# dRICH: aerogel studies

## (INFN BA-FE, sinergy with ALICE 3)

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# Outline

- Aerogel sample characterization
  - Trasmittance
  - Tile shape
  - Test beam

- 2024 activities and financial requests

# Analysed aerogel samples

| Tile | n | t [cm] | Tile | n | t [cm] |
|---|---|---|---|---|---|
| 1 | 1.03 | 2 | 18 | 1.005 | 2 |
| 2 | | 2 | 19 | | 2 |
| 3 | | 2 | 20 | | 2 |
| 4 | | 2 | 21 | 1.03 | 2 |
| 5 | | 2 | 22 | | 2 |
| 6 | | 1 | 23 | 1.02 | 2 |
| 7 | | 1 | 24 | | 2 |
| 8 | 1.04 | 2 | 25 | | 2 |
| 9 | | 2 | 26 | | 2 |
| 10 | | 2 | 27 | 1.02 | 2 |
| 11 | | 2 | 28 | | 2 |
| 12 | | 2 | 29 | | 2 |
| 13 | 1.05 | 2 | 30 | | 2 |
| 14 | | 2 | 31 | | 2 |
| 15 | | 2 | 32 | | 2 |
| 16 | | 2 | 33 | | 2 |
| 17 | | 2 | 34 | | 2 |

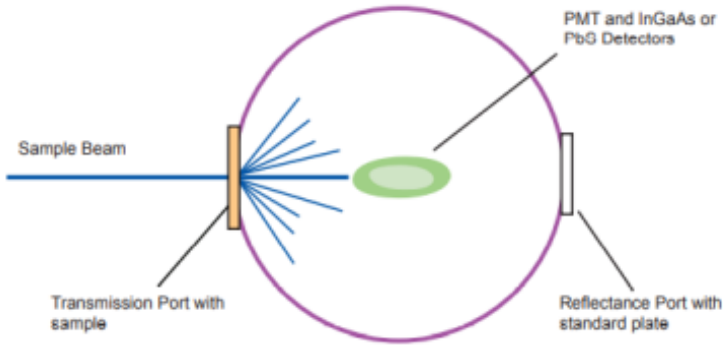
- Measurements performed on **22 silica aerogel tiles** at CERN in July-August 2022.
- Tiles manufactured at Aerogel Factory Co. Ltd (Chiba, Japan) and delivered in March 2021.
- Tiles 6 and 7 manufactured by Matsushita Electric Works (Japan) were bought by INFN-Bari in 2000 as part of the HERMES collaboration.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

