HELIX

High Energy Light Isotope eXperiment

Conor McGrath

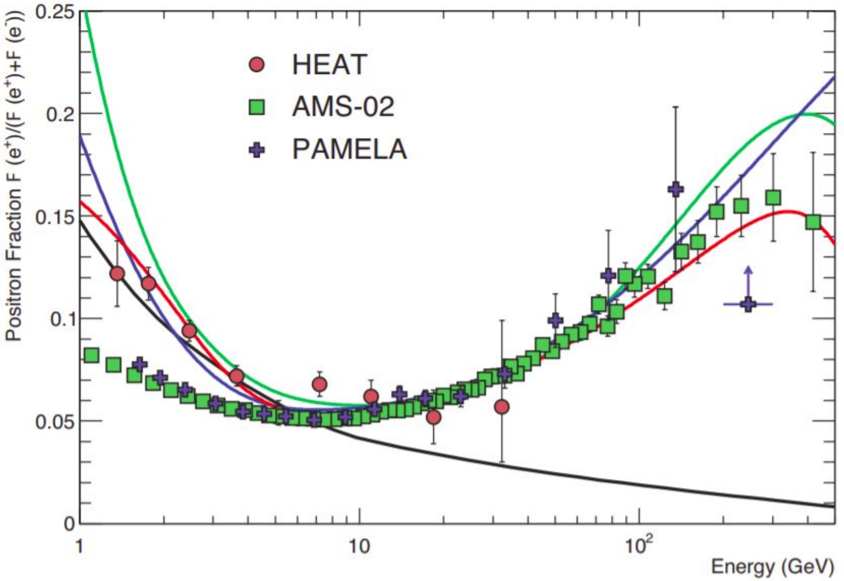
Rough Statistics :
9 Institutes, 25 Members
6 Grad Students, 5 Postdocs*, 12 Faculty/Staff

* At least 1 of which is bad at counting

Scientific Motivation - Investigating CR Propagation

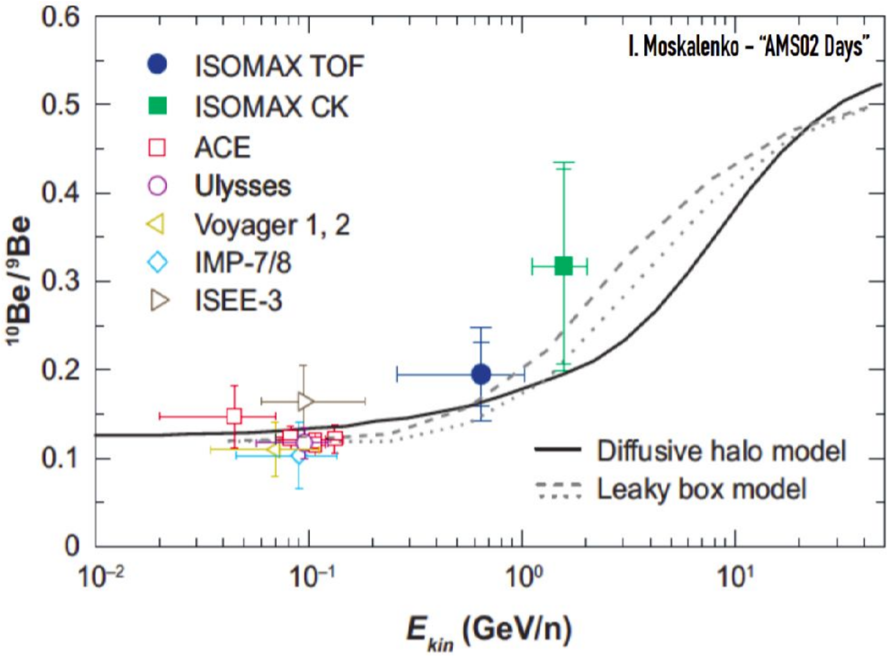
Unexpected results from recent measurements of cosmic-ray fluxes

- Excess positron fraction above 25 GeV
  - Possible explanations : CR Propagation Models, Dark Matter (Or other exotics), Particle Production



Secondary to Primary Ratio

- $^{10}Be/^{9}Be$ ratio
  - Can be used to measure CR propagation times
  - "Clock isotopes" break time vs density degeneracy that other approaches encounter



