dRICH: aerogel studies

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Outline

- **n = 1.03, 1.04, 1.05, 1.005** aerogel sample characterization
  - Trasmittance
  - $\Lambda_{transmission}$, $\Lambda_{absorption}$, $\Lambda_{scattering}$
  - Tile shape
- **n = 1.02** aerogel sample characterization
  - $\Lambda_{transmission}$, $\Lambda_{absorption}$, $\Lambda_{scattering}$
- Aerogel characterization measurements
- 2024 plan

Analysed aerogel samples

Tile	n	t [cm]	Tile	n	t [cm]
1	1.03	2.00	23	1.02 *(2021)*	2.05
2		2.00	24		2.08
3		2.00	25		2.08
4		2.00	26		2.08
5		2.00	27	1.02 *(2022)*	2.05
6		0.98	28		2.06
7		0.97	29		2.04
8	1.04	1.96	30		1.95
9		1.96	31		1.99
10		1.96	32		2.17
11		1.96	33		2.14
12		1.96	34		2.14
13	1.05	2.01	35		2.13
14		2.01	36		2.12
15		2.01	37		1.91
16		2.01	38		1.94
17		2.01	39		2.03
18	1.005	2.00	40		2.03
19		2.06	41		2.04
20		2.06	42		1.97
21	1.03	2.02			
22		2.03			

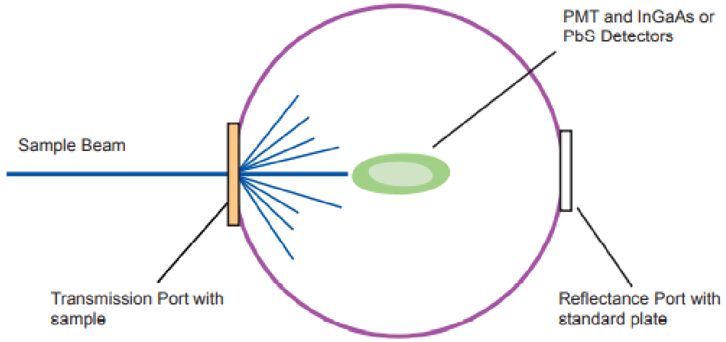
- Measurements performed on **22 silica aerogel tiles** at CERN in July-August 2022.
  - Tiles manufactured at Aerogel Factory Co. Ltd (Chiba, Japan) and delivered in March 2021.
  - Tiles 6 and 7 manufactured by Matsushita Electric Works (Japan) were bought by INFN-Bari in 2000 as part of the HERMES collaboration.
  - Tiles having **different refractive indices** have been characterized in terms of transmittance, thickness and shape.
- Transmittance measurements on **20 tiles** with n = 1.02 (2021 and 2022 production) performed by INFN-Ferrara group.

Tiles with n = 1.03, 1.04, 1.05, 1.005
(INFN – Bari)

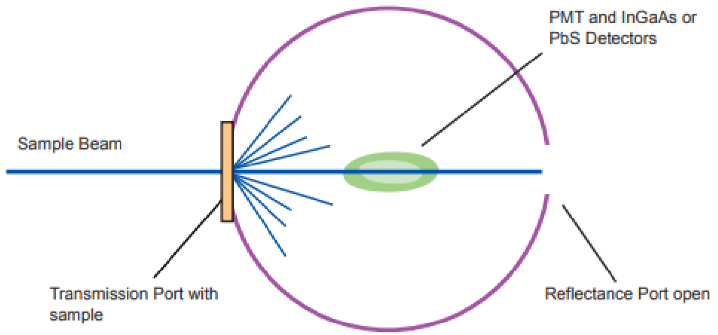
Transmittance measurements

Measurements performed with a Perkin Elmer spectrometer: integrating sphere and two different light sources to cover the range 250 - 800 nm

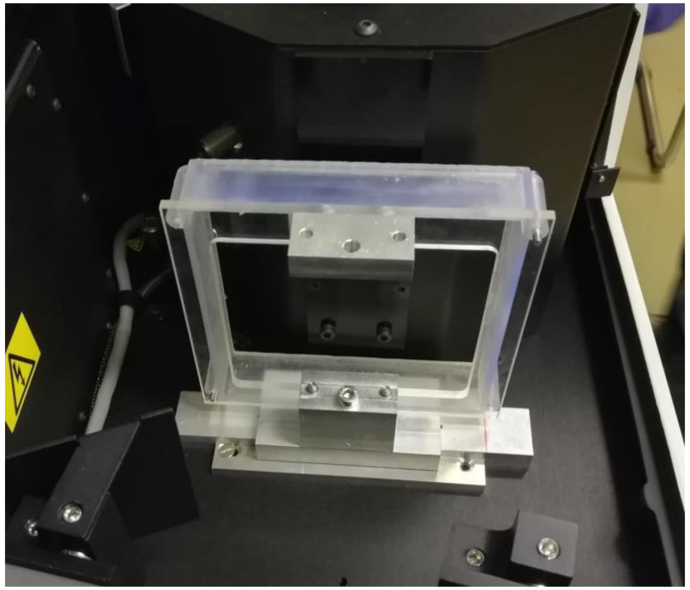
TOTAL TRANSMITTANCE



DIFFUSE TRANSMITTANCE

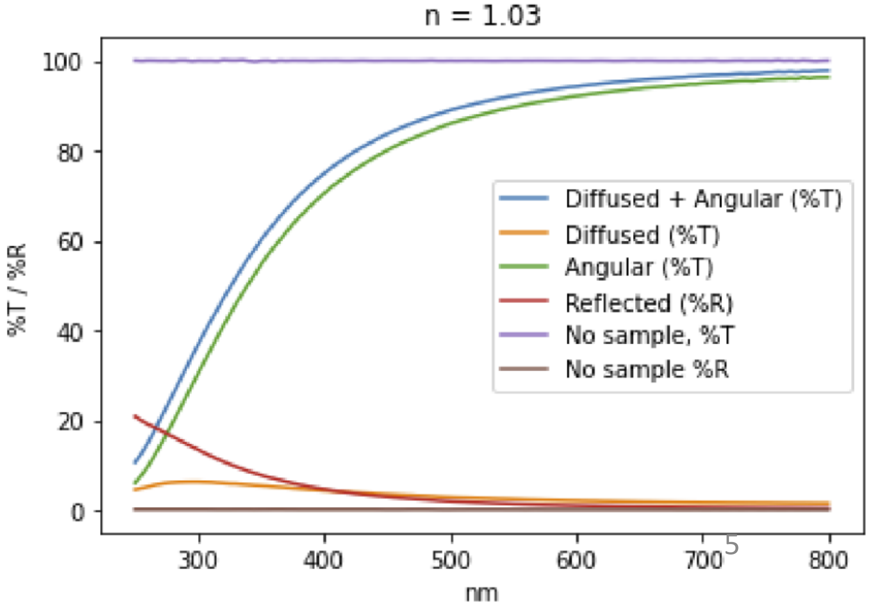


Linear TRANSMITTANCE = total T. – diffuse T.



