Calibration of Aerogel Tiles for the HELIX-RICH Detector

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HELIX (High Energy Light Isotope eXperiment) is a balloon-borne instrument designed to measure the chemical and isotopic abundances of light cosmic-ray nuclei. In particular, HELIX is optimized to measure ^{10}Be and ^{9}Be in the range 0.2 GeV/n to beyond 3 GeV/n. To achieve this, HELIX utilizes a 1 Tesla superconducting magnet with a high-resolution gas drift-tracking system, time-of-flight (ToF) detector, and a ring-imaging Cherenkov (RICH) detector. The RICH detector consists of aerogel tile radiators (refractive index ~1.15) with a silicon photomultiplier detector plane. To adequately discriminate between ^{10}Be and ^{9}Be isotopes, the refractive index of the aerogel tiles must be known to a precision of 0.1%. In this contribution, detailed mapping of the refractive index across the aerogel tiles is presented and the methodology used to obtain these measurements is discussed.

HELIX

High Energy Light Isotope eXperiment (HELIX, [1]) is a balloon-borne experiment designed to measure isotopic and chemical abundances of light cosmic-ray nuclei.

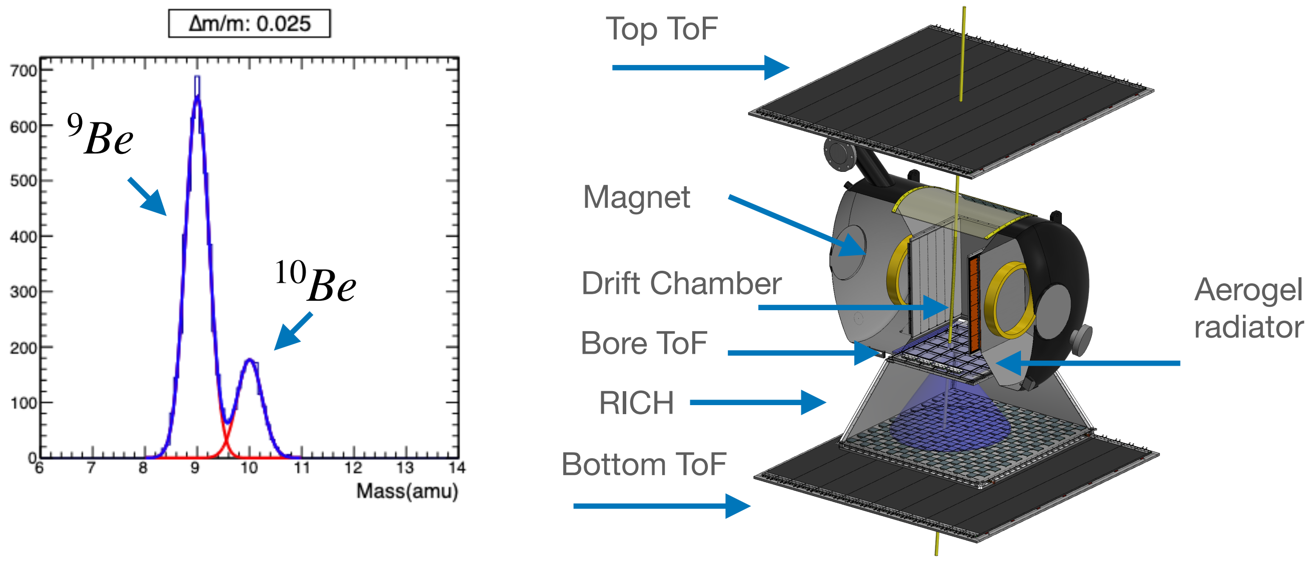

Fig 1. (Left) Expected ^{10}Be and ^{9}Be mass resolution. (Right) The HELIX experiment.

HELIX is optimised to measure the ^{10}Be to ^{9}Be ratio in the 0.2 to > 3. GeV/n range. HELIX utilises a 1Tesla magnet and high-resolution gas drift-tracking system to measure particle rigidity. ToF counters and a RICH detector are used to measure particle velocities.

