Detector R&D Program

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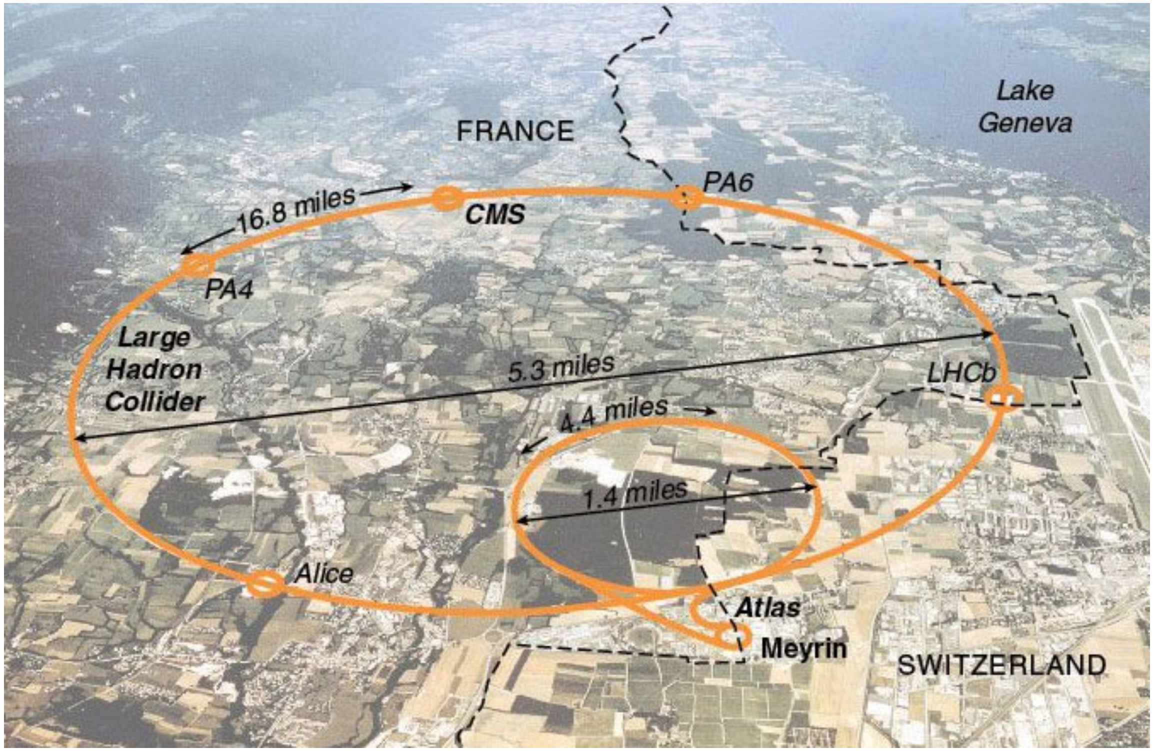
Outline

- Two Thresholds
  - The Threshold of Promise
  - The Threshold of Challenge
- Strategy
- Current Projects
- Thoughts for the Future

Threshold of Promise: LHC

- The LHC has brought us to the threshold of discovery for new physics, and we expect to cross it, …… momentarily ?
- Will deliver ………… what it will deliver remains to be seen



- We're at the dawn of a new era where, no matter what, new frontiers will be explored !

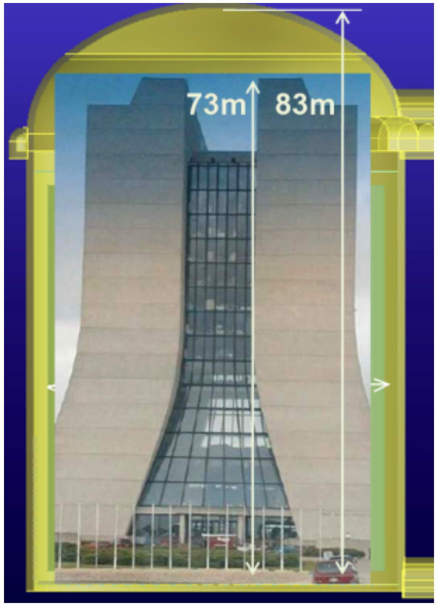
Threshold of Challenge: Beyond the LHC

- However promising the LHC, the field needs to plan beyond the LHC
- The next generation of detectors at all three frontiers – intensity, energy, cosmic – are extremely challenging

- Challenges:
  - Precision physics
  - Cost
  - Complexity
  - Continuance
- Often, a scaling of existing technologies is difficult to justify

Next Generation Detectors

- The next generation of detectors, which will have to improve significantly on the then current measurements, are required to be precision instruments
  - Physics requires it
  - Configuration of future projects requires it
  - The field itself requires it

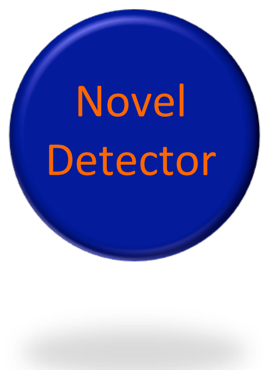


- Need to invest in new technologies; recognized by the division, the laboratory and the field
  - DPF Task Force on Instrumentation appointed
    Ian Shipsey, Marcel Demarteau, co-chairs

- **Strategies for new developments**
  - **Exploration of new detector technologies: "high risk – high gain"**
  - **Improvement of the performance of existing detectors**
  - **Innovation of existing technologies which can substantially reduce the cost and enhance the performance of detector systems**

Detector Development Strategy

- We believe that the seeds for the development of transformational detectors have been planted in several areas
- Development within the High Energy Physics Division



