AEROGEL CHARACTERIZATION

A Preliminary Overview

A.R. Altamura
INFN - Bari

OUTLINE

- List of the silica aerogel tiles under test
- Measurements of optical transmittance
- Fit of transmittance data
- Transmission length evaluation
- Summary

TILES CHARACTERISTICS

Tile	Refractive index @405 nm	Expected t [mm]
1	1.03	20.7
2		20.8
3		20.1
4		20.5
5		20.4
6		10.0
7		10.0
8	1.04	20.3
9		20.5
10		20.3
11		20.4
12		20.5
13	1.05	20.5
14		20.7
15		20.6
16		20.6
17		20.8
18	1.005	20.0
19		20.0
20		20.0

Tile specifications provided by the producer

Measurements performed on **20 silica aerogel tiles** at CERN in July-August 2022.

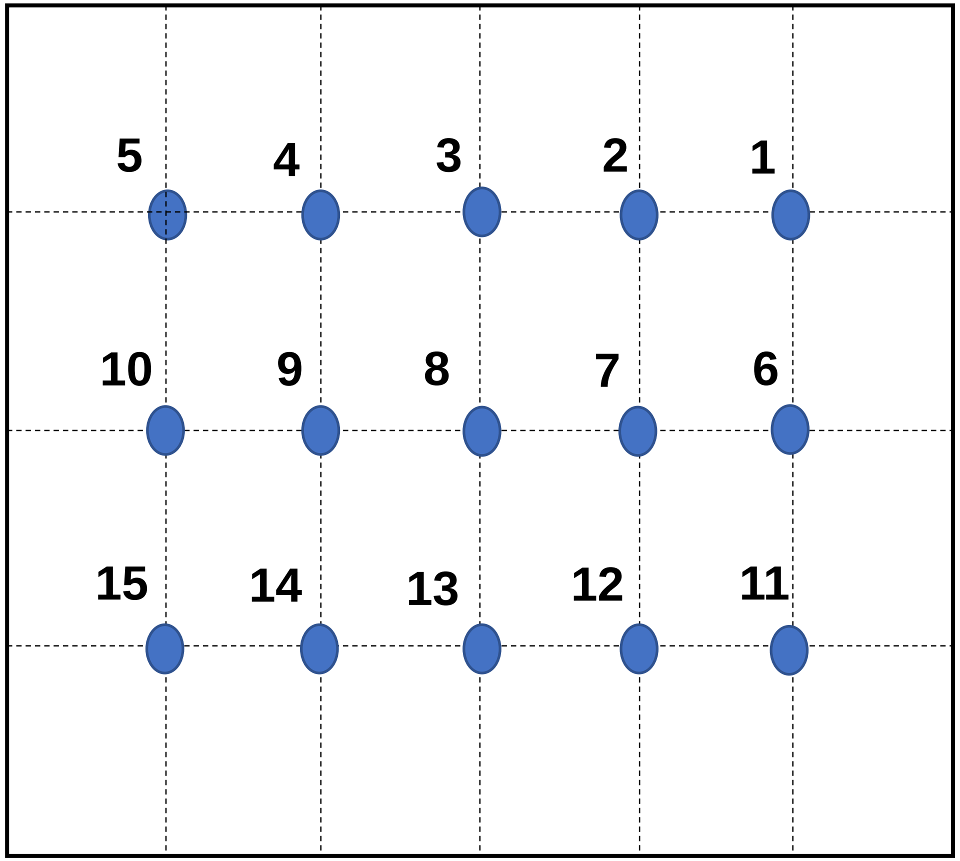
Tiles manufactured at Aerogel Factory Co., Ltd. and delivered in March 2021.

Tiles 6 and 7 were bought by INFN-Bari in 2000 as part of the HERMES collaboration.

Tiles having **different refractive indices** have been characterized in terms of transmittance and tile thickness and shape.