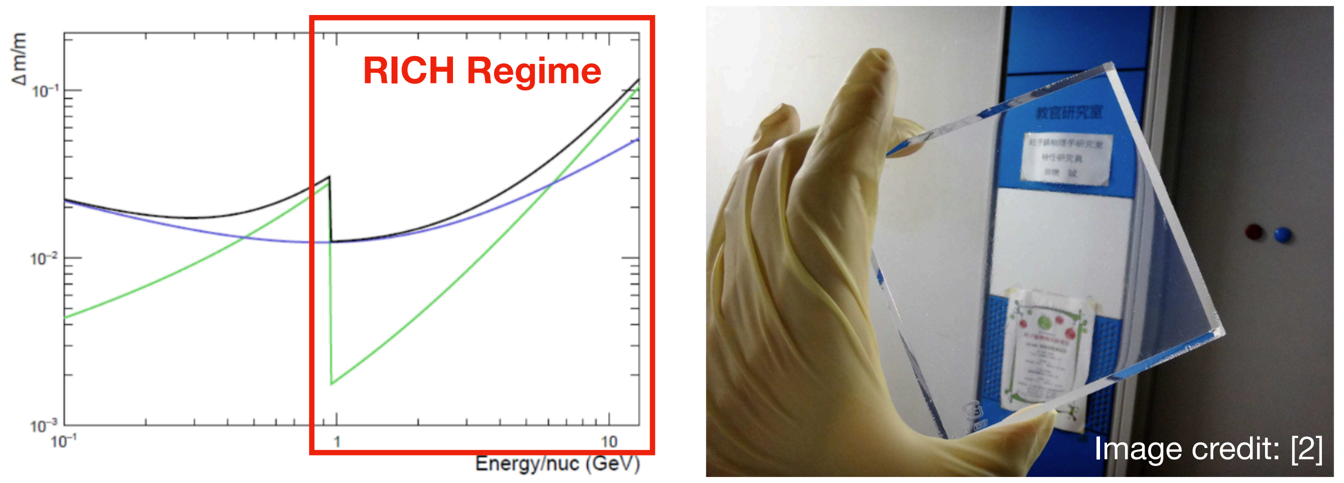

Fig 2. (Left) Predicted mass resolution of the HELIX-ToF and HELIX-RICH detectors. (Right) HELIX aerogel tiles.

The HELIX RICH [3] consists of an aerogel radiator plane and a SiPM detector plane. The radiator plane in made up of 36 (6x6) high-refractive index (n~1.15) aerogel tiles (10cm x 10cm x 1cm) [2]. The RICH is designed to measure velocities of particles with E $\gtrapprox$ 1 GeV/n range.

Measuring The Refractive Index Using Relativistic Electrons

Precise measurements of the refractive index were made by measuring the Cherenkov ring produced by a beam of 35 MeV electron. Theses measurements were performed at the Ionizing Radiation Standards department of the National Research Council in Ottawa [4].

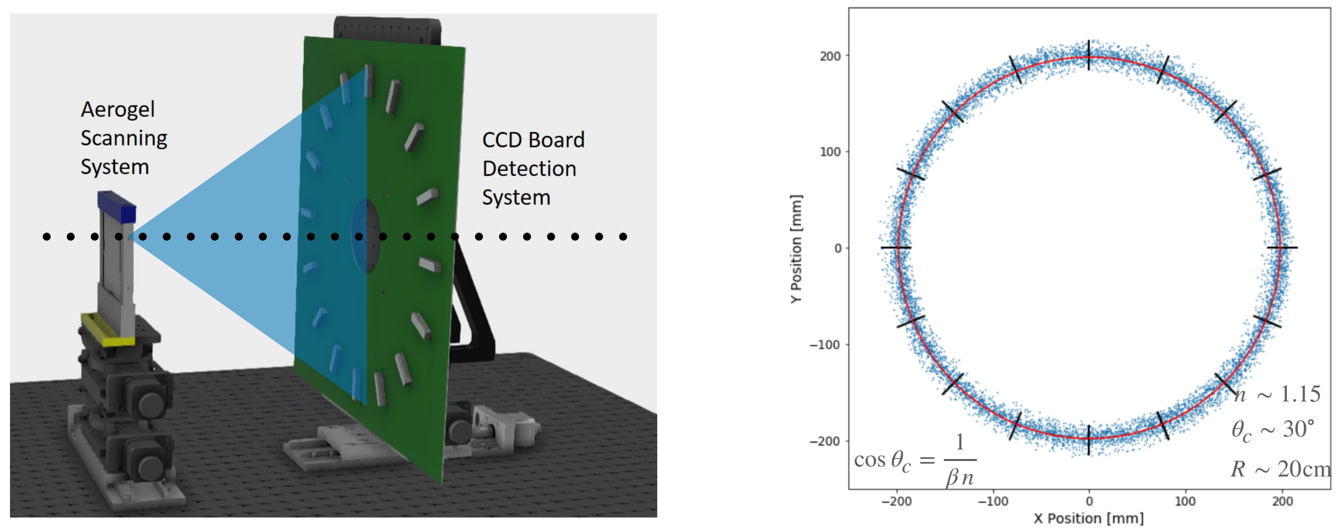

Fig 3. (Left) CAD image of CCD-detector board and aerogel scanning system. (Right) Simulated Cherenkov ring with CCD positions overlaid.

