

Study of Highly Transparent Silica Aerogel as RICH Radiator

Ichiro Adachi

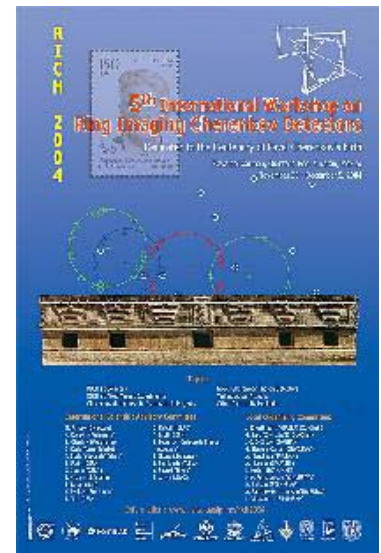
for the aerogel RICH R&D group

KEK

RICH2004

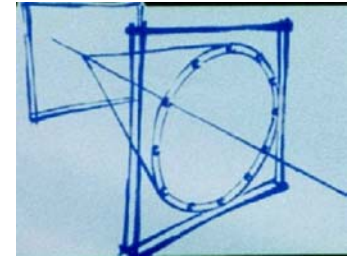
2004.Dec.01

- Introduction
- Aerogel production
- New solvent and optimization
- Optical quality
- Design considerations
- Conclusions





Acknowledgements

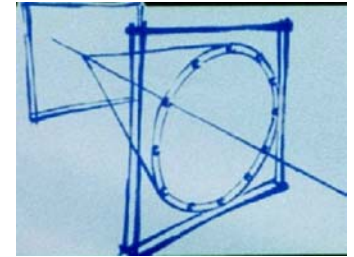


*Coating business promotion group,
Matsushita Electric Works, Ltd.*

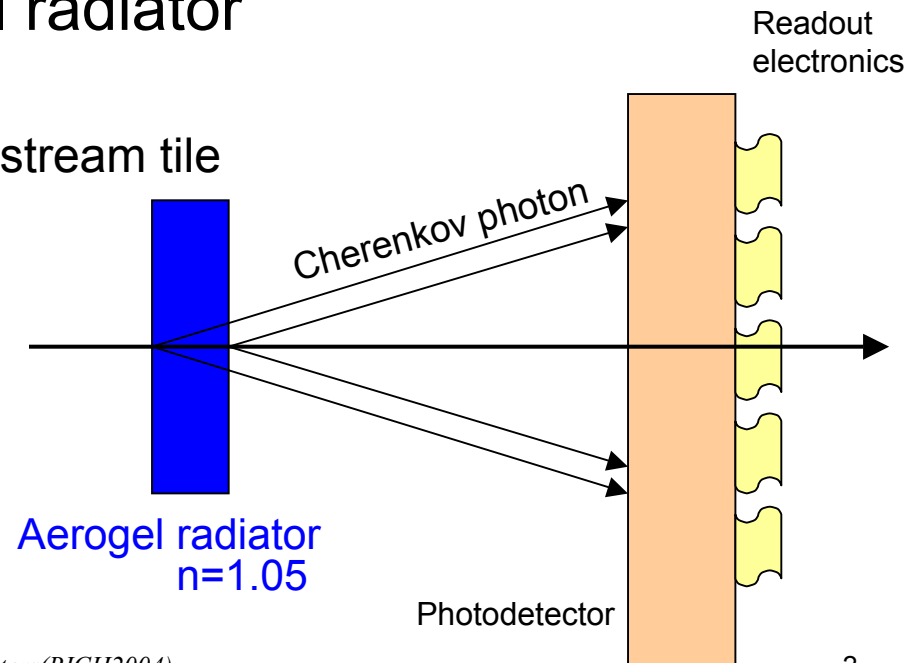
<http://www.mew.co.jp/e-aerogel/>



Introduction

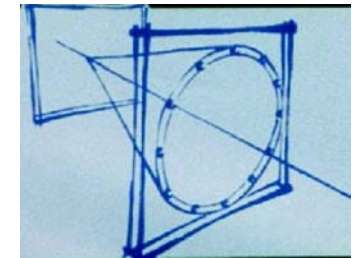


- Proximity focusing RICH using **silica aerogel** as Cherenkov radiator (talked by Peter Krizan)
 - PID device in the forward region at the Belle detector
 - Silica aerogel with $n=1.05$ as baseline design
- Requirements on aerogel radiator
 - Transparent
 - Excellent quality for downstream tile
 - For multiple radiator case (talked by Samo Korpar)
 - Hydrophobic
 - Reasonable size
 - Crack-free

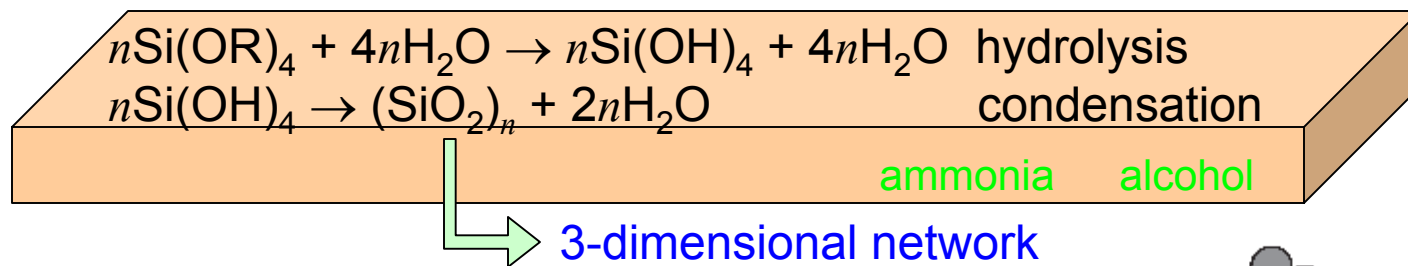




Aerogel production



■ Colloidal formation

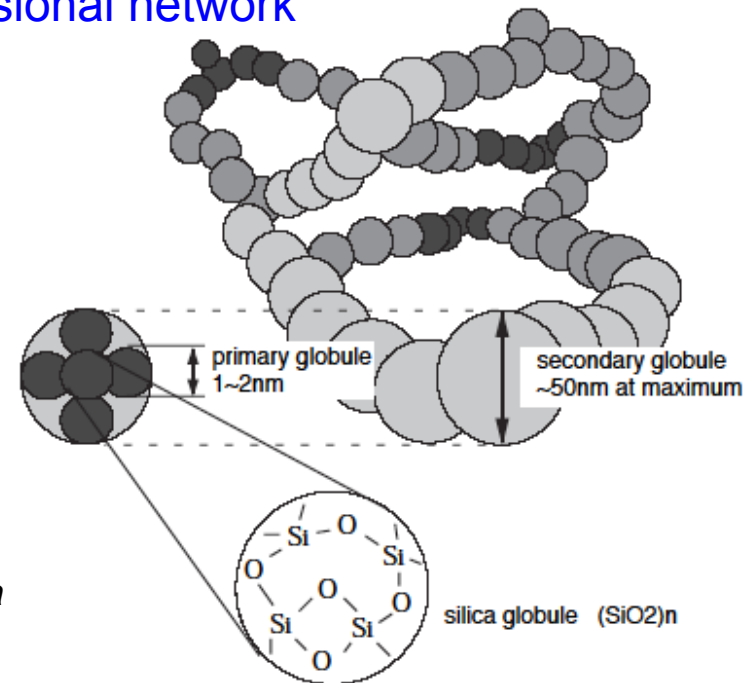


■ Treatment for hydrophobic

■ Supercritical drying

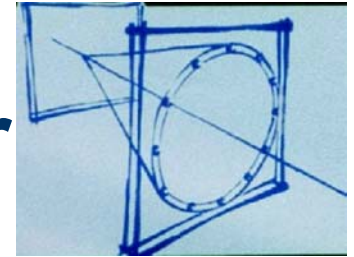
- Use CO₂ extraction
- Safer due to low supercritical point
 - 31degree & 7.5MPa

cf: methanol: 240degree & 8.1MPa

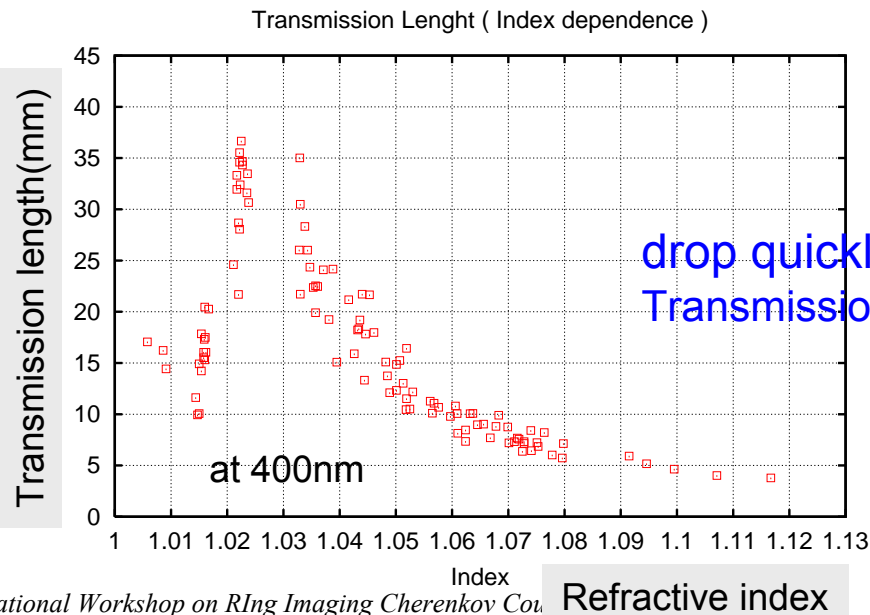




Aerogel production so far

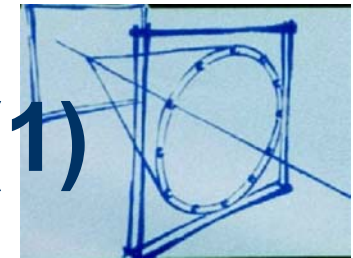


- Lots of experience in making aerogel tiles (1994-1997)
 - For the Belle Aerogel Cherenkov counter
 - ~7000 blocks of $10 \times 10 \times 2 \text{ cm}^3$ ranging $n=1.010-1.030$
 - Optimization done for them
- Optical quality gets worse if index goes beyond ~ 1.04

