Project X Program and India Collaboration

Steve Holmes
July 29, 2011

Outline

- Fermilab Long Range Plan
- Project X Reference Design
- R&D Plan
- Timeline & Strategy
- India Institutes and Fermilab Collaboration

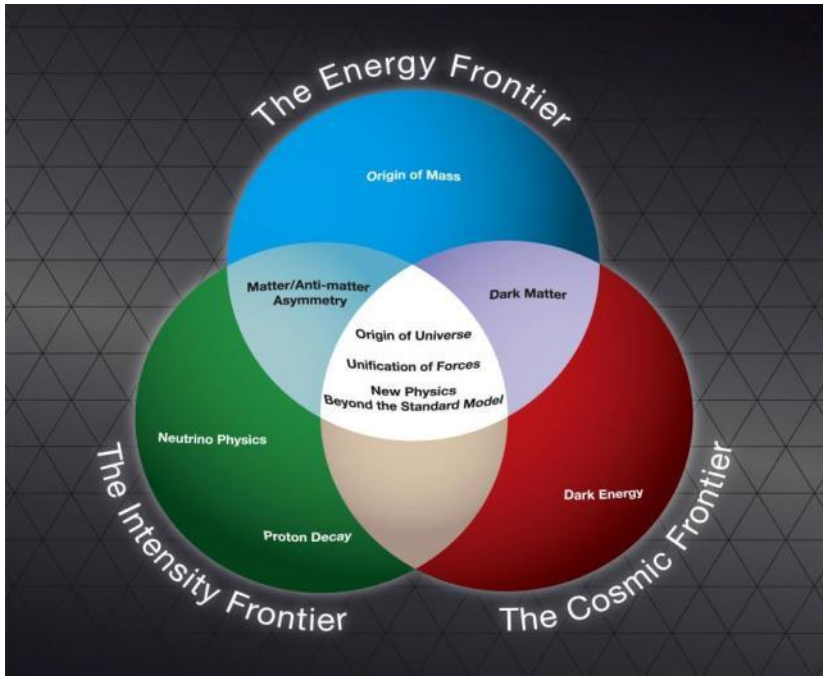
Project X website: http://projectx.fnal.gov

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.

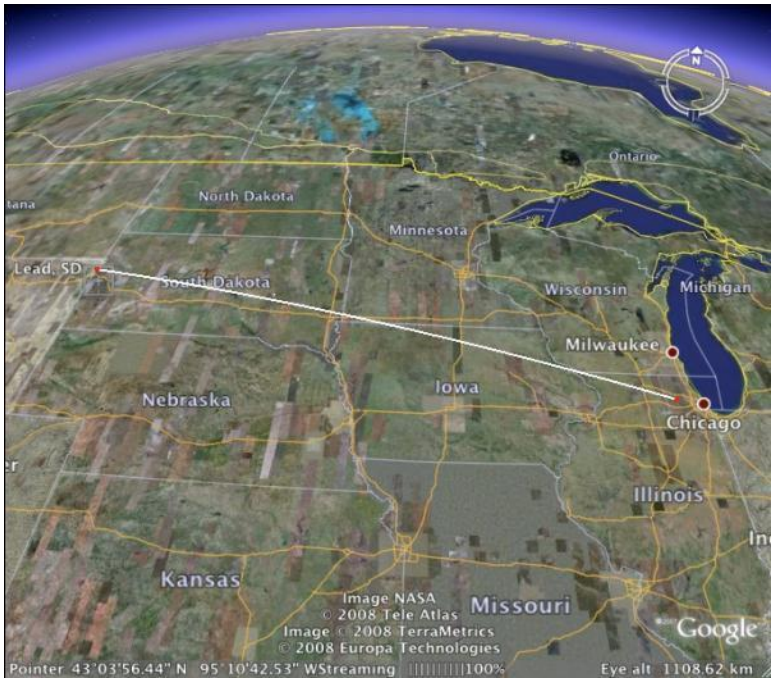
⇒ ***The Fermilab strategy is to mount a world-leading program at the intensity frontier, while using this program as a bridge to an energy frontier facility beyond LHC in the longer term.***

