Project X: Status, Strategy, Meeting Goals

Steve Holmes

Project X Collaboration Meeting

September 8, 2010

Outline

- U.S./Fermilab Strategic Plan
- Update on Activities of the Last Year
- Project X Goals and Initial Configuration-2
- RD&D Plan
- Collaboration Status
- Meeting Goals, Agenda, and Organization

Our websites:

http://projectx.fnal.gov

http://projectx-docdb.fnal.gov

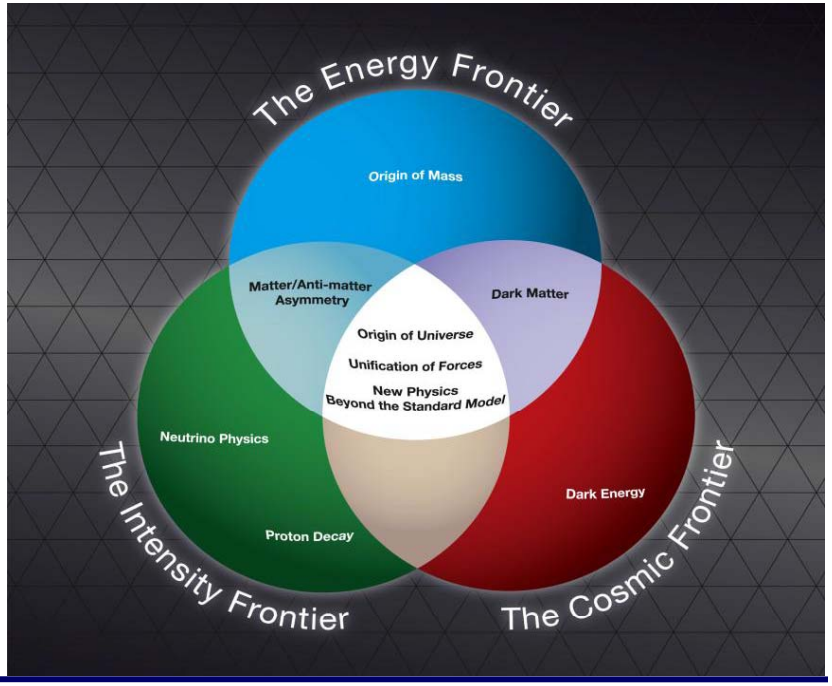
Meeting website:

http://projectx.fnal.gov/sep_10_collab_mtg.shtml

Fermilab Strategic Plan

The U.S. strategy for elementary particle physics over the coming decades has been developed by the P5 sub-panel and endorsed by HEPAP. Fermilab is fully aligned with this strategy.

⇒***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.***

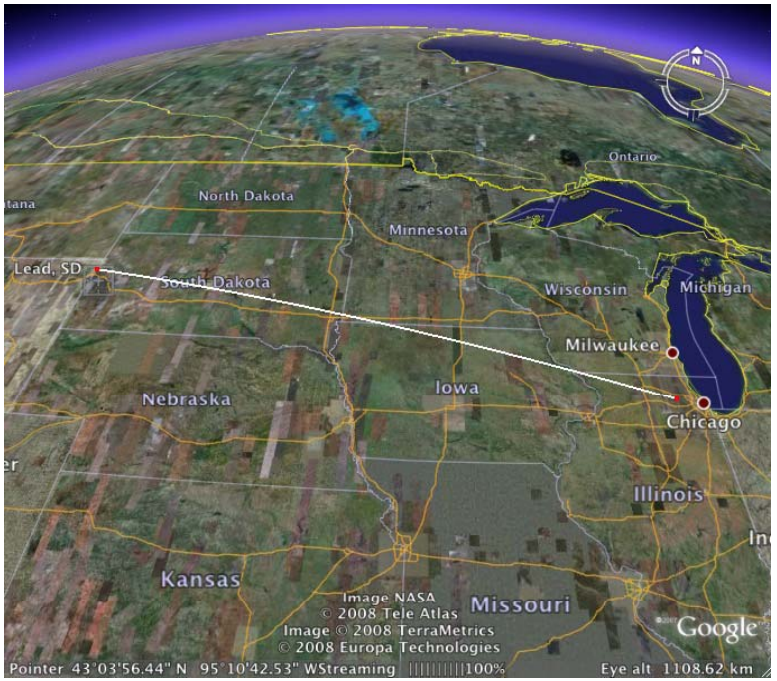


Evolution of the Fermilab Accelerator Complex

- 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

Mission

- 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 ~4 MW at ~5-15 GeV .



- Possible non-HEP missions under consideration
  - Nuclear physics and ADS development

News Since the September 2009 Meeting

- Initial Configuration-2 established as preferred configuration
  - First discussed in last year's meeting
  - This has triggered the start of R&D spending, including the initial releases of funding to collaborators
  - Functional Requirements Specification (FRS) released (draft)
- CD-0 for LBNE and Mu2e experiments
  - New intensity frontier initiatives
- Integration of PX, SRF, and HINS activities at Fermilab
  - Successful testing of first two superconducting spoke resonator cavities
- Development of the India Collaboration
  - Fermilab-Indian Institutions MOU on high intensity proton accelerator R&D
- ICD-2v2, accompanying R&D plan, RLS, and cost estimate in preparation
  - Re-christen as "Reference Design Report"
- Project X Friday meeting now available for participation via webex

