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Progress in the Development of Silica Aerogel as a RICH Radiator in the Belle II Experiment

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Belle II A-RICH Group

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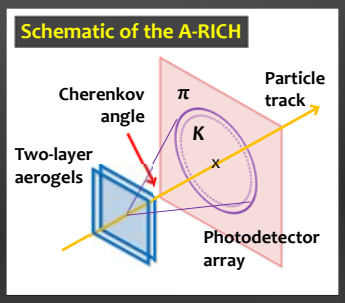
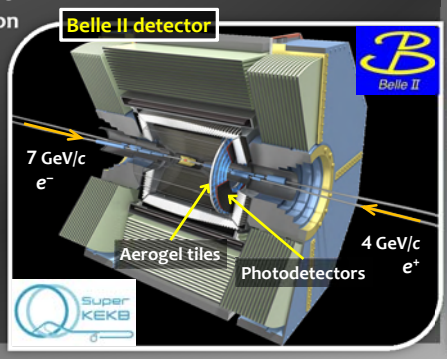
Introduction

- Belle II experiment at the SuperKEKB accelerator in Japan (super *B* factory)
  - Search for new physics beyond the standard model of particle physics through flavor physics and precise *CP* violation measurements
- Particle identification (PID) device for the forward end cap (under upgrade)
  - Aerogel-based proximity-focusing ring-imaging Cherenkov counter (A-RICH)
  - Counter components
    - Aerogel Cherenkov radiators
    - Photodetectors [144ch hybrid avalanche photodetectors (HAPD)]
    - Readout electronics (ASIC/FPGA)
    - 20 cm expansion distance between the aerogel surface and the photodetector surface
  - Focusing-dual-layer radiator (with different refractive indices) scheme
    - Increase the number of detected photoelectrons using thick aerogels with no degradation of the Cherenkov angle resolution

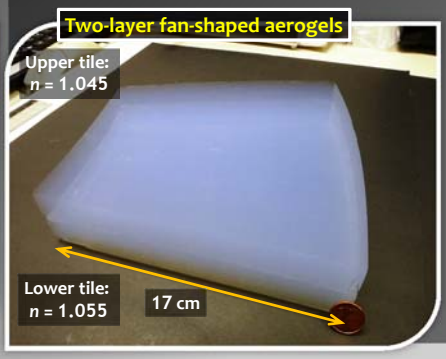


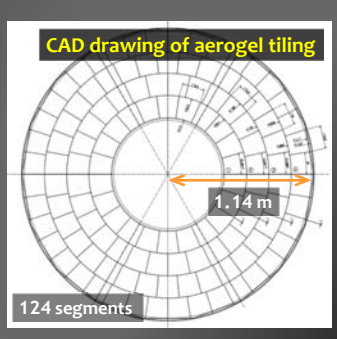


Silica Aerogel and Its Tiling Scheme

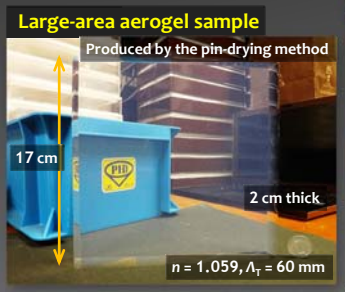
- Silica aerogel as a Cherenkov radiator
  - Tunable refractive index, *n*
    - *n* = 1.003–1.11 (by our conventional production method)
    - *n* = 1.05–1.26 (by our novel pin-drying production method)
  - Long transmission length, Λ_T
    - Λ_T = 40 mm at *n* = 1.05 and λ = 400 nm
  - Hydrophobic material
    - Suppress age-related degradation caused by moisture absorption
- Doughnut-shaped end-cap region
  - Large area: 3.5 m² (Outer radius: 1.14 m)

