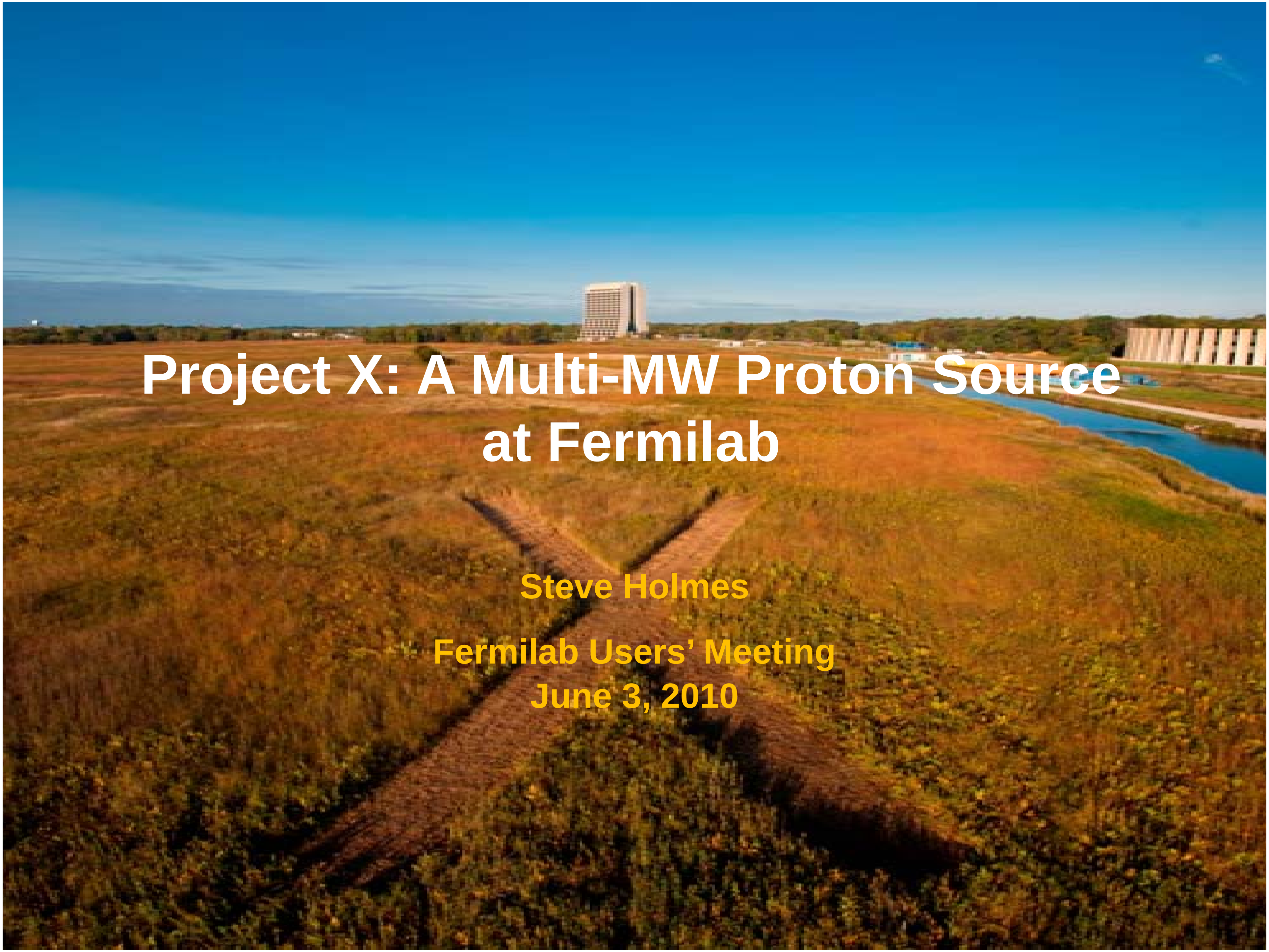


Project X: A Multi-MW Proton Source at Fermilab

Steve Holmes

Fermilab Users' Meeting
June 3, 2010

Outline

- Evolution of the Fermilab Complex
- Project X Goals and Initial Configuration(s)
- Project X R&D Program
- Relationships to other Programs
- Strategy