TILE LAYOUT

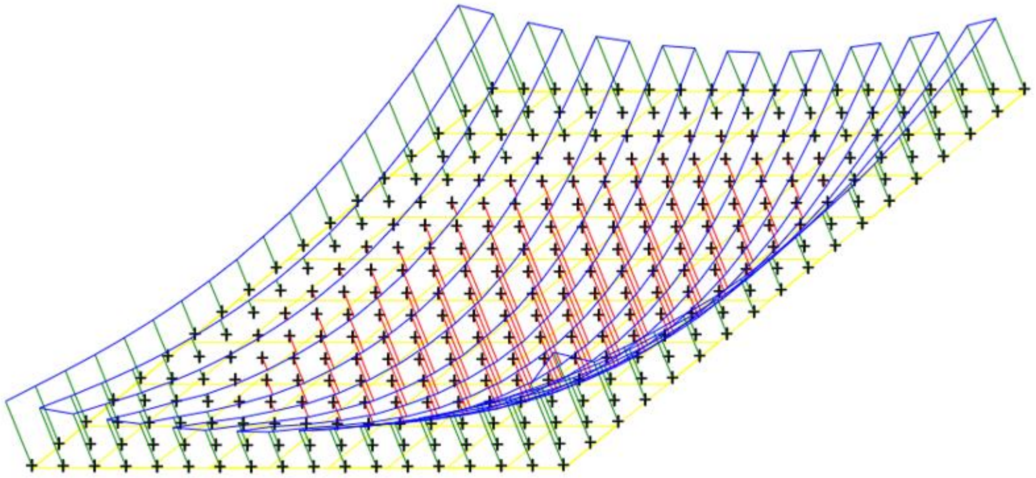
10x10 cm^2 Tile



Transmittance measured at 15 different points on the tile

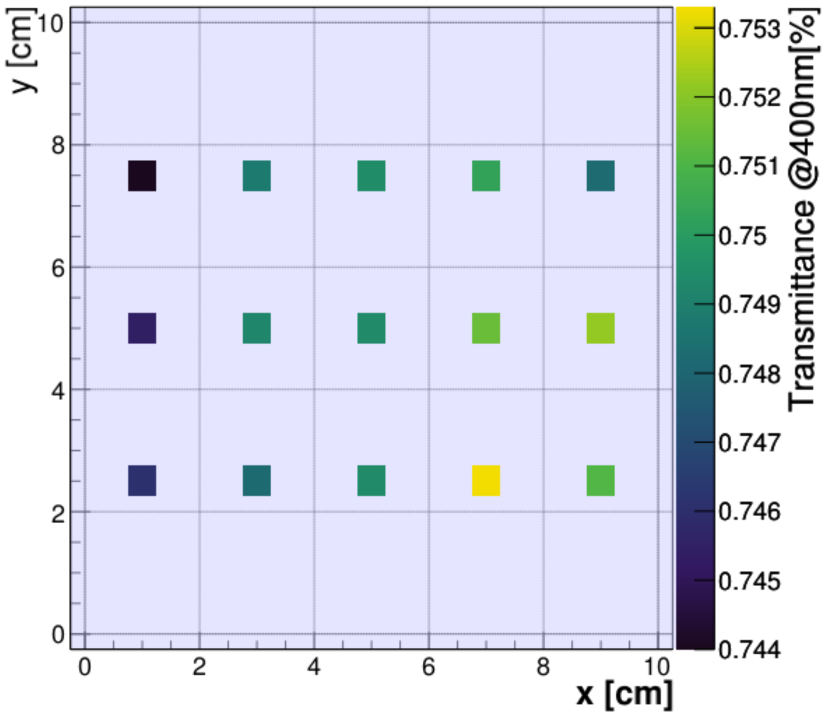
Tile thickness = 2 cm

Thickness not uniform because of the meniscus shape due to fabrication process

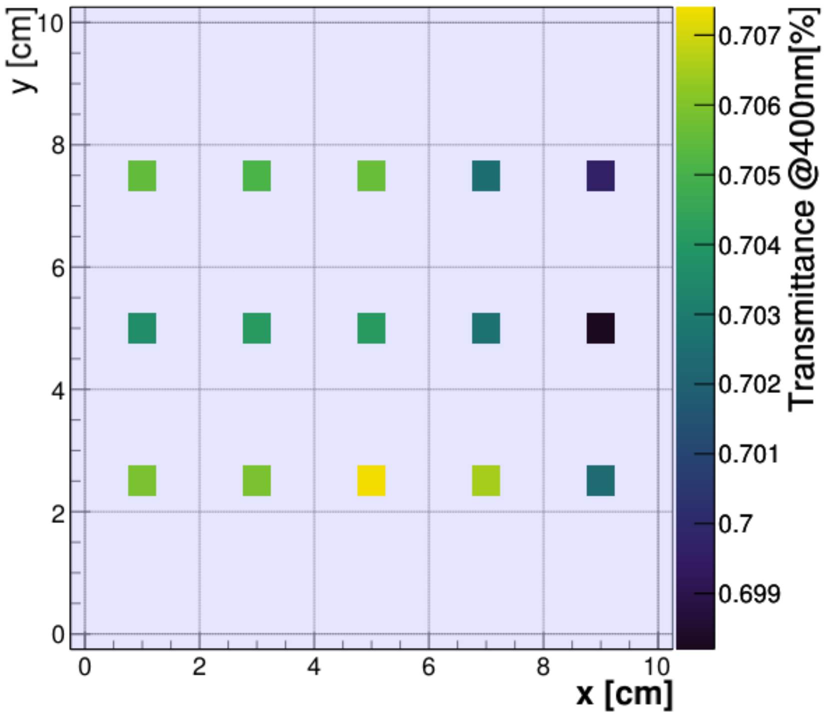


TRANSMITTANCE MEASUREMENTS

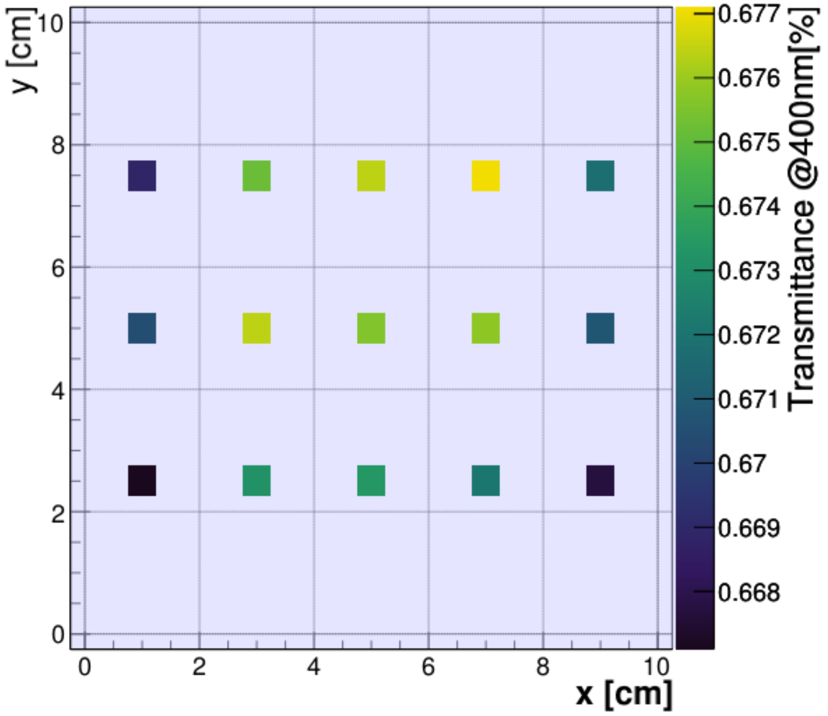
n=1.03



n=1.04



n=1.05

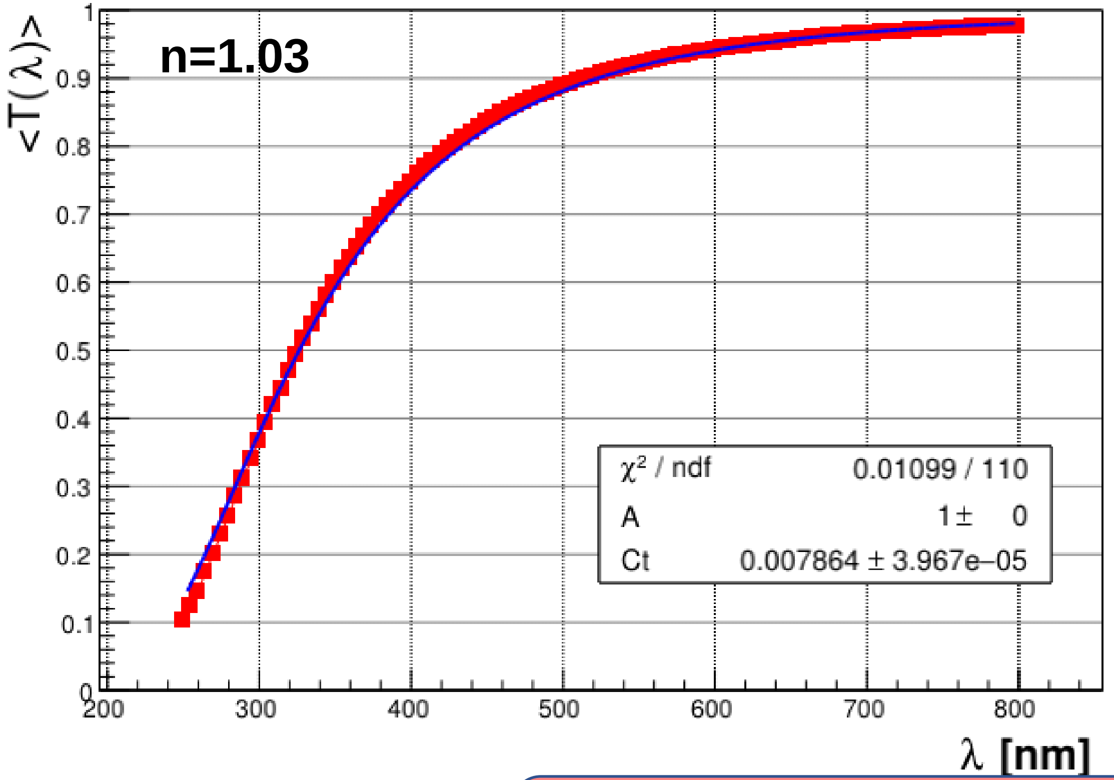


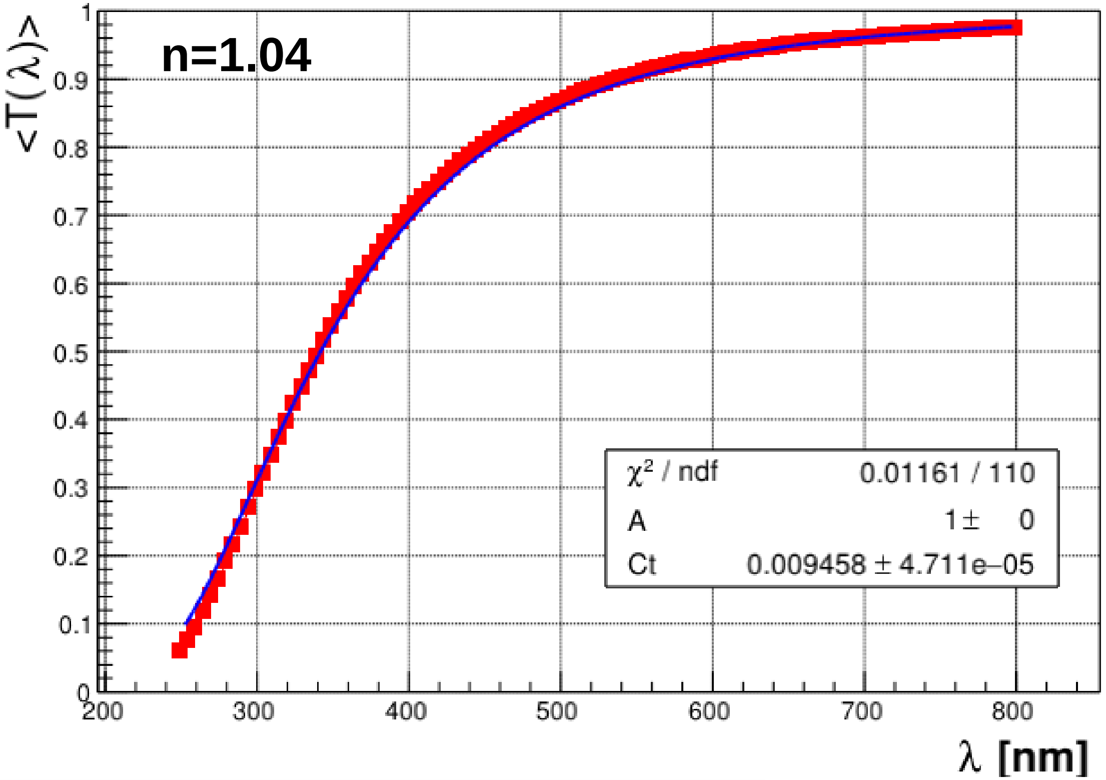
