SALAT Telescope Arm

Alejandro Pérez
IPHC – CNRS Strasbourg

CENTRE NATIONAL
DE LA RECHERCHE
SCIENTIFIQUE

IPHC
Institut Pluridisciplinaire
Hubert CURIEN
STRASBOURG

PICSEL GROUP

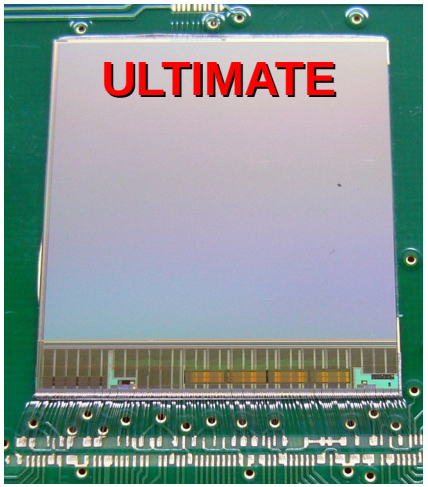
Outline

- Reminder on SALAT Prototype
- Preliminary results on SALAT Beam-Test @ CERN-SPS
- SALAT delivery
- Summary

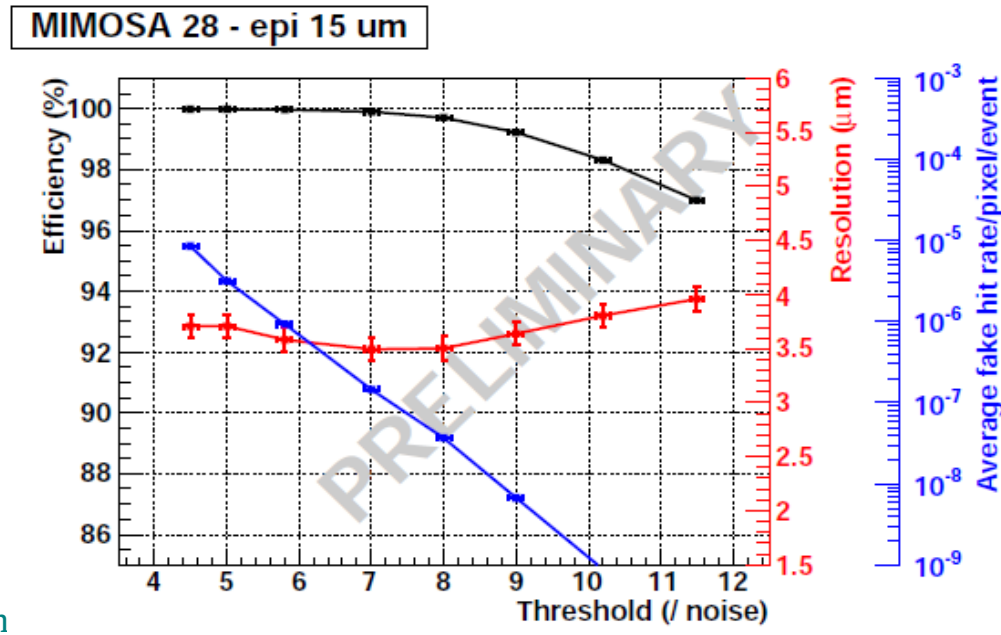
Reminder on SALAT prototype

The Sensors: ULTIMATE (MIMOSA-28)

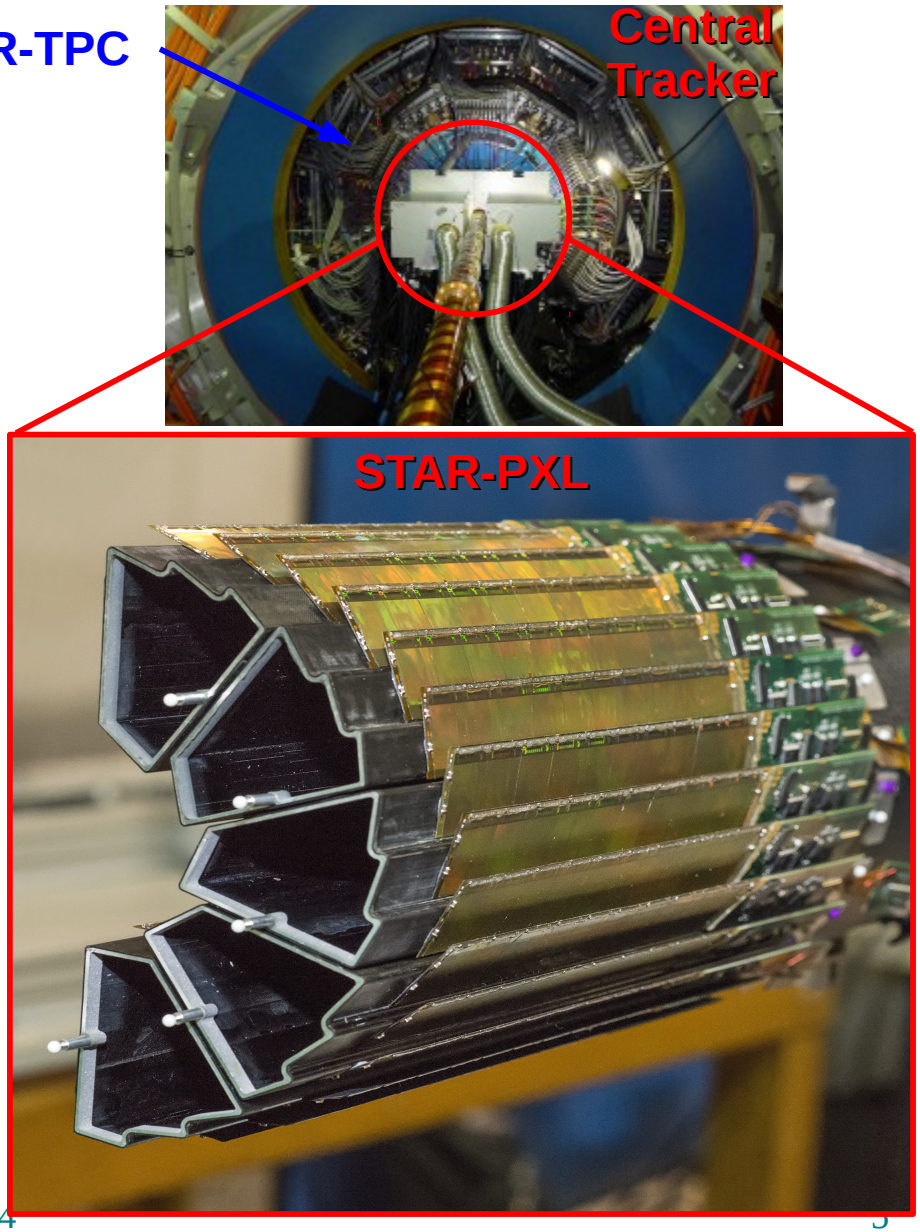
- **ULTIMATE main characteristics**
  - CMOS sensor (0.35µm AMS) high-resistive Epi-layer-15µm
    Sensor thinned to 50µm (total thickness)
  - Column || architecture with in-pixel CDS & amplification
  - End-of-column discriminator & binary charge encoding, followed by ∅-suppression
  - 960x928 (columns 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



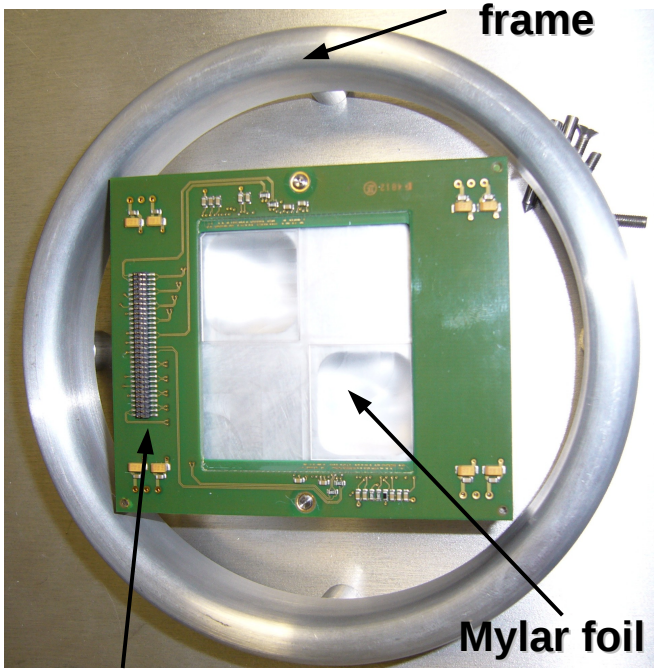
- **STAR-PXL HALF-BARREL**
  - 2 layers: 20 ladders (0.37% X_0)
  - 200 sensors
  - 180×10^6 pixels
  - Air flow cooling: $T \lesssim 35^oC$
  - $\sigma_{sp} \lesssim 4\mu m$
  - Rad. Load 150kRad + 3×10^{12} n.e.q (Full life-time)
  - $t_{o.r.} \lesssim 200\mu s$

SALAT final plane

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

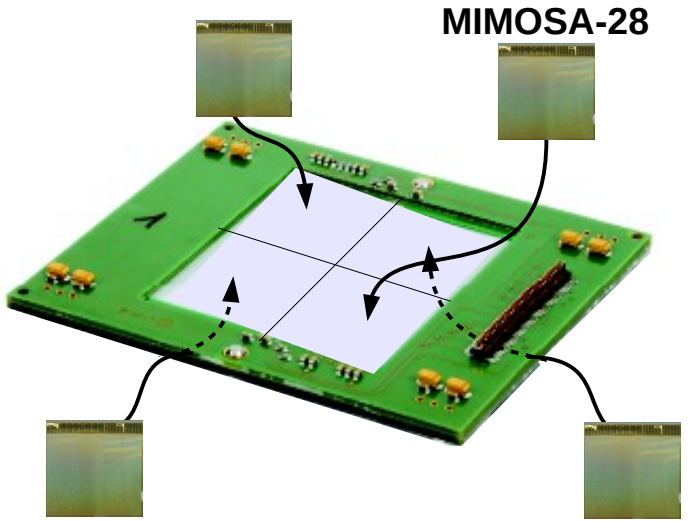
SALAT final plane

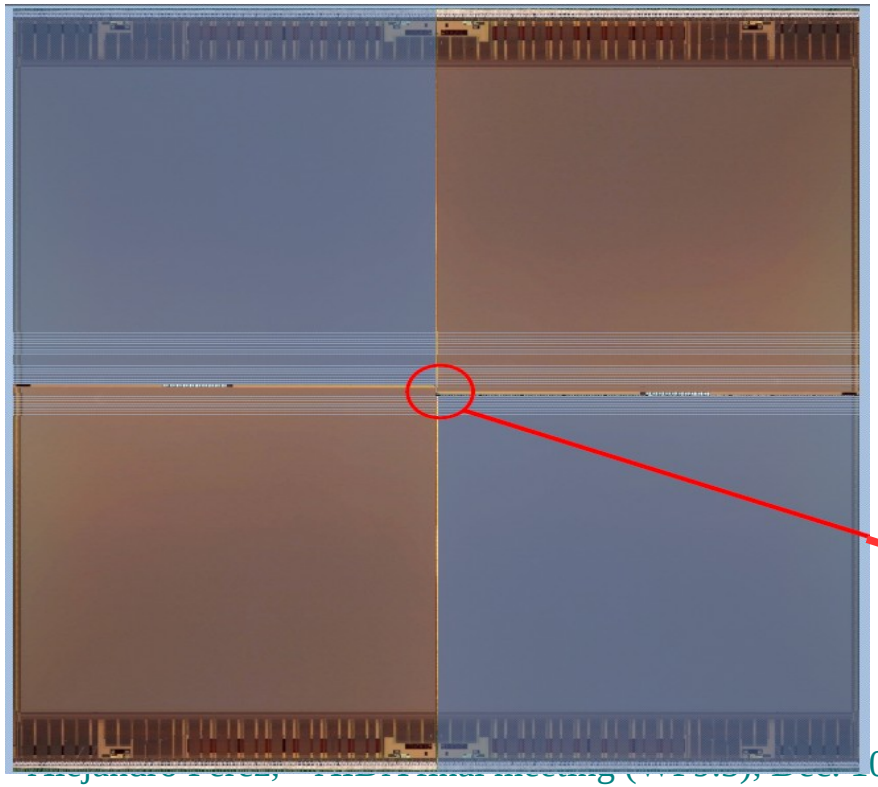
- **LAT motivations**
  - Big surface and thin reference planes
- **Assembly**
  - Stretched 50μm Mylar foil ($X_0^{Mylar} \sim 3 \times X_0^{Si}$)

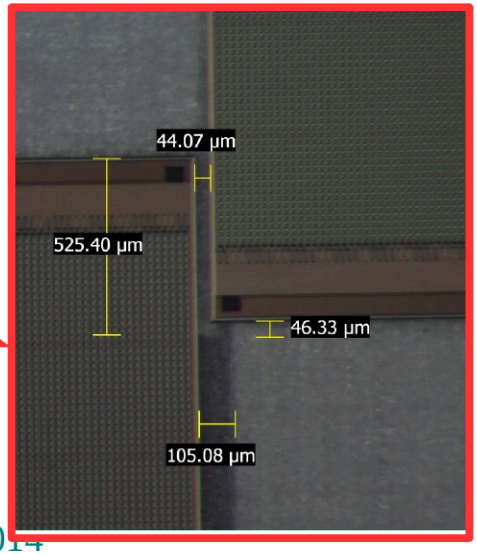


SALAT final plane

- **LAT motivations**
  - Big surface and thin reference planes
- **Assembly**
  - Stretched 50µm Mylar foil ($X_0^{Mylar} \sim 3 \times X_0^{Si}$)
  - Layout: 2 staggered sensors on each side







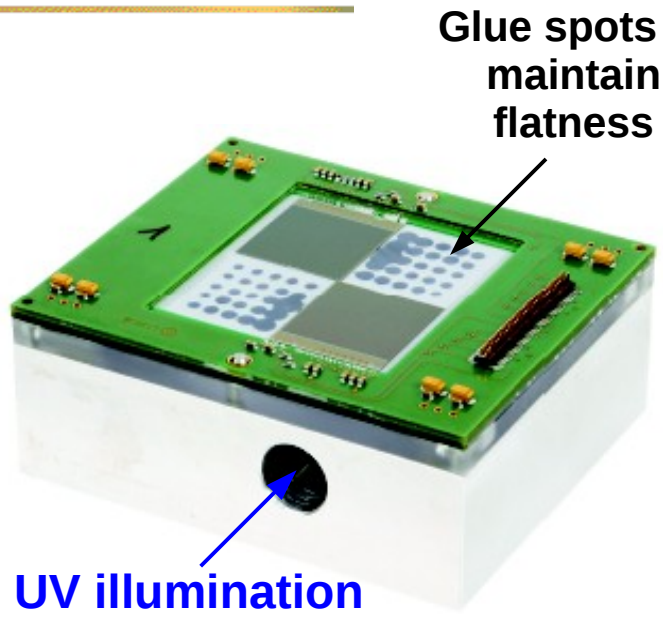
Vertical space between sensors

- Clear region: ~5µm
- Sealing line: ~10µm
- Cutting edge: ~10µm

Expect gap between neighbouring pixels of ~ 100µm

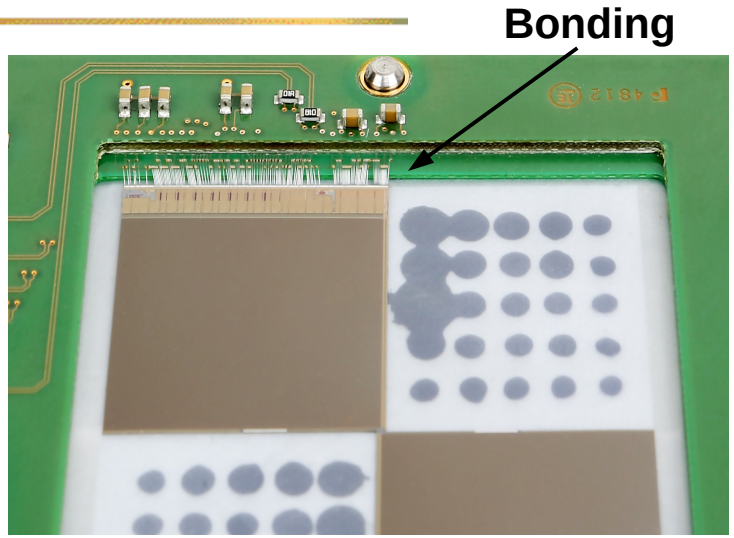
SALAT final plane

- **LAT motivations**
  - Big surface and thin reference planes
- **Assembly**
  - Stretched 50µm Mylar foil ($X_0^{Mylar} \sim 3 \times X_0^{Si}$)
  - Layout: 2 staggered sensors on each side
  - UV cured gluing



