PA-12

Osaka - 28th July, 2000

DETECTION of MINIMUM IONISING PARTICLES with CMOS SENSORS

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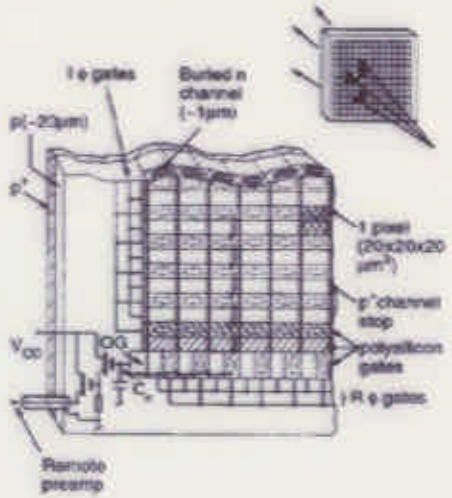
on behalf of the IReS-LEPSI collaboration

Outline:

- Introductory Remarks
- Main Features of the First Prototype
- Simulation of Performances
- Beam Test Results (still preliminary)
- Summary and Outlook

PIXEL DETECTORS

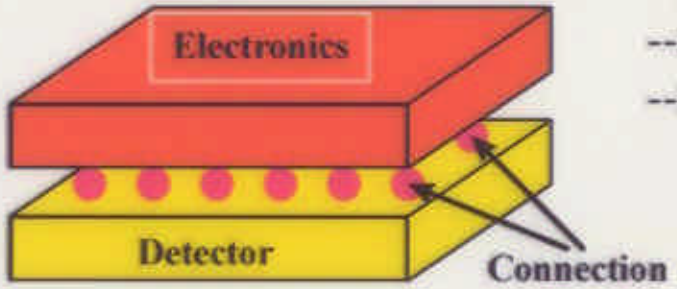
CCD



--> Imaging
--> High Energy Physics (SLD)

APS (Active Pixel Sensor)

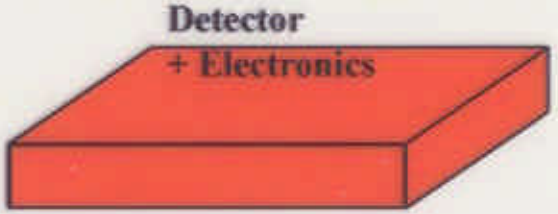
hybride APS



--> High Energy Physics (DELPHI, ...)

High Resistivity monolithic APS

--> High Energy Physics
--> Complex technology



Low Resistivity monolithic APS

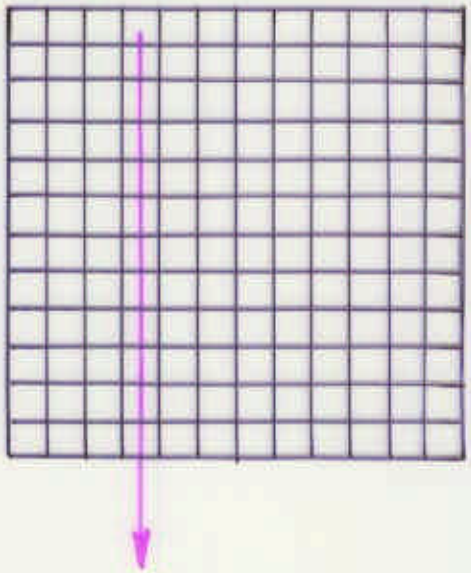
--> Imaging
--> Standard VLSI Technology

Existing Technics

▶ CCD

◆ Specific Limits:

- radiation hardness
- quite slow ($\sim$ 10 - 100 μs)



read-out column wise
by charge transfer

▶ High resistivity hybride APS

◆ Specific limits:

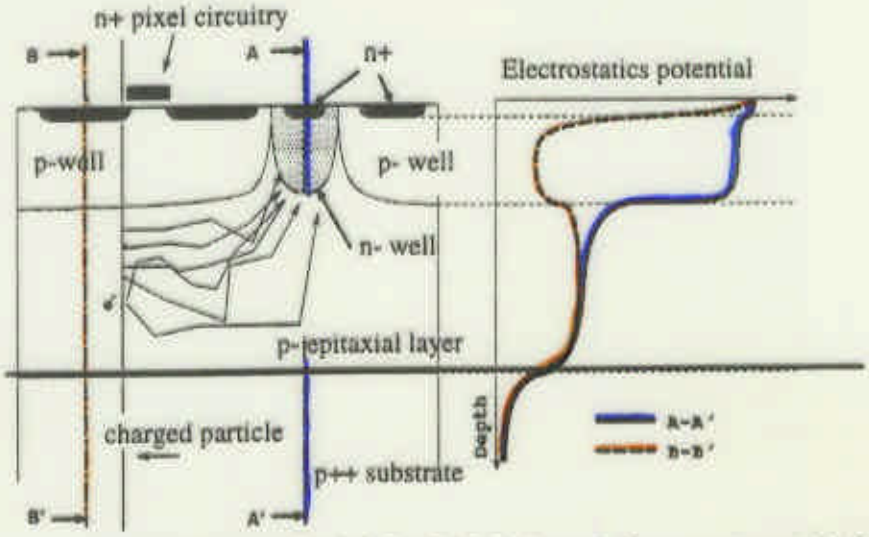
- thickness (200 to 400 μm)
- minimal size of pixels ($>$ 50 x 50 μm^2)

▶ Weakness of both technics $\longrightarrow$ Cost !!! :

