Project X Update

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Argonne-Fermilab-UChicago Collaboration Meeting

December 7, 2010

Outline

- Project X Mission and the Reference Design
- R&D Plan
- Strategy and Timeline

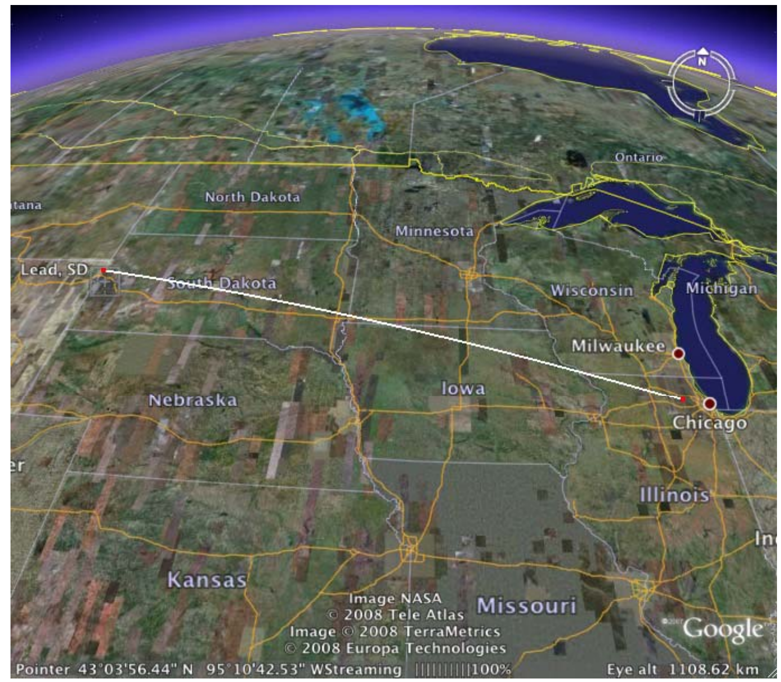
Our websites:

http://projectx.fnal.gov

http://projectx-docdb.fnal.gov

Mission Goals

- 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
  - <u>Operations simultaneous</u> 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

Project X

Concept Evolution

- 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

Over the Last Year

- 3 GeV established as a workable energy for the rare processes program
- Reference Design established
  - 3 GeV CW linac, 3-8 GeV pulsed linac, Recycler/MI modifications
  - Functional Requirements Specification (FRS) released
- Updated RD&D plan, resource loaded schedule (RLS), and cost estimate corresponding to reference design
  - Cost range estimate: $1.7-1.8 B
- ARRA
  - Significant investment in SRF infrastructure at Fermilab and development of domestic vendors

