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# DAQ directions

Gustavo Cancelo

Computing R&D Micro-Retreat

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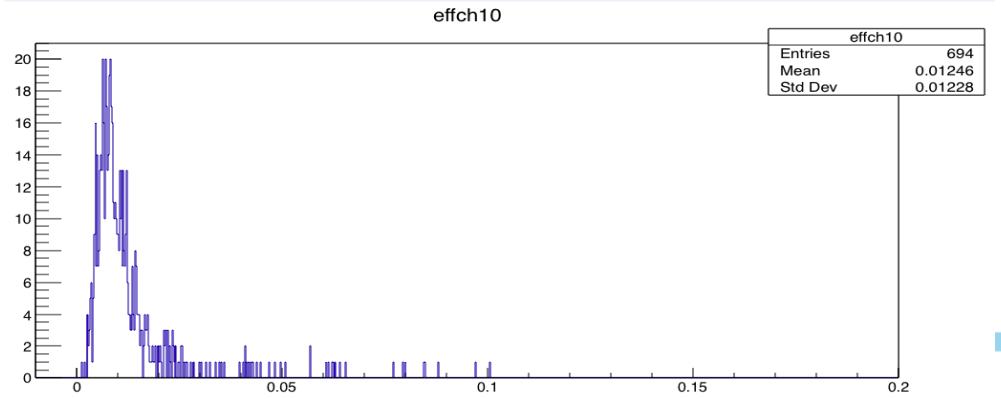
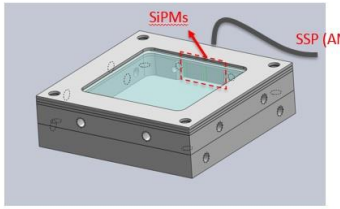
# DUNE Photon Detector R&D

- LDRD to develop a sensor and cold readout for DUNE PD that increases the photon collection efficiency an order of magnitude with respect to light-bar detectors (Eff ~0.1%).
- We improved a concept developed by Ettore Segretto (UNICAMP, Brazil) called ARAPUCA and worked on the active ganging of Silicon photomultipliers to increase sensitive area and lower DAQ cost.
- We run experiments with cosmics at the LAr dewar (TallBo) at PAB.
- In less than 2 years we have succeeded measuring an efficiency of 1.3% and with a lot of room for improvement using more SiPMs and better reflectors and wavelength shifters.
- This work has become the 1st priority for DUNE PD R&D.
- Opens the door to sustained work in DUNE
- PD DAQ past 2016




## The ARAPUCA project a photon detector in LAr

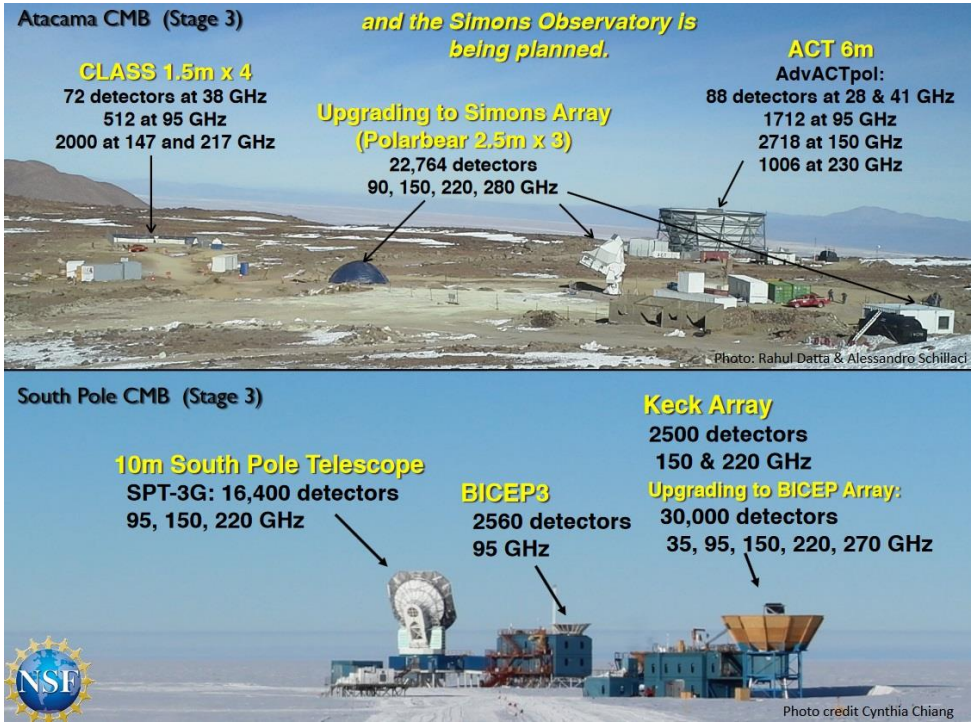
- **The ARAPUCA** (**A**rgon **R**&D **A**dvanced **P**rogram @ **UniCAmp**), originally designed by Ettore Segretto, et. al. at UNICAMP, Brazil.
- It is aimed at increasing the light collection in the DUNE detector.
- The DUNE photon detector has at crucial role for non accelerator events (provides t0 for supernova and proton decay events)
- It requires high sensitivity and background reject.

