From MIMOSA-26 to ULTIMATE

Marc Winter (IPHC-Strasbourg)

(on behalf of the CMOS-ILC Team)

▷ **more information on IPHC Web site: http://www.iphc.cnrs.fr/-CMOS-ILC-.html**

▷ **Most of the information distributed is confidential**

CONTENTS

- **Introductory remarks on CMOS pixel sensors developed at IPHC**
- **MIMOSA-26 :**
  - ▷ performances & applications
  - ▷ standard vs high-resistivity epitaxy
- **Extension of MIMOSA-26 towards ULTIMATE : MIMOSA-22AHR**
  - ▷ larger pitch
  - ▷ signal amplification
  - ▷ radiation tolerance
- **Summary – Conclusions**

-

Overview of IPHC Team

Team composition :

- micro-circuit designers : 9 staff (+2 supports), 1-2 post-doc, 6-7 PhD
- test & instrumentation engineers : 6 staff
- physicists : 3 staff, 4 post-doc, 2 PhD

Involvements besides STAR:

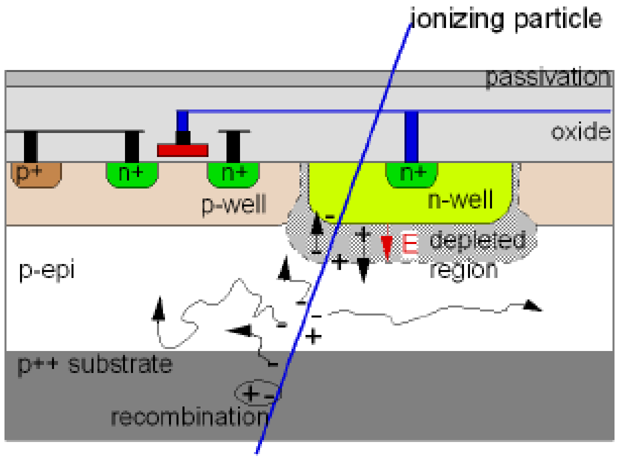
- **Sensor devt:** 3D chips, depleted epi., dosimetry (pixels with ADC), beta camera, ...
- **System integration studies :** double-/single-sided ladders $\equiv$ 0.3%/0.1% X_0 (EU-FP7 projects)
- **HEP experiments besides STAR:** CBM/FAIR, ILC, (ALICE recently)
- **Exploiting MIMOSA sensors** for various beam telescopes & spectrometres

Collaborators (besides STAR coll.)**:**

- IRFU-Saclay for chip design related to ILC (and may be for ALICE upgrade)
- IKF-Frankfurt (CBM) for chip evaluation and system integration studies
- Oxford - Bristol - DESY (& CERN) for system integration studies
- DESY, Univ. Geneva, INFN for EUDET(FP-6) & AIDA (FP-7) Beam Telescope (BT)
- IPN-Lyon (IN2P3) for beta (& proton)imaging
- Nuclear physics teams for hadrontherapy trackers & imagers
- Users of MIMOSA sensors for various applications (subatomic physics as well as spin-offs)

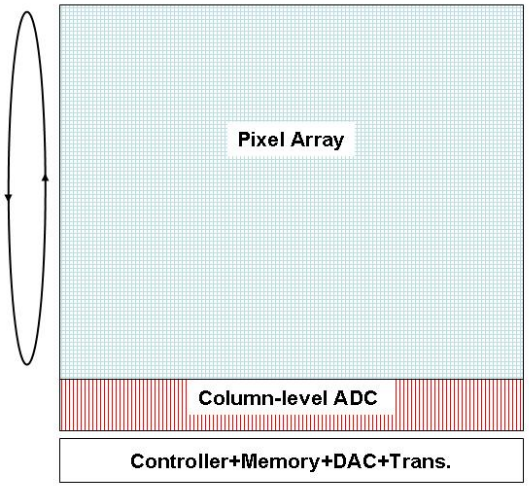
CMOS Pixel Sensors: General Remarks

- **Prominent features of CMOS pixel sensors:**
  - ⋇ high granularity ⇛ excellent (micronic) spatial resolution
  - ⋇ very thin (signal generated in 10-20 μm thin epitaxial layer)
  - ⋇ signal processing μ-circuits integrated on sensor substrate



- Sensor organisation:
  - ⋇ signal sensing and analog processing in pixel array
  - ⋇ mixed and digital circuitry integrated in chip periphery
  - ⋇ read-out in rolling shutter mode

    (pixels grouped in columns read out in //)



CMOS Pixel Sensors: General Remarks

- **Intrinsic limitations of technology :**
  - ⋇ very thin sensitive volume ⇛ impact on signal magnitude
  - ⋇ standard process sensitive volume almost undepleted ⇛ impact on radiation tolerance & speed
  - ⋇ commercial fabrication (parametres) ⇛ not optimised for charged particle detection
    ⇛ impact on sensing performances and radiation tolerance

- **Limitations of the fabrication process retained for ULTIMATE:**
  - ⋇ only 4 ML ⇛ rolling shutter sequencer in 350 μm wide side band
  - ⋇ feature size ⇛ restricted nb of transistors in the pixel
  - ⋇ oxide thickness (from feature size) ⇛ weakens the tolerance to ionising radiation
  - ⋇ double-well technology ⇛ restricted circuitry inside pixel

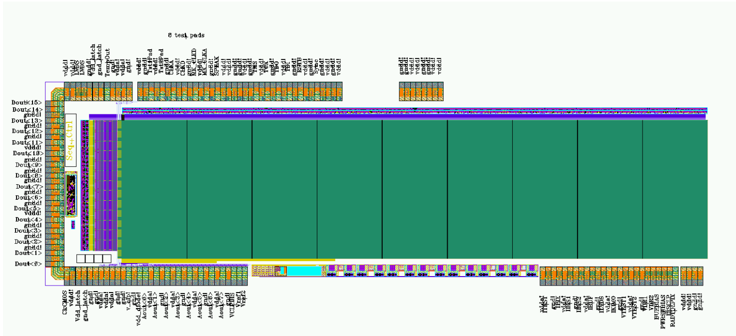
- **Limitations due to the STAR environment :**
  - ⋇ limited cooling ⇛ power consumption is a concern (consequences on SNR, alignment)
  - ⋇ limited cooling ⇛ reduced noise performance, in particular after irradiation (though not critical)

Development Strategy of Fast CMOS Sensors

- **Target value : read-out time $\lesssim$ 20 - - - - 200 μs** $\rightarrowtail$ *sensors organised in pixel columns read out in //*

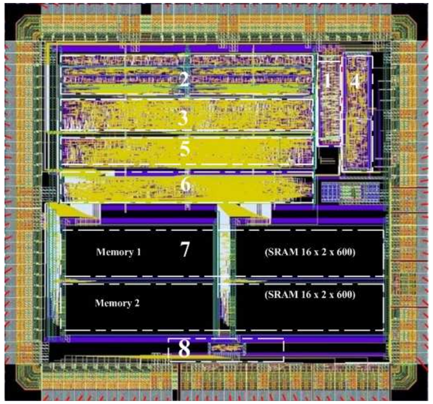
- **R&D organisation : 2 simultaneous R&D lines $\Rrightarrow$ 2 types of μcircuits**

MIMOSA-22



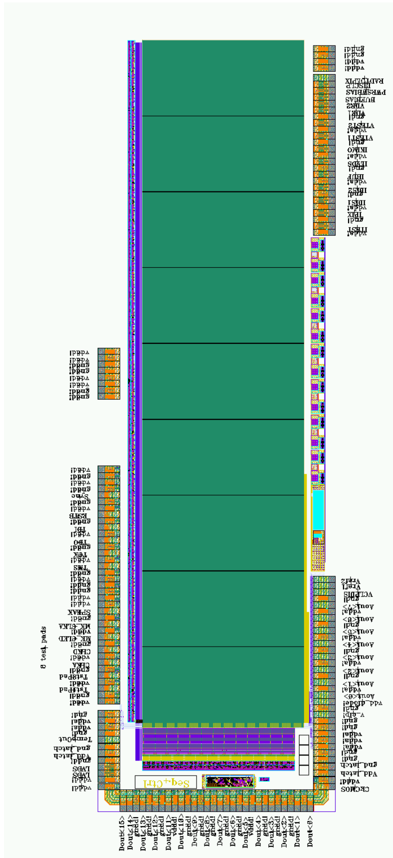
- *architecture of pixel arrays organised in columns read out in //*
  - ▷ *CDS and pre-amp μcircuit in each pixel*
  - ▷ *1 discriminator ending each column*
  - $\hookrightarrow$ *MIMOSA-8 (2004), MIMOSA-16 (2006), MIMOSA-22 (2007/08)*
  - $\hookrightarrow$ *PHASE-1 (2008/09)*

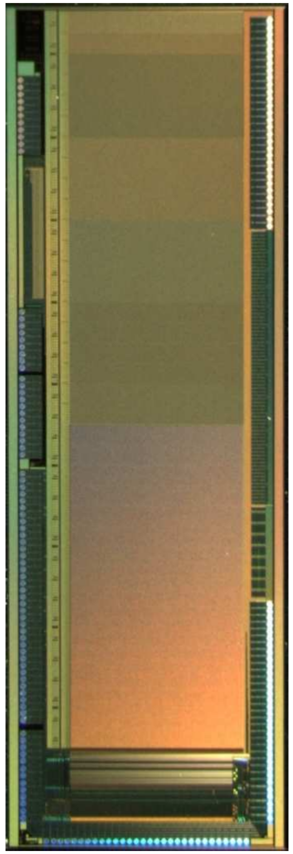
- *Ø μcircuits & output memories : SUZE-01 (2007)* $\longrightarrow$
  - $\hookrightarrow$ *combined with MIMOSA-22 ▷ MIMOSA-26 (2008/09)*
  - $\hookrightarrow$ *ULTIMATE (2010/11)*



Main Characteristics of the MIMOSA-22 Sensor

♣ **Extension of MIMOSA-16 $\longrightarrow$ larger surface, smaller pitch, optimised pixel, JTAG, more testability**





Pixel characteristics :

- **pitch : 18.4 μm** (compromise resolution/pixel layout)
- diode surface : $\sim$ 10 – 20 μm^2 to optimise charge coll. & gain
- **128 columns ended with discriminator**
- **576 pixels per column ($\equiv$ final column length)**
- 8 columns with analog output for test purposes
- 9 sub-matrices of 64 rows :

  17 pixel designs w/o ionising rad. tol. diode

  $\Rightarrow$ **active digital area $\sim$ 25 mm^2** (128 x 576 pixels)
- **read-out time $\sim$ 100 μs ($\sim$ 10^4 frames/s) at 100 MHz**

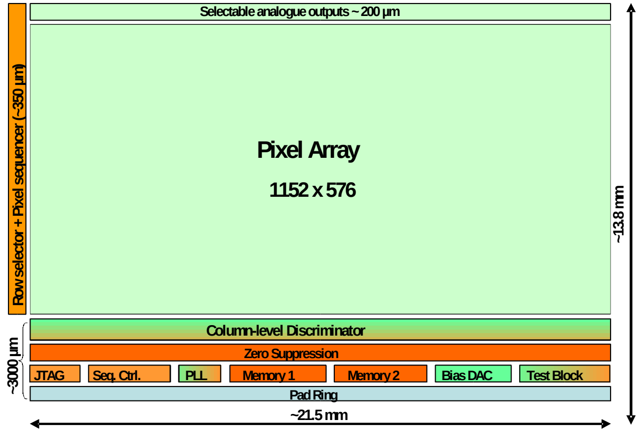
4 different versions fabricated up to now (prototype shuttle)

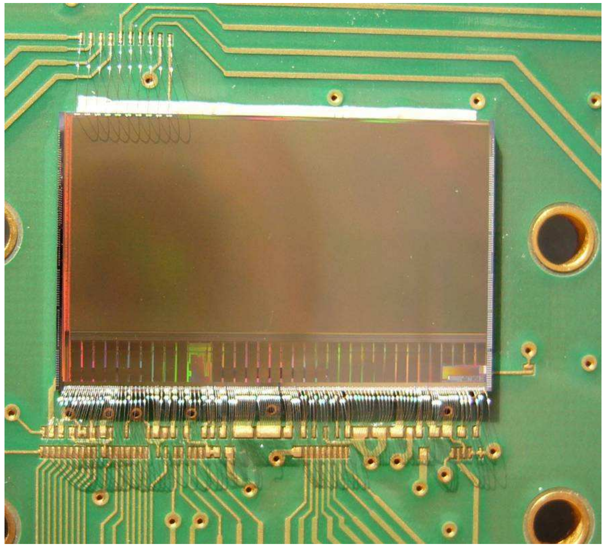
- 3 versions with standard epitaxial layer (2007, 2008, 2009)
- 1 version with high resistivity epitaxial layers (2010)

MIMOSA-26: Architecture Baseline for ULTIMATE

- **Main characteristics of MIMOSA sensor equipping EUDET BT:**

  - ⋇ 0.35 μm process with high-resistivity epitaxial layer
    (coll. with IRFU/Saclay)
  - ⋇ column // architecture with in-pixel amplification (CDS)
    and end-of-column discrimination, followed by $\emptyset$
    $\hookrightarrow$ binary charge encoding
  - ⋇ active area: 1152 columns of 576 pixels (21.2$\times$10.6 mm^2)
  - ⋇ pitch: 18.4 μm $\rightarrowtail$ $\sim$ 0.7 million pixels
    charge sharing $\Rrightarrow$ $\sigma_{sp}\sim$ 3-3.5 μm (despite binary encoding)
  - ⋇ t$_{r.o.}$ $\lesssim$ 100 μs ($\sim$10^4 frames/s)
    $\Rrightarrow$ suited to $>$10^6 part./cm^2/s
  - ⋇ 2 outputs at 80 MHz
  - ⋇ $\sim$ 250 mW/cm^2 power consumption (fct of N$_{col}$)





