Novel sensor technologies for tracking and vertexing:

A 2D position sensitive microstrip sensor with charge division.

A segmented p-type sensor with low-gain charge amplification.

Esteban Currás

Instituto de Física de Cantabria(CSIC-UC)

Centre Nacional de Microelectrònica IMB

IFCA

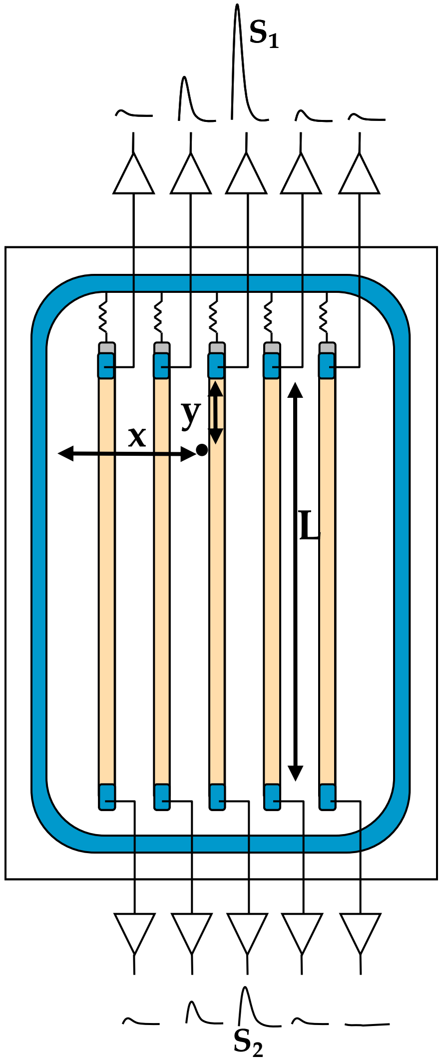
Outline

- Motivations for the R&D.
- A 2D position sensitive microstrip sensor.
  - Laser characterization
  - Electrical equivalent circuit simulations
  - Test beam results
- Segmented p-type sensors with low-gain charge amplification
  - TCAD simulations of the device.
  - Laser characterization of diodes with amplification.
- Conclusions

R&D Motivation

- Charge division in microstrips:
  - Long microstrips ladders (several tens of centimeters) proposed for the ILC tracking detectors.
  - Getting the particle hit coordinate along the strip using the charge division method.
  - Avoid the complexity of double sided sensors and the additional material of a second layer of sensors.
- Low gain segmented p-type pixels (strips)
  - Implementing a small gain in the segmented diode so we can reduce the thickness of the sensors without reducing the signal amplitude
  - Smaller contribution to the material budget.

Charge Division in uStrips



Simple single-side AC-coupled microstrip detectors with resistive coupling electrodes.

X-coordinate: cluster-finding algorithms for strip detectors.

Y-coordinate: Resistive charge division method.

Resistive material

Aluminium

** Electrode resistance >> preamplifier impedance.

S_1=f(y)

S_2=f(L-y)

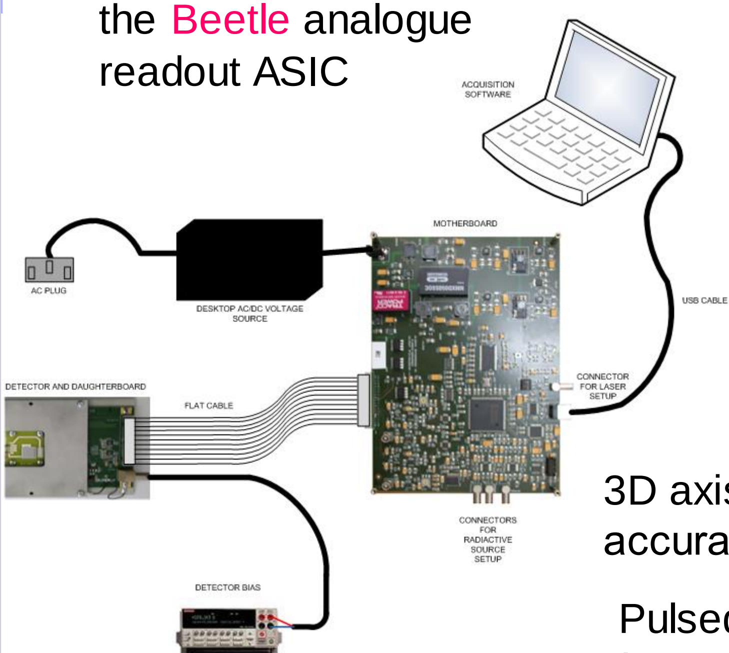
$$\frac{y}{L} = \frac{A_2}{A_1+A_2}$$

Resistive material: high doped polysilicon

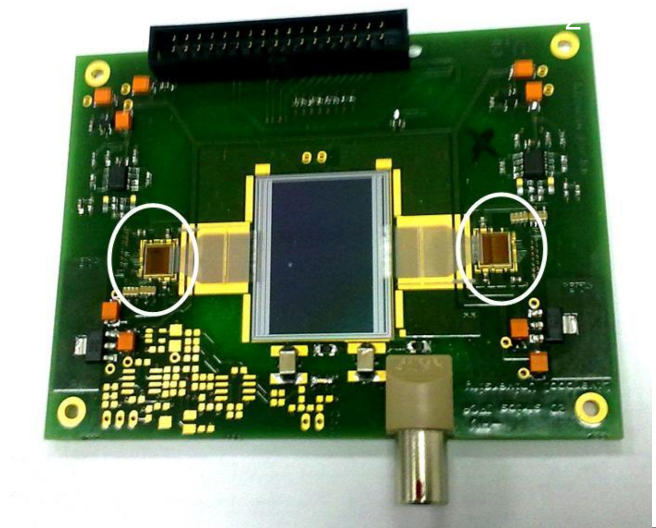
** V. Radeka, IEEE Transaction on Nuclear Science NS-21 (1974) 51

Proof-of-Concept Prototype

ALIBAVA DAQ system for microstrip detectors, based on the Beetle analogue readout ASIC



- 256 channels
- peaking time = 25ns
- S/N≈20 for standard no irradiated detectors



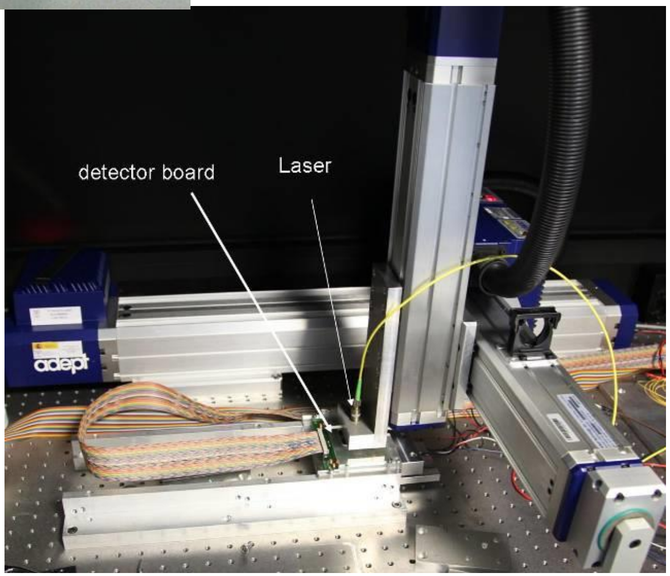
Strip:
- length =20 mm
- width =20 um

Pitches:
- Implant=80 um
- readout= 80 um

Electrode:
- R/um = 2.8 Ohms/um
- R/um = 12.2 Ohms/um

3D axis stage with displacement accuracy ≈ 10 μm

Pulsed DFB laser λ=1060nm
- Gaussian beam spot width ≈ 15 μm
- pulse duration 2ns