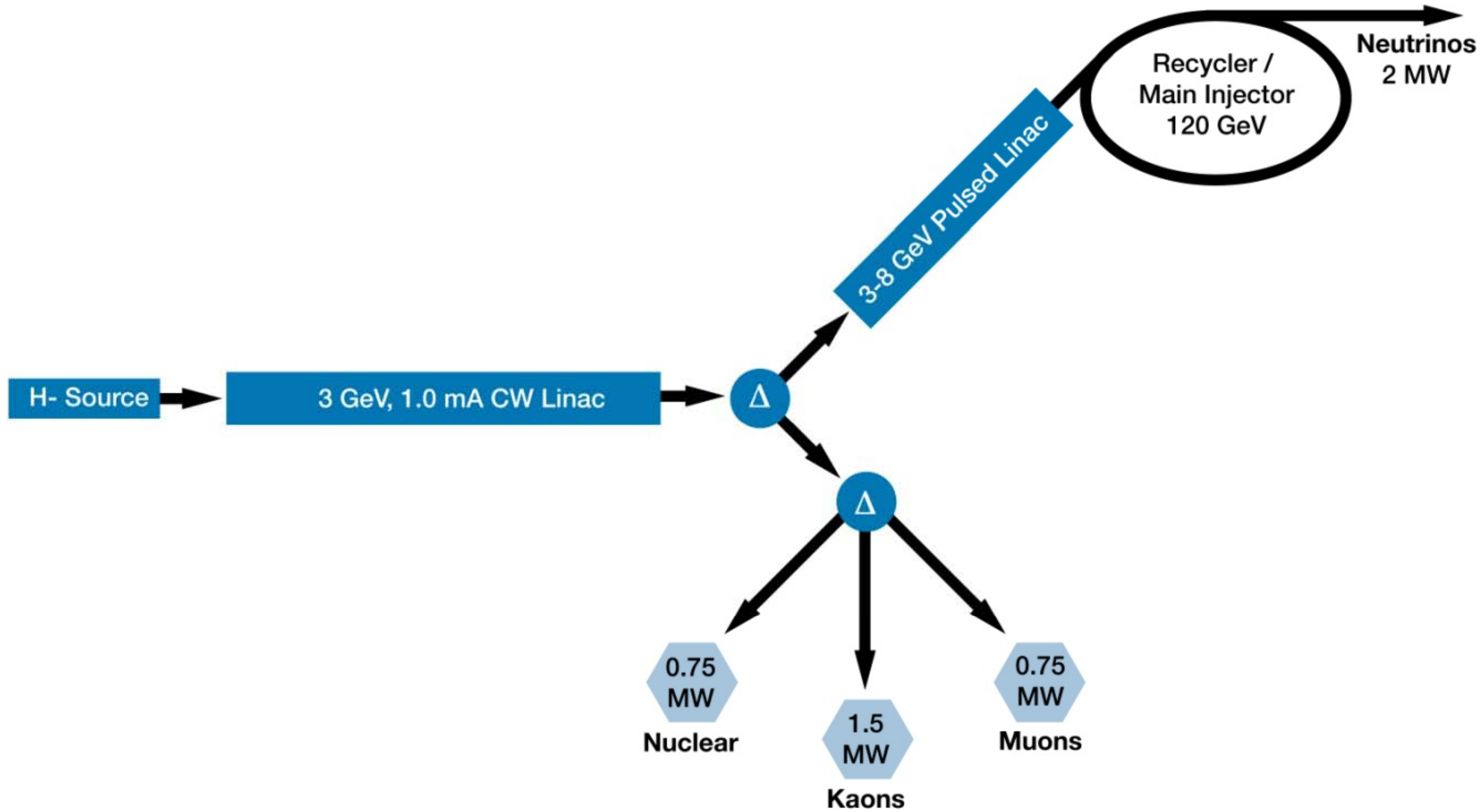
Over the Last Year

- Five Physics/Experiments Task Forces established
  - Neutrinos
  - Kaons
  - Muons
  - Nuclear Physics
  - Nuclear Energy

  Goal: define an initial experiment in each area
  Fall workshops
- New Fermilab Associate Director for Accelerators – Stuart Henderson
  - Steve H. now full time on Project X
- DOE/OHEP briefing in support of Project X CD-0 November 16-17, 2010
  - Reports from the five Task Forces
  - Accelerator facility concept (Reference Design)
  - Cost range estimate ($1.7-1.8B)
- DOE/SC briefing December 6

Project X

Reference Design



Project X Reference Design Scope

- 3 GeV CW superconducting H- linac, capable of delivering 1 mA average beam current.
  - Wideband chopper provides flexible provision for variable beam structures to multiple users
  - 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.
  - Supports the long baseline neutrino program
- Interconnecting beamlines

