HELIX
(High Energy Light Isotope eXperiment)

Presented by Nahee Park

HELIX Collaboration

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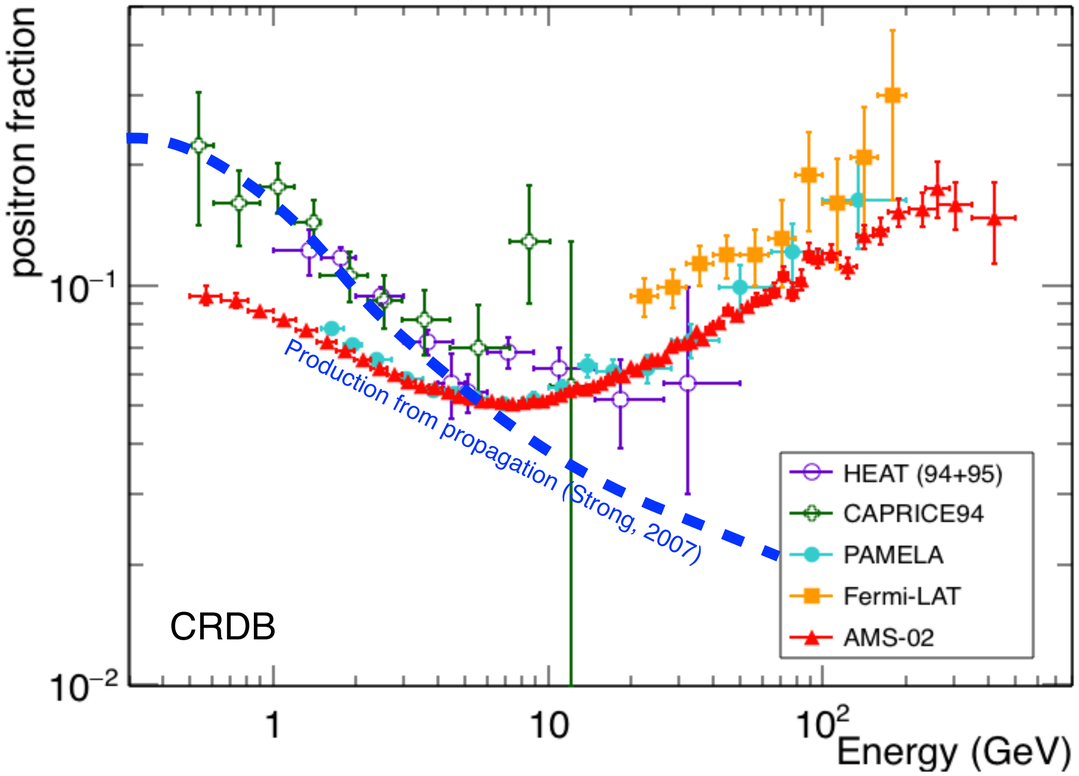
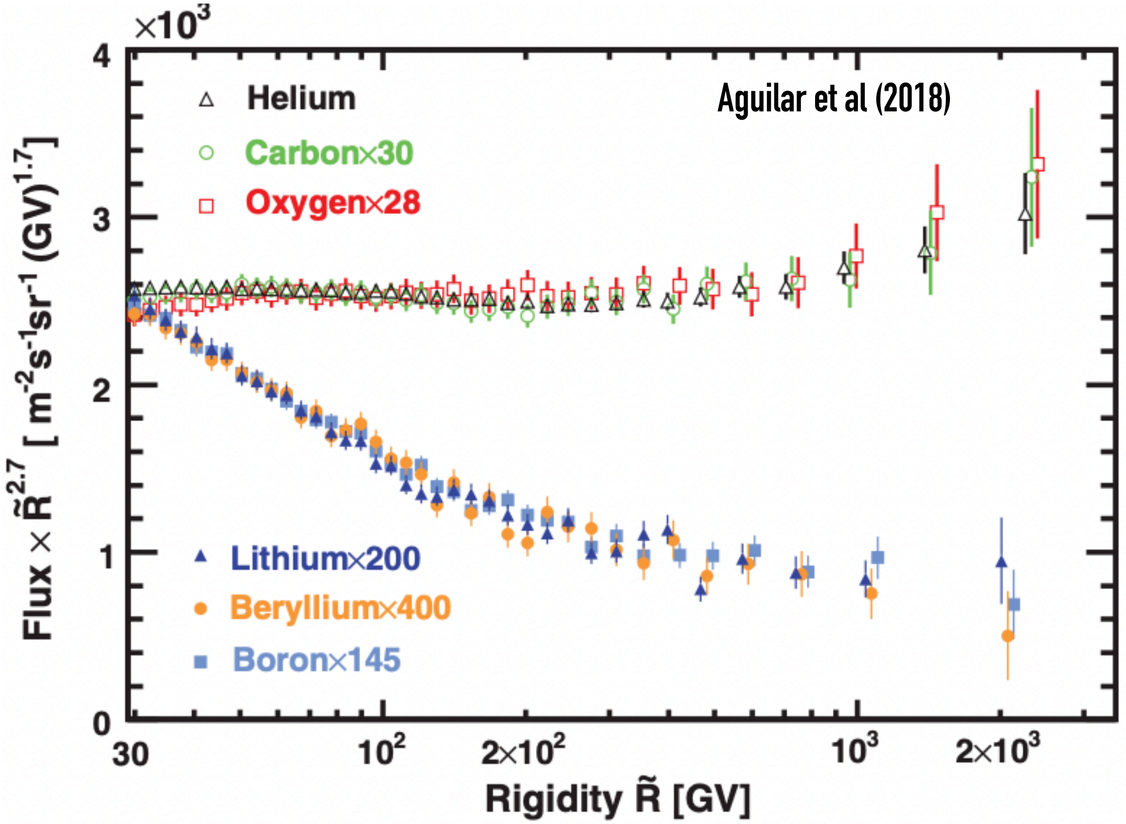
New discoveries challenge classical paradigm of cosmic rays

A new era of precision space-based measurements has brought real surprises

- Rising positron fraction
- Spectral index changes before the knee energy (200 GV, ~10 TeV/n)





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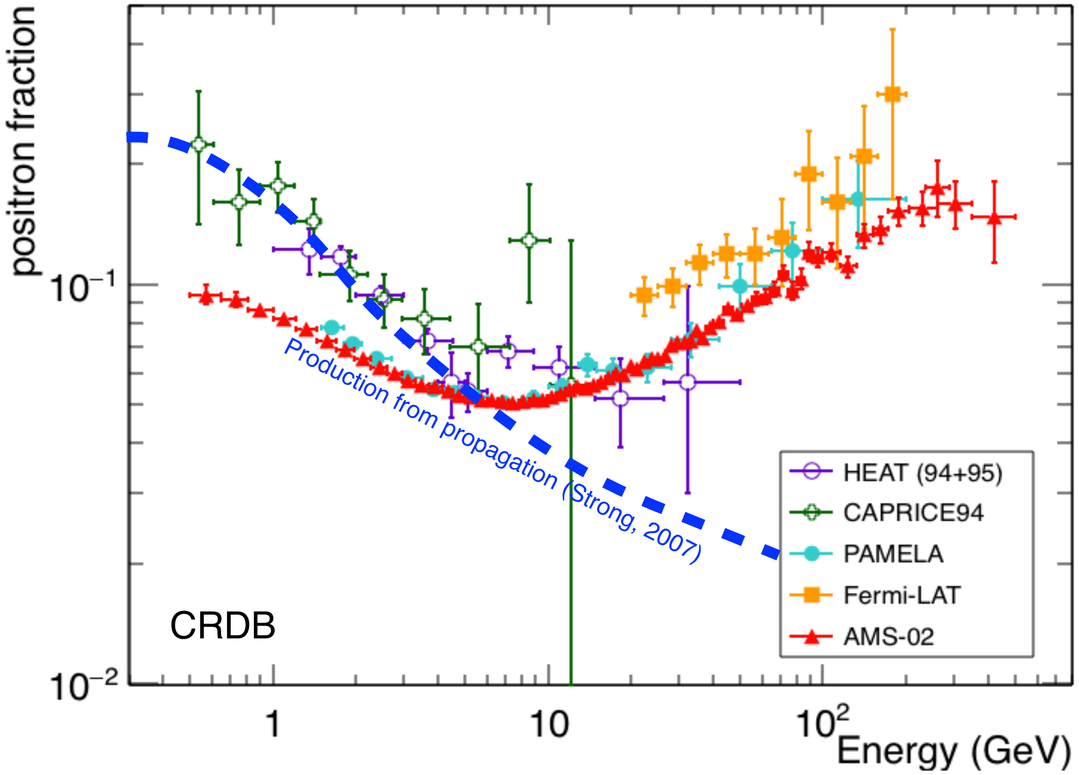
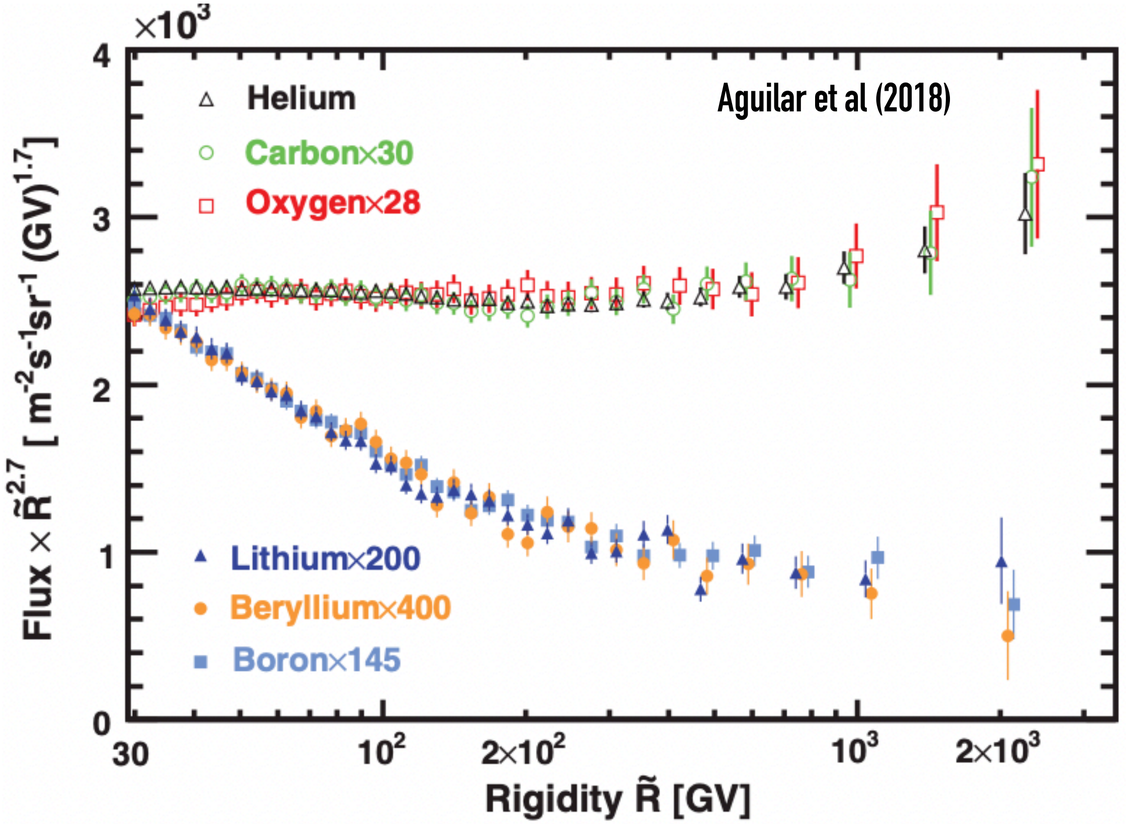