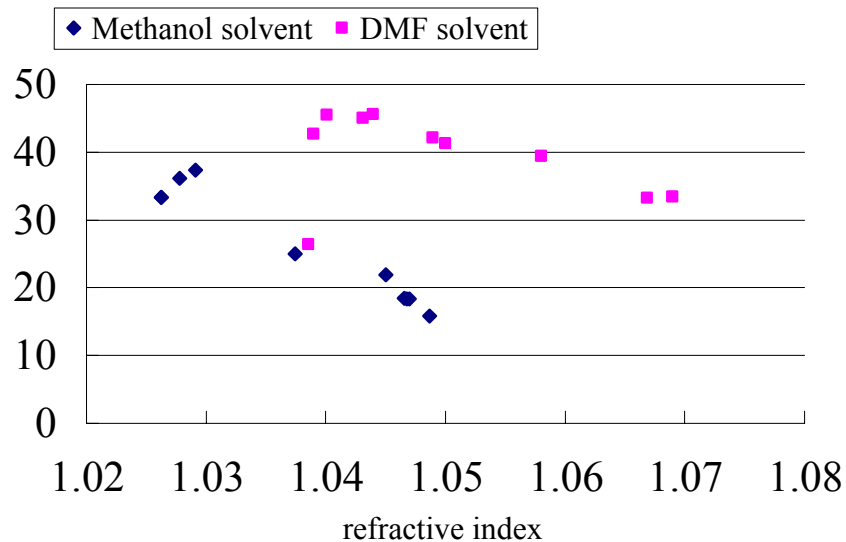




New production technique(1)



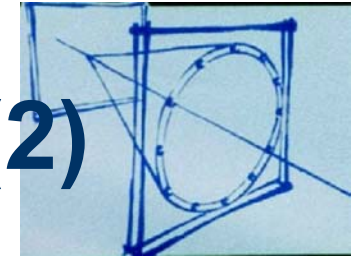
- New solvent introduced: **DMF(N,N-di-methly-formamide)**
 - Use DMF together with Methanol as solvent
- Our trial with DMF
 - Transmission length(400nm)
~40mm for n=1.050 obtained



chemical formula	HCON(CH ₃) ₂
molecular weight	80.14
usage	Dissolve various organic compounds
remarks	Low volatility Stable in normal condition Avoid breathing vapor

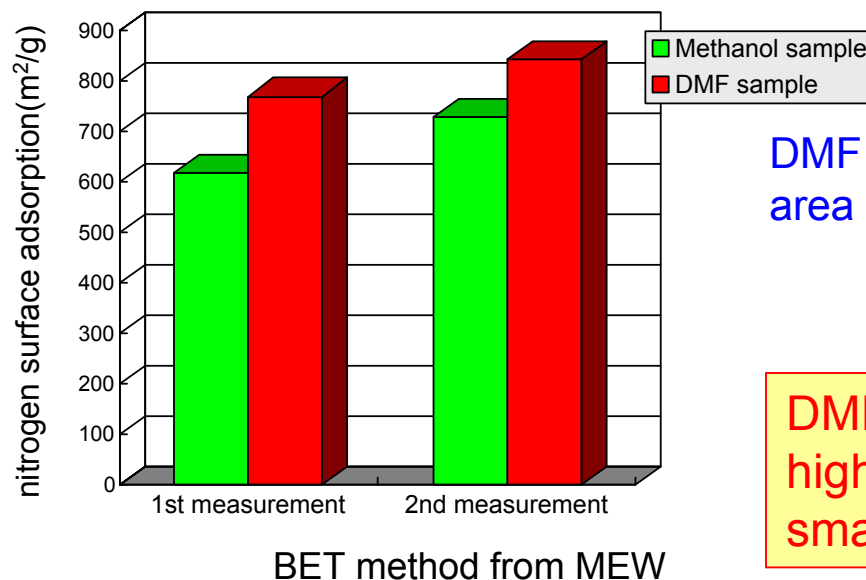


New production technique(2)

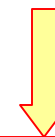


■ Why DMF effective ?

- Internal surface area for methanol and DMF samples were compared in nitrogen vapor adsorption method



DMF sample has larger internal surface area than methanol one

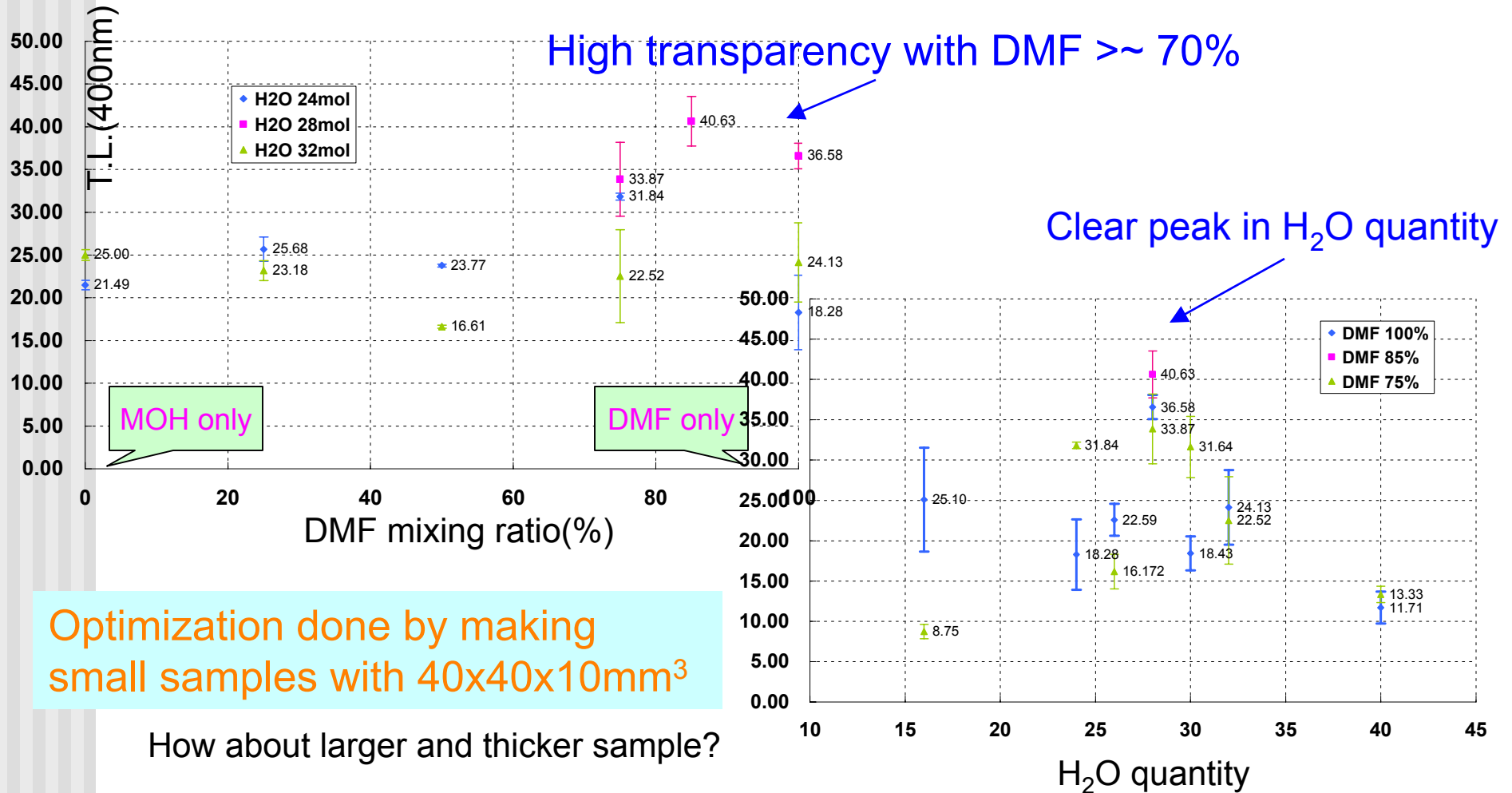
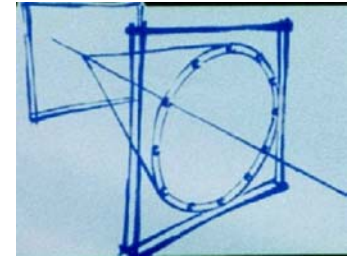


DMF is expected to help making up higher porosity, suggesting making smaller pores in a sol-gel process

