The silicon Hybrid Alignment System

Presented by:

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Outline

- Introduction
- Hybrid alignment systems in HEP experiments
- ILC approach and actual proposals

Framework

IFCA Santander:

- Instituto de Fisica de Cantabria
  IFCA SiLC (a.o.): Marcos Fernandez,Sven Heinemeyer,Amparo Lopez,Celso Martinez,,Alberto Ruiz,Ivan Vila

- IFCA is a member of the EuDET European FP6-I3 project and of the SiLC R&D collaboration

  — SiLC (**Si**licon for the **L**iner **C**ollider) is a generic R&D collaboration that studies all the tracking concepts for the ILC, with or without a TPC

- For CMS, among other activities, we have conceived, developed, tested and now installed the Link alignment system of CMS.

  — This system uses transparent position optical sensors to reference the (inner) central tracker with respect to the (outer) muon system

Multipoint alignment: Alignment of consecutive detectors using a single reference

- For the ILC, the proposal is to **align Si modules using an IR laser beam** which passes through several Si μ-strip sensors ≡ IR multipoint optical system

Si μ-strip "fotosensors"? Advantages

Si is almost transparent to IR light. Still, its (slight) absorption is enough to produce a measurable signal

— Beam position across several sensors can thus be measured.

— Remaining sensors are reconstructed using tracks in overlap region.

— Subsequent track alignment reduces precision 1 order of magnitude.

Advantages of this approach:

— Sensors under study are their own alignment system ⇒ No mechanical transfer errors between fiducial marks and the modules

— Minimum impact on system integration

— Straightforward DAQ integration ⇒ Alignment data is read out using Si DAQ

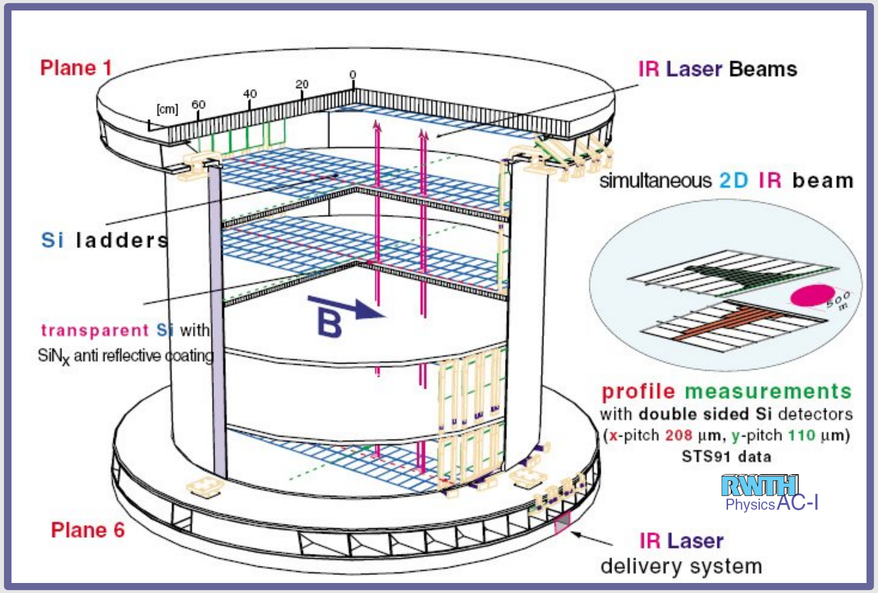
— Alignment system does not compromise tracker design: changes in geometry of the modules have no impact in system precision

