

Project X at Fermilab: Prospects and Plans

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

Project X website: <http://projectx.fnal.gov/>

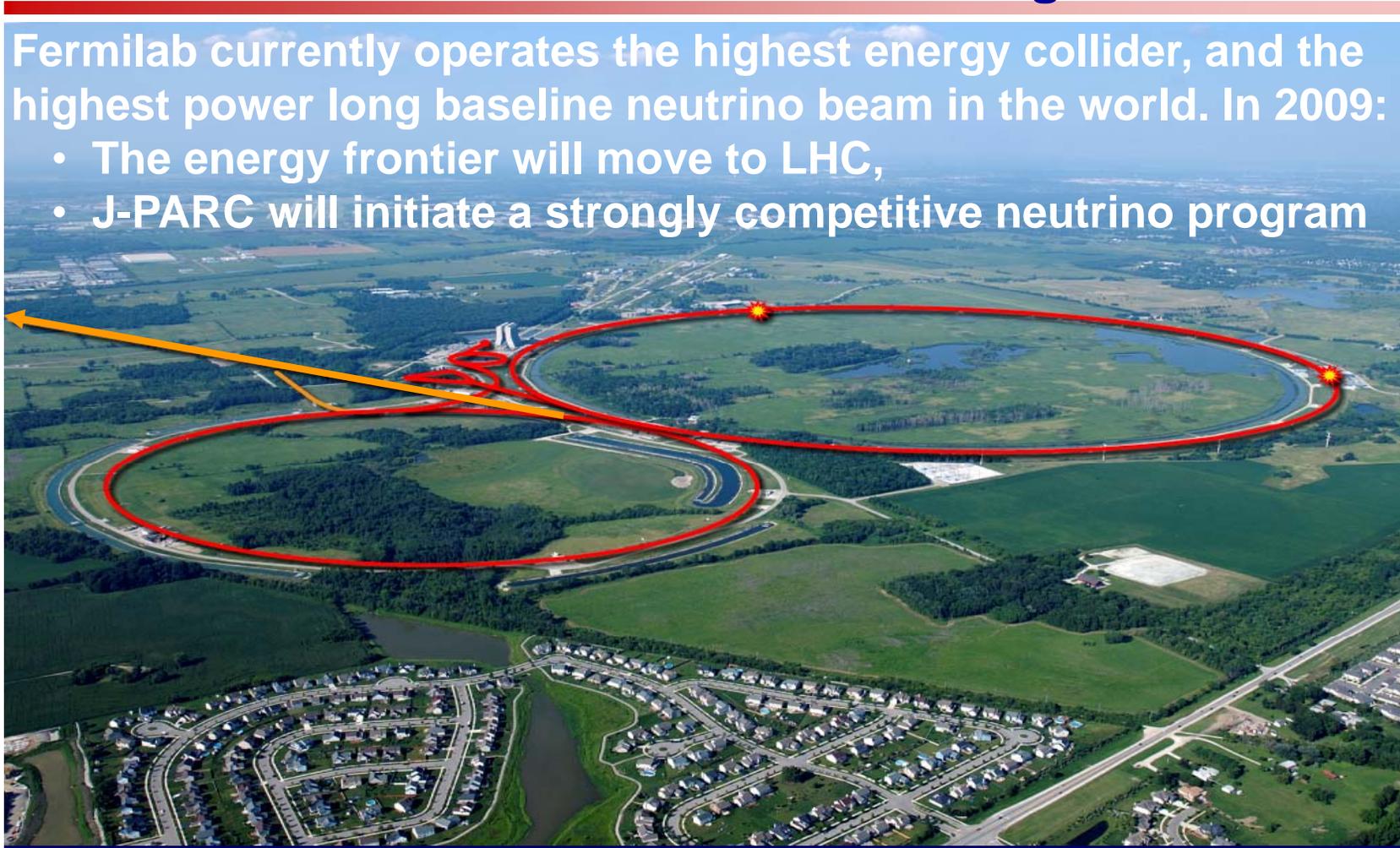
Strategic Context

Fermilab in the World Program



Fermilab currently operates the highest energy collider, and the highest power long baseline neutrino beam in the world. In 2009:

- The energy frontier will move to LHC,
- J-PARC will initiate a strongly competitive neutrino program

