Characterization Studies of Silica Aerogel for Cherenkov Radiator

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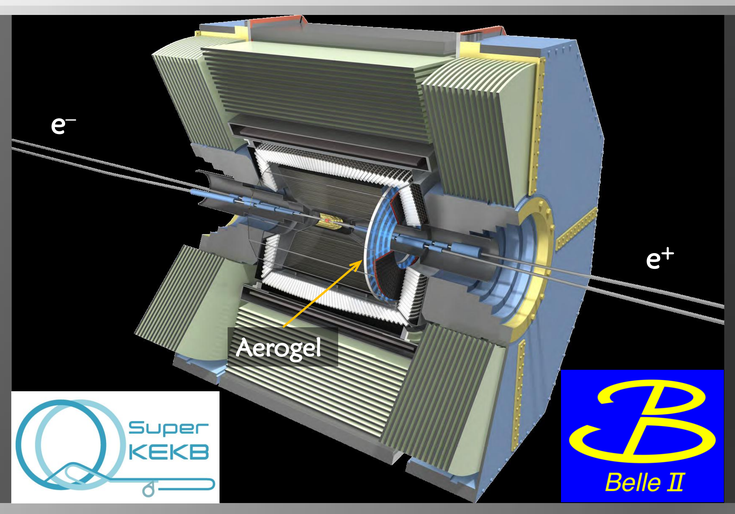
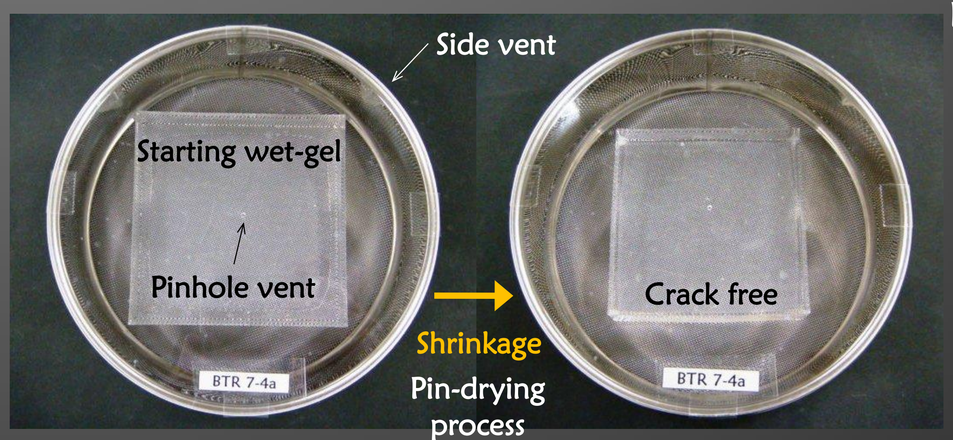
Introduction

- Silica aerogel as a Cherenkov radiator
  - Unique refractive index (can be adjusted)
    - n=1.0026-1.11 (conventional production method)
    - n=1.05-1.26 (new production method)
    - *cf.* air (gas) : n=1.0003, water (liquid) : n=1.33
- New aerogel production technique
  - Pin-drying method
    - High refractive index → New PID window
    - Highly transparent → Ring imaging detector
    - Hydrophobic → Maintenance free