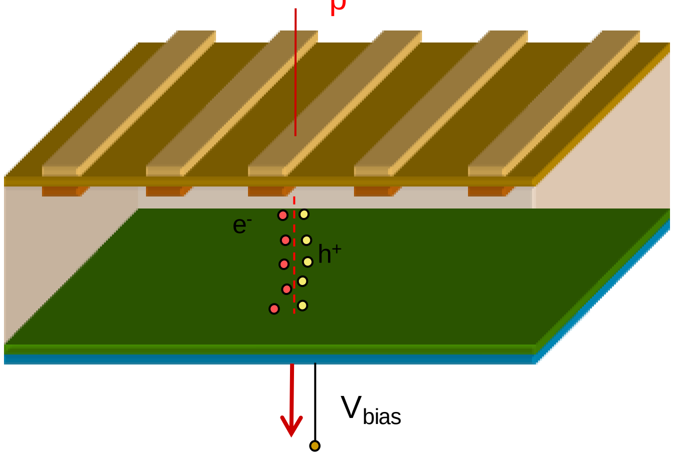


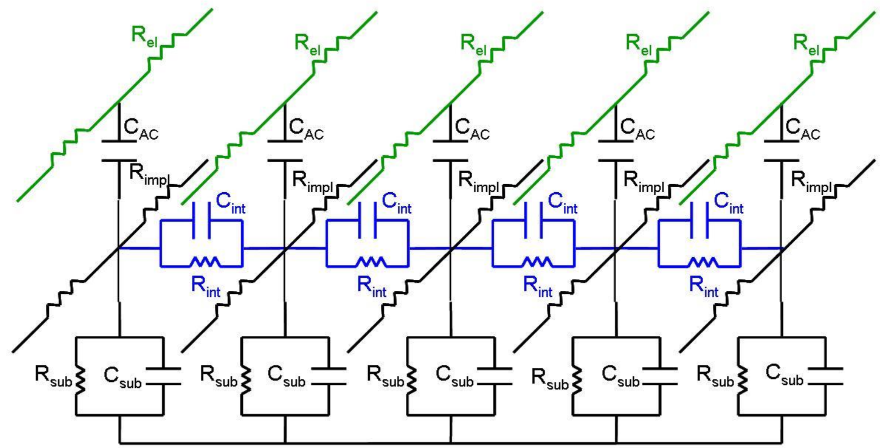
Clean room laboratory at IFCA, Santander

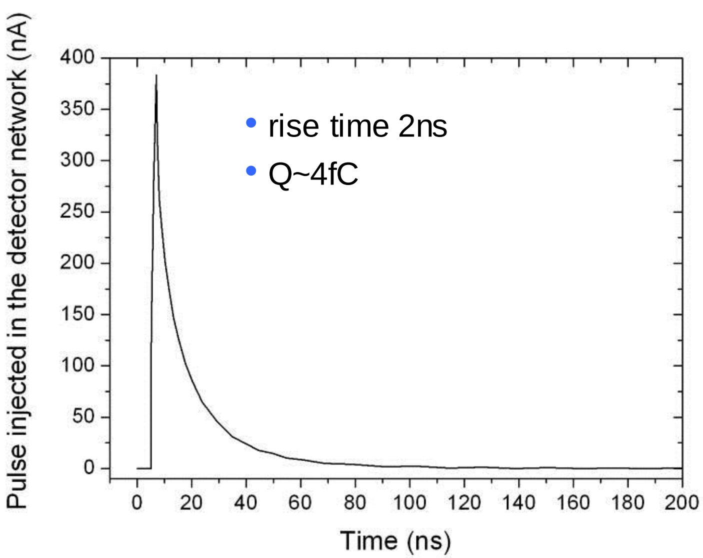
Equivalent Electrical Circuit

Detector (p^+-on-n) model ***

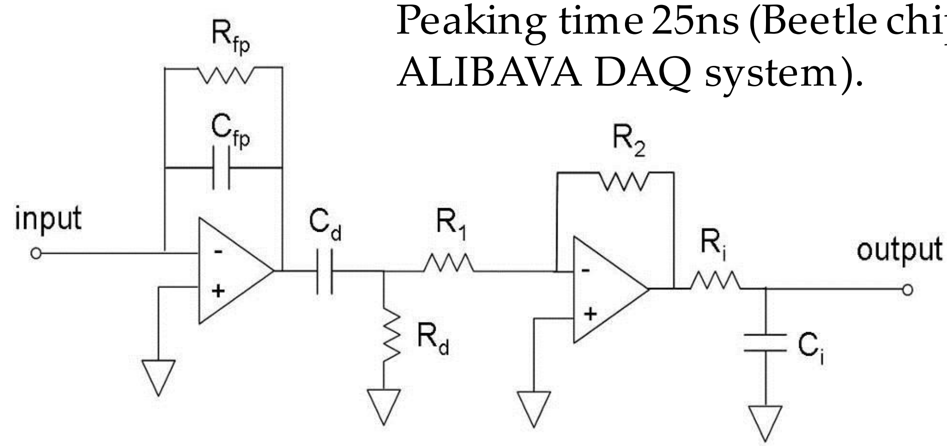
80 cells 250 µm long



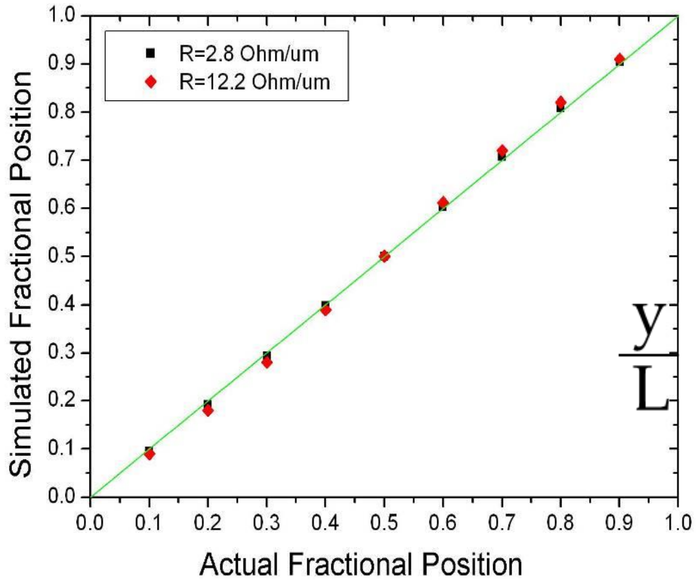




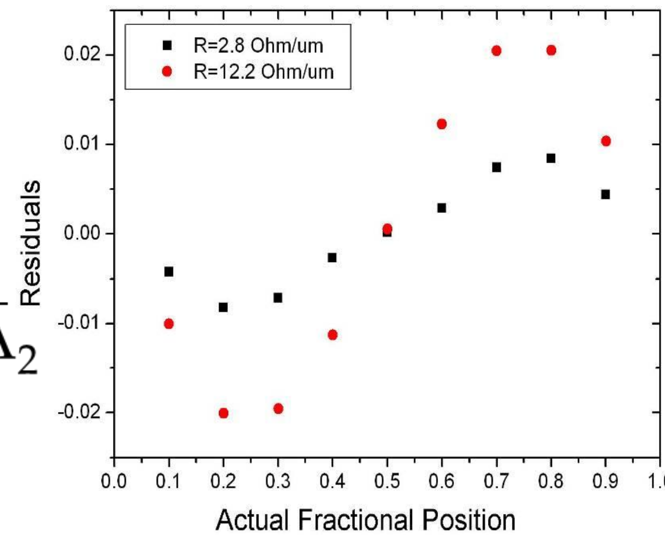
Peaking time 25ns (Beetle chip ALIBAVA DAQ system).