As a result, higher transparency

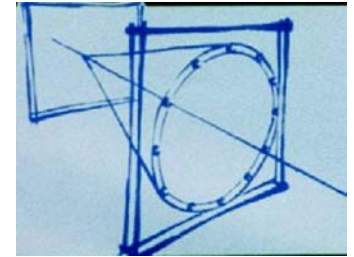


Optimization using DMF

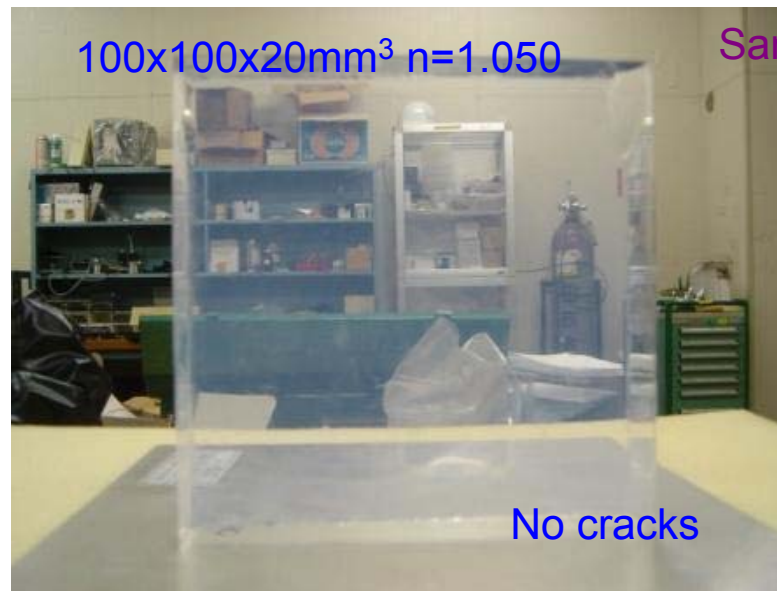




Large sample production

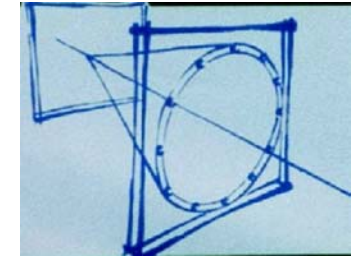


- 100x100mm² with 10/15/20mm thickness
 - Sets of optimized parameters(for $n= 1.050$) provided from small samples.
- produce samples of $n= 1.045-1.060$

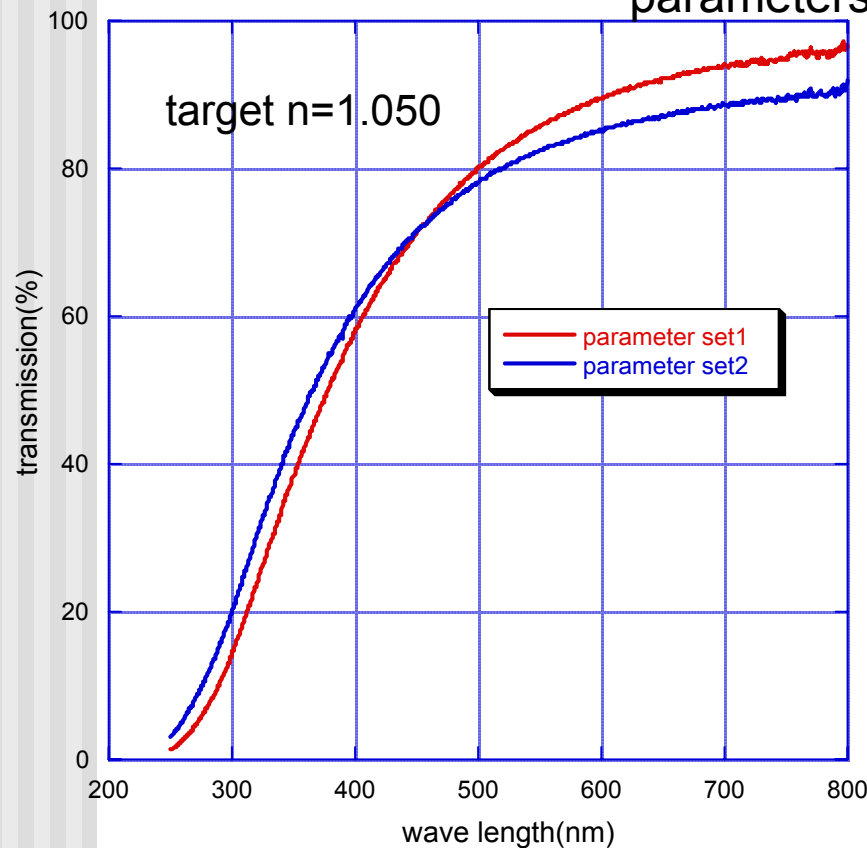




Optical quality - Transmission -

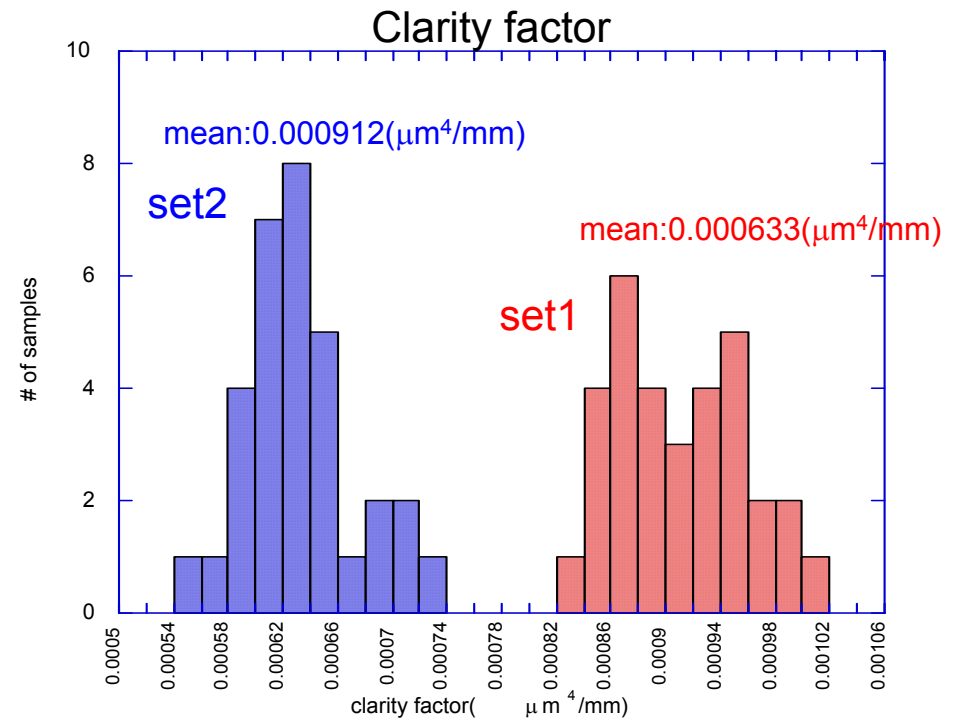


Comparison in transmissions between 2 sets of parameters for 100x100x10mm³ samples



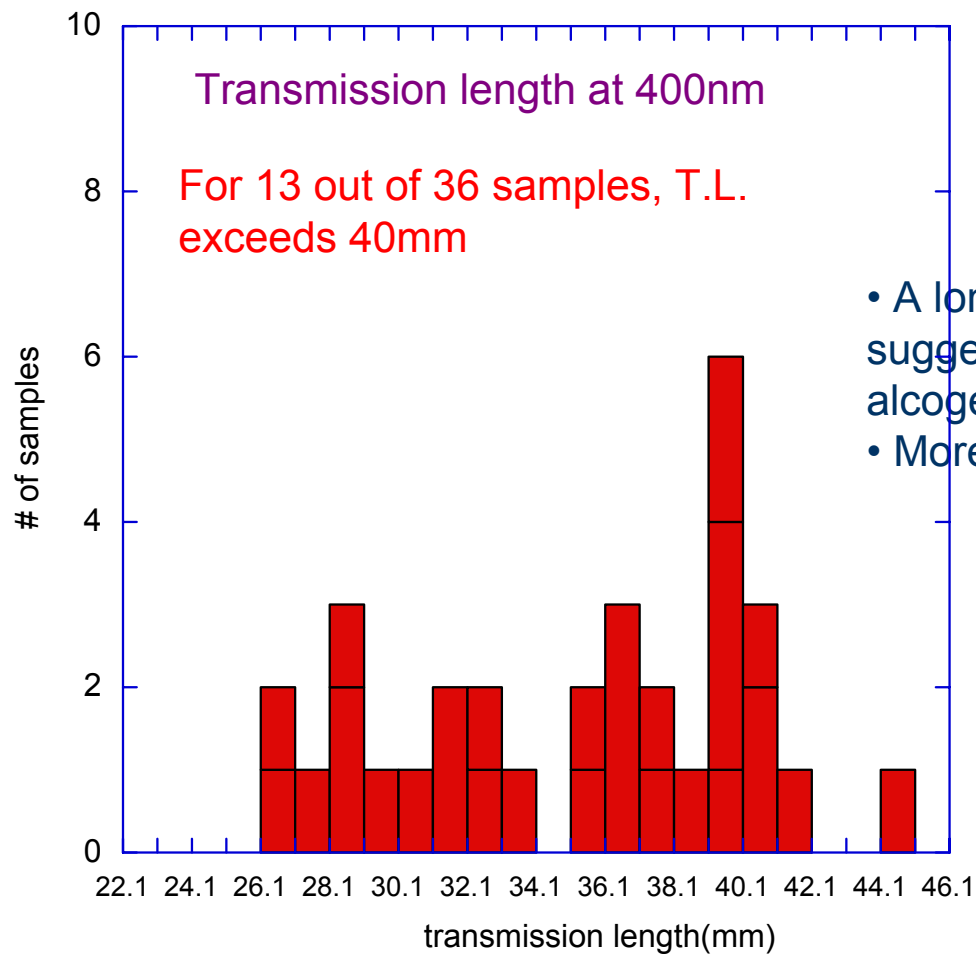
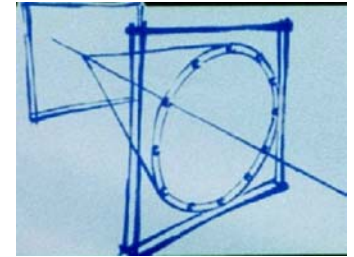
$$T = A * \exp(-C*t/\lambda^4)$$

