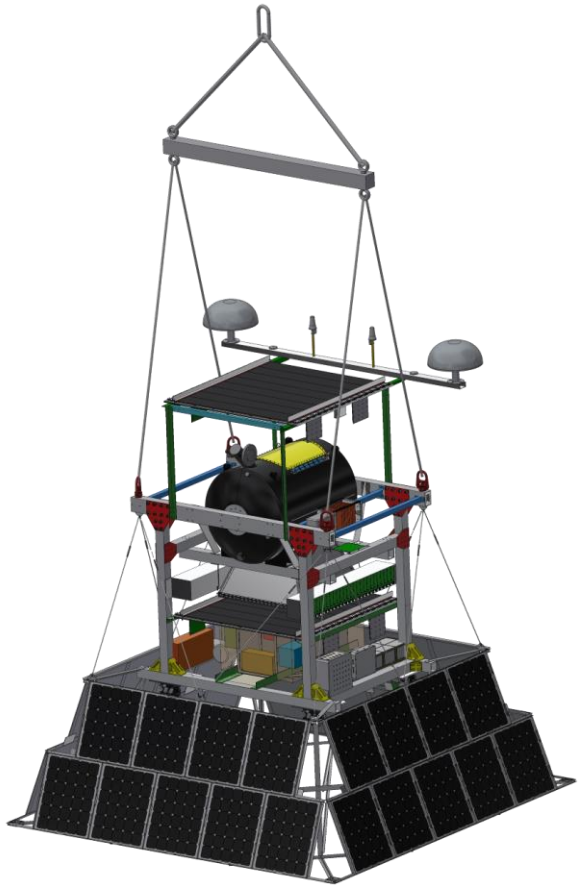
Metrology of The High Energy Light Isotope eXperiment (HELIX)

