XIth Meeting of the Spanish Network for Future Linear Colliders

R&D on u-strpip sensors @ SDR

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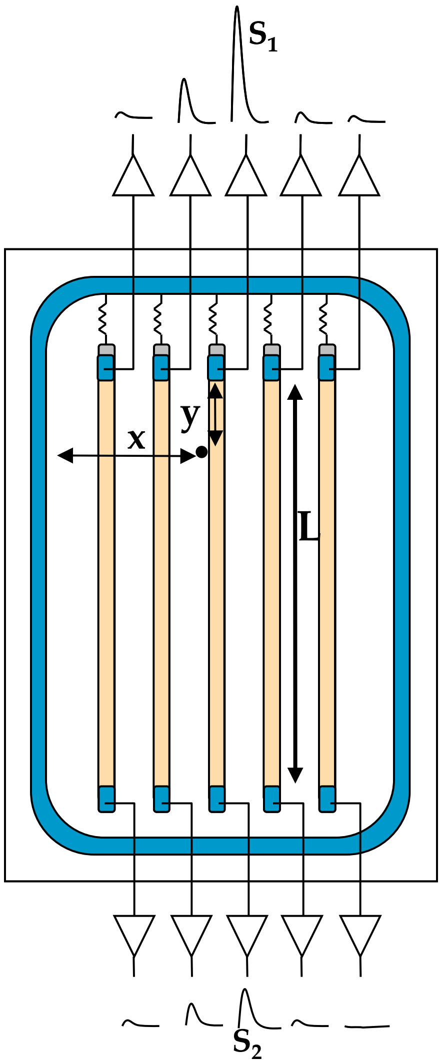
Outline

- Motivations for the R&D.
- A 2D position sensitive microstrip sensor.
  - Laser, radioactive source and particle beam characterization
- Improving the design
  - Integrated signal routing lines (Crosstalk suppression).
  - Incrementing the signal: Low Gain Avalanche Detectors.
- Summary

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)

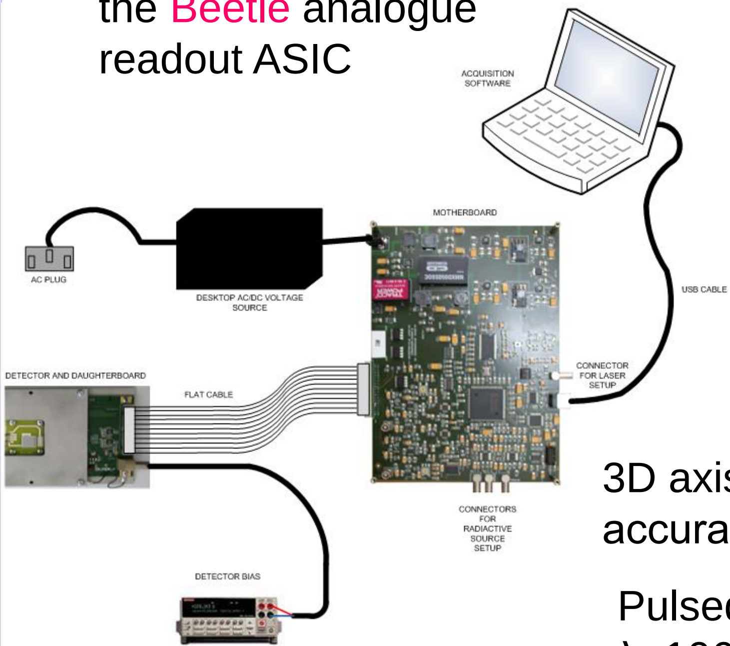
$$\frac{y}{L} = \frac{A_2}{A_1+A_2}$$

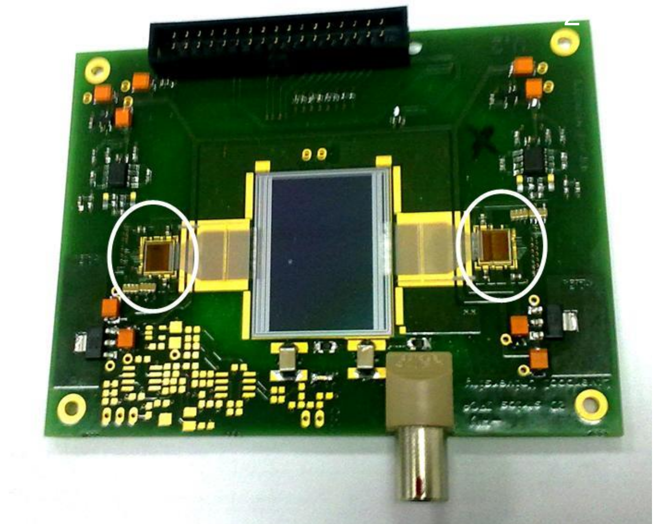
Resistive material: high doped polysilicon

** 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





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

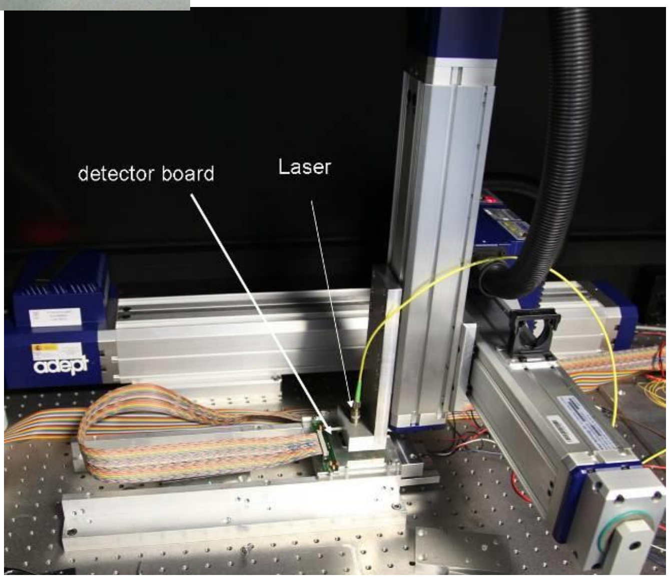
Pitches:
- Implant=80 um
- readout= 80 um

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

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

3D axis stage with displacement accuracy ≈ 10 μm

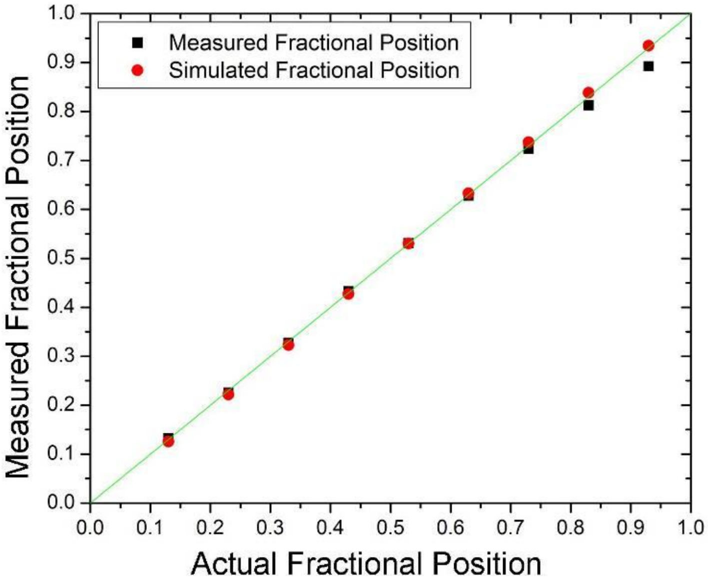
Pulsed DFB laser λ=1060nm
- Gaussian beam spot width ≈ 15 μm
- pulse duration 2ns



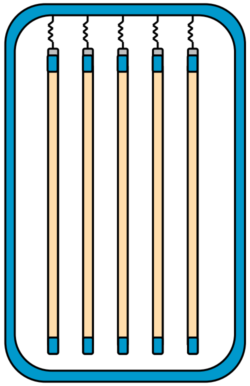
Clean room laboratory at IFCA, Santander