- C: clarity factor
- A: surface factor





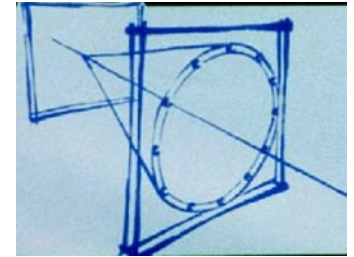
Optical quality - Transmission length -



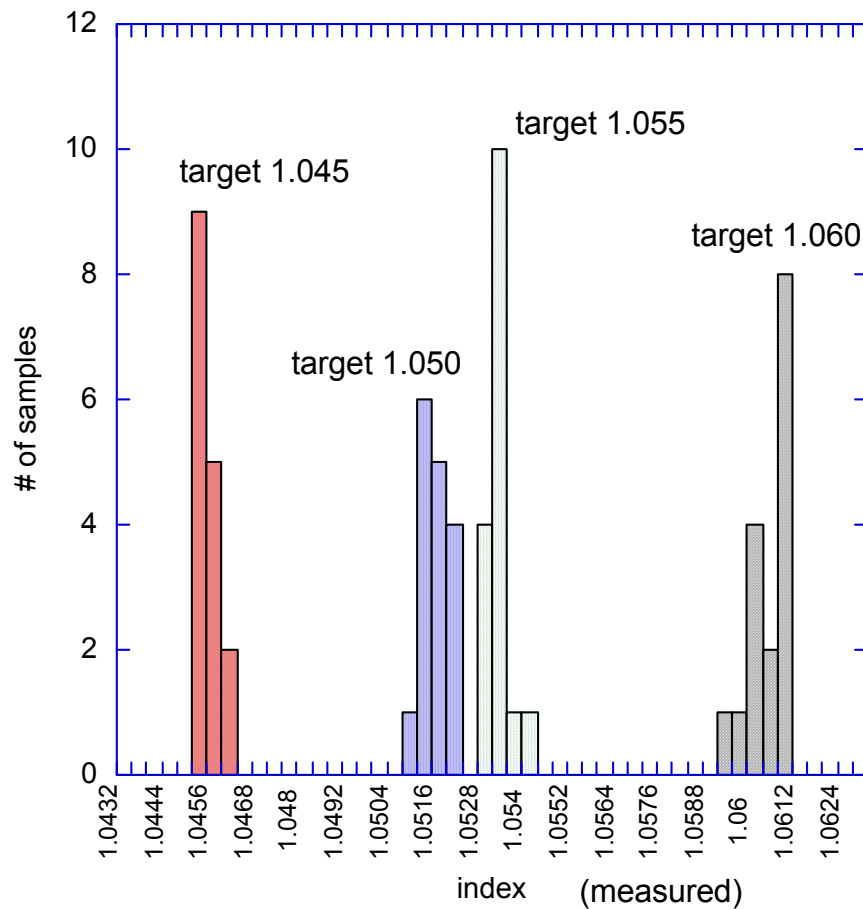
- A long tail to low T.L. region may suggest a possible instability in alcogel production
- More investigation necessary



Optical quality - Refractive index -



Refractive index management



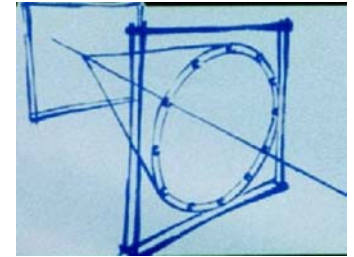
- measured with Fraunhofer method(405nm laser)
- systematic error not included

target index	measured index
1.045	1.0456 ±0.0003
1.050	1.0518 ±0.0003
1.055	1.0534 ±0.0004
1.060	1.0606 ±0.0005

Fine tuning will be done

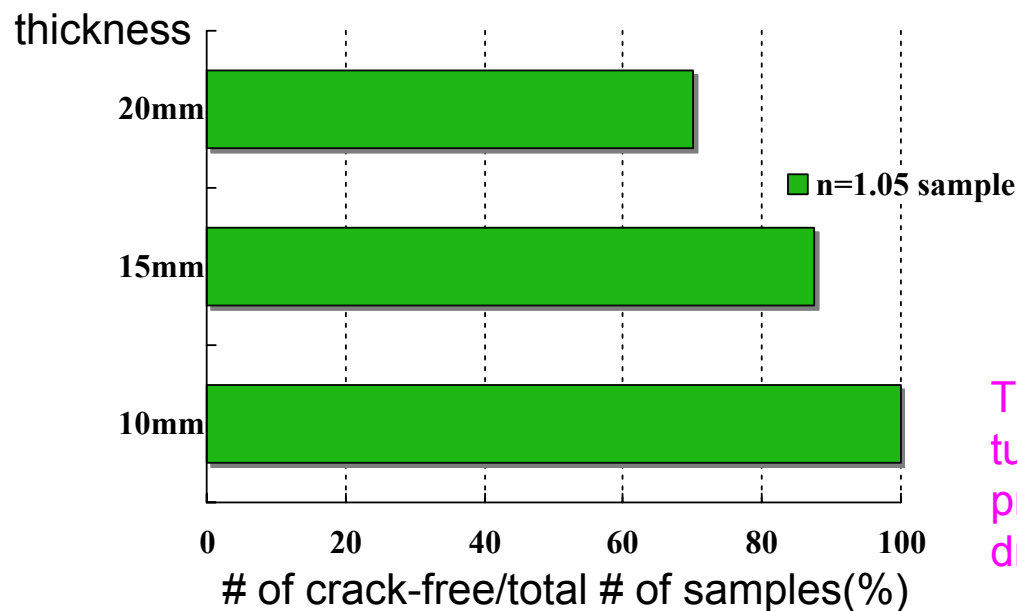


Crack-free sample



- Making “crack-free” aerogel tiles is another issue

100x100mm² cross section

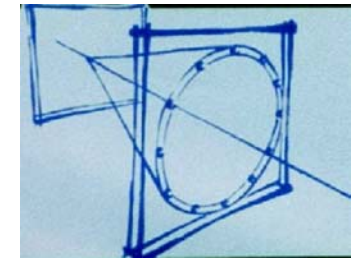


For 10mm thick samples,
100 % crack-free, while
70% if thickness is 20mm

This yield may be improved by
tuning mixing ratio at sol-gel
process as well as supercritical
drying conditions

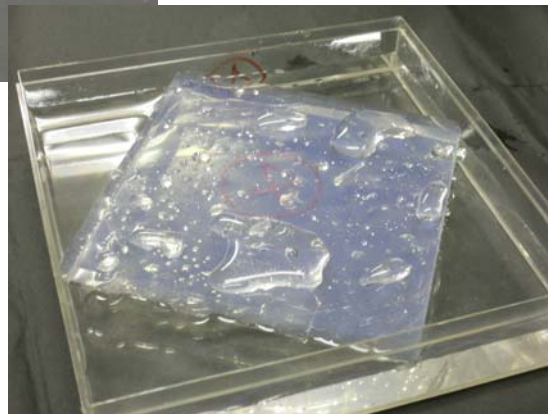
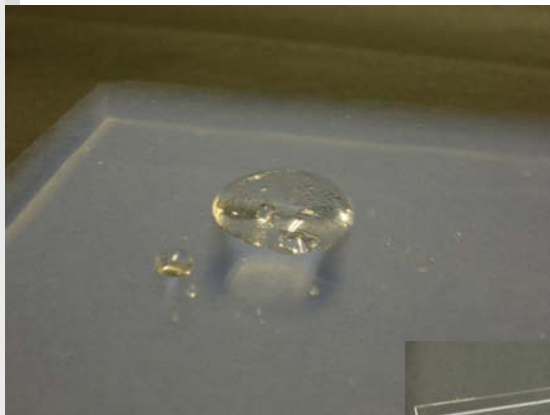


