Recent Progress in the Development of Large Area Silica Aerogel for Use as RICH Radiator in the Belle II Experiment

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Highlights

- We are developing a RICH counter based on aerogel radiators for use in the Belle II experiment.
- In a beam test, we obtained 4.1σ π/K separation capability in a prototype A-RICH counter.
- Aerogel mass production was successfully completed, and optical measurements are ongoing.
- A water-jet-trimming test of the aerogels was successful to install them in a support structure.

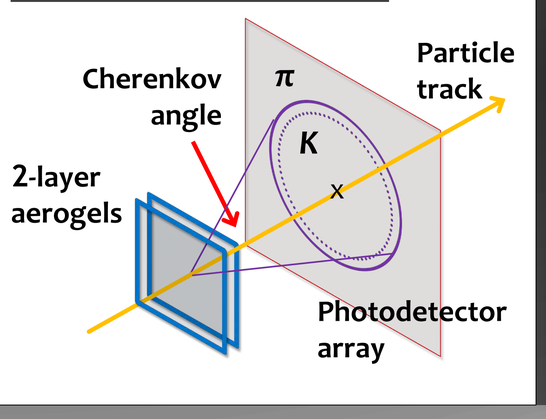
References

- M. Tabata, *et al.*, *Nucl. Instrum. Methods A* 668 (2012) 64.
- M. Tabata, *et al.*, *Nucl. Instrum. Methods A*, (2014) in press.
- L. Šantelj, oral contribution in this conference (June 4).
- S. Iwata, oral contribution in this conference (June 6).

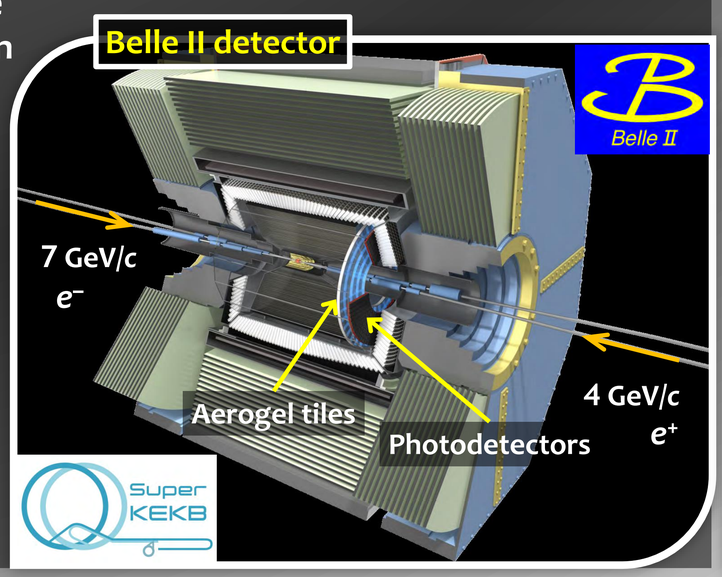
Introduction

- Belle II experiment at the SuperKEKB collider at KEK, Japan (super *B* factory)
  - Search for new physics beyond the Standard Model by investigating flavor physics and precision measurements of *CP* violations
- Particle identification device for the forward end cap (under upgrade)
  - Aerogel-based proximity-focusing ring-imaging Cherenkov counter – A-RICH system (our goal: > 4σ π/K separation capability at 4 GeV/*c*)
  - Counter components
    - Aerogel Cherenkov radiators
    - Photodetectors [144 ch hybrid avalanche photodetector (HAPD)]
    - Readout electronics (ASIC/FPGA)
    - 20 cm expansion distance between the aerogel and HAPD surfaces
  - Multi-layer-focusing radiator (with different refractive indices) scheme
    - Increasing the number of detected photoelectrons using thick aerogels with no degradation of the Cherenkov angle resolution

