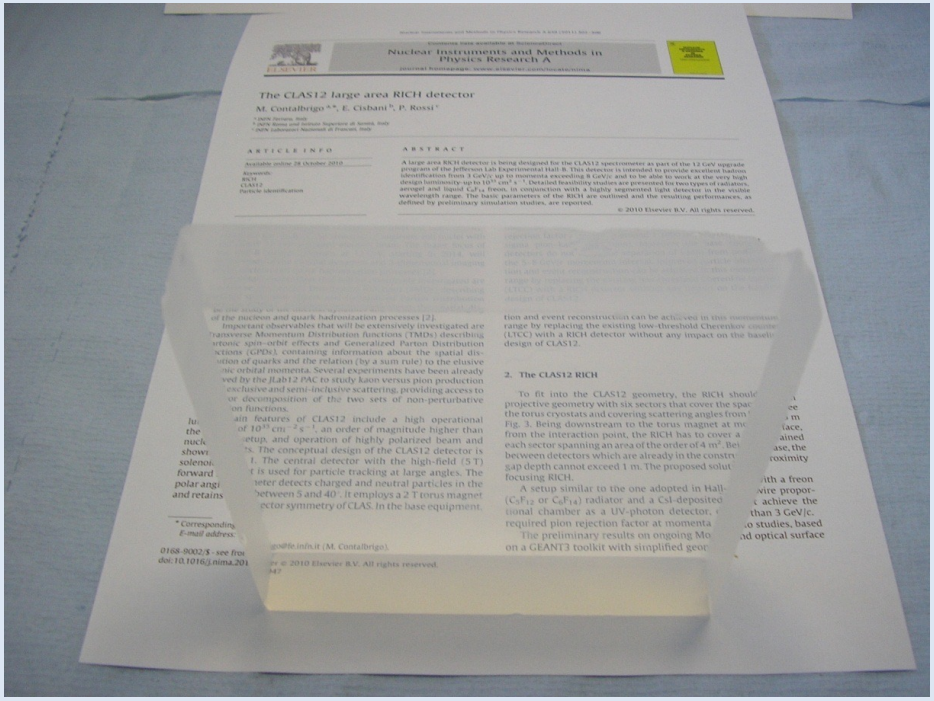
Aerogel Studies



Nuclear Instruments and Methods in Physics Research A

The CLAS12 large area RICH detector

M. Contalbrigo, E. Cisbani, P. Rossi

ARTICLE INFO

ABSTRACT

A large area RICH detector is being designed for the CLAS12 spectrometer as part of the 12 GeV upgrade program of the Jefferson Lab Experimental Hall-B. This detector is intended to provide excellent hadron identification from 3 GeV/c up to momenta exceeding 8 GeV/c and to be able to work at the very high design luminosity up to 10^{35} cm^{-2} s^{-1}. Detailed feasibility studies are presented for two types of radiators, aerogel and liquid C_6F_{14} freon, in conjunction with a highly segmented light detector in the visible wavelength range. The basic parameters of the RICH are outlined and the resulting performances, as defined by preliminary simulation studies, are reported.

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2. The CLAS12 RICH

Contalbrigo Marco – INFN Ferrara

Aerogel Manufacturers

Budker (Russia): past reference → not an option

ASPEN US): initial contacts with CUA (Tanja Horn) → dismissed program

Aerogel Factory (JP):

Spin off from BELLE-II aerogel development at Chiba University

- Performance as a function of n ?

- Mass production capability ?

- Maximum uniform aerogel volume ?

- Mechanical properties ?

Initial goals (synergy with ALICE):

Study reproducibility
1st batch: 1.0206, 1.0206, 1.0199, 1.0204
2nd batch: 1.0201, 1.0207, 1.0210, 1.0218

Negotiate large (20x20 cm^2) tiles

Handling

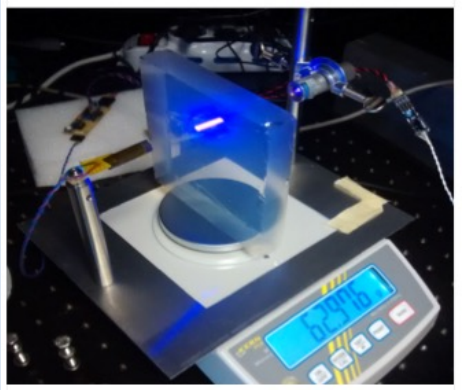
Within sealed envelops and inside a dry-cabinet (few % RH)

Clean Storage
Use gloves & mask
Touch from sides
No sharp contacts

CLAS12 Specifications

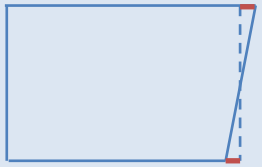
OPTICAL:

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:

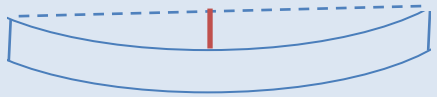
No bubbles, crackes; chips limited to less than 1 % area



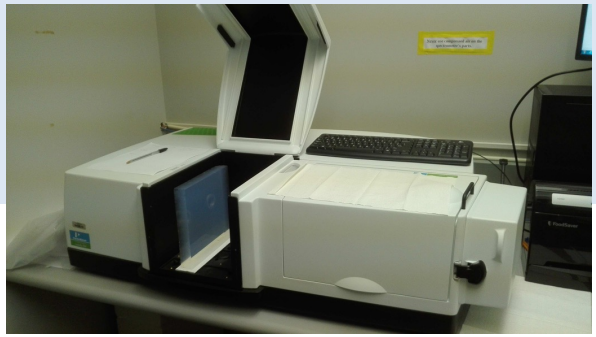
Side to side length variation $\Delta L_{side} < 0.25$ mm

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

Surface planarity $\Delta S_{surf} < 1$ % of lateral side



Light Transmittance



$$T(\lambda) = e^{-\frac{t}{\Lambda_{trasm}}} = e^{-t\left(\frac{1}{\Lambda_A}+\frac{1}{\Lambda_S}\right)} = A \cdot e^{-\frac{B\,t}{\lambda^8}} \cdot e^{-\frac{C\,t}{\lambda^4}}$$

TRANSMISSION LENGTH:

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

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

SCATTERING LENGTH:

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

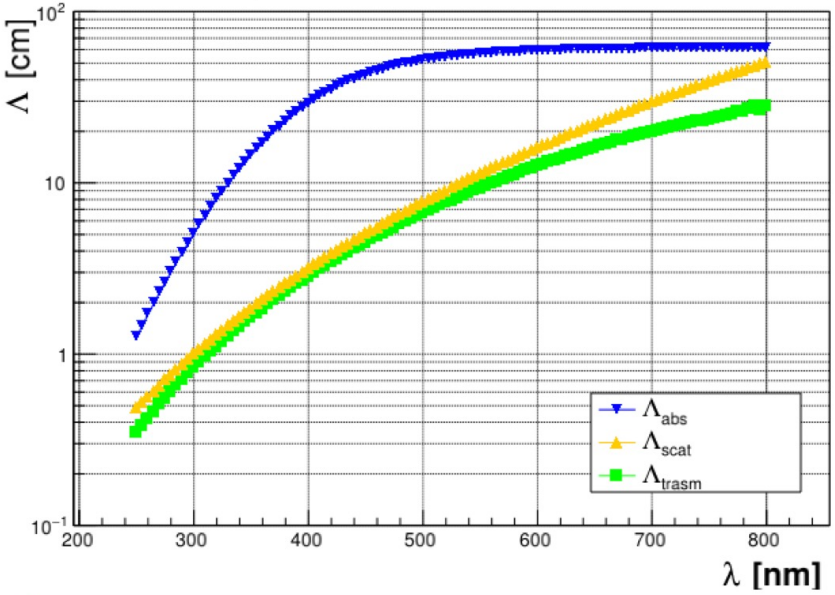
$$\Lambda_{scat} = \frac{\lambda^4}{C}$$

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.

