# Project X: Accelerator Overview

## The Strategic Context and Fermilab's Future

For many years Fermilab has operated both the highest-energy particle collider and the highest-intensity accelerator-based neutrino beam in the world. Now the LHC has surpassed the Tevatron in energy and Japan's J-PARC facility is embarking on a long-baseline neutrino program in strong competition with the Fermilab program. Within this international context, the US elementary particle physics community has adopted a strategic plan for the coming decade that emphasizes research on three frontiers: the Energy Frontier, the Intensity Frontier and the Cosmic Frontier. The plan recognizes that over the coming decade Fermilab will be the sole US site for accelerator-based particle physics research. Fermilab's strategy is fully aligned with the US plan. This plan features the development of a high-intensity proton facility, denoted Project X, that will support a world-leading Intensity Frontier Program at Fermilab while providing the basis for a longer term Energy Frontier facility.

## Evolution of the Fermilab Accelerator Complex

Project X is a multi-MW proton accelerator facility proposed for construction at Fermilab and is the centerpiece of the plan for future development of the Fermilab accelerator complex. Project X is utilizes an H- linear accelerator based on superconducting rf technologies to provide long-term opportunities at both the Intensity and Energy frontiers. Project X will support a diverse Intensity Frontier program, creating opportunities for long-term world-leading programs in neutrino physics and other beyond-the-standard-model phenomena. The technology for Project X also opens opportunities beyond traditional particle physics applications, for example in cold-neutron physics and accelerator-driven subcritical systems (ADS) for energy generation and the transmutation of waste. The technology development for Project X is closely aligned with the technologies required for the proposed International Linear Collider, preserving Fermilab's capability to serve as a host, or major contributor, to such a possible future accelerator. The development of a multi-MW proton facility could also provide the basis for a future Muon Collider or Neutrino Factory.

**Project X Mission Goals and Reference Design**

The design of Project X is based on four mission elements derived from the High Energy Physics Advisory Panel's P5 report on the future of US particle physics:

1. Provide a neutrino beam for long baseline neutrino oscillation experiments, based on a capability of targeting at least 2 MW of proton beam power at any energy between 60 – 120 GeV.
2. Provide MW-class, multi-GeV, proton beams supporting multiple kaon, muon, and neutrino based precision experiments. Simultaneous operations of the rare processes and neutrino programs are required.
3. Provide a path toward a muon source for possible future Neutrino Factory and/or a Muon Collider.
4. Provide options for implementing a program of Standard Model tests with nuclei and/or nuclear energy applications

The development of a design concept for a high intensity proton facility has gone through several iterations. These iterations have culminated in a concept, designated the Project X Reference Design, that supports the mission elements listed above in an innovative and flexible manner. The Reference Design is based on a 3 GeV superconducting CW linac, a superconducting pulsed linac for acceleration from 3-8 GeV, modifications to the existing Recycler and Main Injector Rings at Fermilab, and development of an initial 3 GeV experimental facility. The 3 GeV linac operates at an average current of 1 mA, providing up to 3 MW of beam power to the rare processes and nuclear programs. The utilization of a pulsed linac for acceleration from 3-8 GeV provides input to the Main Injector complex in support of the long baseline neutrino program while additionally providing a platform for future programs of interest to the U.S. High Energy Physics community, in particular future muon based facilities. A unique feature of the Reference Design is the utilization of a wideband chopper in the linac front end, paired with a transverse splitter at 3 GeV. This configuration allows delivery of variable bunch patterns to multiple experiments simultaneously.

The Reference Design provides a facility that will be unique in the world with unmatched capabilities for the simultaneous delivery of very high beam power with flexible beam formats to multiple users. These capabilities lie beyond what is believed to be achievable with synchrotron based facilities, and are beyond any facility either operational or under design in the world today.

**R&D Program**

An intensive R&D program is underway to validate the design choices made in support of the Project X facility design, and to establish fabrication method for major sub-systems and components. The primary elements of the R&D program include:

- Development of a wide-band chopper, capable of removing bunches in arbitrary patterns at 162.5 MHz;
- Development of superconducting radiofrequency acceleration modules at three different frequencies (325, 650, 1300 MHz);
- Development of cost effective rf systems for each of three different frequencies and with duty factors ranging from 5% to 100%;
- Development of instrumentation;
- Development of an H- injection system, capable of injecting pulses of duration 4.4 – 26 msec into the Recycler;
- Development of room temperature radiofrequency acceleration systems for utilization in the Main Injector;
- Development of mitigation strategies for electron cloud effects in the Main Injector.

