Fermilab

Managed by Fermi Research Alliance, LLC for the U.S. Department of Energy Office of Science

Particle Physics Division Engineering

Jonathan Lewis

Engineers' Retreat

20 February 2018

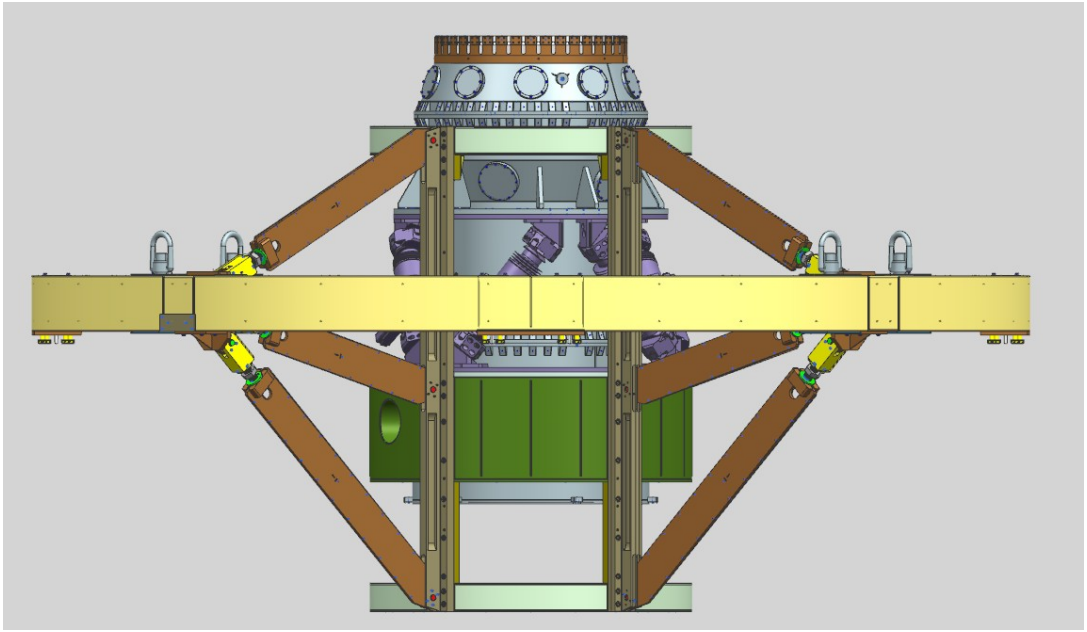
Overview

- PPD Engineers work closely with scientists through all phases of an experiment
  - Detector R&D
  - Design
  - Construction
  - Operation
  - Decommissioning
- Engineers driving technology innovations to expand horizons of science

