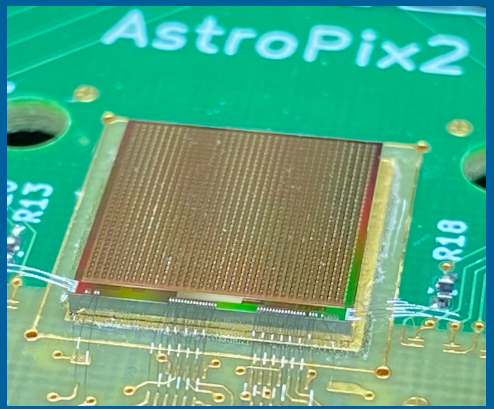
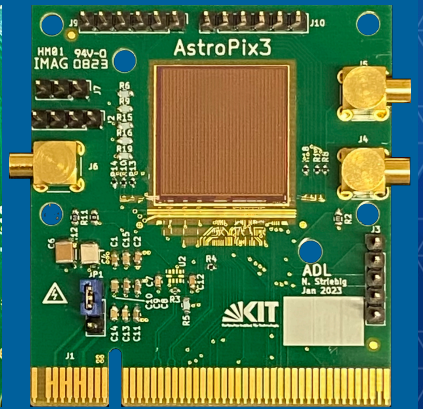
Barrel Imaging Calorimeter Meeting

June 12-16, 2023

AstroPix Setup at Fermilab Testbeam Facility





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ePIC

Argonne NATIONAL LABORATORY

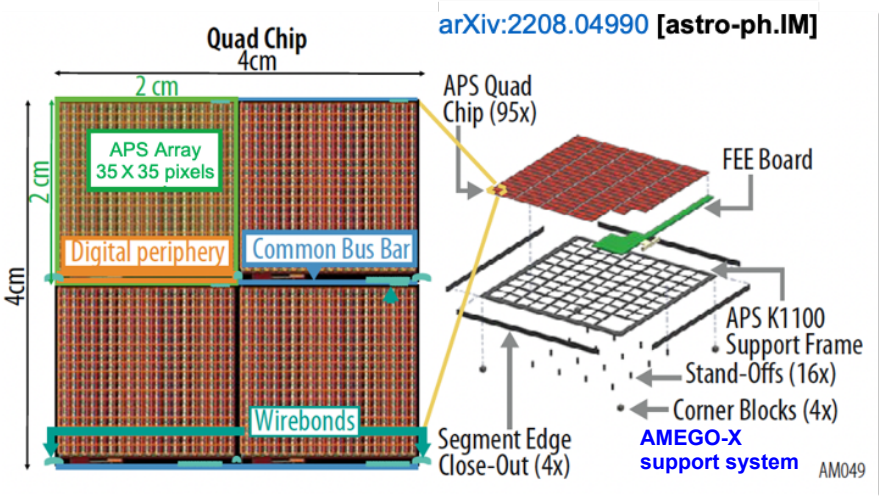
Imaging layers technology

Imaging layers based on AstroPix sensors

- 180nm HV-CMOS MAPS sensor
- Developed for AMEGOX NASA mission
- Based on ATLASpix3 arXiv:2109.13409 [astro-ph.IM]

Key features:

- Very low power dissipation < 1.5 mW/cm^2
- The good energy resolution (<10% @ 60 keV)
- 500 µm X 500 µm pixel size
- Sensor thickness of 700 µm
- Time resolution ~ 3.25 ns (V4)
- Perfect for Calorimetry, with some open studies!

