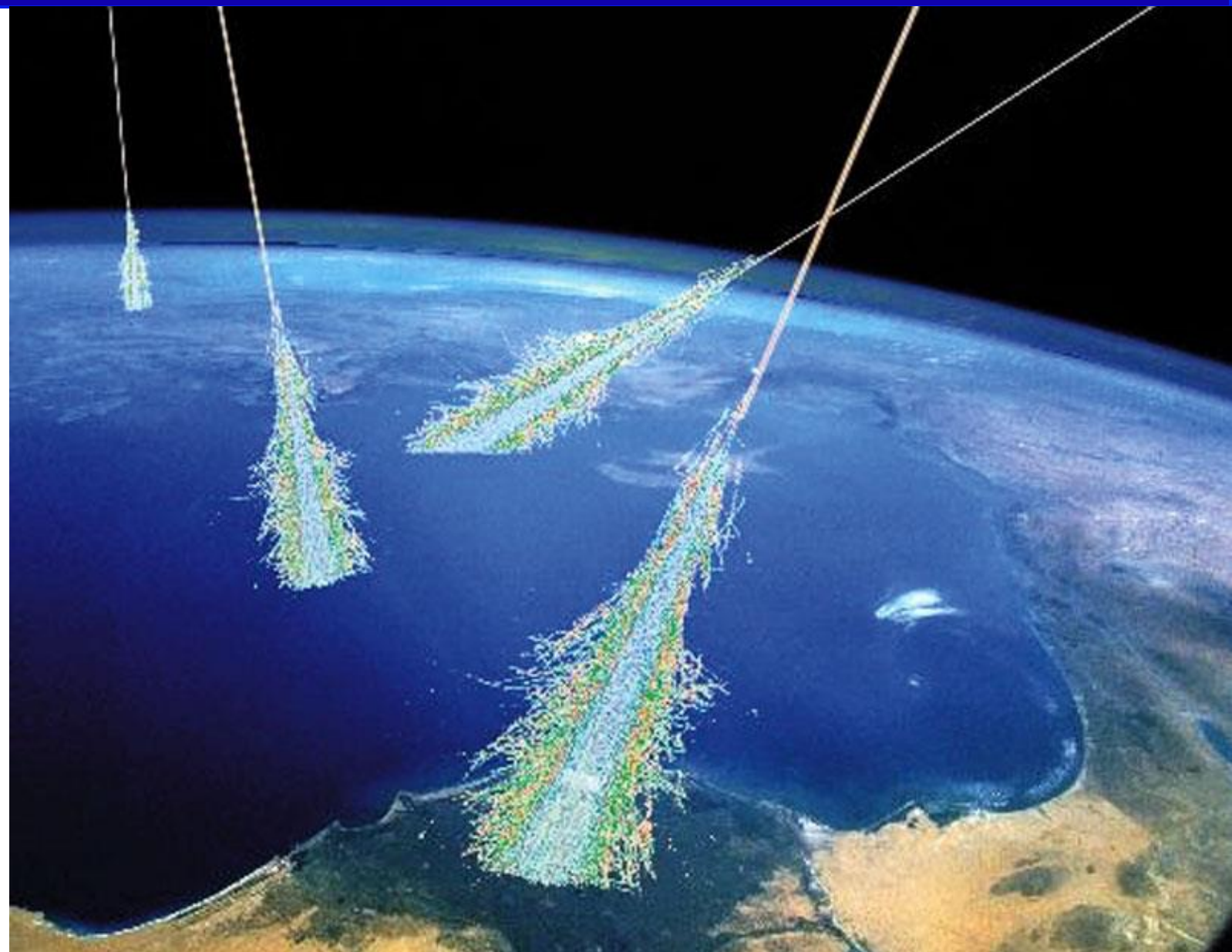
Hodoscope R&D for the High Energy Light Isotope eXperiment (HELIX)

Melissa Baiocchi

Queen's University

Cosmic Rays

- **High Energy Charged Particles**
- **Originating from space**
  - Mostly nuclei: 85% Protons, 12% Helium, 2% Heavy Nuclei
  - This distribution changes with energy



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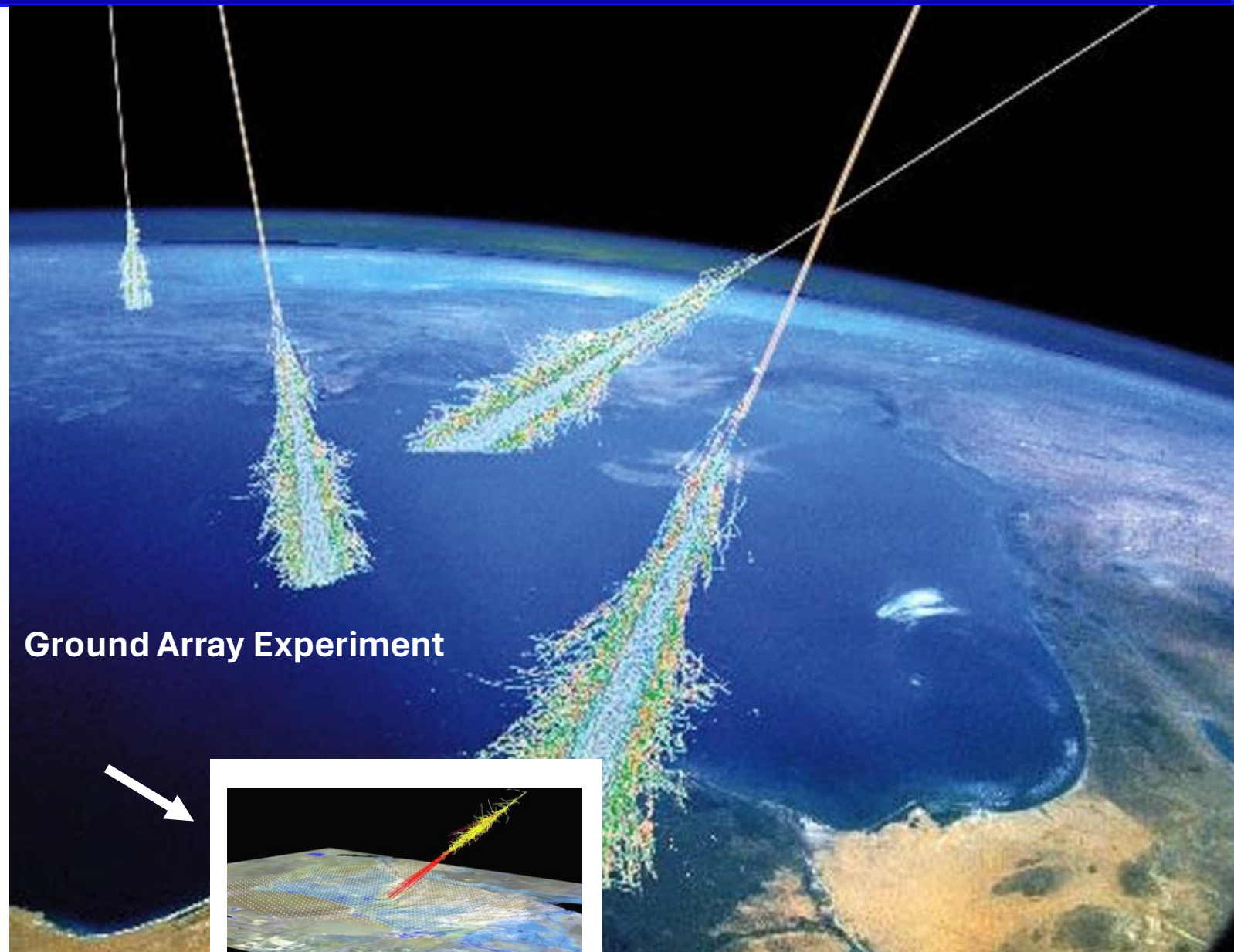

