The production of the large scale aerogel radiators for use in the Ring-imaging Cherenkov detectors

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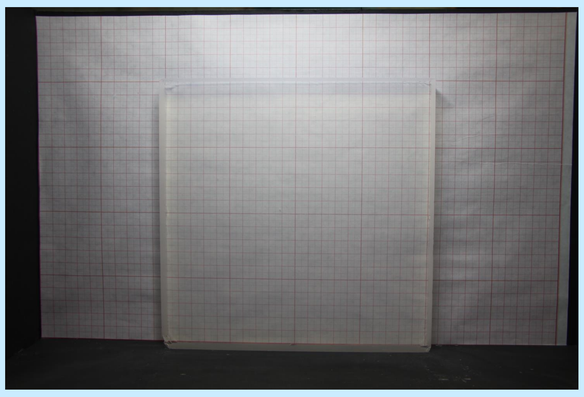
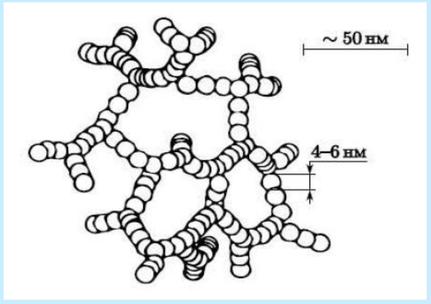
Aerogel for different types of Cherenkov detectors is produced by a collaboration of Budker Institute of Nuclear Physics and Boreskov Institute of Catalysis during more than two decades [1,2]. Until recently, only the production of two sizes was possible in large numbers: 50×50 ***and*** $115 \times 115\ mm^2$. ***This work is devoted to the development of the production technology of large scale aerogel radiators for use in the Ring-imaging Cherenkov detectors. These detectors requires additional parameters to be controlled for each aerogel tile during production. Procedures of measurement of the aerogel tiles refractive index, the light scattering length, the upper surface flatness and the tile dimensions are described. The new precise cutting machine was developed and produced for aerogel tile processing. More than one hundred aerogel tiles with thicknesses of*** 20 ***and*** $30\ mm$ ***size*** $200 \times 200\ mm^2$ ***were produced for the CLAS12 RICH detector [3]. The actual data on the measurement results of controlled parameters are presented.***

Aerogel

Aerogel is a nanomaterial that is a porous substance with a pore size smaller than the wavelength of light in the visible range.

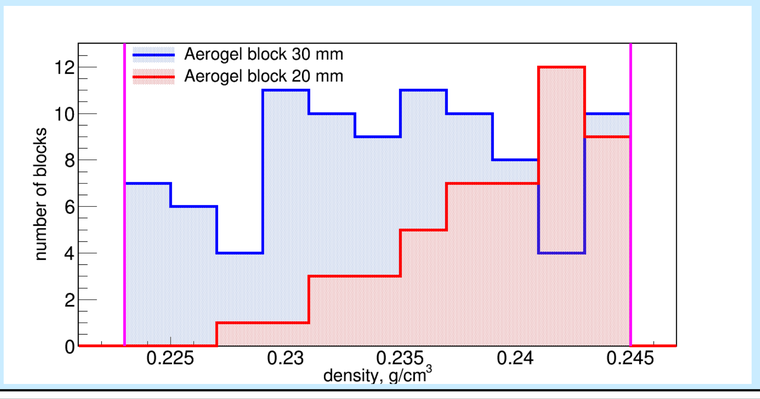




Aerogel consists of spheres of amorphous silica with a diameter of several nanometers, connected in chains (such as "caterpillars"), forming a chaotic three-dimensional structure.

Density

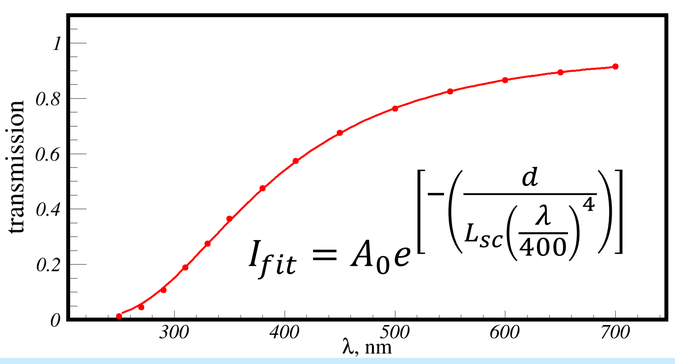
To know the density of the aerogel, the aerogel is weighed, its volume is measured and the density is calculated. The homogeneity of the density is checked by x-ray [4]. The refractive index of an aerogel is related to its density: $n = \sqrt{1 + 0.438 \times \rho}$ [2]. The density distribution for 145 blocks is shown. Selection criterion: aerogel density in the range from 0.223 to 0.245 $^{g}/_{cm^3}$.