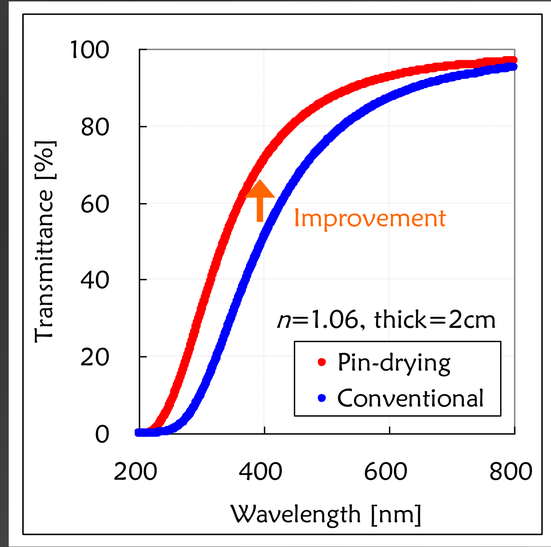
Belle II experiment at SuperKEKB (super *B* factory)
- New PID detector for the forward end-cap
  - Aerogel based proximity ring imaging Cherenkov (A-RICH) counter
  - K/π ID capability > 4σ at 4 GeV/c
- Dual-refractive-index focusing aerogel radiator
  - 3.5 m² x 2 cm x two layers
  - Upstream : n=1.05 (conventional)
  - Downstream : n=1.06 (pin-drying)
  - Requirement : refractive index ununiformity < 4%
    ↔ density (ρ) ununiformity, n=1+$k\rho$ (k : constant)

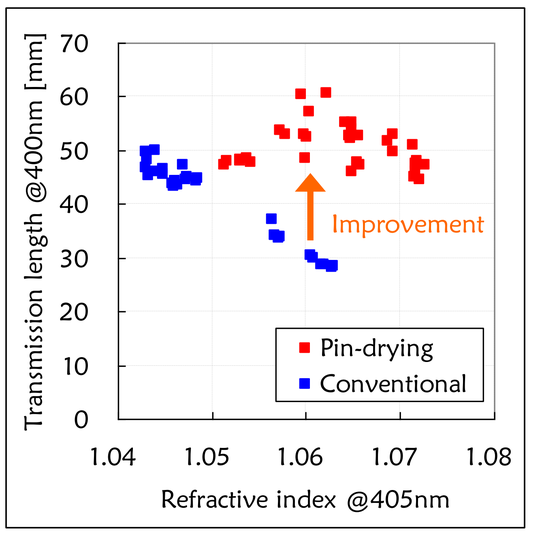
New Aerogel Production Technique – Pin-drying Method –



(monitoring wet-gel weight for density control)

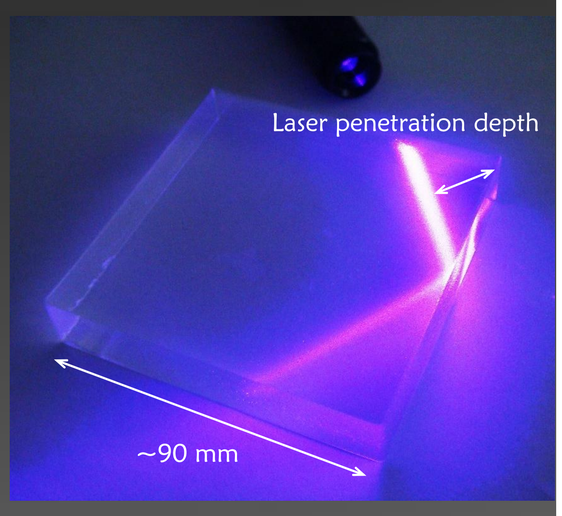
Production process
1. Wet-gel synthesis & aging
2. Pin-drying
   - Enclosing the wet-gel in a semi-sealed container
   - Solvent evaporation from the wet-gel
   - Shrinking the wet-gel and increasing in density (several weeks)
3. Hydrophobic treatment
4. CO_2 supercritical drying