Mechanical Engineering: Mechanical Design Engineering

Don Mitchell
Giuseppe Gallo
Luke Martin
Jim Kilmer

- Structures, supports, shielding, modeling, general detectors

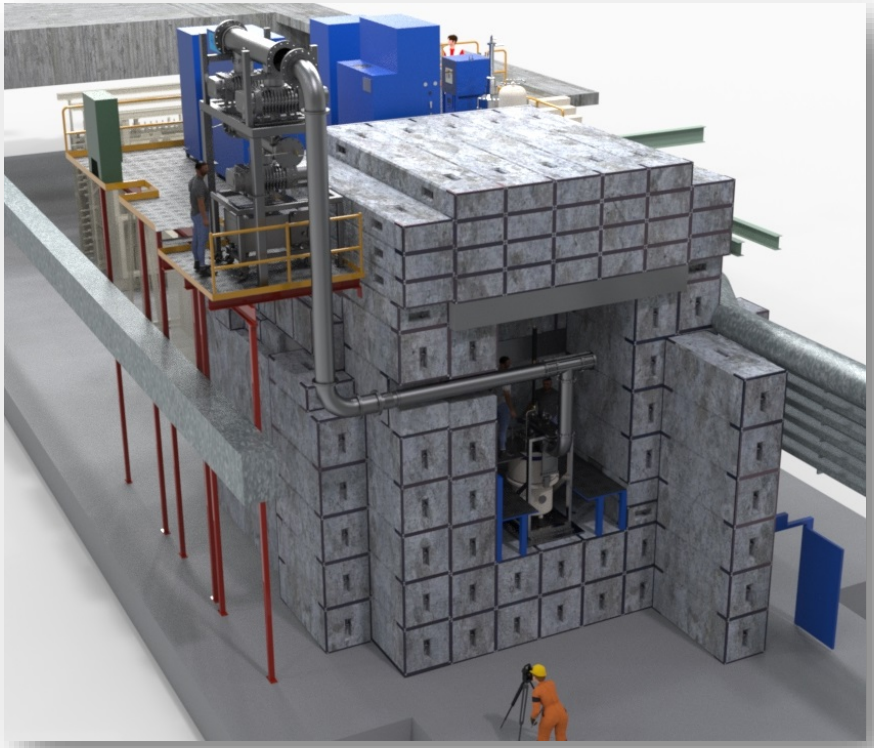


Dark Energy Survey Instrument

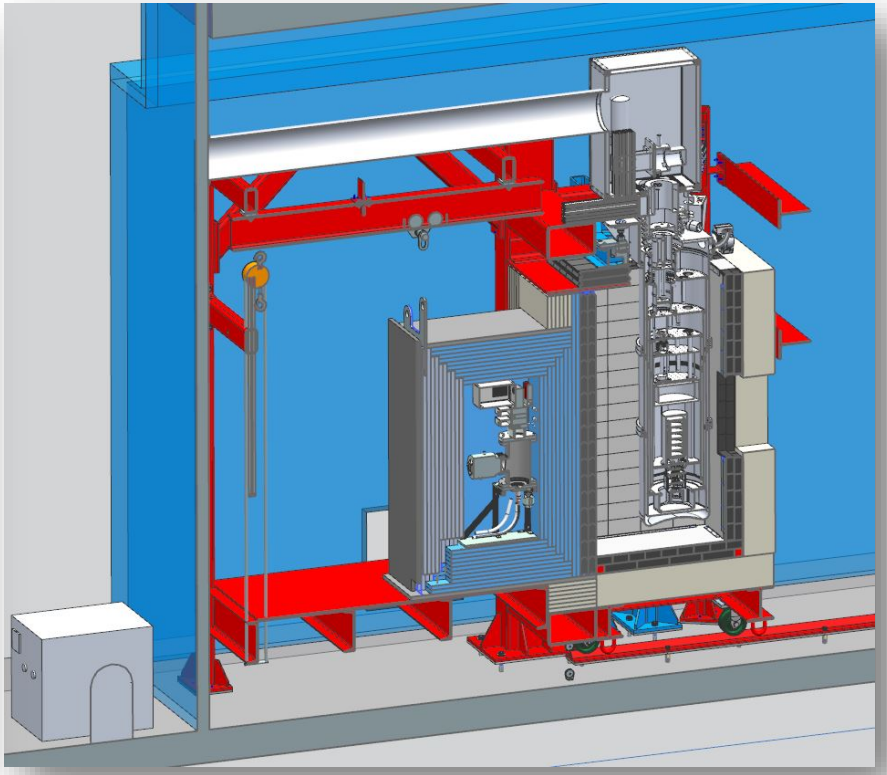
Dept. Head: Russ Rucinski

Mechanical Engineering: Mechanical Design Engineering

- Structures, supports, shielding, modeling, general detectors



E-1039 at NM4

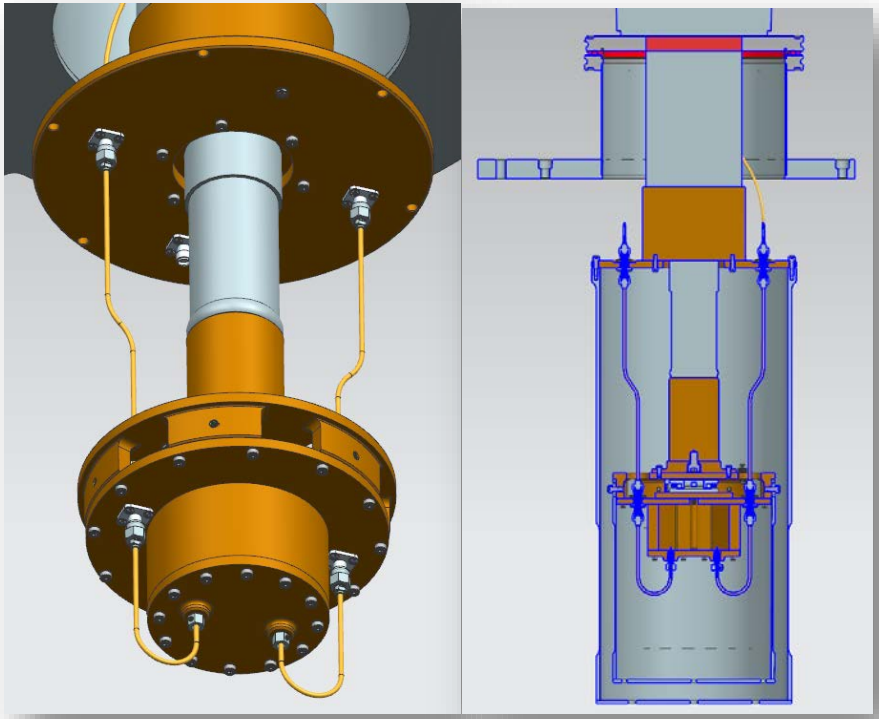


NEXUS dark matter R&D facility in MINOS cavern

Mechanical Engineering: Mechanical Design Engineering

- Structures, supports, shielding, modeling, general detectors

Mu2e Protection Collimator



AXION detector prototype

Mechanical Engineering: High Precision Design Engineering

- Silicon detectors, carbon fiber and special materials

Greg Derylo
C.M. Lei
Stephanie Timpone

CMS detector at CERN

Mechanical Engineering: High Precision Design Engineering

- Silicon detectors, carbon fiber and special materials

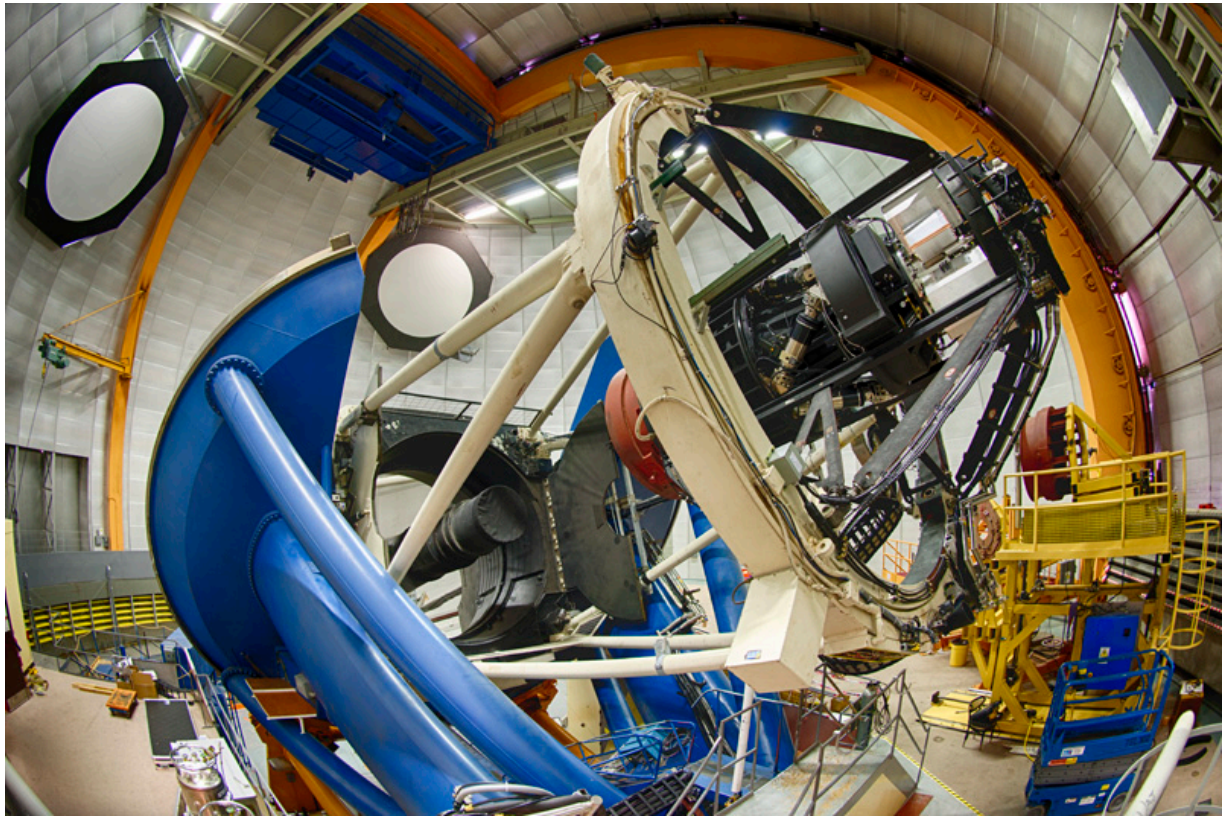
Innovations:

- Dual Phase CO2 cooling
- Structure built with Thermal Pyrolytic Graphite (TPG) encapsulated in carbon fiber

CERN CMS Phase 1 Forward Pixel Detector

Mechanical Engineering: High Precision Design Engineering

- Dark Energy Survey Camera



2003-2012: DECAM, at 0.57 Gigapixels, is the second largest digital camera in the world.

Mechanical Engineering: Fluids and Thermal Engineering

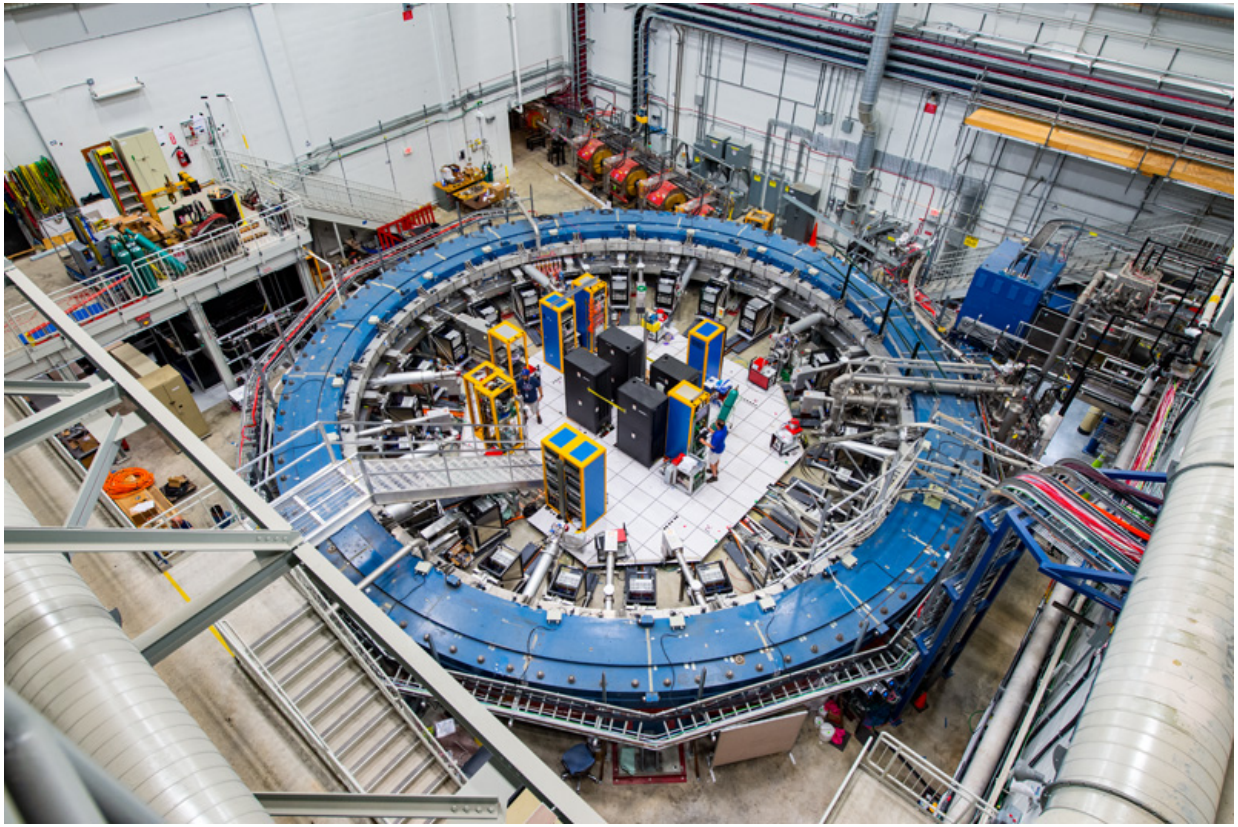
- Heat transfer, fluids and gas systems integrated with detector elements

Del Allspach
Cary Kendziora
Jacob Kintner
Robert Sanders
Erik Voirin

g-2 Experiment – Responsible of the move from BNL

Mechanical Engineering: Fluids and Thermal Engineering

- Heat transfer, fluids and gas systems integrated with detector elements



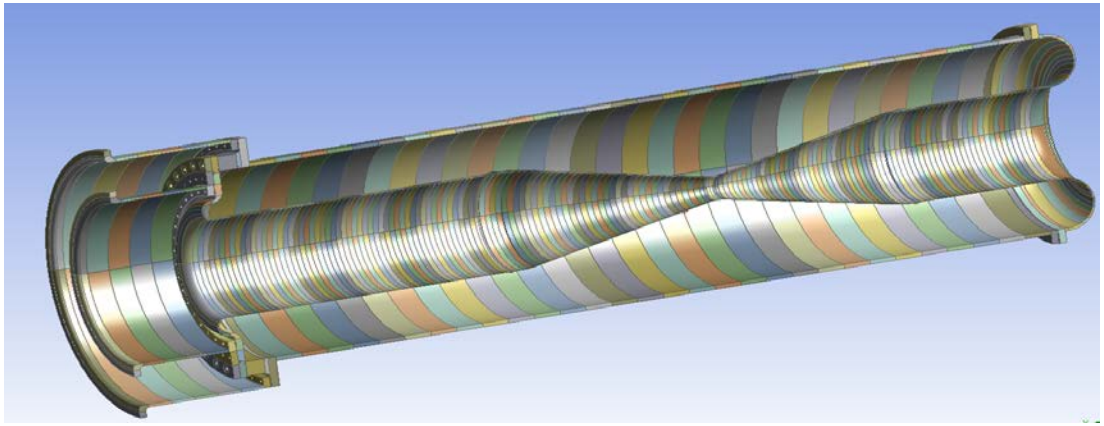
g-2 Experiment

- **Superconducting magnets**
- **Vacuum**
- **Gas systems**

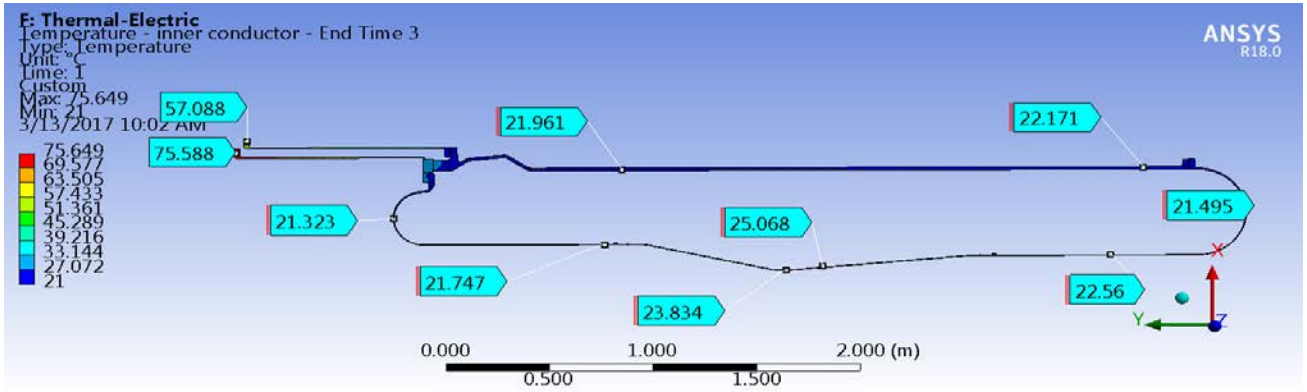
Mechanical Engineering: Engineering Analysis