Project X is the key element of this strategy



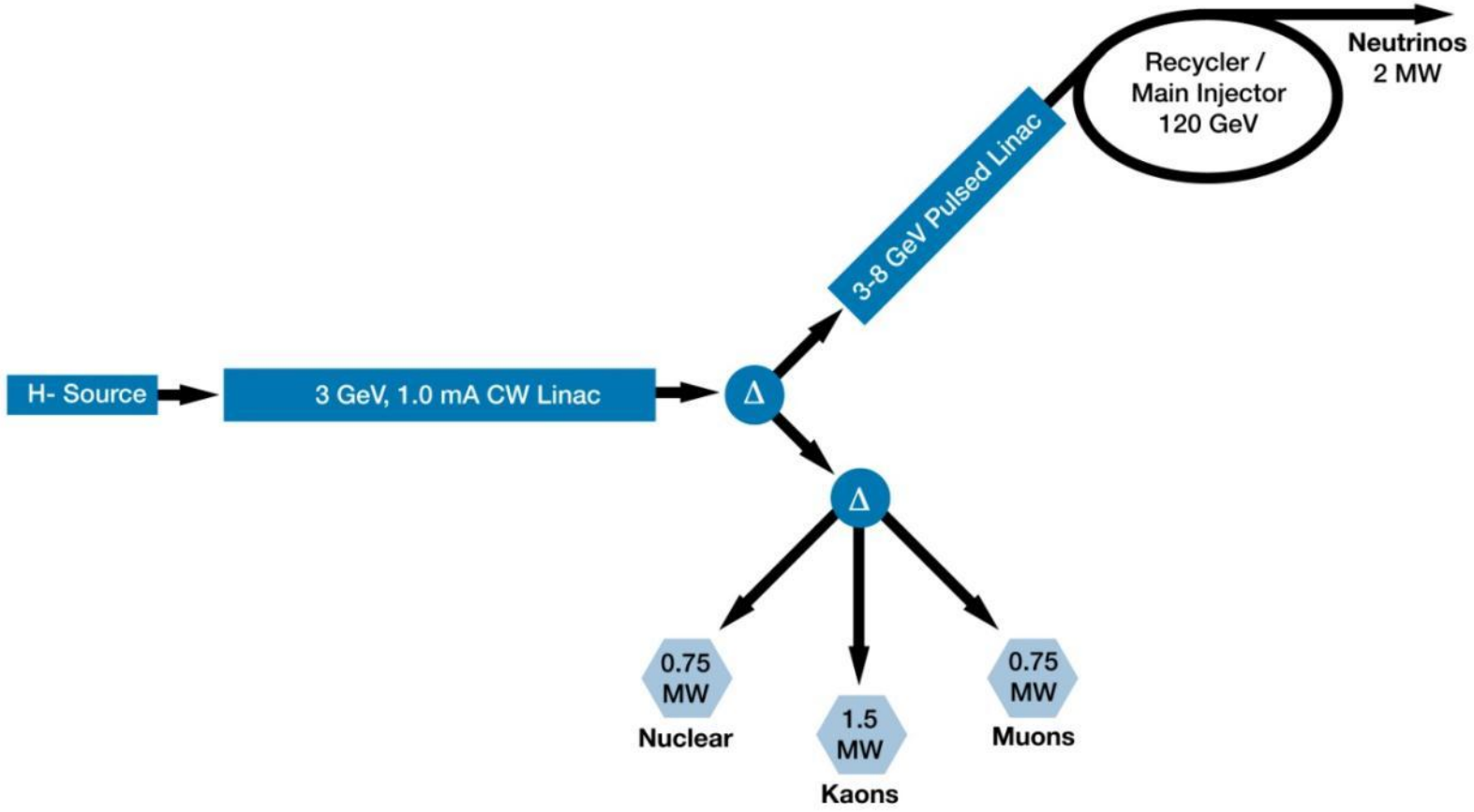
Mission

- 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

Reference Design



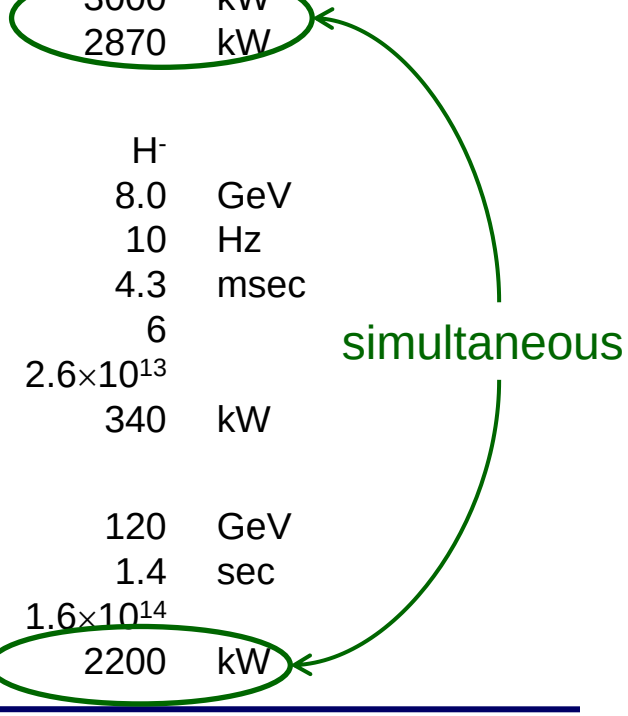
Reference Design Capabilities

