# Detector Development Facilities

Rick Ford

Fermilab Science & Technology Review

November 5-7 2013

U.S. DEPARTMENT OF ENERGY | Office of Science

Fermilab

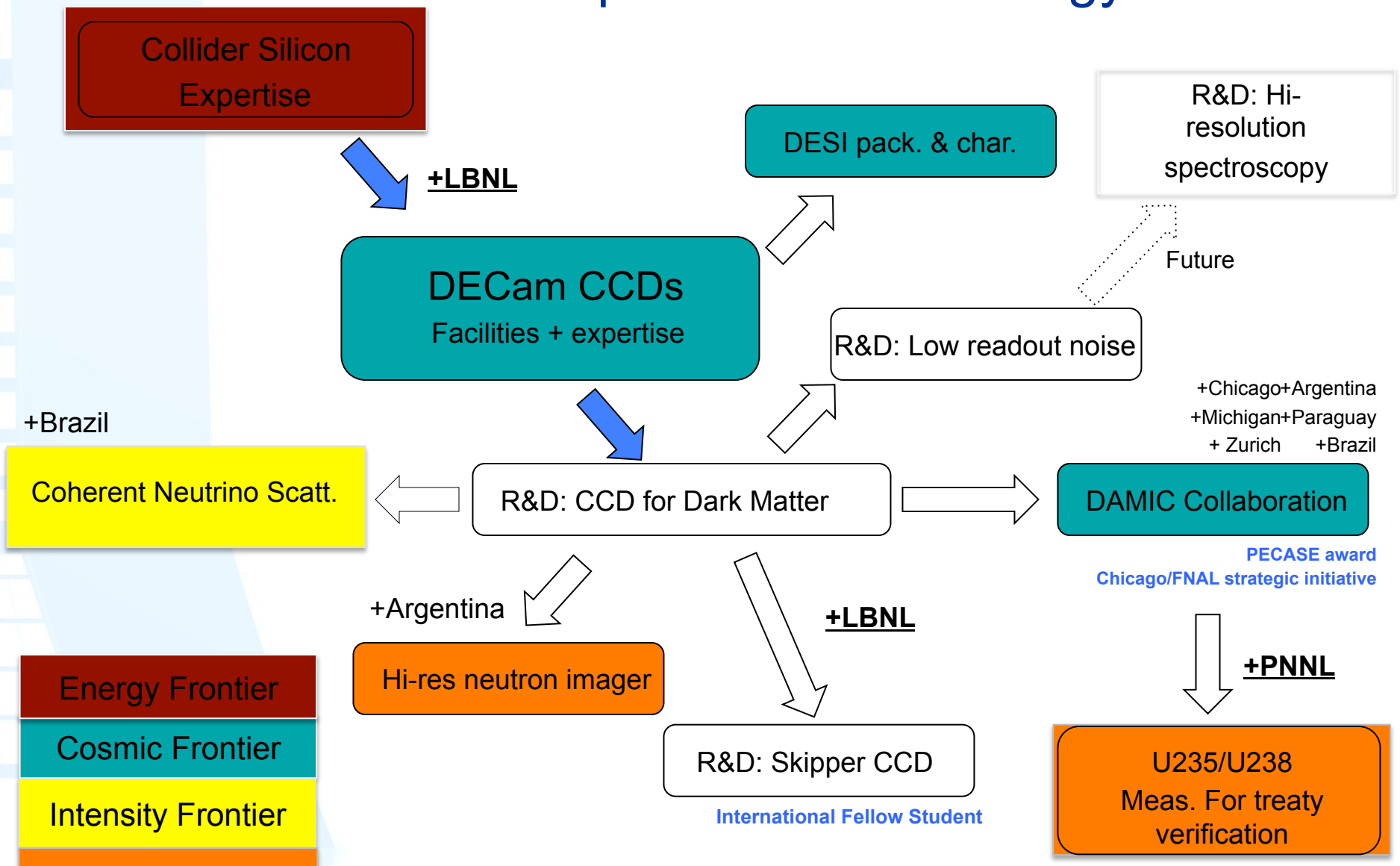
# Outline

- Short history and overview of detector development & experimental support
- Individual facility descriptions
  - Location
  - Overview of each facility
  - Description of experiment support
  - Staffing
  - Planned short and long term future of the facility
- Summary

# Overview of Detector Development & Experiment Support

- Fermilab's world class detector technology has been integral to many major discoveries in particle physics including, most recently, the discovery of the Higgs boson.
- A micro history - detector development and support was first driven by a diverse fixed target program followed by heavy investment in the development of large collider detectors.
  - More recent experiments such as CMS, DES, etc relied on and improved upon these facilities, i.e. all have benefited from previous developments and investments.
  - Expertise from previously developed detectors is essential in driving future development. Continuous cross-fertilization between frontiers…