***Analysis performed by Anna Rita Altamura (INFN-Bari post-doc)***

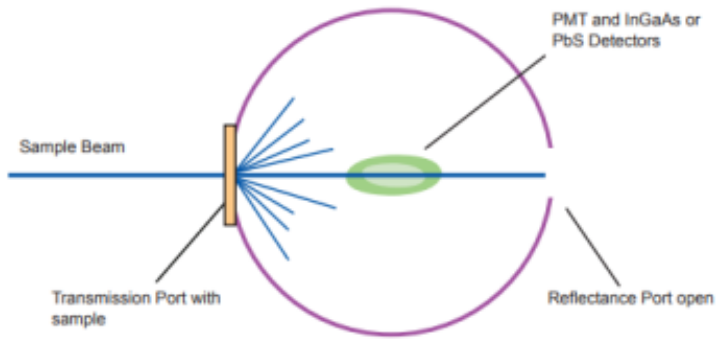
# Transmittance measurements

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

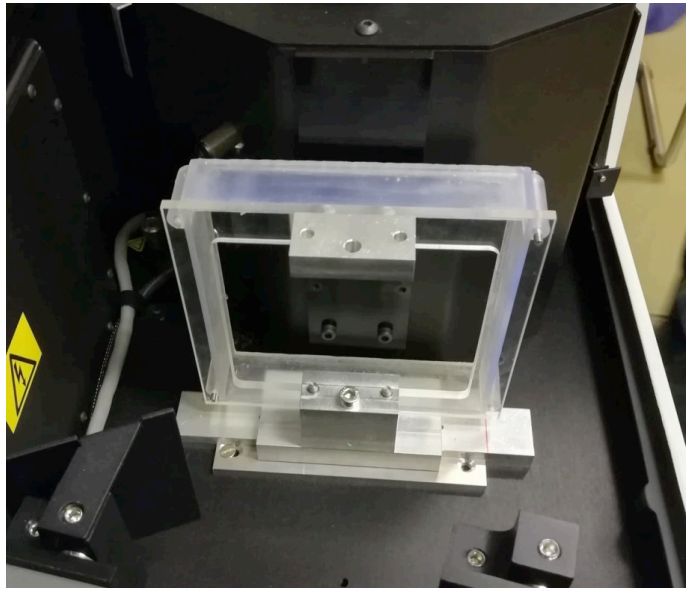
TOTAL TRANSMITTANCE




DIFFUSE TRANSMITTANCE

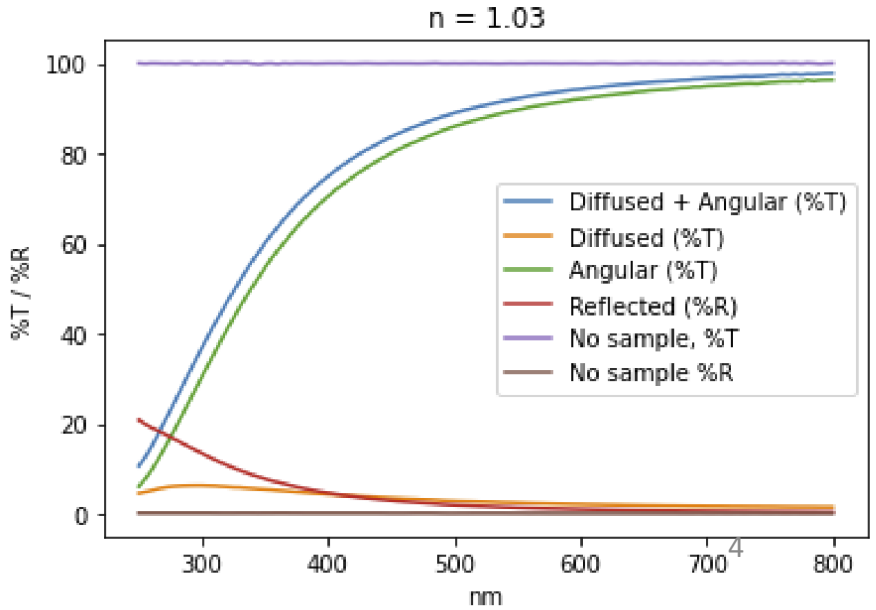



Linear TRANSMITTANCE = **total T. – diffuse T.**



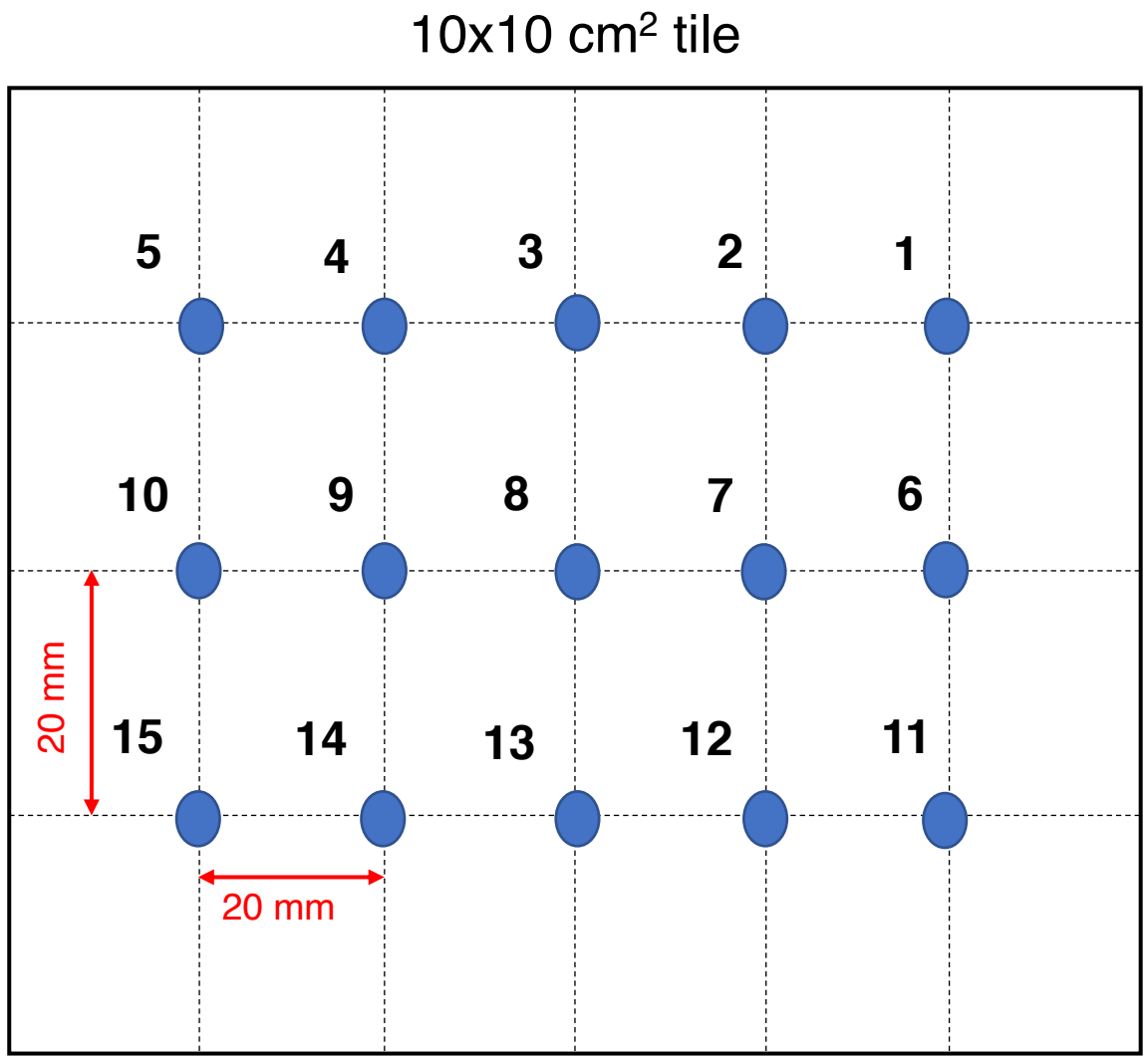
Each tile was placed into a holder (10x10 $cm^2$) and mounted onto a metal ridge sliding perpendicular to the beam to explore different positions of the samples