The Cherenkov ring is sampled using a CCD-detector board consisting of 16 CCDs (Toshiba TCD1304DG, 3694 pixels, each pixel 8μm x200μm) arranged in a circle of radius 20 cm at azimuthal increments of 22.5°. The aerogel tile is mounted in a scanning frame, positioned by stepper motors, allowing for a 5mm (5mm-95mm) X-Y scan across the tile face. The CCD-detector board is mounted on an X-Y-Z stepper motor system, allowing for accurate positioning of the CCD-detector board with respect to the Cherenkov ring.

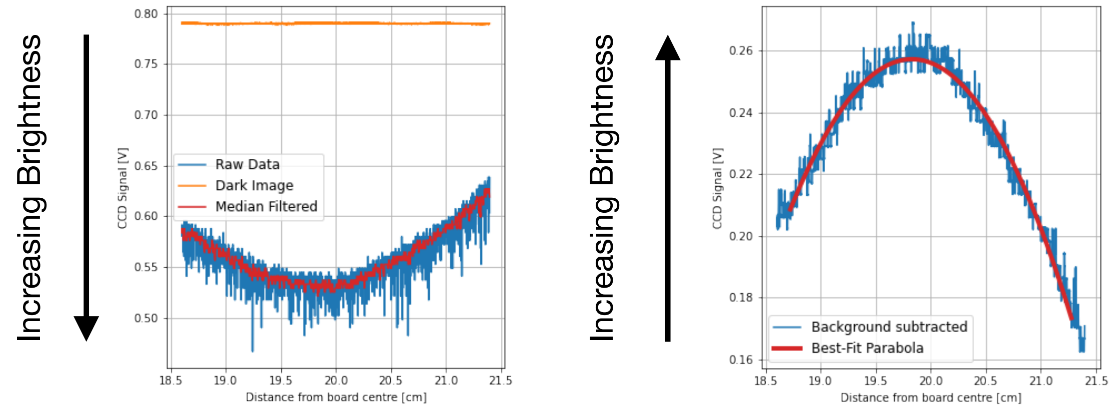

Fig 4. (Left) Example CCD trace. (Right) Background adjusted CCD trace with a median filter applied, and the best-fit parabola.

The CCD traces are digitised using an Acqiris DC270 8 bit FADC. For each scan point, 100 "images", each corresponding to a beam pulse of ~10^{10} electrons, are obtained. Dark (beam-off) images are recorded prior to data taking to account for leakage of any irreducible background light sources. The background subtracted image is well-described by a parabola, with the peak corresponding to the peak of the Cherenkov ring. The broadness of this distribution is due to divergence of the electron beam.

Refractive Index Maps

The position of the ring-max measured in each CCD is projected into the CCD-board X-Y plane. The radius and x-y centre of the ring are obtained by fitting a circle to the peak locations. The refractive index (n) is related to the measured ring radius (r) by:

$$\tan\theta_c = n_0\beta\left(\frac{r - z_e\tan\theta_c}{\sqrt{\left(r - z_e\tan\theta_c\right)^2 + d^2}}\right), n = \frac{1}{\cos\theta_c\beta},$$

where z_e is taken to be the half-thickness of the aerogel, d is the expansion length of the Cherenkov cone and n_0 is the refractive index of air. Thickness variations of the aerogel are corrected for when calculating the refractive index. At $d = 275mm$ the setup can accurately measure a refractive index in the 1.15-1.165 range, with a statistical uncertainty of $\Delta n/n \sim O\left(10^{-4}\right)$. Remote repositioning of the CCD-detector board allows for complete coverage of the expected refractive index range.