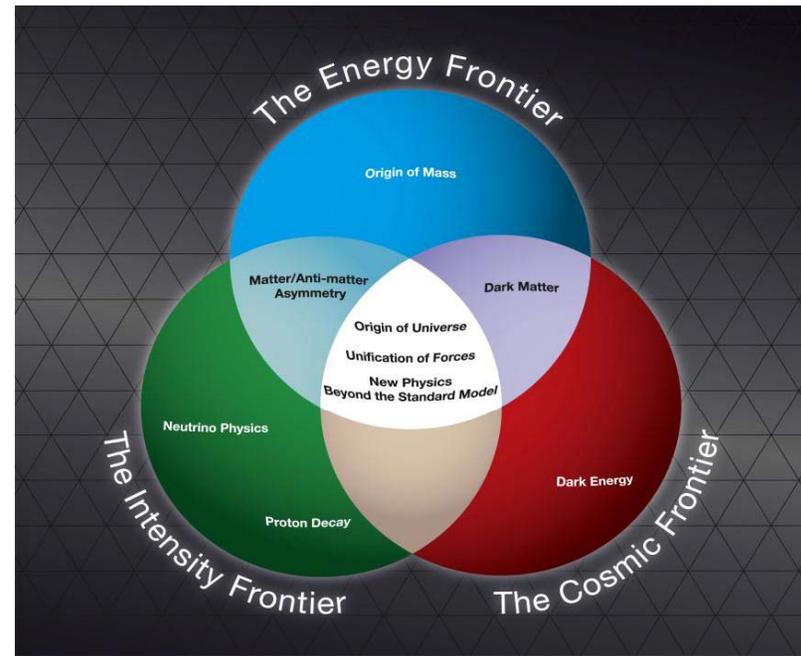


Strategic Context

Fermilab and the U.S. Strategic Plan



- The U.S. community, through its HEPAP/P5 process, has adopted a strategic plan for the U.S. based on initiatives on three frontiers
- Fermilab is fully aligned with the U.S. plan
 - In the coming decade Fermilab will remain the sole site for accelerator-based Elementary Particle Physics in the U.S.
 - Development of accelerator facilities for the Energy and Intensity Frontiers





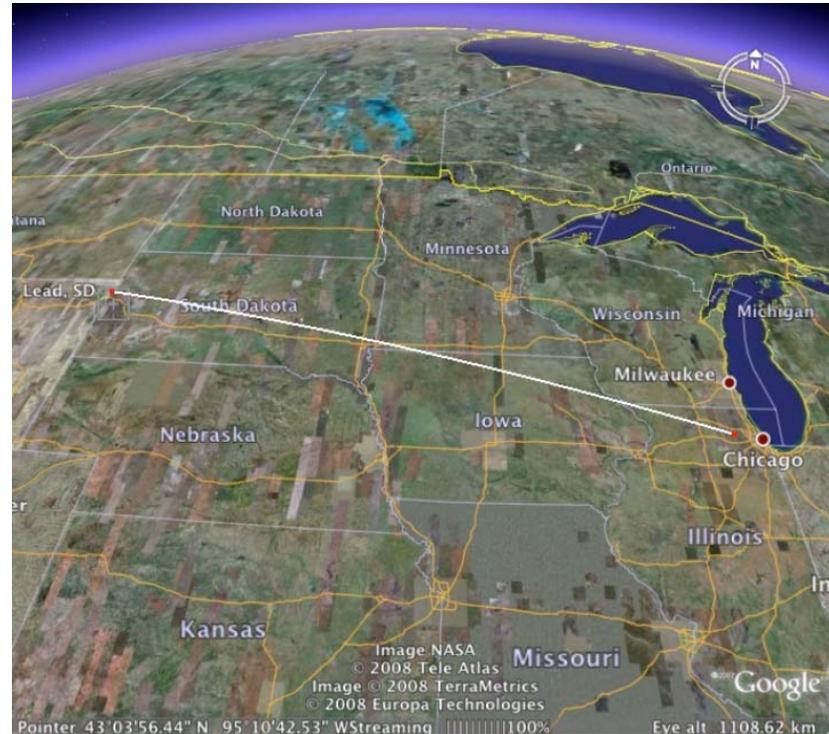
- Energy Frontier
 - “The panel recommends for the near future a broad accelerator and detector R&D program for lepton colliders that includes continued R&D on ILC ... in support of the international effort”
 - “The panel also recommends R&D for alternative accelerator technologies, to permit an informed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