Light scattering length

Measurement of the light scattering length.

The transparency of the aerogel is measured using spectrophotometer СФ-56. The characteristic accuracy of measuring the light scattering length is ~ 1.5%. The light scattering length in aerogel occurs according to Rayleigh's law: $L_{sc} \sim \lambda^4$.



Fit options:

A_0 – coefficient of transparency, fit parameter;

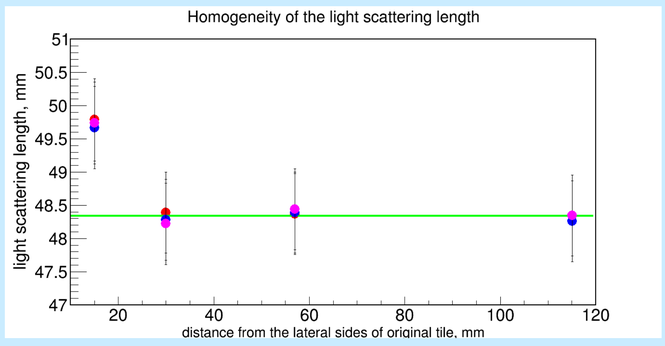
L_{sc} – light scattering length at $\lambda = 400\ nm$, fit parameter;

d – block thickness, constant;

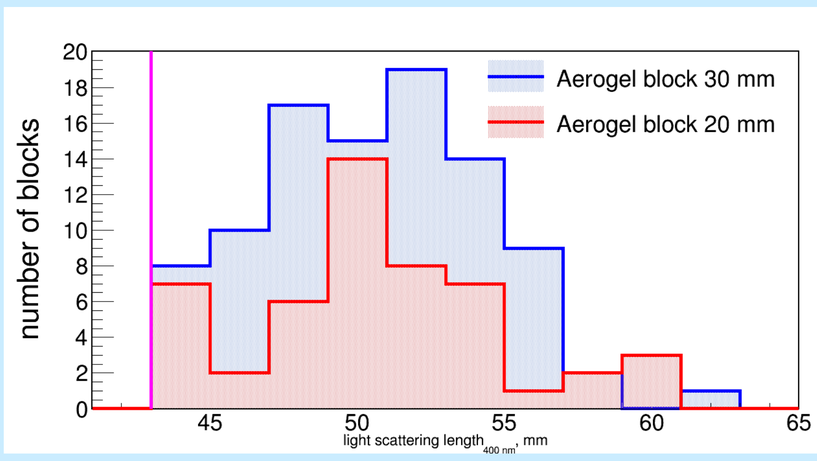
λ – wavelength of light.

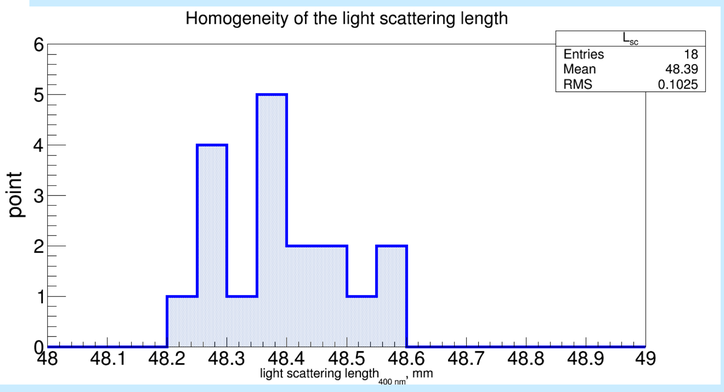
Homogeneity of the light scattering length.

To measure the homogeneity, an aerogel block measuring $\mathbf{240 \times 240\ mm^2}$ was cut in 4 parts. For the resulting 4 parts the light scattering length was measured in 4 points at the distances of 15, 30, 57 and 115 mm from the lateral sides of original tile. It can be seen that at the edge the scattering length is 5% higher. The final block dimension is $\mathbf{200 \times 200\ mm^2}$, the last 40 mm are removed. We can assume that the block $\mathbf{200 \times 200\ mm^2}$ is homogeneous (RMS = 0.1).



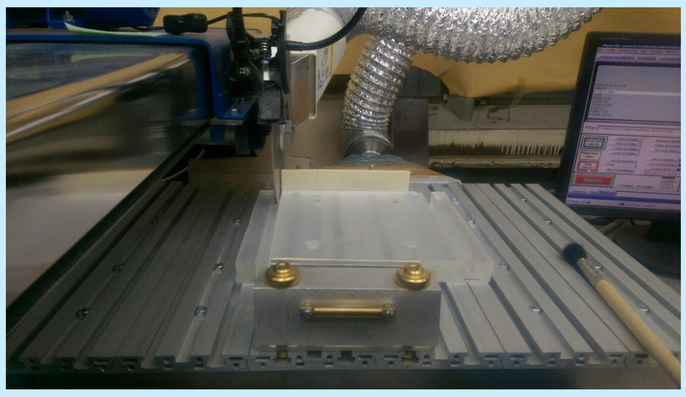
The figure shows the distribution of the light scattering length for 145 aerogel blocks. The mean of the light scattering length is 50 mm for the aerogel tile 20 and 30 mm. All aerogel blocks have the light scattering length greater than 43 mm.





