# Overview of Spanish Activities for FLC

Alberto Ruiz-Jimeno (IFCA, CSIC-Univ. Cantabria)
(on behalf of the Spanish Network for Future Linear Accelerators)

PAC Review VALENCIA

# Coordinated FLC detector- effort in Spain

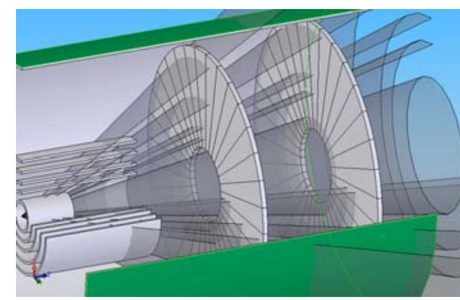

## Silicon for Large Colliders

**IFIC, IFCA (since 2005), UB, CNM, USC**
**IFCA→EUDET member, several associates**
**New EU project: AIDA**

**Strong Spanish participation in DEPFET**
**IFIC (since 2005)**
**USC, UB, URL, CNM (since 2008)**
**IFCA ( mechanical alignment and integration)**

## CALICE

CIEMAT Madrid

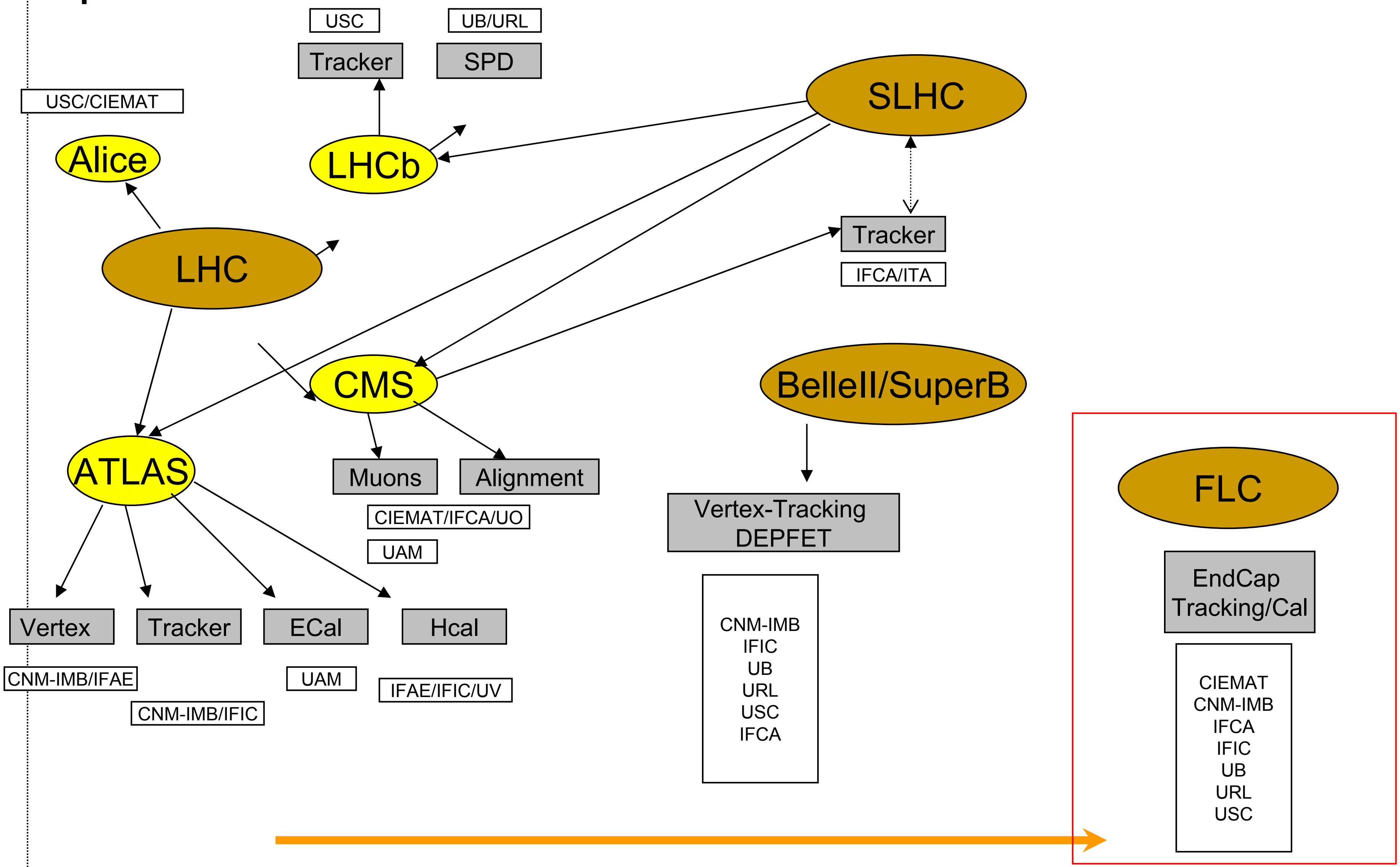


***and activities in accelerators R&D***

***Also some theoreticians involved***

**Coordinated effort :**
- **regular meetings**
- **funding/projects**
- **R&D interests**
- **the forward tracker…**

# Spanish interest and evolution

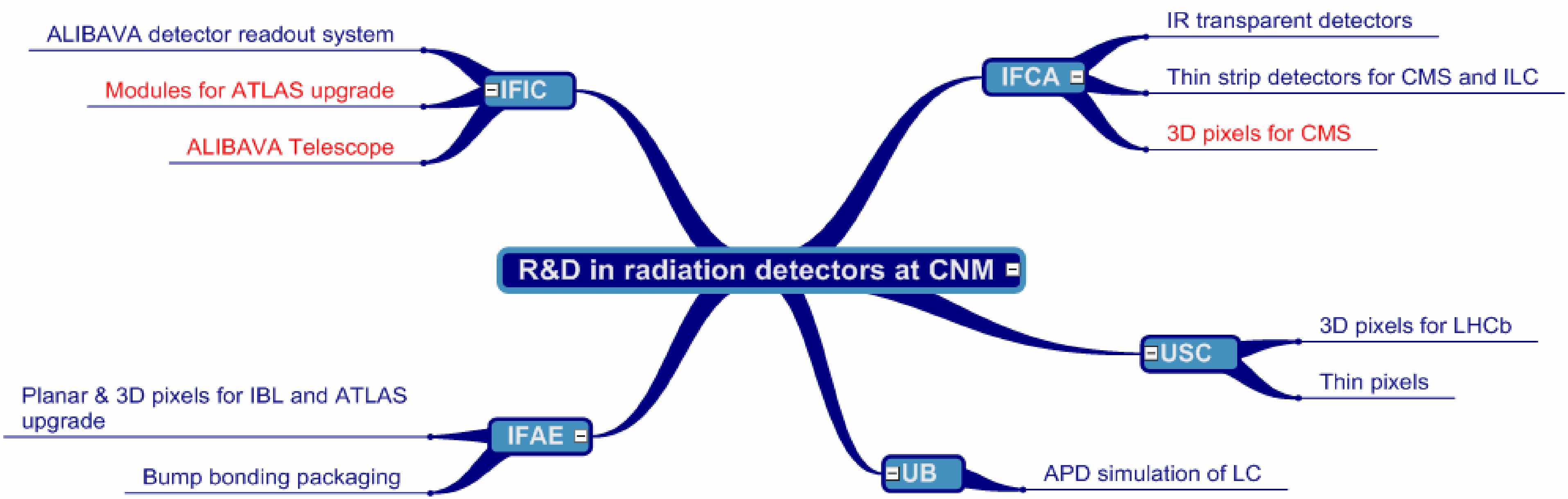


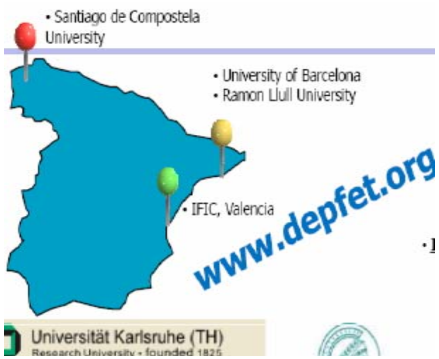
Strong Collaboration between different groups

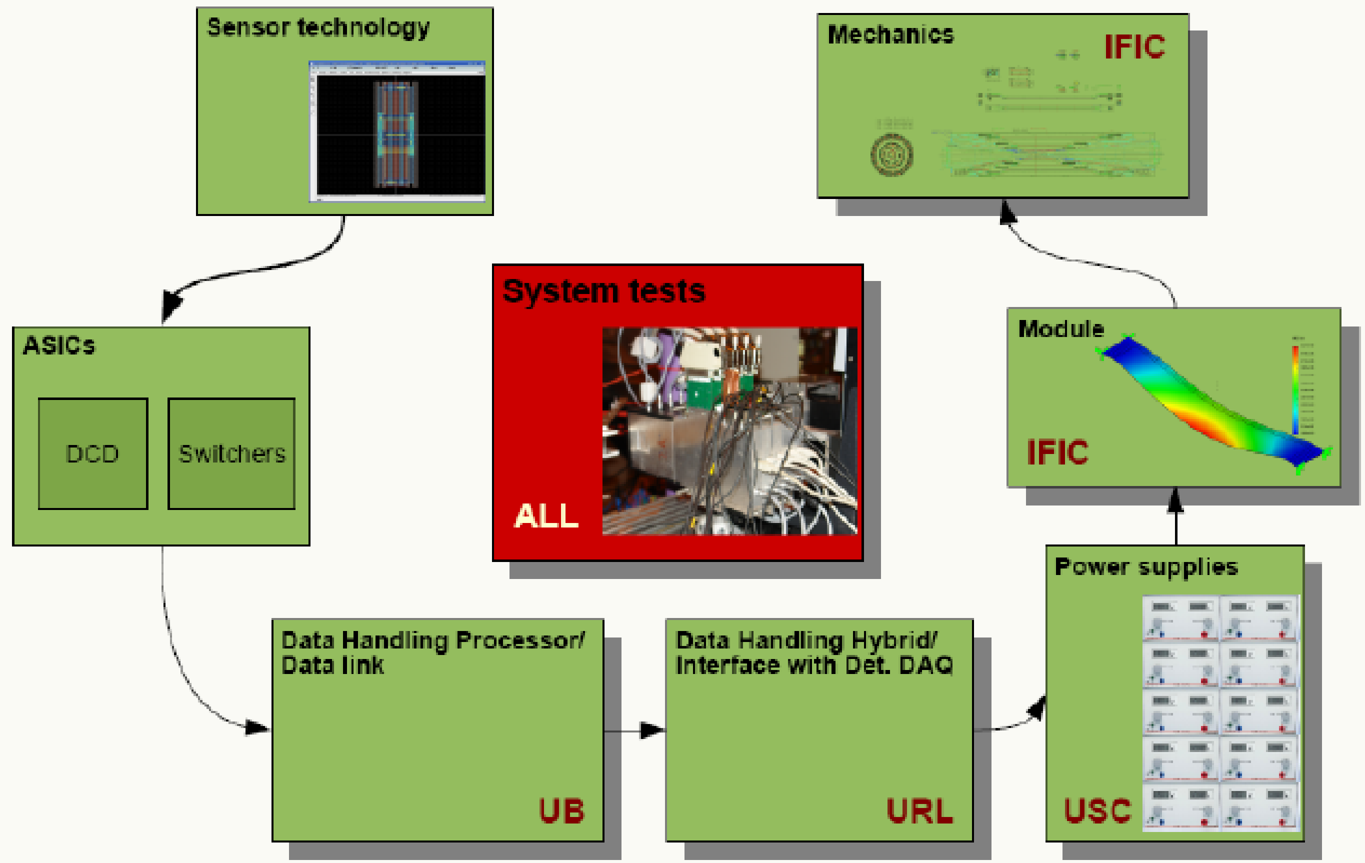
CNM-IMB infrastructure used for R&D, for Future L.C. in particular

**Easy access through the Spanish "Access to Large Facilities" Program: ICTS GICSERV**

**New ion implanter for 6''**

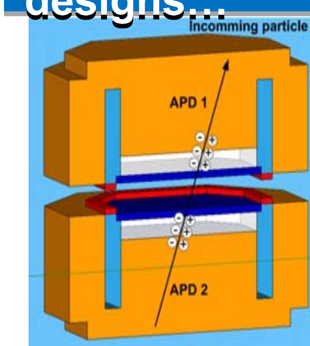





( high gain, simple readout electronics, so low power consumption, extremely fast response)

## Future designs…

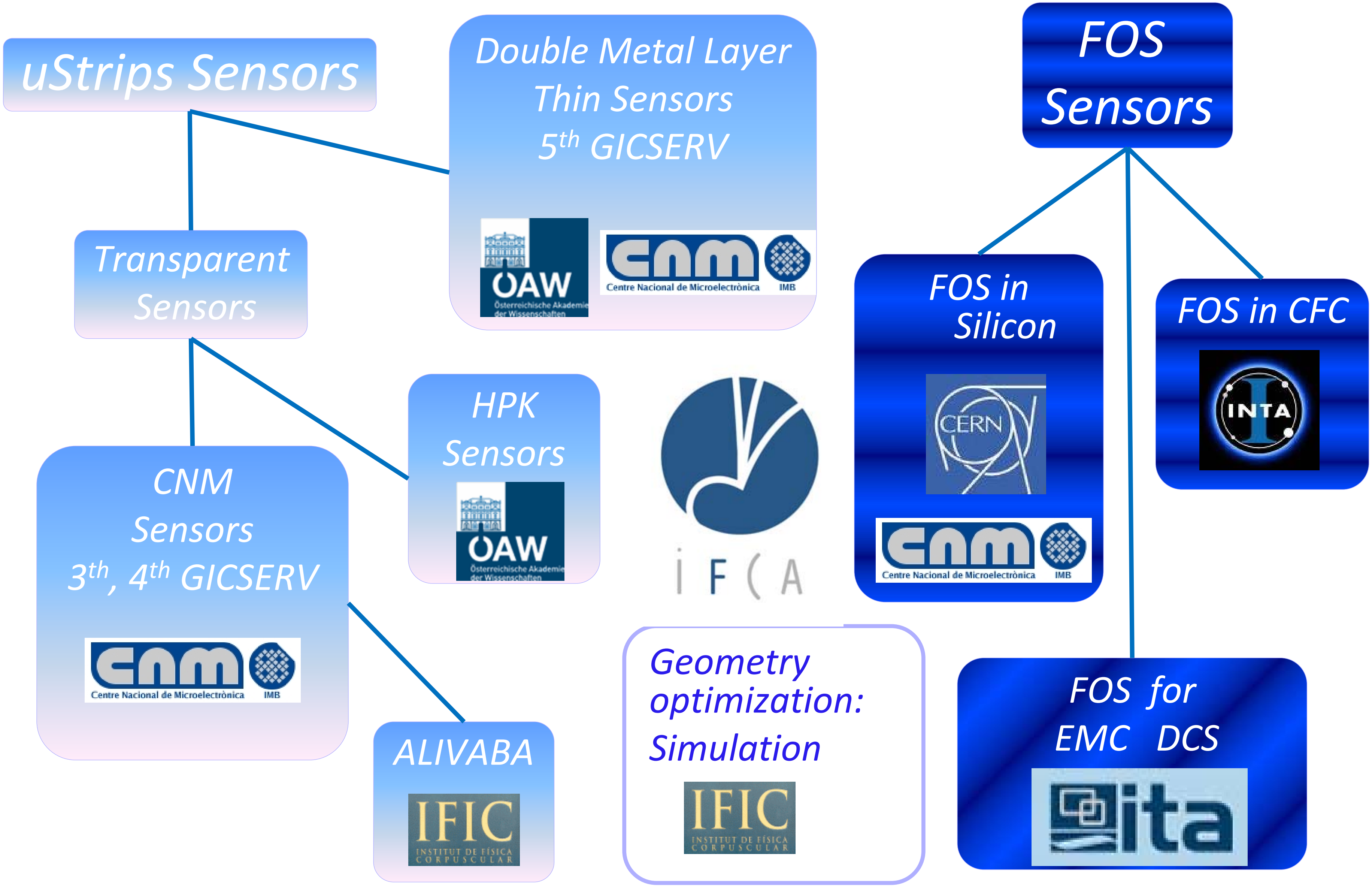



## Avalanche photodiodes in standard CMOS technologies

**Learning from the fabricated structures:** STM 130nm, AMS 0.35um

*Detector instabilities (dark counts, afterpulsing, cross-talk)*

**Trying to learn also from device simulations**


uStrips Sensors
Double Metal Layer
Thin Sensors
5th GICSERV
ÖAW
Österreichische Akademie der Wissenschaften
CNM
Centre Nacional de Microelectrònica
IMB
Transparent Sensors
HPK Sensors
ÖAW
Österreichische Akademie der Wissenschaften
CNM Sensors
3th, 4th GICSERV
CNM
Centre Nacional de Microelectrònica
IMB
ALIVABA
IFIC
INSTITUT DE FÍSICA CORPUSCULAR
IFCA
Geometry optimization:
Simulation
IFIC
INSTITUT DE FÍSICA CORPUSCULAR
FOS Sensors
FOS in Silicon
CERN
CNM
Centre Nacional de Microelectrònica
IMB
FOS in CFC
INTA
FOS for EMC DCS
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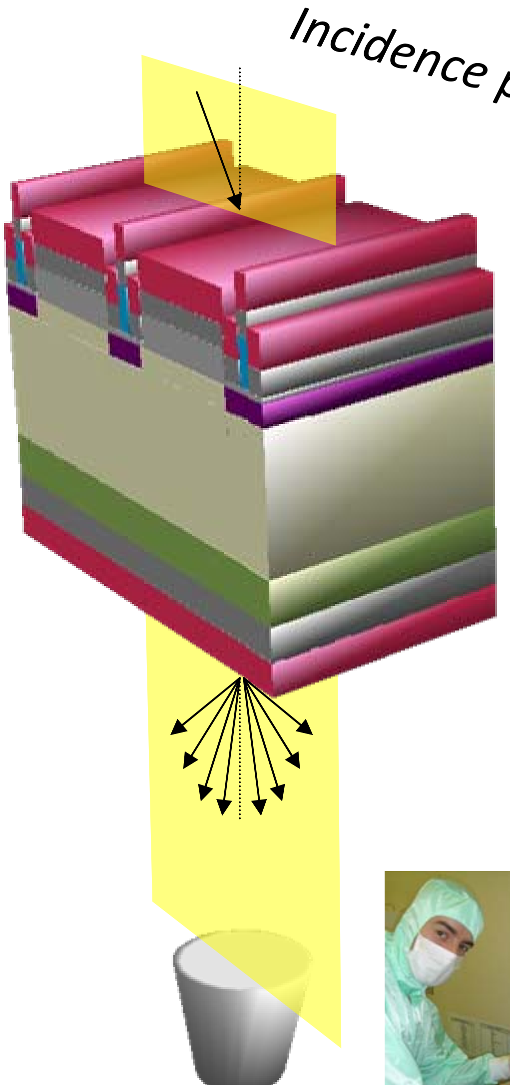
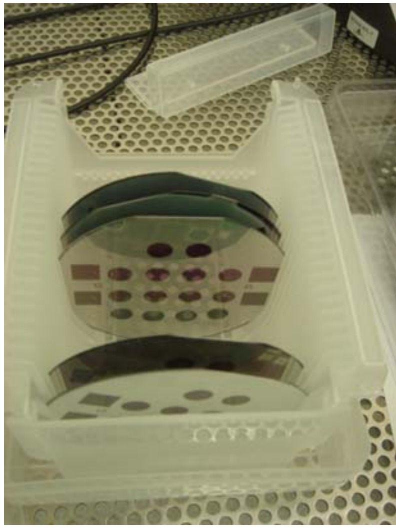
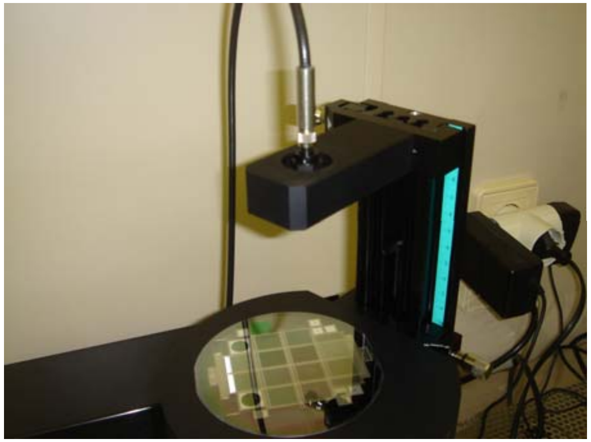
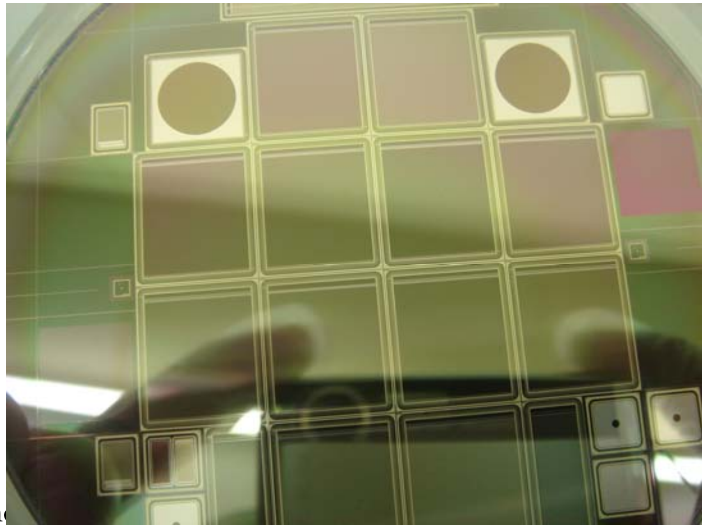
# Alignment: Optical computation validation:




1. Validation of optical simulation software with material samples (planar multilayer samples) Obtain optical parameters
2. Validation of optical simulation for layered diffraction grating.
3. Optical simulation of optical test structures and actual sensors.

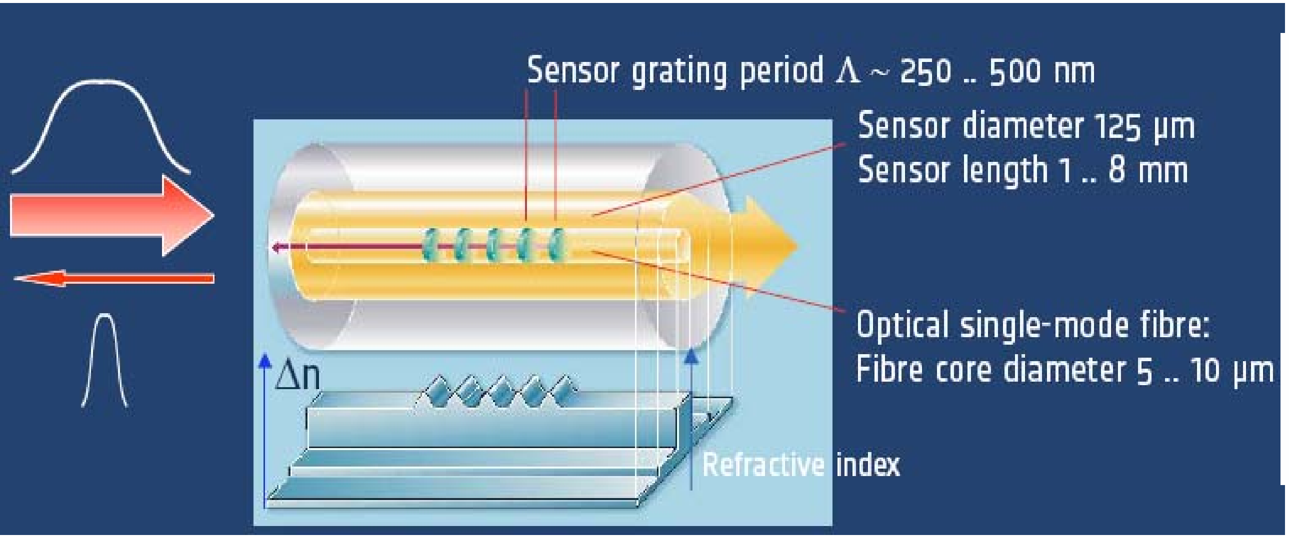


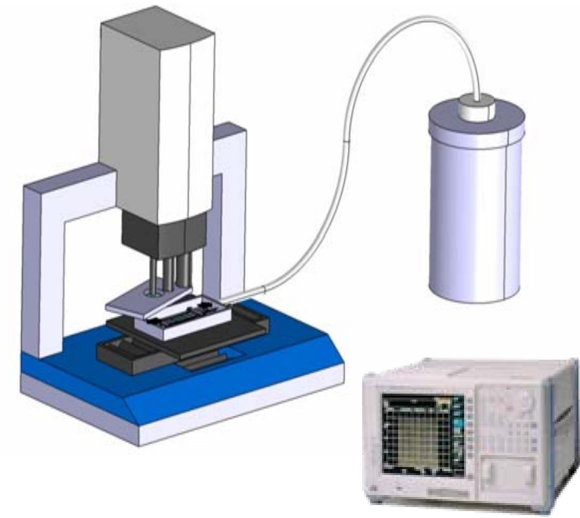


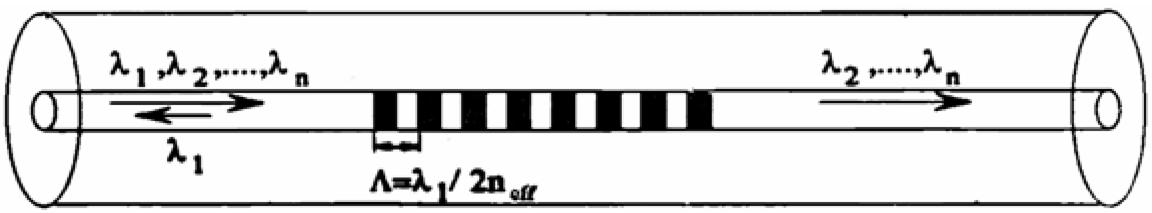


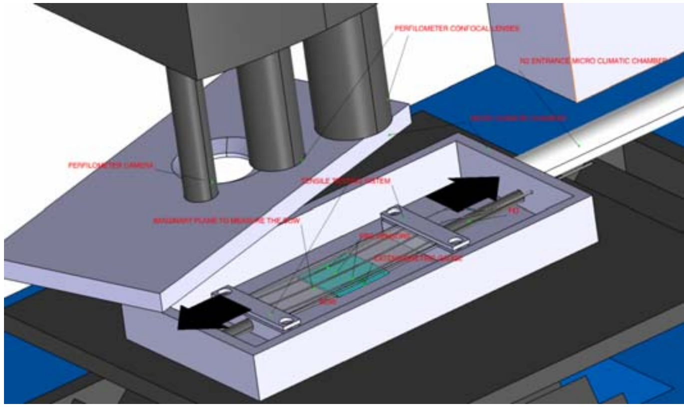
# R&D on mechanics: Bragg grating

- Fiber Bragg Grating optical transducer very common to measure strain and temperature



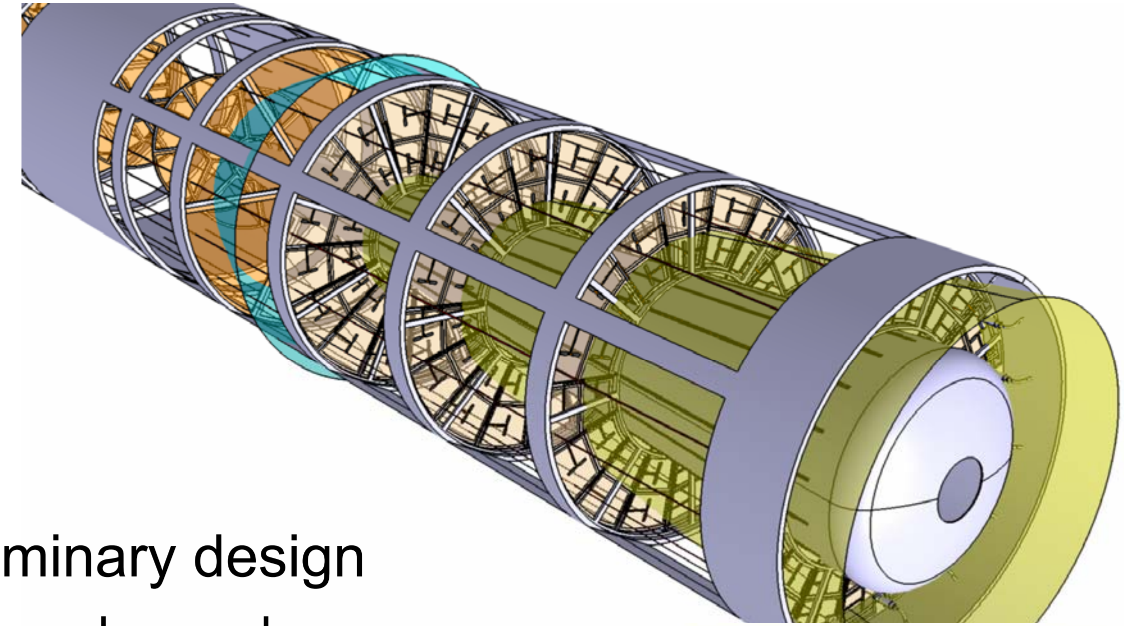





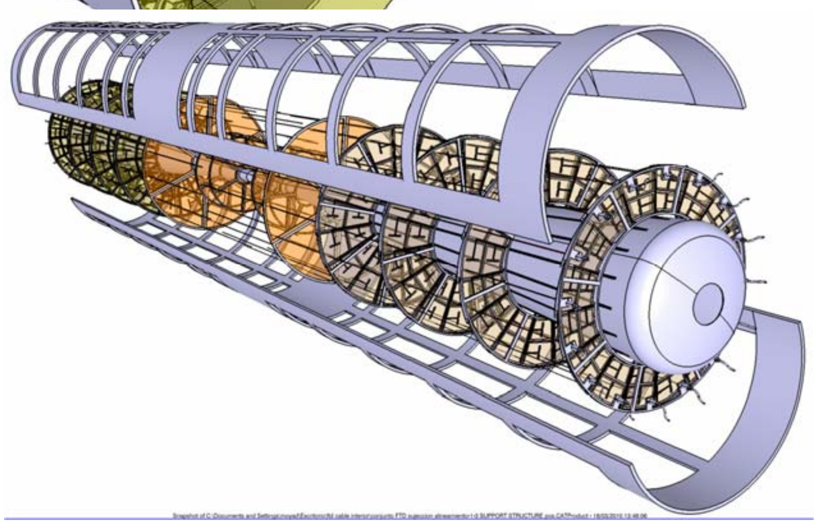



Calibration of bare fibers with different coattings (acrylate, polyimide, ormocer) and without coattings.

