Towards New Cosmic Ray and Neutrino Measurements with Balloon-Borne Detectors

Keith McBride
University of Chicago
Grainger Fellow

My introduction to Prof Jim Beatty's lab

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Cosmic radiation, 1912

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- 100 years later, still use balloon-borne experiments

ANtarctic Impulsive Transient Antenna (ANITA –IV)

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ANITA searches for ultrahigh energy ($>10^{18}$ eV) neutrinos in the Antarctic ice

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- Some things are different
  - We don't put people on the balloons anymore
  - Helium gas instead of Hydrogen

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  - Helium gas instead of Hydrogen

→Jim said "Keith, take some shifts monitoring the payload while its in the air"

ANtarctic Impulsive Transient Antenna (ANITA –IV)

Launched Dec 2016

ANITA searches for ultrahigh energy (>10^{18} eV) neutrinos in the Antarctic ice

I learned things like

I learned things like

Voltage on the solar panels never changed

Science TM Display 675N Comm1 TDRSS 18:45:44

PV_V_MEAS (Analog #1):	66.16	VOLTS
PV_I_MEAS (Analog #2):	6.08	AMPS
+24V_V_MEAS (Analog #3):	26.35	VOLTS
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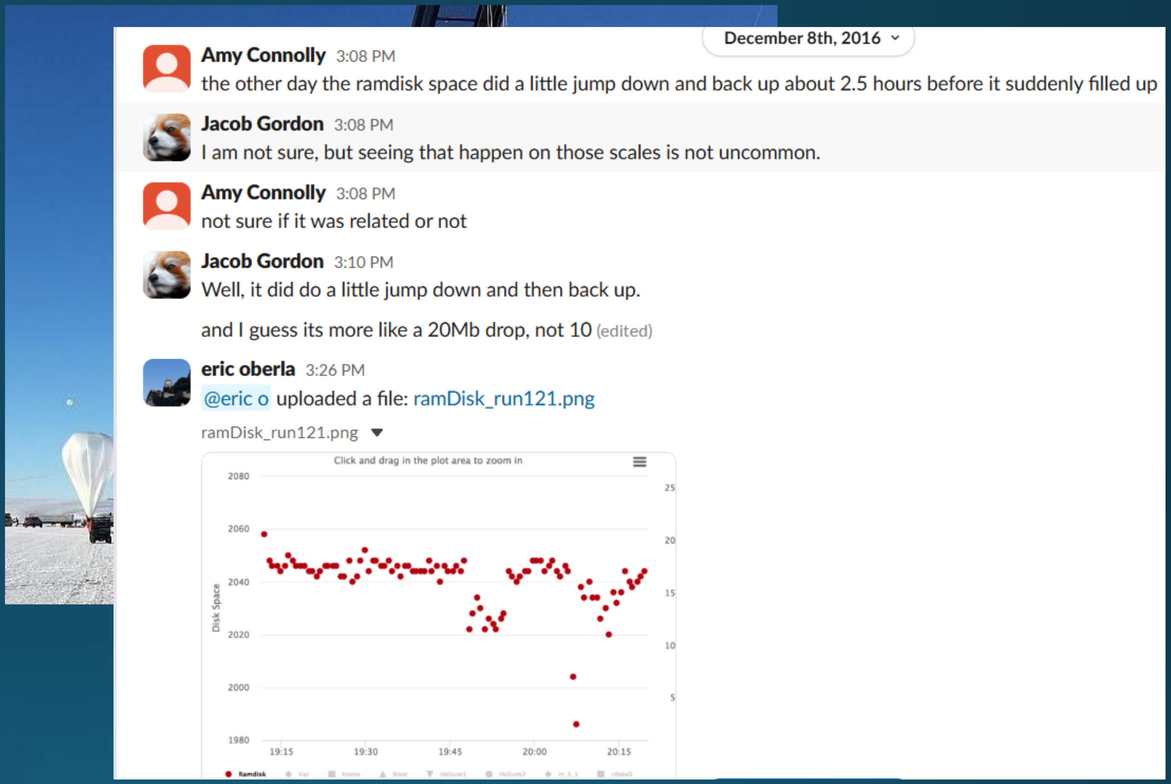
Writing data to hard drives was important to everybody



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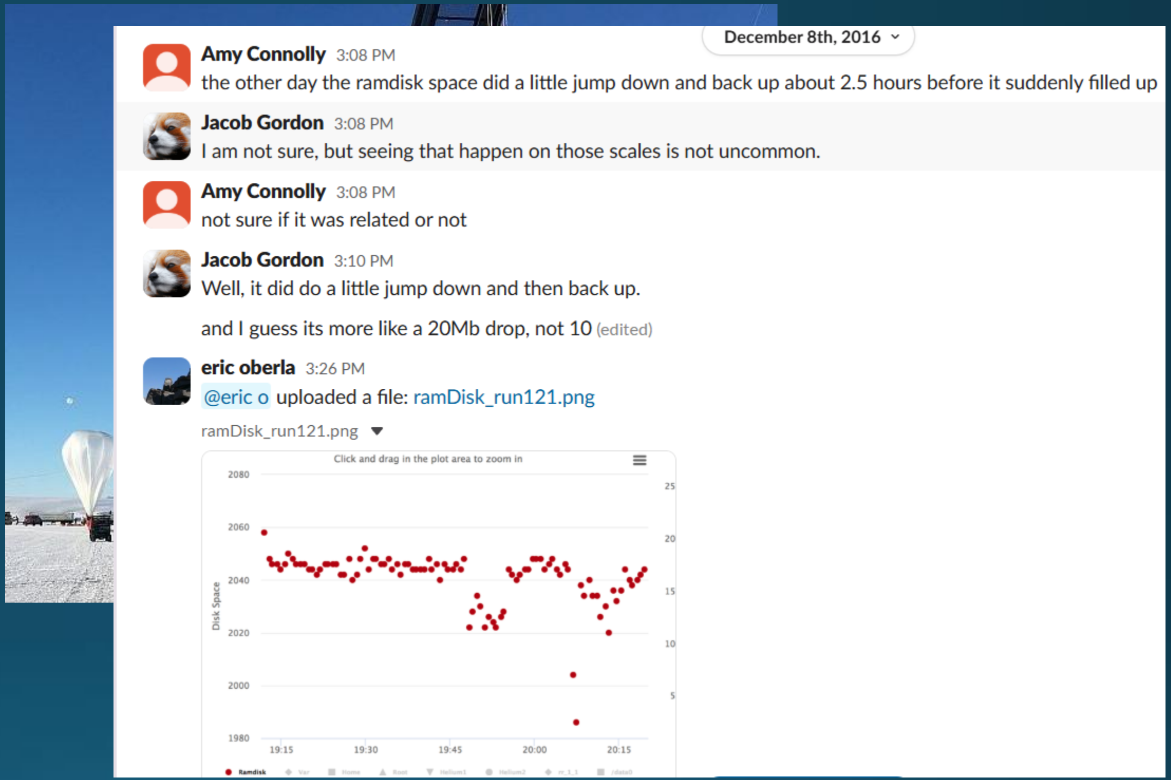


December 8th, 2016

Amy Connolly 3:08 PM
the other day the ramdisk space did a little jump down and back up about 2.5 hours before it suddenly filled up

Jacob Gordon 3:08 PM
I am not sure, but seeing that happen on those scales is not uncommon.

Amy Connolly 3:08 PM
not sure if it was related or not

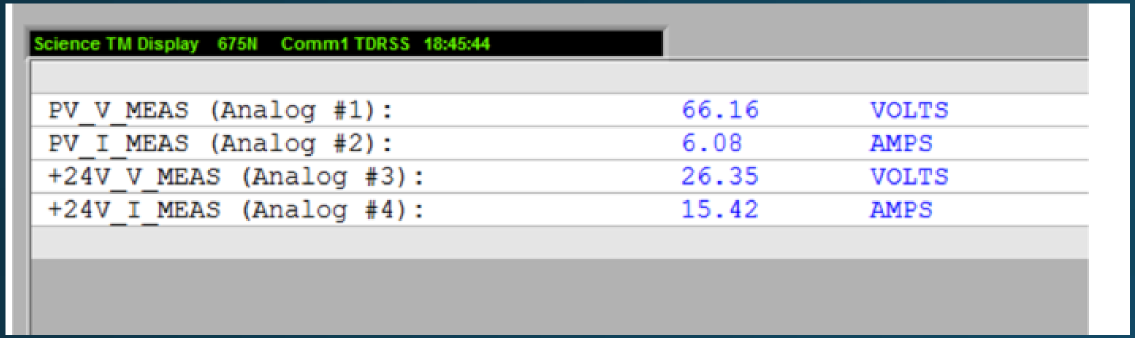
Jacob Gordon 3:10 PM
Well, it did do a little jump down and then back up.

and I guess its more like a 20Mb drop, not 10 (edited)

eric oberla 3:26 PM
@eric o uploaded a file: ramDisk_run121.png

ramDisk_run121.png

Voltage on the solar panels never changed



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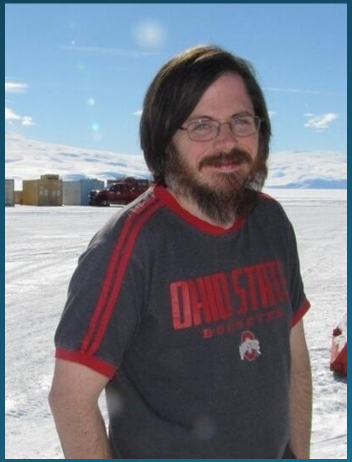

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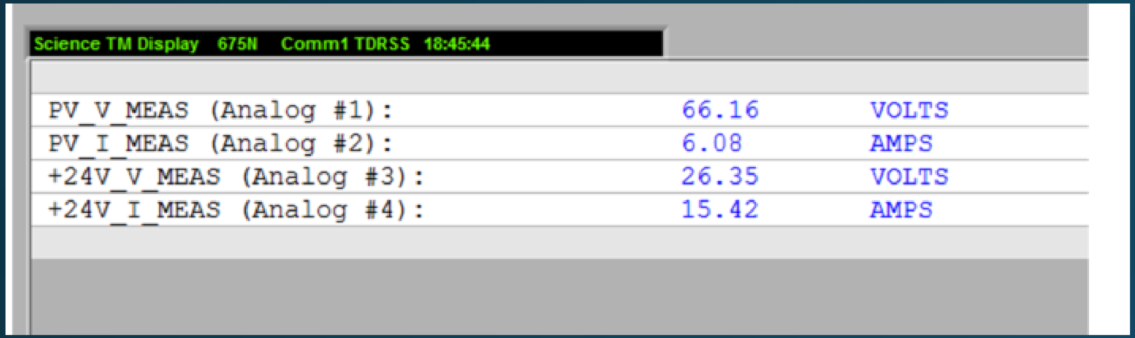

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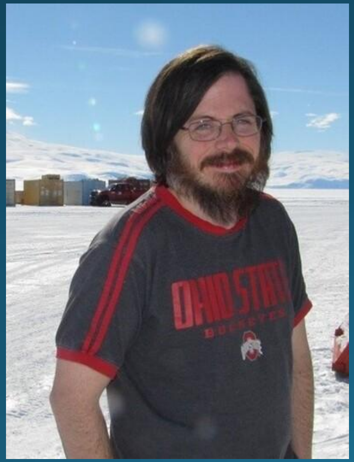

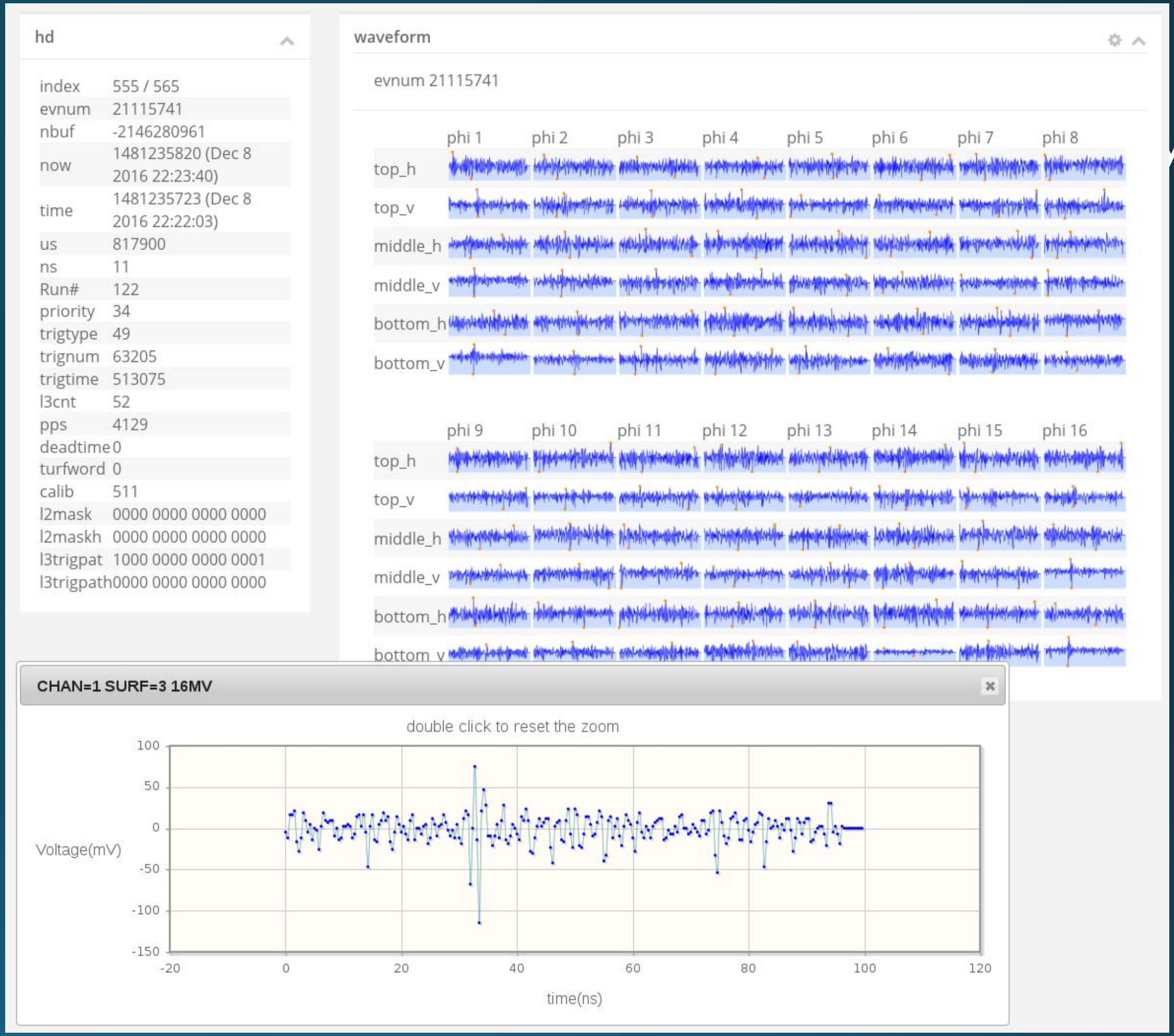

After looking at ~20 events of waveforms/radio data, I found no neutrinos.

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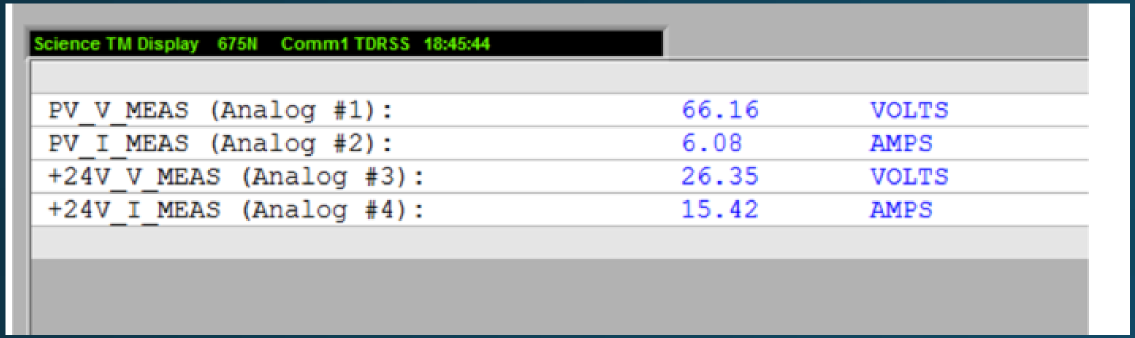

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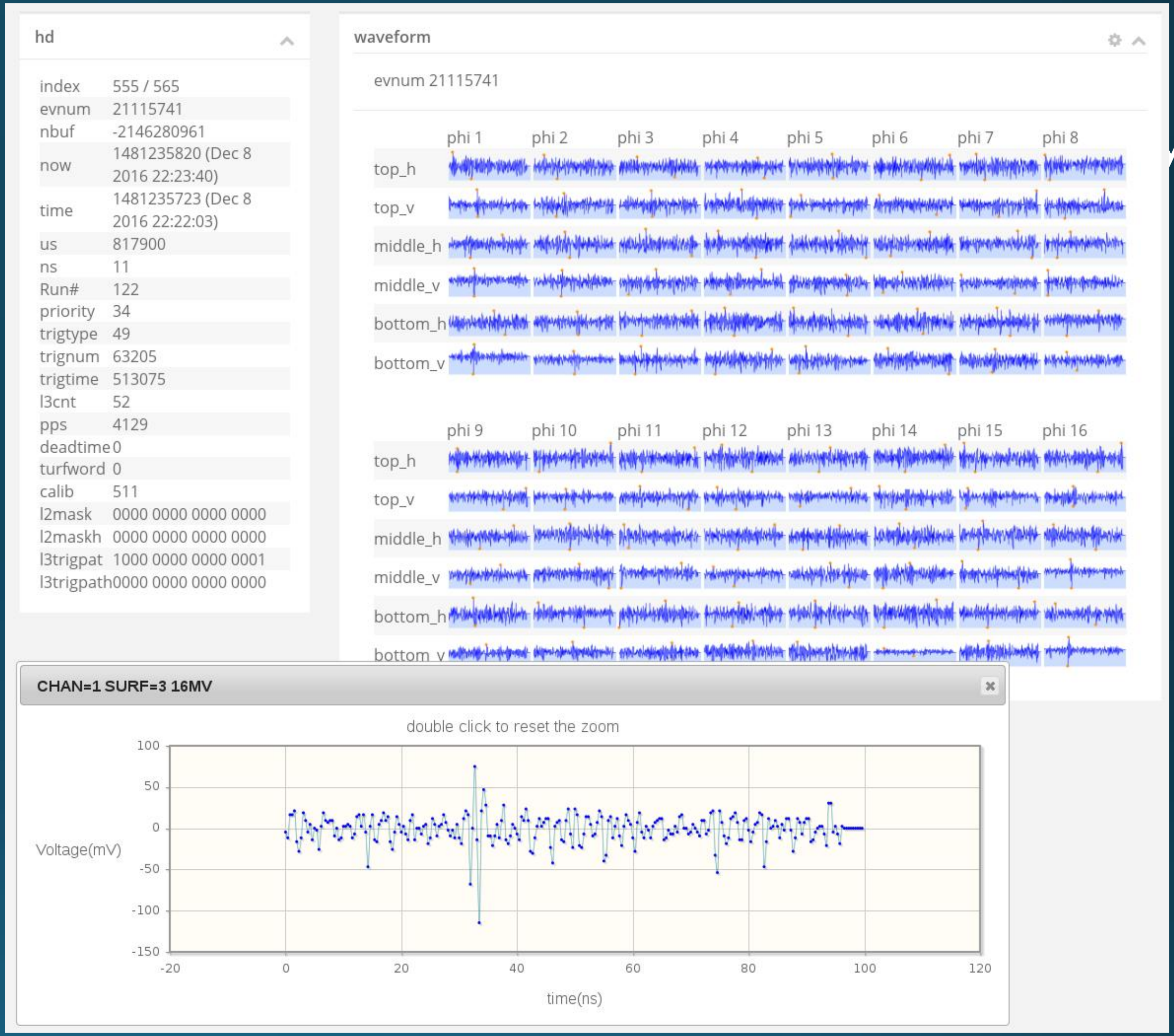

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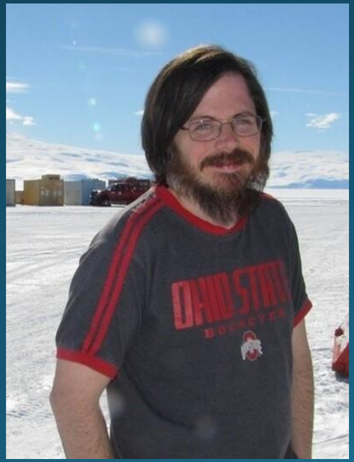
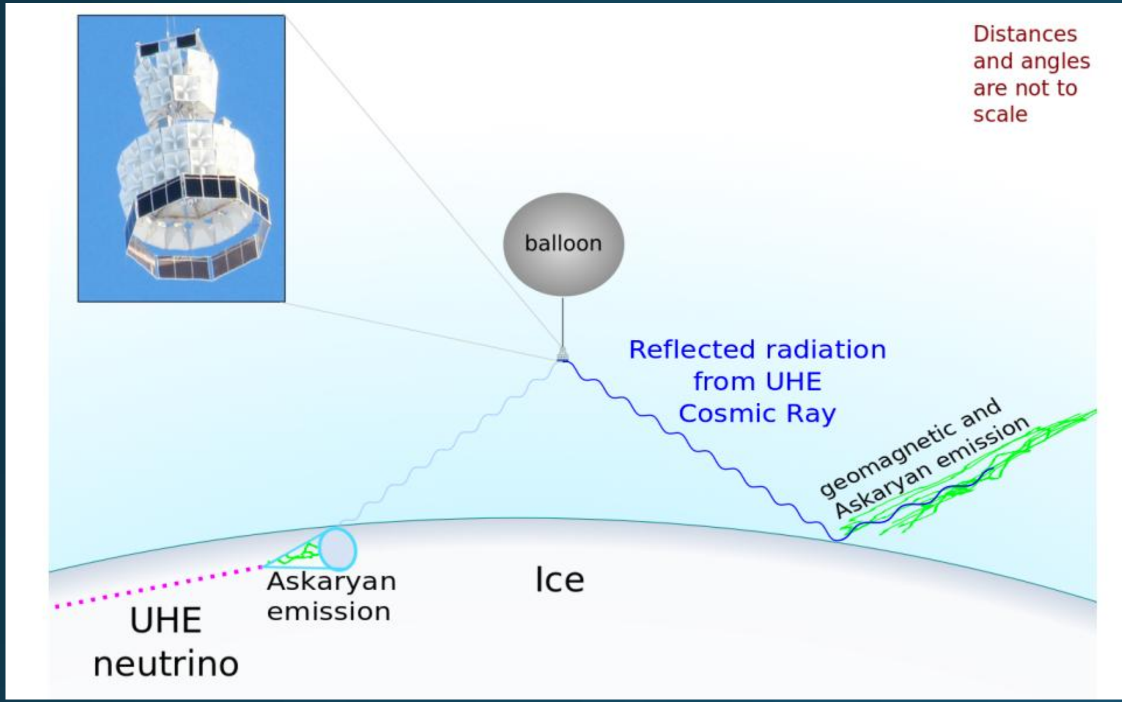


After looking at ~20 events of waveforms/radio data, I found no neutrinos. There were ~100 million triggers…

Early grad student project

Early grad student project



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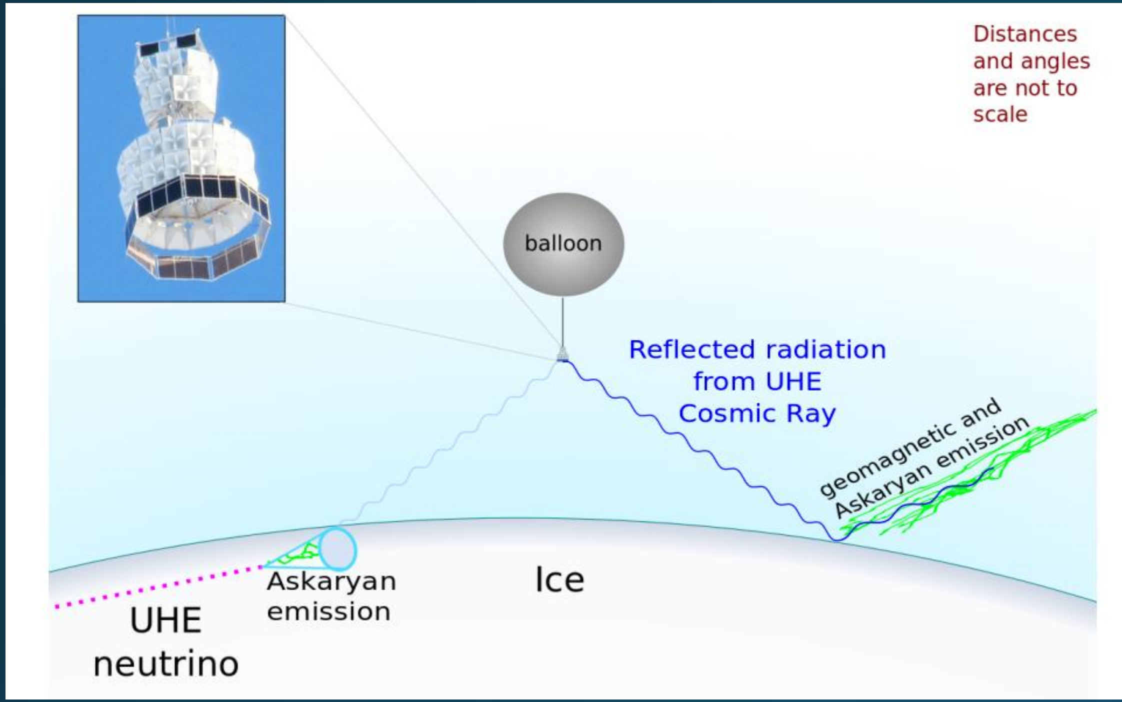


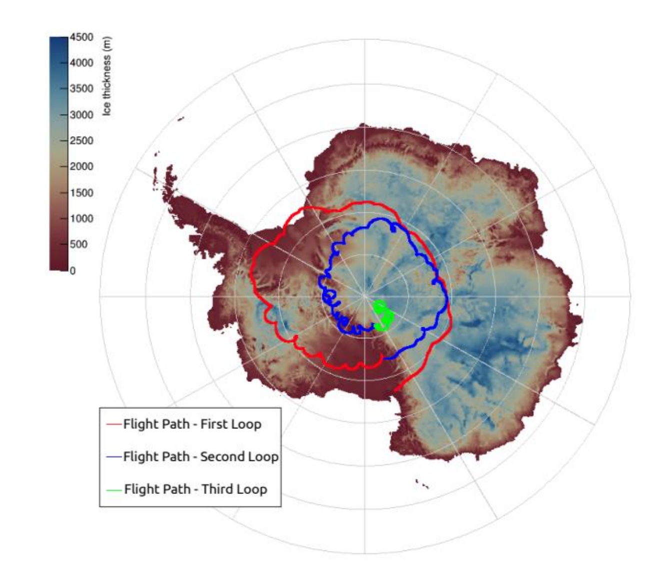
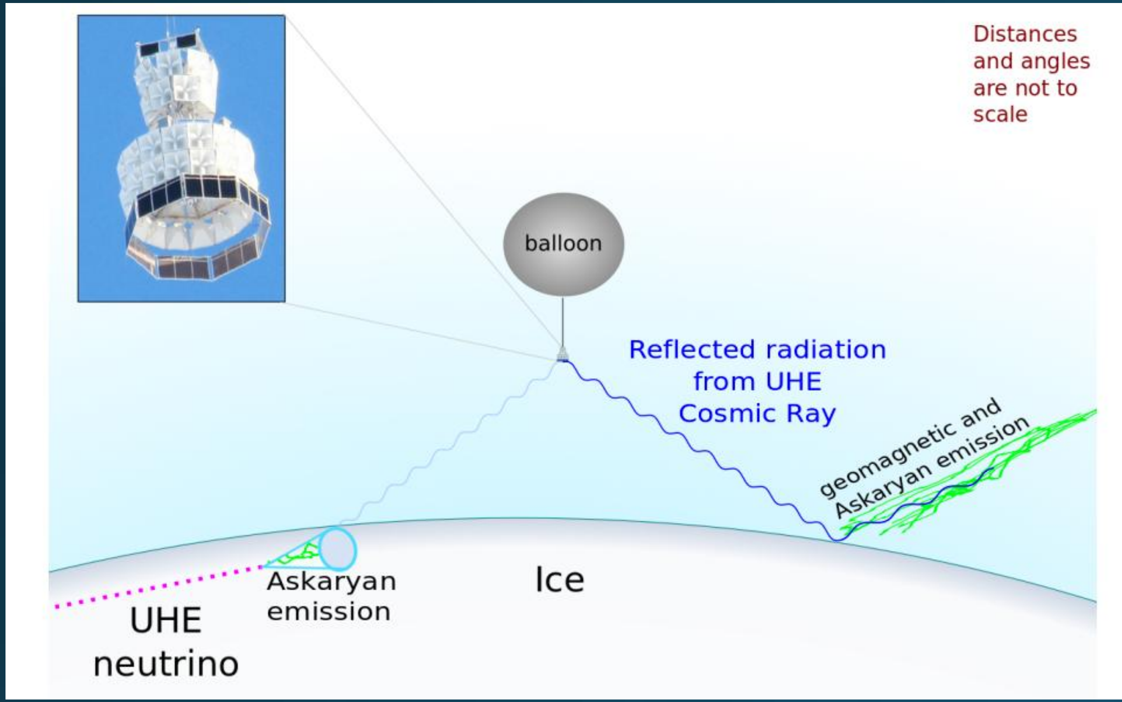
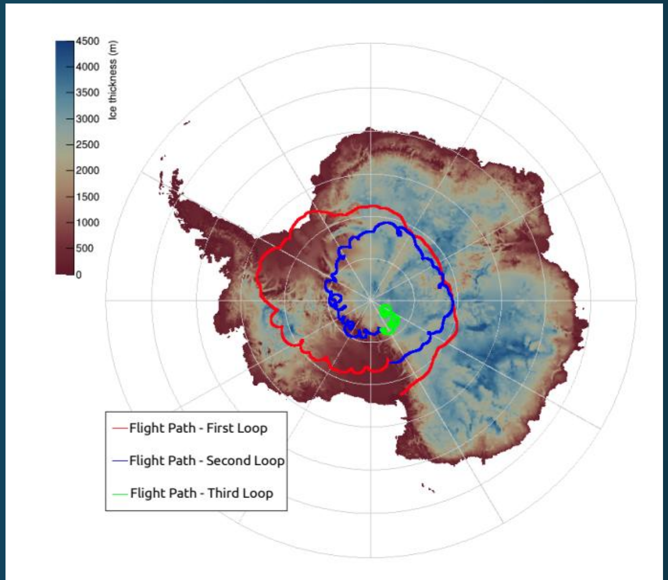


FIG. 3: The ANITA-IV flight path. The flight began at McMurdo Station and made two full passes around the continent, before landing near South Pole Station.

