Fermilab Multi-MW Proton Source: Strategy and Status

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Outline

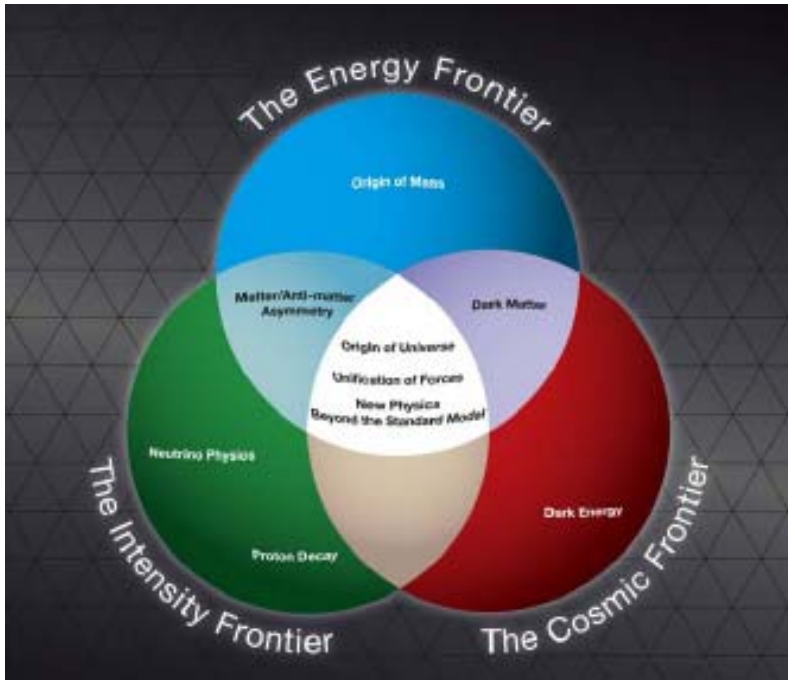
- Strategic Context
- Project X Goals and Configuration
- Project X Research, Design, and Development Plan
- Relationship of Project X to other Programs

Project X website:

http://projectx.fnal.gov/

Strategic Context
Fermilab Long Range Plan

- Fermilab is the sole remaining U.S. laboratory providing facilities in support of accelerator-based Elementary Particle Physics.
- The Fermilab long-term strategy is fully aligned with the P5 plan:
  - Energy and intensity frontiers share strong reliance on accelerators



Strategic Context
P5 Recommendations

- Energy Frontier
  - "The panel recommends for the near future a broad accelerator and detector R&D program for lepton colliders that includes continued R&D on ILC … in support of the international effort."
  - "The panel also recommends R&D for alternative accelerator technologies, to permit an informed choice when the lepton collider energy is established."

- Intensity Frontier
  - "The panel recommends an R&D program in the immediate future to design a multi-megawatt proton source at Fermilab and a neutrino beamline to DUSEL… "
  - "The panel further recommends that in any funding scenario considered by the panel Fermilab proceed with the upgrade of the present proton source by about a factor of two, to 700 kilowatts…"

