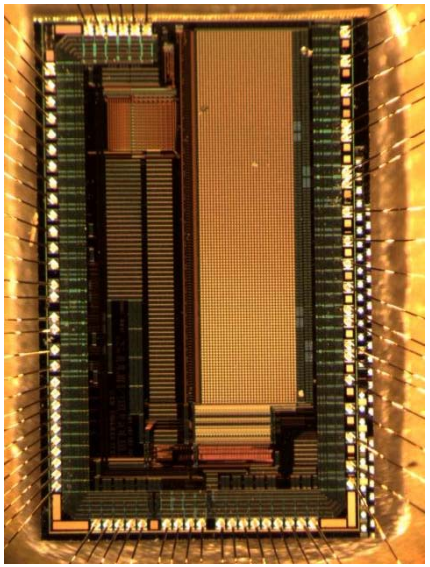
Mimosa 16: « final results » 14 & 20 µm
Mimosa 18: preliminary results

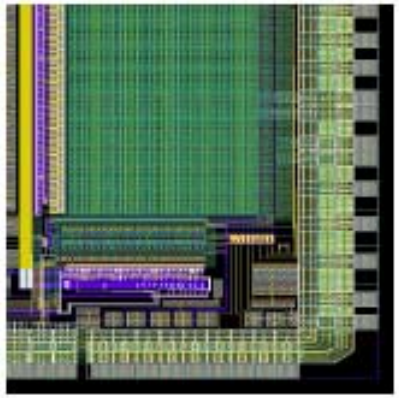
A.B. on behalf of IPHC-Strasbourg/CEA-Saclay

- Mimosa-16 14 µm and 20 µm – digital and analog output
- Mimosa 18

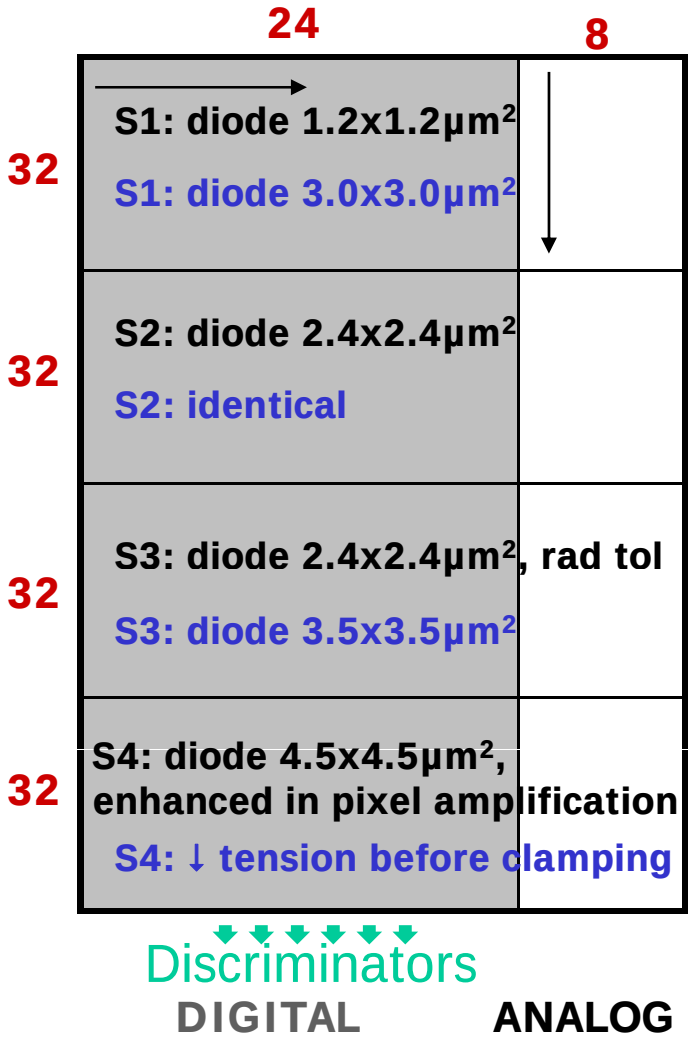
Mimosa 16

- M16 – M16 bis
  - « translation » of M8 in AMS 0.35 µm opto
  - Pitch = 25 µm
  - On pixel CDS
  - Column // read-out
  - Discri @ end of each column
  - 2 epitaxial thicknesses
    - « 14 » & « 20 » µm (actually ~ 11 & 15)