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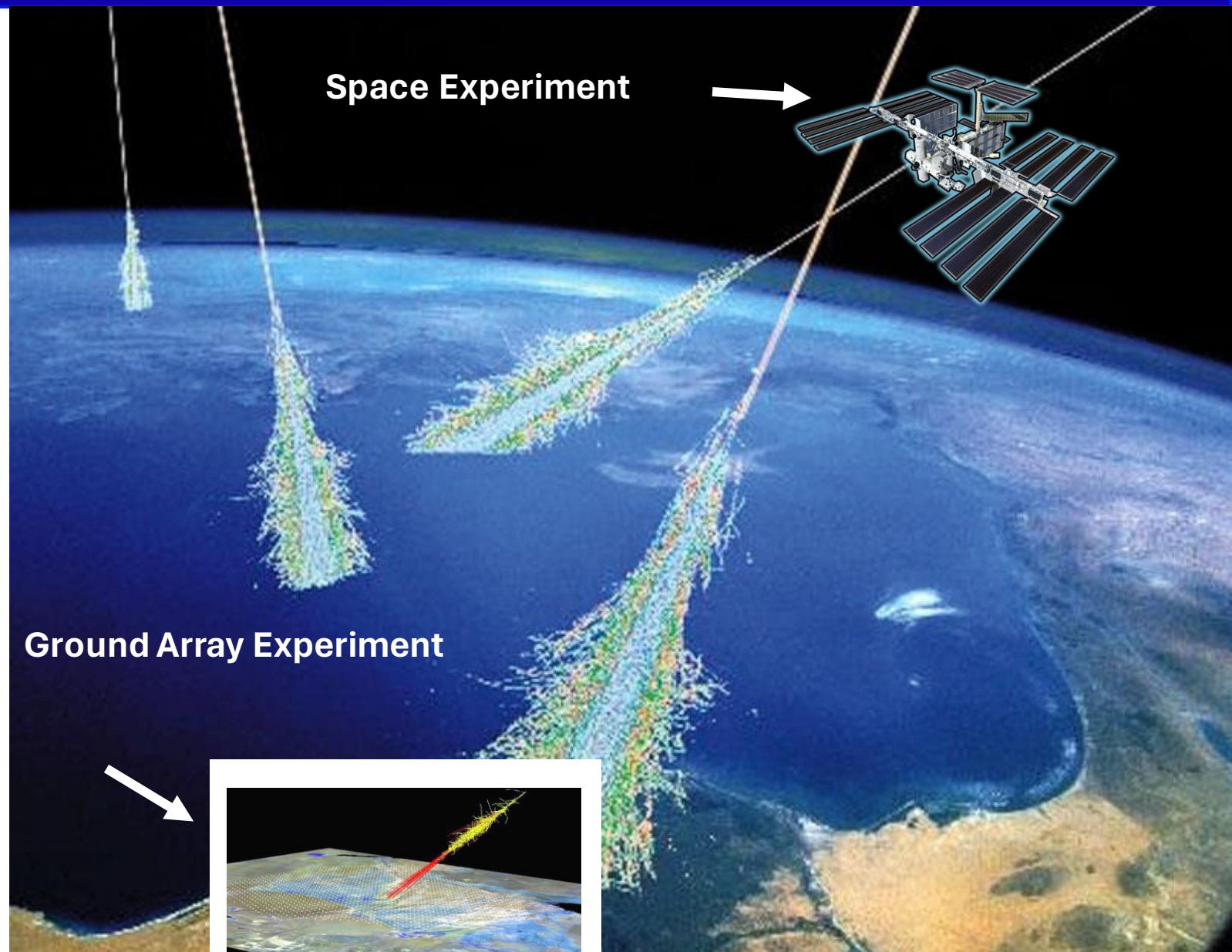

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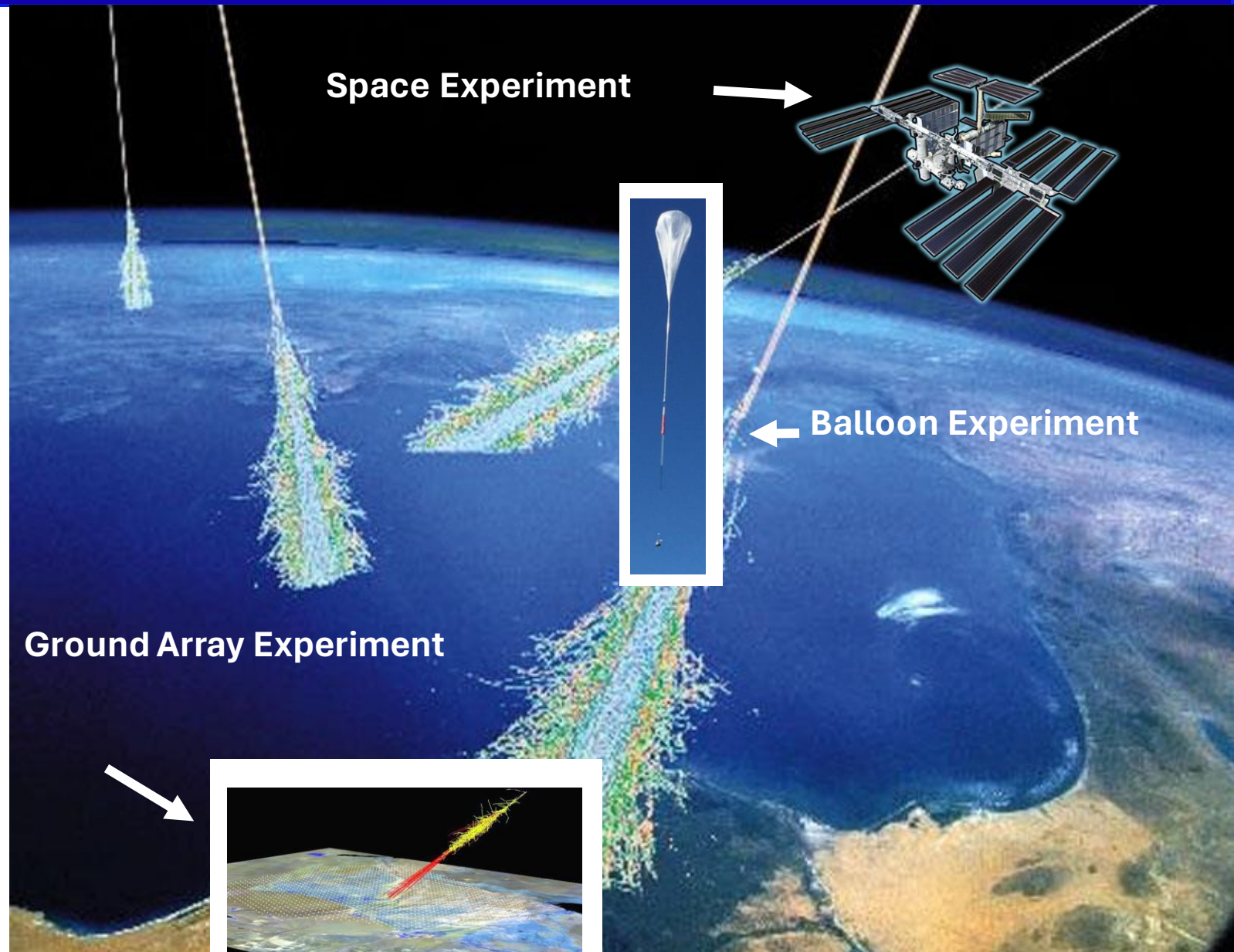


Scientific Motivation

- Every element present in our solar system is measured in CRs. Some elements are more abundant in CRs than in the solar system
- ^{10}Be is an unstable isotope of half-life 1.39 x 10^6 years, ^{9}Be is stable
- Quantifying the ^{10}Be/^{9}Be ratio of cosmic rays would help determine average lifetime of cosmic rays in our galaxy and provide strong constraints for current propagation models