Early grad student project



Dr. Oindree Banerjee



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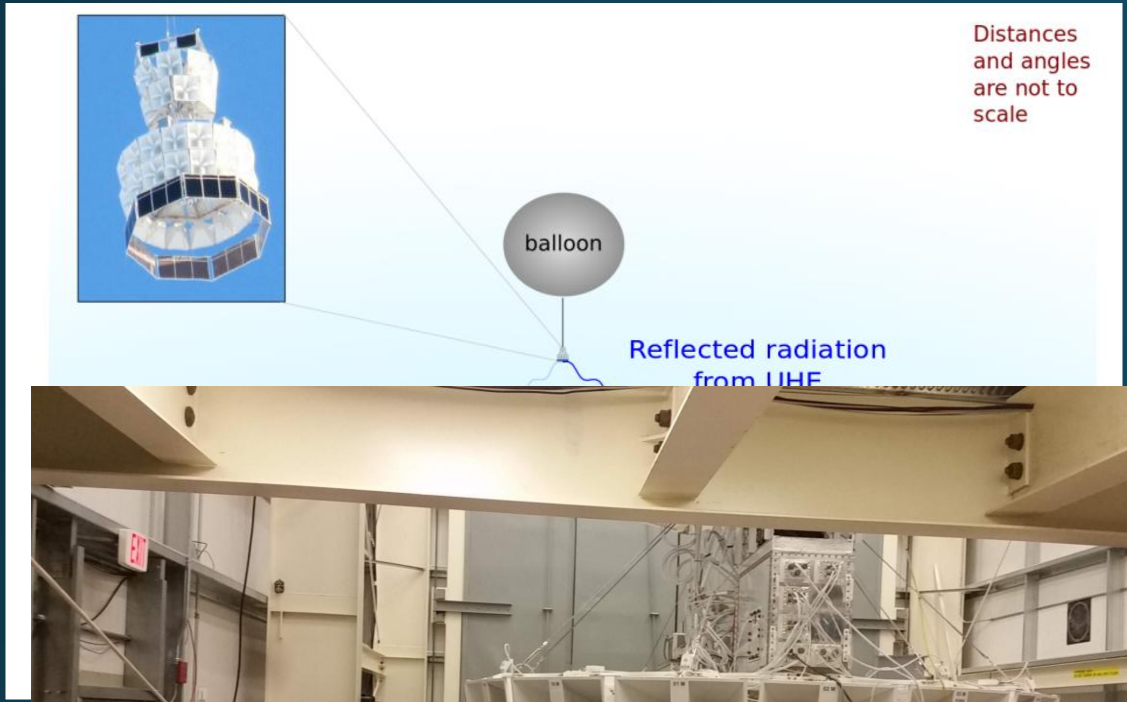

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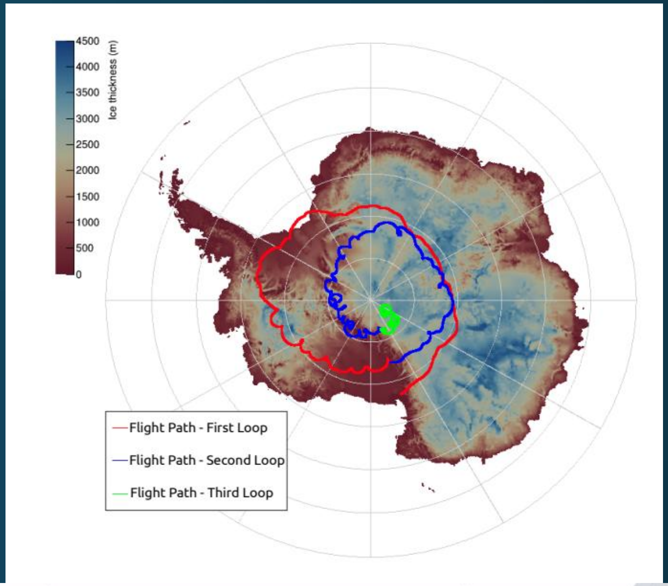

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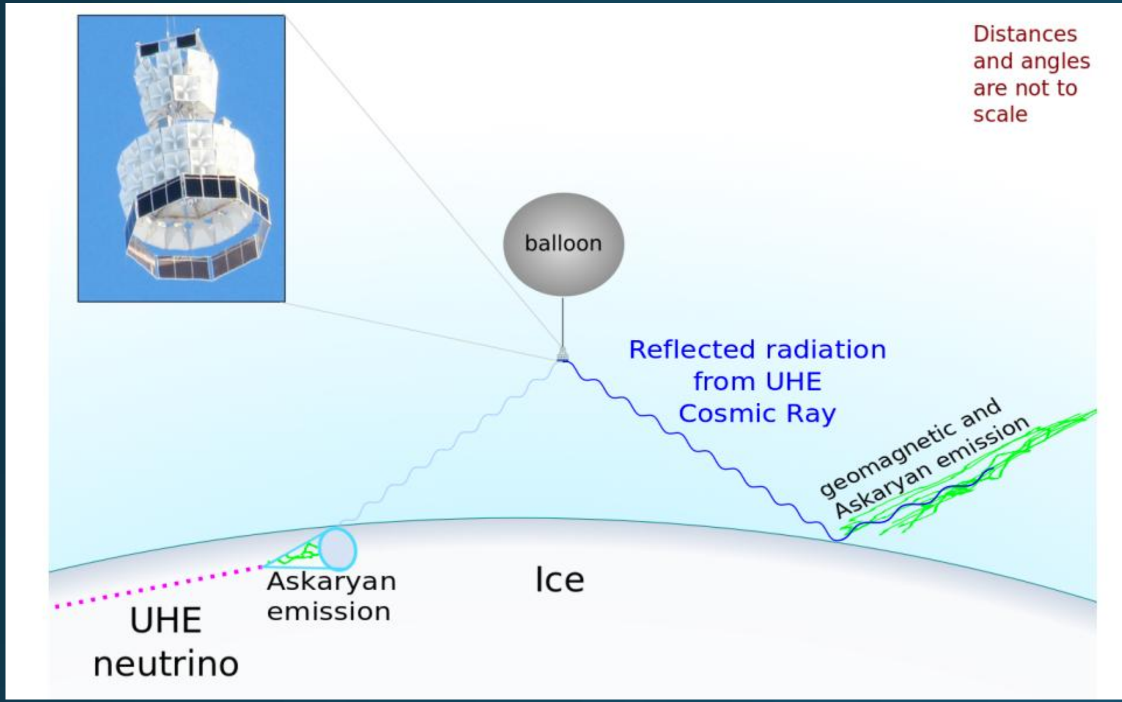

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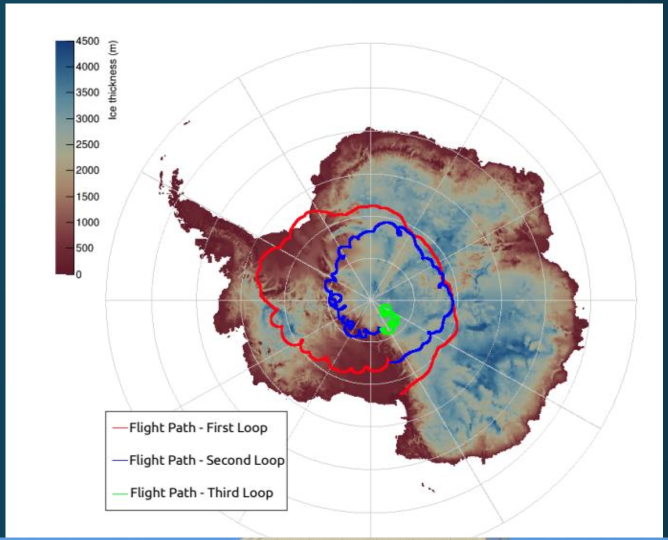

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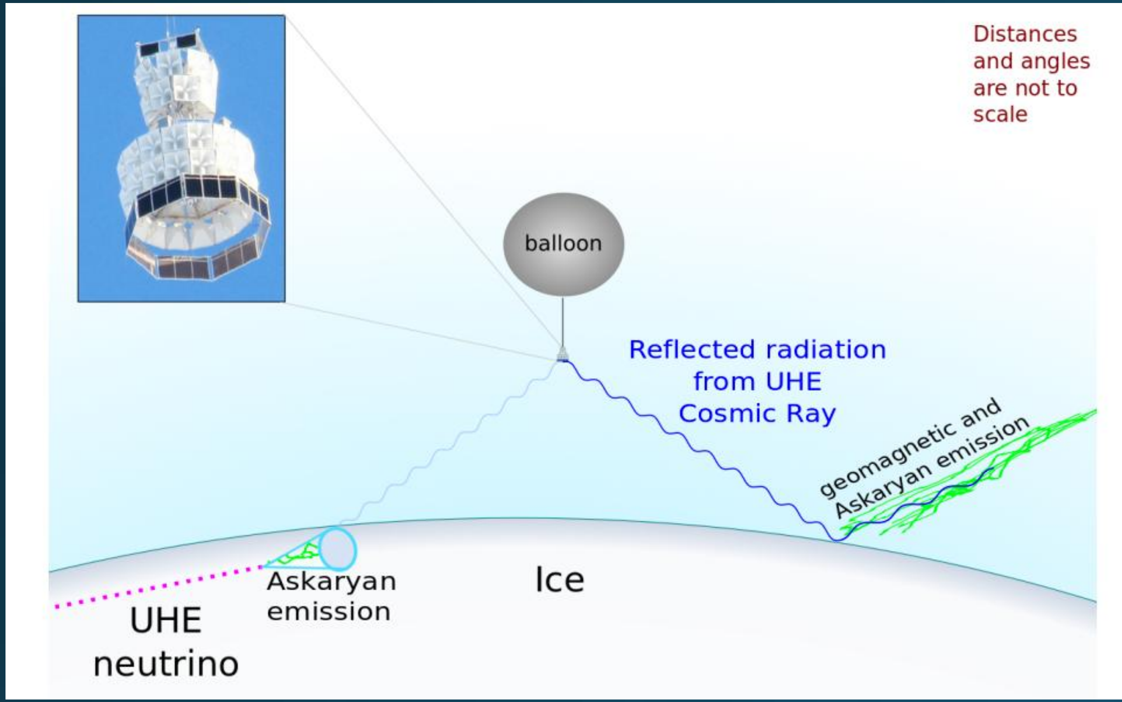

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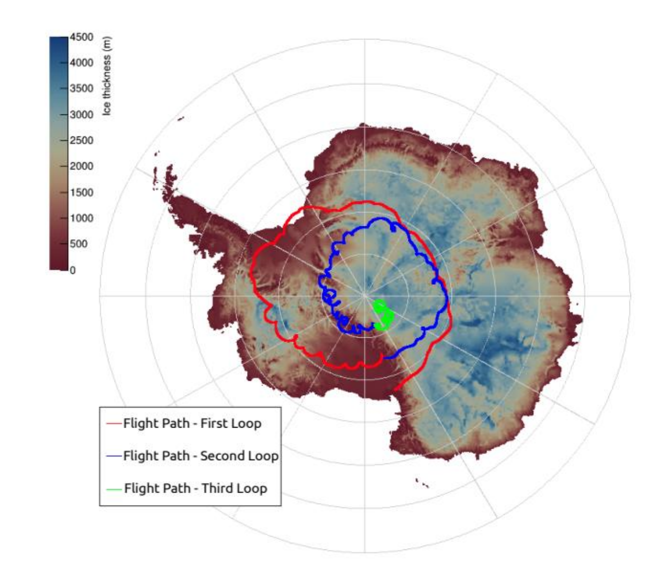

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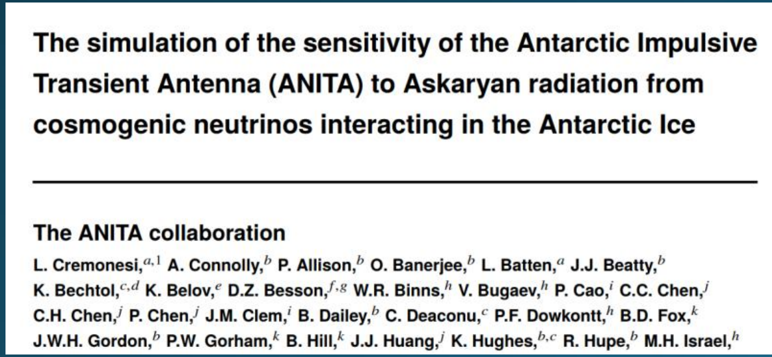

The simulation of the sensitivity of the Antarctic Impulsive Transient Antenna (ANITA) to Askaryan radiation from cosmogenic neutrinos interacting in the Antarctic Ice

The ANITA collaboration

L. Cremonesi,[a,1] A. Connolly,[b] P. Allison,[b] O. Banerjee,[b] L. Batten,[a] J.J. Beatty,[b] K. Bechtol,[c,d] K. Belov,[e] D.Z. Besson,[f,g] W.R. Binns,[h] V. Bugaev,[h] P. Cao,[i] C.C. Chen,[j] C.H. Chen,[j] P. Chen,[j] J.M. Clem,[i] B. Dailey,[b] C. Deaconu,[c] P.F. Dowkontt,[h] B.D. Fox,[k] J.W.H. Gordon,[b] P.W. Gorham,[k] B. Hill,[k] J.J. Huang,[j] K. Hughes,[b,c] R. Hupe,[b] M.H. Israel,[h]

L. Cremonesi et al 2019 JINST 14 P08011

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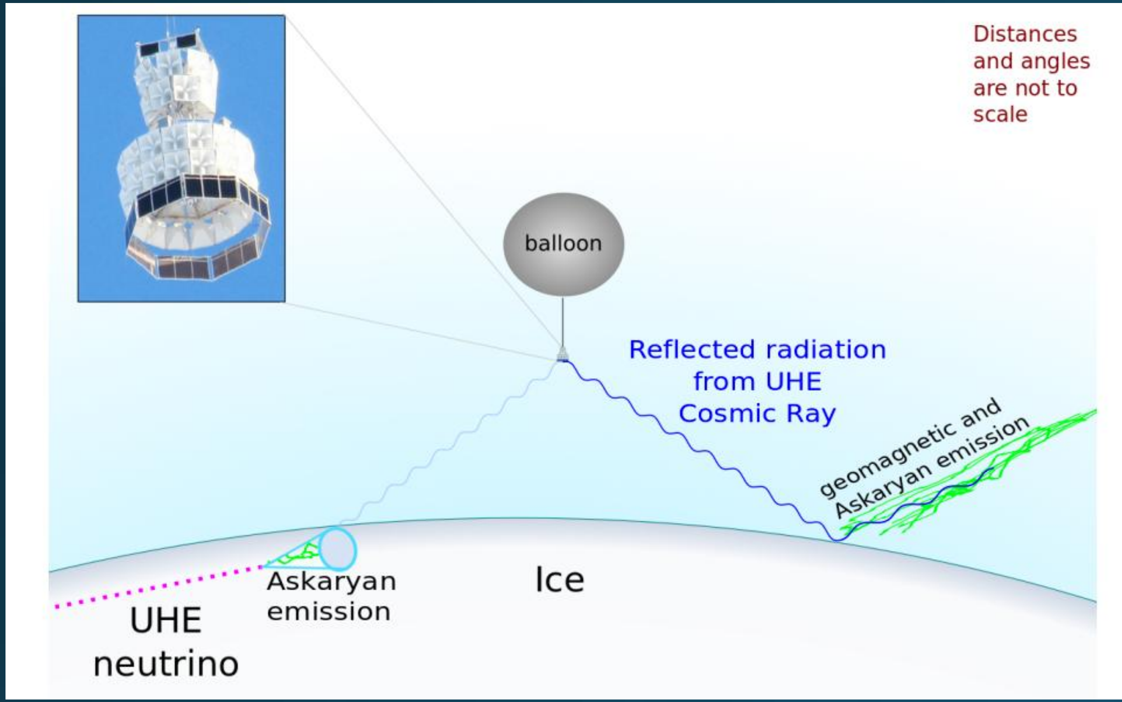

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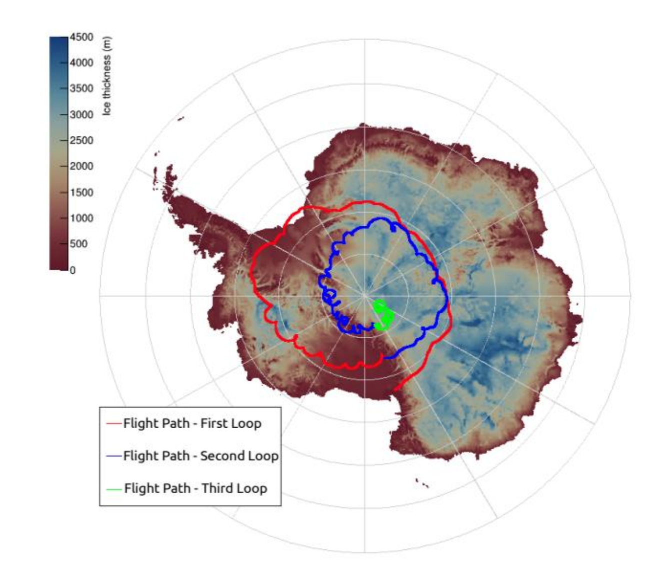

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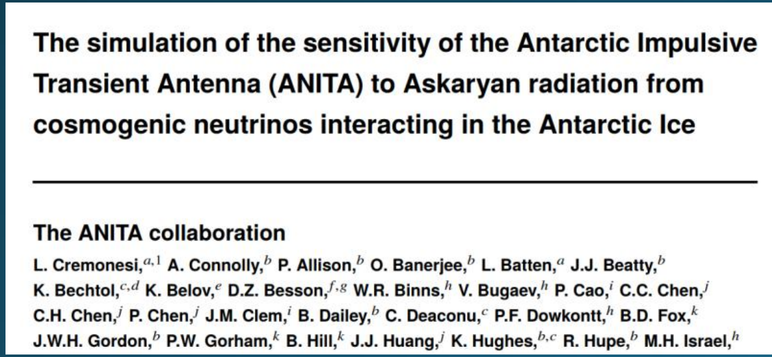

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CASPEN (the **Cosmology and Astroparticle Student and Postdoc Exchange Network**)

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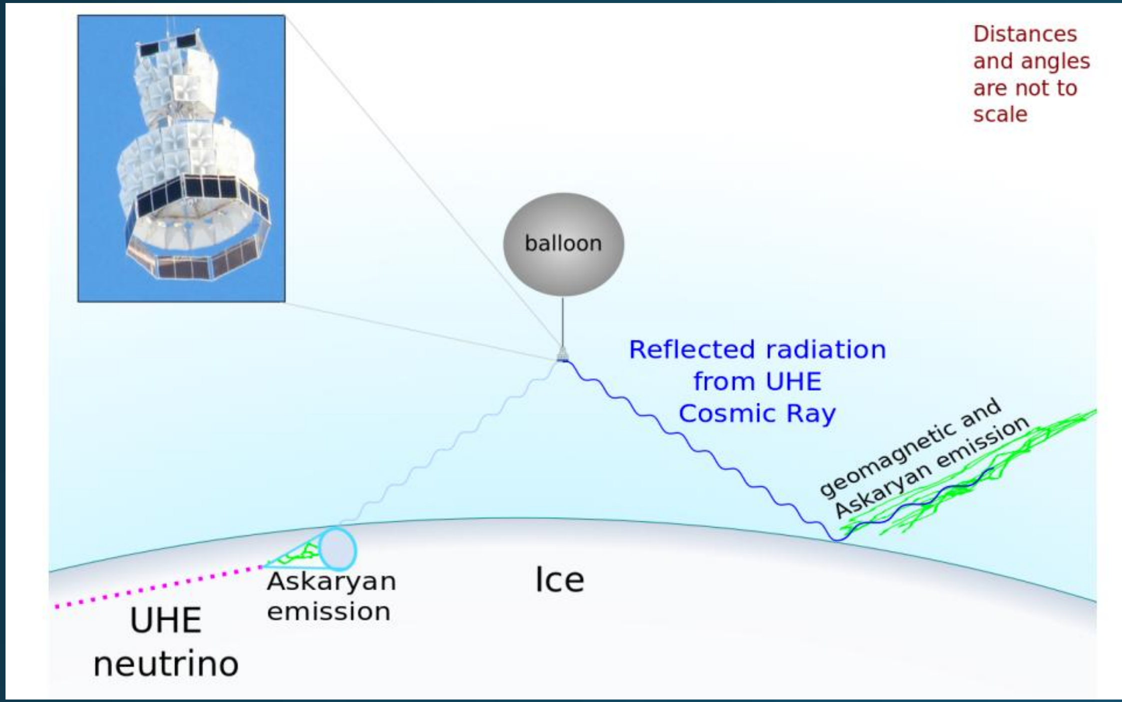

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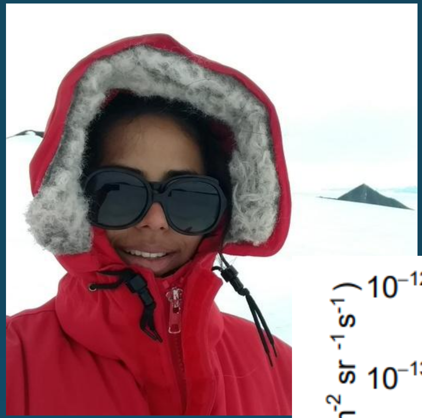

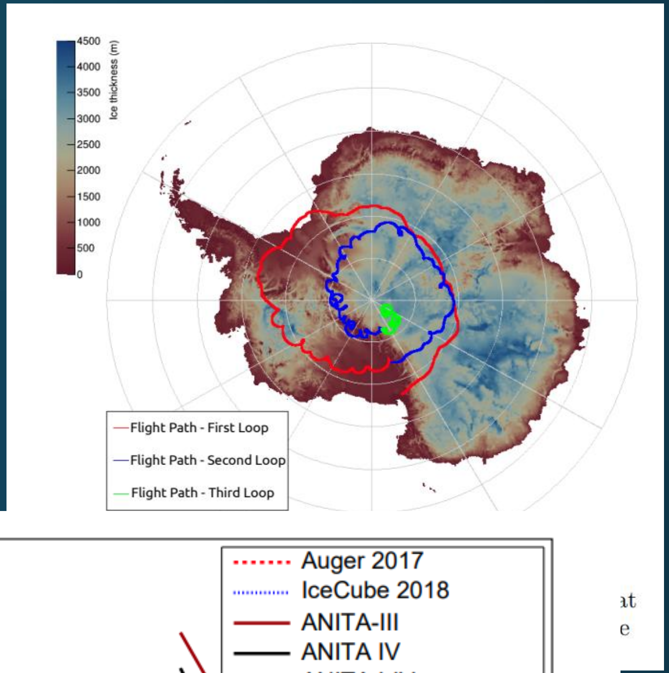

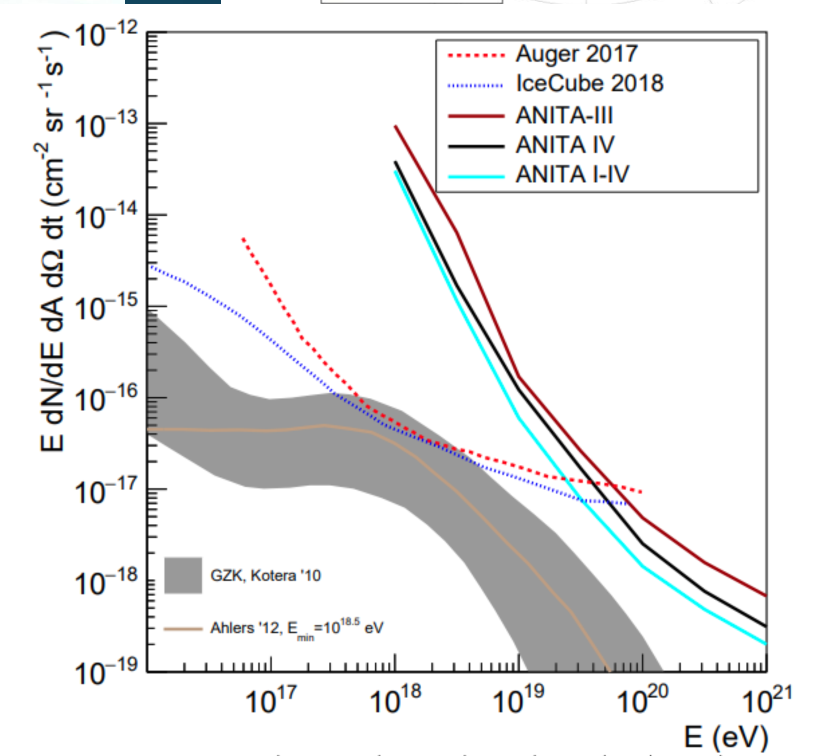

$\log_{10}(E(eV))$	18	18.5	19	19.5	20	20.5	21
$A\ (km^2 \cdot sr)$	0.0032	0.033	0.43	3.1	21	68	167

Gorham et al. Phys. Rev. D 99, 122001

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Astroparticles

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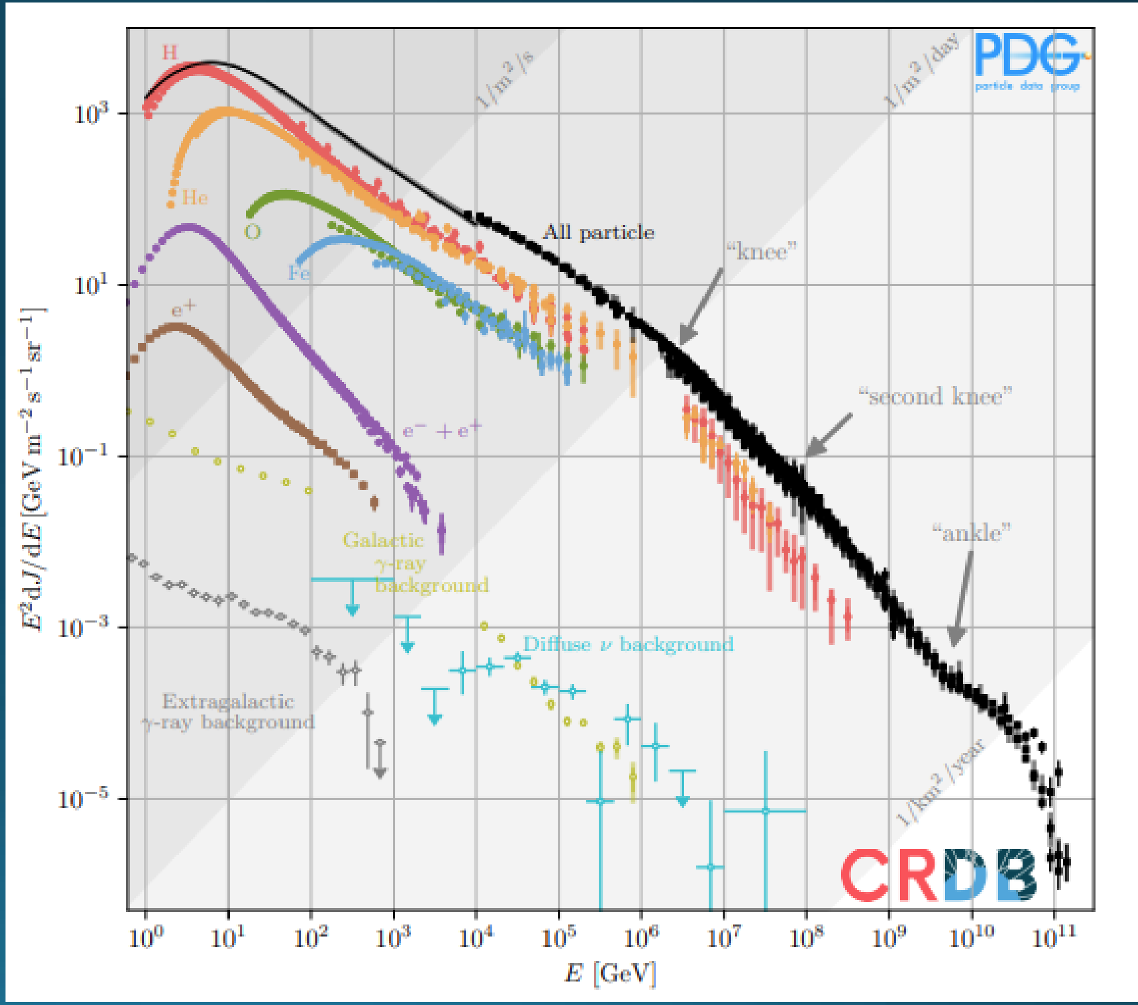
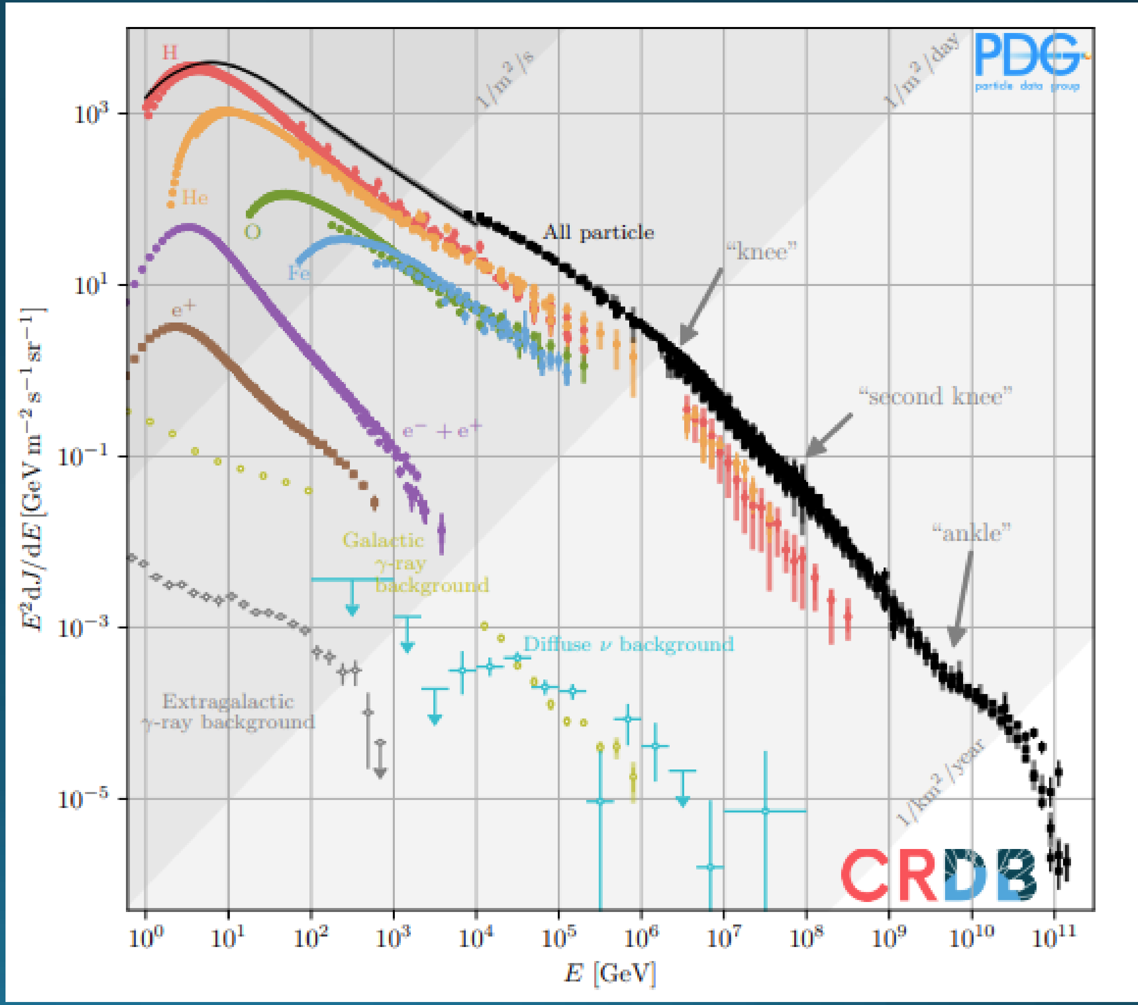


J.Alvarez-Muñiz et al PDG 2024

Astroparticles

- Cosmic rays (charged particles)



