# HELIX
## (High Energy Light Isotope eXperiment)

Presented by Nahee Park

Queen's University

# HELIX Collaboration

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**University of Michigan**

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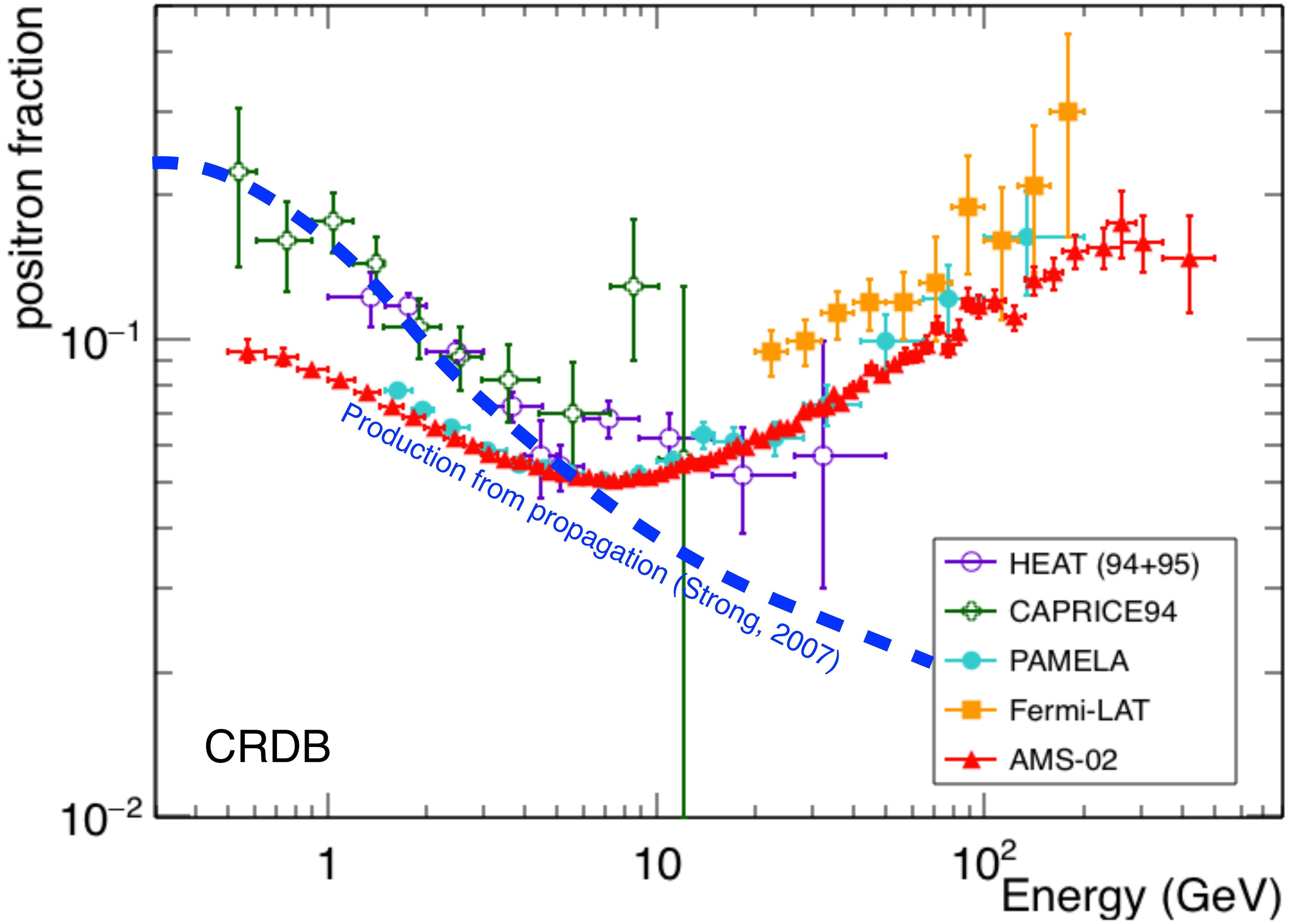
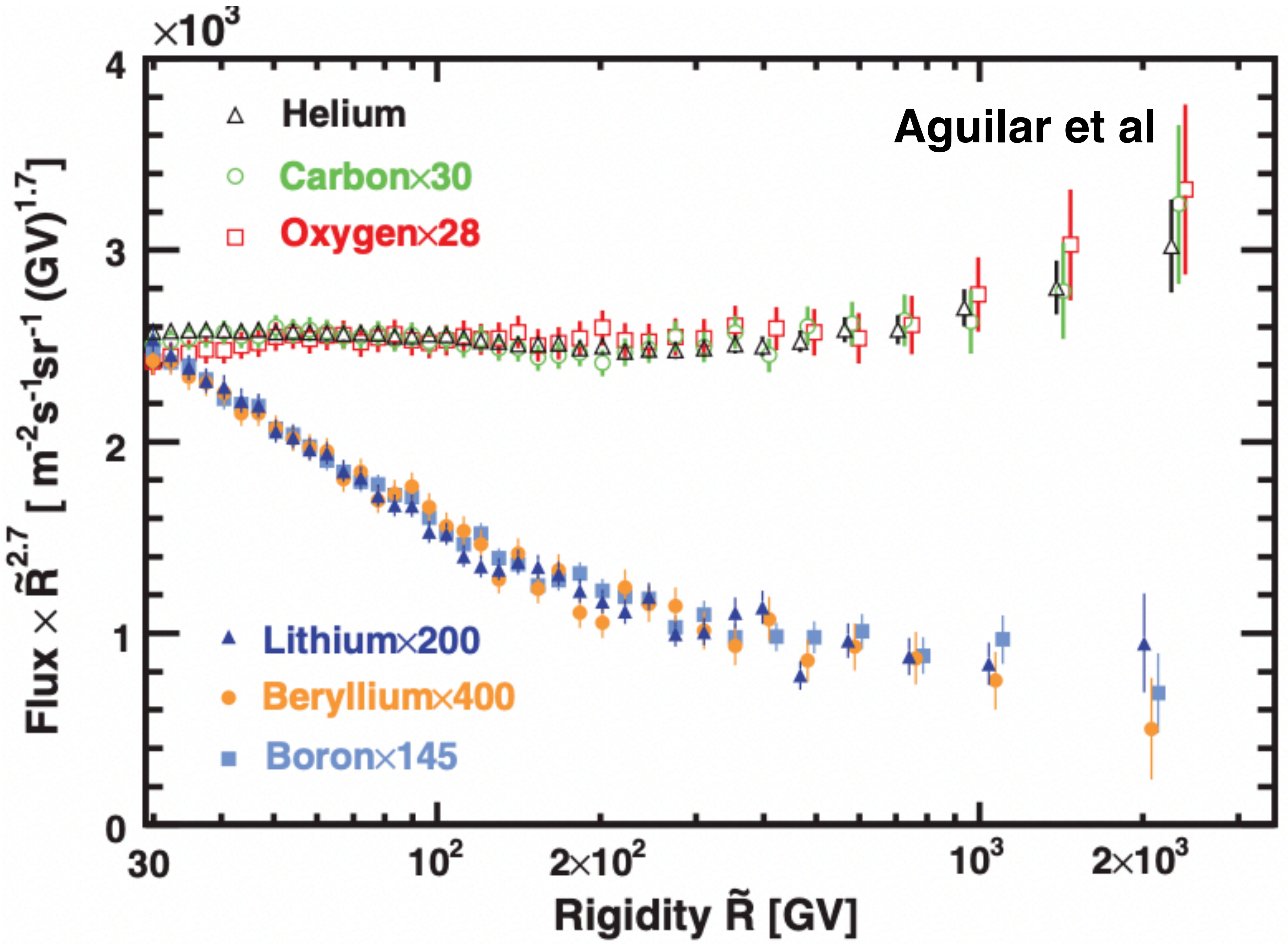
# New discoveries challenge classical paradigm of cosmic rays