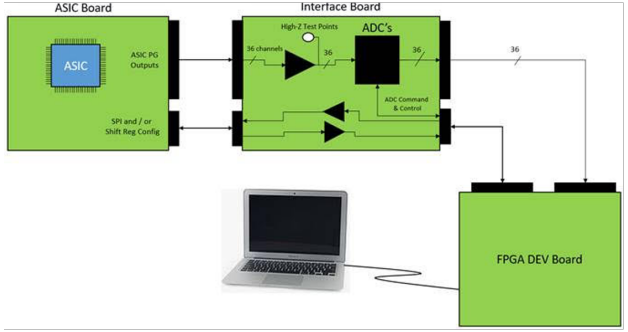


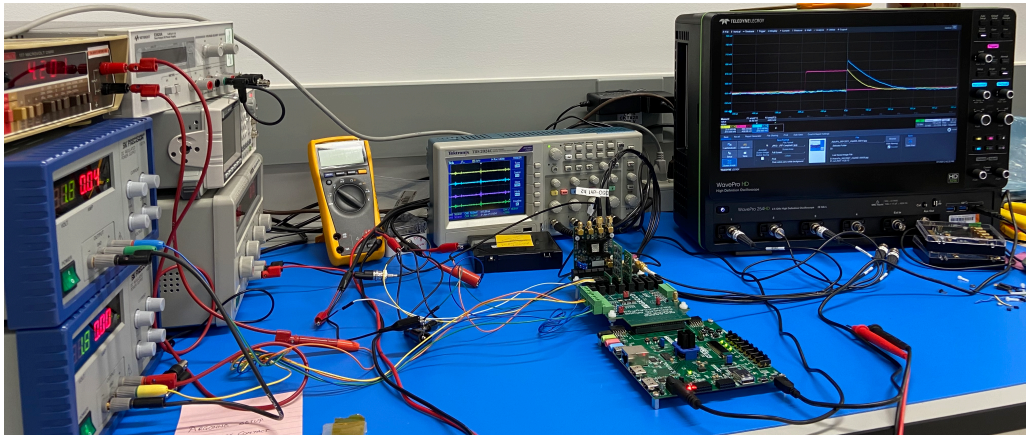
Project Goal

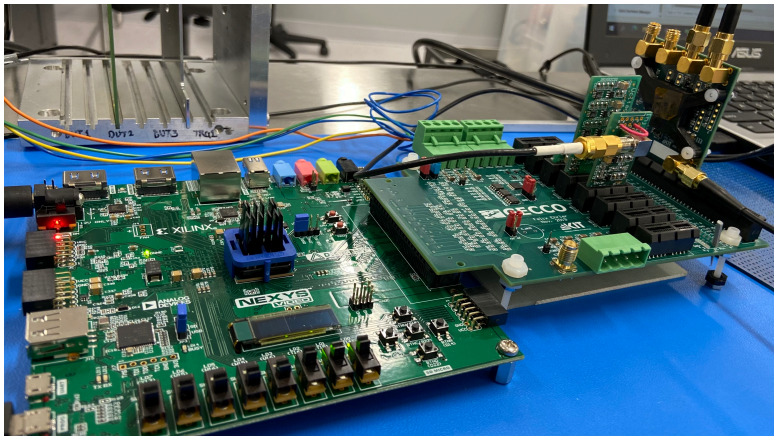
- Assess the feasibility of using an AstroPix-like sensor in an imaging electromagnetic calorimeter environment based on measurements with the test-beam and bench test setup.
- Is the chip readout scheme optimal for calorimetry? → Tests of chip responses to electromagnetic and hadronic showers in the beam environment
- How radiation hard is the chip? → Irradiation tests in a high-intensity proton beam

AstroPix Setup

- Full bench set available
- AstroPix testing setup - NexysVideo FPGA, GECCO
  - Analog (DSO) and Digital data acquisition
- AstroPix chip mounting on chip carrier boards and wire-boding
- Sensor electric characterization using a probe station
- Transient current Technique (TCT)
  - Depletion depth analysis
  - Charge sharing

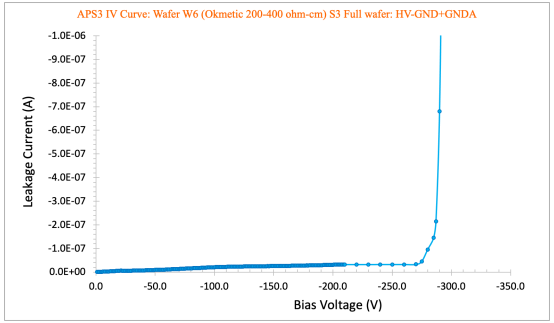


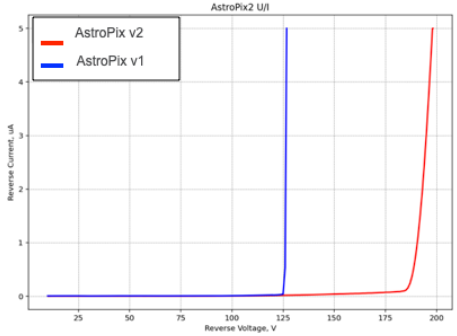




GEneric **C**onfiguration and **CO**ntrol System (GECCO)
Connection to FPGA - NexysVideo (Xilinx Artrix-7)
Vivado Design Suite HLx to program ASIC chip

Imaging layers R&D



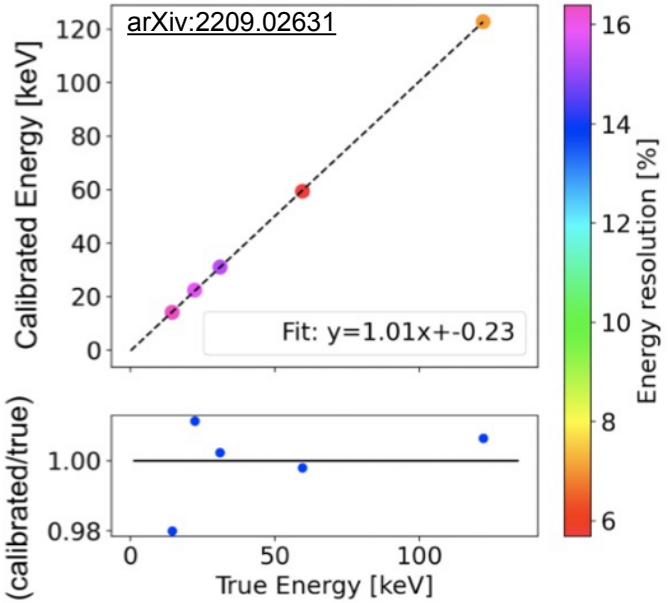


AstroPix sensor validation testing

- Bench tests with **AstroPix v2**
  - Energy resolution studies
  - Noise measurements
  - Digital data acquisition
  - Sensor characterisation (IV, edge-TCT, depletion depth)