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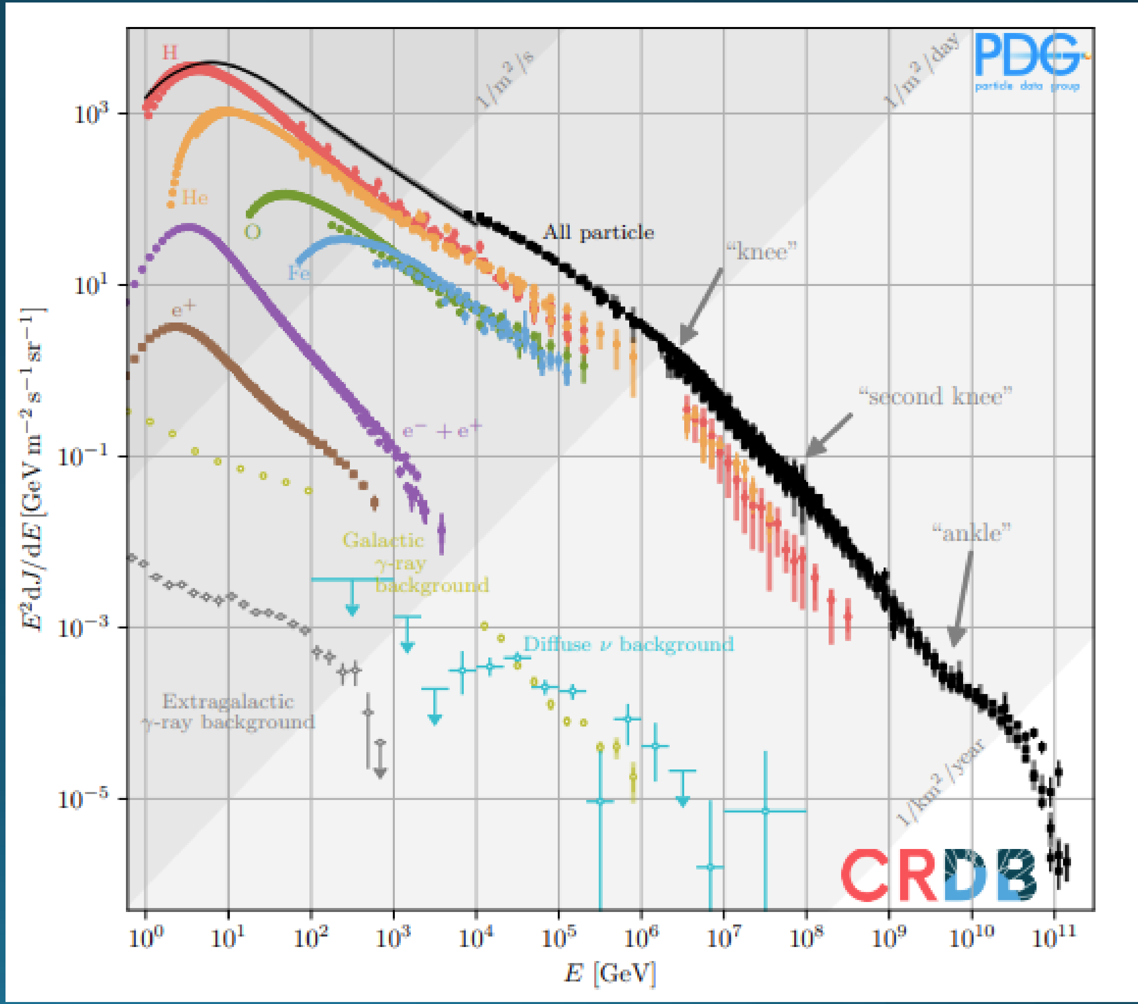

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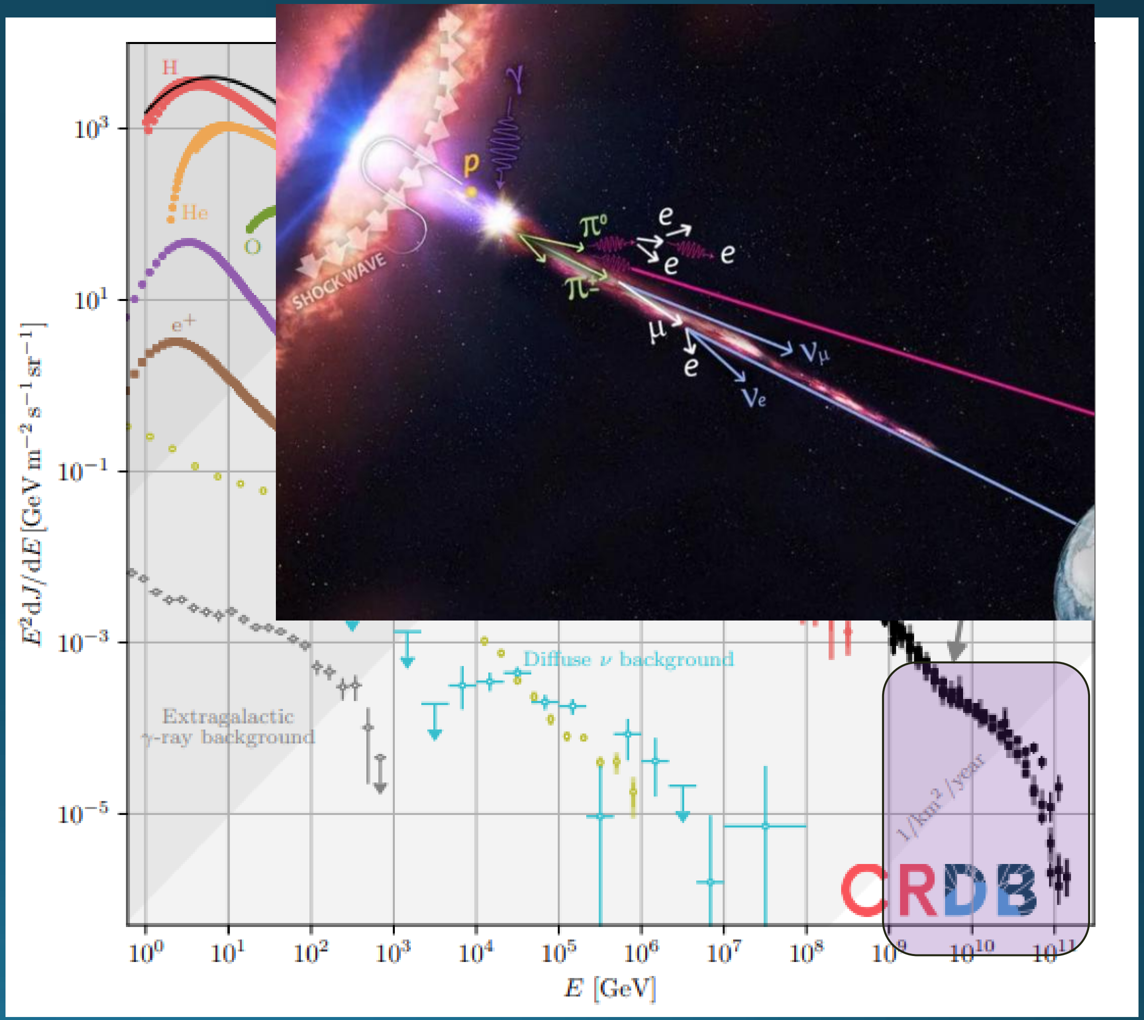

J.Alvarez-Muñiz et al PDG 2024

Astroparticles

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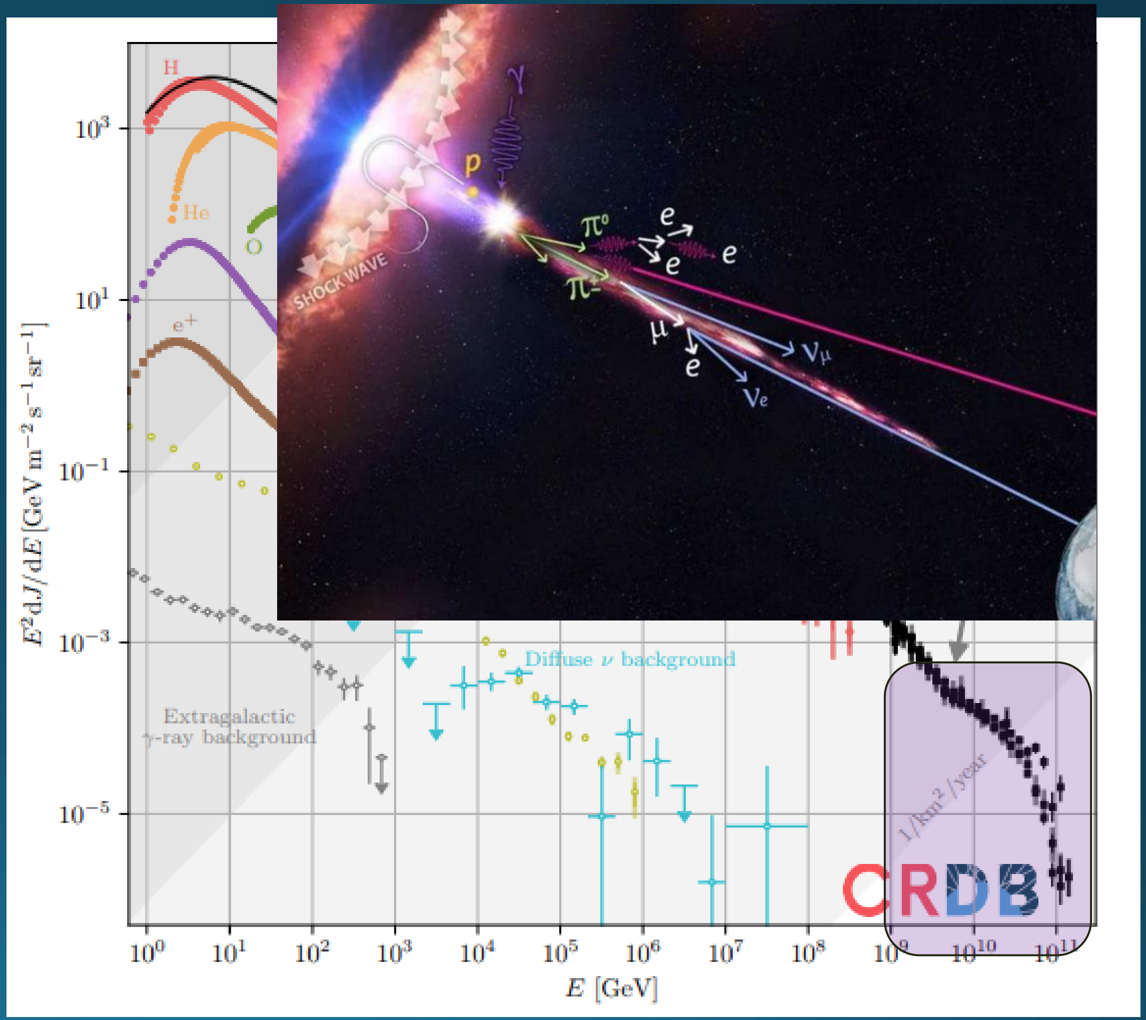
→What are the mechanisms producing such energetic particles?



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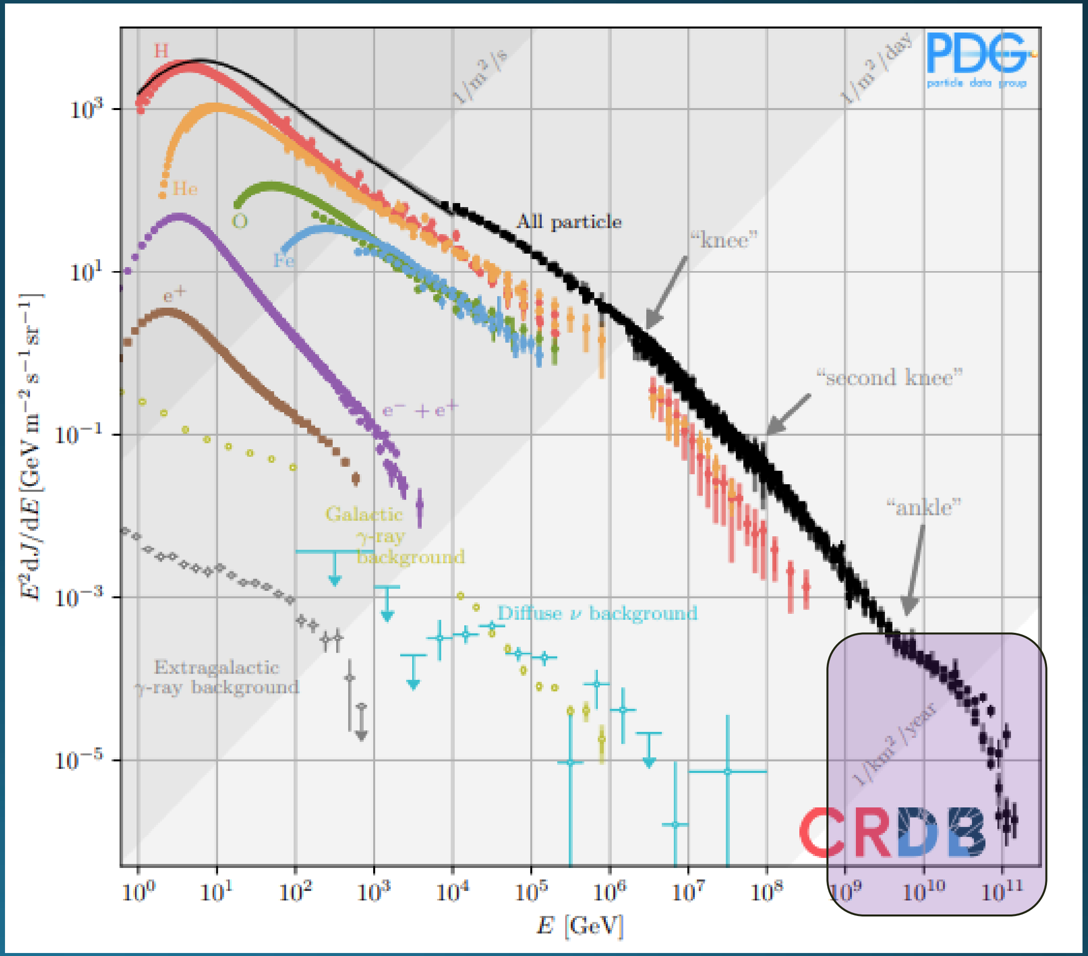
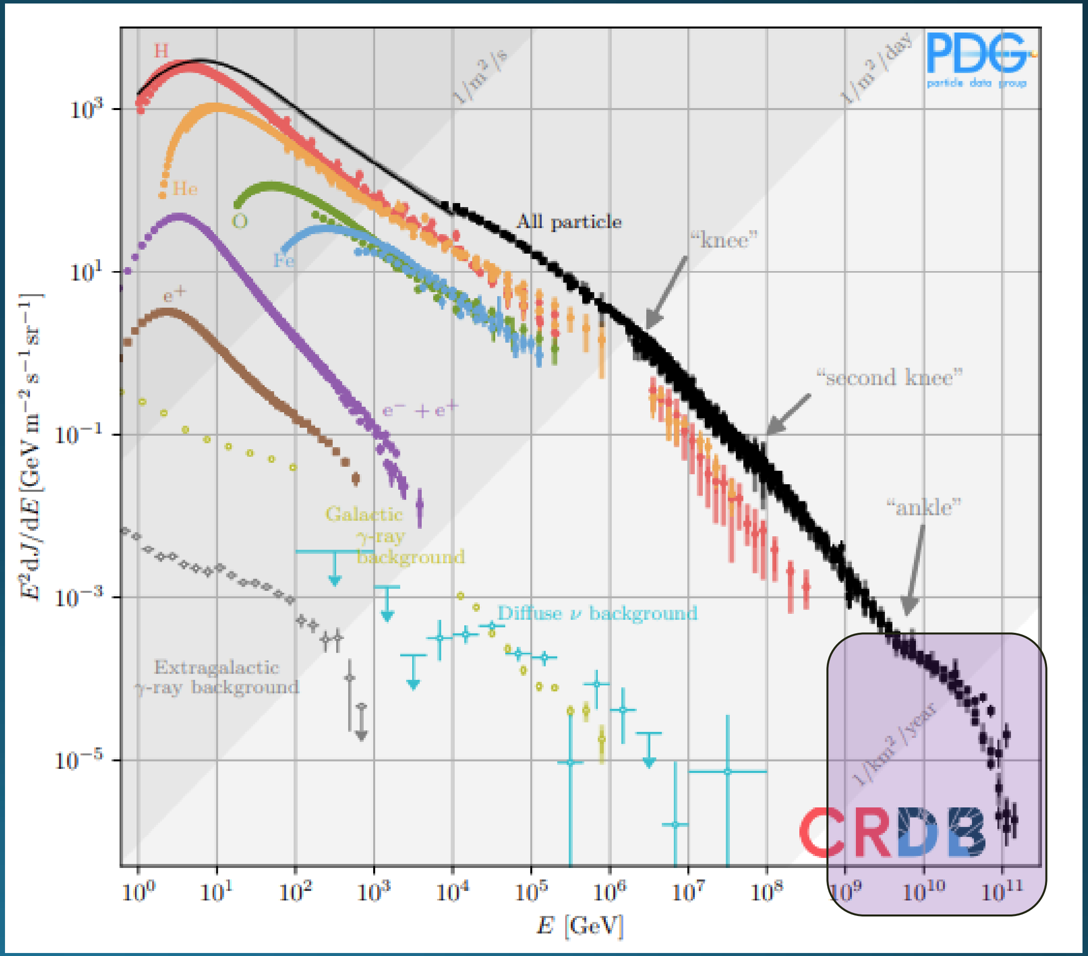
Building a magnet spectrometer

Building a magnet spectrometer



Building a magnet spectrometer

- Jim and Patrick were building a new detector
  - Early 2019



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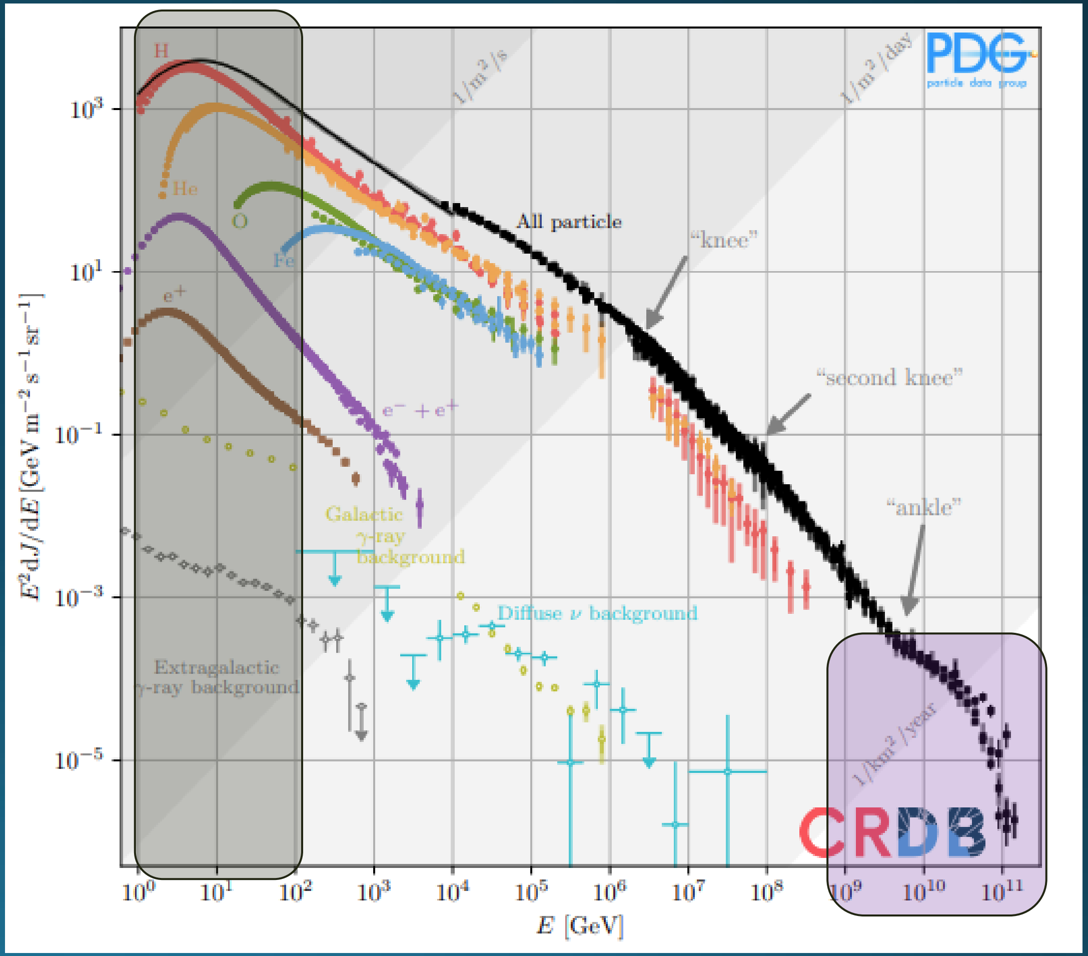

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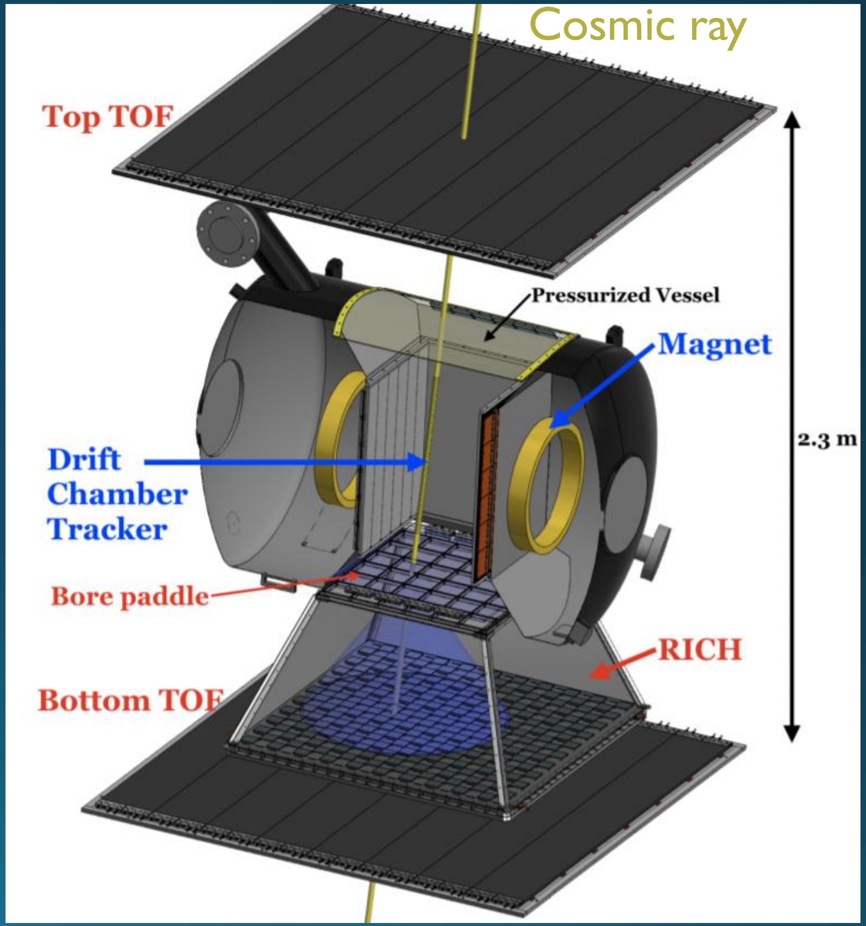

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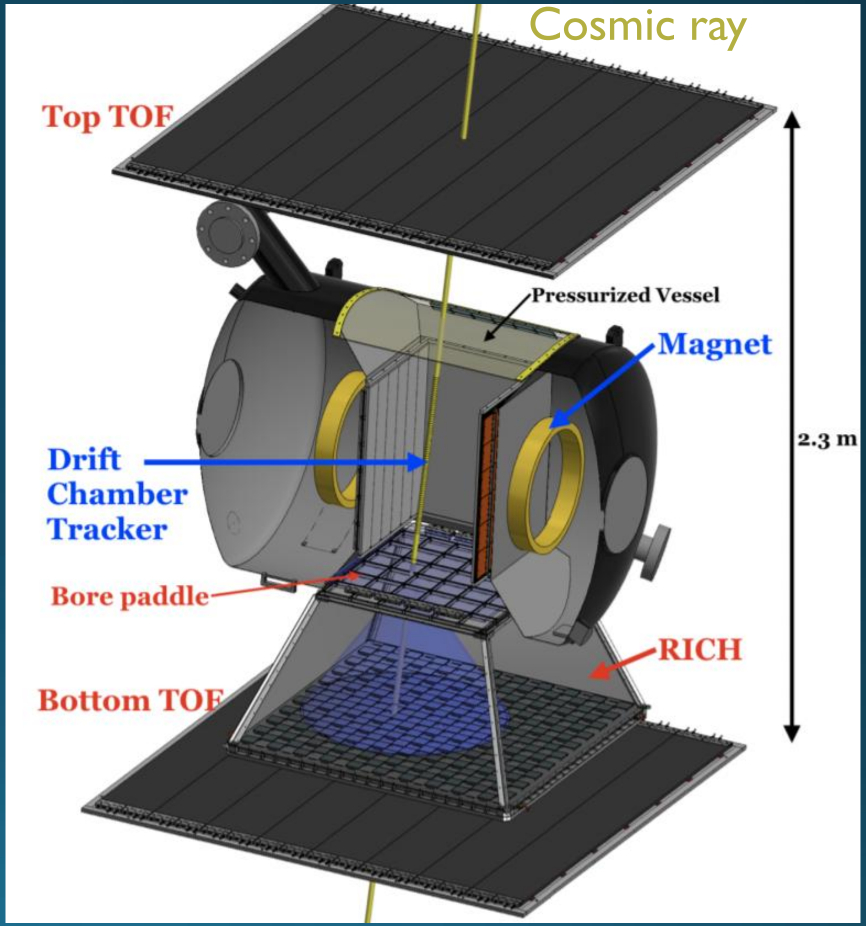

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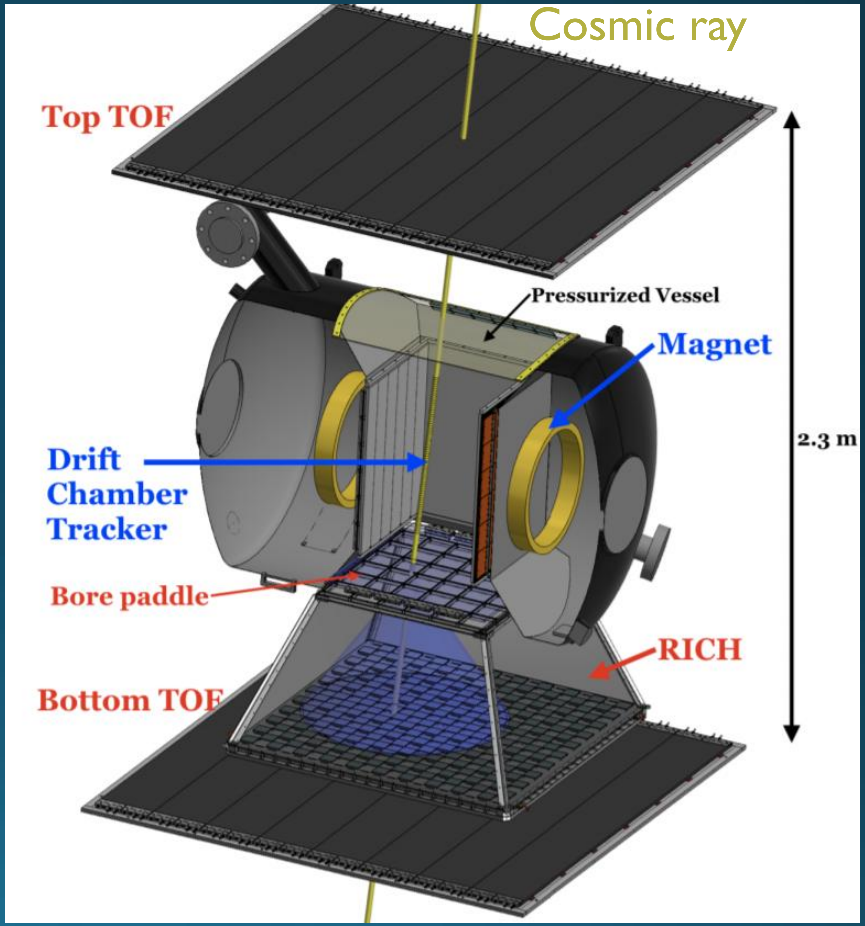

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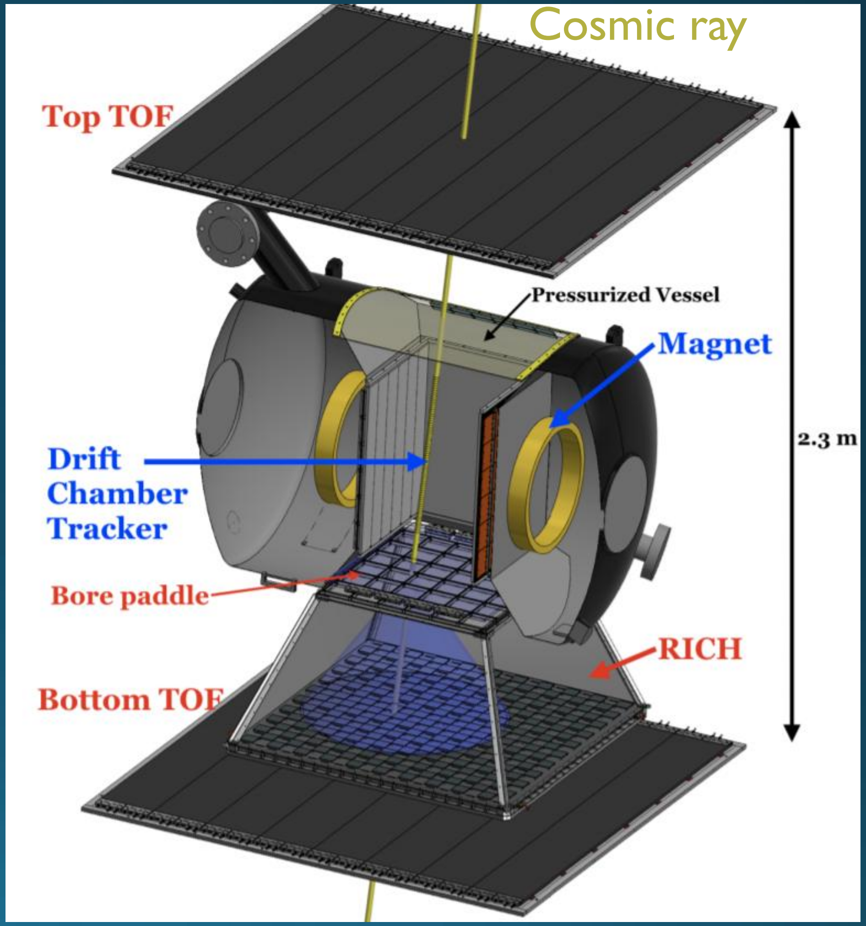
- Measure rigidity in magnetic field
  - $R = \frac{pc}{Ze} = \rho \mathbf{B}$
- Measure velocity, β, and charge, Ze, separately
- Calculate the mass of cosmic ray
  - $mc^2 = R\,\frac{Ze}{\gamma\beta}$



Isotopes offer insights

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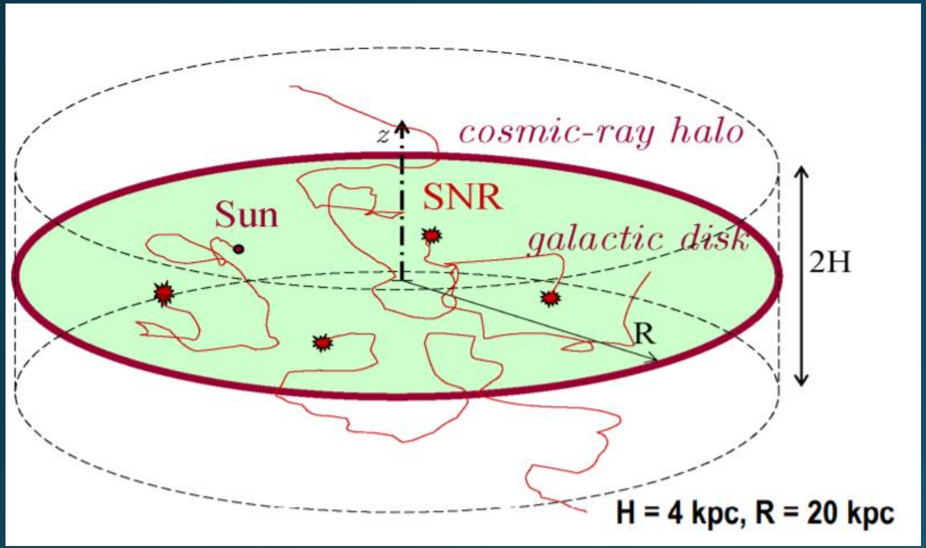
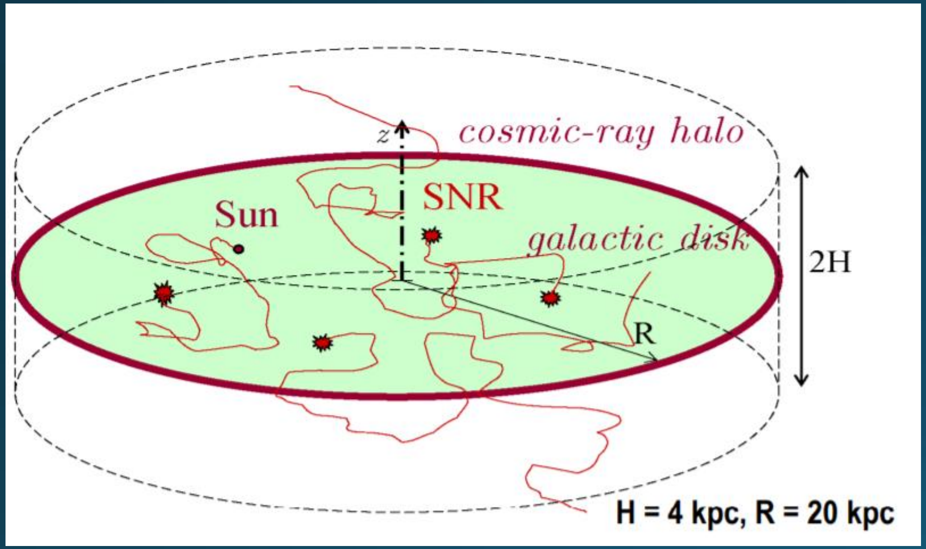