Hydrophobic feature

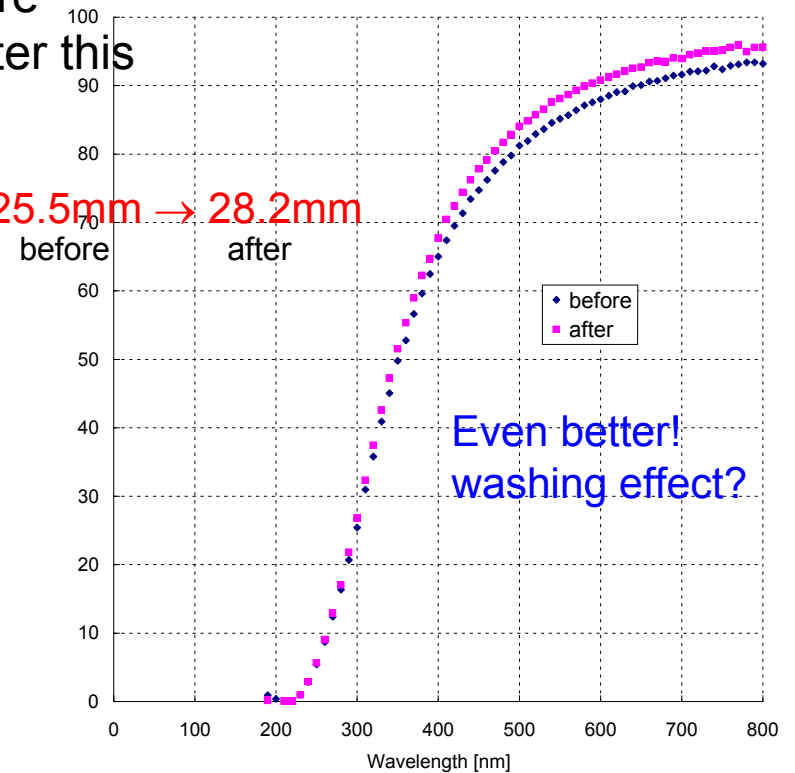


■ Hydrophobic feature tested

- Aerogel put into water and compare transmission between before & after this



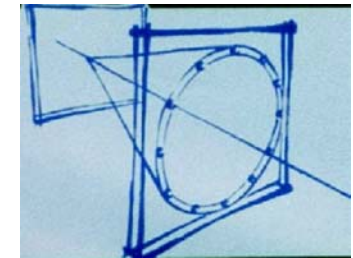
T.L.(400nm): 25.5mm → 28.2mm



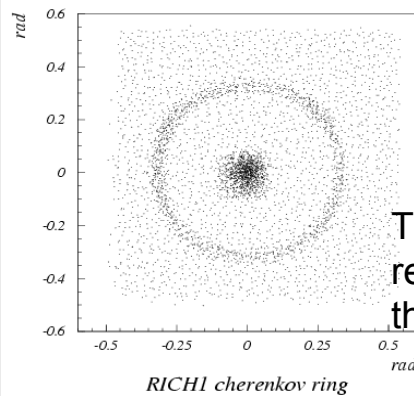
Hydrophobicity well possessed



Beam test results

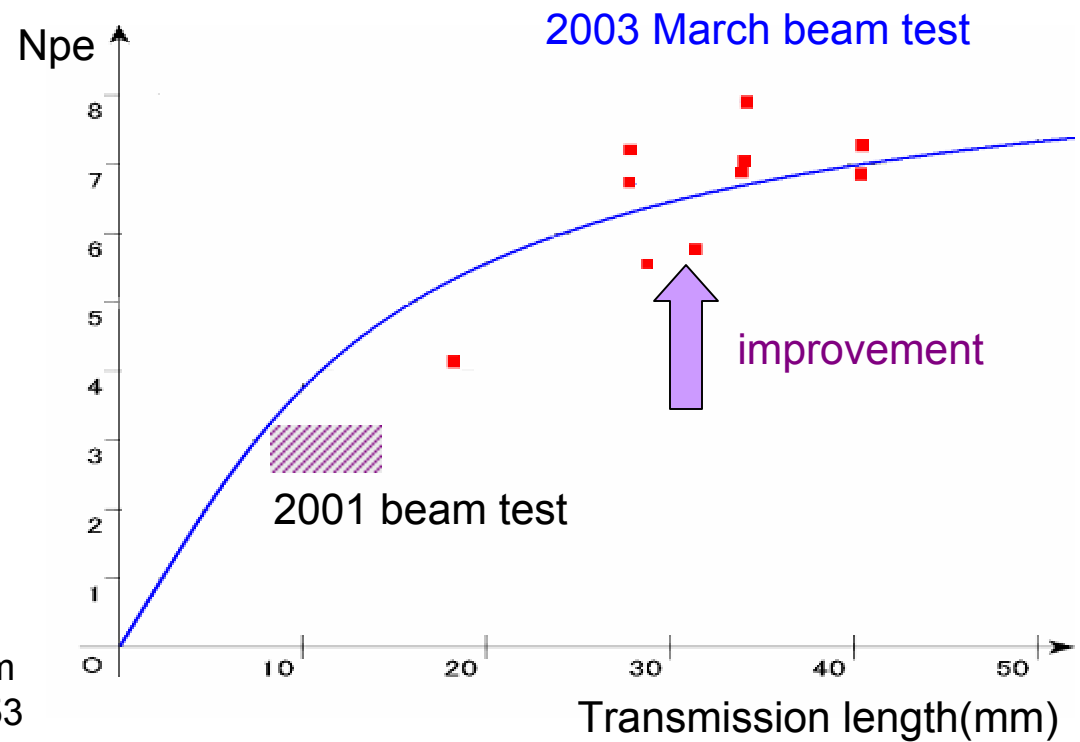


- To confirm aerogel quality, beam test has been performed



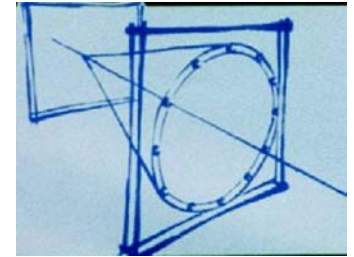
T.L.(400nm):40.9mm
refractive index:1.053
thickness:18.75mm

RICH1 cherenkov ring

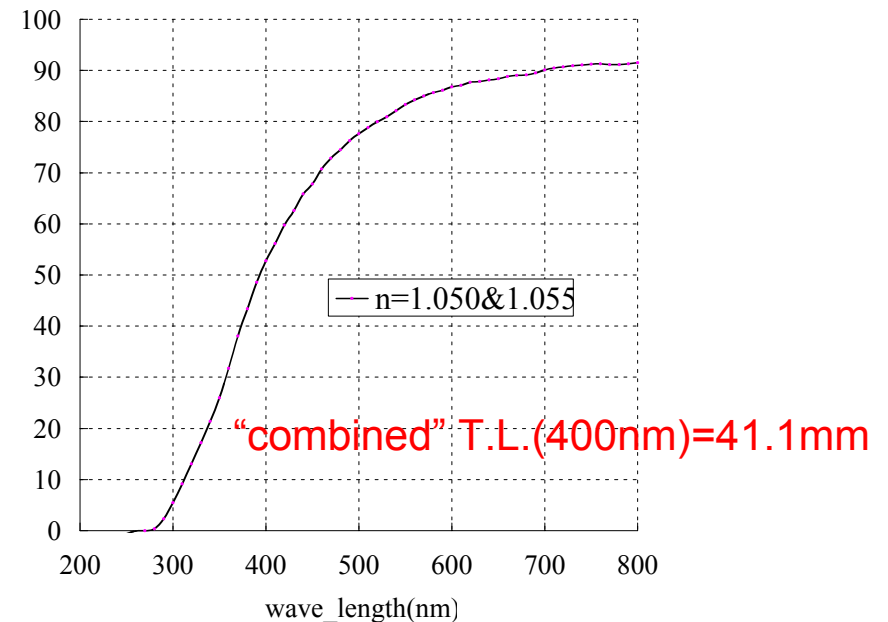
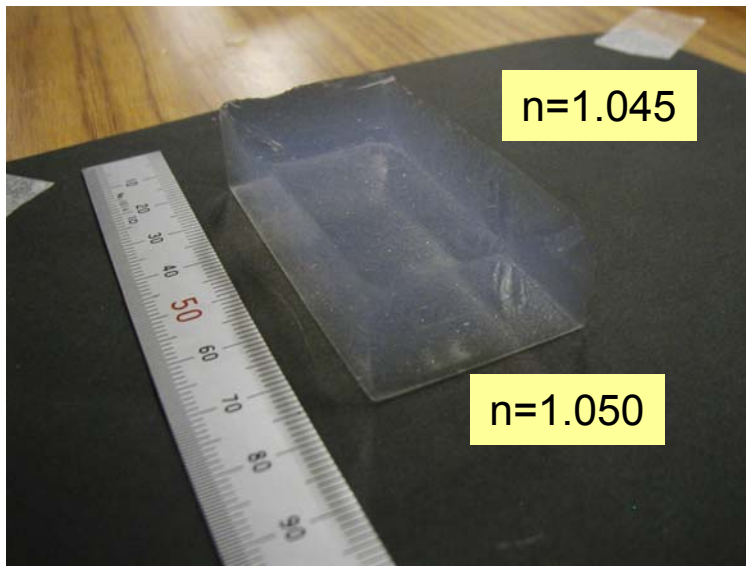




Further attempt for multiple-layer aerogel(1)

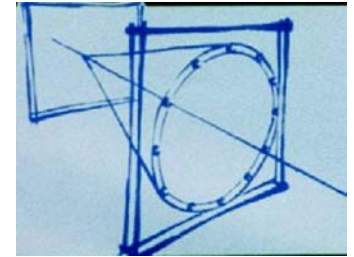


- Multiple-layers in one aerogel tile
 - 2 (or more) layers with different refractive indices
 - Two layers attached directly at molecular level
 - Easy to handle when considering a multiple radiator scheme
 - Insensitive to possible surface effect

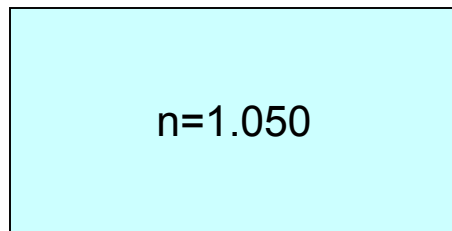




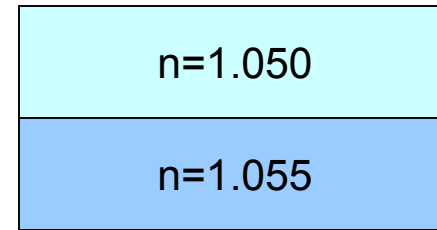
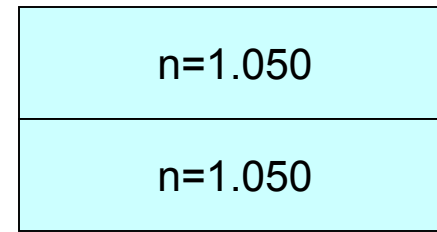
Further attempt for multiple-layer aerogel(2)



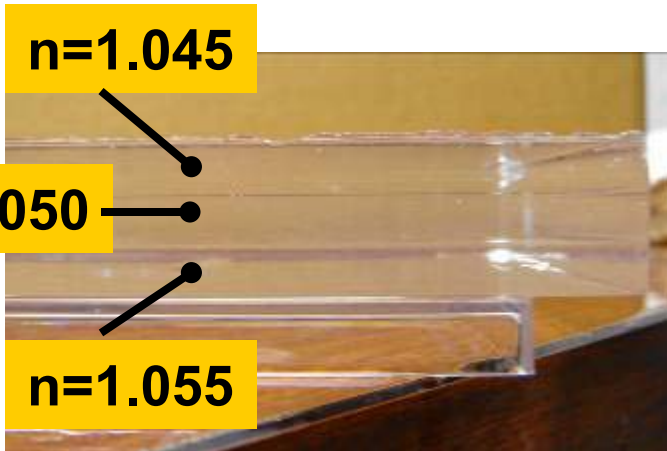
- We will compare various quantities among the following test samples:



index
transparency
crack



Investigating the best solution



boundary

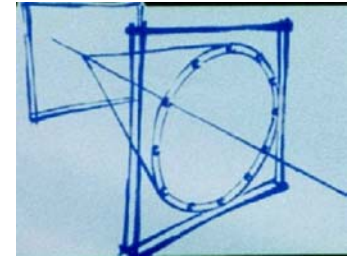
Even triple layers in a single tile produced!