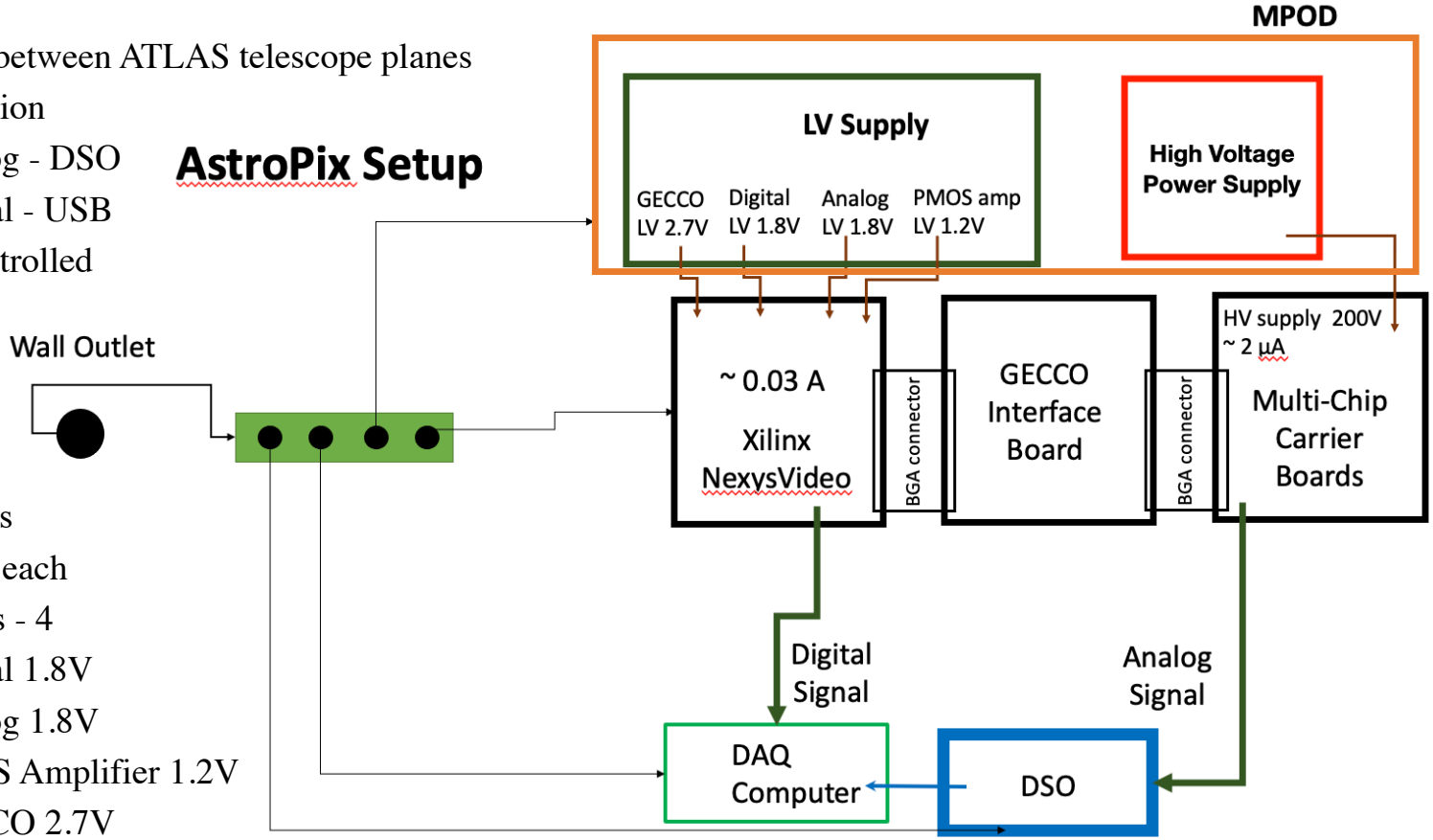
- **Testbeam campaign at Fermilab FTBF**
  - Validate detector performance at 120 GeV proton beam
  - Intergration of AstroPix with ATLAS telescope
  - **AstroPix telescope tracker (4 layers of AstroPix)**
  - **Feasibility with Calorimeter environment** with pions/electron beam at FTBF with tungsten radiator, readout aspects (ANL LDRD grant)

- **Irradiation test**
  - 400 MeV proton (minimum 4.5E12 protons/min) at the FNAL ITA Facility
  - Latch-up tests by NASA with heavy ions (from Argon to Xenon with an atomic tune of 16 MeV/a.m.u.) at LBNL (BASE)