News Since the September 2009 Meeting

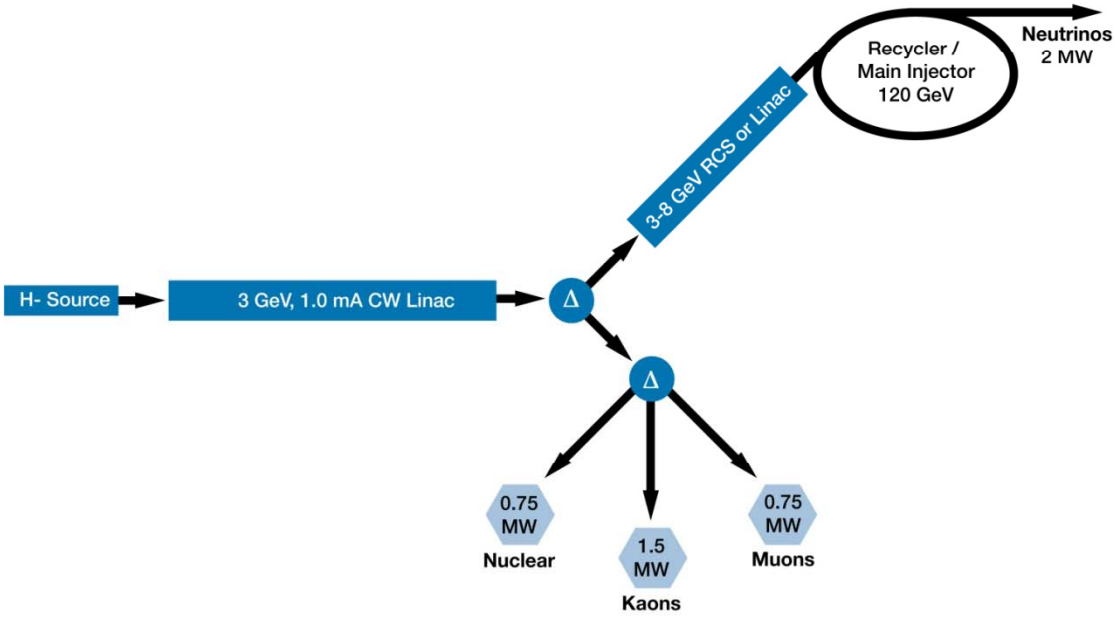
- DOE Science & Technology Review
  - "The Project X machine design is sufficiently well developed for the pre-CD0 stage."
  - "The physics program for Project X is not well defined at this time. The scientific community should be engaged in defining the potential program."
- Five Physics/Experiments Task Forces established
  - Neutrinos
  - Kaons
  - Muons
  - Nuclear Physics
  - Nuclear Energy

  Goal: define an initial experiment in each area
  Fall workshops
- ARRA
  - Significant investment in SRF infrastructure at Fermilab and development of domestic vendors
- New Fermilab Associate Director for Accelerators – Stuart Henderson

Initial Configuration 1 → 2

- Initial Configuration-1 was based on an 8 GeV, superconducting, pulsed linac strongly aligned with ILC
  - Strong capabilities in support of the neutrino mission, but…
  - Does not provide a strong platform for mounting a low energy rare processes program
    - Difficulties providing high beam power/high duty factor beam
    - Difficulties supporting multiple users with differing spill structure requirements
- Initial Configuration-2 addresses the deficiencies in IC-1 through incorporation of a CW linac
  - Solves the slow spill limitations in IC-1 by eliminating slow spill
  - Physics workshop (November 2009) identified 3 GeV as an appropriate energy and also established bunch configuration requirements.

Initial Configuration-2 aka "Reference Design"



- 3 GeV, 1 mA, CW linac
- Greatly enhanced capabilities in the rare processes program
  - MW class beam power to multiple experiments with variable bunch configurations, simultaneous with neutrino operations
- Self-consistent concept with RCS for 3-8 GeV acceleration
  - Pulsed linac preferred, assuming it can be made to work and is cost effective

Project X Goals

- Construct a 3 GeV continuous-wave superconducting H- linac, capable of delivering 1 mA of average beam current.
  - Supports rare processes and nuclear physics programs
  - Can support ADS development with beams energy <2 GeV
- Construct a 3-8 GeV pulsed linac, utilizing an ILC-style RF system, with total beam power delivered to 8 GeV ovf 300 kW.
  - Required for the neutrino program
  - Establishes a path toward a muon based facility
- Upgrade the Recycler and Main Injector to provide ≥ 2 MW to a neutrino production target at 60-120 GeV.
  - Supports the long baseline neutrino program
- Simultaneous operations of the rare processes and neutrino programs

