CLAS12-RICH Project Mid-term Review

AEROGEL

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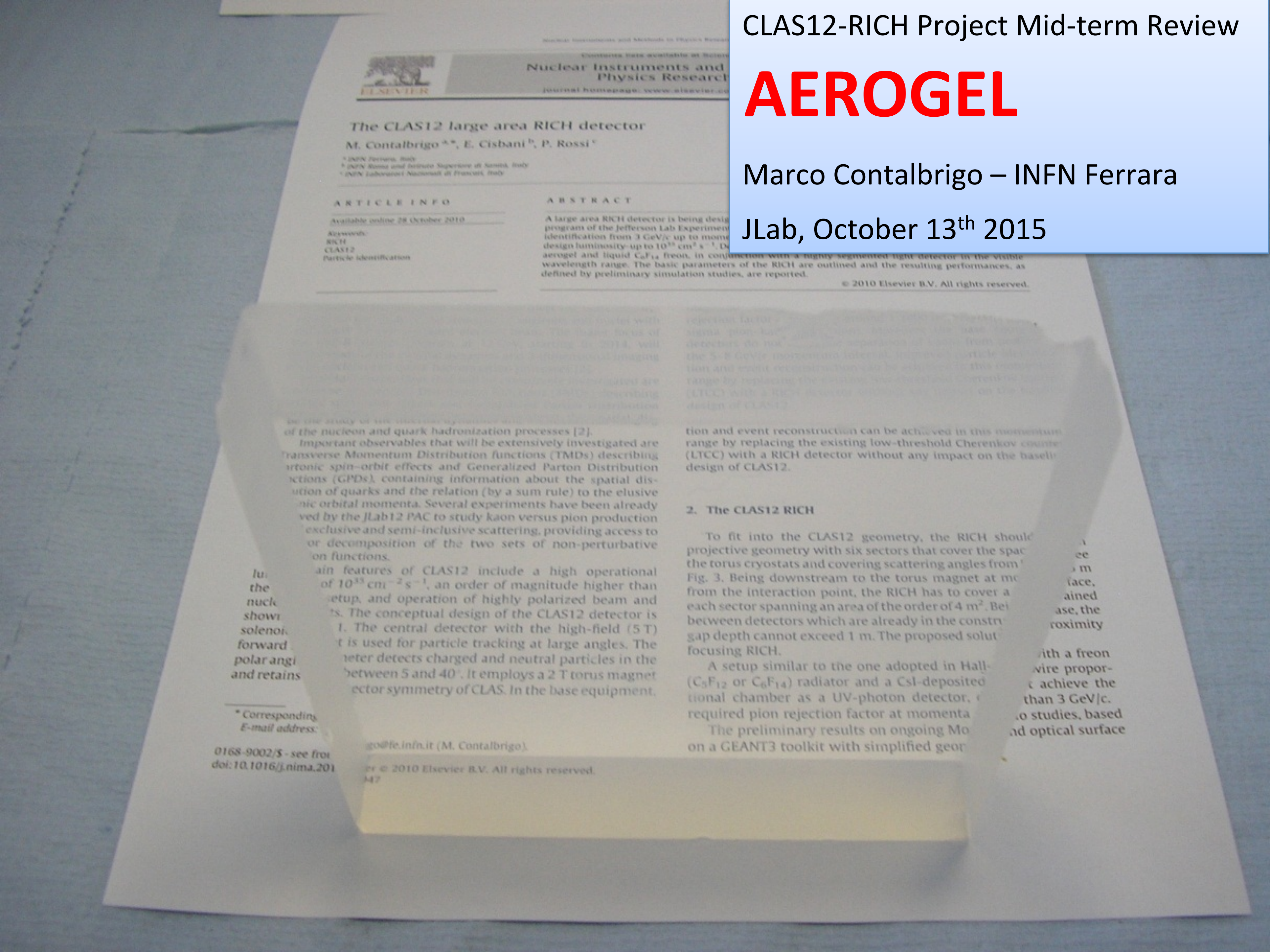
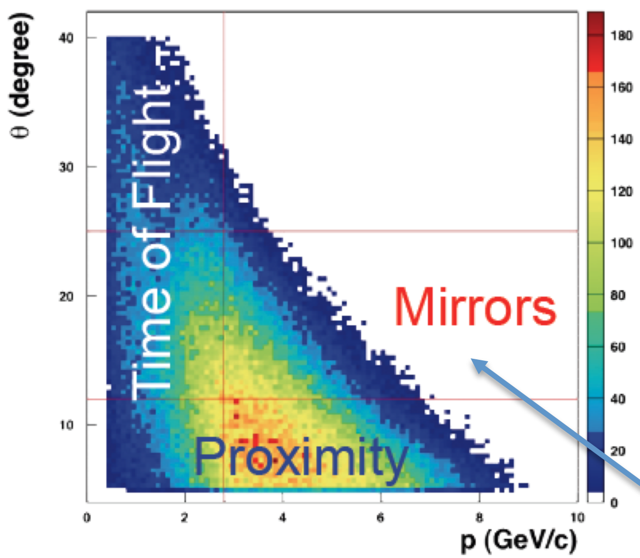
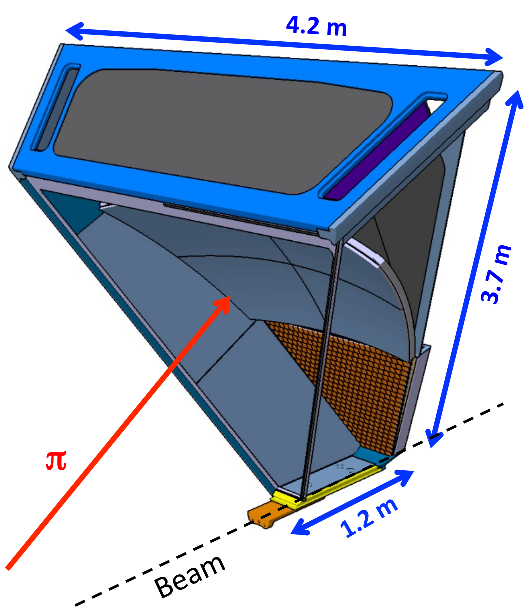
JLab, October 13th 2015

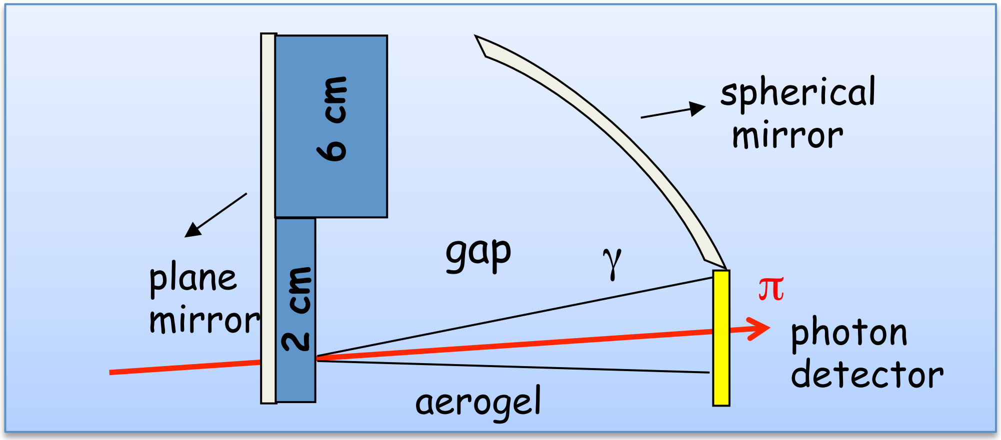


The Hybrid Optics Design

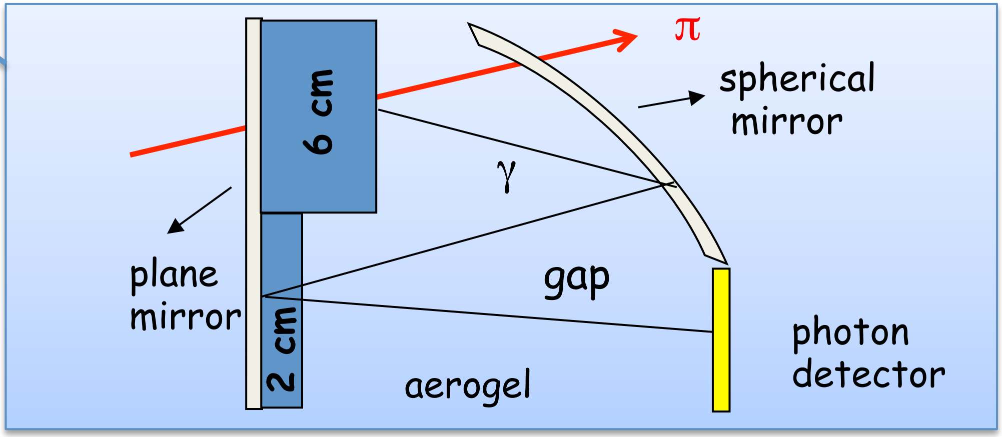




Direct rings and best performance for high momentum particles



Reflected rings for less demanding low momentum particles



- Minimize active area (cost) to about 1 m^2
- Material budget concentrated where TOF is less effective
- Focalizing mirrors allow thick radiator for good light yield
- Time resolution < 1 ns to distinguish direct and reflected patterns

