Si tracking laser based alignment

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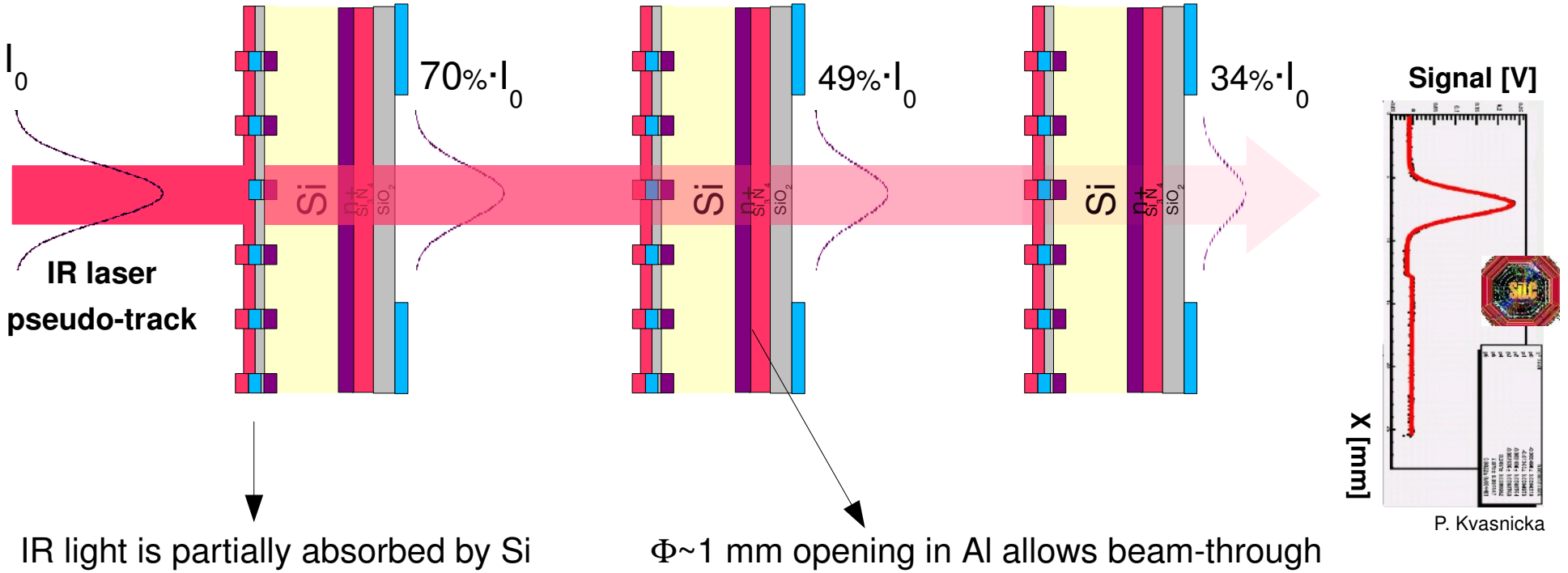
2nd ILD tracker alignment task force meeting

IR track alignment

- Aim: align modules using **IR laser pseudo-tracks**.
  - These IR tracks do not come from the interaction point (they are normal to sensors)



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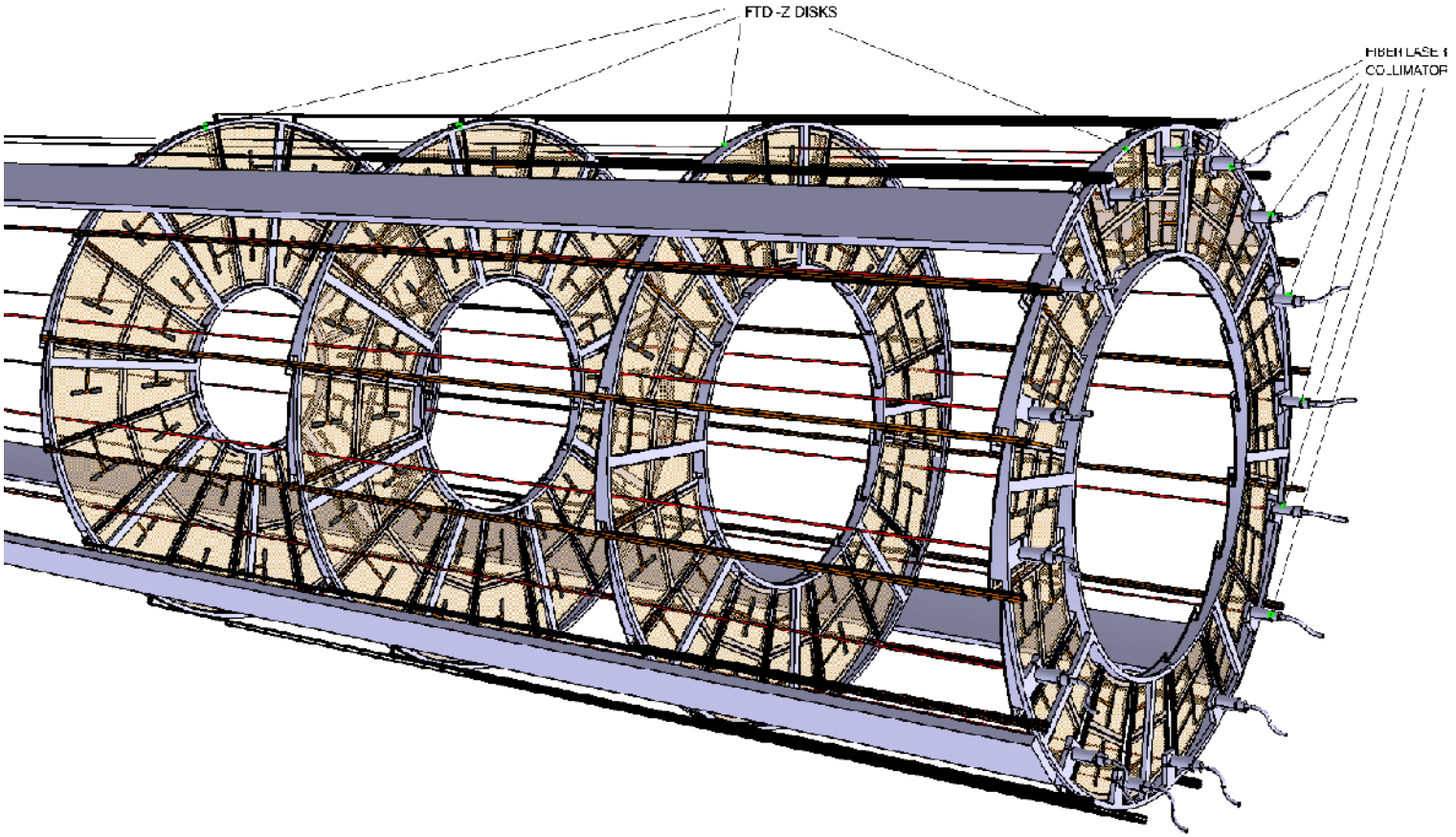
- Enough laser signal to be read out using module electronics
- Only selected sensors are monitored.
- Hardware alignment used as starting geometry for track alignment reconstruction

