IR Transparent Si microstrips

(alignment optimized Si sensors)

...in 11 slides

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Outline

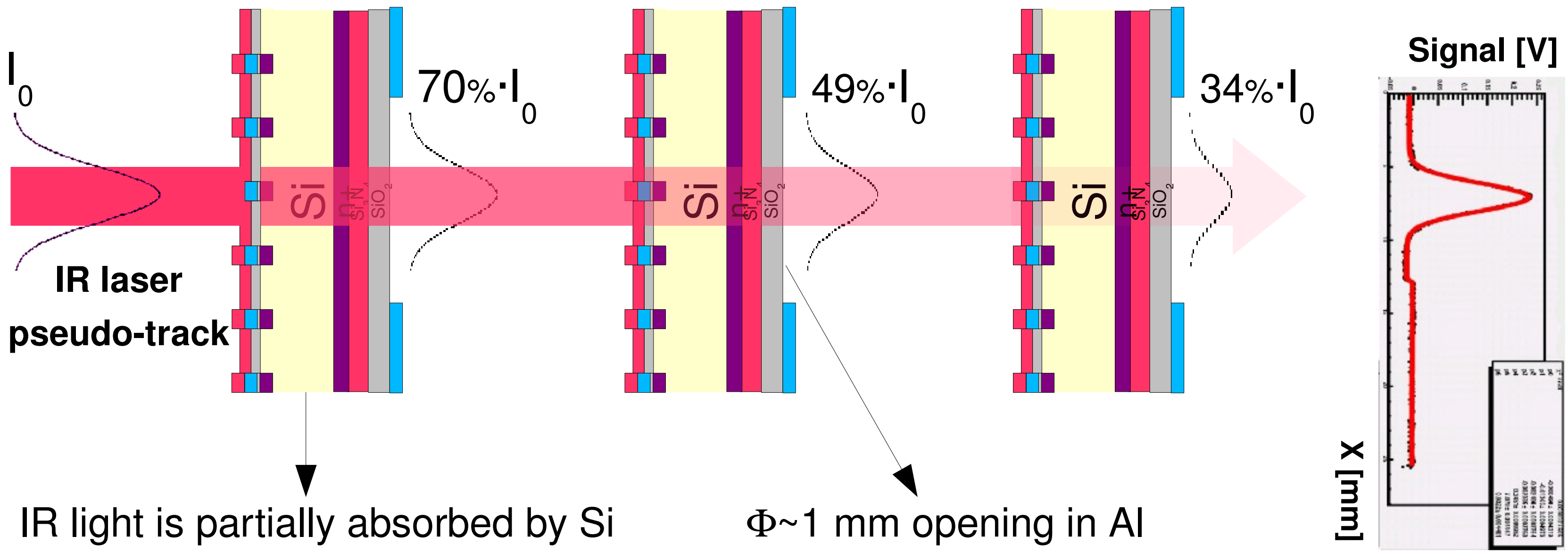
1) IR hardware alignment system description
2) New CNM microstrip alignment-friendly sensors
3) Comparison of measured optical functions with simulation
4) Next steps

Not covered in this talk:

— Digital readout
— Electrical tests

IR track alignment

- Aim: align Si microstrip sensors using IR laser tracks



- Higher %T ⇒ simpler hw-alignment system:

Transmittance	90%	80%	70%	60%	50%	40%	20%
Traversed	30	15	10	7	5	4	2

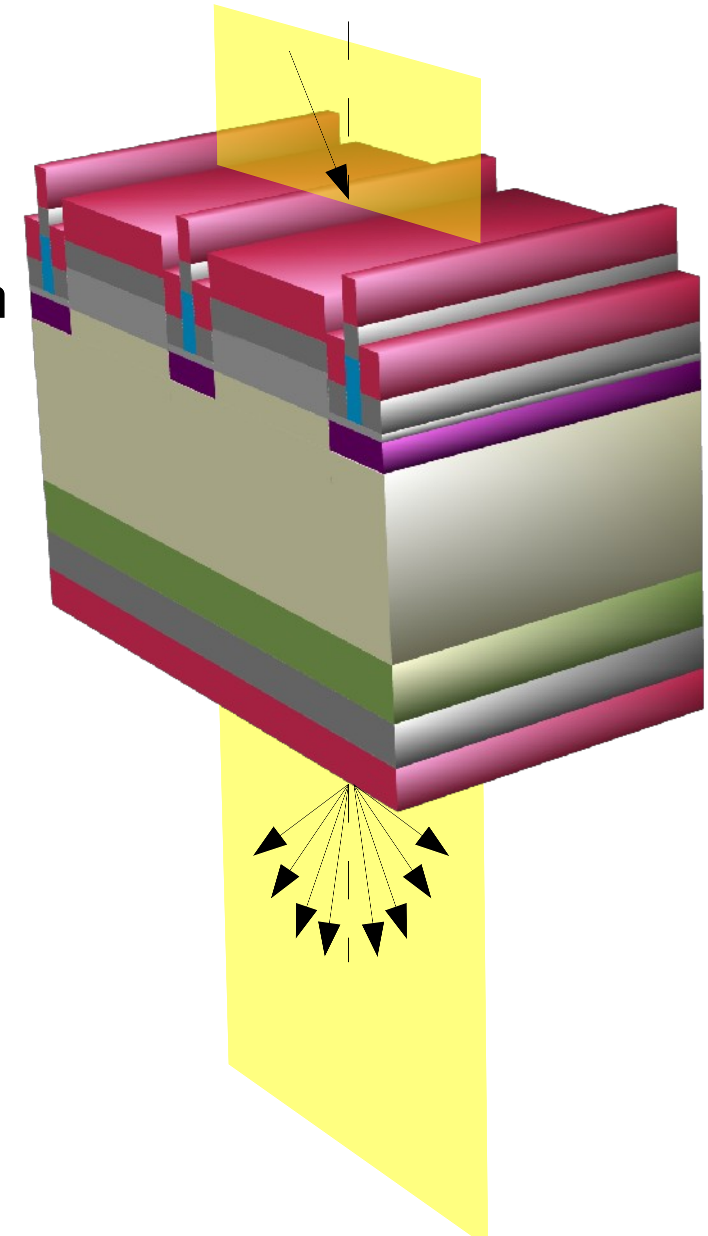
SiLC **HPK**

- System features:
  - Laser intensity~200 MiPS ⇒ **sharing same DAQ as Si detector**
  - Silicon modules are directly monitored, **no external fiducial marks**

Goals and HOWTO

1) Looking for a simple recipe to increase sensor transmittance

2) We developed a full simulation of the interaction of the light with the sensor (sensor≡Grating ⇒ diffraction)



3) Based on the simulation⇒ keys to increase %T:

3.1) Optimize layout (strip pitch, strip width)

3.2) Tune layer thickness

In particular top and bottom passivation (passivation= Si_3N_4 on SiO_2)

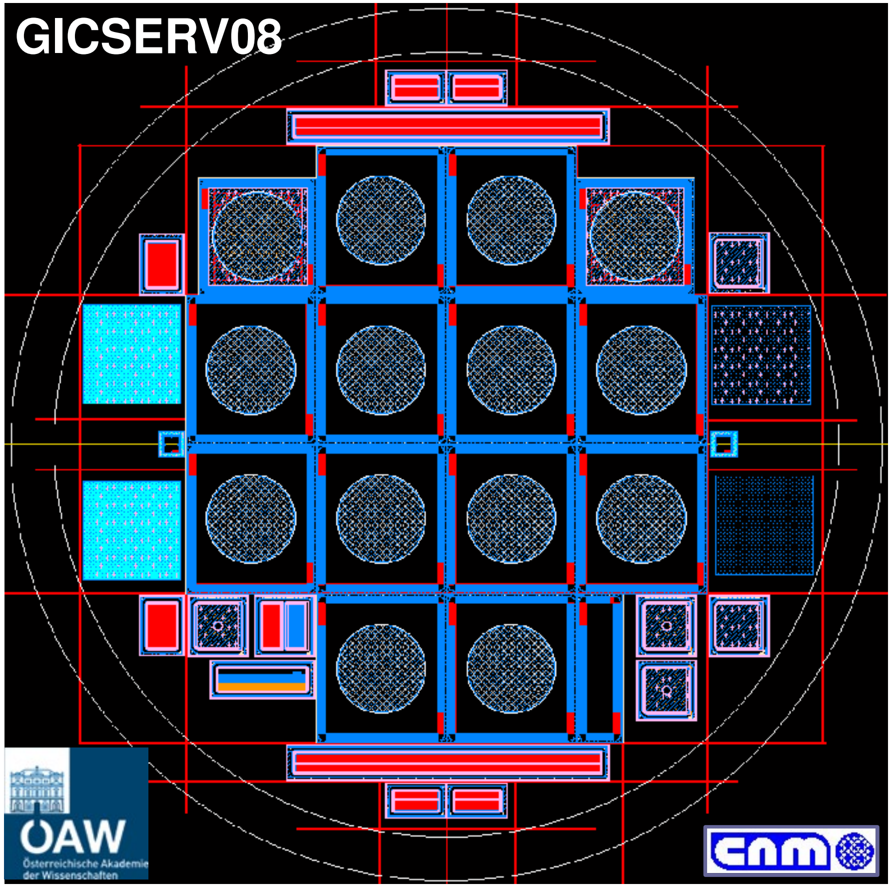
3.3) Take into account deposition tolerances (deposition error~5% at CNM)

1st alignment batch at CNM

• Prototypes built by CNM-Barcelona (Spain)

— Optical test structures (continuous layers) to extract refraction index and control deposition:
Si, Si+p$^+$, SiO_2, SiO_2+passivation

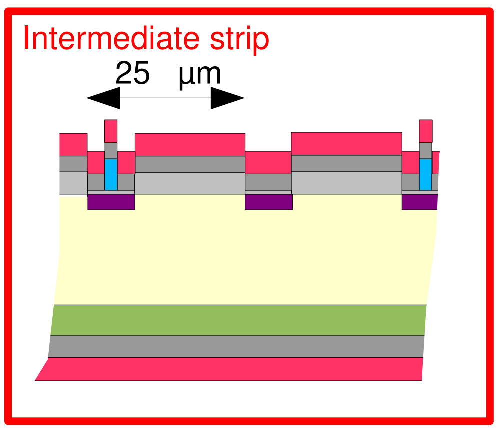
— Electrical test structures,
(CAP TS AC, CAP TS DC, CMS Diode, MOS, GCD, Sheet) designed by HEPHY-Vienna

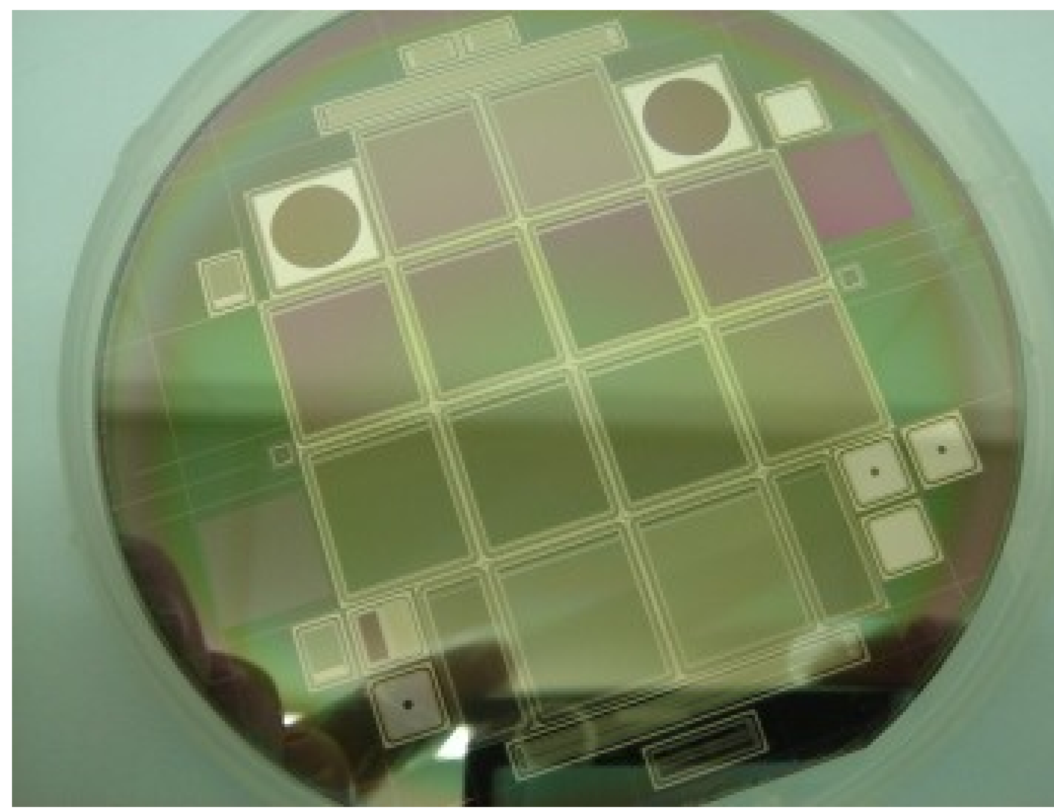


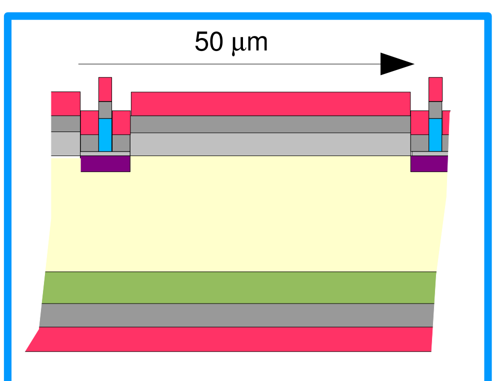
• Mask designed by **D. Bassignana** (CNM)