- A multi-MW Proton Source (aka Project X) is the lynchpin of Fermilab's strategy for future development of the accelerator complex :
 - Energy Frontier:
 - Tevatron → ILC or Muon Collider as options for the Fermilab site
 - Future energy frontier facilities aligned with Project X technology development
 - Intensity Frontier:
 - NuMI → NOvA → LBNE/ $\mu 2e$ → Project X → NuFact
 - World leading program based on continuously increasing sensitivity to neutrino sector physics and other beyond the standard model phenomena

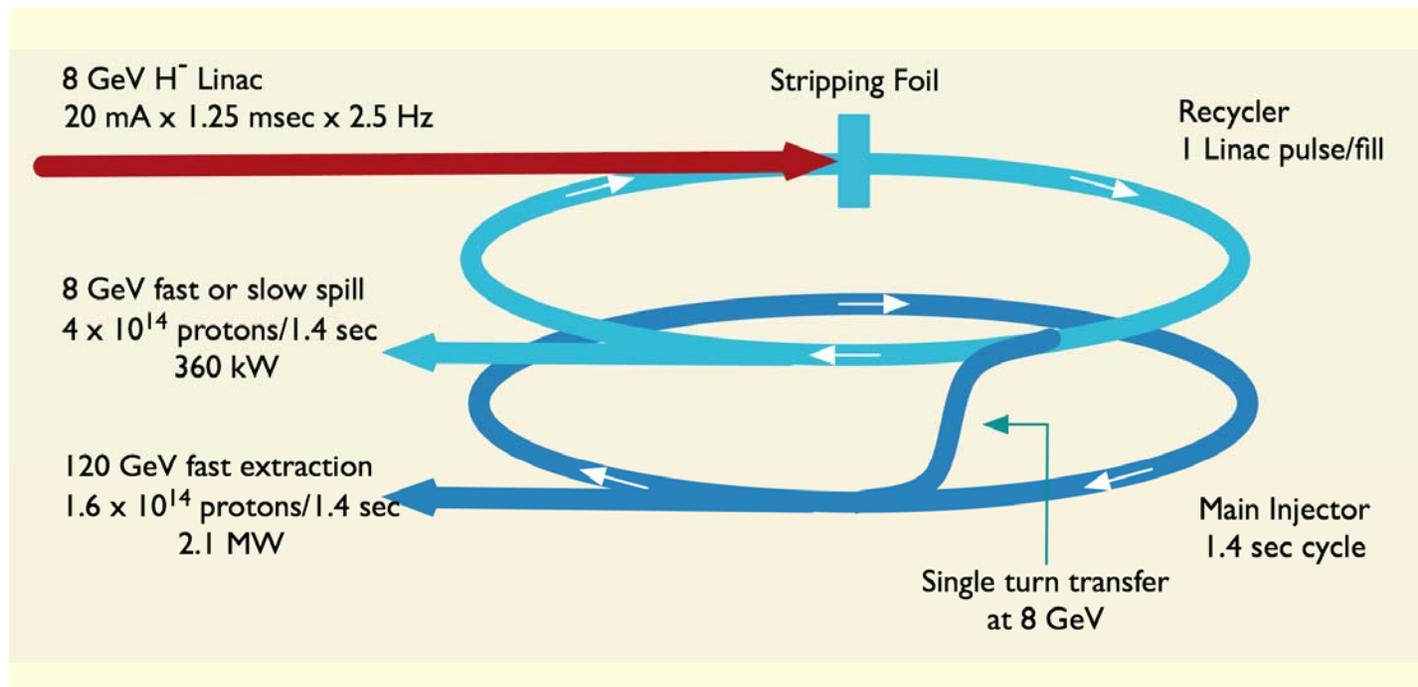


- P5 report defined facility requirements:
 - A neutrino beam for long baseline neutrino oscillation experiments.
 - 2 MW protons at 60 - 120 GeV
 - High intensity 8 GeV protons for kaon and muon based precision experiments
 - Simultaneous operations with the neutrino program.
 - A path toward a muon source for a possible future neutrino factory and/or a muon collider at the Energy Frontier.
 - Requires upgrade potential to 2-4 MW at 8 GeV.





