Fabrication of new p-type pixel strip detectors with enhanced multiplication effect in the n-type electrodes

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RD50 Project

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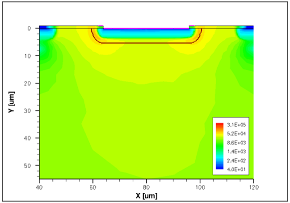
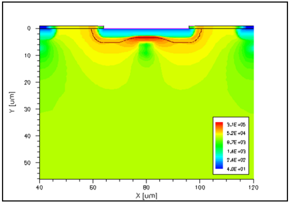
Old results: Simulation of the electric field

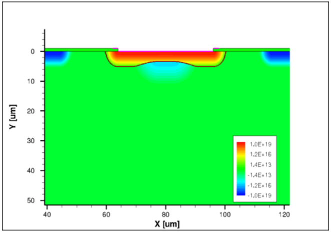
Standard strip

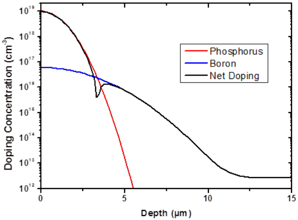


Strip with P-type diffusion



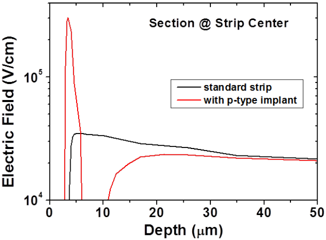
Strip with P-type diffusion: 2D and 1D doping profiles





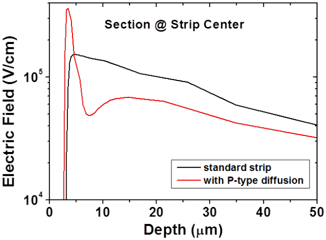
Simulation of the electric field: Curves at 500V

No irradiated



- Standard strip: Electric field strength at the junction increases after irradiation
- Strip with P-type diffusion: electric field strength at the junction is held after irradiation[1]

Irradiated $\phi_{eq} = 1 \cdot 10^{16} n/eqcm^2$



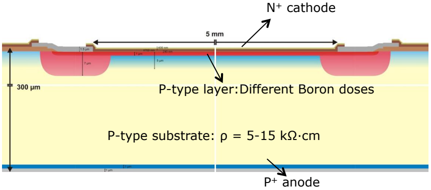
- **Irradiation trap model:**

Acceptor; $E = E_c + 0.46$ eV; η=0.9; $\sigma_e = 5 \times 10^{-15}$; $\sigma_h = 5 \times 10^{-14}$
Acceptor; $E = E_c + 0.42$ eV; η=1.613; $\sigma_e = 2 \times 10^{-15}$; $\sigma_h = 2 \times 10^{-14}$
Acceptor; $E = E_c + 0.10$ eV; η=100; $\sigma_e = 2 \times 10^{-15}$; $\sigma_h = 2.5 \times 10^{-15}$
Donor; $E = E_v - 0.36$ eV; η=0.9; $\sigma_e = 2.5 \times 10^{-14}$; $\sigma_h = 2.5 \times 10^{-15}$

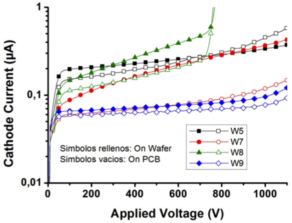
- **Impact Ionization Model:** **Universty of Bolonia**

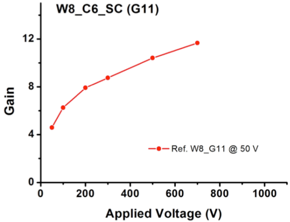
[1] P. Fernandez et al, "Simulation of new p-type strip detectors with trench to enhance the charge multiplication effect in the n-type electrodes"