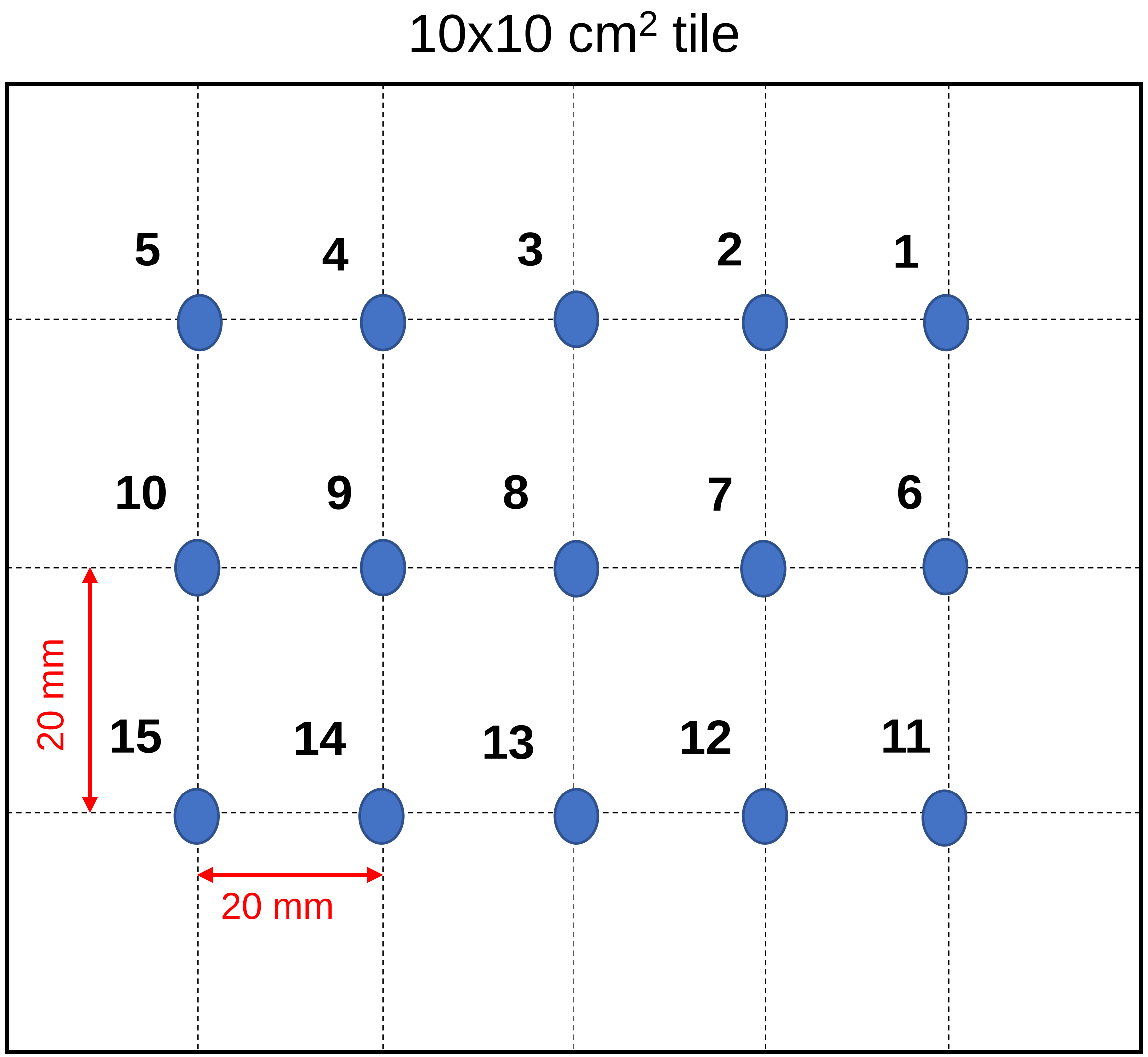
Each tile was placed into a holder (10x10 cm^2) and mounted onto a metal ridge sliding perpendicular to the beam to explore different positions of the samples

