Status and Plans for a Superconducting RF Accelerator Test Facility at Fermilab

Jerry Leibfritz

Fermilab

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The Place with Many Names

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ILC Test Accelerator

ILCTA

ILCTA_NML

STF at NML

New Muon Lab

NML

SRF Test Facility

ASTA

CMTF

PXIE

???

Outline

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- Overview of ASTA Test Facility
- Project Goals and Phases
- Layout of Facility
- Current Status
- Expansion Project
- AARD Program
- Cryomodule Test Facility (CMTF)
- Future Plans
- Schedule

ASTA

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- Advanced Superconducting Test Accelerator (ASTA)
  - ASTA is a multiple purpose facility for testing 1.3 GHz cryomodules
    - International Linear Collider (ILC) R&D
    - Advanced Accelerator R&D (AARD) facility
    - Test facility for Project X pulsed linac
  - A pulsed electron Superconducting Radio Frequency (SRF) linear accelerator
- Overall Goal
  - Build an RF Unit Test Facility at the New Muon Lab (NML)
    - ILC RF Unit = 3 cryomodules, 10-MW RF system
    - Beam with ILC parameters (3.2 nC/bunch @3 MHz, up to 3000 bunches @ 5Hz, 300-μm rms bunch length, 1msec pulse length)
    - ~ 750 MeV beam energy

ASTA Phase–1 (FY07-FY11)

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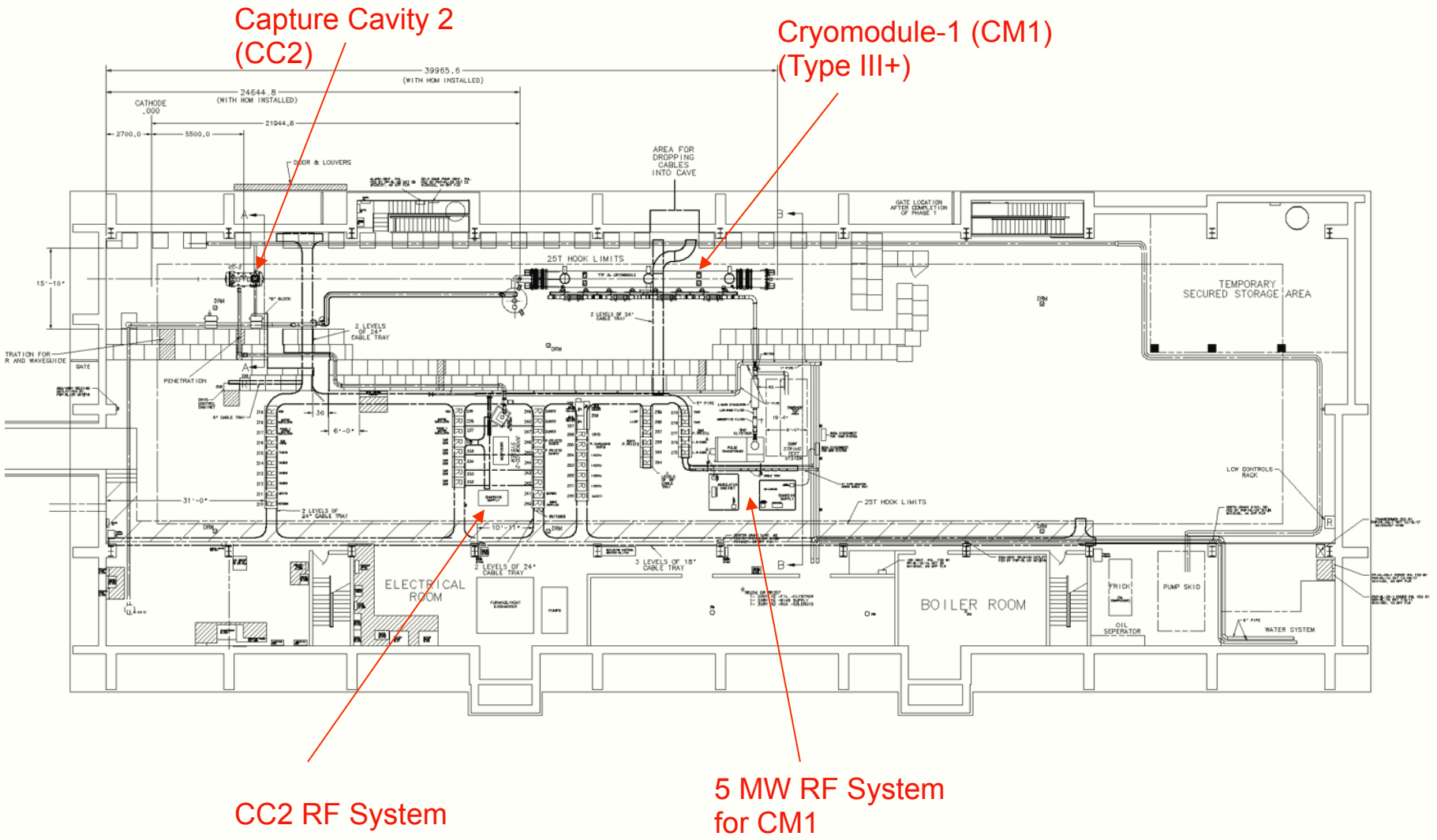
- **Prepare facility for testing first cryomodule (CM1) without beam** (Completed Dec. 2010)
  - **Removal of Chicago Cyclotron Magnet**
  - **Infrastructure, RF power, cryogenics (Tevatron satellite refrigerators #1 & #2**
  - **Install first cryomodule (CM1) and Capture Cavity-2 (CC2), cool down, and begin RF testing**

NML During Removal of Chicago Cyclotron Magnet(CCM) (September, 2006)

NML Facility after CCM Removal and Floor Painting (February, 2007)

