Silicon Microstrip detectors with enhanced Infrared Transmittance

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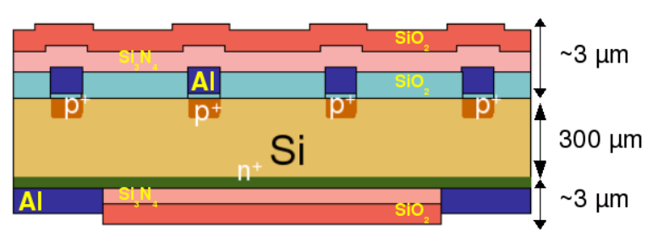
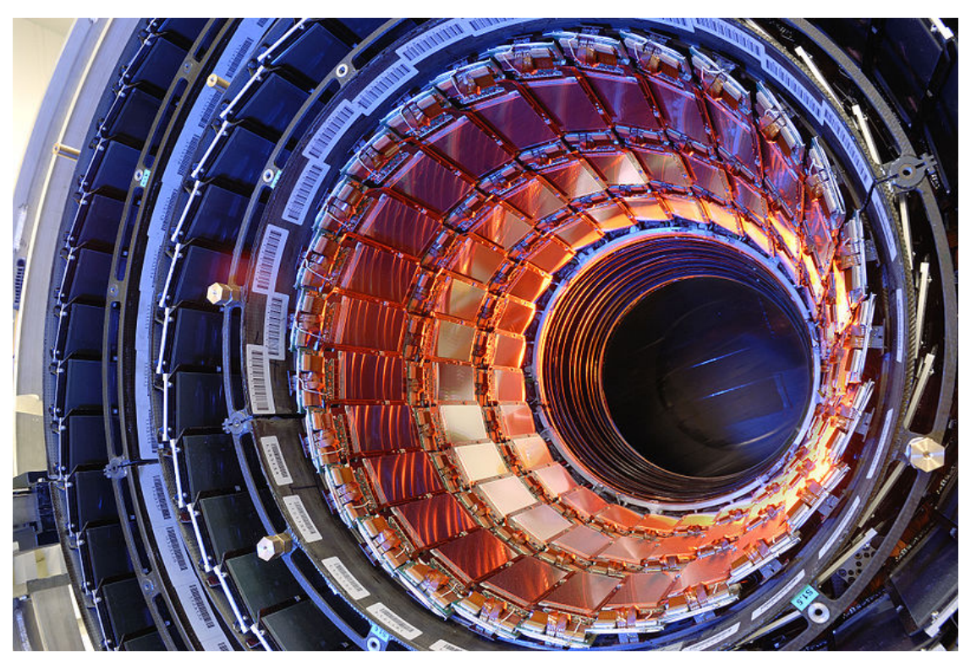
Goal

