First measurements of new p-type strip and pad detectors with LGAD in epitaxial wafers

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1. Thin p-type epitaxial wafers

Detector proposed by Hartmut Sadrozinski and Abe Seiden (UCSC), Ultra Fast Silicon Detectors (UFSD).[1]

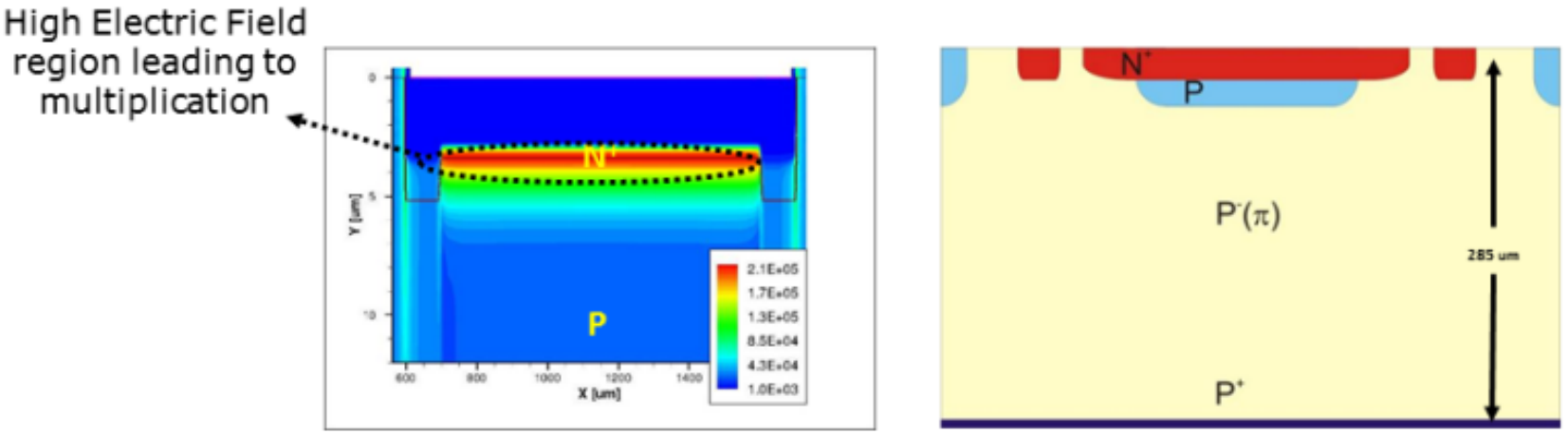
- Provide in the same detector and readout chain:
  - Ultra fast timing resolution [10's of ps]
  - Precision location information [10's of μm]
- Proposed to achieve high electric field using thin p-type epitaxial substrates grown on thick support wafers, p+ type doped, that acts as the backside ohmic contact.

Different thicknesses are used: 10, 50, 75 μm.

[1] H. Sadrozinski, *"Exploring charge multiplication for fast timing with silicon sensors"*

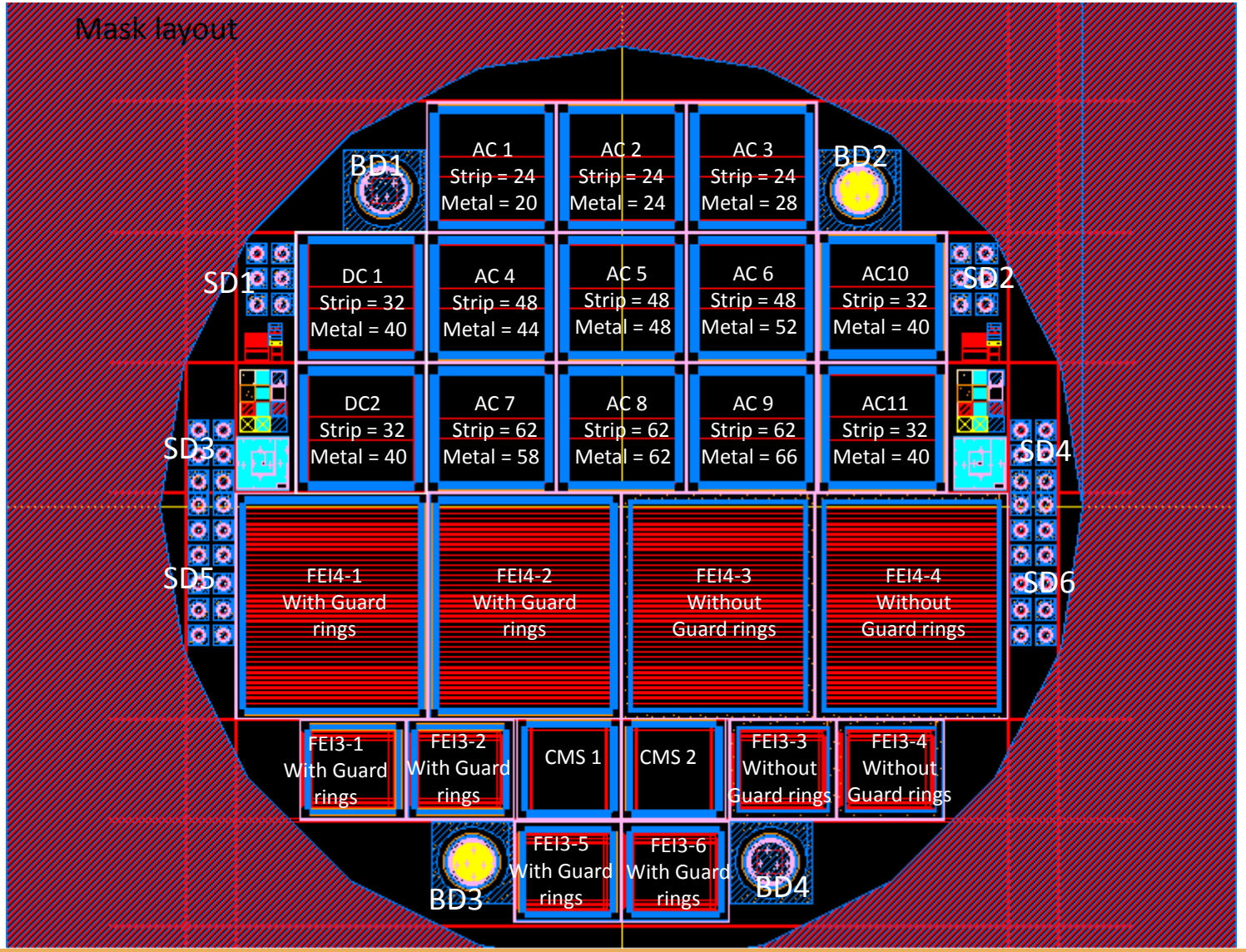
2. Low gain avalanche detectors (LGAD)