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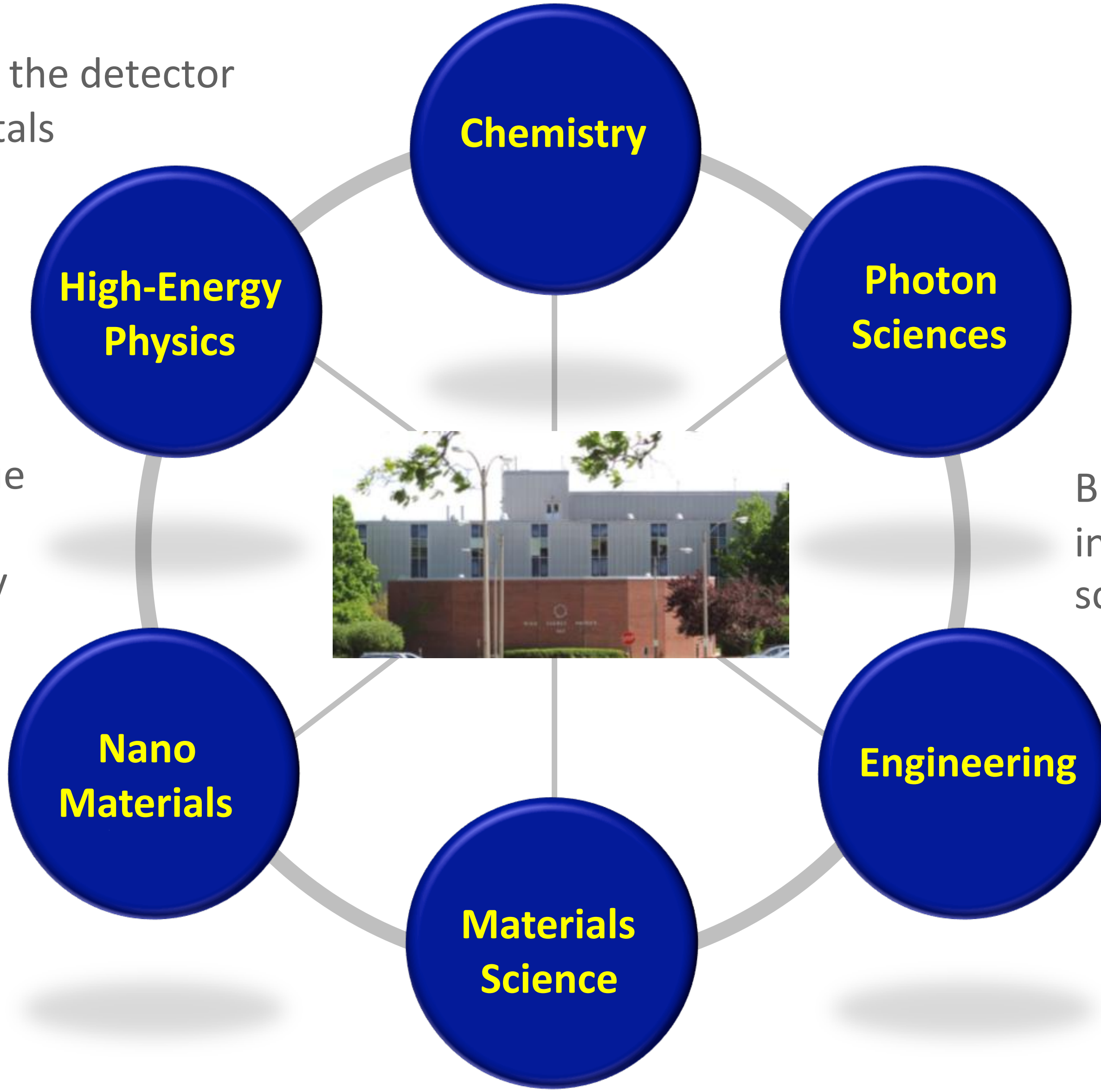
Detector Development Strategy