- 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.

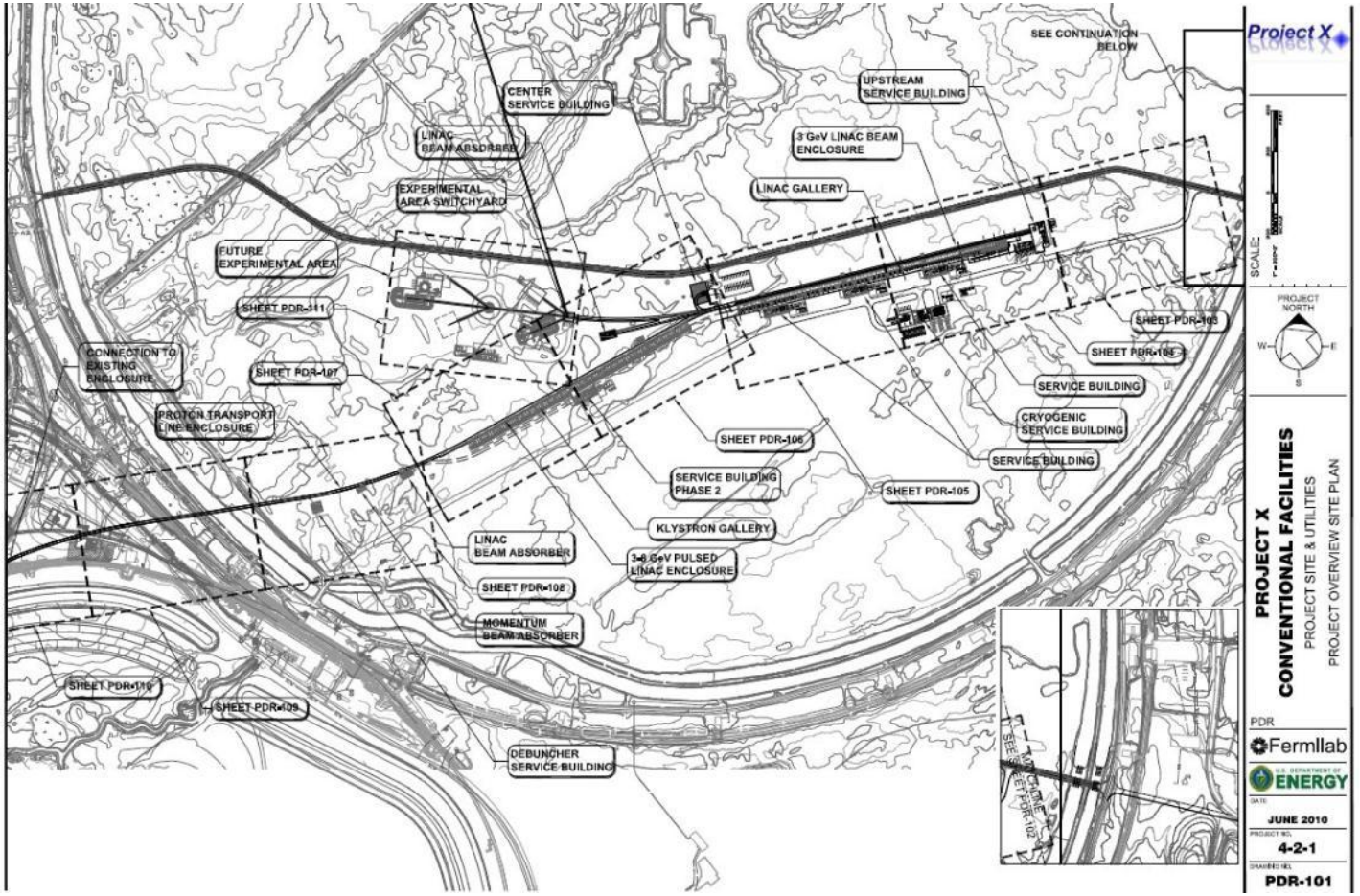
⇒ Utilization of a CW linac creates a facility that is unique in the world, with performance that cannot be matched in a synchrotron-based facility.

