Silica aerogel characterization for the ePIC dRICH detector

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on behalf of the ePIC collaboration

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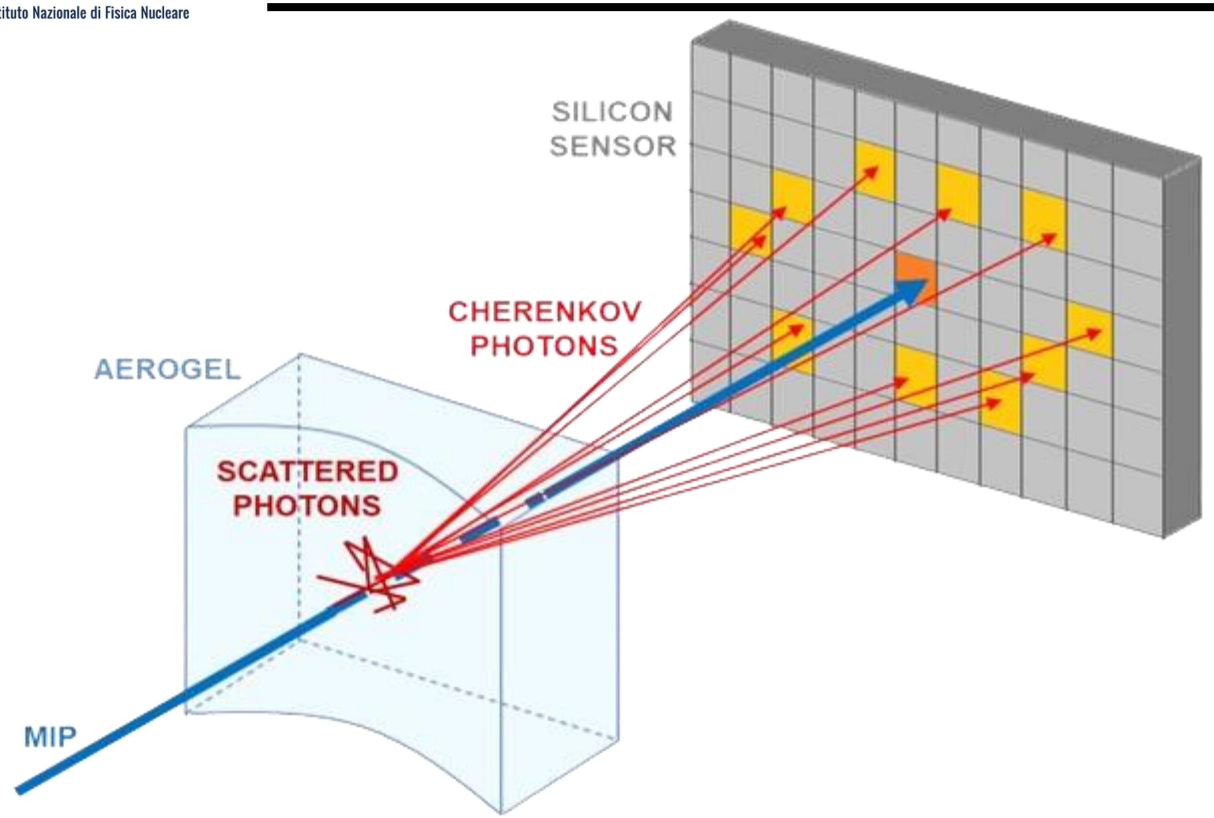
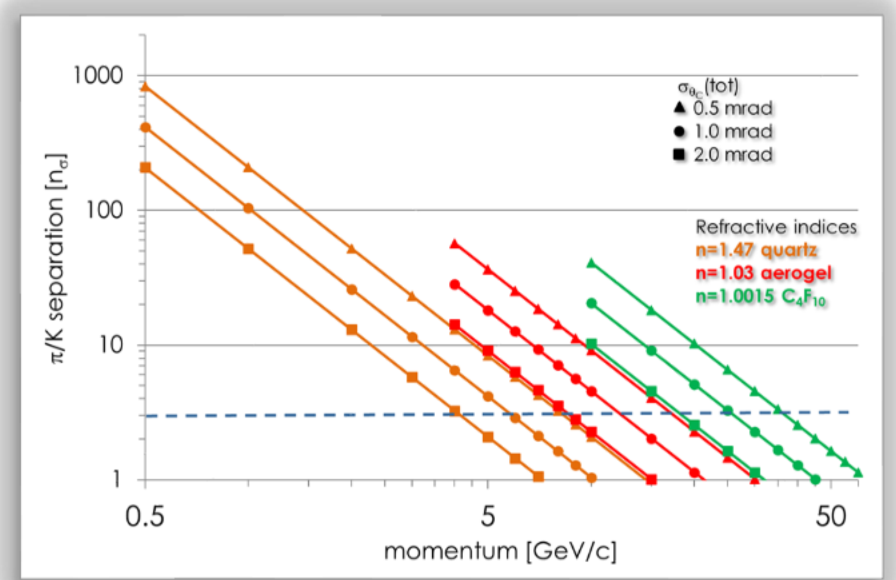
Aerogel as a radiator