- Project X Design Criteria
 - 2 MW of beam power over the range 60 – 120 GeV;
 - Simultaneous with at least 150 kW of beam power at 8 GeV;
 - Compatibility with future upgrades to 2-4 MW at 8 GeV



Initial Configuration

Performance Goals



Linac

Particle Type	H ⁻	
Beam Kinetic Energy	8.0	GeV
Particles per pulse	1.6×10^{14}	
Linac pulse rate	2.5	Hz
Beam Power	500	kW

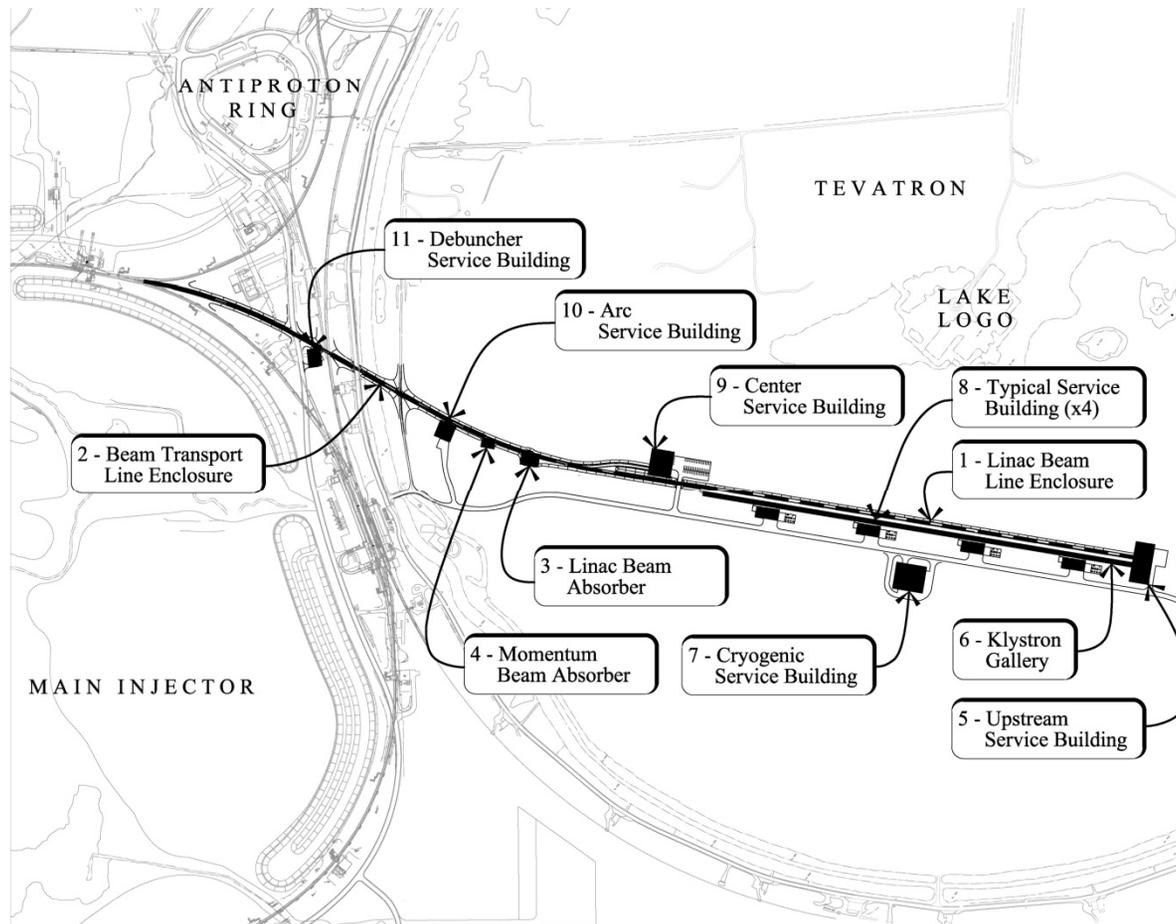
Recycler

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	360	kW

Main Injector

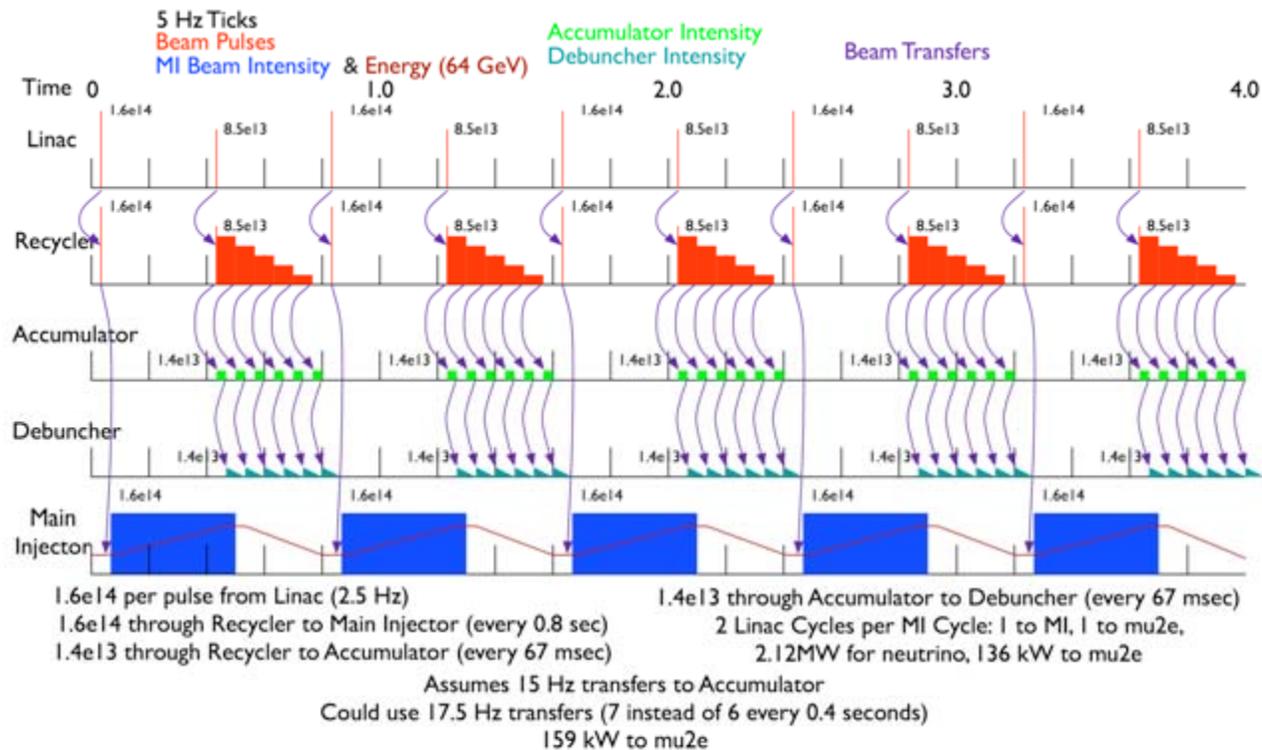
Beam Kinetic Energy (maximum)	120	GeV
Cycle time	1.4	sec
Particles per cycle	1.6×10^{14}	
Beam Power at 120 GeV	2100	kW

Initial Configuration Provisional Siting





- Operating scenario for 64 GeV (2.1 MW)
 - 136 kW at 8 GeV to mu2e experiment in parallel





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- The primary goal of the Research, Design, and Development (RD&D) program is to complete a fully developed baseline scope, cost estimate, and schedule in 2012 (CD-2).
 - Includes technical component development;
 - Undertaken by a multi-institutional collaboration capable of executing both the RD&D plan and the follow-on construction project.
 - **Secondary goals:**
 - Coordinate Project X and ILC scrf development programs;
 - 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.



- Linac (325 MHz)
 - Front end: Peak current 32 mA x 1.25 msec x 2.5 Hz
 - Consistent with SNS performance
 - RF control of multiple accelerating structures from single klystron
 - High speed chopping (325 MHz)
 - Variable chopping patterns
 - Consideration of warm vs. cold front end
 - 30-60 MeV cold front end (currently under development)
- Linac (1300 GHz)
 - 32 mA peak (20 mA average) x 1.25 msec x 2.5 Hz
 - 3 times the charge/pulse of ILC
 - 25 MV/m gradient
 - RF control of multiple accelerating structures from single klystron



- Beam Transfer Line and Injection
 - H⁻ transport without stripping
 - Cryogenically cooled beam pipe
 - Loss control and mitigation
 - Multi-turn injection
 - Transverse and longitudinal painting
 - Losses
 - Foil lifetime
- Recycler/Main Injector
 - Space-charge
 - e-cloud
 - Other collective instabilities

