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CMOS vertex detector for TESLA

Particle Tracking Using CMOS Monolithic Active Pixel Sensor

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Contents

- Idea and basic architecture of a CMOS MAPS
- Prototype MIMOSA chips
- Charge collection : timing and efficiency
- High energy particles beam test results : S/N, efficiency, spatial resolution
- Conclusion and Future Development Prospects

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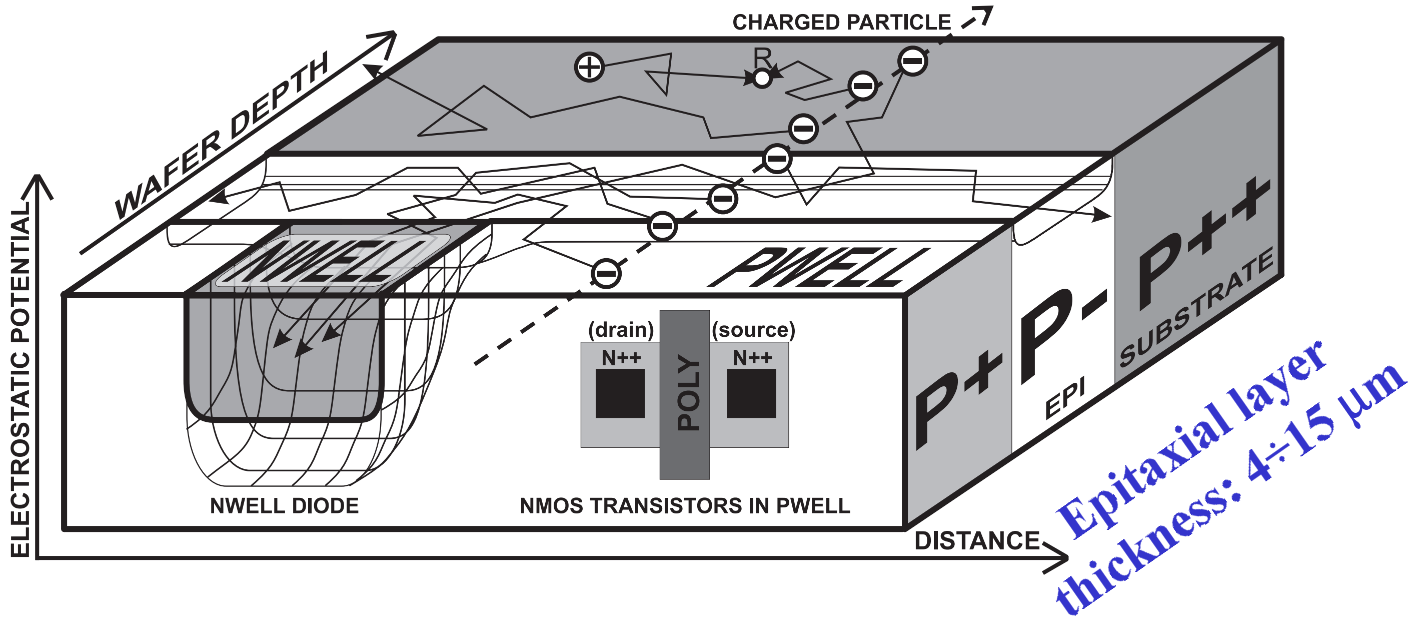
Cross-section of a CMOS twin-tub wafer with a charge collecting structure allowing 100% *Fill Factor*, essential for tracking application



Advantages of a standard (submicron) CMOS : availability, reasonable cost, radiation hardness, feasibility of a "system on a chip" solution

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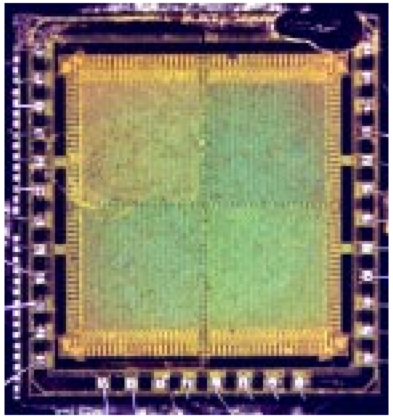
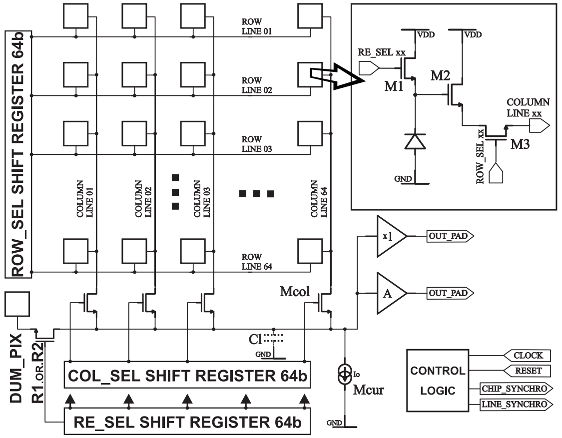


