Status and Plans of 2D Sensor Developments at IPHC

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

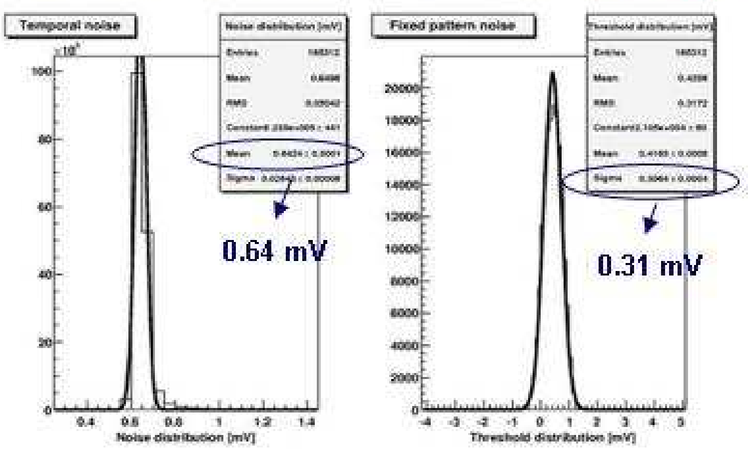
Contents

- **MIMOSA-26 :**
  - ▷ on-going performance assessment ▷ high-res AMS version
- **High-res process investigations :**
  - ▷ AMS ▷ XFAB ▷ others ?
- **Plans for 2011 $\rightarrowtail$ 2013 :**
  - ▷ CBM ▷ ILC ▷ others
- **Questions to address during this meeting**

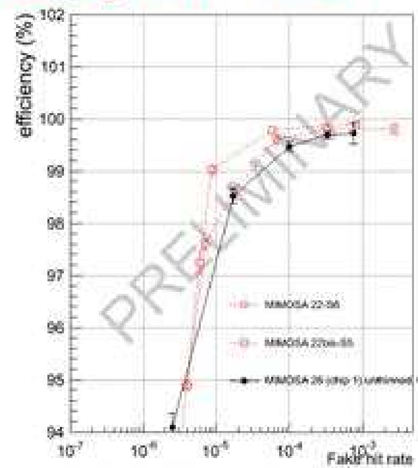
Development of CMOS Pixel Sensors for Charged Particle Tracking

- *2009, an important year for CMOS pixel sensors R&D: MIMOSA26 has been designed, fabricated and tested within the EUDET program*
- *MIMOSA26 is a reticule size MAPS with binary output, 10 k images / s*
  - *Pixel array: 1152 x 576, 18.4 µm pitch*
  - *Architecture:*
    - *Pixel (Amp+CDS) array organised in // columns r.o. in the rolling shutter mode*
    - *1152 ADC, a 1-bit ADC (discriminator) / column*
    - *Integrated zero suppression logic*
    - *Remote and programmable*

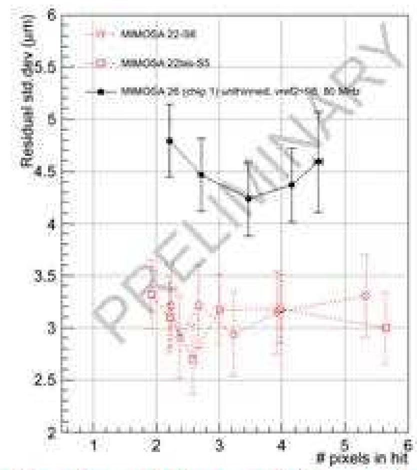
- *Lab. and beam tests: 62 chips tested, yield ~75%*