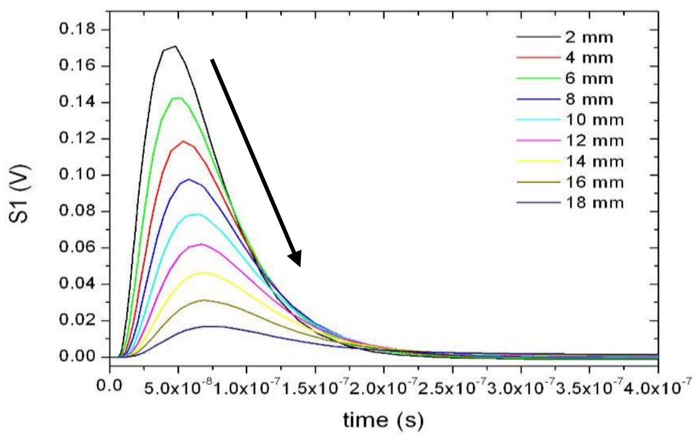


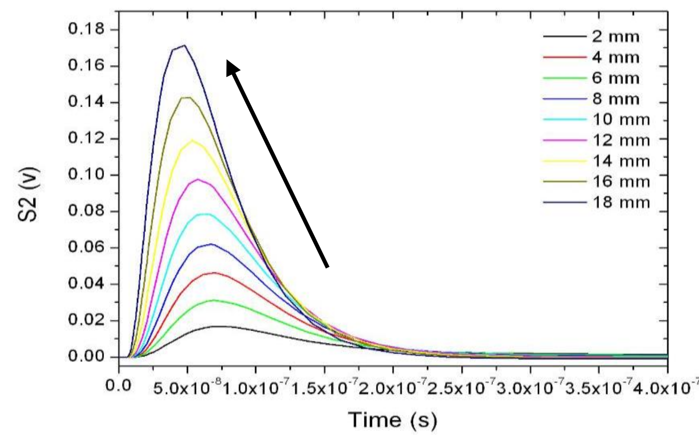
Signal Propagation – Linearity (Simulation)



