# ILD related R&D Activities @ IFCA

Future Linear Collider Workshop, Sevilla, Feb. 10th


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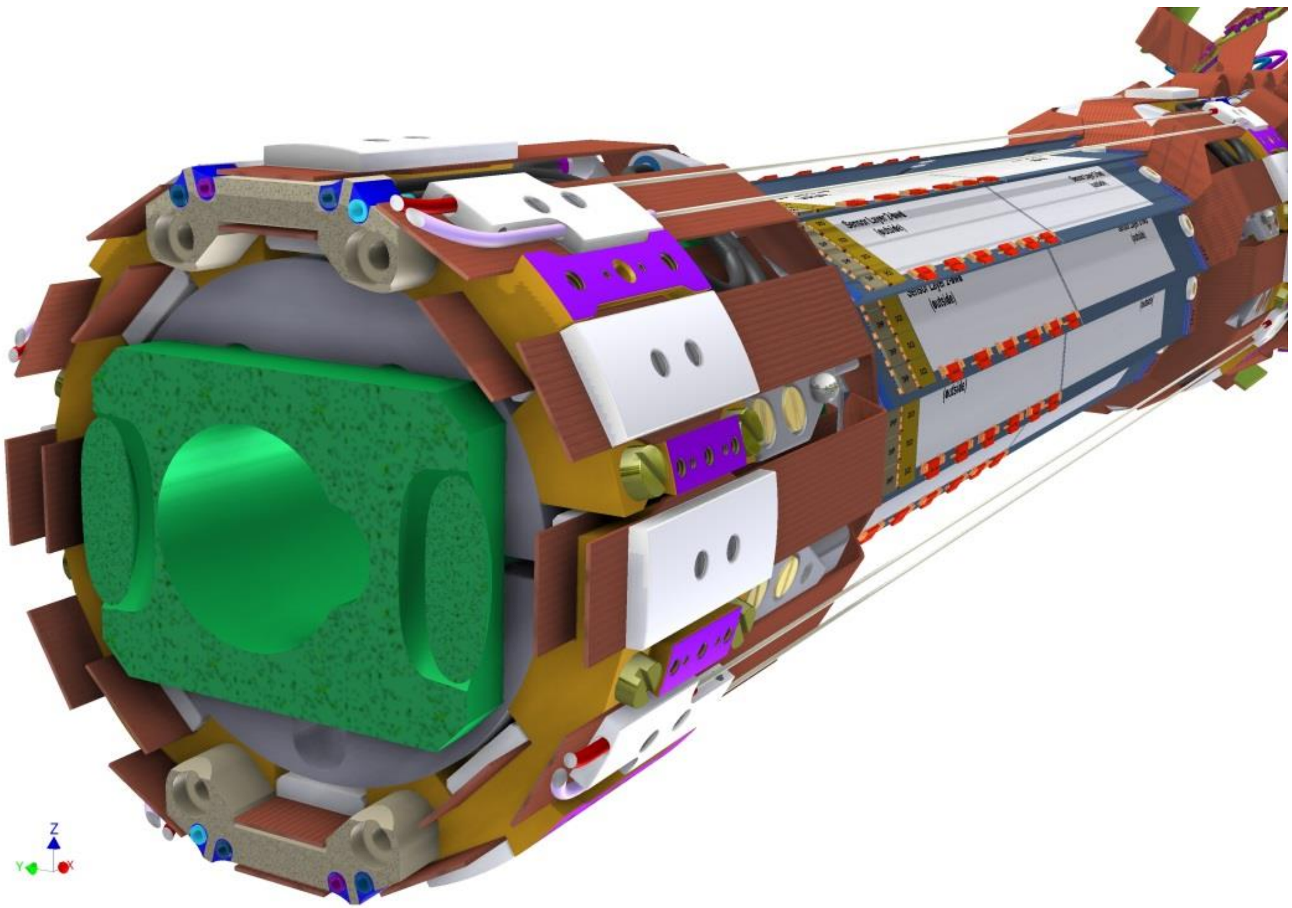
# Outline

– A structural and environmental monitor for Belle-2 vertex detector based on Fiber Optic Sensor (FOS)

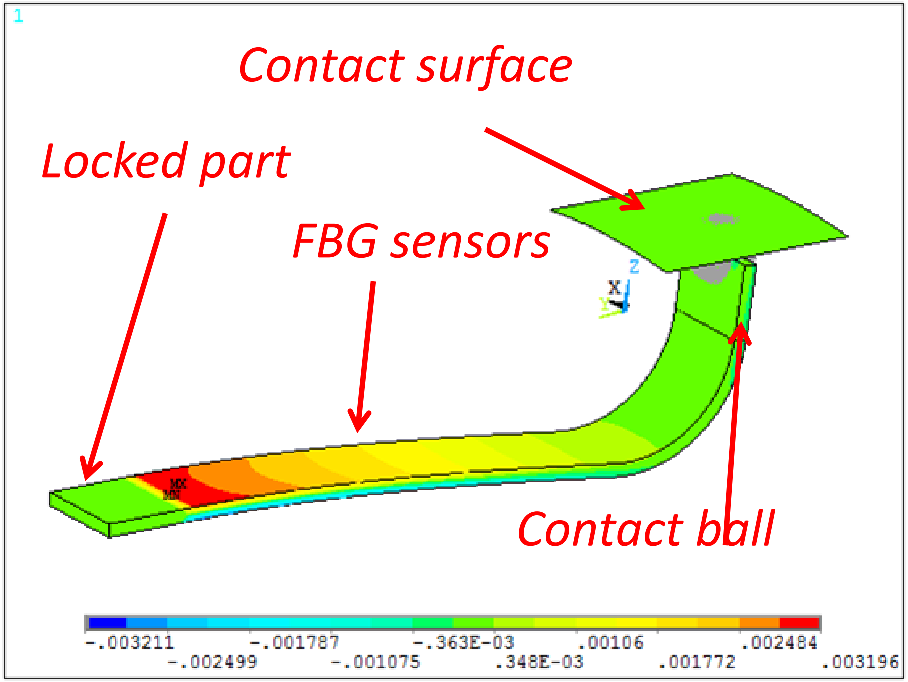
– R&D on microstrips sensors (resistive & low signal gain)

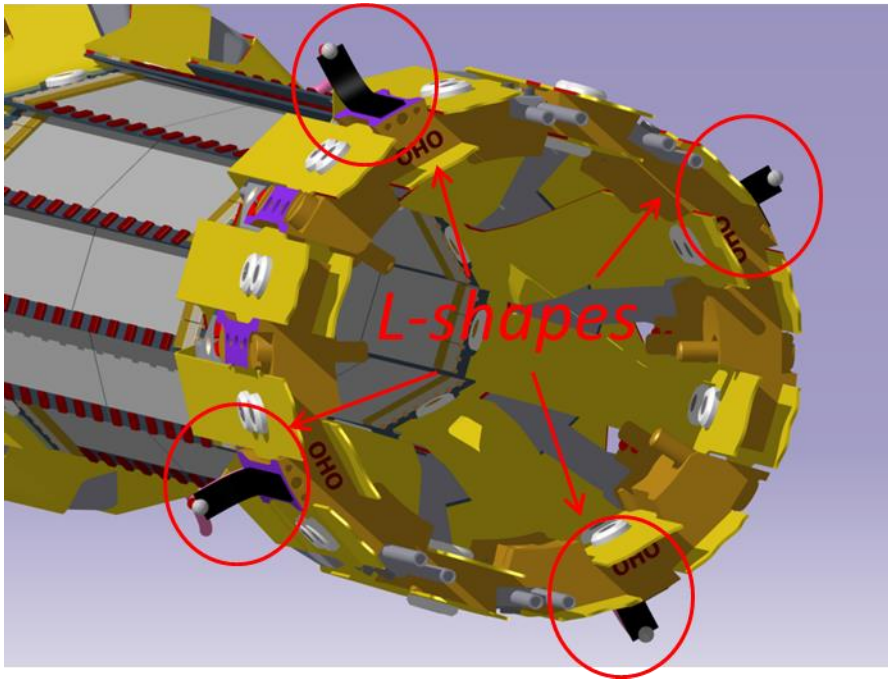
# FOS Monitor



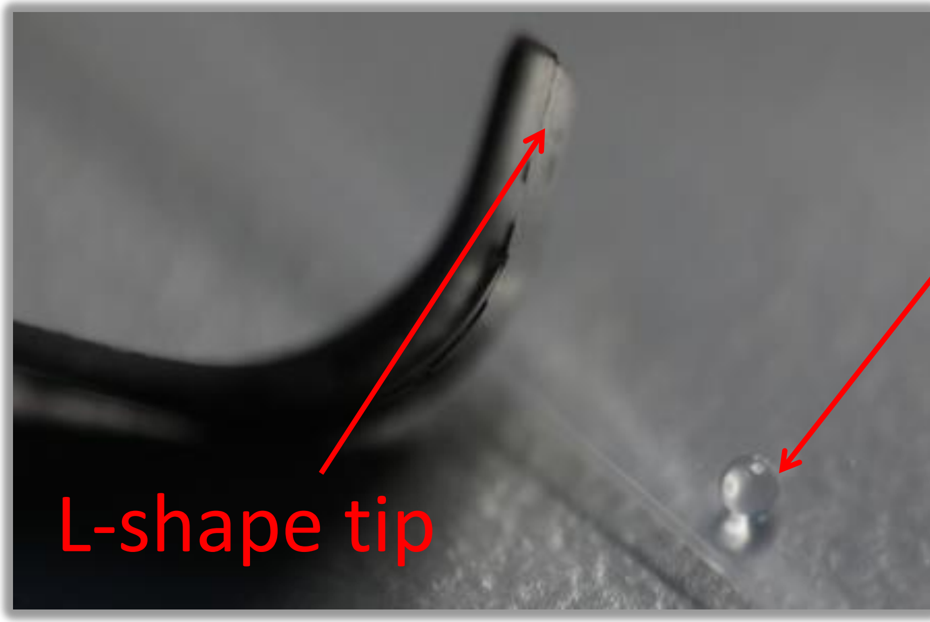
# L-shape basics

– Temperature & strain to displacement transducer with custom geometry for integration in PXD
– Readout speed from zero to 1KHz (vibrations)
– Currently three demonstrators manufactured

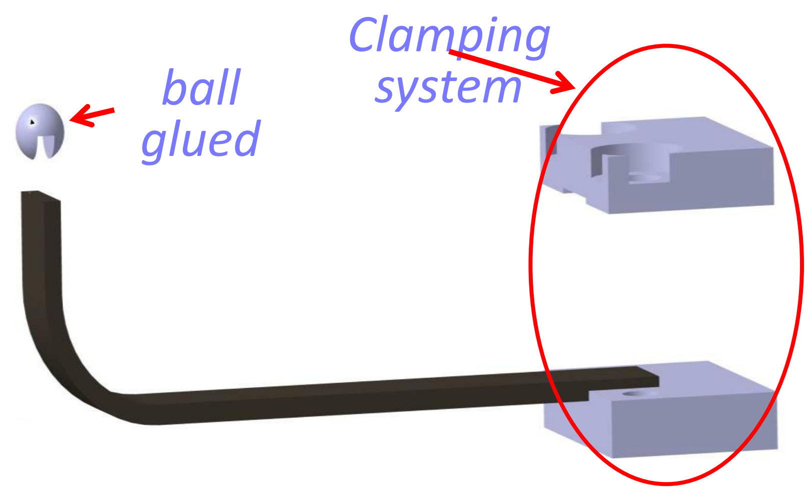


# L-Shape Demostrators



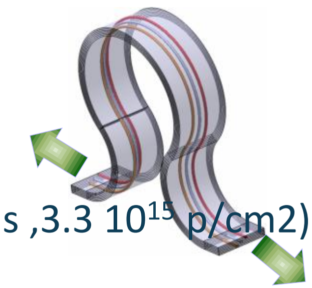

One millimiter Diameter
Quartz contact ball

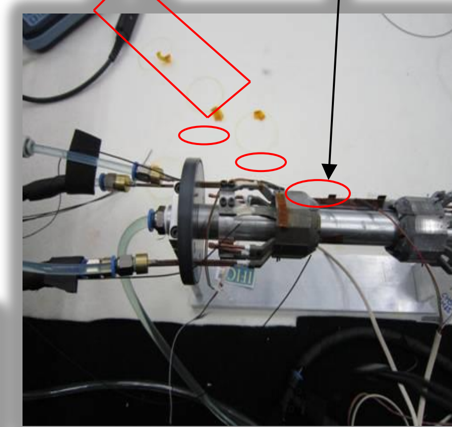


# FOS Monitor Timeline

- ☑ 2009 Oct FOS Monitor proposal
- ☑ 2010 Jan Omega-shape proposal
- ☑ 2010 Oct. FOS radiation hardness study (1.5 GRads ,3.3 $10^{15}$ p/cm2)
- ☑ 2011 January First omega mechanical dummies
- ☑ 2011 Sept. FOS radiation hardness study ( 10 Mrads )
- ☑ 2011 Dec Proof-of-concept-prototype omega
- ☑ 2012 Feb Omega calibration.
- ☑ 2012 March New transducer design L-shape
- ☑ 2012 May Test in depfet mock-up at IFIC
- ☑ 2012 October L –shape calibration