On tiles 6 and 7 only total transmittance has been measured



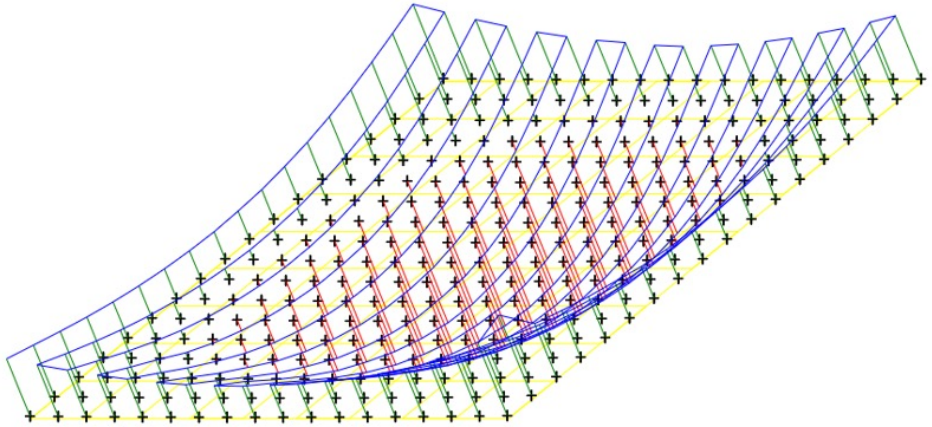
# Transmittance measurements

Transmittance measured in 15 different points on the tile



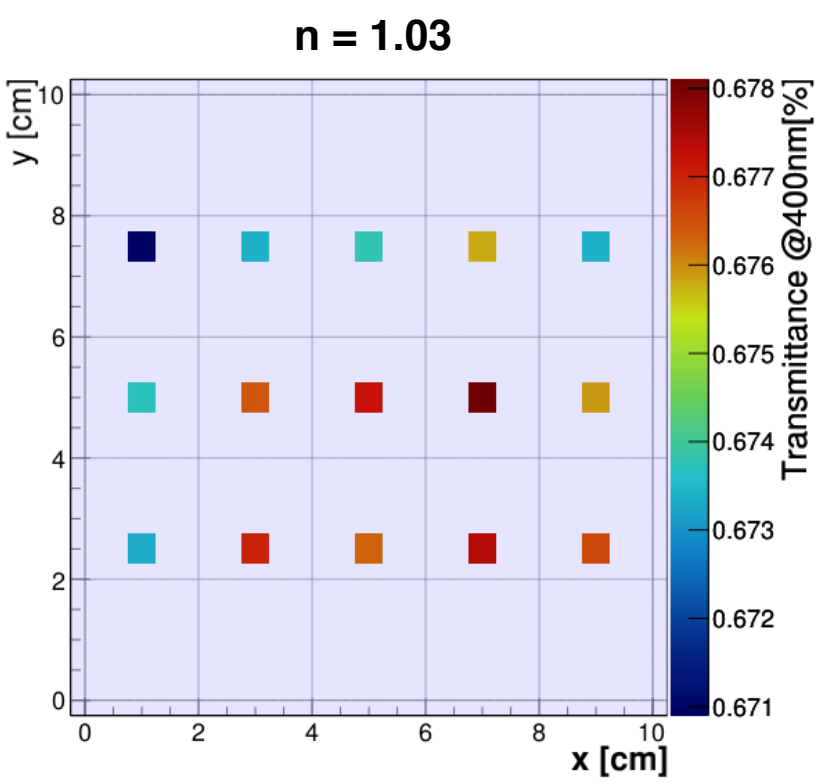

Tile thickness = 2 cm

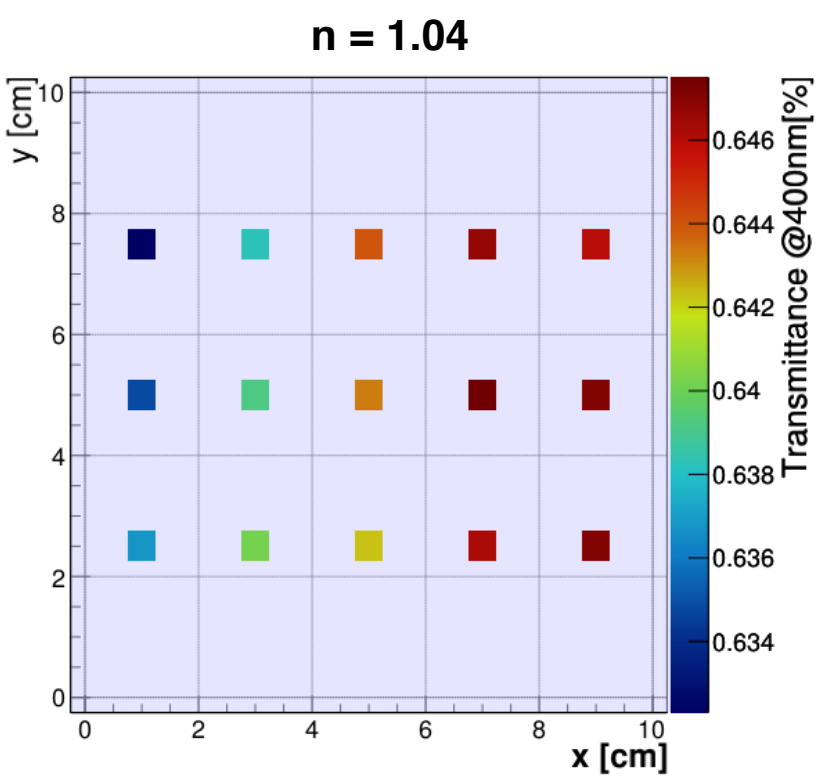
Thickness not uniform because of the meniscus shape due to fabrication process (see next slides)