Strategic Context
Evolution of the Accelerator Complex

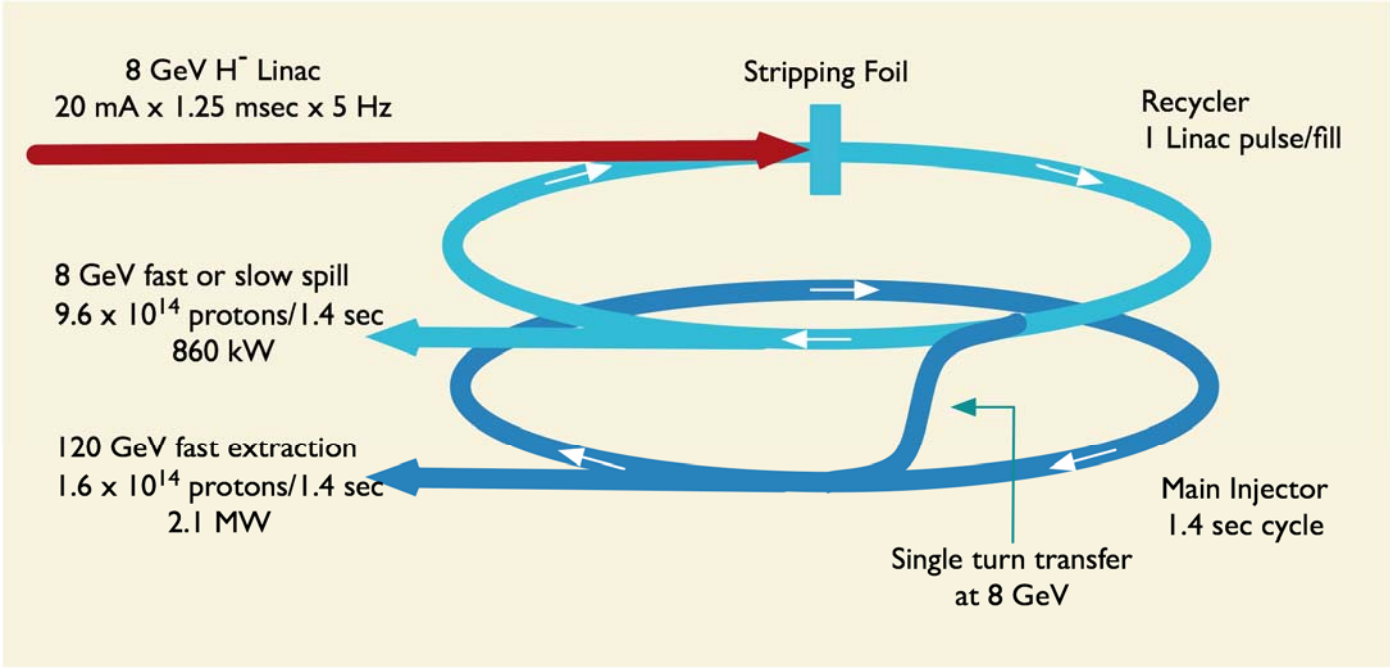
- Energy Frontier
  - Tevatron → ILC or Muon Collider as options for the Fermilab site
- Intensity Frontier
  - NuMI→ NOvA→ very long baseline/mu2e→ multi-MW Proton Source
  - Initial stages supported by ANU (NOνA): 700 kW
- Fermilab view: Most effective implementation of a multi-MW proton facility would be based on a superconducting 8 GeV linac
  - Alignment with ILC technology development
  - Flexibility for the future
  - aka “Project X”

