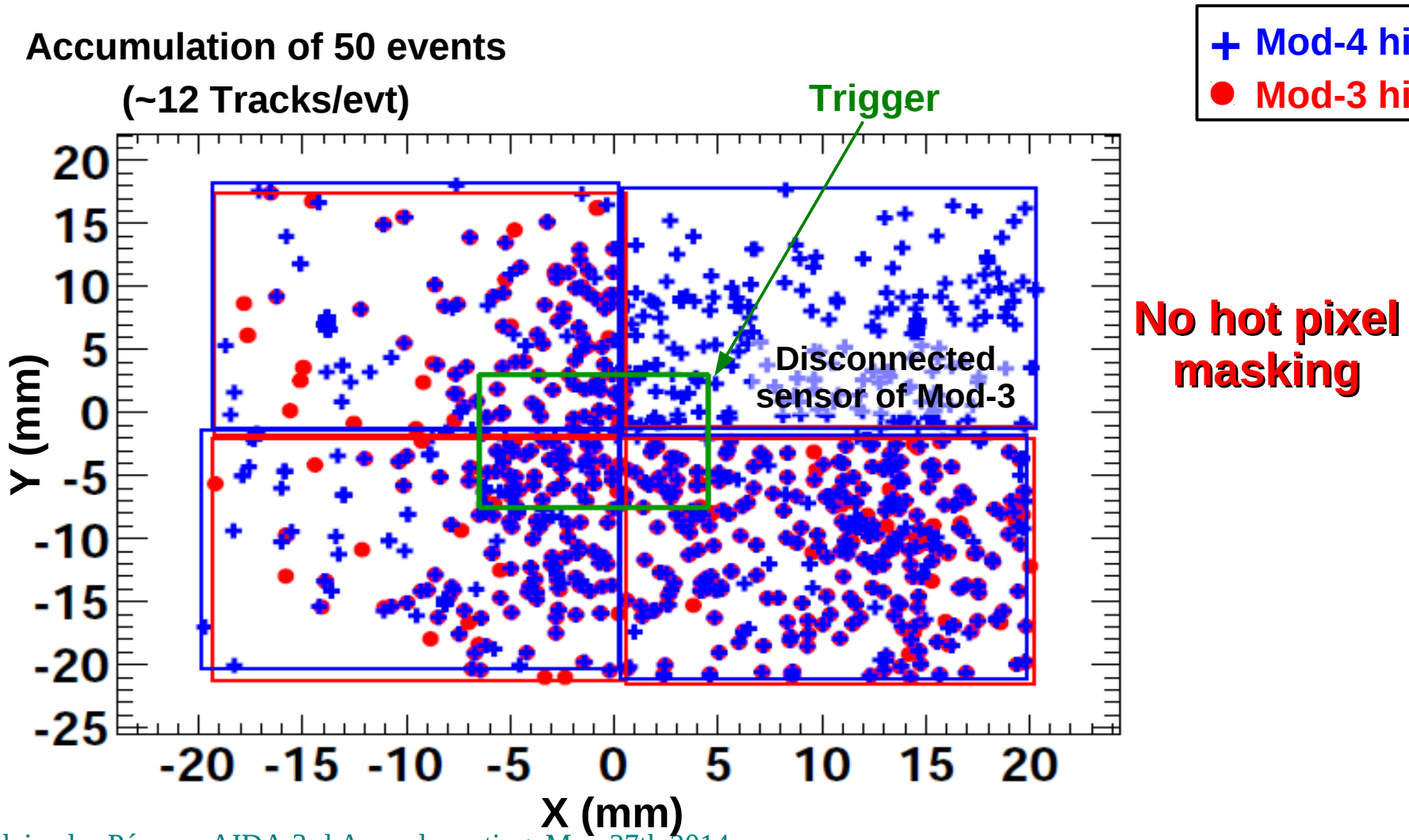

No hot pixel masking

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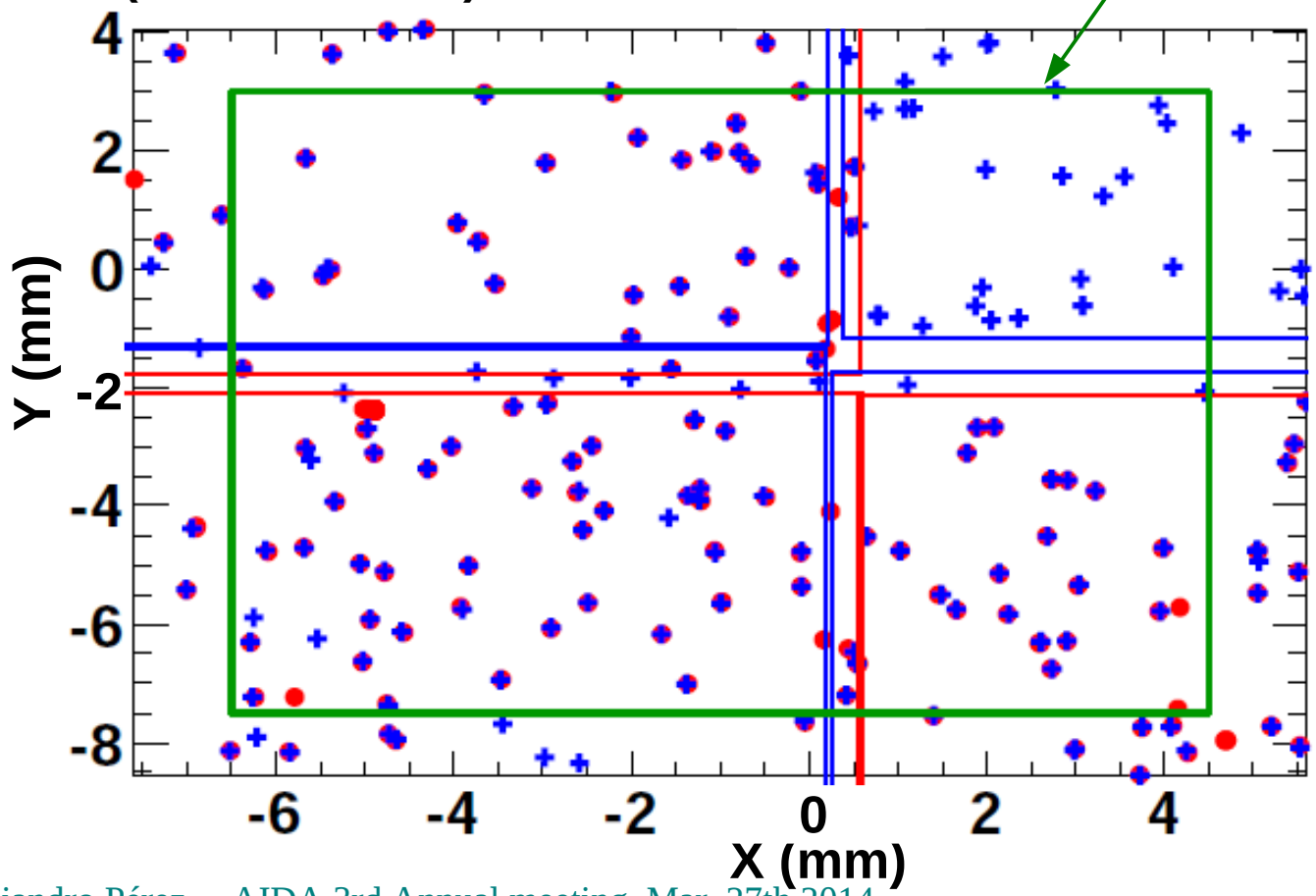

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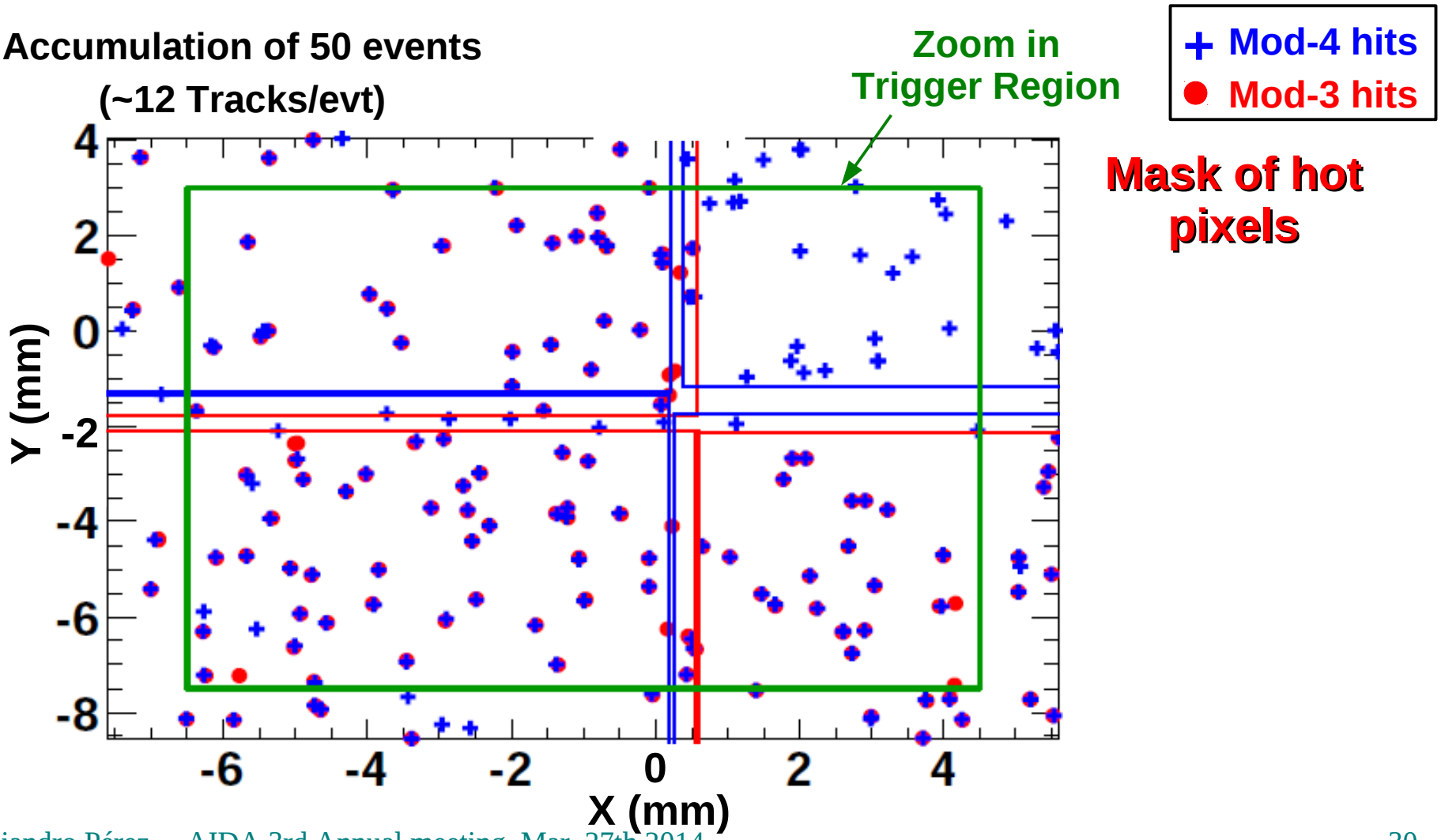

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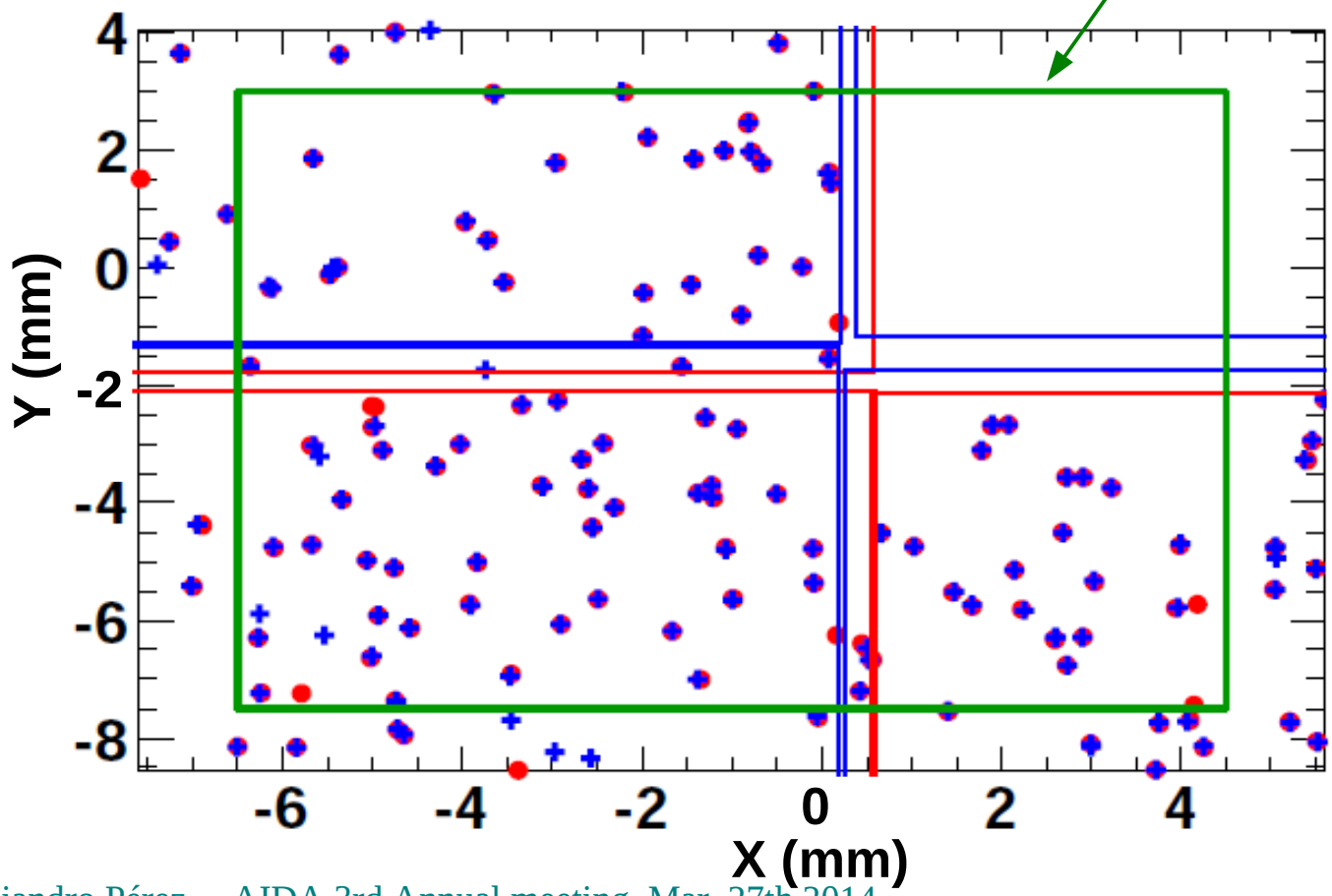


Mask of hot pixels

Hits in sensitive area of both SALAT planes

Clear Correlation between hits of the two SALAT planes!

