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Aerogel Production and Beam Cherenkov Detectors



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Outline

• Topic 1: Aerogel

- Cherenkov Radiator
- Aerogel Production Technology
- Optical Properties

o Topic 2: Beam PID Cherenkov Detector for EMPHATIC

- Threshold-type Aerogel Cherenkov (AC) Counters
- Conceptual Design of EMPHATIC AC
- Preliminary Results from Test-beam Experiment

Topic 1 Recent Aerogel Production

Production Technology

o "Conventional" production steps (Kept in solvent in ALL steps!)

1. Wet-gel synthesis \rightarrow 2. Aging \rightarrow 3. Solvent exchange \rightarrow 4. Hydrophobic treatment



Refractive Index (i.e., Density) Control

- Wet-gel synthesis: Sol-gel polymerization
 - Silica precursor + Water
 - Diluent/solvent: Methanol, Ethanol, and DMF
 - Catalyst: Aqueous ammonia



Major contributions to index control

- Volume fraction of diluents
- Controlled volume shrinkage during pin drying (if applicable)

Other miner contributions

- Molar ratio b/w silica precursor & Water (+ Catalyst)
- Volume shrinkage during wet-gel aging
- Volume shrinkage during supercritical drying

o n=1.0026-1.26 possible











My RICH Aerogel Radiator R&D Program

[Project 1] Belle II ARICH @SuperKEKB

- Super B-factory experiment
- Intermediate index *n*=1.045 & 1.055
- Large area



- Physics run phase
- o [Project 2] HELIX RICH @Antarctica
 - Balloon-born cosmic ray experiment
 - Ultrahigh index *n*=1.16
 - Index uniformity



Mass production phase





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o [Project 3] EMPHATIC RICH @Fermilab

 $\pi/K/p$

EMPHATIC

- Hadron production experiment
- Low index *n*=1.02
- Compact
- Design phase Up to 10 GeV/c

EMPHATIC Beam AC Detectors

EMPHATIC Beam PID Aerogel Ckov System ^{13/25}



- $_{\circ}$ Array of threshold-type AC counters \leftarrow Limited resource (Not RICH)
- e| π| K| p beam @Fermi Test Beam Facility
- 1-10 GeV/*c* coverage
- $_{\circ}$ Nominal φ3 cm beam size → 5 cm x 5 cm radiator caverage

Candidates of Beam AC system

- Minimum 3 AC counters (+ Gas Ckov counter(s))
 - o *n*=1.045
 - o *n*=1.01

○ *n*=1.004 ← (New!) Very challenging due to low photon yield

• Roles

GeV/c	1	2	3	4	5	6	7	8	9	10
π/Κ	<i>n</i> =1.045	<i>n</i> =1.01		<i>n</i> =1.004		Gas Ckov (<i>n</i> =1.001)				
К/р		n =1.045		<i>n</i> =1.01			<i>n</i> =1.004			



Beam Tests of Prototype Counters

- Jan. 2018 @Fermilab
 - Analysis still in progress... (No report shown here)
- Jun. 2018 @ELPH, Tohoku Univ., Japan
 - $_{\circ}$ Parasite experiment \rightarrow Only 1 hour available including setup
 - 3 runs (Preliminary results shown here)
 - Pedestal run, 11k events
 - *n*=1.045 run, 15k events
 - o *n*=1.004 run, 15k events

Design of AC Counter for Beam Test

"Cartridge-type aerogel box" & "PMT support with light guide"

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Aerogel Specifications

o *n*=1.045

- o *n*=1.0446, /_T=35.5mm, *t*=16mm (ID=LLH2-4a)
 - Dimensions: 45mm x 45mm x 64mm (4 layers x 16mm)
 - Expected number of photons emitted: 440 for β =1, λ =300–650nm

o *n*=1.004

○ *n*=1.0040, /_T=12.8mm, *t*=20mm (ID=HP t6-2c)



- Dimensions: 45mm x 45mm x 80mm (4 layers x 20mm)
- Expected number of photons emitted: 52 for β=1, λ=300-650nm (11.8% of n=1.045)



Aerogel Cartridge Assembly



Light Guide Assembly / PMT Specifications 19/25



Experimental Set Up



Performance [n=1.045]

Sufficient number of detected photoelectrons

○ $N_{\rm p.e.}$ = 25 → ~100% detection efficiency



Performance [n=1.004]

• Cherenkov photon detection from *n*=1.004 aerogel succeeded

○ $N_{p.e.}$ = 3.6 → 97% efficiency (... if pedestal distribution ignored)



Performance [n=1.004] (Modified)

• Apply N_{p.e.} threshold



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Performance [n=1.004] (Outlook)

- To improve *n*=1.004 counter performance...
 - Equip 2nd PMT
 - $N_{p.e.}$ = 2 x 3.6 = 7.2 → Detection efficiency = 99.9%
 - ∘ More strictly (2 p.e. cut), $N_{p.e.}$ = 2 x 2 = 4 → Efficiency = 98.2%
 - *n*=1.004 counter will function
 - Add more aerogel layers
 - Install 2nd *n*=1.004 counter

Positional dependences should be measured.



- Highly transparent aerogels with any indices b/w 1.0026 and 1.26 are available.
- Further efforts to improve transparency and to produce large-volume tiles with good uniformity are in progress.
- Threshold-type aerogel Cherenkov counter system for EMPAHTIC beam PID is under investigation.
- Cherenkov photon detection from the index 1.004 aerogels was successful, which was a major milestone for PID at the high momentum range.