On tiles 6 and 7 only total transmittance has been measured



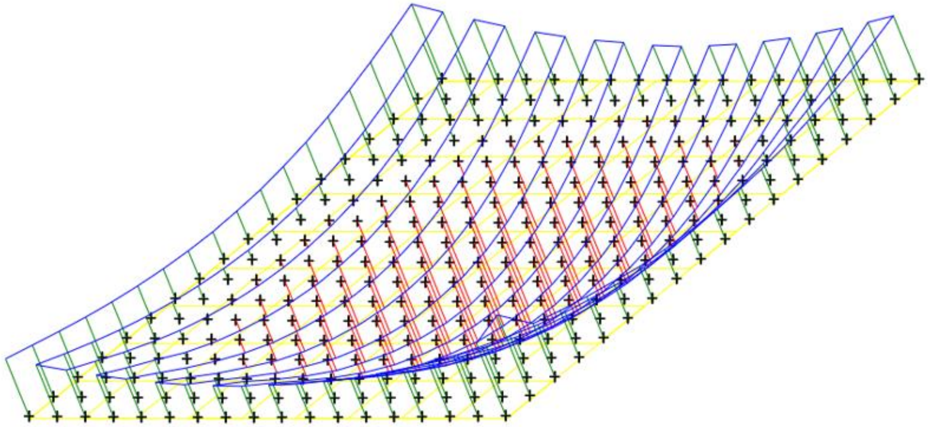
Transmittance measurements

Transmittance measured in 15 different points on the tile



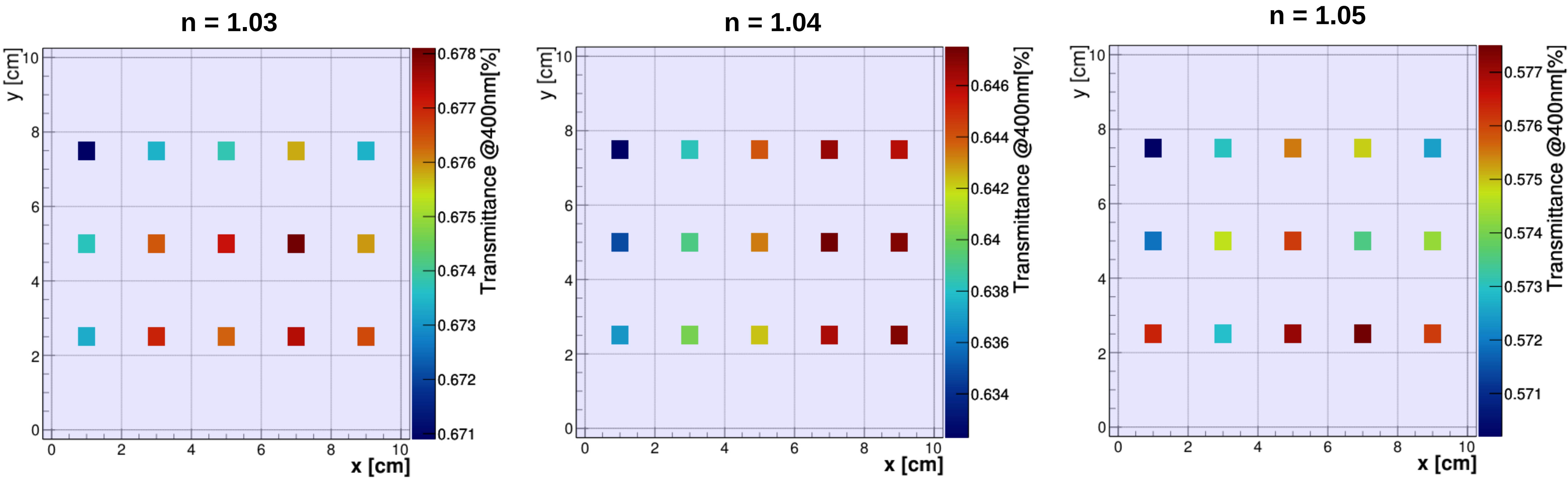
Tile thickness = 2 cm

Thickness not uniform because of the meniscus shape due to fabrication process (see next slides)



Transmittance measurements

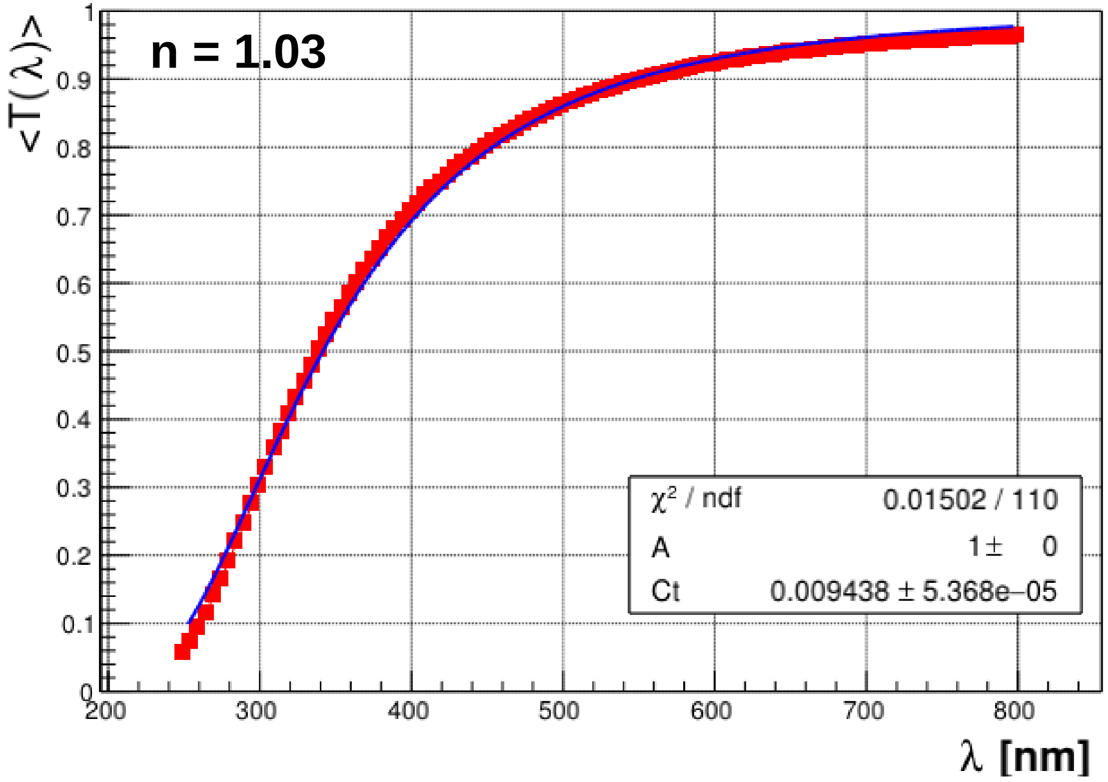
- Transmittance dispersion ≊ 0.6 % → high uniformity
- Maximum transmittance region not localized in the center where tile is supposed to be thinner
- Minimum transmittance on the borders, as expected