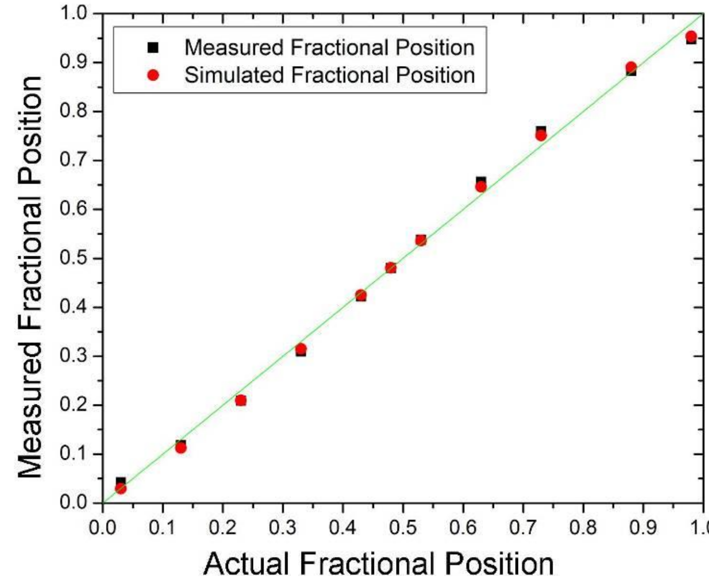
R/l=2.8 Ω/µm

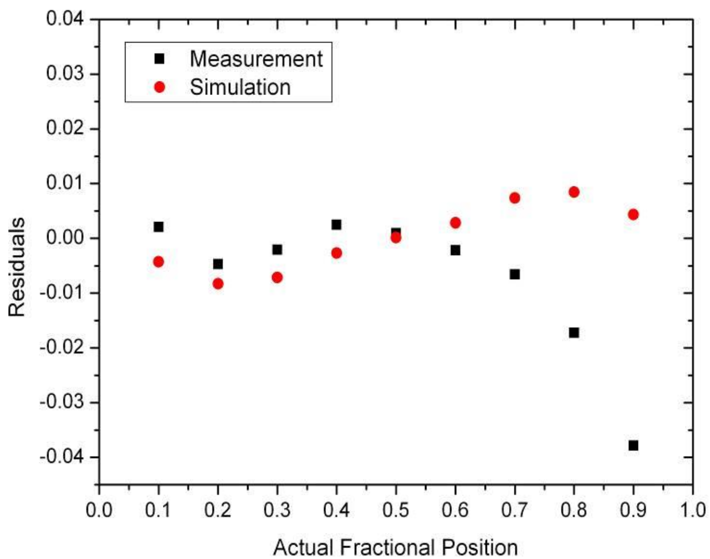
R/l=12.2 Ω/µm



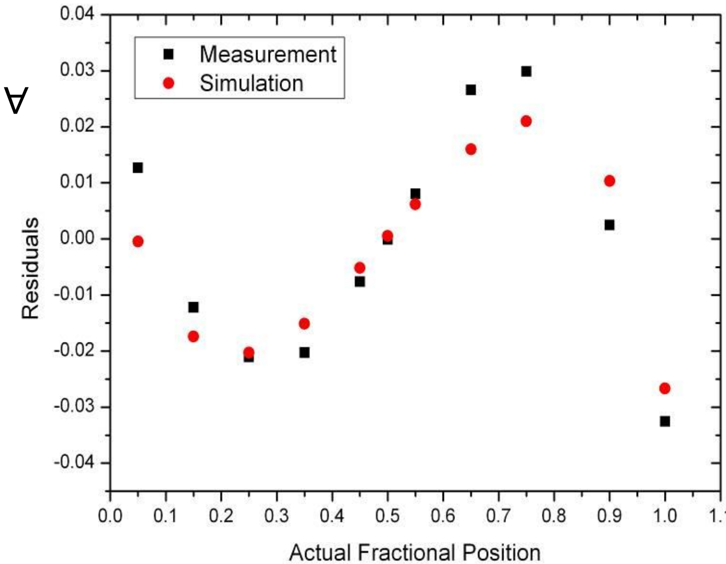
$$\frac{y}{L} = \frac{A_2}{A_1+A_2}$$







20000 events ∀ measurement



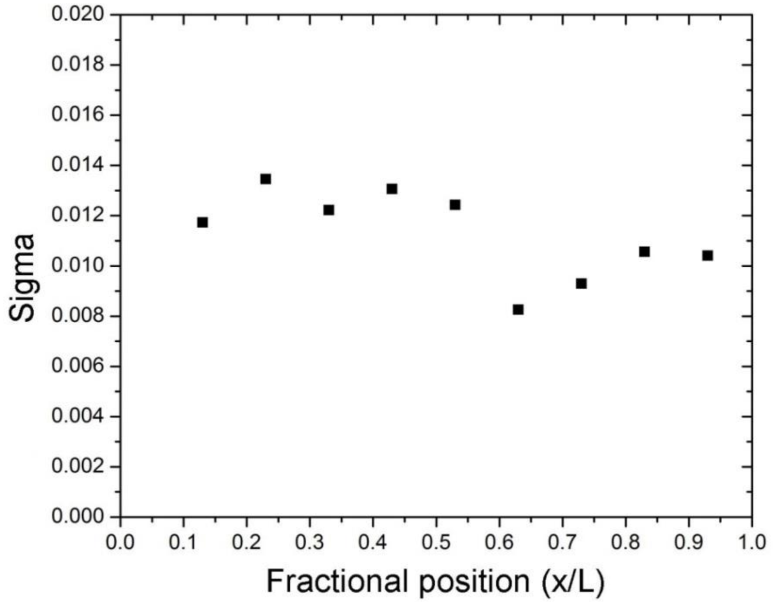
Longitudinal spatial resolution for 6 MIPs signal

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

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

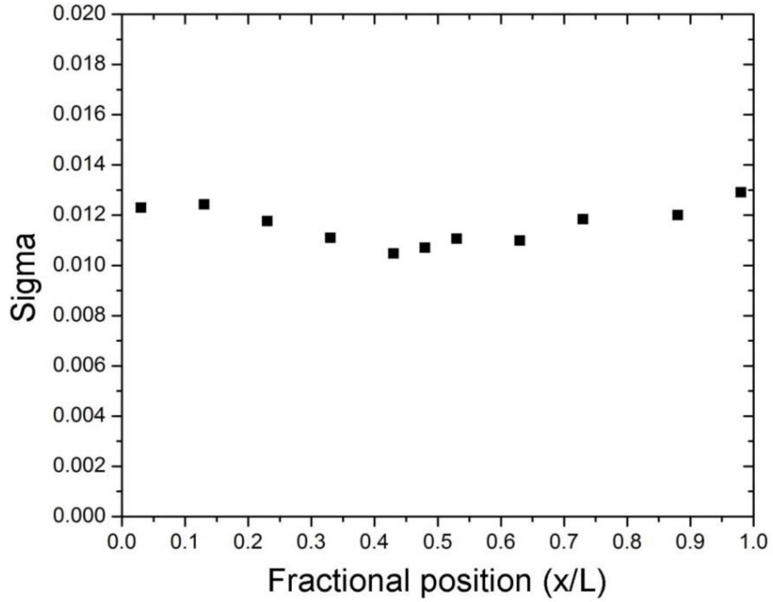
1.1% L => 220 µm

R/l=2.8 Ω/µm

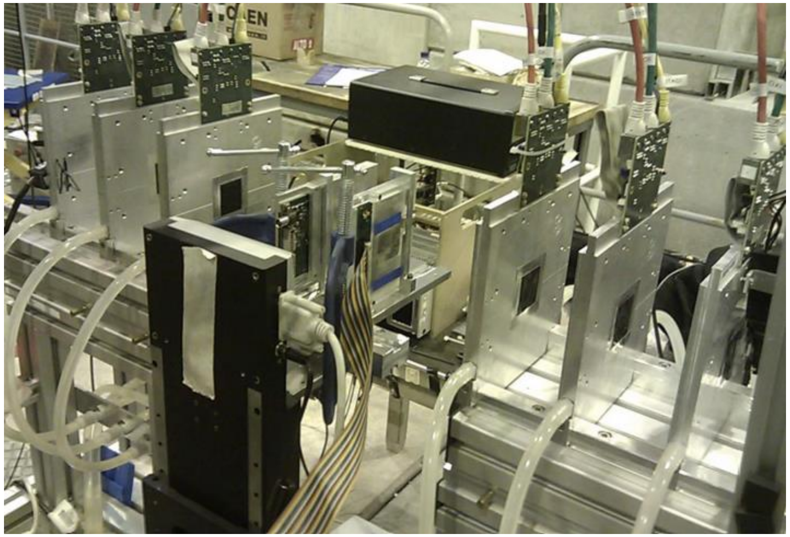


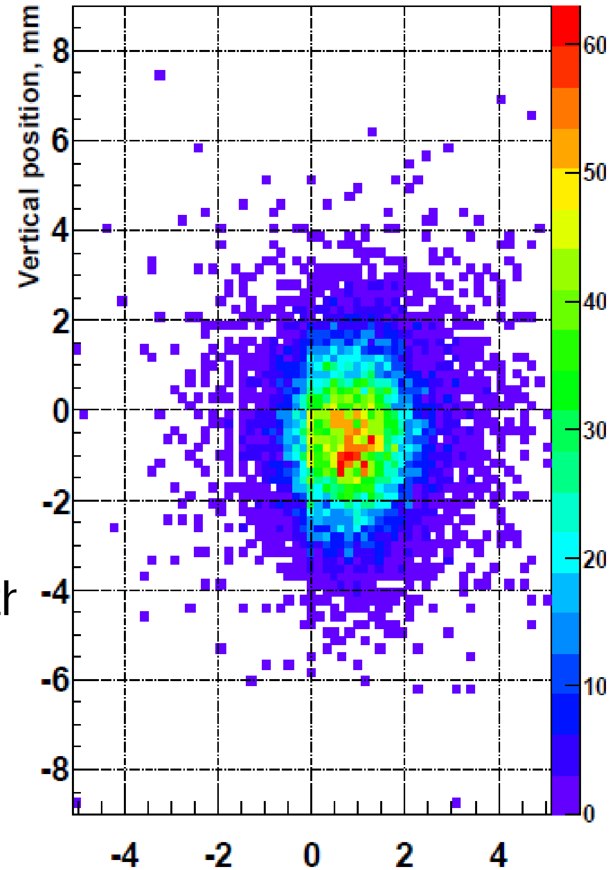
1.2% L => 240 µm

R/l=12.2 Ω/µm



Test Beam Characterization





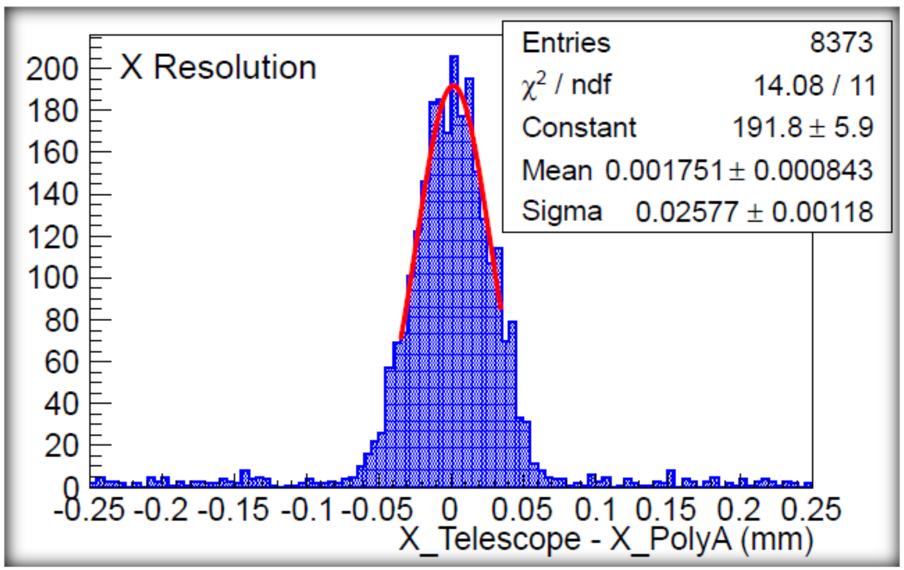
- Test beam at CERN SPS Pion Beam, Nov 2012
- First successful integration and synchronization with AIDA MIMOSA pixel telescope

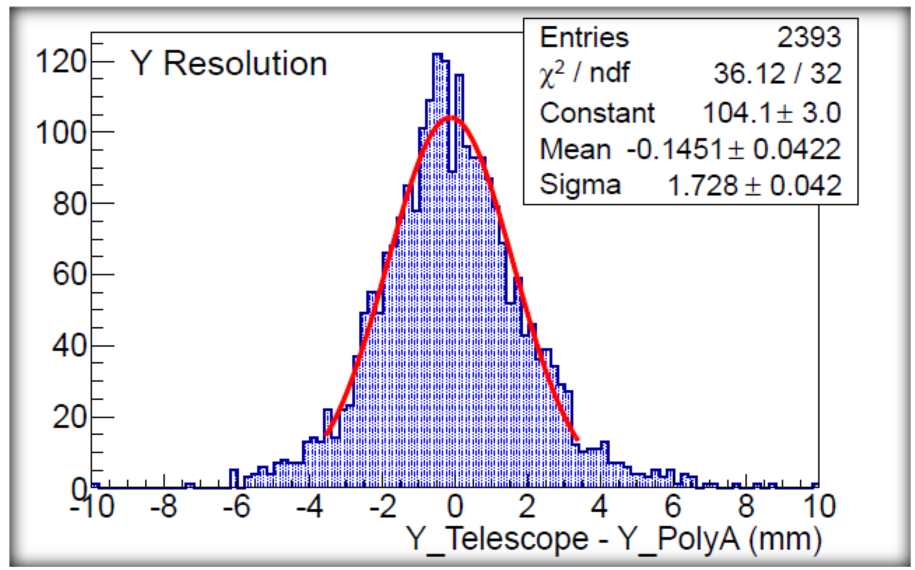
AIDA

Test Beam: Spatial Resolution

Trans. Coordinate X ~ 25 μm (pitch/√12= 23 μm)