Creating an $n++/p+/p-$ junction along the center of the electrodes. Under reverse bias conditions, a high electric field region is created at this localized region, which can lead to a multiplication mechanism[2].



[2]P. Fernandez et al, "Simulation of new p-type strip detectors with trench to enhance the charge multiplication effect in the n-type electrodes", Nuclear Instruments and Methods in Physics Research A658 (2011) 98 102.

Mask layout


Mask layout
BD1
AC 1
Strip = 24
Metal = 20
AC 2
Strip = 24
Metal = 24
AC 3
Strip = 24
Metal = 28
BD2
SD1
DC 1
Strip = 32
Metal = 40
AC 4
Strip = 48
Metal = 44
AC 5
Strip = 48
Metal = 48
AC 6
Strip = 48
Metal = 52
AC10
Strip = 32
Metal = 40
SD2
DC2
Strip = 32
Metal = 40
AC 7
Strip = 62
Metal = 58
AC 8
Strip = 62
Metal = 62
AC 9
Strip = 62
Metal = 66
AC11
Strip = 32
Metal = 40
SD3
SD4
SD5
SD6
FEI4-1
With Guard
rings
FEI4-2
With Guard
rings
FEI4-3
Without
Guard rings
FEI4-4
Without
Guard rings
FEI3-1
With Guard
rings
FEI3-2
With Guard
rings
CMS 1
CMS 2
FEI3-3
Without
Guard rings
FEI3-4
Without
Guard rings
FEI3-5
With Guard
rings
FEI3-6
With Guard
rings
BD3
BD4

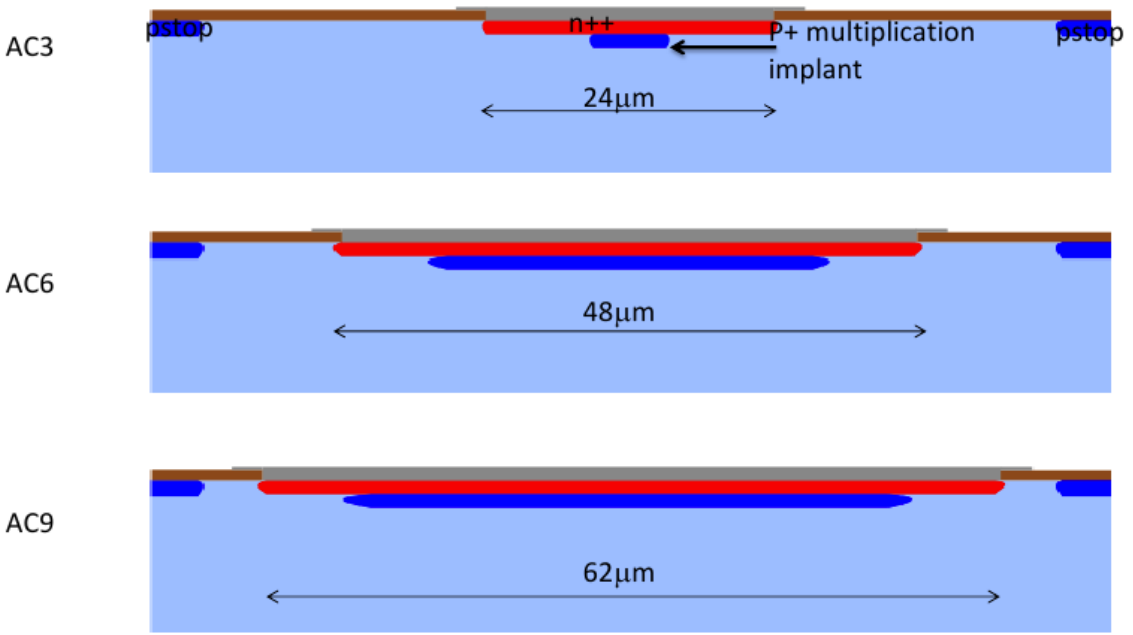
Strip detectors

Pitch $p = 80\mu m$

	Strip $[\mu m]$	Metal $[\mu m]$	P-implant $[\mu m]$	w/p	P-implant / pitch
AC1	24	20	6	0.3	7.5%
AC2	24	24	6	0.3	7.5%
AC3	24	28	6	0.3	7.5%
AC4	48	44	30	0.6	37.5%
AC5	48	48	30	0.6	37.5%
AC6	48	52	30	0.6	37.5%
AC7	62	58	44	0.775	55%
AC8	62	62	44	0.775	55%
AC9	62	66	44	0.775	55%
AC10 and AC11 and DC	32	40	14	0.4	17.5%

Strips cross section

Strip outline



Three different metal width:

- Field plate
- No field plate (metal as width as the strip)
- Metal smaller than the strip width