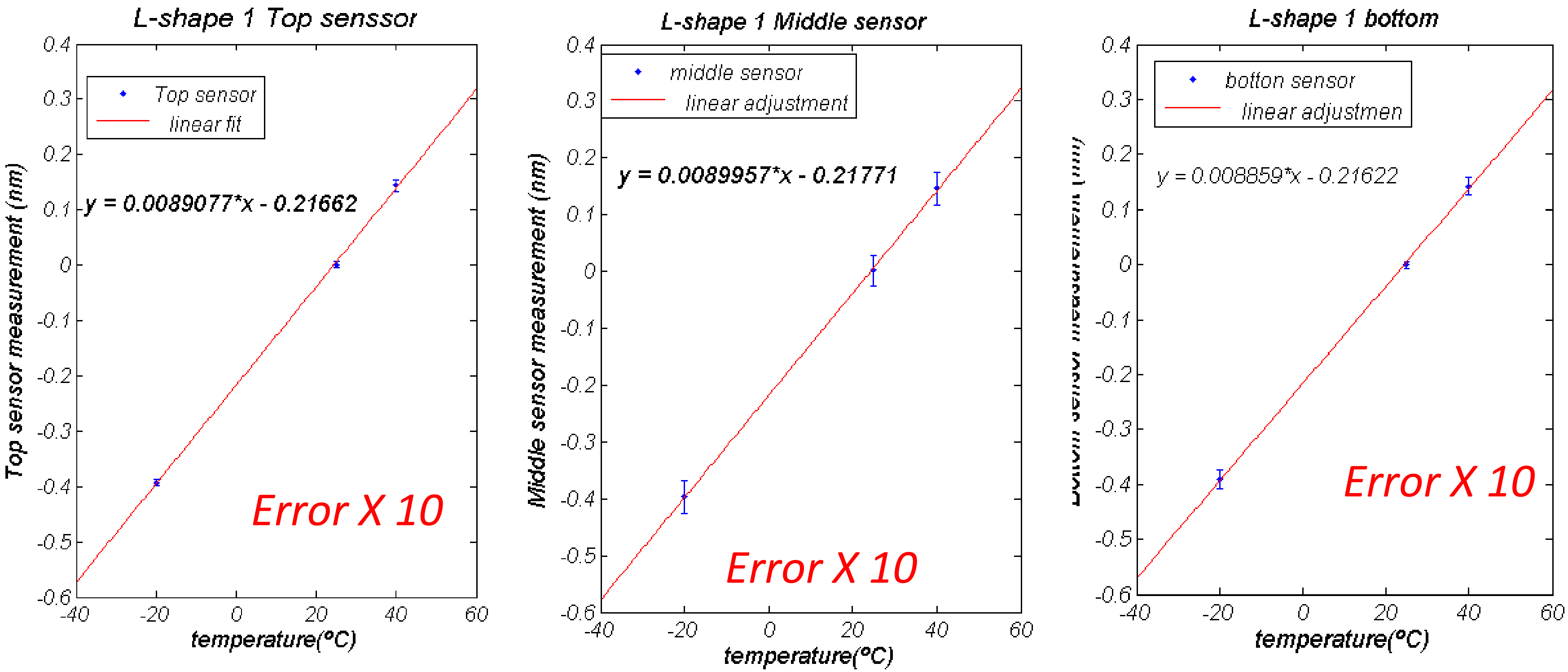
  (resolution less 1 um ,accuracy≈10 um )
- ☑ 2013 May Test in mock-up at IFIC ($N_2$ atmosphere)
- ✓ 2014 January commissioning at PXD-SVD commo





# Thermal calibrations & temperature compensation

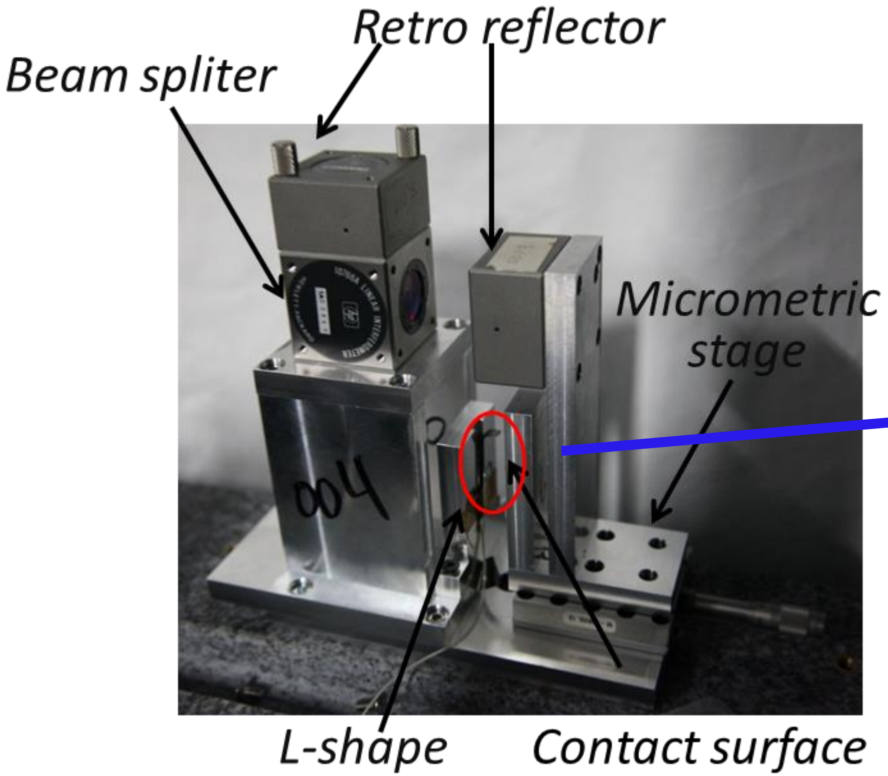
- Calibration using a SIKA thermocouples calibrator.
- The sensitivity of three sensors was constant and near the same (difference<0.6%) *Maximum deviation < 3 pm (0.3 ºC)*

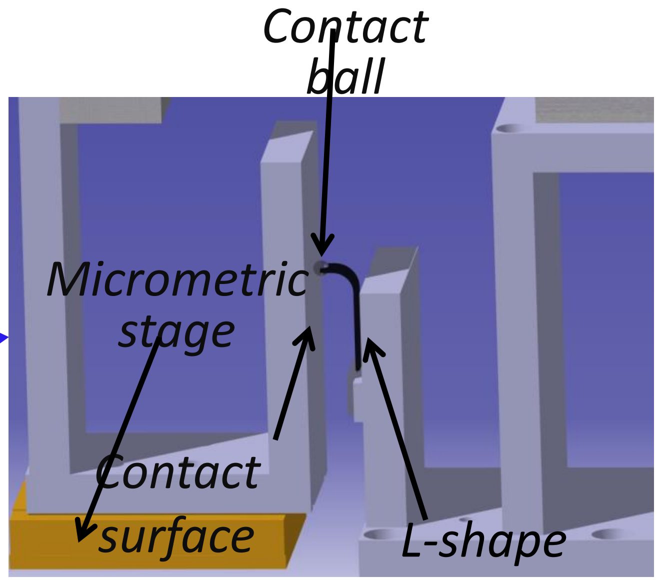



- Trivial approach to temperature compensation

# Displacement Calibration

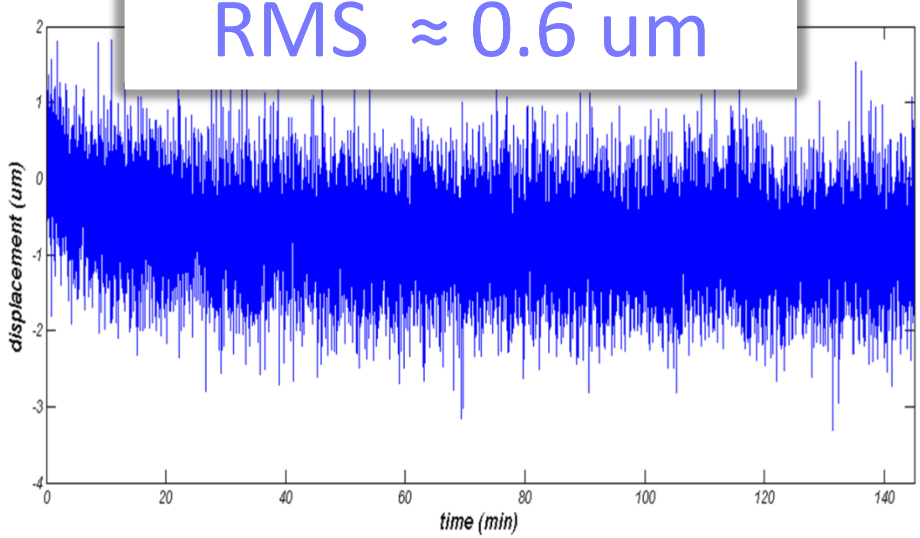
– Displacement measured with Michelson interferometer for high precision calibration (tenth of a micron)
– Readout of L-shape compared with true position (interferometer)

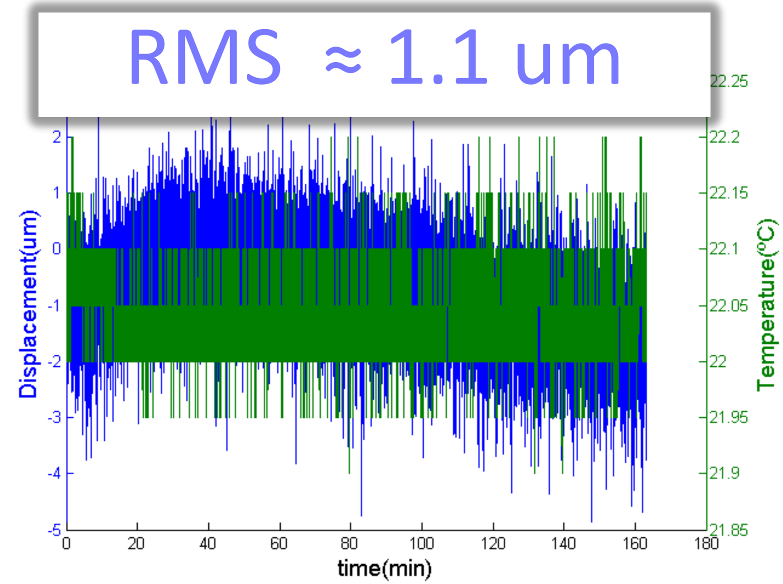


# L-shape Output Stability

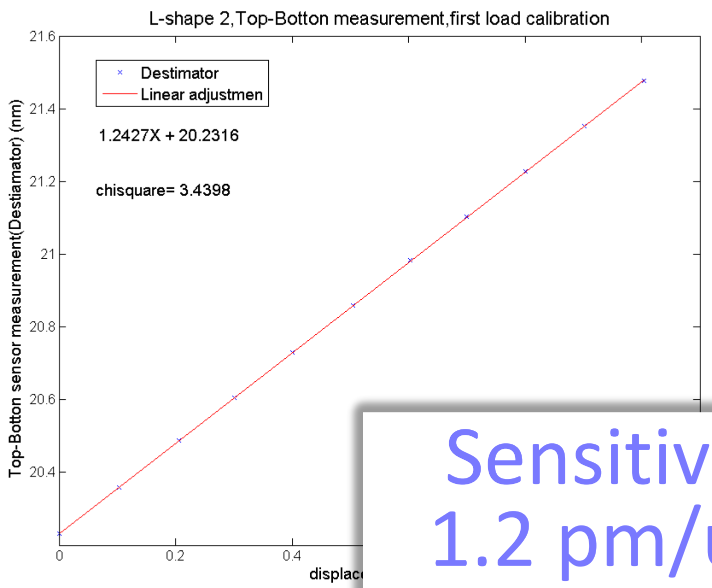
- Short term studies (temperature constant ± 0.1° )
- Continuous readout of the sensor output.
- Stabilities below or about 1um (convolution with mechanics stability)



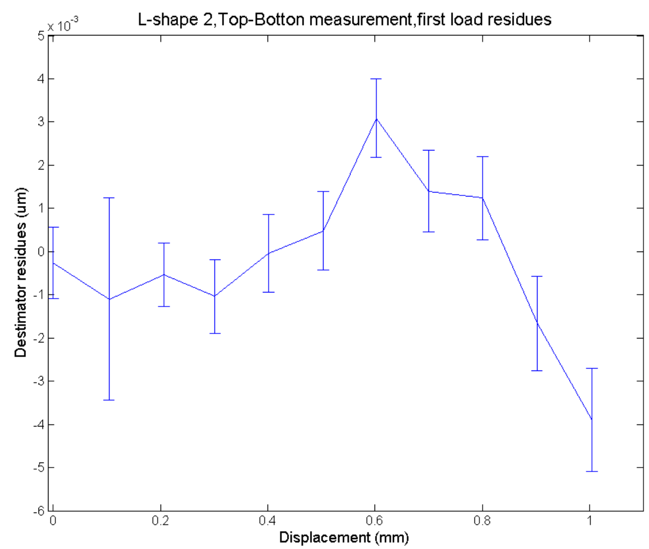



# L-shape Linearity vs. Displacement

- Calibration over a range of 1mm
- Resolution (readout resolution) 0.5 um.
- Accuracy (diff. Between inter & L-shape) ≈ 2 um

