Calibration of the Aerogel Tiles for the HELIX RICH Detector

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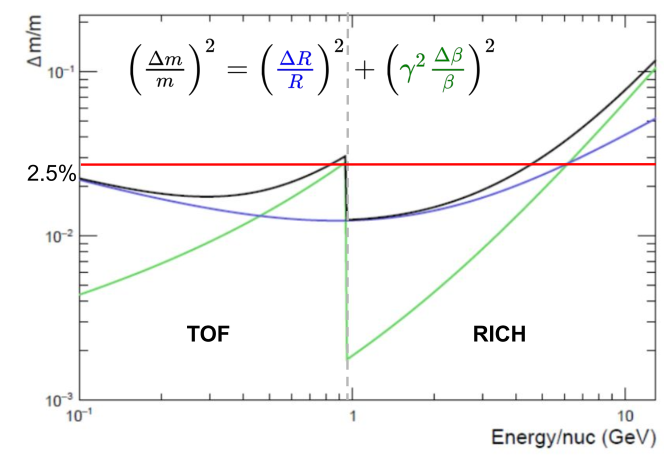
ABSTRACT

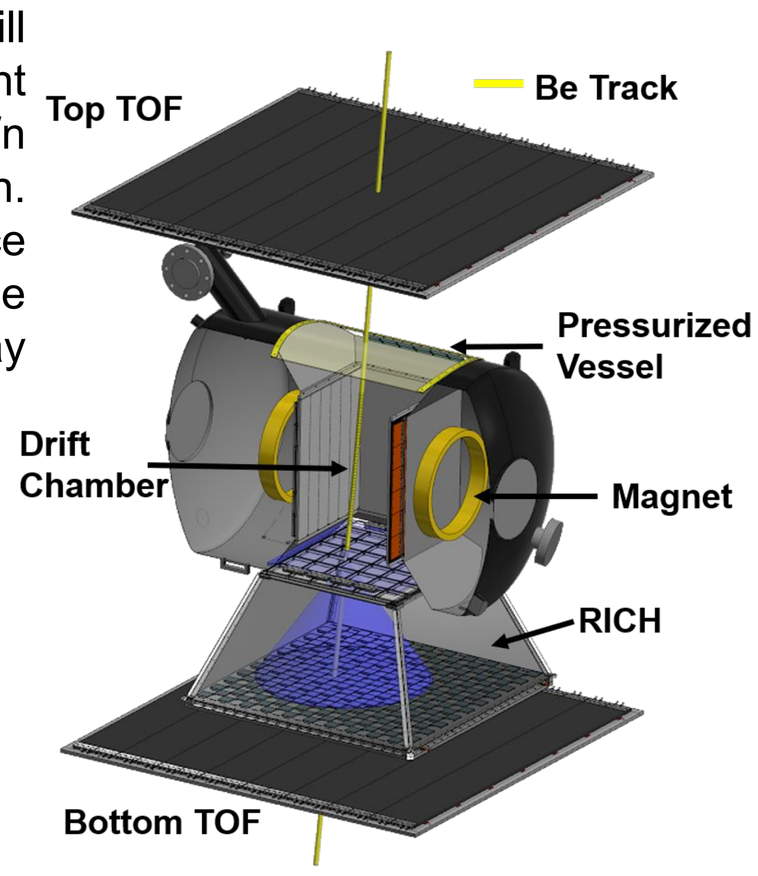
HELIX (High Energy Light Isotope eXperiment) is a balloon-borne experiment designed to measure the chemical and isotopic abundances of light cosmic ray nuclei, especially the ^{10}Be/^{9}Be ratio over the energy range from 0.2 GeV/n to beyond 3 GeV/n. [1] This is a key measurement for constraining cosmic-ray propagation models. The detector is a mass spectrometer, which is built around a 1 Tesla superconducting magnet and a high-resolution tracking system to determine particle rigidity. Time-of-flight counters and a ring-imaging Cherenkov detector (RICH) are used to measure velocities.

The proximity-focused RICH consists of a radiator made of aerogel tiles (refractive index approximately 1.15) and a detector plane of silicon photomultipliers. For discrimination of the ^{9}Be and ^{10}Be isotopes at high energy, the refractive index of the aerogel must be known to a precision of 0.07%. Given the manufacturing tolerances in the production process, the index must be mapped over the lateral extent of aerogel tiles on a fine grid. In this contribution, we describe and show initial results from procedures developed for this task. These include laser-deflection and electron-beam measurements.

