Development of Large Area Silica Aerogel Used as RICH Radiator for the Belle II Experiment

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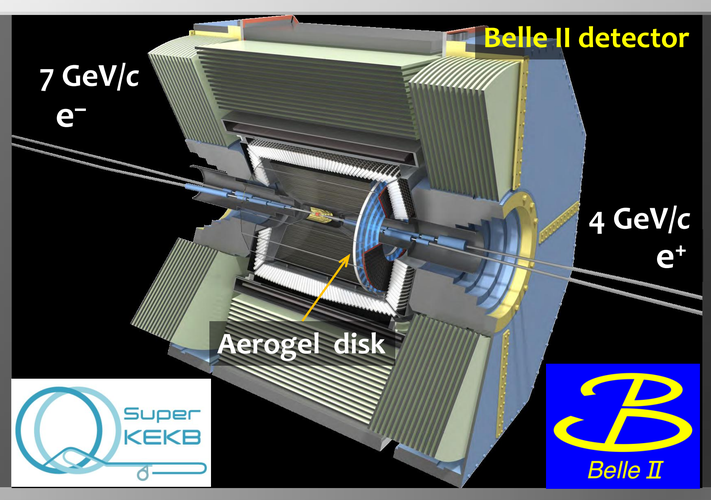
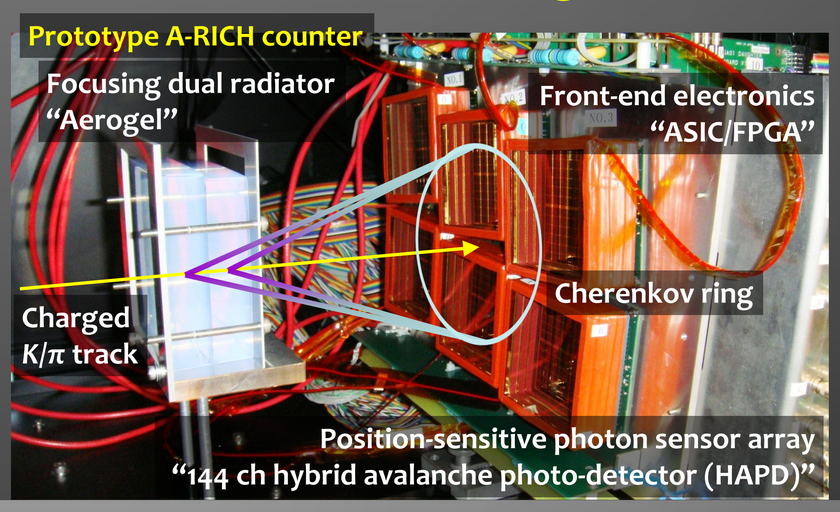
Introduction

- Belle II experiment at SuperKEKB (super *B* factory)
  - A probe of new physics
  - Flavor physics and *CP* violation measurements
- Upgraded particle identification (PID) detector (under development) for the forward end-cap
  - Aerogel-based proximity-focusing ring-imaging Cherenkov (A-RICH) counter
  - Expansion gap: 20 cm (radiator to photo-detector)
  - Our goal: K/π ID capability more than 4σ at 4 GeV/*c*



- Silica aerogel as Cherenkov radiator
  - Tunable refractive index *n*
    n = 1.003–1.11 (our conventional production method)
    n = 1.05–1.26 (novel pin-drying production method)
  - Long transmission length
  - Hydrophobic → Maintenance free
  - Relation between *n* & density ρ: $n-1 = k\rho$ (*k*: constant)
- Focusing aerogel radiator with dual refractive index
  - Dual layer: *n* = 1.045 & 1.055 (up & downstream)
    → Focus Cherenkov photons on photo-detectors