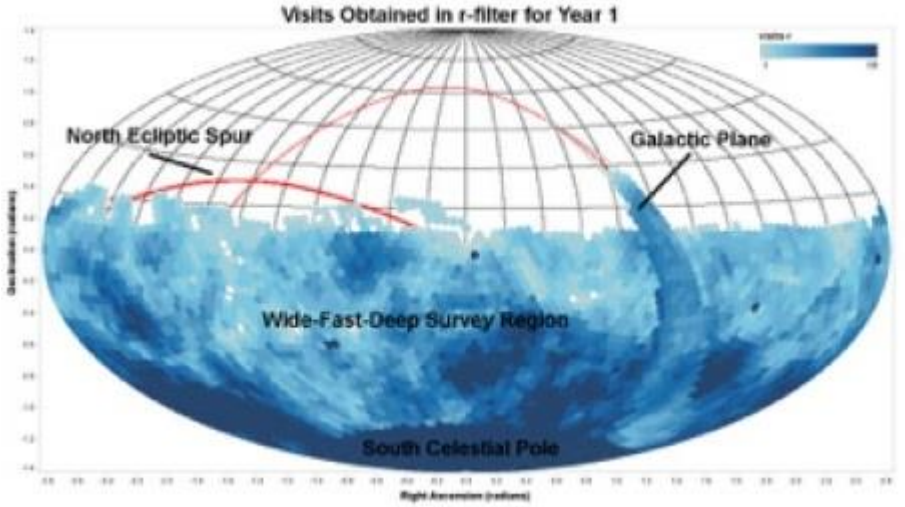



Dichroic filter $\lambda_{cut}$=400nm
Wavelength sifters on both sides of the filter.
Highly reflective internal walls.

**R&D Supportedby FNAL LDRD**-2017-028
**Project title:** Increasing the photon detector light efficiency in a liquid argon detector by an order of magnitude
**Principal investigator:** Gustavo Cancelo.

# DAQs for Dark energy and the evolution of the universe




LSST will generate >1 billion galaxy catalog.
Opportunities for spectroscopic surveys!!

- CMB future: CMB S4
  - A collection of CMB telescopes at the South pole and Atacama
  - Superconducting detectors: Frequency Multiplexed TES or MKIDS.
- Optical surveys:
  - High and low resolution spectroscopy.
  - 100,000 channels high res spectrometer?
  - Low res MKIDs based instrument? Could cover the near infrared spectrum!

**Electronics and DAQ**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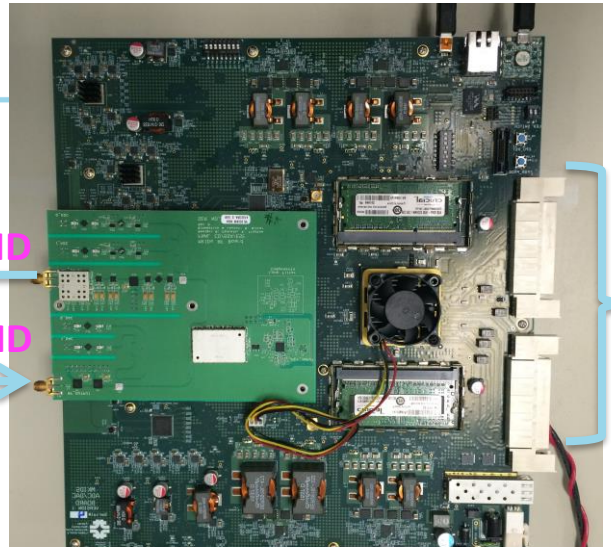
# 2016: How much data?

fMESSI electronics




- Year 2026:
- 500,000 detectors.
- Data into the DAQ: 4 tera bytes/second.
- Data highly processed and crunched into DAQ.
- Data out of the DAQ: 500 mega bytes/second.
  - MKIDs: Photon catalog ~ 100's photons/channel/sec
  - CMB: Store CMB powers at 1KHz/channel
- Fermilab/SCD is leading the field in warm electronics.
- Excellent synergy with quantum computing.
  - About to start working with Andrew Cleland from U. Chicago.