$$\frac{y}{L} = \frac{A_2}{A_1+A_2}$$

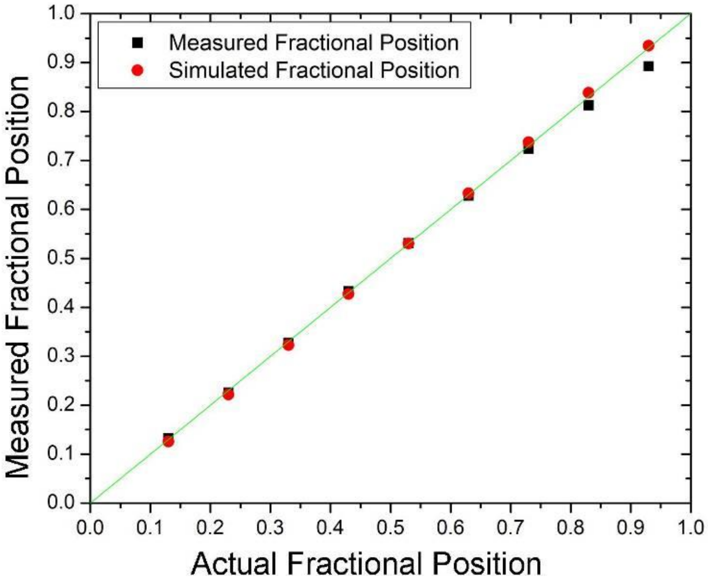




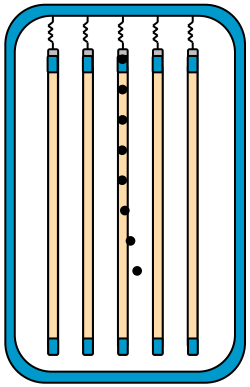


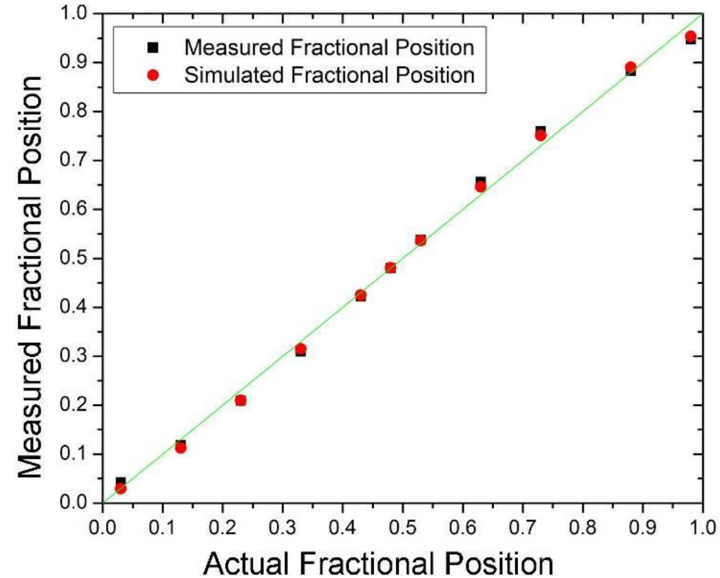
R/l=2.8 Ω/µm

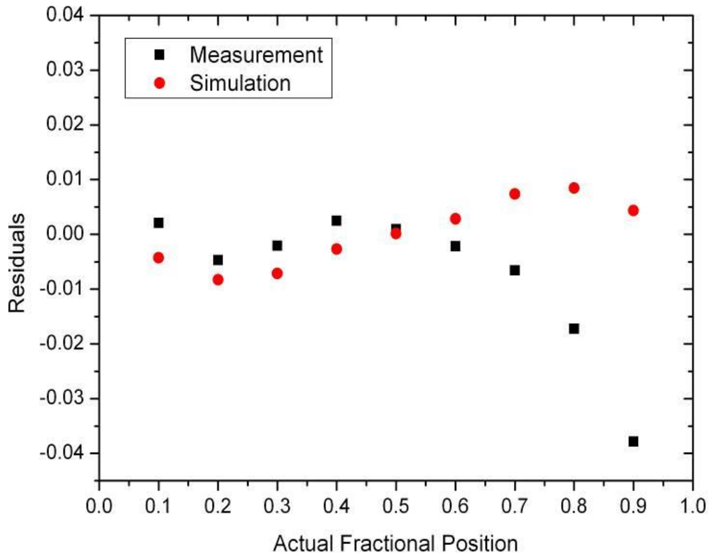
R/l=12.2 Ω/µm



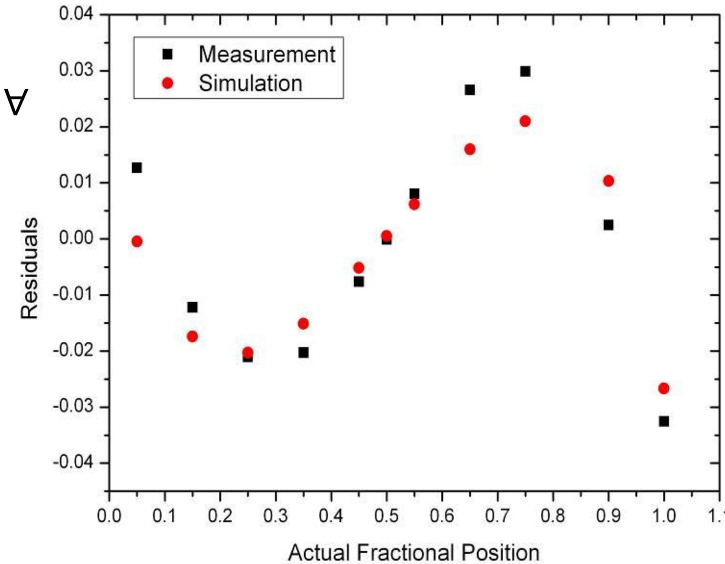
$$\frac{y}{L} = \frac{A_2}{A_1+A_2}$$







20000 events ∀ measurement



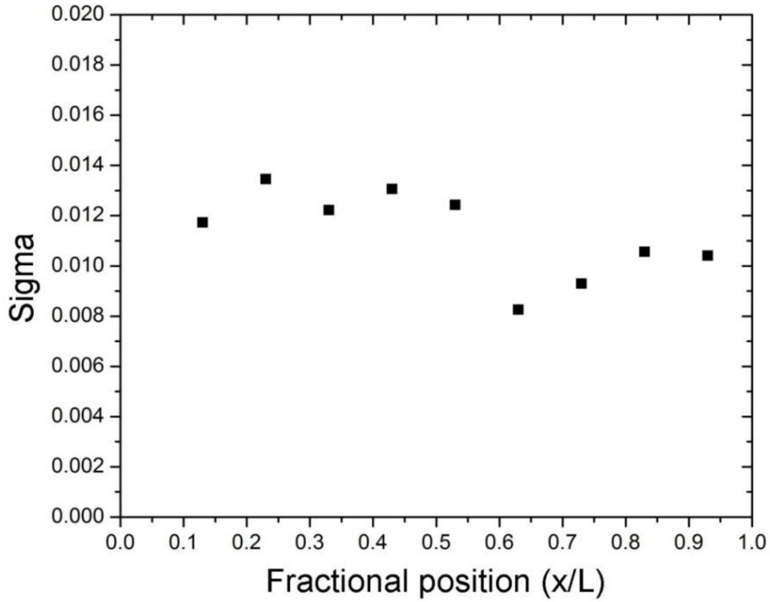
Longitudinal spatial resolution for 6 MIPs signal

$$\frac{A_2}{A_1+A_2}$$

$$\sigma = \frac{A_1 A_2}{(A_1+A_2)^2}\sqrt{\left(\frac{\sigma_{A_1}}{A_1}\right)^2 + \left(\frac{\sigma_{A_2}}{A_2}\right)^2 - 2\rho\left(\frac{\sigma_{A_1}}{A_1}\frac{\sigma_{A_2}}{A_2}\right)},$$