**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)



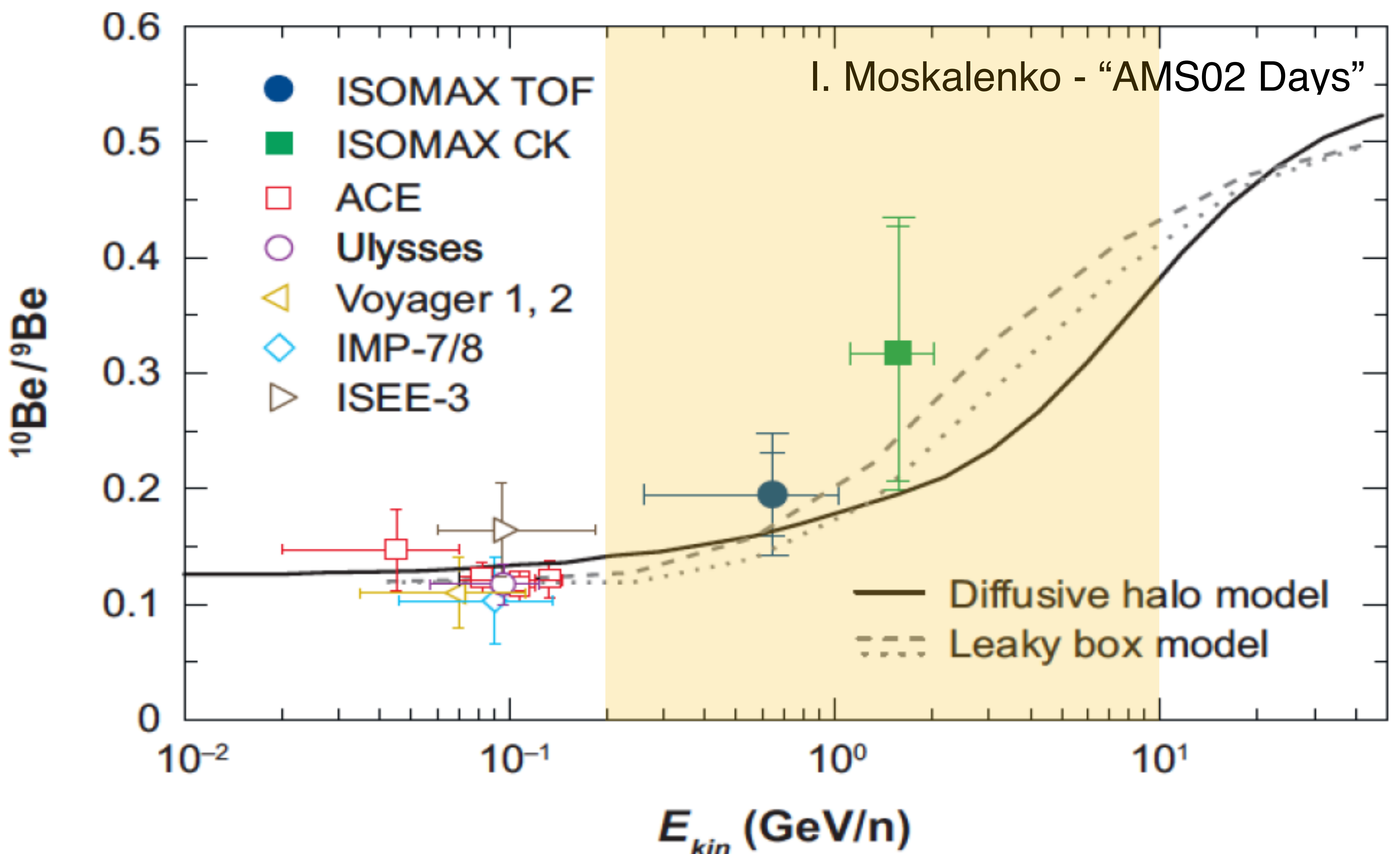




*→ It is critical to understand the propagation!*

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

**$^{10}Be$ : Unstable isotope with known half life of $1.4 \times 10^6$ yr**

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



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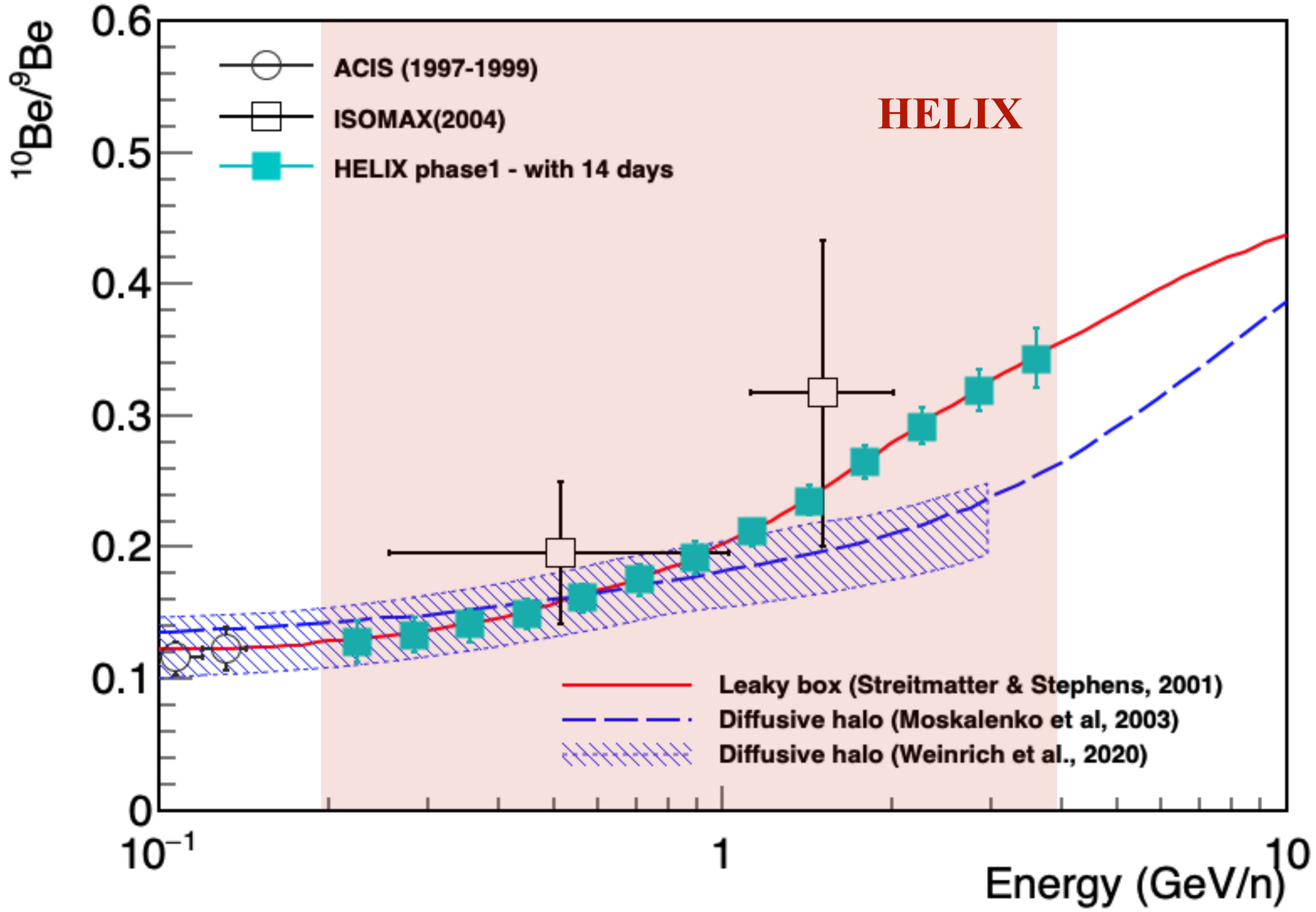
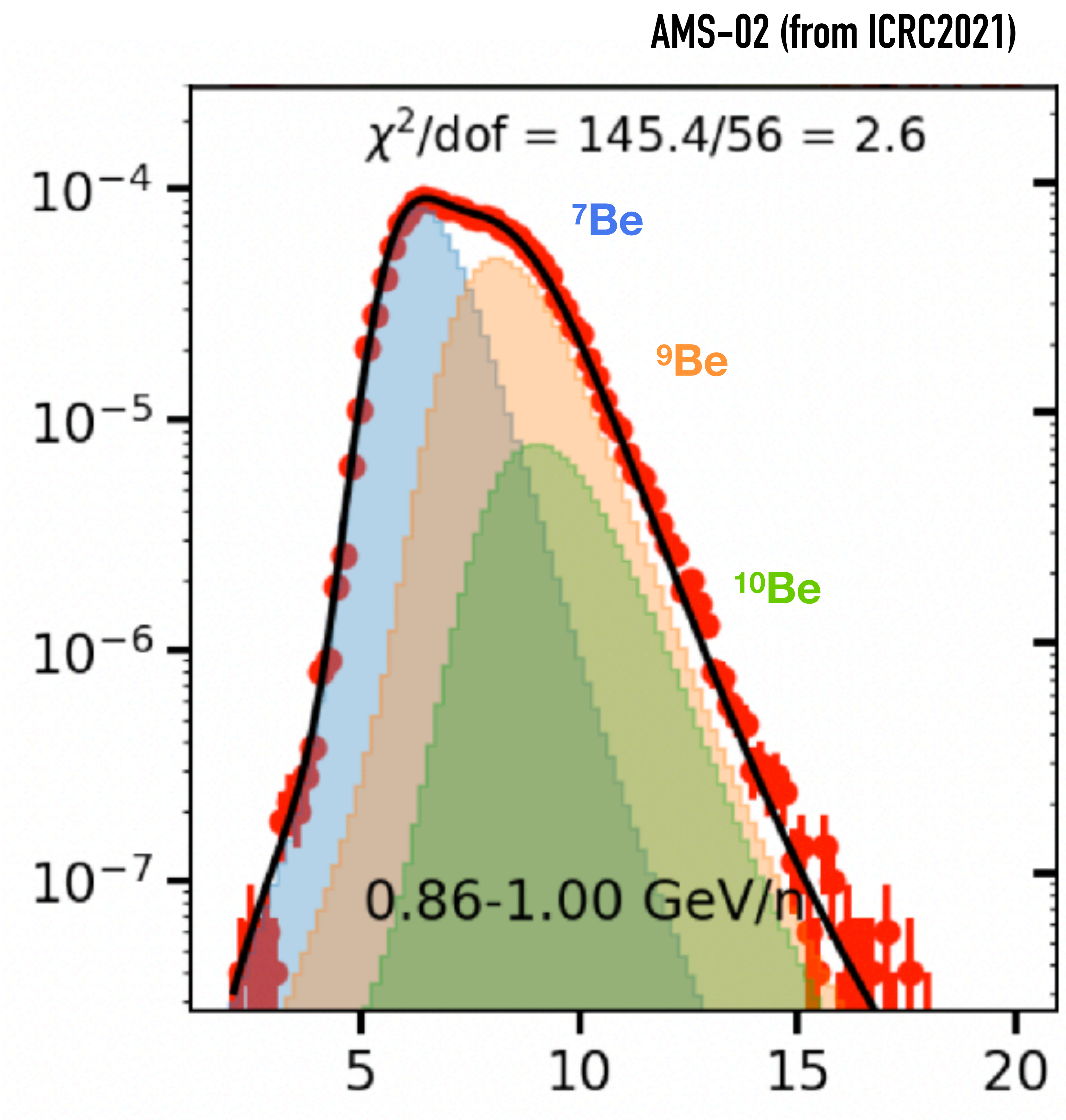
*HELIX is designed to provide a precision measurement of $^{10}Be$!*

