# ADVANCING DETECTOR TECHNOLOGY OVER THE NEXT DECADE

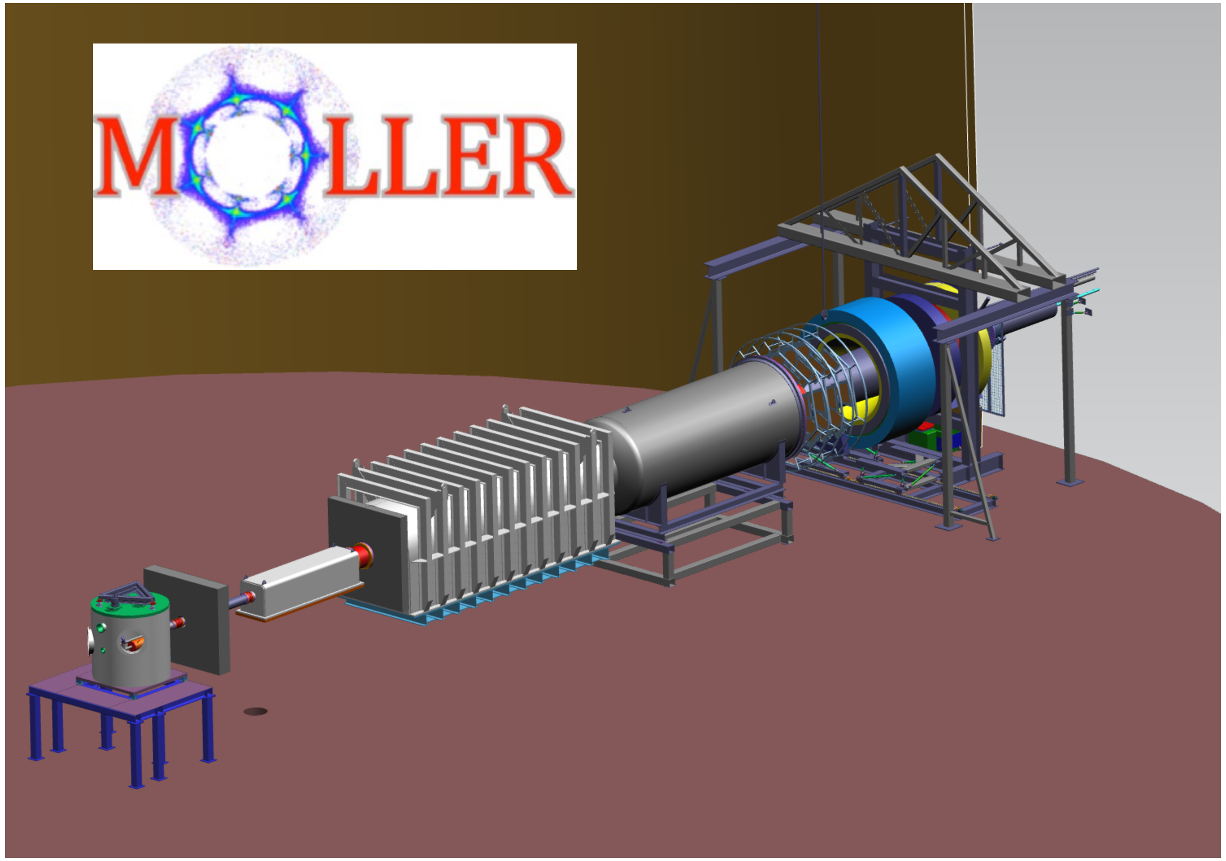
U.S. funding for Detector R&D

R&D Collaborations

University, Lab and Industry Collaboration

Unique Facilities and Capabilities

Workforce Development

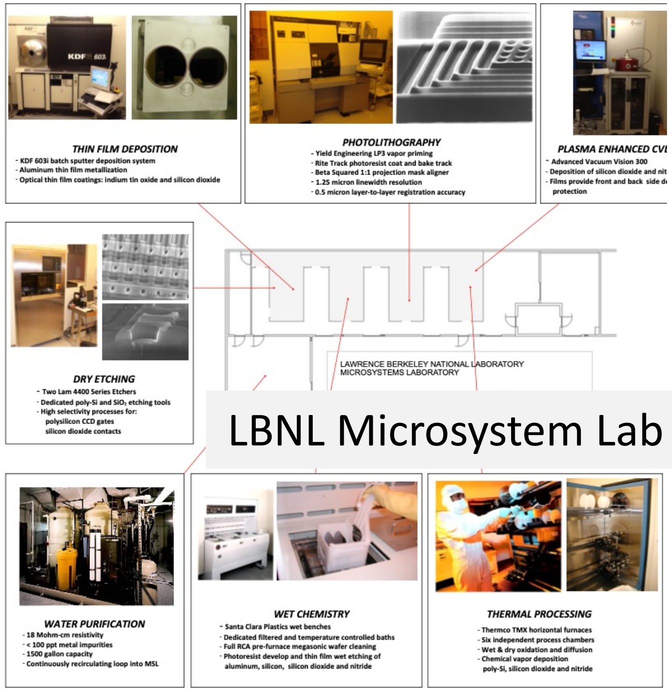



Jim Fast

# U.S. Funding for Detector R&D – institution/PI rather than collaboration focus

- U.S. DOE HEP funds generic detector R&D through the *Advanced Technology R&D* (KA-25) program which funds Accelerator and Detector R&D programs
  - A significant fraction of that funding goes to support national laboratory capabilities, particularly FNAL
    - Test beam (FNAL FTBF, SLAC ESTB*)
    - ASIC design software (FNAL**)
    - SiDet and Noble Liquid Test Facility (FNAL)
    - Microsystems Lab (LBNL)