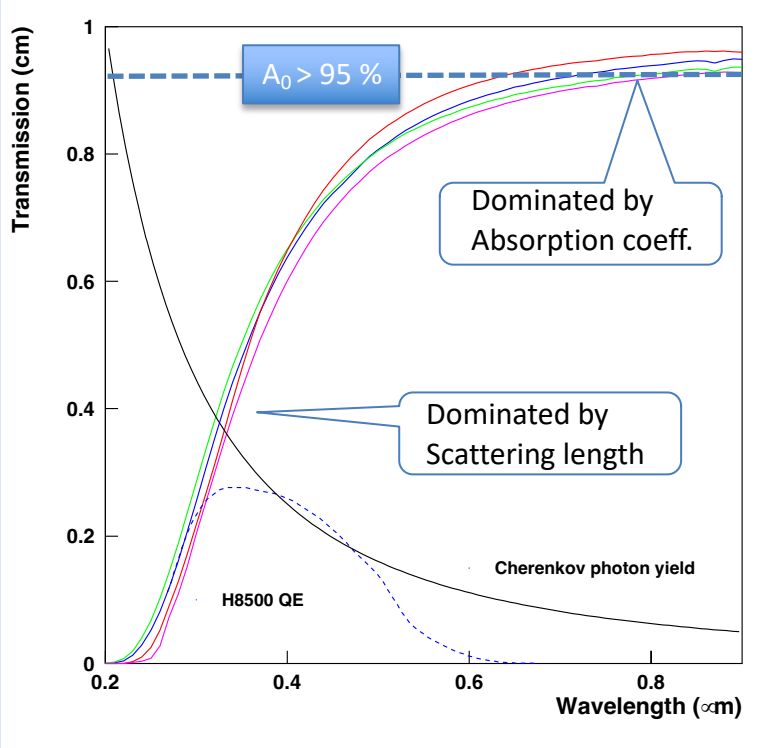


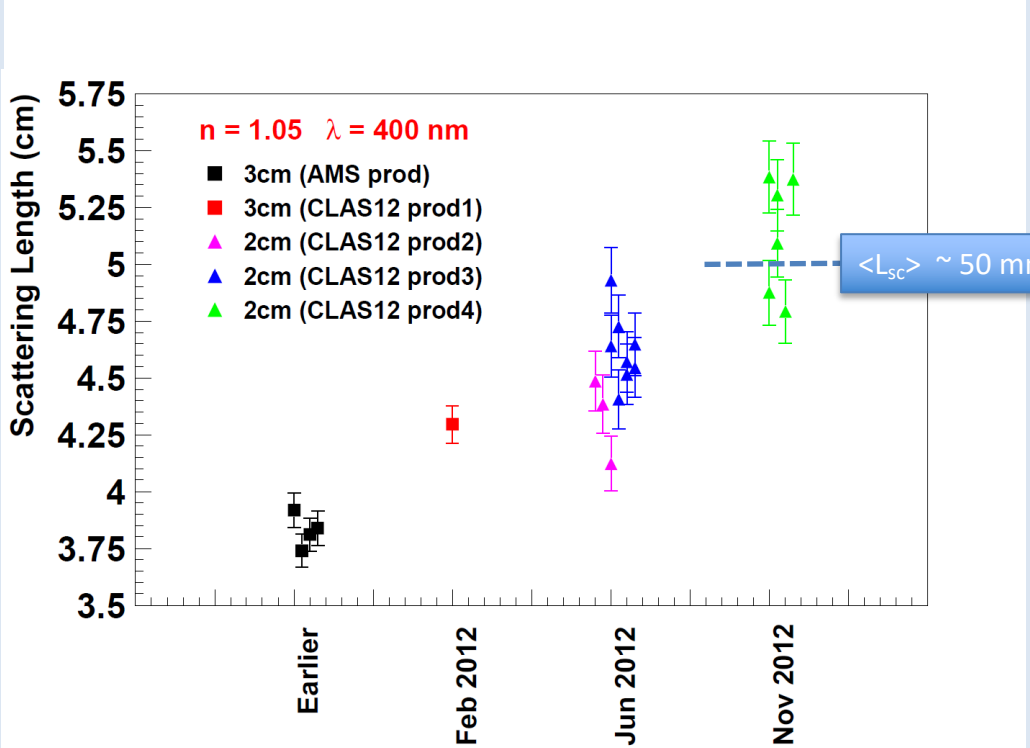
SMALL IMPACT OF THE ABSORPTION ON THE TRANSMISSION LENGTH

Collaboration with Budker and Boreskov Institutes of Novosibirsk

Flexible geometry, mass production capability

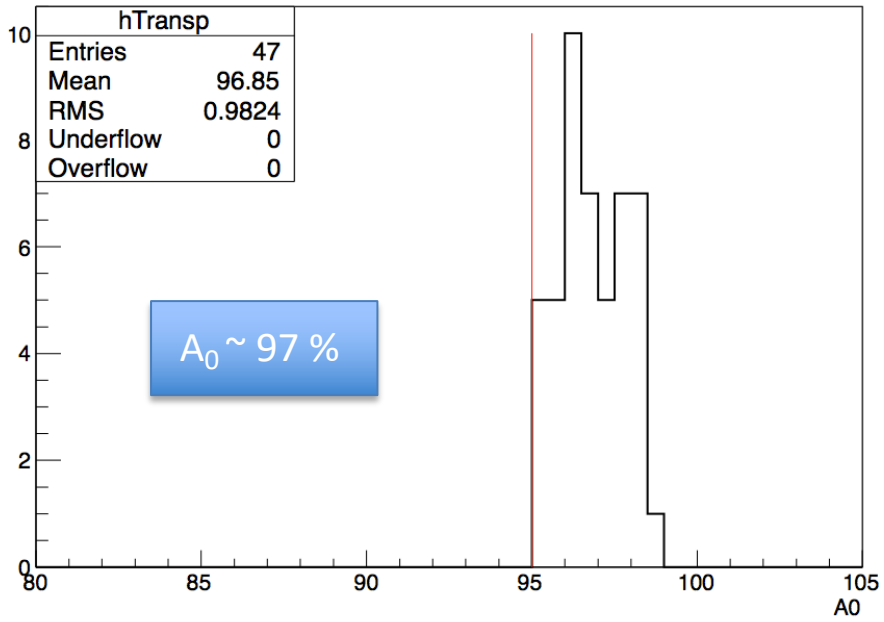
Achieved ~ 0.0050 $\mu m^4\ cm^{-1}$ clarity for large tiles (LHCb had 0.0064 $\mu m^4\ cm^{-1}$ for n=1.03)