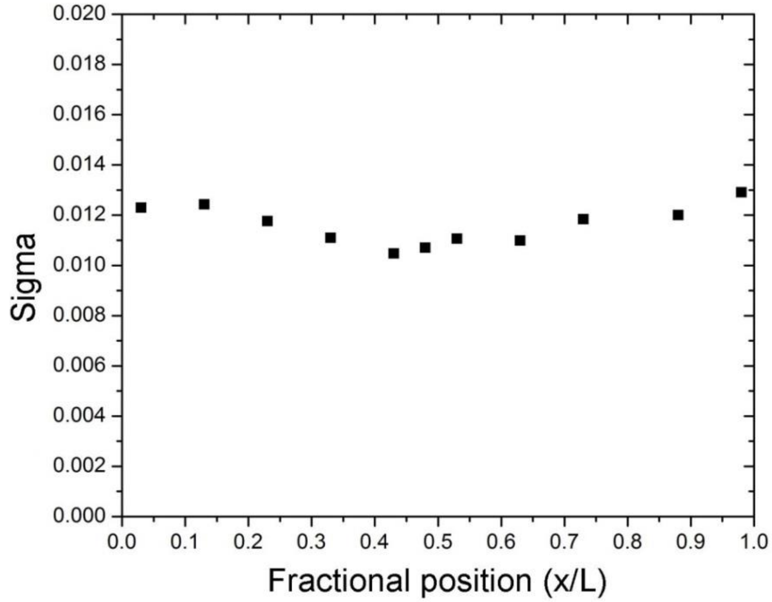
1.1% L => 220 µm

R/l=2.8 Ω/µm

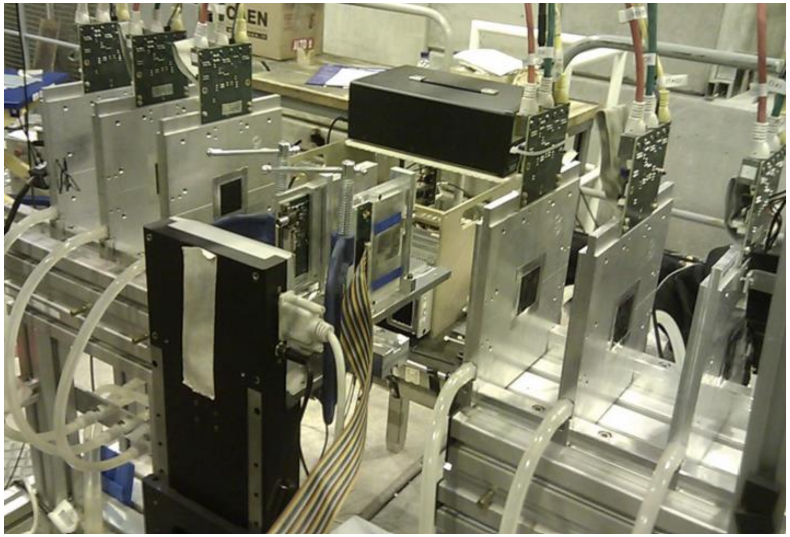


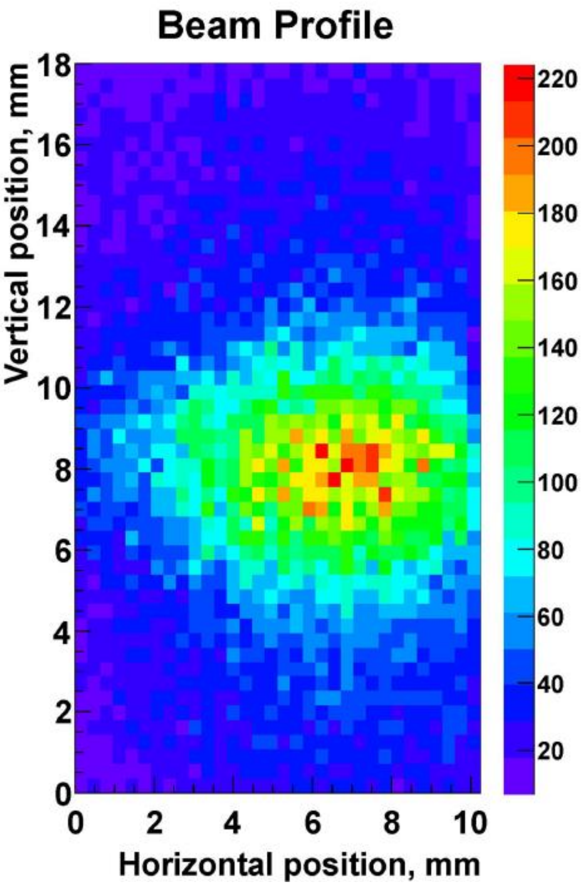
1.2% L => 240 µm

R/l=12.2 Ω/µm



Test Beam Characterization

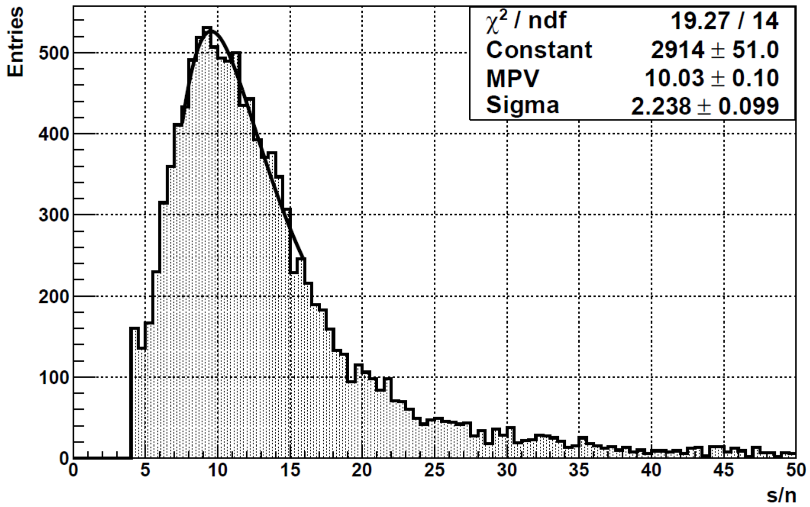


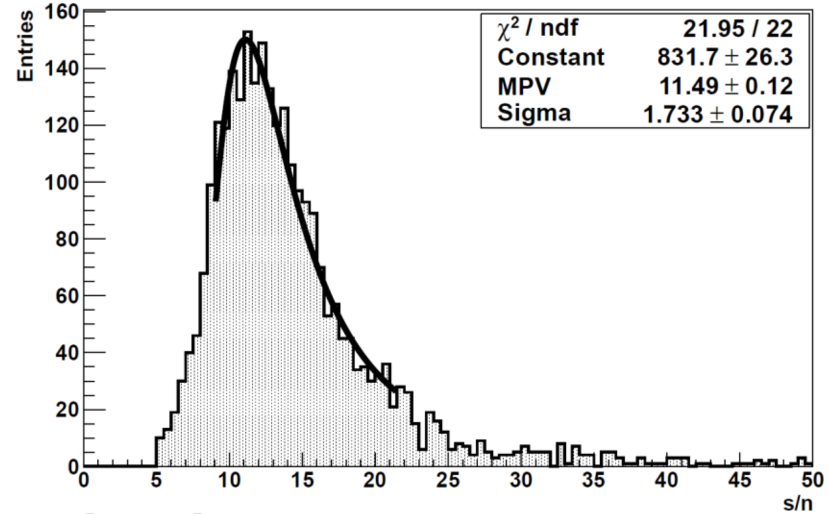


- Test beam at CERN SPS Pion Beam, Nov 2012
- First successful integration and synchronization with AIDA MIMOSA pixel telescope
- Prelimirary results:
  - Monitoring of beam profile.
- Currently in progress:
  - Efficiency and resolution using tracking information.

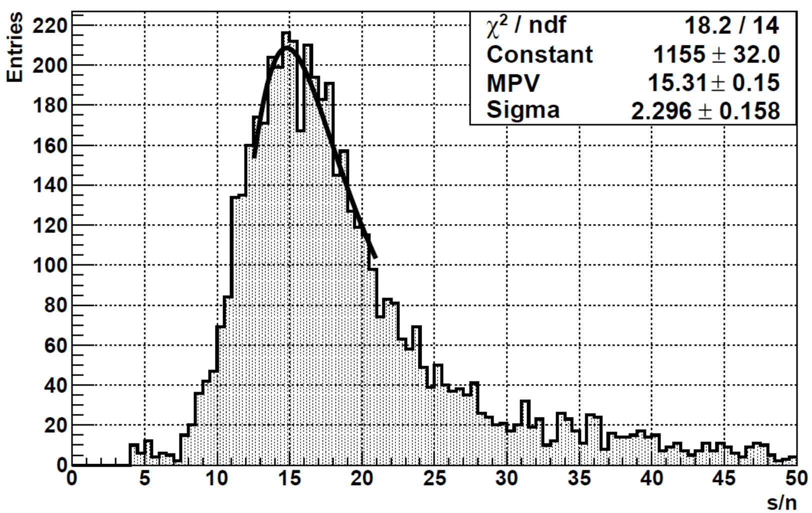
s/n test beam vs s/n radioctive source

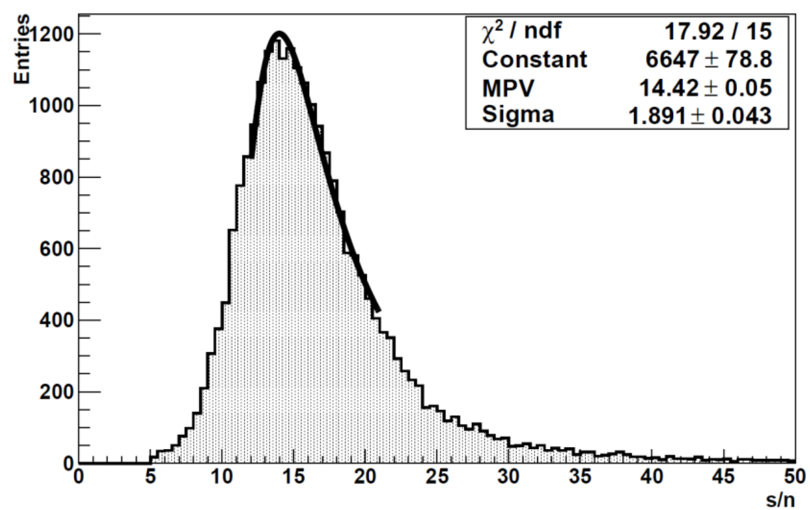
Resistive strips detector





Conventional strips detector





SEGMENTED P-TYPE SENSORS WITH CHARGE AMPLIFICATION

Charge Multiplication- pixel detectors

We are starting the fabrication of new p-type pixel detectors with enhanced multiplication effect in the n-type electrodes, very low collection times and with no cross-talk.

Three different approaches:

1. Thin p-type epitaxyal substrates
2. Low gain avalanche detectors
3. 3D with enhanced electric field.

Two projects funded by CERN RD50 collaboration to work on these technologies.