  - **No analogue in DOE Nuclear Physics at this time**
  - NSF funding through PI grants
- Project-specific R&D funding through "pre-project" programs and early phase of construction projects within DOE
  - This is where more significant funding may be available
  - **Primary funding mechanism in NP**
  - NSF Mid-Scale projects

Fermilab Test Beam Facility


LBNL Microsystem Lab

*SLAC ESTB will not operate again until the LCLS-II upgrade is completed
**Charged 100% to indirects at all labs except FNAL where it is 40% indirects

# Importance of Blue Skies R&D

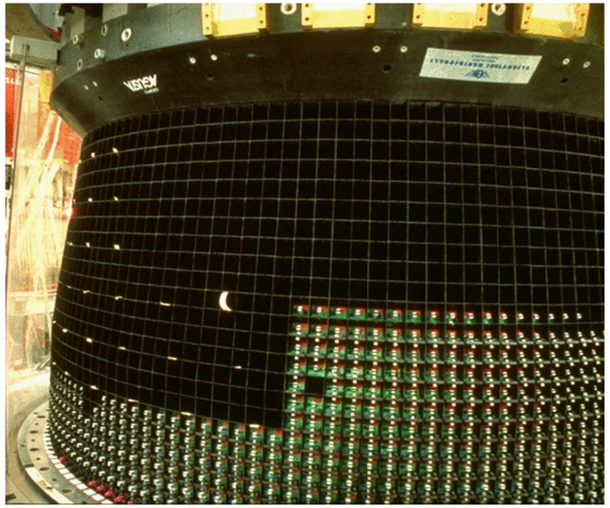
"Blue-sky" developments in particle physics have often been of broader application and had immense societal benefit.

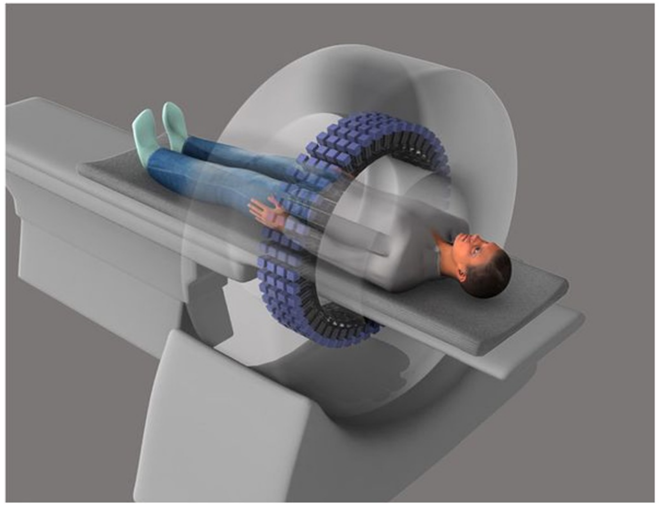
Examples include:

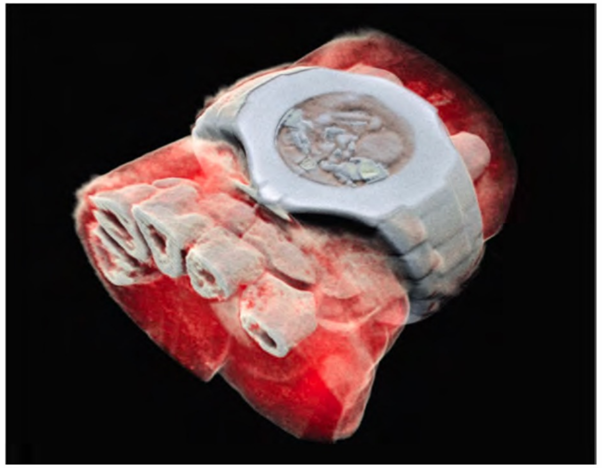
- Development of the World Wide Web
- Magnetic Resonance Imaging, Positron Emission Tomography
- X-ray imaging for photon science.

**It is essential that adequate resources be provided to support more speculative "Blue-Sky" R&D**

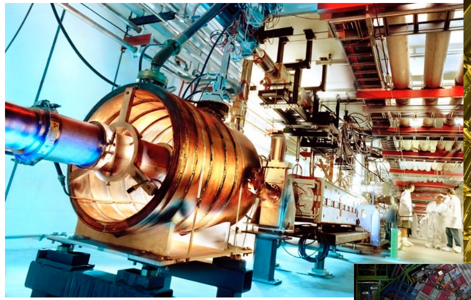
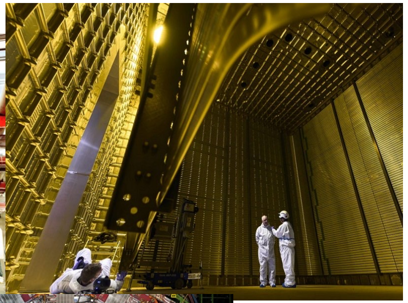
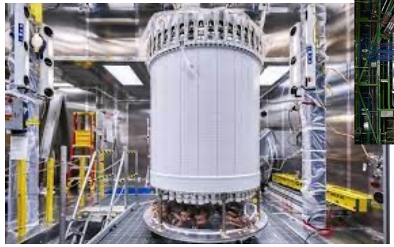
- This includes supporting the careers of junior scientists pursuing high risk, high reward ideas





# Detector Development takes a village – Collaborations, Partnerships and Stewards

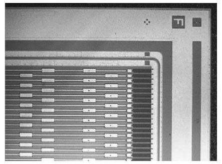

Research Collaborations

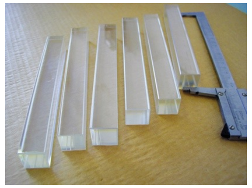
Advanced Detector Development

Facility Stewards

Industry Partnerships



# Collaborations are essential to leadership in advanced detector technology

- University-Lab Collaboration
  - Universities are the incubators for development of ideas and talent
    - Pipeline for new talent in the field
    - Interdisciplinary research can naturally occur through collaboration with experts in other departments
  - Laboratories house unique capabilities, both facilities and expertise in staff
    - Multi-purpose labs provide access to expertise and facilities from other disciplines including materials science, chemistry, hot cells, HPC
- Laboratory role should focus on providing unique capabilities (facilities and personnel) that are not achievable within a typical university environment
  - Providing support to smaller institutions to enable them to fully participate in the field is a another role the laboratories could/should fulfill to maximize technology advancement
- Particle physics technology is often leading industry – new materials, complex sensors

- Collaborating with Industry
  - Industry provides the essential scale-up needed to turn R&D developments into products that can be incorporated into large particle physics experiments
  - SBIR/STTR programs provide funding opportunities to engage with industry
  - Laboratories have Technology Transfer programs/offices dedicated to transferring IP developments to industry
  - The main issue is that low volume or one-time purchases from particle physics do not match well to industrial investment