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



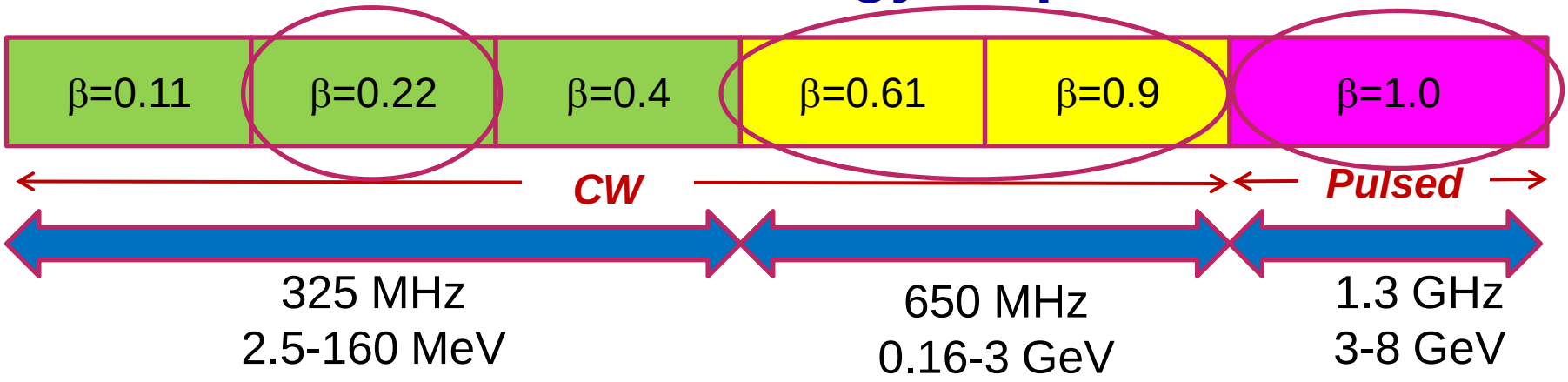
Siting


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
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