HELIX Science Goals

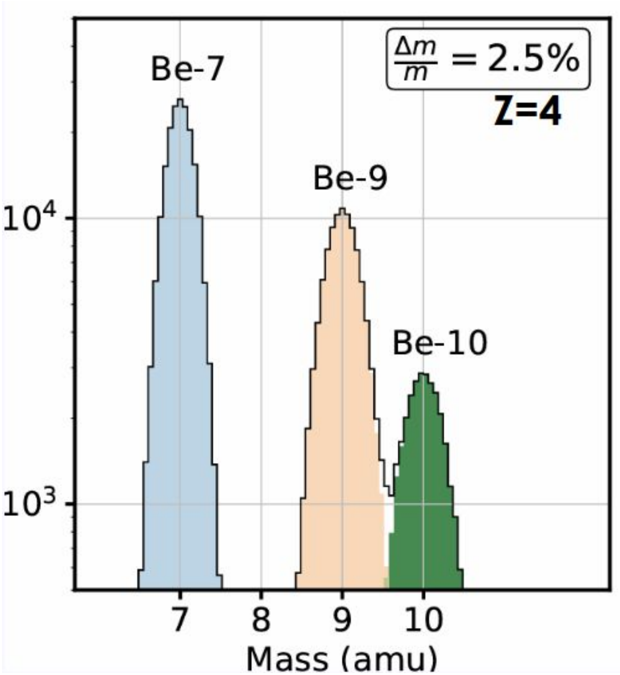
Measure $^{10}Be/^{9}Be$ ratio to provide strong constraints on propagation models

- ^{10}Be is unstable "clock isotope"
  - Known half life of 1.4×10^6 yr
  - Can estimate travel time since production
- Challenging measurement
  - Peaks of ^{10}Be and ^{9}Be are close for E > 1 GeV/n
  - Mass resolution of **<u>~2.5%</u>** required for 4σ separation

$$\left(\frac{\delta m}{m}\right)^2 = \left(\frac{\delta R}{R}\right)^2 + \gamma^4 \left(\frac{\delta \beta}{\beta}\right)^2$$

$$m = R\frac{Ze}{\gamma\beta} \qquad R = \frac{p}{Ze}$$

Simulated mass resolution



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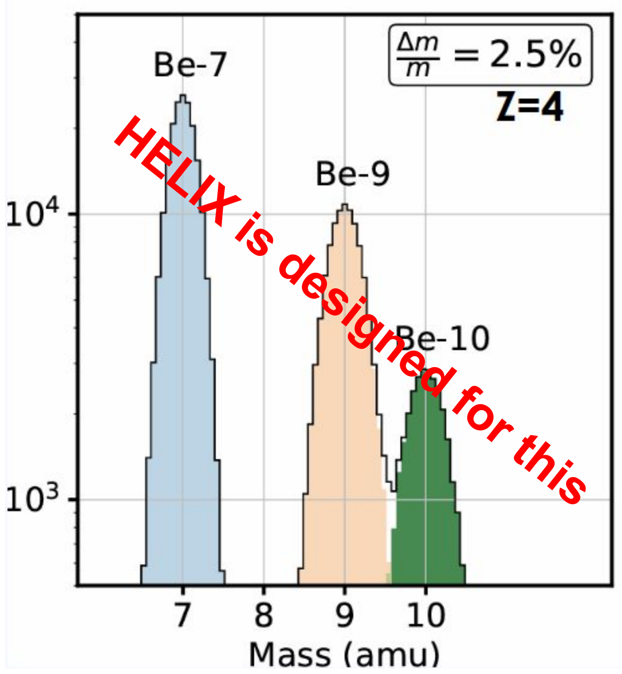
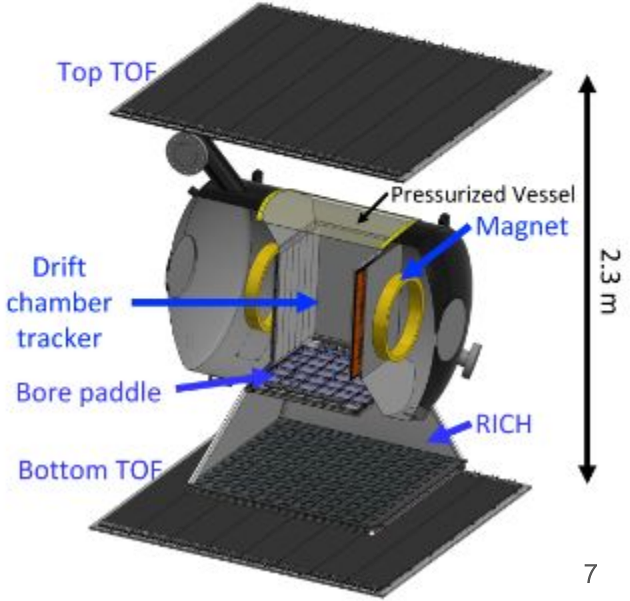


What is HELIX

- High Energy Light Isotope eXperiment
- E ≤ 3 GeV/n - HELIX stage 1
  - E ≤ 10 GeV/n in future flights
- Balloon-borne cosmic-ray detector
  - Magnetic Spectrometer
  - Multiple flights planned
  - One undergone : ~6 days
- 1T superconducting magnet
  - Previously flown on HEAT experiment
- Drift chamber tracker (DCT)
- Ring imaging Cherenkov detector (RICH)
- Time-of-flight system (TOF)



For Further Details - See [Our Brand New Instrument Paper]

