Cosmic-ray isotope measurements with HELIX

Presented by Nahee Park

for HELIX Collaboration

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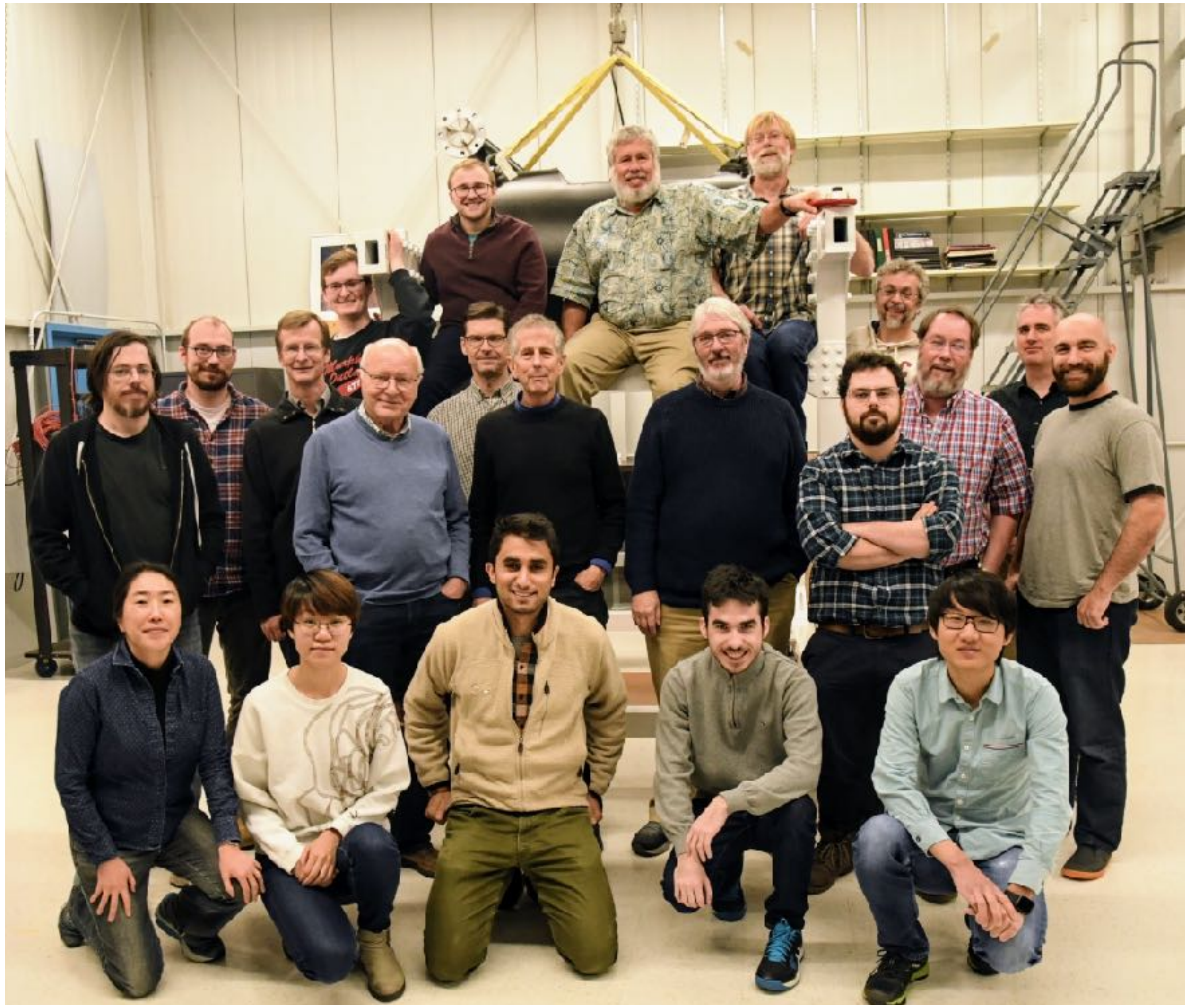
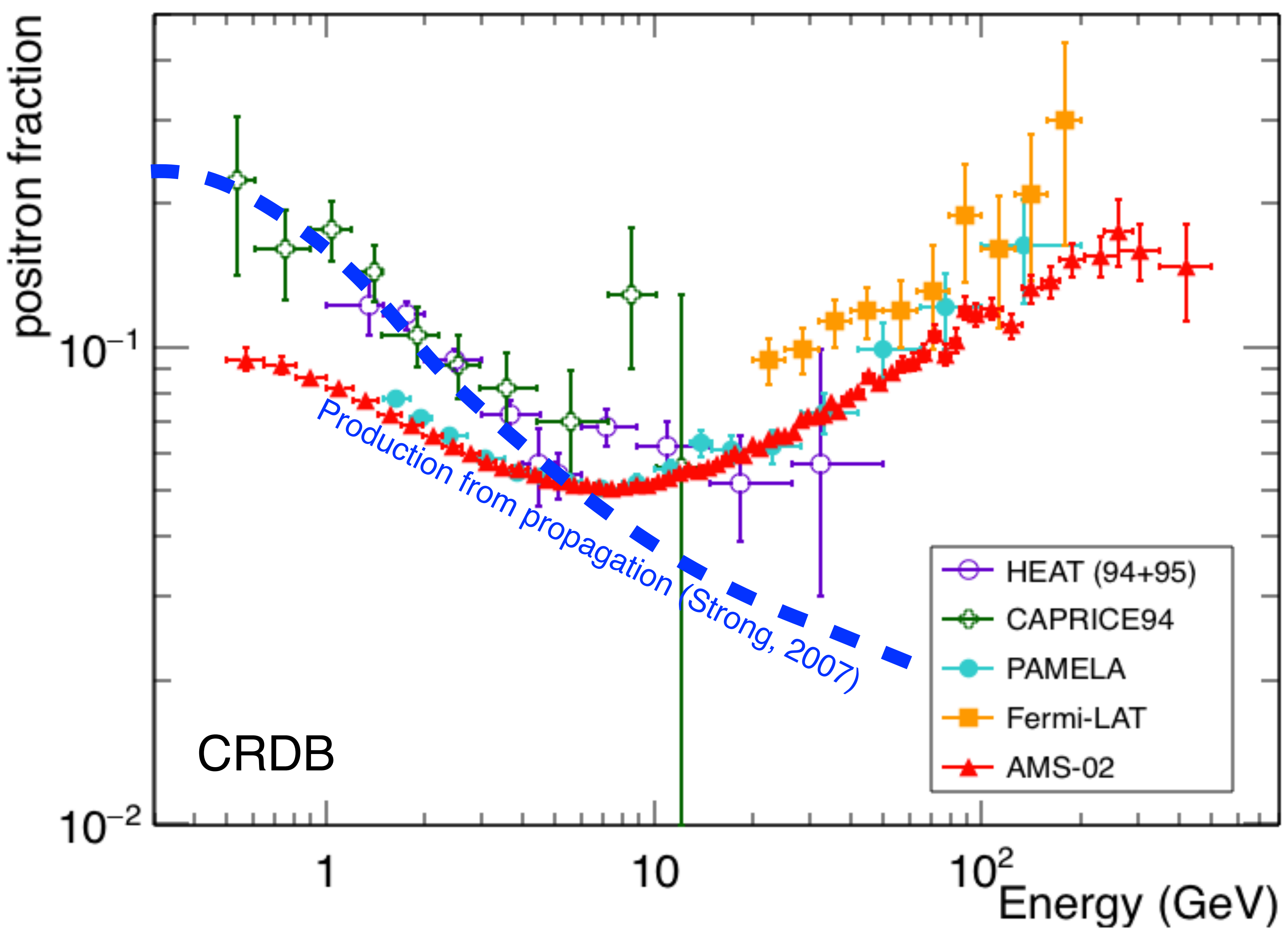


