A novel two-dimensional microstrip sensor for charge division readout

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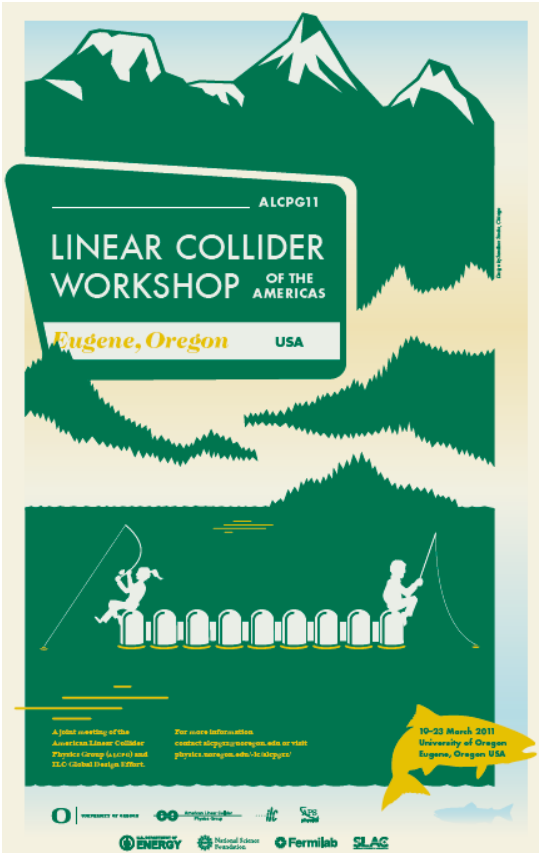
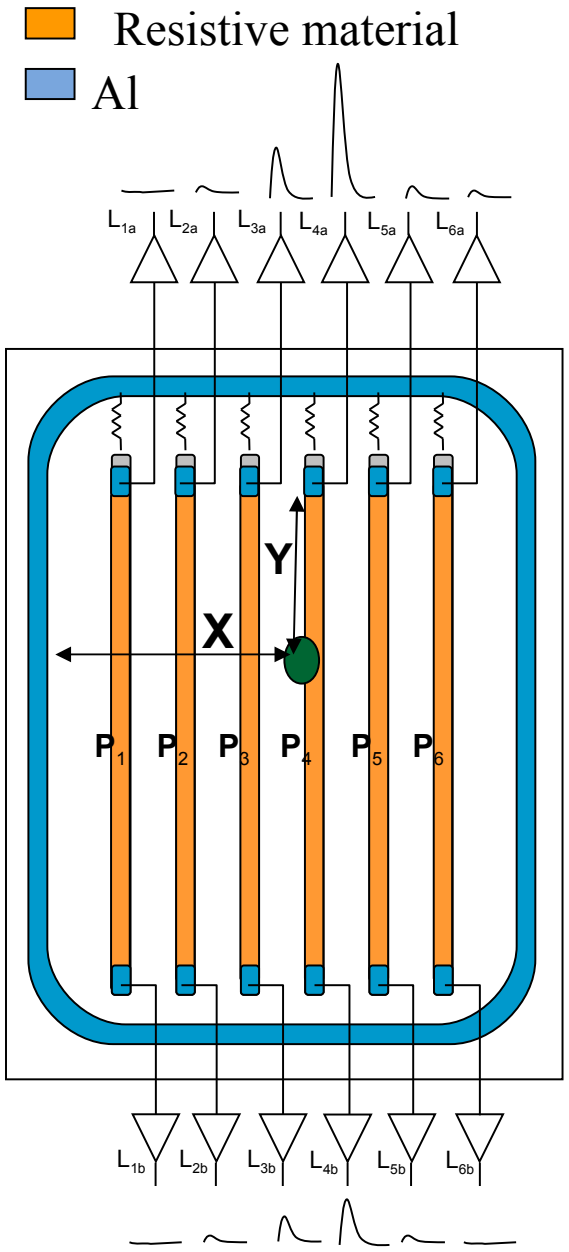


Outline

- Sensor's working principle
- Prototype manufacturing
- Electrical characteristics
- Laser and radioactive source characterization
- Test beam @ SPS
- Conclusions and outlook

Resistive charge division method



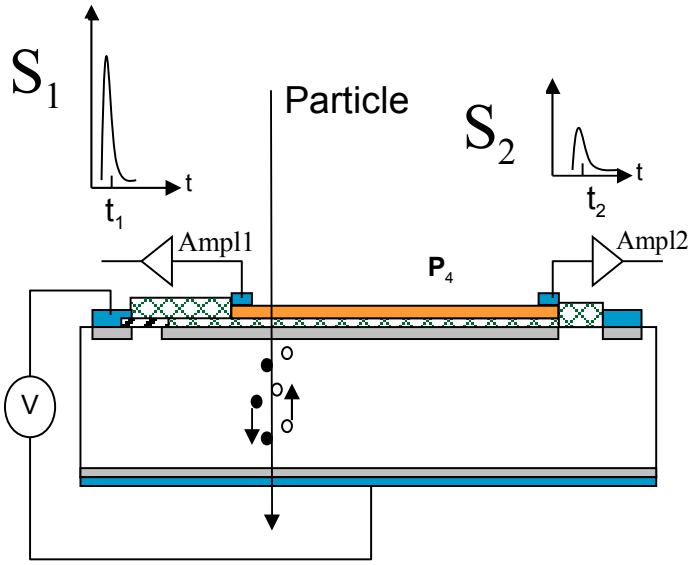
- Charge division used in wire chambers to determine the coordinate along the sensing wire.
- Same concept with conventional microstrips with slightly resistive electrodes

2D readout using 1D sensor

No double side processing ⇒ Cheap

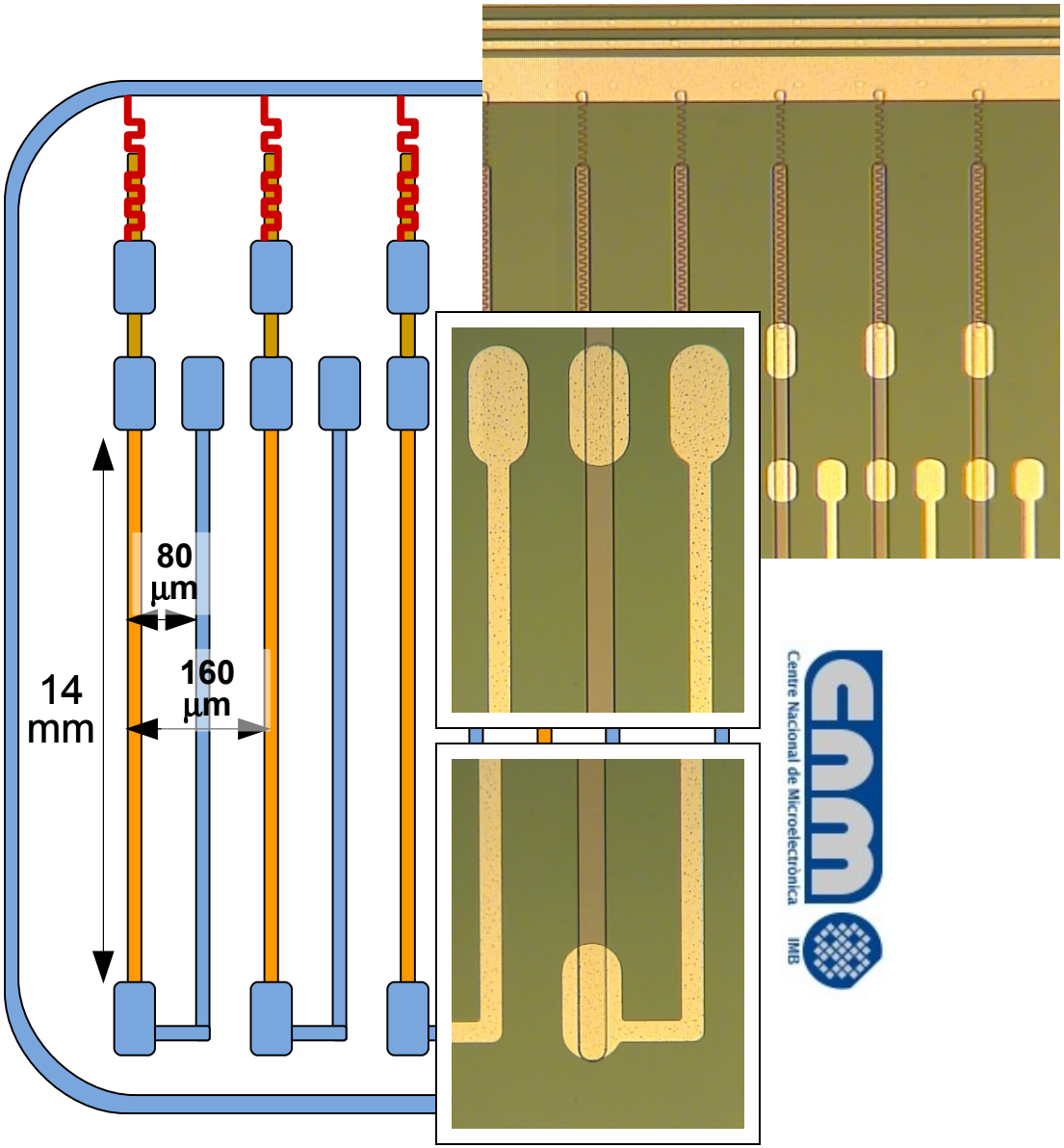
$S_1 = f(Y)$

$S_2 = f(L-Y)$



Concept Demonstrator: poly-Si sensor

Designed and produced at CNM-Barcelona



- Byproduct of 2008's transparent sensor's run
- Standard planar technology p-on-n, 300 µm thick
- Resistive material = highly doped polysilicon.