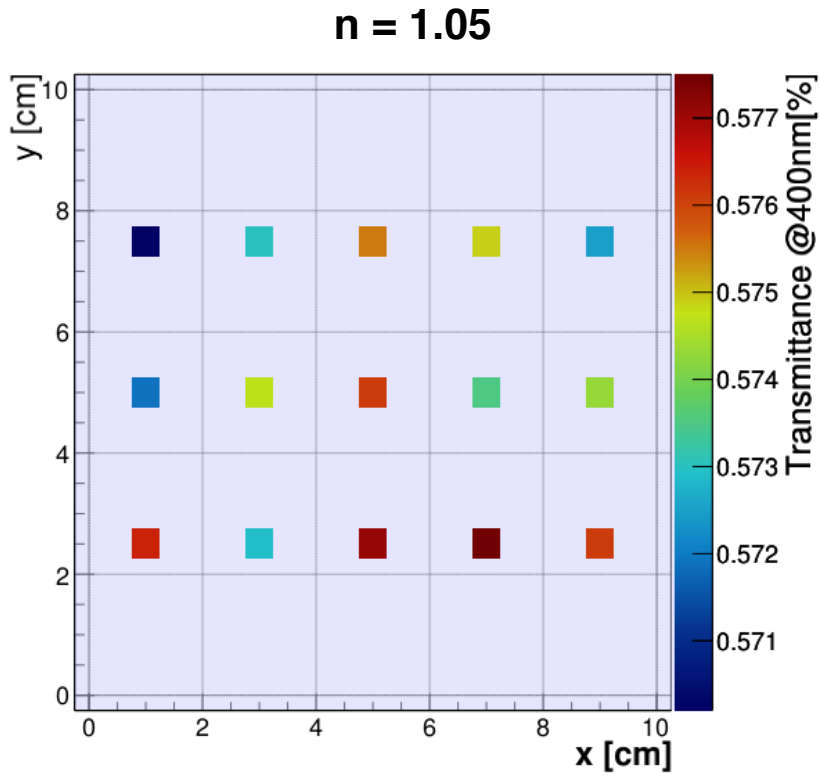


# Transmittance measurements

- 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



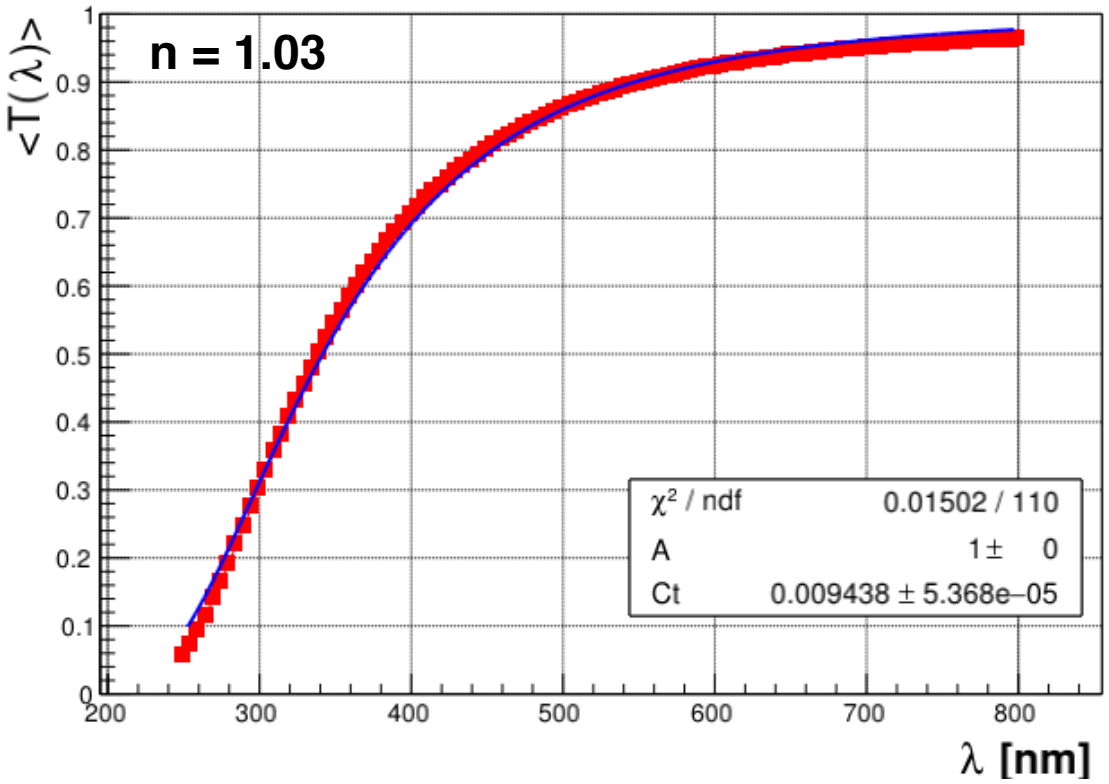



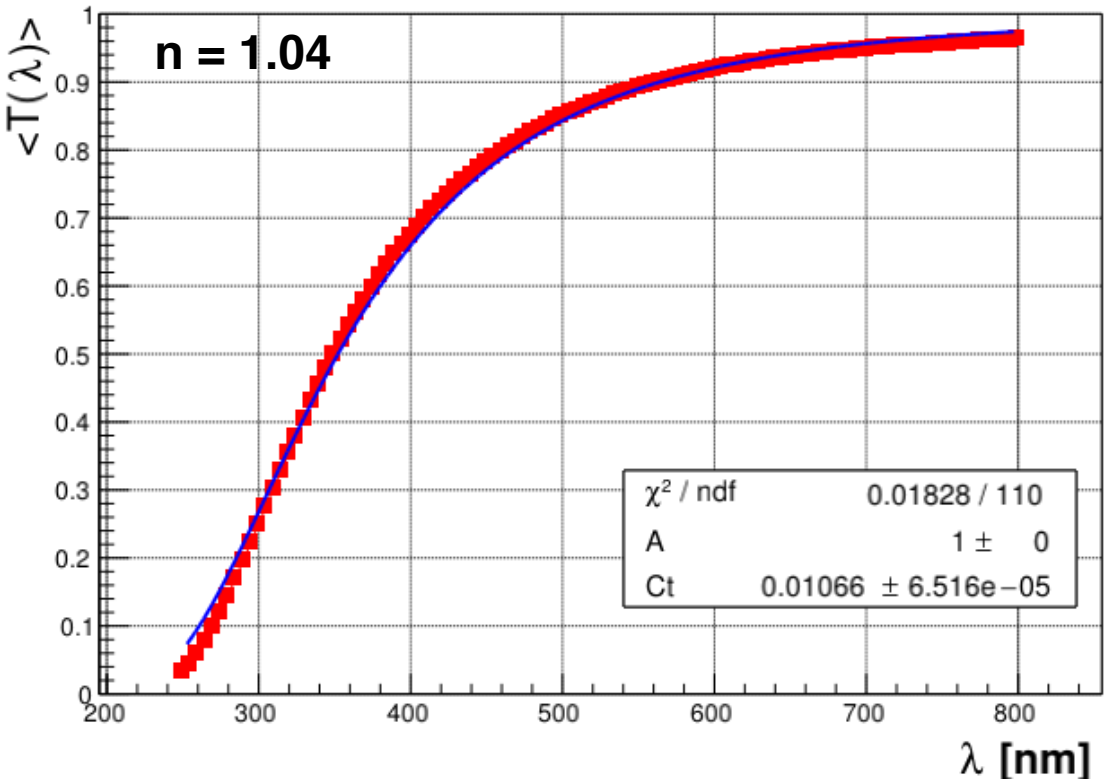



# Trasmittance fitting

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

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



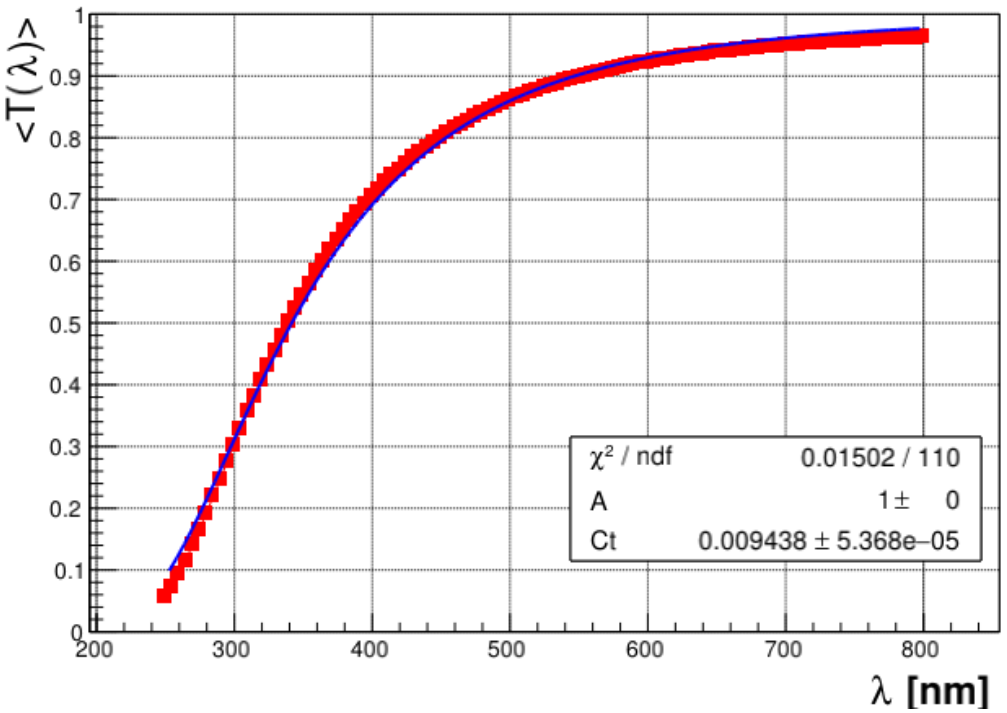



# Trasmittance fitting (including absorption contribution)

Transmittance fitted by **Hunt basic**:

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

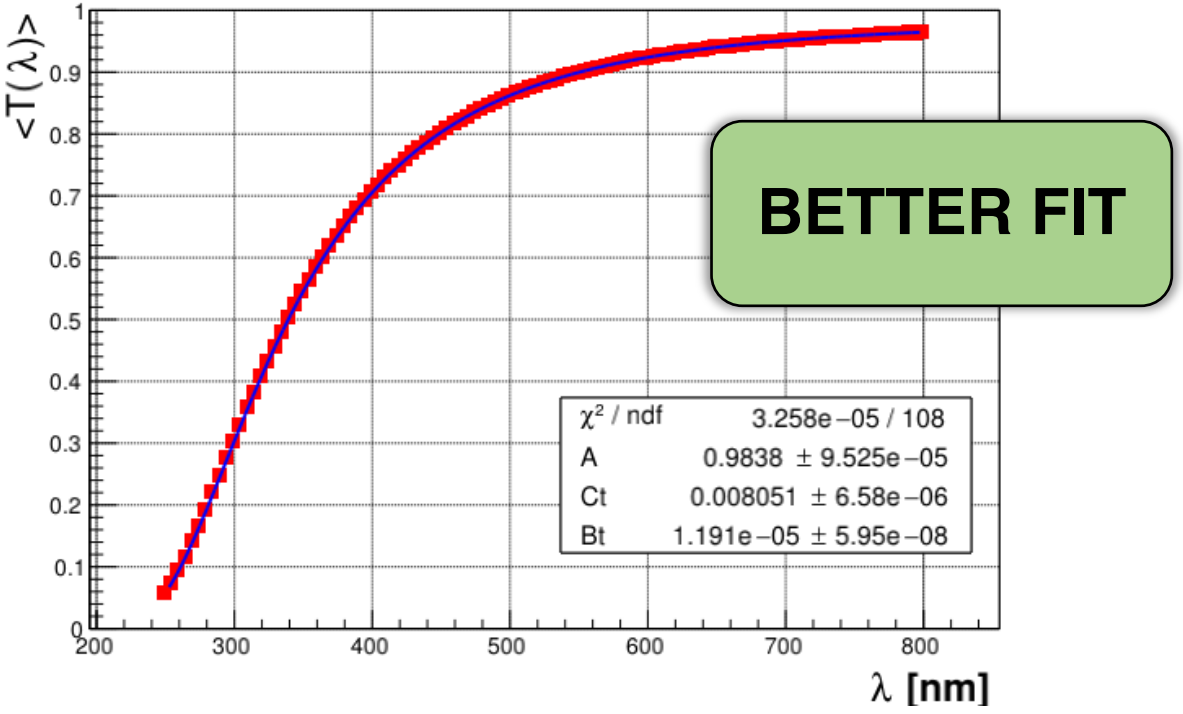
*Assuming:*
$\Lambda_A$ **negligible**
$\Lambda_S \sim \lambda^4$