Machine for aerogel tooling

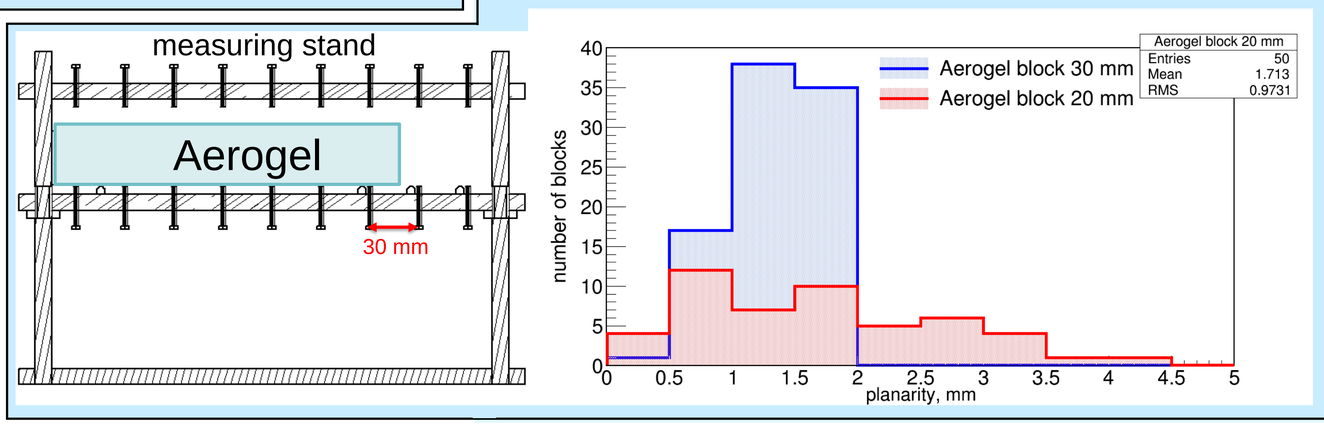
To produce an aerogel block of overall dimensions, a CNC machine diamond wheel cutting was created. The feed speed and frequency of the diamond change. Of the blocks $\mathbf{240 \times 240\ mm^2}$ we produce aerogel blocks $\mathbf{200 \times 200\ mm^2}$. The machine allows to process 6-7 tiles of aerogel a day. The cutting accuracy is 0.25 mm.



Planarity

The aerogel tile planarity is measured mechanically. The aerogel is placed on the measuring stand. The stand has a 30 mm grid. The resulting coordinate field has a size of 7x7 points ($180 \times 180\ mm^2$). During measurement aerogel is protected by a lavsan film of 50 μm. Alignment of the field occurs along the main axes: the extreme points of the 4 axes are averaged, the rest are proportionally recalculated. The plane is defined as the difference between the maximum and minimum values of the coordinate field. The accuracy of the measurements is 0.3 mm. Selection criterion:

- the aerogel tile 30 mm, planarity up to 2 mm;
- the aerogel tile 20 mm, planarity up to 4.5 mm, but the average planarity of all blocks does not exceed 3 mm.



Planarity calculation:

13.28 13.46 13.61 13.56 13.51 13.36 12.98
13.55 13.72 13.88 14.00 14.05 13.76 13.29
13.44 13.87 14.02 14.21 14.15 14.10 13.48
13.53 13.81 14.06 14.11 14.21 14.07 13.53
13.33 13.73 14.05 14.04 14.17 13.93 13.46
13.34 13.58 13.99 13.97 14.01 13.87 13.37
13.03 13.42 13.52 13.56 13.53 13.30 12.95
min: 12.95 max: 14.21 max-min: 1.26

References

[1] Status of aerogel production in Novosibirsk, Barnyakov A Yu et al. Nucl. Instr. Meth. A 639 225 (2011);

[2] Recent results on aerogel development for use in Cherenkov counters, Danilyuk, A.F et al. Nucl. Instr. Meth. A 494 491 (2002);

[3] The CLAS12 large area RICH detector, Contalbrigo, M. et al. Nucl. Instr. Meth. A 639 302 (2011);

[4] Cherenkov Detector with a Focusing Aerogel Radiator, Kravchenko, E.A. SNIC Symposiu m, Stanford, California – 3-6 April 2006, http://www.slac.stanford.edu/econf/C0604032/papers/0045.PDF