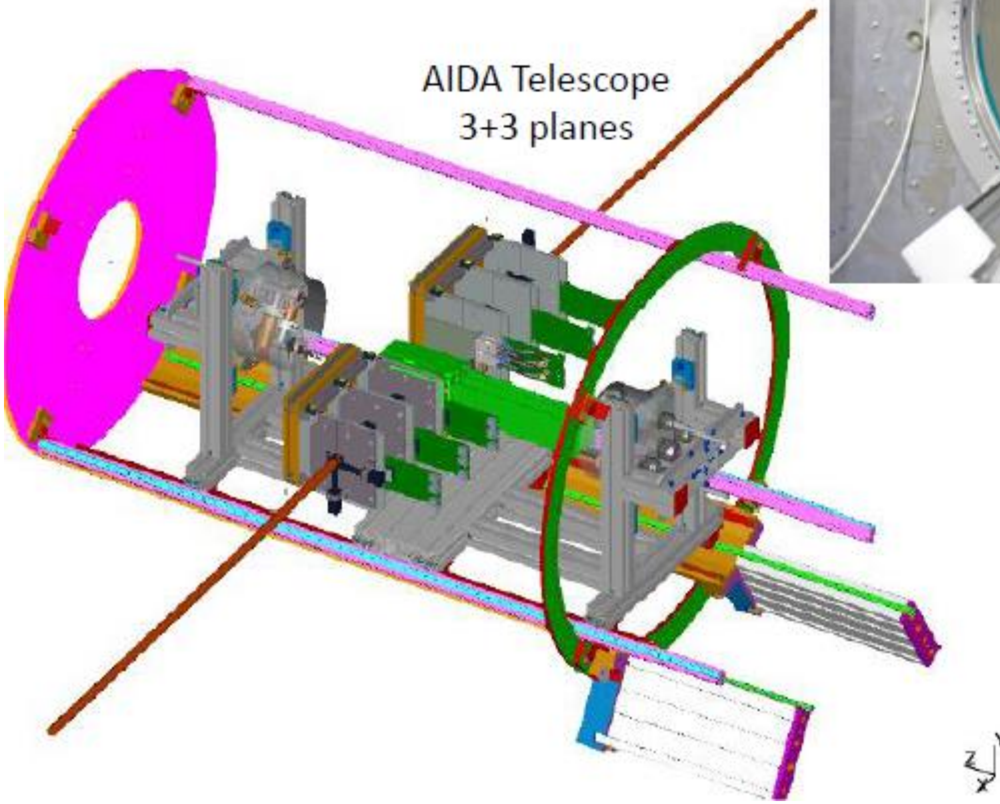


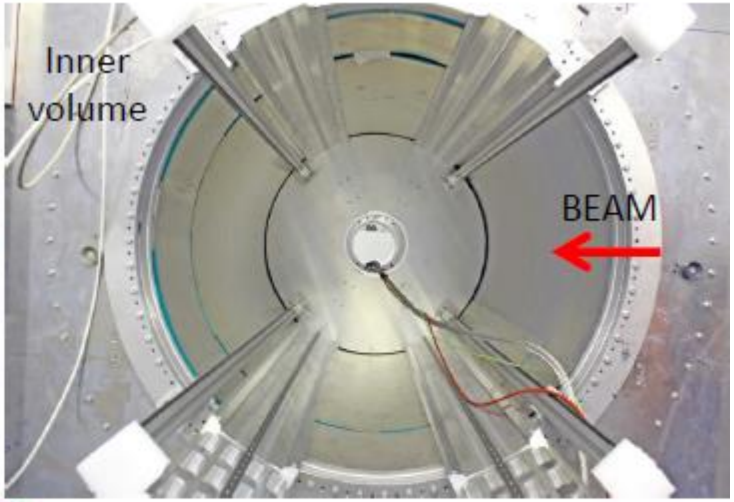

Sensitivity
1.2 pm/um



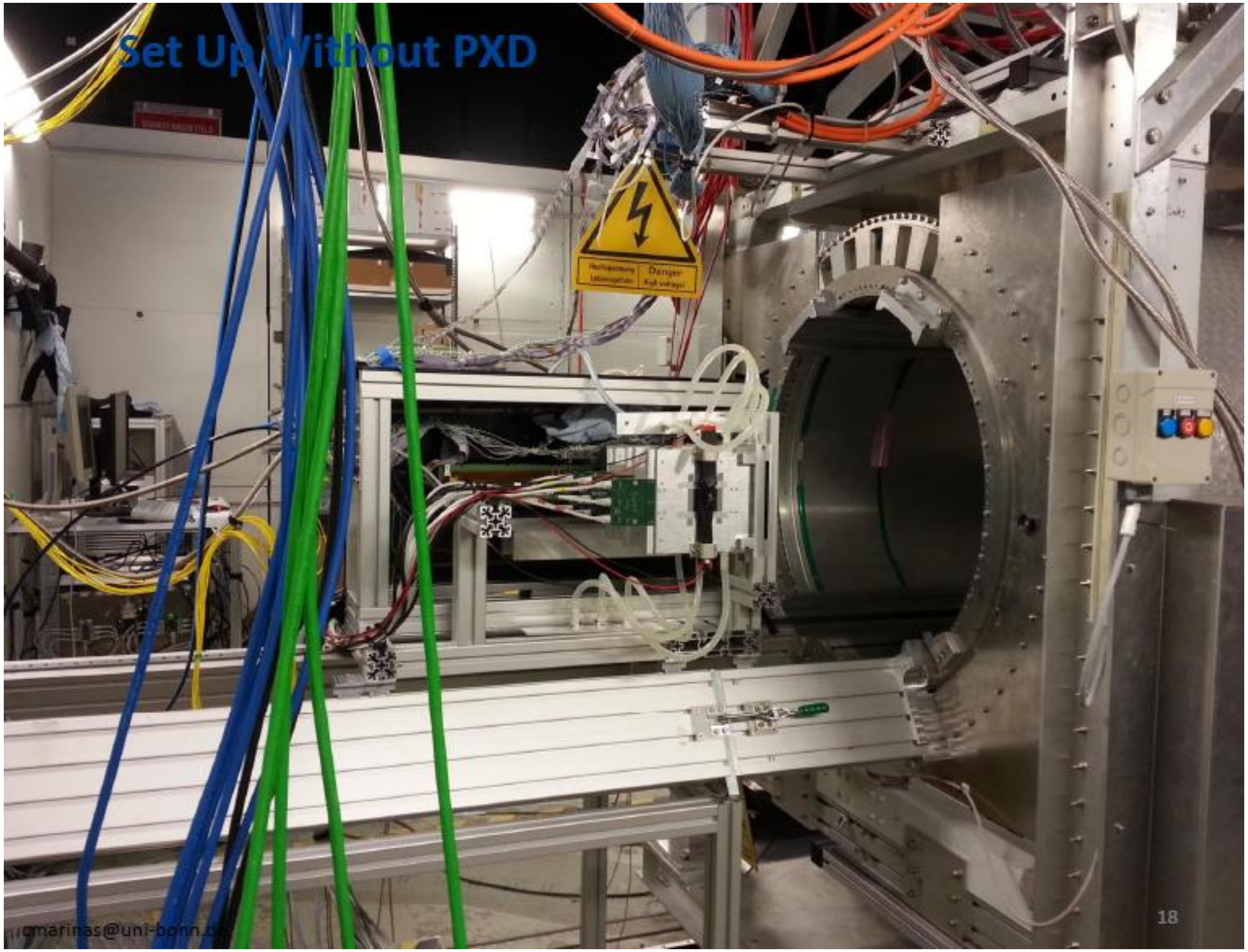
# PXD – SVD Integrated test beam

## Integration into the PCMAG

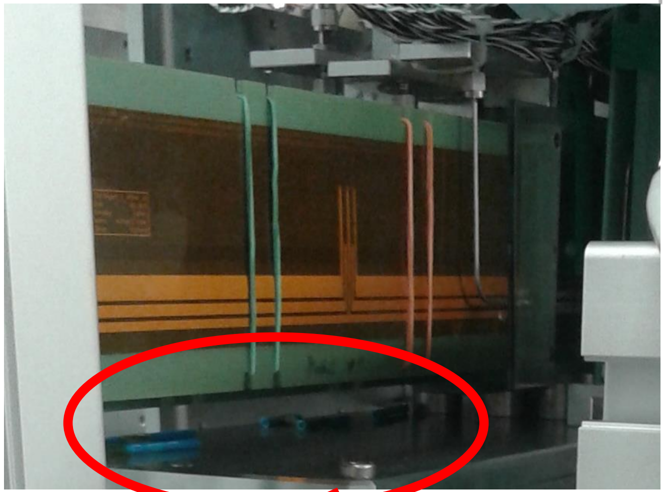


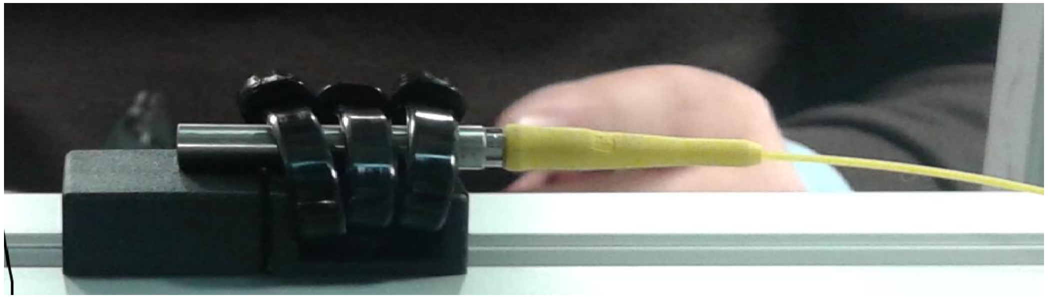



# PXD – SVD Integrated test beam



# FOS Monitor: FOS Packing

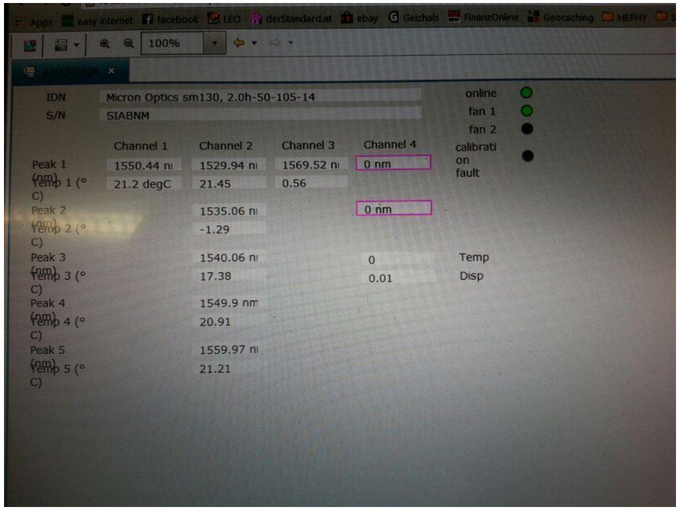




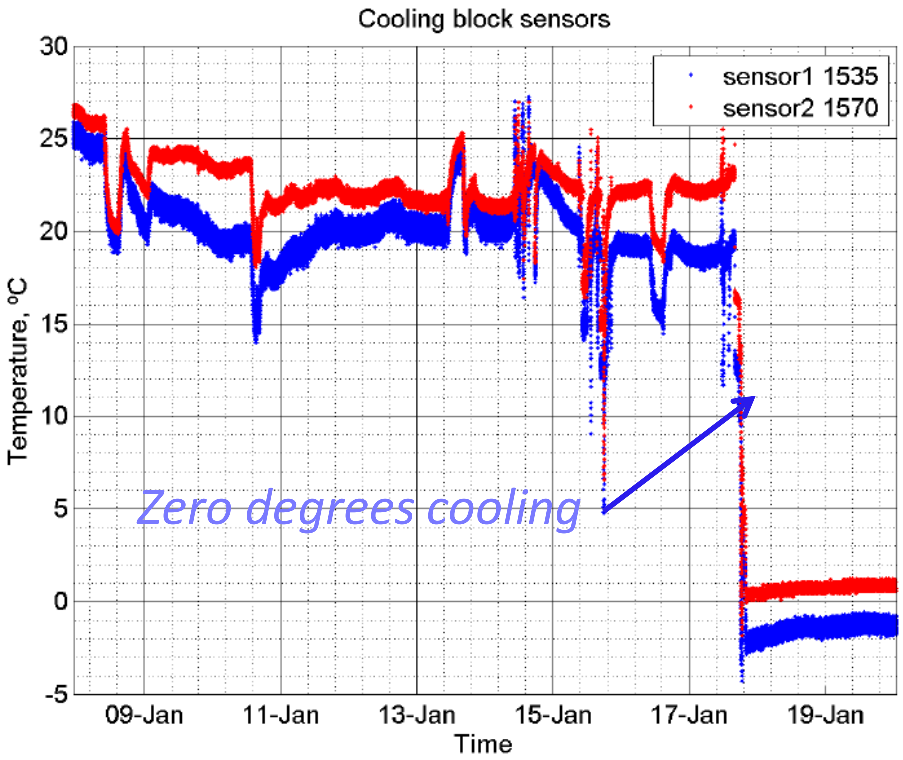
# FOS Monitor: DAQ – SC integration

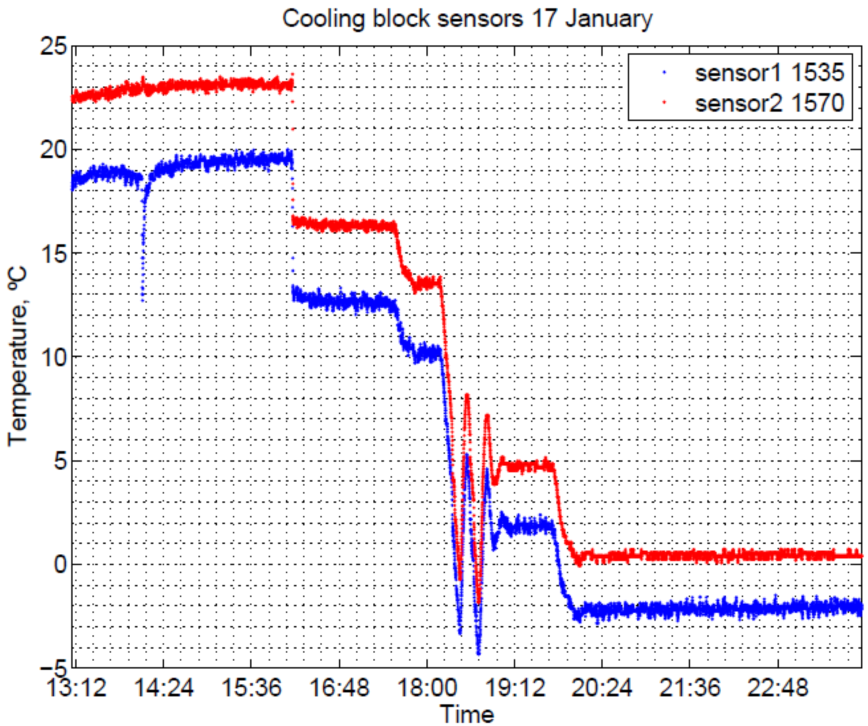
– Optical routing of the sensors up to the interrogating units

– Readout integrated in EPICS (dedicated driver over Ethernet ). The integration went very smooth ready since the January 6$^{th}$

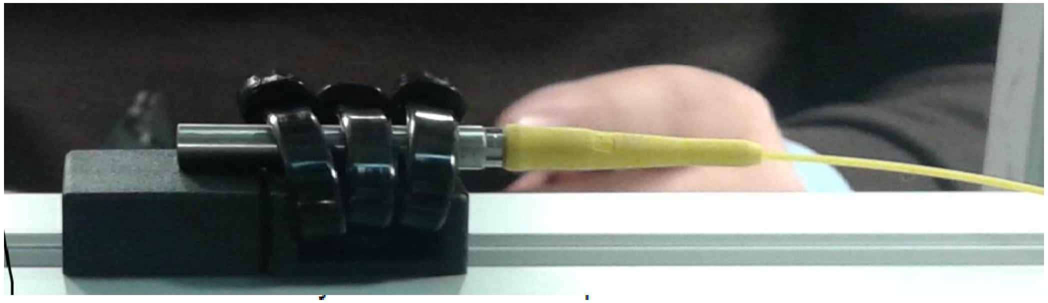



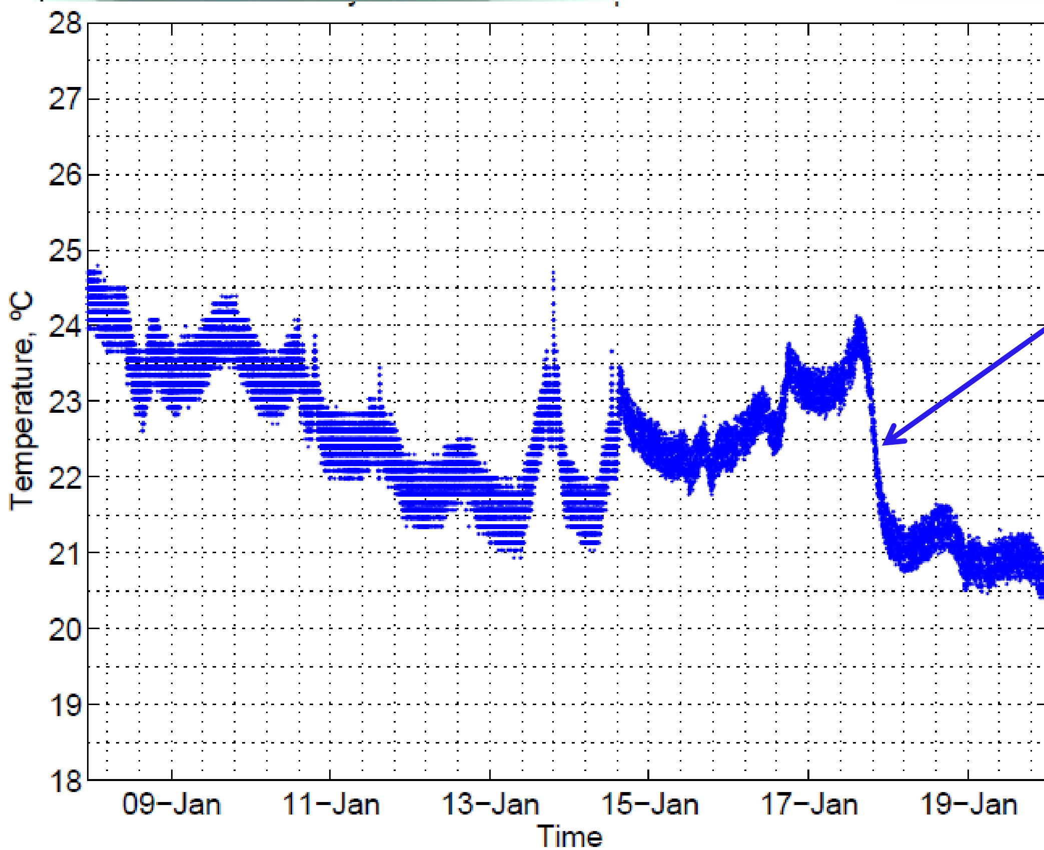
# FOS Monitor: Data: MARCO in-let & out-let lines