- Finite element analysis and computational fluid dynamics, magneto statics

Horn B thermal model



Bob Wands
Ingrid Fang
Ang Lee
Zhijing Tang
Erik Voirin

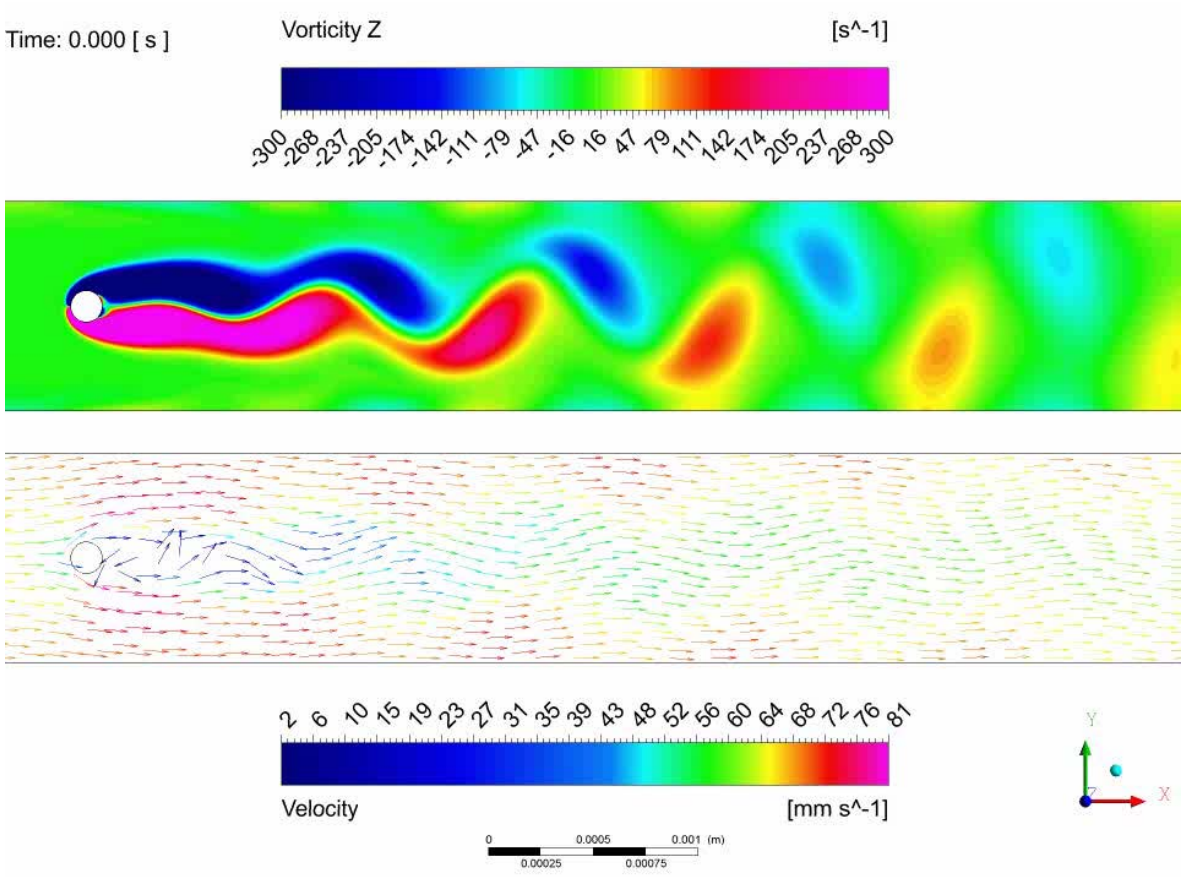


Steady state temperature (C) 1.2 MW

Mechanical Engineering: Engineering Analysis

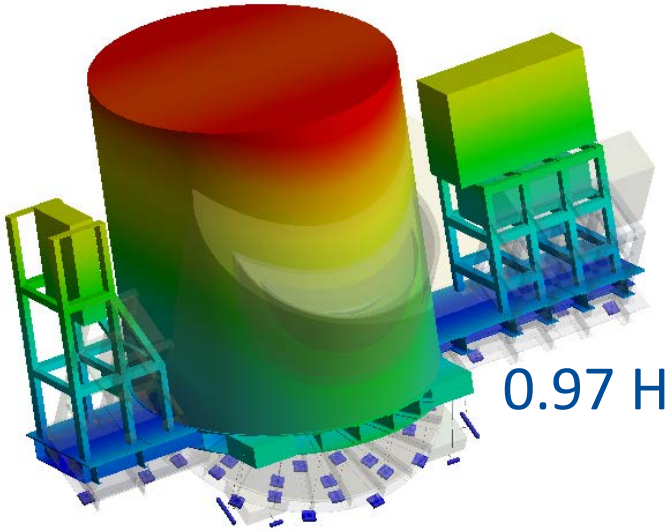
- Finite element analysis and computational fluid dynamics, magneto statics

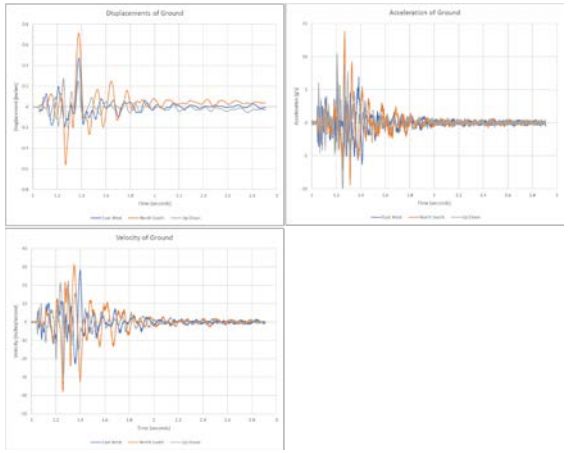
SBN
TPC Wire Forces and Vortex Induced Motion from LAr Flow

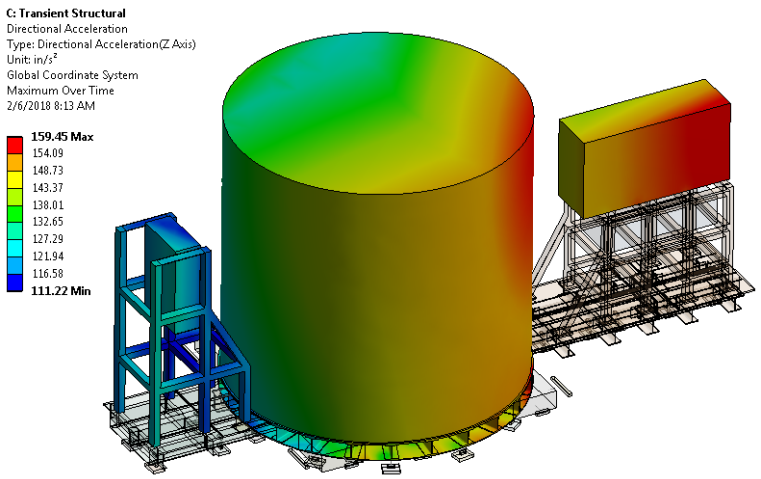


Mechanical Engineering: Engineering Analysis

- Finite element analysis and computational fluid dynamics, magneto statics, vibration analysis