SALAT final plane

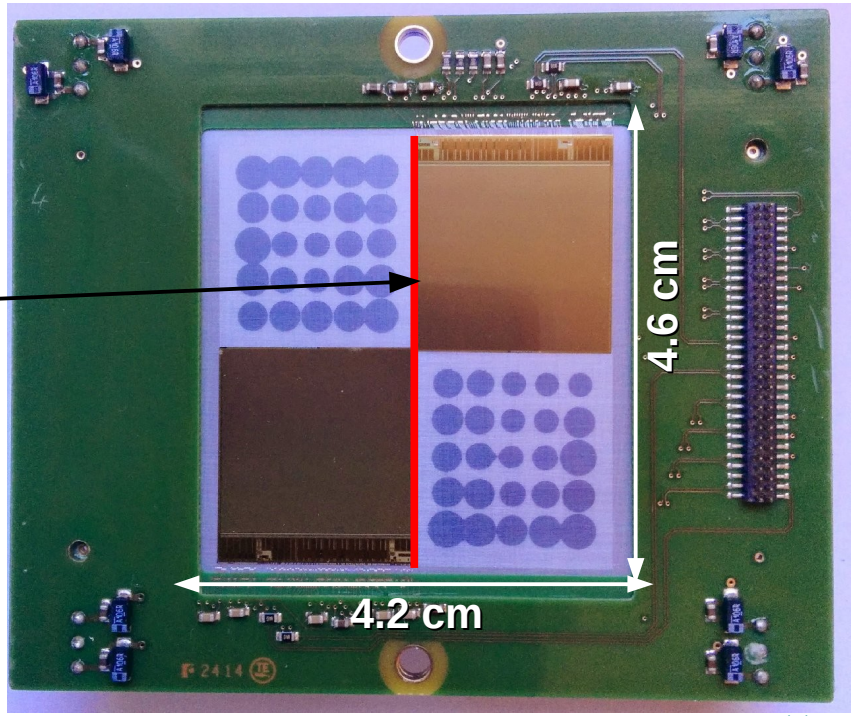
- **LAT motivations**
  - Big surface and thin reference planes
- **Assembly**
  - Stretched 50μm Mylar foil ($X_0^{Mylar} \sim 3 \times X_0^{Si}$)
  - Layout: 2 staggered sensors on each side
  - UV cured gluing
  - Sensor bonding



SALAT final plane

- **LAT motivations**
  - Big surface and thin reference planes
- **Assembly**
  - Stretched 50µm Mylar foil ($X_0^{Mylar} \sim 3 \times X_0^{Si}$)
  - Layout: 2 staggered sensors on each side
  - UV cured gluing
  - Sensor bonding
- **Basic numbers**
  - 3.6 M-pixels over 15.3 cm^2
  - $\lesssim$ 200µs integration time
  - Insensitive areas ~100µm

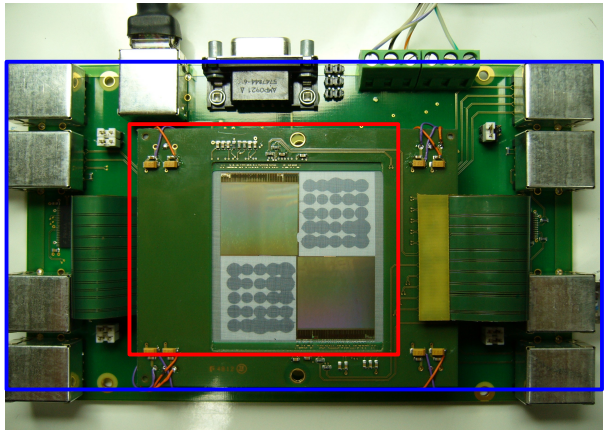
Sensing area = 4 x 3.8cm^2



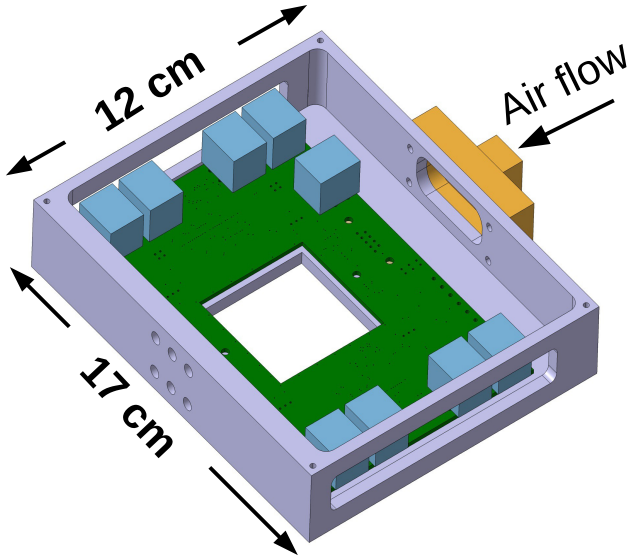
SALAT final plane

- **LAT motivations**
  - Big surface and thin reference planes
- **Assembly**
  - Stretched 50µm Mylar foil ($X_0^{Mylar} \sim 3 \times X_0^{Si}$)
  - Layout: 2 staggered sensors on each side
  - UV cured gluing
  - Sensor bonding
- **Basic numbers**
  - 3.6 M-pixels over 15.3 cm^2
  - $\lesssim$ 200µs integration time
  - Insensitive areas ~100µm
- **Production**
  - Several SALAT modules fully operational
    - 13 Modules mounted
    - 4 Modules fully validated (including beam test): 8, 11, 15 and 16

SALAT PCB, Mechanics and Cooling

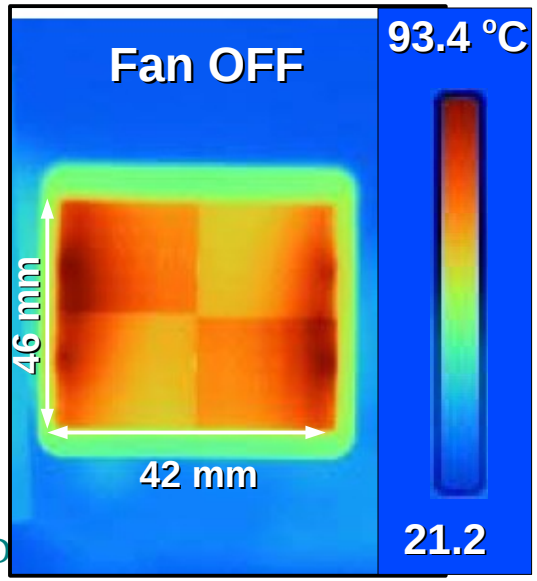


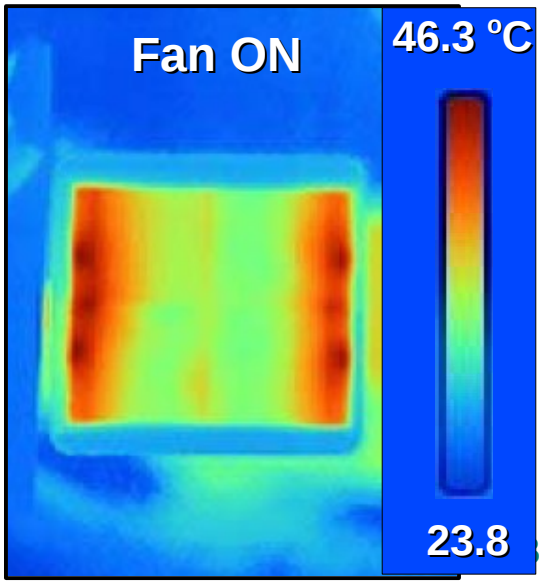
- **PCB design**
  - Mother (10x16 cm^2) and daughter (7x8 cm^2) design and production at IPHC micro-tech group



- **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

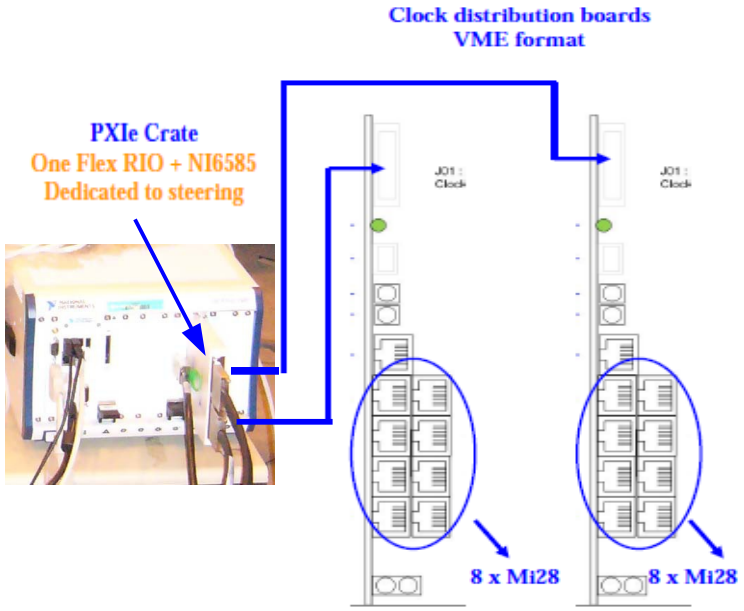




SALAT Data Acquisition System

- **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

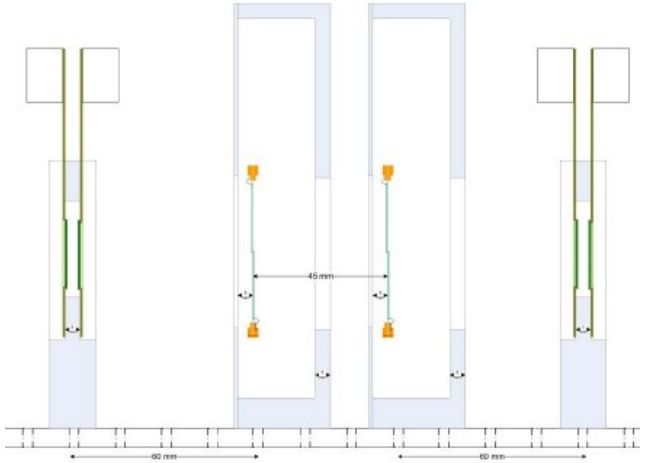
- **New developments**
  - Additional NI-6585 + Flex-RIO boards in PXI
  - New clock distribution board to synchronize 3 SALAT planes (12 Mi-28) and up to 4 SALAT planes if required (16 Mi-28)
  - New software to read 4 SALAT planes (16 Mi-28)
    - Readout validated for up to 14 Mi-28 sensors



SALAT beam test @ CERN-SPS
Preliminary results

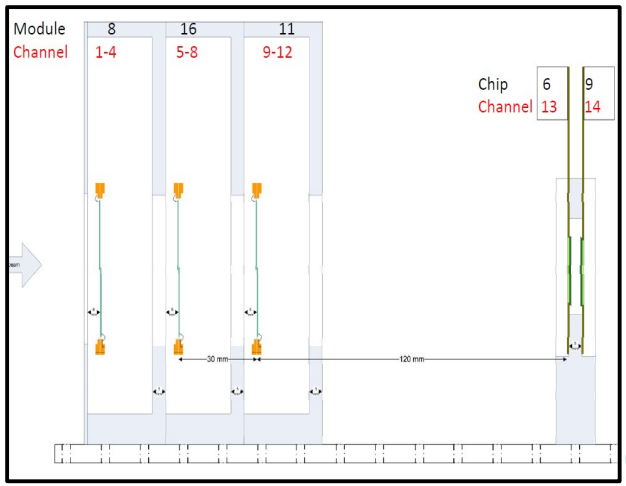
November test beam @ CERN: overview

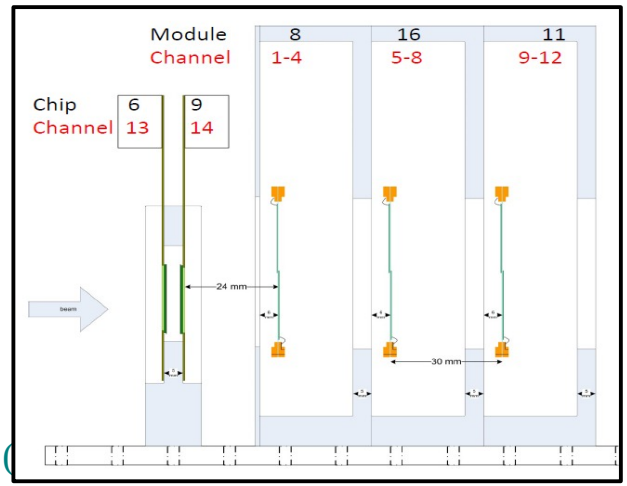
- **Conditions @ CERN-SPS: 23 – 28 Nov. 2014**
  - π^- beam with energy of 120 GeV
  - Different trigger rates: 1 – 50kHz (~1 cm^2 scintillator)
  - Air cooling for SALAT moduli

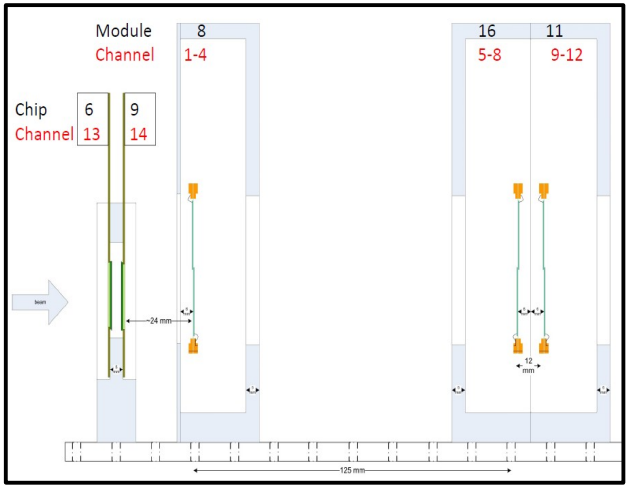


- **SALAT moduli alignment**
  - Relative alignment of Mi-28 sensors in SALAT module

- **Telescope with 3 SALAT moduli**
  - Different geometrical configurations with 3 SALAT modules + 2 Mi-sensors as DUT