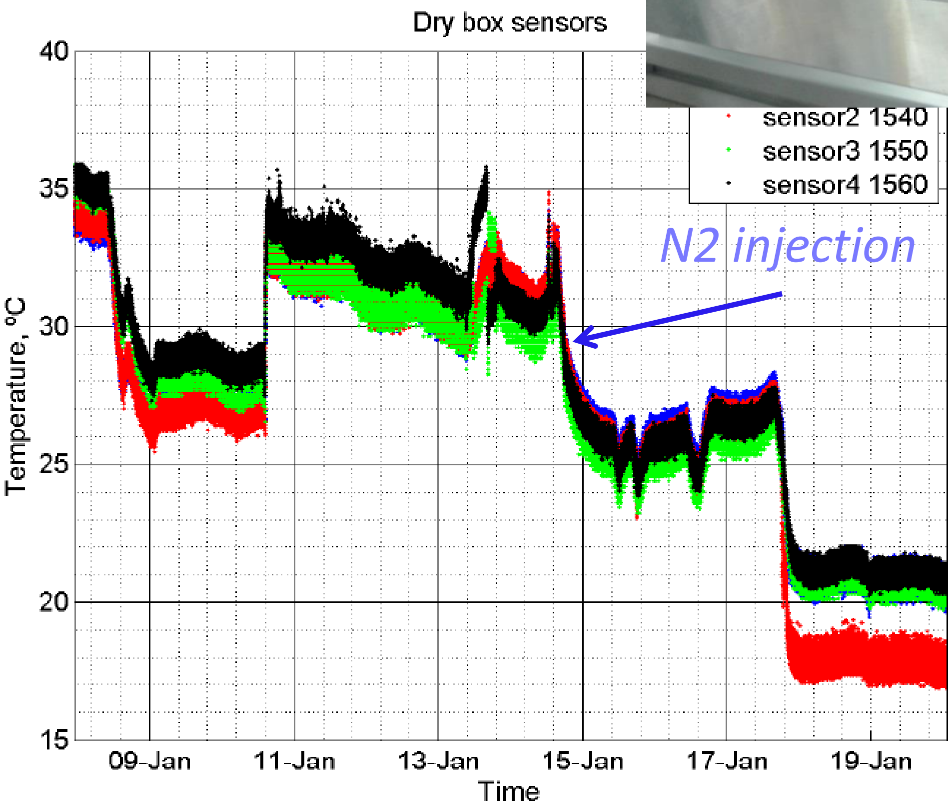
# FOS Monitor Data: Ambient Temp

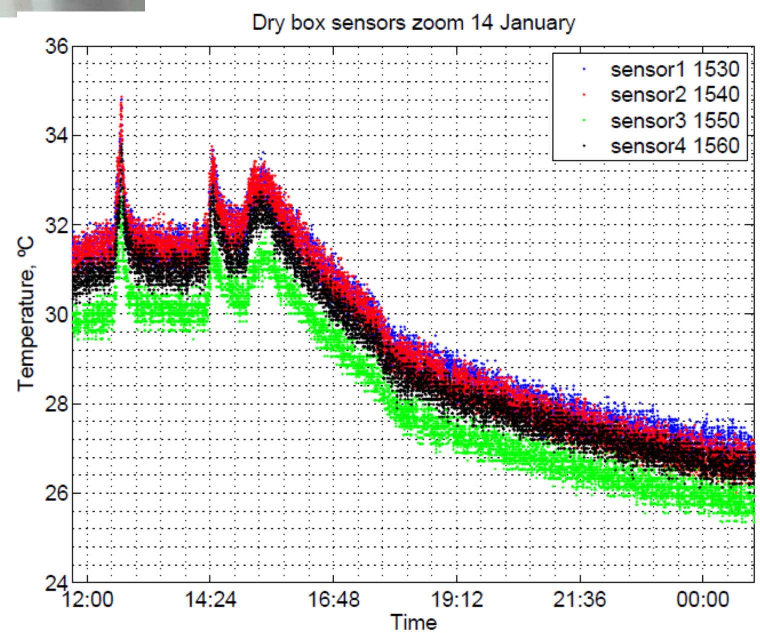





*Zero degrees cooling*

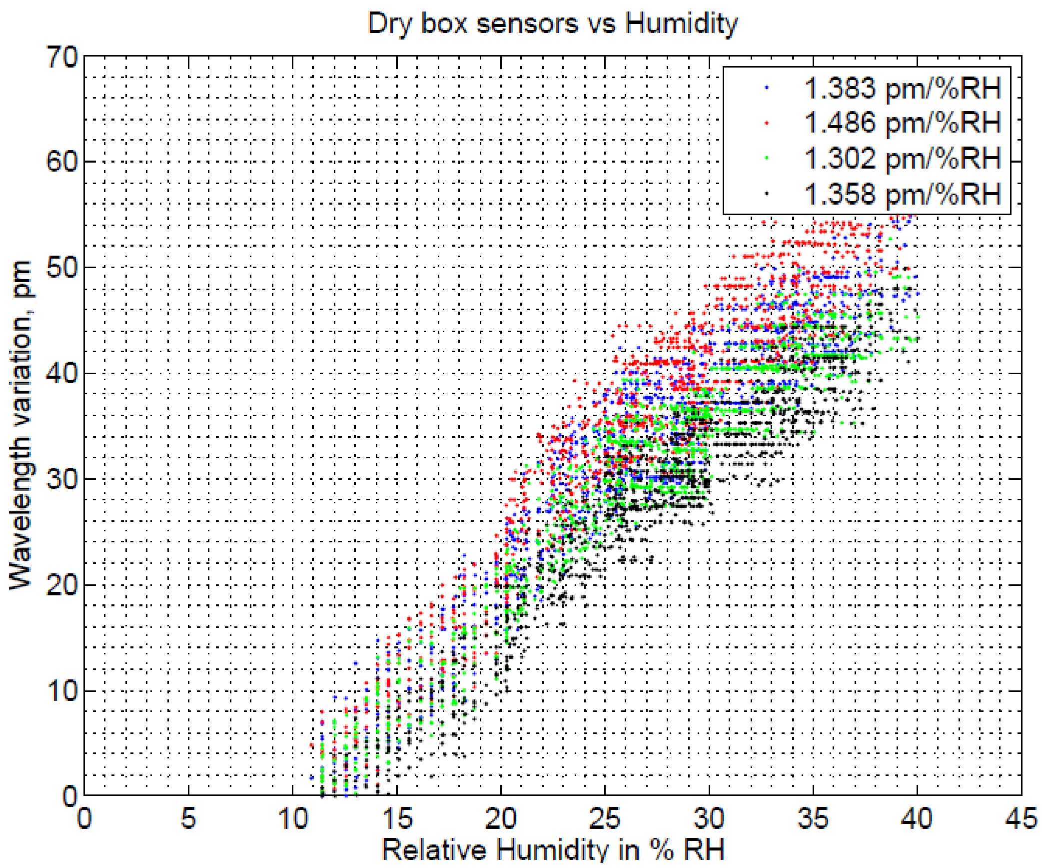
# FOS Monitor: Ambient Temp+%RH



# FOS Monitor:Humidity measurements

- Comparing the wavelength shift of ambient sensors (naked fibers) vs. commercial Humidity sensors inside the dry box.
- Excellent linearity and sensibility after temperature compensation



# Conclusions

- A FOS-based temperature and humidity monitor read-out through EPICS commissioned and running smoothly since the beginning of the test beam.
- Most of the R&D activities required for the implementation of FOS monitor (environmental and displacement) are completed. Still some more "academic " loose ends to be completed this year.
- Next: System-wise activities for mechanical integration in Belle-II.

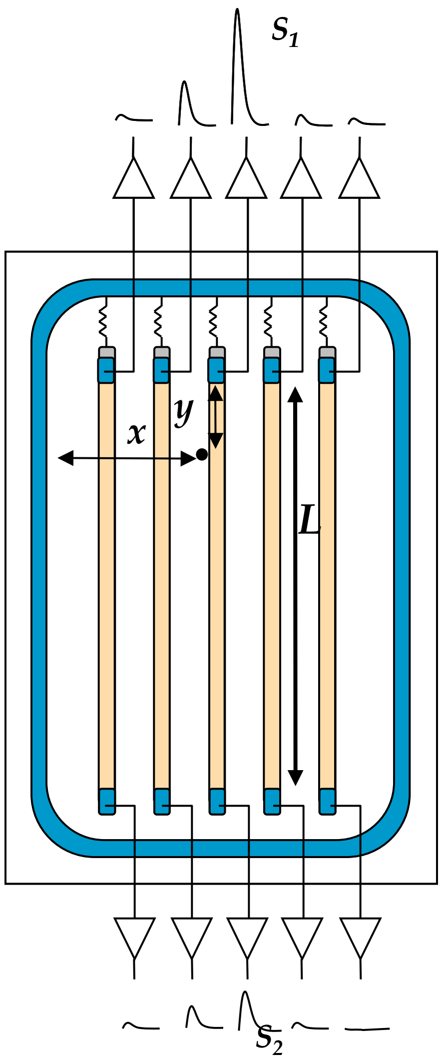
# PART 2 - R&D ON MICROSTRIPS

- Microstrip sensors with resistive electrodes.
- Low Gain Microstrip Sensors.

# 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.*

$$S_1 = f(y)$$
$$S_2 = f(L-y)$$

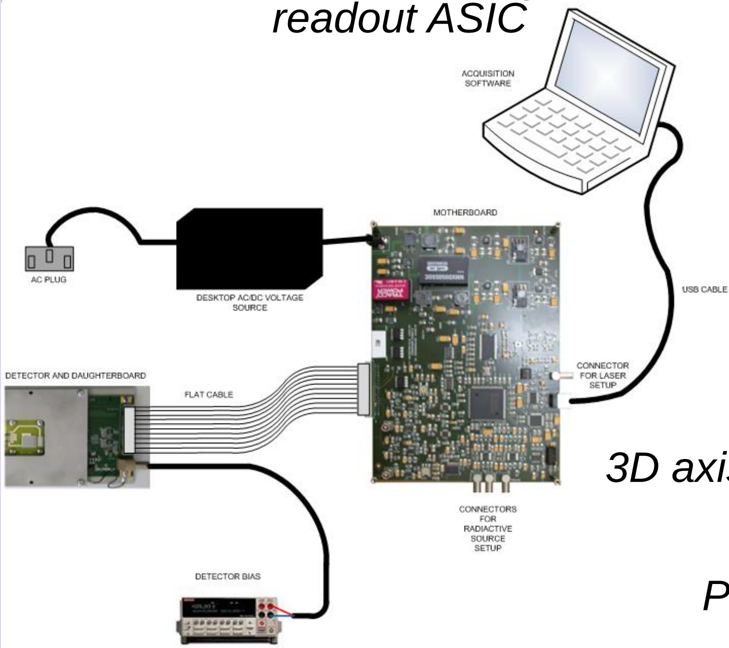
$$\frac{y}{L} = \frac{A_2}{A_1 + A_2}$$

***Resistive material: high doped polysilicon***

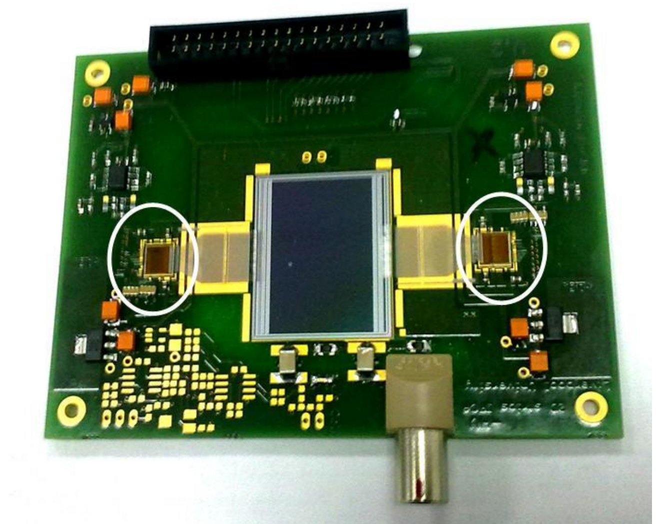
** *V. Radeka, IEEE Transaction on Nuclear Science NS-21 (1974) 51*