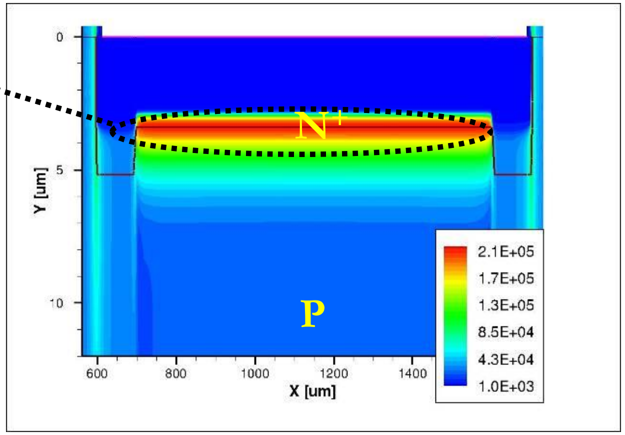
http://rd50.web.cern.ch/rd50/

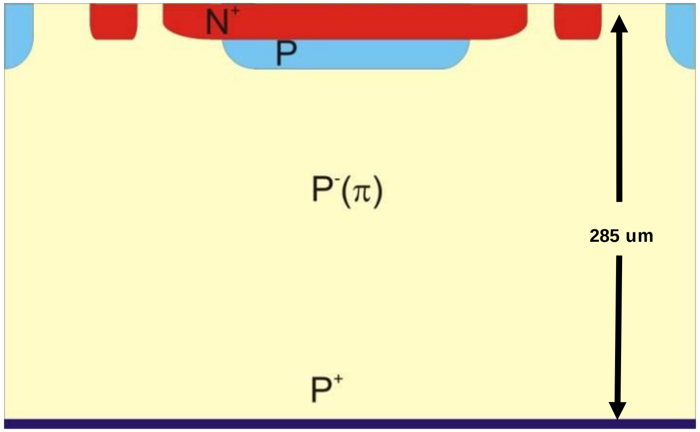
Low gain avalanche detectors (LGAD)

Implating an 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 (impact Ionization).

Advantages = Thinning while keeping same S/N as standard detectors.

High Electric Field region leading to multiplication



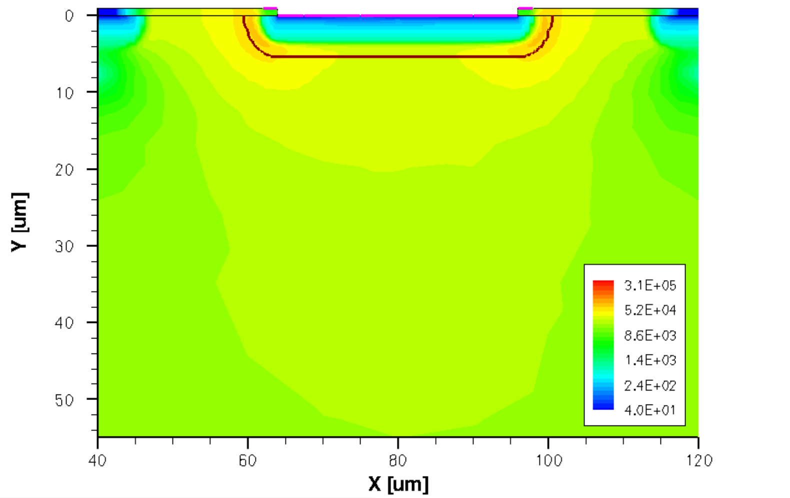


P. Fernandez et al, "Simulation of new p-type strip detectors with trench to enhance the charge multiplication effect in the n-type electrodes" , Nuclear InstrumentsandMethodsinPhysicsResearchA658(2011) 98–102.

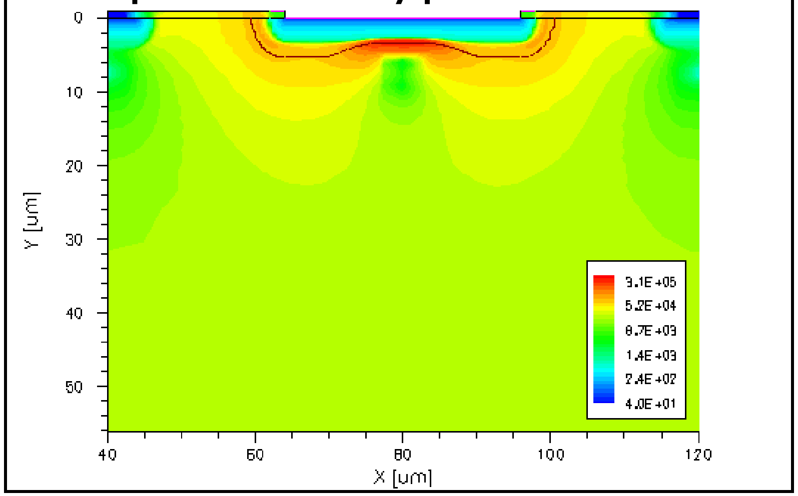
Simulation of the Electric Field

- To obtain the manufacture parameters (doping profiles)