MIMOSA-26: Functionality Implementation

CMOS 0.35 µm OPTO technology

Chip size : 13.7 x 21.5 mm²

- Pixel array: 576 x 1152, pitch: 18.4 µm
- Active area: ~10.6 x 21.2 mm²
- In each pixel:
  - Amplification
  - CDS (Correlated Double Sampling)

- Testability: several test points implemented all along readout path
  - Pixels out (analogue)
  - Discriminators
  - Zero suppression
  - Data transmission

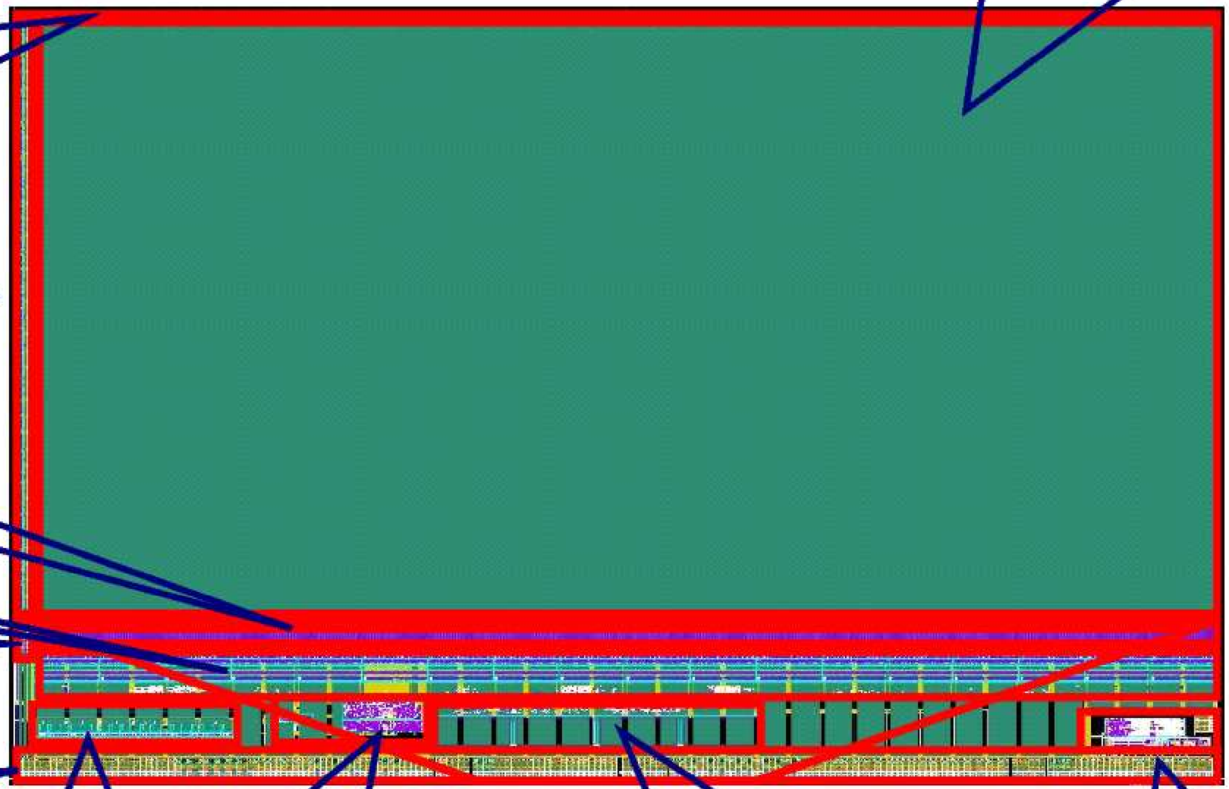
- Row sequencer
- Width: ~350 µm

- 1152 column-level discriminators
  - offset compensated high gain preamplifier followed by latch

- Zero suppression logic

- Reference Voltages Buffering for 1152 discriminators

- I/O Pads
  Power supply Pads
  Circuit control Pads
  LVDS Tx & Rx



- Current Ref.
- Bias DACs

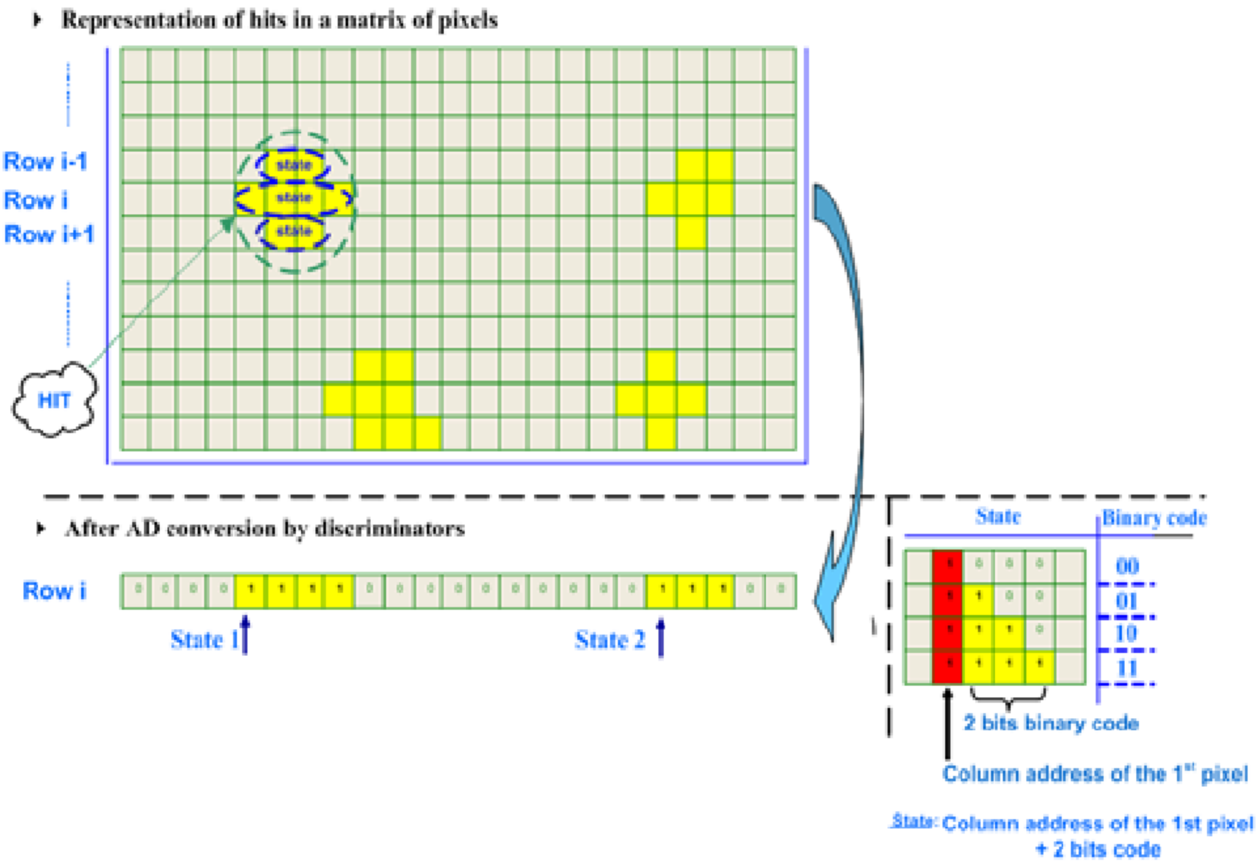
- Readout controller
- JTAG controller

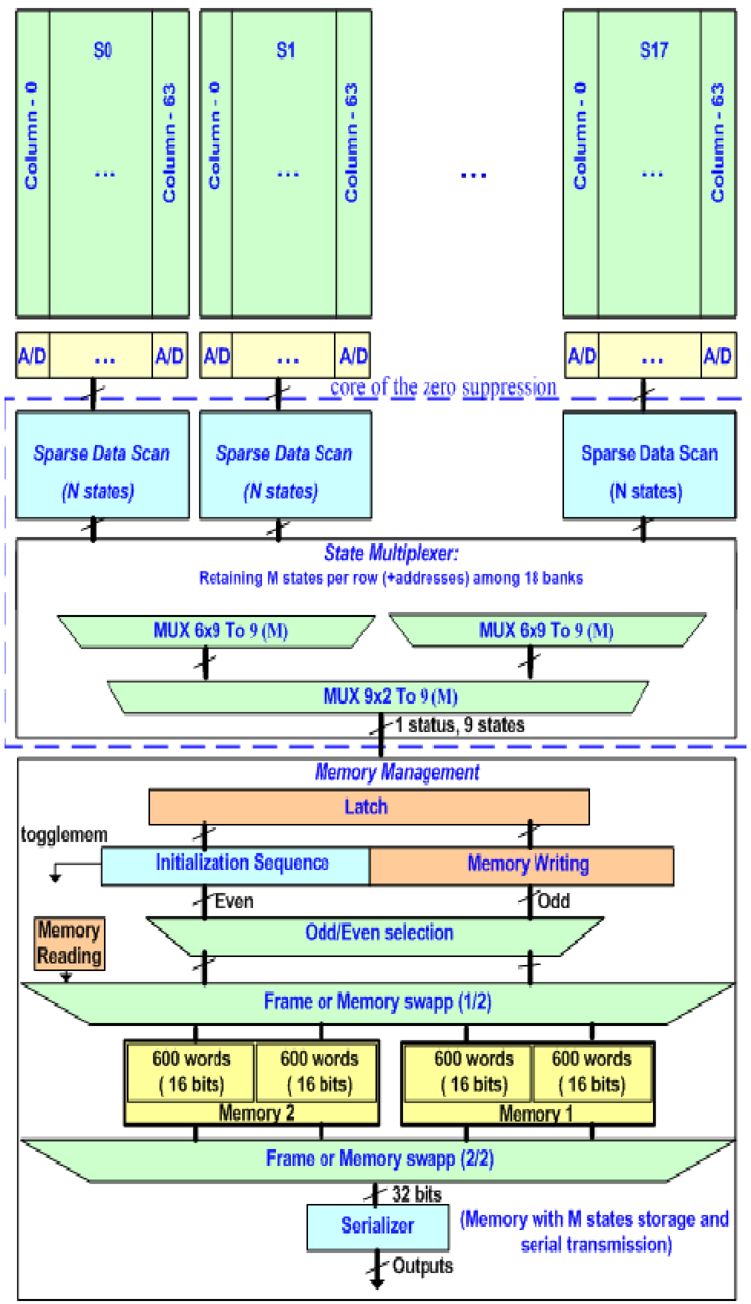
- Memory management
- Memory IP blocks

- PLL, 8b/10b optional

courtesy of Ch. Hu-Guo / TWEPP-2010

MIMOSA-26 Zero-Suppression Logic





- Encoding limited to raws
  - ⇛ no raw to raw correlation for clustering
- Same logic implemented in Ultimate

MIMOSA-26 Tests: General Features

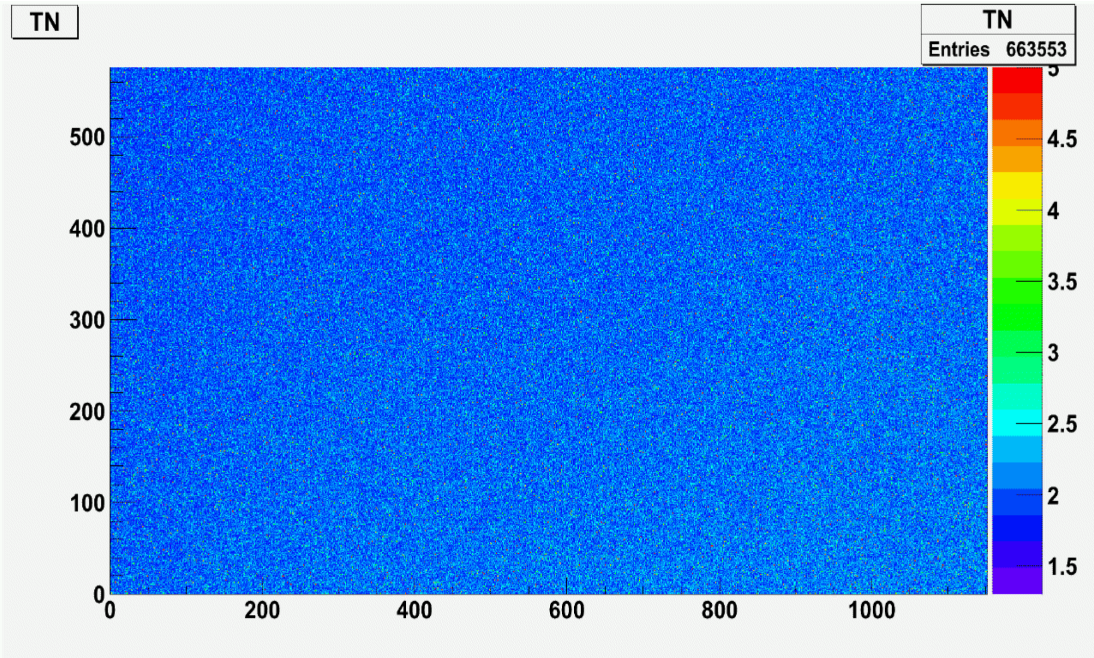
- **2 engineering runs:**
  - ⋇ 2009 ▷ 6 wafers with standard epitaxial layer (14 μm thick)
  - ⋇ 2010 ▷ 6 wafers with various epitaxial layers :
    1 standard (14 μm thick), 5 high-resistivity (10, 15 and 20 μm thick)