Plans for SALAT Delivery

SALAT Deliveries: PCBs and Mechanics

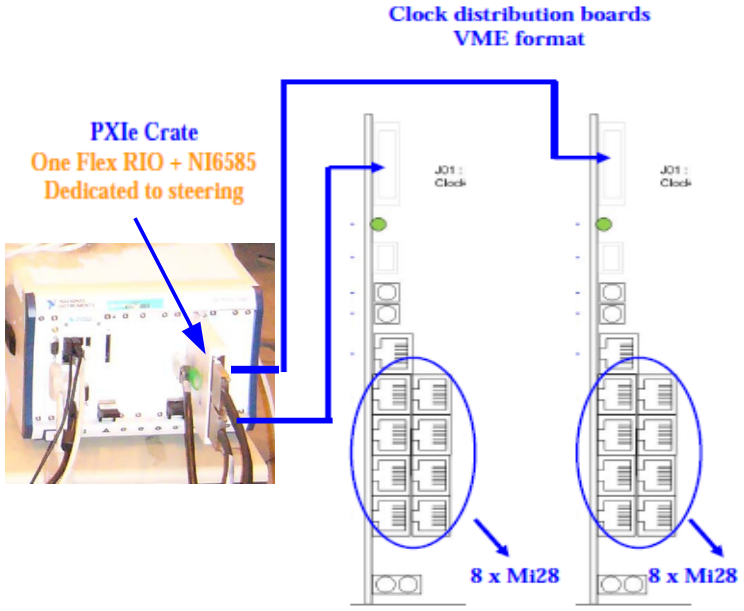
- **Hardware Status**
  - 2 operational modules and characterized in beam at DESY in February 2014
  - Availability for collaborators
    - 1st plane in August
    - 2nd plane in September

- **Final**
  - Modify daughter board $\Rightarrow$ minimizing insensitive areas
    - improve power distribution and readout orientation
    - easing alignment
  - 1st plane in July
  - 4th plane in November
  - Telescope validation: PICSEL beam test on November (SPS)

$\Rightarrow$ Final delivery

SALAT Delivery: Data Acquisition System

- **Context of IPHC contribution**
  - Standalone system driving sensors, acquiring and storing data
    - PXI crate and boards, separated clock distribution board
  - No interface with higher system
  - Provides TLU interface (EUDET handshake) but not tested
- **Developments**
  - Currently limited to 2 LAT planes (8 Mi-28)
  - Additional NI-6585 + Flex-RIO boards required in PXI
  - New software to read 3 LAT planes (12 Mi-28)
  - New clock distribution board to synchronize 3 LAT planes (12 Mi-28) and up to 4 LAT planes if required (16 Mi-28)
    - 2 boards needed, VME format (only for power supply)
- **Availability**
  - Current system for August 2014
  - Upgraded system after November 2014



Summary and outlook

- **Large Area Telescope prototype produced at IPHC**
  - Based on very mature sensors (MIMOSA-28) already used in STAR
  - Full development of Integration, mechanics and DAQ
  - SALAT plane validation @ DESY
    - Ability to readout all the modules synchronously
    - Uniformity of detection efficiency (99.9%) and resolution (~4μm) on full sensitive area
    - Proto-telescope: proof of principle for tracking with low energy electrons

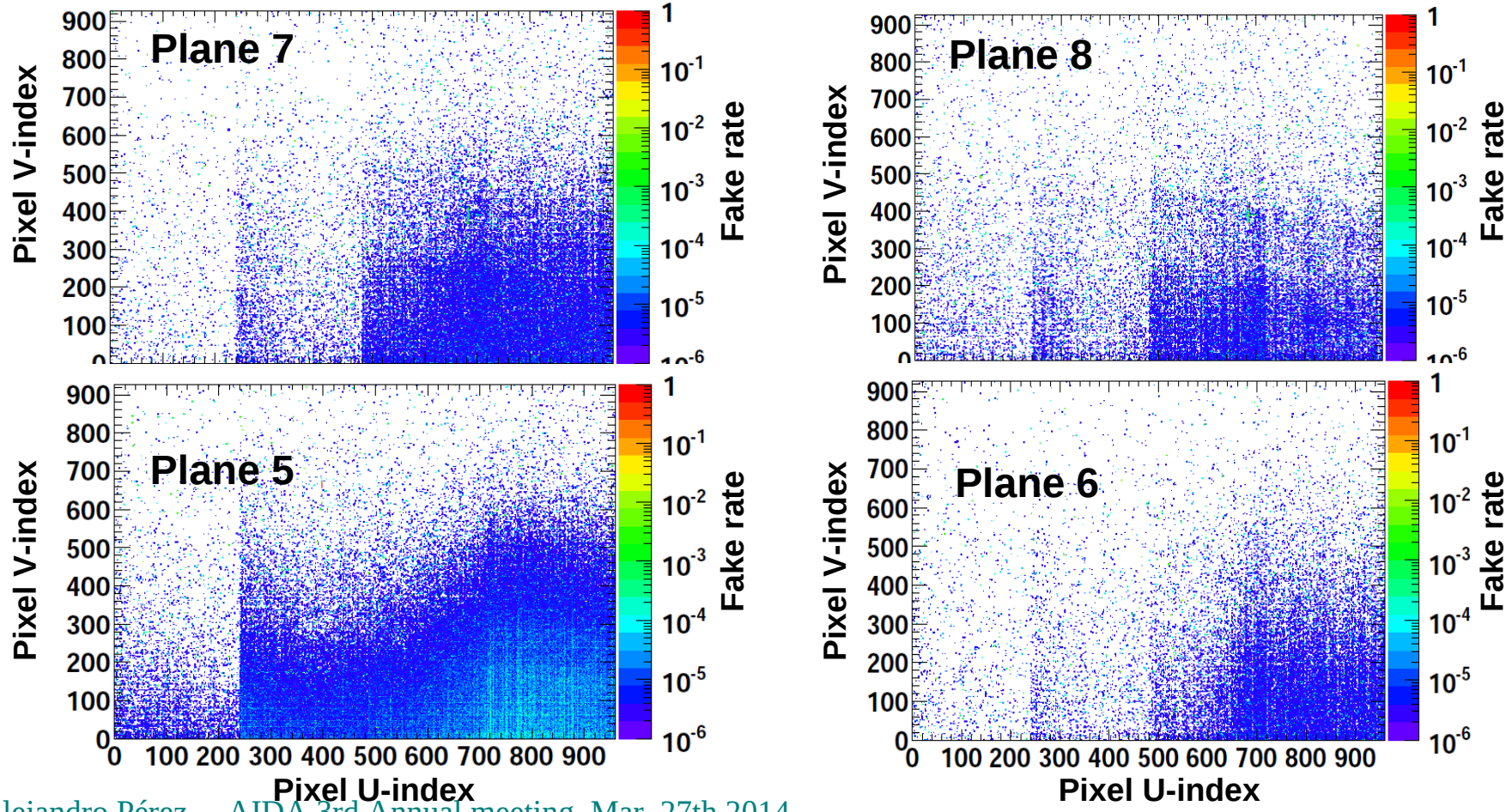
- **Delivery**
  - Can deliver in the coming months the SALAT planes as they are
    - mechanics and DAQ
    - Only 2 SALAT planes
  - Can deliver later (by the end of 2014) improved versions of the system
    - Improved integration to reduce insensitive zones
    - Schematics of mechanic design
    - Improved DAQ to be able to read up to 3 SALAT planes

Back up Slides

Hot pixels map

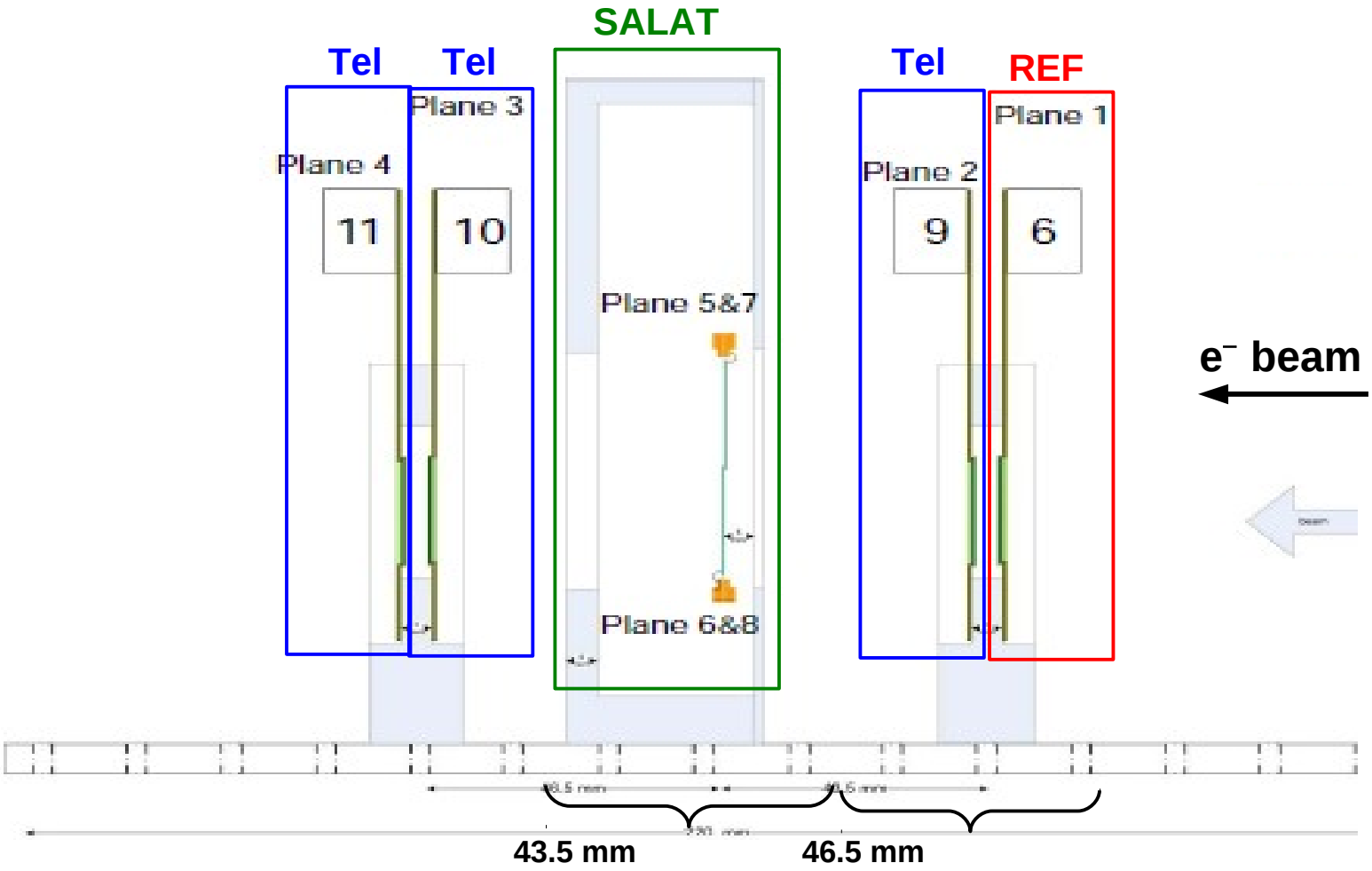
- Data taken @ IPHC test bench with same configuration as in Test Beam
- Identify hot pixels and mask them for data analysis
- Average fake rates from ~10^{-5} to ~10^{-7} for Threshold from 5 to 10 times noise