HELIX

The HELIX experiment will measure abundances of light cosmic ray nuclei to over 3 GeV/n to a 2.5% energy resolution. Measurements of the abundance ratio of clock isotopes like ^{10}Be/^{9}Be will help constrain cosmic ray propagation mechanisms.

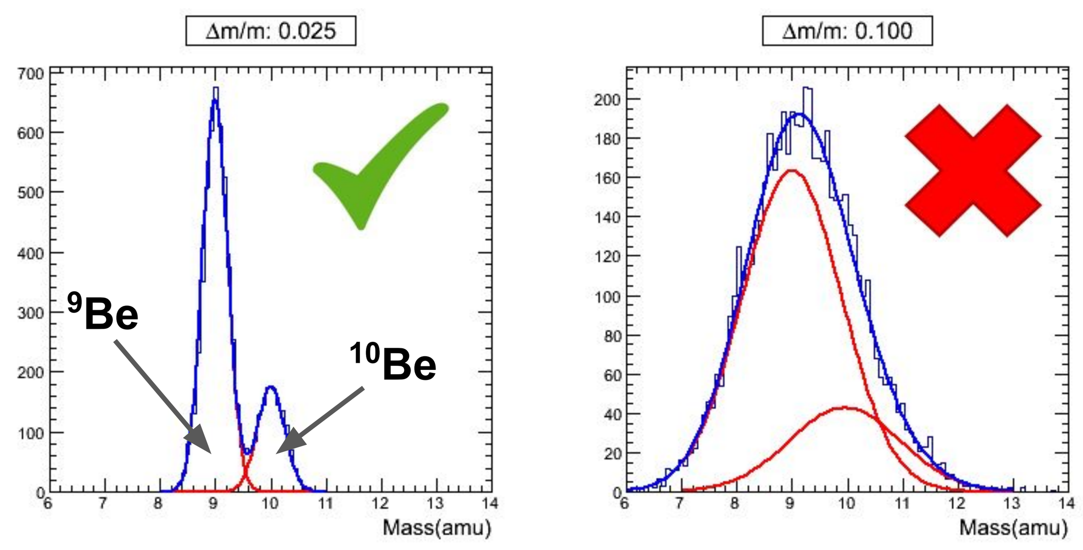




The HELIX detector is a mass spectrometer, built around a 1 Tesla superconducting magnet and a high-resolution tracking system to determine particle rigidity. Time-of-flight (ToF) counters and ring-imaging Cherenkov detector (RICH) measure velocities. Up to 1 GeV the ToF will measure velocities and above 1 GeV the RICH will take over.

THE HELIX RICH

The RICH relies on a plane of aerogel tiles for the radiator and an array of silicon photomultipliers (SiPMs) for the detector plane.



To distinguish Be isotopes, the mass resolution must be below 2.5%. This requires knowledge of the refractive index n to $\Delta n/n$ < 0.07%.

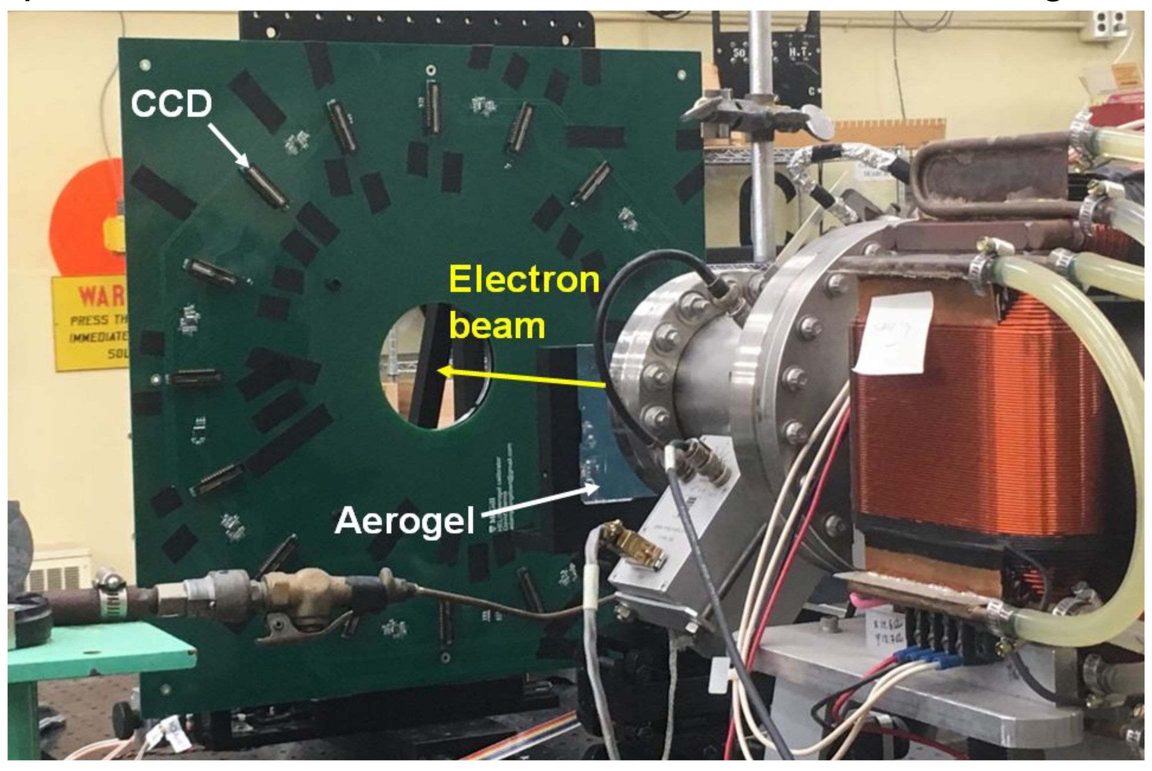
Aerogel manufacturing tolerances result in variations of the index greater than this over a tile so it is necessary to measure the index as a function of lateral position in each tile.