The High-Energy Light Isotope eXperiment (HELIX) Instrument

P. S. Allison[a], M. Baiocchi[b,1], J. J. Beatty[a], L. Beaufore[c,2], D. H. Calderón[a], Y. Chen[d,3], S. Coutu[d], E. Ellingwood[e,4], D. Fuehne[c], N. Green[f], D. Hanna[e,*], H. B. Jeon[c,5], B. Kunkler[g,†], M. Lang[g,†], R. Mbarek[c,6], K. McBride[c], C. E. McGrath[b], I. Mognet[d], J. Musser[g], S. Nutter[h], S. O'Brien[e,7], N. Park[b], T. Rosin[e,8], K. Sakai[c], M. Tabata[i], G. Tarlé[f], G. Visser[g], S. P. Wakely[c], I. G. Wisher[c], M. Yu[d,9]

[a] *The Ohio State University Department of Physics Columbus OH USA*
[b] *Queen's University Department of Physics Engineering Physics & Astronomy Kingston ON Canada*
[c] *University of Chicago Enrico Fermi Institute Chicago IL USA*
[d] *Pennsylvania State University Department of Physics University Park PA USA*
[e] *McGill University Department of Physics Montreal QC Canada*
[f] *University of Michigan Department of Physics Ann Arbor MI USA*
[g] *Indiana University Department of Physics Bloomington IN USA*
[h] *Northern Kentucky University Department of Physics Geology and Engineering Technology Highland Heights KY USA*
[i] *Chiba University Department of Physics Chiba Japan*

Abstract

The HELIX detector is a balloon-borne instrument designed to measure the flux of light ($Z < 11$) cosmic-ray isotopes. In this paper we describe the initial configuration of HELIX, optimized for measurements in the energy range from approximately 0.2 GeV per nucleon to beyond 3 GeV per nucleon. In addition to a spectrometer, which is based on a one-tesla superconducting magnet and a drift-chamber tracker, HELIX employs scintillator-based time-of-flight counters and a ring-imaging Cherenkov detector, allowing event-by-event reconstruction of primary particle mass, charge, and magnetic rigidity.

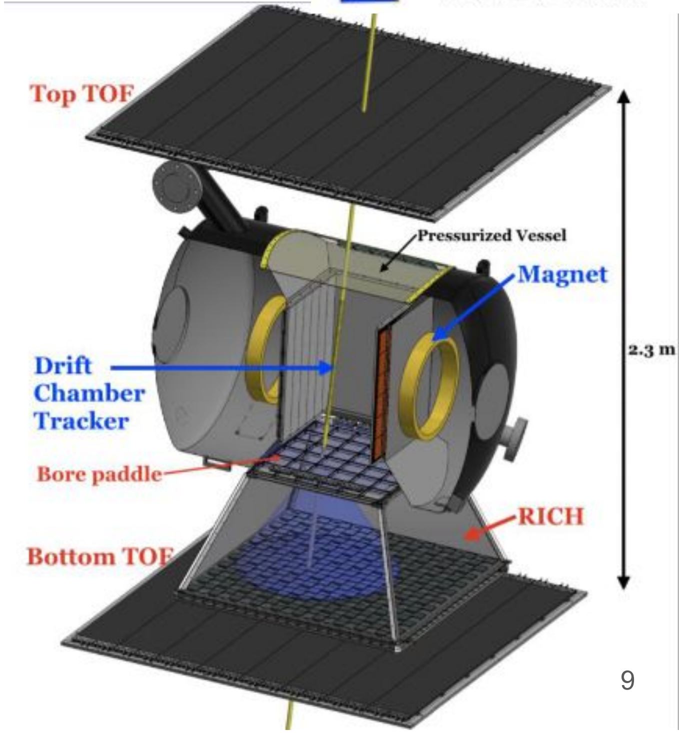
Submitted to Nuclear Instruments and Methods

How Does HELIX Measure Mass?

$$m = R\frac{Ze}{\gamma\beta}$$

- **TOF (Time Of Flight)*** can measure β up to E ~1 GeV/n from Δt and Ze of up to 10
- Higher energy β measurements performed by **RICH (Ring Imaging Cherenkov Detector)***
- Measuring bending of particle in **DCT (Drift Chamber Tracker)** gives R
  - Utilising 1T superconducting magnet

