Aerogel RICH for Belle II

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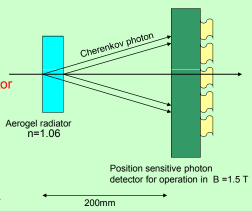
Proximity focusing RICH with silica aerogel radiator

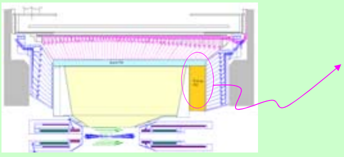
Developed for a new particle ID device in the Belle II forward region to improve π/K separation up to 4σ at 4 GeV/c

- 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 ~5x5mm² pixel size
- Readout electronics to manage ~700k channels





Belle II detector

Multi-Anode Hybrid Avalanche Photo-Detector (HAPD)

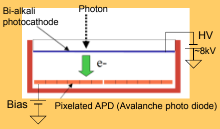
Basic requirements

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

HAPD specifications

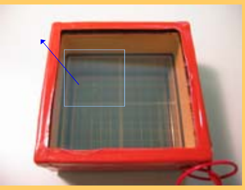
Package	72x72 mm²
# of pixels	12x12(6x6/chip)
Pixel size	5x5 mm²
Effective area	64 %

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



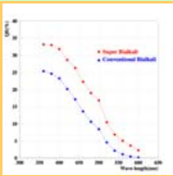
Total gain = "bombardment" gain ~1000 x "avalanche" gain ~40

1 diode chip with 6x6 channels



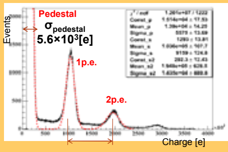
QE improvement

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



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

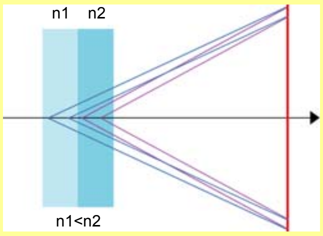
Excellent sensitivity for single photons



pulse height spectrum (HV:-8.5kV , bias:343V)

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



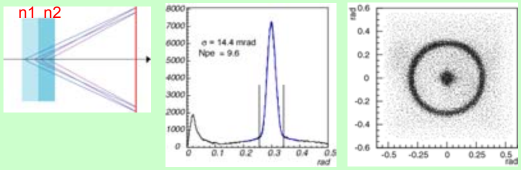
Employ multiple layers with different indices so that Cherenkov images from individual layers overlap on the photon detector.

→ 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

Verified in test beam

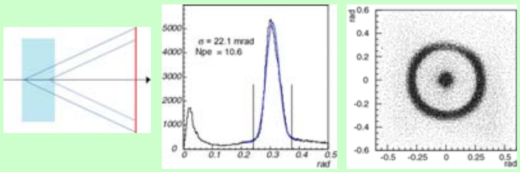
Focusing by 2cm+2cm aerogel (n1:1.047, n2:1.057)



σ_θ(1p.e.) = 14.4 mrad
Npe ~ 9.6

σ_θ(track) = 4.8 mrad

4cm-thick single index aerogel

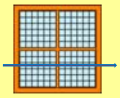


σ_θ(1p.e.) = 22 mrad
Npe ~ 10.6

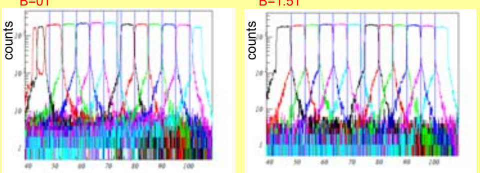
σ_θ(track) = 6.9 mrad

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

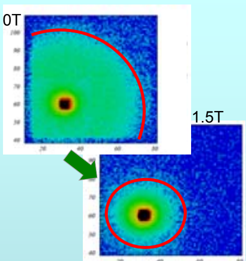


Light incidence position (mm)

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.

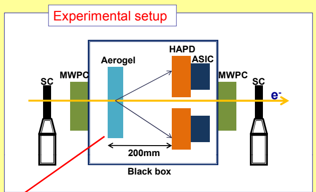
Back-ccattering of photoelectrons

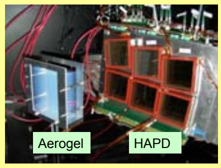


The presence of magnetic field suppresses effects of photoelectron back-scattering from the APD surface

HAPD in a beam test (November 2009)

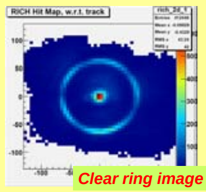
In a RICH prototype, a 2x3 array of HAPDs are arranged with new aerogel tiles



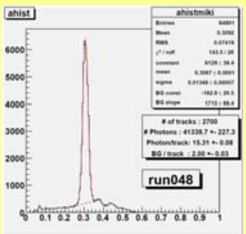


Test set-up in the KEK Fuji test beam line with 2.0GeV/c electrons

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



Clear ring image observed



Cherenkov angle distribution

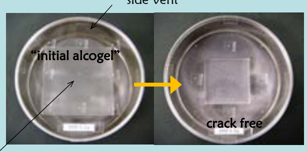
Angular resolution:σ_0=13.5mrad
# of photoelectrons/track: Npe=15.3p.e.

Angular resolution/track: $\sigma_\theta = \sigma_0/\sqrt{Npe}$=3.5mrad

6.6σ π/K separation at 4 GeV/c !

Aerogel Radiator Production

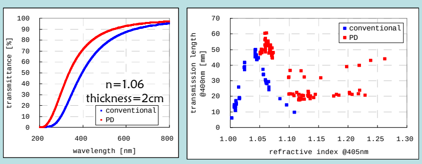
To improve the optical quality (transparency) of aerogel in the higher ref. index region (n>1.05), a new production technique - ***pinhole drying (PD) method*** - was developed



pinhole drying process

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)

Transparency in PD-aerogel improved much



Transmission length almost doubled at n~1.055-1.06

Large size tile also synthesized

Crack free sample with 180 x 260 x 20 mm³ successfully produced

Summary

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

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

References

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2. T.Iijima, S.Korpar et al., NIM A548(2005)383.
3. I.Adachi et al., NIM A581(2008)415.
4. P.Križan et al., NIM A565(2006)457.