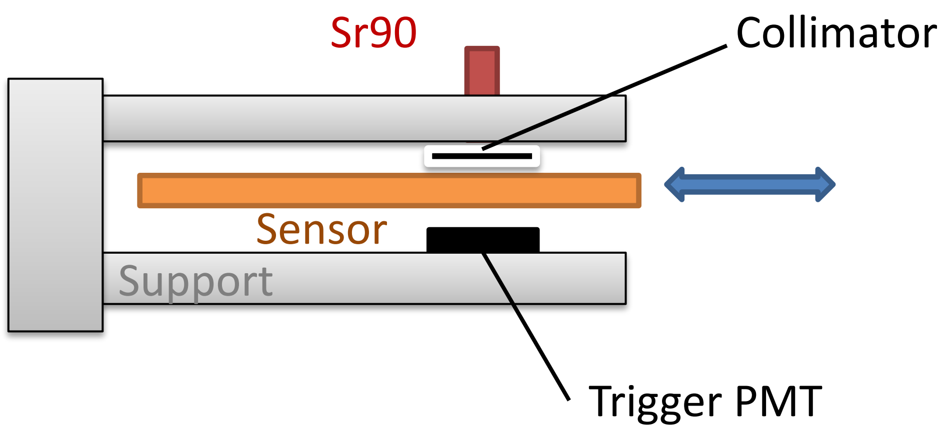
Long. Coordinate Y ~ 1.7 mm (8.5% strip length)

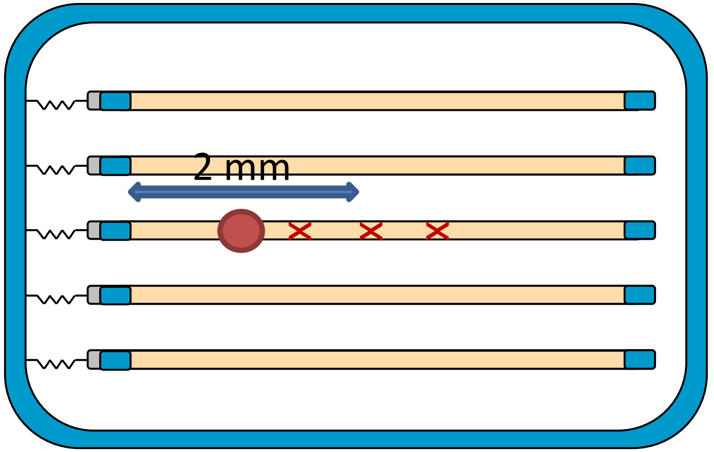


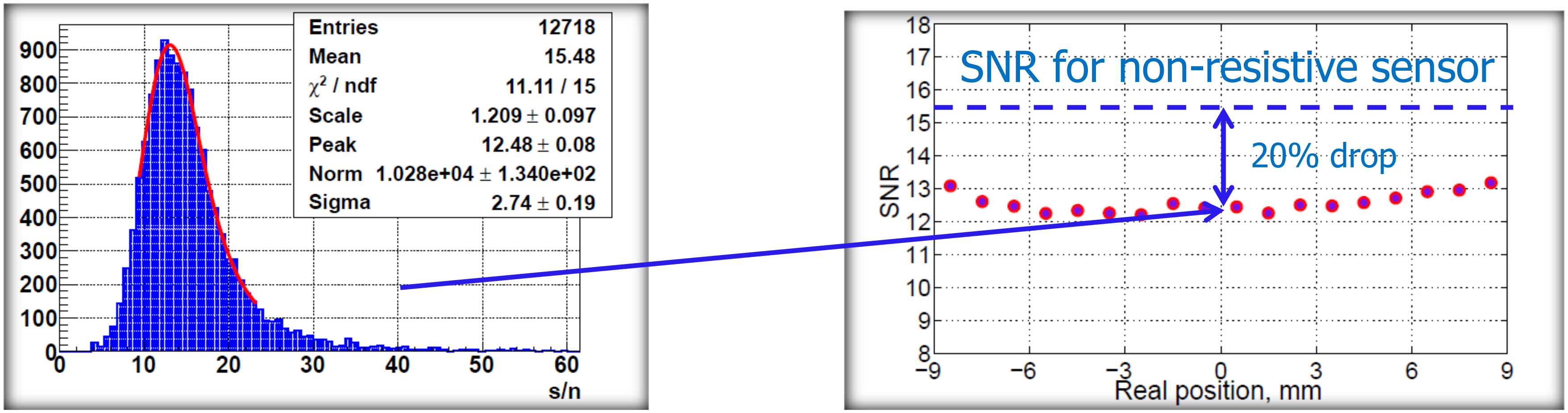


Radioactive Source: SNR estimation

Defined as $SNR \equiv (S1 + S2)/\sqrt{\sigma 1 + \sigma 2}$ (drives the spatial resolution)



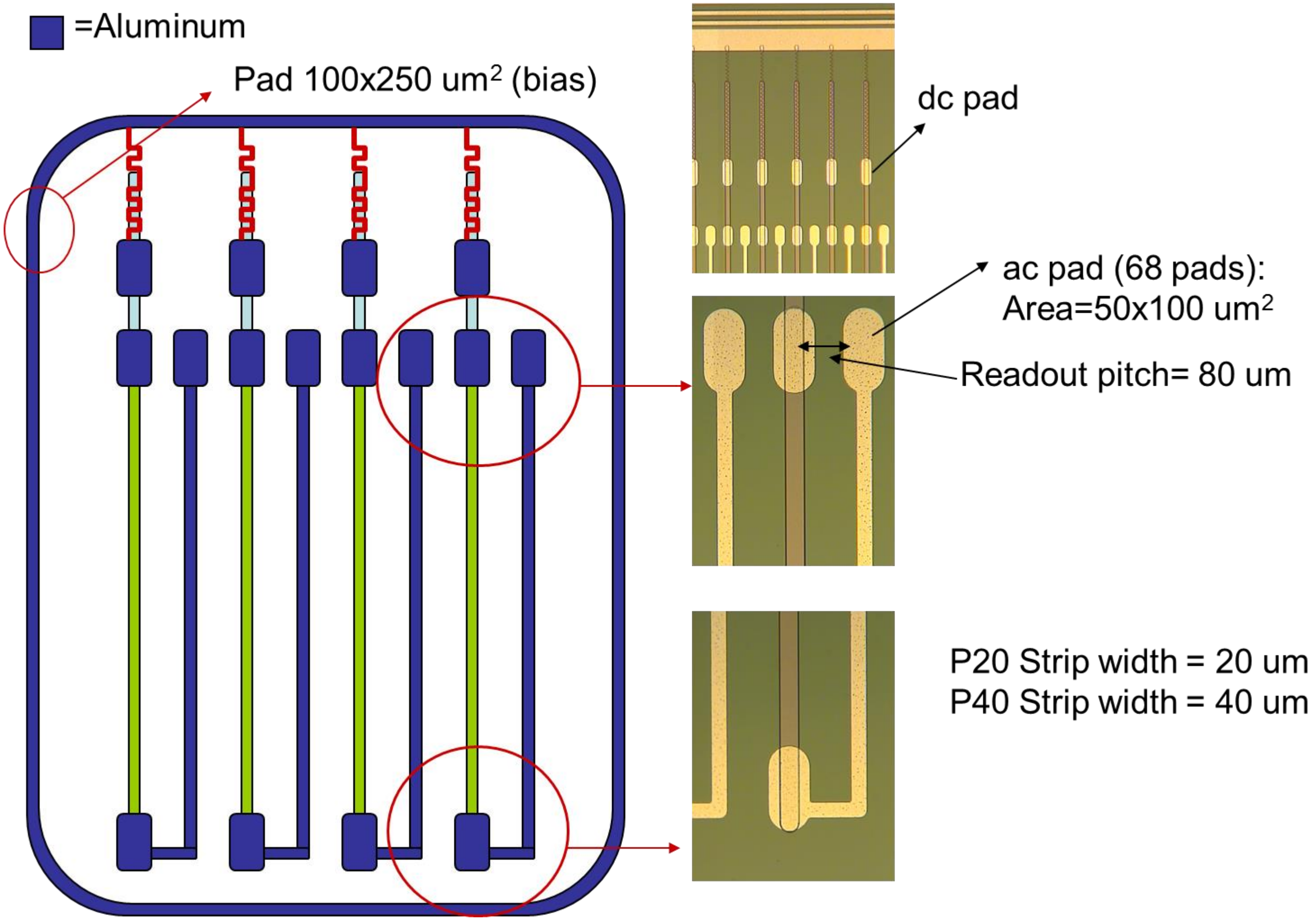




Charge-division sensor: Intermediate summary

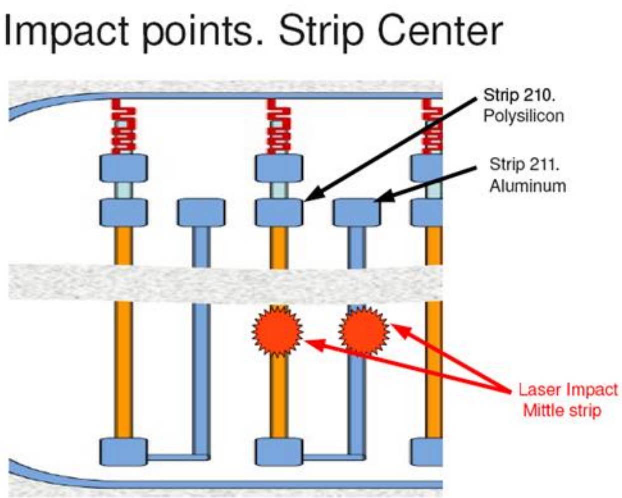
- The charge-division concept on microstrips has been confirmed experimentally, two limitations:
  - Both ends readout difficult to integrate in long ladder (need to combine the information from both ends)
  - Signal attenuation due to the strip resistance (current prototypes 20% signal loss for 2cm length sensor).
- Proposed solutions:
  - Integrated signal lines in the sensor to route the signals to the same end.
  - Reduce the strip resistivity (limited by the amp. charge resolution) and/or integrate charge amplification mechanism in the sensor.