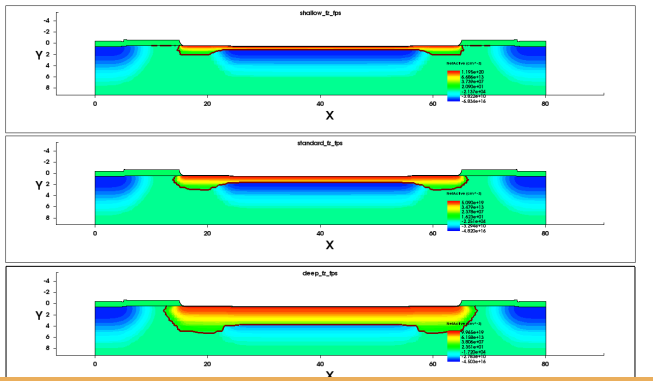
Wafers

Thickness $[\mu m]$	Resistivity $[\Omega cm]$	Resistivity substrate $[\Omega cm]$	Substrate thickness $[\mu m]$	Nominal full depletion
9.8	110.5	0.006	525	9.3V
50.4	96.7	0.006	525	267V
75.2	104.6	0.006	525	550V
285 (FZ)	12000 ± 7000			70V

Diffusion times of the dopant

- Shallow
- Standard
- Deep

Strip cross section

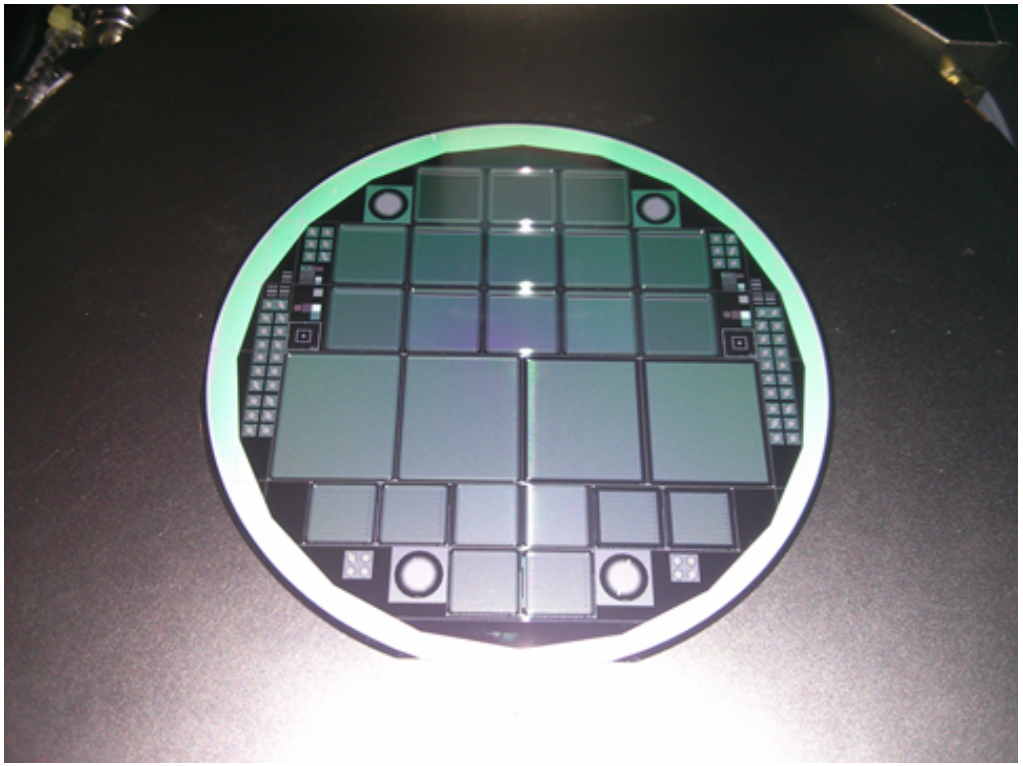


Fabrication finished in June 2013 in CNM Barcelona

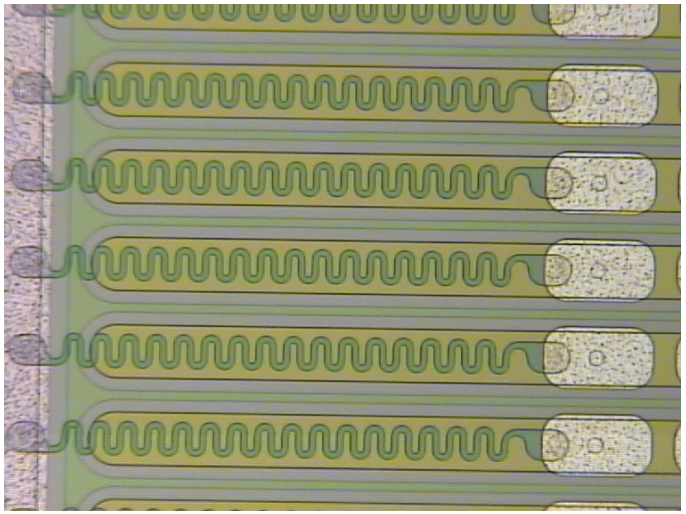
- Epitaxial $10\mu m$
- Epitaxial $50\mu m$
- Epitaxial $75\mu m$
- Float Zone

