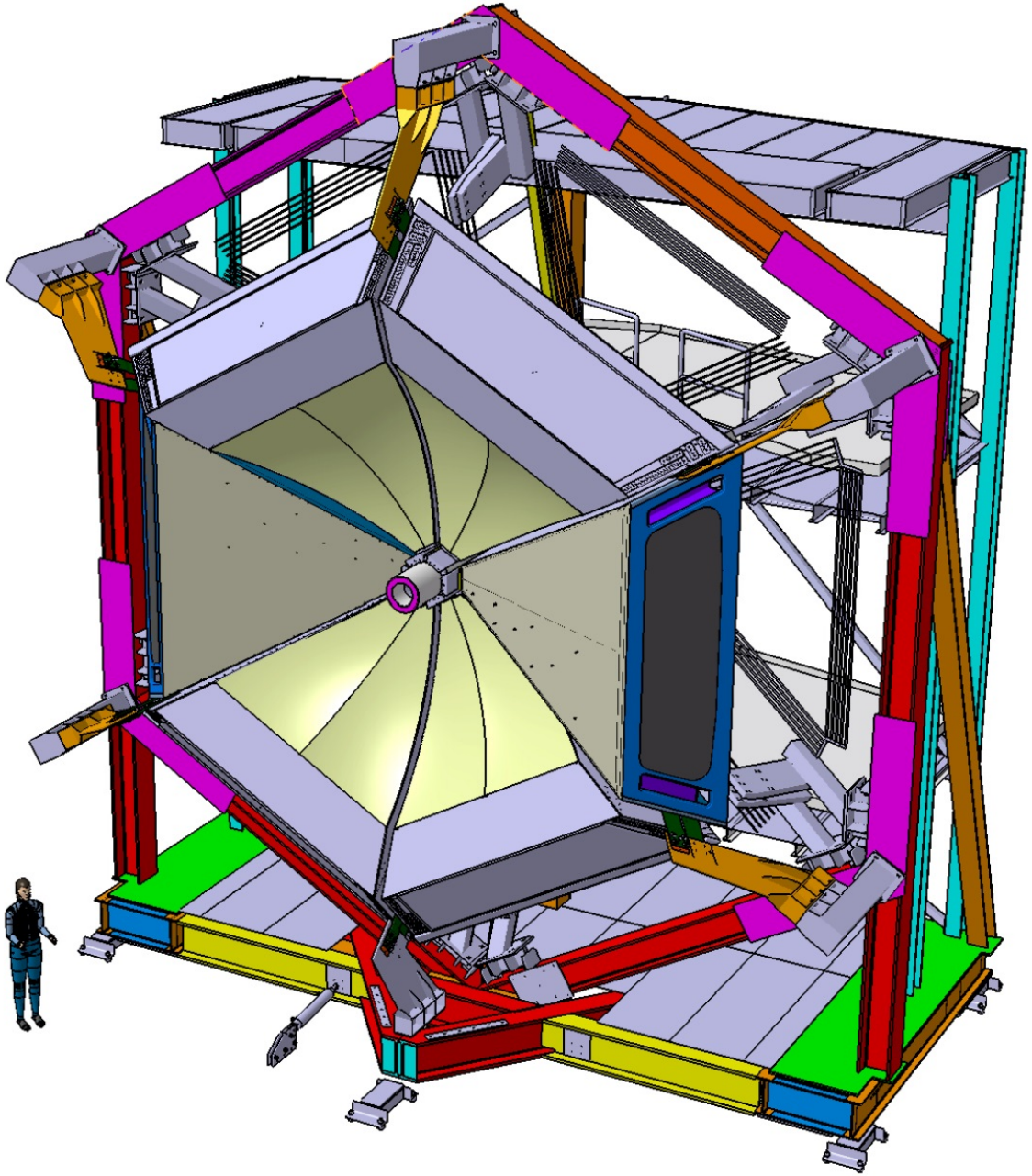
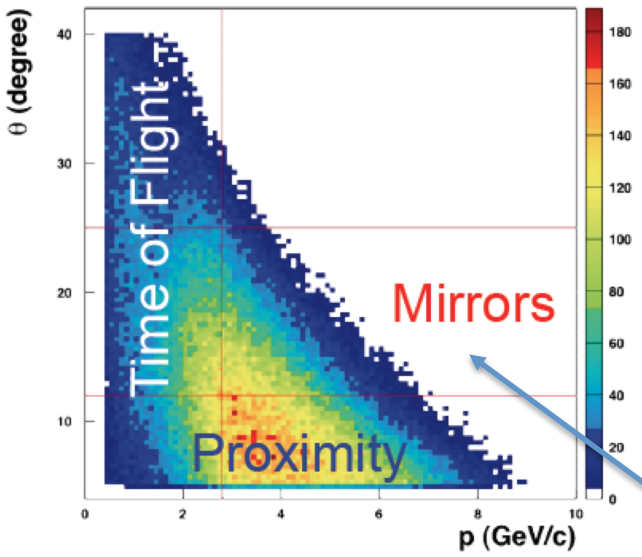
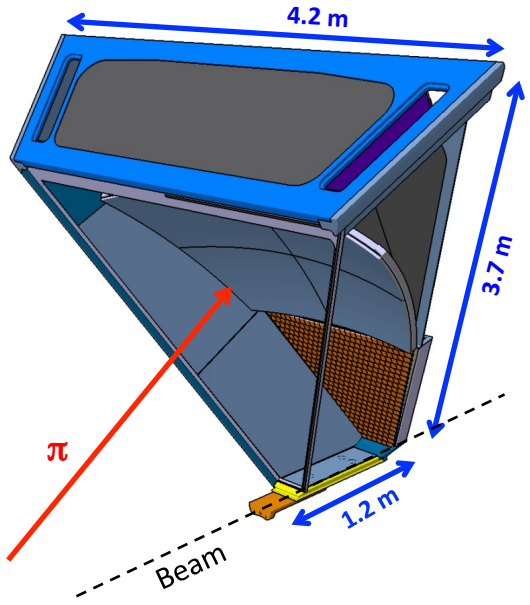


CLAS12-RICH Project-Overview

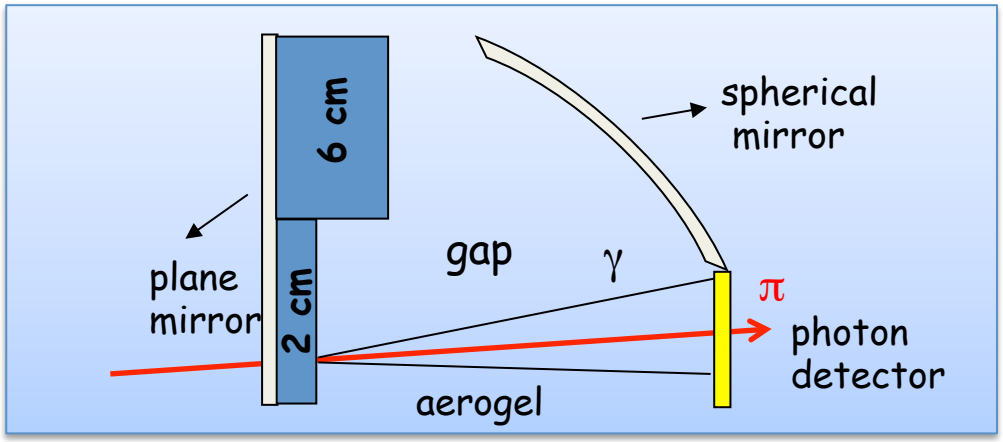
June 24th 2015

The Hybrid Optics Design

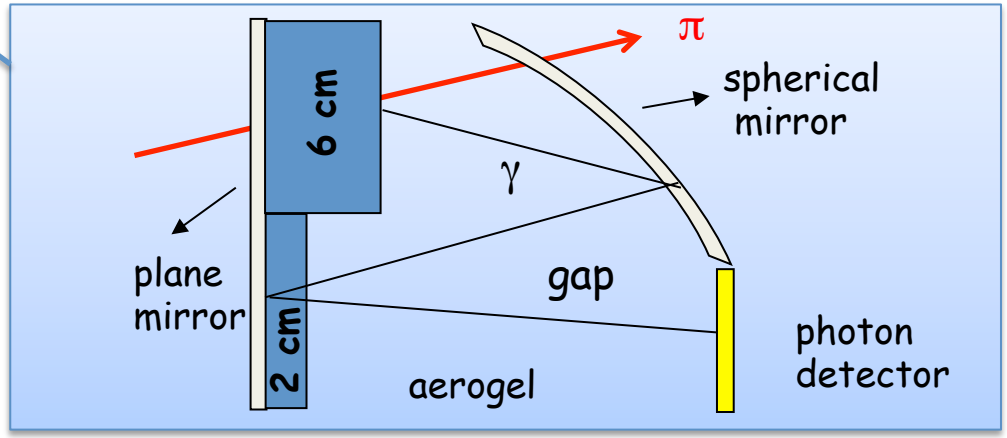




Direct rings and best performance for high momentum particles



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 efficienty & production yield of ~ 50 good tiles (~ 2 m^2) per year

Initial performance (up to 8/15):