Maximum Transmittance not in the center where tile is supposed to be thinner,
Minimum Transmittance on the borders as expected

FIT TRANSMITTANCE (Tile n=1.03 – 1.04)

Transmittance fitted by **Hunt formula**:

$$T(\lambda) = e^{-\frac{t}{\Lambda_{trasm}}} = e^{-t\left(\frac{1}{\Lambda_A}+\frac{1}{\Lambda_S}\right)} = A \cdot e^{-\frac{C\,t}{\lambda^4}}$$





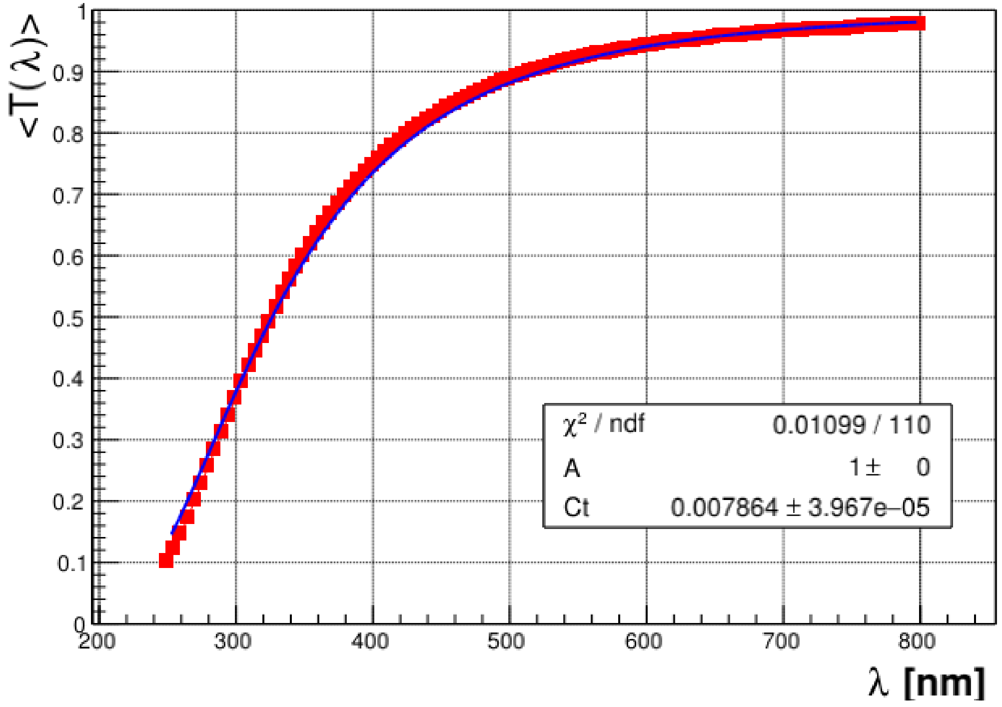
WHAT HAPPENS BY INCLUDING THE ABSORPTION CONTRIBUTION IN THE HUNT FORMULA?