• Production was **paused** before deposition of last layer of passivation
Allows to perform intermediate measure (and debug)

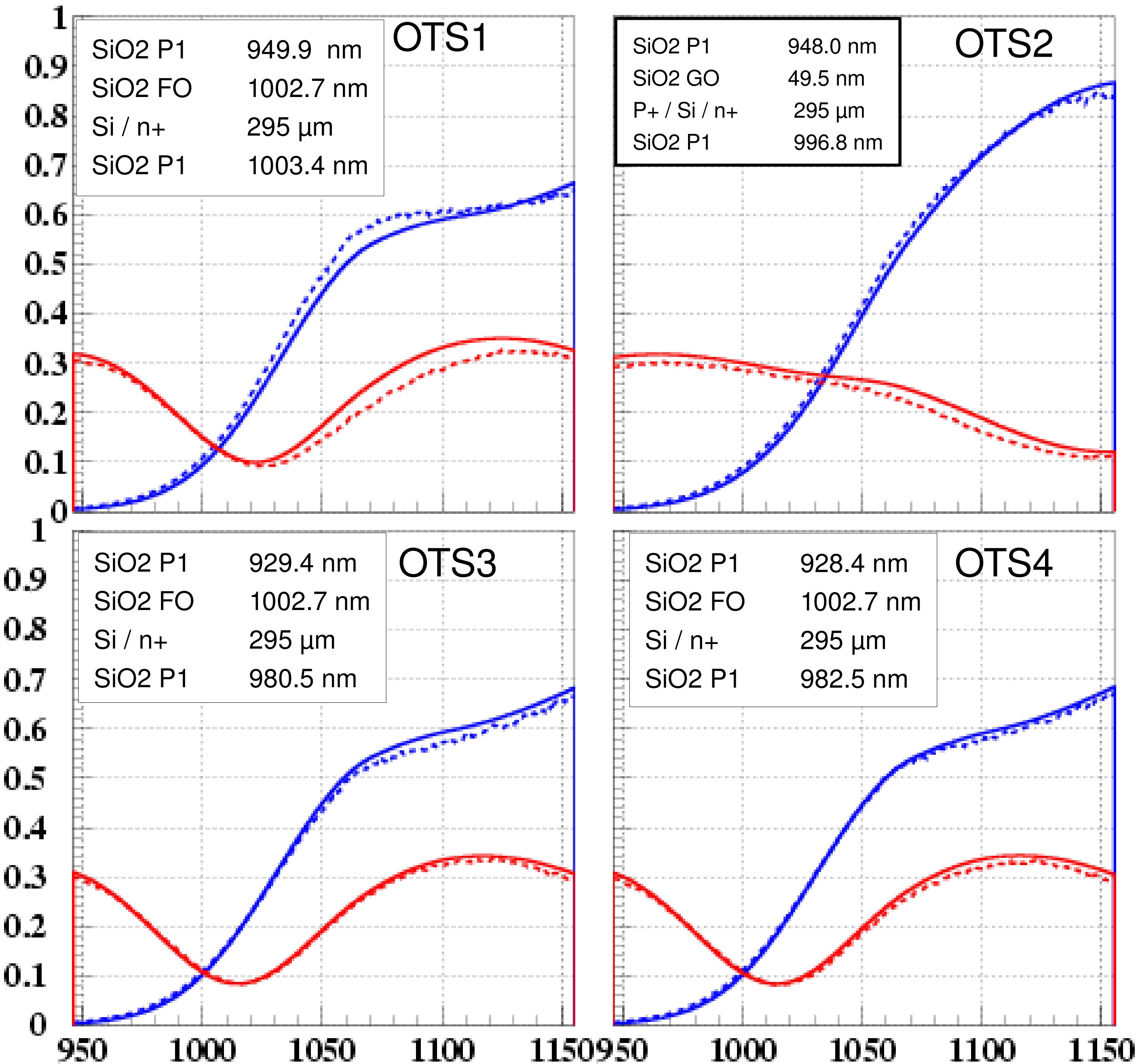
- 5+1 wafers
- 12 μstrip detectors per wafer (6 with intermediate strips, without metal contacts)
- 50 μm RO pitch
(25 μm interm. strip)
- 256 RO strips
- 1.5 cm length varying strip width
(3,5,10,15 μm)







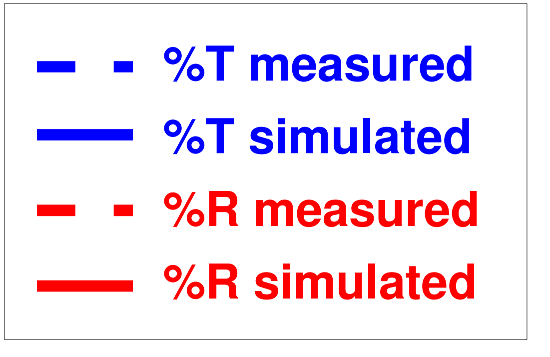
Optical test structures



1st result: Transmittance of Si can be increased by ~30% with just 2 layers of 1 µm SiO2

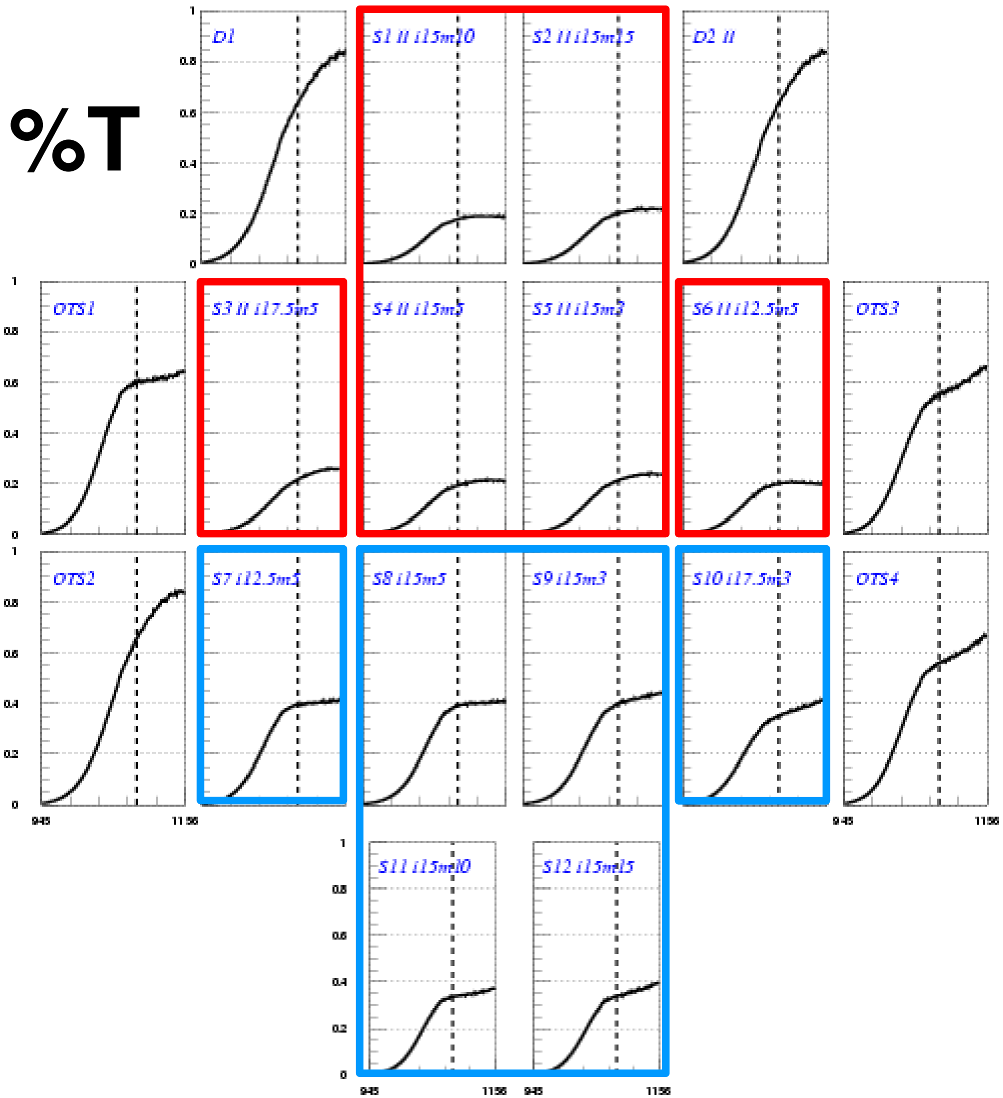
VALIDATION of simulation applied to continuous layers structures

Validation of inputs (n,k;λ)

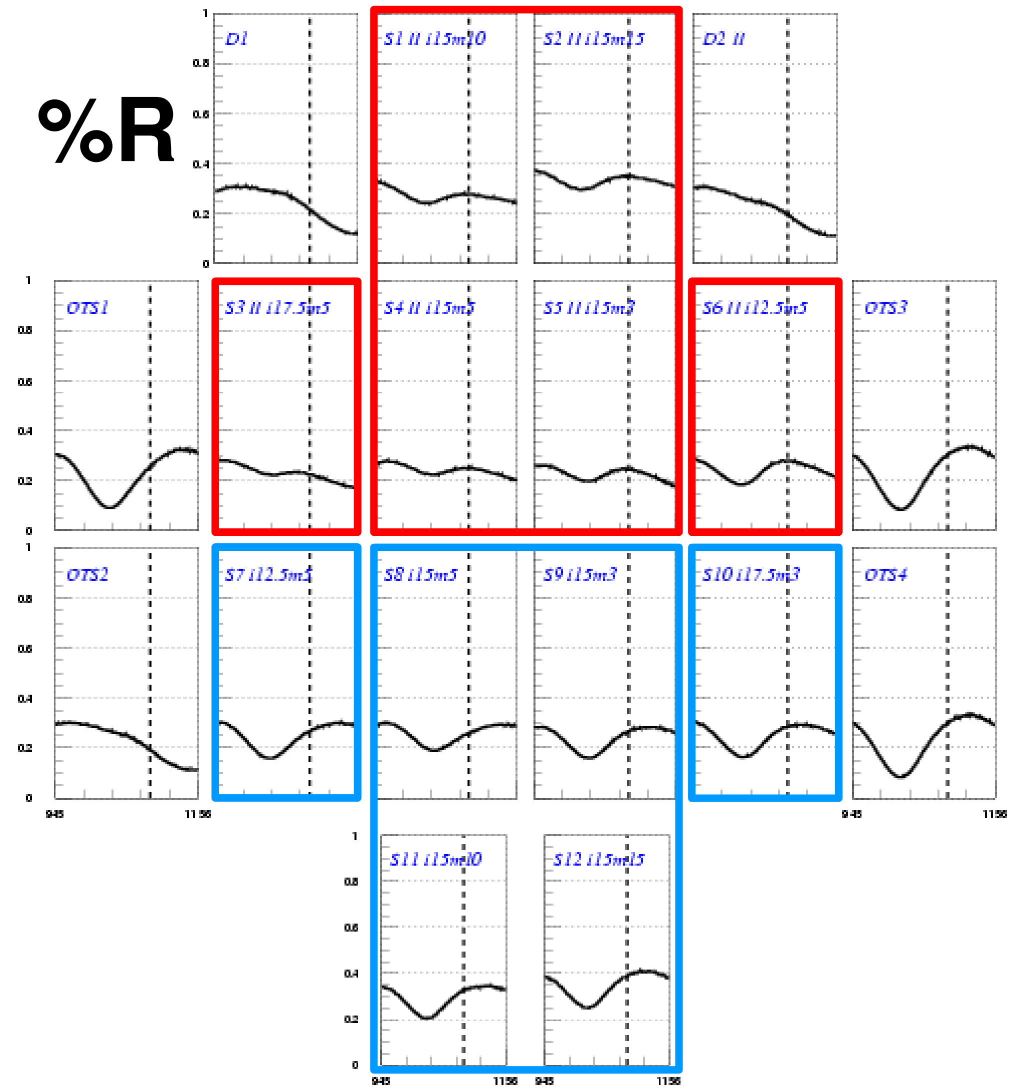


(T,R) one step before completion
[No Si_3N_4 yet]