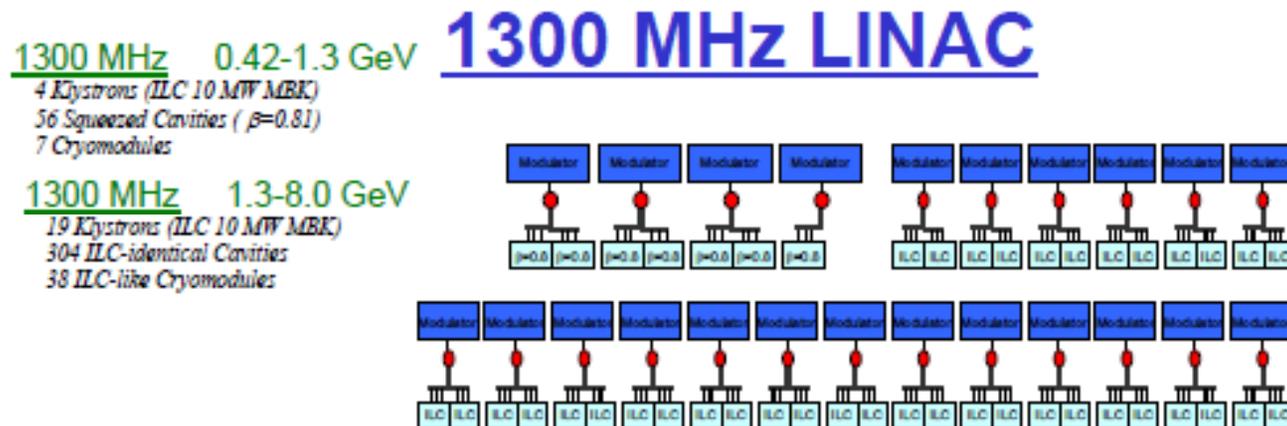
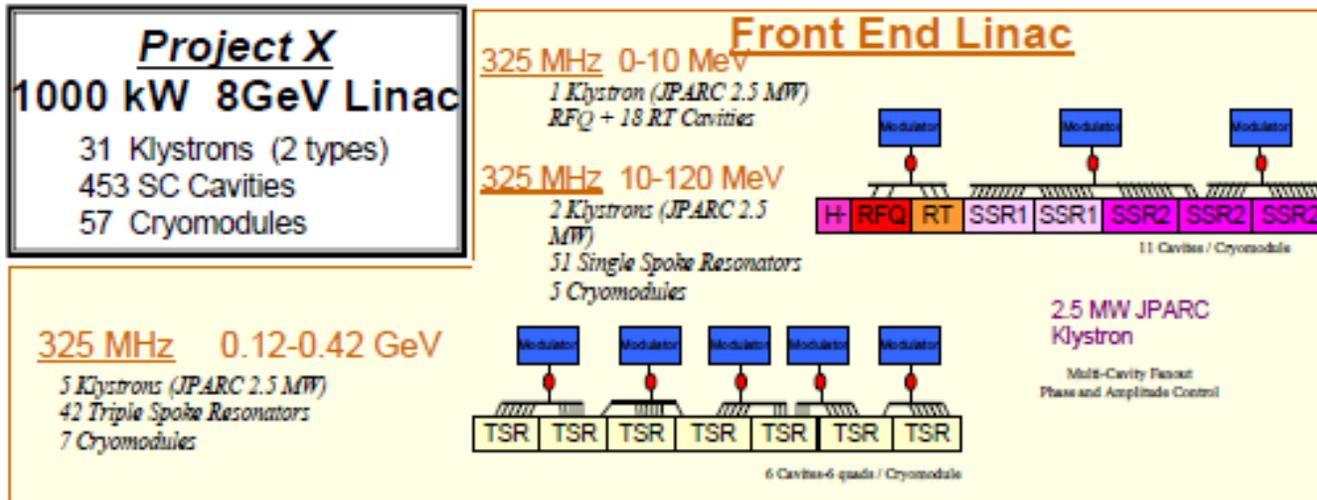


- Develop an Initial Configuration Document
 - Released V1.1 on 3/15/09: (available at <http://projectx.fnal.gov>)
- Revise/update the RD&D Plan
 - ⇒ Released V2.2 on 3/3/09
- Create a preliminary cost range estimate (based on ICD V1.1)
 - Completed and subject to Director's Review March 16-17, 2009
- Establish a multi-institutional collaboration for the RD&D phase
- Formally establish “mission need” (CD-0) in 2009
 - Based on: P5 mission definition, ICD, preliminary cost estimate
 - Coordinated with very long baseline and mu2e