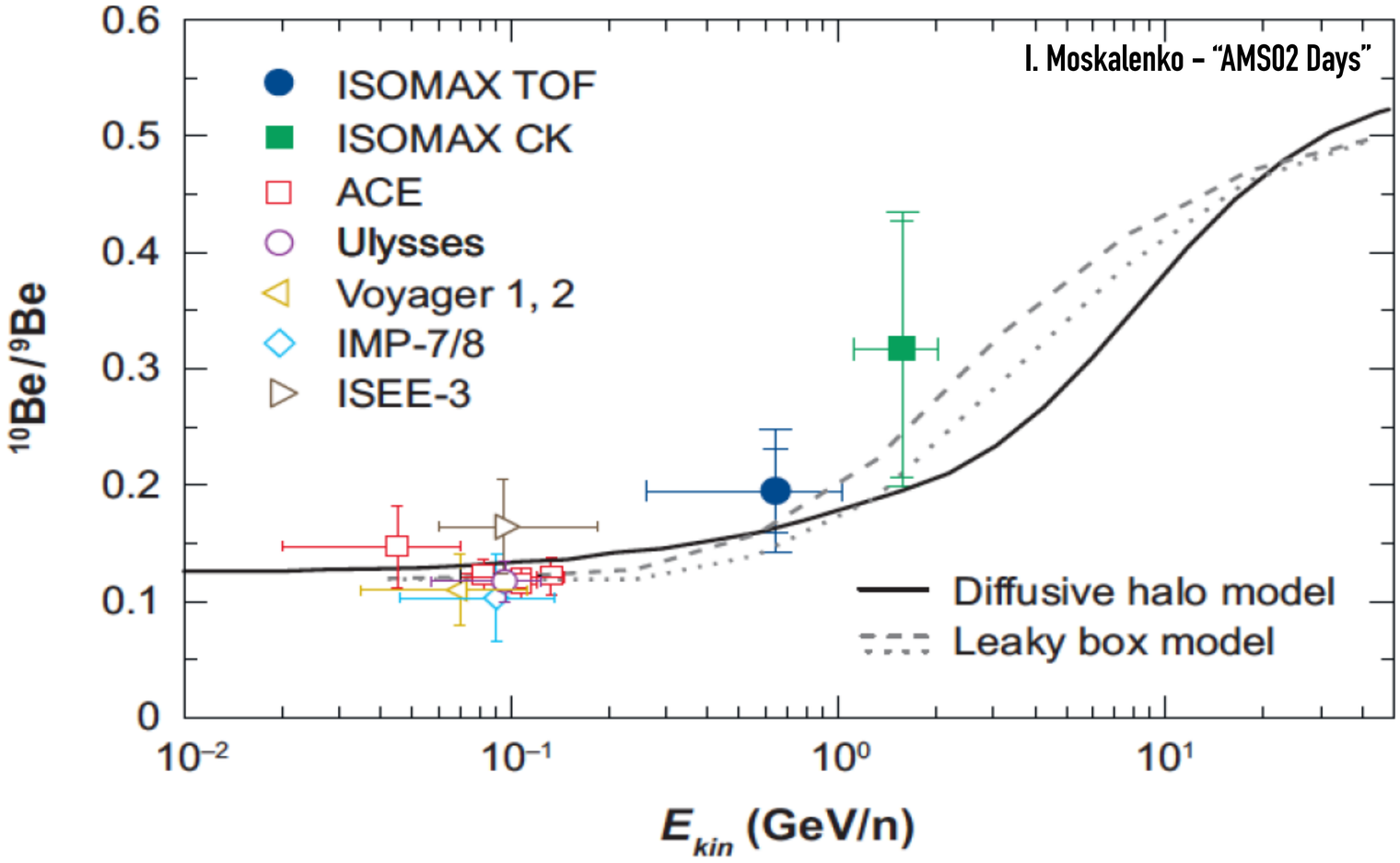


→ ***It is critical to understand the propagation!***

$^{10}Be/^{9}Be$ measurements

^{10}Be : Unstable isotope with known half life of 1.4×10^6 yr

- $^{10}Be/^{9}Be$ ratio provides strong constraints for the propagation models
- Challenging measurements



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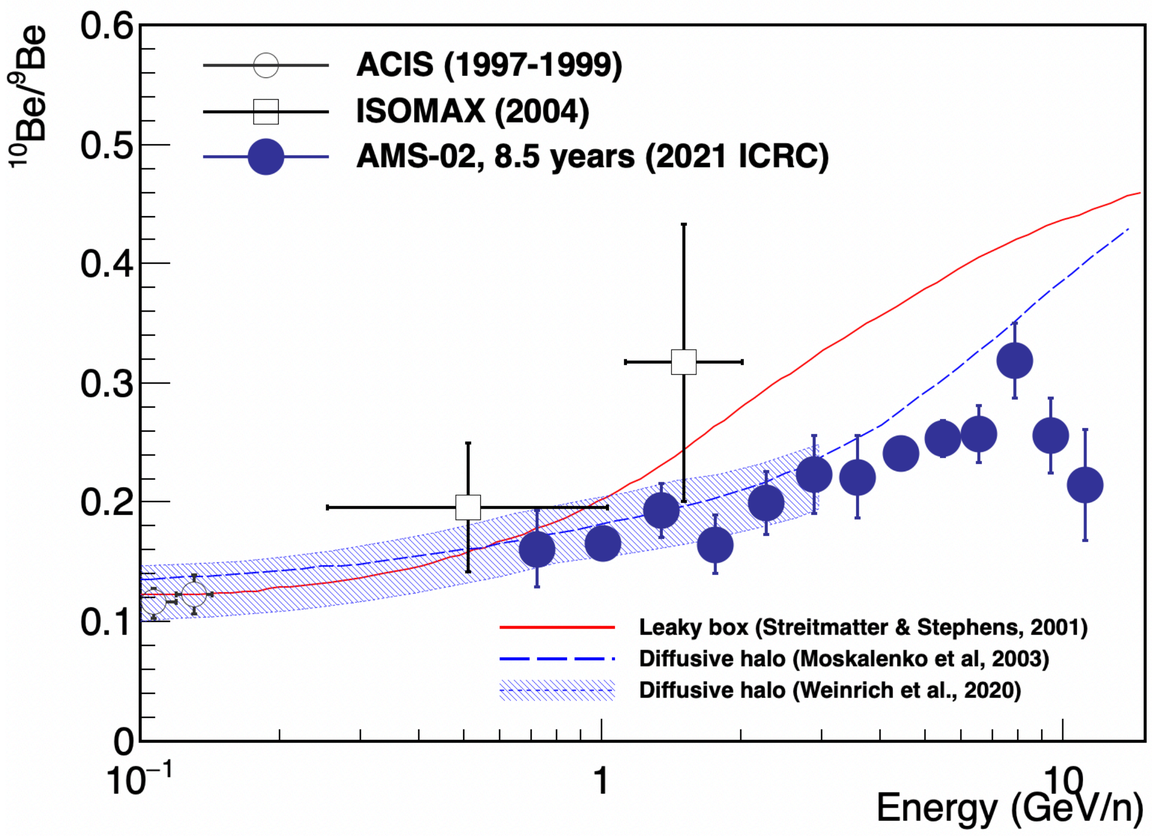