THR 6x noise



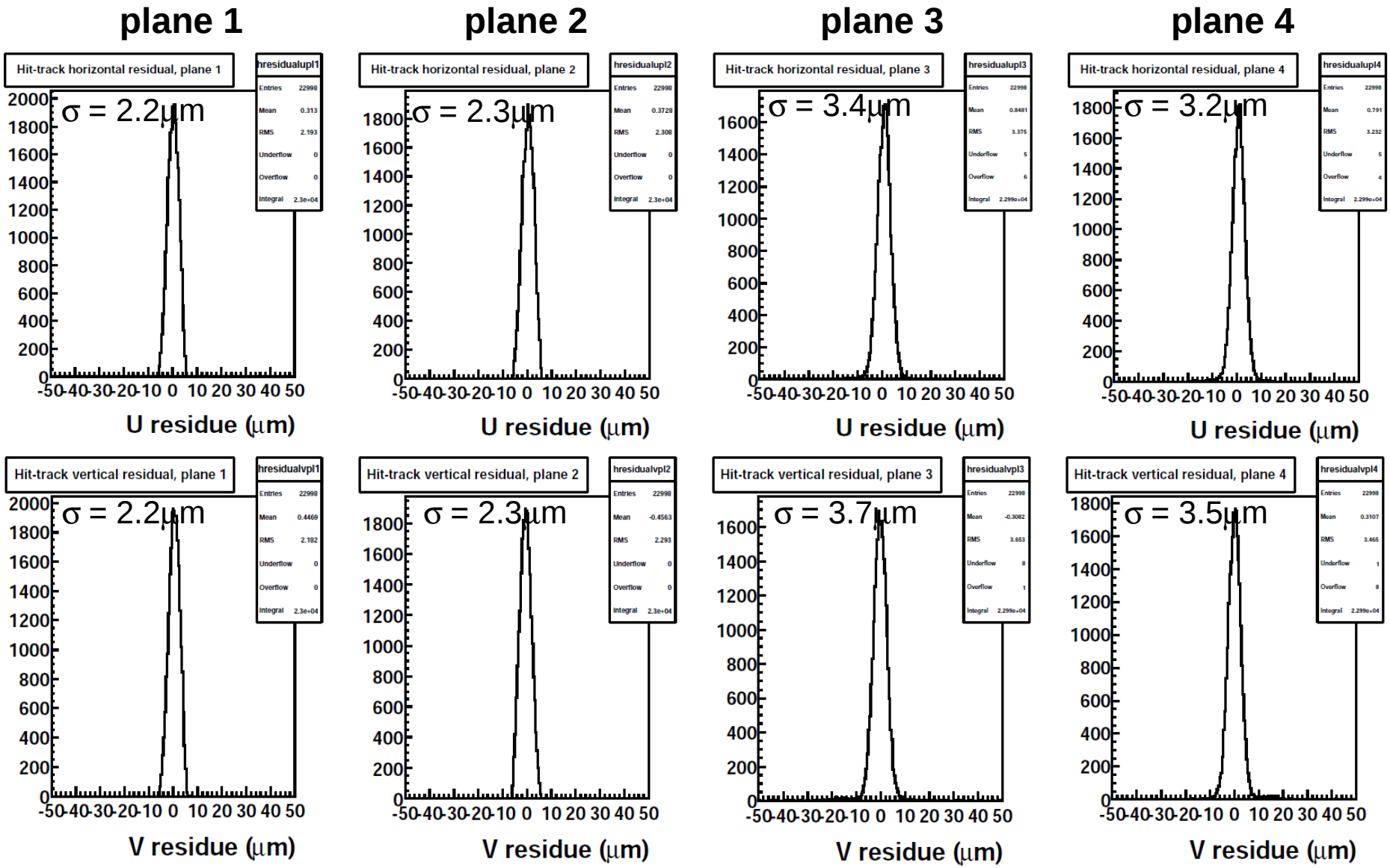
Uniformity Studies: Telescope and DUT alignment

- Use up-stream telescope plane as reference: X and Y positions and rotations at 0
- Iterative approach of telescope planes alignment w.r.t. to reference
- SALAT: independent alignment of 4 SALAT planes w.r.t. the whole telescope



