Fermilab:
America's particle physics laboratory

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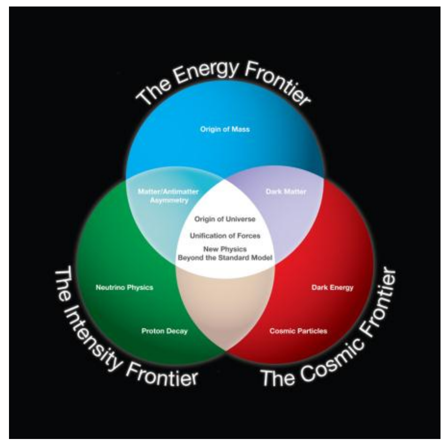
Our vision is to inspire the world and enable its scientists to solve the mysteries of matter, energy, space and time for the benefit of all.

Our mission is to drive discovery in particle physics by:

- building and operating world-leading accelerator and detector facilities
- performing pioneering research with global partners
- transforming technologies for science and industry.

We advance particle physics research using a range of techniques at three interrelated frontiers. These frontiers ask different questions and use different tools, but they ultimately aim at the same scientific goal: a complete understanding of the laws of nature and the cosmos



- At the Intensity Frontier, we explore new physics in unprecedented breadth and detail using intense beams of neutrinos, muons, kaons and nuclei.
- At the Energy Frontier, we discover new particles and directly probe the architecture of the fundamental forces using high-energy colliders.
- At the Cosmic Frontier, we reveal the nature of dark matter, dark energy, and other phenomena of new physics using particles and light from the cosmos.

Our focused scientific mission, coupled with our accelerator and detector facilities and R&D infrastructure, keep the United States a world leader in particle physics research. Our program provides opportunities for international partners to participate in particle physics facilities in the United States.

We operate world-leading user facilities at the Intensity Frontier. We provide the world's most powerful high-energy and low-energy neutrino beams that support both long-baseline and short-baseline neutrino experiments. Our lab and its scientists played a scientific, computing and technical leadership role in the discovery of the Higgs boson at CERN's Large Hadron Collider. Fermilab continues its leadership role at the LHC, supporting the U.S. CMS community and leading the U.S. contribution to CMS and LHC accelerator upgrades. Fermilab is also a critical partner in a number of dark matter and dark energy experiments.

Fermilab's strategy for the future

Over the course of the past six years a strategy has been developed and implemented that ensures a leading role for Fermilab, and for the United States, in the global particle physics enterprise. This strategy meets the following criteria:

1. addresses critical and exciting scientific questions
2. is bold and establishes world leadership
3. leverages the laboratory's expertise and existing facilities
4. attracts international partners
5. fits within a global strategy for the field and within reasonable U.S. funding
6. is focused, yet broad enough to be resilient in the face of unexpected physics discoveries and funding fluctuations.

In executing this strategy, we have the following ten-year goals:

1. Be the world leader at the Intensity Frontier.
2. Be a world leader at the Energy Frontier, at the Cosmic Frontier, and in theoretical particle physics.
3. Play a leadership role in developing the technology for and advancing basic understanding of next-generation accelerator facilities.
4. Play a leadership role in developing the technology for next-generation particle detectors and computing facilities.
5. Play a leadership role in applying particle physics technologies to society's problems by leveraging state and national investment in IARC.

The foundation of this strategy is the fact that, over the next decade, the greatest opportunity for U.S. leadership using facilities at Fermilab lies at the Intensity Frontier. Experiments driven by high-intensity proton beams from the Fermilab accelerator complex will search for new physics phenomena at energies much higher than in experiments at particle colliders such as the LHC. Results from these experiments will also be necessary to interpret and fully understand discoveries made at the LHC.

