Project X: Status, Strategy, Meeting Goals

Steve Holmes
Project X Collaboration Meeting
April 12, 2011

Outline

- Project Goals
- Update on Activities of the Six Months
- Reference Design
- R&D Plan
- CD-0 Status and Strategy
  - Staging
- Collaboration Status
- Meeting Goals, Agenda, and Organization

Our websites:

http://projectx.fnal.gov

http://projectx-docdb.fnal.gov

Meeting website:

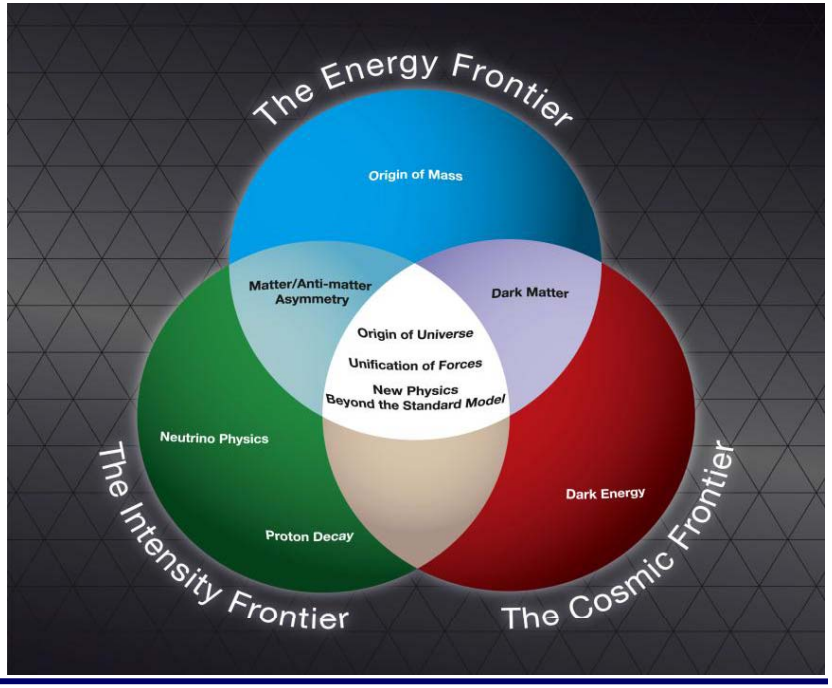
http://projectx.fnal.gov/april_11_collaboration_meeting.html

Fermilab Long Range Plan

Fermilab is the sole remaining U.S. laboratory providing facilities in support of accelerator-based Elementary Particle Physics. Fermilab is fully aligned with the strategy for U.S. EPP developed by HEPAP/P5.

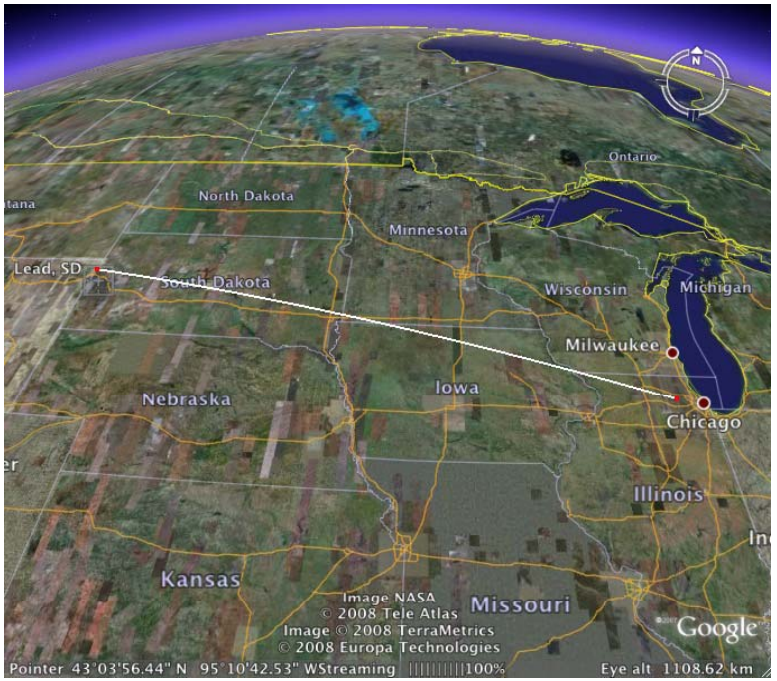
⇒***The Fermilab strategy is to mount a world-leading program at the intensity frontier, while using this program as a bridge to an energy frontier facility beyond LHC in the longer term.***

Project X is the key element of this strategy



Mission Elements

- 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 possible future Neutrino Factory and/or a Muon Collider
  - Requires ~4 MW at ~5-15 GeV



- Possible missions beyond P5
  - Standard Model Tests with nuclei and energy applications

Since the September 2009 Meeting

- Reference Design established as the preferred configuration
  - First discussed in September meeting
  - Functional Requirements Specification (FRS) released
  - Reference Design Report posted to document database
- India Institutes-Fermilab Collaboration Meeting
  - Week of October 23
  - Visits to IUAC, RRCAT, BARC, VECC
- CD-0 supporting documentation developed
  - Functional Requirements Specification
  - Reference Design Report
  - RD&D Plan
  - Cost Estimate
  - RLS

Since the September 2009 Meeting

- CD-0 briefings
  - November 16-17/OHEP
    - Strategic context
    - Physics program
    - Reference Design and how it meets the P5 mission
    - Cost estimate range: $1.7 – 1.8 B
  - December 6/SC
    - Strategic plan
    - Physics program
    - Description of Reference Design and cost
- Dennis Kovar retired 12/31/10
- India Workshop on Intensity Frontier Phsyics
  - January 13-14 in Mumbai
- IHEP-Fermilab Workshop on Proton Accelerators
  - February 15-16 in Beijing
  - IHEP and IMP/Lanzhou participation