Phase-1 Layout of ASTA



ASTA at NML

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CM1 Installation in ASTA

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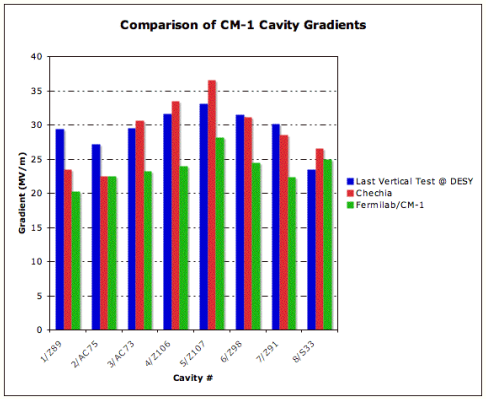
Cryomodule Operations

- **Cryomodule 1 (CM1) was a "kit" from DESY**
  - **Very successful 15 month operational plan of CM1 completed in March 2012**
    - **Goal was to verify our assembly techniques and learn to operate our systems**
    - **Overall accelerating gradient of ~ 200 MeV (avg.=23.7 MeV/m)**
  - **Installation of first high gradient (31.5 MV/m) CM2 in progress**



	1	2	3	4	5	6	7	8	Mean
CM-1 Peak Gradient	20.2	22.5	23.2	24*	28.2	24.5	22.3	25	23.7
Ratio compared to Chechia	0.860	1.00	0.758	0.716	0.773	0.788	0.782	0.940	0.827

ASTA Phase-2 (FY11 – FY13)

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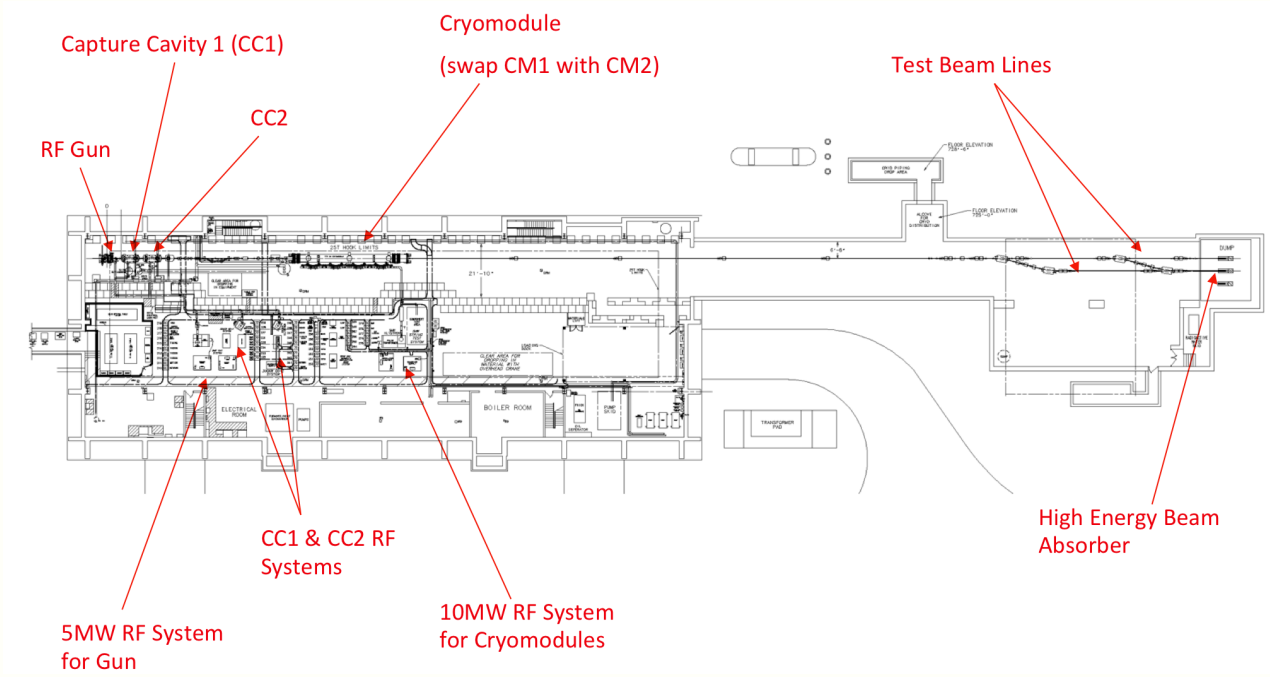
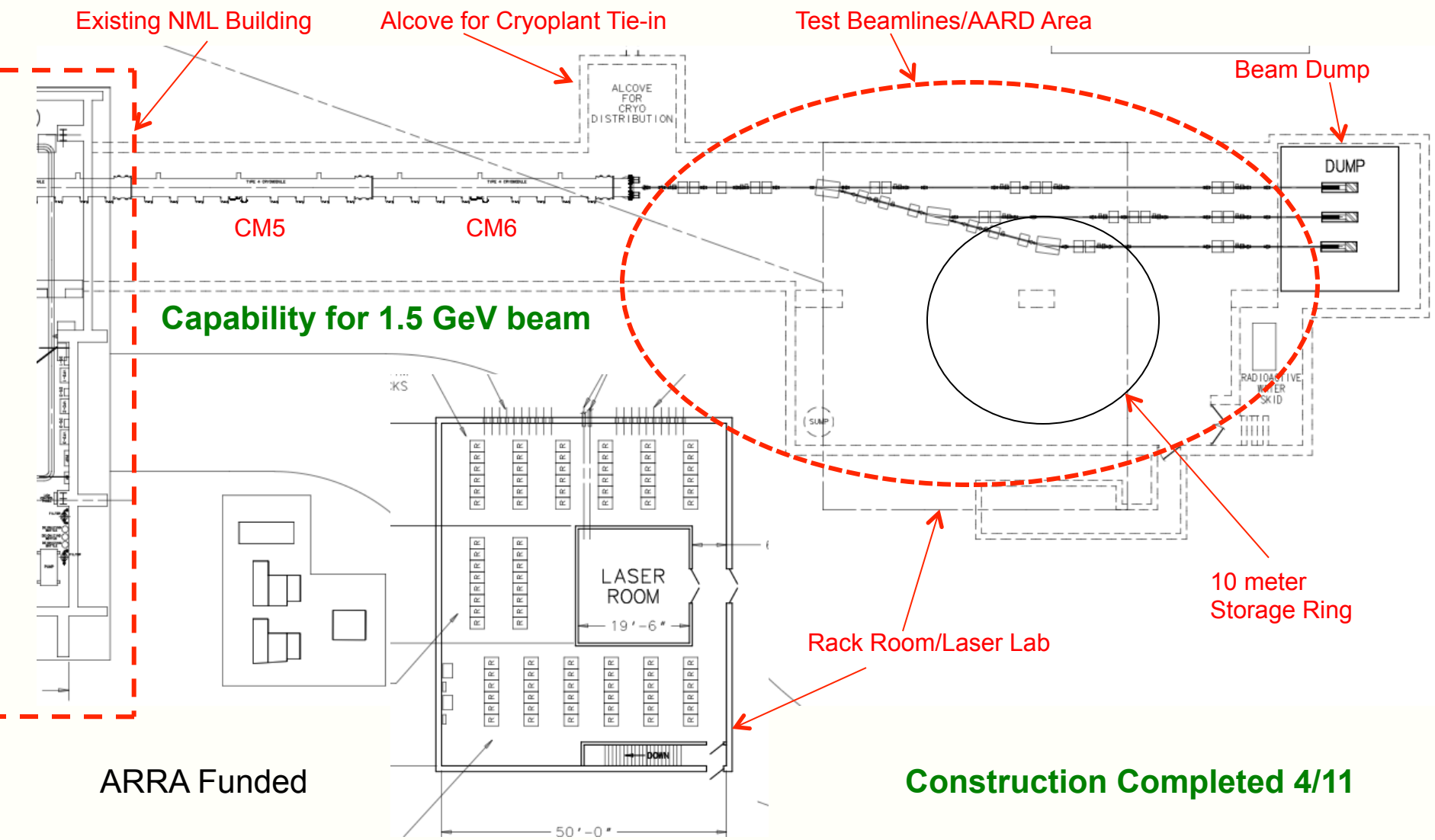
- **Prepare for First Beam**
  - **NML Expansion construction (capability for 2 RF units)**
  - **Construction of new Cryomodule Test Facility**
  - **Install new gun, injector, test beam lines, and beam dump**
  - **Commission gun – generate first beam**
  - **Accelerate beam through single cryomodule**