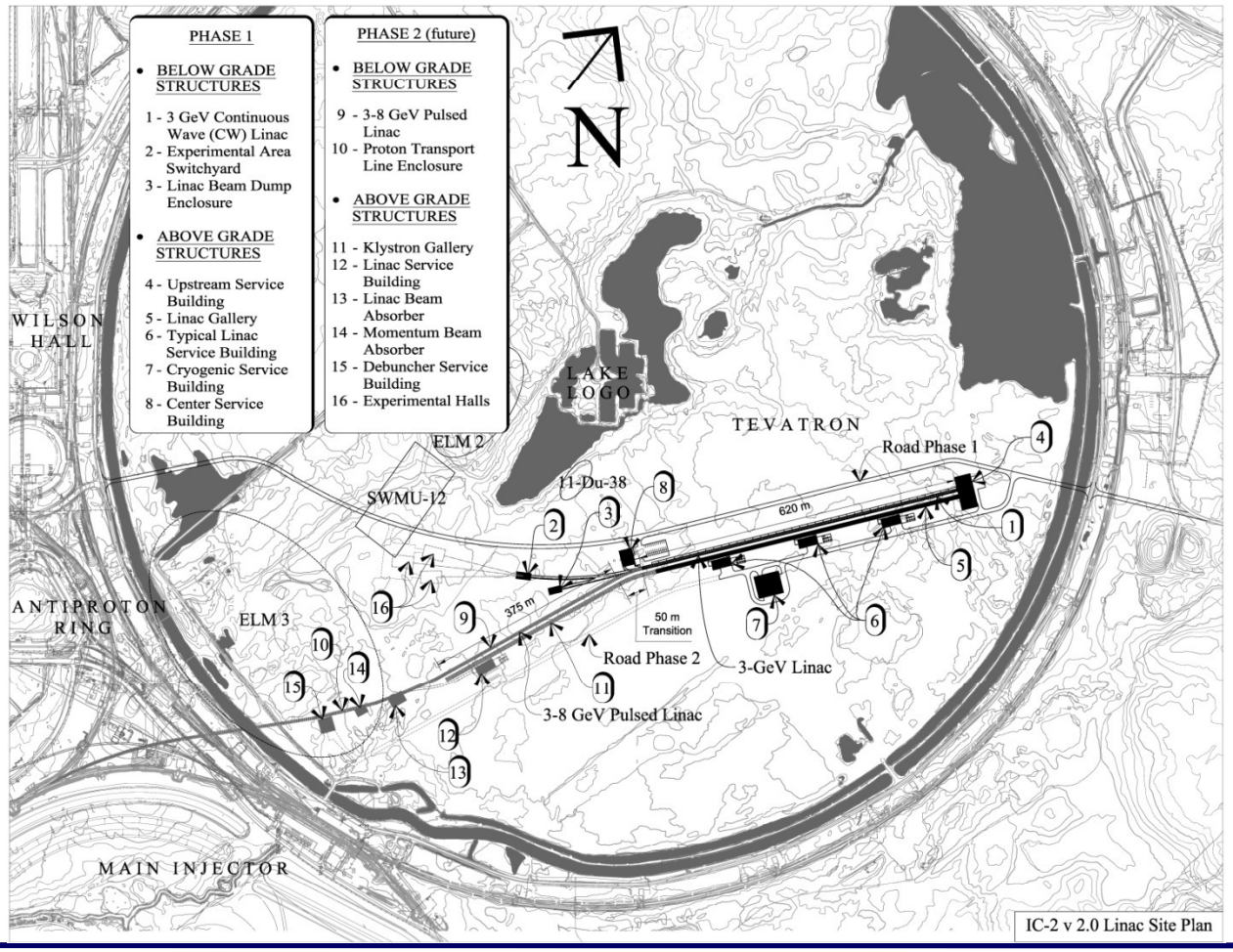
Functional Requirements

Requirement	Description	Value
L1	Delivered Beam Energy, maximum	3 GeV
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 (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