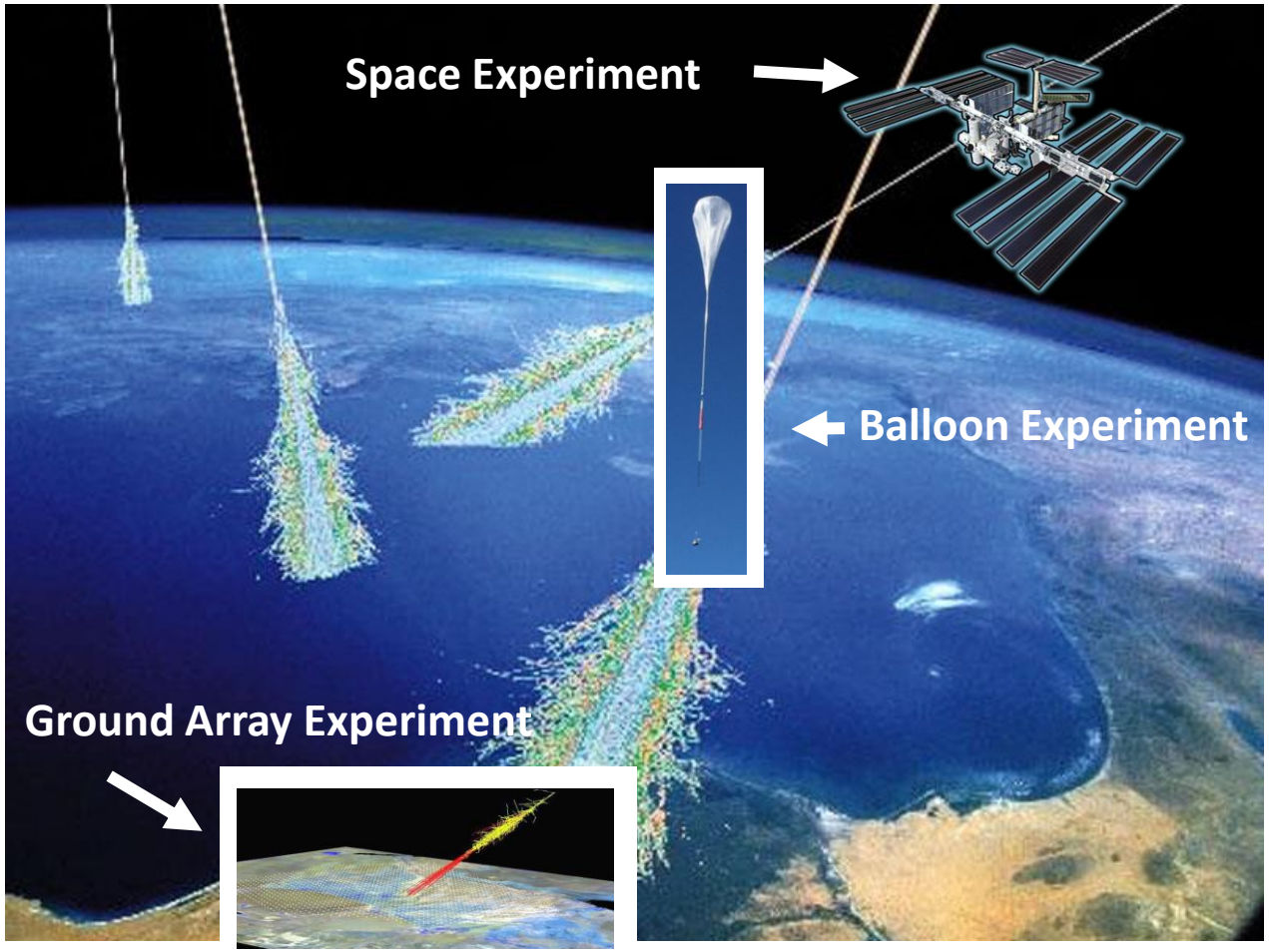
Melissa Baiocchi

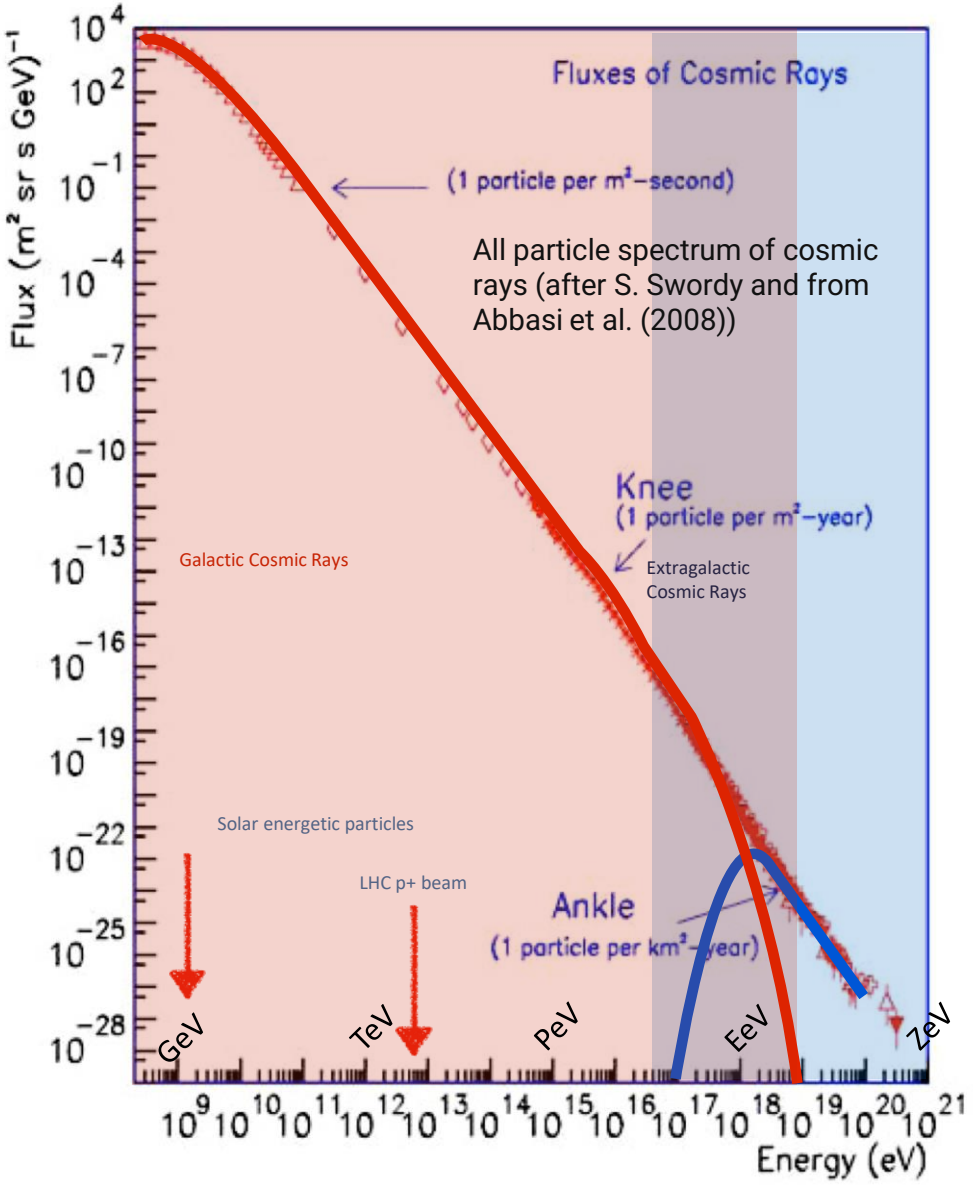
Queen's University



Cosmic Rays

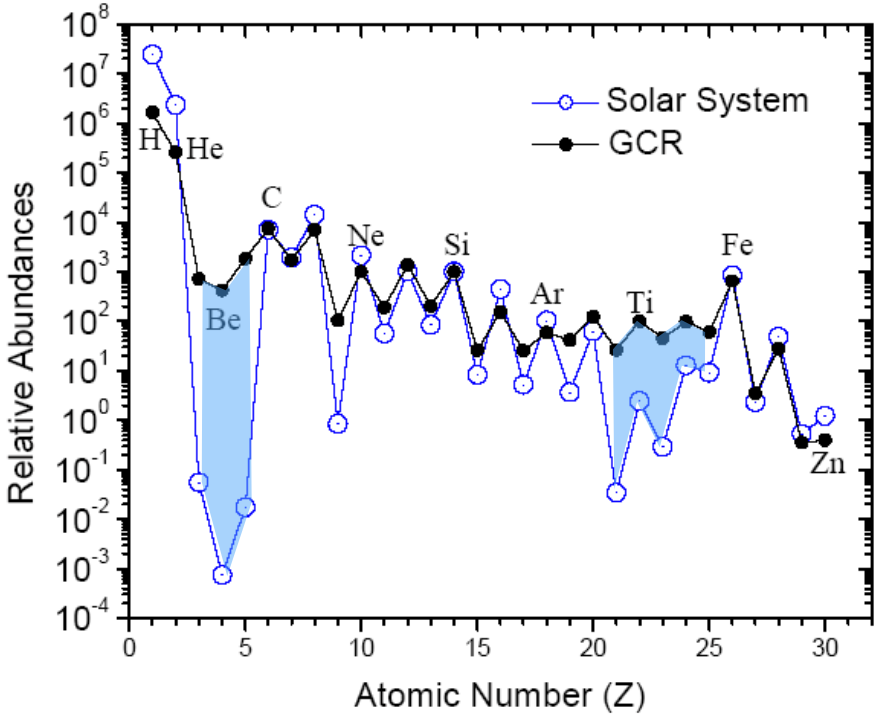
- **High Energy Charged Particles, originating from outer space**
  - Mostly atomic nuclei: 85% Protons, 12% Helium, 2% Heavy Nuclei

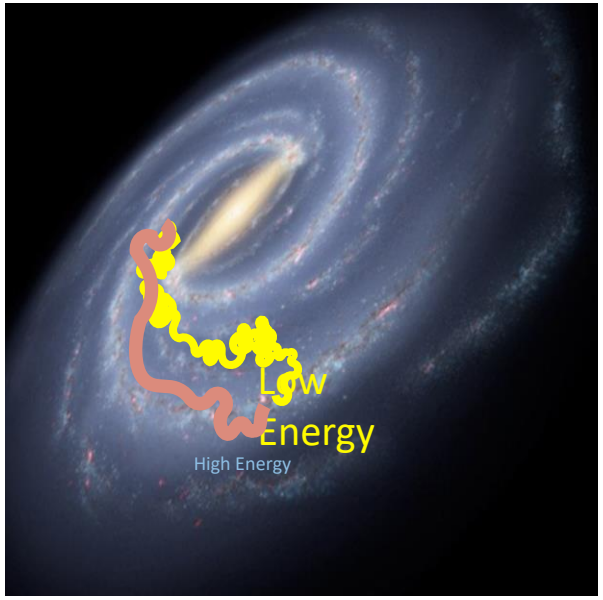


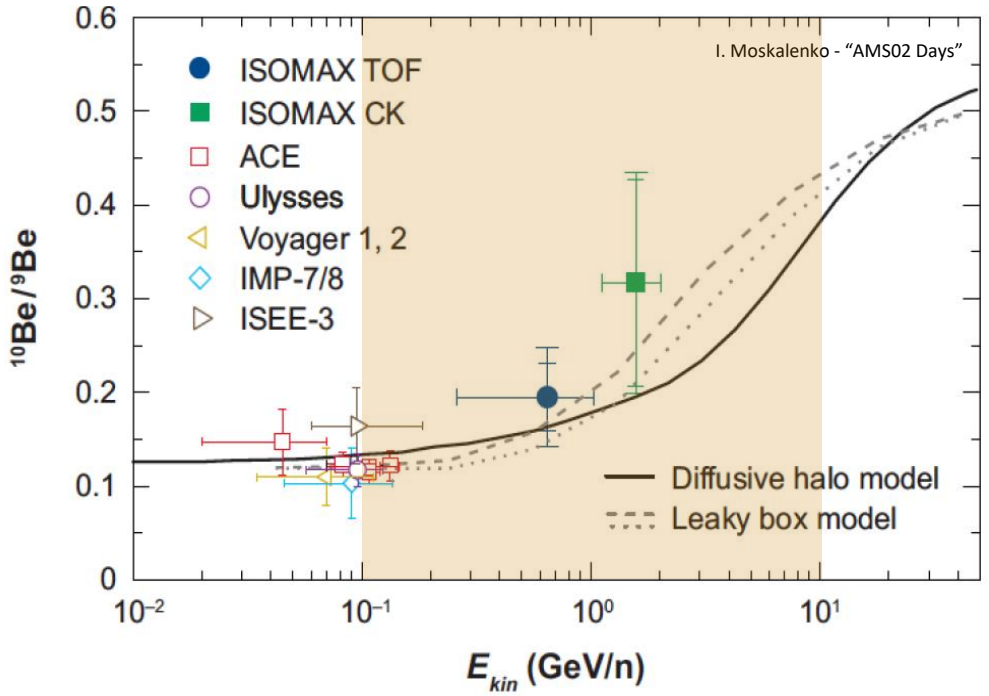


Scientific Motivation

- Primary to secondary cosmic ray ratio of interest: Boron to Carbon
- ^{10}Be is an unstable isotope of half-life 1.4 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 model