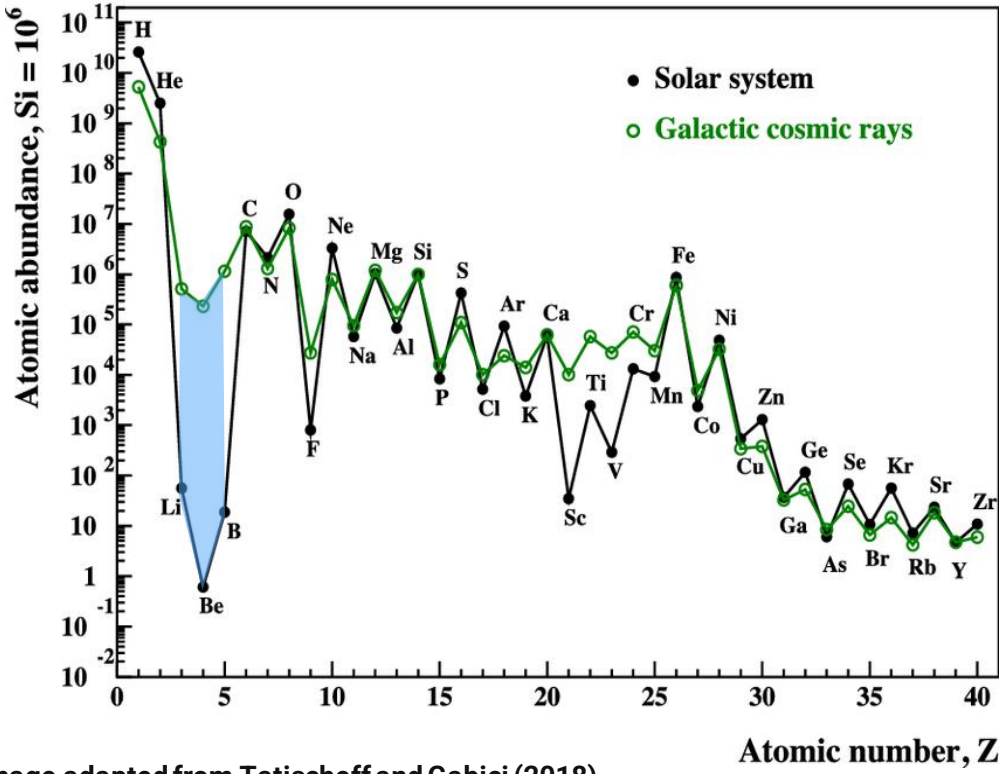
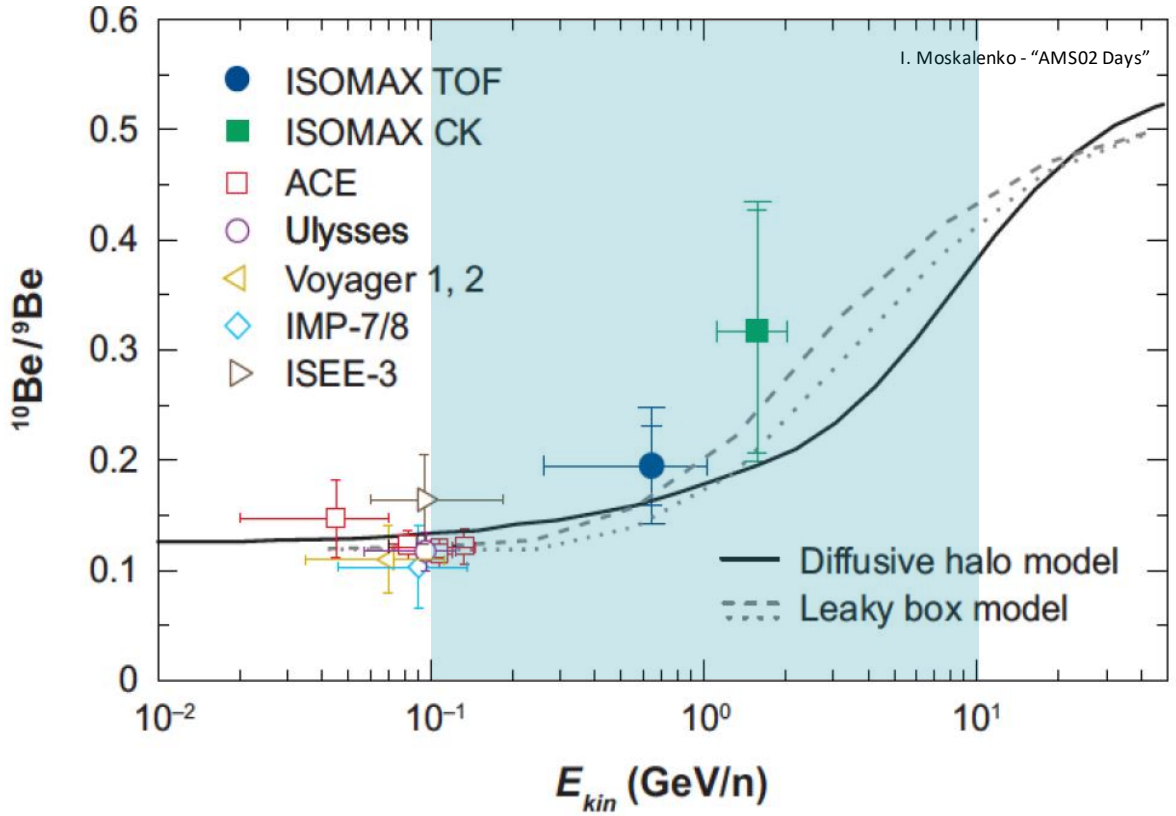


Image adapted from Tatischeff and Gabici (2018)



HELIX Collaboration

University of Chicago
- Hyebin Jeon, Rostom Mbarek, Keith McBride, Dietrich Muller, Kenichi Sakai, Scott P. Wakely

Indiana University
- Brandon Kunkler, Michael Lang, James Musser, Gerard Visser

McGill University
- David Hanna, Stephane O'Brien

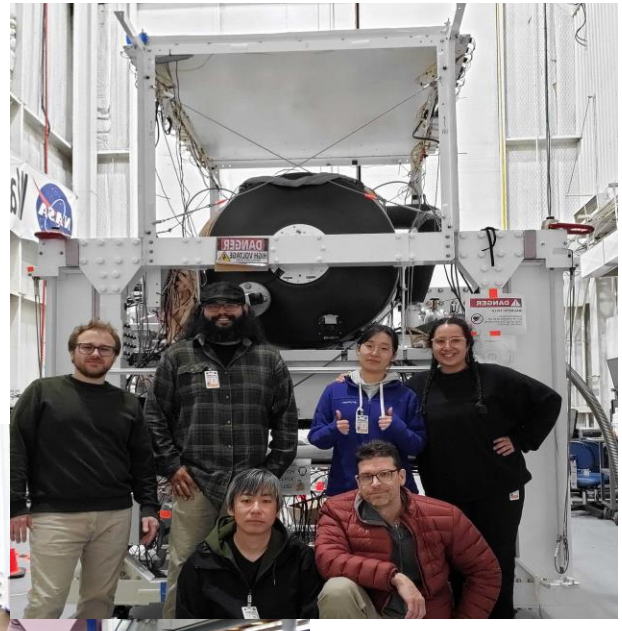
Northern Kentucky University
- Scott Nutter

Ohio State University
- Patrick Allison, James J. Beatty, Lucas Beaufore, Dennis Calderone

Pennsylvania State University
- Yu Chen, Stephane Coutu, Isaac Mognet, Monong Yu

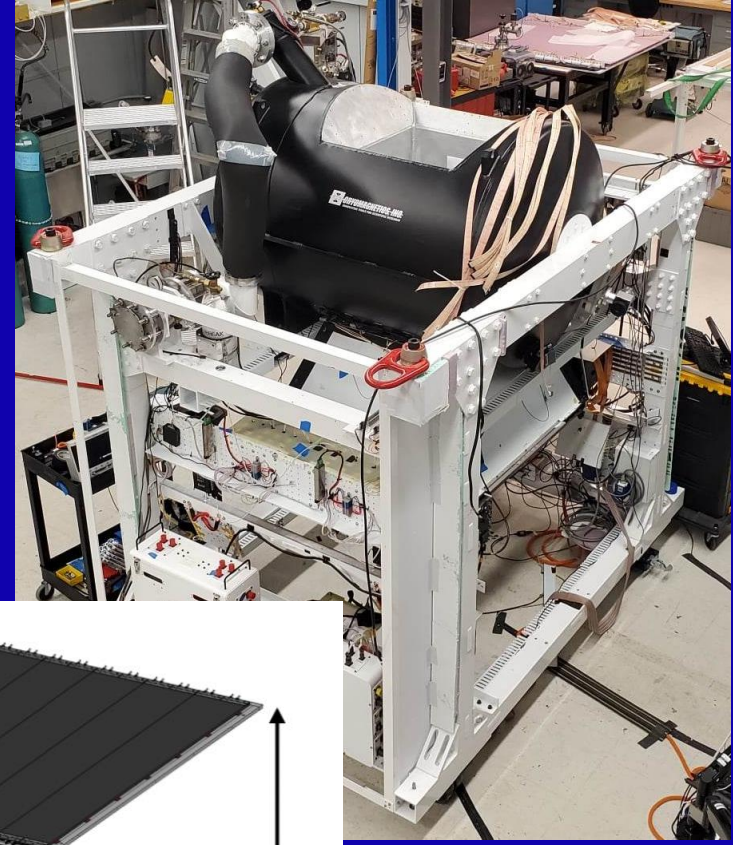
Queen's University
- Melissa Baiocchi, Avani Bhardwaj, Conor McGrath, Nahee Park