Improve transmittance of micropatterned Si devices  to infrared light

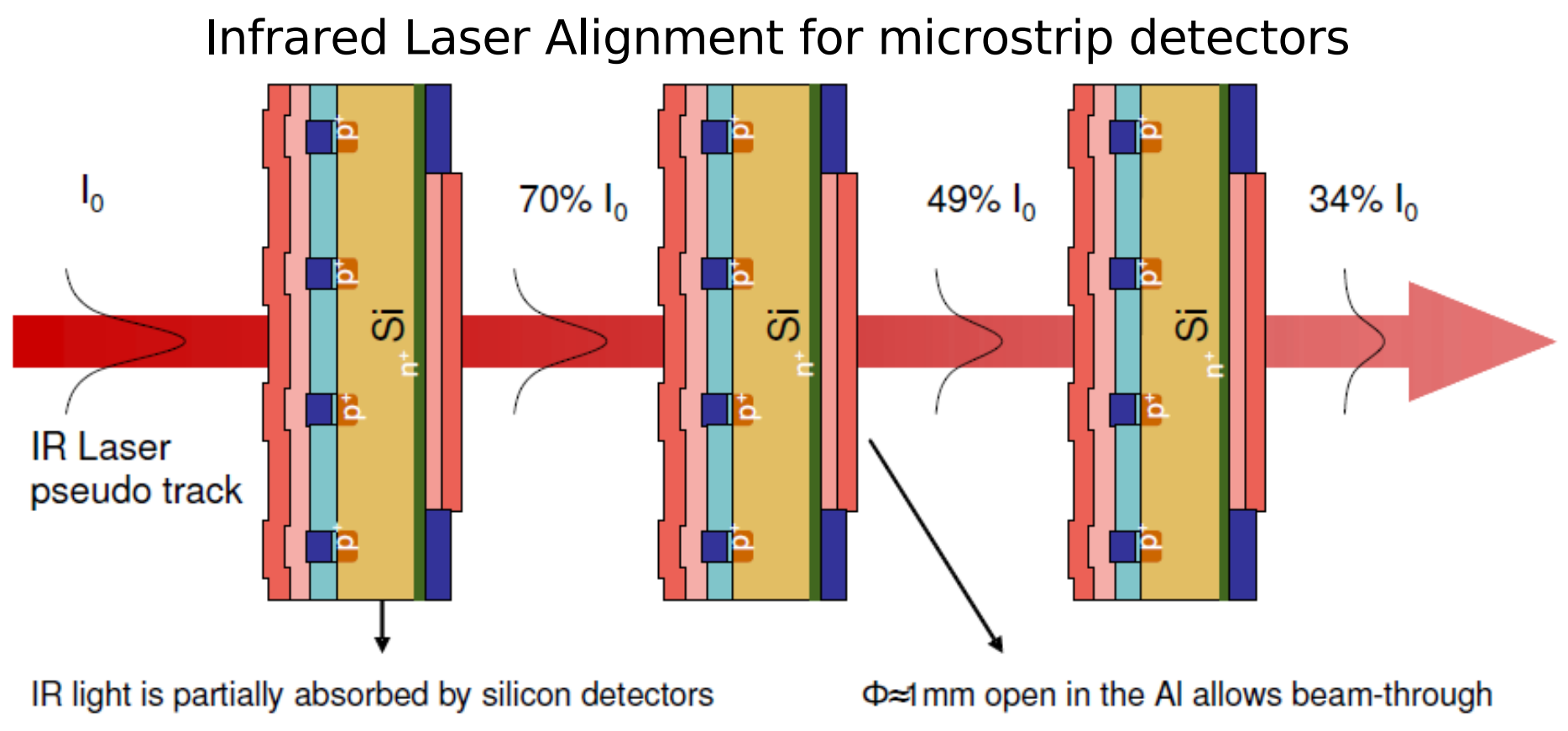
Why

In high energy physics experiments, like CMS, $O(10^4)$ of these micro-patterned devices are used to measure the trajectory of charged particles produced after collisions in the accelerator.



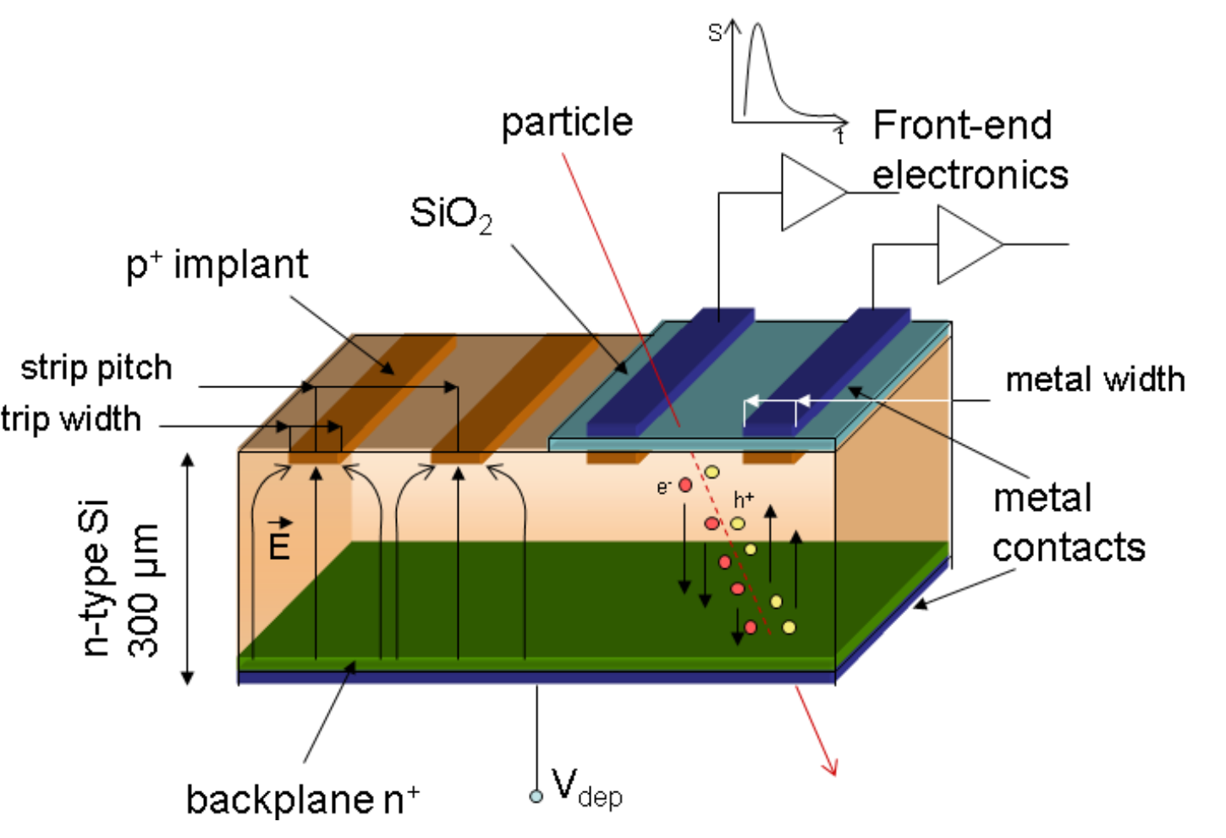
Silicon Tracker system (Diameter~2.2 m)