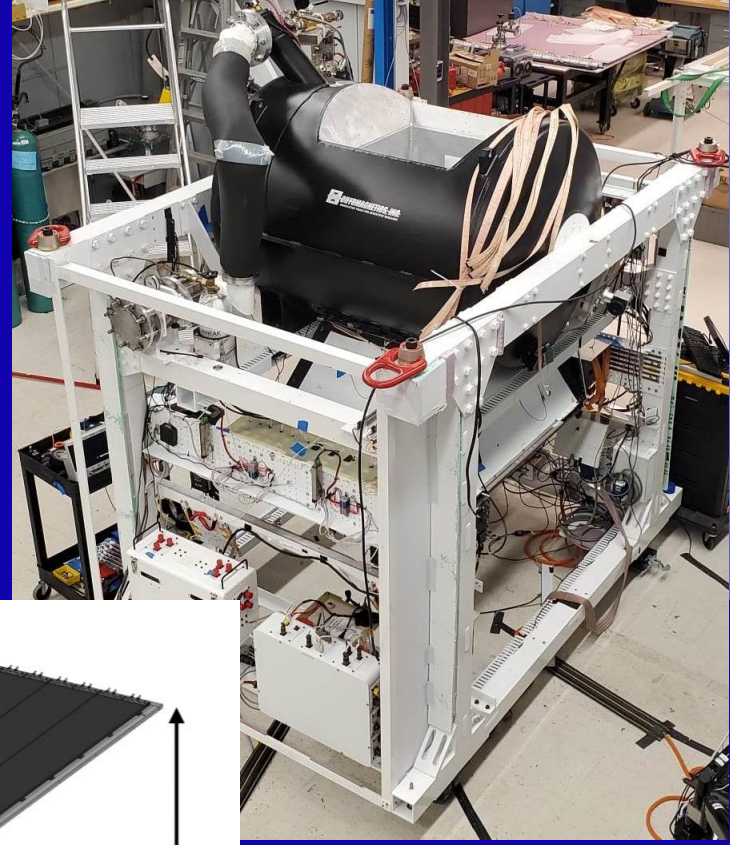




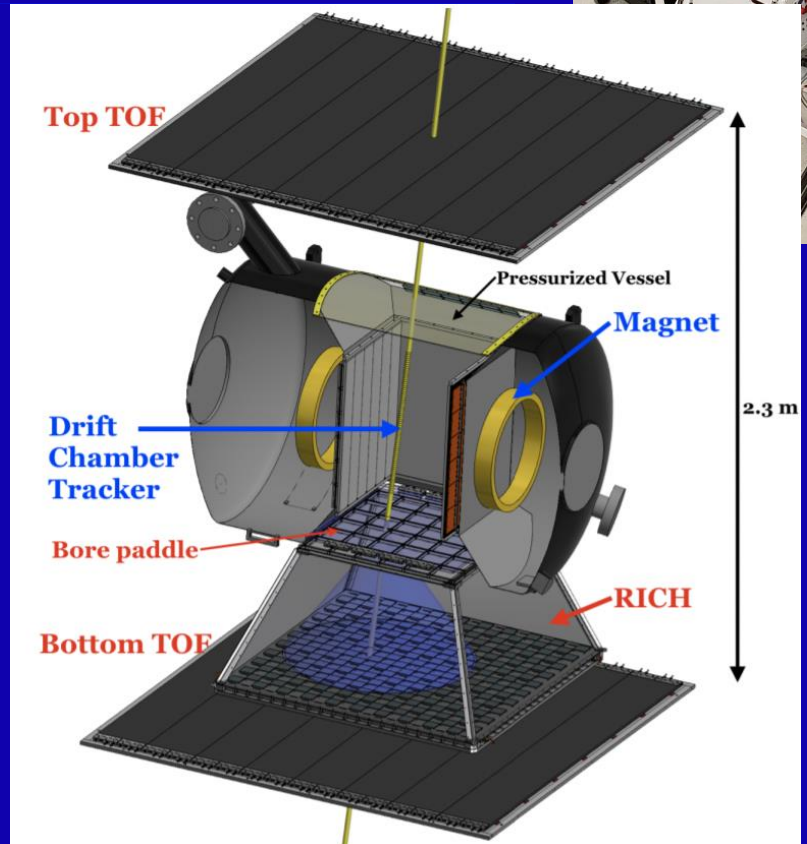


HELIX Introduction

High Energy Light Isotope eXperiment

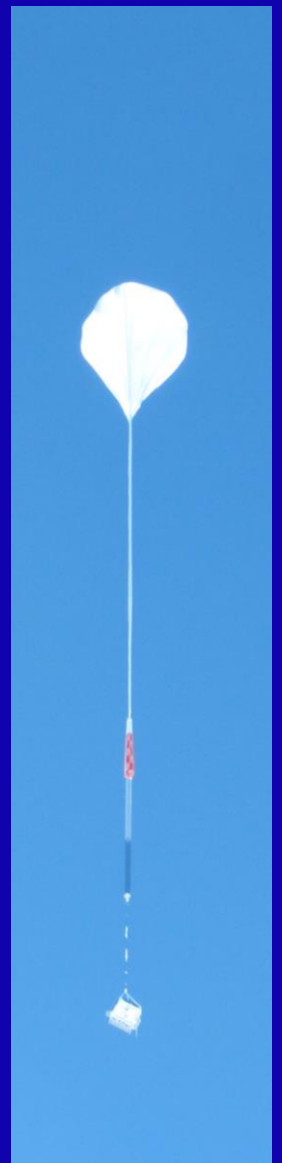


- A magnetic spectrometer to measure ^{9}Be and ^{10}Be masses and achieve mass resolution of 3%
- A payload designed for a long-duration balloon platform
- Energy range: 1-3 GeV/nucleon



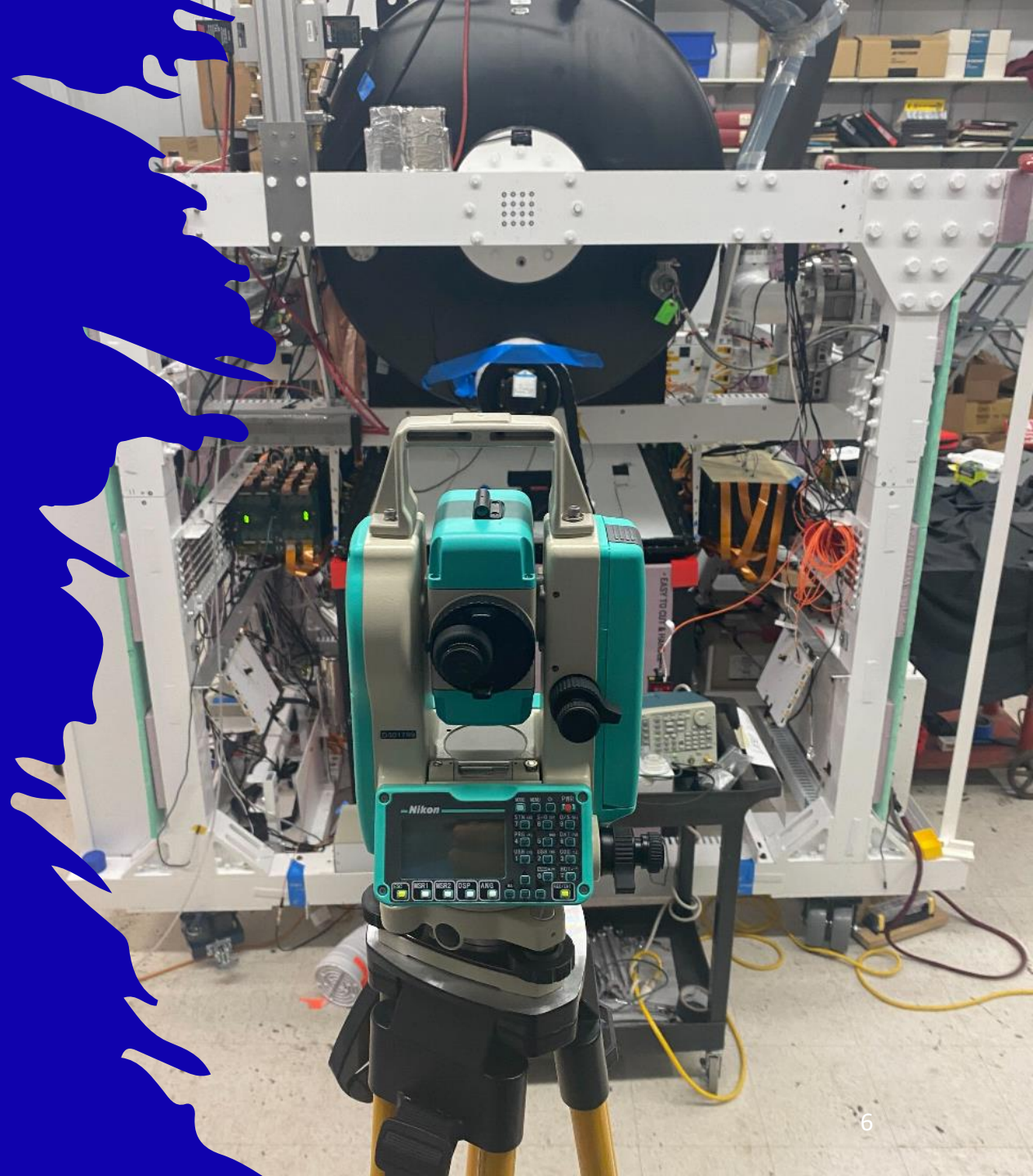
Challenges of Balloon Experiments

- Balloon payload needs to be built within tight power, weight, and data bandwith limitations
- Thermal limitation: Only conductive and radiative cooling
- **Experiment will be disassembled and reassembled many times -> metrology measurements cannot be done while data is being collected**



Metrology

The study of measurement

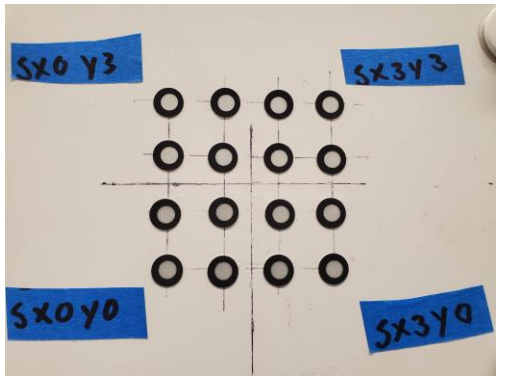


Metrology

The Project:

- Develop a procedure and analysis framework for knowing the precise positions of points and planes on the HELIX payload
- Use knowledge of positions for better understanding of detector distances to each other and to update GEANT4 simulations

(Desired precision depends on detector e.g. DCT w/spatial resolution of 65 micrometres)



Materials:

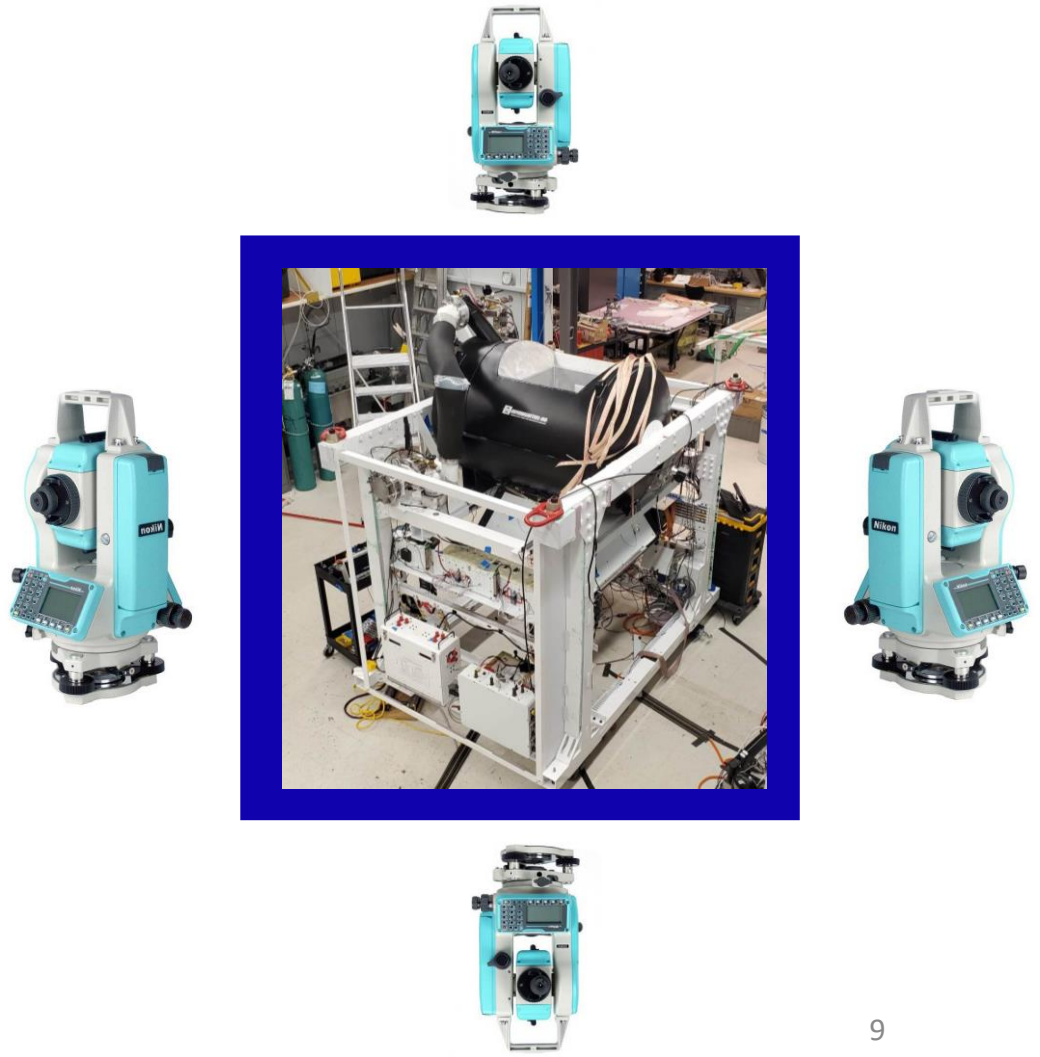
- Nikon Total Station with Tripod
- Retroreflective Dot stickers
- Helix-metrology 3D geometry reconstruction algorithms (my contribution)

Nikon Total Station

- Device that provides precise optical measurements in surveying and construction using a theodolite for measuring angles in vertical and horizontal plane and an optical-electronic distance meter
- Error on Total Station measurements is ±5 mm when the points are between 1.6 m and 5 m to the device

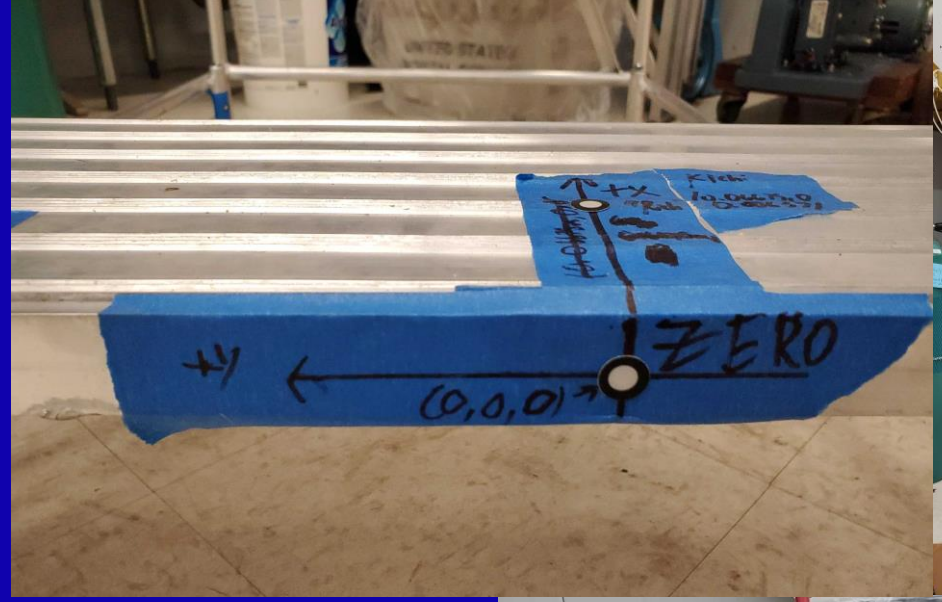
Combining Points from Different Frames

- To measure all points of interest on HELIX requires measurement of multiple frames from different locations
- To consider information from different frames together, coordinates need to be rotated and translated from one frame into another
- Considering each frame has error, we cannot calculate an exact rotation and translation matrix based on matching points, as they will never line up perfectly
- A complete HELIX measurement would require a minimum of eight frames



Test Rig 1: Staircase

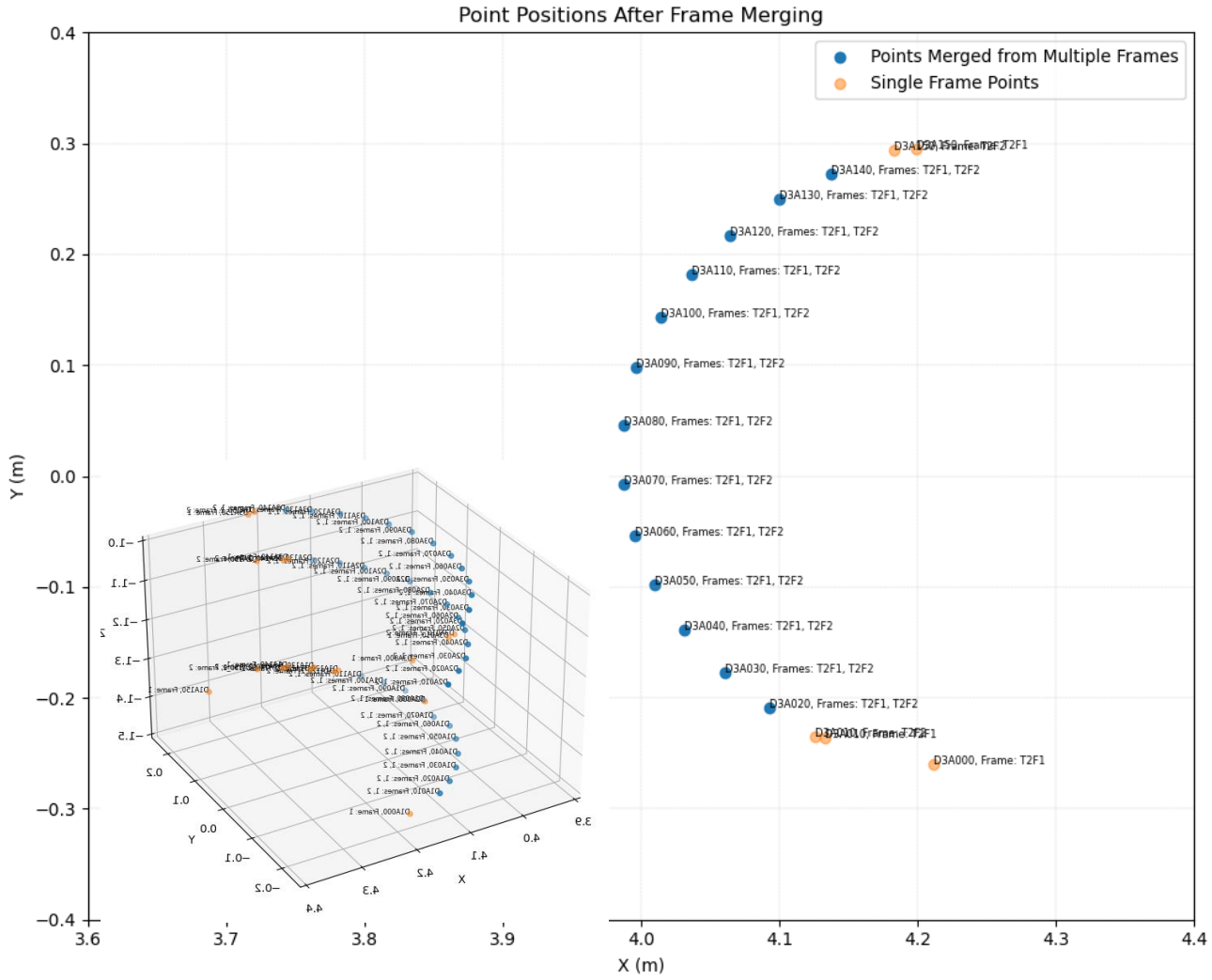
- Motivation: test set up and code



Test Rig 2: Garbage Science

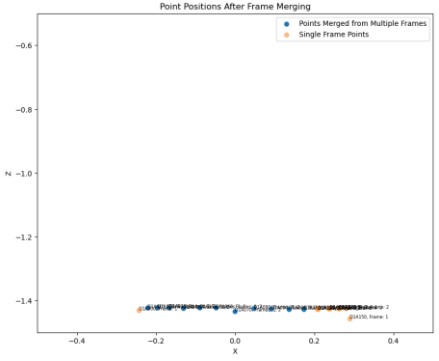
- Motivation: Test angle at which point measurements become less reliable (a cylindrical object is a good geometry for this)