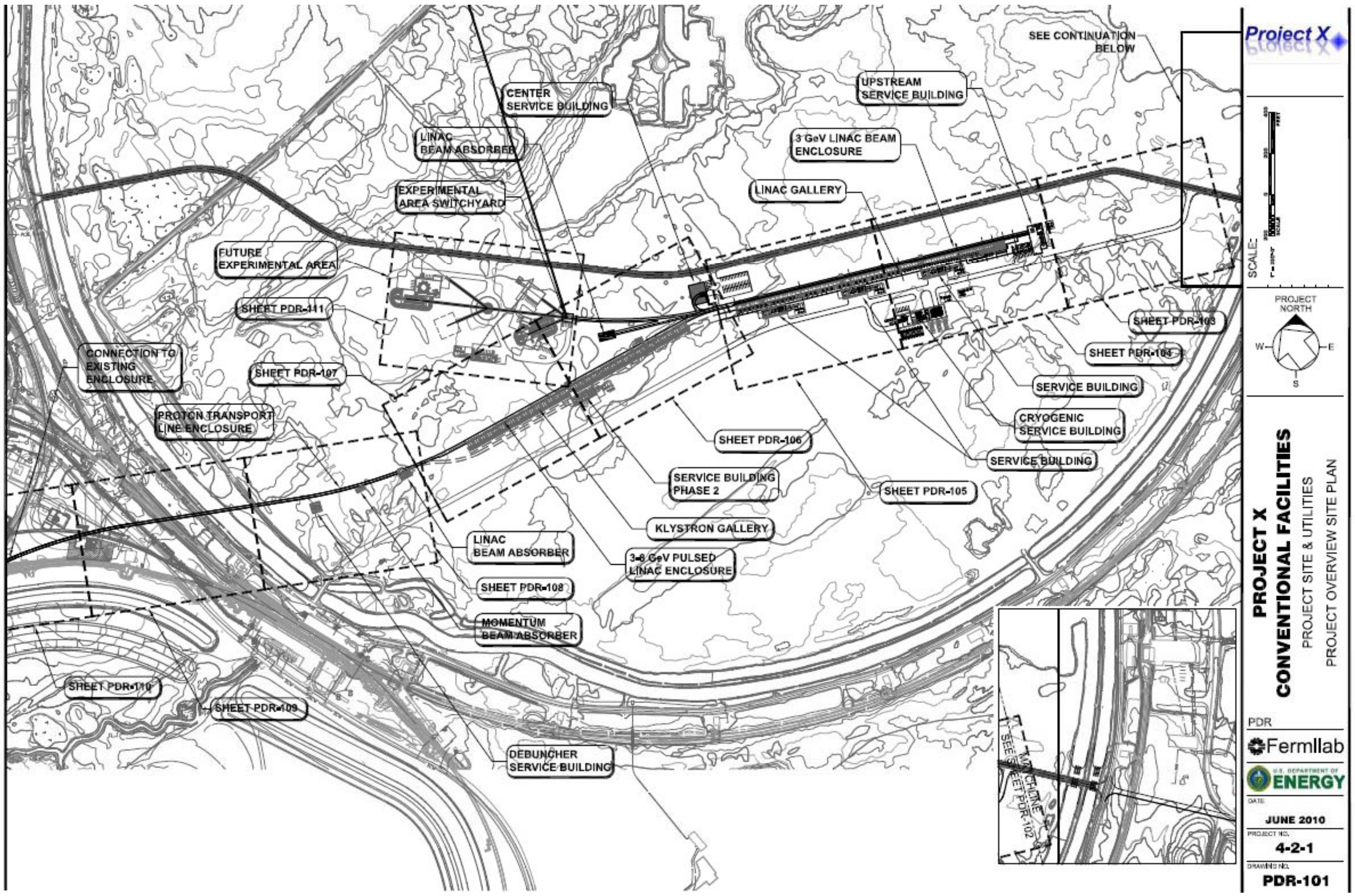
Pulsed Linac

- 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 10 Hz
    - One pulse required to load Main Injector

Capabilities

- > 2 MW delivered to a neutrino target at any energy between 60 – 120 GeV
- Simultaneous delivery of ~3 MW of high duty factor beam power to the 3 GeV program
  - Variable beam formats to multiple users
  - CW beam at time scales >1 μsec
  - 10% duty factor on time scales < 1 μsec
- Potential for development of additional programs at:
  - 1 GeV for nuclear energy experimentation
  - 8 GeV for neutrino or muon experimentation
- The utilization of a CW linac creates a facility that is unique in the world, with performance that is unlikely to be duplicated in any synchrotron-based facility.