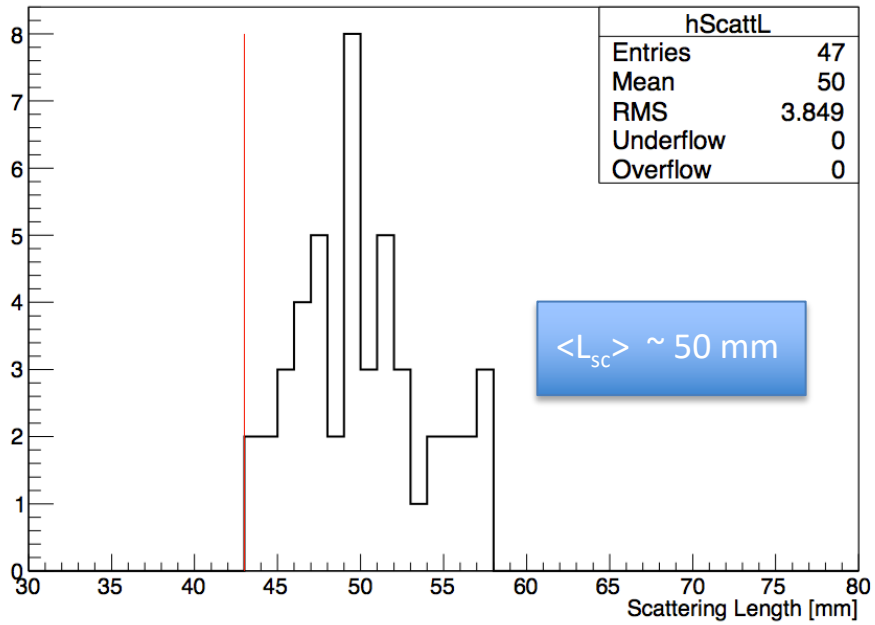


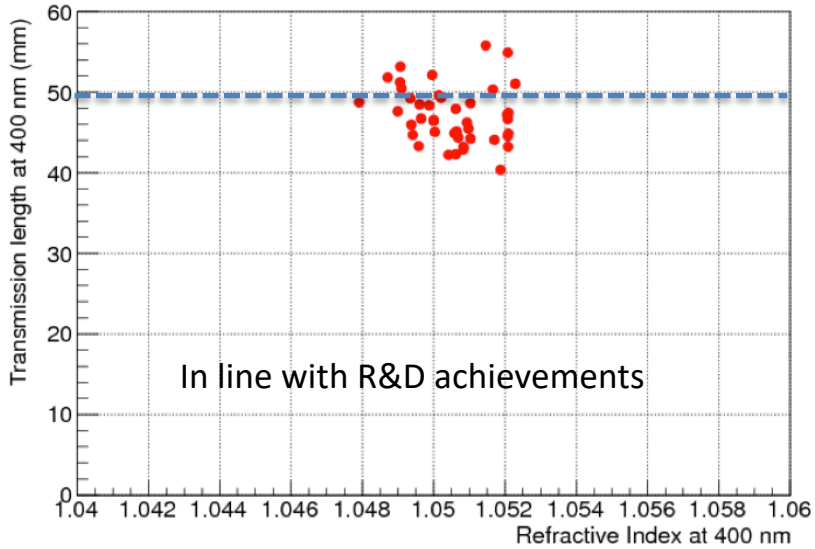


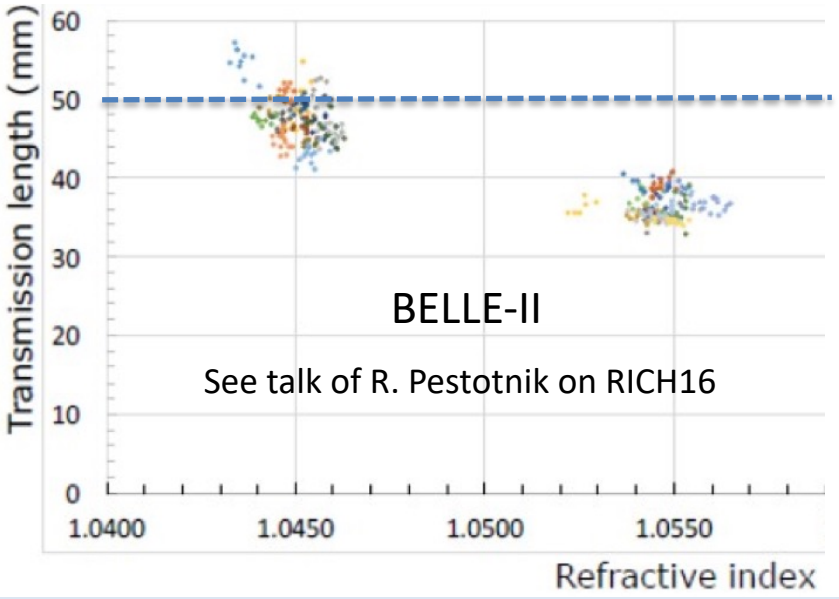
Hygroscopic aerogel requires special care and dry N_2 atmosphere

