A novel 2D Position-Sensitive Semiconductor Detector Concept

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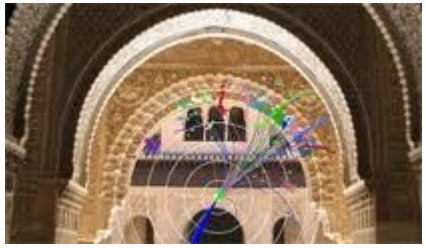

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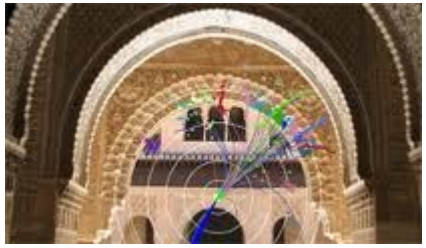
Outline

- New Si-microstrip detector concept
- Signal Propagation
- Prototypes introduction
- Experimental arrangement
- Conclusion
- Next Steps



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New Detectors Concept

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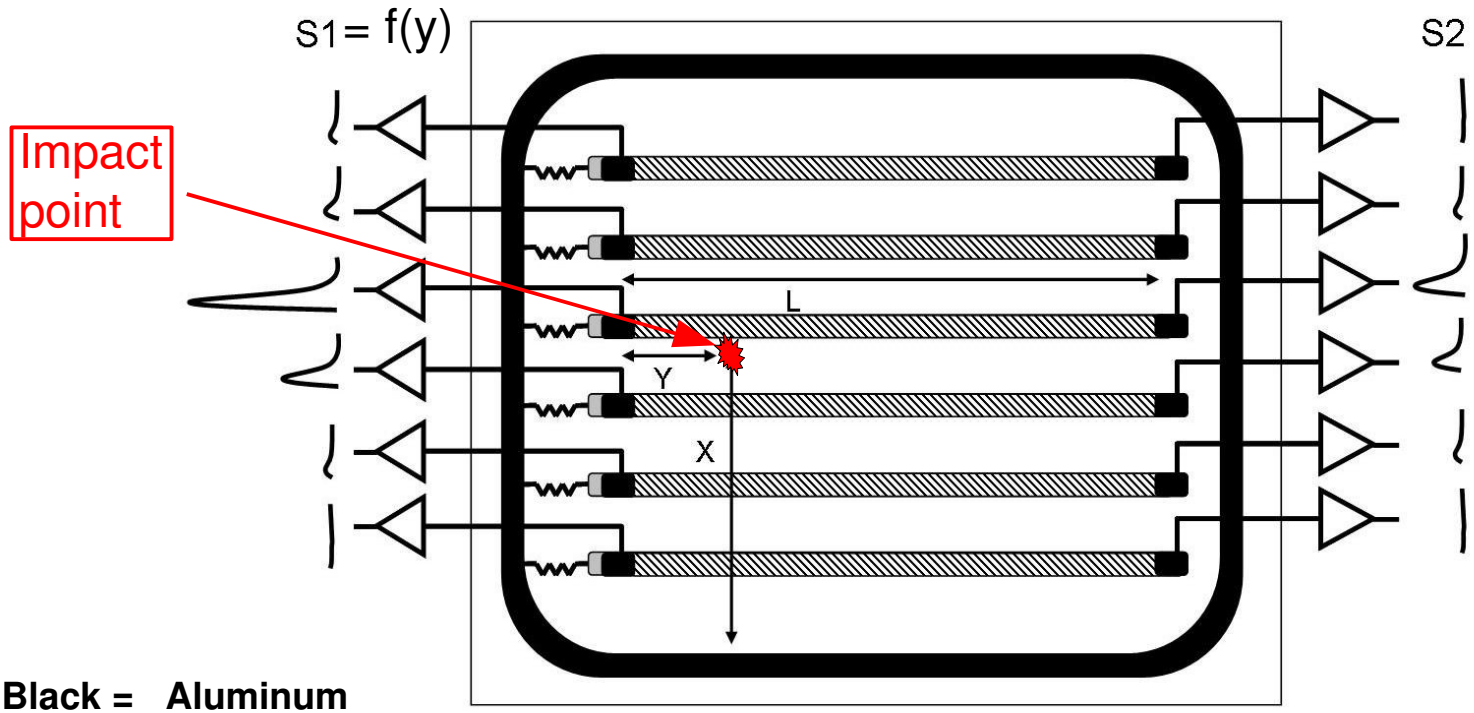
* Simple single-sided AC-coupled microstrip detectors with resistive coupling electrodes*

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

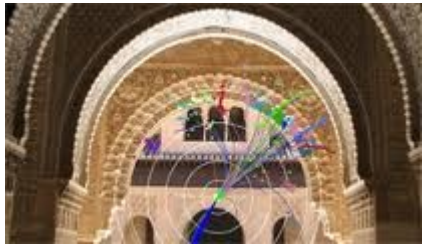
* X-coordinate: charge sharing between neighbouring strips
* Y-coordinate: Resistive charge division method



FRACTIONAL POSITION

$$\frac{y}{L} = \frac{S_2}{S_1+S_2}$$

Black = Aluminum
Striped = resistive electrode



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Signal propagation

Framework: Virtuoso Spectre by Cadence.

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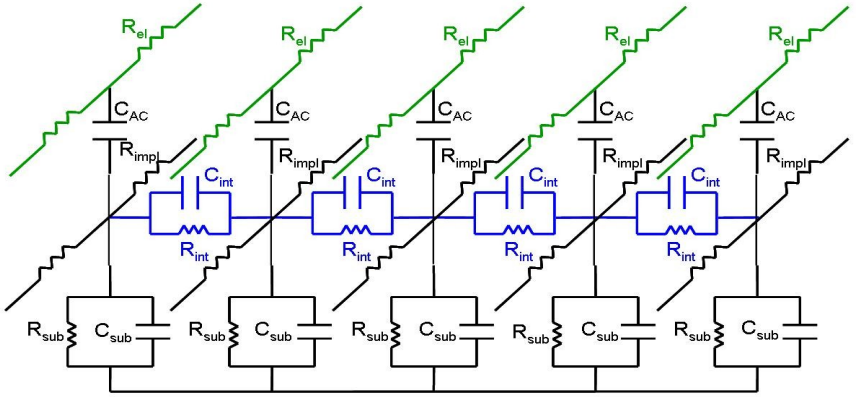
Detector model: *(N, Bachetta et al., IEEE, Vol 47, NO 4, August 1995)*

Five strips (R_{str}, C_{cou}, R_{met}). Interstrip circuital elements (C_{int}, R_{int}, C_m, C_p).Bulk representation (R_{sub}, C_{sub})

56 (or 80) cells 250 µm long

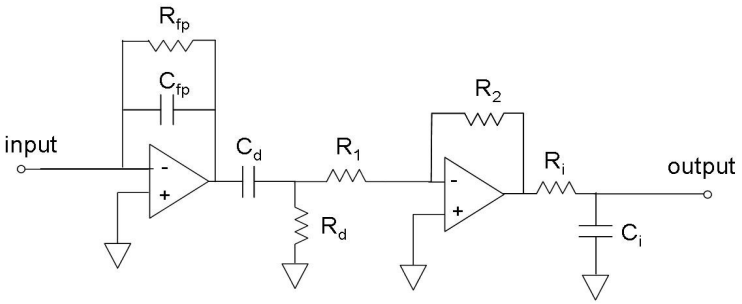
- five strips 14 (or 20) mm long (R_{impl}, C_{AC}, R_{el}),
- C_{int}, R_{int},
- bulk (300 µm thick) representation (R_{sub}, C_{sub}).

The parameters values, as well as the number of cells, have been adapted to the results of the electrical characterization of the real prototypes.



Readout model:

- ideal charge sensitive preamplifiers,
- 1ºorder CR-RC band-pass filter,
- Peaking time 25ns (Beetle chip- ALIBAVA DAQ system).
- Test beam-APV25- (peaking time 50 ns)



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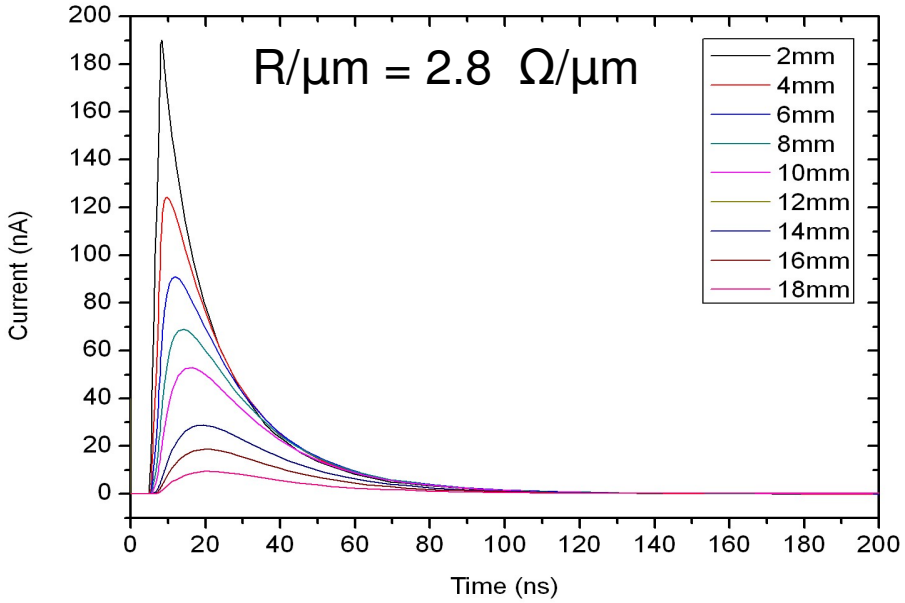
Signal Propagation II