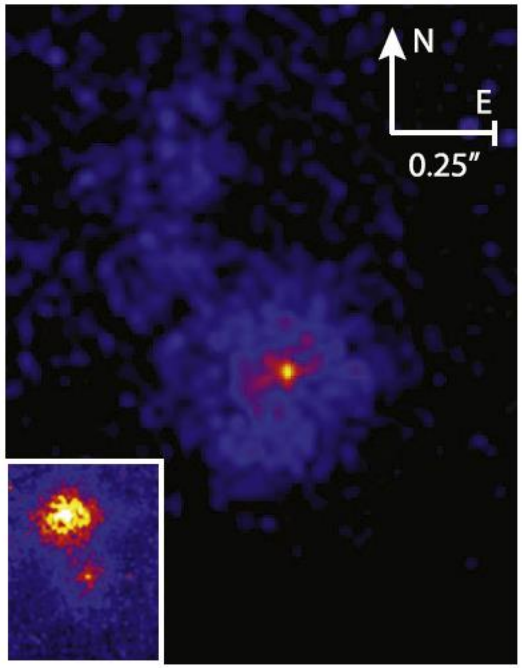
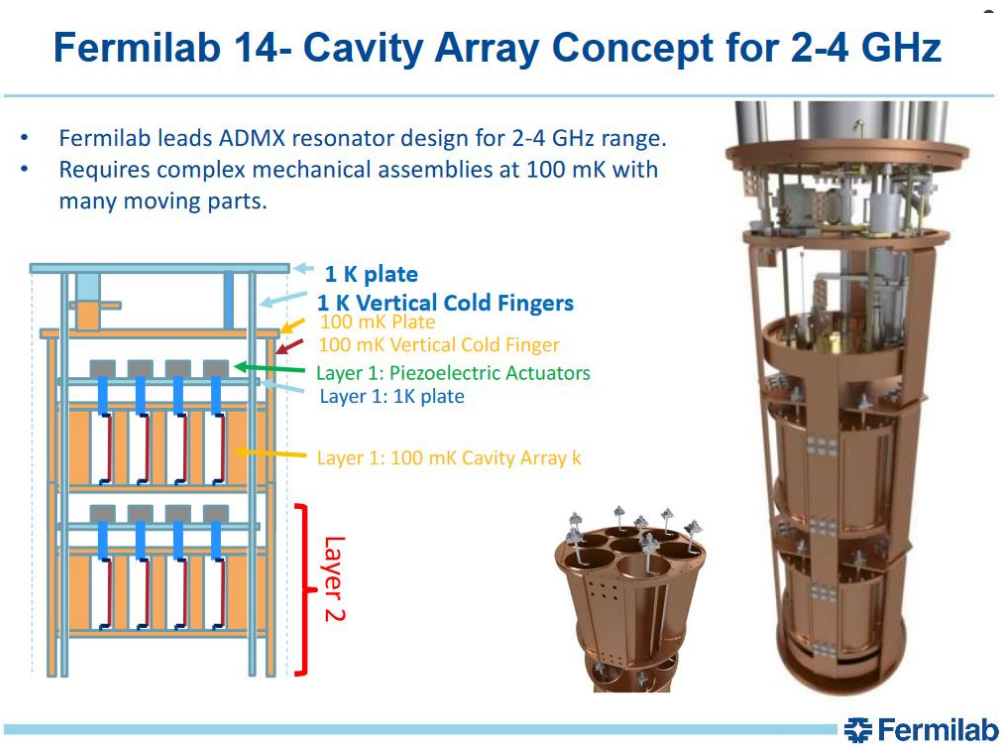



**Figure 13.** Median 1-second J-band image of 10 Uma, a spectroscopic binary with separation of 0.42″ at the time of observation, $V_{prim} = 3.96$, and $\Delta V \approx 2$. The large frame shows the system with the coronagraph FPM installed, and inset shows FPM removed to reveal the primary.

# Dark Matter Fermilab flagship project.

Andrew Sonnenschein's talk




Axion searches are reaching interesting sensitivity and will remain scientifically relevant for many years– best opportunity to find DM in post-WIMP period

Cosmic frontier at Fermilab suffers from lack of major experimental facilities on site. Axion searches could provide this.

Exploits major lab capabilities in cryo engineering, superconducting sensors, RF cavities and magnets.