News Since the September 2009 Meeting

- Physics Workshops
  - November
  - White papers describing facilities and initial experiments
    - Neutrinos
    - Kaons
    - Muons
    - Nuclear Physics
    - Nuclear Energy

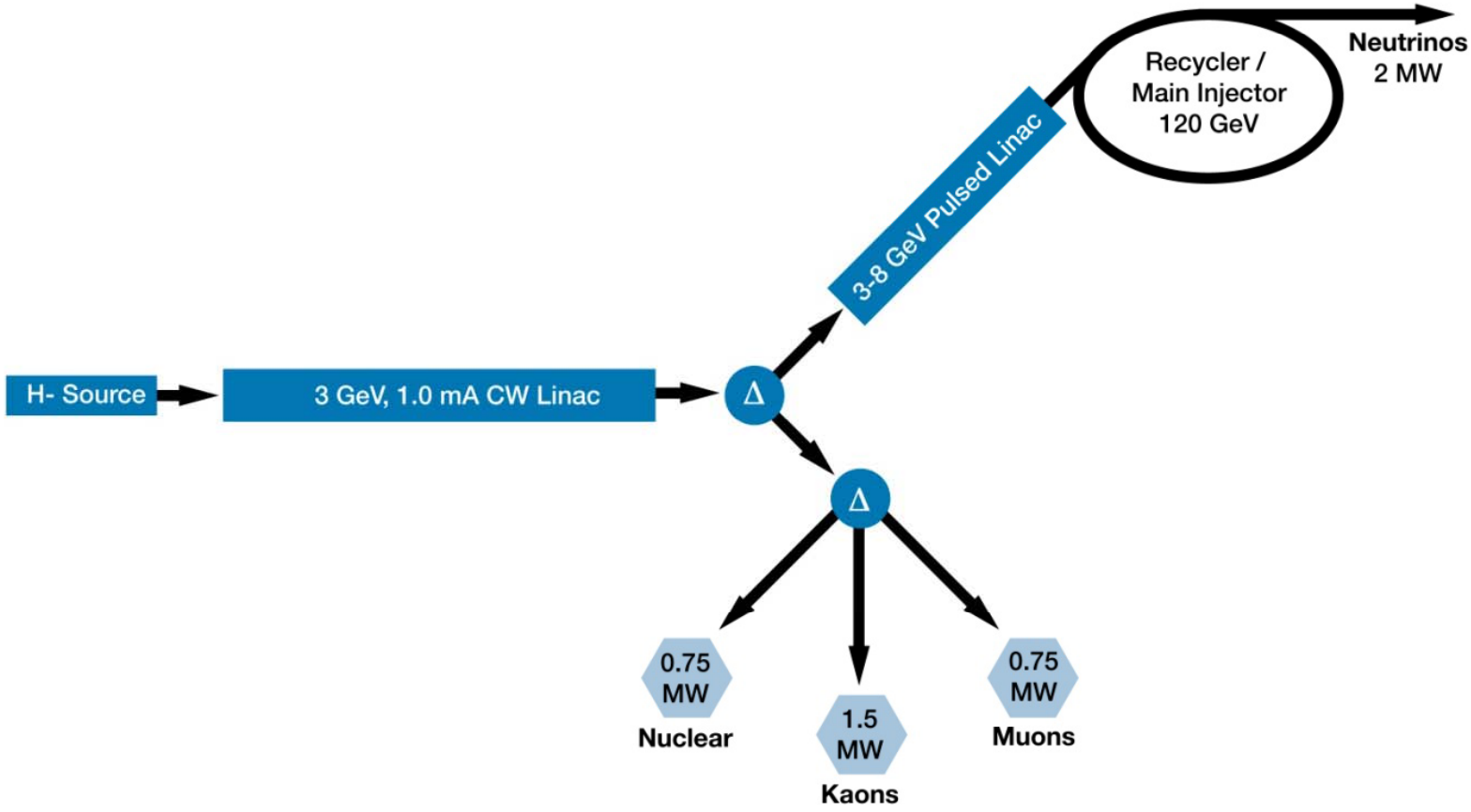
http://www.fnal.gov/directorate/Longrange/Steering_Public/workshop-physics-5th.html

- CD-0 strategy under development
  - See subsequent discussion
- CD-1 Plan developed
  - RLS created in Primavera

Reference Design
How did we get here?

- Three Project X configurations have been developed, in response to limitations identified at each step:
  - Initial Configuration-1 (IC-1)
    - 8 GeV pulsed linac + Recycler/MI
    - Fully capable of supporting neutrino mission
    - Limited capabilities for rare processes
  - Initial Configuration-2 (IC-2)
    - 2 GeV CW linac + 2-8 GeV RCS + Recycler/MI
    - Fully capable of supporting neutrino mission
    - 2 GeV too low for rare processes (Kaons)
    - Ineffective platform for Neutrino Factory or Muon Collider
  - Reference Design
    - 3 GeV CW linac + 3-8 pulsed linac + Recycler/MI
    - Ameliorates above deficiencies

Reference Design



Reference Design Capabilities

- 3 GeV CW superconducting H- linac with 1 mA average beam current.
  - Flexible provision for variable beam structures to multiple users
    - CW at time scales >1 μsec, 10% DF at <1 μsec
  - Supports rare processes programs at 3 GeV
  - Provision for 1 GeV extraction for nuclear energy program
- 3-8 GeV pulsed linac capable of delivering 300 kW at 8 GeV
  - Supports the neutrino program
  - Establishes a path toward a muon based facility
- Upgrades to the Recycler and Main Injector to provide ≥ 2 MW to the neutrino production target at 60-120 GeV.

⇒ Utilization of a CW linac creates a facility that is unique in the world, with performance that cannot be matched in a synchrotron-based facility.