Reference Design
Provisional Siting



Project X

Collaboration

- 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.
  - Collaboration MOUs for the RD&D phase outlines basic goals, and the means of organizing and executing the work. Signatories:

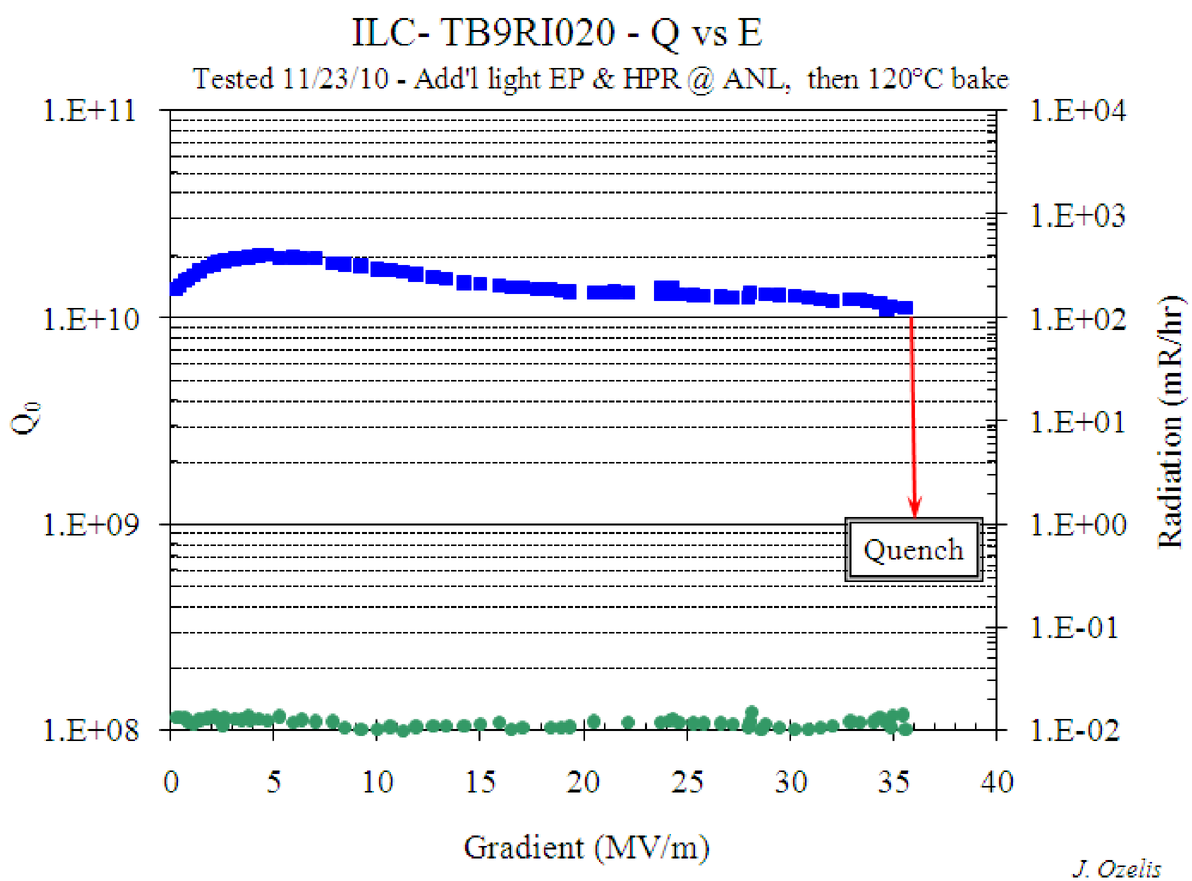
ANL	ILC/ART	RRCAT/Indore
BARC/Mumbai	IUAC/Delhi	SLAC
BNL	LBNL	TJNAF
Cornell	ORNL/SNS	VECC/Kolkata
Fermilab	MSU	

- It would be natural for collaborators to continue their areas of responsibility into the construction phase.