Project X website: http://www.fnal.gov/pub/projectx/

Project X

Strategic Context: Fermilab and the World Program

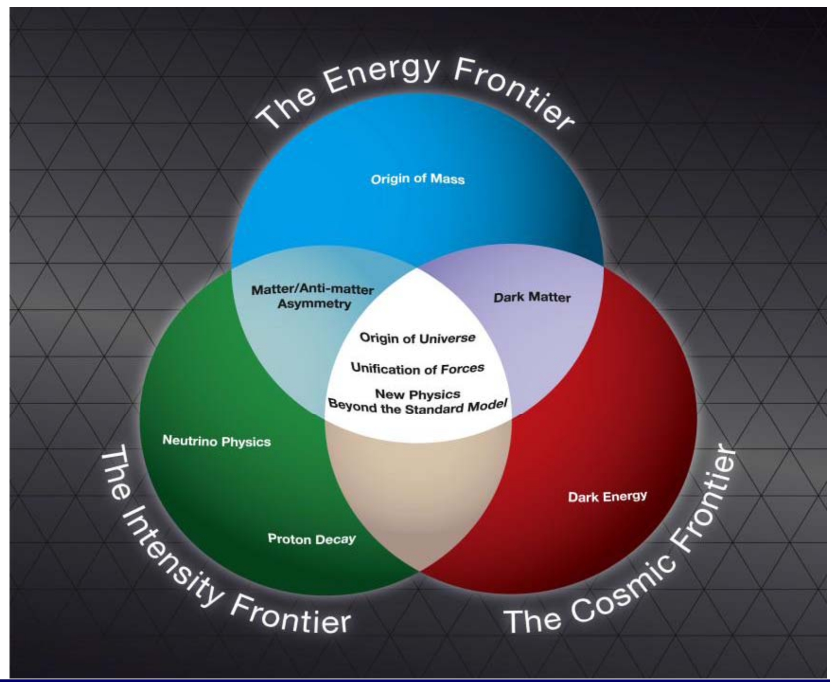
The Tevatron has now ceded the energy frontier to LHC
- Operations at 2 TeV will continue through September 2011

Fermilab operates the highest power long baseline neutrino beam in the world.
- J-PARC is initiating a competitive program

Fermilab Long Range Plan

Fermilab is the sole remaining U.S. laboratory providing facilities in support of accelerator-based Elementary Particle Physics

⇒ ***The Fermilab strategy is to mount a world-leading program at the <u>intensity frontier</u>, while using this program as a bridge to an <u>energy frontier</u> facility beyond LHC in the longer term.***

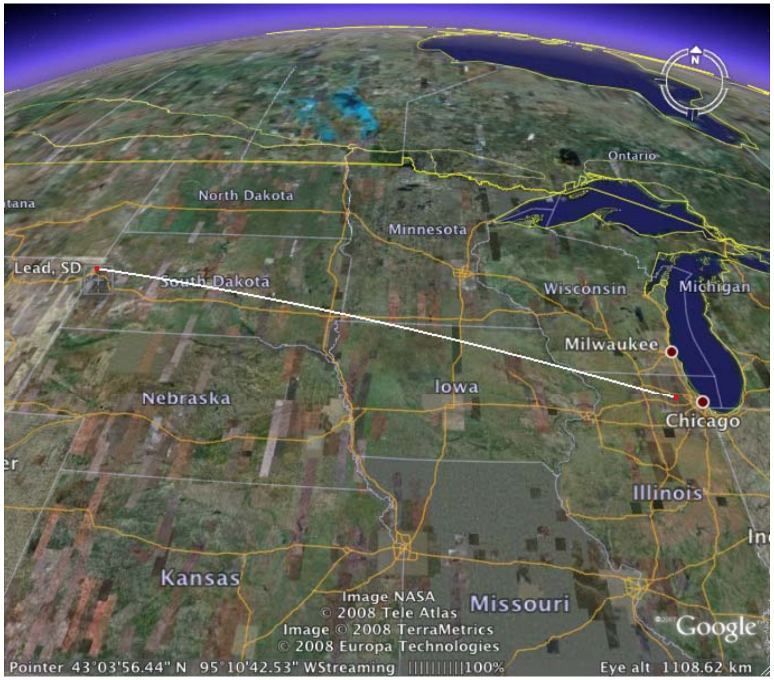


Evolution of the Fermilab Accelerator Complex

- A multi-MW Proton Source, Project X, is the linchpin of Fermilab's strategy for future development of the accelerator complex.
- Project X provides long term flexibility for achieving leadership on the intensity and energy frontiers
  - Intensity Frontier:
    NuMI→ NOνA→ LBNE/mu2e→ Project X → Rare Processes → NuFact
    - Continuously evolving world leading program in neutrino and rare processes physics; opportunities for applications outside EPP
  - Energy Frontier:
    Tevatron → ILC or Muon Collider
    - Technology alignment
    - Fermilab as host site for ILC or MC