Ptuskin slides 2013 Cargese

Isotopes offer insights



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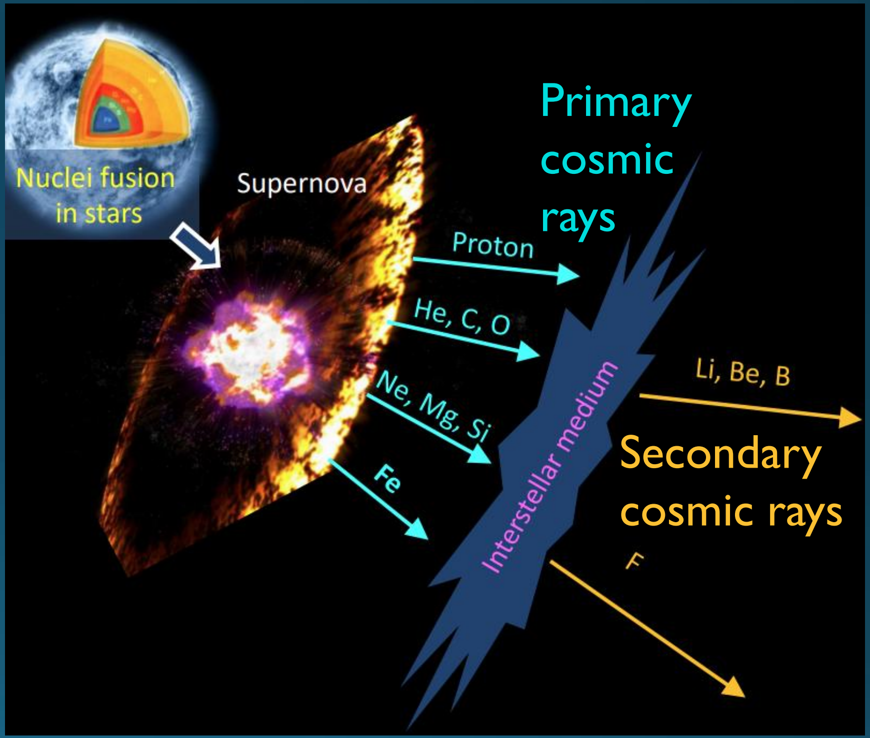
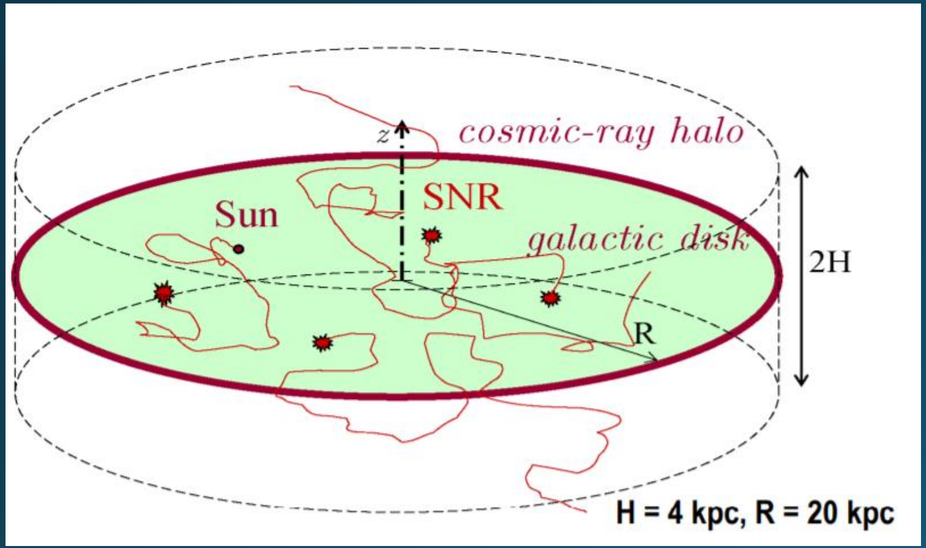


Adapted from AMS-02

Isotopes offer insights



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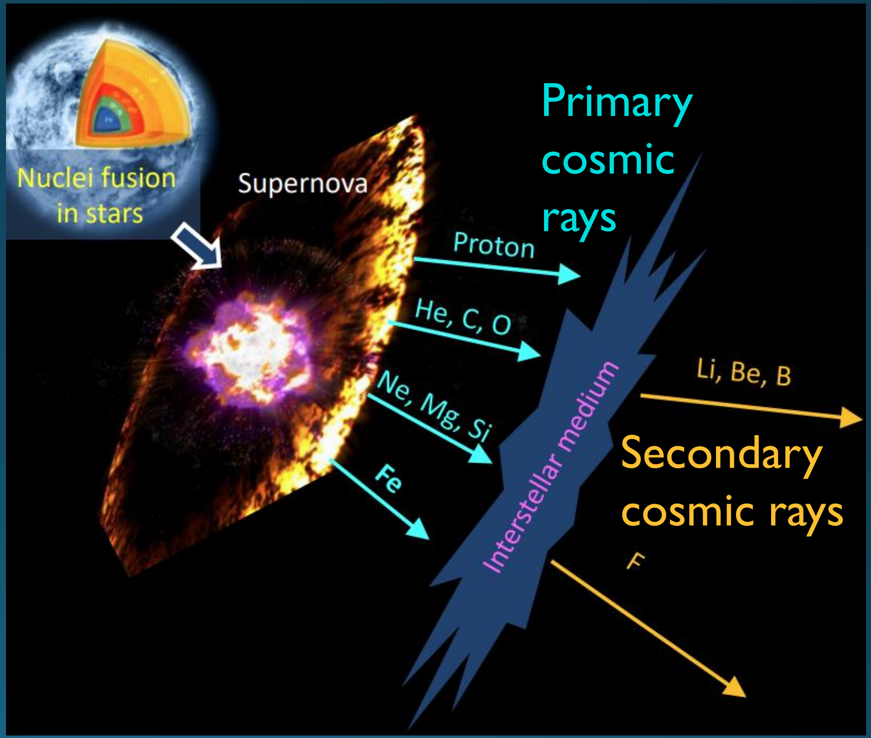
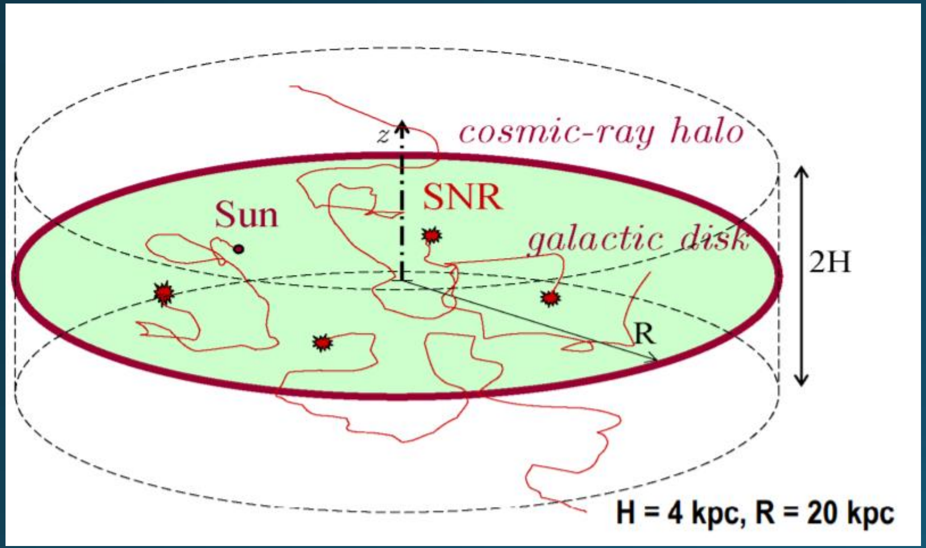


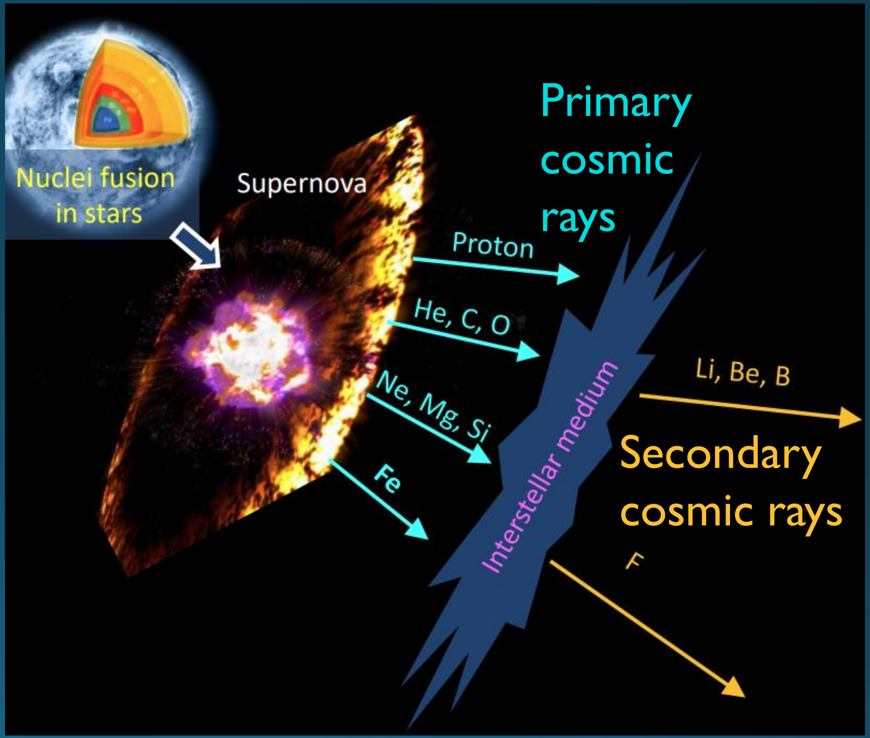
Adapted from AMS-02

1. Primary cosmic rays injected by Galactic sources

Isotopes offer insights



Ptuskin slides 2013 Cargese



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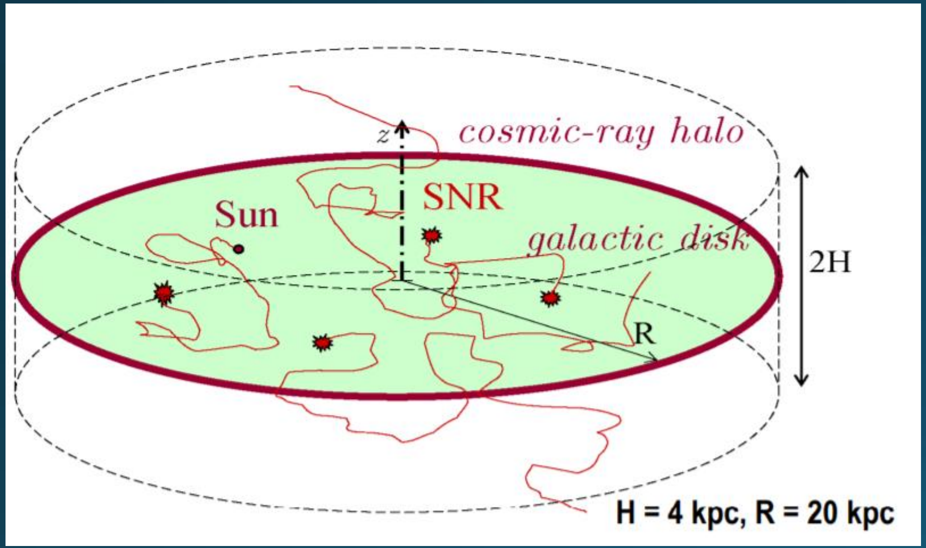

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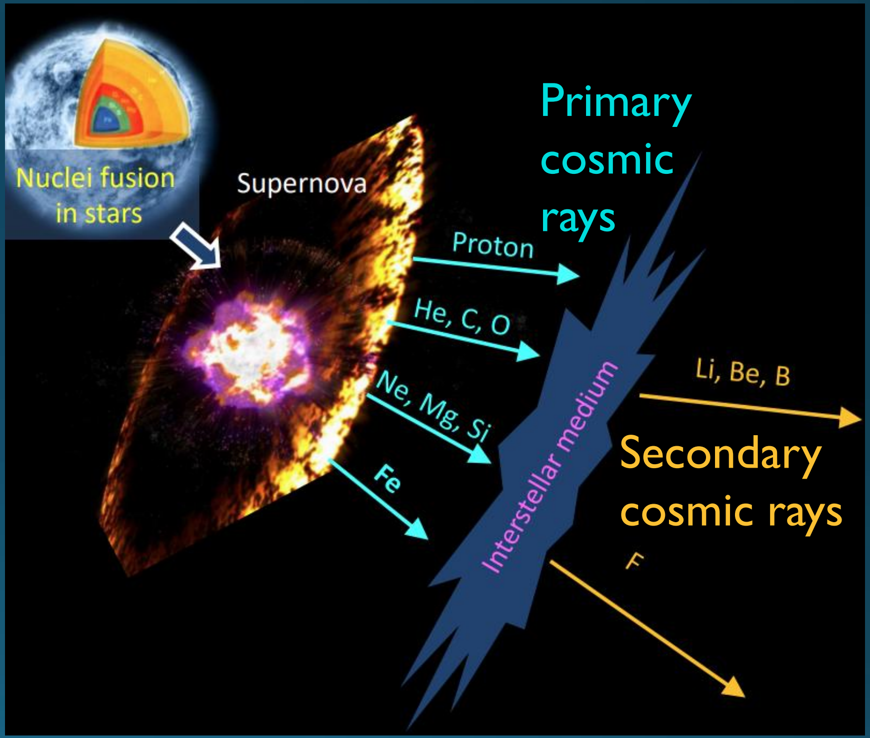

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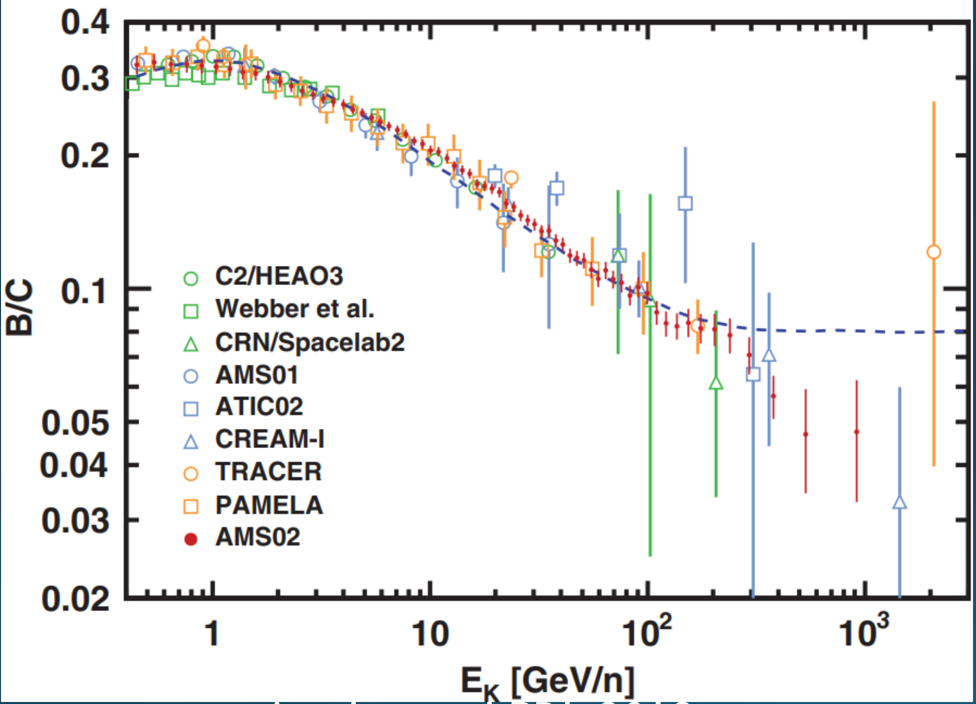
3. Spallation – produce secondary nuclear species

Isotopes offer insights

Secondary-primary ratios are sensitive to the material pathlength, L/D



Aguilar et al PRL 2018

1. Primary cosmic rays injected by Galactic sources
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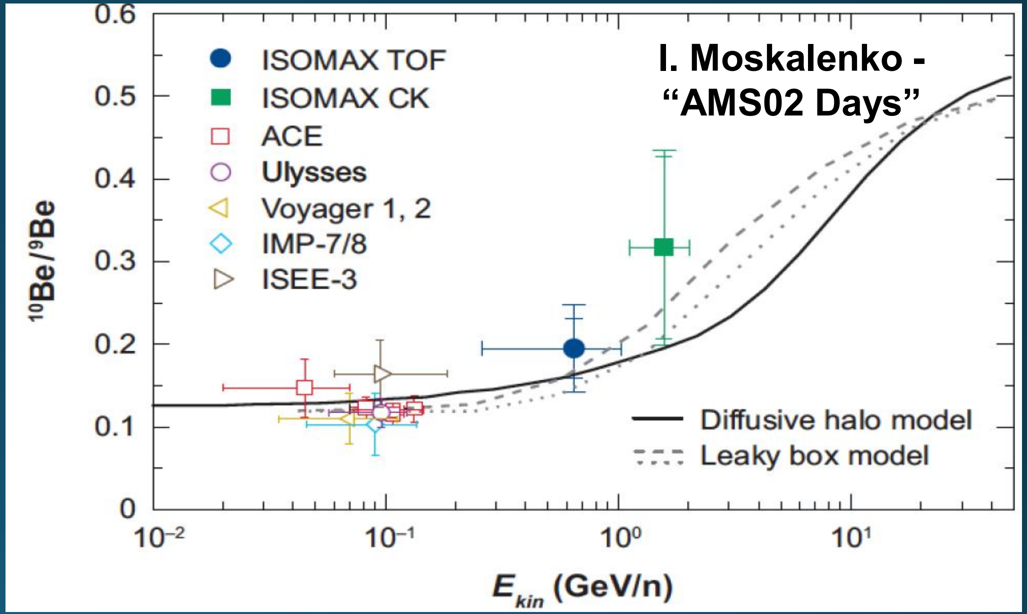
Clock isotopes are sensitive to the timescale of propagation



^{9}Be is stable while ^{10}Be beta-decays with a half-life of 1.4×10^6 yr.

First visit to U. Chicago, Jan 2019

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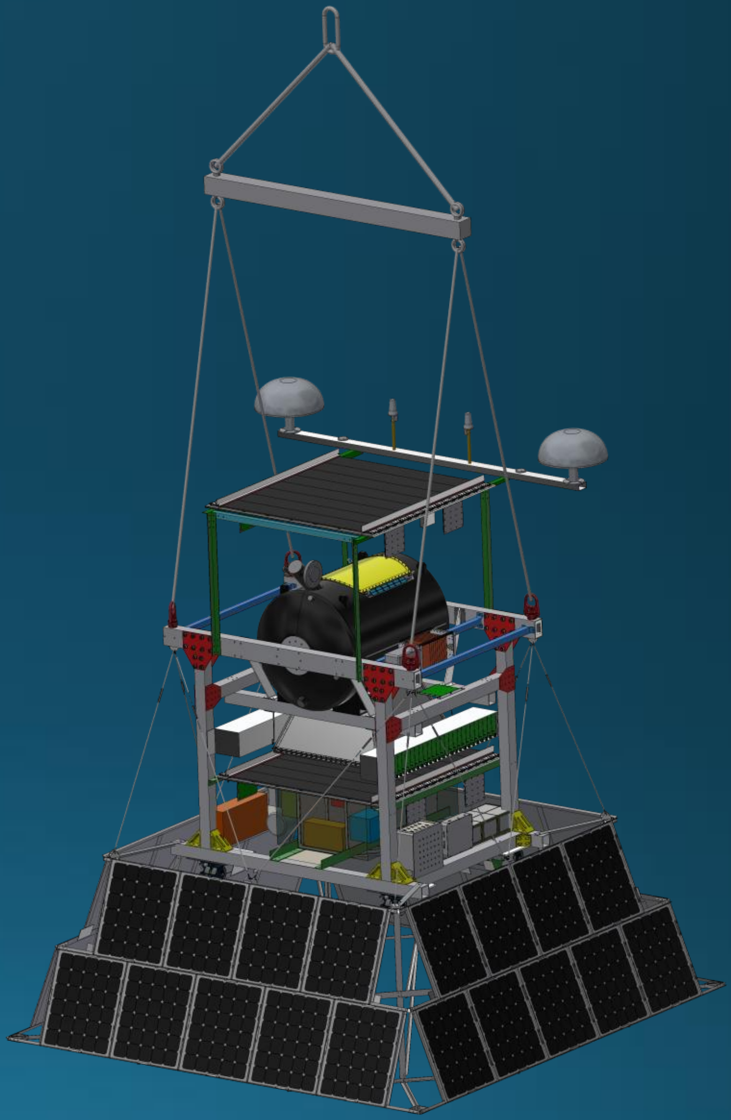

2019-2020

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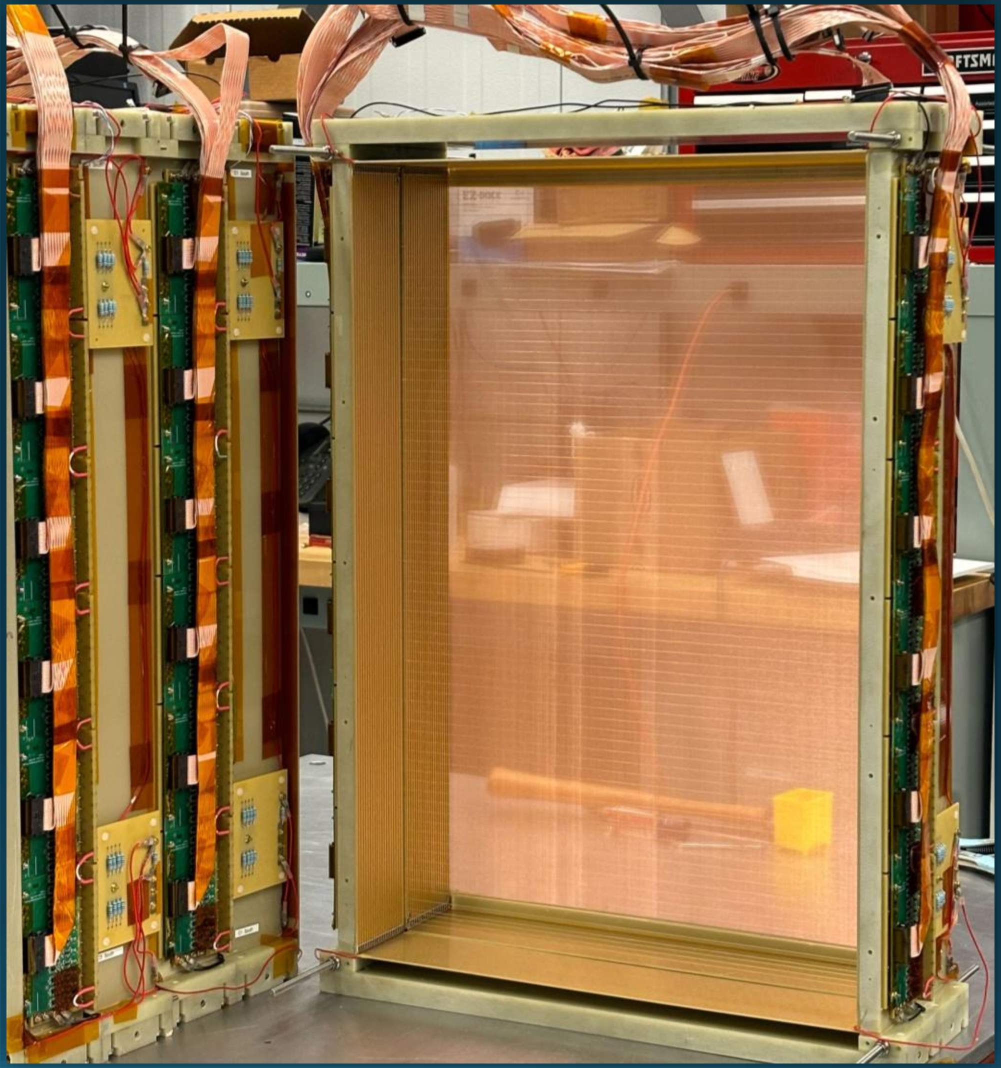
- Build and test detectors



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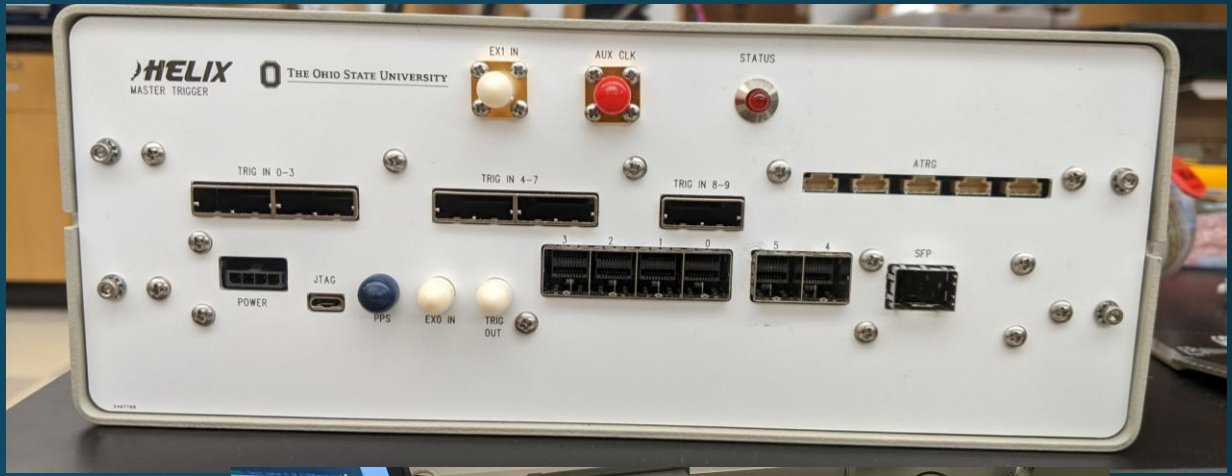

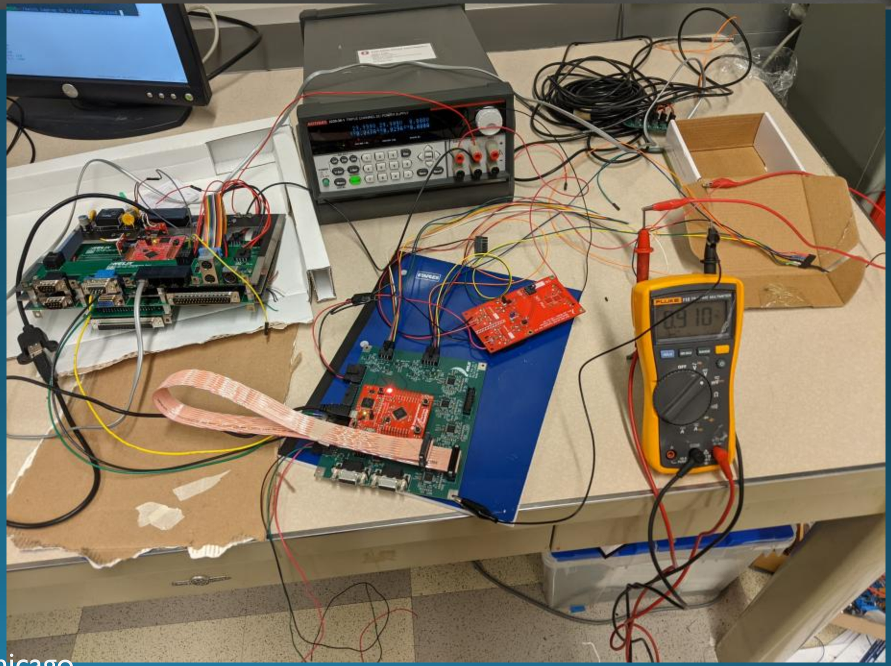

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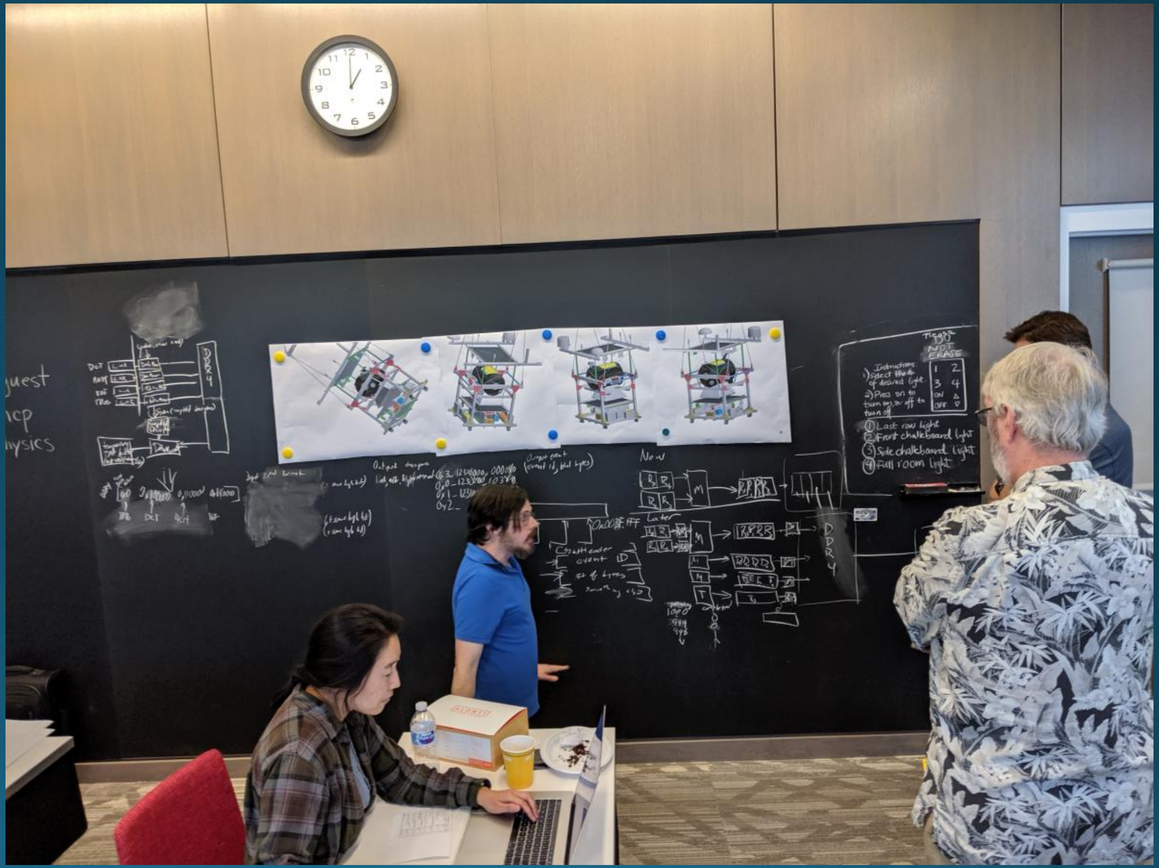

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→A lot of progress!