*SiPMs used for readout due to high magnetic field



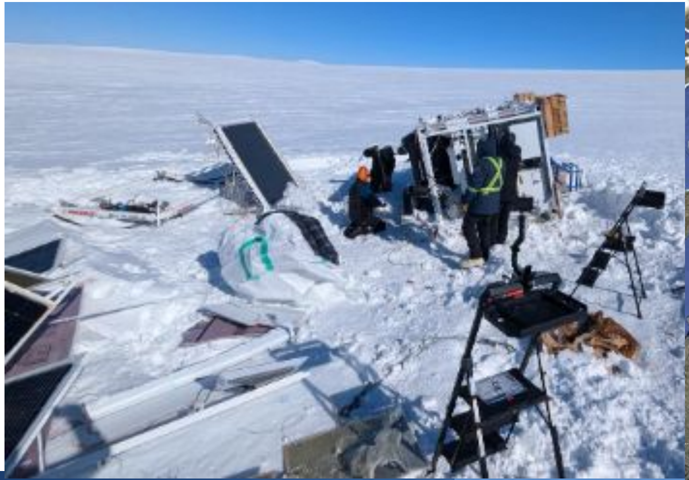
The HELIX Flight 2024

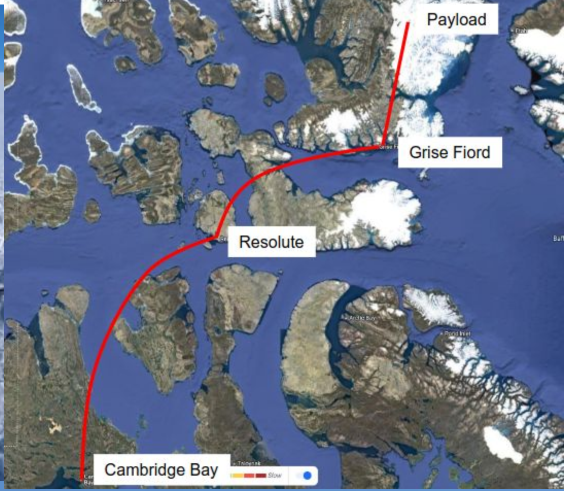
- Successful launch from Kiruna, Sweden on March 28th
- Launched on first attempt
  - Rare!
- Flight time : ~6.3 days
- > 120 million triggers
- Challenging recovery location - Second most northern landing!
  - At the time

https://www.youtube.com/watch?v=Po0fJ8al4S4

Recovery

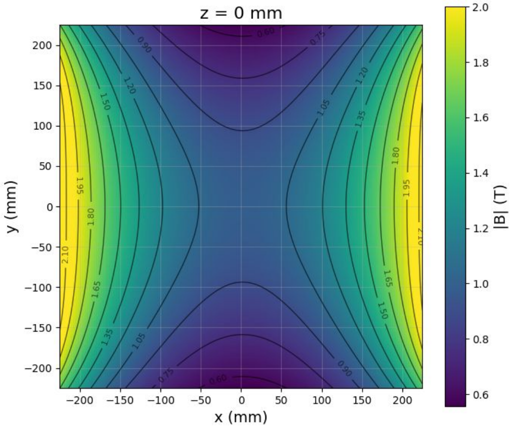
- Most of detectors recovered without any damage
- Refurbishment effort ongoing

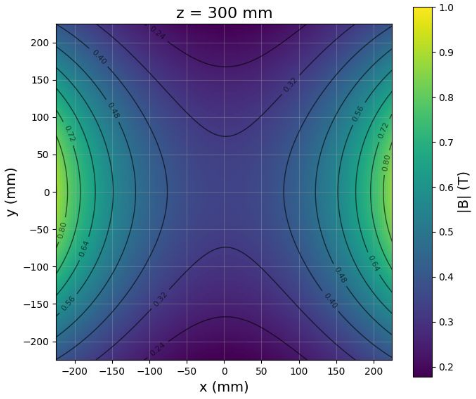




Magnet

- 1T Superconducting magnet
- Formally flown on HEAT experiment
  - Proven flight capable
  - Refurbished to operate without pressure vessel
- Cryogen operations @ 4 K
  - NbTi coils submerged in 260 L LHe
- Stable operations during flight
  - Manually discharged after 6 days



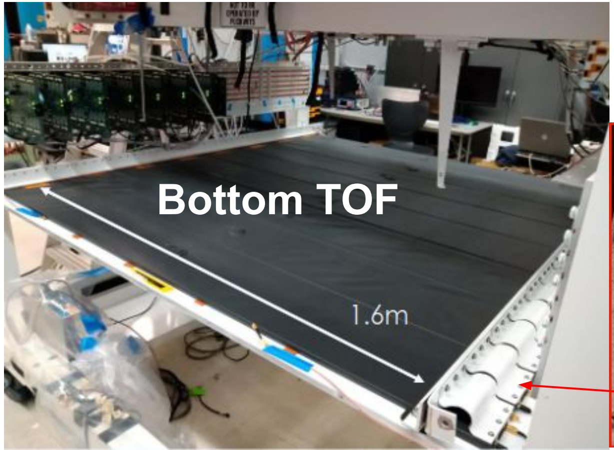


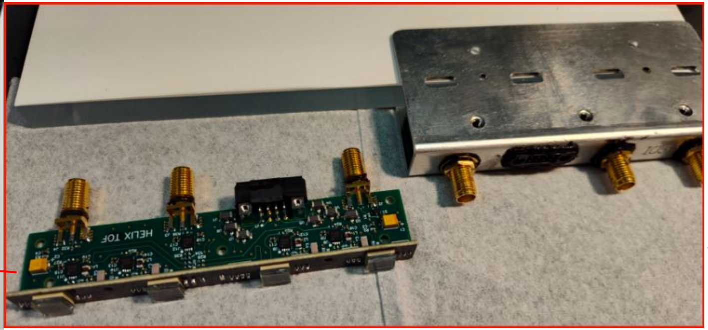
Time Of Flight

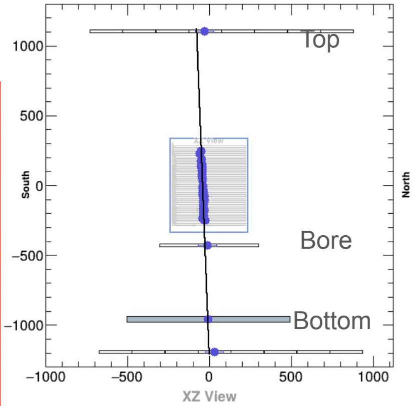
Measures velocity and charge

3 sections (top, bottom,~middle) of 1 cm thick plastic scintillators

- EJ200 scintillator
- 2.3 m separation between top and bottom
- 8 single-pixels (SiPMs) per “paddle” end
- “Bore” paddle used to define acceptance