%T

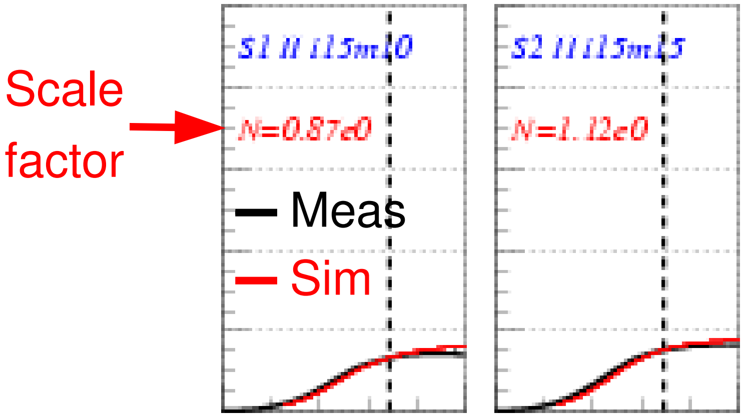


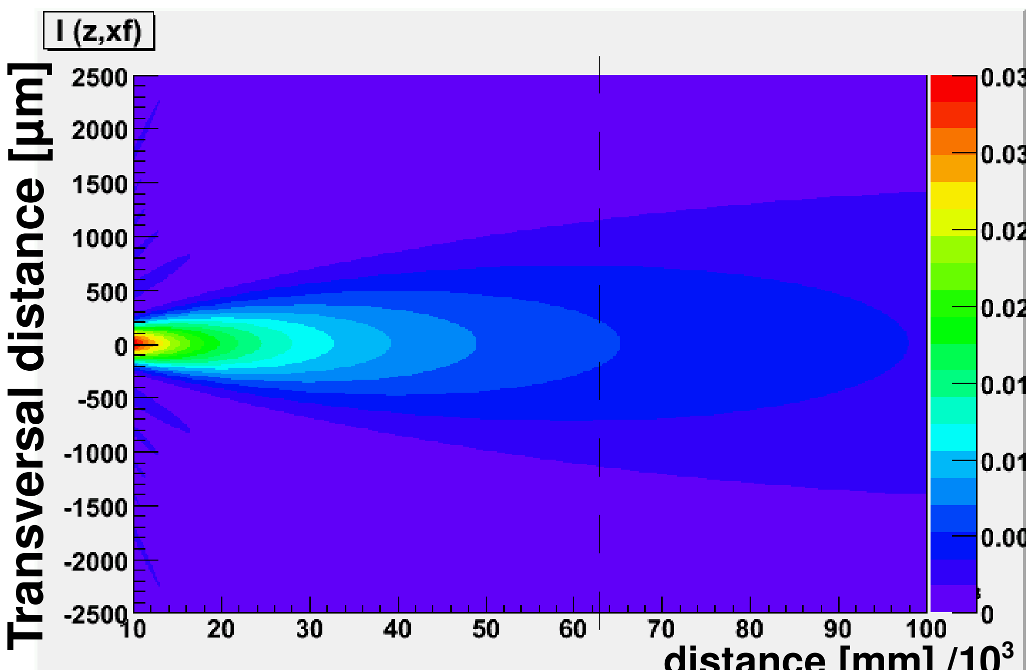
%R



- No intermediate implant ⇒ ΔT=+20% but same %R
- %T linked to homogeneity, %R linked to Al width (2^{nd} order)

Validation of full simulation



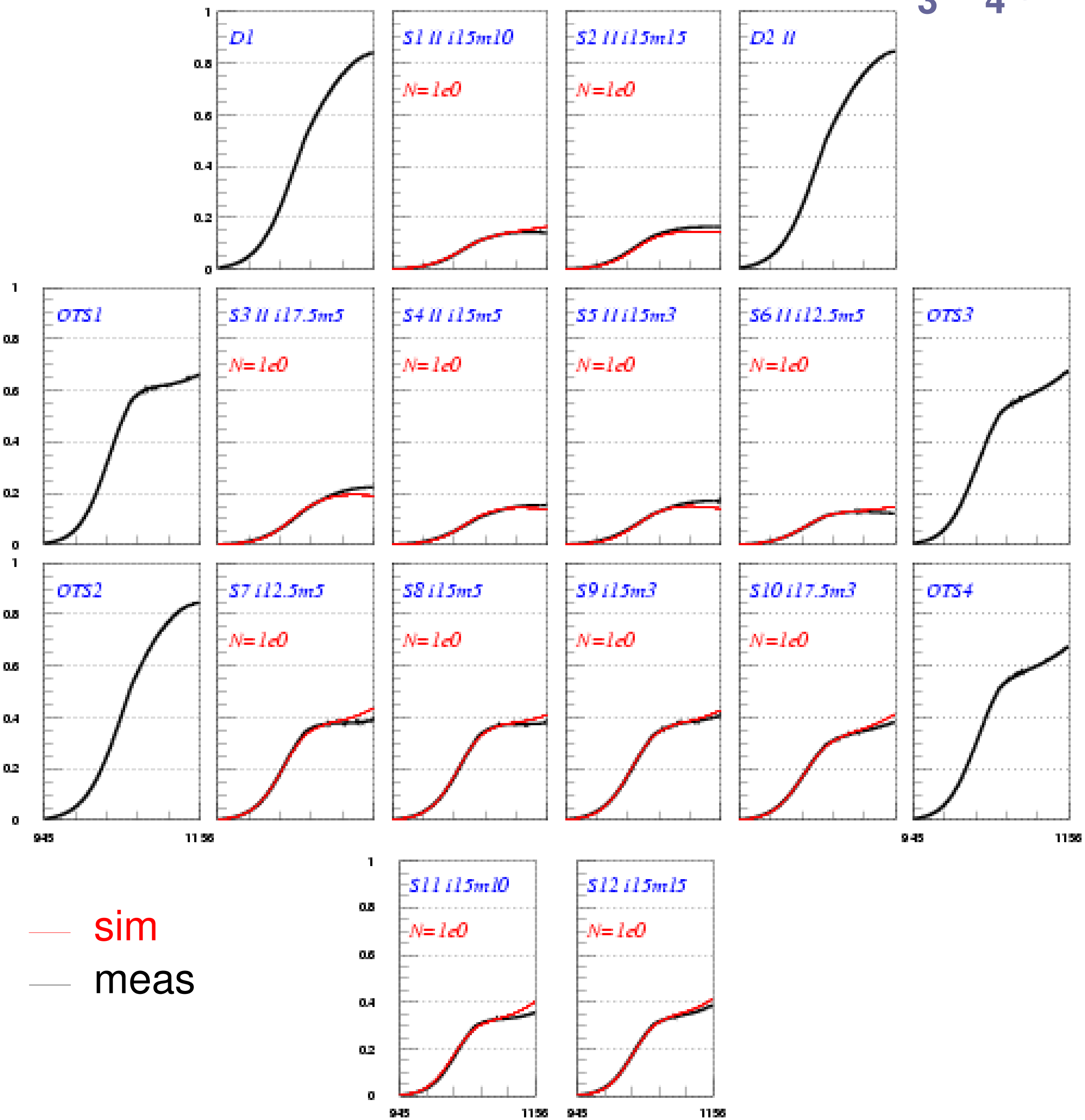


- Measured T is already 20% higher than in CMS sensors **BUT results did not match simulations**
- A **fit** to the data showed we could match the shape, but were off by +20% max. We needed a normalization factor.

(one month later...)

- We realized there is a difference between near field and far field diffraction calculation
- Diffracted beam spreads.

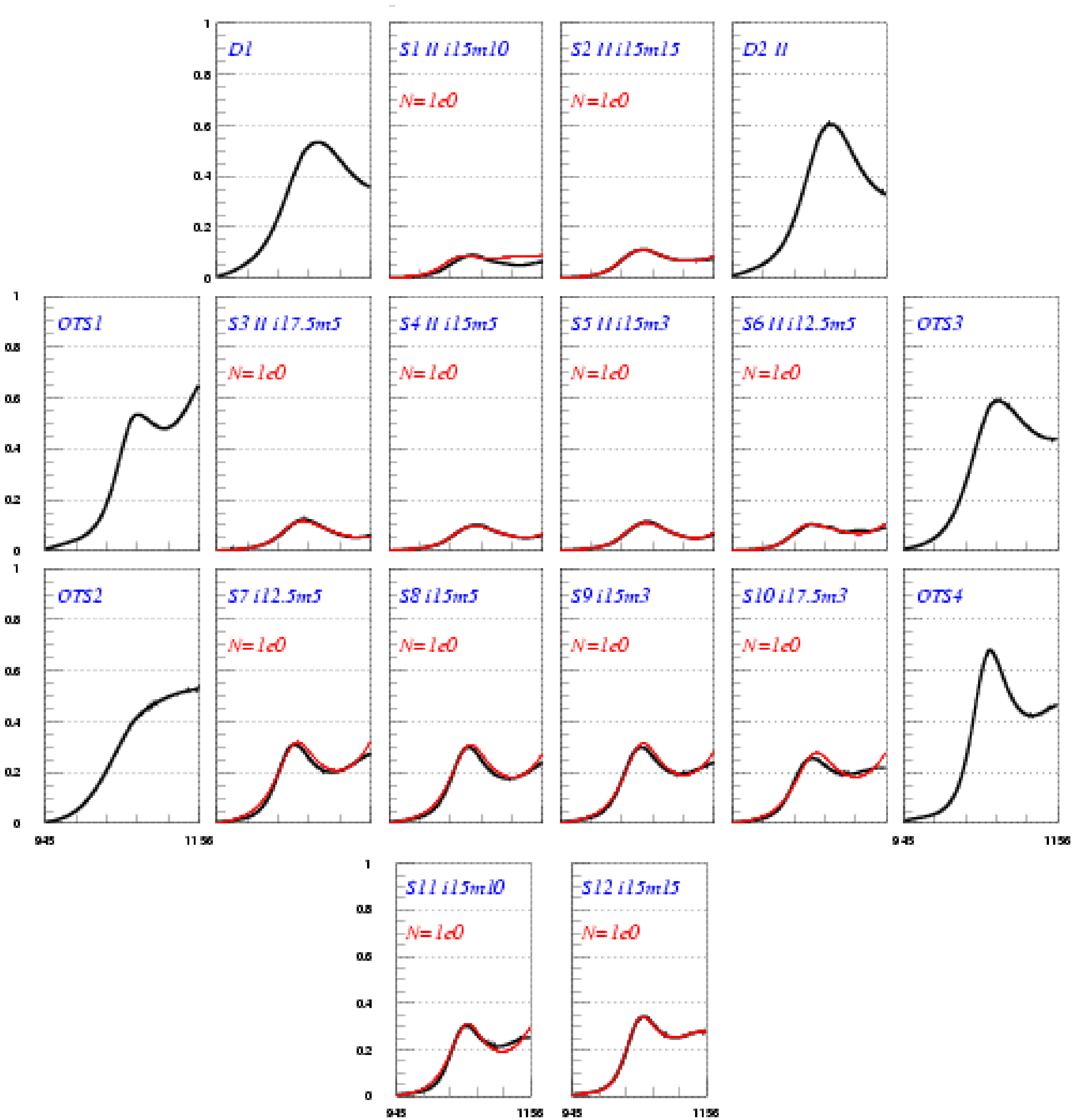
Wafer 1, far field fits
[No Si_3N_4 yet]



- Fit in far field configuration
- Wafer 1 with no Si_3N_4 passivation, only SiO_2
- No need for scaling !
- **VALIDATION** of **full** simulation

Wafer 1, finished

• Wafers 1 and 2 optimized before “far-field” effect was understood. Production had to be started before end of 2009.