Design Criteria

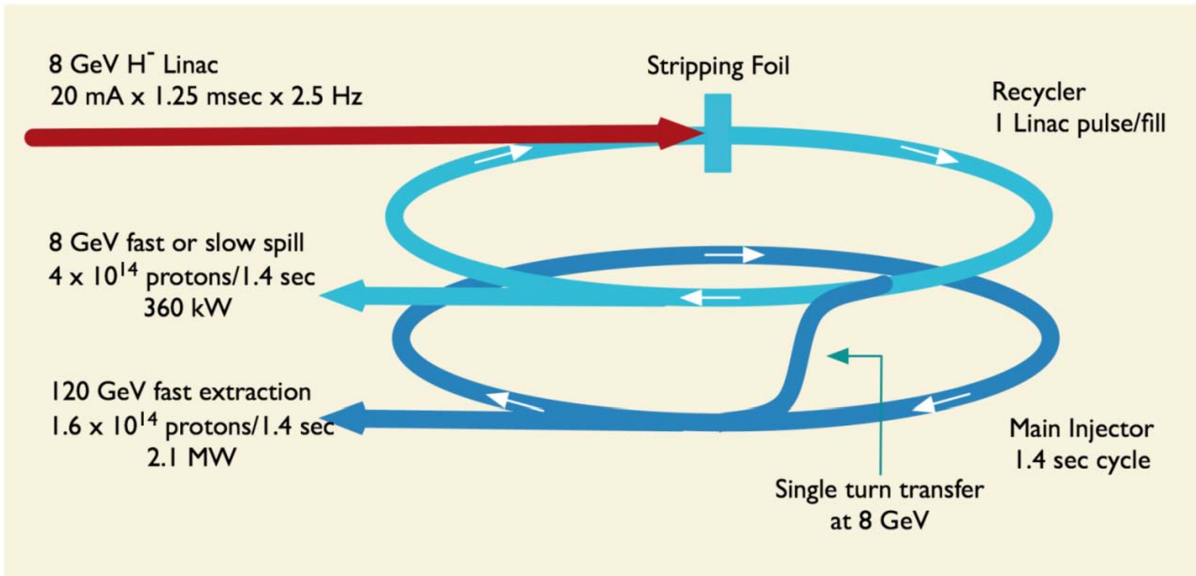
- A neutrino beam for long baseline neutrino oscillation experiments
  - 2 MW proton source at 60-120 GeV



- High intensity, low energy protons for kaon and muon based precision experiments
  - Operations simultaneous with the neutrino program
- A path toward a muon source for a possible future Neutrino Factory and/or a Muon Collider
  - Requires upgrade potential to 2-4 MW at ~5-15 GeV.

Initial Configuration-1

- Initial Configuration-1



- Strong alignment with ILC technologies
- Initial Configuration Document-1 V1.1 released March 2009
  - Accompanying cost estimate ~$1.5B

Initial Configuration - 1
Issues

- IC-1 does a great job of meeting the long baseline neutrino mission, but…
- does not provide a strong platform for mounting a low energy rare processes program
  - The Recycler is ill-suited to providing high intensity slow spilled beam
  - The Debuncher appears limited to <150 kW in this mode
  - ⇒ We believe there is a fundamental limit on the amount of beam power that can be delivered via a resonant extraction system
  - Difficulties supporting multiple users with differing spill structure requirements

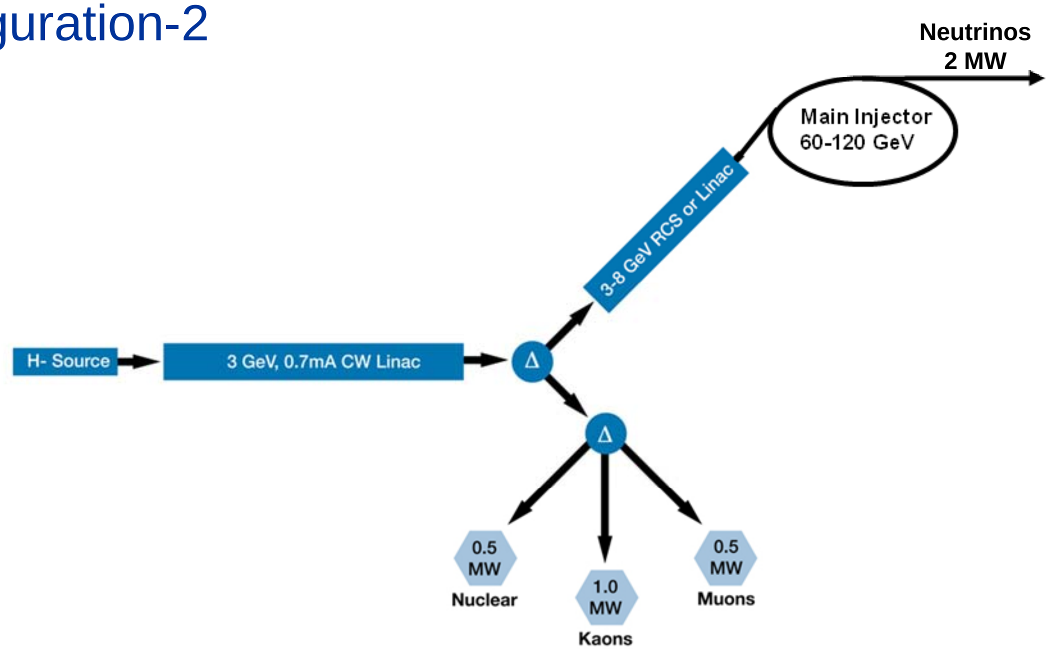
⇒ **These considerations led to the development of IC-2**