NML Expansion Project



NML Expansion Construction

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Digging Tunnel

Finished Tunnel

Electrical Service Building

Installation of Gun & Injector

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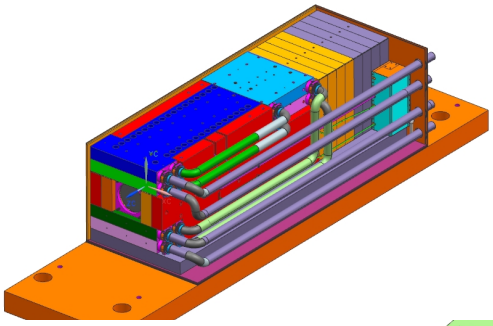
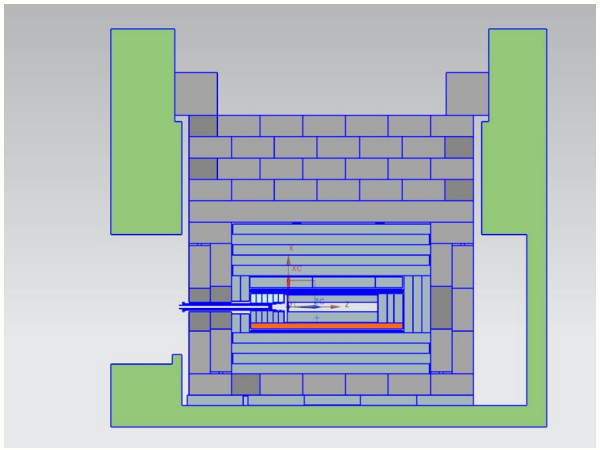
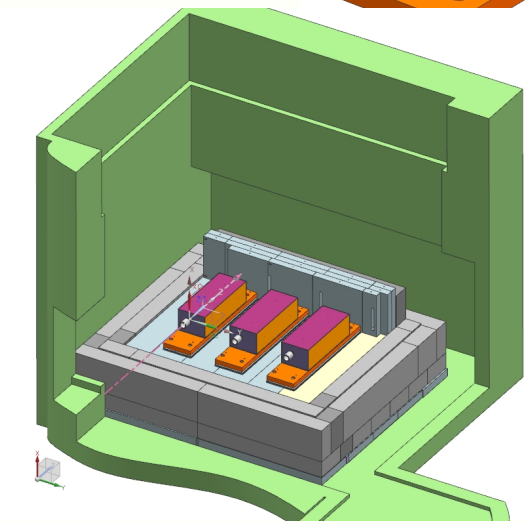
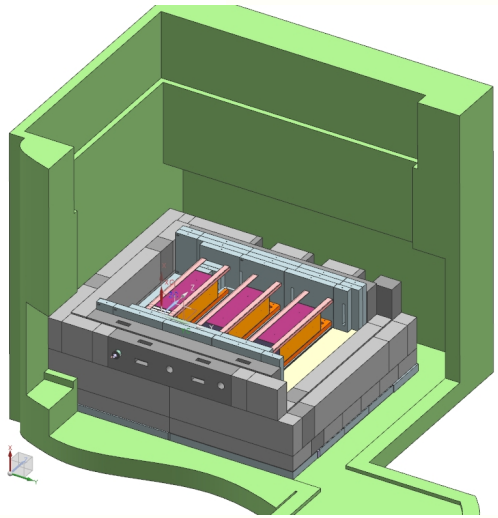
Beam Absorber/Dump

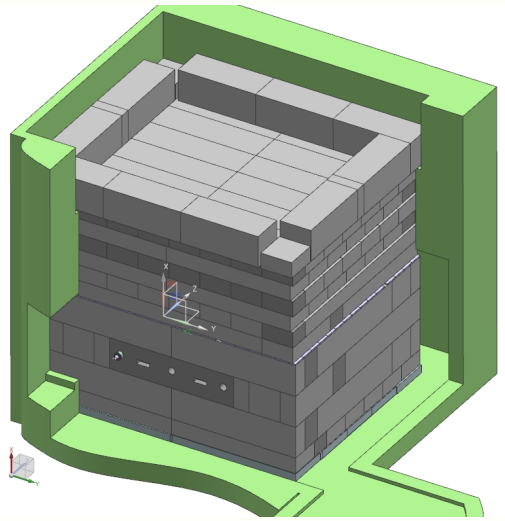
- Three High Power (75 kW) Beam Absorbers
- 1200 Tons of Steel and Concrete



