Zero Suppressed Digital Chip sensor for EUDET-JRA1 beam telescope

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*on behalf of **IRFU – Saclay** and **IPHC - Strasbourg***

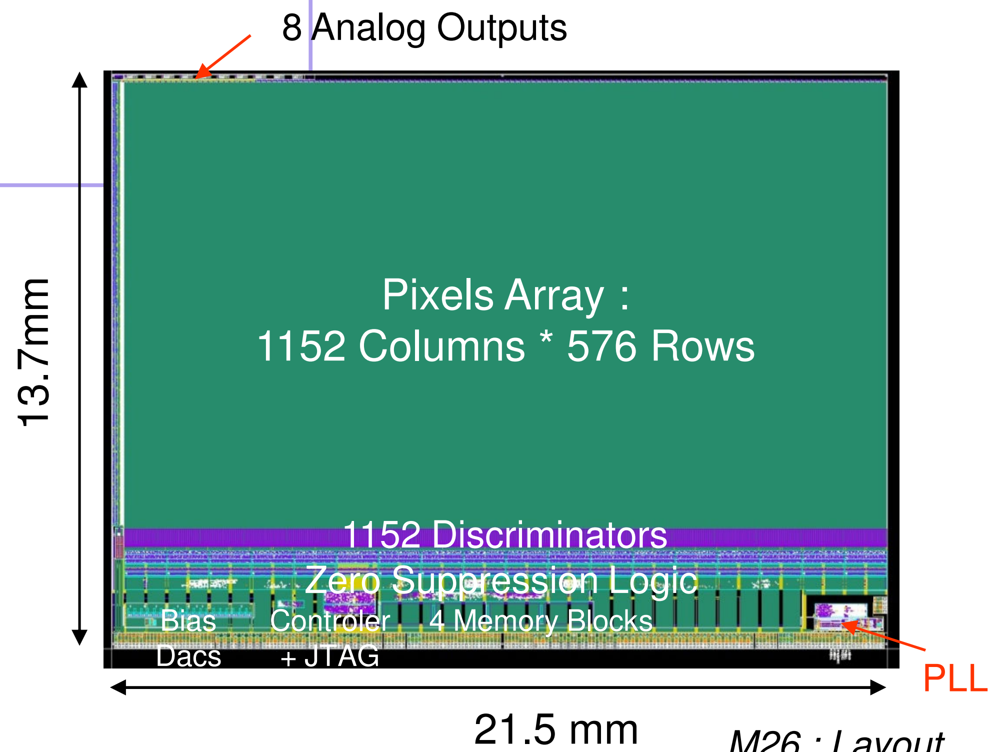
OUTLINE

- Zero Suppressed Digital Chip (MIMOSA26) description
- MIMOSA26 characterization in-lab : summary
- MIMOSA26 characterization in beam (preliminary)
- Summary

MIMOSA 26 : description

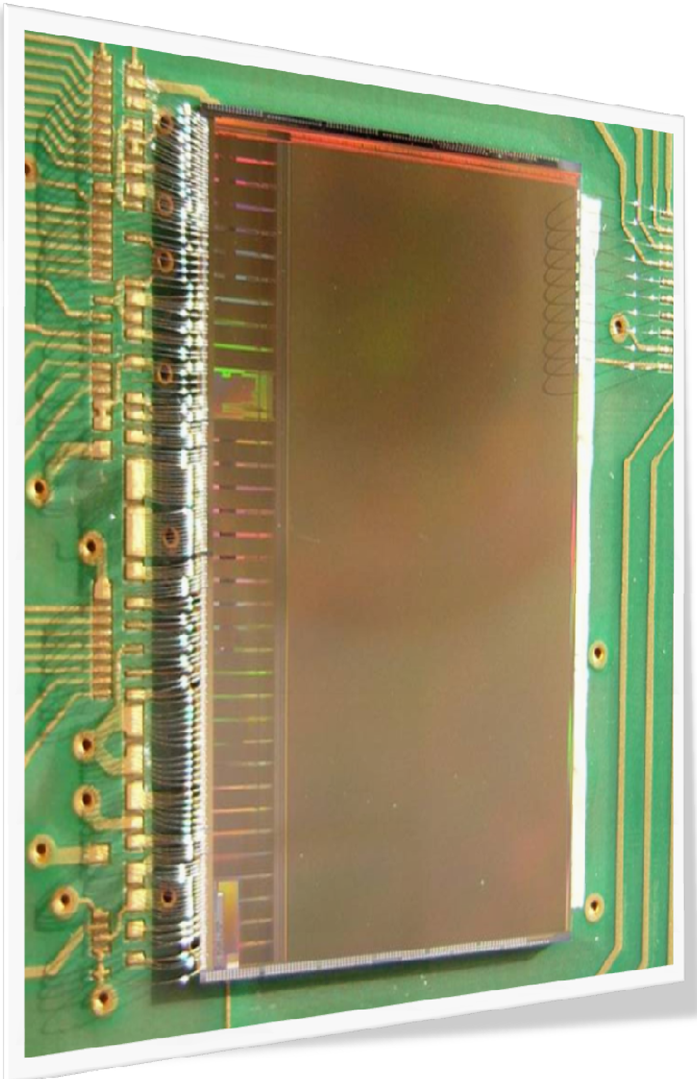
Main parameters & Functionalities :

- **AMS-OPTO 0.35*µm***
- **Pixel Size : 18.4 x 18.4 µm²**
- **Active Area : 1152 x 576 pixels (21.2 x 10.6 mm²)**
- **8 Analog test Outputs**
- **1152 end-column discriminators (663552 pixels)**
- **Slow Control Interface : JTAG**
- **Internal Bias (DACs)**
- **Zero suppression mode (SUZE-01)**



M26 : Layout

Goals of the laboratory tests
(done on IPHC test bench)



Analog test outputs :

- Temporal Noise (TN)
- Fixed Pattern Noise (FPN)
- Charge to Voltage Conversion Factor (CVF)
- Charge Collection Efficiency (CCE) for 3x3 and 5x5 Clusters

Digital test outputs :

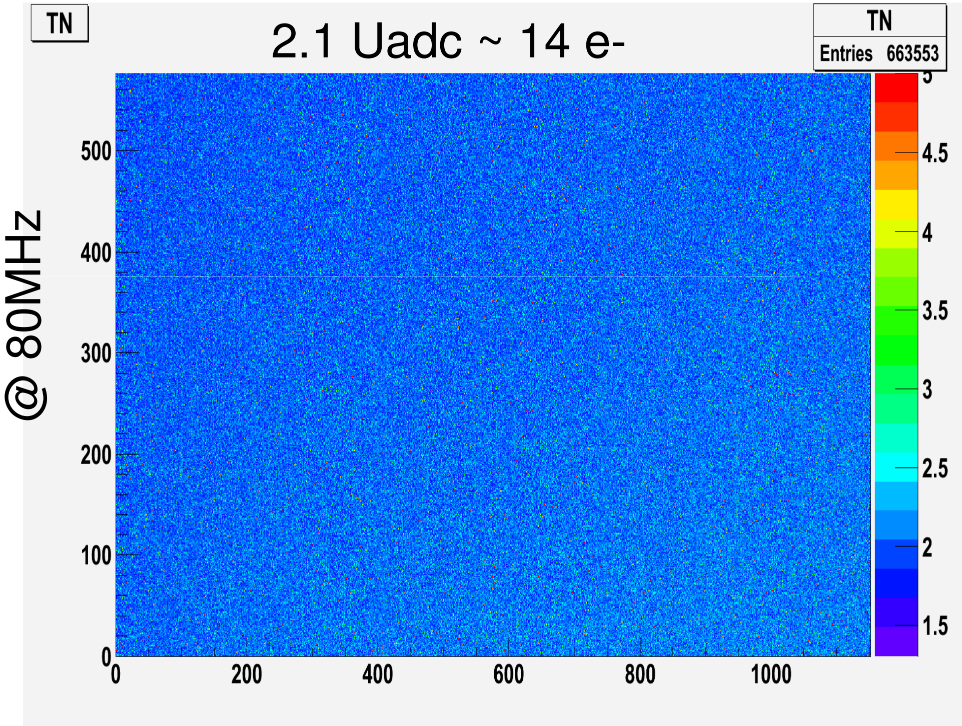
- Characterization of internal DACs
- TN and FPN for discriminators only
- TN and FPN for discriminators + pixels