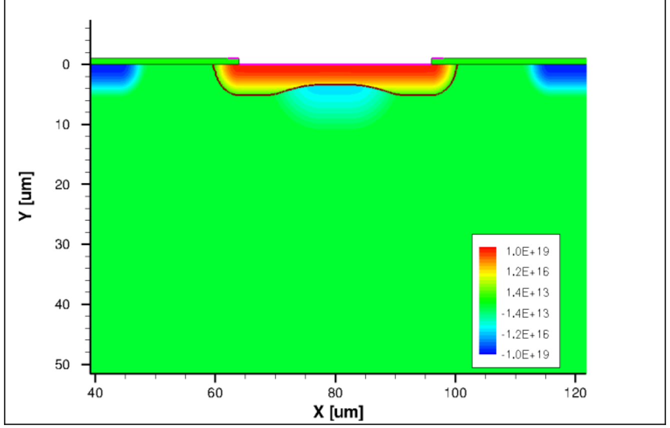
Standard Strip

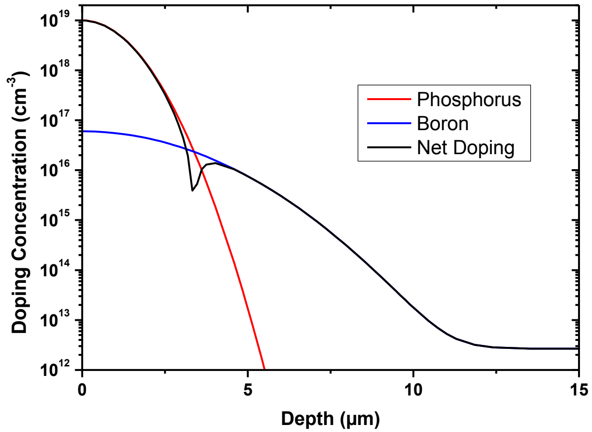


Strip with P-type diffusion



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

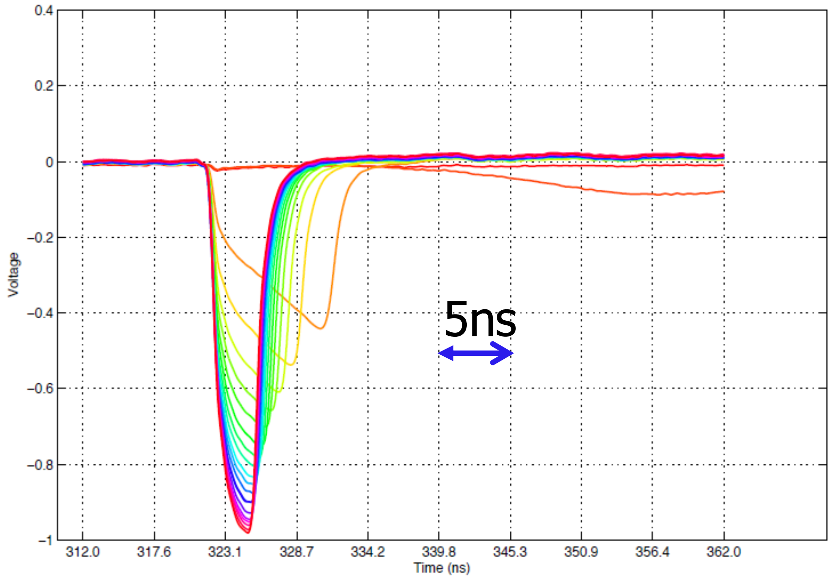




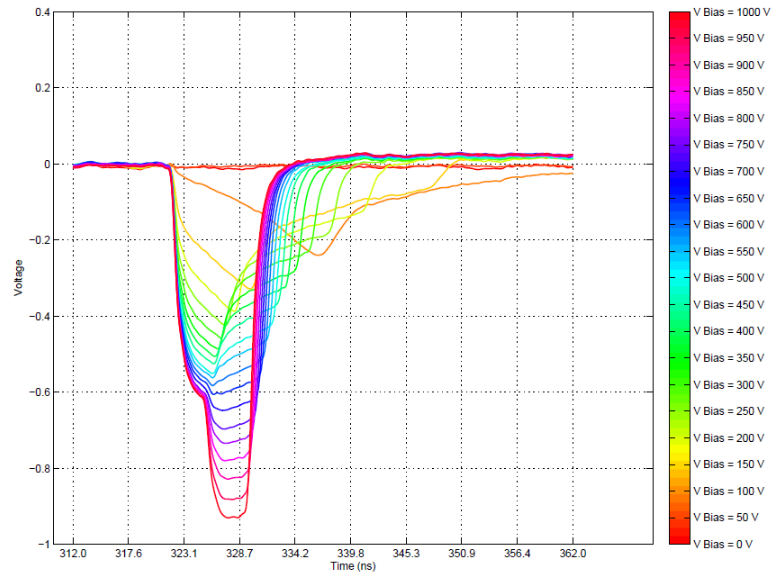
Red laser TCT characterization

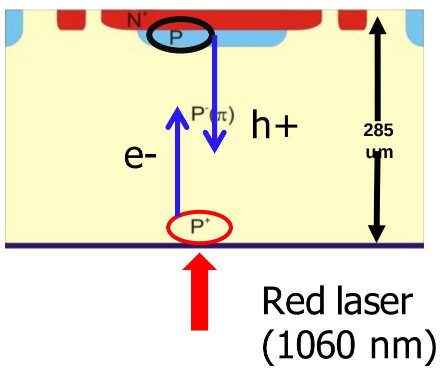
Bottom injection

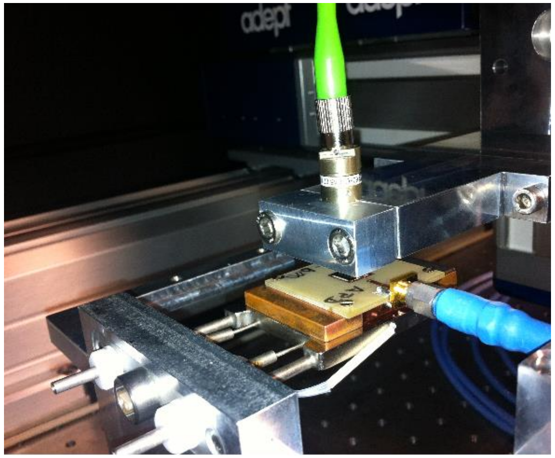
Standard diode n on p



P-type diffusion diode



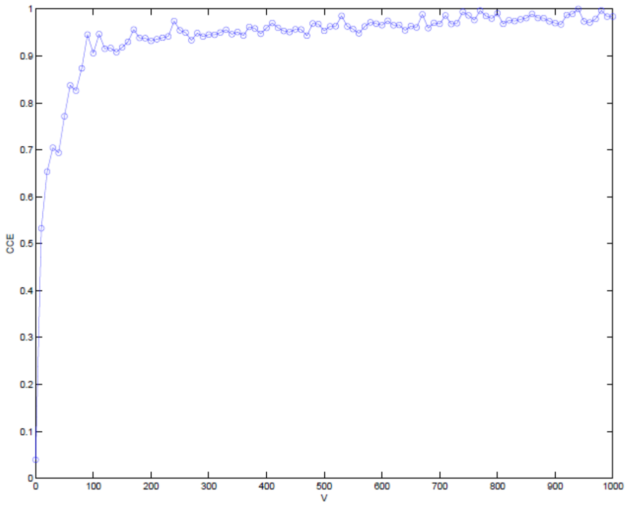




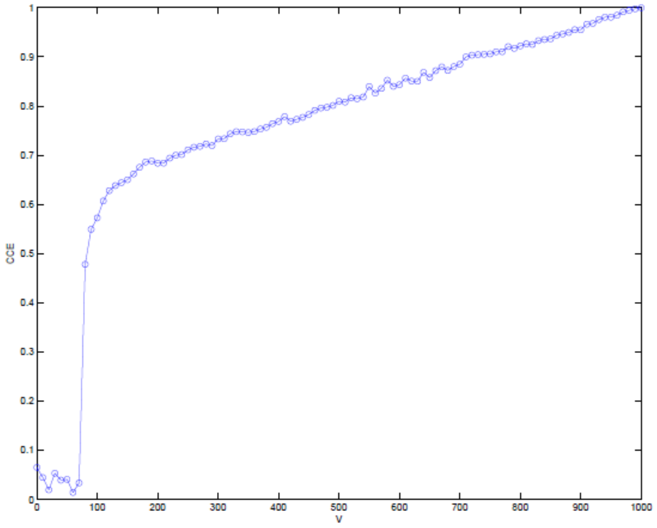
Red laser TCT characterization

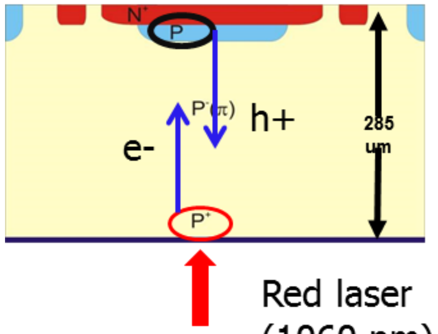
Charge collection efficiency

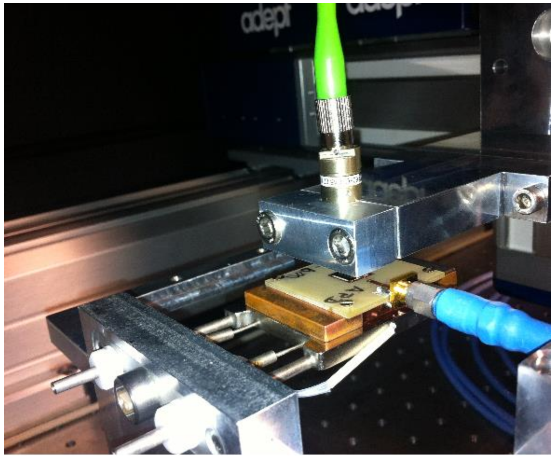
Standard diode



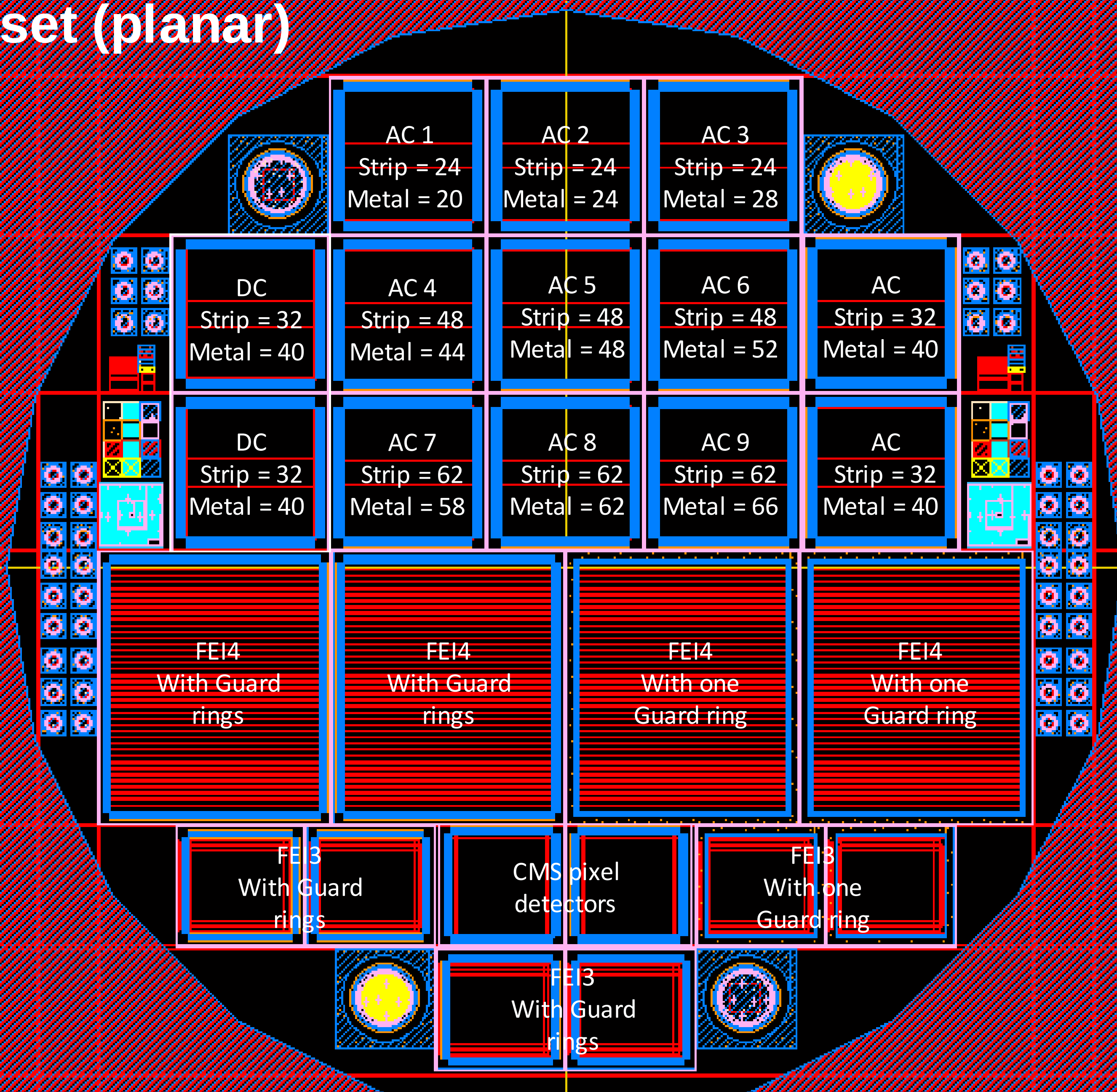
P-type diffusion diode







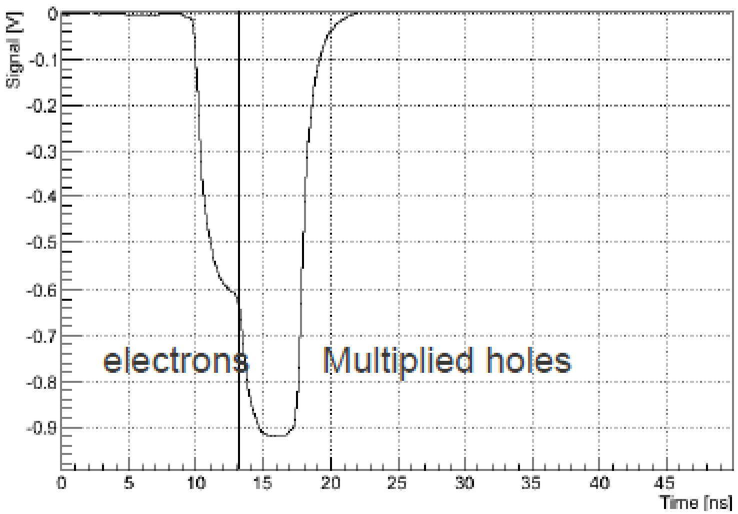
Mask set (planar)



