Progress with 2D Microstrip Detectors with Polycrystalline Silicon Electrodes

19th RD50 Workshop
November 23th CERN, Geneva

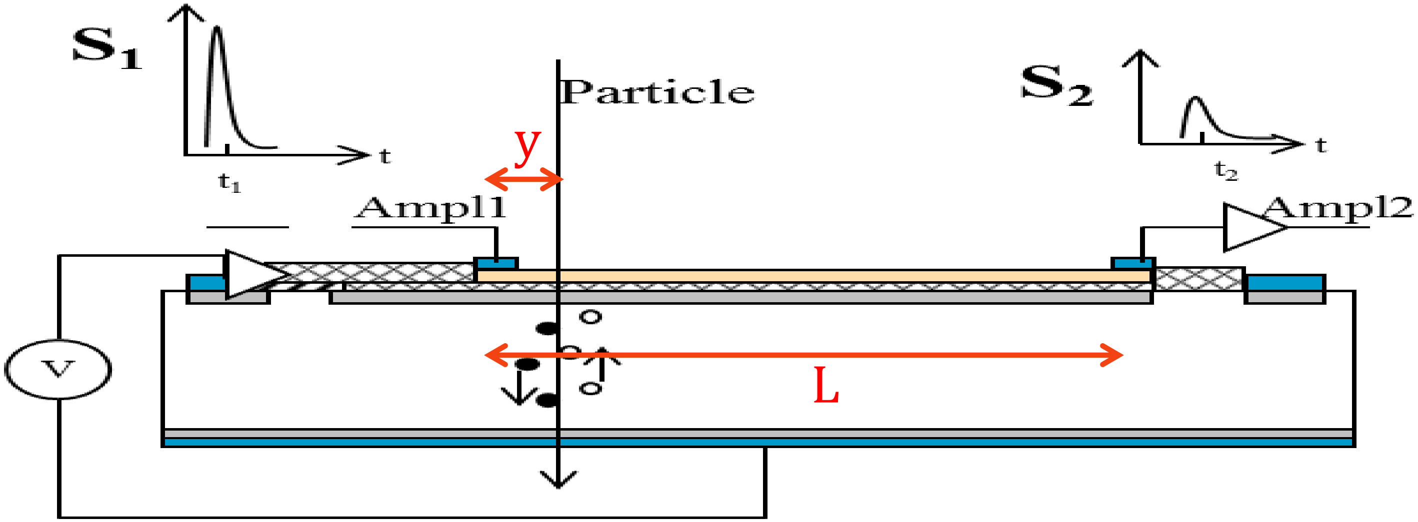
D. Bassignana, M. Lozano, G. Pellegrini, D. Quirion
CNM-IMB (CSIC)
M. Fernández, R. Jaramillo, F.J. Muñoz, **I. Vila**
IFCA (CSIC-UC)

Outline

- Introduction to charge-division concept in microstrip sensors.
- New sensor prototypes: signal processing electronics.
- Experimental arrangement: NIR laser & Test beam characterization
- SPICE sensor equivalent circuit vs. data: position error studies
- Sensor prototypes with integrated signal routing.
- Summary and outlook

Charge-Division Concept in ustrip Sensors (1)

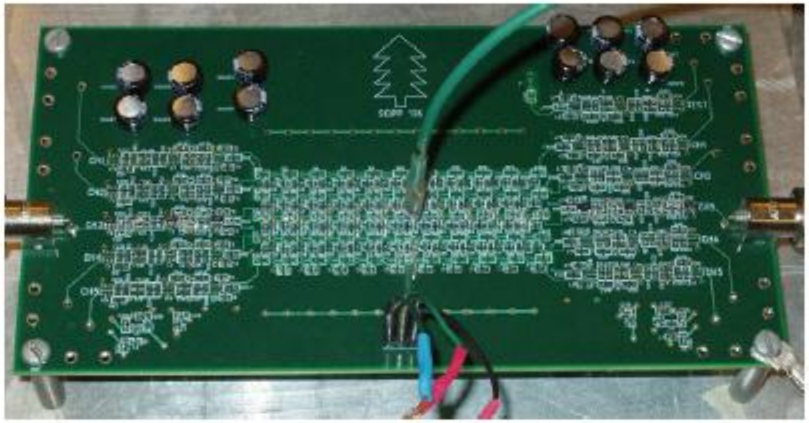
- Charge division used in wire chambers to determine the coordinate along the sensing wire.
- Same concept with conventional microstrips with slightly resistive electrodes (doped polysilicon)



$$\text{Fractional Position} \equiv y/L = S2/(S1 + S2)$$

Charge-Division Concept in ustrip Sensors (2)

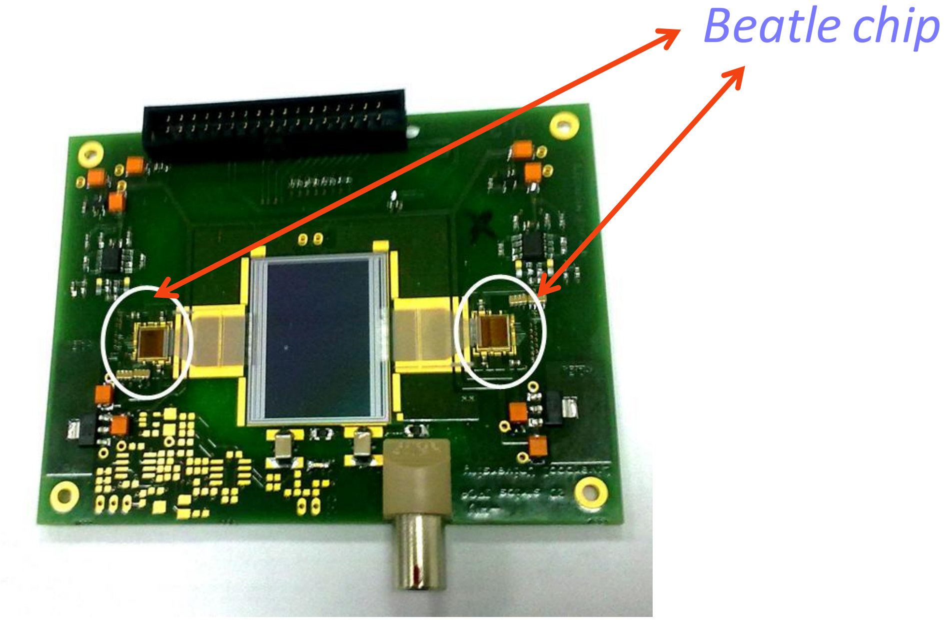
- First proposed by Radeka (TNS Vol. 21, 1964)
  - Microstrip electrode as RC dispersive line.
  - Position dependent ballistic deficit.
- Optimization of the signal processing electronics shaping time (about one third of the detectors RC constant)
- Fractional position resolution independent of strip resistivity
- Recently Radeka's formulation validated @ SCIPP against electronic circuit emulator (NIM A (2011) 646 118)



New Prototypes from CNM

- One year ago very promising results on CNM's first prototypes with integrated on sensor signal routing for single-end readout (affected by parasitic couplings, see later in this talk).
- Now presenting results on two new prototypes with double-end readout.