2020

2020

I worked mainly with…

2020

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2020

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What do you do when you can't work on your experiment?

I worked mainly with…

What do you do when you can't work on your experiment? Graduate!

2020

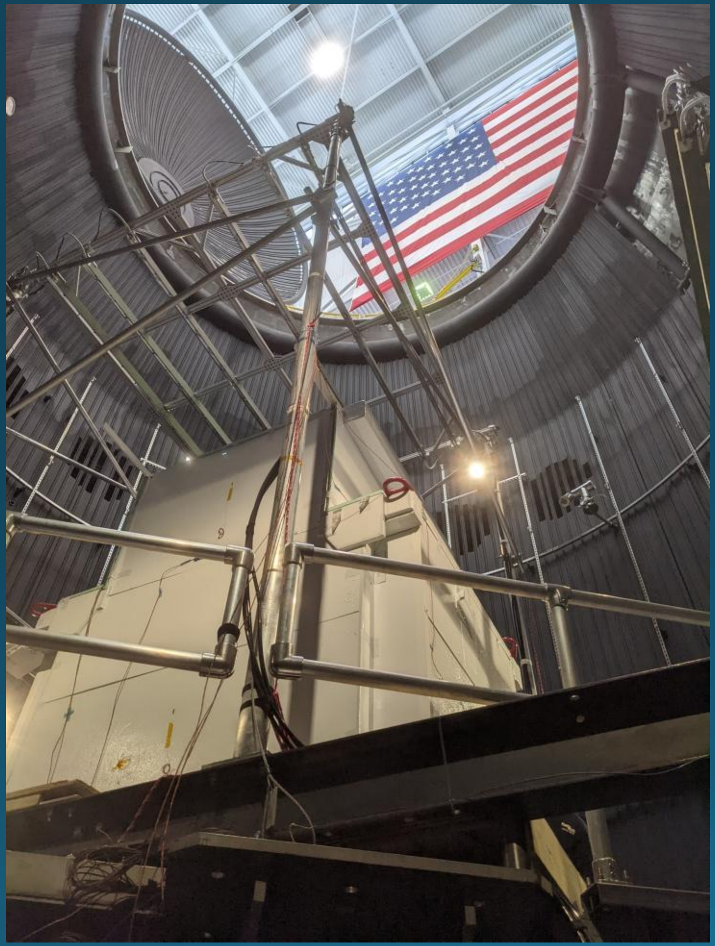
I worked mainly with…

Finally, back to HELIX

Finally, back to HELIX

Lead the vacuum test at Armstrong Test Facility

Finally, back to HELIX



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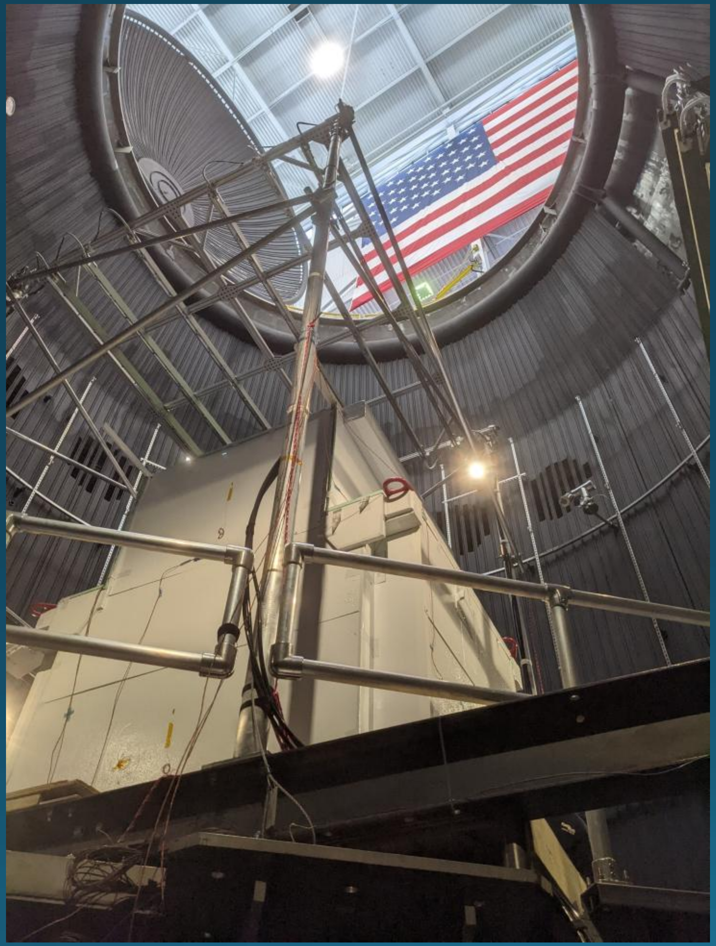

Graduate students:

Madison Jackson
Dennis H. Calderón
Payton Linton
Taylor Coakley

Lead the vacuum test at Armstrong Test Facility

HELIX launch

HELIX launch

- Moved to U. Chicago 2023

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HELIX 2024 Flight Trajectory
Day 6
Day 5
Landing
Day 4
Day 3
Day 2
Day 1
Launch
80°N
75°N
70°N
65°N
60°N
55°N
50°N
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Recovery on Ellesmere Island

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Dennis H. Calderón
graduating this fall!

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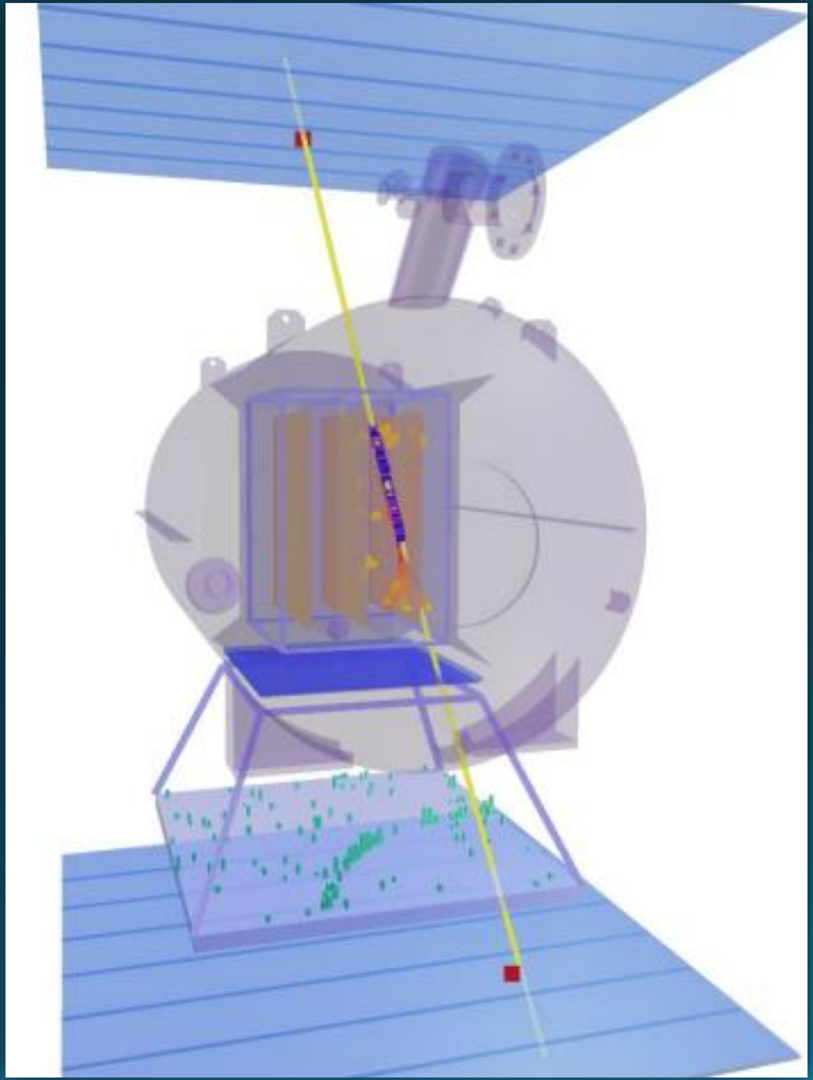
Analyze the data &
refurbish for next flight!

HELIX event



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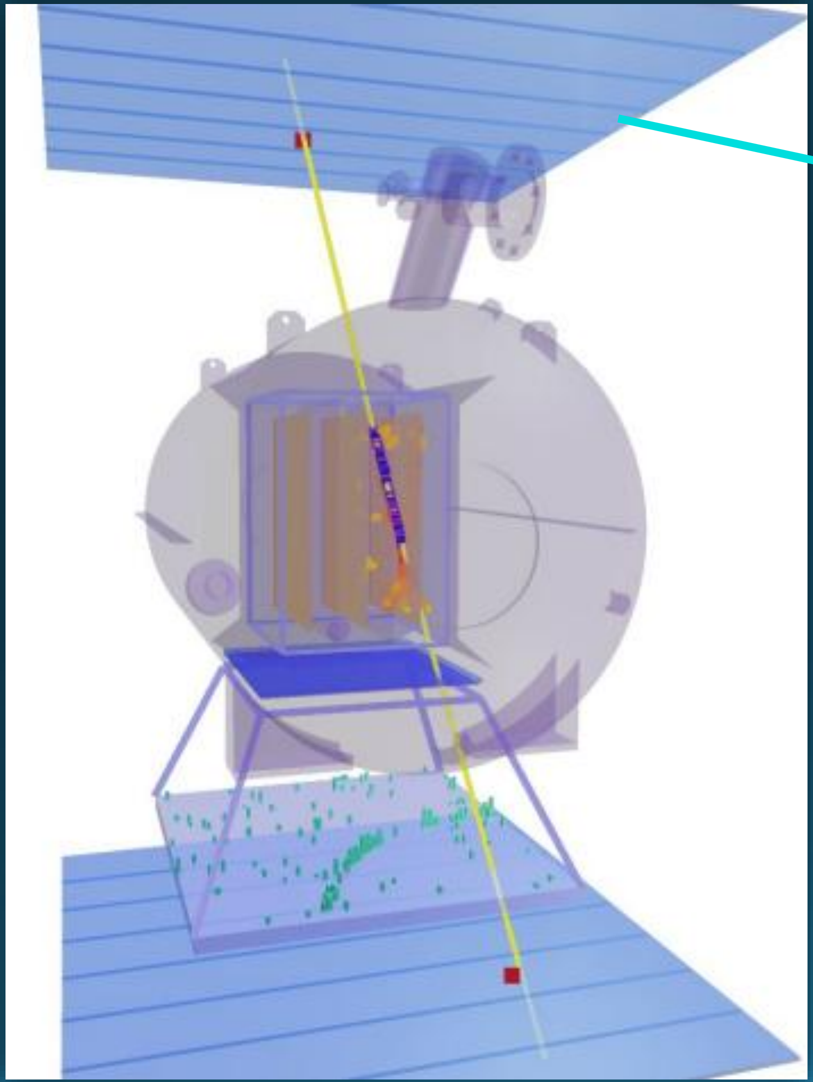
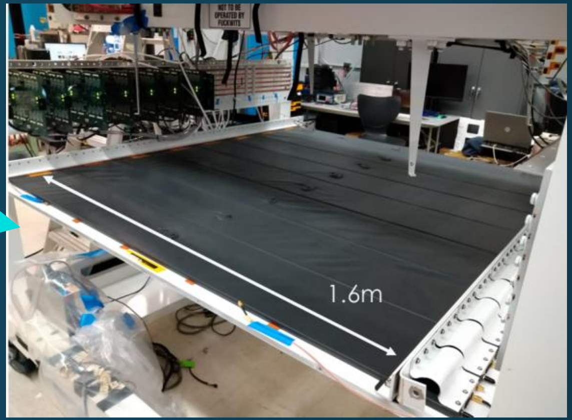


Time of Flight



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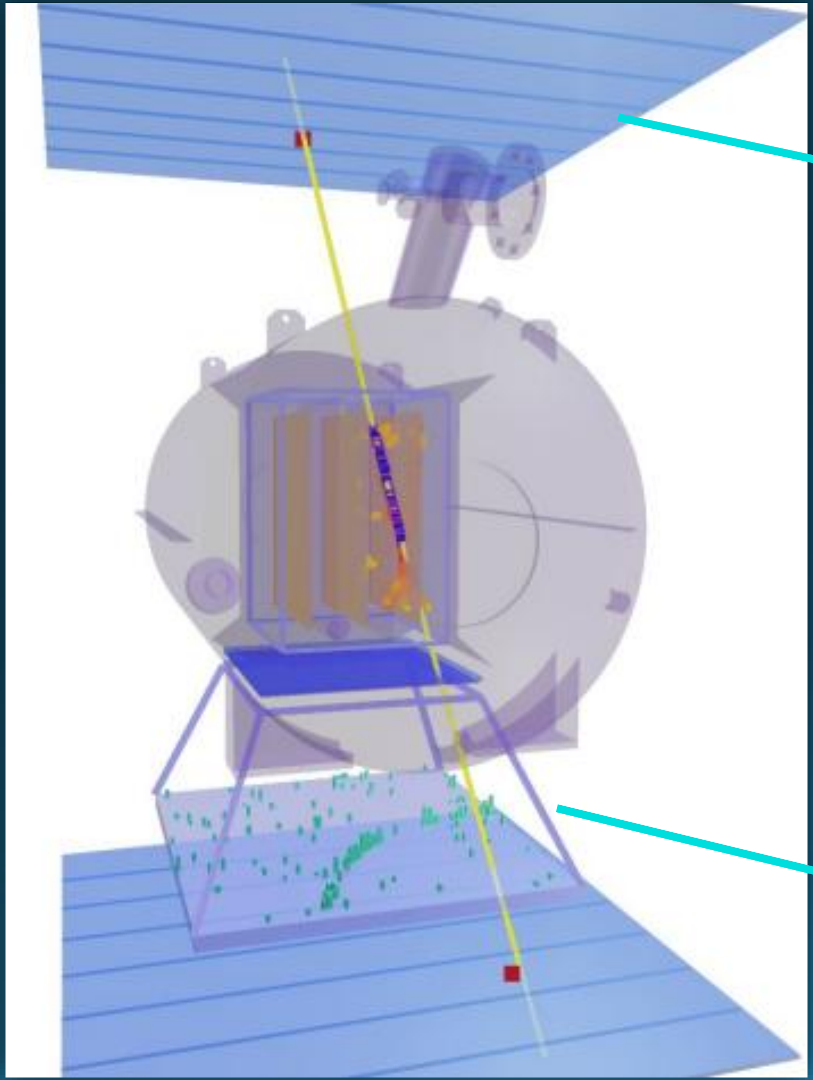

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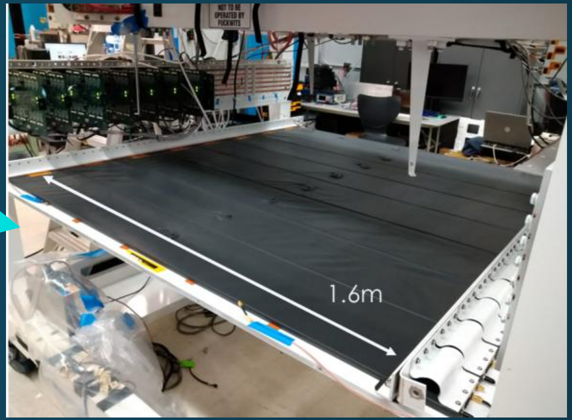
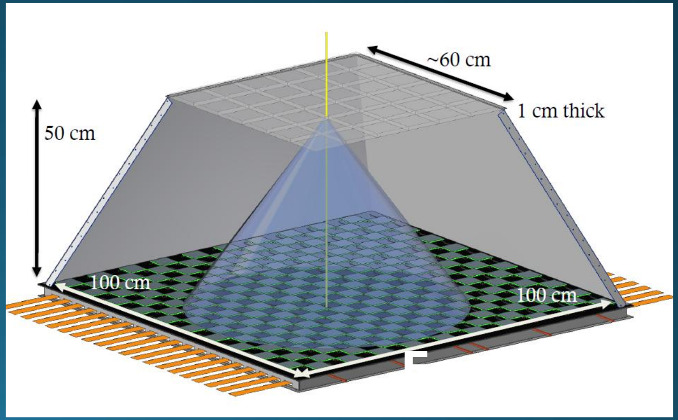


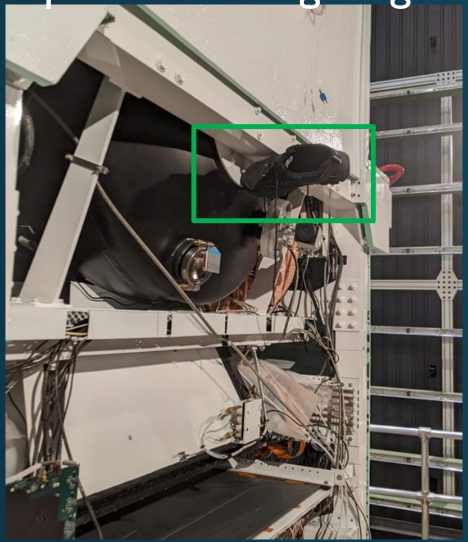
Measure velocity (v) and charge (Z)

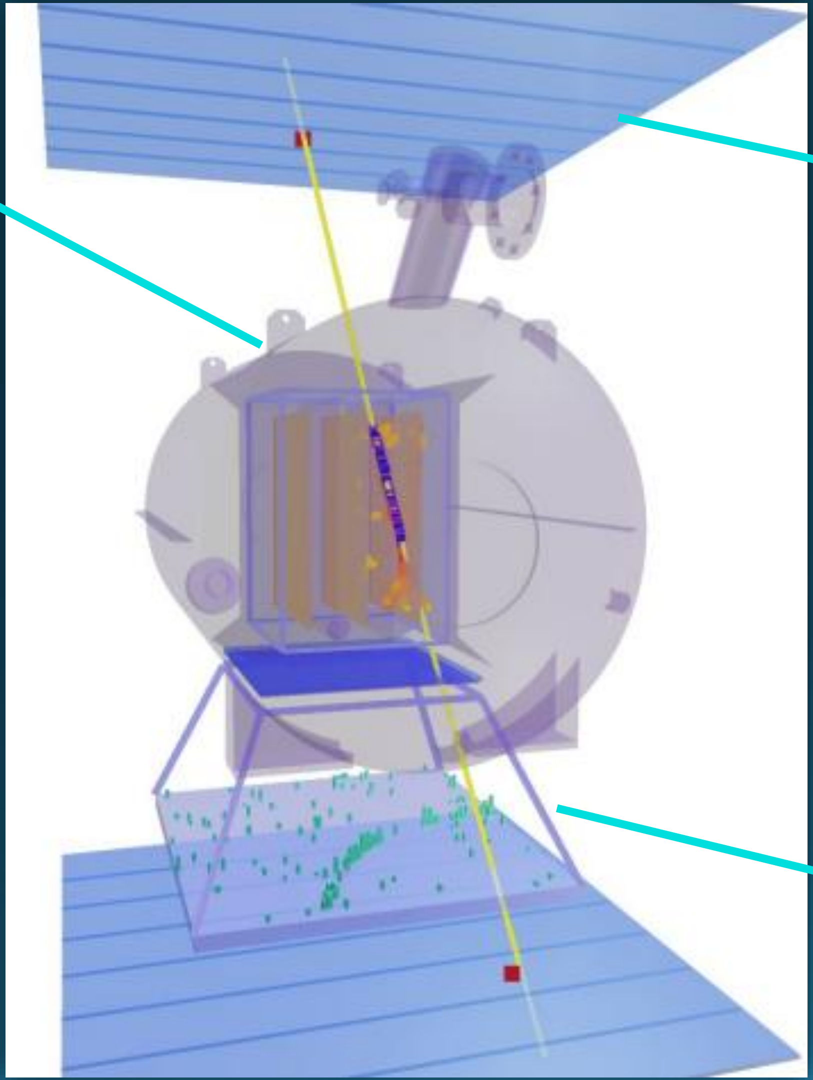
Cherenkov imaging



HELIX event

Superconducting magnet





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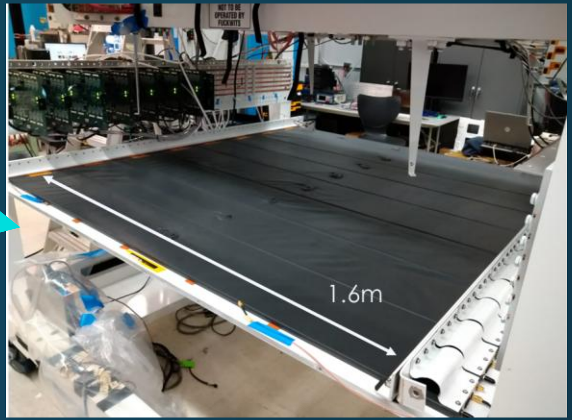

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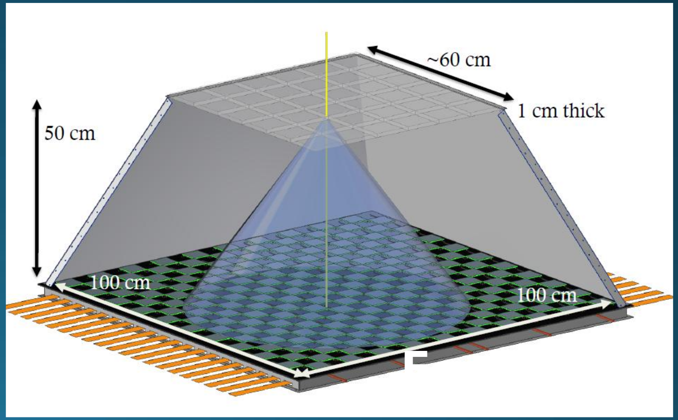

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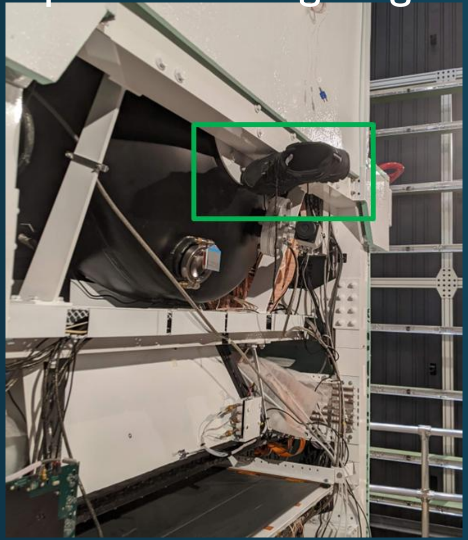

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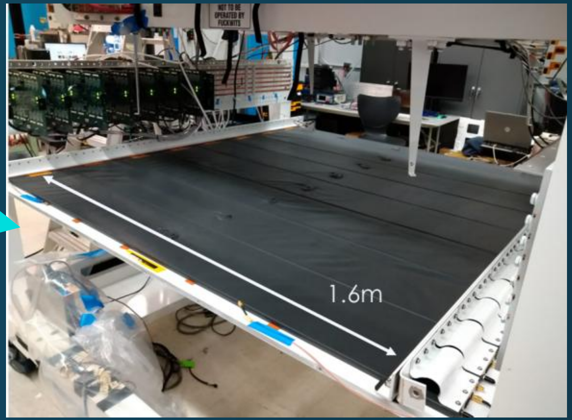
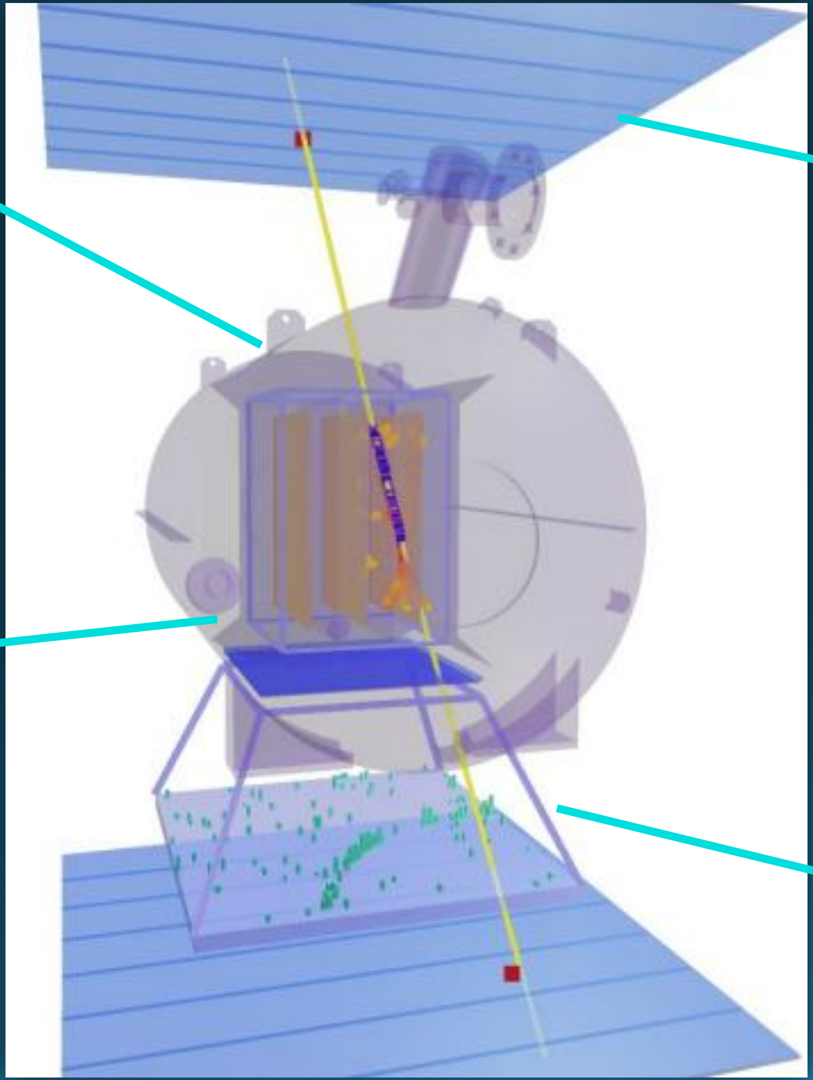
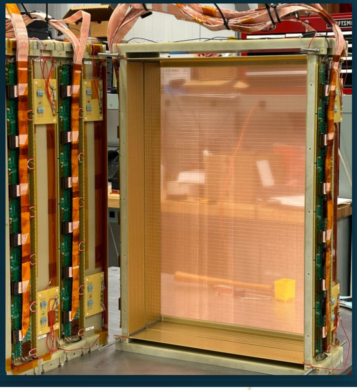
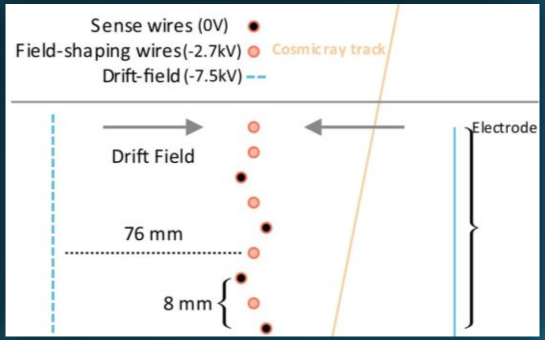




Measure momentum (p)

Tracker





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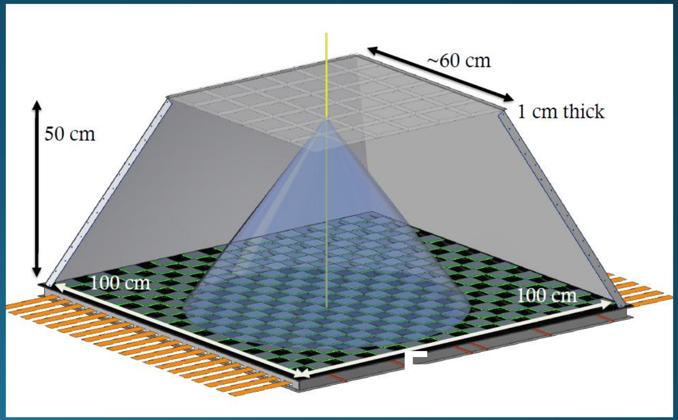
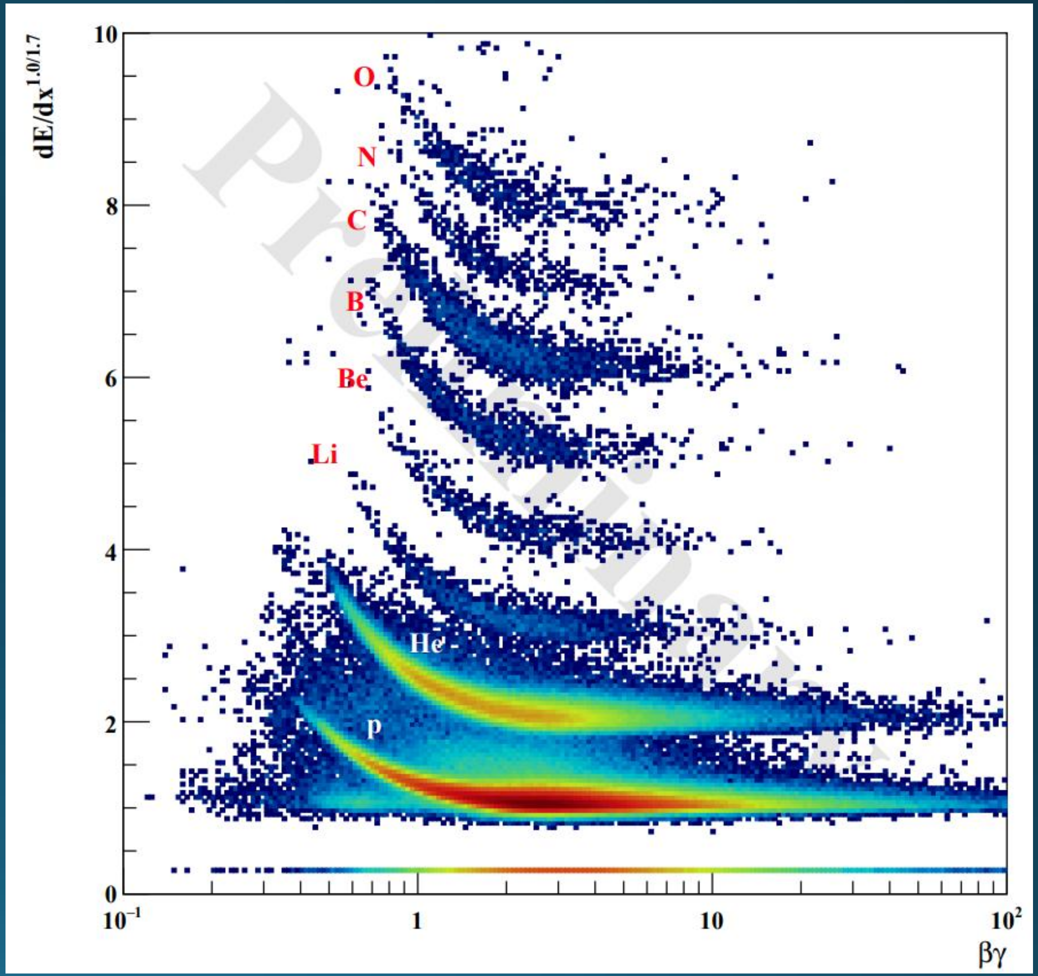