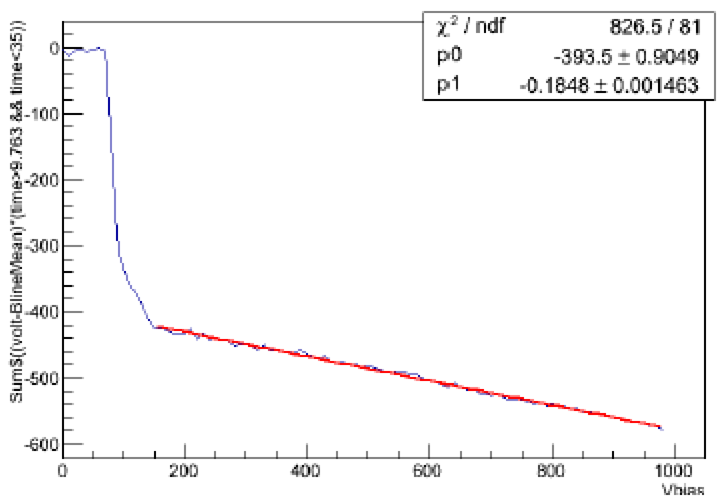
Summary

- A novel 2D position-sensitive semiconductor detector concept based on the resistive charge-division readout method has been introduced.
- The initial results demonstrates the feasibility of the charge division method in a fully fledged microstrip sensor.
- Test-beam studies on detection of minimum ionizing particles are in progress
- The effect of charge multiplication has been observed within RD50 and it was started to be investigated systematically.
- New detector designs aim to fabricate detectors with moderate gain and fast collection times.

At V>>Vdep (for instance 980V) the RC tails are short. Check it with simulation:



Gain(V=980)=Q(holes)/Q(electrons)=3



Gain at lower voltages, extracted from CCE curve:

CCE(980)/CCE(140)=Gain(980)(Gain(140)

Then Gain(140)=2.2