FIT TRANSMITTANCE (Tile n=1.03)

Transmittance fitted by **Hunt formula**:

$$T(\lambda) = e^{-\frac{t}{\Lambda_{trasm}}} = e^{-t\left(\frac{1}{\Lambda_A}+\frac{1}{\Lambda_S}\right)} = A \cdot e^{-\frac{C\,t}{\lambda^4}}$$

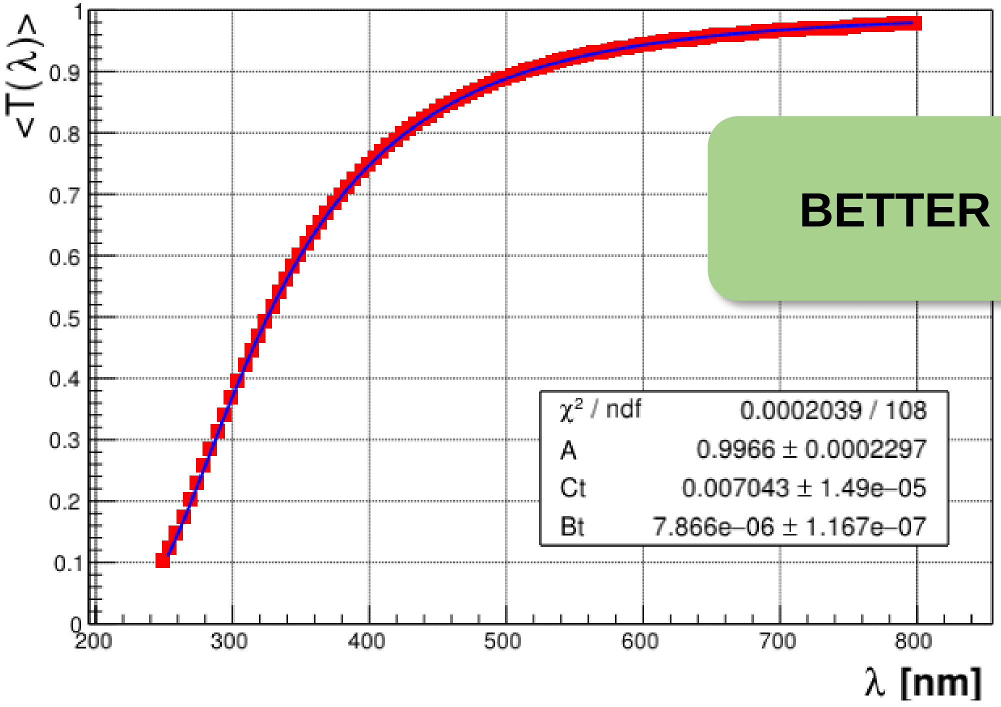
Assuming:
Λ_A *negligible*
$\Lambda_S \sim \lambda^4$



Transmittance fitted by **Hunt extended**:

$$T(\lambda) = e^{-\frac{t}{\Lambda_{trasm}}} = e^{-t\left(\frac{1}{\Lambda_A}+\frac{1}{\Lambda_S}\right)} = A \cdot e^{-\frac{B\,t}{\lambda^8}} \cdot e^{-\frac{C\,t}{\lambda^4}}$$

Assuming:
$\Lambda_A \sim \lambda^8$
$\Lambda_S \sim \lambda^4$



BETTER FIT

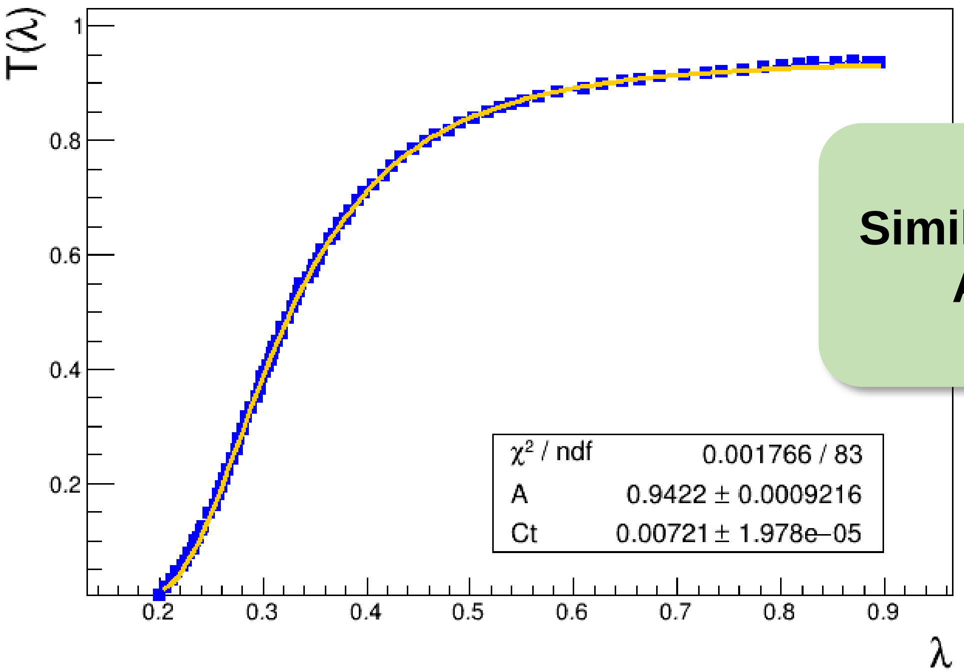
<T> average of the transmittance values at the different points on tile #1 (n=1.03)

TESTING THE HUNT EXTENDED FORMULA ON A KNOWN DATASET

The Hunt extended formula was validate through a fit of the transmittance values from the dataset in *E Aschenauer at al*. **Optical characterization of n=1.03 silica aerogel used as radiator in the RICH of HERMES**

Transmittance fitted by **Hunt formula**:

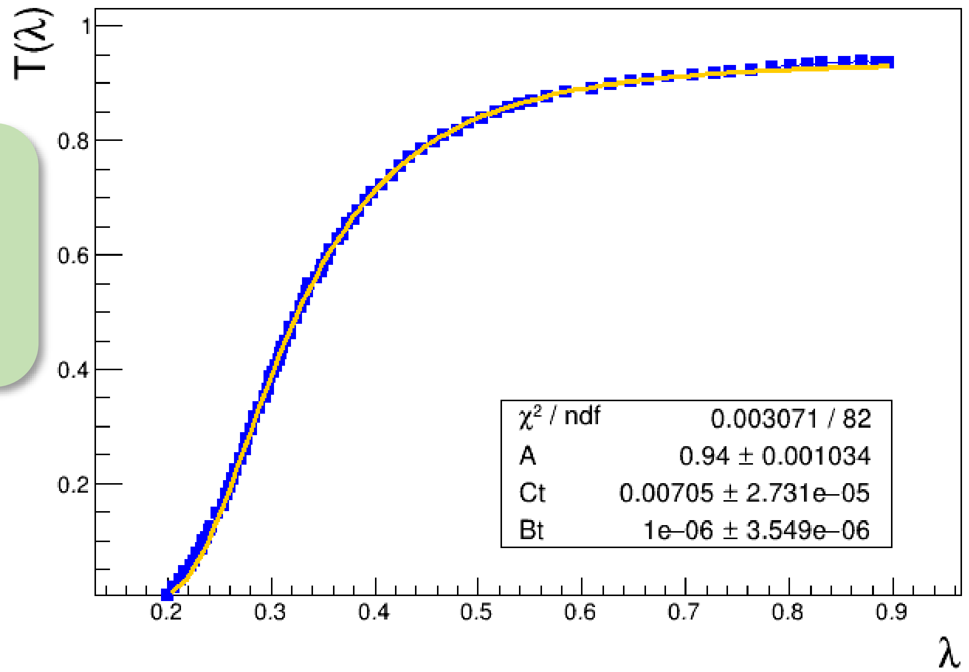
$$T(\lambda) = e^{-\frac{t}{\Lambda_{trasm}}} = e^{-t\left(\frac{1}{\Lambda_A}+\frac{1}{\Lambda_S}\right)} = A \cdot e^{-\frac{C\,t}{\lambda^4}}$$



Similar values of A and Ct

Transmittance fitted by **Hunt extended formula**:

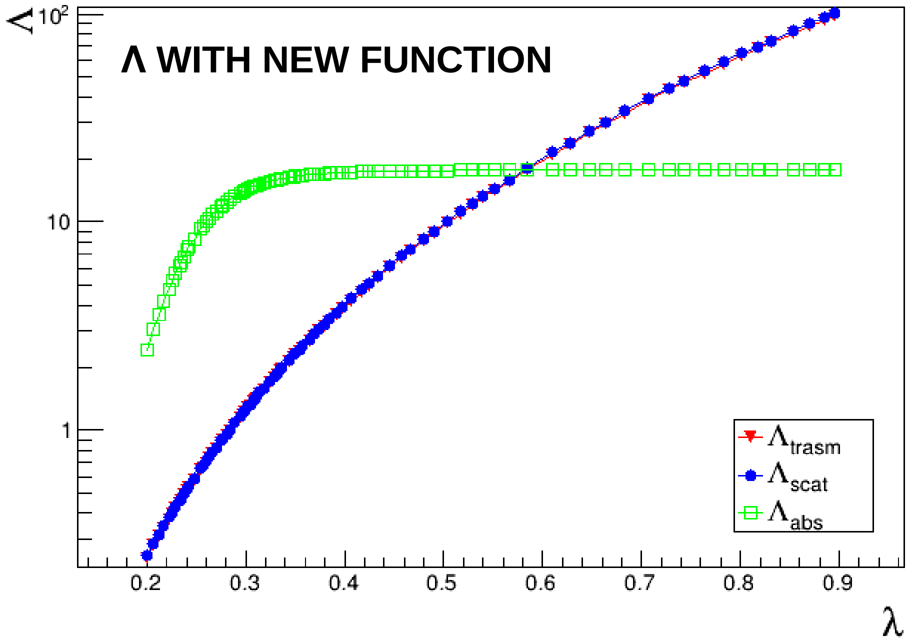
$$T(\lambda) = e^{-\frac{t}{\Lambda_{trasm}}} = e^{-t\left(\frac{1}{\Lambda_A}+\frac{1}{\Lambda_S}\right)} = A \cdot e^{-\frac{B\,t}{\lambda^8}} \cdot e^{-\frac{C\,t}{\lambda^4}}$$

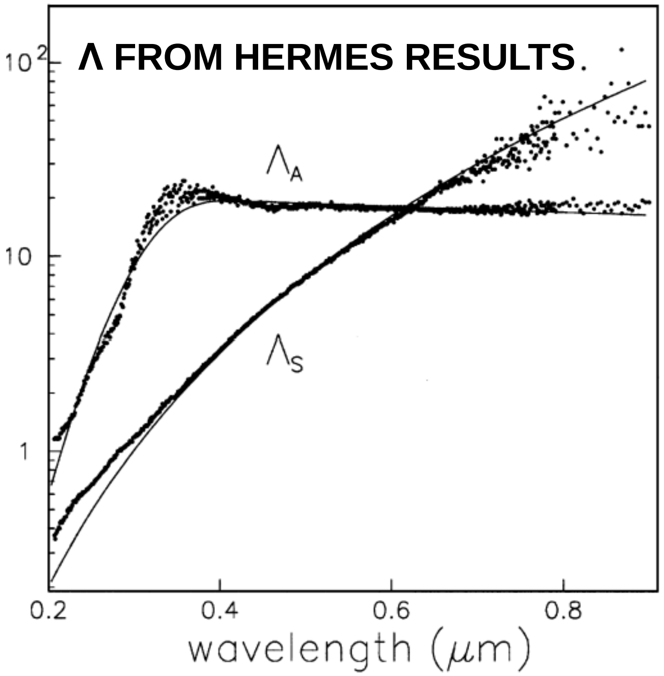


TESTING THE HUNT EXTENDED FORMULA ON A KNOWN DATASET

Transmission, scattering and absorption lengths from the **Hunt extended function**:

$$\Lambda_{trasm} = -\frac{t}{\ln(T)} \qquad \Lambda_{scat} = \frac{\lambda^4}{C} \qquad \Lambda_{abs} = \frac{\lambda^8 \cdot t}{B\ t\ - \lambda^8 \cdot \ln(A)}$$