Pads detectors with multiplication

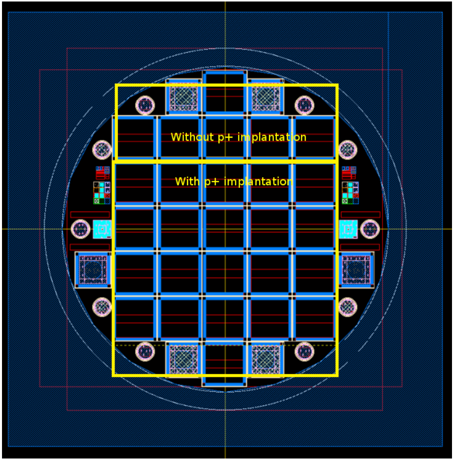


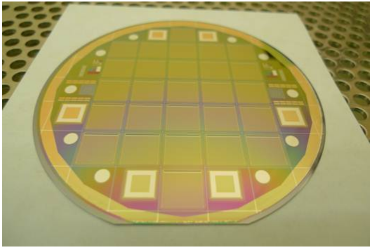
V_{FD} < 30 V
V_{BD} > 1100 V



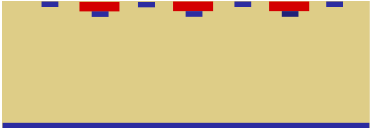


Mask layout: Strip detectors with multiplication





Round diode do not have p+ implant



Ongoing measurements of the detectors in Liverpool and Freiburg

NEW PROJECT

1. Thin p-type epitaxial substrates

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

Provide in the same detector and readout chain:

- Ultra-fast timing resolution [10's of ps]
- Precision location information [10's of μm]

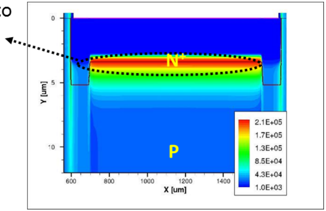
We propose to achieve high electric field using thin p-type epitaxyal substrates[a] grown on thick support wafers, p+ type doped, that acts as the backside ohmic contact. Different thicknesses will be used to study the multiplication effect induced by the high electric field at the collecting electrodes, depending on availability we propose to use: 10, 50, 75μm. **Need very fast pixel readout**.

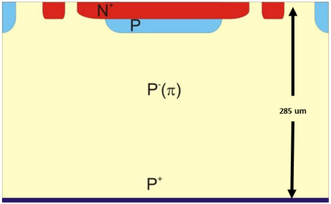
[a] H. Sadrozinski, "*Exploring charge multiplication for fast timing with silicon sensors*" 20th RD50 Workshop, Bari 2012

2. Low gain avalanche detectors (LGAD)

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

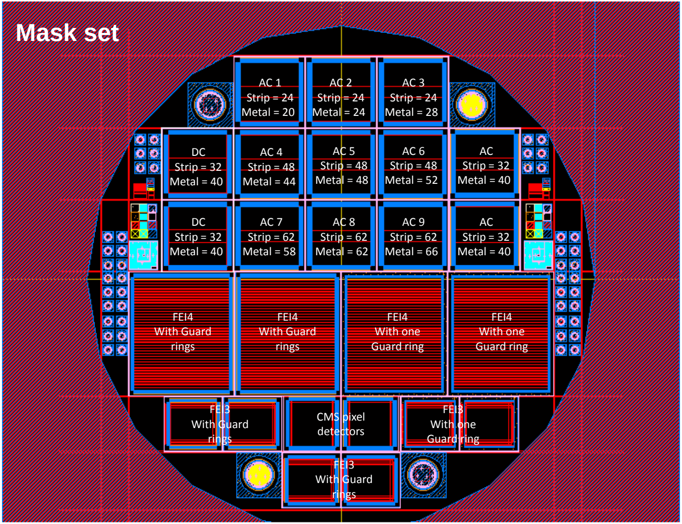
High Electric Field region leading to multiplication