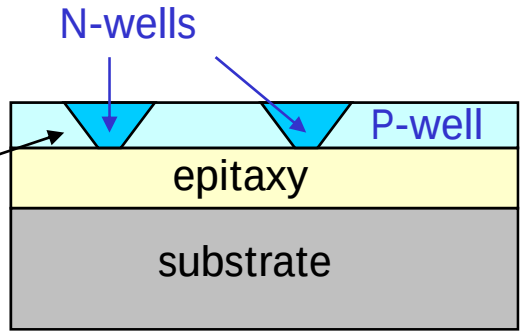


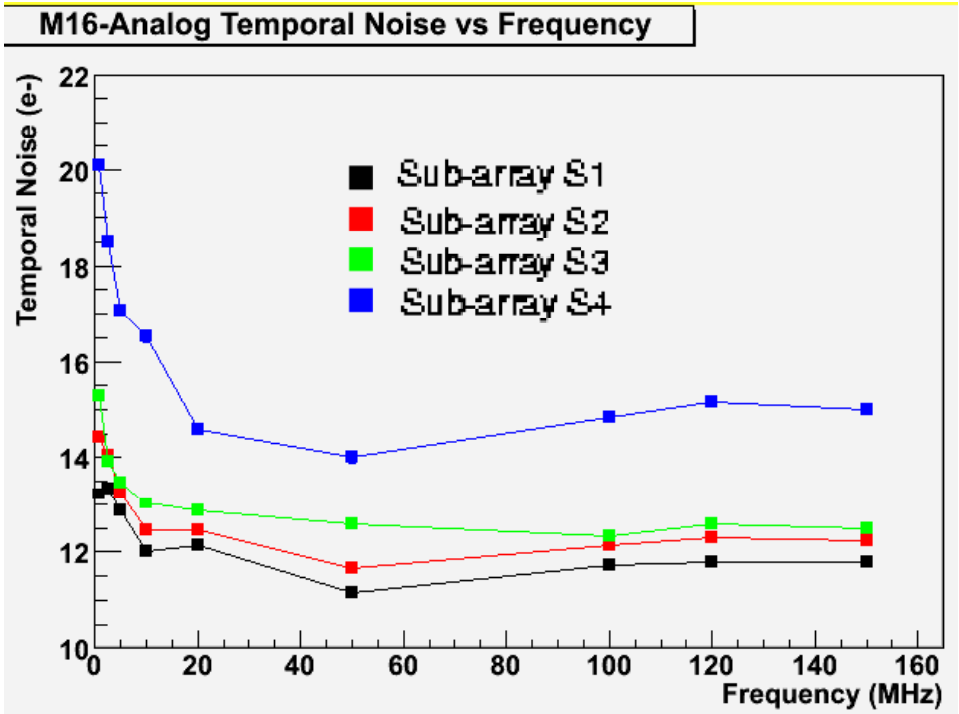
mimosa 16 / mimosa 16 bis



Mimosa 16 lab-tests

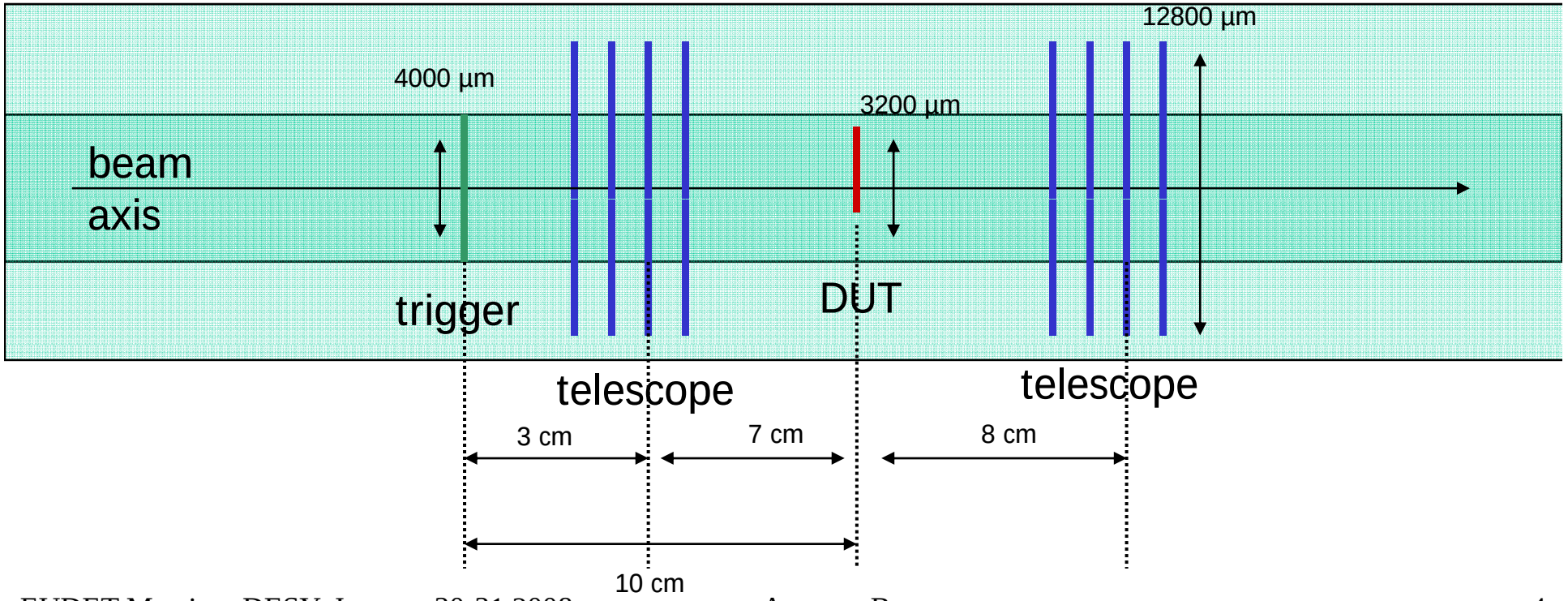
- Pixel noise and charge collection efficiency
  - Noise: ~ like M8 and M15
  - CCE: poor for small diodes
    - (supected origin: diffusion of P-well, reducing the N-Well/epitaxy contact).





test beam conditions

- CERN SPS:
  - 120 GeV pions beam, burst: 4.8 s + 12 s dead time
- DAQ:
  - trigger: 2000-4000 events/burst
  - data: 600 recorded events/burst
  - read-out freq:
    - analog: 2.5 MHz (50 µs read-out time)
    - digital: 20 MHz by 8 columns (50 µs read-out time)



Mimosa-16 14 µm – digital
Test beam

MIMOSA 16 « 14µm » DIGITAL

- Running @ different Discri thresholds (mV)
  - Efficiency
  - Multiplicity
  - Fake rate
  - Resolution

- Pure digital position:
  pitch / √12 = 7.2 µm
  Center of Gravity method:
  ~< 5 µm