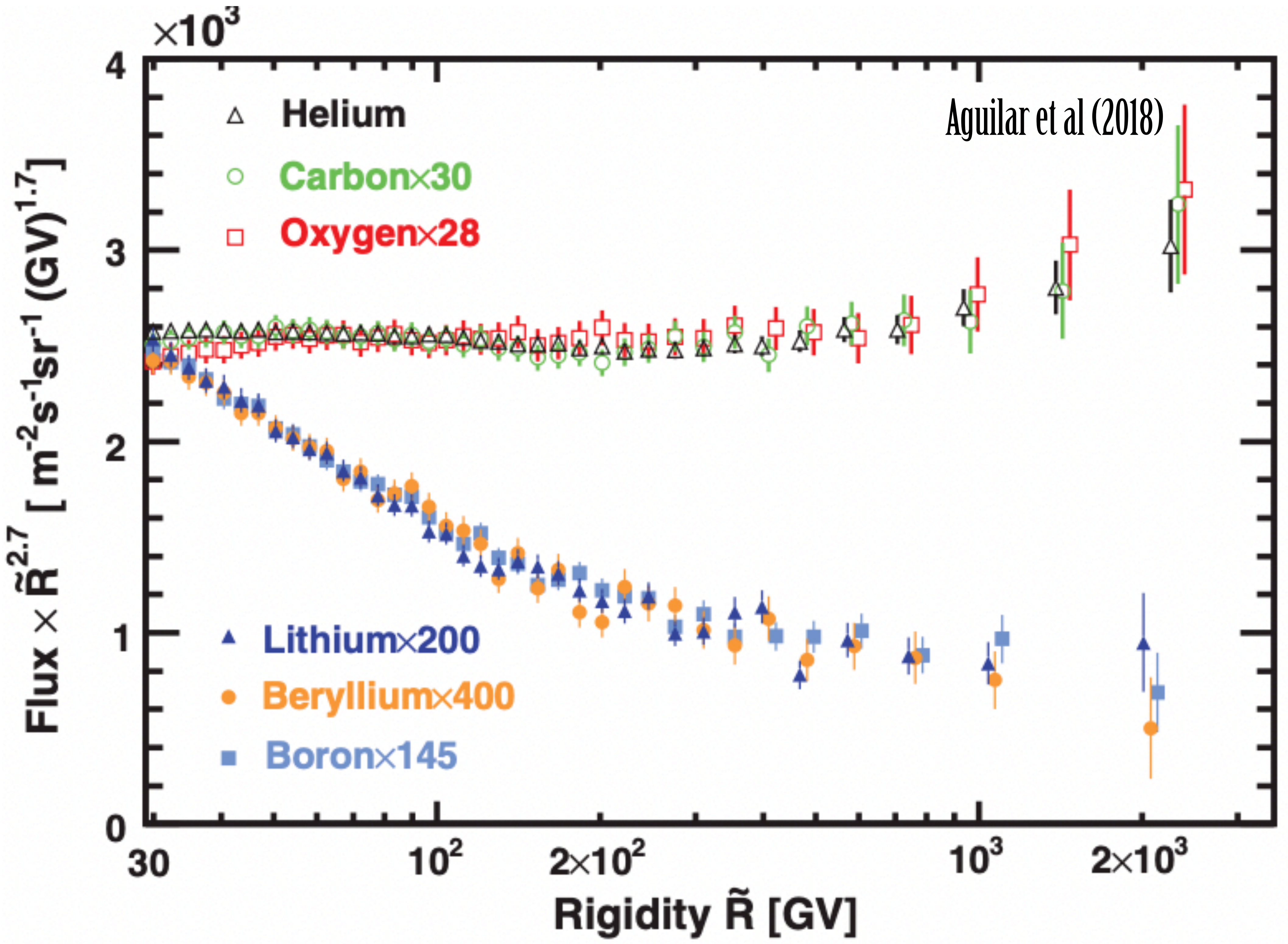
Recent Updates from Direct Measurement

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

- Rising positron fraction
- Potentially rising anti-proton fraction
- Hardening at ~ 300 GV in the spectra of primary nuclei (e.g. H, He, C, O) & secondary nuclei (e.g. Li, Be, B)

→ It is critical to understand the propagation!

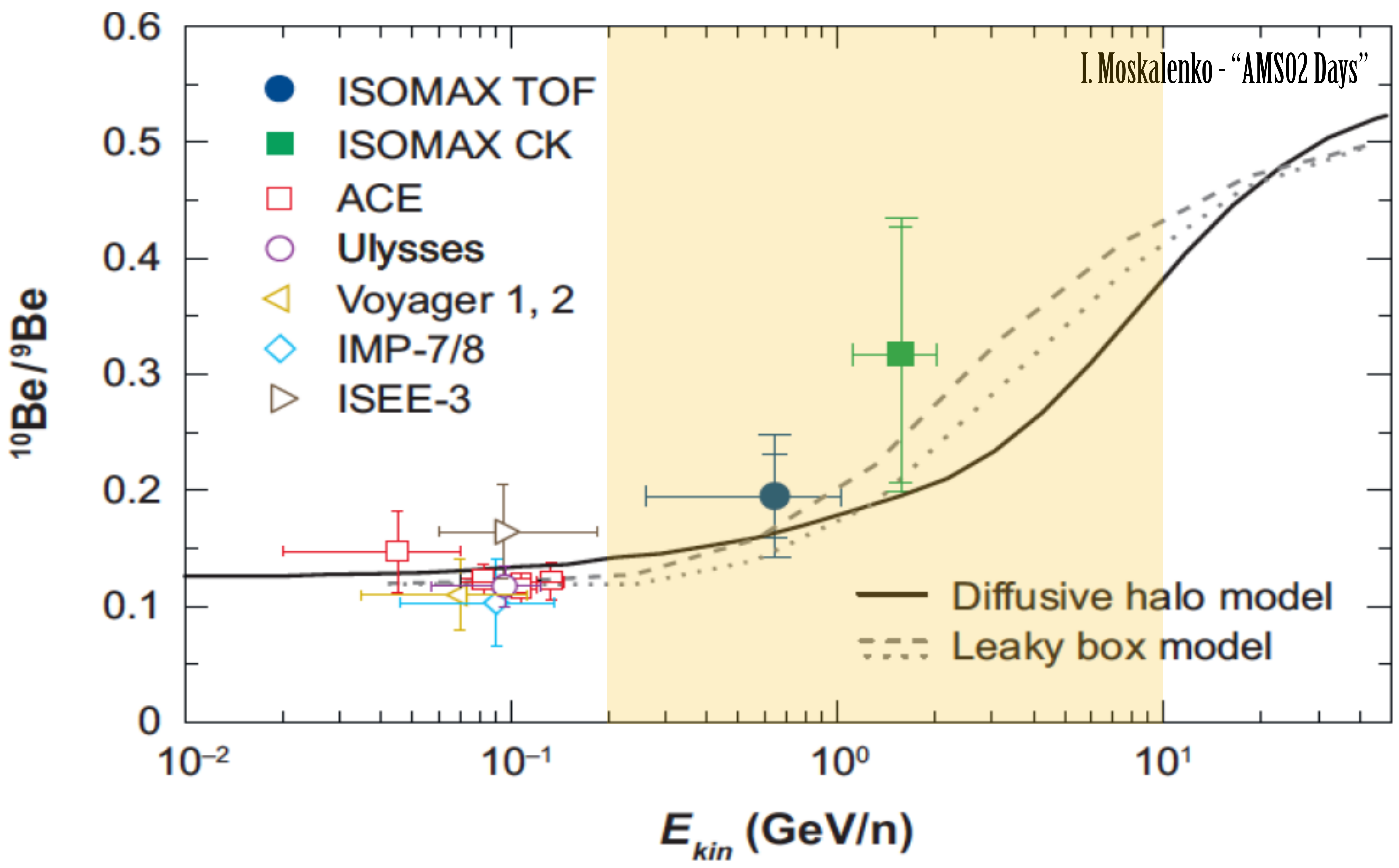




$^{10}Be/^{9}Be$ measurements

^{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
  - "Best target for future experiment" (Weinrich et al, 2020)
- Challenging measurements
  - Several good measurements at a few hundred MeV/n. Above this, the ISOMAX balloon payload covers up to ~2 GeV/n