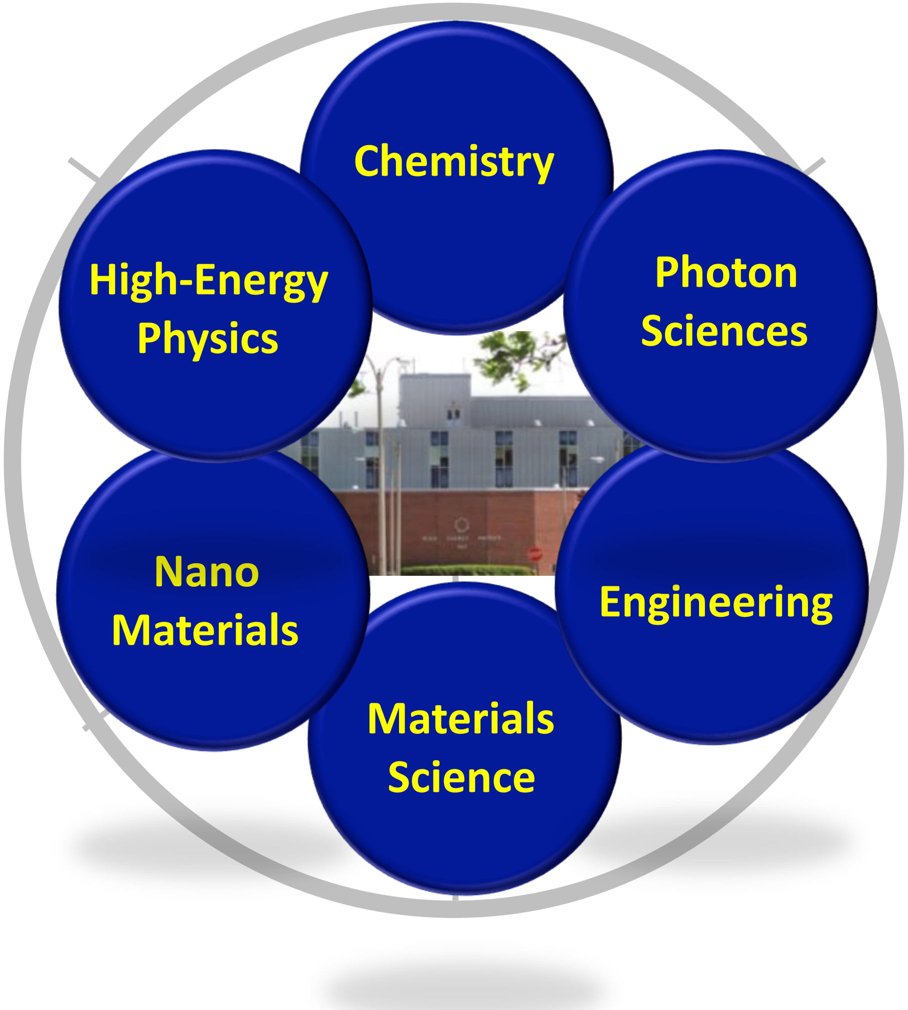
- Go back to the detector fundamentals

Exploit the unique strength of a multi-disciplinary laboratory



Build on advances in other areas of science

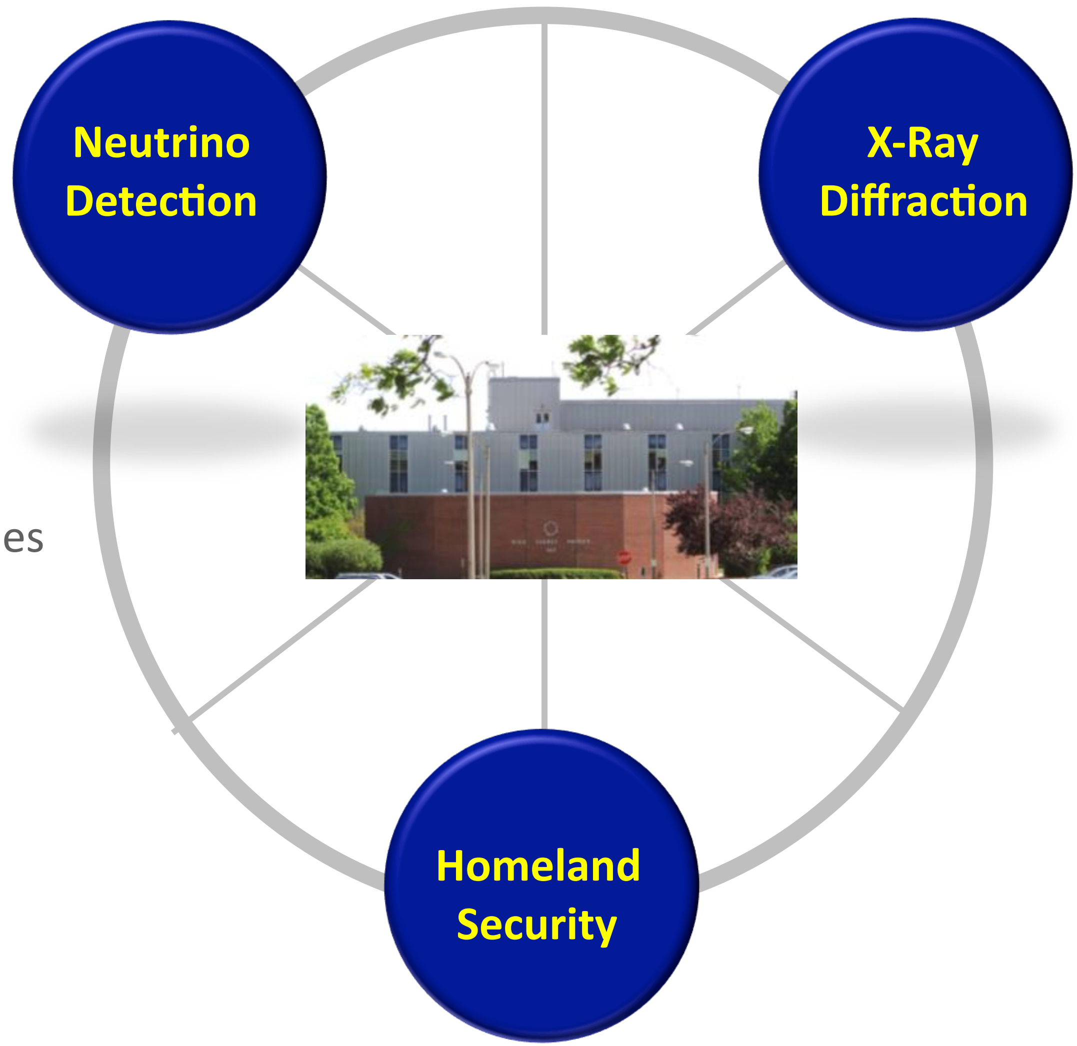
Detector Development Strategy



Detector Development

- Export development

Leverage the development to different disciplines



Detector Development

- Export development

Leverage the development to different disciplines

Current Projects

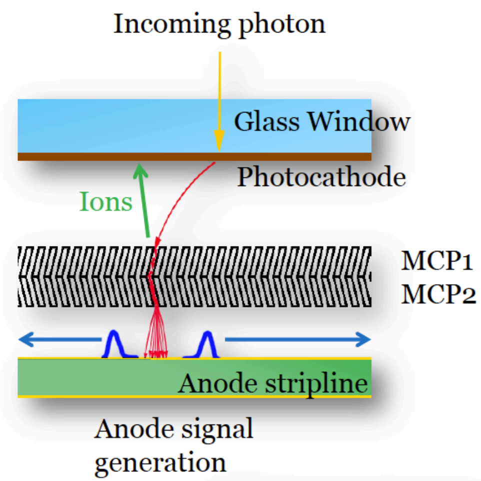
- The division has a good – and we believe unique – start on this development
  - Large-Area Pico-second Photo Detectors (LAPPD)
  - Digital Hadron Calorimeter (DHCAL)
  - Free-space Data Transmission
  - Transition Edge Sensors
  - Veritas Trigger
  - New Telescope Designs
  - …

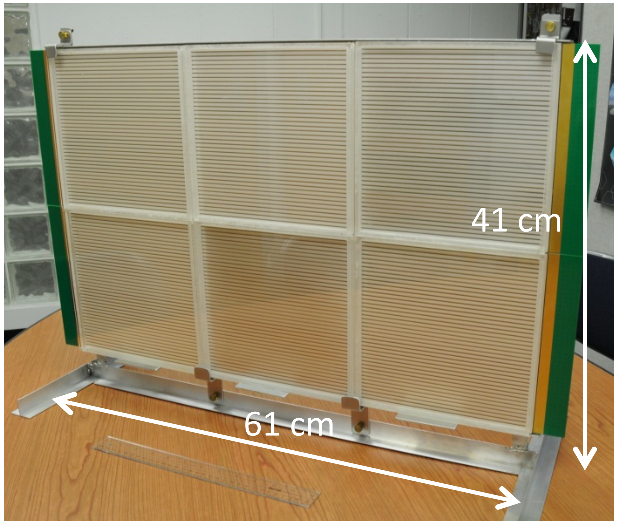
- For all our projects, university participation and collaboration is actively sought

LAPPD: Approach Analogy

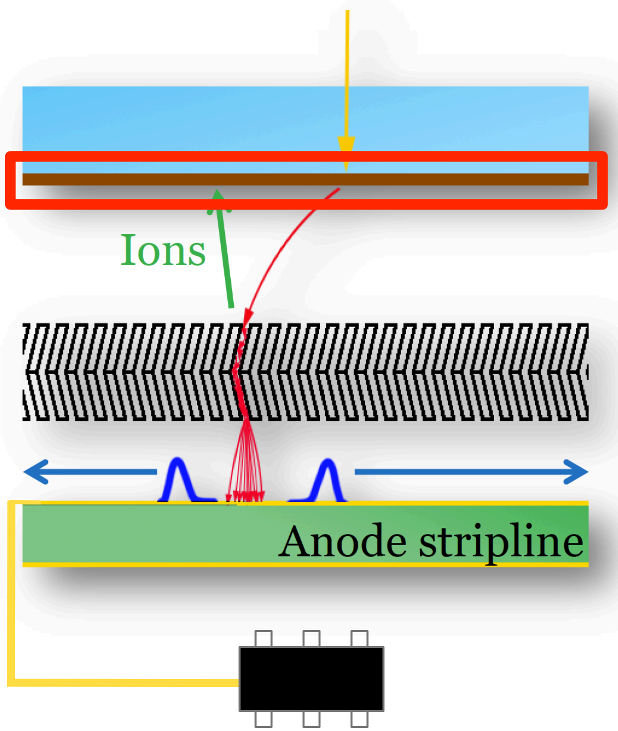
LAPPD: Approach

- Based on existing Technology: Micro Channel Plate (MCP) photo-multiplier
- New Aspect: reinvent the technology, exploiting advances in materials science and electronics, driven by science goals
  - Fully Integrated Approach
  - Gain an order of magnitude in at least one performance characteristic