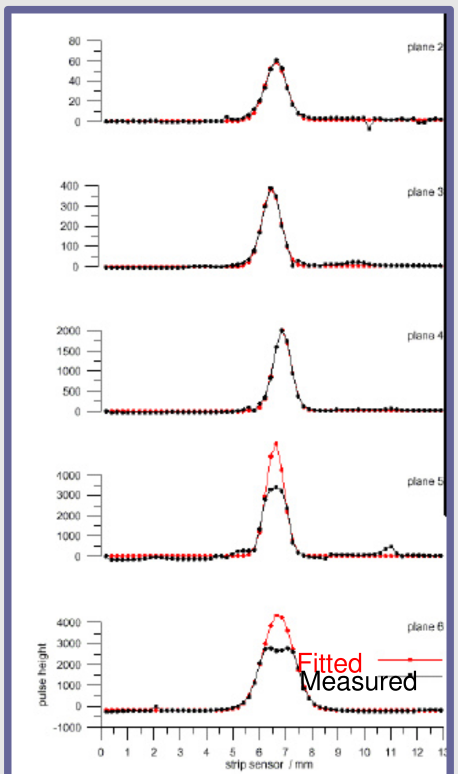
Requirements of this approach:

— Alignment system must be taken into account from the design phase

— Modifications of the sensor needed in a ~10 mm diameter optical window: (removal of aluminum backelectrode locally)

Successful predecesors …





AMS-01 innovation (W. Wallraff)

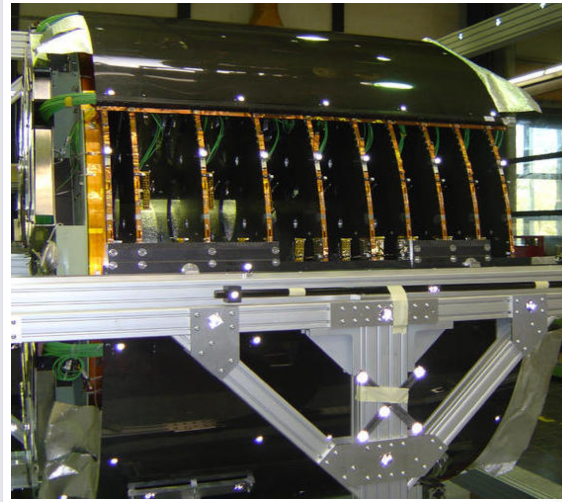
λ = 1082 nm

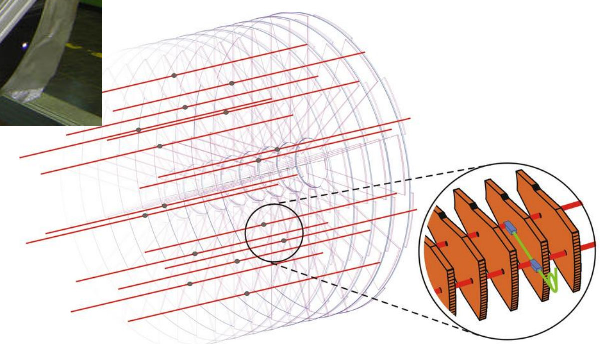
IR “pseudotracks”

1-2 μm accuracy obtained

Transmittance≤ 50%

Up to 4 ladders traversed





λ = 1075 nm

- Optimization of sensors not included from beginning of sensor design ⇒ lower transmittance achieved~20%
- 180 deg beam splitters in the middle of the tracker produce back to back beams measured by modules
- Laser spot reconstructed with 10 μm resolution

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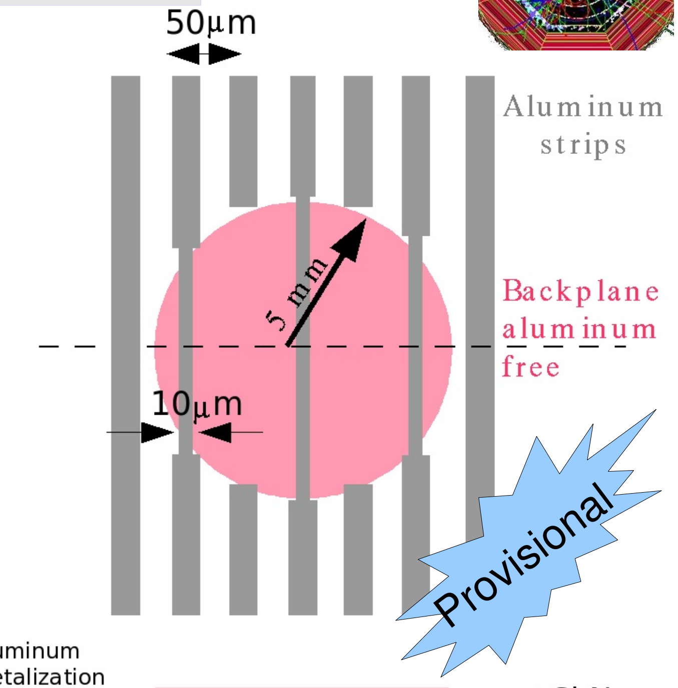
ILC: 2-fold approach