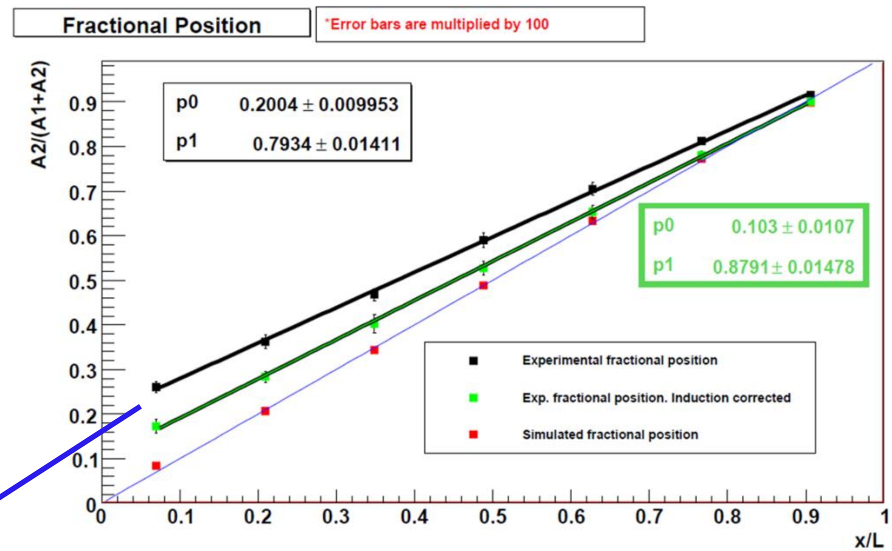
Resistive strips with internal signal routing



Resistive strips with internal signal routing (2)

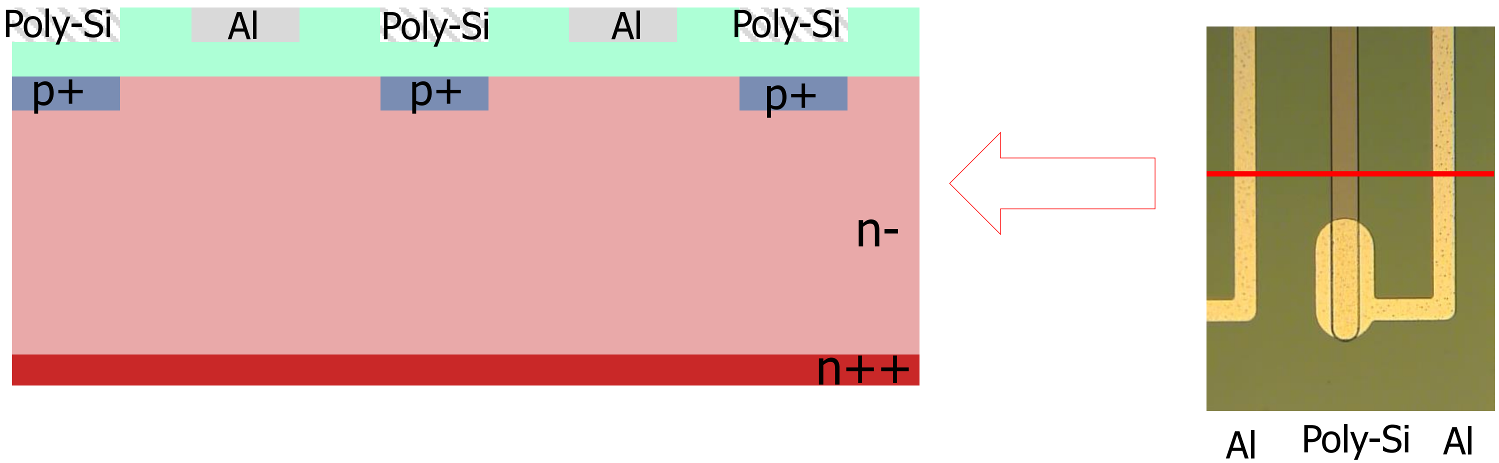
– Induced signal on metallic vias superposed to "direct signal" propagated through polysilicon electrode.



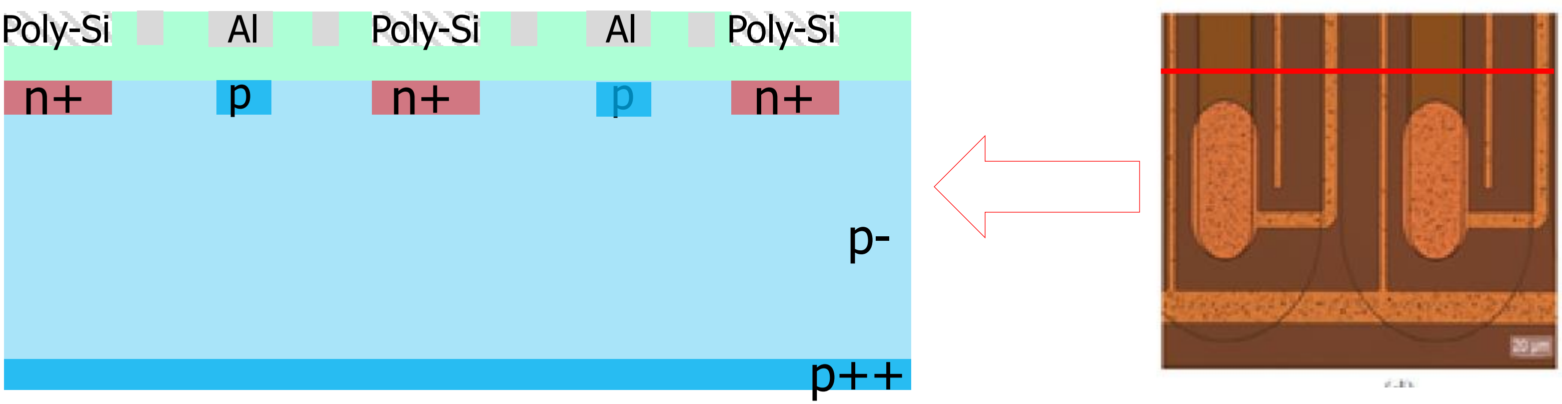


Measured Fractional position shows a clear bias

Isolation structures for cross-talk suppression



OLD DESIGN

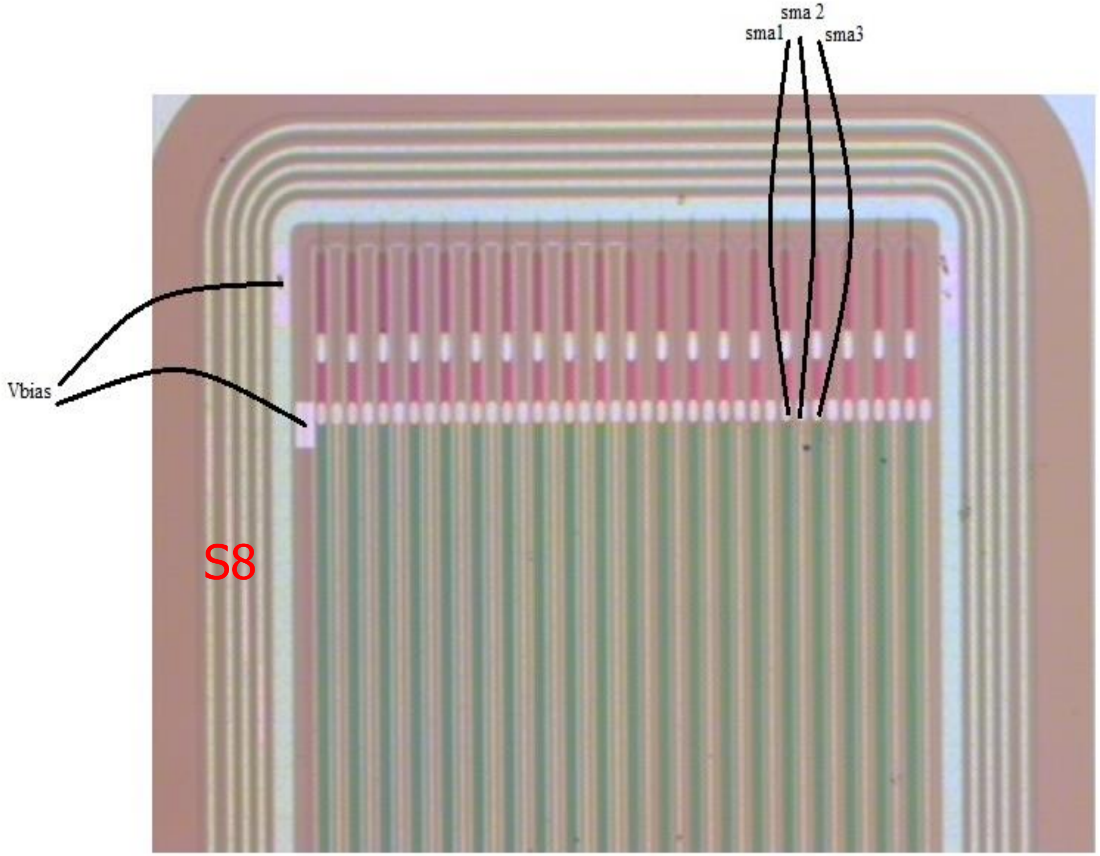


NEW DESIGN Common P-stop and field plates

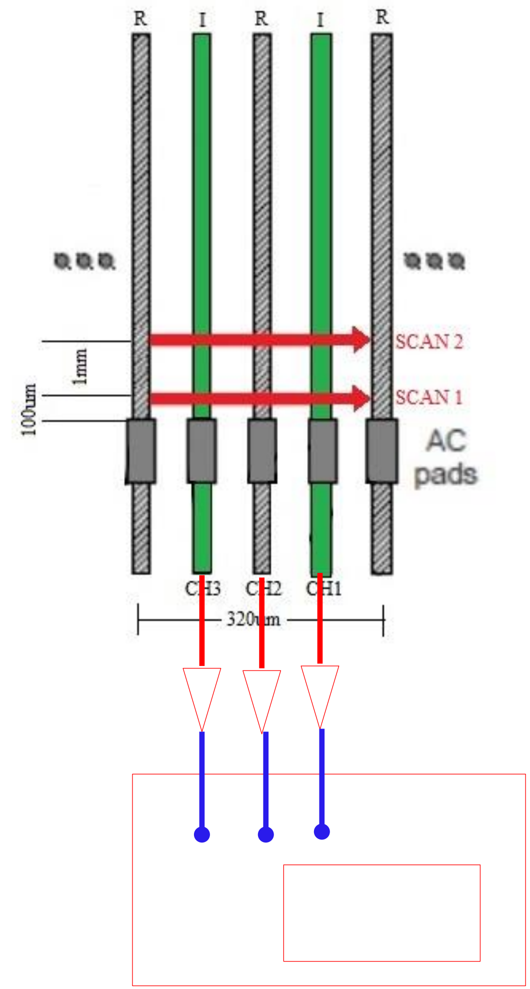
Spin-off of FOSTER sensors proposed by KIT at CMS

Crosstalk suppression (common stop)

– Time Resolved Readout IR-laser induced (e-TCT like measurement)