# Example: CCD Technology Evolution



# Detector Engineering, Development and Operations

## Electrical Engineering

**ASIC**
6 ASIC Engineers
2 Technicians
1 Engineer Physicist

**Electronics Design**
14 Engineers
4 Technicians
1 Layout Designer
1 IT Professional

**Infrastructure & Support**
4 Engineers
7 Technicians

**Online Support**
3 IT Professional
1 Engineer Physicist

## Mechanical Engineering

**FEA**
4 Engineers

**Design Engineering**
10 Engineers

**Fluids & Thermal Engineering**
10 Engineers

**Design & Drafting**
1 Engineers
9 Designers

**Process Controls**
2 Engineers
3 Technicians
1 IT Professional

## Detector Development & Operations

**Silicon Detectors**
1 Scientist
2 Engineer Physicists
6 Technicians

**Scintillation Detectors**
1 Chemist
3 Technicians

**Project Develop.**
2 Engineer Physicists
1 Technician

**Rapid Prototyping**
3 Technicians
1 Designer
1 IT Professional

**Cryogenics & Vacuum**
4 Technicians

**Thin Films**
1 Engineer Physicist
3 Technicians

**Intensity Frontier and Testbeam Ops**
2 Scientists
3 Engineer Physicists
2 Technicians

**Assembly, Installation and Maintenance**
25 Technicians

## Alignment & Metrology

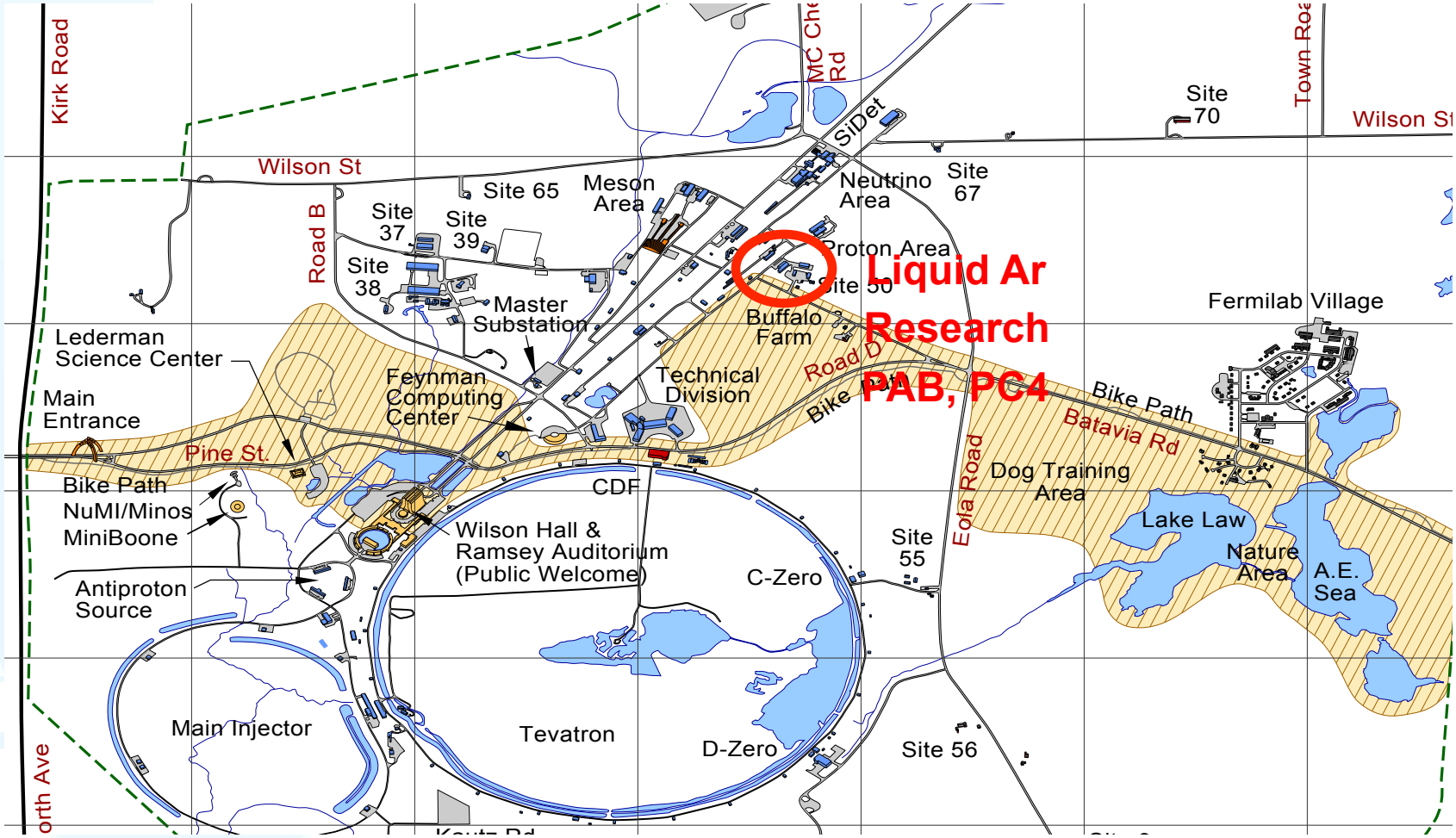
**Geodesy**
4 Geodesists

**Metrology**
9 Technicians

Primary Operations Support

Facilities Covered in this Talk

# Location of Detector Support Facilities

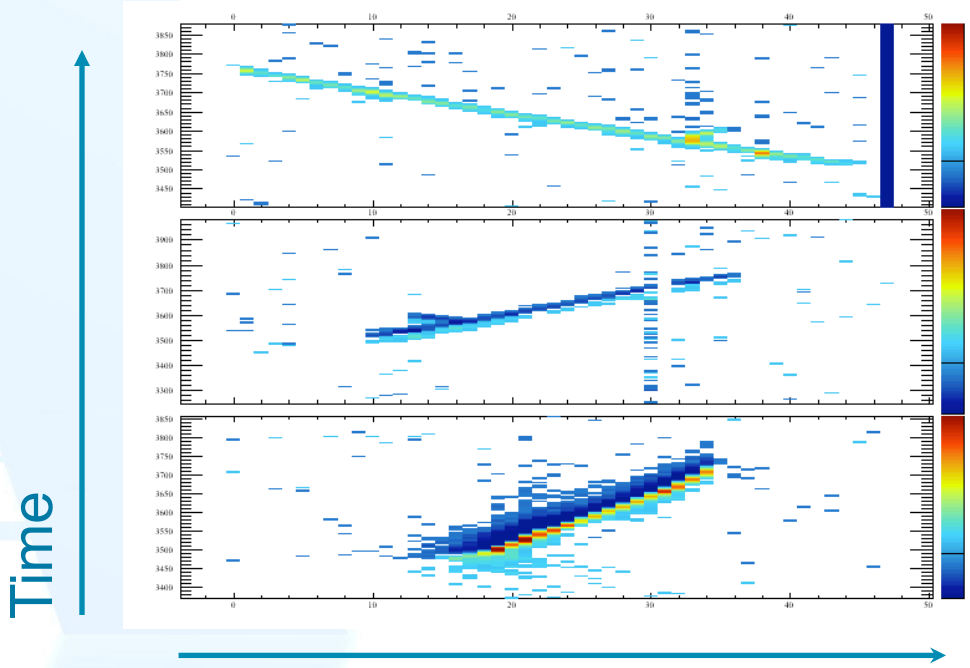


# Cryogenic and Vacuum Instrumentation Group

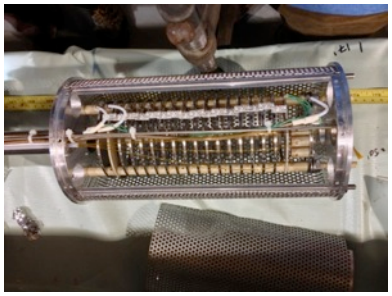
- Principle group involved in LAr development for intensity frontier detectors at the Proton Assembly Bldg (PAB) including LBNE LAr 35t prototype and the Liquid Argon Purity Demonstrator (LAPD).
- Core group of 4 cryogenic techs with an additional 3 techs on long term assignment.
- Recent and current projects include LBNE, MicroBooNE, Darkside, COUPP, g-2
- R&D: LAPD, SCENE, Solid Xenon, LAr materials test stand

# Cryo & Vacuum Inst Grp: Recent Projects

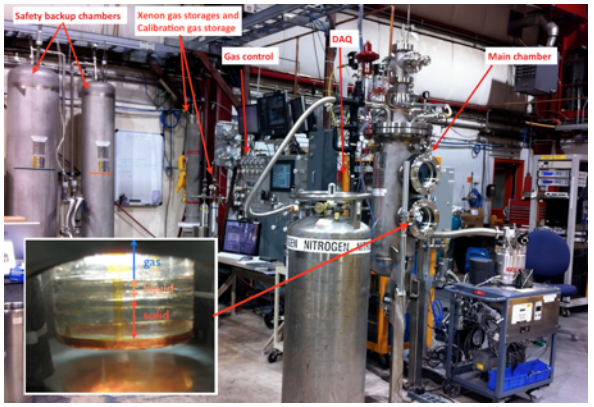
- A 2m long TPC is located in the volume - Long Bo
- PAB group performed the installation and has supported modifications/repairs that had to be performed
- First tracks seen in non-evacuated vessel



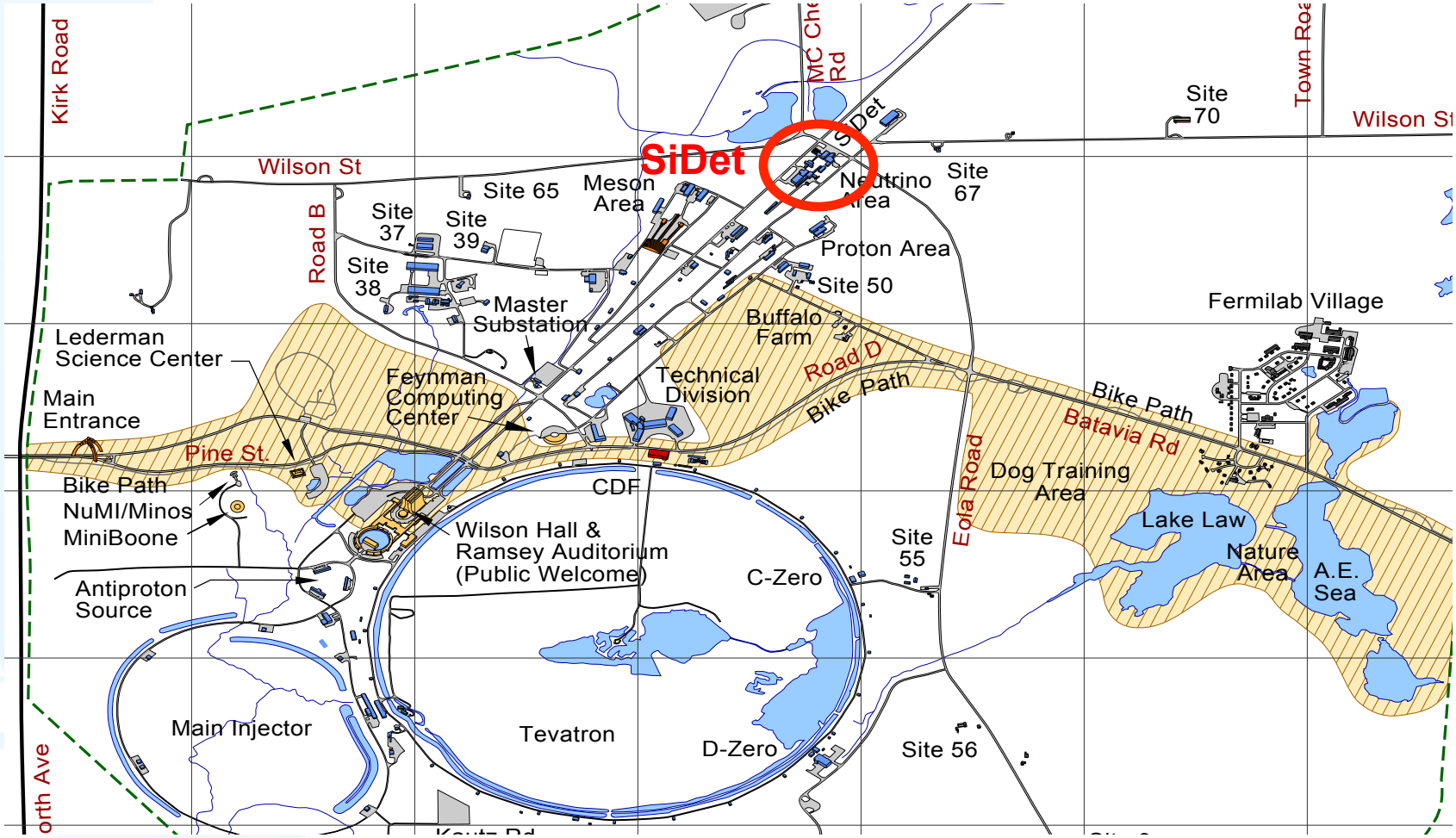
# Cryo & Vacuum Inst Grp: Recent Projects – cont'd



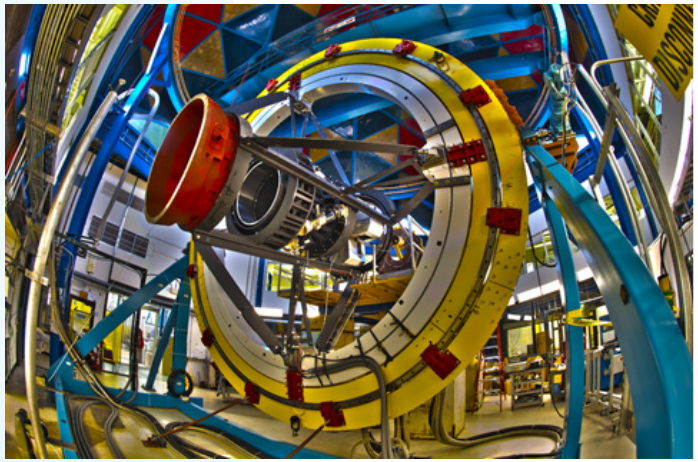
- Purity monitors
- Liquid Argon materials test stand
- Installed the room temperature high purity process piping for the LBNE 35T prototype
- Solid Xenon R&D