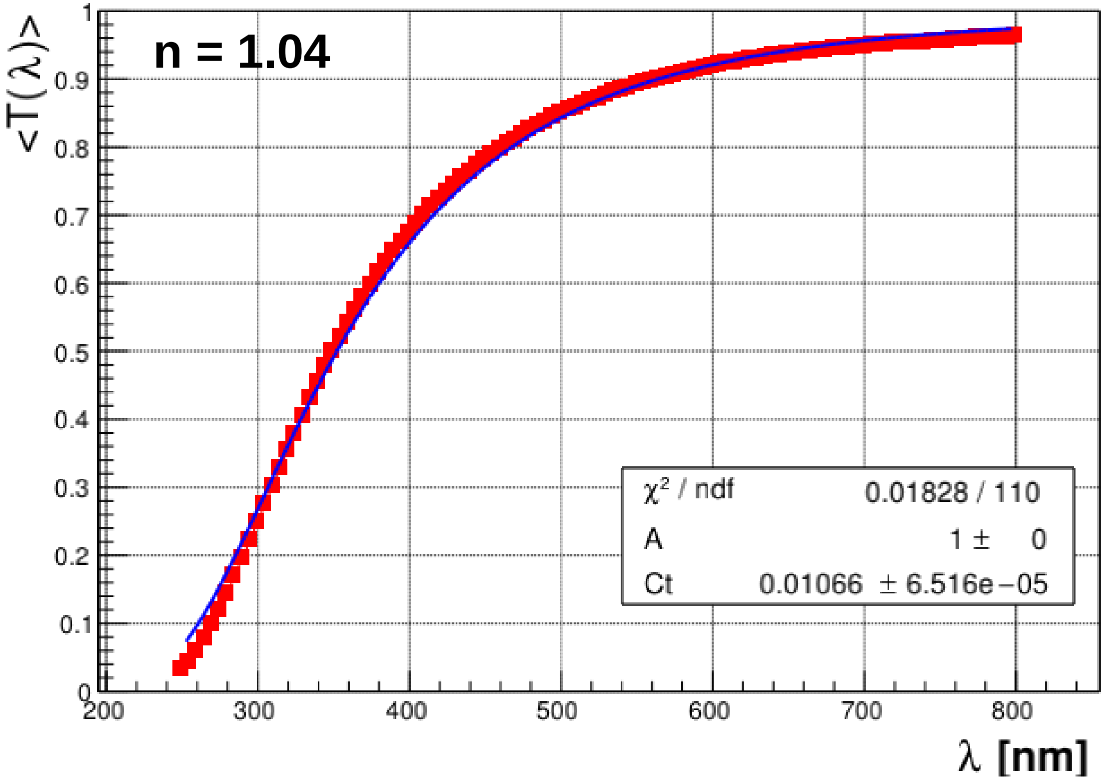


Trasmittance fitting

Transmittance fitted by ***Hunt formula*** [NIM A 440 (2000) 338-347]

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



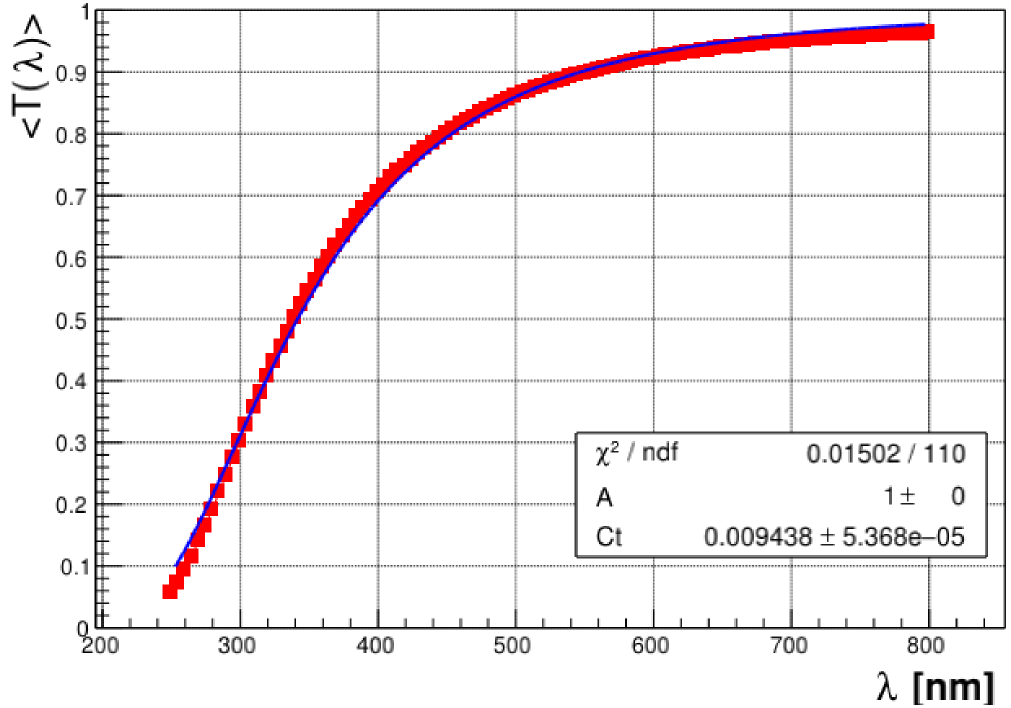


Trasmittance fitting (including absorption contribution)

Transmittance fitted by **Hunt basic**:

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

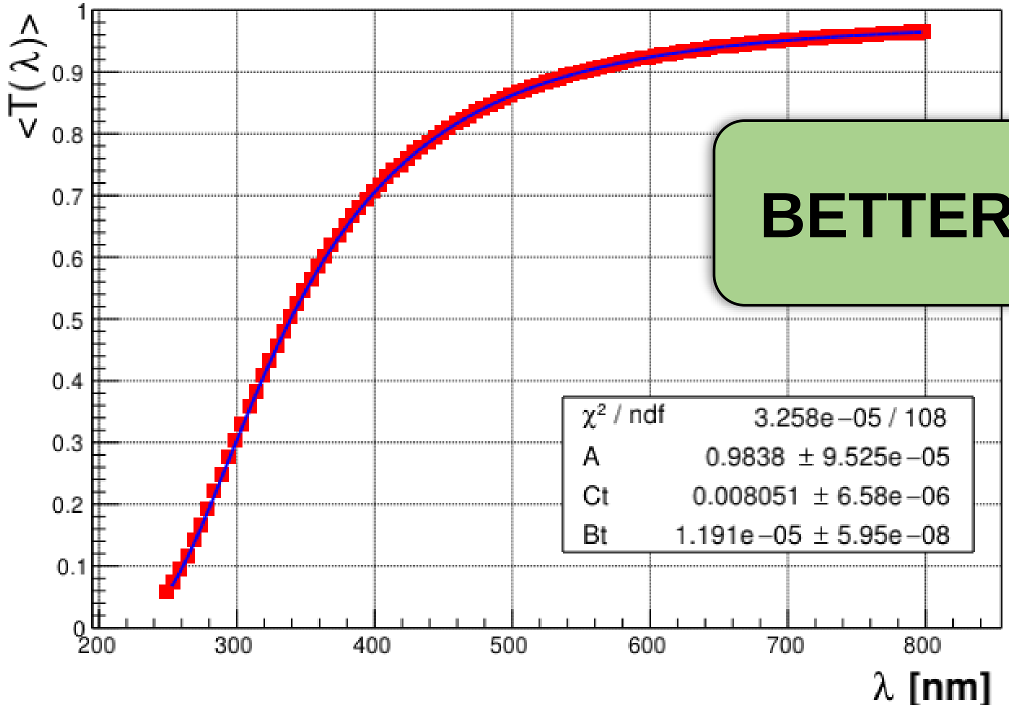
Assuming:
$\boldsymbol{\Lambda_A}$ ***negligible***
$\boldsymbol{\Lambda_S \sim \lambda^4}$



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:
$\boldsymbol{\Lambda_A \sim \lambda^8}$ (https://doi.org/10.1016/S0168-9002(99)00923-7)
$\boldsymbol{\Lambda_S \sim \lambda^4}$



BETTER FIT

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

Trasmission lenght

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

TRANSMISSION LENGTH:

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

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

SCATTERING LENGTH:

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

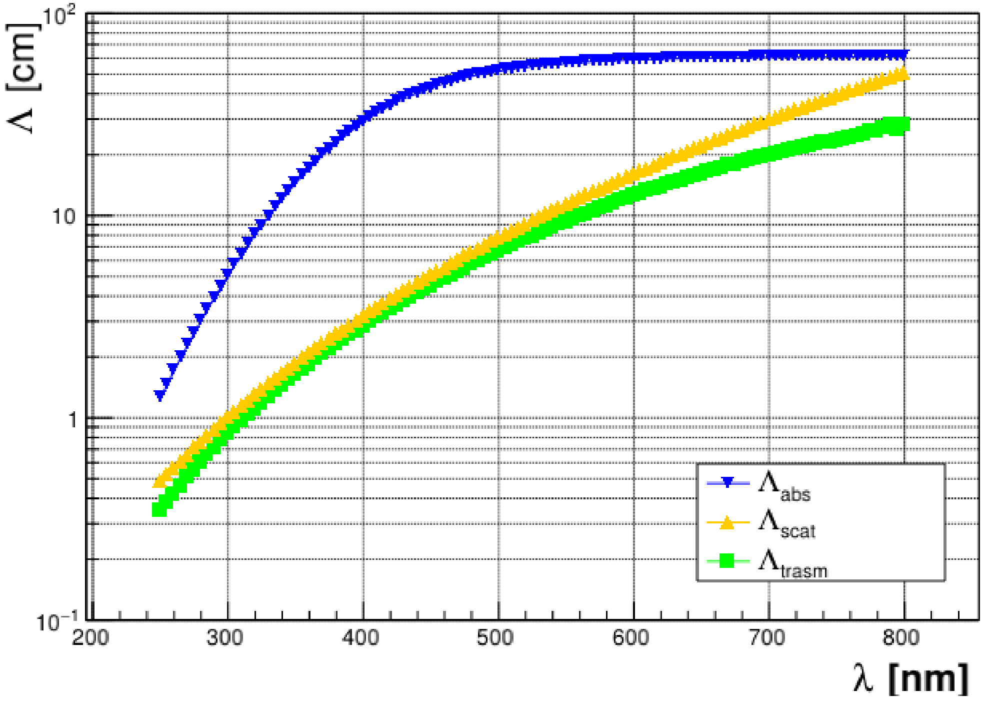
$$\Lambda_{scat} = \frac{\lambda^4}{C}$$

ABSORPTION LENGTH:

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

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

Lengths evaluated from average transmittance values.



SMALL IMPACT OF THE ABSORPTION ON THE TRANSMISSION LENGTH

Aerogel tile shape

Thickness and flatness measurement in metrology lab at CERN!

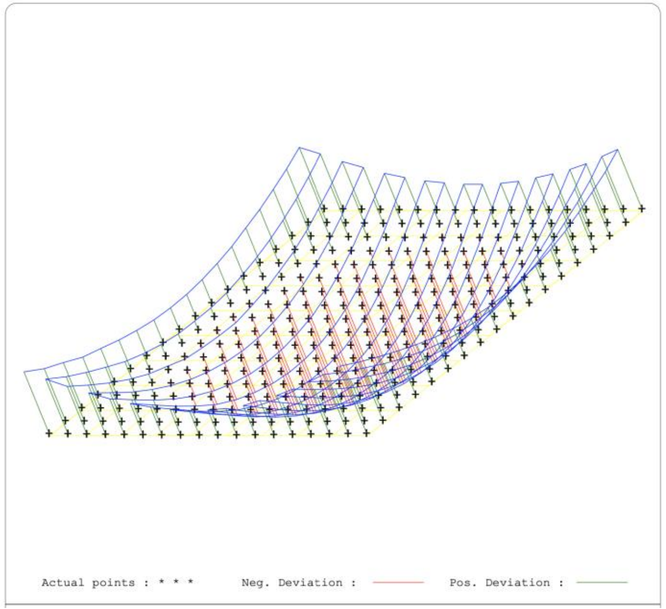
- Results obtained on a tile of n = 1.03 with the touch probe system (force applied by the probe is 2 gr).
- The measuring system is the LEITZ PMMC with $\pm$ 0.3 μm of precision