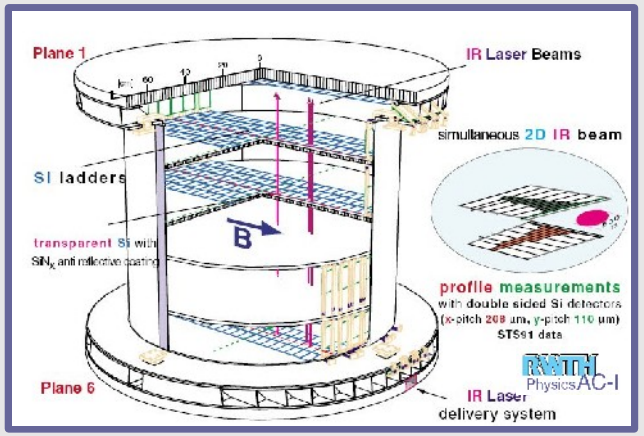
Example for FTD

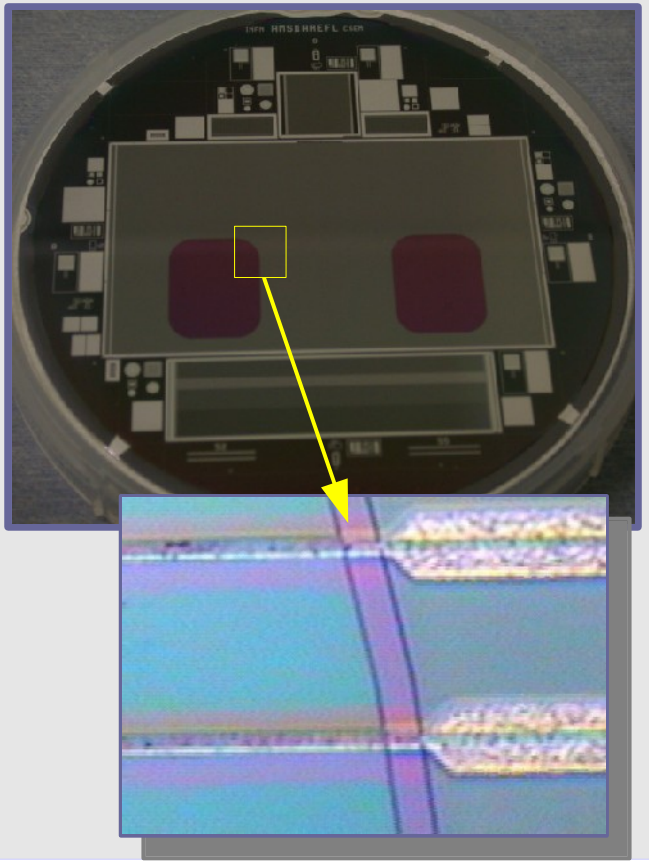
— Collimator heads produce z-parallel beams. Collimators out of the tracking volume
Laser diodes out of the detector (laser room in CMS).



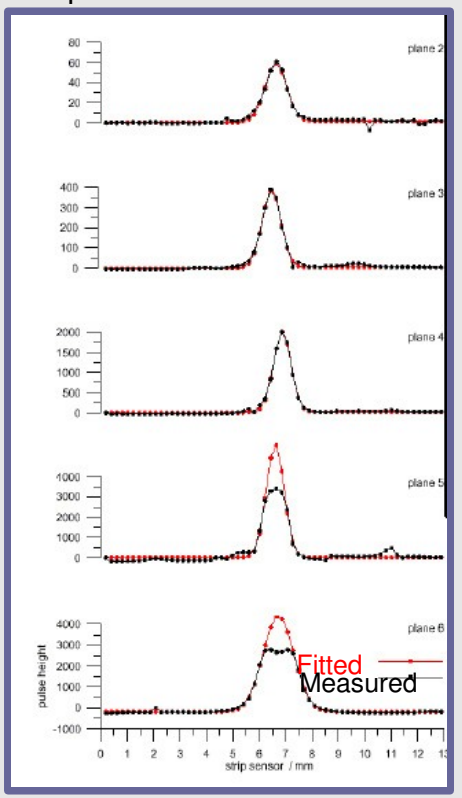
— Very similar to CMS Tracker endcap design