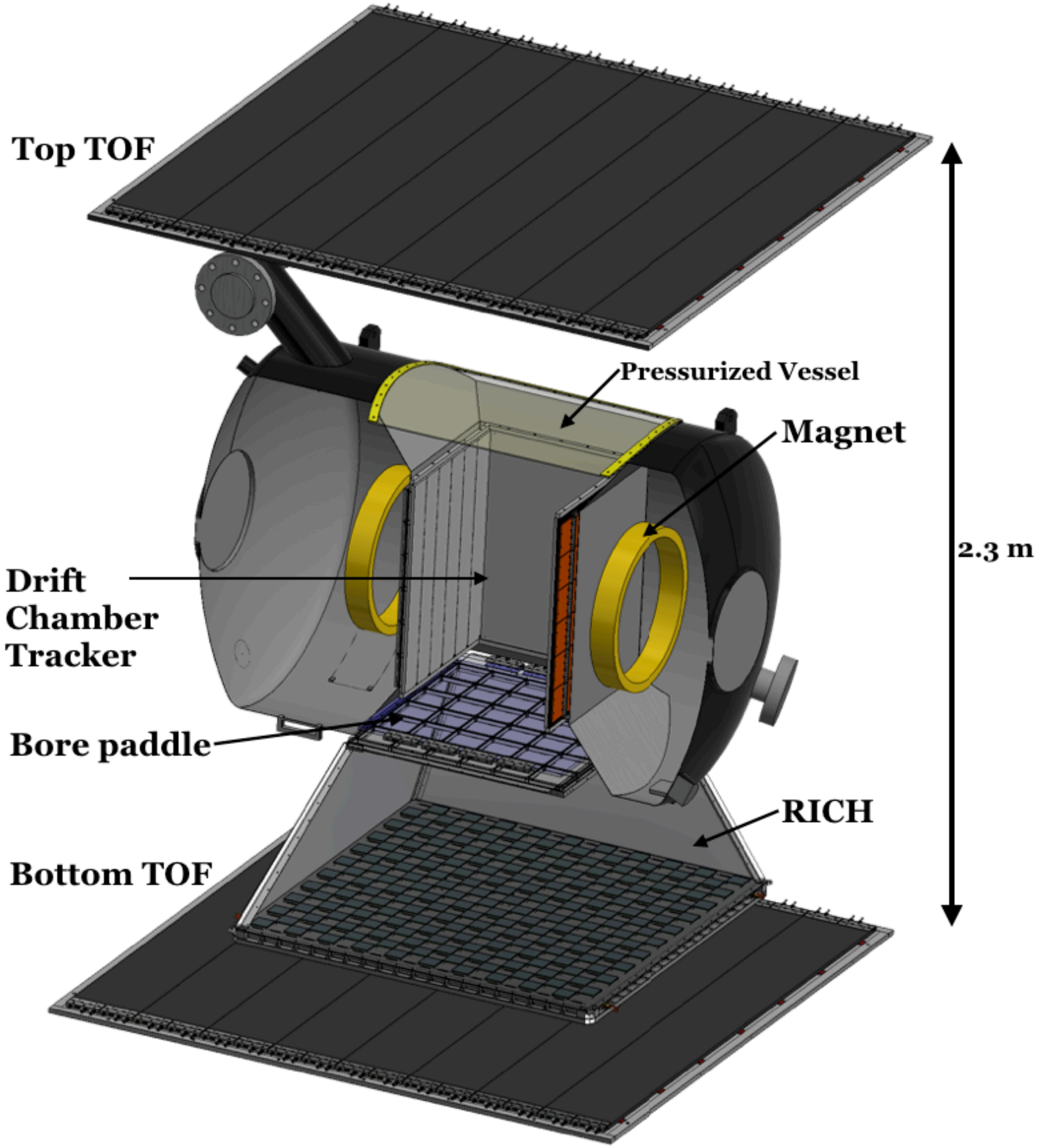


# High Energy Light Isotope eXperiment

**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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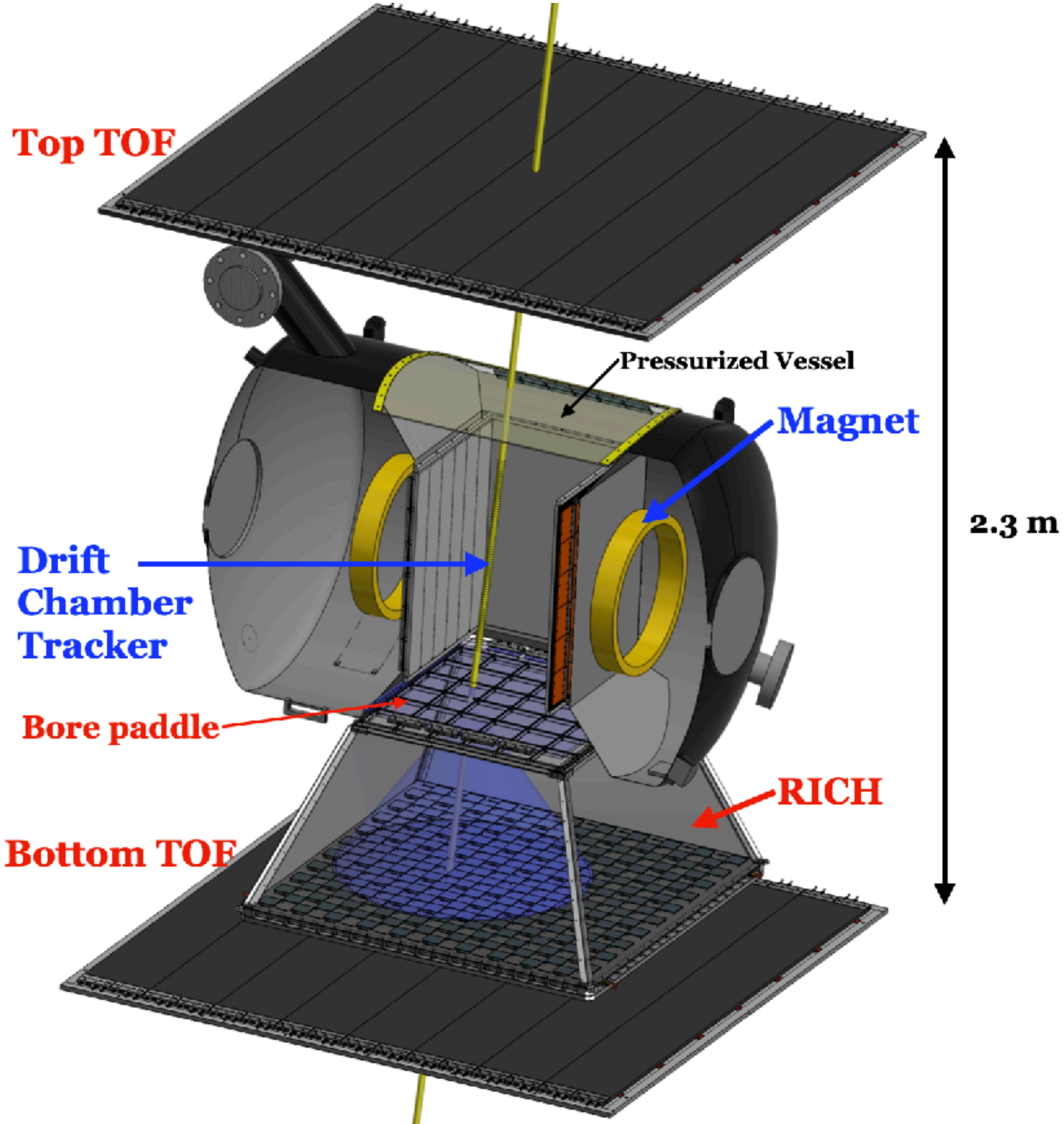
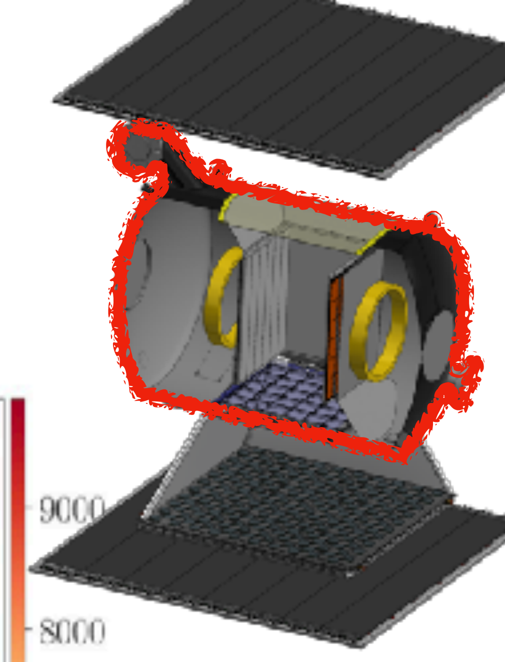
  - -All SiPM readout needs good thermal design
- Two stage approach to cover wider range of energy
  - -Stage 1 : covers up to ~ 3 GeV/n

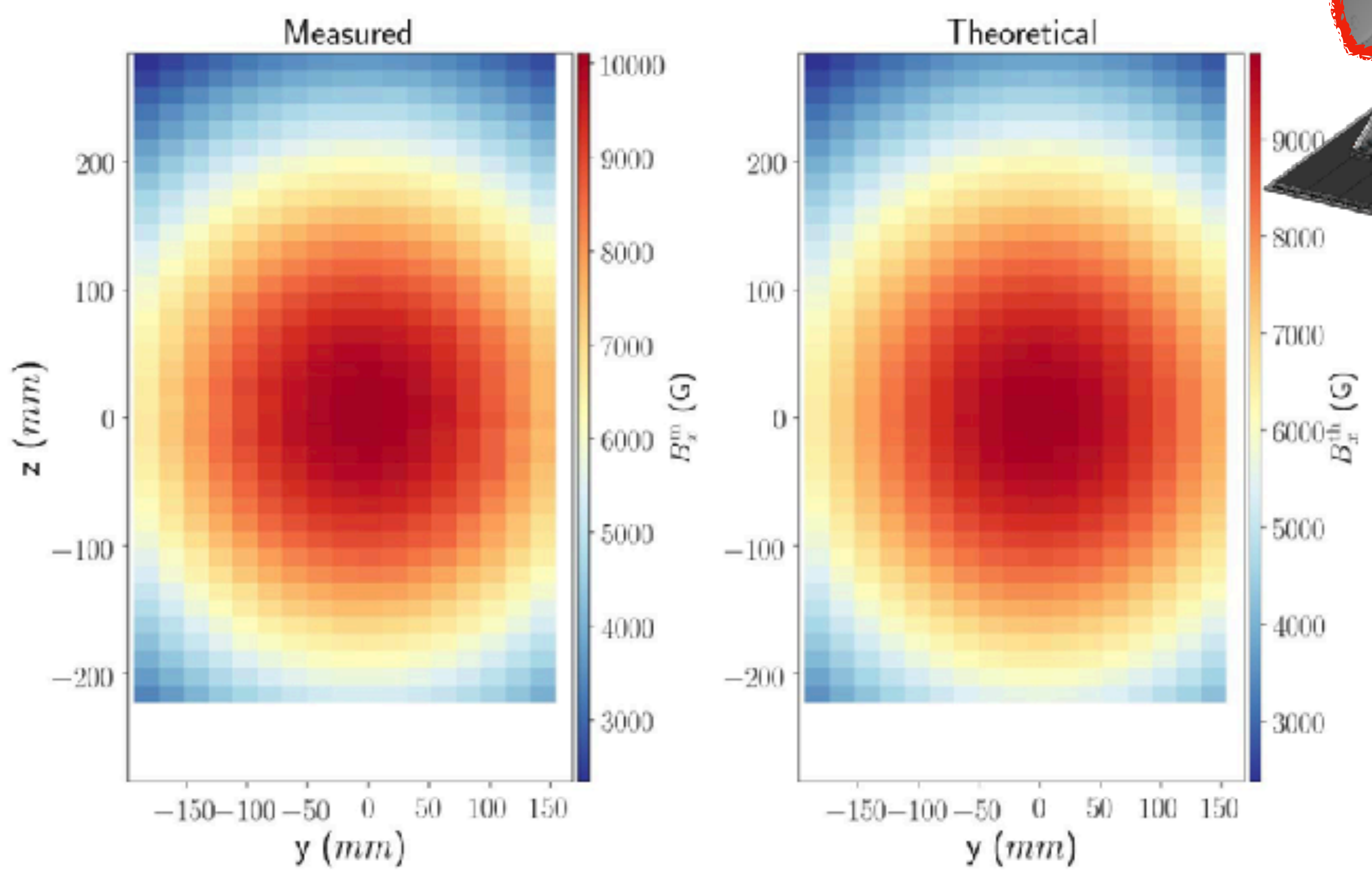


# Magnet



## 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

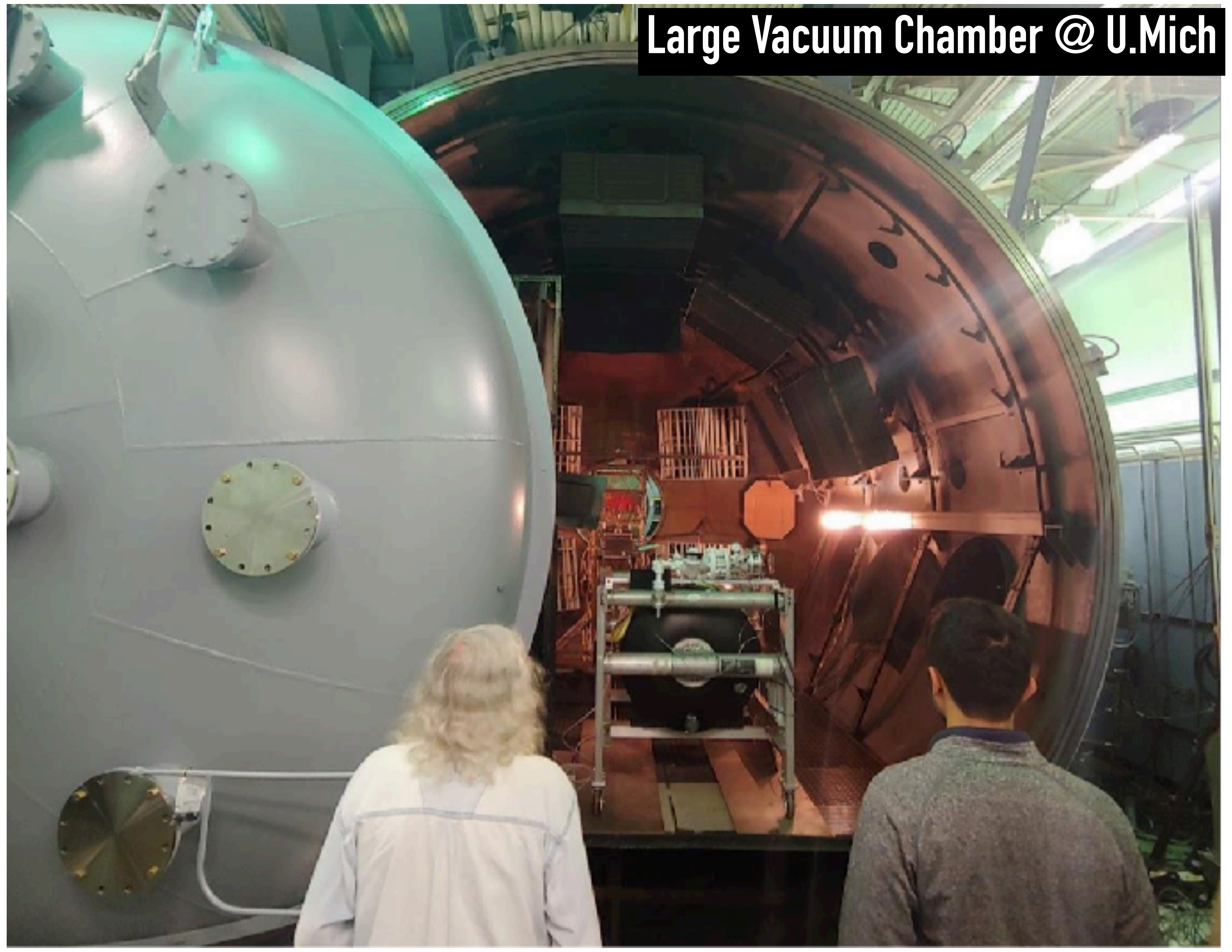



## 2 Successful cool down tests

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

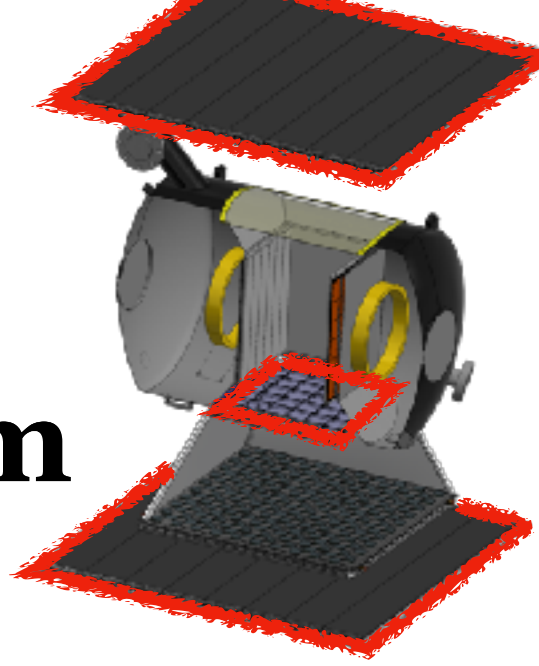
## Successful vacuum test at Large Vacuum Chamber