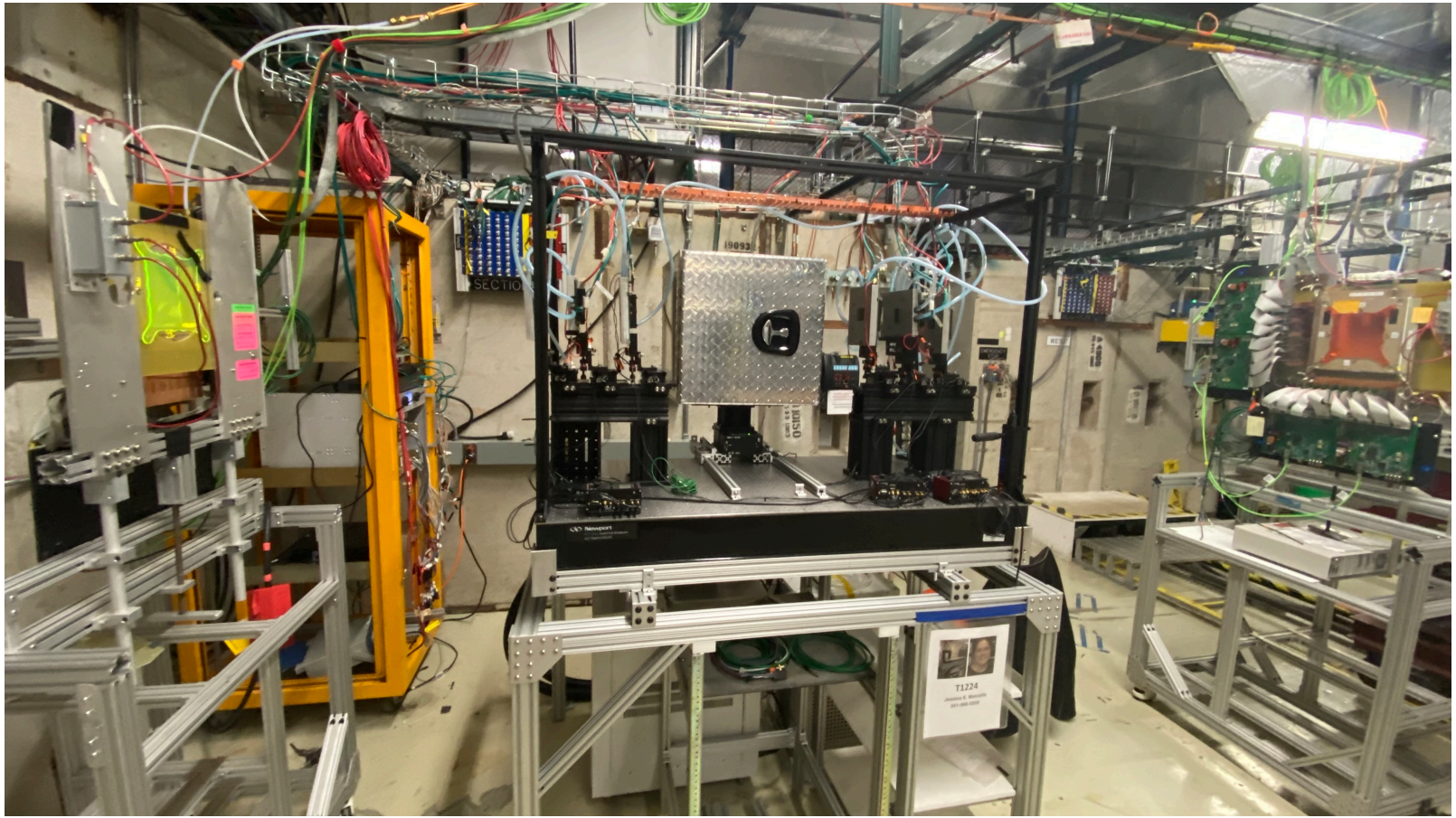
AstroPix FTBF Setup

- AstroPix in between ATLAS telescope planes
- Data Collection
  - Analog - DSO
  - Digital - USB
- Remote Controlled