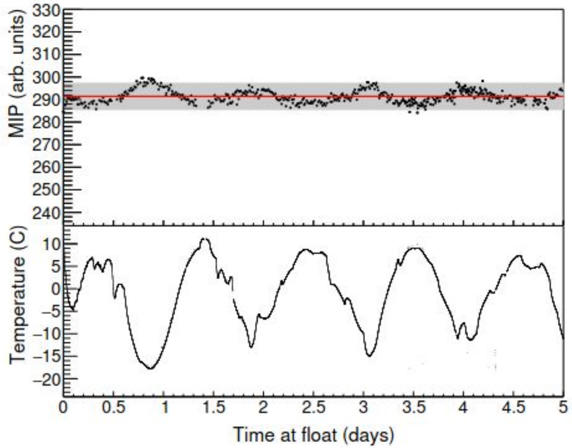


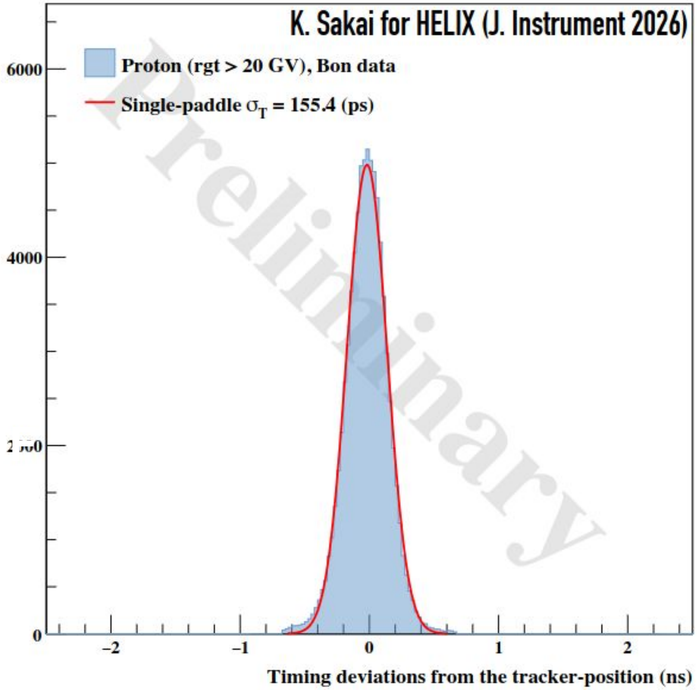


Time Of Flight

Measures velocity and charge

- Preliminary analysis underway
  - Primarily relying on flight data - some preflight muon data used
  - Goal performance can be achieved
- Timing resolution
  - Goal : < 50 ps for Z > 3
  - Current : Better than ~220 psec for Z=1
- Charge resolution
  - Goal : Better than 0.2e for Z<11
  - Current : ~0.2e for Z=1