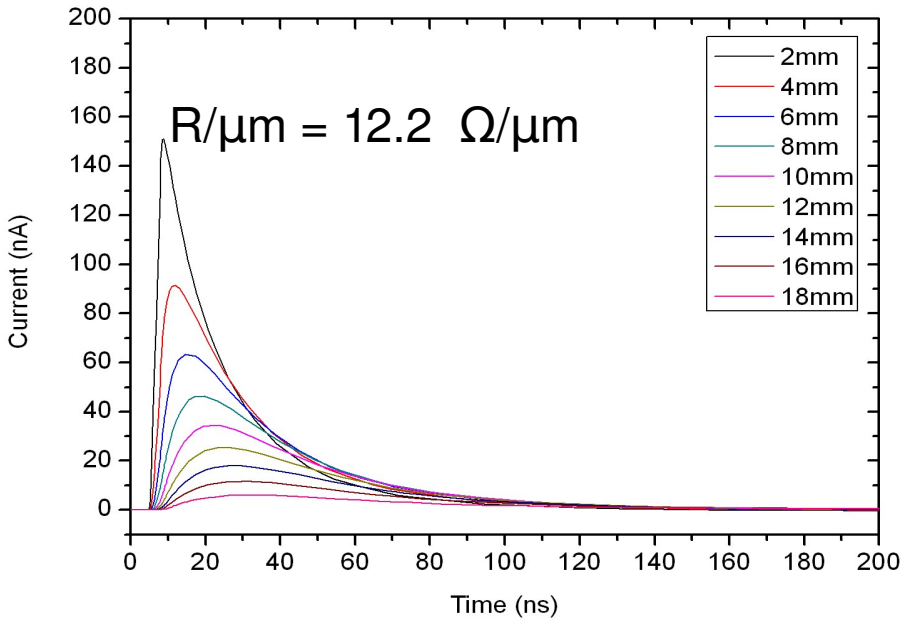


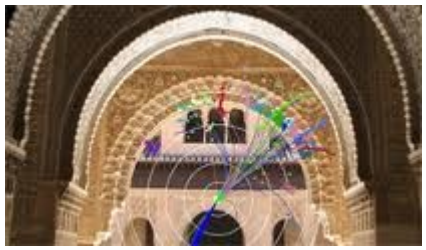
* Amplitude attenuation along the electrode depends on resistivity

* Rise time increases the further the pulse travels along the strip

* Ballistic deficit increases with rise time leading edge

* Worst Case: higher resistivity & max. travel distance
  * rise time ~ peaking time (25 ns- ALIBAVA DAQ)





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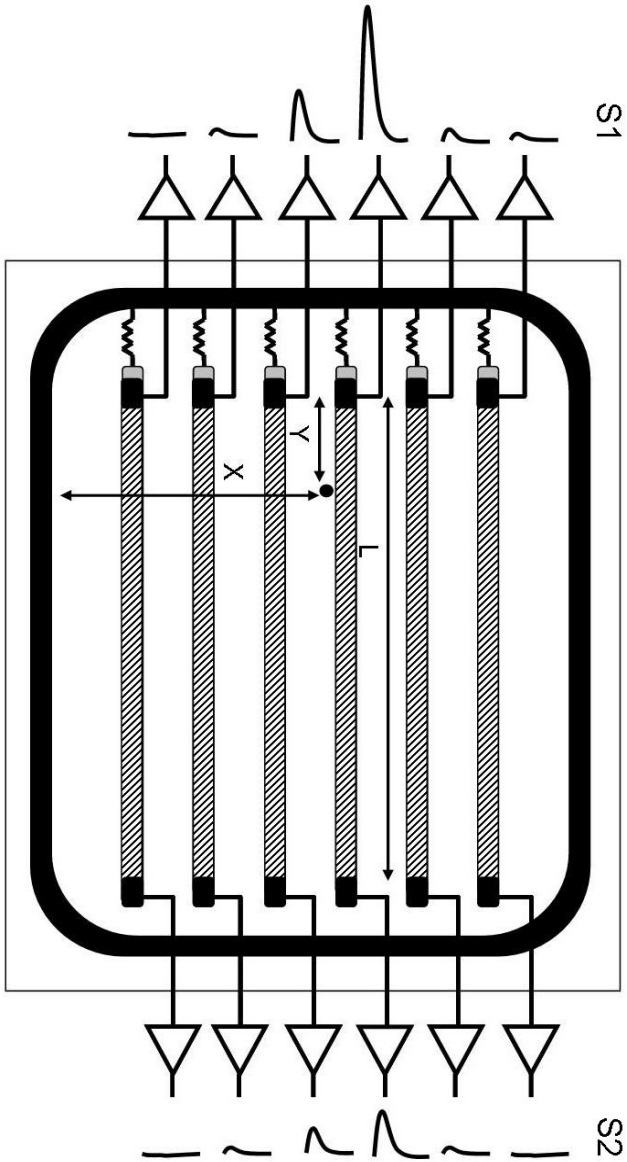
Prototypes

Standard technology

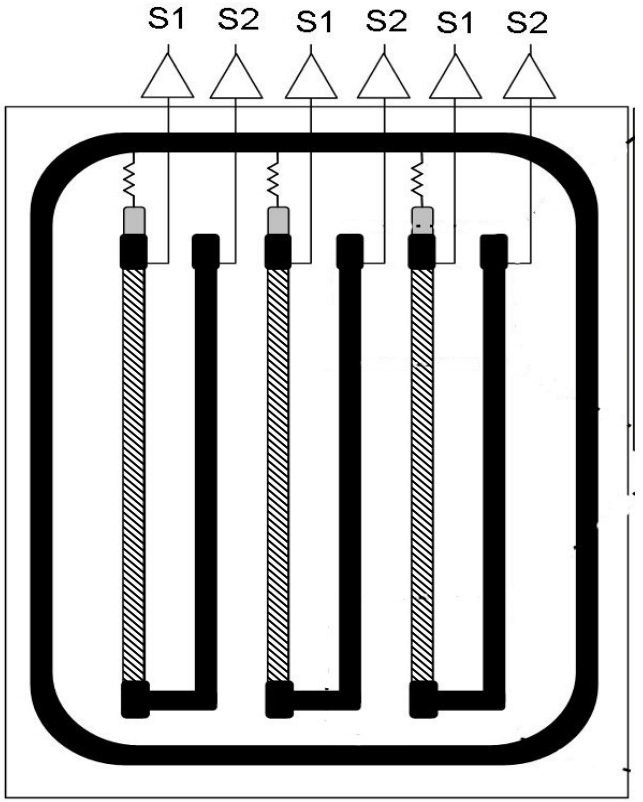
for single-sided p-on-n silicon microstrip detectors.



RESISTIVE ELECTRODE INDEPENDENT OF DIODE JUNCTION

Resistive electrode material = highly doped polysilicon

Doping concentration can be optimized for a given sensor geometry/size



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Prototypes differences

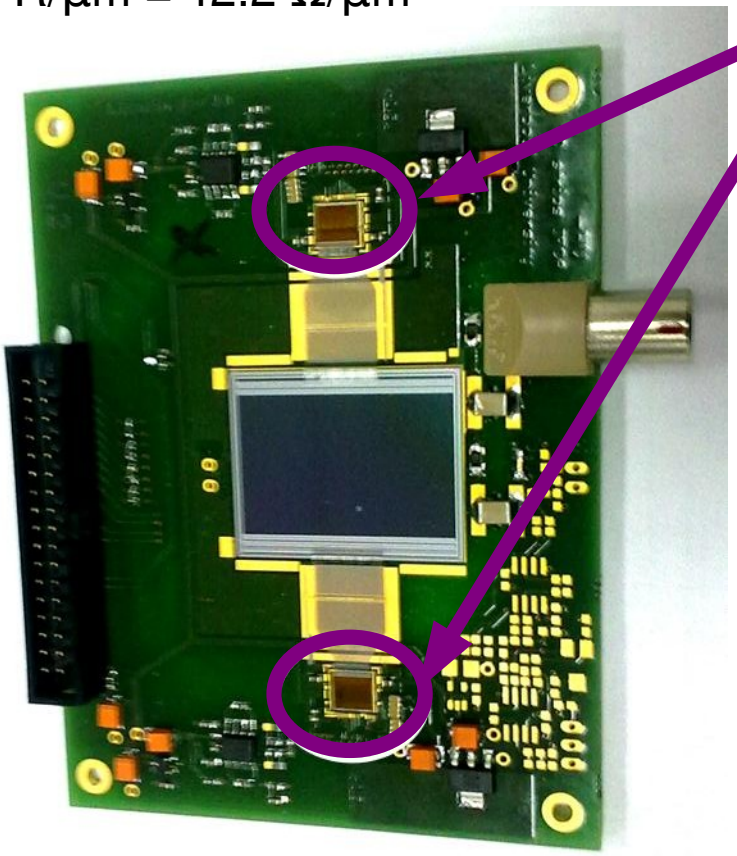
2 different prototypes

Implant & readout pitch =80 µm

Electrode resistance:

R/µm = 2.8 Ω/µm

R/µm = 12.2 Ω/µm



two readout chips

One readout chip

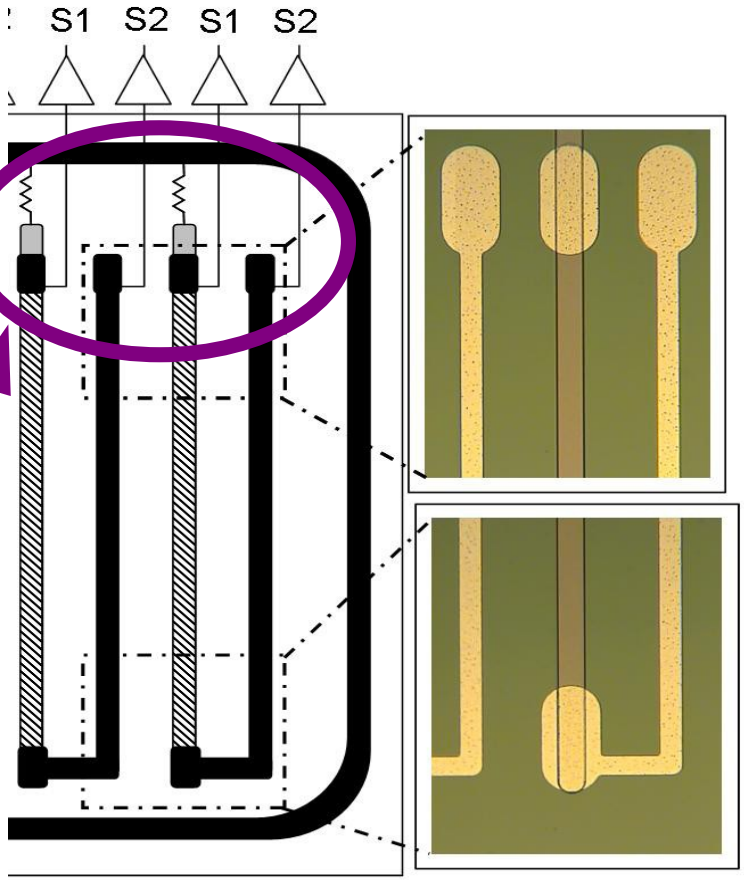
1 prototype:

Implant pitch=160 µm

readout pitch= 80 µm

Electrode: R/µm = 20 Ω/µm

Metal via



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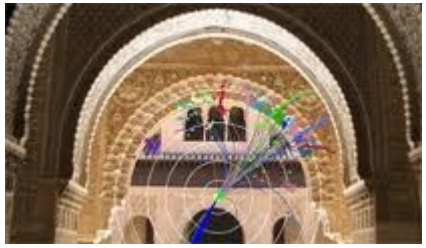
CHARACTERIZATION

- NIR laser characterization
- Radioactive Source characterization
- Test beam at SPS facilities



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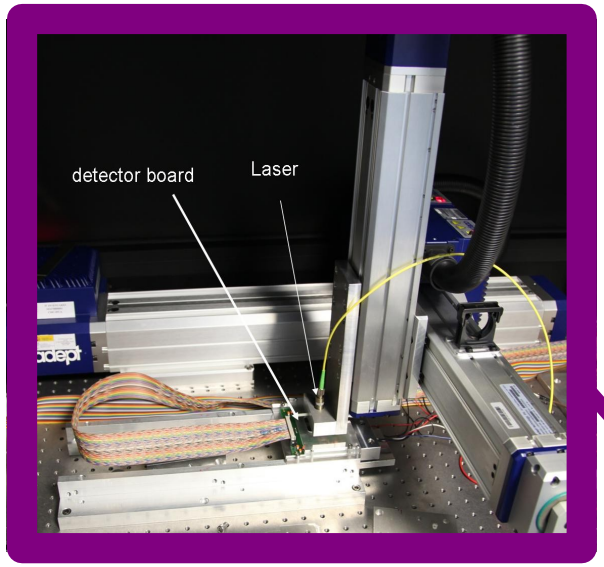
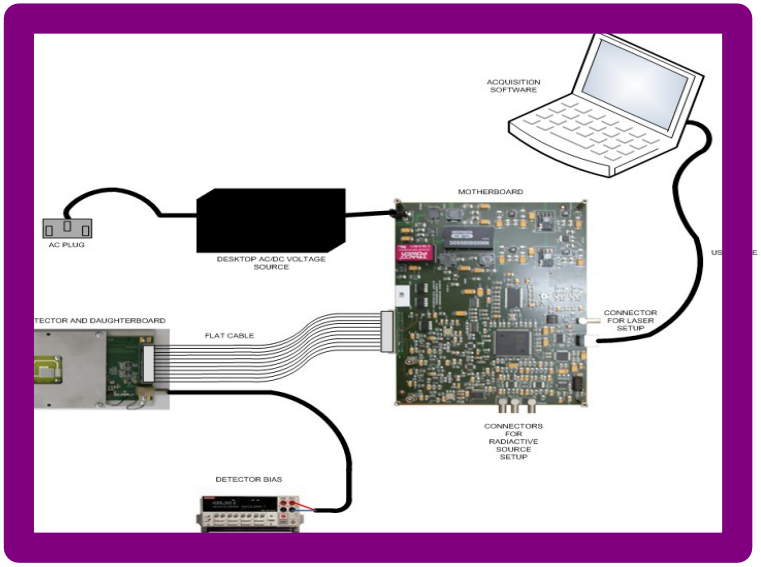
Experimental arrangement

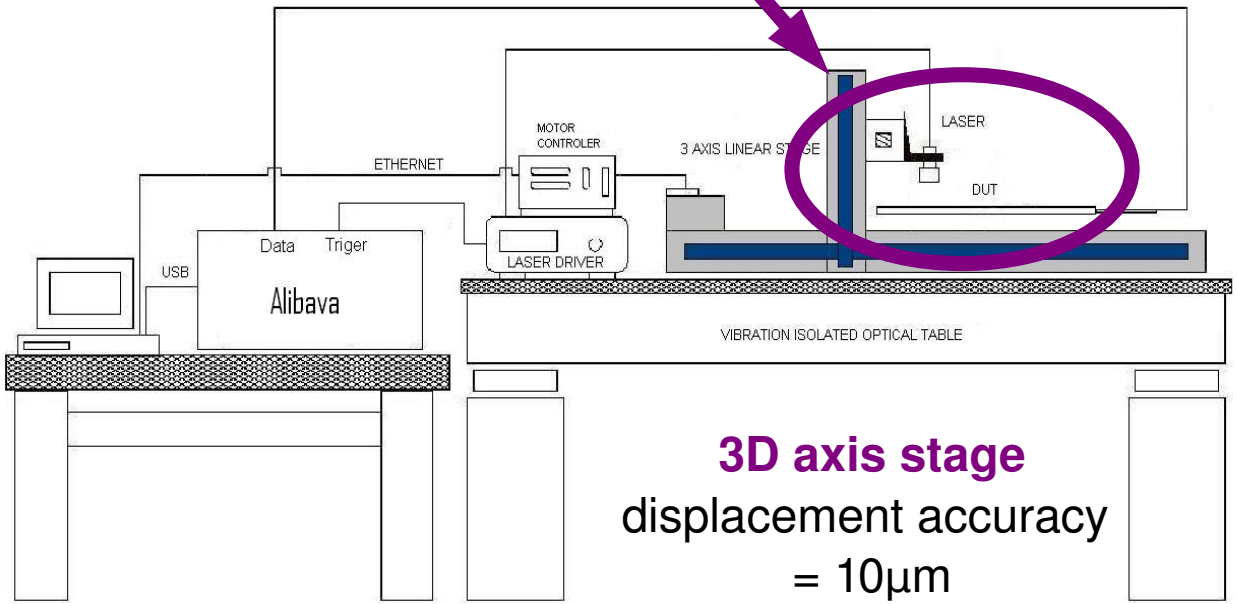
Detectors have been characterized in the IFCA clean room



- **Pulsed DFB laser** λ=1060nm
- σ ~ 5 μm

ALIBAVA DAQ system
* Beetle readout chip
* 256 channels
* peaking time ~ 25 ns





3D axis stage
displacement accuracy
= 10μm

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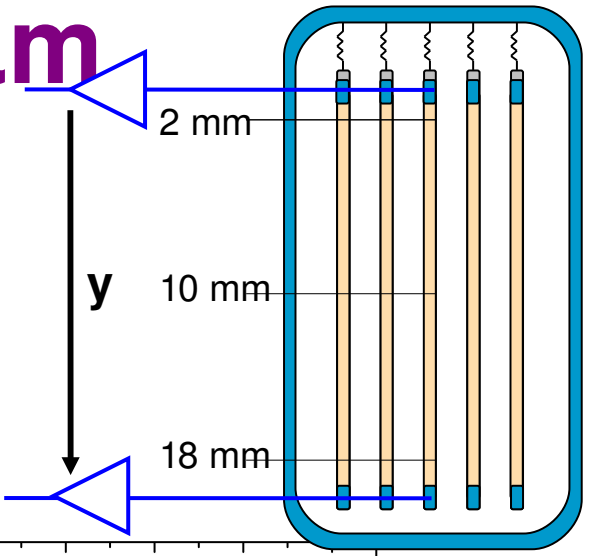
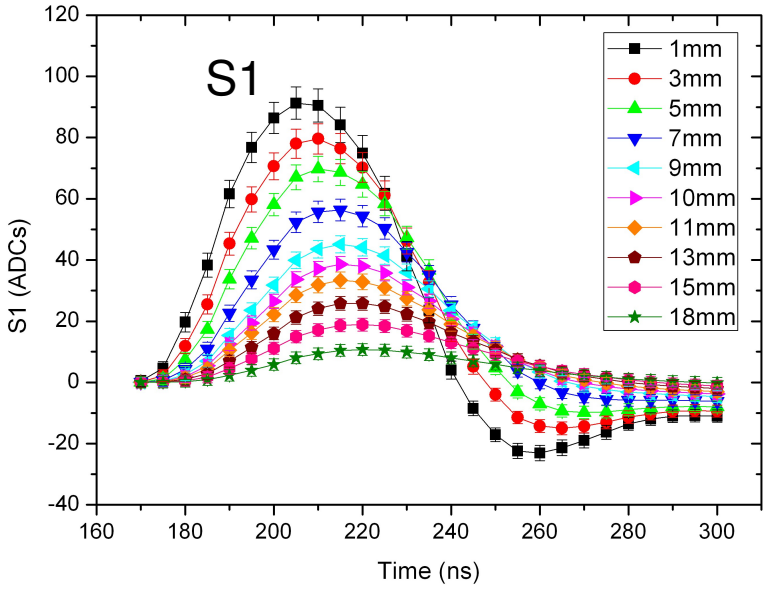
Results on double side readout detectors