Functional Requirements

Requirement	Description	Value
L1	Delivered Beam Energy, maximum	3 GeV (kinetic)
L2	Delivered Beam Power at 3 GeV	3 MW
L3	Average Beam Current (averaged over >1 μsec)	1 mA
L4	Maximum Beam Current (sustained for <1 μsec)	5 mA
L5	The 3 GeV linac must be capable of delivering correctly formatted beam to a pulsed linac, for acceleration to 8 GeV	
L6	Charge delivered to pulsed linac	26 mA-msec in < 0.75 sec
L7	Maximum Bunch Intensity	1.9×10^{8}
L8	Minimum Bunch Spacing	6.2 nsec (1/162.5 MHz)
L9	Bunch Length	<50 psec (full-width half max)
L10	Bunch Pattern	Programmable
L11	RF Duty Factor	100% (CW)
L12	RF Frequency	162.5 MHz and harmonics thereof
L13	3 GeV Beam Split	Three-way
P1	Maximum Beam Energy	8 GeV
P2	The 3-8 GeV pulsed linac must be capable of delivering correctly formatted beam for injection into the Recycler Ring (or Main Injector).	
P3	Charge to fill Main Injector/cycle	26 mA-msec in <0.75 sec
P4	Maximum beam power delivered to 8 GeV	300 kW
P5	Duty Factor (initial)	< 4%

Functional Requirements

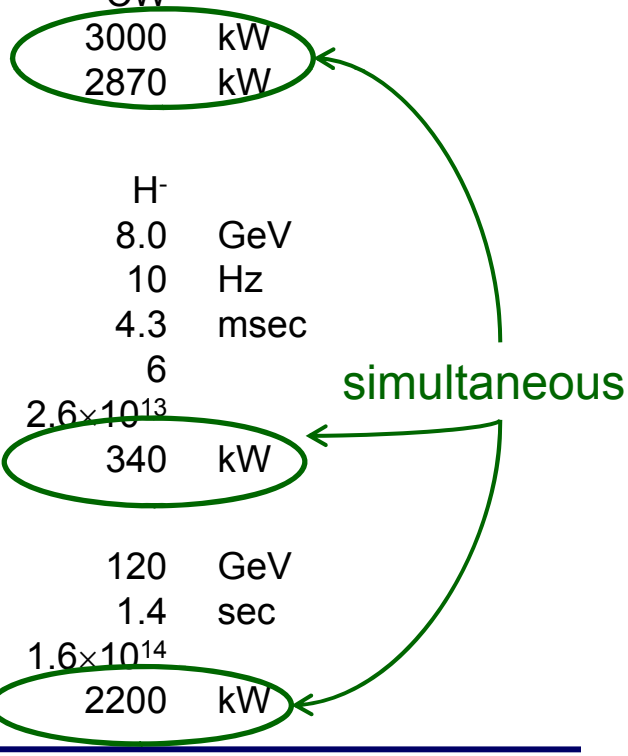
Requirement	Description	Value
M1	Delivered Beam Energy, maximum	120 GeV
M2	Delivered Beam Energy, minimum	60 GeV
M3	Minimum Injection Energy	6 GeV
M4	Beam Power (60-120 GeV)	> 2 MW
M5	Beam Particles	Protons
M6	Beam Intensity	1.6 x 10^{14} protons per pulse
M7	Beam Pulse Length	~10 μsec
M8	Bunches per Pulse	~550
M9	Bunch Spacing	18.8 nsec (1/53.1 MHz)
M10	Bunch Length	<2 nsec (fullwidth half max)
M11	Pulse Repetition Rate (120 GeV)	1.2 sec
M12	Pulse Repetition Rate (60 GeV)	0.75 sec
M13	Max Momentum Spread at extraction	2 x 10^{-3}
I1	The 3 GeV and neutrino programs must operate simultaneously	
I2	Residual Activation from Uncontrolled Beam Loss in areas requiring hands on maintenance.	<20 mrem/hour (average) <100 mrem/hour (peak) @ 1 ft
I3	Scheduled Maintenance Weeks/Year	8
I4	3 GeV Linac Operational Reliability	90%
I5	60-120 GeV Operational Reliability	85%
I6	Facility Lifetime	40 years
U1	Provisions should be made to support an upgrade of the CW linac to support an average current of 4 mA.	
U2	Provisions should be made to support an upgrade of the Main Injector to a delivered beam power of ~4 MW at 120 GeV.	
U3	Provisions should be made to deliver CW proton beams as low as 1 GeV.	
U4	Provision should be made to support an upgrade to the CW linac such that it can accelerate Protons.	
U5	Provisions should be made to support an upgrade of the pulsed linac to support a duty factor or 10%.	
U6	Provisions should be made to support an upgrade of the CW linac to a 3.1 nsec bunch spacing.	