This strategy leverages Fermilab's considerable on-site expertise in accelerator and detector technologies, and its high-caliber technical and computing infrastructure, to enable Energy and Cosmic Frontier discoveries using accelerators, experiments and telescopes around the world. It also sets the stage for the long-term development of the laboratory, putting our R&D programs to work developing technologies for the next generation of accelerators and detectors while the world awaits the discoveries that will point the way to the next Energy and Intensity Frontier accelerators. Figure 2 illustrates how Fermilab's short- and medium-term efforts at the three frontiers fit together to support the laboratory's long-term strategy for science and facilities.

Fermilab's program will continuously produce physics as demonstrated in Fig. 2, supporting several thousands of users from across the country and around the world. In 2012 alone, Fermilab supported 4,300 users—2,200 of whom visited the Fermilab site for their research and 2,100 who used the laboratory's computing infrastructure.

We execute our strategy and deliver on our goals in partnership with universities and laboratories worldwide. We train the next generation of particle physicists, accelerator physicists and engineers. We have a profound influence on the workforce in diverse sectors of the national economy wherever highly developed analytical and technical skills, the ability to work in large teams on complex projects, and the ability to think creatively to solve unique problems are required by employers.

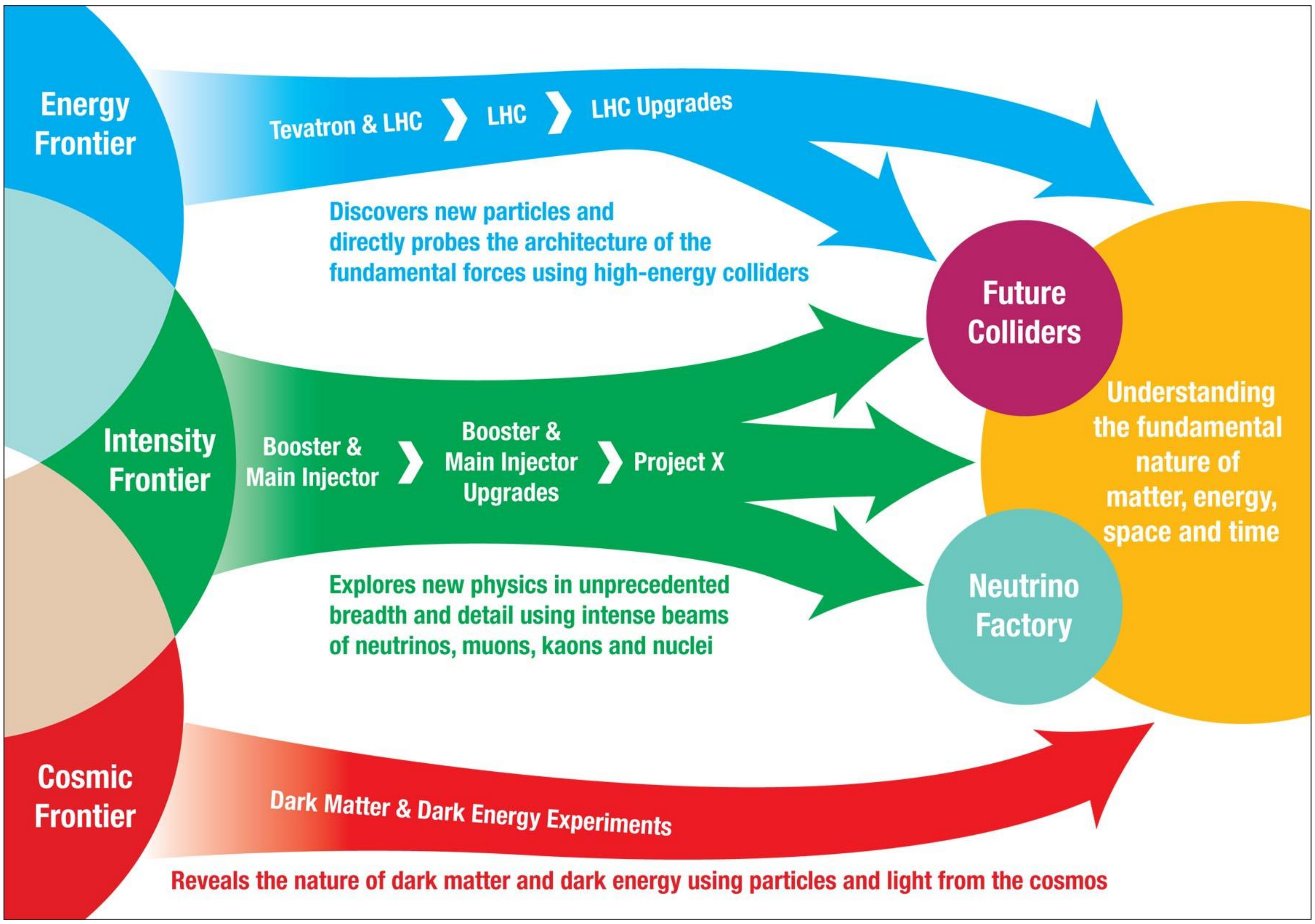


Figure 1: Graphic illustrating how Fermilab's short- and medium-term efforts at the three frontiers fit together to support the laboratory's long-term strategy for science and facilities.