Uniformity Studies: Telescope and DUT alignment

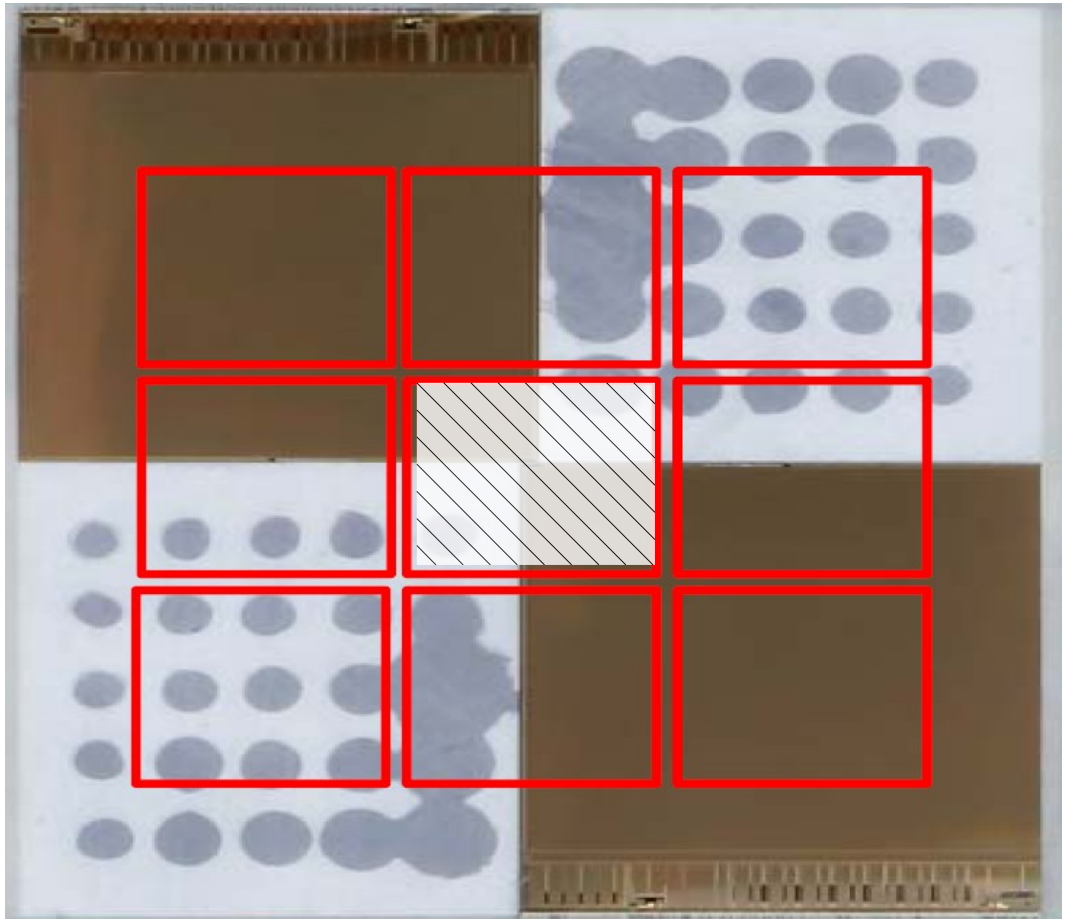
e^- beam



The data @ THR 5x noise

- Scan over the SALAT surface
- 9 regions, several thresholds: 5, 6, 8 and 10

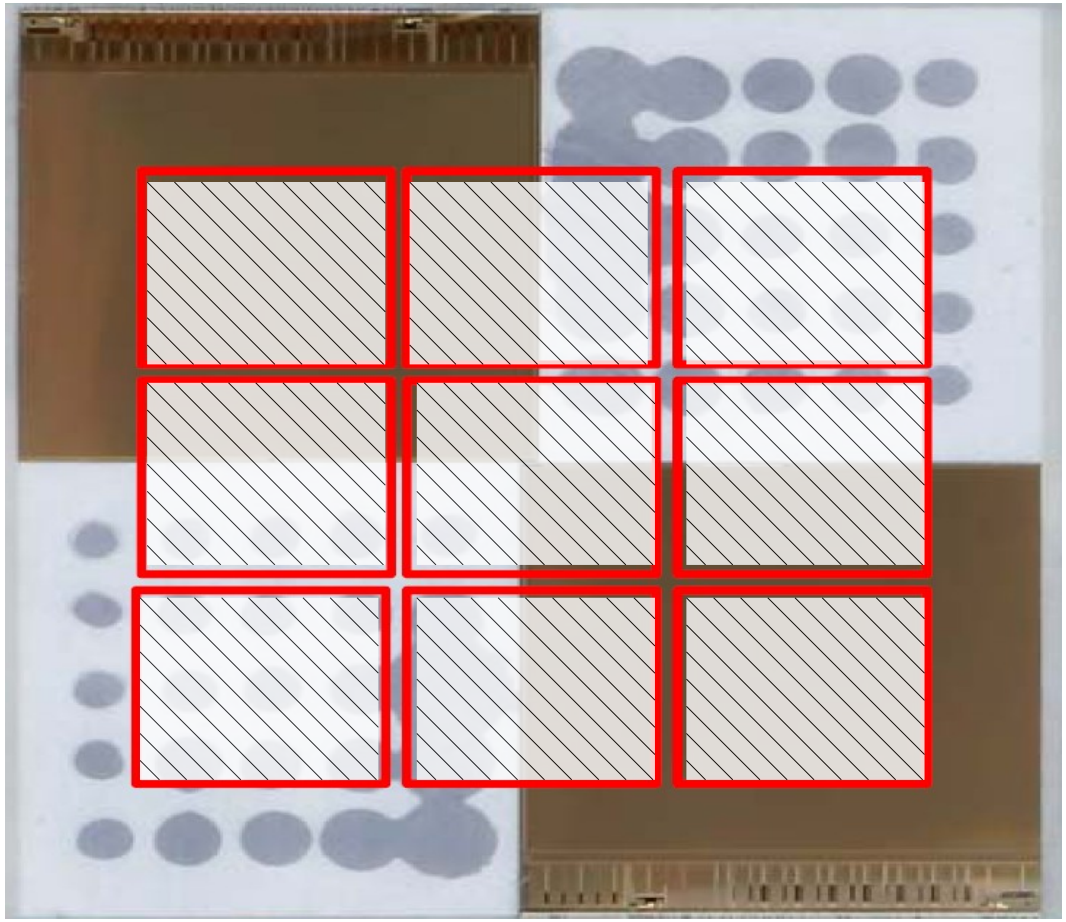
Data: Threshold @ 5x noise



The data @ THR 6x noise

- Scan over the SALAT surface
- 9 regions, several thresholds: 5, 6, 8 and 10

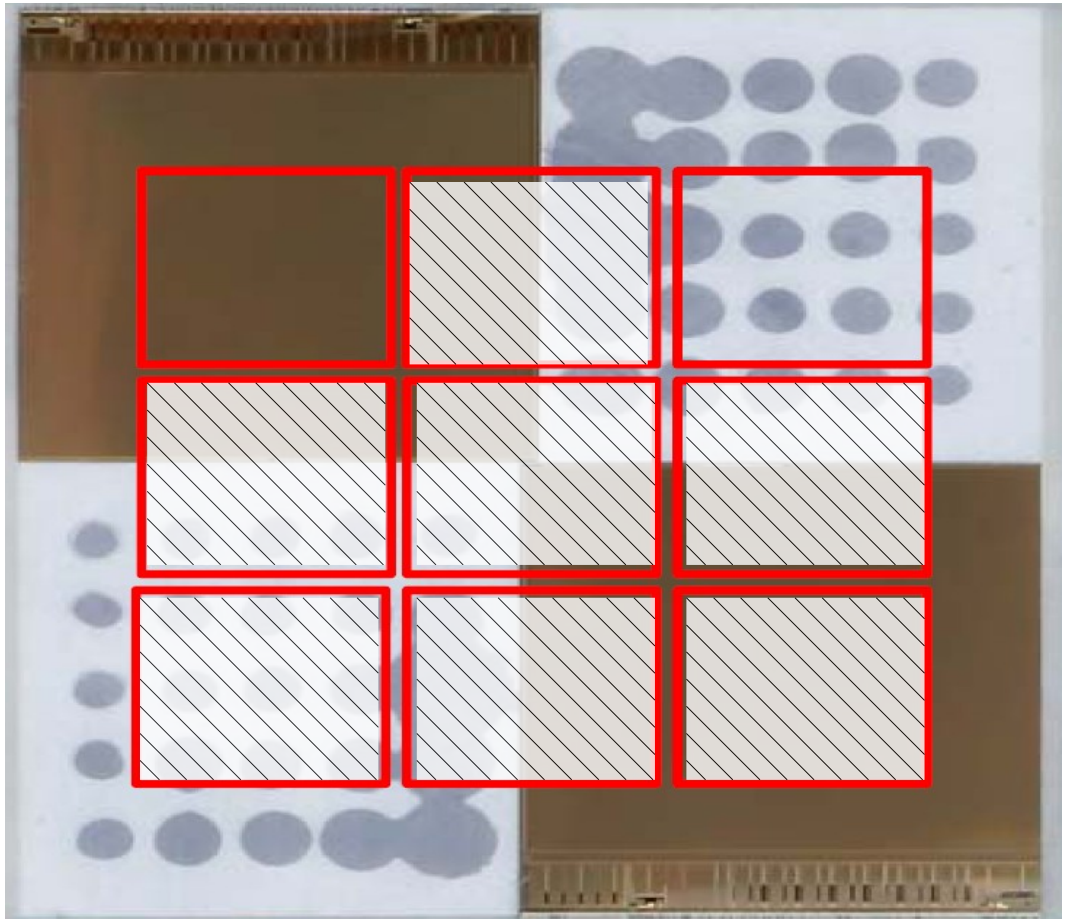
Data: Threshold @ 6x noise



The data @ THR 8x noise

- Scan over the SALAT surface
- 9 regions, several thresholds: 5, 6, 8 and 10

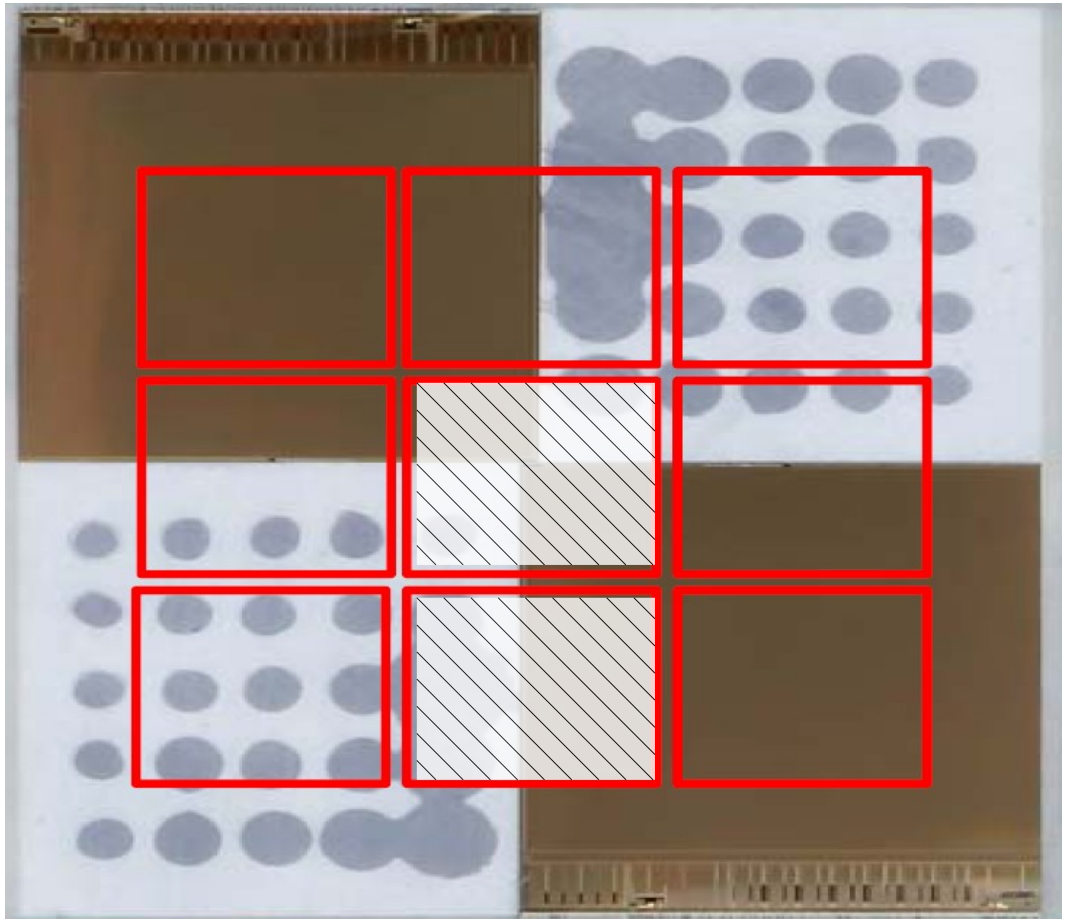
Data: Threshold @ 8x noise



The data @ THR 10x noise

- Scan over the SALAT surface
- 9 regions, several thresholds: 5, 6, 8 and 10

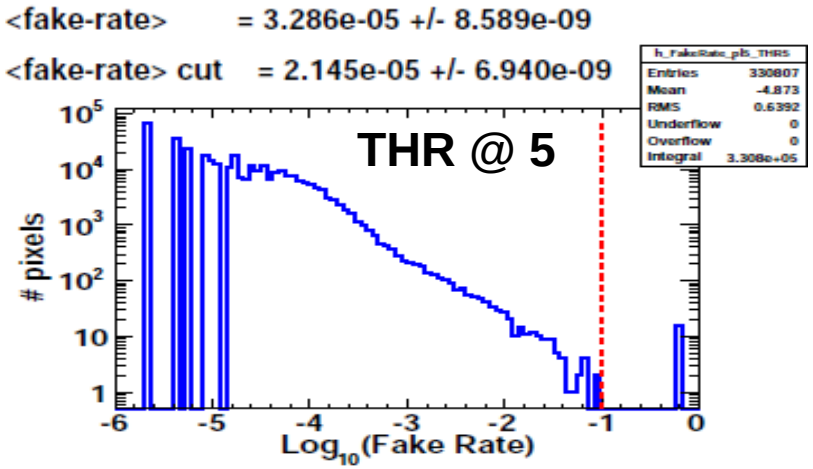
Data: Threshold @ 10x noise

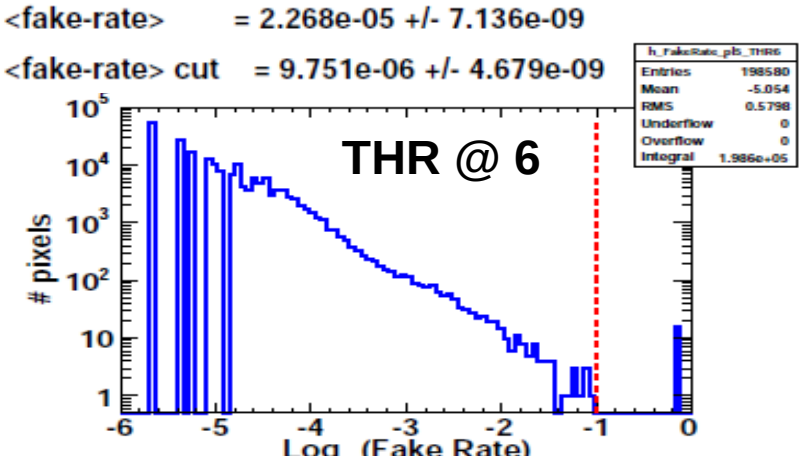


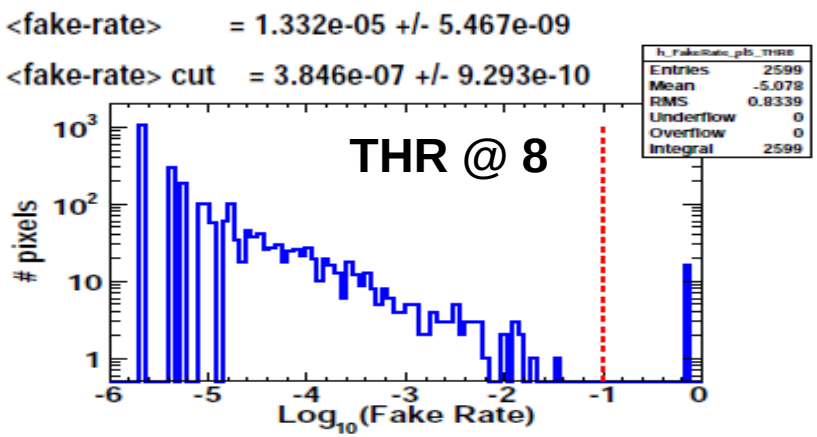
Hot pixels map

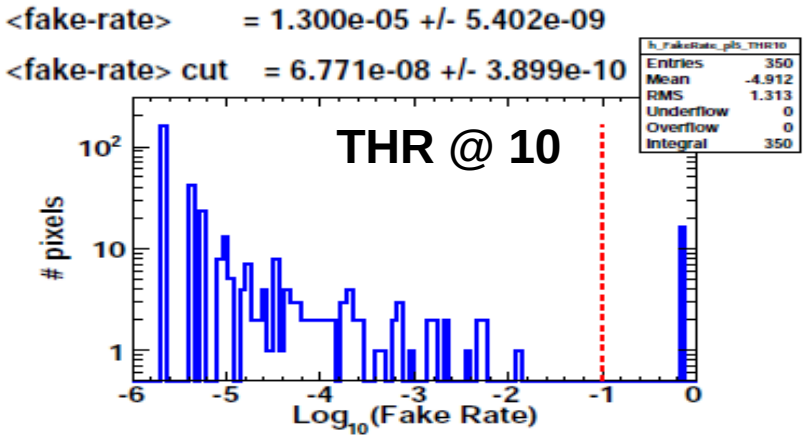
- Data taken @ IPHC test bench with same configuration as in Test Beam
- Identify hot pixels and mask them for data analysis
- Average fake rates from ~10^{-5} to ~10^{-7} for Threshold from 5 to 10 times noise