# Location of Detector Support Facilities



# SiDet : Facility Highlights



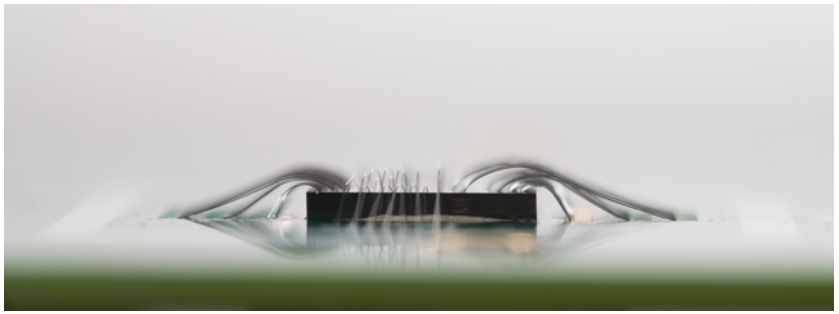
Large assembly area (Lab-A) :

Support for experiment with significant space requirements. (DECAM, COUPP, SCENE, and R&D)

Clean-room space for detector assembly, QA and characterization in controlled environment. (CMS, DESI, DAMIC/CONNIE, detector R&D)

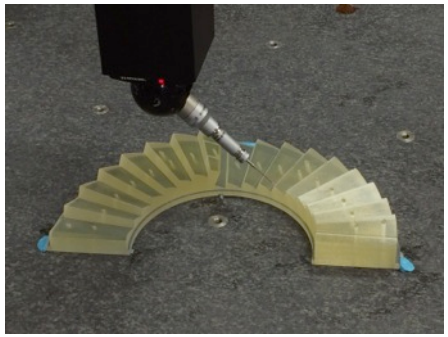
Lab space for detector characterization and QA (CMS, COUPP, DESI, SIPM R&D, CCD R&D)

# SiDet Clean Rooms: 5000 sq-ft from 10,000 to class 100



Manual and automated microbonding (production facility)

Optical and mechanical CMMs for precision metrology of detector components.

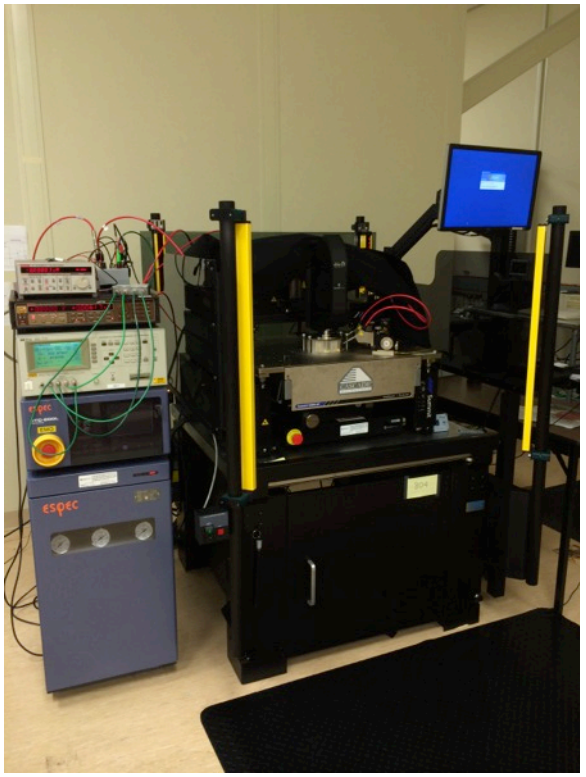


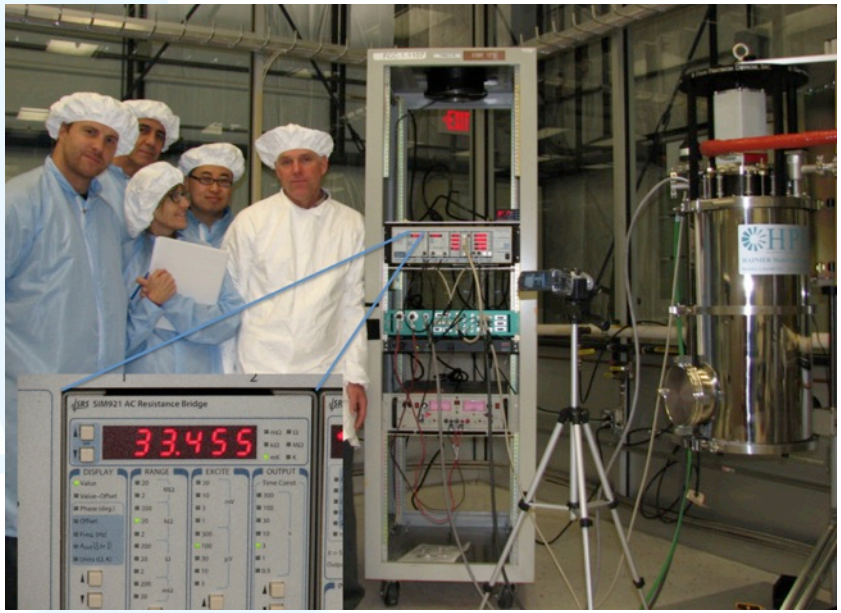
Silicon detectors fabrication facility (Hybrids, staves, prototype structures)

# SiDet: Three Recent Investments

$CO_2$ cooling -40C to -20C (CMS tracker)

Probe station capable of wafer level probing at temp range -55C to 200C ( CMS + others )

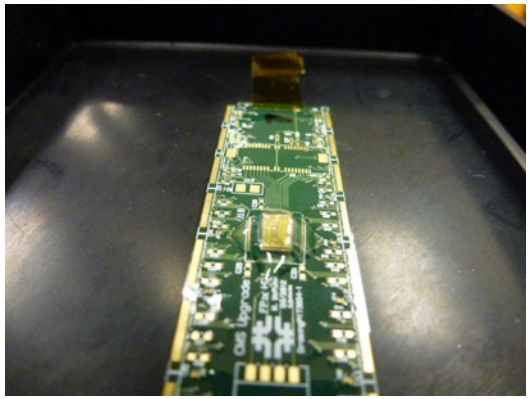


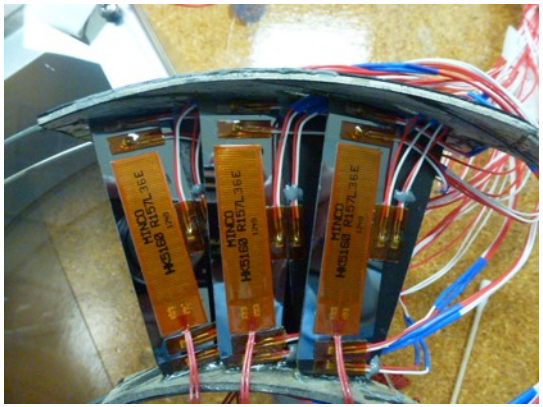

Adiabatic Demagnetization Refrigerator. Coldest place in the history of FNAL : 33mK! MKIDs + CDMS + others

# SiDet Projects: CMS upgrade

Support for forward pixel detector upgrade

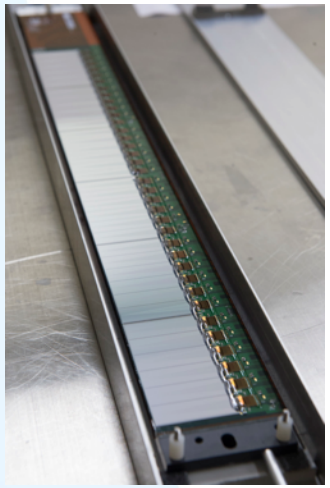


HDI testing and assembly for CMS forward pixels

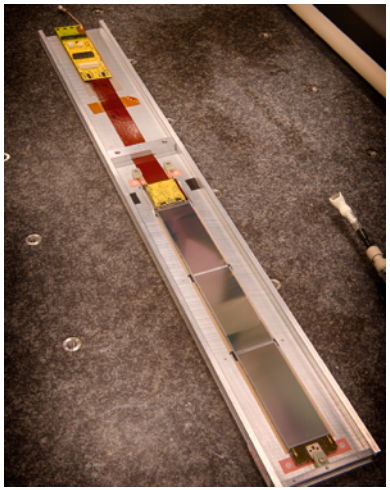


Thermal modeling for forward pixel detector.

# SiDet Projects: RHIC & JLab

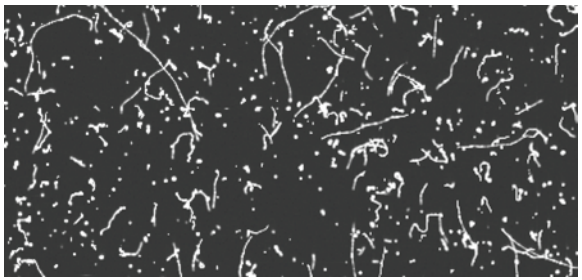


Modules for the STAR experiment at RHIC completed (2013).