LAPPD Deconstructed



1. Photo-Cathode (PC)
   - Conversion of photons to electrons
   - Engineer III-V materials to develop robust high QE photo-cathodes
   - ANL Photon Science, ANL Materials Science, UWash, Space Science Lab Berkeley, UIC, Arradiance, …
2. Micro-Channel Plates
   - Amplification of signal
   - Atomic Layer Deposition (ALD), ANL Energy Systems, APS, ANL Physics, Fermilab, Incom, …
3. Transmission line, high speed readout
   - 50Ω scalable anode strip line, silk-screen printing
   - Hawaii, UofC, …
4. Hermetic Packaging
   - Maintain vacuum and provide support. No internal connections; no penetrations
   - ANL glass shop, ANL Materials Science, ANL Physics

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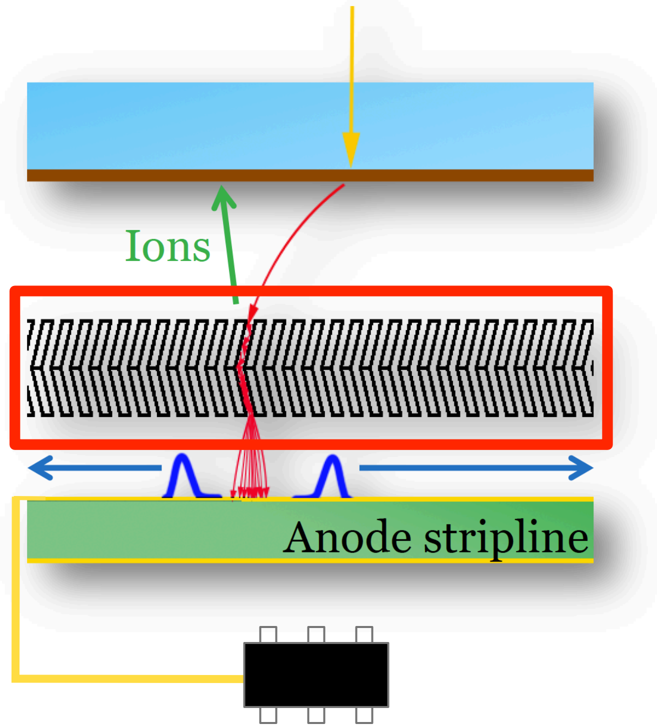

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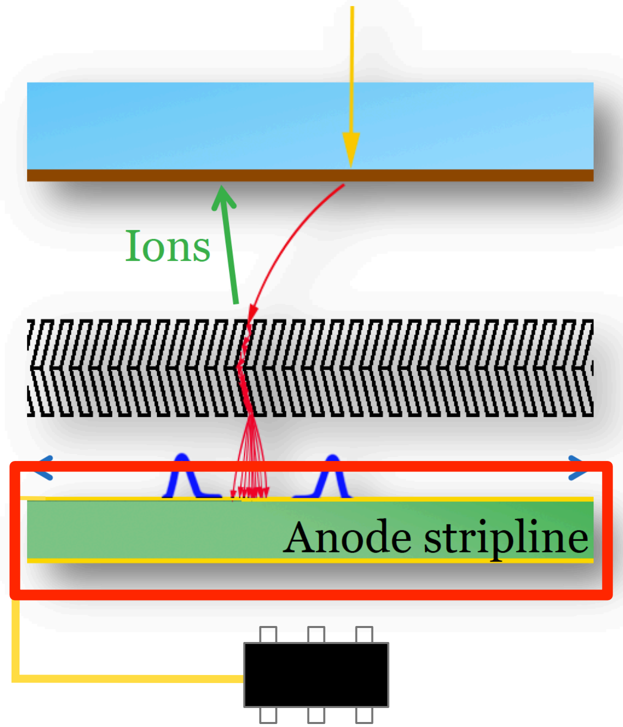

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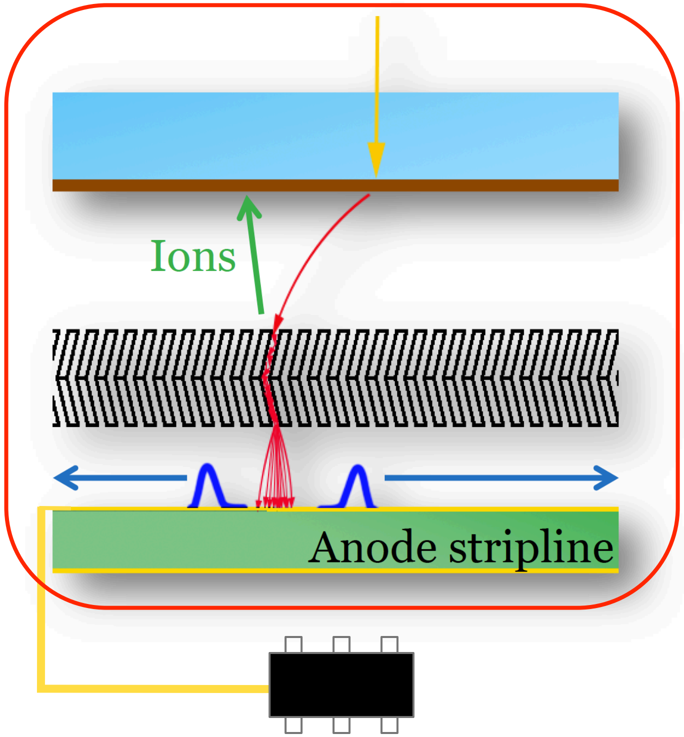