Past Standards



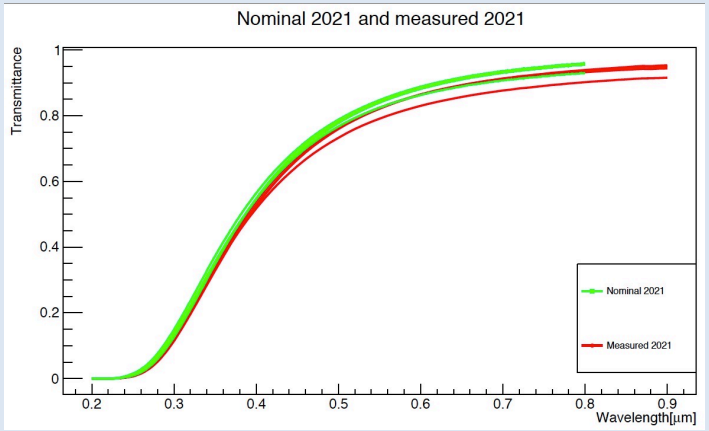




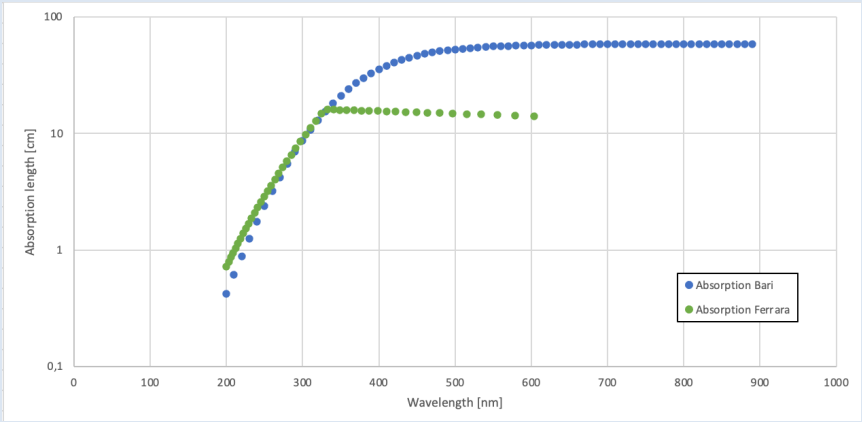


Light Transmittance @ EIC

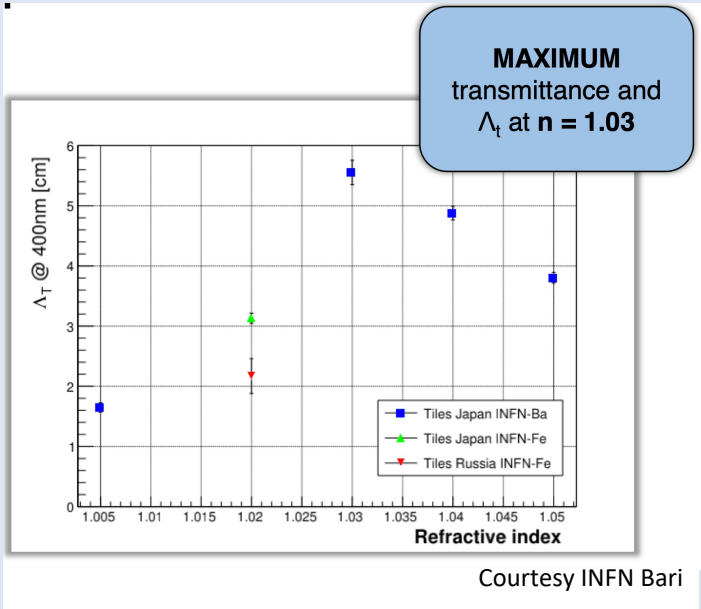
Quality assurance



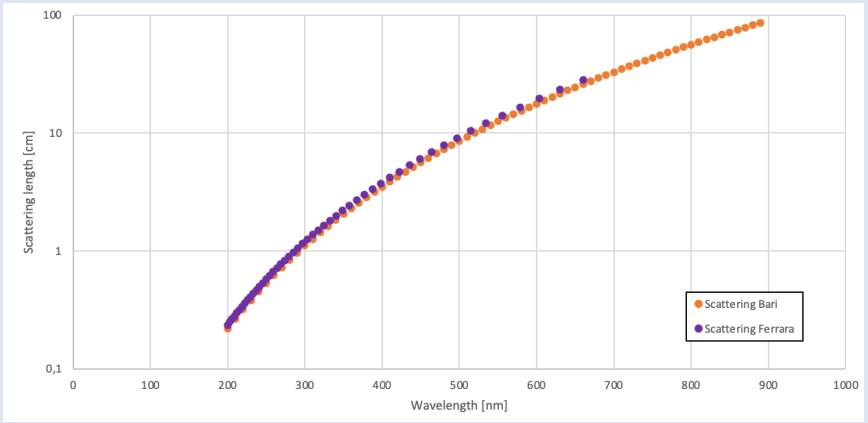
Improve simulation model



Optimization

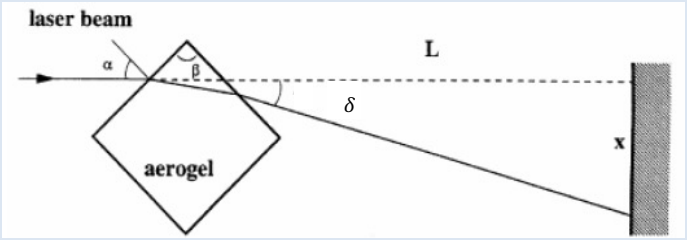


Courtesy INFN Bari

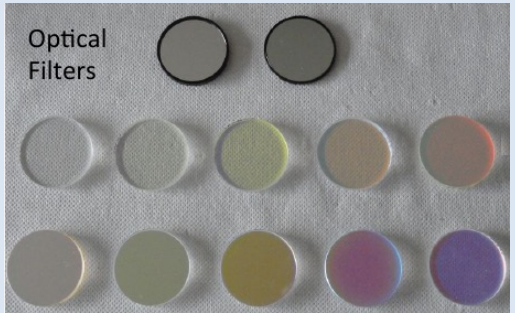


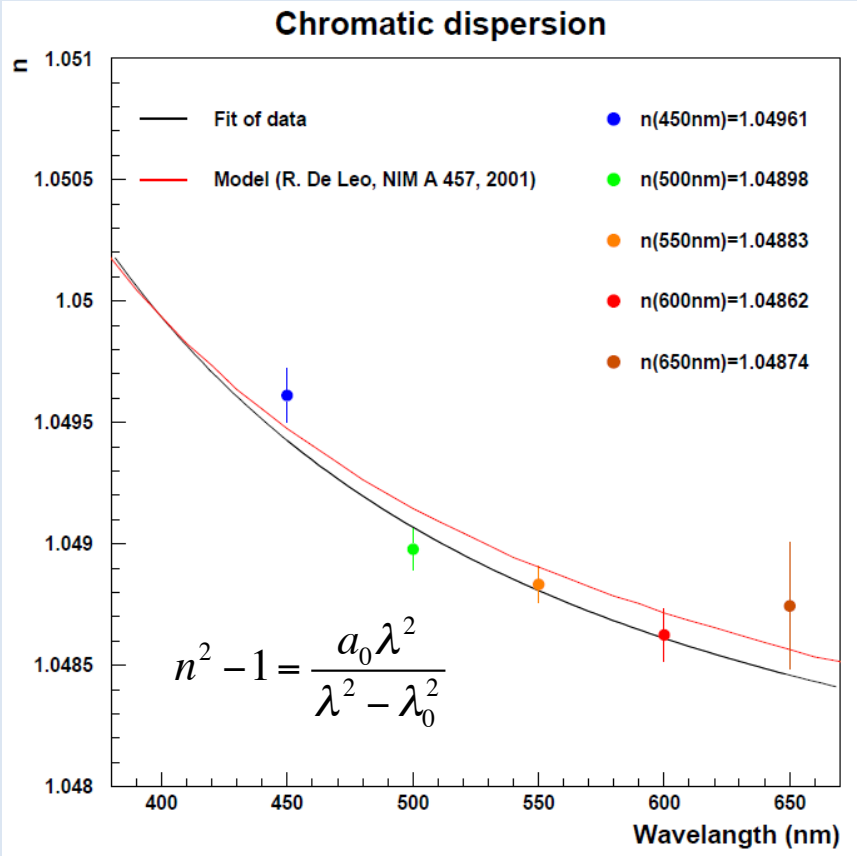
Chromatic Dispersion @ CLAS12

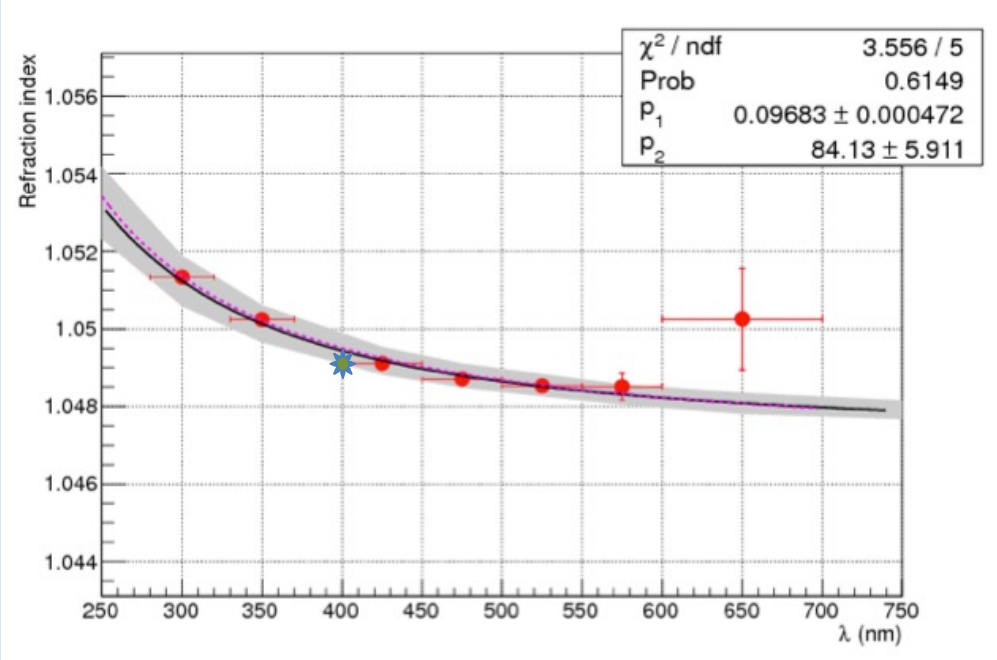
Measured by prisma method:



Measured by prototype with optical filters:



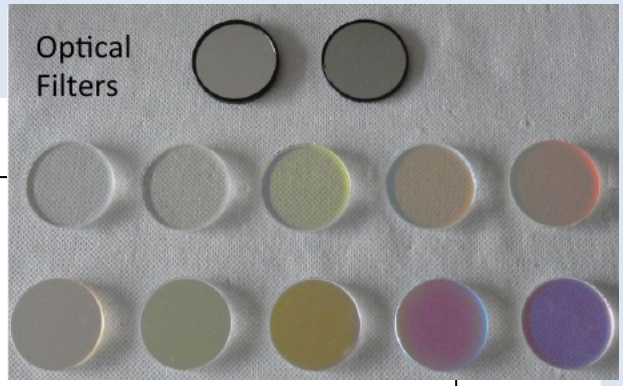