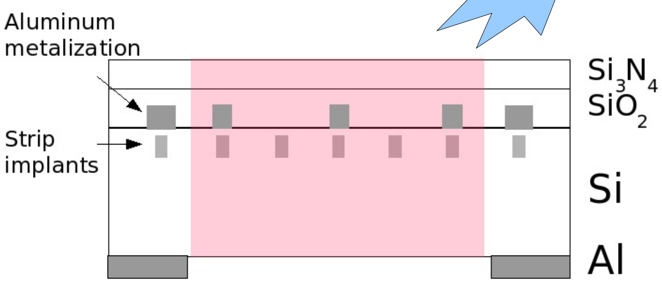


AMS-like approach:

Baseline version: Minimum set of changes requested

- ∅~10 mm window where Al back-metalization has been removed
- Strip width reduction (in alignment window)
- Alternate strip removal (in alignment window)

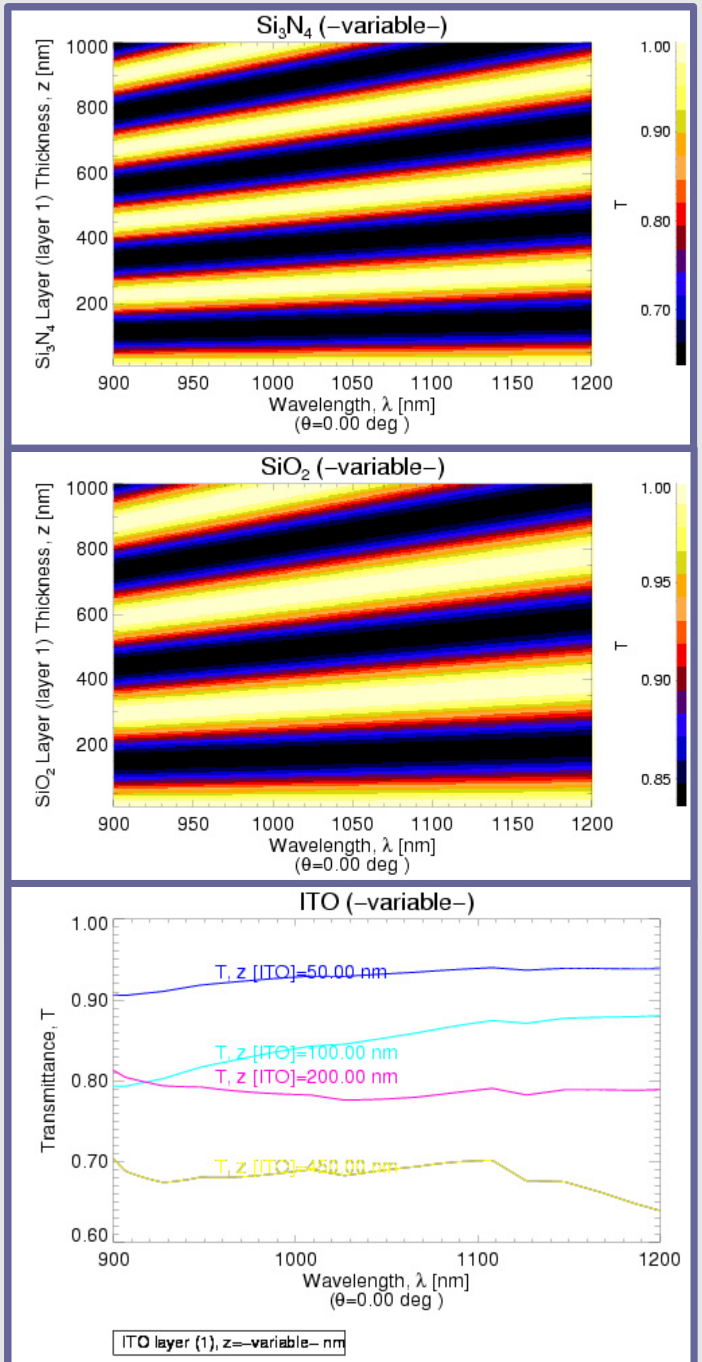
T-improved version: Baseline version + thickness optimization in local alignment window