JLAB SVT module first round of production completed in Sept. 2013

# R&D

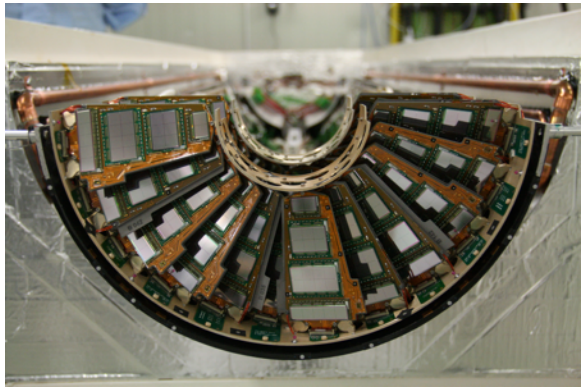


DECam CCD showing diffusion limited hits (neutrons) and electron tracks

# SiDet Team

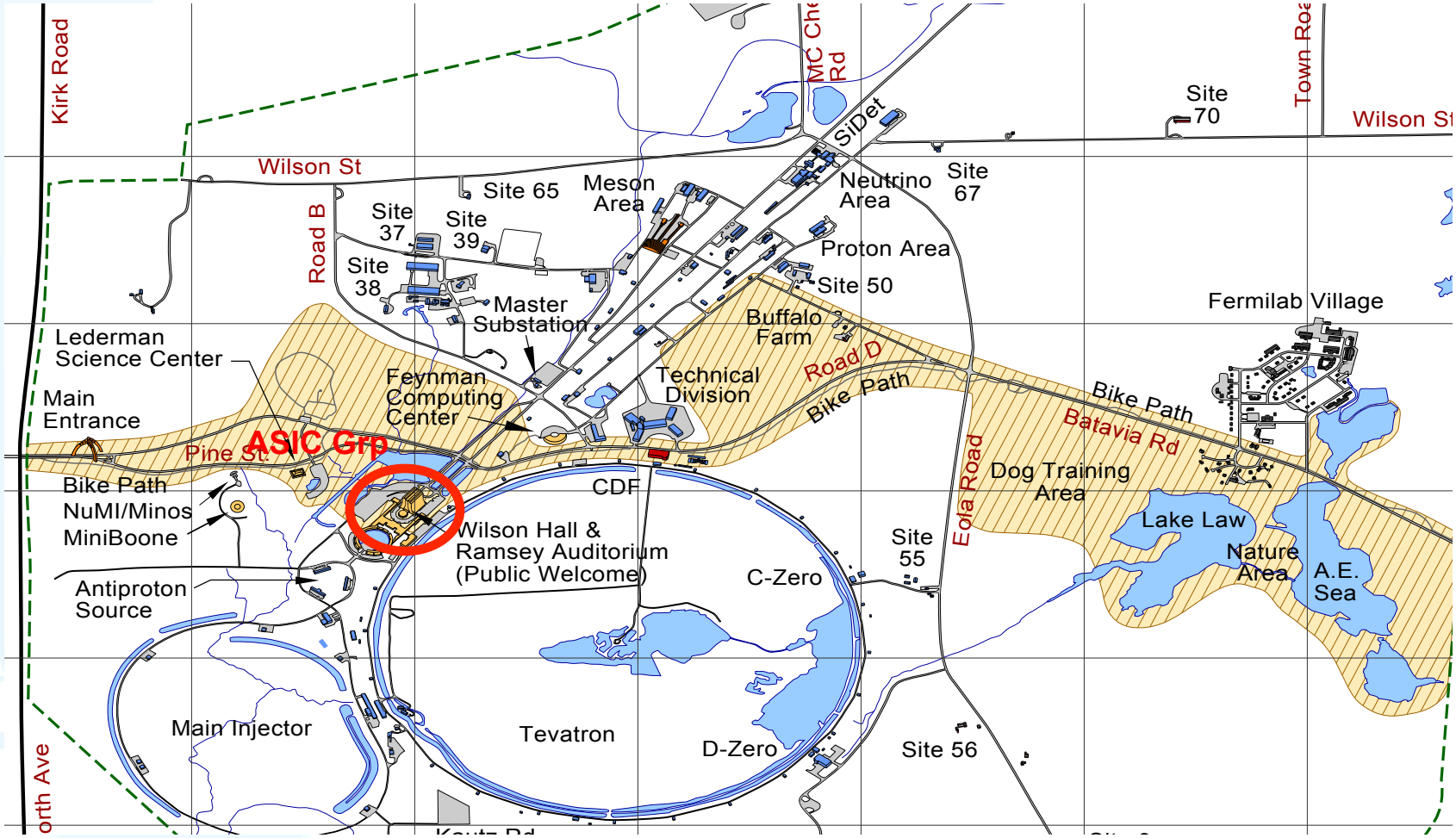
**The most valuable part of the facility is the SiDet Team, composed of physicists, technicians and engineers with expertise in:**

- **Metrology :**
  - **Optical and mechanical CMMs programing and operation**
- **Silicon detector assembly:**
  - **Precision mounting, gluing processes, alignment**
- **CCD detector assembly:**
  - **Fabrication of large format detectors with very tight specifications on flatness to be used for astronomical projects**
- **Microbonding:**
  - **Programming and operation of automated microbonders**
  - **Operation of manual bonders**
  - **QA of bonded parts**
- **Detector operation:**
  - **Cryogenics**
  - **Vacuum**
  - **Control and monitoring systems (labview support)**



Recently completed CMS FPIX repair

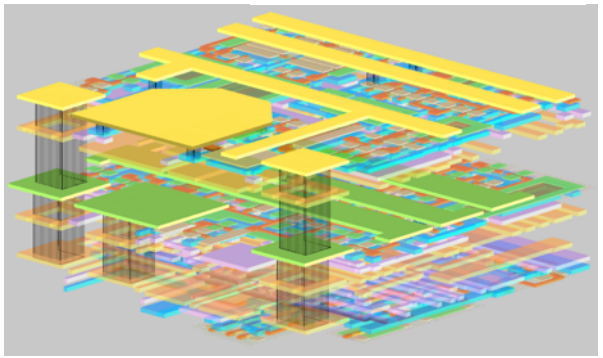
# Location of Detector Support Facilities



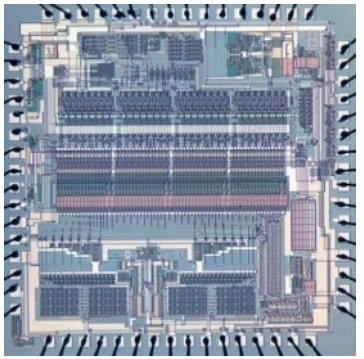
# EE Dept. ASIC/Microelectronics Group

- Design custom integrated circuits
  - For imaging, tracking systems, analog front-ends, mixed signal designs, data acquisition and trigger systems
  - Radiation tolerant design
  - Cold electronics
  - Compact, light weight vertically integrated devices (3D) designs
- Targeting HEP applications
  - Calorimetry, silicon strips, pixels
  - New sensors such as pixelated photon detectors
- Staff
  - 6 ASIC engineers, 1 engineering physicist and 2 techs

VIP-I,II, IIb
3D R&D



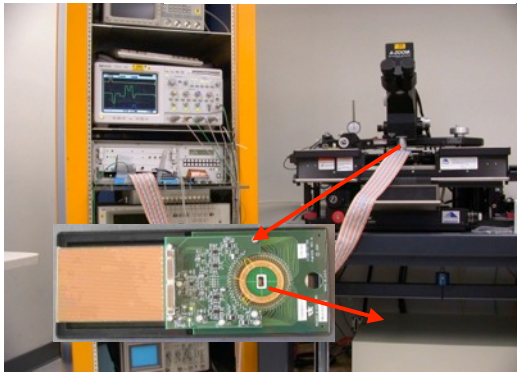
QIE (ADC) for CMS



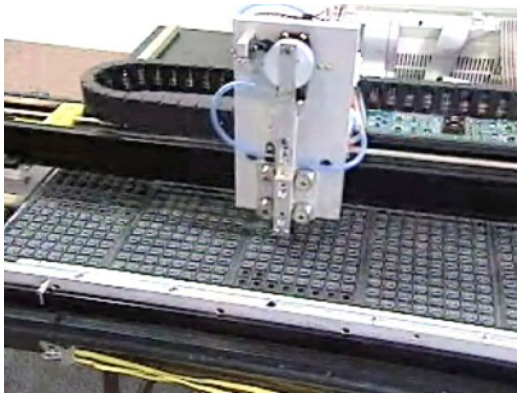
# EE Dept. ASIC Group Activities / Facilities

- Provide
  - Wire bonding
  - Robotic tester for components
  - Clean room
  - Cold vacuum chamber
  - Wafer probing
- Design and Test
  - Printed circuit boards
  - Field programmable gate array (FPGA)
  - Systems for test stands and test beam
  - focuses on ASICs, front-end, mixed signal, electronics infrastructure