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



Signal Processing: shaping time issue

- Electrodes as RC dispersive lines: attenuated and delayed signals, moreover serial noise is increased (larger shaping times favored)
- But, suppressing parallel noise contribution requires smaller shaping times.
- Trade-off: shaping time optimized for a given RC characteristic (about 1/3 of the RC from Radeka)
- ALIBAVA readout has a fixed 25ns shaping time (τ_{shape})

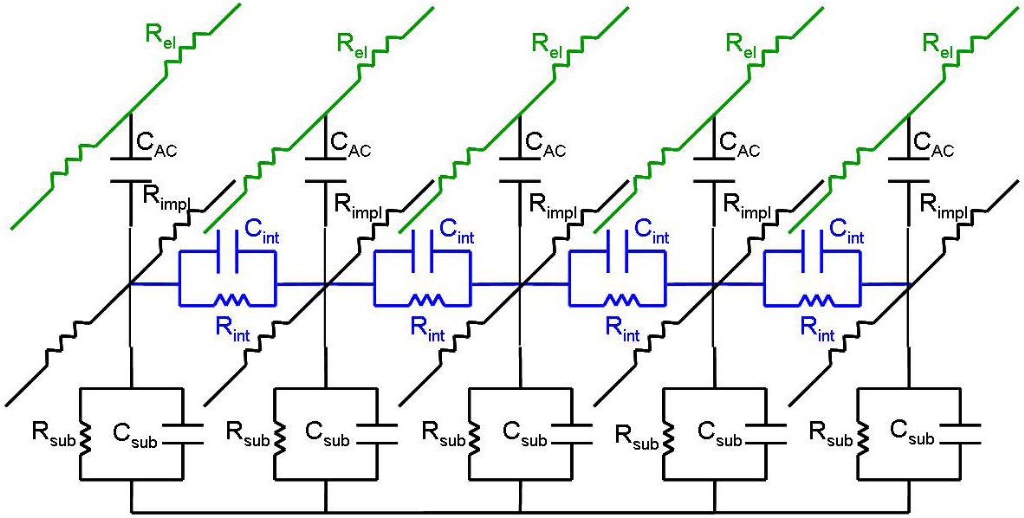
Is this a sensible τ_{shape} for our prototype sensors?

Is the response linearity preserved?

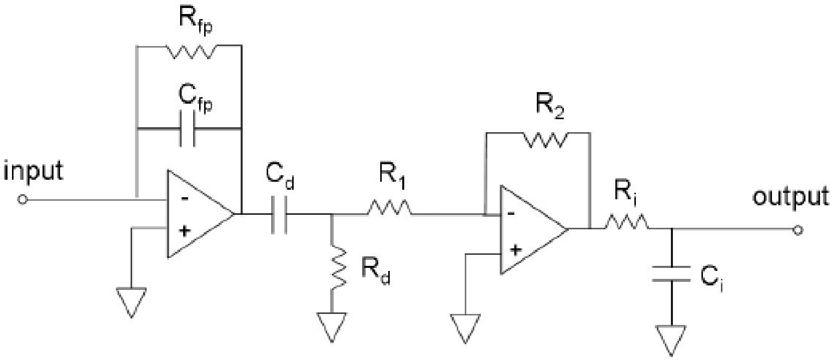
Spice simulation: sensor+signal processing electronics

Spice simulation (1): Equivalent Circuit

- Detector cell model including five consecutive strips.
- Total sensor: periodic structure composed of 80 cells.
- Realistic parameters (from sensor electrical characterization)
- Already validated microstrip simulation.
- charge sensitive preamplifier + CR-RC filter, which peaking time 25 ns.



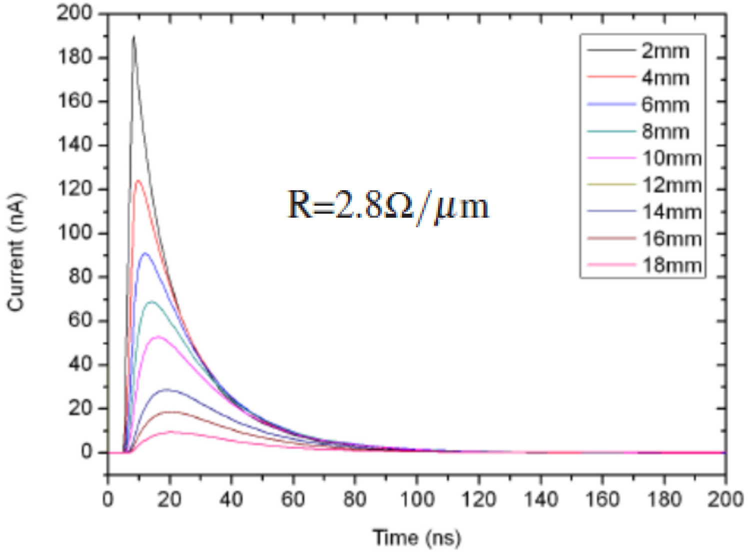
"SPICE Analysis of Signal Propagation in Si Microstrip Detectors" N. Bacchetta et al. , IEEE TRANSACTIONS ON NUCLEAR SCIENCE, VOL. 42, NO. 4, August 1995.

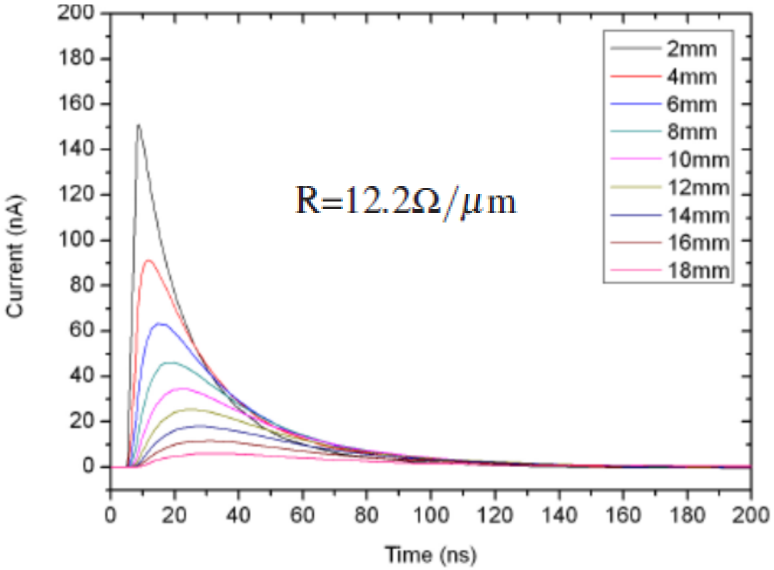


SPICE Simulation (2): Signal Propagation.