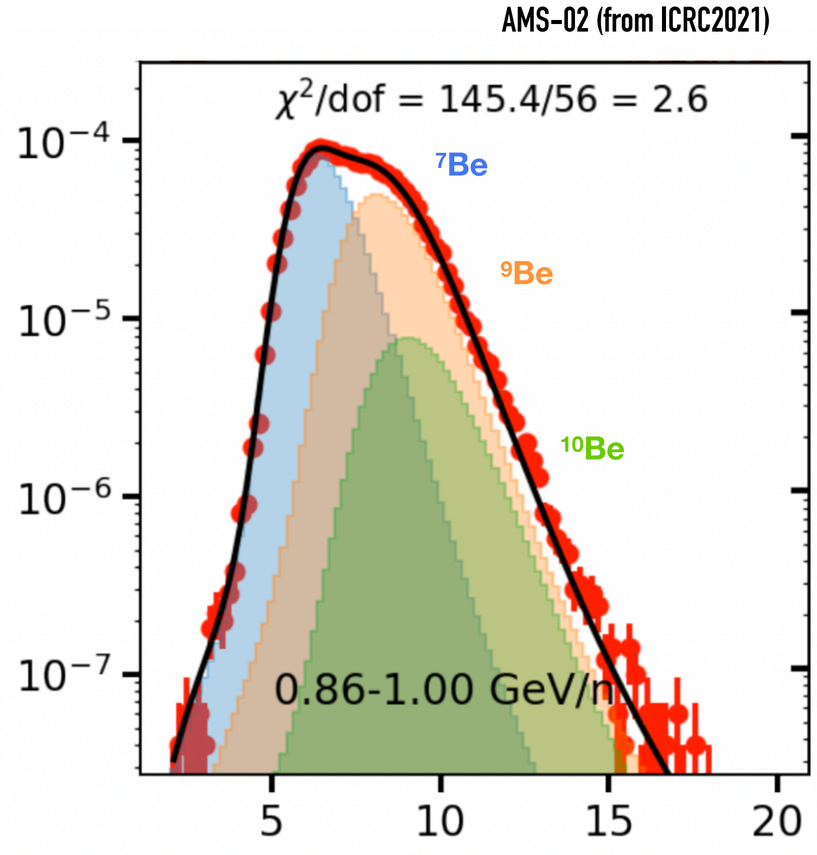

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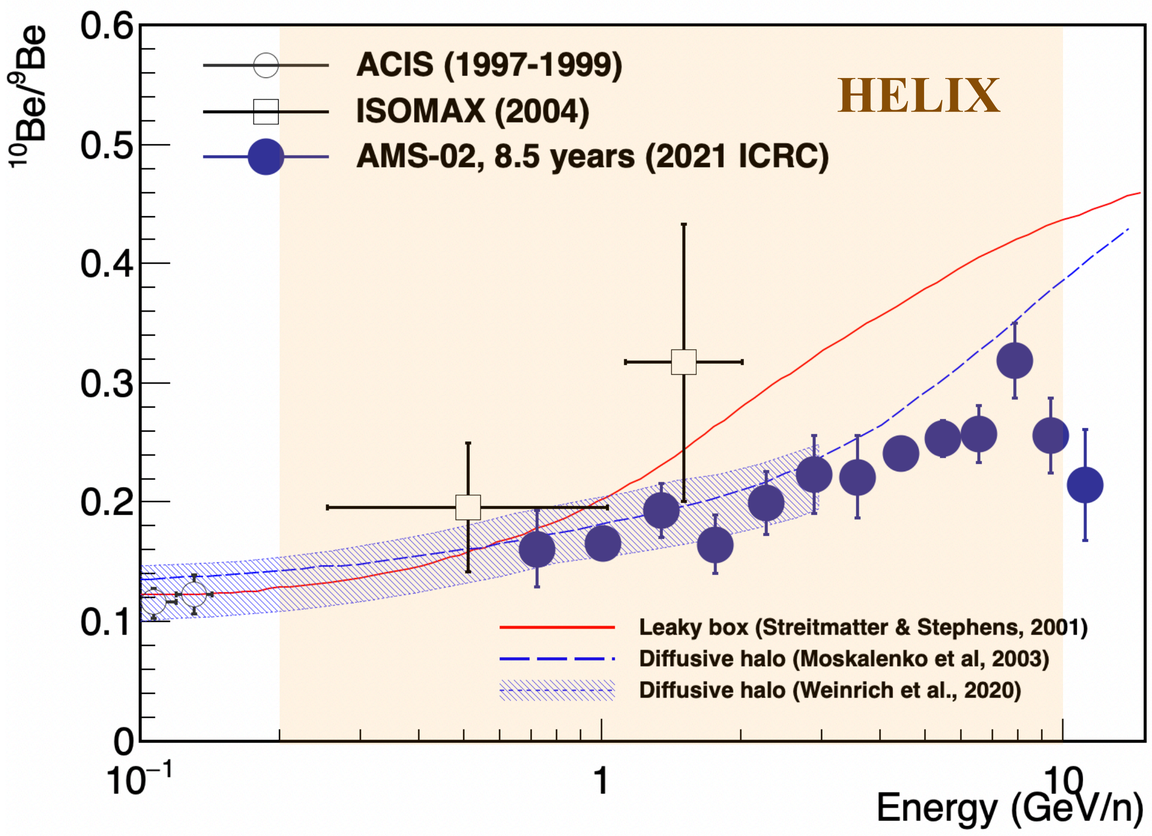
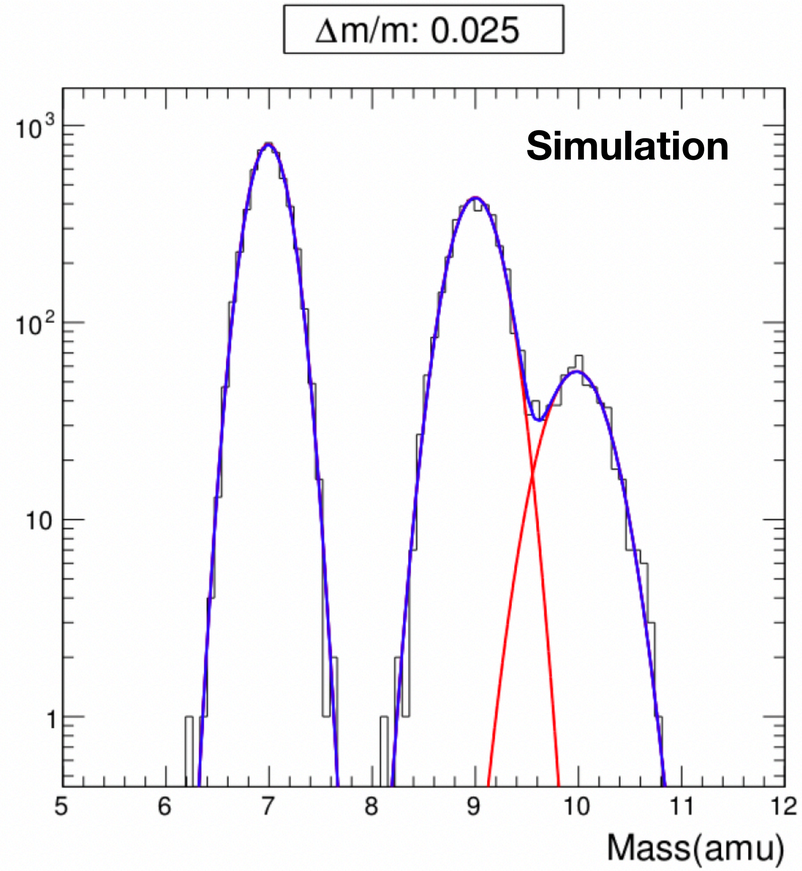
HELIX is designed to provide a precision measurement of ^{10}Be!