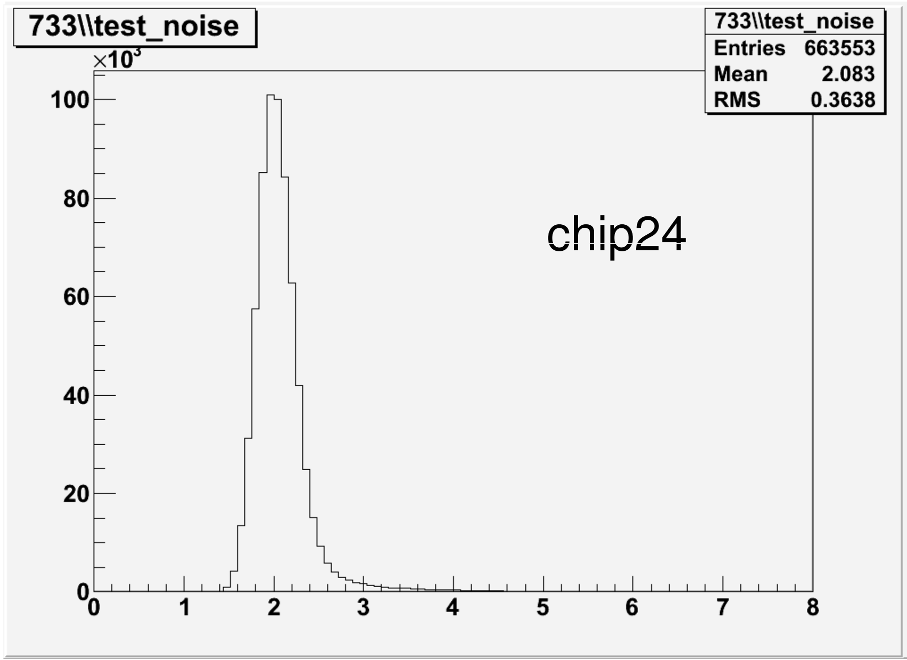
Working conditions :

$F_{CLK-(chip)}$=80MHz (→20 MHz) ⇒ T_{integ}=112.5 µs ; I_{pix_sf} = 50µA ; T_{chip}≈20°C

Results on analog test outputs

@ 80MHz





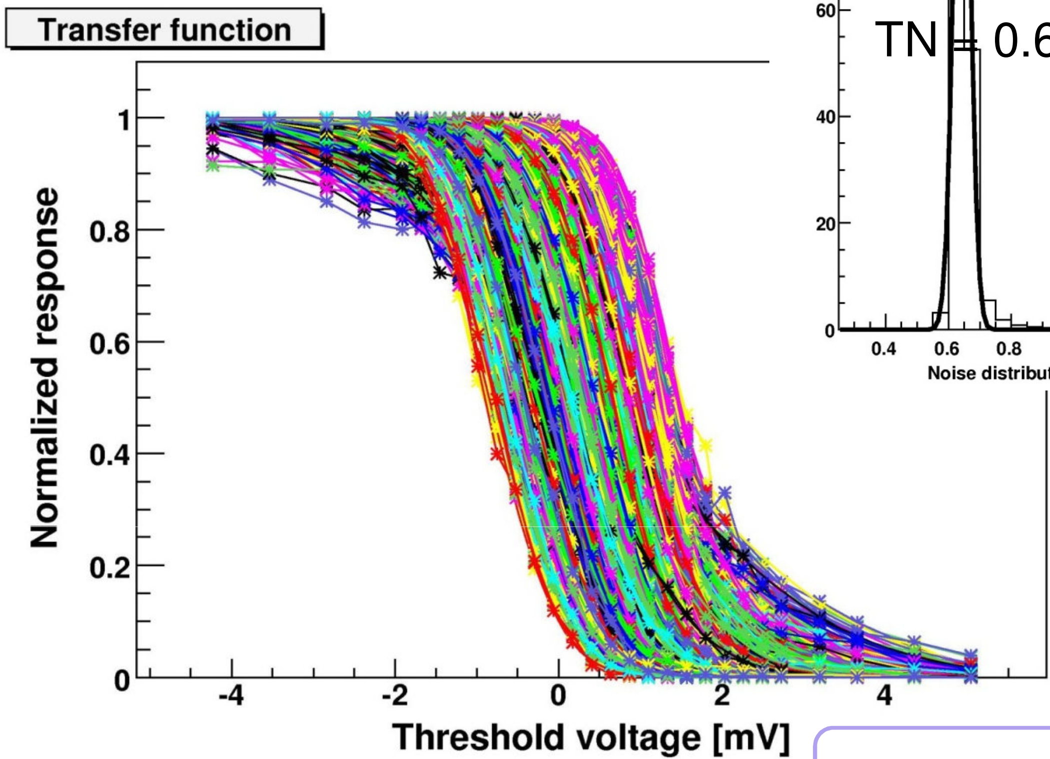
@ 20MHz

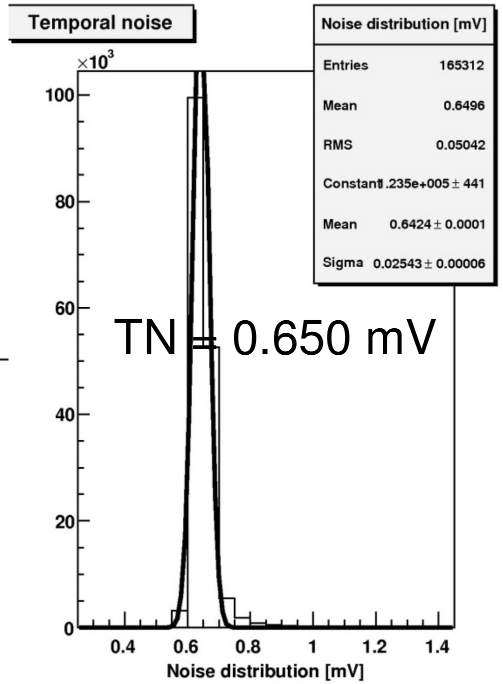
Cluster size	Seed (1x1)	2x2	3x3	5x5
MIMOSA 26	22 %	55 %	73 %	83 %
MIMOSA 22	22 %	58 %	75 %	86 %