AEROGEL

HELIX's aerogel is a high-refractive-index (n~1.15) hydrophobic tile made using a pin-drying technique.[2] Each tile is 10 cm x 10 cm x 1cm and they are glued into an aluminum frame for protection and for metrology purposes. The HELIX radiator will comprise 36 tiles in a 6 x 6 layout. 60 tiles will be calibrated before the flight.

ELECTRON BEAM METHOD

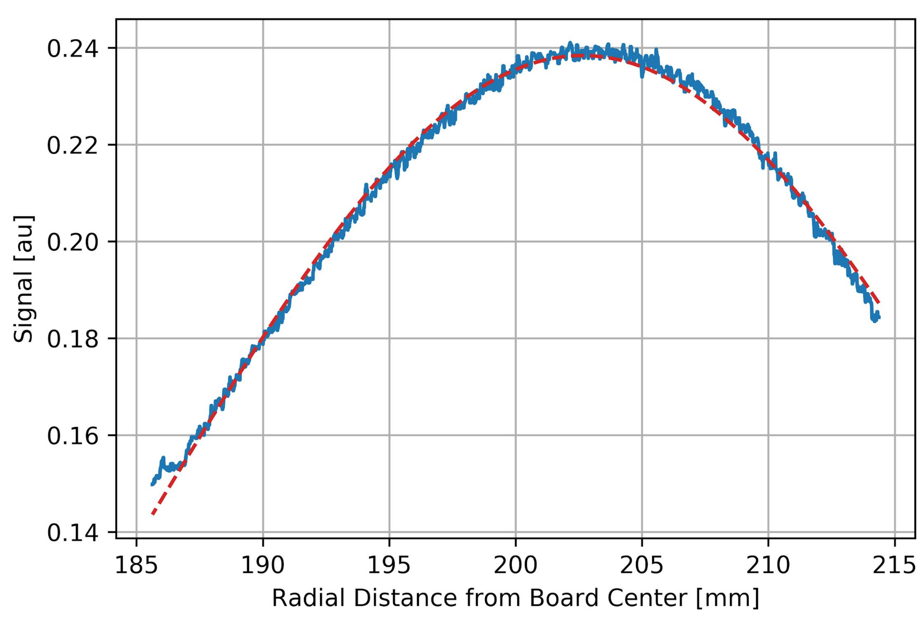
The most direct method for measuring the refractive index of the aerogel tile is to place it in a high-energy particle beam and measure the radius of the resulting Cherenkov ring.



To calibrate aerogel we constructed a detector plane of 16 one-dimensional CCDs (Toshiba TCD-1304-DG) with 3694 8 µm x 200 µm pixels, giving an effective length in the radial direction of 29 mm. The CCDs are arrayed radially in a circle with their mid-points at 200 mm radius. The output is digitized using a 16 channel Acqiris DC270 8-bit 1 GS/s digitizer.