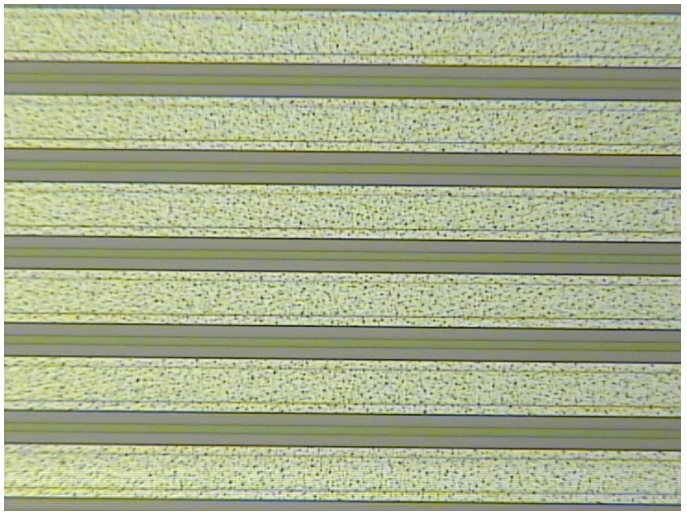
Fabrication of 2 runs

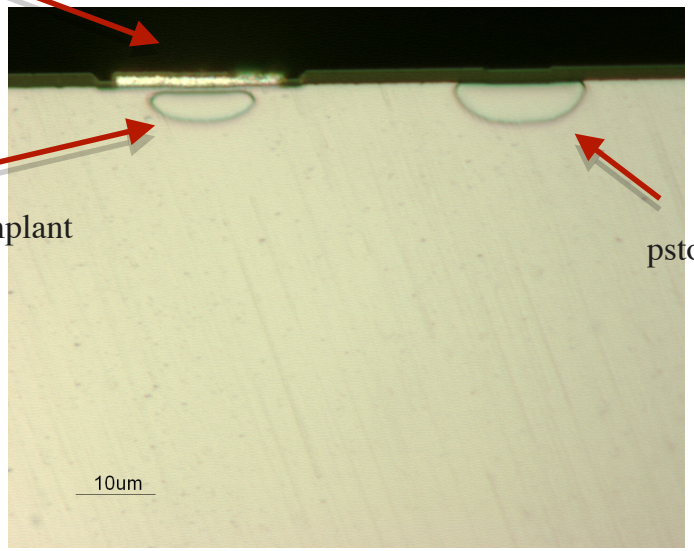
- 14 wafers with LGAD
- 14 wafers without LGAD