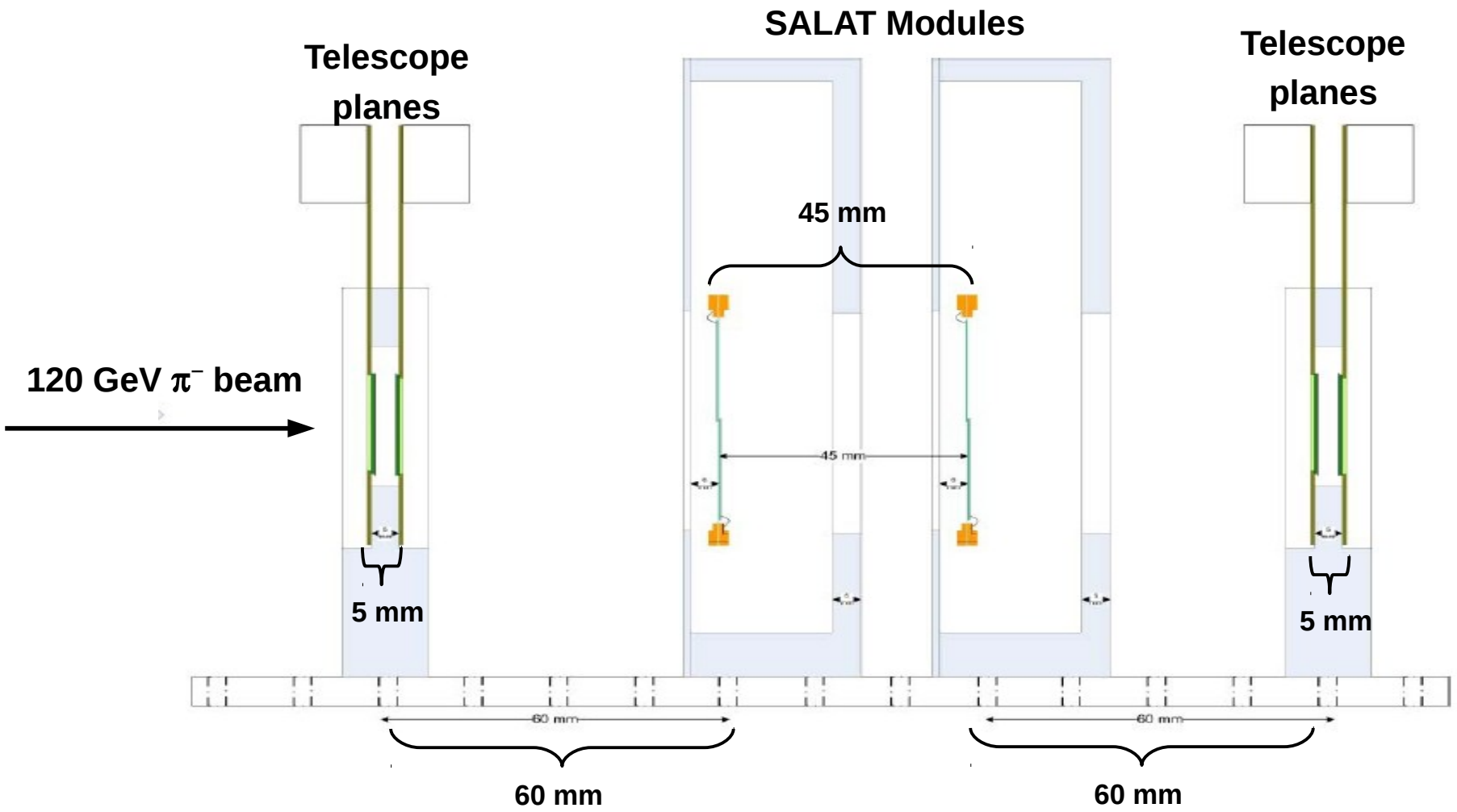






Relative Alignment of SALAT sensors: set-up

- **Configuration:** 4 reference planes (Telescope) and two SALAT modules
  - Relative alignment of the sensor in SALAT module

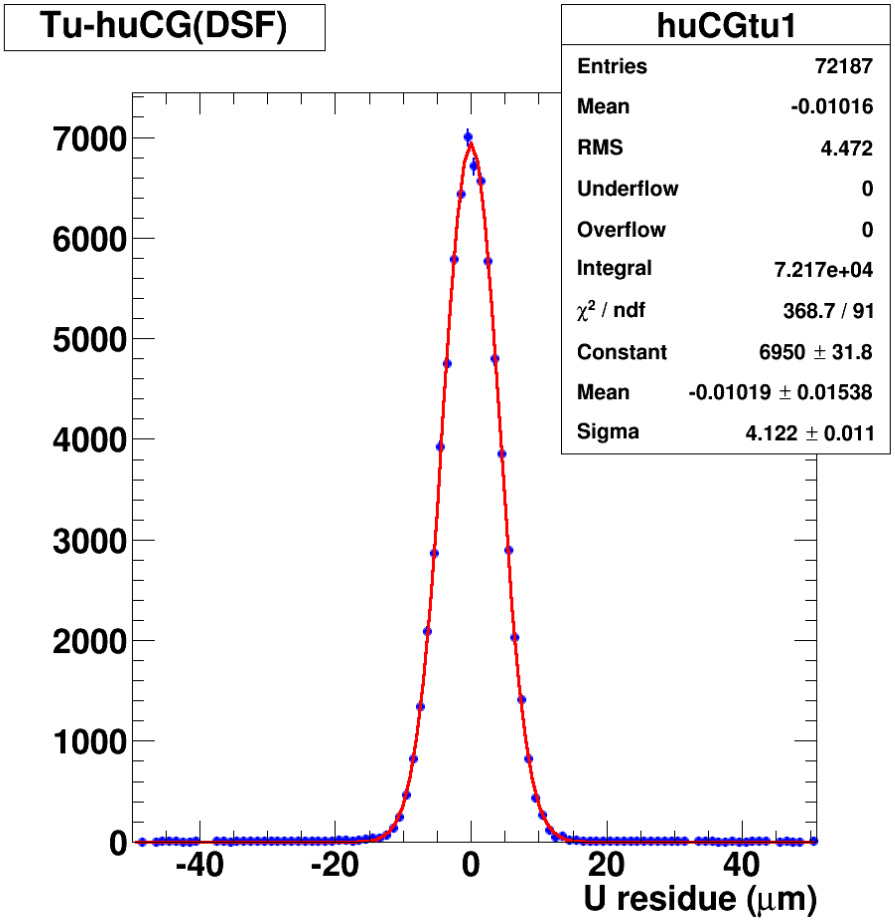


Relative Alignment of SALAT sensors: residues

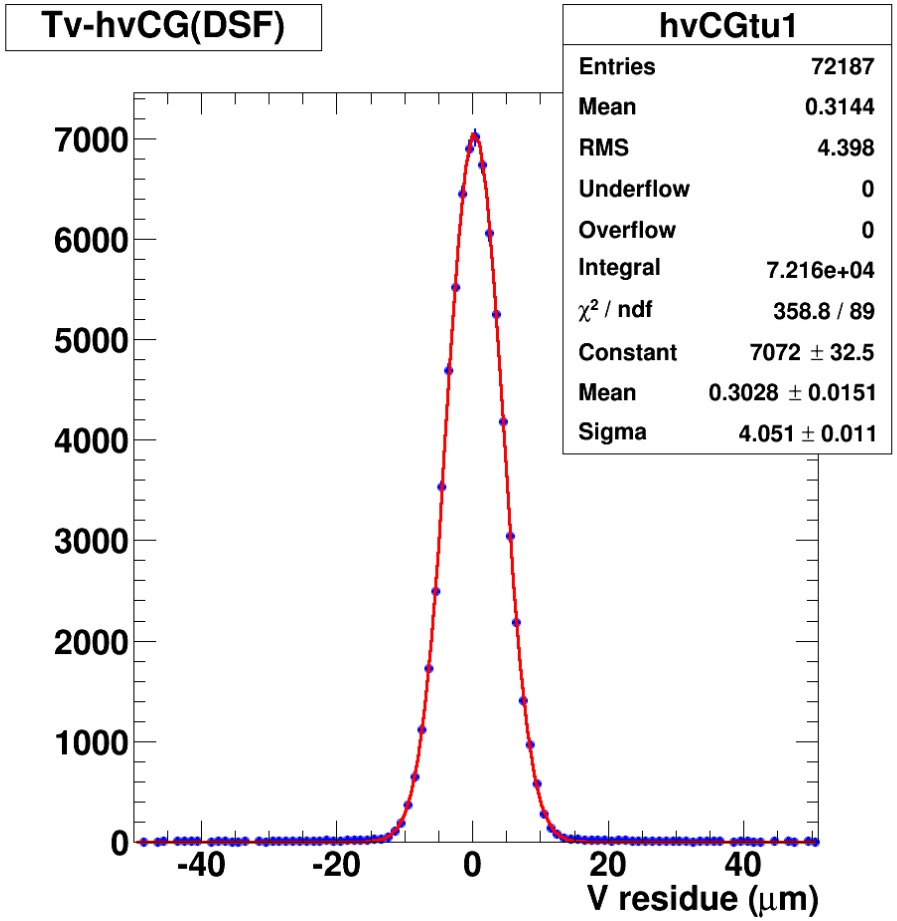
Example: one of the sensor of Module 16

THR @ 8x noise

Residual U



Residual V

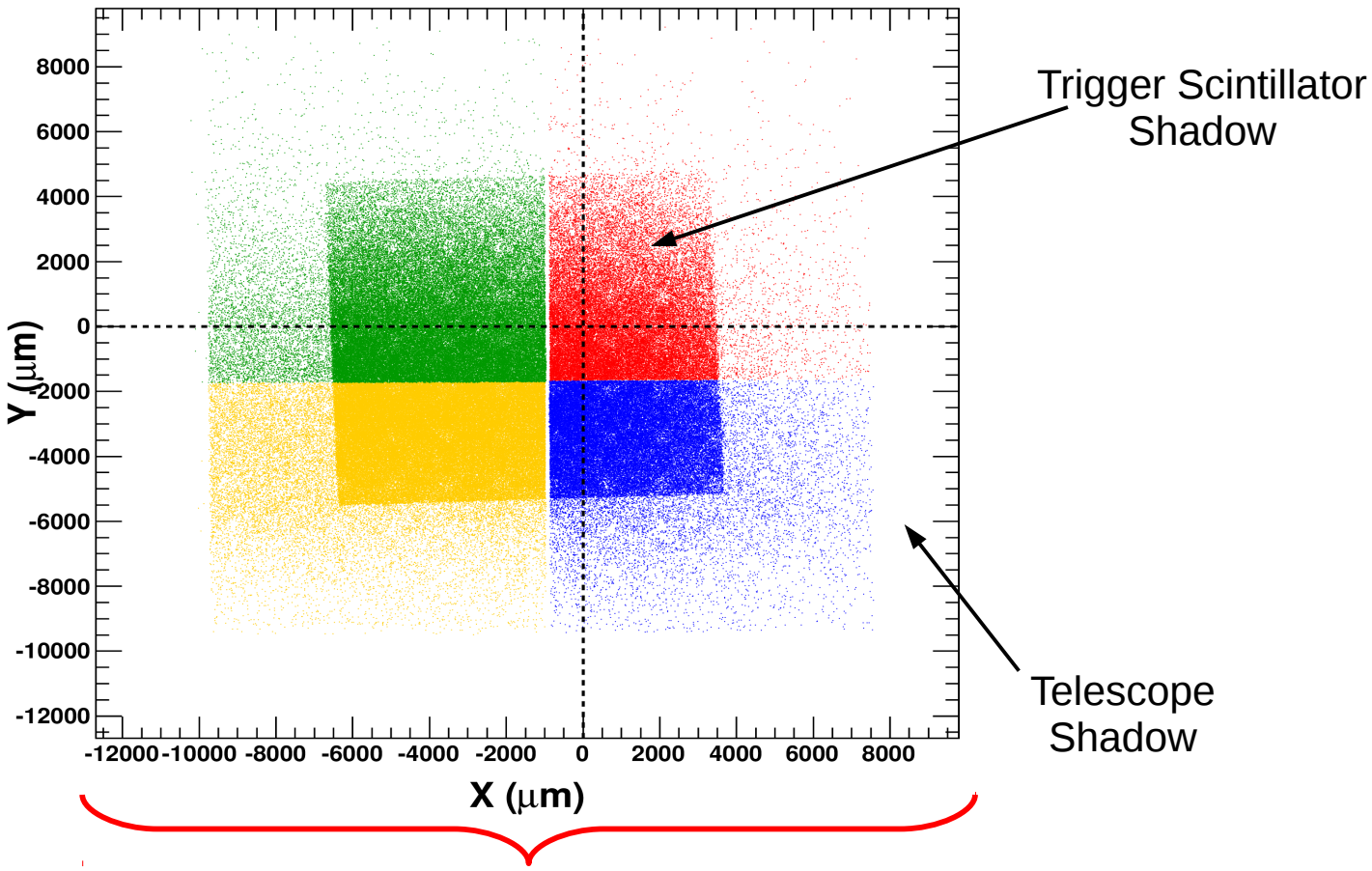


Relative Alignment of SALAT sensors: Insensitive Zones

π^- beam

Module 8

Hit associated to Track Map



Each Quadrant = one MIMOSA-28 Corner

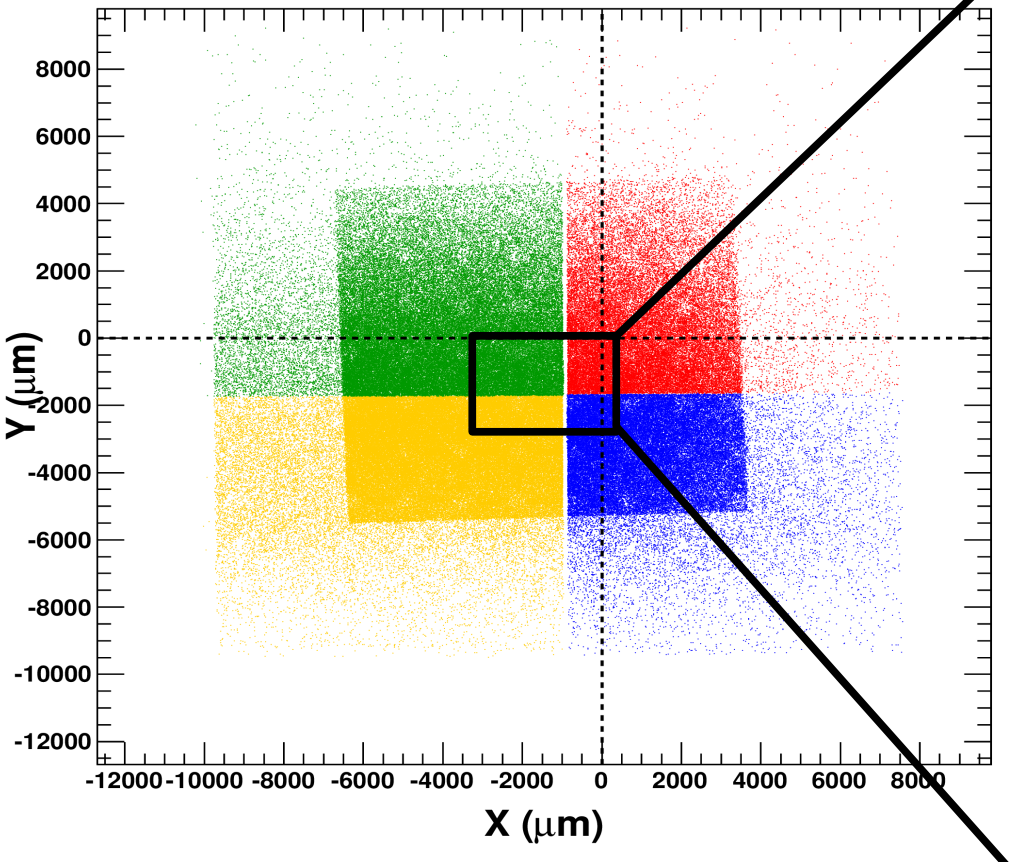
Relative Alignment of SALAT sensors: Insensitive Zones