University of Michigan
- Noah Green, Gergory Tarle

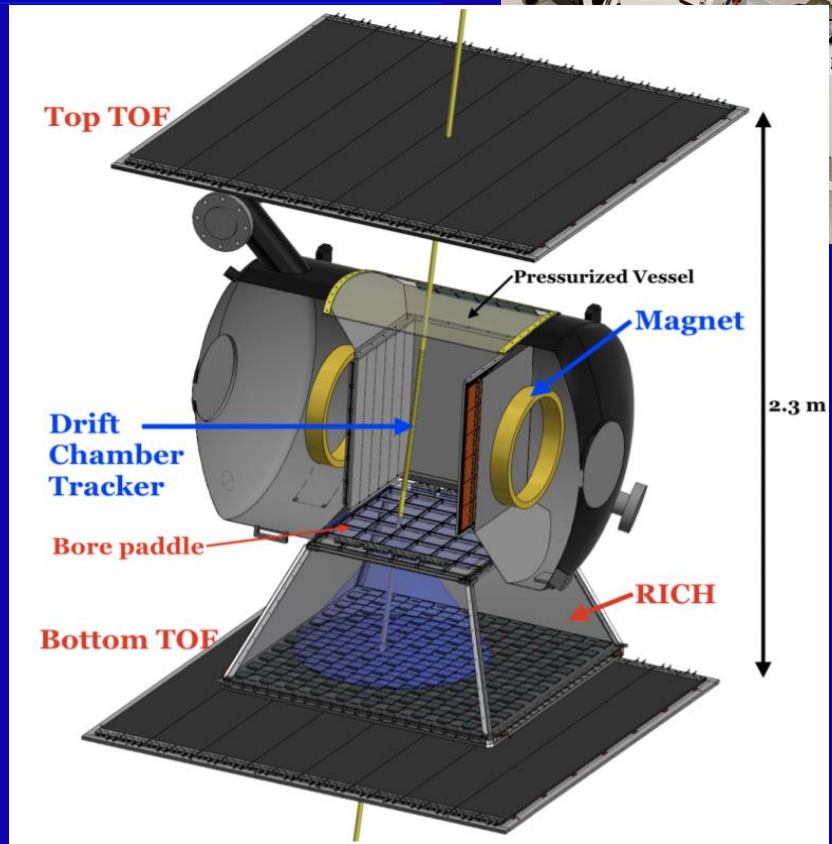


HELIX!

High Energy Light Isotope eXperiment

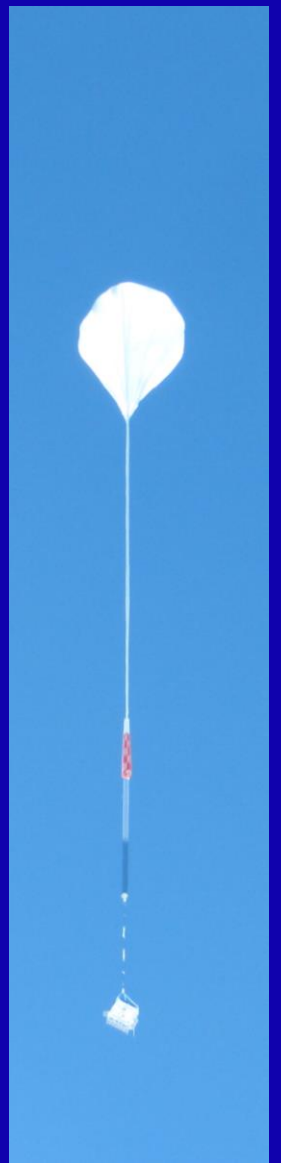


- A magnetic spectrometer to measure ^{9}Be and ^{10}Be masses and achieve mass resolution of 3%
- 1 T superconducting magnet
- A payload designed for a long-duration balloon flight
- Energy range: 0.1-3 GeV/nucleon → Stage 1 (first flight)



Challenges of Balloon Experiments

- Power: Only Solar Panels + Batteries
- Suspended Weight <2700 kg (To reach 40 km Alt.)
- Bandwidth limitation: High gain TDRSS: ~ 100 kbps
- Thermal limitation: Only conductive and radiative cooling
- **You cannot repair or modify apparatus after launch!**



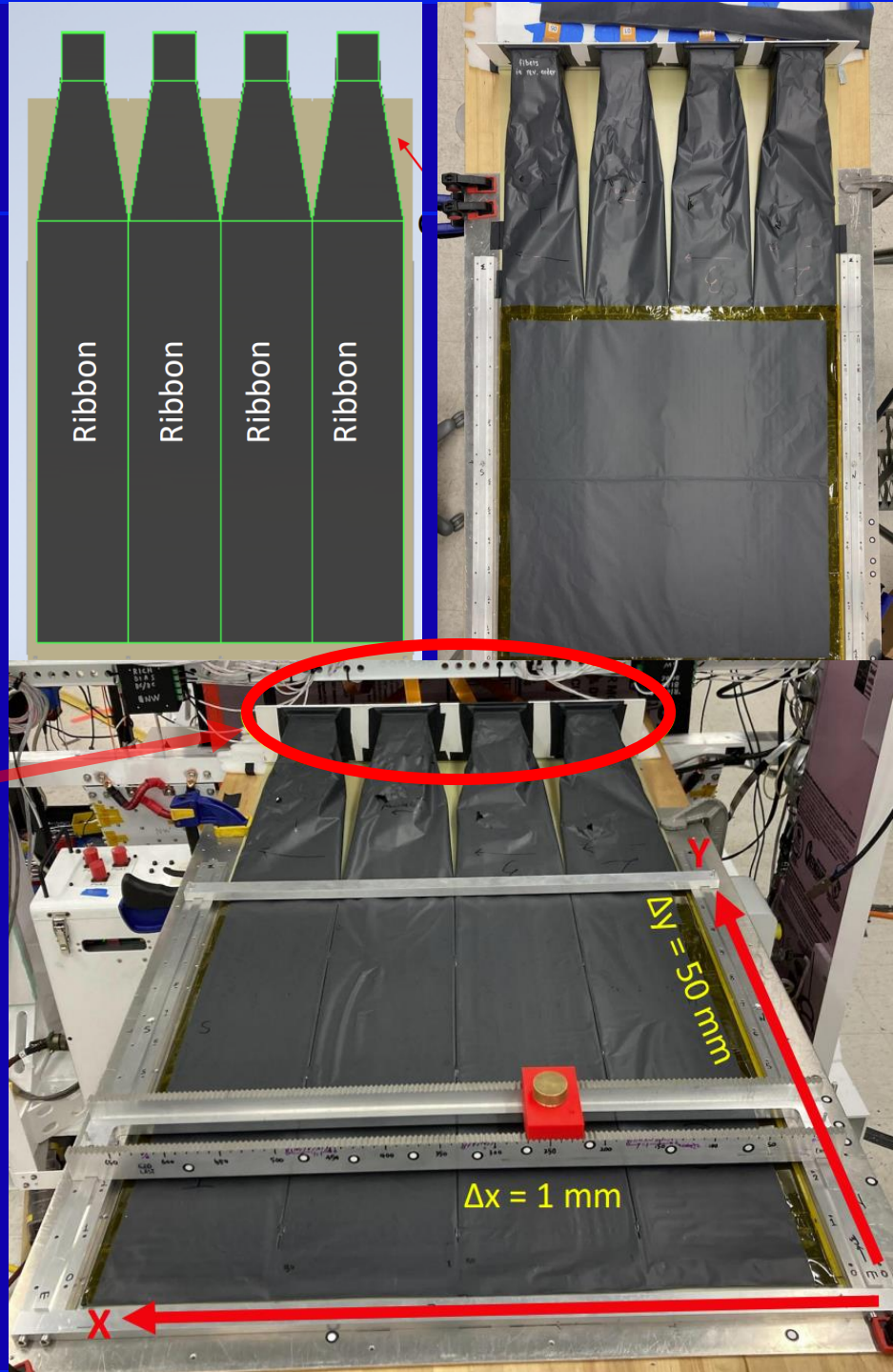
NASA's Goddard Space Flight Center Conceptual Image Lab/Michael Lentz

Hodoscope

- "Hodos" and "Skopos" → Path Observer
- Four flat bundles of scintillating 1 mm diameter fibres in parallel (1 axis)
- When charged particles pass through, fibres transmit light to the ends and are read out by SiPMs

HELIX First flight hodoscope:

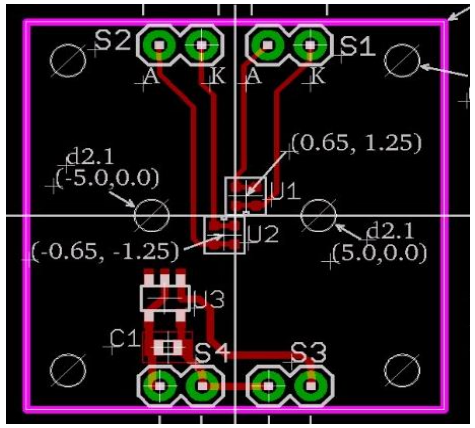
- Uses a fiber "weave" - limited by allowable fiber bend radius
- Multiple fibers read out by the same SiPMs
- Calibration set up shown to the right