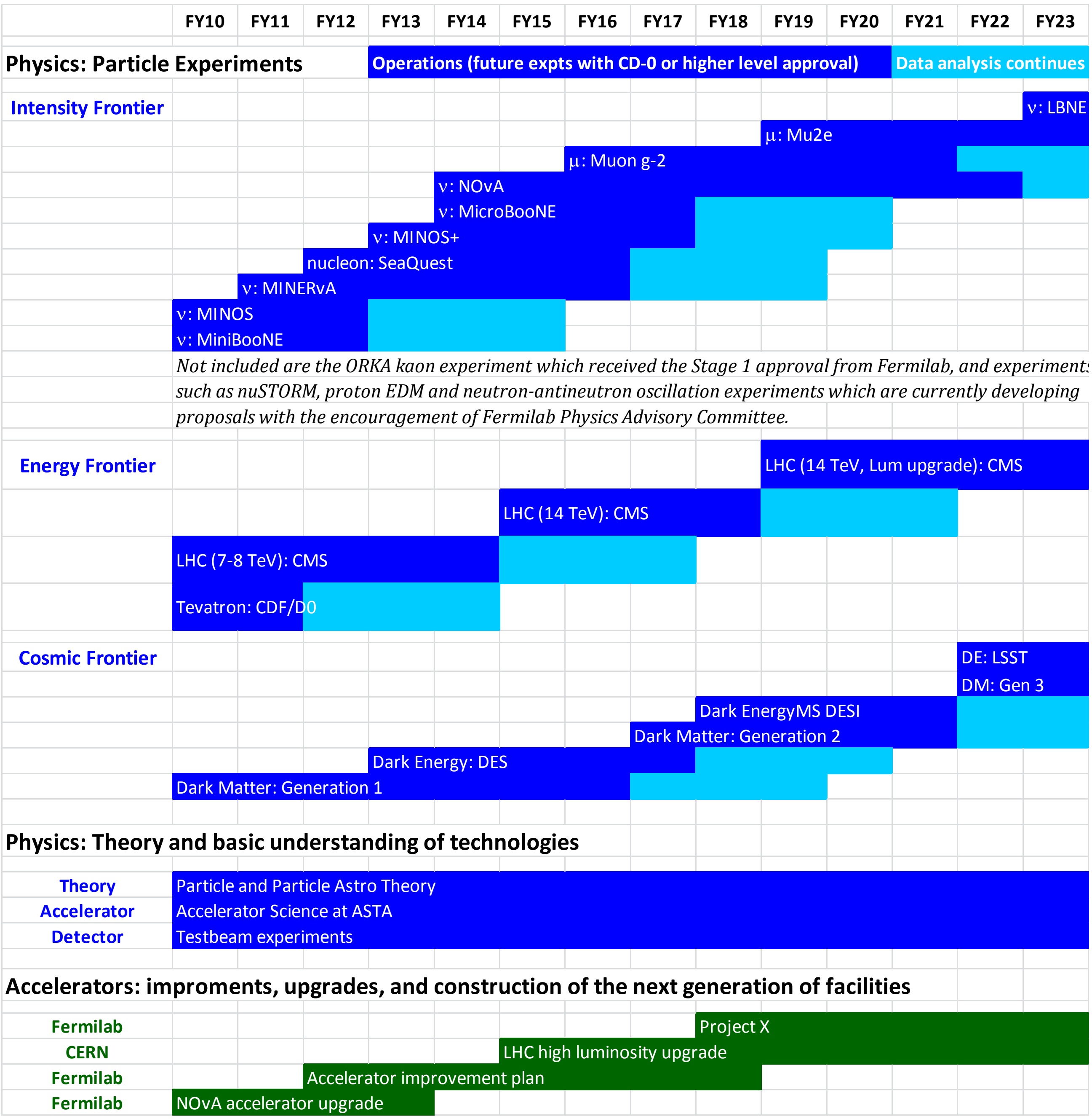


Figure 2: Particle physics program (blue) and accelerator construction program (green) for the next ten years at Fermilab.

Appendix A: Breadth of Intensity Frontier Experiments

Each intensity frontier experiment is typically designed to make one or two key measurements. But equally typical is that an array of new measurements is enabled by the construction of ground breaking equipment even if it has just one or two numbers as its focus.

A canonical example is provided by the MINOS experiment which has run at Fermilab for the last 9 years and has amply fulfilled it prime purpose of making some of the most precise measurements of neutrino parameters. It has also, however, produced 54 peer reviewed publications and 65 PhD theses on subjects that range far beyond the primary purpose of the experiment. These papers cover topics as far afield as seasonal variation in the cosmic muon flux, measurements of the speed of neutrinos, and searches for the violation of Lorentz symmetry.

The MiniBooNE experiment was operated with the primary purpose of testing an oscillation interpretation of the LSND anomaly, but has so far produced 23 peer reviewed publications and 16 