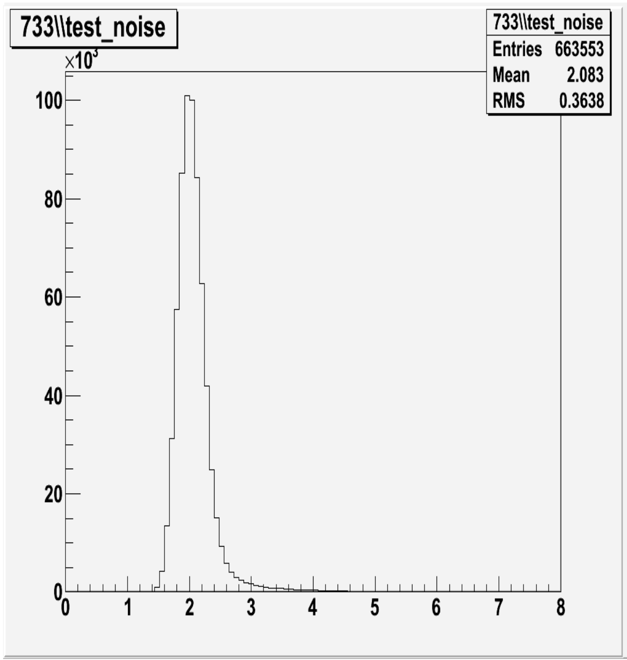
- **$>$ 90 sensors tested :**

Epitaxial layer	fully operational	$<$ 10^{-3} dead pixels	few 10^{-3} dead pixels	unusable
standard	*55*	*6*	*6*	*3*
high-res	*19*	*1*	*2*	*1*

- **Global figure of fabrication yield:**
  - ⋇ yield : $\sim$ 75% "perfect" sensors and $\sim$ 90 % usable
  - ⋇ 50 μm thin (4, 1, 0, 1) and high-resistivity sensors do not behave differently (statistics limited)

MIMOSA-26 Lab Tests: Noise Performance



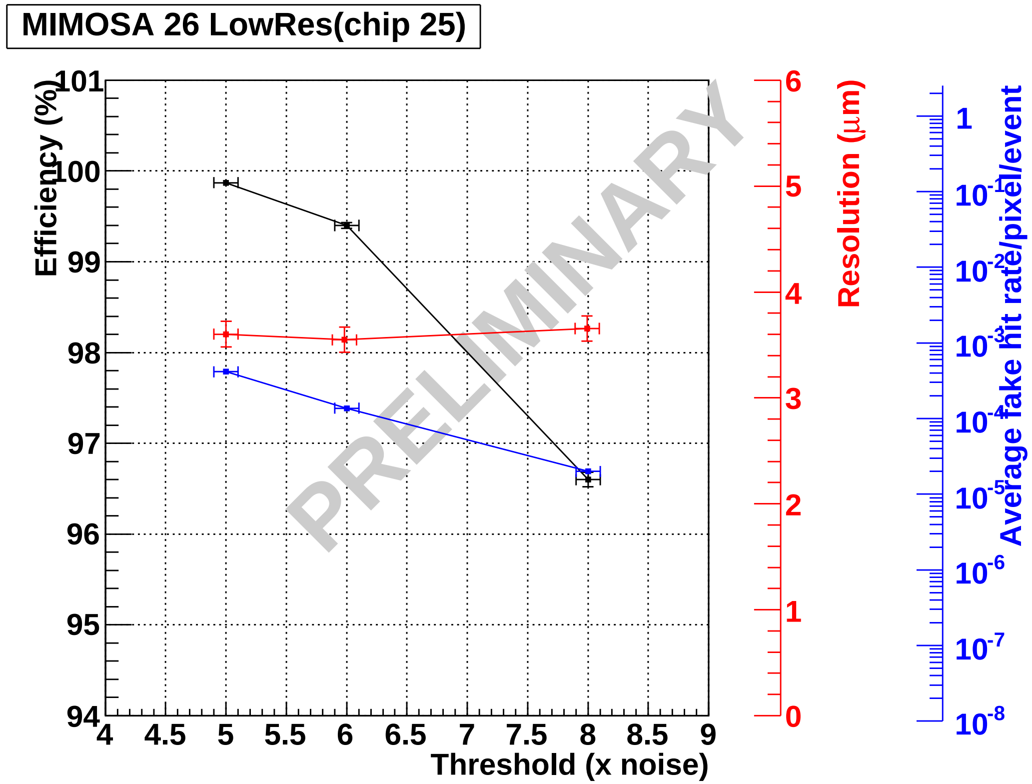


- **Noise uniformity tested on $>$ 60 sensors (analogue output)**

- **Main conclusions:**
  - ⋇ no dead pixel over $>$ 50 arrays of 665,000 pixels !
  - ⋇ N $\lesssim$ 14 e^{-}ENC
  - ⋇ marginal noise dispersion between chips

MIMOSA-26 Beam Tests: Summary

- **MIMOSA-26 sensors quite extensively characterised by now (**analysis not yet completed):
  - ⋇ MIMOSA-26 operated with
    $\gtrsim$ 99.5 % detection efficiency
    over the whole sensitive area,
    with a fake rate $\lesssim$ O(10^{-4})
  - ⋇ Optimal discri. threshold $\sim$ 5–6 $\times$ Noise value
  - ⋇ $\sigma_{sp}^{M26} < 4\ \mu m$

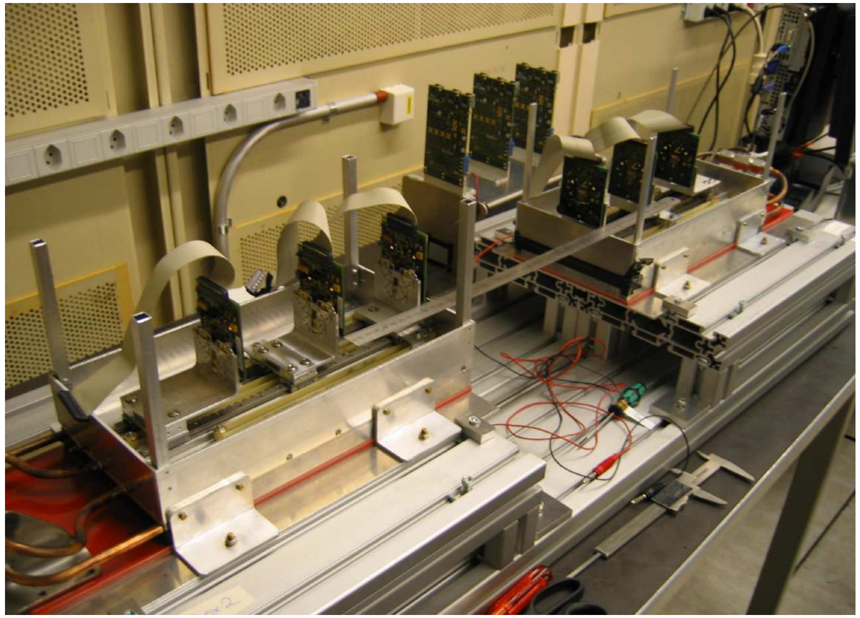


- **Conclusion on MIMOSA-26:**
  - ⋇ chip operational for the final EUDET BT and several other applications (BT and Vx Det.)
  - ⋇ chip architecture validated for developpement of application specific sensors:

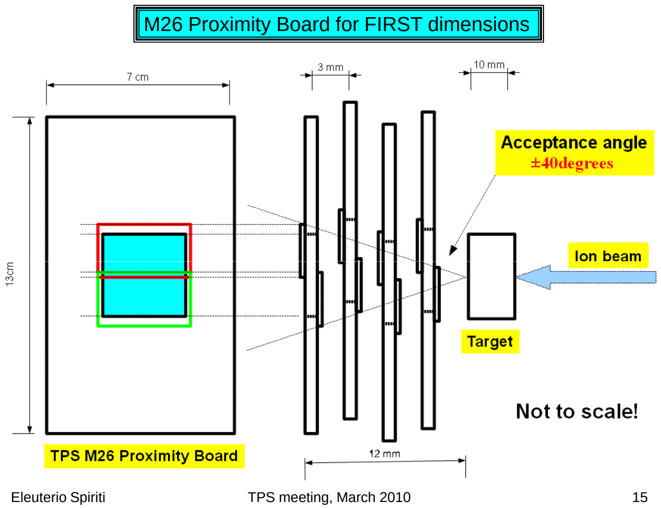
    ▷ **STAR-**PXL ▷ CBM-MVD ▷ ALICE-ITS ▷ ILD-VTX, ...

Direct Applications of MIMOSA-26

- **Beam telescope of the FP6 project EUDET**
  - ⋇ 2 arms of 3 planes (plus 1-2 high resolution planes)
  - ⋇ M-26 thinned to 50 μm
  - ⋇ $\sigma_{extrapol.} \sim$ 1-2 μm EVEN with e^- (3 GeV, DESY)
  - ⋇ frame read-out frequency O(10^4) Hz
  - ⋇ running since '07 (demonstrator: analog outputs)
    at CERN-SPS & DESY (numerous users)

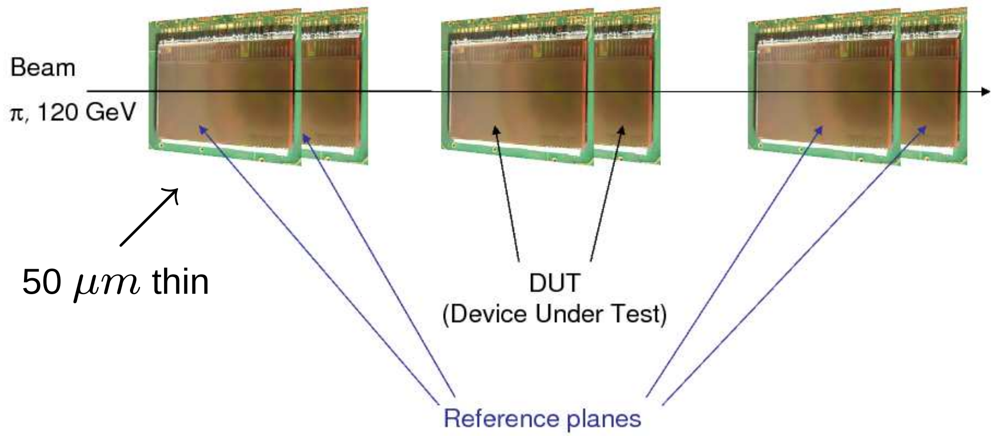


- **Spin-offs :**
  - ⋇ **Several BT copies :** foreseen for detector R&D
  - ⋇ BT for mass spectroscopy, proton radiography, etc.
  - ⋇ **CBM (FAIR) :** MVD demonstrator (2-sided layers) for CBM-MVD
    (HP-2 project)
  - ⋇ **FIRST (GSI) :** VD for hadrontherapy $d\sigma/d\Omega$ measurements ▷▷

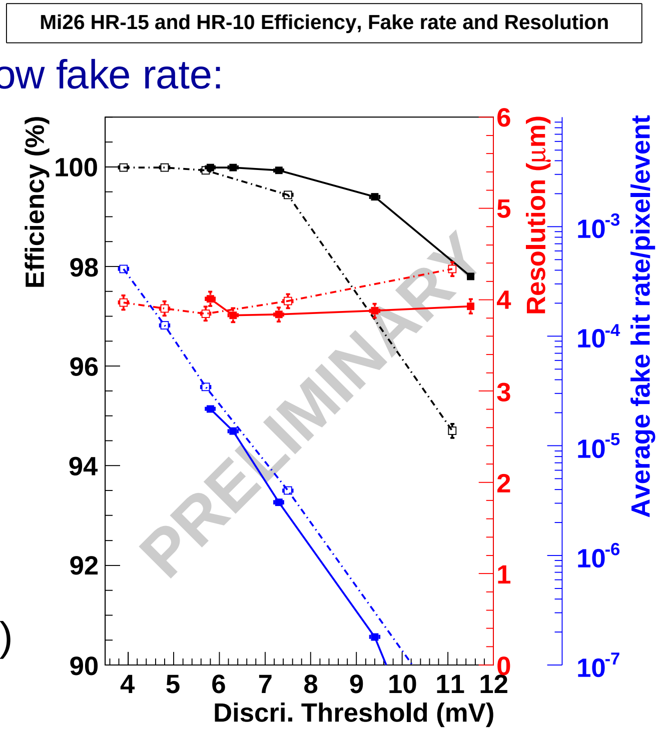


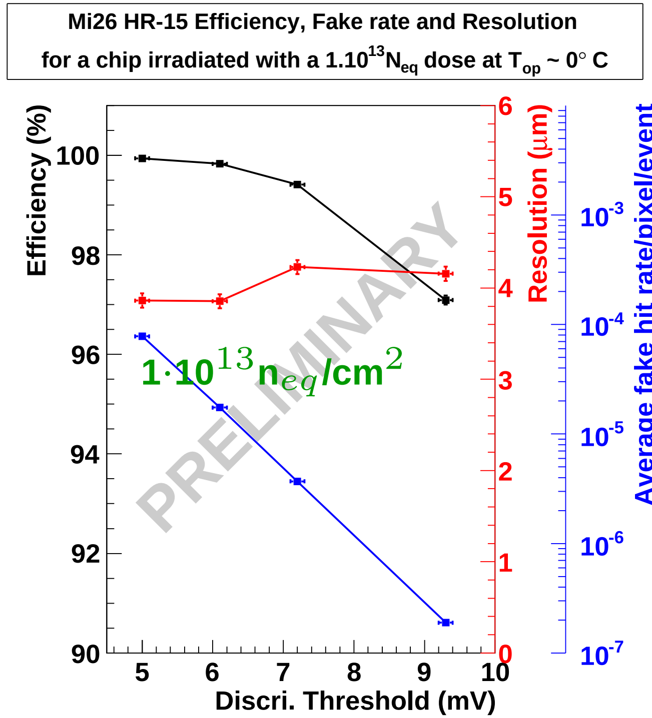
MIMOSA-26 with High-Resistivity Epitaxial Layer