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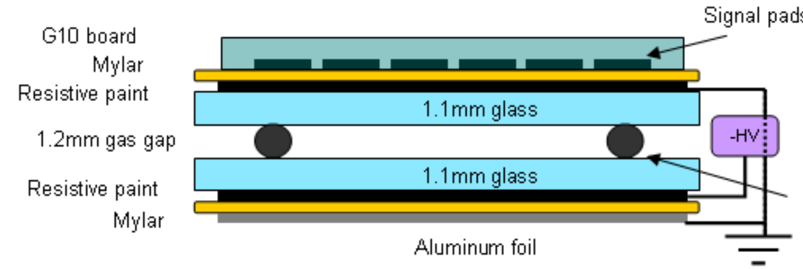
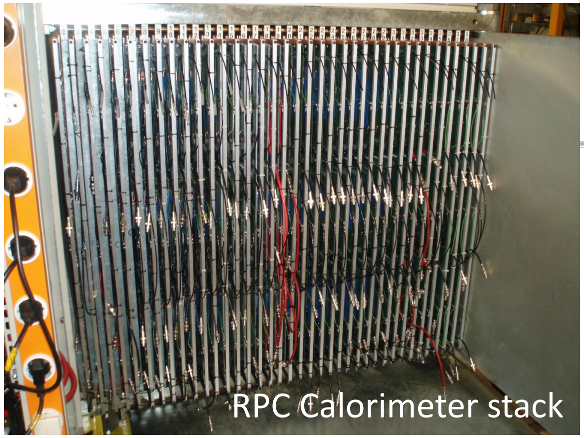
Digital Hadron Calorimetry

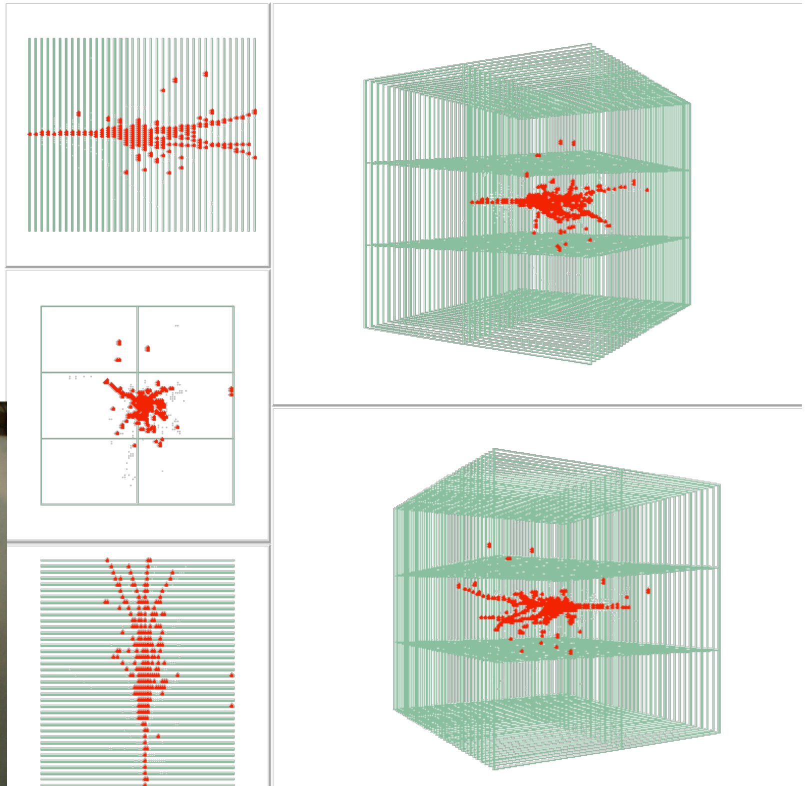
- Based on an innovation in existing technology: Glass-based Resistive Plate Chambers
- New Aspect: pixelate detector using modern readout electronics



- Fully designed and constructed at Argonne
- 1 m^3 stack; total # channels = 450,000
  - > ATLAS + CMS calorimeters combined
- Calorimetry with unprecedented granularity
  - Truly imaging calorimeter
  - Finest segmentation to date

Prototype close to demonstrating the concept of Particle Flow Calorimetry

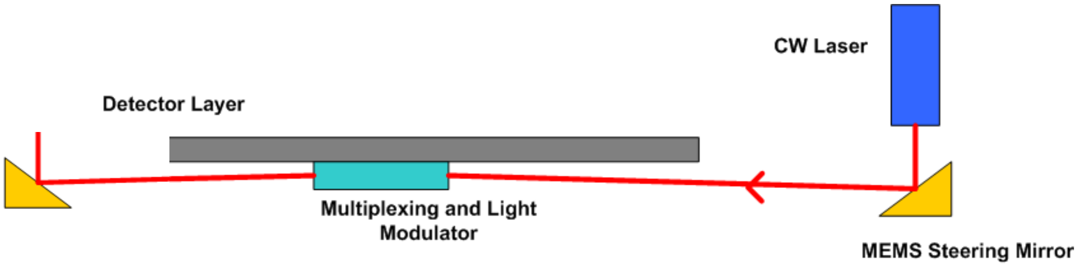




π @ 32 GeV

Free-Space Optical Data Transmission

- Data cables are a nuisance
  - mass, signal loss, …



- Wireless data transmission:
  - CW laser aimed at detector
  - Laser light modulation

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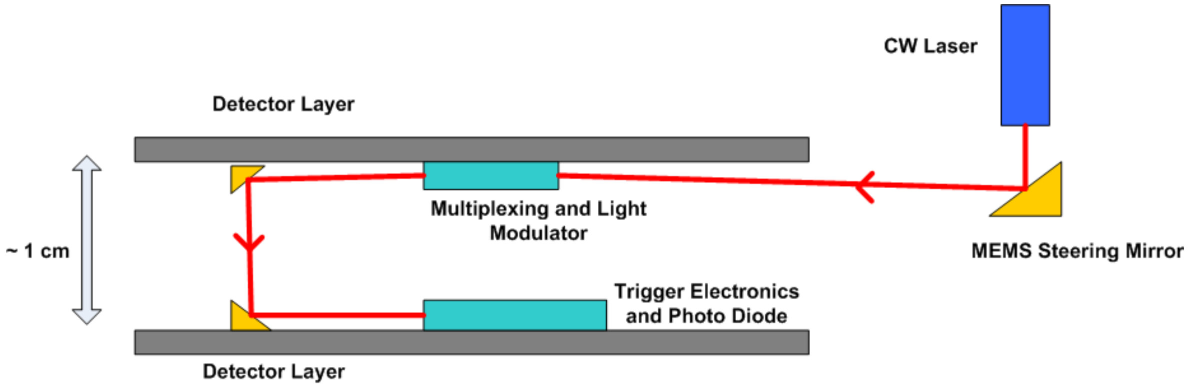