Accelerator Requirements: Rare Processes

	Proton Energy (kinetic)	Beam Power	Beam Timing
Rare Muon decays	2-3 GeV	>500 kW	1 kHz – 160 MHz
(g-2) measurement	8 GeV	20-50 kW	30- 100 Hz.
Rare Kaon decays	2.6 – 4 GeV	>500 kW	20 – 160 MHz. (<50 psec pings)
Precision K^0 studies	2.6 – 3 GeV	> 100 mA (internal target)	20 – 160 MHz. (<50 psec pings)
Neutron and exotic nuclei EDMs	1.5-2.5 GeV	>500 kW	> 100 Hz

Initial Configuration-2

- Initial Configuration-2



- 3 GeV CW linac provides greatly enhanced rare process program
  - 2-3 MW; flexible provision for beam requirements supporting multiple users
- Options for 3-8 GeV acceleration: RCS or (1.3 GHz) pulsed linac
  - Linac would be 1300 MHz with 4-5 msec pulse length
- Initial Configuration Document-2 in preparation for spring release

Initial Configuration-2
Performance Goals

Linac		
Particle Type	H^-	
Beam Kinetic Energy	3.0	GeV
Average Beam Current	1	mA
Linac pulse rate	CW	
Beam Power	3000	kW
Beam Power to 3 GeV program	2870	kW
RCS/Pulsed Linac		
Particle Type	protons/H^-	
Beam Kinetic Energy	8.0	GeV
Pulse rate	10	Hz
Pulse Width	0.002/4.3	msec
Cycles to MI	6	
Particles per cycle to MI	2.6×10^{13}	
Beam Power to 8 GeV program	200	kW
Main Injector/Recycler		
Beam Kinetic Energy (maximum)	120	GeV
Cycle time	1.4	sec
Particles per cycle	1.6×10^{14}	
Beam Power at 120 GeV	2200	kW