0	0	0	0	0
0	0	1	0	0
0	1	1	1	0
0	1	1	0	0
0	0	0	0	0

Th.	Resolution (μm)							
	S1		S2		S3		S4	
	U	V	U	V	U	V	U	V
3.0	N.A.	N.A.	6.41±0.06	6.56±0.07	6.69±0.06	6.38±0.07	6.01 ±0.07	5.60±0.07
3.5	N.A.	N.A.	6.21±0.06	6.09±0.06	6.48±0.06	6.11±0.06	5.74 ±0.06	5.24±0.06
4.0	N.A.	N.A.	5.93±0.05	5.80±0.05	6.05±0.05	6.09±0.05	5.04 ±0.06	4.74±0.05
4.6	N.A.	N.A.	5.74±0.05	5.76±0.06	6.02±0.06	6.00±0.06	4.96 ±0.05	4.64±0.05
5.0	N.A.	N.A.	5.71±0.06	5.71±0.06	5.66±0.05	5.79±0.05	4.88 ±0.05	4.68±0.05
6.0	N.A.	N.A.	5.77±0.07	5.64±0.06	5.59±0.06	5.71±0.07	4.64 ±0.05	4.64±0.06
7.0	N.A.	N.A.	5.60±0.07	5.55±0.06	5.52±0.06	5.51±0.06	4.75 ±0.05	4.68±0.05
7.8	N.A.	N.A.	5.52±0.08	5.42±0.08	5.46±0.09	5.40±0.09	4.91 ±0.05	4.70±0.06
10.0	N.A.	N.A.	5.10±0.13	5.02±0.12	5.00±0.11	5.50±0.13	5.13 ±0.07	5.14±0.07

TAB. *4 – Digital : Resolutions pour MIMOSA-16 "14 µm"*

Threshold	Efficiency (%)			
(mV)	S1	S2	S3	S4
3.0 ± 0.10	21.86 ± 1.71	99.68 ± 0.07	99.08 ± 0.11	99.94 ± 0.04
3.5 ± 0.10	9.43 ± 1.21	99.07 ± 0.11	98.16 ± 0.15	99.96 ± 0.03
4.0 ± 0.10	6.33 ± 0.95	95.63 ± 0.25	92.33 ± 0.28	99.96 ± 0.03
4.6 ± 0.10	4.70 ± 0.90	90.69 ± 0.36	85.69 ± 0.40	99.94 ± 0.03
5.0 ± 0.10	3.44 ± 0.66	84.98 ± 0.45	78.66 ± 0.47	99.88 ± 0.05
6.0 ± 0.10	2.68 ± 0.47	72.68 ± 0.59	65.61 ± 0.62	99.79 ± 0.07
7.0 ± 0.10	1.54 ± 0.42	57.66 ± 0.63	51.87 ± 0.58	99.19 ± 0.13
7.8 ± 0.10	1.09 ± 0.16	44.87 ± 0.66	39.90 ± 0.74	98.43 ± 0.19
10.0 ± 0.10	0.05 ± 0.30	27.95 ± 0.74	24.40 ± 0.57	94.34 ± 0.41

TAB. *2 – Digital : Efficacités de détection pour MIMOSA-16 "14 µm"*

Threshold	Average Multiplicity			
(mV)	S1	S2	S3	S4
3.0±0.10	1.81±0.06	5.75±0.07	4.96±0.06	7.43±0.11
3.5±0.10	1.91±0.08	4.88±0.06	4.25±0.05	6.22±0.09
4.0±0.10	2.07±0.10	3.48±0.04	3.11±0.03	5.14±0.07
4.6±0.10	1.87±0.14	2.98±0.04	2.69±0.03	4.46±0.06
5.0±0.10	2.04±0.16	2.67±0.04	2.46±0.03	4.00±0.06
6.0±0.10	1.84±0.18	2.24±0.03	2.18±0.04	3.57±0.06
7.0±0.10	1.62±0.19	2.04±0.03	1.96±0.03	2.88±0.04
7.8±0.10	1.96±0.29	2.00±0.04	1.96±0.05	2.54±0.04
10.0±0.10	1.96±0.29	1.88±0.06	1.87±0.05	2.14±0.04

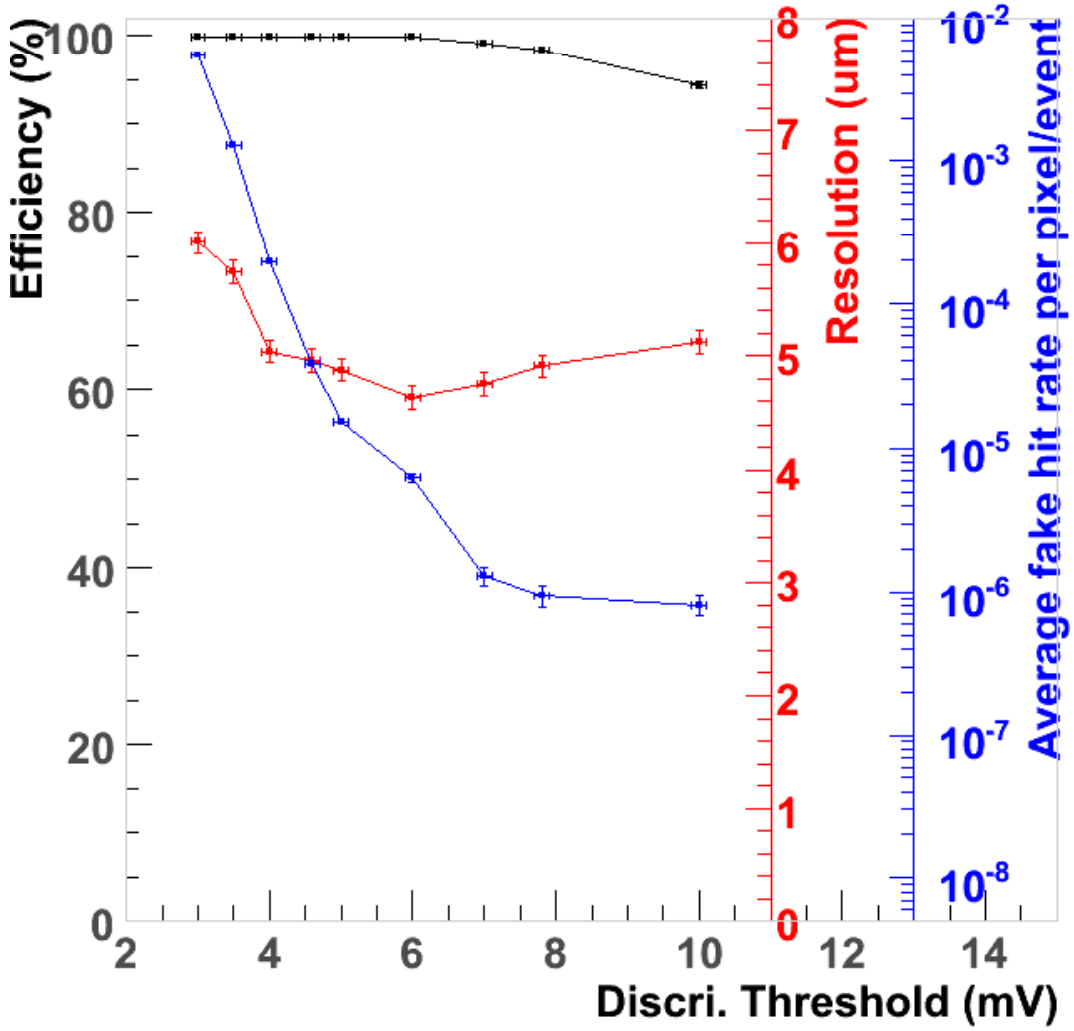
TAB. *5 – Digital : Average hit multiplicity pour MIMOSA-16 "14 µm"*