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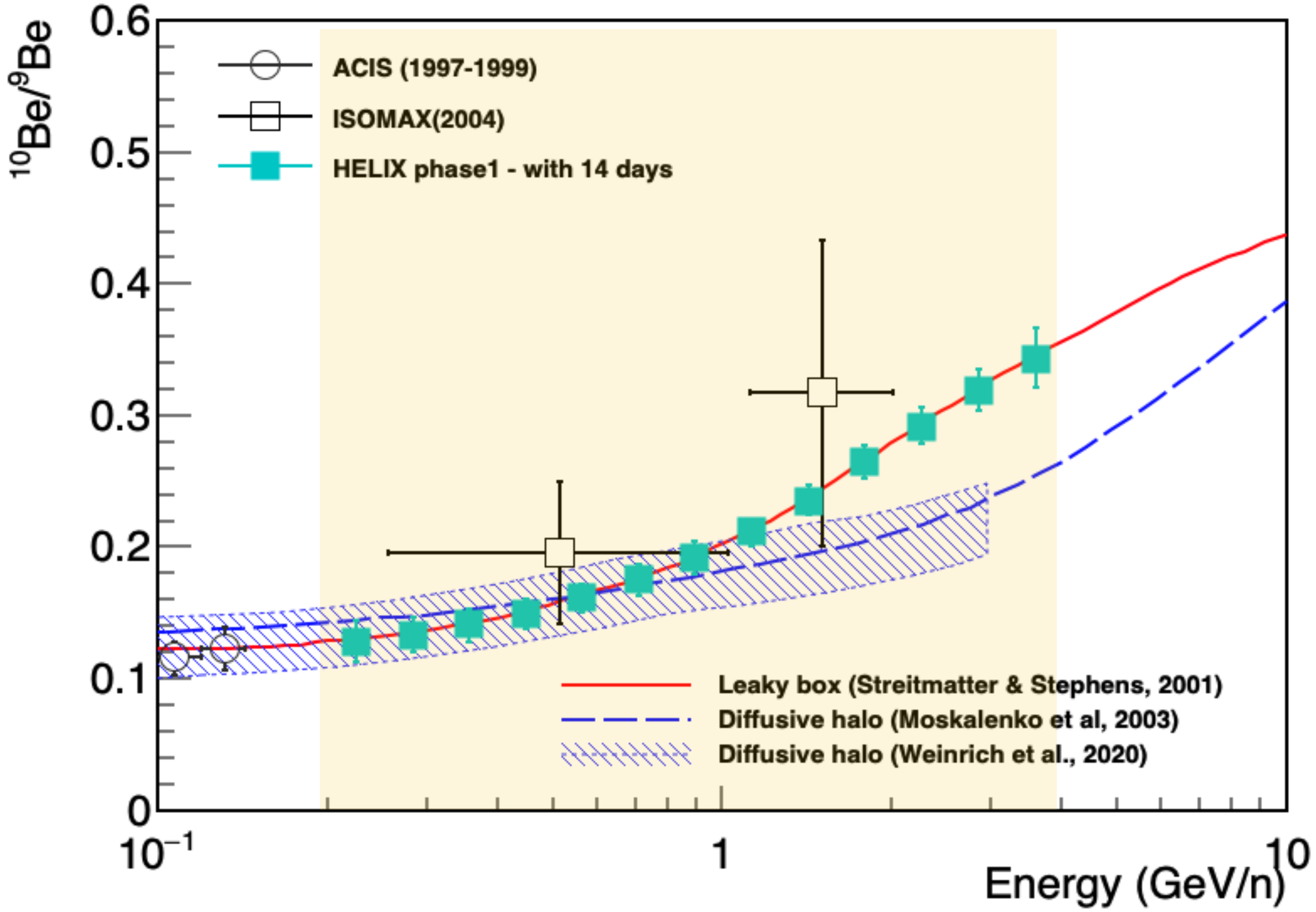
HELIX is designed to provide a precision measurement of ^{10}Be!