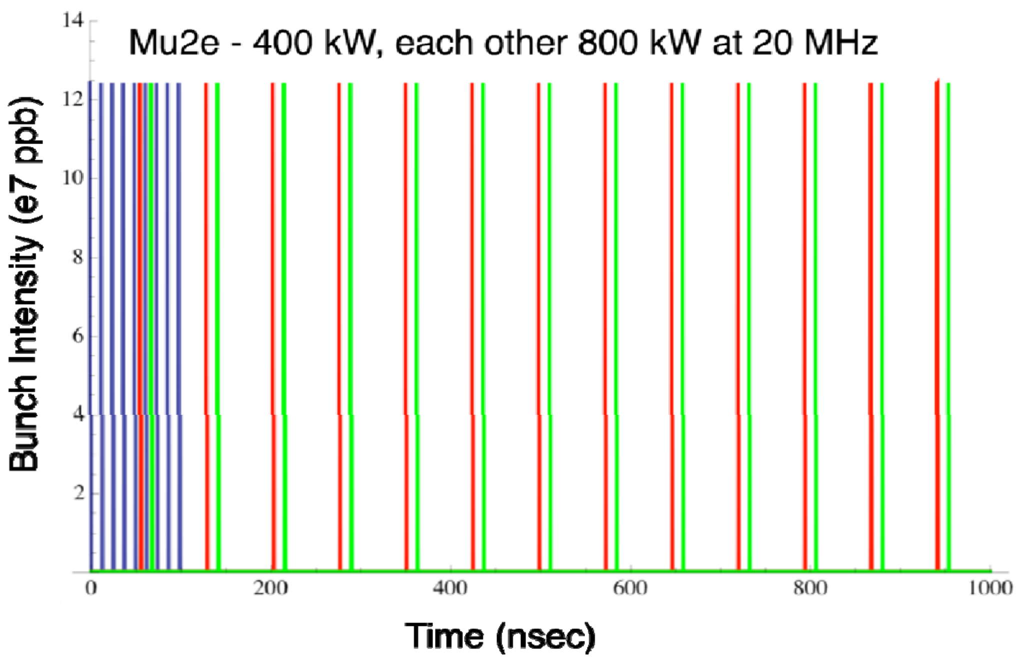
simultaneous

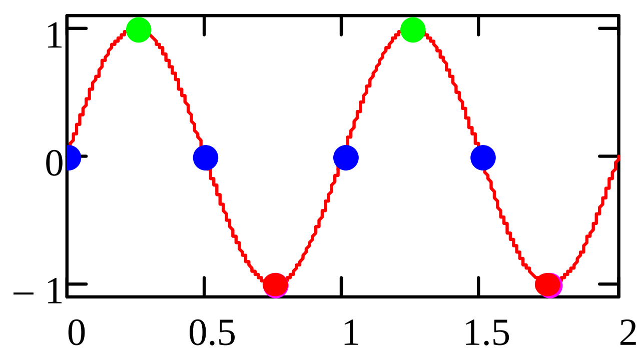
Project X

Initial Configuration-2
Operating Scenario

<u>1 μsec period at 3 GeV</u>

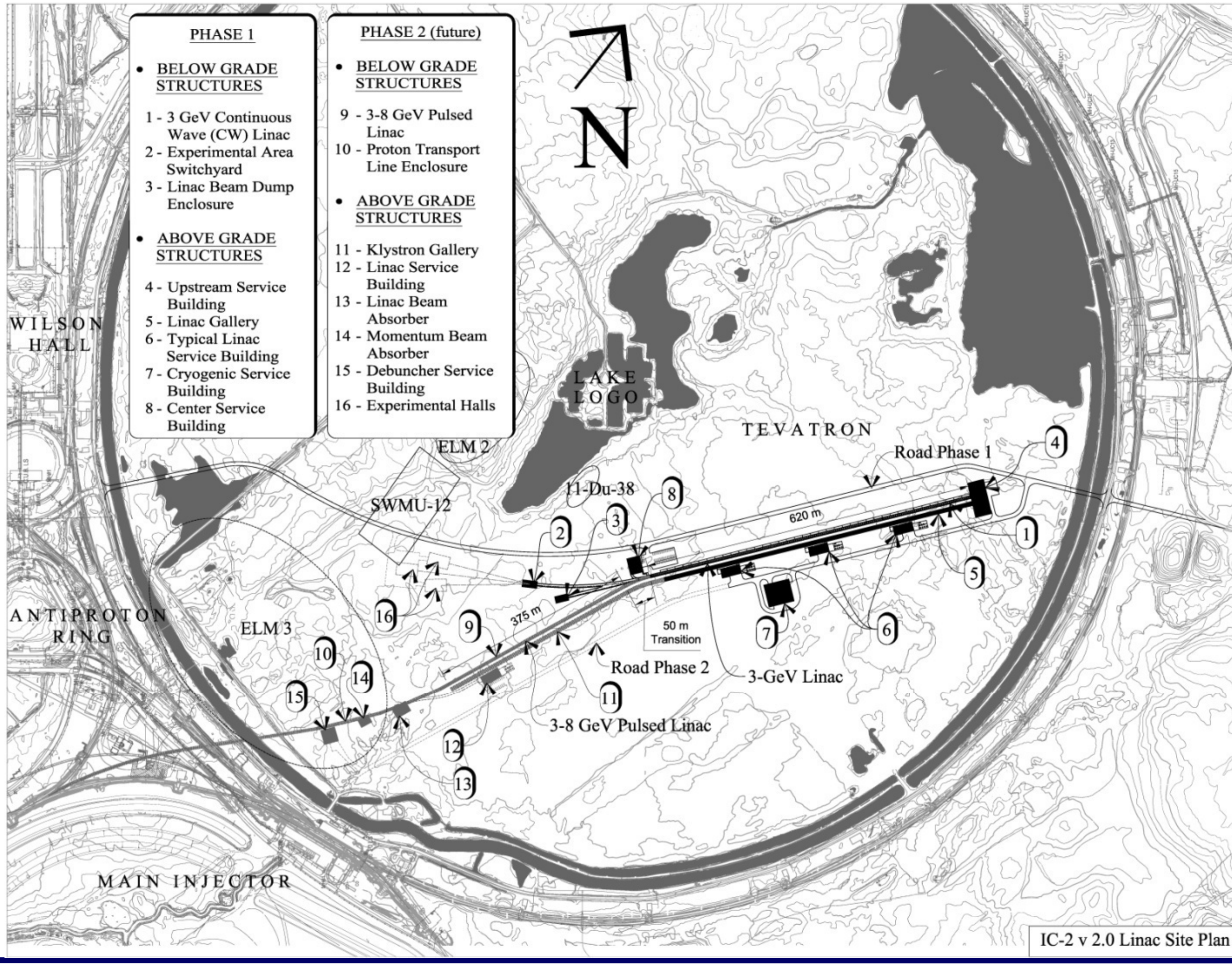
mu2e pulse (9e7) 162.5 MHz, 100 nsec	400 kW
Kaon pulse (9e7) 27 MHz	800 kW
Other pulse (9e7) 27 MHz	800 kW