Pulsed Linac

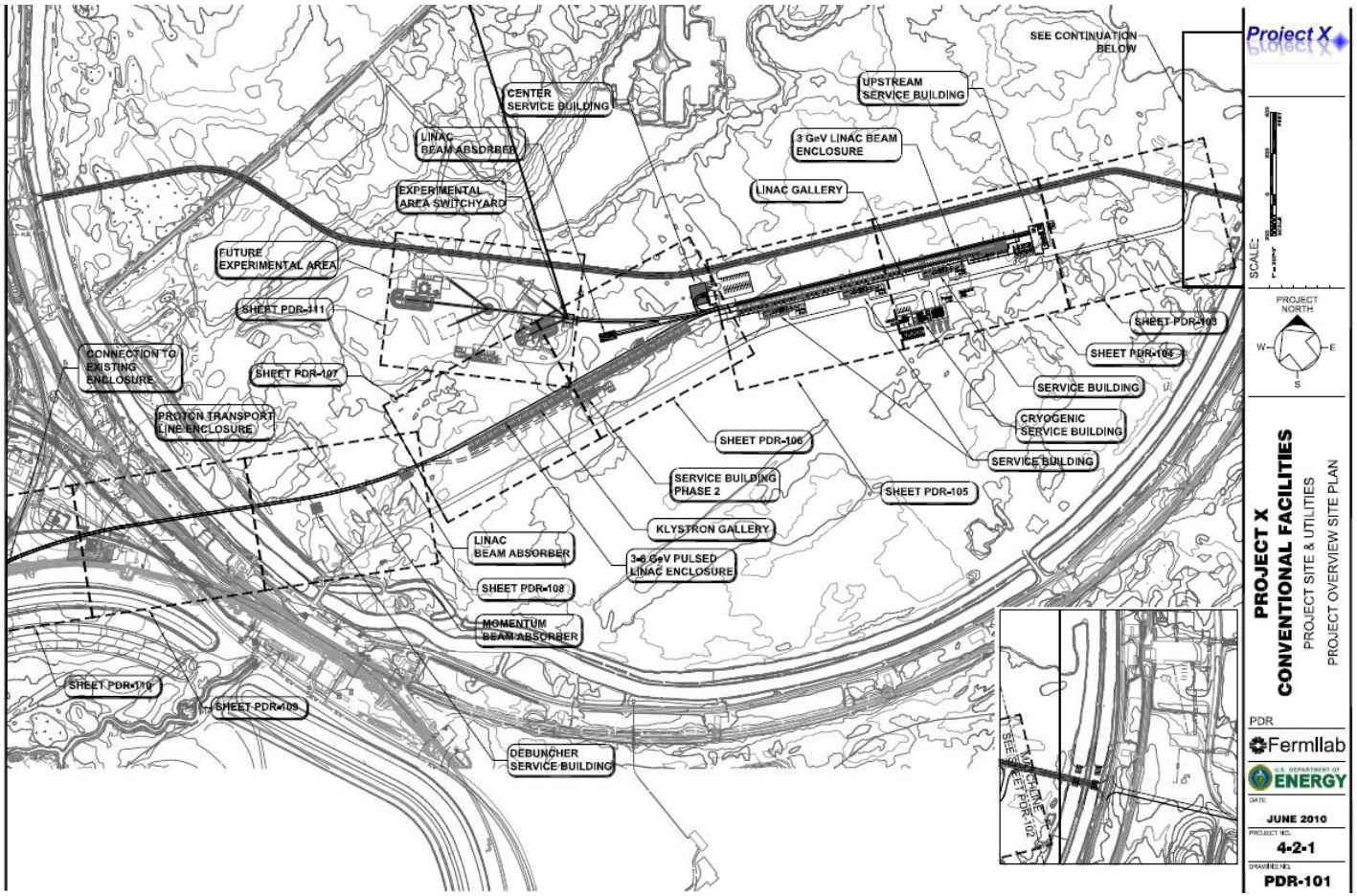
- The Reference Design utilizes a superconducting pulsed linac for acceleration from 3 to 8 GeV
- ILC style cavities and cryomodules
  - 1.3 GHZ, β=1.0
  - 28 cryomodules (@ 25 MV/m)
- ILC style rf system
  - 5 MW klystron
  - Up to four cryomodules per rf source
- Must deliver 26 mA-msec to the Recycler every 0.75 sec. Options:
  - 1 mA x 4.4 msec pulses at 10 Hz
    - Six pulses required to load Recycler/Main Injector
  - 1 mA x 26 msec pulses at 1.3 Hz
    - One pulse required to load Main Injector

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
Pulsed Linac		
Particle Type	H^-	
Beam Kinetic Energy	8.0	GeV
Pulse rate	10	Hz
Pulse Width	4.3	msec
Cycles to MI	6	
Particles per cycle to MI	2.6×10^{13}	
Beam Power to 8 GeV	340	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