Aerogel Production

First 3 cm thick layer (44 tiles) under production since November 2014

Initial goal: 25 % production efficiency

Initial performance (up to 8/15):

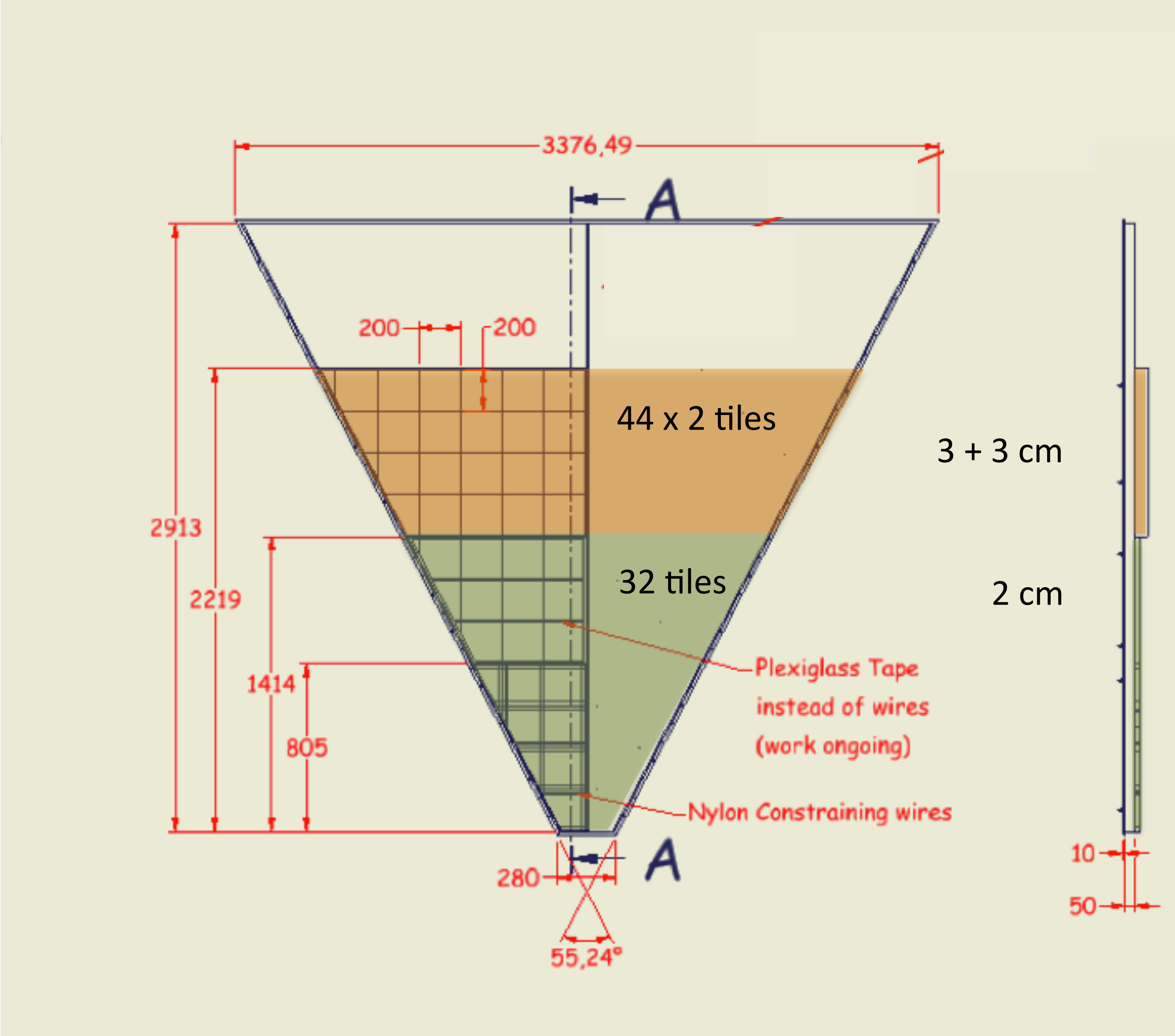
~ 2 months delay
for initial lack of chemicals

~ 3 months
to finalize acceptance test procedure

7 batches in ~4 months
- 105 tiles synthesized
- 50 tiles without cracks
- 18 tiles within specifications

Production rate capability
2 batches/month
Production efficiency
2.5 tiles/batch -> 17 % (conservative)

21 months up to completion



Aerogel Specifications

OPTICAL:

Density		$0.223 < \rho < 0.245$ gr/cm^3
Refractive index	$(n^2=1+0.438\,\rho)$	$1.0477 < n < 1.0523$
Scattering length		$L_{sc} > 43$ mm
Absorption coefficient		$A>0.95$

MECHANICAL:

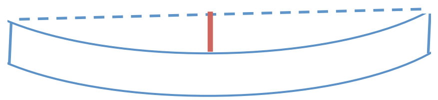
Side to side length variation $\Delta L_{side} < 0.25$ mm

from diamond wire to diamond wheel for better precision

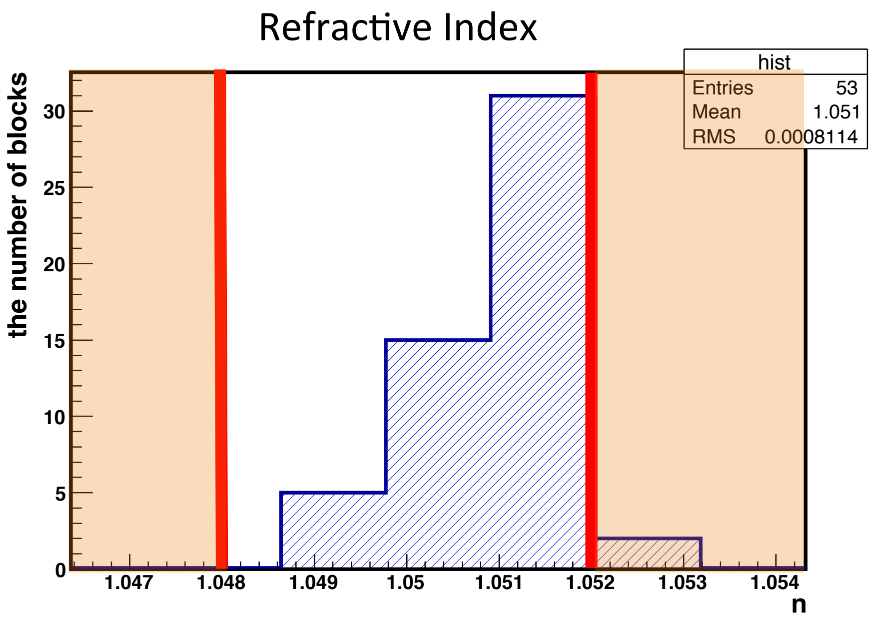
Tile to tile thickness variation $\Delta H_{tile} < 1.5$ mm