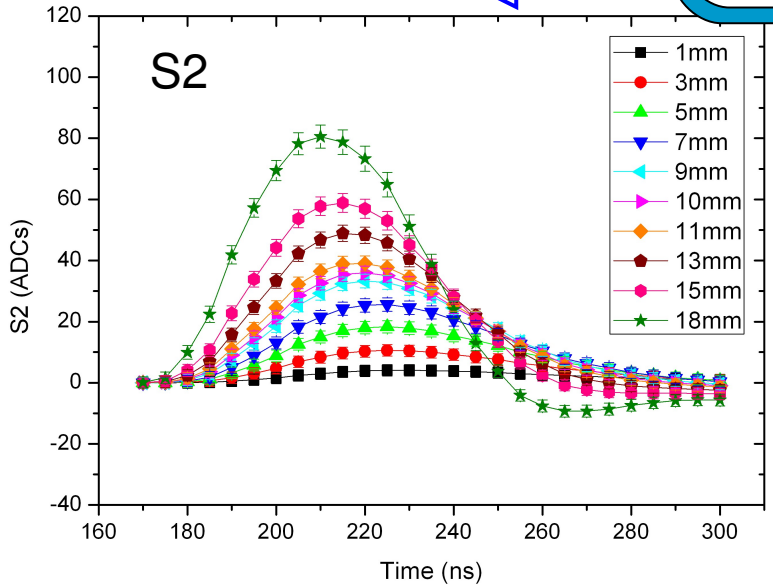
$R_{electrode}$ = 12.2 Ω/µm



* Laser Longitudinal scan & sampling time scan in order to measure the full pulse shape at each position along the strip

* Estimation of the signal is the amplitude value





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Results on double side readout detectors

$R_{electrode}$ = 12.2 Ω/µm (RC = 450ns)

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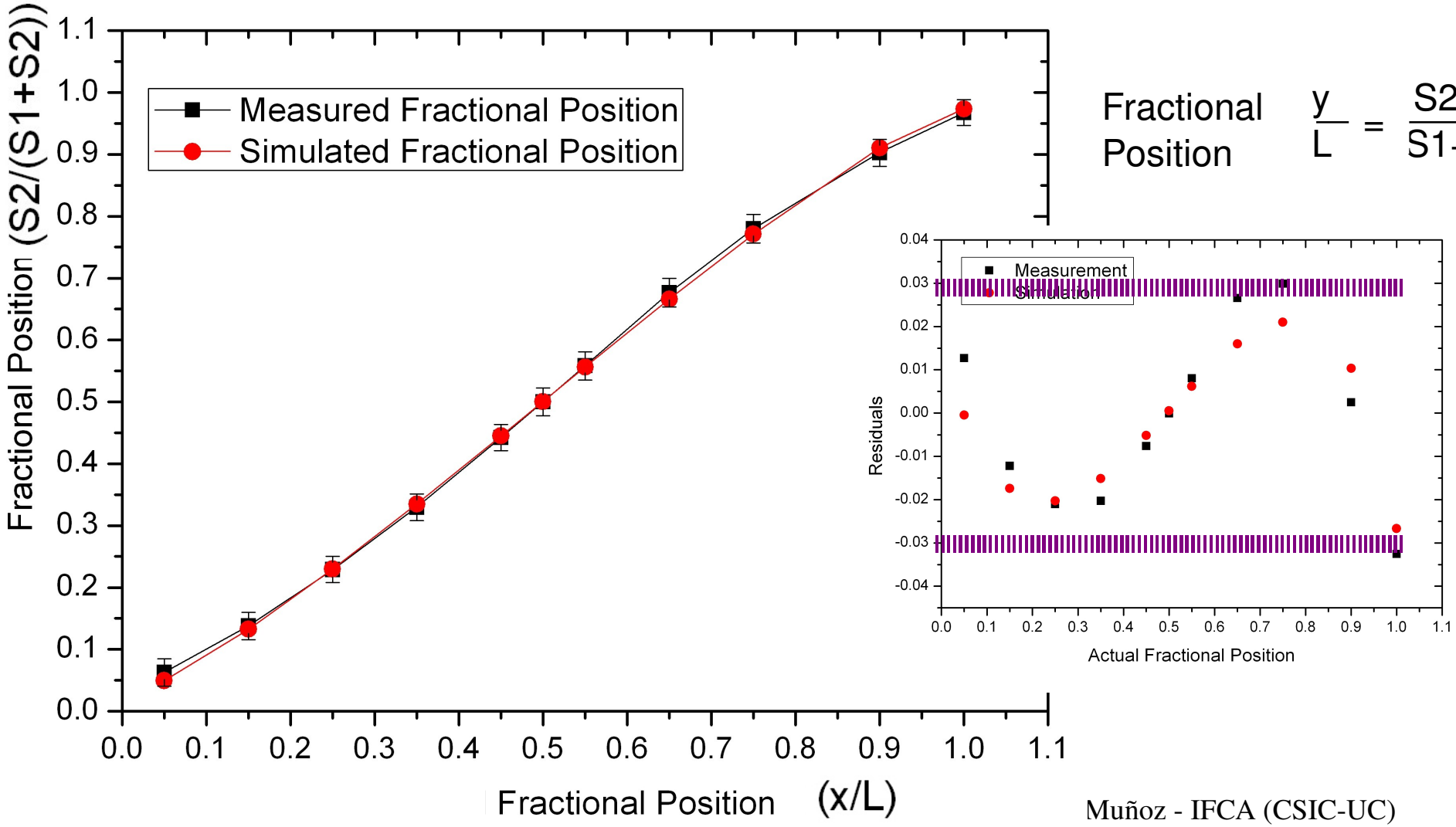
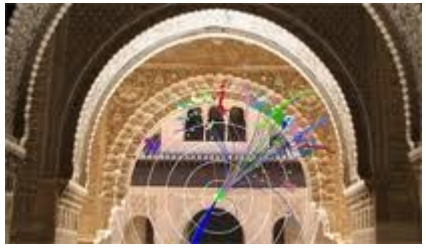


Fractional Position $\frac{y}{L} = \frac{S2}{S1+S2}$



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Results on double side readout detectors