Project X Fermilab-ANL Collaboration

- ANL has had significant influence over the design of the low energy portion of the linac
  - All superconducting design starting at 2.5 MeV
- Scope of Work under development for FY11 and beyond. Current thinking:
  - SSR2 (β=0.4) cavity development
  - Cavity processing
  - Linac design and beam dynamics
  - SSR0 (β=0.1) alternative designs
- Physics program development
  - Nuclear Physics Task Force co-chaired by Jerry N. and Guy S.
  - Nuclear Energy Task Force co-chaired by Yousry G. and Shekhar M.

Fermilab-ANL Collab
Cavity Processing



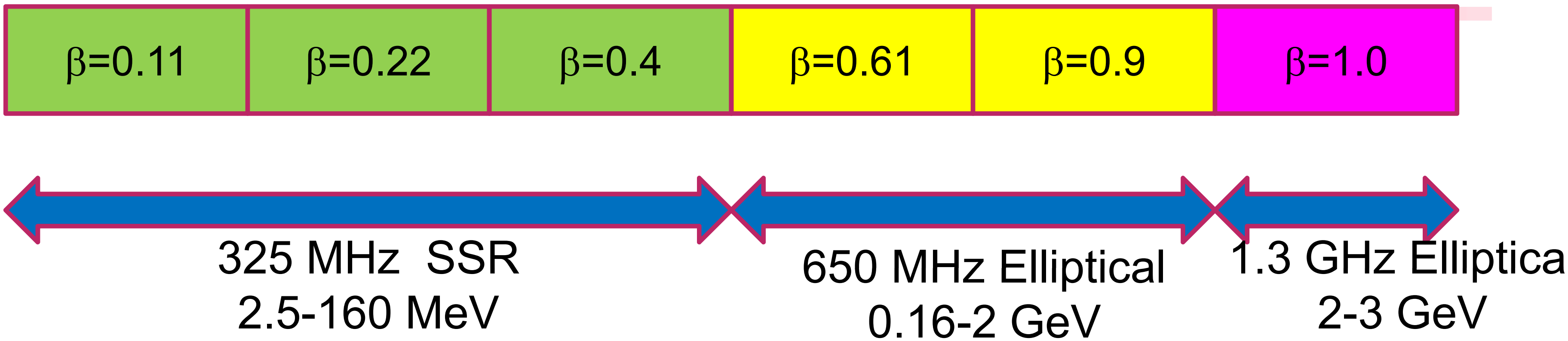
Project X

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 325 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
    - Includes development of qualified industrial partners
- Goal is to complete R&D phase by 2015

Project X

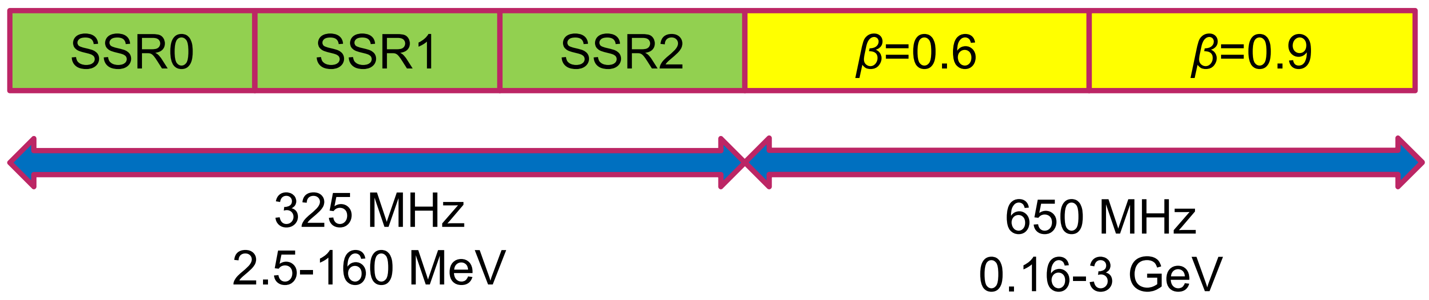
3 GeV CW Linac
Technology Map



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	44 /22/4	SSR, solenoid
LB 650 (β_G=0.61)	650	160-520	42 /42/7	5-cell elliptical, doublet
HB 650 (β_G=0.9)	650	520-2000	96 /24/12	5-cell elliptical, doublet
ILC 1.3 (β_G=1.0)	1300	2000-3000	72 /9 /9	9-cell elliptical, quad