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  - CW laser aimed at detector
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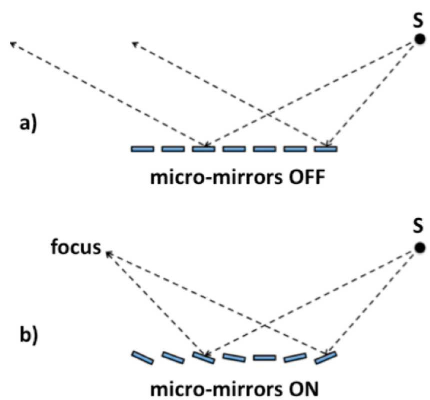
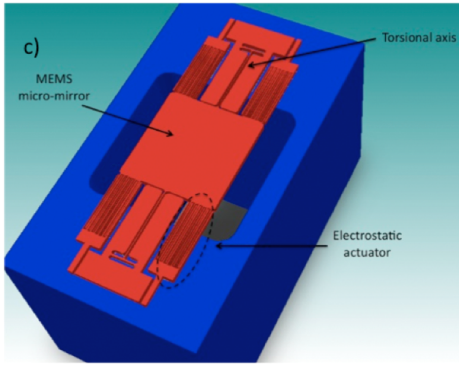
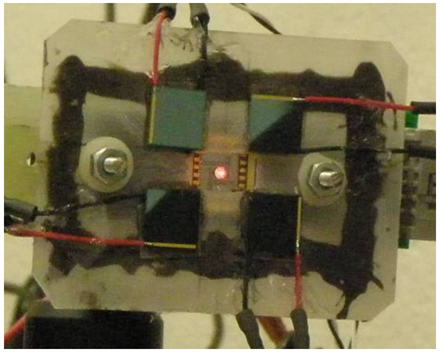
- Based on adaptive X-ray optics
- Developed in X-ray division and center for nano-materials



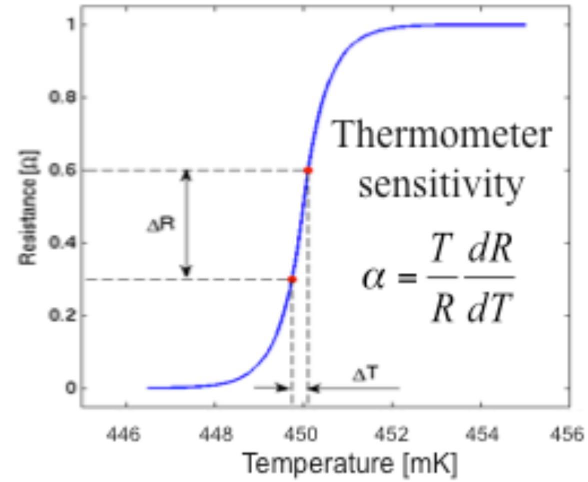




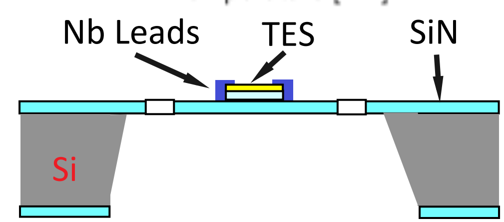
- First tests with data beam transmitting at 1Gb/s, at 1550 nm, over 1 meter with bit error rate < 10^{-13}
- CNM designing and evaluating MEMS mirror(s)

Transition Edge Sensors

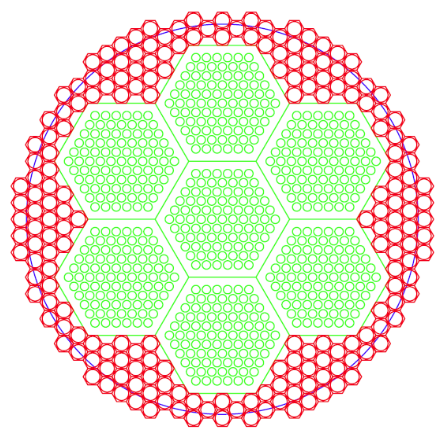
- Superconducting Transition Edge Sensor (TES): bolometer of (bi-) layer of superconducting film operated under voltage bias
- Detect B-mode polarization of CMB
  - Half-wave length dipole antenna efficiently absorbs EM waves in the defined band, transfers EM energy to heat

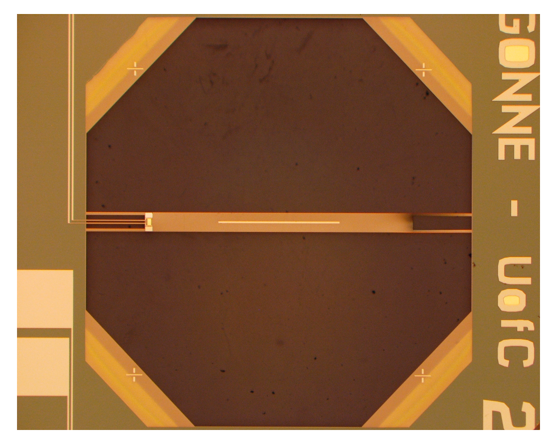


- Sensor constructed (from scratch) by ANL Materials Science and Center for Nanoscale with UofC
  - 8 μm × 1186 μm PdAu dipole on 200 μm×2100 μm SiN



- Development for SPT-Pol focal plane:
  - 588 150 GHz dual-pol. pixels
  - 188 95 GHz dual-pol. pixels
  - Two chips mounted crossed, face to face for dual pol action





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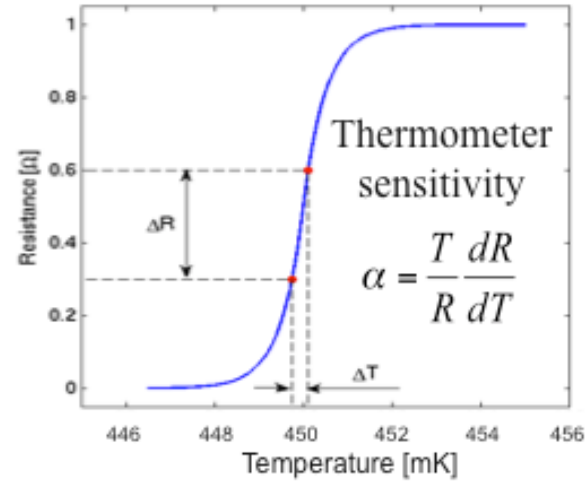

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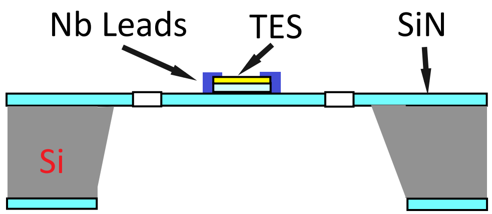