# Towards an engineering design



- Naïf preliminary design
  - Must be enhanced
    - June Workshop in Paris ( Vertex, MDI,FTD)
    - Cabling / Services
    - Realistic Module design
    - Support Structure
      - Beam Pipe / Vertex / FTD as a part (IMP)
      - IMP with TPC



(Plots:David Moya (IFCA))

# Forward tracking physics case

Forward tracking requirements at the next $e^+e^-$ collider
part I: the physics case for forward tracking

J. Fuster [v], S. Heinemeyer [s], C. Lacasta [v], C. Mariñas [v], A. Ruiz [s], M. Vos [v*]

[s] IFCA Santander

[v] IFIC Valencia

February 12, 2009

**Abstract**

In this note we explore the detector requirements of the forward tracking region for a future $e^+e^-$ collider with a center-of-mass energy in the range from 500 GeV to 3 TeV. The relevance of the forward region is explored for a wide range of physics processes.

Little guidance for forward detector design from standard benchmark reactions ($\cos\theta < 0.95$)

**Together with many other analyses and channels that we didn't discuss:**

- $A_{FB}$ in the bb and cc system
- Degenerate staus and neutralino
- center-of-mass energy determination using $\mu\mu\gamma$ events

**These examples make the physics case for orward tracking:**

At a high-energy $e^+e^-$ collider several potentially very interesting physics analyses require excellent tracking and vertexing performance. These arguments become more urgent as the center-of-mass energy increases. Precise electron reconstruction is of particular importance.

# CALICE

|  | Absorber | #layers | Cell | Sensor |
|---|---|---|---|---|
| **ECAL** | W | 20-30 | 0.5x0.5mm$^2$ | Si |
| **(D)ECAL** | W | 20-30 | 0.04x0.04mm$^2$ | MAPS |
| **ECAL** | Pb | 20-30 | 1x1cm$^2$ | Scintillator |
| **AHCAL** | Steel | ~50 | 3x3cm$^2$ | Scintillator |
| **(s)DHCAL** | Steel | ~50 | 1x1cm$^2$ | GRPC/GEM/μMEGAS |

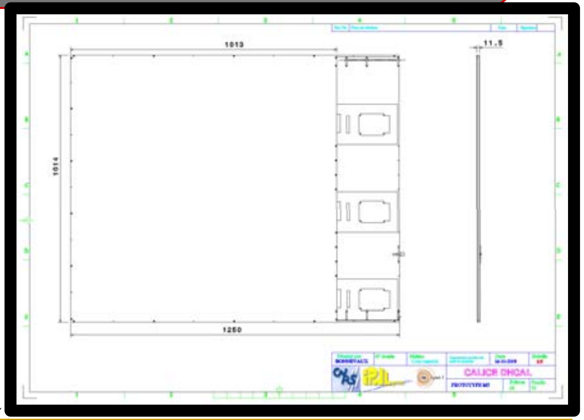
**Main CIEMAT participation**

**Semi Digital HCAL using GRPCs or Micromegas as active material.**

**Purpose: assembly of a 1m$^3$ physics prototype to be tested together with other CALICE prototypes. In order to validate PF**

**Main CIEMAT contribution. It will consist of 40 to 50 layers of detector/absorber. Enough to contain hadronic shower.**

**Working on design (technological prototype, having in mind using ILD techniques for a final design)**



Aims:

- LongTerm: participate in the design and construction of the forward tracker and vertex detectors of the FLC

→

- Research and development of technologies to reach accurate and efficient reconstruction of charged particle trajectories as well as primary and secondary vertexes
- Alignment and Integration
- Simulation and optimization studies
- Calorimetry, particle flow algorithms,…

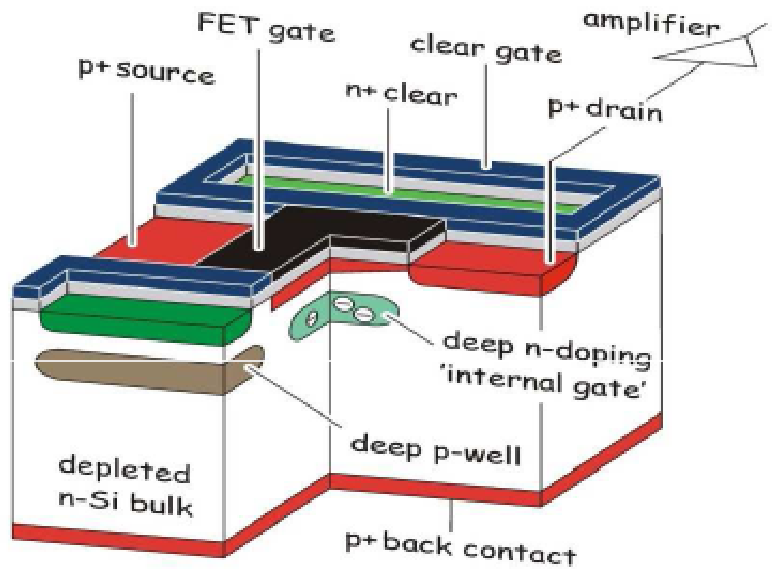
# Backup

# DEPFET – DEpleted P-channel Field Effect Transistor

- Each pixel is a p-channel FET integrated on a completely depleted bulk.
- A deep n-implant creates a potential minimum for electrons under the gate (internal gate)

- Signal electrons created in the substrate are accumulated in the internal gate and modulate the transistor current ($g_q \approx 600 pA/e^-$)
- Accumulated charge can be removed by a clear contact placed in the periphery of each pixel

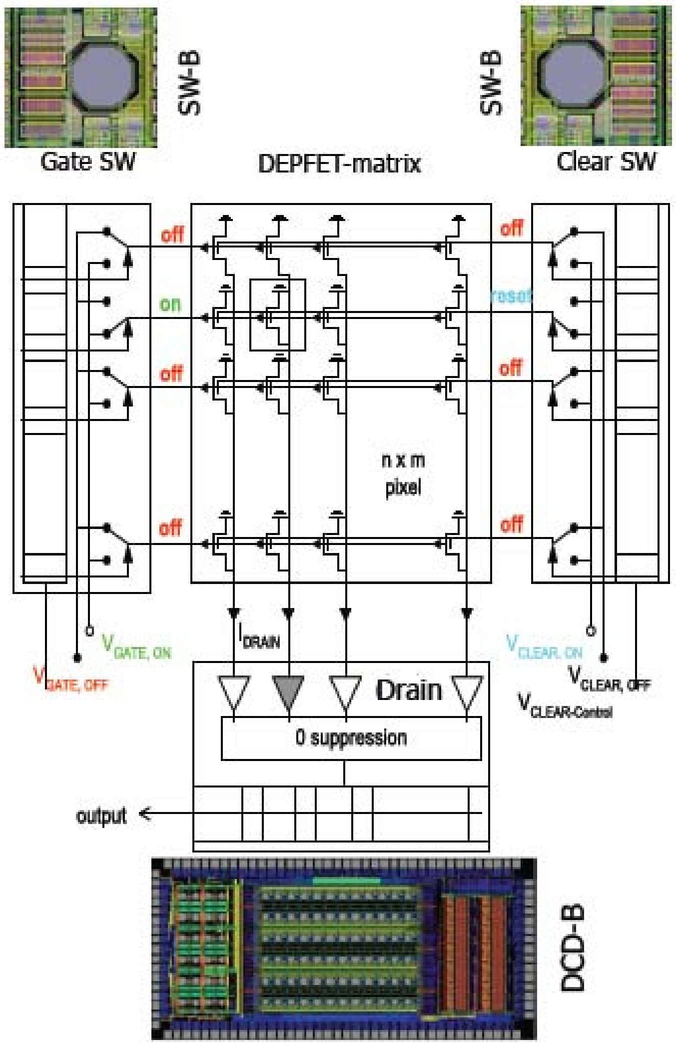
- Internal amplification
- Low power consumption: Readout on demand (Sensitive all the time, even in OFF state)




**GOAL (ILC)**

- Small pixel size ~25μm
- r/o per row ~50ns (20MHz) (drain)→Fully depleted bulk
- Noise≈40e⁻ at high bandwith→Small capacitance and first in-pixel amplification
- Thin Detectors≈50μm

# DEPFET Basics: Readout

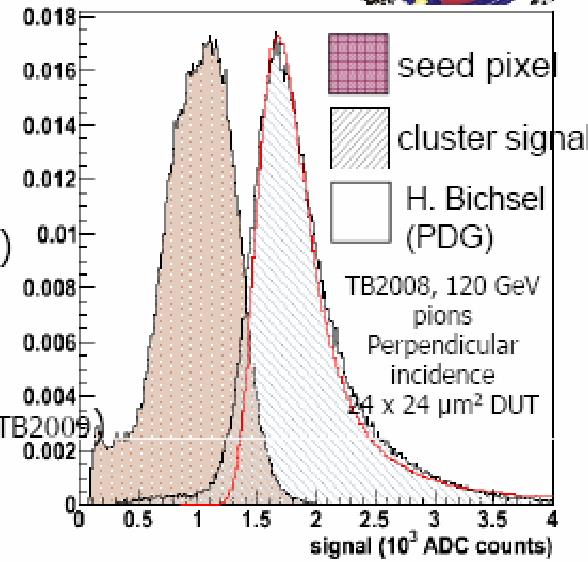



Row wise r/o (Rolling Shutter):

- Select row with external gate, read current, clear DEPFET, read current again The difference is the signal
- Low power consumption: Only one row active at a time; Readout on demand (Sensitive all the time, even in OFF state)
- 100 ns readout time per pixel
- Two different auxiliary chips needed: Switchers for gate and clear
- Limited frame rate, but still: 50 kHz readout for 500 kPixel modules

## TB 2008 and 2009 results

- 64x128, 24x24 $\mu m^2$ Common Cleargate (TB2008)
  MPV=1715 ADC counts
  **$g_q$=363pA/e⁻**
- 64x256, 32x24 $\mu m^2$ Capacitative Coupled Cleargate (TB2009)
  MPV~2400 ADC counts
  $g_q$~500pA/e⁻
- 64x256, 20x20 $\mu m^2$ Common Cleargate, $Length_{Gate}$=5µm (TB2009)
  MPV~3100 ADC counts
  **$g_q$~650pA/e⁻** (2x previous $g_q$, as expected)

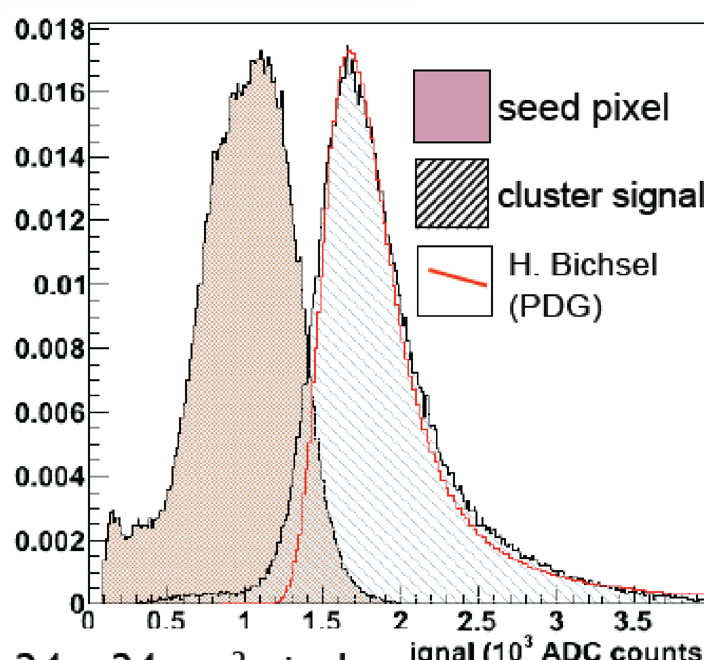



| Module # | 0 | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| X Residual (µm) | 2.9 | 2.2 | 2.3 | 2.0 | 3.1 | 3.4 |
| Y Residual (µm) | 2.3 | 1.7 | 1.7 | 1.7 | 2.2 | 2.6 |
| X Resolution (µm) | 2.1 | 1.6 | 1.9 | 1.3 | 2.6 | 2.4 |
| Y Resolution (µm) | 1.5 | 1.3 | 1.2 | 1.2 | 1.8 | 1.7 |

Extremely high resolution

DEPFET ( good resolution and sensitivity, low power consumption, low material budget, good Signal over Noise)

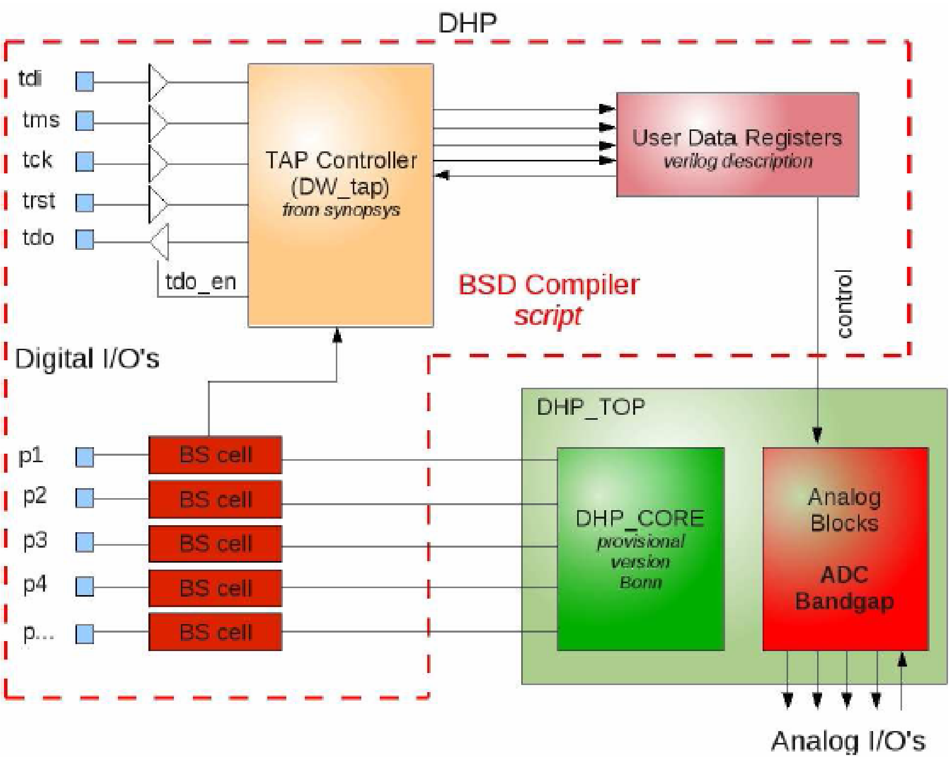
| | ILC | Belle-II |
|---|---|---|
| Occupancy | 0.13 hits/mm$^2$/s | 0.4 hits/mm$^2$/s |
| Radiation | < 100 krad/year | > 1Mrad/year |
| Duty cycle | 1/200 | 1 |
| Frame time | 25-100 µs | 10 µs |
| Momentum range | All momenta | Low momentum (< 1 GeV) |
| Acceptance | 6º-174º | 17º-150º |


- High spatial resolution for 24 x 24 µm$^2$ pixels: $\sigma_x$ = 1.3 ± 0.2 µm, $\sigma_y$ = 1.2 ± 0.1 µm

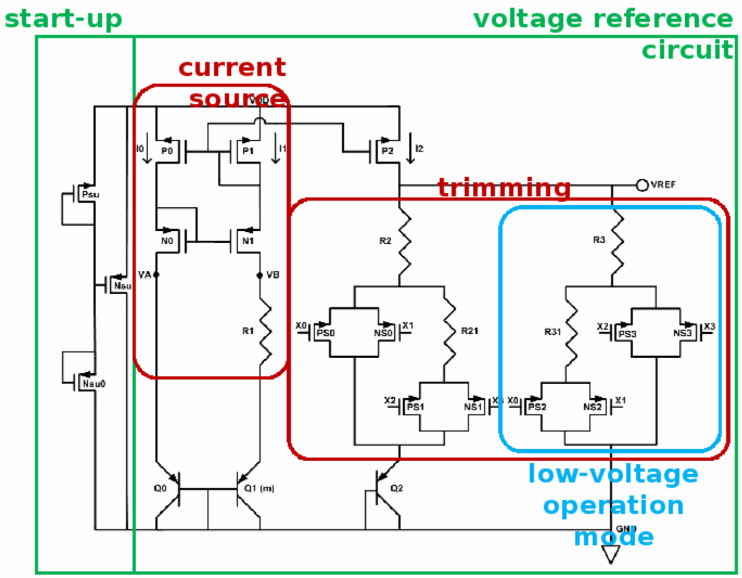
## Digital contribution to the DHP

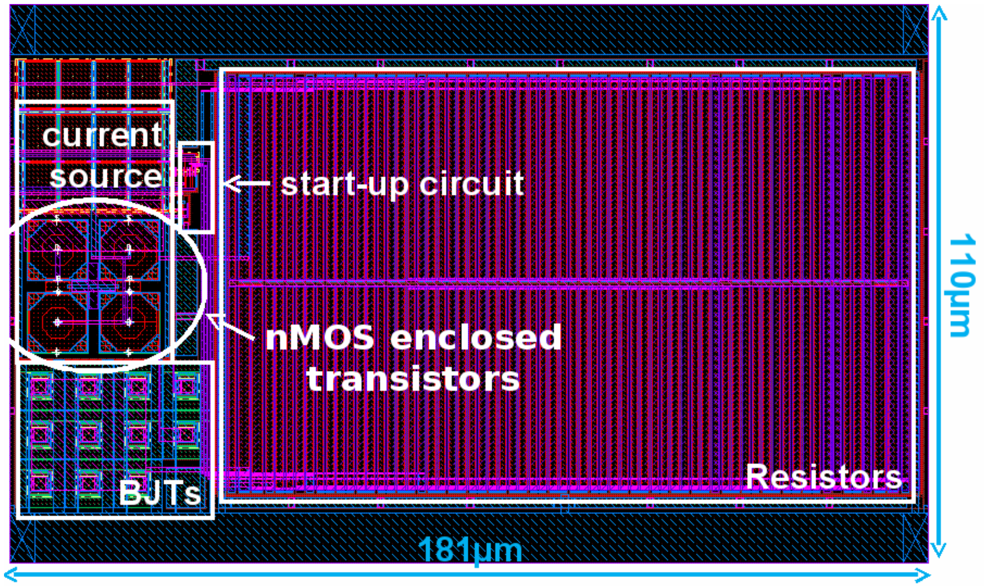
**Slow Control Interface:** User Data Registers connected to JTAG.
**Design for testing:** Automatic insertion of test and control logic compliant with IEEE 1149.1.
**Boundary Scan:** BS chain connected to the same JTAG.



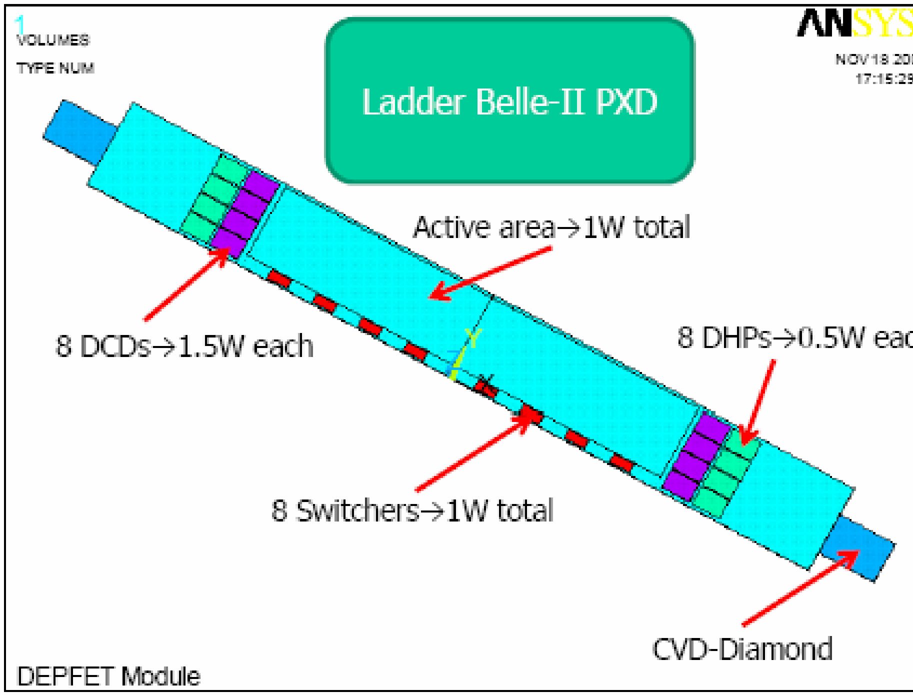
## Analog blocks

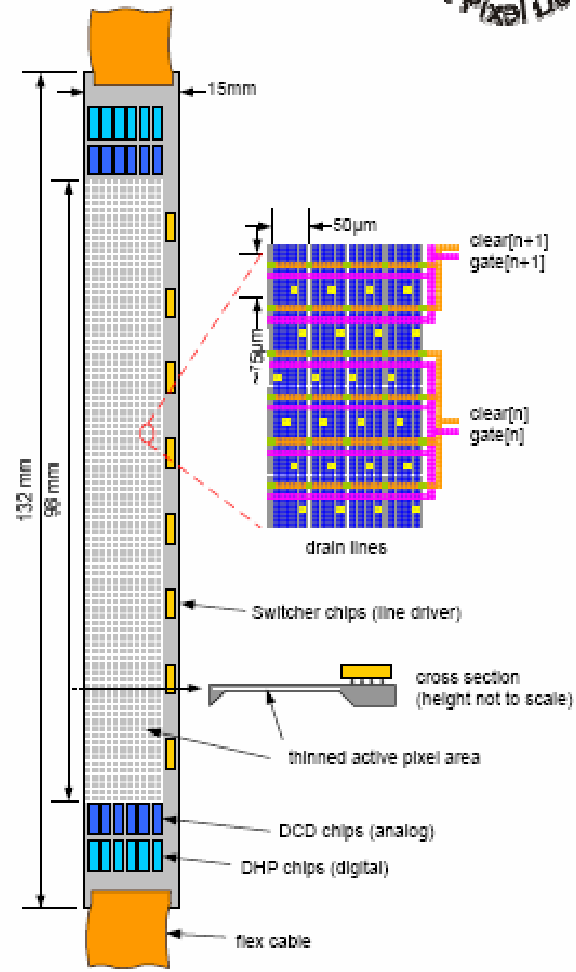
**Digital to Analog Converter:** 8 bits, slow (DC), 1V or 1V2 power supply, radiation tolerant.
**Bandgap:** 1V or 1V2 power supply, radiation tolerant.
**Analog to Digital Converter:** 10 bits, slow (DC), 1V or 1V2 power supply, radiation tolerant.
**Analog mux** for multiplexing ADC input



# Thermal studies




- Full Belle-II ladder implemented in FE software
- Development of cooling options imposing limits on the temperatures:

  $T_{max}$ (Sensor)<30ºC

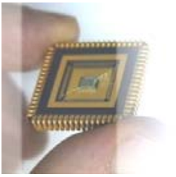
  $T_{max}$ (Chips)<60ºC

# The Road Ahead

- DEPFET technology matches Belle-II requirements
  - excellent signal to noise, low material budget for thin detectors, high resolution
- TDR for Belle-II in preparation: Submission in April

- Final DEPFET prototype production currently ongoing: Test devices in fall
  - Fully thinned modules: 50 μm thick silicon
  - Large size matrices, also ILC-type pixel geometry (small pixels)
  - ▸ Final production starting early 2011
- Foreseen start of Belle-II data taking in 2014

- Design for Belle-II PXD being finalized
  - Mechanical support with integrated cooling structure
  - Performance and background studies under way
  - DAQ System being developed



# ASIC Design

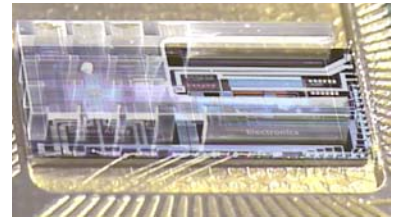
## RESEARCH LINES

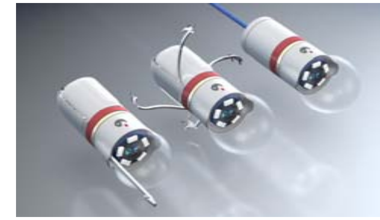
**Design and Test of Analogue and Mixed-signal Systems**
- Sensor interfaces
- Low cost vision systems
- Measurement/Control in high energy physics

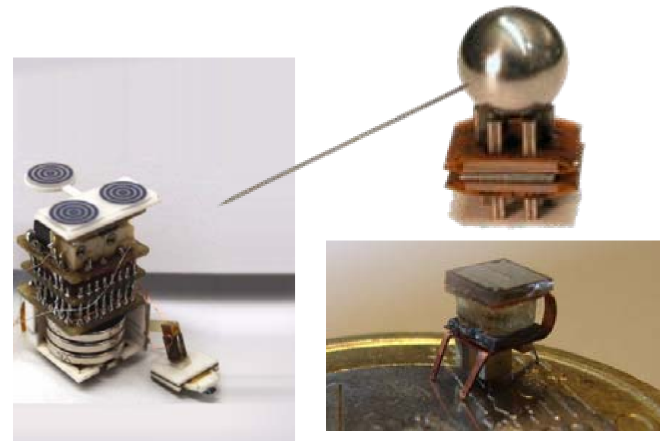
**Design and Test of Digital ICs**
- Smart-power digital control systems
- HW/SW embedded systems
- SoC plattforms for embedded aplications
- Low power high performance CMOS circuits
- Microarchitecture design
- Reconfigurable HW and retargetable architectures

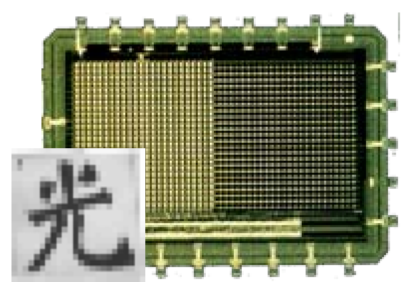
**Smart Power Integrated Circuits**
- DC-DC converters
- LDO regulators
- Inductorless DC-DC Converters

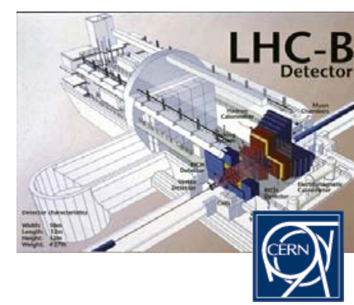
**Formation of Engineers in Design and Test of VLSI systems**