Drift Chamber Tracker

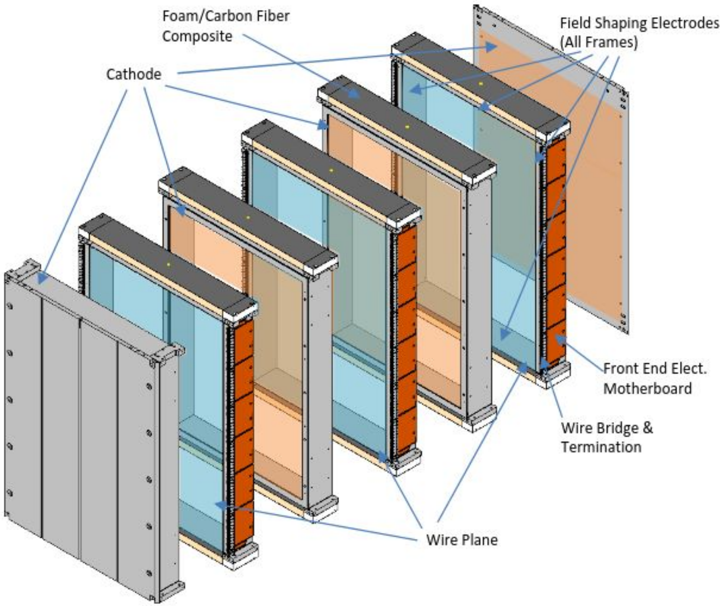
Measures rigidity

Multi-wire gas (90% CO_2 + 10% Ar) drift chamber tracker

- Custom designed to fit in magnet bore

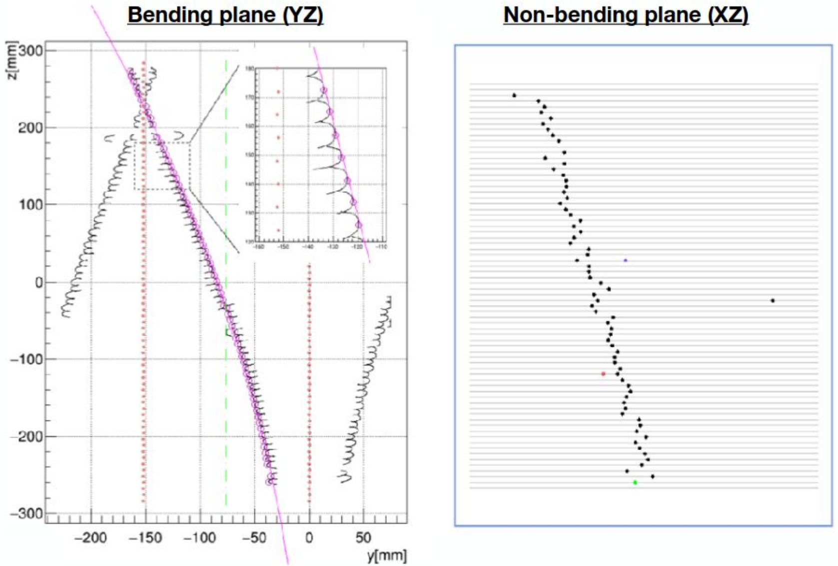
Detects ionisation tracks left by charged nuclei in two 2D planes

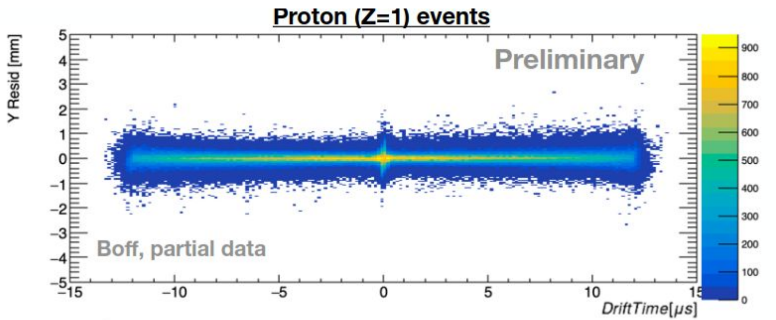
- Spatial resolution 70 μm for Z>3
- 72 sense layers
- 80 MHz sampling

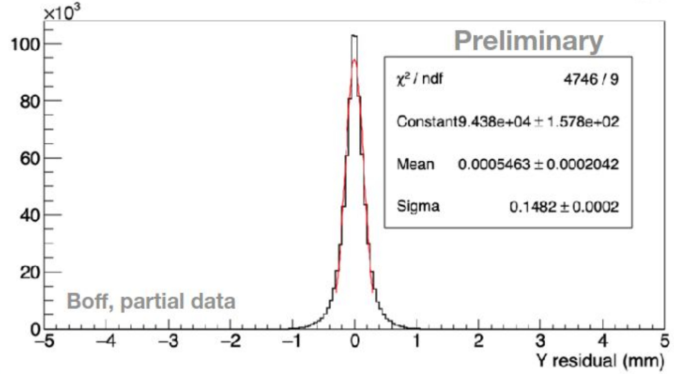


Drift Chamber Tracker Performance

- Preliminary analysis underway
  - Goal performance can be achieved
- Both data driven and simulation based approaches taken to calibration
  - Time dependance is considered
- Garfield++ simulations used to model ionisation inside detector
  - Isochrones describe particle drift distances
- Physical wire stagger used to solve L/R ambiguity







