Project X at Fermilab: Prospects and Plans

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Outline

- 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

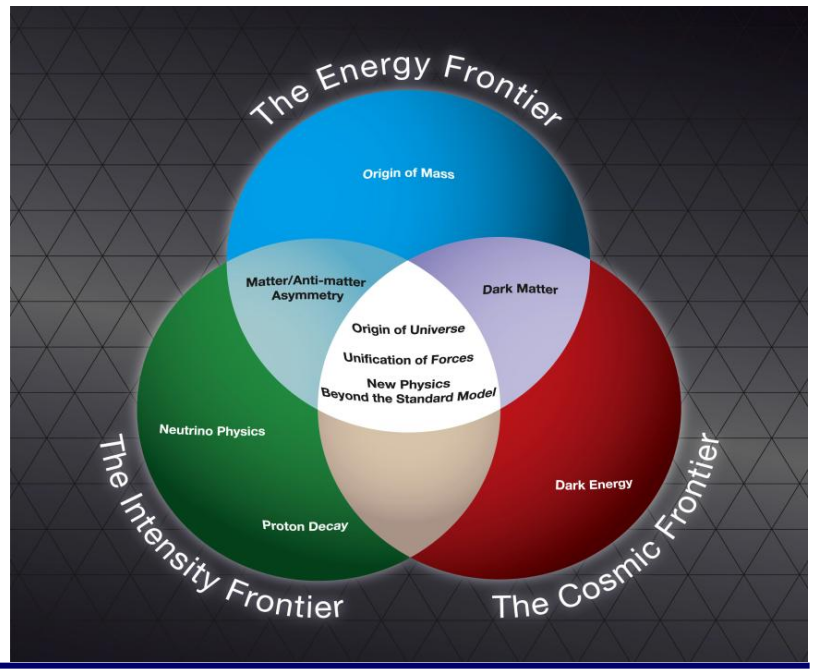
Fermilab currently operates the highest energy collider, and the highest power long baseline neutrino beam in the world. In 2009:

- **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



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… "

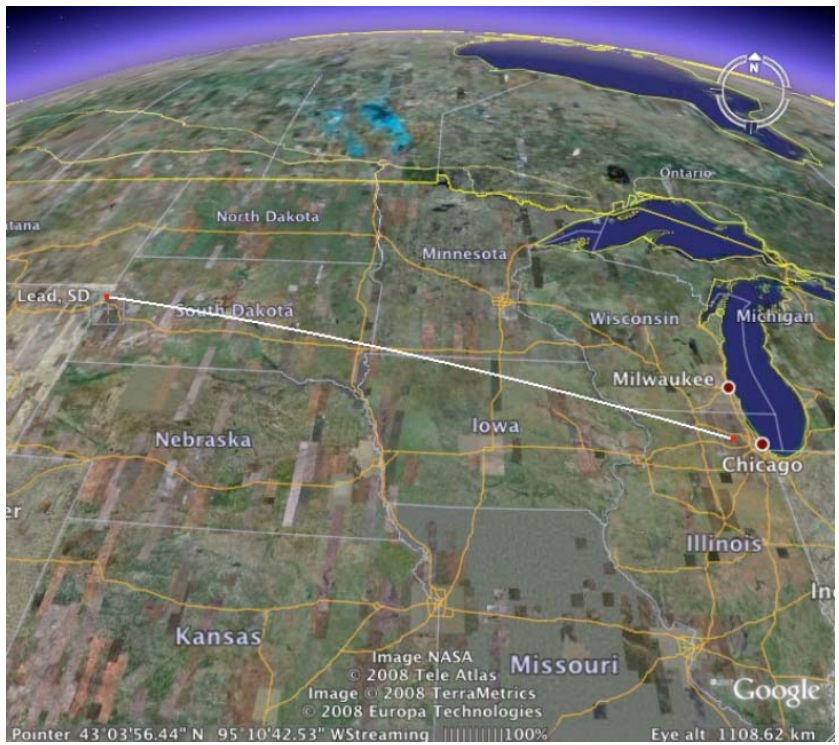
Strategic Context
Evolution of the Accelerator Complex

- 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→ NOνA→ LBNE/μ2e→ Project X→ NuFact
    - World leading program based on continuously increasing sensitivity to neutrino sector physics and other beyond the standard model phenomena

