Aerogel measurements and monitoring

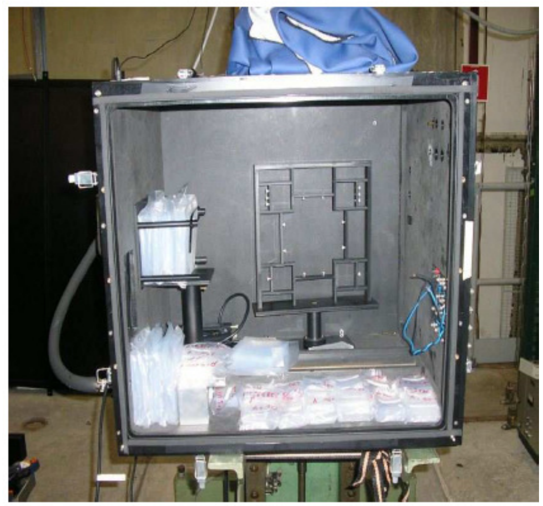
L. Barion, M. Contalbrigo, L.L. Pappalardo
INFN-Ferrara

Restoring the transparency

The Novosibirsk aerogel is hydrophilic, i.e. tends to absorb humidity from the air, resulting in a worsening of the optical preformances, and in particular of the transparency.

Several methods were tested to restore the transparency after exposure to air (i.e. humidity):

- Storing the tiles in a dry atmosphere environement (e.g. in dry cabinet)
- Storing the tiles in a box fluxed with nitrogen
- Baking the tiles at few hundreds (celsius) degrees for a few hours



We experienced that the transparency is approximately preserved if the tile is sealed within a small plastic bag.

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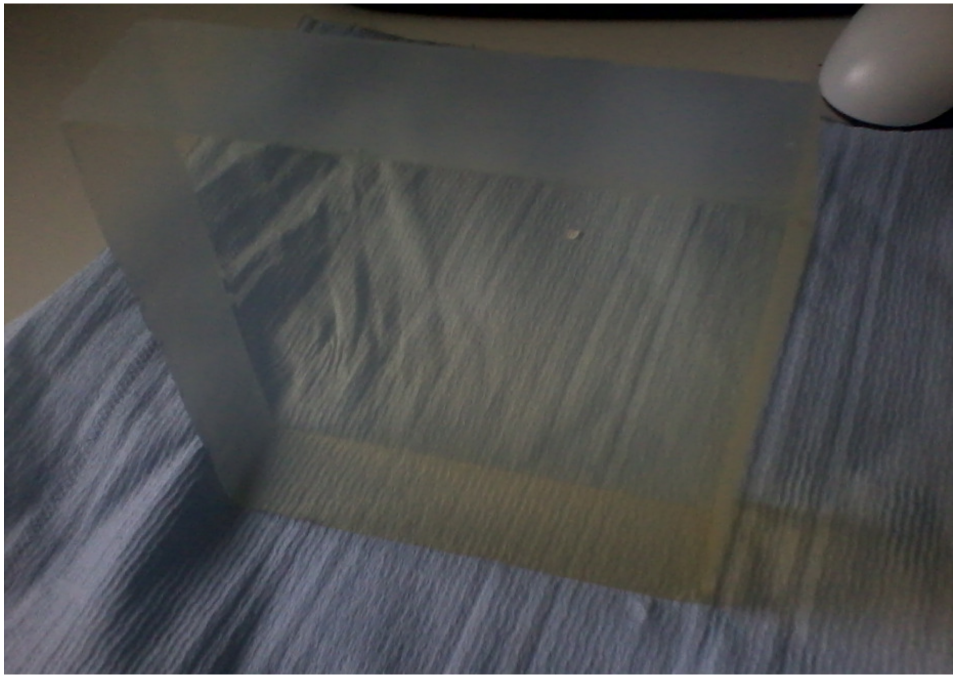


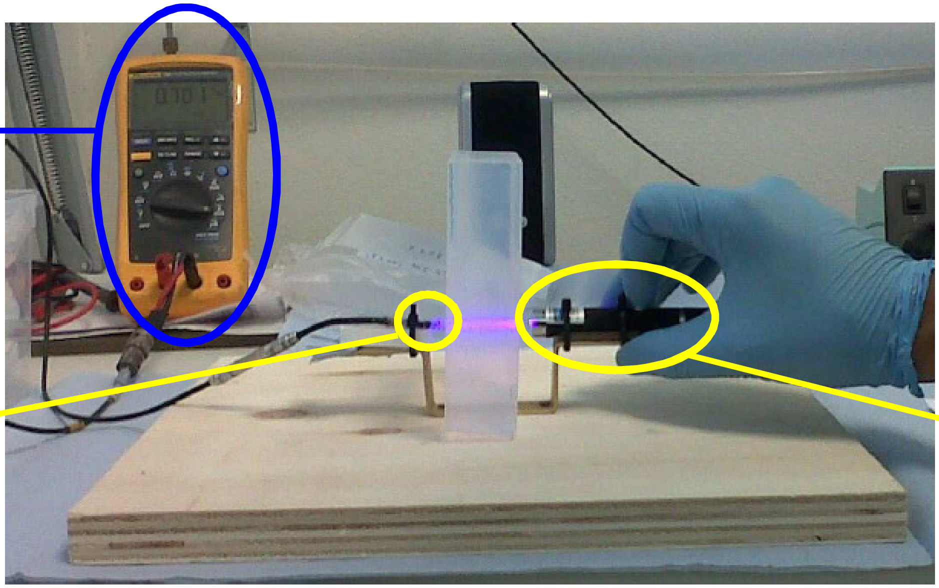
- First aerogel tile exposed to Nitrogen line (not clean!)
- Always check that Nitrogen line is clean enough!!

Monitoring the transparency (1)

The aerogel transparency was moniotored many times during the test beam at CERN, usually before and after being used on beam (i.e. exposed to air).

Fast measurements were performed with a very simple set-up:

Multimeter:
reads current



Photodiode
output in mA

Laser:
blue light
405 nm

$$T_i = \frac{I_{aerogel}}{I_0}$$

I_0 → Measured without aerogel (background)

$$\langle T \rangle = \frac{1}{10} \sum_{i=1,10} T_i$$

Monitoring the transparency

The method is fast (a few minutes for each set of 10 measurements) but introduces several systematic effects:

- the photodyode was not tightly fixed to the support (to prevent damages), so its position relative to the laser could have slightly changed during the measurements

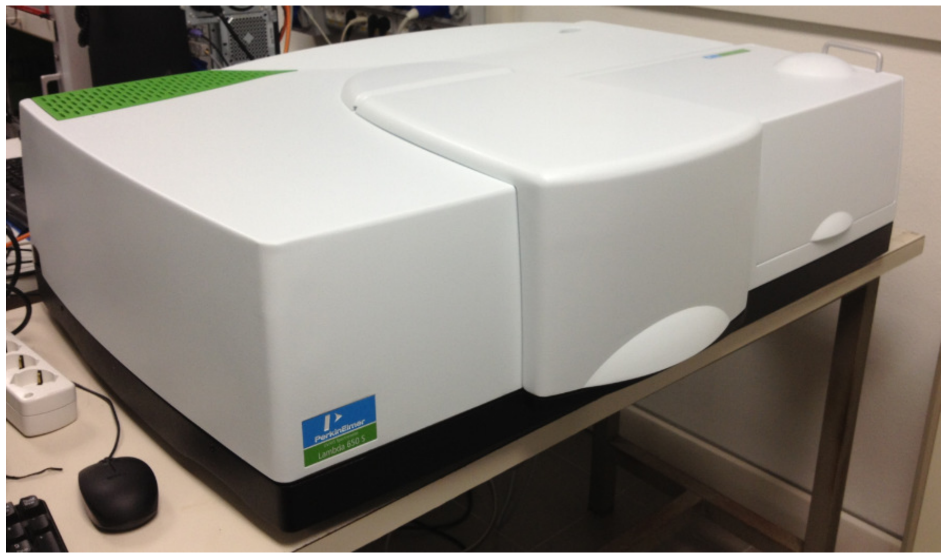
- Impossibility of illuminating every time the same point of the aerogel surface. Possible effect of local non-homogeneities

- During each measurement the multimeter quickly reaches a pseudo-stable value (for 1-2 seconds) followed by a slow fall-down of the signal amplitude, probably due to the non-uniform intensity of the laser (powered by standard batteries) over time.