R&D on transparent Silicon µstrip sensors:

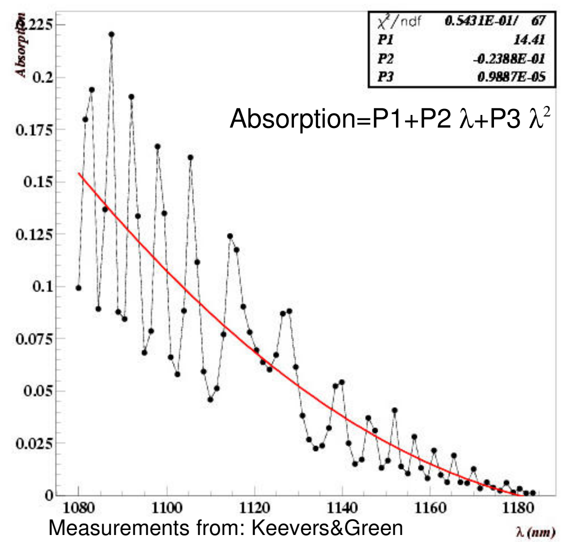
- Together with IMB-CNM (Barcelona), we will develop prototypes of these sensors (Sep'07)
- Aluminum electrodes and strip are perfect mirrors. Substitute Al electrodes by TRANSPARENT ELECTRODES.
- Candidates TCOs available: ITO, AZO,...

Optical figures for common Si μstrip materials



- Passivation, insulator, ITO-electrodes λ_{ITO} [0-300] nm, all transmit>80% in a broad wavelength range

- Typical absorption for Silicon [200-320] μm thick



Measurements from: Keevers&Green
Appl. Phys. Lett. 66 (2), pgs174-176

λ = 1140 nm $\Rightarrow$ A~5%

- Typical laser diodes of 10^8photon/pulse

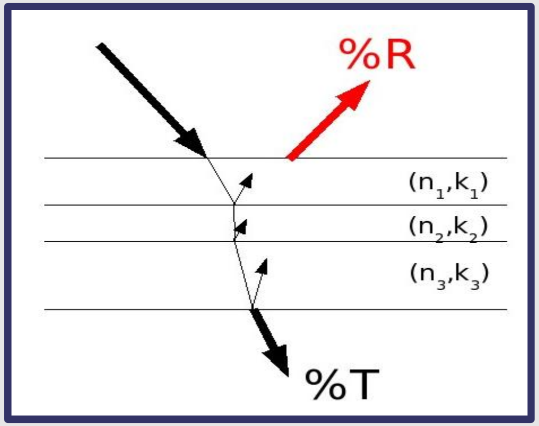
1 MIP in 320 μm Si produces~25000 e-

$$\text{Min. Signal} = \frac{10^8}{25000} \times 5\% = 200 \text{ MIPs}$$

Simulation of Si μ-strip sensors

- In the following slides we show **simulated** optical figures of Si-μstrip sensors (Transmittance, Reflectance and Absorptance)