GOOD AGREEMENT BETWEEN THE RESULTS,
LET'S TRY THE FUNCTION ON OUR DATA

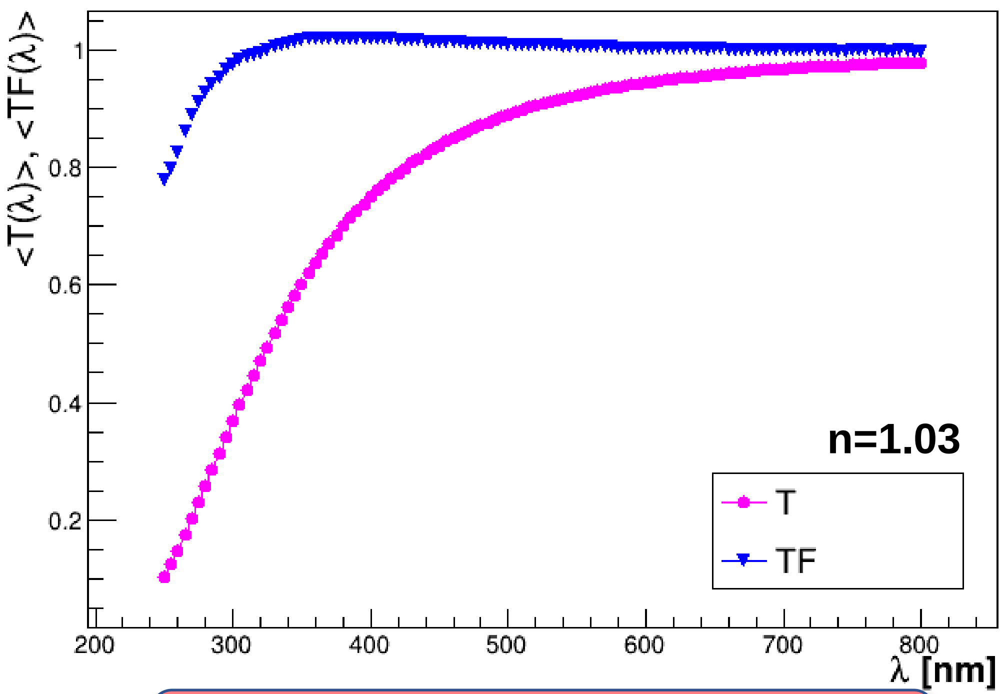
Data from: *E Aschenauer at al*. **Optical characterization of n=1.03 silica aerogel used as radiator in the RICH of HERMES**

TRANSMITTANCE AND TRANSFLECTANCE (Tile n=1.03)

T and TF fitted by **Hunt formula**:

$$T(\lambda) = A \cdot e^{-\frac{Ct}{\lambda^4}}$$

$$TF = T(\lambda) \cdot e^{\frac{Ct}{\lambda^4}}$$



TF > 1 at 300 < λ < 400
(SOMETHING IS NOT WORKING FINE)

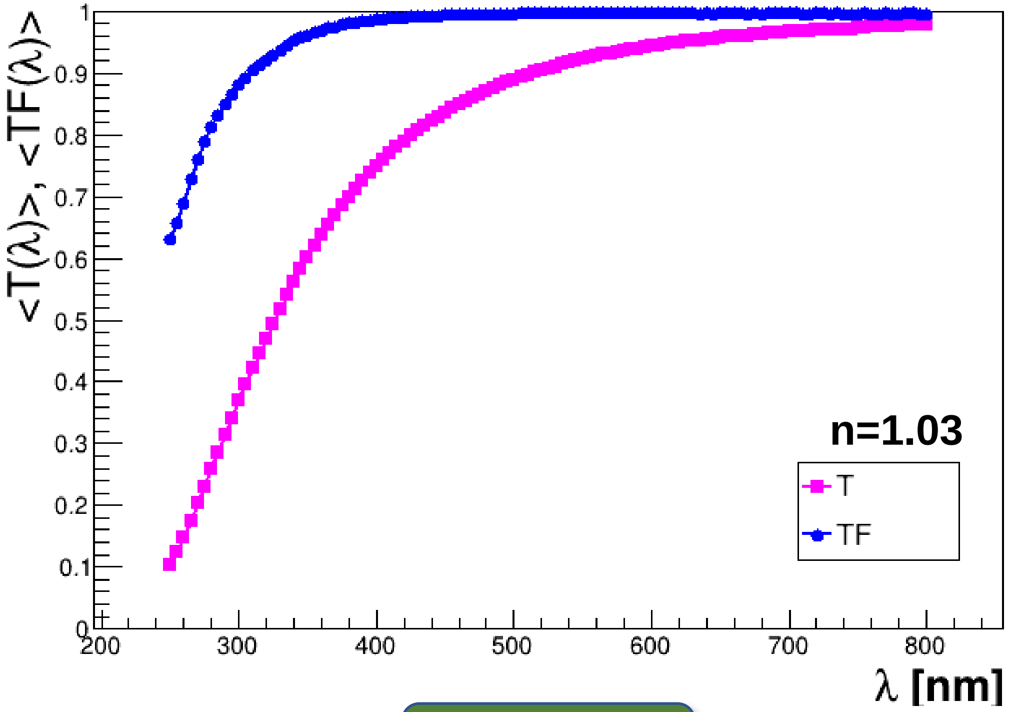
T and TF fitted by **Hunt extended**:

$$T(\lambda) = A \cdot e^{-\frac{Bt}{\lambda^8}} \cdot e^{-\frac{Ct}{\lambda^4}}$$

$$TF = T(\lambda) \cdot e^{\frac{Ct}{\lambda^4}}$$

NOTE

Ct values are different because they come from different fit functions



TF < 1

TRANSMISSION LENGTH (Tile n=1.03)

$$T(\lambda) = e^{-\frac{t}{\Lambda_{trasm}}} = e^{-t\left(\frac{1}{\Lambda_A}+\frac{1}{\Lambda_S}\right)} = A \cdot e^{-\frac{B\,t}{\lambda^8}} \cdot e^{-\frac{C\,t}{\lambda^4}}$$