With a network of interconnected silica nanoparticles, resulting in a low-density solid with an open-cell structure, silica aerogel aims to cover the refractive index gap between liquid (> 1.27) and gaseous radiators (< 1.0018).

This allows to detect particles in different momentum ranges.



DETECTION OF PARTICLES VIA CHERENKOV EMISSION

Detection of high-momentum particles through the Cherenkov photons produced by the MIP passing through the radiator, with a speed larger than the speed of the light in that medium.

Analysed aerogel samples

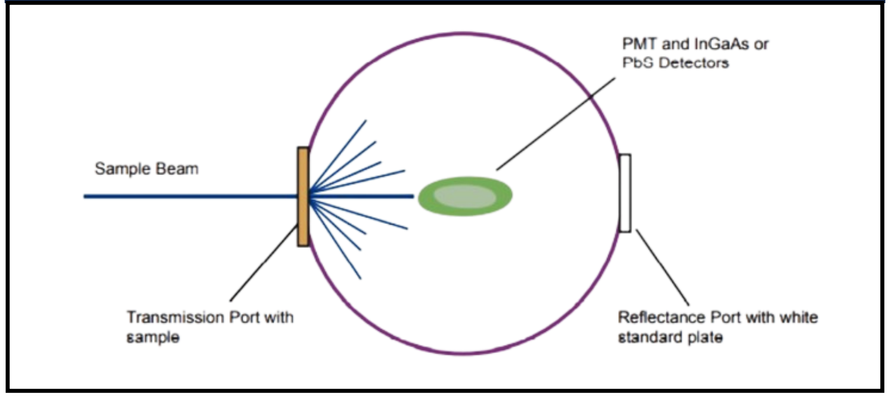
Tile	n	t [cm]	Tile	n	t [cm]
1	1.03	2.00	23	1.02 *(2021)*	2.05
2		2.00	24		2.08
3		2.00	25		2.08
4		2.00	26		2.08
5		2.00	27	1.02 *(2022)*	2.05
6		0.98	28		2.06
7		0.97	29		2.04
8	1.04	1.96	30		1.95
9		1.96	31		1.99
10		1.96	32		2.17
11		1.96	33		2.14
12		1.96	34		2.14
13	1.05	2.01	35		2.13
14		2.01	36		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.