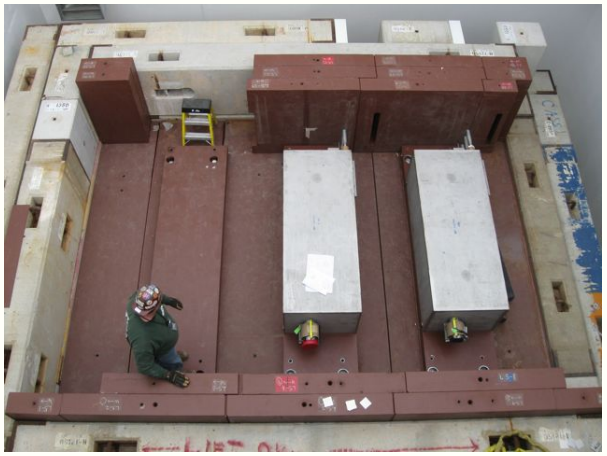








Beam Absorber/Dump



WEPPD034 - C. Baffes, et al., "Mechanical Design of a High Energy Beam Absorber for the Advanced Superconducting Test Accelerator (ASTA) at Fermilab"

ASTA Summary and Future Plans

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- **Phase-1 of Project is complete!**
  - CC2 and CM1 have been cooled to 2K and RF powered
  - CM1 operations complete
- **Phase-2 in progress**
  - Installation of gun, injector, beam lines, absorber/dump
  - First beam in 2012
- **Phase-3**
  - Full accelerator operation (beam through at least 3 CM's)
  - Advanced Accelerator R&D (AARD) Program
    - Low Energy ~ (40-50 MeV)
    - High Energy ~ (150 MeV to 1.5 GeV)

AARD Program Proposals

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Proposals for NML (1)

Experiment	Energy	proponent	Motivation/ application
Long. → transverse EEX	low	FNAL/ANL	Proof-of-principle; possible application in FELs and X-ray sources
Slit microbunching generation	low	FNAL	For wakefield investigations;
Ellipsoidal beam generation	low (egun)	NIU	Low emittance beams
Microbunching investigations	low, high	ANL	Beam physics; diagnostics
ODR instrumentation development	high	ANL	Non-invasive emittance diagnostic
Flat beam transform and image charge undulator	low	FNAL/NIU	Compact UV/ soft X-ray source
Flat beam transform	high	LANL	Proof-of-principle for MaRIE
Emittance exchange	high	LANL	Proof-of-principle for MaRIE
6-D muon cooling	high	IIT	Proof-of-principle for muon collider
Optical stochastic cooling	high	IIT	Proof-of-principle; muon collider
γ-ray enhancement by crystal channeling	high	ANL	Unpolarized e^+ source
High gradient wakefield acceleration with dielectric structures	Low?, high?	ANL/NIU	many

AARD Program Proposals - 2

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Proposals for NML (2)

Experiment	Energy	proponent	Motivation/ application
PIC lattice test	high	Muons Inc	Muon collider
Reverse emittance exchange	Low, high	Muons Inc	Muon collider
Dielectric Wall Accelerator section	Low- high	FNAL	Muon collider; induction linac
Measure plasma wakes with long bunch trains	high	USC	Application to 2-beam plasma acceleration
Measure plasma wakes with laser interferometry	high	USC	Application to 2-beam plasma acceleration
Photoproduction of muons @ 300 MeV	high	FNAL	Homeland security; verify production model
Test of integrable beam optics	high	FNAL	Proof-of-principle; future high current proton machines
Study HOM absorprtion	high	FNAL	Project-X and Muon Collider; ADS
Study coupler kicks on beams	low	FNAL	ILC, Pr-X, Muon collider, ADS
Study cavity BPM	Low-high	FNAL	ILC, Project-X , Muon Collider; ADS
High charge bunch loading	high	FNAL	Muon Collider (acceleration of 1e12)
MC IR optic method test	Low - high	FNAL	Muon collider, ADS

AARD Program Plan

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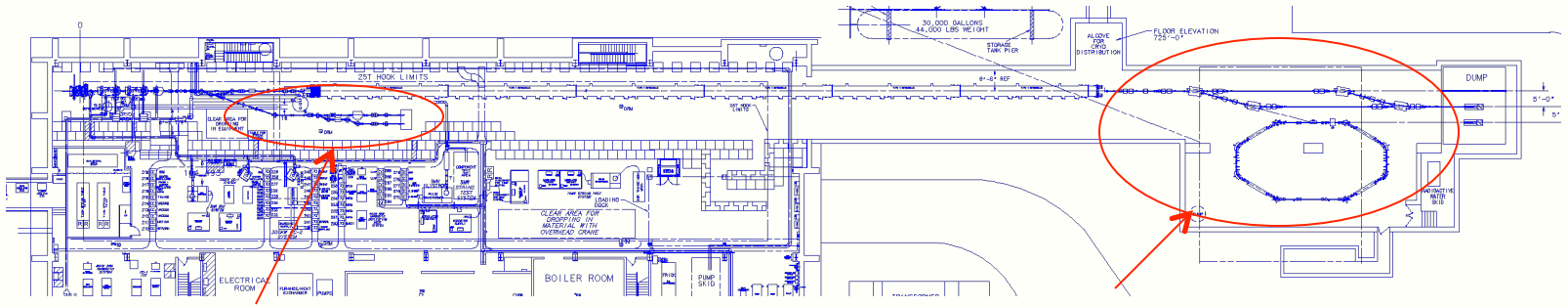
- **Selected Three "Phase-1" AARD Experiments for ASTA**
  - **Double Emittance Exchange (D-EEX) beam line for pulse shaping experiments (at 250-350 MeV)**
  - **High Brightness Compact Diamond Radiator (NIU/Vanderbilt) test experiment (at 40 MeV)**
  - **Integrable Optics Test Accelerator (IOTA) to demonstrate new nonlinear optics solution (at 150-300 MeV)**