TRANSMISSION LENGTH:

$$T(\lambda) = e^{-\frac{t}{\Lambda_{trasm}}}$$

$$\Lambda_{trasm} = -\frac{t}{\ln(T)}$$

SCATTERING LENGTH:

$$e^{-\left(\frac{t}{\Lambda_S}\right)} = e^{-\frac{C\,t}{\lambda^4}}$$

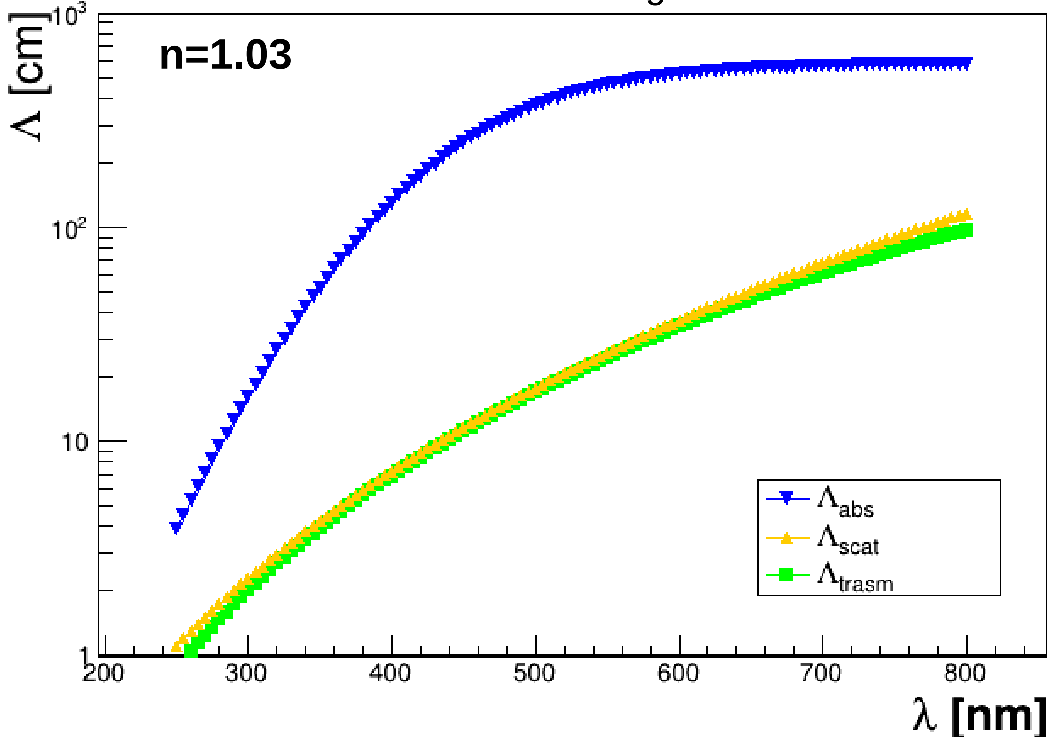
$$\Lambda_{scat} = \frac{\lambda^4}{C}$$

ABSORPTION LENGTH:

$$e^{-\left(\frac{t}{\Lambda_A}\right)} = A \cdot e^{-\frac{B\,t}{\lambda^8}}$$

$$\Lambda_{abs} = \frac{\lambda^8 \cdot t}{B\,t - \lambda^8 \cdot \ln(A)}$$

Average transmission length, evaluated from average transmittance values.

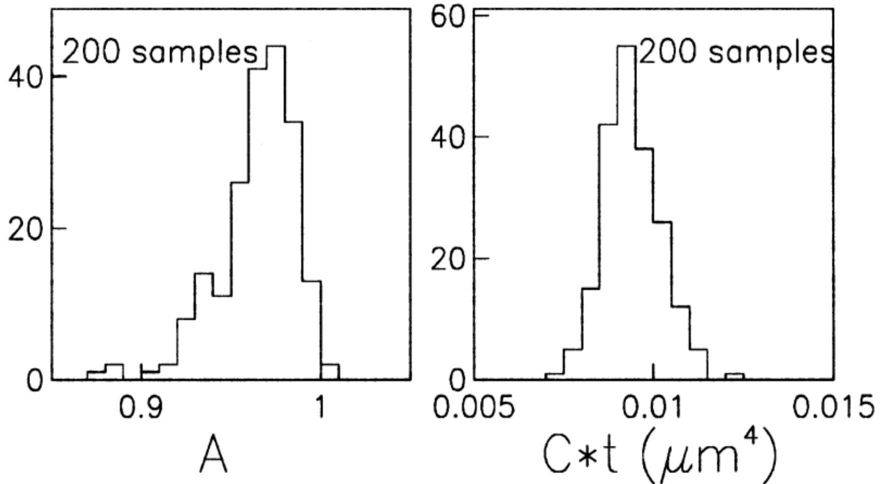


SMALL IMPACT OF THE ABSORPTION ON THE TRANSMISSION LENGTH

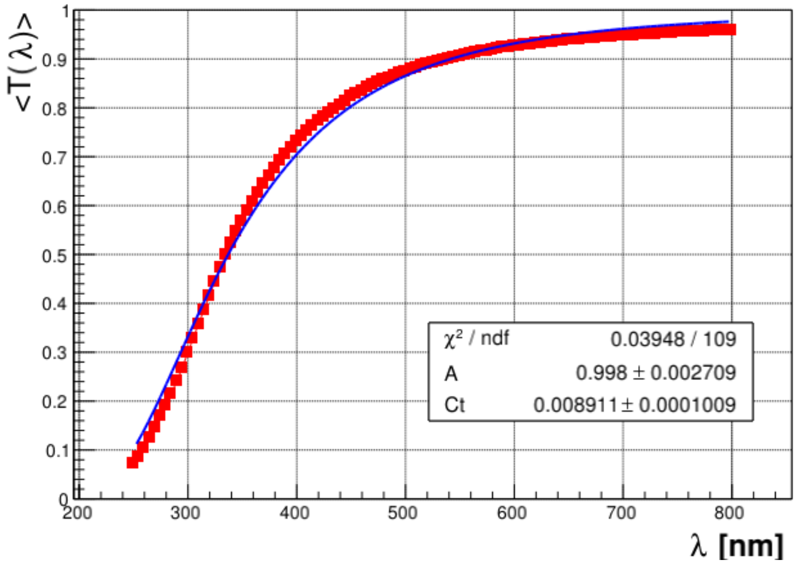
Tile 6-7: DEGRADATION IN TIME

Tiles 6 and 7 (t=1 cm) were originally bought for the HERMES collaboration back in 2000.

They have been stored in air without particular care.
It is reasonable to think that they have undergone degradation.