- Charge injected at different strips positions.
- Current shapes at the entrance of the charge pream after propagation.
- As expected: delayed and attenuated pulses
- Worst case (most resistive):

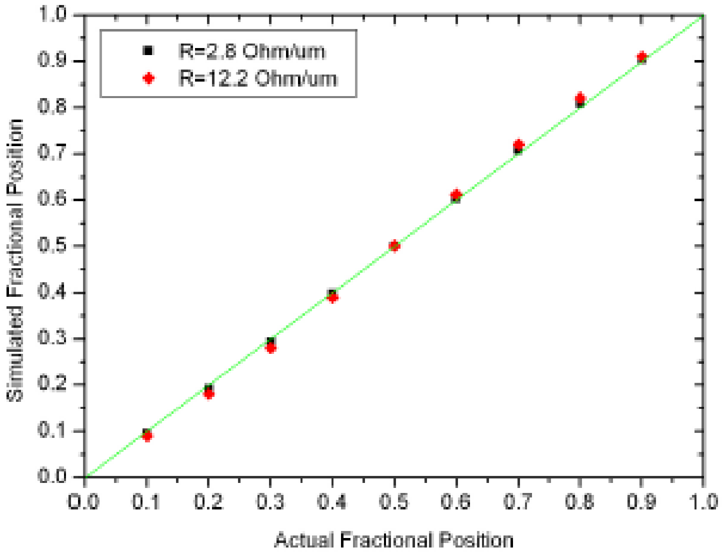
  $\tau_{shape} \geq$ Signal rise time

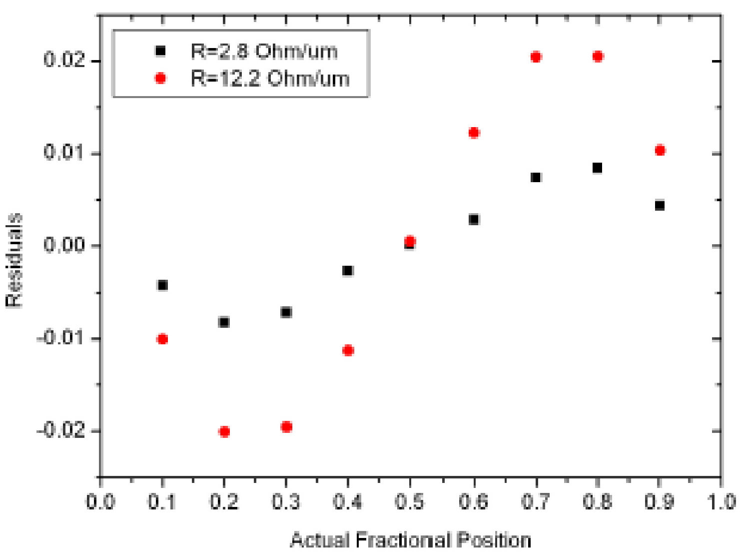




SPICE Simulation (3): Linear Response

- sub-optimal τ_{shape} but still good enough to preserve the linear response, significantly better for the low resistance prototype





Green line is ideal Fractional Position $\equiv S2/(S1+S2)$

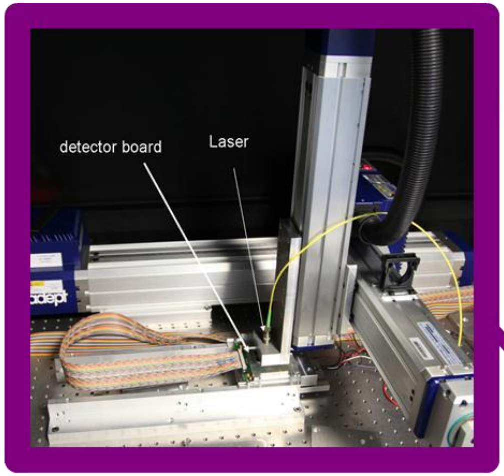
What about the real data?

GOALS:

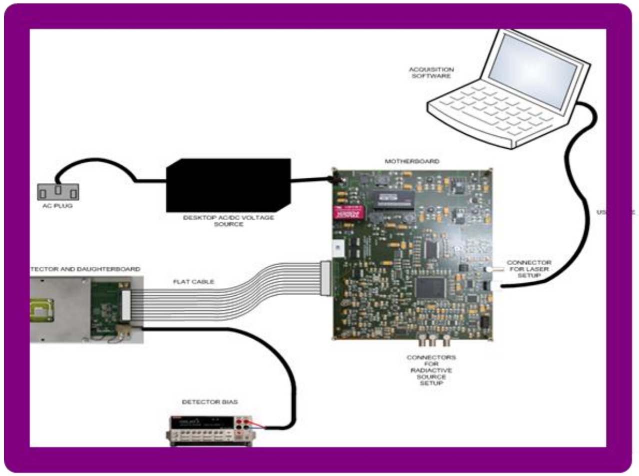
- **NIR Laser:** Experimental validation of the Charge-Division concept in a full-fledged microstrip sensor.
- **NIR Laser:** Benchmarking of the spice simulation as a designer tool for future prototypes.
- **SPS pions:** SNR studies for MIP particles, aka, feasibility of technology for HEP trackers.

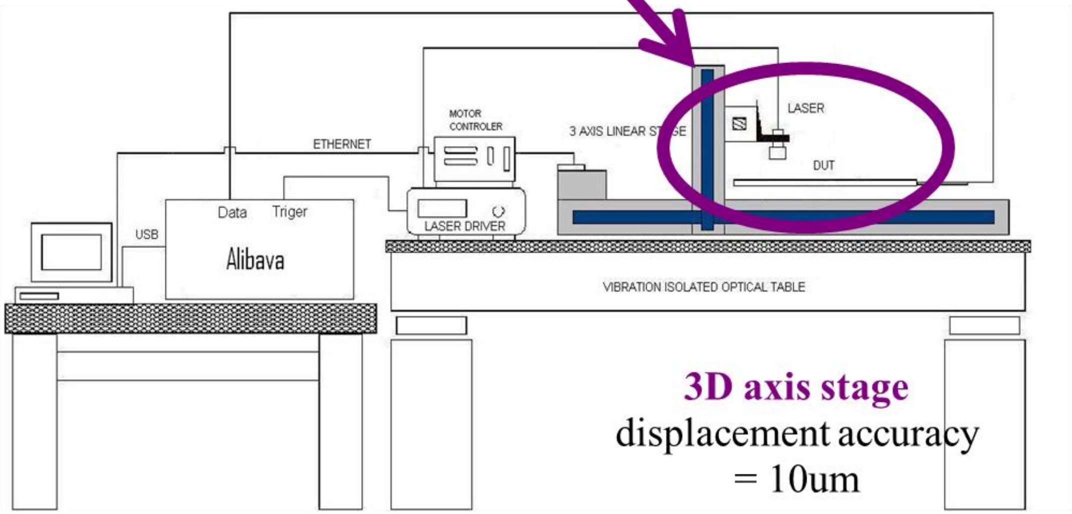
NIR laser test stand

ALIBAVA DAQ system
* Beetle readout chip
* 256 channels
* peaking time ~ 25 ns
* S/N ~ 20 (standard and non irradiated detectors)



Pulsed DFB laser λ=1060nm
- gaussian beam spot width ≈ 20 μm
- rise time 2ns
- **total charge ≈ 5-10 MIPs**