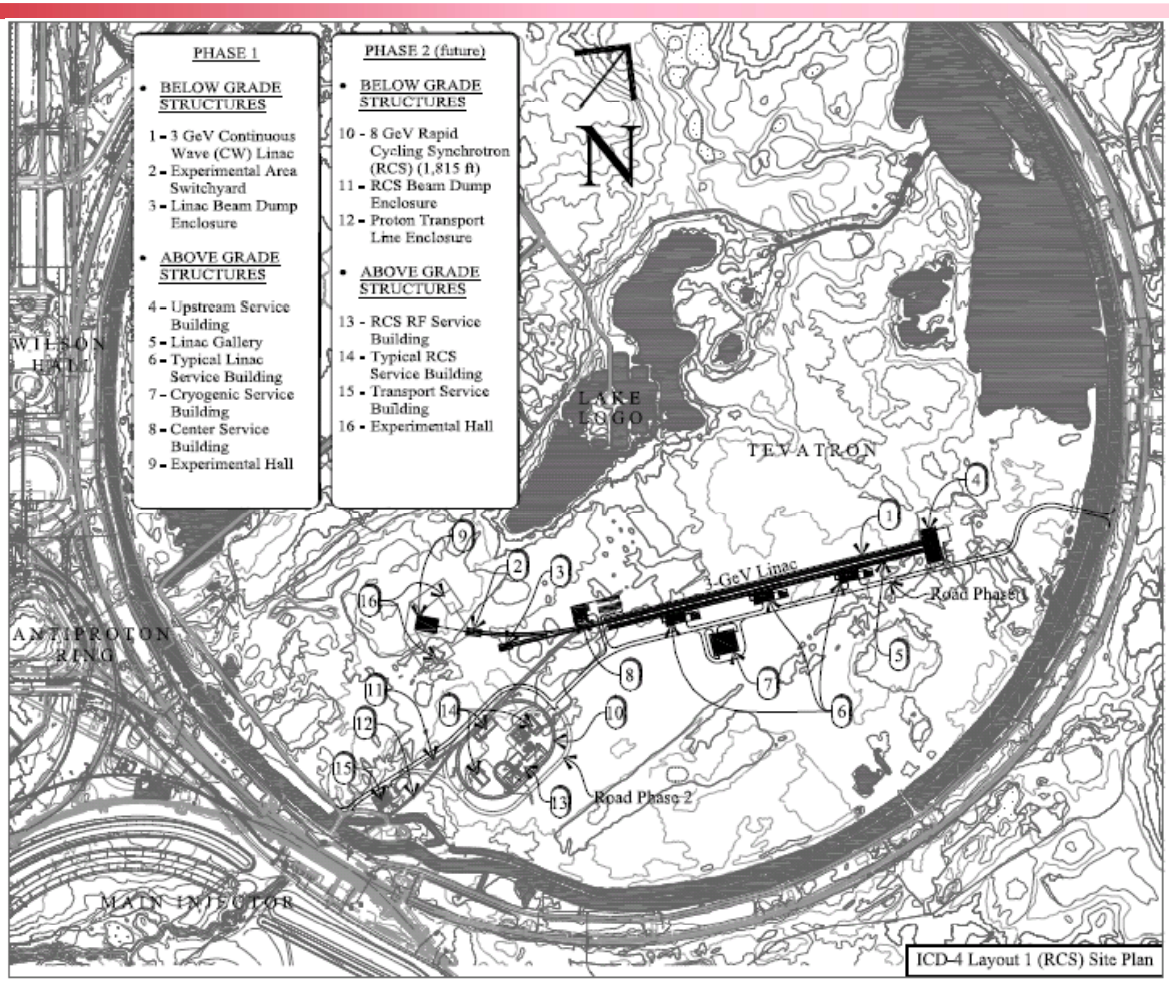
Functional Requirements

Requirement	Description	Value
M1	Delivered Beam Energy, maximum	120 GeV
M2	Delivered Beam Energy, minimum	60 GeV
M3	Beam Power (60-120 GeV)	> 2 MW
M4	Beam Particles	Protons
M5	Beam Intensity	1.6 x 10^{14} protons per pulse
M6	Beam Pulse Length	9.5 μsec
M7	Bunches per Pulse	504
M8	Bunch Spacing	18.8 nsec (1/53.1 MHz)
M9	Bunch Length	<2 nsec (fullwidth half max)
M10	Pulse Repetition Rate (120 GeV)	1.333 sec
M11	Pulse Repetition Rate (60 GeV)	0.75 sec
I1	The 3 GeV and neutrino programs must operate simultaneously	
I2	Residual Activation from Uncontrolled Beam Loss	<20 mrem/hour (average) <100 mrem/hour (peak) @ 1 ft
I3	Scheduled Maintenance Weeks/Year	4
I4	Operational Reliability	90%
I5	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	

Reference Design
Provisional Siting



Reference Design
Provisional Siting



Technical Issues (for discussion at this meeting)

- Discussions in the context for the Functional Requirements
  http://projectx-docdb.fnal.gov:8080/cgi-bin/ShowDocument?docid=658
- Configuration
  - Establish a self-consistent concept for acceleration from 3 to 8 GeV based on a pulsed linac with an ILC-style (1300 MHz) rf system
  - Explore the optimal set of operating frequencies in the CW linac
  - Explore the pluses and minuses of various cryogenic segmentation schemes
- Technical
  - Evaluate need for HOM dampers in the CW linac
  - Develop a strategy/requirements for microphonics control in the CW linac
  - Develop a better understanding of beam loss mechanisms (including intra-beam stripping) and mitigation strategies
  - Develop a self-consistent concept for H- injection into the first circular accelerator

RD&D Plan
Goals

- RD&D = Research, Design, and Development
- RD&D Plan corresponding to ICD-2
  - Updated to reflect the new configurations
  - Most recent version available at: http://projectx-docdb.fnal.gov:8080/cgi-bin/ShowDocument?docid=628
- Goals
  - Complete design of the Project X facility including all technical and conventional construction elements
  - Identification of key accelerator physics and engineering challenges and validation of performance of critical technology items
    - Simulations, experimentation, and prototype construction as appropriate
  - Development of an acquisition strategy for key technical elements, including development and qualification of vendors for critical components
  - Development of a technical/cost/schedule baseline for construction
  - Preliminary identification of performance upgrade paths

RD&D Plan
Scope/Deliverables

- Scope
  - All activities required to bring Project X from ICD-2v2 through final design (CD-3 in the DOE management system).
  - Integrates efforts funded directly by Project X and other superconducting rf development programs at Fermilab.
- Deliverables
  - Documentation required for CD-0, CD-1, CD-2, and CD-3
  - Supporting technical R&D required to validate the design and establish fabrication methods
- Assumed Critical Decision dates
  - CD-0: January 2011
  - CD-1: July 2012
  - CD-2: August 2013
  - CD-3: September 2014