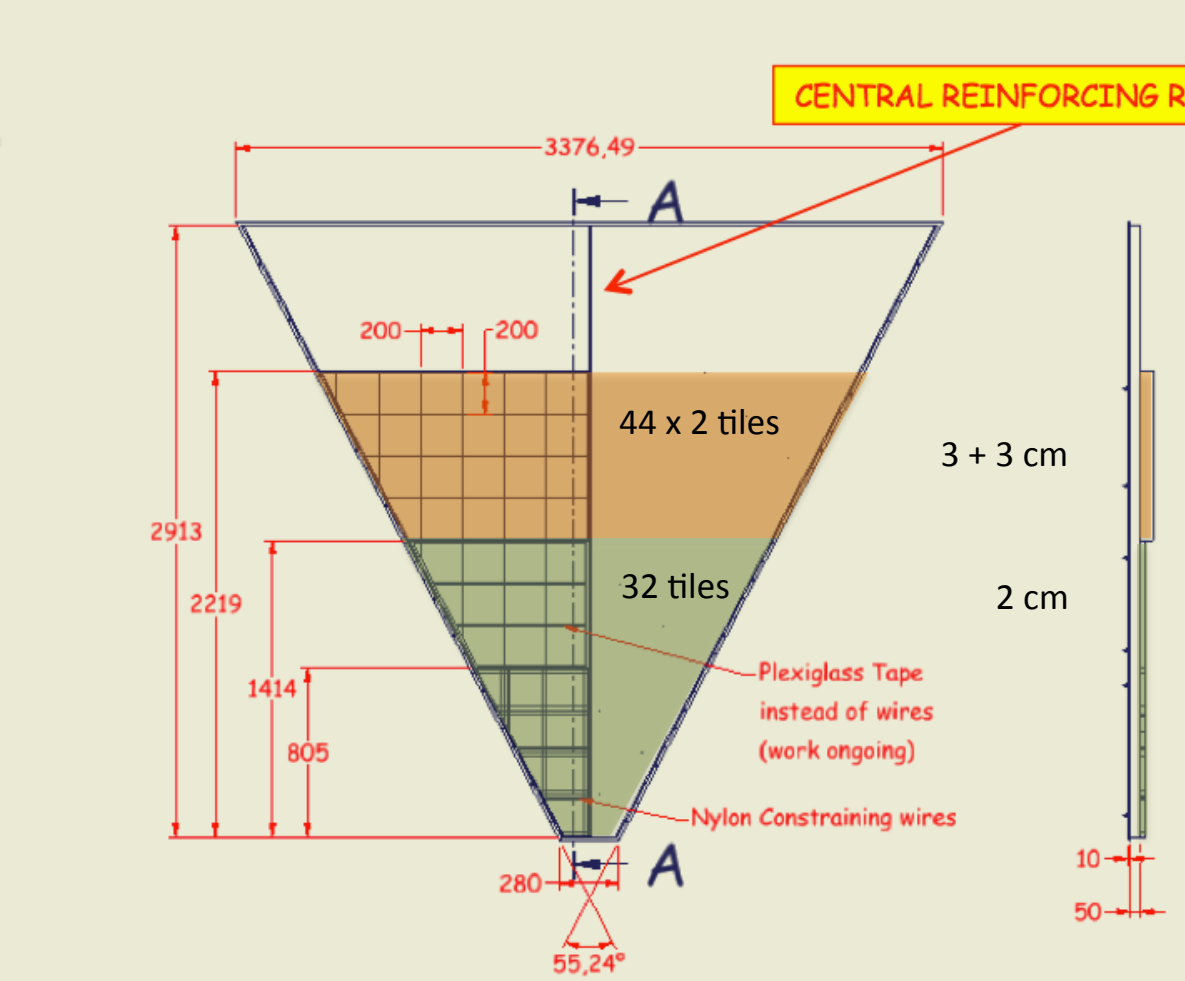
~ 2 months delay
for initial lack of chemicals

~ 3 months
to finalize acceptance test procedure

7 batches in ~5 months
- 105 tiles synthesized
- 50 tiles without cracks
- 18 tiles within specifications

Production rate capability
≤ 2 batches/month (optimistic)
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	($n^2=1+0.438\ \rho$)	$1.0477 < n < 1.0523$	goal $n \approx 1.05$
Scattering length		$L_{sc} > 43$ mm	goal $L_{sc} \approx$ 50 mm
Absorption coefficient		$A>0.95$	

MECHANICAL:

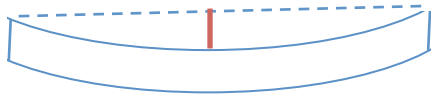
Side to side length variation $\Delta L_{side} < 0.25$ mm

from diamond wire to diamond wheel for better precision

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

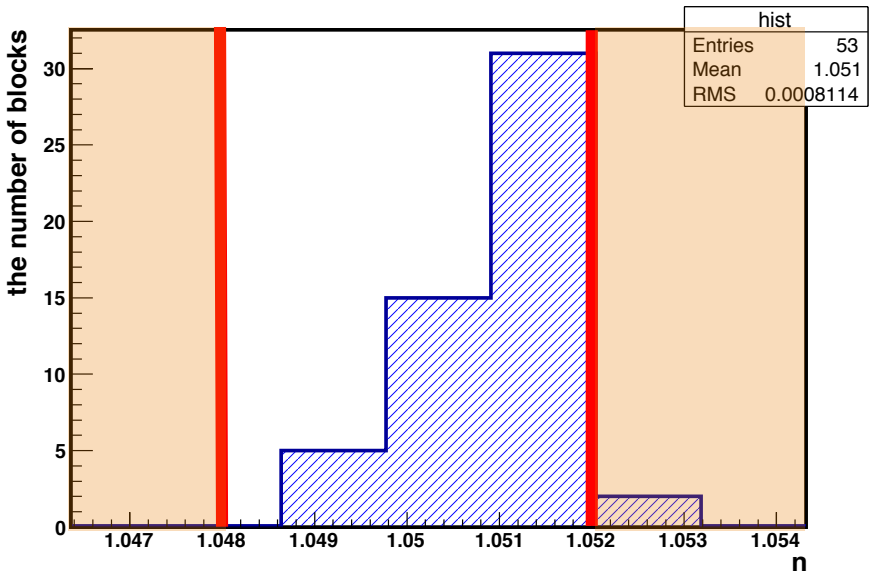
disregard molds with bad performance

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

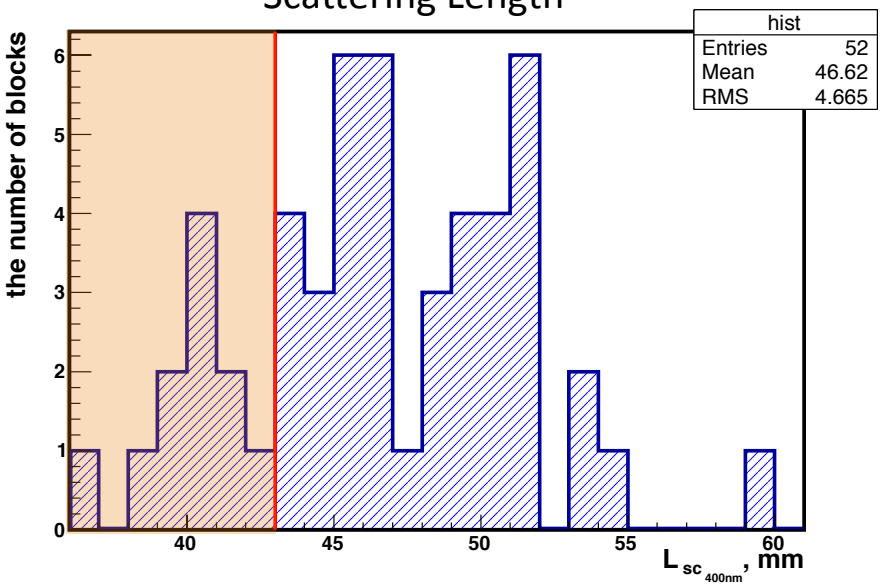


Aerogel Specifications

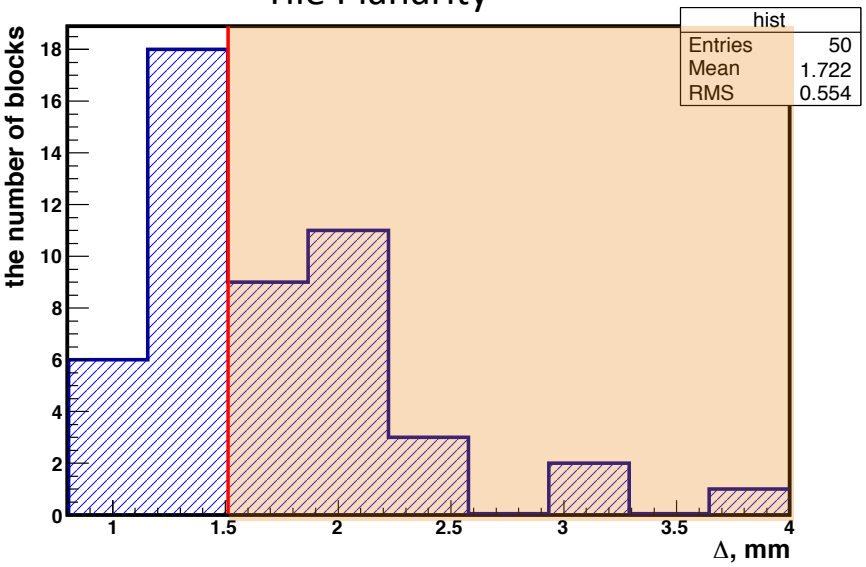
Refractive Index



Scattering Length



Tile Planarity



Homogeneous refractive index ✔

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

50 % losses due to planarity ✔
Under investigation: relax planarity specifications
- increase the production efficiency close to 25 %
- achieve the expected ~ 50 tiles/year production yield