Threshold	Fake rate /event/pixel			
(mV)	S1	S2	S3	S4
3.0±0.10	N.A.	7.56E-04±4.30E-06	7.65E-04±4.33E-06	5.51E-03±1.16E-05
3.5±0.10	N.A.	1.84E-04±2.30E-06	2.97E-04±2.92E-06	1.30E-03±6.11E-06
4.0±0.10	N.A.	1.41E-05±6.62E-07	3.55E-05±1.05E-06	1.94E-04±2.46E-06
4.6±0.10	N.A.	2.09E-06±2.47E-07	7.93E-06±4.82E-07	3.82E-05±1.06E-06
5.0±0.10	N.A.	1.75E-06±2.48E-07	3.27E-06±3.40E-07	1.53E-05±7.35E-07
6.0±0.10	N.A.	1.24E-06±1.70E-07	9.58E-07±1.49E-07	6.29E-06±3.82E-07
7.0±0.10	N.A.	4.92E-07±1.11E-07	5.95E-07±1.22E-07	1.30E-06±1.81E-07
7.8±0.10	N.A.	2.19E-07±7.61E-08	3.83E-07±1.01E-07	9.35E-07±1.57E-07
10.0±0.10	N.A.	3.68E-07±9.34E-08	3.43E-07±9.03E-08	8.12E-07±1.39E-07

TAB. *6 – Digital : Fake rate / pixel /event pour MIMOSA-16 "14 µm"*

MIMOSA 16 « 14µm » DIGITAL

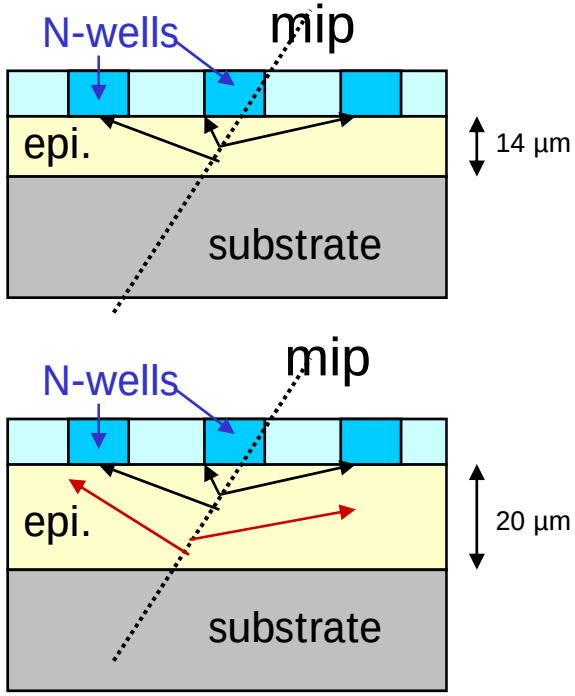
- S4: discri threshold optimal range
  - 4.6 mV:
    - eff = 99.94± 0.03
    - fake ~ 4 x 10^{-5}
    - Resolution ~ 5 µm
  - 5 mV:
    - eff = 99.88± 0.05
    - fake ~ 1.5 x 10^{-5}
    - Resolution ~ 5 µm
  - 6 mV
    - eff = 99.79± 0.07
    - fake ~ 6 x 10^{-6}
    - Resolution ~< 5 µm



Mimosa-16 20 µm - digital

Mimosa-16 20 µm - digital

- Efficiency
  - Roughly the same
- Multiplicity
  - A bit higher
  (thermal diffusion wider)
- Fake rate
  - ~ identical
- Resolution
  - ~ identical



Residual (µm)

Th.		
	S4	
	U	V
3.5	5.69 ±0.10	5.95±0.10
4.0	5.29 ±0.06	4.96±0.06
5.0	4.73 ±0.06	4.86±0.06
6.0	4.84 ±0.06	4.68±0.06
7.0	4.88 ±0.05	4.58±0.05
8.0	4.95 ±0.05	4.78±0.05

Threshold	Average Multiplicity			
(mV)	S1	S2	S3	S4
3.5±0.10	2.30±0.15	4.89±0.07	4.28±0.06	9.58±0.19
4.0±0.10	2.30±0.16	3.65±0.05	3.21±0.04	6.88±0.10
5.0±0.10	3.23±0.59	2.85±0.04	2.55±0.04	6.01±0.10
6.0±0.10	1.65±0.19	2.45±0.04	2.28±0.03	4.43±0.07
7.0±0.10	1.48±0.19	2.22±0.04	2.12±0.04	3.49±0.05
8.0±0.10	1.56±0.28	2.10±0.04	2.12±0.04	3.08±0.04