The effects above result in a broadening of the measured transparencies for each tile.
The RMS of each set of measurements was assigned as an estimate of the global systematic uncertainty ΔT

Measurement of transparency (2)

More precise measurements were performed in Ferrara (before and after) the CERN test-beam using a Perkin-Elmer spectrophotometer.



The uncertainty assigned to the spectrophotometer measurements takes into account the spread of T values obtained by illuminating 6 different positions of a given tile:

$$\Delta T_{spectr} = \frac{1}{8} \sum_{i=1,8} \left(\frac{T_{max} - T_{min}}{2} \right) \approx 0.007$$

Table 1: Aerogel tiles used in the test-beam

Name	n	thickness (cm)	area (cm × cm)
Nov 1.04 2cm tile1	1.04	2	6×6
Nov 1.05 2cm tile1	1.05	2	6×6
Nov 1.05 2cm tile2	1.05	2	6×6
Nov 1.06 2cm tile1	1.06	2	6×6
Nov 1.05 3cm tile1	1.05	3	6×6
Nov 1.05 3cm tile3	1.05	3	6×6
Nov 1.05 3cm tile4	1.05	3	6×6
Nov 1.06 3cm tile1	1.06	3	6×6
Nov 1.06 3cm tile2	1.06	3	6×6
Nov 1.05 2cm Sample1	1.05	2	10×10
Nov 1.05 2cm Sample2	1.05	2	10×10
Nov 1.05 2cm Sample3	1.05	2	10×10
Nov 1.05 2cm Sample4	1.05	2	10×10
Nov 1.05 2cm Sample5	1.05	2	10×10
Nov 1.05 2cm Sample6	1.05	2	10×10
Nov 1.05 2cm Sample7	1.05	2	10×10
Nov 1.05 2cm Sample8	1.05	2	10×10
Nov 1.05 3cm AMS1	1.05	3	10×10
Nov 1.05 3cm AMS2	1.05	3	10×10
Nov 1.05 3cm AMS3	1.05	3	10×10
Nov 1.05 3cm AMS4	1.05	3	10×10

3 refractive indices
(1.04, 1.05, 1.06)

2 thicknesses
(2cm, 3cm)

2 areas
($6 \times 6\ cm^2, 10 \times 10\ cm^2$)

Results

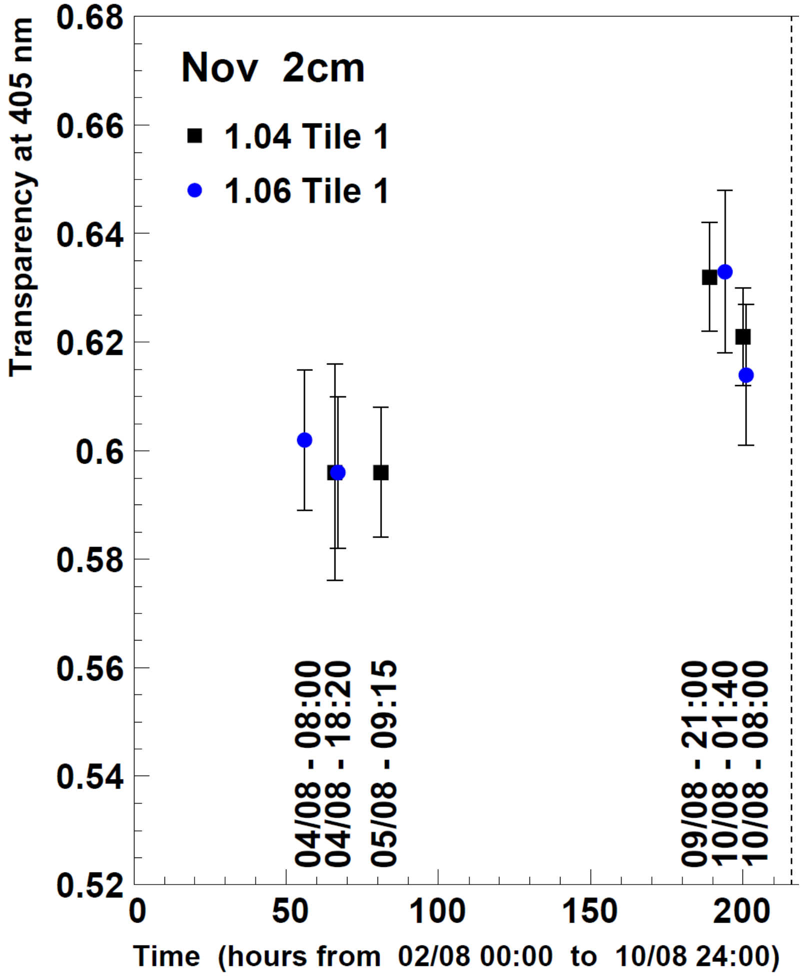


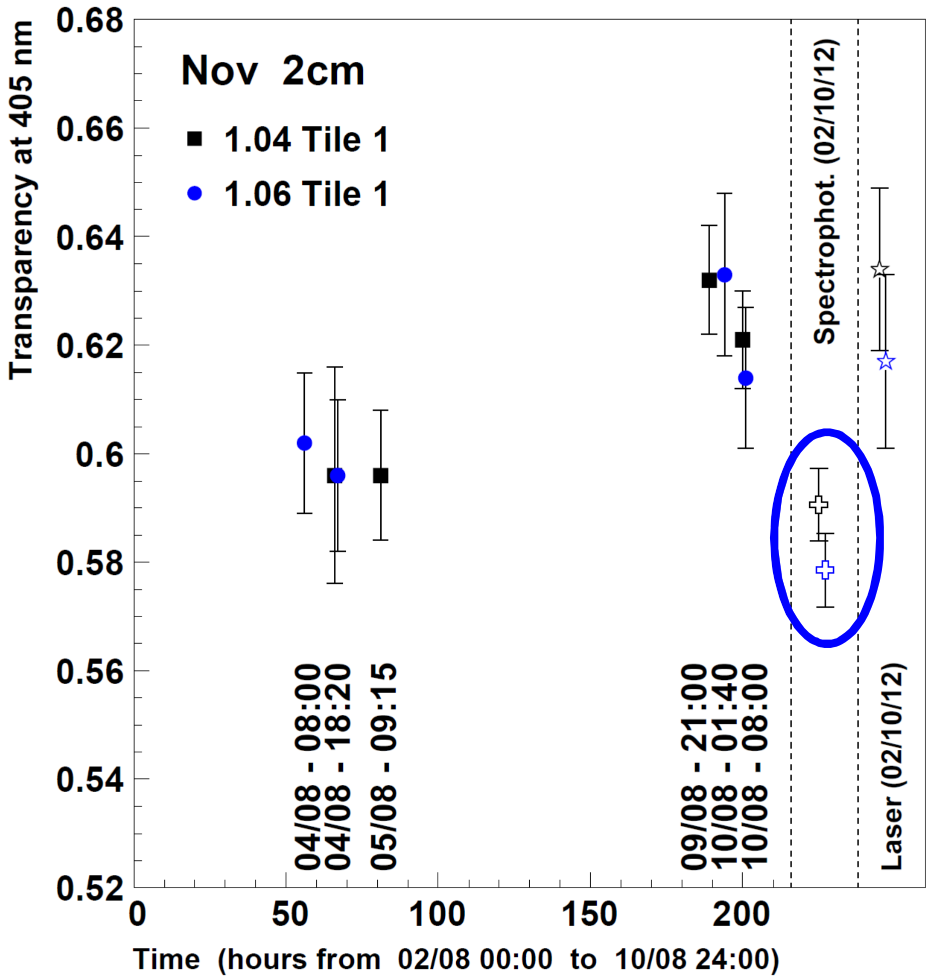
Table 2: **Nov. 1.04 2cm tile1**

Date/time of meas.	T_{min}	T_{max}	$T_{average}$	ΔT	notes
04/08/2012 18:20	0.570	0.638	0.596	0.020	meas. before SiMP run 390
05/08/2012 09:15	0.580	0.611	0.596	0.012	meas. after SiMP run 390
09/08/2012 21:00	0.614	0.648	0.632	0.010	meas. before SiMP run 432
10/08/2012 08:00	0.608	0.637	0.621	0.009	meas. before final packing