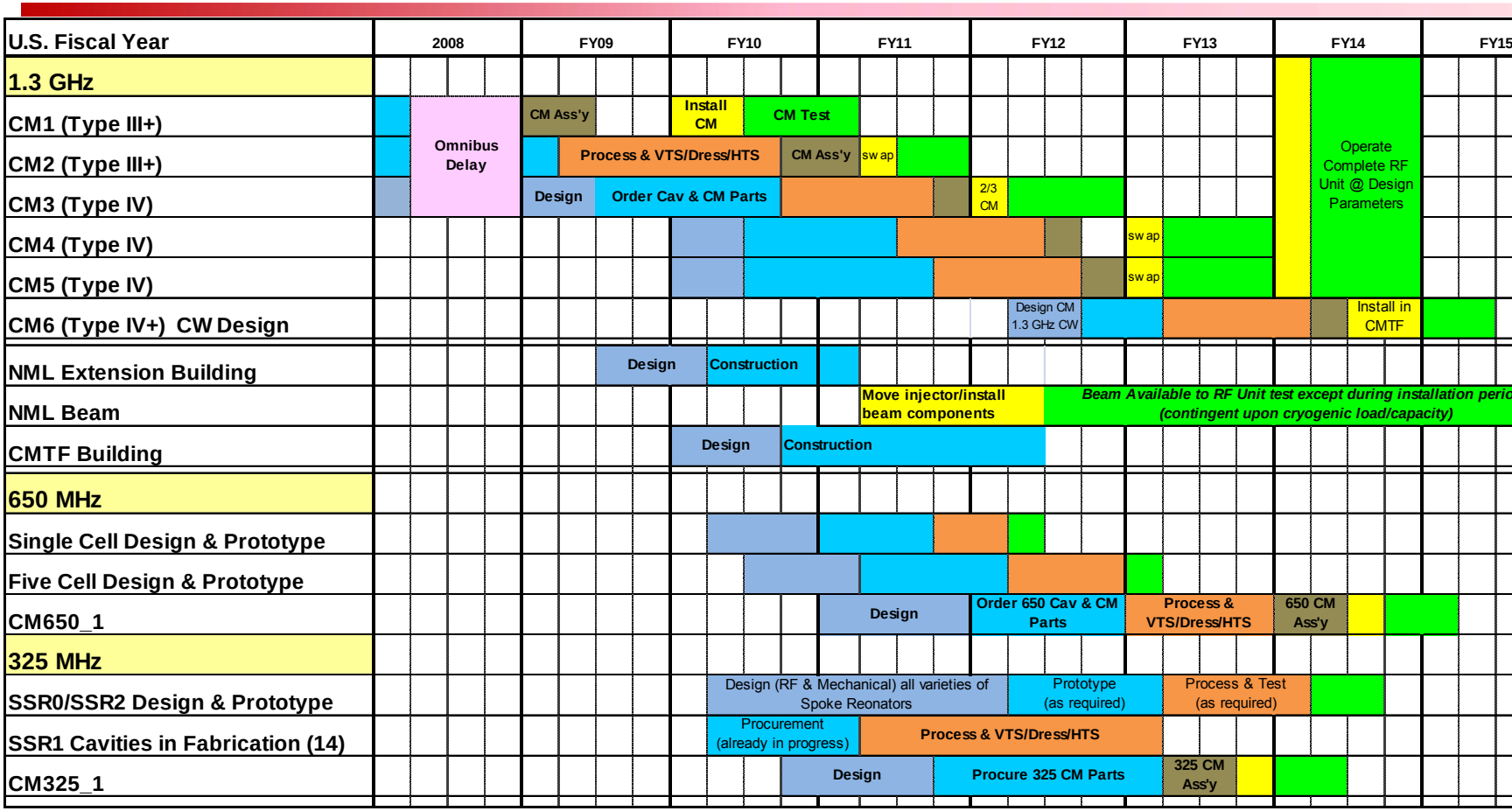
Project X/ILC/SRF
Integrated Plan

- All srf programs at Fermilab are being integrated into a single, centrally managed program.
  - Effective FY2011
  - Brings all srf activities under the purview of the ILC/SRF Program Director
    - ILC and Project X management define requirements
- Discontinue the HIgh Intensity Neutrino Source (HINS) program as a stand-alone R&D program
  - Rescope the beam facility to support chopper and instrumentation development for Project X. Fund via Project X R&D
  - Retain low beta cavity development under the direction of the ILC/SRF Program Director
  - Eliminate HINS as a budget line item

Project X/ILC/SRF
Integrated Plan

- Establish clear deliverables for the srf program over the period FY2010-15:
  - Six 1300 MHz cryomodules, culminating in a CW Project X prototype
    - High power rf tests.
    - ILC rf unit test, with beam, at NML based on three 1300 MHz ILC cryomodules
  - One 650 MHz cryomodule for Project X. High power rf test.
  - One 325 MHz cryomodule for Project X. High power rf test.
  - Complete Project X test facility at Meson Lab

Integrated SRF Plan
ILC + PX



Organization

- Project X is organized as a national project with international participation
  - Fermilab as the lead laboratory
- Fermilab PX Organization
  - Associate Director for Accelerators: Stuart Henderson
  - Project Manager: Steve Holmes
  - Project Scientist: Sergei Nagaitsev
  - Project Engineer: Jim Kerby
  - SRF Coordinator: Bob Kephart
  - International Coordinator: Shekhar Mishra
  - Subsystem Managers: Numerous (All identified)
- Collaboration Council
  - Inter-institutional communication to facilitate execution of the RD&D phase, and prepare for a construction pahse
  - Institutional representation from each of the MOU signatories

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 sources in place between Fermilab and Indian institutes:

  BARC/Mumbai

  IUAC/Delhi

  RRCAT/Indore

  VECC/Kolkota

Near Term Strategy (~Next 6 months)

- Complete Reference Design documentation:
  - RDR (fka ICD-2v2)
  - Accompanying cost estimate
  - Updated R&D plan
- Develop plan on critical technical issues
  - Baseline concept for the chopper
  - Concepts for marrying a 3-8 GeV pulsed linac to the CW front end
  - Injection into the first circular accelerator
  - Establishment of beam requirements for initial experiments
- Transition to the CW R&D program
- Conduct DOE briefing
  - Physics and accelerator concept