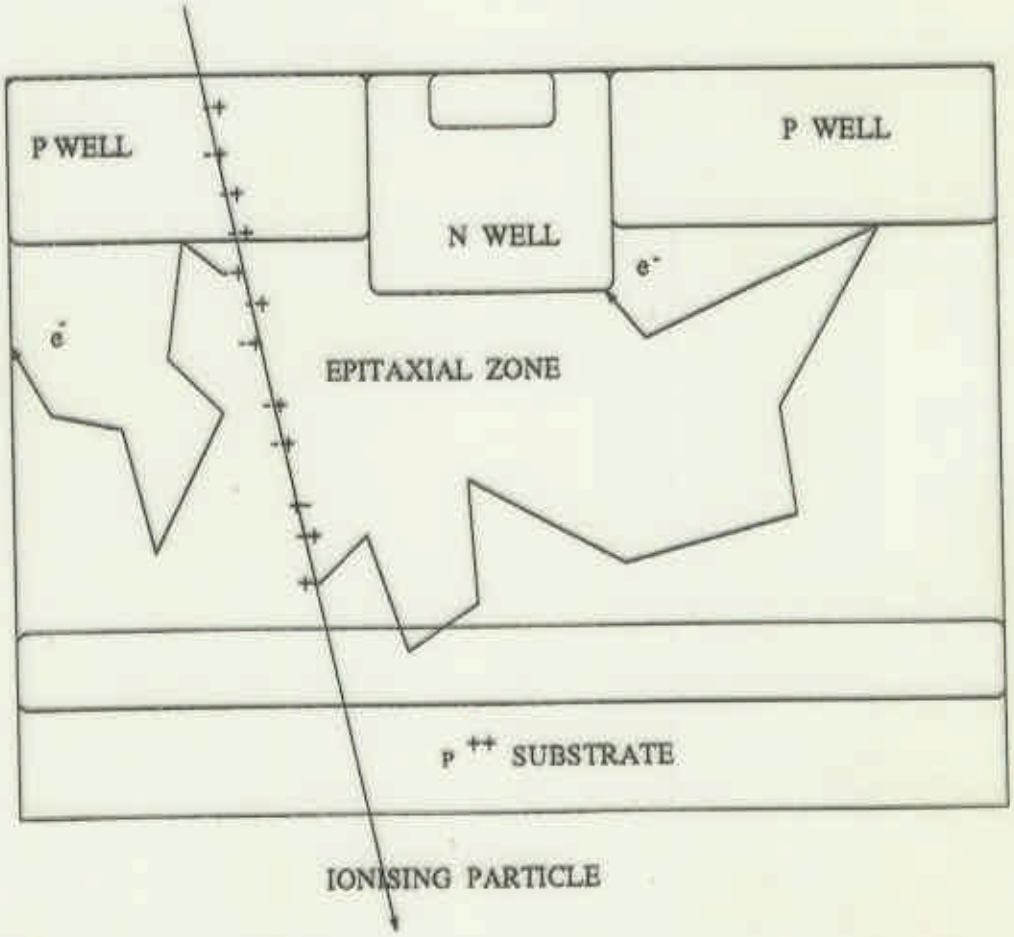
$>$ 100 CHF / cm^2 $\Rightarrow$ Vertex Det. cost several MCHF

Principle of Operation of CMOS Sensors (2)

Internal Structure of Pixel



→ no external drift field (no bias potential)



- Signal produced in epitaxial layer
- ? Does the substrate contribute ???

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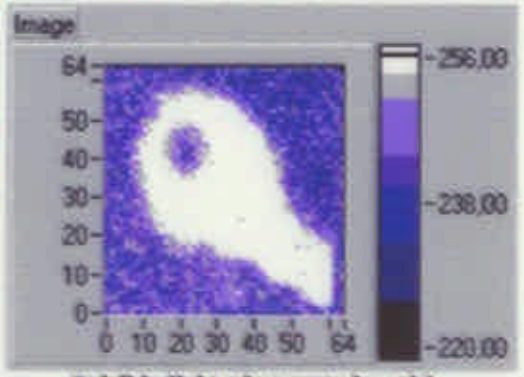
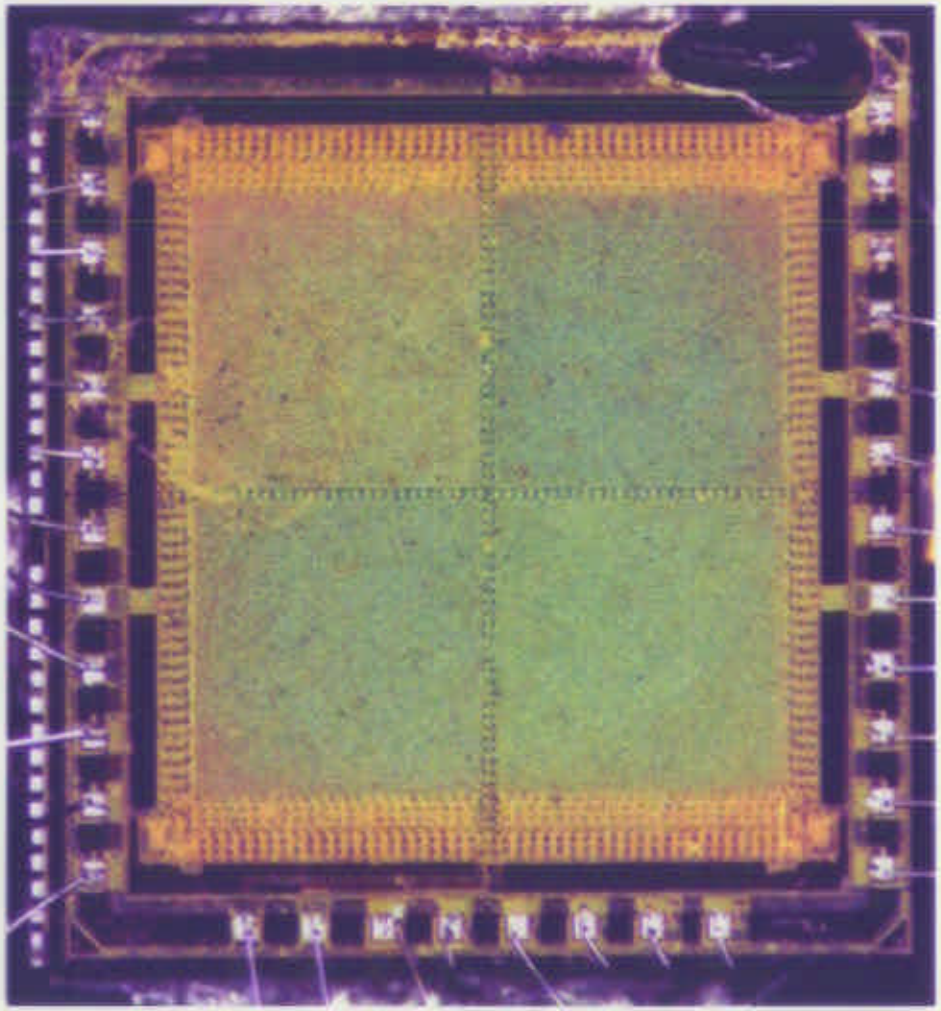
MIMOSA I (Minimum Ionising particle MOS Active pixel detector)