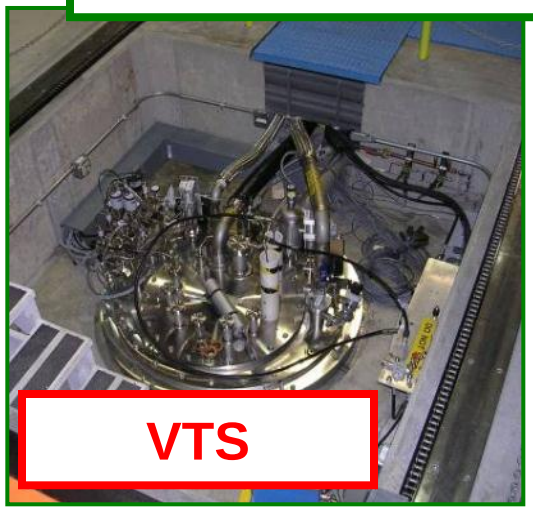
SRF Linac Technology Map

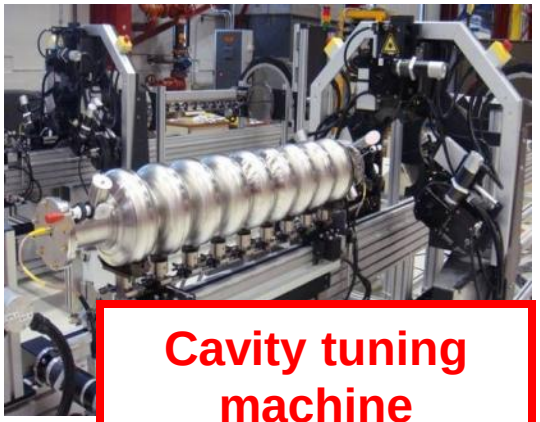


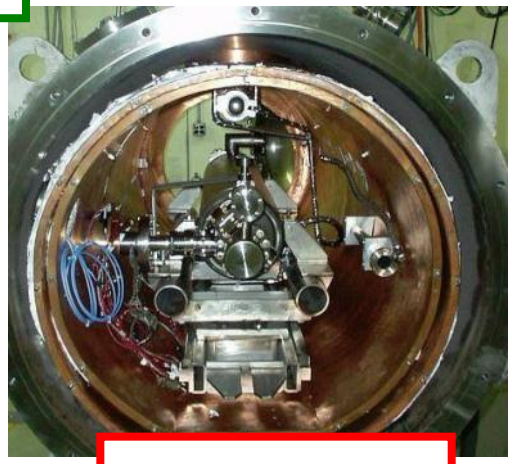
Section	Freq	Energy (MeV)	Cav/mag/CM	Type
SSR0 (β_G=0.11)	325	2.5-10	18 /18/1	SSR, solenoid
SSR1 (β_G=0.22)	325	10-42	20/20/ 2	SSR, solenoid
SSR2 (β_G=0.4)	325	42-160	40/20/4	SSR, solenoid
LB 650 (β_G=0.61)	650	160-460	36 /24/6	5-cell elliptical, doublet
HB 650 (β_G=0.9)	650	460-3000	160/40/20	5-cell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

Fermilab SRF infrastructure


VTS


VTS


Cavity tuning machine


HTS


String Assembly


MP9 Clean Room


Final Assembly


1st U.S. built ILC/PX Cryomodule


1st Dressed Cavity

Strategy and Timeline

- The DOE has a formalized process for moving projects from pre-conceptual designs through construction
- Current activities
  - Design development
  - R&D
- A set of documentation exists that form the basis for the first step
  - CD-0 = “Mission Need”
  - Reference Design Report
  - R&D Plan
  - Cost Estimate
- The timeline for Project X has not been established within the DOE
  - Internal planning has been based on a start of construction in late 2015/early 2016
  - 5 year construction period (spans two Indian 5-year plans)

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 established via bi-lateral MOUs.
  - Collaboration MOUs 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/Kolkata
LBNL	ILC/ART	

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

Review of Current Institutional Responsibilities

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

Indian Collaboration

- Phase 1 and 2 (R&D)
  - Collaboration initiated in 2007
    - ILC/SRF
  - Reorientation to High Intensity Proton Accelerator in 2009
    - SRF at low betas
  - Expanded into other technical areas in 2010
    - All major technical components in the CW linac
  - Formalized management structure for IIFC implemented in 2010
- Phase 3 (Construction)
  - In process of outlining a schedule of Indian deliverables
  - Alignment of Indian technical aspirations with Project X requirements
  - Indian participation in installation and commissioning of Project X
  - Two Indian projects under discussion
    - SNS: 1-2 GeV linac + ring
    - ADS: ~1 GeV CW linac

Indian Collaboration Phase 3

- Accelerating cavities
  - 325 MHz: SSR1, SSR2 ?
  - 650 MHz; β=0.6, 0.9
- RF Power
  - 325 MHz
  - 650 MHz
- Cryomodules
  - 325 MHz: focusing solenoids
  - 650 MHz: focusing quadrupole + other components
- Cryogenic Plant
- Instrumentation/controls
  - 325 MHz: BPMs, LLRF components
  - 625 MHz: BPMs, LLRF components
- Personnel
  - ~20 Scientist/engineer
    - Management, design, fabrication, installation, commissioning