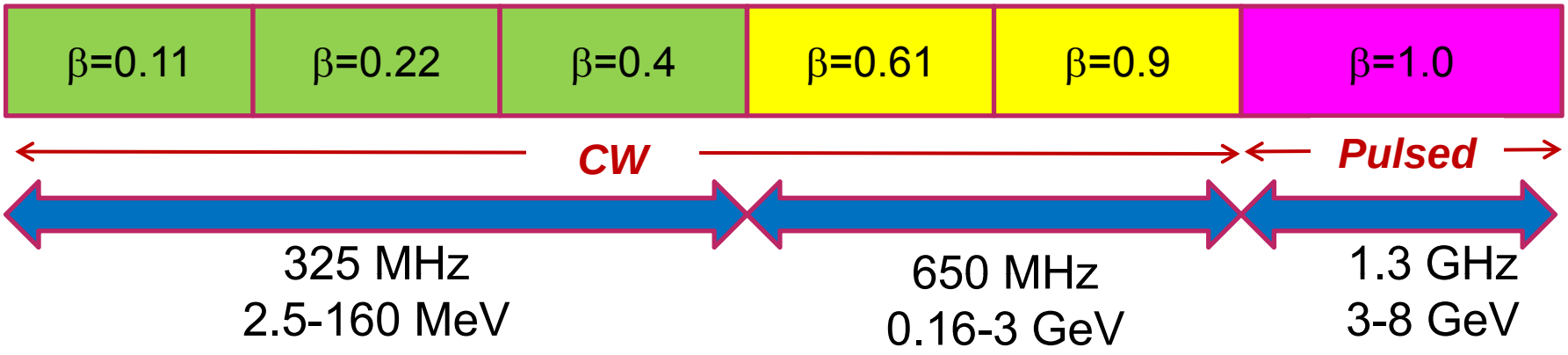
Siting


SEE CONTINUATION BELOW
CENTER SERVICE BUILDING
UPSTREAM SERVICE BUILDING
LINAC BEAM ABSORBER
3 GeV LINAC BEAM ENCLOSURE
EXPERIMENTAL AREA SWITCHYARD
LINAC GALLERY
FUTURE EXPERIMENTAL AREA
SHEET PDR-111
SHEET PDR-103
SHEET PDR-104
CONNECTION TO EXISTING ENCLOSURE
SHEET PDR-107
SERVICE BUILDING
PROTON TRANSPORT LINE ENCLOSURE
CRYOGENIC SERVICE BUILDING
SHEET PDR-106
SERVICE BUILDING
SERVICE BUILDING PHASE 2
SHEET PDR-105
KLYSTRON GALLERY
LINAC BEAM ABSORBER
3-8 GeV PULSED LINAC ENCLOSURE
SHEET PDR-108
MOMENTUM BEAM ABSORBER
SHEET PDR-110
SHEET PDR-109
DEBUNCHER SERVICE BUILDING
SEE SHEET PDR-102
Project X
SCALE:
PROJECT NORTH
PROJECT X
CONVENTIONAL FACILITIES
PROJECT SITE & UTILITIES
PROJECT OVERVIEW SITE PLAN
PDR
Fermilab
ENERGY
JUNE 2010
4-2-1
PDR-101

R&D Program

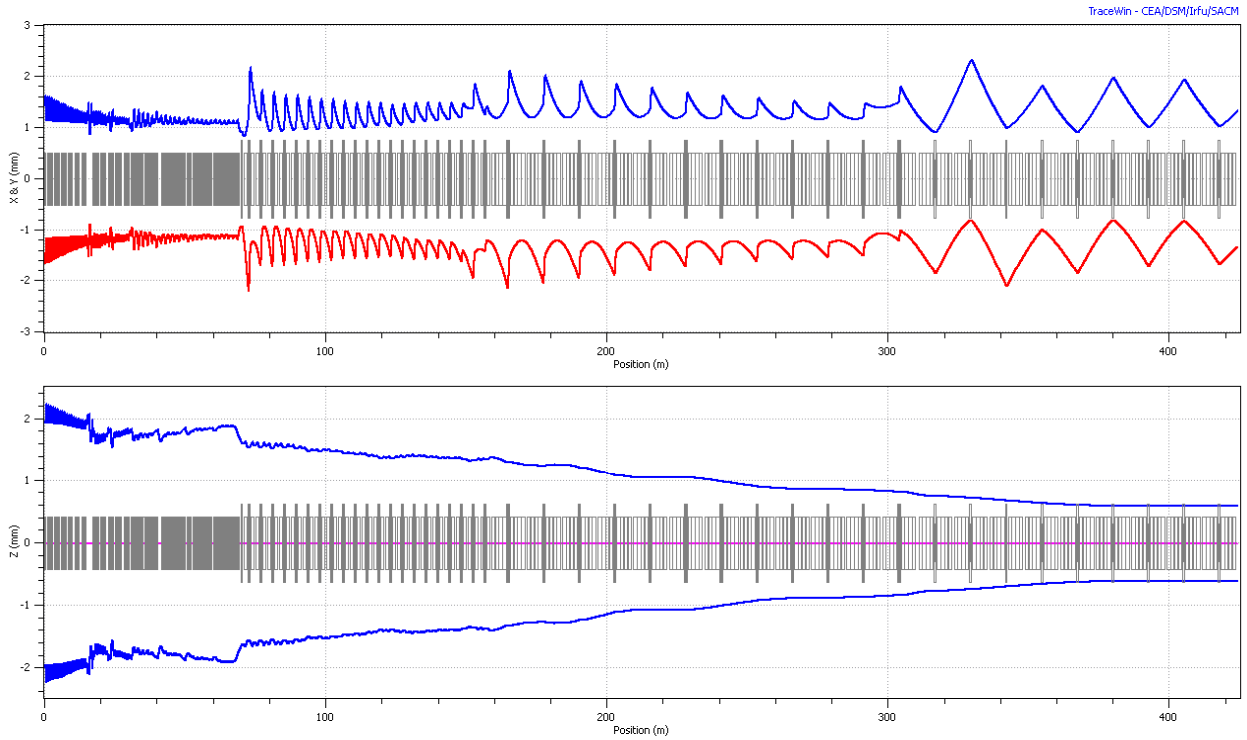
- The primary elements of the R&D program include:
  - Development of a wide-band chopper
    - Capable of removing bunches in arbitrary patterns at a 162.5 MHz bunch rate
  - Development of an H- injection system
    - Require between 4.4 – 26 msec injection period, depending on pulsed linac operating scenario
  - Superconducting rf development
    - Includes six different cavity types at three different frequencies
    - Emphasis is on Q_0, rather than high gradient
      - Typically 1.5E10, 15 MV/m (CW)
      - 1.0E10, 25 MV/m (pulsed)
    - Includes appropriate rf sources
    - Includes development of partners
- Goal is to complete R&D phase by 2015