Try more!!!

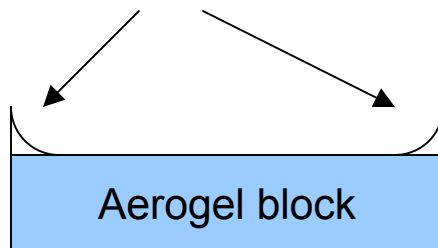
“aerogel-focusing”



Design considerations as RICH radiator(1)



- Flatness of aerogel block is important when one stacks or cover a certain area with aerogel tiles
- Meniscus causes “gap” between radiators



This was made by the fact that one surface of an alcojel always faces outside during aging process.



Produce alcojel in the sealed vessel (with a cover) and is left inside it during aging
Another merit: surface quality can be better

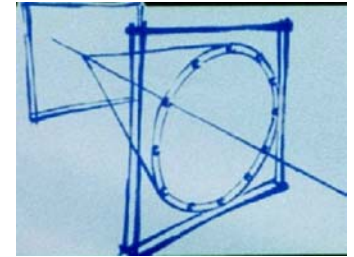


3 layers (100x100x10mm³ size) stacked

Gap found ~< 1.0mm



Design considerations as RICH radiator(2)



- Aerogel tile in hexagonal shape is desirable due to smaller loss of Cherenkov photons at edges
 - Cut into hexagonal shape from square block
 - Machining device of “water-jet” thanks to hydrophobic nature

1cm thick of 1.050 sample

QuickTime®
TIFF (LZW) Compression
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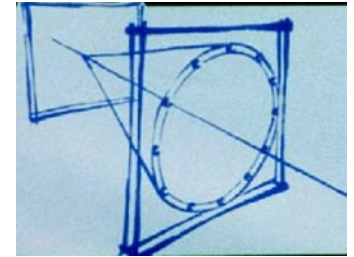
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Surface quality has to
be checked in a test
beam

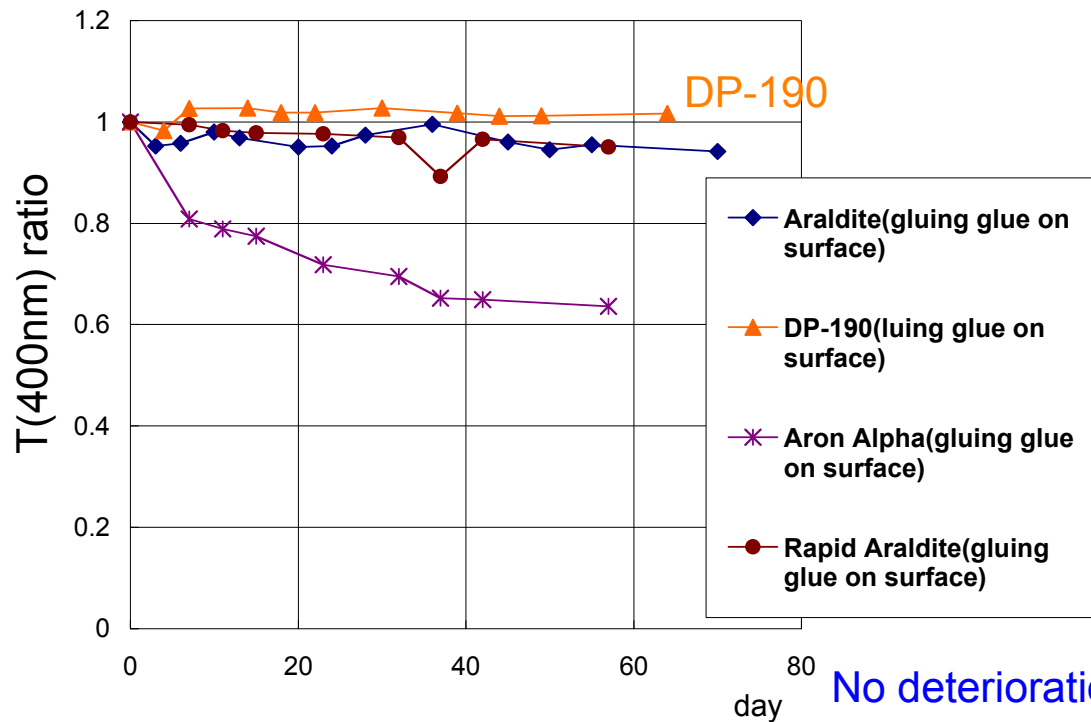
Excellent precision in angle and length



Design considerations as RICH radiator(3)



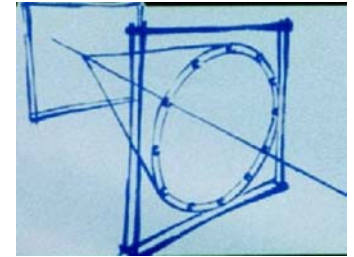
- How to hold aerogel blocks can be a potential problem in mechanical design
- Adhesive can deteriorate aerogel optical quality
- If not, we can use a simple bonding in constructing a real detector



No deterioration when DP-190 is used



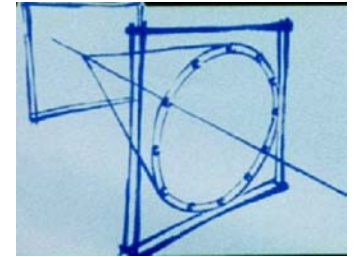
Conclusions



- Aerogel for RICH radiator has been developed
- Production of aerogel tiles with $n=1.05$ has been successfully done and transmission length at 400nm has reached 40mm
 - Issues for a stable production and index management
- Optical quality of our samples has been examined in a test beam and improvements confirmed
- Further challenges are going on
 - Thicker and bigger blocks
 - Multiple-layer blocks
 - Machining possibility
 - etc