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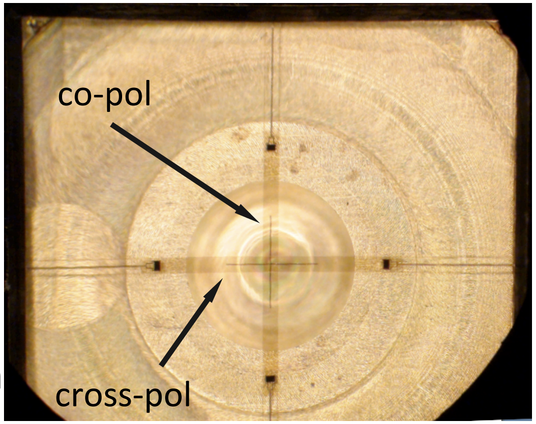
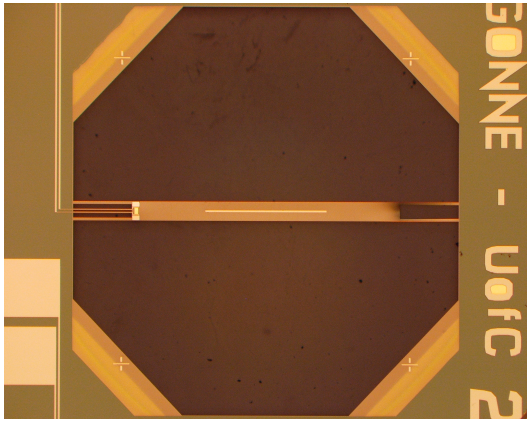


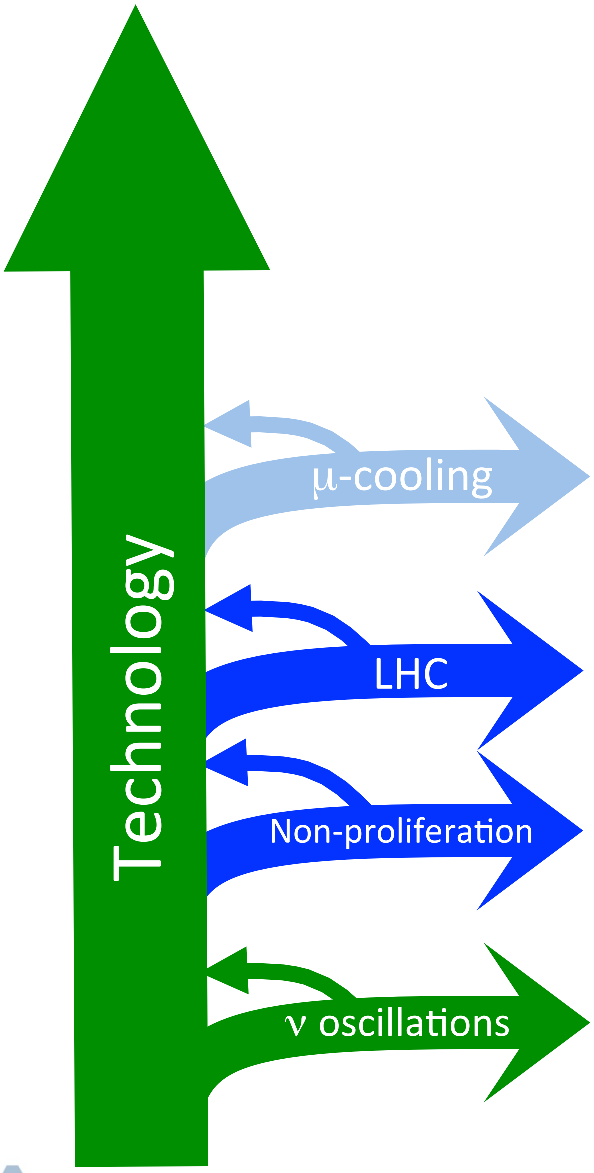


Funded by LDRD

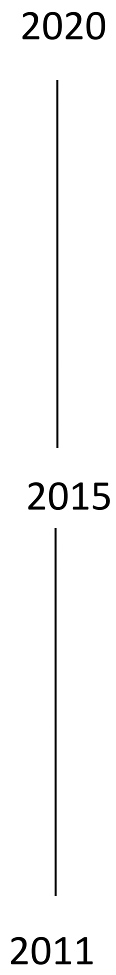
Plan: Four-Prong Approach

- **Incremental Improvements**
  - Leveraging the strength of a multi-disciplinary laboratory, enhance the performance of new detector technologies (LDRD)
- **System Development**
  - After having established proof of principle, take the technology to a small scale real science project
  - Avoid a “valley of death” because of the timescale of science projects
- **Development of transformative technologies**
  - Identify an area in science where the development and application of a new technology would have a tremendous impact
  - Ensure that the technology has broad range of applicability
- **Align Development Above with Future Physics Program of the Division**
  - Maximum leverage of new efforts in support of future physics program

Interconnection



Technology closely inter-connected to our long-term science program and vice-versa