$R_{electrode}$ = 2.8 Ω/µm

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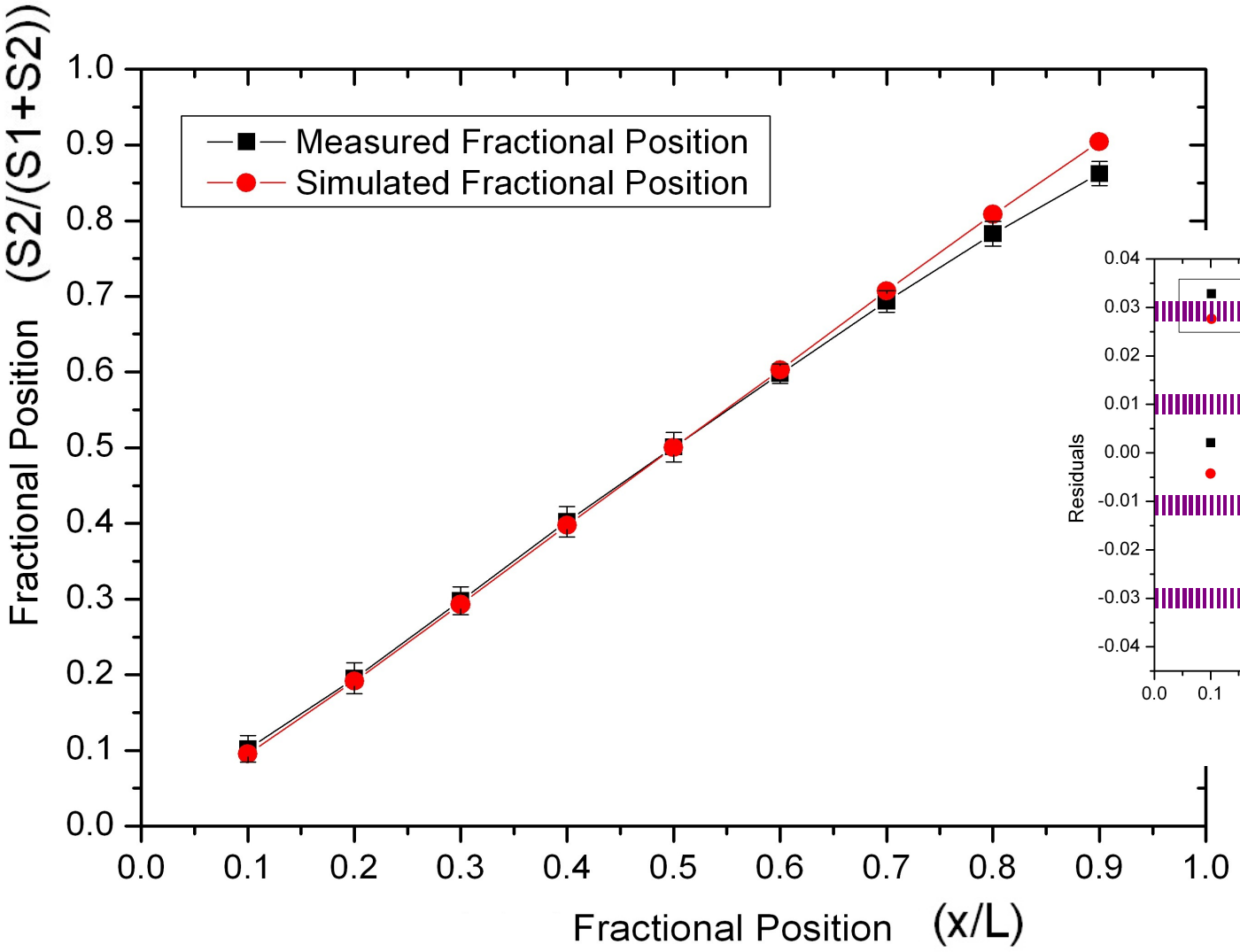
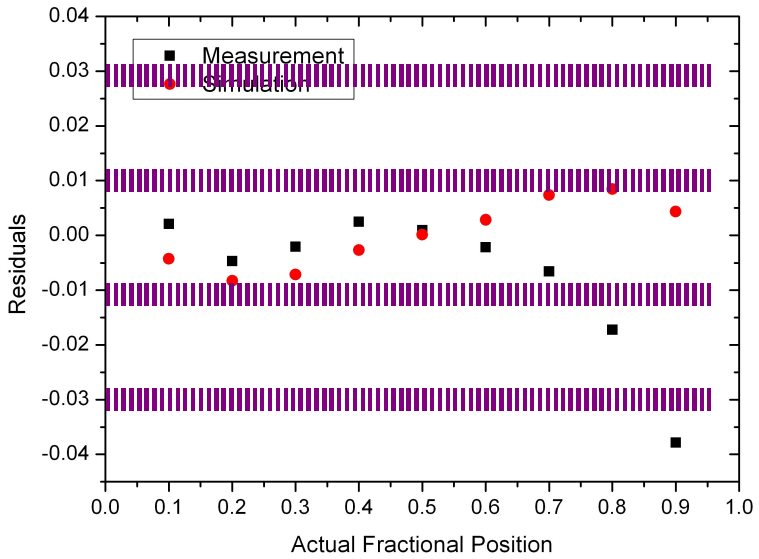
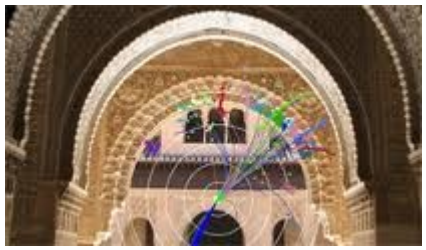


Fractional Position $\frac{y}{L} = \frac{S2}{S1+S2}$





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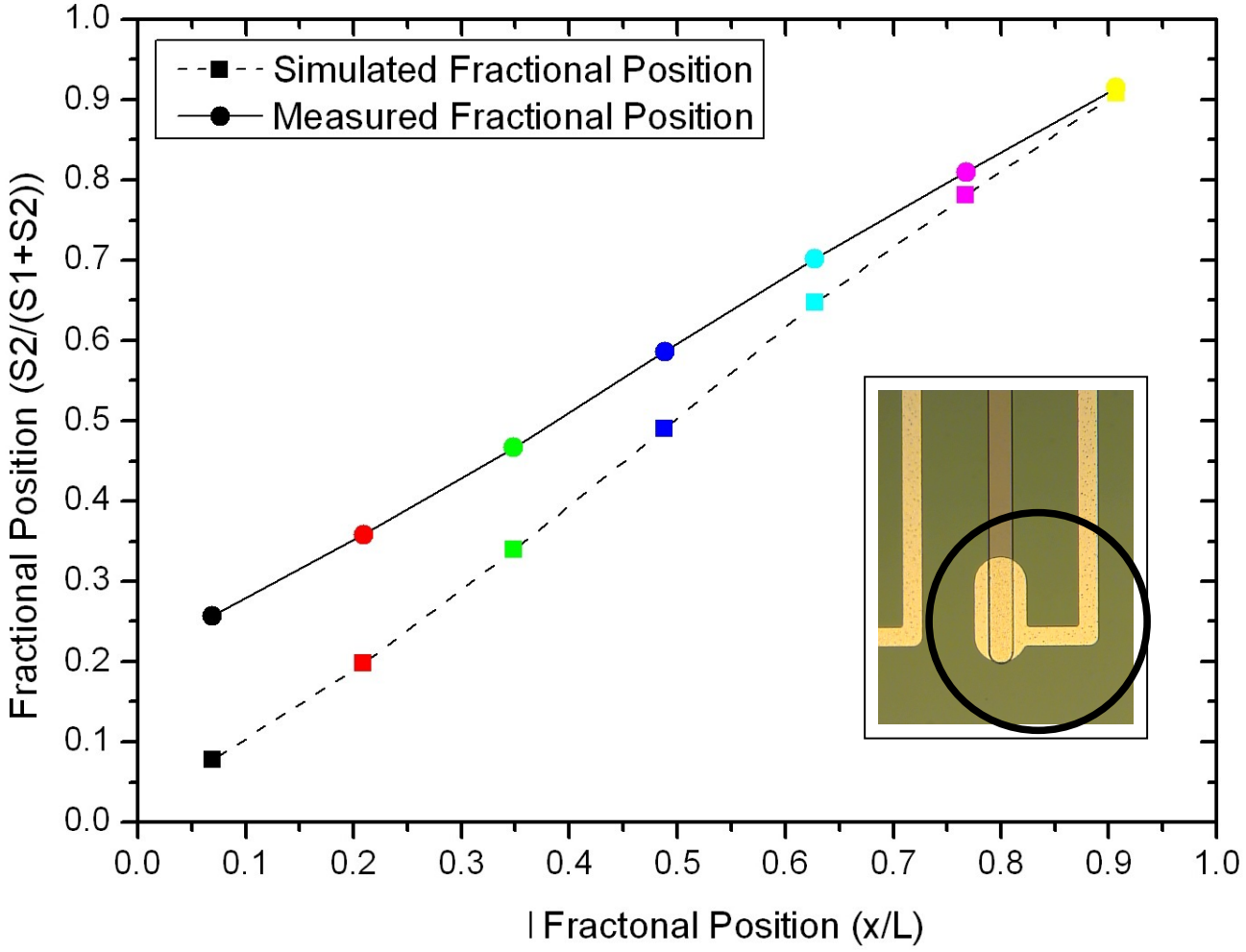
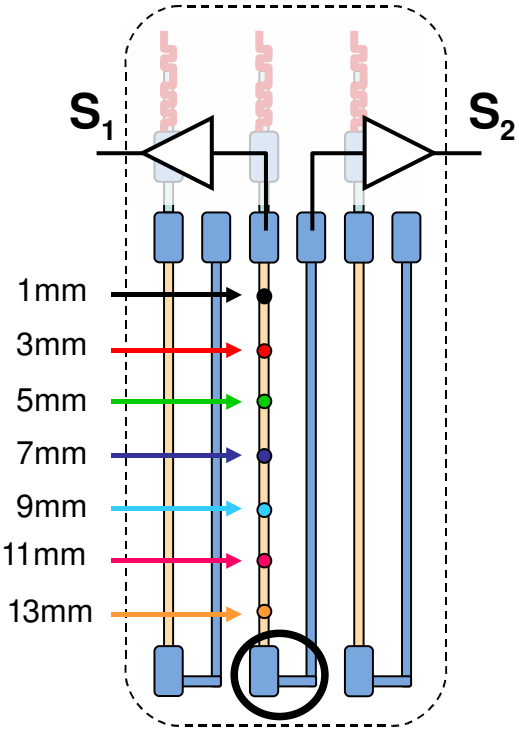
Results on single side readout detectors