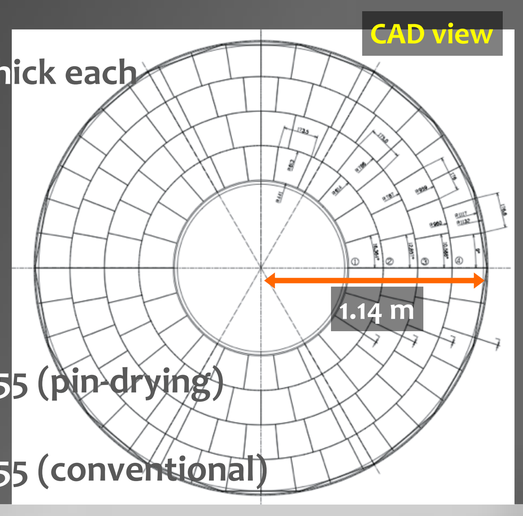
A-RICH Detector Configuration



- A-RICH counter components
  - Radiator
  - Photo-detector
  - Read-out electronics
- K/π identification concept
  → Measure Cherenkov angle ϑ_{ch}
  $\vartheta_{ch}(\pi)-\vartheta_{ch}(K)$ = 21.6 mrad
  at *n* = 1.055 and *p* = 4 GeV/*c*
- Basic performance in a beam test
  - Angular resolution: ~14 mrad
  - # of detected photons: 10–15
  - K/π identification capability: 5–6σ

Aerogel Radiator Tiling Scheme

- Large area: 3.5 m²
- Two-layer configuration: 2 cm thick each
- Wedge shape tiles
  18 × 18 × 2 cm³ tile preparation
  Cut out with a water jet cutter
- Total number of tiles: 248
- Refractive index combination
  - Primary
    n = 1.045 (conventional) + 1.055 (pin-drying)
  - Backup
    n = 1.045 (conventional) + 1.055 (conventional)



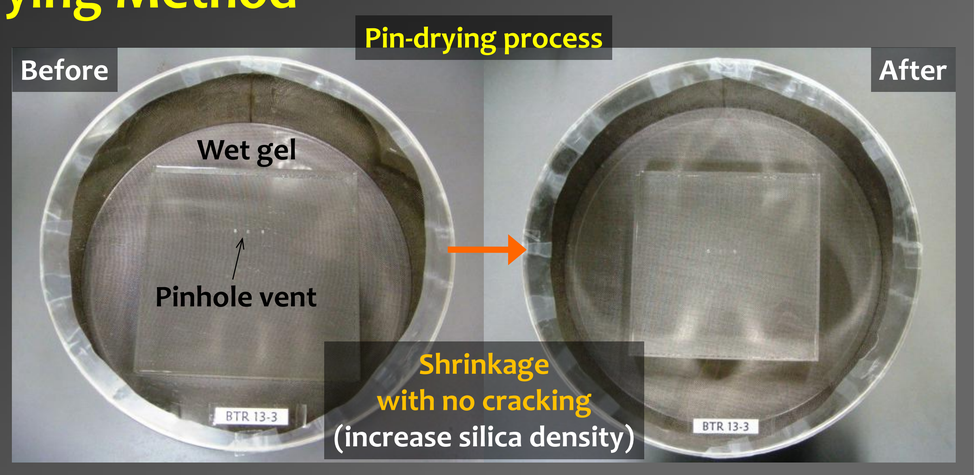
New Aerogel Production Technique – Pin-drying Method –