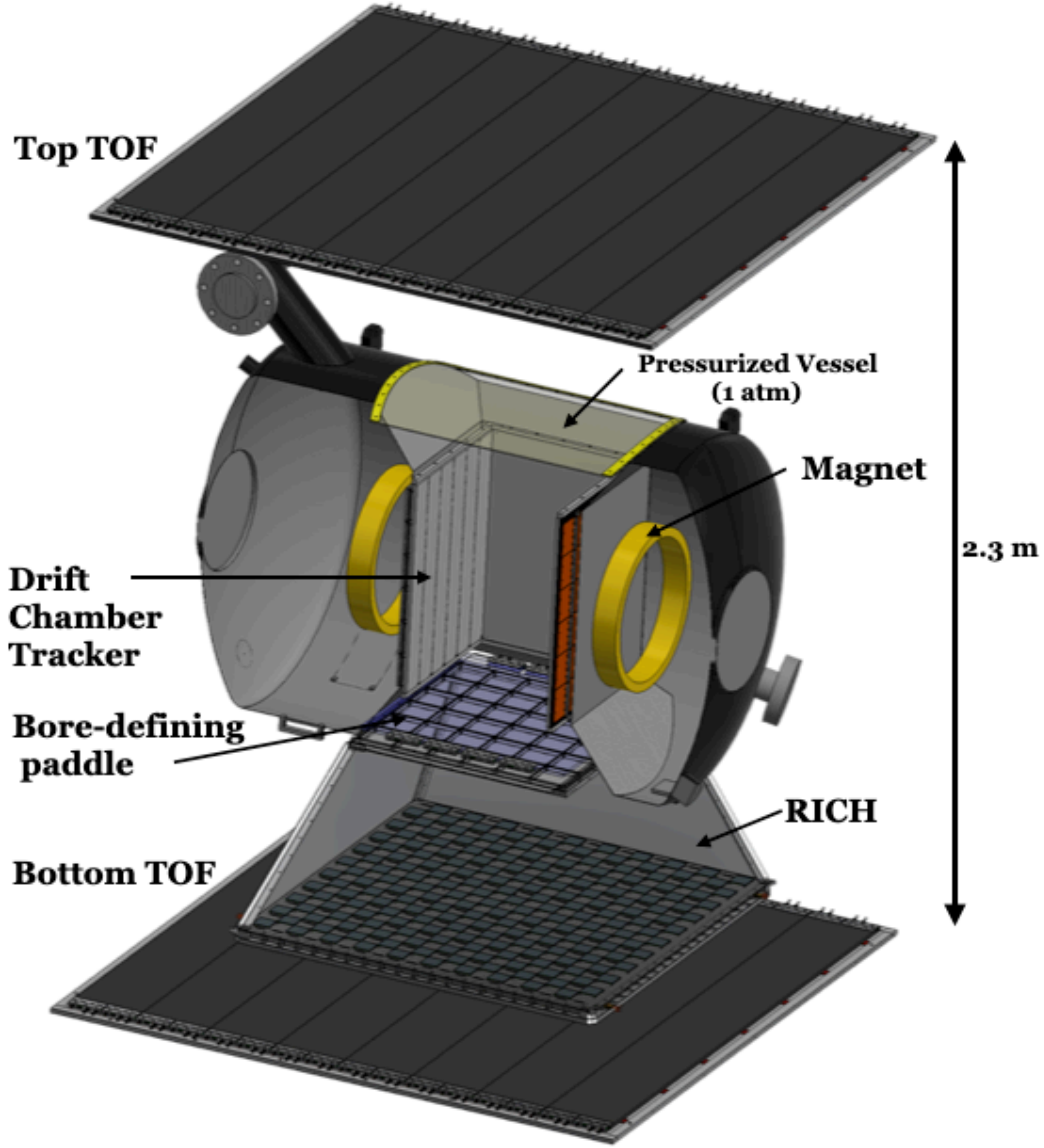


High Energy Light Isotope eXperiment

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

$$m = Ze\ R\ \frac{\sqrt{1-\beta^2}}{\beta}$$

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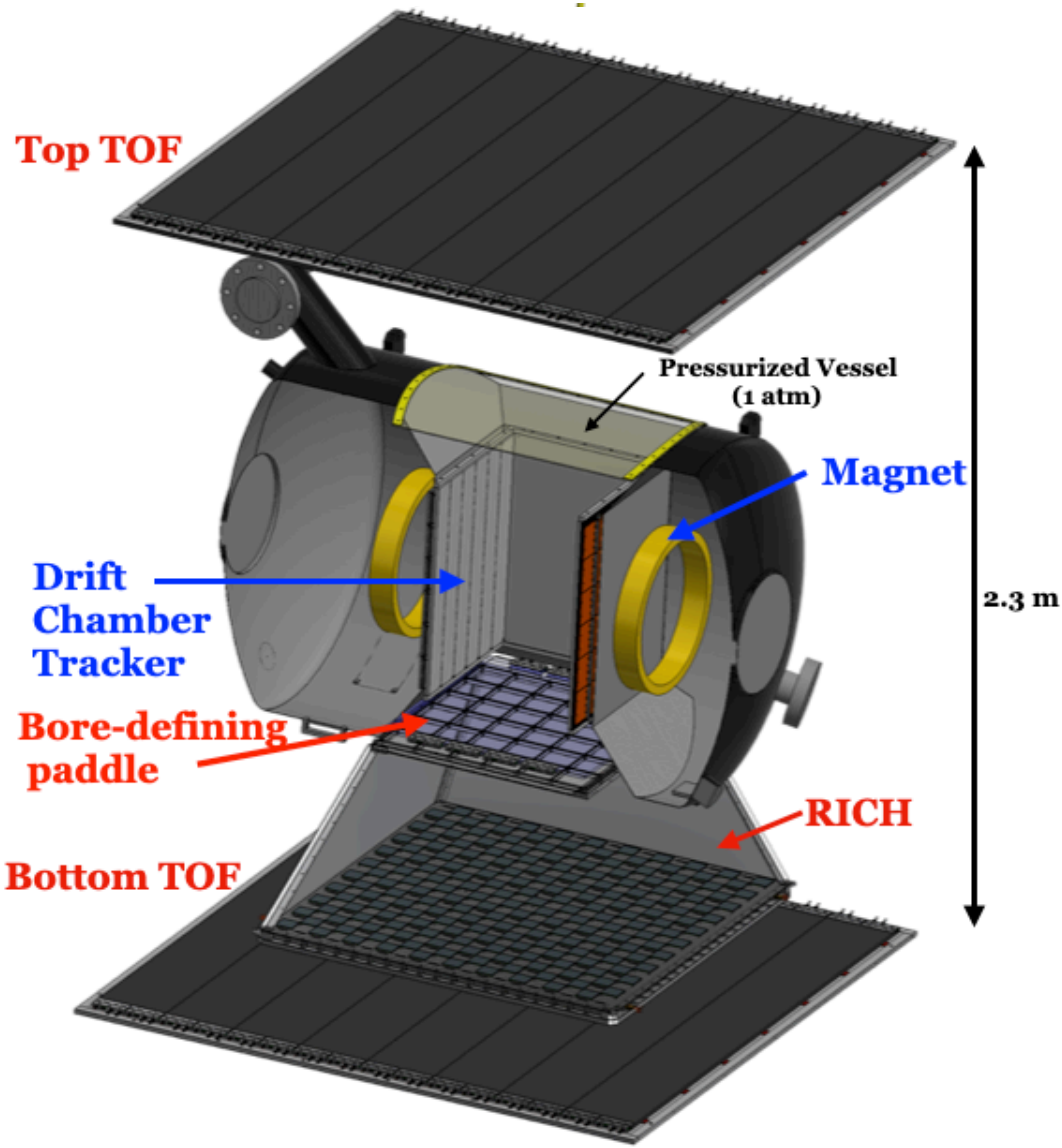
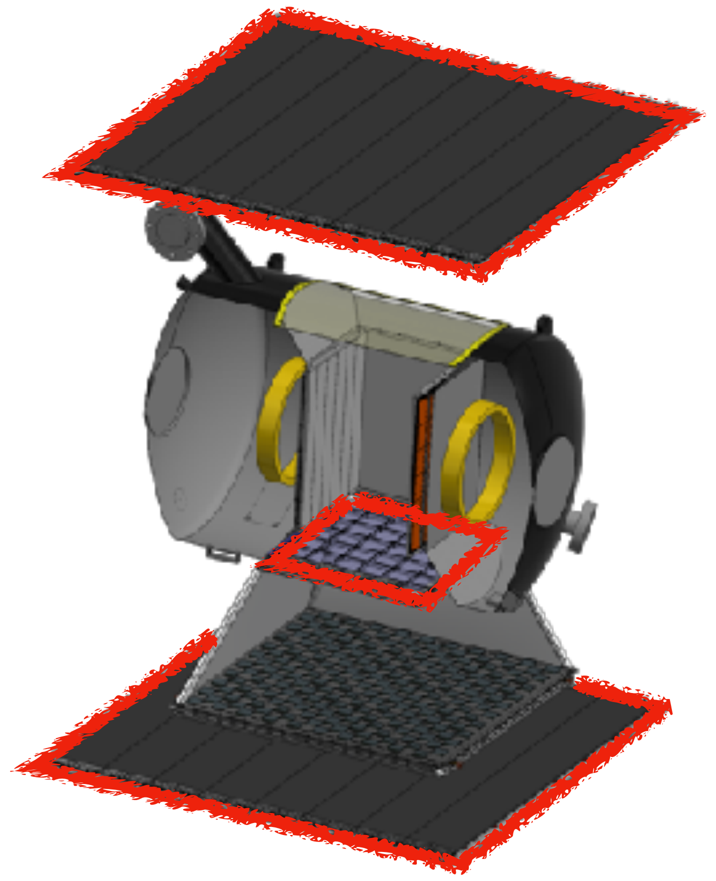
- Two stage approach to cover wider range of energy
  - Stage 1 : covers up to ~ 3 GeV/n