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




**<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:

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

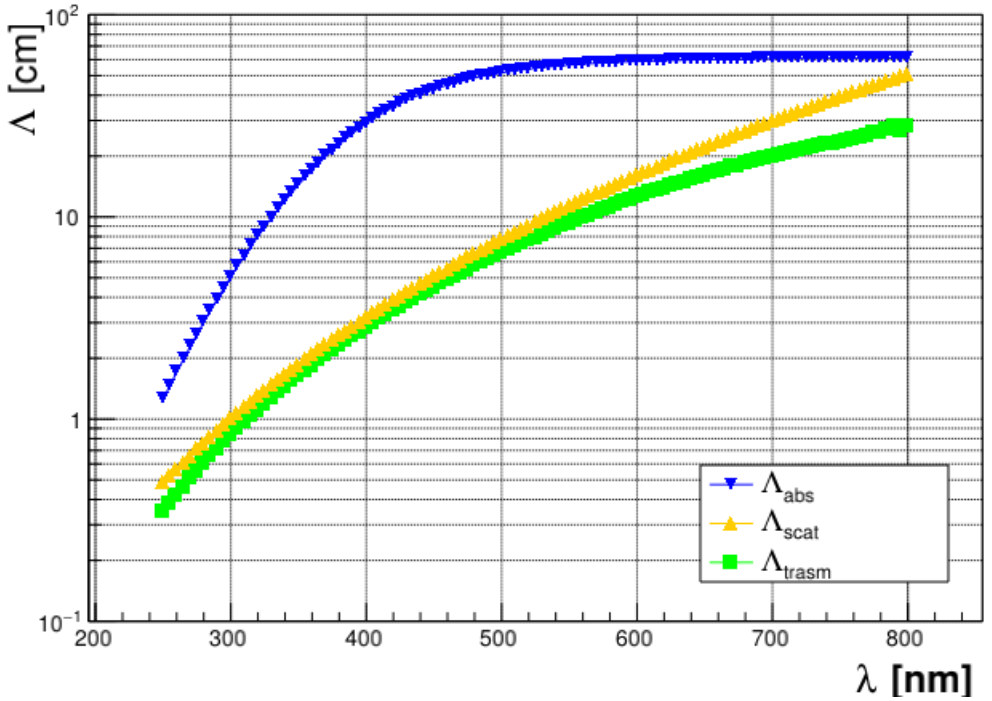
$$\Lambda_{scat} = \frac{\lambda^4}{C}$$

## 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!**

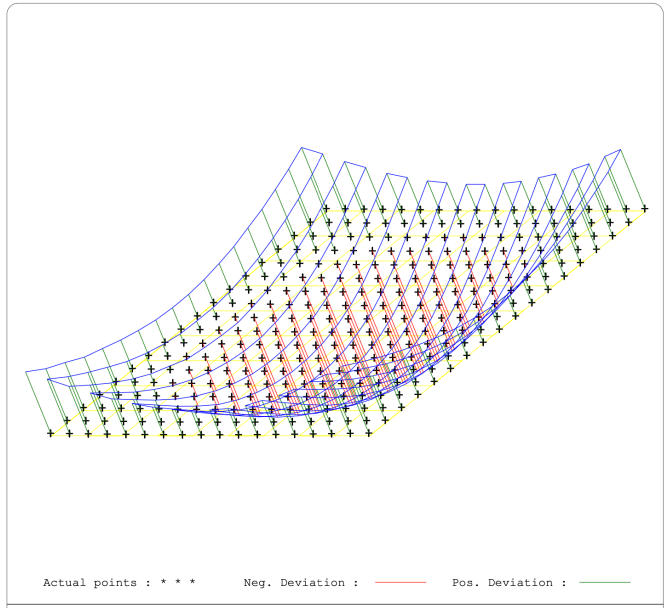
- Results obtained on a tile of n = 1.03 with the touch probe system (force applied by the probe is 2 gr).
- The measuring system is the LEITZ PMMC with ± 0.3 μm of precision

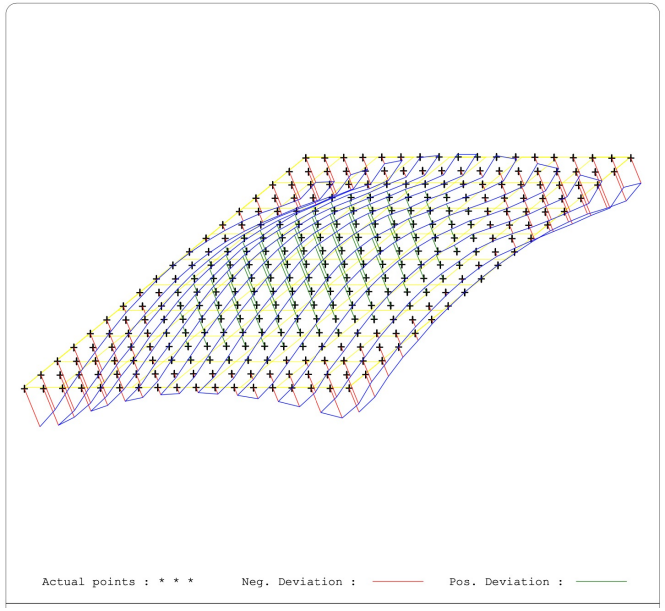
Thickness = 19.96 ± 0.17

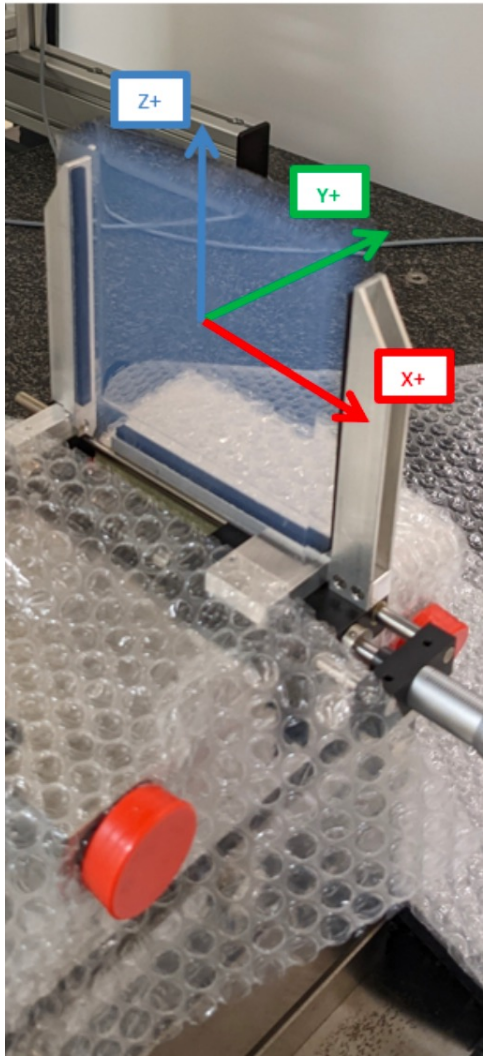
Plane Y- side = 0.7060

Plane Y+ side = 1.2716

Meniscus shape due to fabrication process



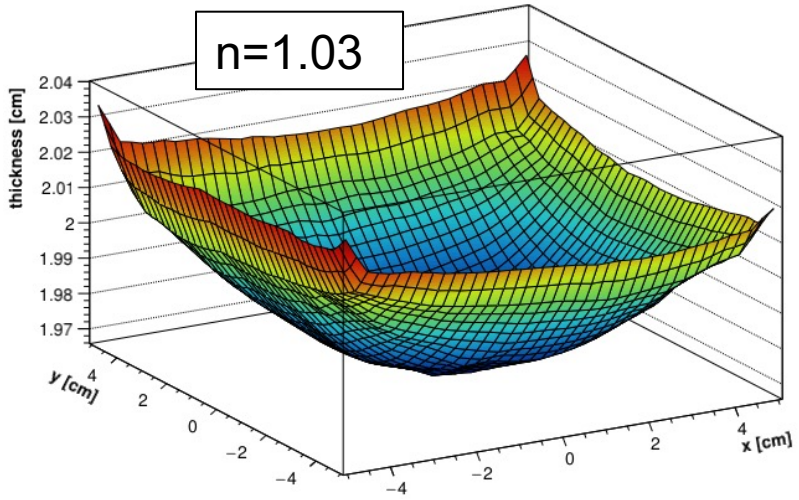



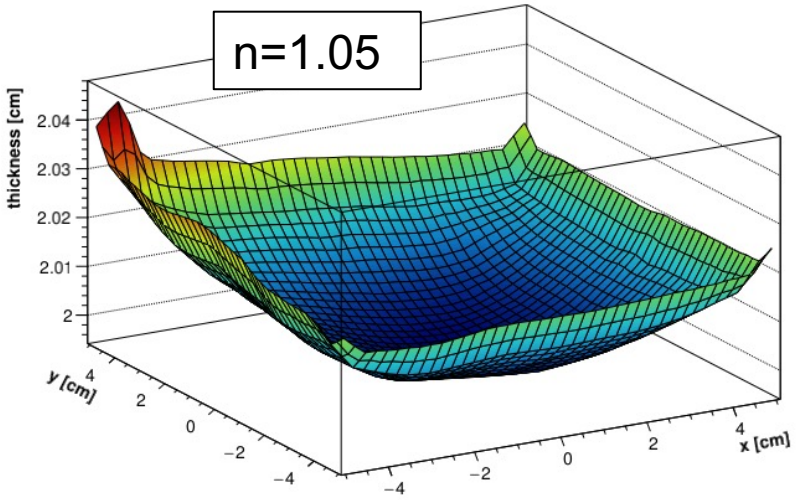

There is a variation in thickness from the centre to the edges, of the order of 0.4 mm, and a different planarity in the two faces, one 0.7 mm, the other 1.27 mm. In general the tiles have the shape of a dome.