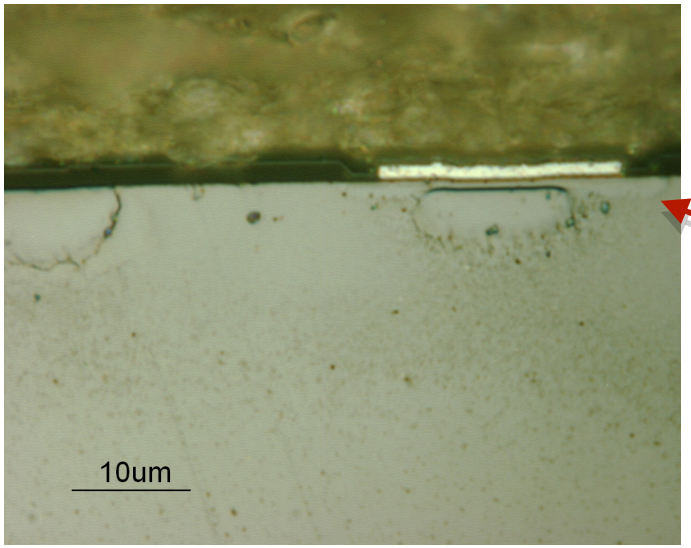


Strips detectors (AC) Pitch 80 μm



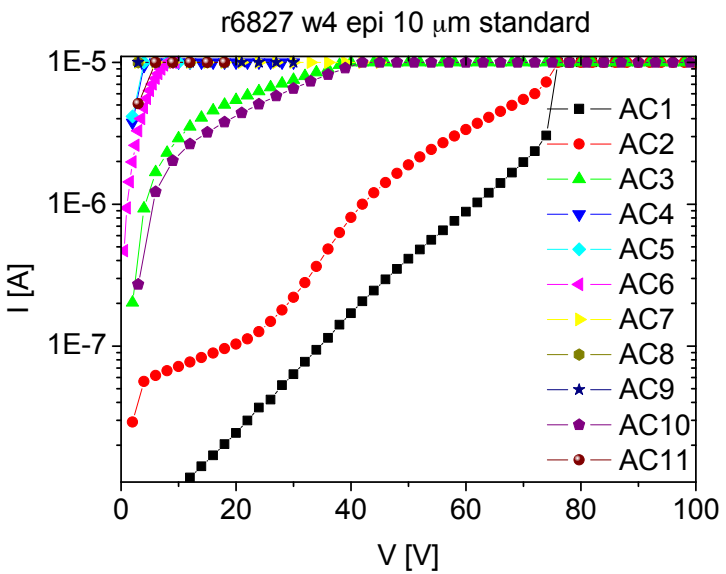






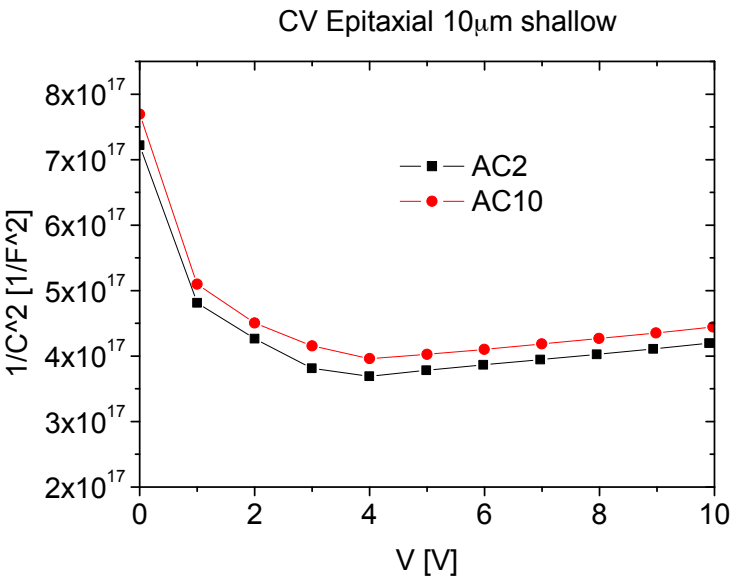
Epitaxial 10 μm

IV epi10μm



Low break down voltage

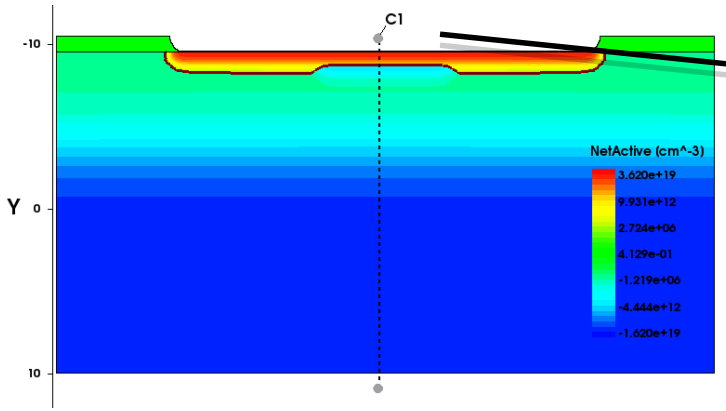
CV epi10μm



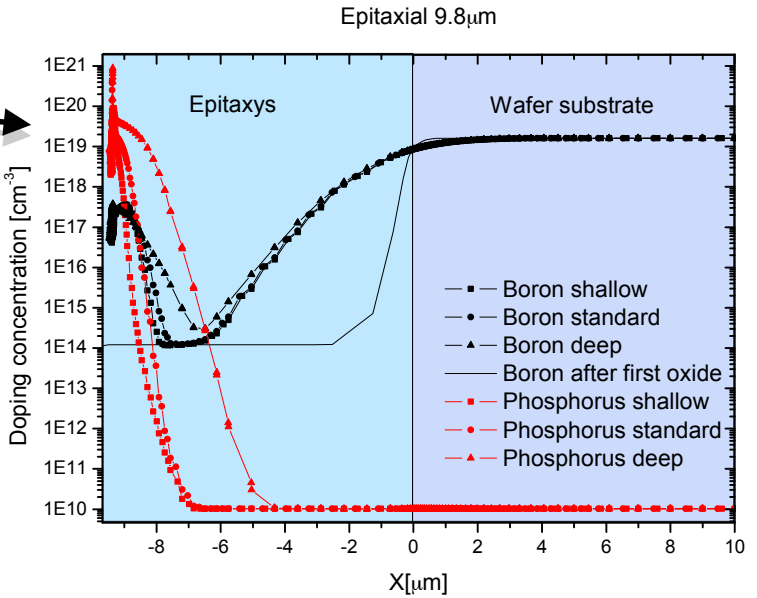
Capacitance of the order of μF (very big)

Epitaxial 10 μm technological simulation

Cross section of the strip

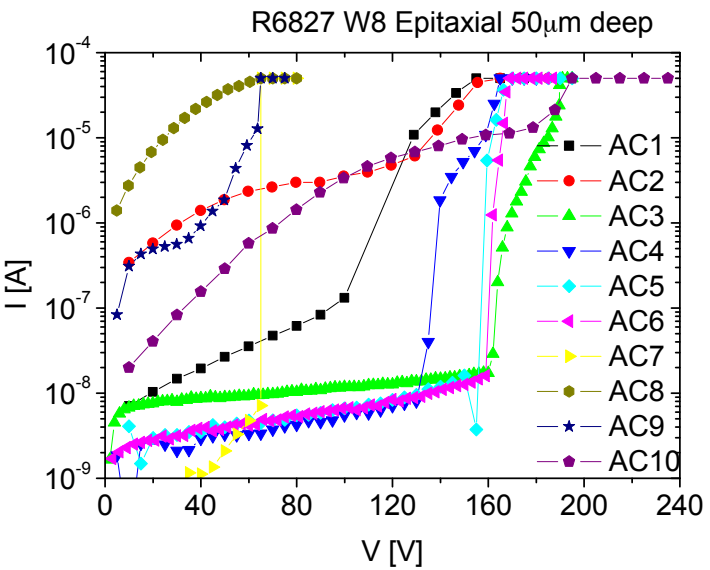


Strip doping profile

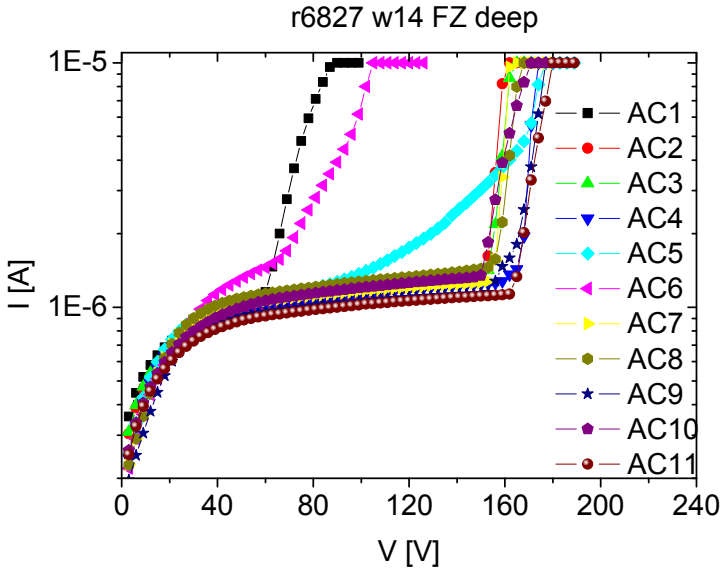


- Boron (p+ implant) may have diffused to the substrate wafer
- Simulations with Sentaurus TCAD