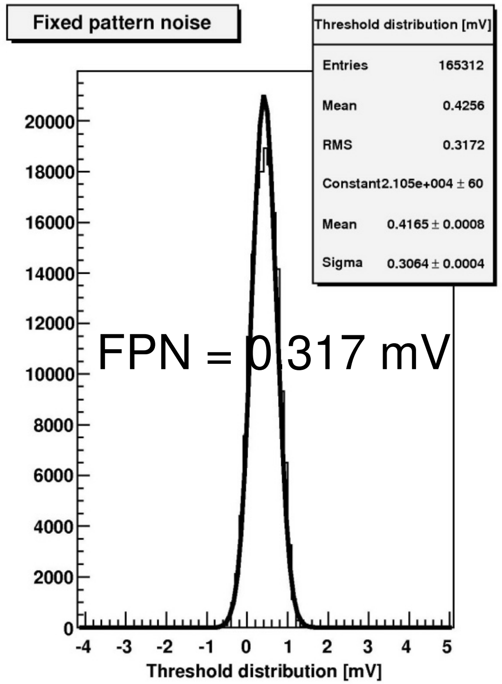
TN ≤14 e⁻ @80MHz, it decreases to≤12e⁻@ 20MHz

Results on digital test outputs

Group of 288 discriminators connected to pixels (165312 pixels)





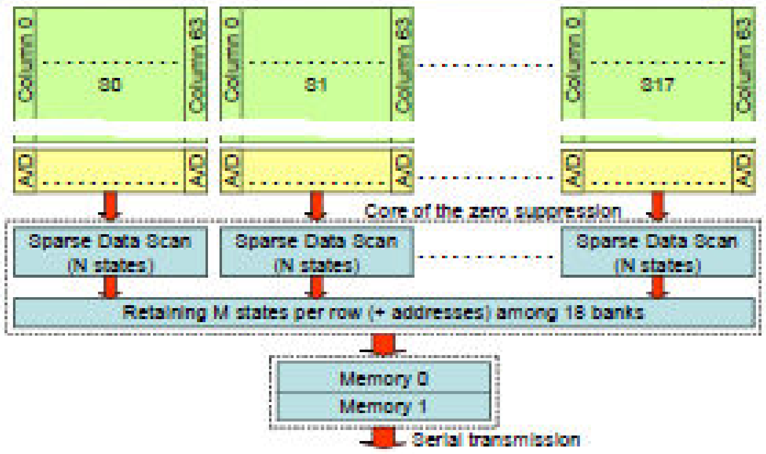


Chip6 –sub-array A

Noise values for the different groups and chips :

- TN ~ 0.6-0.7 mV
- FPN ~ 0.2-0.3 mV

Zero suppression logic test



Zero suppression is based on row by row sparse data scan readout

Zero suppression logic has been extensively investigated

(disconnected from the rest of the chip)

Various patterns were emulated with a pattern generator,

running through the logic millions of time without any errors up to 115 MHz

(1.44 times nominal frequency)

Summary of lab-characterized Chips

Characterization of 2 different types of sensors :

- 1 wafer of « standard » sensors (23 characterized) → 7 for Ingrid + 1 for Angelo
- 1 wafer of 120µm thinned sensors (6 characterized)

34 chips tested

1 chip from each wafer doesn't work (2chips) → 32 chips working

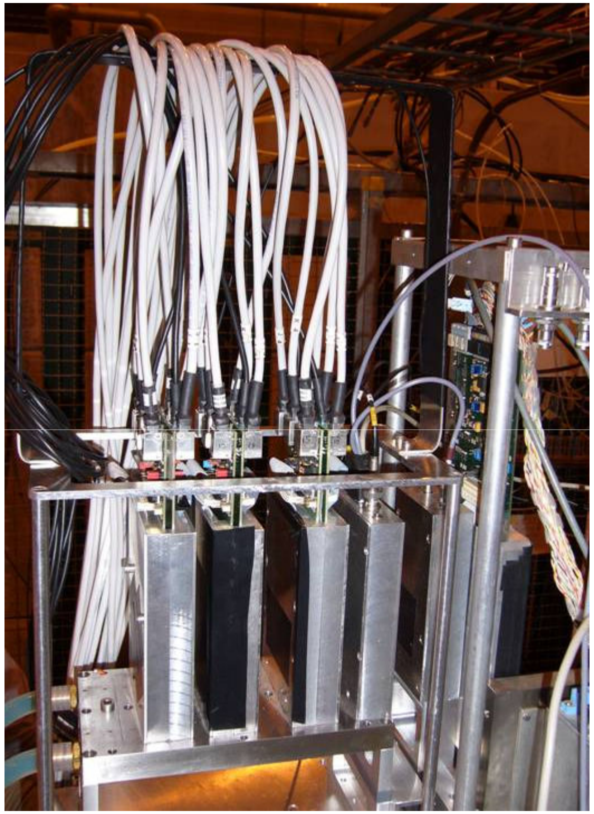
29 chips completely characterized

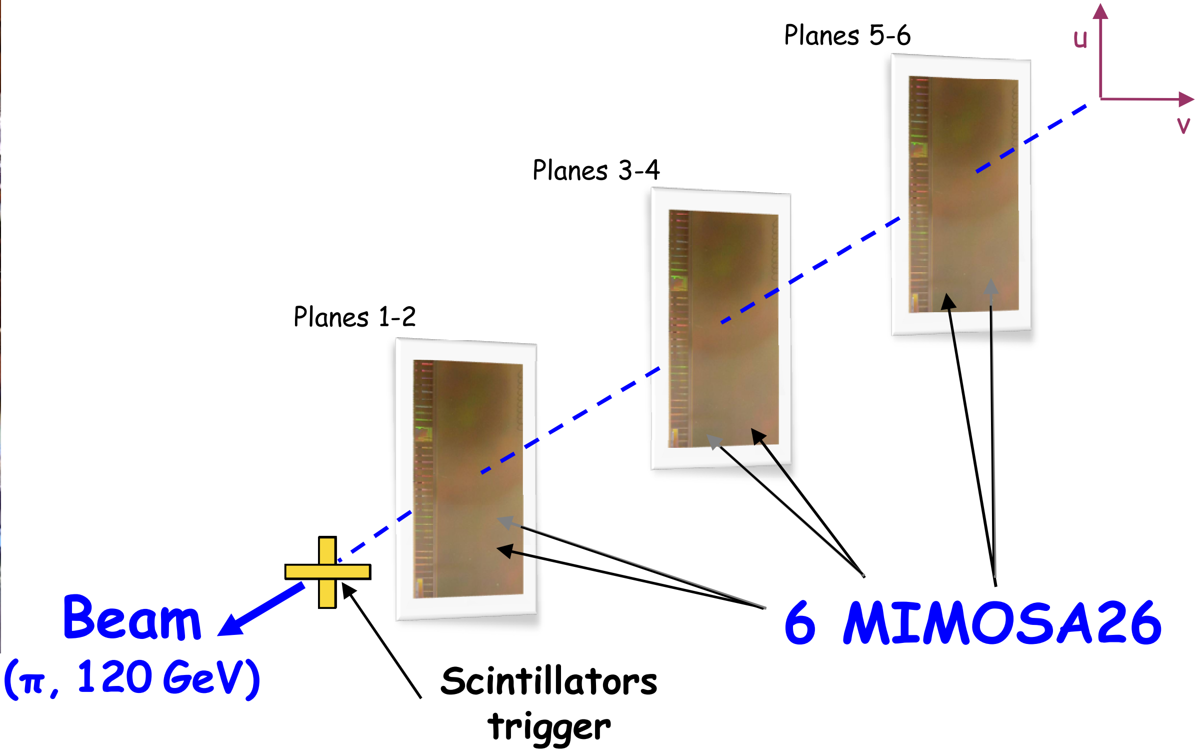
1 chip with 1 dead row and 1 dead column
4 chips with 1 row or 1 column dead
→ 24 chips fully working (77%) / 28 chips working correctly (>90%)