SCDMS
Seismic Base Analysis

Mechanical Engineering: Process Controls

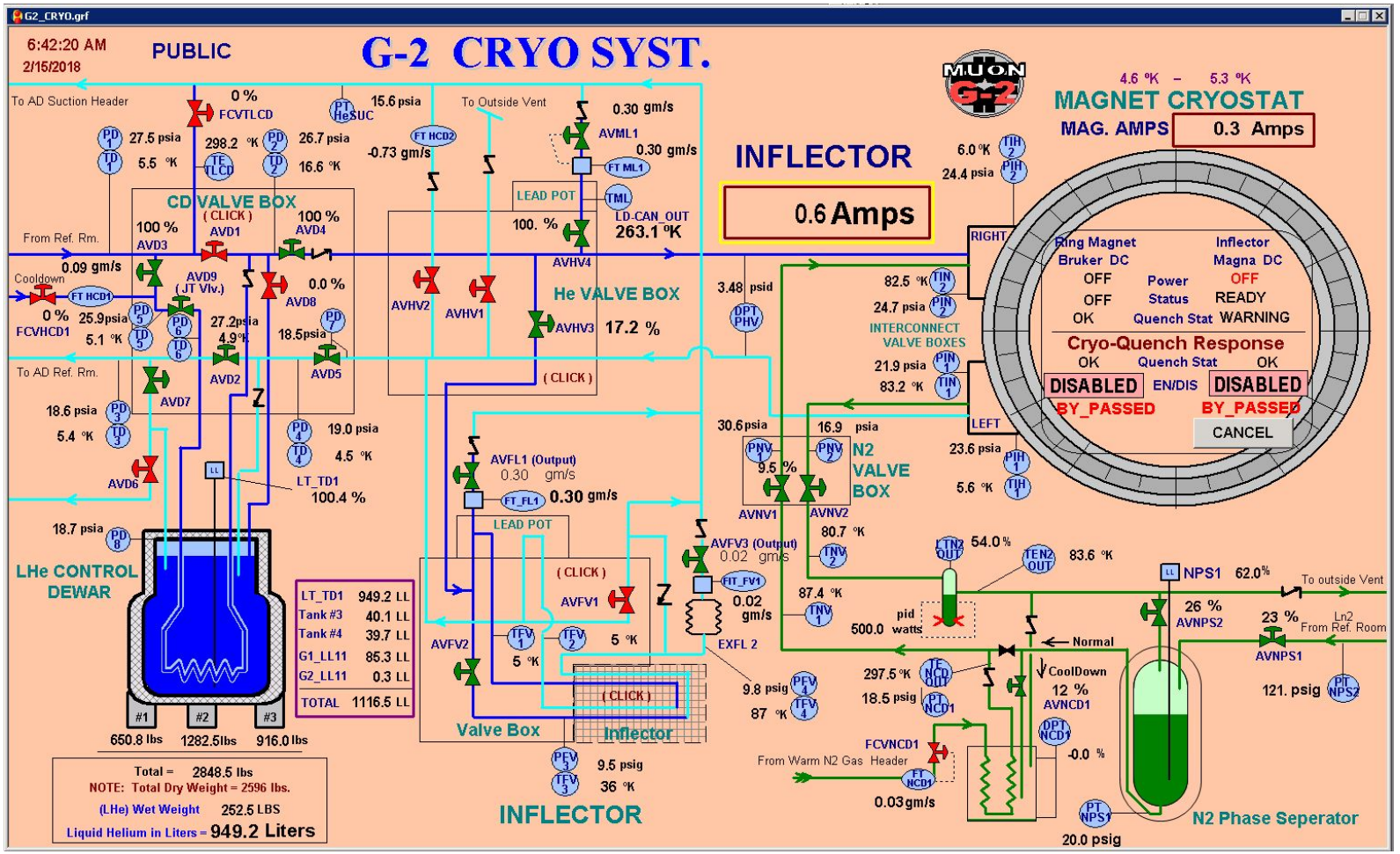
- Process Control systems design and implementation

Daniel Markley
Roberto Davila
Timothy Martin
Kim Overhage
Shreya Ranpariya
Michael Sarychev
Ian Young

User Interface to access Controls For Experiments

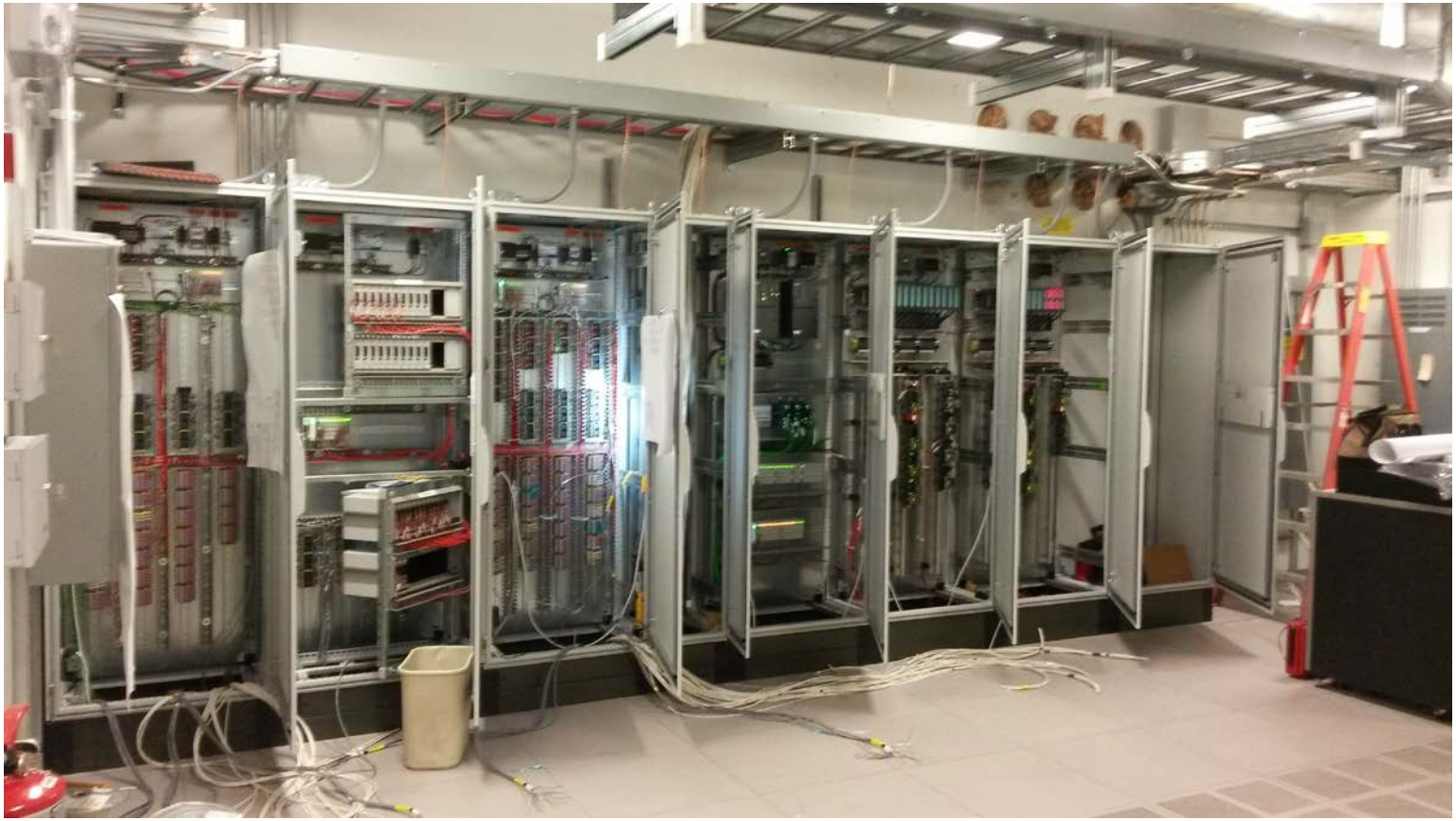
Mechanical Engineering: Process Controls

- Process Control systems design and implementation



Mechanical Engineering: Process Controls

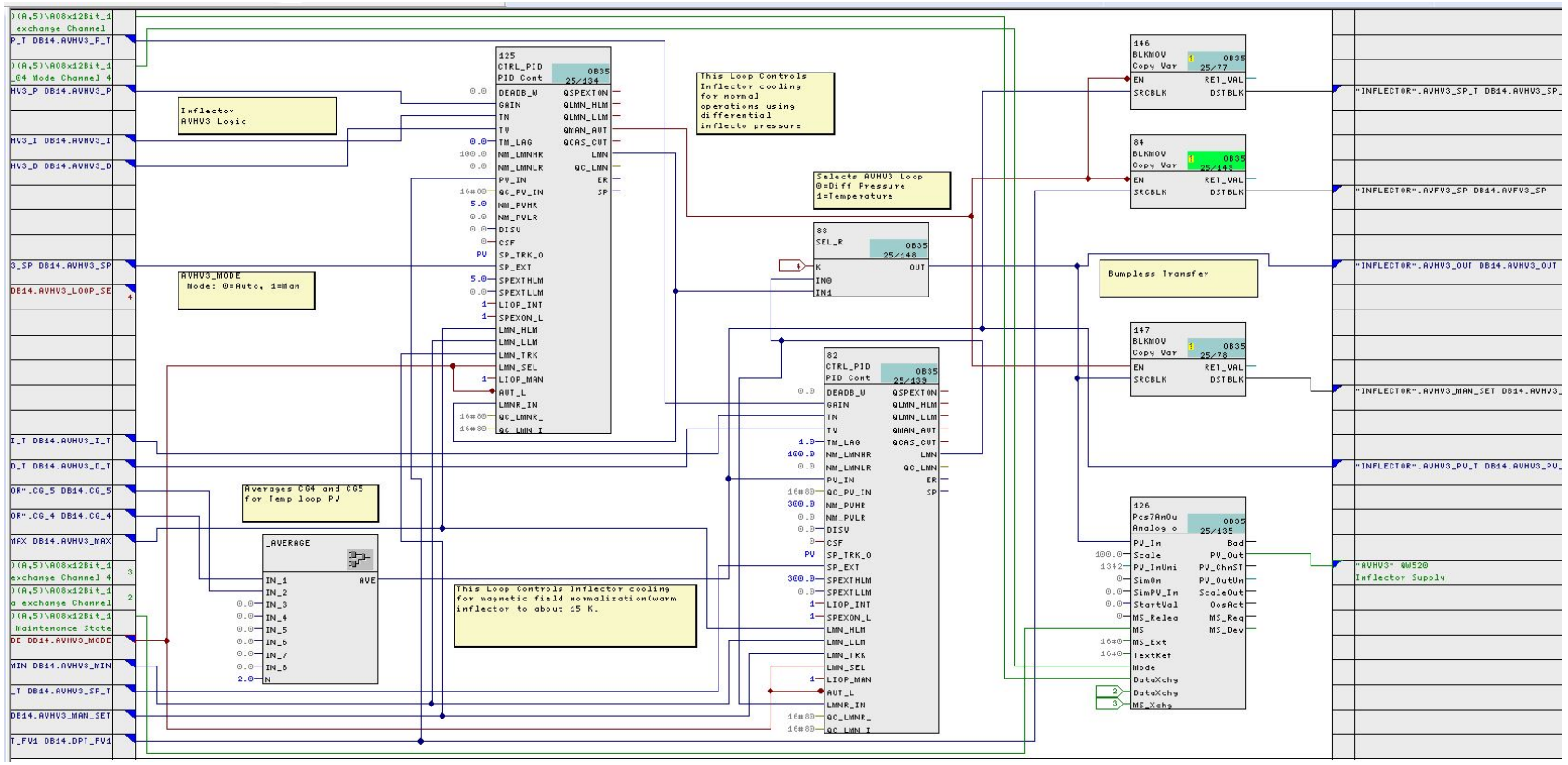
- Process Control systems design and implementation