$R_{electrode}$ = 20 Ω/µm

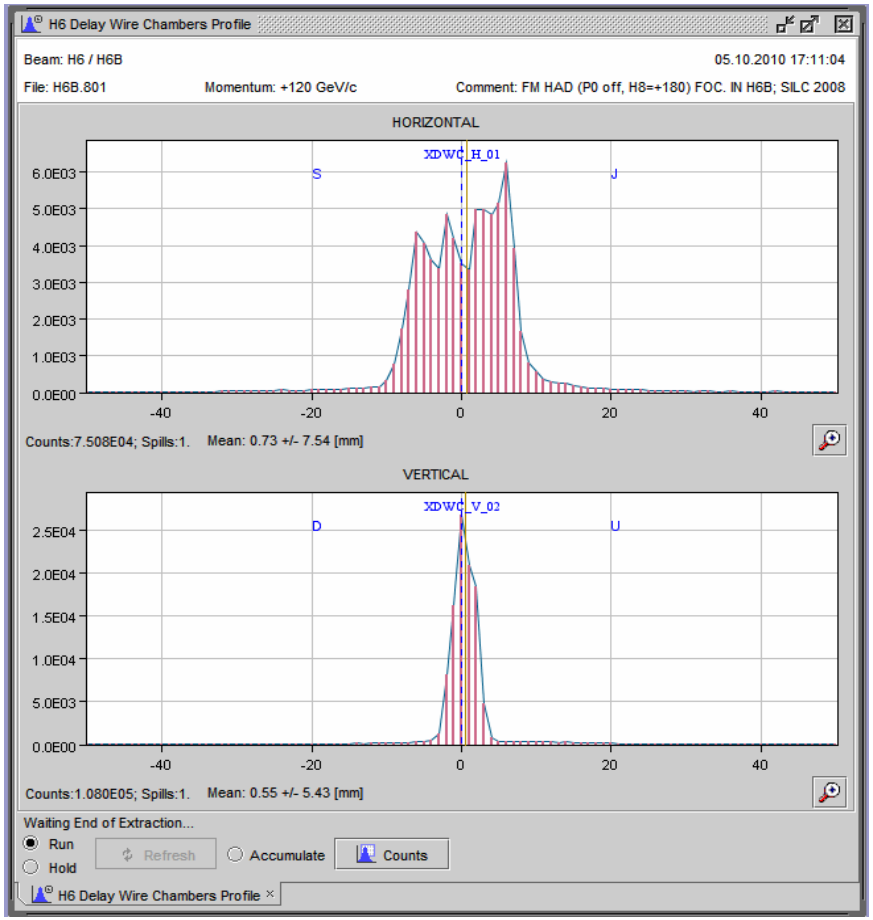
Contribution of induced signal decrease when the laser is placed close to the connection between the resistive electrode and the metal line



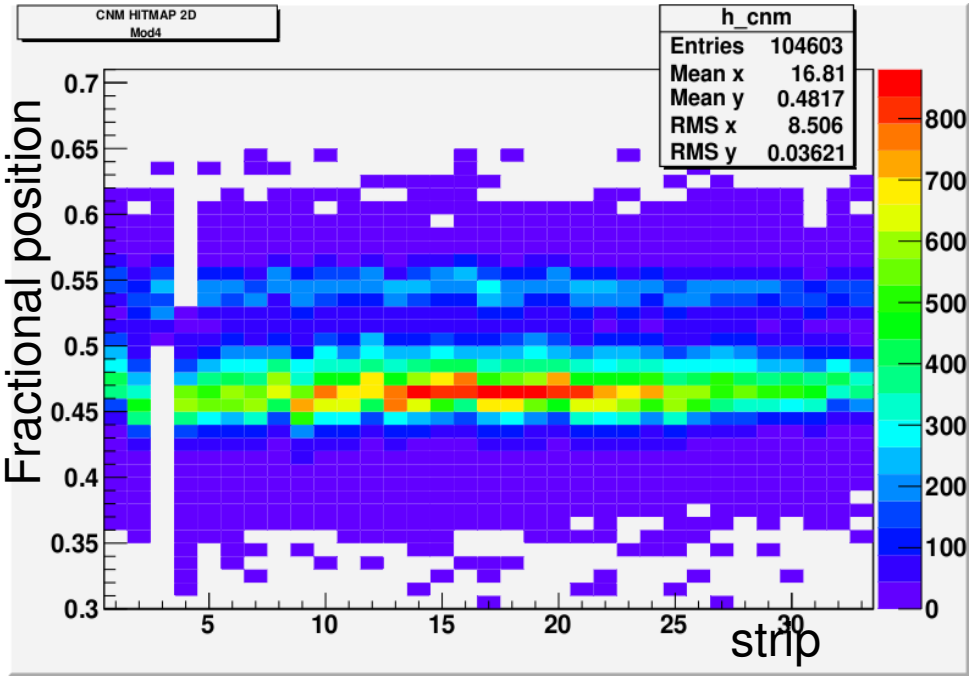


TEST BEAM@ SPS (CERN). APV25 DAQ – system
120 GeV pions beam

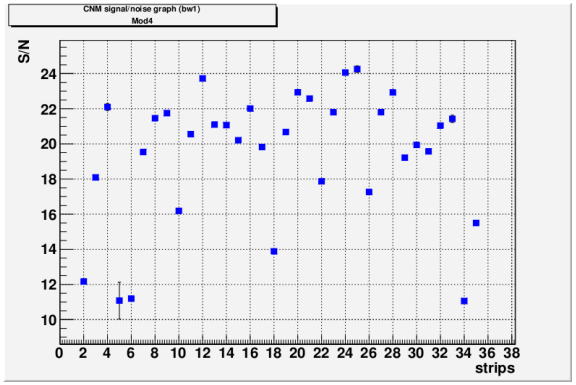
BEAM Profile by SPS facilities



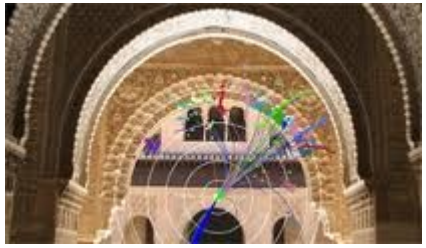
BEAM Profile by a 2D position sensitive sensor



Averaged S/N= 19.9



Erik Huemer



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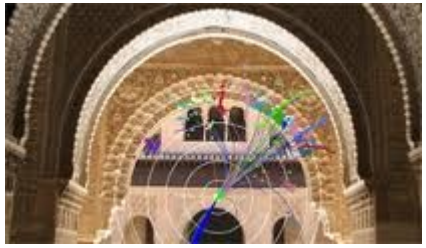
Conclusions

- The feasibility of resistive charge-division method in microstrip detector has been demonstrated
- Different prototypes have been produced, tested with a NIR laser and validated against a simulation of sensor's equivalent circuit
- **Excellent agreement between experimental and simulation data**
- MIP response from SPS test beam (120 GeV pions). SNR ~ 20



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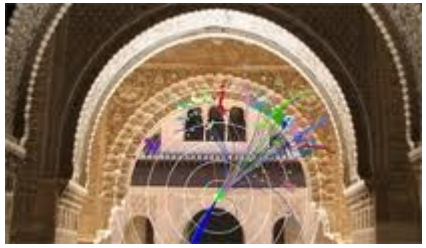
ONGOING

This work has been submitted to JINST

- Test beam data to be analysed including EUDET telescope data
- New test beams and laser characterization in progress
- Use of the simulation to optimize spatial resolution for MIPs according to the FE readout peaking time



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Acknowledgements

- Marko Dragicevic (HEPHY institute, Vienna) for his contribution to the mask design
- Gianluigi Casse (University of Liverpool) in bonding availability
- Ricardo Marco, Carlos Lacasta (IFIC) for their ALIBAVA support
- IFIC & University of Liverpool bonding service for detector bonding

Thank you for your attention!

&

Enjoy Granada as much as possible!

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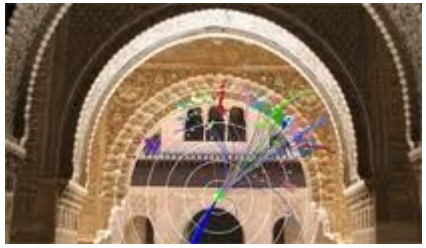
Backups



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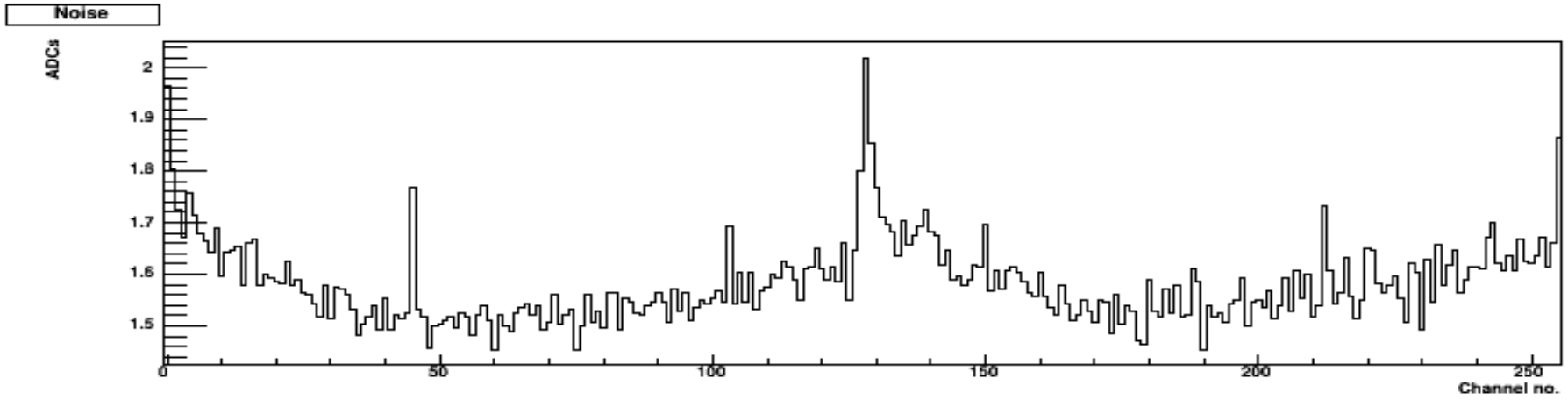
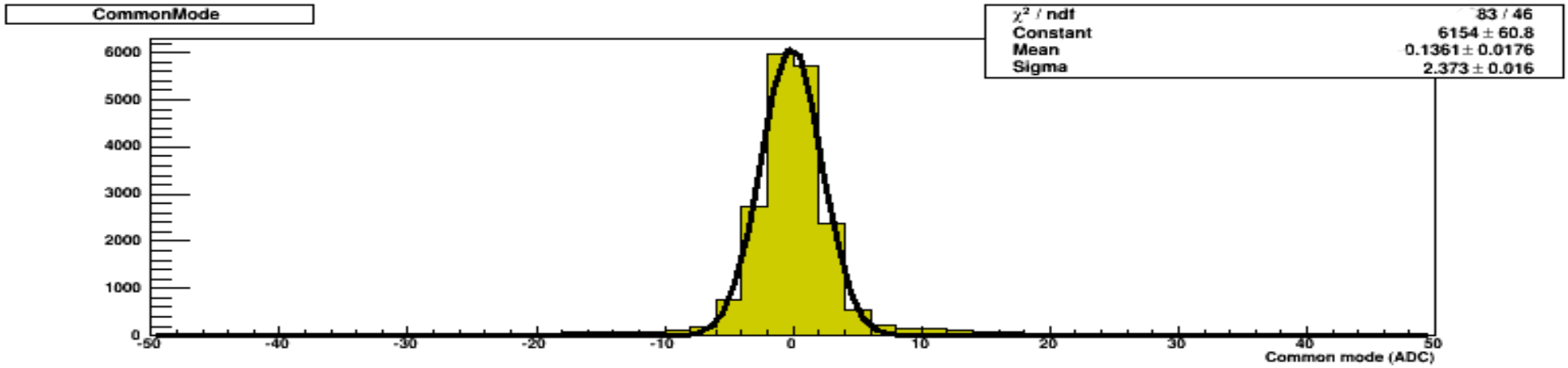
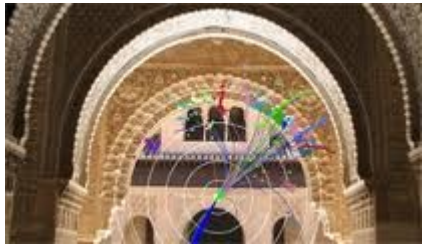
Noise.
Higher $R_{electrode}$ sensor