► Strip length= 14 mm

► Two prototypes with different strip widths: (20,40) µm

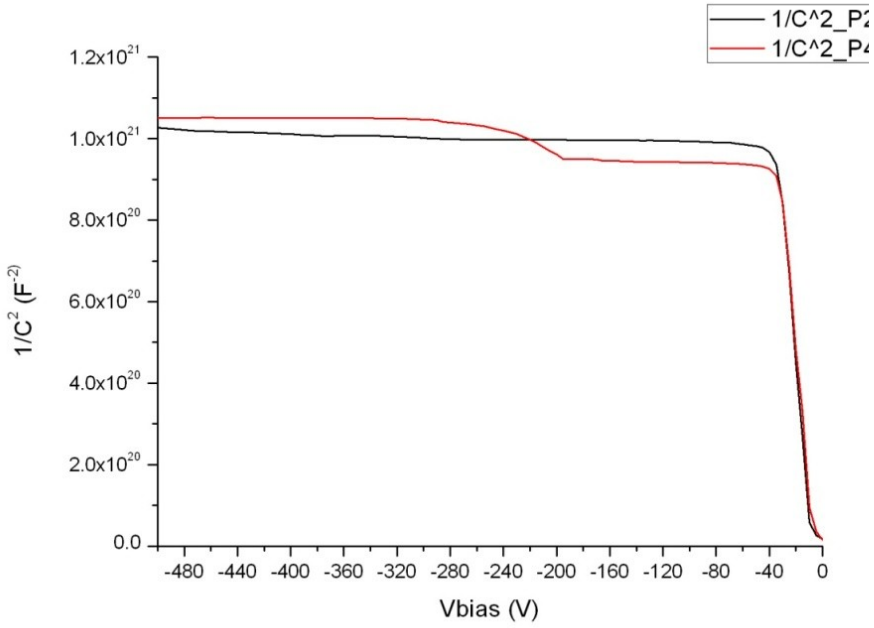
► Metal guides to drive the contact pads at the same edge of the detector (not implanted). Only 1 chip to readout the detector!!!

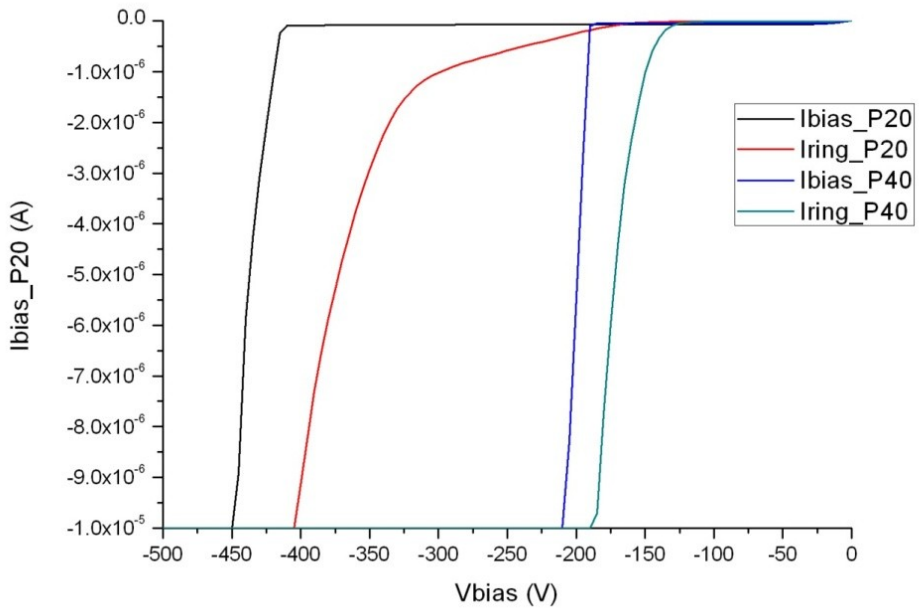
► Implant pitch= 160 µm

► Read out pitch= 80 µm

► Multiple guard rings

Electrical Characterization

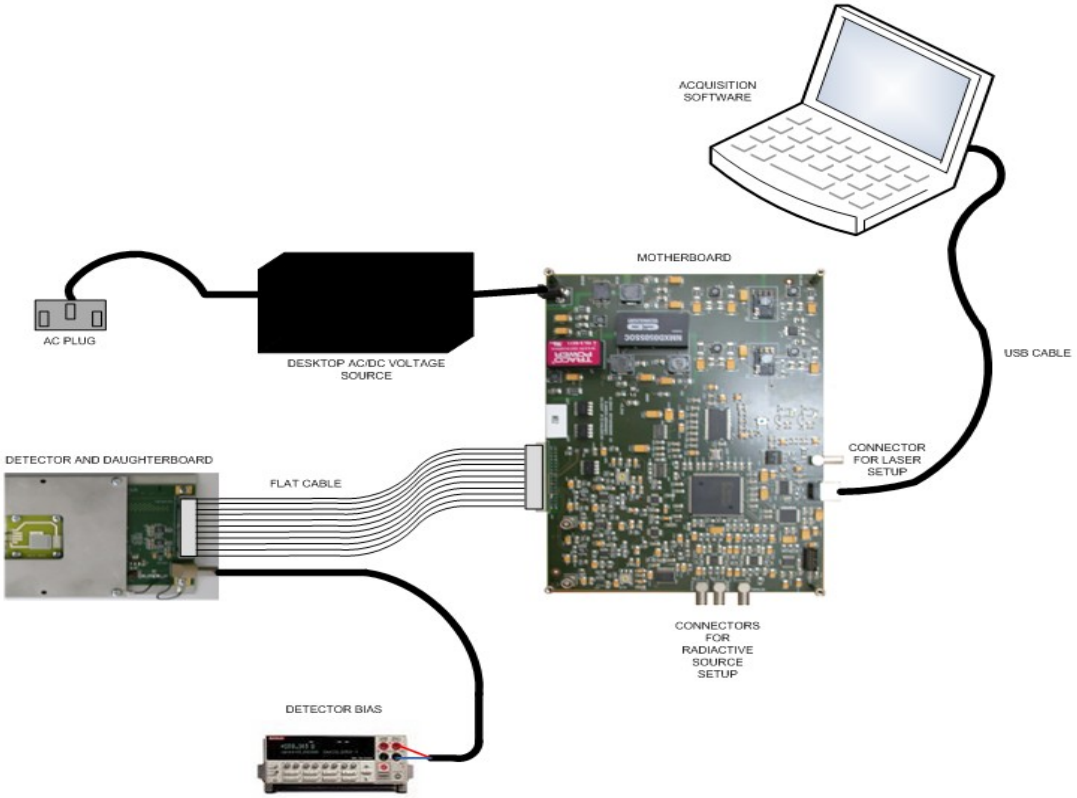


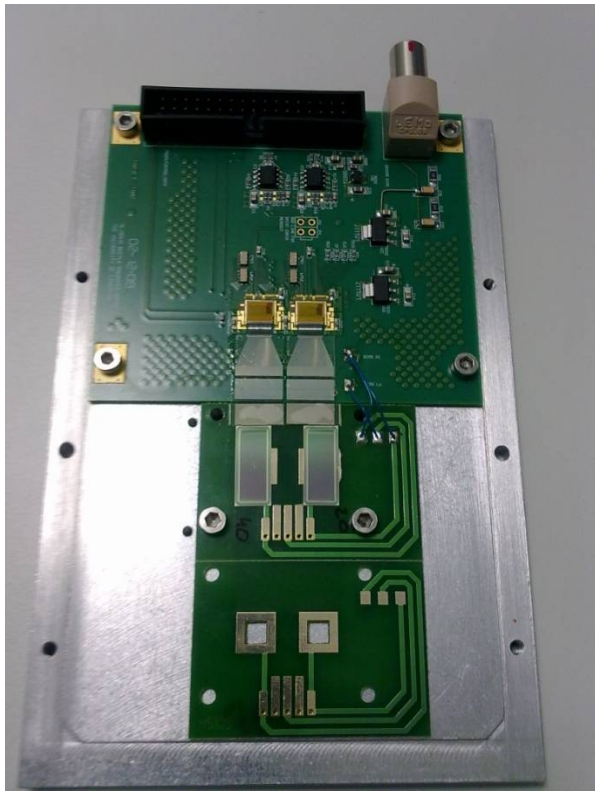


Strip Width	V_{depl}	V_{bd}	R_{bias}	R_{int}	C_{int}	C_{coupl}	$R_{electrode}$/ □	$R_{electrode}$/µm
20µm	40 V	> 400 V	1,31 MΩ	> GΩ	1,32 pF	248 pF	400 Ω/□	20 Ω/µm
40µm	40 V	> 200V	1,37 MΩ	> GΩ	1, 60 pF	487 pF	400 Ω/□	10 Ω/µm

Readout Electronics

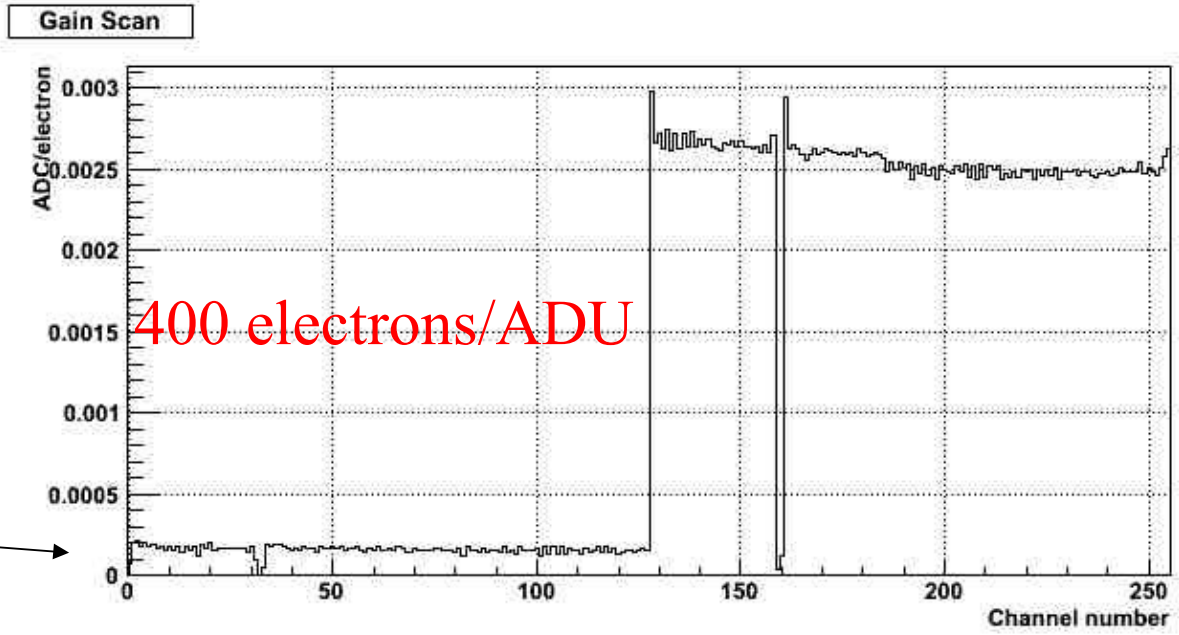
ALIBAVA SYSTEM – Sensors P20 & P40 bonded at IFIC- Valencia