⇒**All cost/configuration info available**

- Push for CD-0

Longer Term Strategy

- Execute R&D plan oriented toward Reference Design
  - Emphasis on srf development at all relevant frequencies
  - Consolidated Project X and SRF infrrastructure efforts in common organization with rationalized funding sources
  - Engagement of collaborators
- Identify/engage stakeholders outside HEP
- Establish possible upgrade path for a muon facility front end
- DOE has advised us that the earliest possible dates are:
  - CD-0: FY2011
  - CD-3 (construction start): FY2015
- Prepare for a 5-year construction period

Working Timeline

- FY2010
  - Complete Reference Design Report and preliminary cost estimate
  - Revise RD&D plan and initiate work
- FY2011
  - CD-0
  - Initiate work on Conceptual Design Report
  - Initiate permitting documentation
- FY2012
  - CD-1
- FY2013
  - CD-2/3a
- FY2014
  - CD-3: Initiate Construction
- ~FY2015~2019
  - Construct

Collaboration Meeting: Goals

- Discuss Current Project X Configuration
  - Review of ICD-2/Reference Design
  - Discussion and input from collaboration on specified technical issues
    - See slide 15
- [Establish RD&D Plan for FY11]
  - Review the RD&D plan corresponding to IC-2
  - Discuss/establish work plan for FY11-12
    - Goals, milestones, assignments
    - Strawman budgets for FY11 will be provided as starting point
    - FY11 budgets will be established following the collaboration meeting
  - Understand integration with the ILC and SRF infrastructure programs.
- Collaboration Council Meeting
  - Review of Project X status and strategy
  - Review current institutional assignments
  - Discuss potential interactions with international and university collaborators
  - Discuss establishment of a Technical Advisory Committee
  - Establish next Collaboration Meeting dates and site

Collaboration Meeting:
Agenda

- Wednesday, September 8
  - Opening plenary session 08:30-10:30
    - Project X Introduction and Strategy — Steve H.
    - Project X ICD-2 Overview — Sergei N.
  - Coffee Break (1 West) 10:30-11:00
  - Working Groups session one 11:00-12:30
  - Lunch (self-serve) 12:30-13:30
  - Working Groups session two 13:30-15:30
  - Coffee Break (WH2, W&C) 15:30-16:00
  - Working Groups session three 16:00-17:30
  - Collaboration Council meeting 16:00-17:30
  - Adjourn 17:30

Collaboration Meeting:
Agenda

- Thursday, September 9
  - Working Group Reports 08:30-10:00
    - Linac Integration
    - Cavities and Cryomodules
    - Linac RF
    - Cryogenics
  - Coffee Break 10:00-10:30
  - Working Group Reports 10:30-12:00
    - Linac Front End
    - Main Injector/Recycler
    - Instrumentation and Controls
    - Pulsed Linac and Injection
  - Adjourn 12:00

Collaboration Meeting:
Working Groups

- Charge to the working groups:
  - Review and confirm understanding of IC-2
  - Discuss and identify any potential issues/modifications to IC-2
    - With particular emphasis on technical issues on slide 15
  - [Establish goals and work plan for FY2011-12 (elements and sequencing);]
  - [Provisional distribution of responsibility, and funding, for FY2011-12]
  - Identify any issues related to the above that need resolution

- Provisional FY2011 budget distribution ($K, direct costs only):

	M&S	SWF	Collabs	Total
Available*	$2830	$5639	$1350	$9834

*Notes:
  - Includes beam test facility at MDB (formerly known as HINS)
  - Does not include FY2010 carryover estimated at: $500-750K
  - Intend to establish FY2011 budget following this meeting

Collaboration Meeting:
Working Groups

• RF Systems	R. Pasquinelli/B. Chase
• Cavities & CMs	M. Champion/B. Rimmer
• Main Injector/Recycler	I. Kourbanis/R. Ryne
• Instrumentation/Controls	M. Wendt/C. Briegel/W. Blokland
• Cryogenics	A. Klebaner/B. Petersen
• Linac Integration	S. Yakovlev/J. Kerby/J. Galambos
• Pulsed Linac/Injection	S. Nagaitsev/D. Johnson/D. Raparia
• Linac Front End	R. Webber/D. Li

Agenda: http://indico.fnal.gov/conferenceDisplay.py?confId=3542

Summary

- Project X is central to Fermilab's strategy for future development of the accelerator complex:
  - Energy Frontier: Aligned with ILC technology development; Fermilab as potential site for ILC or a Muon Collider
  - Intensity Frontier: World leading program in neutrinos and rare processes; Fermilab as potential Neutrino Factory site
- Initial Configuration-2 established as preferred concept
  - To be known as the Reference Design going forward
  - 3 GeV identified as an effective energy for the rare processes program
  - 3 GeV CW linac identified as providing flexible support to this program
  - Simultaneous operations of multiple 3 GeV experiments with different bunch configurations.
  - Prefer a pulsed linac for 3-8 GeV acceleration; we are closing in on a self-consistent concept
- Project X could be constructed over the period ~2015 - 2019
- Collaboration Meeting Goals:
  - Look at ICD-2, in particular discuss areas of technical uncertainty
  - Formulate the plan for next year