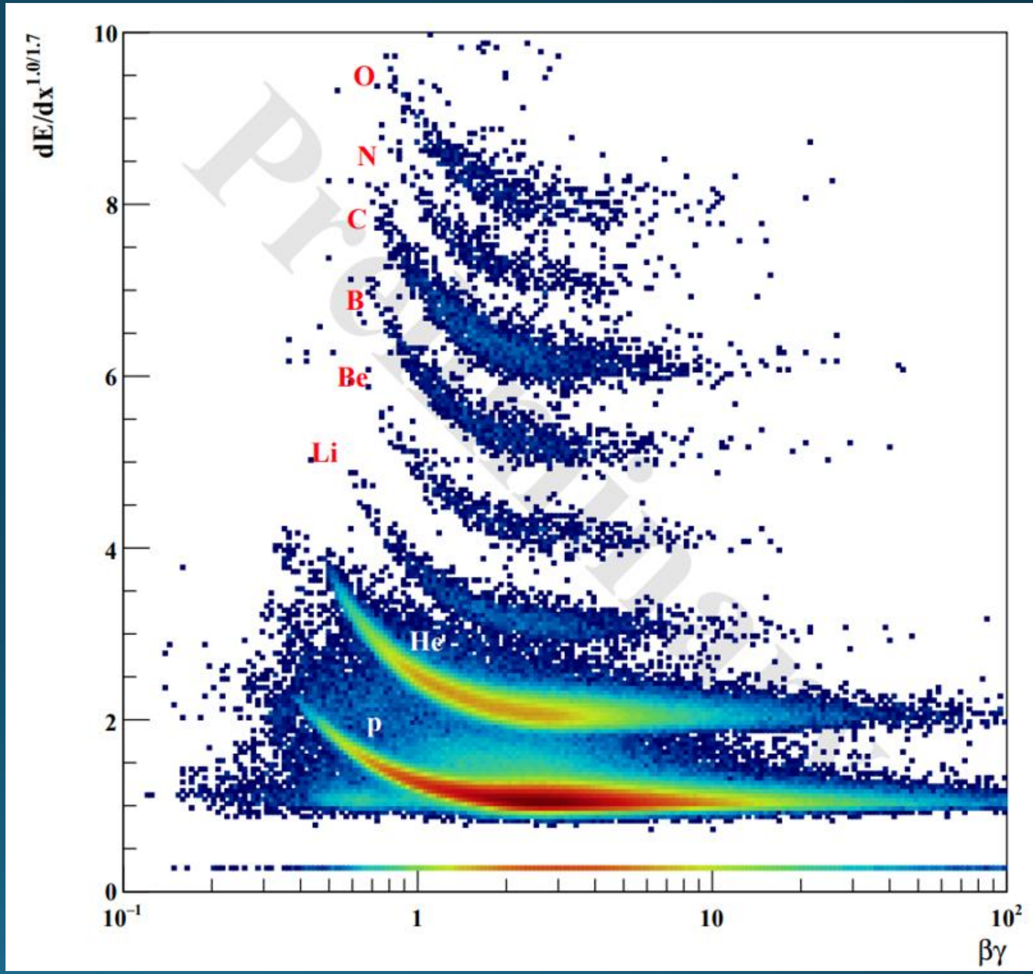
Ongoing analysis



Sakai et al 2026 JINST 21 C03014

Ongoing analysis

- 120 million triggers



Sakai et al 2026 JINST 21 C03014

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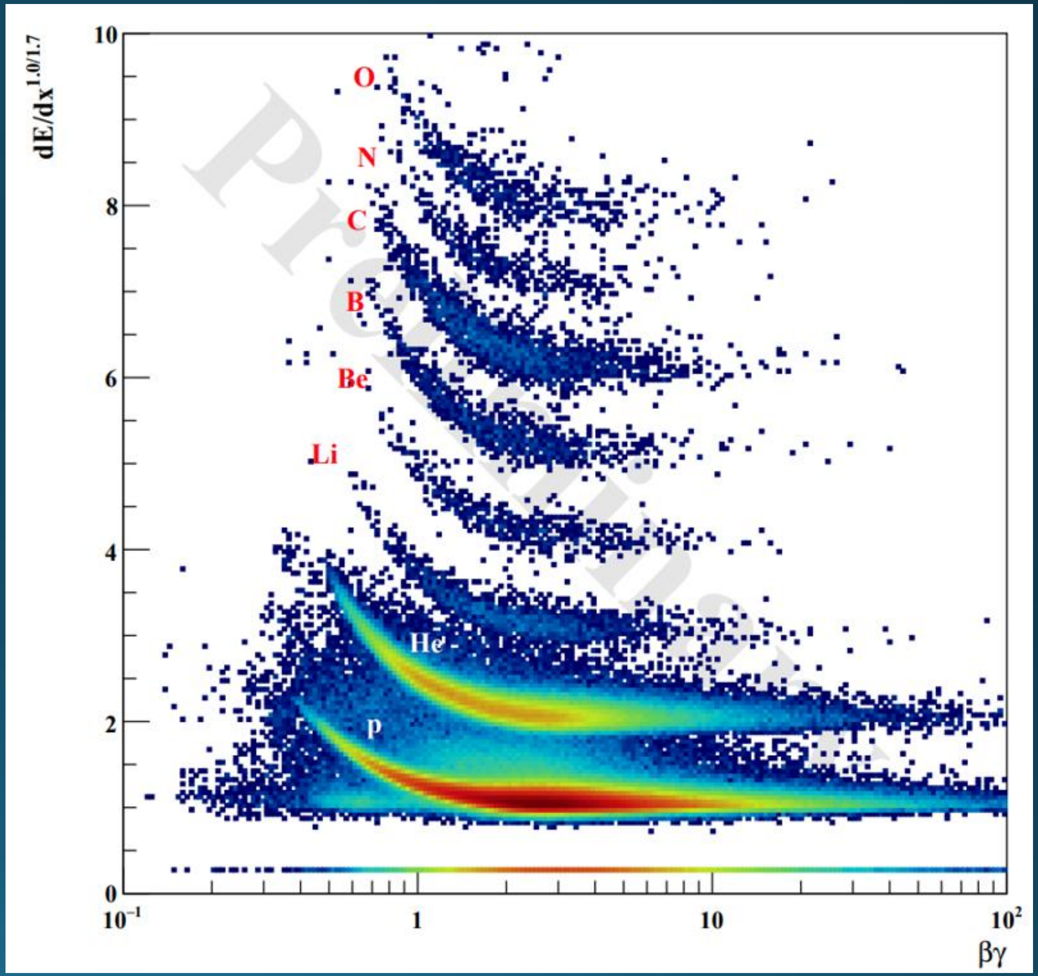

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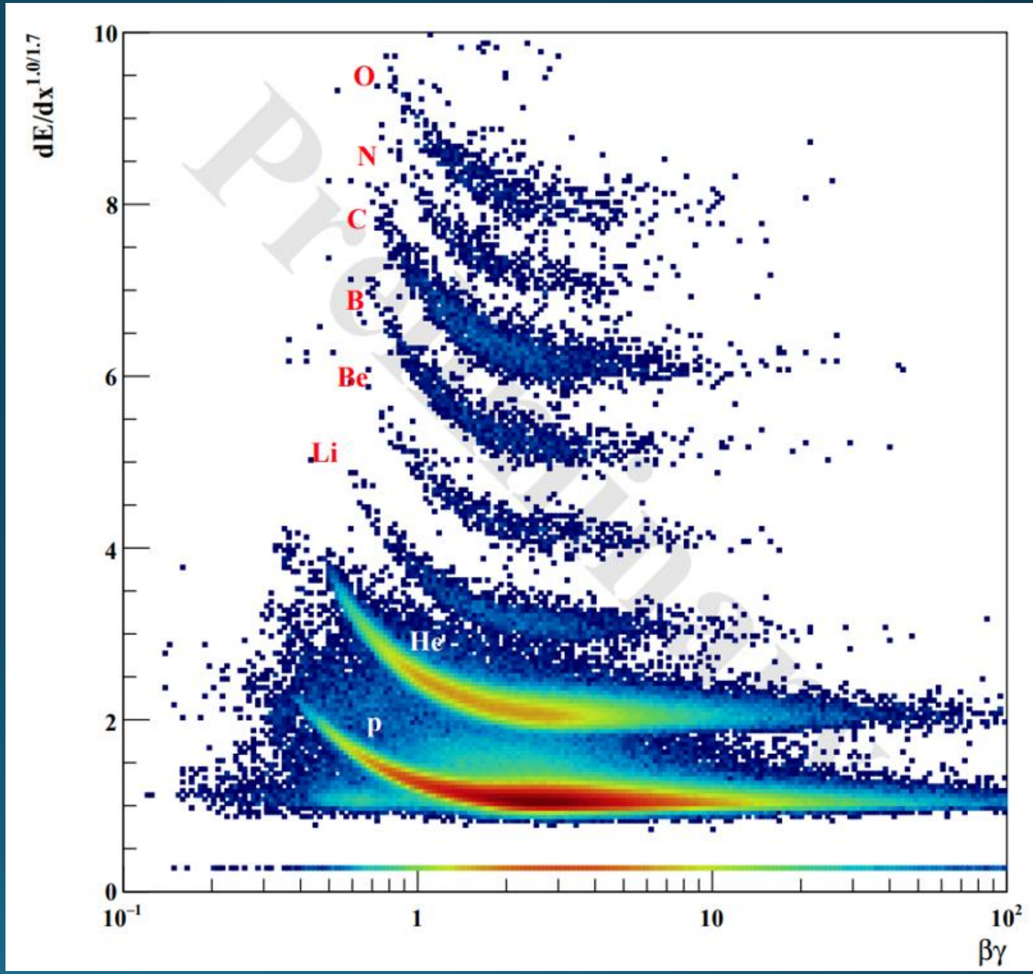

Sakai et al 2026 JINST 21 C03014

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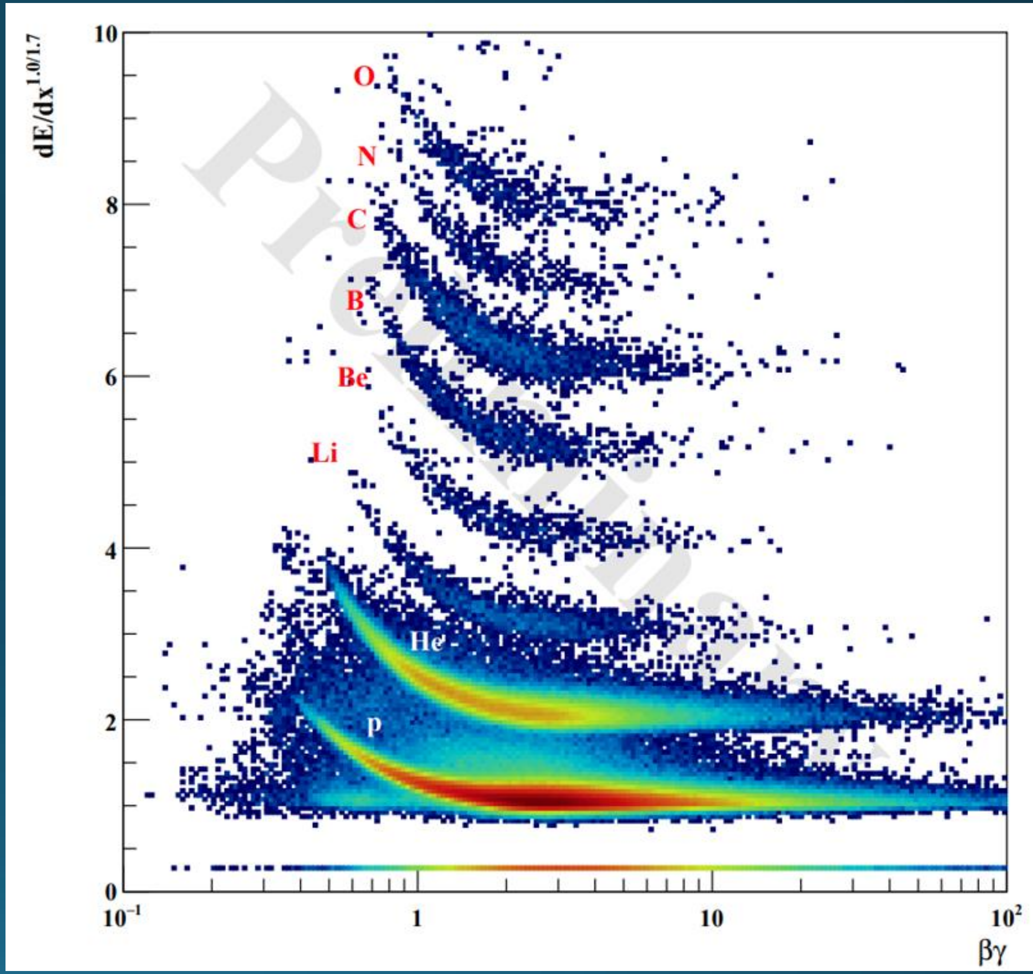

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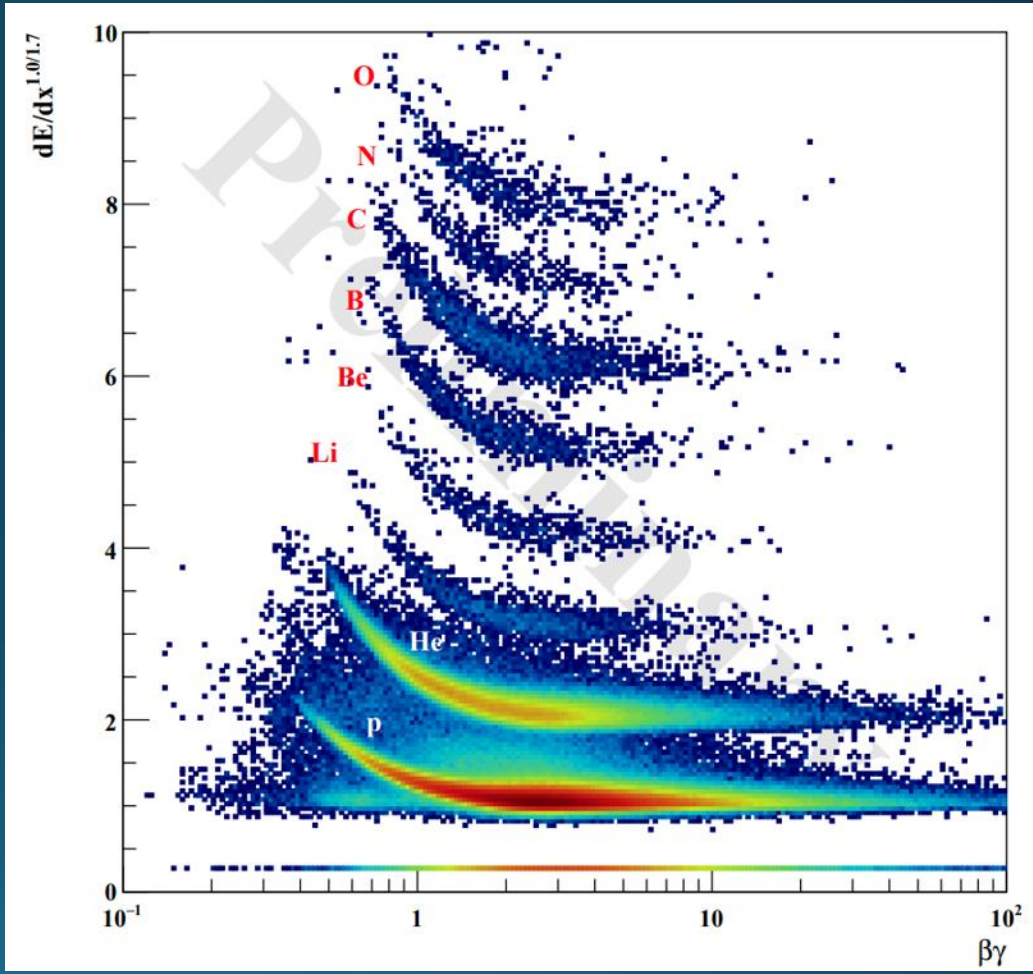
Stay tuned for instrumentation paper and analysis of first flight results



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The Payload for Ultrahigh Energy Observations (PUEO)

Graduate students:
Dennis H. Calderón
Payton Linton
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The Payload for Ultrahigh Energy Observations (PUEO)

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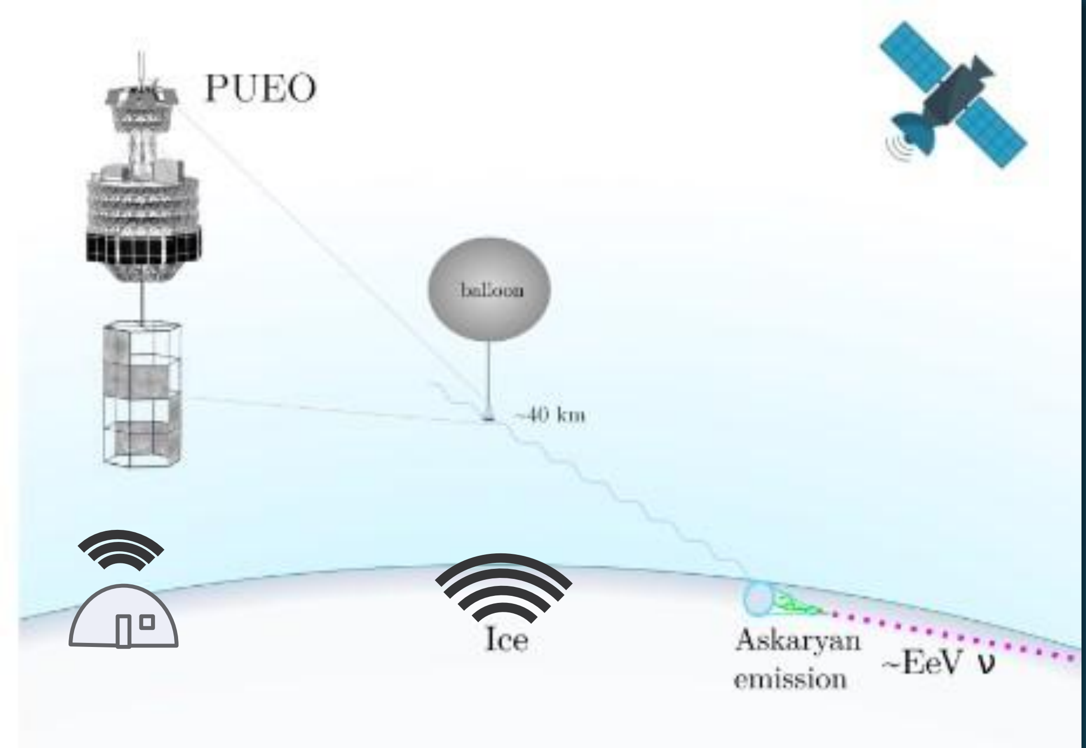
- Another balloon-borne instrument



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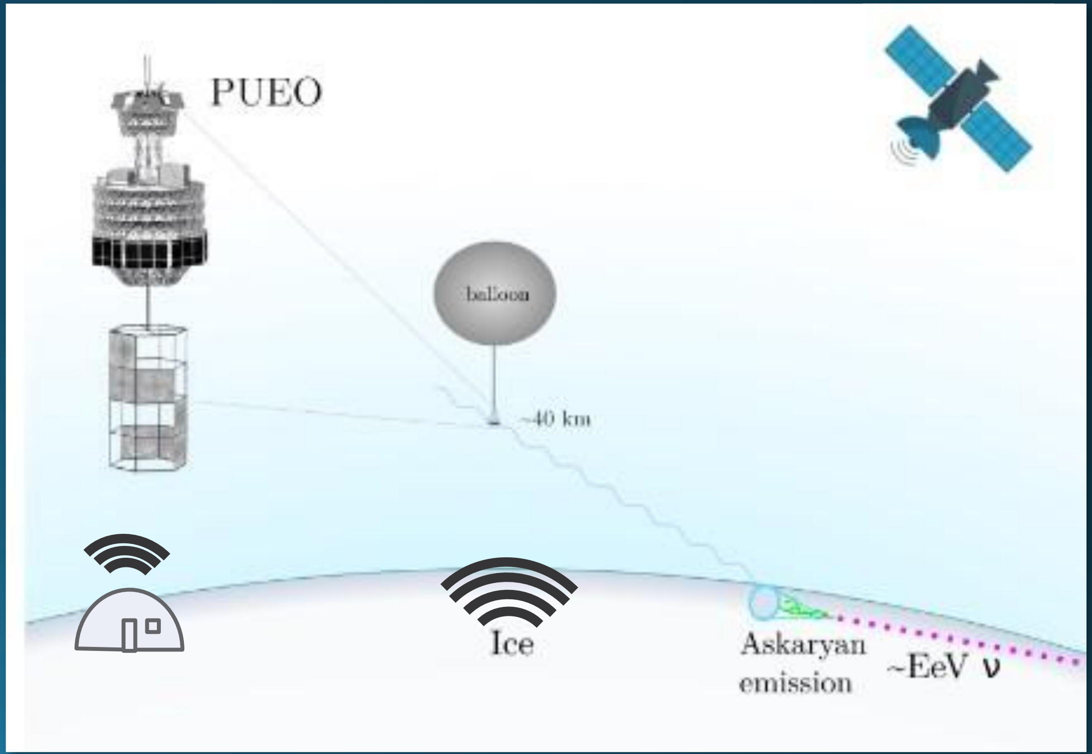

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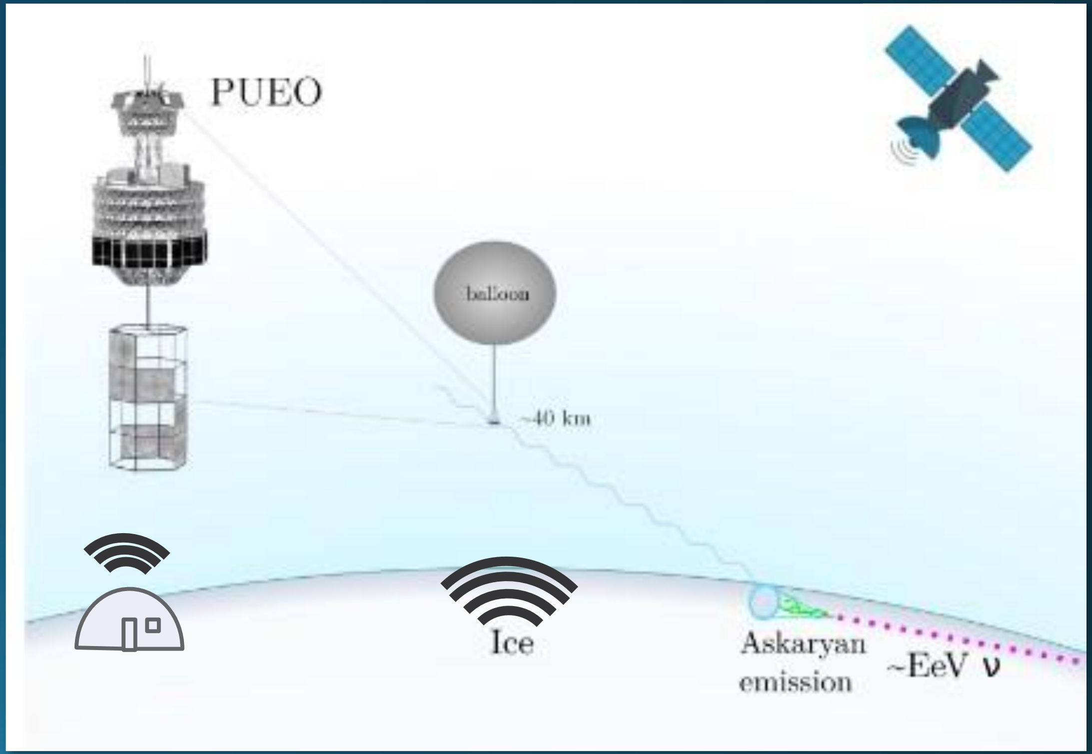

UChicago · KU · NTU · OSU · PSU · QMUL · UCL · UD · UHM · USC · Washu
PUEO

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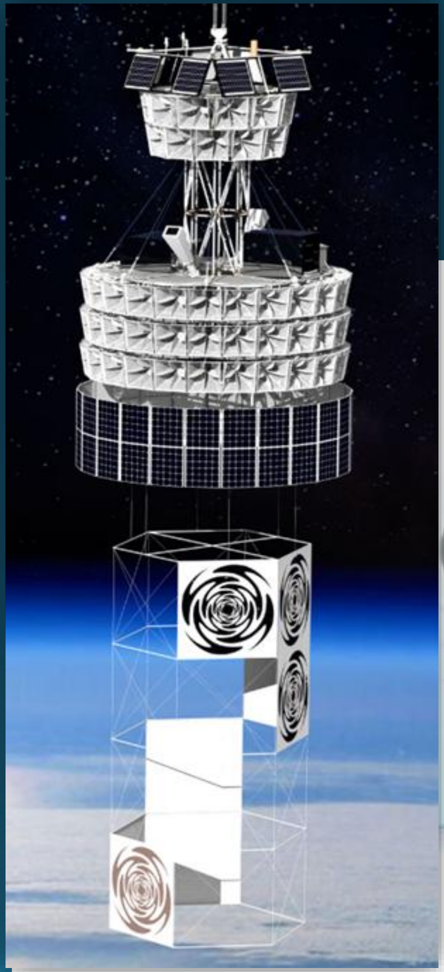
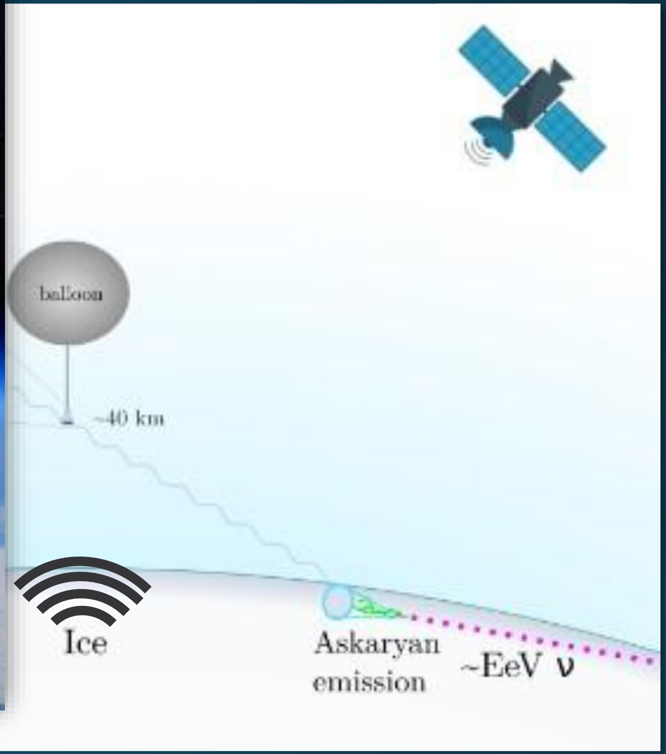
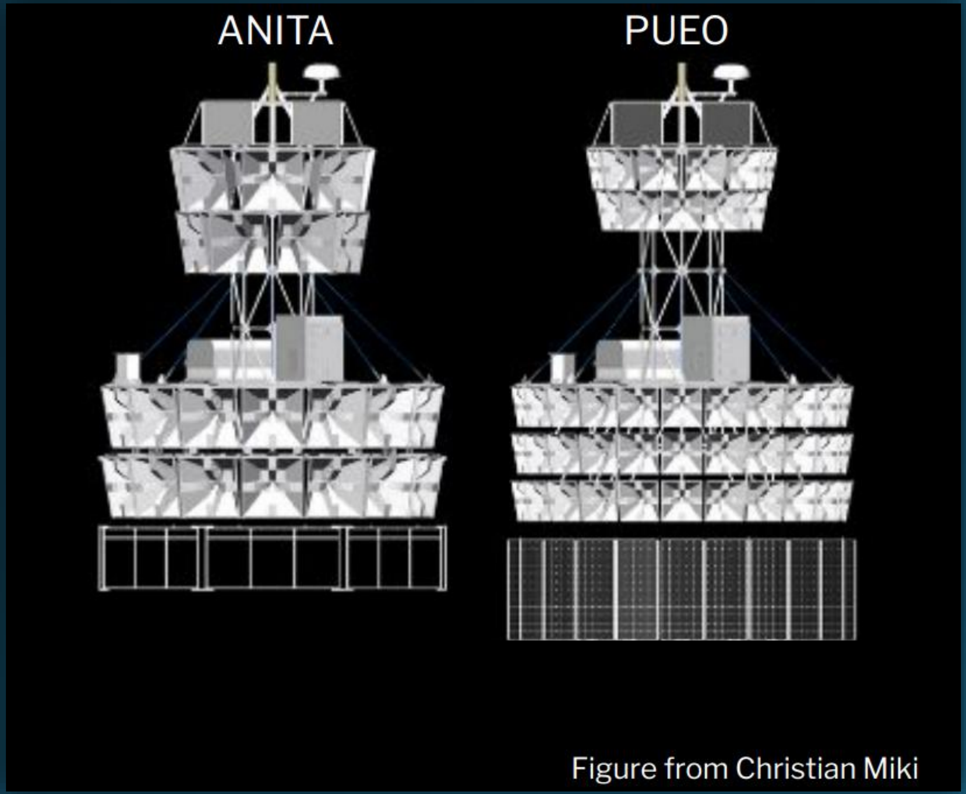




PUEO is the successor of ANITA



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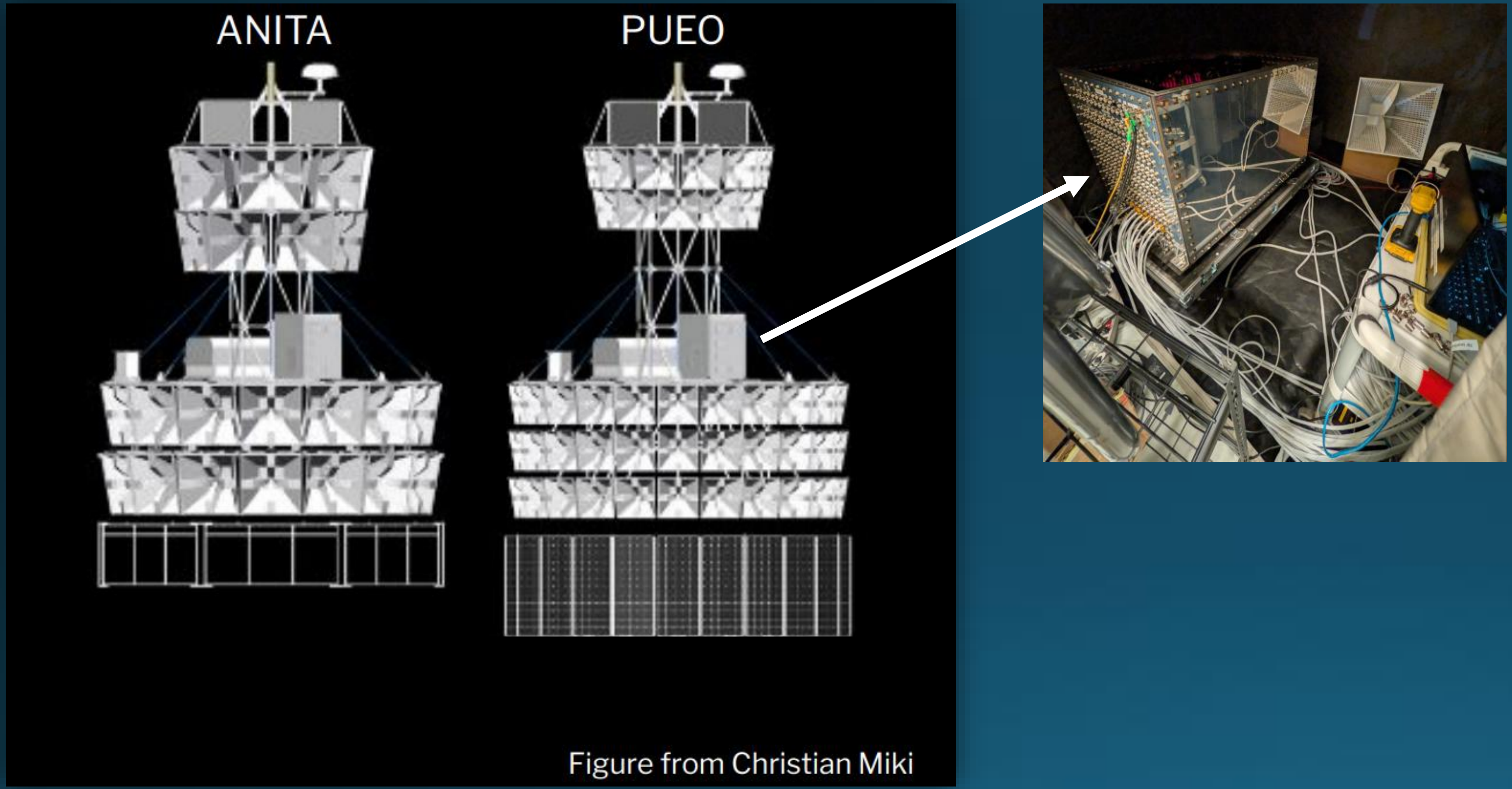