g-2 process controls racks

Mechanical Engineering: Process Controls

- Process Control systems design and implementation

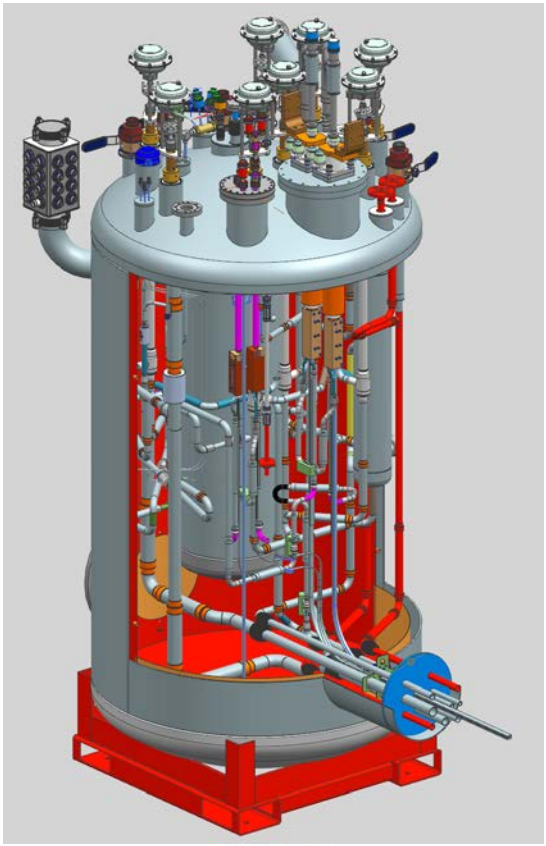


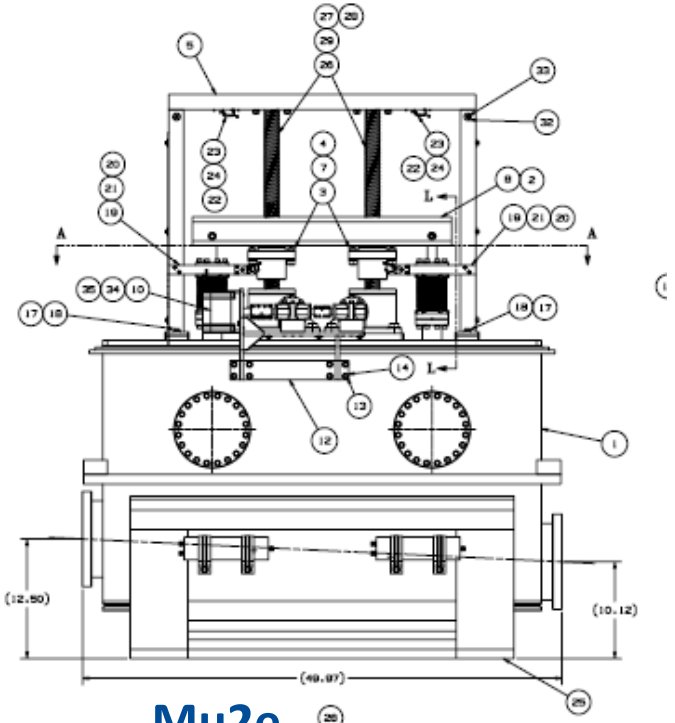
Programmable Logic Controller programming

Mechanical Engineering: Design and Drafting

- Designer 3D modeling, detail drawing, and P&ID drafting services

Mu2e Feedbox





Mu2e Protection Collimator

John Rauch
Bill Cyko
Brian Ellison
Don Friend
Richard Reinert
Sean Sellberg
Gary Smith
Tom Sperry

Electrical Engineering

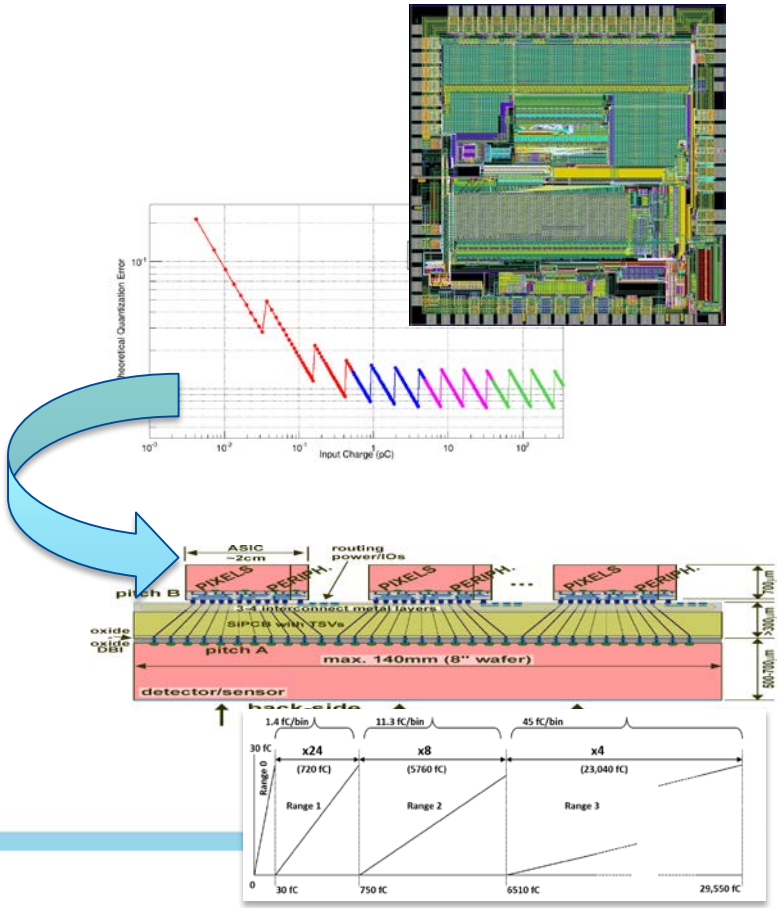
Dept. Head: Terri Shaw

- PPD/EED provides support for a wide variety of High Energy Physics, Astrophysics and other basic science experiments.
- Our work is far-ranging and our products can be found at Fermilab, CERN, the top of a mountain in Chile, and many other locations.
- Support is available for new experiments in terms of consulting and infrastructure design. Long-term support is available for any operating experiments.
- Many design and support disciplines are available within EED.

Electrical Engineering: ASICs

- Leading US ASIC group in HEP
- Driving innovative technology
  - 3D chips for triggers, X-ray cameras
  - Cold electronics for DUNE
- Past success leads to new innovation
  - QIE: a multi-decade development effort in high dynamic range floating-point readout chips for HEP
  - Translate QIE experience to a dense pixel array application
  - FASPAX: a wafer scale X-ray camera of small pixels with unprecedented dynamic range
    - 100u X 100u pixels
    - Multi-range device
    - Dynamic range: 1.4 fC to 30 pC

Grzegorz Deptuch
Al Baumbaugh, Davide Braga, Lou Dal Monte, Farah Fahim, Jim Hoff, Scott Holm, Sandeep Miryala, Alpana Shenai, Tom Zimmerman



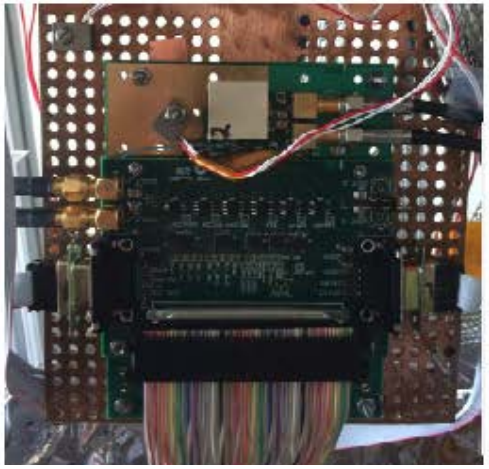
Electrical Engineering: ASICs

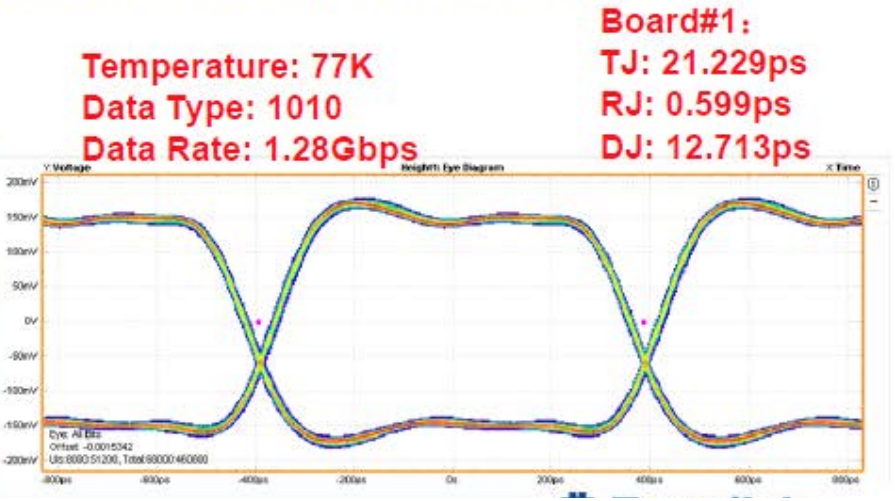
- DUNE

COLDATA: COLd DAta Transmission ASIC for DUNE (CDP1 prototype under tests - OK)
Data transmission from cryostat to warm side at 1.2Gbps over up to 30m of Cu links and for control of Front- End and ADC chips, TSMC 65nm, cold models and digital libraries developed, collab. with SMU and BNL