Expected value from density:
$n(400nm) = [1+0.438\rho]^{1/2} = 1.0492$

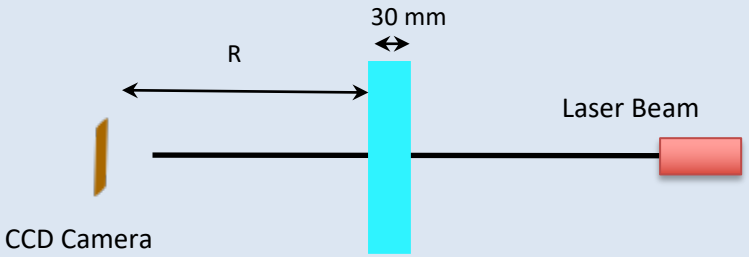
Chromatic Dispersion @ EIC

Chromatic dispersion measured by prototype with optical filters (n=1.02)



Forward Scattering @ CLAS12

Description of the setup

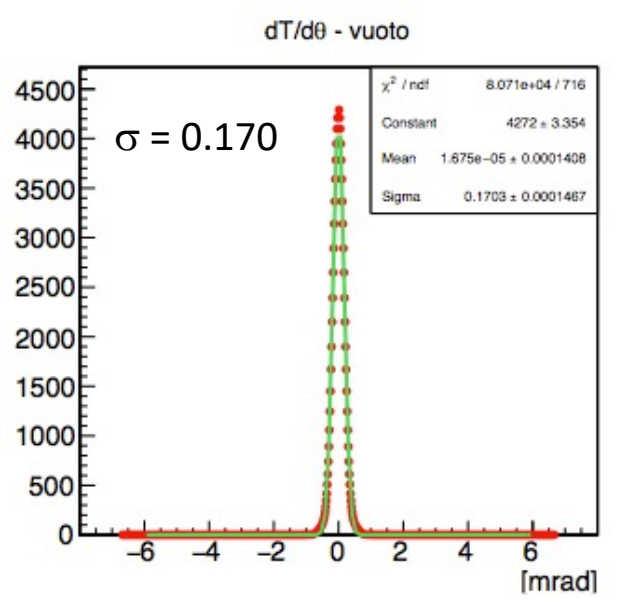


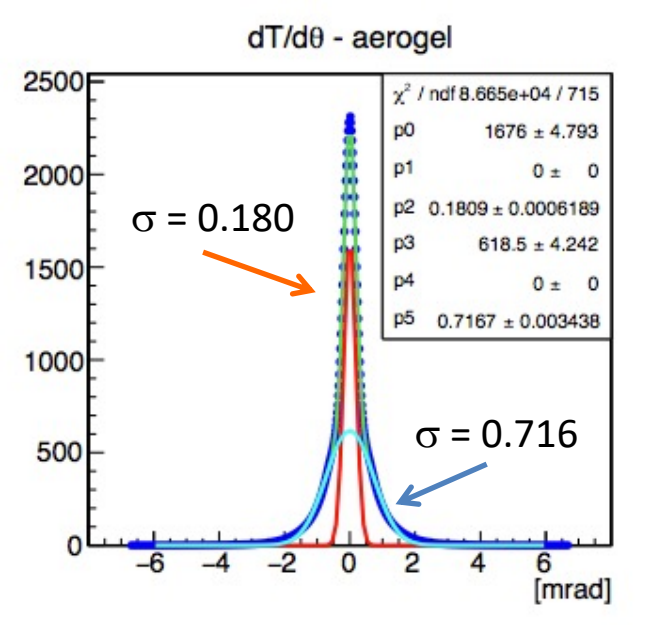
Scattering of the light in the medium due to the anisotropy of the dielectric properties caused by density microscopic fluctuations

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

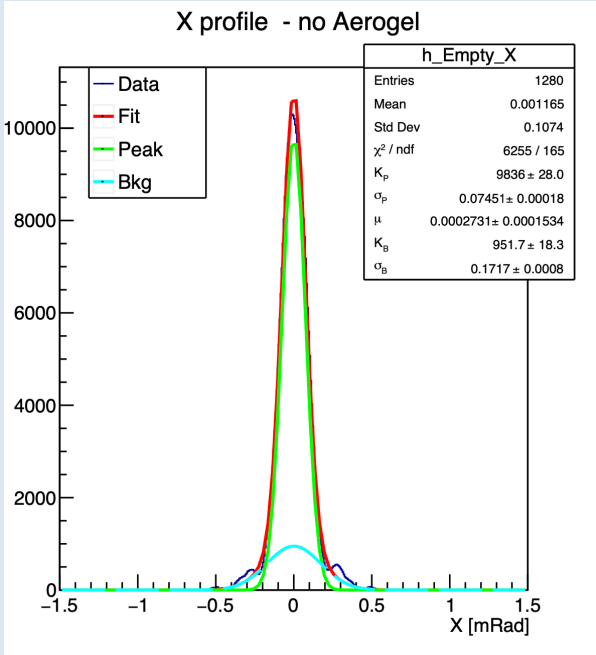
Take the average X & Y profiles of the spot