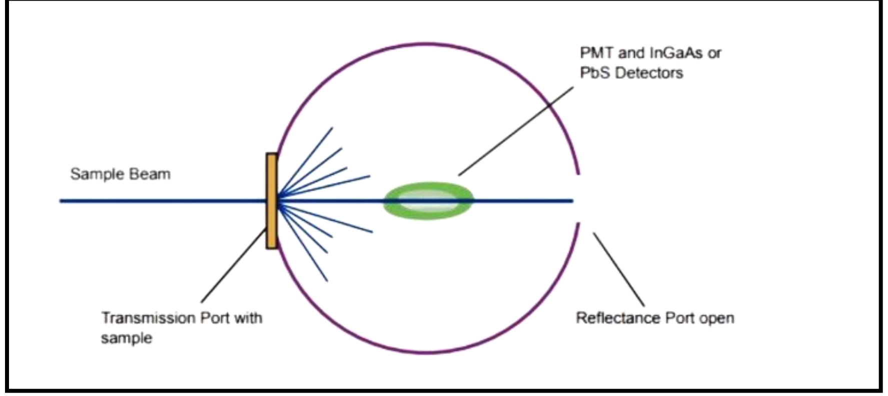
Transmittance measurements

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

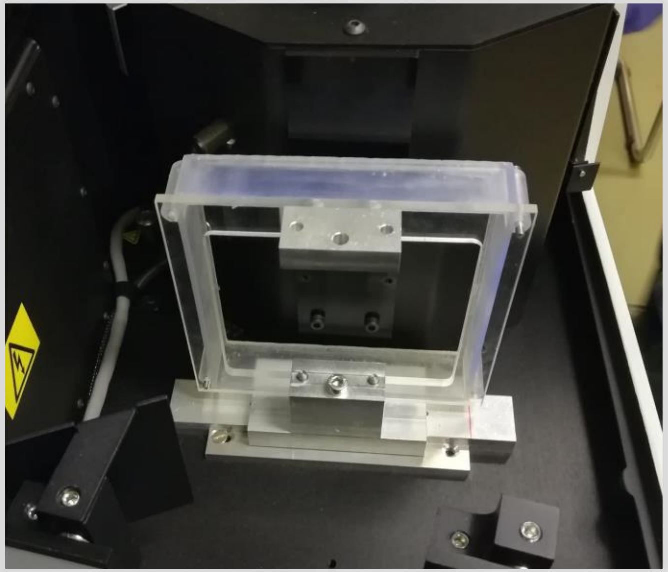
TOTAL TRANSMITTANCE



DIFFUSE TRANSMITTANCE

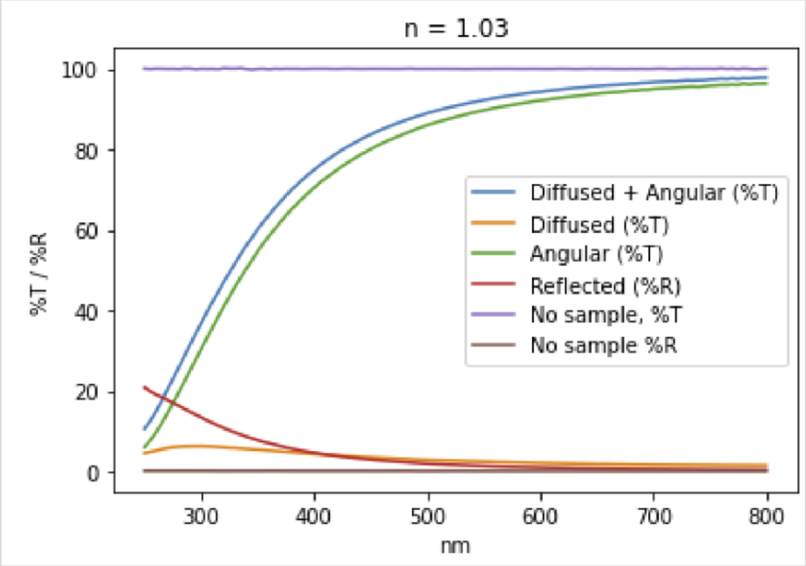


Linear TRANSMITTANCE = total T. – diffuse T.