ENC ~ 13-14 e-



Efficiency 99.5% for fake rate 10^{-4}

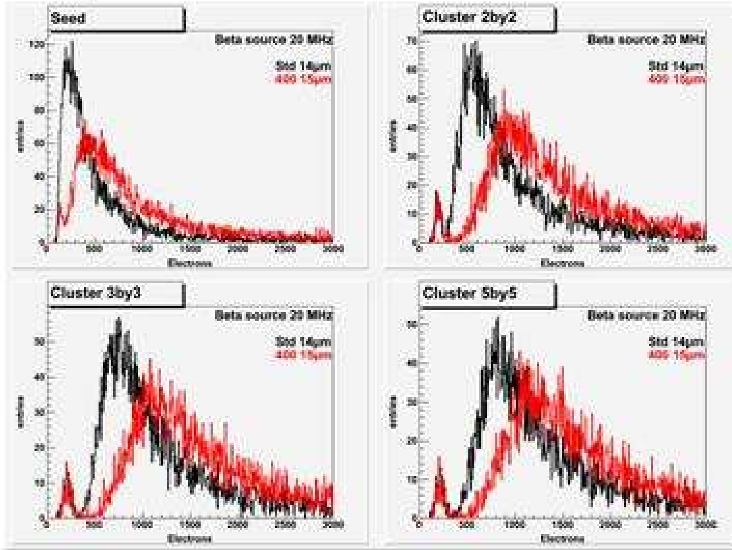


Single point resolution ~4 µm

MIMOSA26 Test

- *Standard EPI layer (fab. end 2008) v.s. high resistivity EPI layer (fab. end 2009)*
  - *Charge collection & S/N (Analogue output, Freq. 20 MHz)*

EPI layer	Standard (~10 Ω.cm) 14 μm			High resistivity (~400 Ω.cm)			
	Seed	2x2	3x3	EPI	seed	2x2	3x3
Charge Collection (^{55}Fe source)	~21%	~ 54 %	~ 71 %	10 μm	~ 36 %	~ 85 %	~ 95 %
				15 μm	~ 31 %	~ 78 %	~ 91 %
				20 μm	~ 22 %	~ 57 %	~ 76 %
S/N at seed pixel (^{106}Ru source)	~ 20 (230 e$^-$/11.6 e$^-$)			10 μm	~ 35		
				15 μm	~ 41		
				20 μm	~ 36		



  - *Radiation test under way for applications more demanding than ILC*
    - *Ionising TID: 150 K , 300 K, 1M Rad*
    - *Non Ionising NIEL: $3x10^{12}$, $6x10^{12}$, $1x10^{13}$, $3x10^{13}$ N_{eq}/cm^2*

- *MIMOSA26 can be operated at a high readout speed*
  - *Clock frequency: from 80 $MHz_{typ.}$ (~110 μs) up to 110 MHz (~80 μs)*

➔ *MIMOSA26: design base line for STAR Vx upgrade, CBM MVD*
Its performances are close to the ILD vertex detector specifications

Mimosa26HR, batch 2010

- Preliminary results
  - Standard epi. layer
  - 10 µm, 15 µm and 20 µm 400 Ω.cm EPI Layer
- Before irradiation

Analog calibration with X ^{55}Fe source, F=20 MHz, T=20°C, VDDA =3 V
* Calibration with beta ^{106}Ru source

Epi.Layer	Noise (e-)	Cal.Peak (ADC u.)	Seed Pixel (%)	Cluster 3x3 (%)	S/N*
Standard	11.8	358	21	73	21
10 µm	11.7	363	36	96	35
15 µm	11.8	375	32	92	41
20 µm	11.8	376	22	77	36

- After non-ionizing irradiation at 6 10^{12} n_{eq}/cm^2

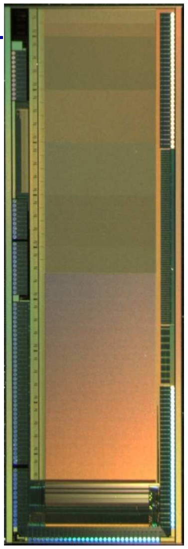
Analog calibration, F=20 MHz, T=15°C, VDDA =3.3 V
* Calibration with beta ^{106}Ru source