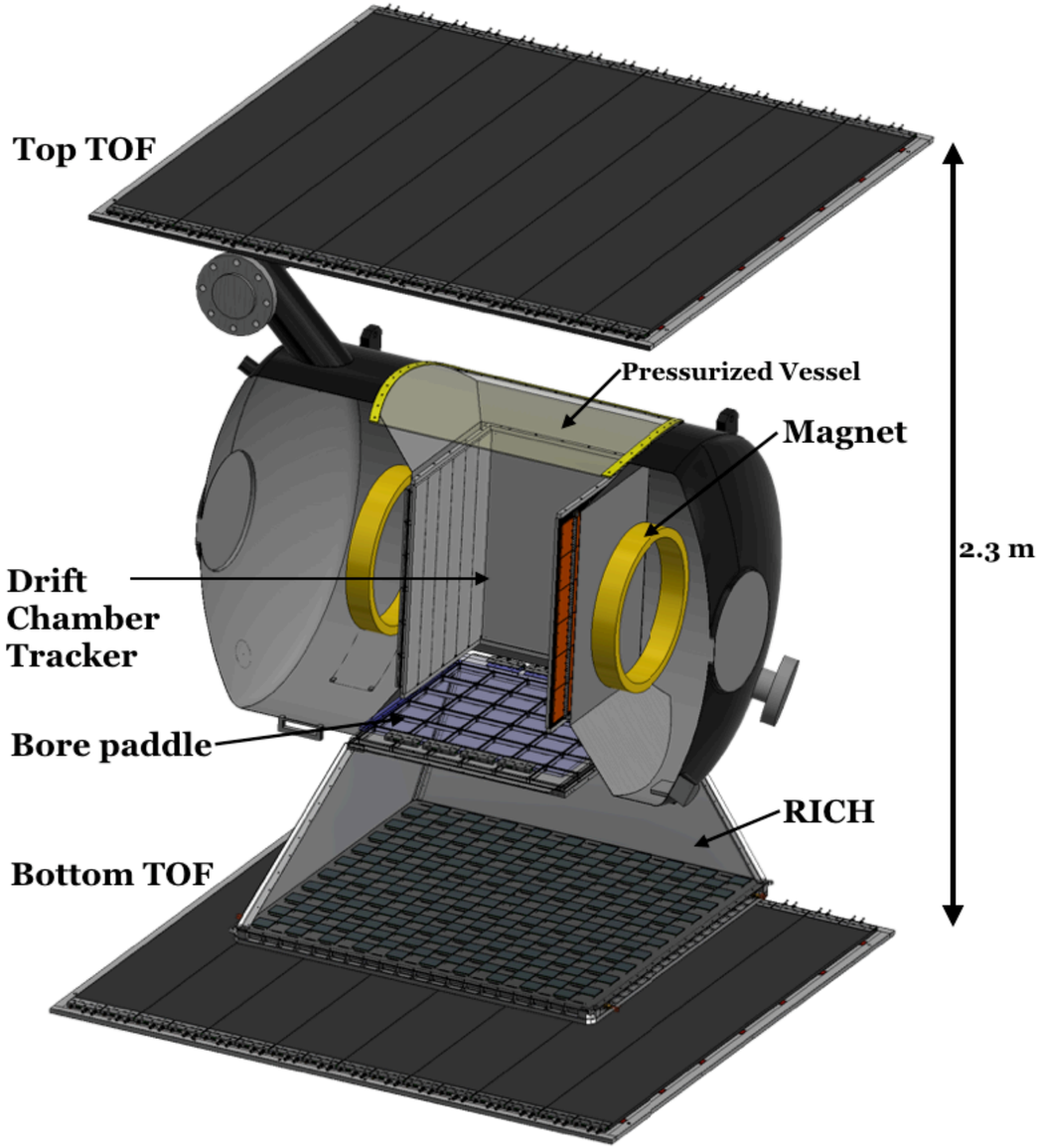




High Energy Light Isotope eXperiment

A new magnet spectrometer payload to measure $^{10}Be/^{9}Be$ isotope ratio up to 10 GeV/n

- Design considerations
  - -A mass resolution of few % up to 10 GeV/n
  - -Readout within a very strong magnetic field (Superconducting magnet used for HEAT balloon payloads, B field at the center ~ 1 T)
  - -All SiPM readout needs good thermal design



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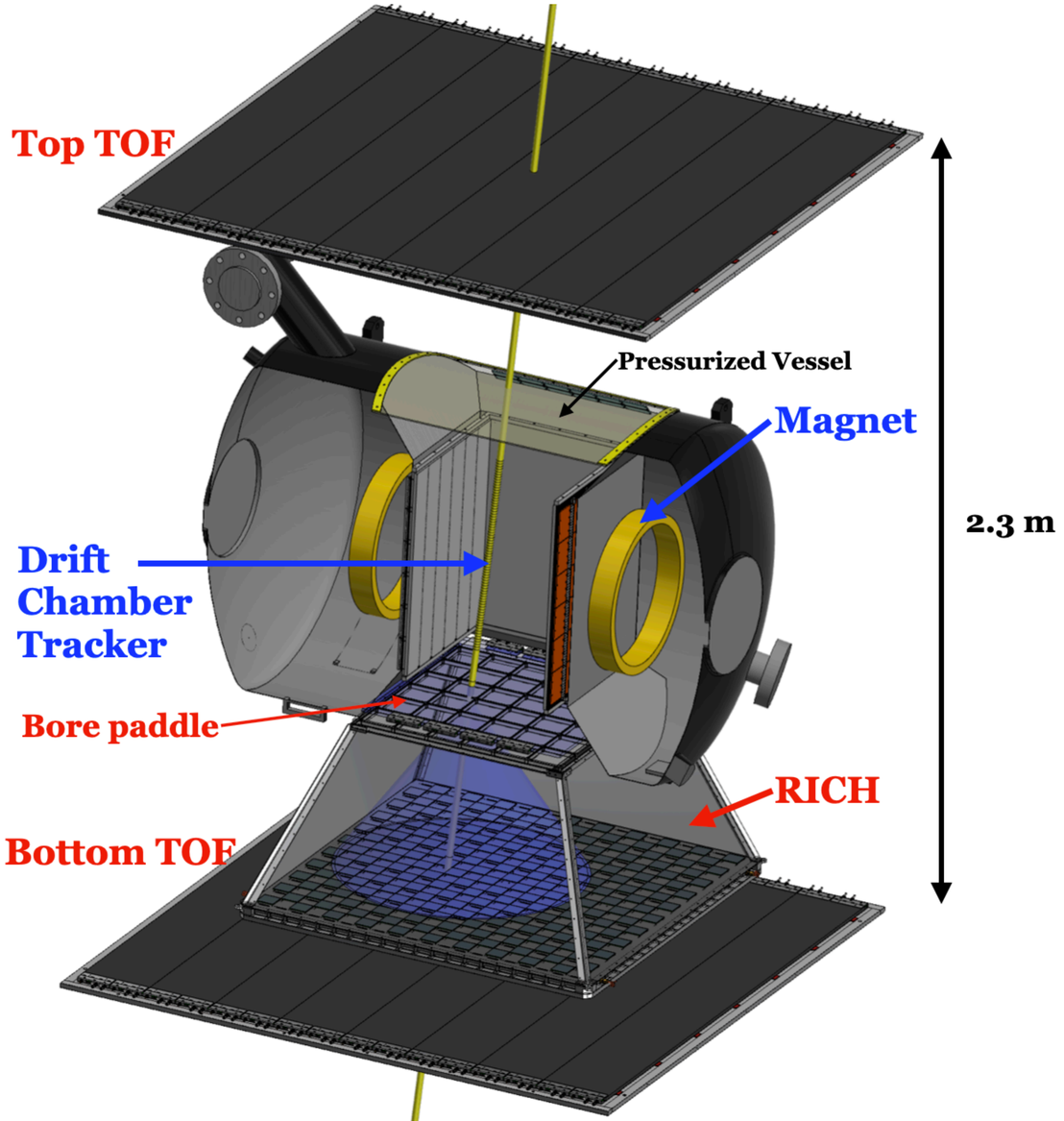
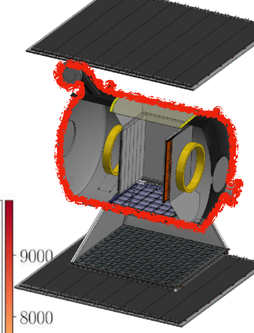
- Two stage approach to cover wider range of energy
  - -Stage 1 : covers up to ~ 3 GeV/n

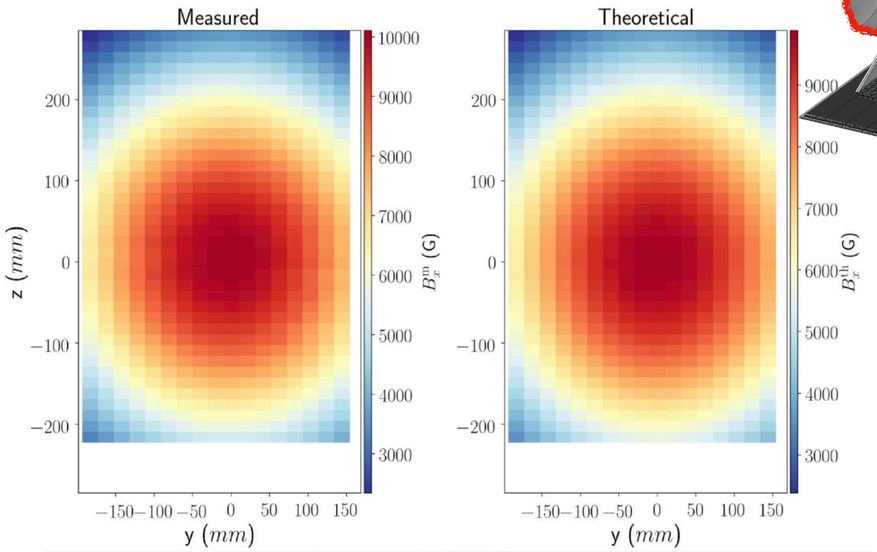


Magnet



1T Superconducting magnet

- Hold time : ~7 days
- Reused from the HEAT instrument
  - -Refurbished to operate the magnet without pressure vessel
- NbTi coils cooled to ~ 4.2 K

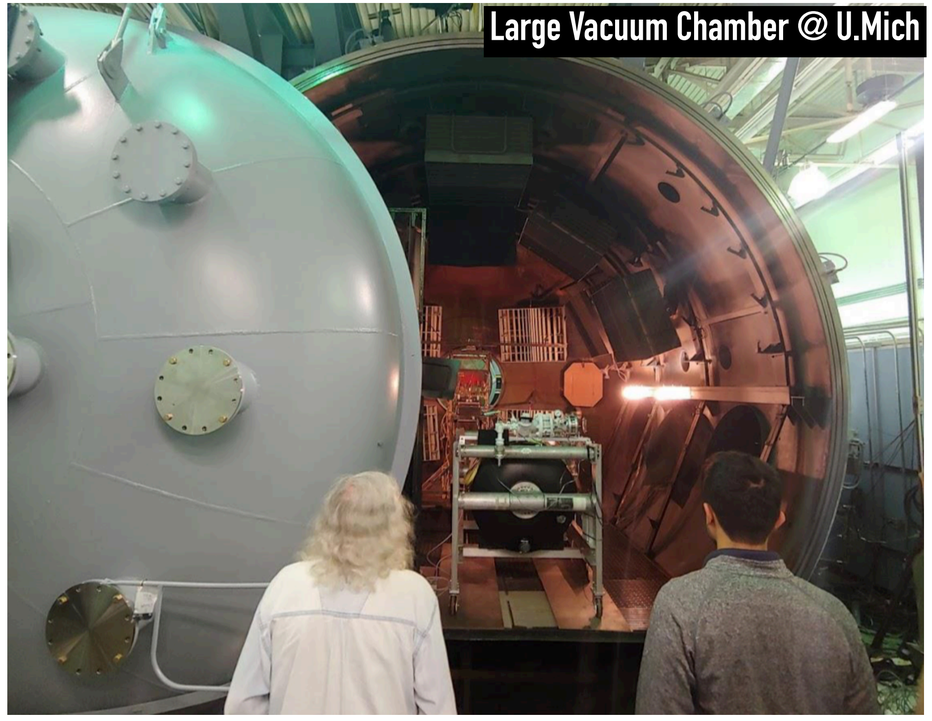


Many successful cool down tests

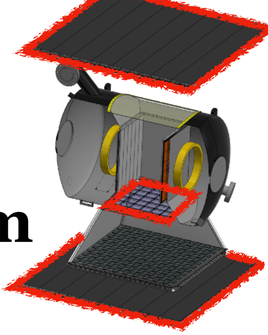
- Measured detailed 3D magnetic field map
  - -Matching well with the theoretical model