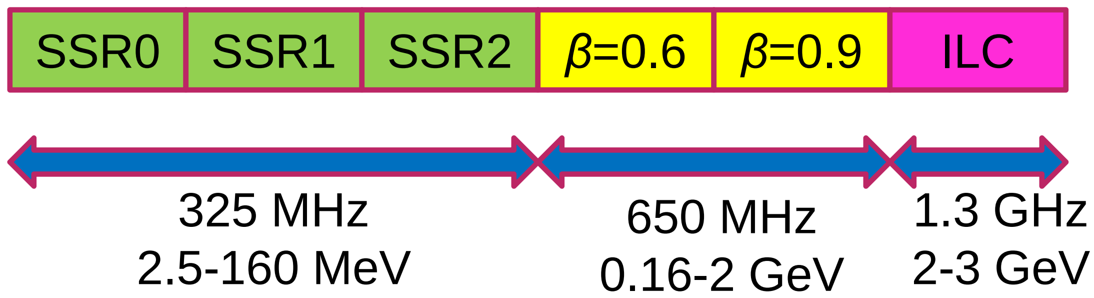


Separation scheme

Initial Configuration-2
Provisional Siting



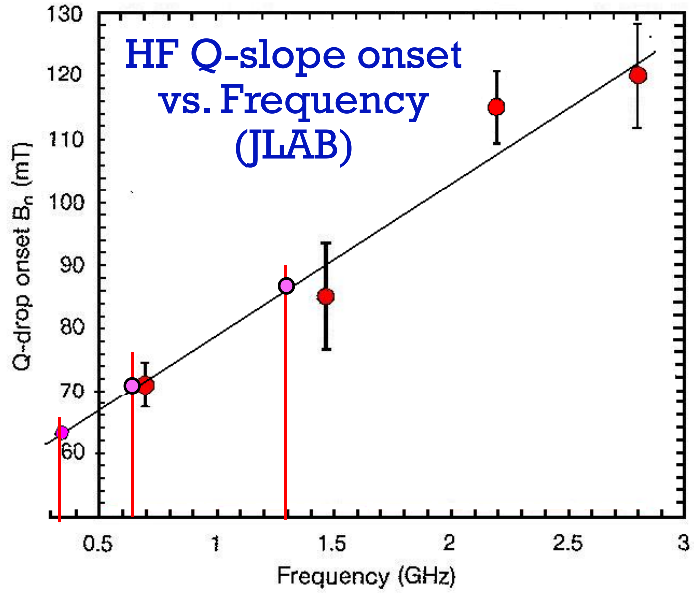
Initial Configuration-2
Technology Map



Section	Freq	Energy (MeV)	Cav/mag/CM	Type
SSR0 (β_G=0.11)	325	2.5-10	26 /26/1	SSR, solenoid
SSR1 (β_G=0.22)	325	10-32	18 /18/ 2	SSR, solenoid
SSR2 (β_G=0.4)	325	32-160	33 /18/3	SSR, solenoid
LB 650 (β_G=0.61)	650	160-520	42 /21/7	5-cell elliptical, doublet
HB 650 (β_G=0.9)	650	520-2000	64 /8 /8	5-cell elliptical, doublet
ILC 1.3 (β_G=1.0)	1300	2000-3000	64 /8 /8	9-cell elliptical, quad

R&D Program
Choice of Cavity Parameters

- Identify maximum achievable surface (magnetic field) on basis of observed Q-slope "knee"
- Select cavity shape to maximize gradient (subject to physical constraints)
- Establish Q goal based on realistic extrapolation from current performance
  - Goal: <20 W/cavity
- Optimize within (G, Q, T) space

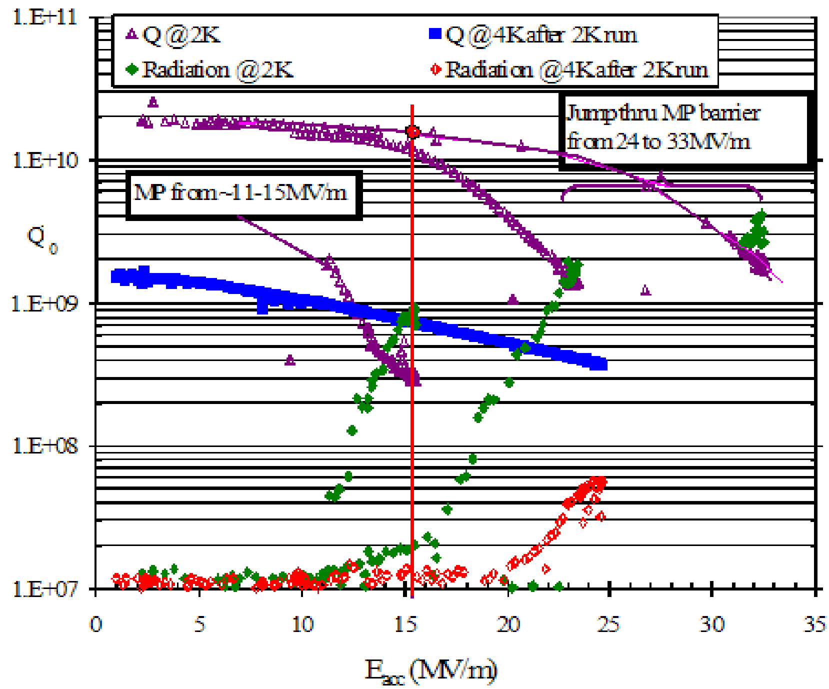


(Initial) Performance Goals

Freq (MHz)	B_{pk}(mT)	G (MV/m)	Q	@T (K)
325	60	15	1.4E10	2
650	72	16	1.7E10	2
1300	72	15	1.5E10	2