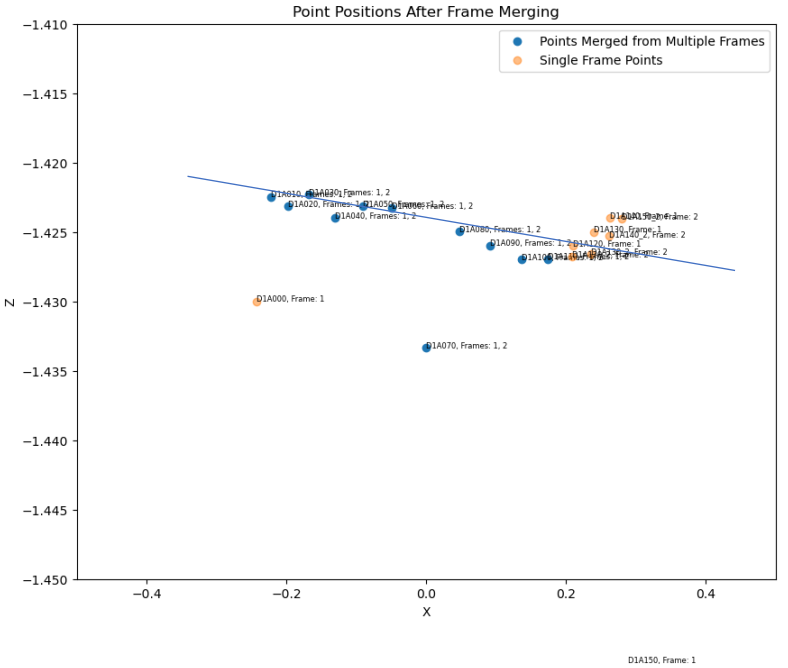
Test Rig 2 Bottom Layer Visualization



- Points within 60 degrees of Total Station lens merge within 2 mm

Zooming in on the Z- Axis

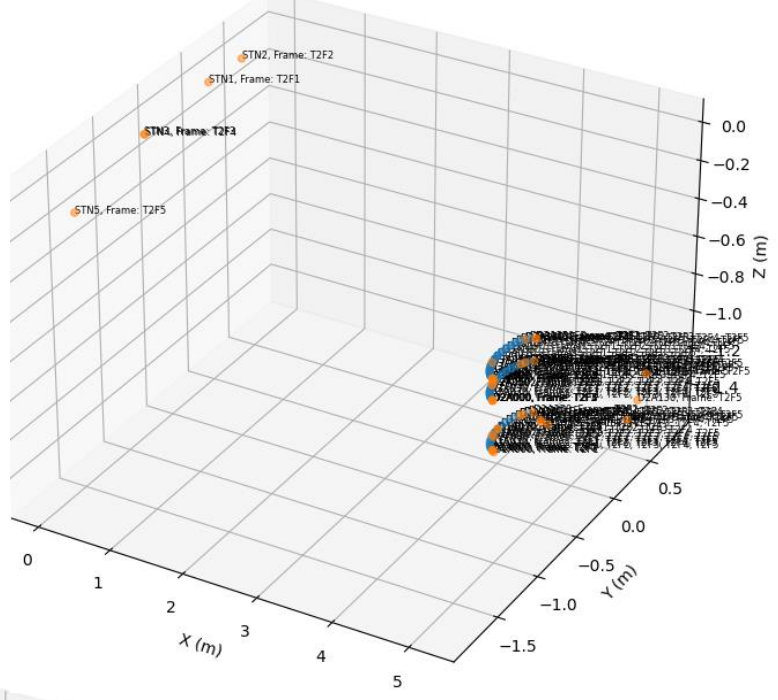


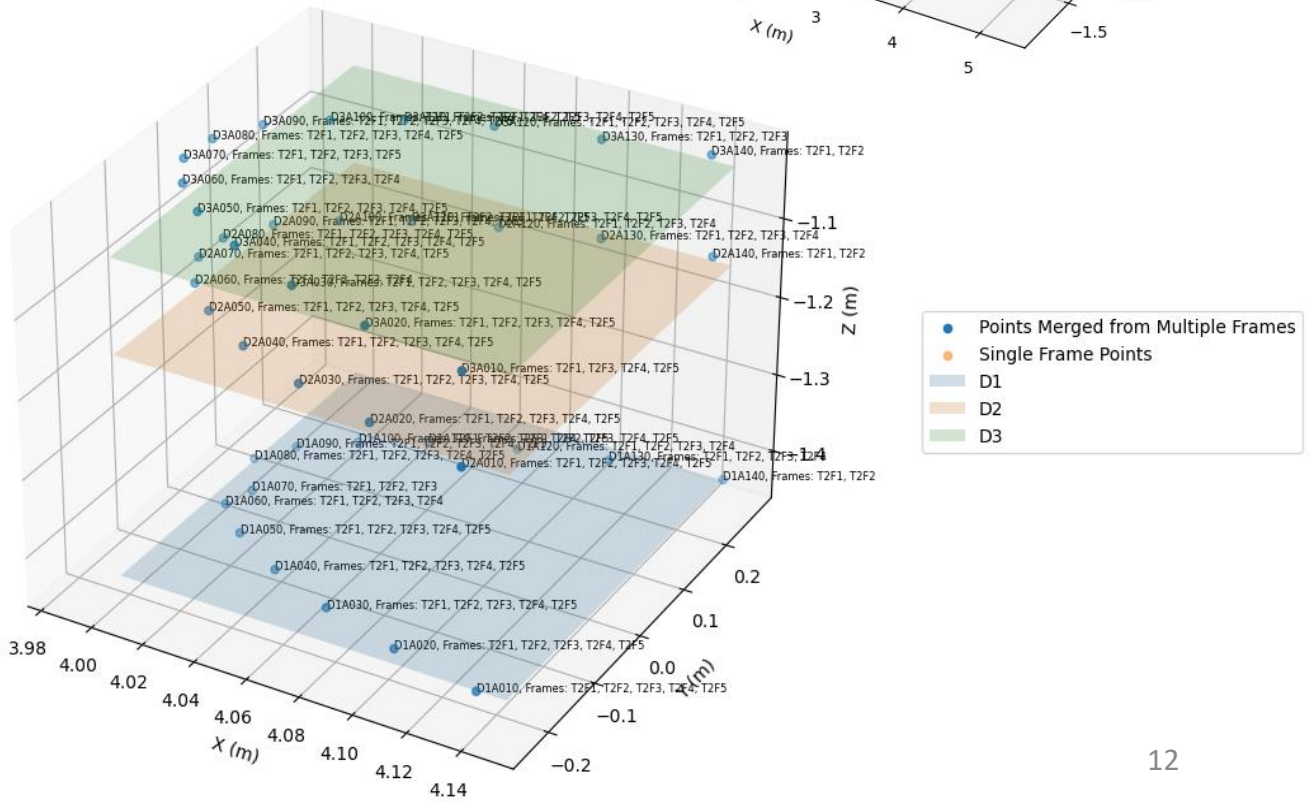


(All Axes in metres)

Metrology class: All Measured Frames

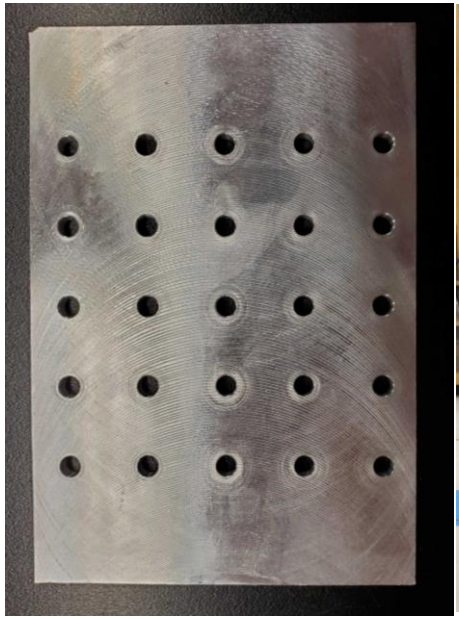
- All five measured frames were combined, cleaned and plotted using metrology code
- Distance between planes matches physical measurement within 1 mm.
- Taper angle of bin accurate to within 0.04 ° deg of reality
- Angle between plane 1 and 2: 0.026 °
- Angle between plane 2 and 3: 0.79 °
- Angle between plane 1 and 3: 0.78 °