Successful vacuum test at Large Vacuum Chamber

- Successful operation at the flight vacuum condition

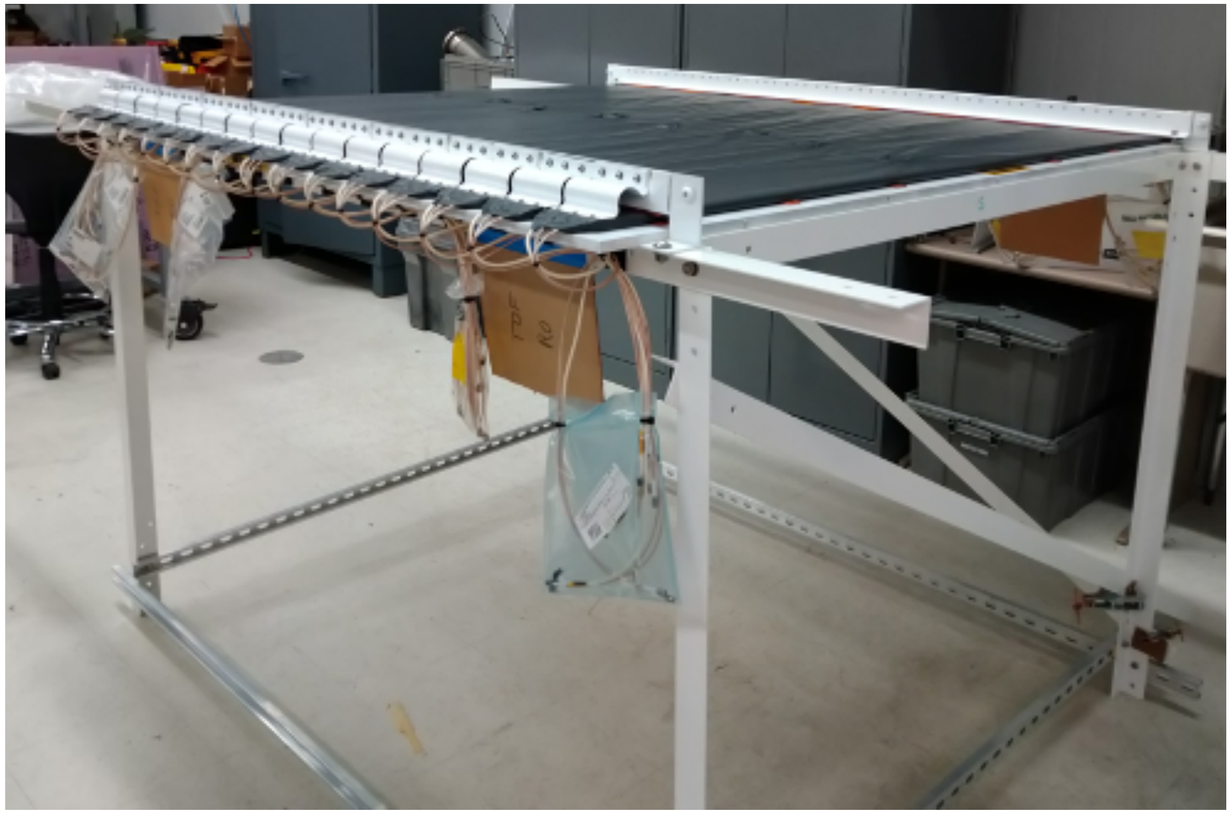


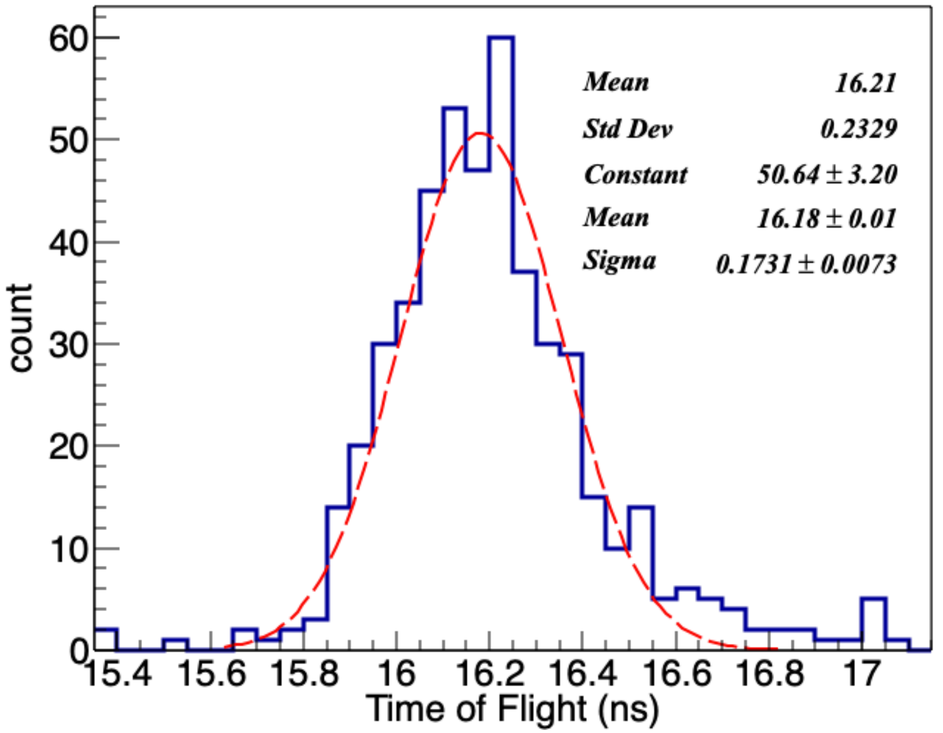
Time-Of-Flight



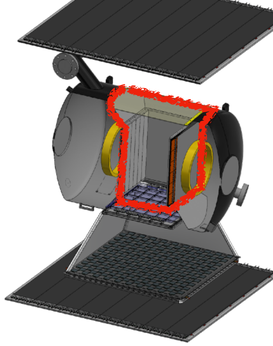
Three layers of 1 cm thickness fast plastic scintillator, 2.3m top to bottom

- Timing resolution of <50 ps for Z>3
  - -Each 20cm EJ200 scintillator paddle with each end read by 8 SiPMs
  - -TDC timing resolution better than 25 ps
- Preliminary analysis on the muon test shows a timing resolution better than 200 ps