SRF Linac Technology Map



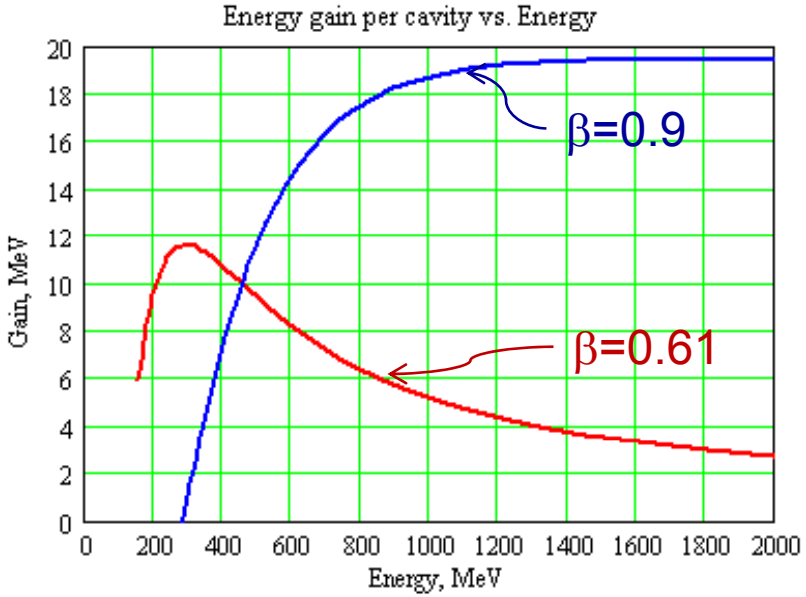
Section	Freq	Energy (MeV)	Cav/mag/CM	Type
SSR0 (β_G=0.11)	325	2.5-10	18 /18/1	SSR, solenoid
SSR1 (β_G=0.22)	325	10-42	20/20/ 2	SSR, solenoid
SSR2 (β_G=0.4)	325	42-160	40/20/4	SSR, solenoid
LB 650 (β_G=0.61)	650	160-460	36 /24/6	5-cell elliptical, doublet
HB 650 (β_G=0.9)	650	460-3000	160/40/20	5-cell elliptical, doublet
ILC 1.3 (β_G=1.0)	1300	3000-8000	224 /28 /28	9-cell elliptical, quad

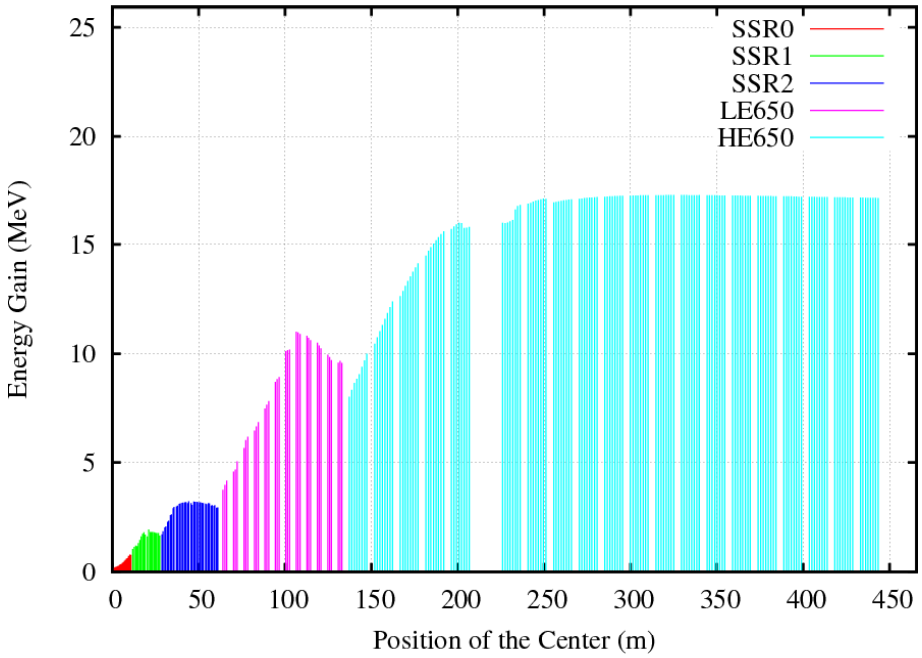
3 GeV CW Linac
Beam Dynamics at 1 mA



- 1 σ beam envelopes
  - Transverse (upper)
  - Longitudinal (lower)