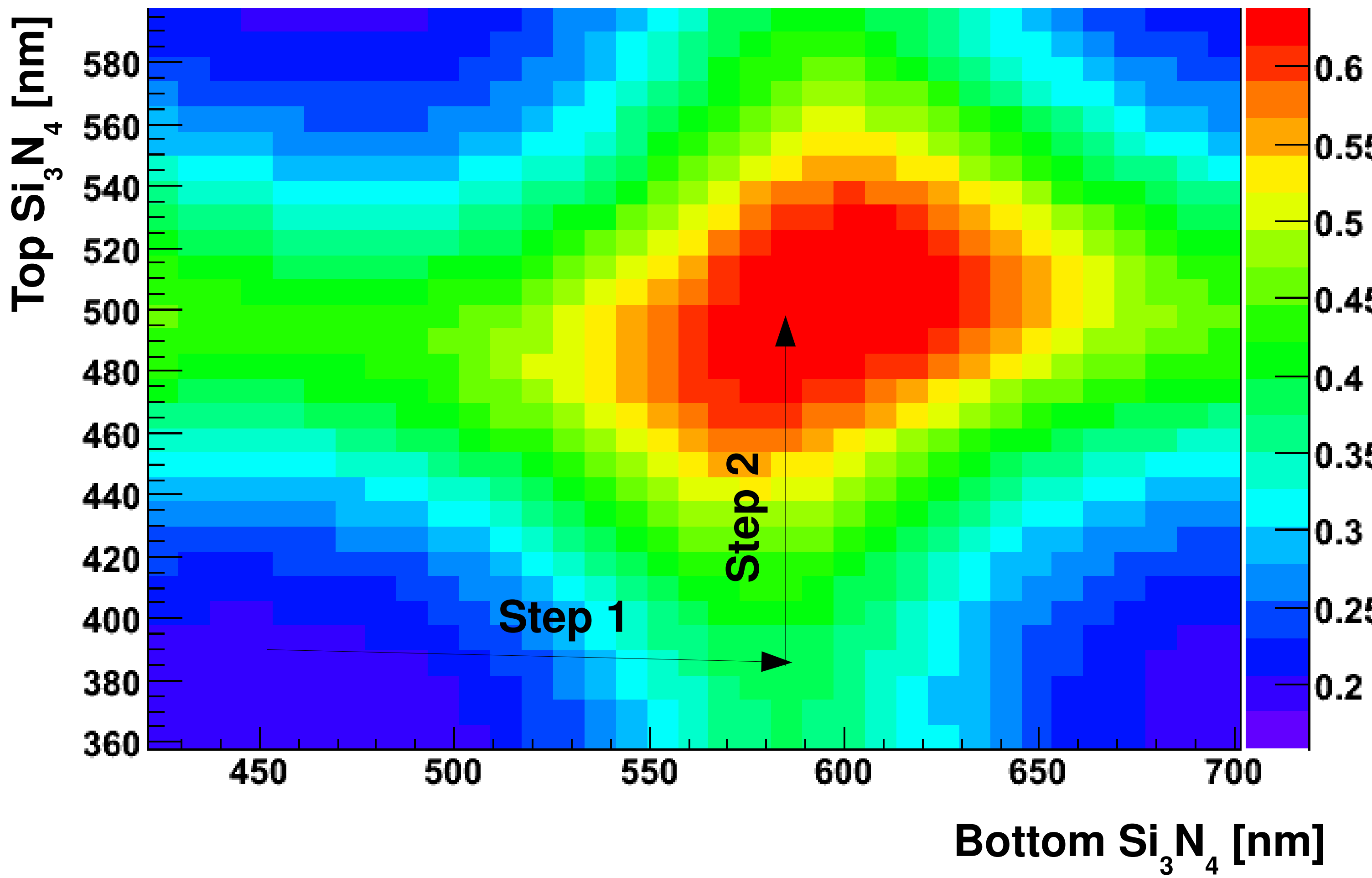
• Not optimum Si_3N_4 thickness deposited ⇒ We managed to reduce the final transmittance (was 40% max with only SiO_2)

• We have recalculated optimum thickness for the 3 wafers left. We will proceed with sequential deposition

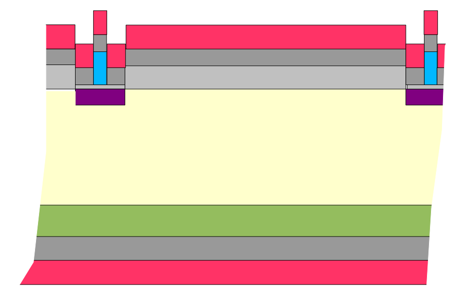
Safe mode: sequential deposition

• Feedback from 1st run: reduce thickness of passivation nitride to avoid stress

• New search method for this run: look for islands of maximum %T in sequential deposition steps. Example:



Maximum %T~60%



Conclusions & next steps

- We are producing 5+1 wafers of IR enhanced transmittance
- Deposition process pause&hold to crosscheck:
  - Continuous and Full simulations
  - Continuous simulation was validated with measurements
  - Full simulation unmatched
    - We discovered the effect of far field computations
    - Data could be fit using full simulation

    $\rightarrow$ Full simulation has been validated

- Next 3 wafers will be grown in a very conservative approach
  - Several steps to reach maximum

- Open issues:
  - Binary readout
  - Electrical tests of the sensors (already started)

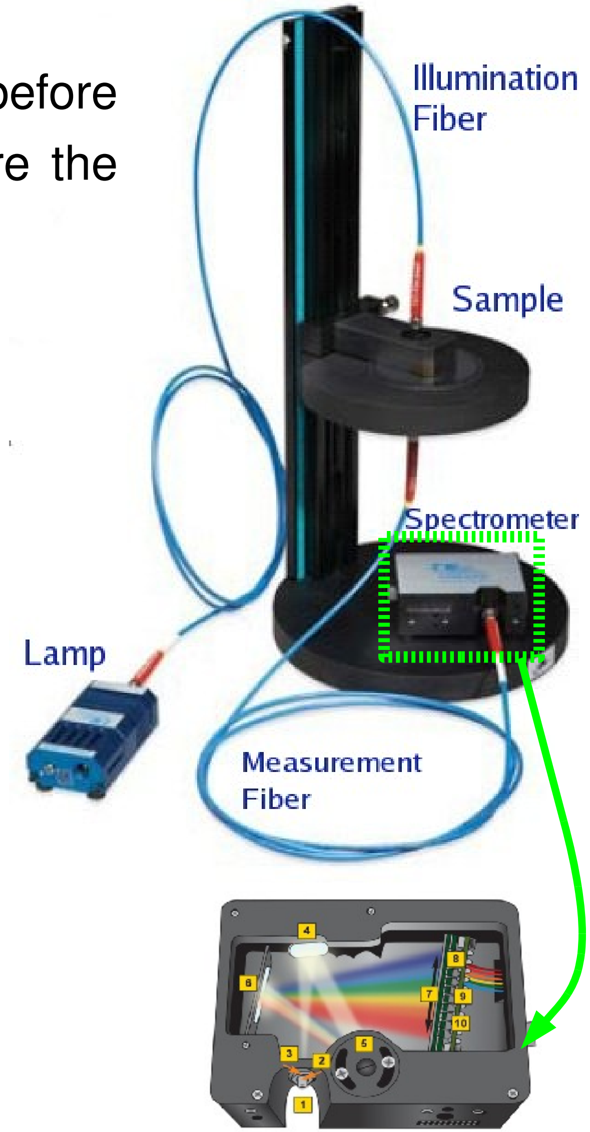
BACKUP

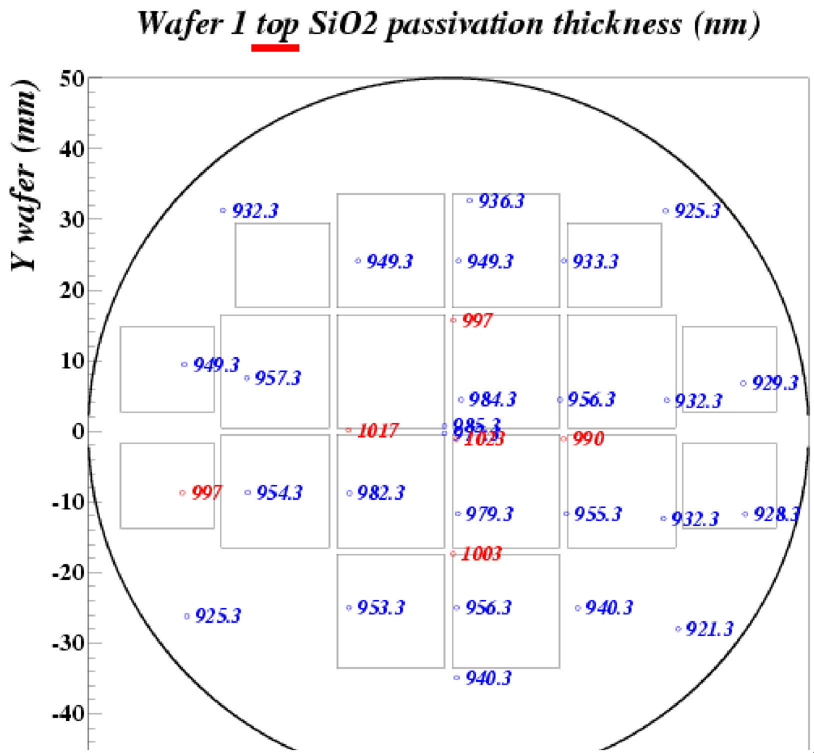
Production progress

- Production started on 11th of May 09
- All processes done until deposition of 1st passivation layer (end of July 09)
- Thickness of all layers measured after each deposition
- For the 1st batch, we decided to hold the production just before deposition of the last passivation layer. Like this we can measure the wafer at an intermediate step

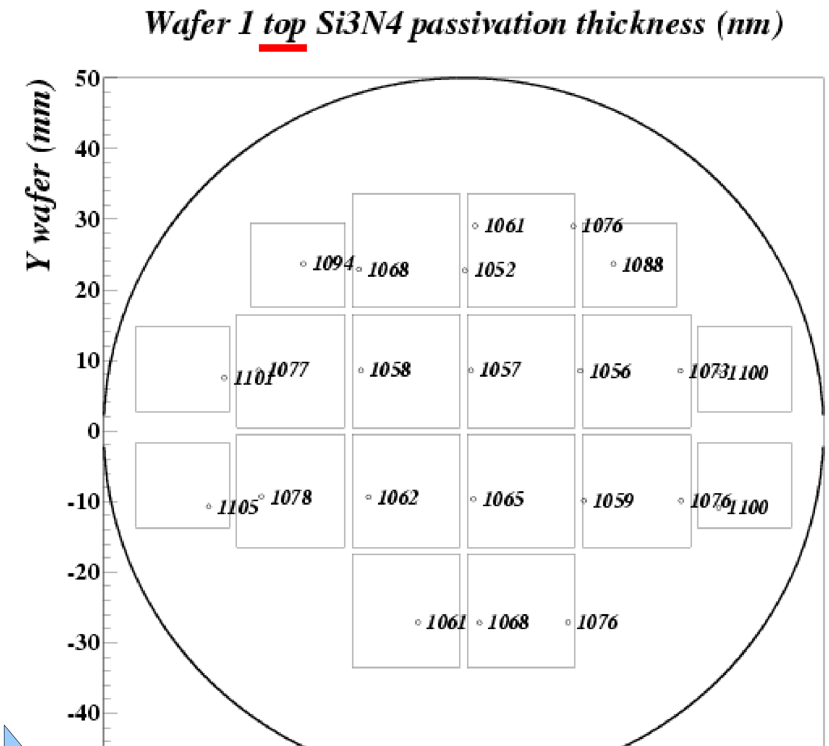
- Optical measurements were taken by end of July
  - — Test structures (no internal structure)
  - — Sensors (strips ⇒ diffraction)