Goal of fabrication:

- feasibility study
- understanding/tests
  - standard 0.6μm CMOS *(tox=12.7nm)*
  - 14μm thick EPI layer *($10^{14}cm^{-3}$)*
  - 4 arrays 64x64 pixels
  - pixel pitch 20x20μm
  - diode *(nwell/pepi)* size 3x3μm - *3.1fF*
  - readout clock f<10MHz
  - readout - serial analog
  - die size 3.6x4.2mm²



"visible light photography with MIMOSA"



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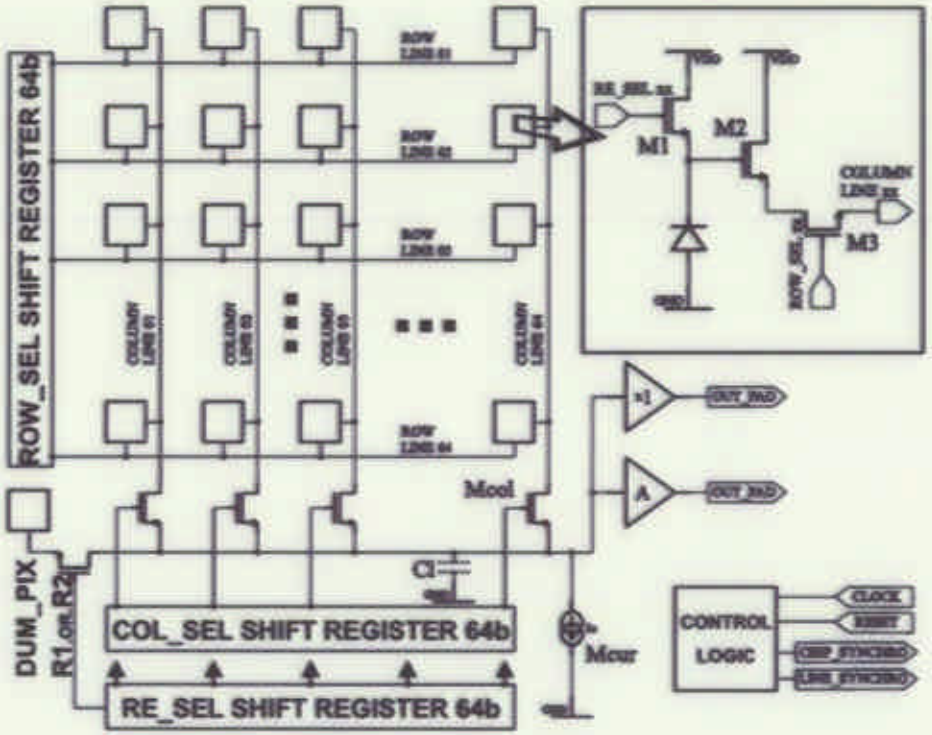
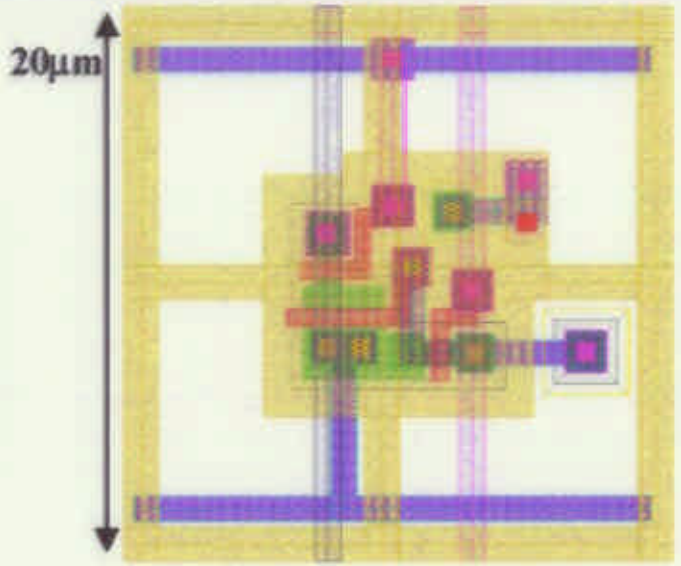
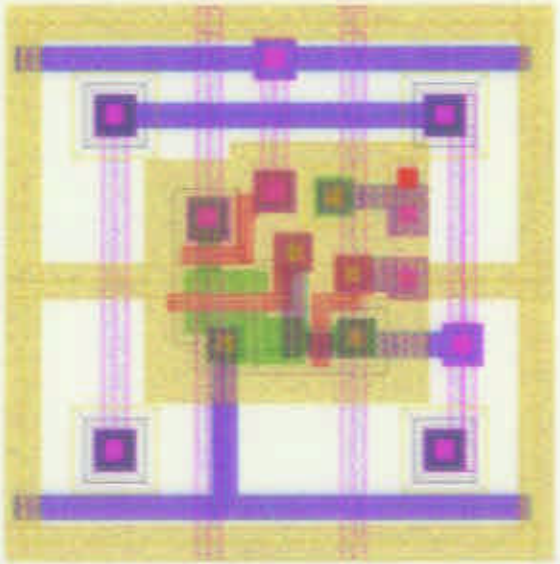
MIMOSA I

Single cell electronics and readout:





1P



4P

- work regime:

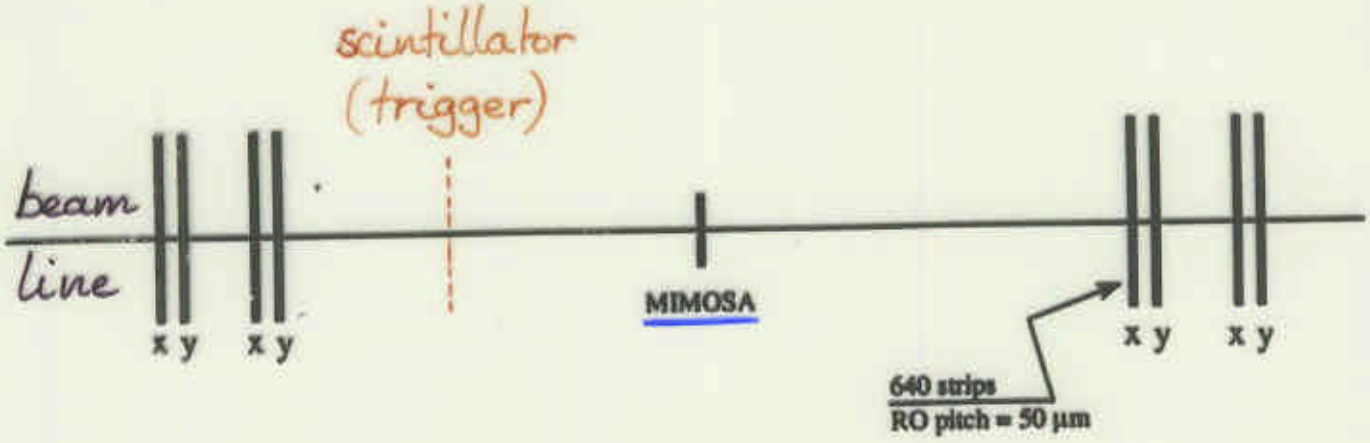
  ... RESET ... READOUT ... RESET...

- technology 3M+2P
- power supply 4÷5V

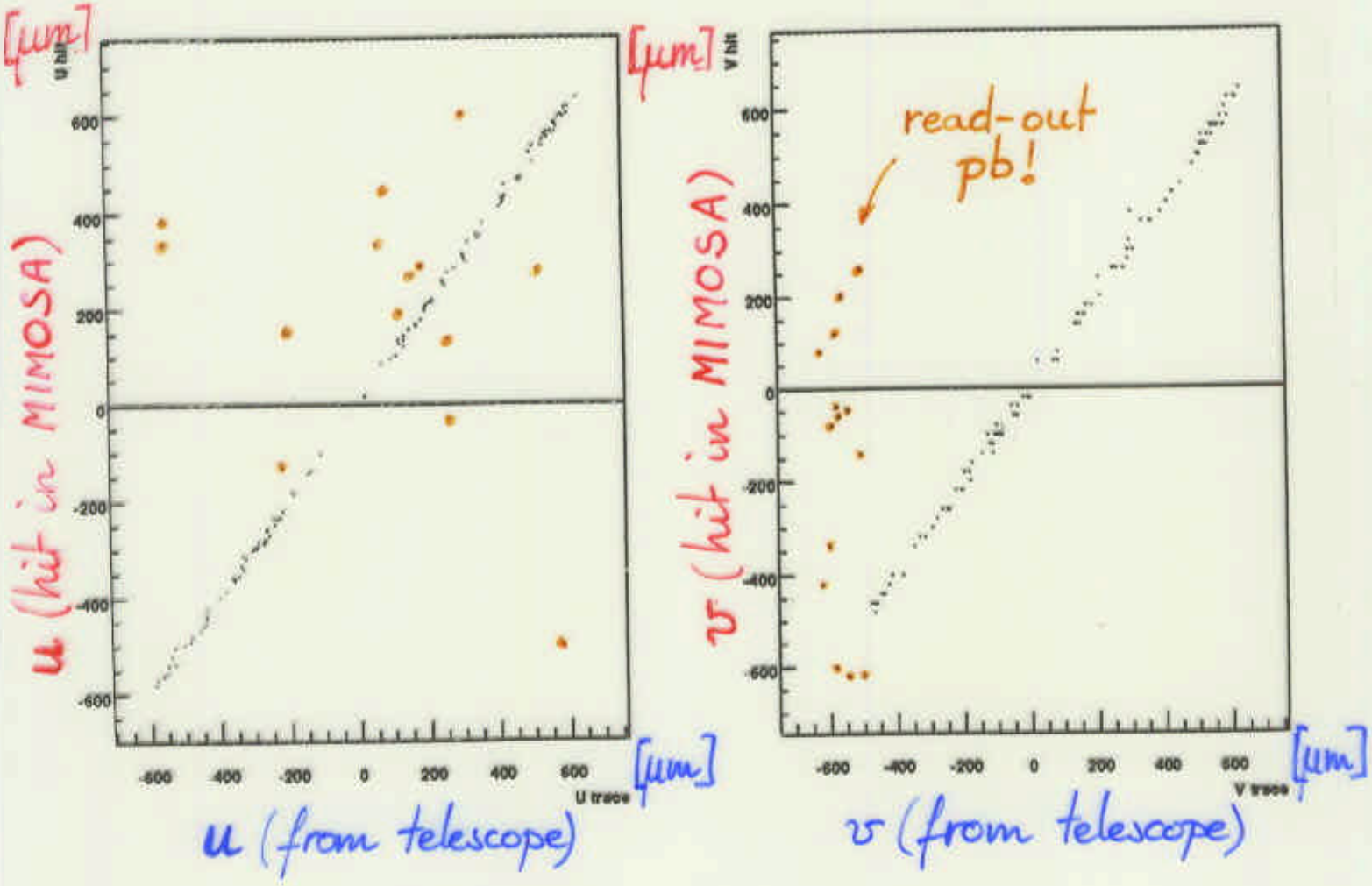
Beam Tests : 15 GeV/c π (CERN)