theses on a range of subjects much broader than the experiments main purpose. The MiniBooNE paper diversity covers searches for neutrinos from galactic supernovae and paradigm shifting, precision measurements of neutrino cross-sections.

Whilst not universal, this feature of Intensity Frontier experiments is the norm rather than the exception.

Appendix B: Evolution of LBNE

The extraordinary physics that will be achieved with LBNE has attracted 384 scientists from 67 institutions and 5 countries to the collaboration. LBNE science covers the following topics:

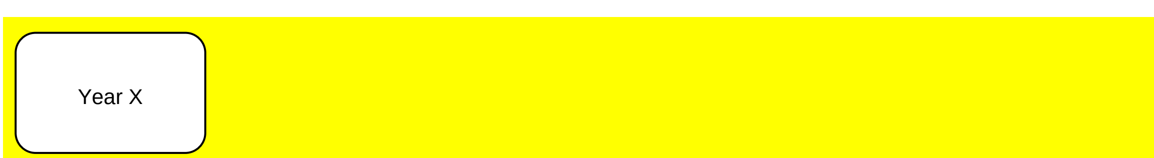
- Neutrinos: Do they explain why matter dominates over antimatter in our universe? Do they show new symmetries? Do they tell us something about the unification of forces? LBNE will shed light on these questions through measuring crucial mixing angles, the mass-ordering of neutrinos and, most importantly, CP violation in the neutrino sector.
- Proton decay: Its discovery would have a profound significance for theories of unification.
- Supernova neutrinos: Their measurement will allow the only direct experimental view of the complex dynamics of supernova core collapse and may probe some of neutrino properties.