Table 3: **Nov. 1.06 2cm tile1**

Date/time of meas.	T_{min}	T_{max}	$T_{average}$	ΔT	notes
04/08/2012 08:00	0.584	0.619	0.602	0.013	meas. before SiMP run 383
04/08/2012 18:20	0.575	0.622	0.596	0.014	meas. after SiMP run 389
10/08/2012 01:40	0.615	0.657	0.633	0.015	meas. before SiMP run 439
10/08/2012 08:00	0.597	0.639	0.614	0.013	meas. before final packing

Results



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02/10/2012	0.608	0.654	0.634	0.015	meas. in Ferrara (laser)
02/10/2012			0.591	0.007	meas. in Ferrara (spectrophot.)

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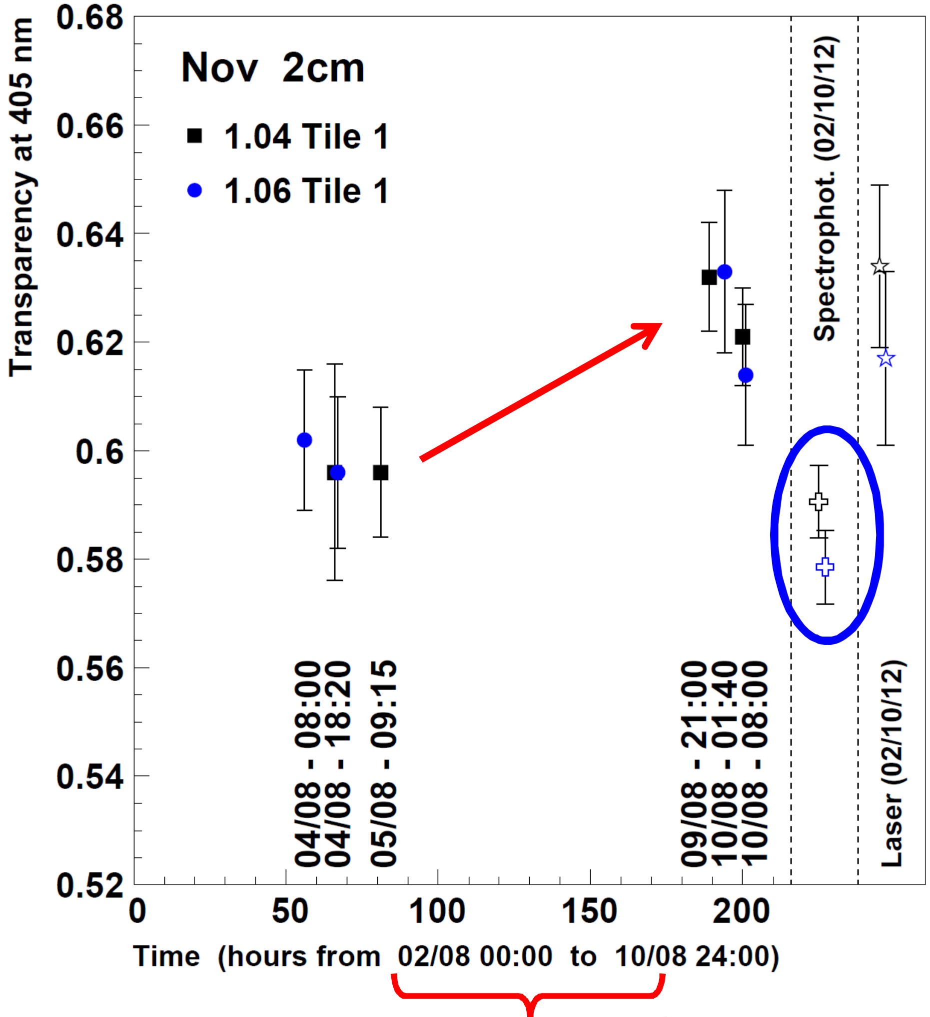

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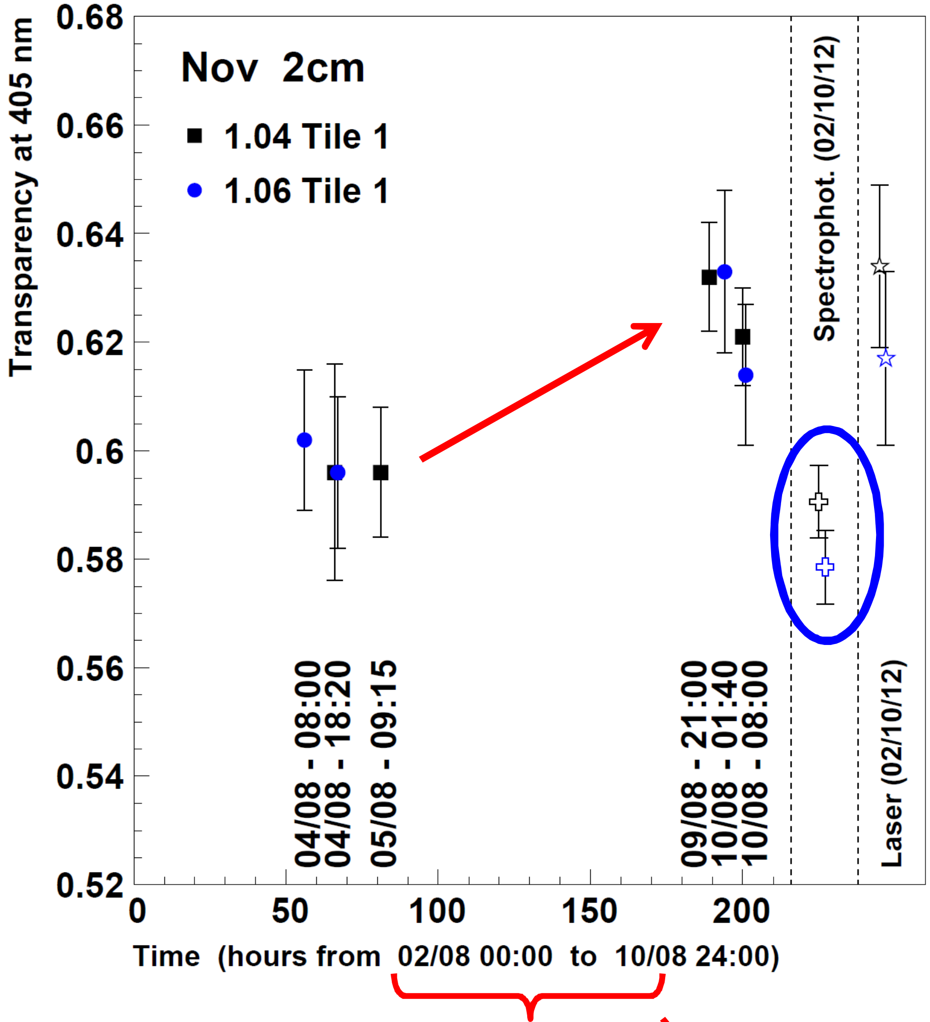
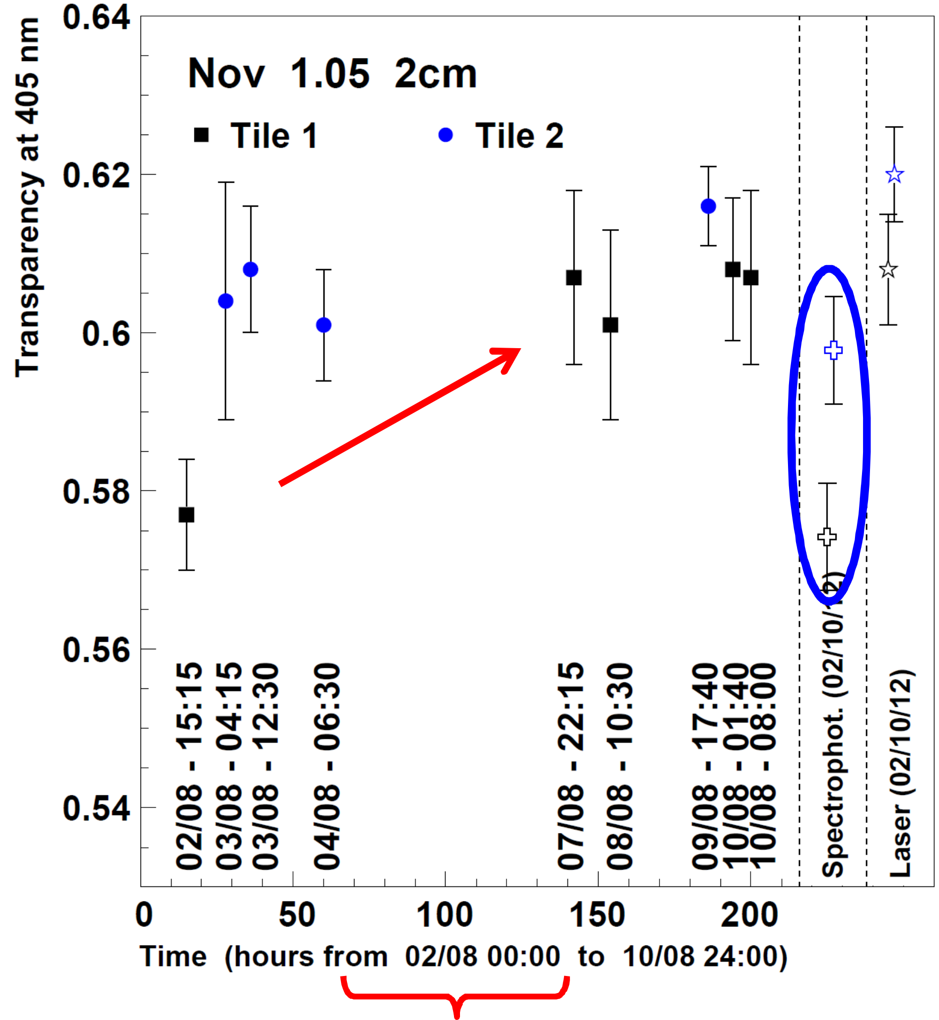
Storage in box with nitrogen