COLD ADC: for DUNE (start with LBL lead, digital back-end Fermilab)
12b, 2Msps ADC for DUNE liquid Ar TPC, pipeline with auto-calibration, TSMC 65nm, collab. with LBL, BNL

- *Built library of standard cells based on modified transistor dimensions to meet lifetime requirements and characterize it using Cadence-Liberate for synthesis-place-route*
- *Submitted prototype CDP1 ASIC in the TSMC 65nm process in May 2017 through CERN-IMEC Foundry Services using RD-53 agreement*
- *Tests underway and show good operation of the chip both in RT and CT*



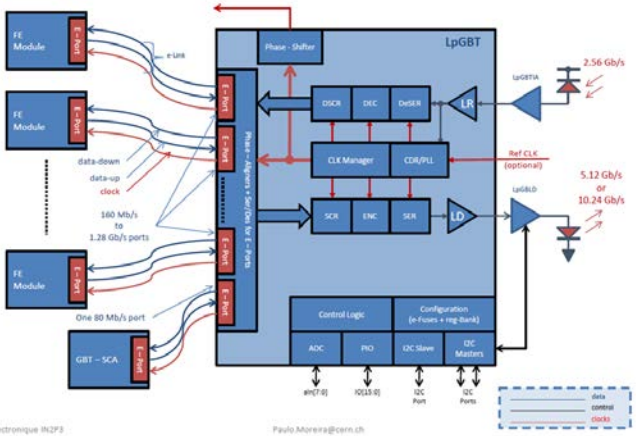


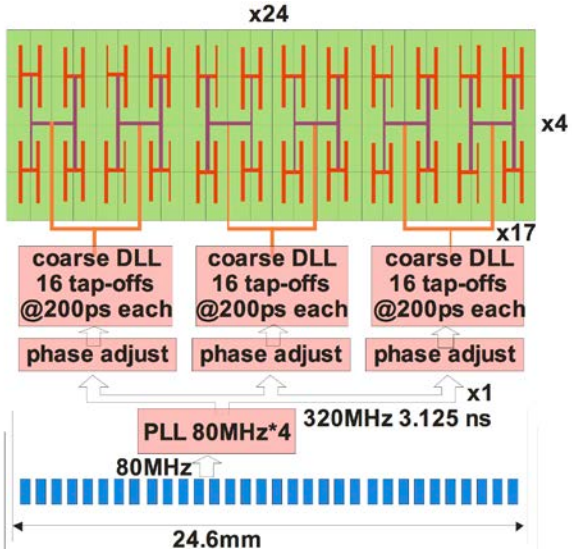
Electrical Engineering: ASICs

- CMS HL-LHC

ECON: Endcap CONcentrator

- Concentrates data for two paths:
  - Trigger Path: Consistent data quantity grabbed every beam crossing to be captured, processed, and relayed via four 10Gbps outputs.
  - DAQ Path: variable data quantity; variable data rate; data must be captured, processed, and relayed via 8 x1.28Gbps eLink outputs.





FanTastIC: Fast Timing Integrated Circuit

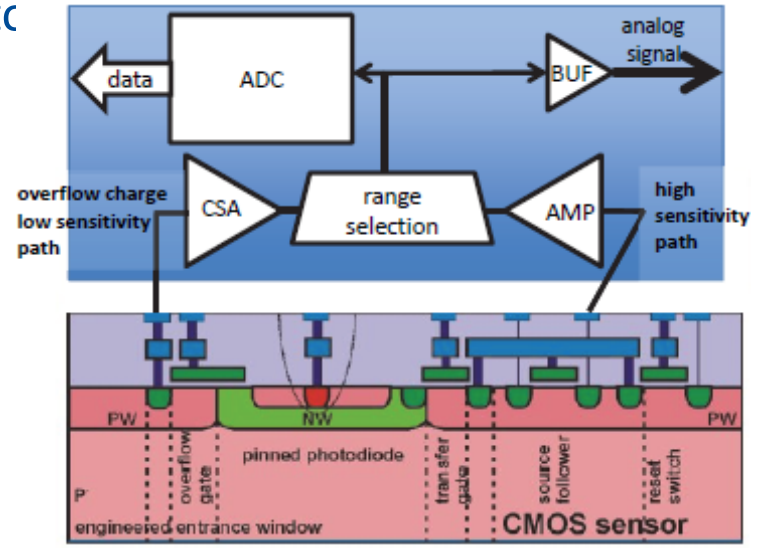
- ~20ps resolution
- Synchronization and clock distribution challenging
- Large pixels (1 x 3 mm)
- Low power (~mW/channel) but fast readout of large pixels • Radiation hard (~200Mrad)
- Collaborating TD-SRS for 3D EM studies of transmission line effects on global routing

Electrical Engineering: ASICs

- Readout for cameras at X-ray light sources (BES)

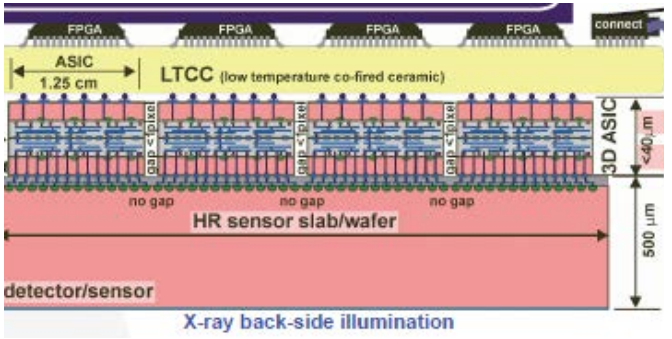
FLORA: Fermilab-**L**CLS CM**O**S 3D-integ**R**ated detecto with **A**utogain

- 50 um× 50 um pixel size
- High QE in the soft X-ray range
  - 0.25-2.0 keV
- Single photon sensitivity
  - Low noise: ~ 10 e- r.m.s.
- Large dynamic range: max. ~500 keV /pixel/pulse
- Fast frame readout >10 kHz

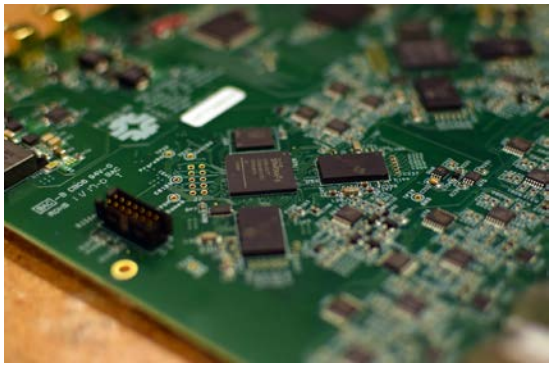


VIPIC-L: **V**ertically-**I**ntegrated **P**hoton **I**maging **C**hip – **L**arge

- 1.3 M-pixel, single module camera for Timing X-ray Photon Correlation Spectroscopy, 8-12 keV X-rays
- ASIC is a two tier 3D ASIC of 65µm pixel pitch configurable in zero suppression or imaging mode

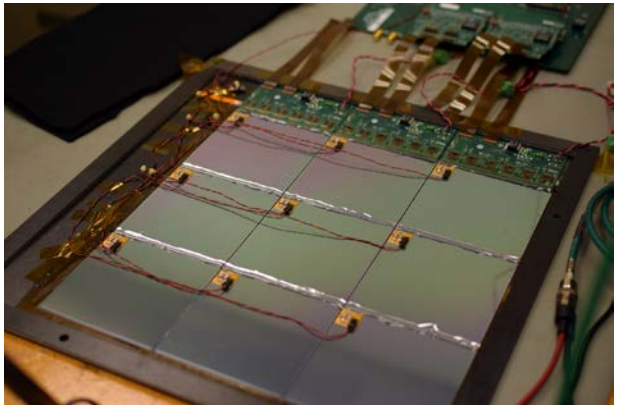


Electrical Engineering: Detector Electronics



Mu2e Cosmic Ray Veto front end boards

CCD characterization for Astrophysics experiments



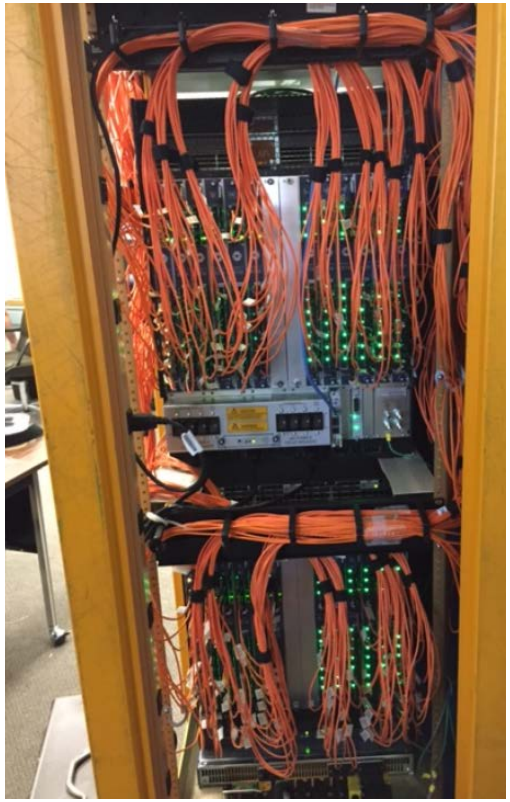
Silicon Muon Scanner

Jamieson Olsen
Cristinel Gingu
Sten Hansen
Terry Kiper
Sergey Los
Paul Rubinov
Michael Utes
Jin-Yuan Wu

Electrical Engineering: Detector Electronics

- CMS

CMS HCAL Front End Electronics – front-end board (using Fermilab designed ASIC), firmware, SiPM control board and custom backplanes