What the U.S. is offering to the world community:

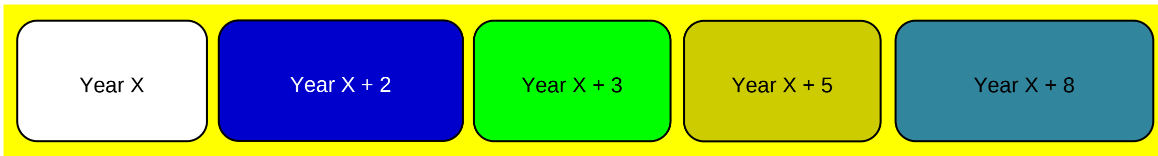
- Neutrino beam
    - accelerator facilities: They exist now! (go up to 700kW in the next couple of years) → the expanding future accelerator Project X (up to 2.3 MW)
    - beamline
- Baseline: great baseline (1,300 km)
- Underground facility: an operating underground facility that can host a large detector → expandable

Evolution of LBNE detectors (all detectors are located underground at 4850 ft level)

- Step 1 (components which are operational at year ~X)
    - Primarily U.S. DOE, but with some contributions from other partners
        - Construct a beamline
        - Excavate a cavern that can house at least 35 kt LAr detector (yellow box – see below)
        - Build a ~5kt LAr TPC detector (white box – see below)
    - Country 1^{++} builds a near detector



- While Step 1 is being executed,
  - Region 1^{++} builds 5~10 kt LAr TPC detector (operational at year X + ~2),
  - Country 2^{++} builds 5 kt LAr TPC detector (operational at X + ~3),
  - ...



While the mass of the LBNE far detector increases (up to > 35 kt in total), the neutrino flux continues to increase from Project X (up to 2.3 MW).

Note: The DOE's CD-1 was needed to attract international collaboration. The CD-1 process did not assume non-DOE contributions. In this constraint, a 10 kt surface detector was the only viable option for physics justification to receive the approval (an underground detector is too small for any physics). The DOE's CD-1 approval document in December 2012 states "If additional domestic or international funding commitments are secured sufficiently prior to CD-2, the DOE LBNE Project baseline scope could be refined before CD-2 to include scope opportunities such as a Near Neutrino Detector complex at Fermilab or an underground location at SURF for the far detector."

Appendix C: HEPAP Facilities Panel Report

On December 20, 2012, the DOE Office of Science charged all of its Federal Advisory Committees to help with their task of prioritizing facilities (> $100M). Based on the ability of a facility to contribute to "world-leading science" in the next decade, the HEPAP's facilities panel delivered their report--without prioritization of facilities--in March 2013.

The Intensity Frontier:

- LBNE Stage 1 begins a world-leading program in neutrinos. The science reach of Stage 1 is important and it lays the groundwork for an absolutely central facility. It is ready for construction. *[Note that Stage 1 referenced in this report did not assume any scope enhancement with non-DOE contributions described in Appendix B.]*
- Mu2e will search for muon-to-electron conversion in the field of a nucleus with unparalleled sensitivity. It is absolutely central and ready for construction.
- Project X is a unique, world-leading facility at Fermilab for Intensity Frontier physics. It is absolutely central and although it is pre-CD0 it is ready for construction.
- nuSTORM is a muon storage ring that would provide neutrino beams with well-defined flavor composition and spectrum. While the committee is not aware of major technical challenges in realizing nuSTORM, its performance requirements are not yet fully defined. While nuSTORM has great potential the committee doesn't know enough yet to assess nuSTORM's role in world-leading science.

The Energy Frontier:

- Measuring Higgs properties and searching for Beyond-the-Standard-Model effects are of primary scientific significance.
- The LHC accelerator and ATLAS and CMS detector upgrades and the 500 GeV ILC in Japan can address these questions in complementary fashions, are absolutely central to progress in high-energy physics, and are ready for construction.