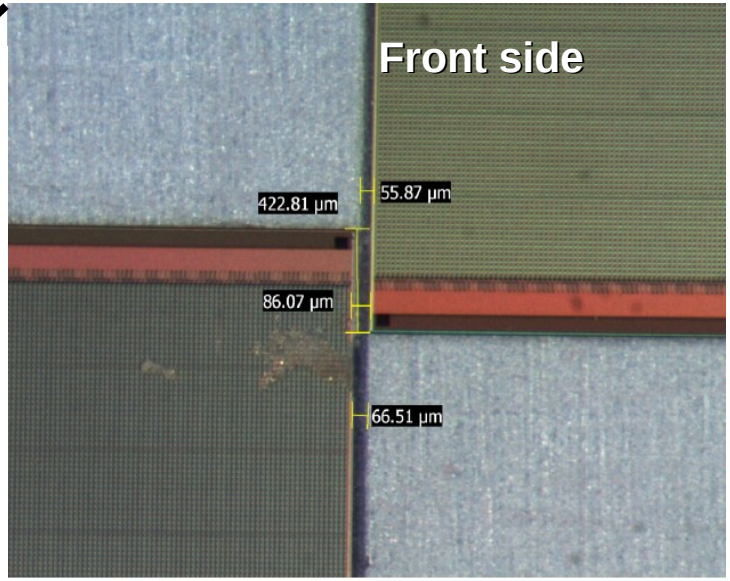
π^- beam

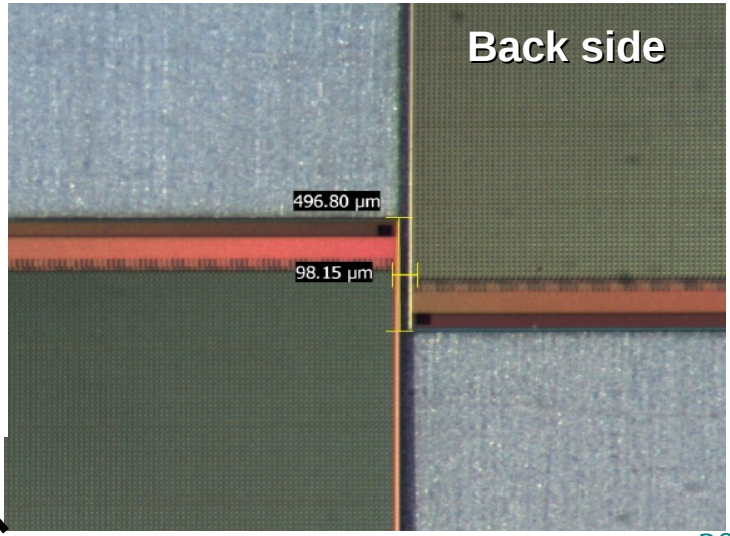
Module 8

Visual inspection

Hit associated to Track Map







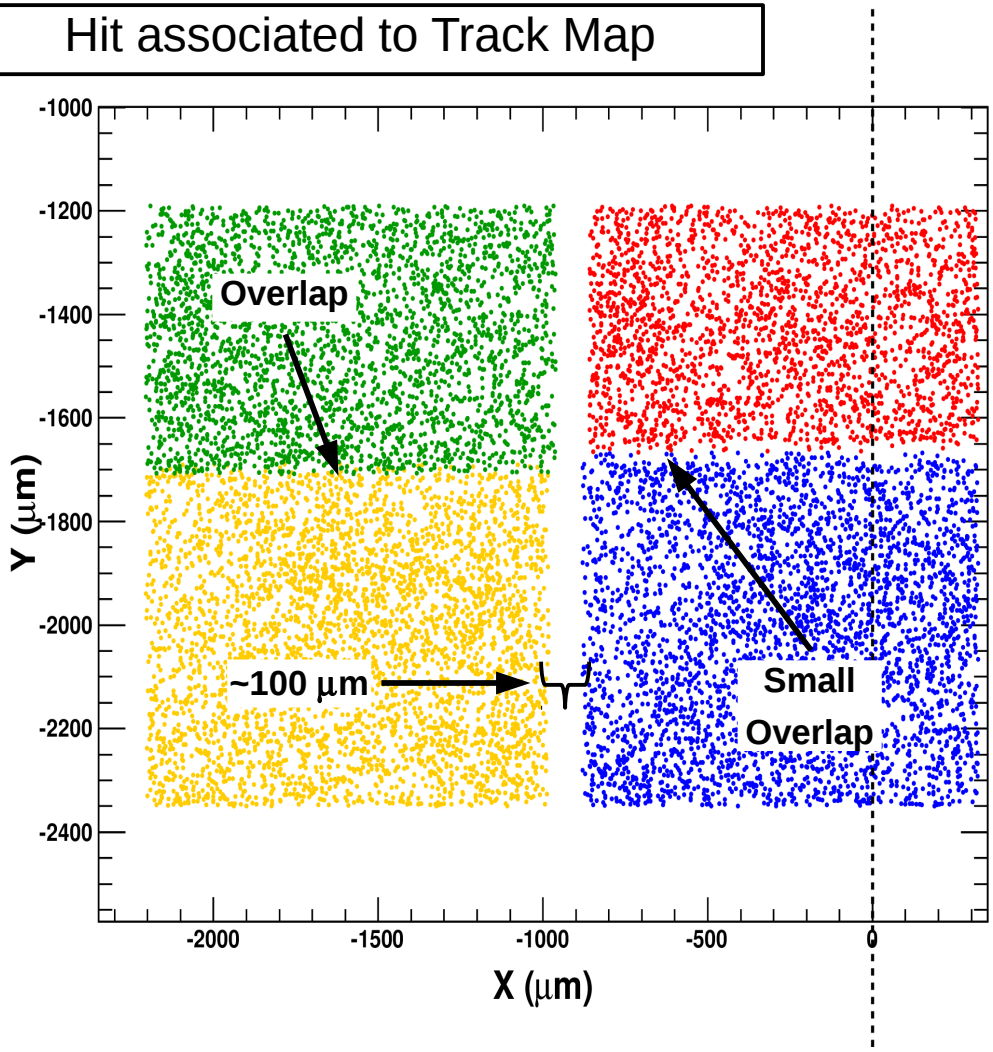
Relative Alignment of SALAT sensors: Insensitive Zones

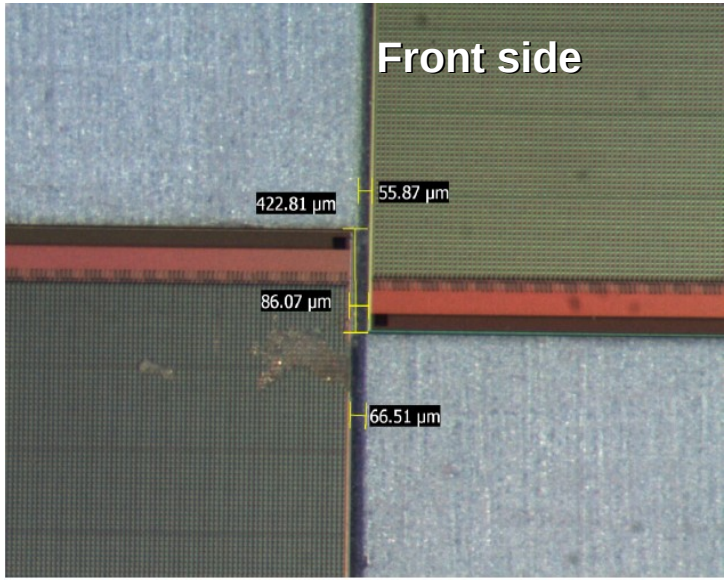
π^- beam

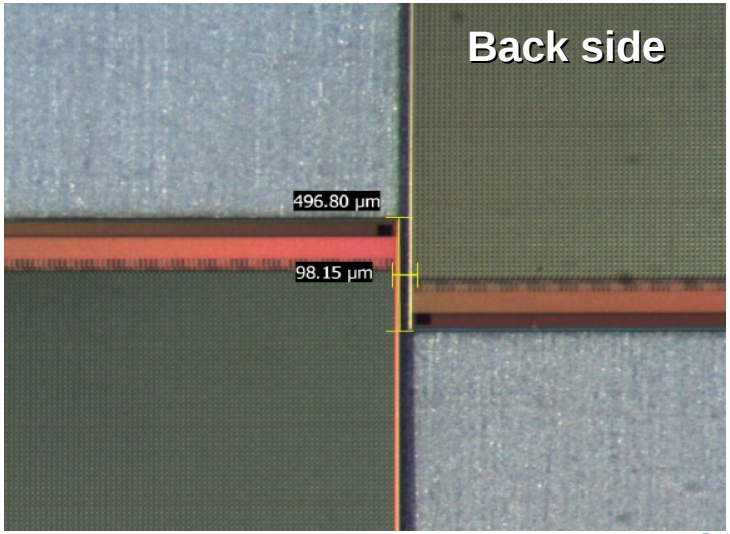
Module 8

Visual inspection

Hit associated to Track Map







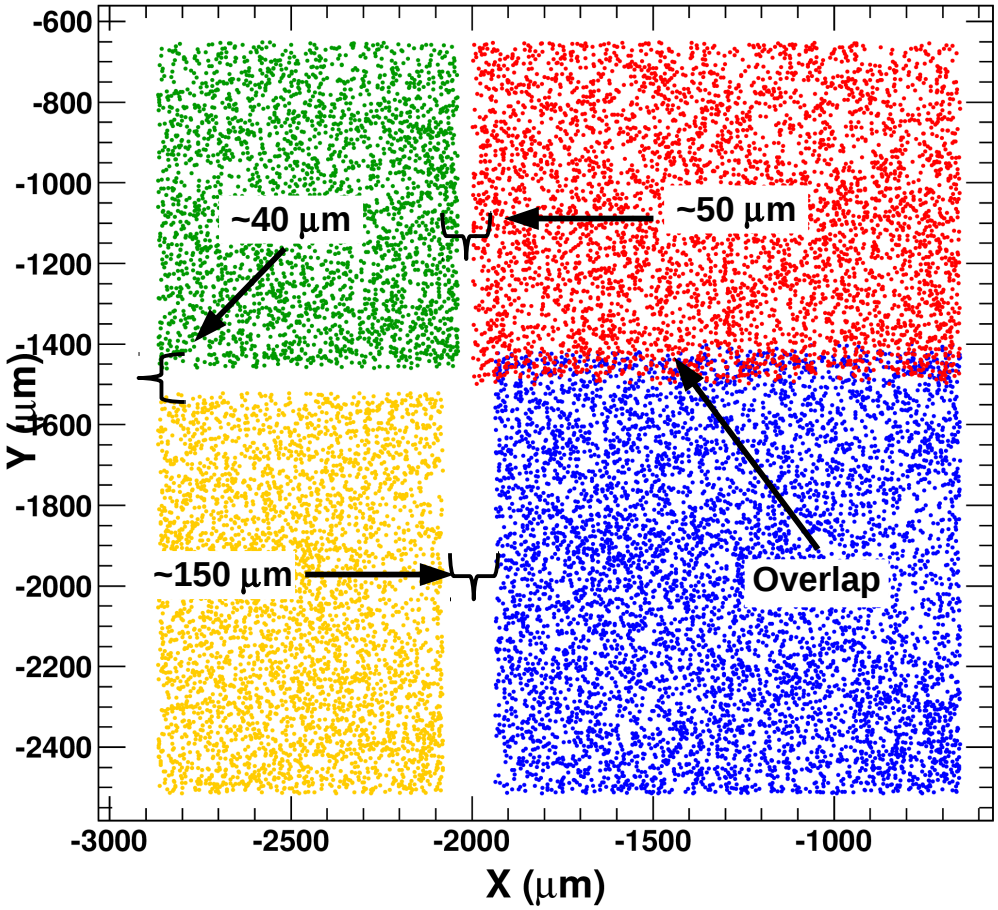
Relative Alignment of SALAT sensors: Insensitive Zones