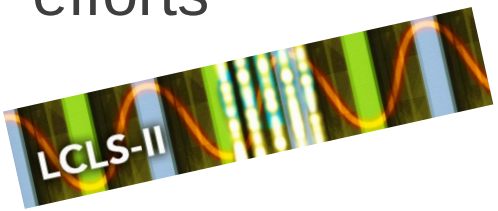


Pattern Recognition and Track Finding Firmware/Hardware

Electrical Engineering: Infrastructure Support

Mike Matulik
Steve Chappa
Arnab Ghosh
David Huffman
Walt Jaskierny

- Power supplies, grounding and shielding, cabling, fabrication, etc. for many experiments and other efforts



ICARUS

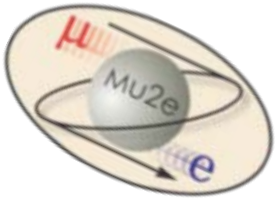
protoDUNE

PPD / DDOD

CDMS

Fermilab Astrophysics

ANNIE



Lederman Science Center

Fermilab AD

Fermilab ESH&Q Security

SNOLAB

Fermilab TD

PPD / EED ASIC

PPD / MED

FTBF

SMS

LArIAT

MINERvA

PPD / DO

SeaQuest

DES / DEC

Alignment and Metrology

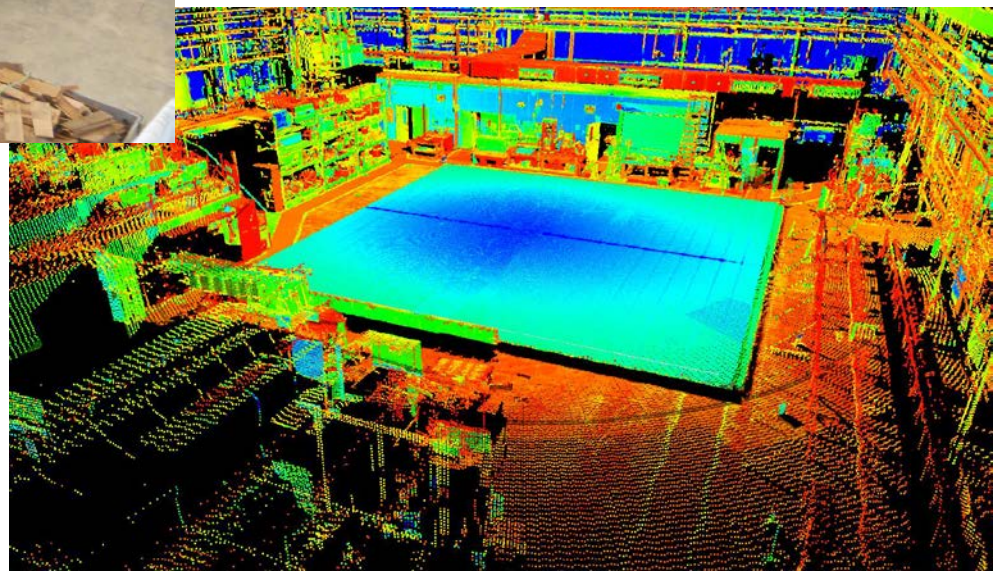
- Works across all divisions and supports the Fermilab user community
  - Usually the first in on a project and the last out
    - Providing the coordinate information for locating new project construction
    - Installing control networks for the positioning of the accelerator components
    - Laying out the blue line for support stands to referencing and aligning many beam-guiding and instrumentation components
    - Providing as found information to the physics groups
  - Operate high precision specialist instrumentation that needs to be kept in proper working condition.

Alignment and Metrology

Horst Friedsam (Dept. Head)
Virgil Bocean
Jana Hejdukova
John Kyle
Babatunde Oshinowo

g-2 alignment support

Laser Scanner test at Argonne of the first NOvA far detector plane

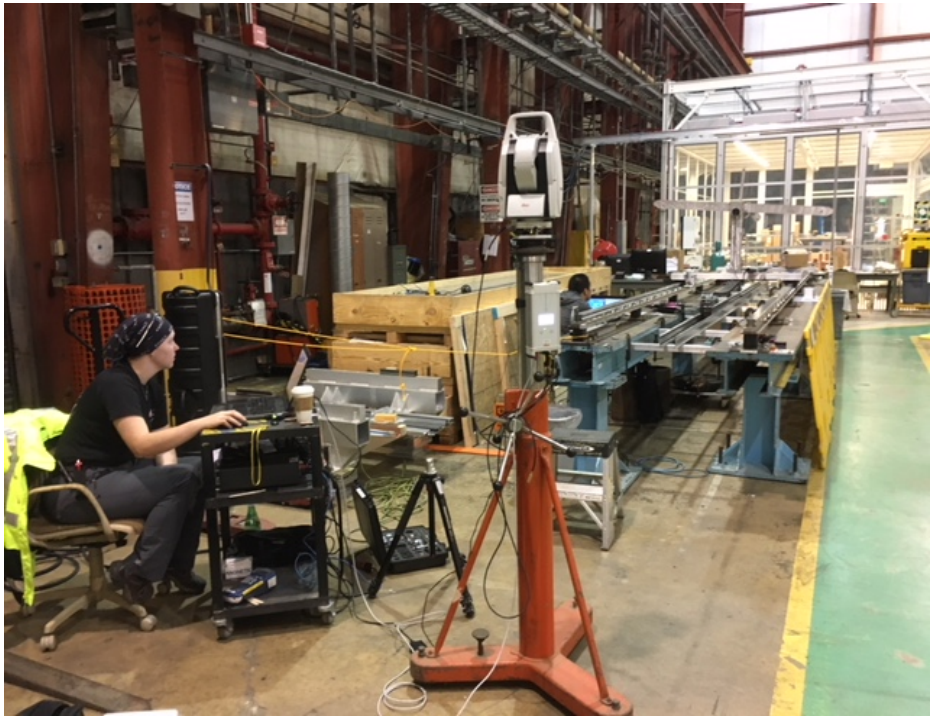


Alignment and Metrology

- Mu2e alignment support

Alignment support locating the vibrating wire position of the TS prototype

Tracking the position of the detector solenoid magnetic field mapper



Alignment and Metrology

- LBNF/DUNE

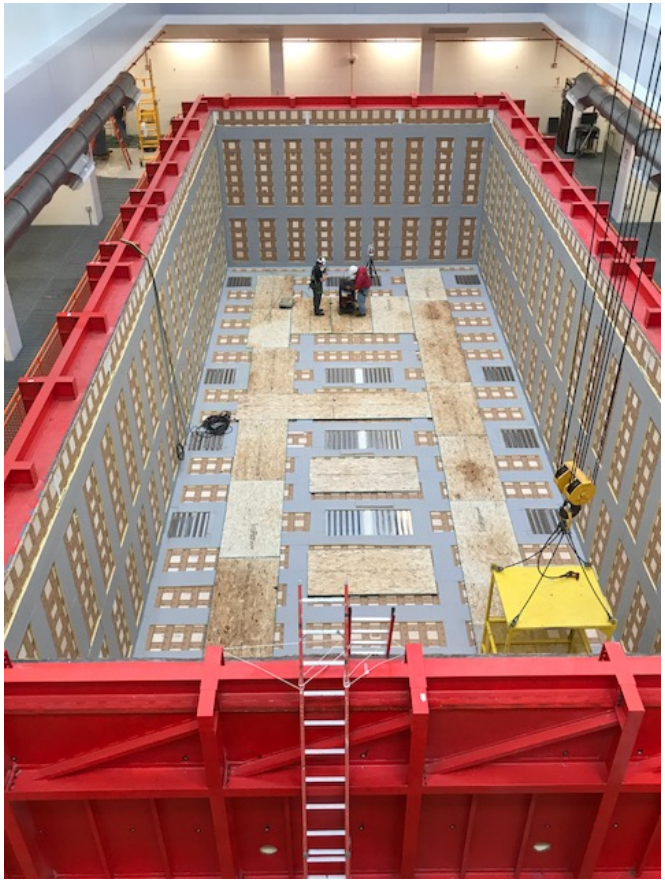
Measuring the position of the world longest plumb line at the Ross shaft (1 Mile)

Survey party at the home stake mine utilizing a gyroscope to determine the azimuth between two GPS points

Depth measurement with an electronic distance meter

Alignment and Metrology

Short Baseline Neutrino Project (SBN): Deformation measurements load testing the ICARUS support vessel



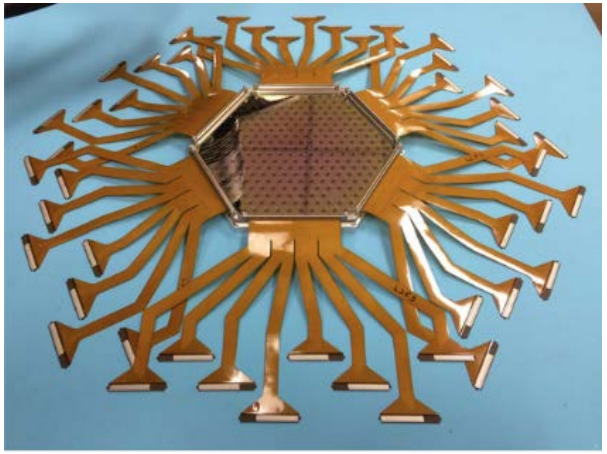
LCLSII: Laser Tracker measurements

Detector Operations and Development Department

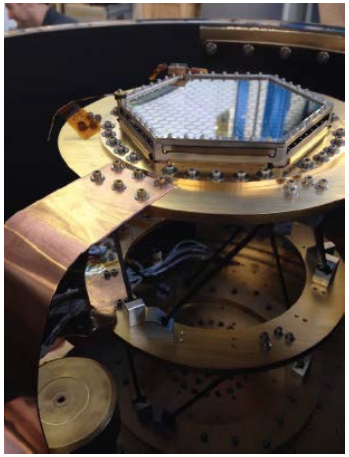
Rick Ford (Dept. Head)
Eileen Hahn
Donna Kubik
Mike Roman
Greg Sellberg
Ewa Skup
Jerry Zimmerman