For precise reconstruction of the path of the particle, the relative position of each individual sensor must be first known with O(10-100)µm precision. A quick and redundant alignment of individual sensors is achieved by optical methods, using a network of IR laser beams sensed by the detectors [1].

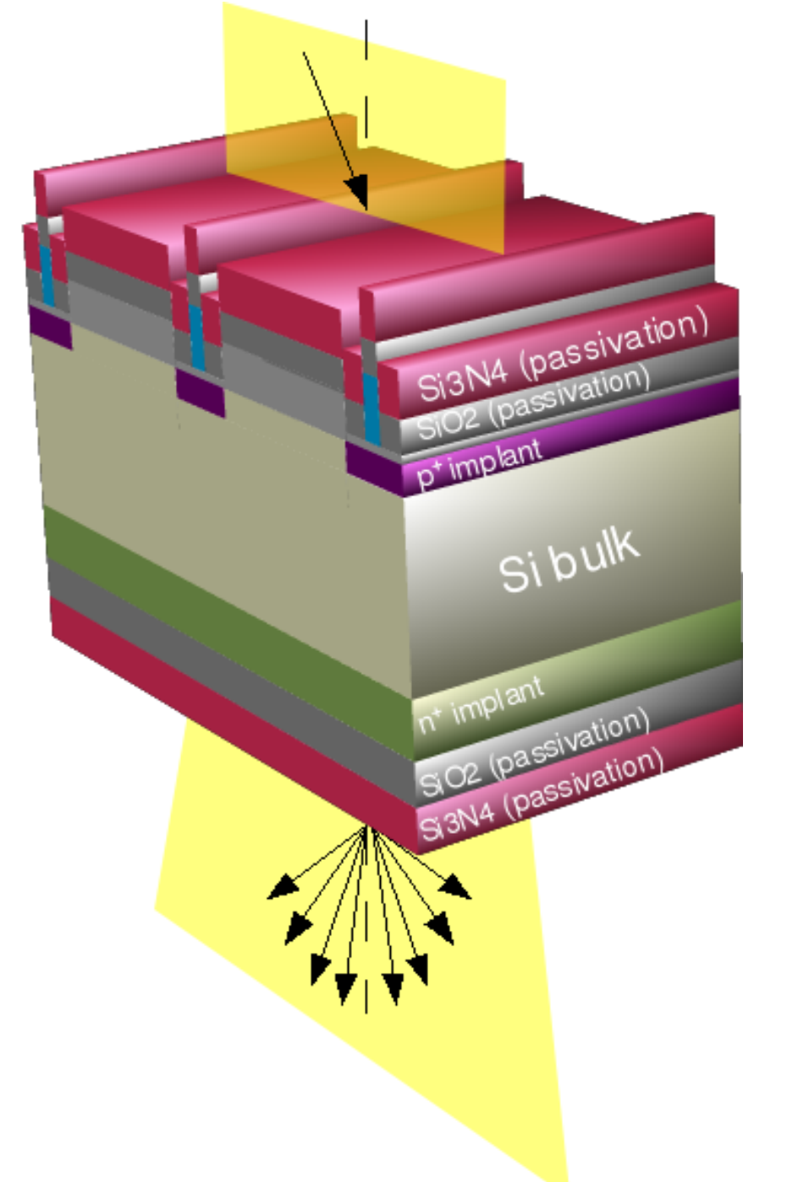


Microstrip Silicon detectors

Detectors with micro-patterned implants and electrodes (O(10)µm wide) measure the path of charged particles and photons by the ionization trail they leave in the bulk of the device. These sensors work as inversely polarized fully depleted pn junctions. The drift of e-h pairs in the externally applied electric field induces a signal in the implants. The signal is capacitively induced on the metallic strips and amplified by the front end electronics (AC coupling). The center of gravity of the charge collected by the strips gives an estimation of the passage coordinate of the particle.