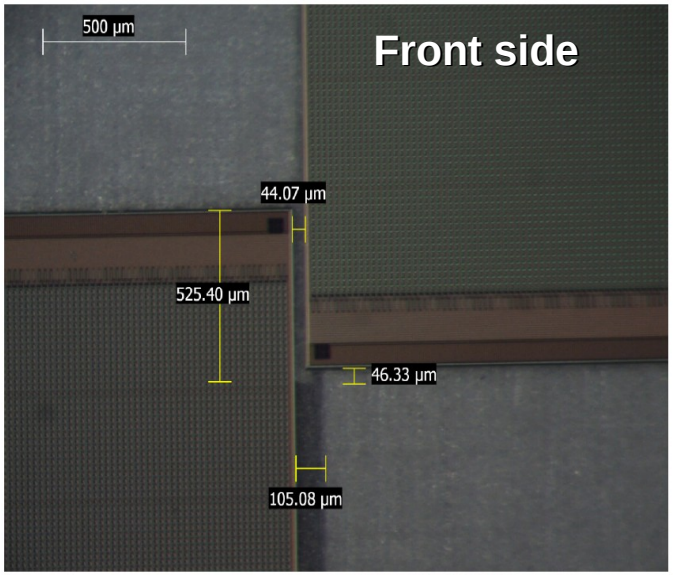
π^- beam

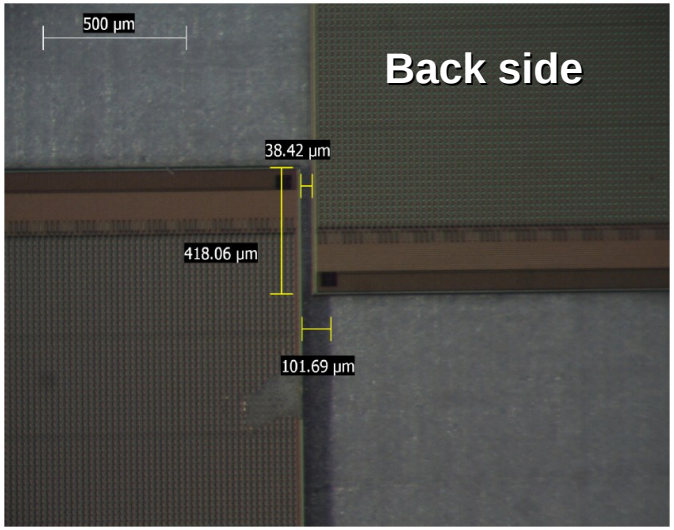
Module 16

Visual inspection

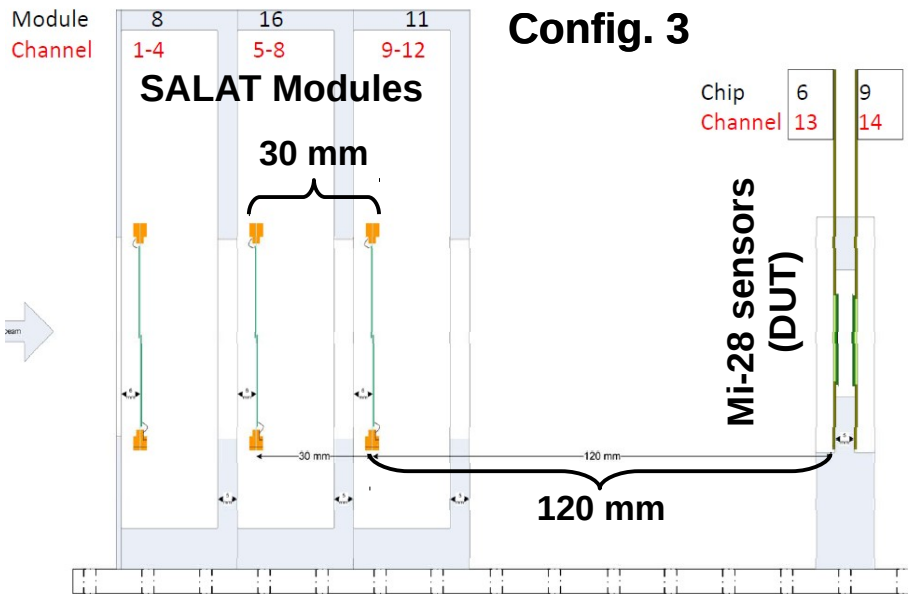
Hit associated to Track Map

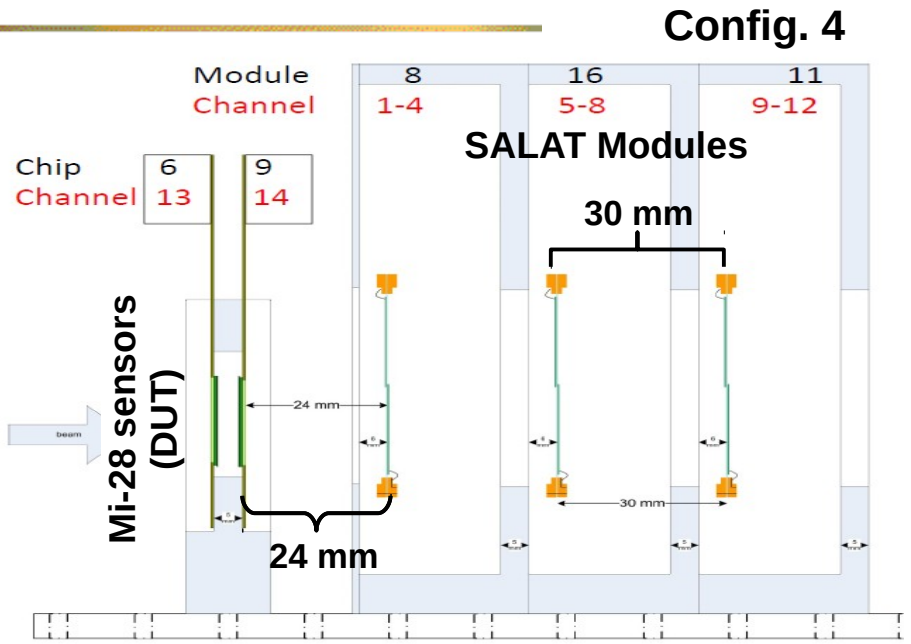


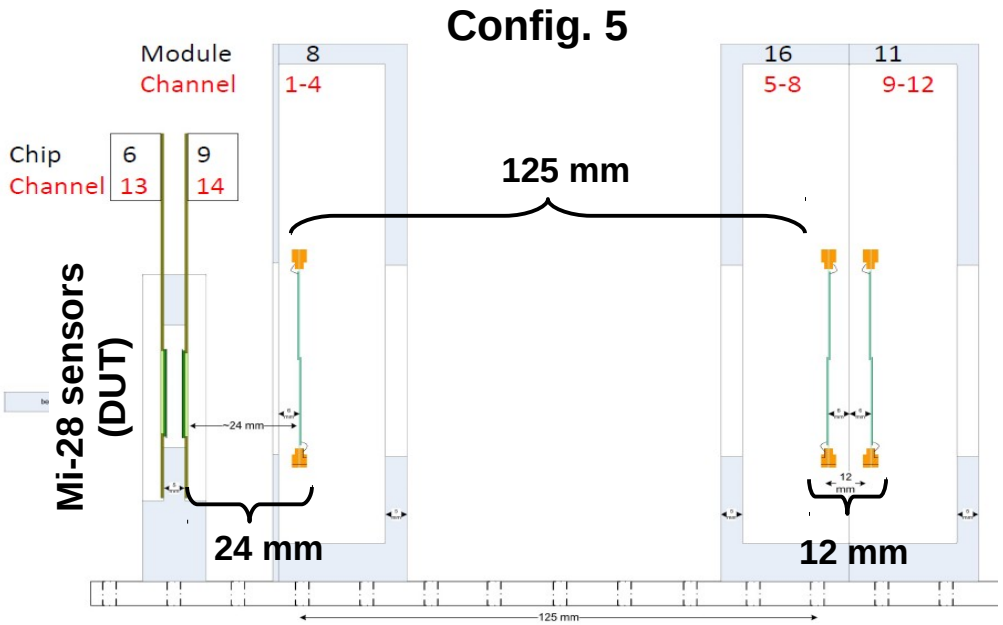




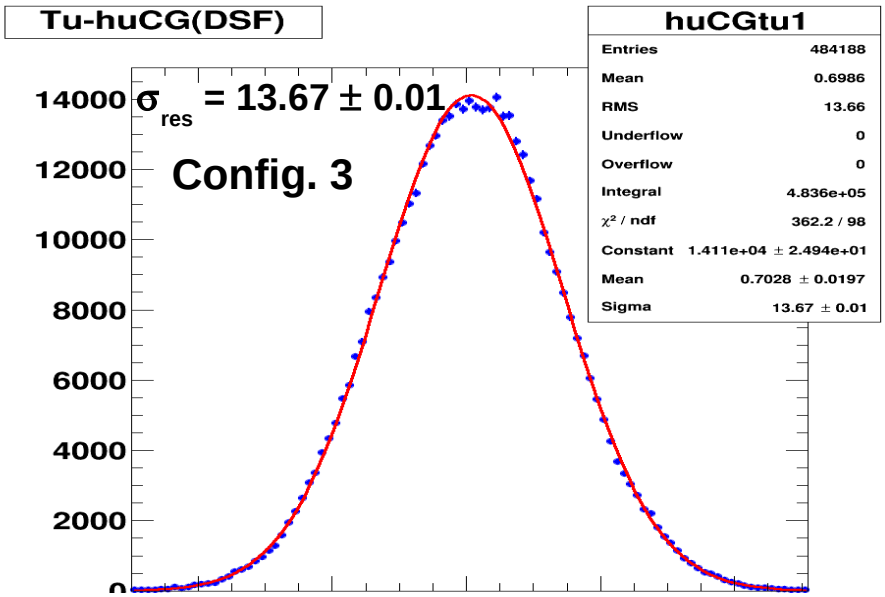
Telescope with SALAT modules: set-up

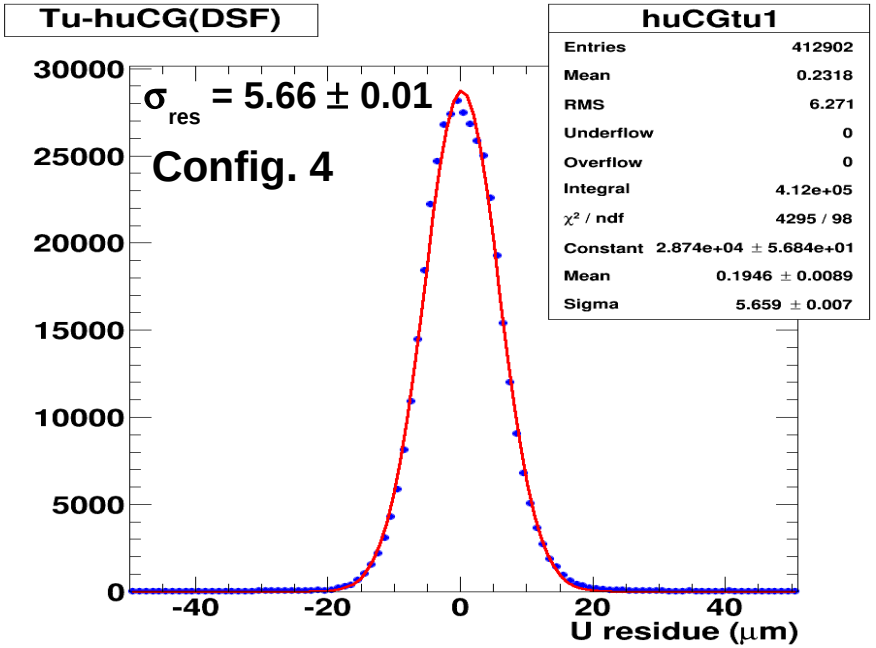


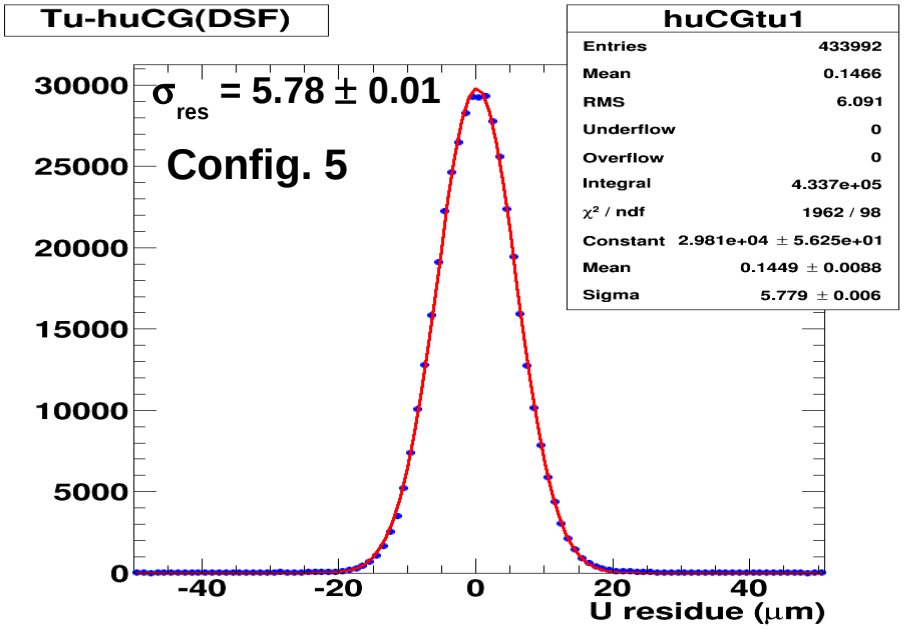




Telescope with SALAT modules: Telescope precision



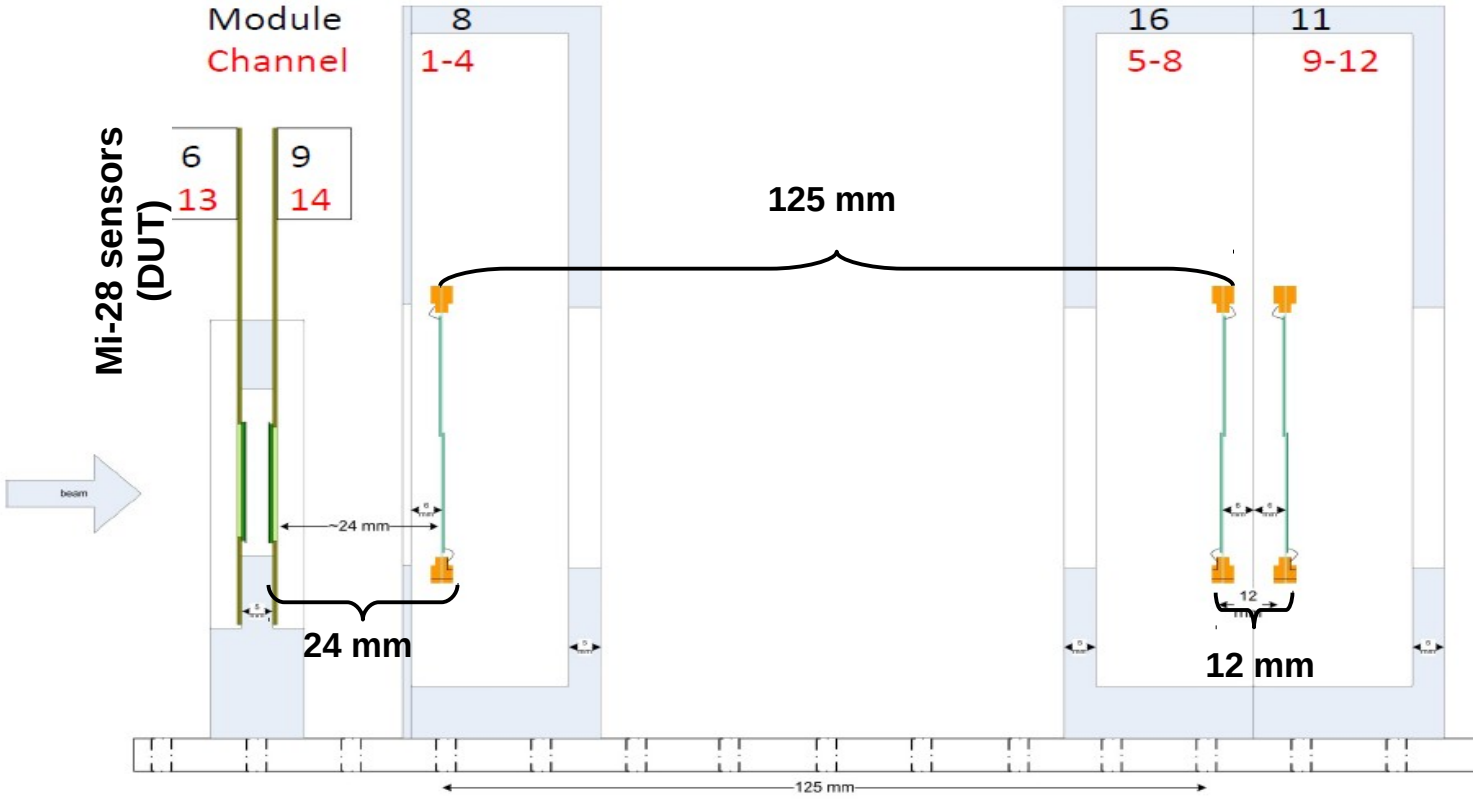




Config.	σ_{res} (μm)	σ^{exp}_{tel} (μm)	σ^{theo}_{tel} (μm)
3	13.67 ± 0.01	13.21 ± 0.01	13.0
4	5.66 ± 0.01	4.44 ± 0.01	4.9
5	5.78 ± 0.01	4.60 ± 0.01	4.2