- Engineering Physicists develop and construct novel particle detectors
  - Silicon Detector Facility

Detector assembly



Detector testing



Cryostat assembly/testing

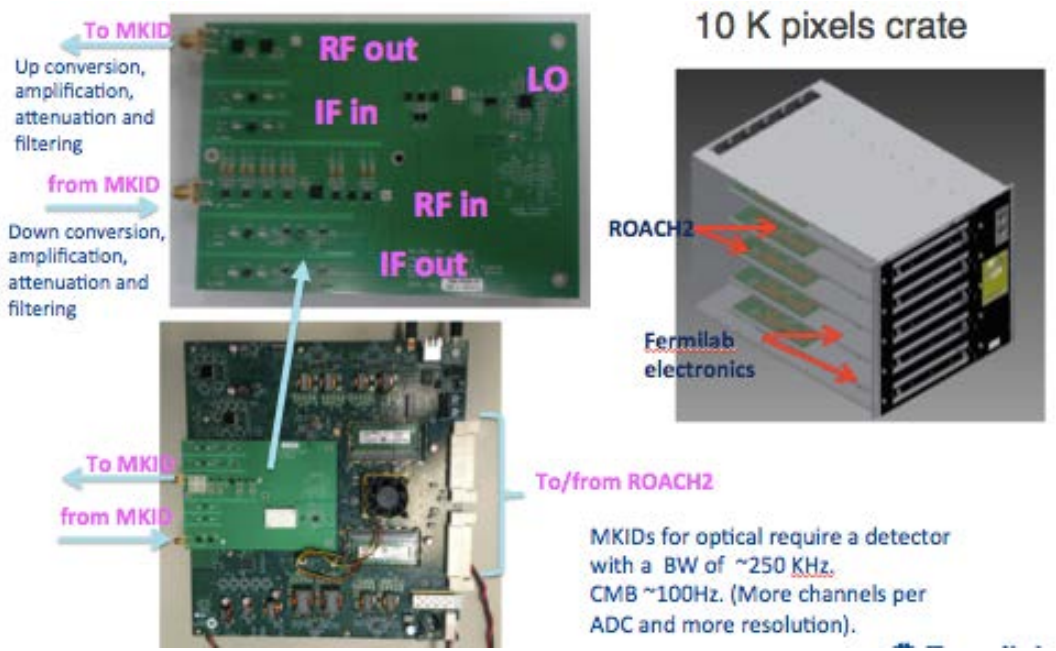
SPT-3G deployed a new receiver on the 10-meter South Pole Telescope to study the Cosmic Microwave Background. The receiver comprises ~2700 dual-polarization multichroic pixels each pixel with broadband microwave antenna.

Detector Operations and Development Department

- Cosmic Microwave Background (CMB) detectors of the future
  - An example of cross-divisional engineering

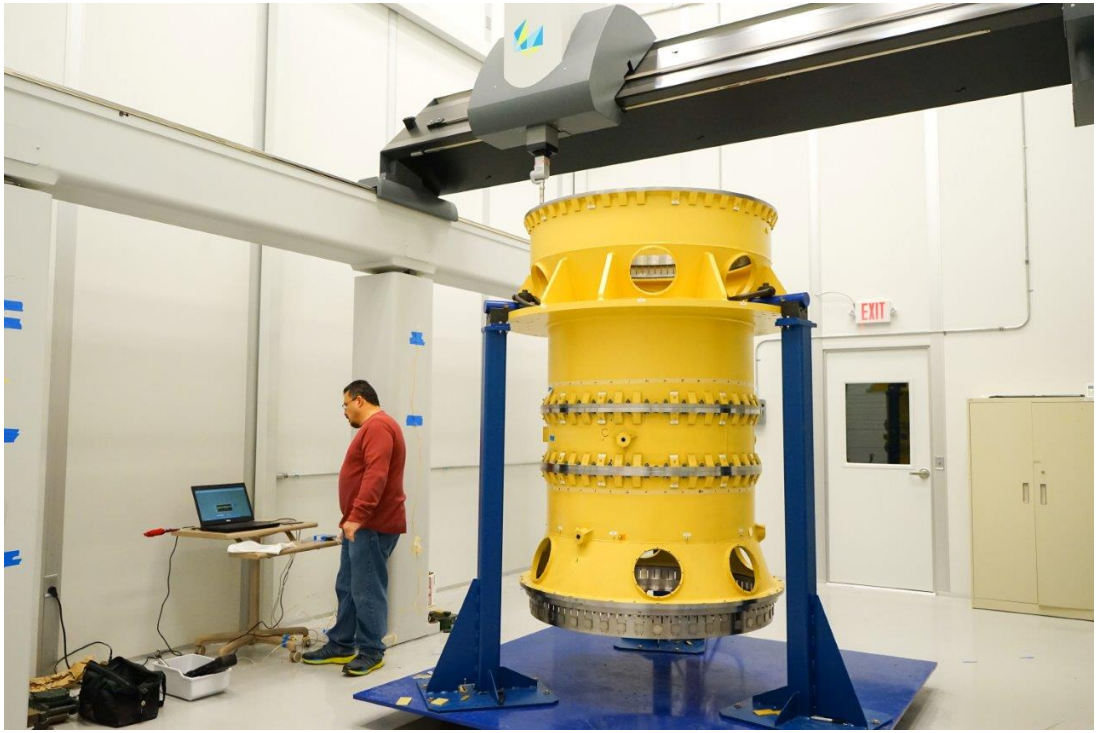
We are studying MKIDs (Microwave Kinetic Induction Detectors) as potential microwave detectors for future CMB arrays.

The associated electronics we are testing is called FMESSI (Frequency Multiplexed Electronics for Superconducting Sensor Instrumentation), developed by Gustavo Cancelo's group at FNAL.



Detector Operations and Development Department

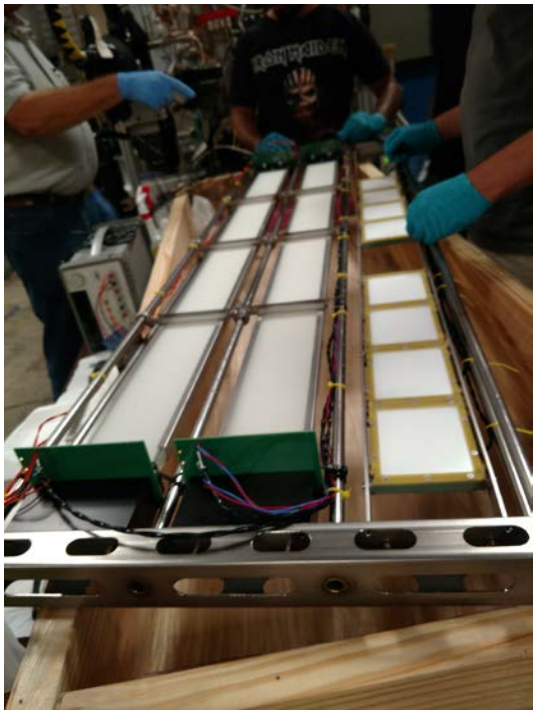
- Precision Metrology
  - Assembly and measurement of DESI barrel that supports telescope optics

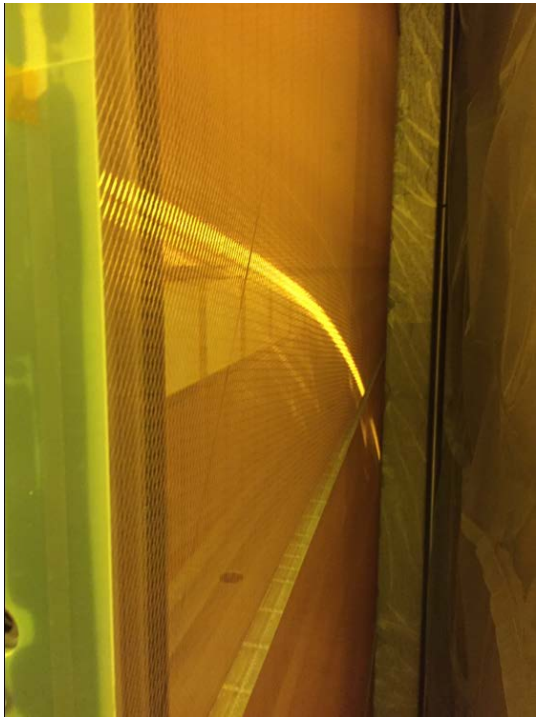


Detector Operations and Development Department

- Advanced Detectors
  - Assembly and polishing of optical fibers
  - Advanced coatings

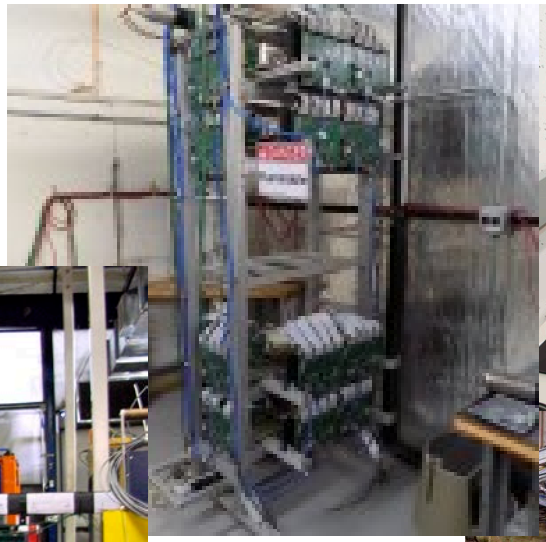
Arapucas for ProtoDUNE





Detector Operations and Development Department

- Fermilab Test Beam Facility
  - Operate beamline instrumentation
  - Assist users in mounting their experiments



Detector Operations and Development Department

- Mr. Freeze