Project X Initial Configuration
Mission Need

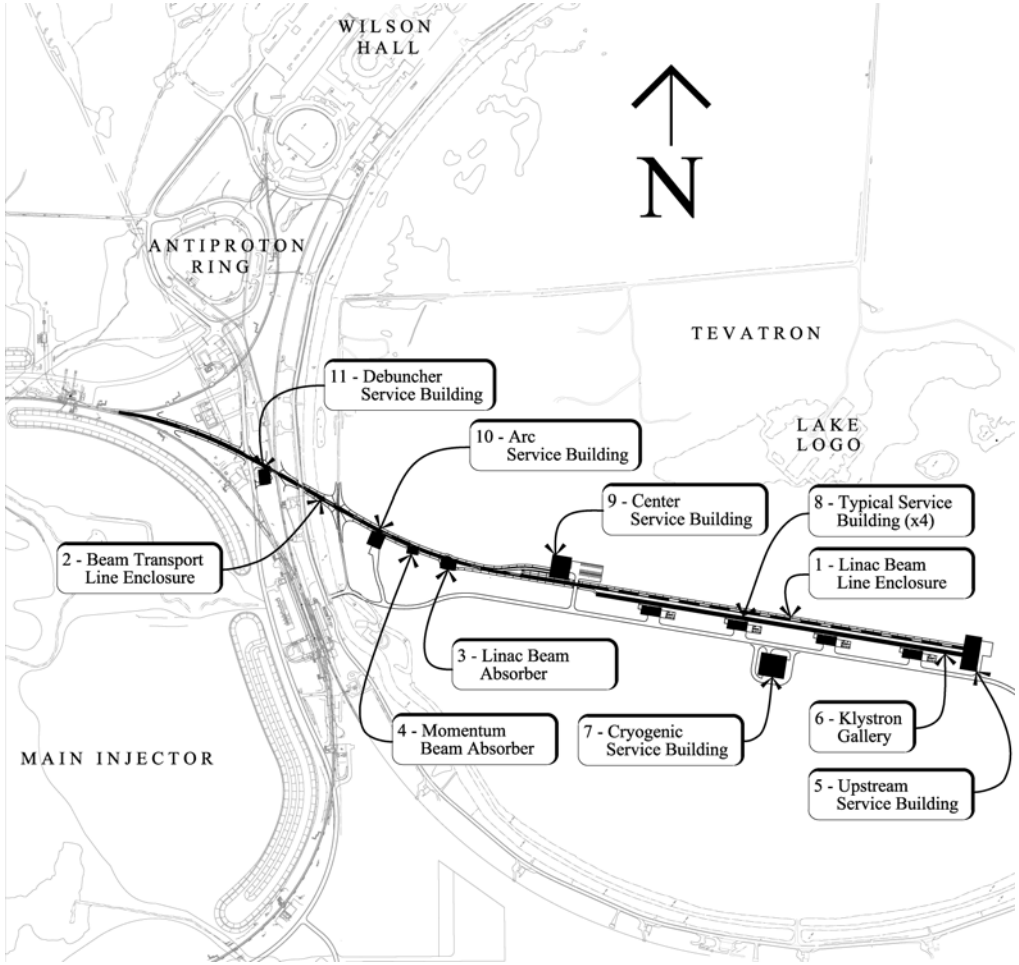
- The P5 report identifies mission need based on:
  - **A neutrino beam for long baseline neutrino oscillation experiments.**
    A new 2 megawatt proton source with proton energies between 50 and 120 GeV would produce intense neutrino beams, directed toward a large detector located in a distant underground laboratory.
  - **Kaon and muon based precision experiments exploiting 8 GeV protons from Fermilab's Recycler, running simultaneously with the neutrino program.**
    These could include a world leading muon-to-electron conversion experiment and world leading rare kaon decay experiments.
  - **A path toward a muon source for a possible future neutrino factory and, potentially, a muon collider at the Energy Frontier.**
    This path requires that the new 8 GeV proton source have significant upgrade potential.

Project X Initial Configuration

- Project X Design Criteria
  - 2 MW of beam power over the range 60 – 120 GeV;
  - Simultaneous with at least 600 kW of beam power at 8 GeV;
  - Compatibility with future upgrades to 2-4 MW at 8 GeV



Project X Initial Configuration
Provisional Siting



Project X Facility Overview
High Level Performance Goals

Linac		
Particle Type	H^-	
Beam Kinetic Energy	8.0	GeV
Particles per pulse	1.6×10^{14}	
Linac pulse rate	5	Hz
Beam Power	280-1000	kW
Recycler		
Particle Type	protons	
Beam Kinetic Energy	8.0	GeV
Cycle time	1.4	sec
Particles per cycle to MI	1.6×10^{14}	
Particles per cycle to 8 GeV program	1.6×10^{14}	
Beam Power to 8 GeV program	140-860	kW
Main Injector		
Beam Kinetic Energy (maximum)	120	GeV
Cycle time	1.4	sec
Particles per cycle	1.7×10^{14}	
Beam Power at 120 GeV	2100	kW

Initially:
2 linac beam pulses/1.4 seconds
Remaining (5) pulses available for
- Maintain 2 MW down to 60 GeV
- Future upgrades
- Diagnostics