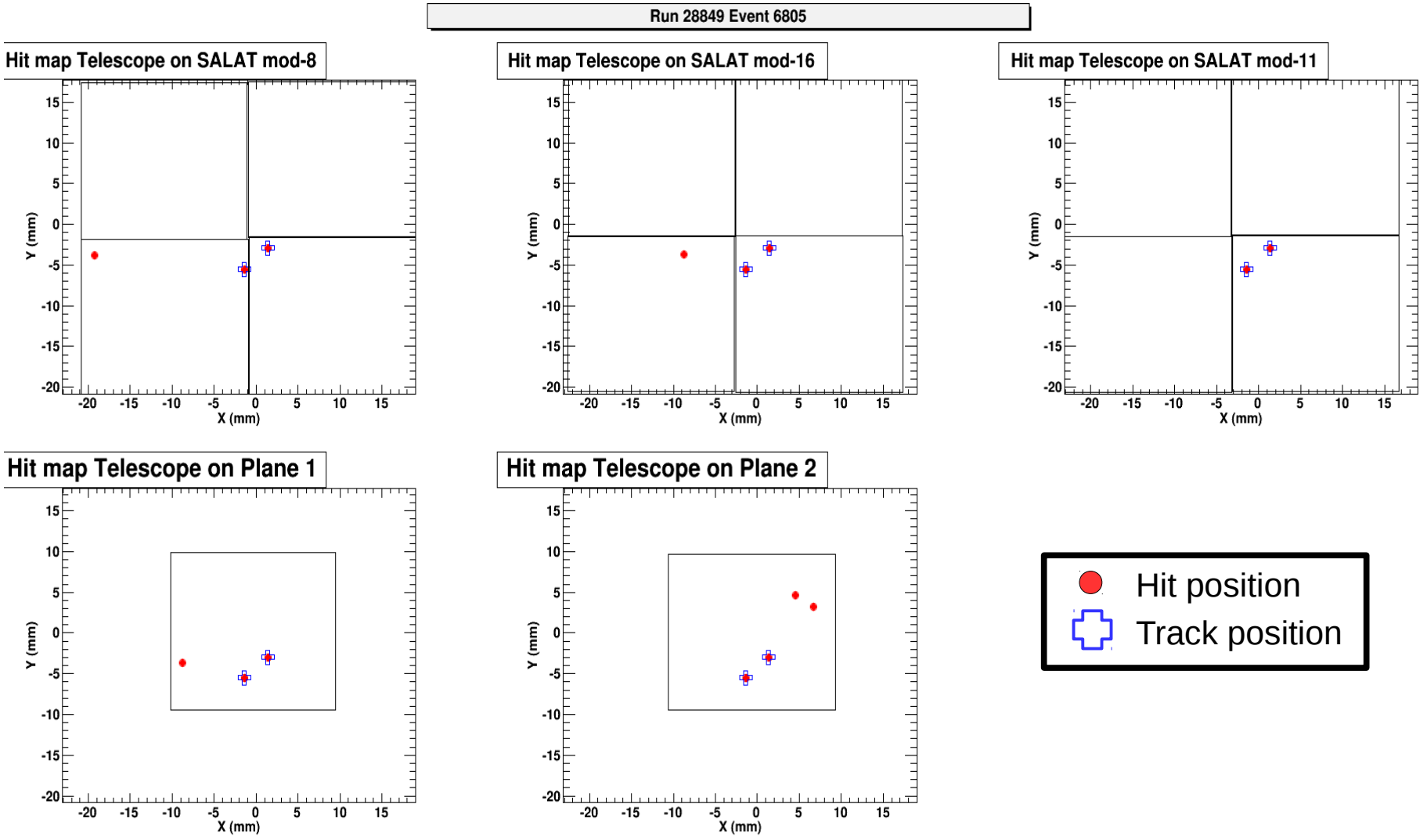
Telescope with SALAT modules: Multi-tracking

- Configuration 5: Study of tracking performances of the SALAT modules



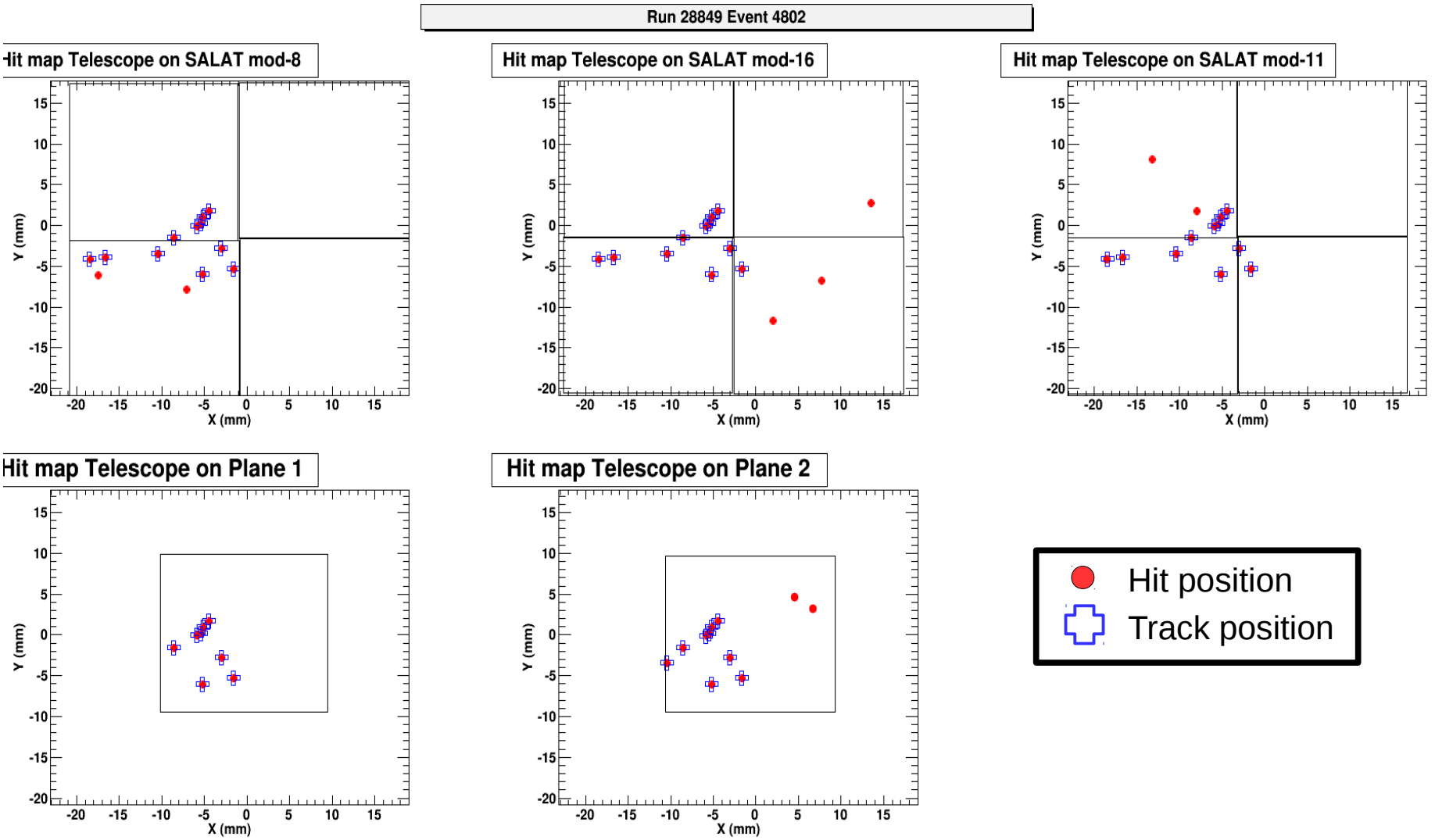
Telescope with SALAT modules: Multi-tracking

- $R_{trigger}$ ~ 1 kHz, Evt 6805, N_{rec} tracks = 2
- Tracking only with SALAT planes (Mod-8,16,11). Planes 1 and 2 are DUT



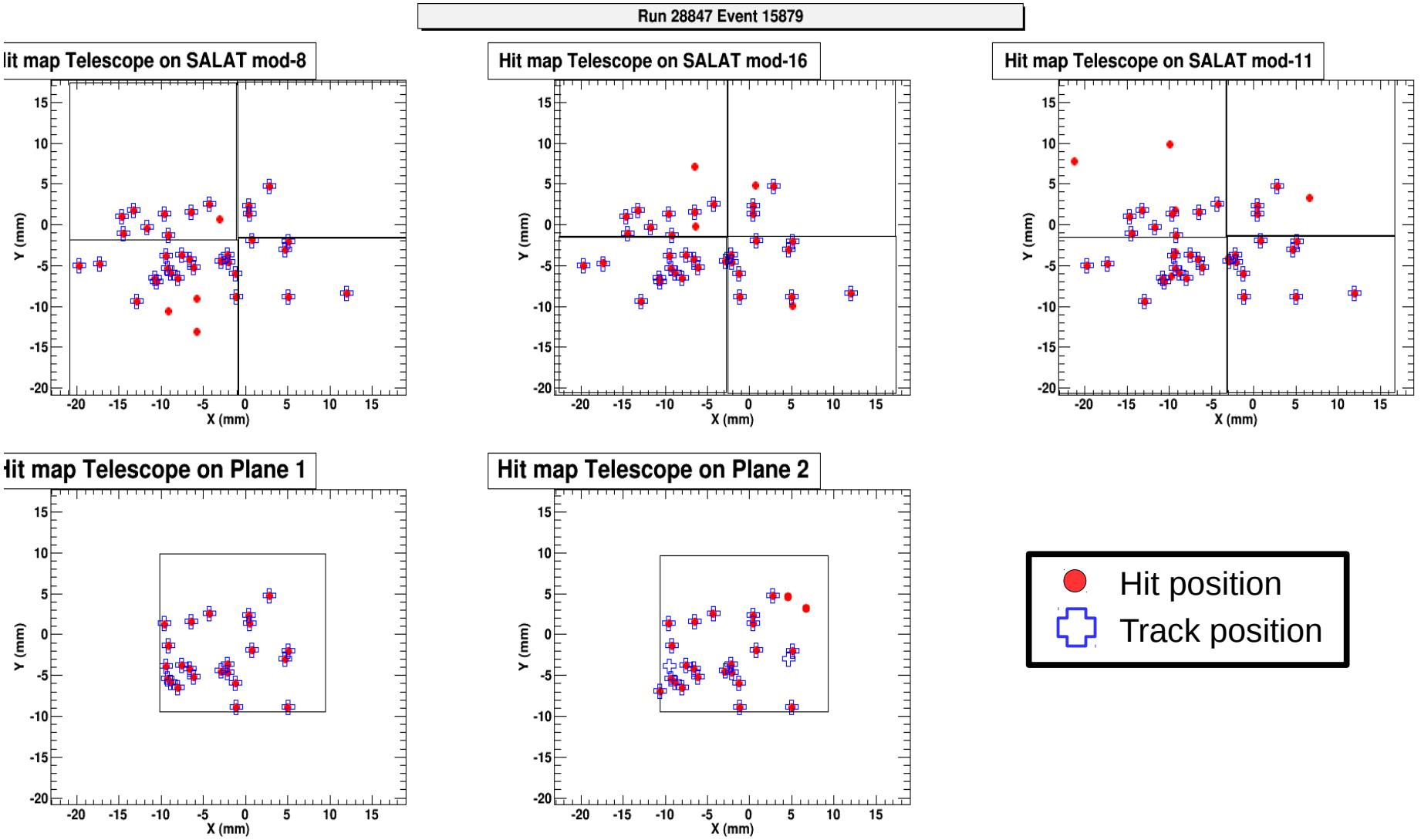
Telescope with SALAT modules: Multi-tracking

- $R_{trigger}$ ~ 1 kHz, Evt 4802, N_{rec} tracks = 10
- Tracking only with SALAT planes (Mod-8,16,11). Planes 1 and 2 are DUT



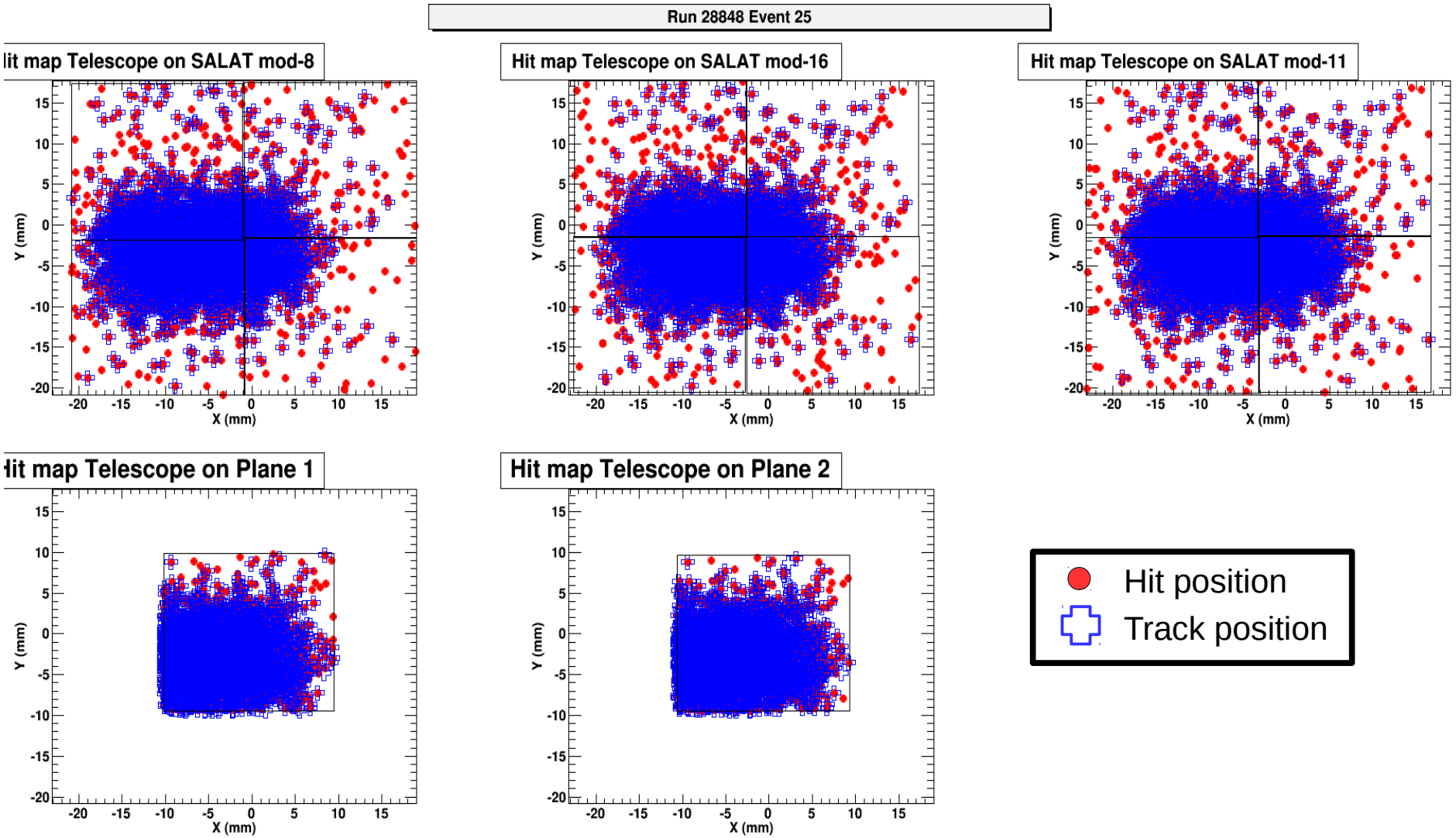
Telescope with SALAT modules: Multi-tracking

- $R_{trigger}$ ~ 5 kHz, Evt 15879, N_{rec} tracks = 33
- Tracking only with SALAT planes (Mod-8,16,11). Planes 1 and 2 are DUT