**Wafer Probing**



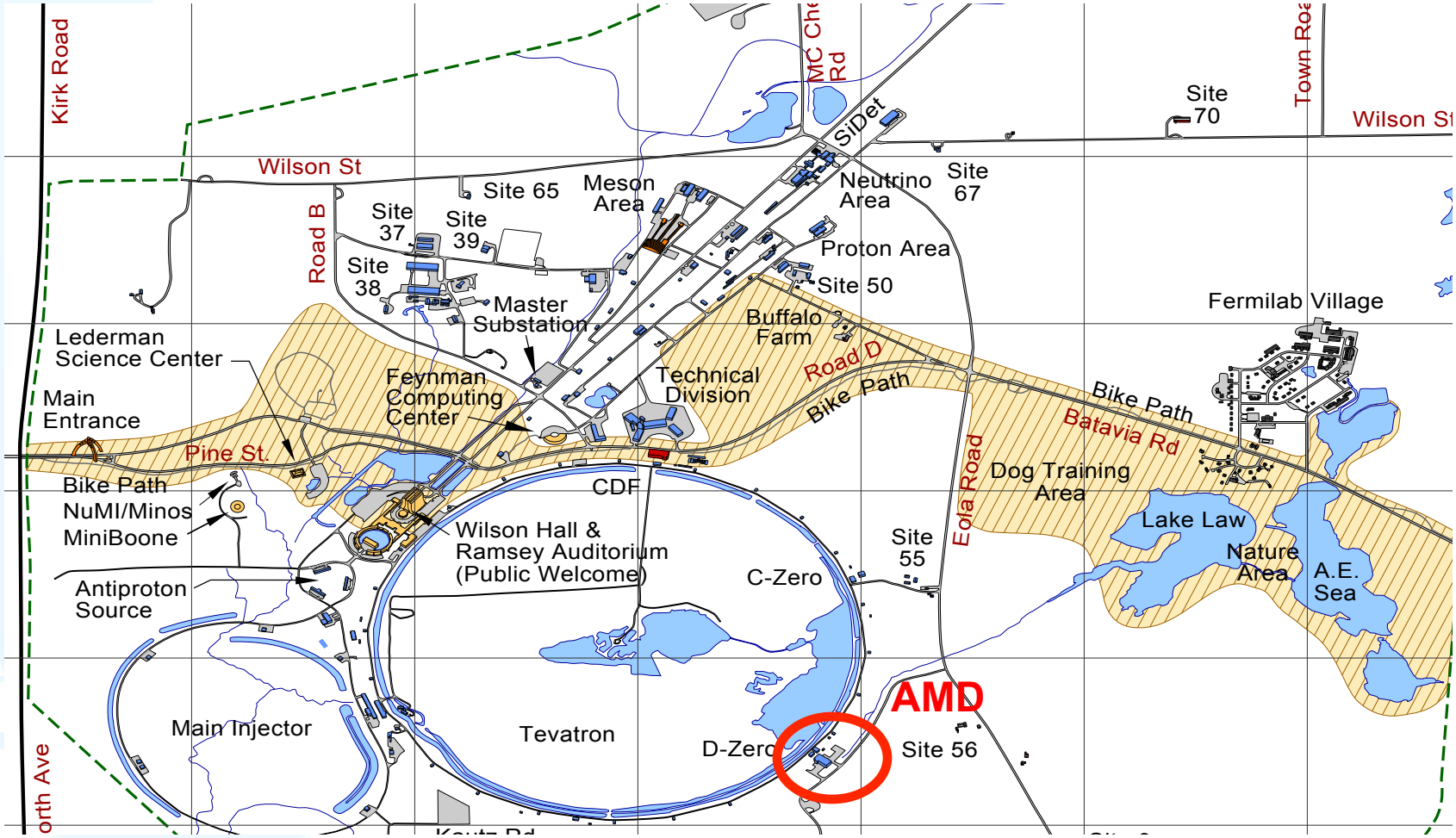
**Robotic Tester**

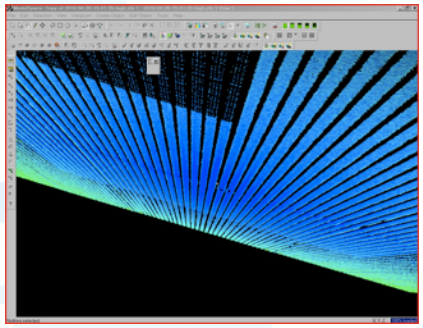


# EE Dept. ASIC Group R&D Effort

- Collaborating world wide with HEP institutions on multi-project submission and providing integration of designs
  - Partnership with Argonne to design readout chips for calorimetry and R&D
  - Collaborating with CERN and others on next generation Pixel readout for LHC experiments
  - Cold electronics in partnership with BNL
  - Collaborating with BNL and ANL on photon science applications
- Detector R&D
  - CMS upgrades
    - Track finding, triggering, charge integration/ADC
  - Cold electronics testing for LAr tolerant devices
  - Developed 3D ASICs technology for future experiments

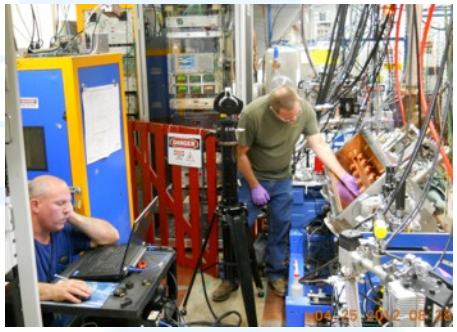
# Location of Detector Support Facilities





# Alignment and Metrology Dept

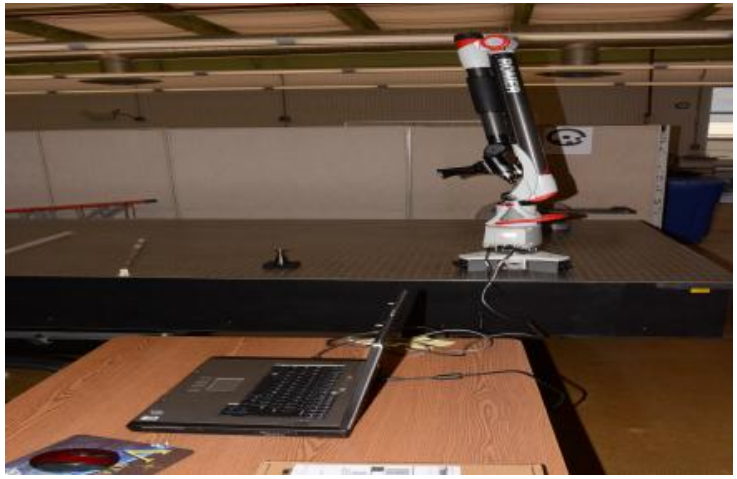
- The Fermilab Alignment & Metrology Dept. supports all experiments, accelerators, beamlines, and civil construction activities.
- Recently relocated to former D0 office bldg due to village facilities being destroyed by flooding.
- Uses the most modern tools and techniques available, which include laser scanners, laser trackers, photogrammetry, and CMMs.
- Specialized Staff – 4 geodesists, 6 metrologists

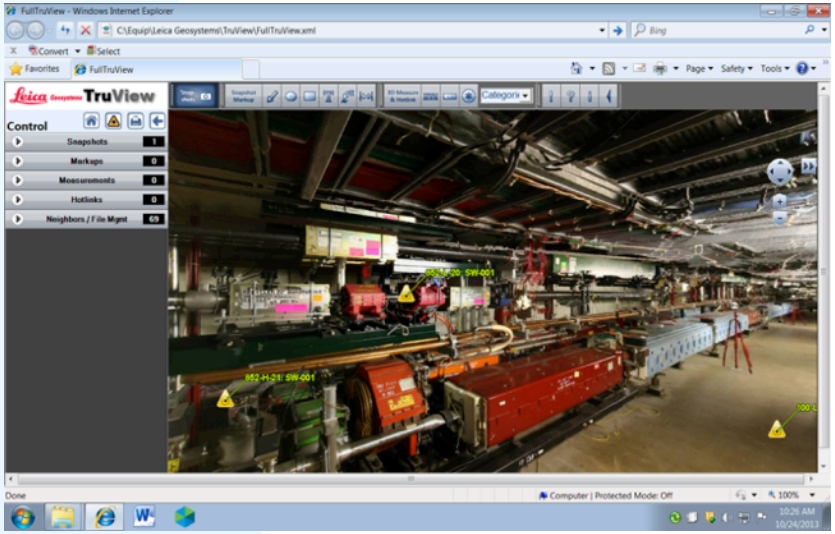


# Alignment and Metrology Dept cont'd

## Portable Measurement Arm

Used for precision measurements on large devices in the field



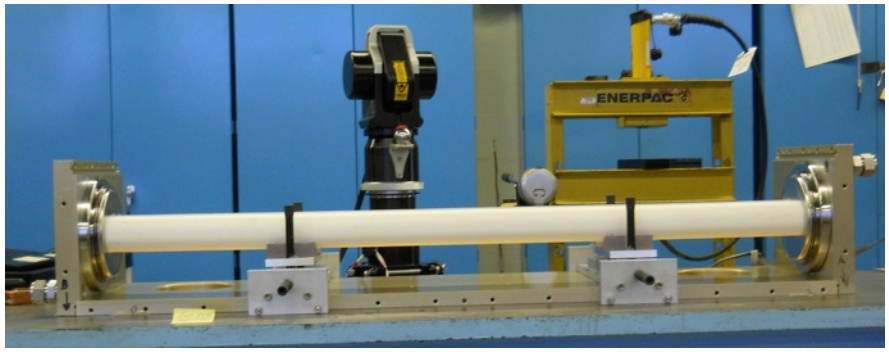



## Laser Scanner

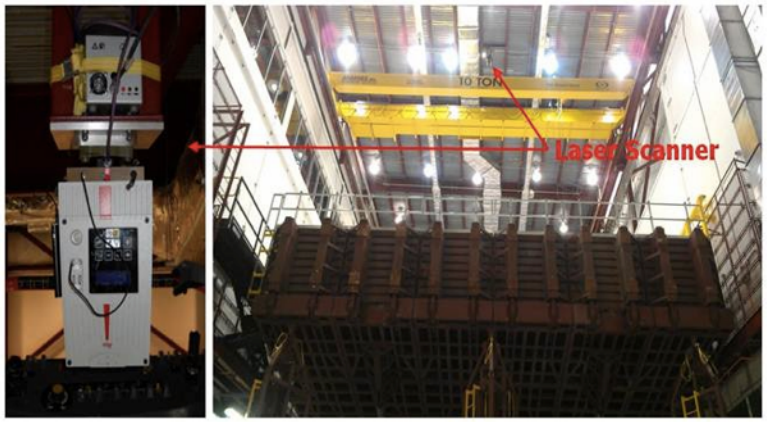
Used to accurately measure Nova detectors. Left: Figure shows photo overlaid on 3D measurements made in Main Injector.