Plane 5

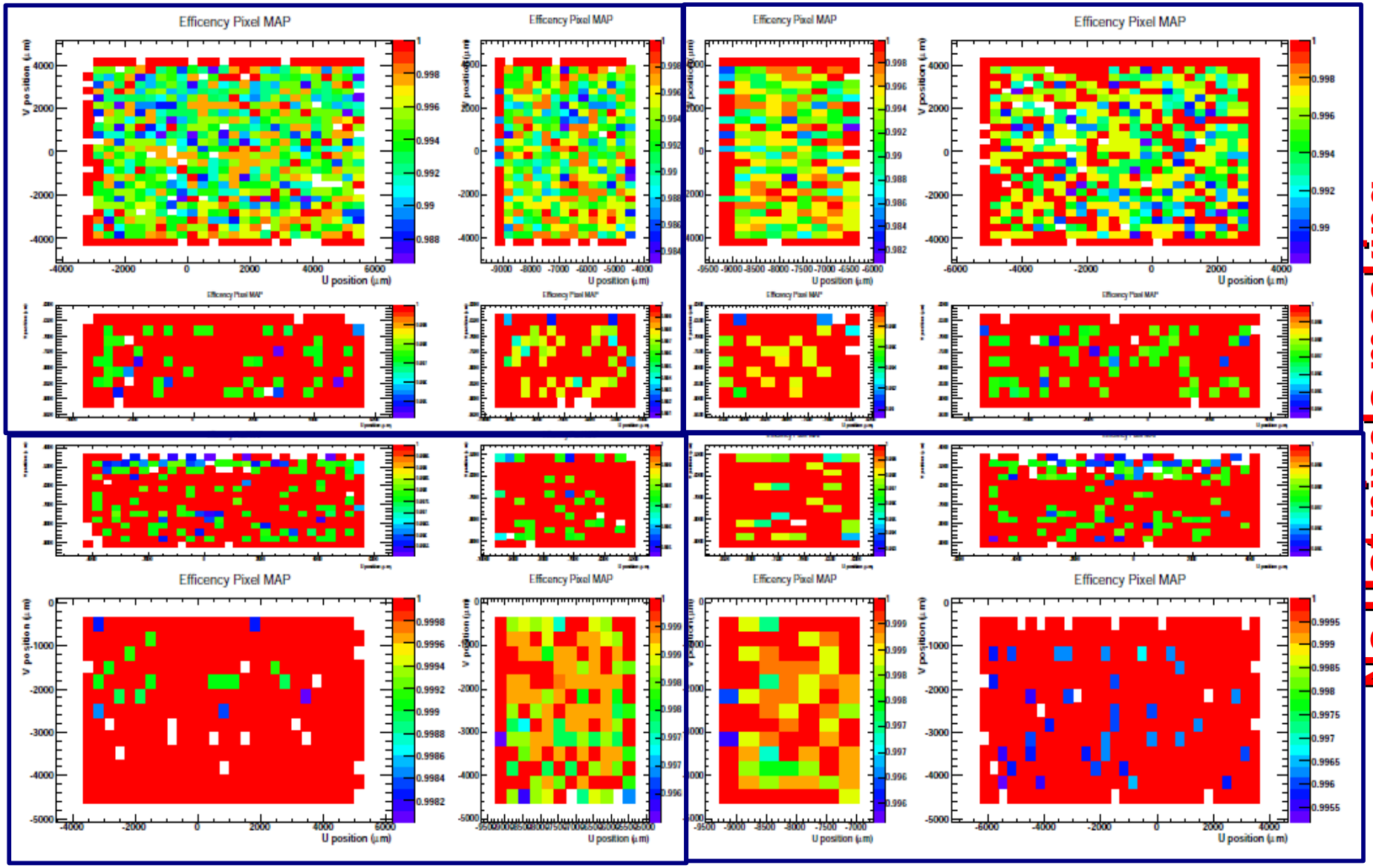






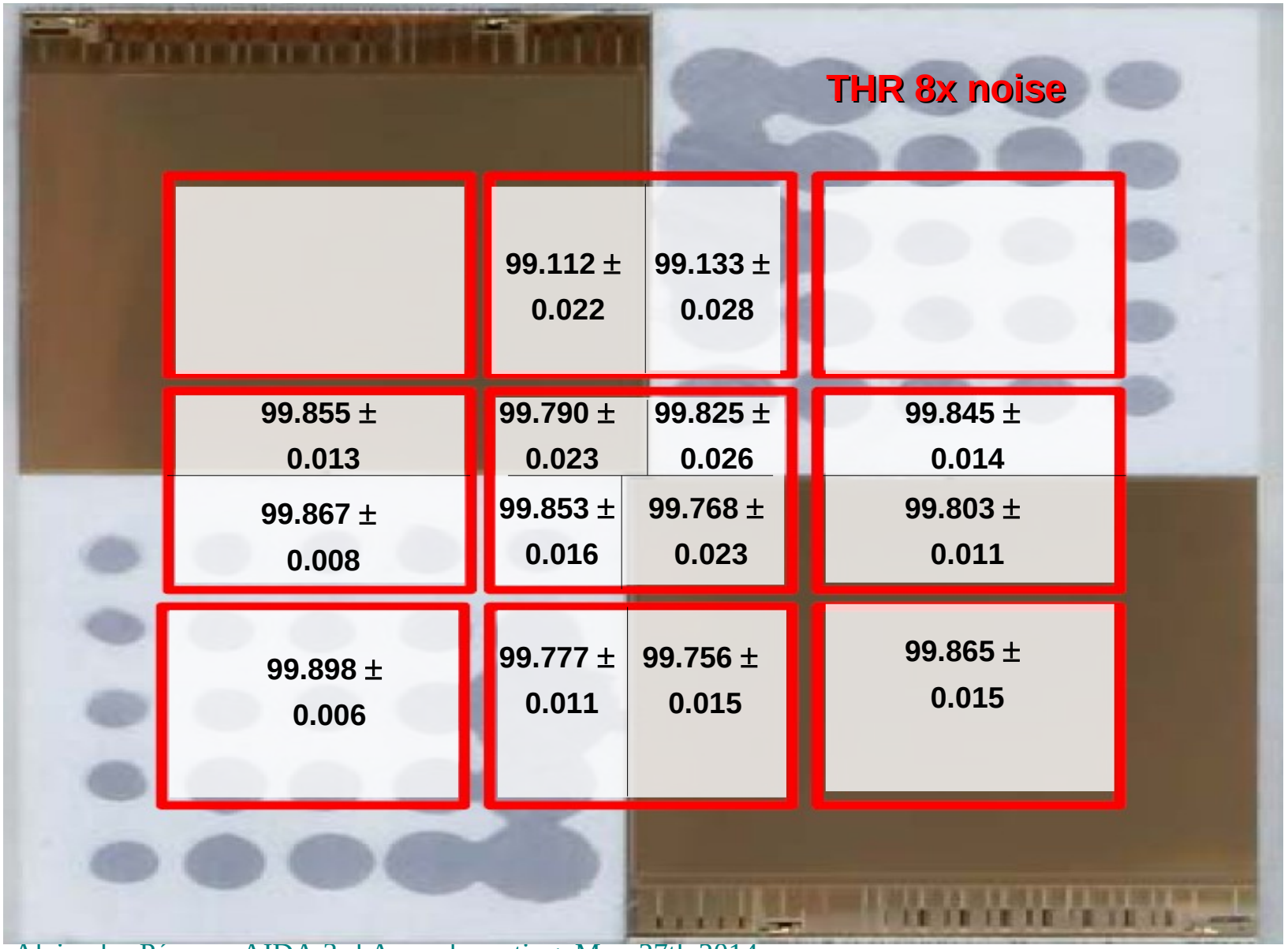


Efficiency (%) Homogeneity: Threshold @ 6

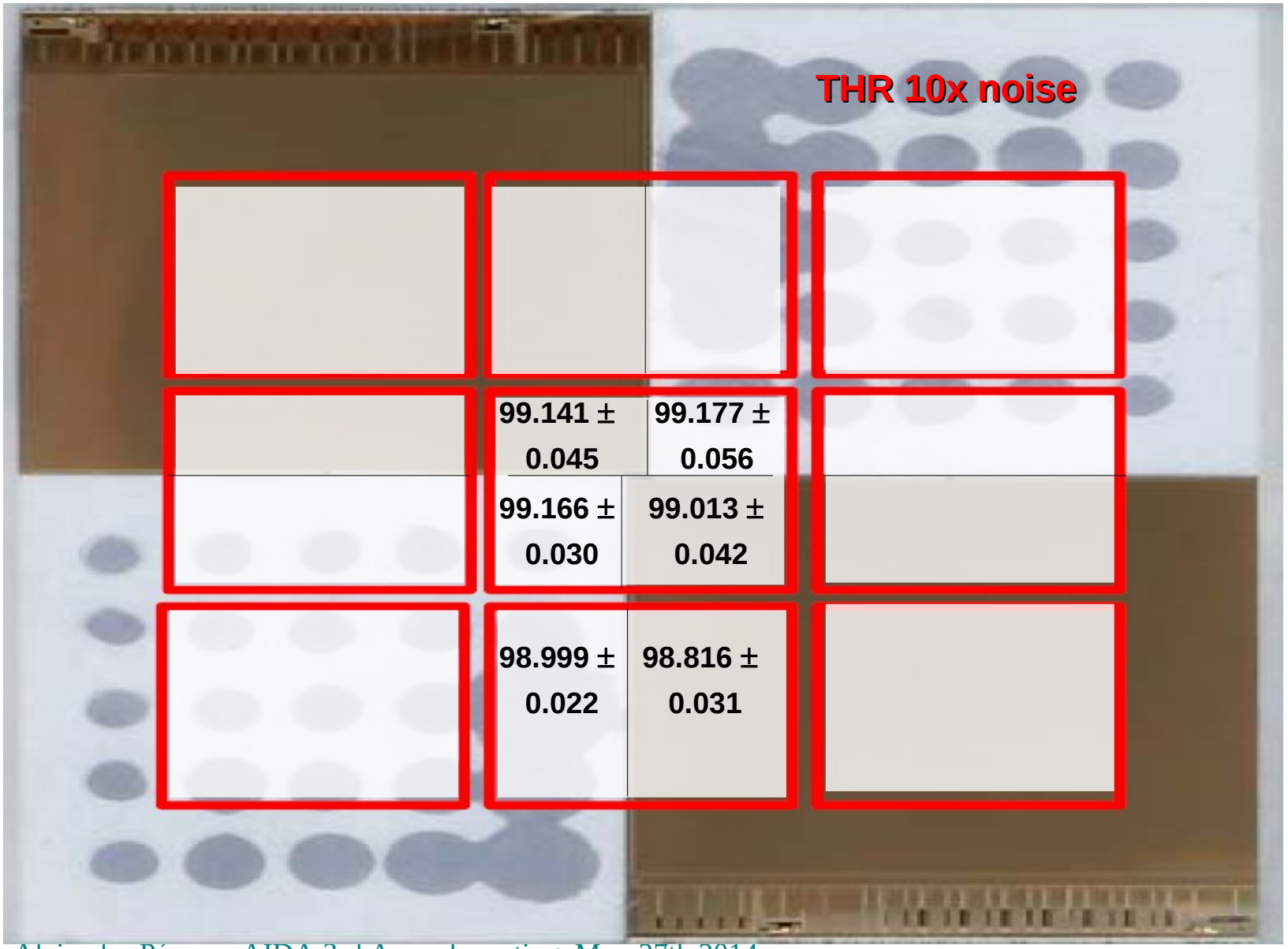


No Hot pixels masking

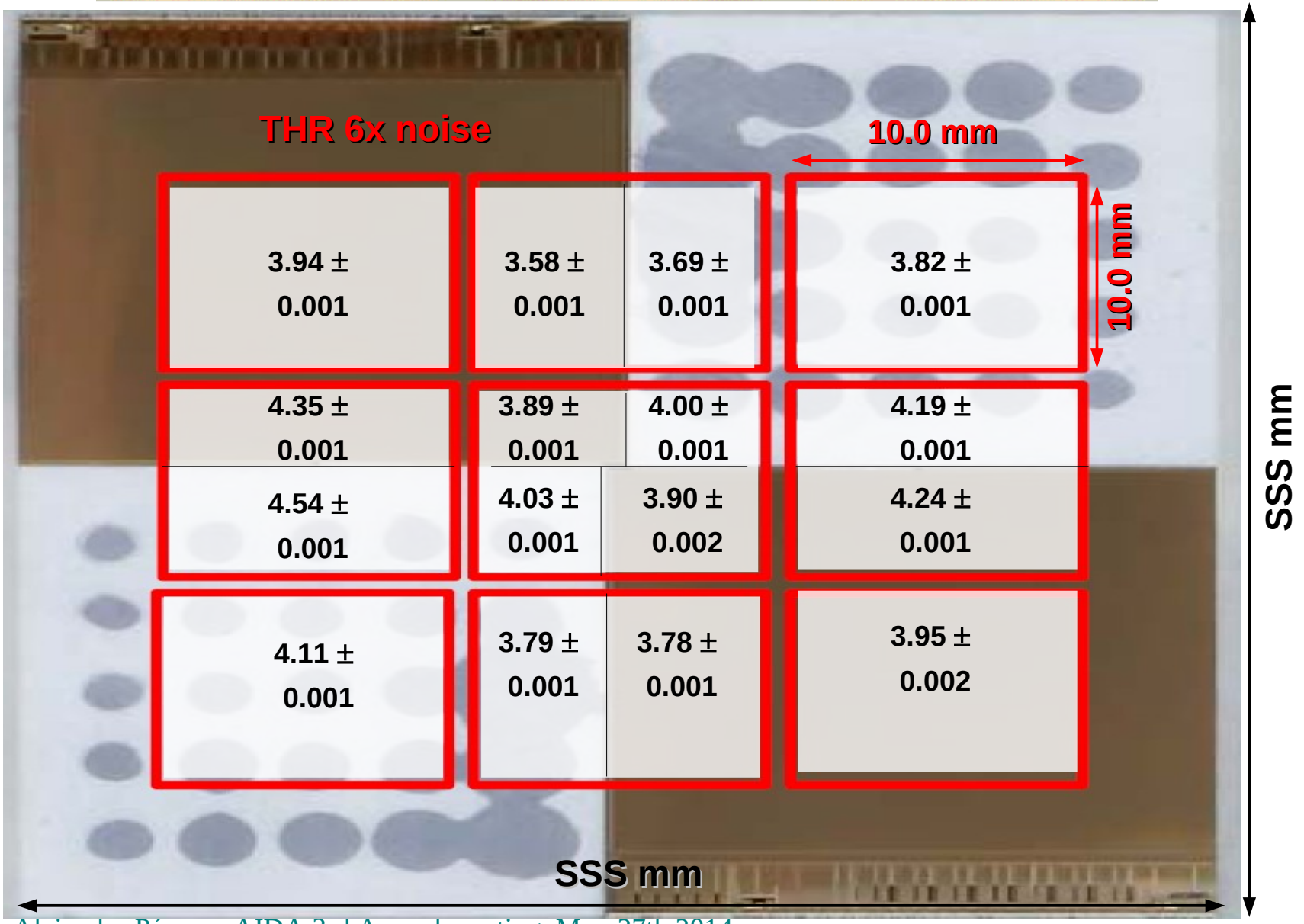
Uniformity Studies: Efficiency (%)