- A multi-institutional collaboration is being formed for the RD&D phase
 - RD&D program undertaken as a “national project with international participation”;
 - Fermilab holds overall responsibility as host laboratory;
 - Recognize it would be natural for responsibilities to carry over into the construction phase.
- An MOU covering the RD&D phase is currently circulating for signatures among potential U.S. laboratory collaborators:
 - ANL
 - BNL
 - Cornell
 - LBNL
 - ORNL/SNS
 - MSU
 - TJNAF
 - SLAC
 - ILC/ART

Project X Technology Development Linac Layout



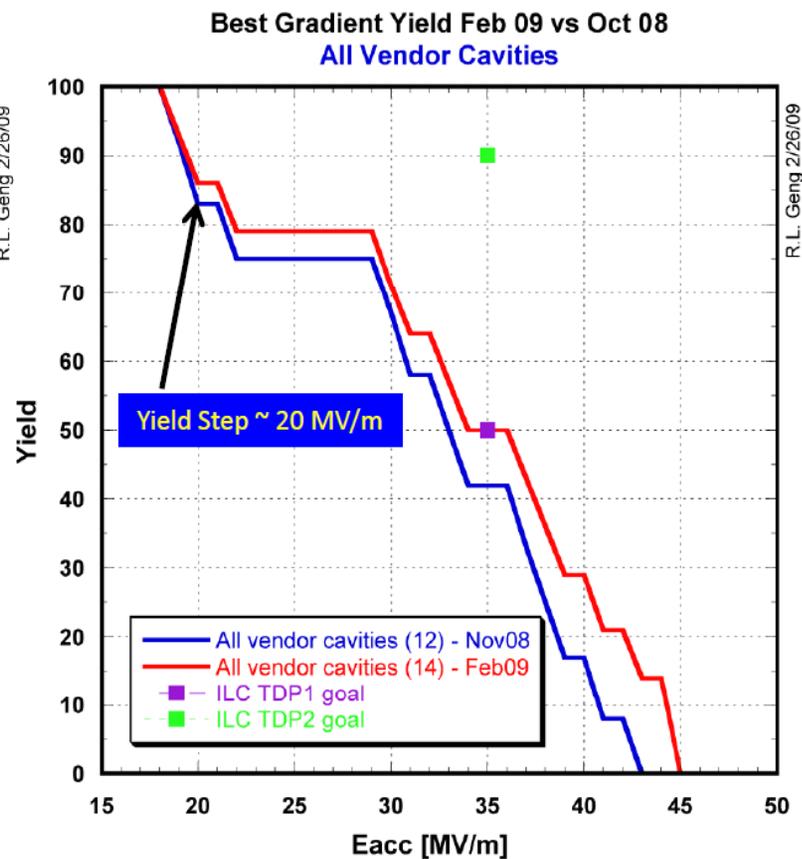
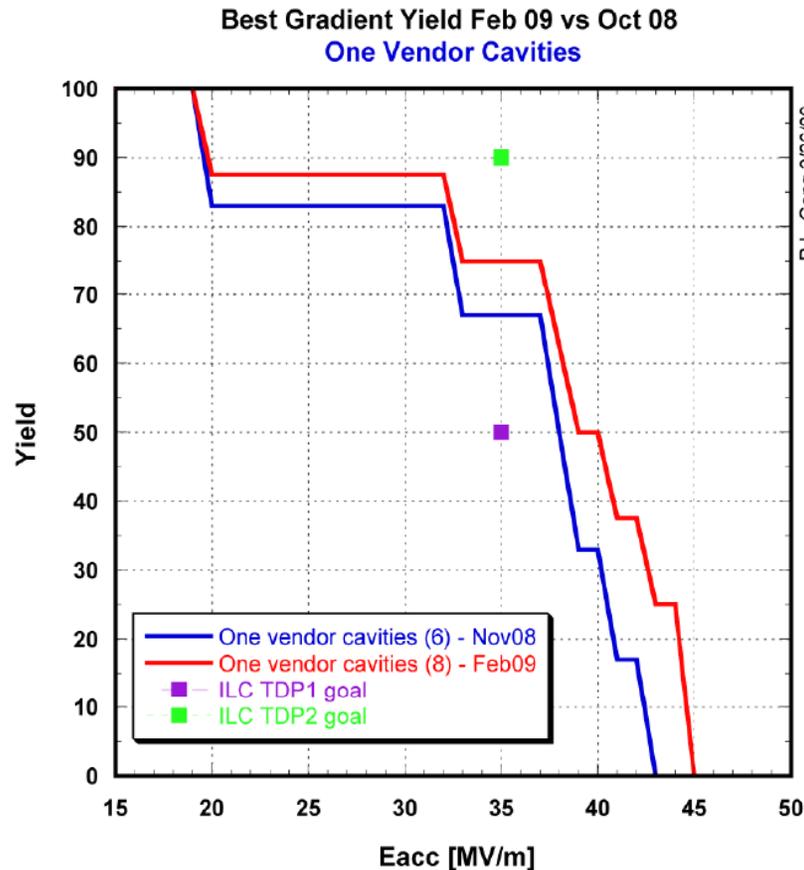