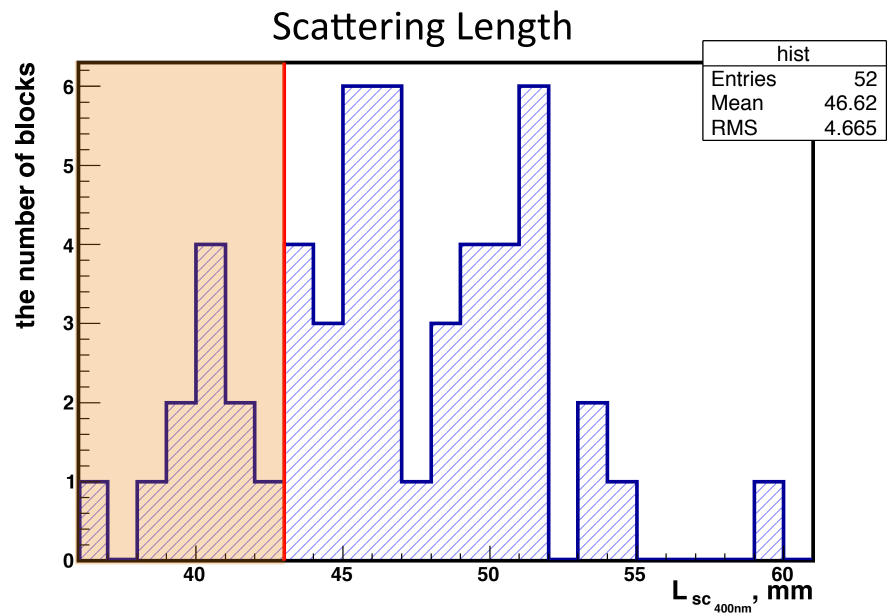
disregard molds with bad performance

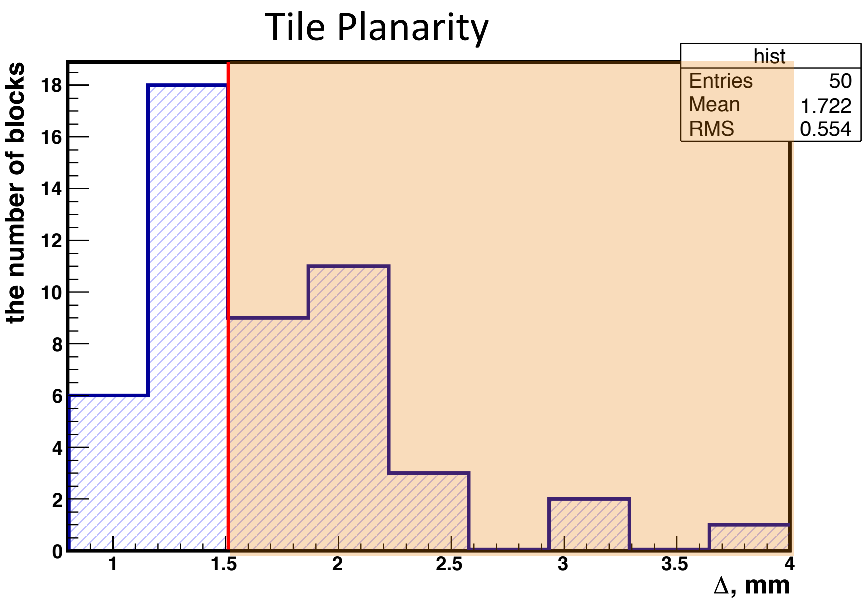
Surface planarity $\Delta S_{surf} < 1.5$ mm



Aerogel Specifications







Homogeneous refractive index ✔

20 % losses due to scattering length ✔
Average Scattering Length L_{sc} = 48.3 mm

50 % losses due to planarity ✔
Mitigation actions: relax planarity specifications
- increase the production efficiency close to 25 %

CLAS12 RHIC: Resolution

Resolution	**Direct (mrad)**	**Reflected (mrad)**
Emission Point	1.7	1.7
Readout Accuracy	2.1	1.0
Chromatic Aberration	3.0	2.5
Aerogel Optical Prop.	≤ 1	≤ 2
Mirror System		≤ 1
σ_θ (1 p.e.)	4.2	3.9
Requirements	Direct	Reflected
Max. momentum	8 GeV/c	6 GeV/c
σ_θ (4σ separation)	1.4 mrad	2.5 mrad
Np.e. Yield	≥ 10	≥ 3

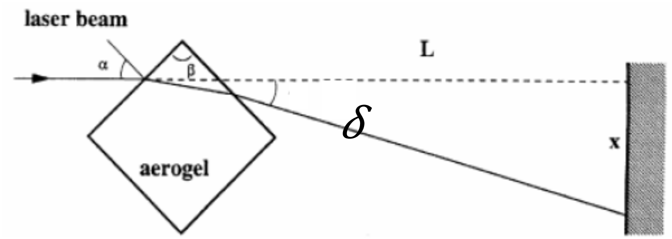
Validated with large scale prototype

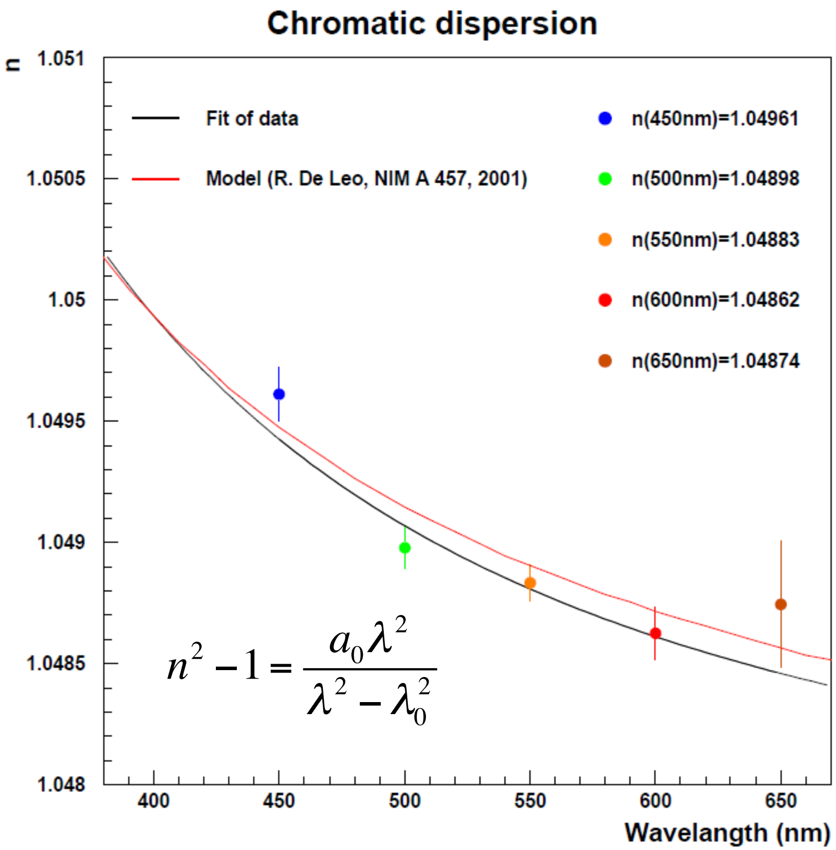
Studied in laboratory

$$\sigma_{\vartheta_{Ch}} = \sqrt{\sum_i \frac{\left(\sigma^i_{\vartheta_{Ch}}\right)^2}{N_{p.e.}}}$$

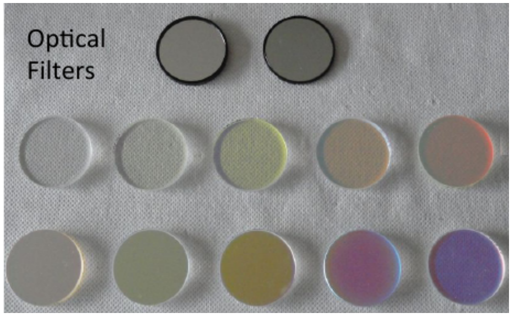
Aerogel Chromatic Dispersion

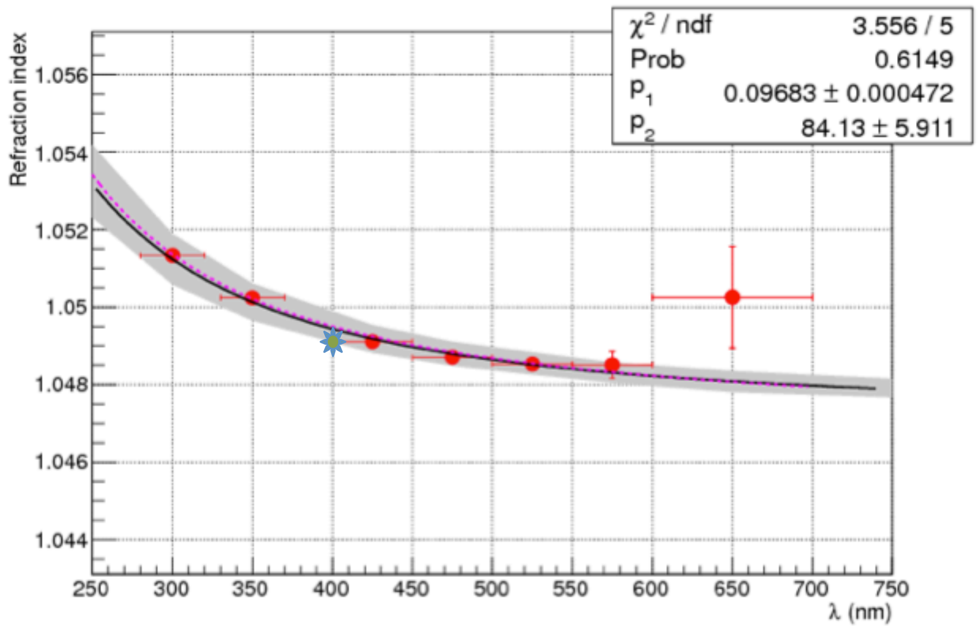
Measured by prisma method:





Measured by prototype with optical filters:



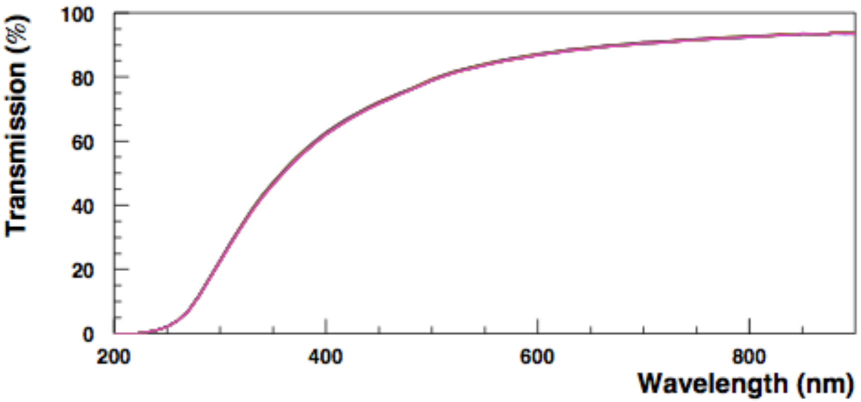


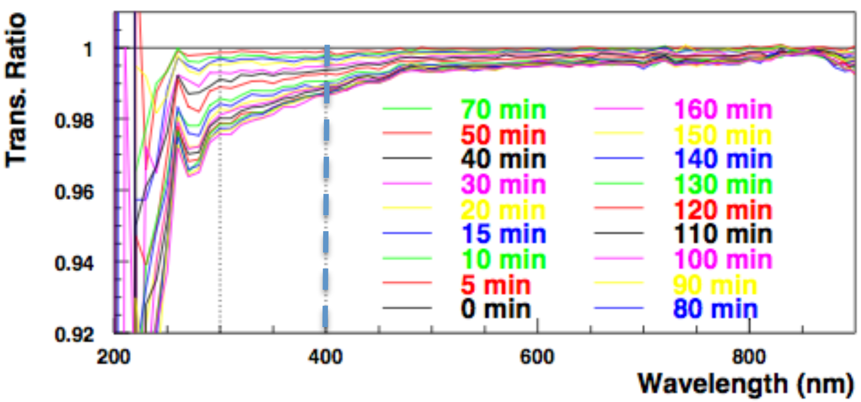
Expected value from density:

n(400nm) = $[1+0.438\rho]^{1/2}$ = 1.0492

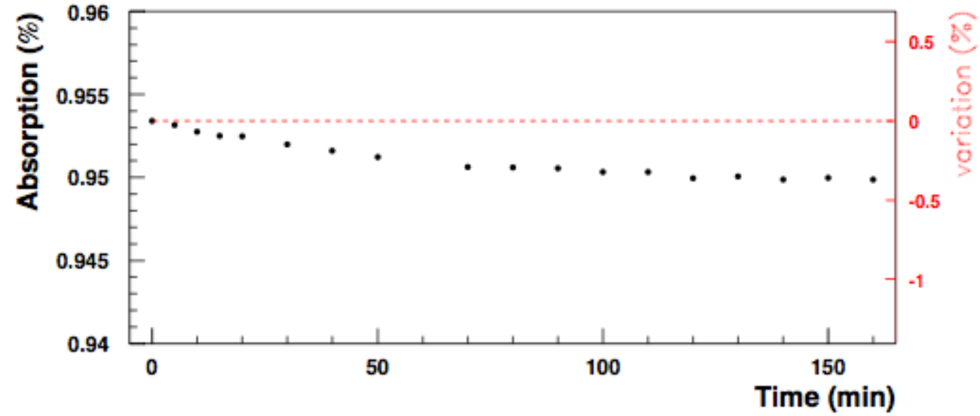
Aerogel Characteristics in the Air

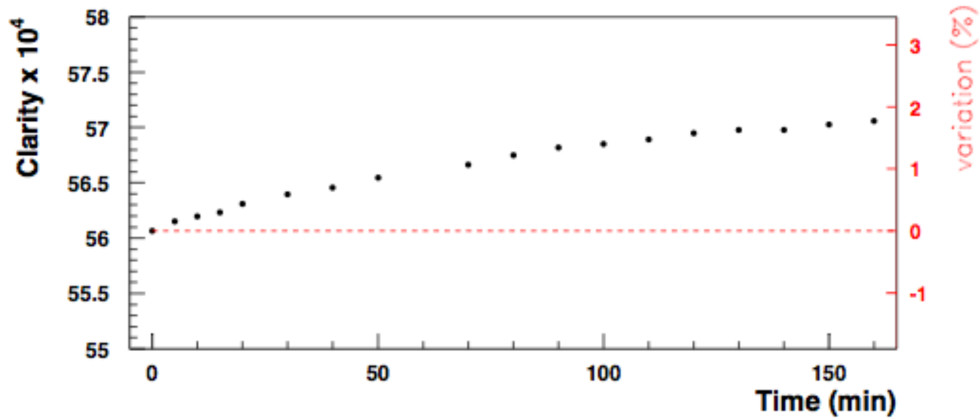
Transmission vs Time





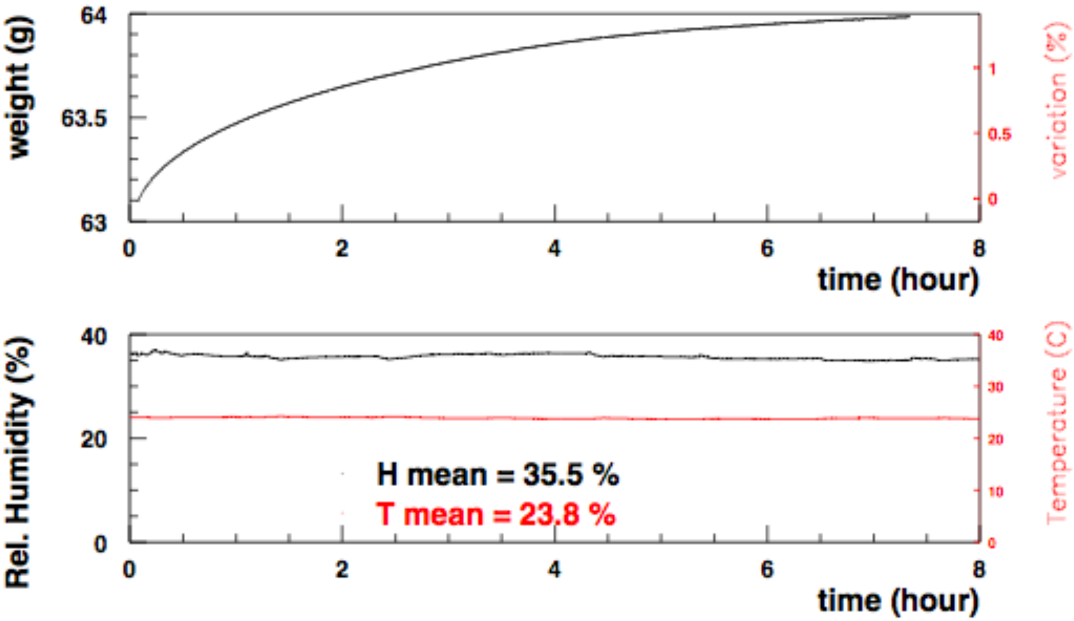
Absorption and Clarity @ 400 nm

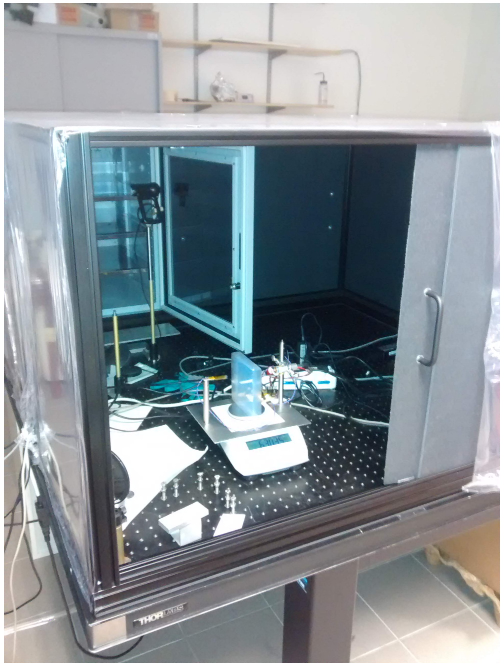




Monitoring the time dependence of the transmission of aerogel tile in environment of non-zero relative humidity (~ 40 %)