~ $5\,10^4$ triggers

▸ MIMOSA-I mounted on Si-strip Telescope

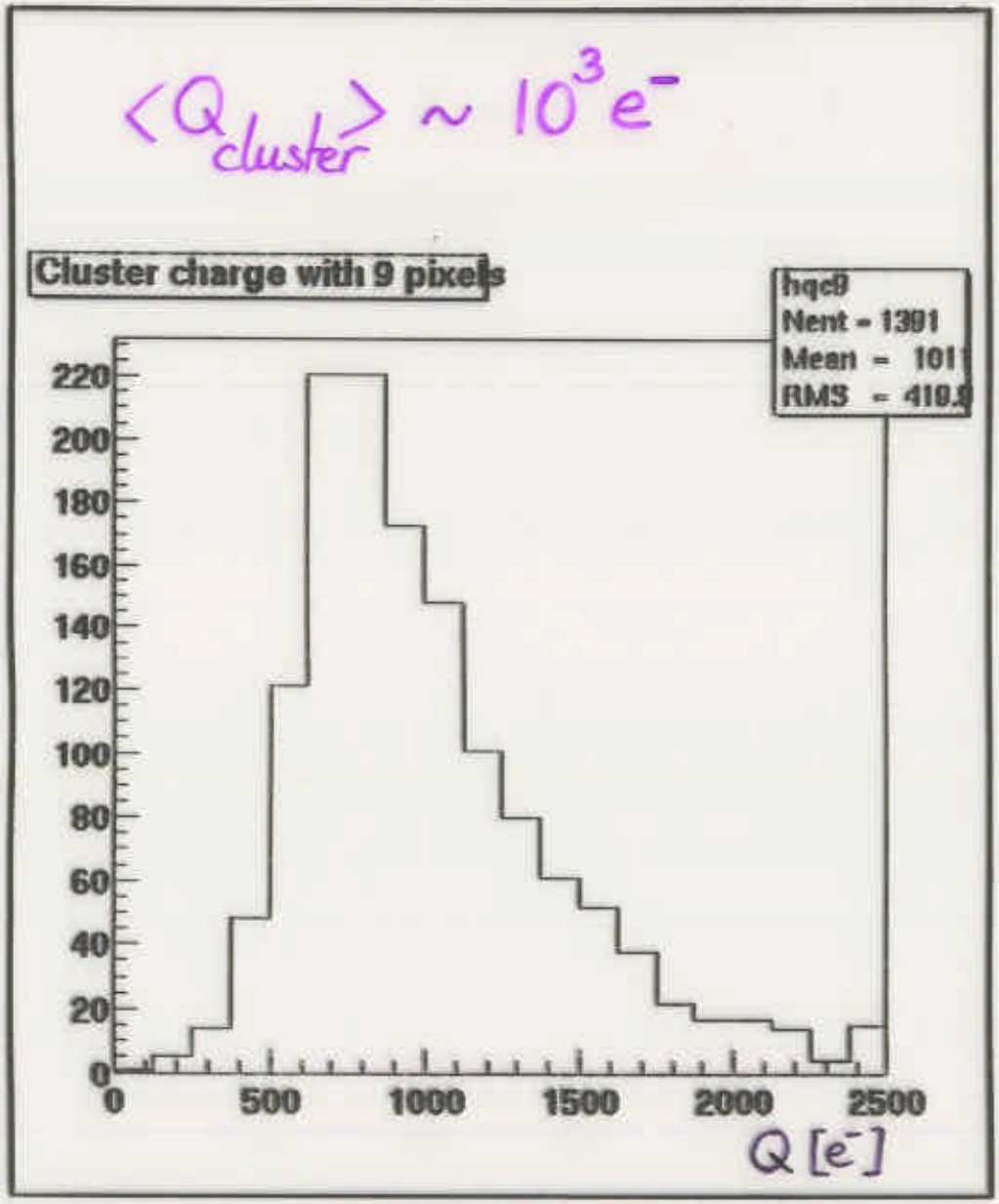


▸ Correlation between tracks in telescope and hits in MIMOSA-I

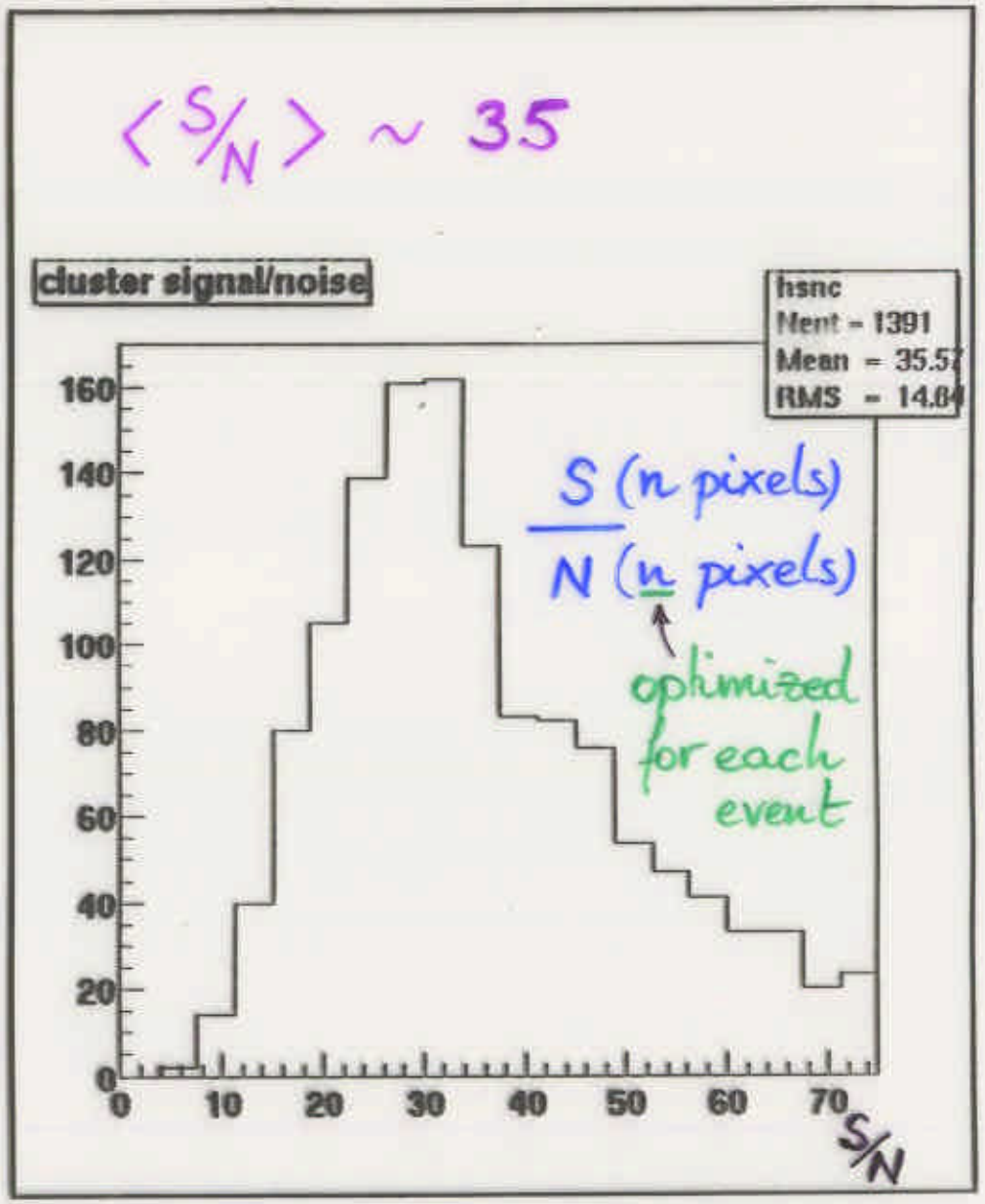