Epi.Layer	Noise (e-)	Cal.Peak (ADC u.)	Seed Pixel (%)	Cluster 3x3 (%)	S/N*
Standard	12.6	387	15	47	10.7
10 µm	13.8	381	34	87	22
15 µm	15.7	385	30	85	28

High Resistivity Sensitive Volume: Recent Step

- **Motivations for improving the MIMOSA-26 design :**
  - ⋇ validation of High-Res substrate against latch-up
  - ⋇ higher depletion voltage (SNR, rad. tol.): 0.7 V $\rightarrowtail$ $\lesssim$ 2 V
  - ⋇ larger pitch (power dissipation, speed) for STAR-PIXEL : 18.4 μm $\rightarrowtail$ 20.7 $\mu m \Rrightarrow$ validate
  - ⋇ higher in-pixel amplification (SNR, rad. tol.) $\Rrightarrow$ less sensitivity to FPN
- **Engineering run submitted April 14th shared with IRFU $\Rrightarrow$ back from foundry end of June**
  - ▷ delay generated by High-Res unavailability

Generic name	X(mm)	Y(mm)	Description
TopLatchUp-AHR	2.07	2.35	Test structure: Anti-latchup digital cells
Memory	3.01	3.08	Test structure: Anti-latchup memory cells
MIMOSA-18AHR	5.70	6.50	Pixels with 10, 12 and 25 μm pitch
MIMOSA-22AHR	3.70	13.00	M-22 replica, 18.4μm pitch, 128 col. with discri. ▷▷▷



▷▷▷ 3 epitaxial layer thicknesses: 10, 15 and 20 μm

- **Essential input for ULTIMATE design optimisation:**
  - ⋇ lab tests in Summer
  - ⋇ beam tests (CERN-SPS) in August : tight schedule ! $\Rrightarrow$ flexibility in ULTIMATE submission date ?

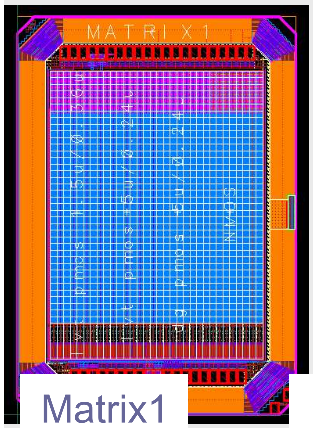
On-Going Performance Assessment

- **Still under evaluation :**
  - lowest Vdd value
  - highest read-out frequency (beam tests)
  - radiation tolerance
  - SNR vs operating temperature
  - surface temperature (vs time)

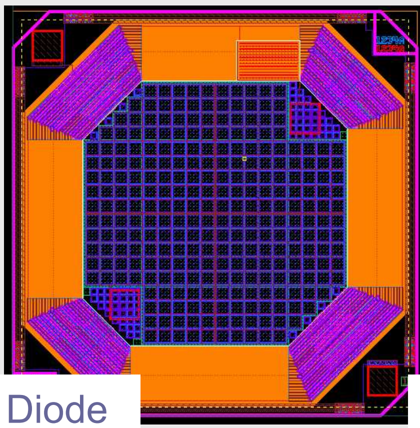
R&D PLANS until 2011/13

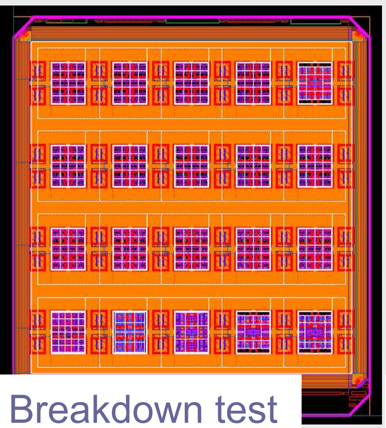
LePIX: monolithic detectors in advanced CMOS