Figure from Christian Miki

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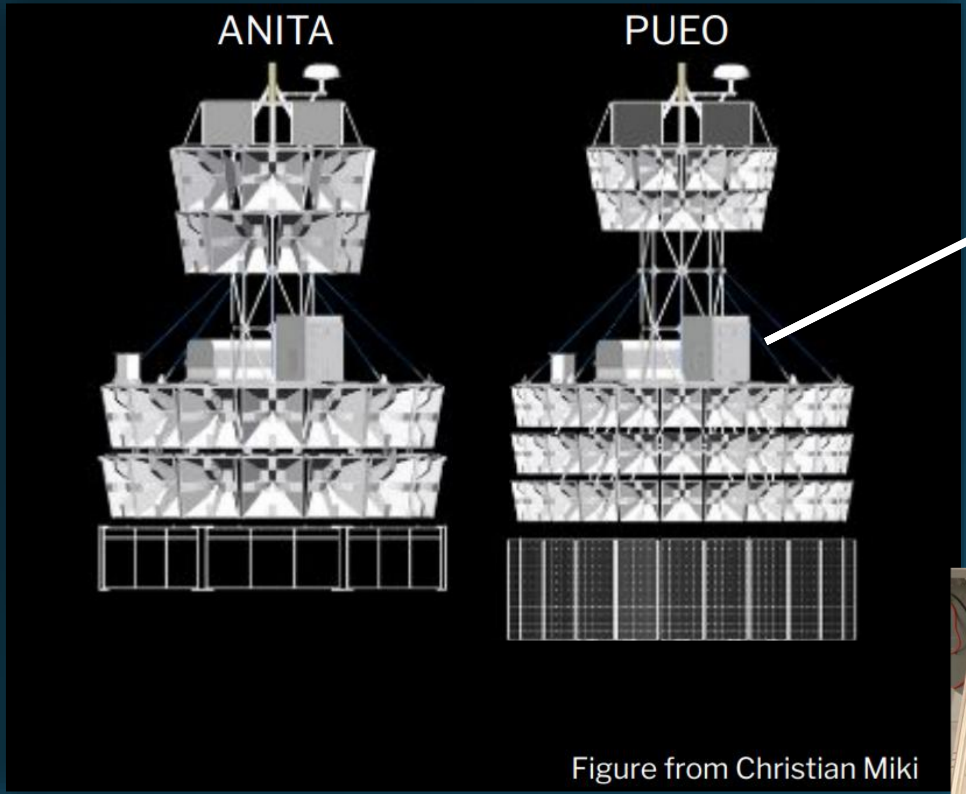

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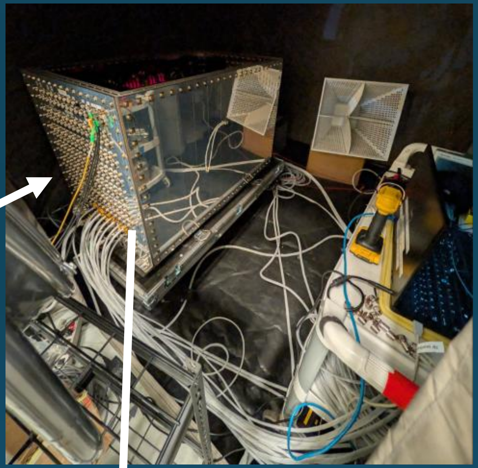

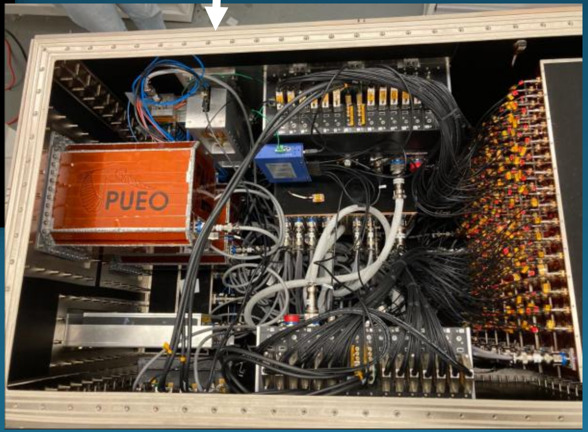

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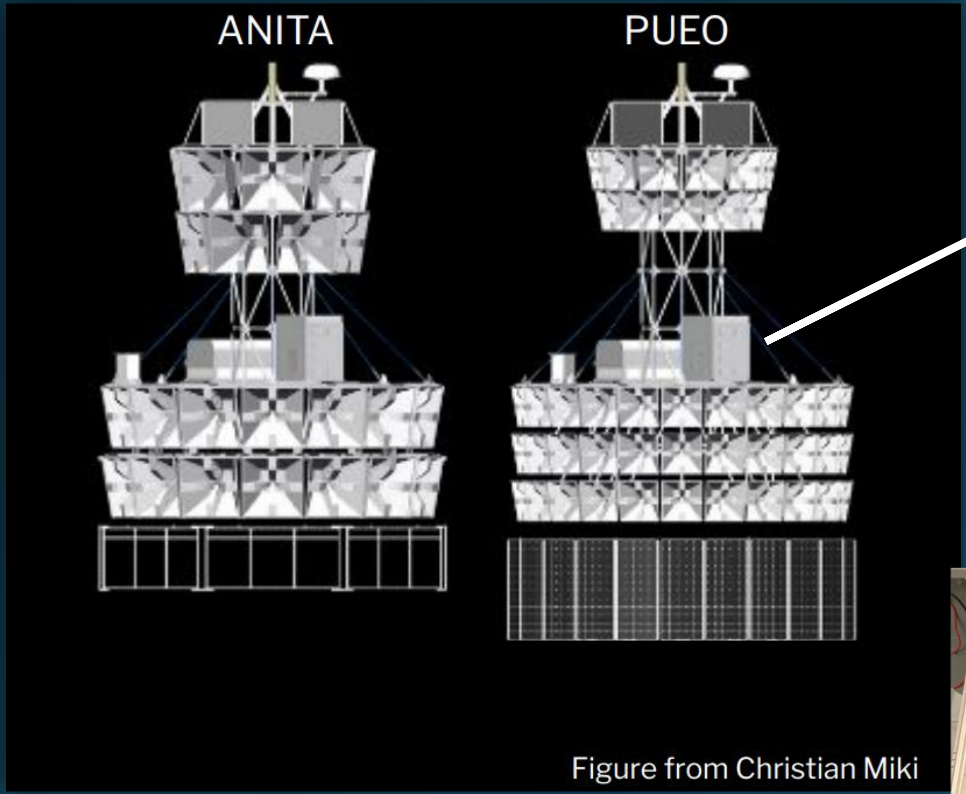

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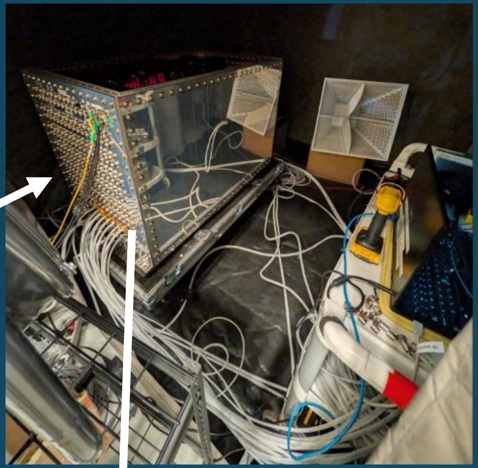

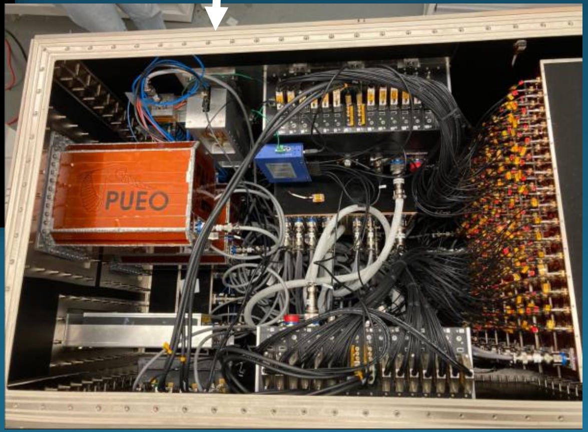

Taylor Coakley at Ohio State, expert on the data acquisition system.

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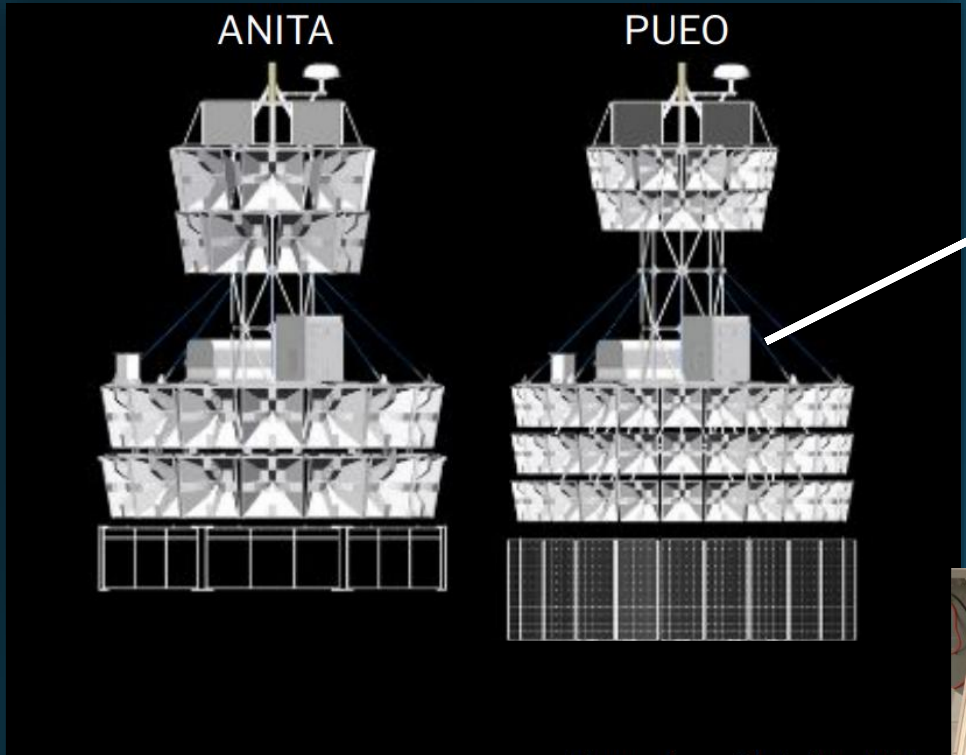

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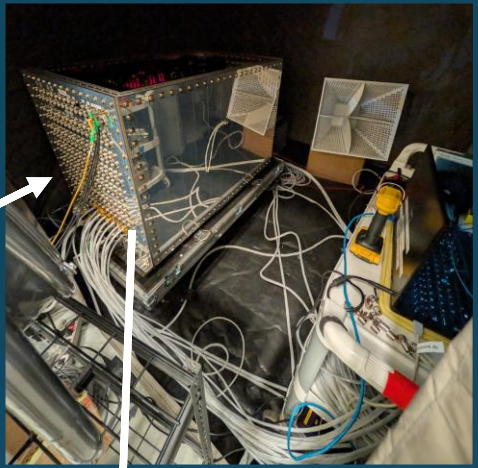

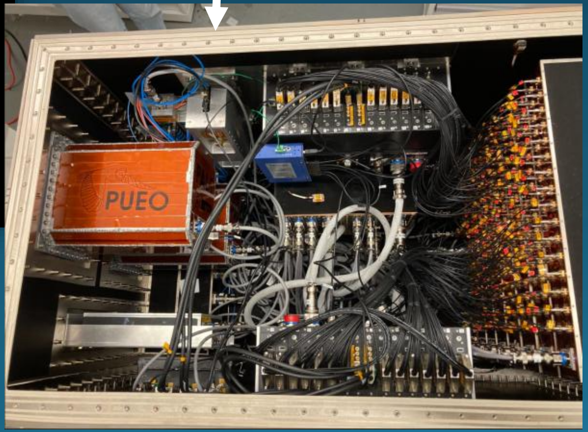

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1. Interferometric phased array trigger with optimized trigger band

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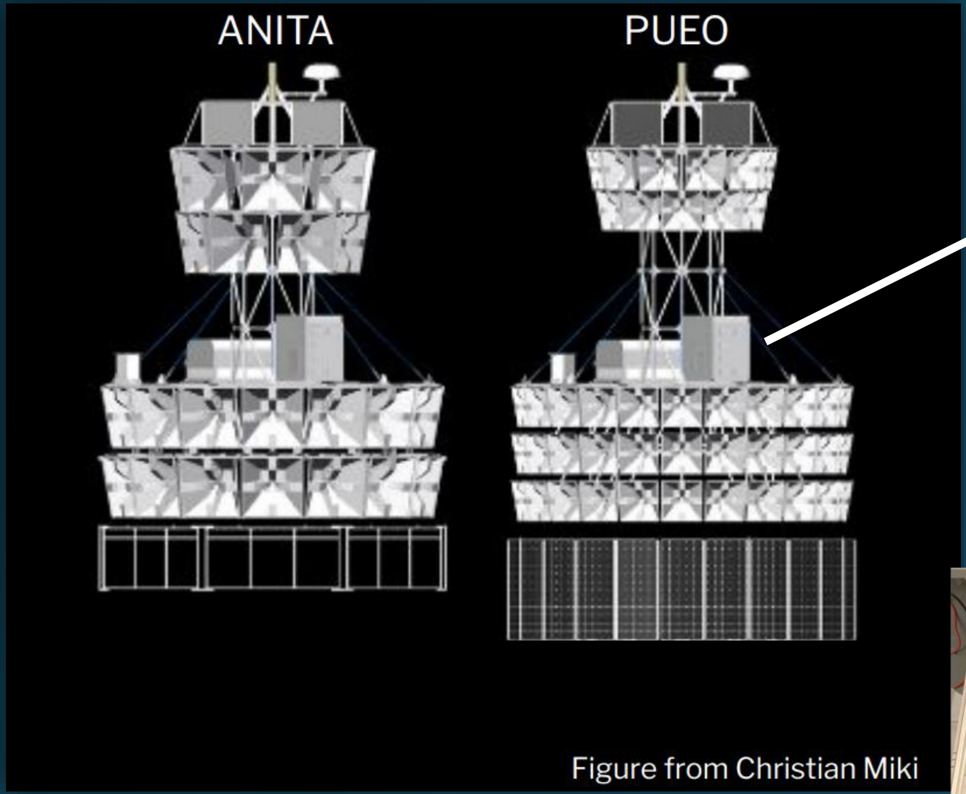

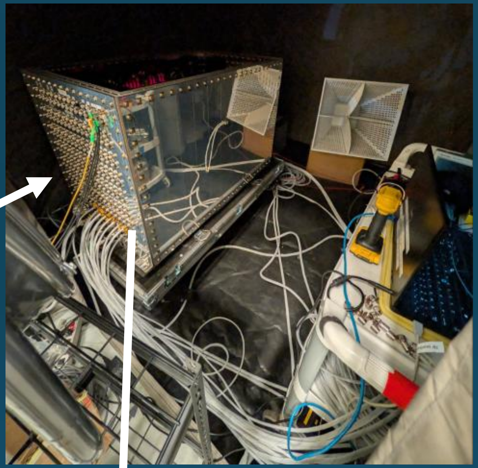

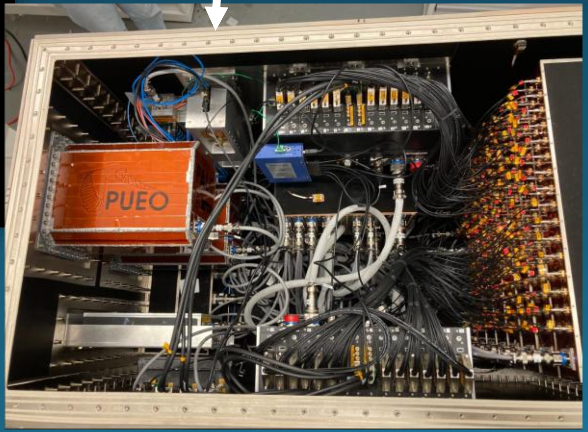

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1. Interferometric phased array trigger with optimized trigger band
2. x2 collecting area in the frequency band

PUEO Launch and deployables

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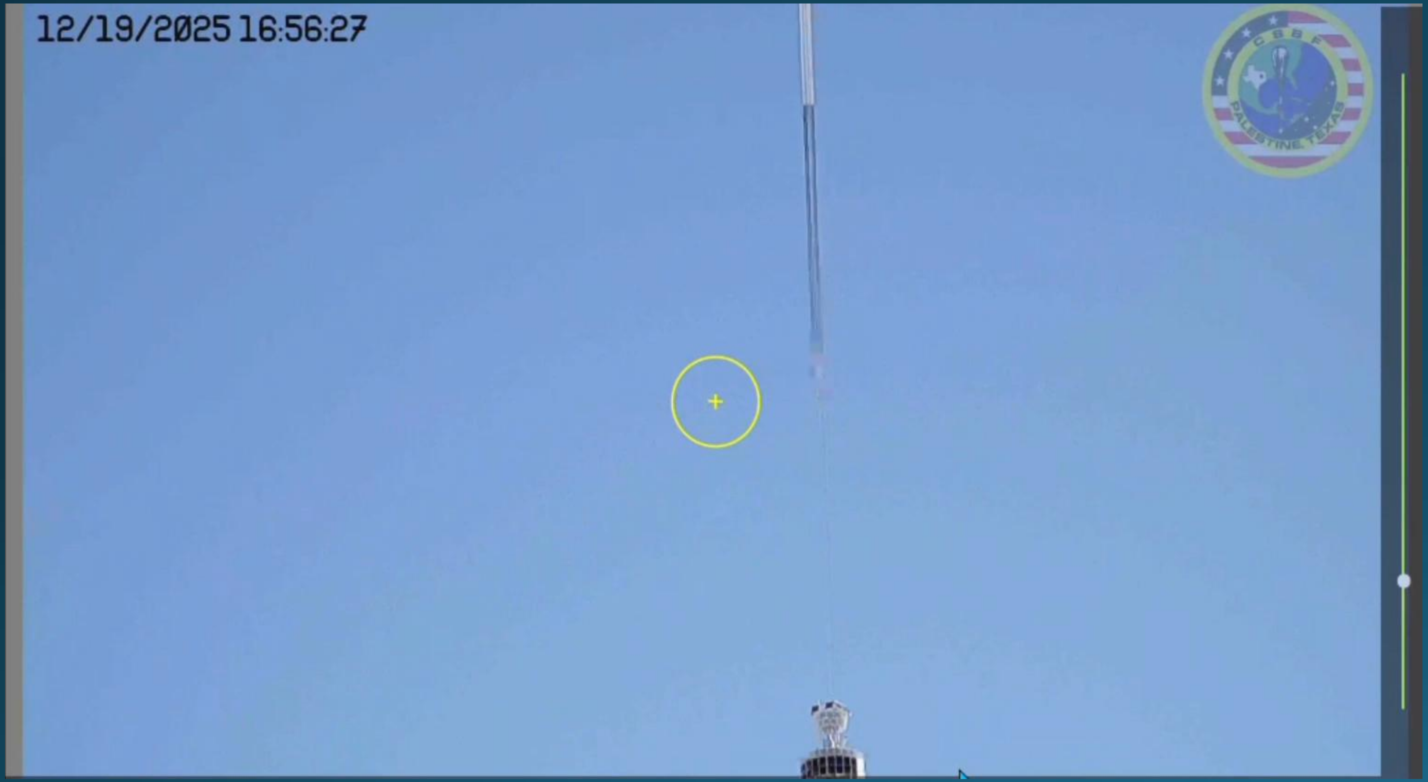
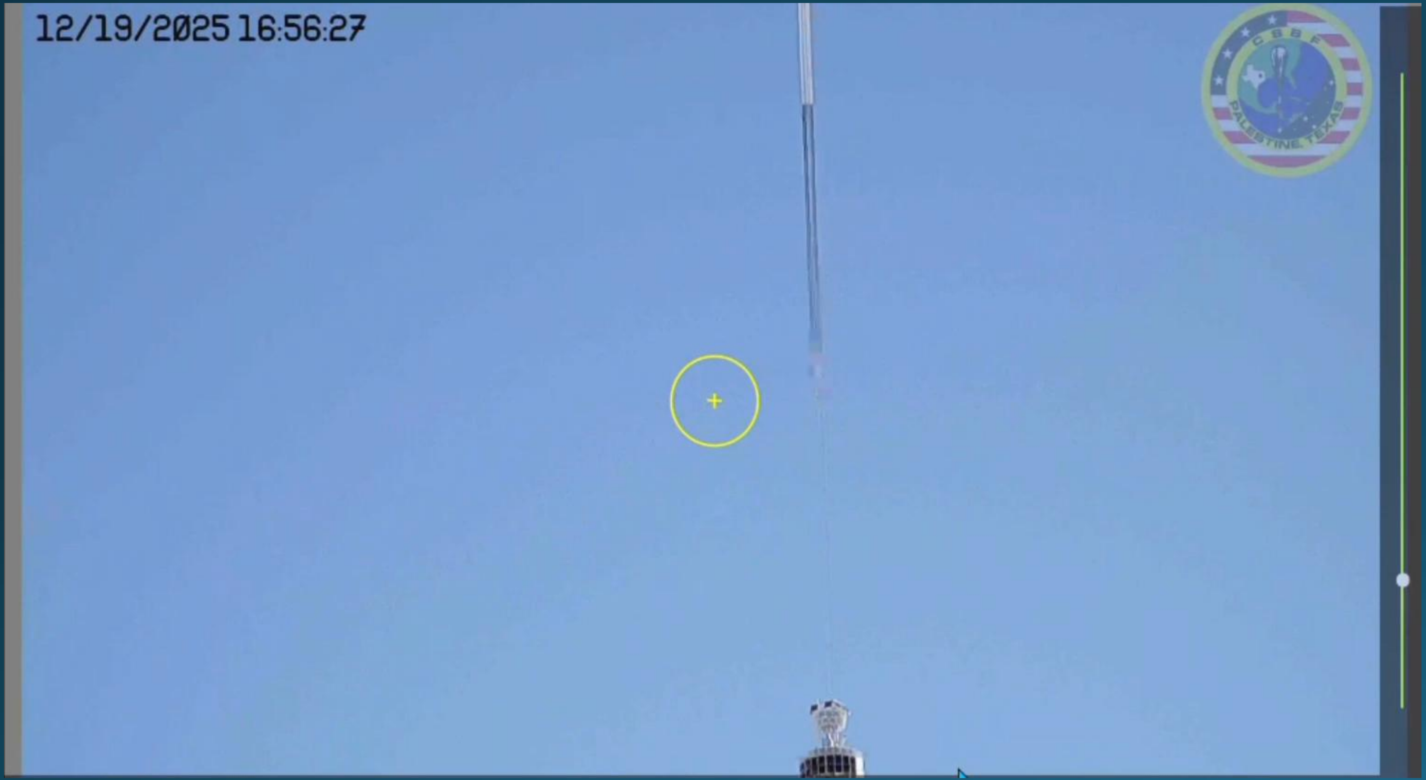
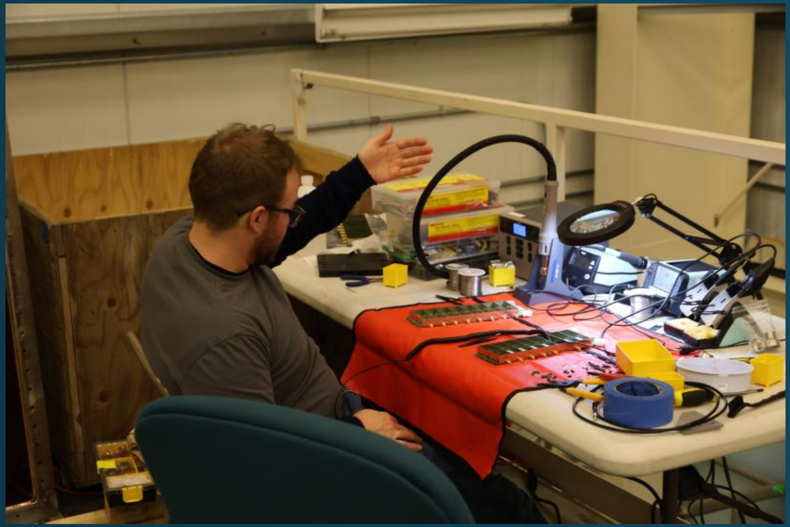


PUEO Launch and deployables



CCAPP on campaign



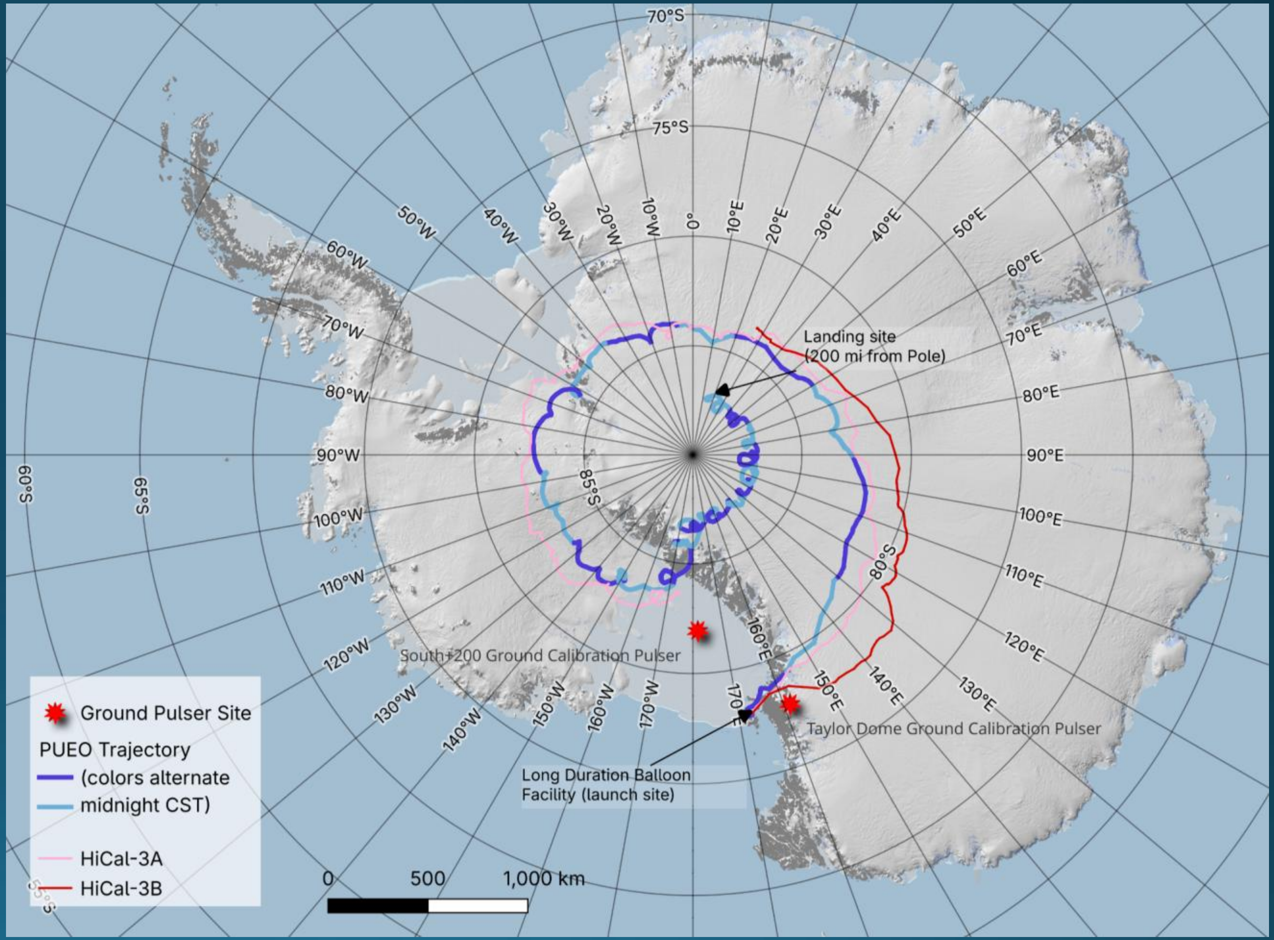
Dr. Quin Abarr

Dr. Lucas Beaufore

Taylor Coakley

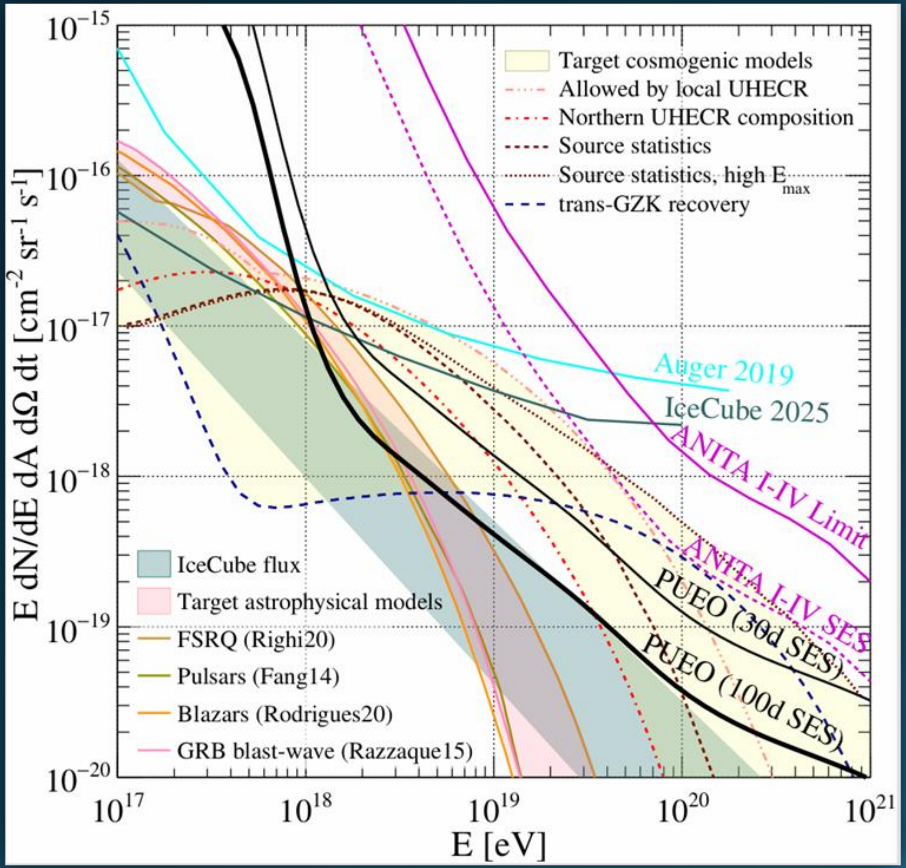
Ongoing analysis and calibration

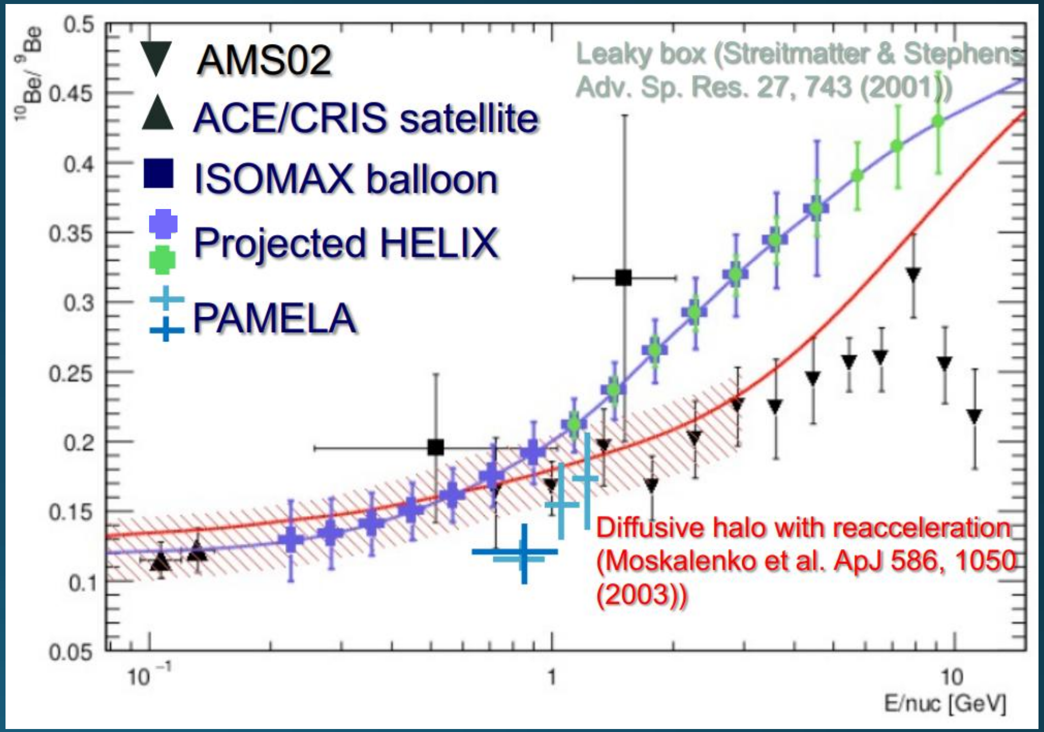
- Over 55TB of data collected
  - And data received
- Flew from Dec 19th 2025 to January 13th 2026
- Calibration with HiCal following payloads and ground pulsing.
- Stay tuned for results!