- **M.i.p. detection with LOW & HIGH resistivity CMOS sensors combined in a Beam Telescope (BT)**
  - ⋇ 4 EUDET ref. sensors & 2 sensors under test
  - ⋇ June 2010 at CERN-SPS ($\sim$ 120 GeV pions)
  - ⋇ sensor variants : standard epitaxy (14 μm thick)
    & high-resistivity epitaxy (10 & 15 μm thick)



- **Conclusions:**
  - ⋇ det. eff. $\sim$ 100 % (SNR $\sim$ 40) for very low fake rate:
    - ▷ plateau until fake rate of few 10^{-6}
  - ⋇ single point resolution $\lesssim$ 4 μm
  - ⋇ det.eff. still $\sim$ 100 % after exposure
    to fluence of $1{\cdot}10^{13} n_{eq}/cm^2$ (T $\sim$ 0°C)

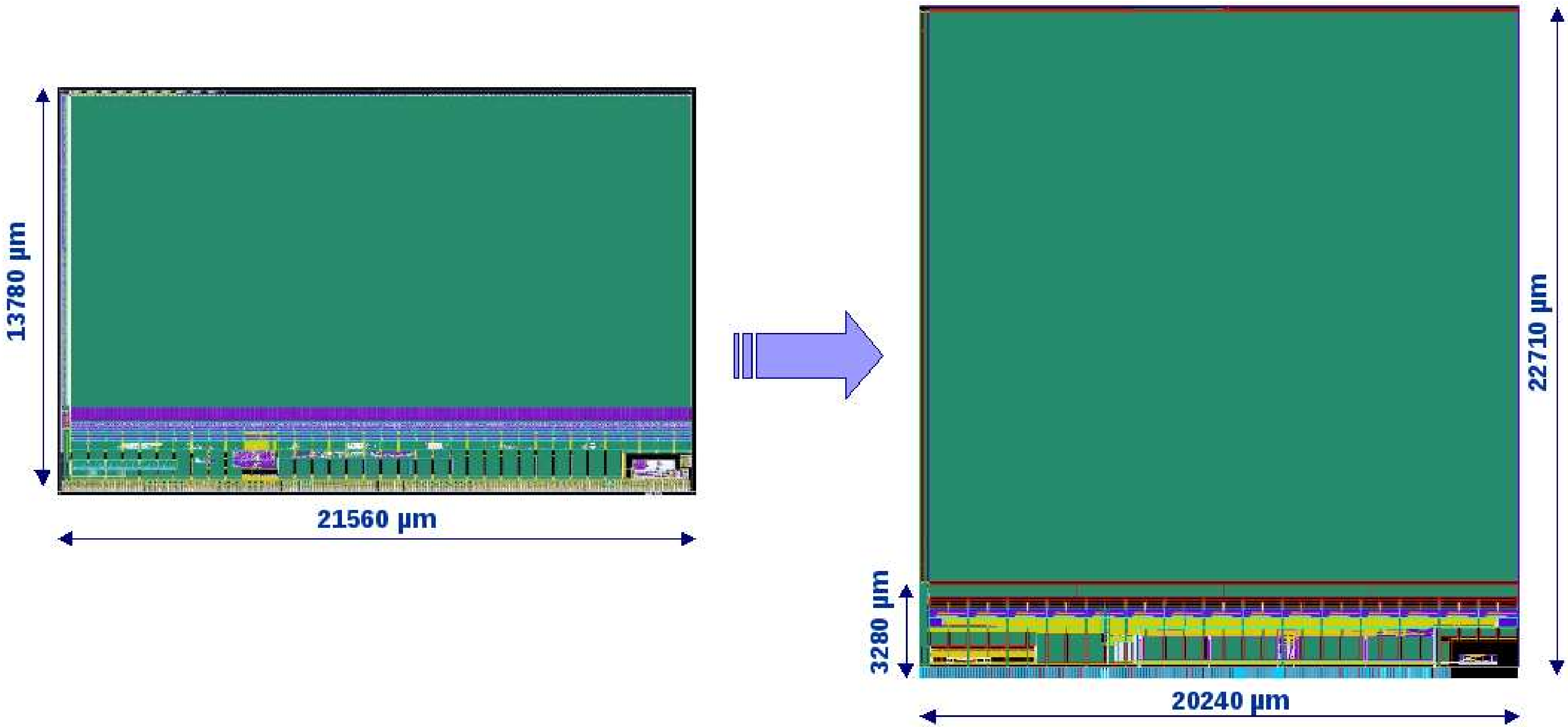




$\Rightarrow$ **Excellent detection performances**
with high-resistivity epitaxial layer
despite moderate resistivity (400 $\Omega \cdot cm$)
and poor depletion voltage ($<$ 1 V)

EXTENSION of MIMOSA-26 to ULTIMATE

From MIMOSA-26 to Ultimate



- Half reticle 1152 x 567 pixel matrix
- Temperature ~20 °C
- Light power consumption constrains
- Space resolution ~4 µm
- No constrains on radiation tolerance

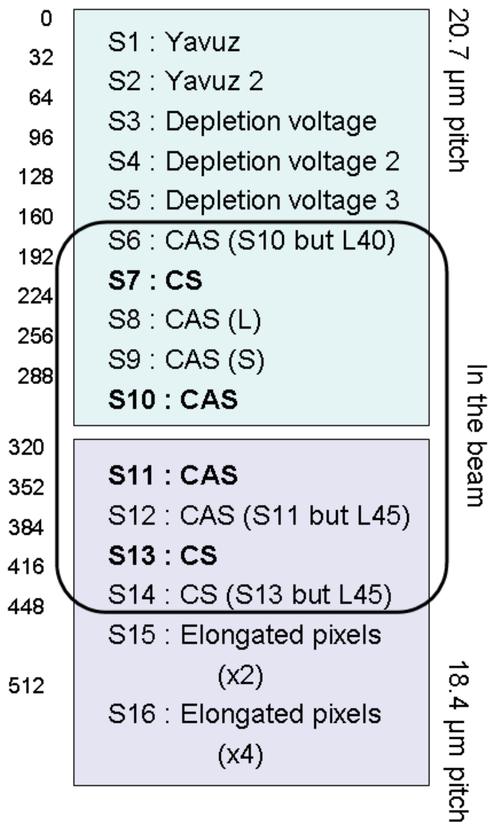
- Full reticle 960 x 928 pixel matrix
  - Longer integration time ~200 µs
- Temperature 30-35 °C
- Power consumption ~100 mW/cm²
- Space resolution < 10 µm
- 150 kRad / yr & few 10^{12} Neq /cm² /yr

➔ Optimisation

courtesy of Ch. Hu-Guo / TWEPP-2010

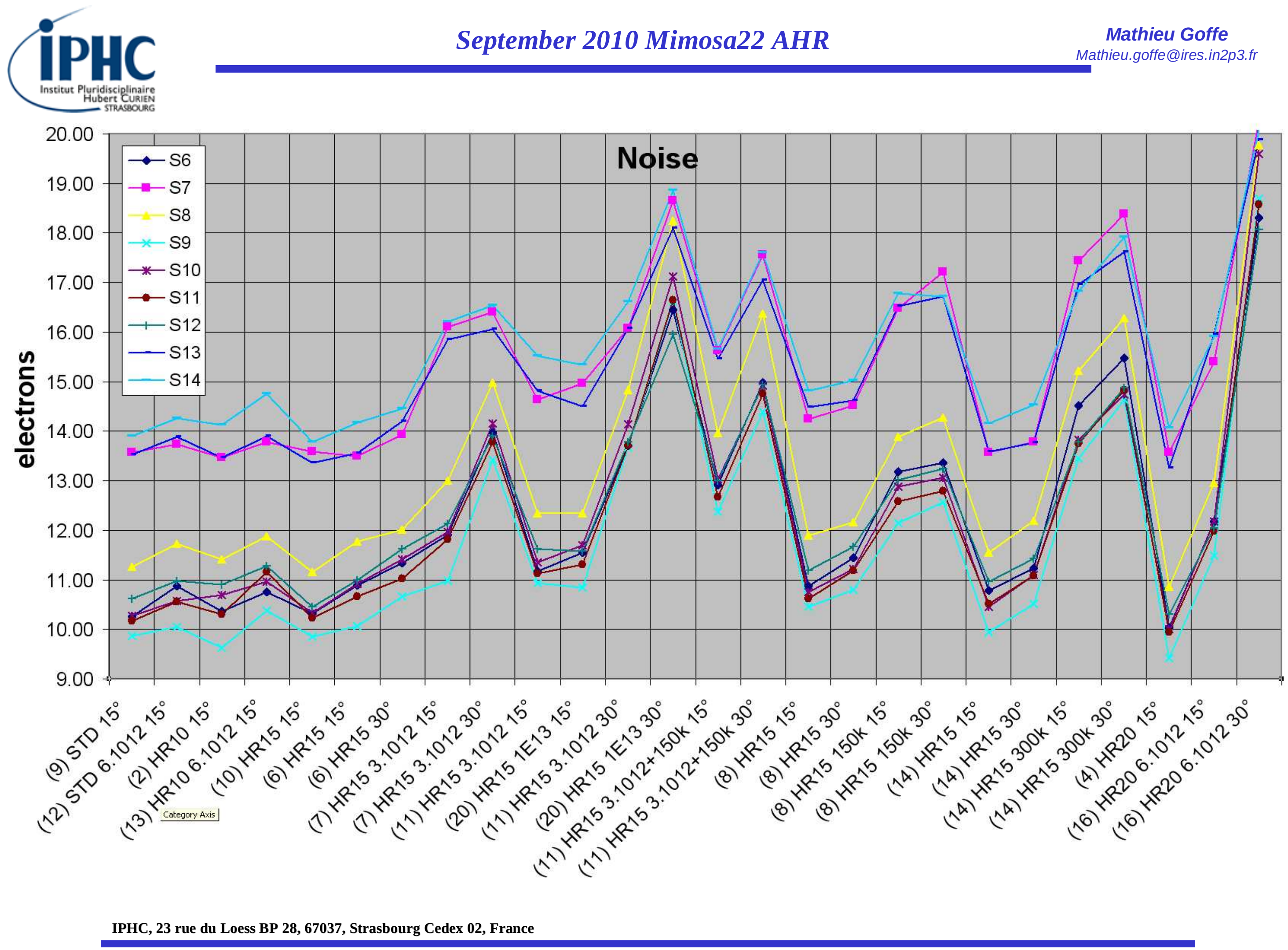
MIMOSA-22AHR: Motivations, Properties, Tests Performed

- **Motivations :**
  - ⋇ validate larger pitch design ⇛ power dissipation
  - ⋇ try enhancing in-pixel amplification ⇛ sensitivity to discri. offset
  - ⋇ enhance radiation tolerance at 30°C
  - ⋇ explore and validate new epitaxial layers (AMS home made vs provider)
- **Main components:**
  - ⋇ pitch: 20.7 μm (UTIMATE) and 18.4 μm (MIMOSA-26)
  - ⋇ in-pixel amplification: Common Source & Cascode
  - ⋇ various features against ionising radiation damage: ETL, wide T gate
  - ⋇ features against non-ionising radiation damage: diode size, depletion potential



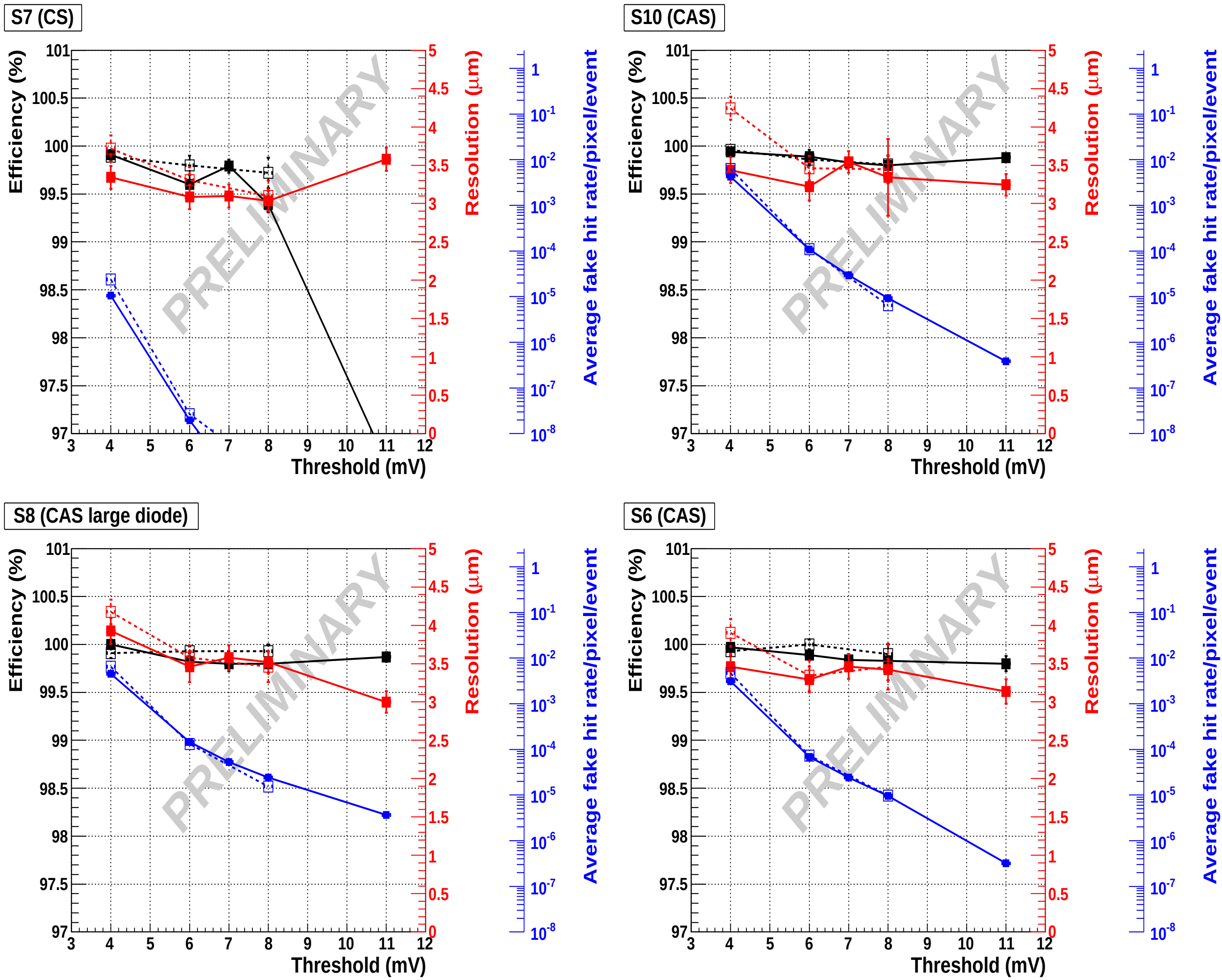
- **Fabrication:**
  - ⋇ part of an AMS-0.35 μm engineering run submitted in May 2010 ⟶ back in July
  - ⋇ various epitaxial layers: standard (M-22 & M-26), HR-10 (M-26), HR-15 (AMS), HR-20 (AMS)
- **Tests performed** (mainly at 3.3 V)**:**
  - ⋇ extensive lab tests: CCE (^{55}Fe), noise (fake rate)
  - ⋇ HR-15 and HR-10 tested at CERN-SPS (August & Sept. 2010)
  - ⋇ irradiation tolerance tests: 150 kRad, $3{\cdot}10^{12}$n$_{eq}$/cm^2 and combined
  - ⋇ temperature dependence: 20°C and 30°C
  - ⋇ "STAR running conditions": 150 kRad $\oplus$ $3{\cdot}10^{12}$n$_{eq}$/cm^2 $\oplus$ 30°C $\oplus$ 75 MHz (should have been 50 MHz)