- The sensor is modeled as a multilayer media. Simulation features:
  - Interferential effects due to multiple reflections are considered
  - Absorption effects are included
  - Refraction index (n,k) is a function of λ
  - Typical deposition thicknesses considered
  - Deposition tolerances are included $\Rightarrow$ We simulate realistic designs
  - Laser spectral width is assumed (±2.5 x 2 nm)



T+R+A = 1

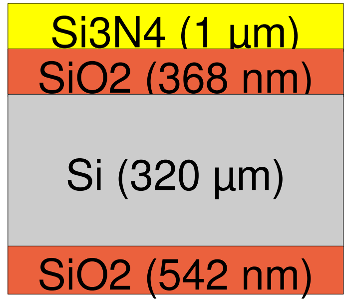
- Simulation particularities:
  - Multilayers are left/right borderless
  - Effect of aluminum electrodes is not included yet
  - Energy going to secondary and higher order maxima (grid effect) is included

- Aim is to achieve a transmittance as high as possible with moderate absorption (>3%)

Transmittance	90%	80%	70%	60%	50%	40%
Traversed	30	15	10	7	5	4

T-improved approach (AMS-like)

2007/03/02



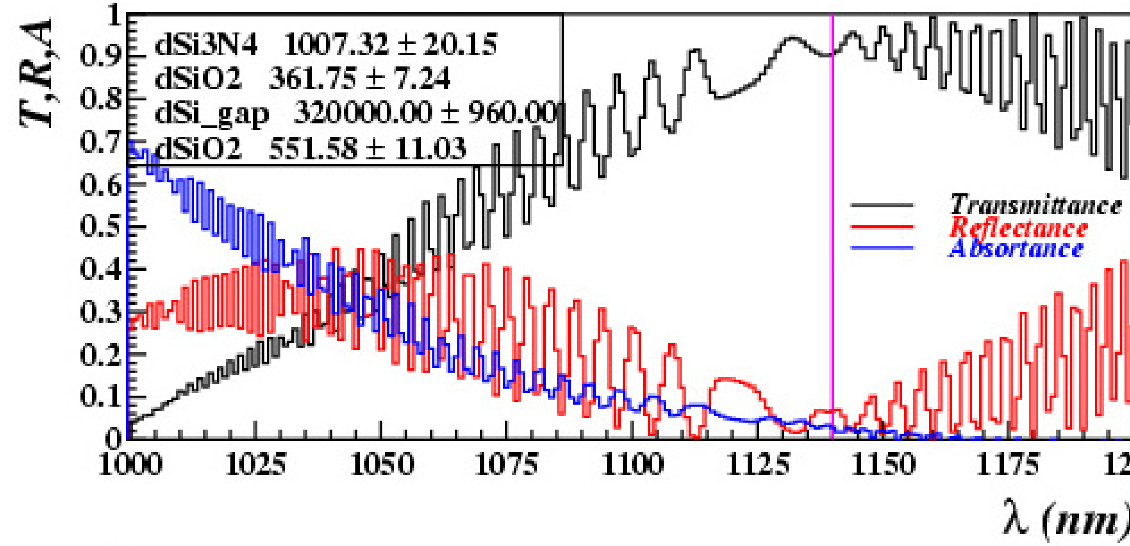
- Simulated DC type sensor with **optimized thickness** of layers
- Tolerances of deposited materials are taken into account: (2% for Si3N4 and SiO2)