[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 set


Mask set
AC 1
Strip = 24
Metal = 20
AC 2
Strip = 24
Metal = 24
AC 3
Strip = 24
Metal = 28
DC
Strip = 32
Metal = 40
AC 4
Strip = 48
Metal = 44
AC 5
Strip = 48
Metal = 48
AC 6
Strip = 48
Metal = 52
AC
Strip = 32
Metal = 40
DC
Strip = 32
Metal = 40
AC 7
Strip = 62
Metal = 58
AC 8
Strip = 62
Metal = 62
AC 9
Strip = 62
Metal = 66
AC
Strip = 32
Metal = 40
FEI4
With Guard
rings
FEI4
With Guard
rings
FEI4
With one
Guard ring
FEI4
With one
Guard ring
FEI3
With Guard
rings
CMS pixel
detectors
FEI3
With one
Guard ring
FEI3
With Guard
rings

Wafers

Total of 24 wafers with three different annealings (shallow, standard and deep)

	Epitaxial $9.8\mu m$	**Epitaxial** $50.4\mu m$	**FZ**
With p-implant	2 Shallow 1 Standard 1 Deep	2 Shallow 1 Standard 1 Deep	2 Shallow 1 Standard 1 Deep
Without p-implant	2 Shallow 1 Standard 1 Deep	2 Shallow 1 Standard 1 Deep	2 Shallow 1 Standard 1 Deep
Total:	8	8	8

Substrates

Epitaxial

Substrate: $100mm$, $525\mu m$ Boron type with resistivity $0.006\Omega \cdot cm$ $< 100 >$

Epilayer:

Thick	Resistivity
$9.8\mu m$	$110.5\Omega \cdot cm$
$50.4\mu m$	$96.7\Omega \cdot cm$

FZ

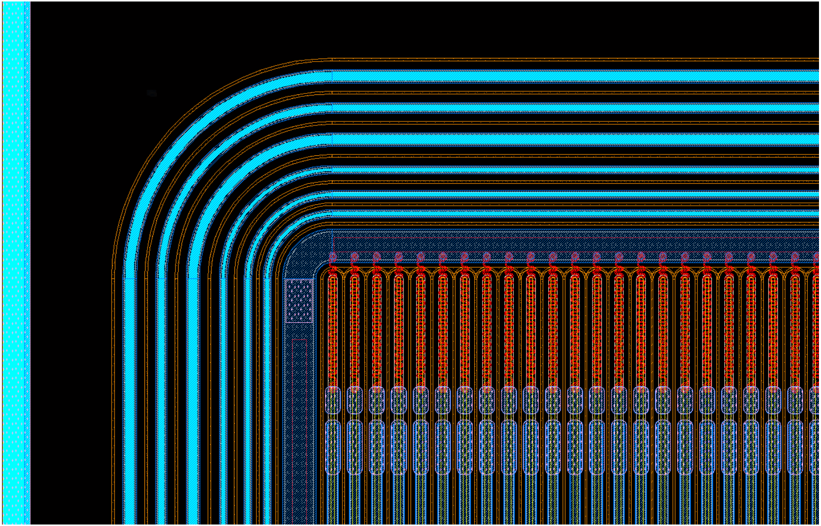
p-type $285\mu m$ $< 100 >$ resistivity $(12 \pm 7)k\Omega \cdot cm$