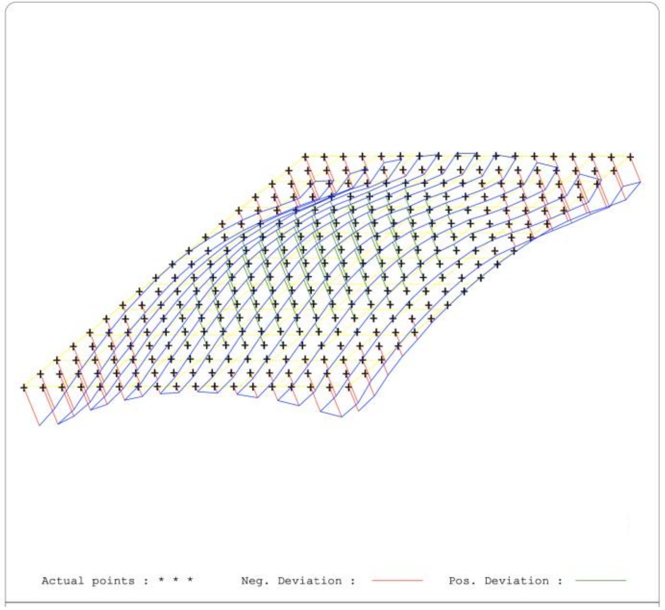
Thickness = 19.96 ± 0.17

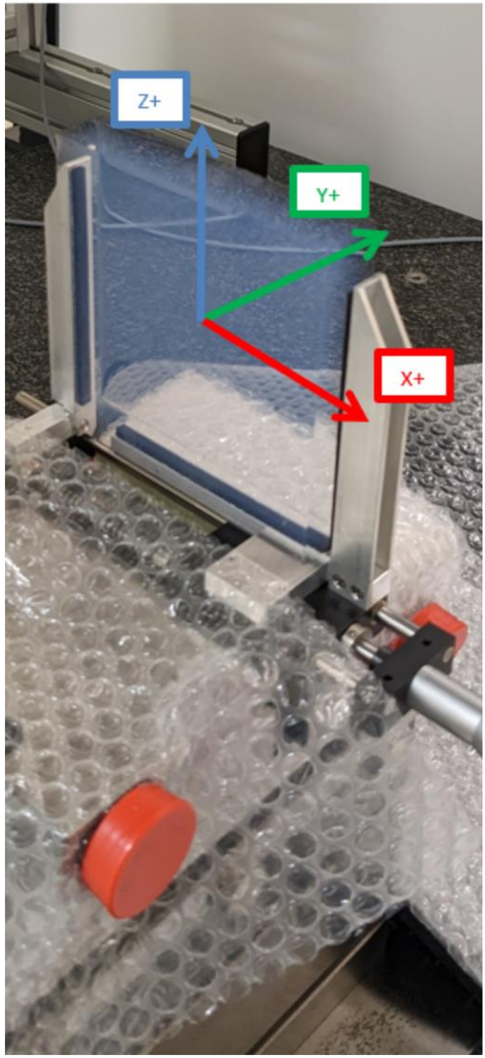
Plane Y- side = 0.7060

Plane Y+ side = 1.2716

Meniscus shape due to fabrication process





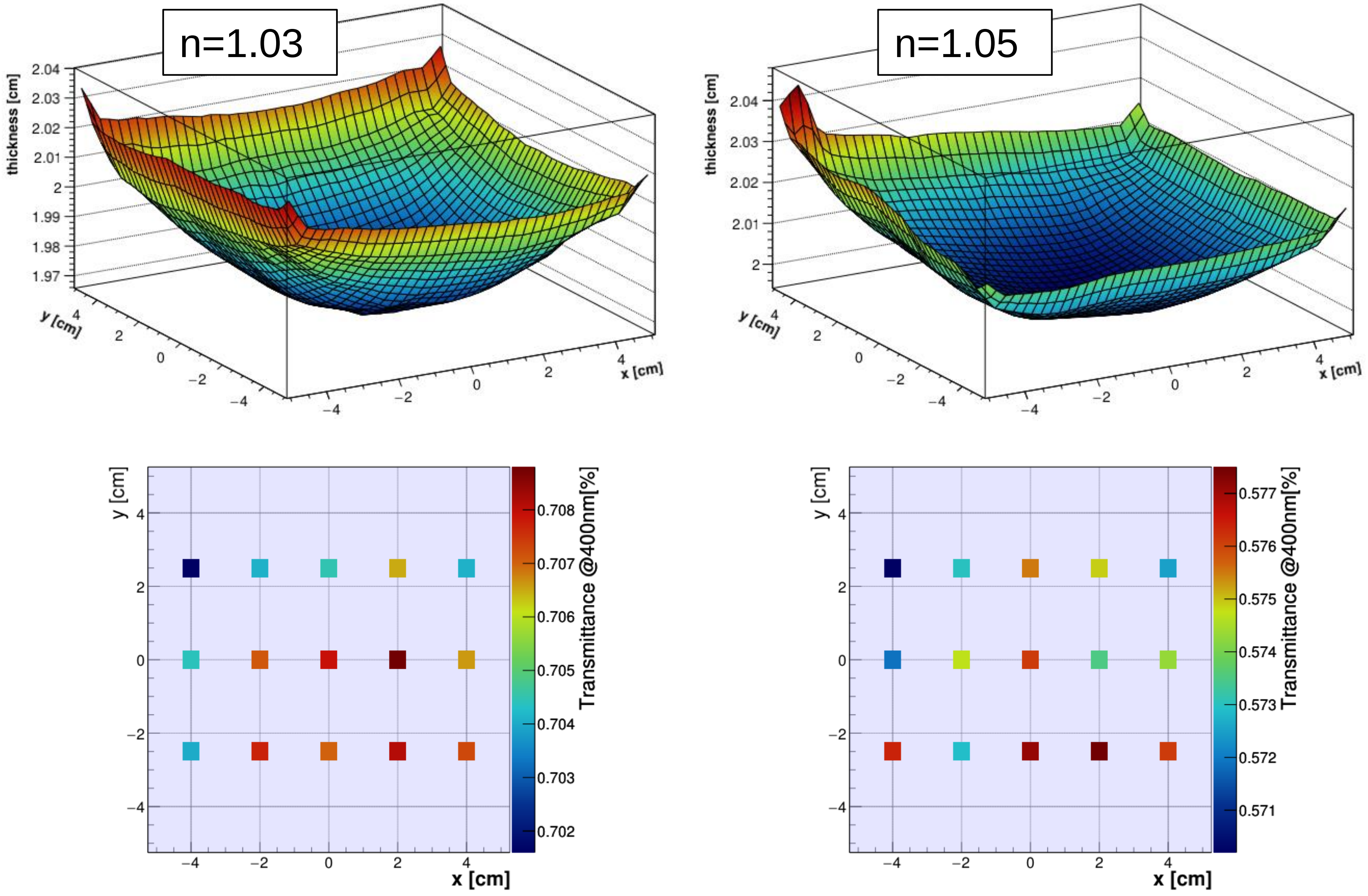


There is a variation in thickness from the centre to the edges, of the order of 0.4 mm, and a different planarity in the two faces, one 0.7 mm, the other 1.27 mm. In general, the tiles have the shape of a dome.

- The manufacturer (Aerogel Factory Ltd, Chiba, JP) stated that it is possible to improve the flatness and the thickness uniformity;
- the planarity can be mapped, to include the defect in the reconstruction of the Cherenkov angle.

Aerogel tile shape

The shape of the tile has implications on the transmittance.



n=1.03
min tickness (mm): 19.690
max tickness (mm): 20.385
standard deviation: 0.172
average (mm): 19.955

n=1.04
min tickness (mm): 19.271
max tickness (mm): 21.798
standard deviation: 0.335
average (mm): 19.641

n=1.05
min tickness (mm): 19.965
max tickness (mm): 20.479
standard deviation: 0.098
average (mm): 20.106

Measurement summary

Results @ 400 nm

Tile	n	T [%]	$\Lambda_{T_{nom}}$ [cm]	$\Lambda_{T_{exp}}$ [cm]	Λ_{abs} [cm]	Λ_{scat} [cm]	t_{avg} [cm]
1	1.03	0.71	6.27	5.73	56.82	6.36	2.00
2		0.71	6.32	5.73	57.91	6.33	2.00
3		0.70	6.13	5.67	44.33	6.49	2.00
4		0.70	6.06	5.58	41.86	6.42	2.00
5		0.70	6.00	5.54	40.96	6.38	2.00
6		0.69	4.40	2.65	24.69	2.69	0.98
7		0.76	4.40	3.47	36.85	3.58	0.97
8	1.04	0.66	5.47	4.80	52.90	5.25	1.96
9		0.67	5.61	4.96	51.14	5.57	1.96
10		0.66	5.58	4.79	47.68	5.26	1.96
11		0.67	5.71	4.95	45.80	5.53	1.96
12		0.68	5.86	5.00	42.76	5.64	1.96
13	1.05	0.63	3.59	4.40	33.16	4.46	2.01
14		0.58	3.54	3.74	31.48	4.22	2.01
15		0.58	3.45	3.72	30.36	4.23	2.01
16		0.57	3.79	3.60	31.03	4.06	2.01
17		0.57	3.86	3.63	55.23	3.74	2.01
18	1.005	0.29	1.79	1.61	17.07	1.85	2.00
19		0.29	1.72	1.65	55.39	1.73	2.06
20		0.29	1.75	1.69	54.91	1.76	2.06
21	1.03	0.69	6.40	5.40	85.54	5.78	2.02
22		0.69	6.34	5.49	87.04	5.87	2.03