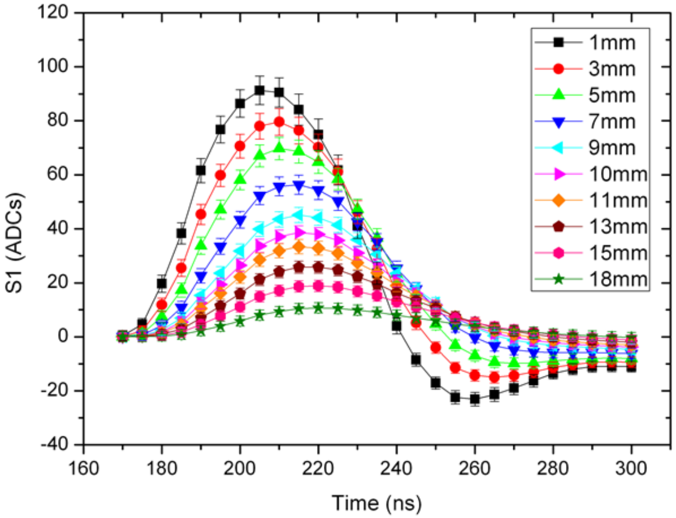


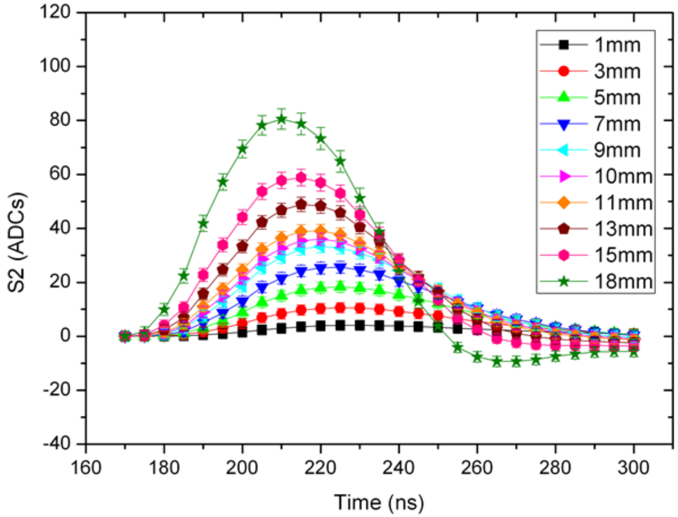


3D axis stage
displacement accuracy = 10um

Laser Data: Pulse propagation

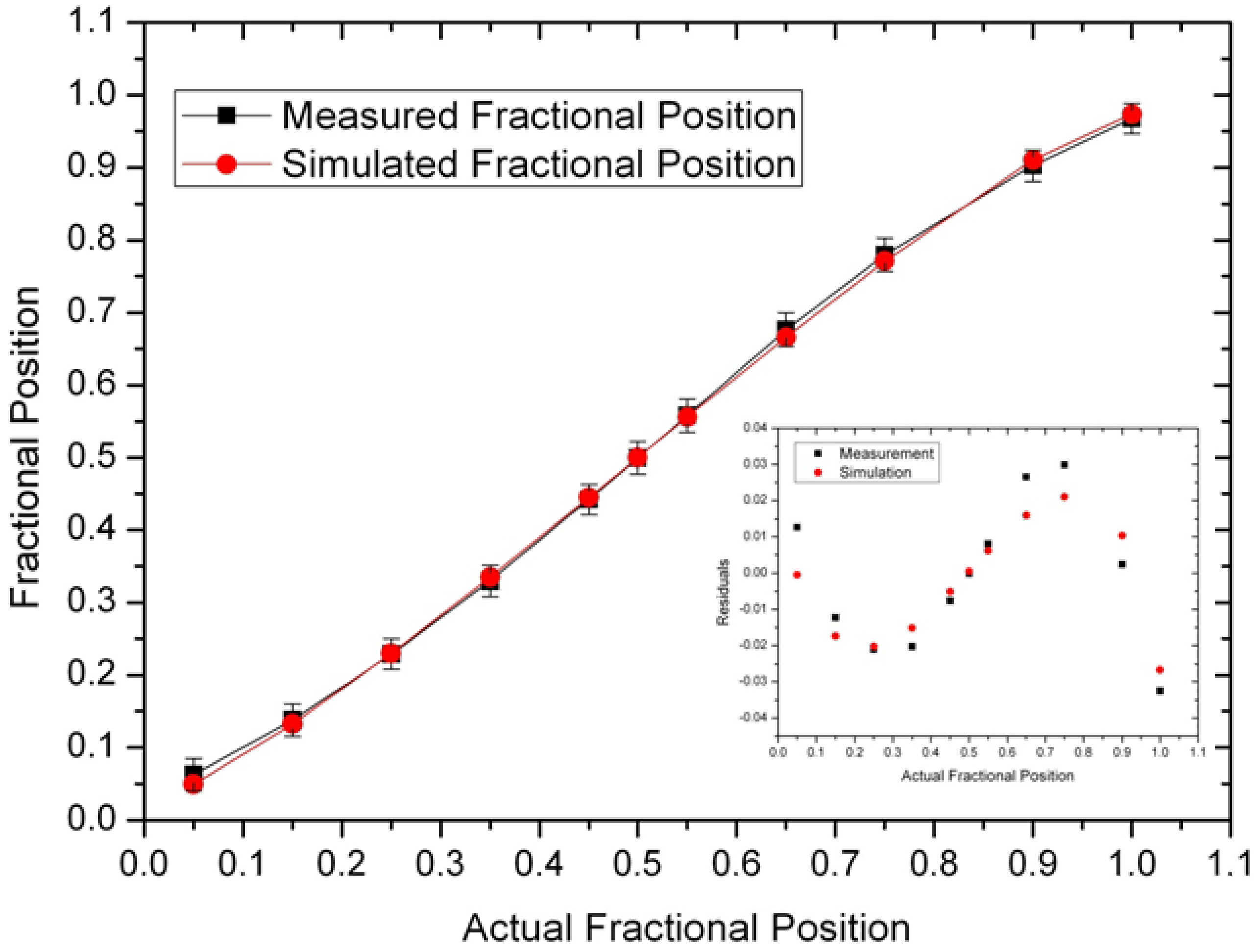
- High resistivity sensor: 12.2 Ω/μm, RC = 450ns
- Laser longitudinal scan & sampling time scan to measure the full pulse shape at each position along the strip.
- Signal out of shaper is delayed & attenuated