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

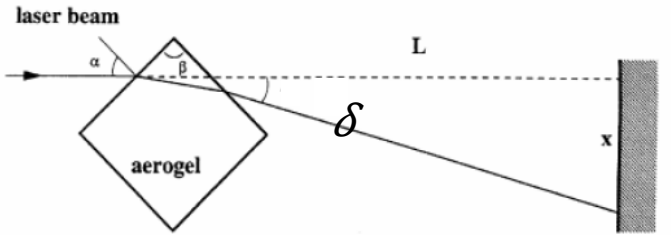
Validated with large scale prototype

Studied in laboratory

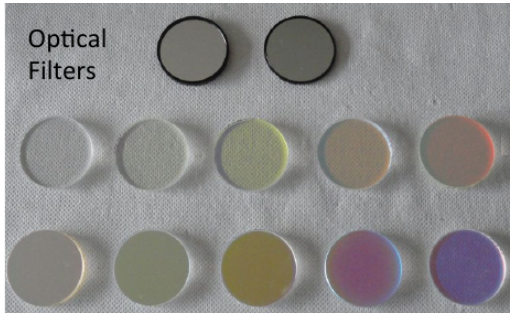
$$\sigma_{\vartheta_{Ch}} = \sqrt{\sum_i \frac{\left(\sigma^i_{\vartheta_{Ch}}\right)^2}{N_{p.e.}}}$$

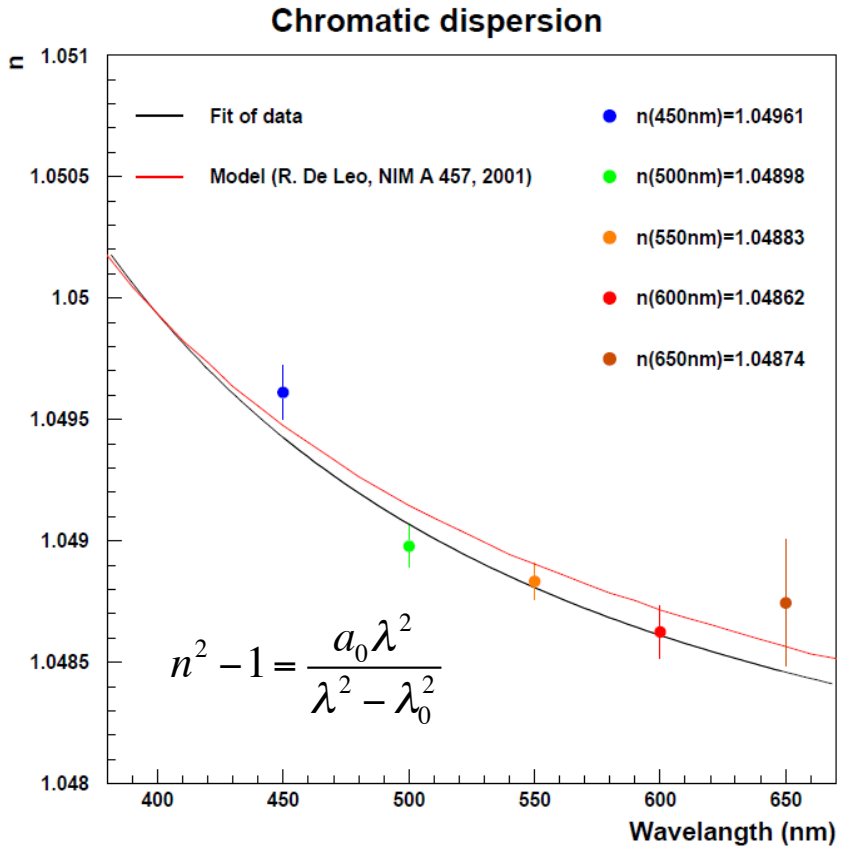
Aerogel Chromatic Dispersion

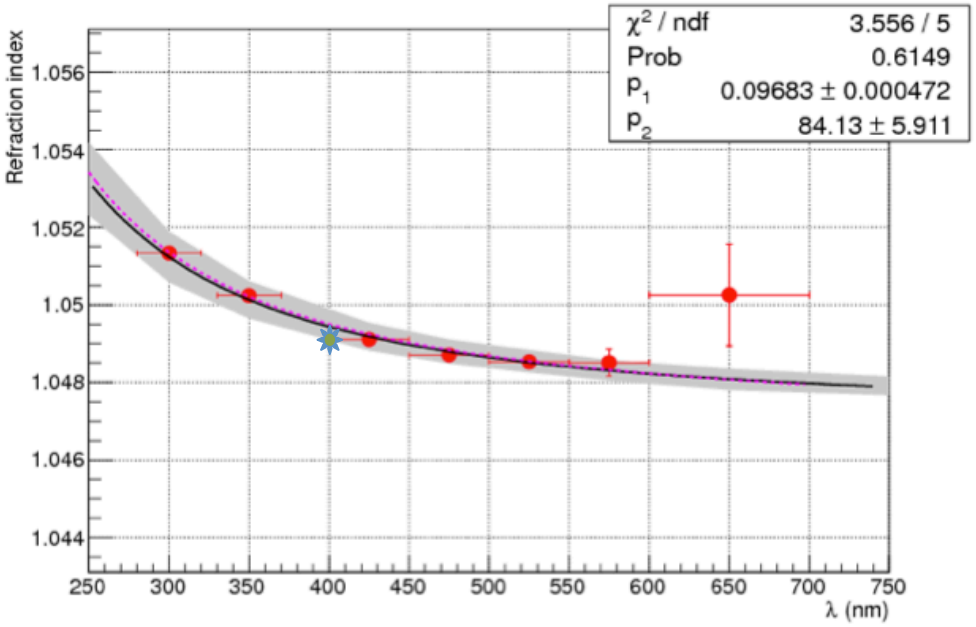
Measured by prisma method:



Measured by prototype with optical filters:



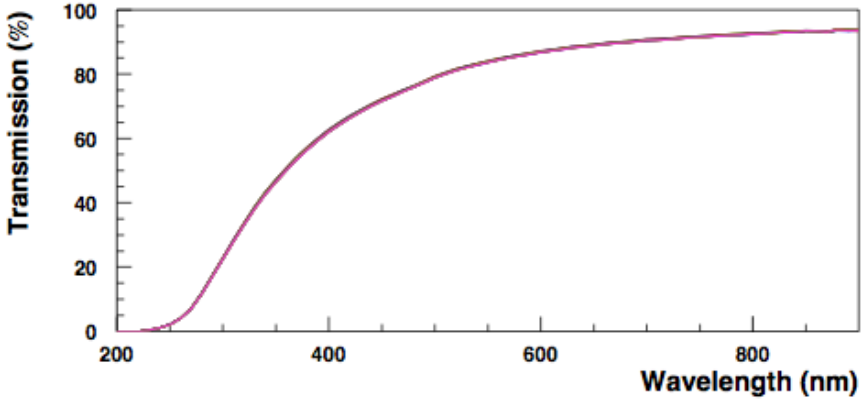


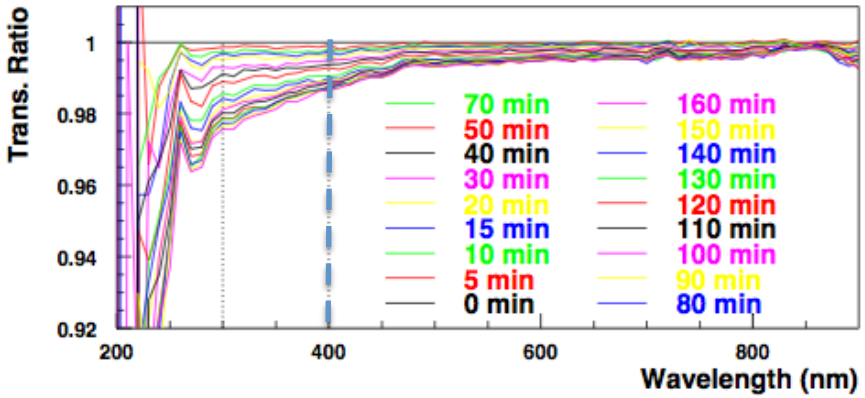


Expected value from density:
$n(400nm) = [1+0.438\rho]^{1/2} = 1.0492$

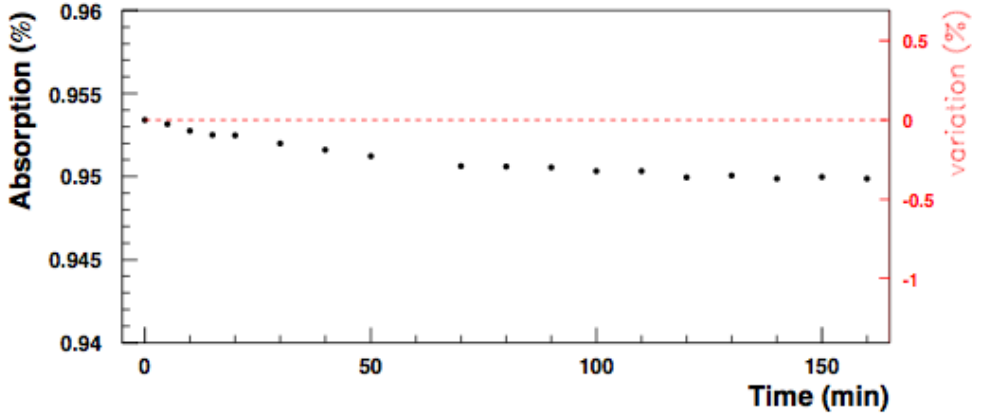
Aerogel Characteristics in the Air

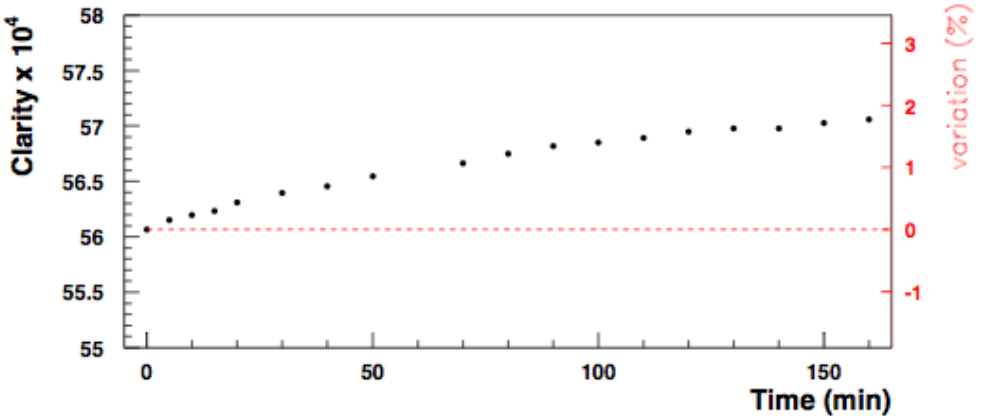
Transmission vs Time





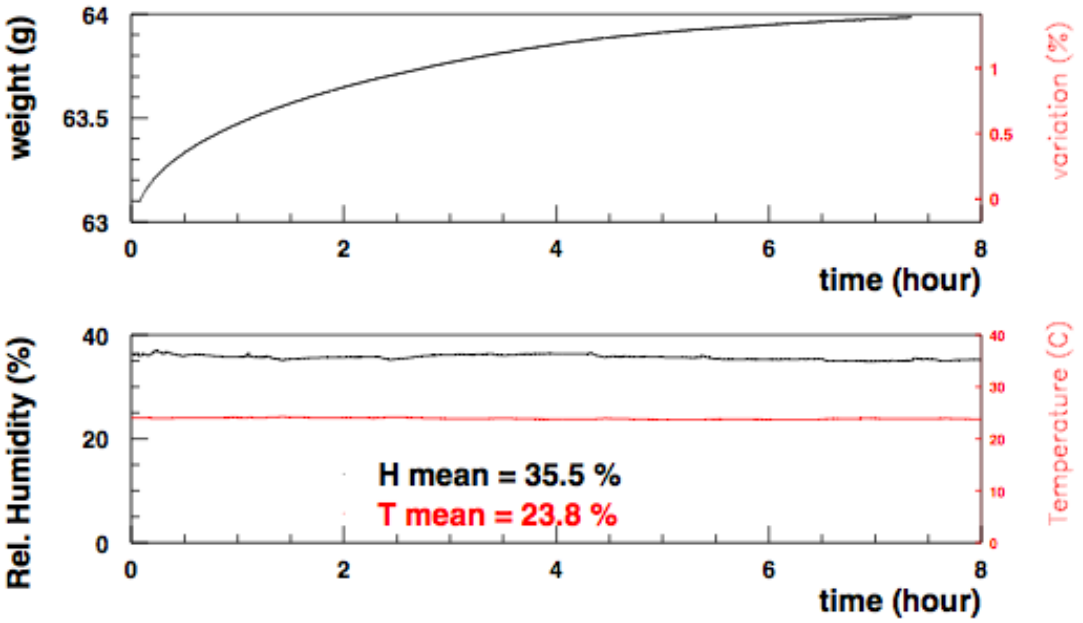
Absorption and Clarity @ 400 nm

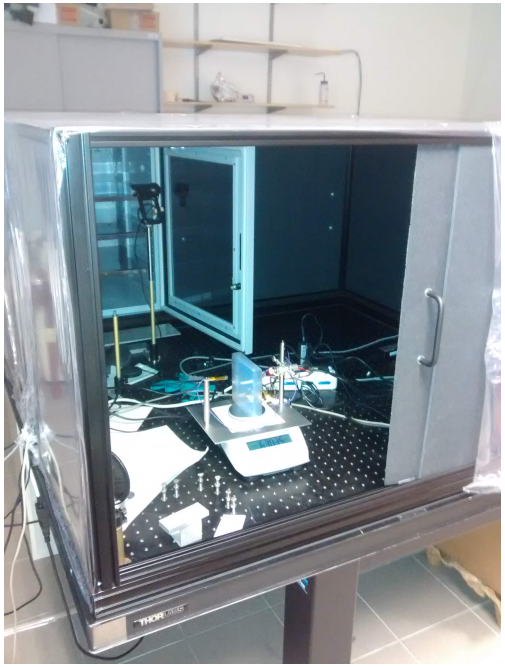




Monitoring the time dependence of the transmission of aerogel tile in environment of non-zero relative humidity (~ 40 %).

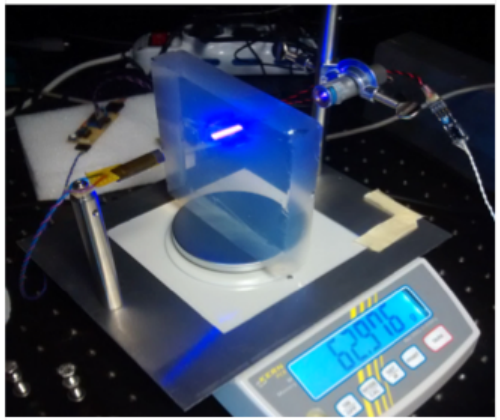
Aerogel Weight

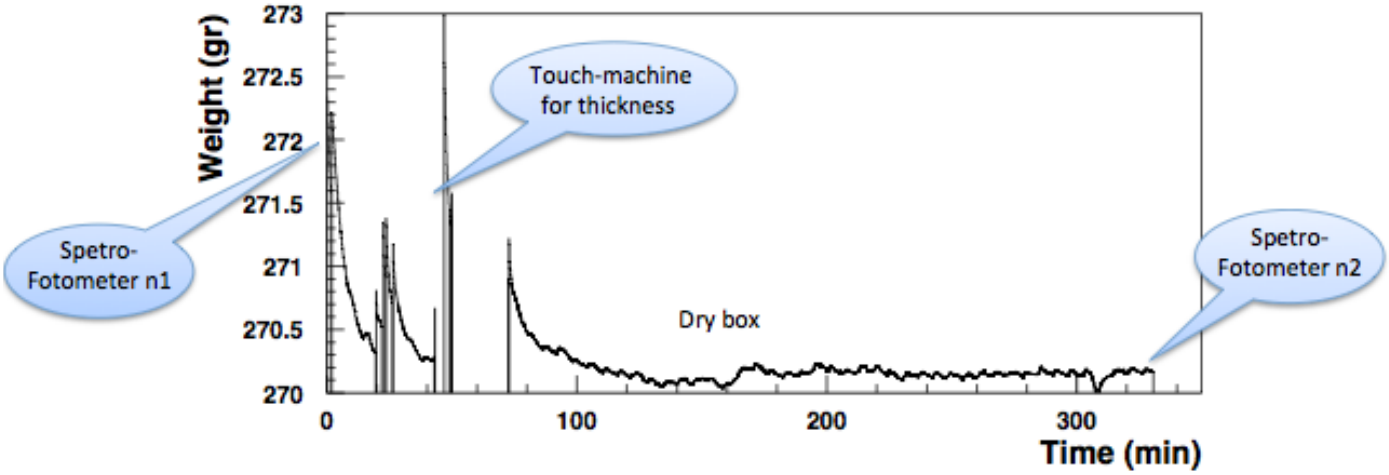




In Air (~ 40 % RH)

Inside Dry-Box (~ 1 % RH)





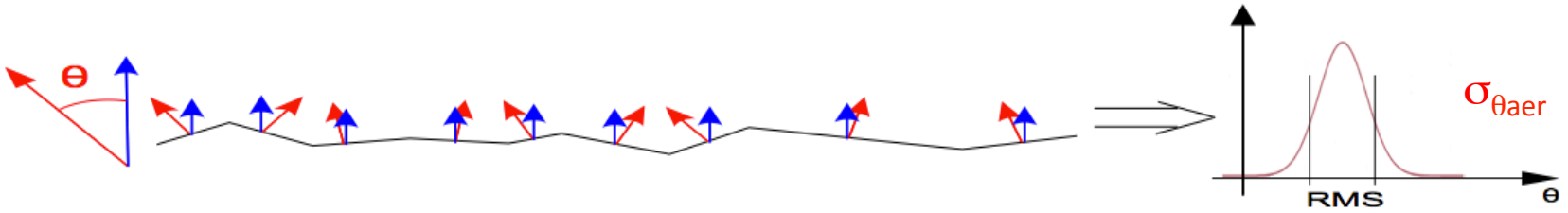
Spectro-fotometer Measurements

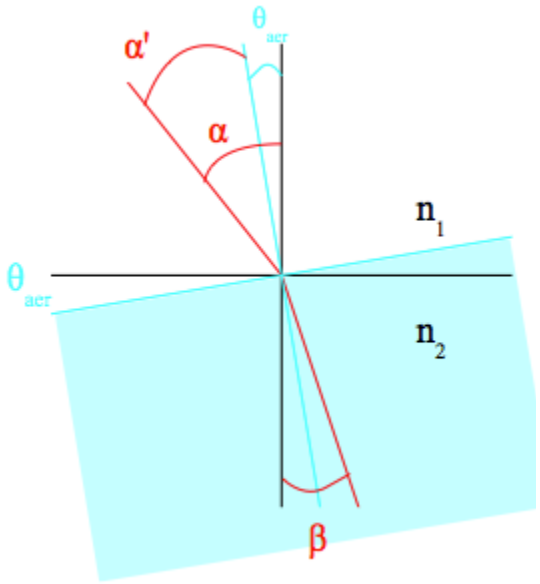
Acceptance tests during vendor visit in Ferrara (April 2015)