Maybe 650

3 GeV CW Linac
Technology Map



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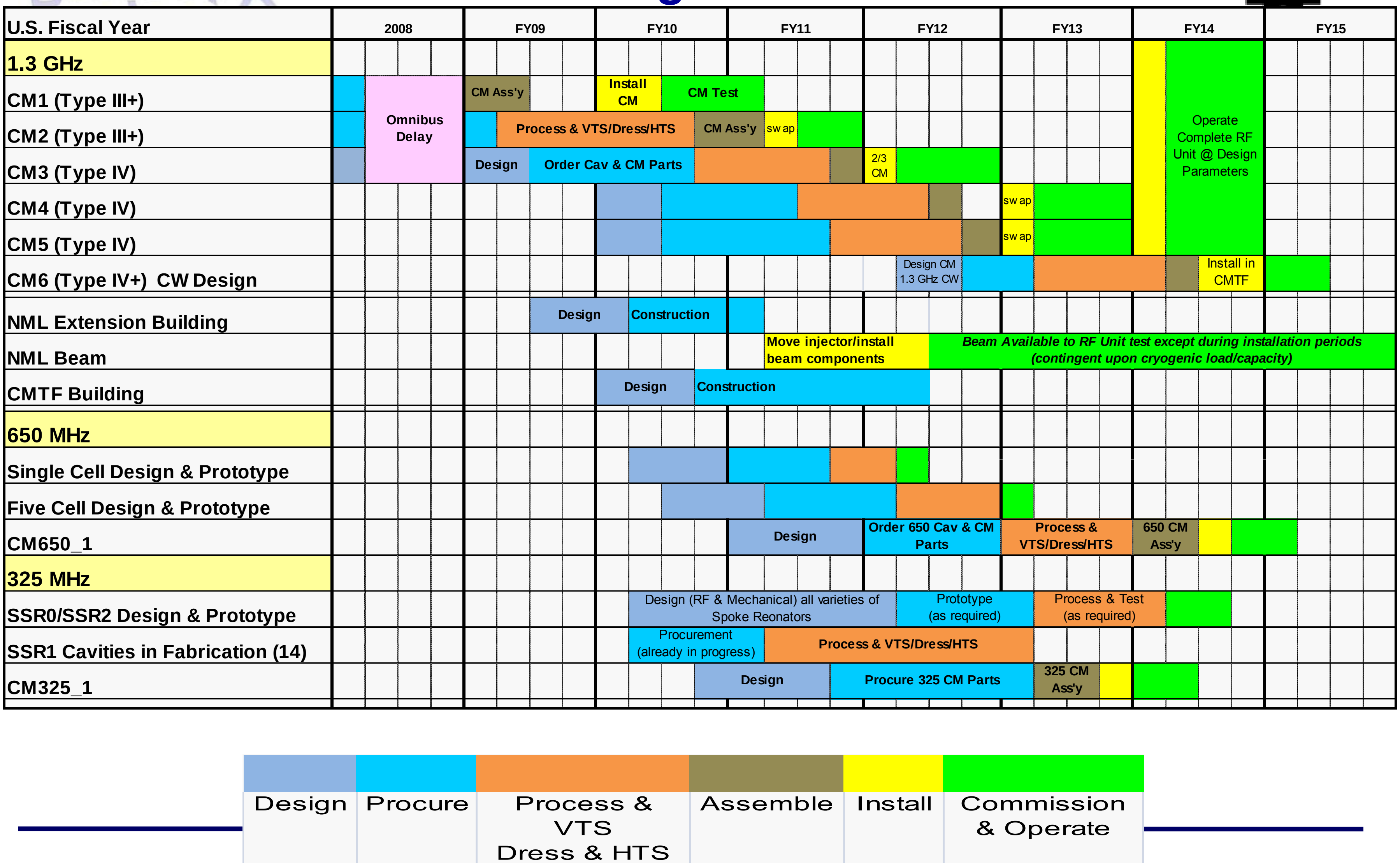
SSR1 (β_G=0.22)	325	10-32	18 /18/ 2	SSR, solenoid
SSR2 (β_G=0.4)	325	32-160	44 /24/ 4	SSR, solenoid
LB 650 (β_G=0.61)	650	160-520	36 /24/ 4	5-cell elliptical, doublet
HB 650 (β_G=0.9)	650	520-3000	144 /34/18	5-cell elliptical, doublet