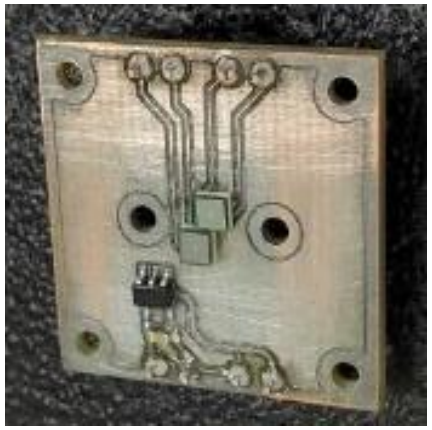


Hodoscope and Photos provided by Hyebin Jeon

Hodoscope Design Improvement Plan

- No fibre weaving
- Each fibre optically connected to its own SiPM
- Combining signals from multiple SiPMs electronically

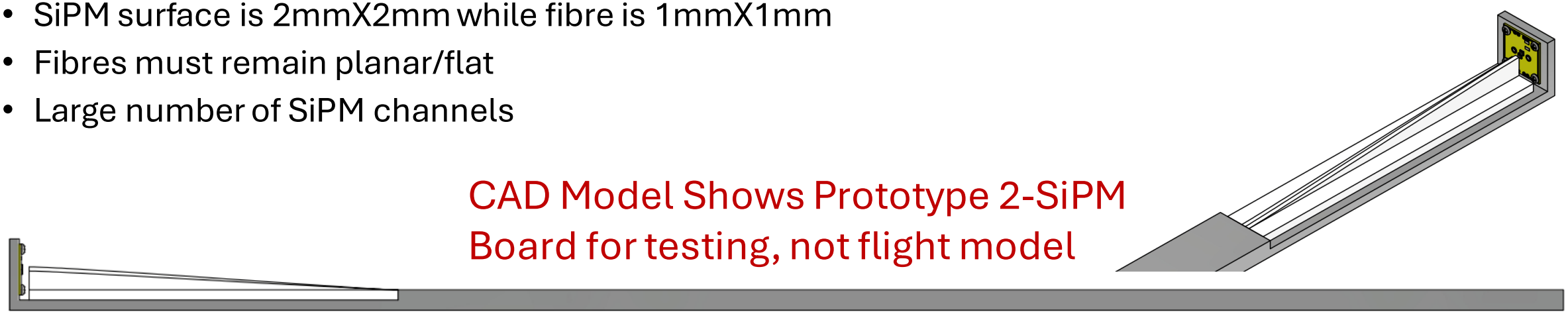




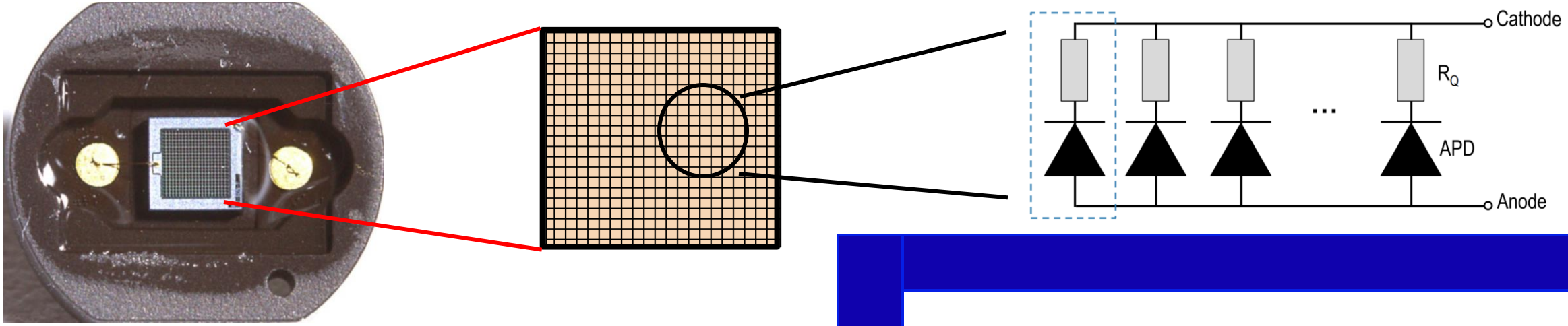
Challenges:

- Fibres: no bending <100 mm D
- SiPM surface is 2mmX2mm while fibre is 1mmX1mm
- Fibres must remain planar/flat
- Large number of SiPM channels

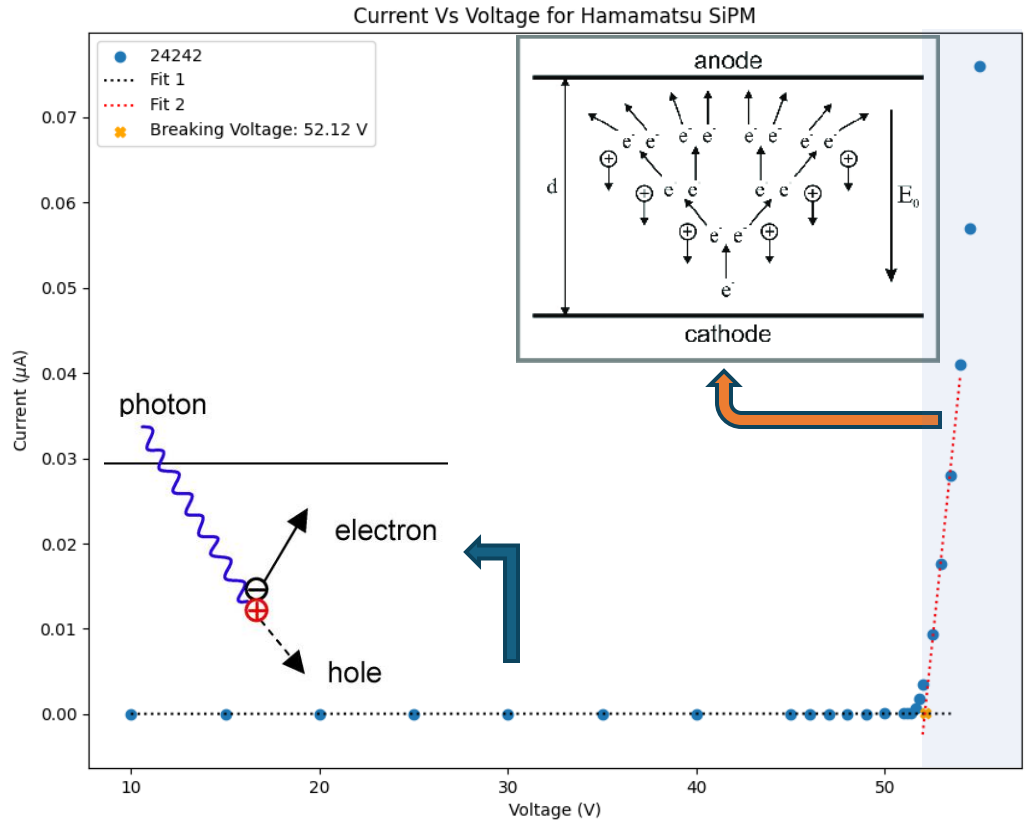
CAD Model Shows Prototype 2-SiPM Board for testing, not flight model



The Goal is to improve hodoscope step by step while checking the design!