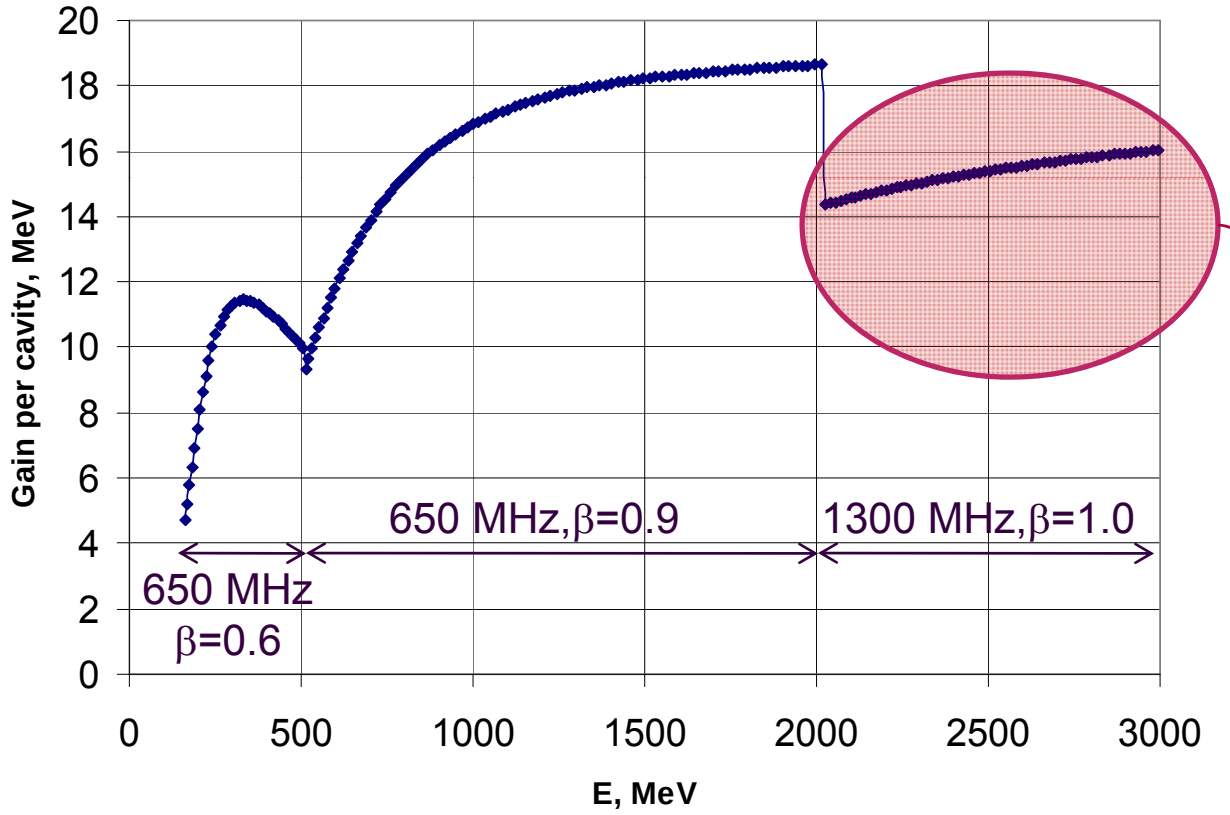
Working Group Room Assignments (session 1)

RF Systems	1-North
Cavities & CMs	Hermitage (ICB2)
Main Injector/Recycler	Req Room (WH4NW)
Instrumentation/ Controls	1-West Curia II (WH2SW)
Cryogenics	Comitium (WH2SE)
Linac Integration	1-West
Pulsed Linac/Injectiontegration	1-West
Linac Front End	1-West

Backup Slides

R&D Program
Cavity: Further Optimizations

Energy gain/cavity

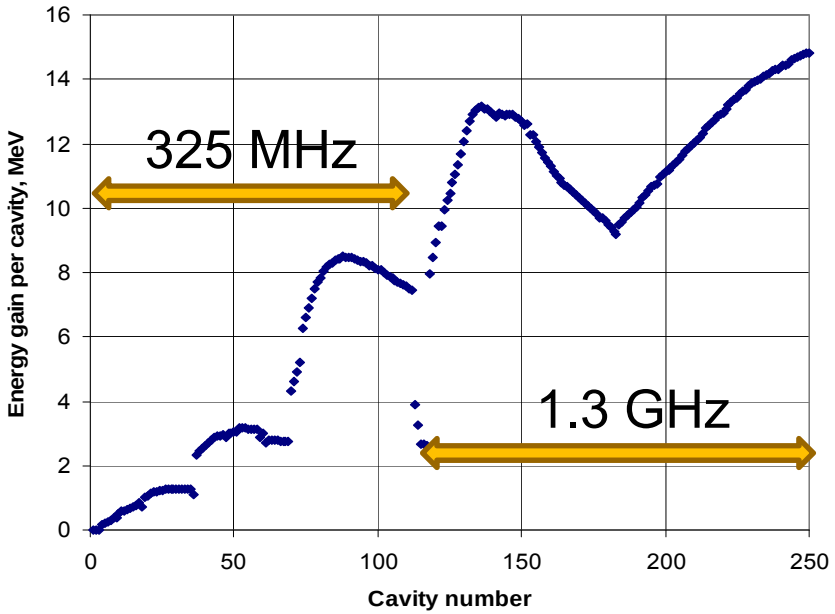


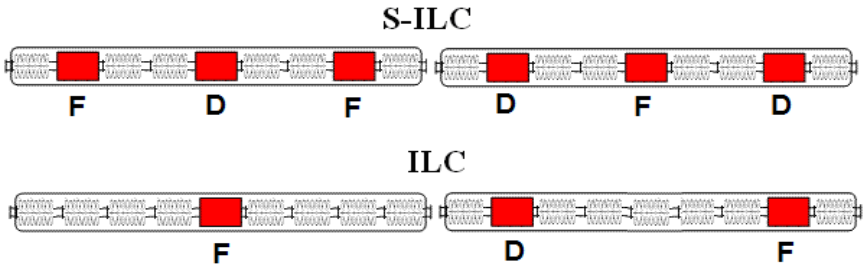
Discontinuity may be substantially reduced with a β=0.95 cavity