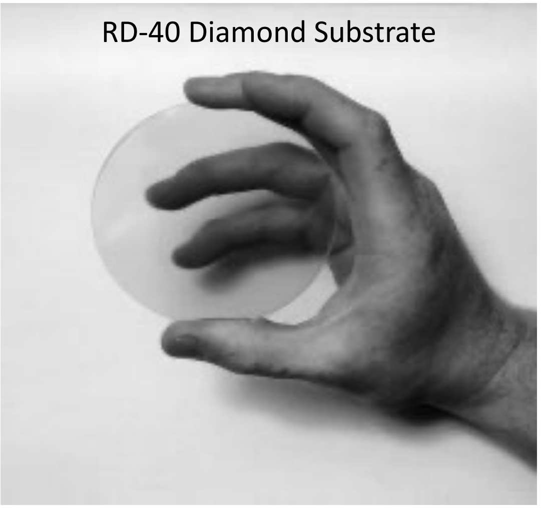
The LAPPD program was a foray into a well-funded, multi-year lab university and industry partnership to address a Grand Challenge in detector technology
- Funded over 2009-2016
- ANL, FNAL
- U. Chicago, U. Hawaii, UC Berkeley
- Arradiance, Incom

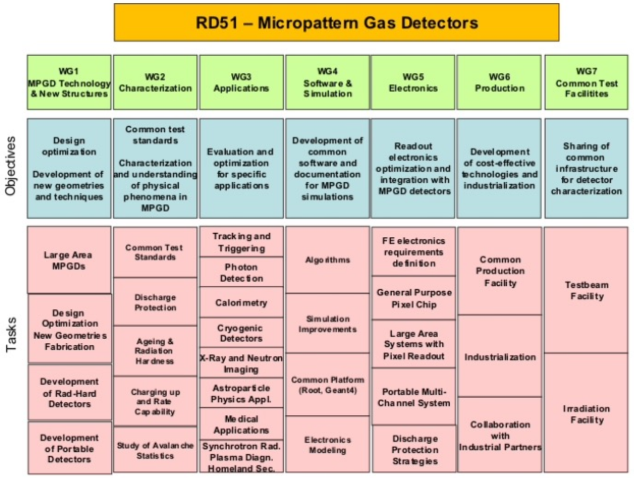
**Commercialized by Incom**

# New R&D frameworks could enhance U.S. leadership in detector technology

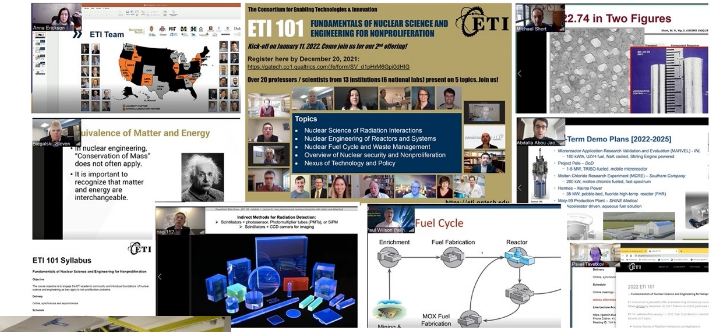
- CERN RD Collaboration Model
  - Topical collaborations around specific technology developments
  - Originated in 1990 with RD-1, now at RD-53
  - ECFA Detector Roadmap (2021)recommended creation of new ones in Calorimetry, Photo Sensors & PID, Liquid Detectors and Quantum Sensing. These RD Collaborations are proposed to be global in extent. **The US HEP community should engage broadly and early to help shape these new RD collaborations**

- NNSA Office of Defense Nuclear Nonproliferation (NA-20) Consortia
  - Topical collaborations around specific thrust areas in nonproliferation
  - Based out of Universities
  - Laboratories participate via existing funding streams from NA-22 and benefit from students and pipeline for career scientists in the field
  - **Strong focus on workforce development**