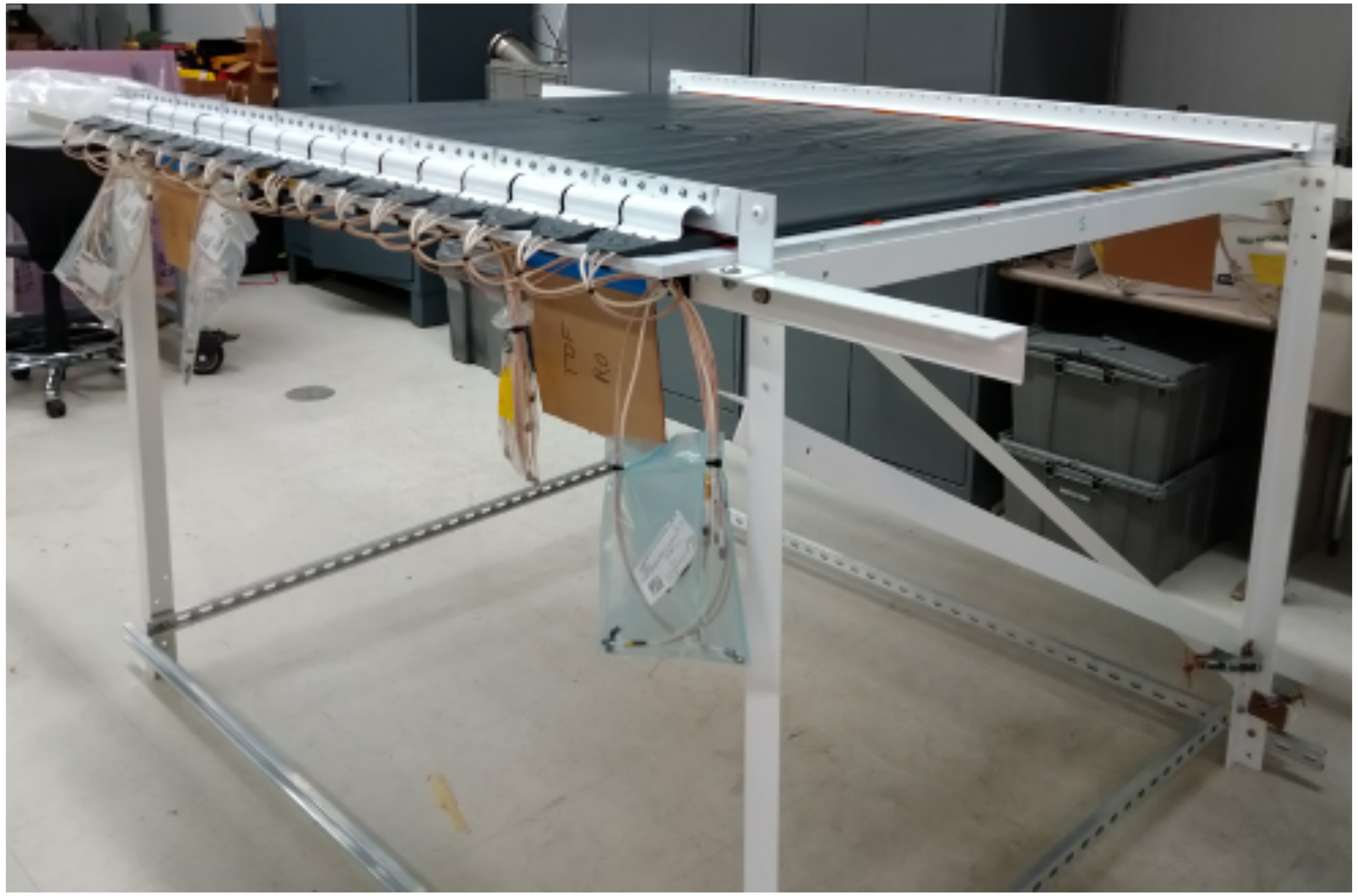


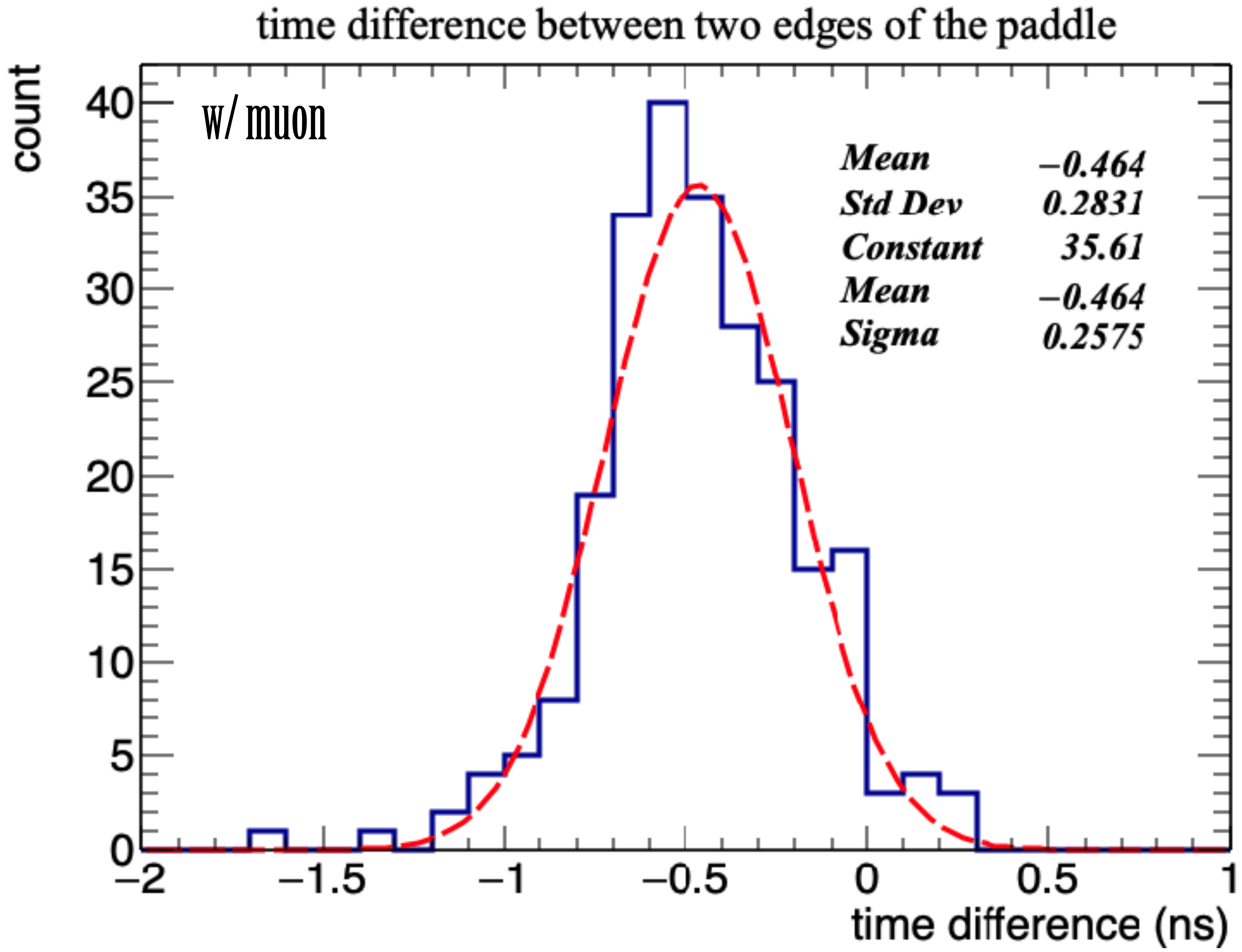
Time-Of-Flight



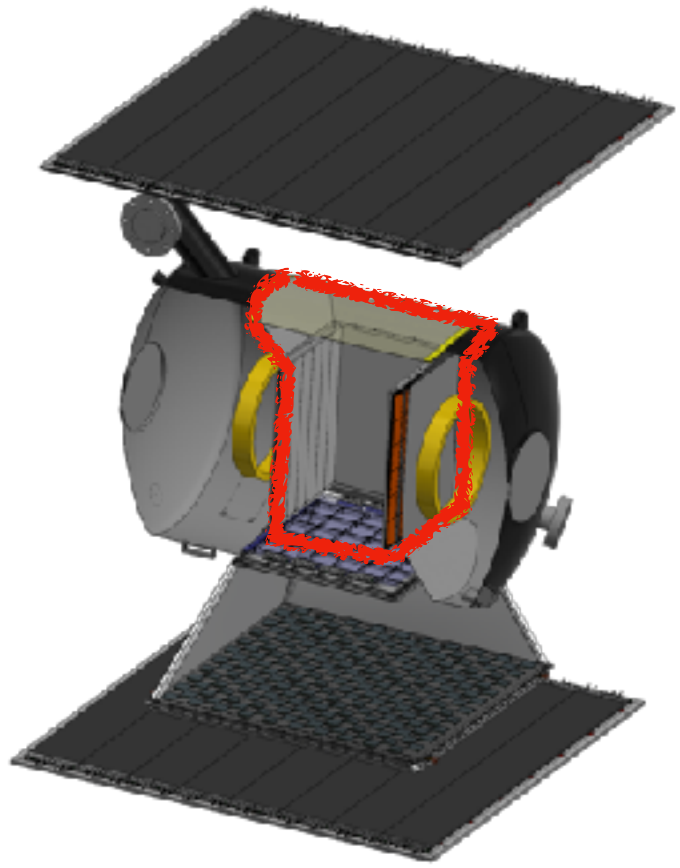
Three layers of 1 cm thickness fast plastic scintillator, 2.3m top to bottom

- Timing resolution of <50 ps for Z>3
  - Each top and bottom layer consists of 8 of 20cm EJ200 scintillator paddles with each end read by 8 SiPMs
  - Smaller middle layer to constrain the trigger geometry
  - Fast signal output used to measure the timing information with TAC circuit. TDC timing resolution better than 25 ps
  - Slow signal output used to measure the charge information with dynamic range of ~1000
- Preliminary analysis on the muon test shows a timing resolution of 260 ps