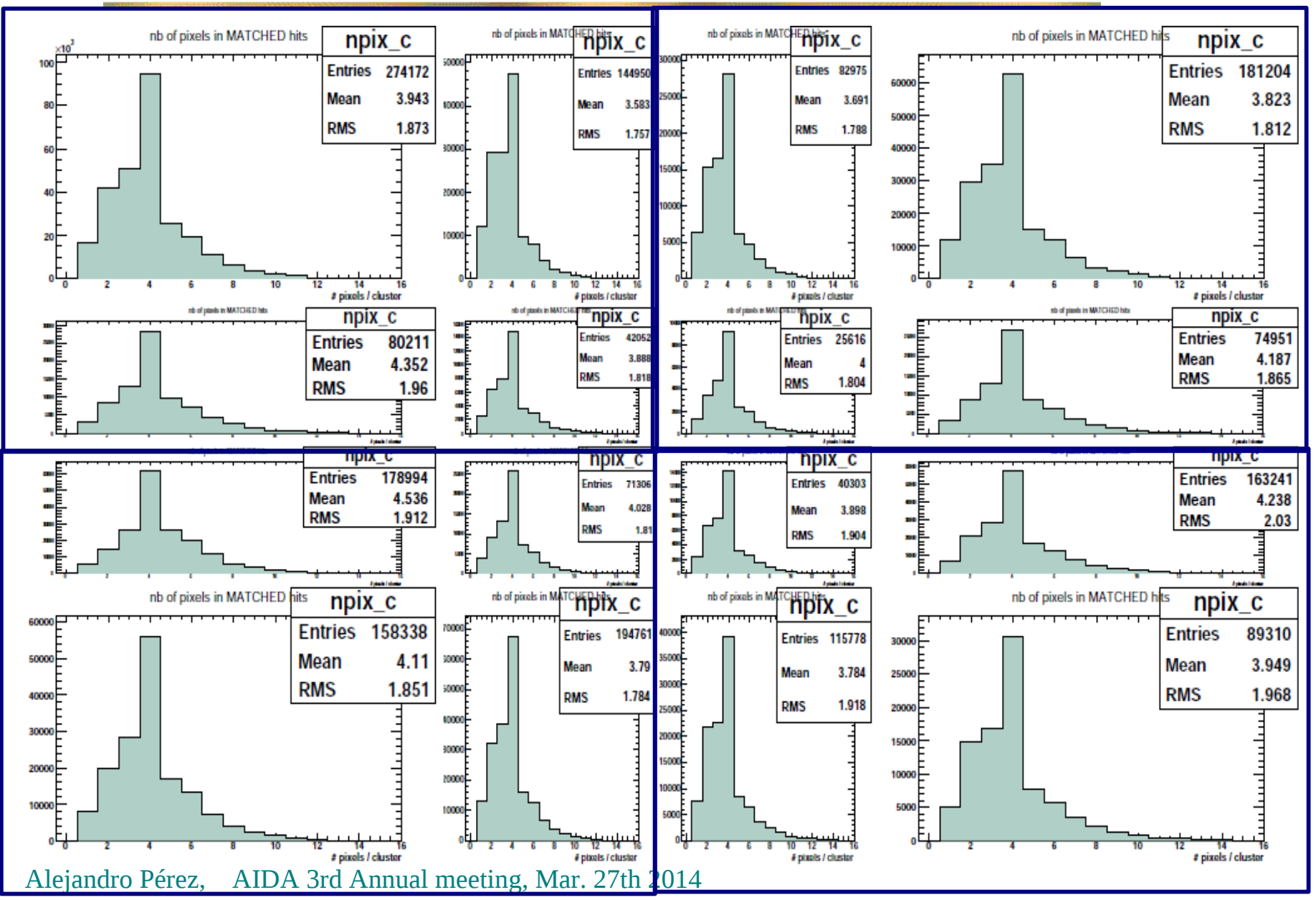
Uniformity Studies: Efficiency (%)



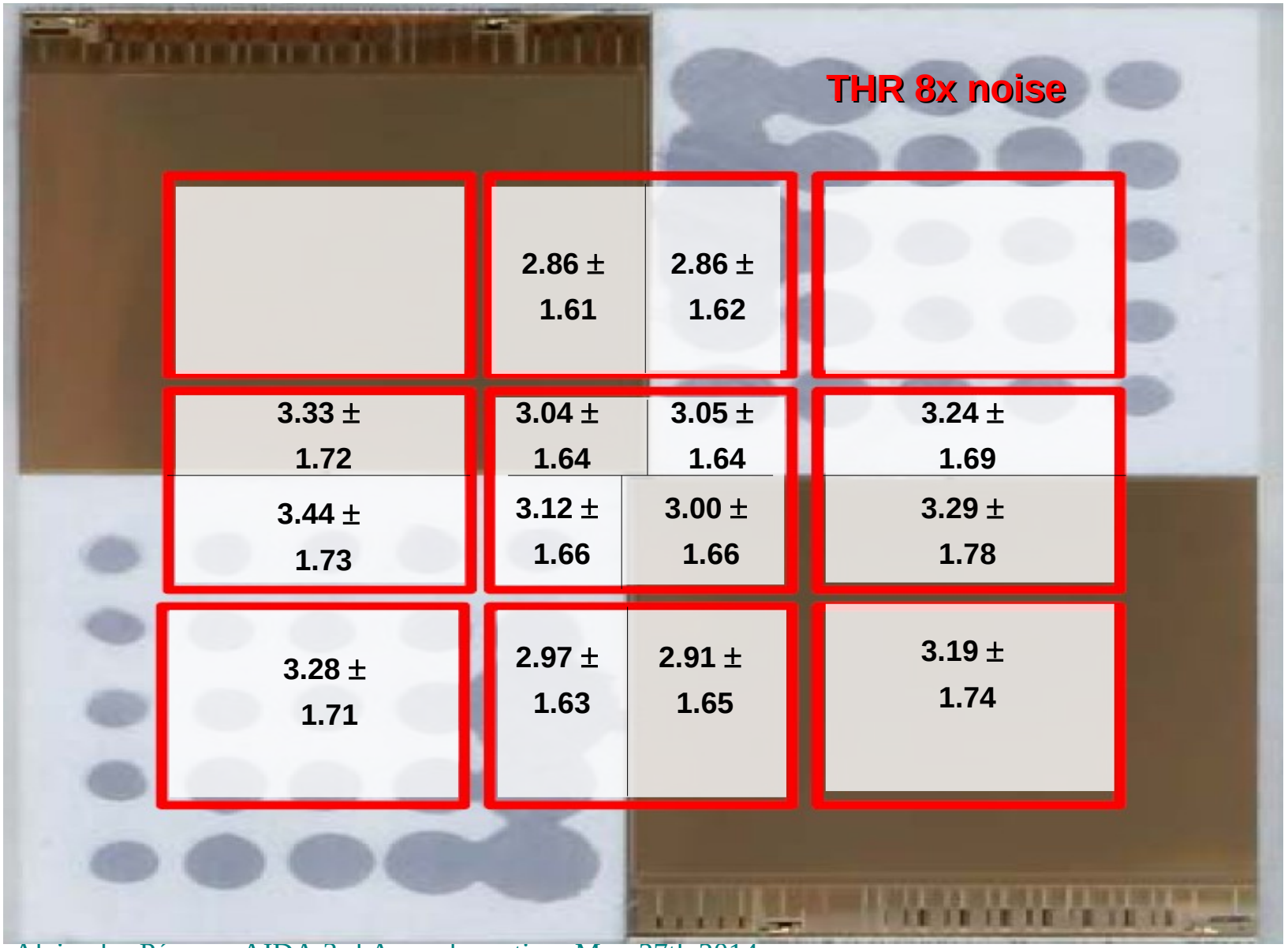
Uniformity Studies: Cluster multiplicity (DIMENSIONS)