RD-40 Diamond Substrate





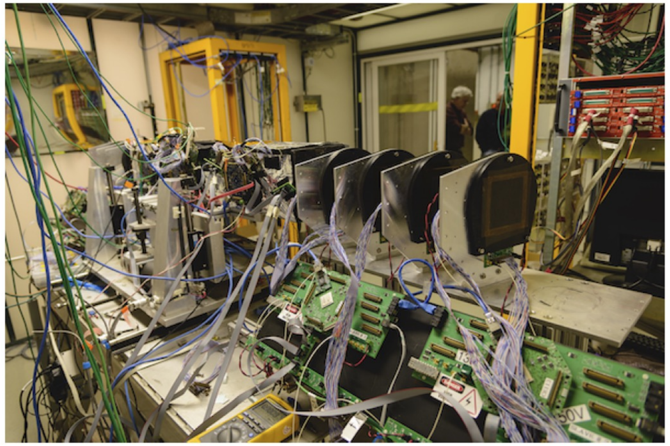


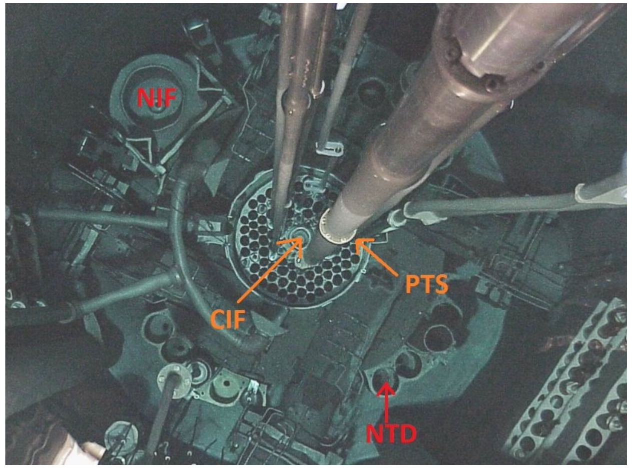



Jefferson Lab

# Facilities/Capabilities are a vital element of detector technology development

- Test Beams
  - Hadrons at FNAL, LANL, CERN, KEK
  - Electrons at SLAC, Mainz, JLab
- Calibration Facilities
  - Low energy beams, especially neutrons
- Irradiation Facilities
  - BNL, FNAL, PNNL, Sandia
- Dedicated detector development labs
  - SiDet and NLTF at FNAL
  - MSL at LBNL
- Ultra-low background materials and radioassay
  - PNNL, SURF, LBNL
- Ultra-low-background radiochemical analysis and mass-spectrometry
  - PNNL (ICPMS), ANL (AMS)
- Microelectronics, sensor and imager design
  - BNL, FNAL, LBNL, SLAC, Sandia
  - Penn, Northwestern, SMU, Stony Brook University, Washington University, UIC, UIUC, Purdue, UW, Columbia, Stanford etc.

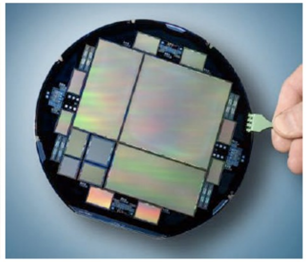





Lithography

Etching

Film Deposition



CCD Wafer

# Current and potential gaps in facilities for advanced detector development

- Foundry access for radiation hard microelectronics development/production
  - Access is getting more complex and costly for advanced (<45 nm) technology nodes
  - Access for superconducting device fabrication
  - HEP timelines are long and volumes are low compared to industry drivers (e.g. IOT, auto)
  - Similar issues facing defense sector, specifically nuclear deterrent (also rad hard needs)
- High-quality electron test beams (SLAC plans to restore after LCLS-II upgrade)
- High energy (TeV-scale) hadron beams
- Accessible low temperature facilities
  - mK test facilities (available in many PI labs, but no user facilities)
  - LAr test facilities (is NLTF at Fermilab adequate to meet community needs?)
- Low noise test facilities
  - Low seismic/vibration noise
  - Low RF/EMI noise
  - Low radioactive background
- Low level radioactivity calibration sources and techniques for cross-calibration
- High dose irradiation
  - NNSA high dose facilities exist (e.g. at Sandia) but are operating at capacity for their mission

# Advancing detector technology relies on a broad, highly skilled workforce

Many areas require expertise and multi-disciplinary work electronics, CS, DAQ, mechanical engineering, cryogenic systems, composites design and fabrication, microfabrication and assembly, analytic chemistry, radiochemistry, materials science, ...