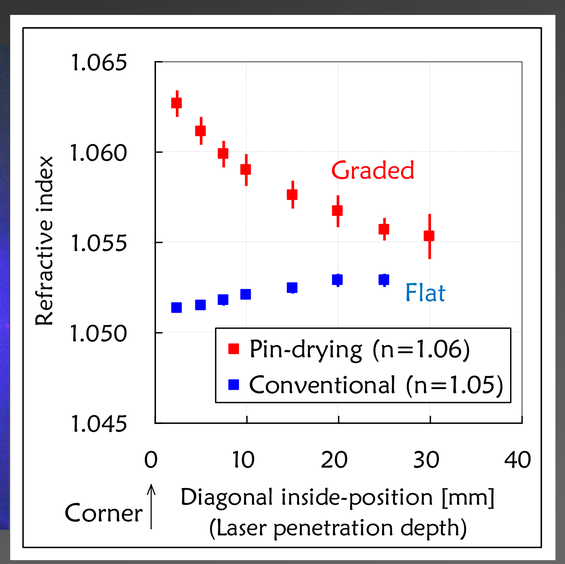




Measurement 1 (Refractive Index Uniformity) – Laser Fraunhofer Method –

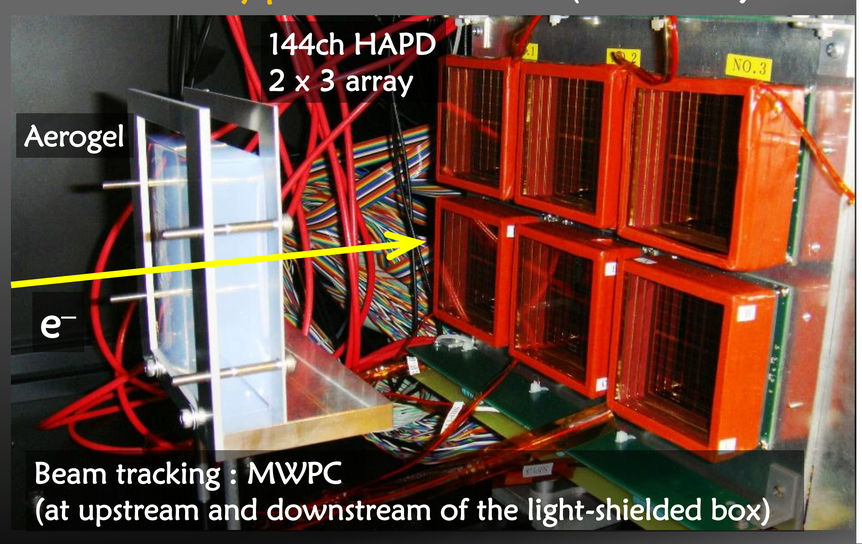
- Using blue-violet semiconductor laser (405 nm)
- Measurement of the minimum angle of deviation
- Refractive index can be measured at the corner of aerogel tiles

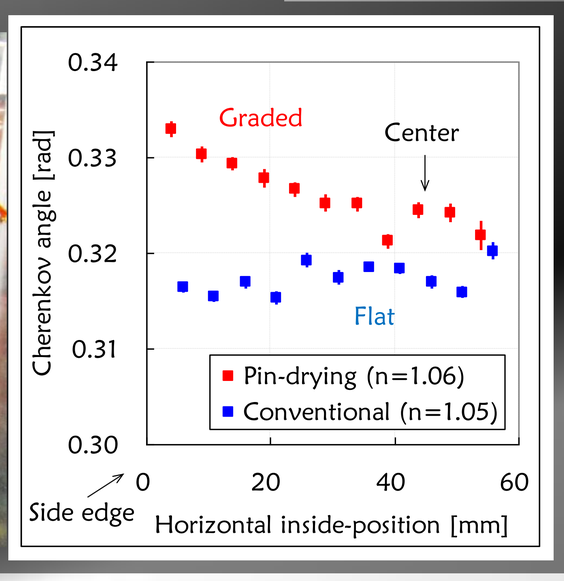




Measurement 2 (Cherenkov Angle Uniformity) – Beam Test –

- Using prototype of the Belle II A-RICH counter
  - 20 cm distance between the upstream surface of aerogels and the photodetection plane (proximity RICH)
- At the KEK Fuji test beam line
  - 2 GeV/c electron beams
- The position of incident beams was recorded with two MWPCs
  - Point by point measurement (3 x 3 mm²)