RD&D Plan
Scope/Deliverables

- Scope
  - All activities required to bring Project X from the Reference Design through final design (CD-3).
- Deliverables
  - All documentation required by the Department of Energy prior to authorizing construction
  - Supporting technical R&D required to validate the design and establish fabrication methods
- Assumed Critical Decision dates
  - CD-0: 2011
  - CD-1: 2012
  - CD-2: 2013
  - CD-3: 2014
  - CD-4: 2019

Project X/ILC/SRF

Integrated Plan



Project X SRF Development Status

- 1300 MHz
  - 88 nine-cell cavities ordered
  - ~ 44 received (16 from U.S. industry, AES)
  - ~ 30 processed and tested, 8 dressed
  - 1 CM built (DESY kit) + second under construction (U.S. procured)
    - CM1 is now cold and about to initiate rf testing
- 650 MHz
  - MOU signed with Jlab for 2 single cell β =0.6 cavities
  - Order for six β = 0.9 single cell cavities in industry
- 325 MHz
  - 2 SSR1 β =0.22 cavities (Roark, Zannon) both VTS tested
  - 1 SSR1 dressed and under test at STF
  - 2 SSR1 being fabricated in India
  - 10 SSR1 ordered from Industry (Roark)
- Design work started on 325 and 650 MHz CM

Strategy/Timeline

- Now: Complete all preliminary design, configuration, and cost range documentation for CD-0.
  - Functional Requirements Specification
  - Reference Design Report
  - RD&D Plan
  - Cost estimate/range
  - Resource Loaded Schedule
- Continue conceptual development on outstanding technical questions
  - Baseline concept for the chopper
  - Concepts for marrying the 3-8 GeV pulsed linac to CW front end
  - Injection into the Recycler/Main Injector
  - Emphasis of srf development at all relevant frequencies
- The DOE has advised that the earliest possible construction start is FY2015
- Planning for a five year construction schedule

$\Rightarrow$Project X could be up and running in ~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;
  – Potential applications beyond elementary particle physics;
  – Aligned with ILC, Muon Accelerators, and Nuclear Energy
- Project X design concept is well developed and well aligned with the requirements of the physics program:
  – 3 GeV CW linac operating at 1 mA: 3 MW beam power
  – 3-8 GeV pulsed linac injecting into the Recycler/Main Injector complex
- We are expecting CD-0 for Project X in early 2011
- Project X could be constructed over the period ~2015 – 2019