TAB. *11 – Digital : Average hit multiplicity pour MIMOSA-16 "20 µm"*

Threshold	Efficiency (%)			
(mV)	S1	S2	S3	S4
3.5 ± 0.10	9.79 ± 0.62	98.93 ± 0.15	96.92 ± 0.24	99.79 ± 0.09
4.0 ± 0.10	4.48 ± 0.31	94.62 ± 0.30	88.45 ± 0.37	99.89 ± 0.05
5.0 ± 0.10	5.24 ± 0.93	81.84 ± 0.50	73.73 ± 0.55	99.94 ± 0.04
6.0 ± 0.10	1.82 ± 0.20	67.88 ± 0.60	59.34 ± 0.56	99.71 ± 0.08
7.0 ± 0.10	1.25 ± 0.16	48.06 ± 0.67	41.26 ± 0.56	99.45 ± 0.11
8.0 ± 0.10	0.63 ± 0.11	37.44 ± 0.56	31.58 ± 0.49	98.55 ± 0.17

TAB. *9 – Digital : Efficacités de détection pour MIMOSA-16 "20 µm"*

Threshold	Fake rate /event/pixel			
(mV)	S1	S2	S3	S4
3.5±0.10	N.A.	2.35E-04±2.87E-06	1.16E-04±2.02E-06	2.36E-03±9.10E-06
4.0±0.10	N.A.	2.48E-05±8.43E-07	8.10E-06±4.81E-07	2.16E-04±2.48E-06
5.0±0.10	N.A.	1.89E-06±2.04E-07	1.46E-06±1.79E-07	8.79E-05±1.39E-06
6.0±0.10	N.A.	1.16E-06±1.53E-07	1.06E-06±1.46E-07	8.98E-06±4.25E-07
7.0±0.10	N.A.	1.02E-06±1.48E-07	7.97E-07±1.31E-07	1.51E-06±1.80E-07
8.0±0.10	N.A.	5.65E-07±1.19E-07	6.94E-07±1.31E-07	1.59E-06±1.99E-07

TAB. *12 – Digital : Fake rate / pixel /event pour MIMOSA-16 "20 µm"*

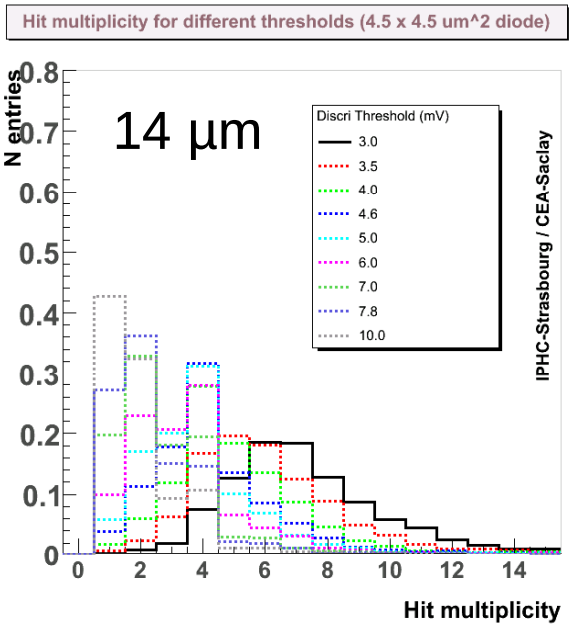
Mimosa-16 14 & 20 µm – digital :
multiplicity (2 pixels in cluster).

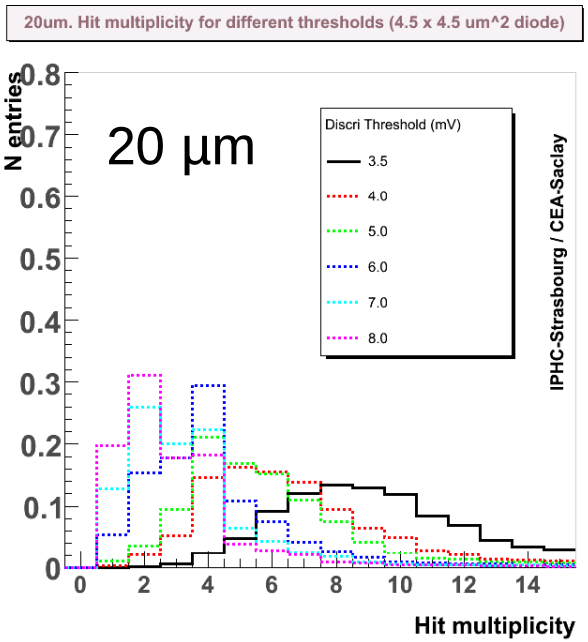
Mimosa-16 14 & 20 µm – digital : multiplicity

- Can we take advantage of the highest multiplicity ?
  - Hit selection with at least 2 pixels in clusters

0	0	0	0	0
0	0	1	0	0
0	1	1	1	0
0	1	1	0	0
0	0	0	0	0

0	0	0	0	0
0	0	0	0	0
0	0	1	0	0
0	0	0	0	0
0	0	0	0	0





Optimal threshold range:

3.5 mV

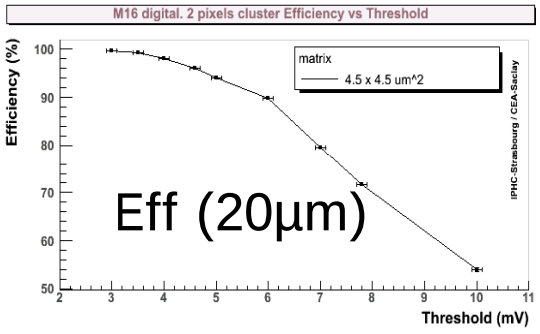
eff = 99.79± 0.09

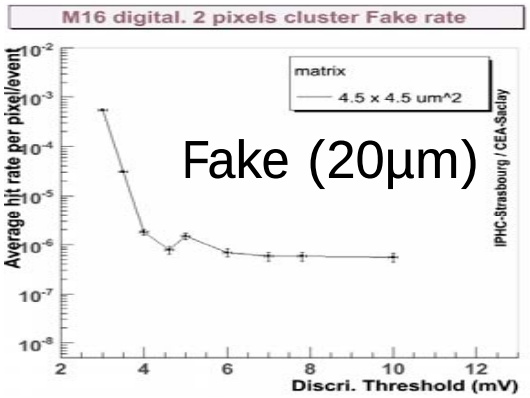
fake ~ 1 x 10^{-4}

4 mV

eff = 99.63± 0.05

fake ~ 3 x 10^{-6}





- Doesn't improve performances
- But might be interesting for smaller pitch

M16 digital: global comparison

- DIGITAL
  - 14 µm > 20 µm
  - 1 pixel > 2 pixels
- ANALOG
  - S/N(MPV) ~16-17

Chip	cluster	Threshold (mV)	Eff (%)	Fake rate
14 µm	1 pixel	4.6	99.94±0.03	4×10^{-5}
14 µm	1 pixel	5	99.88±0.05	1.5×10^{-5}
14 µm	1 pixel	6	99.79±0.07	6×10^{-6}
14 µm	2 pixels	3	99.66±0.04	5×10^{-4}
20 µm	1 pixel	4	99.89±0.05	2×10^{-4}
20 µm	1 pixel	5	99.94±0.04	9×10^{-5}
20 µm	1 pixel	6	99.71±0.08	9×10^{-6}
20 µm	2 pixels	3.5	99.79±0.09	1×10^{-4}
20 µm	2 pixels	4	99.63±0.05	2×10^{-6}

Chip	Run	Mtx	Eff(%)	Residu		S/N(MPV)	N	Fake	Ch 1	Ch 9	Ch 25
2 ($14\mu m$)	16503	S4	99.65±0.18	2.1	2.3	16.6±0.3	14.9		244	731	781
2 ($14\mu m$)	16509	S4	99.93⊥0.07	2.4	2.5	17.1⊥0.3	14.7		252	734	793
12 ($14\mu m$)	16526	S4	99.85±0.11	2.5	2.4	15.3±0.3	15.4		240	712	746
4 ($14\mu m$)	16532	S4	99.75±0.15	2.4	3.0	17.4±0.3	14.6		260	744	811
10 ($20\mu m$)	16510	S4	99.90±0.10	2.2	2.3	16.6±0.3	14.6		253	850	1002

TAB. *15 – Analogique : résumé. Charges en électrons, résidus en µm.*

Mimosa 18

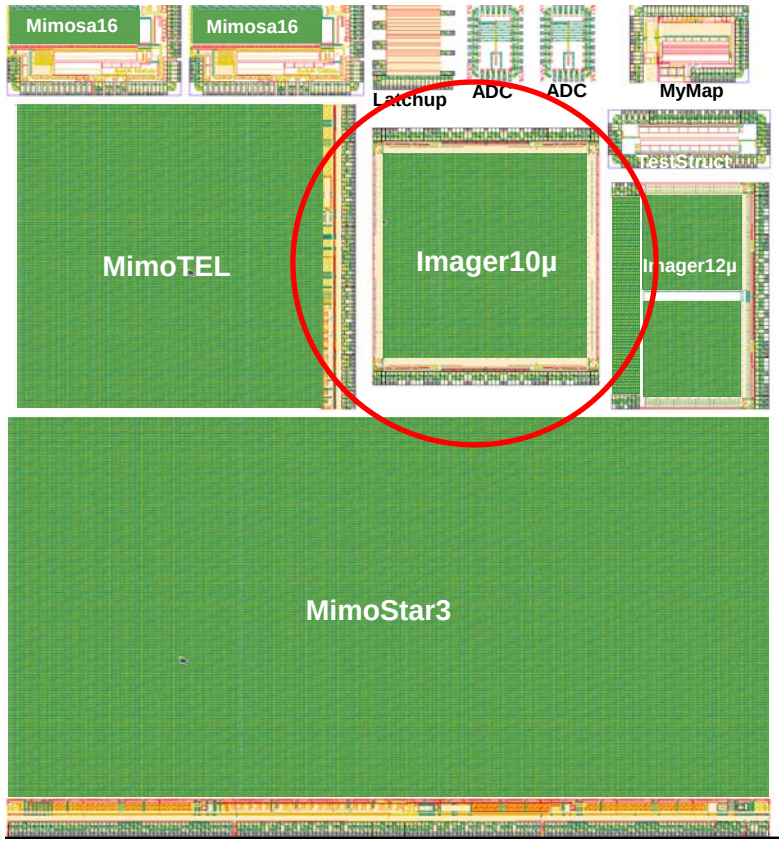
Test beam:

Jérôme Baudot, Gilles Claus, Rita De Masi, Christina Dritsa, Wojciech Dulinski, Mathieu Goffe , Yolanta Sztuk-Dambietz.