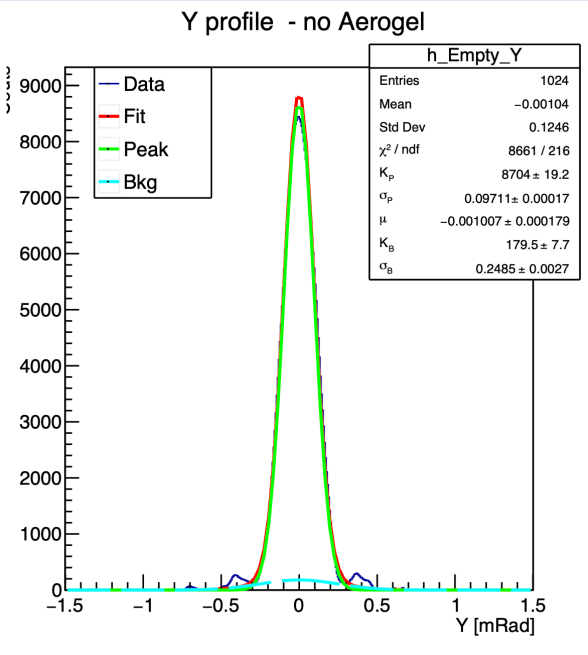




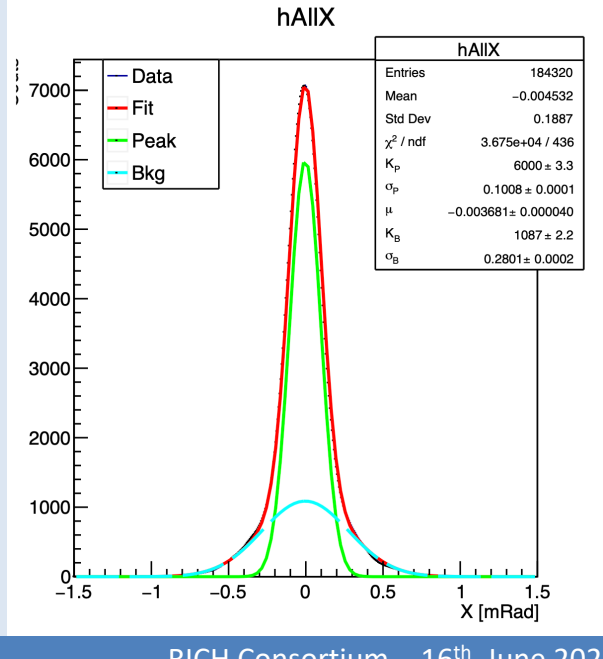
Forward Scattering @ EIC

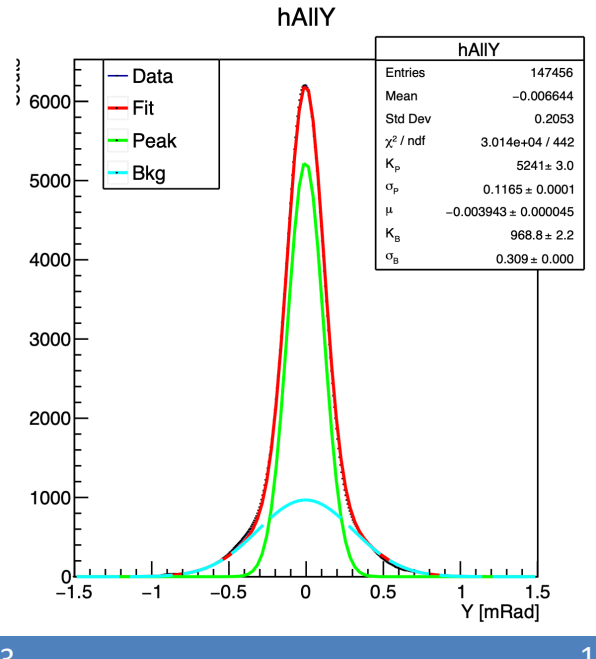
No aerogel



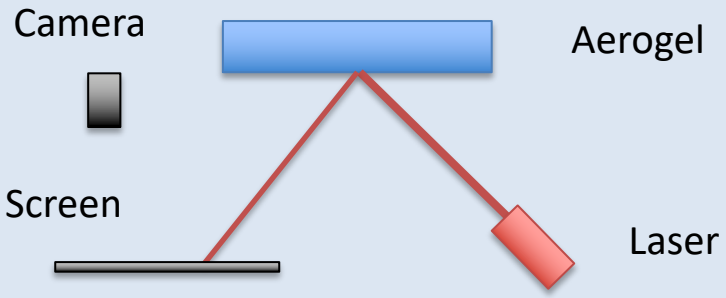


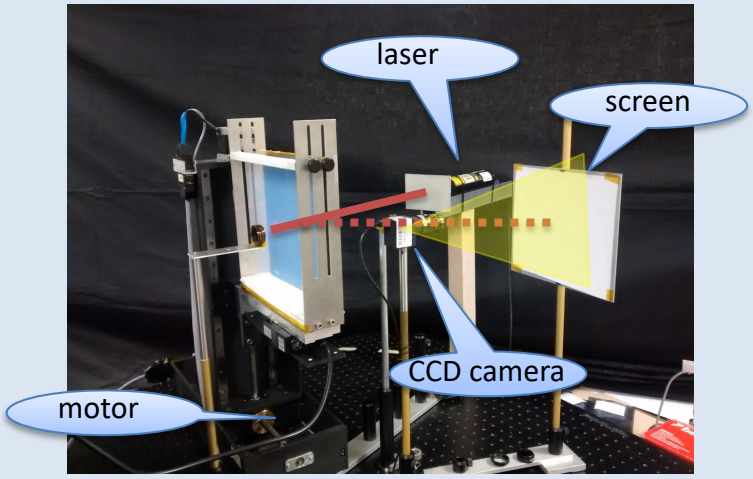
3 x 2 cm aerogel





Surface Scan @ CLAS12

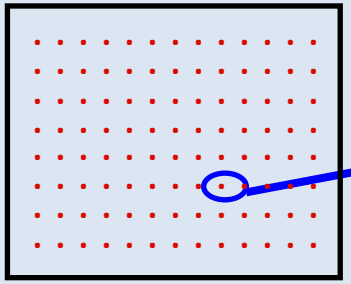


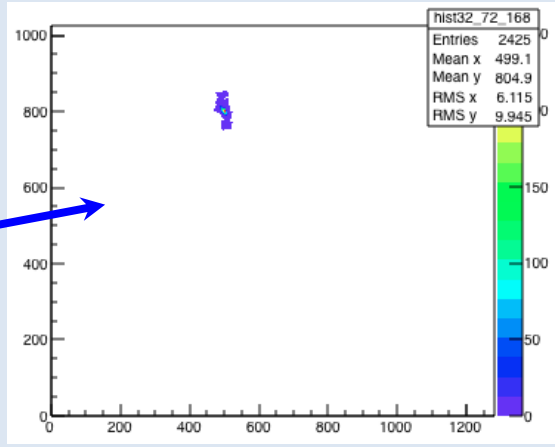


x-y axis movable table

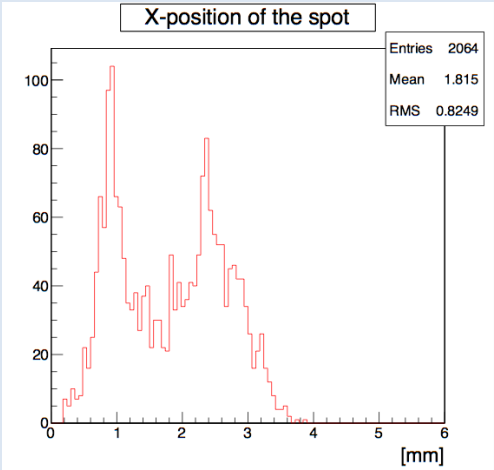
CCD camera [ThorLabs DCU 224c]
- sensitive area [5.95-4.76 mm]
- resolution [1280-1024 pixels]
- pixel size 4.65 µm