IIFC: 1.3 GHz Single Cell

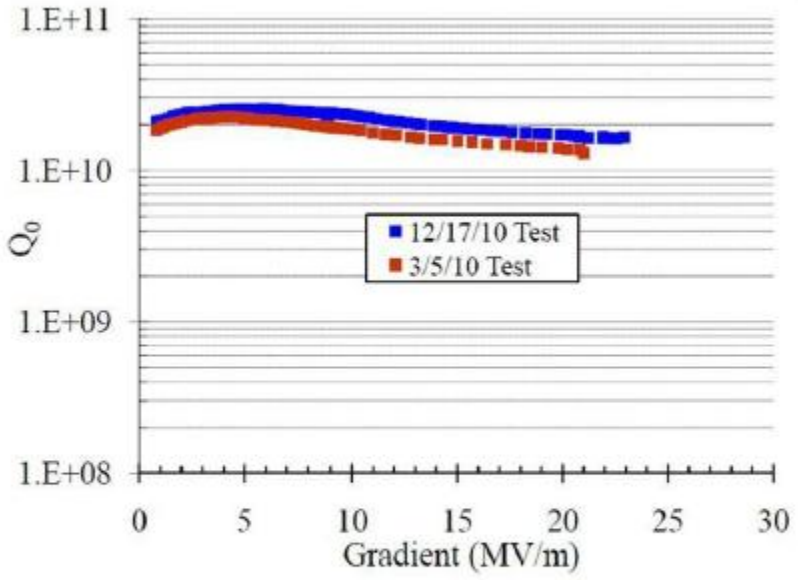
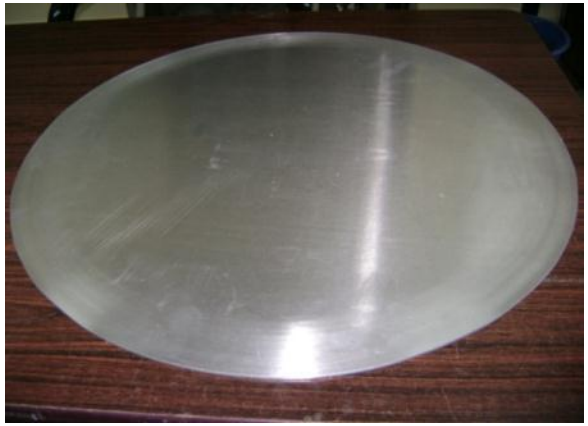


Figure 8: Quality factor Q_0 as a function of accelerating gradient at 2 K, on the second 1.3 GHz single cell cavity.