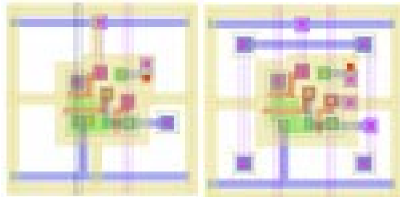
MIMOSA I die photo

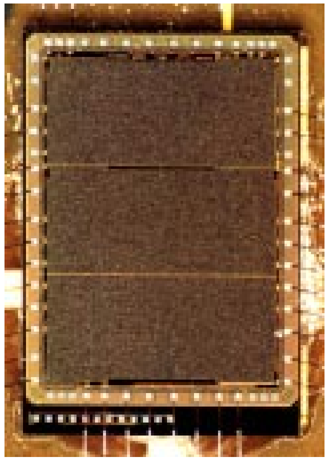


MIMOSA I block schematic diagram

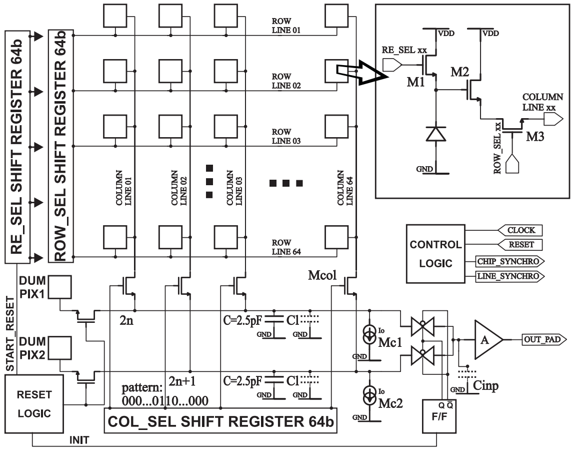
- standard 0.6µm CMOS (tox=12.7nm)
- 14µm thick EPI layer ($10^{14}cm^{-3}$)
- 4 arrays 64x64 pixels
- pixel pitch $20x20\mu m^2$
- diode (nwell/p-epi) size $3x3\mu m^2$ - 3.1fF
- serial analogue readout
- max. clock freq.: 5MHz
- die size 3.6x4.2mm2
- technology 3M+2P
- power supply 5V

MIMOSA I pixels layouts





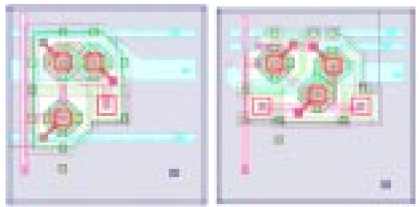
MIMOSA II die photo



MIMOSA II block schematic diagram

- standard 0.35µm CMOS (tox=7.4nm)
- 4.2µm thick EPI layer ($10^{15}cm^{-3}$)
- 6 arrays 64x64 pixels
- pixel pitch $20x20\mu m^2$
- diode (nwell/p-epi) size $1.7x1.7\mu m^2$ - 1.65fF
- serial analogue readout
- max. clock freq.: 25MHz
- die size 4.9x3.5mm2
- technology 5M+2P
- power supply 3.3V
- radiation tolerant
- transistor design

MIMOSA II pixels layouts



Mimosa* I and Mimosa* II single cell electronics and readout architecture

*Minimum Ionising Particles MOS Active Pixel Sensor

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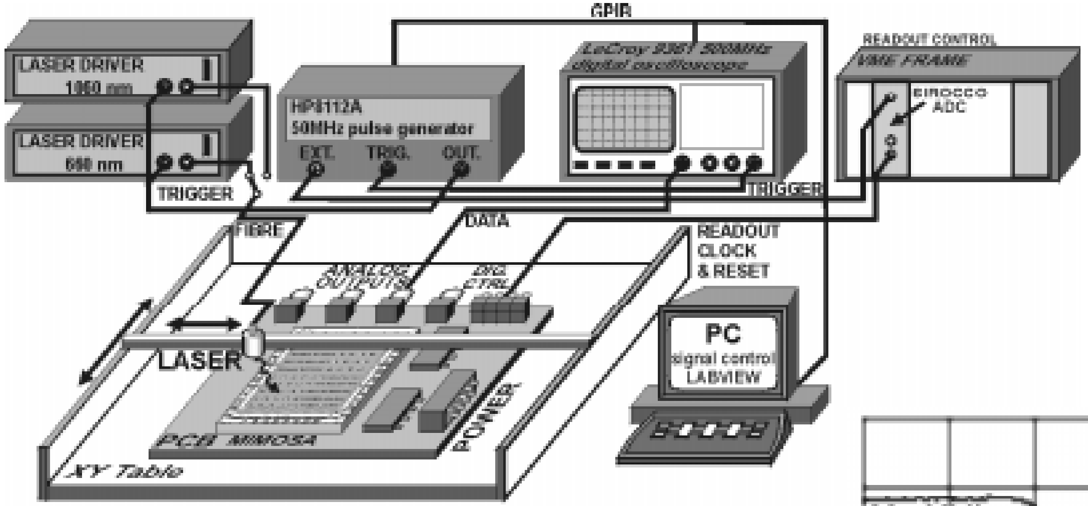
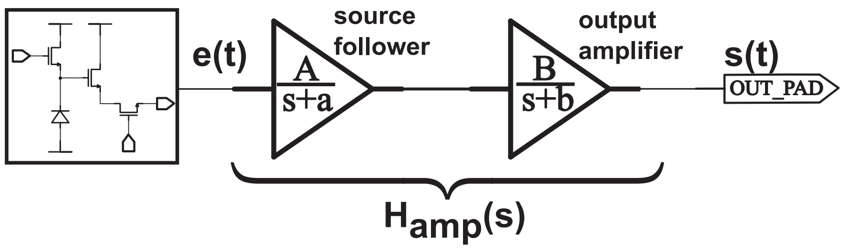
Charge collection timing properties : tests using visible and IR laser pulse (Δt<10ns)