- Thinning
- Efficiency
- Resolution

Mimosa 18

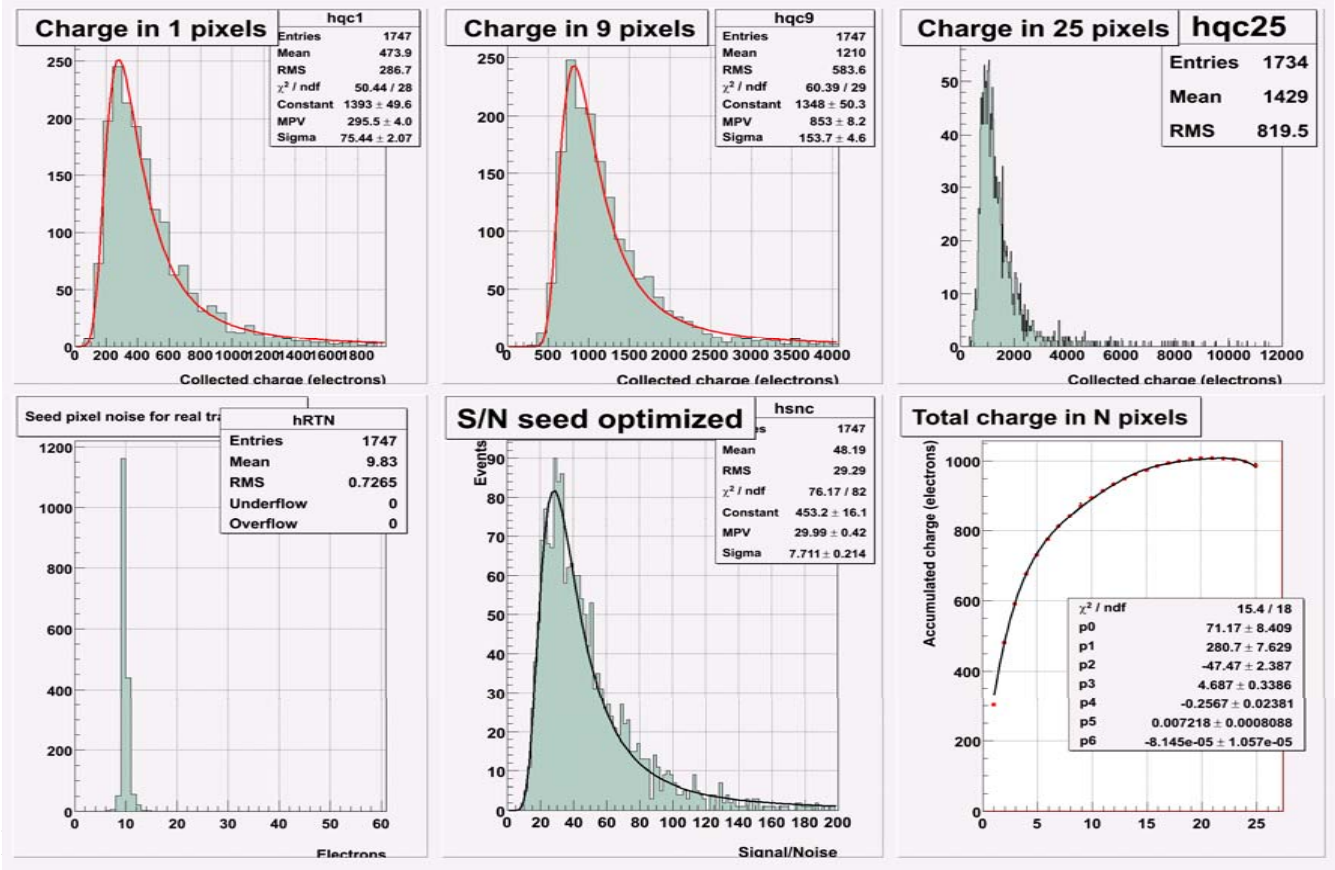
- High resolution sensor using AMS 0.35 µm OPTO CMOS process from IPHC 2006 engineering submission. Two types of epitaxy thickness: 14 µm and 20 µm



- **Pixel pitch: 10 µm**
- **2-transistors circuit, continuously biased diode**
- **Array size 512x512 pixels**
- **Active surface: 5x5 mm²**
- **Readout clock: 25 MHz max**
- **Integration time: 3 ms (four parallel output channels)**
- **Dark current < 1fA @room temperature**
- **Excellent yield: (100%, based on 21 tested devices, including two thinned to 50 µm)**

M18: Performances

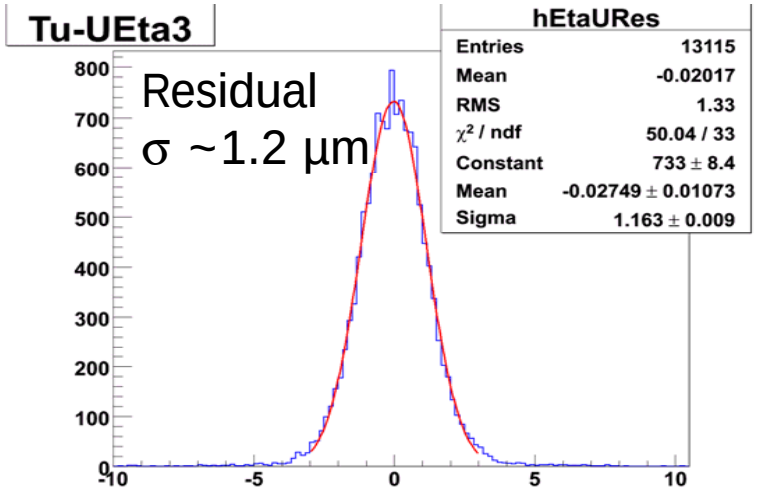
- Excellent performances: (preliminary)
  - Noise: ENC ~ 9.8 electrons @room temperature
  - S/N (MPV) ~ 30 (27) for « 14µm » (« 20µm »)
  - Efficiency ~ 99.85±0.15 % (prelim.)
  - (fake rate in progress)