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

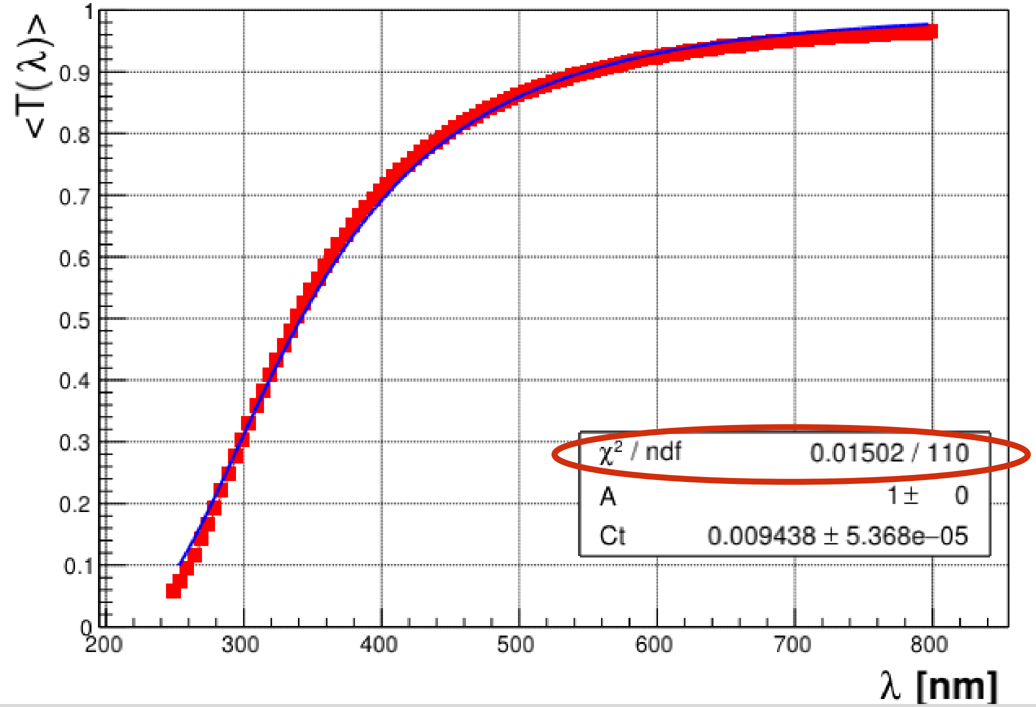


Trasmittance fitting (including absorption contribution)

Transmittance fitted by **Hunt basic**:

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

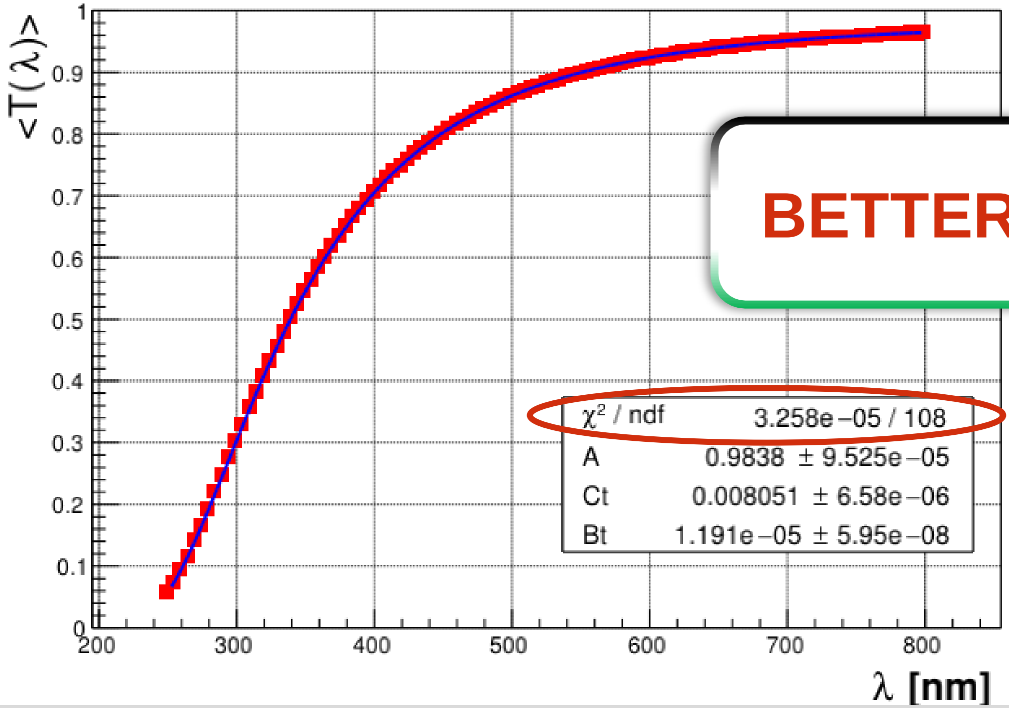
Assuming:
Λ_A negligible
$\Lambda_S \sim \lambda^4$