An idea that works …





Up to 4 ladders traversed



AMS-01 innovation (W. Wallraff)

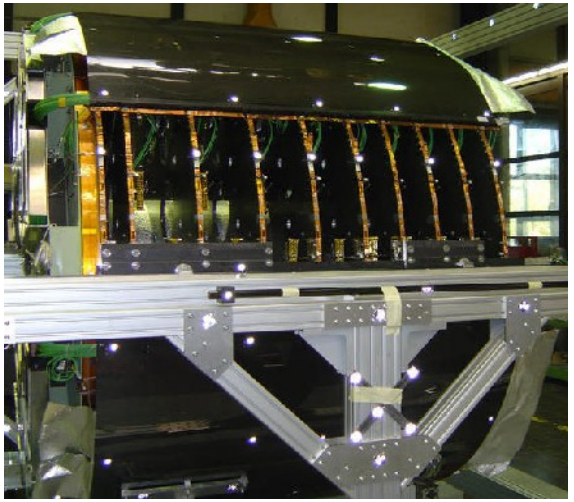
λ = 1082 nm, 110 µm RO pitch

IR "pseudotracks"

1-2 µm accuracy obtained

Transmittance~ 50%

CMS
TEC



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

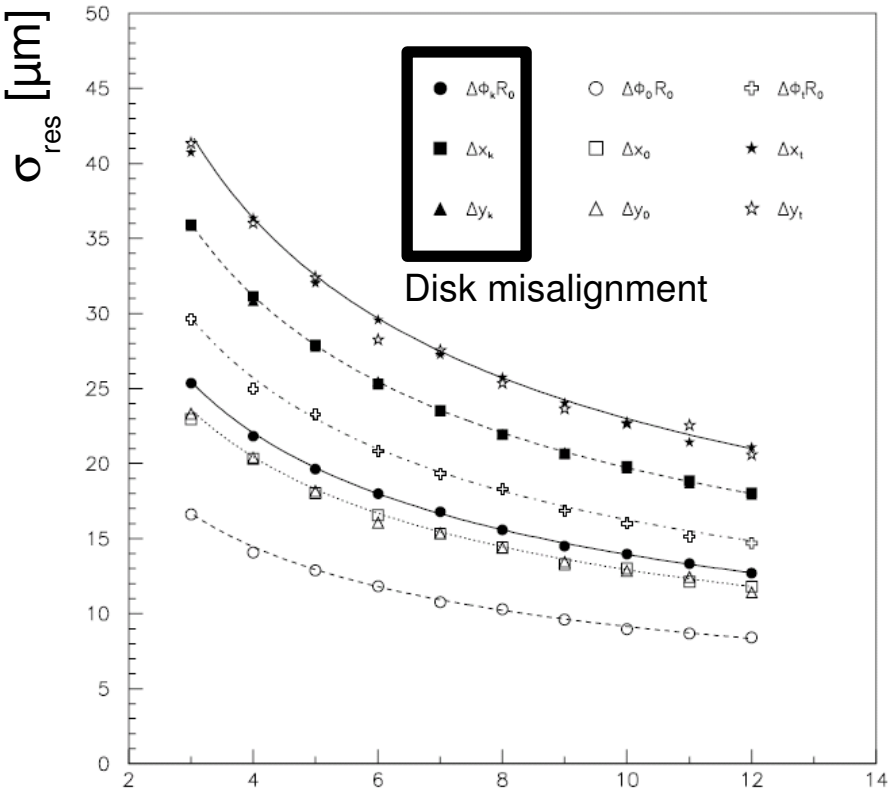
• Laser spot reconstructed with **10 µm resolution** (1st sensor)

9 TEC disks (18 petals) reconstructed using 2 beams with 50 µm accuracy (100 µm required in CMS)

Accuracy of the system: CMS TEC

1) Depends on the number of beams

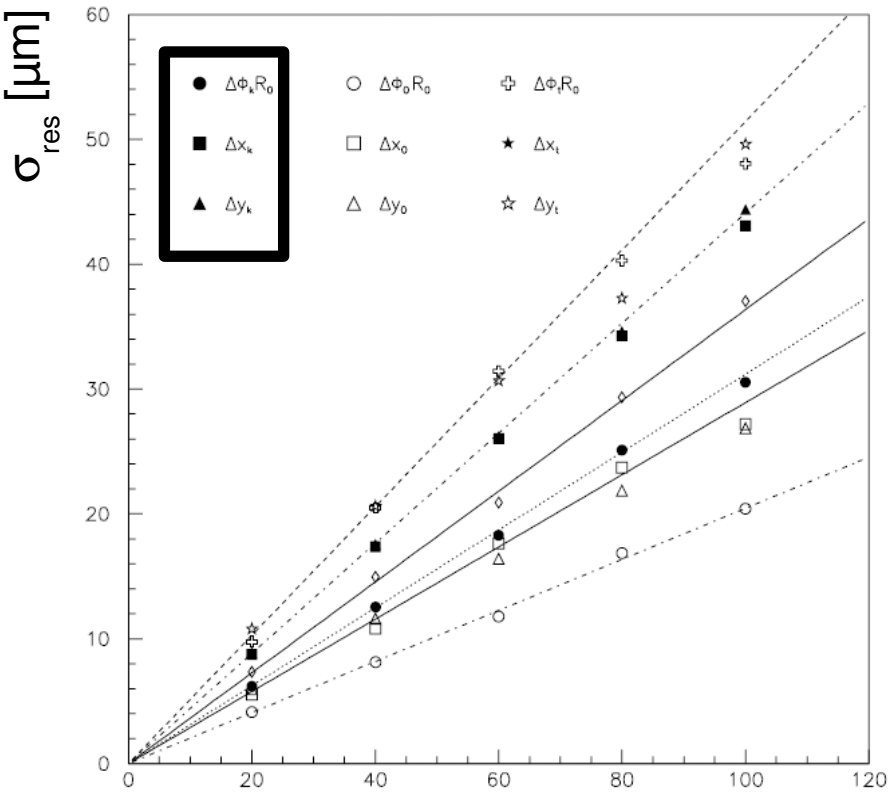
– MC study of reconstructed (x,y,ϕ) displacements as a function of the number of beams employed (CMS TEC).
– The 9 disks placed at nominal positions
– Beams at fixed radius
– Precision for laser hit~50 μm