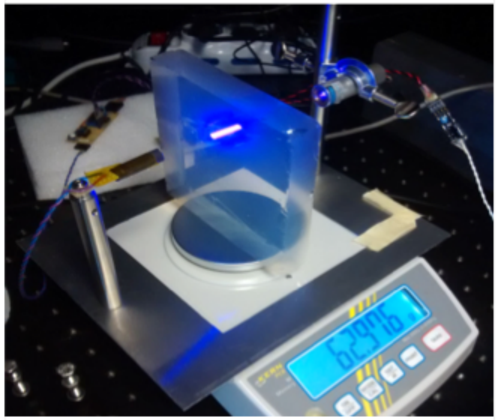
Aerogel Weight

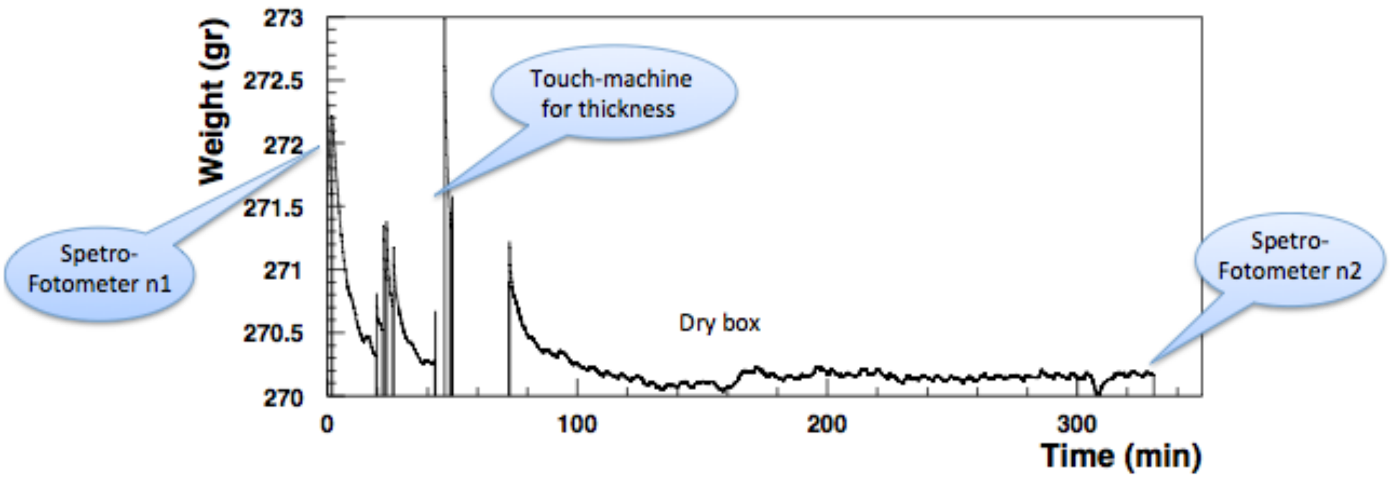




In Air (≈ 40 % RH)

Inside Dry-Box (≈ 1 % RH)





Aerogel Storage

Within sealed envelops

Inside a dry-cabinet (few % RH)

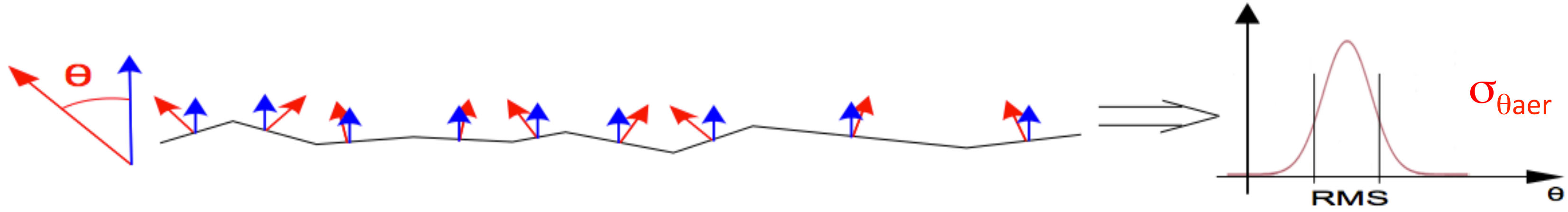
Spectro-fotometer Measurements

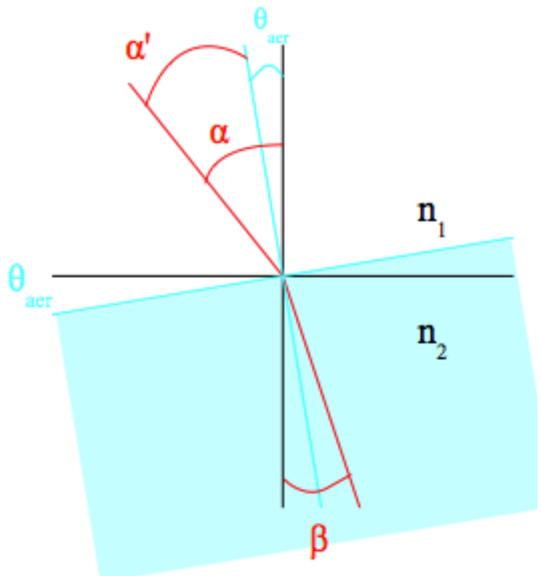
Acceptance tests during vendor visit in Ferrara (April 2015)

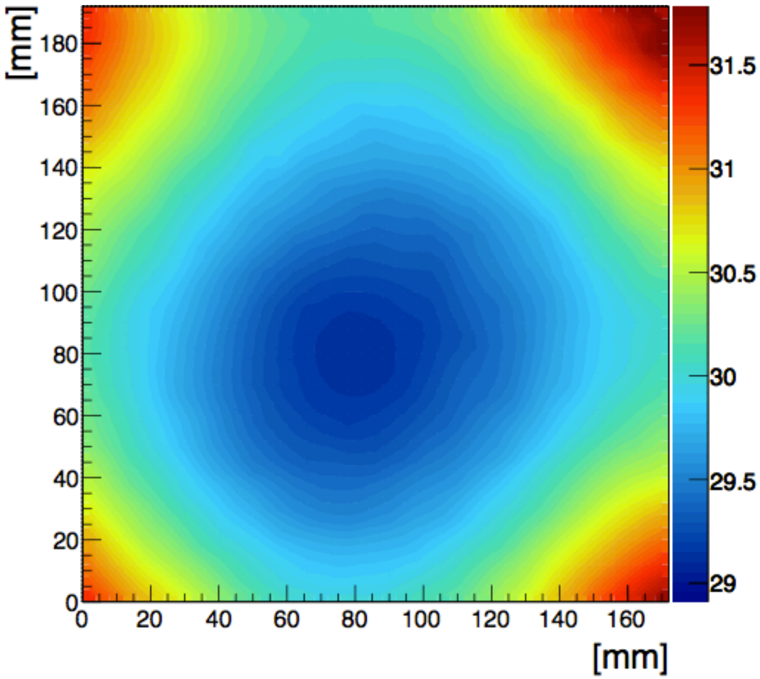
		Novosibirsk	Fe re-fit	Ferrara 1	Ferrara 2
	Date Meas.	28 Dec 2014	28 Dec 2014	16 Apr 2015 after delivery	17 Apr 15 after -1day drying
397m10	Lsc (mm)	49.2 ± 1.5	48.46 ± 0.50	45.59 ± 0.38	45.99 ± 0.39
	Abs (%)	97.7 ± 0.9	98.06 ± 0.61	95.60 ± 0.98	95.60 ± 1.06
	Date Meas.	20 Jan 2015		14 Apr 2015 after delivery	28 Apr 15 after 10-day drying
398m3	Lsc (mm)	40.93 ± 0.51		37.35 ± 0.47	37.59 ± 0.47
	Abs (%)	98.35 ± 0.7		96.37 ± 1.41	96.50 ± 1.36
	Date Meas.	28 Dec 2014	28 Dec 2014		
397m0	Lsc (mm)	48.20 ± 0.63	48.01 ± 0.42		
	Abs (%)	92.98 ± 0.5	93.05 ± 0.37		
	Date Meas.	22 Apr 2015 after trip to Novo	22 Apr 2015 after trip to Novo	16 Apr 2015 pre-baking	17 Apr 15 after baking
NOV LNF2 t1	Lsc (mm)	50.35 ± 0.36	49.79 ± 0.18	44.64 ± 0.63	49.62 ± 0.46
	Abs (%)	96.08 ± 0.05	96.26 ± 0.06	96.59 ± 0.42	96.59 ± 0.47

Result: Russian vendor agrees to bake twice: after production and before delivering

Aerogel Surface Quality







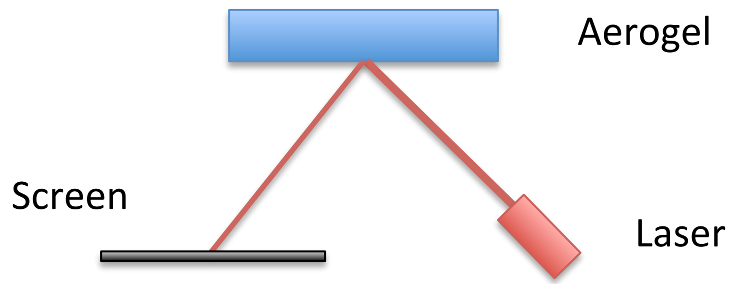
Refraction from a surface
with local normal deviation θ