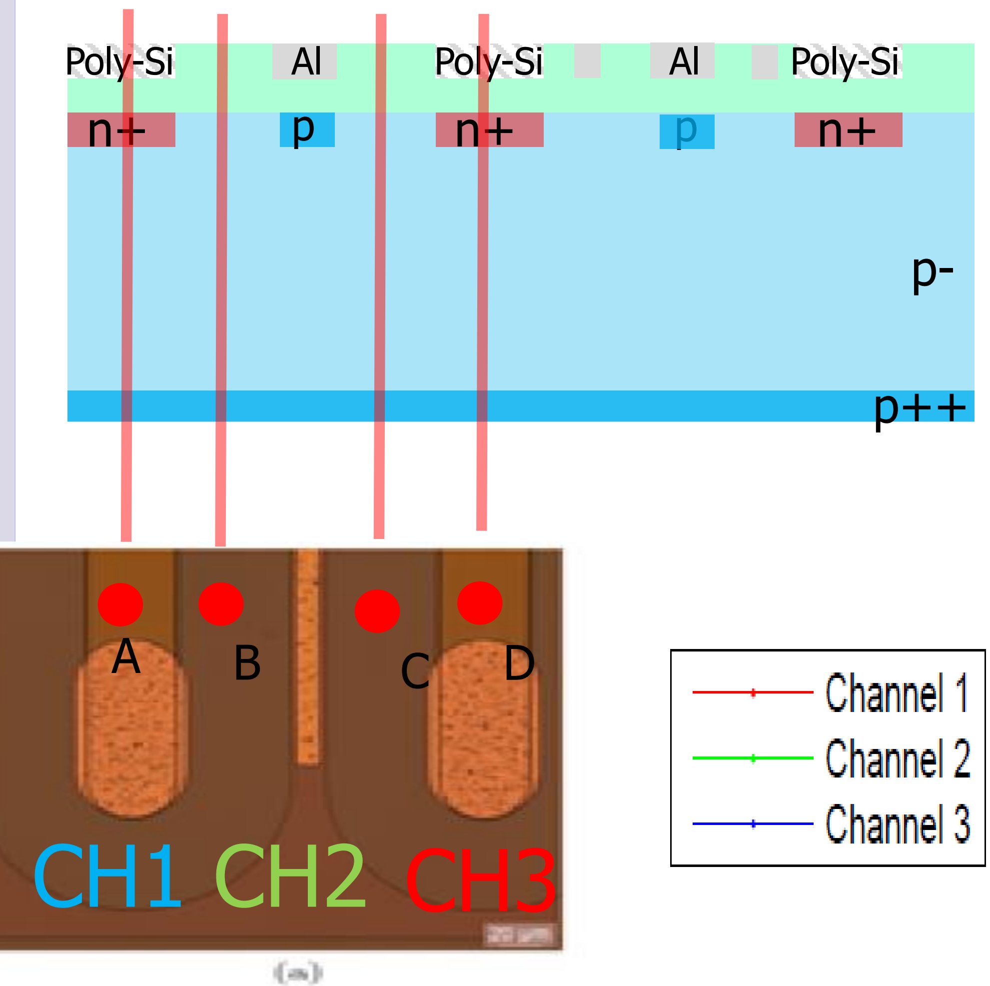
No grid Al. Implant – Al routing – Implant

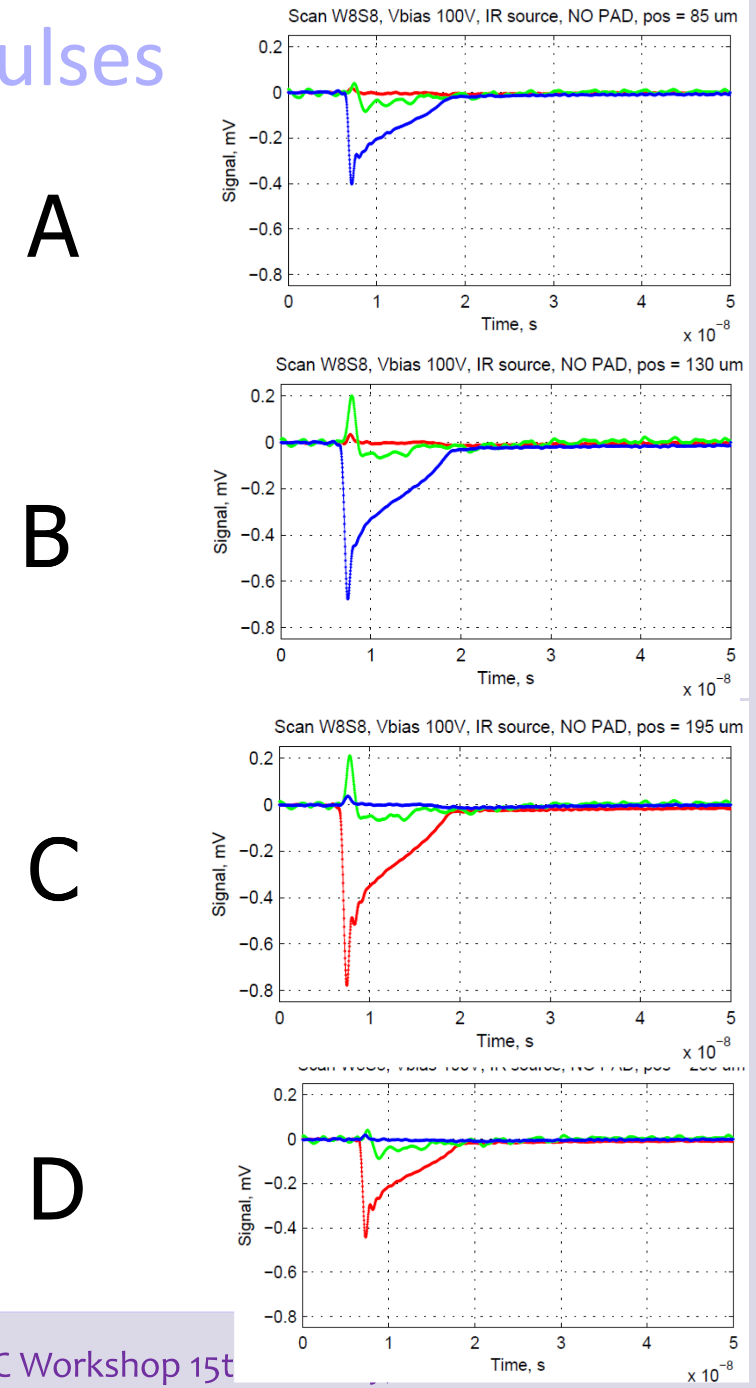


Crosstalk Suppression: Current pulses

Infrared pico second laser

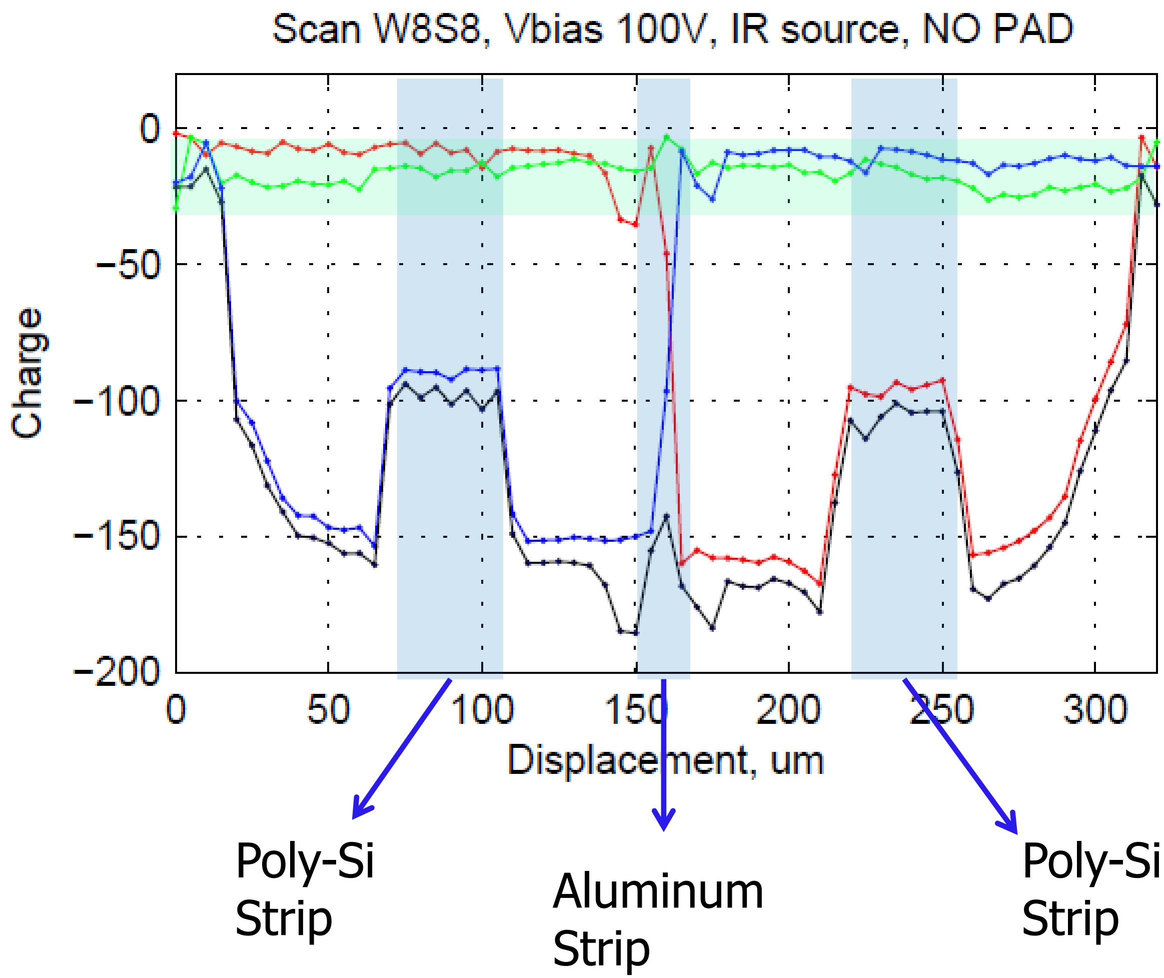
(fast, 1GHz readout channel)

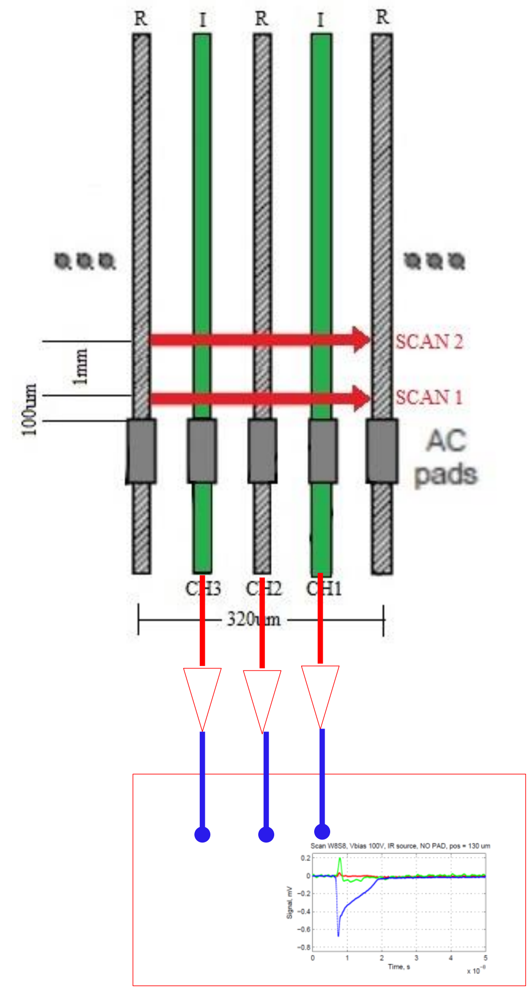




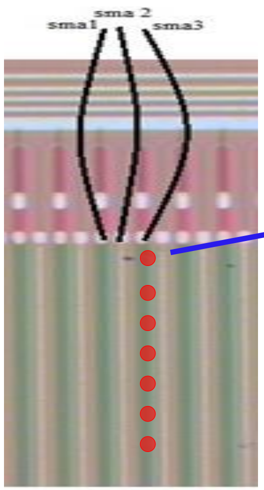
Cross-talk suppression: Integrated charge