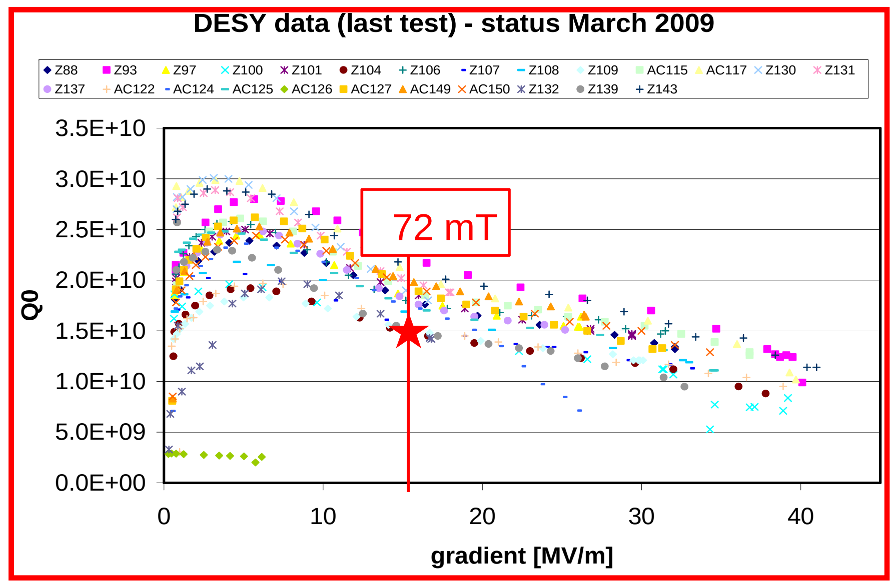
R&D Program

Choice of Cavity Parameters

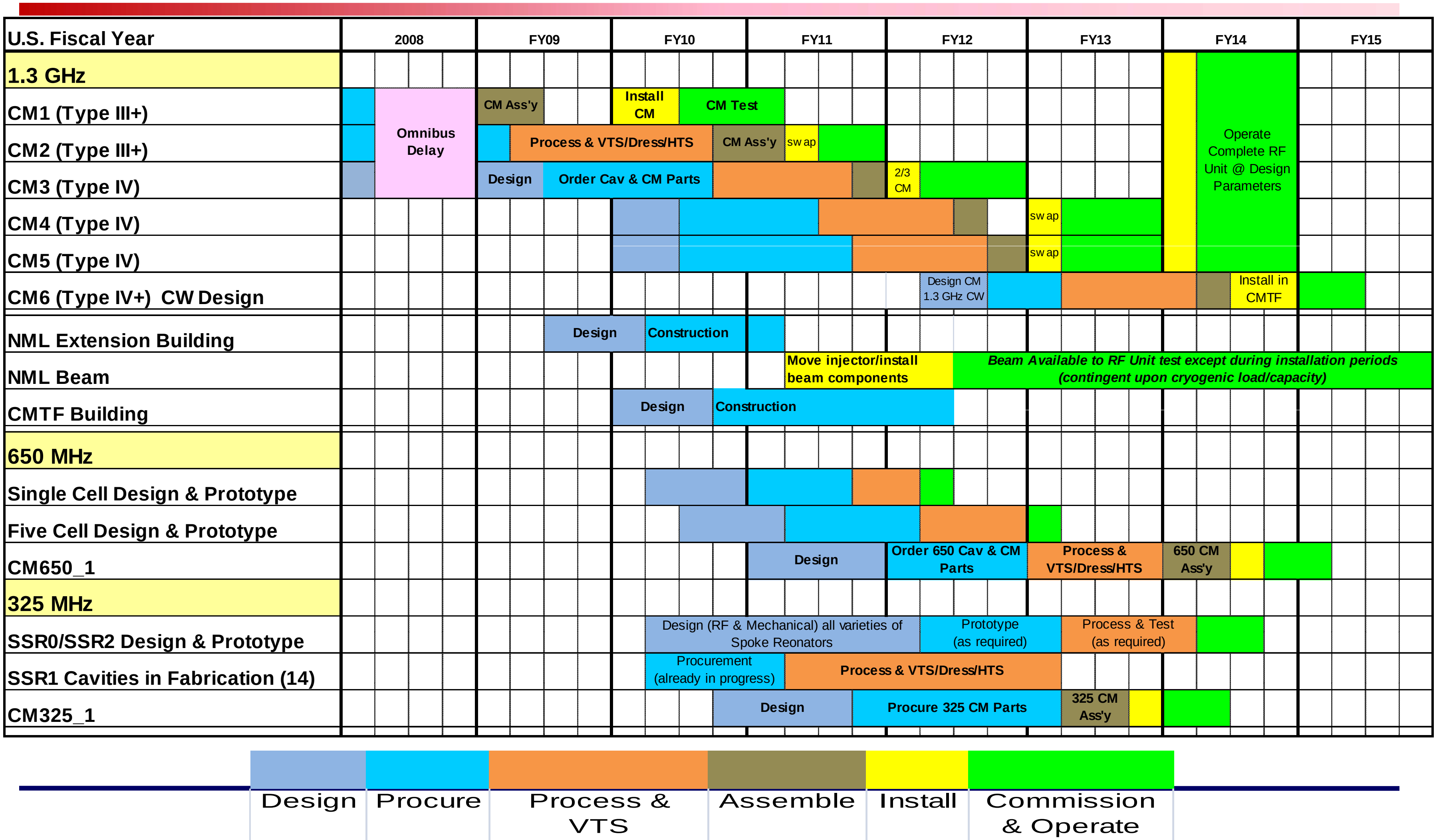


SSR1:
325 MHz
$Q_0=1.4 \cdot 10^{10}$ @ 2K

ILC:
1.3 GHz
$Q_0=1.5 \cdot 10^{10}$ @2K



Integrated SRF Plan
ILC + Project X

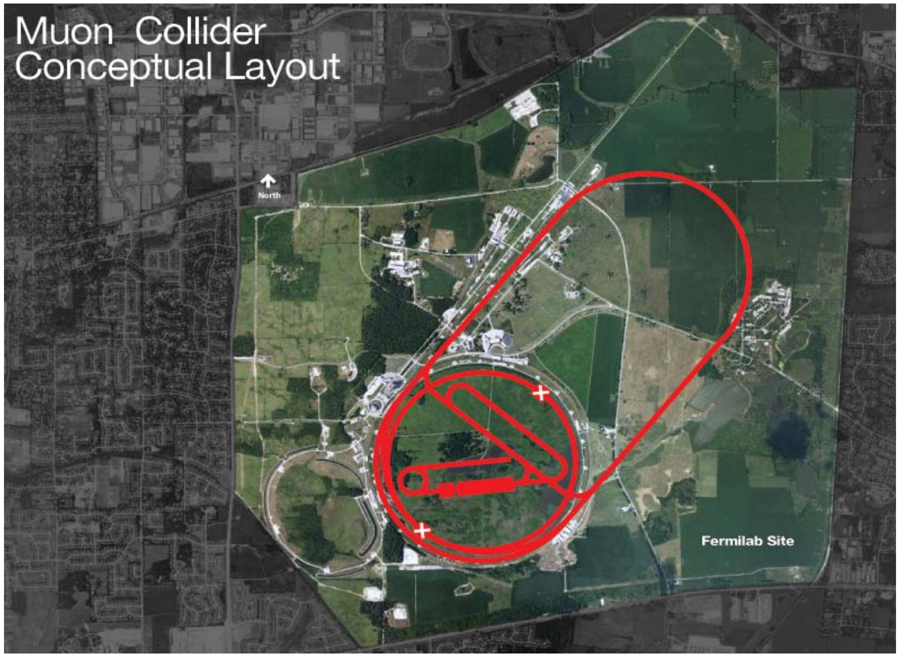


Integrated SRF Plan
ILC + Project X


NML test facility: ILC and Project X R&D

Joint PX/NF/MC Strategy

- Project X shares many features with the proton driver required for a Neutrino Factory or Muon Collider
  - NF and MC require ~4 MW @ 10± 5 GeV
  - Primary issues are related to beam "format"
    - NF wants proton beam on target consolidated in a few bunches; Muon Collider requires single bunch
  - Project X linac is not capable of delivering this format



⇒ It is inevitable that a new ring(s) will be required to produce the correct beam format for targeting.

Collaboration Plan

- A multi-institutional collaboration has been established to execute the Project X RD&D Program.
  - Organized as a "national project with international participation".
    - Fermilab as lead laboratory
    - International participation via in-kind contributions, established through bi-lateral MOUs. (First MOU with India in place)
  - Collaboration MOU for the RD&D phase outlines basic goals, and the means of organizing and executing the work. Signatories:

ANL	ORNL/SNS	BARC/Mumbai
BNL	MSU	IUAC/Delhi
Cornell	TJNAF	RRCAT/Indore
Fermilab	SLAC	VECC/Kolkota
LBNL	ILC/ART	

  - Collaborators to assume responsibility for components and sub-system design, development, cost estimating, and potentially construction.