$\varepsilon_{det.} \gtrsim 99.5 \pm 0.2\ \%$

$\langle Q_{cluster} \rangle \sim 10^3 e^-$

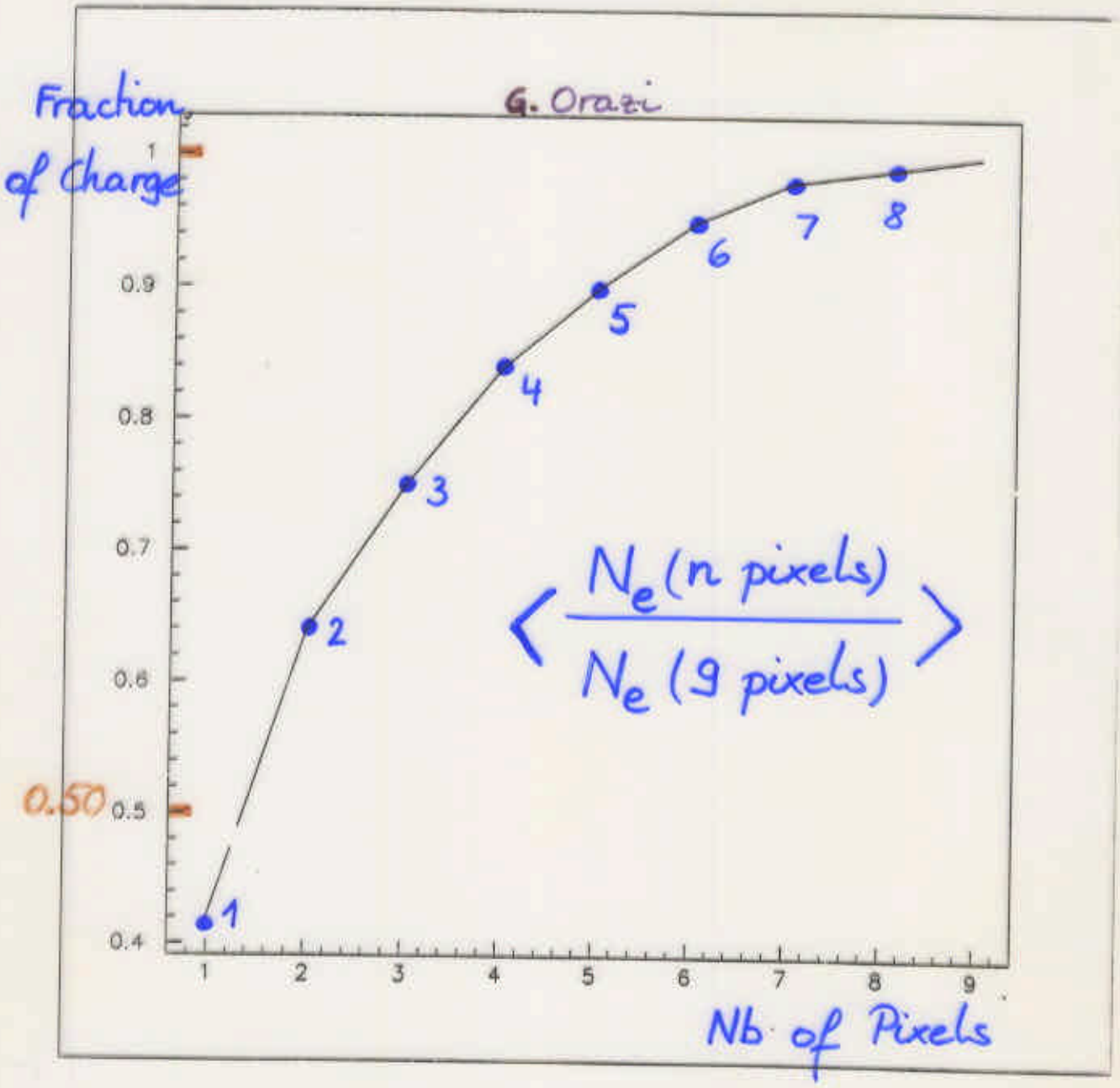


$\langle S/N \rangle \sim 35$



calibrated with ^{55}Fe X ray (5.9 keV)

Charge Spread over Pixels (1)