Project X RD&D Plan

- The primary goal of the Research, Design, and Development (RD&D) program is to support Critical Decision 2 in 2012, leading to a 2013 construction start.
  - Design and technical component development;
  - Fully developed baseline scope, cost estimate, and schedule;
  - Formation of a multi-institutional collaboration capable of executing both the RD&D plan and the follow-on construction project.
- Secondary goals:
  - Coordination of Project X and ILC scrf programs to provide maximal benefit to each;
  - Retain alignment of Project X and the Neutrino Factory and Muon Collider programs to assure that Project X could serve as a stepping stone to either facility.
- Resources
  - Current Fermilab estimate is ~$100M (fully burdened) through CD-2

Project X RD&D Plan
Near-term Strategy

- Develop an Initial Configuration Document
  - Meeting the design criteria and program goals
  - ICD subject to configuration control
  - ⇒ Released 10/31: available at http://projectx.fnal.gov/index.html
- Revise/update the current RD&D Plan
  - Based on the ICD
  - Review existing plan to emphasize reduction of risk
  - ⇒ In process, expect to have initial re-edit available for November Collaboration Meeting
- Create a preliminary cost estimate
  - Based on the ICD
  - ⇒ In process, available early 2009

Project X RD&D Plan
Near-term Strategy

- Establish a multi-institutional collaboration for the RD&D phase
  - Fermilab holds overall responsibility as host laboratory;
  - Achieve maximal alignment with institutional expertise and experience;
  - Recognize it would be natural for responsibilities to carry over into the construction phase.

  ⇒ Collaboration Meeting scheduled November 21-22, 2008 at Fermilab
- CD-0 in FY2009
  - Requires independent review since (we suspect) >$750M
  - Coordinated with very long baseline and mu2e
  - Based on:
    - ICD
    - Preliminary cost estimate
    - P5 mission definition

Project X RD&D Plan
Working Timeline (technically limited)

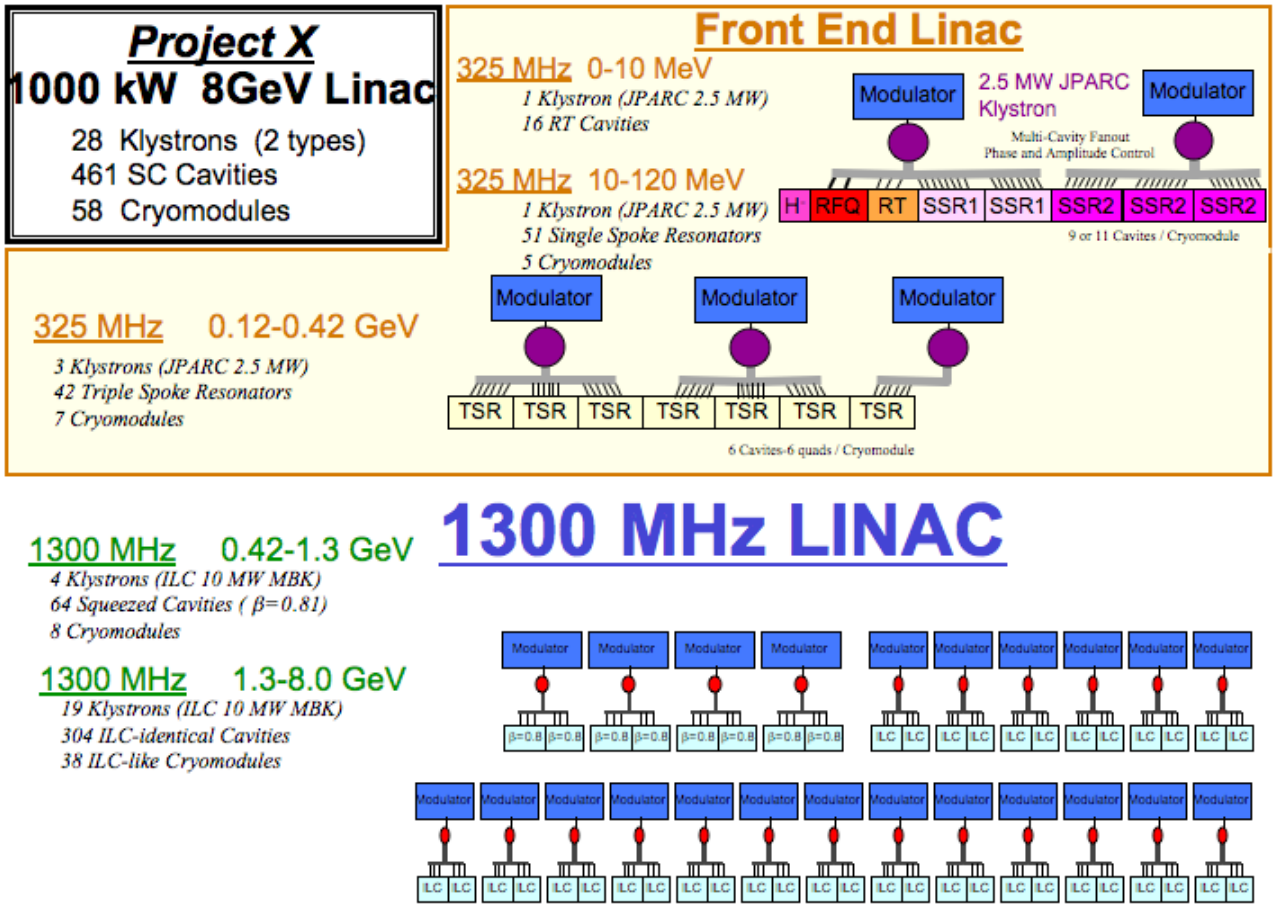
- FY2009
  - Complete Initial Configuration Document (ICD)
  - Develop Upgrade Concept for 2-4 MW at 8 GeV
  - Form RD&D Collaboration
  - Establish Project Management team
  - Revise RD&D plan and initiate work
  - Complete a preliminary cost estimate based on the ICD
  - Complete Mission Needs Statement and Mission Need Independent Review
  - Receive CD-0
  - Request PED funds for FY2011
  - Initiate work on Conceptual Design Report
  - Develop NEPA strategy