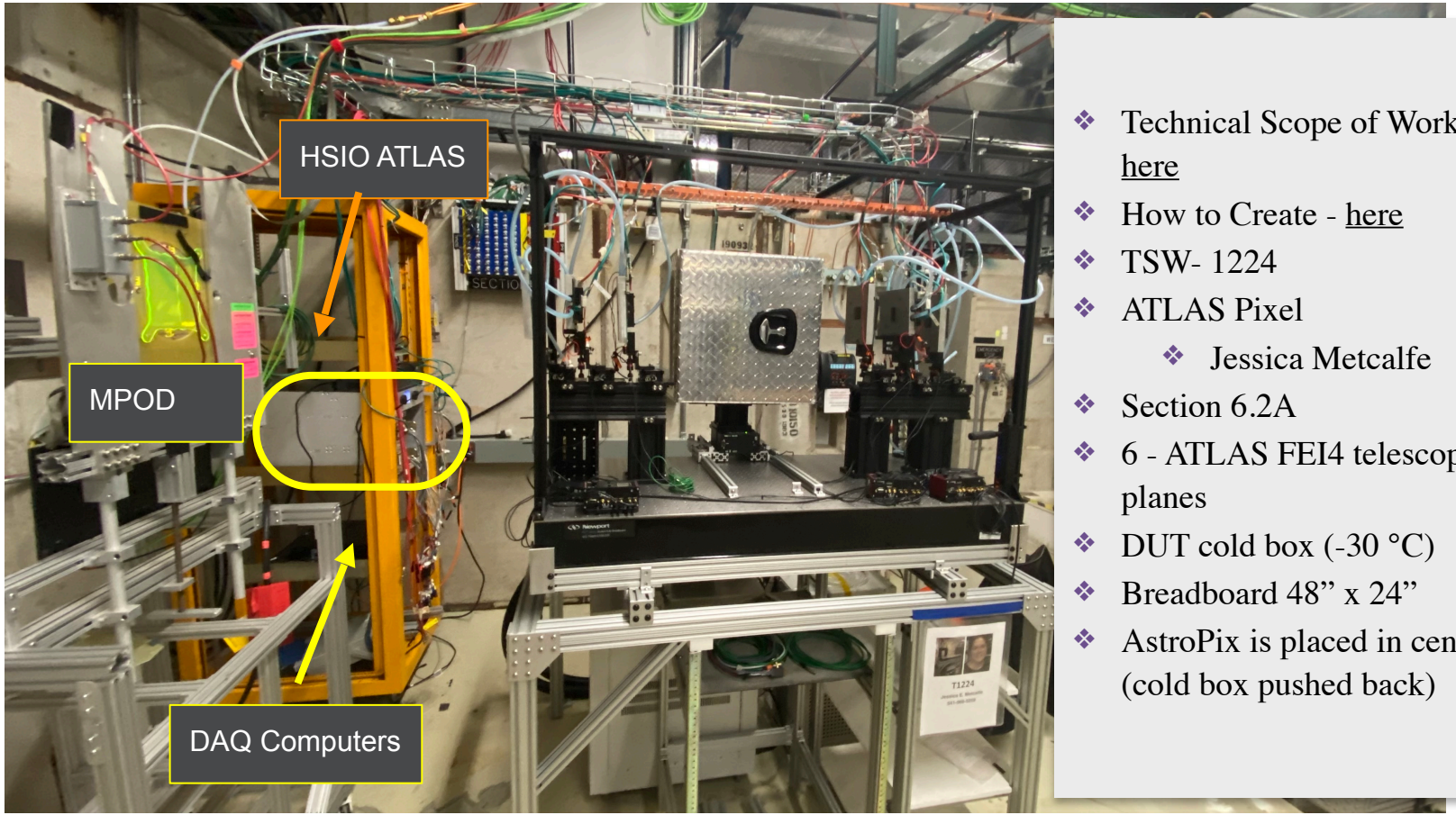


- HV Channels
  - 200V each
- LV Channels - 4
  - Digital 1.8V
  - Analog 1.8V
  - PMOS Amplifier 1.2V
  - GECCO 2.7V