TE1CAT003 with RRCAT-IUAC & FNAL team members

IIFC: 650 MHz forming

Die- Punch Set at RRCAT

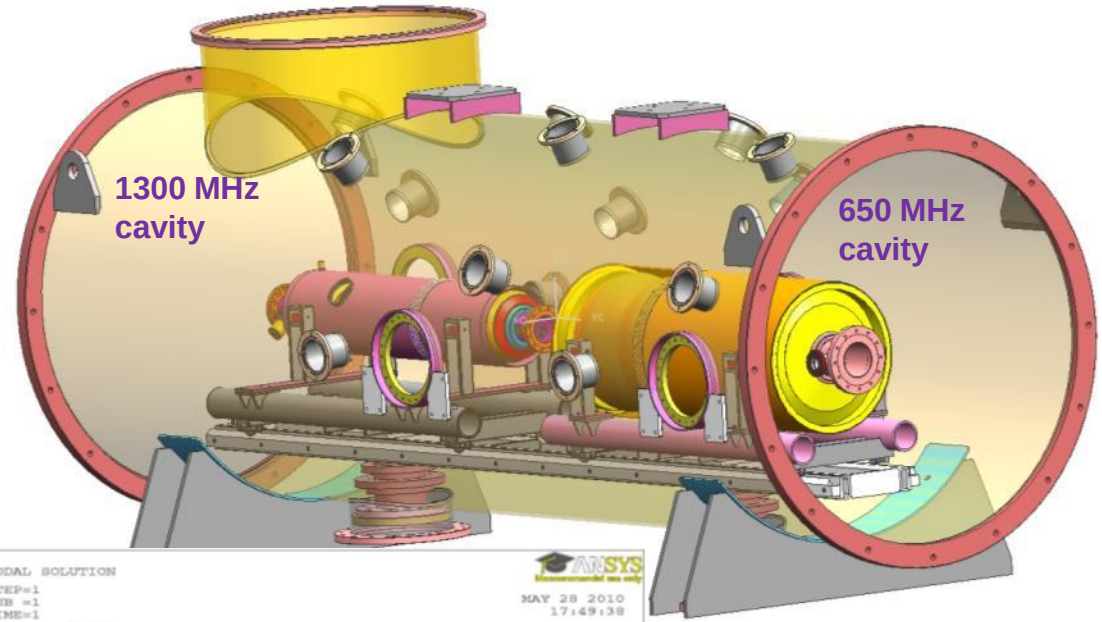


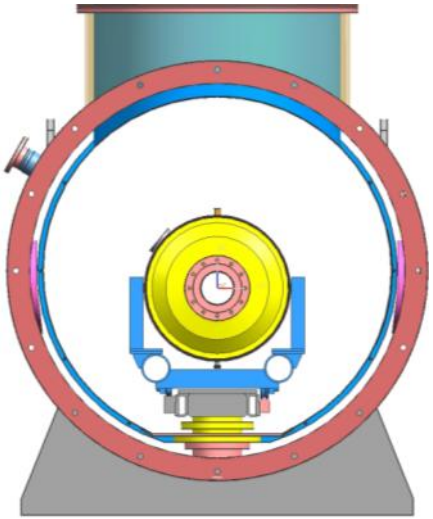
Aluminum blank, 3mm thickness

Die-Punch Set mounted on Press at RRCAT

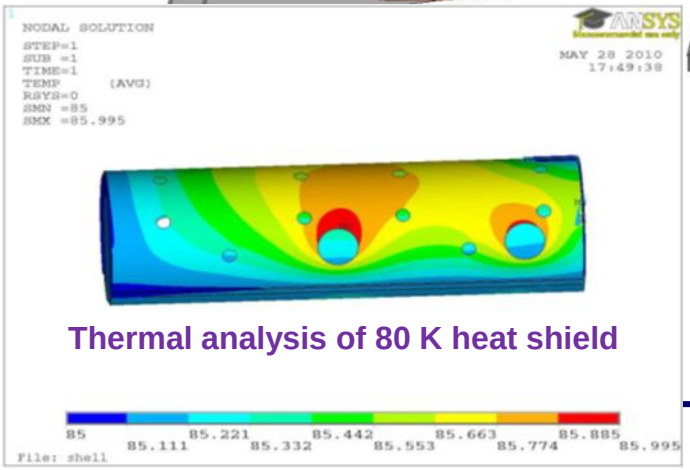
Beginning of forming trials with aluminum