Strip detectors

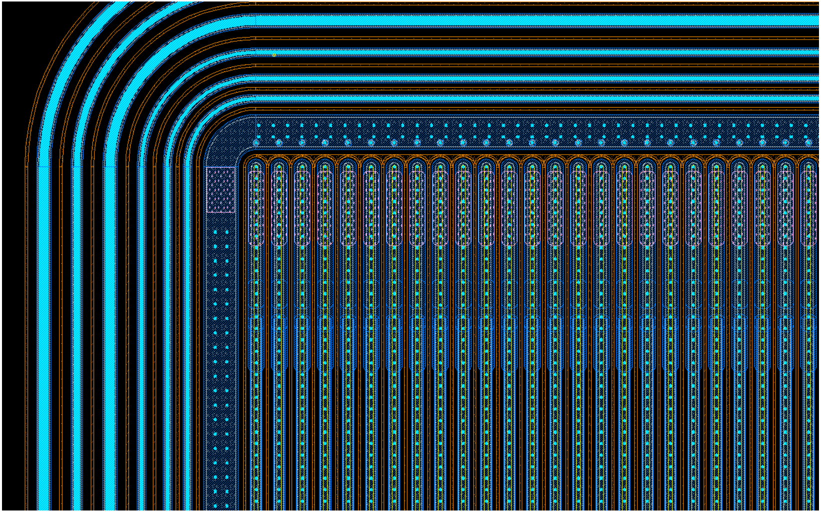
Pitch $p = 80\mu m$

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

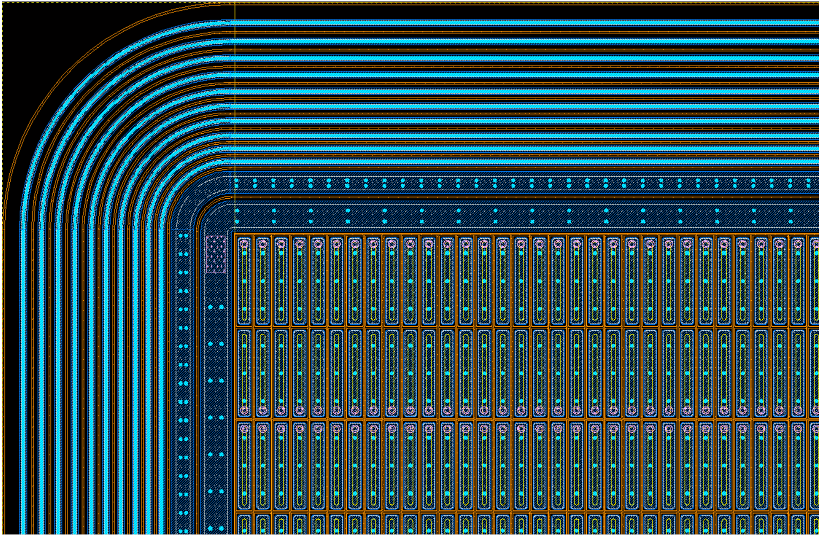
Strips AC



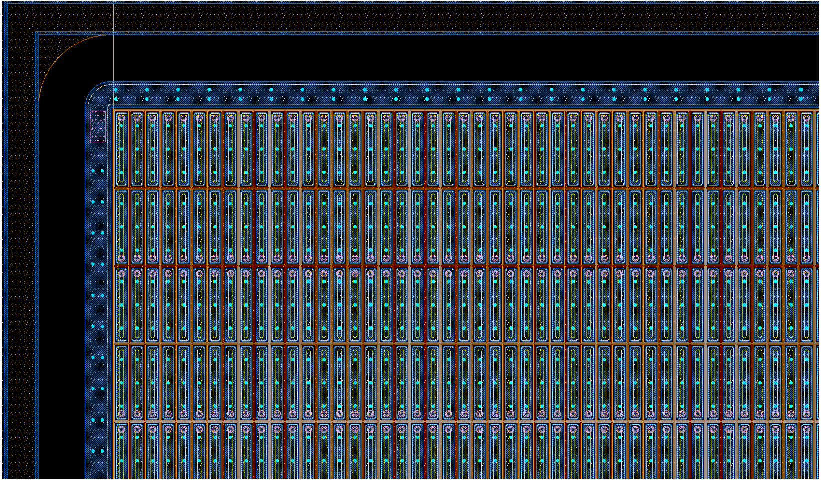
Strips DC



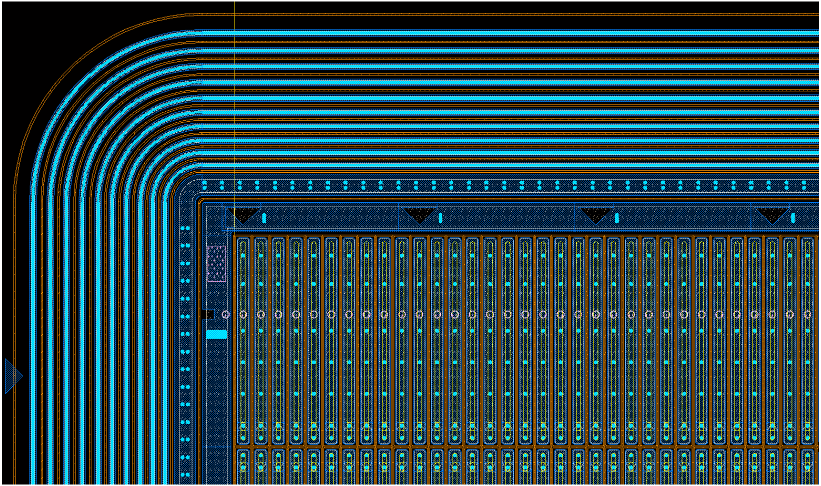
FE-I4



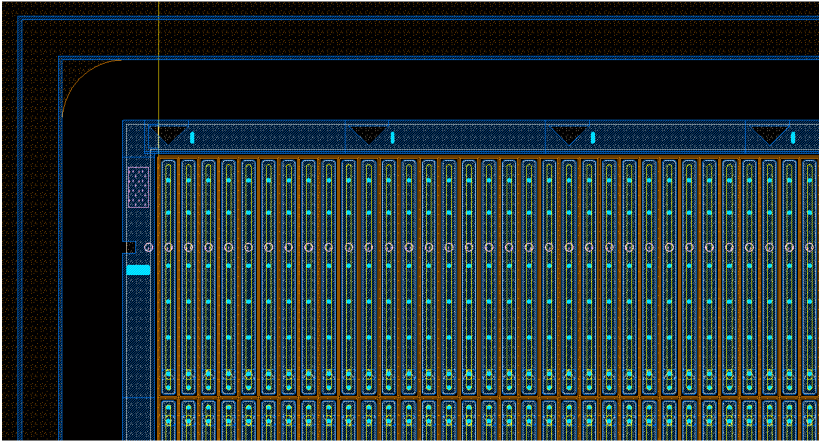