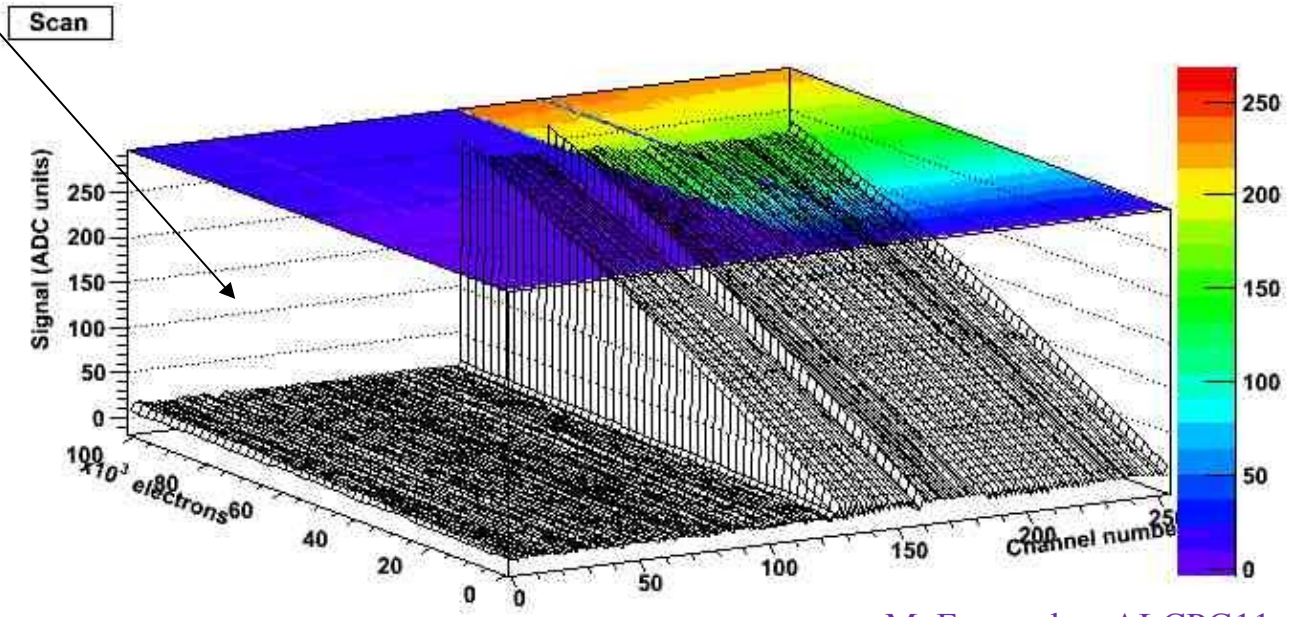




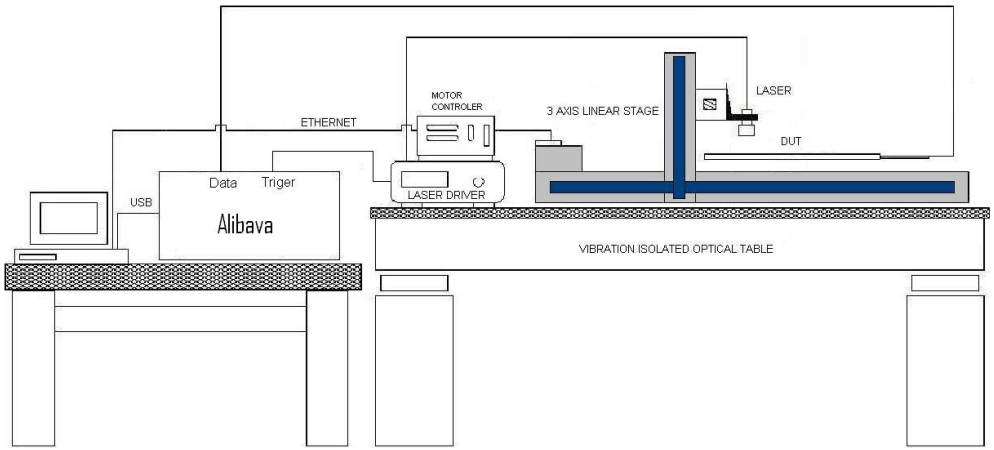
FE chip calibration

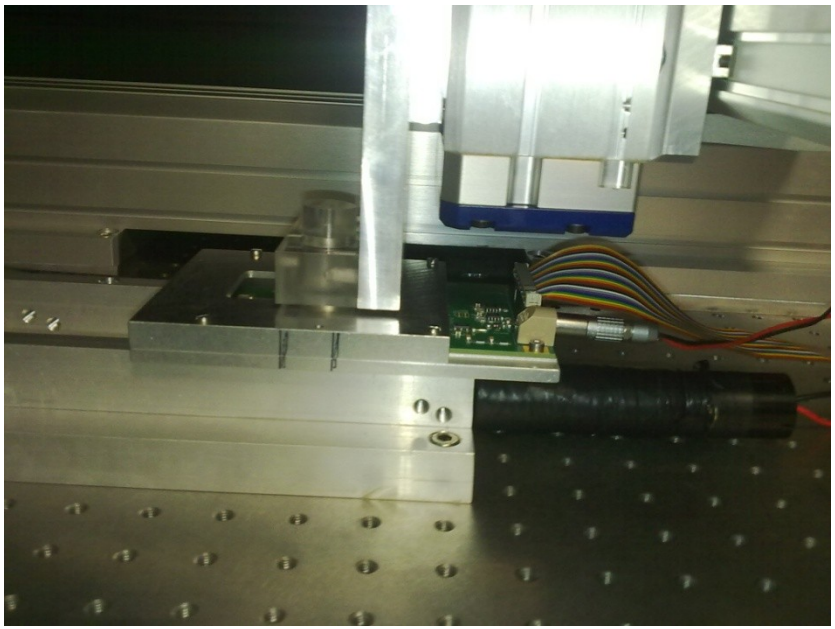
Chip 1 did not perform calibration





Laser characterization: test stand

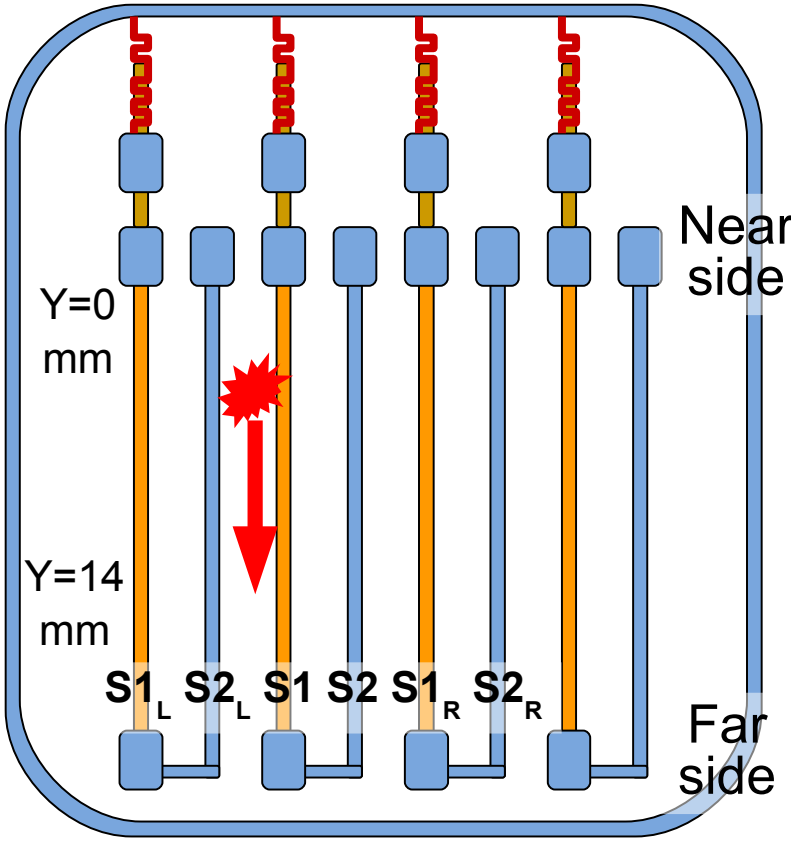


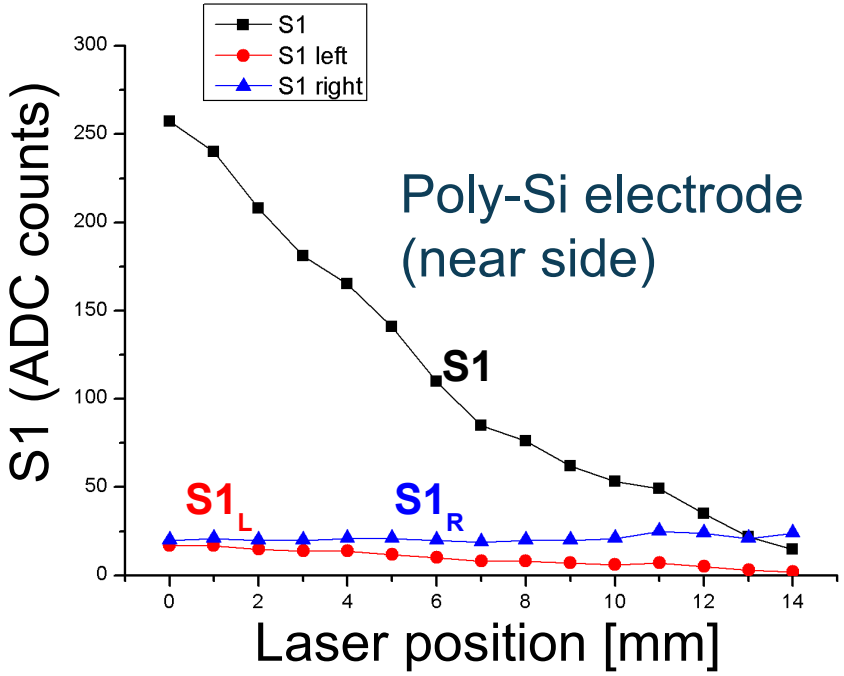


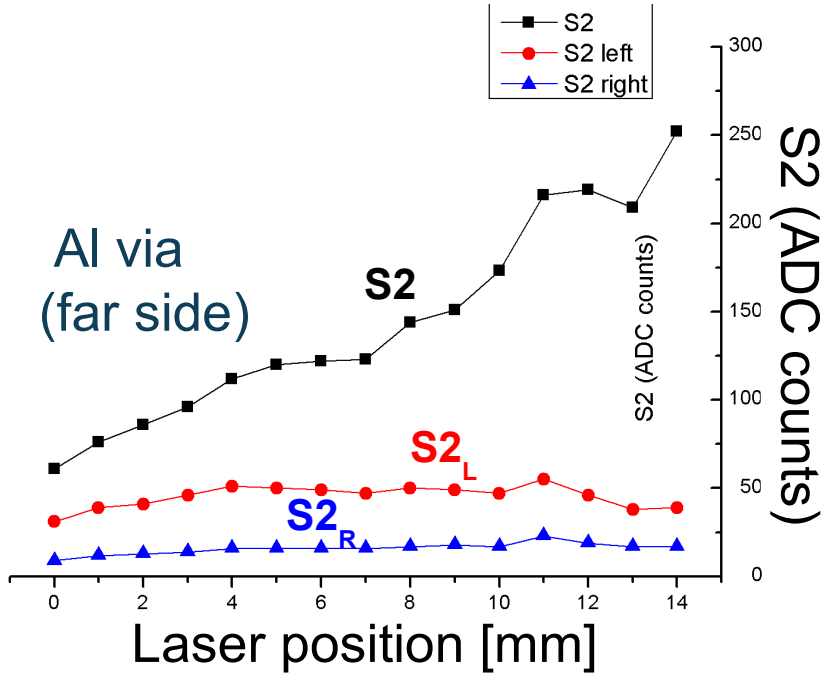
- Laser head on 3D platform (~ 5 um accuracy):
  - Gaussian profile with microspot width 2σ < 10um
  - Wavelength 1080 nm
  - Pulse duration < 1ns
  - Pulse energy ~ 10% gaussian fluctuation.

Longitudinal Laser scan

Laser scan along the polysilicon electrode (S1)



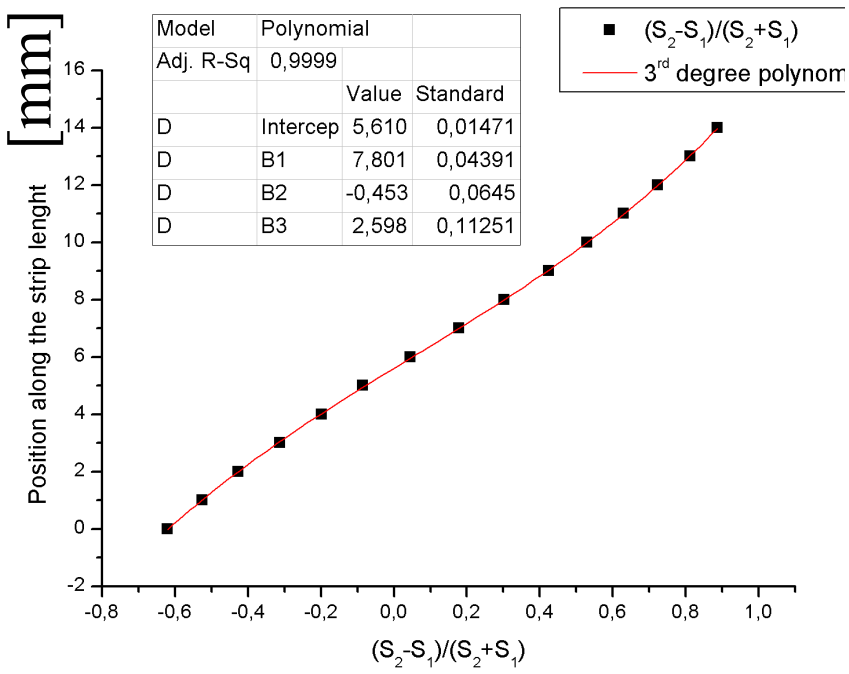




