

Aerogel RICH for Belle II

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Proximity focusing RICH with silica aerogel radiator

Developed for a new particle ID device in the Belle II forward region to improve π/K separation up to 4σ at 4 GeV/c

- limited space
- operation in 1.5 T magnetic field

Key components

- Hydrophobic aerogel with refractive index of ~ 1.06 as a Cherenkov radiator
- Position sensitive photodetector with $\sim 5 \times 5 \text{mm}^2$ pixel size
- Readout electronics to manage $\sim 700\text{k}$ channels

Belle II detector

RICH with a novel "focusing" radiator – a two layer radiator

Innovative idea to increase the number of detected Cherenkov photons with a thicker radiator without degrading the angular resolution

Employ multiple layers with different indices so that Cherenkov images from individual layers overlap on the photon detector.

→ Only possible because refractive index of aerogel radiator can be adjusted in the production
→ Require further improvement of aerogel transparency not only for $n=1.050$ but for other indices

Multi-Anode Hybrid Avalanche Photo-Detector (HAPD)

Basic requirements

- High sensitivity to single photon
- Immune to 1.5 Tesla magnetic field
- Large effective area

HAPD specifications

Package	72x72 mm ²
# of pixels	12x12(6x6/chip)
Pixel size	5x5 mm ²
Effective area	64 %

QE improvement

"Super Bi-alkali" technique applied for HAPD photocathode fabrication

QE successfully increased: more than 30% at 360 nm !

Hybrid avalanche photon detector was developed in collaboration with Hamamatsu Photonics K.K.

1 diode chip with 6x6 channels

Excellent sensitivity for single photons

pulse height spectrum (HV=8.8kV, bias:343V)

Total gain = "bombardment" gain ~ 1000 x "avalanche" gain ~ 40

Verified in test beam

Focusing by 2cm+2cm aerogel ($n_1:1.047, n_2:1.057$)

$\sigma_\theta(1p.e.) = 14.4 \text{ mrad}$
 $N_{pe} \sim 9.6$
 $\sigma_\theta(\text{track}) = 4.8 \text{ mrad}$

4cm-thick single index aerogel

$\sigma_\theta(1p.e.) = 22 \text{ mrad}$
 $N_{pe} \sim 10.6$
 $\sigma_\theta(\text{track}) = 6.9 \text{ mrad}$

HAPD tests in magnetic field

Surface scan was made with and without a magnetic field of 1.5 Tesla with a laser intensity at ~ 0.4 p.e. level

Results from a one row scan

Light incidence position (mm)

No deterioration in photon sensitivity observed

As expected, the distortion of the detected position near the side wall is improved in a magnetic field of 1.5T.

Back-scattering of photoelectrons

The presence of magnetic field suppresses effects of photoelectron back-scattering from the APD surface

HAPD in a beam test (November 2009)

In a RICH prototype, a 2x3 array of HAPDs are arranged with new aerogel tiles

Experimental setup

Test set-up in the KEK Fuji test beam line with 2.0GeV/c electrons

	Refractive index	Transmission length at 400nm
upstream	1.054	47.8mm
downstream	1.065	55.2mm

Angular resolution: $\sigma_\theta = 13.5 \text{ mrad}$
of photoelectrons/track: $N_{pe} = 15.3 p.e.$

Angular resolution/track: $\sigma_\theta = \sqrt{N_{pe}} = 3.5 \text{ mrad}$

6.6 σ π/K separation at 4 GeV/c !

Aerogel Radiator Production

To improve the optical quality (transparency) of aerogel in the higher ref. index region ($n > 1.05$), a new production technique - **pinhole drying (PD) method** - was developed

Initial alcogel placed into a semi-sealed container
Solvent evaporation through small pinholes
Artificial shrinkage of alcogel volume to make higher density (i.e. higher index)

pinhole vent pinhole drying process

Transparency in PD-aerogel improved much

Transmission length almost doubled at $n \sim 1.055-1.06$

Large size tile also synthesized

Crack free sample with $180 \times 260 \times 20 \text{ mm}^3$ successfully produced

Summary

- We have been studying a proximity focusing RICH counter for the Belle II forward particle identification system
- New hybrid avalanche photo-detector was developed with HPK.
 - Various tests & improvements (high QE/test in B-field/neutron radiation damage) have been made
- Highly transparent aerogel radiator was produced.
- Results from beam test demonstrate a 6σ π/K separation at 4 GeV/c

Prepare for the real detector construction to be ready for the 1st SuperKEKB beams in 2014

References

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