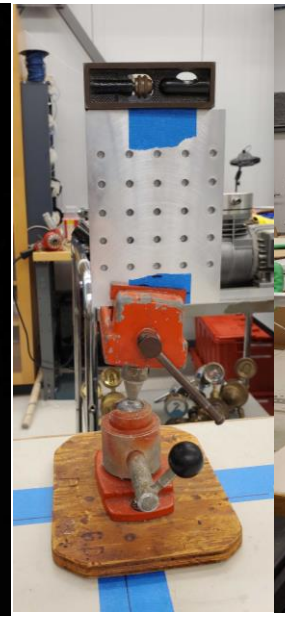


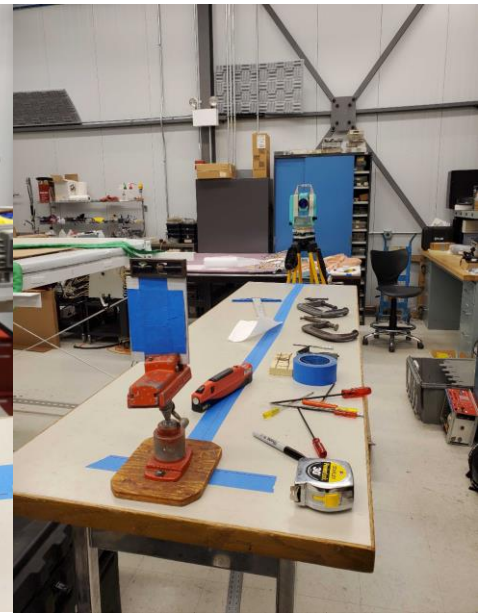


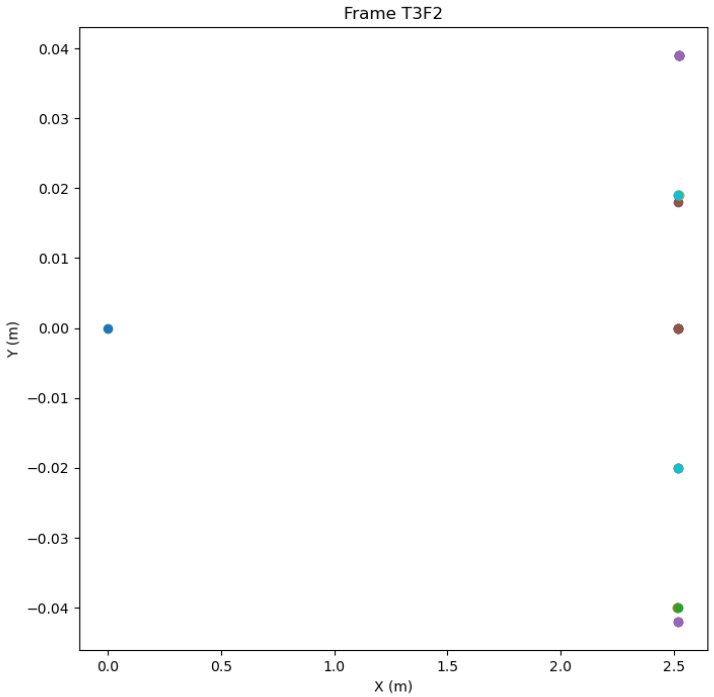
Test Rig 3

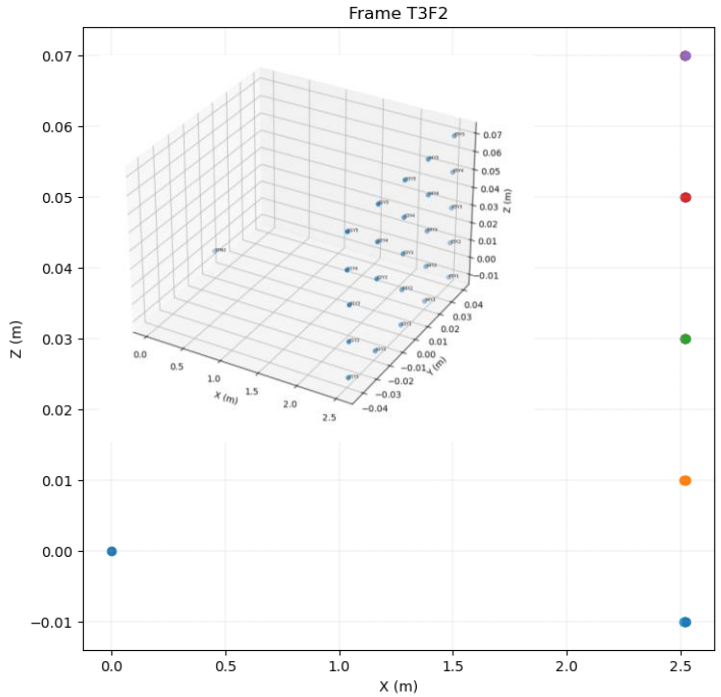
- Motivation: Test Rig 3 is intended to be a test of absolute error on a grid with dimensions known to within a few microns