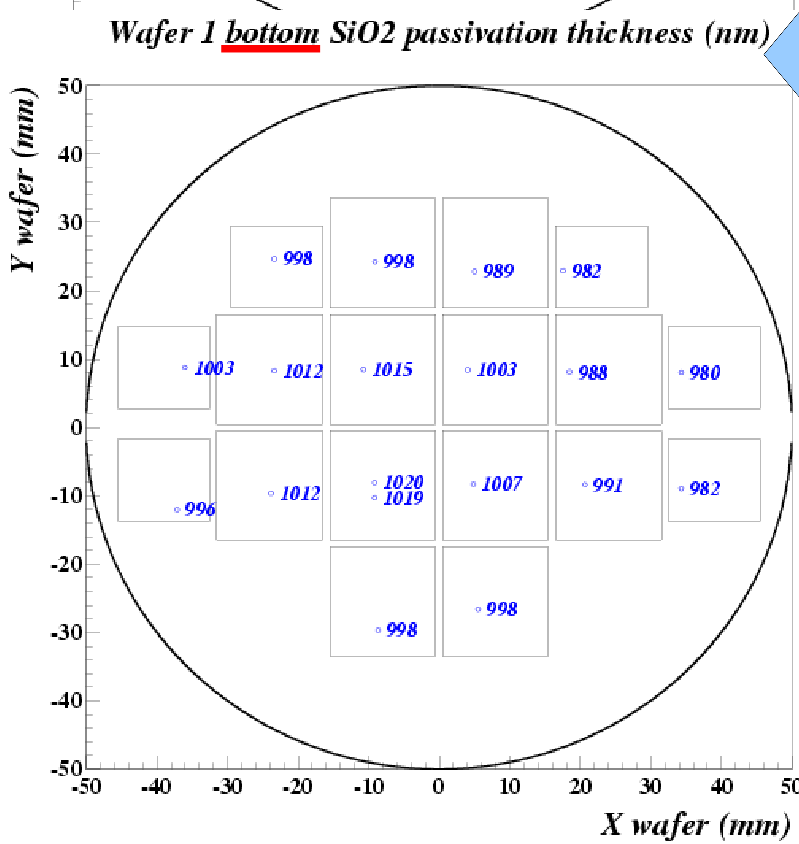
- NIR spectrophotometer used for Optical measurements
  - — %T : Measures spectrum with sample in/out
  - — %R: Comparison against calibrated reflector





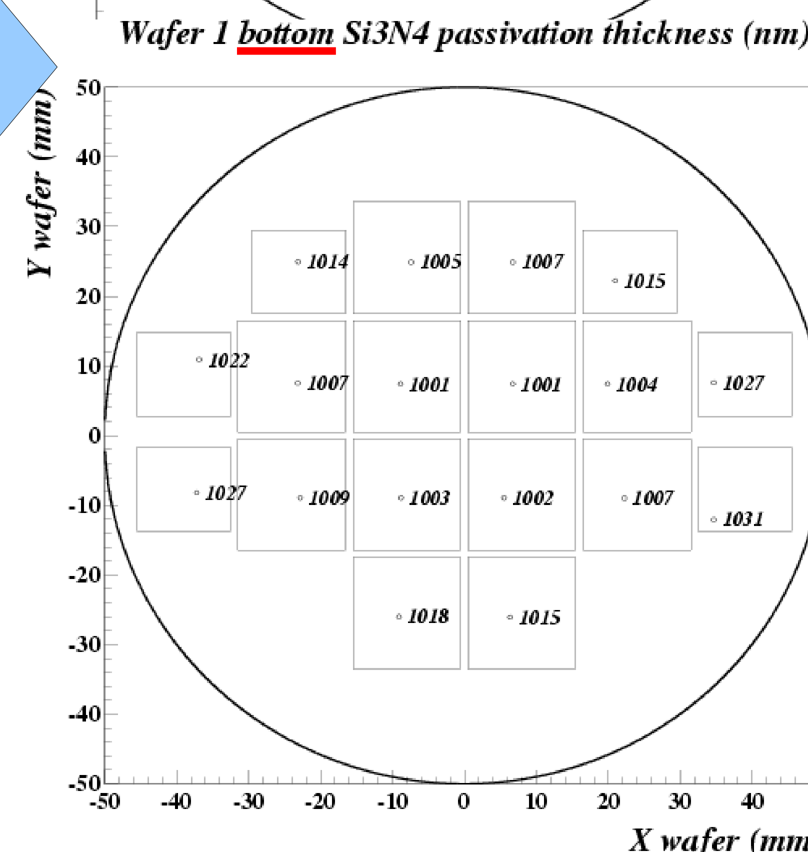
PASSIVATION
(wafer 1)
MEASURED!!





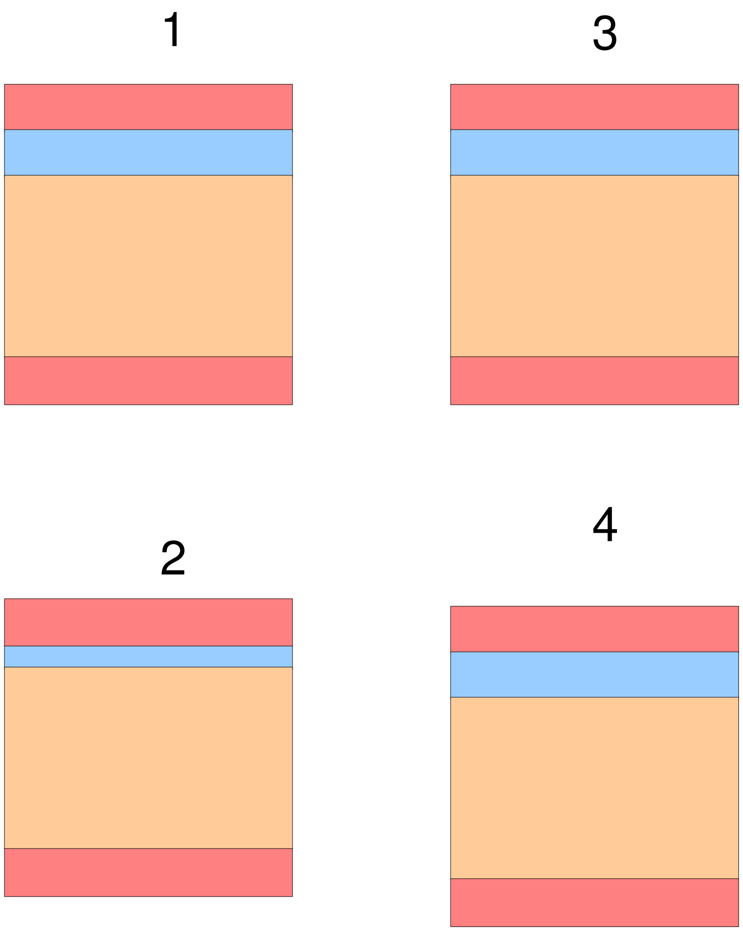
SiO2

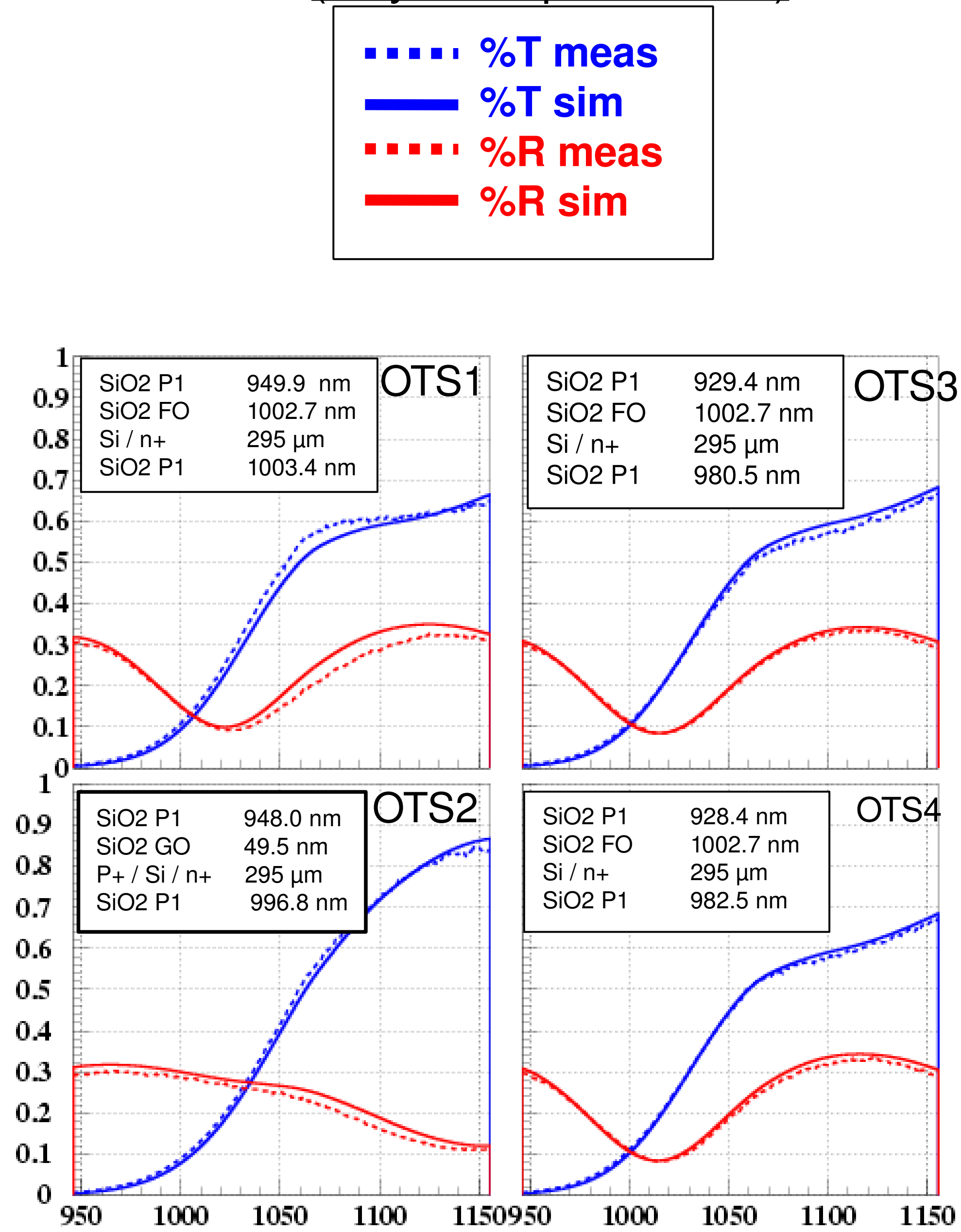
Si3N4



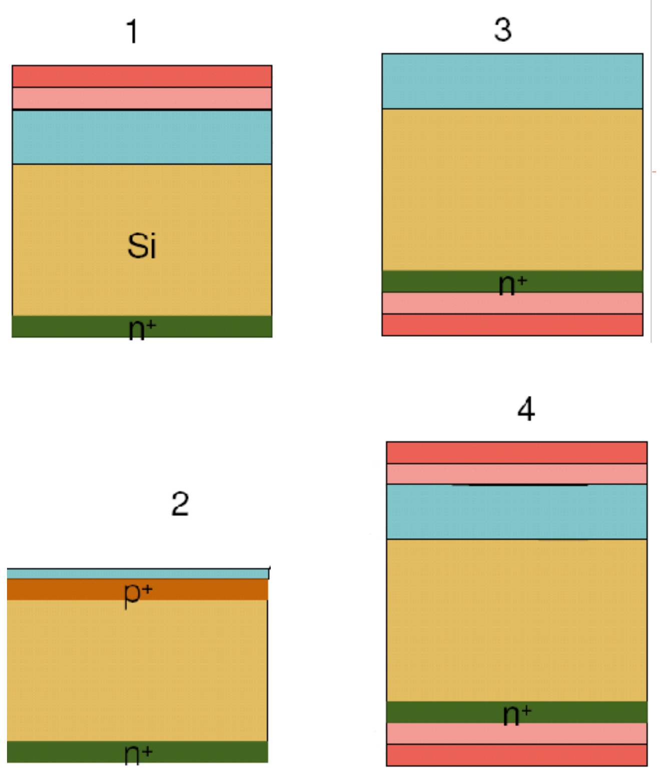
<u>Optical Test Structure stacks with only SiO2 on top</u>