Goals and Configuration

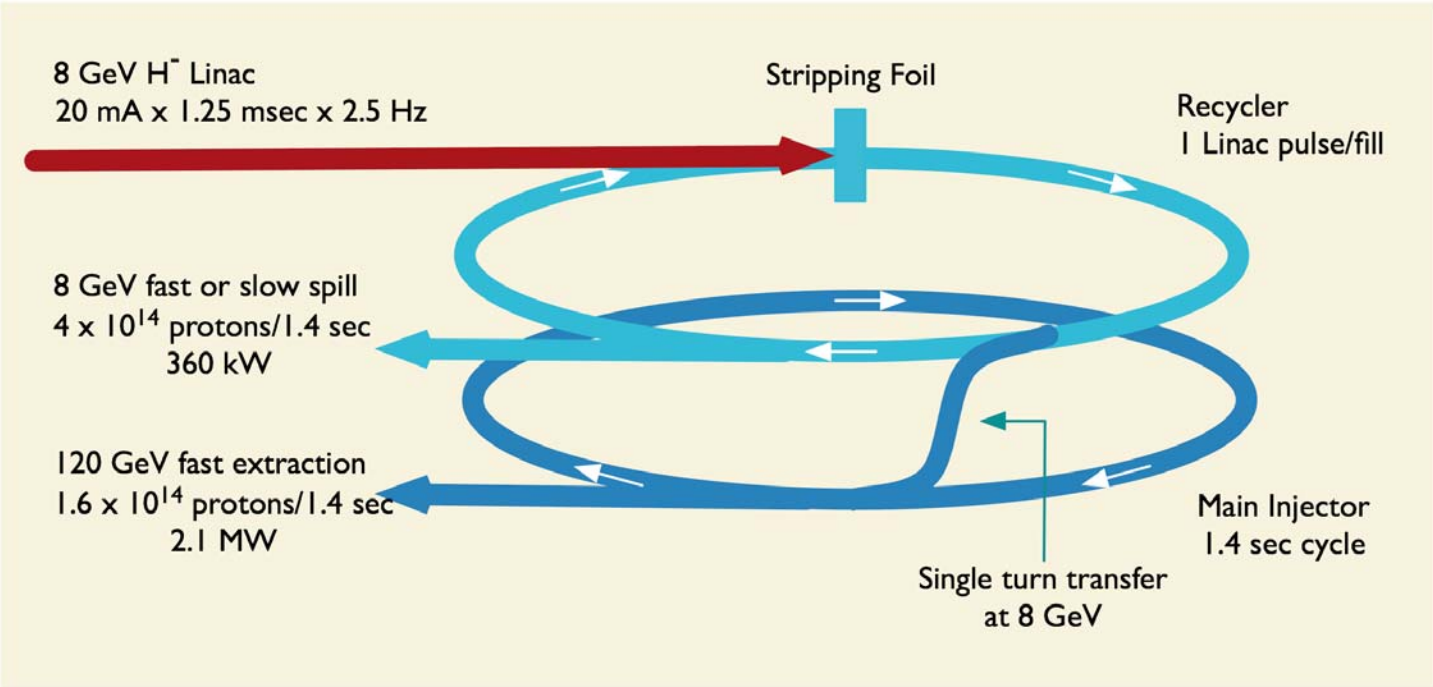
Mission Need

- 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.