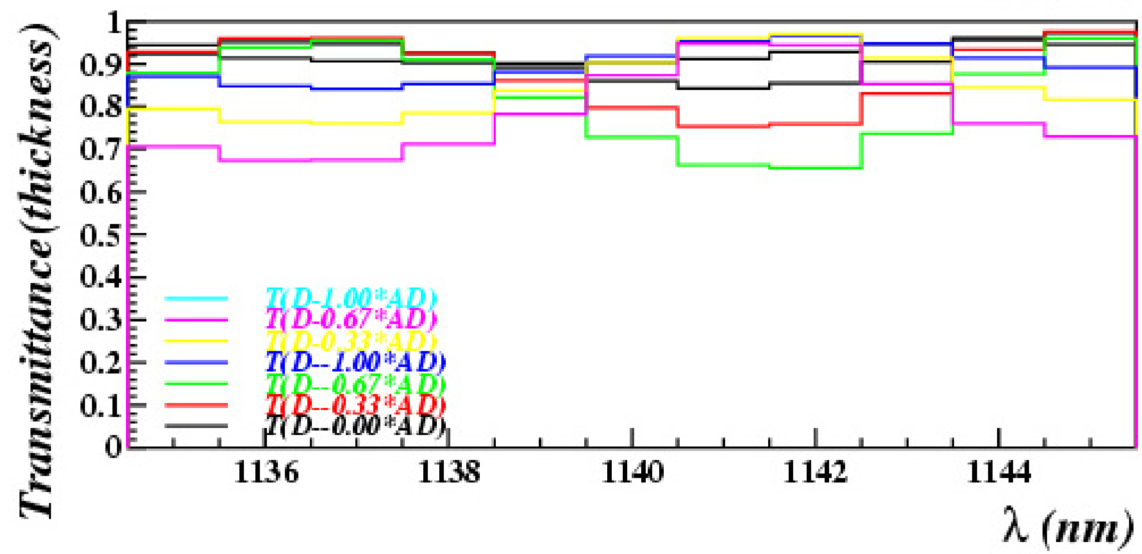
  Upper plot shows T,R,A for the sensor specified in the box. Calculated thicknesses ±tolerances are specified

  Bottom plot shows T in a narrow wavelength range, for thicknesses varied within tolerances

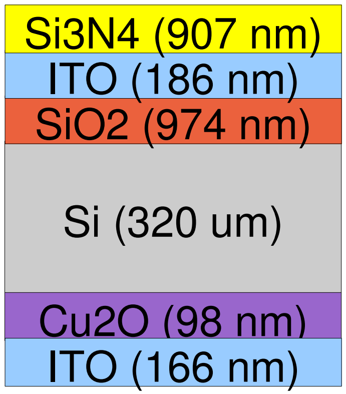
- Ripples due to thick layers. Thinned top and bottom layer smoother ripples
- **Aluminum strips** not simulated. (work is ongoing)
  - naïve (and probably wrong) approximation: $T_{Al} = T \times \left(1 - \frac{S_{Al}}{\pi r^2}\right)$

T_{al}/T ~ 80% (90%) with 10 µm wide strips "pitched" each 50 (100) µm





Transparent Sensors



<u>Characteristics of design:</u>

• Electrodes simulated: Transparent strips made of ITO (continuous layer, yet)

• Typical deposited thicknesses

• Tolerances taken into account:

  2% SiO2, Si3N4

  10% ITO

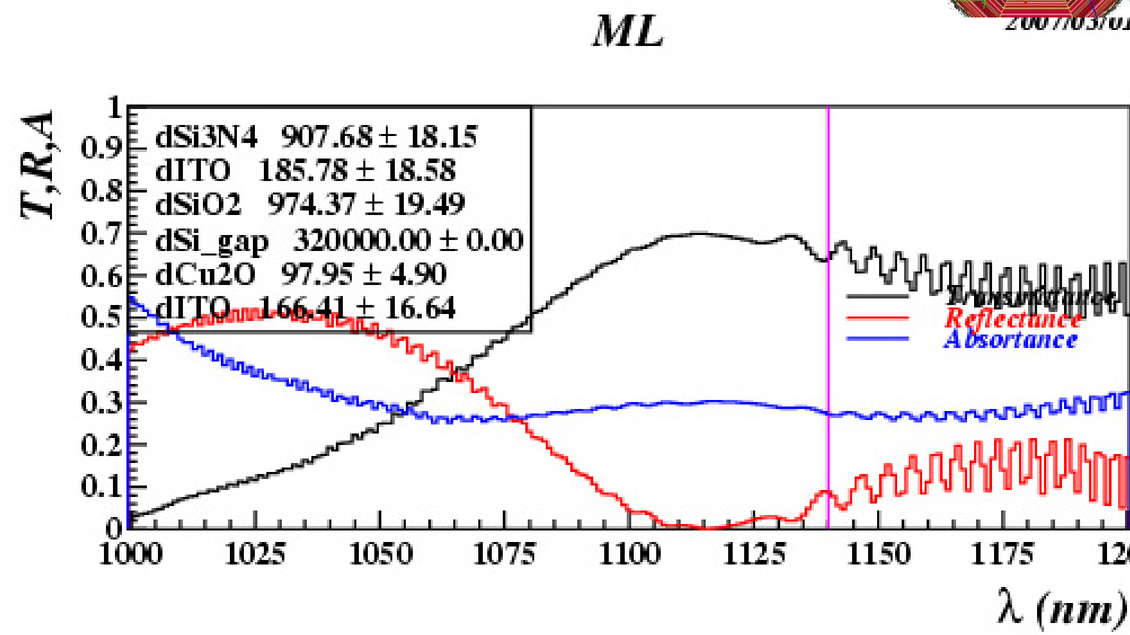
  5% Cu2O

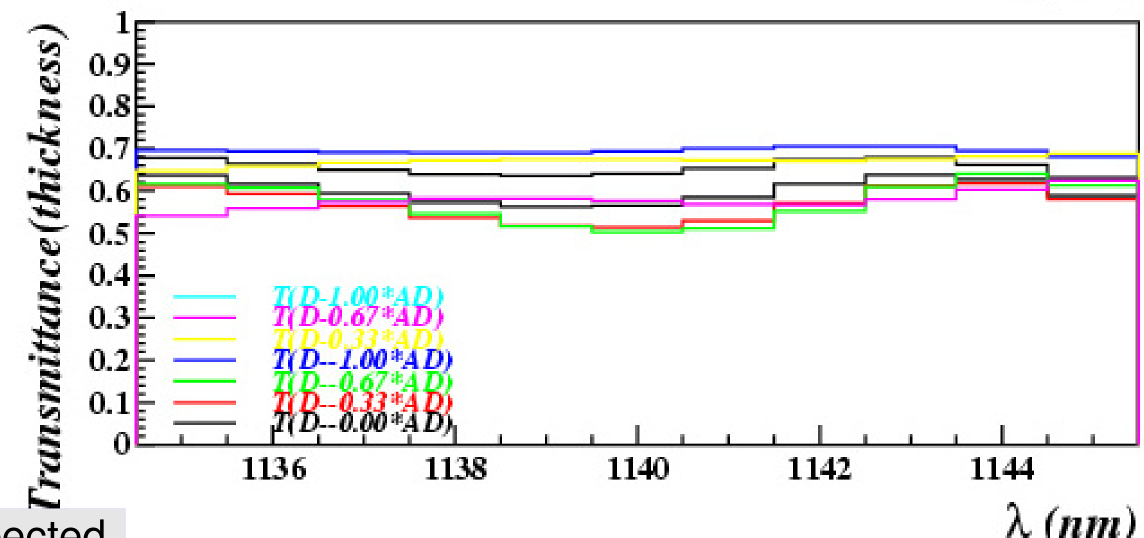
• Higher absorption (lower laser power needed)

• Lower interferential effects, less energy lost in secondary maxima, better precision.

• First prototypes with IMB-CNM (Barcelona) expected by Sept. 2007

• We have more time to refine it, yet





Summary

- Presented R&D activity developed within SiLC Collaboration and EuDET project

- Alignment of Si µstrip sensors is eased using IR beams (pseudotracks).
  - No need for external monitoring systems
  - No impact on system integration and Si-DAQ
  - No extra material budget

- Changes during production process:
  - Al backplane must have a 10 mm diameter window (very easy during production)
  - Fraction of Aluminum strip on this window (front side) must be minimized as much as possible

- If the thickness is not optimized transmittance values will be, most likely, below 50%
  - Tuning of thicknesses in the local window boosts transmittance

- R&D on sensors with transparent electrodes started