FE-I4 with one guard ring



FE-I3

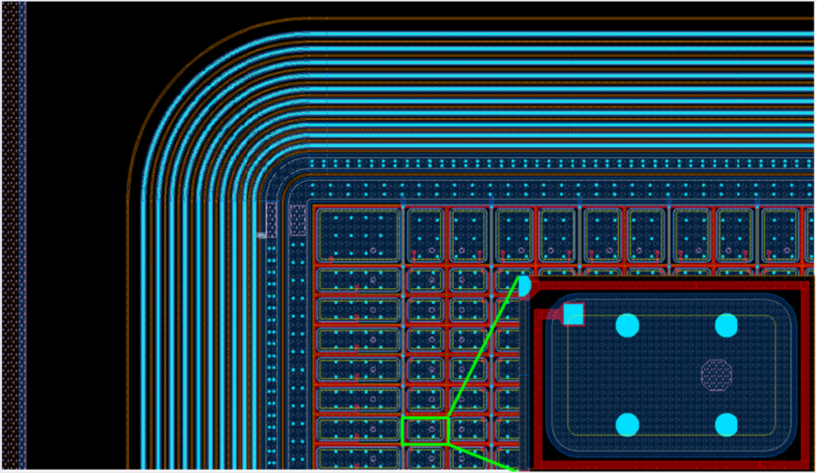


FE-I3 with one guard ring



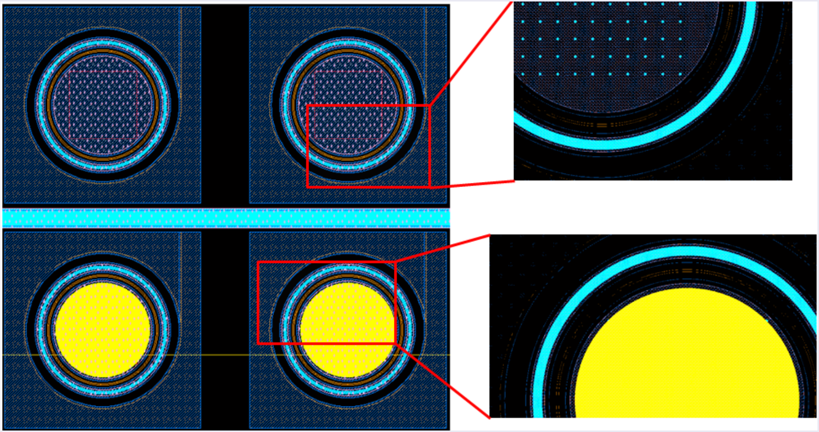
CMS

Pixels with polysilicon bias resistor



Diodes

Diodes without and with p-implant 1000μm diameter

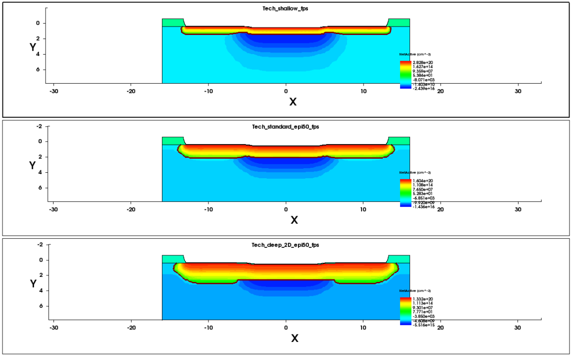