AstroPix FTBF Setup

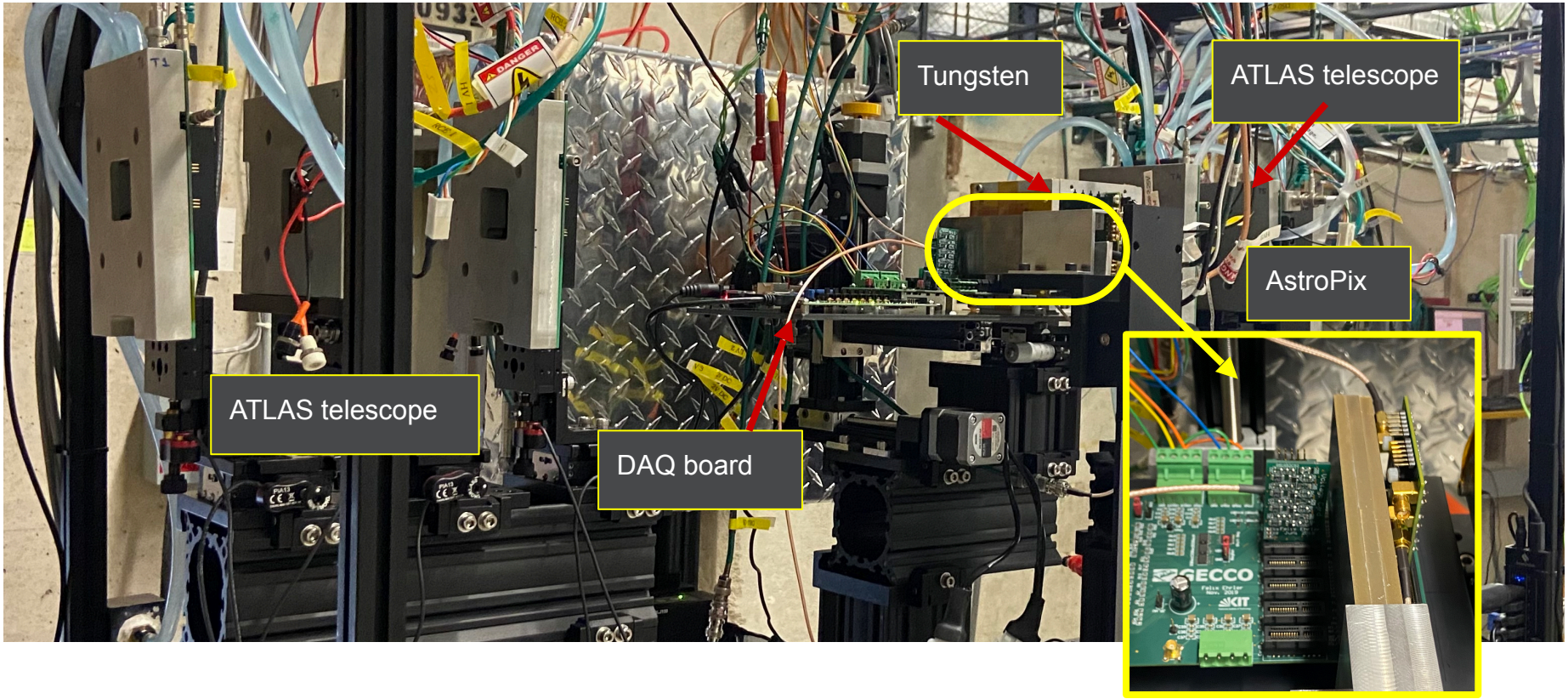


AstroPix FTBF Setup

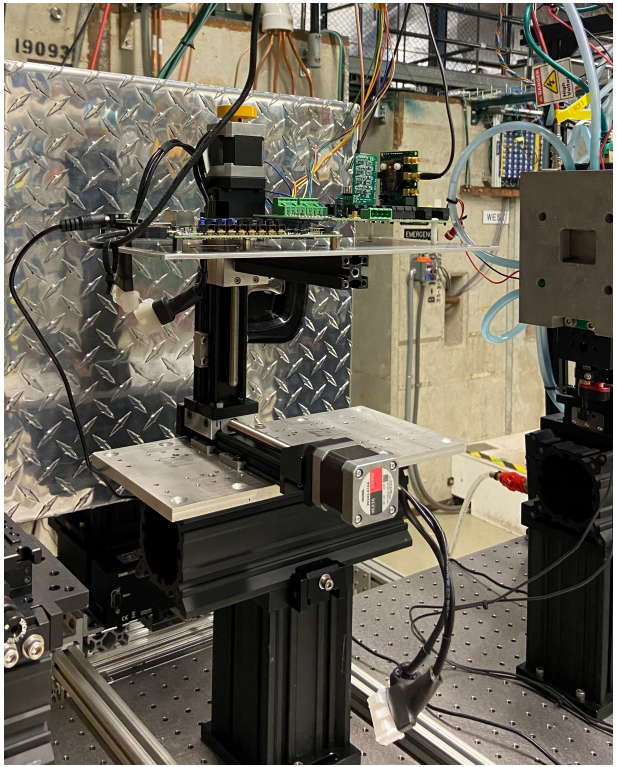


- Technical Scope of Work - here
- How to Create - here
- TSW- 1224
- ATLAS Pixel
  - Jessica Metcalfe
- Section 6.2A
- 6 - ATLAS FEI4 telescope planes
- DUT cold box (-30 °C)
- Breadboard 48” x 24”
- AstroPix is placed in center (cold box pushed back)