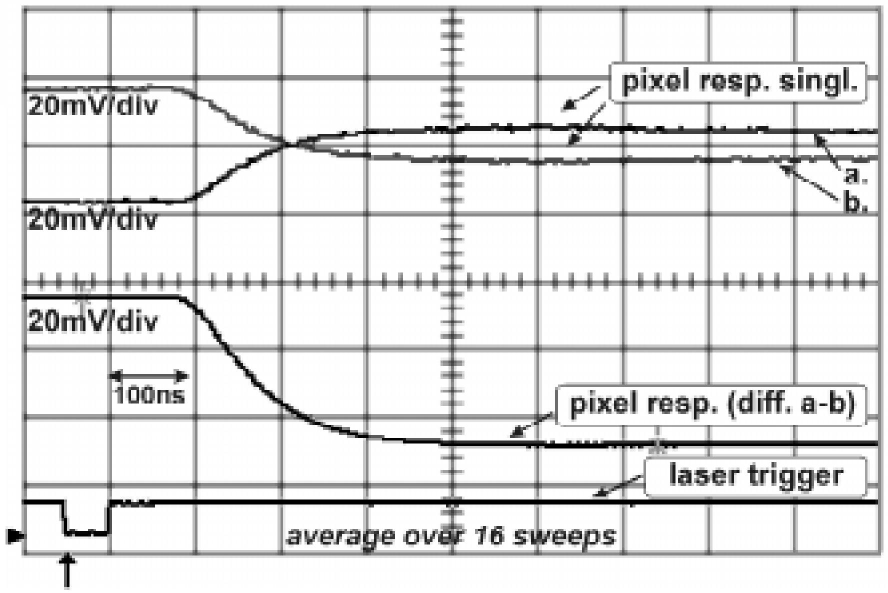
❑ Use of laser diodes :

- 660nm and 1060nm
- rise time = 0.2ns
- pulse width = 8.5ns
- spot size = 10μm *(FWHM)*
- delay after trigger = 65ns



$$e(t)=\frac{1}{A\cdot B}\left[\frac{d^2s(t)}{dt^2}+(a+b)\frac{ds(t)}{dt}+a\cdot b\cdot s(t)\right]$$

Equation is solved for e(t) using discrete differentiation of the measured signal



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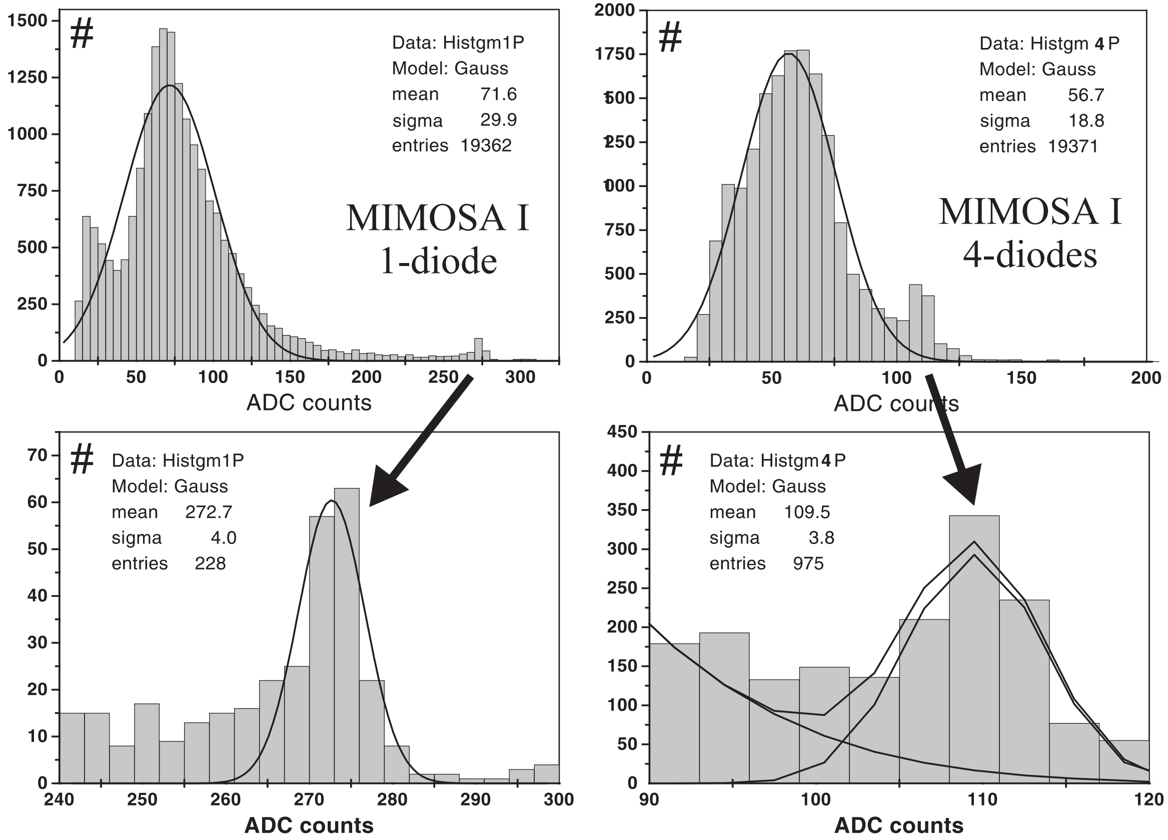
Gain calibration using soft X-rays (5.9 keV from ^{55}Fe)



- **According to MC simulation the "big peak" doesn't correspond with 100% of charge collection efficiency !!!**

- **Taking second peak position (conversion in a depletion region of the collecting diode)...**