Cluster Multiplicity Homogeneity: Threshold @ 6

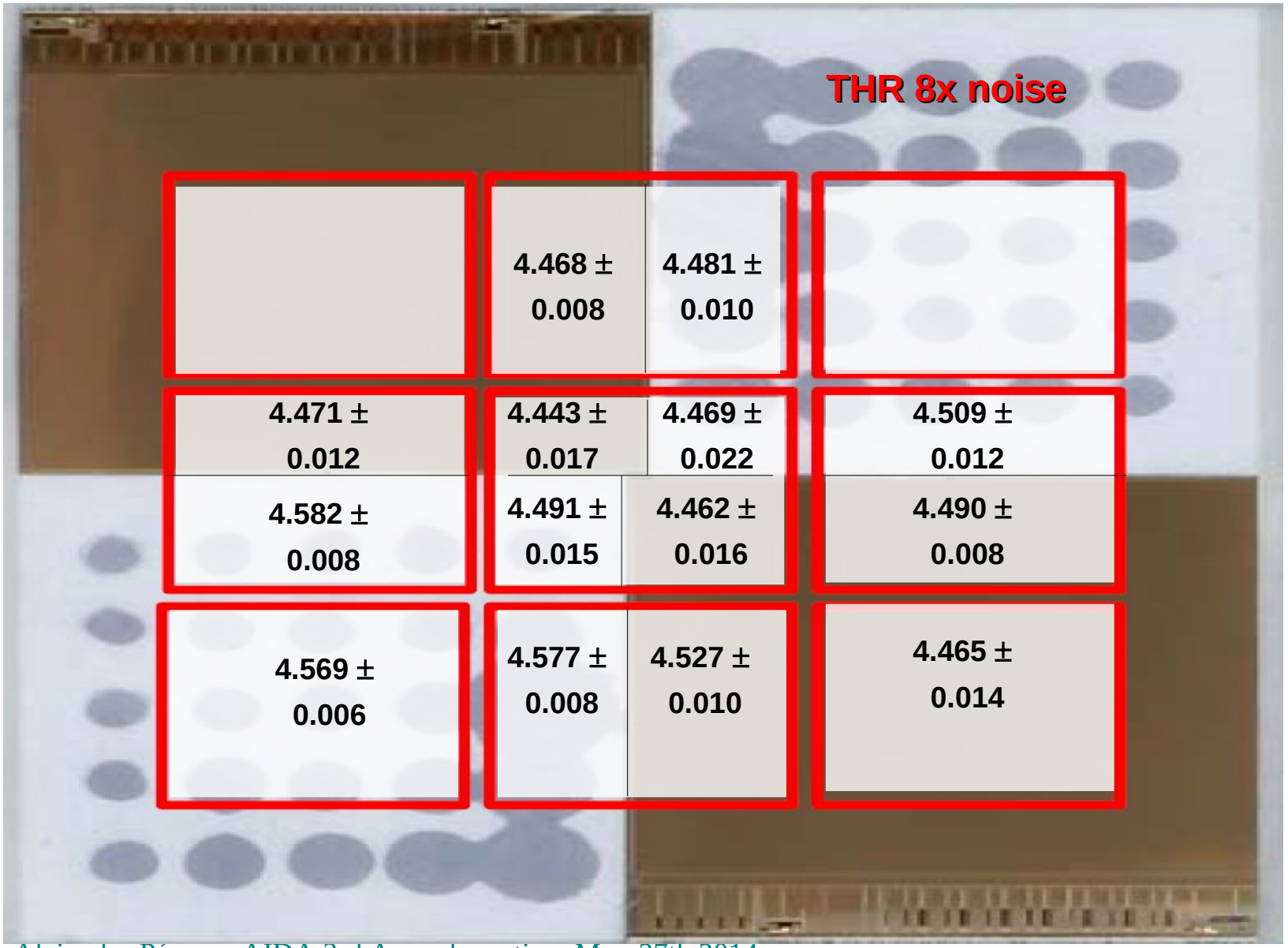


Uniformity Studies: Cluster multiplicity

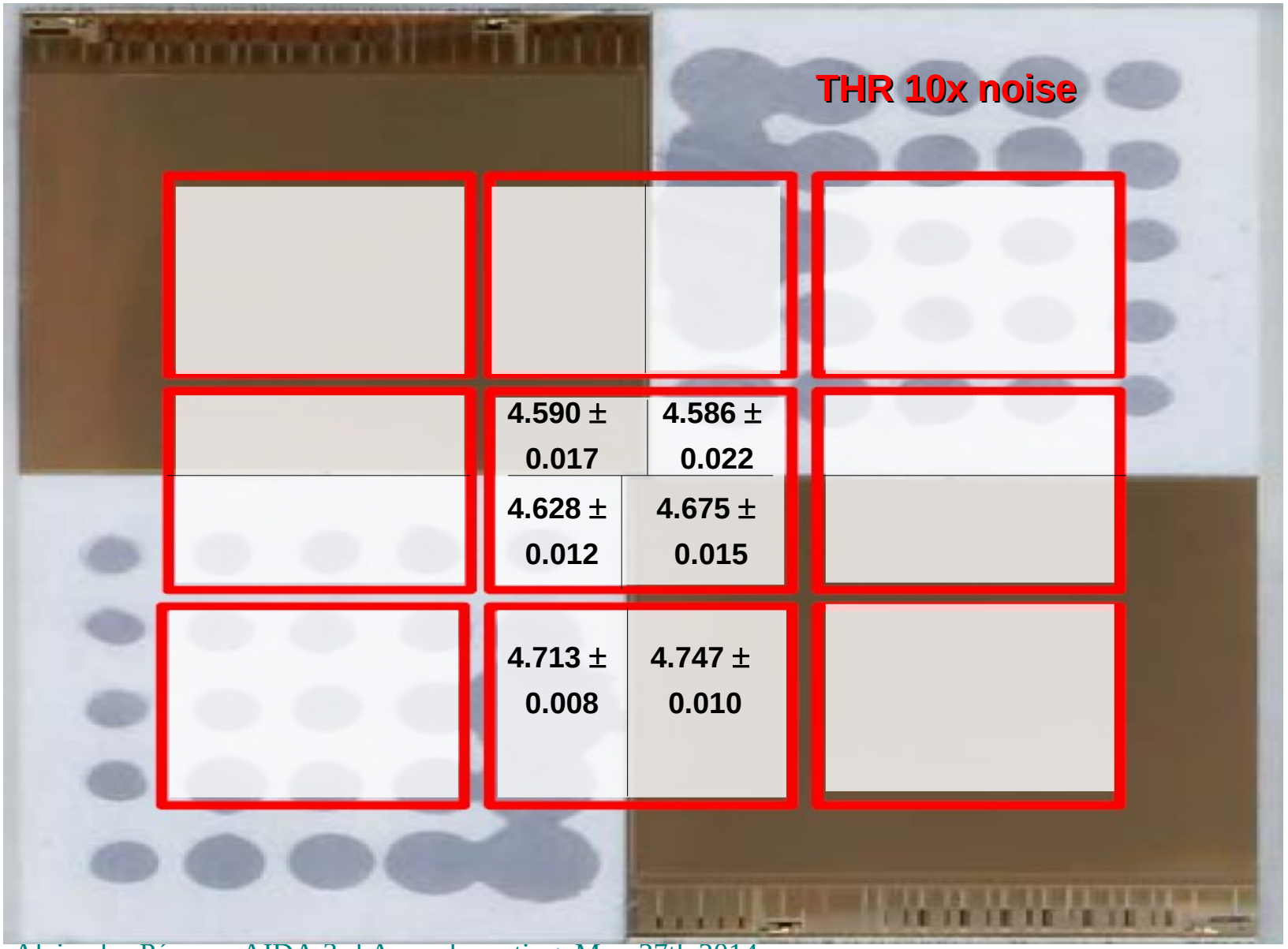


Uniformity Studies: Cluster multiplicity

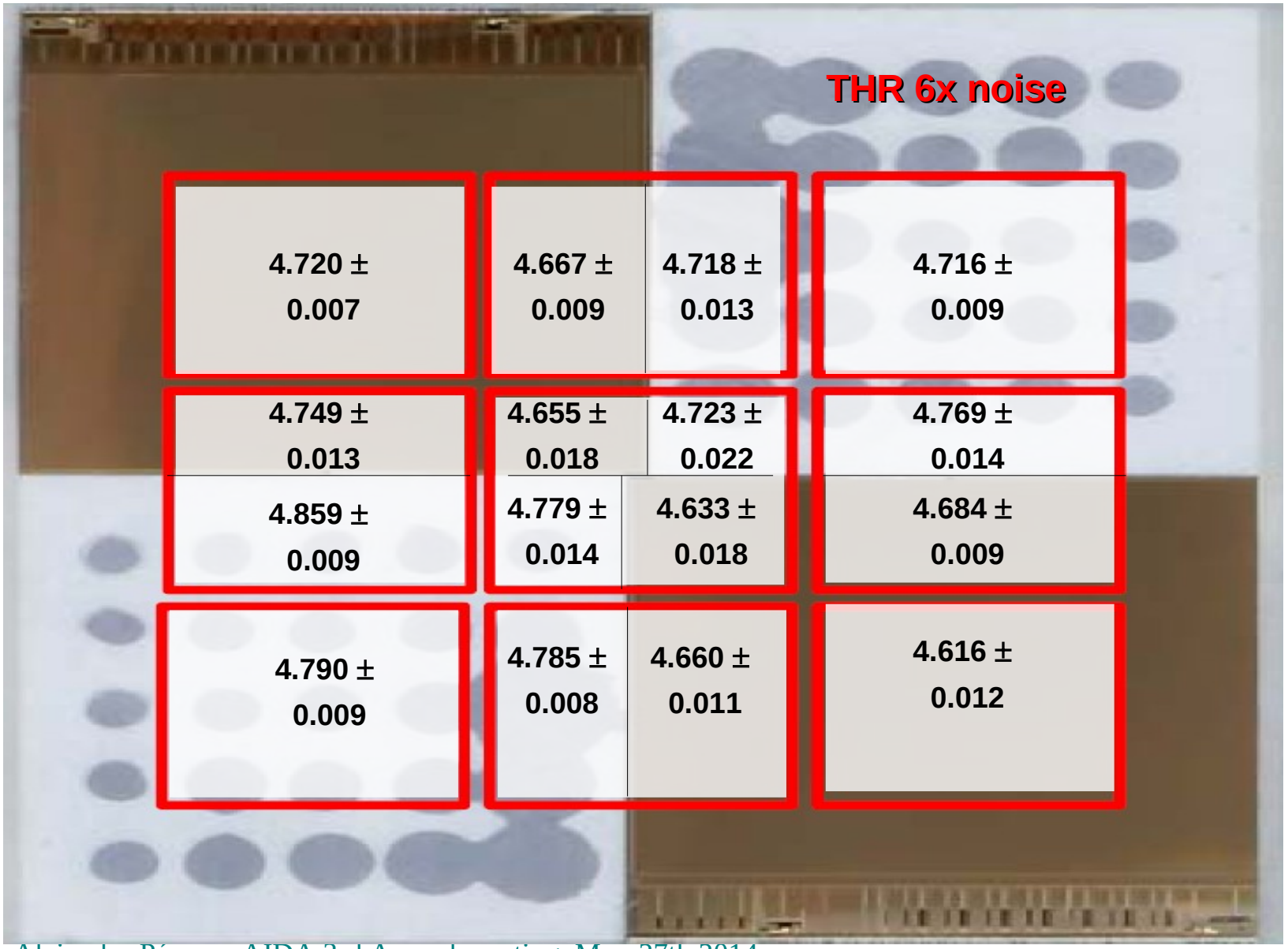
Uniformity Studies: Residual-U (µm)



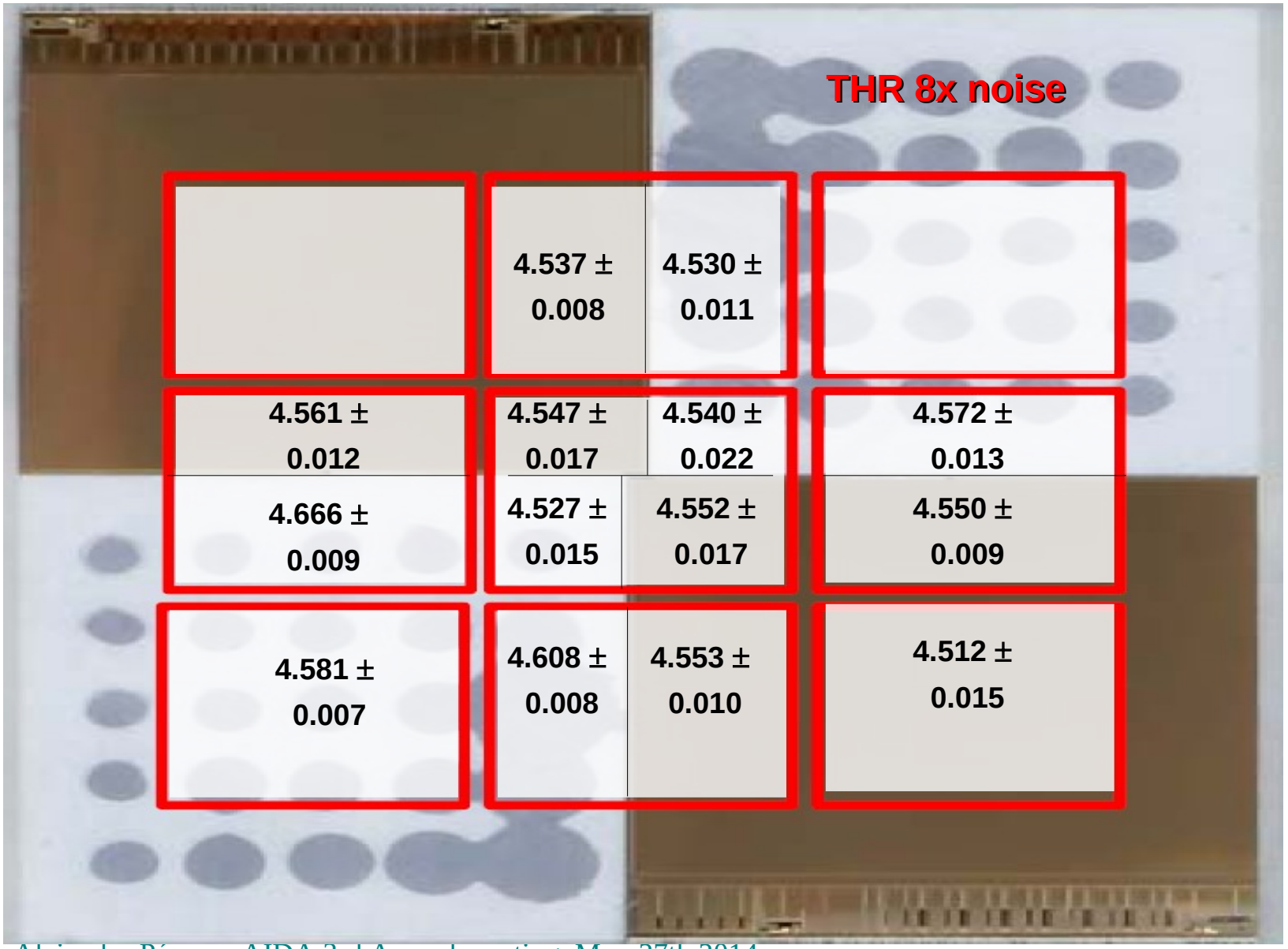
Uniformity Studies: Residual-U (µm)



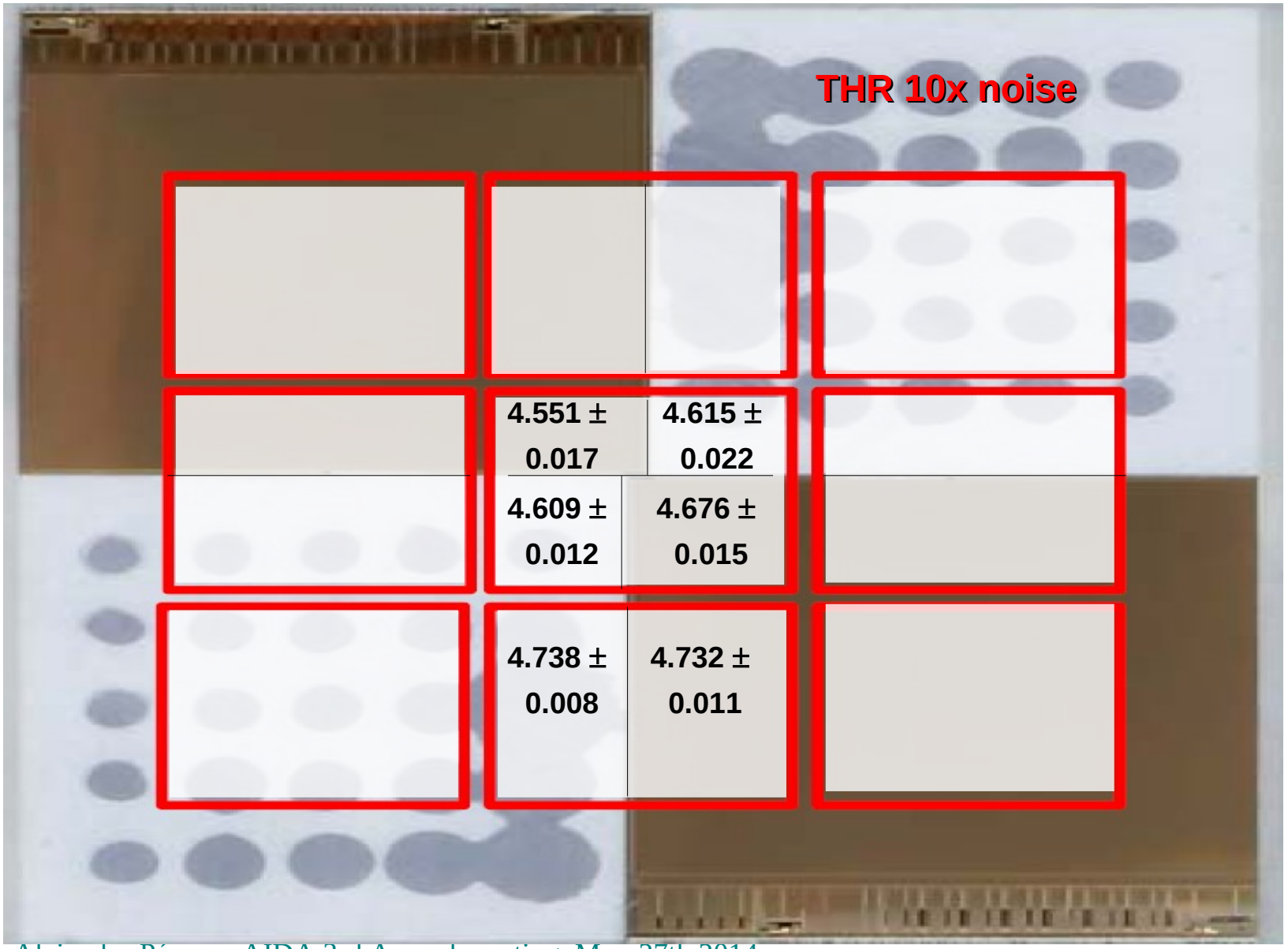
Uniformity Studies: Residual-V (µm)



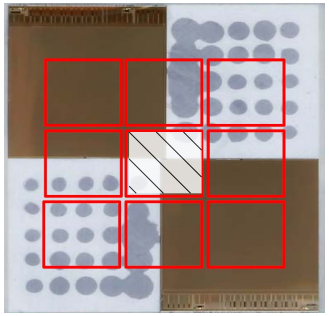
Uniformity Studies: Residual-V (µm)