- Successful operation at the flight vacuum condition

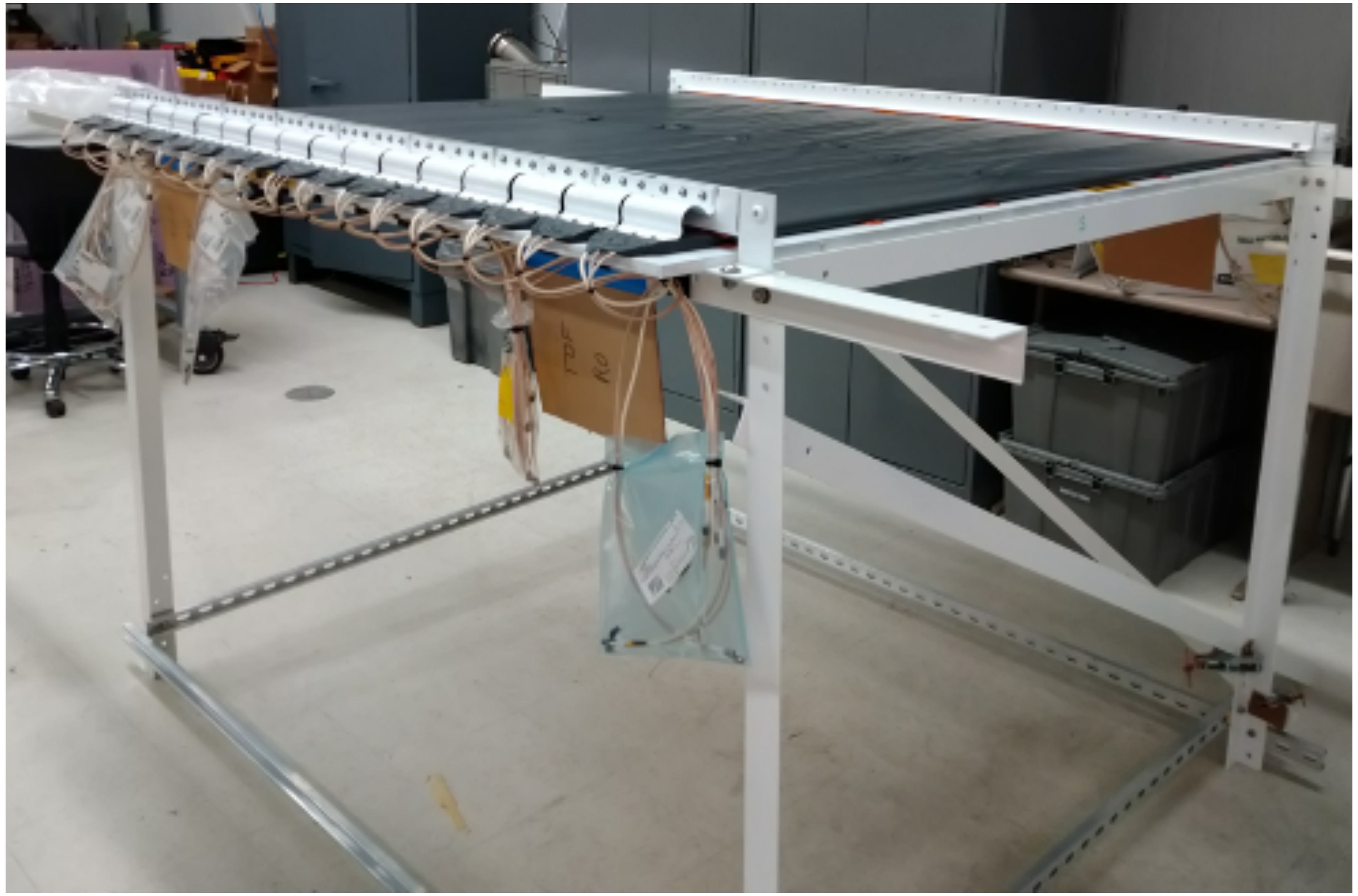


# Time-Of-Flight

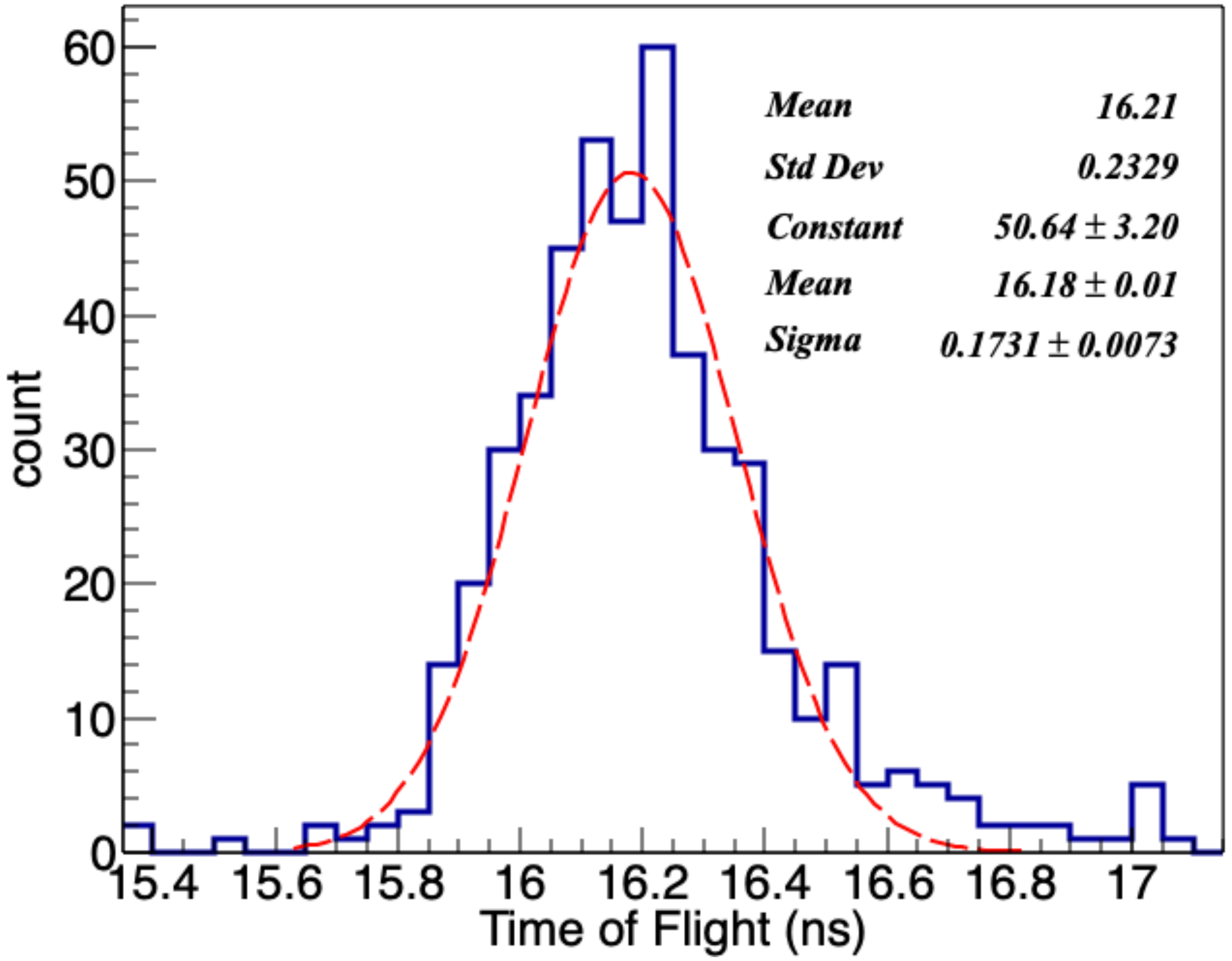
**Three layers of 1 cm thickness fast plastic scintillator, 2.3m top to bottom**



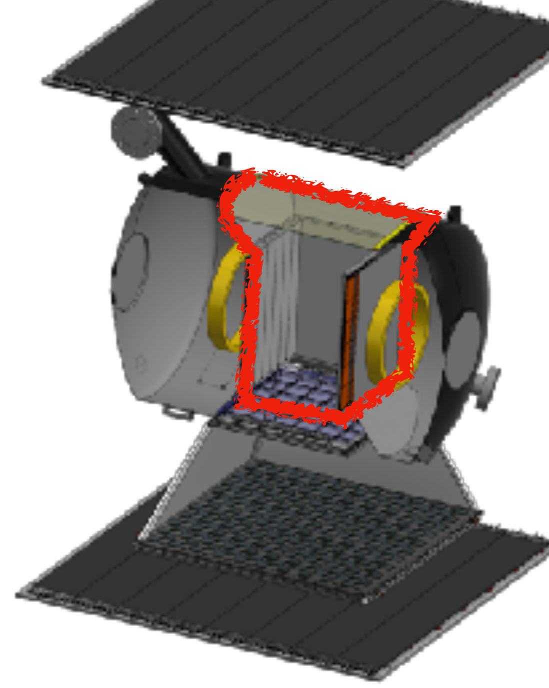
- Timing resolution of <50 ps for Z>3
  - -Each 20cm EJ200 scintillator paddle with each end read by 8 SiPMs
  - -TDC timing resolution better than 25 ps
- Preliminary analysis on the muon test shows a timing resolution better than 300 ps



Δt between Top TOF and bottom TOF w/ muon (limited geometry)