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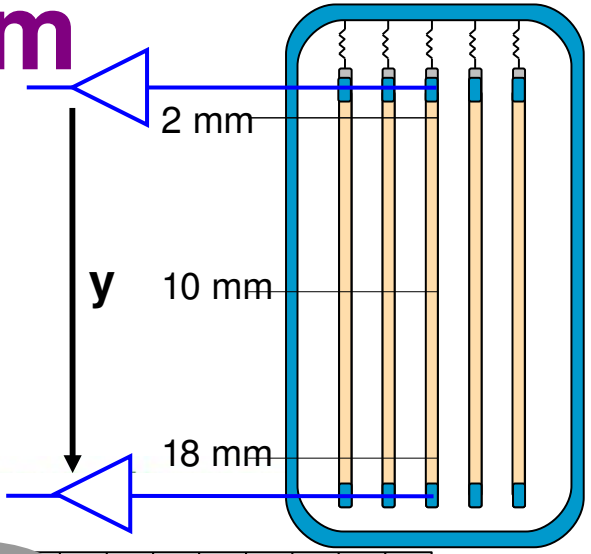
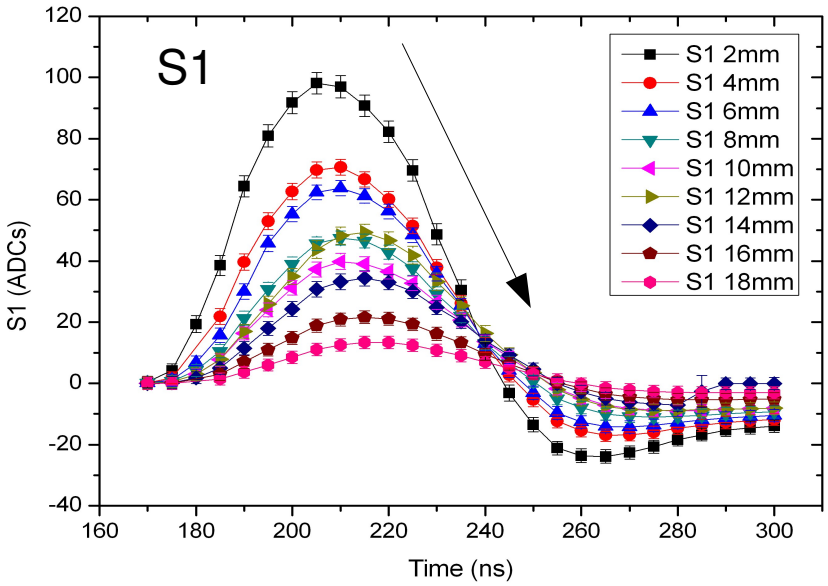
Results on No-metal via detectors

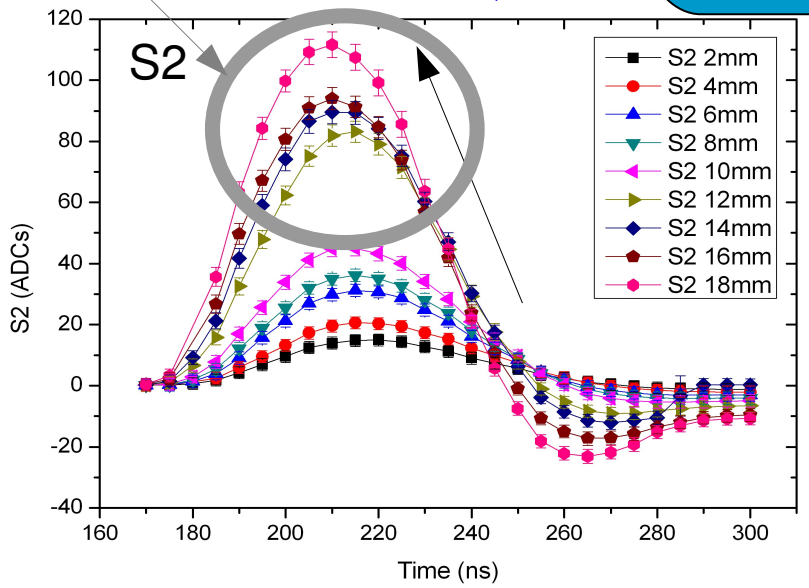
$R_{electrode} = 2.8\ \Omega/\mu m$

* Laser Longitudinal scan & delay scan in order to determine the pulse shape along the strip

* Asymmetry in the last 4scan's points --> Laser misalignment







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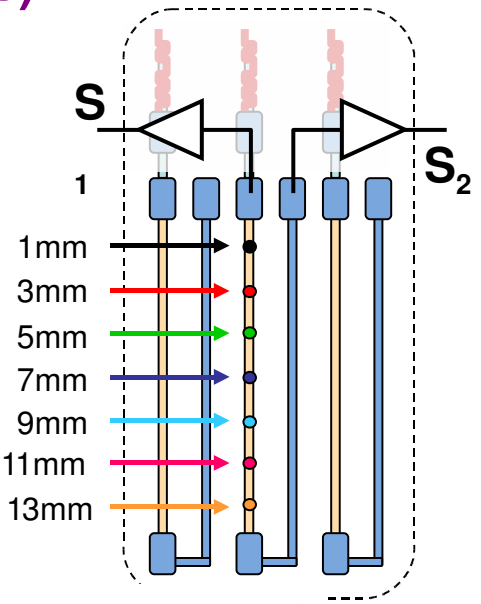
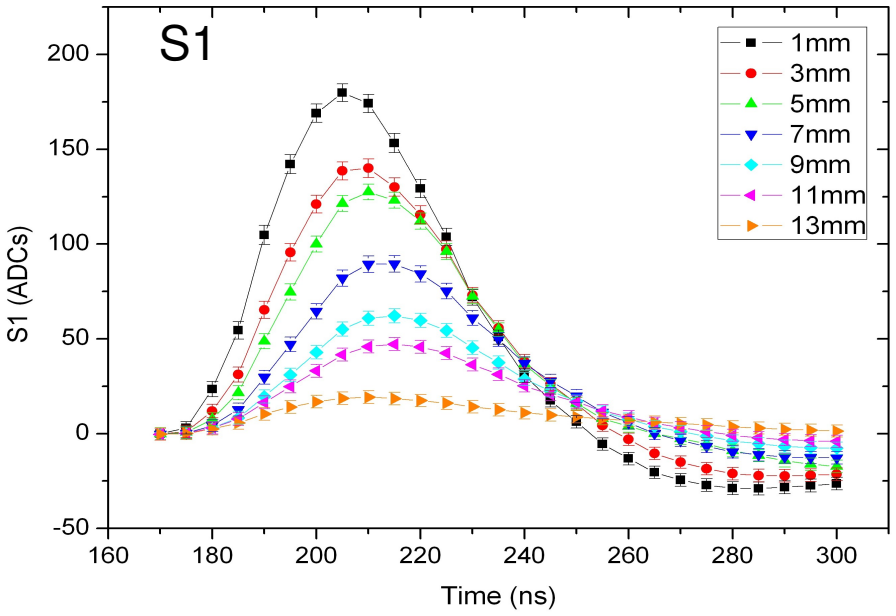
Results on metal via detectors