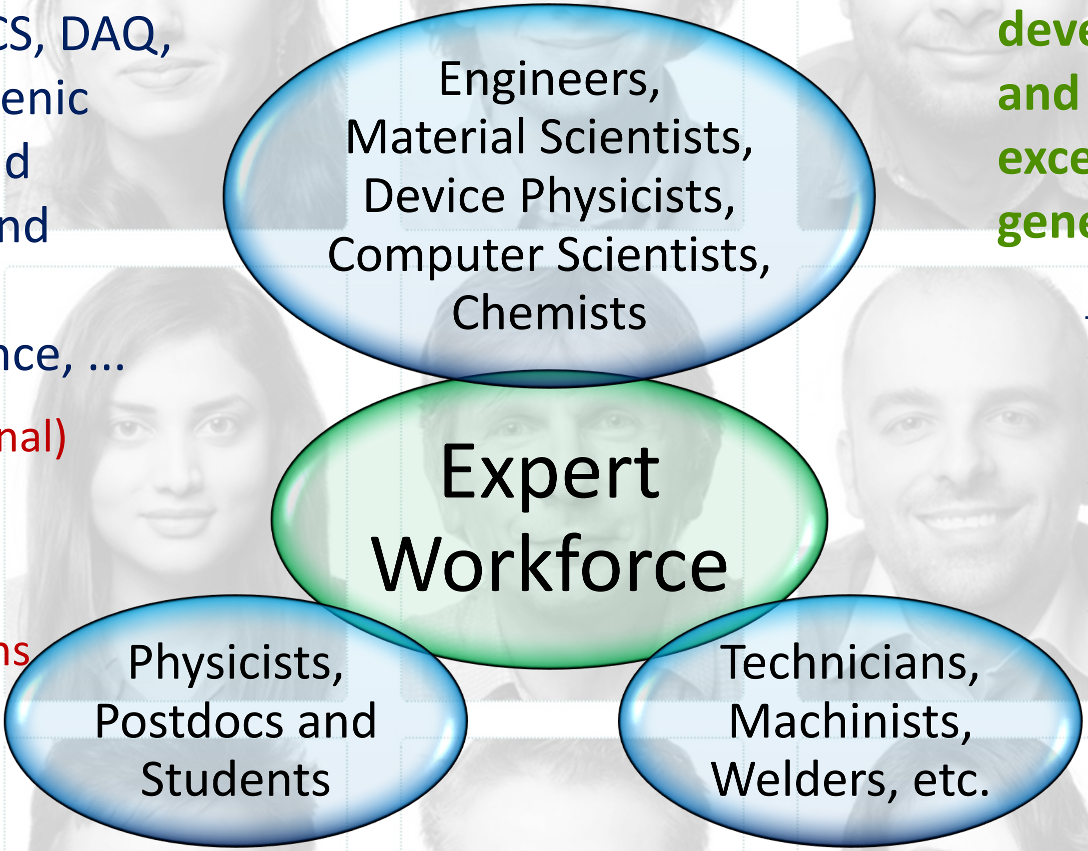
Diverse pipeline (in US, international)

University/lab partnerships

Connections to other disciplines

Supporting alternative career paths including multi-disciplinary

**Appropriate recognition across all of the workforce**




**To succeed in advanced detector development in the next decade and beyond, we need to succeed in excellence in the current and next generation of people**

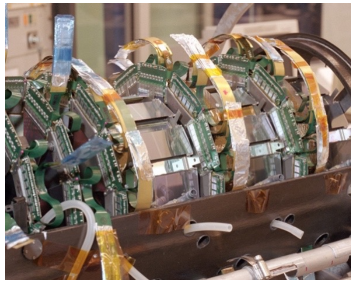
**Fostering careers in instrumentation**

- Historically challenging career path for particle physicists in the U.S.
- CPAD has spearheaded some changes in recent years
- Physics faculty jobs focused on instrumentation are uncommon
- Several Nuclear Engineering departments have strong support for instrumentation experts

***These experts, in turn, educate the next generation in advanced HEP instrumentation techniques and development transforming not only HEP but other fields too.***

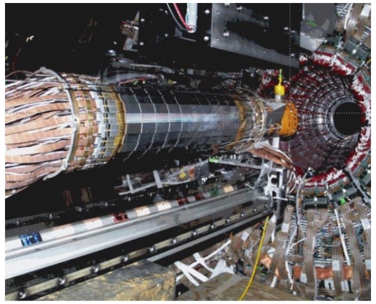
# Pursuing a career in instrumentation – my personal experience

Engineering Physicist II at FNAL
D0 silicon assembly/install;
SiDet engineering group lead;
BTeV pixels, DECam design
2000-2005

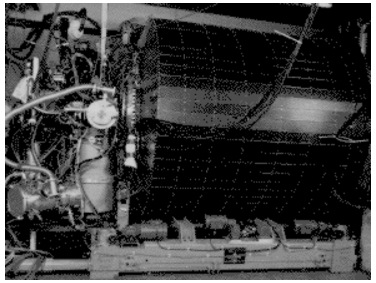


~1995 ***"You're committing career suicide"***
J. Cherwinka

Research Associate
with Purdue University
on CLEO II/II.V/III
Designed/built Silicon
1992-2000