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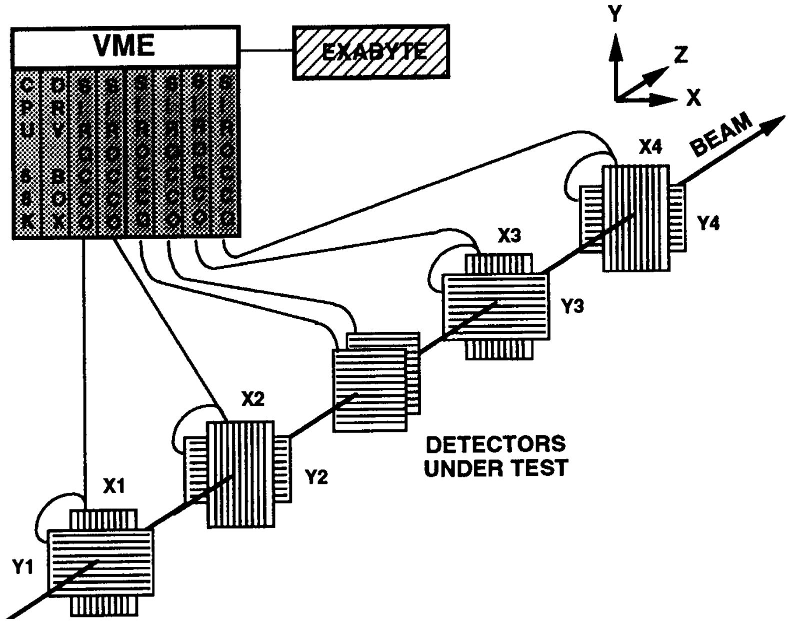
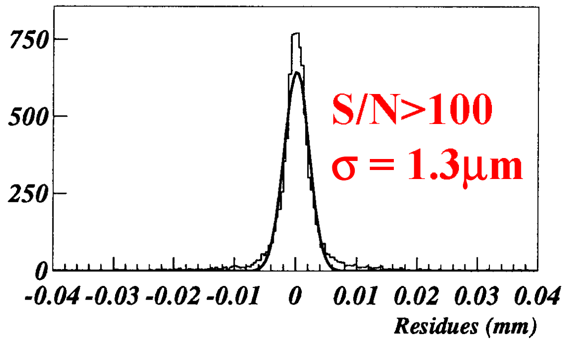
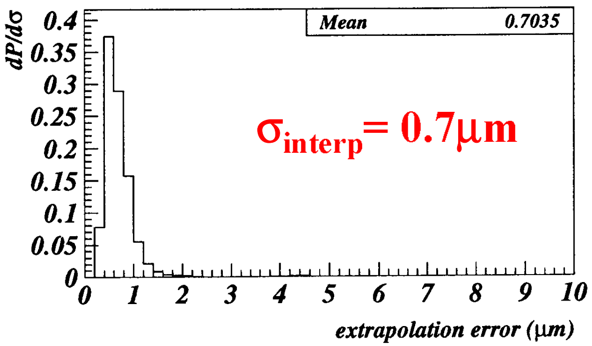
Particle tracking tests using 120 GeV/c pions and high precision beam telescope





Single plane resolution



Track position resolution
in the middle of telescope

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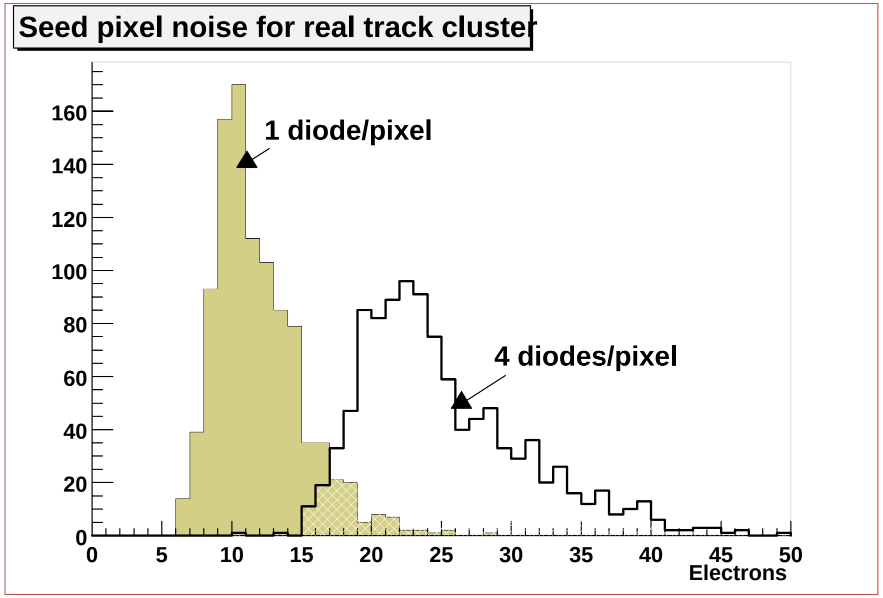
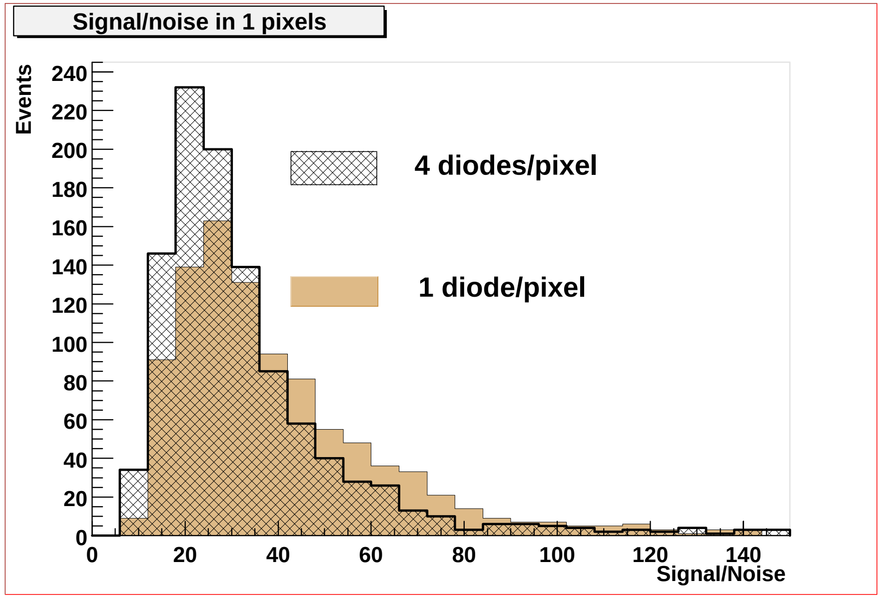
Tracking tests using 120 GeV/c pions