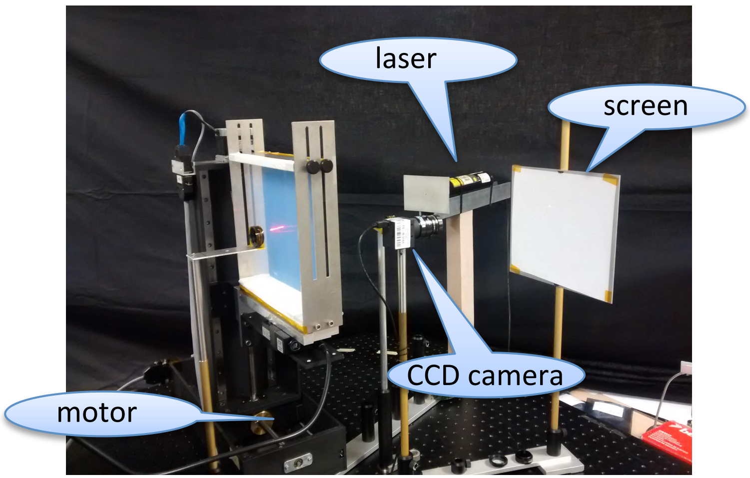
$$\beta = \vartheta_{aer} + \arcsin\left(\frac{1}{n}\sin(\alpha - \vartheta_{aer})\right)$$

Contribution on light dispersion
at small incident angles

$$\sigma_{\vartheta_{light}} = \left(1 - \frac{1}{n}\right) \cdot \sigma_{\vartheta_{aer}} \approx 0.05 \cdot \sigma_{\vartheta_{aer}}$$

Aerogel Surface Scan

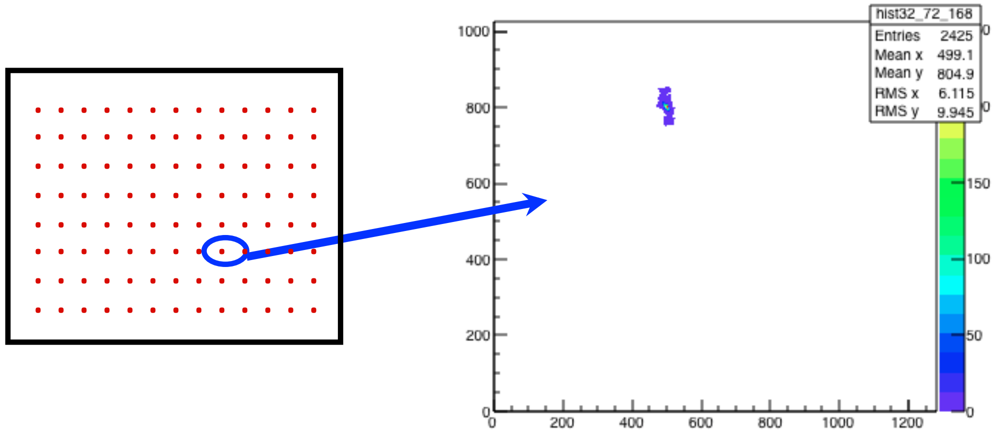




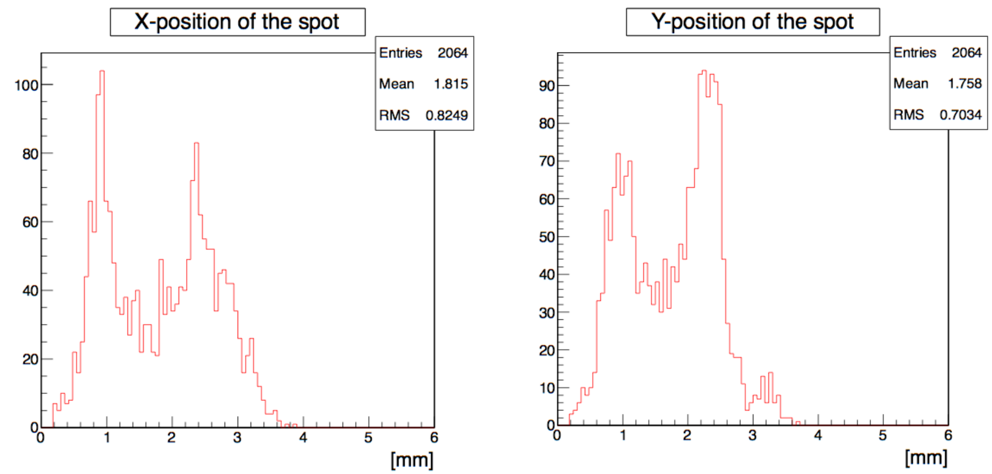
x-y axis movable table

CCD camera [ThorLabs DCU 224c]
- sensitive area [5.95-4.76 mm]
- resolution [1280-1024 pixels]
- pixel size 4.65 μm

Scan of aerogel surface



Distributions of X & Y positions of the spot



Aerogel Surface Planarity

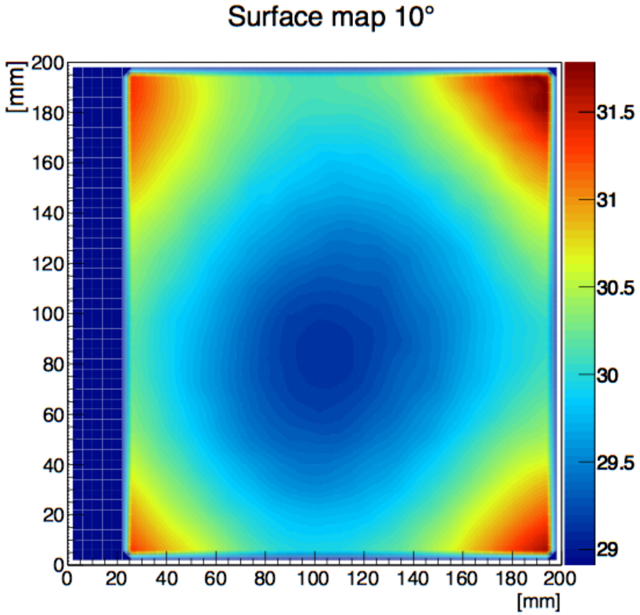
From laser spot shits to surface gradients

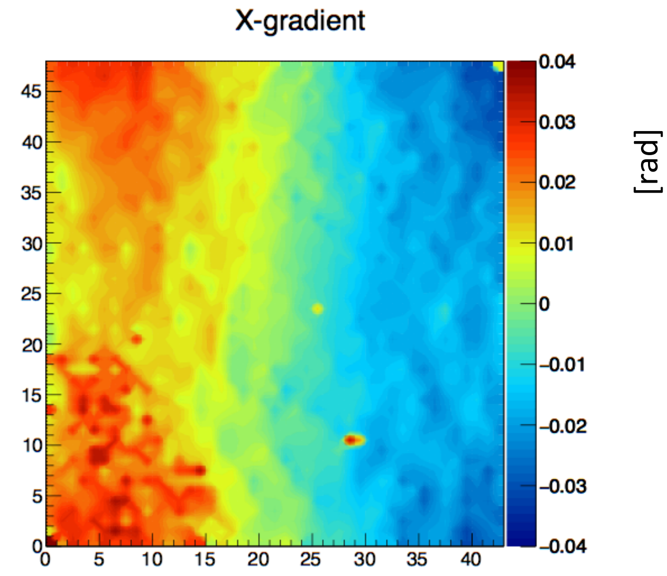
$$\nabla_x = \frac{(x - x_{mean})c_l}{2L}\cos(\theta)$$

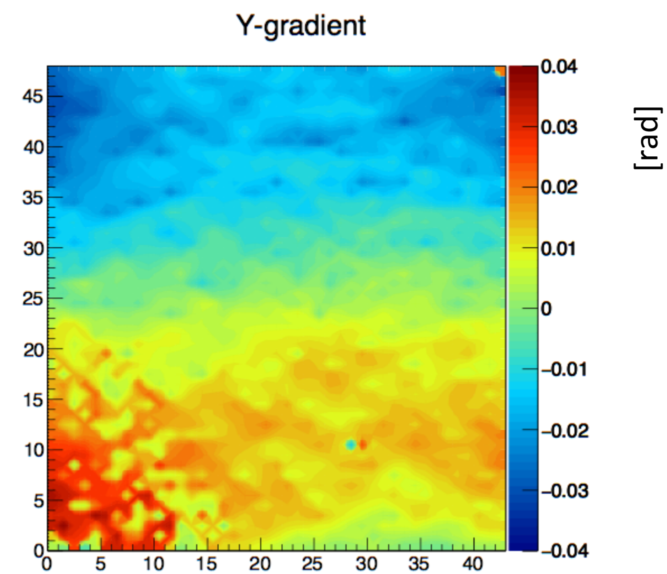
$$\nabla_y = \frac{(y - y_{mean})c_l}{2L}$$