B. Wittmer, The Laser alignment sytem for the CMS silicon microstrip tracker, Phd. thesis

2) Accuracy laser hit reconstruction

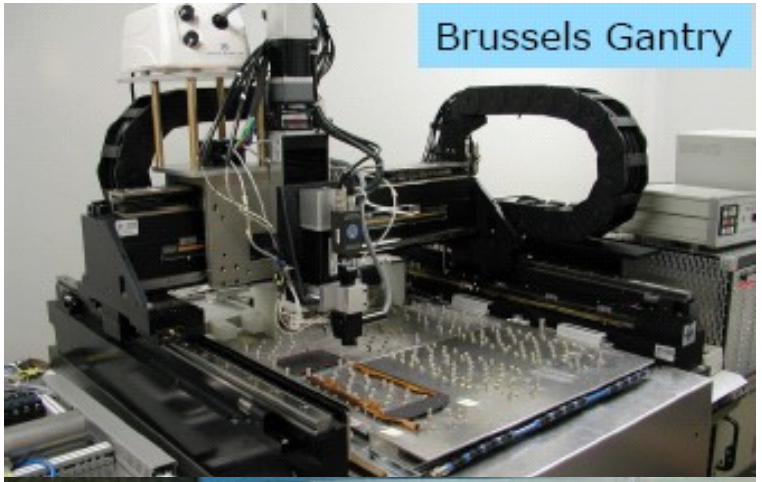
– Reconstructed displacements as a function of the accuracy with which the intersection point of laser beams and disk is found
– 8 beams at fixed radius
– Note: Linear behavior & Slope~0.5