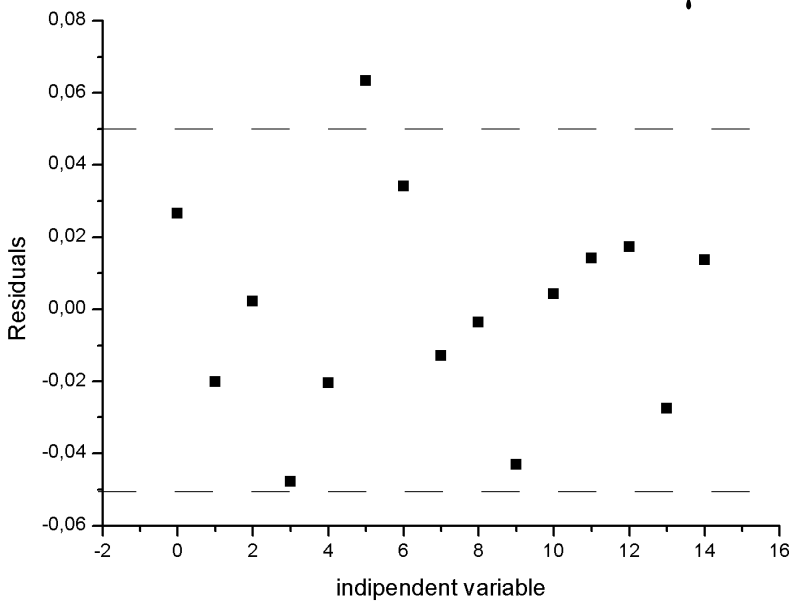
Longitudinal coordinate from Q_{div}

– Naïve computation of position along the strip:

$$S = \frac{Q_{far} - Q_{near}}{Q_{far} + Q_{near}} \qquad -1 \leqslant S \leqslant 1$$



Fit residuals within ±50 μm band



Longitudinal coordinate: Simulation vs. measurement

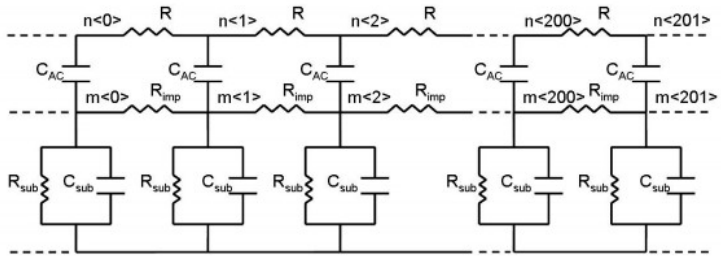
D. Bassignana (CNM-Barcelona)

Spice simulation using electrical parameters (based on [1])

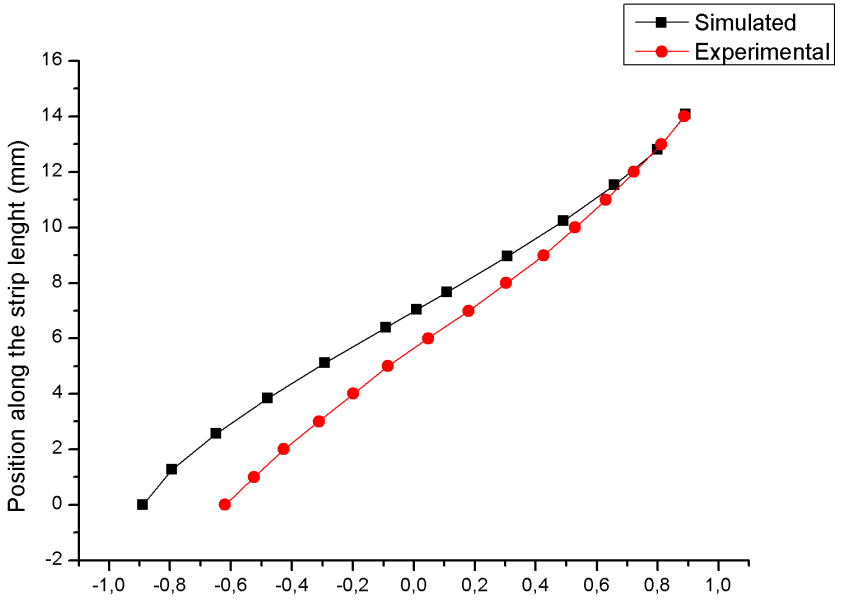
Five strips (R_{str}, C_{cou}, R_{met}).

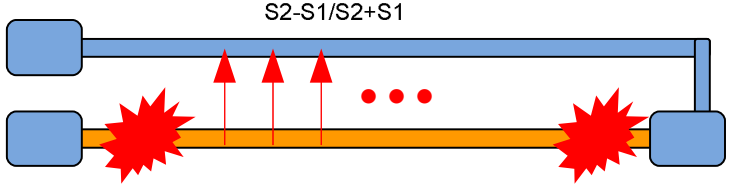
Interstrip circuital elements (C_{int}, R_{int}, C_m, C_p).