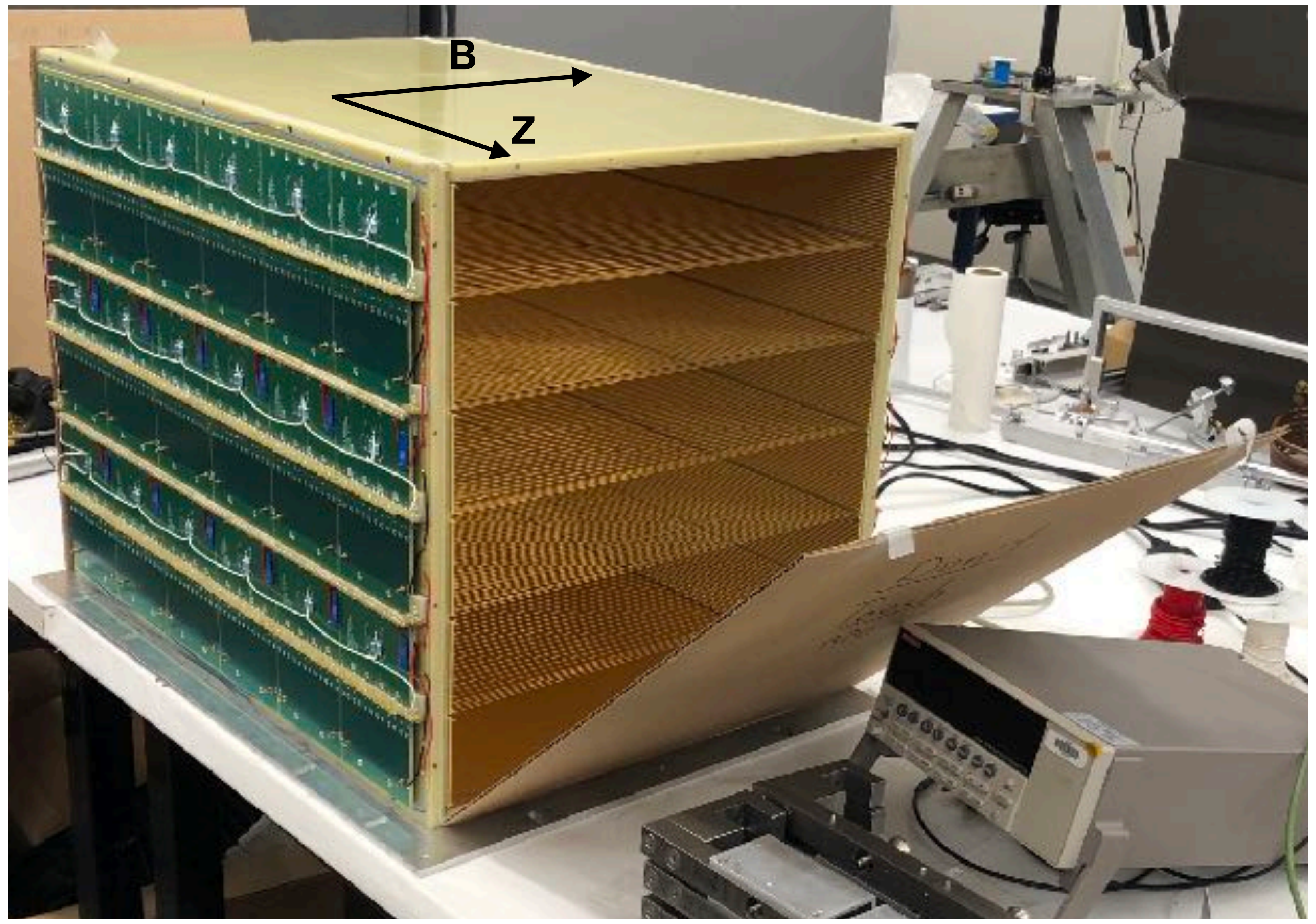


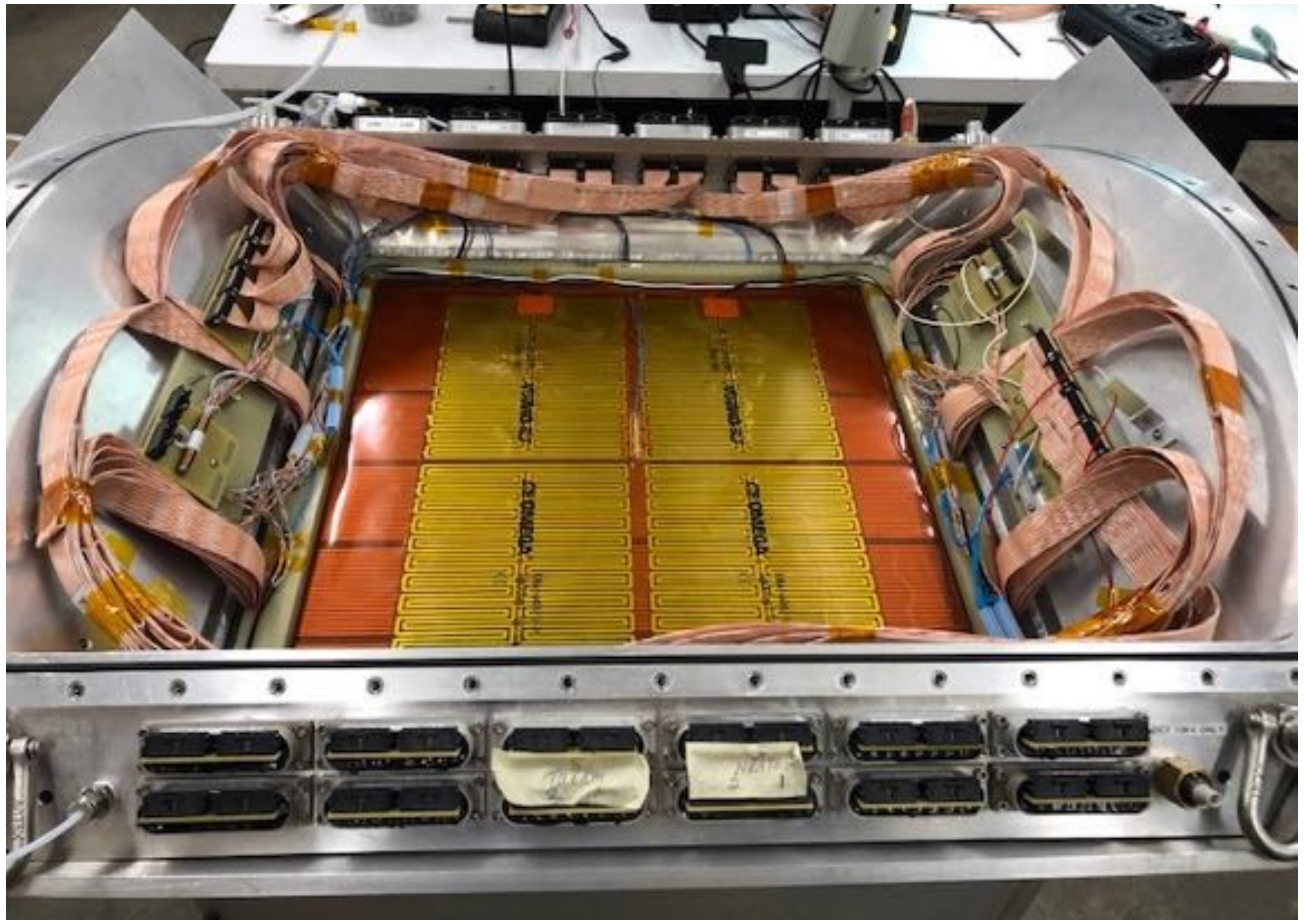
# Drift Chamber Tracker

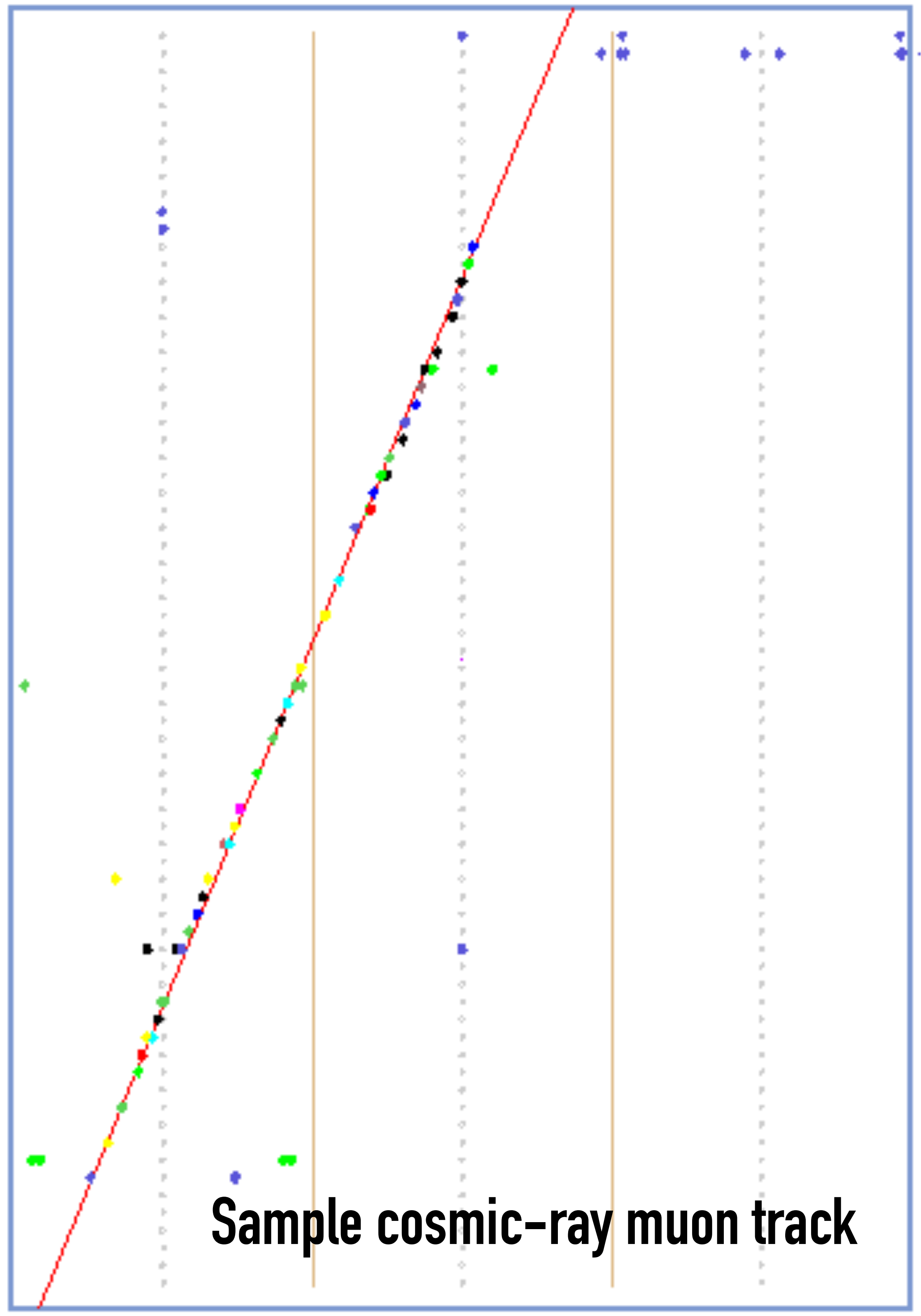


**Multi-wire drift chamber with drift gas $CO_2$ + Ar**

- 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

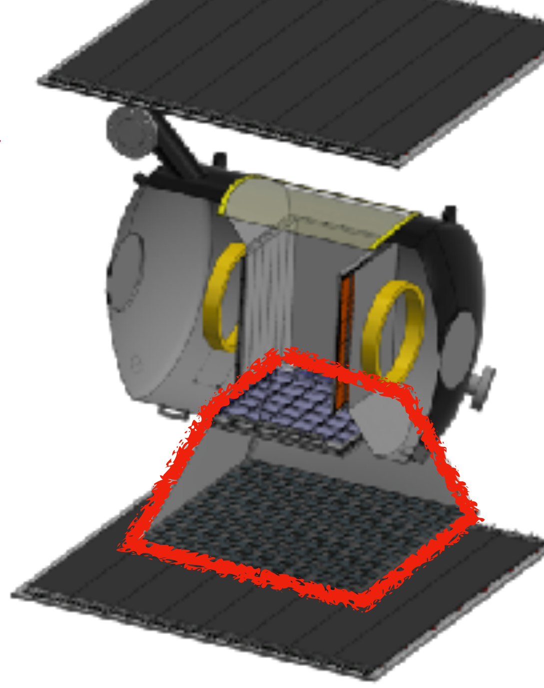




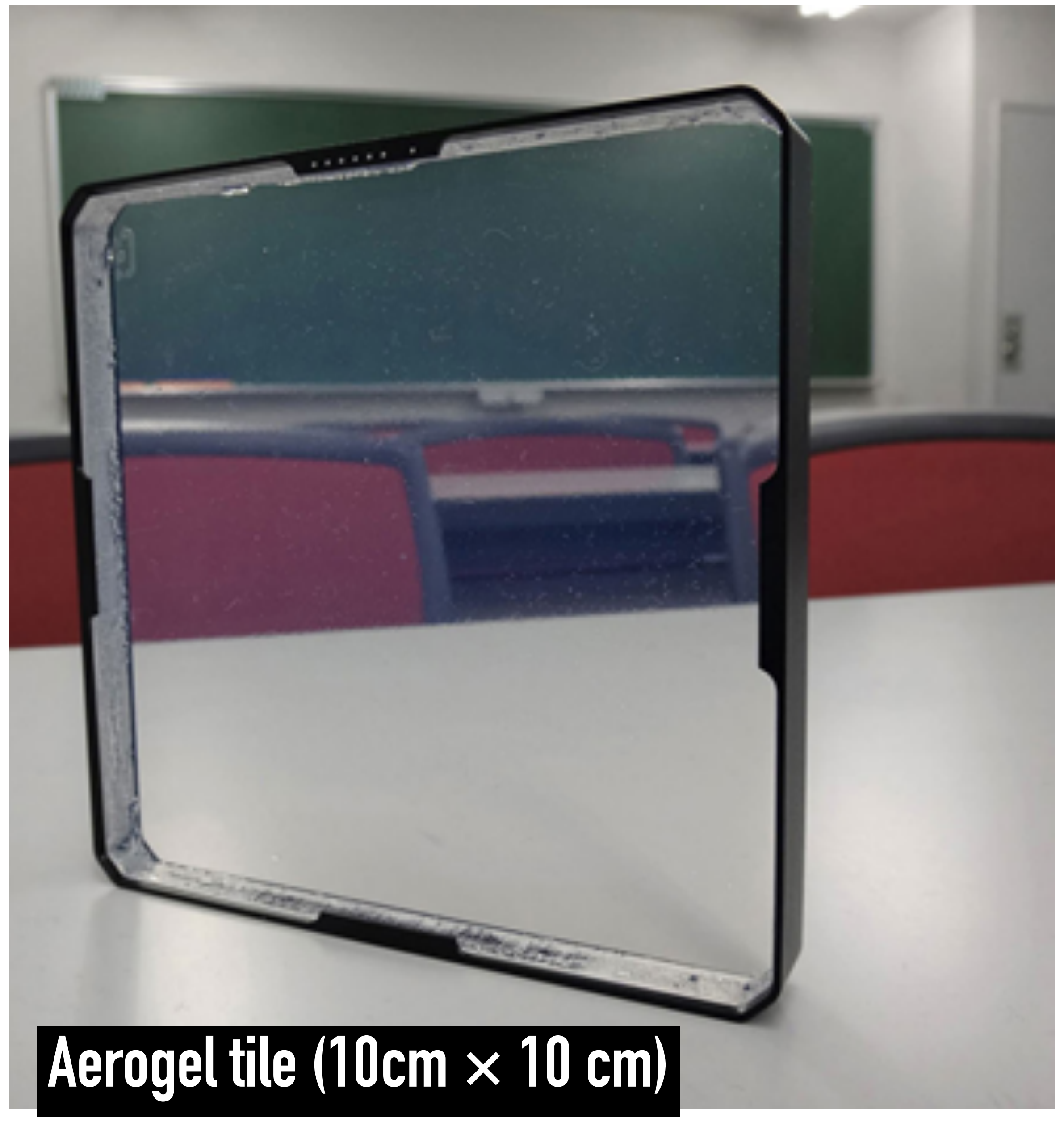