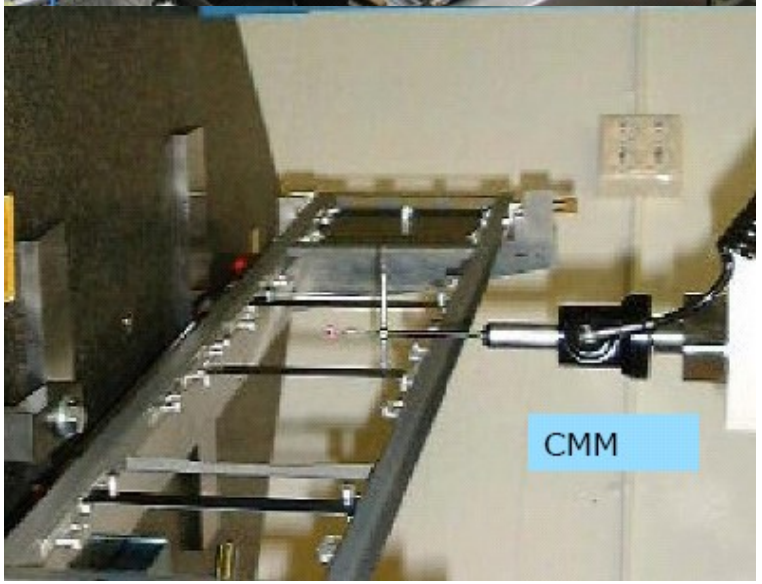


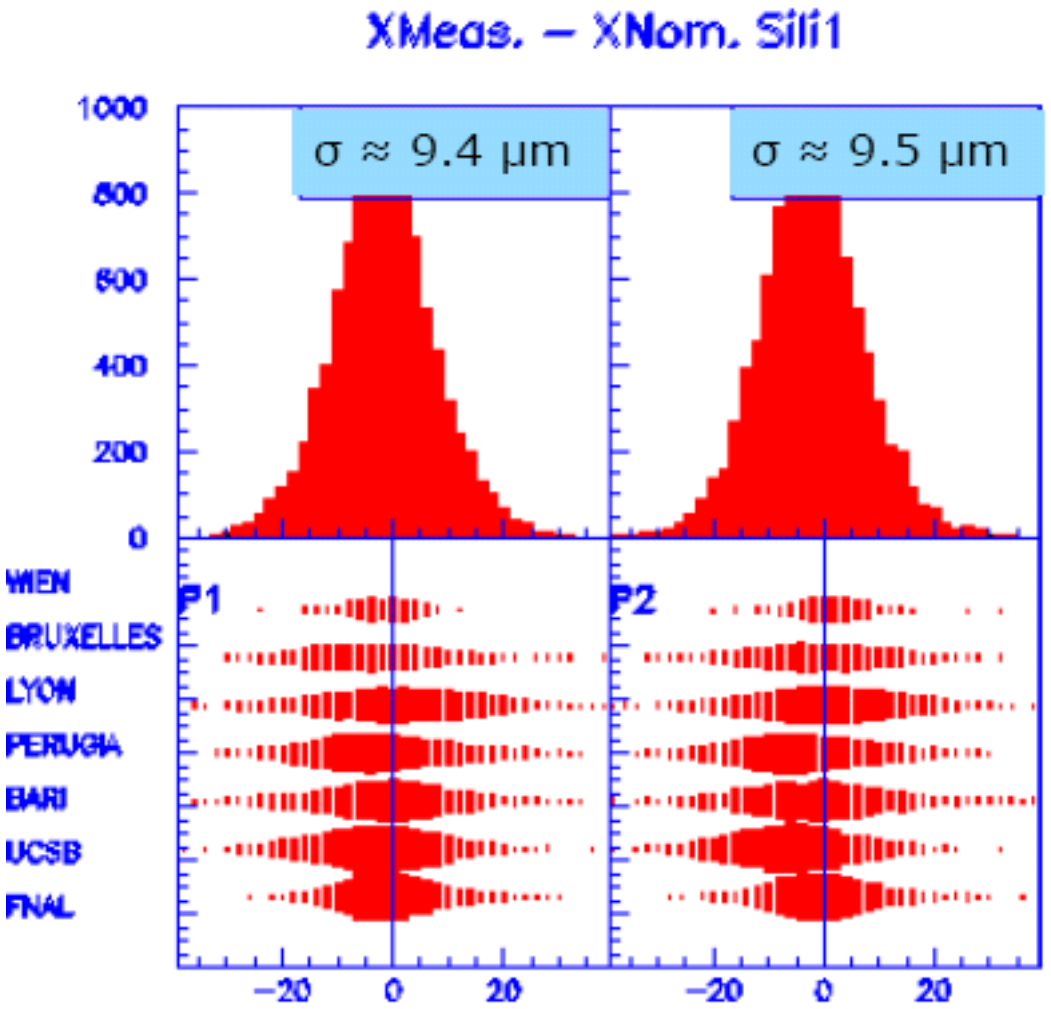
Laser track precision (I)

Accuracy with which the intersection point of laser beams and disk is found, depends on:

1) Laser spot fit accuracy on the strip detectors ~7 μm (pitch=50 μm)
2) Mechanical placement accuracy~10 μm (can be improved later with tracks)





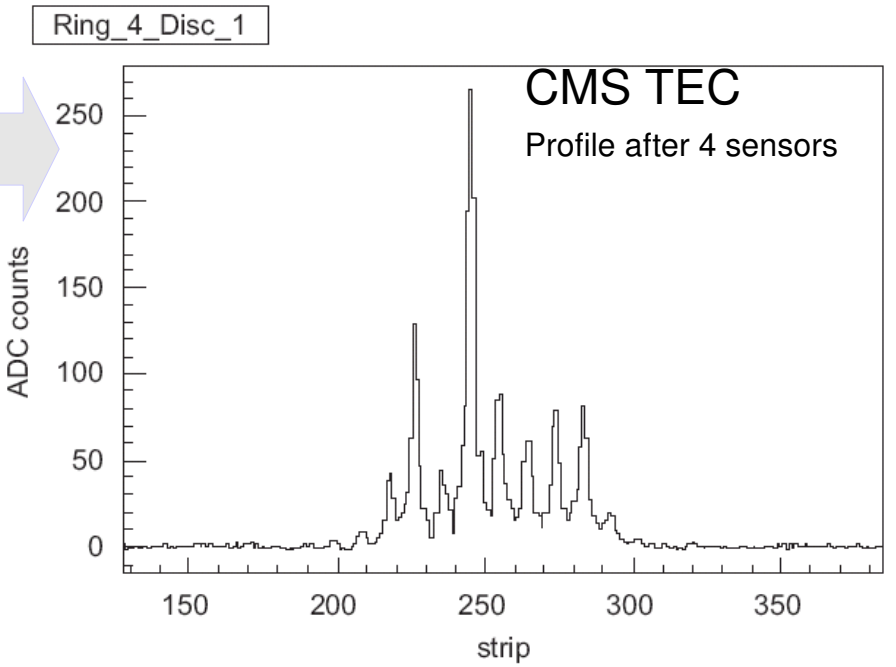


Therefore ~12 μm error to find intersection point of a track

Laser track precision (II)

3) Distortion of beam profile, due to interferences and diffraction of laser beam

4) Limited transmittance of beams



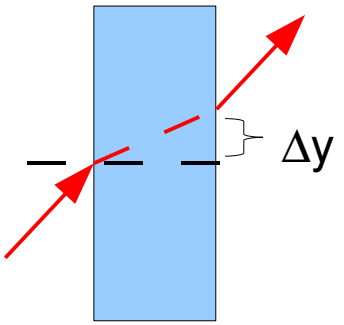
IFCA R&D program to solve 3) and 4)

Goals:

3) $\rightarrow 0$

4) Maximum

5) Refraction of beam (contrarily to tracks), due to inclined incidence (either inclined beam or inclined endcap disk)