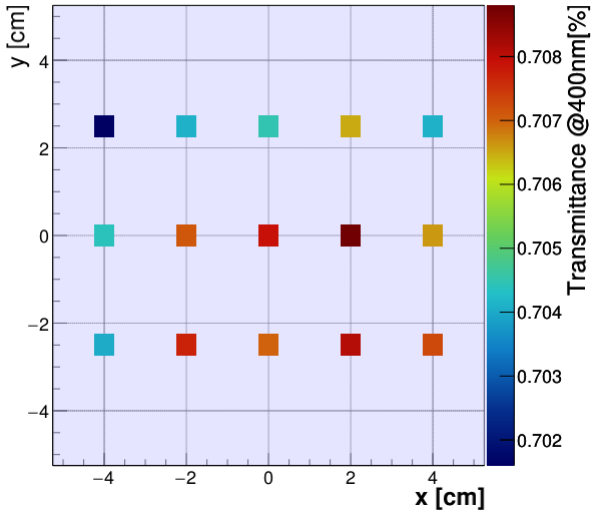
- The manufacturer (Aerogel Factory Ltd, Chiba, JP) stated that it is possible to improve the flatness and the thickness uniformity;
- the planarity can be mapped, to include the defect in the reconstruction of the Cherenkov angle.

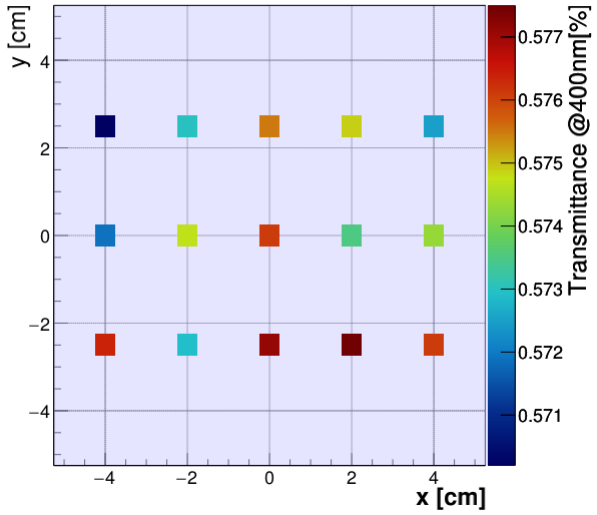
# Aerogel tile shape

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**

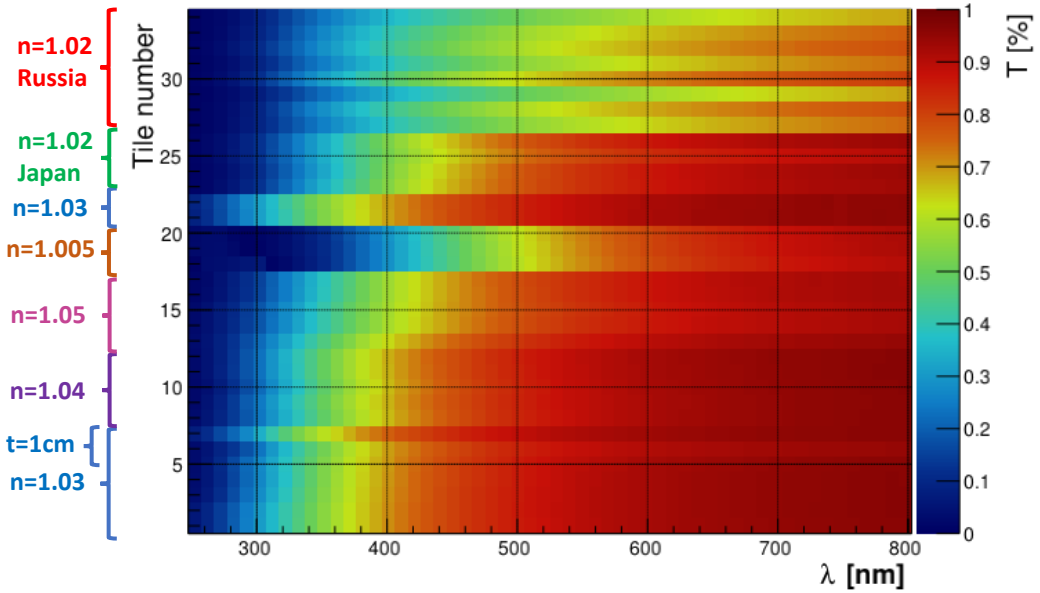
| Tile | n | $T_{meas}$ [%] | $\Lambda_t$ [cm] | $\Lambda_t$ datasheet | $t_{avg}$ [cm] | Tile | n | $T_{meas}$ [%] | $\Lambda_t$ [cm] | $\Lambda_t$ datasheet | $t_{avg}$ [cm] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | 0,71 | 5,64 | 6,27 | 1,97 | 18 | | 0,29 | 1,61 | | 2,00 |
| 2 | | 0,71 | 5,68 | 6,32 | 1,98 | 19 | 1,005 | 0,29 | 1,65 | | 2,06 |
| 3 | | 0,70 | 5,64 | 6,13 | 1,99 | 20 | | 0,29 | 1,69 | | 2,06 |
| 4 | 1,03 | 0,70 | 5,54 | 6,06 | 1,98 | 21 | 1,03 | 0,69 | 5,40 | | 2,02 |
| 5 | | 0,70 | 5,47 | 6,00 | 1,97 | 22 | | 0,69 | 5,59 | | 2,03 |
| 6 | | 0,69 | 2,65 | | 0,98 | 23 | | 0,54 | 3,24 | | 2,00 |
| 7 | | 0,75 | 3,47 | | 0,97 | 24 | 1.02 | 0,53 | 3,10 | | 2,00 |
| 8 | | 0,66 | 4,73 | 5,47 | 1,94 | 25 | | 0,52 | 3,04 | | 2,00 |
| 9 | | 0,67 | 4,92 | 5,61 | 1,95 | 26 | | 0,53 | 3,13 | | 2,00 |
| 10 | 1,04 | 0,66 | 4,78 | 5,58 | 1,96 | 27 | | 0,38 | 2,09 | | 2,00 |
| 11 | | 0,67 | 4,96 | 5,71 | 1,97 | 28 | | 0,42 | 2,32 | | 2,00 |
| 12 | | 0,68 | 5,00 | 5,86 | 1,96 | 29 | | 0,34 | 1,85 | | 2,00 |
| 13 | | 0,63 | 4,41 | 3,59 | 2,02 | 30 | 1.02 | 0,45 | 2,56 | | 2,00 |
| 14 | | 0,58 | 3,73 | 3,54 | 2,01 | 31 | | 0,38 | 2,09 | | 2,00 |
| 15 | 1,05 | 0,58 | 3,73 | 3,45 | 2,02 | 32 | | 0,42 | 2,31 | | 2,00 |
| 16 | | 0,57 | 3,59 | 3,79 | 2,00 | 33 | | 0,40 | 2,19 | | 2,00 |
| 17 | | 0,57 | 3,60 | 3,86 | 1,98 | 34 | | 0,36 | 1,94 | | 2,00 |