SiPMs (MPPC) © Hamamatsu

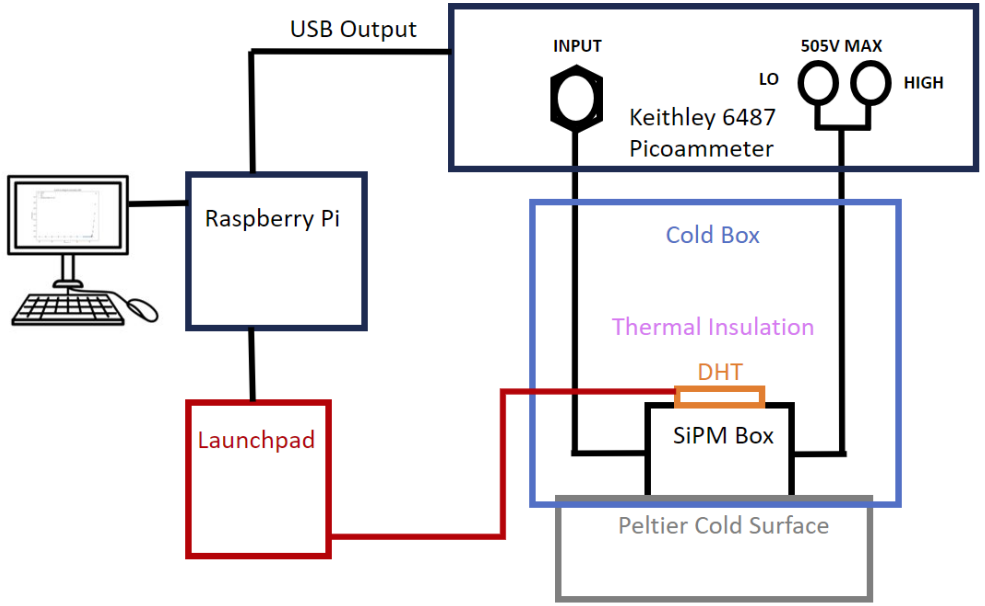


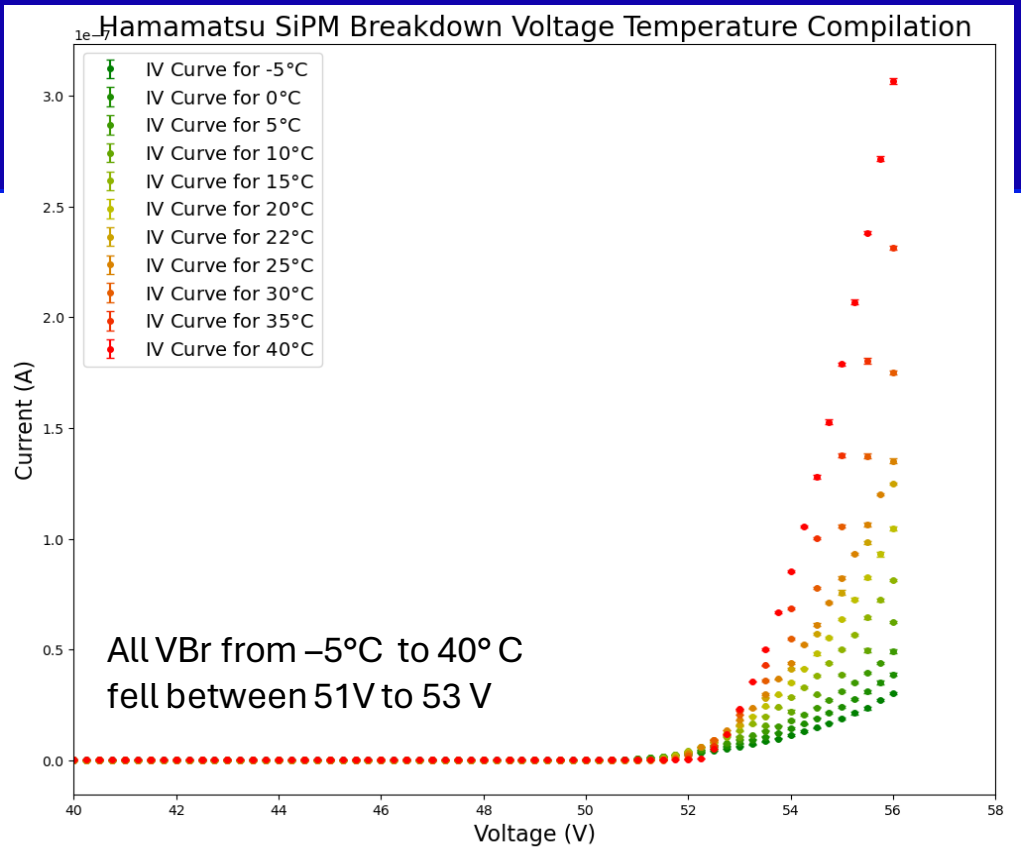
SiPMs!

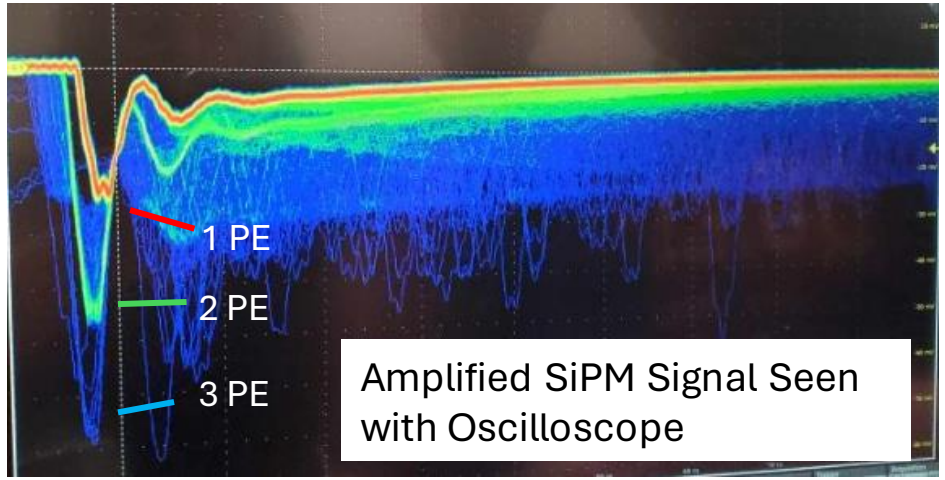
- Silicon Photo-Multipliers
- Each pixel is an avalanche photo-diode
- SiPMs are efficient in a high magnetic field!

Characterizing SiPMs

- Use temperature dependent IV-Curve measurement to find breakdown and operating voltage
- Amplify Signal!
- Get photo-electron spectrum (dark counts in this case)





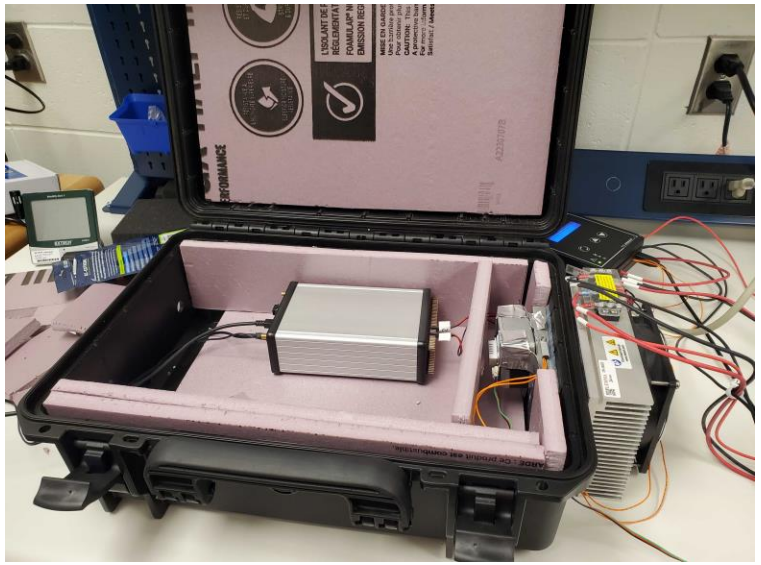


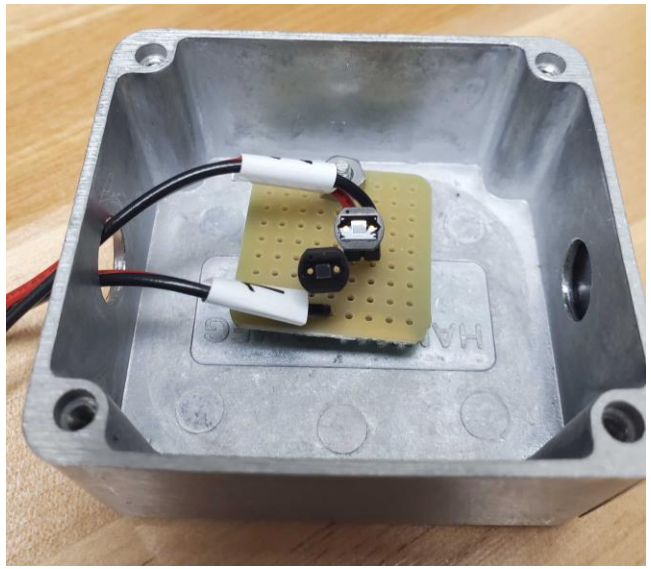
(Shockingly) No SiPMs were harmed in the collection of this data