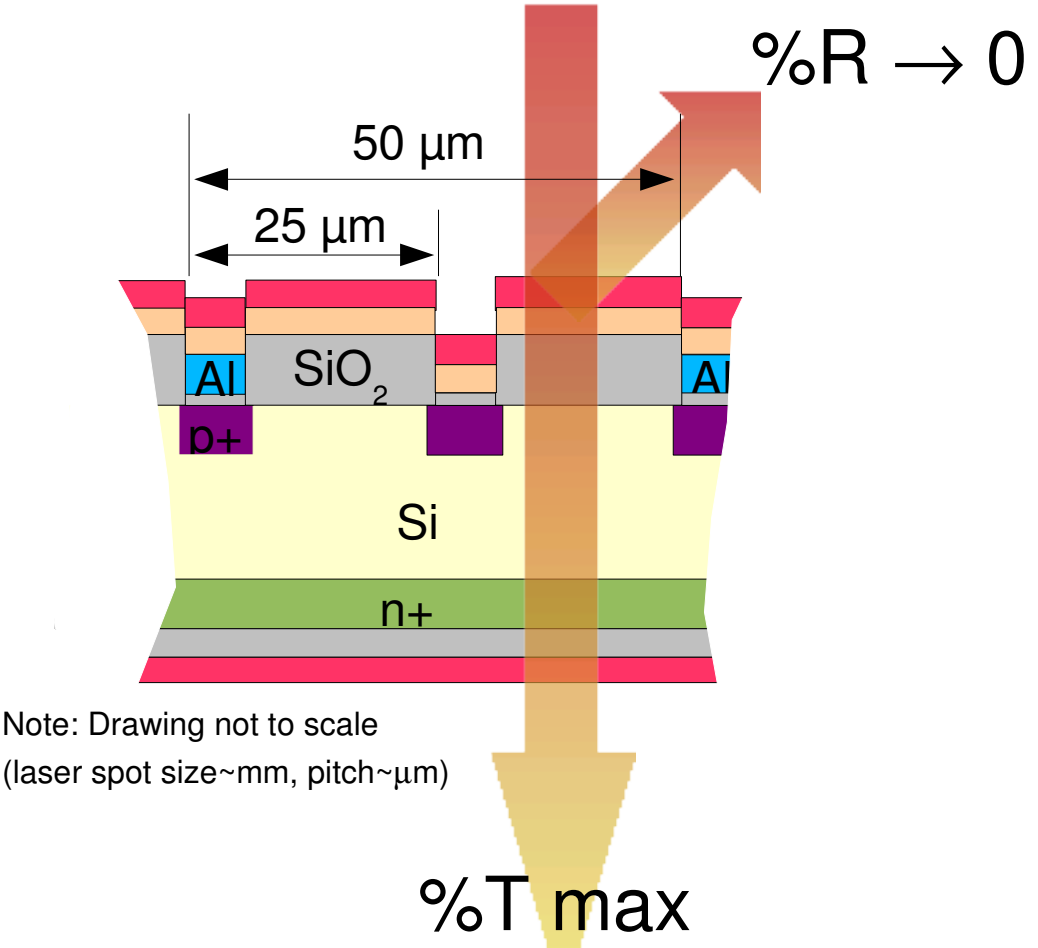
Optical design of microstrip sensors

• Reduce interference and diffraction systematic effects and achieve maximum transmittance, while making the minimum changes to the sensor

• No antireflection coating (as CMS or AMS) but tune the layer thicknesses to act as an ARC

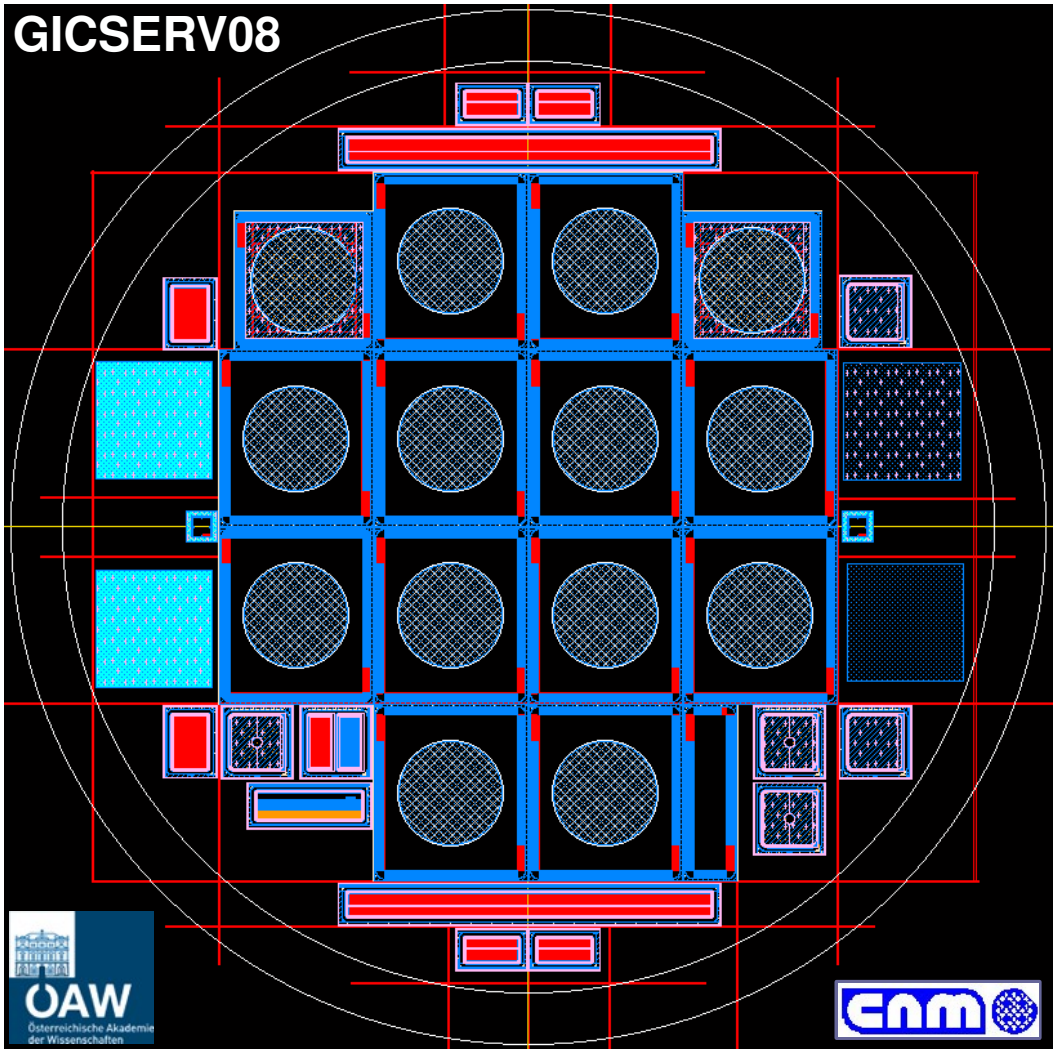
• Full optical simulation (including interferential and diffraction effects) developed