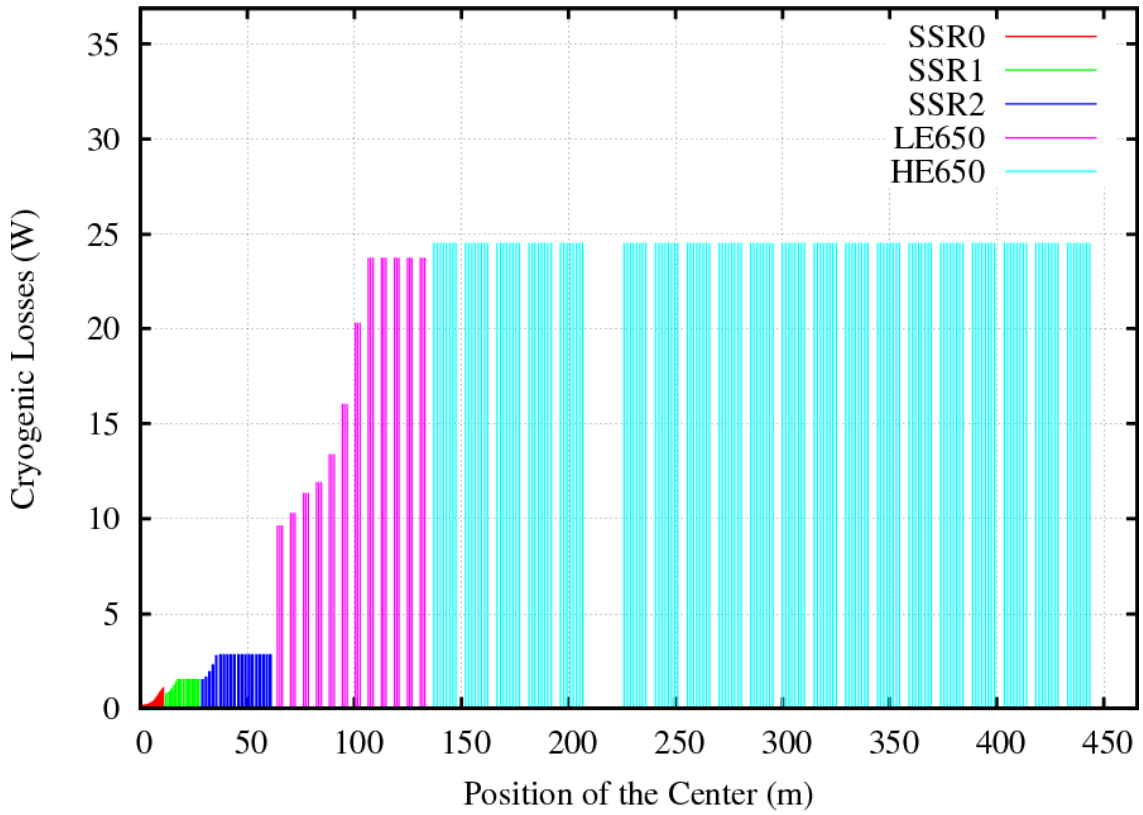
3 GeV CW Linac
Energy Gain per Cavity





- Based on 5-cell 650 MHz cavity
  - Crossover point ~450 - 500 MeV

3 GeV CW Linac
Cryogenic Losses per Cavity



- ~42 kW cryogenic power at 4.5 K equivalent

CD-0 Strategy/Status

- Requirements
  - Mission Needs Statement – approved by Director/Office of Science
    - Includes a cost range and funding profile
  - Independent Cost Review – new requirement
  - CD-1 Plan
  - Mission Validation Independent Review
  - CD-0 approved by the Deputy Secretary (or designee)
- Staging
  - Serious discussion of a staged approach – see P. Oddone presentation to HEPAP
  - Motivated by desirability to reduce costs of initial steps

“Plug and play” - physics

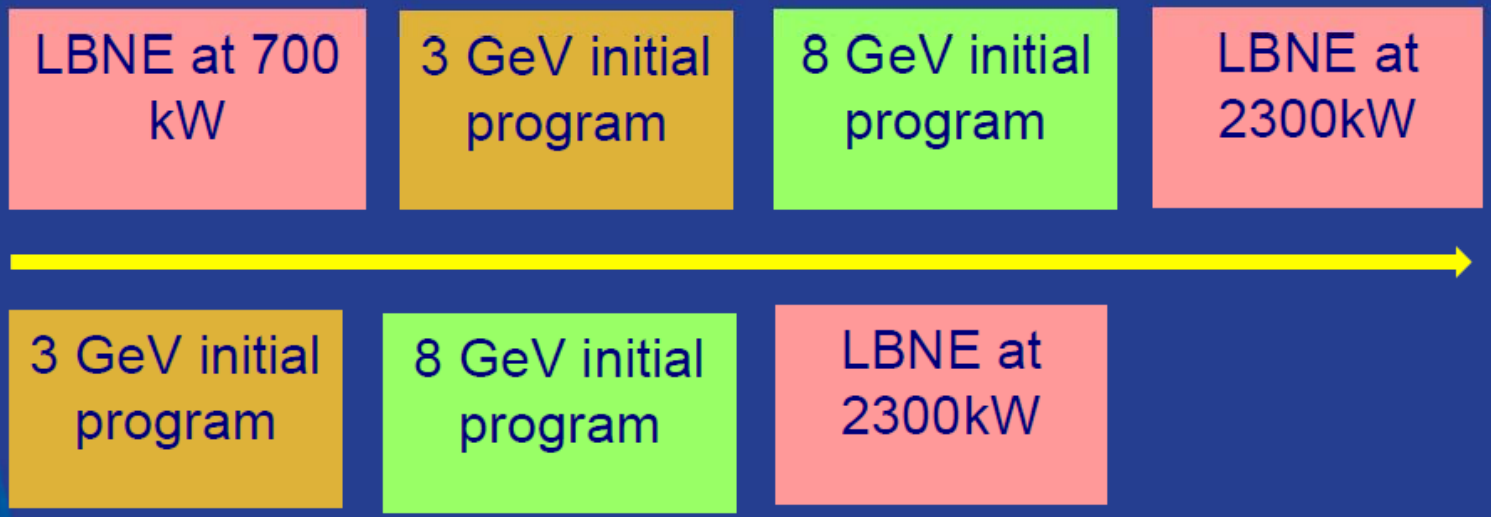
3 GeV CW linac	• Muons • Kaons • Nuclei (ISOL) • Materials (ADS)
3-8 GeV pulsed linac	• Neutrinos vs. antineutrinos • Muons
8-120 GeV existing machines	• Long base line neutrino oscillations

What will it take? – cost to day one

With full contingency and escalation
(P5 Cost were in FY08$)

3 GeV CW linac	Accelerator	$1.2B
	Experiments	$0.2B
3-8 GeV pulsed linac	Accelerator	$0.5B
	Experiments	$0.2B
8-120 GeV existing machines	Accelerator	$0.1B
	Experiment	$1.0B

Sequencing is flexible



We are capable of doing the whole program at once in the next ten years, or it can be sequenced over a longer period

CD-0 Strategy/Status

- Mission Needs Statement
  - Description of the full scientific program enabled by the Reference Design
  - Description of staged approach:
    - Stage 1: 3 GeV CW linac + intial experimental program
    - Stage 2: Everything else
  - Cost range and funding profile associated with Stage 1
  - Dates

    CD-0 FY2011
    CD-1 FY2013
    CD-2 FY2014
    CD-3 FY2016
    CD-4 FY2021
- Independent Cost Review
  - Conducted by OECM, utilizing SC/OPA (Lehman)
  - Current assumption is this will cover Stage 1
  - OHEP has asked us to develop a cost range that includes variations of the point estimate with respect to:
    - Perfomance parameters (beam current, energy, duty factor)
    - Other factors (design maturity, commodities, escalation)