Bulk representation (R_{sub}, C_{sub})



- Overall shape reproduced by simulation
- Bias probably introduced by direct coupling of the pulse to the Al via





[1] Bachetta et al., IEEE, Vol.43, 3, 1996

SNR determination

- Laser characterization demonstrated the soundness of the charge division method for strip sensors.
- Increased level of noise but not much (900 ENC)
- In the real world:

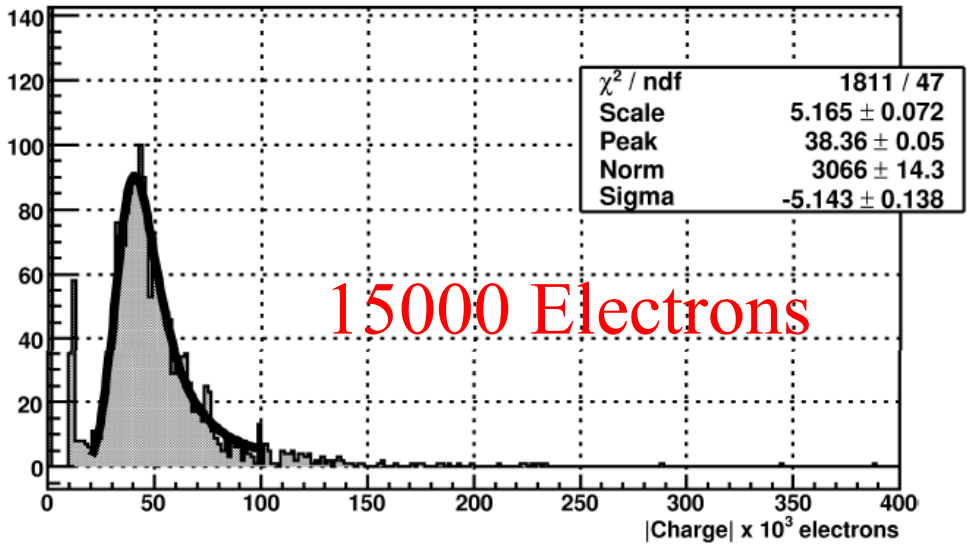
What signal/noise ratio we should expect for a MIP particle ?

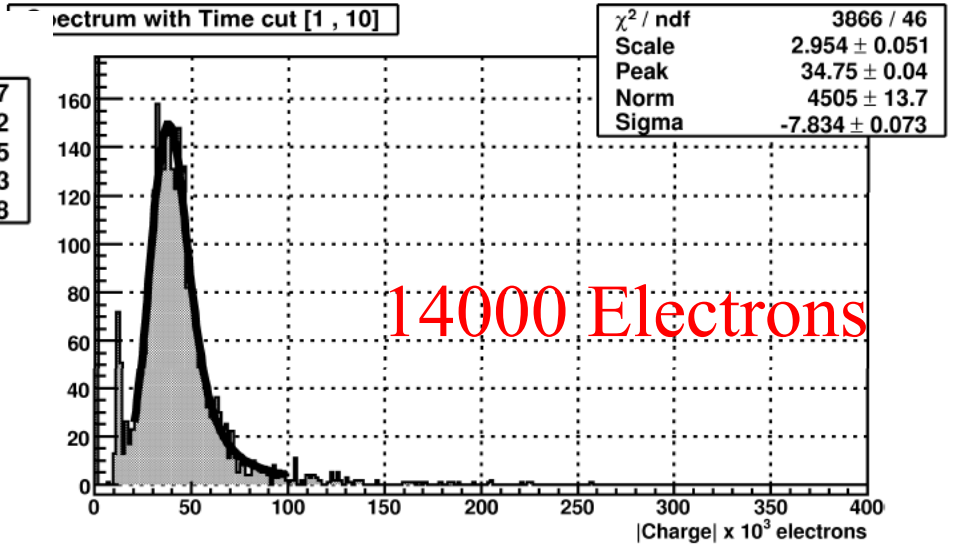
Sr90 beta source

120 GeV Pion test beam at SPS.

Sr90 Beta source

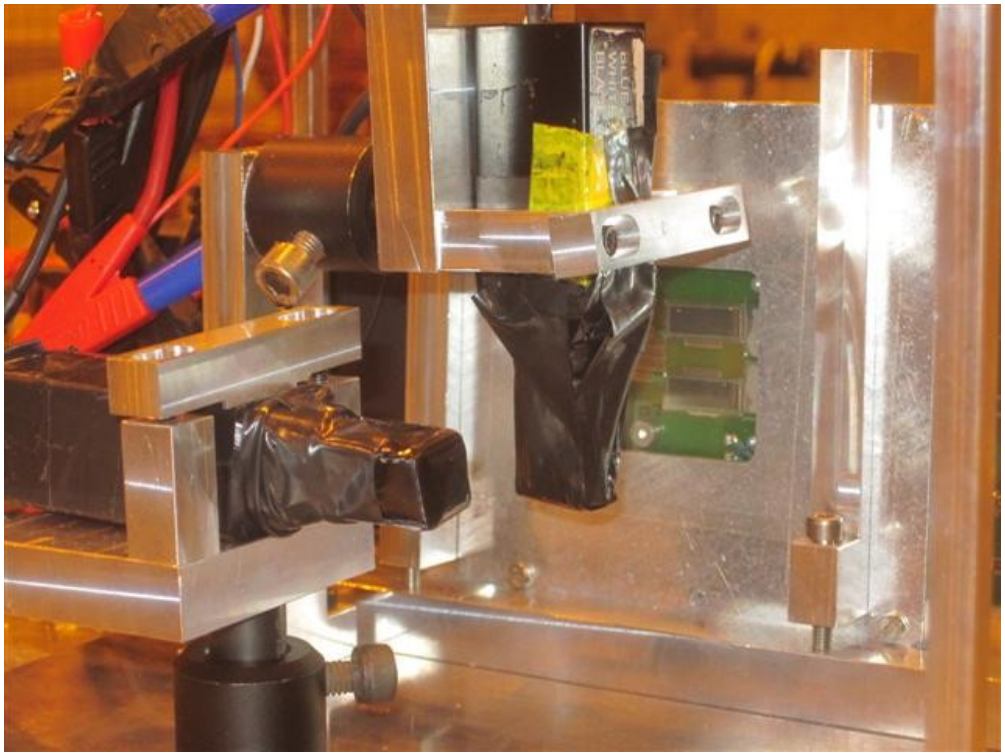
- Collimated (1mm) β-source, at the strip center
- Signal / Noise ~ 15



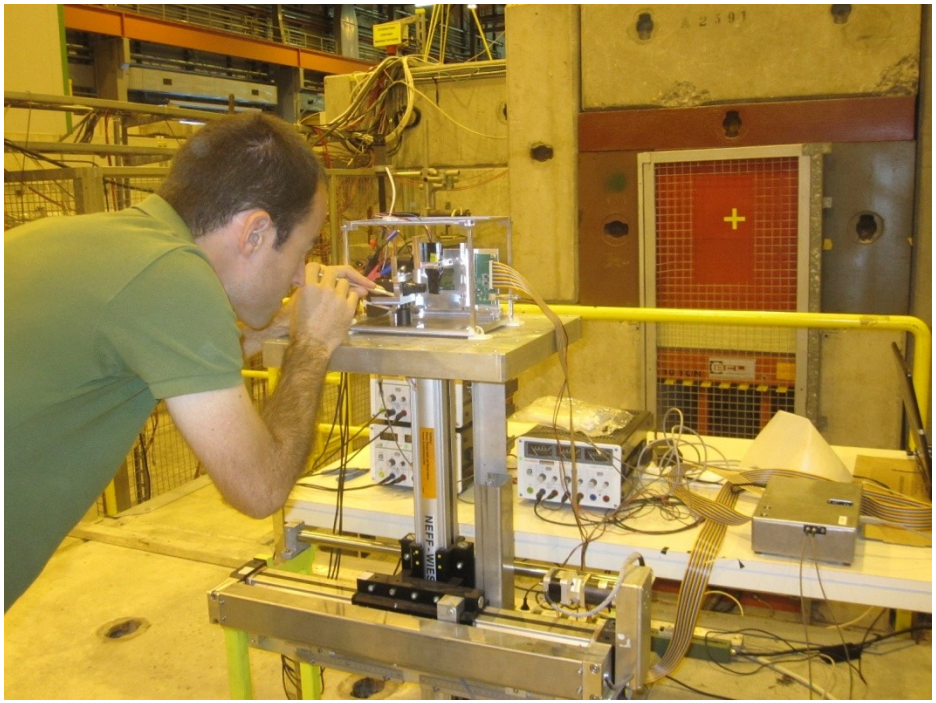


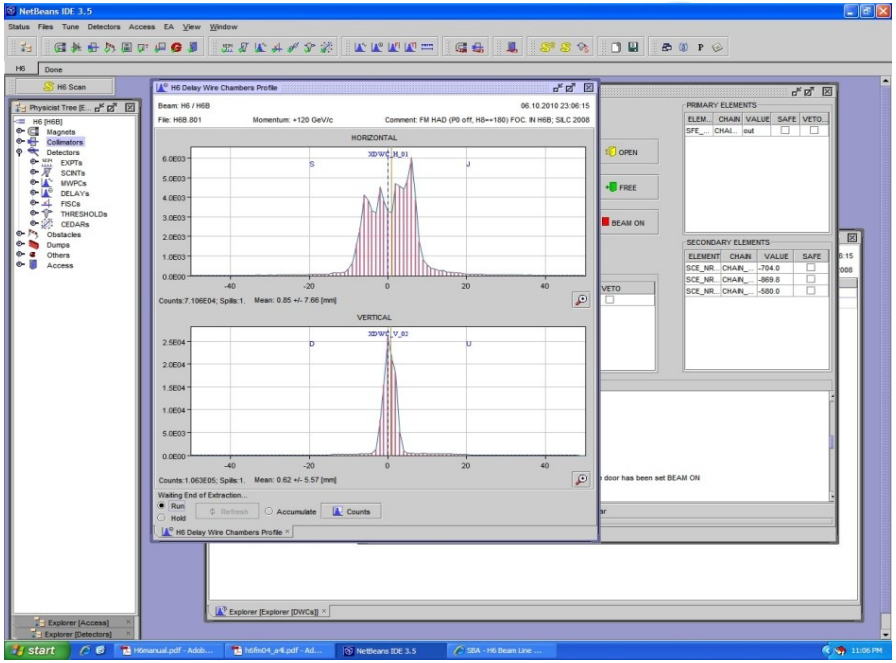
Test Beam @ SPS

- During the first week of October testing at SPS pion beam in parasitic mode:
  - Standalone Testing (ALIBAVA daq) around 800Kevt.
  - Inside the EUDET mimosa telescope (APV25 daq)