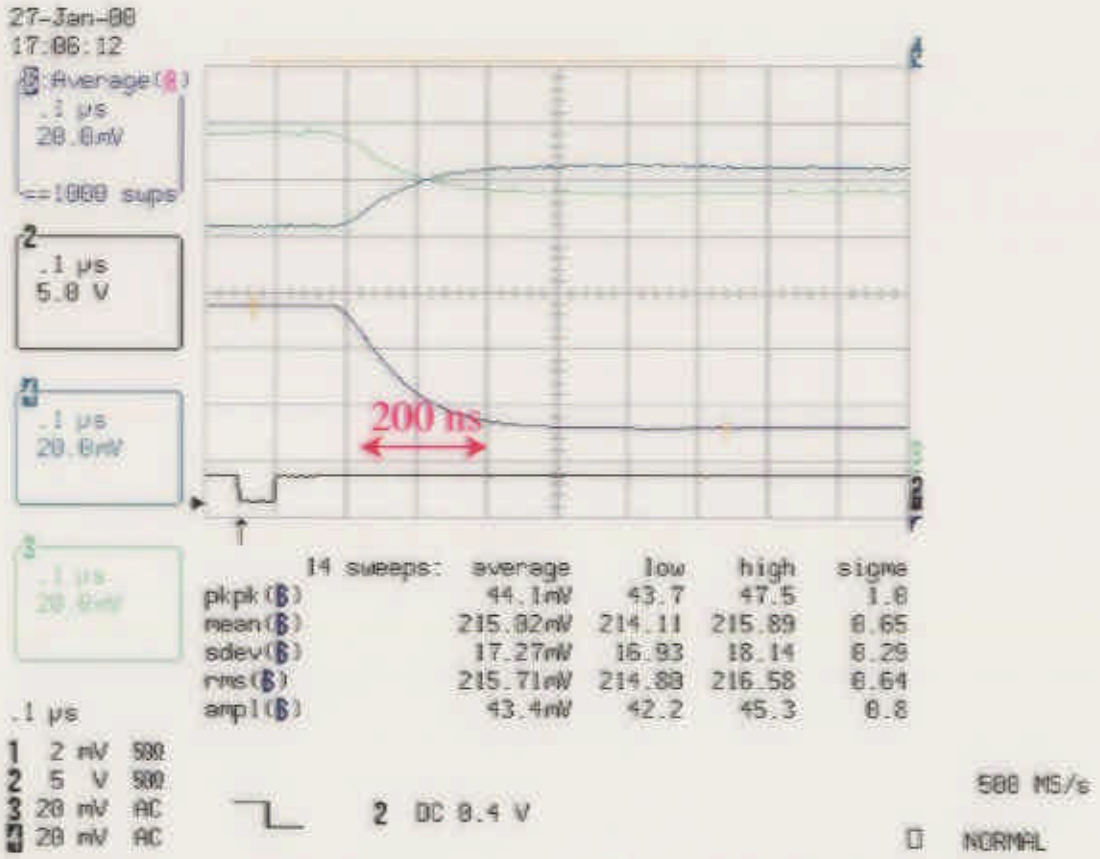


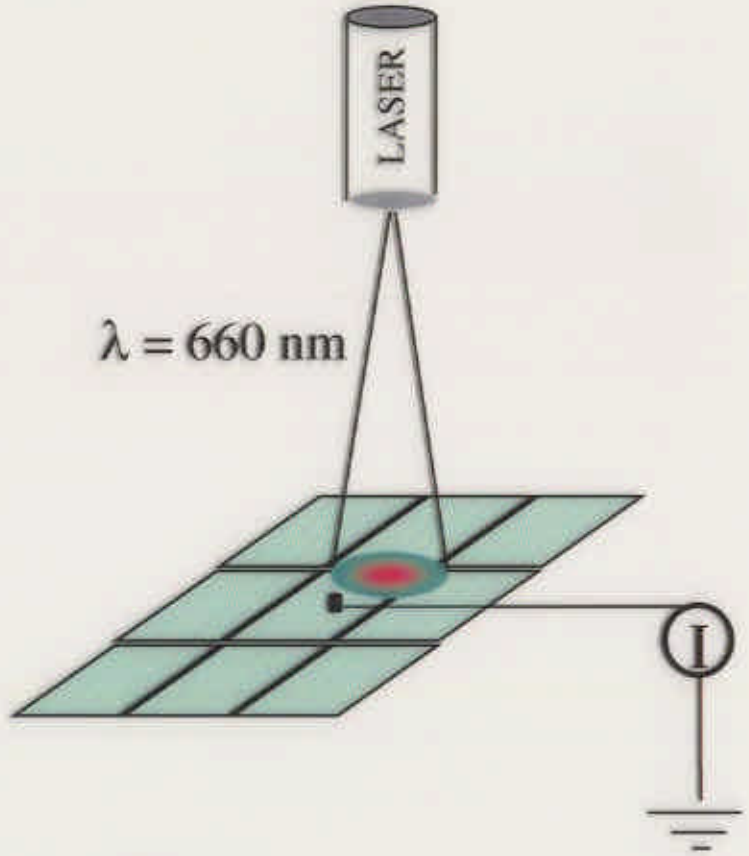
~ 40% of charge in central pixel

~ 65-75% of charge contained in first 2 or 3 pixels

Measurement of MIMOSA-I's Charge Collection Time

→ simulate m.i.p. with laser shot





$\tau \approx 150$ ns

SUMMARY and OUTLOOK

- **Detection of m.i.p. with CMOS sensors WORKS !**

$$< S/N > \sim 30 - 35 \qquad \epsilon > 99.5\%$$

➡ **Performances already similar to those of CCDs combined with better radiation hardness (> 10 krad)**

- **Next Steps:**

1 • **additional studies and tests of MIMOSA-I:**

- **determine spatial resolution, increase statistics, ...**
- **test radiation hardness (neutrons, protons, ...)**
- **test reaction to magnetic field and low temperature**