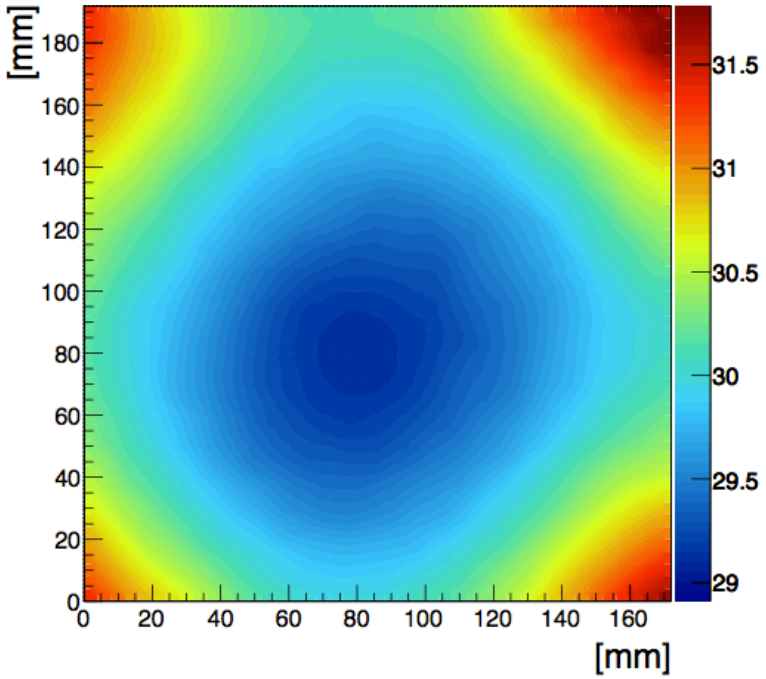
		Novosibirsk	Fe re-fit	Ferrara 1	Ferrara 2
	Date Meas.	28 Dec 2014	28 Dec 2014	16 Apr 2015 after delivery	17 Apr 15 after -1day drying
397m10	Lsc (mm)	49.2 ± 1.5	48.46 ± 0.50	45.59 ± 0.38	45.99 ± 0.39
	Abs (%)	97.7 ± 0.9	98.06 ± 0.61	95.60 ± 0.98	95.60 ± 1.06
	Date Meas.	20 Jan 2015		14 Apr 2015 after 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	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







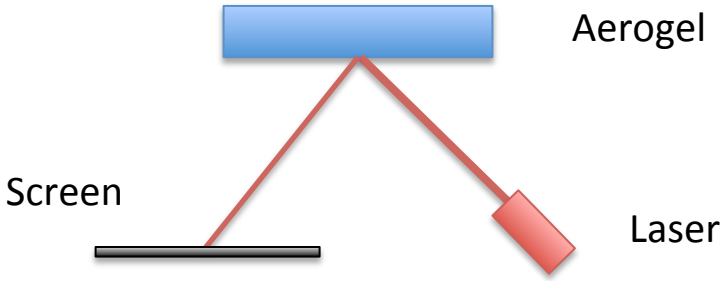
Refraction from a surface with local normal deviation θ

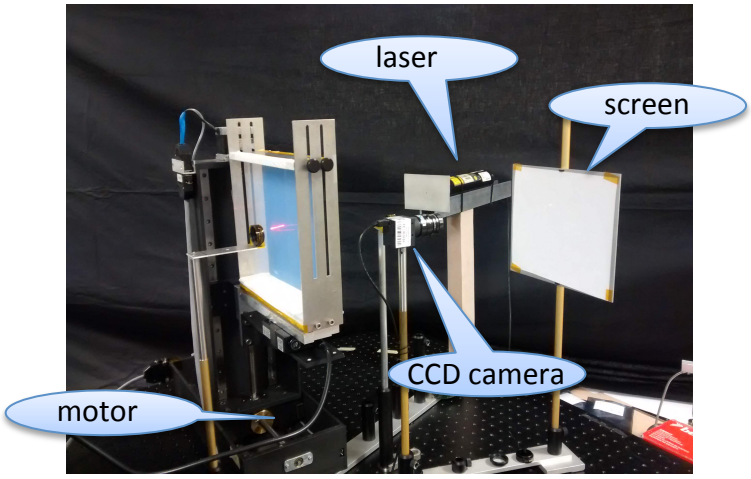
$$\beta = \vartheta_{aer} + \arcsin\left(\frac{1}{n}\sin(\alpha - \vartheta_{aer})\right)$$

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

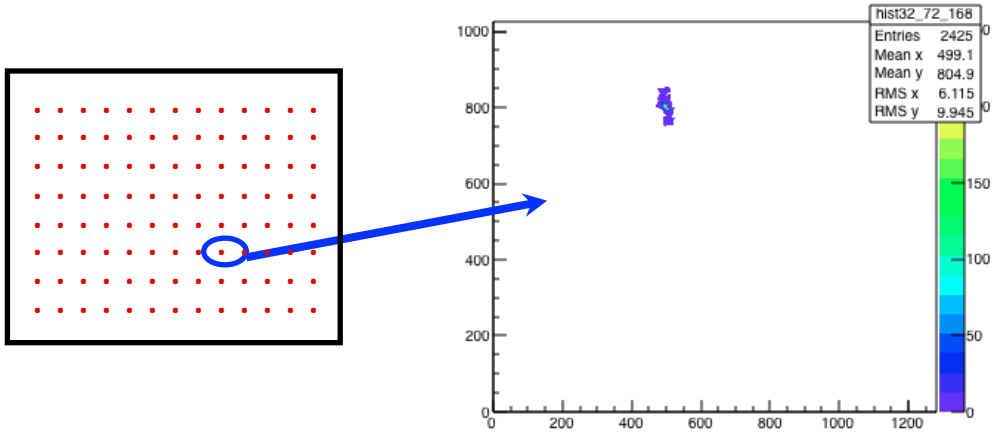




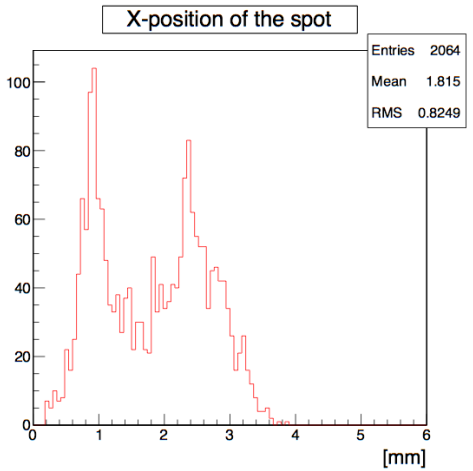
x-y axis movable table

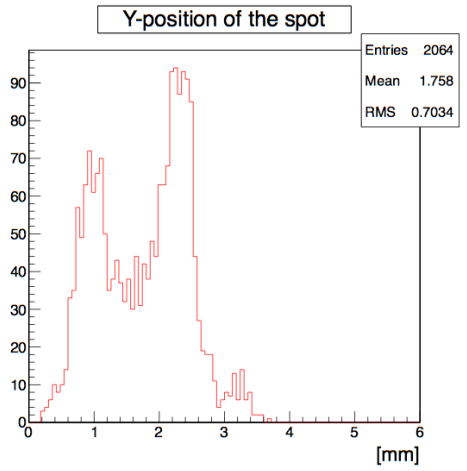
CCD camera [ThorLabs DCU 224c]
- sensitive area [5.95-4.76 mm]
- resolution [1280-1024 pixels]
- pixel size 4.65 μm

Scan of aerogel surface



Distributions of X & Y positions of the spot





Aerogel Surface Planarity

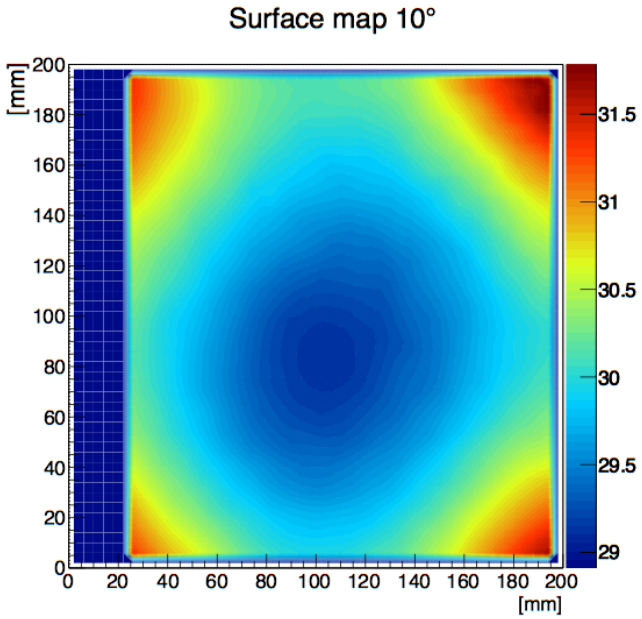
From laser spot shits to surface gradients