Ring Imaging Cherenkov Detector

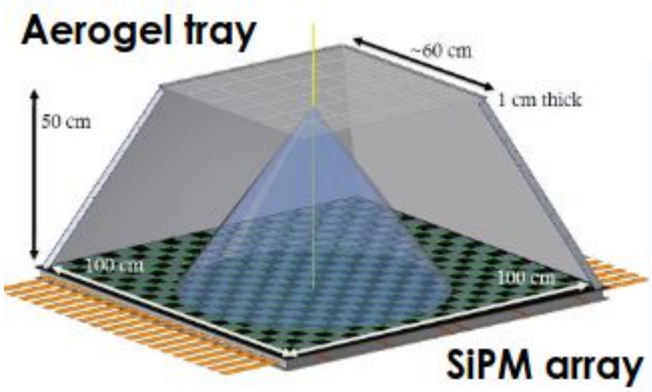
Measures velocity

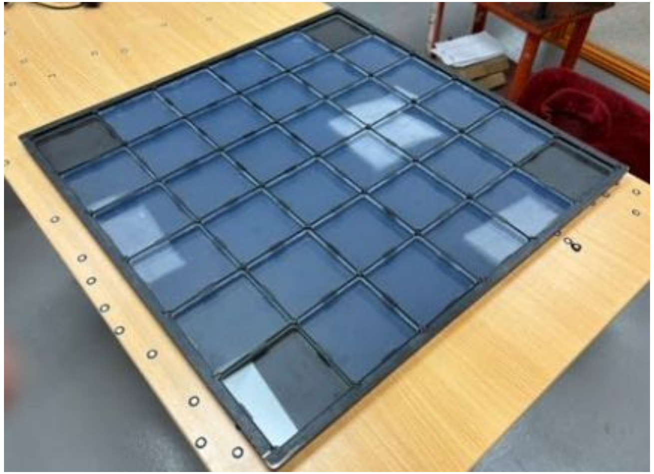
Aerogel radiator used to induce Cherenkov radiation

- Transparent with refractive index n ~1.15

Focal plane made of 200 SiPM arrays (6 mm x 6 mm, 12800 pixels)

- 1 m^2 area half-filled with SiPMs
- β resolution of 0.1% for Z>3 and E>1 GeV/n

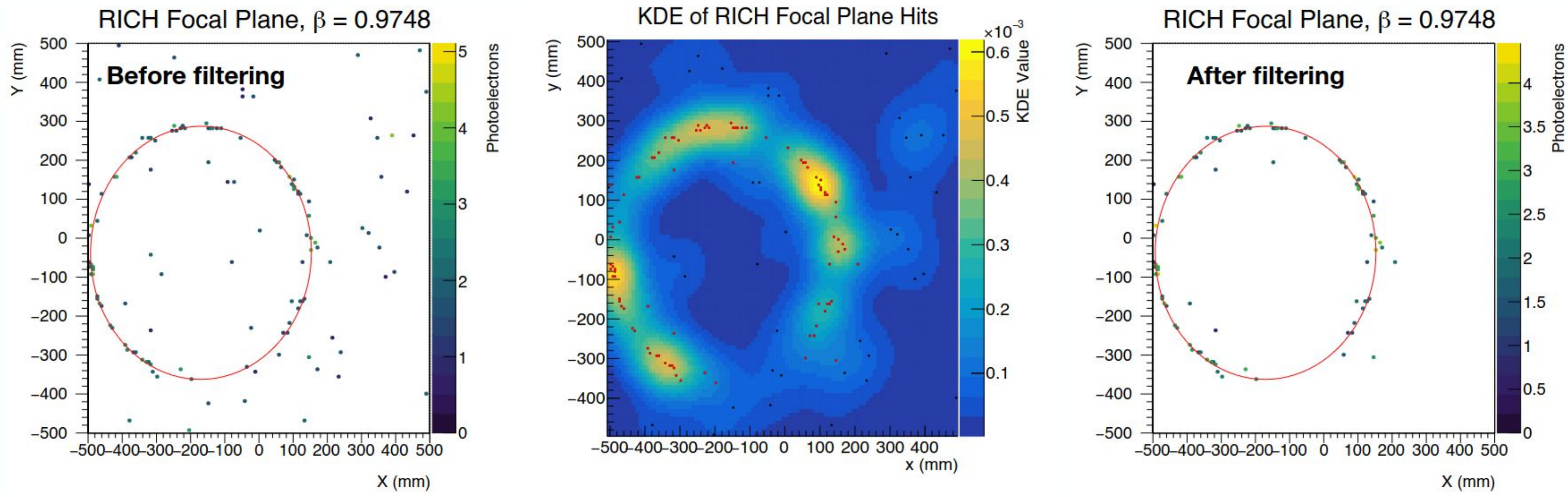




Ring Imaging Cherenkov Detector Performance

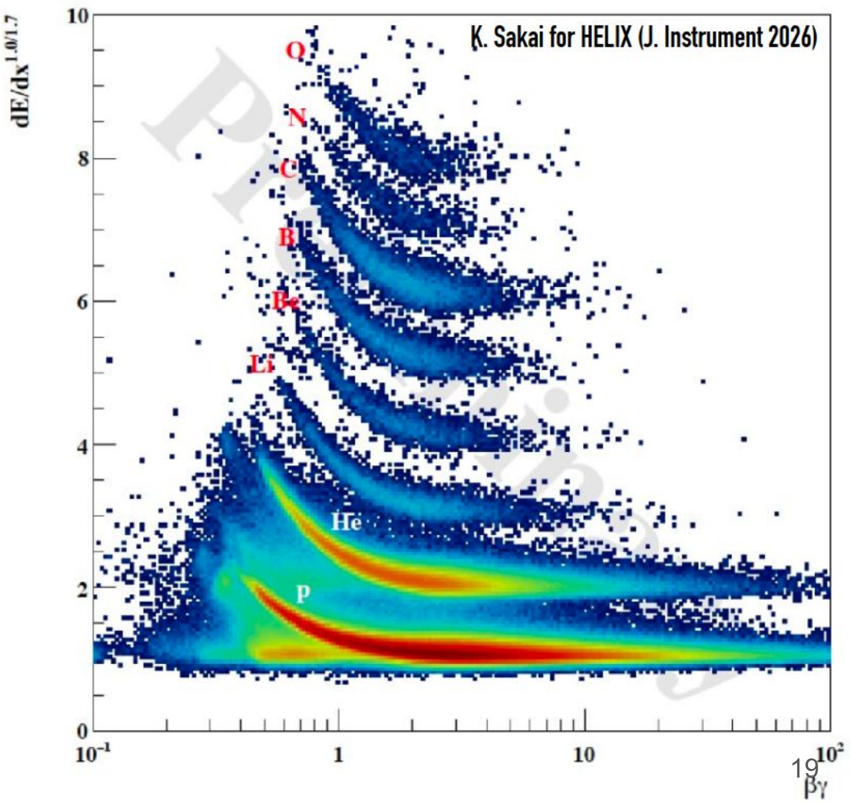
- Preliminary analysis underway
  - Primarily relying on flight data
  - Promising results so far
- Using timing based hit selection and filtering cherenkov rings can be reconstructed
  - Despite higher noise levels as a result of greater temperatures than expected