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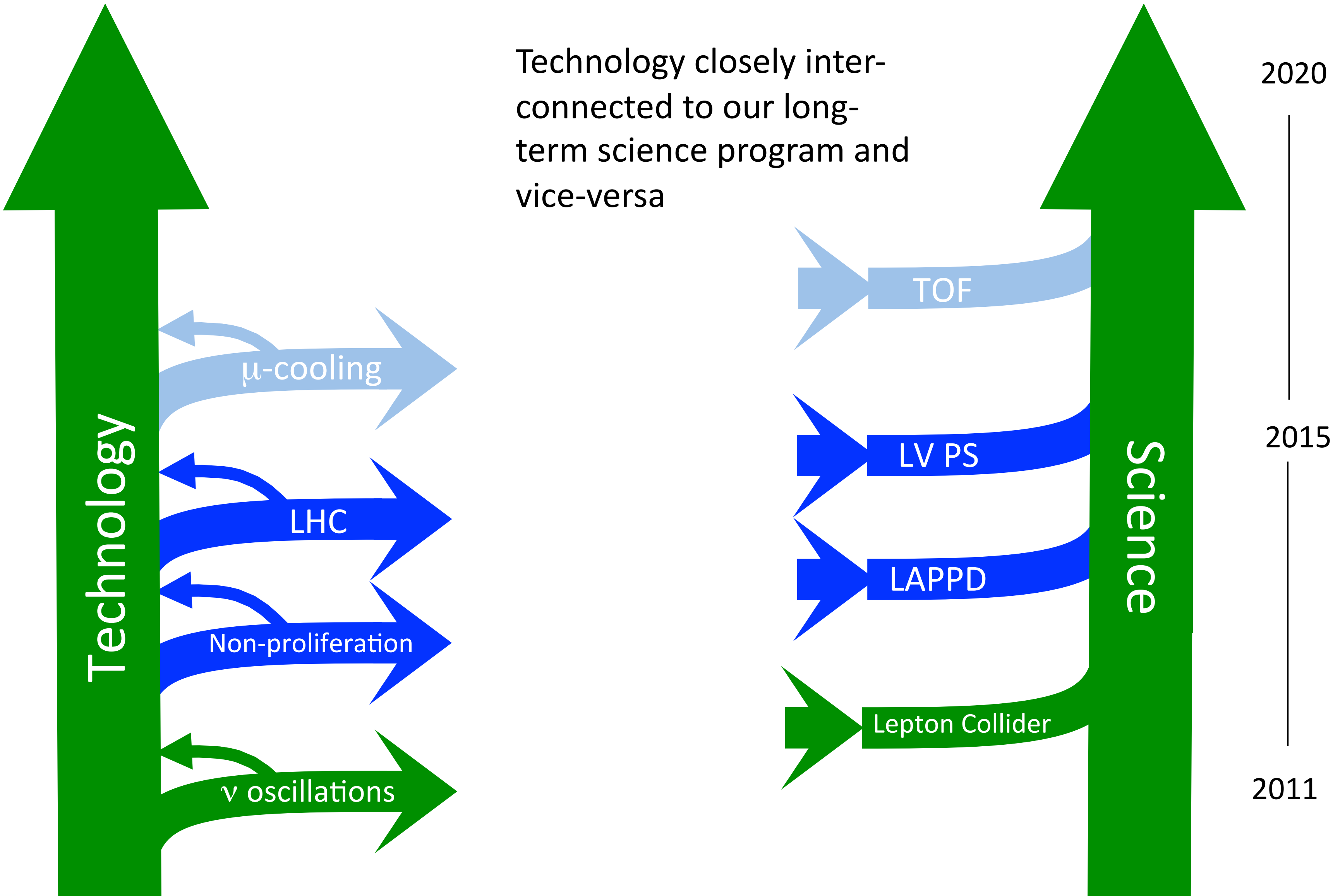
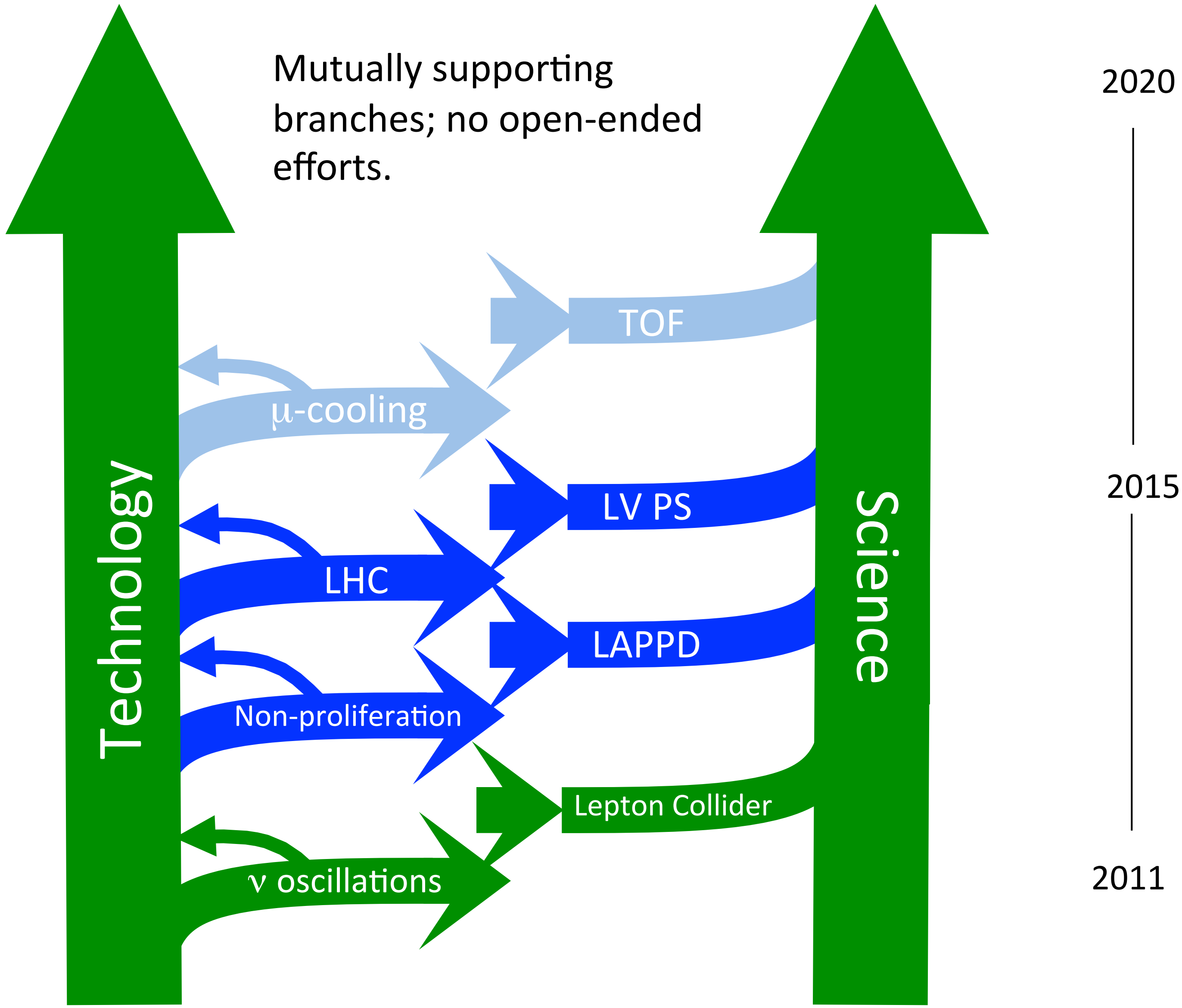


Interconnection

Mutually supporting branches; no open-ended efforts.



Summary

- The mission goal for the division is to '**Enable** science in a **Unique** capacity'
- A reinvestment is being made in fundamental technologies going back to basic science; the support from the DOE to date, and ARRA funding, has been instrumental
- The division has initiated a sensor and detector development program with a very good start through some unique projects
  - Multi-disciplinary nature of the laboratory is a key element
- Goal is to grow this program to support experiments in high-energy physics and the laboratory as a whole