Test Beam @ SPS (2)

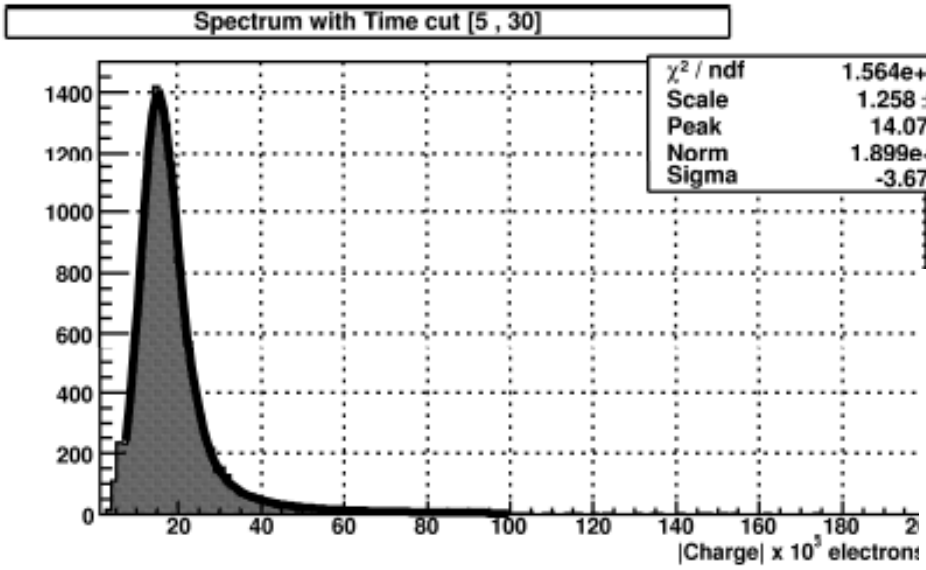


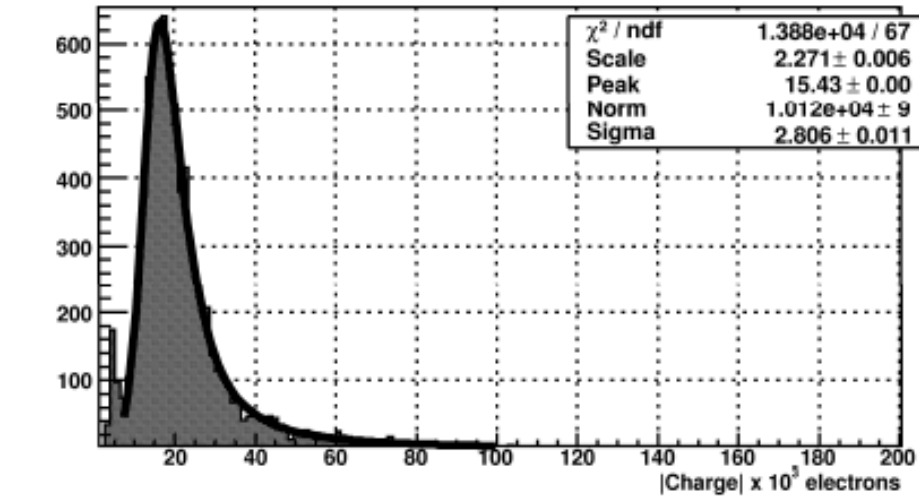


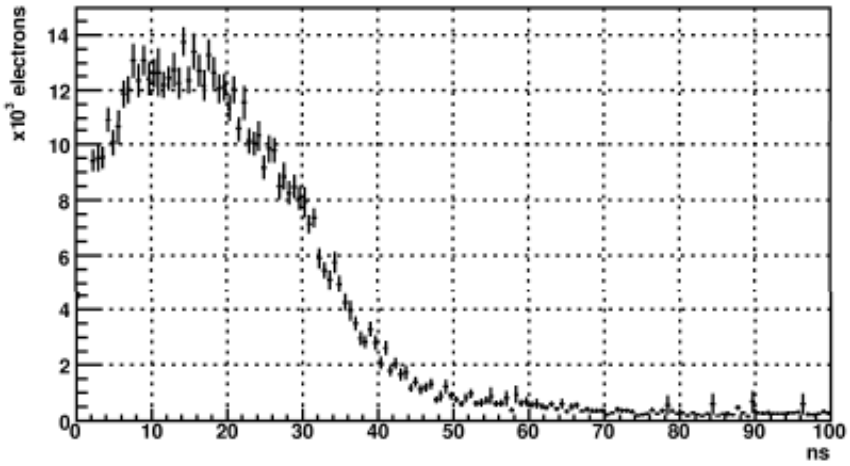
- —SPS beam very stigmatic along the longitudinal (strip) direction.
- —Last run with ALIBAVA as DUT inside EUDET telescope (BUT TLU too long trigger delay)

Test Beam @ SPS (3)

Signal Spectrum & pulse shapes





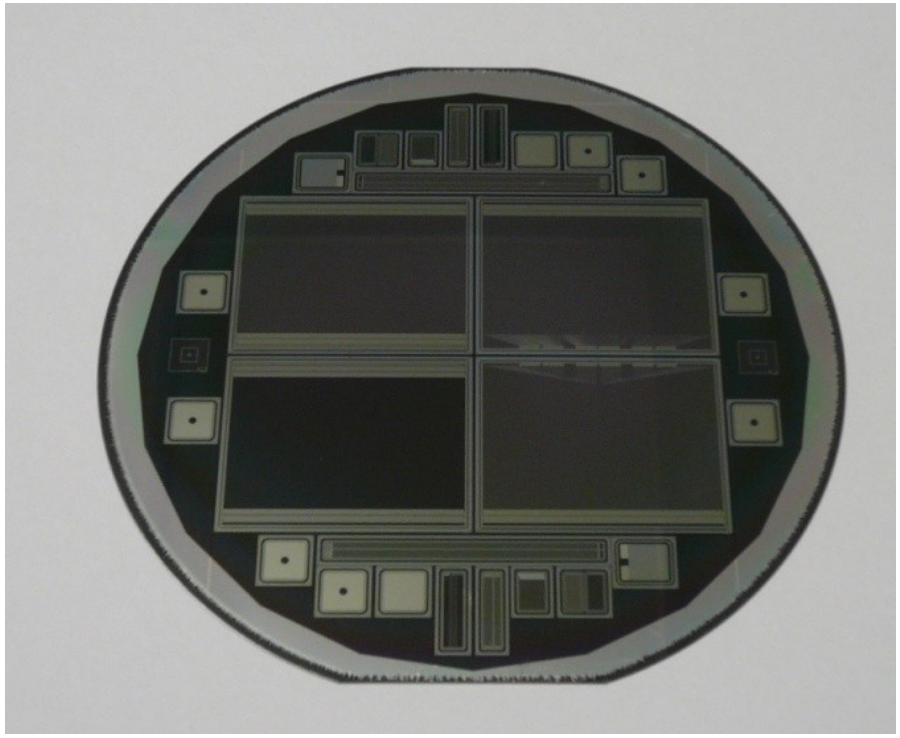


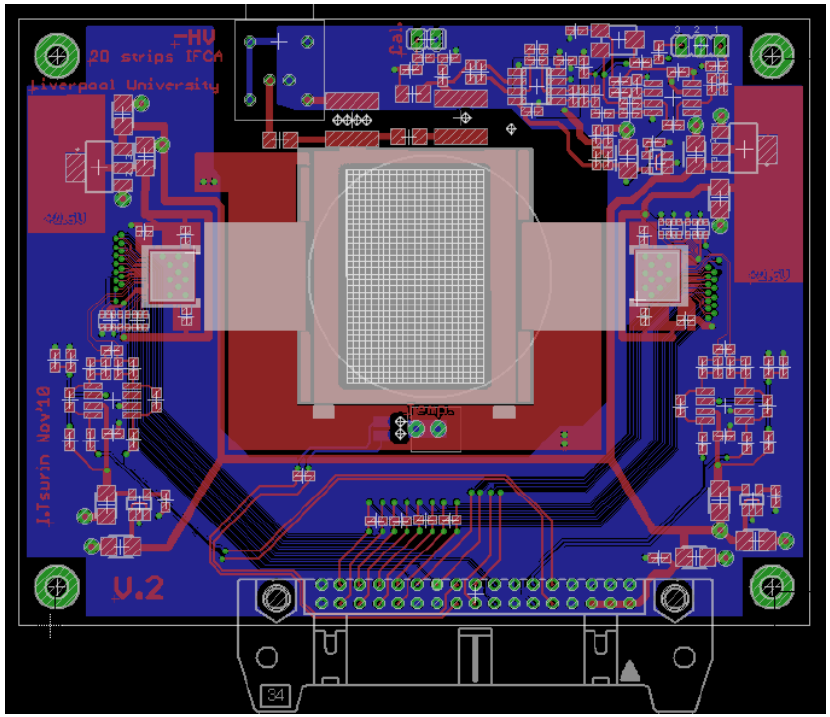
Short term plans

- Almost all the data from the test beam yet to be analyzed : ALIBAVA & APV25 (Including EUDET telescope tracking).
- New 2D strip sensor of larger dimensions (~3 cm) already produced at CNM.
- Designed with contacts at both strip ends to be read out by two independent FE chips.