e.g. Beryllium candidate event



Ongoing Analysis Status

- Tracking and charge calibrations are ongoing
- Preliminary performance using early TOF + DCT analyses
  - Time dependant analyses to come
- Cross calibrations efforts underway
  - Between sub-detectors
- βγ estimation from TOF top and bottom timing difference
- Rigidity measurements ongoing
- Detector performance is promising



MI Contributions

Nahee Park - Project scientist, simulation, Time of Flight, RICH, metrology/geometry

Conor McGrath (Post Doc) - Drift chamber calibrations, aerogel measurements and characterisation (previously **Avani Bhardwaj***), Time of Flight

Minya Bai (PhD) - Time of Flight calibrations

Gurpreet Kainth (MSc) - Thermal simulations and testing

Lily Moss (UG) - SiPM characterisation

Kaitlyn Broad (UG) - Time of Flight

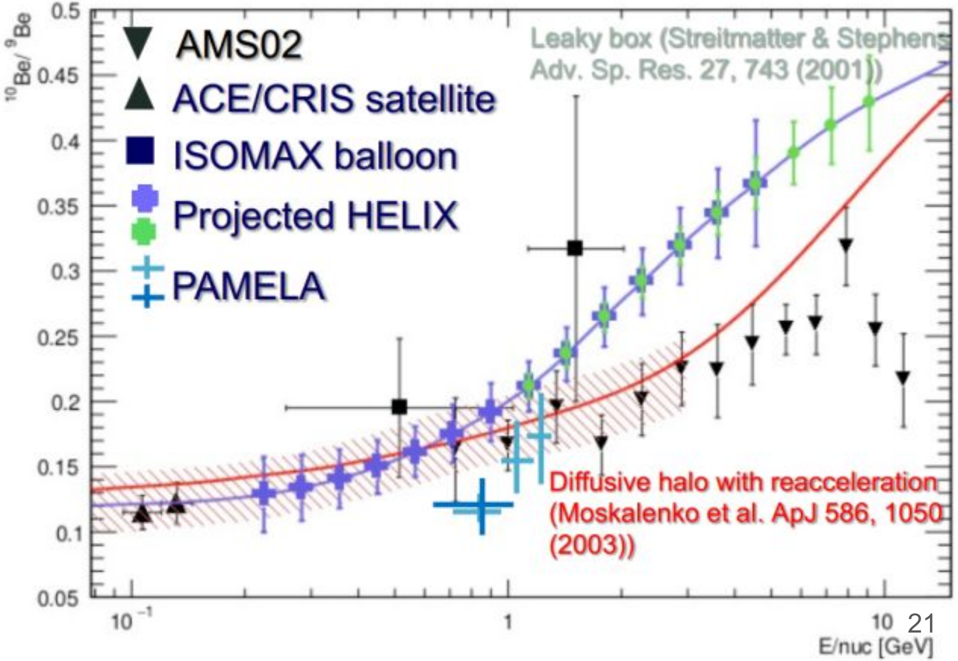
David Hanna - Aerogel measurements, Recovery, Publications

Canadian team are also collectively working on the development of future detectors

* Best poster award RICH2025
[Spectral-domain optical coherence tomography for thickness and refractive-index characterization of silica aerogel radiators]

Going Forward

- Goal : Extend measurements up to 10 GeV/n
- Greater magnet hold time
  - -> 28 days
- Greater DCT spatial resolution
  - 70 μm -> 5 μm
  - Si strip detectors
- Improved velocity measurements
  - Full RICH detector plane
  - Duel refractive index aerogel?
- Thermal system improvements
  - A lesson learned from engineering flight
- Antarctic flight?



Summary

- HELIX is designed to measure Be isotopes
  - Mass resolution better than 3%
  - Stage 1 : Up to 3 GeV/n
  - Further : Up to 10 GeV/n
- Successful first flight and recovery
- Calibrations, analysis and refurbishment ongoing
  - Performance goals look achievable