# 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*



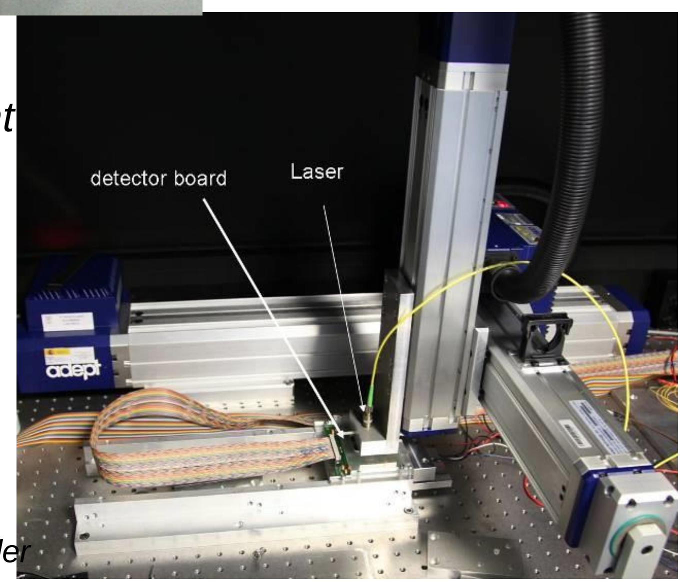
Strip:
- length =20 mm
- width =20 um

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*

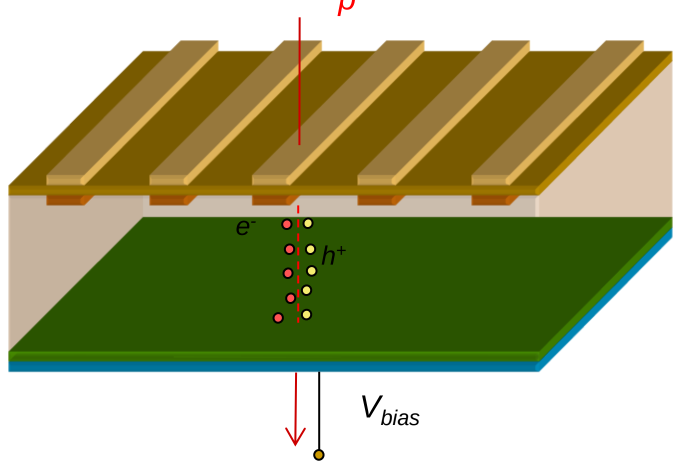


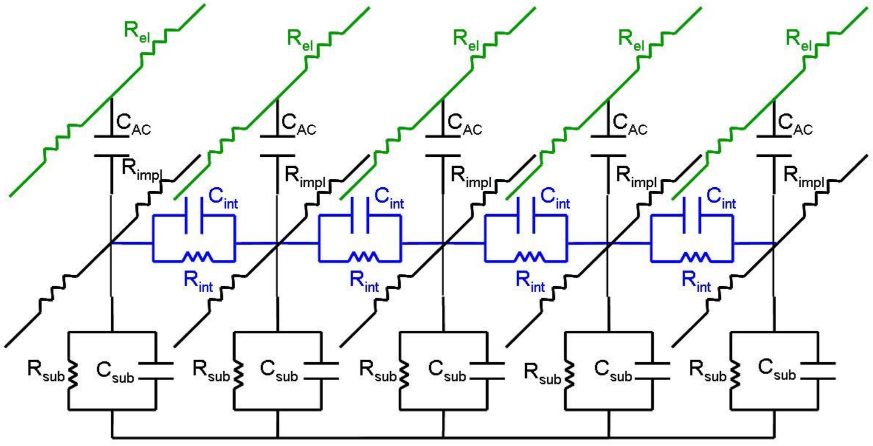

*Clean room laboratory at IFCA, Santander*

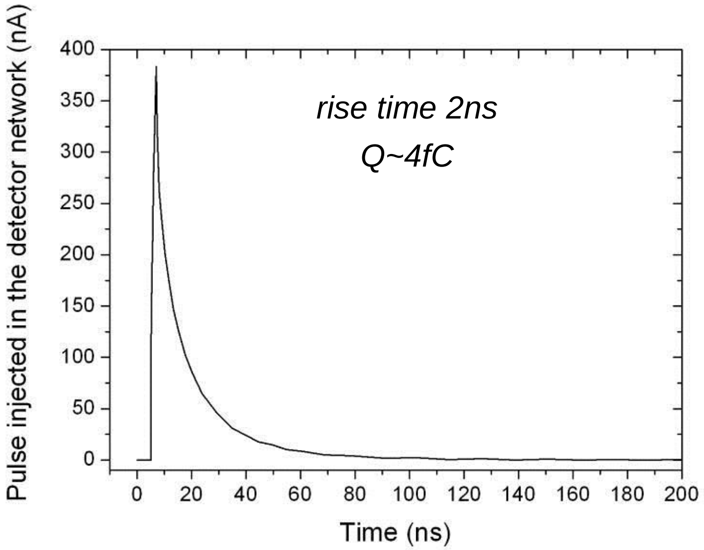
# Equivalent Electrical Circuit

*Detector (p⁺-on-n) model* ***

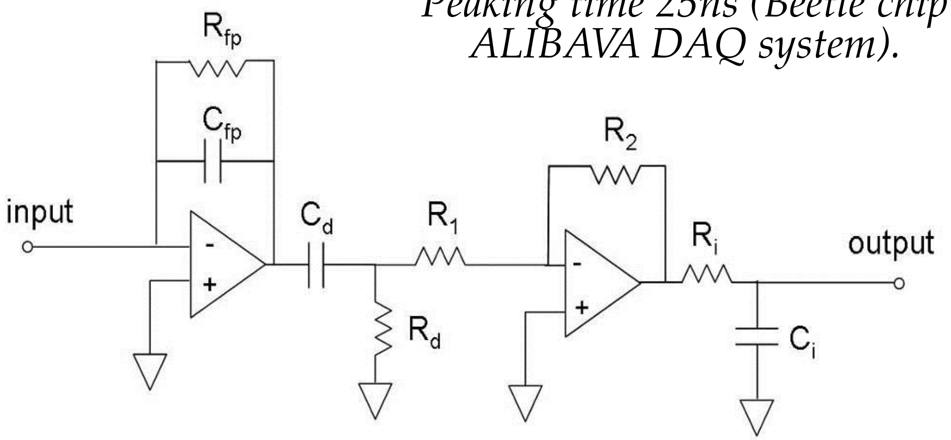
*80 cells 250 μm long*



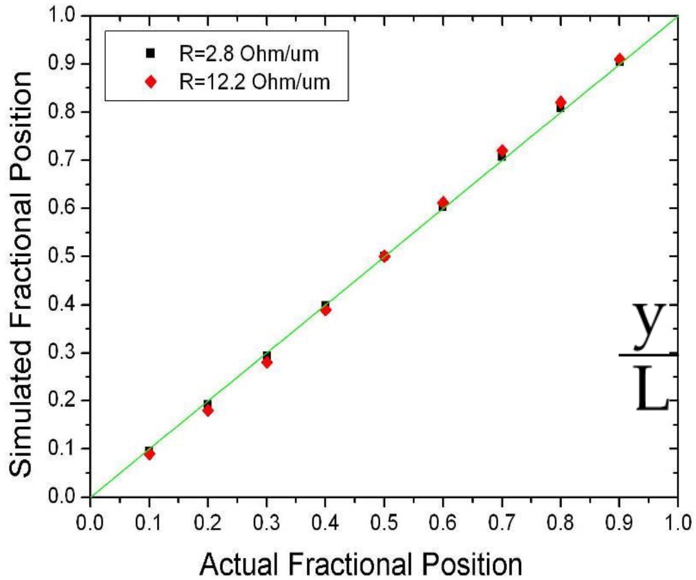



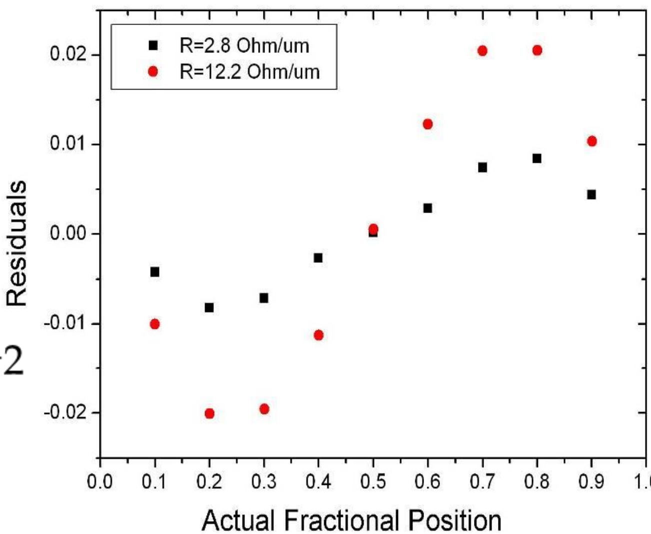

*Peaking time 25ns (Beetle chip ALIBAVA DAQ system).*

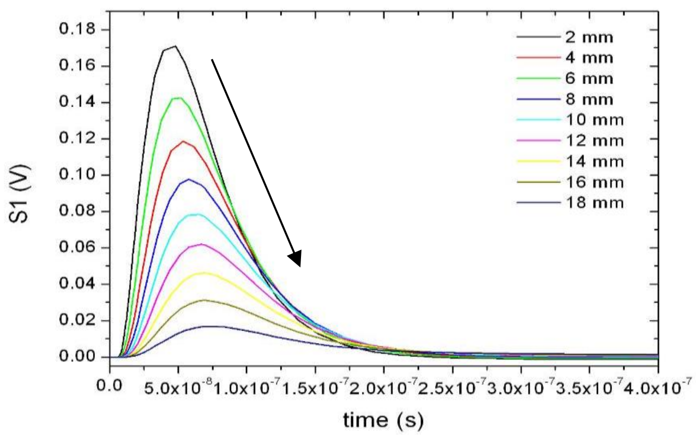


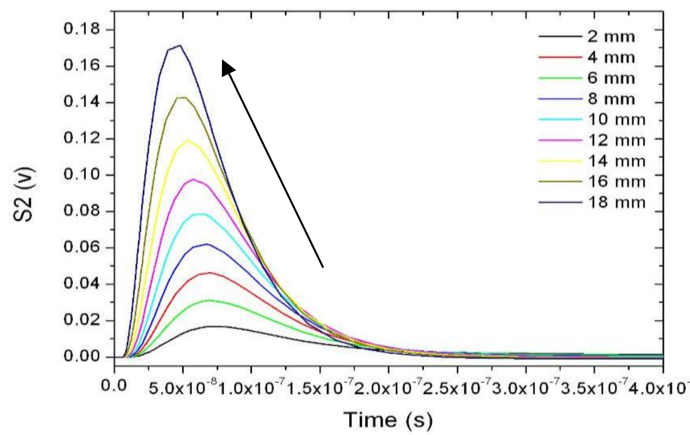
# Signal Propagation – Linearity (Simulation)




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



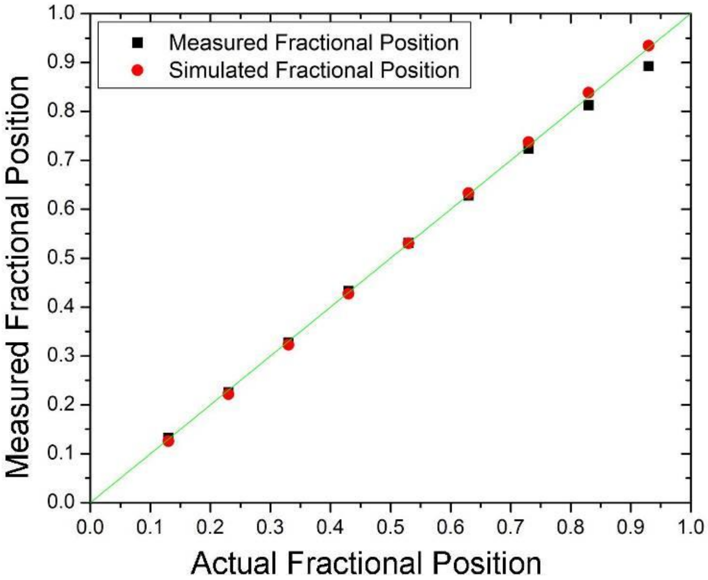



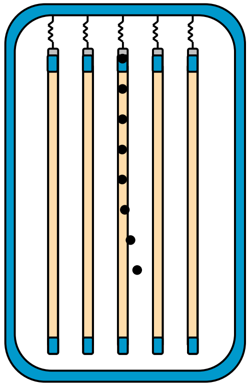



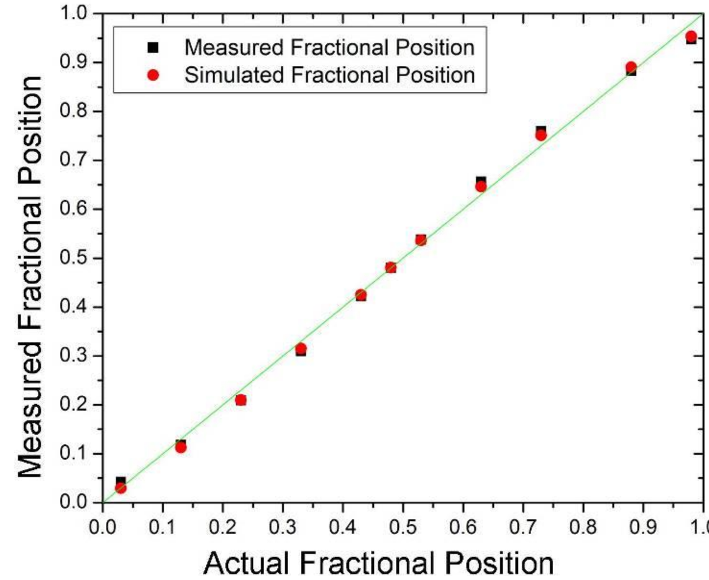
*R/l=2.8 Ω/μm*

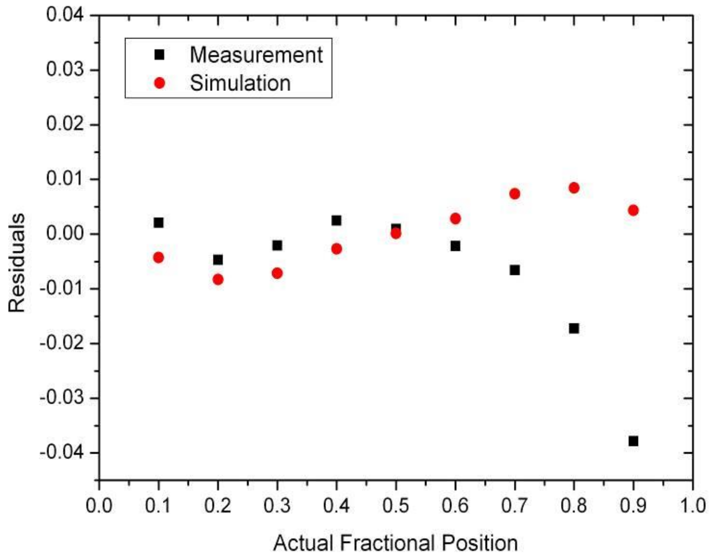
*R/l=12.2 Ω/μm*

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

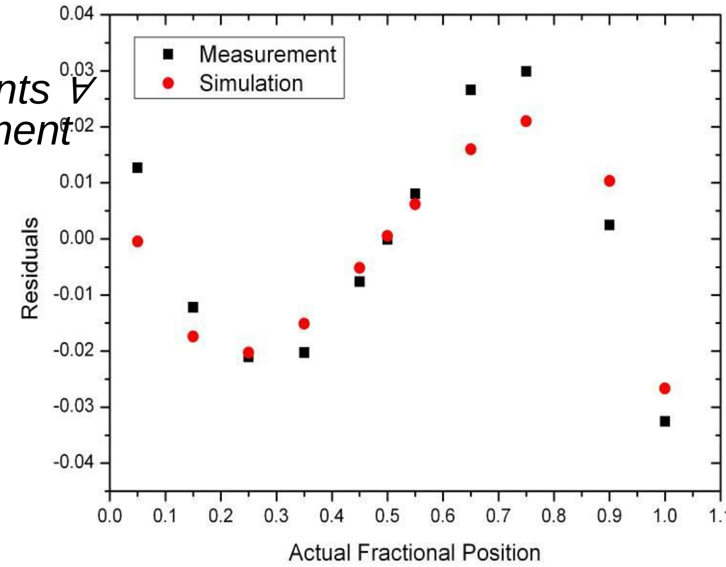





*20000 events ∀ measurement*



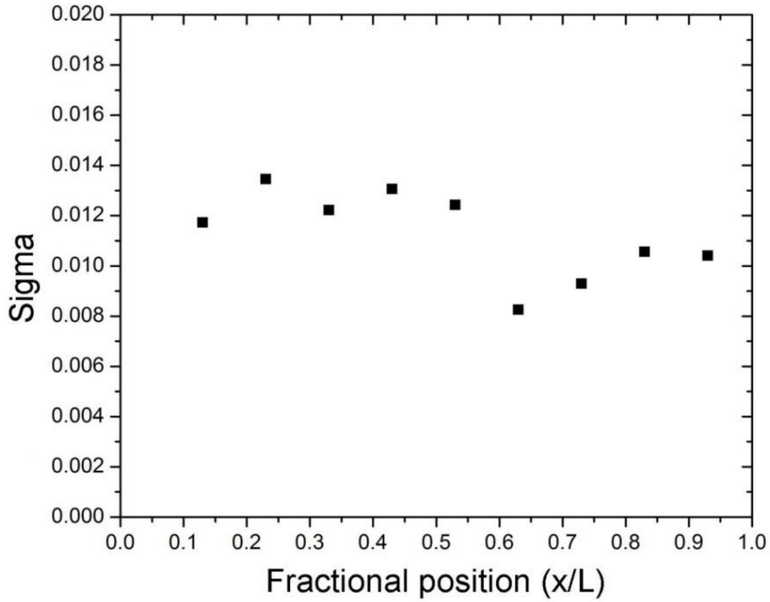
# Longitudinal spatial resolution for 6 MIPs signal