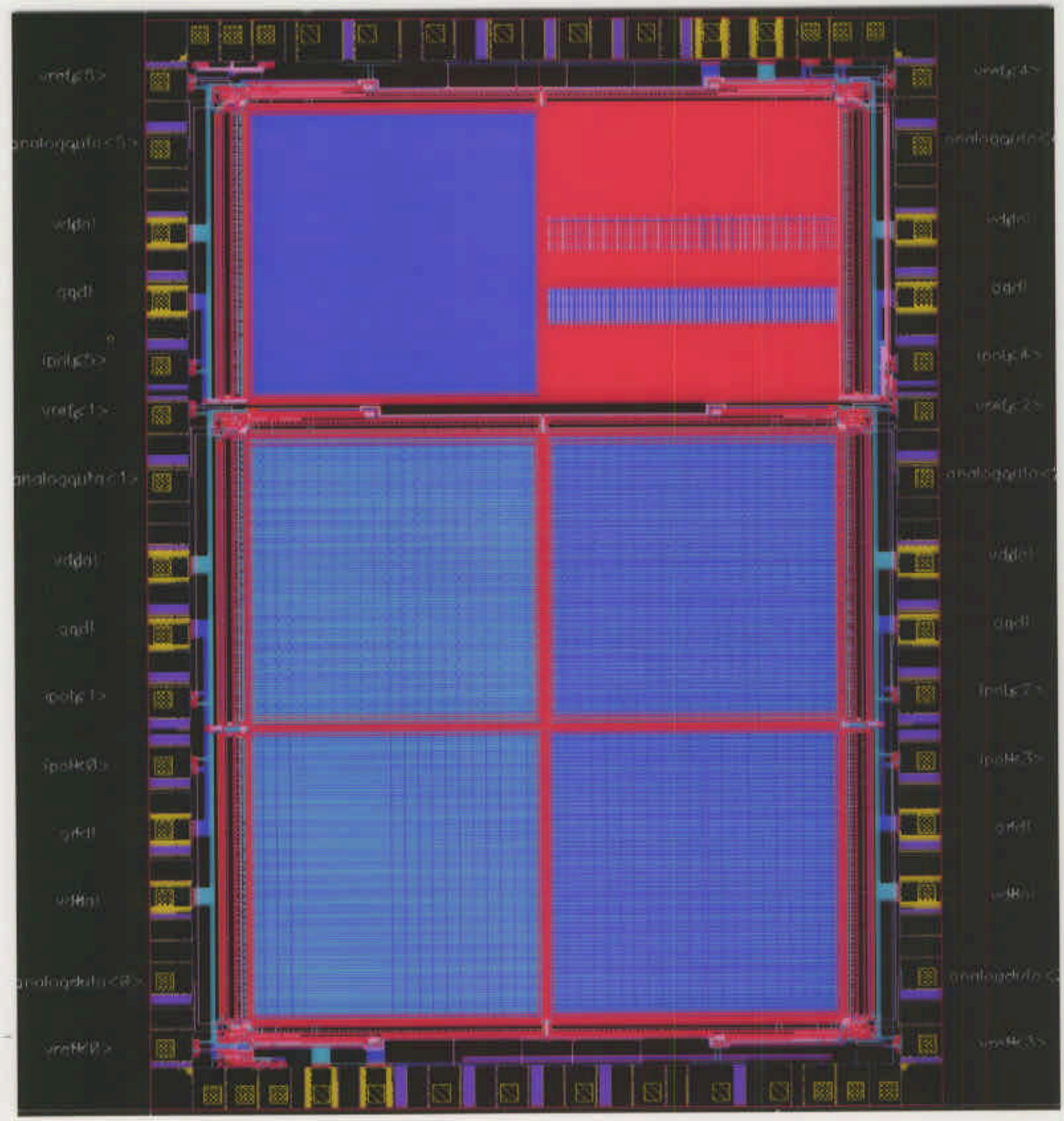
2 • **test MIMOSA-II ⟶ several improvements:** Fig.

- **radiation hard design**
- **optimised S/N (0.35 μm ⇒ thinner epi-layer)**
- **hexagonal geometry ⇒ better geometrical precision**

3 • **make a macroscopic detector module (> 10 cm^2)** Fig.

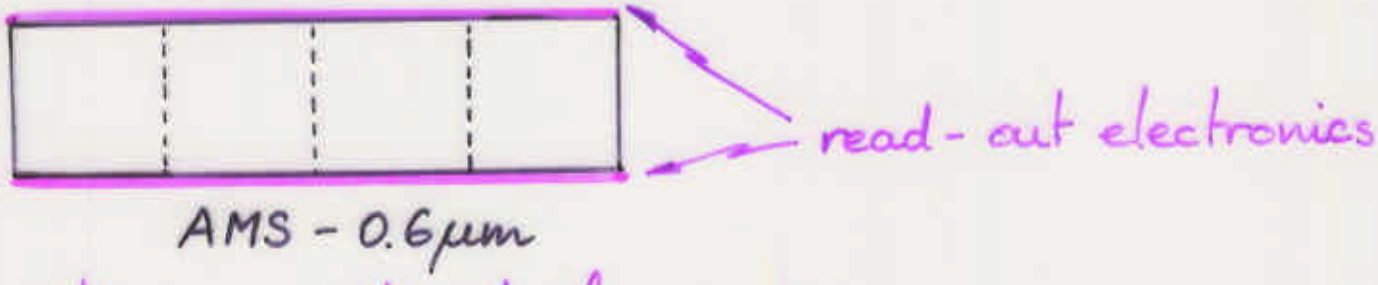
4 • **go for an intelligent and fast sensor:**

- **integrate decision electronics in each pixel**
- **develop read-out electronics with 0 suppression**


vdd!
gnd!
vdd!
gnd!
gnd!
vdd!

First CMOS Macrostructure

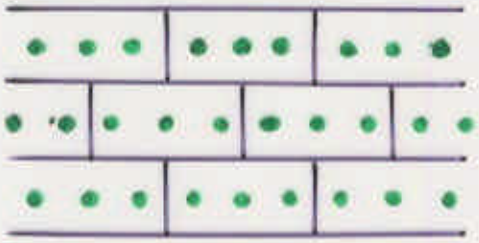
aim for $15 \times 45\text{-}60\ mm^2$ slab (≡ MIMOSA-I)



optimise read-out frequency

→ send layout in Sept. 2000 ⇒ back in December

- pixel size : ~ $50 \times 100\ \mu m^2$ (aim of BELLE)?
  ⇒ $32\ 10^3$ pixels (≈ 128 x 256) / module
  read with 30 MHz frequency / frame
- tot. thickness / layer ~ 150 μm
- geometry :



3 diodes / pixel ?