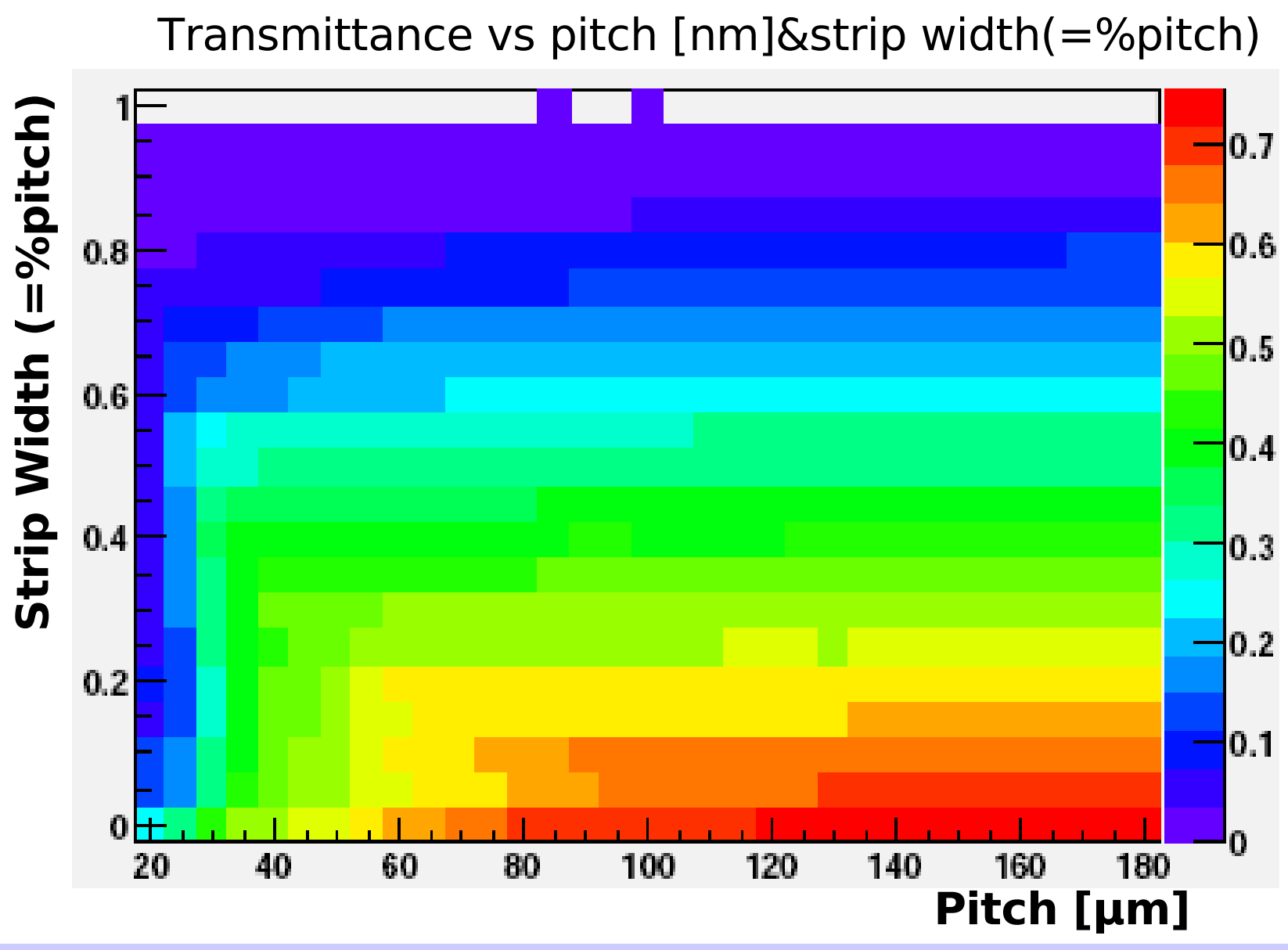
Optically, each individual tracking device behaves as a diffraction grating made of Al ridges on a 150-300 µm thick Si wafer. In this work we consider sensors with 50 µm electrode spacing, strip width=3-15 µm, λ~1 mm.