Initial Configuration

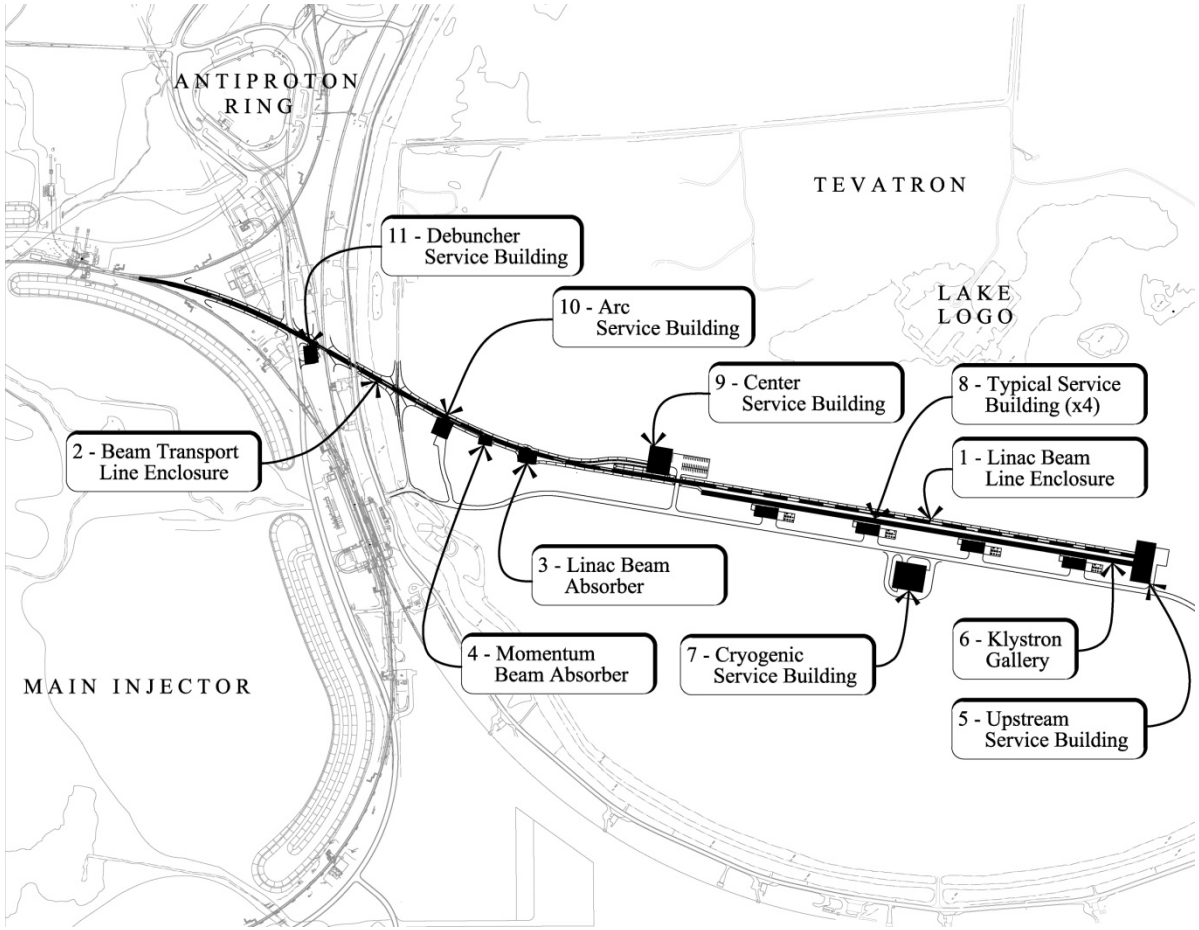
- Project X Design Criteria
  - 2 MW of beam power over the range 60 – 120 GeV;
  - Simultaneous with at least 150 kW of beam power at 8 GeV;
  - Compatibility with future upgrades to 2-4 MW at 8 GeV