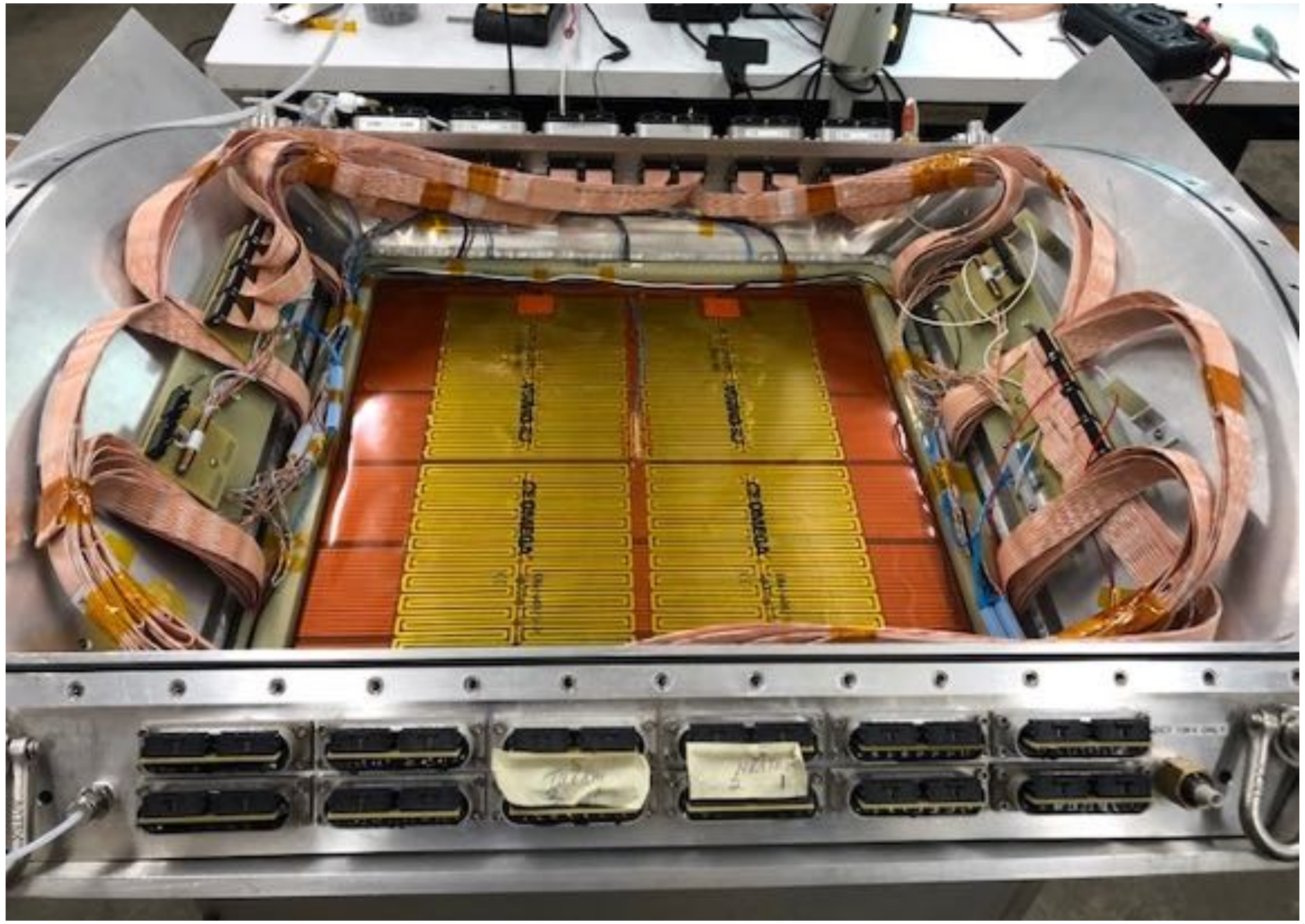


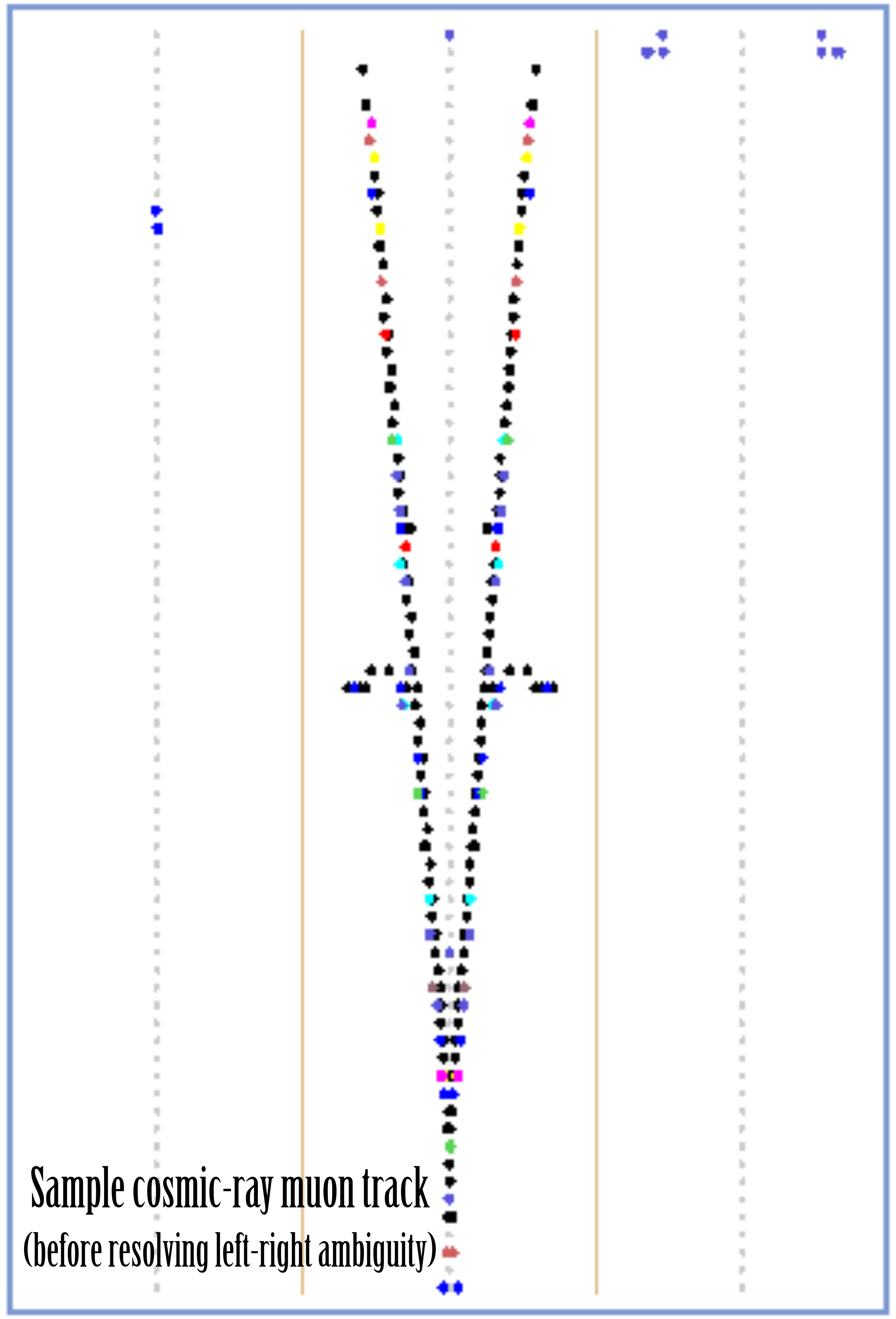
Drift Chamber Tracker



Multi-wire drift chamber with drift gas CO_2 + Ar

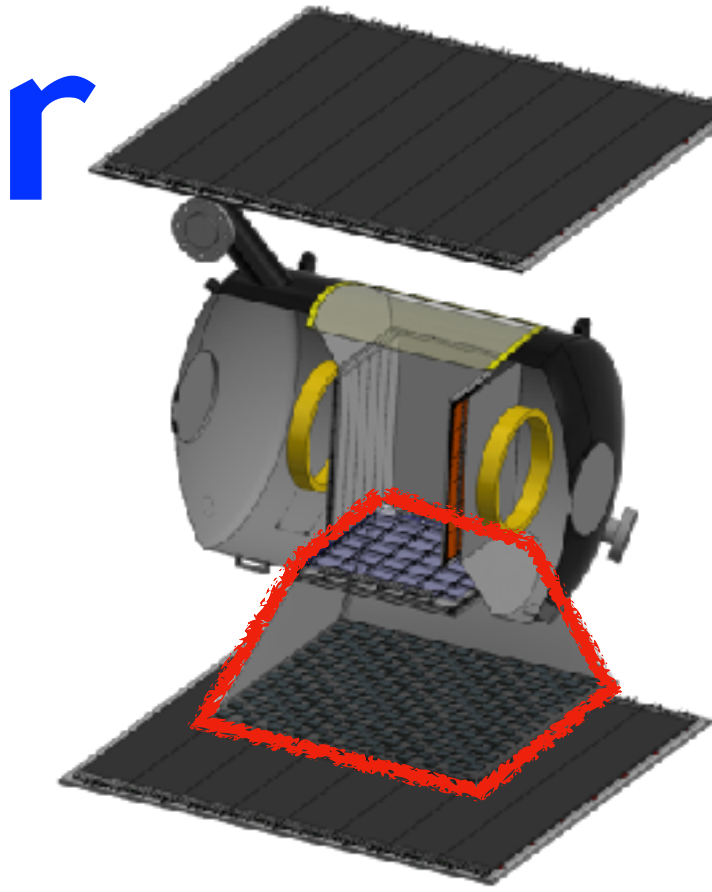
- Spatial resolution of 65 μm for Z>3
  - 72 sense layers, read out with 80 MHz sampling
- Installed in the bore of magnet within a thin pressure vessel (1 atm)
- Prototype measurements show a tracking resolution for muons to be consistent with reaching the design goal