- Production procedure

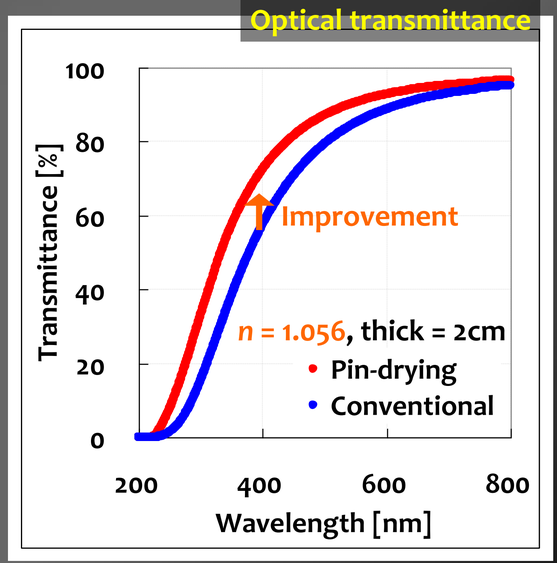
A. Our conventional method
1. Wet gel synthesis & aging
2. Hydrophobic treatment
3. Rinse in alcohol
4. CO_2 supercritical drying

B. Pin-drying method
Add pin-drying process
(the other procedures same as the conventional method)

- Aerogel's refractive index can be adjusted in
  - Wet gel synthesis process (recipe of chemicals for sol-gel step)
  - Pin-drying process (monitor wet gel's weight to control density)

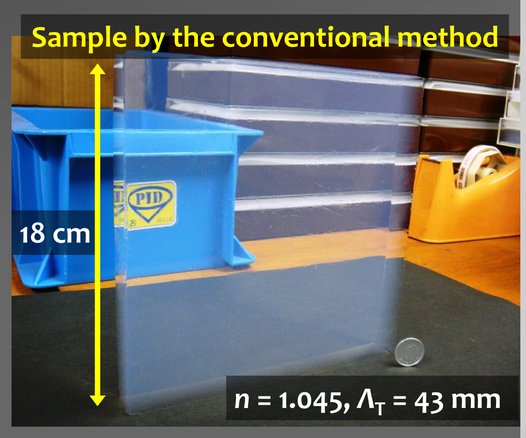


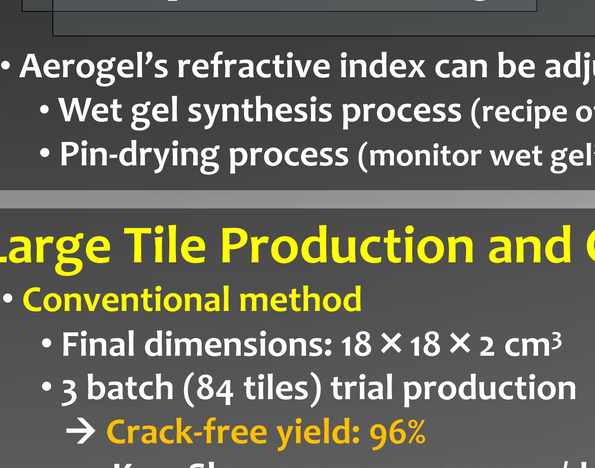
(Enclose a wet gel in a semi-sealed container with pinholes)

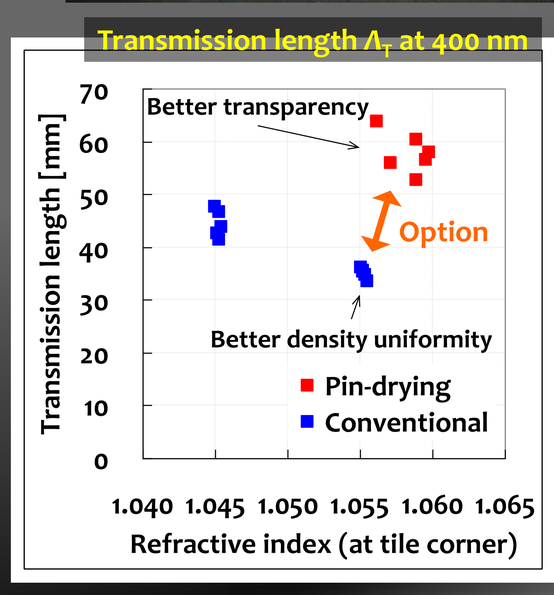


Large Tile Production and Optical Performance

- Conventional method
  - Final dimensions: 18 × 18 × 2 cm³
  - 3 batch (84 tiles) trial production
    → Crack-free yield: 96%
    Key: Slow pressure ramp up/down in the supercritical drying
    → Reasonable transparency
  - Ready for mass production
- Pin-drying method
  - Trial dimensions: 17 × 17 × 2 cm³
  - First crack-free sample (obtained)
  - Excellent transparency
  - Further trial in progress