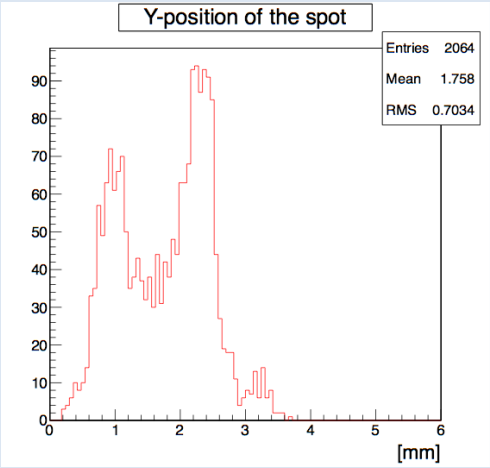
Scan of aerogel surface





Distributions of X & Y positions of the spot

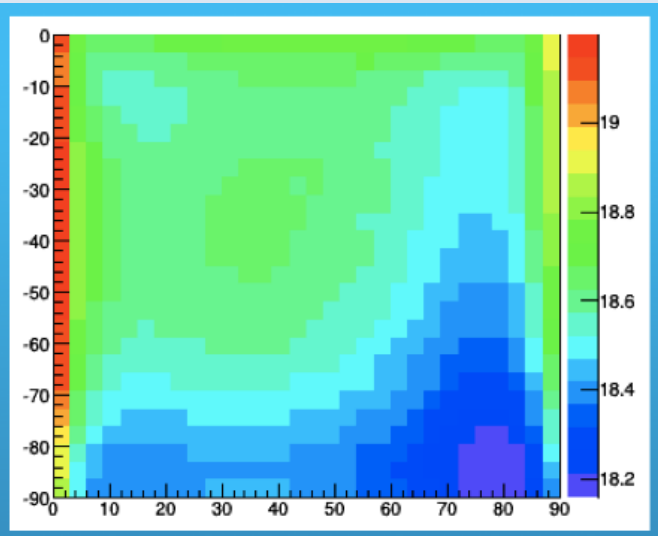




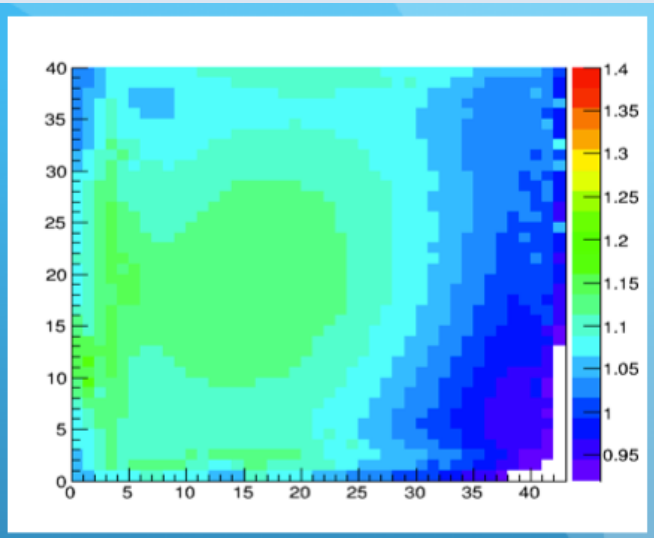
Surface Map @ CLAS12

Face 1

Touch Machine

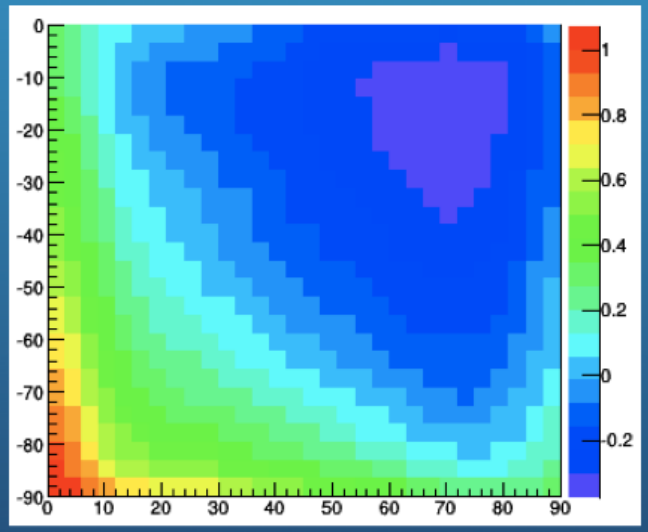


Laser Setup

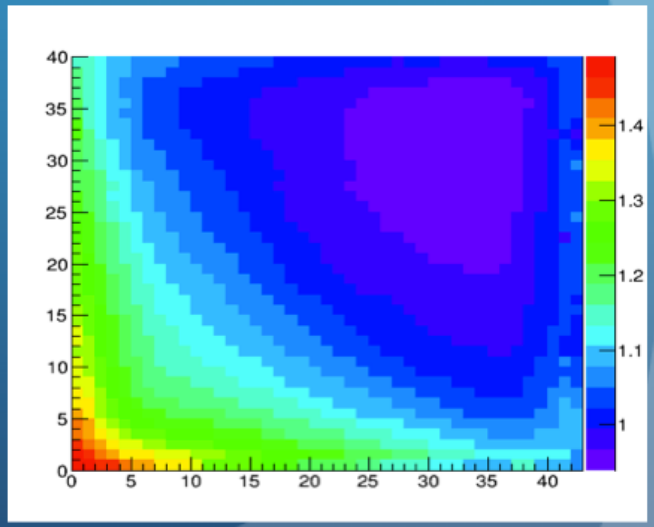


Face 2

Touch Machine



Laser Setup

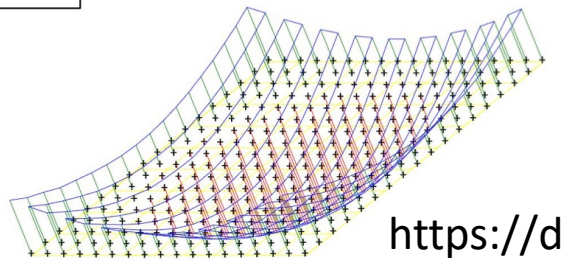


TOUCH PROBE

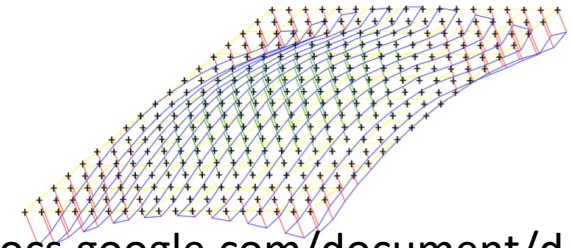
Minimum, maximum, average and std deviation of the measured thickness:

n = 1.03

Y -



Y +

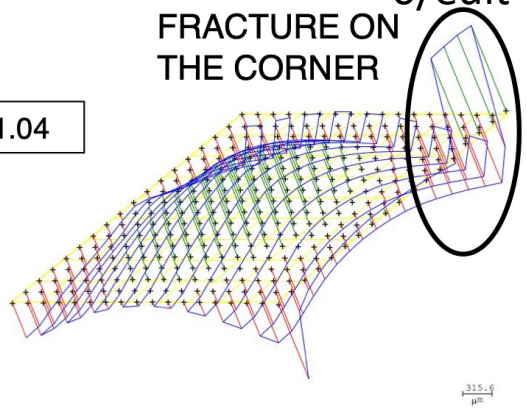


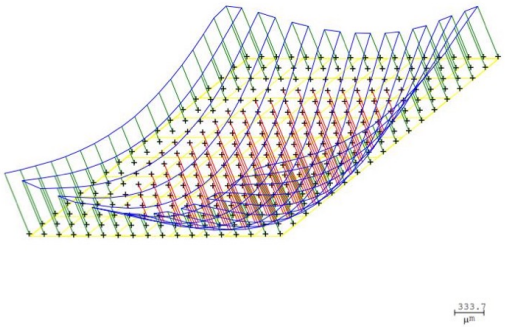
```
n=1.03
min tickness (mm):    19.690
max tickness (mm):    20.385
standard deviation:   0.172
average (mm):         19.955

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
```

https://docs.google.com/document/d/1YpN7gx85JjoQnoB9NblD61N9B1YhRGwBh2GIKZ25T-0/edit

FRACTURE ON THE CORNER

n = 1.04



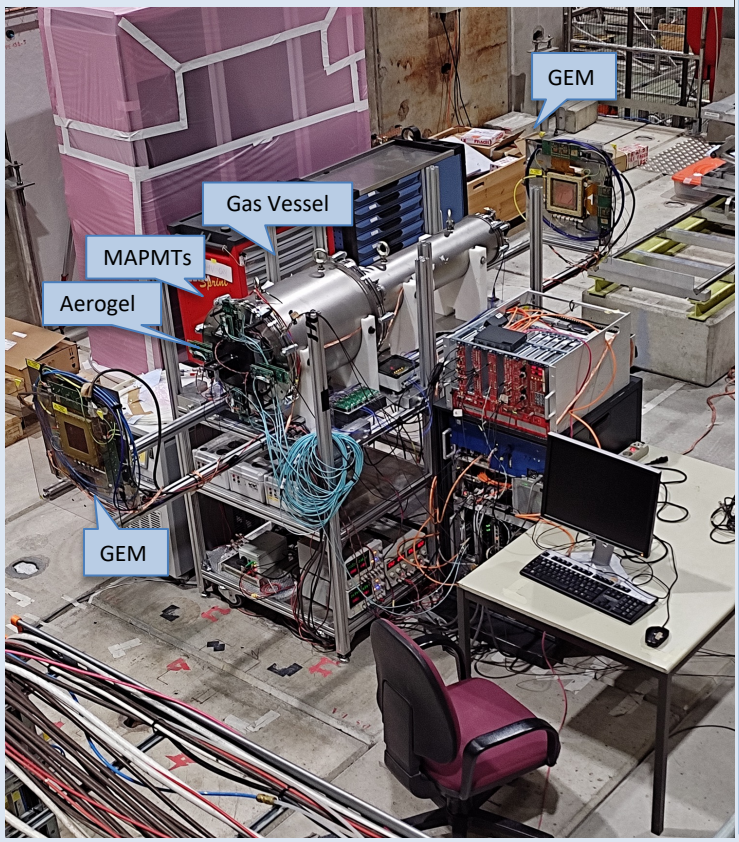


MENISCUS SHAPE DUE TO FABRICATION PROCESS

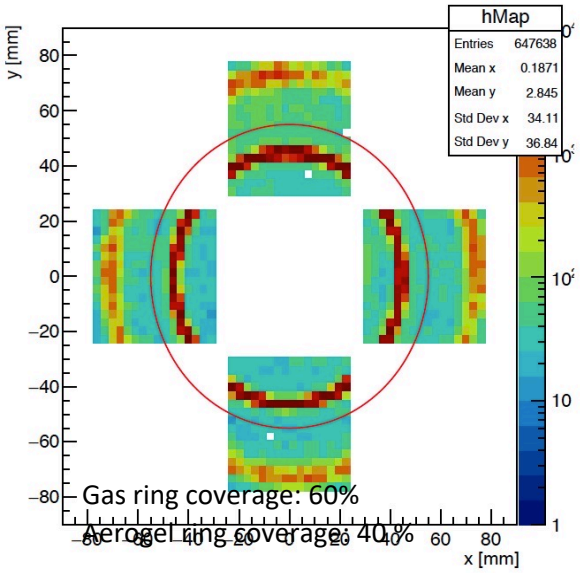
Courtesy INFN Bari

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).

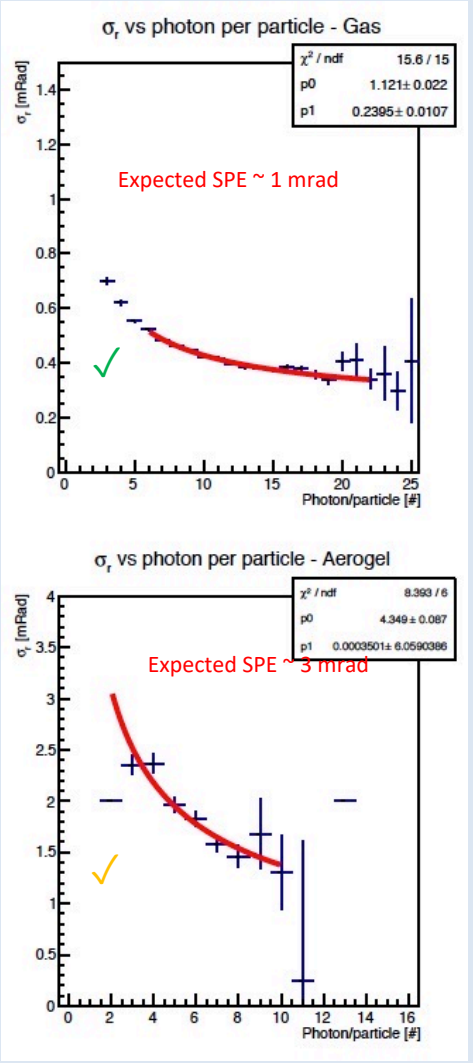


Reference readout from CLAS12 RICH:
H13700 MA-PMTs + ALCOR3 ToT chip



Gas ring coverage: 60%

Aerogel ring coverage: 40%



https://docs.google.com/document/d/1YpN7gx85JjoQnoB9NblD61N9B1YhRGwBh2GIKZ2ST-0/edit

Aerogel Characterization

Protocol under definition for the EIC dRICH Detector

dRICH aerogel is assumed to shape a cylindrical volume of about 90 cm radius and 4 cm thickness radiator with a nominal refractive index of n=1.02.

Based on the past achievements, the baseline aerogel element is assumed to be a tile of 2 cm thickness and maximum lateral dimension of 20 cm, that can be shaped by water jet (or mechanical) cutting. The tile dimensions are maximized to limit the edge effects and shaped to best cover a circular area.

The quality assurance tests should guide the R&D towards the dRICH specifications and serve as a reference for acceptance during production. They represent the current understanding and could evolve in time.