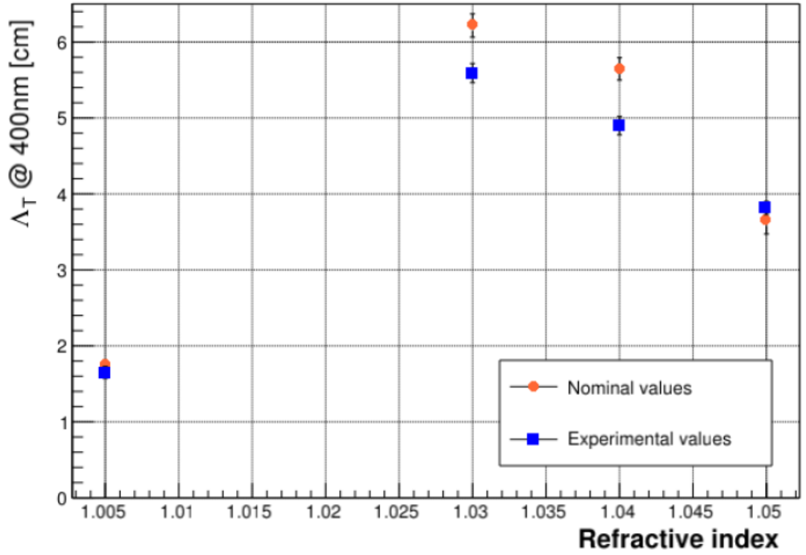
MIGHT BE OVERESTIMATED BECAUSE
ONLY TOTAL TRANSMITTANCE IS AVAILABLE

Estimated Λ_t @400nm lower than datasheet values

FURTHER INVESTIGATION REQUIRED

REMARK

Tiles 6-7 were not considered in this plot, since only the total transmittance was available

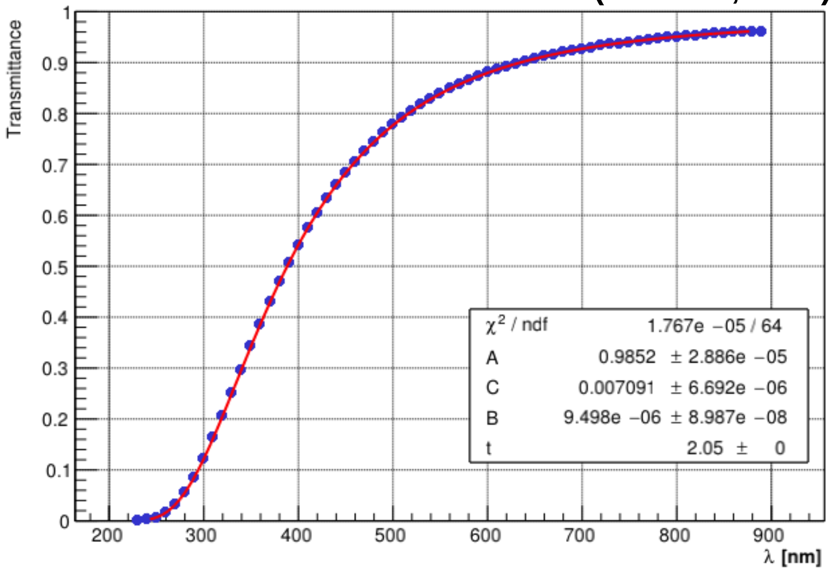


MAXIMUM transmittance and Λ_t at **n = 1.03**

Tiles with n = 1.02
(INFN – Ferrara)

Measurement summary

Tile 27 – AG22J001 (n=1.021 , *2022*)



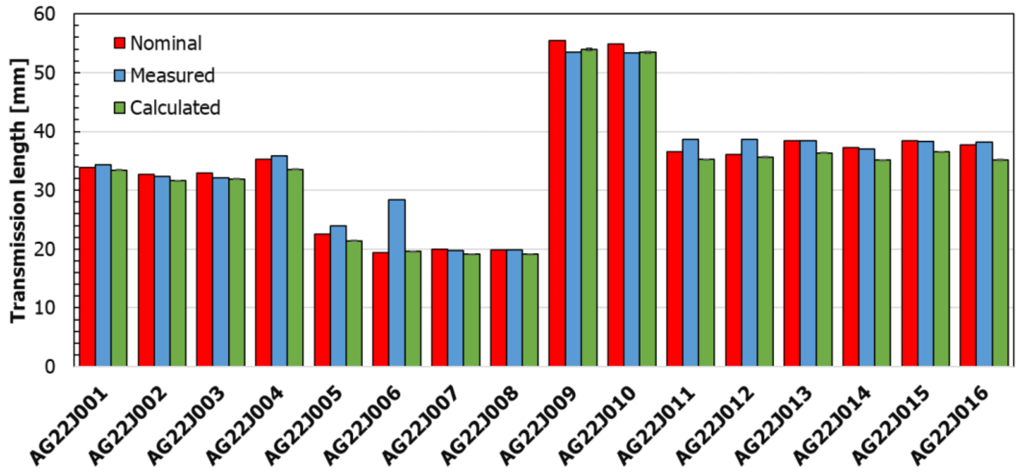
ID	Year	n	Lambda_T			Absorption lenght [cm]			Scattering lenght [cm]		
			Nominal	Measured	Calculated	Nominal	Measured	Calculated	Nominal	Measured	Calculated
TSA2-1a	2021	1.0206	35.8	30.91	31.14	157.4	29	25.44	3.68	3.46	3.55
TSA1-2b	2021	1.0206	34.3	33.82	33.7	51.1	55.9	33.5	3.67	3.6	3.75
TSA1-3b	2021	1.0199	34.5	32.54	32.31	377.9	71.2	36.47	3.51	3.41	3.55
TSA2-4a	2021	1.0204	34.4	31.99	32.6	192.9	75.5	52.51	3.44	3.34	3.48
AG22J001	2022	1.021	33.9	34.29	33.42	158.9	132.1	45.93	3.52	3.52	3.61
AG22J002	2022	1.0201	32.7	32.36	31.63	192.3	103.7	39.59	3.37	3.34	3.44
AG22J003	2022	1.0207	32.9	32.1	31.94	110.8	77	44.81	3.4	3.35	3.43
AG22J004	2022	1.0218	35.3	35.9	33.54	188.3	71.6	36.49	3.87	3.78	3.69
AG22J005	2022	1.0152	22.5	23.96	21.42		45.2	13.7		2.53	2.52
AG22J006	2022	1.0158	19.4	28.39	19.57		64.3	14.85		2.97	2.25
AG22J007	2022	1.0158	20	19.79	19.17		37.1	12.93		2.09	2.24
AG22J008	2022	1.0158	19.8	19.89	19.2		50.7	13.97		2.07	2.22
AG22J009	2022	1.026	55.5	53.53	53.93		137.3	60.98		5.57	5.93
AG22J010	2022	1.0261	54.9	53.34	53.44		150.1	62		5.53	5.86
AG22J011	2022	1.0232	36.5	38.67	35.24		116.4	45.54		4	3.82
AG22J012	2022	1.0232	36.1	38.6	35.61		189.2	53.12		3.94	3.82
AG22J013	2022	1.0205	38.4	38.48	36.38		89.9	33.65		4.02	4.07
AG22J014	2022	1.0208	37.3	37.02	35.12		72.9	30.76		3.9	3.96
AG22J015	2022	1.0208	38.4	38.26	36.5		145.1	40.25		3.93	4.01
AG22J016	2022	1.0207	37.7	38.16	35.14		78.7	30.72		4.01	3.95