Setup for the beam tests

A lot of measurements:

- 8 chips used : 2 standard, 6 120µm thinned
- 4 studied as DUT : 2 standard, 2 120µm thinned
- 54 runs taken, 25.10^6 events, 0.5To data



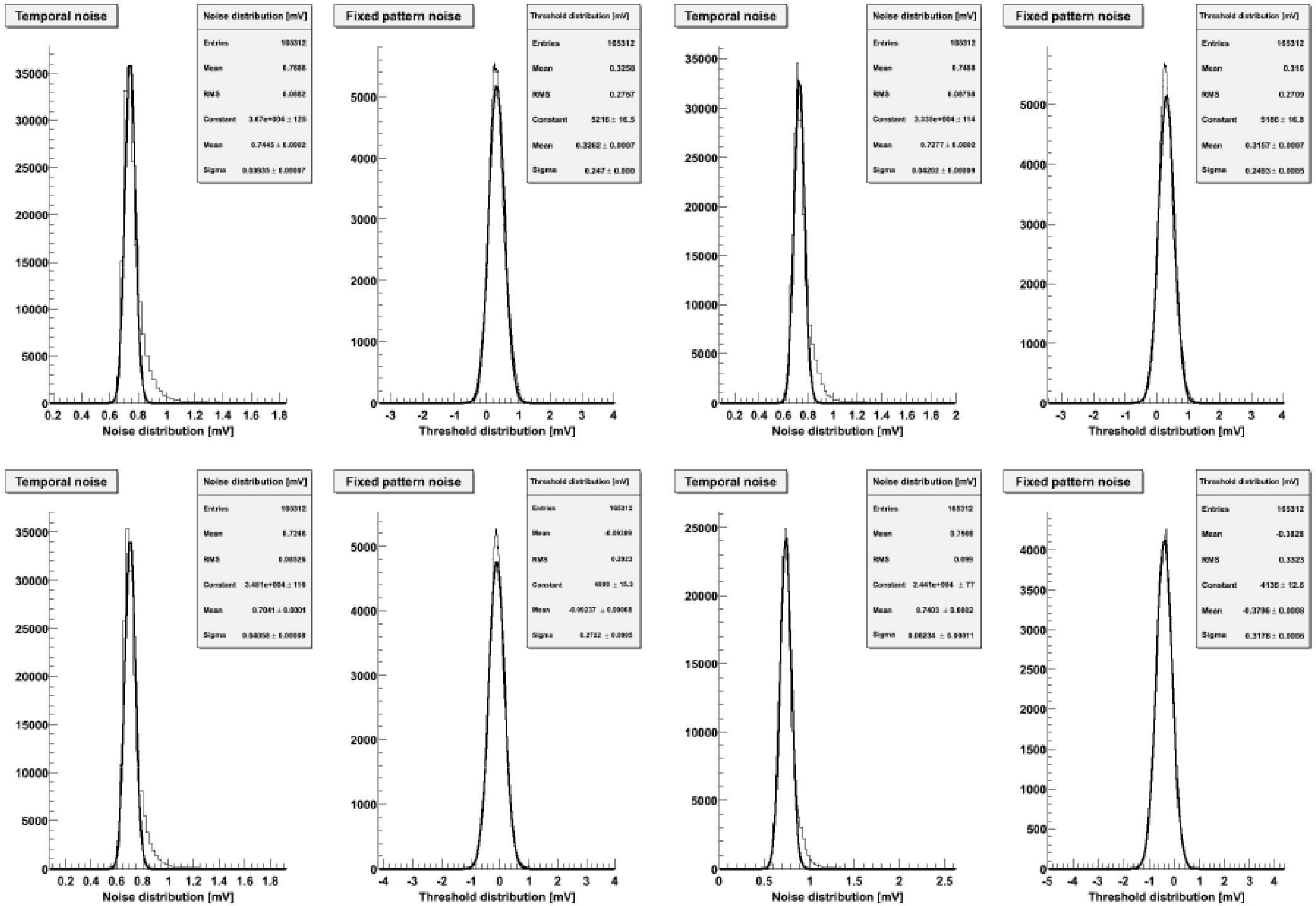


The different measurements

The different validation steps of the test beam:

1. ***validation of our setup***
   → 4 Runs with threshold from 14N to 6N
2. ***characterization of a 120µm thinned chip (chip24)***
   → 7 Runs with threshold from 12N to 4N
3. ***characterization of a unthinned chip (chip1)***
   → 9 Runs with 10N to 4.5N thresholds, 2 Vref2
4. ***DUT rotation***
   → 8 Runs at 0°, 45°, 58° (5N-8N threshold)
5. ***Homogeneity of all the arrray check***
   → 7 Runs by moving the beam or connected only 128 discri.
6. ***Characterization of 2 other chips as DUT***
   One 120µm thinned chip (13) and one unthinned chip (4)
   → 4 Runs (3N-10N threshold)
7. ***Telescope check with different beam intensity***
   → 3 Runs (5,5k→1.3k)
8. ***Characterisation of chip1 & chip24 @ 20MHz***
   → 3 Runs (5N→8N)