The calibration is conducted at a Vickers electron linear accelerator located at the National Research Council in Ottawa. The accelerator produces 35 MeV electrons in 2.5 µs pulses at a 60 Hz rate, each pulse has approximately 12.5 x 10^{9} electrons.

During calibration, the aerogel tile is scanned in 5 mm steps over an x-y grid. Variations in refractive index across the aerogel tile result in changes to the Cherenkov ring radius.

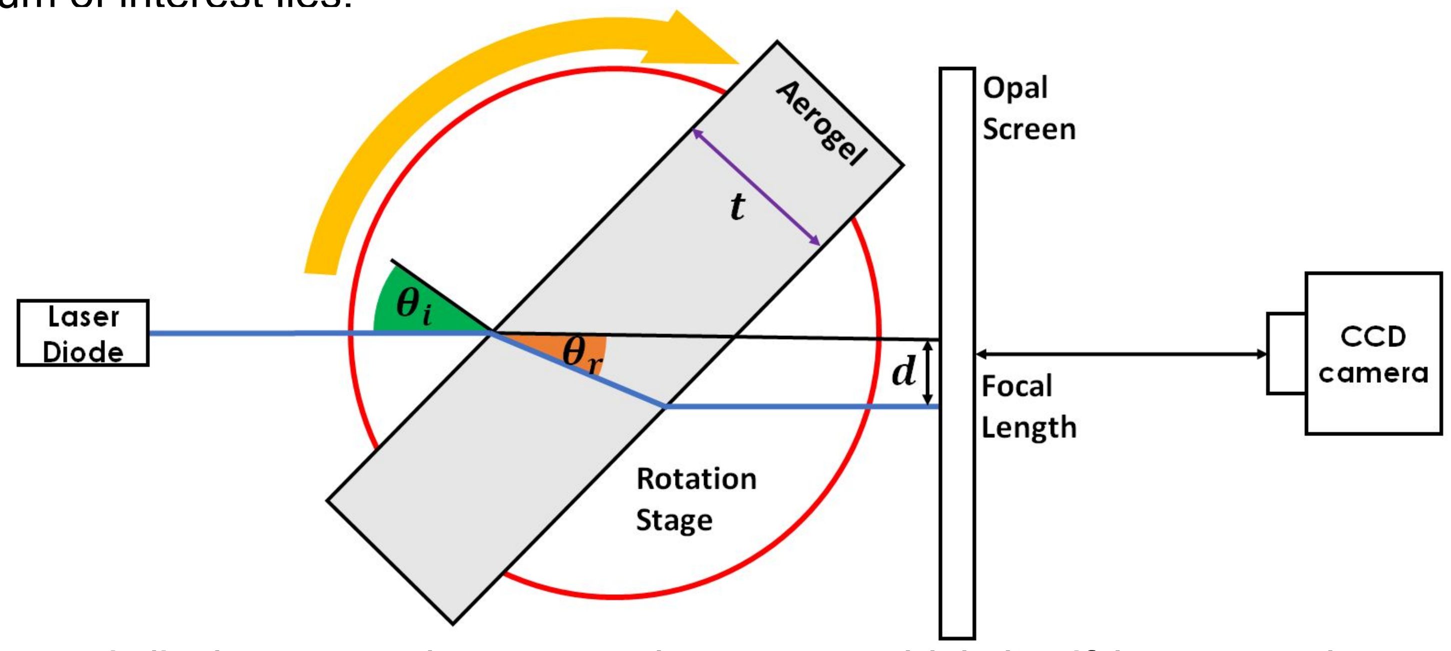


The figure shows sample data from a single CCD. The width is mostly due to divergence of the uncollimated beam. For each CCD, the data are smoothed using a 11-sample median filter and are then fit with a Gaussian distribution. The 16 means thus obtained are fit to a circle to obtain the radius of the Cherenkov ring. The fit residuals can be used to calculate the uncertainty and this predicts a statistical uncertainty of O(10^{-4}) in the measurement of the refractive index when data from 16 CCDs are combined.