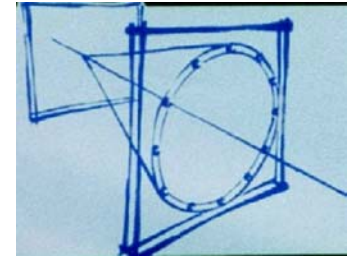


Backup slide

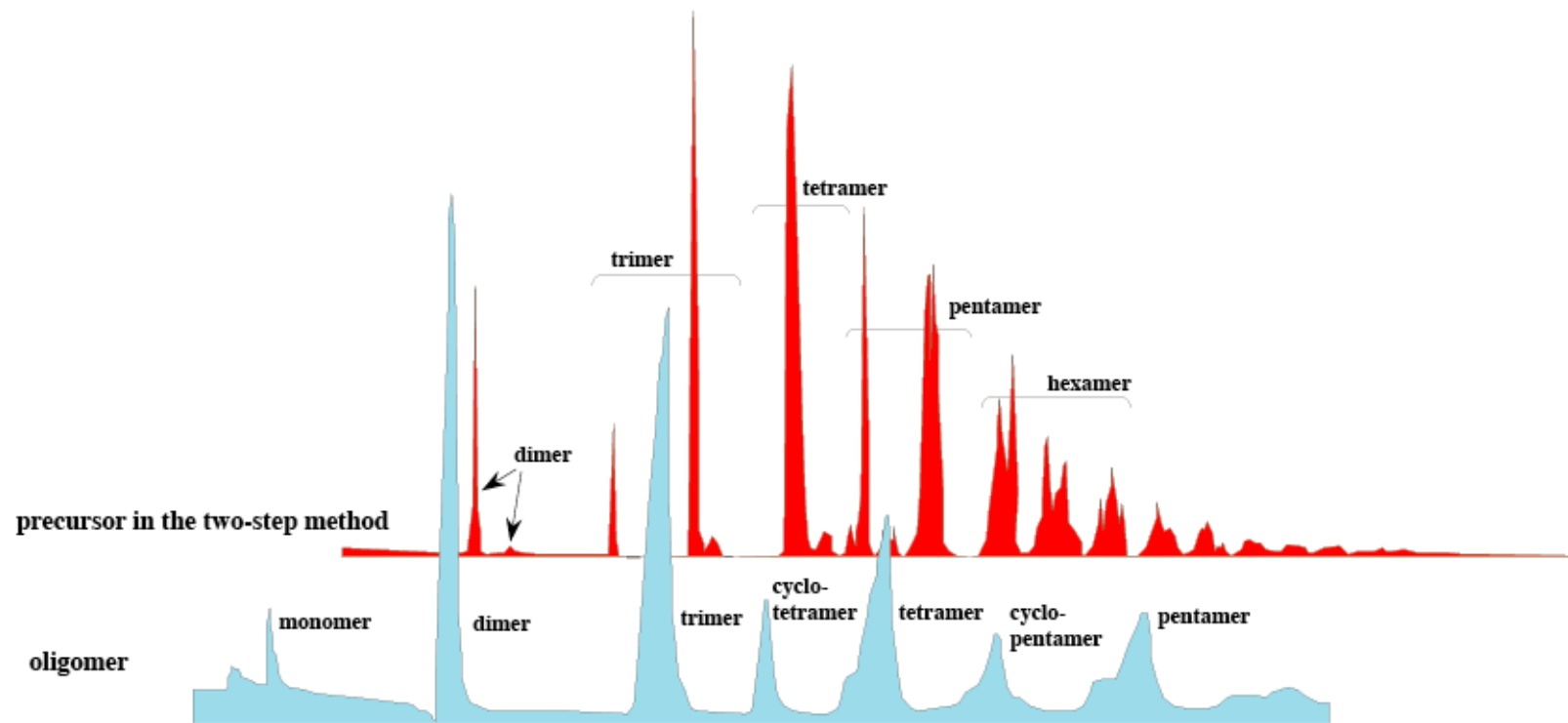




Silica oil: oligomer

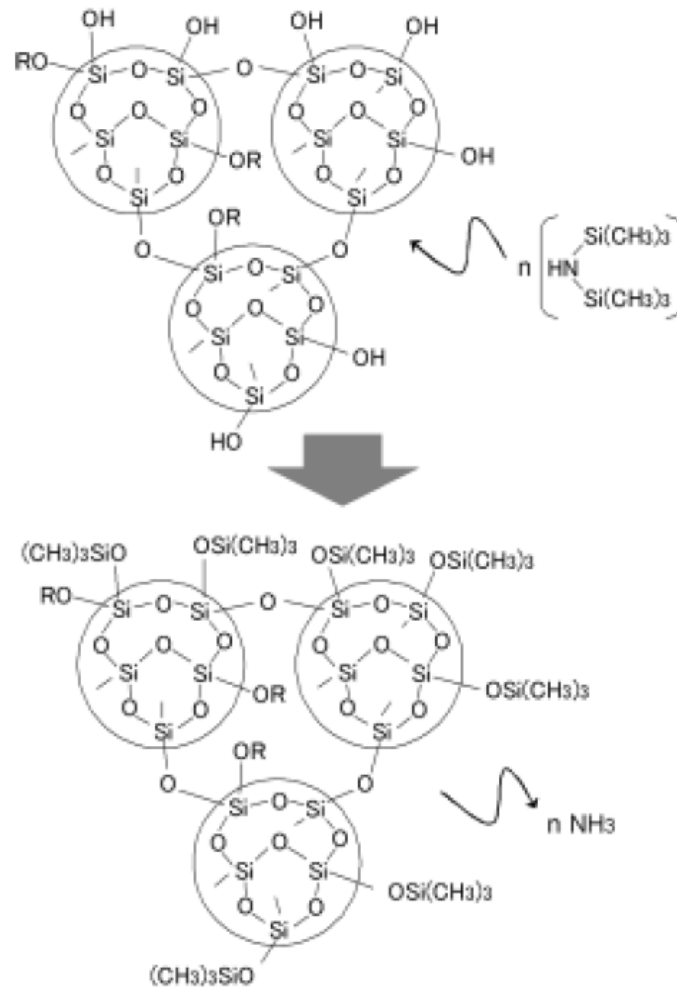
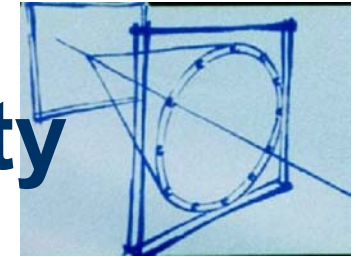


- Methylalkoxide:Methyl-silicate 51
 - Components are almost similar to that in precursor from 2-step method



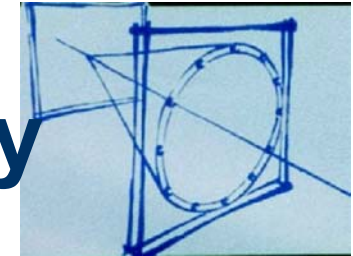


Treatment for hydrophobicity

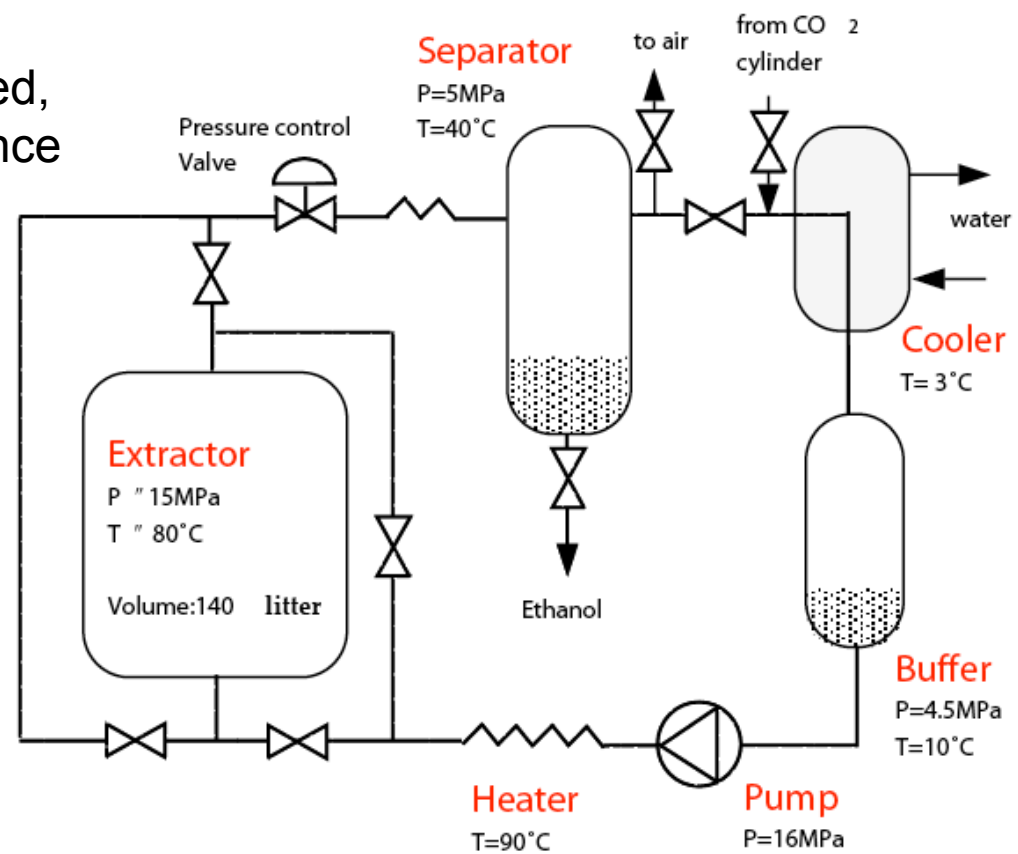




Supercritical drying facility

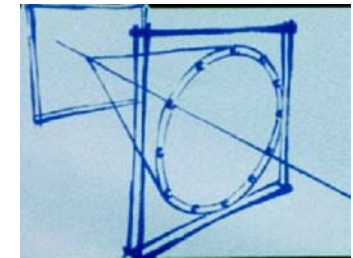


- Extraction volume: 140 liter
- Once shutdown after Belle aerogel production completed, being resumed operation since this summer