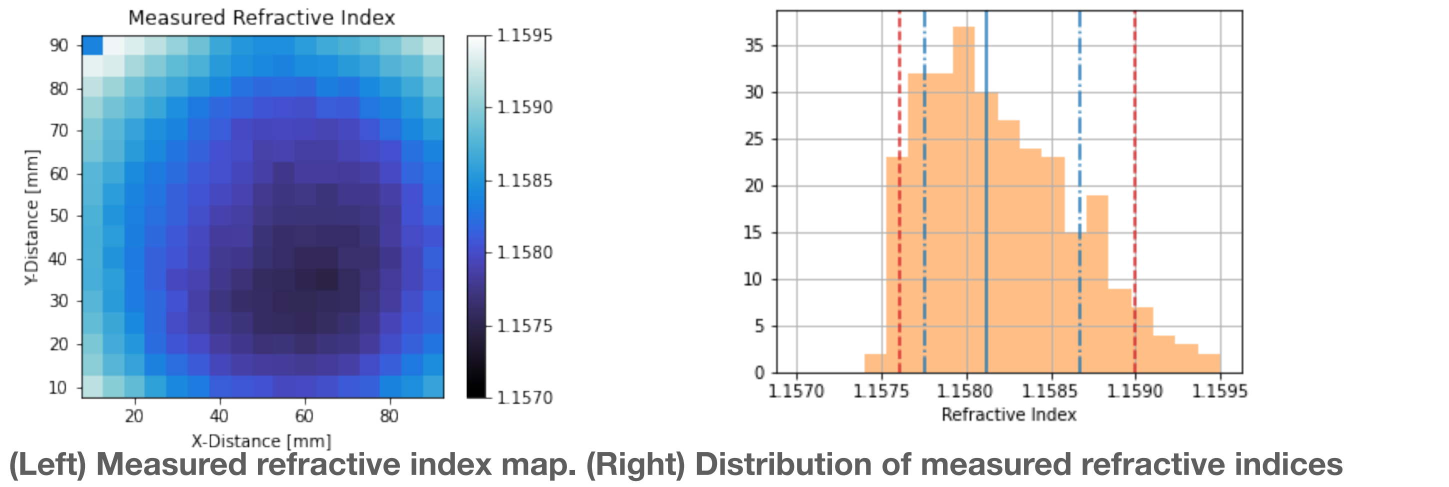

Fig. 5 (Left) Measured refractive index map. (Right) Distribution of measured refractive indices measured across the same tile.

The refractive index varies smoothly across the tile, with the variations well-fit by a 2D-polynomial fit. A refractive index map Fig. 5 (left) with Fig. 6 showing a slice across the same tile. The tile-median index is shown as a solid blue line, the 68% and 90% containment of the refractive index distribution (Fig. 5, right) are shown as blue "dot-dashed" and red "dashed" lines respectively. A 2D polynomial fit to the refractive index map is shown as a black line.

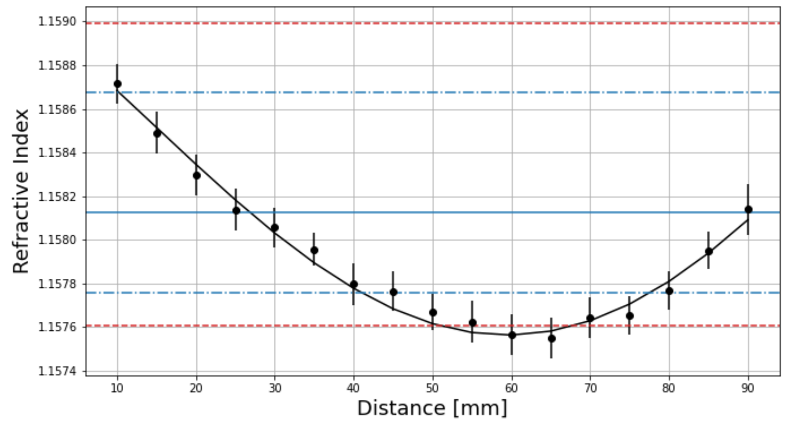

Fig. 6 Slice across refractive index map.

Systematic uncertainties due to the CCD board setup are estimated to be O(0.06%). Additional systematic effects, such as the effects of the varying aerogel thickness, multiple scatter of electrons and beam divergence, are currently being studied. Additional methods of calibrations, such as a laser deflection method, are also being investigated [5]. Refractive index maps, along with precise thickness maps of the aerogel tiles, are being produced for the analysis of HELIX data.

Acknowledgements:
HELIX is funded by NASA in the US and by NSERC and CSA in Canada. We thank M. McEwan and S. Walker at the National Research Council in Ottawa for use of the electron linac and N. Hessey and T. Stack at TRIUMF for use of their coordinate measuring machine.

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