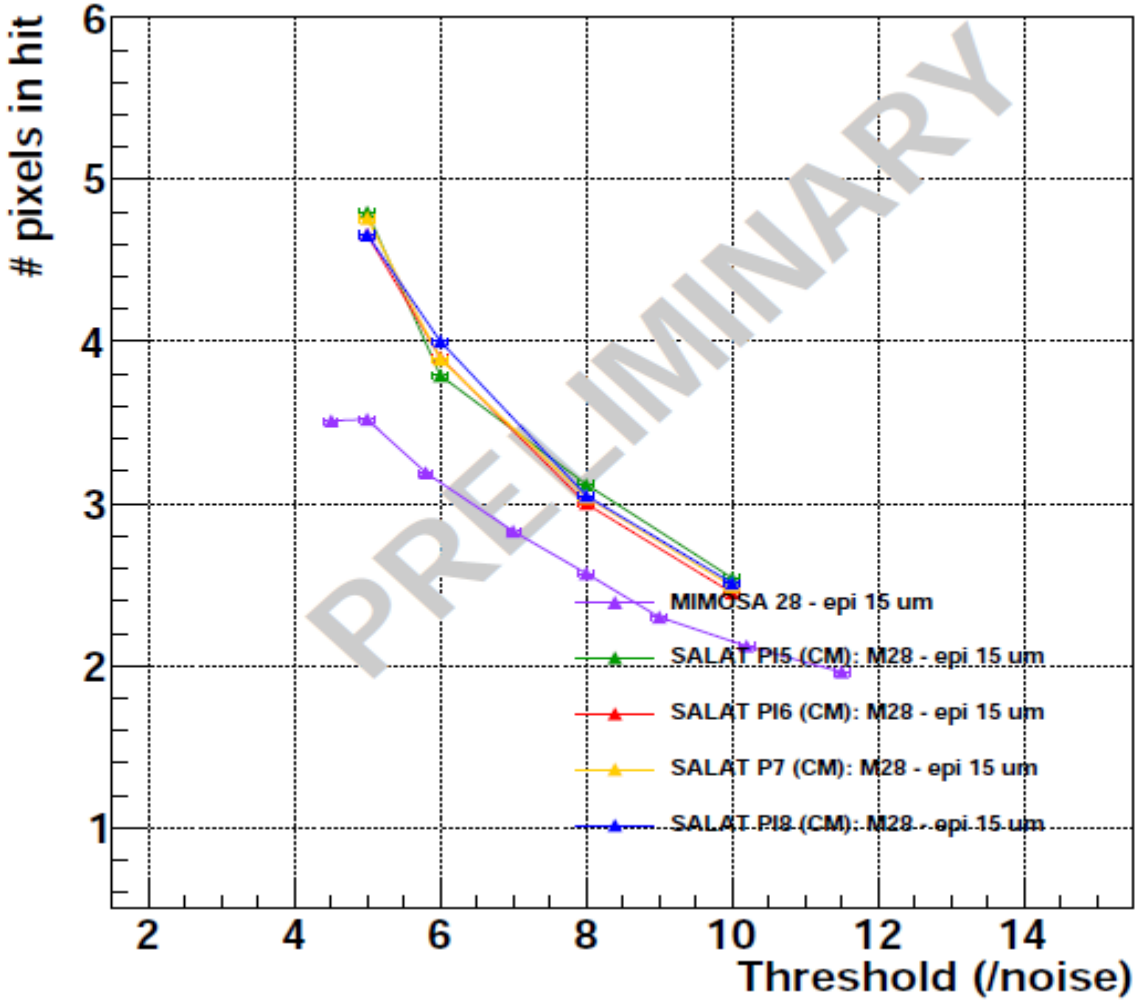
Uniformity Studies: Residual-V (µm)



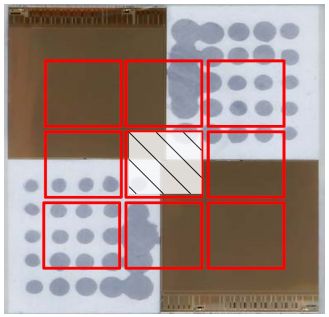
Sensor performances vs Threshold

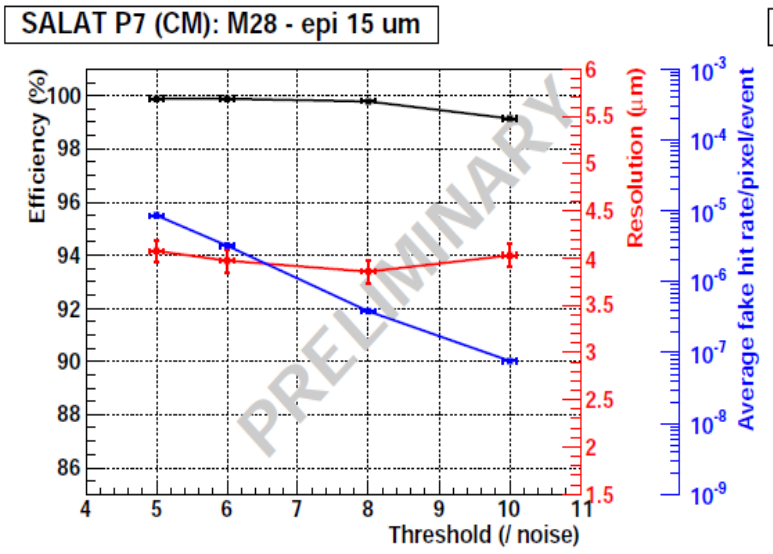


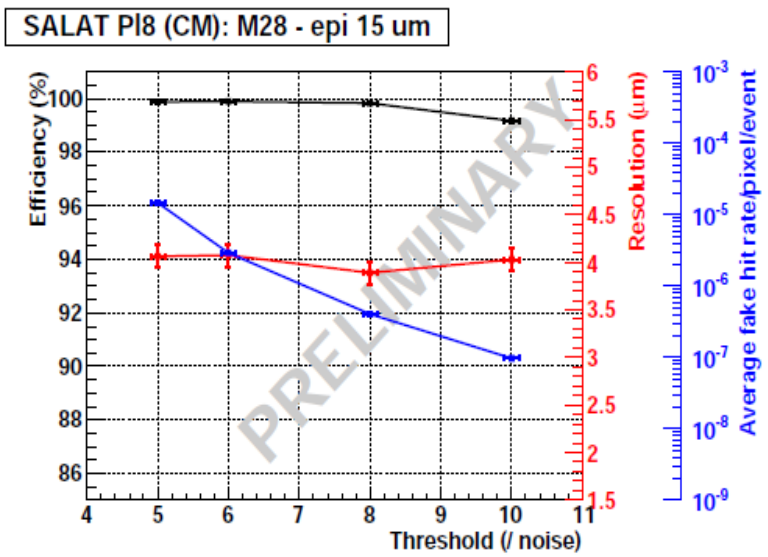
Pixel multiplicity vs Threshold

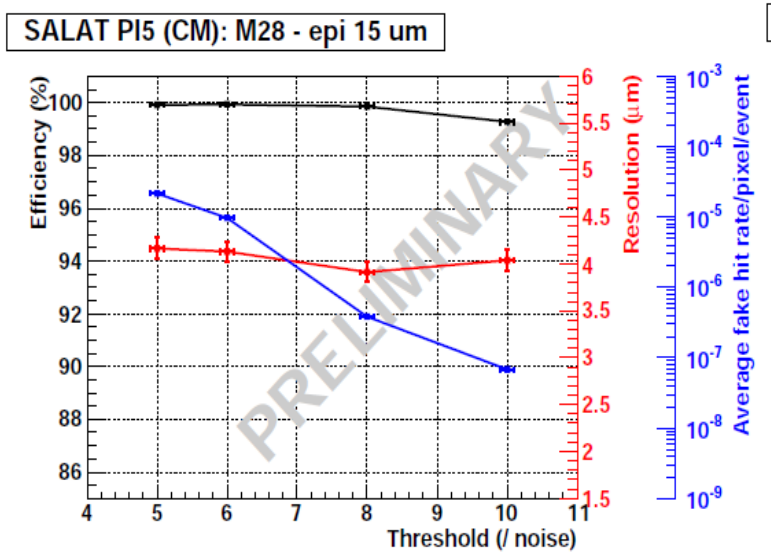


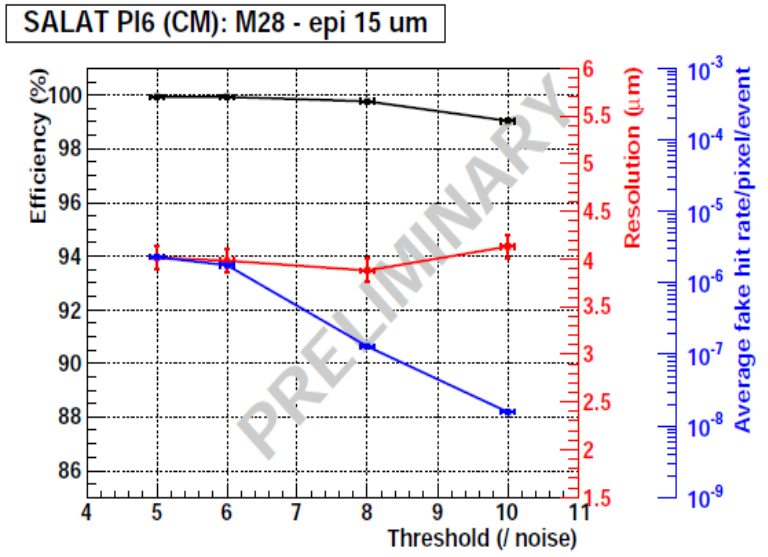
Uniformity Studies: Sensor performances vs THR



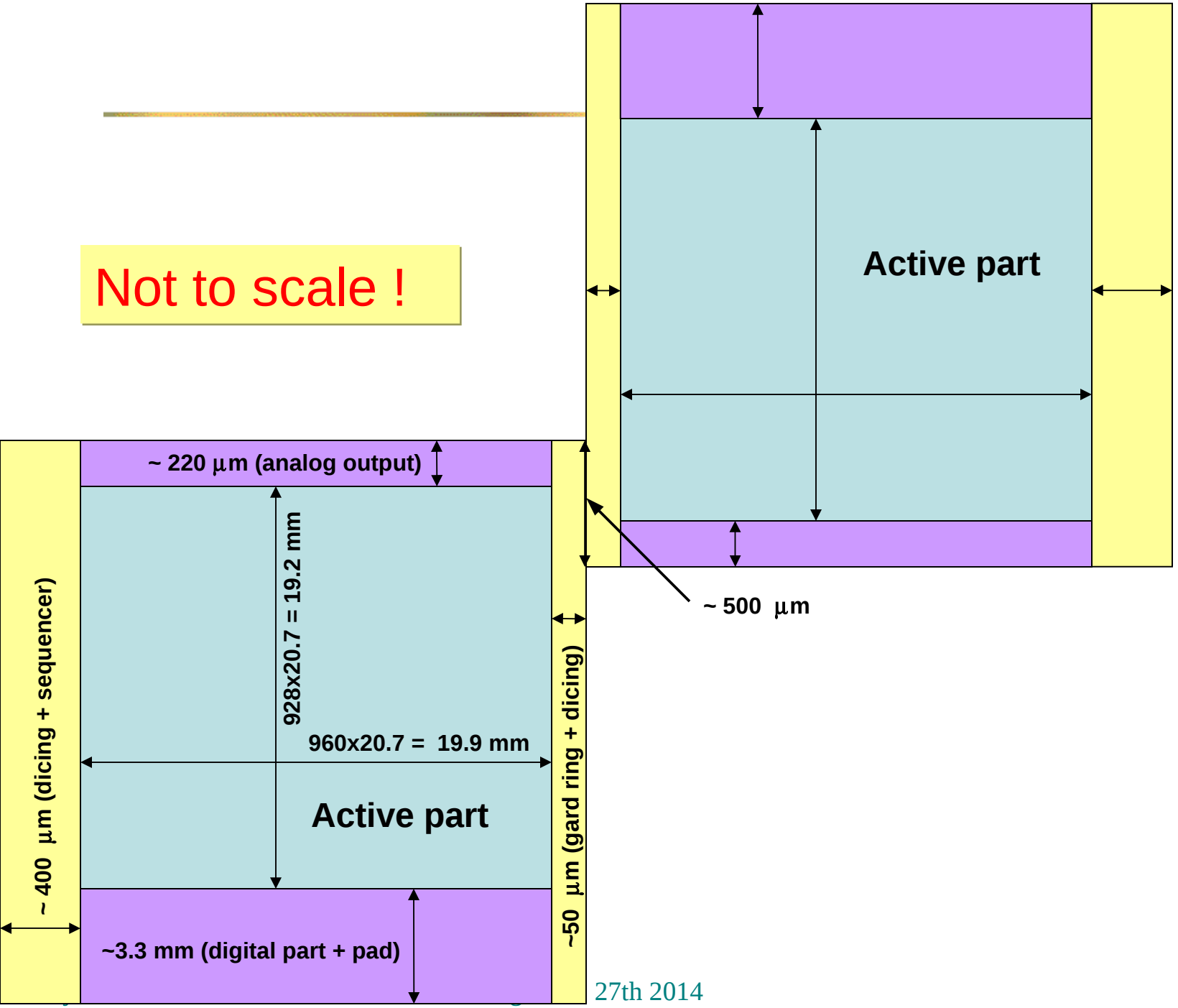








Not to scale !


Active part
~ 500 µm
~ 220 µm (analog output)
928x20.7 = 19.2 mm
960x20.7 = 19.9 mm
Active part
~ 400 µm (dicing + sequencer)
~50 µm (gard ring + dicing)
~3.3 mm (digital part + pad)