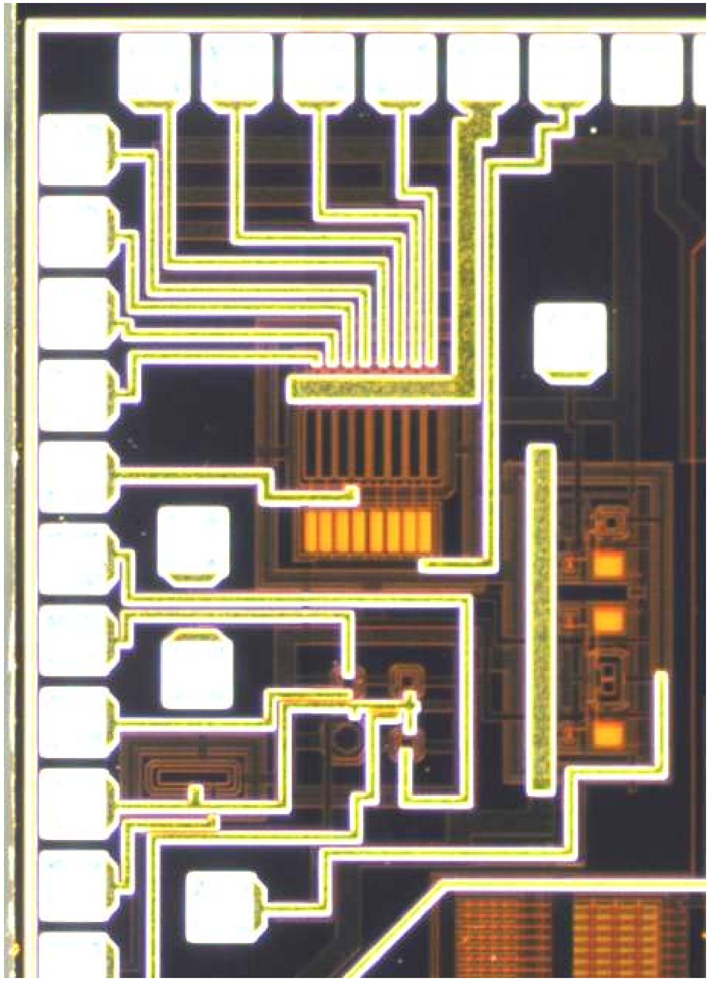




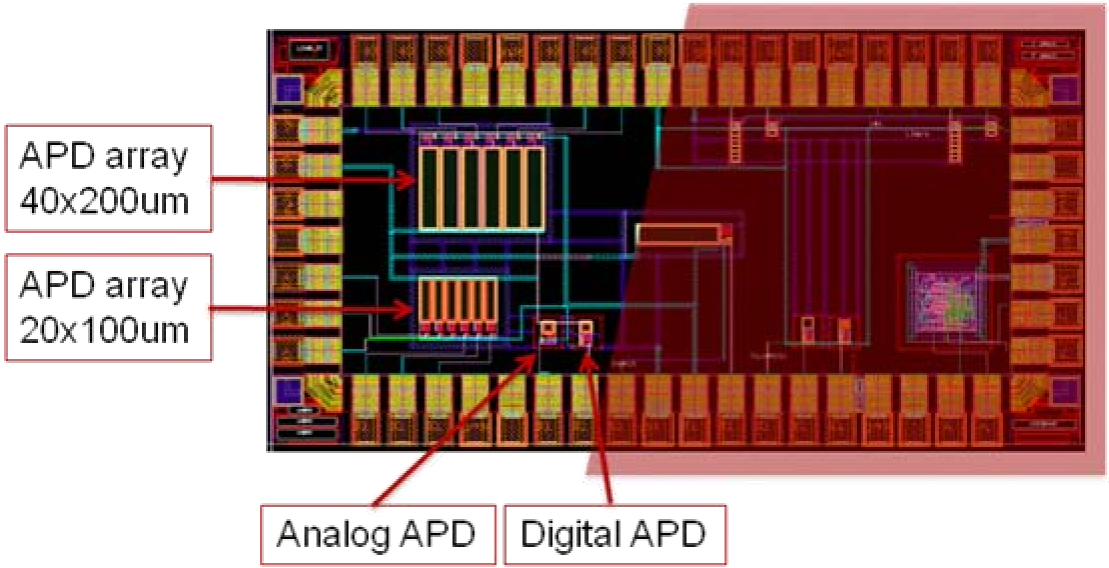




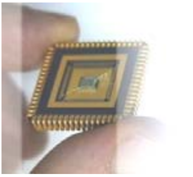

- cadence SYNOPSYS COVENTOR ALTERA
- Full custom, semicustom and FPGA designs can be implemented
- Design is possible at the behavioral, RTL, logic and transistor levels
- Fabrication through EUROPRACTICE or CMP at low cost
- Expertise in different CMOS and BiCMOS technologies: AMS, ST, AMI, …



AustriaMicrosystems CMOS 0.35um




STMicroelectronics CMOS 130nm



# APDs for the FT region

( high gain, simple readout electronics, so low power consumption, extremely fast response)

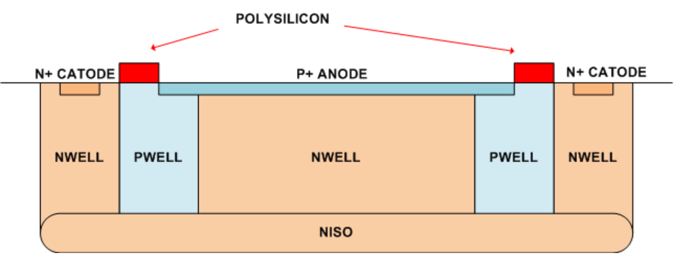
## Avalanche photodiodes in standard CMOS technologies

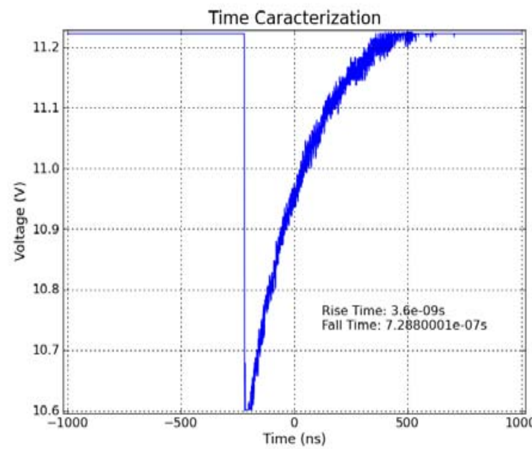
**Learning from the fabricated structures:** STM 130nm, AMS 0.35um

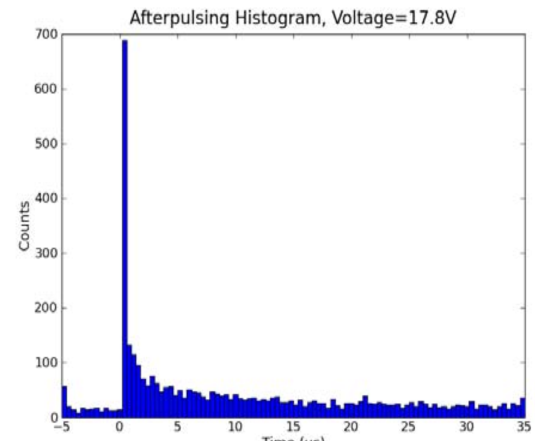
*Detector instabilities (dark counts, afterpulsing, cross-talk)*

**Trying to learn also from device simulations**

Centre Nacional de Microelectrònica IMB



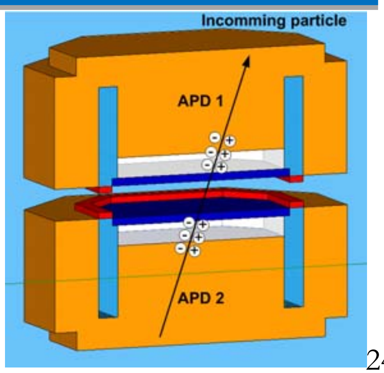




## News designs including readout…

**Pixel in Geiger mode with active quenching + control of recharge time**
**(adapted to detector/testbeam)**
**10ns signal and 300ns to send data in ILC (50% / 50% in testbeam)**
**Occupancy determined by dark count ..0.7avalanches/pixel/ms**
**3 x 3mm2 translates to a 25 x 152 pixels matrix**

## Future designs…



# APDs for the FT region

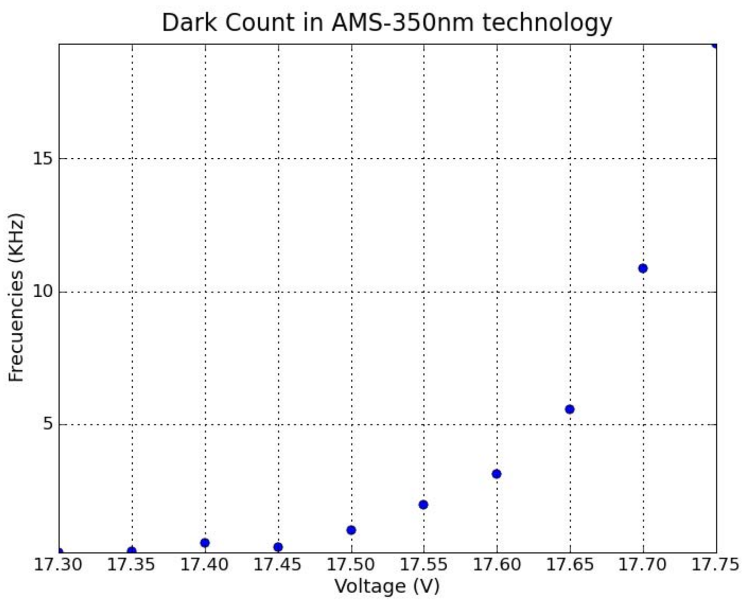
## Avalanche photodiodes in standard CMOS technologies

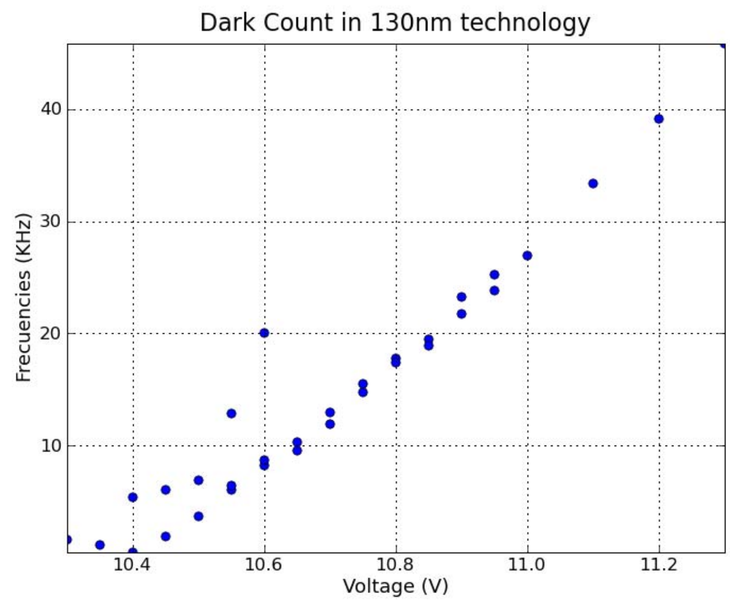
**Learning from the fabricated structures:** STM 130nm, AMS 0.35um

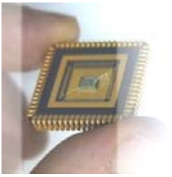
*Detector instabilities (dark counts, afterpulsing, cross-talk) are instabilities contributing to the detector response. Have deep impact on the readout details. It is very important to understand their origin and to reduce their incidence.*

**Trying to learn also from device simulations**

**Design of pixels and readout structures:** Active quenching and fast readout.





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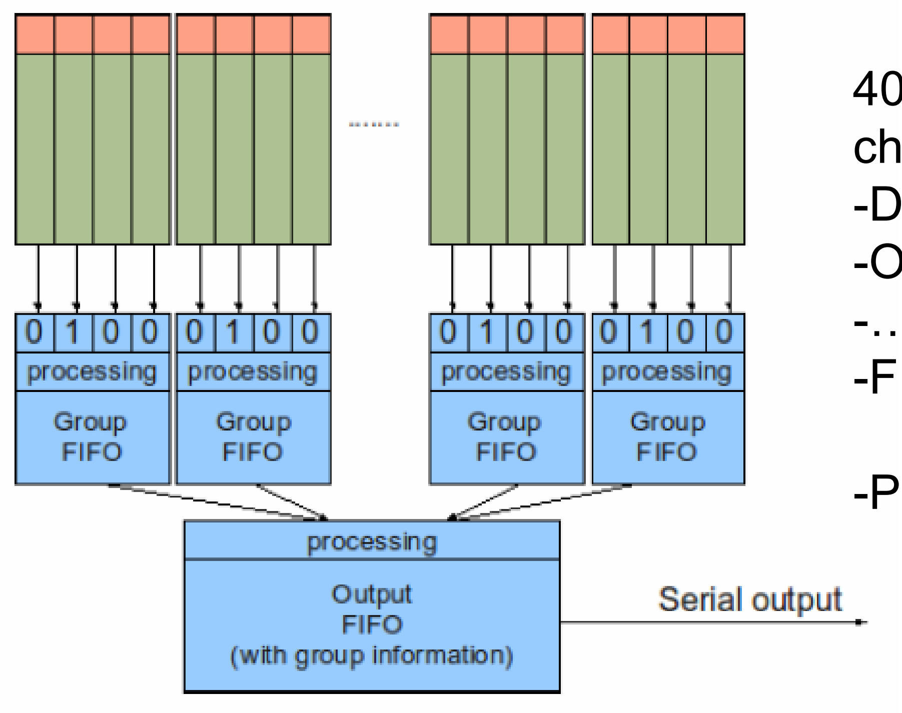
**Trying to learn also from device simulations**
**Design of pixels and readout structures:** Active quenching and fast readout.

| Parameter | AMS HV 350 nm | STM LV 130 nm |
|---|---|---|
| Vb | 17.2V | 10.4 V |
| Tq | 40-70 ns | 1.5 – 2 ns |
| Dark count | 5kHz (ΔV~0.3V) | 10kHz (ΔV~0.3V) |
| Afterpulsing | high | Low |
| Crosstalk | <5% | ? |

## News designs including readout…

**Pixel in Geiger mode with active quenching + control of recharge time (adapted to detector/testbeam)**
**10ns signal and 300ns to send data in ILC (50% / 50% in testbeam)**
**Occupancy determined by dark count ..0.7avalanches/pixel/ms**
**3 x 3mm2 translates to a 25 x 152 pixels matrix**

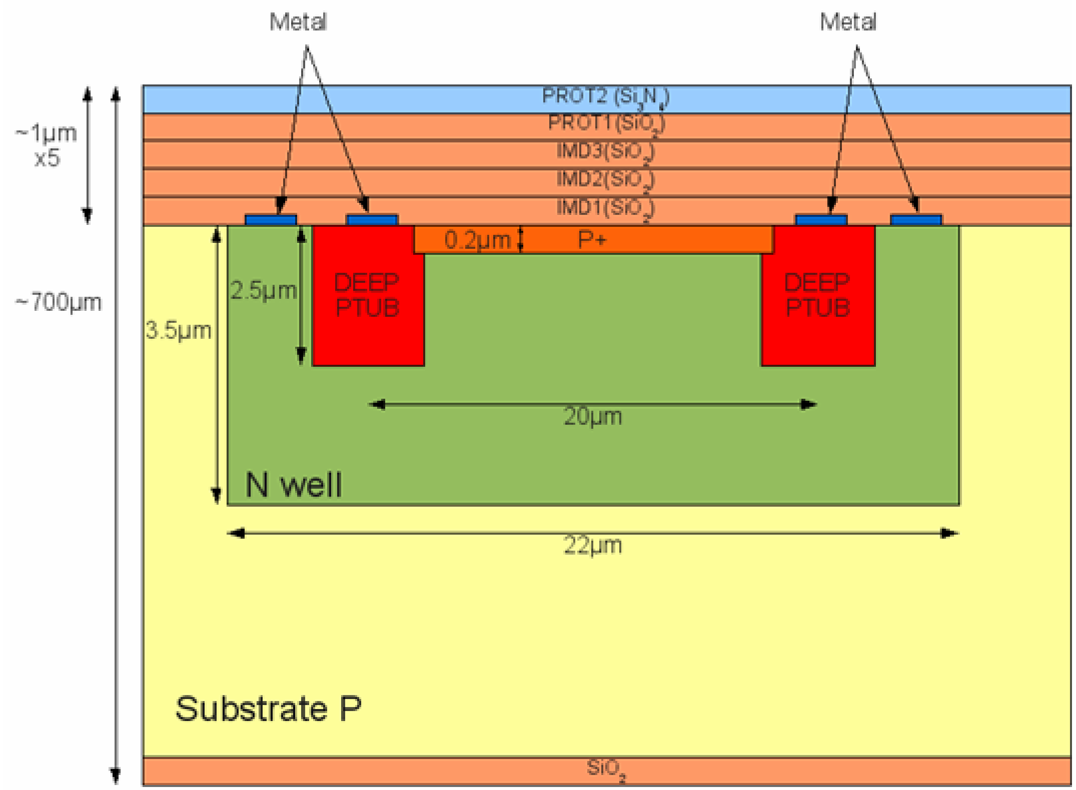


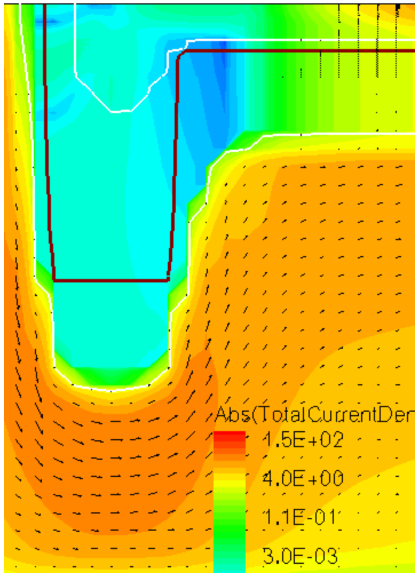

400MHz clock is needed in the chip for FIFOs
-DLL on chip
-On chip clock
-…
-FIFOs, control, …

-PIXEL

## Avalanche photodiodes in standard CMOS technologies

**Learning from the fabricated structures**
**Trying to learn also from device simulations**
**Design of pixels and readout structures:** Active quenching and fast readout.



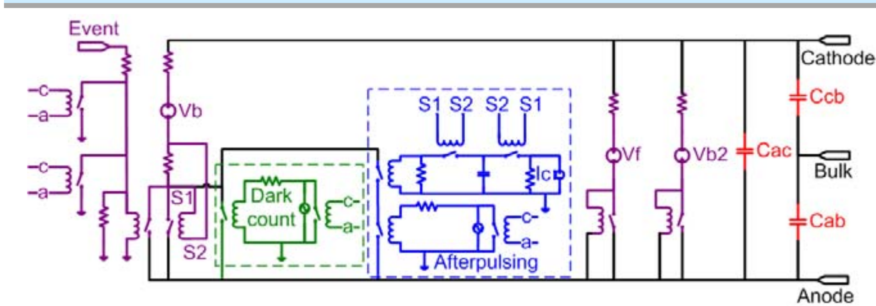
## Future designs…

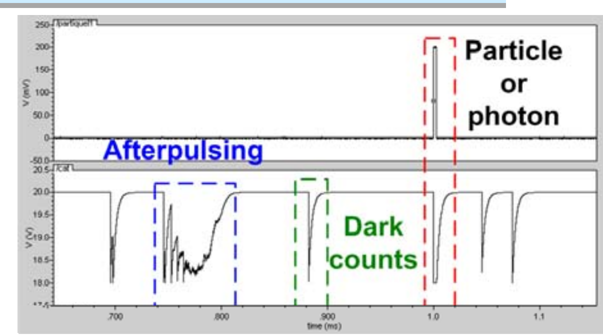
**3D interconnection for**

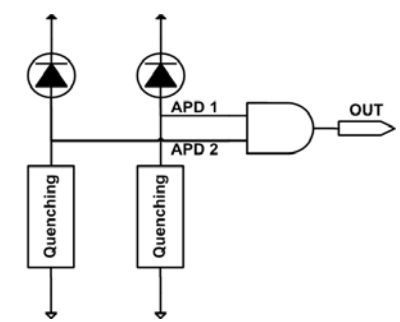
**1) coincidence filtering , triggering**

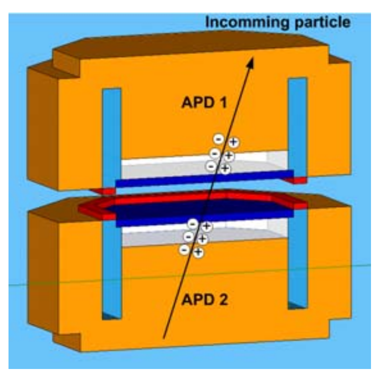
**2) 100% coverage**

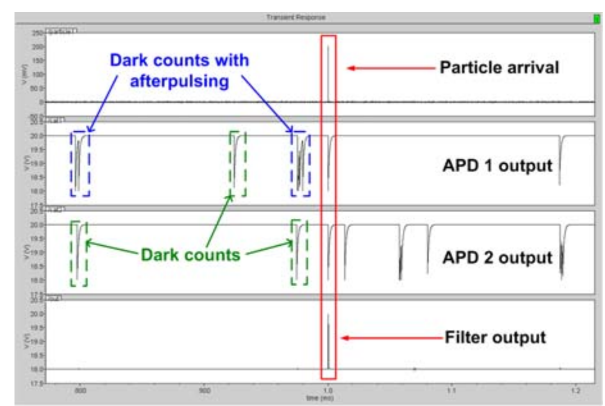
**Design for test beam for a developed APD array, radiation tolerance tests, …**



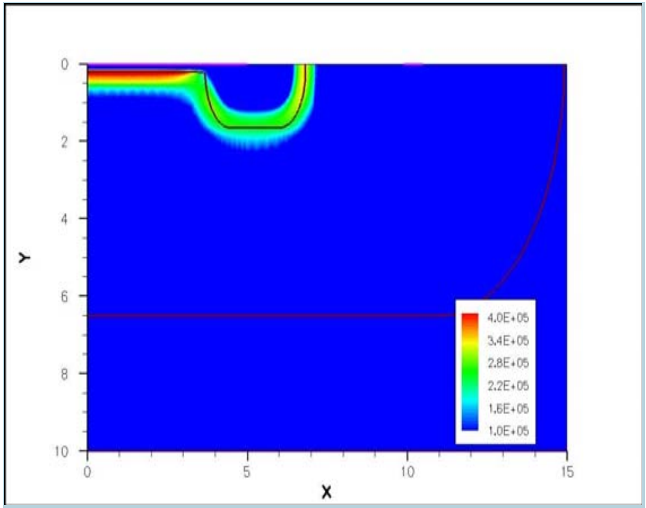



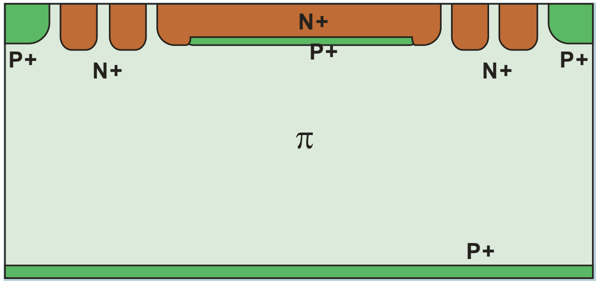



# Avalanche Photodiodes (APDs)

- Power Devices and Radiation Detectors Groups at IMB-CNM have started a new research line in
  optoelectronic silicon detectors.
- Cover the needs of the scientific community with custom made devices designed for specific applications
- We have finished electrical and technological simulations
- We are now designing the masks
- Next year we will process the devices.
- We plan to develop
  - Linear mode APDs (to use with scintillators)
  - Geiger mode APDs high energy tracking
  - In the future, also SiPMs
- We are open for collaboration and feedback from other groups




**Electric field in the avalanche zone**



## Studies for the first 3 disks of the FTD:

Thin active pixels, readout by TIMEPIX (time stamping capable, thinning needed on the sensor and the chip, power cycling to be studied)

- Performance evaluation in test beams TimePix assembly last summer and laser/source test stand this year.

**55 um pixel size**

**300 um thickness**

**Hit resolution ~5 um**

**Track resolution ~2.6 um**

- Thinning of sensor substrate in collaboration with CNM Centre Nacional de Microelectrònica IMB

• Beside that, in col. With CERN and UK :

Telescope based on Timepix with following characteristics

Active area: 2.8x2.8 cm2

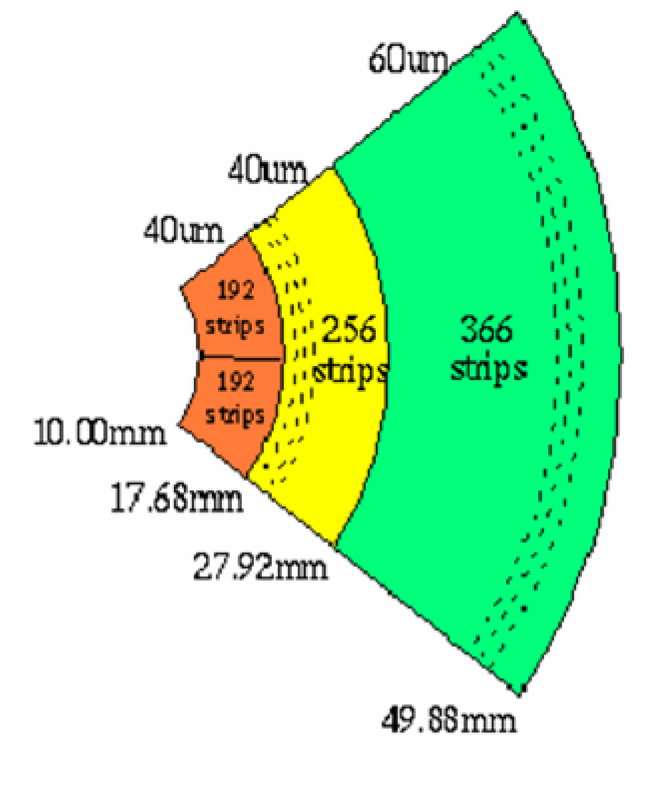
Resolution: 2 um, 1 ns

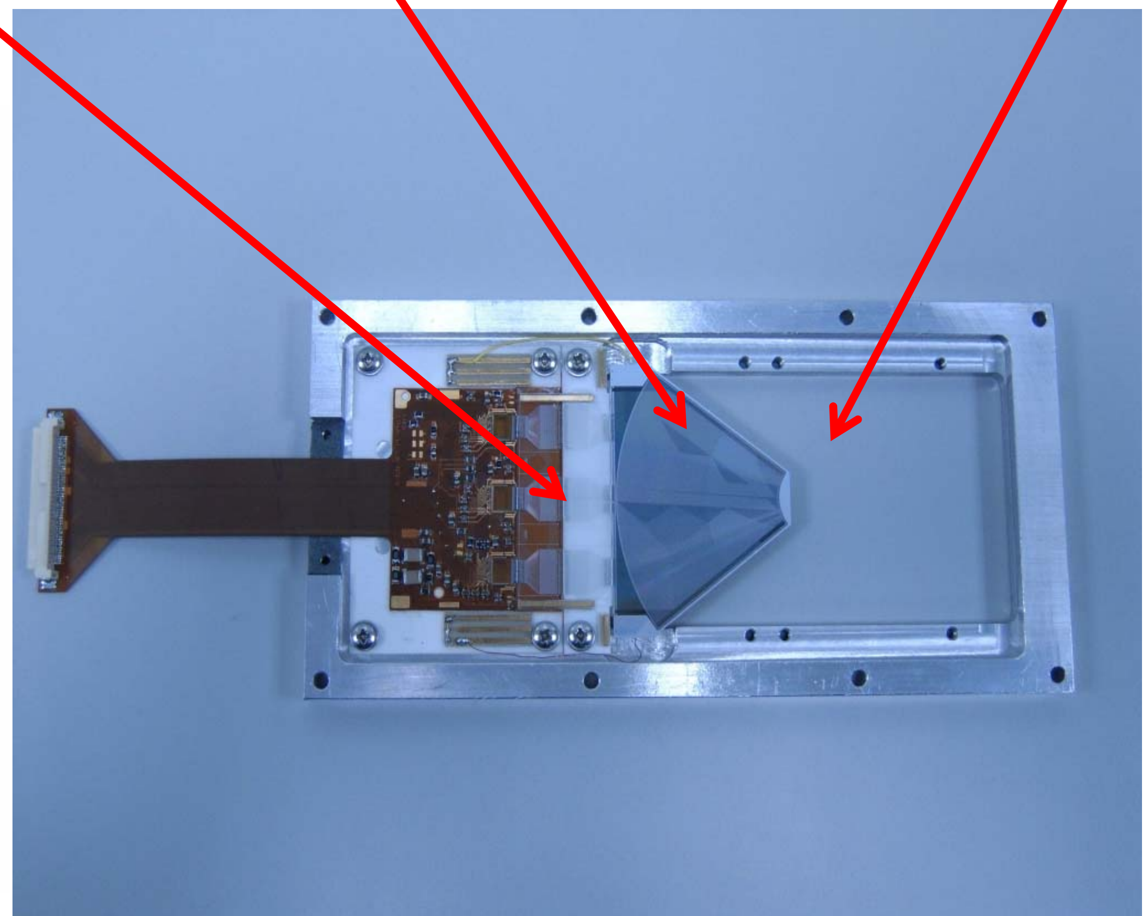
Readout rate: 75 kHz

(To be used in R&D in detectors for ILC or LHC upgrades)

# R&D in microstrip silicon detectors

- 1 module assembled in Santiago to be tested in the lab and in testbeam
  - IT hybrid (3 beetles) + 2 pitch adapters + PR01 Hamamatsu sensor

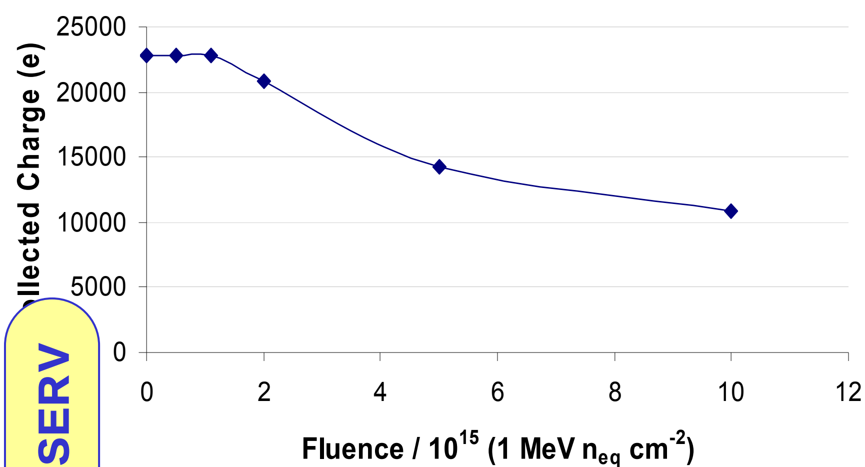


# 3D detector technology

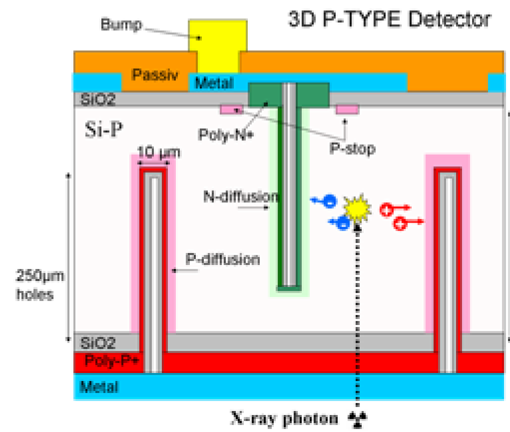
- Second institute in the world (after Stanford) in developing a 3D detector technology
- Success with Medipix type pixel sensors
- Now we are designing of a new mask set for ATLAS pixel sensors
- Work done in the framework of RD50 collaboration.