Results

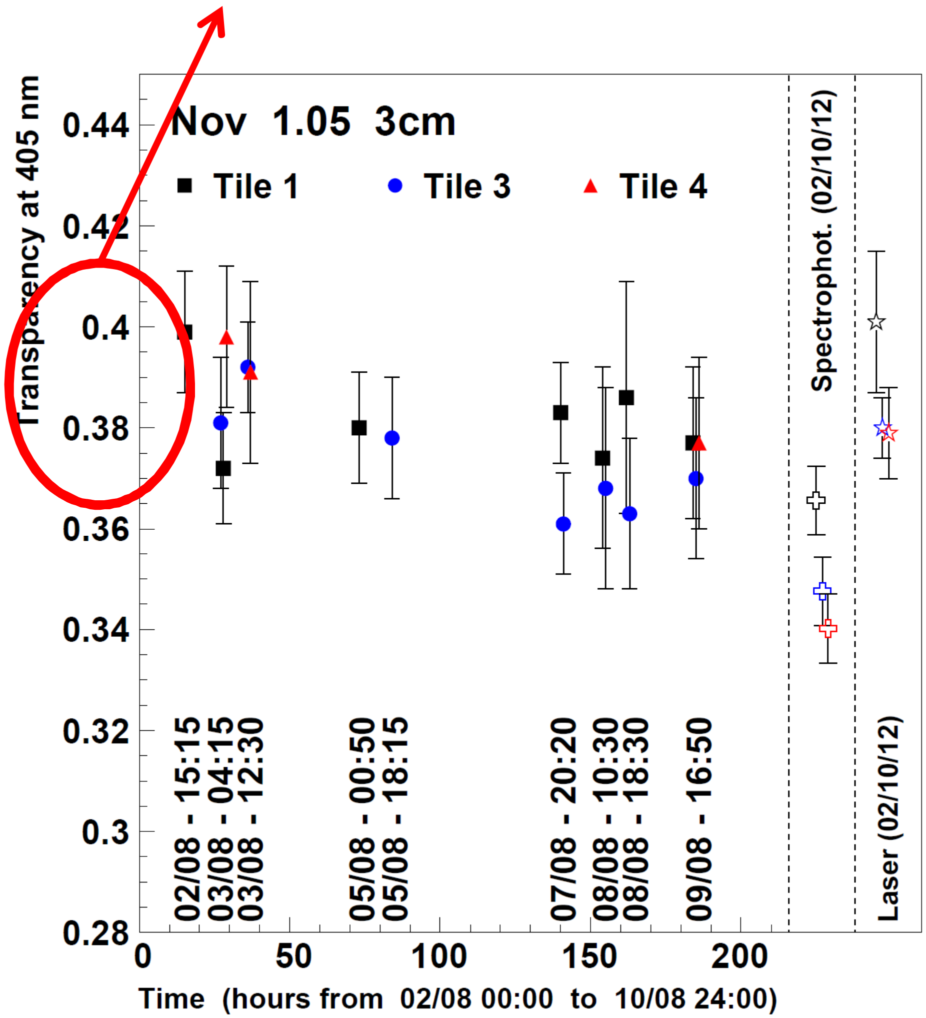


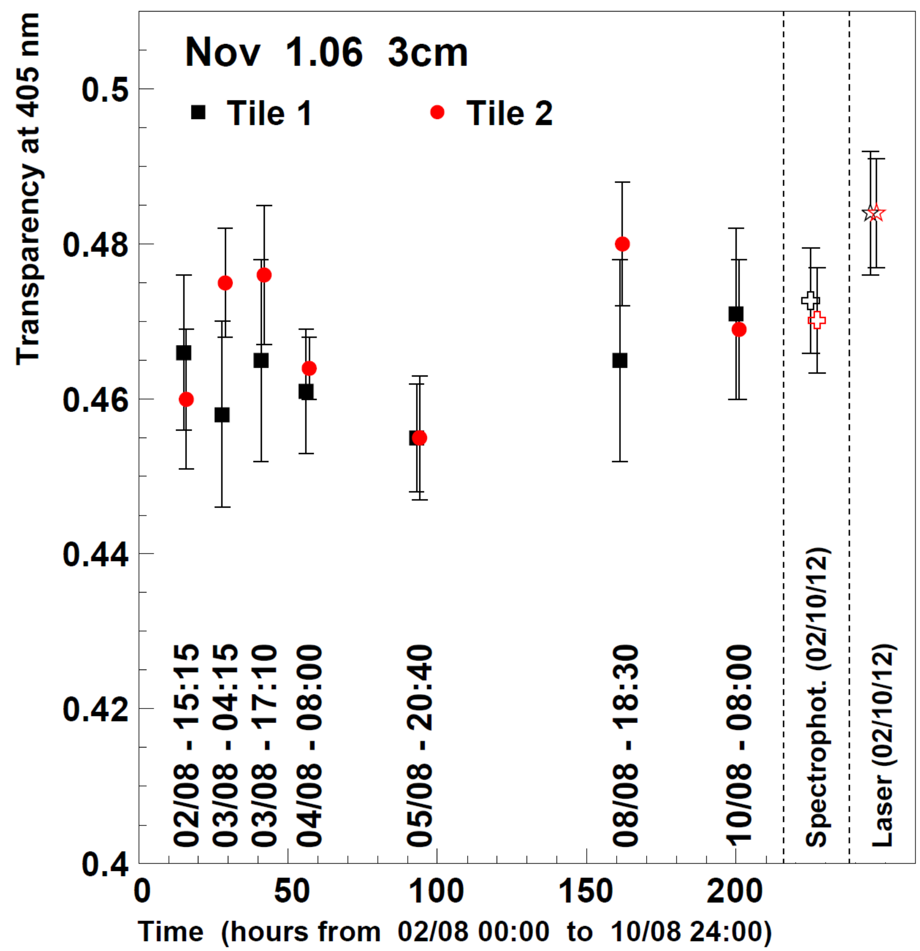


Storage in box with nitrogen

Results

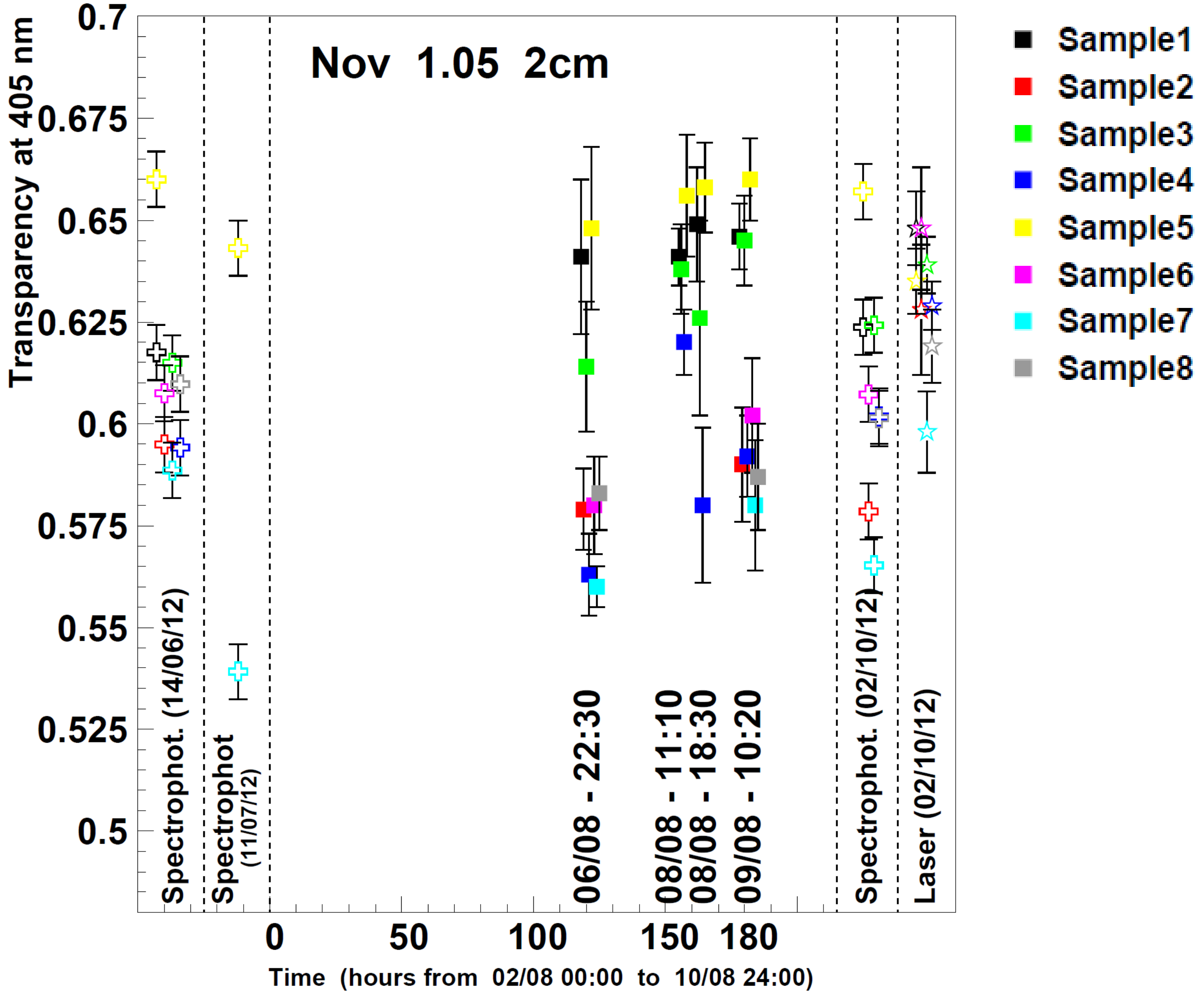
Very poor performances





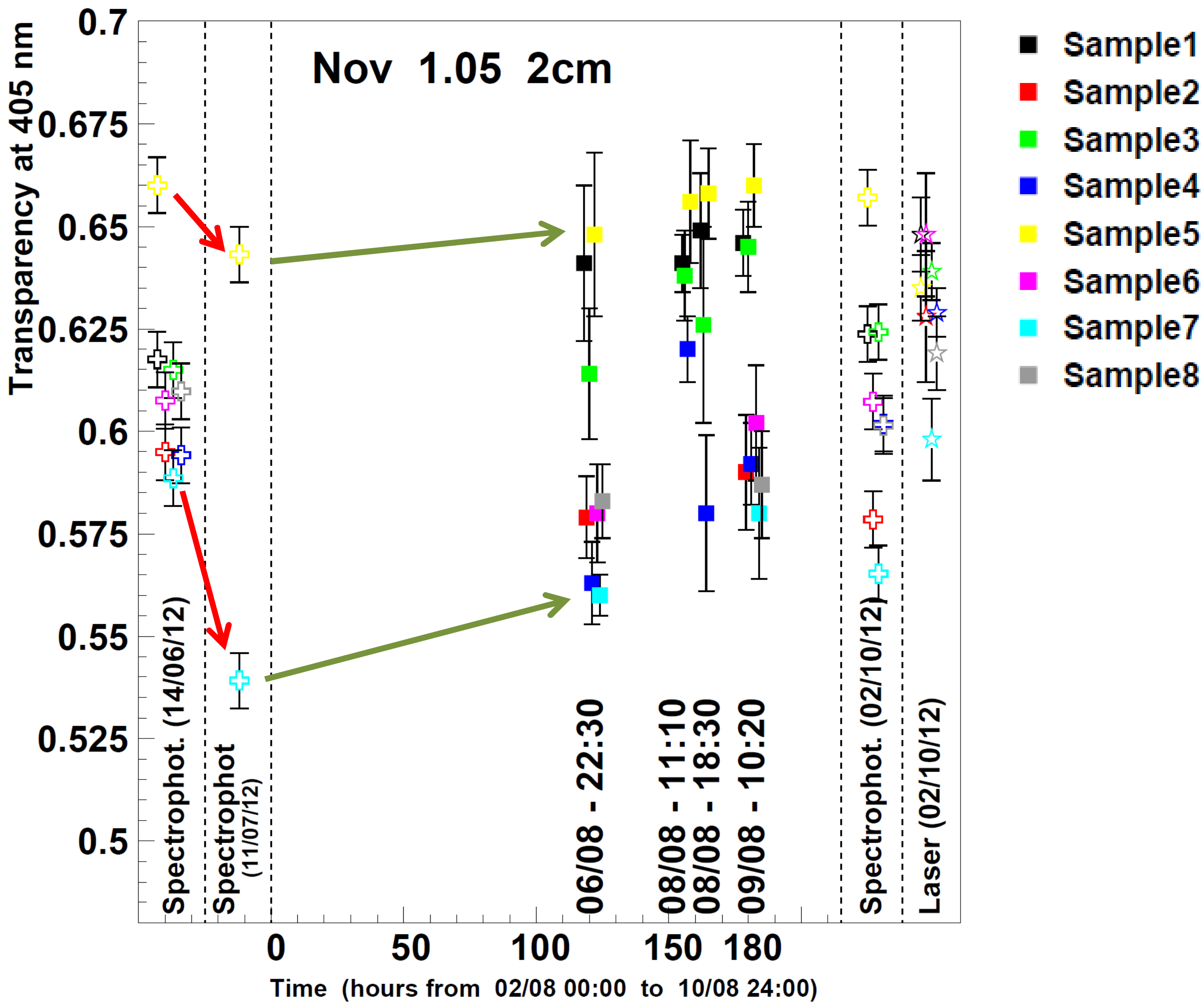
Results are relatively stable

Results



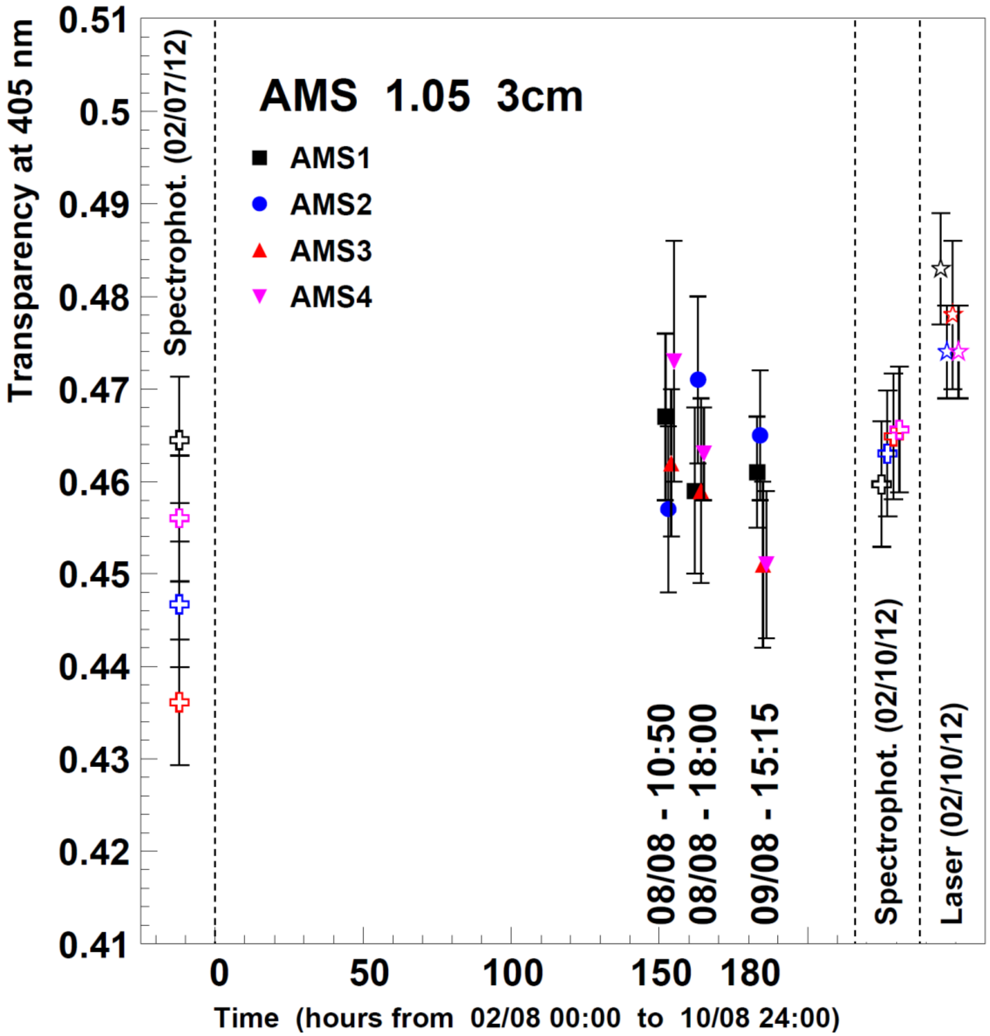
Nov 1.05 2cm