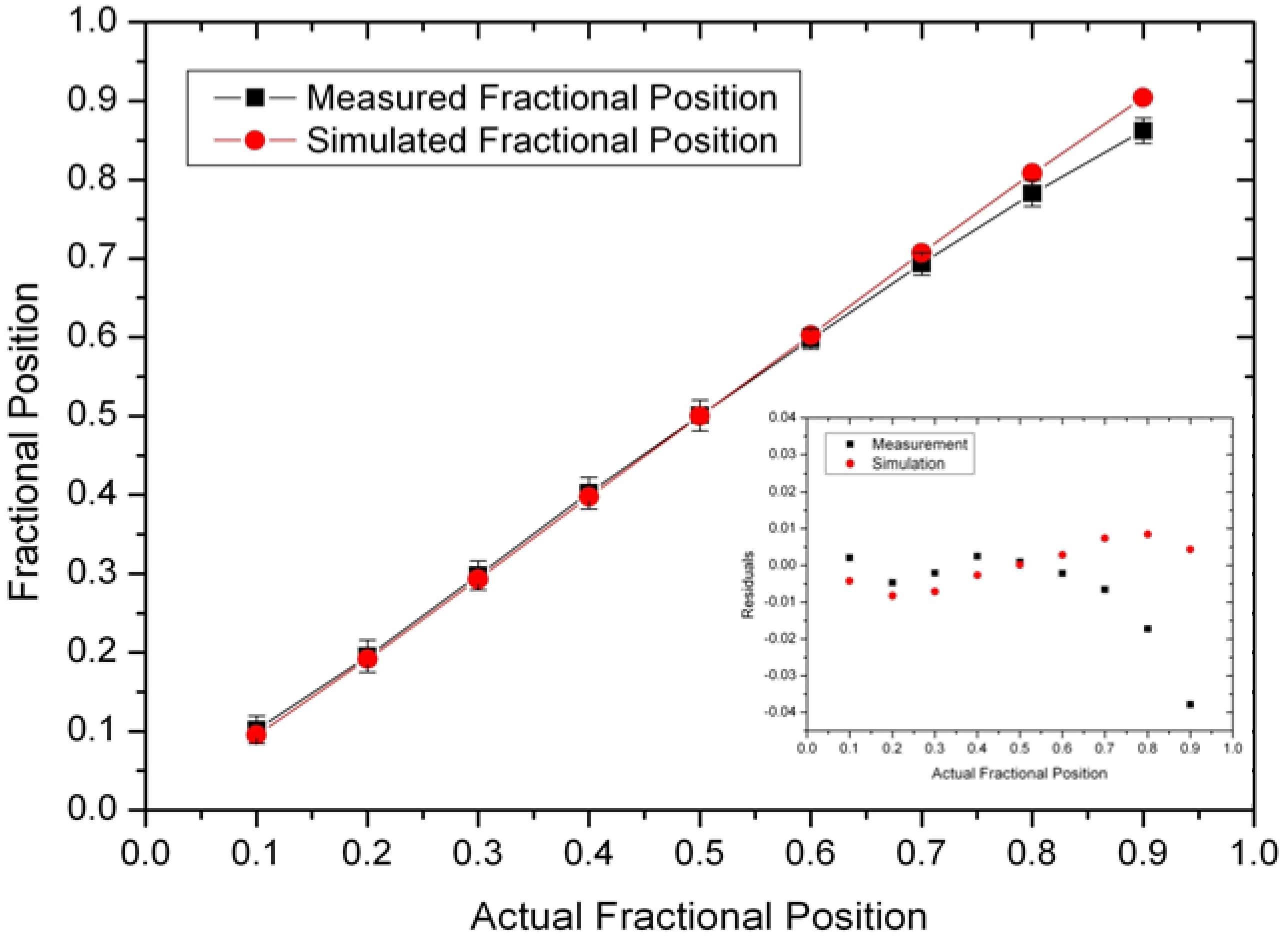
Data vs. Simulation: Fractional position (1)

- High resistivity sensor: 12.2 Ω/µm, RC = 450ns



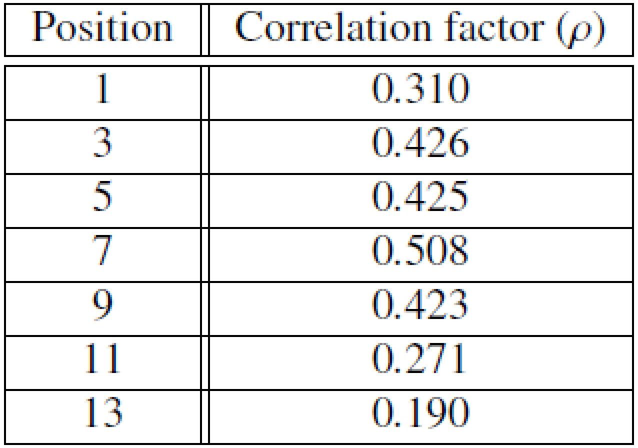
Data vs. Simulation: Fractional position (2)

– Low resistivity prototype: 2.8 Ω/µm, RC = 100ns

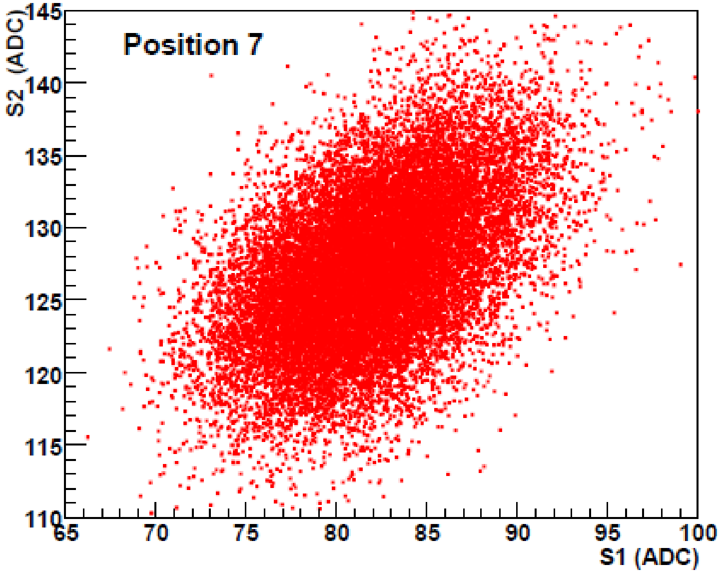


Laser Data: Noise Study

- Errors computed propagating Radeka's analytical expressions.
- A Resistive electrode introduces and anti-correlation between the noise excursions at both end of the strip.
- Laser fluctuation introduces a correlated components in the noise excursions
- The actual noise correlation between the two ends of the strips at each scanning point will depend on which of the two components dominates.