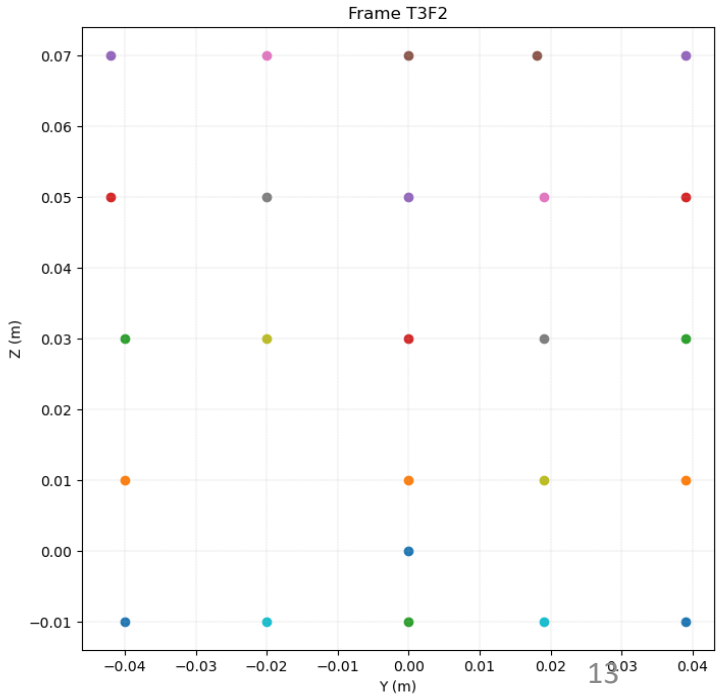








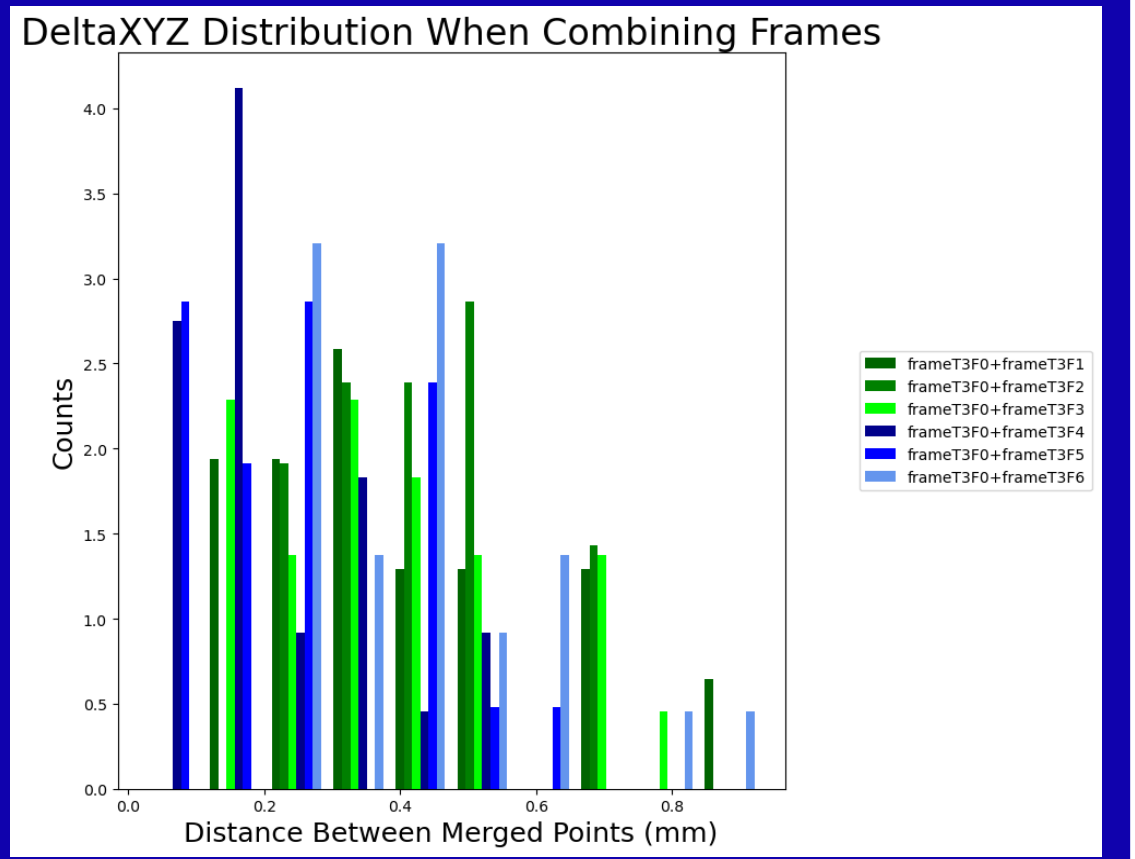


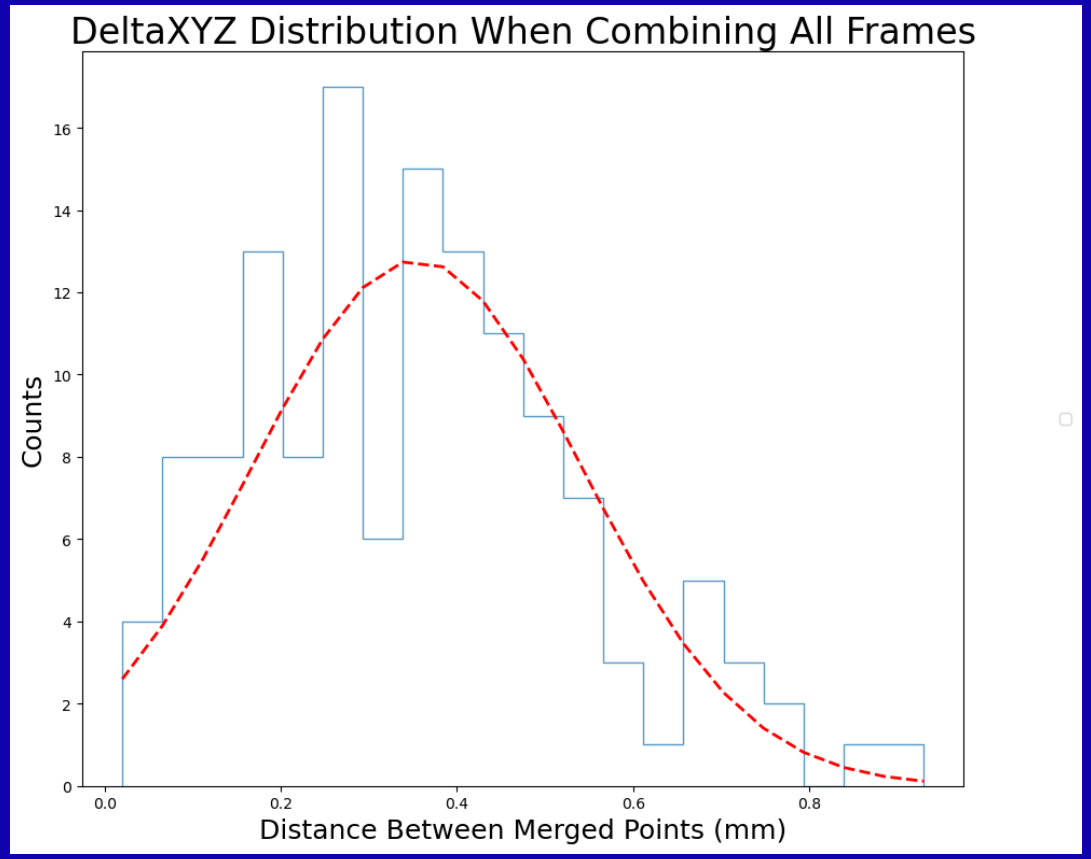


Measurement vs Machine Shop

- Histogram distribution of the distances between the same points when compared to their exact locations
- Mean: 0.35 mm
- Standard deviation: 0.19 mm