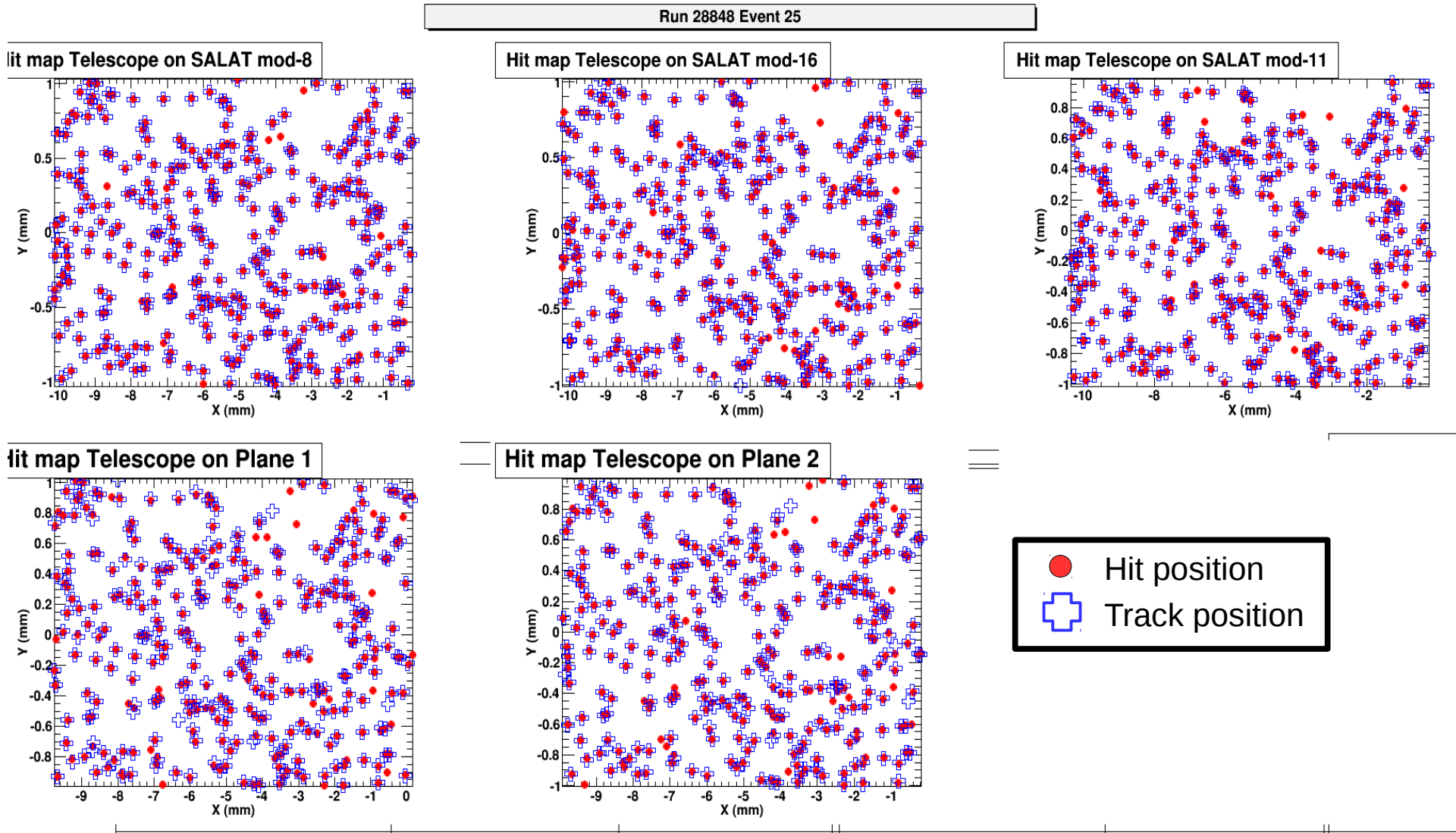
Telescope with SALAT modules: Multi-tracking

- $R_{trigger}$ ~ 50 kHz, Evt 25, N_{rec} tracks = 1372
- Tracking only with SALAT planes (Mod-8,16,11). Planes 1 and 2 are DUT



Telescope with SALAT modules: Multi-tracking

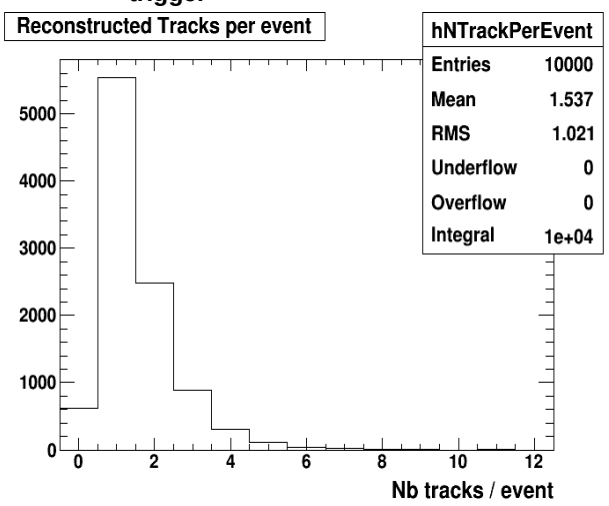
- $R_{trigger}$ ~ 50 kHz, Evt 25, N_{rec} tracks = 1372
- Tracking only with SALAT planes (Mod-8,16,11). Planes 1 and 2 are DUT

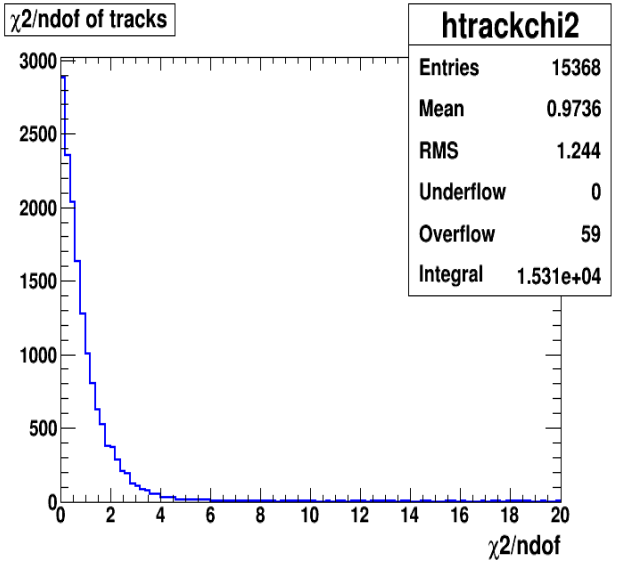


Telescope with SALAT modules: Multi-tracking

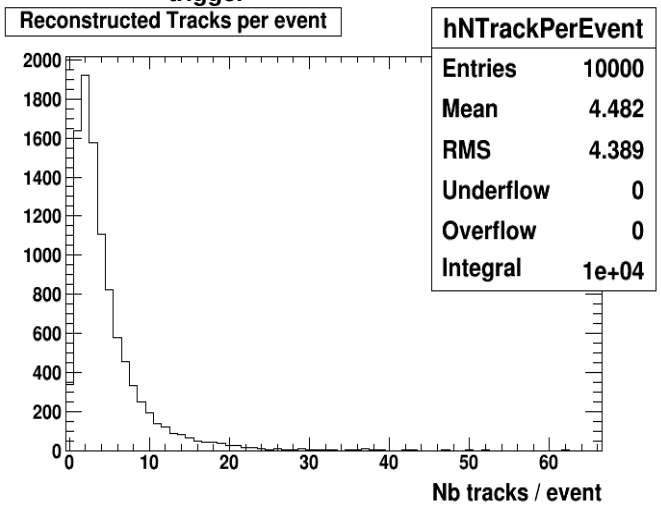
Mi-28 integration time = 200µs ⇒ readout rate of 5kHz

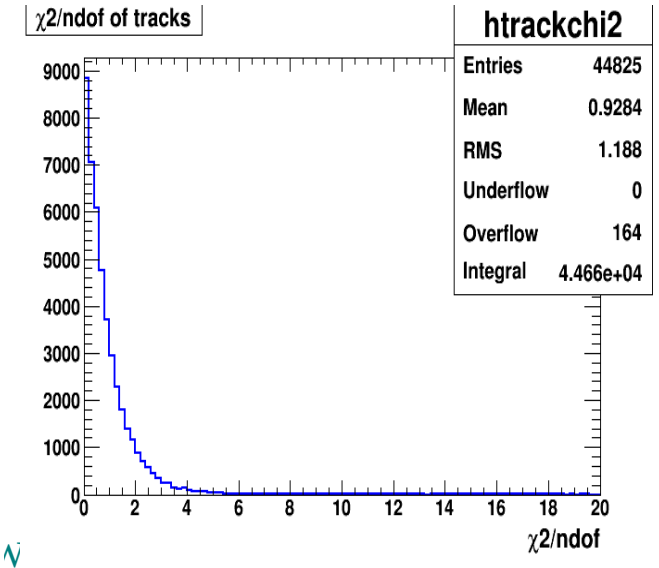
$R_{trigger}$ ~ 1 kHz (/ 1cm²)



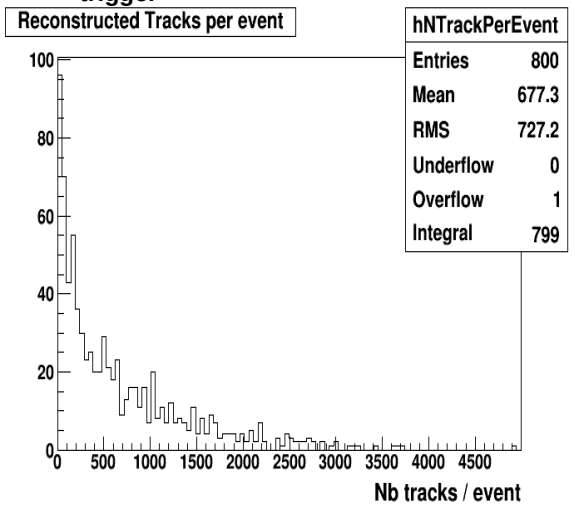


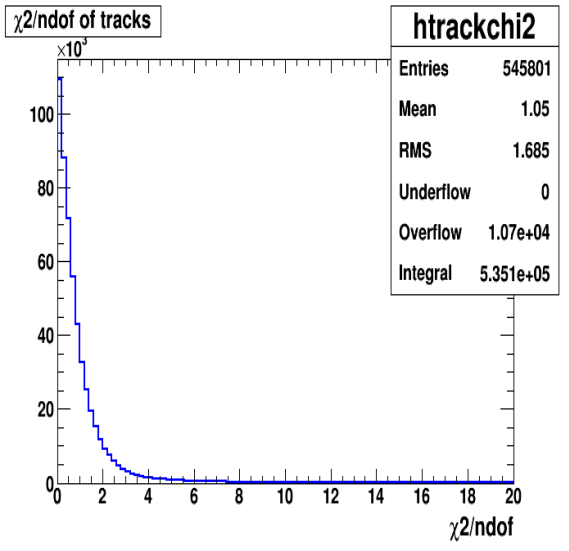
$R_{trigger}$ ~ 5 kHz (/ 1cm²)





$R_{trigger}$ ~ 50 kHz (/ 1cm²)



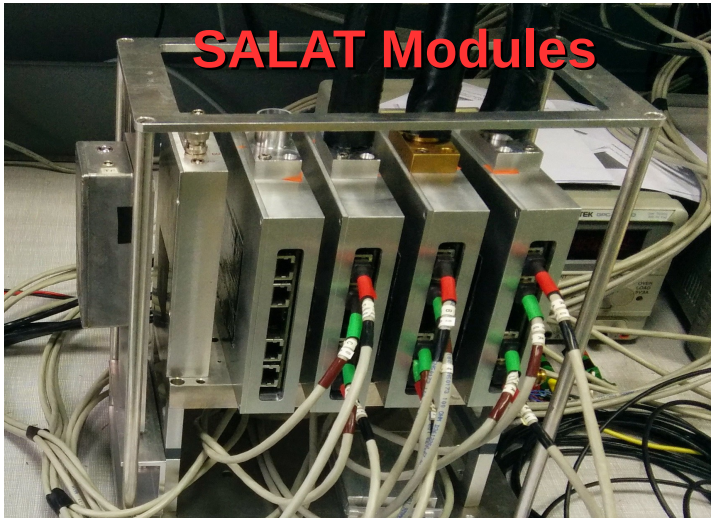


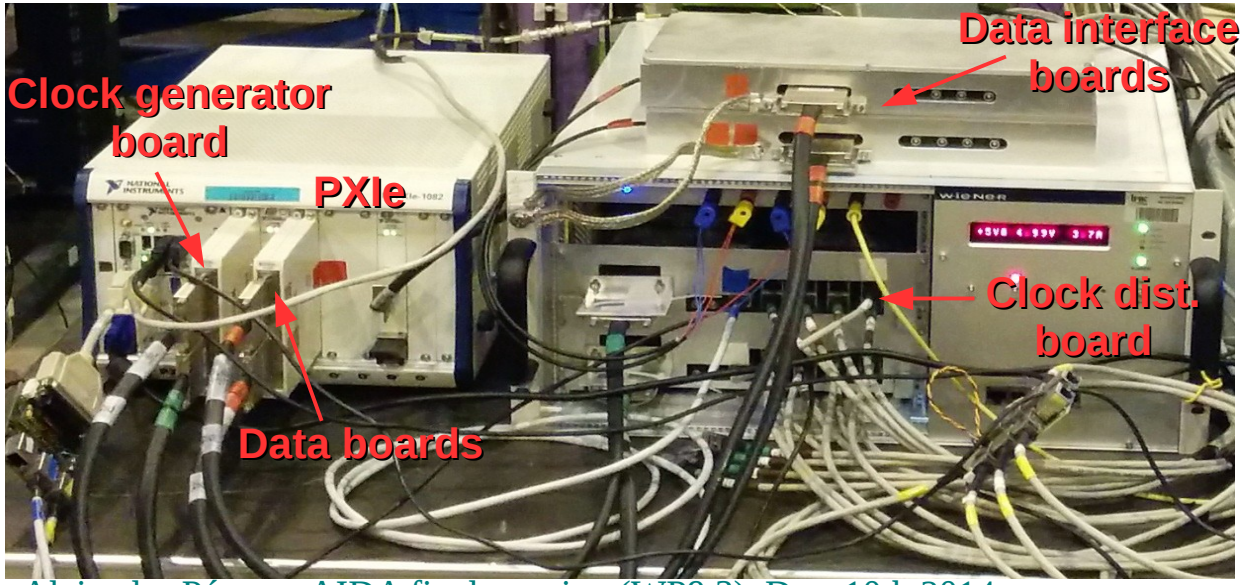
SALAT Delivery

SALAT Deliveries

- **Possible delivery by the end of Jan. 2015: Hardware + Doc**
  - 4 (3 + 1 spare) operational modules characterized in beam at CERN in Nov. 2014
    - Mechanic support + PCBS (daughter + mother)
    - Beam test data analysis in advance stage

      ⇒ final results for beginning 2015
  - 2 Clock distribution + JTAG + data interface boards
  - Documentation (board and SALAT characterizations)
  - Details to be defined w.r.t. IPHC priorities emerging in the coming weeks