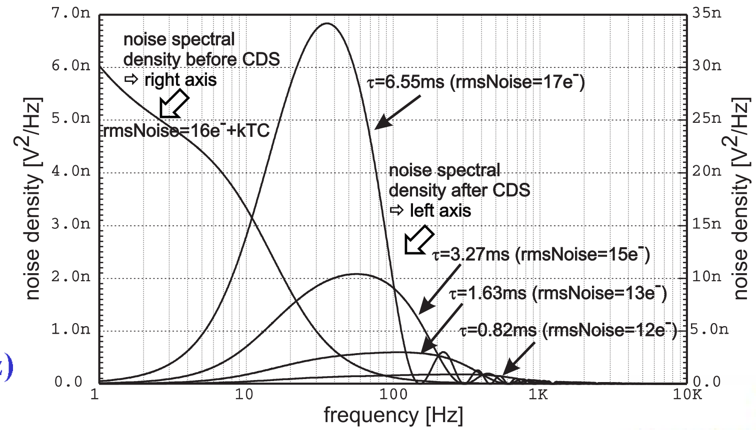


Noise : 12 e- (1 diode), 25 e- (4 diodes)

S/N (central pixel)

Analog (Serial) Readout using
<u>Correlated Double Sampling</u> (CDS)

Goal : suppression of both kTC Noise and Fixed Pattern (Noise)



Noise power spectral density for MIMOSA I
for samppling frequencies of 0.625, 1.25, 2.5, 5 MHz)

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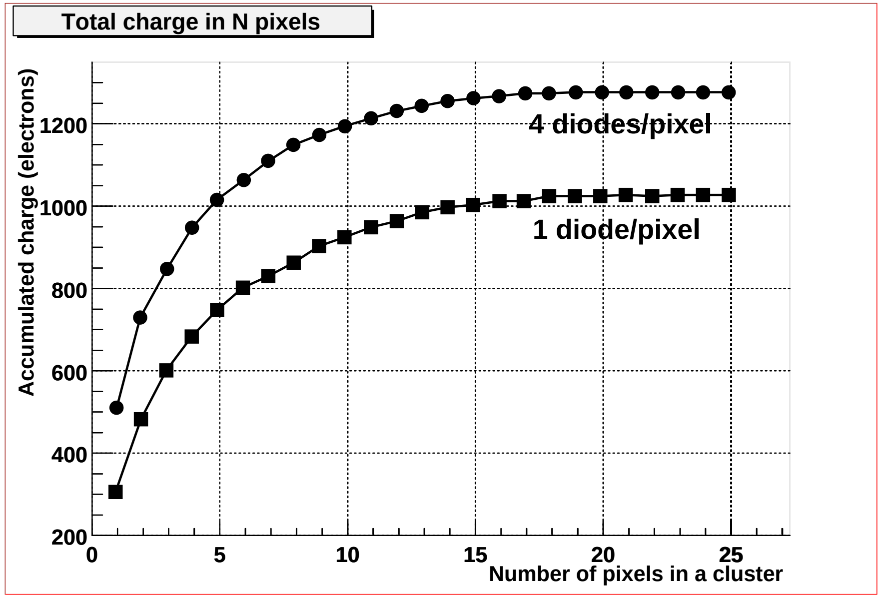
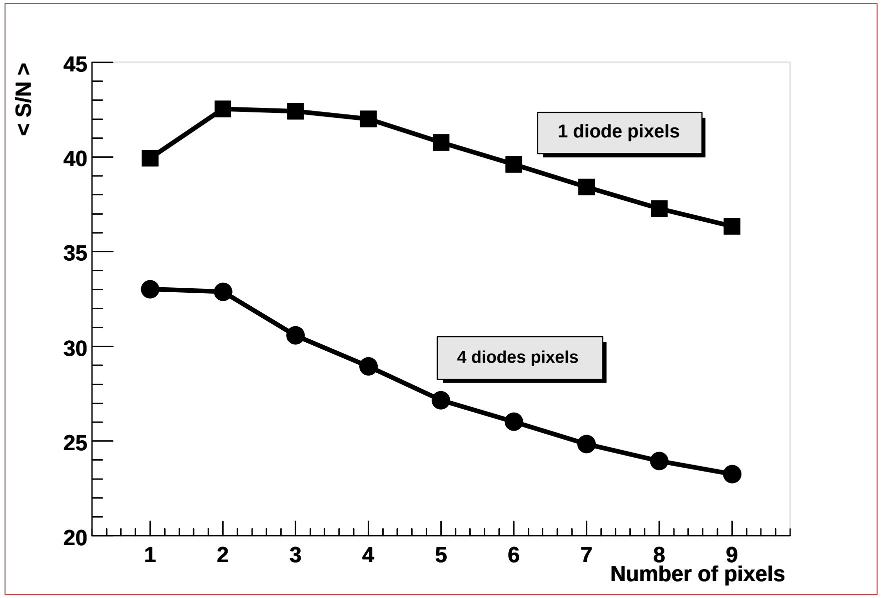
Tracking tests using 120 GeV/c pions