Low Energy AARD Area
(~ 40-50 MeV)

High Energy AARD Area
(~ 150 MeV to 1.5 GeV)

IOTA Storage Ring at ASTA

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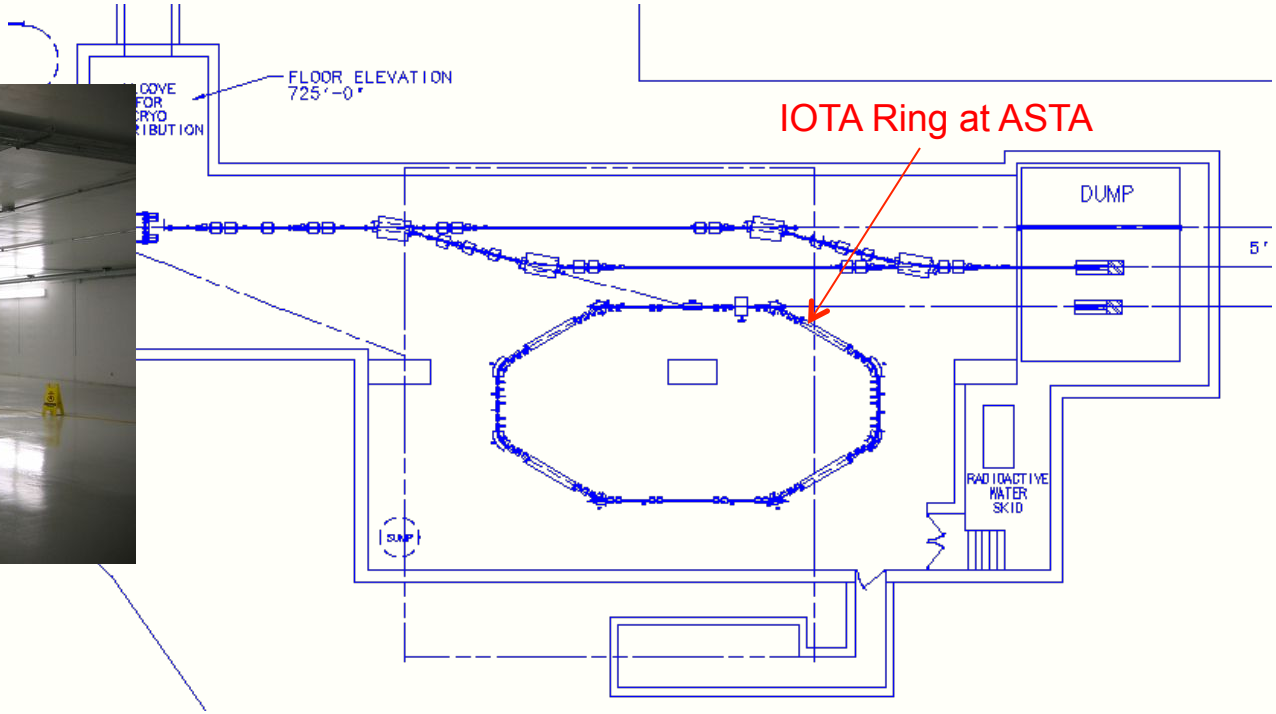
- **Integrable Optics Test Accelerator (IOTA)**
  - **30-meter circumference storage ring that will study non-linear accelerator optics (at 150-300 MeV)**



MOYCP01 – S. Nagaitsev et al., "Design and Simulation of IOTA – A Novel Concept of Integrable Optics Test Accelerator"

CryoModule Test Facility (CMTF)

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- CMTF is a new set of buildings (adjacent to NML) originally designed to house two helium cryoplants and two cryomodule test stands. Now being repurposed to house PXIE.

CMTF Layout

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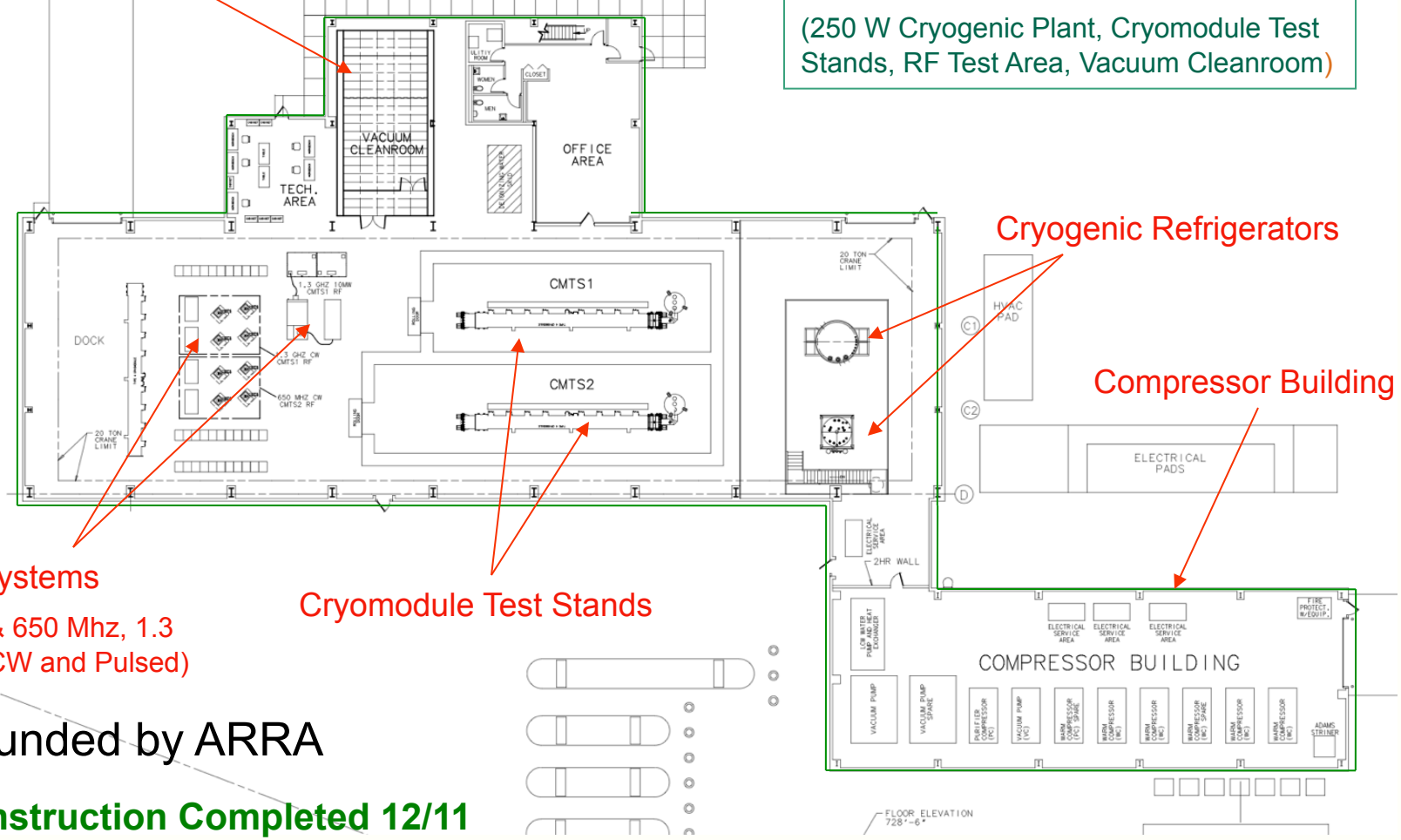
Vacuum Cleanroom