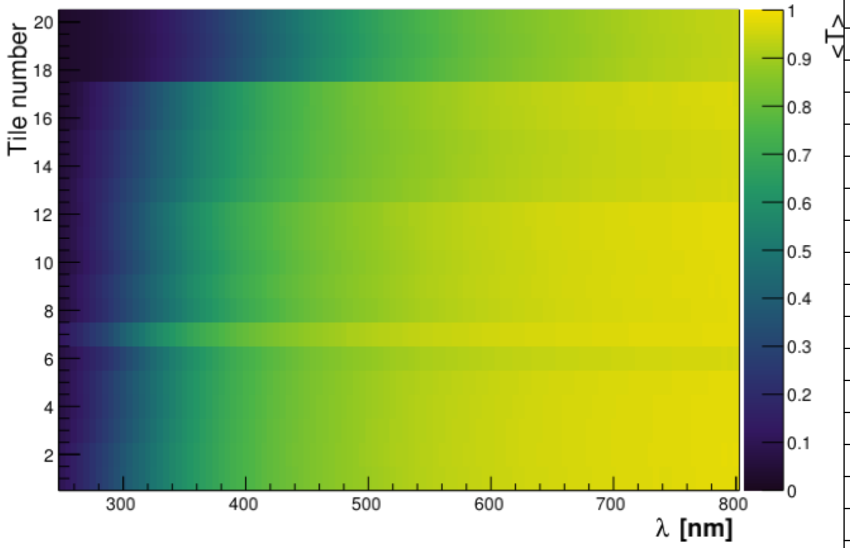
A and Ct estimated as the average over 200 samples

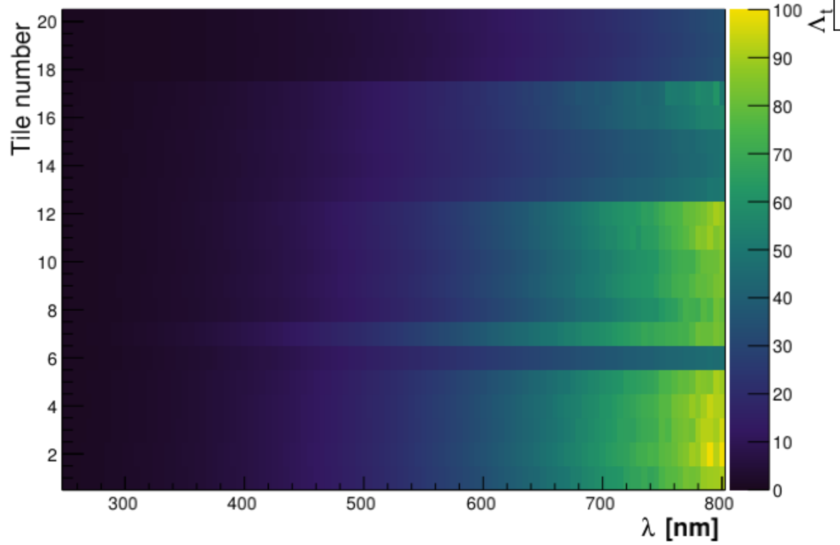


Tile	2000		2022	
	A	Ct	A	Ct
6	0.964	0.0094	0.998 ± 0.003	0.0089 ±0.0001

Slight increase of absorption-related A and decrease of scattering-related Ct.
FURTHER INVESTIGATION REQUIRED.

OPTICAL PROPERTIES - SUMMARY

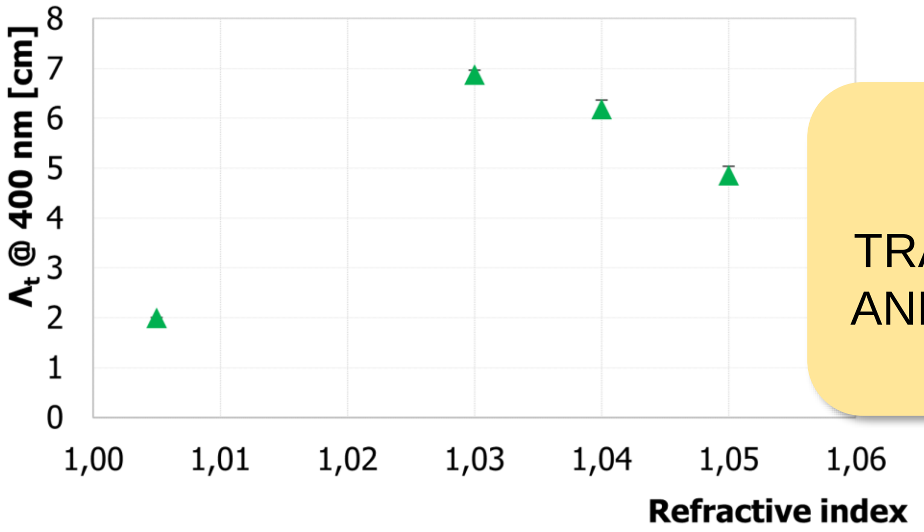




Tile	n	T_{meas}(400 nm) [%]	Λ_t (400 nm) [cm]	Λ_t datasheet (400 nm) [cm]	t_{min} [cm]	t_{max} [cm]
1		0,75	6,9	6,27	1,9	2,0
2		0,75	6,9	6,32	2,0	2,0
3		0,75	6,8	6,13	2,0	2,1
4	1,03	0,74	6,7	6,06	2,0	2,0
5		0,74	7,1	6,00	1,9	2,0
6		0,73	3,5		1,0	1,4
7		0,80	5,0		0,9	1,3
8		0,70	5,9	5,47	1,9	2,0
9		0,72	6,3	5,61	1,9	2,0
10	1,04	0,70	6,0	5,58	1,9	2,0
11		0,71	6,3	5,71	1,9	2,0
12		0,72	6,4	5,86	1,9	2,0
13		0,67	5,2	3,59	1,8	2,1
14		0,66	4,9	3,54	2,0	2,1
15	1,05	0,66	4,8	3,45	2,0	3,0
16		0,65	4,7	3,79	2,0	2,0
17		0,65	4,7	3,86	1,9	2,0
18		0,36	2,0		2,0	2,1
19	1,005	0,35	2,0		2,0	2,3
20		0,36	2,0		2,0	2,2

PARAMETERS EVALUATED ASSUMING t=2cm

Λt HIGHER IN OUR EVALUATION THAN IN THE DATASHEET. POSSIBLE IMPROVEMENTS INCLUDING A PROPER THICKNESS



MAXIMUM TRANSMITTANCE AND Λ_t AT **n = 1.03**

CONCLUSION

- 20 silica aerogel tiles characterized in terms of transmittance
- Data fitted by a 3-parameters Hunt extended formula
- Transmission, absorption and scattering lengths extracted from transmittance measurements
  - **Absorbance negligible** with respect to the transmission length
- Maximum and minimum thickness value per tile estimated from transmittance data
  - **Not uniform thickness** on the tile due to meniscus shape
- **Maximum transmittance** and transmission length observed for tiles with **n = 1.03**

WHAT'S NEXT?

- Performing more in-depth measurements of the Tile 6 and 7 to investigate their degradation in time
- Metrology measurements on the tile with higher accuracy
- Improvement of the accuracy of the transmission length evaluation including high-precision thickness values