- Submission for fabrication just finalized
  - Several issues: ESD, special layers and mask generation, guard rings
  - Still need to discuss some outstanding fabrication issues with IBM
- 7 chips submitted :
  - 4 test matrices
  - 1 diode for radiation tolerance
  - 1 breakdown test structure
  - 1 transistor test: already submitted once in test submission
- Will require very significant testing effort for which we need to prepare (measurement setup, test cards…)



Matrix1


Diode

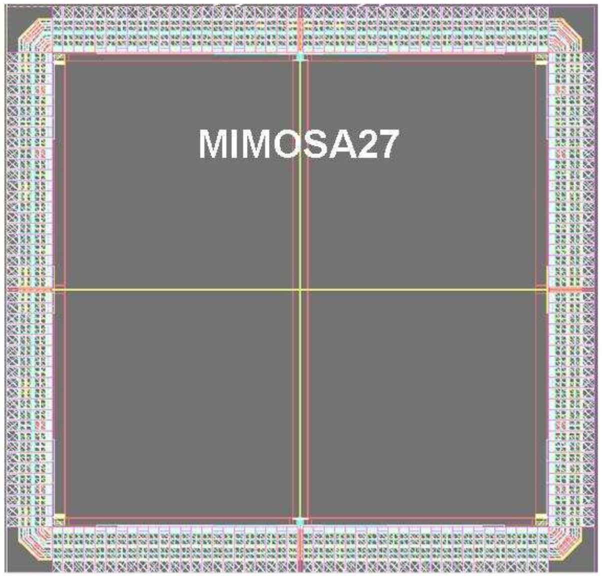

Breakdown test


Transistor test

MIMOSA-27 : First sensor in 0.18 μm technology

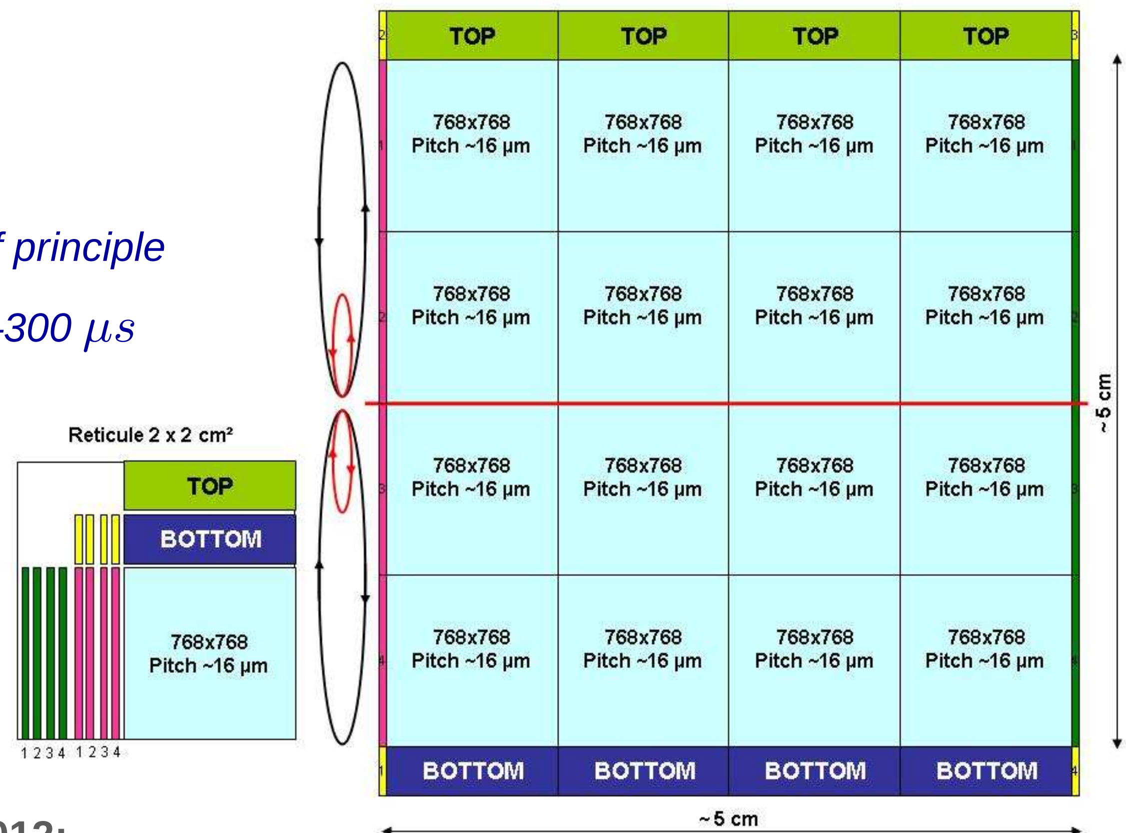
- **Advantages expected from smaller feature size:**
  - ⋇ *higher operation speed inside chip*
  - ⋇ *reduced digital design surface*
  - ⋇ *reduced power consumption*
  - ⋇ *more metal layers for interconnections* $\Rrightarrow$ *reduced peripheral (insensitive) area*