A bigger demonstrator

- 6 new wafers. 1 reference sensor, 1 poly sensor, 2 DML integrated PA sensors (per wafer)
- Reduced polysilicon resistivity (366 and 84 Ohm/□)
- Modified ALIBAVA daughter board for 2 sides read out



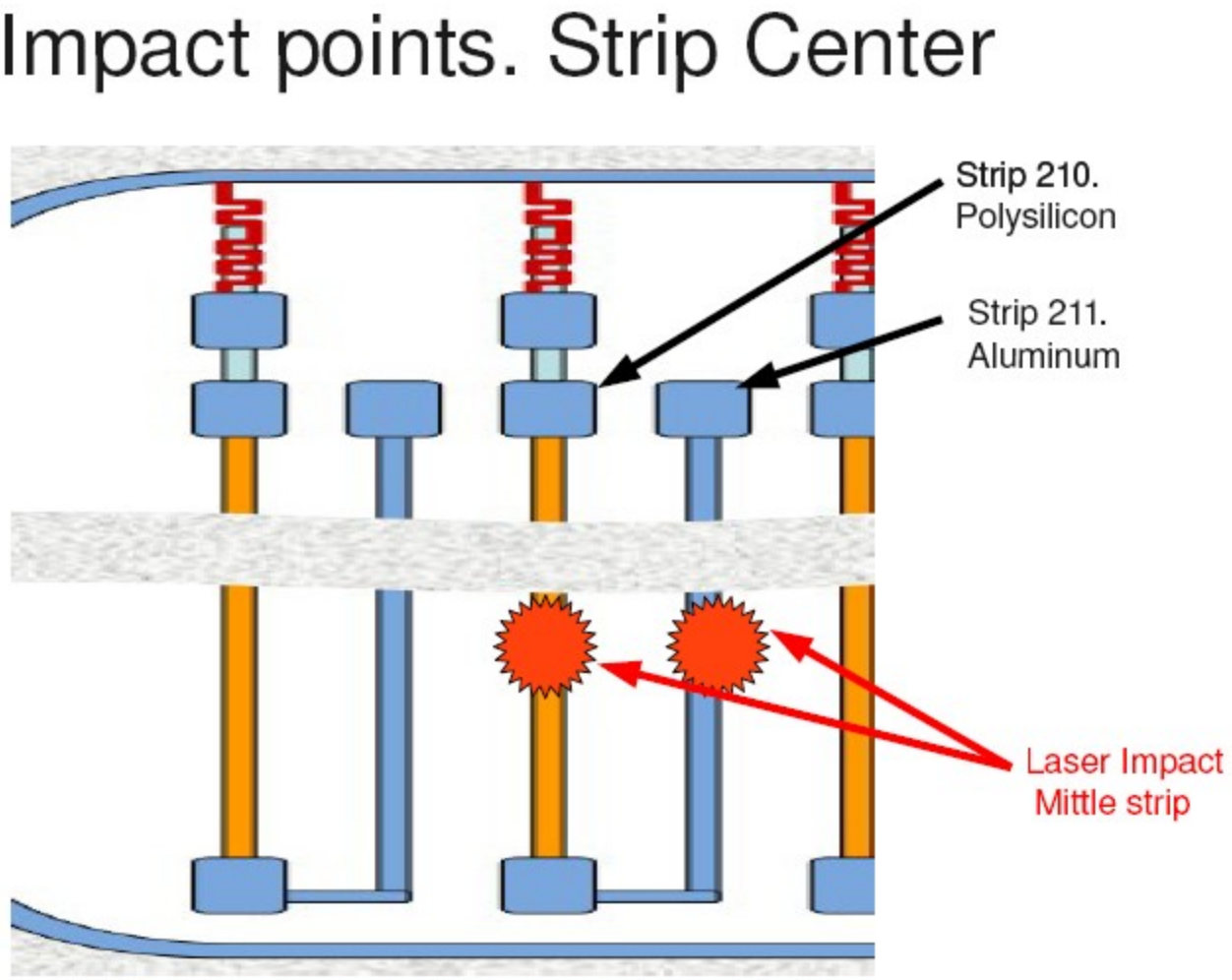


Conclusions

- We have demonstrated the feasibility of the charge division method in microstrip sensors to determine the coordinate along the strip.
- Resolution in the determination of the strip coordinate about few tens of micron.
- We have used the standard (cheap) technology to produce this genuine 2D single sided strip detector.
- Possible application targets:
  - Future detector outer trackers (trigger capable modules)
  - Ion tracking systems.
  - Neutron imaging (+ conversion element).
  - Space applications.
- New few cm long demonstrator under preparation
- International patent pending: PCT/ES2011/070088

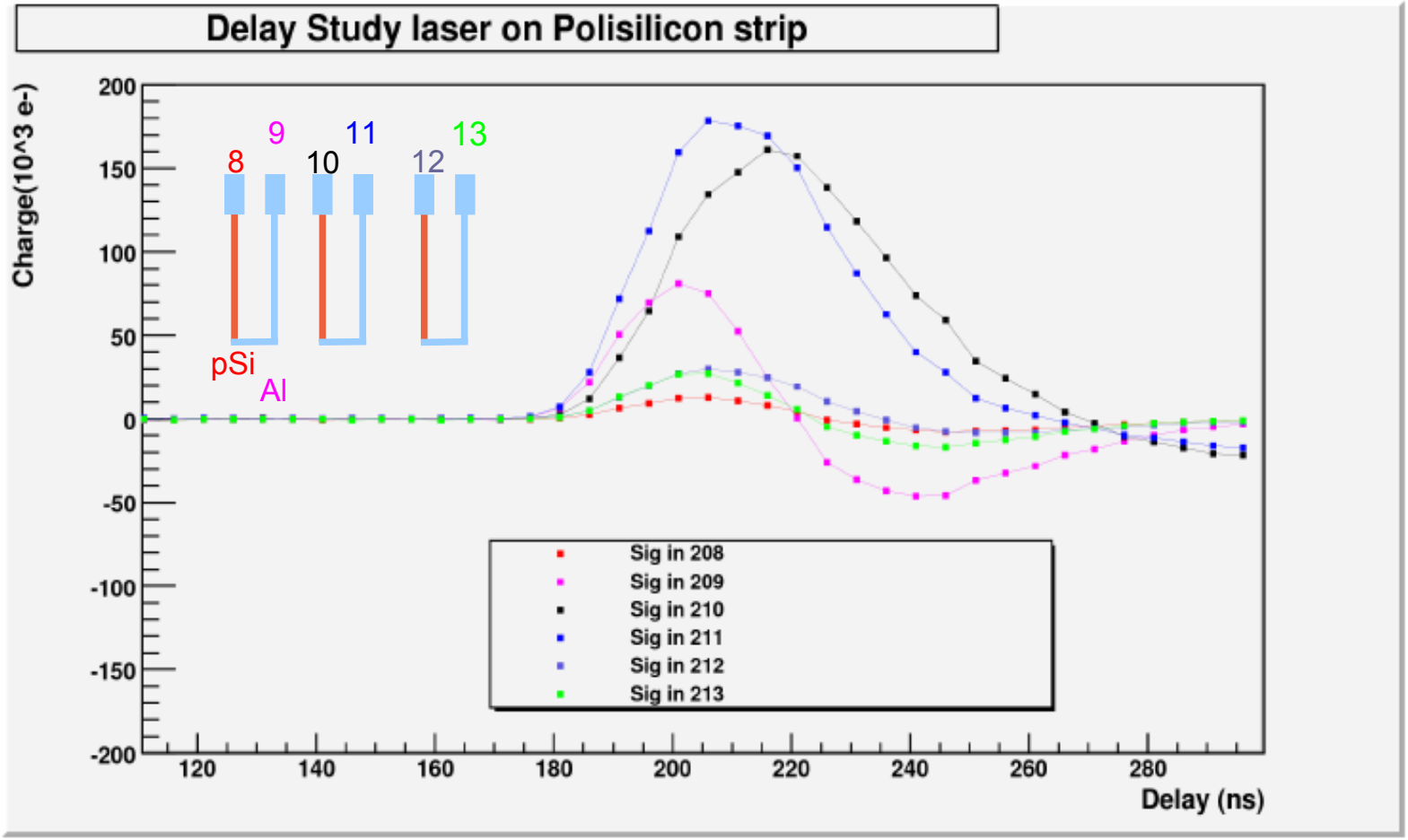
BACK-UP

Signal directly induced in the metal via from sensor far side (1)



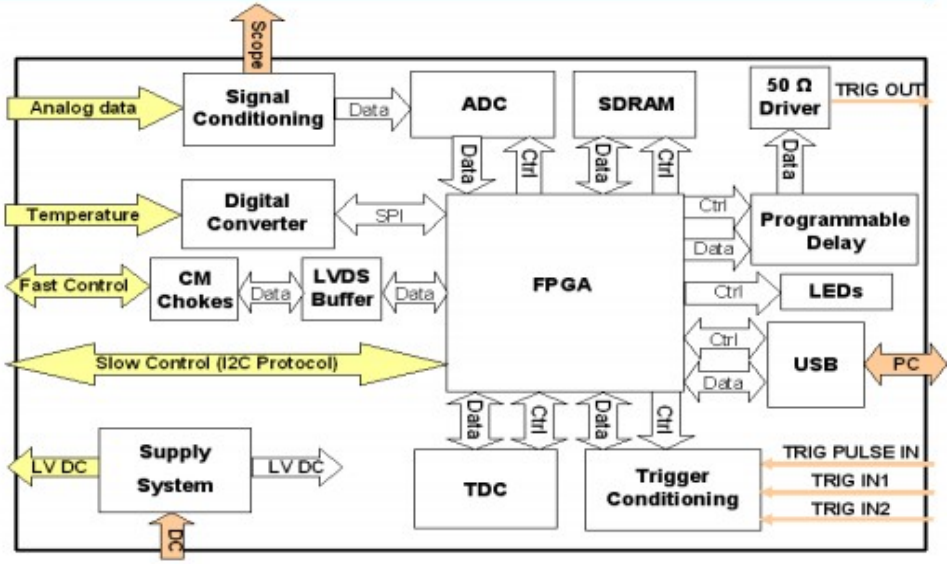
Signal directly induced in the metal via from sensor far side (2)