New Cryoplant & CM Test Facility

(250 W Cryogenic Plant, Cryomodule Test Stands, RF Test Area, Vacuum Cleanroom)



Cryogenic Refrigerators

Compressor Building

RF Systems

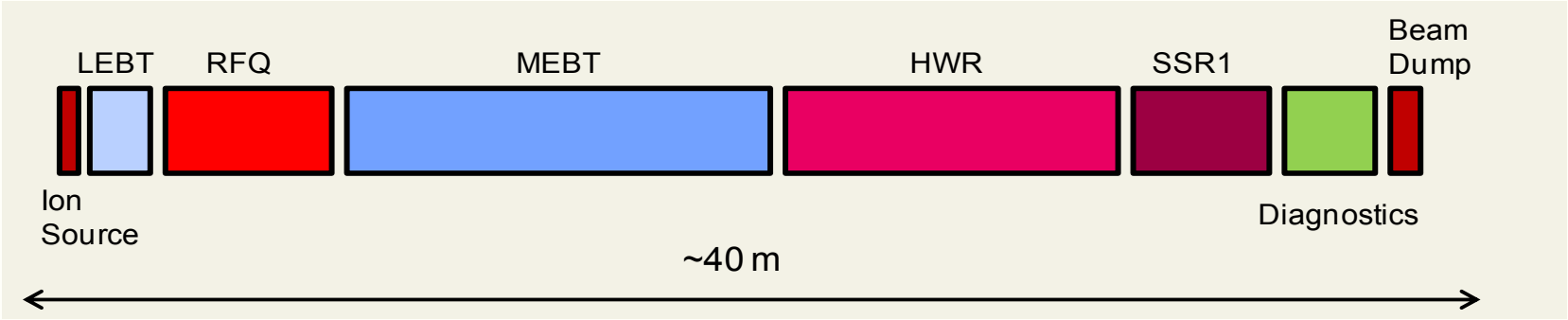
(325 & 650 Mhz, 1.3 GHz CW and Pulsed)

Cryomodule Test Stands

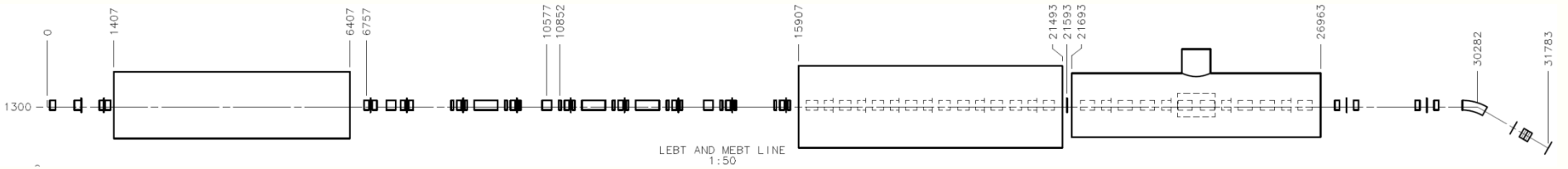
Funded by ARRA

Construction Completed 12/11

Project X Injector Experiment (PXIE)



- **Goal: Build a prototype of the first ~15-30 MeV of Project X**
- **CW H^- linear accelerator**
- ***Beam through β=0.1 , 0.2 CM at ~15 MeV with nearly final parameters (1 mA CW, 5 mA peak, arbitrary bunch chopping***