## Laser Tracking Interferometer

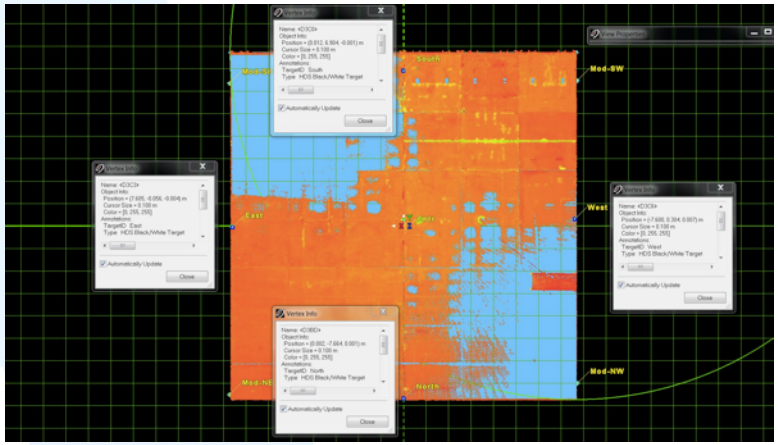
Used to measure most beamline devices and detectors at Fermilab. Right: measurement of ceramic kicker tubes.



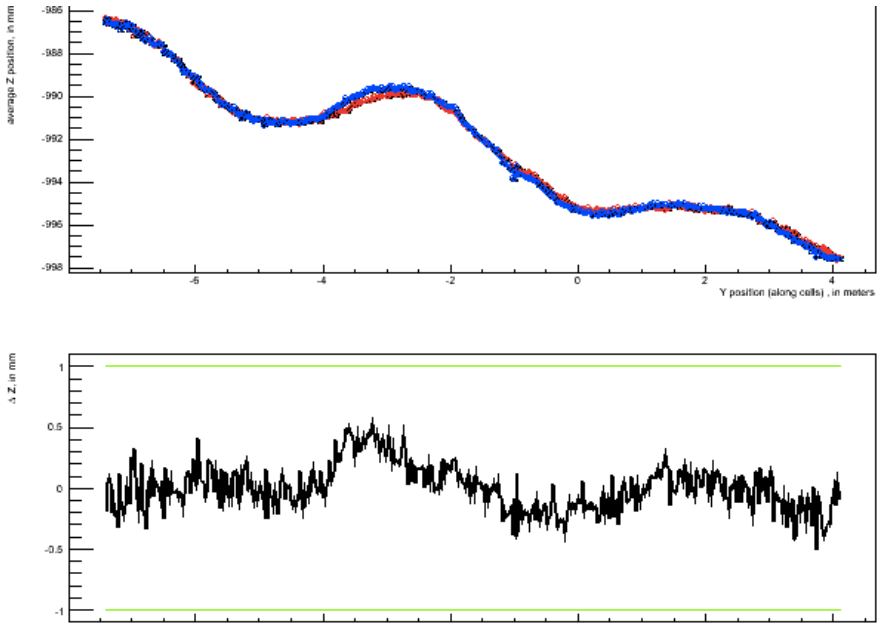
# Alignment and Metrology: NOVA FD




Laser scanner mounted on ceiling at Ash River

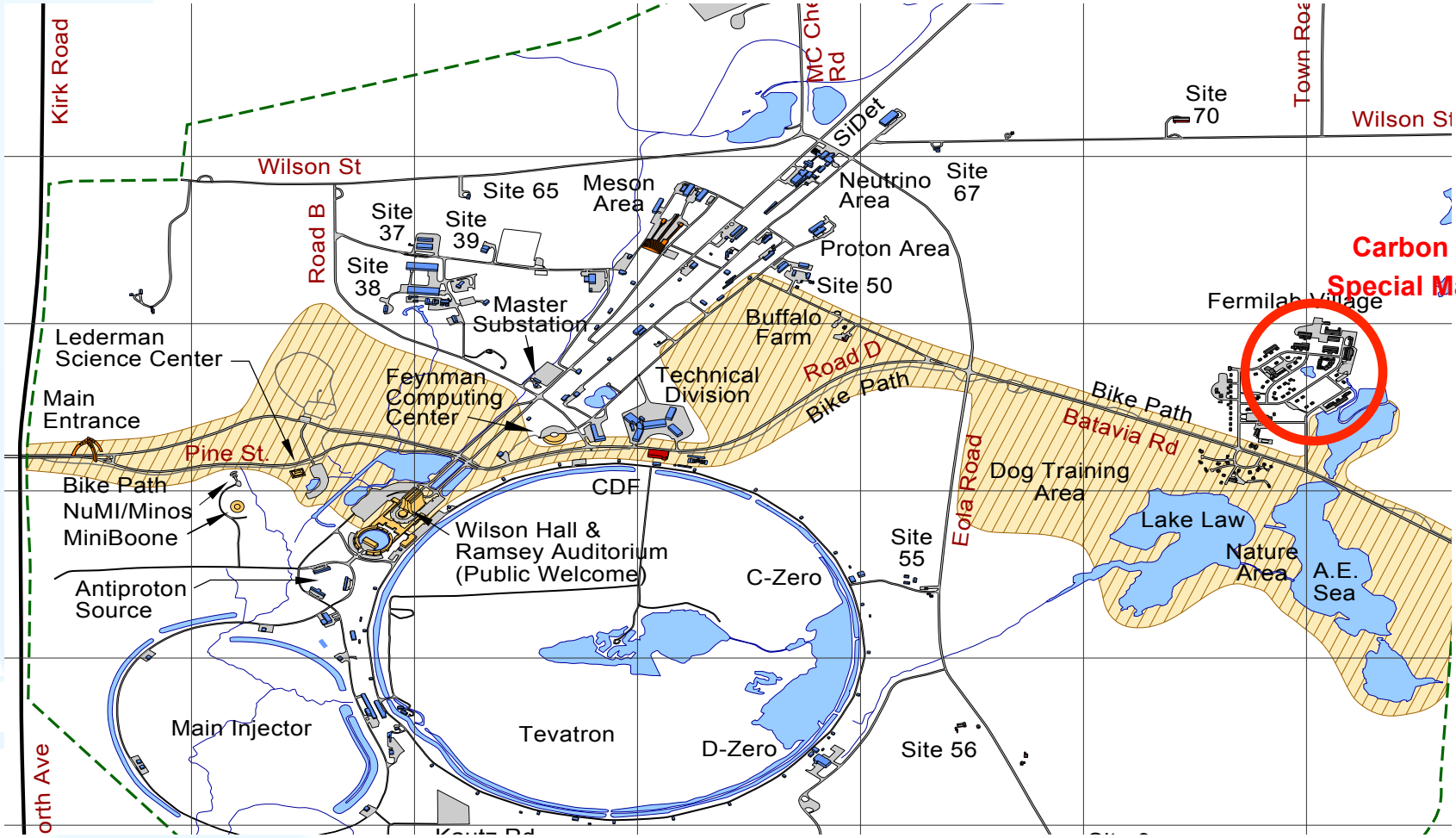


Flatness measurement of NOVA block pivoter




Absolute & relative height of layer 17 between 2 modules

# Location of Detector Support Facilities





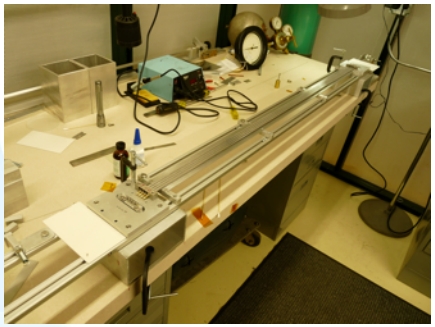



Fermilab

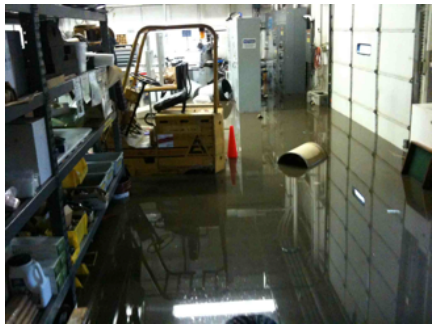
# Rapid Prototyping and Special Materials Grp

- Located in the Village Lab 3 and Lab 8
- Two multipurpose clean rooms
  - Originally developed for D0 fiber tracker
  - Roughly 3000 sq ft for both
  - Current experiment uses – g-2 and mu2e (straw tracker), SuperCDMS
  - Also used for Proton CT prototype fabrication for NIU
  - Contains largest volume CMM on site; used for DECam and likely u
  - Had to be refurbished from flood waters in FY13
- Recent upgrades for dark matter detectors
  - Class 100 & 10 inner clean rooms - used for COUPP bubble chamber assembly
  - Low radioactivity water supply
- Carbon fiber facility
  - Used for CMS Pixels, Jlab SVT