Technological simulation for epitaxial wafers

Simulation of shallow standard and deep implantations

Epitaxial

- Shallow
- Standard
- Deep

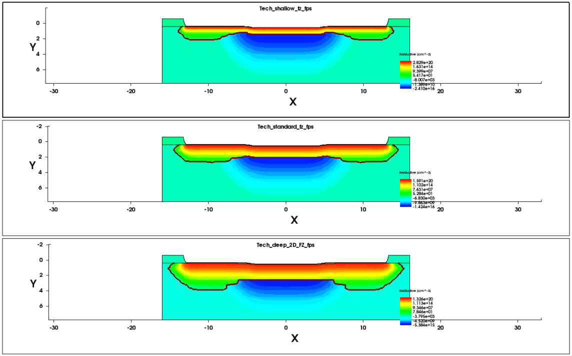


Technological simulation for the FZ wafer

Simulation of shallow standard and deep implantations

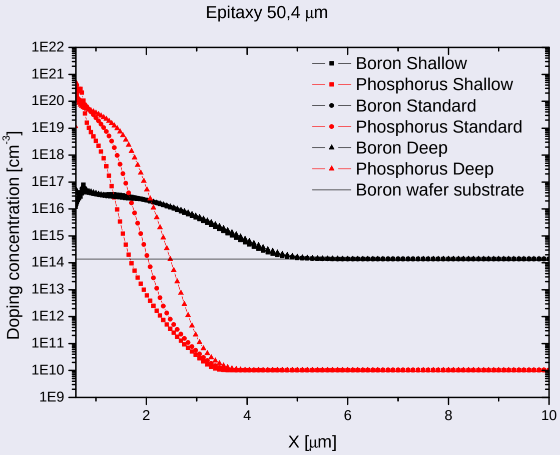
Float Zone (FZ)