Several Papers on Project X and PXIE at IPAC 12

PXIE Layout in CMTF Building

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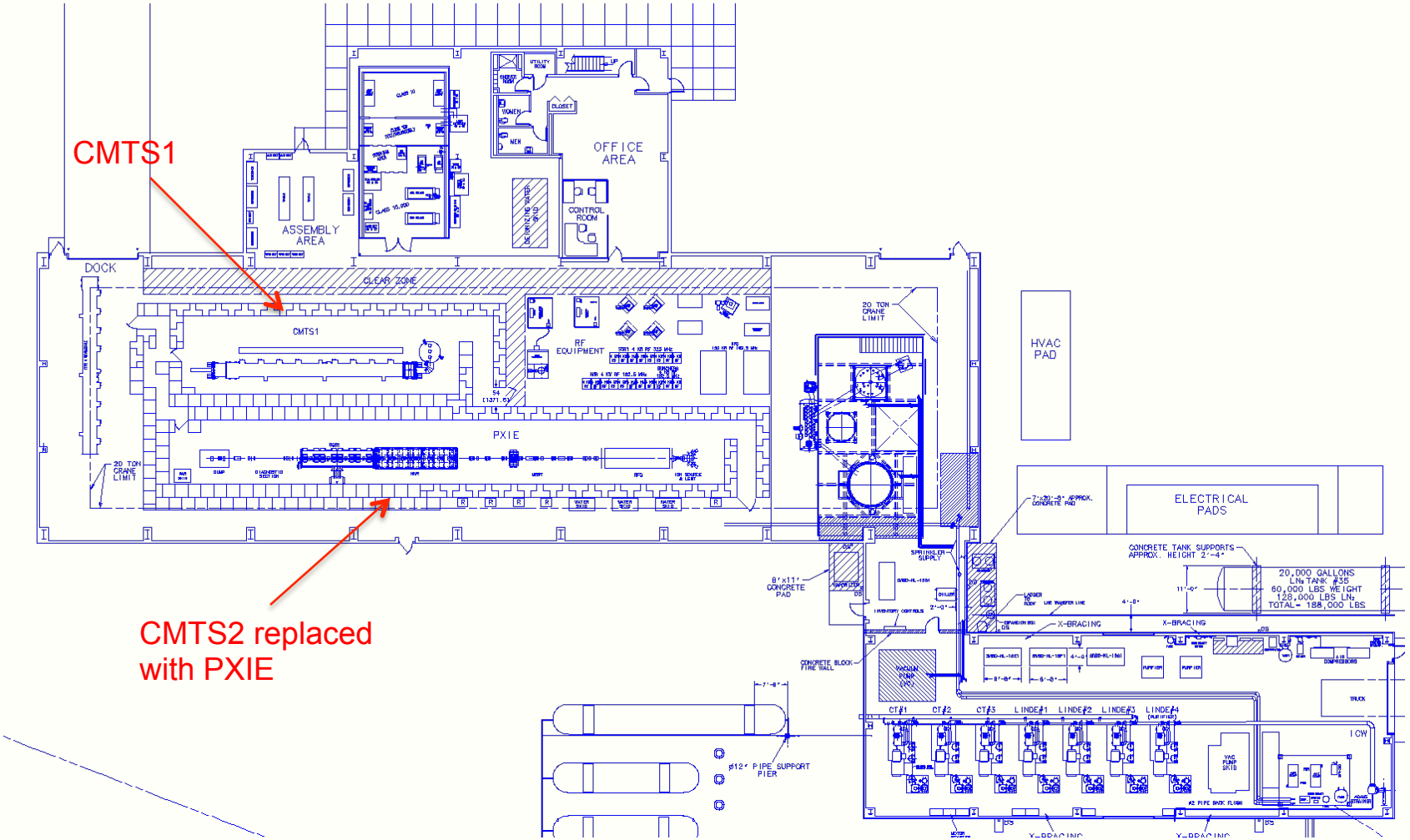

Cryogenic System

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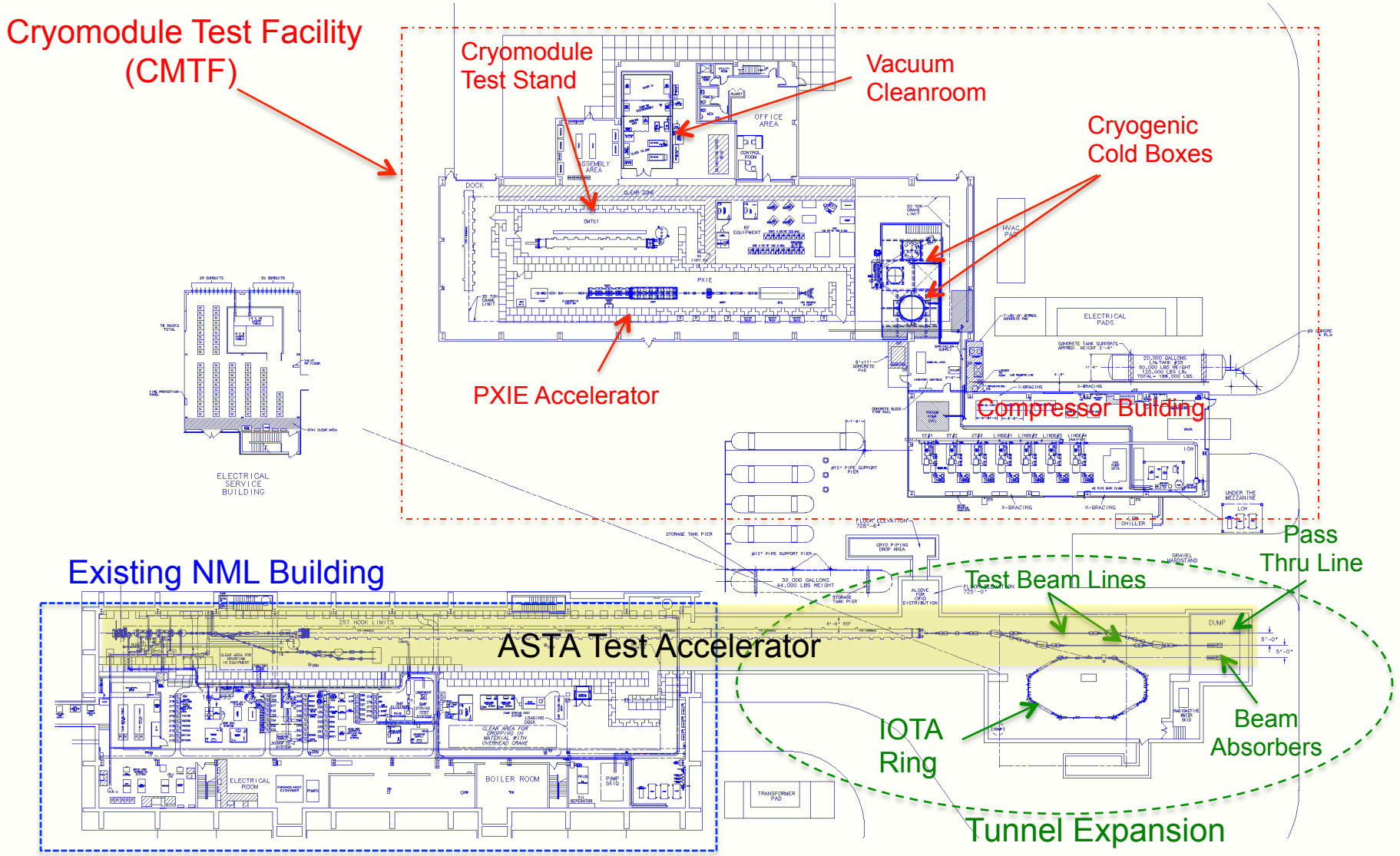
- **Combined Cryogenic Systems Should Have the Following Functionality**
  - Operate NML/ASTA with 2 Capture Cavities and up to 6 Cryomodules (Pulsed)
    - CW Cryomodule operation is possible, but is not in current plans
  - Operate PXIE with 1 HWR and 1 SSR1 Cryomodule (CW)
  - Operate CMTS1 capable of testing 1 Cryomodule
    - 1.3 GHz Cryomodules - Pulsed or CW
    - 325 MHz SSR or 650 MHz Cryomodules (CW)
  - Pressure stability goal 0.1 mbar (rms)