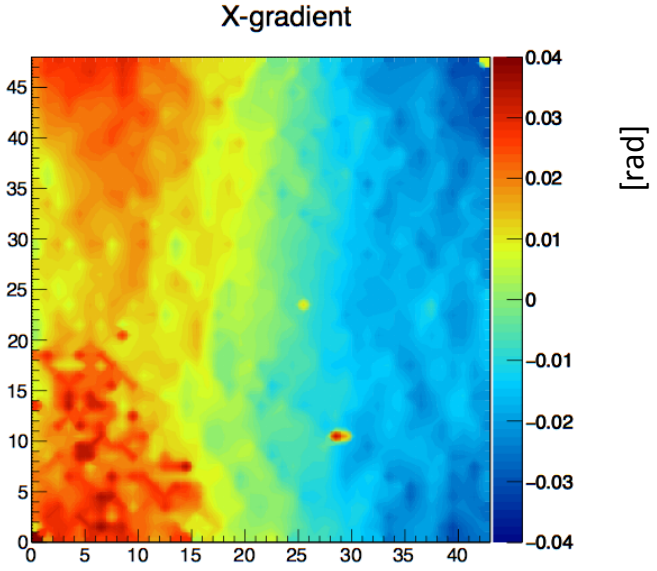
$$\nabla_x = \frac{(x - x_{mean})c_l}{2L}\cos(\theta)$$

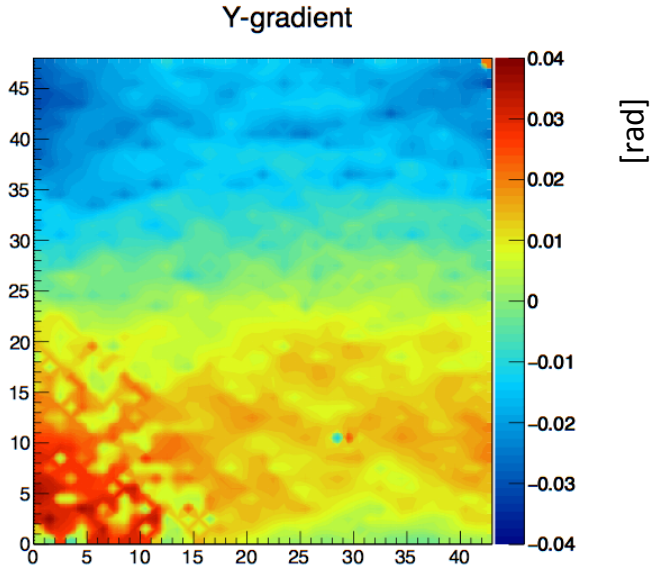
$$\nabla_y = \frac{(y - y_{mean})c_l}{2L}$$

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

From surface gradients to surface map by linear regression

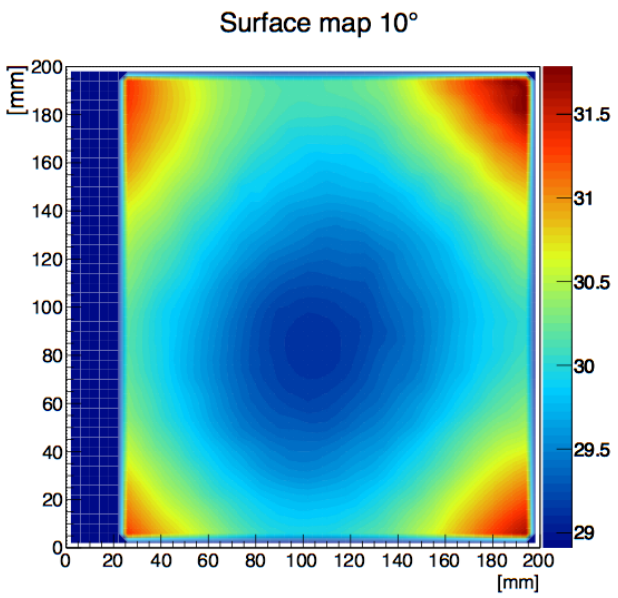


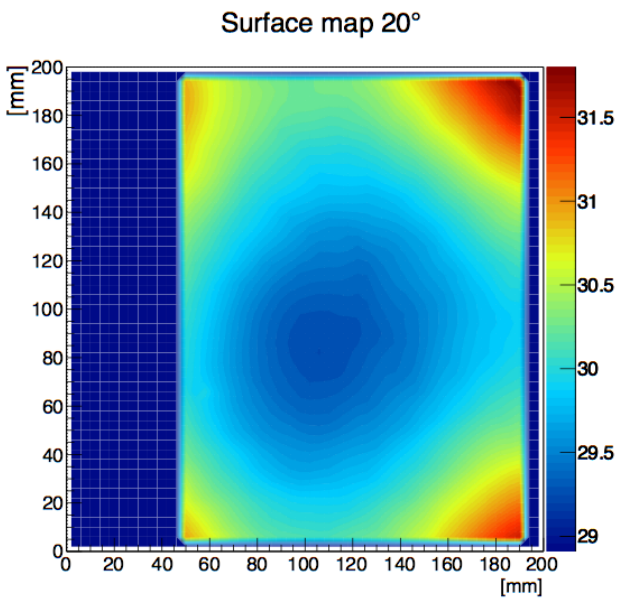


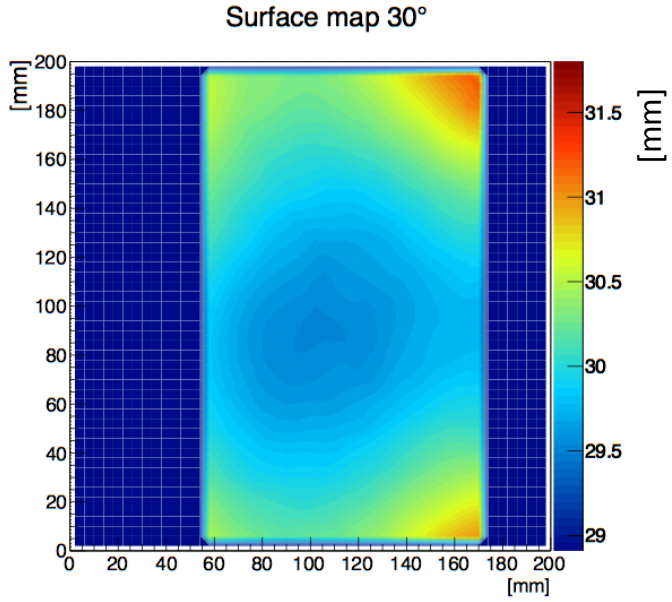


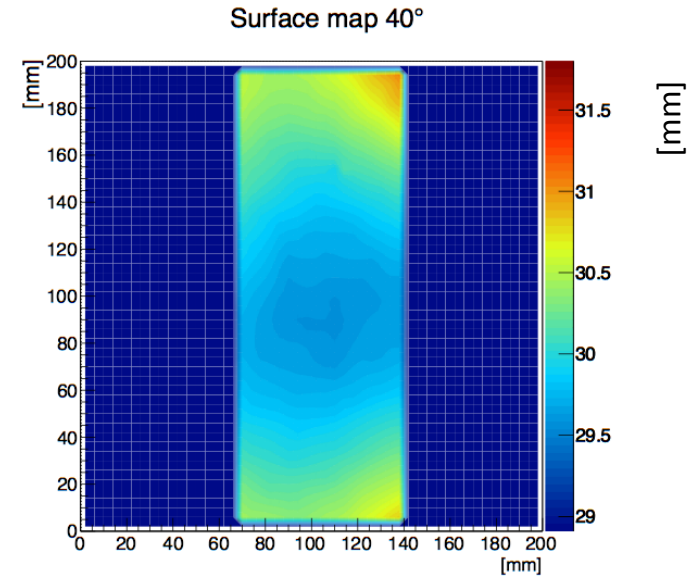
Validated with touch machine measurements
Consistent with Russian vendor evaluation