Initial Configuration
Performance Goals

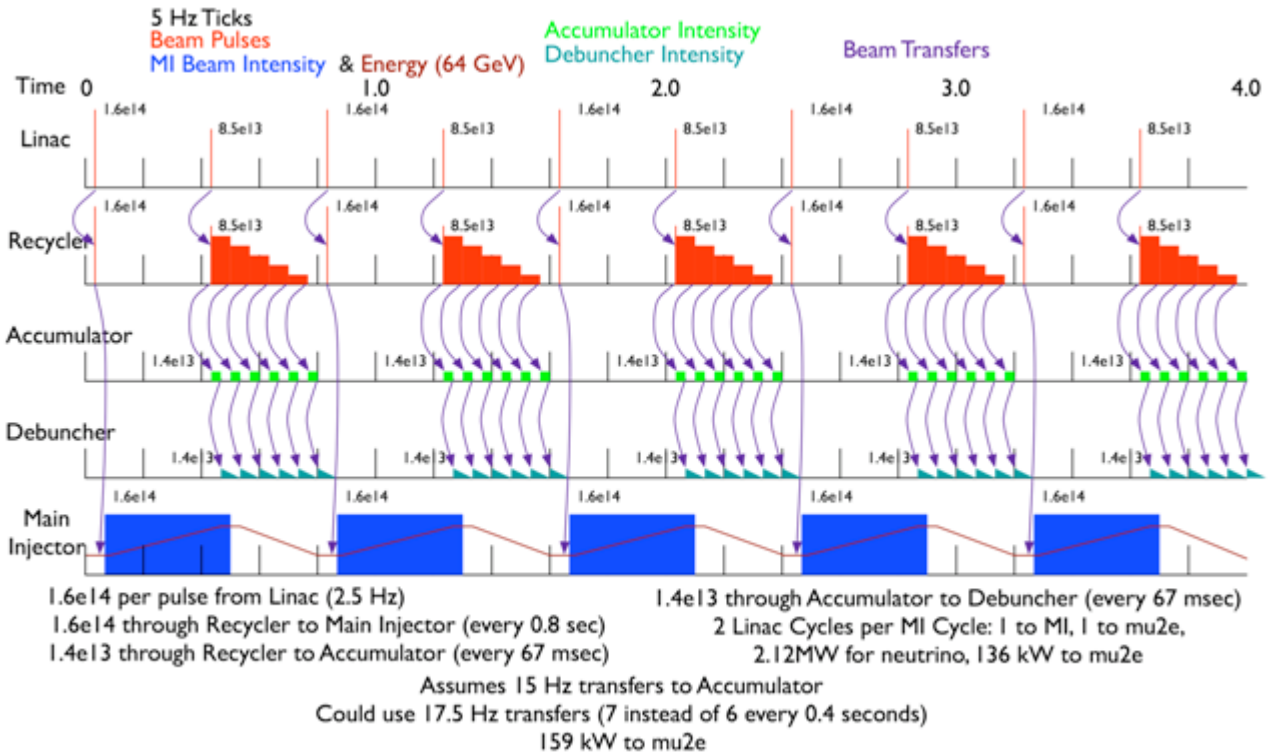
Linac		
Particle Type	H^-	
Beam Kinetic Energy	8.0	GeV
Particles per pulse	1.6×10^{14}	
Linac pulse rate	2.5	Hz
Beam Power	500	kW
Recycler		
Particle Type	protons	
Beam Kinetic Energy	8.0	GeV
Cycle time	1.4	sec
Particles per cycle to MI	1.6×10^{14}	
Particles per cycle to 8 GeV program	1.6×10^{14}	
Beam 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



Initial Configuration
Operating Scenarios

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



RD&D Plan

- 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.