CD-0 Strategy/Status

- CD-1 Plan
  - Resource loaded schedule created in Primavera
    - Prototype for the project controls tools we will be using on the Project
      - Accounting integration through Cobra
    - Allows for identification of resource types from both within and outside Fermilab
      - Not yet fully incorporated
  - Dates:
    CD-0 March 2011
    CD-1 March 2013
- Mission Needs Independent Review
  - DOE/OHEP will be organizing an Intensity Frontier Physics Workshop in the late summer/early fall (of 2011)
  - This will likely feed into a HEPAP process to demonstrate community support for a High Intensity Proton Facility at Fermilab

Strategy and Timeline

- Strategy (next six months)
  - Respond to DOE requests for information and analysis associated with CD-0
  - Update RDR to reflect modifications from this and other meetings
  - Continue R&D
  - Rework the CD-1 plan to reflect the new schedule and incorporate collaborators' resources
  - Support DOE in conducting the Intensity Frontier Physics Workshop
  - Complete ICR
  - Come up with a new name
- Timeline
  - CD-0: Late 2011/early 2012
  - Approve Start of Construction: Late 2015/early 2016

$\Rightarrow$Project X could (still) be up and running in ~2020

Collaboration Status

- Collaboration MOU for R&D phase:

ANL	ORNL/SNS
BNL	MSU
Cornell	TJNAF
Fermilab	SLAC
LBNL	ILC/ART

- MOU/Addendum on development of High Intensity Proton Accelerators in place between Fermilab and Indian institutes:
  - BARC/Mumbai
  - IUAC/Delhi
  - RRCAT/Indore
  - VECC/Kolkota
- Draft Collaboration Governance Plan
  - Discussion in Collaboration Council Meeting

Collaboration Meeting: Goals

- Establish the plan for FY12-13 based on the Project X Reference Design
  - Identify technical issues and alternatives decisions required prior to establishment of the Project X baseline
  - Establish goals, milestones, assignments
  - Understand the integration with the ILC and SRF infrastructure programs
  - Take advantage of being at the site of the world's highest power sc proton accelerator!
- Collaboration Council Meeting
  - Discuss CD-0 strategy
  - Discuss the draft Collaboration Governance Plan
  - Review current institutional assignments
  - Establish next Collaboration Meeting dates and site

Collaboration Meeting
Agenda

- Tuesday, April 12
  - Opening plenary session 09:00-11:45
    - Welcome to ORNL/SNS — Ian A.
    - SNS Operational Experience — Kevin J.
    - Project X Status and Strategy — Steve H.
  - Coffee Break 10:30-11:00
    - Project X Reference Design Overview — Sergei N.
  - Lunch (self-serve) 11:45-12:45
  - Working Groups session one 12:45-15:00
  - Collaboration Council meeting 13:30-15:00
  - Coffee Break 15:00-15:30
  - Working Groups session two 15:30-17:30
  - Adjourn 17:30
  - Reception 18:00-19:00

https://indico.fnal.gov/conferenceTimeTable.py?confId=4043#20110412

Collaboration Meeting
Agenda

- Wednesday, April 13
  - Working Group session three 08:30-13:00
  - Coffee Break 10:30-11:00
  - Working Group session four 11:00-12:00
  - Lunch 12:00-13:00
  - Working Group session five 13:00-15:00
  - Coffee Break 15:00-15:30
  - Working Group session six 15:30-17:30
  - Adjourn 17:30

Collaboration Meeting
Agenda

- Thursday, April 14
  - Discussion of Beam Loss Experiments 8:30-9:30
  - Working Group Reports 09:30-10:30
    - WG1: Front End TBD
    - WG2: Cavities & CMs TBD
    - WG3: RF Systems TBD
  - Coffee Break 10:30-11:00
  - Working Group Reports 11:00-12:00
    - WG4: Main Injector/Recycler TBD WG5: Instrument/Controls/Protect TBD
    - WG6: Integration TBD
  - Adjourn 12:00

Collaboration Meeting
Working Groups

- Charge to the working groups:
  - Detailed discussion of Reference Design, including specifically targeted technical issues and questions;
  - Discuss possible alternative implementations and define technical options that require decisions;
  - Integrate relevant SNS experience into discussions as appropriate;
  - Establish goals and work assignments for the period FY12-13;
  - Develop strategies for test facilities, as appropriate;
- Provisional FY2012 budget distribution ($K, direct costs only):

	M&S	SWF	Collabs	Total
Available*	$2,800	$6,700	$1,900	$11,400

*Notes:
  - Does not include the SRF program at Fermilab
  - FY12 budget distributions will be established in summer, including feedback from this meeting

Collaboration Meeting
Working Groups

• WG1: Front End	S. Nagaitsev/D. Li
• WG2: Cavities & CMs	M. Champion/S. Kim
• WG3: RF Systems	B. Chase/Y. Kang
• WG4: Main Injector/Recycler	D. Johnson/M. Plum
• WG5: Instrument/Controls/Protect	M. Wendt/W. Blokland
• WG6: Integration	J. Kerby/V. Lebedev/J. Galambos

⇒Note that we are limiting ourselves to two parallel sessions during this meeting

Summary

- Project X is central to the U.S. strategy for accelerator based particle physics over the coming decades
  - World leading programs in neutrinos and rare processes;
  - Aligned with Muon Accelerators technology development;
  - Potential applications beyond elementary particle physics
- Reference Design established as preferred concept
  - 3 GeV/3 MW CW linac delivering independent beam formats to multiple users
  - 3-8 GeV pulsed linac to support the long baseline neutrino program
  - CW linac is unique for this application, and offers capabilities that would be hard/impossible to duplicate in a synchrotron
- R&D program underway with very significant investment in srf
- CD-0 strategy established
  - Will likely involve a staged approach
  - DOE sponsored Physics Workshop this fall
- Planning still based on construction over the period FY16-20
- Collaboration Meeting Goals:
  - Look at RDR, in particular discuss areas of technical uncertainty
  - Formulate the plan for next year