Flat charge pedestal for Al routing track, suppressed by calibration



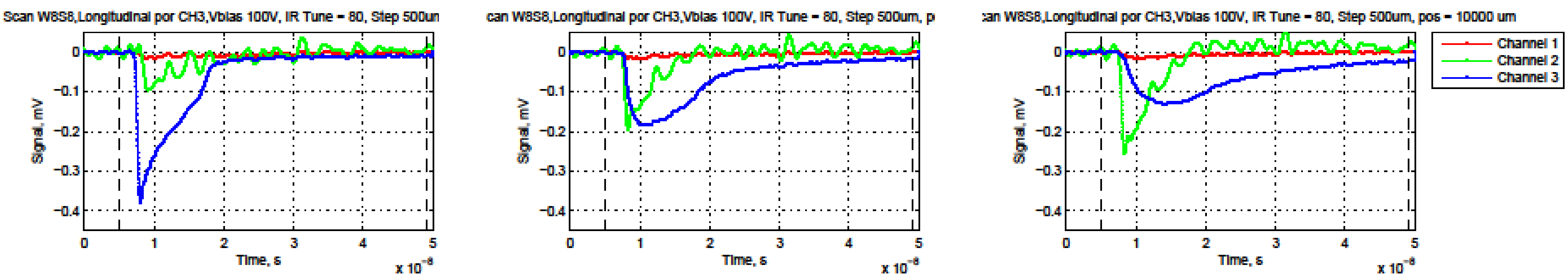


Signal Attenuation studies



Laser longitudinal scan
(42 points, 500um steps

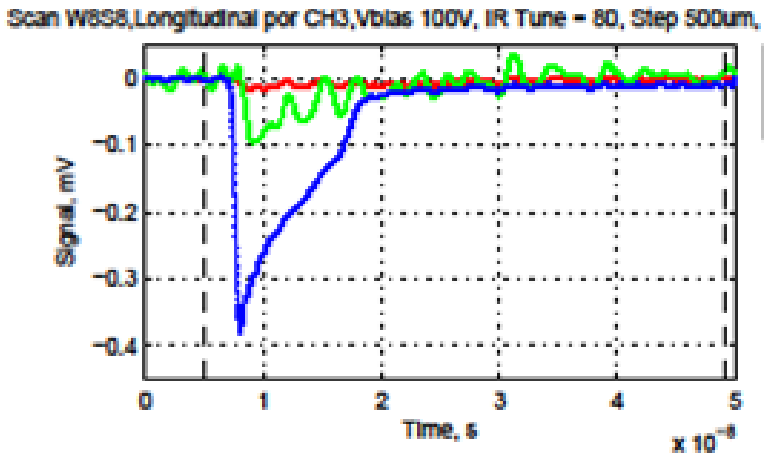
Time-resolved study of the pulse shape and charge

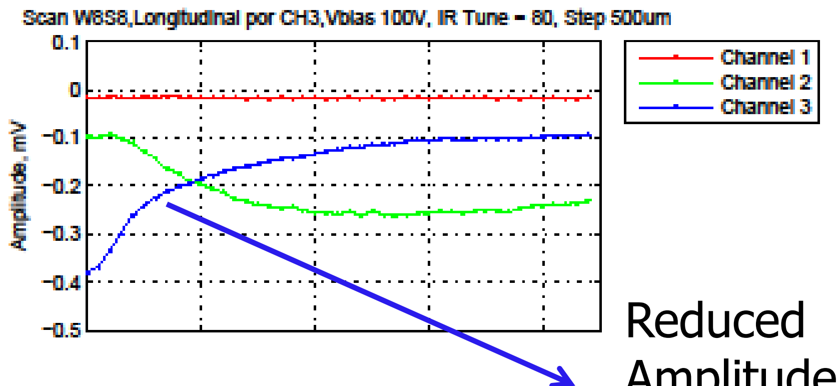


0 mm from r/o pad | 5 mm from r/o pad | 10 mm from r/o pad

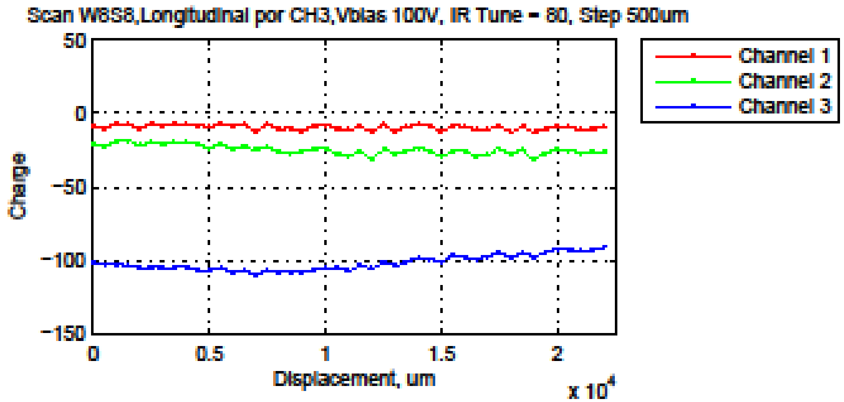
Signal Attenuation studies (2)

Charge and amplitude vs. distance





Reduced Amplitude



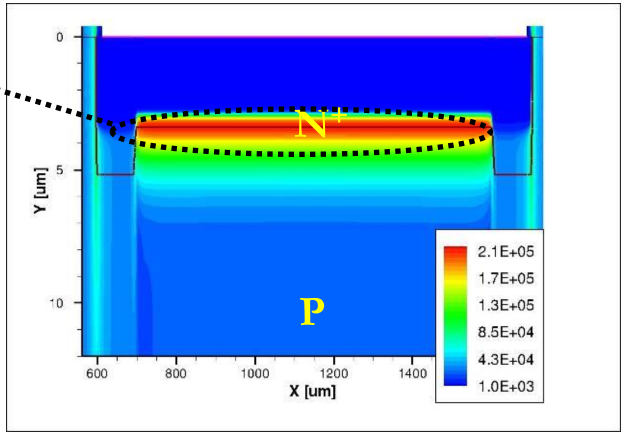
Constant charge

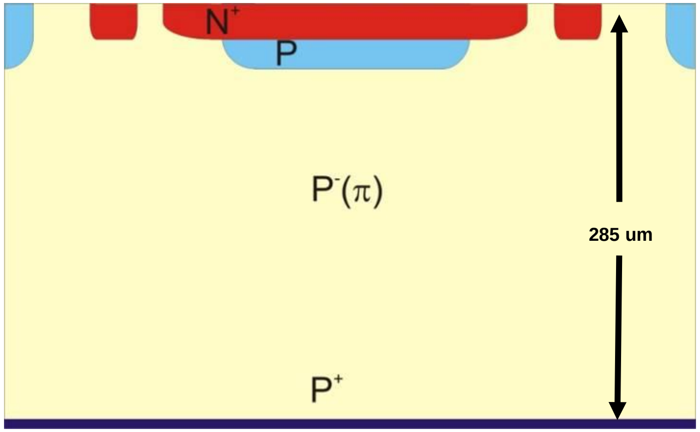
Increasing the signal: LGAD

Implanting 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



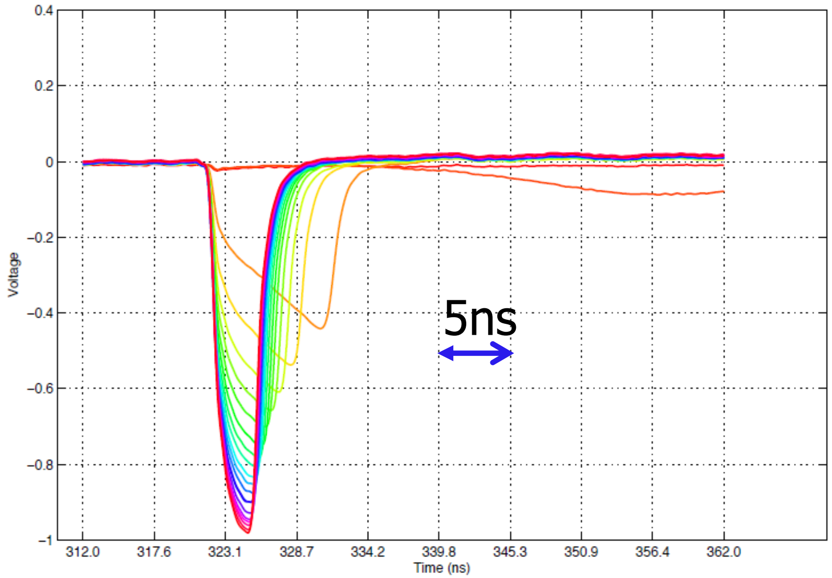


P. Fernandez et al, "Simulation of new p-type strip detectors with trench to enhance the charge multiplication effect in the n-type electrodes" , Nuclear InstrumentsandMethodsinPhysicsResearchA658(2011) 98–102.