- Shallow
- Standard
- Deep



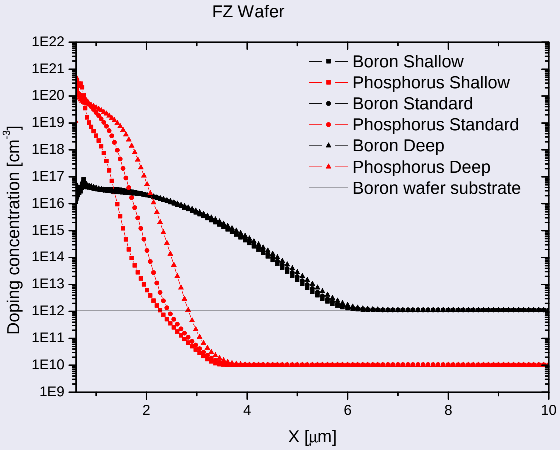
Doping profiles for epitaxial wafers

Simulation of shallow standard and deep implantations



Doping profiles for FZ wafer

Simulation of shallow standard and deep implantations

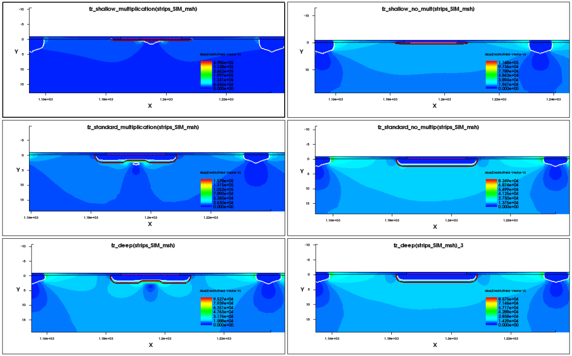


AC1

Electric field for FZ wafers for AC1 detector at 200V

With multiplication Without multiplication

- Shallow
- Standard
- Deep

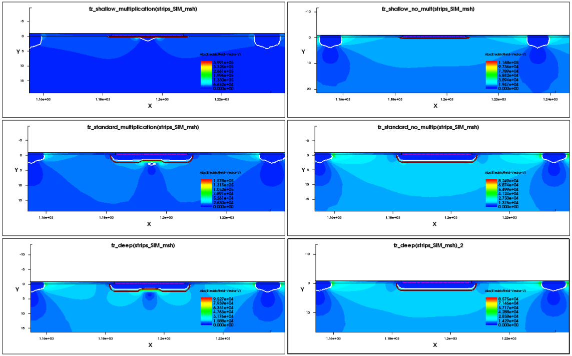


AC2

Electric field for FZ wafers for AC2 detector at 200V

With multiplication Without multiplication

- Shallow
- Standard
- Deep

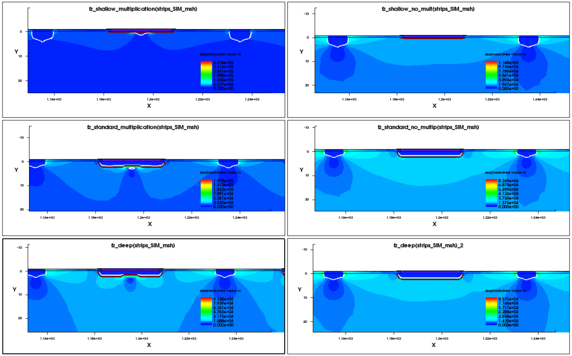


AC3

Electric field for FZ wafers for AC3 detector at 200V

With multiplication Without multiplication

- Shallow
- Standard
- Deep



Conclusions

- We have measured pads with multiplication from the previous fabrication
- Measurements of strip detectors are ongoing
- More electrical simulations need to be performed
- The fabrication of the new devices will begin soon in the clean room facility at CNM Barcelona (end of February)
- More information in Hartmut Sadrozinki's talk "*Ultra Fast Silicon Detectors*"

Thanks for your attention