$$L = R/cos(\theta)$$

From surface gradients to surface map by linear regression



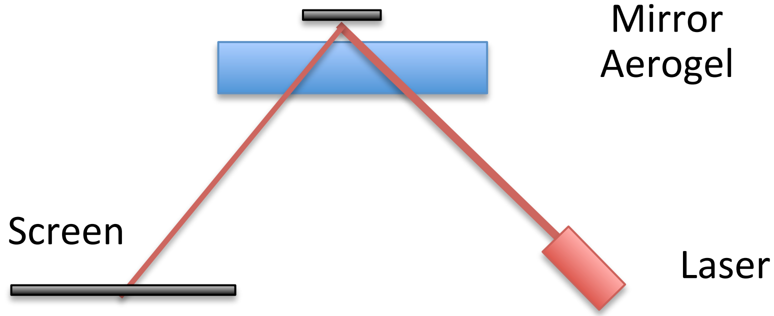


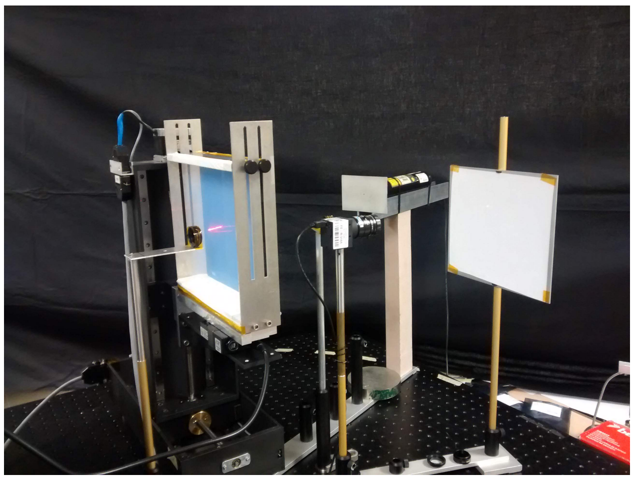


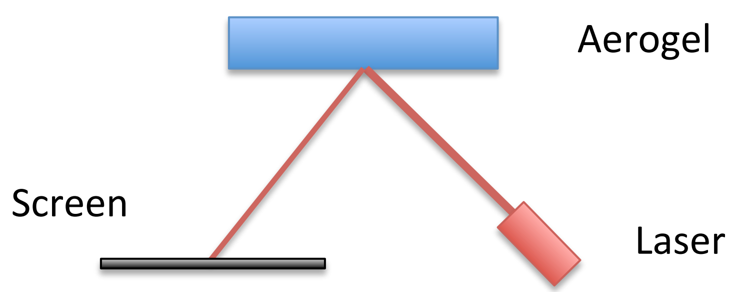
Validated with touch machine measurements

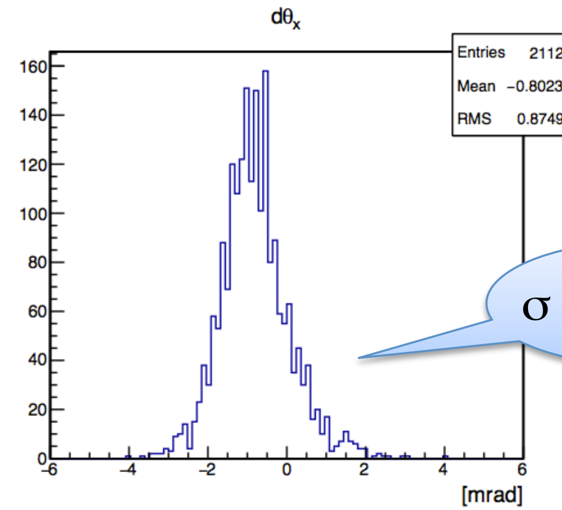
Consistent with Russian vendor planarity evaluation

Light Dispersion vs Aerogel Surface Quality

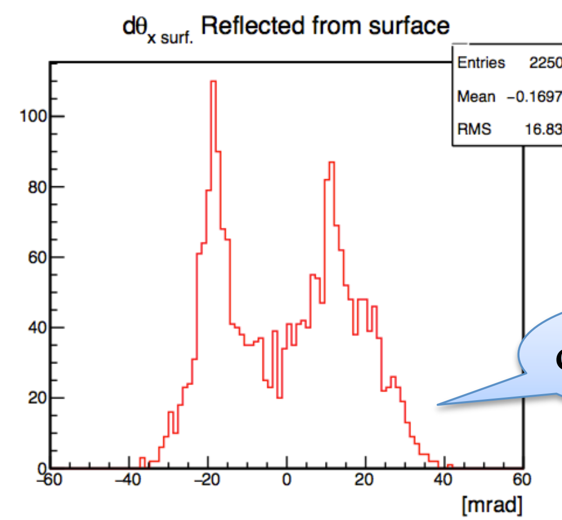








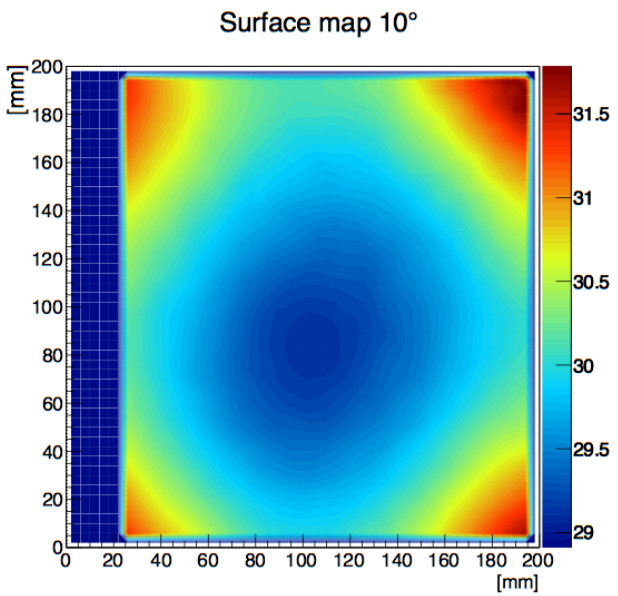
σ ~ 0.9 mrad

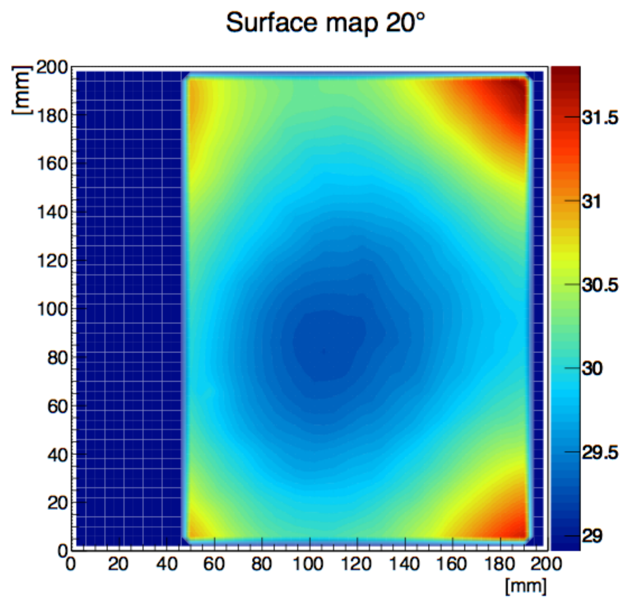


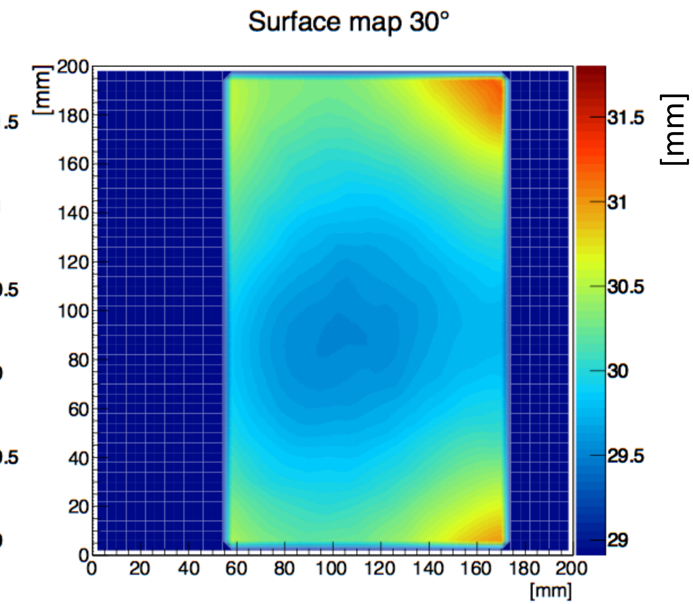
σ ~ 16 mrad

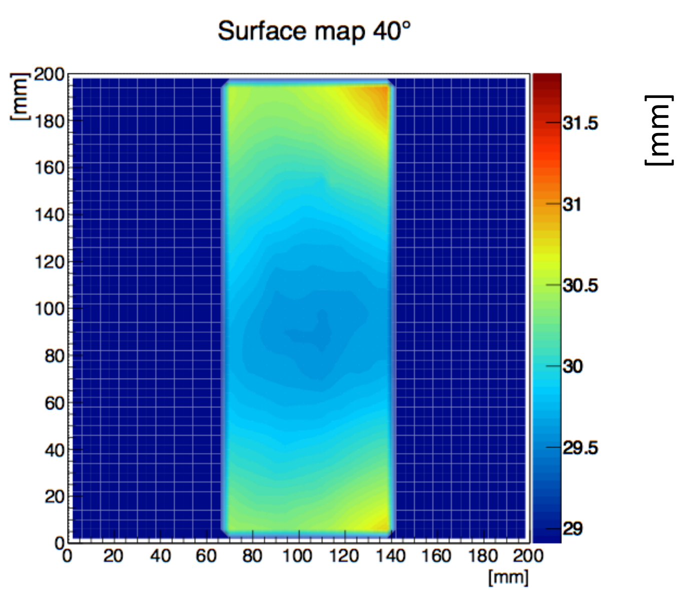
Acceptable light dispersion
up to ΔS_{surf} = 2.5 mm planarity