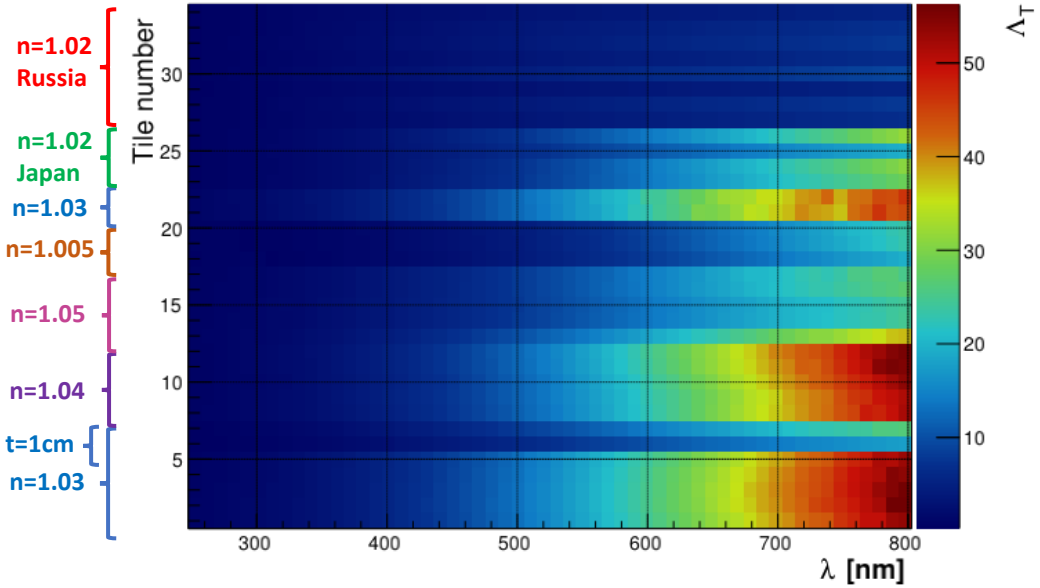
Estimated $\Lambda_t$ @400nm lower than datasheet values