Sample cosmic-ray muon track

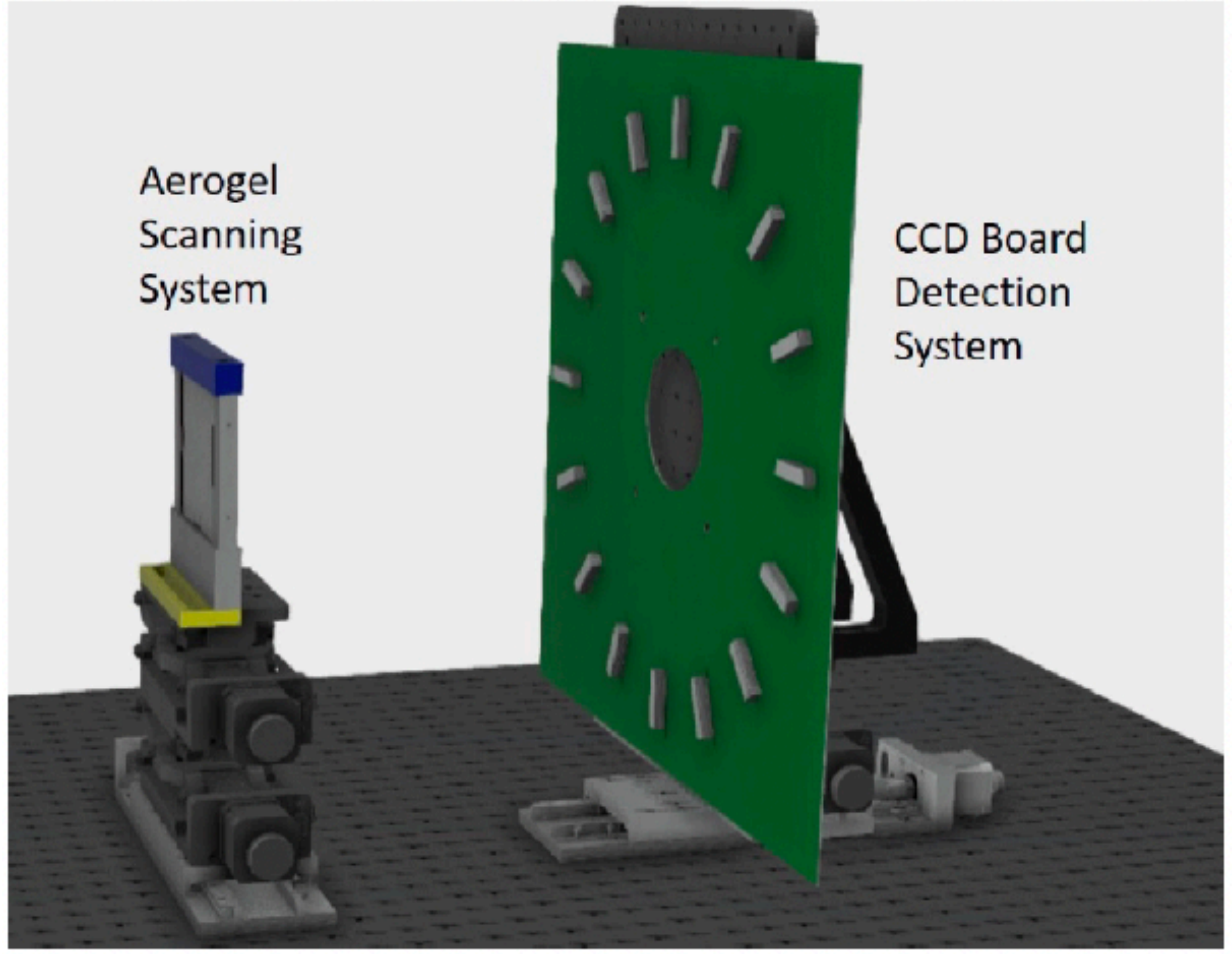
# Ring Imaging Cherenkov Counter

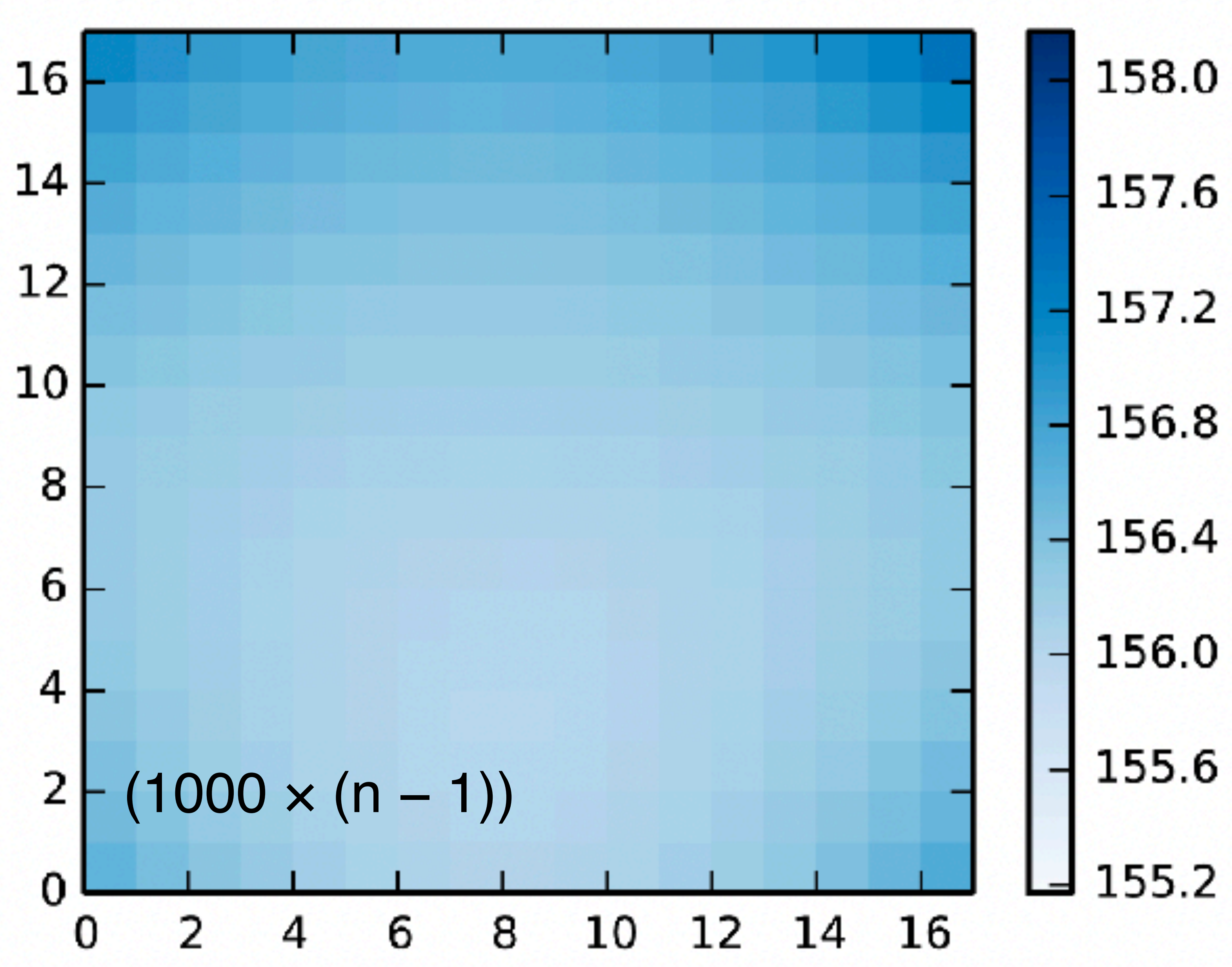


**Proximity-focused RICH with SiPM readout**

- 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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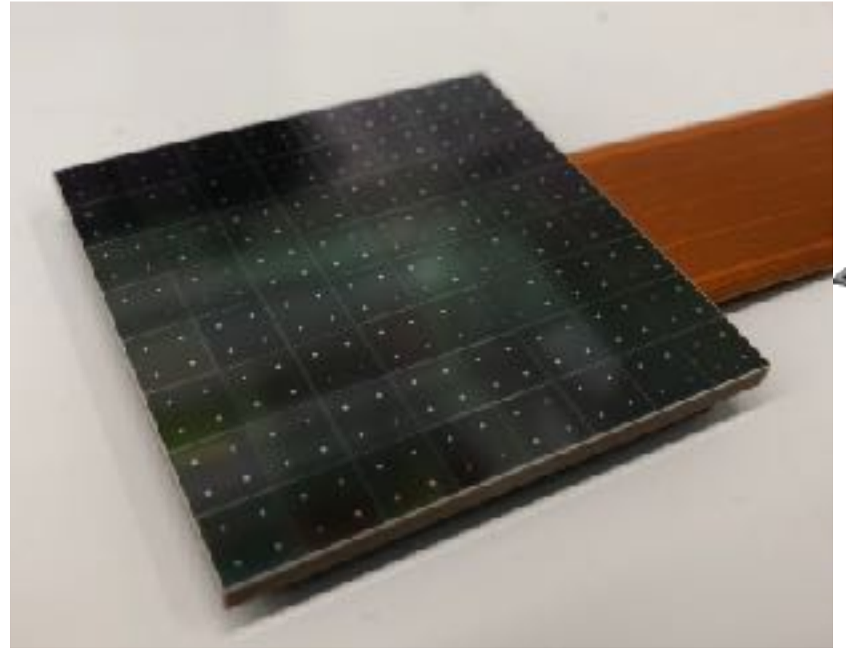