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



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:

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

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

SCATTERING LENGTH:

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

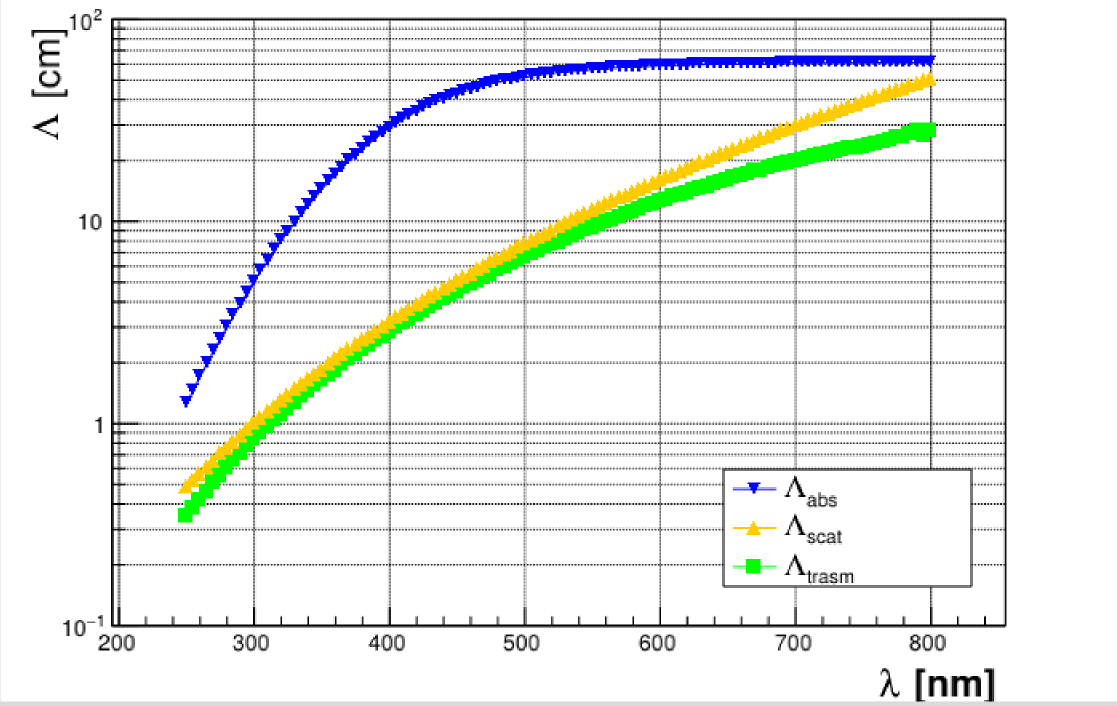
$$\boldsymbol{\Lambda_{scat} = \frac{\lambda^4}{C}}$$

ABSORPTION LENGTH:

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

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

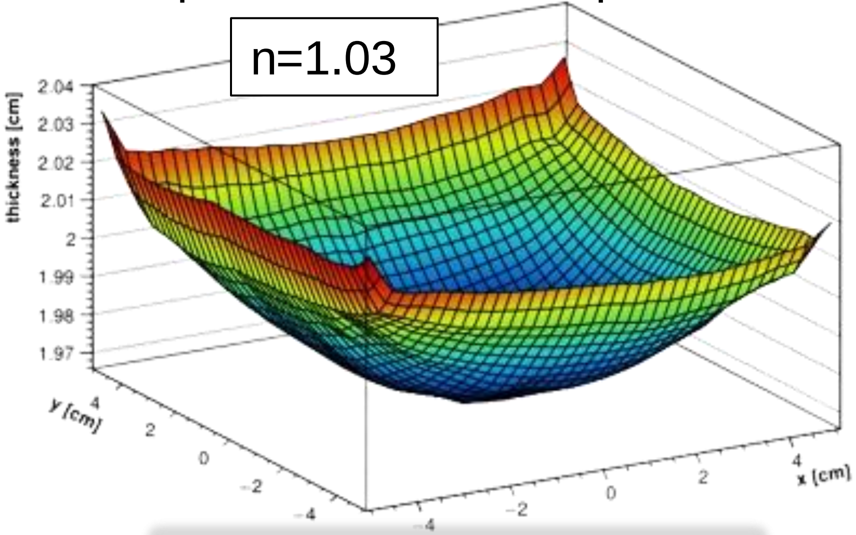
Lengths evaluated from average transmittance values.