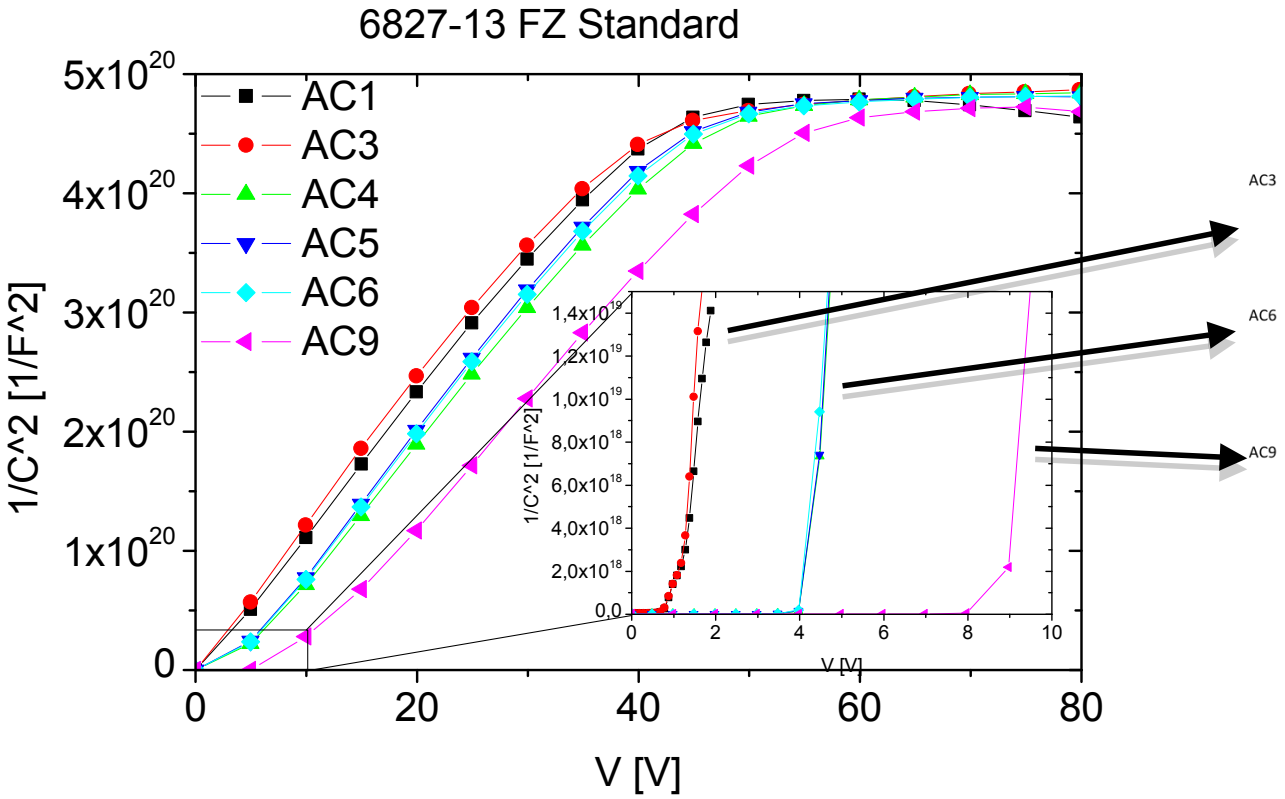
IV curves epitaxial 50μm deep annealing

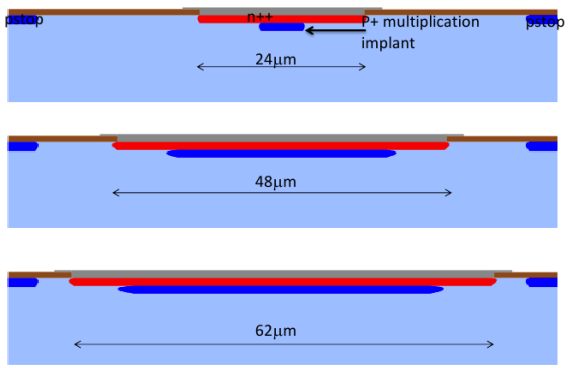


IV curves FZ wafer deep annealing



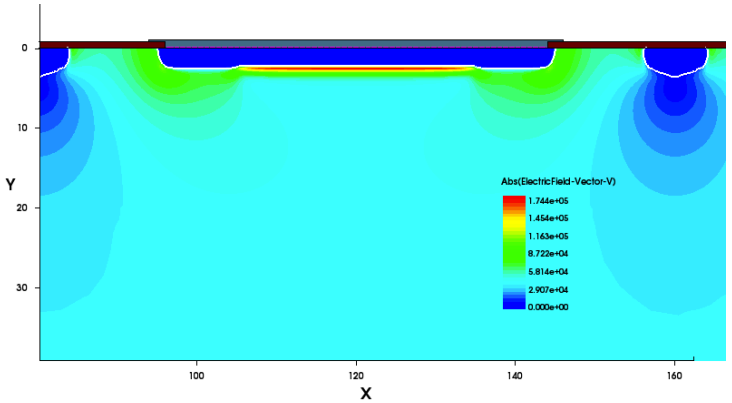
CV curves strip detectors for FZ wafer





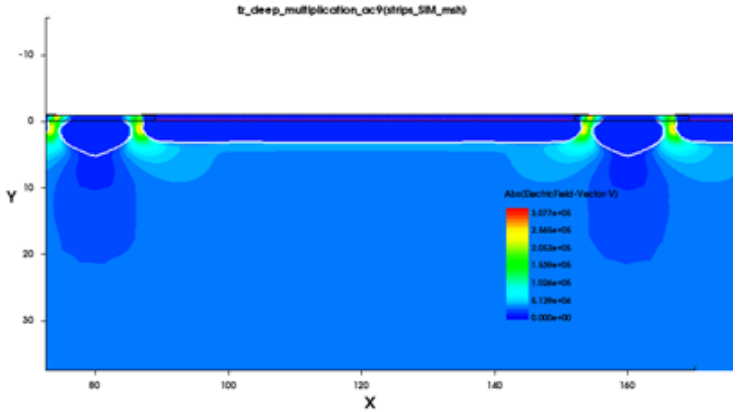
Simulations

AC6 electric field @ 1000V

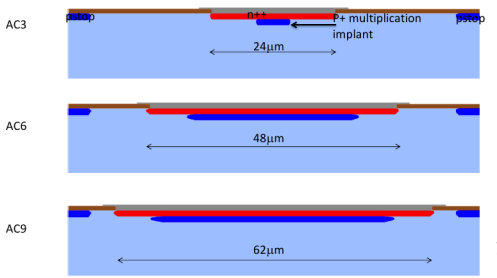


High electric field below the strip

AC9 electric field @ 600V

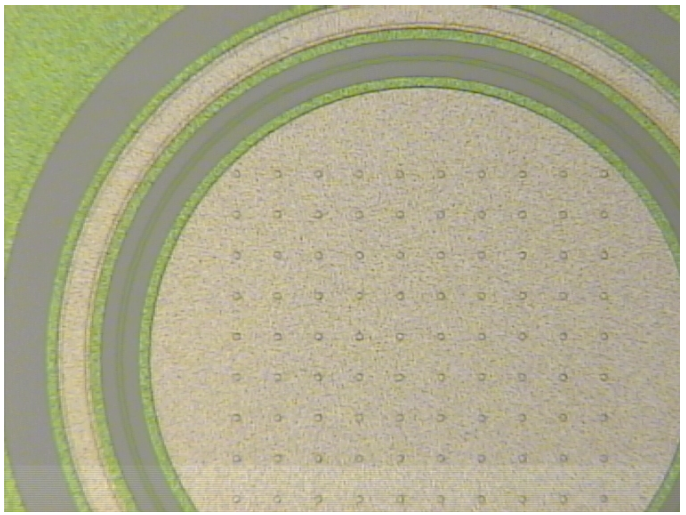


High electric field at the edge of the strips

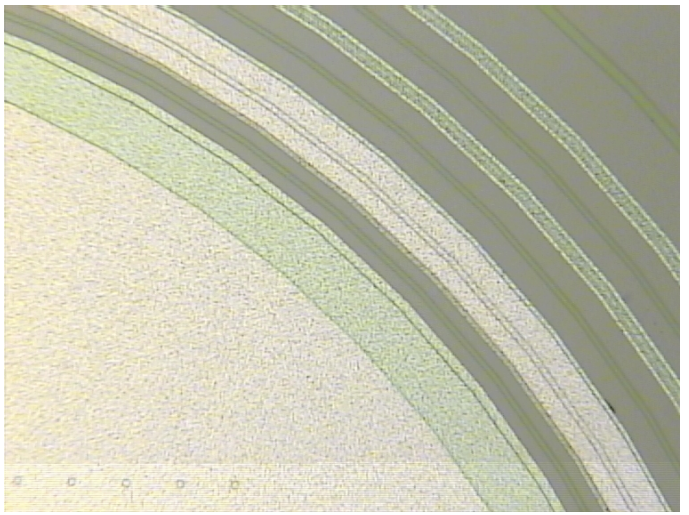


Pad detectors

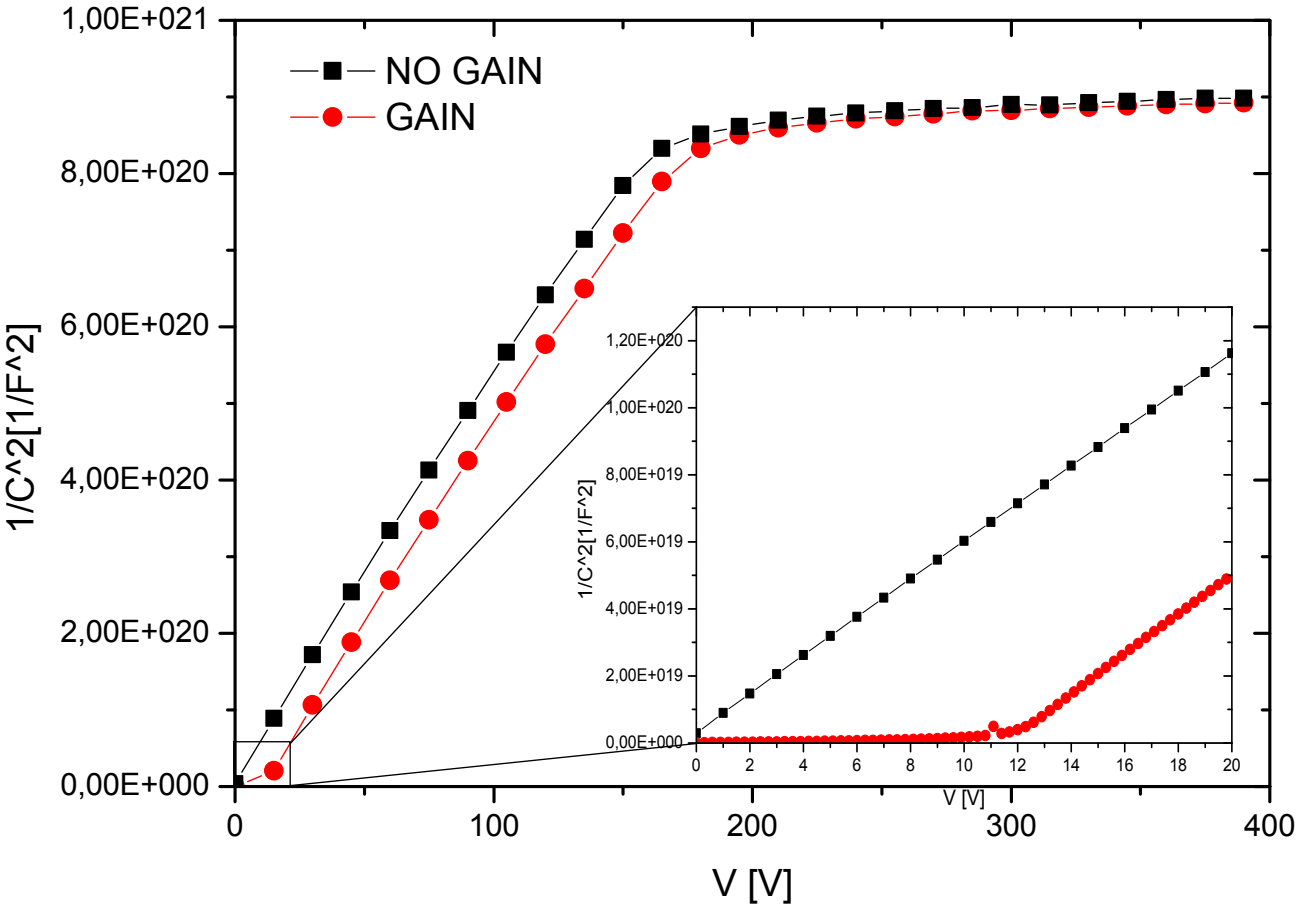