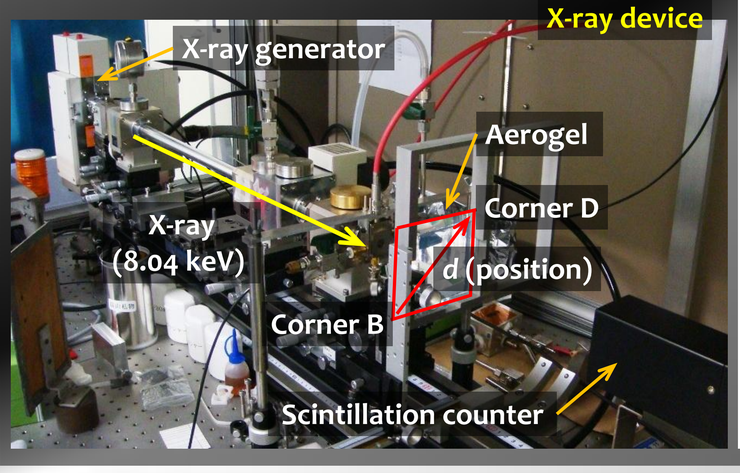


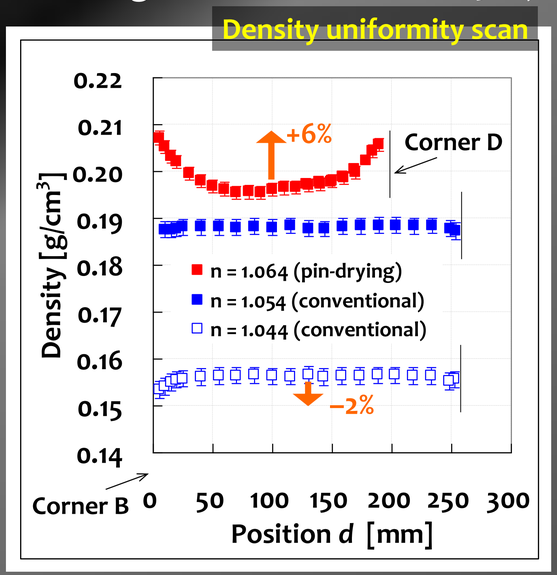




Tile Density Uniformity Measurements

- Measurement concept
  → Exponential attenuation law of X-rays in materials: $I/I_0 = \exp(-\mu_m x)$
  $x = \rho t$: Mass thickness, ρ: Aerogel density
  I/I_0: X-ray transmittance, μ_m: X-ray mass-absorption coefficient, *t*: Aerogel thickness
- Measurement items
  - X-ray fluorescent (XRF) analysis for mass-absorption coefficient
  - X-ray absorption measurement for X-ray transmittance
  - Thickness mapping using a measuring microscope
- Requirements: Highly transparent and uniform tiles, $|\delta(n-1)/(n-1)| < 4\%$
  (all Cherenkov photons pass through the downstream layer)
- Pin-drying aerogels are transparent, but their uniformity needs to be improved





Summary

- The A-RICH counter is under construction as PID detector in the forward end-cap under the Belle detector upgrade program.
- We have studied large area silica aerogel as Cherenkov radiator: Large tile production, optical measurements, and tile uniformity evaluation for both the conventional and pin-drying production method.
- Further studies to evaluate the performance of the A-RICH counter are ongoing.

References

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- (ASIC) A. Seljak, *et al.*, Poster in this symposium, N14-45.