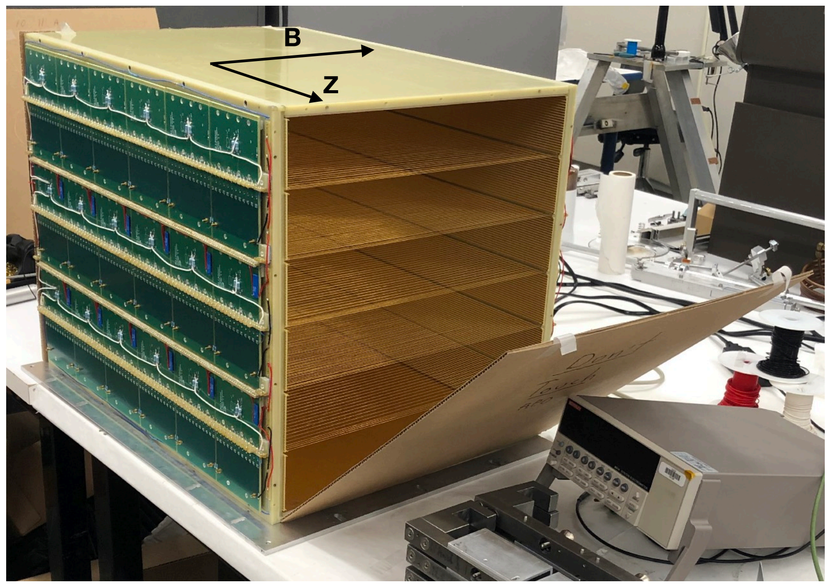


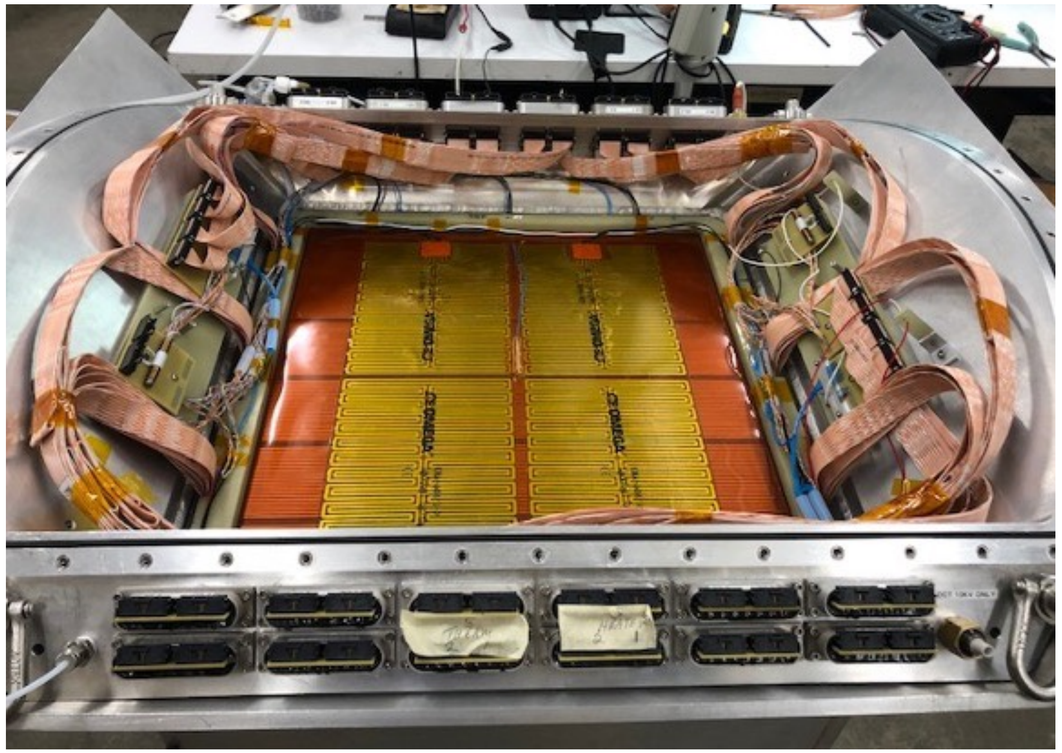
Drift Chamber Tracker

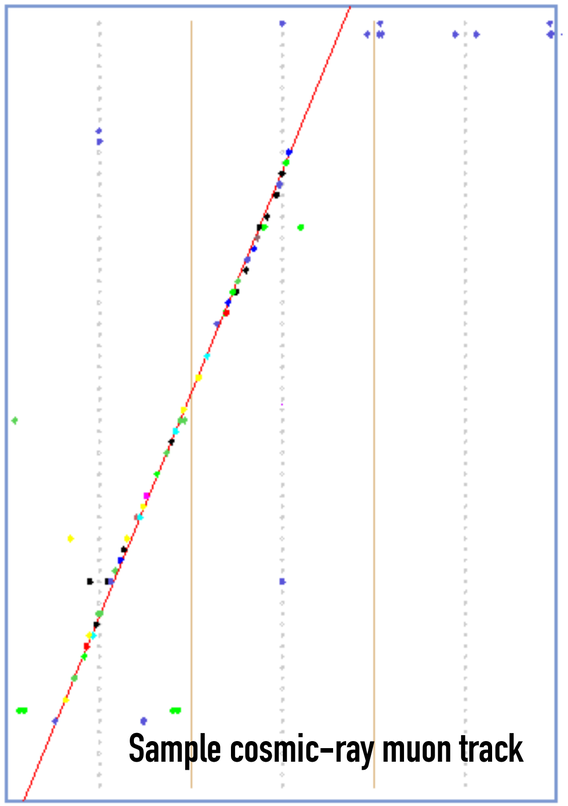


Multi-wire drift gas CO_2 + Ar

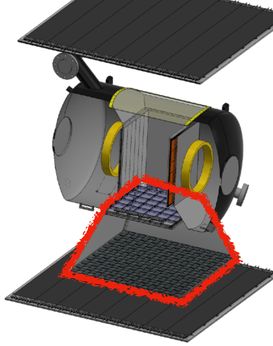
- Spatial resolution of 65 μm for Z>3
  - -72 sense layers, read out with 80 MHz sampling
- Installed in the bore of magnet within a thin pressure vessel
- Prototype measurements show a tracking resolution for muons to be consistent with reaching the design goal







Ring Imaging Cherenkov Counter

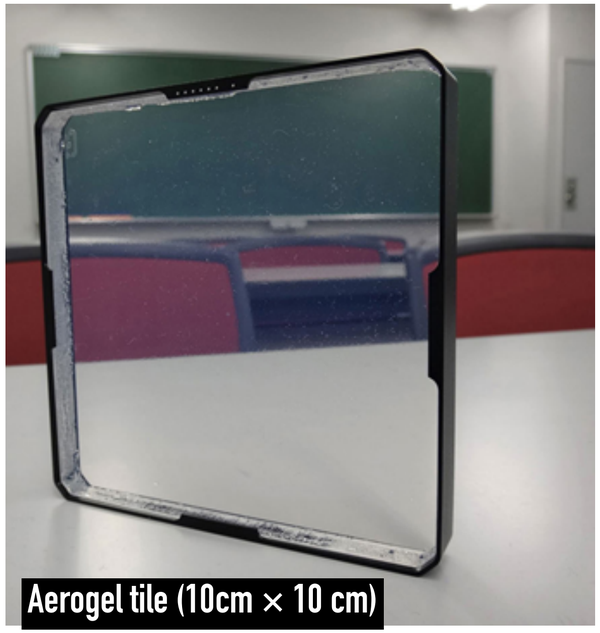


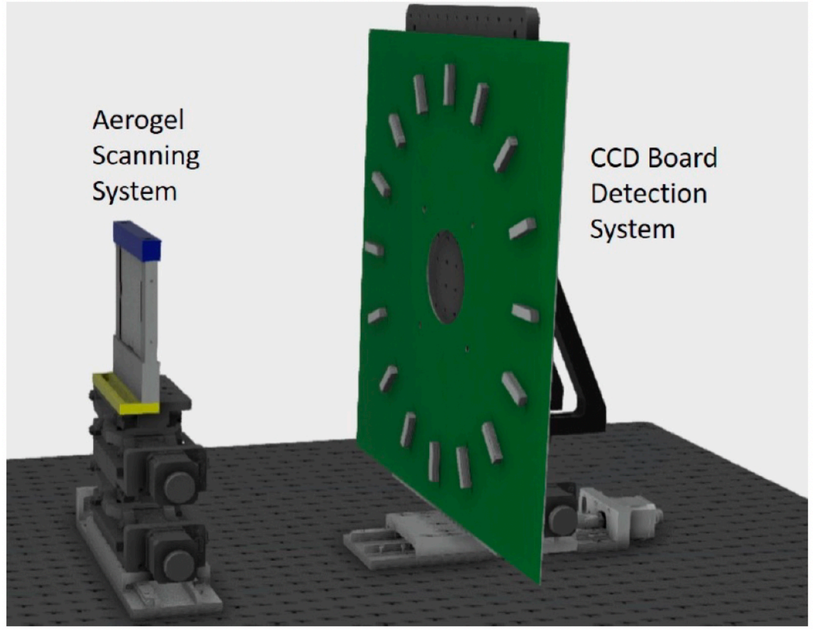
Proximity-focused RICH with SiPM readout

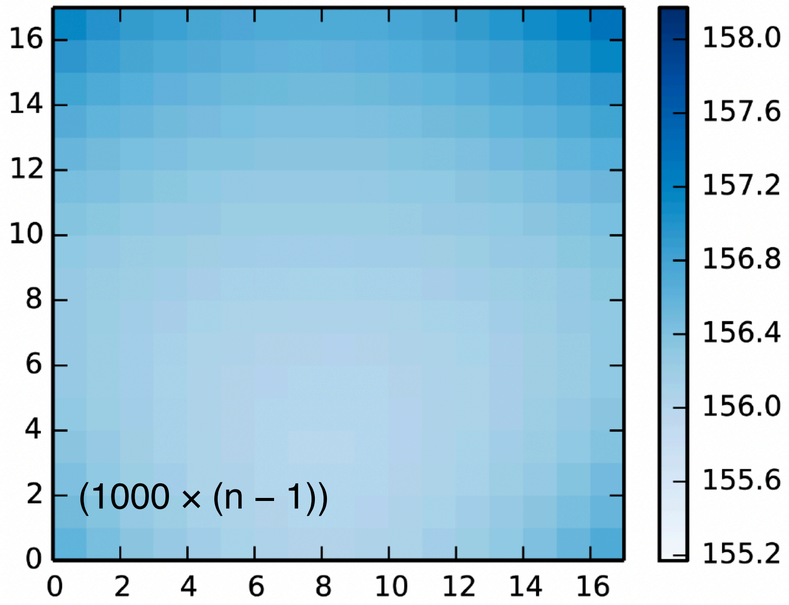
- Velocity resolution of $\Delta\beta/\beta \sim 1\times10^{-3}$ for Z>3 for E>1 GeV/n

  -Main radiator : Highly transparent & hydrophobic high refractive index aerogel (n~1.15)

  - Refractive index calibration w/ systematic error at 10^{-4} level for 51 tiles (paper in preparation)
    - Thickness measured w/ CMM at TRIUMF
    - Electron-beam calibration at 35 MeV electron linac at National Research Countil, Ottawa
    - Interferometry measurements for thickness/refractive index measurements







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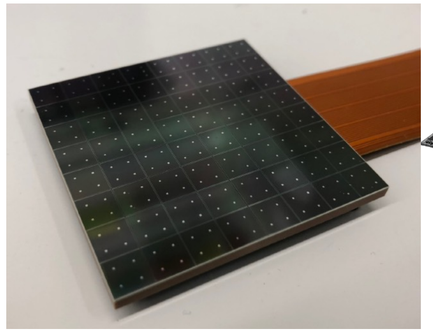