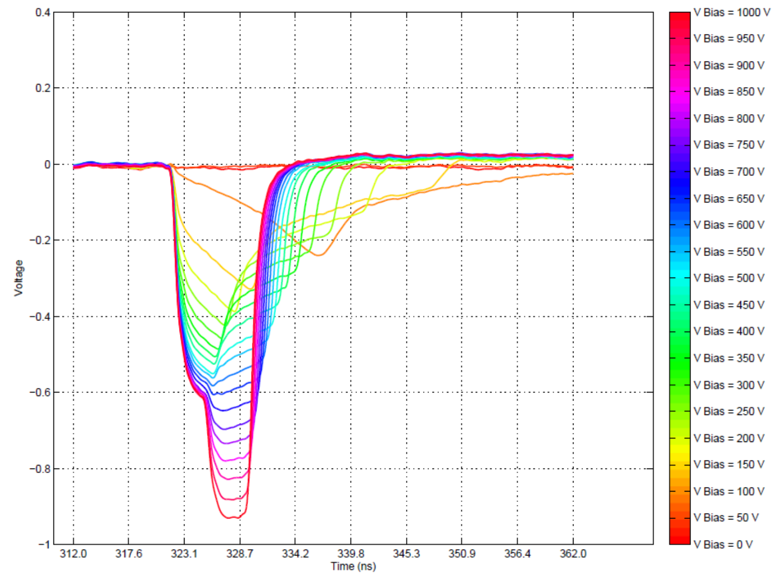
PAD LGAD: Red laser TCT characterization

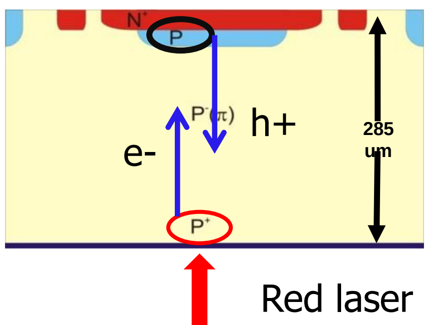
Bottom injection

Standard diode n on p

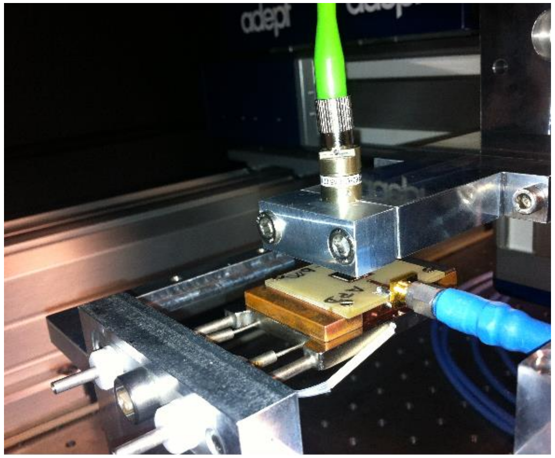


P-type diffusion diode





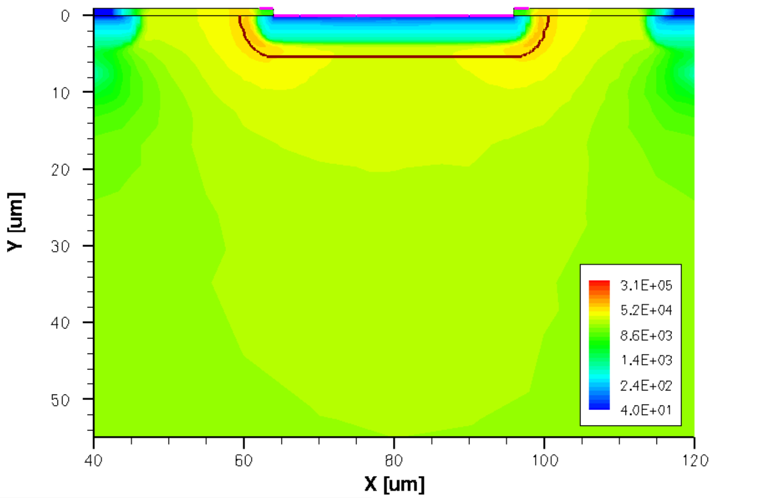
Red laser
(1060 nm)



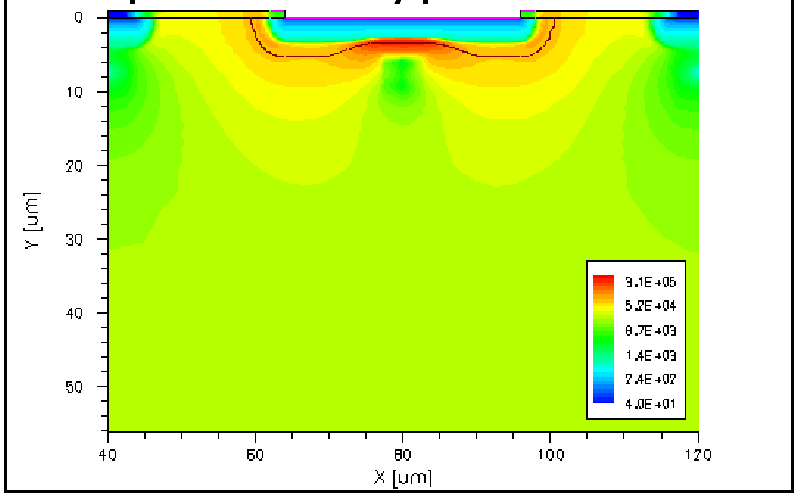
Strip LGAD: Electric Field

- To obtain the manufacture parameters (doping profiles)

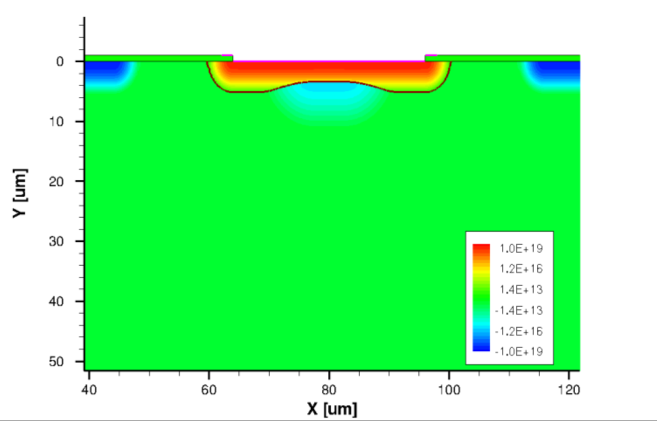
Standard Strip

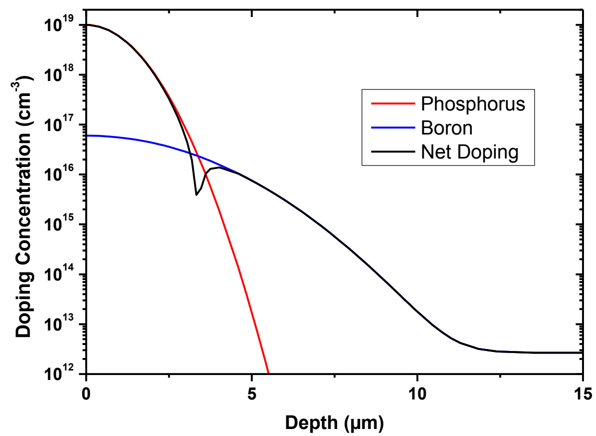


Strip with P-type diffusion

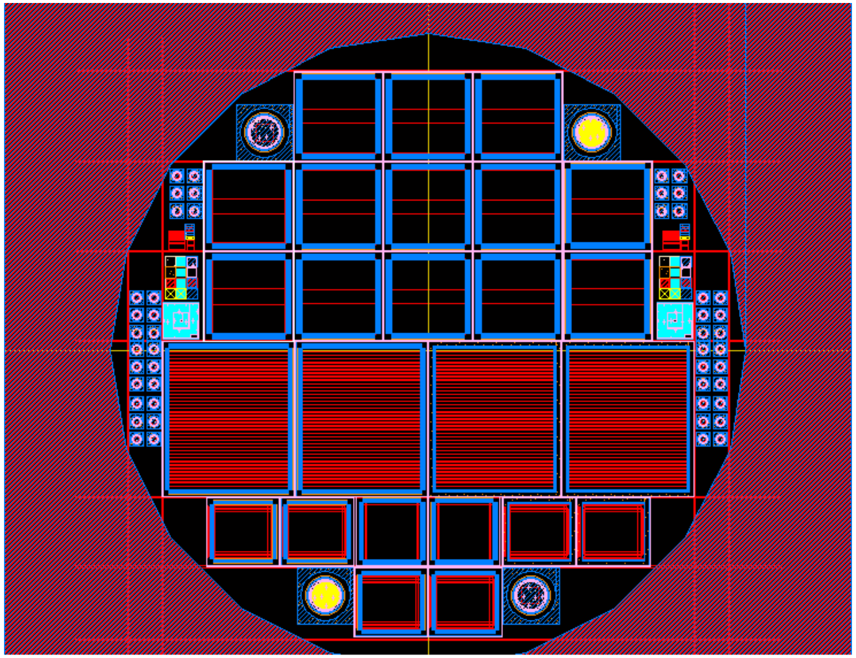


Strip with P-type diffusion: 2D and 1D doping profiles





Current status: preliminary results on strips



RD50 LGAD GROUP
(CERN, CNM, Barcelona, Torino, Ljbljiana, Santander, SCIPP, Freiburg, Glasgow, Liverpool)

- Very preliminary test do not show signal amplification.
- New run in progress and new concept to implement: p-on-p sensor (holes readout with electron amplification in a non-structured anode (pad-like) to ensure uniform amplification

Summary

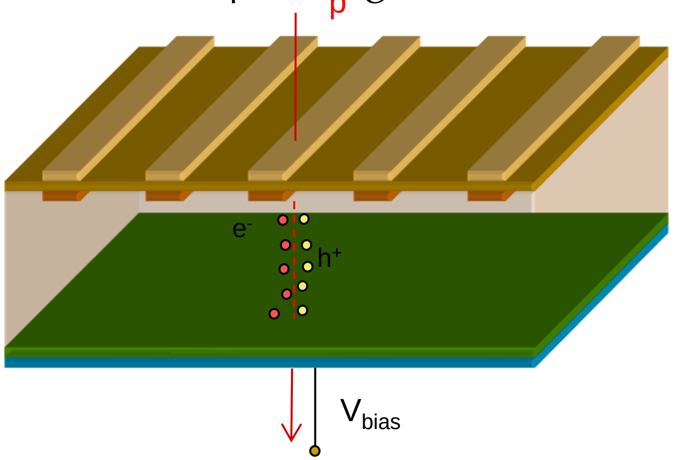
- A novel 2D position-sensitive semiconductor detector concept based on the resistive charge-division readout method and manufactured using standard semiconductor planar techniques has been introduced.
- A full testing cycle of this technology has been successfully completed: laser, RS and test beam source.
- To be used as a tracking sensor suitable:
  - Single end readout → the integration in the sensor of signal routing tracks
  - Increase SNR → Reduction of the strip resistivity and Linear gain of the signal
- The first issue has been tackled integrating isolation structures (preliminary results are positive).
- New detector designs aim to fabricate detectors with moderate gain (RD50) and p-on-p strip LGAD.

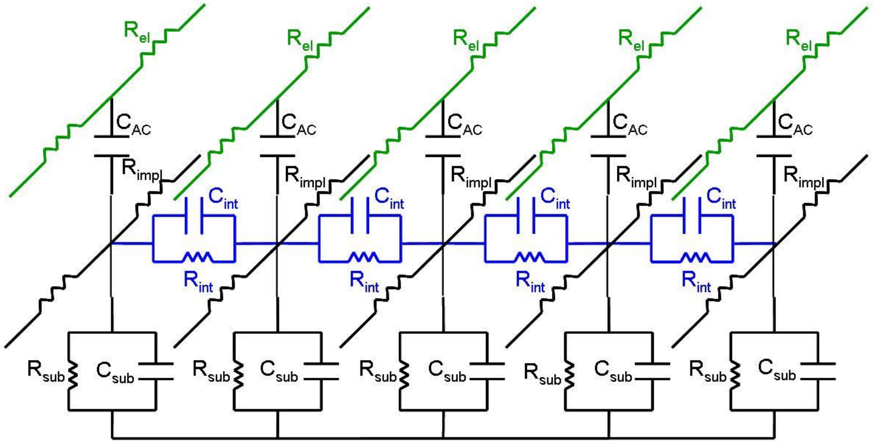
THANK YOU !