Aerogel Surface Map

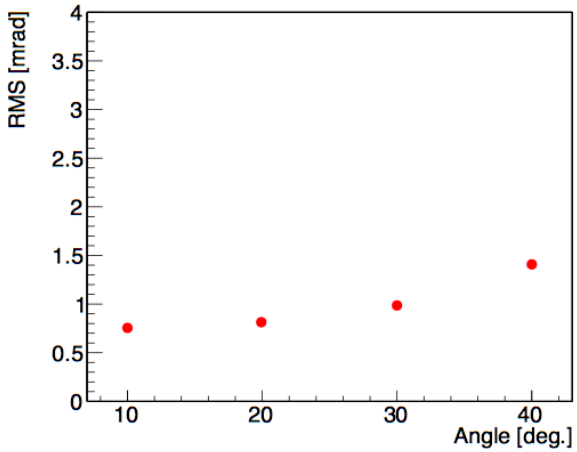




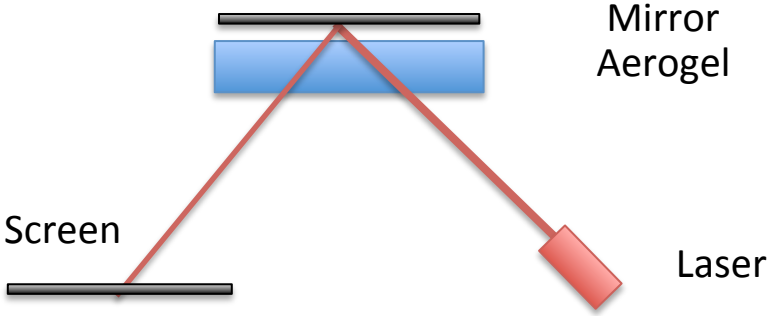


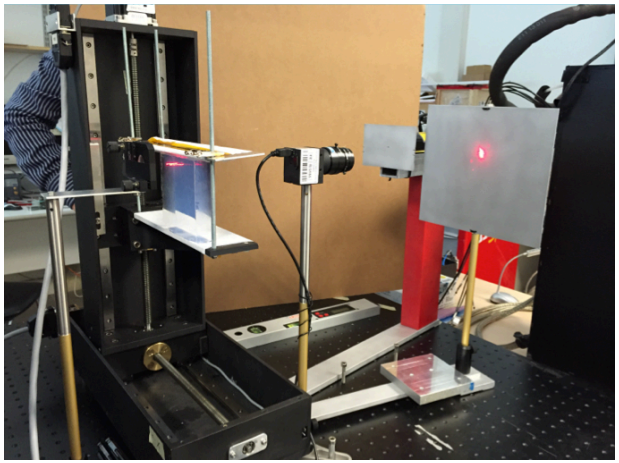


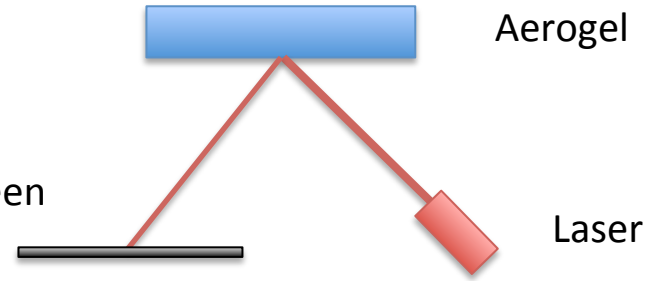
Light dispersion as a function of incident angle:

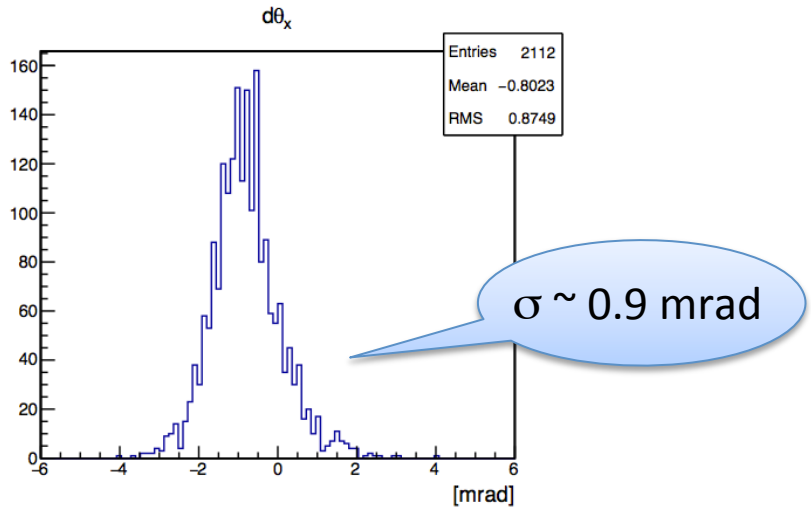


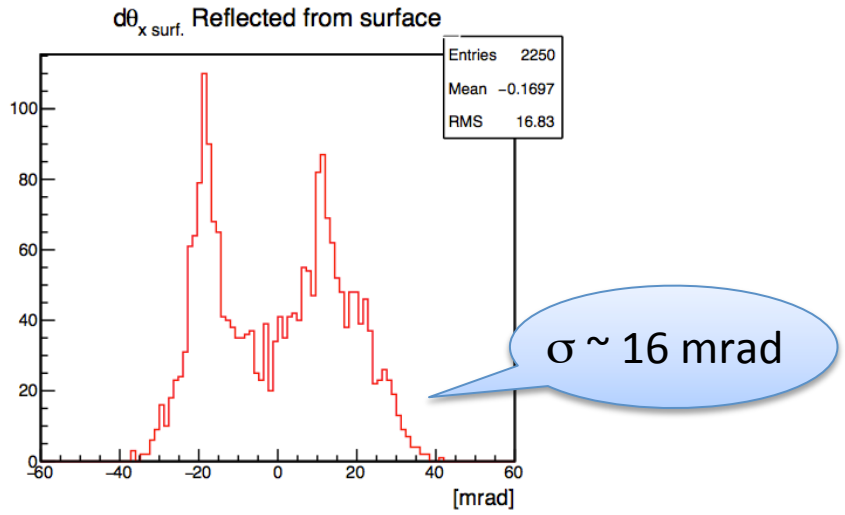
Light Dispersion vs Aerogel Surface Quality







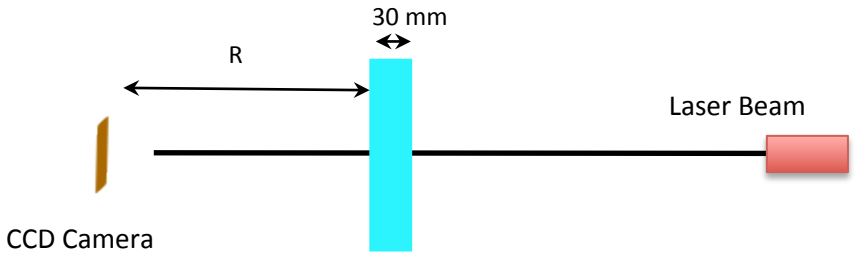




Acceptable light dispersion
up to ΔS_{surf} = 2.5 mm planarity

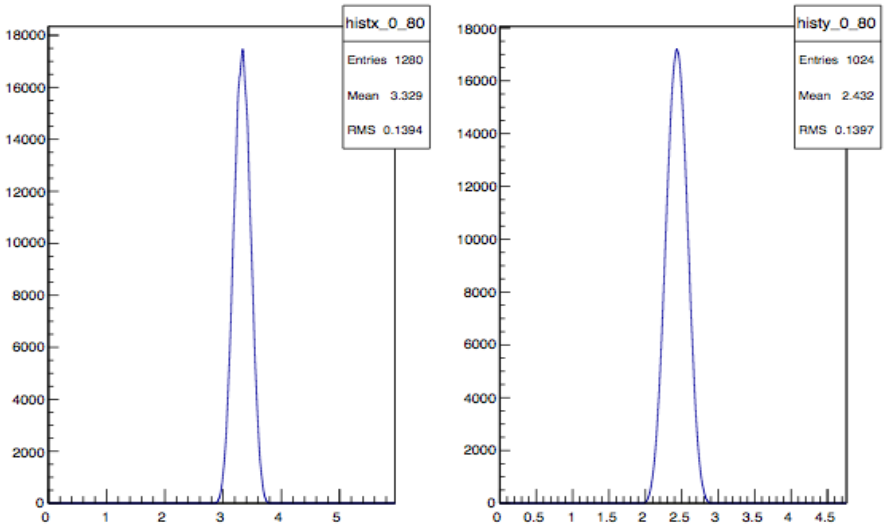
Forward Scattering

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

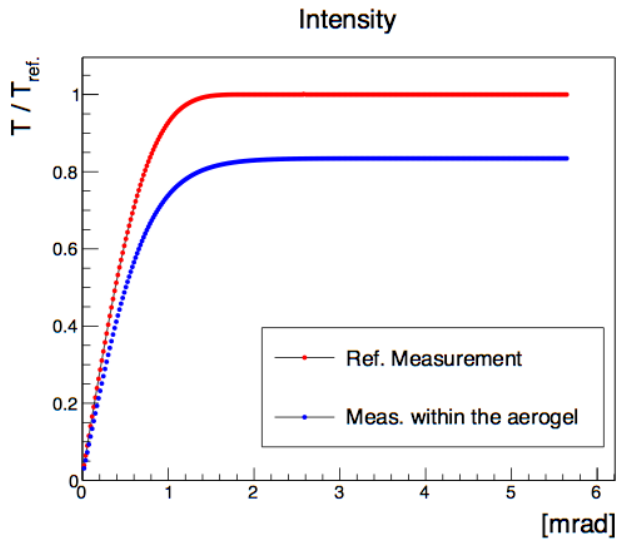


Analysis steps:

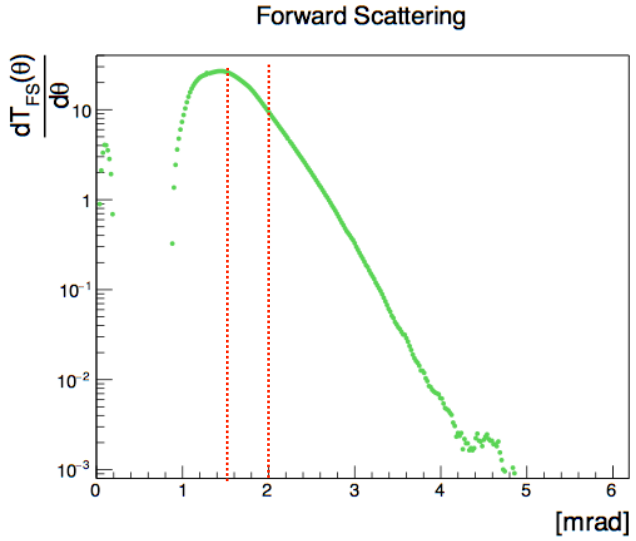
- Reference beam profile taken without aerogel
- Extract laser beam profile and compare with reference measurement
- Extract angular dependence of light intensity after passage through the aerogel

Forward Scattering

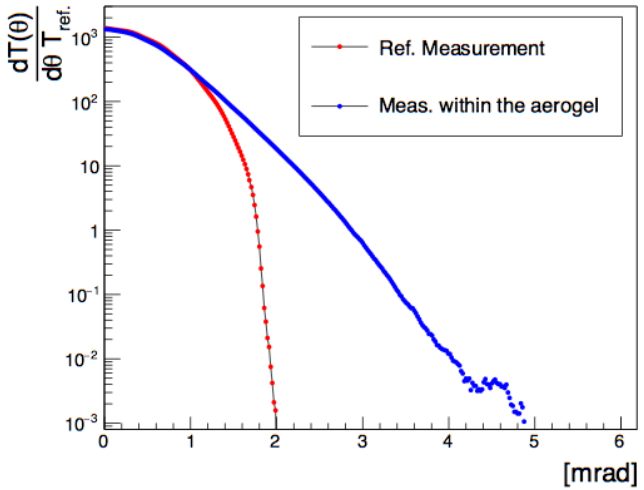
Angular dependence of the measured intensity:



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



Differential of the measured intensity:



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

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

Negligible scattering
at angles relevant for Cherenkov resolution

Conclusions

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.