- **MIMOSA-27 $\equiv$ 1st sensor in 0.18 μm techno. (5 ML) $\Rrightarrow$ submitted on April 9th:**
  - ⋇ 4 sub-arrays of 64x64 pixels with 20 μm pitch
  - ⋇ up to 16 options:
    - ◇ diode size and type of configuration
    - ◇ 3T and self-bias
    - ◇ in-pixel amplification
  - ⋇ prominent studies motivating the submission:
    - ◇ charge collection efficiency (10 μm thin epitaxy)
    - ◇ technology features
    - ◇ SNR
    - ◇ radiation tolerance
    - ◇ ......



Investigating Large Area Sensors

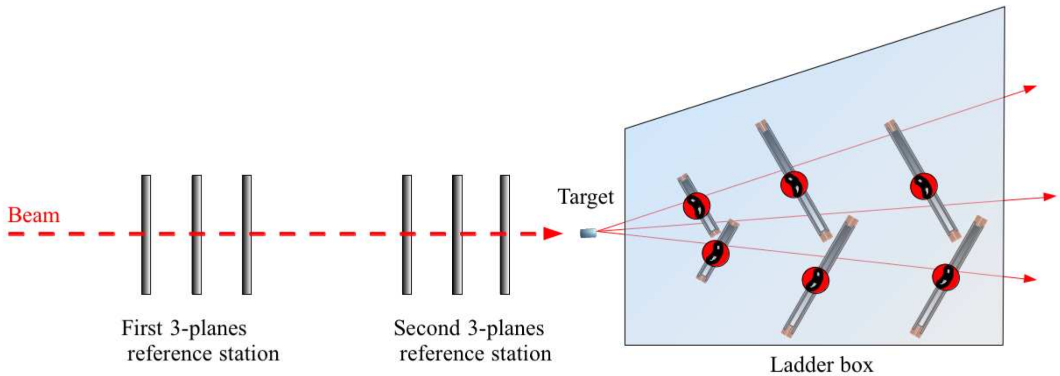
- **Prototype multireticule sensor for large area stations:**
  - ⋇ *3072$\times$3072 pixels (16 μm pitch)*
    $\Rrightarrow$ *5$\times$5 cm^2 sensitive area*
  - ⋇ *requires combining several reticules*
    $\Rrightarrow$ *stitching process* $\Rrightarrow$ *establish proof of principle*
  - ⋇ *double-sided 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*