**Excellent opportunities for instrumentation and computing.**
**Good synergy with quantum computing and superconducting detector instrumentation.**

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# CCDs for Dark Matter, neutrinos and nuclear safety

- 6K x 6K pixels, 1mm thick = 20g of mass.
- Can operate at 140K. Dark current could achieve $10^{-7}$ $e^{-}$ $pix^{-1}$ $day^{-1}$.
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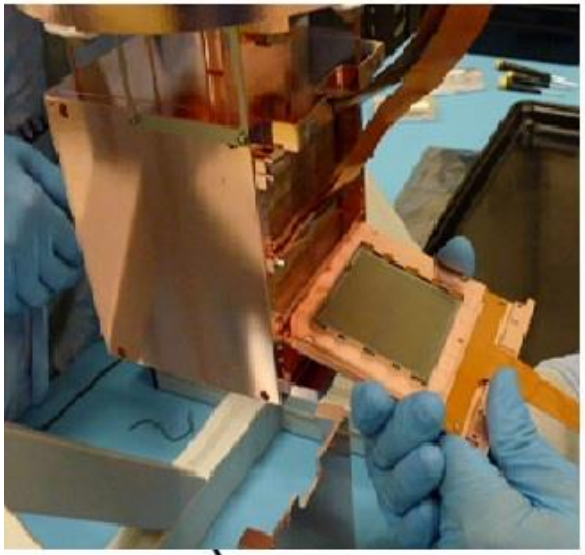

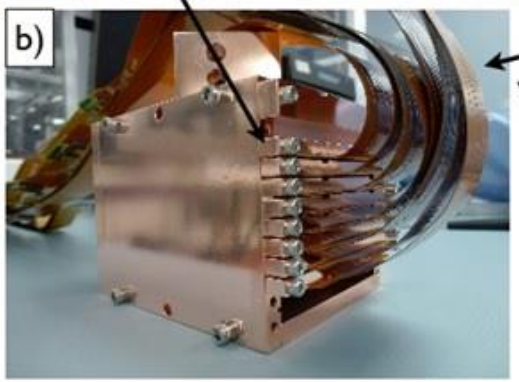


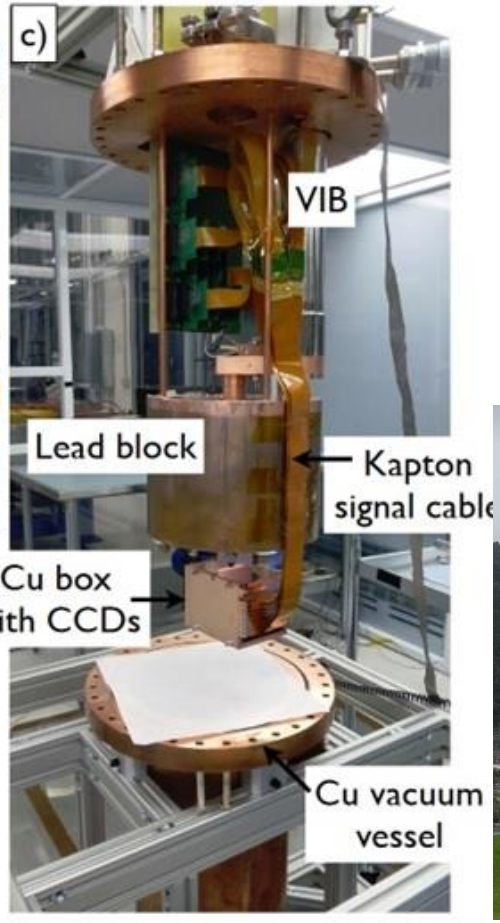


Current experiments:
DAMIC, CONNIE, SENSEI.
1Kg CCD experiment approved.
10 Kg for 2026+


In steady-state operation, the neutrino flux produced by the reactor is $1.21 \times 10^{20}\,\nu_e/s$ approximately, and the flux density at the detector ($L = 30$ meters from the core) is $7.8 \times 10^{12}\,\nu_e/cm^2/s$. These large numerical values justify the use of nuclear reactors as neutrino source for the CONNIE experiment.

# How much data?

- 10 Kg of CCD mass at 10g/CCD means 1000 CCDs (4 readout channels/CCD)
- CCDs are continuously readout to at 50MB/s/channel.
- Total input BW 50GB/s.
- Data output: 1 mega image/hr, each mega image is a collection of 16 Mpixels for each of the 1000 channels.
- Total image size 64GB/hr. (x~3000 reduction)
- Data processing using image pipeline and object extractor.
- Final catalogs ~ 10,000 objects/channel/hr, Estimated to 1GB/hr.
- It requires computing to store and process images.
- Images are kept on storage.