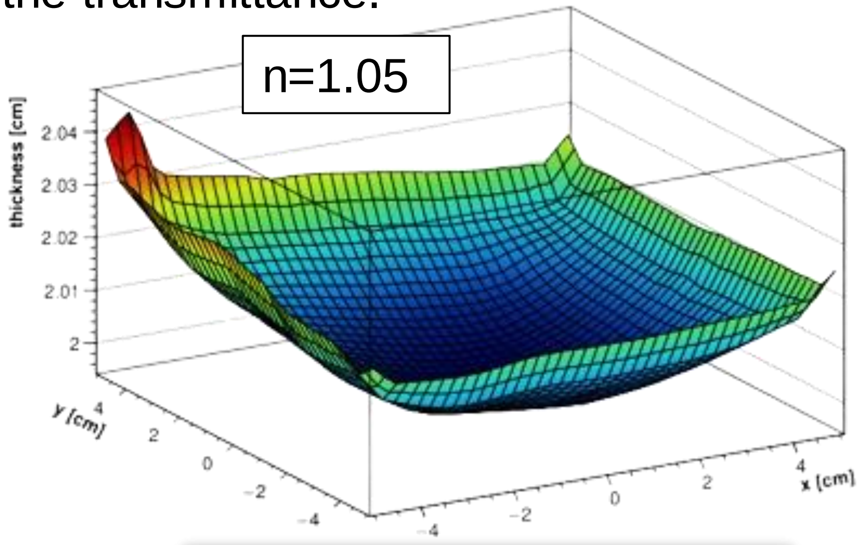


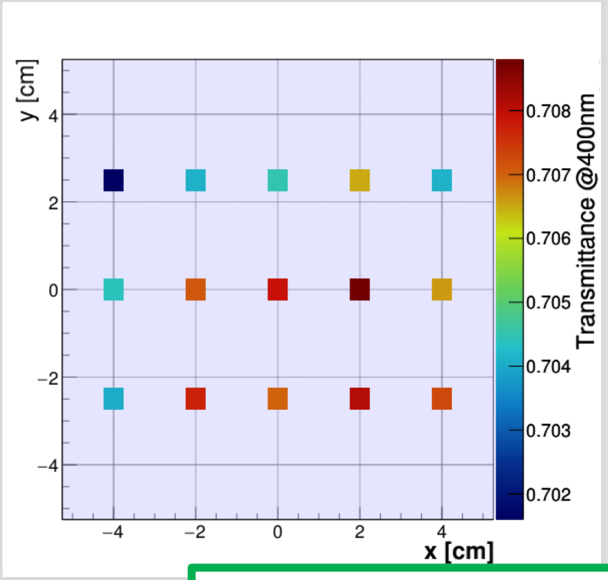
SMALL IMPACT OF THE ABSORPTION ON THE TRANSMISSION LENGTH

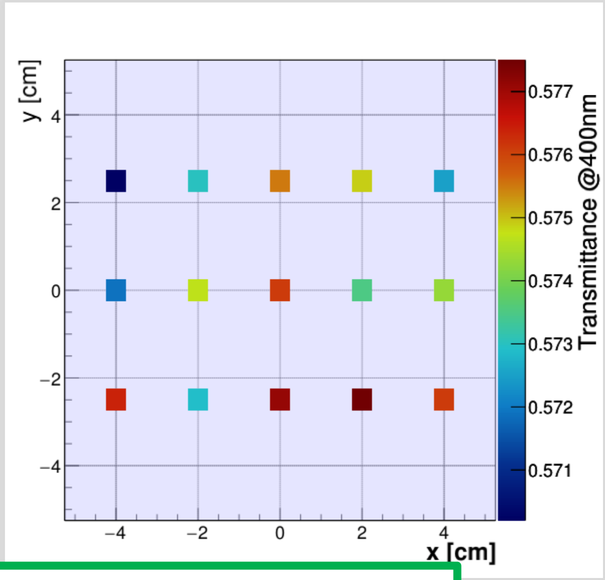
Aerogel tile shape

The shape of the tile has implications on the transmittance.