  $\Rightarrow$ This can largely be accomplished under the FY09 (half-year) CR

Project X RD&D Plan
Working Timeline (technically limited)

- FY2010
  - Alternative implementations studies
  - Initiate Environmental Assessment
  - Initiate permitting documentation
  - Draft of all CD-1 documentation, including CDR
- FY2011
  - CD-1
- FY2012
  - CD-2/3a
- FY2013
  - CD-3
- ~FY2013~2017
  - Construct

Relationship to Other Programs:
Linac Technology



Relationship to Other Programs:
ILC/SRF Joint Development Strategy

- 38 ILC-like cryomodules are required for Project X. In detail they will not be identical to ILC:
  - Gradient: 25 MV/m
  - Beam current: 20 mA × 1.25 msec × 5 Hz
  - Focusing: Quadrupole element required in each CM
  - Consistent with upgrade path
    - ➢ 1.25 → 2.5 msec pulse length
    - ➢ 5 → 10 Hz pulse rate

    } 4 MW at 8 GeV
- Close coordination between Project X and GDE during development phase
  - Strategy based on ILC "plug compatibility"
    - ➢ Retain ILC cavity spacing and primary interface dimensions
  - Cryomodule development is through the ILC program
  - CAF and ILCTA-NML are constructed via the SRF program: 1 CM/month assembly capability and beam testing of a complete rf unit

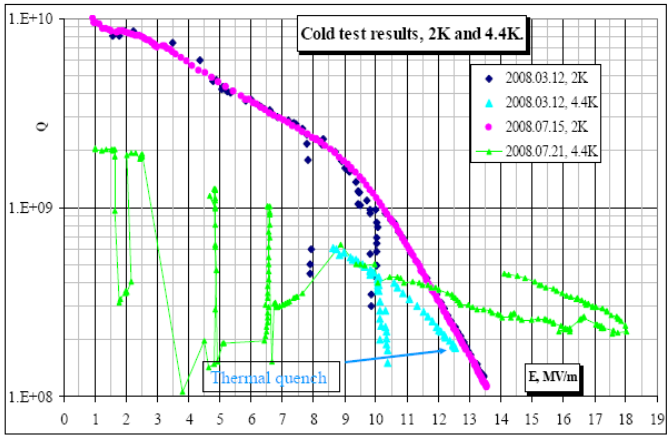
Relationship to Other Programs:
ILC/SRF Joint Development Strategy

- Industrialization
  - Production of 38 ILC-like (plus 8 β=0.8) CMs over a 2-3 year period is consistent with CAF capabilities in ~2013; however, the production rate remains well <u>below</u> that required by ILC

⇒This activity could represent the initial phase of an industrialization buildup for ILC (in the U.S.).