Conclusions

PUEO will teach us about the highest energy accelerators in the universe!





HELIX will significantly improve our understanding of GCR propagation

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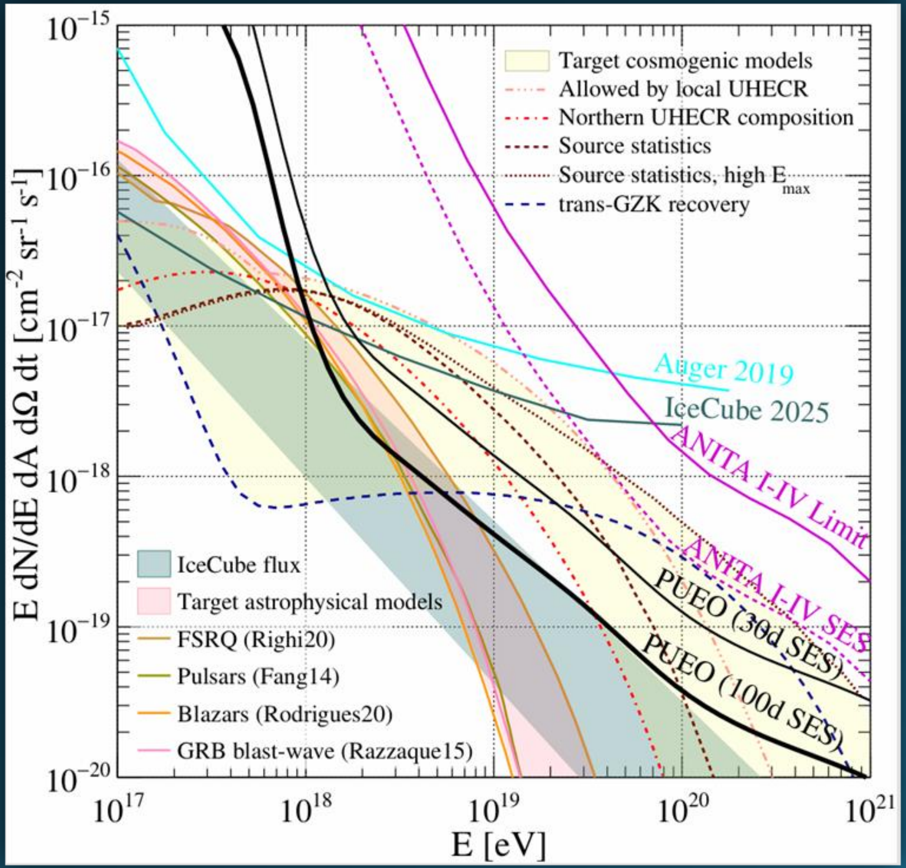
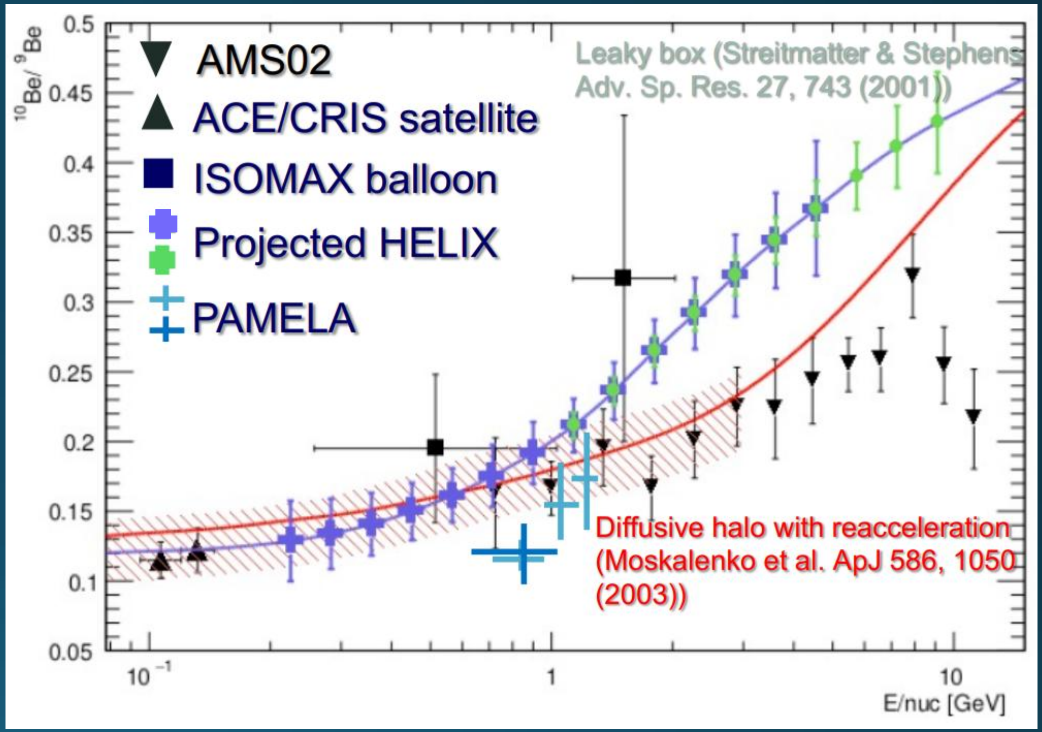


1. Both experiments successfully flown



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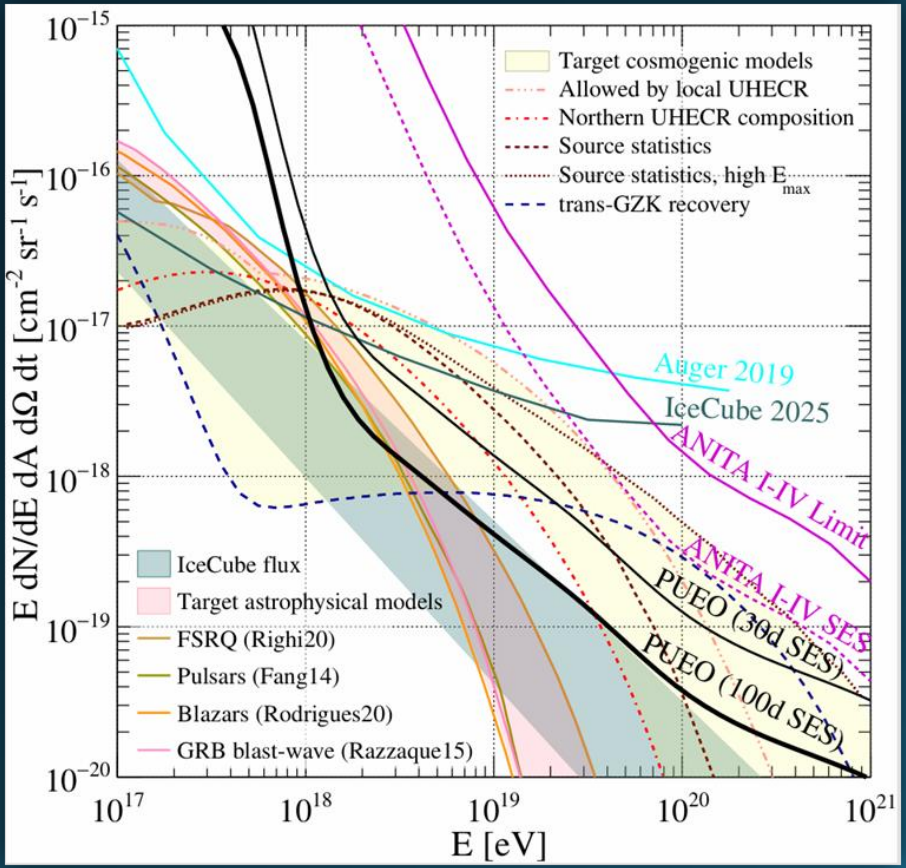
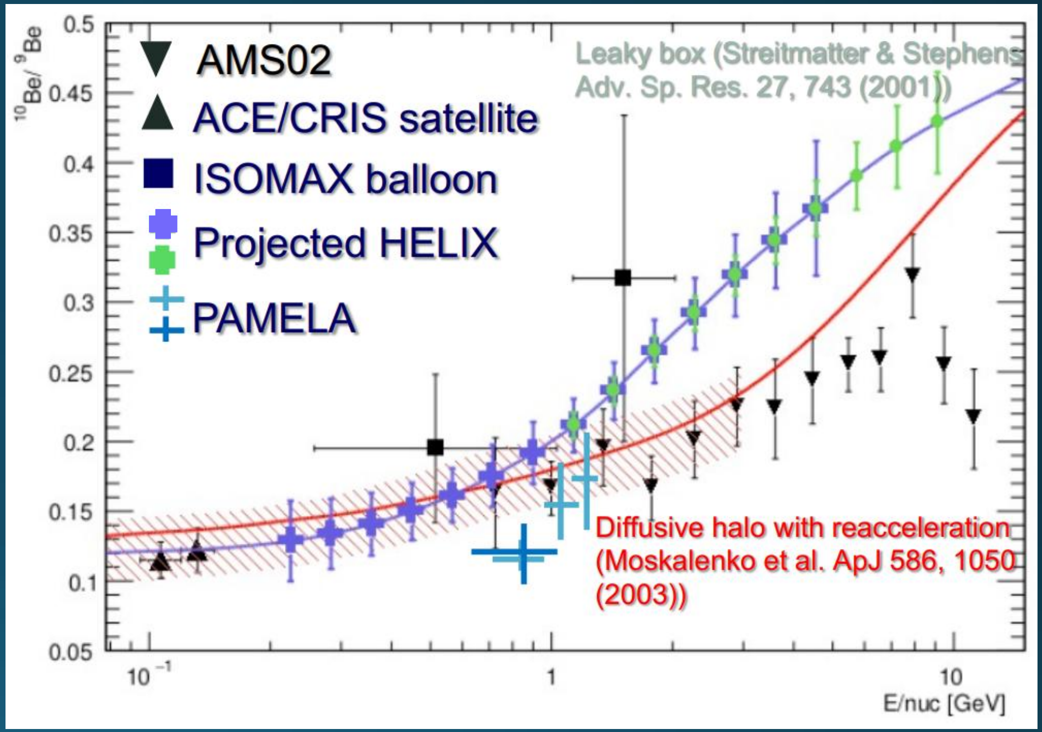


1. Both experiments successfully flown
2. Results coming very soon



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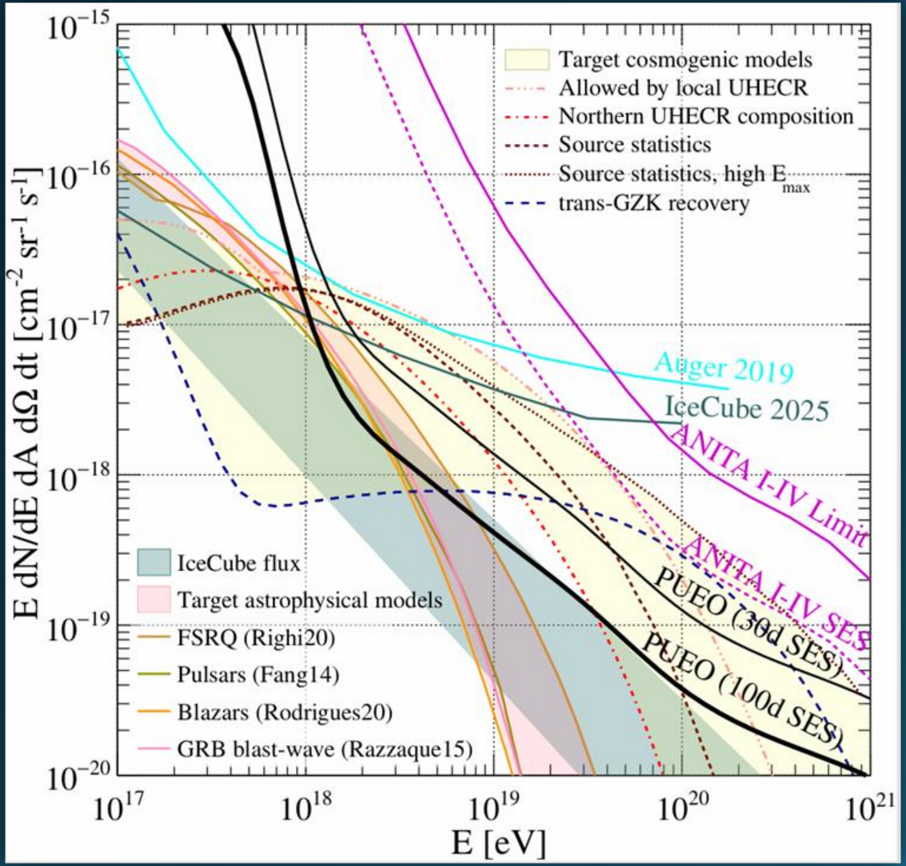
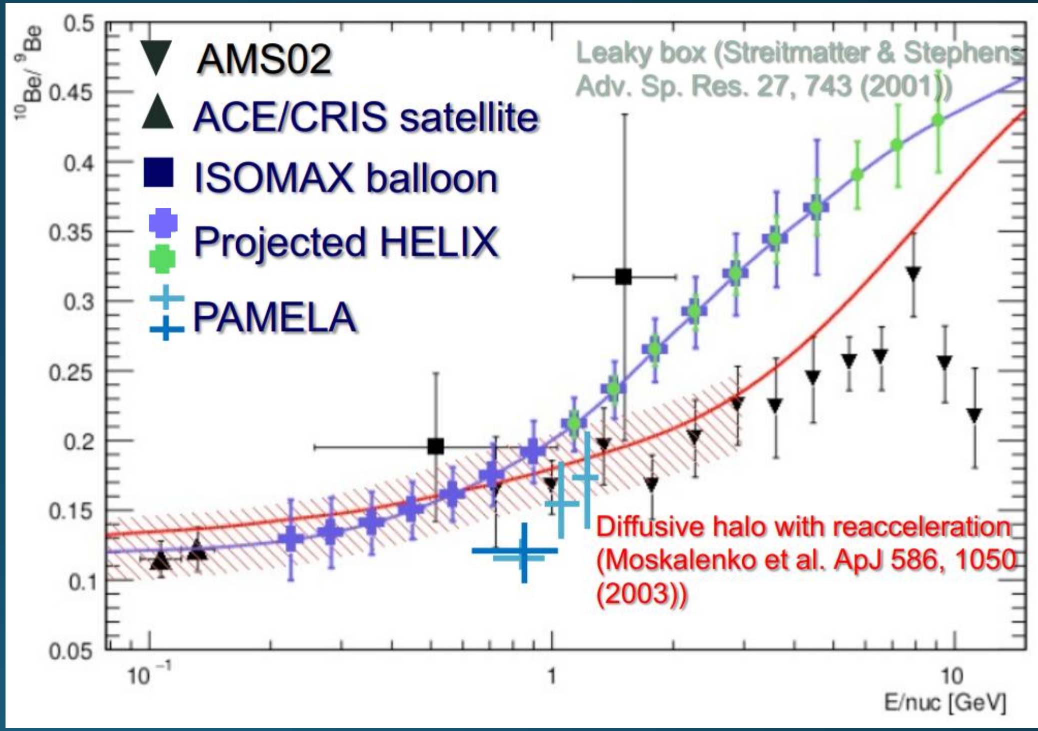


1. Both experiments successfully flown
2. Results coming very soon
3. Recovery completed



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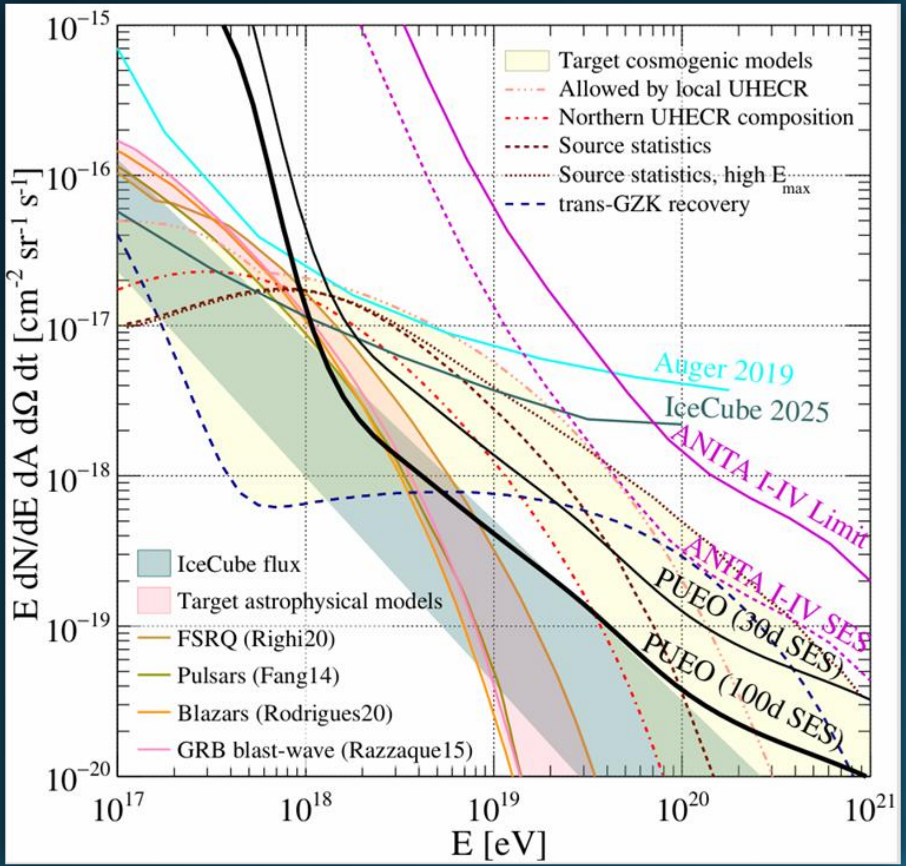
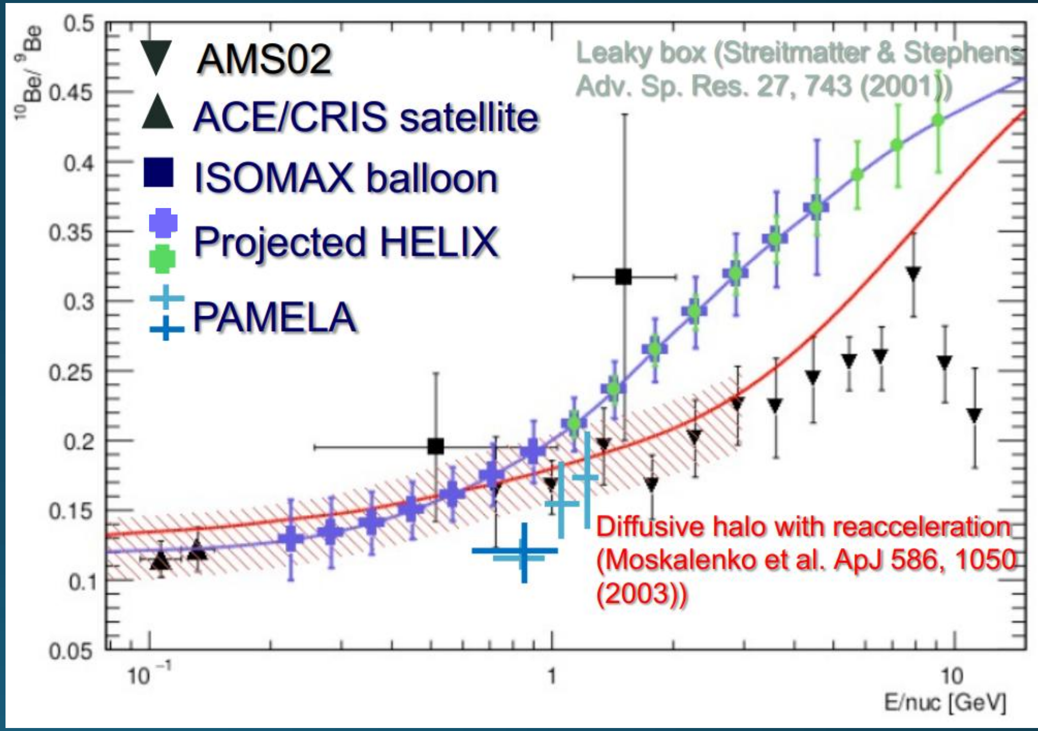


1. Both experiments successfully flown
2. Results coming very soon
3. Recovery completed
4. Refurbishment underway



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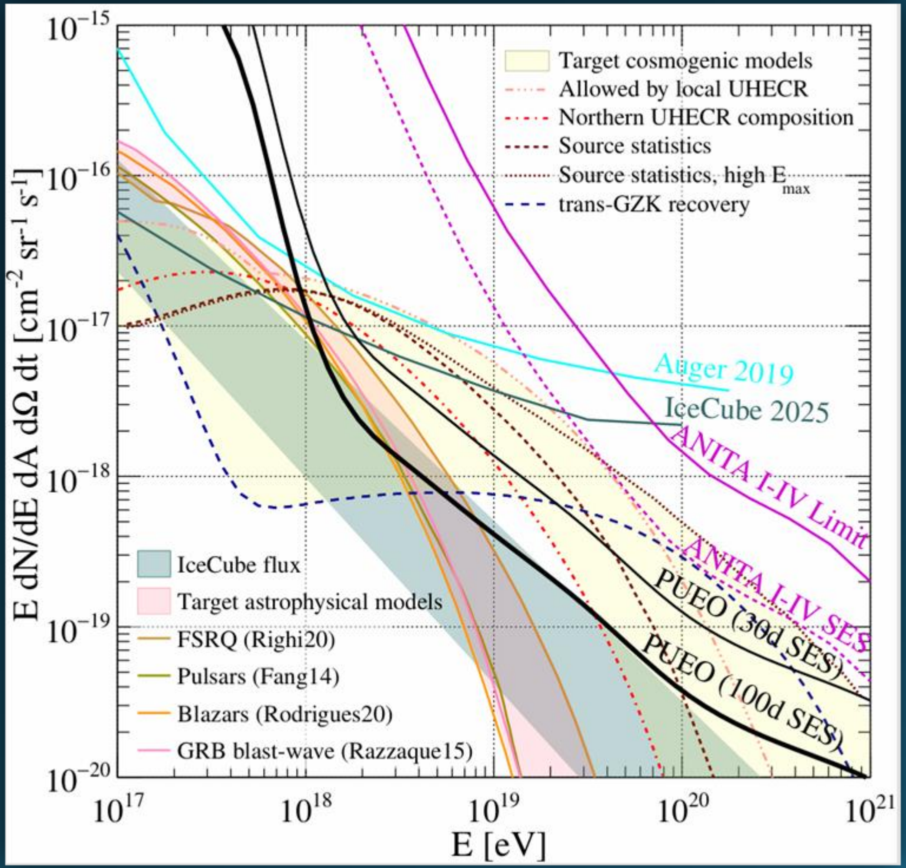

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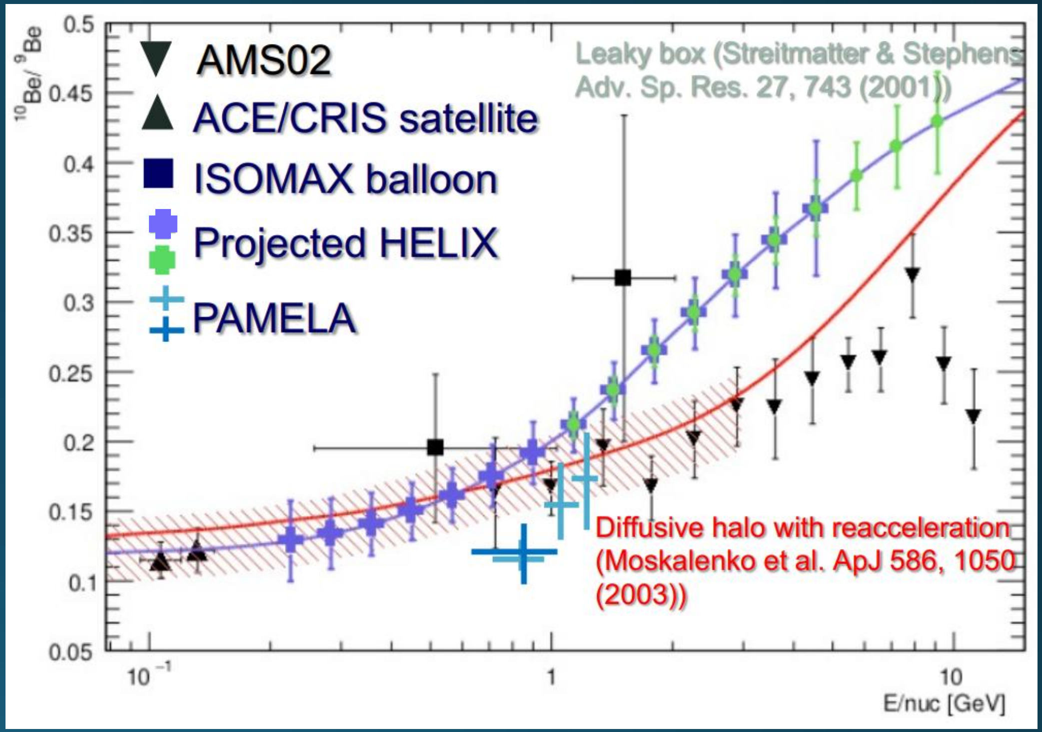

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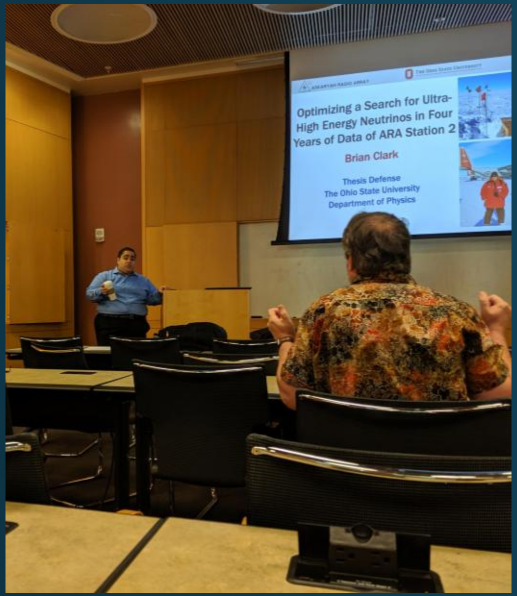
Optimizing a Search for Ultra-High Energy Neutrinos in Four Years of Data of ARA Station 2
Brian Clark
Thesis Defense
The Ohio State University
Department of Physics


#ThisIsPAST
Developing Software to Monitor the HELIX Instrument's Temperature on NASA's High Altitude Balloon.
Thomas Millender, 12th grade, Metro Early College High School
NASA
CCAPP
CENTER FOR COSMOLOGY AND ASTROPARTICLE PHYSICS
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Results
Future Work
Objectives
Conclusion
References
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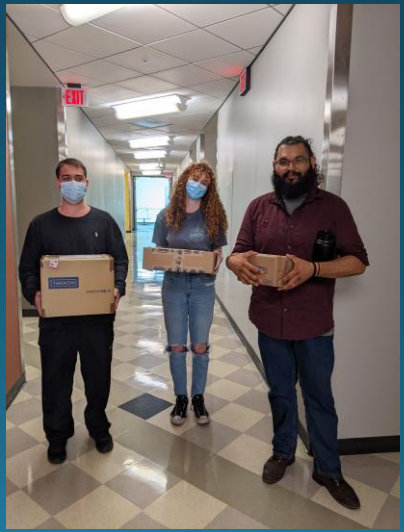

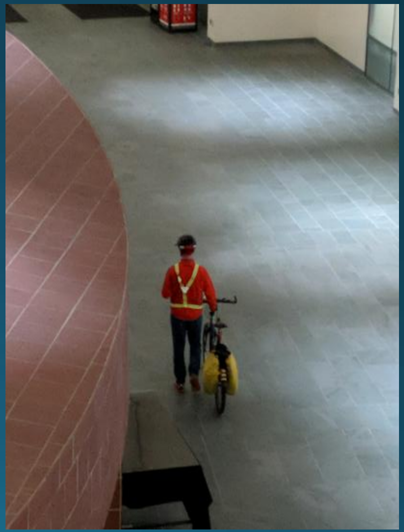

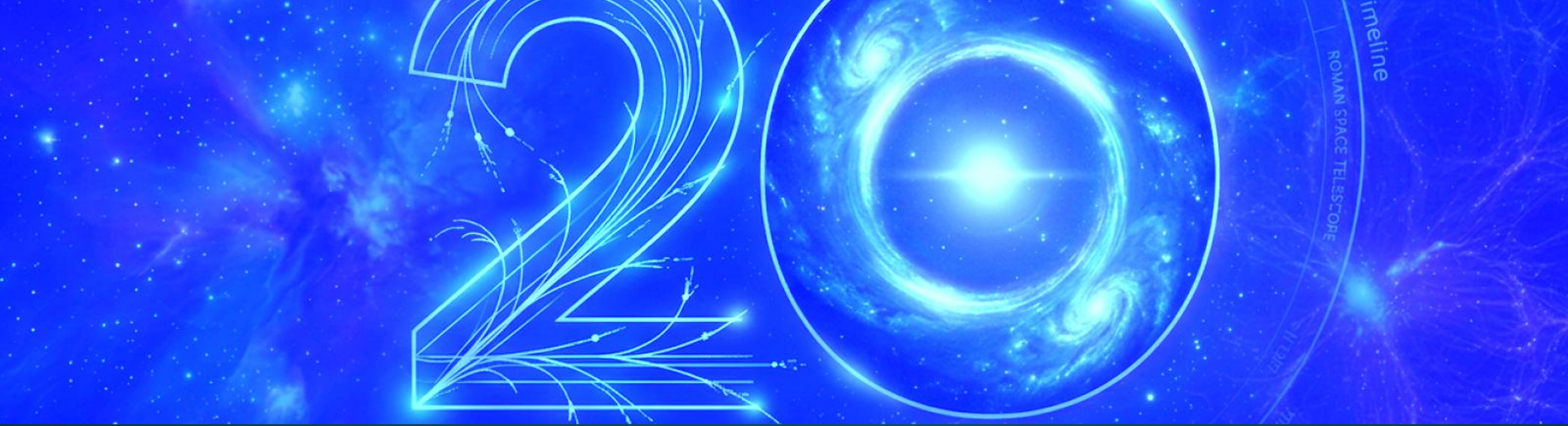

Thank you!