MIMOSA-22AHR : Noise Performance



MIMOSA-22AHR: Before Irradiation

- **Tests performed at CERN-SPS:**
  - ⁜ sensor mounted on beam telescope (4 pairs of Si-strip detectors)
  - ⁜ vary discriminator threshold (JTAG), temperature, clock frequency
  - ⁜ measure detection efficiency, fake hit rate, single point resolution



- **Results for 20.7 μm pitch pixels ▷ mV-SNR equivalence at 30°C**

Threshold ▷	4 mV	6 mV	8 mV
S7	*4.1*	*6.4*	*8.7*
S10	*2.5*	*4.2*	*5.9*
S6	*2.7*	*4.4*	*6.1*
S8	*2.5*	*4.2*	*5.9*

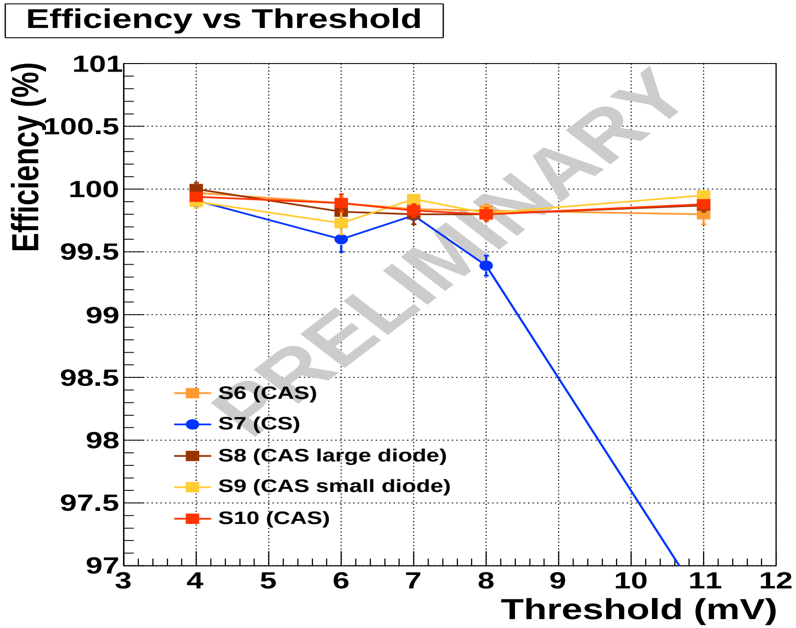
- **Typical noise performance :** 12-14 e^- ENC

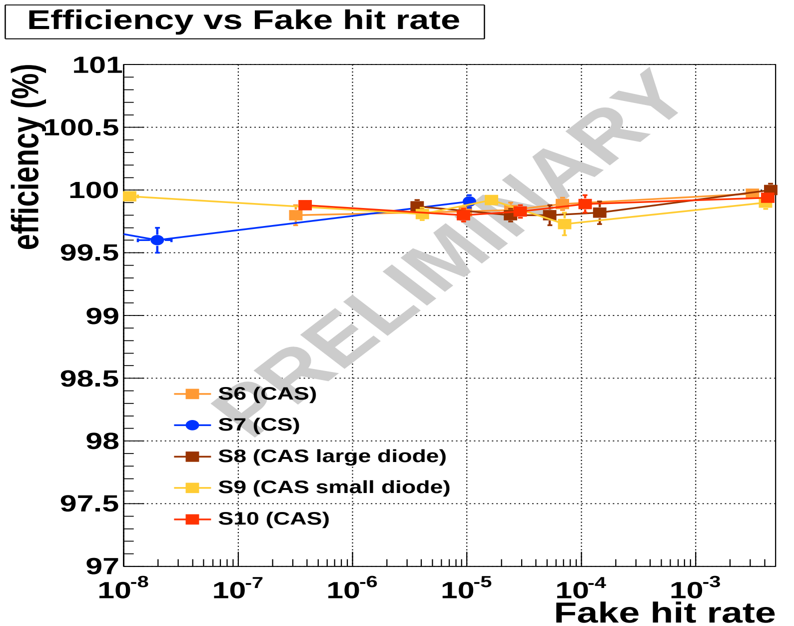
MIMOSA-22AHR: Before Irradiation

- **Efficiency vs fake hit rate:**
  - ⋇ define threshold values allowing high detection efficiency and low fake rate
  - ⇛ keep fake rate $\lesssim 10^{-4}$

- **Results for 20.7 μm pitch pixels ▷ mV-SNR equivalence at 30°C**

Threshold ▷	4 mV	6 mV	8 mV
S7	*4.1*	*6.4*	*8.7*
S10	*2.5*	*4.2*	*5.9*
S6	*2.7*	*4.4*	*6.1*
S8	*2.5*	*4.2*	*5.9*



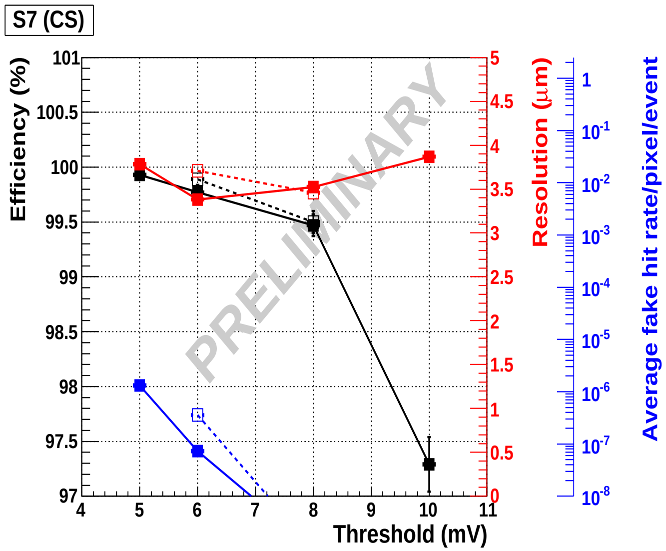


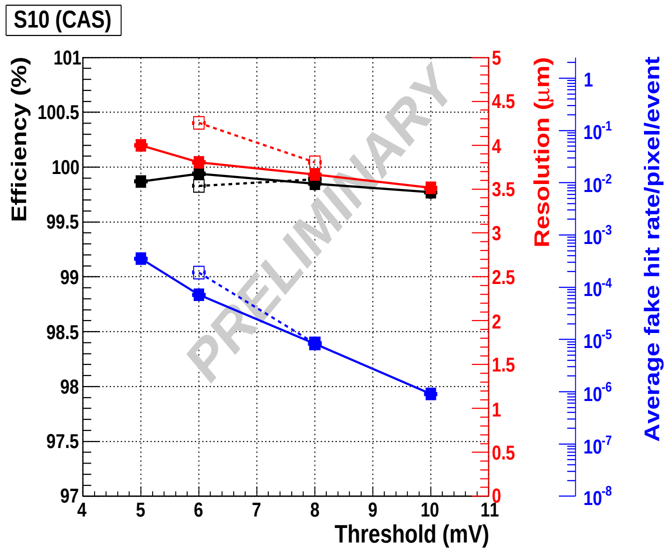
MIMOSA-22AHR: After $3\cdot10^{12} n_{eq}/cm^2$

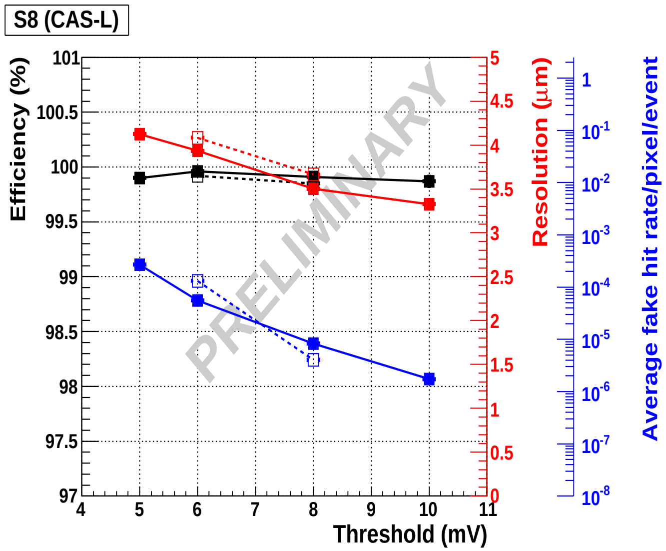
- **Tests performed at CERN-SPS:**
  - ⋇ sensor mounted on beam telescope (4 pairs of Si-strip detectors)
  - ⋇ vary discriminator threshold (JTAG), temperature, clock frequency
  - ⋇ measure detection efficiency, fake hit rate, single point resolution

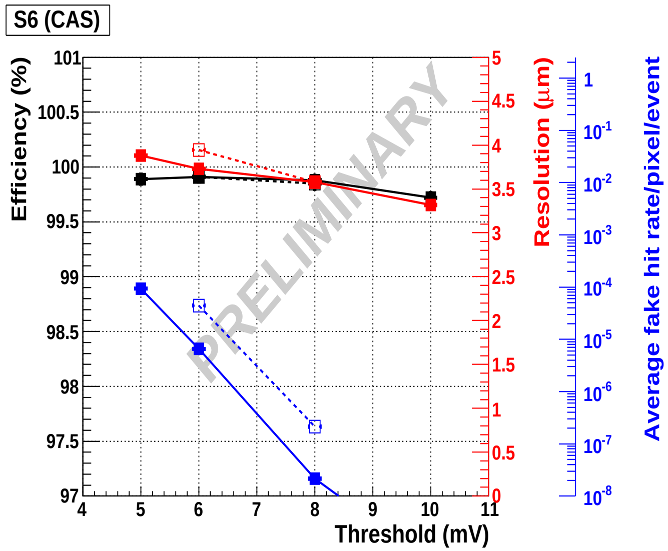
- **Results for 20.7 μm pitch pixels ▷ mV-SNR equivalence at 30°C**

Threshold ▷	6 mV	8 mV
S7	*5.5*	*7.7*
S10	*4.1*	*5.6*
S6	*5.0*	*6.8*
S8	*4.3*	*5.8*







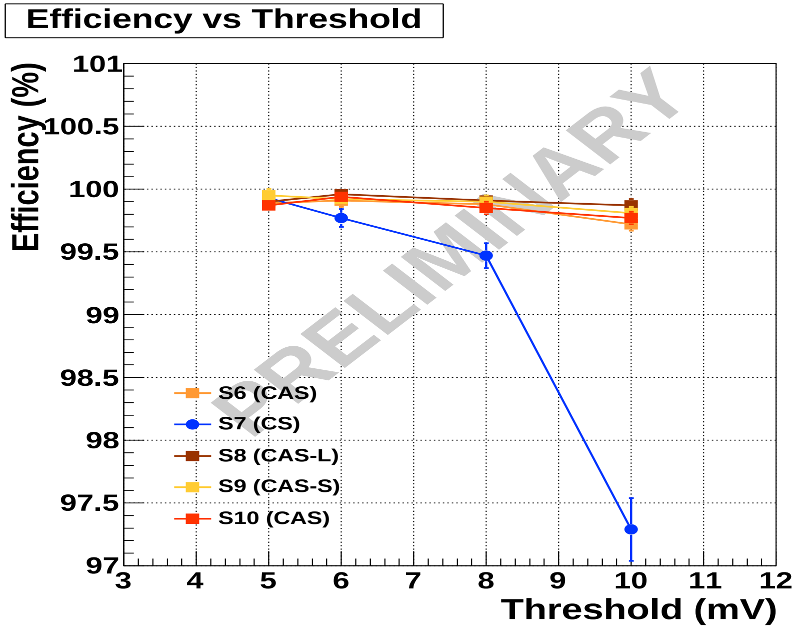


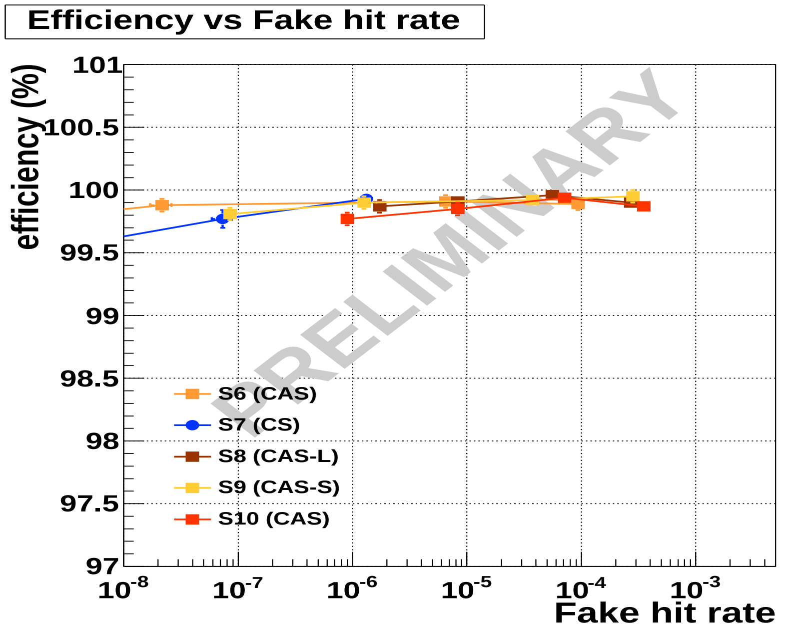
MIMOSA-22AHR: After $3{\cdot}10^{12}$ n_{eq}/cm^2