Transparency at 405 nm
0.7
0.675
0.65
0.625
0.6
0.575
0.55
0.525
0.5
Spectrophot. (14/06/12)
Spectrophot (11/07/12)
06/08 - 22:30
08/08 - 11:10
08/08 - 18:30
09/08 - 10:20
Spectrophot. (02/10/12)
Laser (02/10/12)
0
50
100
150
180
Time (hours from 02/08 00:00 to 10/08 24:00)
Sample1
Sample2
Sample3
Sample4
Sample5
Sample6
Sample7
Sample8

Results



After storage in dry cabinet

Results



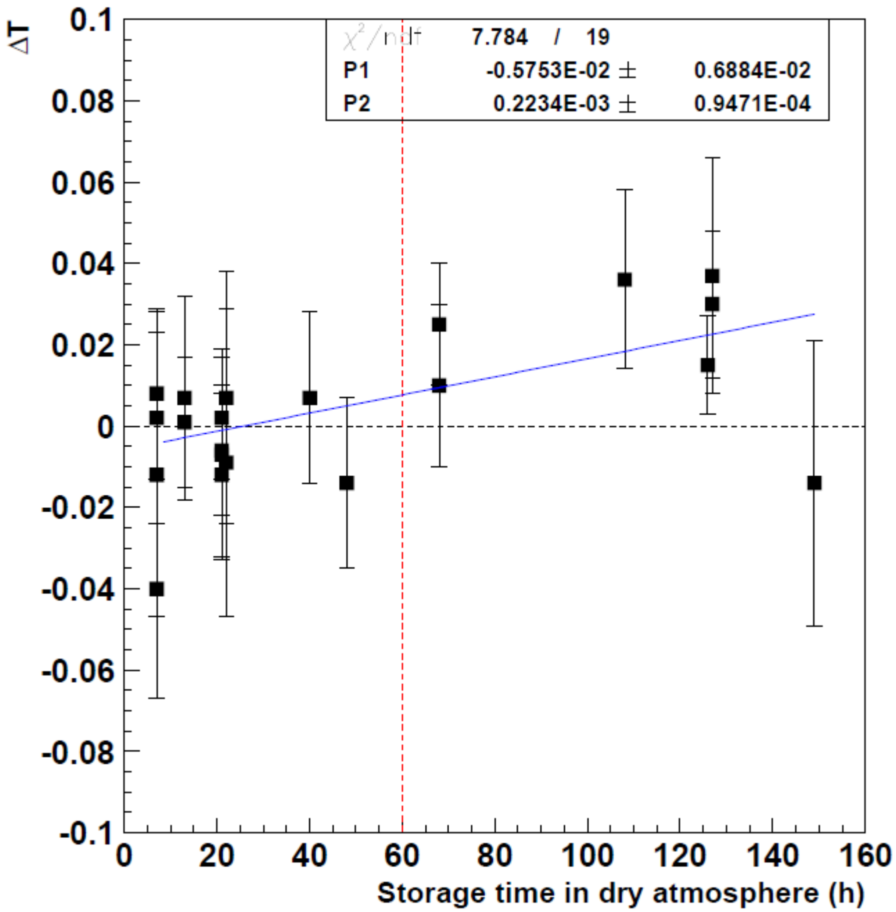
AMS 1.05 3cm
AMS1
AMS2
AMS3
AMS4
Transparency at 405 nm
0.51
0.5
0.49
0.48
0.47
0.46
0.45
0.44
0.43
0.42
0.41
Spectrophot. (02/07/12)
08/08 - 10:50
08/08 - 18:00
09/08 - 15:15
Spectrophot. (02/10/12)
Laser (02/10/12)
0
50
100
150
180
Time (hours from 02/08 00:00 to 10/08 24:00)