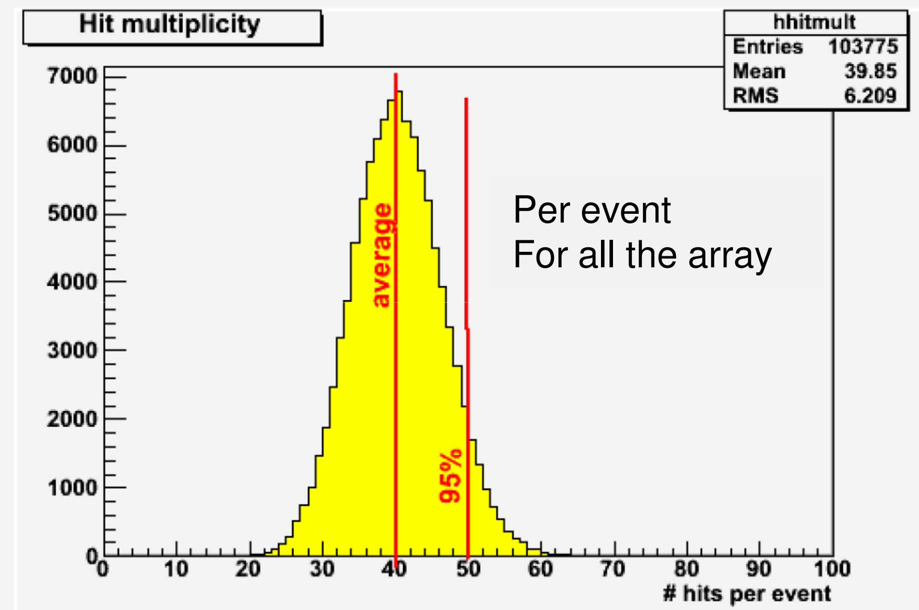
Noise Study

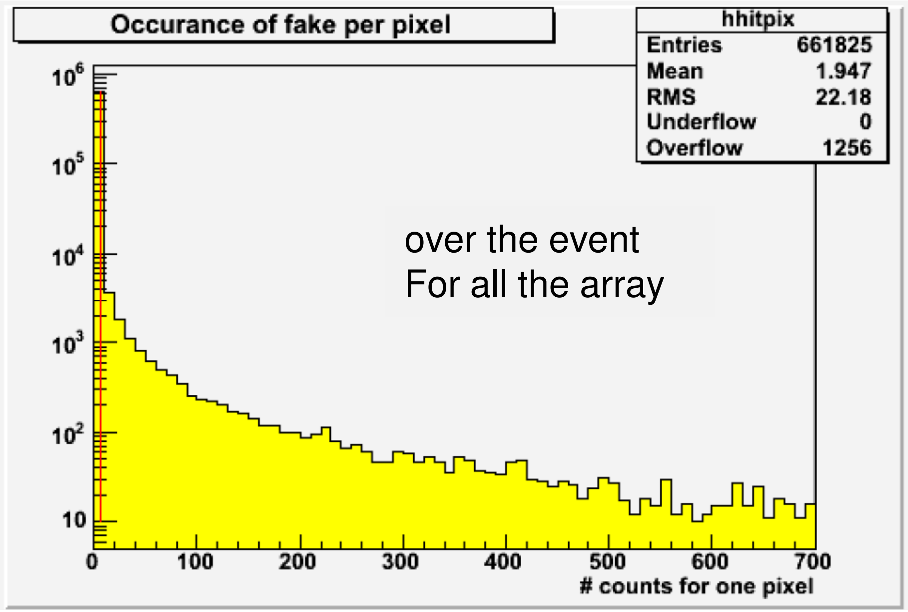


Noise:

- scan of discriminator thresholds performed
→ Same results as in lab

Fake hit rate study





- 40 pixels touched /event at a 6N threshold → $0.6 \cdot 10^{-4}$ rate
- Noise fluctuation :a few pixels are singing

Fake hit rate (10^{-4}/pixel/event):

Discri. threshold	5 N	6 N	7N	8 N	10 N	12 N
Chip24 (120µm thinned)	1.6	0.6	0.24	0.095	0.026	0.017
Chip1 (standard)	3.3	1.2	-	0.23	0.054	-

∅ output performances with MIPs

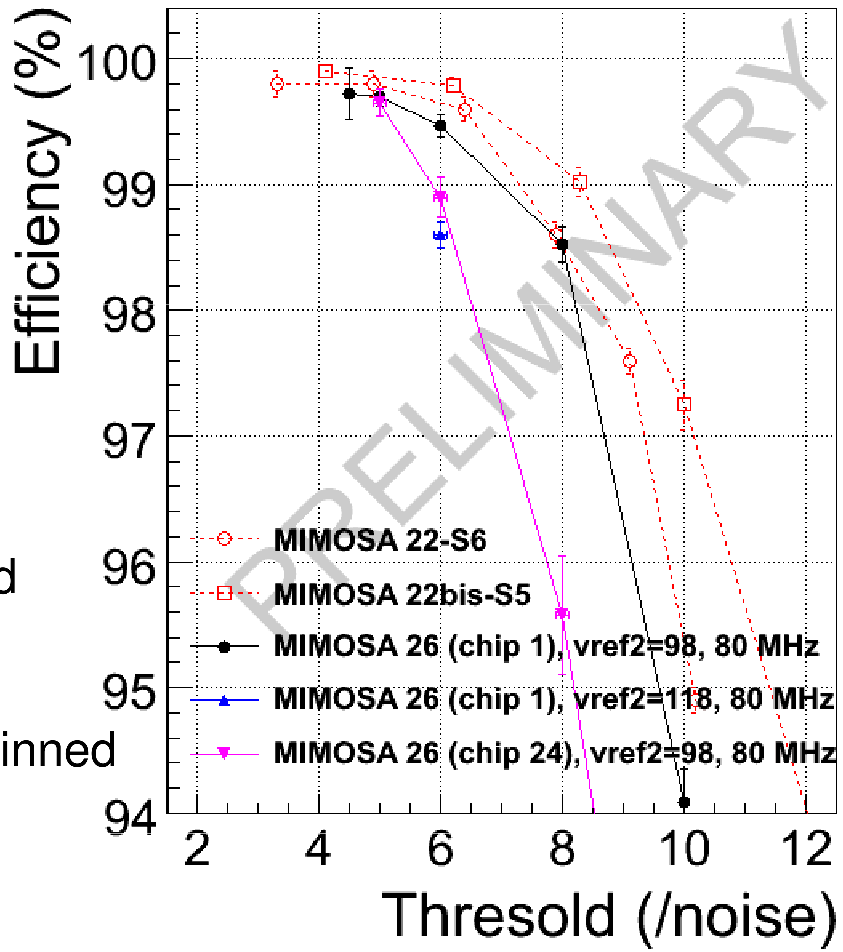
Irfu cea saclay

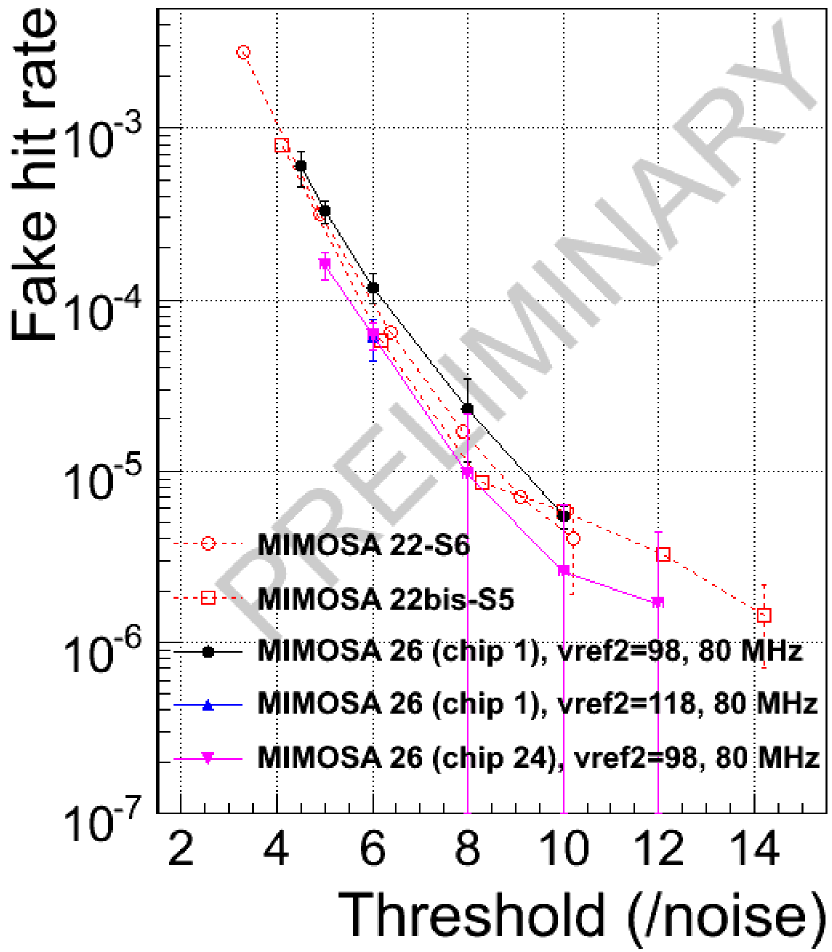
IPHC Institut Pluridisciplinaire Hubert Curien Strasbourg

EUDET

Chip1 :
Unthinned

Chip24 :
120µm thinned





- det. eff. ~ 99.5 +/-0.1 % for a fake hit rate ~1.10^{-4}
- satisfactory performances for Mi26

(even if they are a little bit bellow one observed for Mi22/Mi22bis)