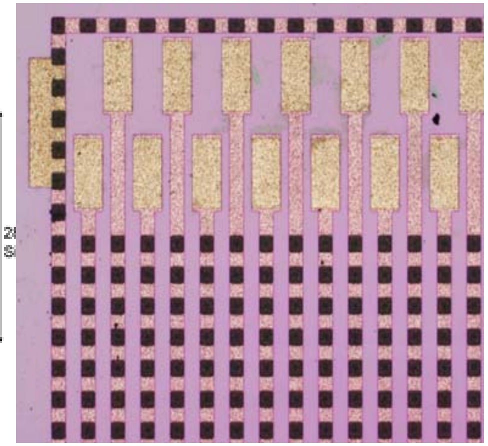
**Electron collecting strip detectors**




GICSERV

**Partially funded GICSERV**

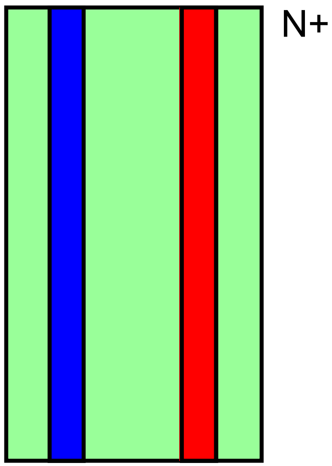


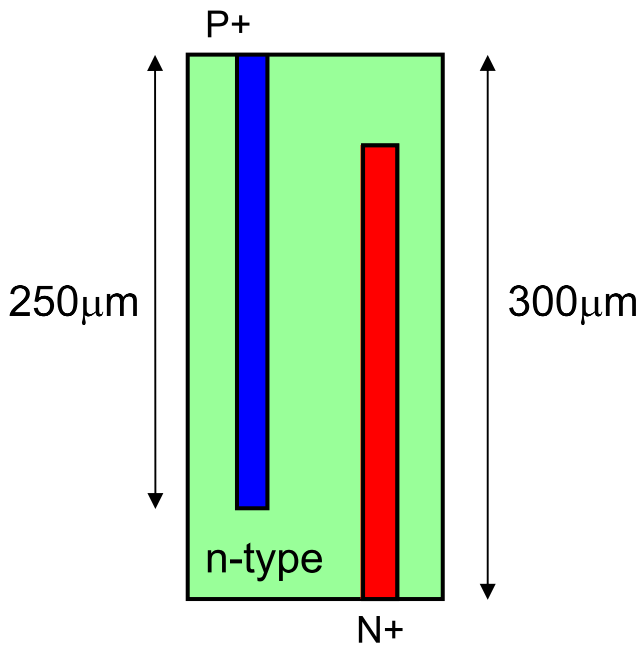
- **Bias Voltage fixed at 150V for all irradiated samples**
- **Non-irradiated sample biased at 18V**
- **Detector's ceramic based board temperature between -10°C to -15°C**
- **Measured with ALIBAVA system (25ns shaping time)**

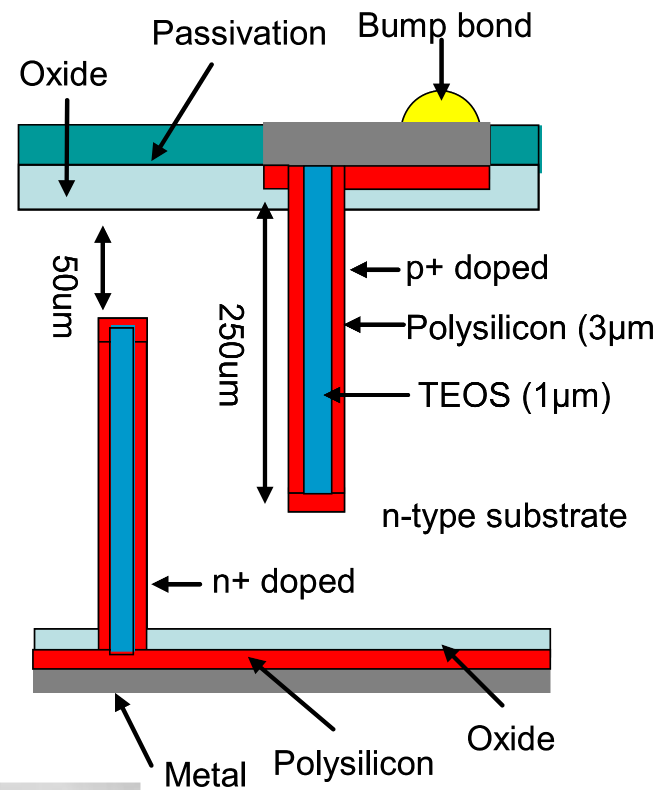
# 3D sensors – CNM, UB

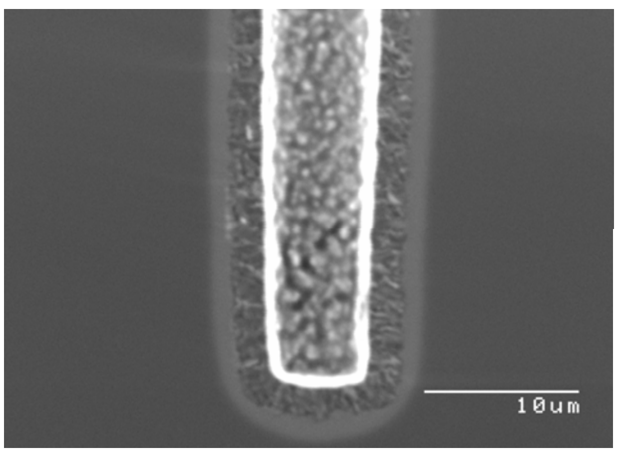
**Full 3D**

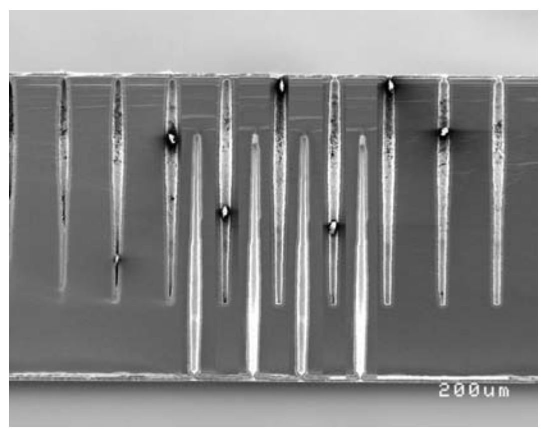


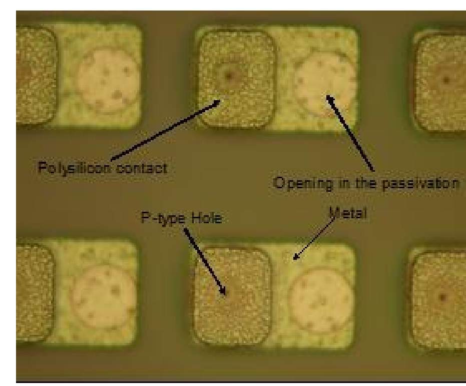

**Double–sided 3D**



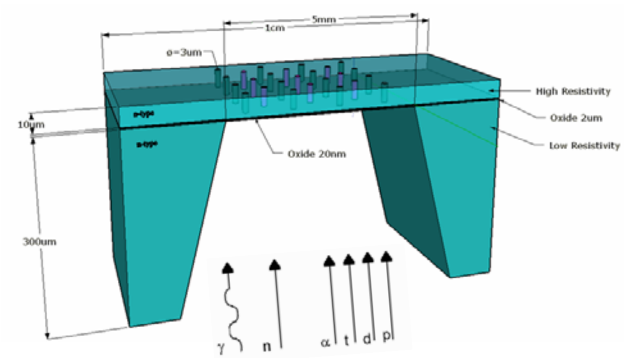



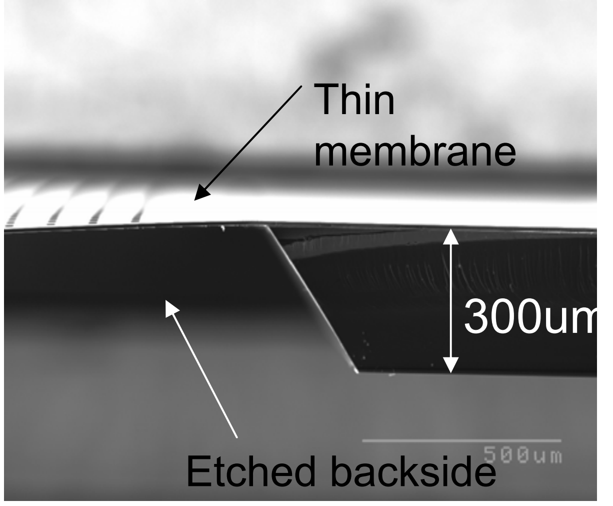



**GICSERV**

# Ultrathin 3D detector

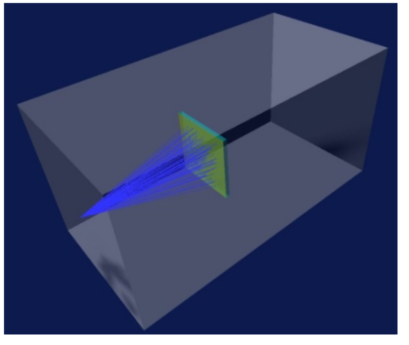
- 10 μm thick detector
- Virtually no entry window
- Used for tracking of light particles



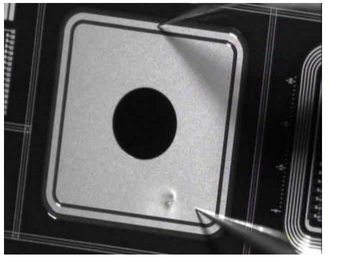



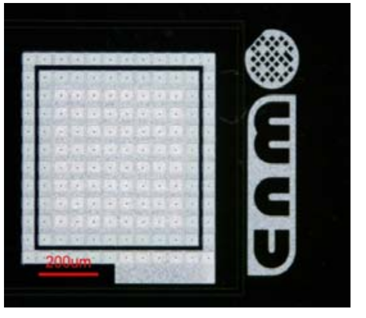

# Neutron detectors

- Geant4 simulation
- Detector design and manufacturing
- Conversion layer deposition
- Used for dosimetry



**Planar detector**

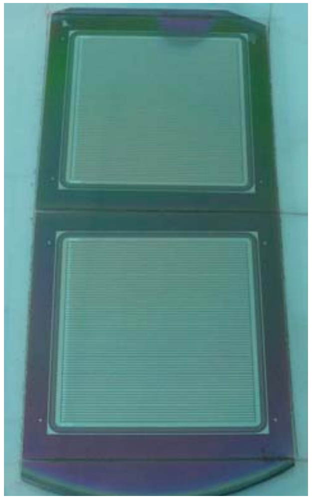





**Perforated detector**

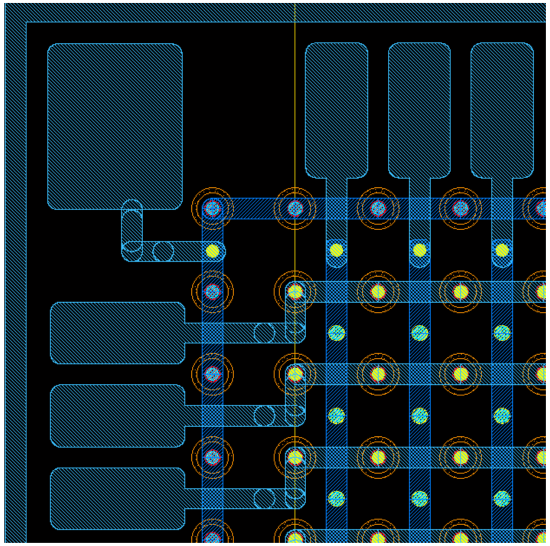
# Double side strip detectors

- Double side strip detectors developed for Monash University (Australia)
- Also developing double side packaging and wire bonding
- Future collaboration with Universidad de Huelva for nuclear physics



# Stripixels

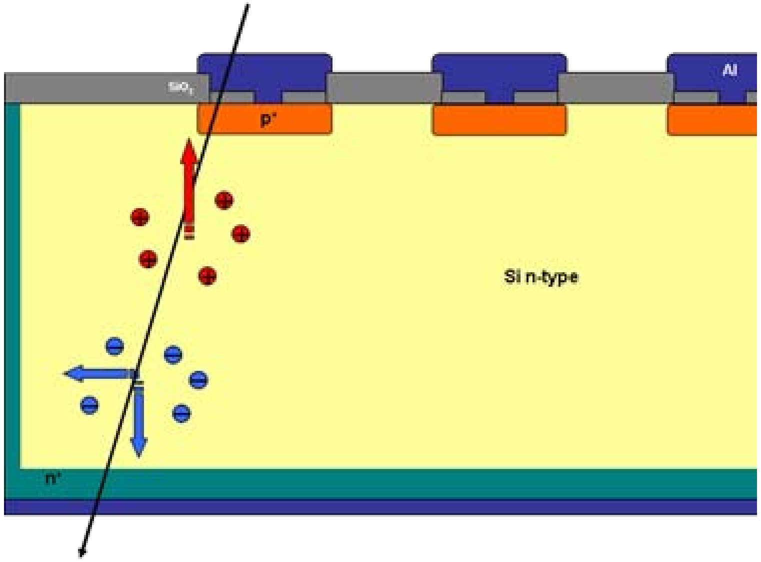
- Combination of the concept of double side reading with 3D contacts
  - Better performace than classic stripixels
  - Single side processing
  - 2D position sensitivity
  - 2N readout channels (instead of $N^2$)
- Simulations and mask design ready
- Wafers to be processed



GICSERV

# Active edge and trenched detectors

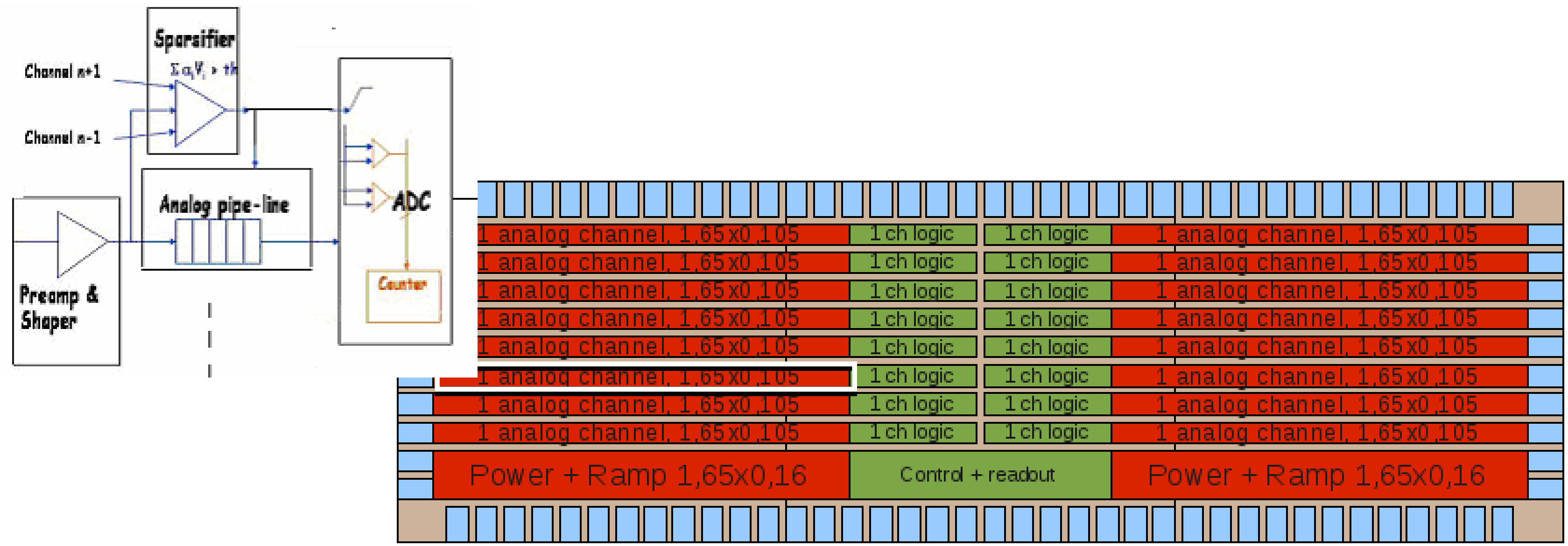
- Trenches used to reduce the dead area at the edge of the sensor
  - (also named edgeless, slim-edge, ...)
- Work started in collaboration with IFAE (Cristobal Padilla)
- Features:
  - Implanted edge side
  - Backplane and edge in the same electrode
- Designed detectors:
  - PAD
  - Microstrips
  - MediPix2
  - Circular

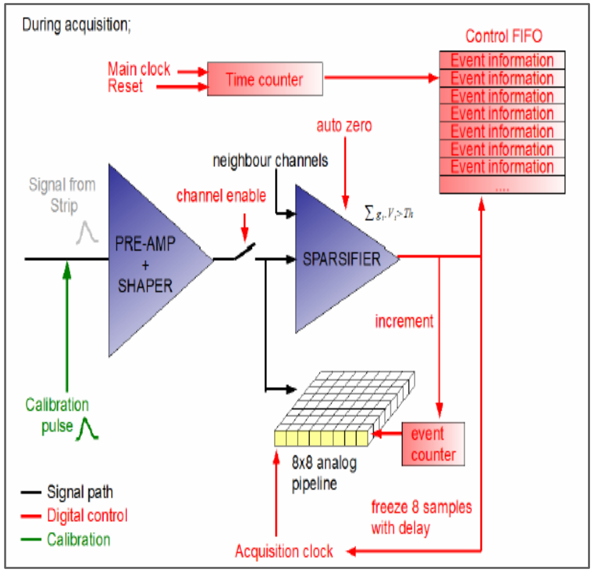


# Si strips readout – col. In2P3

## Plan for future SiStr chip

**Define technology:** 130nm IBM, 130nm ST, 90nm IBM
**Adapt 1 channel electronics:** both Analog and Digital
**Build 8-16 channel module:** Adapt control electronics to a basic module of 8-16 channels. Build 1st complete module in Si.
**…128 channels**



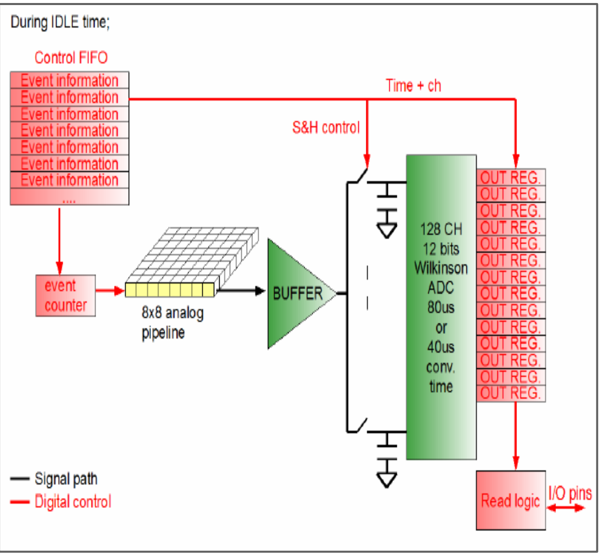


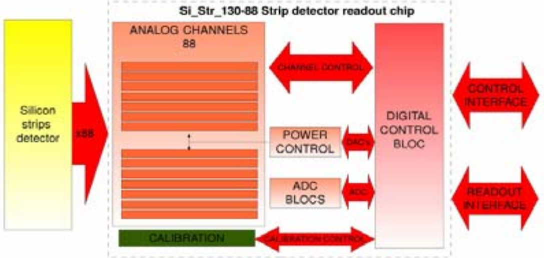

**UMC CMOS 130nm**
**ASIC received first week of October'08**

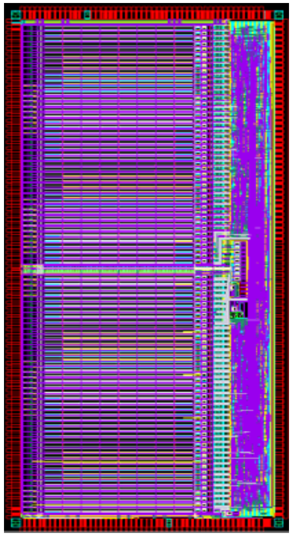
**Mixed signal ASIC for readout of Si strip sensors in ILC**

88 channels

**Analog part designed by IN2P3**
**Digital part designed by UB**



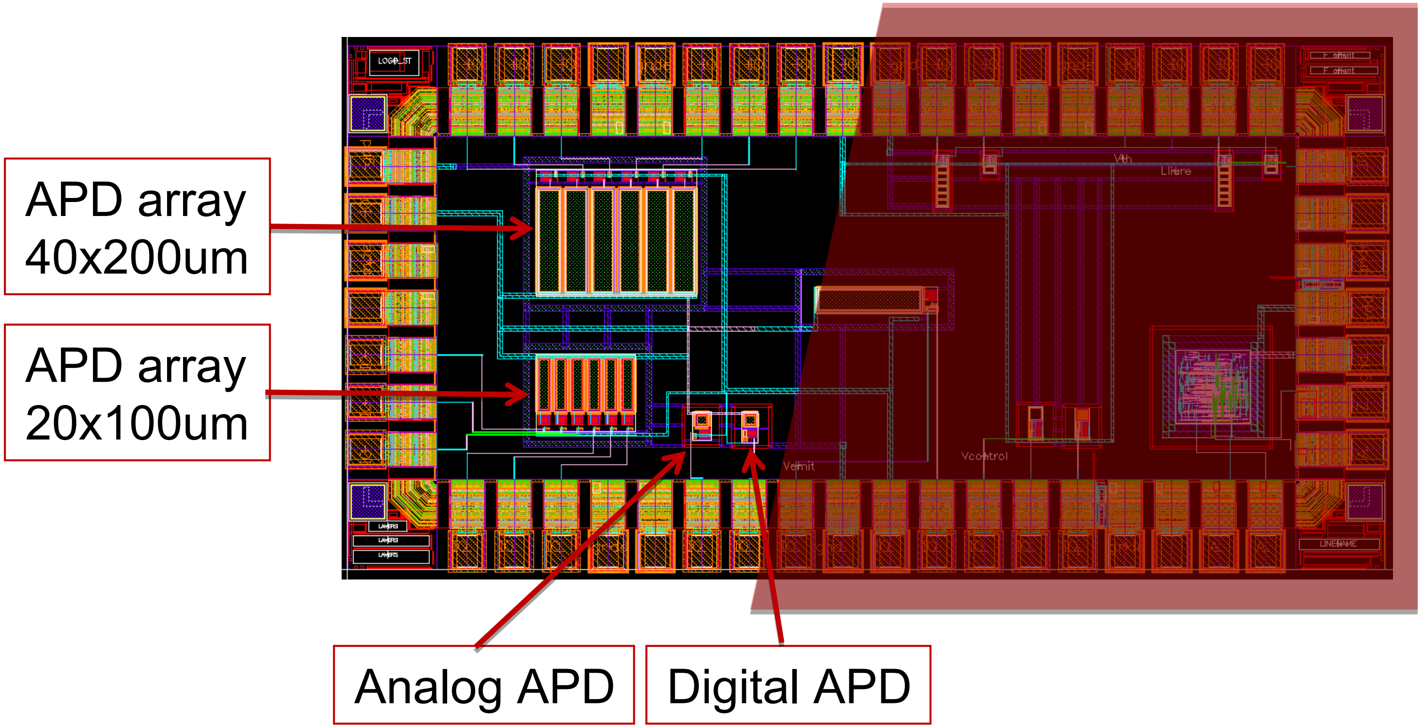
**Collaboration with LPNHE-Paris in digital circuitry for Si-strips**

# Digital GAPD– CNM, UB, URL

**…on design of sensors for future trackers**

*Integrate electronics and sensors using industrial CMOS processes*
*Reduce analog readout electronics by using high sensitivity devices*

*STMicroelectronics CMOS 130nm*

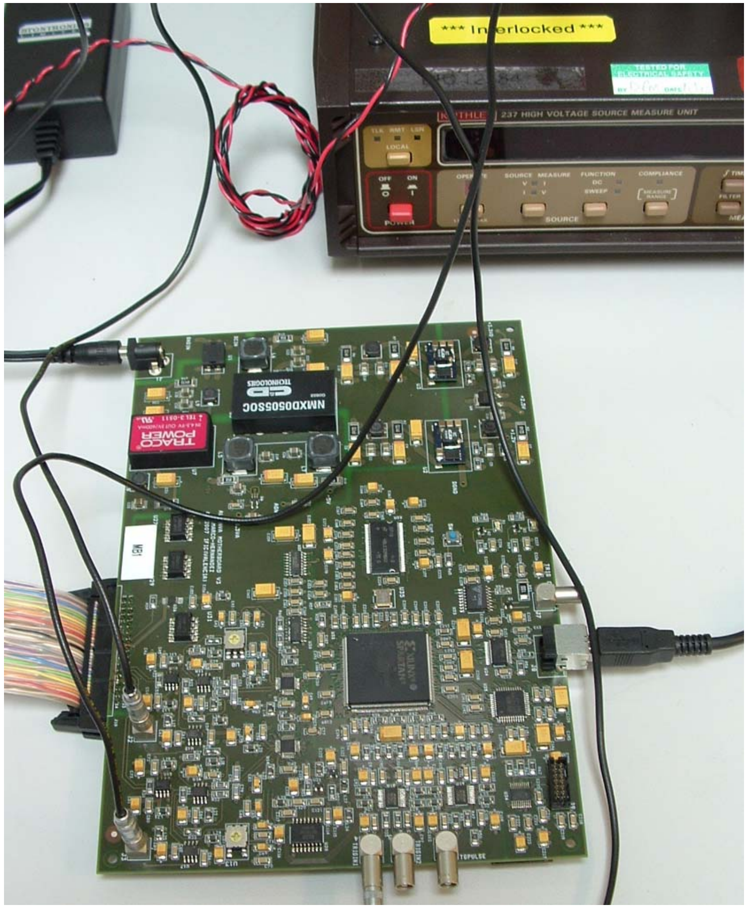


# ALIBAVA: A readout system for microstrip silicon sensors

IFIC
INSTITUT DE FÍSICA CORPUSCULAR

- System finished
- 20 units already distributed
- 20 more units manufactured

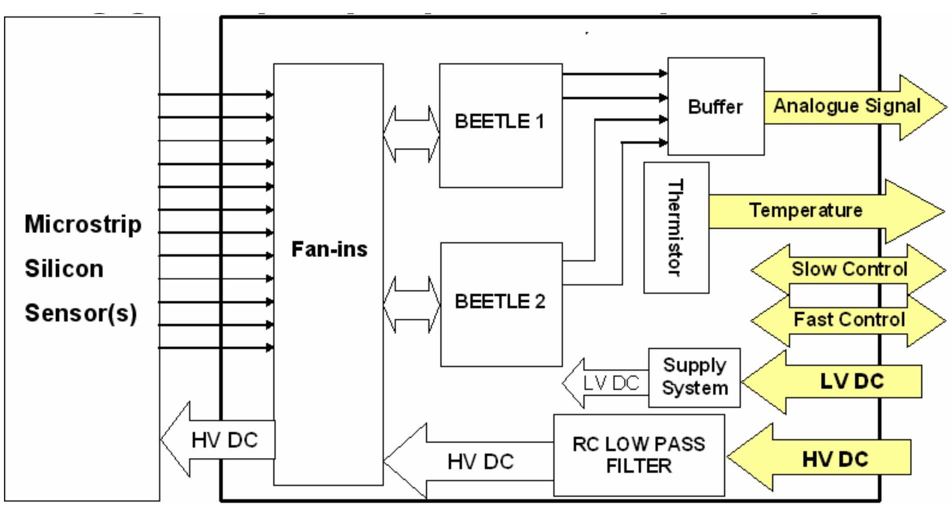
- Upgrade for test beam telescope



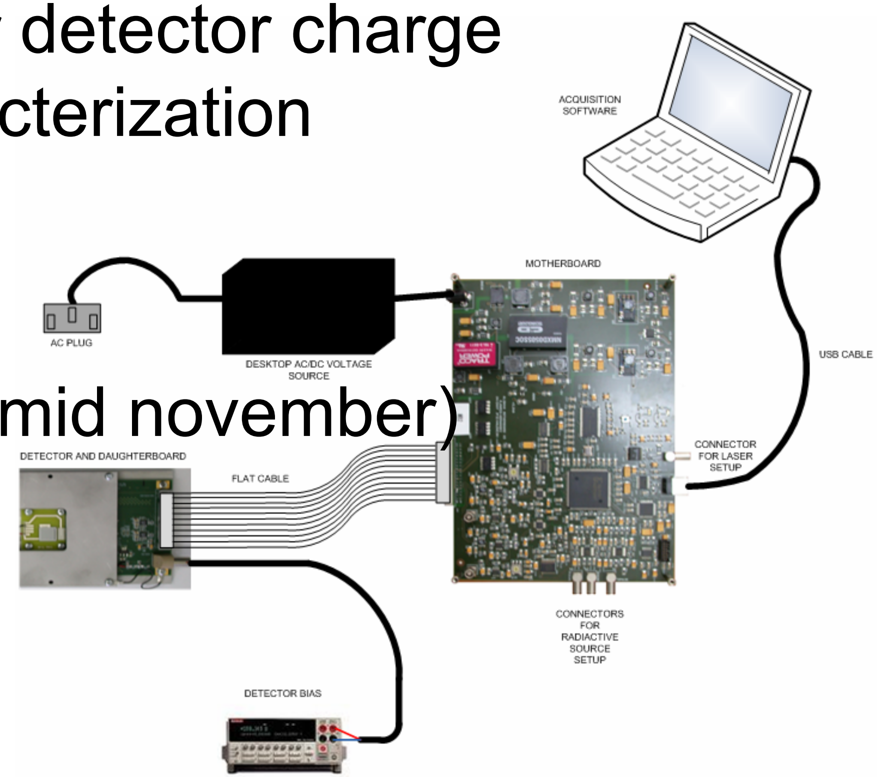
# Electronics (2) - CNM, UB, URL

## ALIBAVA: A readout system for microstrip silicon sensors

- Joint development of Liverpool Univ., IFIC-Valencia and CNM-Barcelona
- Simple and cheap system for detector charge collection performance characterization