Class 10 & 100 cleanrooms for dark matter at Lab 3



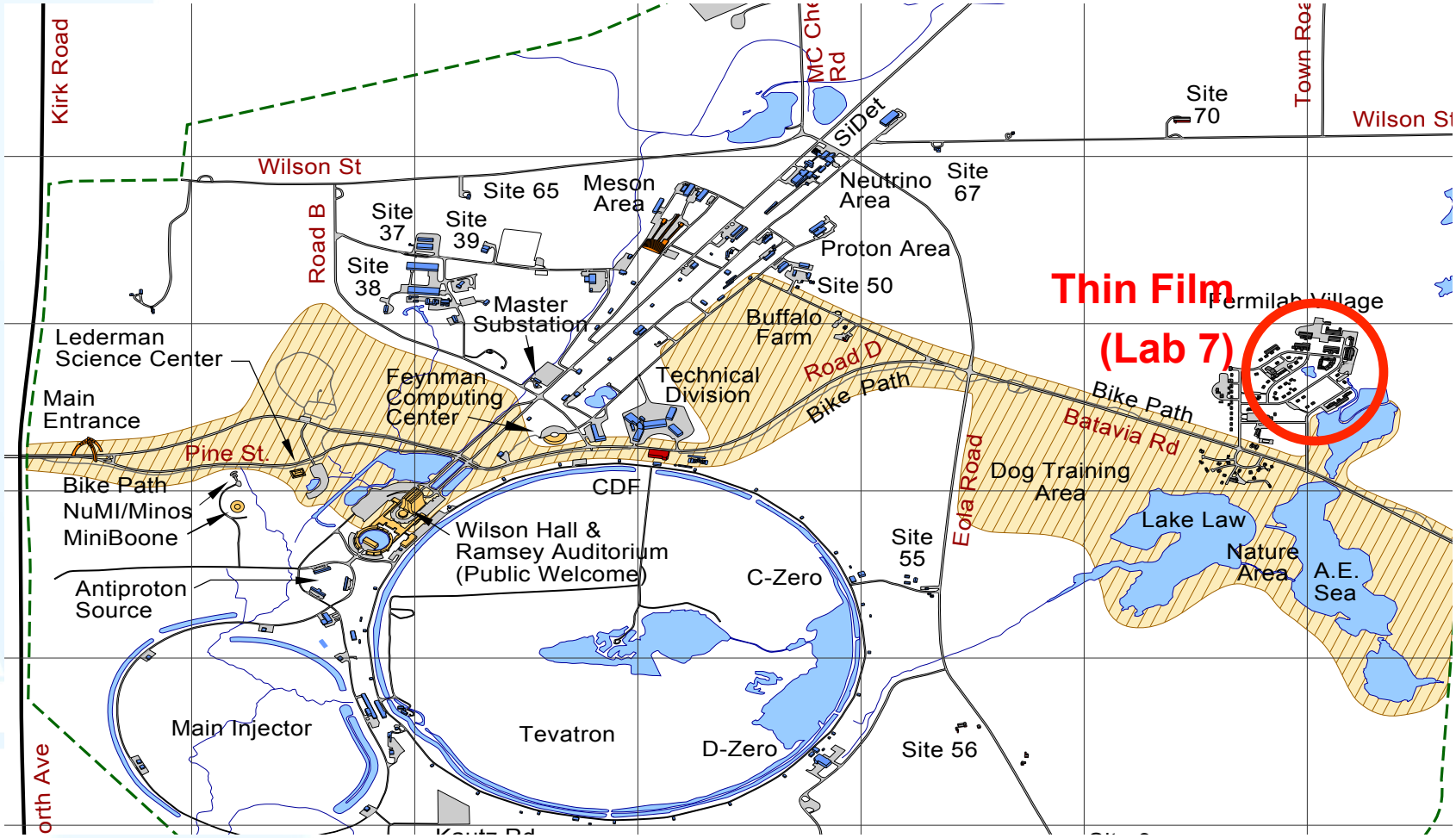
Straw tube development for Mu2e



# Rapid Prototyping and Special Materials Grp, cont'd

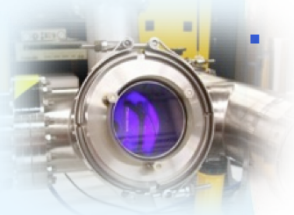
- Lab 8 houses large, specialized machines adapted for large jobs with special materials:
  - Low mass such as carbon fiber & rohacell. Also scintillator, other plastics & polymers
  - Recent or current projects: CMS muon panels, Jlab SVT, pCT
  - Machines are quite old: no longer supported and difficult to find parts. Looking into alternatives for long term future.
- Staff – Carbon fiber expert, electro-mech-computer interface expert, designer & machine programmer, machine operators
- Near term planned Improvements
  - Autoclave for carbon fiber curing – Lab 3
  - New HVAC

# Location of Detector Support Facilities



# Thin Film Facility

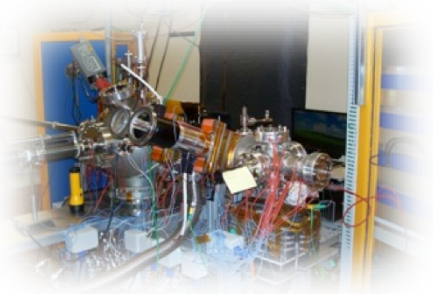
- **Major activities**
  - Evaporated and sputtered coatings
  - Optical fiber and plastic connector polishing
  - Heat treatment in vacuum of metals
  - Fiber splicing



- **Equipment**
  - 9 coating systems
  - 2 specialized diamond polishing machines
  - 4 plastic splicing machines

- **Staff**
  - 1 Coatings expert
  - 3 Fiber & vacuum techs

- **Location**
  - Lab 7 in Village

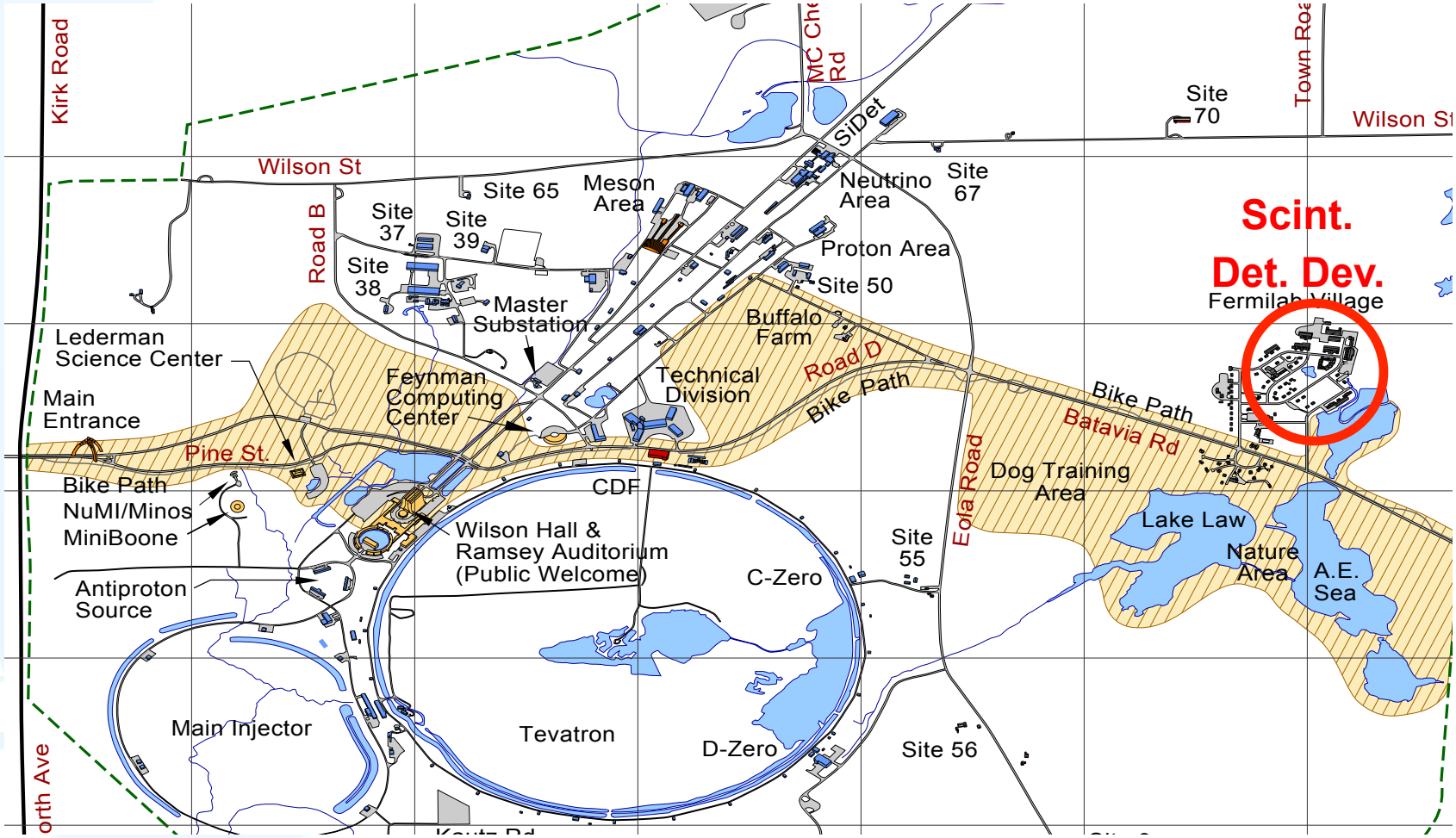


- **Recent and Current Projects**
  - LAPPD (Large-Area Pico-second Photo Detector) R&D in collaboration with Univ. of Chicago, ANL, and Berkley's SSL in "electroding" of MCPs.
  - Proton Computed Tomography with NIU in polishing and mirroring of optical fibers and polishing of connectors.
  - CMS HCal upgrades i.e. TATA mega tile cable connector polish
  - ADRIANO-ORKA R&D fiber polish & mirroring & PtIr sputtered coatings.
  - AD beam diagnostics & Optical SWIC
  - SRF test facility (NML) cathode UHV coating of Cs2Te on Molybdenum substrates.