Project X RD&D Plan
Technology Challenges

- 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

Project X RD&D Plan
Technology Challenges

- 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

RD&D Plan
Near-term Strategy

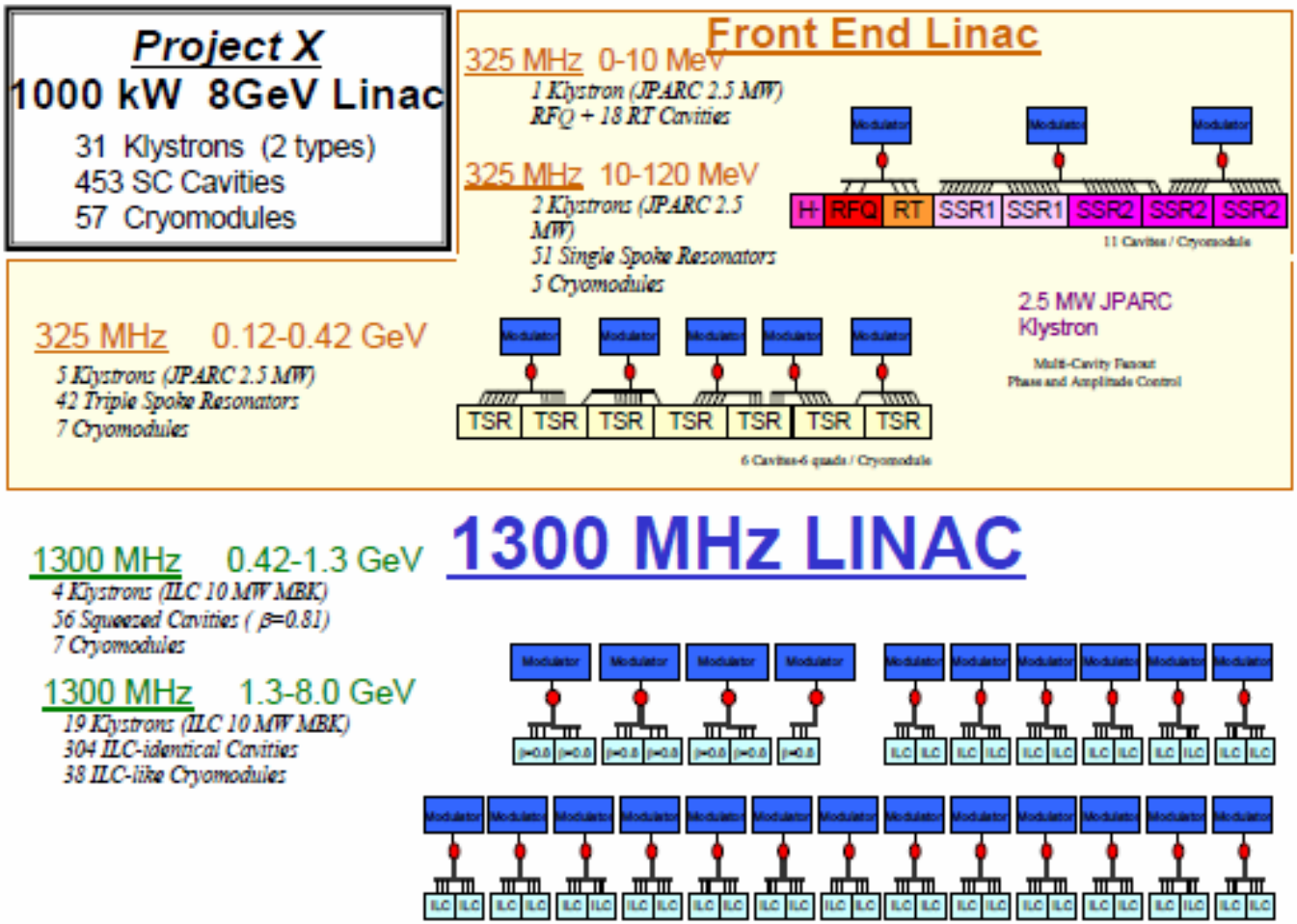
- Develop an Initial Configuration Document
  - Released V1.1 on 3/15/09: (available at http://projectx.fnal.gov)
- Revise/update the RD&D Plan
  - ⇒ Released V2.2 on 3/3/09
- Create a preliminary cost range estimate (based on ICD V1.1)
  - Completed and subject to Director's Review March 16-17, 2009
- 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