Schematic of the A-RICH



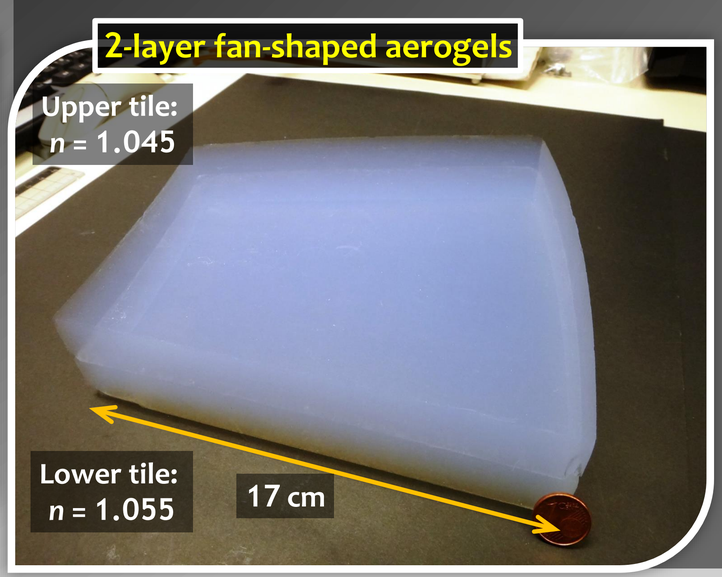
Belle II detector



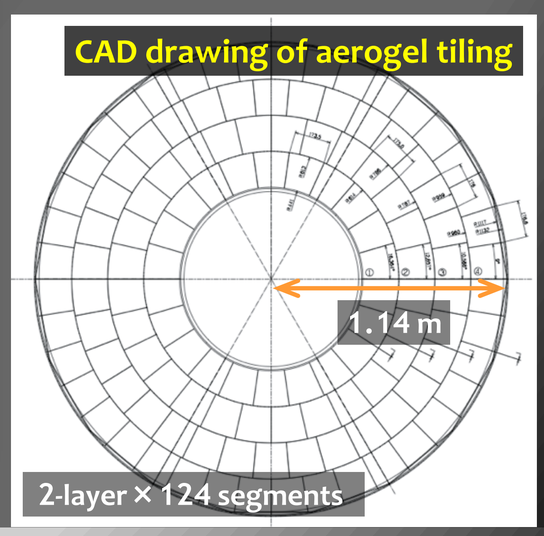
Silica Aerogel and Its Tiling Scheme

- Silica aerogel as a Cherenkov radiator
  - Tunable refractive index, *n*
    - *n* = 1.003–1.26 (by our conventional KEK or pin-drying methods)
  - Long transmission length, Λ_T
    - Λ_T = 40 mm at *n* = 1.05 (λ = 400 nm)
  - Hydrophobic material
    - Suppressing age-related degradation caused by moisture absorption
- Doughnut-shaped end-cap region
  - Large area: 3.5 m^2 (outer radius: 1.14 m)
    - 2-layer × 2-cm-thick aerogels: A total of 4 cm thick
    - Segmented fan-shaped aerogels
      - Trimming from 18 × 18 × 2 cm^3 tiles with a water jet cutter
    - A total of 248 aerogels (2-layer × 124 tiles)