The Cosmic Frontier:

- Questions of dark matter and dark energy are fundamentally important.
- The generation-3 dark matter and LSST dark energy experiments are absolutely central and are ready for construction.

- The mission and technical requirements of the next generation dark energy experiments are not yet fully defined.

Appendix D: Projects under DOE CD (Critical Decision) processes and definitions

							Project: from CD-0 to CD-4					
Project	**FY2006**	**FY2007**	**FT2008**	**FY2009**	**FY2010**	**FY2011**	**FY2012**	**FY2013**	**FY2014**	**FY2015**	**FY2016**	**FY2017**
Intensity Frontier												
MINERvA	CD-0	**CD-1/2/3a**	**CD-3b**		**CD-4**							
NOvA	CD-0	**CD-1**	**CD-2**	**CD-3a**						CD-4		
MicroBooNE					CD-0/1	CD-2/3a	CD-3b		CD-4			
Muon g-2							CD-0	CD-1/3a	CD-2/3b		CD-4	
Muon (AIPs, GPPs)												
Mu2e					CD-0		CD-1	CD-3a	CD-2/3b	CD-3		
LBNE					CD-0			CD-1		CD-3a	CD-2	CD-3b
Project X									CD-0	CD-1		
Energy Frontier												
LHC CMS			CD-4				**CD-0**	**CD-1**	CD-2/3			
LHC Machine			CD-4						CD-0/1	CD-2/3		
Cosmic Frontier												
DE Cam	**CD-0**		**CD-1/2/3a**	**CD-3b**			CD-4					
Gen2 Dark Matter							CD-0		CD-1	CD-2		
Infrastructure												
SLI				**CD-0**		CD-1			**CD-2** **CD-3**		CD-4	

Figure 4: Timelines of projects under DOE CD processes

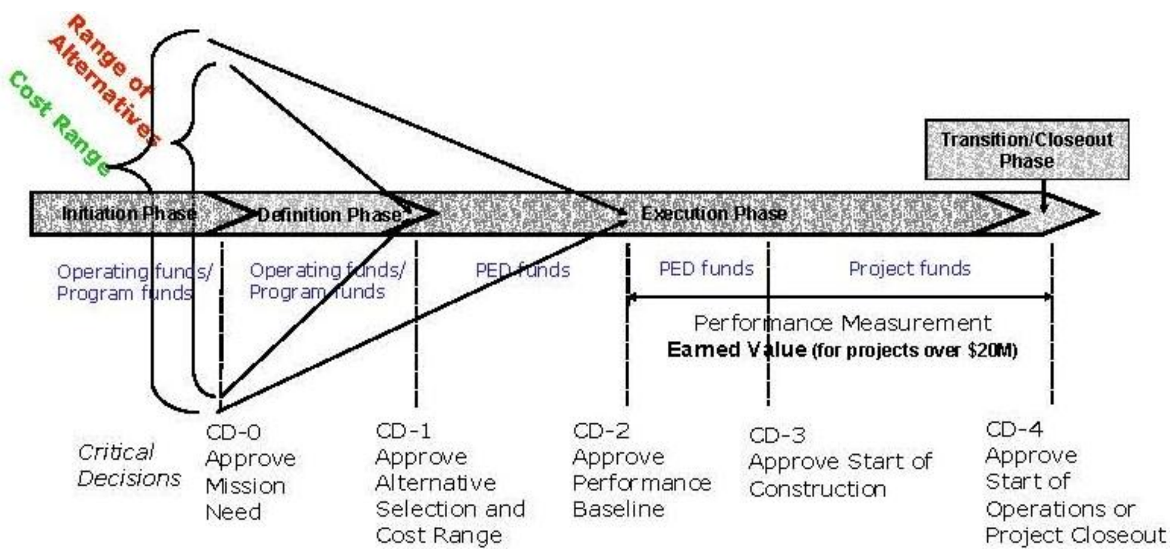


Figure 5: Definitions of DOE CD processes