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Silica Aerogel Radiator for the HELIX RICH System

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Outline

• Topic 1:

HELIX RICH System Overview

• Topic 2:

Recent Progress in Aerogel Mass Production • Topic 3:

Previous Aerogel Characterization Results

(as a Guide of the Future Investigation)

Topic 1HELIX RICH System Overview

HELIX Program

o HELIX (High Energy Light Isotope eXperiment)

- Balloon-borne cosmic-ray spectrometer designed to measure the mass of light cosmic-ray isotopes (in particular, those of Beryllium)
- Goal: Experimental investigation of cosmic-ray propagation models
- On schedule to fly during the 2019/2020 Antarctic Season.



HELIX Proximity-focusing RICH System



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HELIX RICH Radiator

• Refractive index requirements:

- \circ n ~ 1.15 for the 1st flight (covering 1-3 GeV/nec)
- \circ n ~ 1.03 for the 2nd flight (covering up to 10 GeV/nec)

• Silica aerogels cover these index range

- $n \sim 1.03$ can be fabricated by the conventional method
- n ~ 1.15 can be produced by introducing the pin-drying technology
 - $_{\odot}~$ First validated in 2005
 - o Tabata et al., Conf. Rec. on IEEE NSS/MIC (2005).
 - $_{\odot}$ Methodology established by 2010
 - o Tabata et al., NIMA 623 (2010) 339.
 - \circ Now mass production possible (in-house manufacture at Chiba Univ.)



Optical Requirements

- Transmission length @400 nm:
 - > 30 mm (realistic; comparable to the Belle II ARICH)

 \rightarrow Tabata *et al.*, Poster #24

- o Refractive index uniformity:
 - $\circ \sim 1\%$ across tile
 - \circ 0.1% by mapping by a adequate method prior to flight and to be calibrated using in-flight data
 - o e.g., Direct Cherenkov angle measurement by electron beams

or tile scan by a laser, etc.

- Thickness uniformity (less strict requirement):
 - $\circ \sim 1\%$ across tile
 - To be mapped prior to flight

Topic 2 Progress in Mass Production

Production Technology



Mass Production Schedule

• Requirements: 36 tiles (with no cracking)

- Dimensions: 100 mm × 100 mm × 10 mm (after water-jet trim)
- Nominal production

88 tiles × 0.9 × 0.5 × 0.9 = 36 tiles
 Crack-free yield
 Index screening (mean, uniformity)

Additional (backup) production

o 8 tiles

- Total 96 tiles (scheduled)
 - \circ 32 tiles \times 3 seasons



Corner chipping (possible during machining)

Mass Production Status

Nominal production (begun in late March)

- $_{\odot}$ 32 tiles (Season 1) completed in the last week
 - Crack-free yield: 28/32 tiles (88%)
 → Close to expectation (90%)
- \circ 56 tiles (Season 2 + 3) in progress (pin drying)
 - 1st batch available in late September
 - Will finish by mid-October

- Additional production
 - $_{\odot}$ 8 tiles (Season 3⁺) to be synthesized after this workshop





The First Tile

"Rayleigh" blue tile: Scattered light

Colorless tile:

Transmitted light

n = 1.160

Transmission length = 36 mm @400 nm

HLX19-2

Dimensions

= 112 mm × 112 mm × 10.5–10.7 mm One of the world's heaviest aerogels

Transparency Check / Mean-Index Check ^{13/20}

- \circ UV-vis spectrum measured with a spectrophotometer
- \circ Refractive indices at 4 tile corners measured with a laser



Discussion on Refractive Index

• Results from the 1st mass production batch

- \rightarrow Mean index: Not 1.15 but 1.16
- $_{\odot}$ Index of 1.16 rather ideal for HELIX
 - \rightarrow Low energy threshold
 - \rightarrow Cross calibration with TOF possible much more



Keep fabrication parameters for later production

Refractive Index (Uniformity Check)

o 8 tiles survive out of 16 tiles (50% > 45% expectation)



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Topic 3 Previous Aerogel Characterization —Supporting Information

Previous Study for 1st Generation Samples ^{17/20}

• X-ray absorption technique for measuring density uniformity o Tabata et al., NIMA 697 (2013) 52. X-ray transmittance Thickness Constant $n - 1 = k \cdot \rho$ — Density $I/I_0 = \exp(-\mu_m \cdot \rho \cdot t)$ Mass attenuation coefficient X-ray absorption X-ray source φ1-mm beam Measuring microscope (Thickness) Fluorescent X-ray (Elemental analysis) Aerogel 75X X-ray detector

Comparison b/w X-ray and Laser Measurements ^{18/20}



Water-jetting Test

• First cut of n = 1.15 aerogel^{*} \rightarrow Successful ! (last week...)

- $_{\odot}\,$ Aerogel powder generated during cutting still adhere on the surface.
 - \rightarrow Should be remove carefully with a blower, soft brush, and etc.



Summary

- The HELIX RICH system employs aerogel tiles with the highest-refractive index ever used as Cherenkov radiator in the upcoming its first flight in Antarctica.
- For this application, we are now mass-producing 96 aerogel tiles with a refractive index of 1.16.
- We have just completed the first 16 tiles, and their basic optical properties were confirmed.

One More Child...

Princess Aerogel stopped over in Russia and Japan and flew on spacecraft from USA. Russian princess lives in AMS-D2RICH, and Japanese princess is now in Tanpopo cosmic dust collector aboard the International Space Station.

... And one more child will be born in Antarctica ...



Tanpopo aerogel

The HELIX Collaboration

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Additional Information

Improving Pin Containers

- \circ 3 generations of pin containers
 - \rightarrow Enhance index uniformity \rightarrow Avoid excess shrinkage at tile edge



Thickness Measurements

Ruler results consistent with microscope results



Mass Production Scheme

- \circ 3 types of grouping:
 - \circ 4 tiles per lot: wet-gel synthesis at one time
 - o 16 tiles per batch: supercritical drying at one time
 - 32 tiles per season: 8 lots (= 32 tiles) prepared for 8 straight days
- Total 3 seasons (=96 tiles) for mass production
 - Season 3 to Season 5 (Final mass production)
 - o Season 1 (Pilot production)
 - o Season 2 (Engineering production)

Pilot Production (Season 1)

 \circ Oct. 2016 to Jul. 2017

- Feasibility test for n = 1.12 and 1.15 by pin drying
- Starting index candidates: n = 1.08 and 1.10

 \rightarrow 1.10 selected in view of the final degree of pin-shrinkage

- $_{\odot}$ A total of 62 tiles investigated
 - \rightarrow HLX Season 1 (Lots: HLX1 to HLX12)

 \circ Results

 \rightarrow n ~ 1.13 and 1.15 confirmed

 \rightarrow Our final choice: n = 1.15

Engineering Production (Season 2)

- $_{\odot}$ Nov. 2017 to Mar. 2018
- $_{\circ}$ Final production test for n = 1.15
 - \rightarrow Index control (Parameter adjustment in pin drying)
 - \rightarrow Thickness control
- $_{\odot}$ A total of 23 tiles investigated
 - \rightarrow HLX Season 2 (Lots: HLX13 to HLX18)
- \circ Results
 - \rightarrow n = 1.145-1.152 \rightarrow Adjustment needed
 - → Transmission length ~ 34 mm → OK
 - → Thickness (before water-jet cut) = 10.5 mm → OK