# Thin Film Facility-Future Vision

- **Mission**
  - Continue to provide various coatings for R&D of detectors and SRF research
- **Planned Near Term Upgrades**
  - Invest in new cleaning equipment-multiple station cleaning system
  - Dry leak checker
  - New RGA equipment to match current software
  - Purchase Effusion cell evaporation units for more precise organic material control
- **Future Vision**
  - New e-beam coating system to accommodate requests for high evaporation temp metal carbides, ceramics, transparent conductive coatings, etc

# Location of Detector Support Facilities








Fermilab

# SDD – LAB 6

- **SCINTILLATION DETECTOR DEVELOPMENT (SDD) GROUP:**
- Facilities:
  - Lab 6 – Wire Chamber Winding Facility, SDD Chemistry and Analytical Laboratories
  - Lab 5 – SDD Scintillator Extrusion Facility

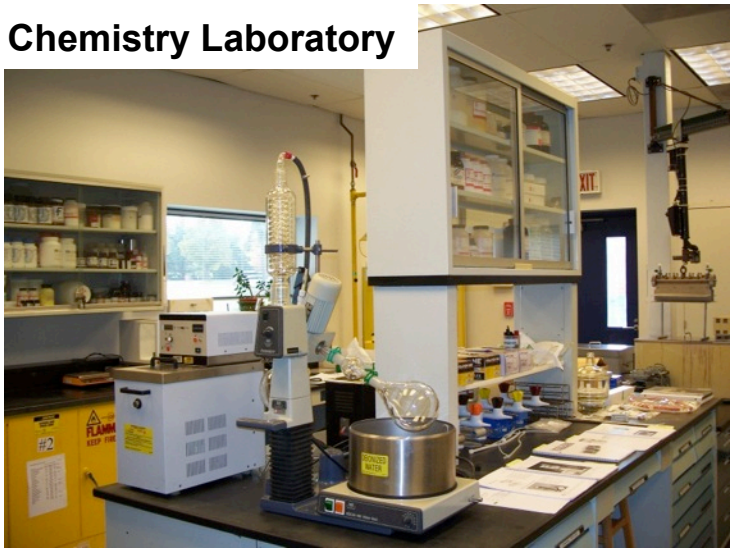
- WIRE CHAMBER WINDING FACILITY:
  - 1 expert winding technician
  - Three winding machines of different frame sizes
- Activities:
  - R&D: make unique wire windings and chambers used in support of liquid argon and liquid xenon R&D.
  - Production: Beam profile & align. monitors
- Customers:
  - Univ. Iowa, Univ. Washington, Univ. Michigan, LBNE, MINERVA, NOVA, Seaquest, MicroBooNE

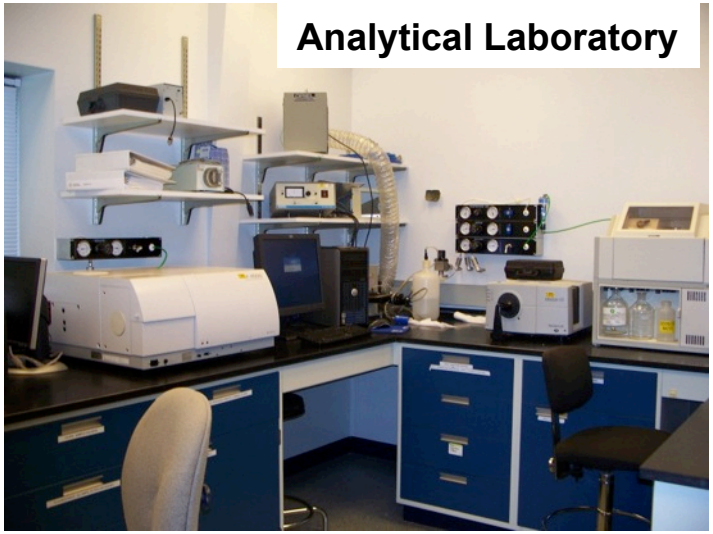
**Wire Chamber Winding Room**

# SDD – LAB 6

- CHEMISTRY AND ANALYTICAL LABS:
  - 1 expert technician – spectroscopic measurements, polymerizations, castings, distillations
  - Several rooms in Lab 6:  3 fume hoods, UV/is, reflectivity and fluorescence spectrophotometers, gas chromatograph with mass selective detector (GC/MS)
- Activities:
  - R&D:  Styrene polymerizations with dopants for neutron sensitive scintillators; scintillator 3D printing
  - Support/Production:  QC for raw materials (extruded scintillator), QA for experiments
- Customers:
  - MINOS, MINERVA, NOVA, MiniBooNE, MicroBooNE, SuperCDMS, COUPP

**Chemistry Laboratory**





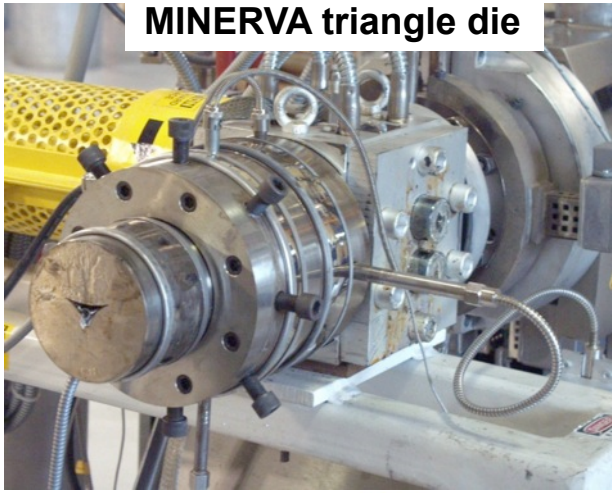
**Analytical Laboratory**

# SDD – LAB 5

- SCINTILLATOR EXTRUSION FACILITY:
  - 2 technicians
  - Extruder purchased by NICADD in 2003
  - Co-extruder purchased by FNAL in 2005
- **Unique capability → Extruded Scintillator**:
  - Extrude scintillator with hole for WLS fiber
  - Co-extrusion of white reflective coating
  - Used at R&D level to test different shapes
  - Used at production level to build scintillator for detectors
  - Expertise was vital for NOVA QA planning
- R&D Activities:
  - Test different materials to improve coating reflectivity
  - Change co-extrusion process to improve light yield
  - Extrude scintillator directly around WLS fiber
- Customers:
  - TRIUMF, CERN, MINERVA, PNNL, Sandia Labs, Jlab, Pierre Auger, Mu2e, LBNE, T2K, Double CHOOZ
  - KEK, INFN (Italy: Gran Sasso, Brescia, Catania). Recent procedural problems collaborating outside US National Labs. Situation improving with new head of Tech. Transfer office.

**Scintillator Extrusion Facility**

**MINERVA triangle die**



# Detector Operations Support

- Fermilab has redirected its collider detector operations support expertise towards intensity frontier experiments.
- Experiment Liaison Officers (ELO)
  - Act as an interface between experiments and lab resources; especially the experts who have built the detectors.
- Facility coordinators, e.g. MINOS underground
- We expect operations support staff to increase as more experiments come on line.

# Detector Development & Experiment Support Moving Forward

- The challenge remains: How do we keep these facilities at a world class level and aligned with Fermilab's mission in the current funding environment?
  - Reorganize the engineering/technical side of the Division emphasizing the Intensity Frontier while still supporting and developing Cosmic and Energy frontier detectors - 2012
  - Assess each facility, reuse viable equipment, then decommission aging and unusable equipment and detectors used for the Tevatron colliders and recover space for future initiatives - Ongoing
  - Upgrade, replace, or purchase new equipment to accommodate upcoming projects or detector R&D initiatives as funding allows - Ongoing

# Detector Development & Experiment Support Moving Forward, cont'd

- Maintain existing expertise while developing new detector expertise – Ongoing
  - Take on "gap" projects from other institutions in order to keep skills honed and serve wider community
  - Attract & train early career sci/tech staff & students as resources allow.
  - Cross train existing staff in key technologies.

# Summary and Conclusion

- Fermilab has a world class detector development and support program.
- We develop, build, and support most types of particle detectors used in HEP and beamline applications.
- In recent years, we have heavily increased our detector R&D support for the intensity frontier but also maintaining world leading cosmic and energy frontier expertise and technology
- We are also increasing our efforts to transfer Fermilab technology & expertise to other institutions and the private sector.

# Glossary

- **VIP I & II**: Vertical Integrated Pixel chip
- **QIE**: Charge Integrating Encoder
- **SiPM:** Silicon Photomultiplier
- **MKID:** Microwave Kinetic Inductance Detector
- **DESI:** Next generation dark energy experiment. Formerly named Big Boss
- **Skipper CCD**: Super low noise Charged Coupled Device.
- **TPC**: Time Projection Chamber
- **NICADD**: Northern Illinois Center for Accelerator and Detector Development
- **COUPP:** Chicagoland Observatory for Underground Particle Physics
- **RGA**: Residual Gas Analyzer
- **SWIC**: Segmented Wire Ion Chamber
- **Jlab SVT:** Jefferson Lab Silicon Vertex Tracker. Part of the CLAS12 upgrade
- **CMM:** Component Measuring Machine
- **pCT**: proton Computed Tomography