1mm diameter pad



4mm diameter pad

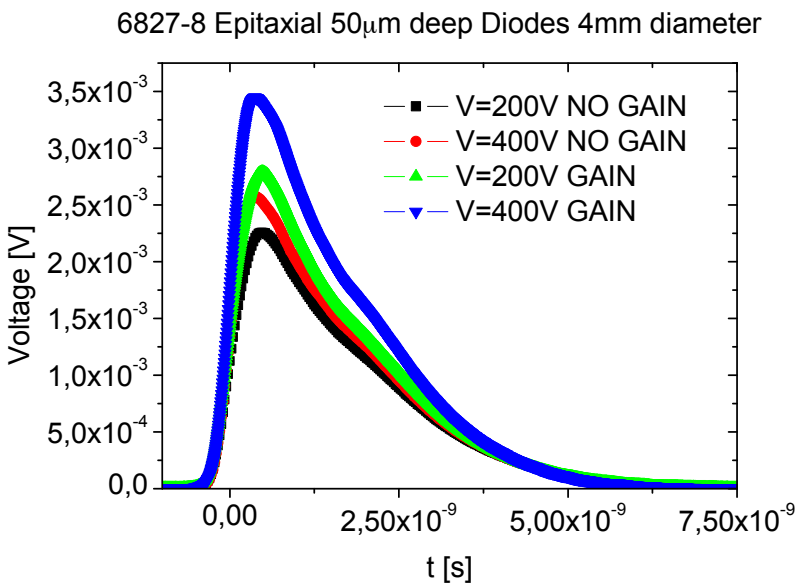


CV curves for pads 4mm diameter epitaxial 50 μm deep annealing

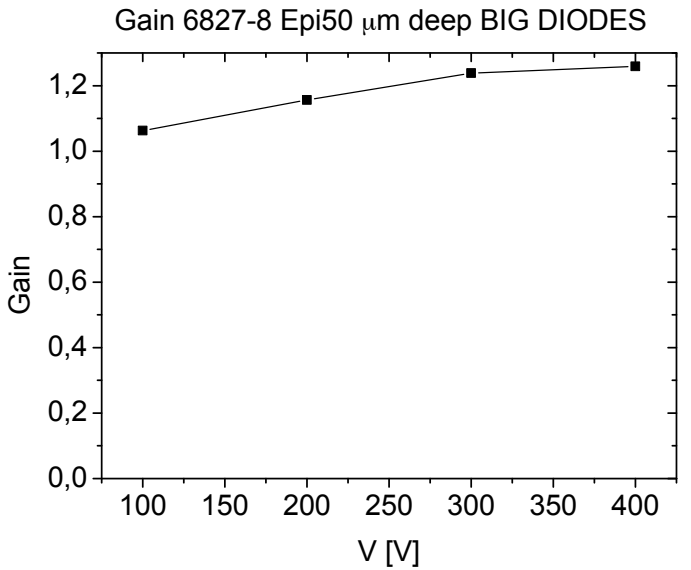


TCT measurements for diodes with Am^{241} from the front average 1000 pulses

TCT big diodes

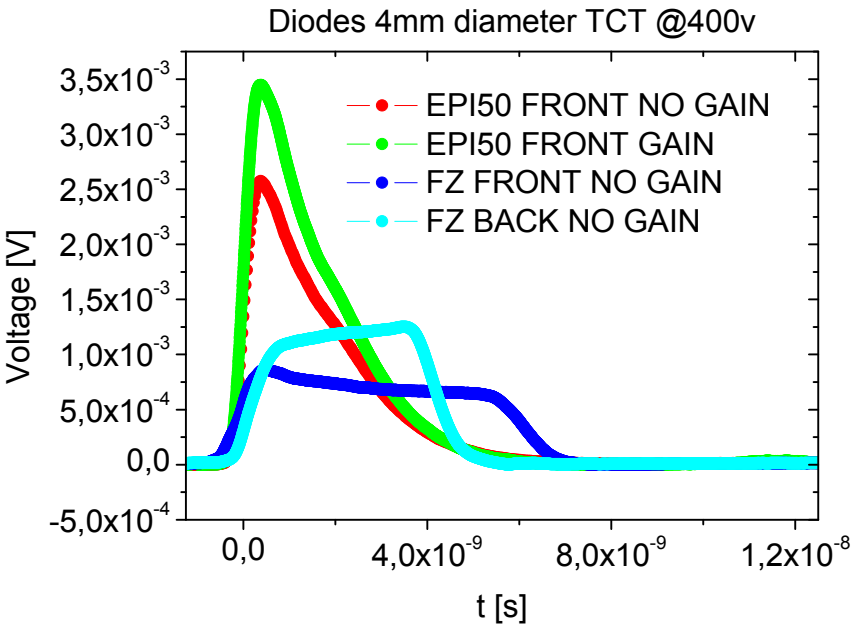


GAIN



Gain values around 1.2

Rising times: Am^{241} alphas



Sensors	1000 average pulses rise time $[ps]$	Height [mV]
Epi50 NO gain front	425	2.575
Epi50 gain front	445	3.240
FZ NO gain front	705	0.865
FZ NO gain back	765	1.1

Conclusions

Conclusions

- The sensors have been successfully fabricated in CNM Barcelona
- Epitaxial sensors 10 μm with multiplication the boron have diffused to the wafer substrate
- For epitaxial wafers alpha particles had to be situated in front of the detector
- Sensors are as fast as 425 ps pulses for epitaxial 50 μm with Am^{241}
- More measurements in Hartmut Sadrozinski's Talk

Wafers

Still there are some wafers to be measured

- 4 (with gain) + 4 (no gain) wafers at IZM (for UBM)
- 4 half wafers at UCSC (some sensors are used)
- 1 half wafer at SELEX (for UBM)
- some strips sensors are at Glasgow
- the others are in CNM

Thanks for your attention