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

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

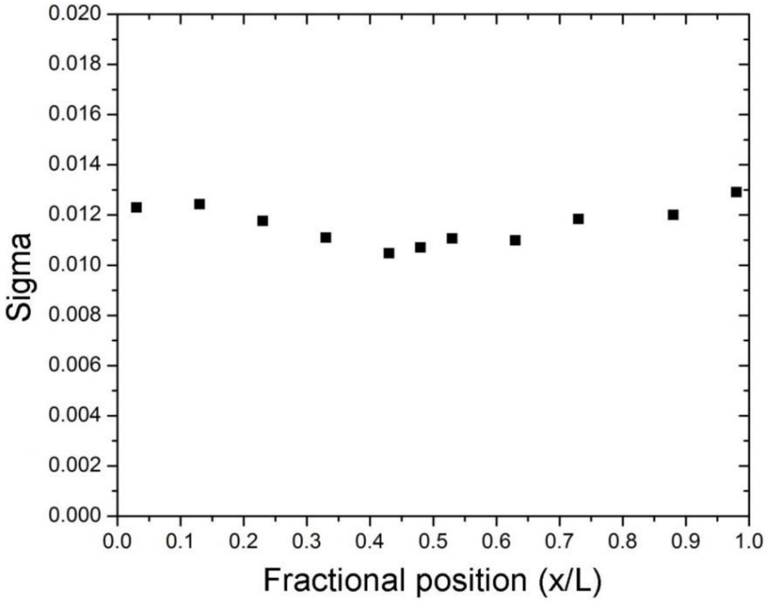
*1.1% L => 220 µm*

*R/l=2.8 Ω/µm*

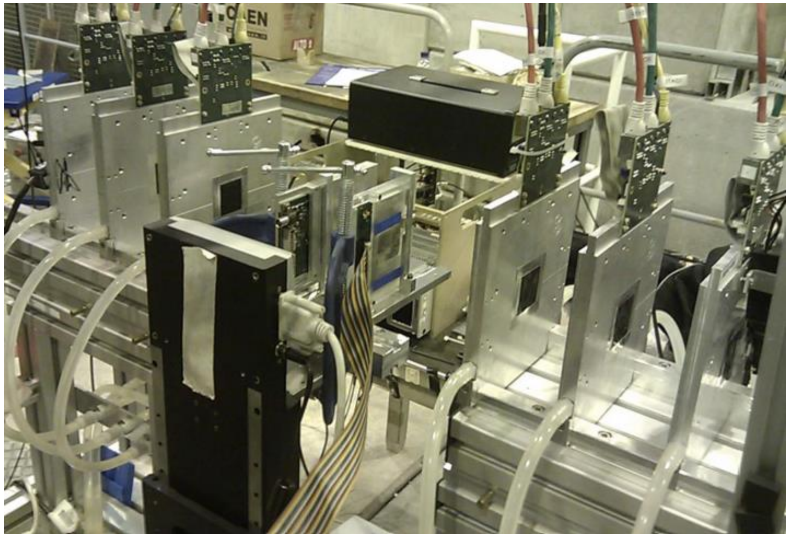


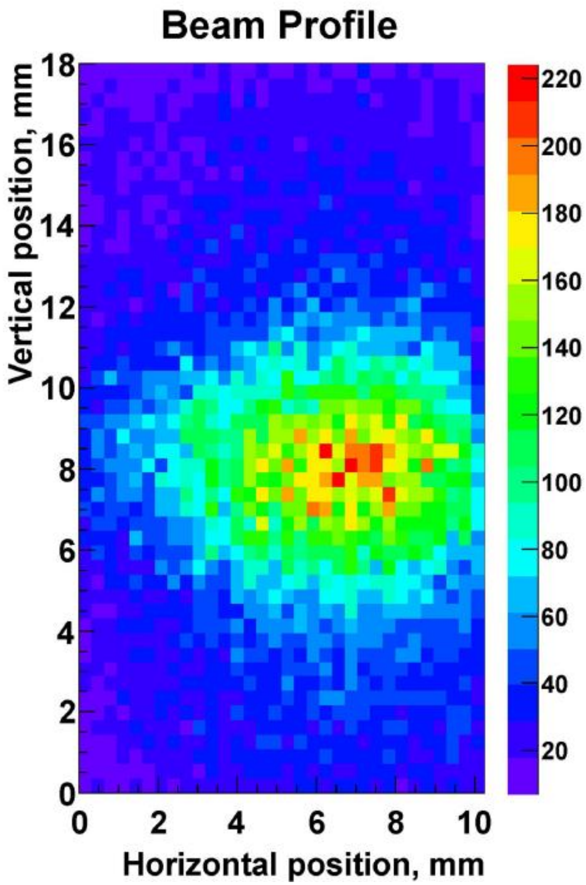

*1.2% L => 240 µm*

*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*

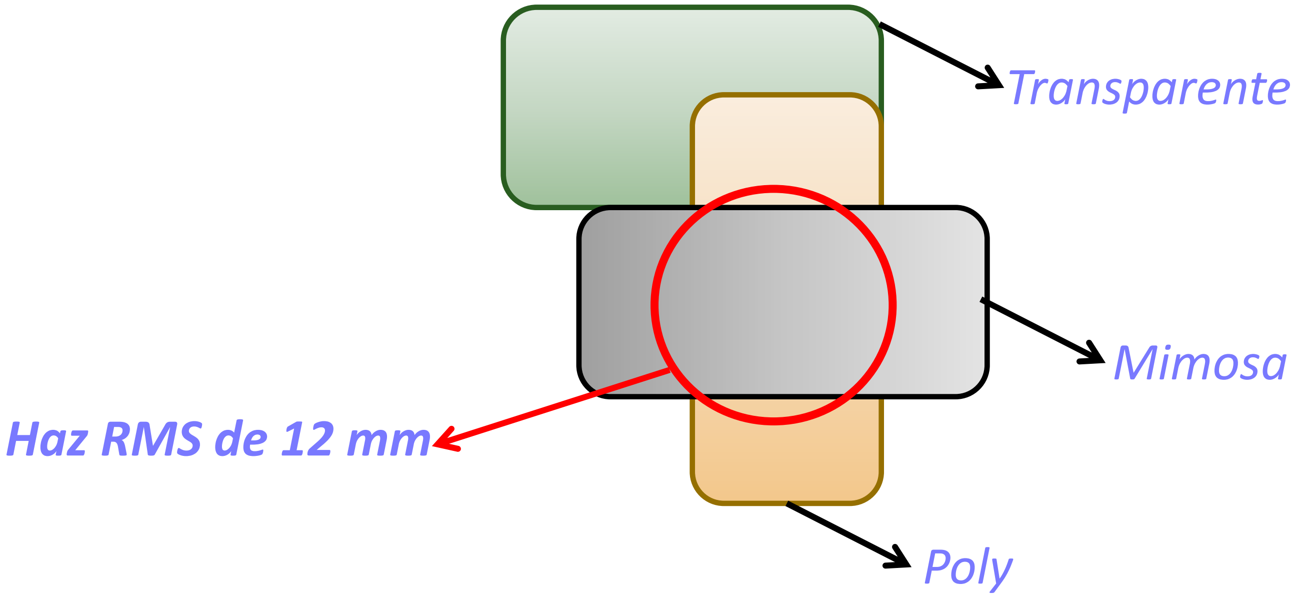
*Prelimirary results:*

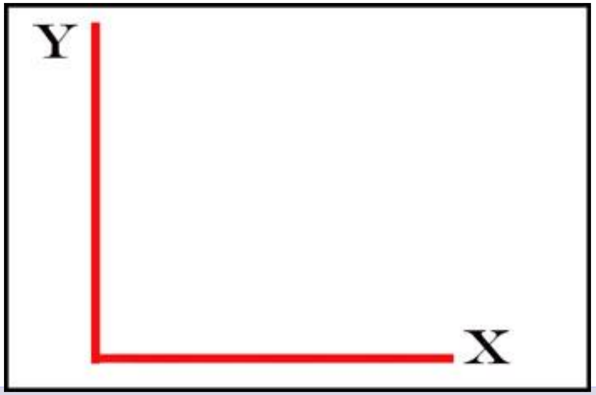
- *Monitoring of beam profile.*

*Currently in progress:*

- *Efficiency and resolution using tracking information.*

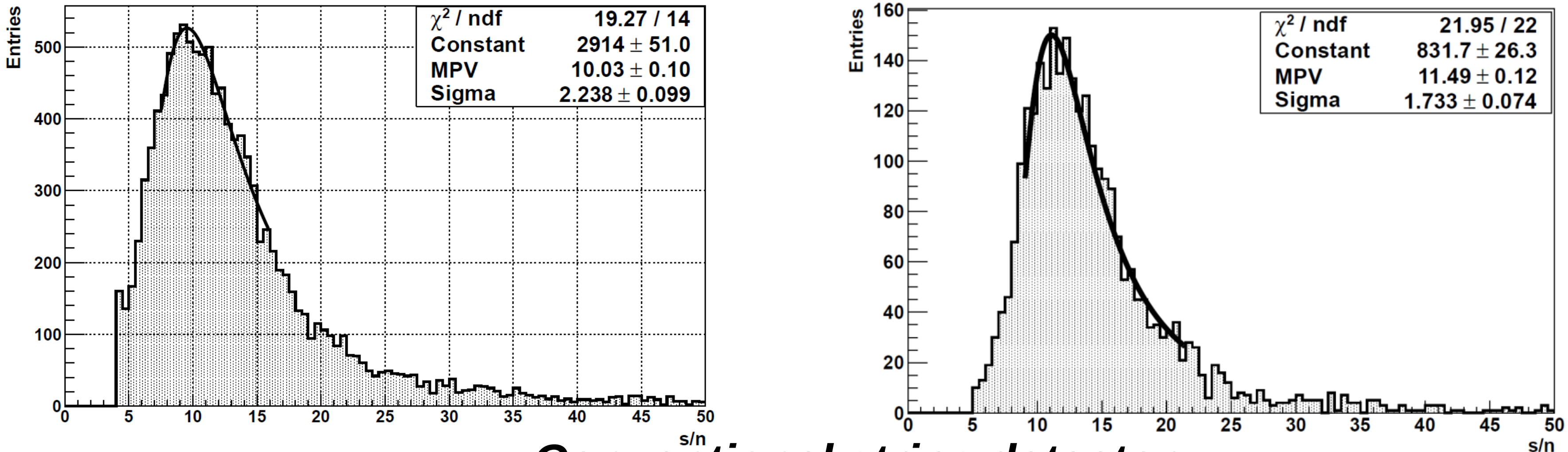
# *Vista frontal del setup a escala (aproximada)*