- resolution ~4.5µm (Mi22 ~4µm) → still in progress to be understood

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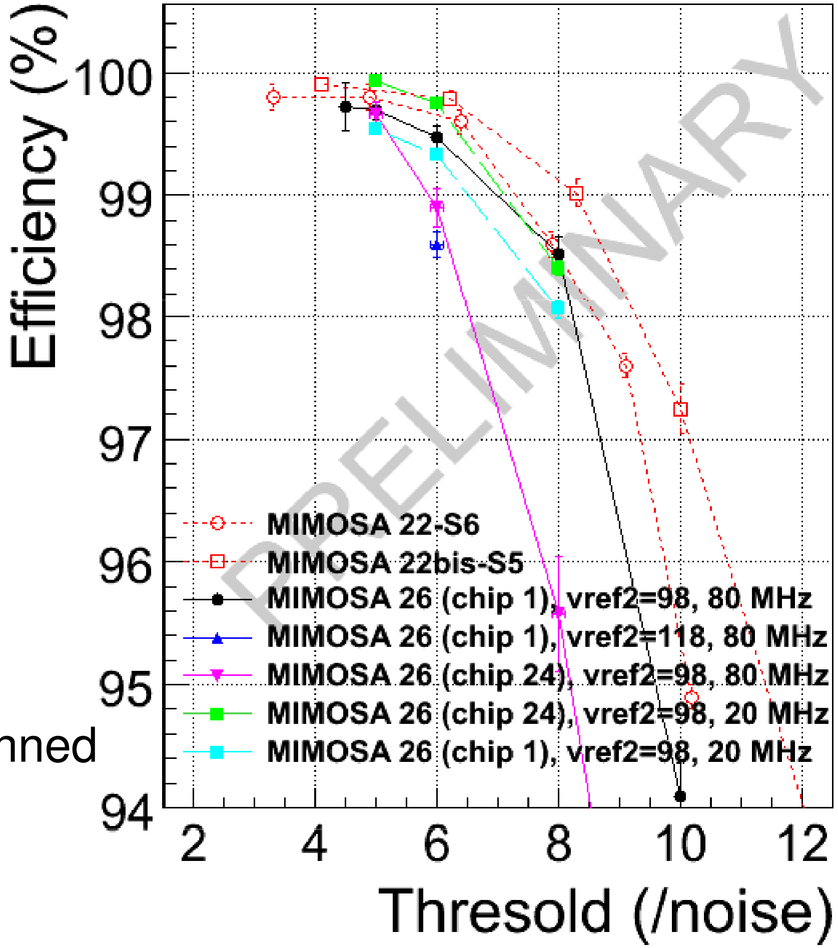
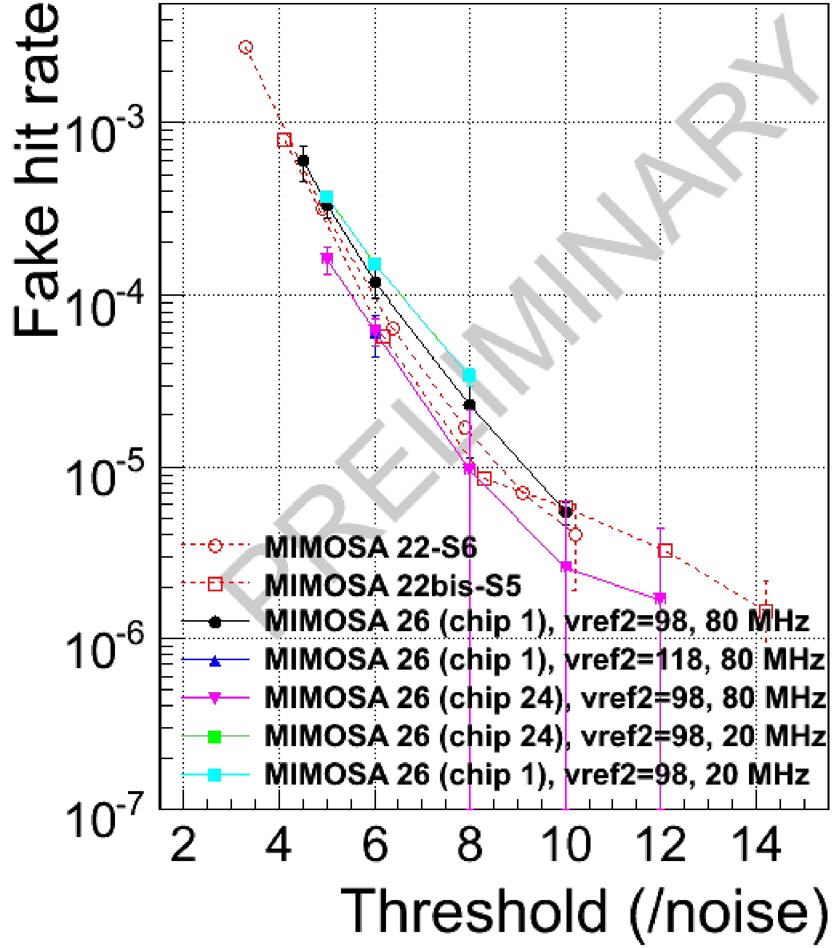
Unthinned