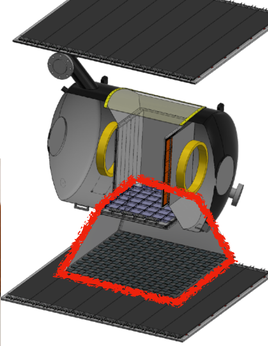

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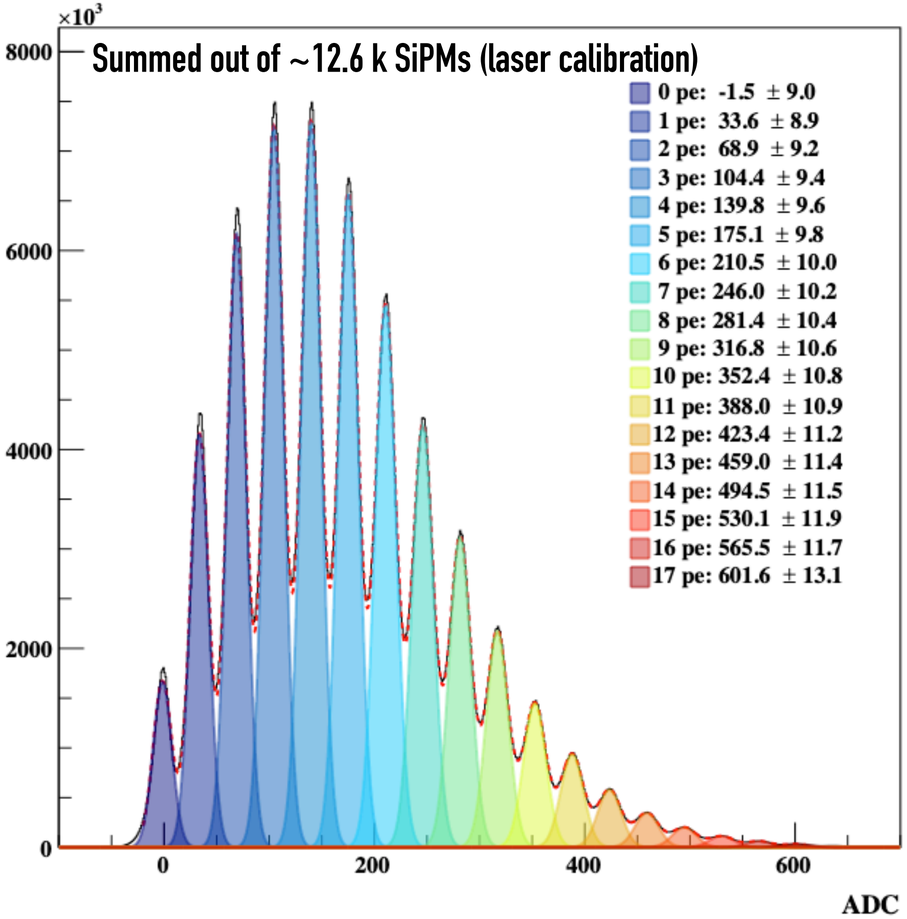
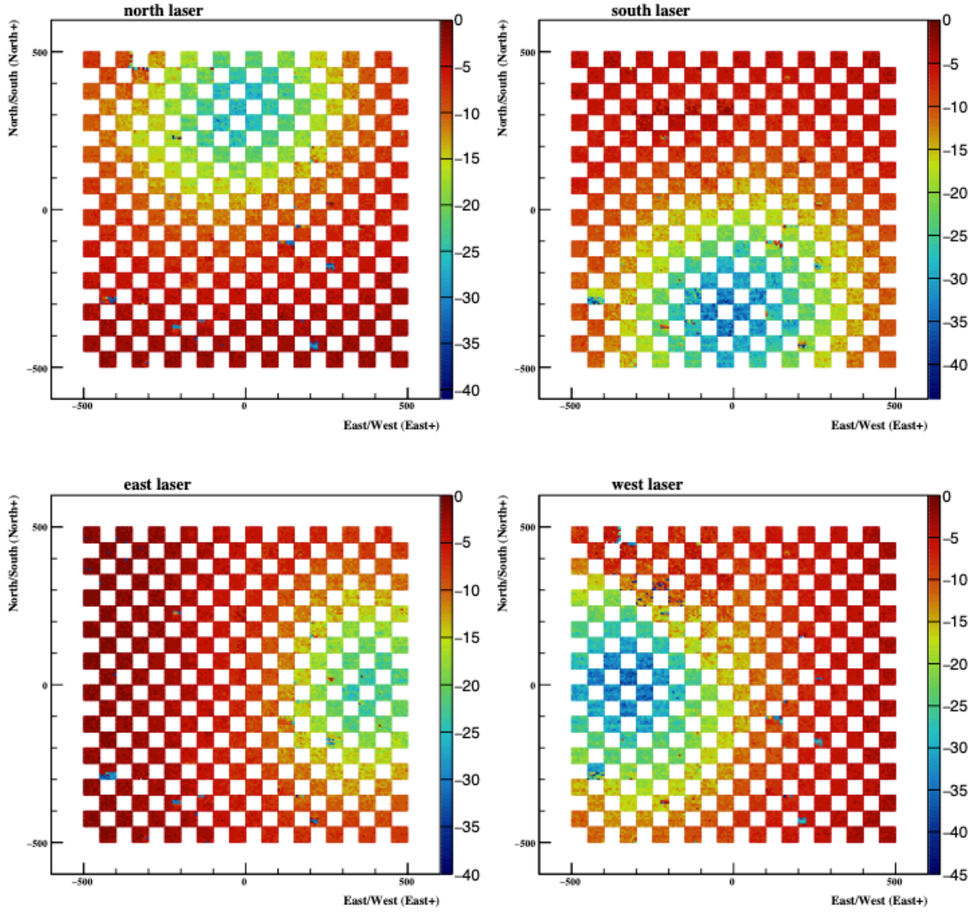
  - Focal plane (1 m × 1 m) covered by 6 mm × 6mm SiPM array in checker board configuration: 12.8k channels!

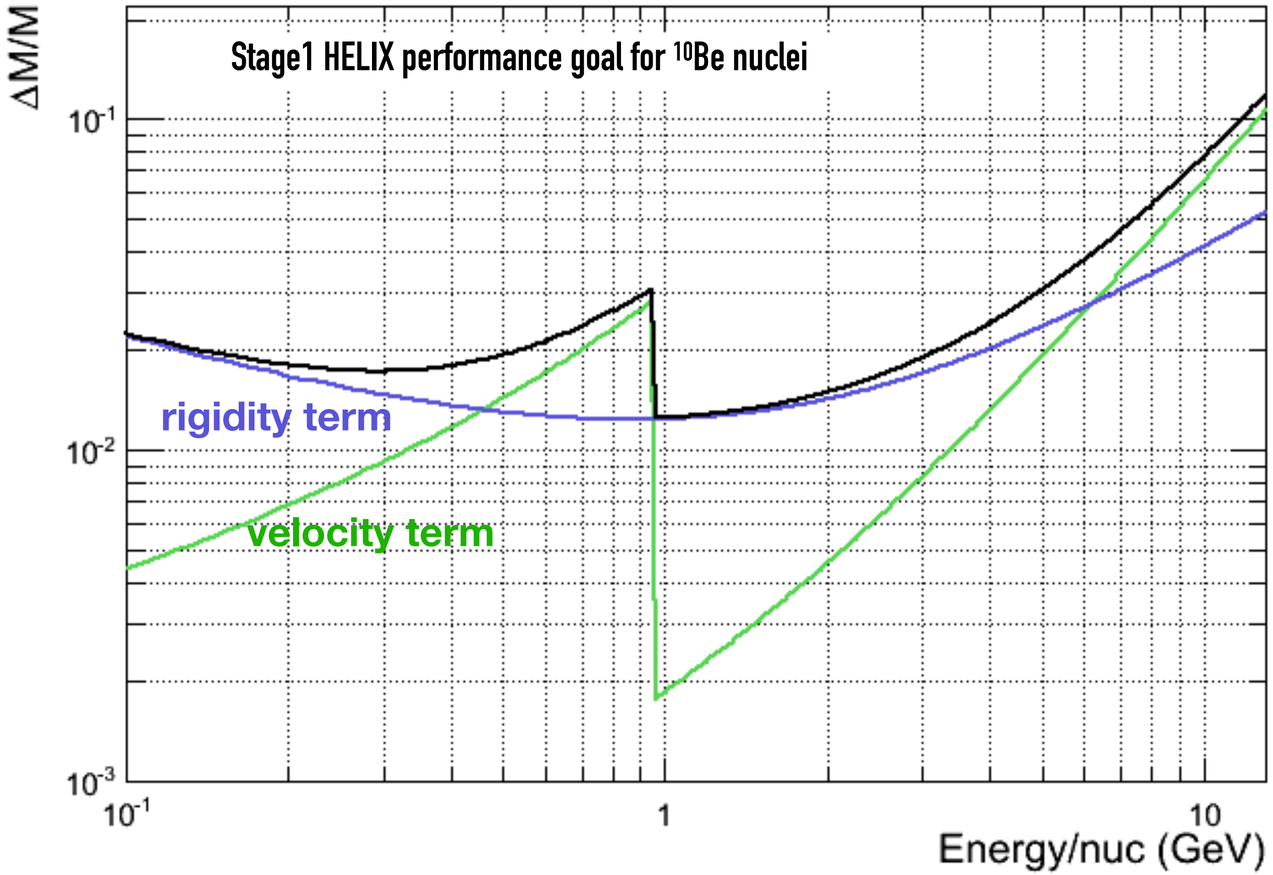




HELIX Stage1 Performance

^{10}Be/^{9}Be ratio up to ~3 GeV/n with Δm/m ~2.5%

- 7-14 day exposure with 0.1 m²sr geometry factor
- Measure the charge of CR up to neon (Z=10)
- Mass resolution of few percentage for light isotopes up to 3 GeV/n