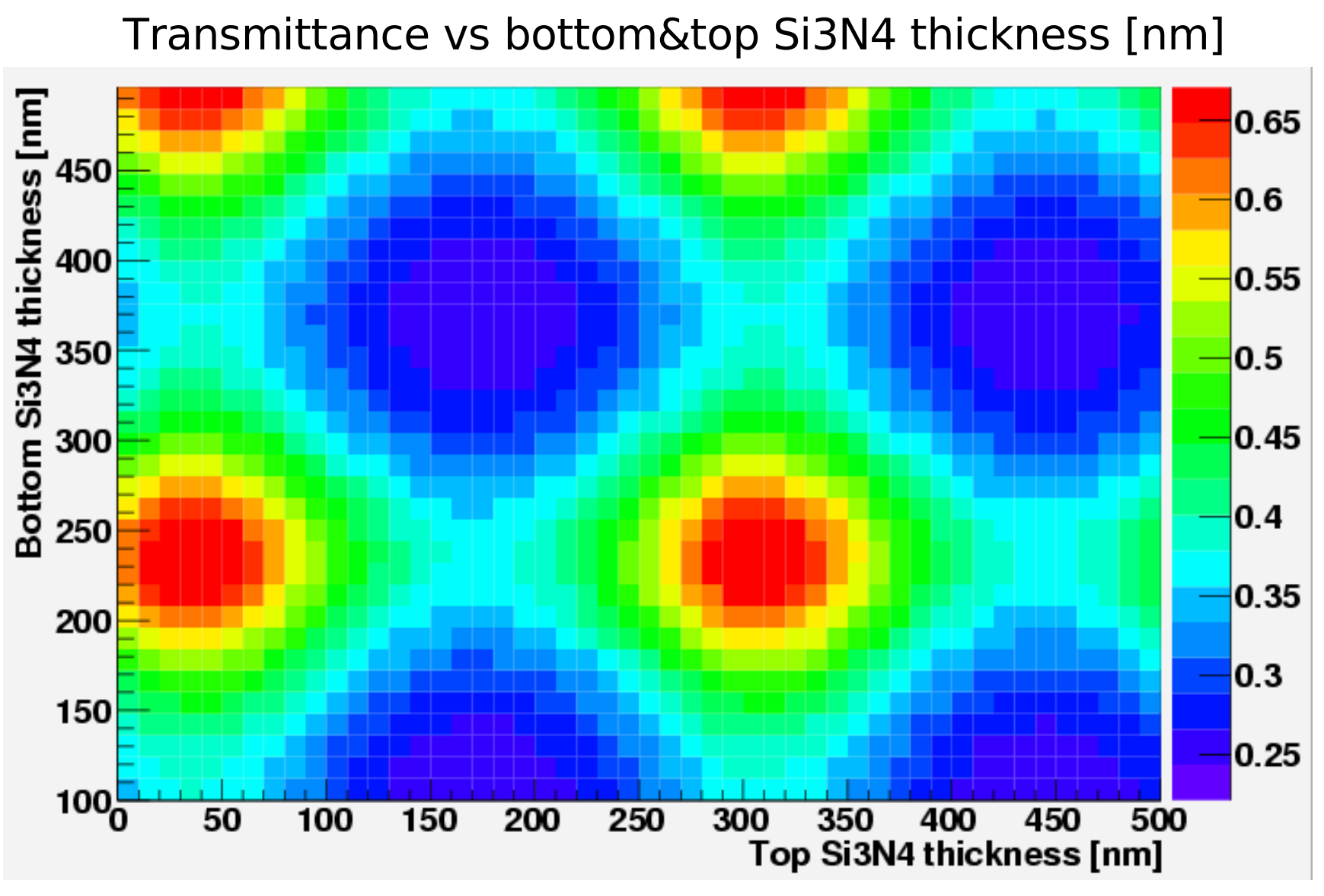
Optical simulation of microstrip detectors

- We developed a full optical simulation of the passage of light through a silicon microstrip detector. The code uses RODIS [2], a rigorous Maxwell's equation solver (RCWA). Effects of multiple reflections and diffraction by the microstrips have been included

- Layout parameters were simulated. Transmittance found to depend on pitch to strip width ratio. We chose the strip width to be 10% of the pitch.