Sample cosmic-ray muon track
(before resolving left-right ambiguity)

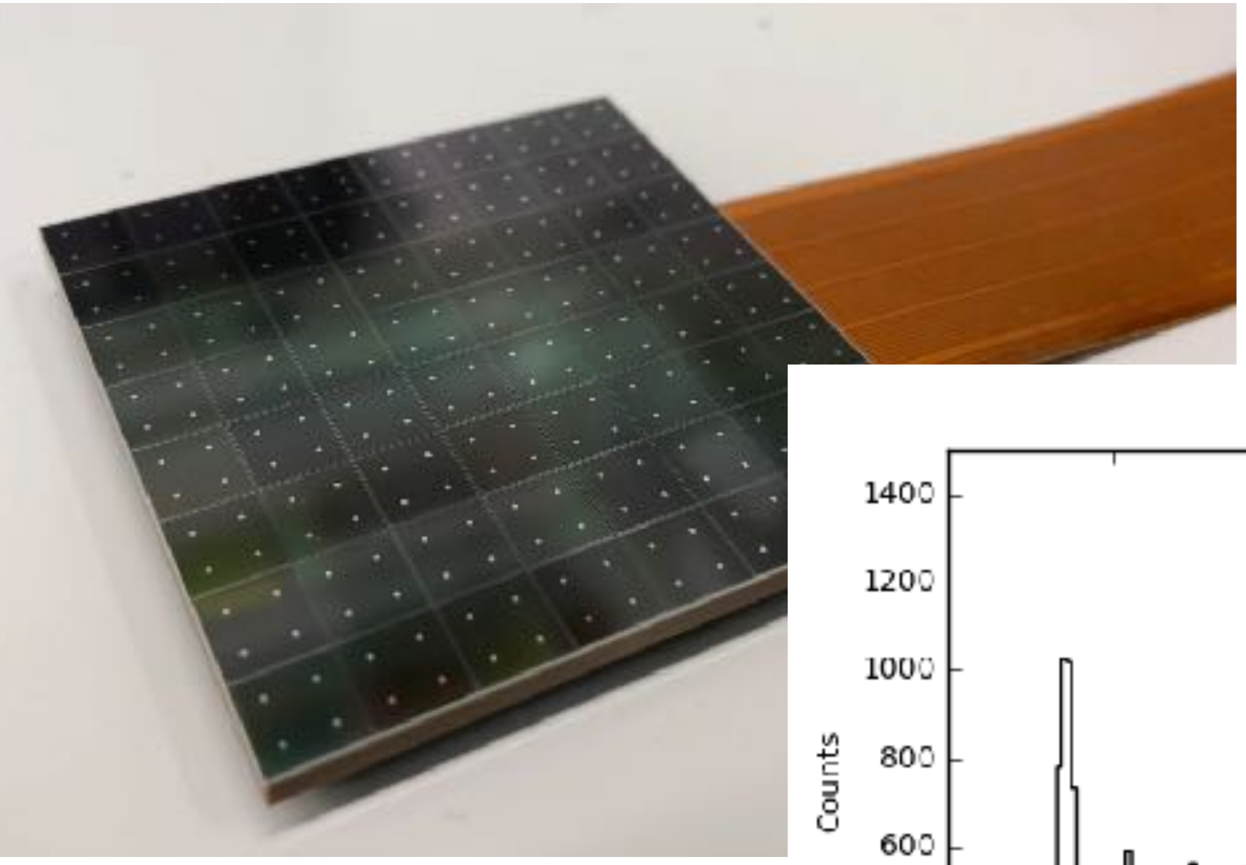
Ring Imaging Cherenkov Counter

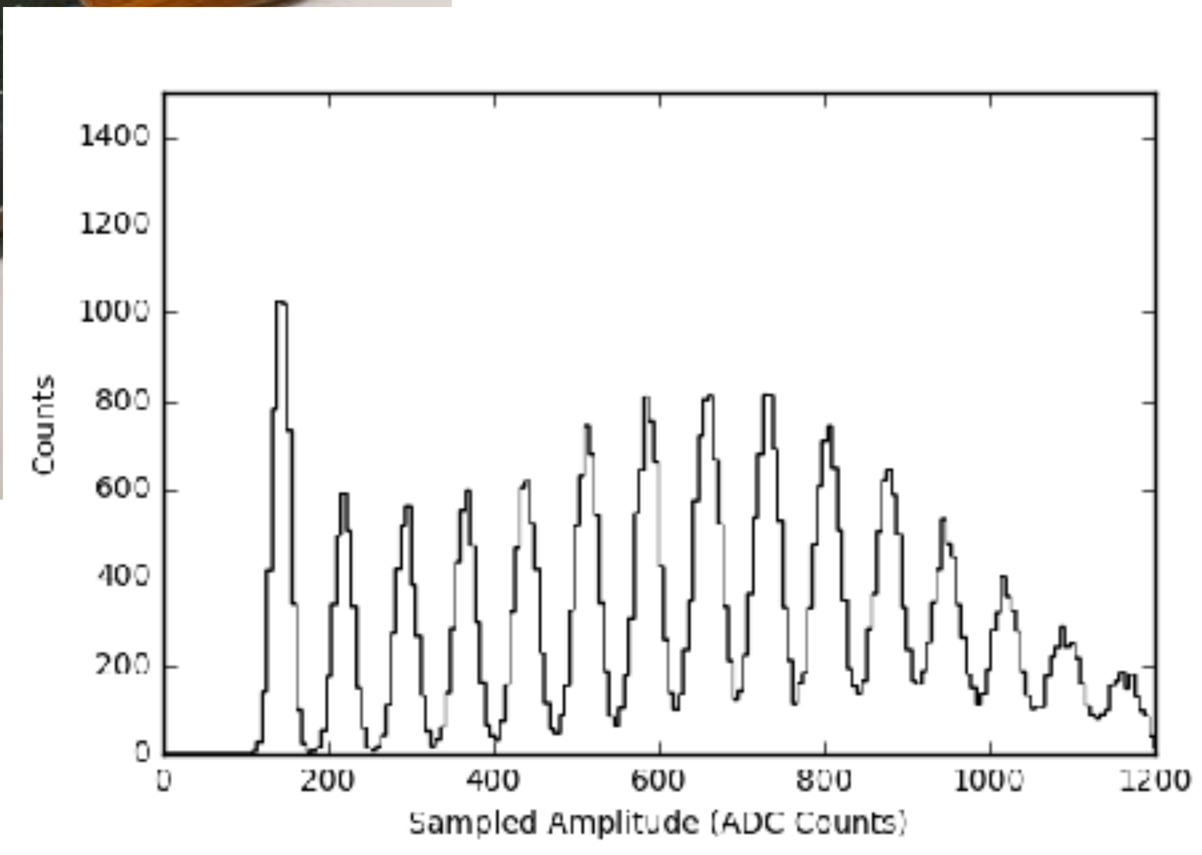


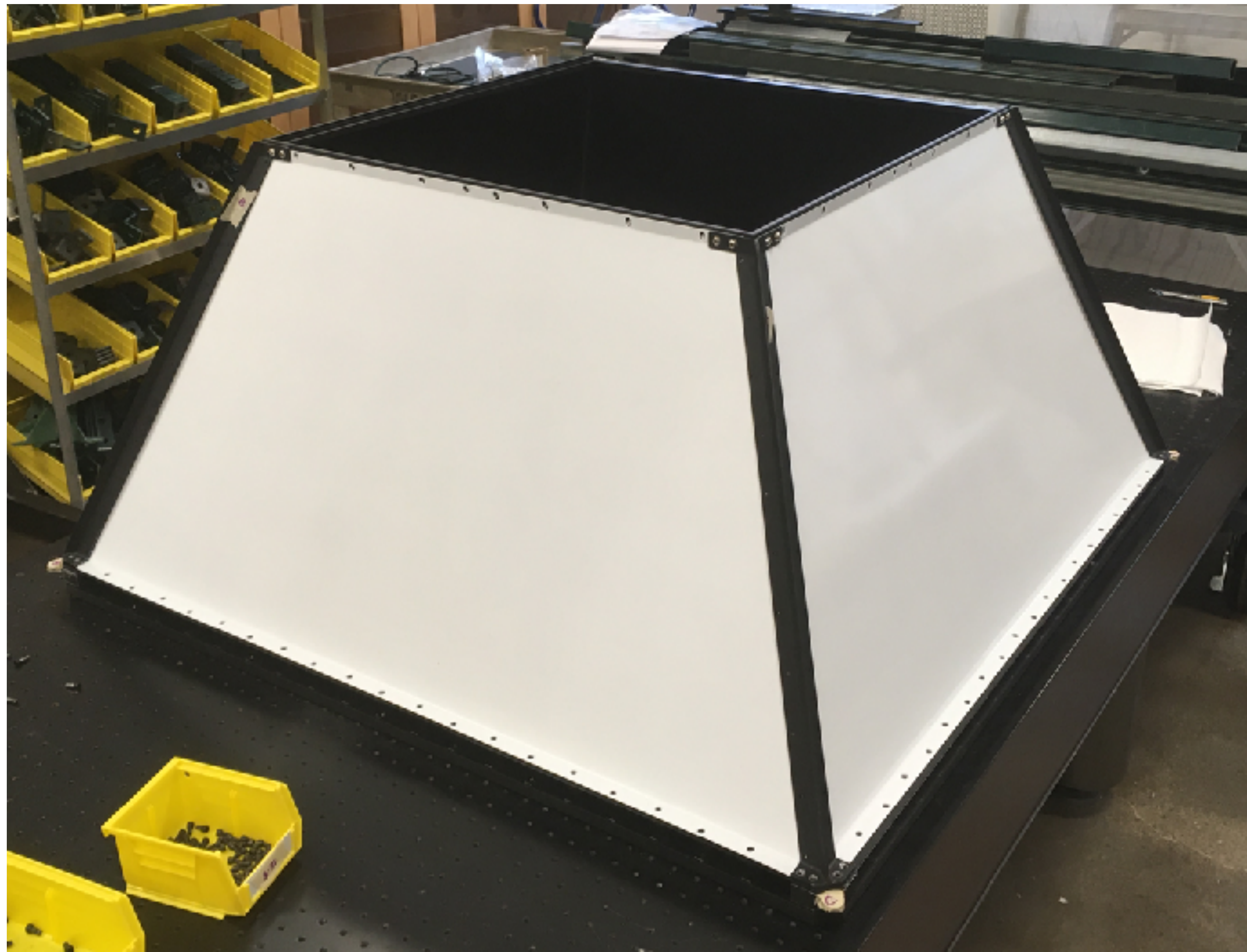
Proximity-focused RICH with SiPM readout

- Velocity resolution of $\Delta\beta/\beta \sim 1\times10^{-3}$ for Z>3 for E>1 GeV/n
  - Radiator : Highly transparent & hydrophobic high refractive index aerogel (n~1.15)
    - Refractive index calibration w/ systematic error at 10^{-4} level (→ ICRC poster #1372: S. O'Brien)
  - Focal plane
    - 1 m × 1 m focal plane covered by Hamamatsu SiPM array (half-filled in checkerboard pattern, ~13 k channels)
      - Single p.e. detectability