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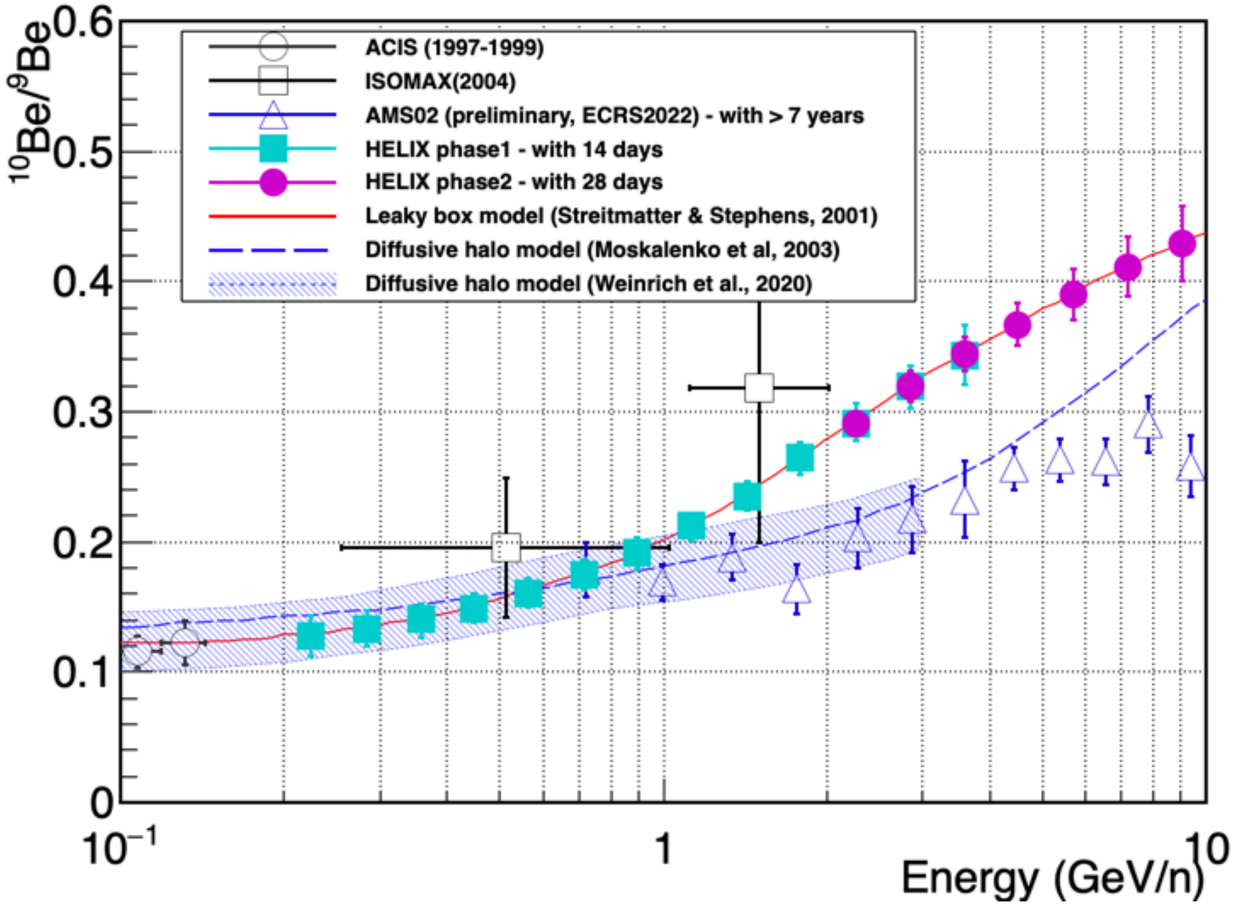
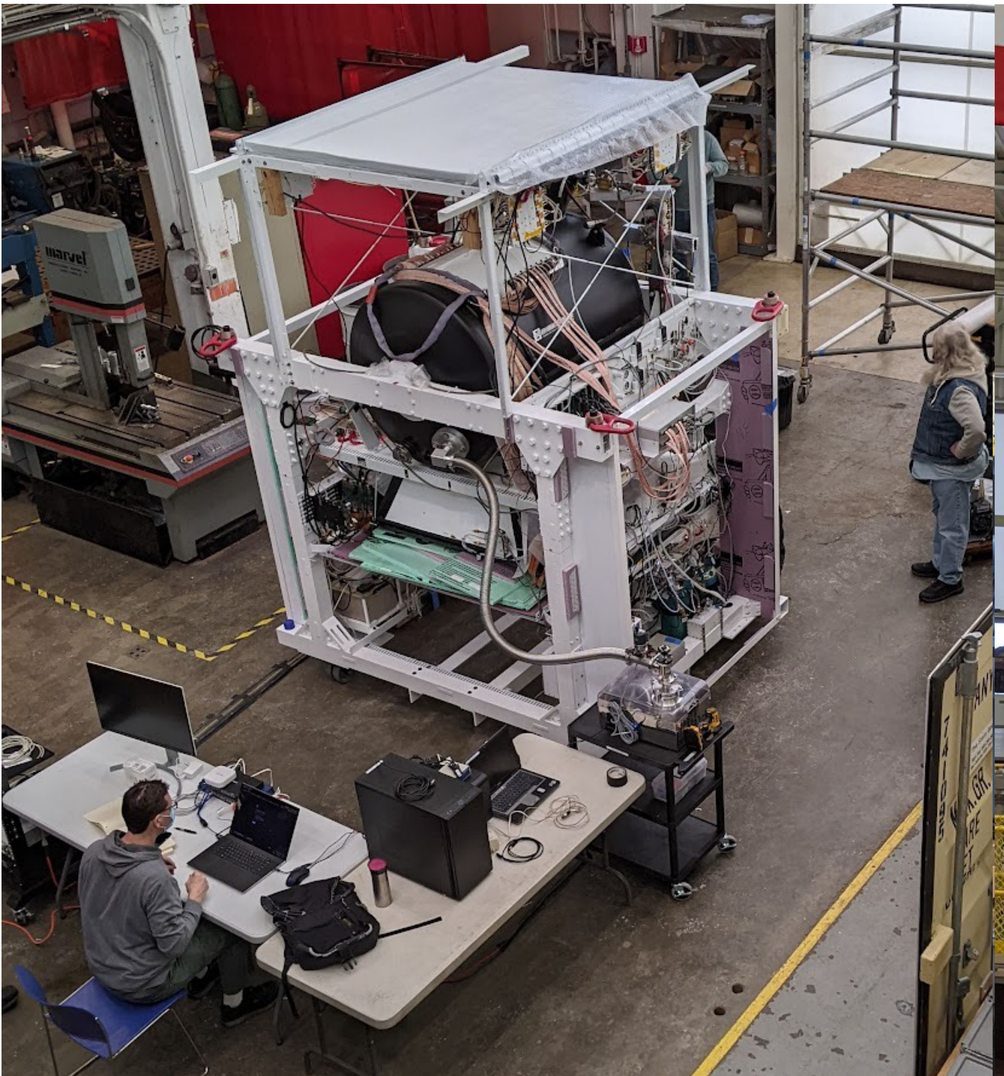


Tests and integrations

Successful thermal-vacuum test in 2022

Integration test on-going

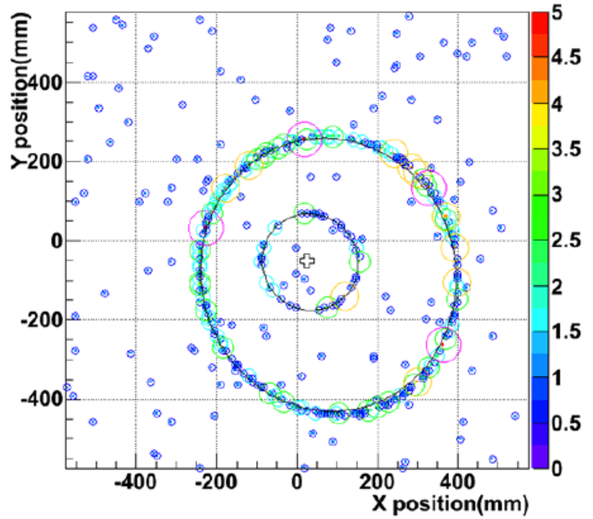


HELIX Stage2

Needs extend to the measurements to 10 GeV/n with several new detector developments

- Magnet upgrade: longer exposure time (7 days → 28 days)
- Tracker upgrade: better resolution (65 μm→ 5 μm)

  → moving to 4-6 layers of silicon strip trackers
- RICH upgrade
  - -Upgrade to a full focal plane
  - -Potential upgrade to a dual refractive radiator



Summary

HELIX will have a full integration test w/ muon in 2023, aiming to catch the earliest flight opportunity from 2024 summer at Kiruna

Recent discoveries of new features of CRs require better understanding of CR propagation. Measurement of propagation clock isotope, such as ^{10}Be can provide essential data.

HELIX is a magnet spectrometer designed to measure the light isotopes from proton up to neon (Z=10). The instrument is optimized to measure ^{10}Be from 0.2 GeV/n to beyond 3 GeV/n with a mass resolution ≲ 3%.

The production of flight hardware has finished, and its performance was tested. Integration and testing are underway.