**Project X Collaboration**

A national collaboration with international partners has formed to develop Project X. The national collaboration comprises Argonne National Laboratory, Brookhaven National Laboratory, Cornell University, Fermilab, Lawrence Berkeley National Laboratory, Michigan State University, Oak Ridge National Laboratory, Thomas Jefferson National Accelerator Facility, SLAC National Accelerator Laboratory, and the Americas Regional Team of the ILC Global Design Effort.

Additionally, Fermilab has formed a collaboration with four Indian Institutions for the development of the Project X design and associated technologies. The Fermilab-Indian collaboration comprises the Bhabha Atomic Research Center (Mumbai), Inter-University Accelerator Center (New Delhi), Raja Ramanna Center for Advanced Technology (Indore), and Variable Energy Cyclotron Center (Kolkata).

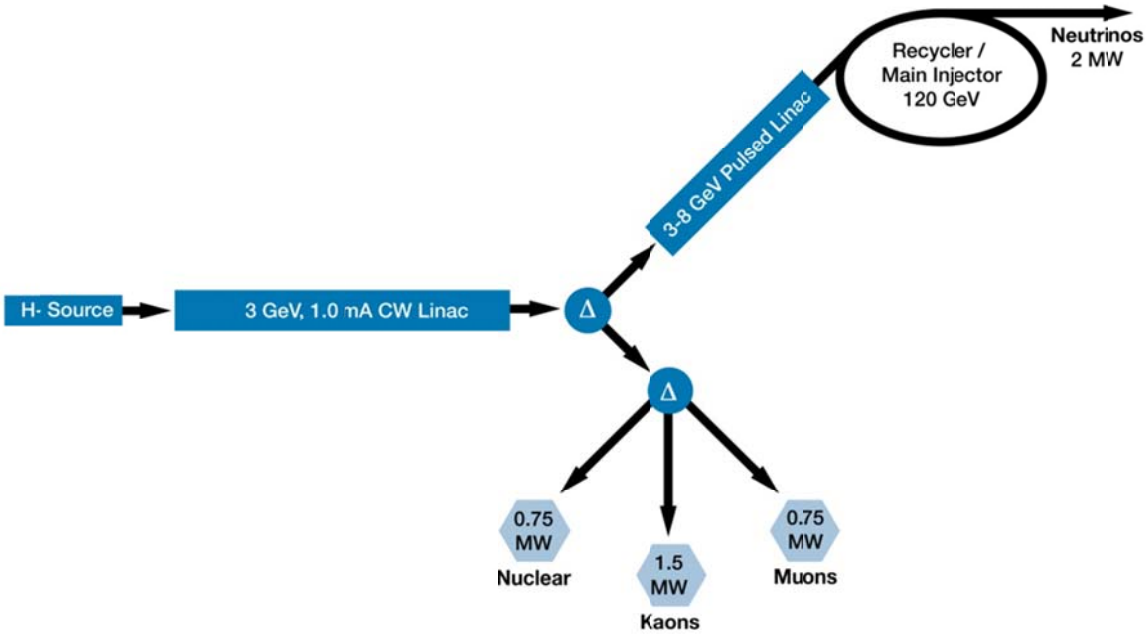
**Construction Period**

The earliest start date for Project X construction as communicated to Fermilab by the Department of Energy is FY2016. Planning for Project X is based on a five year construction period, 2016-2020.

**Other Applications**

The technologies required for Project X have broad potential applications in areas beyond research in elementary particle physics, including:

- Rare isotope production for nuclear physics
- Neutron sources
- Accelerator-driven energy systems
- X-ray FELs
- Energy recovery linacs
- Muon facilities for materials research




*Project X, a high-power proton facility, will support world-leading programs in long-baseline neutrino physics and the physics of rare processes. It will be unique among accelerator facilities worldwide in its flexibility to support multiple physics programs at the intensity frontier. Project X is based on a 3 GeV continuous-wave superconducting H- linac. Further acceleration to 8 GeV, injected into Fermilab's existing Recycler/Main Injector complex, will support long-baseline neutrino experiments. Project X will provide 3 MW of total beam power to the 3 GeV program, simultaneously with 2 MW to a neutrino production target at 60-120 GeV. A multi-laboratory collaboration with international participation has undertaken the development of Project X.*