• Simulation achieves 70% maximum transmittance (20% higher than best AMS detector up to now)



Note: Drawing not to scale
(laser spot size~mm, pitch~µm)

High %T alignment prototypes



Implant width	Metal width	Intermediate strips
Alignment sensors		
15	15	1
15	10	1
15	5	1
17.5	5	1
12.5	5	1
15	3	1

- 156 RO strips
- 50 μm RO pitch
- 1.5 cm length varying strip width (3,5,10,15 μm)

- Run in progress.

Expected due date by end of summer 09.

- 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

Limitations of the system

• The laser alignment system is meant to detect movements and deformation of the tracker support structures

• Collective movements of the structures cannot be separated from collective movements of all beams (in opposite direction) at the same time.

• Some weak modes of the endcaps can be solved connecting both forward/backward halves

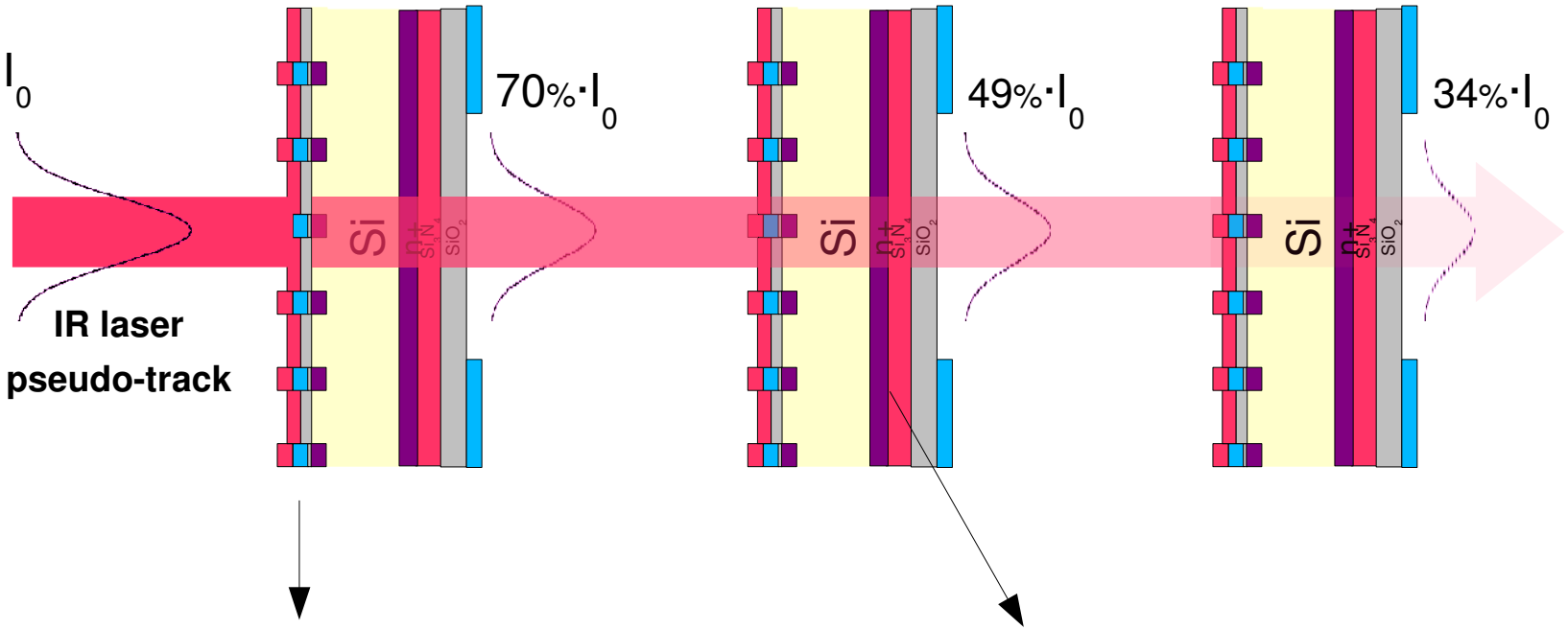
• Usage of inclined beams connecting different rings is very complicated