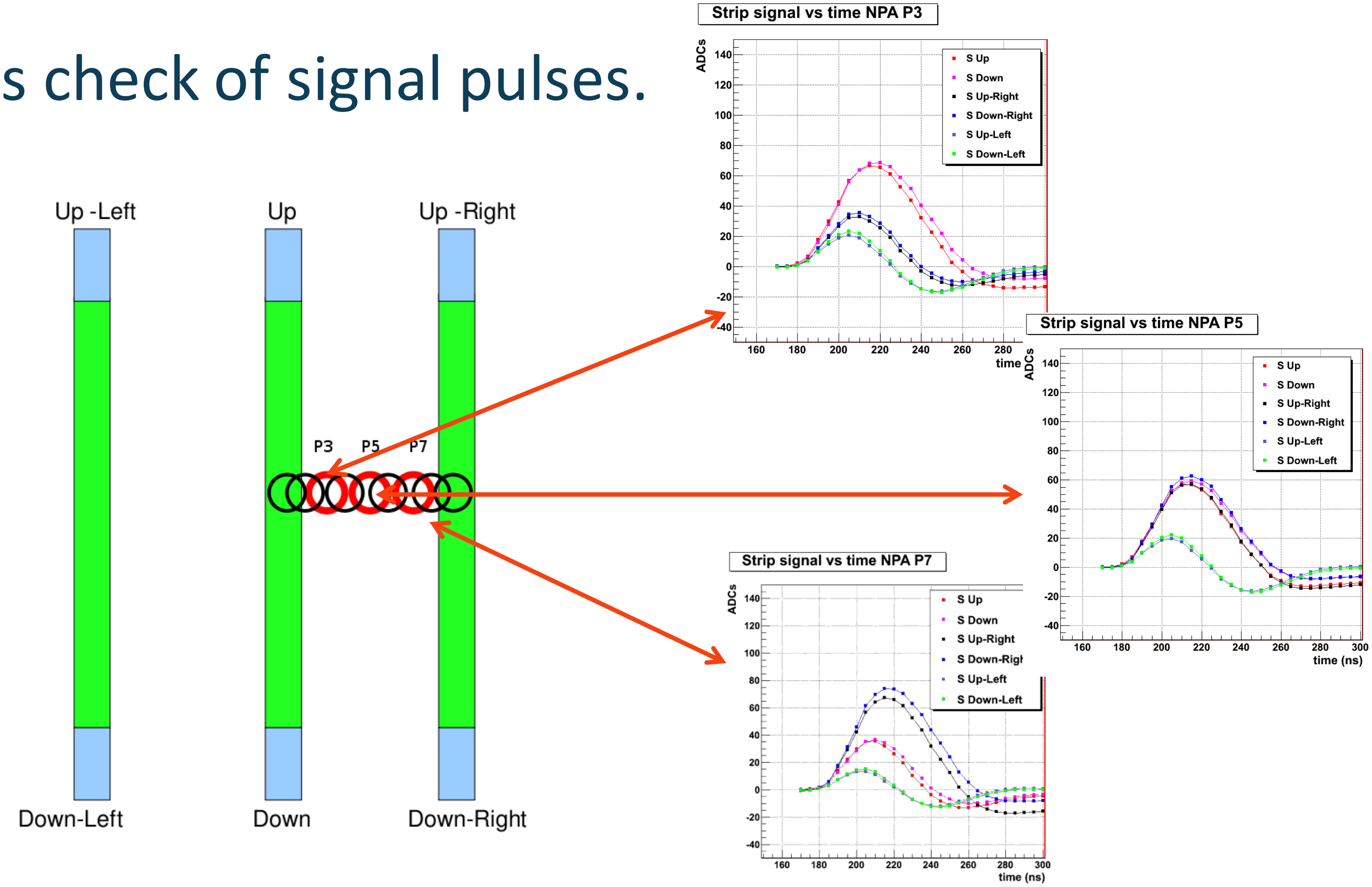


Position	Correlation factor (ρ)
1	0.310
3	0.426
5	0.425
7	0.508
9	0.423
11	0.271
13	0.190



Laser Data: Transversal scan between two strips

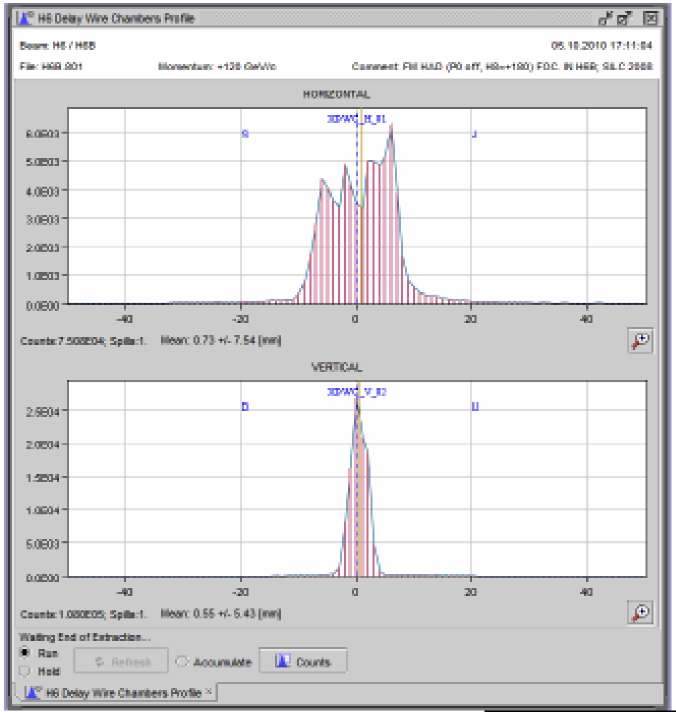
Cross check of signal pulses.



Test beam Data: beam profiles and SNR

- Initial & still preliminary results on last year test beams at SPS 120 GeV pion beams (using both ALIBAVA and APV25 Daq)

BEAM Profile by SPS facilities



H6 Delay Wire Chambers Profile

Beam: H6 / H6B

05.10.2010 17:11:04

File: H6B.001

Momentum: +120 GeV/c

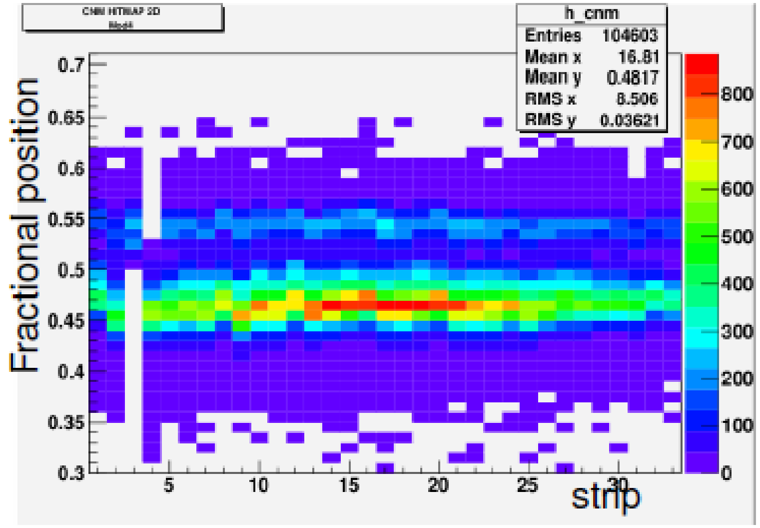
Comment: FM HAD (P0 off, H8=+180) FOC. IN H6B; SILC 2666

Counts:7.508E04; Spills:1. Mean: 0.73 +/- 7.54 [mm]

Counts:1.080E05; Spills:1. Mean: 0.55 +/- 5.43 [mm]

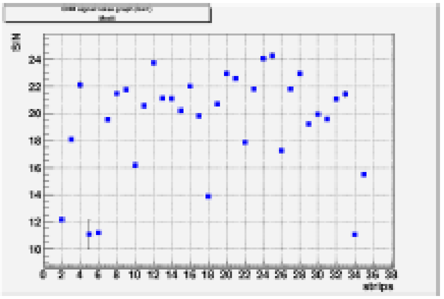
Waiting End of Extraction...