PhD from UC Irvine
on FNAL E-760
Built Pb-glass ECAL
1987-1992

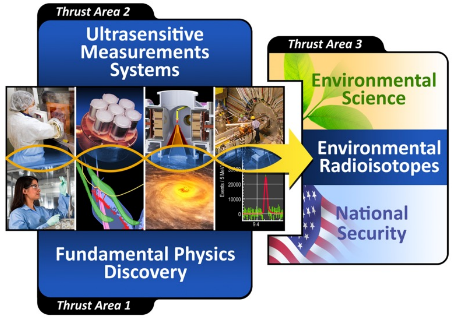


Stalled career in HEP
Changed direction

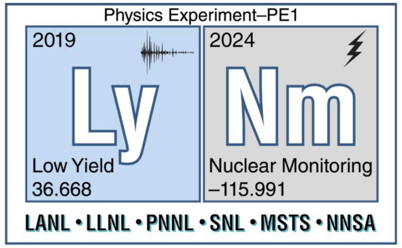
Soft Money Positions

Hard Money Positions

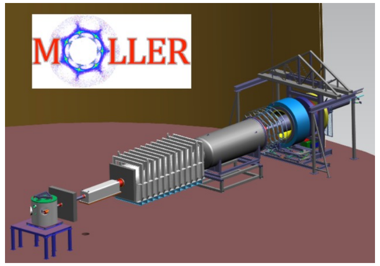
Scientist 4 at PNNL hired
primarily for National
Security detector R&D
2005-2008




Scientist 5 at PNNL
Lead for $15M+ LDRD
program; NNSA work
Belle II PM
2008-2019




PNNL Laboratory Fellow
Ongoing NNSA work;
**HEP Program Manager**
2019-2020




JLab – MOLLER MIE
Project Manager
2020-2022

# Workforce diversity, equity and inclusion

- Particle Physics, HEP in particular, has a poor track record for DEI relative to it’s peers

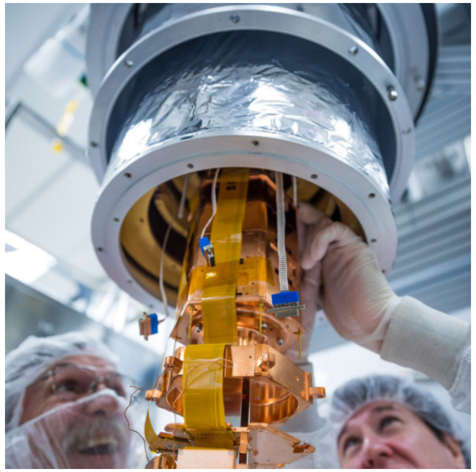
- Instrumentation development programs in the NP, BES, BER, NNSA, DHS, DOD, NASA all have broader workforce diversity than HEP

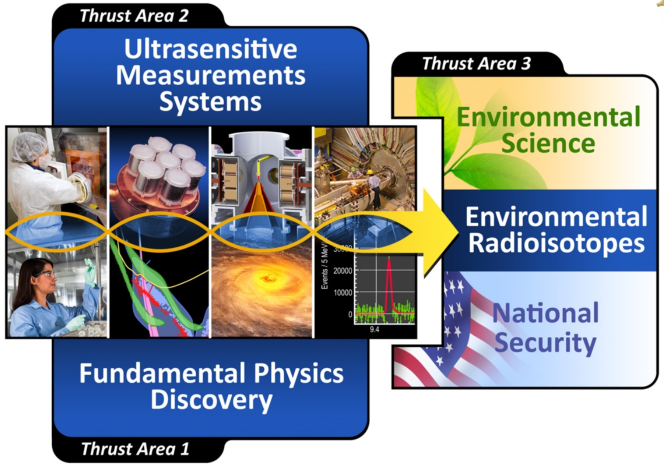
HEP would benefit from exposure to the improved gender and racial diversity of other disciplines.
The broader field of instrumentation would benefit from cross-pollination with a larger pool of talent.

# Instrumentation Development Ecosystem

Keys to the success of this enterprise are **people**, **facilities and resources**, and **connections and collaborations**

- Advanced workforce
- Unique capabilities and facilities
- Connections to other programs, other offices, other agencies, private foundations, commercial partners, global collaborations



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MIT LINCOLN LABORATORY
SenseICs