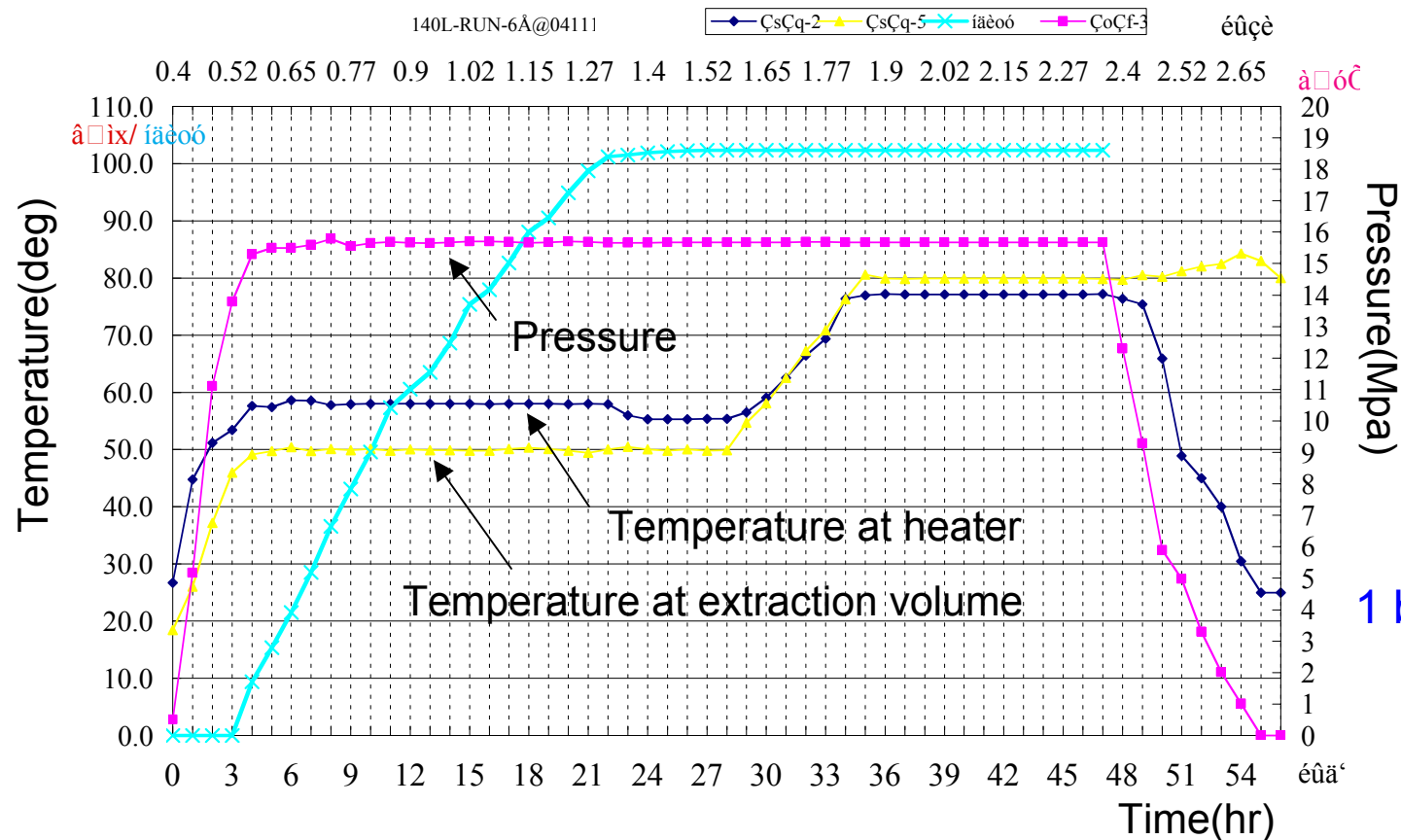




Supercritical drying

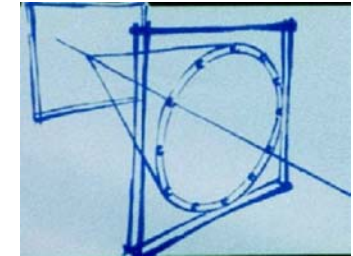


Well follow temperature and pressure control used at KEK in '90s

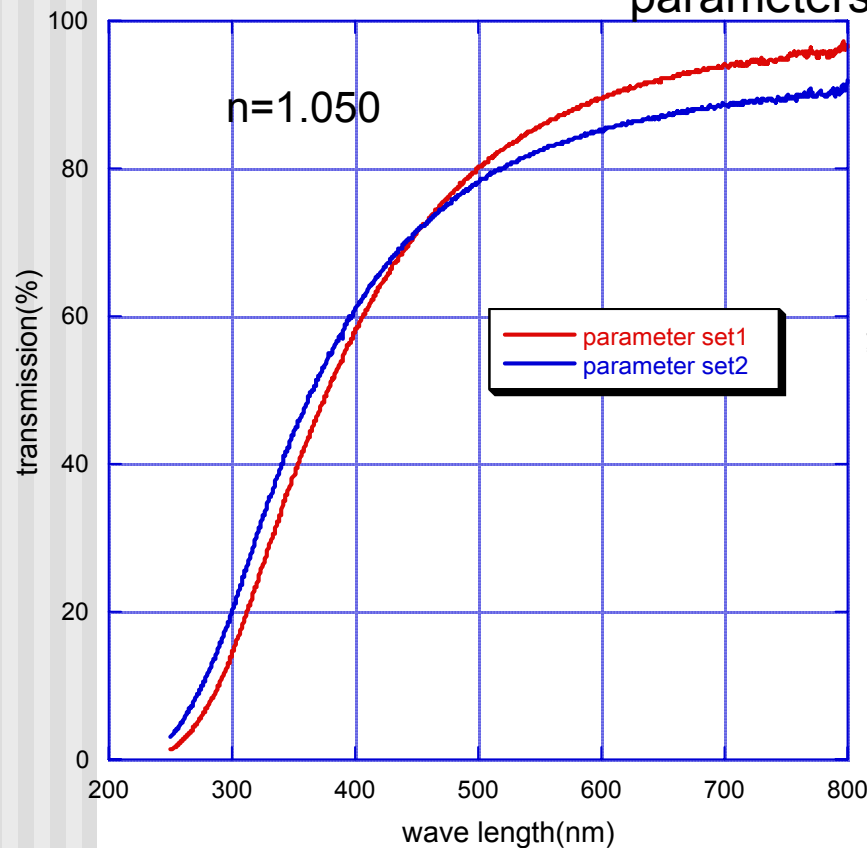




Optical quality - Transmission -

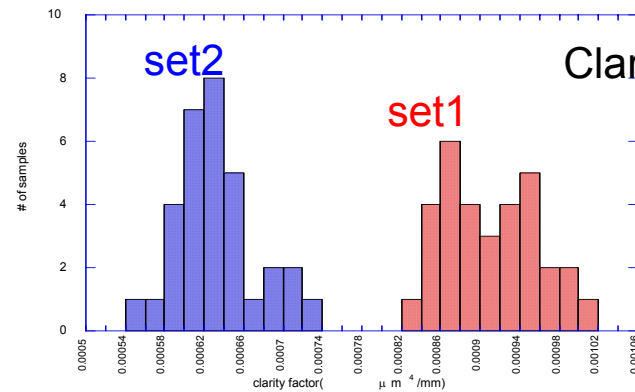


Comparison in transmission between 2 sets of parameters for 100x100x10mm³ samples

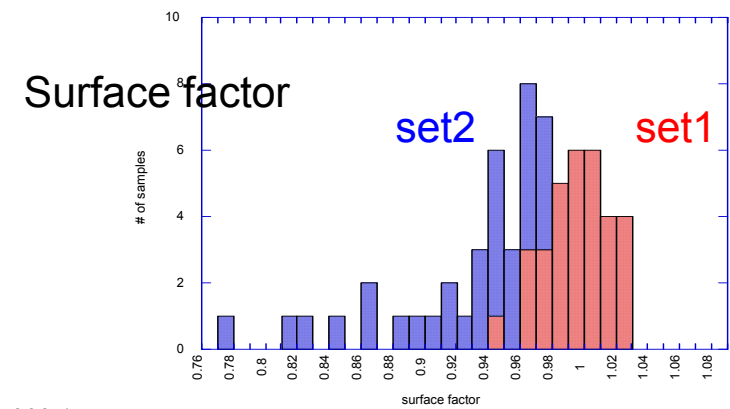


$$T = A * \exp(-C * t / \lambda^4)$$

- C: clarity factor
- A: surface factor

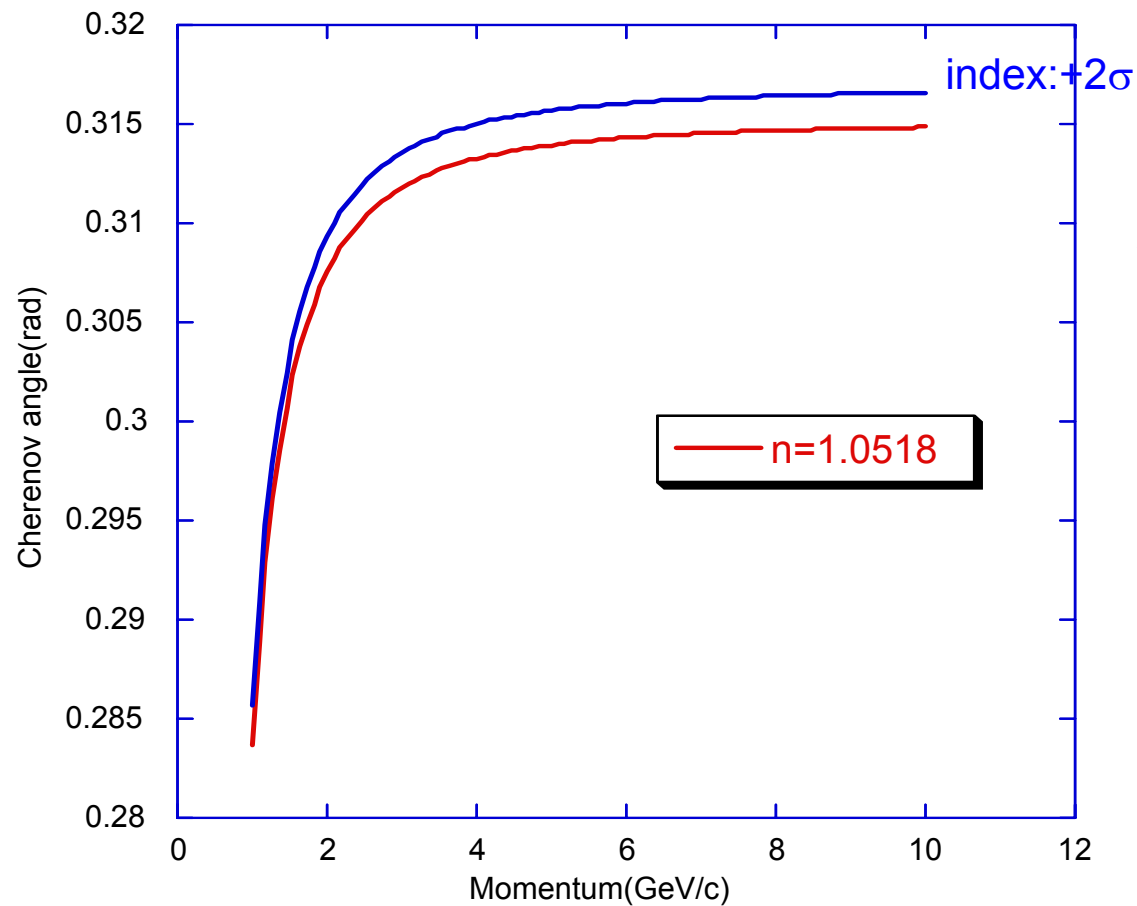
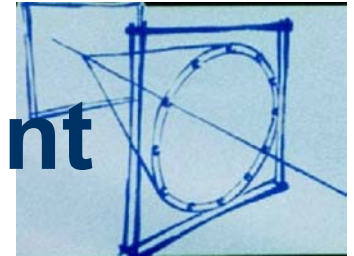


1: 0.000912($\mu\text{m}^4/\text{mm}$)
2: 0.000633($\mu\text{m}^4/\text{mm}$)





Effect on angle measurement



Angle difference :
1.8mrad(0.56%) at 4GeV/c for
pions