<u>Comparing measurement with simulated nominal (only SiO2 passivation)</u>



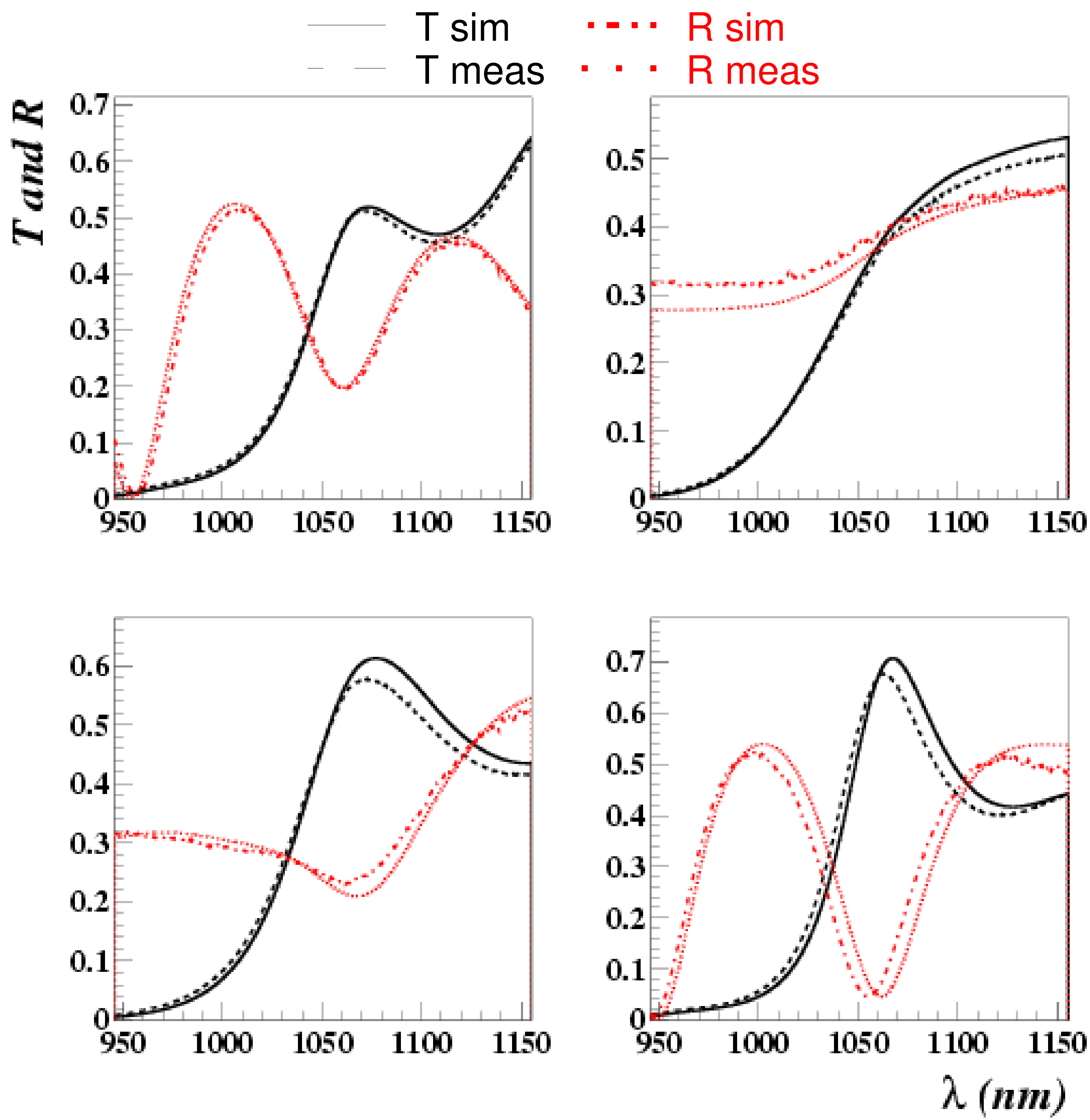


Optical Test Structure stacks (full passivation)

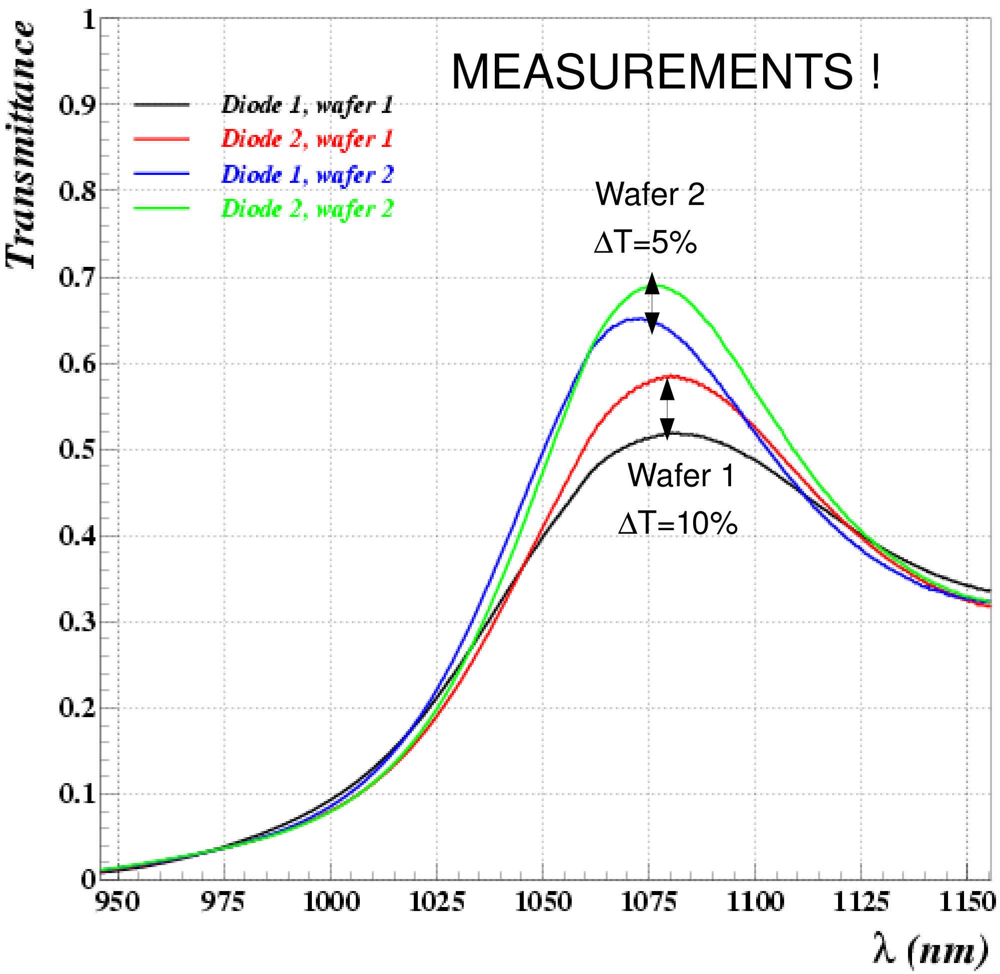


(after March10)

Comparing measurement with simulated nominal (full passivation)



Diodes (wafer 1&2)



- Diodes stack structure (=thin OTS1):
  Top passi+Gate oxide+Si+Bottom pass
- Wafer 1 vs 2: D T=20%
- Differences in deposition:

Si3N4 (passi)

	Wafer 1		Wafer 2	
	D1	D2	D1	D2
Top	1094	1088	1067	1076
Bottom	1014	1015	1034	1020

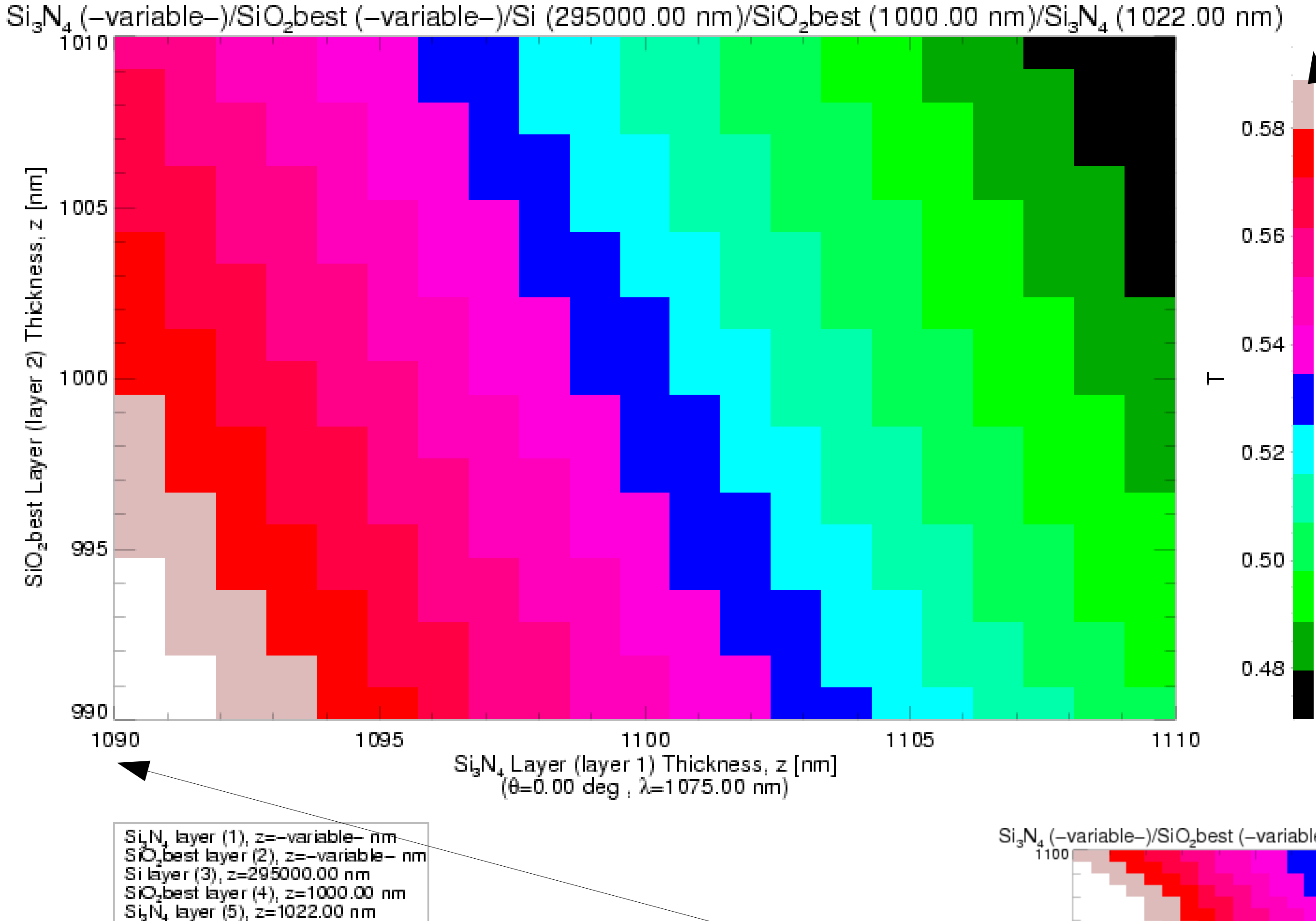
SiO2 (passi)

	Wafer 1		Wafer 2	
	D1	D2	D1	D2
Top	—	—	—	—
Bottom	998	982	—	—

Si3N4 (passi)

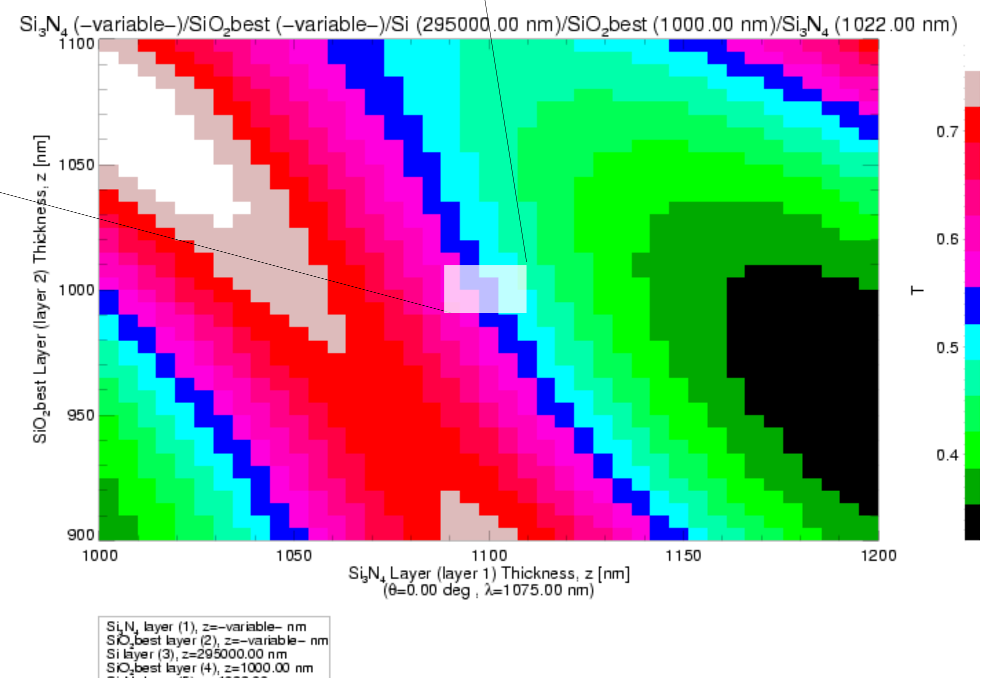
Wafer 1	Wafer 2
D1-D2	D1-D2
6	-9
1	14

- 1% change in thickness leads to 10% change in %T. Is it true? ...