BEAM Profile by a 2D position sensitive sensor



h_cnm	
Entries	104603
Mean x	16.81
Mean y	0.4817
RMS x	8.506
RMS y	0.03621

Averaged S/N= 19.9



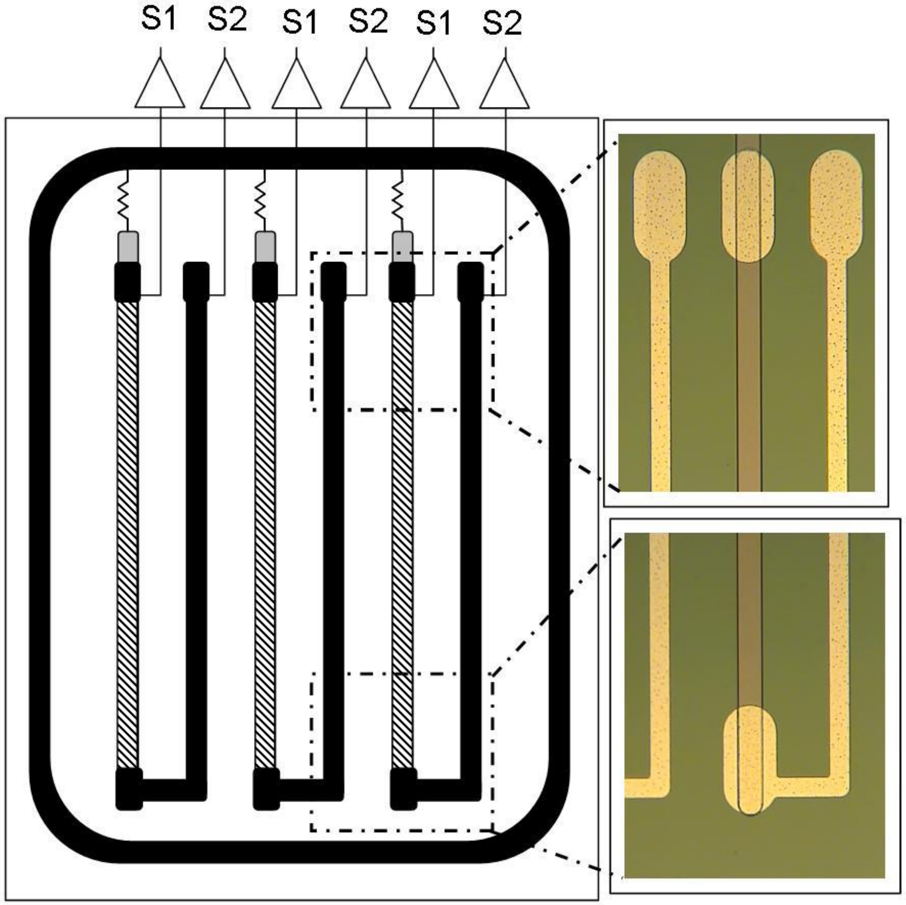
14

Erik Huemer

HEPHY

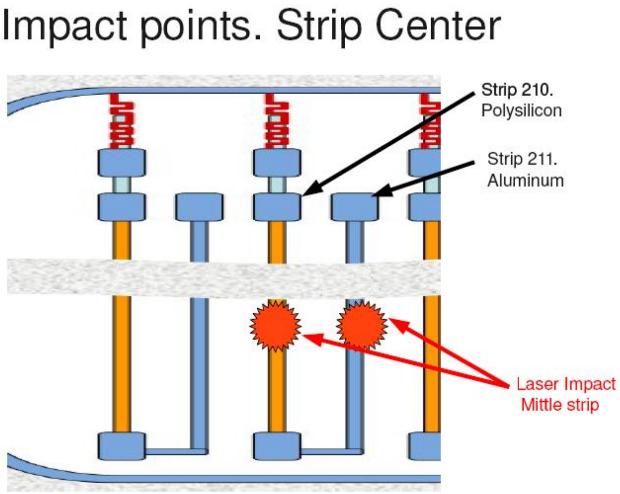
Signal routing integrated on sensor: issue & proposal.

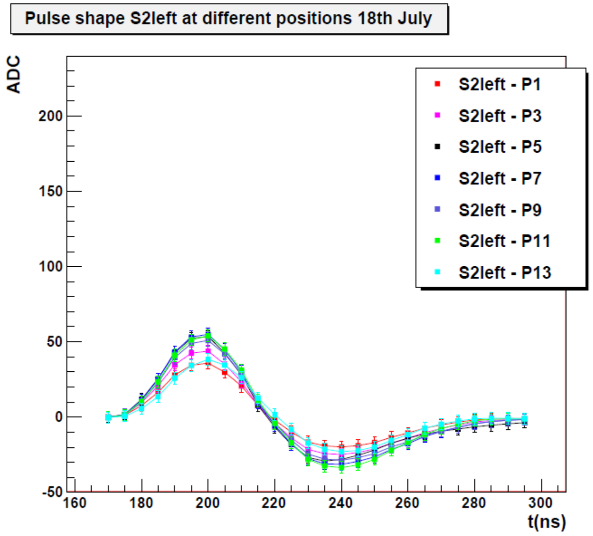
- HEP Tracking use case requires local in-situ cluster finding
- Charge readout at both ends of the strip to be add-up to find hit clusters.
- Cheap and easy technological solution: integrate on the sensor a extra metal via for routing all the signals to one single end.



Prototypes: parasitic couplings

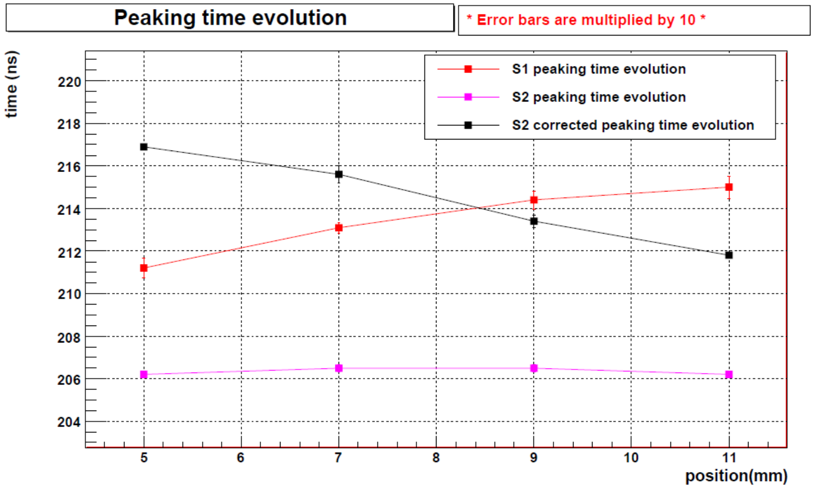
- Induced signal on metallic vias superposed to “direct signal” propagated through polysilicon electrode.
- Induced signal constant delay & shape with respect to the laser pulse while signal pulse delay increases with longer propagation distance along the polysilicon strip.
- Position dependent bias of the signal routed through the via.