Chip24 :
120µm thinned





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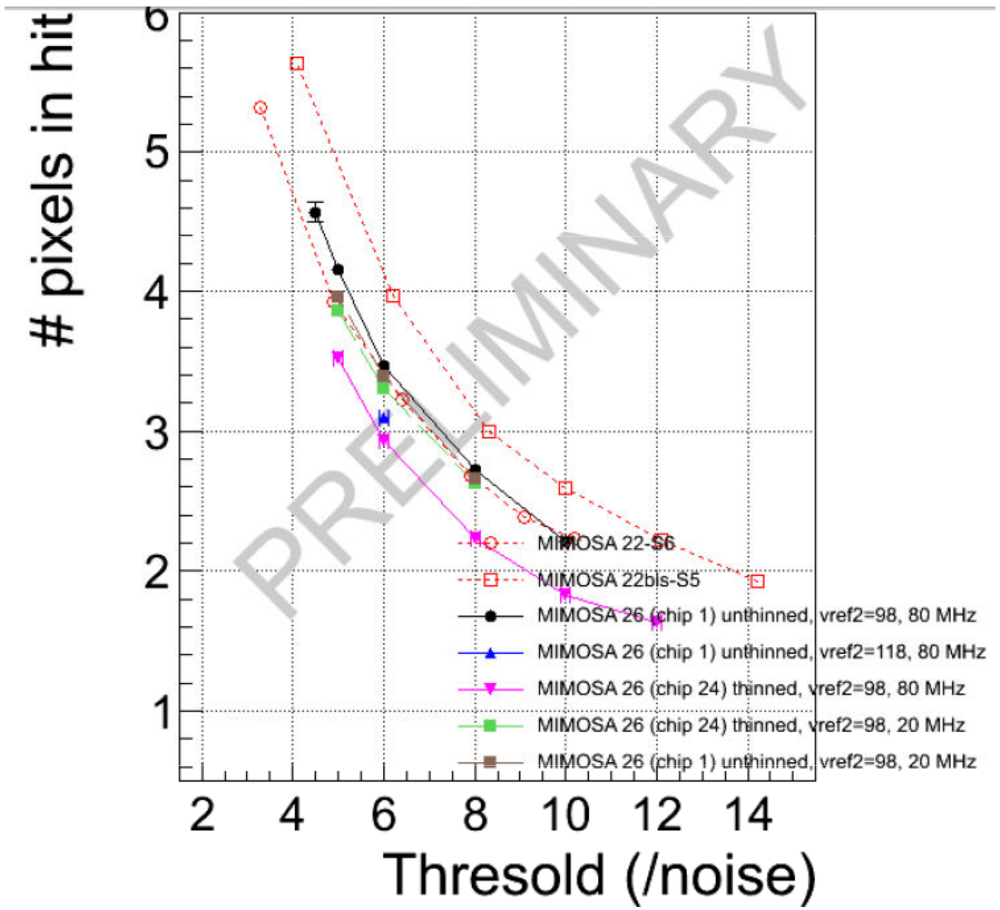
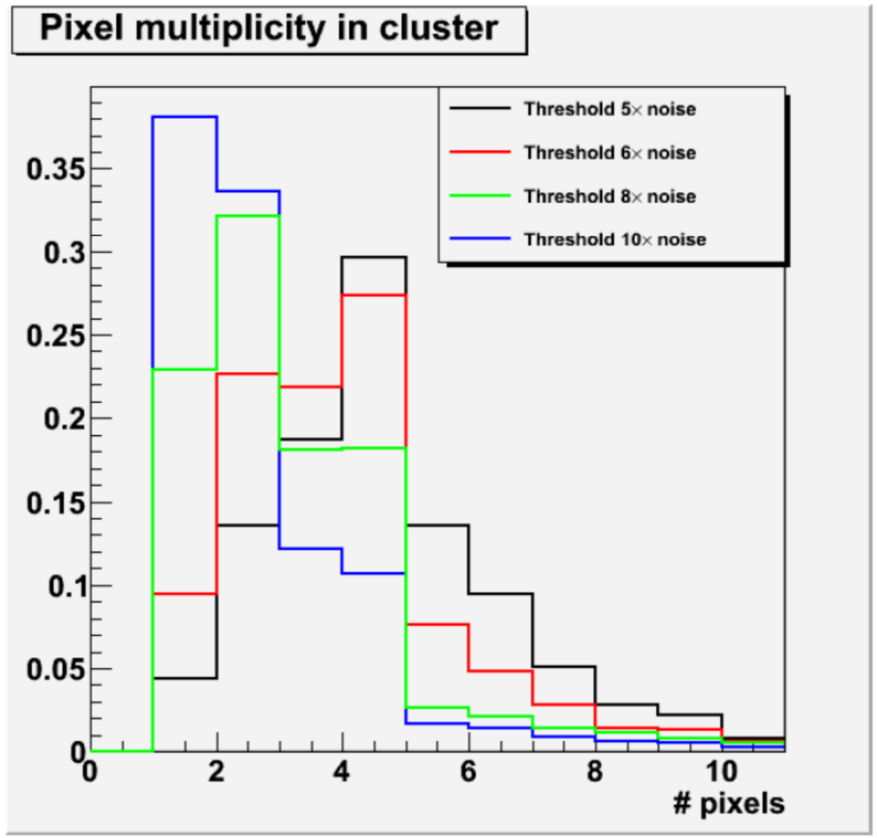
Cluster characteristics

Pixel multiplicity vs threshold





- similar tendency between the different MIMOSA22/22bis and MIMOSA26 chips
- for 6N cut -> 3.5 pixels hit in average, for 10%of the events just one pixel touched

Summary

Lab tests :

- MIMOSA26 is working properly compared to what is expected with MIMOSA22
- TN ~ 0.6-0.7 mV – FPN ~ 0.2-0.3 mV

Beam tests :

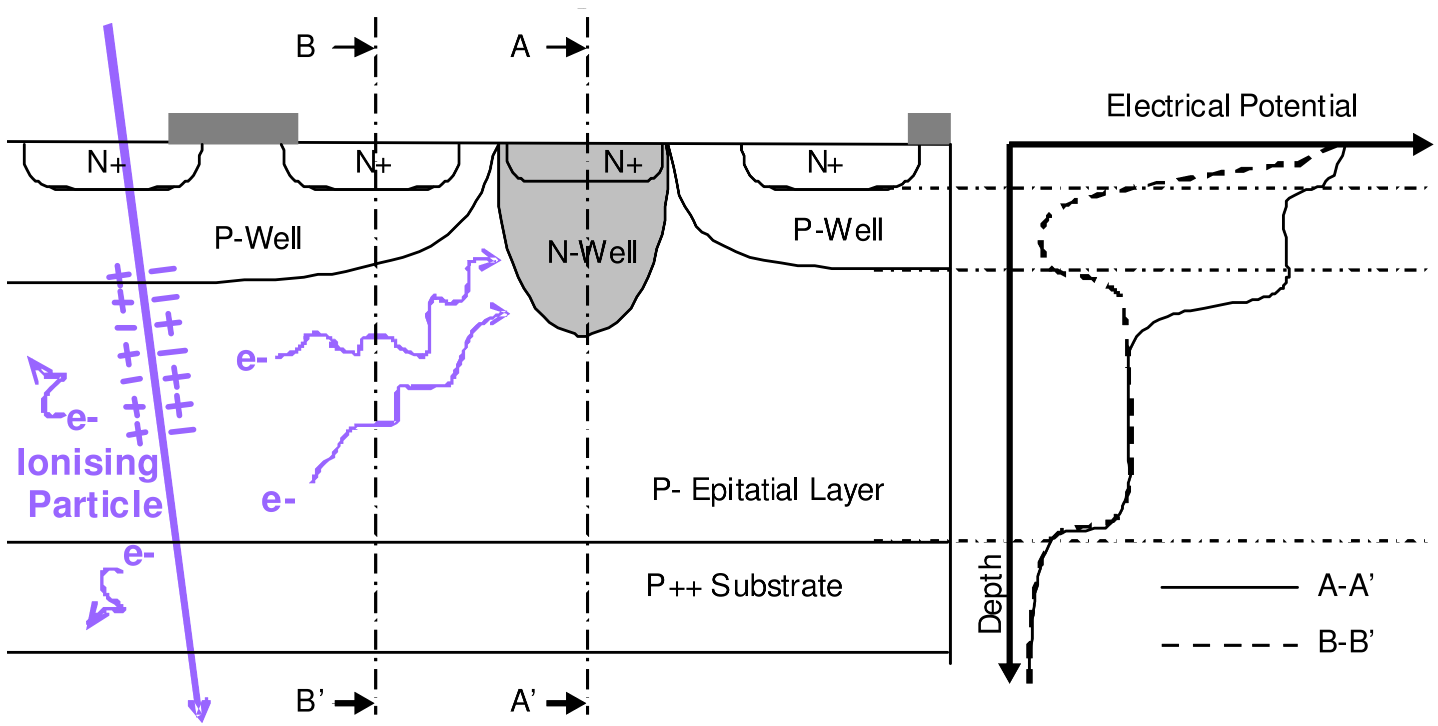
- analysis still in progress:
  - improve the cluster position reconstruction
  - Study efficiency per sub-array
  - study “angle” run
- det. eff. ~ 99.5 +/-0.1 % for a fake hit rate ~1.10^{-4}
- resolution ~4.5µm (Mi22 ~4µm)