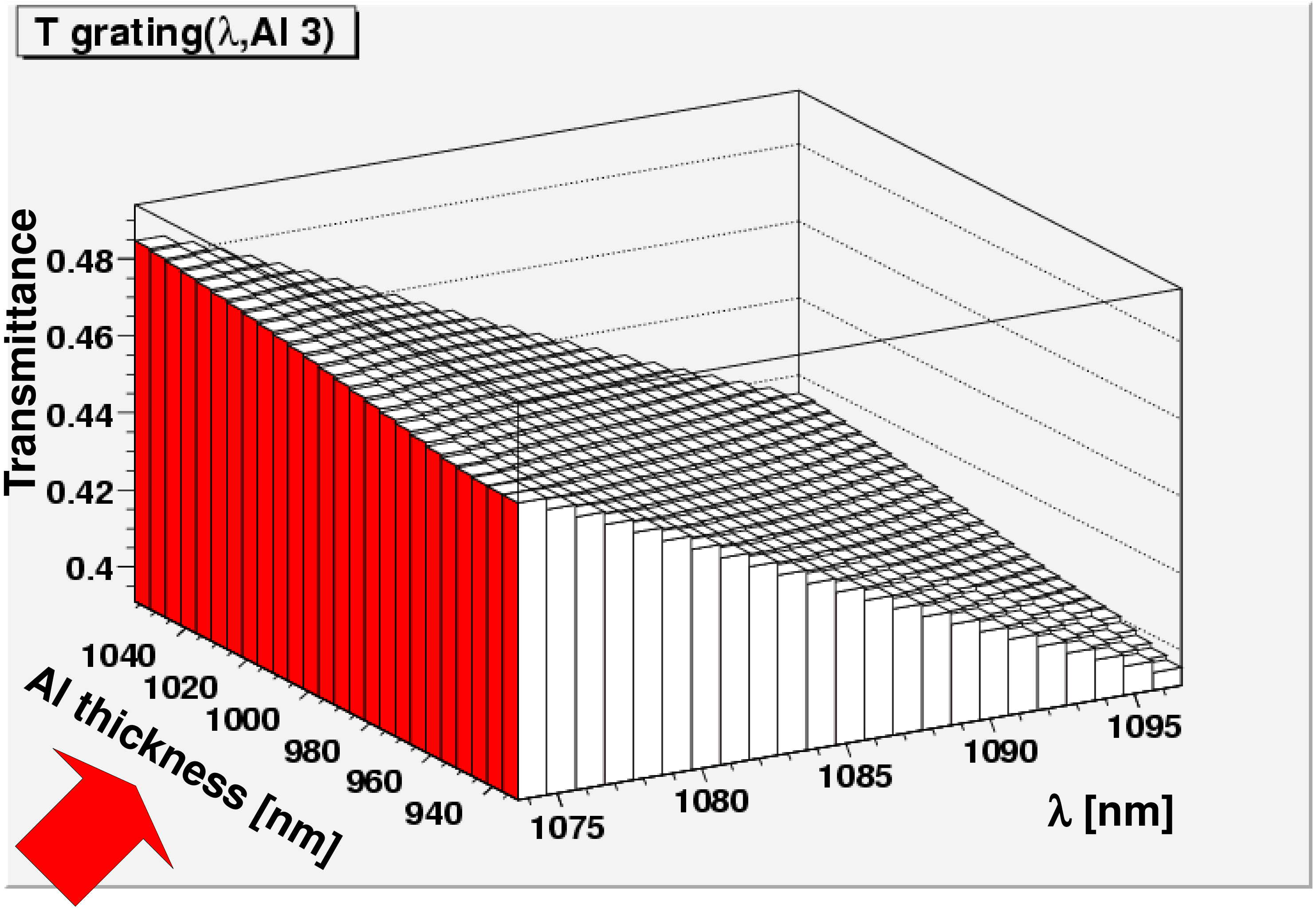


ΔT=10% for ±10 nm change in the thicknesses (upper passivation only)

SIMULATION



Transmittance and Aluminum thickness



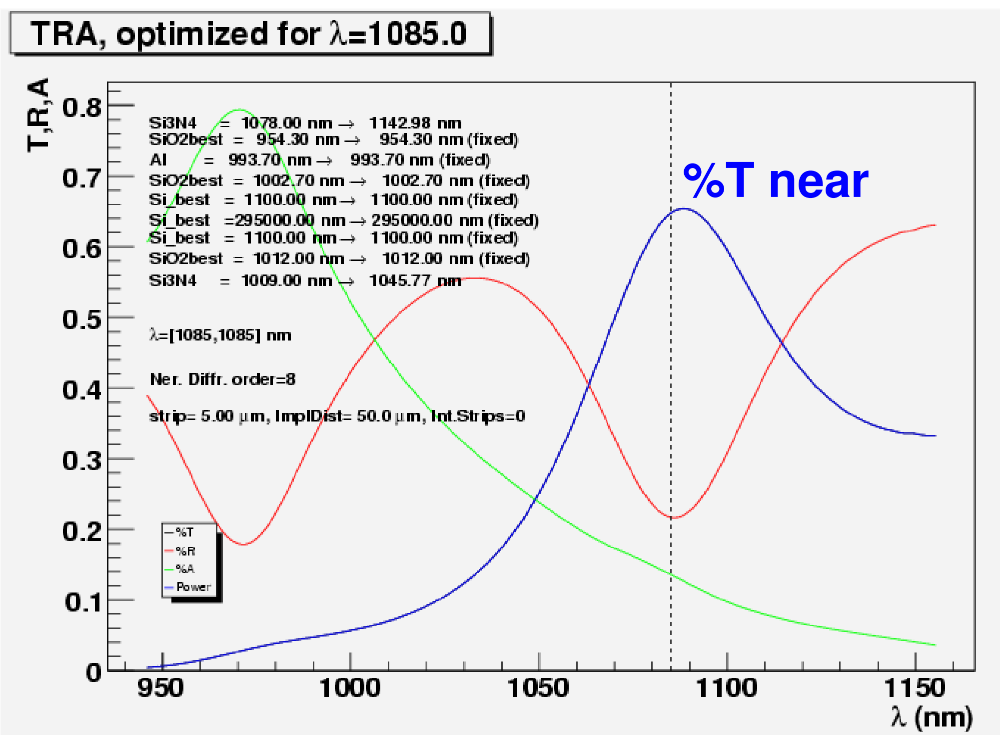
Little dependence on Al thickness (ΔT~1% for Δd_{Al}~100 nm)

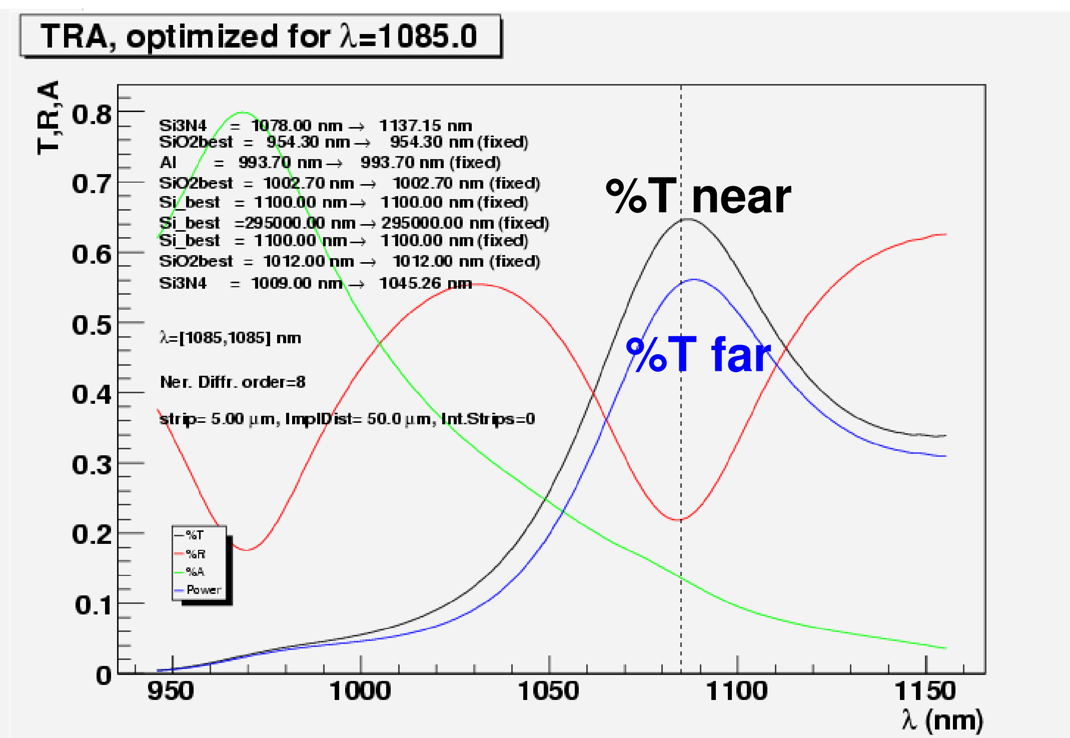
For the same thickness, higher %T for lower λ (ΔT~8% for $\Delta\lambda$~20 nm)

Fixing Al in the fit

Far vs near field optimization

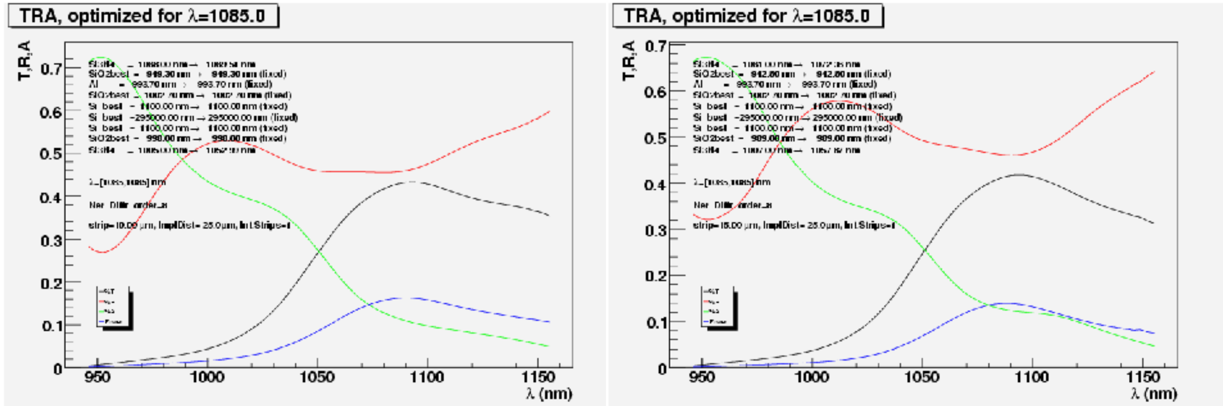
- Finding maximum %T at λ=1085 nm. Requested $T_{max} \rightarrow 1$
- Left plot. Maximun %T calculated in near field.
  Right plot: far field maximization
- Maximum of %T is found in near and far configuration in almost the same configuration.
What it is different is the magnitude of the maximum.