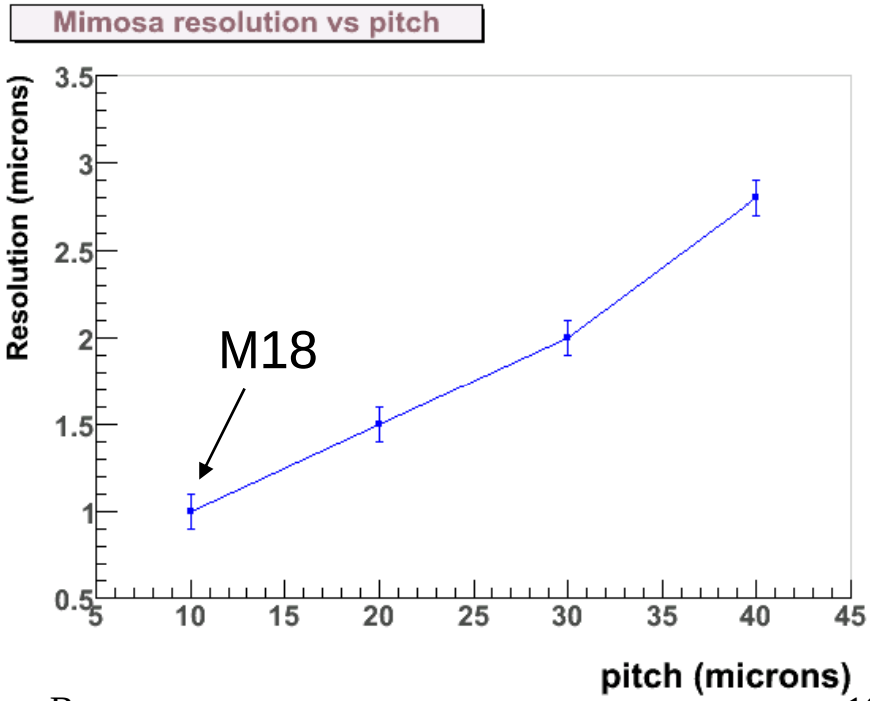


M18: Resolution

- Test beam with 4 M18
  - CoG for the 3 telescope planes
  - Eta function used for DUT
  - Analysis in progress (alignment)

➢ Resolution = 1 µm ± 0.1 µm !





Mimosa18 – tinned down to 50 µm and bonded to PCB

- Thinning of AMS 0.35 µm reticles
  - Thinning performed by APTEK (S.F. bay) via LBNL (STAR collab.)
  - Thickness claimed by provider : 50 µm
    - measured with IPHC bonding machine ~ 50-70 µm
  - Mimosa-18 (5.5x7.5mm^2) and -17 mounted on PCB for test ⇨ keep them flat

MIMOSA-18: First gluing trial *Second gluing trial*

  - Tests with ^{55}Fe show no loss in performances (noise, gain)
  - Tests of M-18 mounted on TAPI with 120 GeV π^- beam @CERN-SPS (Nov 07)
    - No loss in performances observed: Eff ~99.8 ± 0.2 % (prelim)

➢ Thinning down to ~ 50 µm seems on good track

Summary

- Mimosa-16: figures to keep in mind :
  - Digital: Eff ~ 99.9 % ; fake ~2 x 10^{-5} ; digital resolution ~5 µm;
  - Analog: S/N(MPV) ~ 16-17 ; residual ~2.1-2.5 µm
  - « 14 µm » >~ « 20 µm » : comparable performances (larger clusters for 20 µm)
    - ➢ Very satisfactory performances
- Mimosa-18
  - S/N(MPV) ~ 30
  - Eff >~ 99.85 ± 0.15 % (prelim)
  - Resolution ~ 1 ± 0.1 µm (prelim)
    - ➢ Best resolution ever obtained with CMOS chips
  - **Technique of thinning down of MAPSs to 50 µm seems to be reliable & industrially available**

Back up

mimosa 16, « 14 µm », « 20 µm », « bis »

mimosa 16

Sous-matrice	Diode	Architecture du pixel
Nom : Pixel 1 Taille : 32 lig. x 33 col. Sorties Discriminées : 24	Taille : 1,7 µm x 1,7µm Forme : carrée Rad-tol : non	Ampli : source follower Reset : reset par transistor Charge de l'ampli : normal CDS : capa MOS de clamping
Nom : Pixel 2 Taille : 32 lig. x 33 col. Sorties Discriminées : 24	Taille : 2,4 µm x 2,4µm Forme : octogonale Rad-tol : non	Ampli : source follower Reset : reset par transistor Charge de l'ampli : normal CDS : capa MOS de clamping
Nom : Pixel 3 Taille : 32 lig. x 33 col. Sorties Discriminées : 24	Taille : 2,4 µm x 2,4µm Forme : octogonale Rad-tol : oui	Ampli : source follower Reset : reset par transistor Charge de l'ampli : normal CDS : capa MOS de clamping
Nom : Pixel 4 Taille : 32 lig. x 33 col. Sorties Discriminées : 24	Taille : 4,5 µm x 4,5µm Forme : carrée Rad-tol : non	Ampli : source follower avec feedback Reset : self-biais diode Charge de l'ampli : améliorée CDS : capa MOS de clamping

mimosa 16 bis

Sous-matrice	Différences par rapport à MIMOSA 16
Pixel 1	Diode : Taille : 3 µm x 3 µm Forme : ? Architecture du pixel : identique
Pixel 2	Diode : taille identique forme Architecture du pixel : identique
Pixel 3	Diode : Taille : 3,5 µm x 3,5 µm Forme : ? Architecture du pixel : identique
Pixel 4	Diode : identique Architecture du pixel : ajout d'un abaisseur de tension avant la capacité de clamping pour améliorer ces performances.

test beam conditions

- CERN SPS:
  - 120 GeV pions beam, burst: 4.8 s + 12 s dead time
- DAQ:
  - trigger: 2000-4000 events/burst
  - data: 600 recorded events/burst
  - read-out freq:
    - analog: 2.5 MHz (50 µs read-out time)
    - digital: 20 MHz by 8 columns (50 µs read-out time)
- Data
  - 35 runs (+Noise runs)
  - 262 Go (!)
  - 6 chips testés
    - 3 mimosa 16 « 14 µm »
    - 1 mimosa 16 « 20 µm »
    - 2 mimosa 16 bis