- **Helium cryoplants in CMTF and NML (nominal capacities)**
  - New Superfluid Refrigerator
    - 250W @ 1.8K or 500W @ 2K
  - Repurposed SLAC CTI-4000 Refrigerator - supplies LHe to NML/ASTA
    - 1500W @ 4.5K
  - Repurposed Tevatron Satellite Refrigerators (2) in NML
    - 1250W @ 4.5K

SRF Test Facility Complex



Rendition of SRF Complex

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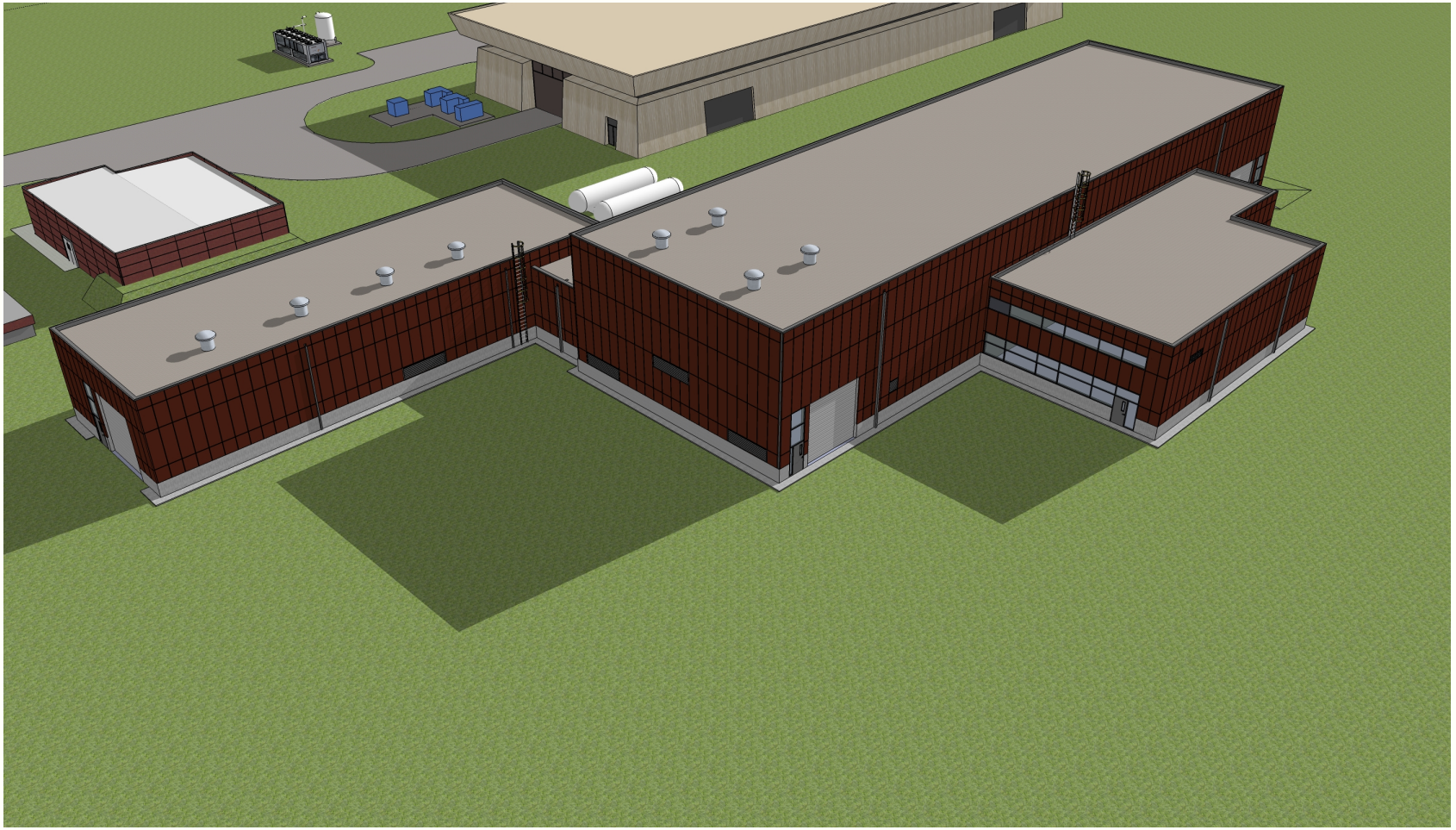

Actual SRF Complex

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Schedule/Milestones

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• Phase-1 Cryogenic System Operational	(August 2007)
• Delivery of First Cryomodule to NML	(August 2008)
• Cold RF Testing of First Cryomodule	(Dec. 2010)
• Completed Construction of NML Expansion	(April 2011)
• Completed Construction of CMTF Building	(Dec. 2011)
• Beam Absorbers/Dump Installed	(Dec. 2011)
• CM1 Testing Complete	(March 2012)
• Cold RF Testing of Second Cryomodule	(July 2012)
• Install Injector & Test Beam Lines	(2011-2012)
• First Beam	(2012)
• New Cryoplant Installation/Operation	(2013-2014)
• Install 3 Cryomodule String	(2013-2014)
• RF Unit Test with Beam (S2)	(2014)

Thanks to…

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The Entire ASTA/NML Team!