Polysilicon strip



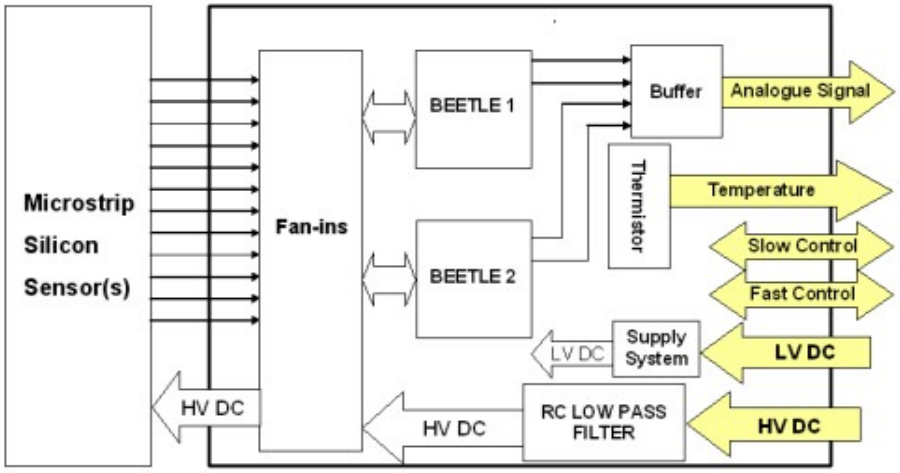
Mother board

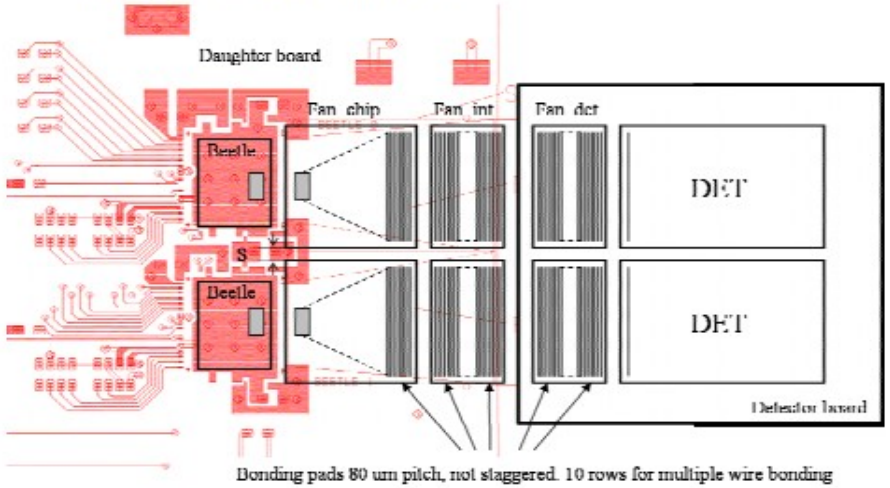
- Analogue signal conditioning:
  - Amplification and filtering: minimization of noise.
  - Buffering: two copies of the Beetle multiplexed analogue outputs for spying with a scope
- ADC: digitalization at 40 MSps of the Beelte analogue multiplexed signals.
- Digital converter: temperature analogue signal digitalization.
- Generation of control signals for Beetle chips by FPGA: DAQ sequences and configuration.
- Trigger conditioning and TDC for obtaining a time stamp of each trigger with radioactive source setup.
- Generation of a trigger output with programmable delay for the laser source.
- USB controller.
- SDRAM (512 Mb) for temporal storage of acquired data.
- FPGA (40 MHz): custom logic and embedded µP.
  - Control of the hardware.
  - Synchronization of DAQ sequences.
  - Generation of Beetle control signals.
  - Communication with the software.
- Supply system: from AC/DC desktop power supply (5V).
  - Generation of MB and DB supply levels.



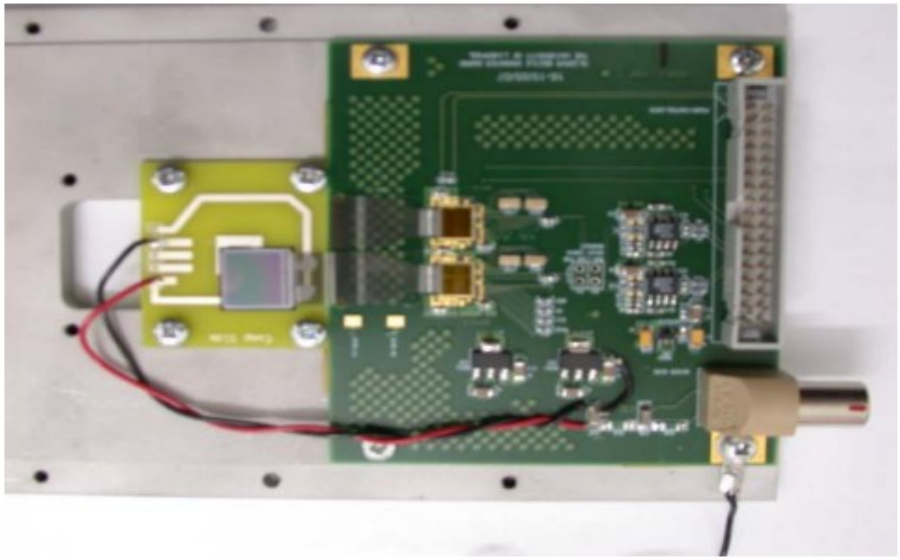
Daughter board

- Two Beetle readout chips in parallel mode.
  - 256 input channels.
  - Analogue front-end with 25 ns of peaking time.
  - Analogue multiplexed readout of each chip.
  - Output dynamic range ~ ±110000 electrons.
- Buffer stage for sending the analogue output signals to the mother board.
- Control signals provided by the mother board and shared by both Beetle chips.
- A thermistor (NTC) for sensing the temperature close the Beetle chips.
- Low voltage DC level (5 V) for Beetle chips (2.5 V) and buffer stage power supply (3 V): provided by the motherboard.
- High voltage DC level for silicon detector(s) bias: external power supply.
- Fan-ins and detector board: multiple wire bonding and two different sensor sizes.





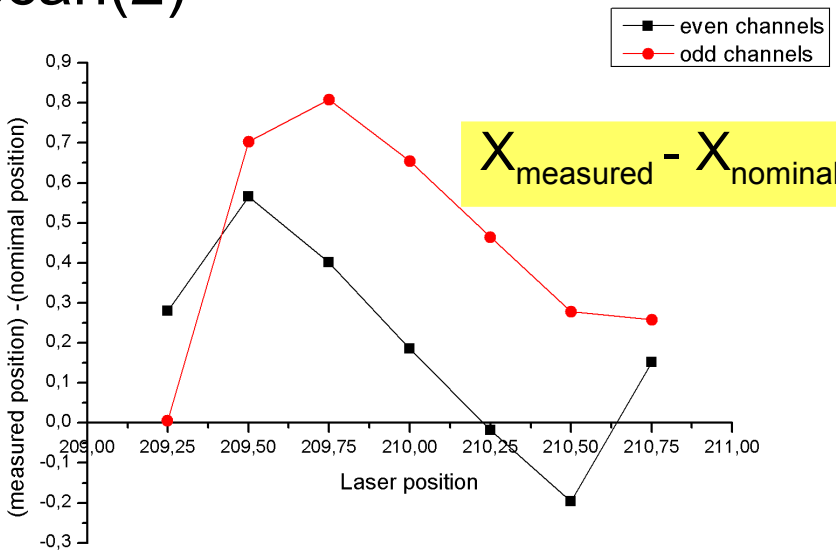
Bonding pads 80 um pitch, not staggered. 10 rows for multiple wire bonding

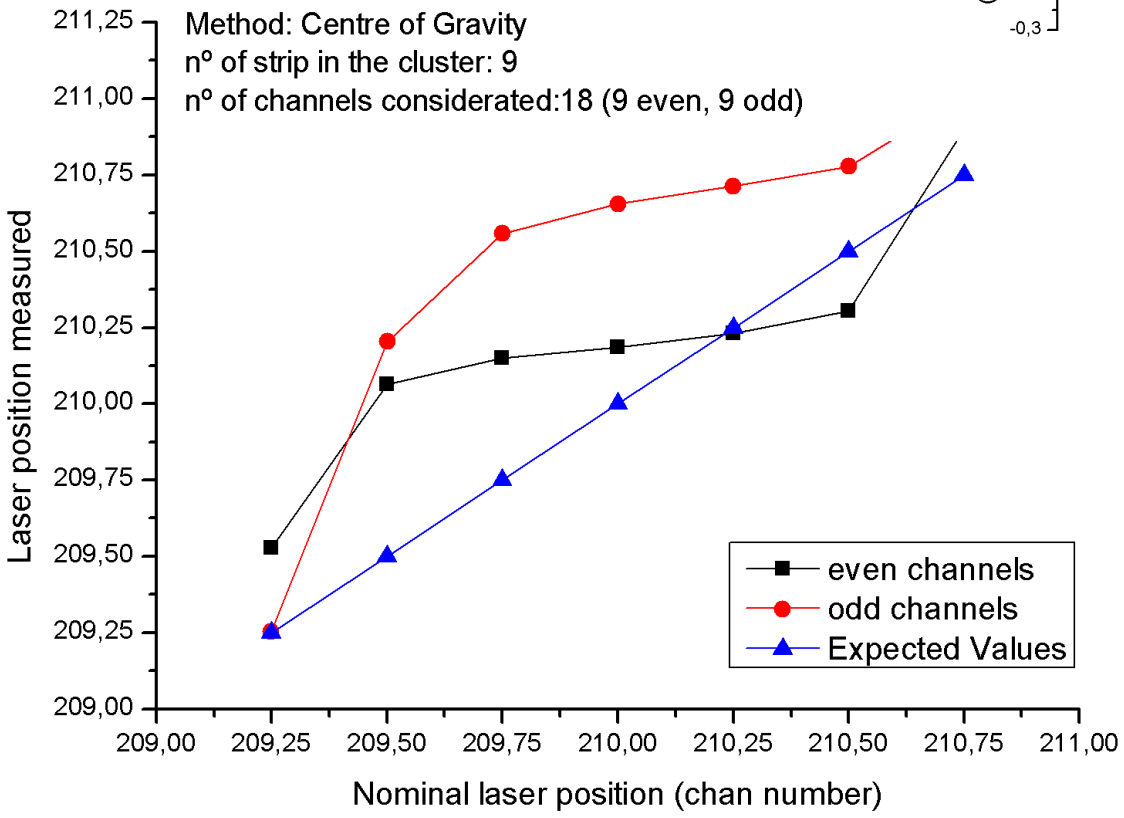


Transversal scan(2)

X-coordinate measured using the Centre of Gravity Method for the even and the odd channels **separately**.

Results are displayed as a function of the laser position.





Legend:

Position of the laser 209.25 means that the laser was 20 um far from the channel 209.

Position 209,50 means the laser was in the middle between channel 209 and 210.

And so on…