The CAEN CITIROC

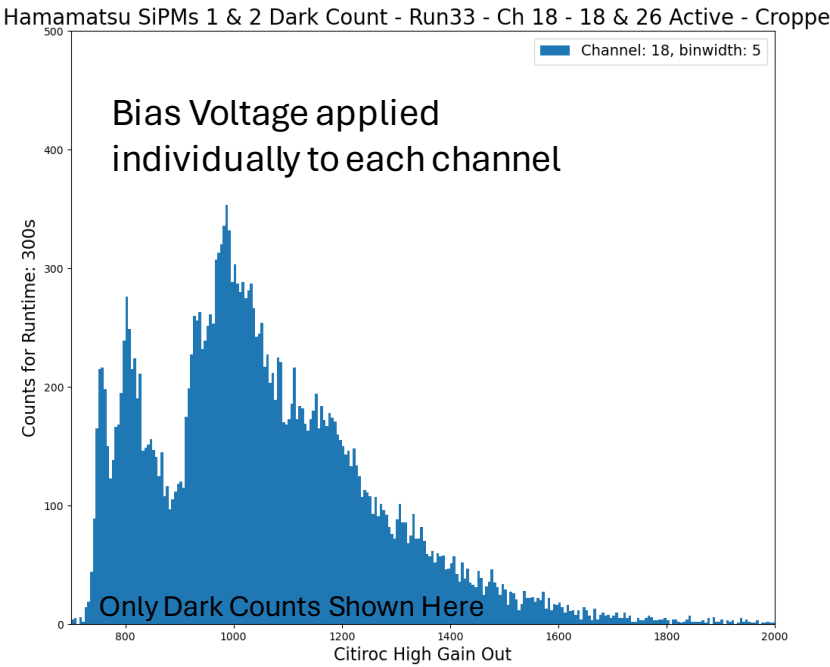
For all your hodoscope readout needs

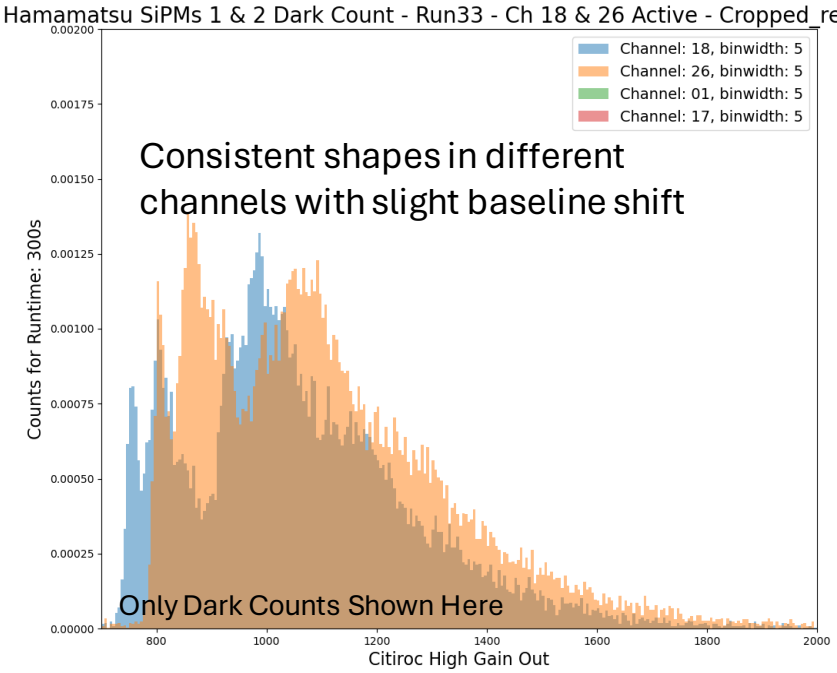
- 64 Channels for Measuring SiPMS!
- We need to optimize our data without full pulses!
- CITIROC is currently in use for hodoscope and RICH and working well!
- **CITIROC is compact and has low power consumption!**





2 SiPMs (in box) connected to Citiroc, cooled down to 10°C





Summary & Project Outlook

- A new HELIX hodoscope prototype is being designed and tested at Queen's!
- The design will use custom made SiPM boards, scintillating optic fibres and multiple custom CITIROC ASIC chips for read-out

Next Steps:

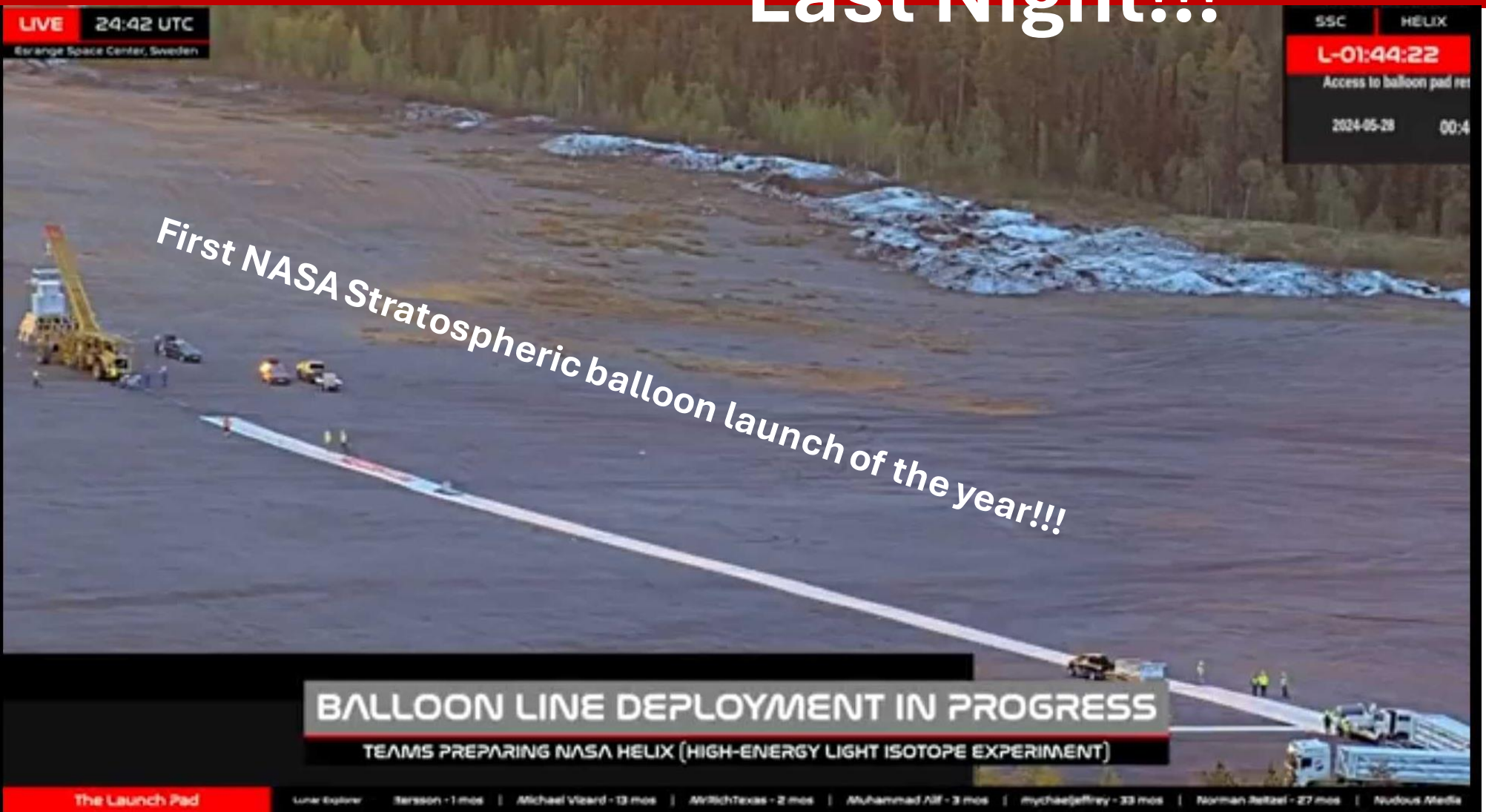
- Building jig to test optical coupling
- Combining electrical signals and calibrating hodoscope
- If successful, the new hodoscope will be on the next HELIX flight out of Antarctica!

HELIX to Launch Soon Out of Kiruna, Sweden!

HELIX HAS LAUNCHED!!!!!

HELIX to Launch ~~Soon~~ Out of Kiruna, Sweden!

Last Night!!!