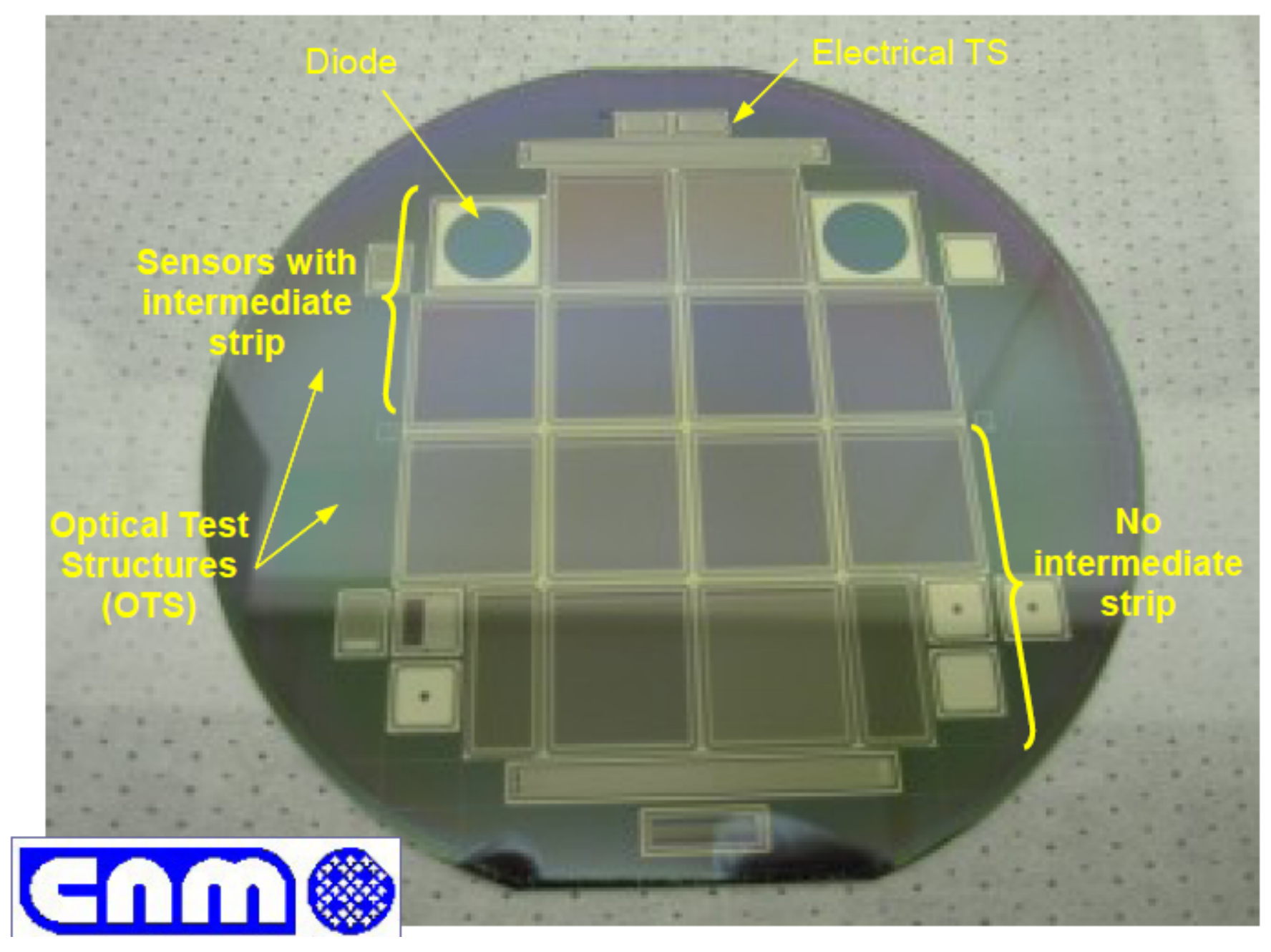


- Maximum transmittance of the detector to IR light can be chosen by tuning the thickness of the 2 outermost layers of passivation. These 2 layers behave as an antireflection coating of the structure. This technique is also used to optimize solar cells for maximum absorption.