Relationship to Other Programs:
HINS Joint Development Strategy

- The HINS program is developing front end technology beyond the requirements of Project X initial goals:
  - 60 MeV front end @ 27 mA × 1 msec × 10 Hz
  - Demonstrate novel technologies for a high intensity non-relativistic linac
    - Multiple room temperature and sc cavities driven by a single rf source (high power vector modulators)
    - High speed (nsec) beam chopping at 2.5 MeV
  - Establish technical feasibility and cost basis by ~2011
  - Integrate into Project X R&D effort at time of CD-0



Project X RD&D Plan
Integrated SRF Plan

	FY08	FY09	FY10	FY11	FY12	FY13
ILC C+CM	CM1	CM2		CM3 (Type IV)	CM4 (PX)	rf unit sys tst
ILC RF Power		MBK	PFN modulator			
SRF Infra.				NML complete		CAF complete (1 CM/month)
HINS				60 MeV beam tests		
Project X		CDR		FE decision Final gradient decision		rf unit sys tst

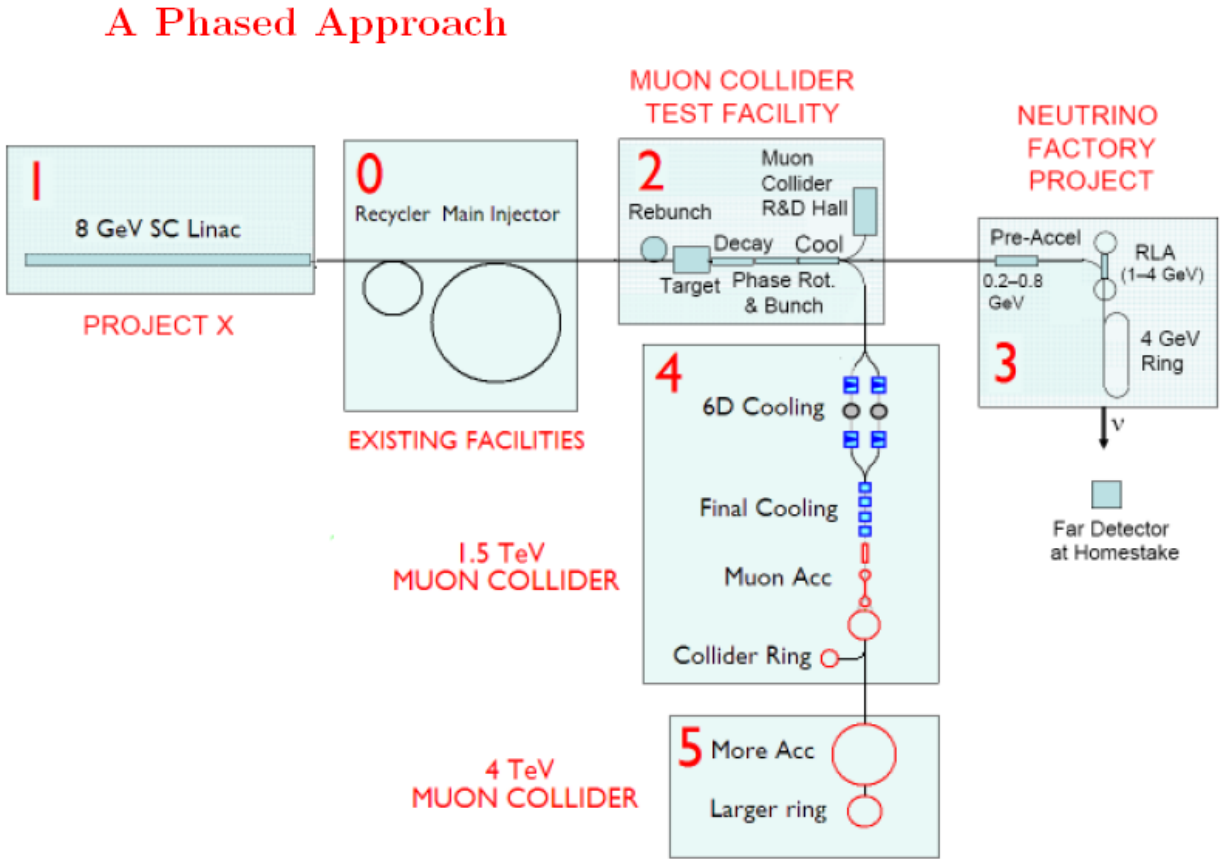
Relationship to Other Programs:
Muons

- Project X shares many features with the proton driver required for a Neutrino Factory or Muon Collider
  - IDS-NF shows 4 MW @ 10± 5 GeV proton energy
  - Muon Collider requires similar power, but requires charge consolidated into a single bunch

- Natural evolutionary schemes through neutrino superbeams:

  NOνA$\rightarrow$ Very Long Baseline$\rightarrow$ Neutrino Factory$\rightarrow$ Muon Collider
  - (see P5 presentations by Y-K. Kim and R. Palmer)

Relationship to Other Programs:
Muons: Possible Evolution (Palmer/P5)



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Project X RD&D Plan

Muon Facilities Joint Development Strategy

- Develop upgrade concept for the Project X linac aimed at 2-4 MW
  $\Rightarrow$ The ICD includes such a concept (up to 4 MW)
- Develop a performance specification for a Proton Driver supporting a Neutrino Factory and Muon Collider, consistent with Project X concepts.
  - Issues: Average beam power, repetition rate, particles/bunch, bunch intensity
  - These issues are likely to require a new storage ring downstream of the linac.