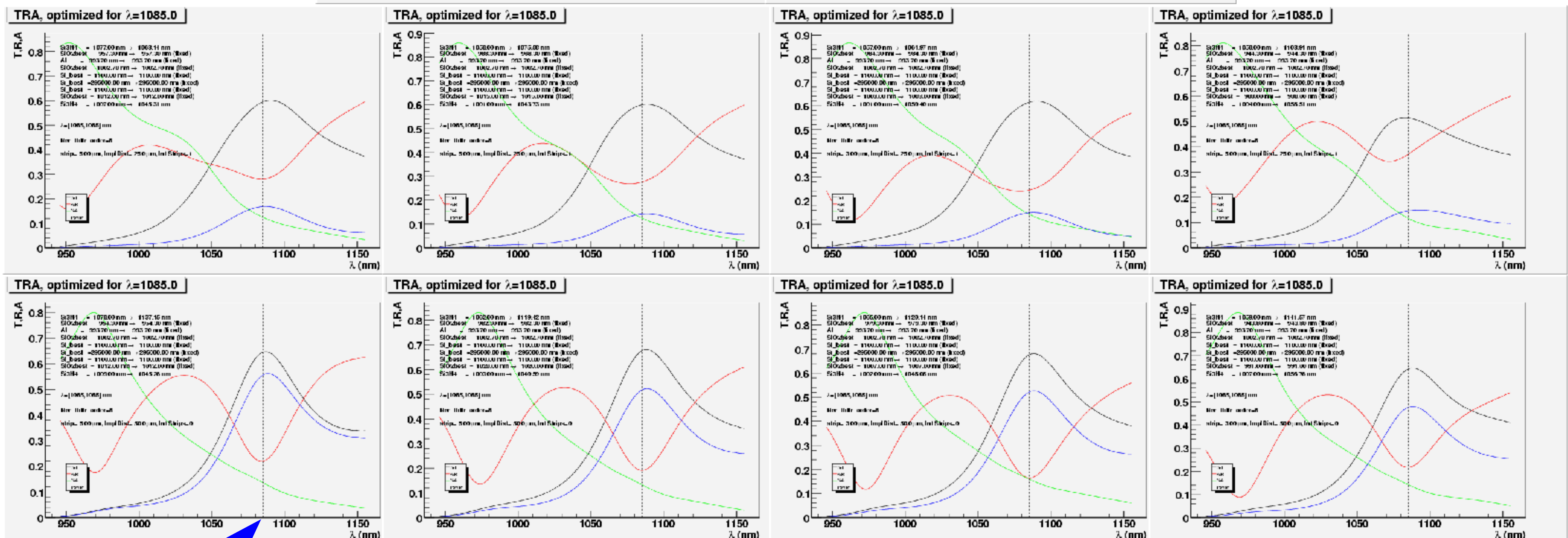


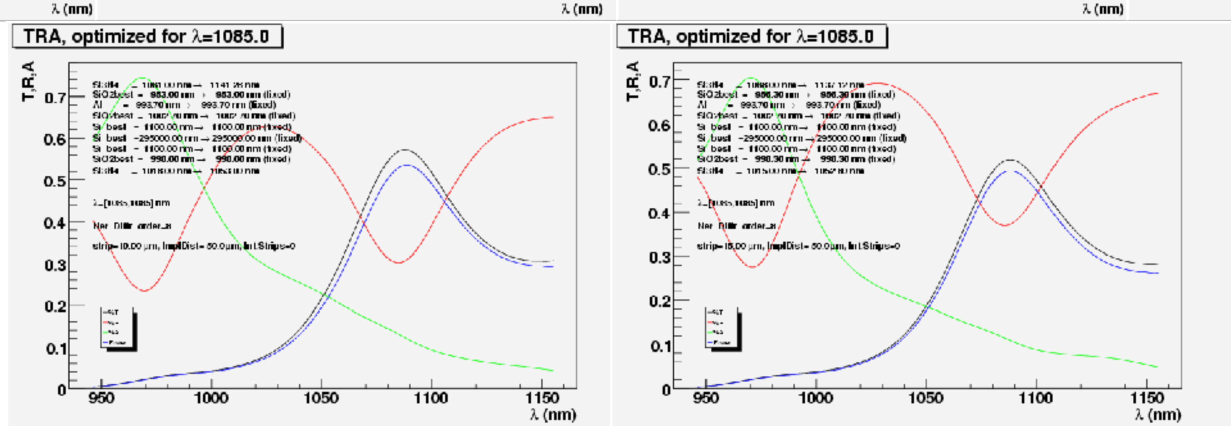
Near field (8 diff orders)

Far field

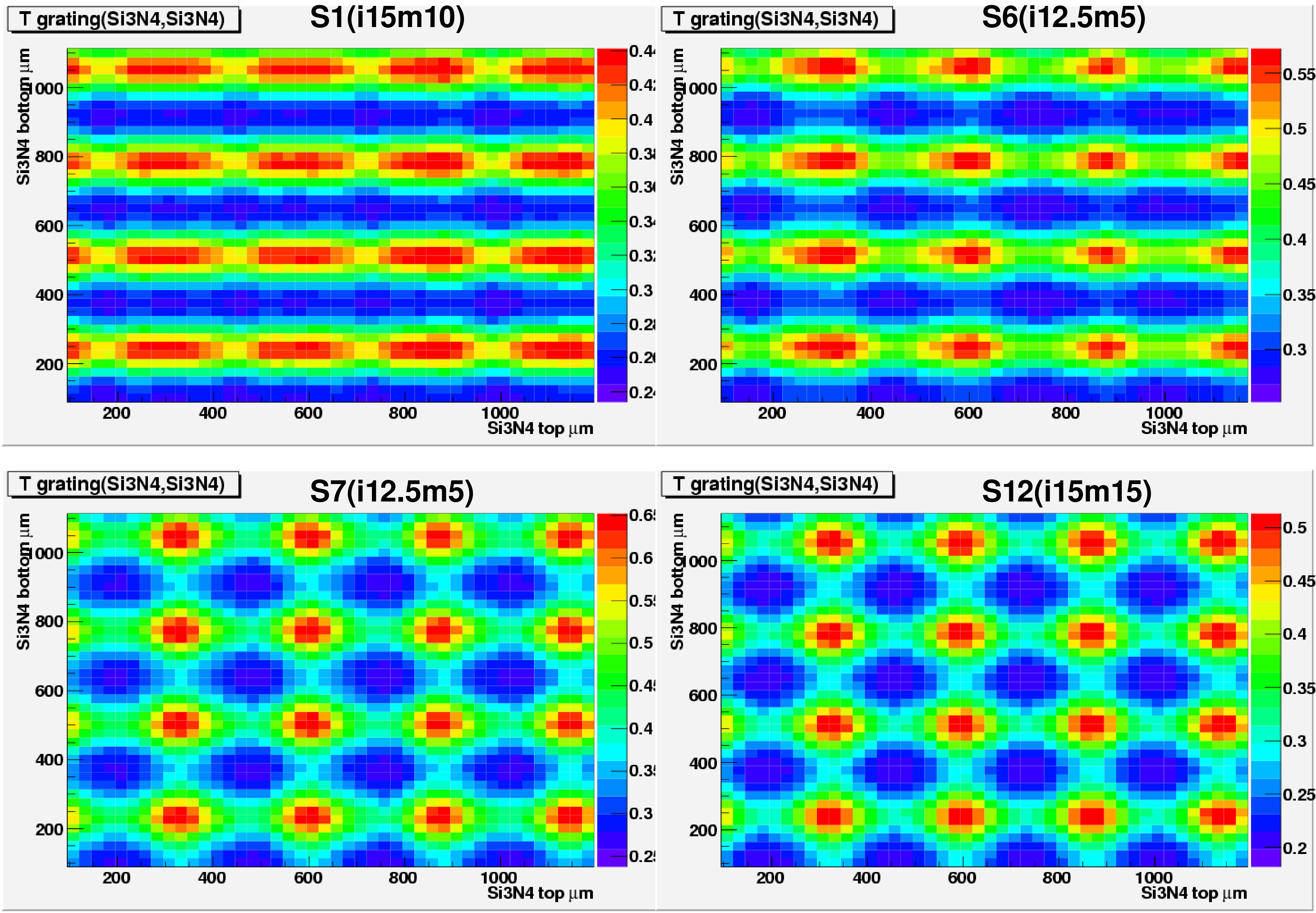


Note that %Tmax is 50% smaller in far configuration for 1 intermediate strip



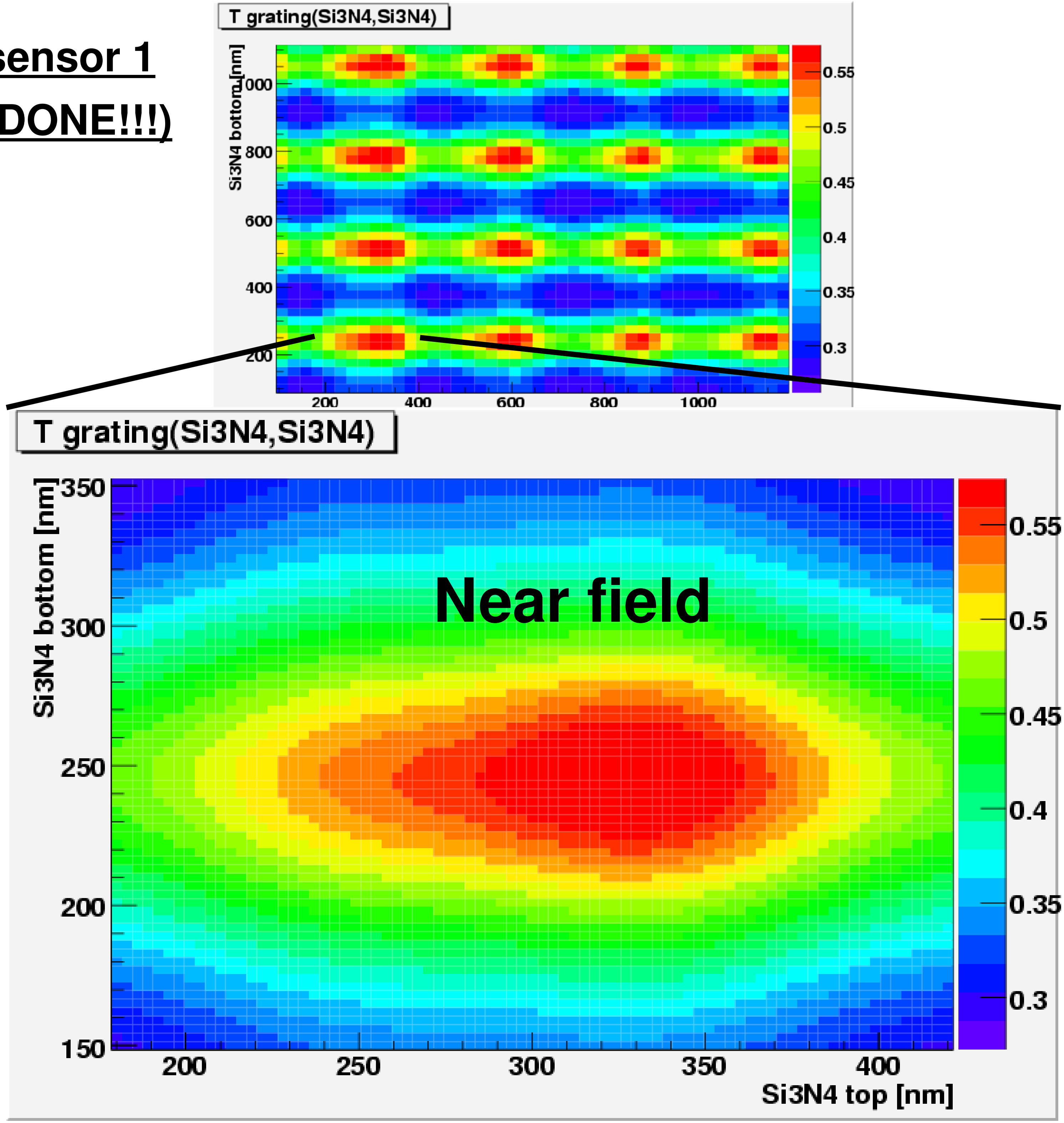


We can still scratch 60% transmittance


T grating(Si3N4,Si3N4)
S1(i15m10)
Si3N4 bottom μm
Si3N4 top μm
T grating(Si3N4,Si3N4)
S6(i12.5m5)
Si3N4 bottom μm
Si3N4 top μm
T grating(Si3N4,Si3N4)
S7(i12.5m5)
Si3N4 bottom μm
Si3N4 top μm
T grating(Si3N4,Si3N4)
S12(i15m15)
Si3N4 bottom μm
Si3N4 top μm

Example: sensor 1

(TO BE REDONE!!!)



Intensity as seen by the lens system of the SPM

Python routine: EyvsZ(2D).py