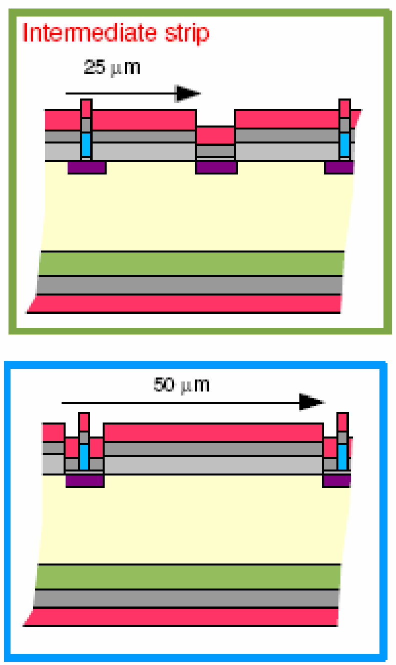

(mid november)

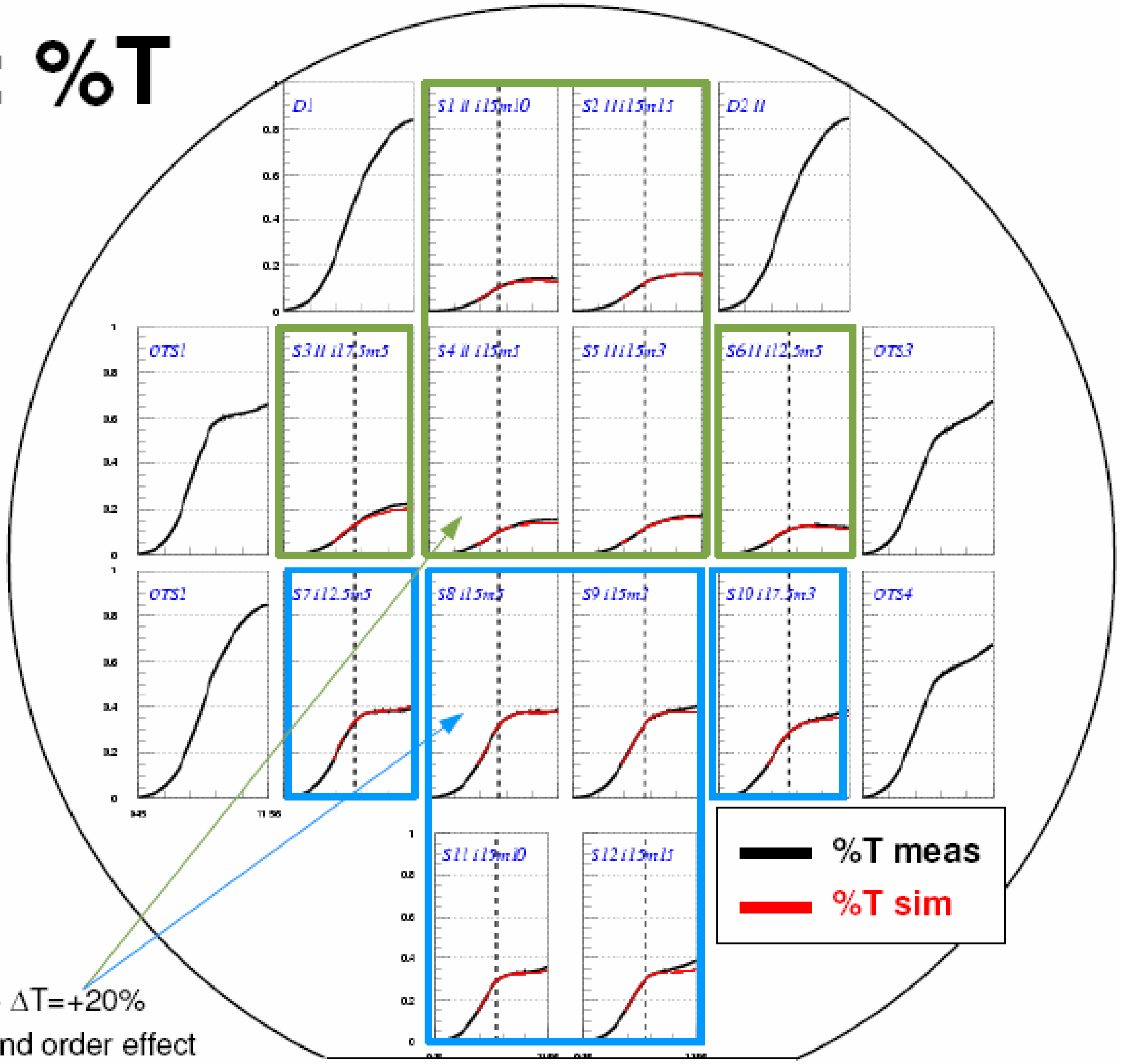


# Sensor measurement vs. calculations.

## Wafer 1:: %T

(no $Si_3N_4$ yet)




- T~70-80% test structures
- No intermediate implant ⇒ ΔT=+20%
- Metal width [3-5] µm: second order effect
- Metal width >10 µm: ΔT≤-5%

# R&D on sensors: Thinned ustrips

- GICSERV09 access on ustrip thin sensors.
- Direct wafer bonding and deep anisotropic etching.
- Aim: frame layout design, FEA analysis, mechanical characterization of dummies, bonding tests, bench & test beam testing.

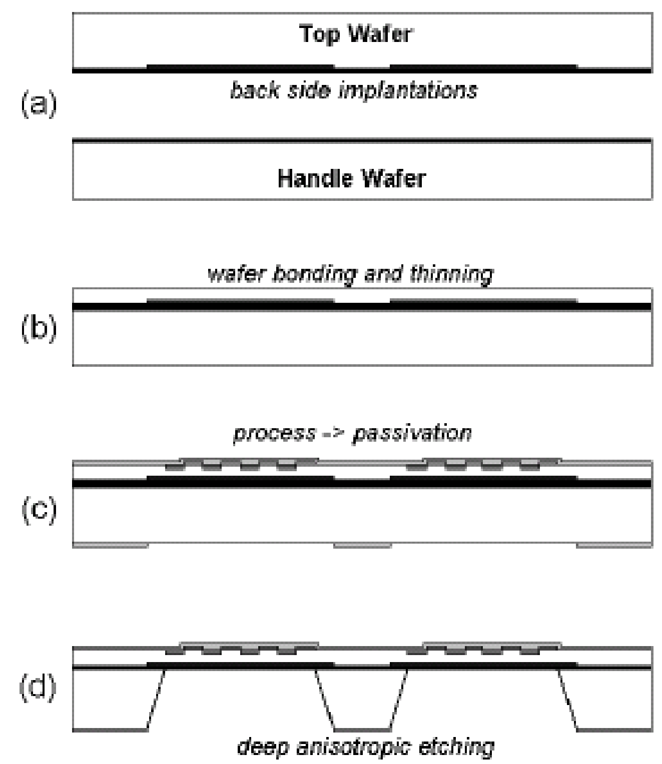
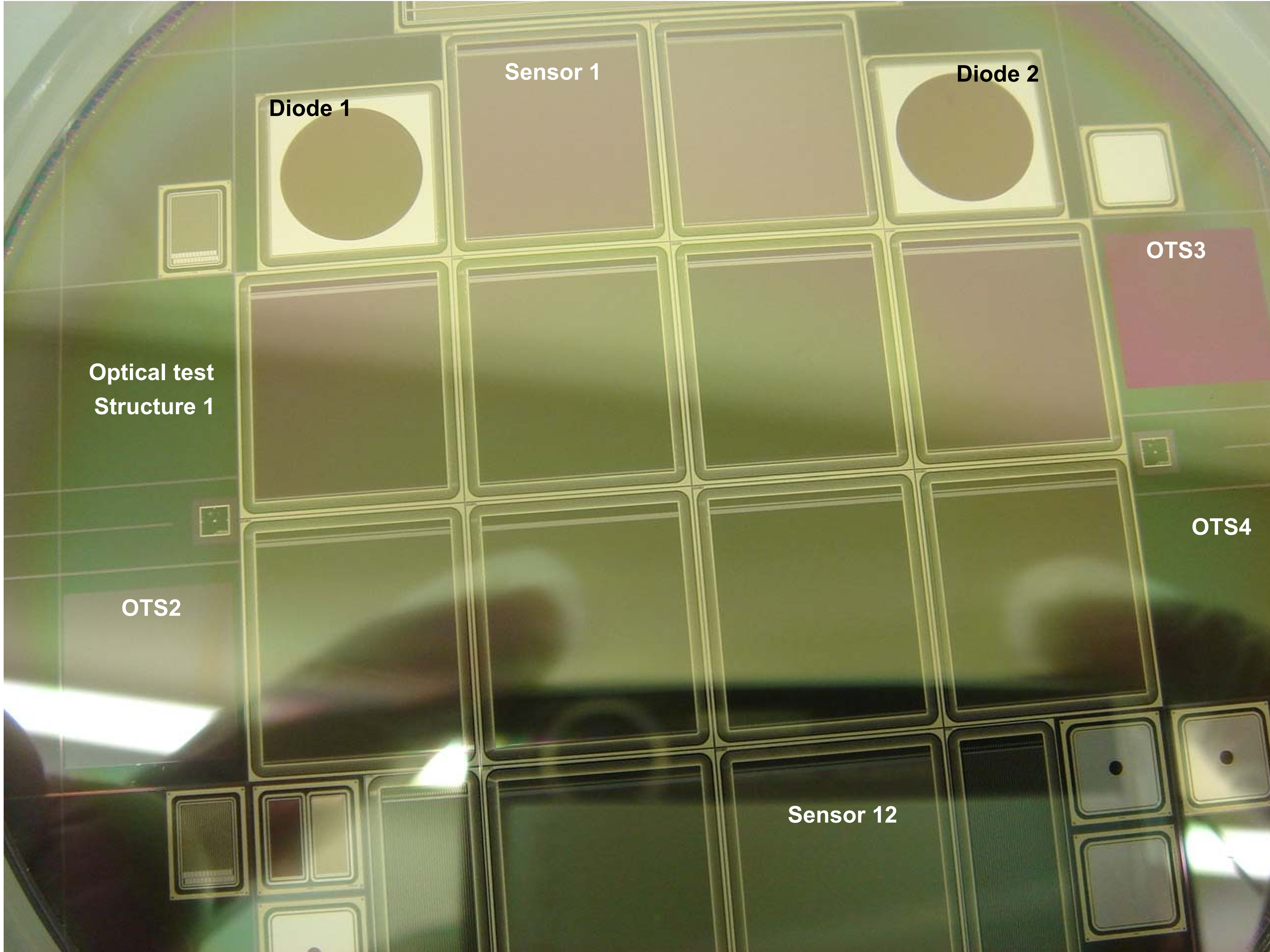
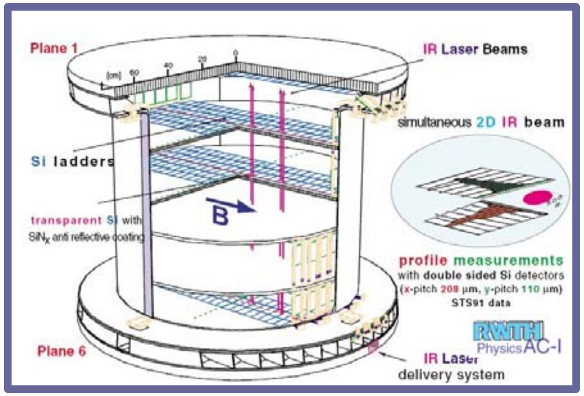


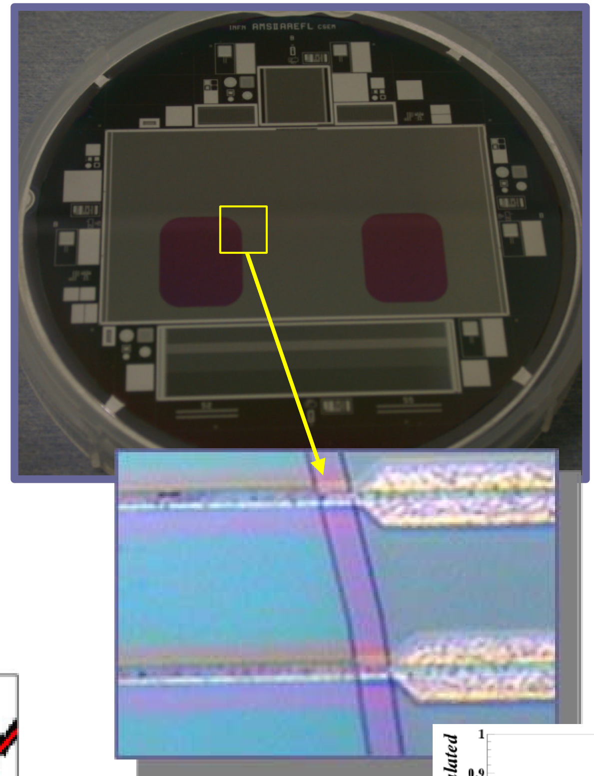
Figure 2: Thinning of double-sided processed detectors. See text and ref. [6] for further details.

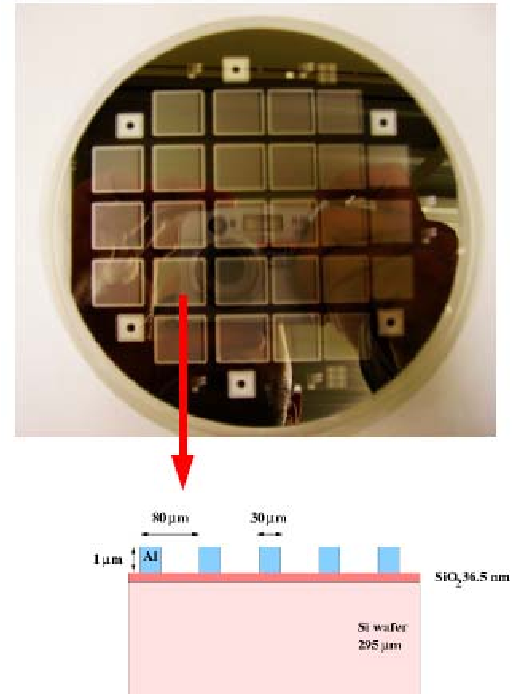


Sensor 1
Diode 1
Diode 2
OTS3
Optical test
Structure 1
OTS4
OTS2
Sensor 12

# Microstrips - IR Transparent CNM, IFCA





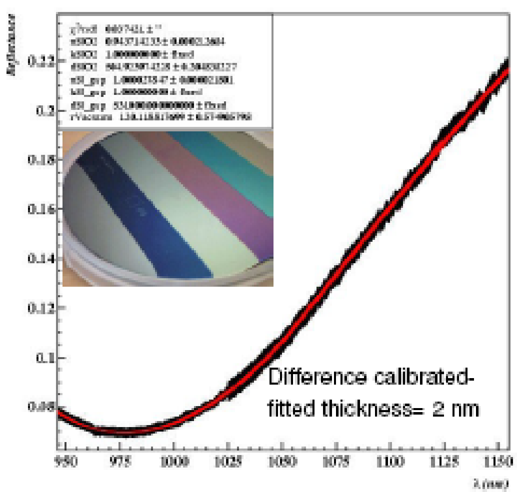

**AMS-01** innovation (W. Wallraff)

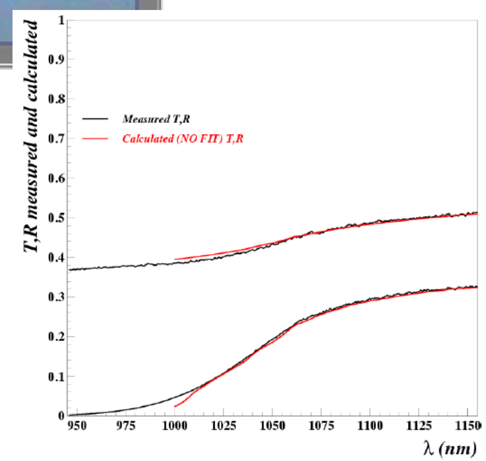
λ = 1082 nm

IR "pseudotracks"

1-2 µm accuracy obtained

**Transmittance~ 50%**




Reflectance and transmittance of wafer 5 matched. No fits involved!!

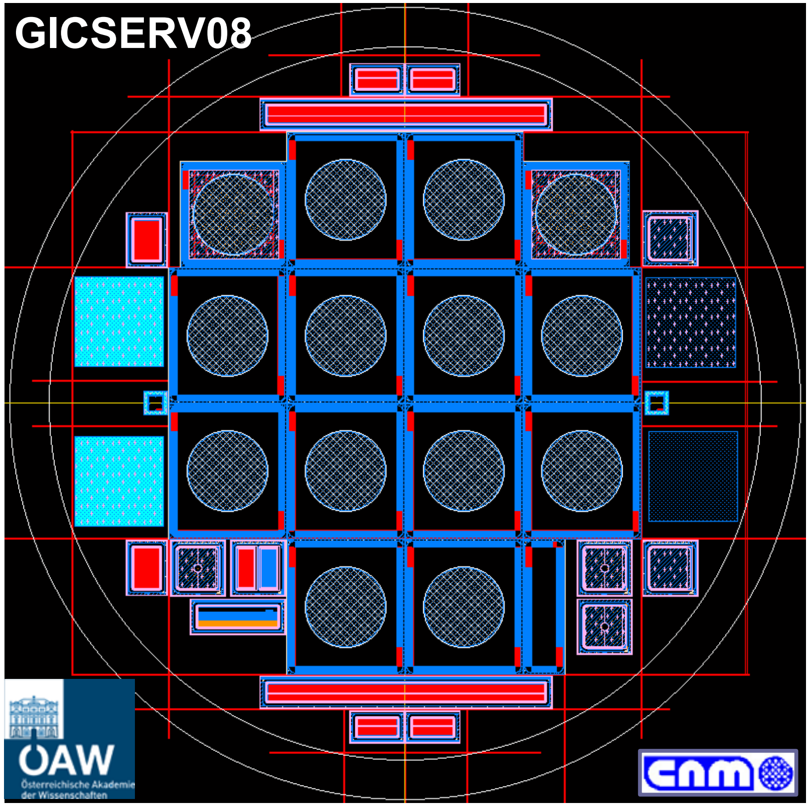
Compatible with 45 nm roughness of Al surface

Is this real? We need to measure the wafer roughness. I think it is possible to be done at CERN.

# CNM sensors (GICSERV08)

- Prototypes built by CNM-Barcelona (Spain)

- Aims:
  — Test %T vs multigeometry
  — Use optical test structures (continuous layers) to extract refraction index and control deposition
  — Test of electrical test structures

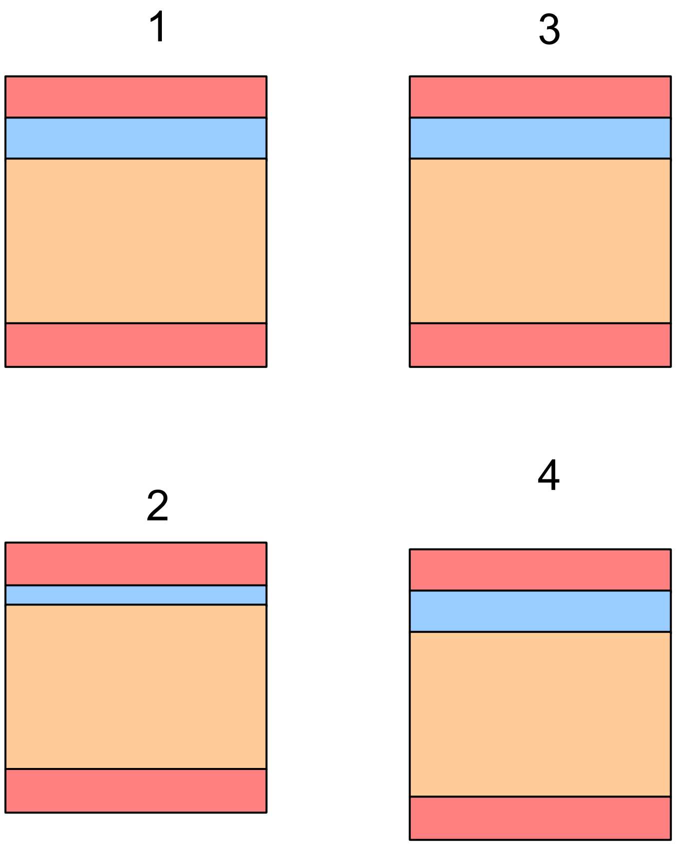


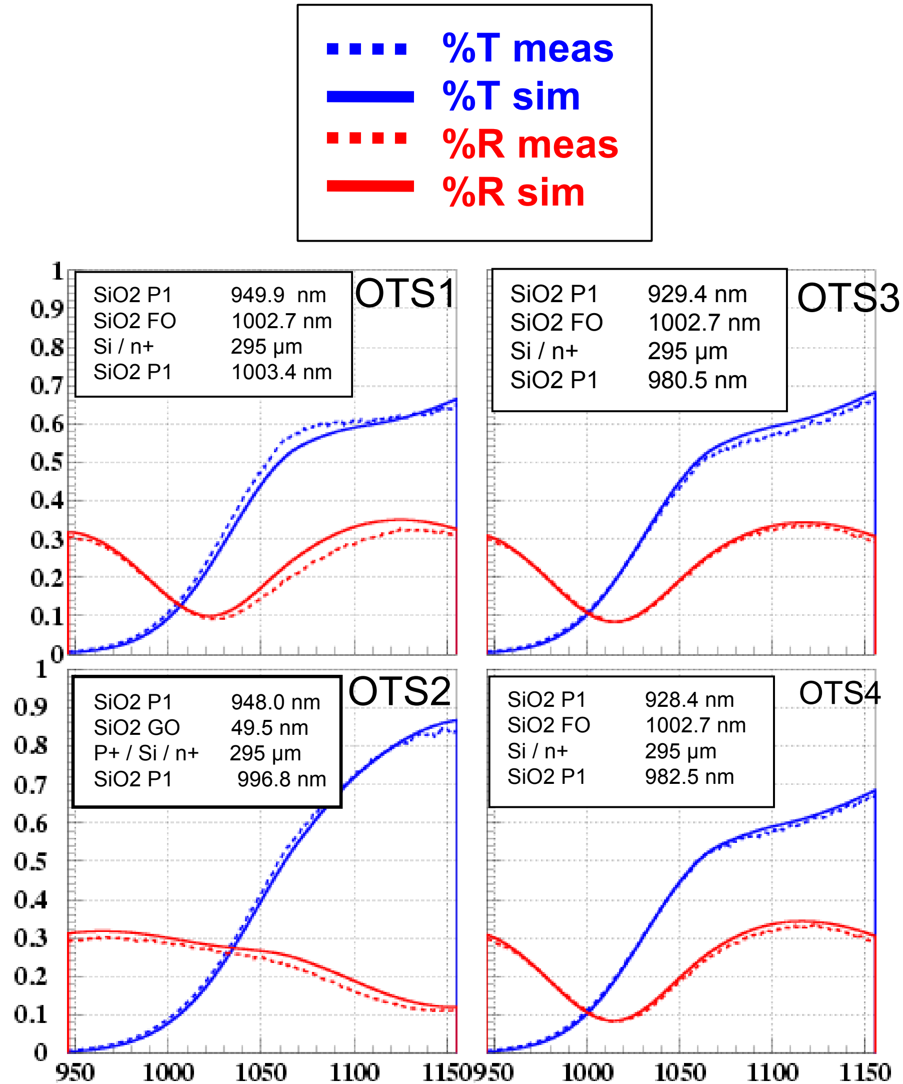

- 5+1 wafers
- 12 μstrip detectors per wafer (6 with intermediate strips, without metal contacts)
- 50 μm RO pitch (25 μm interm. strip)
- 256 RO strips
- 1.5 cm length varying strip width (3,5,10,15 μm)

- Mask designed by **D. Bassignana** (CNM)
- Electronic test structures designed by **M. Dragicevic** (Vienna) including:
  CAP TS AC, CAP TS DC, CMS Diode, MOS, GCD, Sheet
- Optical test structures available (Si, Si+$p^+$,$SiO_2$, $SiO_2$+passivation)

## Comparing measurement with simulated nominal (only SiO2 passivation)

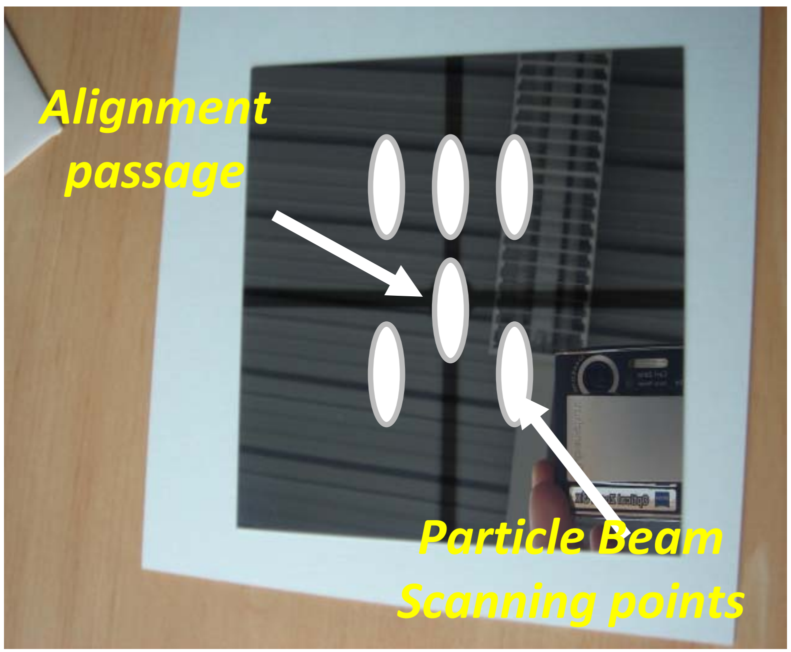
## Optical Test Structure stacks with only SiO2 on top

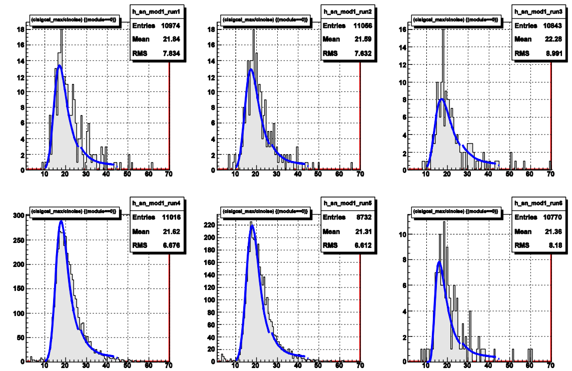


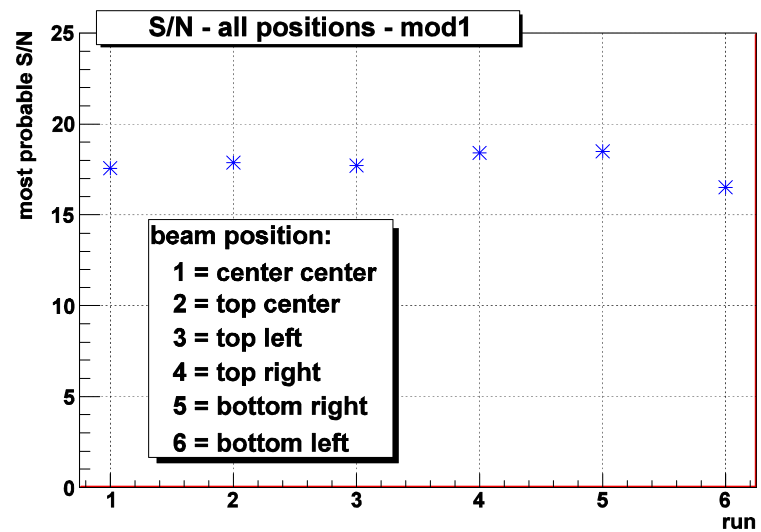



# Preliminary TB results

- SNR sensor scanning comparing Back side with Al vs. n Back side with Al metallization