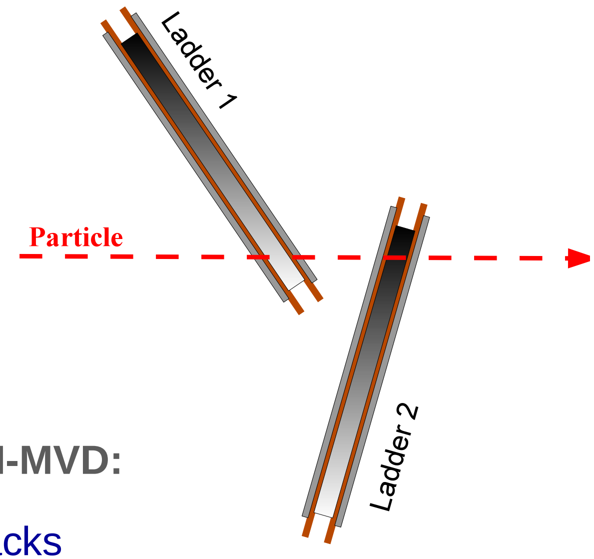


- **Submission expected end fo 2011 or early 2012:**
  - ⋇ bonus: avoid paving MVD with reticule size sensors $\Rrightarrow$ dead zones, material, connectics/complexity
  - ⋇ synergy with forward disk projects on collider experiments (e.g. EIC project at BNL)
  - ⋇ 6 sensors will compose a beam telescope at CERN (AIDA project deliverable)
    - ▷ few ns time stamping resolution associated to each hit by TLU (scintillator)

VTX Oriented Infrastructures Proposed for AIDA

- AIDA $\equiv$ EU FP-7 Integrated Infrastructure project : approved in March 2010
- **On-beam (CERN-SPS) test infrastructure (contents still under discussion):**
  - ⋇ Large Area beam Telescope (LAT) :
    - ◇ LAT demonstrator : based on 2 arms of 3 ULTIMATE sensors
    - ◇ final LAT : 5$\times$5 cm^2 sensor (16 μm pitch) using stitching
  - ⋇ Alignment Investigation Devices (AID):
    - ◇ box hosting pairs of ladders (PLUME) and unsupported pixelated systems (HP-2)
    - ◇ box front panel contains removable target





- **Work program topics ▷▷▷ motivated by ILD-DBD and CBM-MVD:**
  - ⋇ alignment capabilities: dedicated equipment and particle tracks
  - ⋇ vertex reconstruction accuracy
  - ⋇ track reconstruction with different devices (high spatial resolution combined with fast detectors)

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Sensor Development Plans until 2013 (incomplete)

- **Driving applications :**
  - Expts : STAR, FIRST, CBM, ILD, ALICE, eIC, CLIC
  - EU projects: EUDET, HP-2, AIDA, HP-3 (proposal)
  - R&D on 2D-sensors, 3D-sensors, 2-sided ladders, unsupported ladders
- **CBM-MVD :**
  - MIMOSIS-100 : 3 prototypes (2010, 2011, 2013) to finalise sensor design for 2014
  - specs: 5 μm, $\leq$ 50 μm, $\leq$ 40 μs, 10^{14} n_{eq}/cm^2, few MRad
  - R&D on: 2-sided read-out, radiation-tolerance, multi-Suze design
  - prototype fab (XFAB-0.35 HR): intermediate proto. mid-April '10, final proto. end '12, prod. end '13
- **ILD-VTX :**
  - Detector Baseline Document ($\lesssim$ TDR) to be delivered by end of 2012
  - 2-sided r.o. with 16μm pitch proto. (XFAB-0.35) to be submitted mid-April '11
  - pixel array with columns ended with 4-bit ADC to be submitted in Q3 ('11)
  - M-22 like sensor in XFAB-0.18 with 2-sided r.o. and 14μm pixel pitch to be submitted in Q1 ('12)
- **Others :**
  - anti-latchup memory (XFAB-0.35 HR) : to be submitted Q4('10) or Q1('11)
  - 3D sensors: next submission early 2011
  - etc.

Some of the Questions to Address during the Meeting

- latch-up tests: who, where, when ?
- design review : where, when, reviewers ?
- ULTIMATE production procedure (steps ? wafers ?) and time line (hard limit ?)
- 50 μm butting: any interest ?
- next DoE review : when, IPHC representation ?
- next face-to-face meeting: when ?
- ULTIMATE-2 as a back-up ?