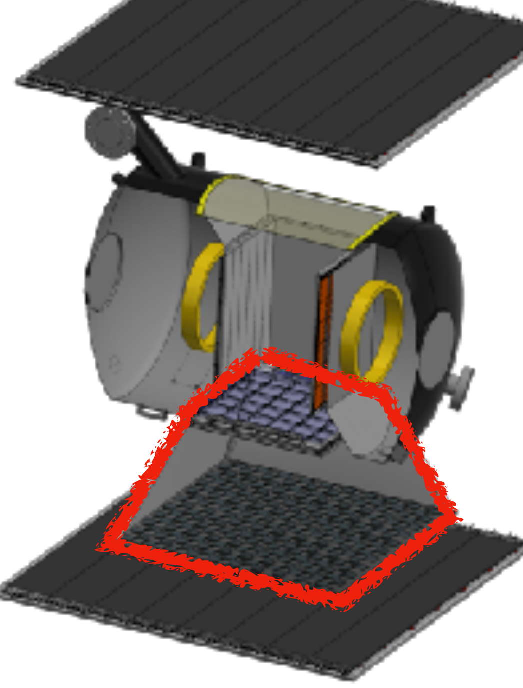
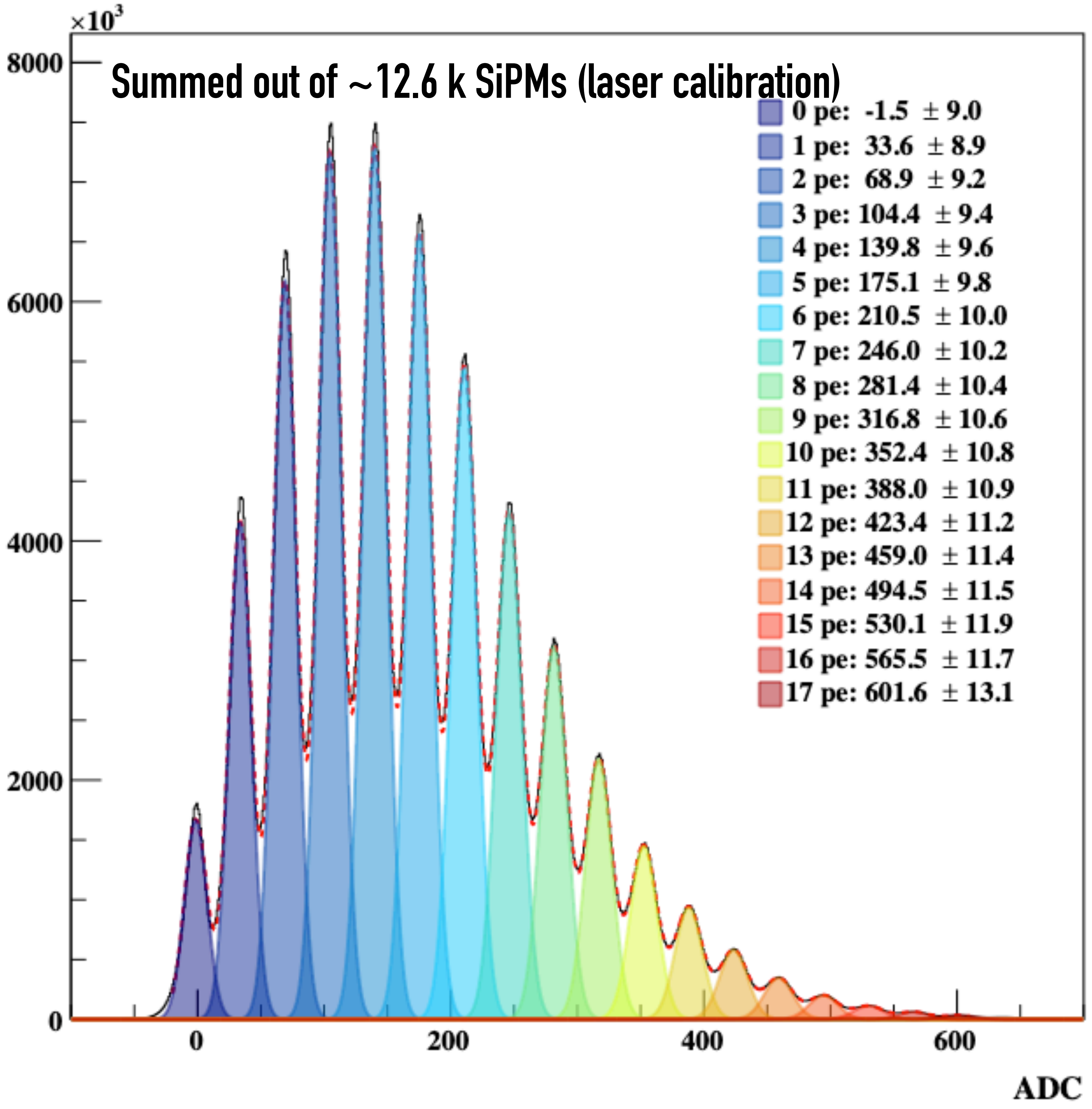
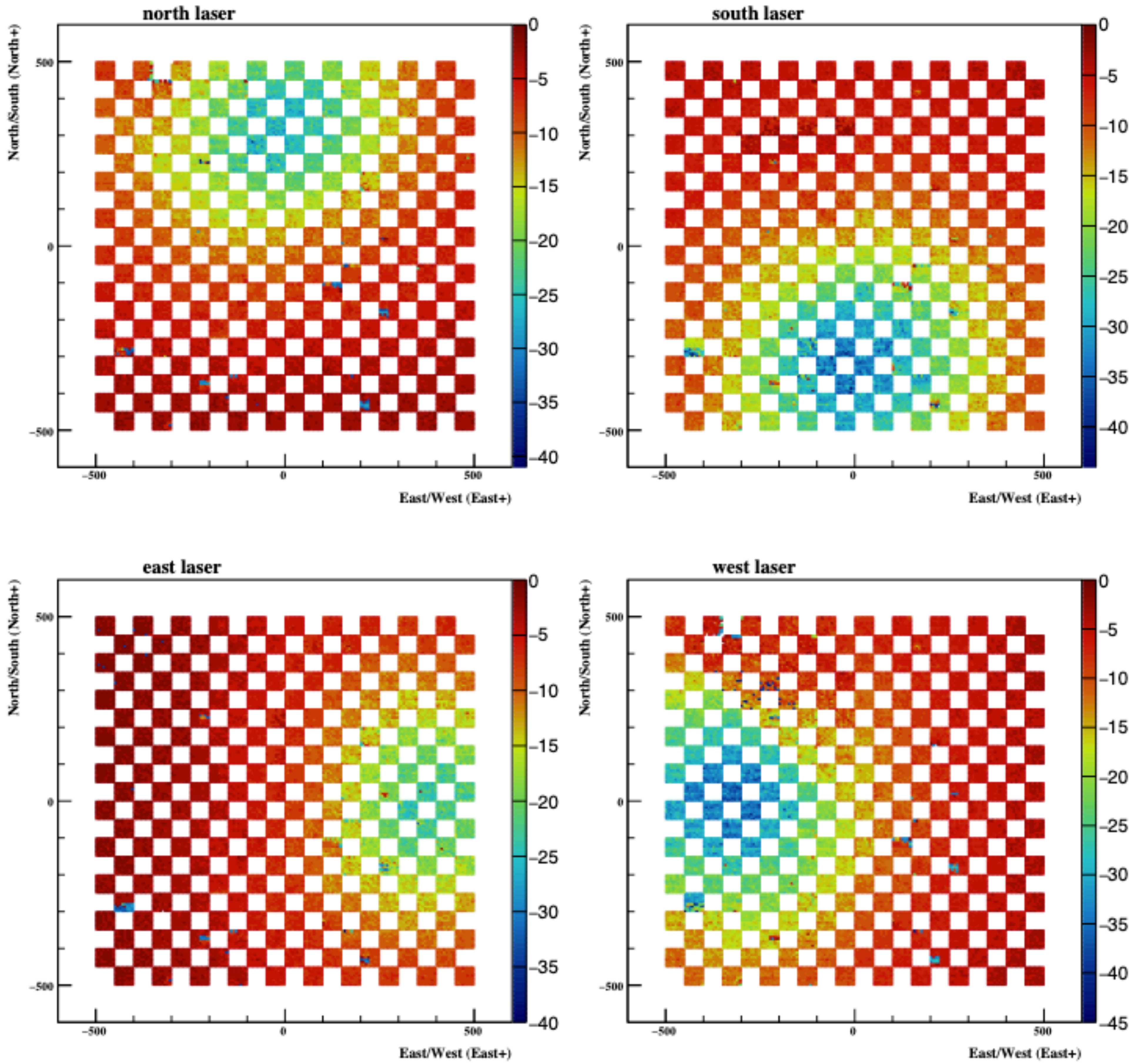




## Proximity-focused RICH with SiPM readout

- Velocity resolution of $\Delta\beta/\beta$ ~ $1\times10^{-3}$ for Z>3 for E>1 GeV/n
  - -Focal plane (1 m × 1 m) covered by 6 mm × 6mm SiPM array in checker board configuration: 12.8k channels!