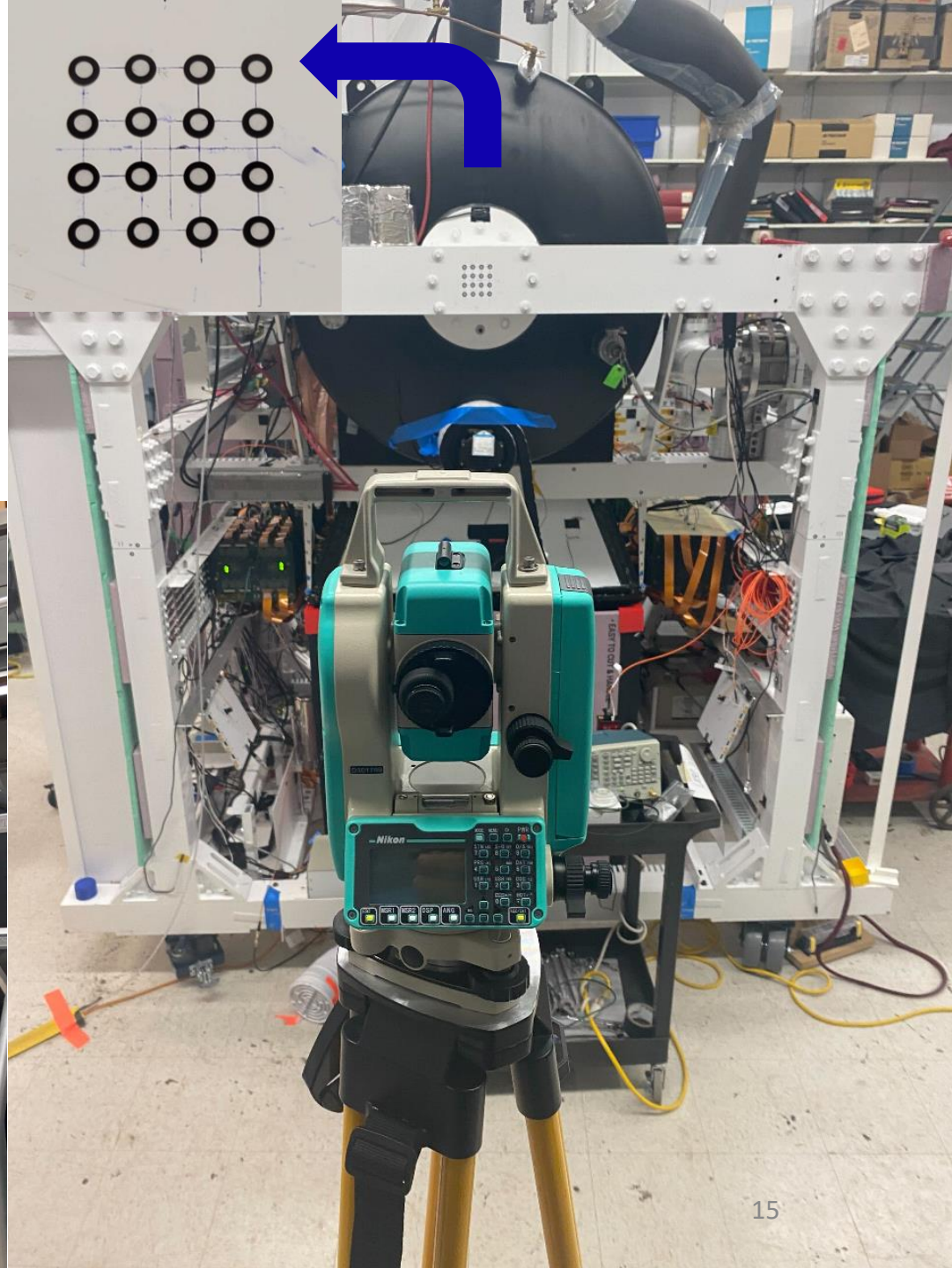
Combining and fitting data



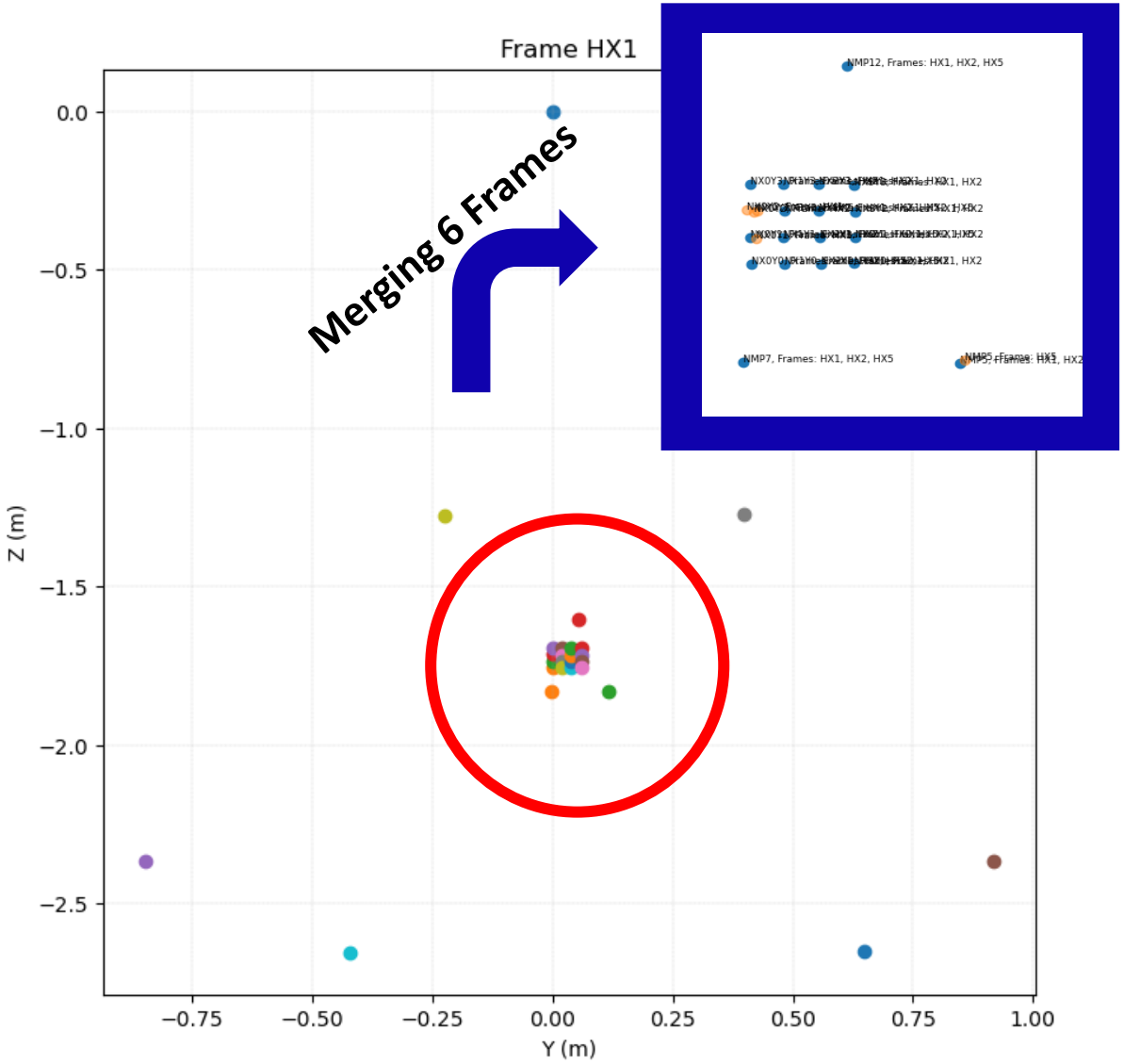


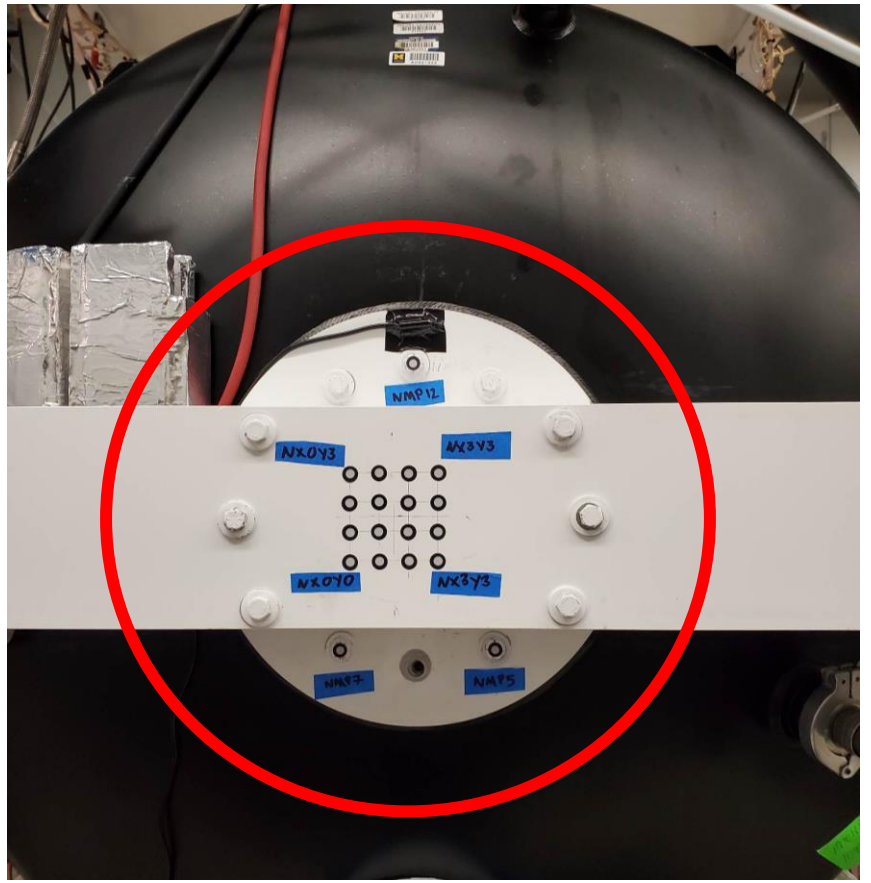
~~Test Rig 4~~ HELIX Payload!

- Two little grids on North and South side of frame for merging frames with less error



HELIX Frames – Analysis Ongoing



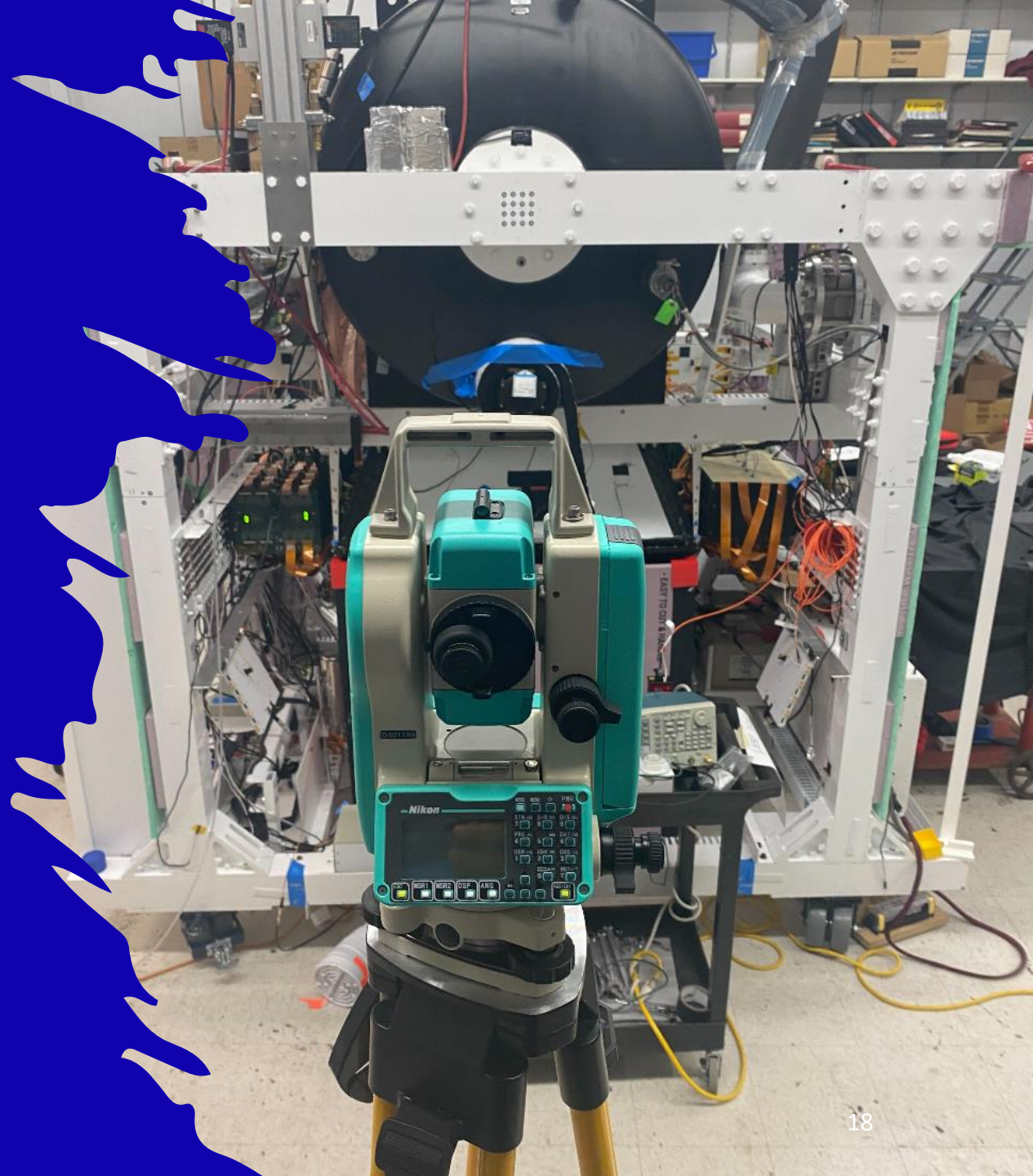


Position measurement and measurement error analysis is ongoing

Summary & Outlook

- HELIX Metrology is the project dedicated to position tracking key locations on particle detectors and relative distances when installed in the balloon payload
- HELIX testing will require a minimum of two dis-assemblies and reassemblies before flight, providing validation opportunities for tracking HELIX part positions with metrology
- The minimum number of frames and time required for complete HELIX metrology will be estimated and reflected in deployment plan
- First HELIX flight is scheduled for Arctic summer of 2024!

Thank You!



Acknowledgements

A special thank you to the HELIX collaboration, my supervisor Dr. Nahee Park, and the University of Chicago for hosting me from January to February of 2023

University of Chicago
- Lucas Beaufore, Hyebin Jeon, Rostom Mbarek, Dietrich Muller, 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, Dennis Calderone, Keith McBride

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

Queen's University
- Melissa Baiocchi, Nahee Park

University of Michigan
- Noah Green, Gergory Tarle