Charge vs. cluster size

S/N vs. cluster size

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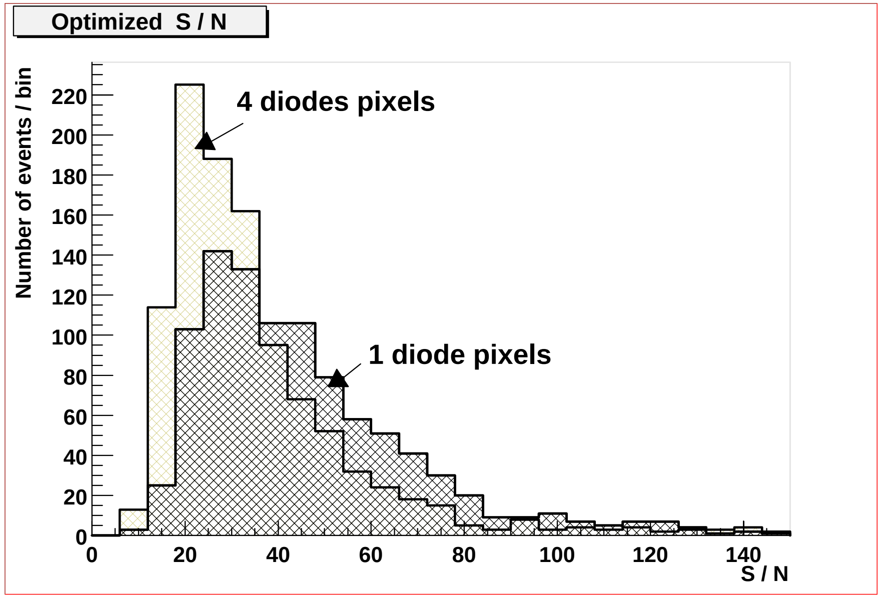
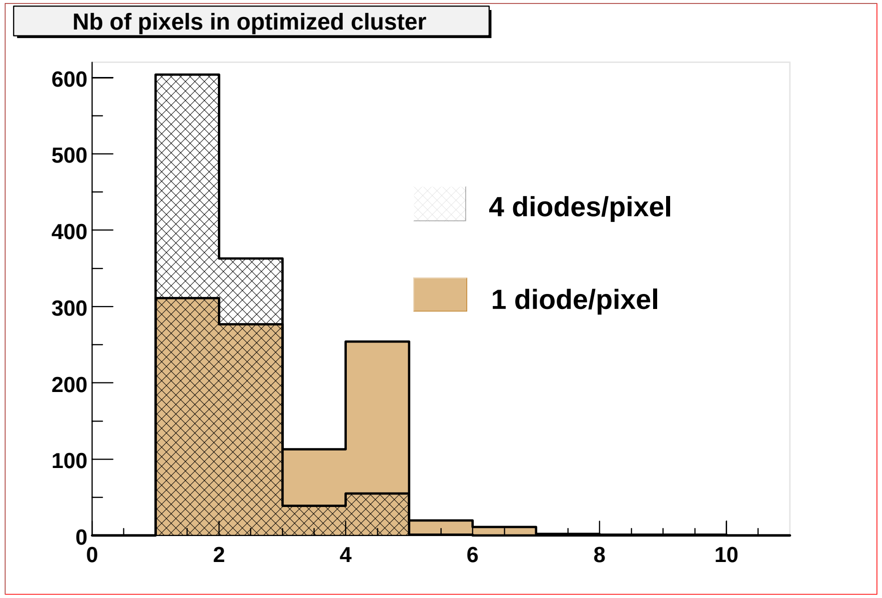
Tracking tests : S/N event-to-event optimisation