Configuration Evolution
Physics Requirements

	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

Strategy and Evolution
Initial Configuration-2v1

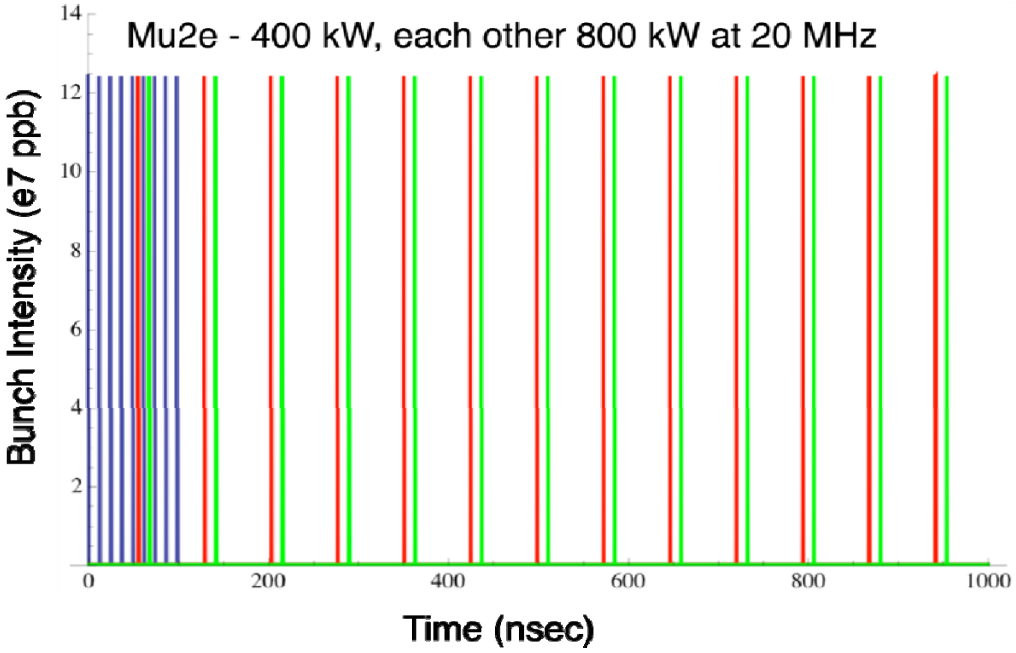


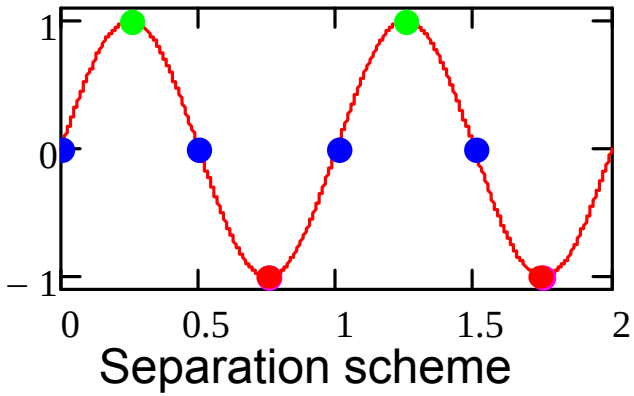


Initial Configuration-2
Operating Scenario

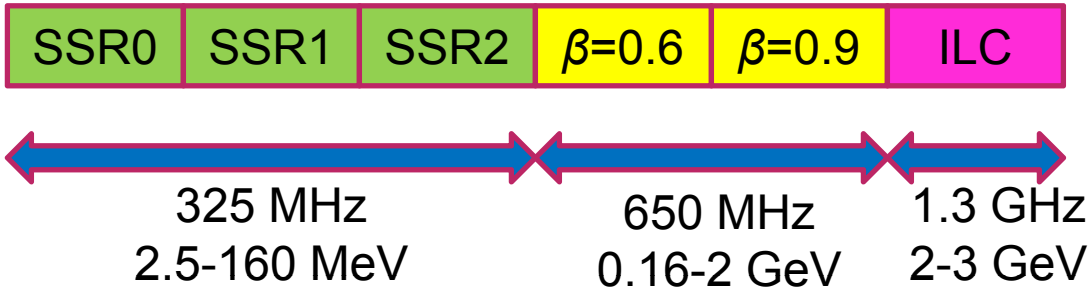
1 μsec period at 3 GeV

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





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

RD&D Plan
Institutional Activities

	Front End	Cav & CMs	RF	Cryo	Instru	Cntrls	MI/Recycler	Beam Trnspt	Accel Phys	Systm Integ	Test Facil
ANL		X	X						X		
BNL								X			
Cornell		X					X				
Fermilab	X	X	X	X	X	X	X	X	X	X	X
LBNL	X				X				X		
SNS					X						
MSU		X		?							
TJNAF		X									
SLAC	X		X				X		X		X
ILC/ART		X									
BARC	X		X		X						X
IUAC		X									
RRCAT		X									X
VECC		X									