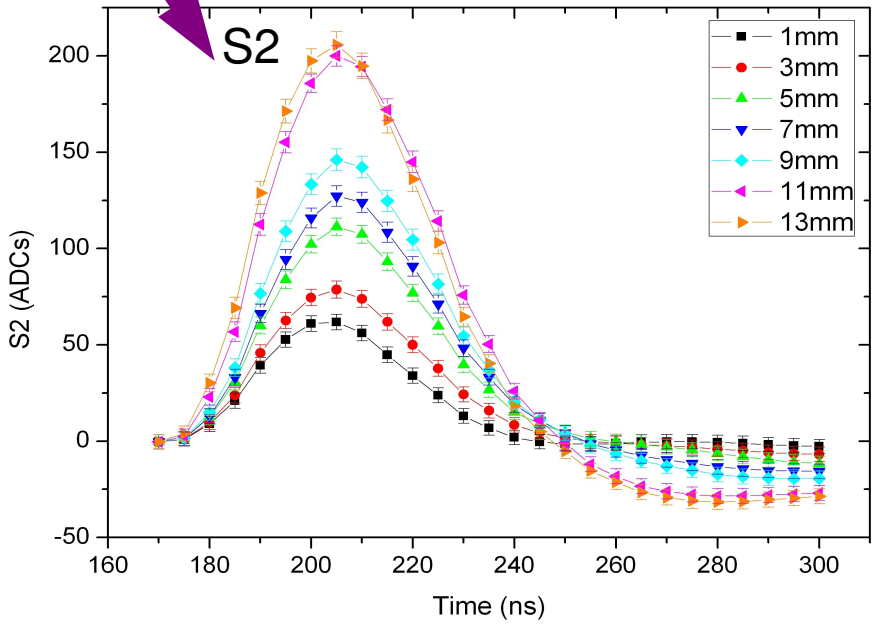
$R_{electrode}$ = 20 Ω/µm (RC = 100ns)



* Laser Longitudinal scan & delay scan in order to reproduce the pulse shape along the strip
* Asymmetry in detector response
  Metal guides capacitively coupled with neighbouring strips

Induced signal components contribute to signal S2.
Signal excess in S2 in every scan's points





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Estimation of spatial resolution (MIP)

- Signal values are mean of the Gaussian fit to the signal
- Correlation parameter ρ= <S1S2>/σ1σ2
- Error in fractional position: *

$$\sigma_x = x \sqrt{\left(\frac{\sigma_1}{S_1}\right)^2 + \left(\frac{\sigma_2}{S_2}\right)^2 - 2\rho \frac{\sigma_1 \sigma_2}{S_1 S_2}}$$

** Jerome K. Carman et al. Nuclear Instruments and methods in Physics Research A 646 (2011) 118*

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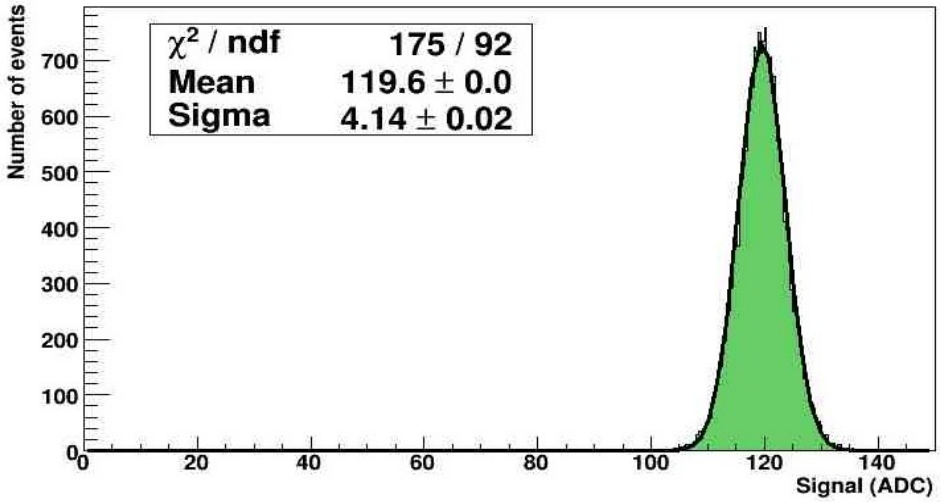
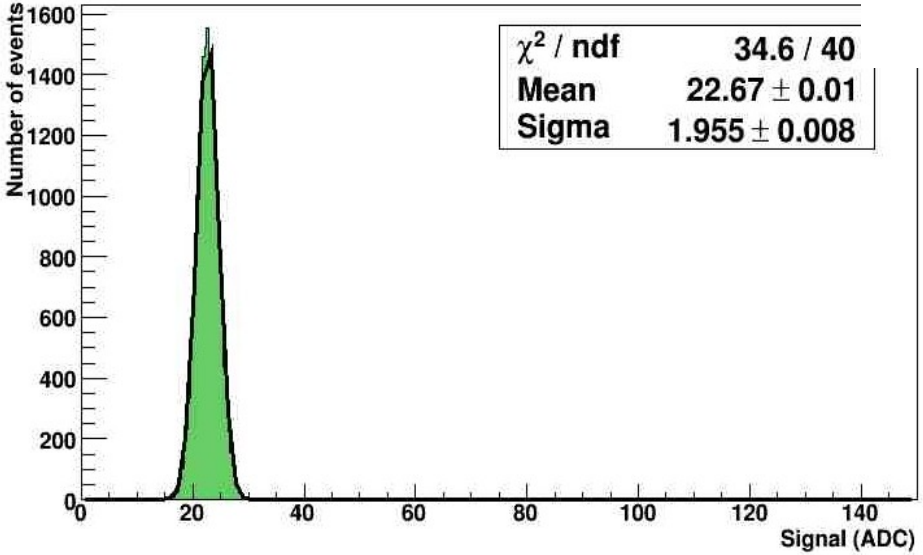
Gaussian fit

~10000 events

S1,No metal via sensor. Position 5mm



S2, No-metal via sensor. Position 5mm



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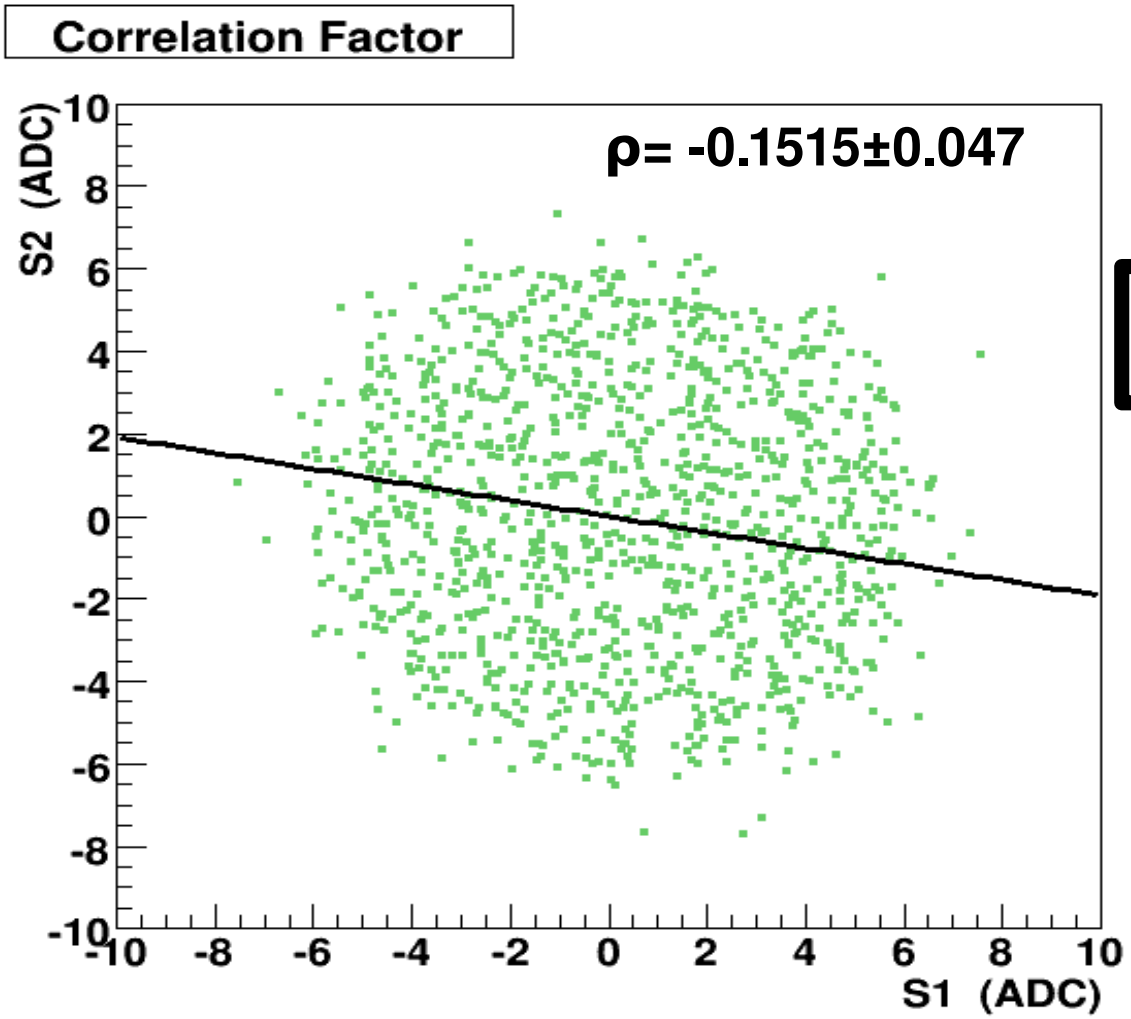
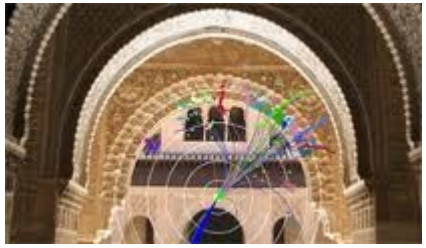
Correlation factor



$\rho = \langle S1S2 \rangle / \sigma 1 \sigma 2$



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