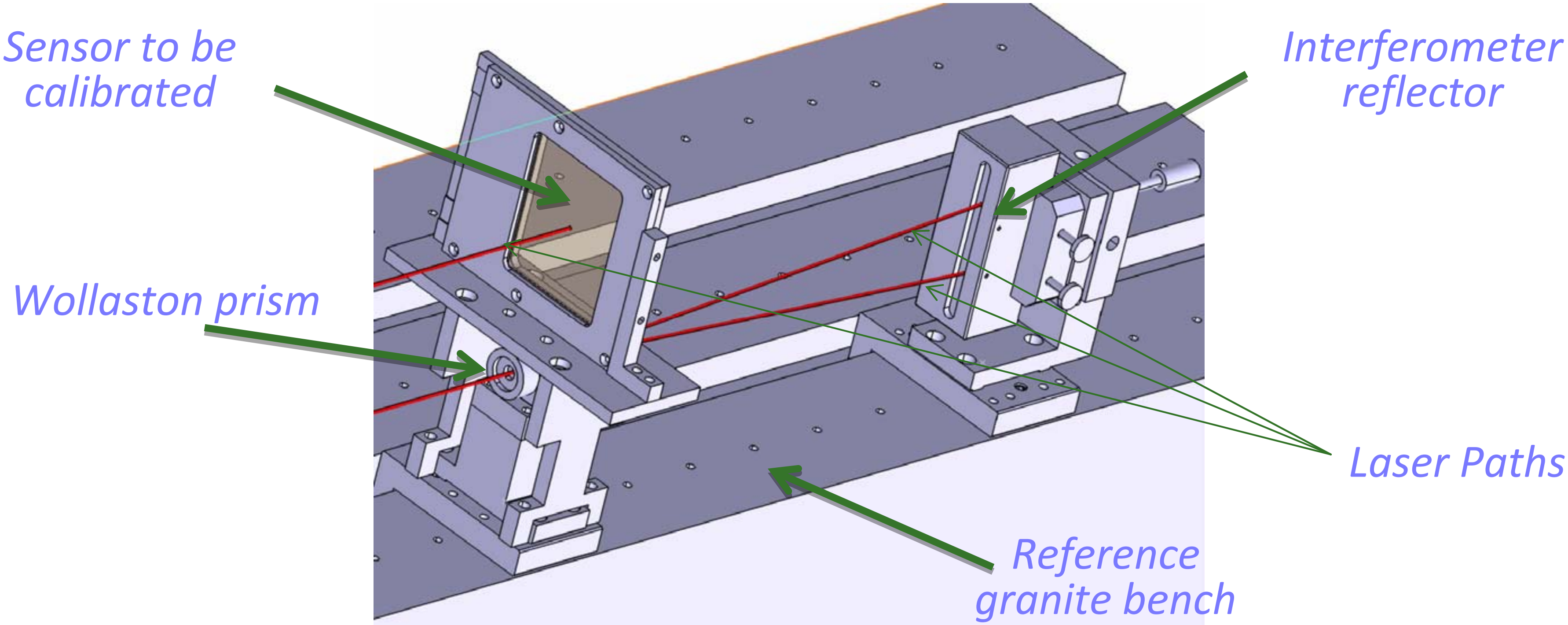


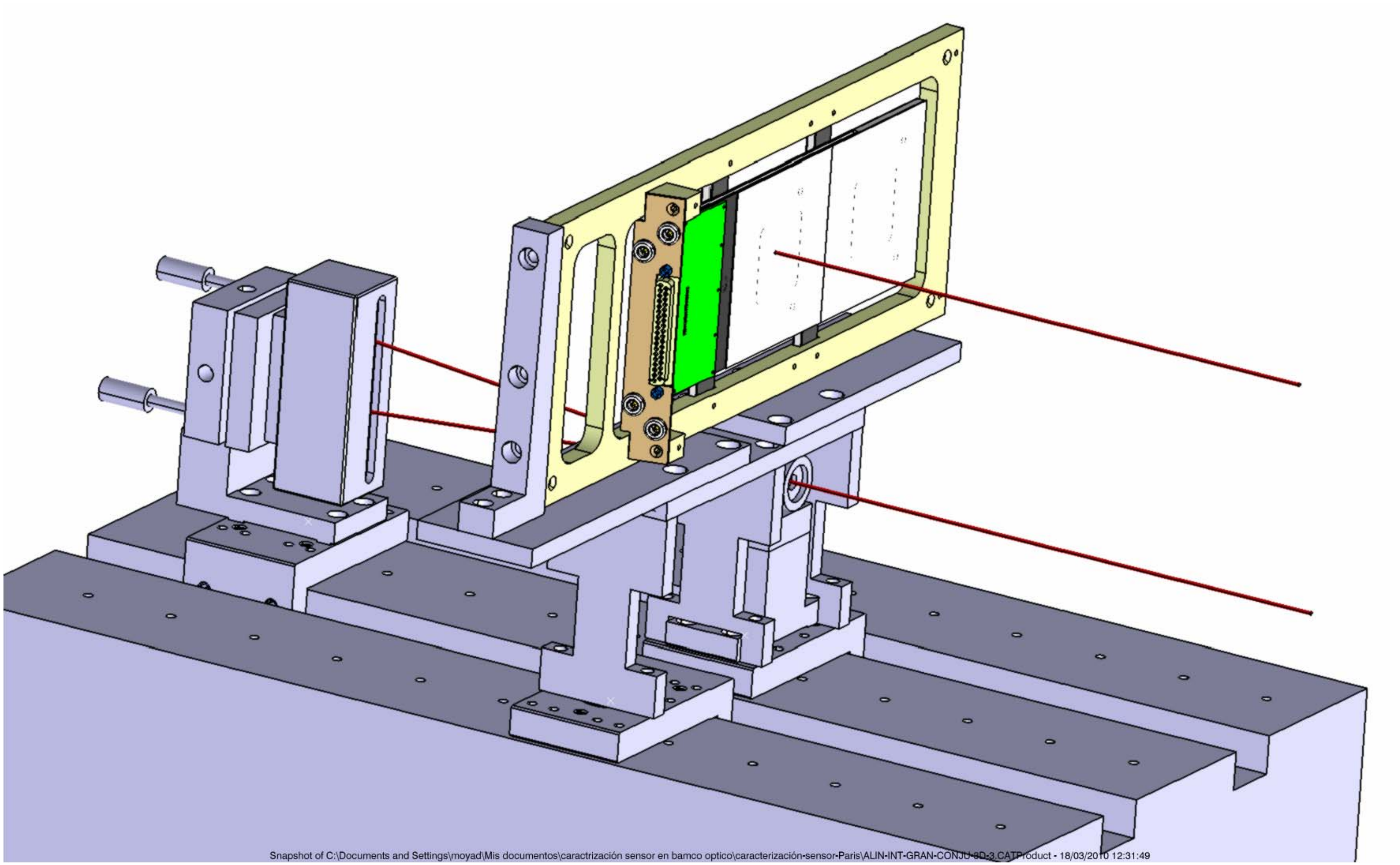



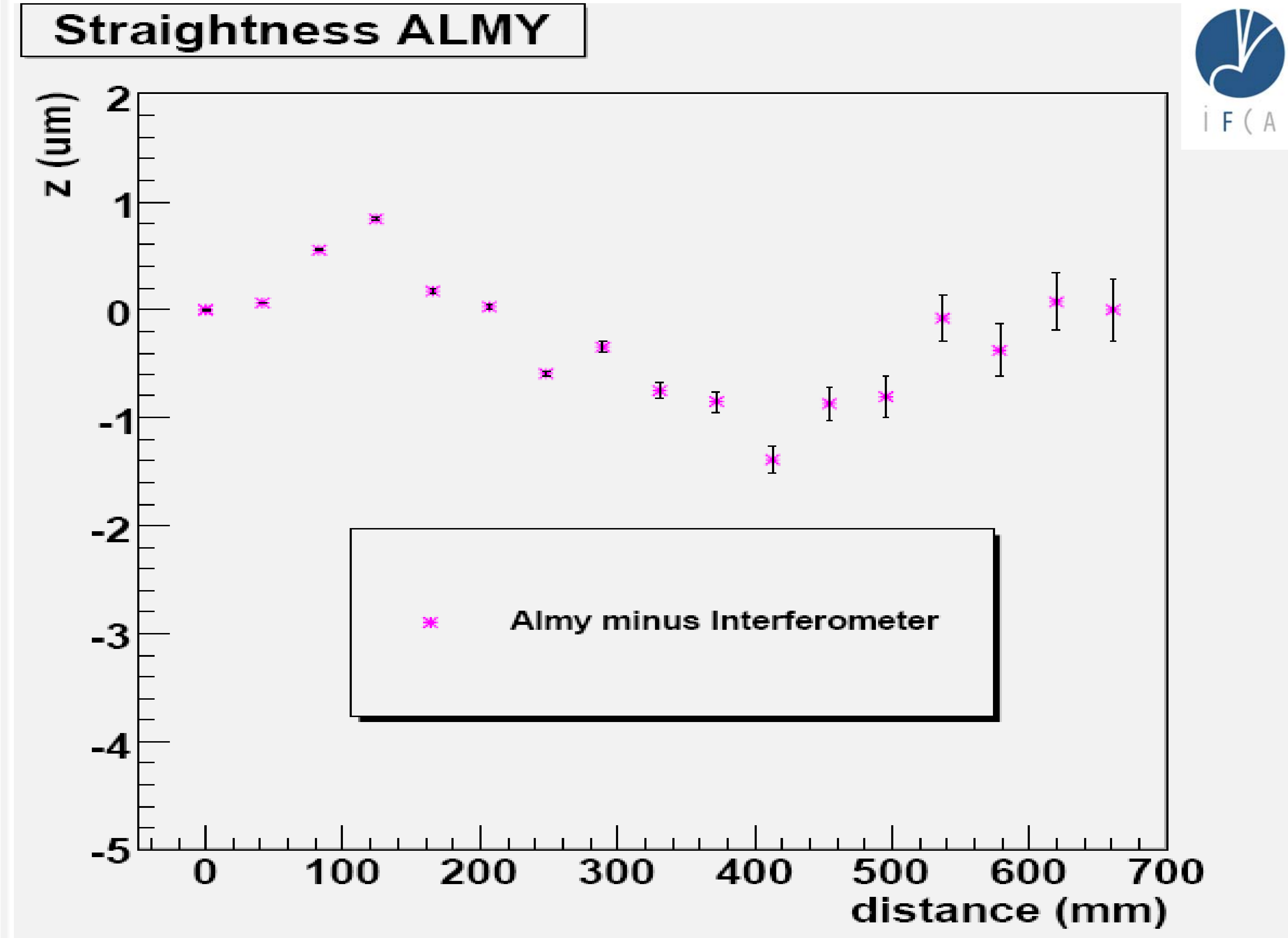


# Absolute accuracy Determination

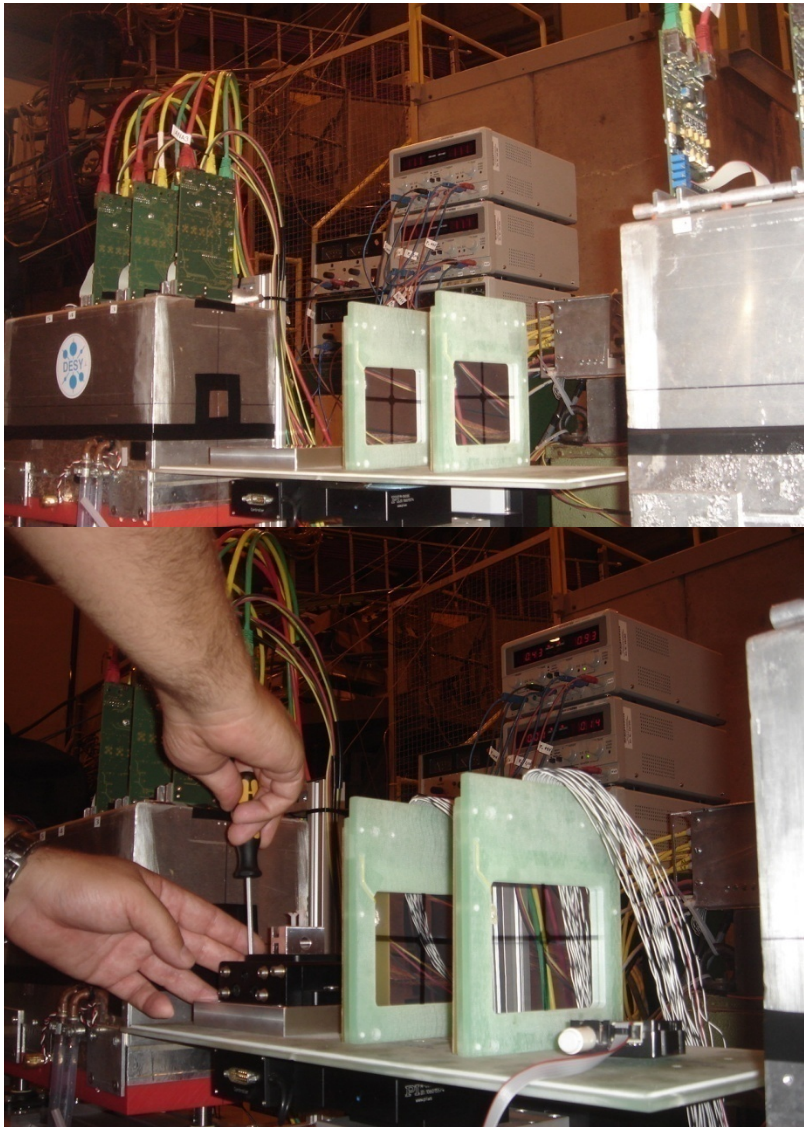
- Direct comparison with interferometric measurement (accuracy better than 1 um).




Snapshot of C:\Documents and Settings\moyad\Mis documentos\caractrización sensor en bamco optico\caracterización-sensor-Paris\ALIN-INT-GRAN-CONJU-3D-3.CATProduct - 18/03/2010 12:31:49


Straightness ALMY
z (um)
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700
distance (mm)
Almy minus Interferometer

# SiTRA Alignment – SPS Test beam




**AIM:**

**Assessment of SNR for backside removed metallization.**

**Comparison between track-based and laser alignment.**

**Testbeam at CERNs SPS**

**(19. to 26. August 2009)**

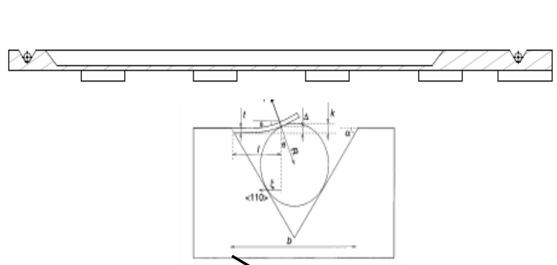
- CERN SPS North Area: H6B
- We used the *EUDET* Beam Telescope to get triggers and tracks

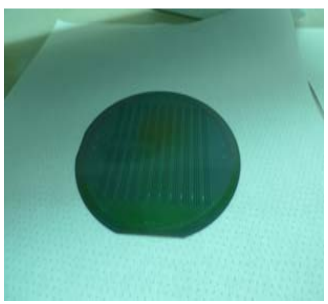
**Results**

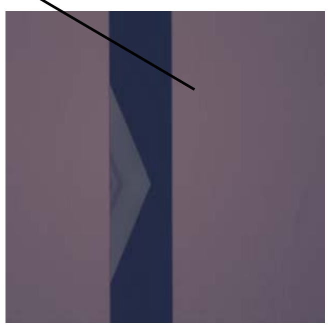
- About beam 100Kevents + laser 100Kevents.
- Analysis still in progress

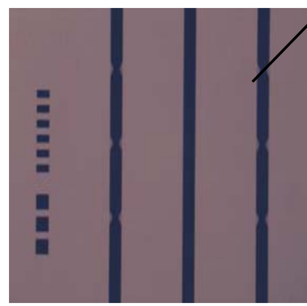
# Sensors attachment to Silicon

- Which fixation is the best ?
- Multi-groove wafer produced (CNM, HEPHY)



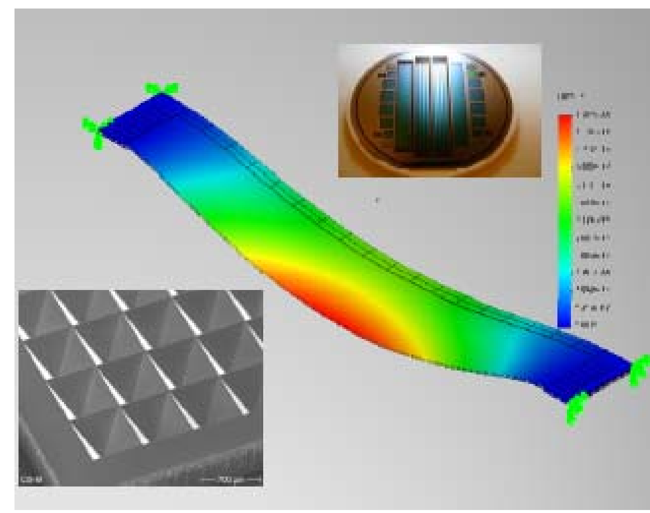




## Mechanics

IFIC

IFCA



## Embedding on CF composites

INTA

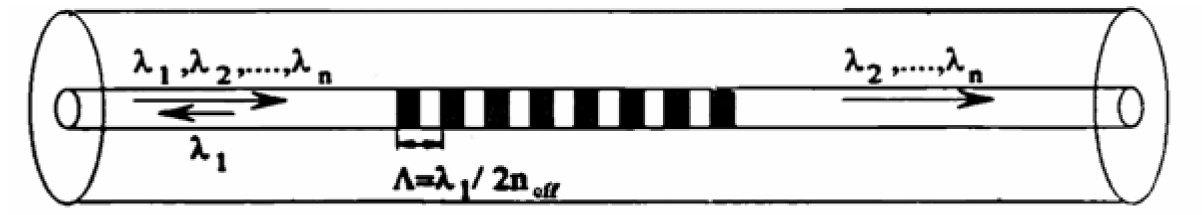
IFCA

Joint project with Spanish Aerospace Agency (INTA)

# R&D FOS targets: Sensor reliability

Stability of the FBG FOS response write in a bare fiber (same response under same conditions T, ε)

Bragg Grating




Selective narrow band mirror

$$\lambda_B = 2n_{eff} \cdot \Lambda$$

TEMPERATURE CHANGE

Thermal expansion for $\Lambda$
Termo-optic effect for $\mathbf{n_{eff}}$

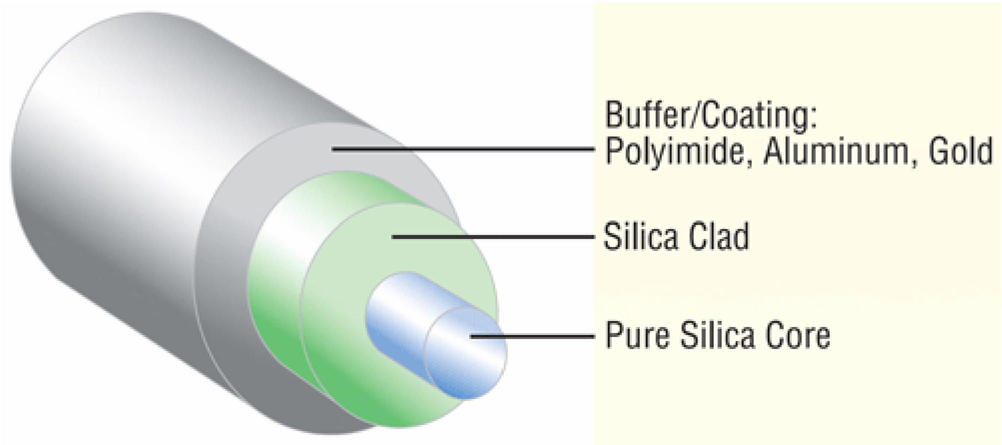
STRESS

Elasto-optic effect for $\mathbf{n_{eff}}$
Direct Strain for $\Lambda$

Depends on refraction Index and geometry stability

# R&D targets: Sensor reliability

## "Bare" Optical Fibers are quite inhomogeneous

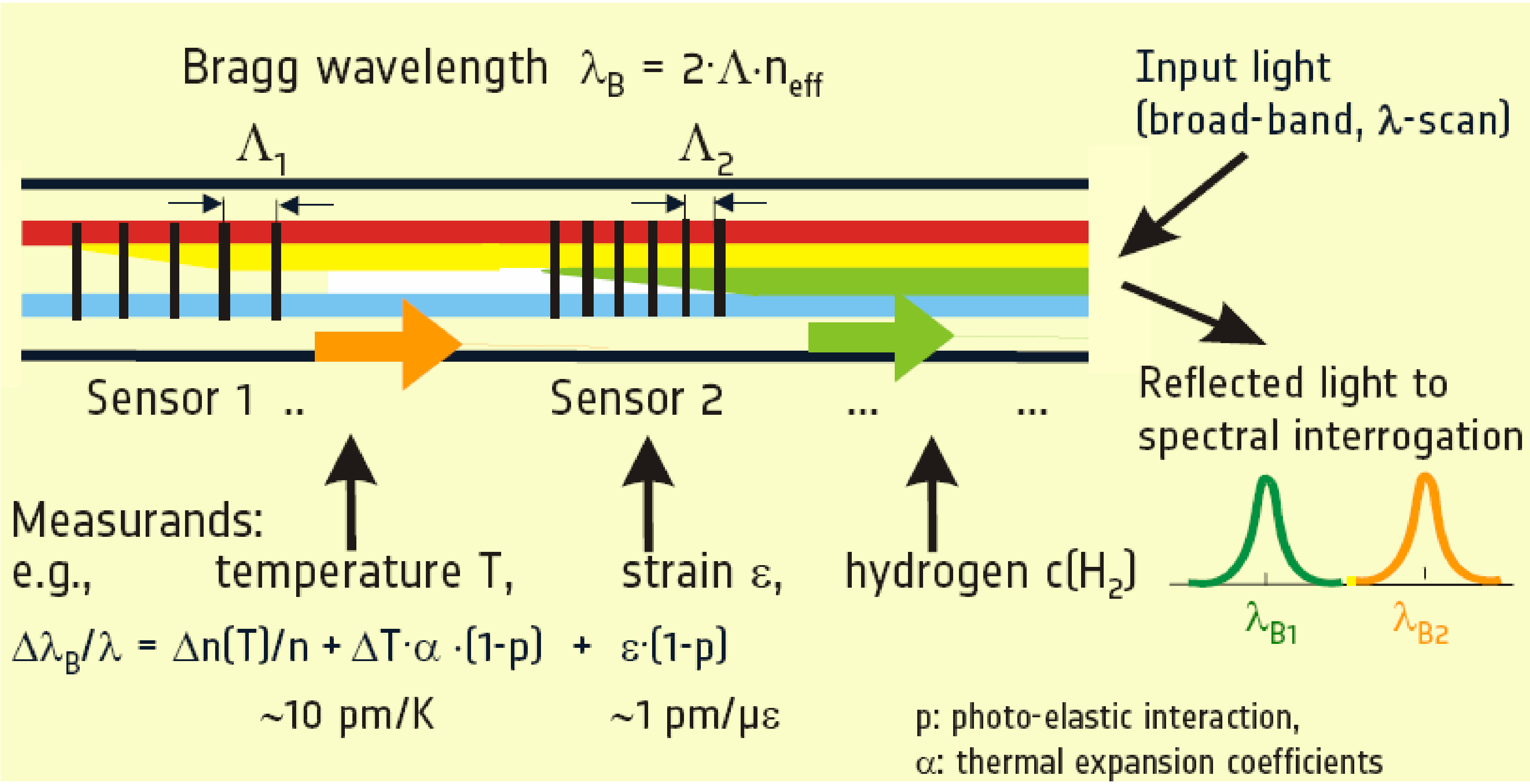



*Many coating available:*

*Acriyate, polyimide, ormocer, metalic, …*

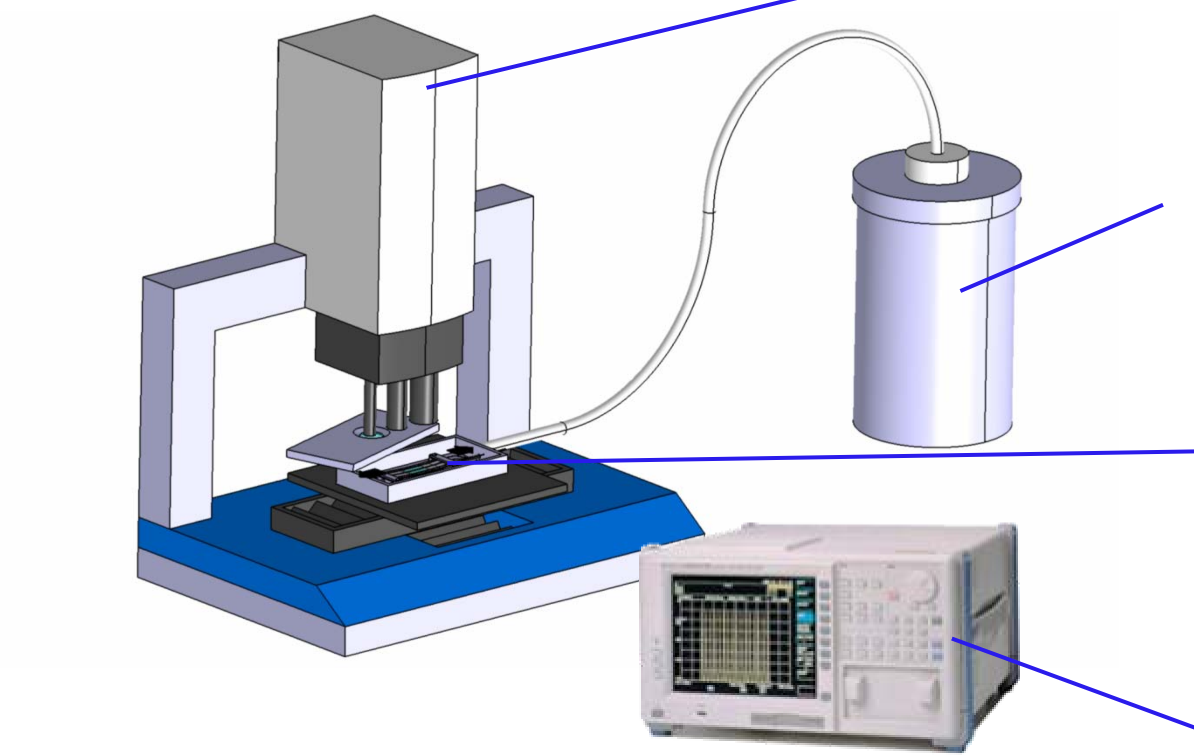
- External agents can induce changes of the mechanical properties of the fiber materials (young, poisson parameters) $\Rightarrow \Lambda$ changes
- Others (radiation) can also induce changes in n

# R&D on mechanics: Bragg grating



# R&D Targets: Test Setup (1)

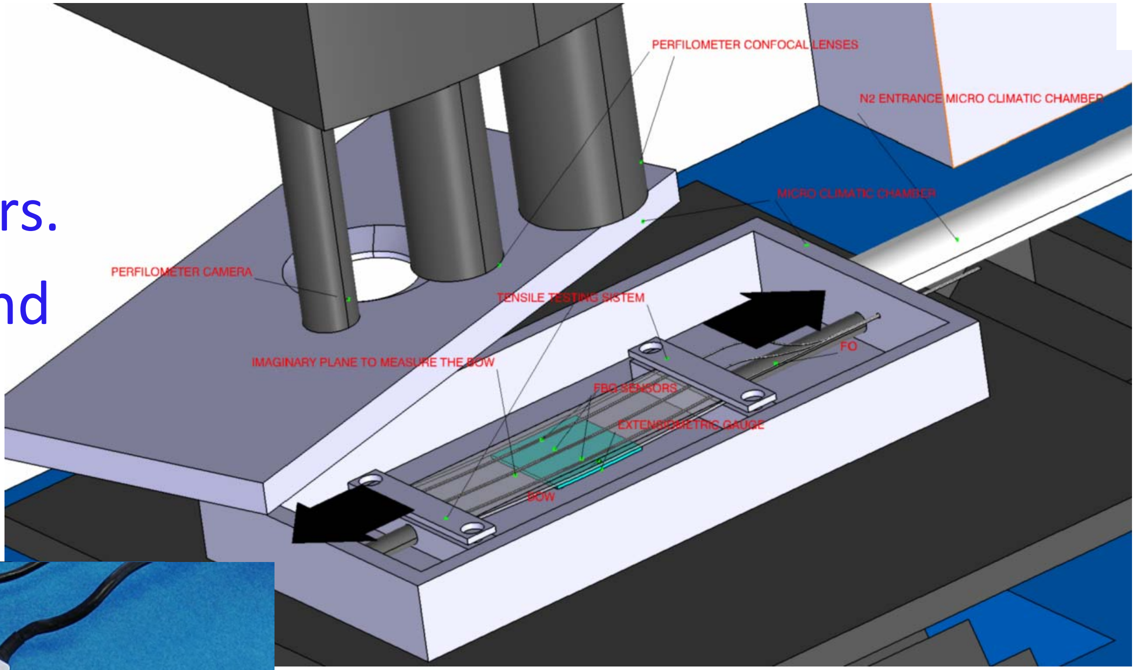
Calibration of bare fibers with different coattings (acrylate, polyimide, ormocer) and without coattings.