- 38 ILC-like cryomodules are required for Project X. In detail they will not be identical to ILC:
 - Beam current: $20 \text{ mA} \times 1.25 \text{ msec} \times 2.5 \text{ Hz}$
 - Focusing element required in each CM
 - Gradient: 25 MV/m
- Close coordination with ILC/GDE during development phase
 - Strategy based on ILC “plug compatibility”
 - Joint cryomodule development program
 - Shared facilities for assemble and testing
 - ILCTA:rf unit beam test



Project X Technology Development

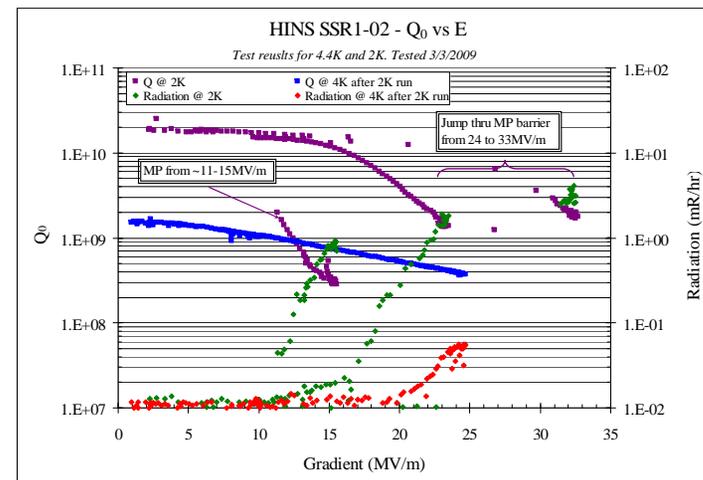
Summary of 9-cell Vertical Tests in U.S.



Project X Technology Development Front End



- Fermilab and collaborators have been developing front end technology beyond the requirements of Project X initial goals:
 - 60 MeV front end @ 27 mA × 1 msec × 10 Hz
 - 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



Project X Technology Development Muon Joint Development Strategy



- Project X shares many features in common with the proton driver required for a Neutrino Factory or Muon Collider
 - IDS-NF shows 4 MW @ 10 ± 5 GeV proton energy
 - Project X linac: 20 Hz upgrade = 4 MW @ 8 GeV
 - Muon Collider requires similar power, but requires charge consolidated into a single bunch
 - ⇒ Issues of peak and average beam power, repetition rate, bunch length will require new accumulation/compressor rings downstream of the linac
- Natural evolutionary schemes through neutrino superbeams:
NO_vA → LBNE → Project X → Neutrino Factory → Muon Collider
- Utilization of Project X as a front end for NF or MC coordinated with NFMCC, MCTF, and IDS_NF



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- 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: Supports a world leading program in neutrinos and rare processes; preserves Fermilab as potential Neutrino Factory site
 - An initial configuration has been established meeting requirements as specified in the P5 report
 - >2 MW at 60-120 GeV, simultaneous with >150 kW at 8 GeV
 - The facility could be constructed over the period ~2014 - 2018
 - The initial configuration can be upgraded to 2-4 MW at 8 GeV
 - R&D integrates effort on Project X, ILC, SRF, and Muon Facilities
 - Collaboration being formed
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Multi-MW Proton Facility – Project X

NuMI (NOvA)

DUSEL

8 GeV ILC-like Linac

Recycler: 100-200 kW (8 GeV) for kaons, muons, ...
Main Injector: >2 MW (60-120 GeV) for neutrinos