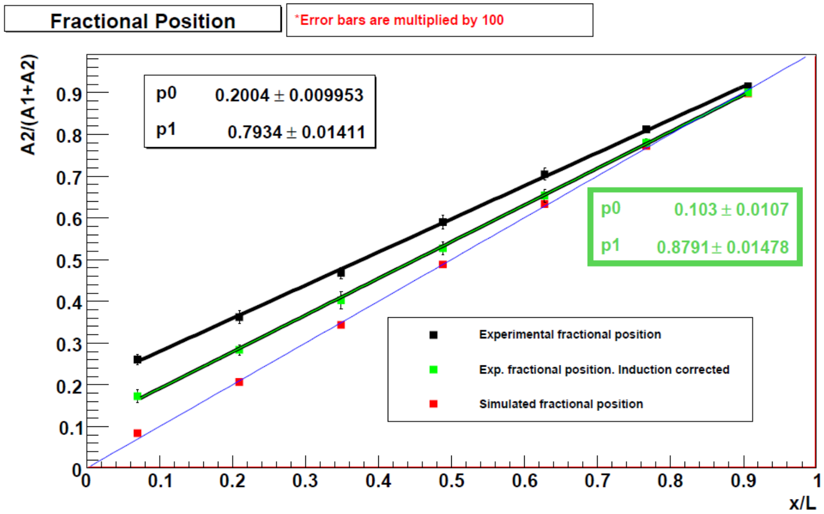

Impact points. Strip Center


Pulse shape S2left at different positions 18th July

Parasitic couplings (2): Offline Correction

- Offline subtraction of induction bias in the right direction but not enough.
- Relatively easy technological solution: increase oxide thickness or go to a double metal process.





Summary and Outlook

- Feasibility of the charge-division method in microstrip sensors has been demonstrated (radiation resistance?)
- Excellent agreement between data and electronic simulation to be used as sensor designing tool.
- Full-fledged baby-sensors tested at SPS pion beam deliver a SNR of around 20.
- A technological implementation for a simplified engineering integration of the sensors with the readout hybrid has been proposed.
- A new prototype in preparation to improve the implementation of the sensors with integrated signal vias.

arXiv:1106.5405v2

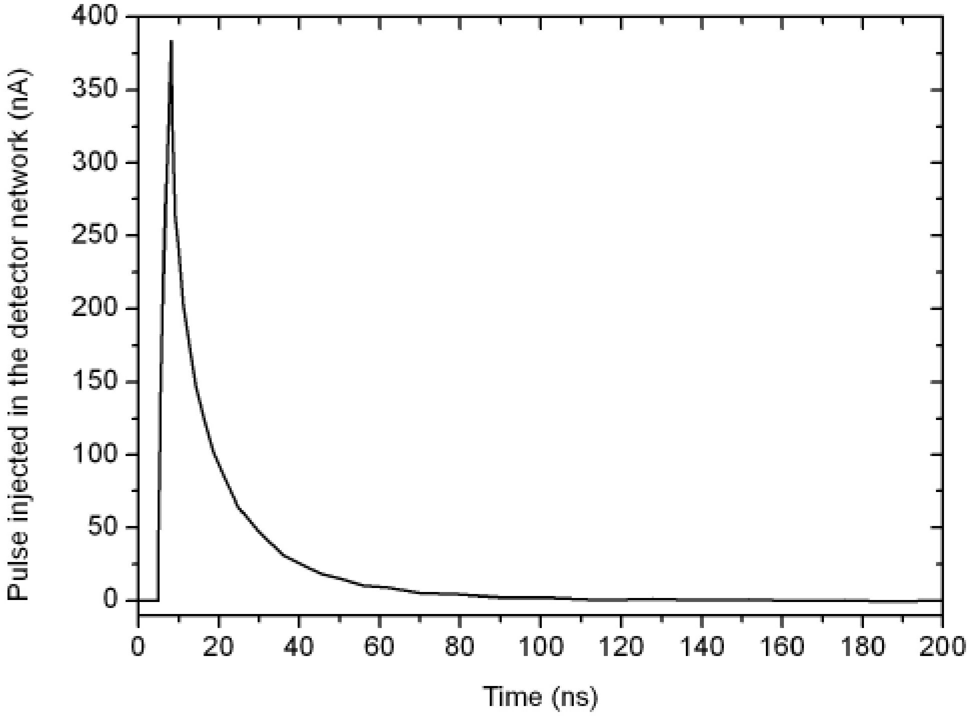
THANK YOU FOR YOU ATTENTION !

And especial thanks to:

- 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

BACK UP

Injected pulses for Spice simulation

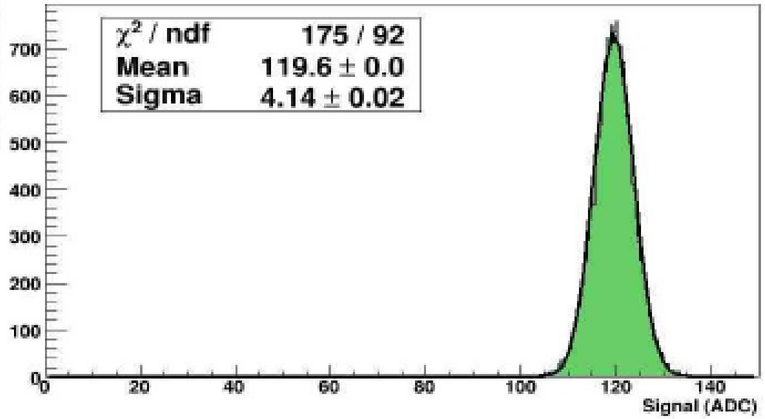


"SPICE Analysis of Signal Propagation in Si Microstrip Detectors" N. Bacchetta et al. , IEEE TRANSACTIONS ON NUCLEAR SCIENCE, VOL. 42, NO. 4, August 1995.

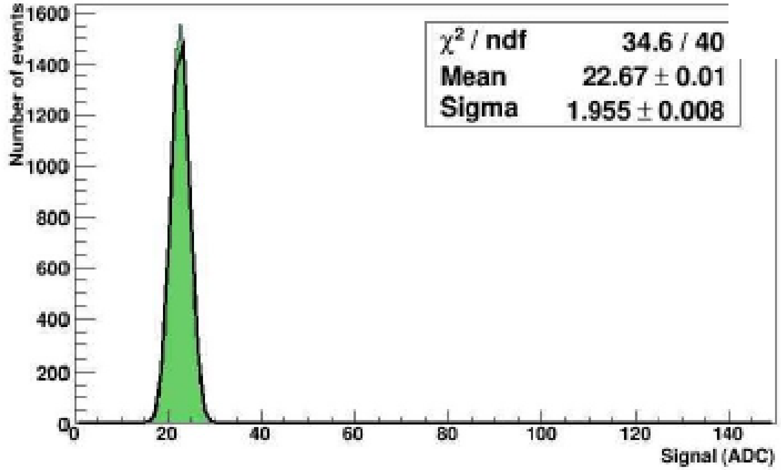
Raw signal distributions

~10000 events

S1,No metal via sensor. Position 5mm



S2, No-metal via sensor. Position 5mm



Test beam Data (2): beam profiles with ALIBAVA

– VERY VERY PRELIMINARY, still work in progress.