Ongoing measurements indicates the planarity requirement is too stringent and can be released to achieve a 25 % production efficiency

CLAS12 RICH Project Midterm Status

✔ Mechanics

✔ Electronics

✔ Photodetector

- In line or better vs the project

✔ Mirrors

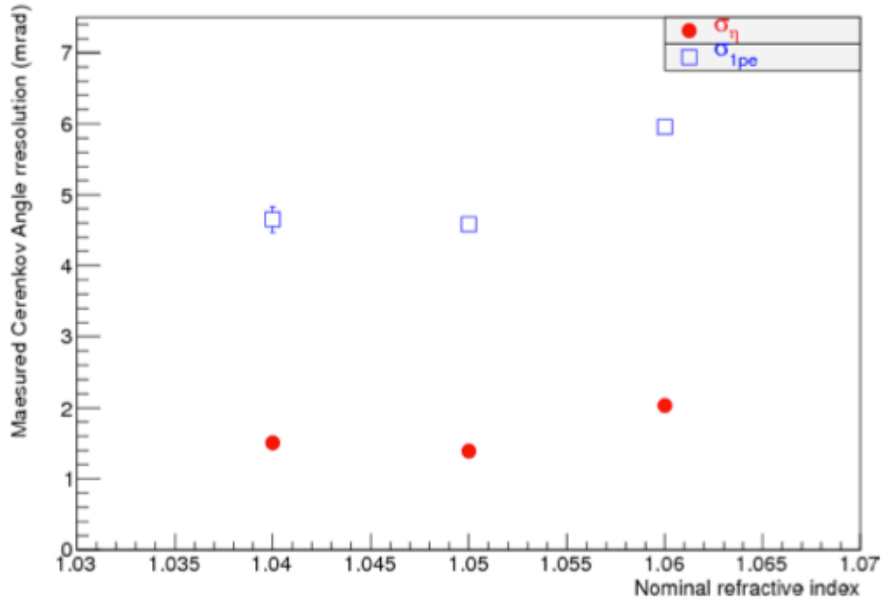
- Technological issue identified and overcame
- Initial delay is being recovered

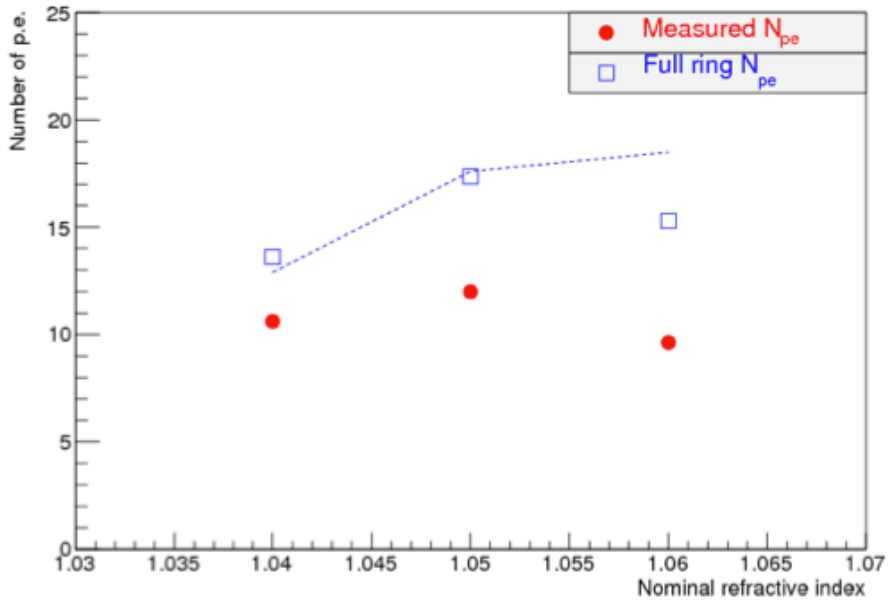
✔ Aerogel

- Most critical part
- Slow production start, should improve with time
- Working to optimize specifications vs production efficiency

RHIC Prototype: Direct Light Case

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





RICH Project: Aerogel

Activity Name	Date	MS Lvl	Finish Date
RICH Milestone Schedule			
Start of US Scope of RICH Project	9/30/13	1	9/30/13
PMT Contract Awarded	9/30/13	1	9/30/13
Start Aerogel Procurement	12/31/13	1	1/31/14
Start PMT Production	1/1/14	1	1/31/14
FE Interfaces Defined; Preliminary Electronics Design Completed	3/31/14	2	4/30/14
Identification of Mirror Technical Specification	3/31/14	2	4/30/14
Identification of External Frame & Electronic Panel Tech Specs	3/31/14	2	4/30/14
First 20 PMT Delivery	4/30/14	2	5/30/14
Start Mirror Procurement	6/2/14	1	7/1/14
PMT First Delivery Acceptance Testing Completed	6/30/14	2	7/30/14
First 1 m2 Aerogel: Order for Procurement Submitted	6/30/14	2	7/30/14
Start Metallic External Frame Procurement	8/1/14	2	9/3/14
DAQ: FPGA Board Design and Firmware Develop Completed	9/30/14	2	10/30/14
Start Mirror Production	12/31/14	1	3/31/15
DAQ FPGA: Order for Procurement Submitted	1/30/15	2	2/27/15
FE Electronics: Order for Procurement Submitted	2/27/15	2	3/31/15
2 m2 Aerogel Production Completed	3/31/15	2	9/30/15
Start Electronic Panel Procurement	4/1/15	2	5/1/15
Start First Spherical Mirror Characterization	6/30/15	2	8/31/15
FE and DAQ FPGA Boards: Production Completed	7/30/15	1	8/31/15
2 m2 Aerogel Acceptance Tests Completed	9/30/15	2	11/30/15
External Frame & Electronic Panel Completed	10/1/15	2	10/30/15
Mirror Production Completed	12/31/15	1	3/31/16
PMT Production Completed	12/31/15	1	2/1/16
Start Mechanical Assembly Test	12/31/15	2	2/29/16
Start FE and DAQ Electronics Characterization	1/29/16	2	2/29/16
PMT Characterization Completed	3/31/16	2	4/29/16
Mechanical Assembly Survey of Spherical Mirrors Completed	3/31/16	2	4/29/16
3 cm Thickness Aerogel Production Completed	5/31/16	2	10/31/16
Mirrors/Ext Frame/Elect Panel Arrive at JLab	8/31/16	2	9/30/16
Start RICH Assembly	10/3/16	2	11/2/16

Initial delay due to lack of chemicals

25 % ready for delivery

Aerogel Production

Критерий отбора:

$L_{sc} > 43$; $A_0 > 0.95$; $1.048 < n < 1.052$ {$0.224 < \rho < 0.244$} $n^2 = 1 + 0.438\rho$

№	Experiment	Density ρ, g/cm^3	Scattering length L_{sc}, mm	A_0, %	Date of measurement (L_{sc})	Kp ±0.2
1	оп397ф15	0.237	49.56±0.79	99.04±0.4	19.12.14	1.7
2	оп397ф16	0.233	47.67±1.19	97.77±0.9	23.12.14	1.5
3	оп397ф10	0.234	49.2±1.54	97.73±0.9	28.12.14	1.5
4	оп397ф	0.234	48.2±0.63	92.98±0.5	28.12.14	1.4
5	оп397ф33	0.237	51.32±1.28	98.91±0.6	29.12.14	1.5
6	оп398ф3	0.228	40.93±0.51	98.35±0.7	20.01.15	
7	оп397ф40	0.246	46.12±0.58	97.84±0.5	20.01.15	0.9
8	оп397ф9	0.241	46.87±0.8	96.66±0.4	20.01.15	1.5
9	оп398ф6	0.238	41.56±0.52	97.90±0.9	20.01.15	
10	оп398ф4	0.233	43.3±1.2	98.75±0.4	26.01.15	
11	оп398ф13	0.236	47.05±1.34	98.76±0.5	26.01.15	1.5
12	оп398ф31	0.237	51.28±1.31	99.54±0.5	04.02.15	1.7
13	оп398ф32	0.234	48.09±1.26	97.75±0.6	04.02.15	1.5

Aerogel Planarity < 1.5