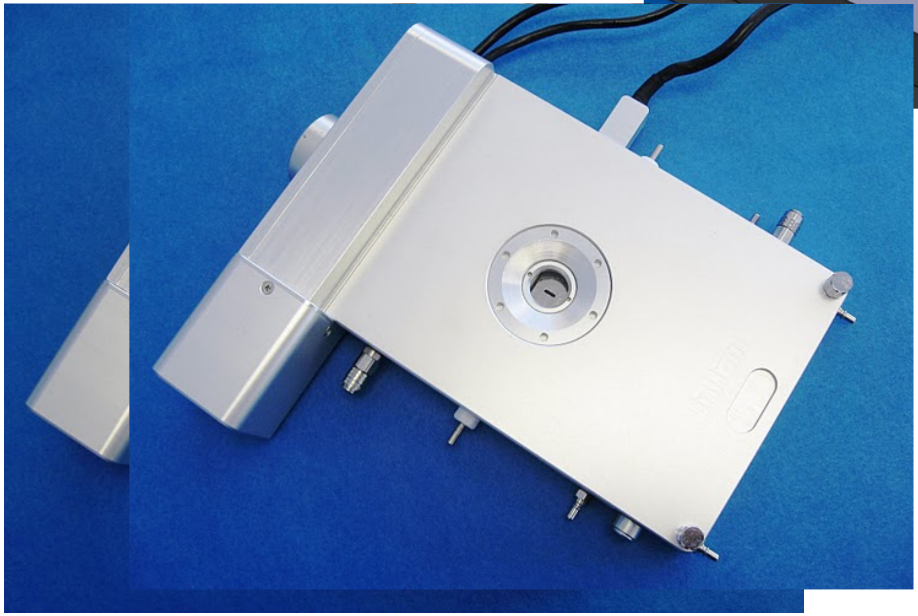


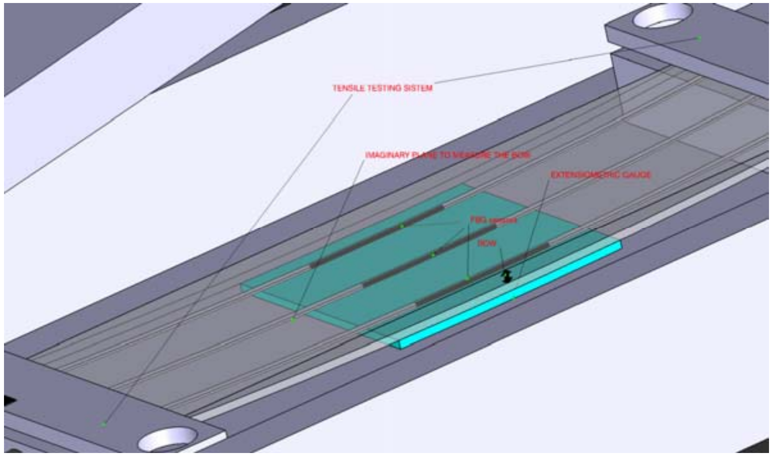
# R&D Targets: test setup (2)

Redundant calibration:

- Reference T and ε sensors.
- Tensile testing system and confocal profile meter





# OFS & FBG advantages

## General attributes of fibre optic sensors:

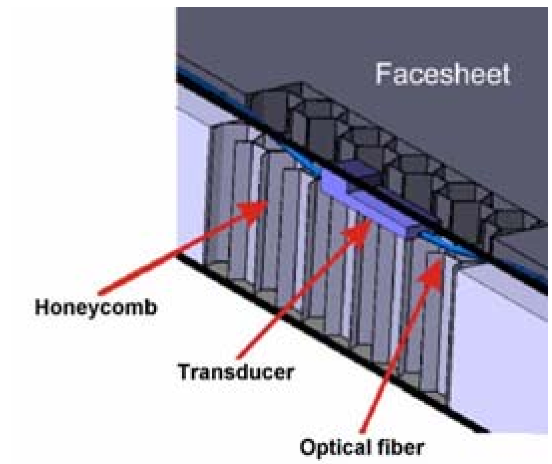
- Immunity against, i.e., applicable in
  - Electro-magnetic fields, high voltage, lightning
  - Explosive or chemically aggressive + corrosive media
  - High and low temperatures
  - Nuclear / ionising radiation environment (to be specified)
- Light-weight, miniaturised, flexible; low thermal conductivity
- Non-interfering, low-loss, long-range signal transmission ("Remote Sensing")

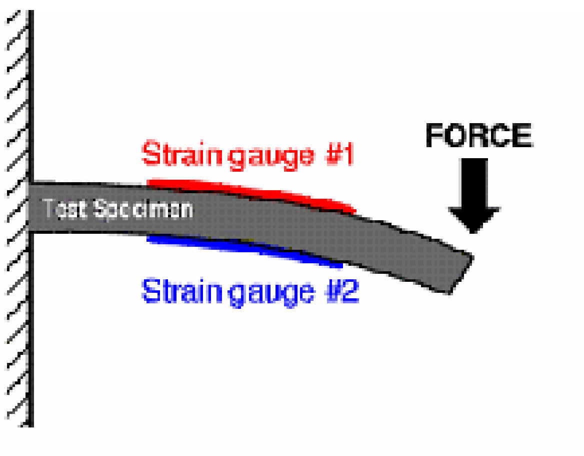
## Specific FBG attributes:

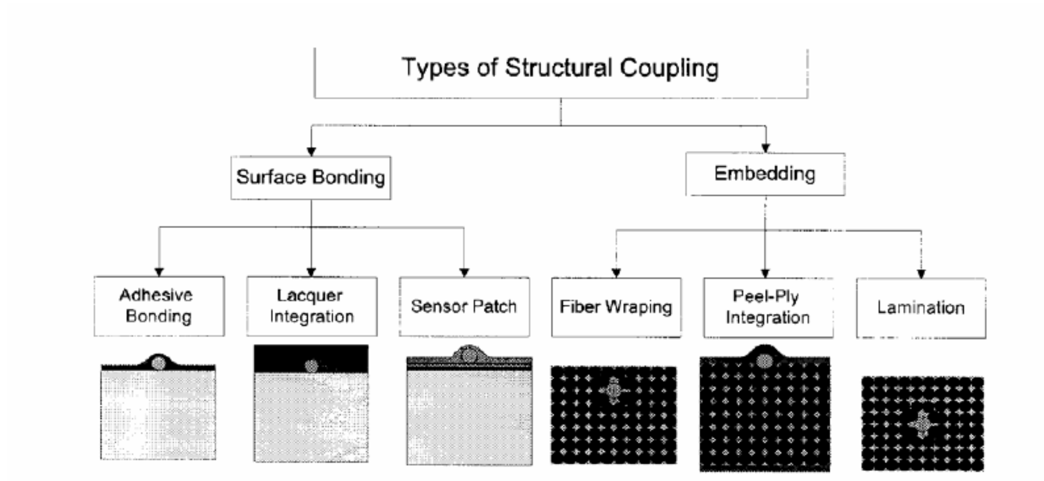
- Multiplexing capability ("Sensor Networks")
- Embedding in composite materials ("Smart Structures")
- Wavelength encoded – transferable measurement, neutral to intensity drifts
- Mass producible at reasonable cost
- Durable to high strain 5..6% ("Draw Tower Gratings", with any kind of coating)
- High and low temperatures (4 K .. 900 °C)

# Integrating OFS & carbon fiber composites

- For the Track structure would be interesting to use a embedded fiber optic sensor.
  - more precise and reliable data
- It could be use 2 side solution
  - Better understanding of the results
  - Useful to quantify the thermal strain



# Embedding on CF composites

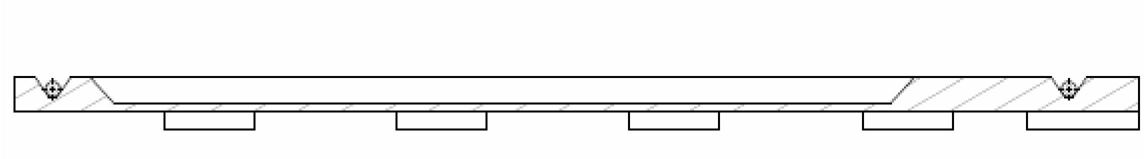
- Joint project with Spanish Aerospace Agency (INTA)
- Initial step: irradiation of embedded fibers with different coatings (required to increase the mechanical resistance of the non-coated bare fiber)
- Small samples 15x3x3 $mm^3$ of composite laminates with different stack configurations with and without optical fiber embedded in preparation
- Nano-indentation characterization of the different components of the samples (coating, cladding) and composite matrix for extracting the mechanical parameters: poisson, young, …

# Short term plans

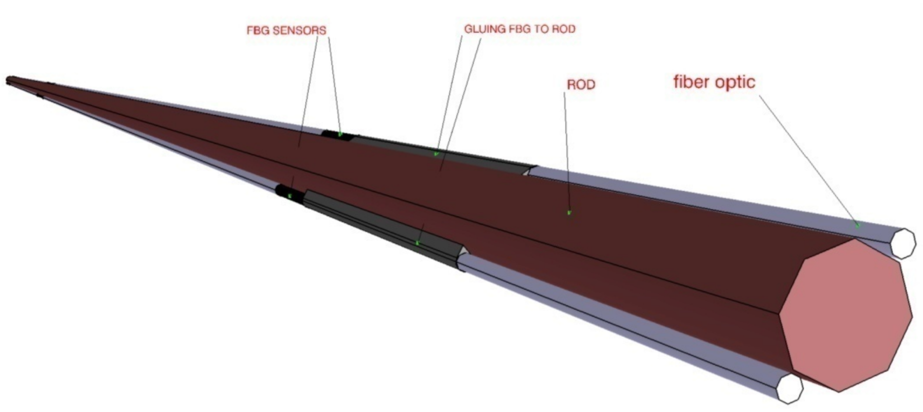
- Working together with the thermo-mechanical group on a strawman design for a temperature and position monitor for the PXD
- Use FBG in the Valencia thermal test stand.
- Expect first results concerning the FBG sensors calibrations (reliability studies) in the 3QT of 2010.
- By the end of the year characterization of the fiber materials and embedded fibers in Carbon Fiber composites.
- Design of displacement FBG sensors by the end of the year.

# What about DEPFETS?

- During the thinning process  V-groove could be also etched.



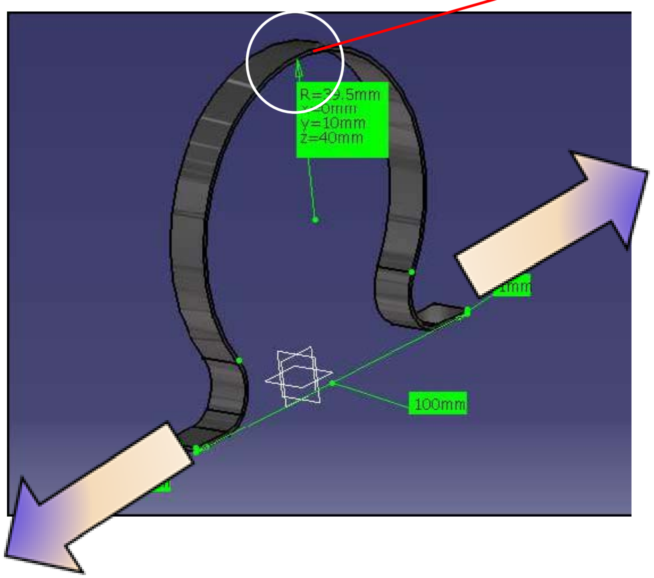
Integration on other Vertex supporting structures very doable

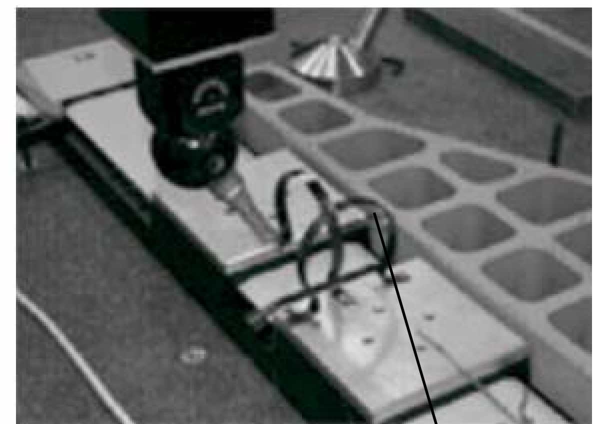


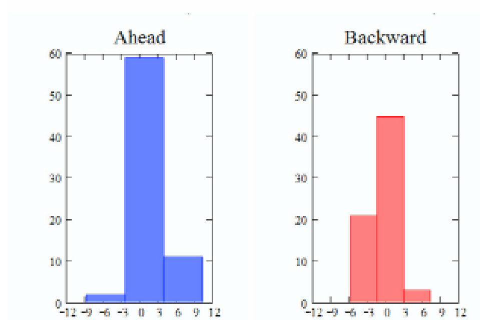
# Displacement sensors based on strain FBG

- Original idea from the late BTeV vertex detector: " The omega-like gauge"
- Mechanical displacement range adapter.

*STRAIN FBG SENSOR ON THE TIP*



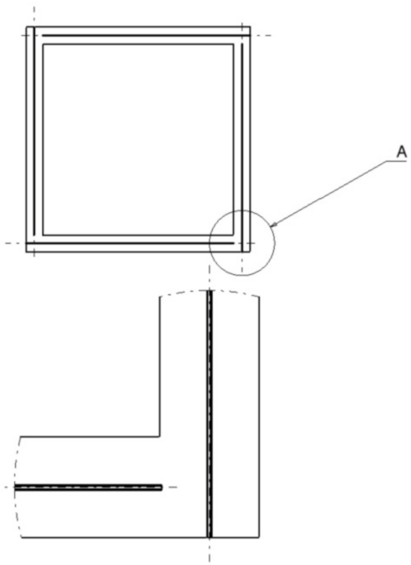



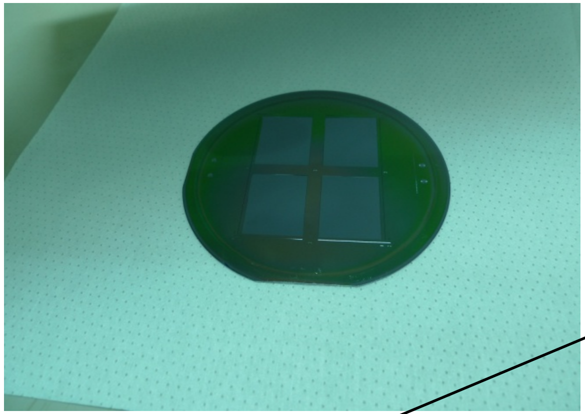


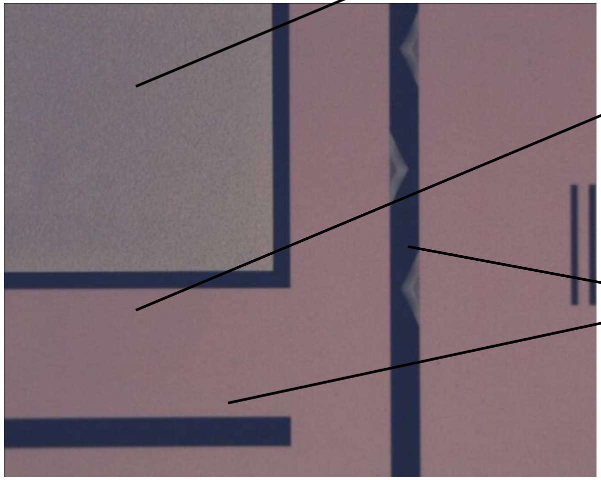

*Temperature Compensating "omega"*

# Thin Sensor  mechanical dummies

- Thinned (100, 150, 200 um) sensor mechanical dummies.





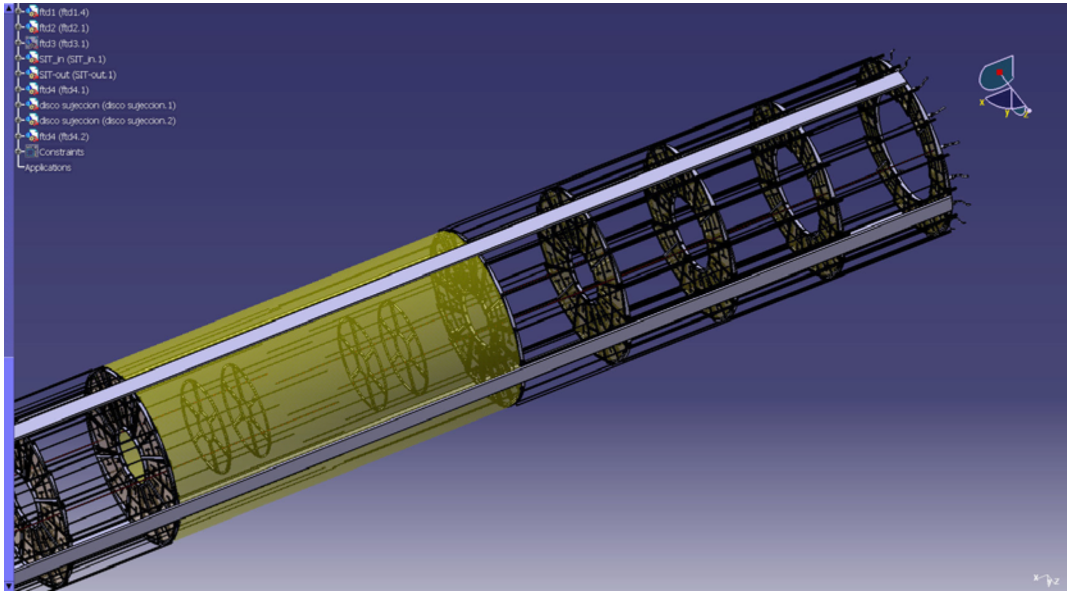

*Exp. validation of FEA simulations.*

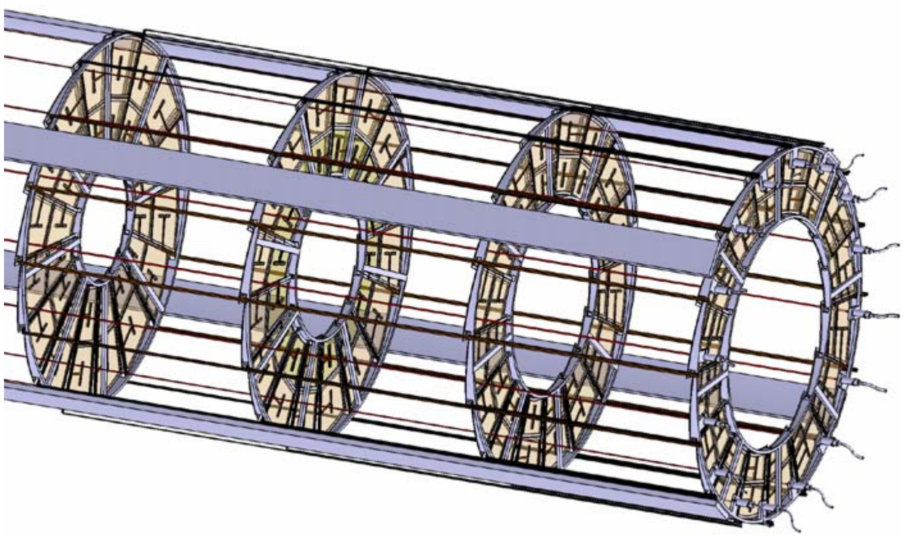
*Conventional KOH anisotropic etching on SOI wafer.*

# Displacement sensors based on strain FBG

- Improvement paths:
  - Adjust the mechanical design to our displacement range.
  - Embedding of the fiber, avoid glues.
  - Integrate the temperature composition FBG
  - Now first toy montecarlos.

# ILD Forward Tracking Disks IFCA, IFIC

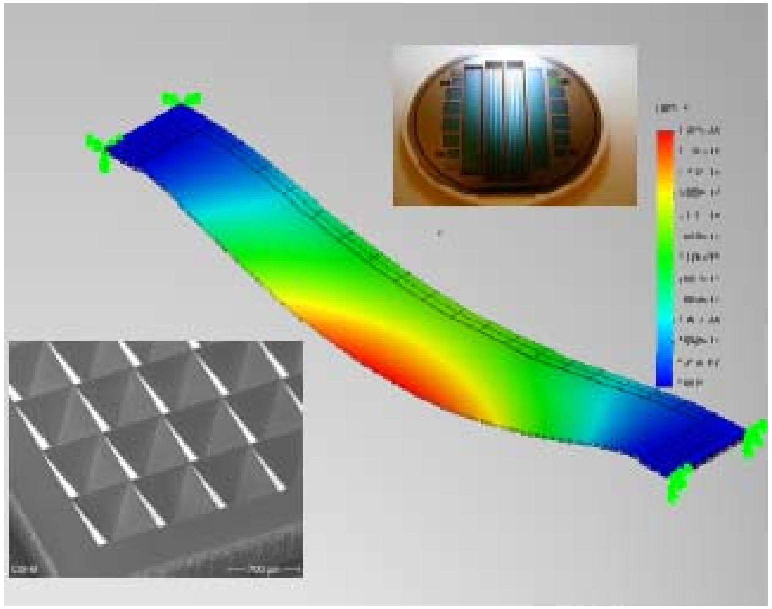


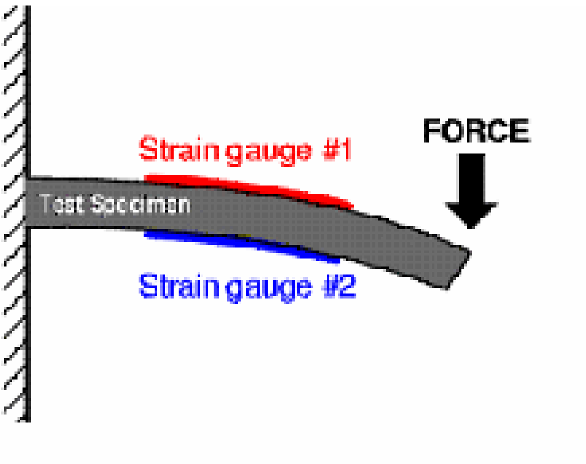



*Three inermost disks pixels*

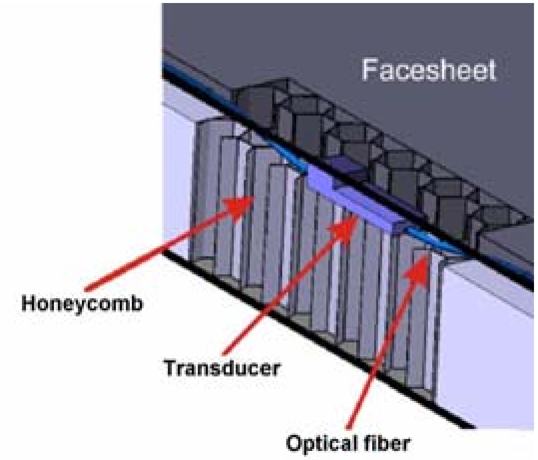
*Four outermost disks microstrips*

# Mechanics – IFIC, IFCA





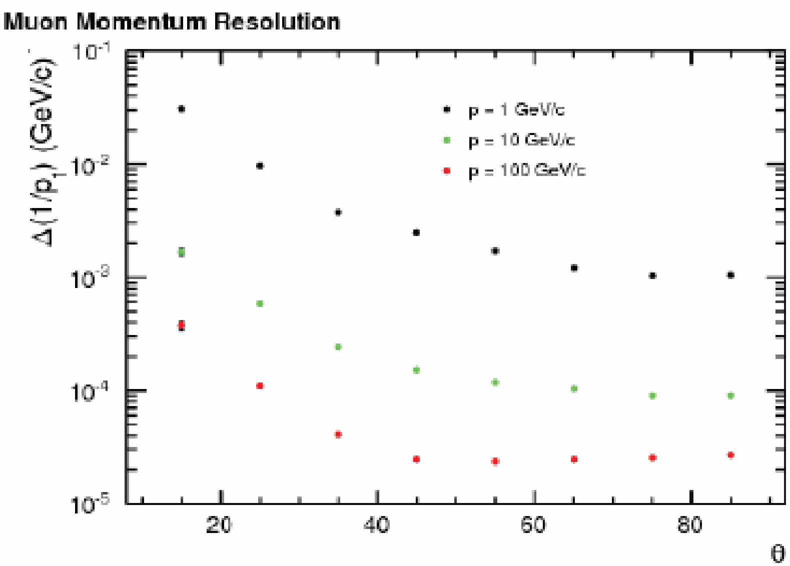

- For the Track structure would be interesting to use a embedded fiber optic sensor.
  - more precise and reliable data
- It could be use 2 side solution
  - Better understanding of the results
  - Useful to quantify the termical strain

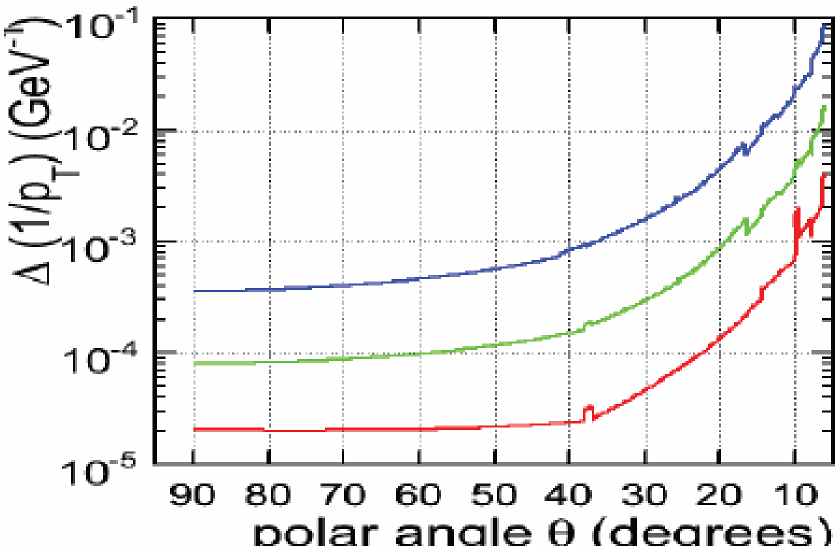


# Challenges for the Forward Tracking

## Momentum Resolution: Single Electrons

- Generated Single electron samples (private but available)
- Simulated with ILD_00 model and Reconstructed following the standard processors availables in the framework (Marlin, ..)
- Compared with LOI results for muons

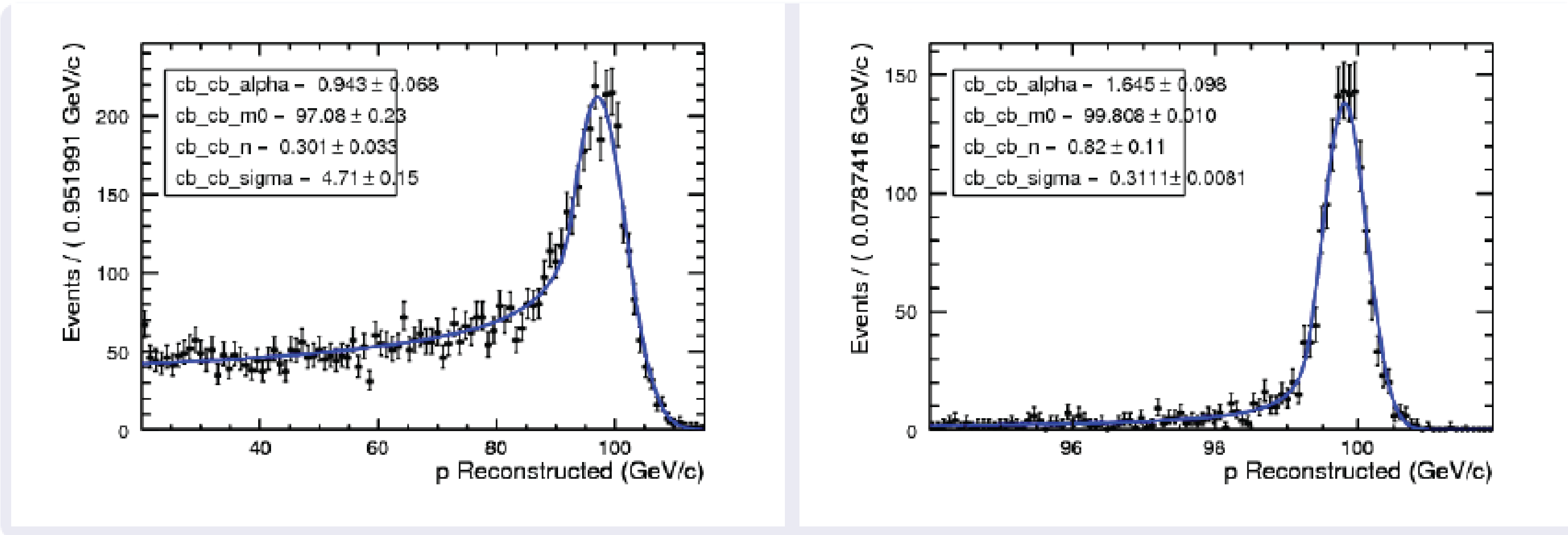


# Challenges for the Forward Tracking

## Momentum Resolution: Single Electrons

$5^o < \theta < 10^o$ $\qquad$ $85^o < \theta < 90^o$



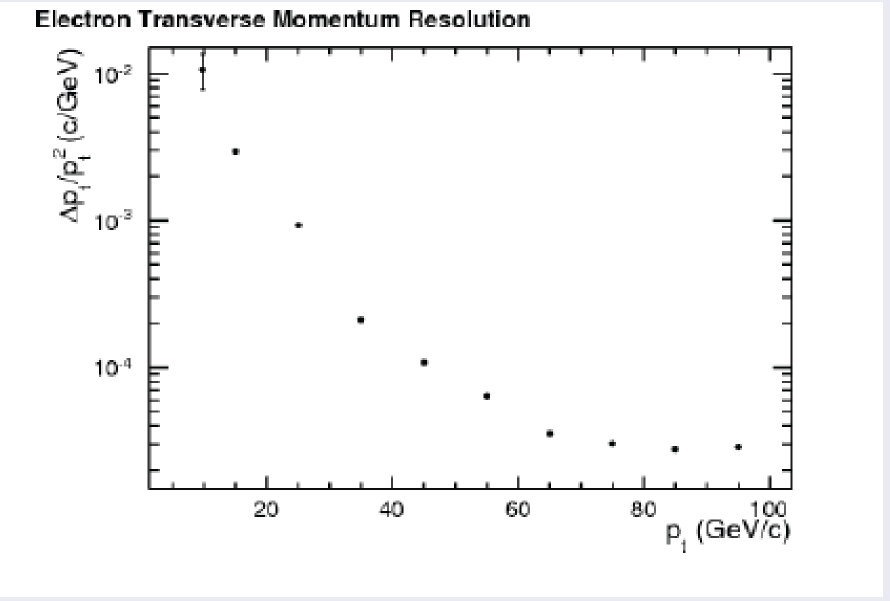

Energy Loss:

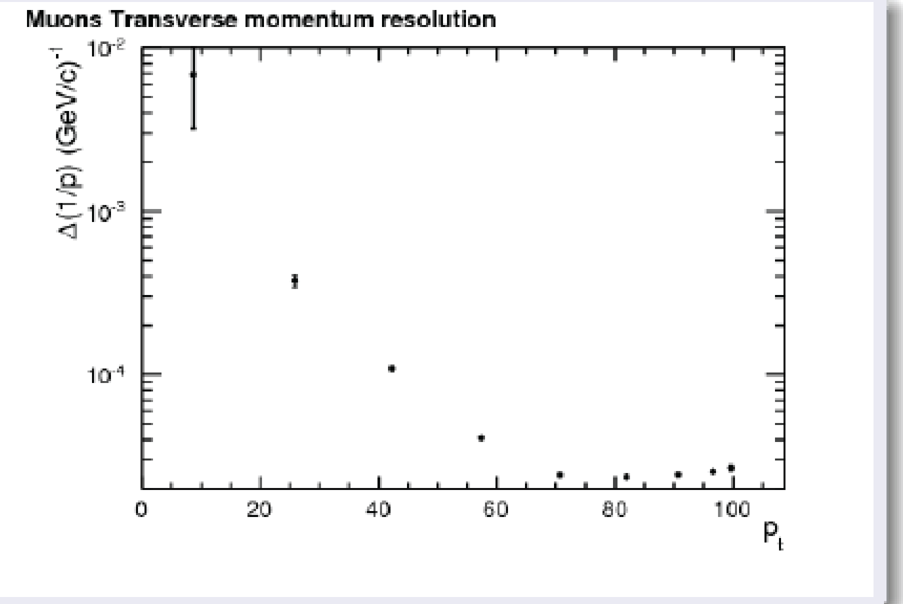
- 3 GeV/c in average (forward)
- 150-200 MeV/c in average (central)

# Challenges for the Forward Tracking

## Momentum Resolution: Single Electrons

Fixed p=100 GeV/c (ongoing study for differents shoots, p=1GeV/c, p=10GeV/c,...)