- **Efficiency vs fake hit rate:**
  - ⋇ define threshold values allowing high detection efficiency and low fake rate
  - $\Rightarrow$ keep fake rate $\lesssim 10^{-4}$

- **Results for 20.7 μm pitch pixels $\triangleright$ mV-SNR equivalence at 30°C**

Threshold ▷	6 mV	8 mV
S7	*5.5*	*7.7*
S10	*4.1*	*5.6*
S6	*5.0*	*6.8*
S8	*4.3*	*5.8*



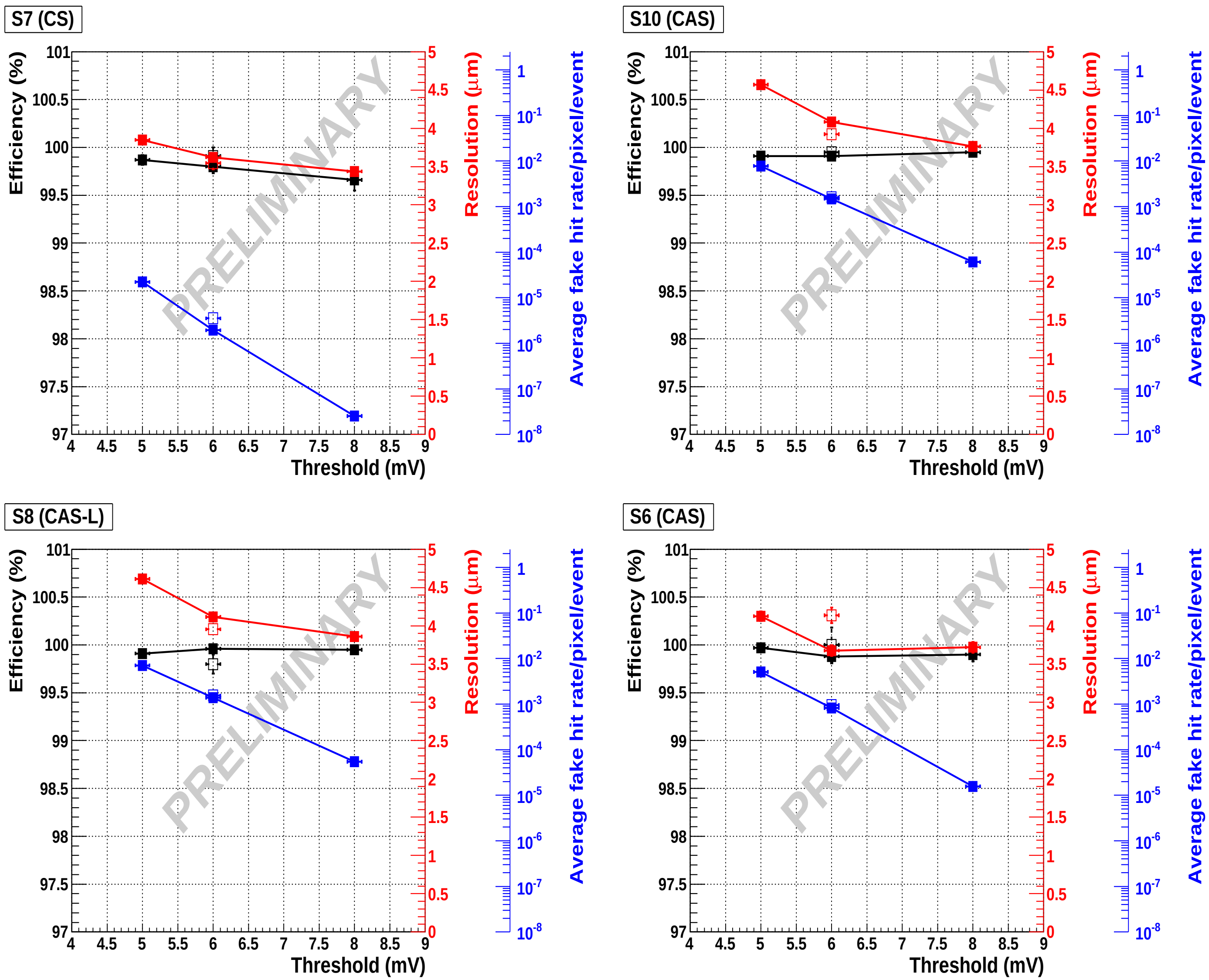


MIMOSA-22AHR: After 150 kRad

- **Tests performed at CERN-SPS:**
  - ⁂ sensor mounted on beam telescope (4 pairs of Si-strip detectors)
  - ⁂ vary discriminator threshold (JTAG), temperature, clock frequency
  - ⁂ measure detection efficiency, fake hit rate, single point resolution

- **Results for 20.7 μm pitch pixels ▷ mV-SNR equivalence at 30°C**

Threshold ▷	5 mV	6 mV	8 mV
S7	*4.5*	*5.4*	*7.2*
S10	*2.6*	*3.2*	*4.4*
S6	*2.7*	*3.4*	*4.6*
S8	*2.6*	*3.2*	*4.4*

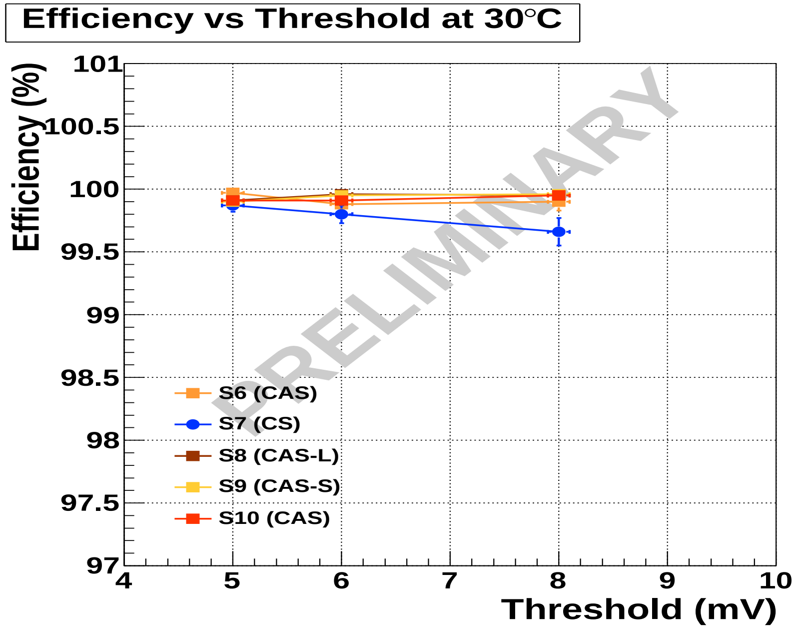


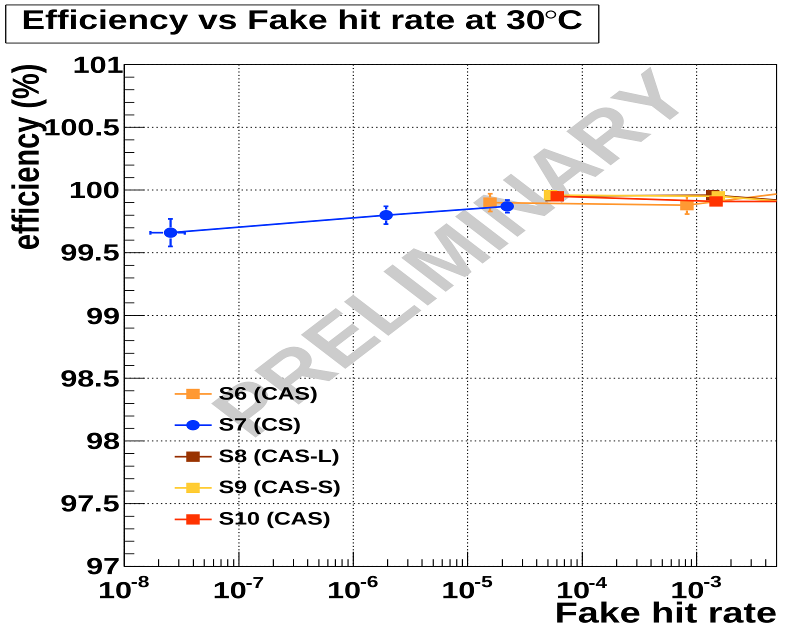
MIMOSA-22AHR: After 150 kRad

- **Efficiency vs fake hit rate:**
  - ⁎ define threshold values allowing high detection efficiency and low fake rate
  - ⇛ keep fake rate $\lesssim 10^{-4}$

- **Results for 20.7 μm pitch pixels ▷ mV-SNR equivalence at 30°C**

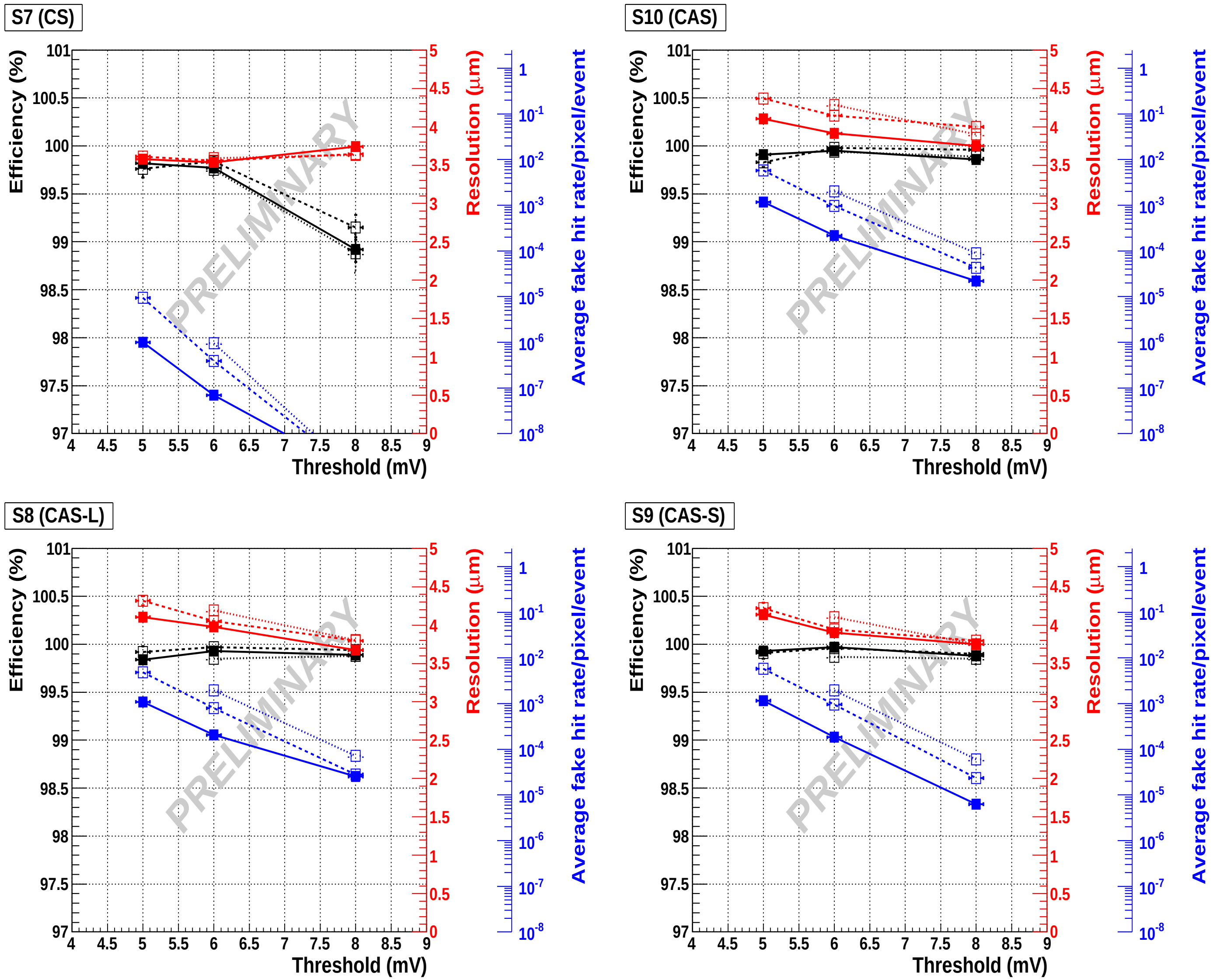
Threshold ▷	5 mV	6 mV	8 mV
S7	*4.5*	*5.4*	*7.2*
S10	*2.6*	*3.2*	*4.4*
S6	*2.7*	*3.4*	*4.6*
S8	*2.6*	*3.2*	*4.4*