Transmittance dispersion < 1% → high uniformity

Results of the metrology measurements:

```
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
```

Thinner tiles implies higher transmittance

Measurement summary

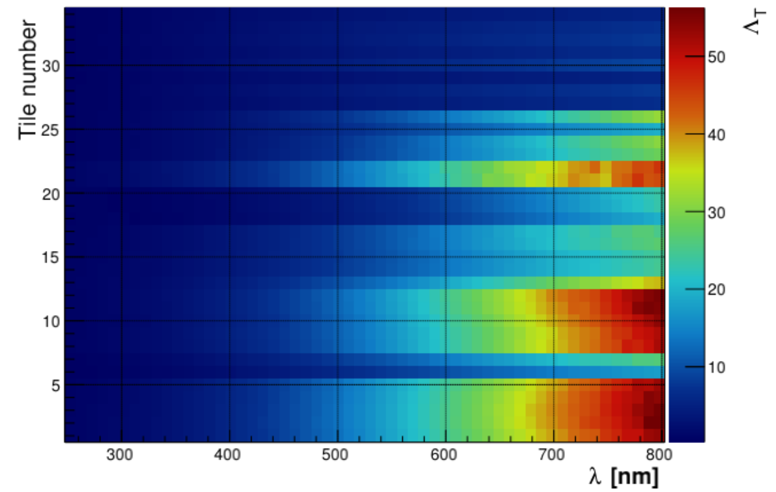
Results @ 400 nm

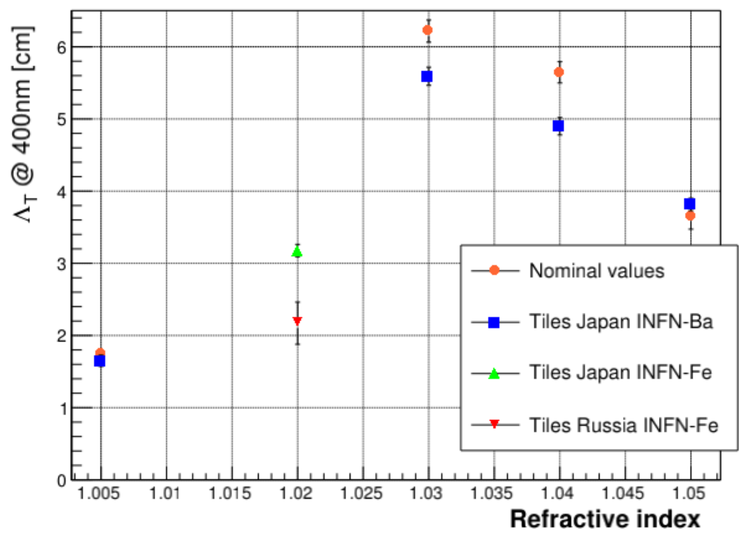
Tile	n	T [%]	$\Lambda_{T_{nom}}$ [cm]	$\Lambda_{T_{exp}}$ [cm]	Λ_{abs} [cm]	Λ_{scat} [cm]	t_{avg} [cm]
1	1.03	0.71	6.27	5.73	56.82	6.36	2.00
2		0.71	6.32	5.73	57.91	6.33	2.00
3		0.70	6.13	5.67	44.33	6.49	2.00
4		0.70	6.06	5.58	41.86	6.42	2.00
5		0.70	6.00	5.54	40.96	6.38	2.00
6		0.69	4.40	2.65	24.69	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
23	1.02	0.52	3.11	3.58	25.44	3.55	2.05
24		0.54	3.37	3.43	33.50	3.75	2.08
25		0.53	3.23	3.45	36.47	3.55	2.08
26		0.53	3.26	3.44	52.51	3.48	2.08

Estimated Λ_t @400nm lower than datasheet values

MEASUREMENT REPETITION IN PROGRESS

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





Data analysis on the n = 1.02 tiles (2022 production) are still ongoing.

Thank you!