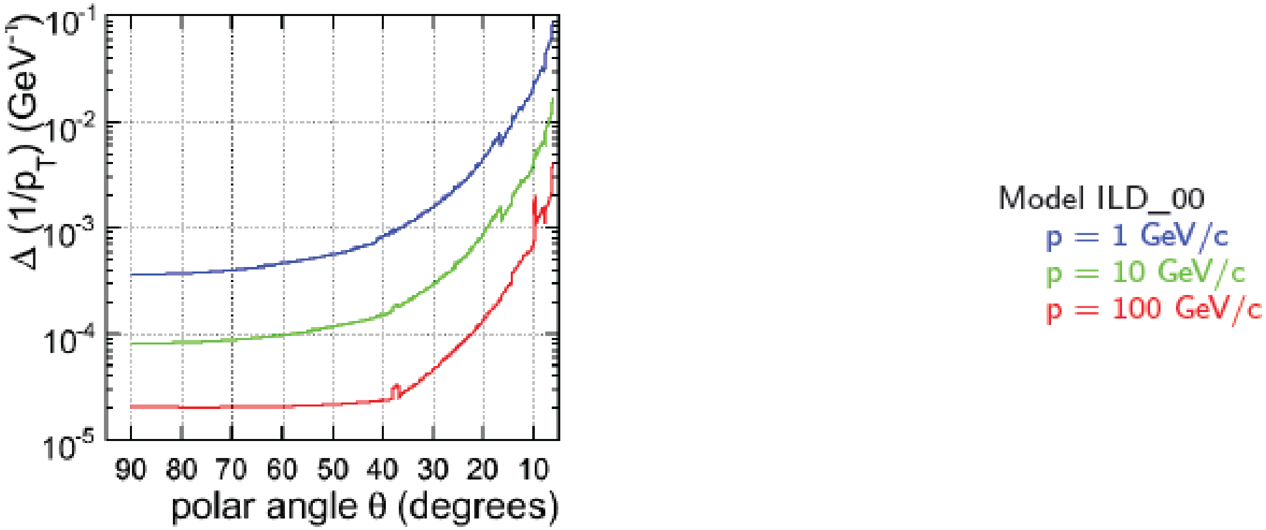




Worse resolution than muons in the forward region, but in the same order.

ILC specifications are yield in the central region $\theta \gtrsim 50^o - 60^o$

# ILC tracking specification: $\Delta(1/p_t) < 5 \cdot 10^{-5}\,(GeV/c)^{-1}$

Precision required to reconstruct the Higgs boson using the recoil method, and to reconstruct SUSY end-points




## Momentum resolution Single Muons

- Performance ~ stable down to $36^o$
- Sudden loss between $6^0 - 36^o$.
  - Magnetic field orientation (inevitable within $4\pi$ detector geometry)
  - loss of number of measurements in TPC

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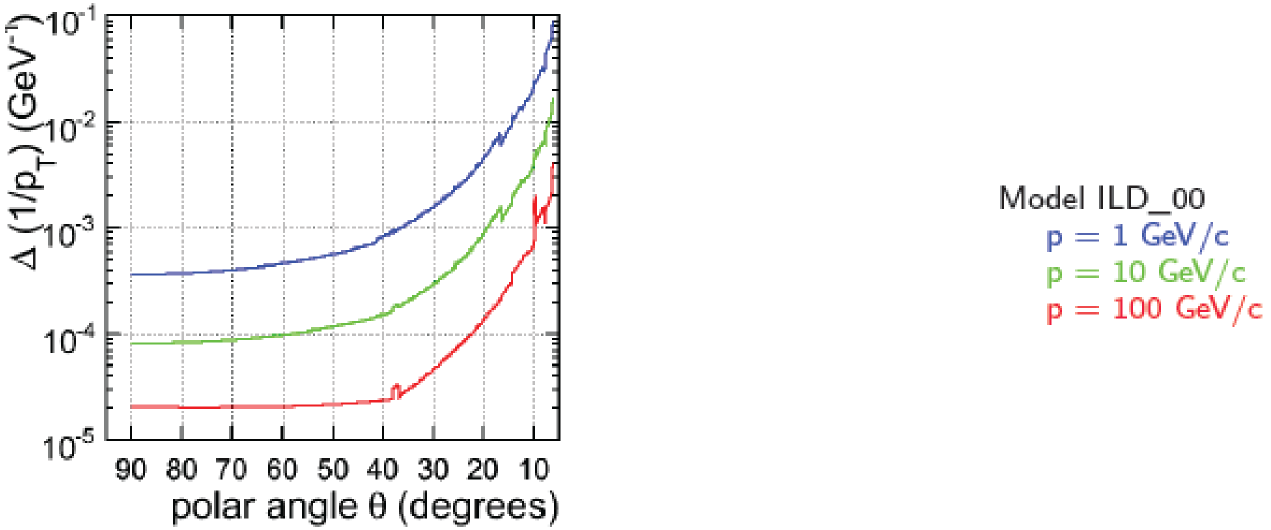


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- Performance ~ stable down to $36^o$
- Sudden loss between $6^0 - 36^o$.
  - Magnetic field orientation (inevitable within $4\pi$ detector geometry)
  - loss of number of measurements in TPC

## VXD: impact parameter resolution 5 - 10 $\mu m$.

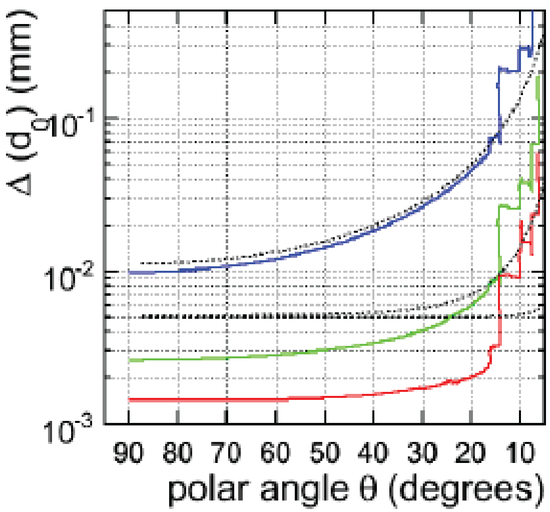
This precision is required to achieve excellent heavy flavour tagging, particularly for couplings of the Higgs boson to charm ($c\tau \sim 150\mu m$) and bottom ($c\tau \sim 450\mu m$)

| | a (µm) | b (µm GeV) |
|---|---|---|
| LEP | 25 | 70 |
| SLD | 8 | 33 |
| LHC | 12 | 70 |
| ILC | 5 | 10 |

$$\sigma_{IP} = a \oplus \frac{b}{p sin^{3/2}\theta}$$

**Unprecedented precision** (small pixels, 20x20 µm$^2$)

**Strongly reduce the multiple Coulomb scattering term** (material: 0.1 % $X_0$ / layer ~ 100 µm Si)

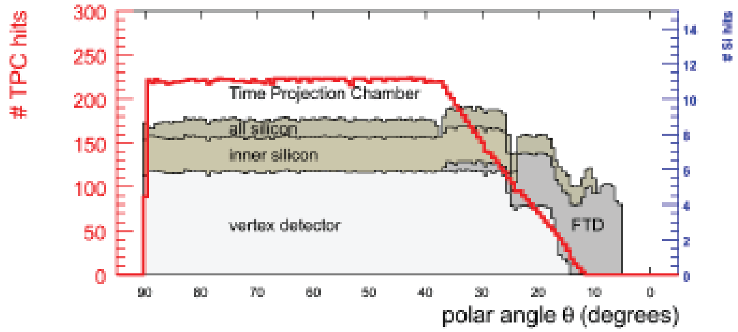



- Barrel: $a \simeq 1.7\mu m$
- forward: performance down

# Challenges for the Forward Tracking

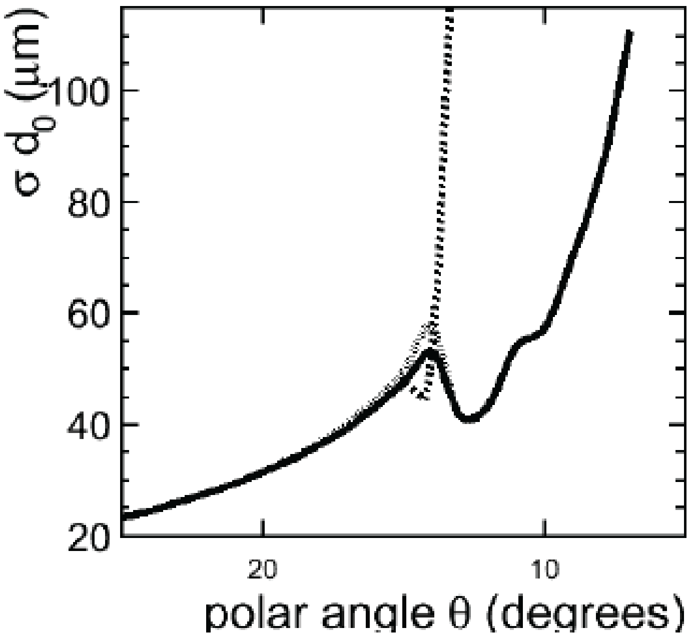
## Pattern Recognition

- Clearly, 6-15 degrees is weakest region in ILD in terms of number of measurement
  - Ongoing study (C. Iglesias) evaluate hit densities in $t\bar{t}$ events per disk and per petal, subdividing disks in several single-wafers segments.
- The combinatorial algorithm on stand-alone FTD i able to efficiently and cleanly reconstruct tracks down to a $p_t$ of 100 MeV/c (see M.Vos talk, ILC meeting Sendai)
  - R-segmentation: in innermost disks 500$\mu m$ required, in outermost disks O (1$cm$)
  - Read-out speed: beyond several 10 sec of integrated bunch crossings the density of low momentum tracks prevents algorithm convergence
  - Material: an increase of the material beyond 1 %/disk has dramatic consequences on pattern recognition

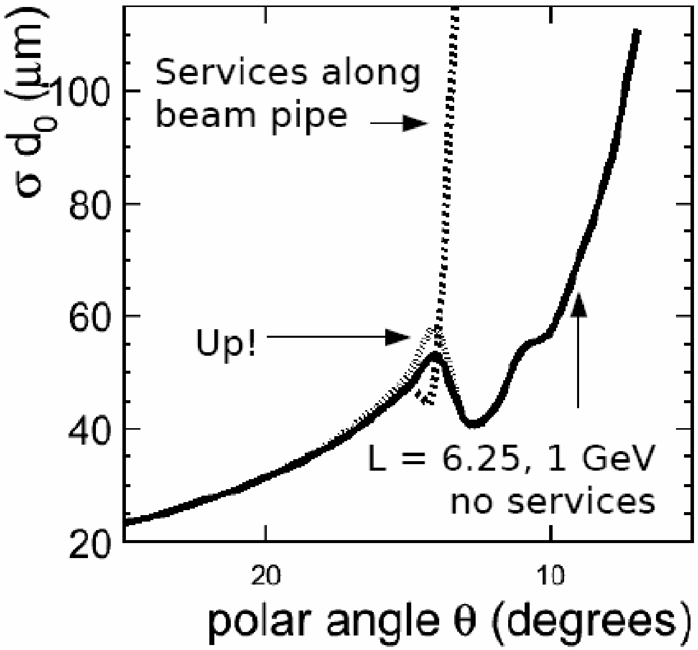


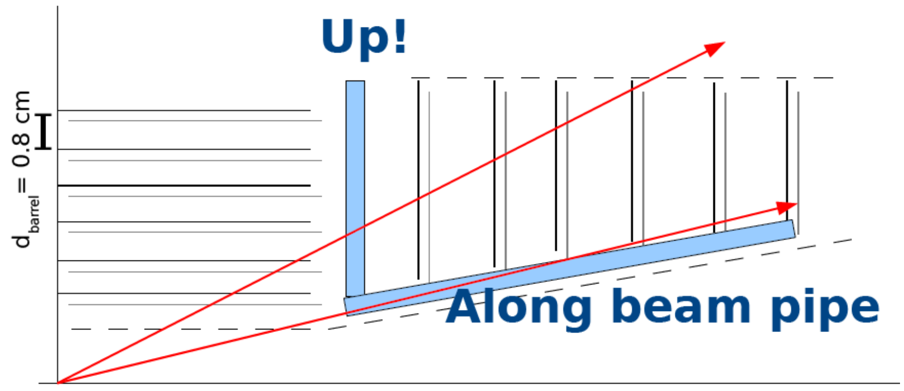
To improve performance in the forward region: routing the barrel VXD services
See talk A.Ruiz, M.Vos ALCPG Alburquerque of the Toy model for barrel+end-cap vertex detector

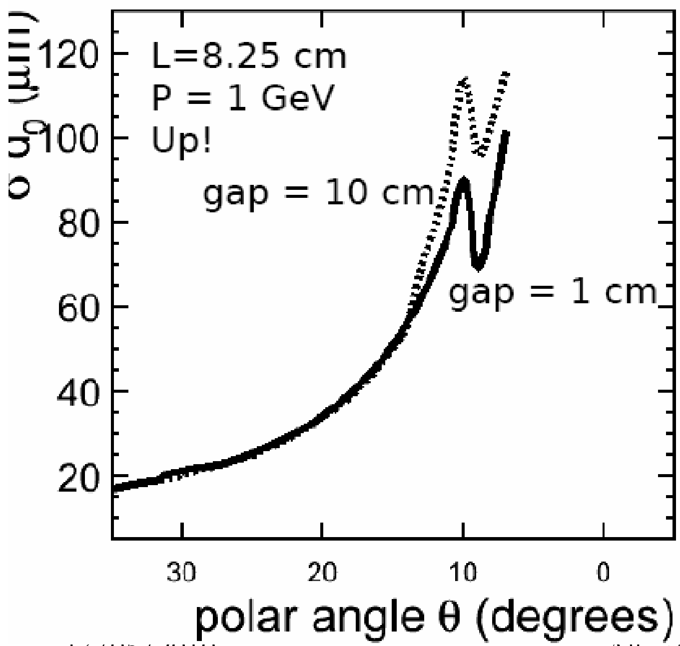
- The forward region clearly does NOT like the services routed along the beam pipe
- If anything close to a few radiation lengths comes in the way between endcap and interaction point we can forget about forward vertexing

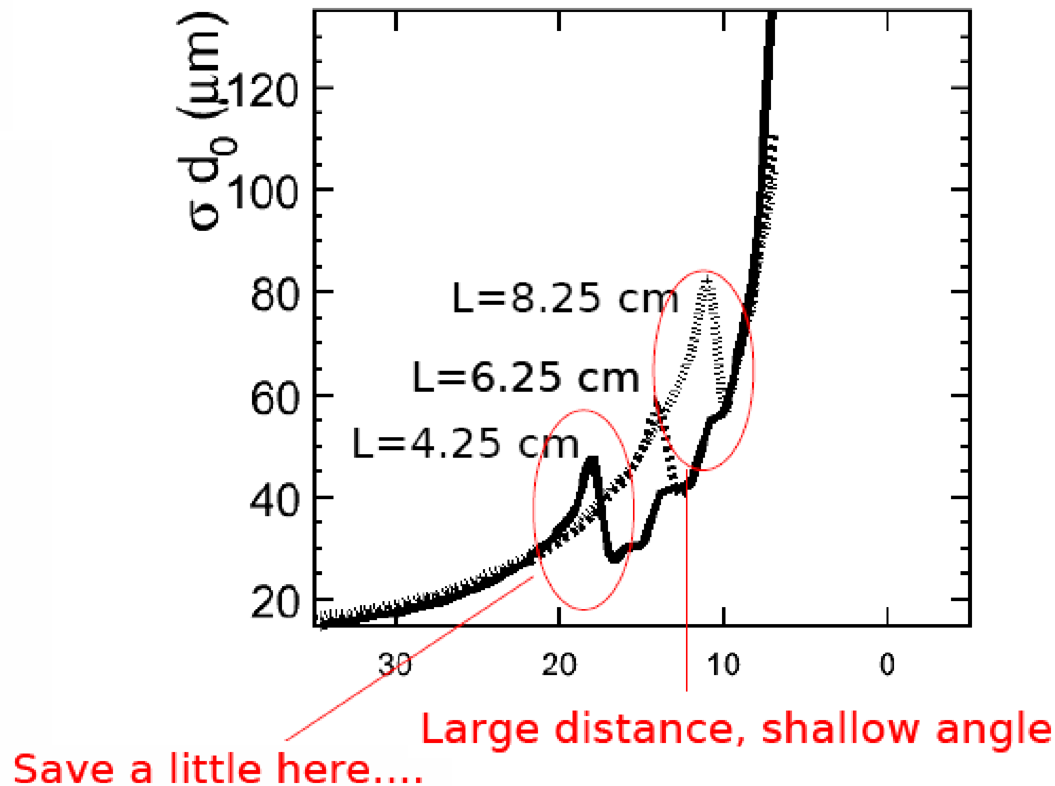


# Choosing a toy geometry



# Choosing a toy geometry

**There is significant physics to be gained (or lost) in the forward region (6-30°)**

**If the central vertexing performance is somewhat of a challenge, maintaining good performance at small polar angle is close to impossible**

**A simple-minded layout optimization (see caveats) of the VXD-FTD layout for forward vertexing performance yields:**

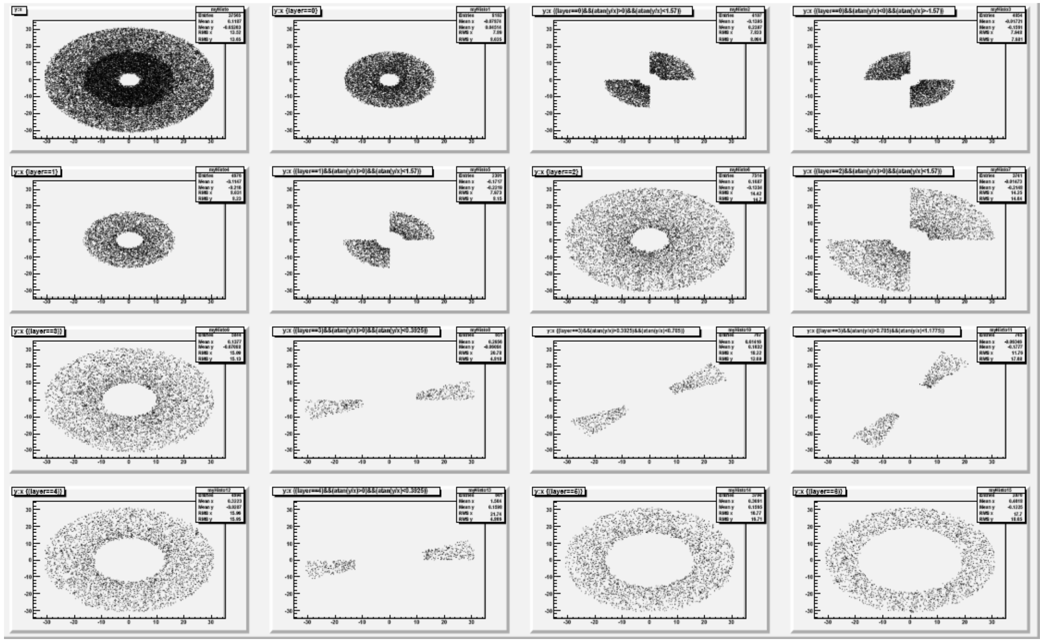
- Minimize $z_{gap}$

**Service routing/material is essential in choosing optimal geometry:**

- Upward ⇔ very short barrel + closely packed end-cap:
  + works well even at low angle
  - any material (beam pipe) in front of the disks will destroy the performance
- Along beam pipe ⇔ very long barrel
  + no "material bump" due to services down to ~15°
  - limited vertexing beyond first barrel layer coverage

# ILC Forward Tracking Disks Simulations

- Disk segmentation in petals has also been optimized with the constrain of the wafer size
- Hit density more uniform than a simple 8 petal/disk segmentation



| nhits/cm$^2$/BX | Area cm$^2$ | Muons 1 GeV | Muons 10 GeV | Muons 100GeV | Ttbar-> bbcssc |
|---|---|---|---|---|---|
| FTD_1 (8 pet) | 99.6 | 1.90 *10-4 | 2.14 * 10-4 | 2.11 * 10-4 | 1.06 *10-2 |
| FTD_2 ( 8 pet) | 99.13 | 1.12 *10-4 | 1.35 *10 -4 | 1.36*10 -4 | 6.01 *10-3 |
| FTD_3 (20pet) | 165.93 | 3.01 * 10-5 | 2.94*10-5 | 3.56 *10-5 | 2.56 *10 -3 |
| FTD_4 (16 pet) | 167.72 | 2.35* 10-5 | 2.61 *10-5 | 2.67 *10-5 | 2.07 * 10-3 |
| FTD_5 (16 pet) | 154.13 | 2.23 * 10-5 | 1.65*10-5 | 1.65*10-5 | 1.98 * 10-3 |
| FTD_6 (16 pet) | 136.93 | 2.67* 10-5 | 1.69 *10-5 | 1.37 *10-5 | 1.81 *10-3 |
| FTD_7 (16 pet) | 116.19 | 2.02*10-5 | 1.42 *10-5 | 8.39 *10-6 | 1.67 * 10-3 |

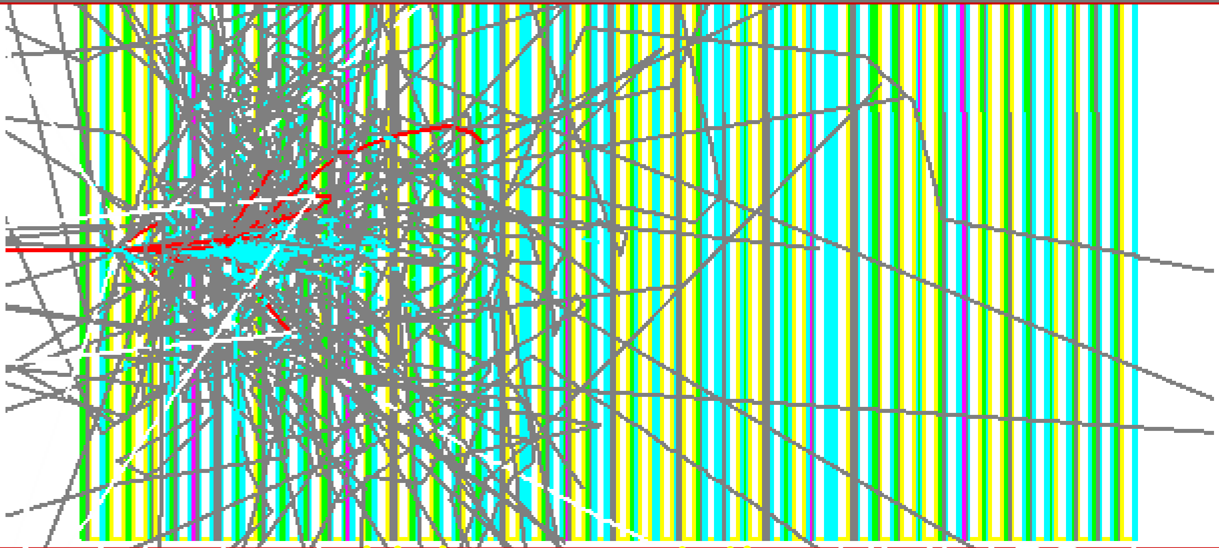
- According to the hit density disk 3 should probably have the same technology than the outer disks

# European SDHCAL

**Main CIEMAT participation**

Semi Digital HCAL using GRPCs or Micromegas as active material.

Purpose: assembly of a 1m$^3$ physics prototype to be tested together with other CALICE prototypes. In order to validate PF



**Compact** (thin detectors), **high segmentation** (digital RO, 1 cm2 pads)

Excellent tracking capability, energy resolution comparable to analogue HCAL

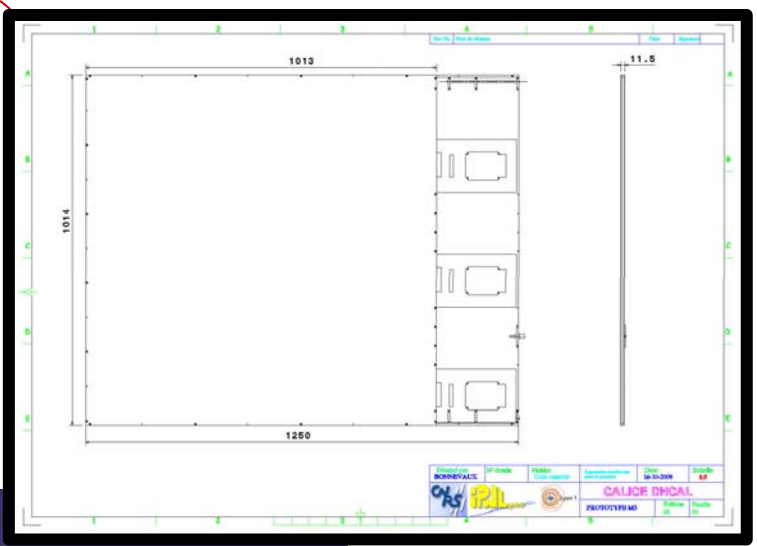
Common electronics with other detectors (DAQ)

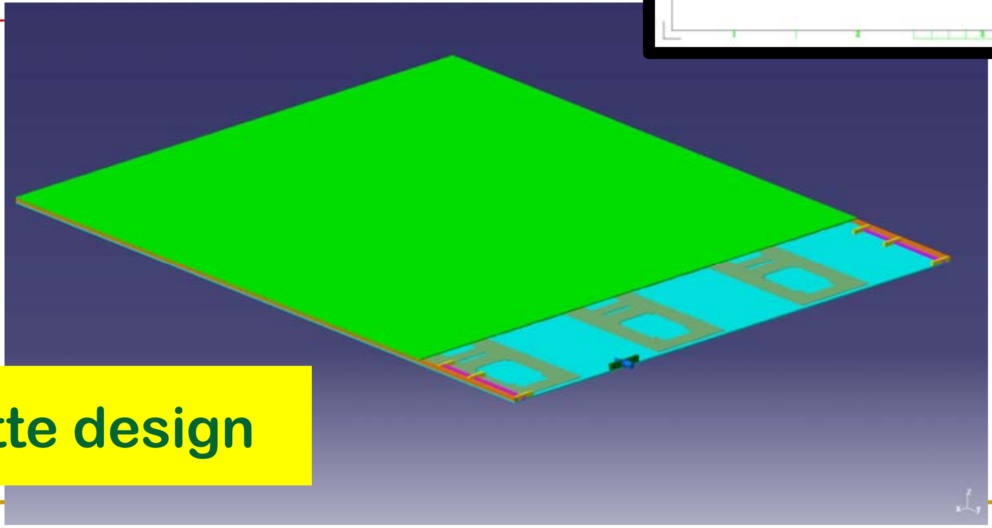
# Towards 1m3 prototype
# Mechanical structure

Main CIEMAT contribution. It will consist of 40 to 50 layers of detector/absorber. Enough to contain hadronic shower.

Working on design (technological prototype, having in mind using ILD techniques for a final design)

Slide detector (protected by casette) in self-supporting structure



RPC Cassette design

Same thickness as

# Sensor developments for the endcap tracker

- More relaxed conditions of material budget (~0.25 % X0 first three disks, ~0.65 % X0 last four disks), spatial resolution of 7 μm in Rφ. Very thin ( 150-200 μm thick ) silicon microstrip sensors, pitch of ~ 40 μm. Low power FEE
- Both pixel and micro-strip silicon technologies are being considered
- Characterization of the sensors in the lab
- Edgeless studies to reduce dead zones, removal of pitch adapter to increase signal over noise
- Readout electronics, connectivity
- Integration, mechanical and thermal studies
- Alignment sensors, FOS sensors
- Test beams

# Ongoing optimizations activities for FLC-Spain

- Definition of benchmarks for forward tracking
  - typical benchmarks do not constrain the design sufficiently
  - involve (Spanish) theorists
- Finish part II of of forward tracking paper (M. Vos)
  - including electron studies presented today (J. Duarte)
- Further develop ILD FTD Monte Carlo model
  - to be discussed with SiLC and Frank Gaede
- Optimize forward tracking design
  - forward vertexing, pattern recognition can be improved
- Forward tracking at 1 TeV, multi-TeV (CLIC)
  - physics tends to be more forward peaked
- Time vs. spatial resolution
  - forward region requires more aggressive time-slicing (but exactly how much?)

Identify manpower and responsabilities.