      - Thermal plate underneath to reduce thermal noise in SiPMs

#1372 S. O'Brien (aerogel calibration)

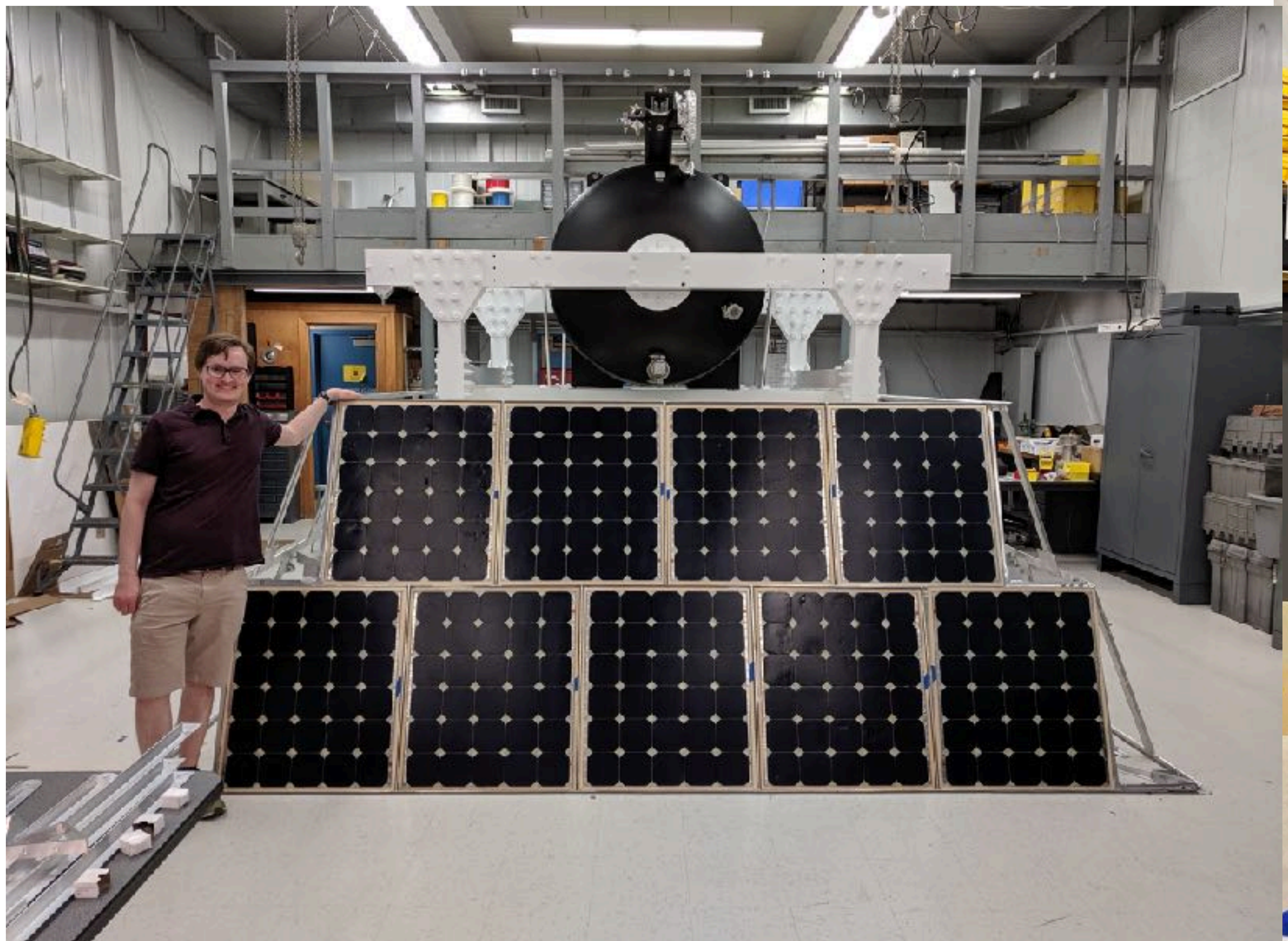






Integration underway...

- ☑ Flight hardware mass production
- ☑ Magnet refurbishment and passed vacuum test
- ☑ Individual component thermal-vacuum test
- ☑ Individual component magnet field test
- ☑ DAQ & flight software initial integration test
- ☐ Detector final integration tests : on-going
- ☐ Payload environment test
- ☐ Hang test
- ☐ Ready for flight



Summary

HELIX is moving forward to be ready for the full integration test in 2021, and a flight in 2022 from Kiruna, Sweden!

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 tests are underway.