- Develop a conceptual design for the NF/MC Proton Driver based on Project X linac and downstream accumulation/packaging ring(s).
- Coordinate with NFMCC, MCTF, and IDS_NF

Project X RD&D Plan
Collaboration Plan

- The intention is to organize and execute the RD&D Program via a multi-institutional collaboration.
  - Goal is to assign collaborators complete sub-projects ⇒ responsibility for design, engineering, cost estimating, and potentially construction if/when Project X proceeds.
  - Project X R&D Collaboration to be established via a Collaboration Memorandum of Understanding (MOU) outlining basic goals of the collaboration, and the means of organizing and executing the work.
  - It is anticipated that the Project X RD&D Program will be undertaken as a “national project with international participation”. Expectation is that the same structure of MOUs described above would establish the participation of international laboratories.

Project X RD&D Plan
Collaboration Plan

- A draft MOU covering the period through CD-2 is currently circulating for comment among the following potential U.S. laboratory collaborators:
  - ANL
  - BNL
  - Cornell
  - LBNL
  - ORNL/SNS
  - MSU
  - TJNAF
  - SLAC
  - ILC/GDE
- Hope to finalize/sign at the initial Project X Collaboration Meeting on November 21-22, 2008 at Fermilab
  - There will be international participation in the meeting.

Summary

- Project X is central to Fermilab's strategy for future development of the accelerator complex:
  - Energy Frontier: Aligned with ILC technology development; preserves Fermilab as potential site for ILC or a Muon Collider
  - Intensity Frontier: Ultimate goal is 2 MW beam to very long baseline neutrino experiment and >1 MW to rare processes experiments; preserves Fermilab as potential site for a Neutrino Factory
- An initial configuration has been established meeting requirements as specified in the P5 report
  - >2 MW at 60-120 GeV, simultaneous with >600 kW at 8 GeV
- The initial configuration can be upgraded to 2-4 MW at 8 GeV
- Project X RD&D plan developed (through CD-2)
  - Integrates effort on Project X, ILC, SRF, and HINS
- Collaboration being formed