Strategy/Timeline

- Next six months: Complete all preliminary design, configuration, and cost range information for IC-2
  - ICD-2v2.0
  - Cost estimate
- Continue conceptual development on outstanding technical questions
  - Baseline concept for the chopper
  - Concepts for marrying a 3-8 GeV pulsed linac to CW front end
  - Injection into RCS or Recycler
- Pursue R&D aimed at the CW linac
  - Emphasis of srf development at all relevant frequencies
  - Engage external collaborators and identify roles
- The DOE has advised that the earliest possible construction start is FY2015
  - We are receiving very significant R&D support for Project X and SRF development (~$35M in FY10, excluding ARRA)
- We believe that we could construct Project X over a five year time period, assuming a commensurate funding profile

$\Rightarrow$ **Project X could be up and running ~2020**

Summary

- Project X is central to Fermilab's strategy for development of the accelerator complex over the coming decade
  - World leading programs in neutrinos and rare processes
  - Aligned with ILC and Muon Accelerators technology development;
  - Potential applications beyond elementary particle physics
- The design concept has evolved over the last year, providing significantly enhanced physics capabilities
- Current configuration:
  - >2 MW at 60-120 GeV, simultaneous with 3 MW at 3 GeV
  - Flexibility for supporting multiple experiments
  - CW linac is unique for this application, and offers capabilities that would be hard/impossible to duplicate in a synchrotron
- Project X could be constructed over the period ~2015 - 2019