Backup Slides

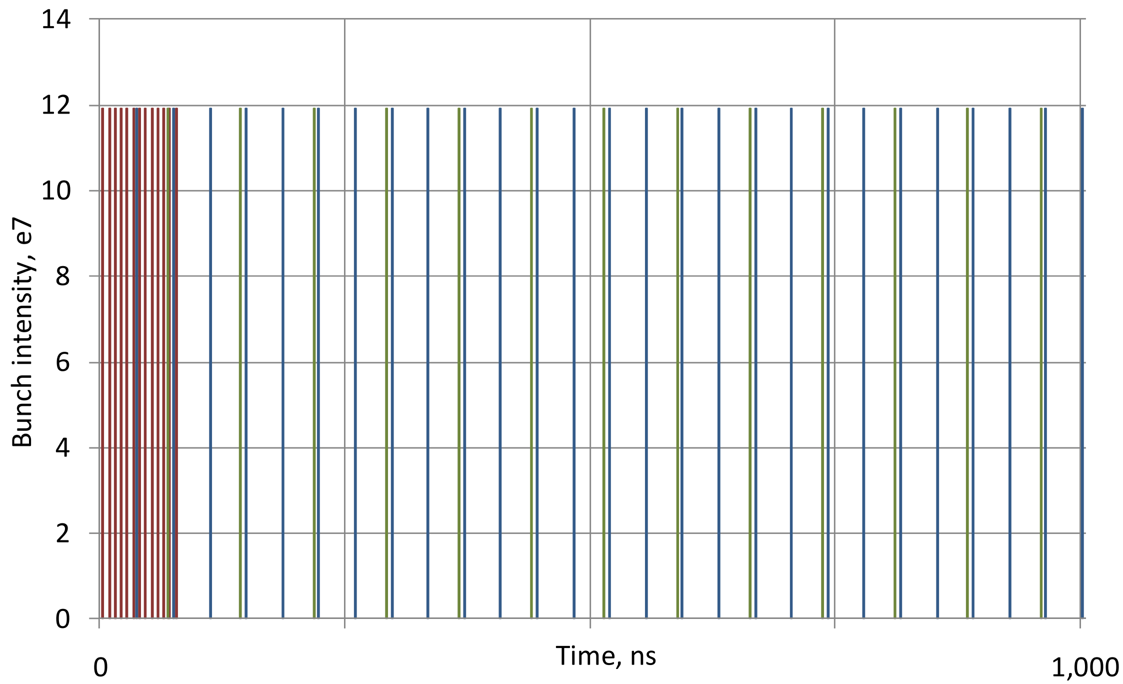
Operating Scenario
3 GeV Program

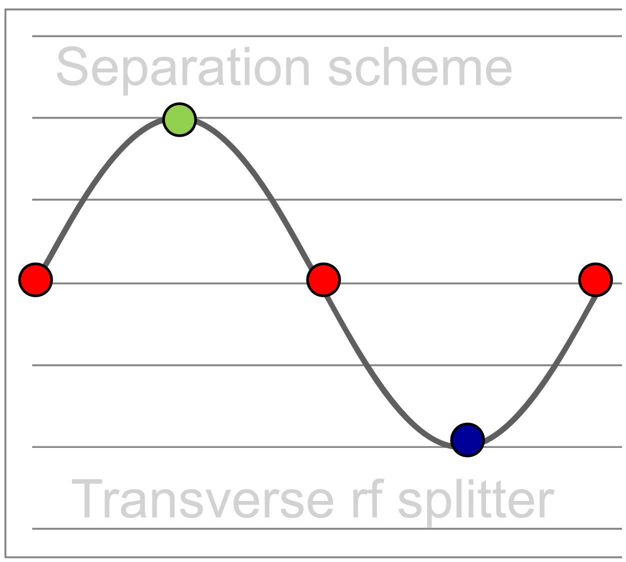
<u>1 μsec period at 3 GeV</u>

Muon pulses (12e7) 162.5 MHz, 80 nsec	750 kW
Kaon pulses (12e7) 27 MHz	1500 kW
Nuclear pulses (12e7) 13.5 MHz	750 kW

Ion source and RFQ operate at 6.2 mA

83% of bunches are chopped @ 2.5 MeV ⇒ maintain 1 mA over 1 μsec





Project X 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)	10 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	3.1 nsec (1/325 MHz)
L9	Bunch Length	<50 psec (full-width half max)
L10	Bunch Pattern	Programmable
L11	RF Duty Factor	100% (CW)
L12	RF Frequency	325 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	1.6×10^{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	2×10^{-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 support 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.	