MIMOSA-22AHR: After $3\cdot 10^{12} n_{eq}/cm^2$ & 150 kRad at 75 MHz

- **Tests performed at CERN-SPS:**
  - ⁎ sensor mounted on beam telescope (4 pairs of Si-strip detectors)
  - ⁎ vary discriminator threshold (JTAG), temperature = 20°C and 30°C clock frequency = 75 MHz (instead of 100 MHz)
  - ⁎ measure detection efficiency, fake hit rate, single point resolution



- **Results for 20.7 μm pitch pixels ▷ mV-SNR equivalence at 30°C**

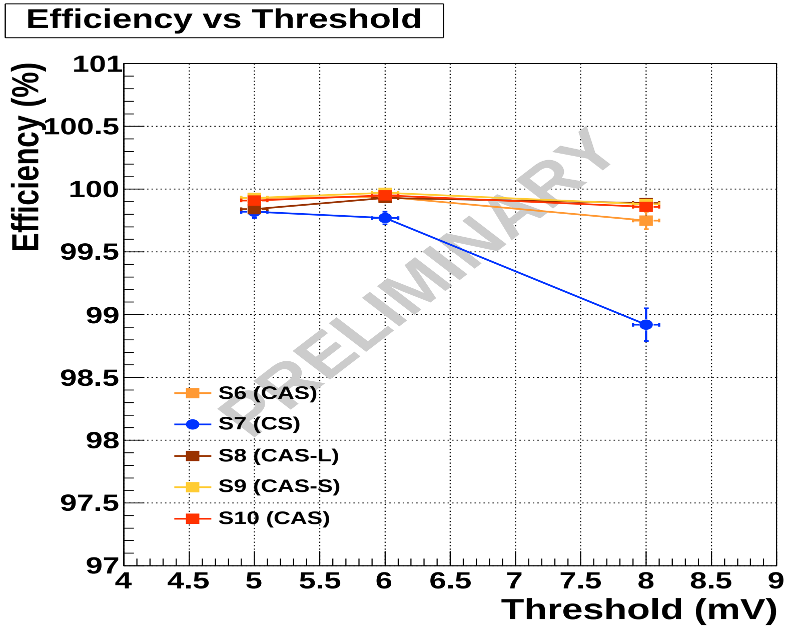
Threshold ▷	6 mV	8 mV
S7	*5.2*	*6.9*
S10	*3.2*	*4.3*
S9	*3.2*	*4.3*
S8	*3.2*	*4.3*

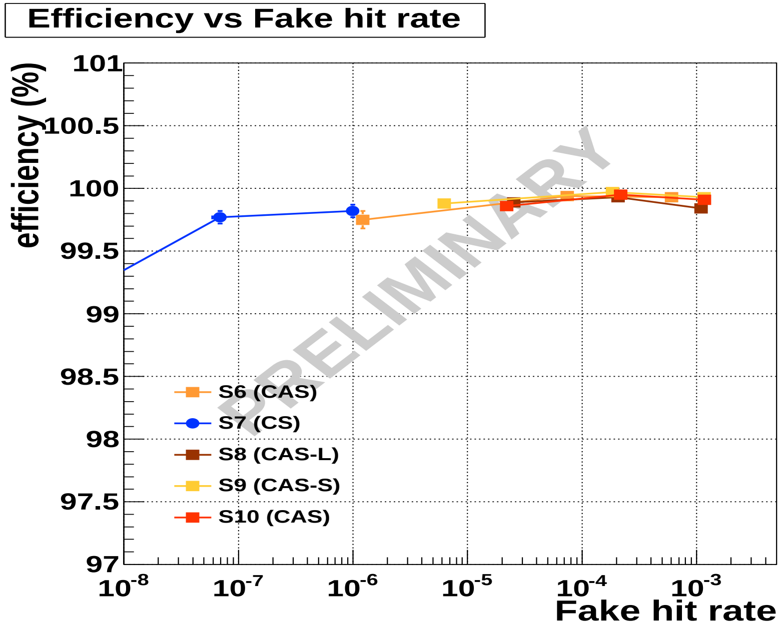
MIMOSA-22AHR: After $3{\cdot}10^{12}n_{eq}/cm^2$ & 150 kRad at 75 MHz

- **Efficiency vs fake hit rate:**
  - ⋇ define threshold values allowing high detection efficiency and low fake rate
  - $\Rightarrow$ keep fake rate $\lesssim 10^{-4}$

- **Results for 20.7 μm pitch pixels ▷ mV-SNR equivalence at 30°C**

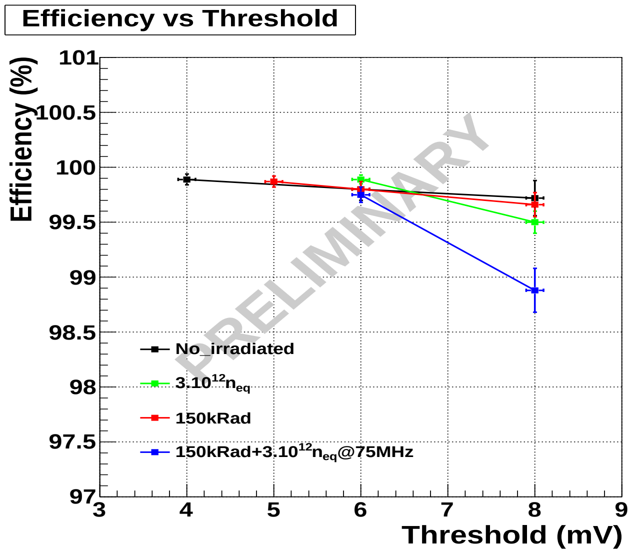
Threshold ▷	**6 mV**	**8 mV**
S7	*5.2*	*6.9*
S10	*3.2*	*4.3*
S9	*3.2*	*4.3*
S8	*3.2*	*4.3*

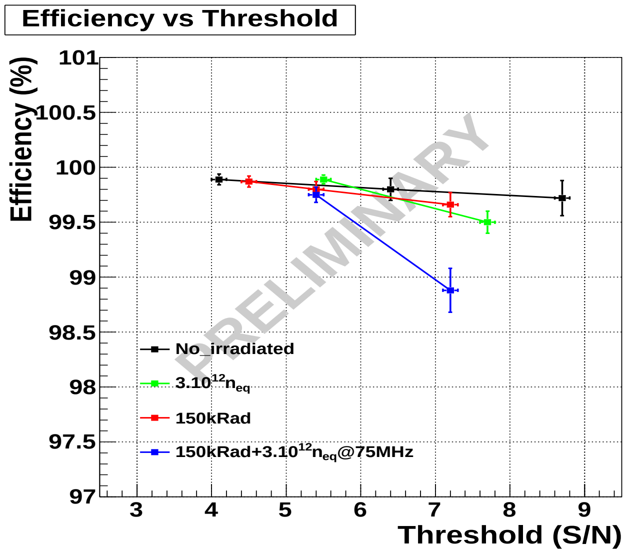




MIMOSA-22AHR S7 Pixel : Summary

- **Summary of results obtained with S7 (CS) :**
  - ⋇ evolution of detection efficiency
  - ⋇ evolution of fake hit rate
    - ↪ look for viable working point

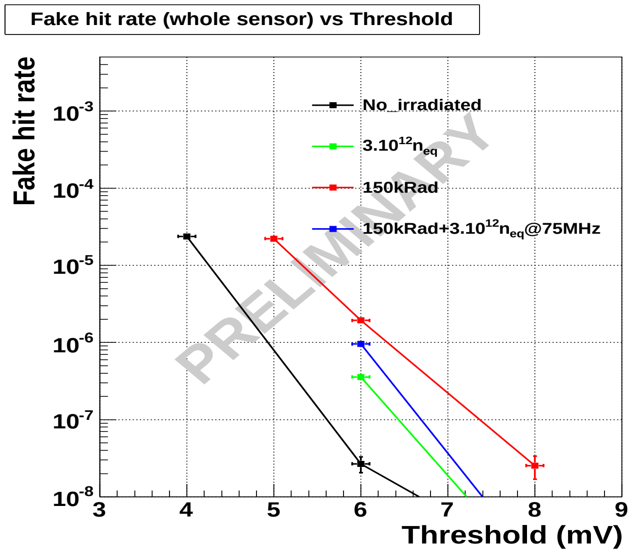


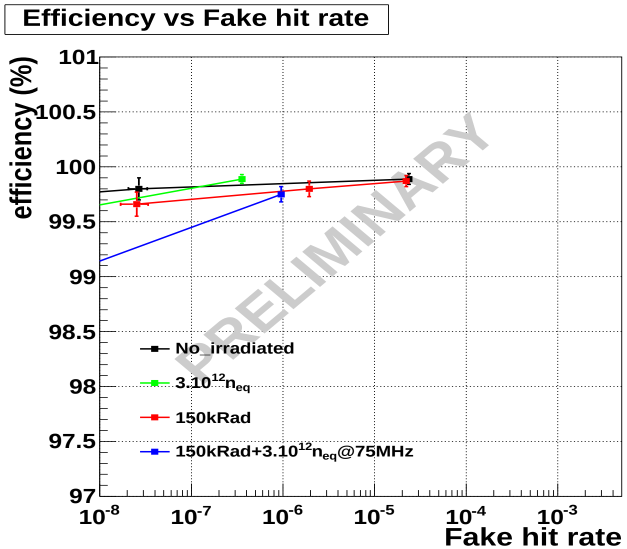


- **Results for 20.7 μm pitch pixels ▷**

  mV-SNR equivalence at 30°C

Threshold (mV) ▷	**4**	**5**	**6**	**8**
before irrad.	*4.1*		*6.4*	*8.7*
$3{\cdot}10^{12}$ n_{eq}/cm^2			*5.5*	*7.7*
150 kRad		*4.5*	*5.4*	*7.2*
combined (75 MHz)			*5.2*	*6.9*





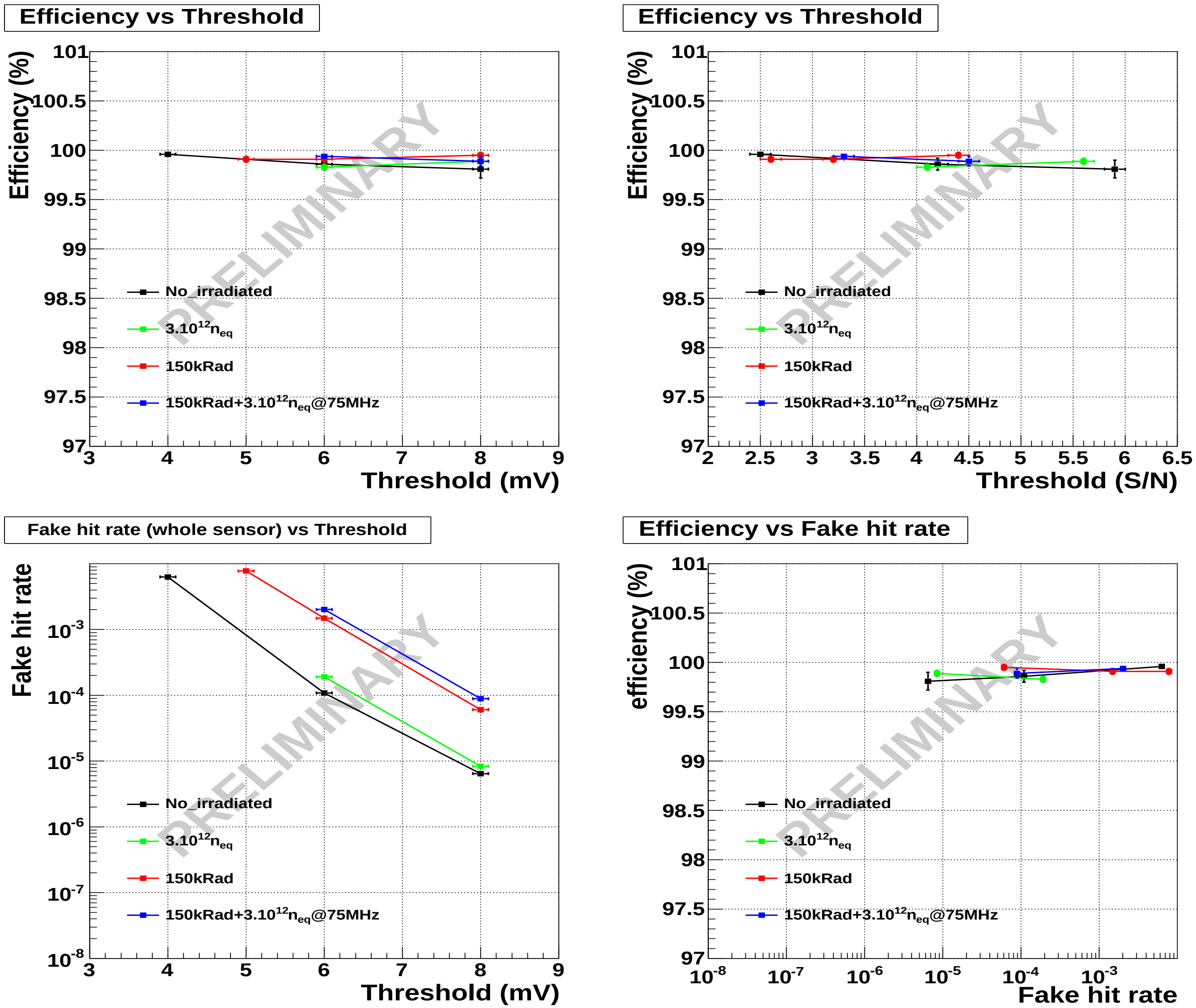
$\Rightarrow$ **No problem to find a threshold where the detection efficiency is $>$ 99.5 % while the fake hit rate remains negligible**