⇒ **Mi26 performances are efficient for EuDet telescope**

Thank you for your attention

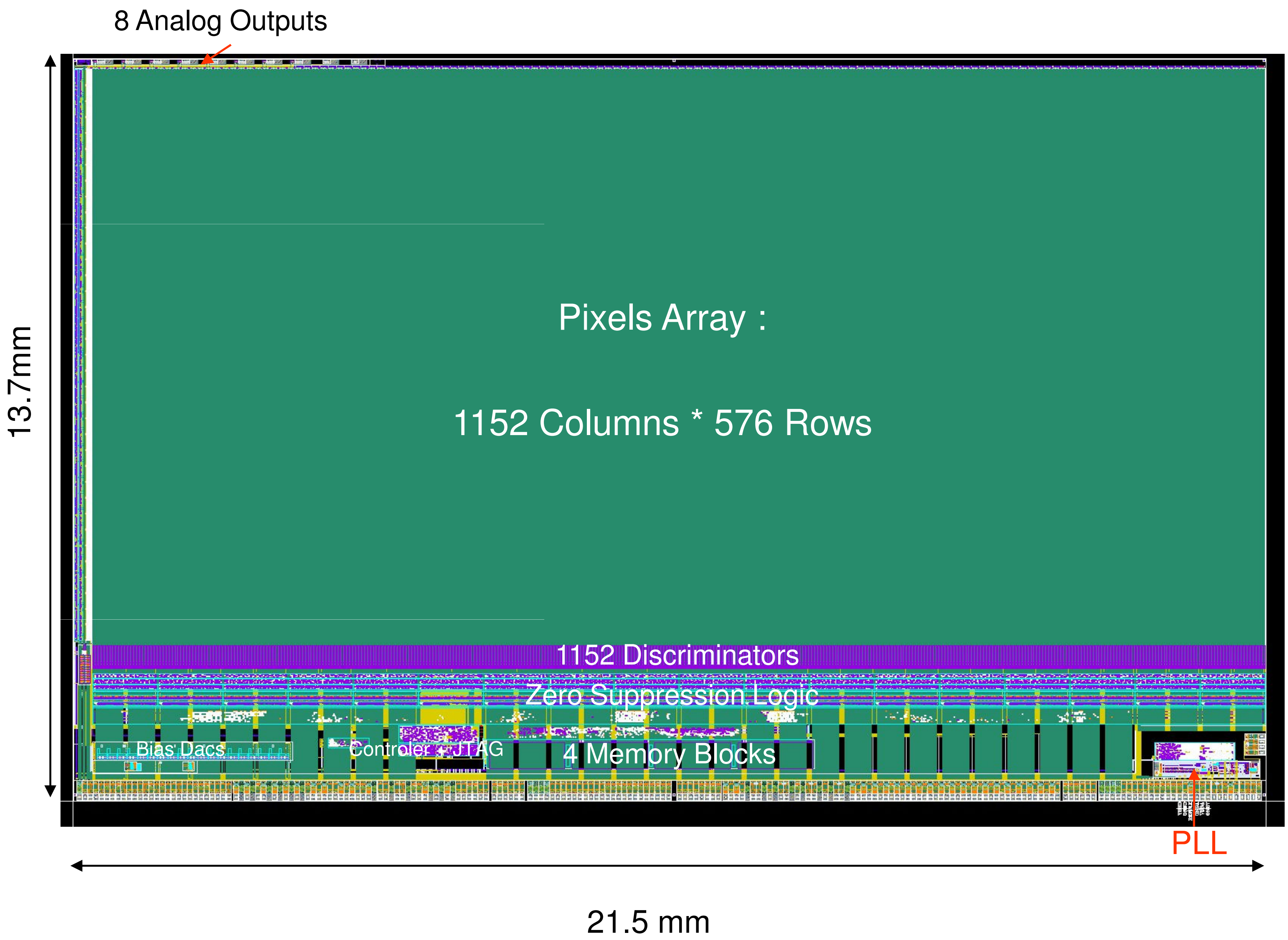
MAPS (*Monolithic Active Pixel Sensor*) Principle

- sensing elements and processing electronics on the same substrate using a standard CMOS process
- Ionizing particles create e-h pairs in the lowly doped epi-layer
- electrons diffuse thermally to the N-well/P-Epi diode



100% Fill Factor

80 e-h/µm (MIP)

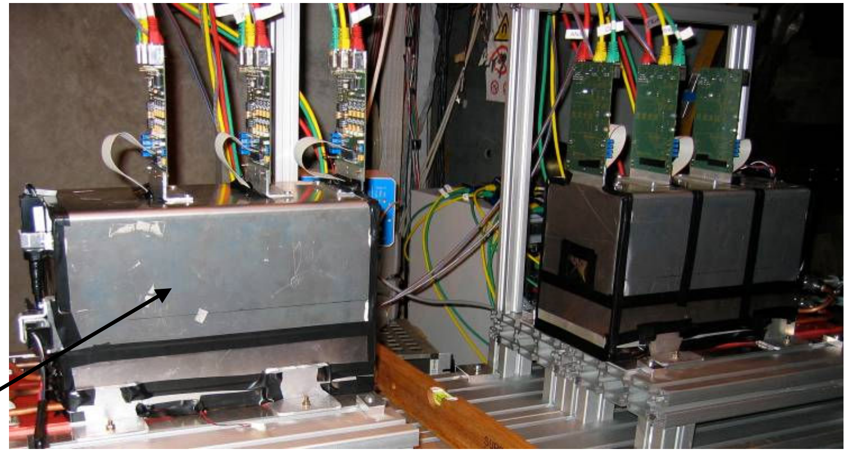

8 Analog Outputs
13.7mm
Pixels Array :
1152 Columns * 576 Rows
1152 Discriminators
Zero Suppression Logic
Bias Dacs
Controler + JTAG
4 Memory Blocks
PLL
21.5 mm

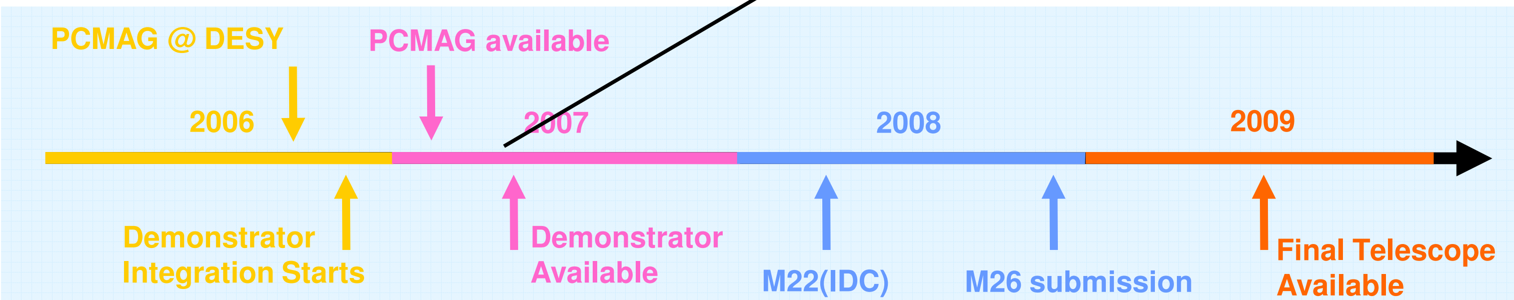
EUDET Testbeam Infrastructure (JRA1)
(Detector R&D toward International Linear Collider)

Irfu
cea
saclay

IPHC
Institut Pluridisciplinaire Hubert CURIEN STRASBOURG

- Provide a large high field magnet
- **Provide beam telescope with 6 layers of MAPS with :**
  - Very high precision (< 3µm precision even at lower energies)
  - High readout speed (frame rate > 1 kHz), $T_{\text{integ time}}$ ~100µs/frame
  - Binary readout
  - Easy to use (well defined/described interfaces)
  - Wide range of conditions for devices under test (cooling, positioning, magnetic field)
- **Major users :**
  Pixels, CCD and DEPFET detectors, TPC, ...
- Initial setup @ DESY
  < 6 GeV/c electrons
- Transportable :
  Hadron beams at FNAL, SLAC or CERN





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