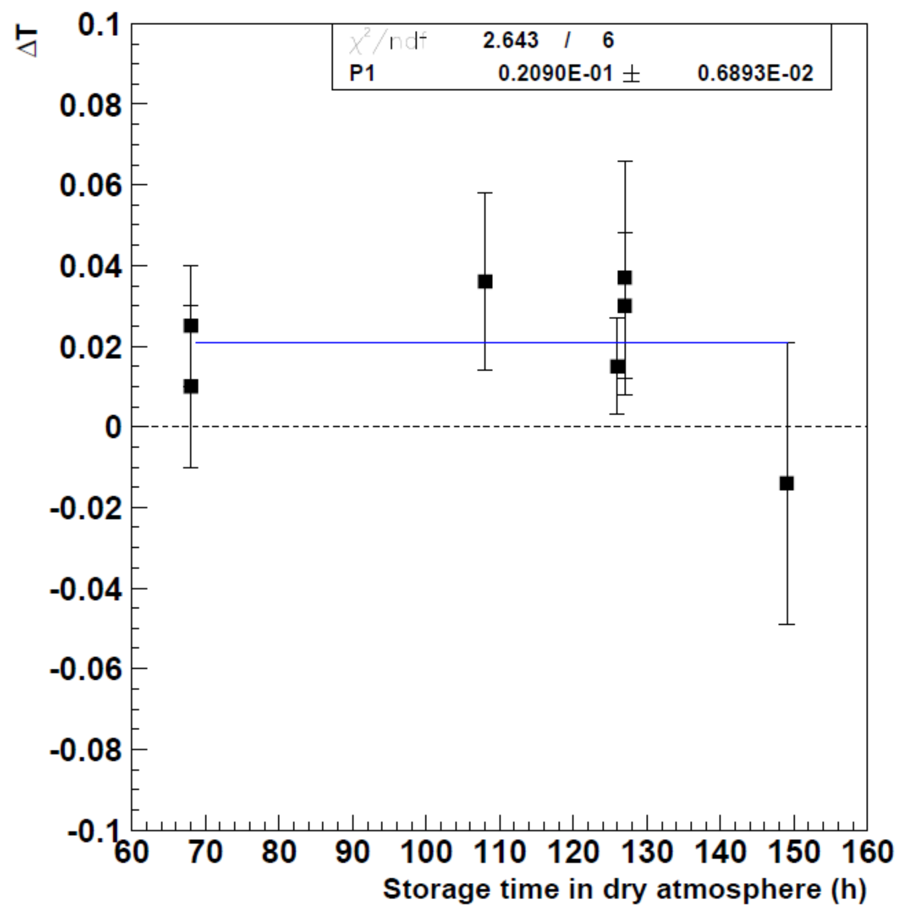
Looking for a general trend

Table 23: **After storage in dry atmosphere**

Aerogel tile	storage time (h)	T_{before}	T_{after}	**ΔT**
Nov. 1.05 3cm tile4	149	0.391 ± 0.018	0.377 ± 0.017	-0.014 ± 0.035
Nov. 1.06 2cm tile1	127	0.596 ± 0.014	0.633 ± 0.015	+0.037 ± 0.029
Nov. 1.05 2cm tile1	127	0.577 ± 0.007	0.607 ± 0.011	+0.030 ± 0.018
Nov. 1.05 2cm tile2	126	0.601 ± 0.007	0.616 ± 0.005	+0.015 ± 0.012
Nov. 1.04 2cm tile1	108	0.596 ± 0.012	0.632 ± 0.010	+0.036 ± 0.022
Nov. 1.06 3cm tile1	68	0.455 ± 0.007	0.465 ± 0.013	+0.010 ± 0.020
Nov. 1.06 3cm tile2	68	0.455 ± 0.007	0.480 ± 0.008	+0.025 ± 0.015
Nov. 1.05 3cm tile3	48	0.392 ± 0.009	0.378 ± 0.012	-0.014 ± 0.021
Nov. 1.05 2cm tile1	40	0.601 ± 0.012	0.608 ± 0.009	+0.007 ± 0.021
Nov. 1.05 3cm tile1	22	0.386 ± 0.023	0.377 ± 0.015	-0.009 ± 0.038
Nov. 1.05 3cm tile3	22	0.363 ± 0.015	0.370 ± 0.016	+0.007 ± 0.031
Nov. 1.05 3cm AMS1	21	0.459 ± 0.009	0.461 ± 0.006	+0.002 ± 0.015
Nov. 1.05 3cm AMS2	21	0.471 ± 0.009	0.465 ± 0.007	-0.006 ± 0.016
Nov. 1.05 3cm AMS3	21	0.459 ± 0.013	0.452 ± 0.013	-0.007 ± 0.026
Nov. 1.05 3cm AMS4	21	0.463 ± 0.007	0.451 ± 0.013	-0.012 ± 0.020
Nov. 1.06 3cm tile1	13	0.458 ± 0.012	0.465 ± 0.013	+0.007 ± 0.025
Nov. 1.06 3cm tile2	13	0.475 ± 0.007	0.476 ± 0.009	+0.001 ± 0.016
Nov. 1.05 2cm sample1	7	0.641 ± 0.007	0.649 ± 0.014	+0.008 ± 0.021
Nov. 1.05 2cm sample3	7	0.638 ± 0.011	0.626 ± 0.024	-0.012 ± 0.035
Nov. 1.05 2cm sample4	7	0.620 ± 0.008	0.580 ± 0.019	-0.040 ± 0.027
Nov. 1.05 2cm sample5	7	0.656 ± 0.015	0.658 ± 0.011	+0.002 ± 0.026

Looking for a general trend





1^{st} order polynomial fit:
hint of a slop (but low significance)

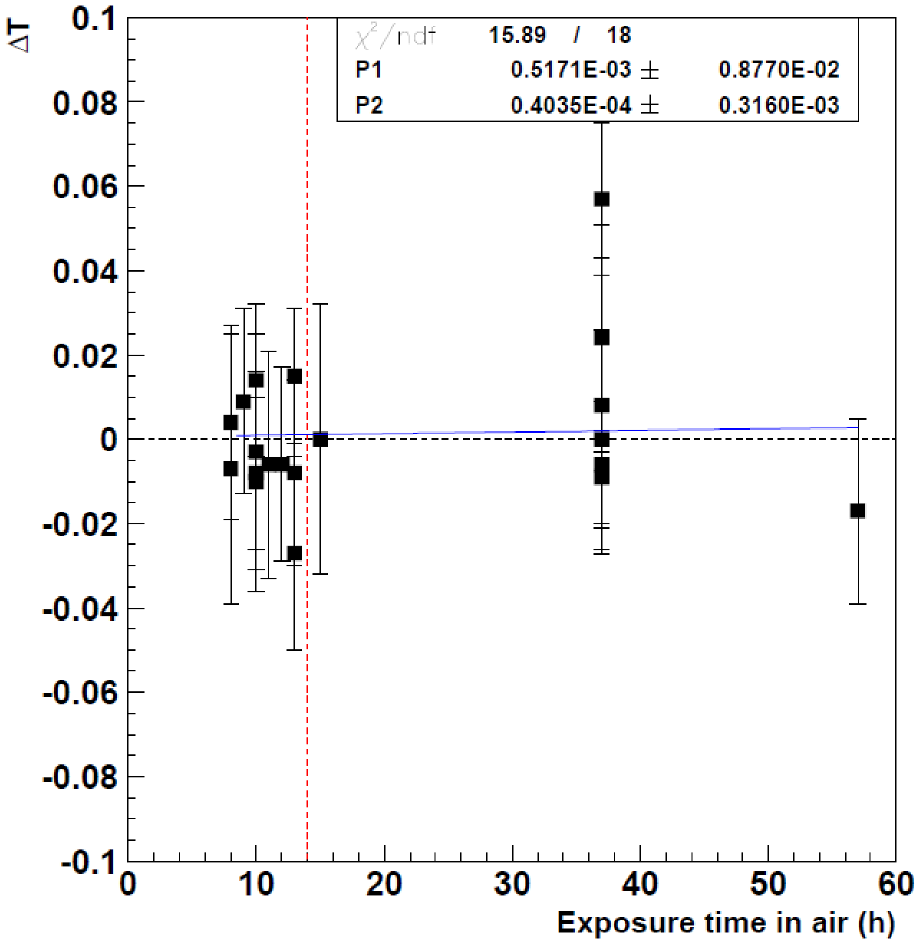
0^{th} order polynomial fit (constant):
$const \approx 0.021 \pm 0.007 \quad \rightarrow 3\sigma$