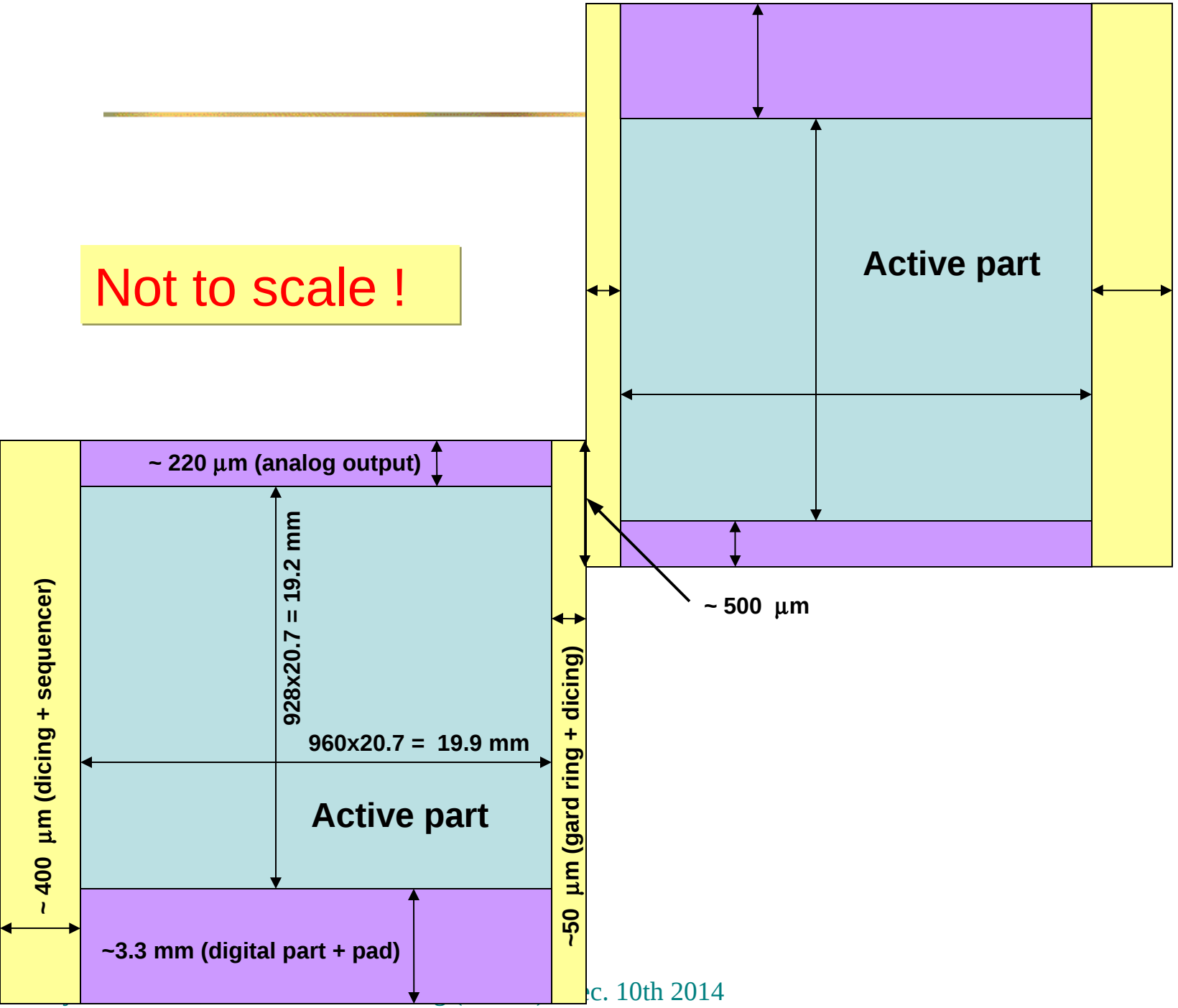
Summary

- **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 and CERN-SPS
    - Still need to finish CERN beam-test data analysis ⇒ Full characterization of SALAT telescope

- **Deliveries**
  - 4 (3 + 1 spare) fully operation SALAT modules
  - Clock distribution + JTAG + data interface boards

Back up Slides

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)

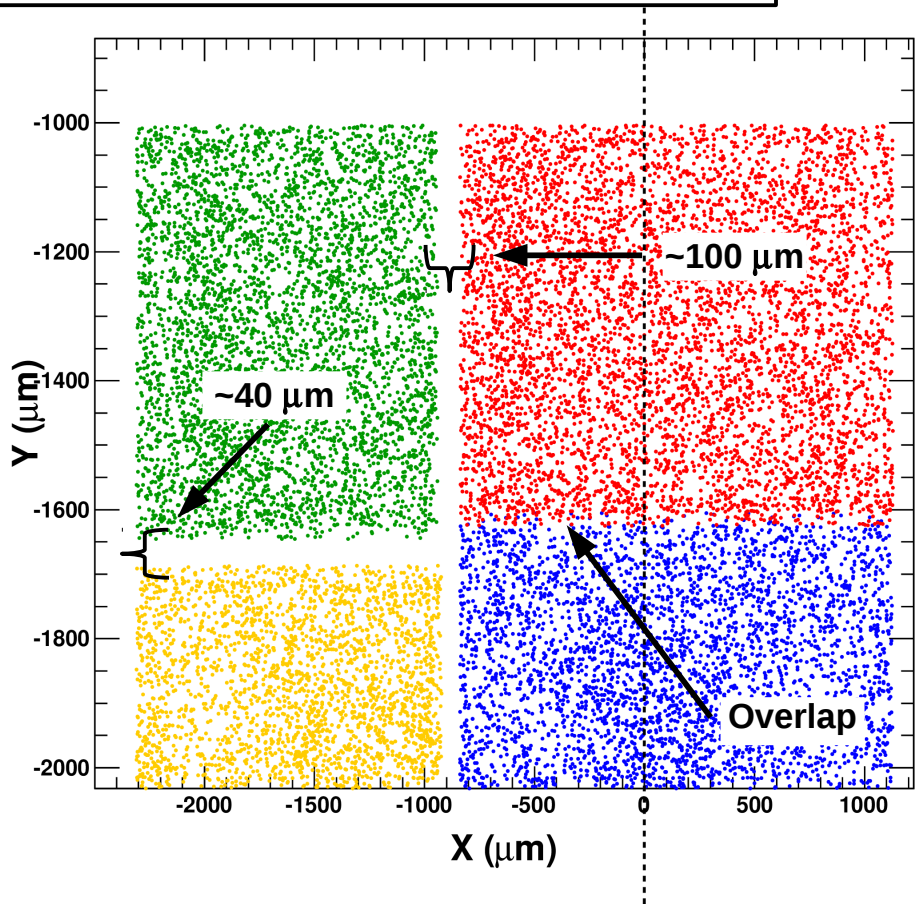
Relative Alignment of SALAT sensors: Insensitive Zones

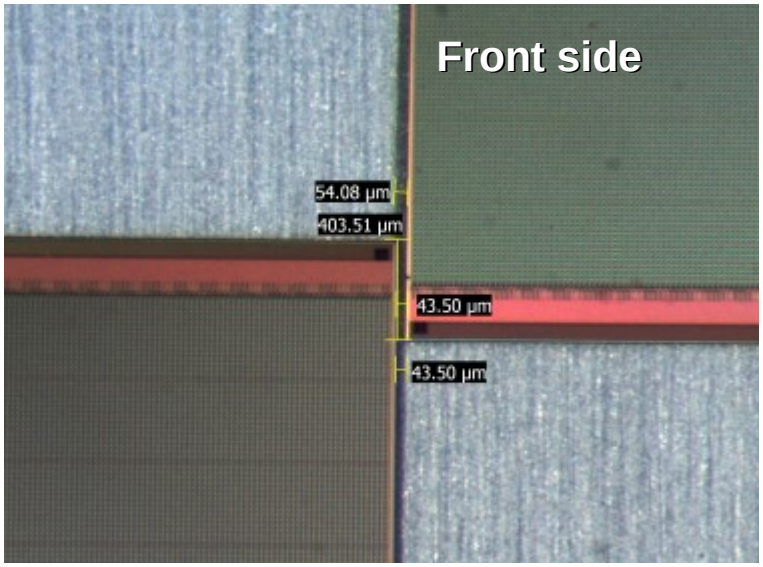
π^- beam

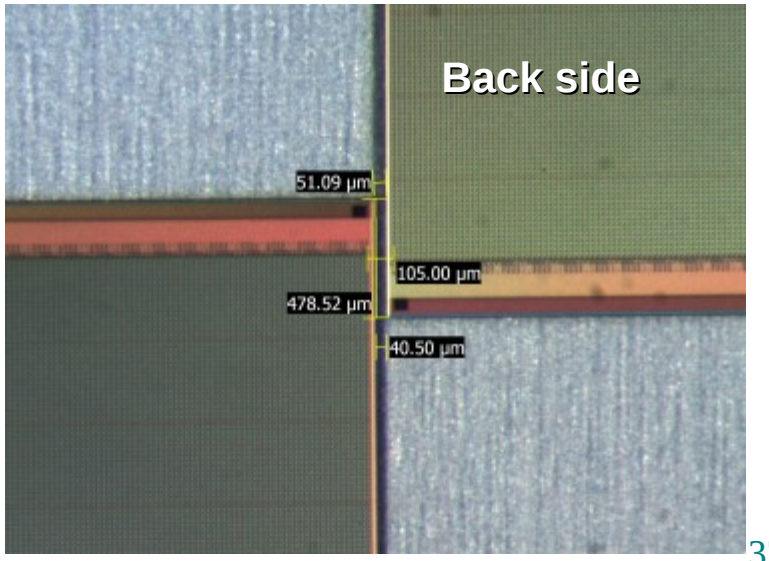
Module 11

Visual inspection

Hit associated to Track Map







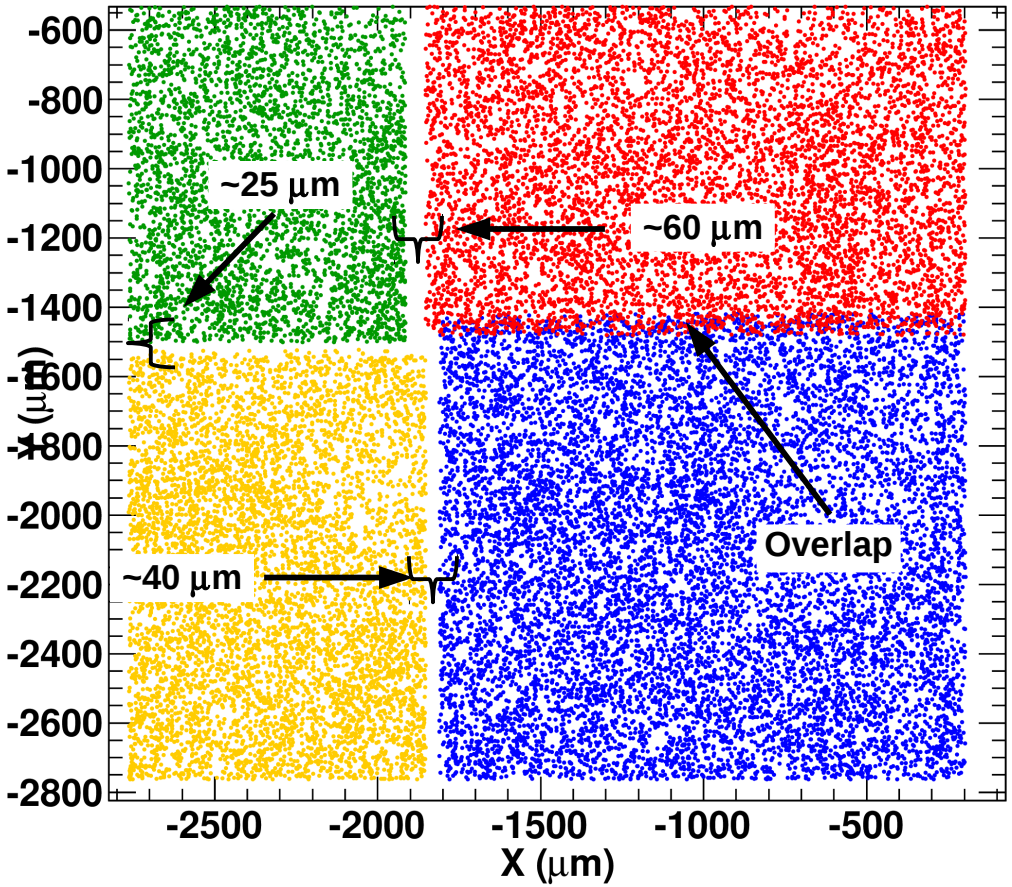
Relative Alignment of SALAT sensors: Insensitive Zones

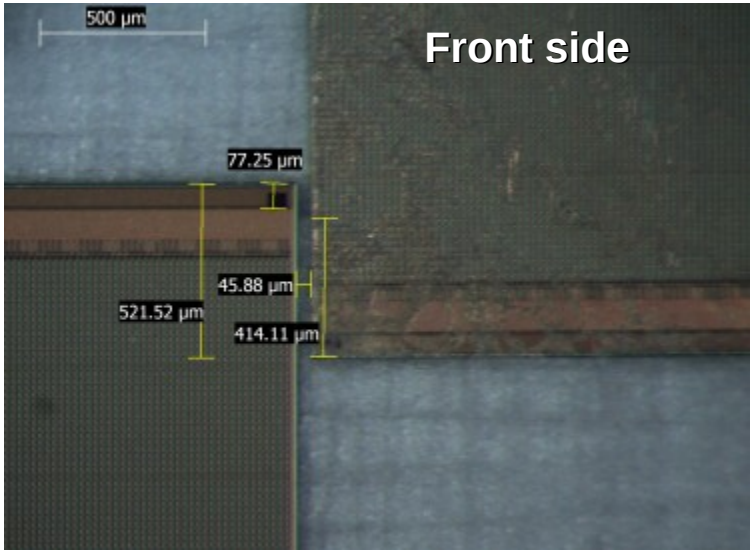
π^- beam

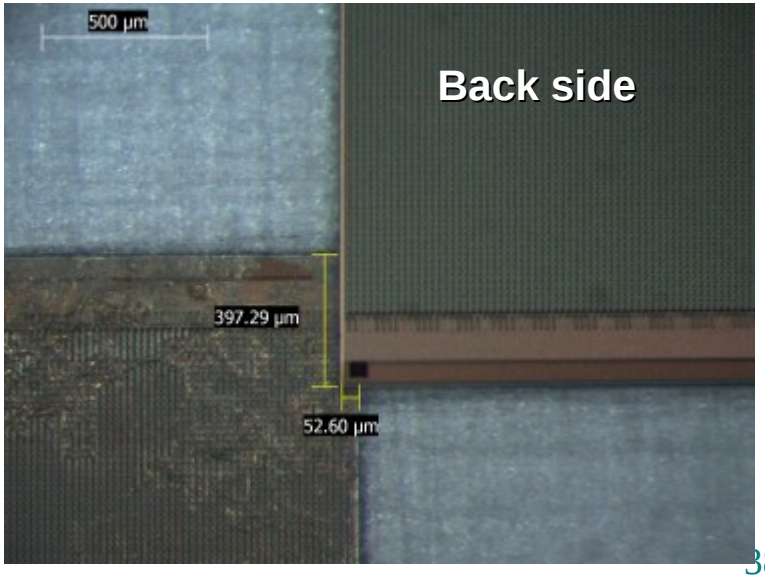
Module 15

Visual inspection

Hit associated to Track Map







SALAT Deliveries

- **Possible delivery by the end of Jan. 2015: Hardware + Doc.**
  - 4 operational modules characterized in beam at CERN in Nov. 2014
    - Mechanic support + PCBS (daughter + mother)
    - Beam test data analysis in advance stage ⇒ final results for beginning 2015
  - SALAT planes power supply board
  - 1 JTAG auxiliary board + 1 JTAG distribution board + 2 Clock distribution boards
  - 2 Data boards ⇒ RJ45 to VHDCI converter (1 board = 8 x Mi28 max)
  - Documentation (board and SALAT plane characterizations)
  - Details to be defined w.r.t. IPHC priorities emerging in the coming weeks

SALAT Deliveries

- **Possible delivery by the end of Apr. 2015: Hardware + DAQ**
  - To be confirmed at the beginning 2015 (**depending on IPHC priorities**)
    - Hardware (as in previous point)
    - Code source software ⇒ to be interfaced to with EUDET framework
    - Code source firmware
  - Procedure ⇒ Expected delivery by April 2015
    - **DESY provides PXIe crates (CPU + 2 FlexRio + NI6562 boards + Raid interface board) and send it to IPHC ASAP**
    - Setup of all system at IPHC in April 2015 with Hendrik Jansen