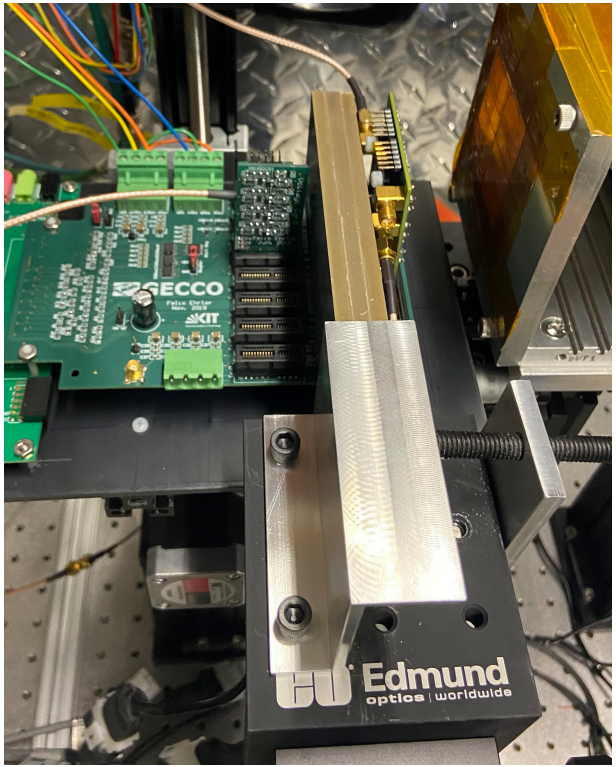
AstroPix FTBF Setup



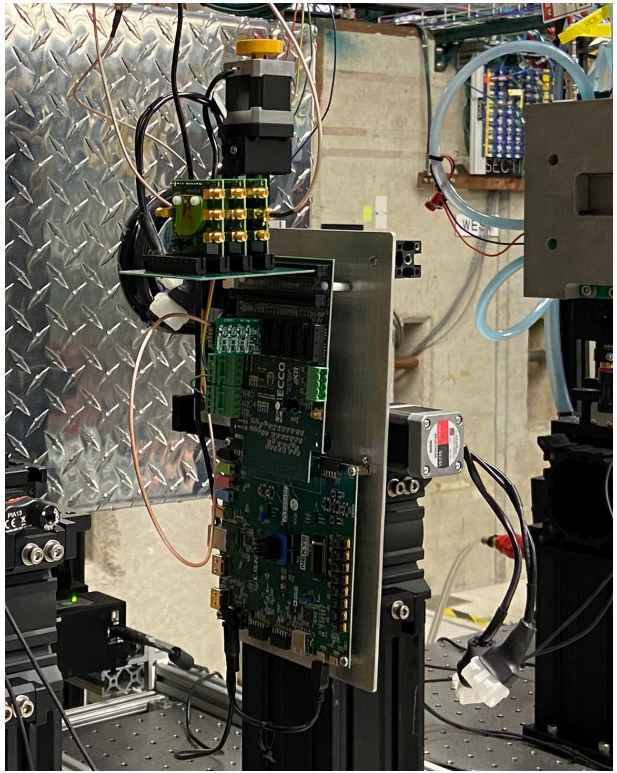
AstroPix FTBF Setup



Single Chip

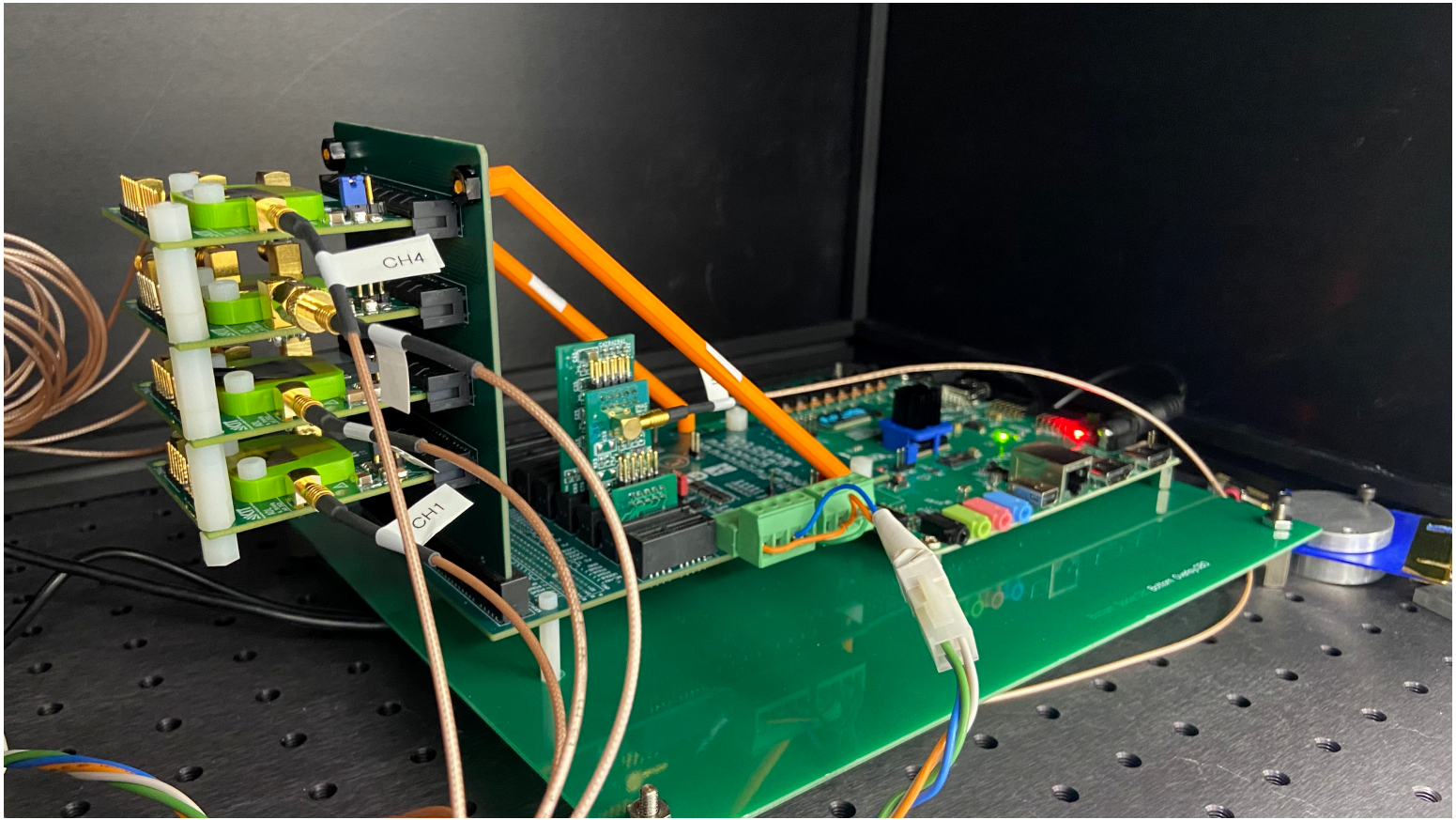


Single Chip w/ Tungsten



Multi-Chip (Ongoing)