IIFC: HTS-2 cryostat design



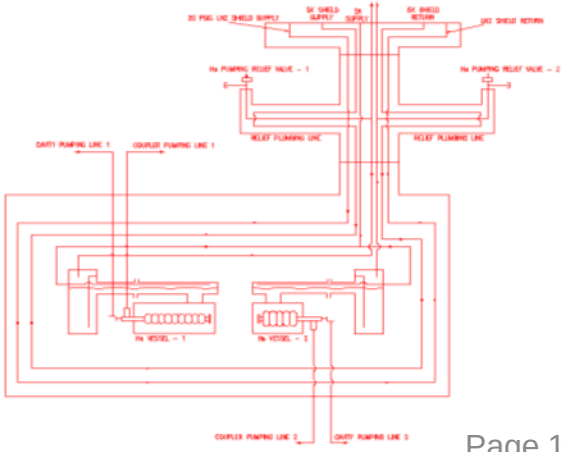


HTS-2 COOLING CIRCUIT OPTION

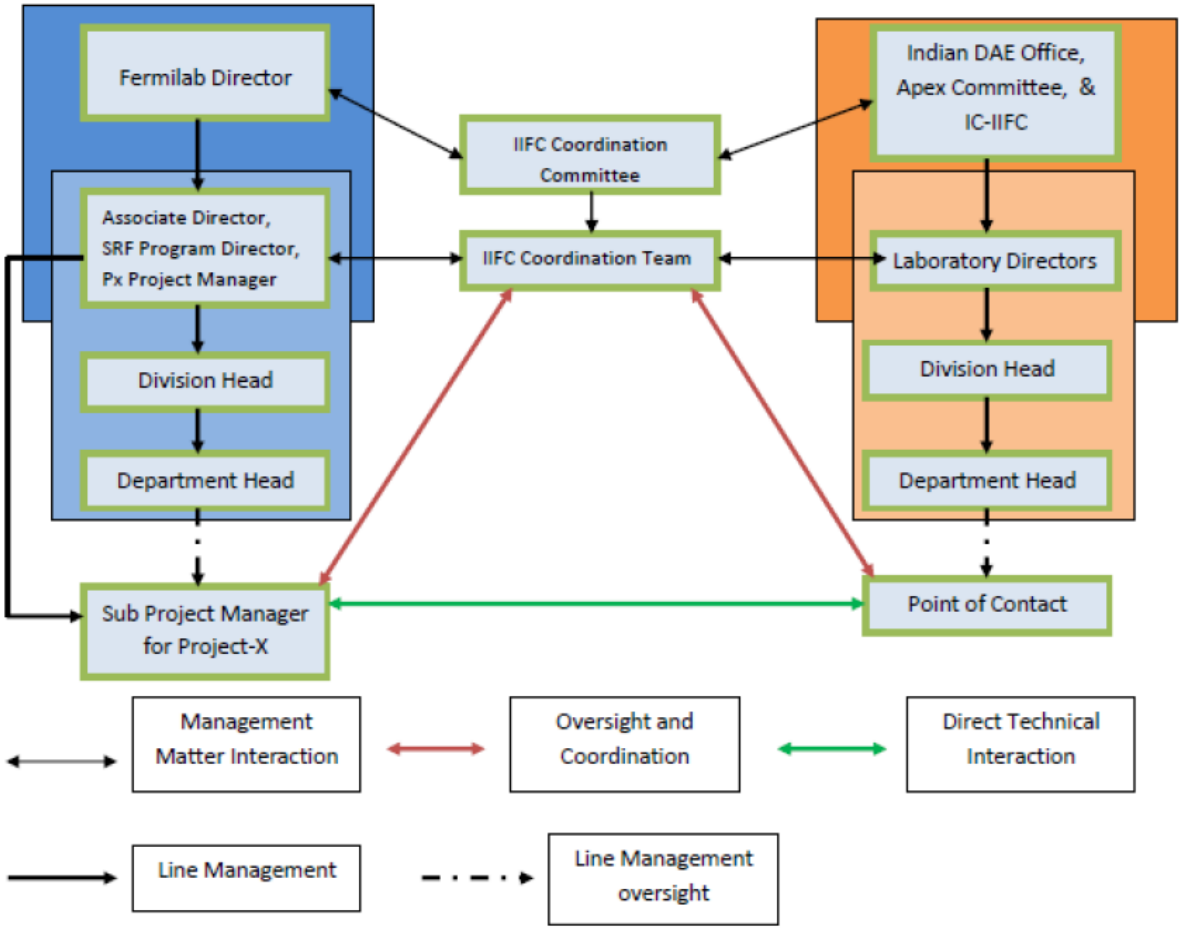


Thermal analysis of 80 K heat shield

Preliminary cooling circuit design



IIFC Joint Management (iifc.fnal.gov)



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
- A mature design concept has been established, offering capabilities that are unique among any high intensity facility in existence or under design
  - 2 MW to the neutrino program over 60-120 GeV
  - 3 MW to the rare processes program
  - Flexible provision for variable beam formats to multiple users
- R&D underway with very significant investment in srf infrastructure and development
- Strategy for moving the project forward is being developed with DOE
  - Likely staging with CW linac as initial stage
- Indian collaboration has been a primary driver in getting Project X to where it is today
- Project X could be constructed over the period ~2016 – 2020