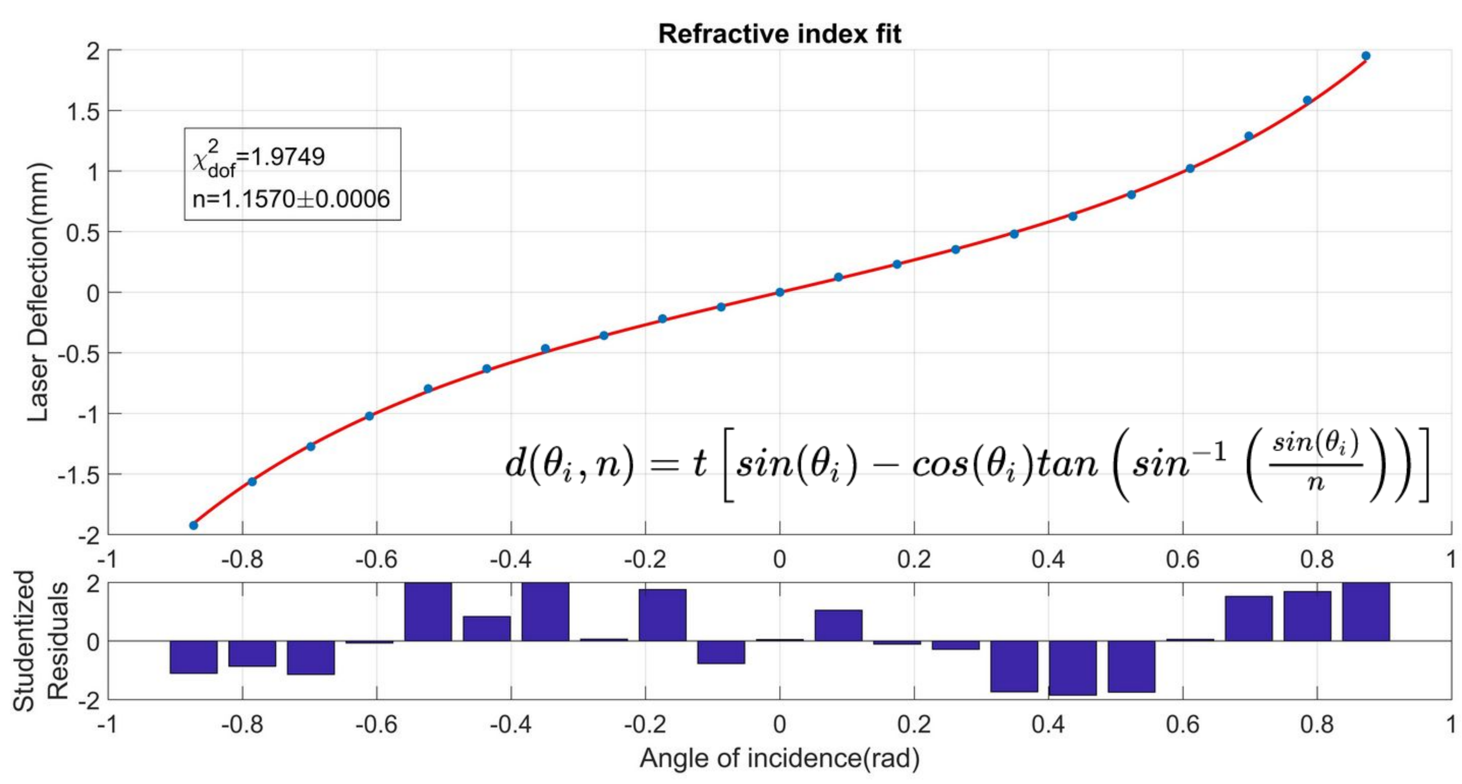
LASER DEFLECTION METHOD

We measure the refractive index of an aerogel tile using the deflection of a laser beam as it traverses the tiles. The deflection ***d*** of a laser spot on a screen downstream from a tile of thickness ***t*** depends on the angle $\boldsymbol{\theta_i}$ between the incident beam direction and the tile surface normal. Fitting the data to this model gives an estimate of ***n***.

To measure ***n*** we use the setup shown below. The laser diode has wavelength of 405 nm since we are interested in the UV-blue range where most of the Cherenkov spectrum of interest lies.



The aerogel tile is mounted on a rotation stage, which itself is mounted on an X-Y scanning stage. For each X-Y point (in a grid of points at 5 mm intervals) we acquire laser-spot images from -50° to 50° in 5° increments



The laser deflection method assumes knowledge of tile thickness and surface shape. We obtain these by scanning the tiles with a Mitutoyo QV606 coordinate measuring machine it can measure the thickness with a 35 µm precision.

REFERENCES

[1] J. Beatty et al, *Cosmic-ray isotope measurements with HELIX*, PoS ICRC 2017 , 226 (2018). doi:10.22323/1.301.0226

[2] M. Tabata et al., *Developing a silica aerogel radiator for the HELIX ring-imaging Cherenkov system*, arXiv:1901.06663

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