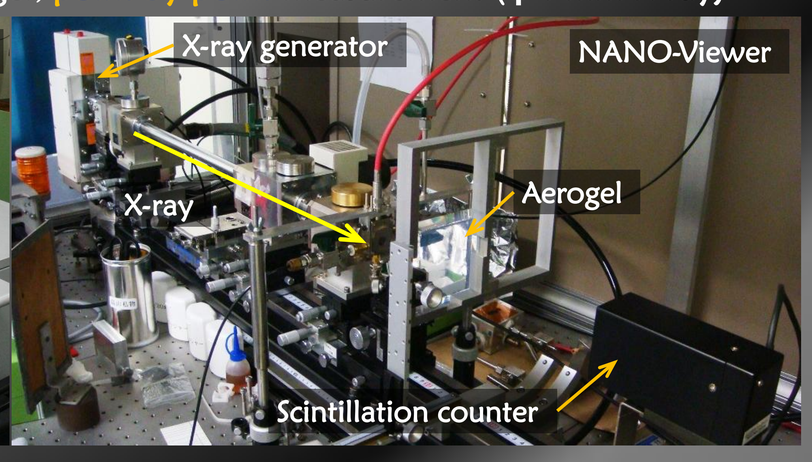


Measurement 3 (Density Uniformity) – X-ray Absorption Technique –

- Exponential attenuation law: $I/I_0 = \exp(-\mu_m x)$, $x = \rho t$ (mass thickness)
  I/I_0: X-ray transmittance, μ_m: X-ray mass-absorption coefficient, t : aerogel thickness
- X-ray fluorescent analysis (XRF) for mass-absorption coefficient
  - Using XRF instrument ZSX (Rigaku)

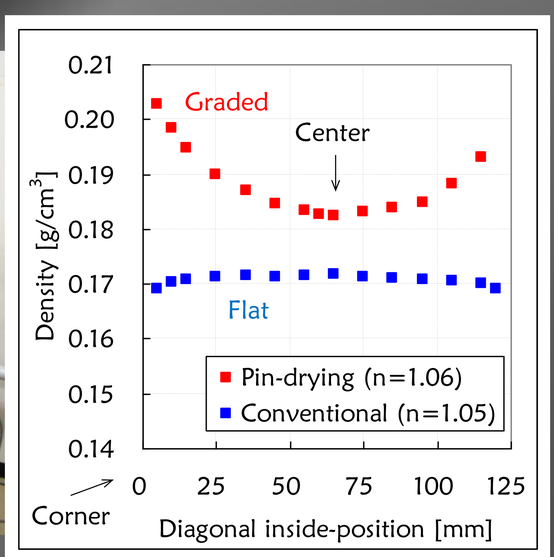
	Silicon	Oxygen	Carbon	Aerogel
Mass absorption coefficient @7.95 keV [cm²/g]	64.65	11.31	4.44	35.2
Atomic fraction by weight [wt%]	45.5	48.5	6.0	—

- X-ray absorption measurement for X-ray transmittance
  - Using NANO-Viewer (Rigaku) system
    - Monochromatized X-ray generator (Cu Kα, λ=1.54 Å, 7.95 keV)
    - Scintillation counter using PMT
  - Movable X-Z stage for aerogel, point by point measurement (φ 1 mm X-ray)



- Thickness measurement
  - Using measuring microscope UMM200 (Tsugami) (1 μm resolution)
  - Cutting aerogel along the X-ray scan line with a water jet cutter

Measuring microscope



Summary

- To investigate the inside-uniformity of refractive index of aerogel tiles, we used three methods.
- We observed an increase in refractive index at the edge of the pin-dried aerogel.
- Further studies for improving the tile uniformity in the pin-drying process are ongoing.

References

- M. Tabata, et al., Nucl. Instr. and Meth. A 623 (2010) 339.
- K. Hara, et al., 2010 IEEE Nucl. Sci. Symp. Conf. Rec. p.415.
- S. Korpar, talk in this symposium, N26-6.