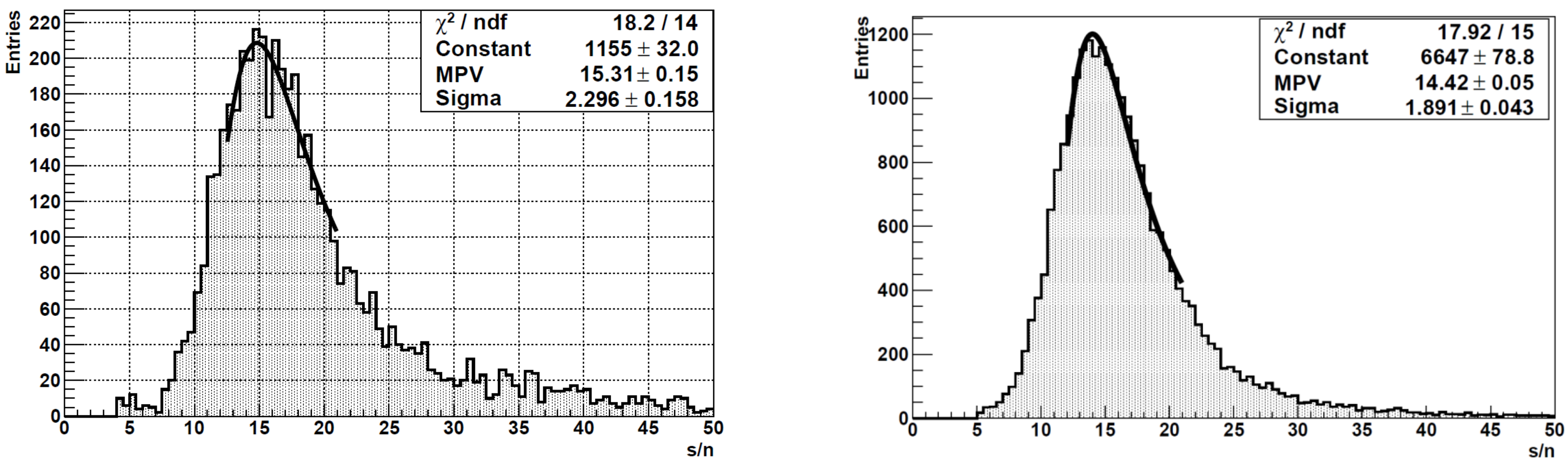



# s/n test beam vs s/n radioctive source

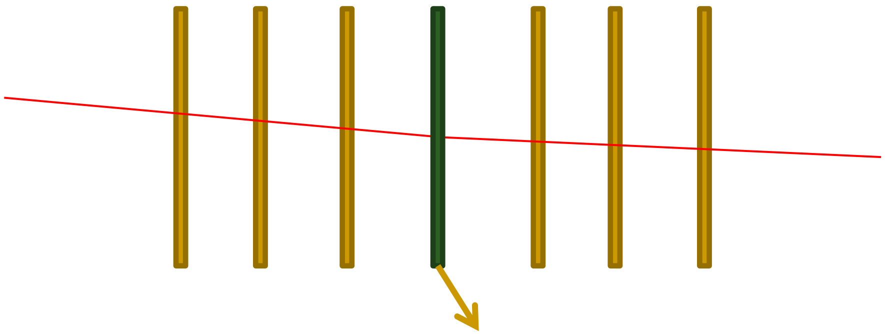
## *Resistive strips detector*



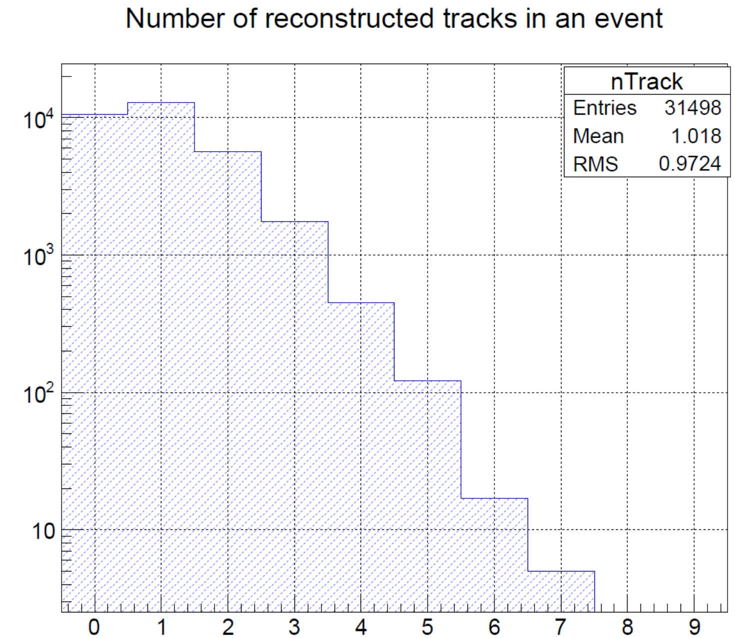

## *Conventional strips detector*



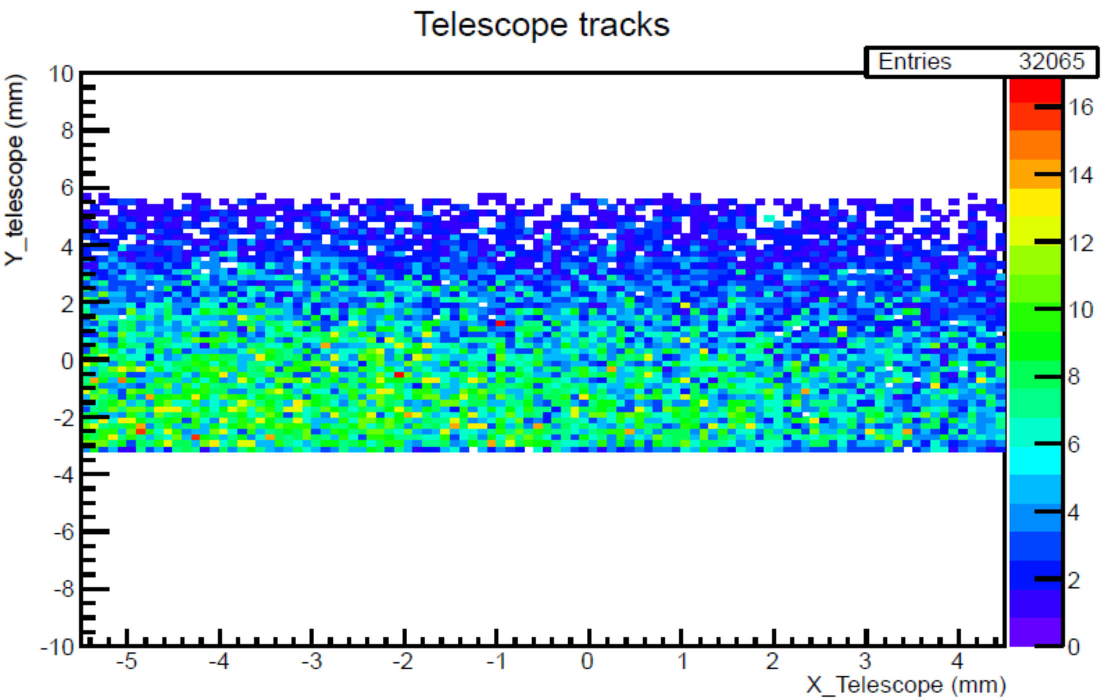
# Tracking (Telescopio)



*Proyección plano DUT*



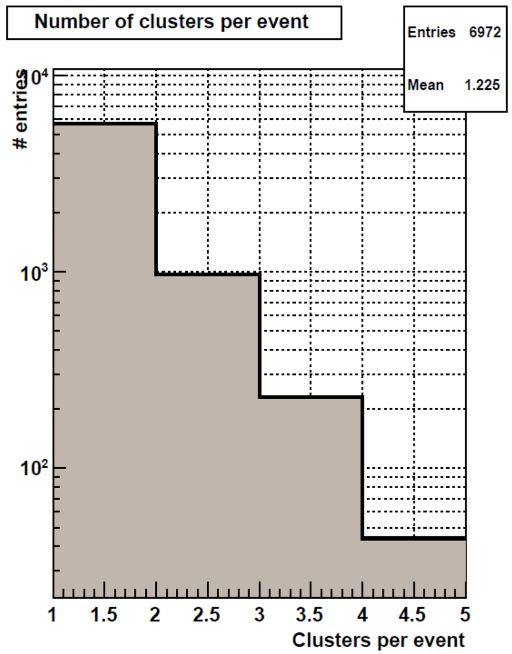

*Distribución del número de trazas*
*Totales por evento del telescopio*
*en el plano del DUT*

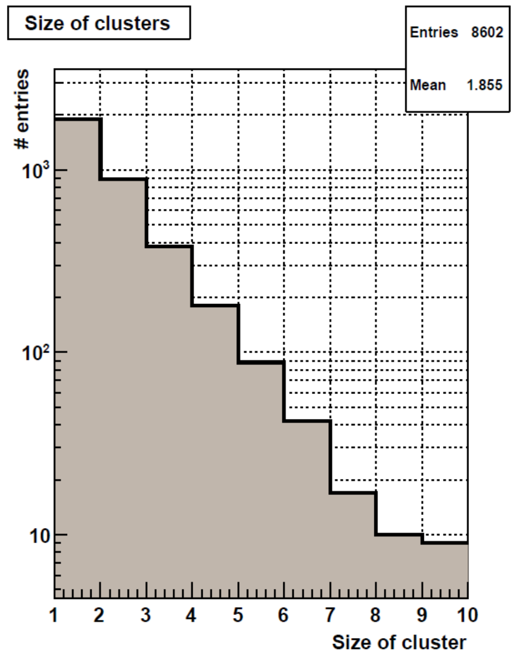



*Trazas del telescopio proyectadas*
*en el plano del DUT*

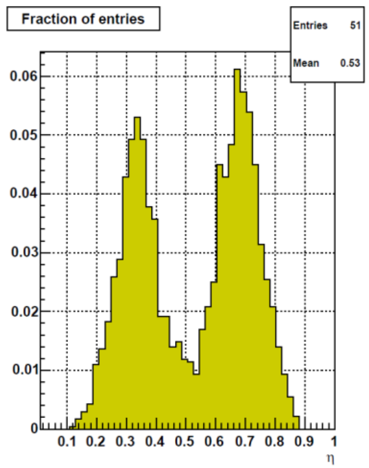
# Tracking (PolyA)

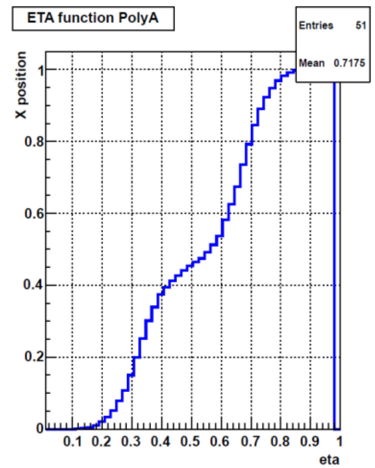
*Distribución del número de clusters*
*Detectados en el DUT:*
*Corte de 4 y 2 sigmas*
*No hay corte en tiempo 0-100 ns*
*Con un corte de 20-40 ns (selecciono el pico), no varían las resoluciones.*

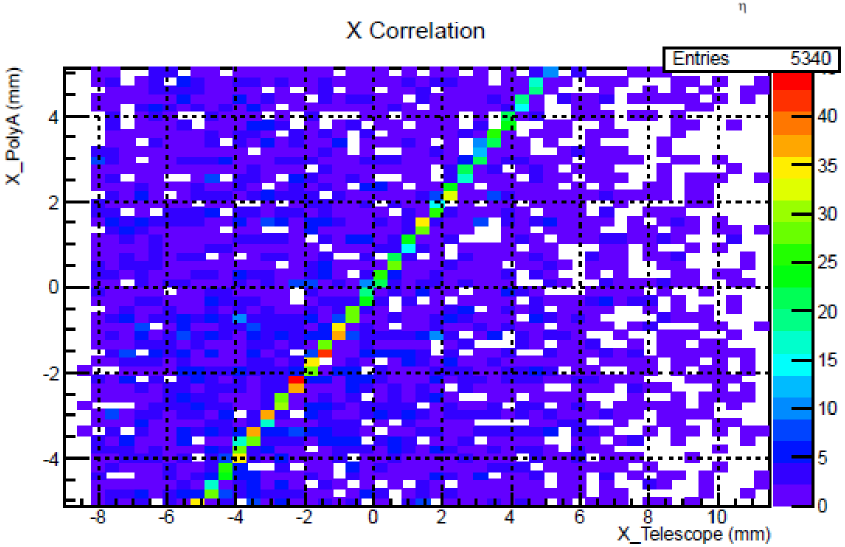


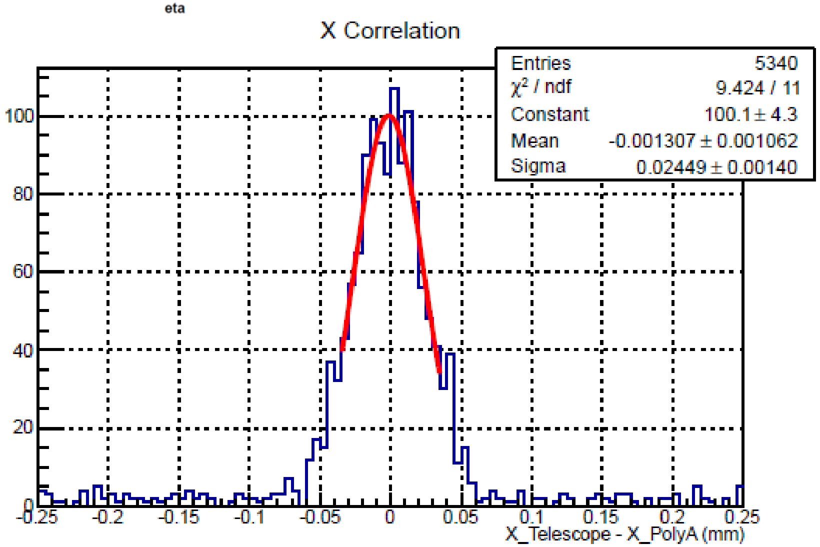



# X Resolution (transversal)



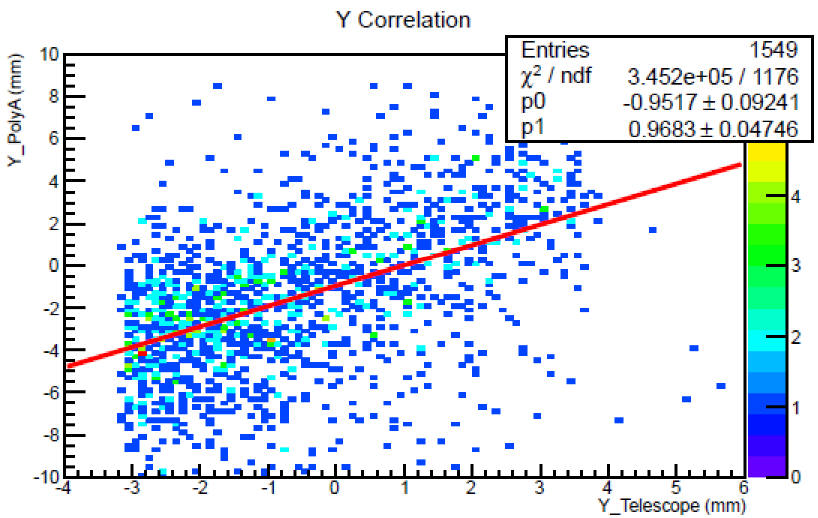



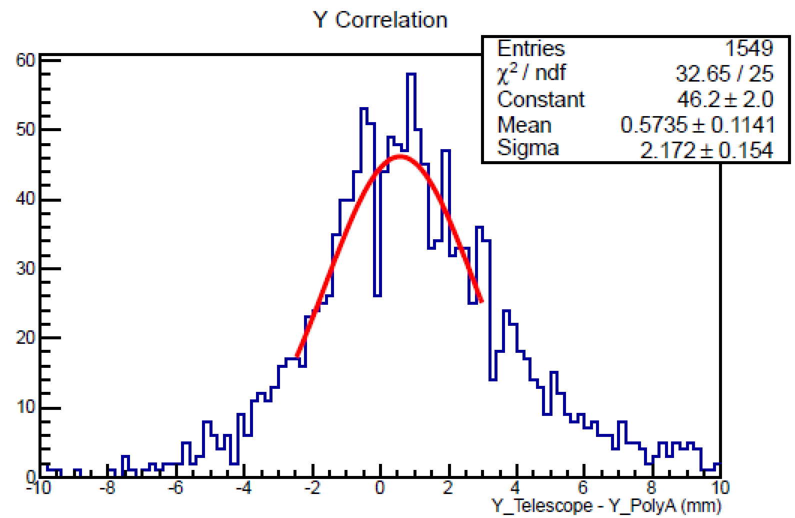



# Y resolution (logitudinal)

*Se usan sólo los clusters que machean previamente el la posición transversal,*
*Se toma un corte de 5 sigmas (0.025 mm).*



# Summary

- In terms of position resolution the sensors behaves as predicted. Is it enough ?
- No result on efficiency due to problems with the timing sensor  and wrong  sensor biasing.