RD&D Plan
Collaboration Plan

- 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

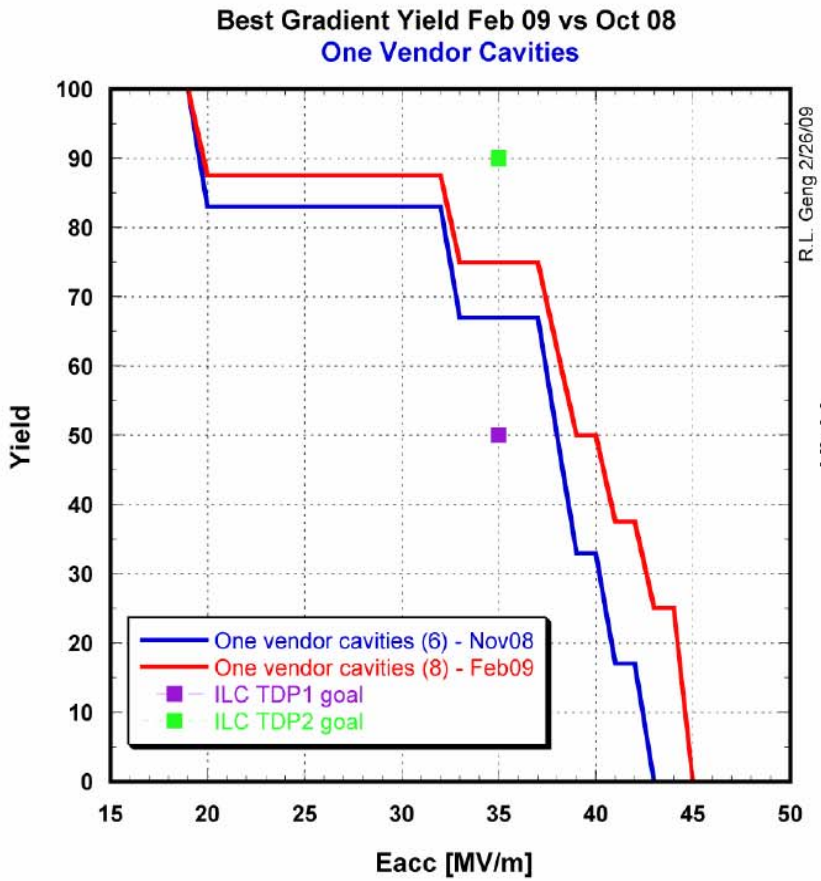


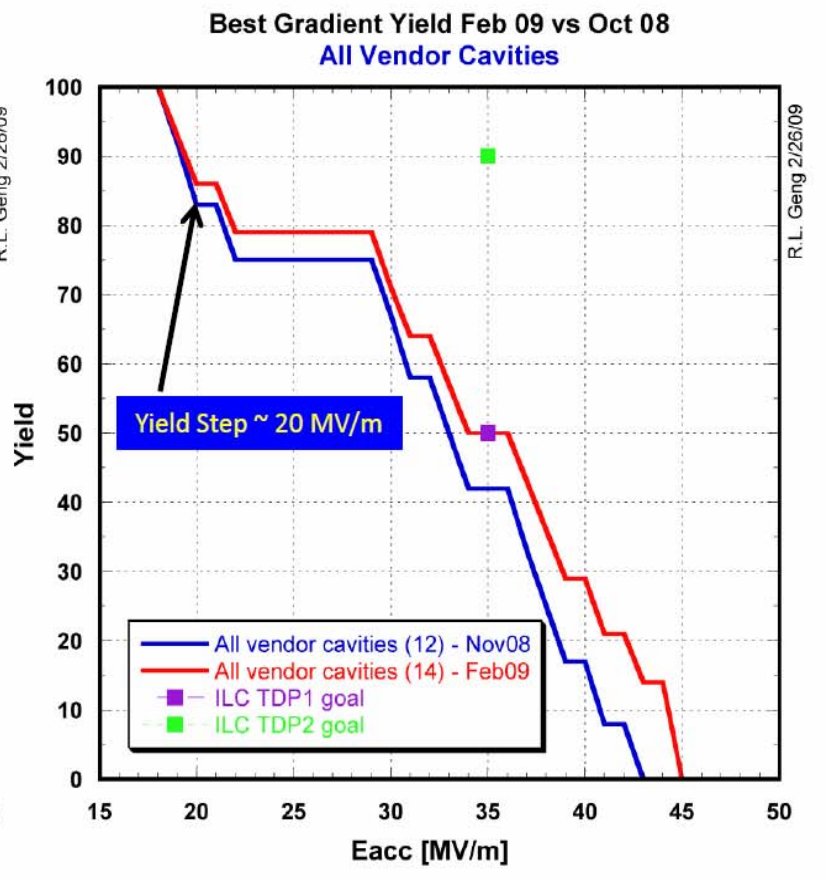
Technology Development
ILC/SRF Joint Development Strategy

- 38 ILC-like cryomodules are required for Project X. In detail they will not be identical to ILC:
  - Beam current: 20 mA × 1.25 msec × 2.5 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

Technology Development

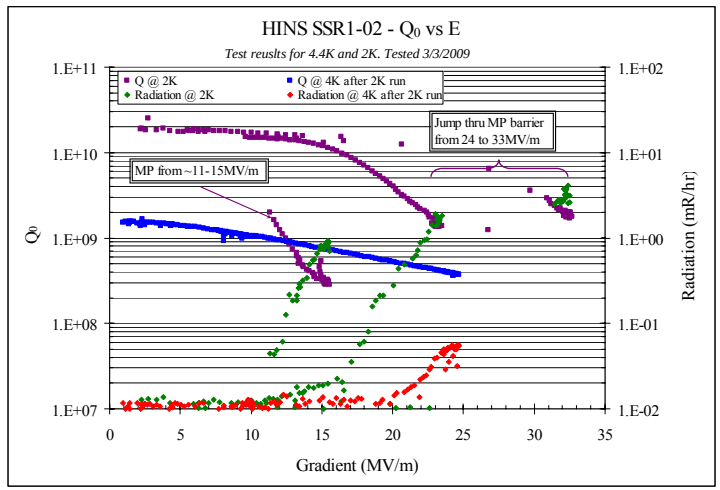
Summary of 9-cell Vertical Tests in U.S.





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



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:

  NOνA$\rightarrow$ LBNE $\rightarrow$ Project X $\rightarrow$ Neutrino Factory$\rightarrow$ Muon Collider
- Utilization of Project X as a front end for NF or MC coordinated with NFMCC, MCTF, and IDS_NF

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: 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

Multi-MW Proton Facility – Project X