MIMOSA-22AHR S10 Pixel : Summary

- **Summary of results obtained with S10 (CS) :**
  - ⁂ evolution of detection efficiency
  - ⁂ evolution of fake hit rate
    - ↪ look for viable working point

- **Results for 20.7 μm pitch pixels ▷ mV-SNR equivalence at 30°C**

Threshold (mV) ▷	4	5	6	8
before irrad.	*2.5*		*4.2*	*5.9*
$3{\cdot}10^{12}$ n_{eq}/cm^2			*4.1*	*5.6*
150 kRad		*2.6*	*3.2*	*4.4*
combined (75 MHz)			*3.2*	*4.3*



⇛ **No problem to find a threshold where the detection efficiency is $>$ 99.5 % while the fake hit rate remains negligible**

SUMMARY

- **The design of ULTIMATE benefits from extensive experience and expertise gained with real scale sensors (PHASE-1, MIMOSA-26), many being thinned to 50 μm, and widely used since $\sim$ 2 years**

- **The use of a high-resistivity epitaxial layer was extensively studied**
  $\Rrightarrow$ it can reliably be used for ULTIMATE

- **Various MIMOSA-26 pixels optimised for ULTIMATE were characterised on beam with MIMOSA-22AHR irradiated with 150 kRad $\oplus$ 3·10^{12}n$_{eq}$/cm^2 and operated at 30°C and with $\sim$ 125 μs integration time**
  $\Rrightarrow$ all pixel architectures (3.3 V) satisfy the specifications in terms of detection efficiency, fake hit rate, spatial resolution, radiation tolerance (no critical path identified)
  $\hookrightarrow$ operation at 3.0 V still to be fully validated (critical elements validated independently only)

- **A slightly improved version of the MIMOSA-26 pixel (CS amplifier) was validated**
  $\Rrightarrow$ it offers the advantage of having been used on **numerous real scale** sensors (665,000 pixels)

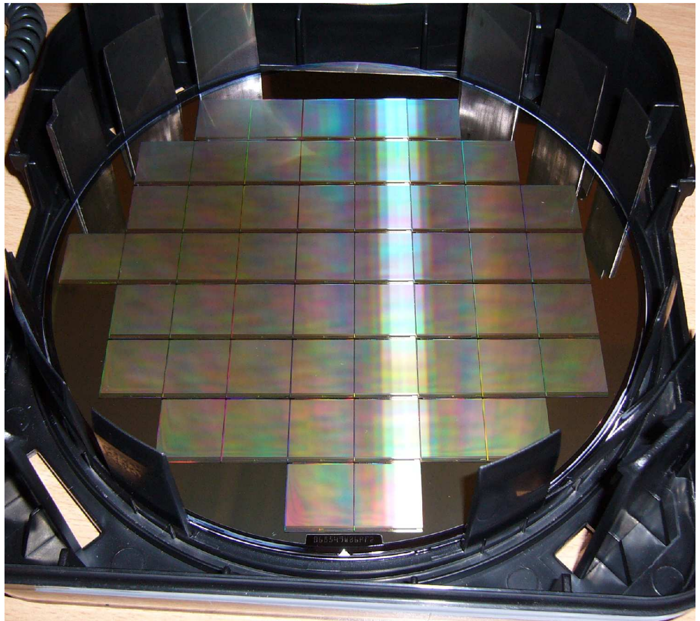
- **Details on ULTIMATE design and testing plans follow:**
  - ⋇ Overall design of upstream part (analogue and mixed circuitry) : Isabelle Valin
  - ⋇ Design of zero-suppression and data transfer : Guy Dozière
  - ⋇ Test & characterisation : Gilles Claus

BACK-UP SLIDES

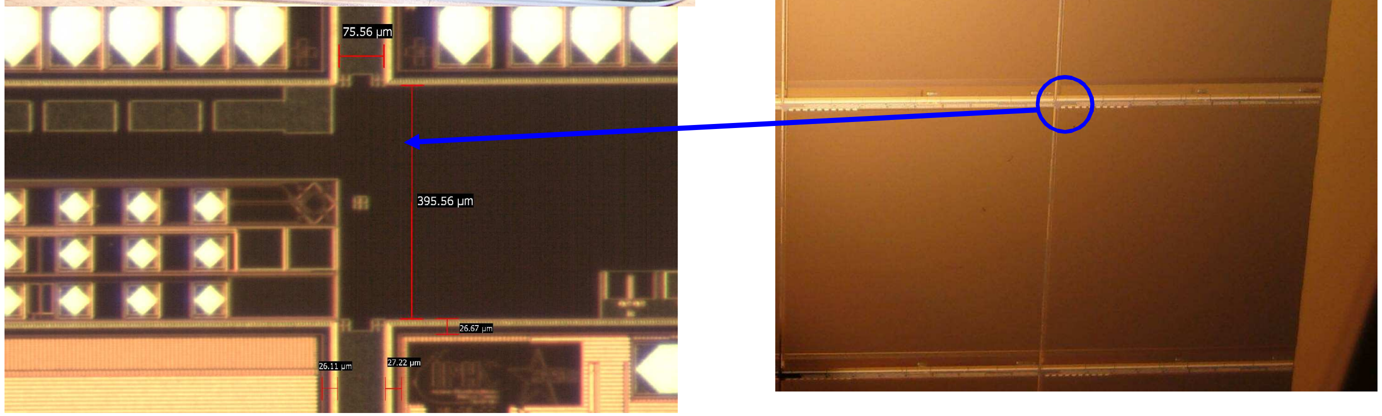
The Question of Butting

- **Motivations:**
  - simplified sensor assembly
  - reduced insensitive area
    inbetween neighbouring sensors
  - improved alignment

- **Plans with AMS-0.35 via CMP:**
  - aim for $\lesssim$ 100 μm distance between
    sensitive arrays of neighbouring chips
  - question of yield ?
  - possibility of dicing ???

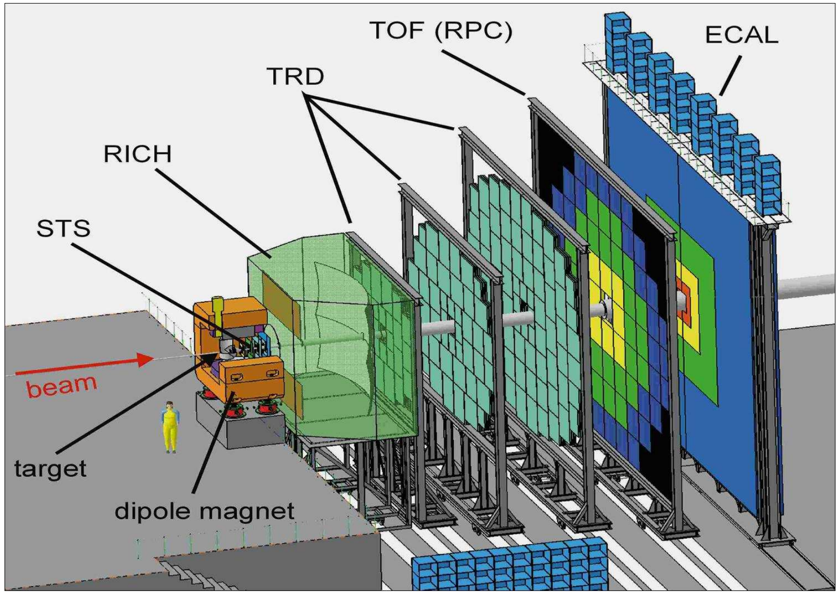


2009 wafer Mimosa23 (Phase1)
AMS 0.35

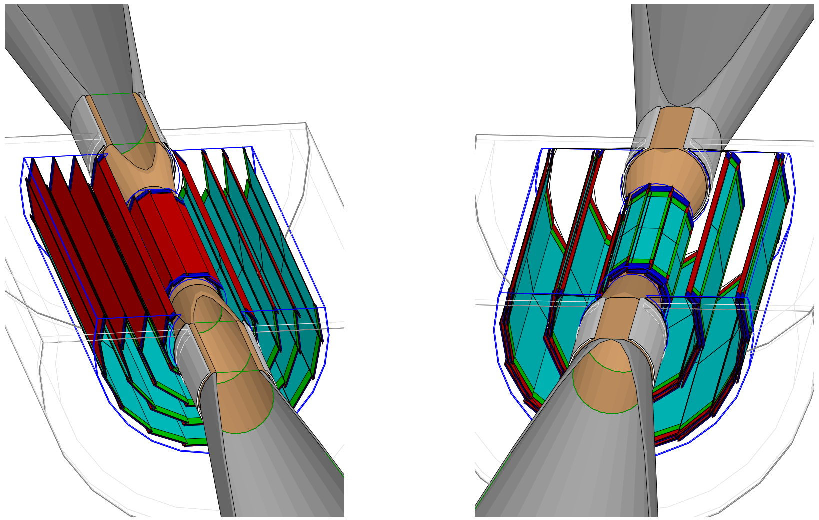


Next Extensions of MIMOSA-26

- **Vertex Detector of the CBM expt / FAIR**
  - ⋇ 2 double-sided stations operated in vacuum
  - ⋇ 0.3–0.5 % X_0 per station
  - ⋇ $\lesssim$ 5 μm single pt resolution
  - ⋇ $\lesssim$ 10 μs r.o. time
  - ⋇ several MRad & $> 10^{13}$ $n_{eq}/cm^2/s$
  - ⋇ data taking $\gtrsim$ 2016 (SIS-100) ... 2020 (SIS-300)



- **ILD Vertex Detector** (option) **:**
  - ⋇ geometry : 3 double-sided or 5 single-sided layers
  - ⋇ $\sim$ 0.2 % X_0 total material budget per layer
  - ⋇ $\sigma_{sp} \lesssim 3\ \mu m$
  - ⋇ r.o. time $\lesssim$ 25–100 μs (500 GeV)

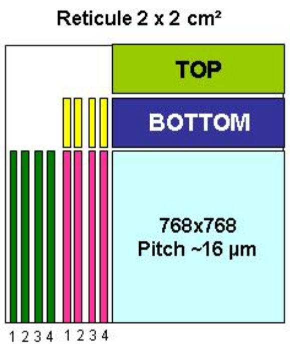


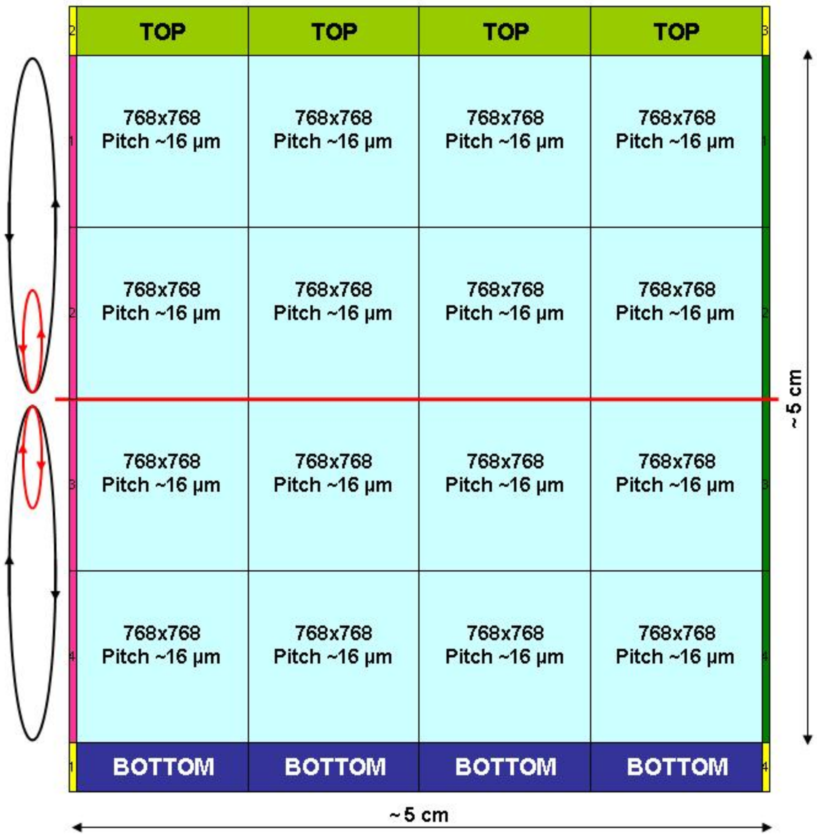
- **Other applications under consideration :**

  VD/EIC, FOCAL/ALICE, VD/CLIC, (HL-)LHC upgrades, etc.

Investigating Large Area Sensors

- **Prototype multireticule sensor for "large" area detectors:**
  - ⋇ *3072$\times$3072 pixels (16 μm pitch) $\Rrightarrow$ 5$\times$5 cm^2 sensitive area*
  - ⋇ *requires combining several reticules*
    - $\Rrightarrow$ *stitching process* $\Rrightarrow$ *establish proof of principle*
  - ⋇ *double-sided read-out of 1536 rows in 250–300 μs*
    - $\Rrightarrow$ *Large Area Telescope for AIDA project*
      (EU-FP7 approved recently)
  - ⋇ *windowing of $\lesssim$ 1$\times$5 cm^2 (collim. beam)*
    - $\Rrightarrow$ $\lesssim$ *50–60 μs r.o. time*
  - ⋇ *50-100 μm pitch variants under discussion*
    - $\Rrightarrow$ *suited to trackers & FW disks*





- **Submission expected in 2012:**
  - ⋇ bonus: avoid paving "large" areas with reticule size sensors $\Rrightarrow$ dead zones, material, connectics/complexity
  - ⋇ synergy with tracker layers and forward disk projects on collider & fixed target experiments
  - ⋇ 6 sensors will compose a beam telescope at CERN (AIDA project deliverable)
    - ▷ few ns time stamping resolution associated to each hit by TLU (scintillator)