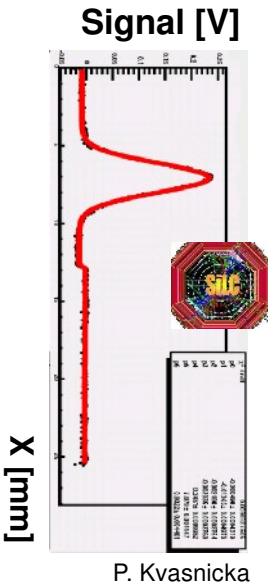
Conclusions

- Laser alignment system for microstrip trackers uses the own microstrip sensors for alignment
- No need for external readout
- Monitors in-sensor plane displacements
- It works even without particle collisions
- Very useful to provide quick internal alignment without need of survey
- Precision can be optimized:
  - Tuning the number of beams (simulation of system performance)
  - Improving optical performance of the sensor
- Laser alignment system will be complemented with optical fiber sensors (strain, T,...).
  IFCA is working on this too
- ILC tracker alignment optimization is ongoing for the last $2^{1/2}$ years

BACKUP

IR track alignment





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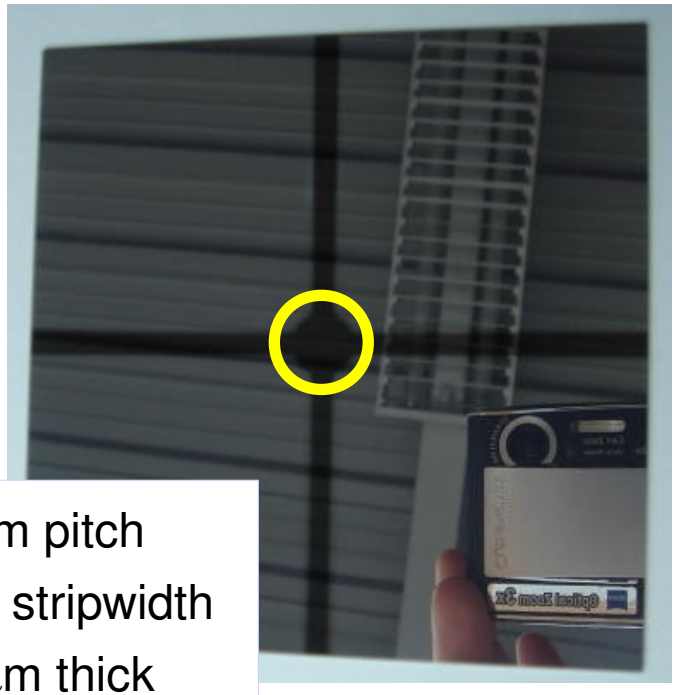
Transmittance	90%	80%	70%	60%	50%	40%
Traversed	30	15	10	7	5	4

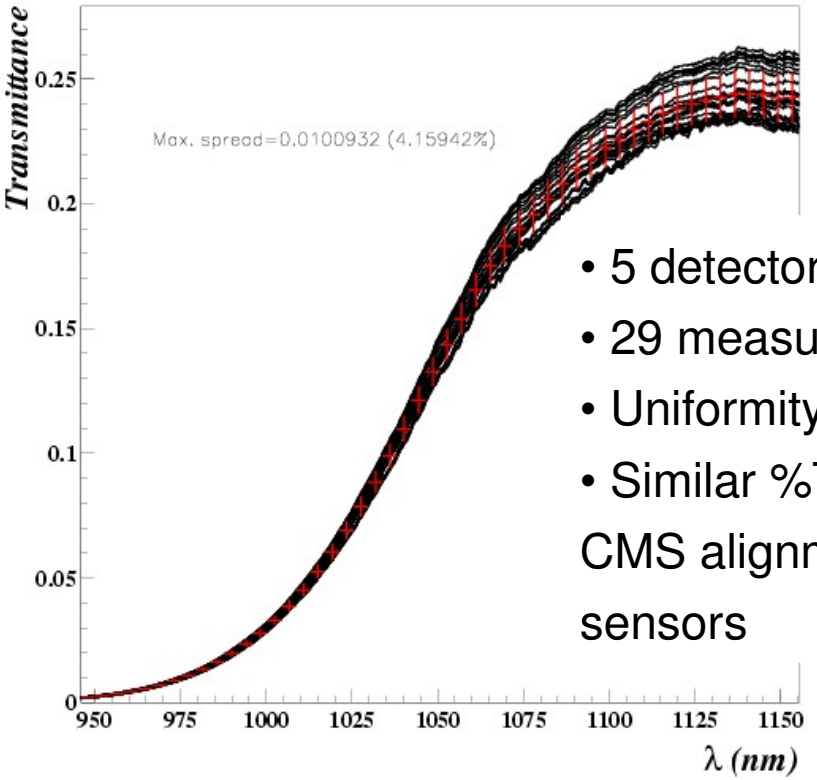
- System features:
  - Laser intensity~200 MIPS ⇒ sharing same DAQ as Si detector
  - Silicon modules are directly monitored, no external fiducial marks
  - No extra material added
  - Gaussian laser intensity is spatially **reconstructed**: spot size covers *O(10)* strips

Alignment Roadmap

• As members of EUDET collaboration we implemented **CMS-like alignment modifications** in 5 microstrip detectors produced by Hamamatsu. They were used to populate the EUDET alignment prototype



50 μm pitch
12.5 μm stripwidth
312 μm thick



• 5 detectors
• 29 measurements
• Uniformity~4%
• Similar %T as CMS alignment sensors

• Our ultimate **goal** is to find a minimum set of changes to the design/layout of the detectors that yield **maximum transmittance** in the IR without "touching" the tracking performance of the detectors. These changes would be a **recipe for a large scale producer** of future alignment microstrip detectors.

• All the new ideas are tested with prototypes **produced by CNM-IMB (Barcelona)**

Measurement of CNM diffraction sample

- CNM produced a simple wafer to test the simulation, using GICSERV07 access.