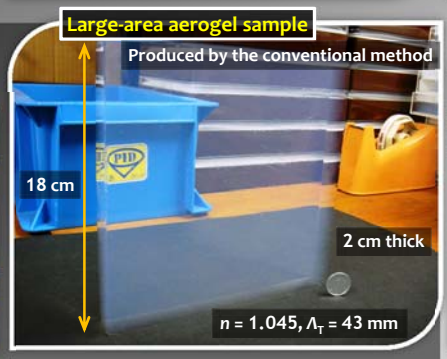
Our decision
→ 2-layer × 2 cm thick aerogels: A total of 4 cm thick
→ Segmented fan-shaped aerogels:
Trim from 18 × 18 × 2 cm³ tiles with a water jet cutter
→ A total of 248 aerogels (2-layer × 124 tiles)



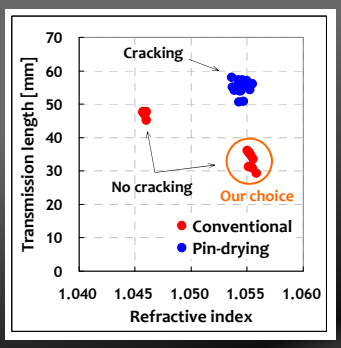


Large Tile Production

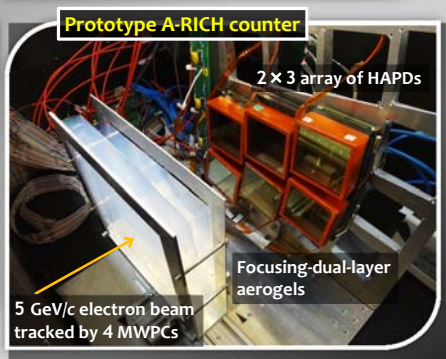




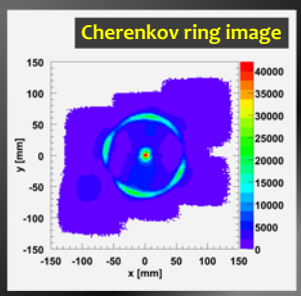
- Key issue in large tile production: Avoid cracking in the supercritical drying
- Test production results in 2012–2013
  - Conventional production method
    - Reasonable transparency
    - Final dimensions: 18 × 18 × 2 cm³
      - Crack free yield: more than 80%
    - Better refractive index control
  - Pin-drying production method (for the downstream layer)
    - Excellent transparency
    - Trial dimensions: 17 × 17 × 2 cm³
      - Crack free yield: ~50%
    - Final dimensions: 19 × 19 × 2 cm³
      - No crack free sample



Our decision
→ Produce both the upstream and downstream aerogels by the conventional method
→ Refractive indices: *n* = 1.045 and 1.055
→ Mass production in progress



Beam Test



- Our goal: pion/kaon separation capability of more than 4σ at 4 GeV/*c*
- Test beam experiment using 5 GeV/*c* electron beam at DESY in May 2013
  - Prototype A-RICH counter
    - Practical focusing-dual-layer aerogels by the conventional method
      - Full size tiles trimmed with a water jet (fan shape)
      - Refractive index combination: *n* = 1.046 and 1.055
    - 2 × 3 array of HAPDs and front-end electronics under development
    - Track electrons by 4 multiwire proportional chambers
- Simple performance evaluation
  - Cherenkov angle difference: $\Theta_\pi - \Theta_K$ = 23 mrad at 4 GeV/*c* and *n* = 1.05
  - Observed parameters
    - Cherenkov angular resolution per single photon: σ_θ = 14.5 mrad
    - Number of detected photoelectrons: N_{pe} = 6.6
    - Cherenkov angular resolution per track: $\sigma_{track} = \sigma_\theta/(N_{pe})^{1/2}$ = 5.6 mrad
  - π/K separation capability: $(\Theta_\pi - \Theta_K)/\sigma_{track}$ = 4.1σ
- Expect further improvements
  - Fine-tune the refractive index combination: Reduce σ_θ by ~1 mrad
  - Full spec HAPDs and readout electronics

Summary

- We are developing a RICH counter based on aerogel radiators for use in the Belle II experiment.
- We have decided to manufacture *n* = 1.045 and 1.055 aerogels by the conventional method.
- In a beam test, we have obtained 4.1σ π/K separation capability in a prototype A-RICH counter.

References

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- M. Tabata, *et al.*, *IEEE Trans. Nucl. Sci.* 59 (2012) 2506.