FURTHER INVESTIGATION REQUIRED

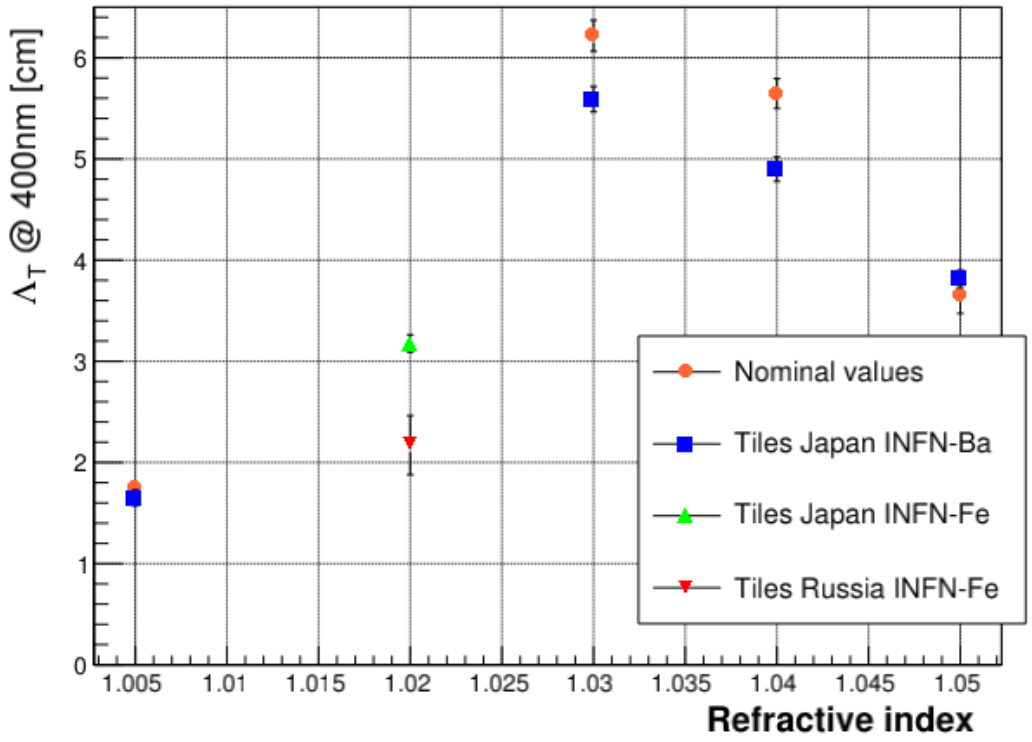
MIGHT BE OVERESTIMATED BECAUSE
ONLY TOTAL TRANSMITTANCE IS AVAILABLE

# Measurement summary



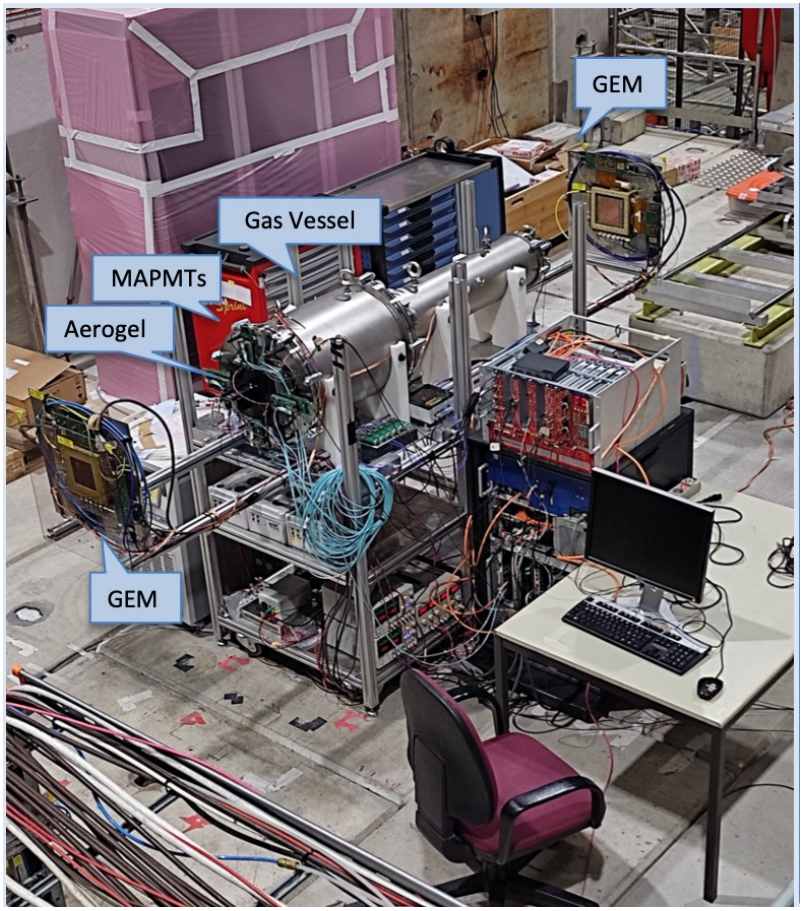



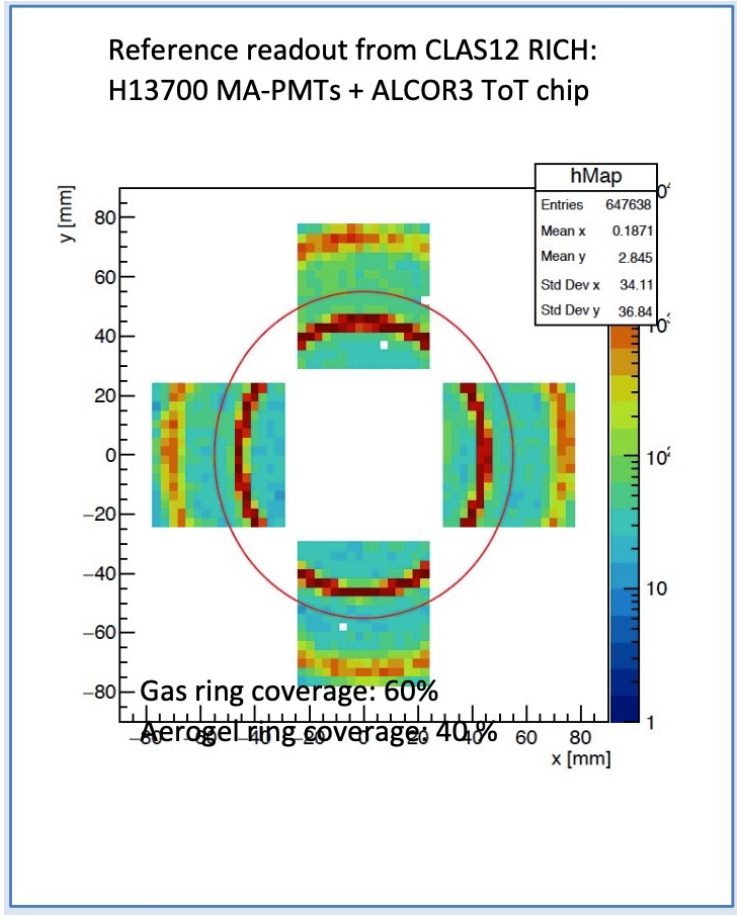

Maximum **transmittance** and $\Lambda_t$ at **n = 1.03**

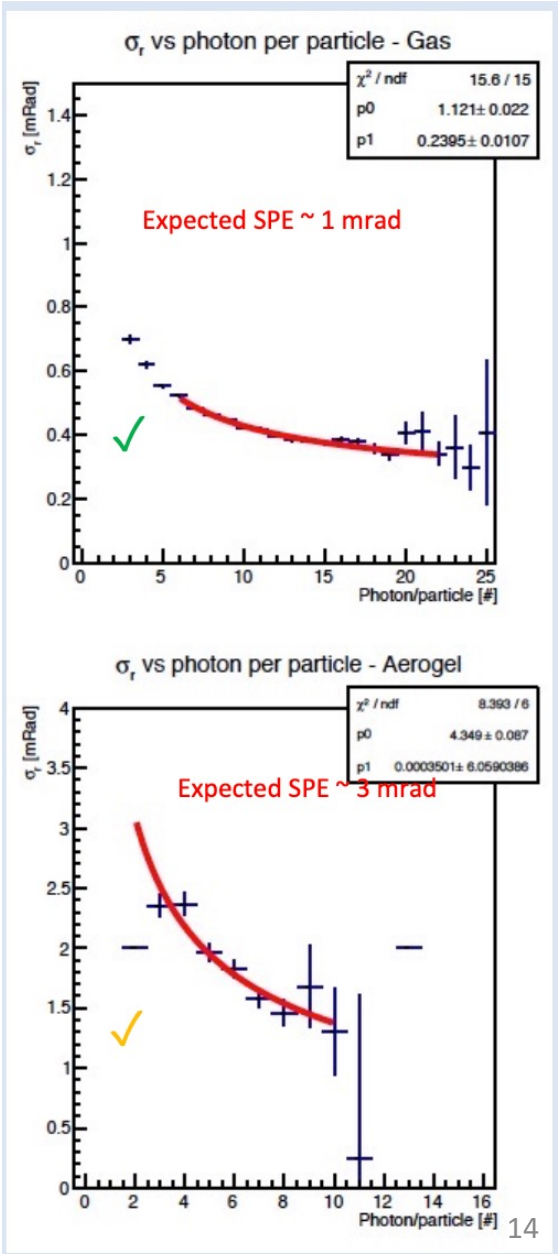


# Test beam

Operative prototype commissioned (‘21-’22). Double ring imaging achieved. Performance in line with expectations except for aerogel single-photon angular resolution (worse by a factor 1.5-2).



# 2024

- Continue aerogel tiles characterization in term of optical properties and shape
  - Further investigation on transmission length discrepancy between estimated and datasheet values
  - Performing more precise measurements of the tile 6 and 7 to investigate their degradation in time

- Investigate about the possibility do obtain new specifications, in terms of optical properties and dimensions
  - R&D activities in collaboration with the manufacturer (Chiba, Japan)
    - To obtain new samples with larger dimensions (20x20 $cm^2$?)
    - To optimize the ref. index vs the optical properties
  - New characterization
  - Beam-test

# Financial requests

| Missioni | |
|---|---|
| Importo | Descrizione |
| 3 k€ (Bari) | Partecipazione test beam campioni aerogel (CERN): 7gg x 3 persone (sinergia ALICE 3) |

| Consumo, inventario, etc | |
|---|---|
| Importo | Descrizione |
| 20 k€ (Bari) | Campioni di aerogel per R&D e caratterizzazione (sinergia ALICE 3) |
| 2 k€ (Bari) | Metabolismo di laboratorio per studi aerogel e SiPM (sinergia ALICE 3) |
| 10 k€ (Ferrara) | Dimostratori aerogel: tavola di grande area sagomata con taglio ad acqua (SINERGIA DRD4 WP4.3.1) |

# Cost justification

**Aerogel**:

Projected cost for targeted size is about 4 keuro for Large production (50 tiles).

We plan to contribute with at least two tiles to motivate the R&D.

```
From makoto@hepburn.s.chiba-u.ac.jp Tue Mar 14 19:45:33 2023
Date: Wed, 15 Mar 2023 03:45:21 +0900
From: Makoto Tabata / Chiba Univ. <makoto@hepburn.s.chiba-u.ac.jp>
To: "Kiselev, Alexander" <ayk@bnl.gov>
Cc: Marco Contalbrigo <mcontalb@fe.infn.it>
Subject: Re: My address for the quotation purposes

    [ The following text is in the "UTF-8" character set. ]
    [ Your display is set for the "ANSI_X3.4-1968" character set.  ]
    [ Some characters may be displayed incorrectly. ]

Dear Alexander,

I am assuming 50 tiles of n~1.04 with water-jet cutting. (The sizes
before cutting are shown.)

Belle II quality 18 x 18 x 2 cm:
USD 140k (after re-tuning the production process; Belle II production
was 10 years ago!).

Belle II quality with thickness increase, 18 x 18 x 2.5 cm:
USD 180k (after some R&D for thickness).

J-PARC quality, 14 x 14 x 2.5 cm:
USD 90k.

Because of the pressure vessel?s capacity limitation, the price may
almost double if you genuinely need 20 cm. Thus, we designed the aerogel
segmentation with 18 cm at Belle II. On the other hand, the increase
from 14 cm to 15 cm will be covered by a relatively moderate price up of
~30%.

Please let me know if you have any missing info.

Best regards,

    Makoto
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# Backup