AstroPix FTBF Setup



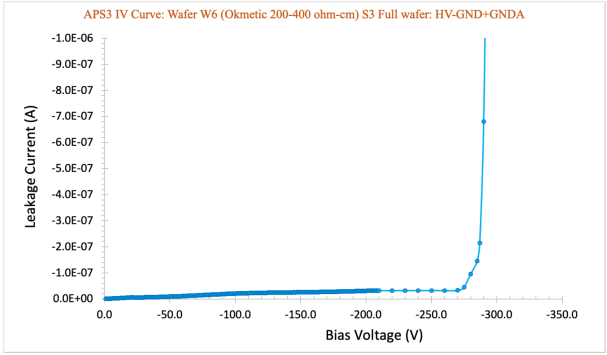
Snapshots from the Sensor Irradiations

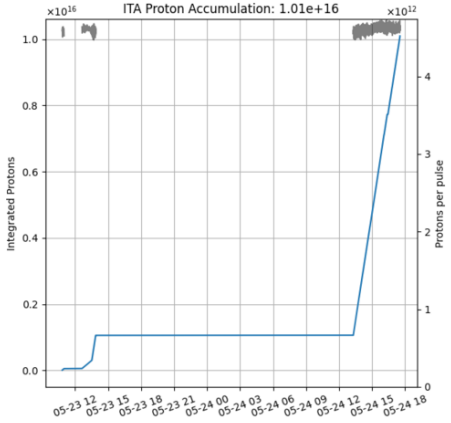
400 MeV protons

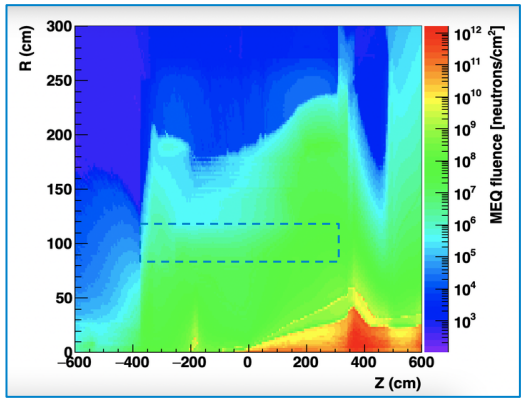
- **9 samples of AstroPix v2 chips prepared for the passive irradiation in the FNAL MTA Facility**

- IV and CV measurements performed for the v2 chips before irradiations
  - Same measurements will be repeated post irradiation
- Plan to irradiare next 6 v3 chips and run active irradiation tests

Nb of samples	Doses (400 MeV protons)
3	4.50E+13
3	1.08E+15
1	1.01E+16
1	5.02E+16





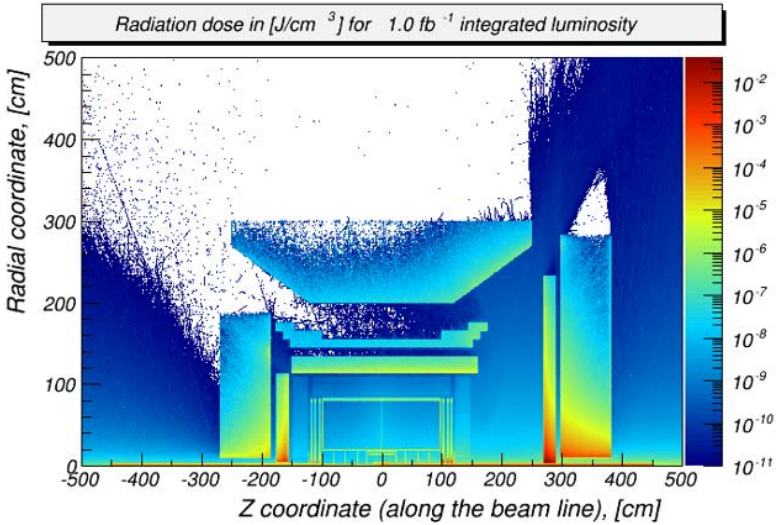


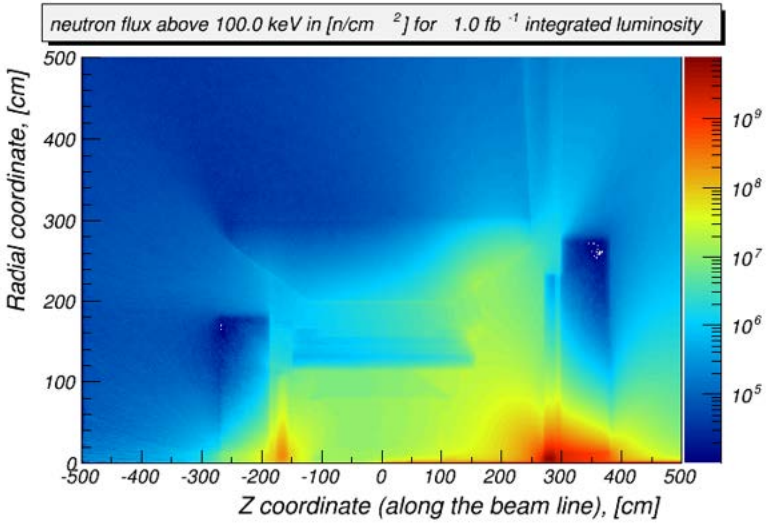
AstroPix FTBF R&D

1. AstroPix chip performance studies with test beam
    1. DAQ with different triggering schemes, a benchmark set for the test with v3 chip ✅
    2. Initial data obtained with single layer setup with and without W-radiator, in self-triggering streaming data mode ✅
    3. Multilayer AstroPix standalone telescope with radiator layer 🚧
    4. External trigger from existing ATLAS telescope to study tracking efficiency, position resolution, etc. 🚧
    5. External trigger and multilayer readouts are being currently tested at FNAL MTest Facility 🚧
2. Irradiation test with v2 and v3 chips, irradiation plan tested
    1. v2 chip pre-irrad characterization and Irradiation performed at different radiation doses ✅
    2. Irradiation beam test Ongoing at FNAL MTA Facility 🚧
        1. Passive Irradiation of v2 chips is completed, v3 chip will be irradiated this week
        2. Active Irradiation of the v3 chip will be performed in the coming weeks

Backup

Ionization radiation and neutron flux





- Maximum ionizing radiation dose from e+p collisions at the highest EIC luminosity ($10^{34}cm^{-2}s^{-1}$): ~1 Rad/year
- Neutron flux: 10^8 neutrons/cm^2 per year at the top luminosity (two order of magnitude lower than the near-beam-line detectors)