Looking for a general trend

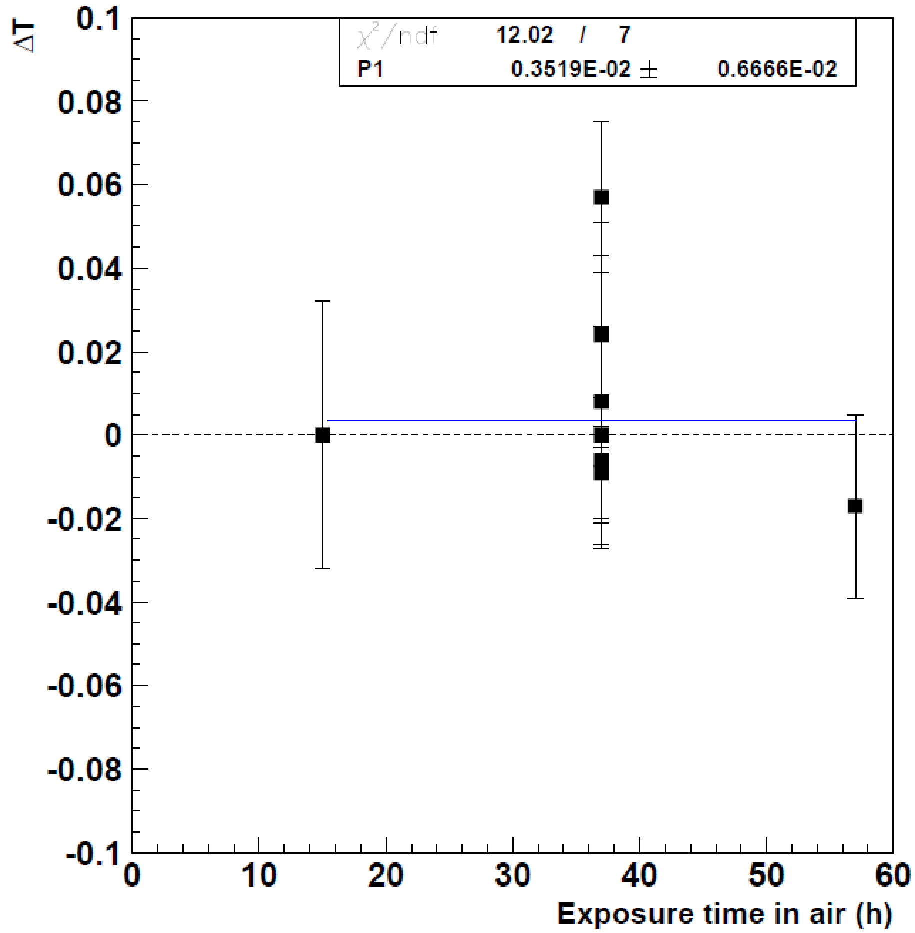
Table 24: **After exposure to air**

Tile	exposure time (h)	T_{before}	T_{after}	ΔT
Nov. 1.05 3cm tile3	57	0.378 ± 0.012	0.361 ± 0.010	-0.017 ± 0.022
Nov. 1.06 3cm tile1	37	0.461 ± 0.008	0.455 ± 0.007	-0.006 ± 0.015
Nov. 1.06 3cm tile2	37	0.464 ± 0.004	0.455 ± 0.007	-0.009 ± 0.011
Nov. 1.05 2cm sample1	37	0.641 ± 0.019	0.641 ± 0.007	0.000 ± 0.026
Nov. 1.05 2cm sample3	37	0.614 ± 0.016	0.638 ± 0.011	+0.024 ± 0.027
Nov. 1.05 2cm sample4	37	0.563 ± 0.010	0.620 ± 0.008	+0.057 ± 0.018
Nov. 1.05 2cm sample5	37	0.648 ± 0.020	0.656 ± 0.015	+0.008 ± 0.035
Nov. 1.04 2cm tile1	15	0.596 ± 0.020	0.596 ± 0.012	0.000 ± 0.032
Nov. 1.05 3cm tile1	13	0.399 ± 0.012	0.372 ± 0.011	-0.027 ± 0.023
Nov. 1.06 3cm tile1	13	0.466 ± 0.010	0.458 ± 0.012	-0.008 ± 0.022
Nov. 1.06 3cm tile2	13	0.460 ± 0.009	0.475 ± 0.007	+0.015 ± 0.016
Nov. 1.05 2cm tile1	12	0.607 ± 0.011	0.601 ± 0.012	-0.006 ± 0.023
Nov. 1.06 2cm tile1	11	0.602 ± 0.013	0.596 ± 0.014	-0.006 ± 0.027
Nov. 1.05 3cm AMS1	10	0.467 ± 0.009	0.459 ± 0.009	-0.008 ± 0.018
Nov. 1.05 3cm AMS2	10	0.457 ± 0.009	0.471 ± 0.009	+0.014 ± 0.018
Nov. 1.05 3cm AMS3	10	0.462 ± 0.015	0.459 ± 0.013	-0.003 ± 0.028
Nov. 1.05 3cm AMS4	10	0.473 ± 0.019	0.463 ± 0.007	-0.010 ± 0.026
Nov. 1.05 3cm tile3	9	0.381 ± 0.013	0.392 ± 0.009	+0.009 ± 0.022
Nov. 1.05 2cm tile2	8	0.604 ± 0.015	0.608 ± 0.008	+0.004 ± 0.023
Nov. 1.05 3cm tile4	8	0.398 ± 0.014	0.391 ± 0.018	-0.007 ± 0.032

Looking for a general trend



1^{st} order polynomial fit:
No significance (too short exposure times)



0^{th} order polynomial fit (constant):
No significance (too short exposure times)

Conclusions

- We developed a simple set-up for measuring the aerogel transparency, which is sufficiently precise for testing large scale variations and general behaviours;
- A more precise set-up (spectrophotometer) is available in Ferrara;
- The general behaviour of the aerogel transparency during the cern test-beam was consistent with expectations (no bad surprises!) and with earlier measurements done with spectrophotometer
- The transparency can be restored with different methods:
  - storage in nitrogen (check that line is clean!) for at least a few days
  - storage in dry cabinet (few days/weeks)
  - baking (200 celsius, for a few hours)
- The transparency has shown to be stable if tiles are sealed in small plastic bags
- The spectrophotomter data show a systematically smaller transparency than measyred with the laser method. To be understood.

Backup

Basic formalism

Transmittance

Hunt formula

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

$$A = TF = e^{-\frac{t}{\Lambda_A}} \implies \Lambda_A = \frac{-t}{\ln A}$$

Transflectance

$\Lambda_A = \frac{-t}{\ln A}$ **Absorption length**

$\Lambda_S = \frac{\lambda^4}{Ct} t$ **Scattering length**

Procedure: measure $T(\lambda) \rightarrow$ fit with Hunt formula $\rightarrow$ extract Λ_A and Λ_S

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Nuclear Instruments and Methods in Physics Research A 440 (2000) 338–347

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

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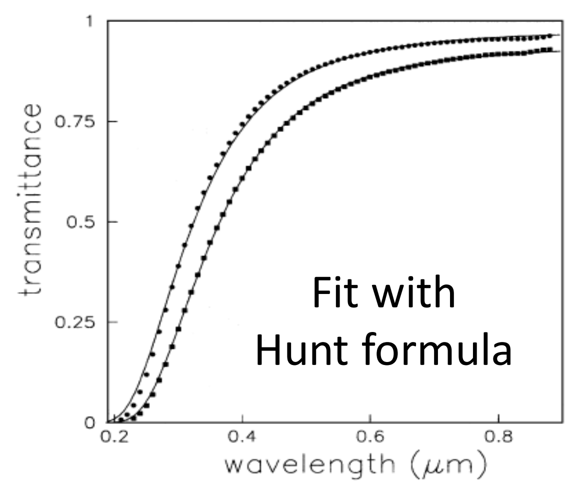
Optical characterization of $n = 1.03$ silica aerogel used as radiator in the RICH of HERMES

Hunt parameter	Average value	σ (%)
A	0.964	2.4
Ct (μm^4)	0.0094	8.3



Ferrara measurements