Fitted by Hunt-extended formula to obtain:

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

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

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



Slight discrepancy between the measured values and the ones extracted by the transmittance measurements.

FURTHER INVESTIGATION REQUIRED

Next steps

Aerogel characterization measurements

Tile shape

- Check the presence of meniscuses along the edges of the tile (that would alter the thickness and create points of fragility). Measure the flatness of the tile surface, that would affect the light propagation by refraction.
- Touch probe system (metrology lab at CERN)

Transparency and forward scattering

- Measure the light transmission (transflectance, reflection) as a function of the wavelength by means of a spectro-photometer (better with an integration sphere).
- Measure the broadening of a laser beam passing trough the tile

Refractive index

- Aerogel nominal refractive index can be derived by the density.
- Comparison with direct measurement vs photon wavelenght along the tile surface.

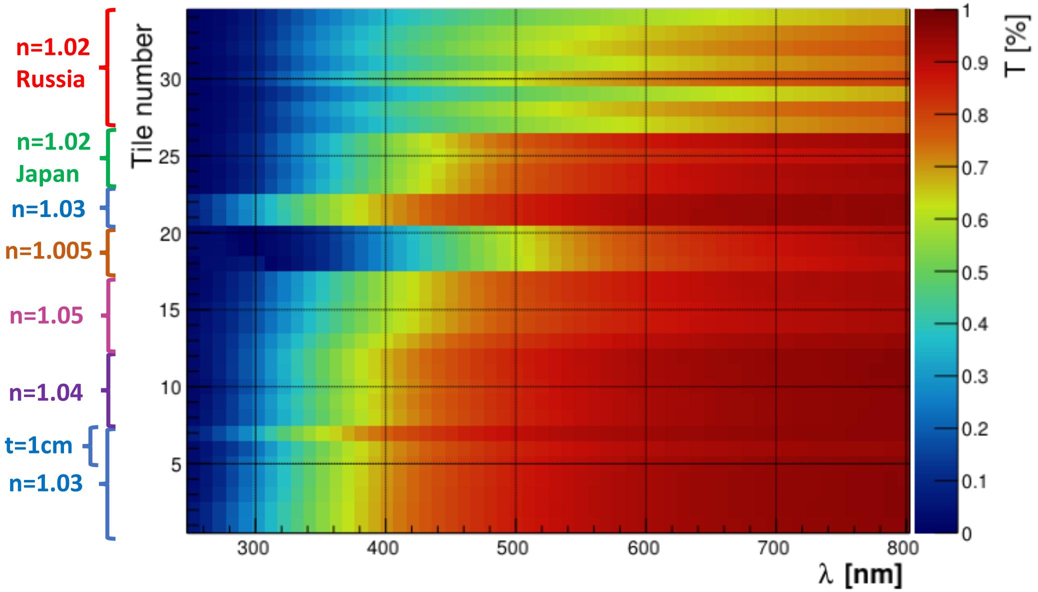
2024 plan in Bari

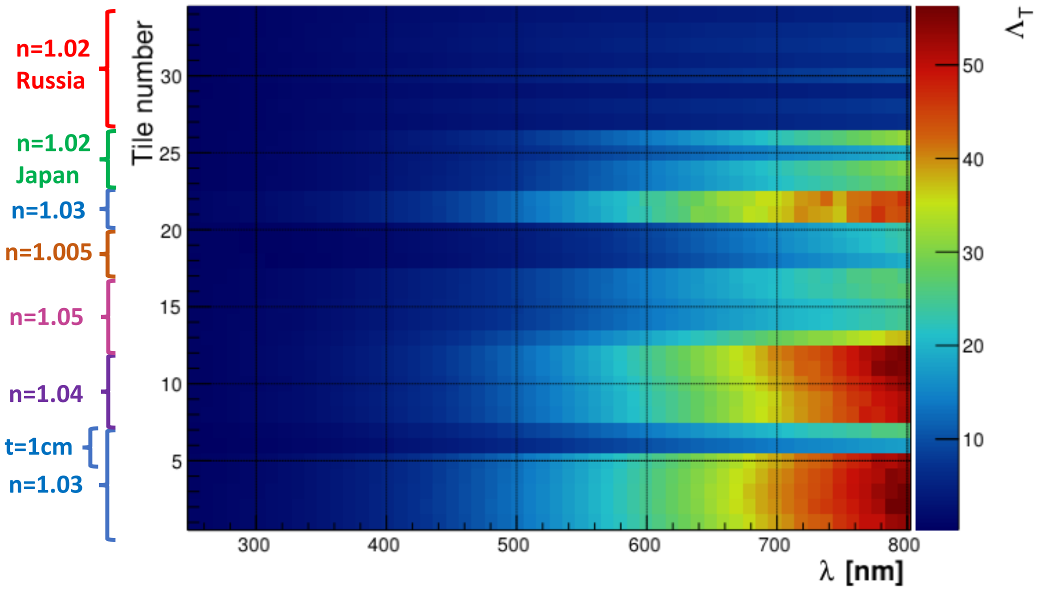
- Setting up dedicated laboratory for Cherenkov detector (strong sinergy between ALICE3 and ePIC), in particular for aerogel characterization.
  - Photo-spectrometer with integration shpere already ordered → delivered beginning next year.
  - Setting up system to measure the refractive index (already done here in Bari in the past)

- Start characterization of the larger tiles (15x15 cm^2).

Backup

Measurement summary





Maximum **transmittance** and **Λ_t** at **n = 1.03**