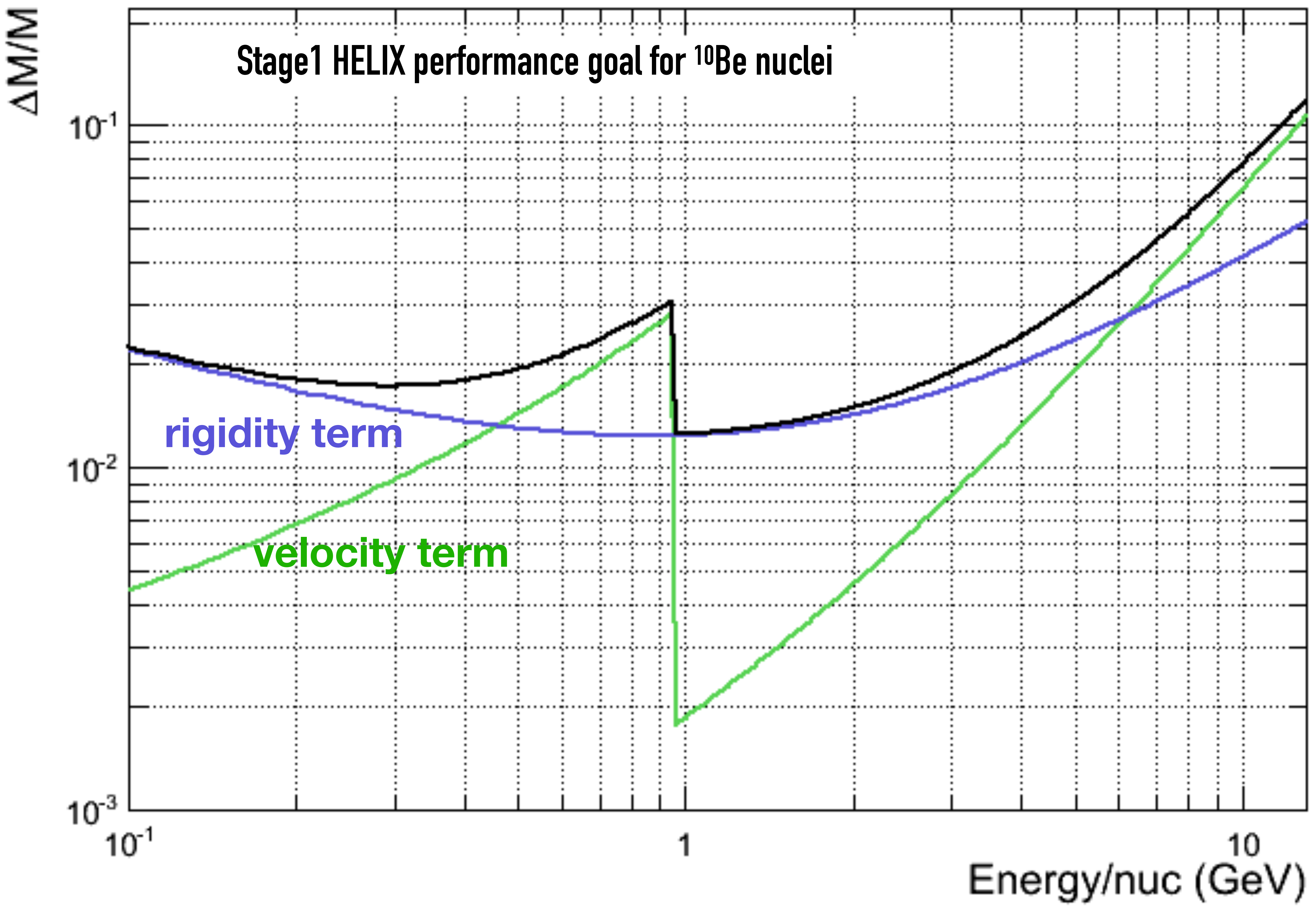


# HELIX Stage1 Performance

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

- 7-14 day exposure with 0.1 m$^2$sr 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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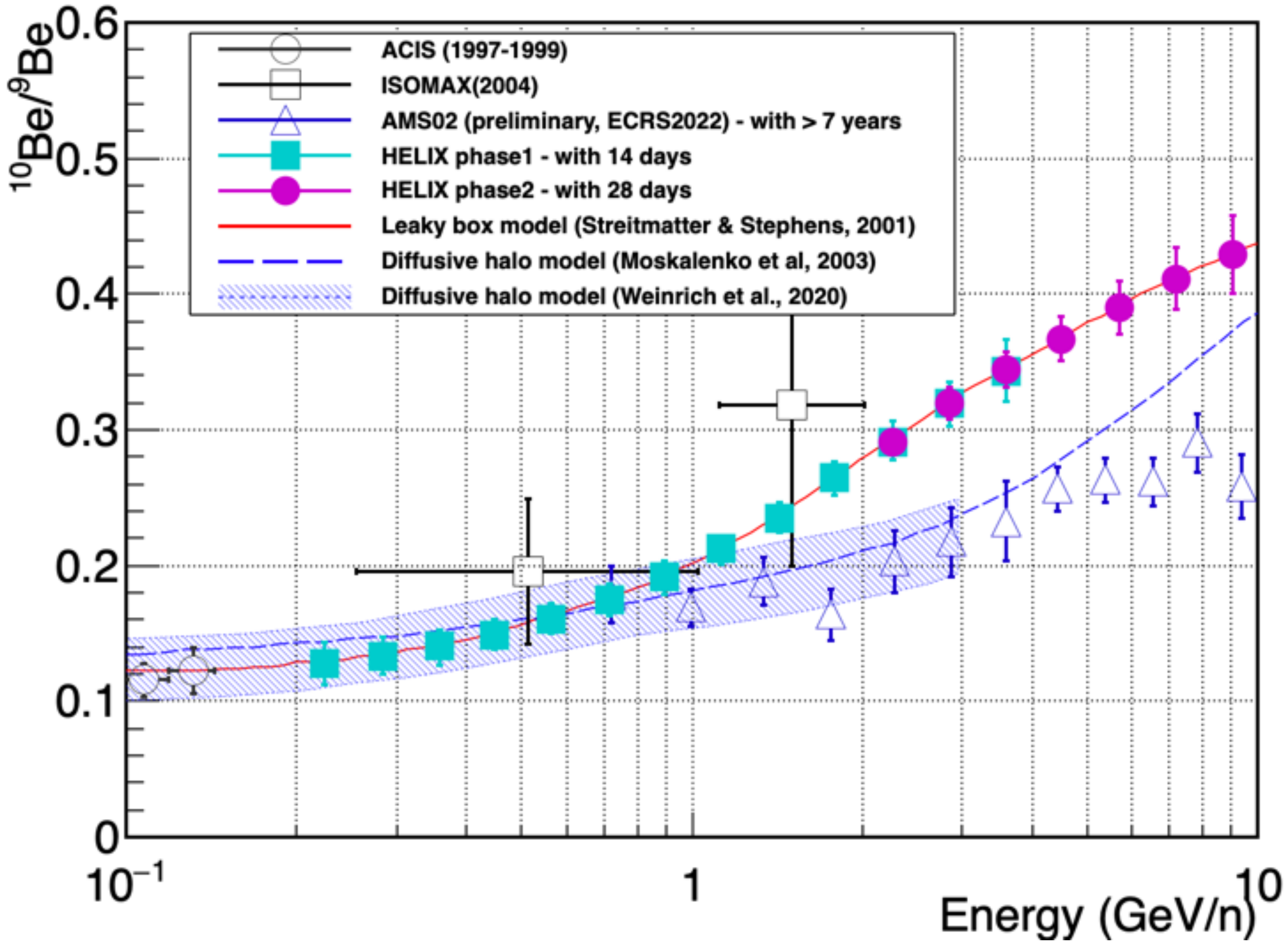
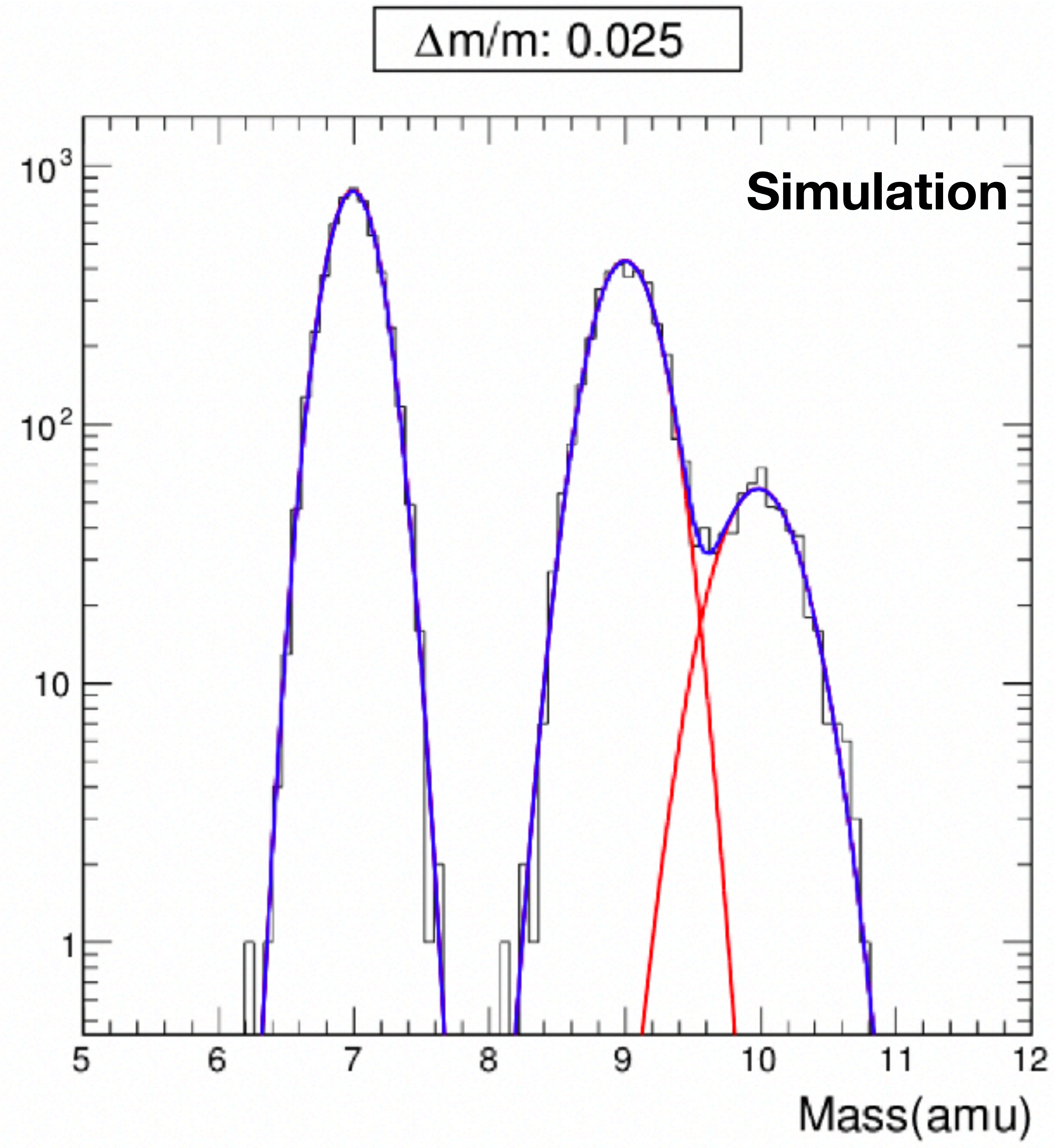
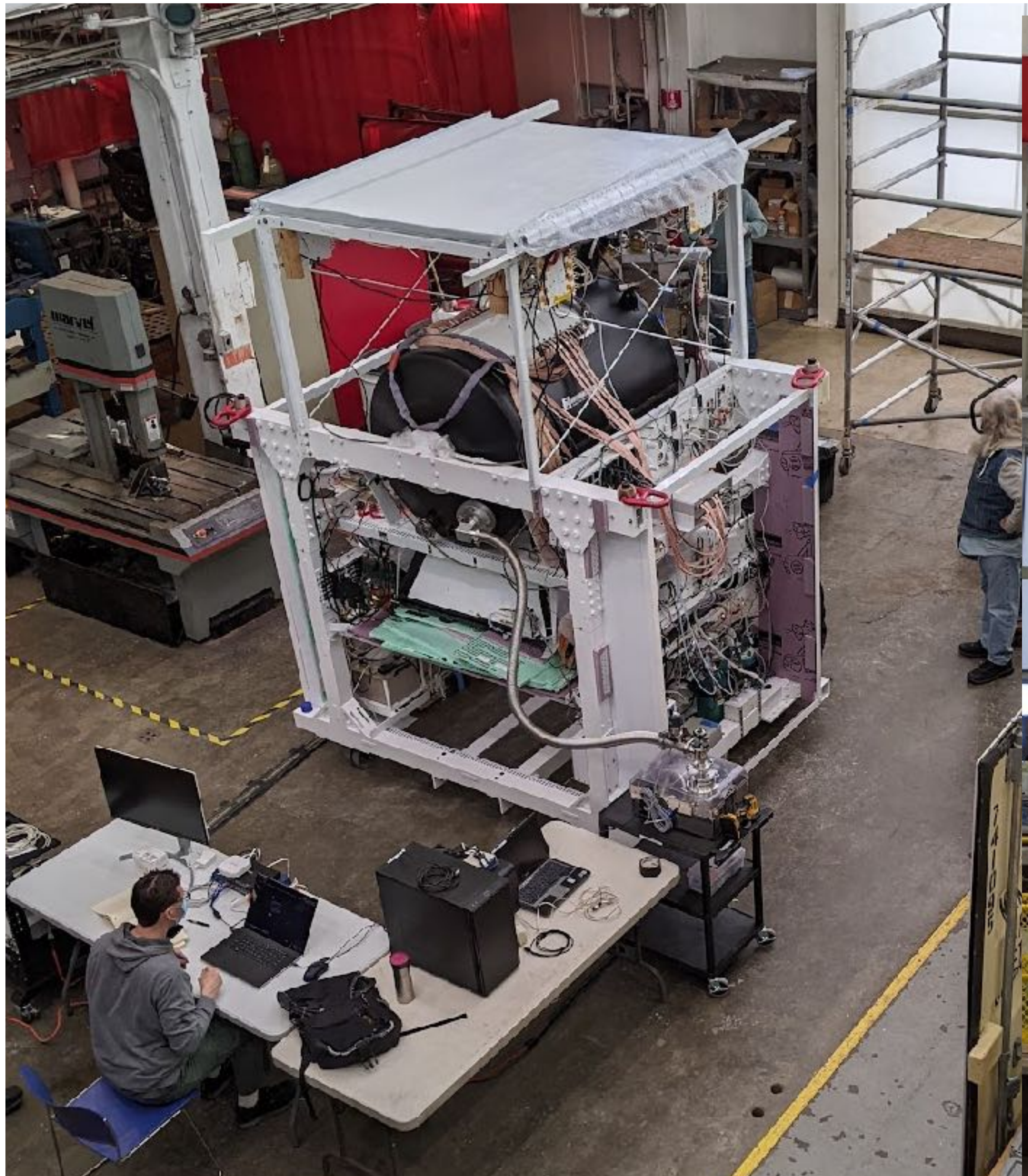


# Tests and integrations

**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**

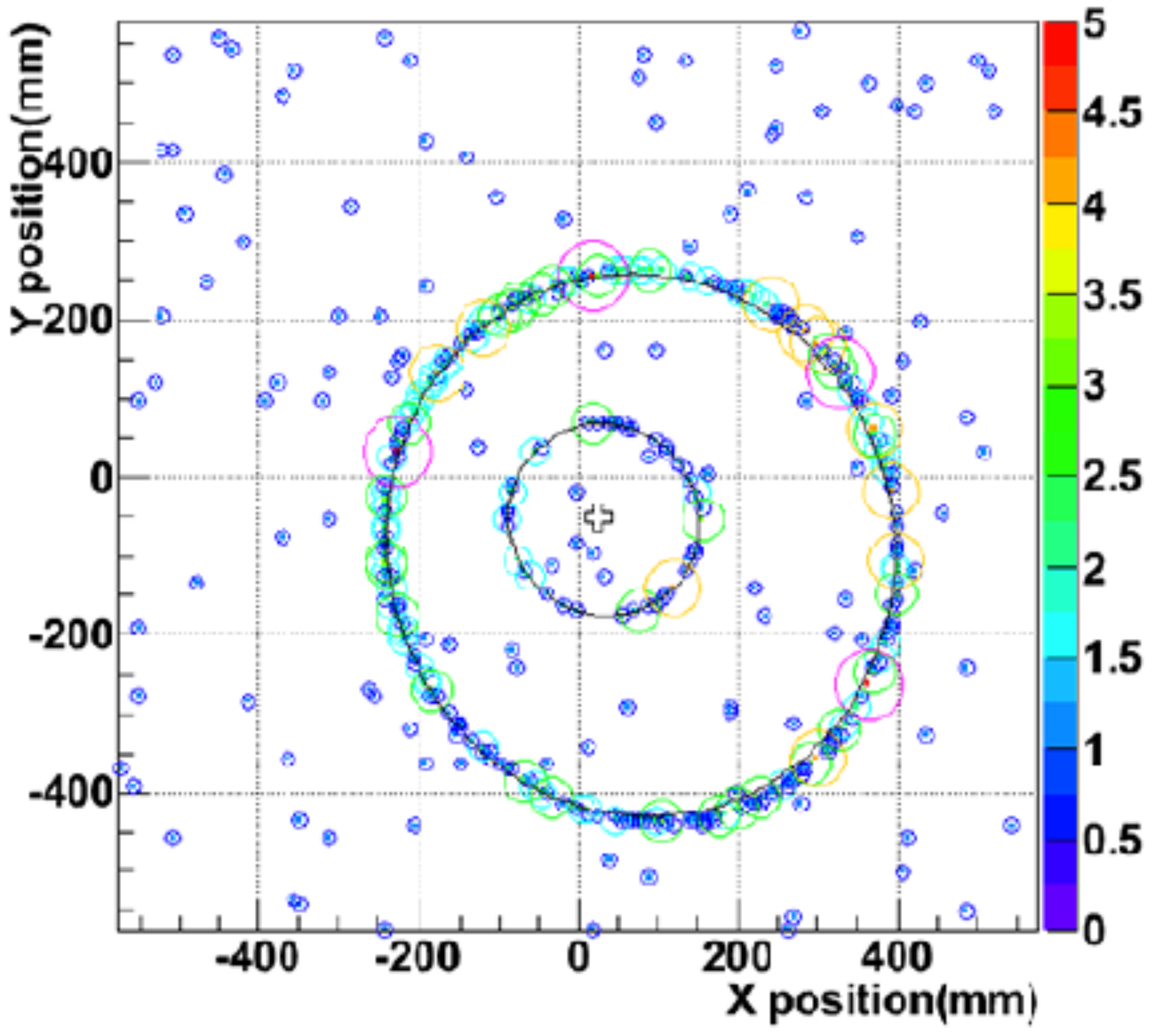
- Magnet upgrade: longer exposure time (7 days → 28 days)
- Tracker upgrade: better resolution (65 μm→ 5 μm)

  → moving to 4-6 layers of silicon strip trackers

- RICH upgrade

  -Upgrade to a full focal plane 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 $\lesssim$ 3%.

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