# 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.

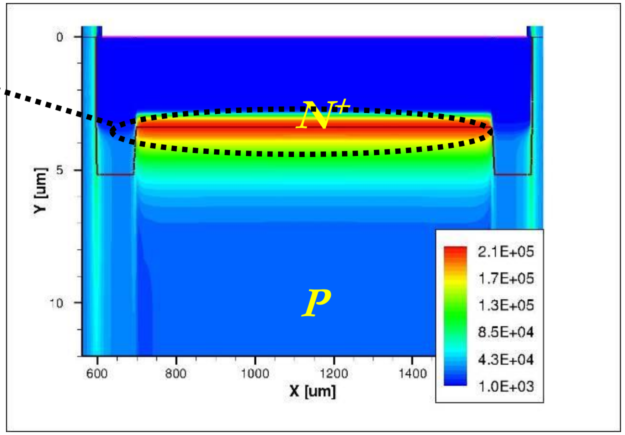
http://rd50.web.cern.ch/rd50/

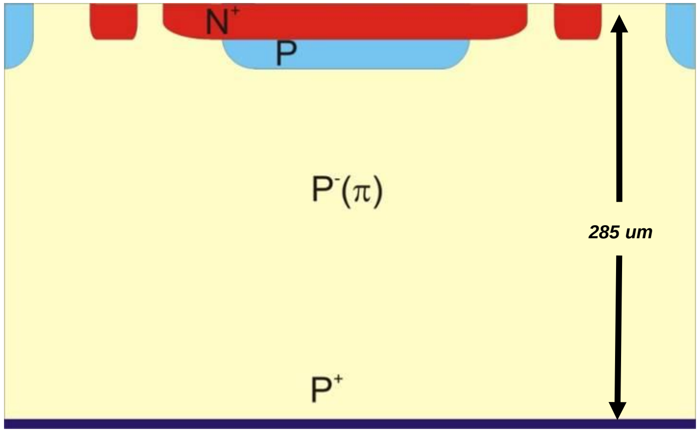
# Low gain avalanche detectors (LGAD)

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*



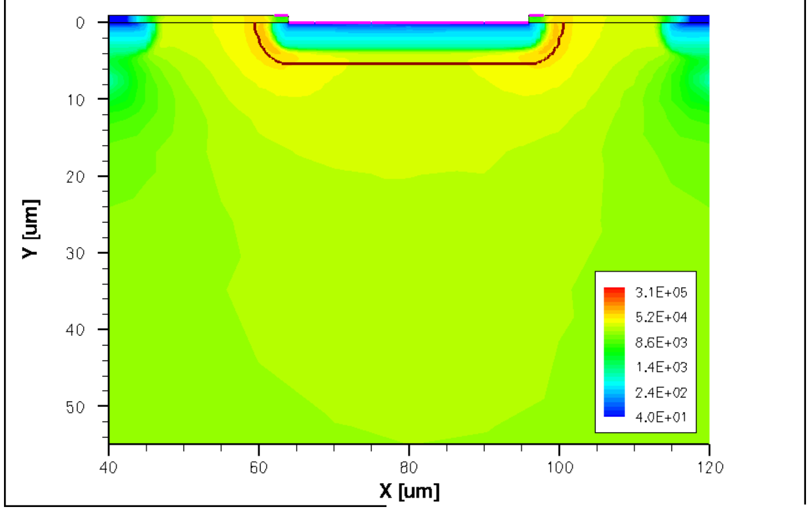




*P. Fernandez et al, "Simulation of new p-type strip detectors with trench to enhance the charge multiplication effect in the n-type electrodes" , Nuclear InstrumentsandMethodsinPhysicsResearchA658(2011) 98–102.*

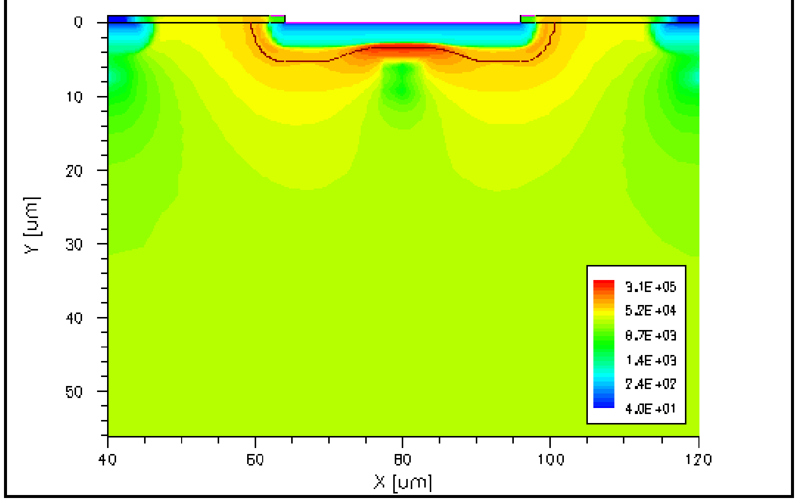
# Simulation of the Electric Field

- *To obtain the manufacture parameters (doping profiles)*

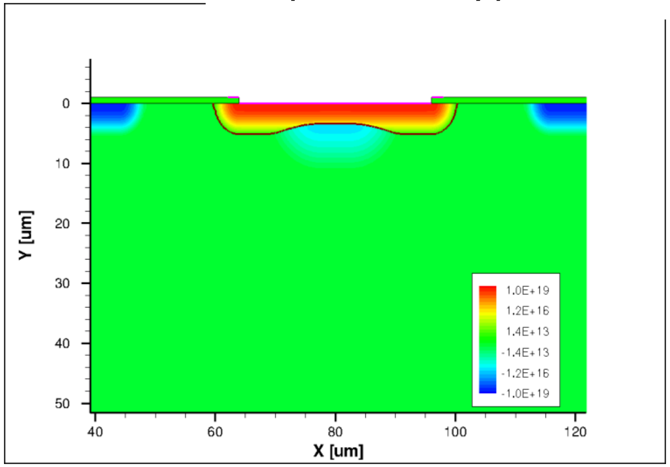
*Standard Strip*

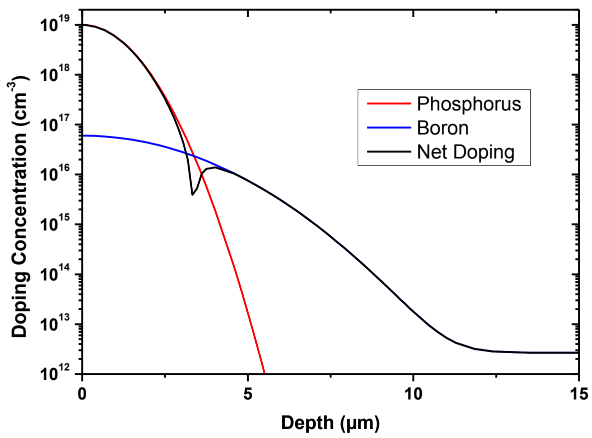



*Strip with P-type diffusion*




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



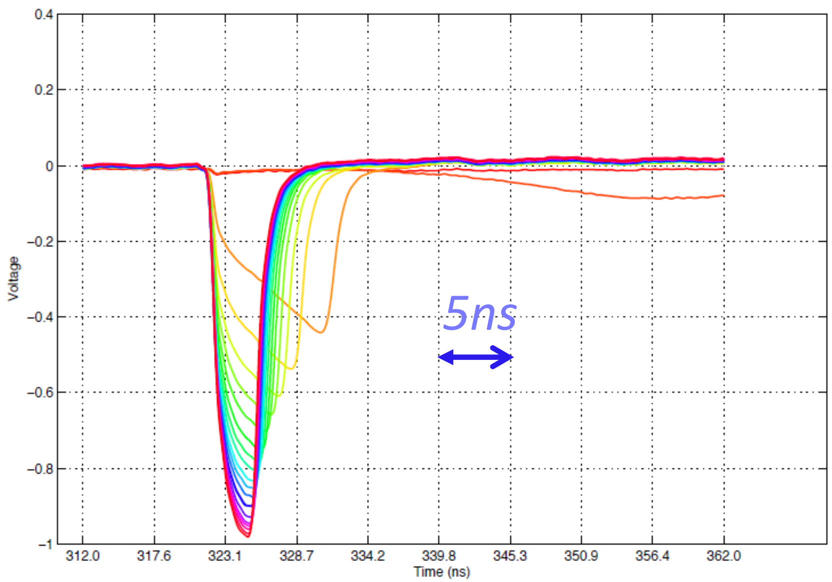



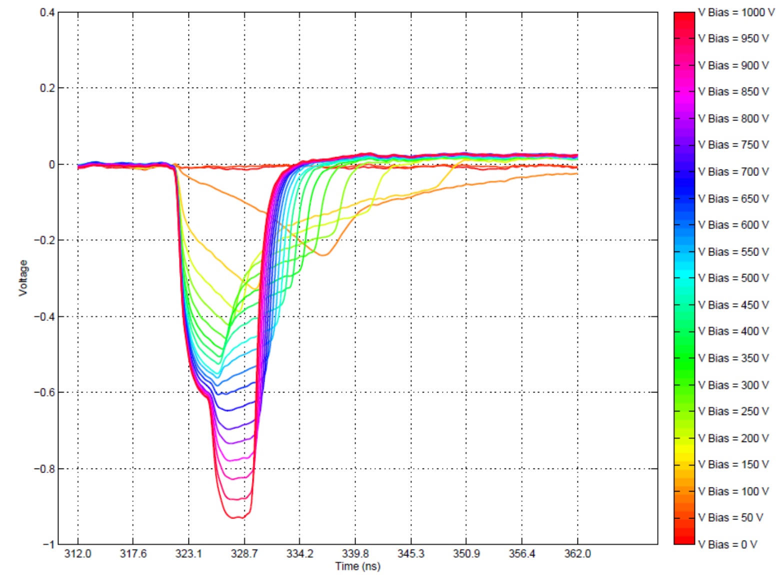
# Red laser TCT characterization

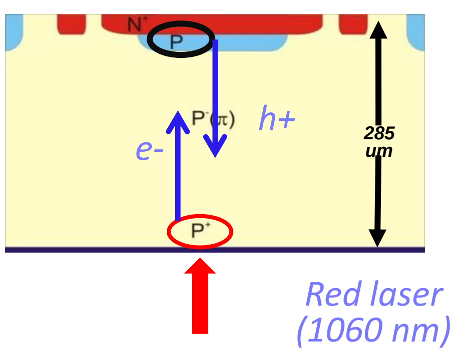
*Bottom injection*

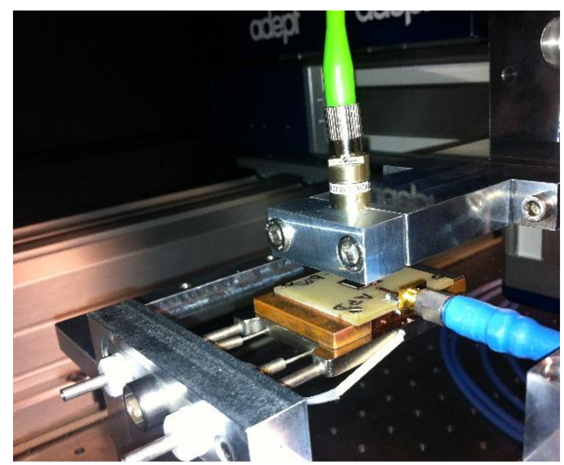
*Standard diode n on p*

*P-type diffusion diode*



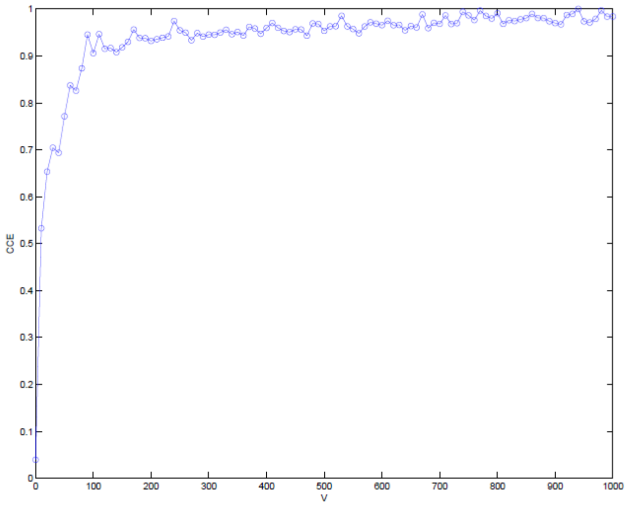



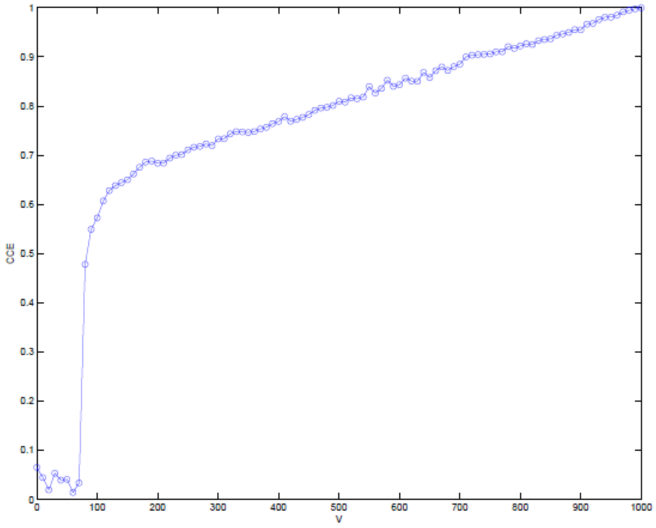
# Red laser TCT characterization

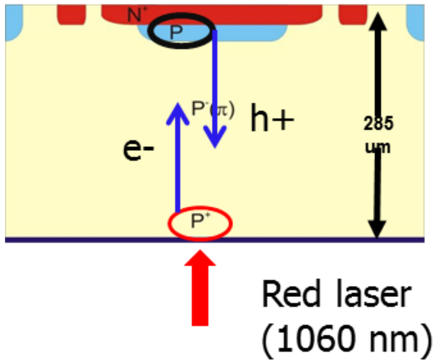
## *Charge collection efficiency*

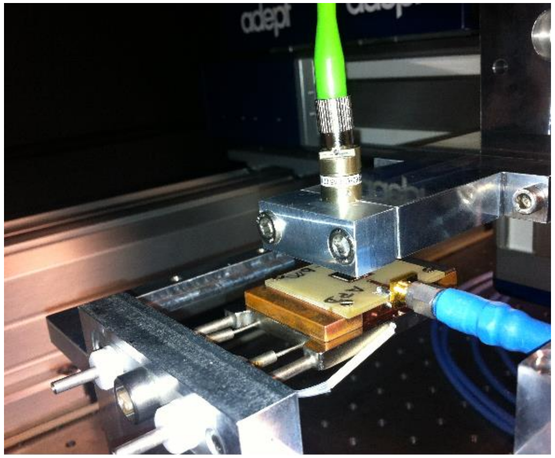
*Standard diode*




*P-type diffusion diode*



# GRACIAS !