Optimised S/N

Optimised cluster multiplicity

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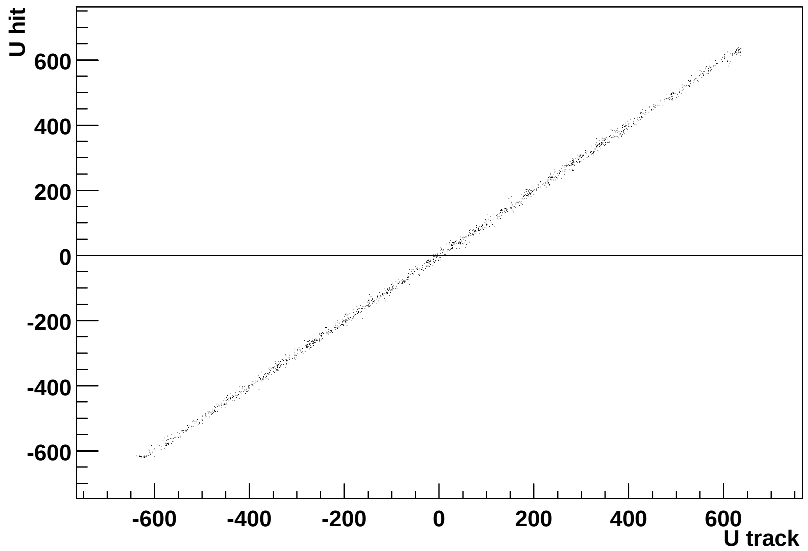
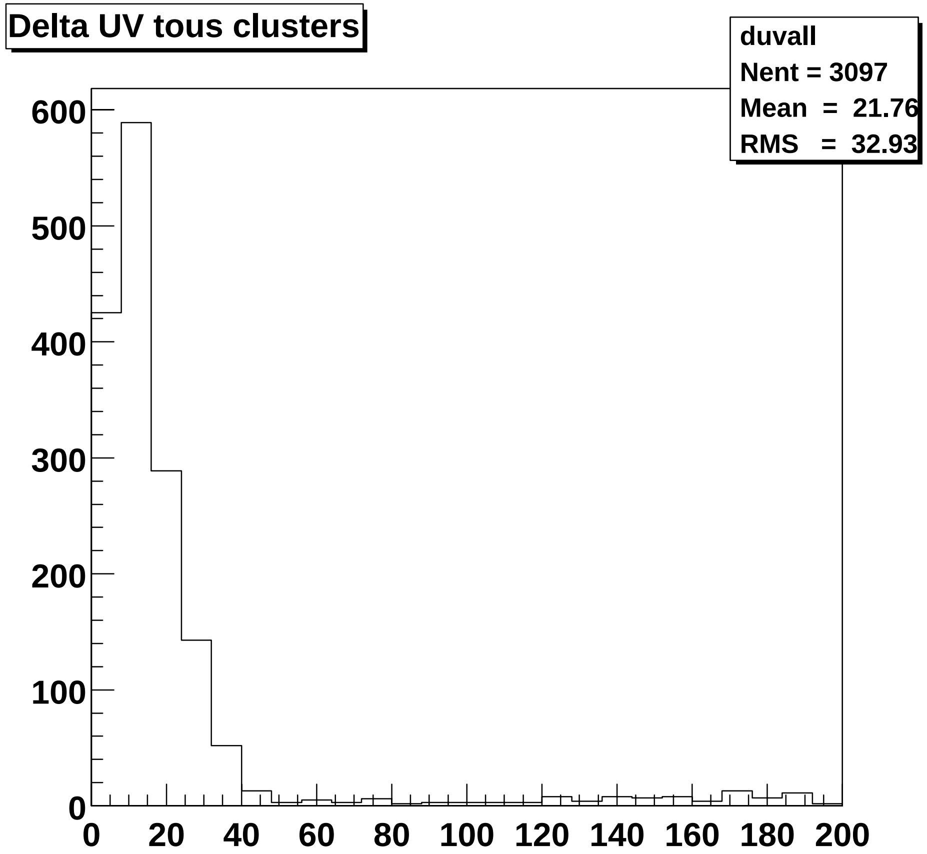
Tracking tests : reconstruction efficiency



MAPS - telescope
hit correlation



$$\varepsilon_{\text{hits} < 50\ \mu\text{m}} = 99.5 \pm 0.2\ \%$$

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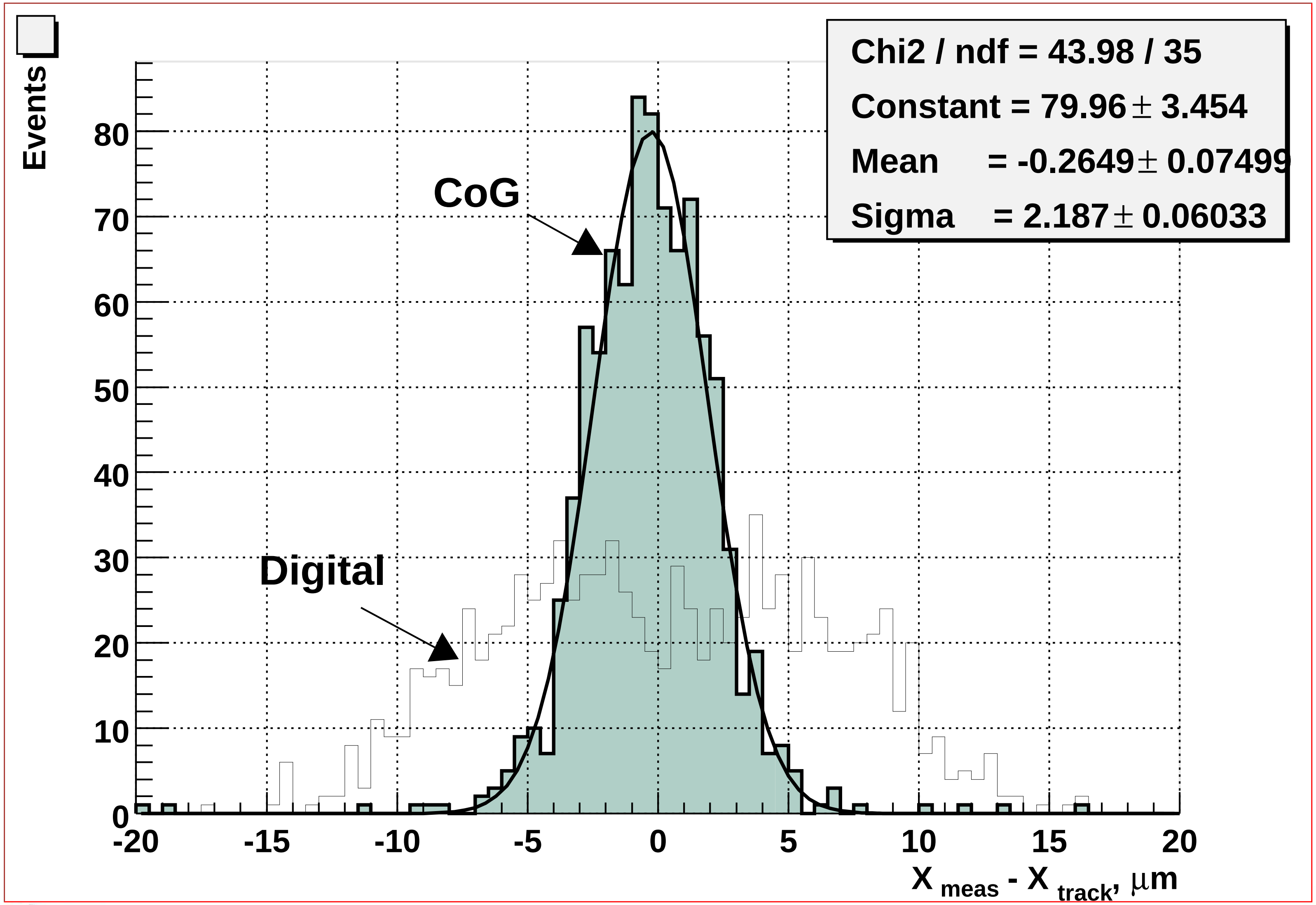
Tracking tests : spatial resolution