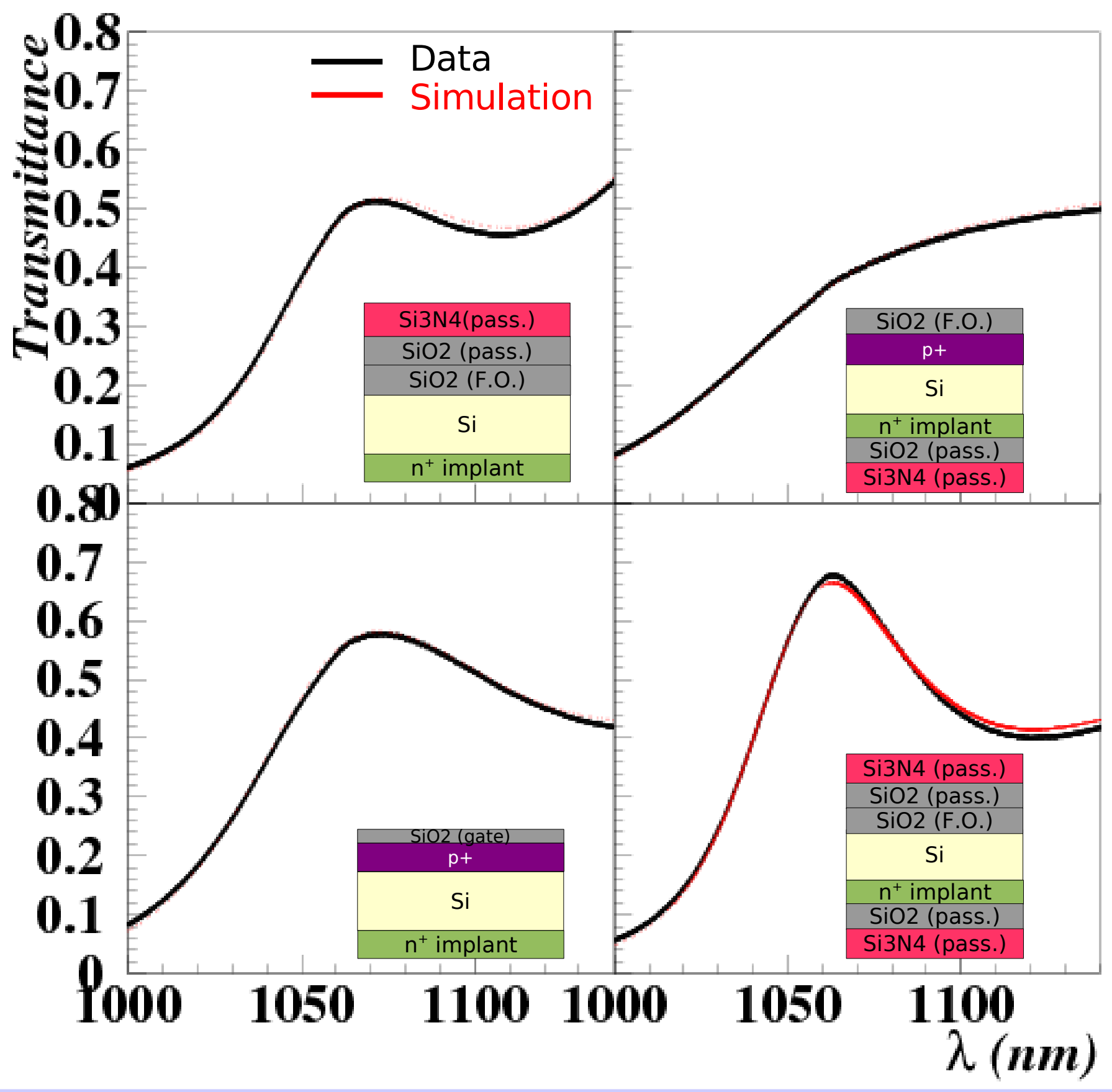


Fabrication of Transmittance optimized sensors at CNM-Barcelona

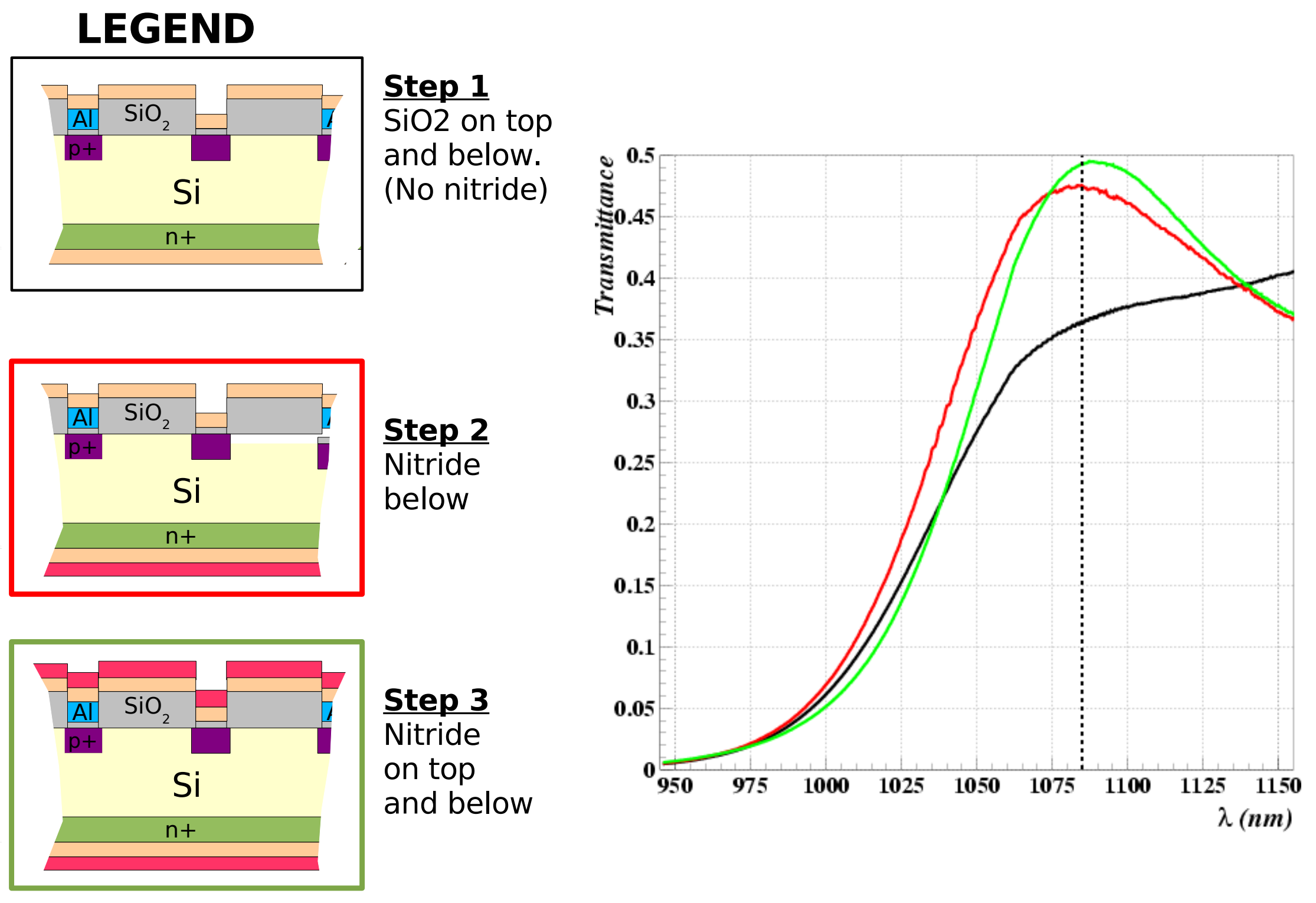
- 5 transmittance-optimized wafers were produced at CNM-IMB. Each wafer contains 12 baby-sensors (1.2×1.5 cm²). Six sensors have an intermediate implant in-between 2 electrodes, to improve spatial resolution by capacitive coupling, however reducing transmittance by a factor 2. The other six sensors have implants spaced 50 µm. Four optical test structures were placed on the wafer to monitor thickness and optical constants of the different materials.



- After each deposition step, the thickness of the new material was measured using an ellipsometer. Thickness of the deposited layers was matched with 5% precision for all wafers. The refraction index of the material was calculated from measurements of transmittance and reflectance of the continuous optical test structures.



- Using the new inputs (refraction index and thickness), the simulation was used again to predict new values for the thickness of the remaining materials. The beneficial effect of passivation in the maximum transmittance can be seen comparing the measured transmittance T=T(λ) at 3 different deposition stages



Conclusions

- Microstrip detectors are sensitive to IR light. If the stack of layers of the detector is optimized for maximum transmittance, then an IR laser beam will propagate through several sensors as if it were an infinite momentum track. The laser signal in each detector is readout using its front-end module electronics. This method can be used to align selected sensors of a tracking system.

- Alignment performance depends on the transmittance of the detectors to IR light. We have boosted the transmittance by adjusting the thickness of the passivation layers. Passivation plays the role of an antireflection coating for this grating-like structure.

- A batch of T-optimized sensors was produced at CNM-Barcelona using the guidelines explained here. Sensors were optimized at λ=1085 nm. Maximum transmittance measured with this method is 50%, which means a ×2.5 improvement with respect to non optimized detectors.
- A recipe to optimize transmittance of microstrip detectors is: control deposited thickness to 5% level and choose the thickness of the last 2 layers of nitride passivation.

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References:
[1] W. Wallraff, AMS Alignment System, ICATPP-7, Oct. 2001, ISBN 981-238-180-5. pp. 149–153.
[2] B. Dhoedt, D. Delbeke, "RODIS: Rigorous Optical Diffraction Software",
http://www.photonics.intec.ugent.be/research/facilities/design/rodis/

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