Aerogel Surface Map

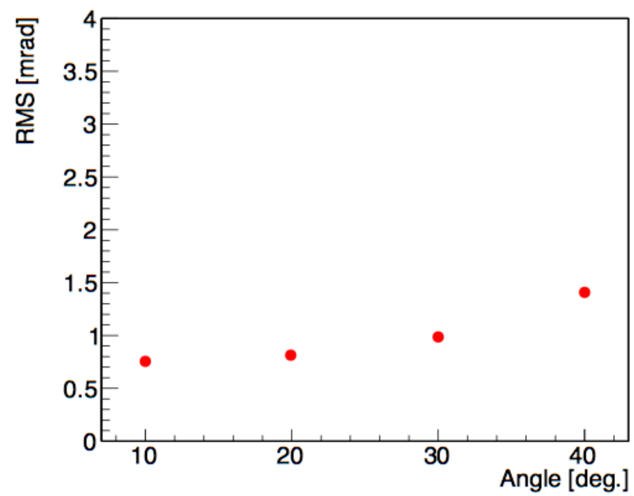






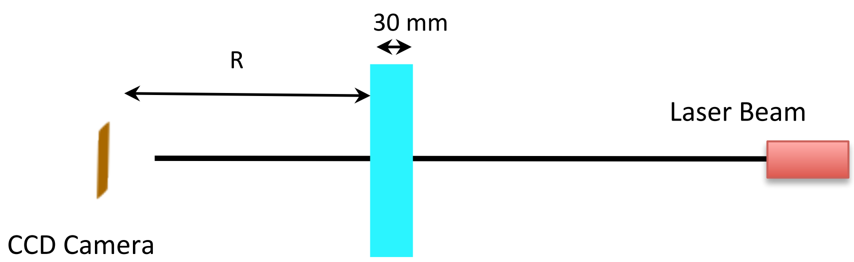


Light dispersion as a function of incident angle:



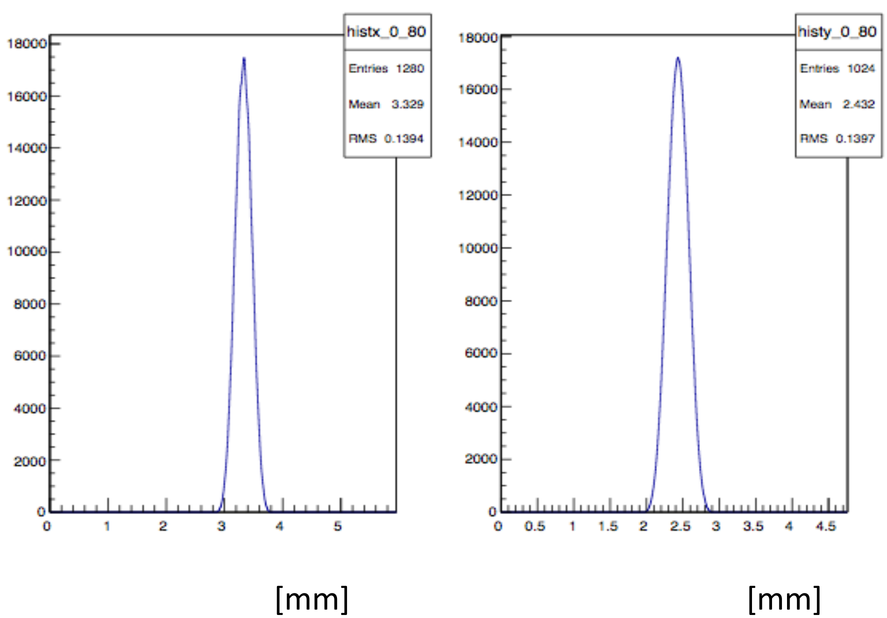
Forward Scattering

Description of the setup



Scattering of the light in the medium due to the anysotropy of the dielectric properties caused by density microscopic fluctuations

Examples of X & Y profiles of the spot

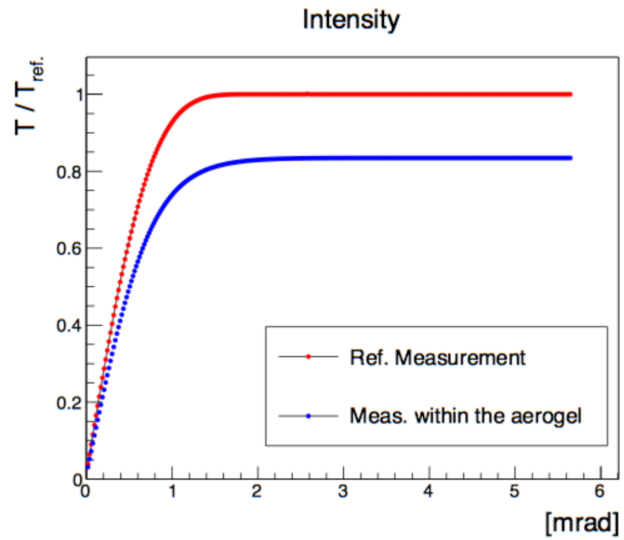


Analysis steps:

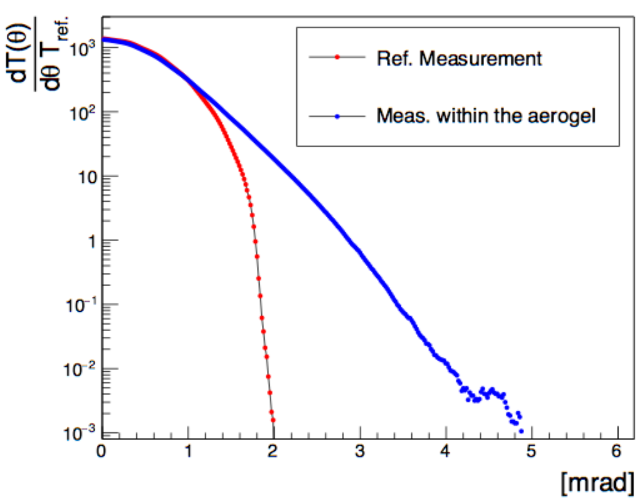
- Reference beam profile taken without aerogel
- Extract laser beam profile and compare with reference measurement
- Extract angular dependence of light intensity after passage through the aerogel

Forward Scattering

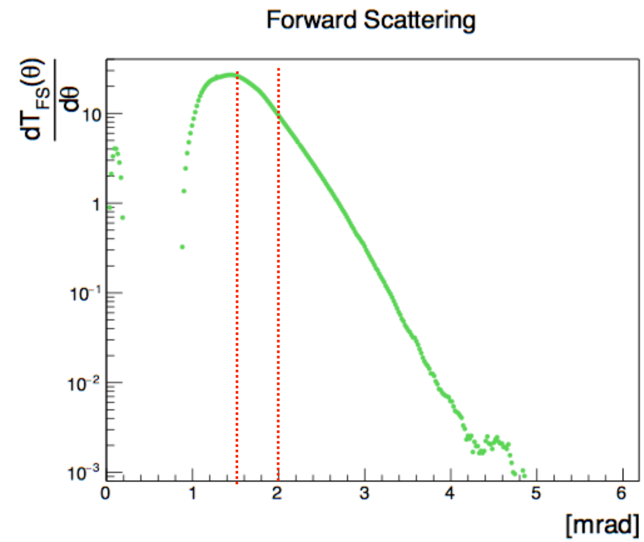
Angular dependence of the measured intensity:



Differential of the measured intensity:



$$\frac{dT_{FS}(\theta)}{d\theta} = \frac{dT(\theta)}{d\theta}\frac{1}{T_{ref.}} - \frac{T_0(\theta)}{d\theta}\frac{1}{T_{ref.}}$$



$$\frac{\int_2^6 T(\theta)d\theta}{\int_0^6 T(\theta)d\theta} \rightarrow 0.6\%$$

$$\frac{\int_{1.5}^6 T(\theta)d\theta}{\int_0^6 T(\theta)d\theta} \rightarrow 2.7\%$$

Negligible scattering
at angles relevant for Cherenkov resolution

Conclusions

Aerogel production is ongoing

✔ Good average optical quality

✔ Suboptimal 17% production efficiency

Dedicated measurements indicates the planarity requirement is too stringent
It will be released to achieve the expected 25 % production efficiency

✔ Tools for measurements and monitoring of the aerogel characteristics are operational and have stable performance.

✔ Mismatch between the measurements done in Novosibirsk and in Ferrara was observed, indicating the necessity to bake the aerogel before delivery. Corresponding agreement was obtained with the producer.

✔ Storing (in dry cabinets) and handling procedures has been defined