2-layer fan-shaped aerogels



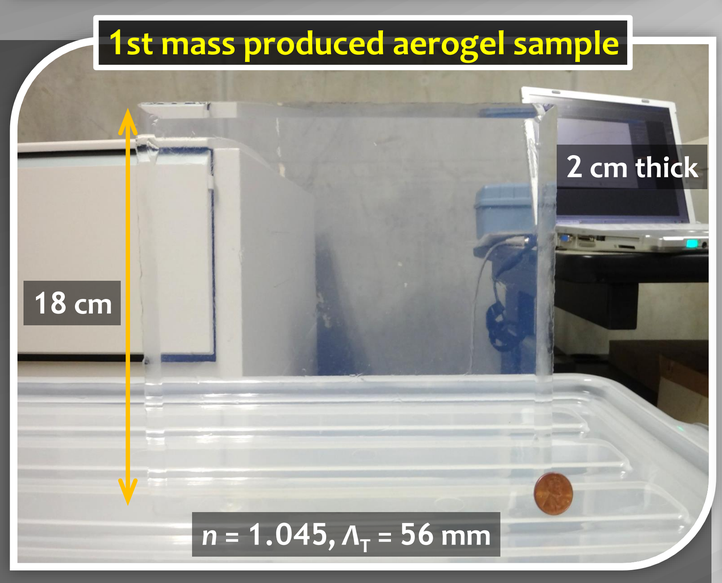
CAD drawing of aerogel tiling

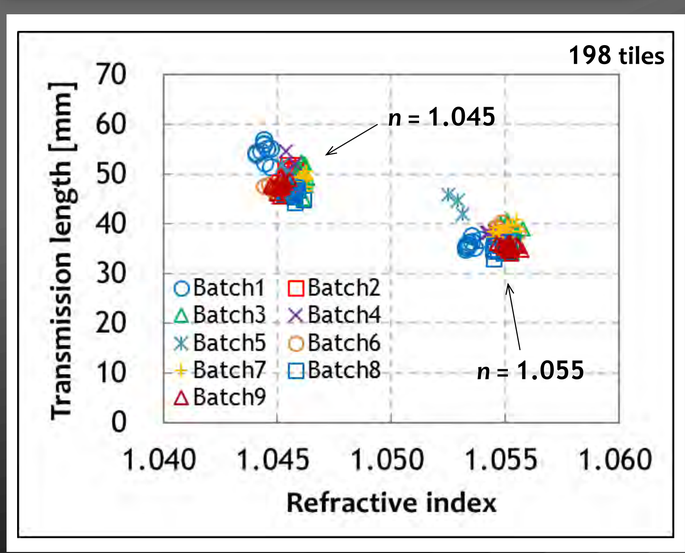


Mass Production

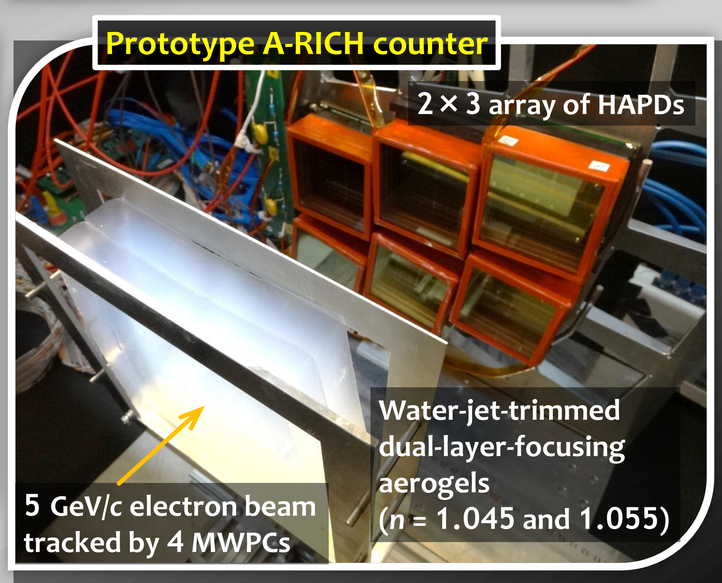
- Specifications
  - Modernized KEK production method (elected because of high crack-free yield)
  - n_{up} = 1.045
  - n_{down} = 1.055
  - 18 × 18 × 2 cm^3 large tile
  - Approx. 450 tile production (including spare tiles)
- Requirements
  - Crack free
  - No surface damage
  - Λ_T > 45 mm (n_{up} = 1.045)
  - Λ_T > 35 mm (n_{down} = 1.055)
  - $|\delta n_{up}| < 0.002$ for n_{down} = 1.055
  - $|\delta n_{down}| < 0.002$ for n_{up} = 1.045
- Mass production status
  - Began in September 2013
  - Completed in May 2014
  - Collaborating with the Japan Fine Ceramics Center (wet-gel synthesis and processing) and Mohri Oil Mill Co., Ltd. (supercritical carbon dioxide drying)
- Optical measurement (quality check) status (in progress)
  - A total of 239 tiles characterized
    - Crack-free yield (in the supercritical drying): 91% out of 239 tiles
    - Undamaged and transparent tile yield: 69% out of 239 tiles
  - Confirmed good samples: 95 tiles (n_{up} = 1.045) + 70 tiles (n_{down} = 1.055)
  - Will obtain good samples greater than 300 tiles

1st mass produced aerogel sample



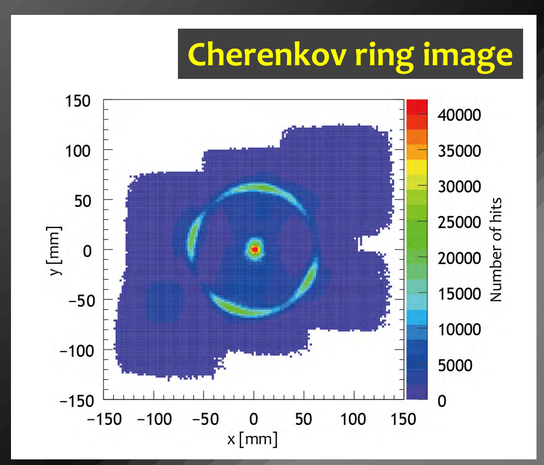


Prototype A-RICH counter



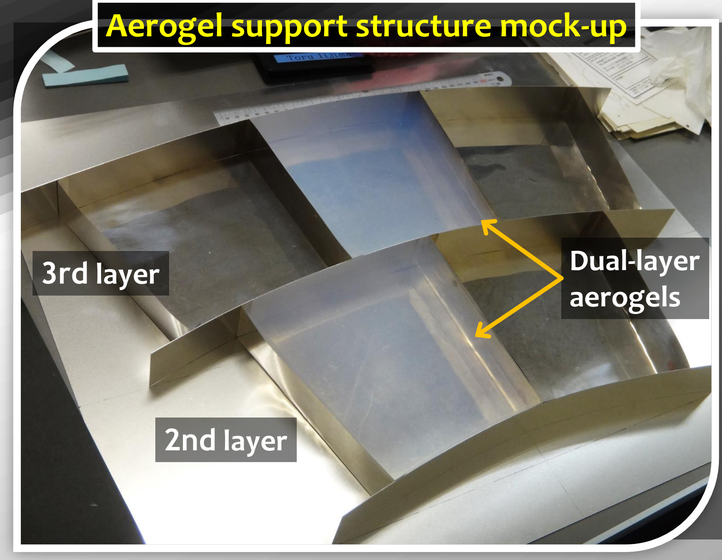
Beam Test

Cherenkov ring image



- Test beam experiment using 5 GeV/*c* electron beam at DESY in May 2013
  - 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
  - Naïve estimation: π/K separation capability of $(\Theta_\pi - \Theta_K)/\sigma_{track}$ = 4.1σ

Aerogel support structure mock-up



Mock-up Test

- Water-jet-trimming test of mass-produced aerogels in March
  - A total of 8 tiles
  - Dimension error below 0.5%
- Aerogel installation test in April
  - Support structure mock-up made of aluminum
    - 2nd and 3rd concentric layers from the inside
  - Successful installation