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Thank You!
Merci!

https://www.youtube.com/live/r1cZiLHMxNQ?si=xyl2lmDRbqQ5wYR_&t=25290

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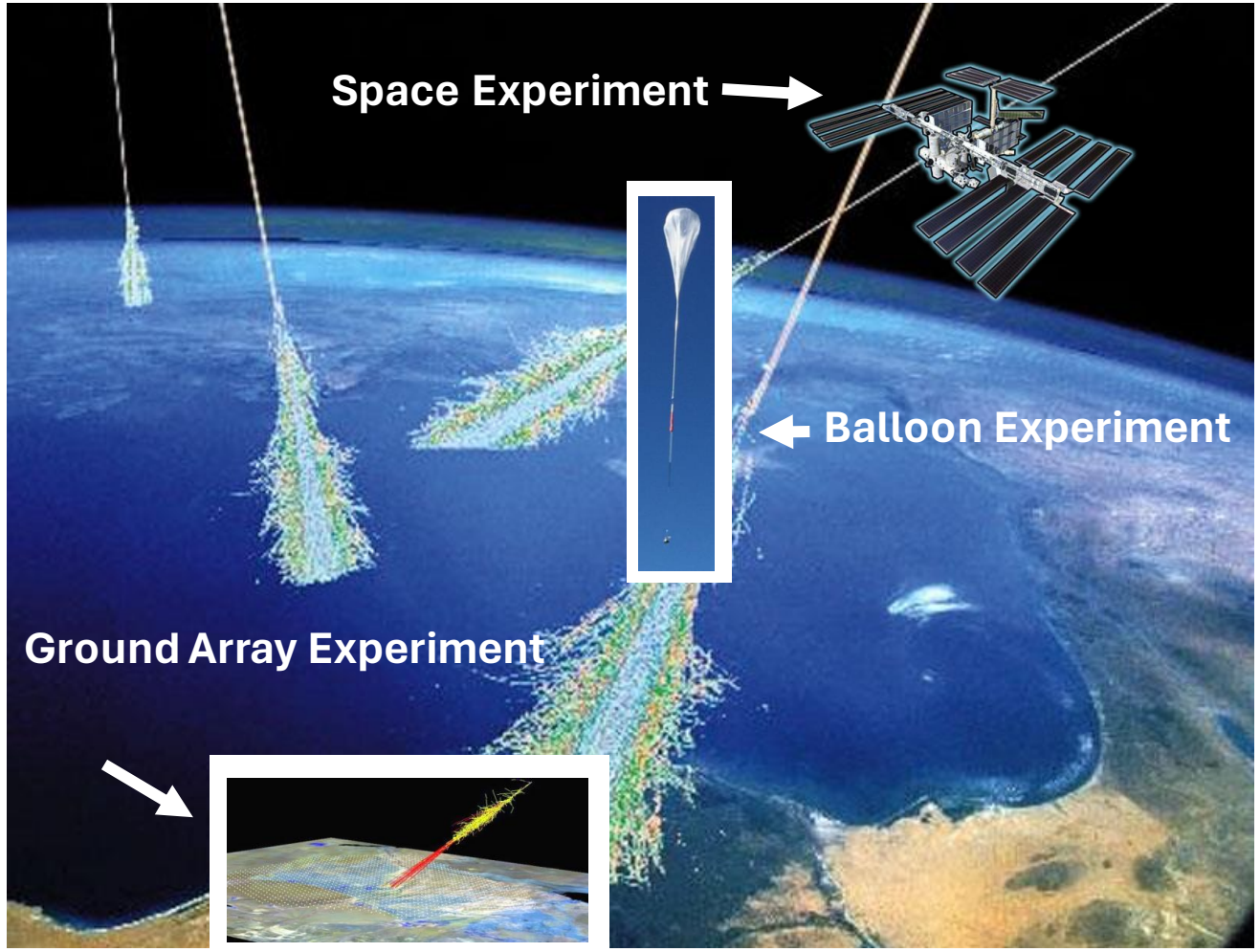

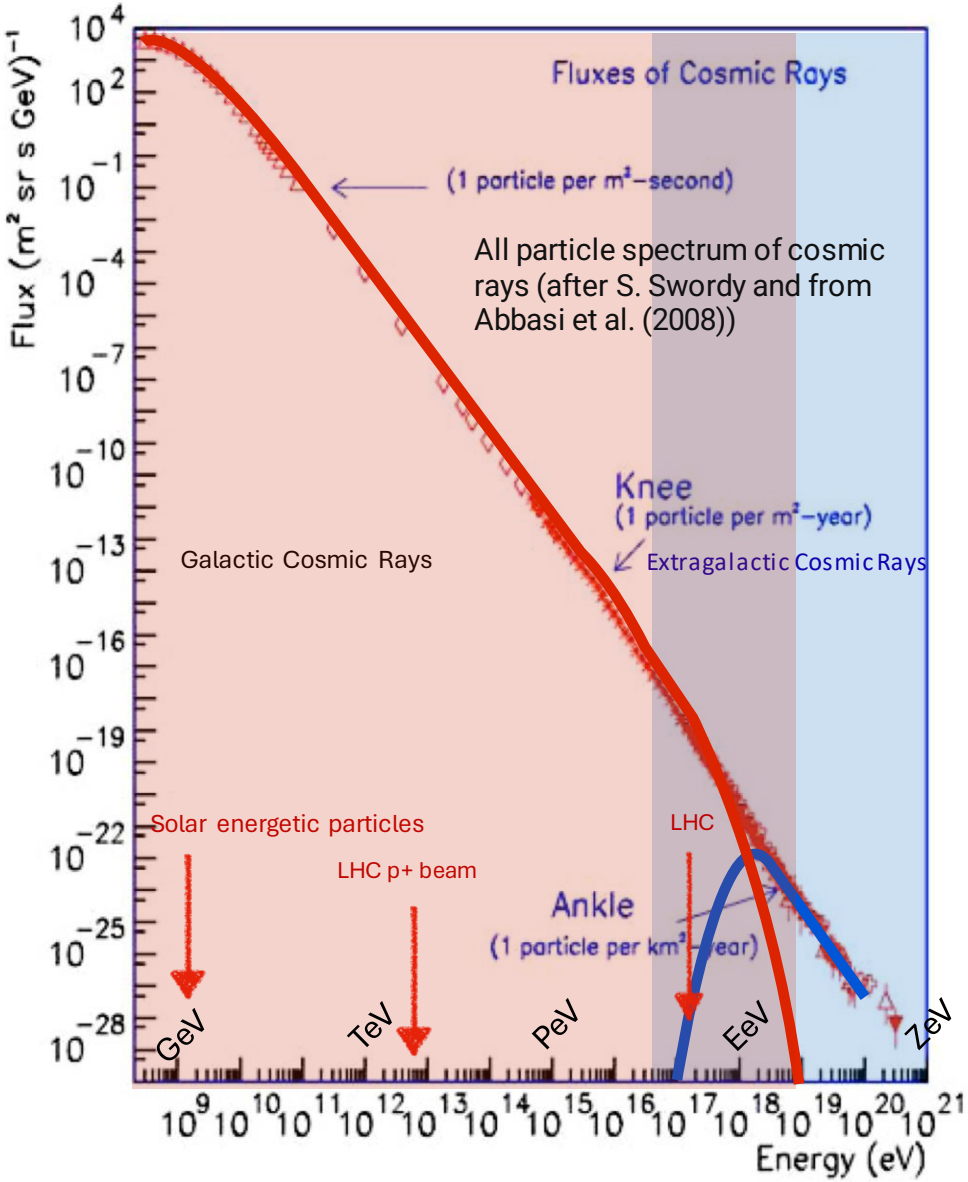

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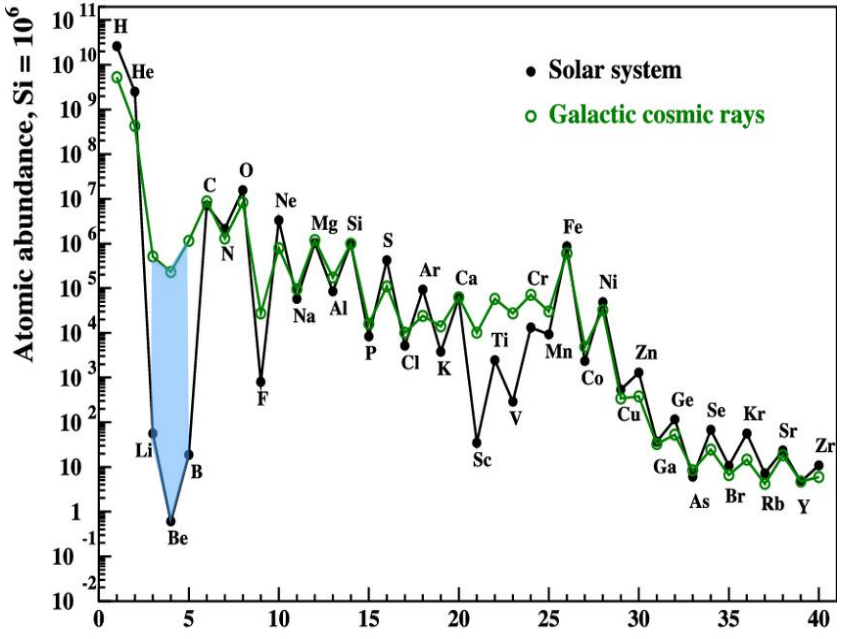

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