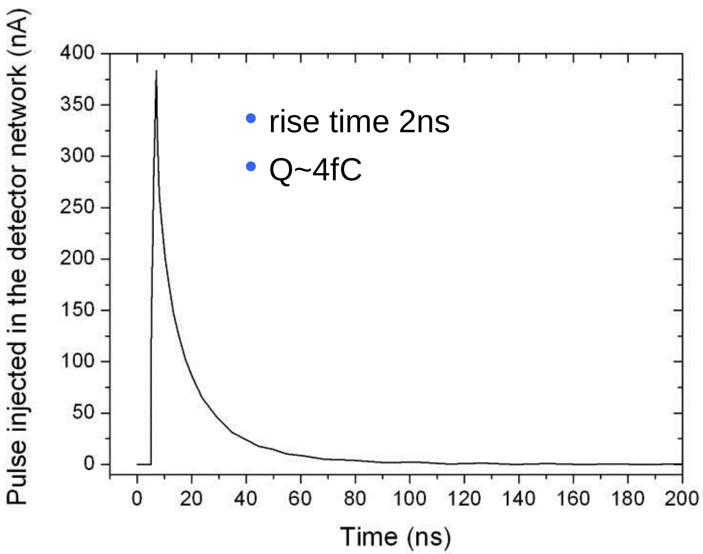
Equivalent Electrical Circuit

Detector (p⁺-on-n) model ***

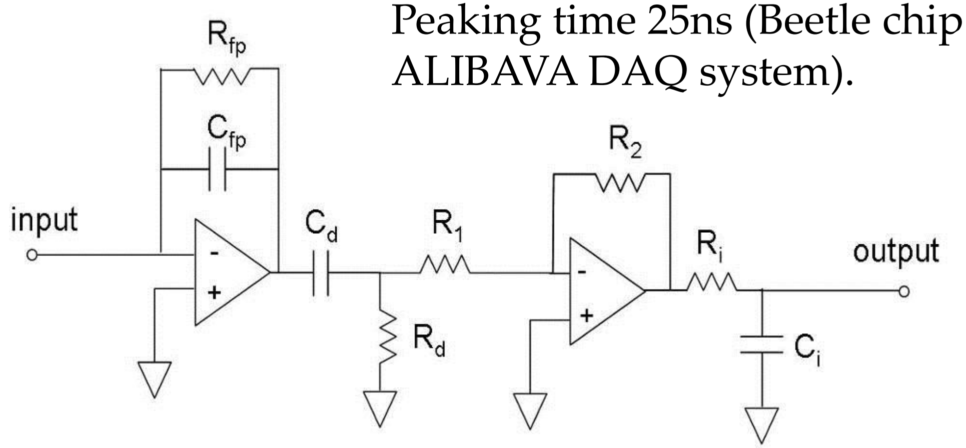
80 cells 250 μm long



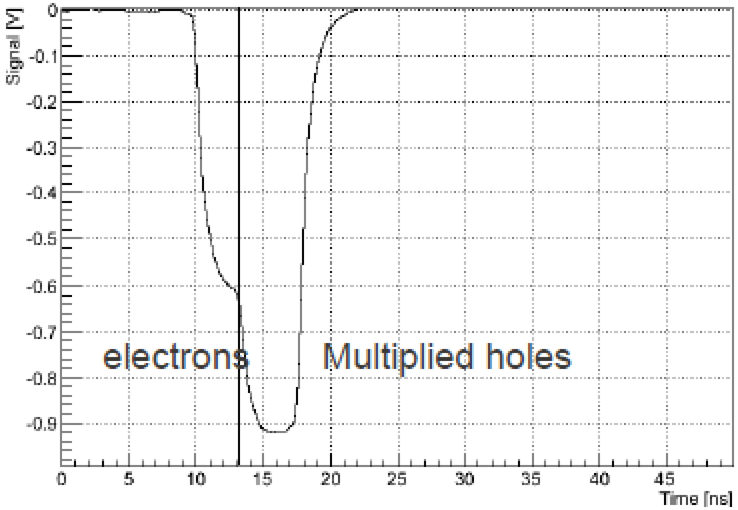




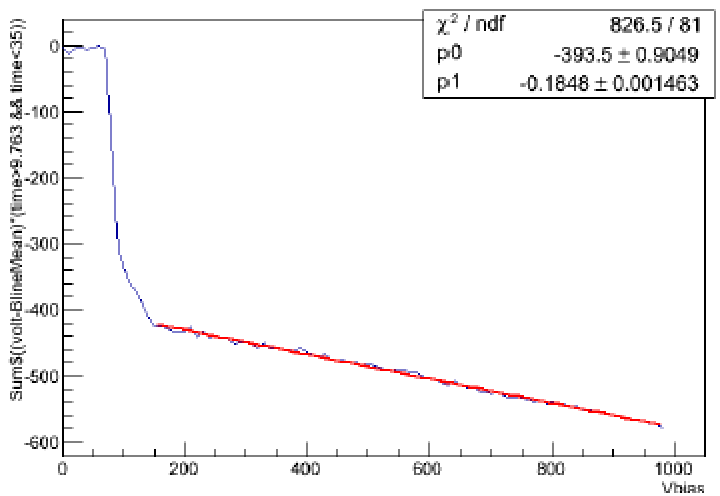
Peaking time 25ns (Beetle chip ALIBAVA DAQ system).



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



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

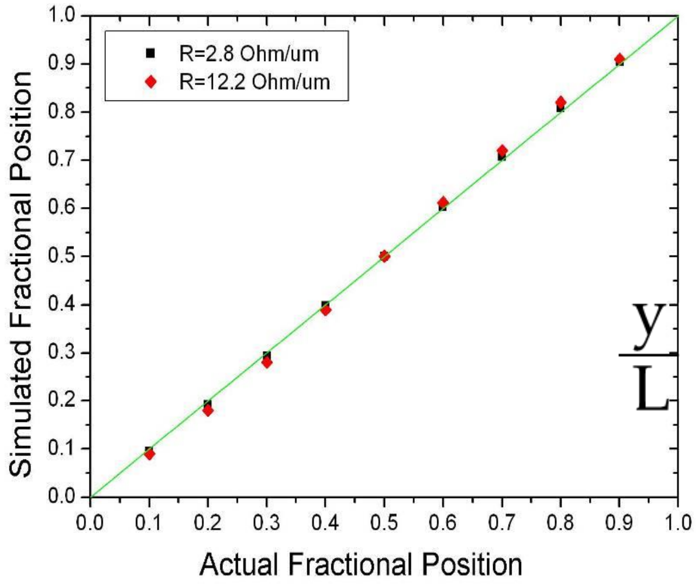


Gain at lower voltages, extracted from CCE curve:

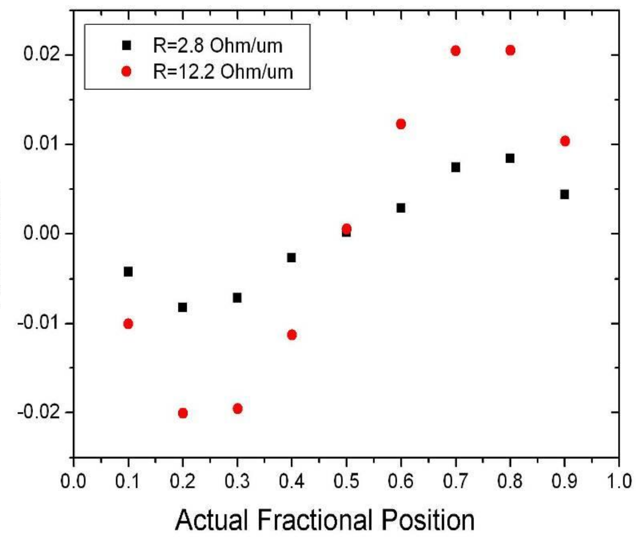
CCE(980)/CCE(140)=Gain(980)(Gain(140)

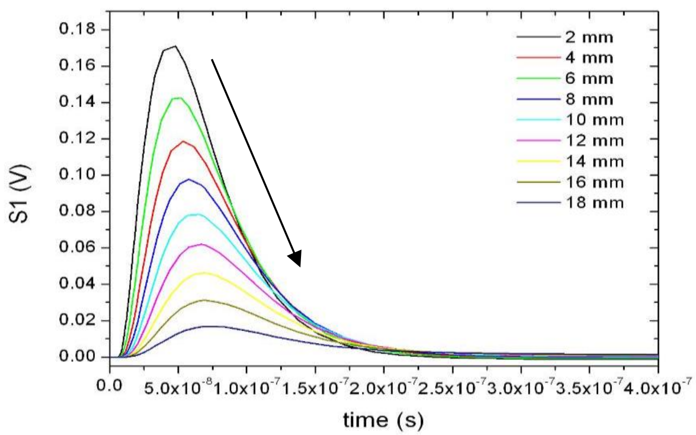
Then Gain(140)=2.2

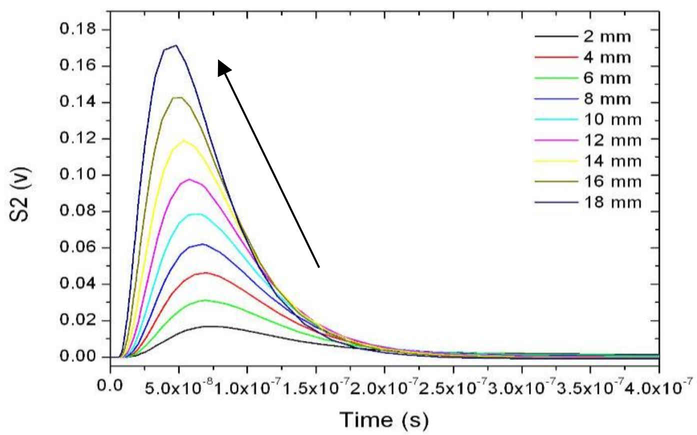
Signal Propagation – Linearity (Simulation)



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



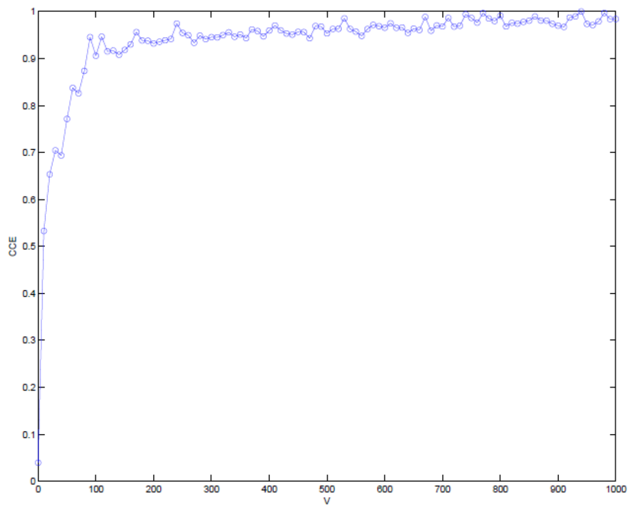




Red laser TCT characterization

Charge collection efficiency

Standard diode



P-type diffusion diode