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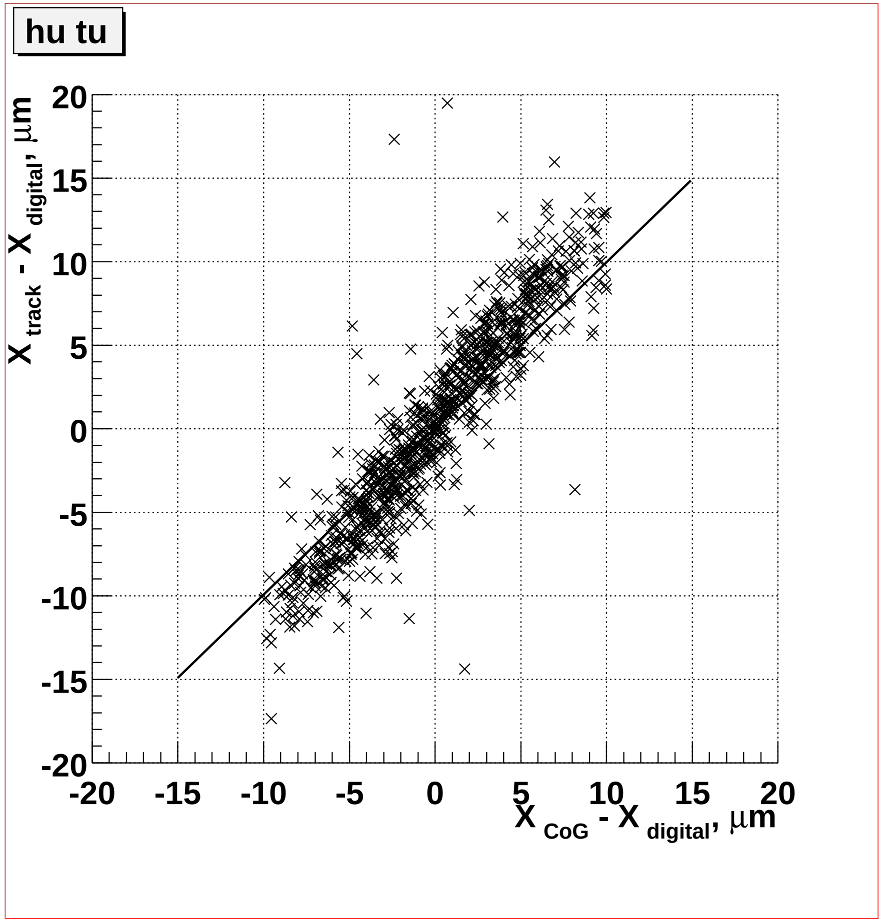
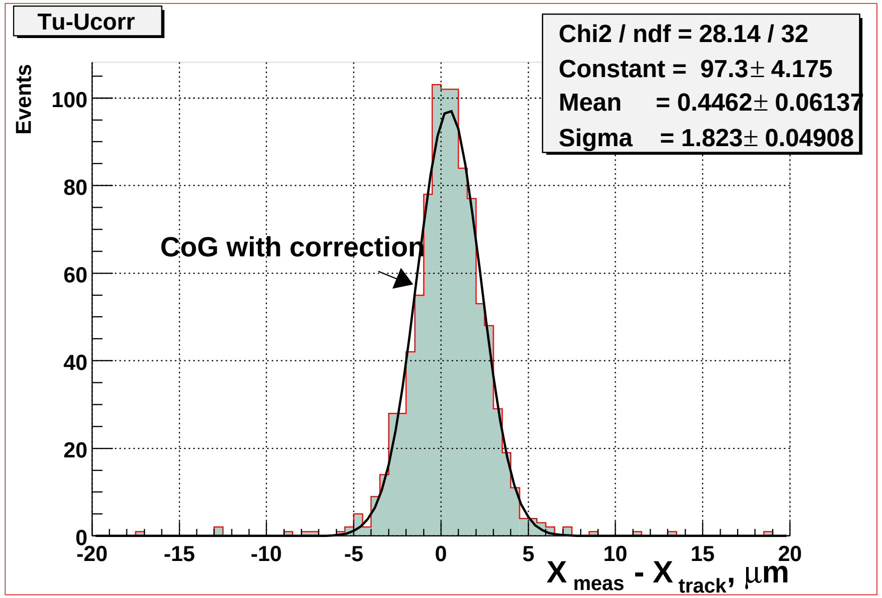
Spatial resolution : optimisation





σ = 1.6 µm (preliminary)

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Conclusion and prospects

- Prototype CMOS Monolithic Active Pixel Sensor works as a minimum ionising particles detector!

- Charge collection : reasonably fast (~100ns), spread limited to few pixels, good agreement between device simulation and measurements, NO effects of magnetic field (up to 8 Tesla, both directions)

- High energy particles beam test results :

S/N>30, 100% detection efficiency, spatial resolution : < 1.6 μ

- Rad-tolerant device (Mimosa II, 0.35 μm CMOS) : tracking performance similar to the 0.6 μm prototype, radiation hardness tests soon

- Short term future : large area (~10 cm^2) device (~mid 2001)

- Long term future : intelligent, high precision, ultimately thin, large area and low cost device.