SRF Beam Test Facility at NML

Jerry Leibfritz

Sept. 13, 2010

Outline

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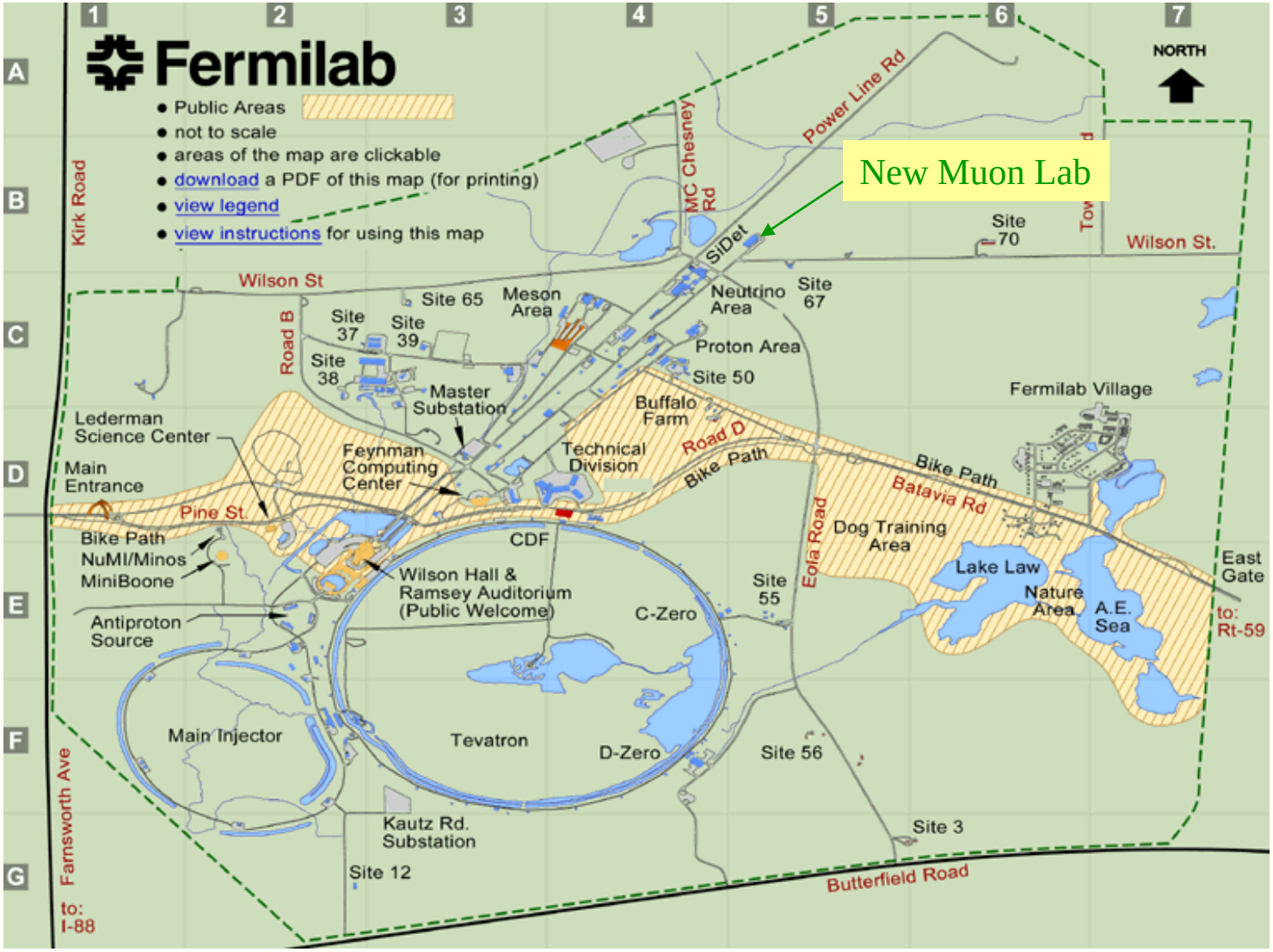
- NML Project Overview and Goals
- Layout of Facility
- Technical Progress
- Schedule
- Budget

Location


Fermilab
Public Areas
not to scale
areas of the map are clickable
download a PDF of this map (for printing)
view legend
view instructions for using this map
NORTH
New Muon Lab
Power Line Rd
MC Chesney Rd
SiDet
Site 70
Wilson St.
Wilson St
Site 65
Meson Area
Neutrino Area
Site 67
Kirk Road
Road B
Site 37
Site 39
Site 38
Master Substation
Proton Area
Site 50
Buffalo Farm
Fermilab Village
Lederman Science Center
Main Entrance
Feynman Computing Center
Technical Division
Road D
Bike Path
Batavia Rd
Pine St.
Bike Path NuMI/Minos MiniBoone
CDF
Wilson Hall & Ramsey Auditorium (Public Welcome)
Eola Road
Dog Training Area
Lake Law
Nature Area
A.E. Sea
East Gate
to: Rt-59
Site 55
Antiproton Source
C-Zero
Main Injector
Tevatron
D-Zero
Site 56
Kautz Rd. Substation
Site 3
Site 12
Farnsworth Ave
to: I-88
Butterfield Road

NML Project Overview

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- **Overall Goals**
  - **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)**
  - **Build Test facilities for Project-X cryomodules**
- **Phase-1 (FY07 – FY10)**
  - **Prepare facility for testing first cryomodule (CM1) without beam**
    - **Infrastructure, RF power, cryogenics (Tevatron satellite refrigerators #1 & #2)**
    - **Install first cryomodule (CM1) and Capture Cavity-2 (CC2), cooldown, and RF test**

NML Project Overview

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- **Phase-2 (FY10 - FY11)**
  - **Prepare for first beam**
    - Civil construction to expand facility (capability for 2 RF units)
    - Move parts from FNPL photo-injector to NML
    - Install new gun, injector, test beamlines, beam dump
    - Install/test second cryomodule (CM2)
- **Phase-3 (FY11 – FY14)**
  - **Complete RF Unit**
    - Upgrade RF system to 10 MW, install third cryomodule (CM3)
    - Commission new Cryogenic Plant
    - Operate full RF Unit with beam
    - Begin installation of 2nd RF Unit

Phase-1 Layout of NML

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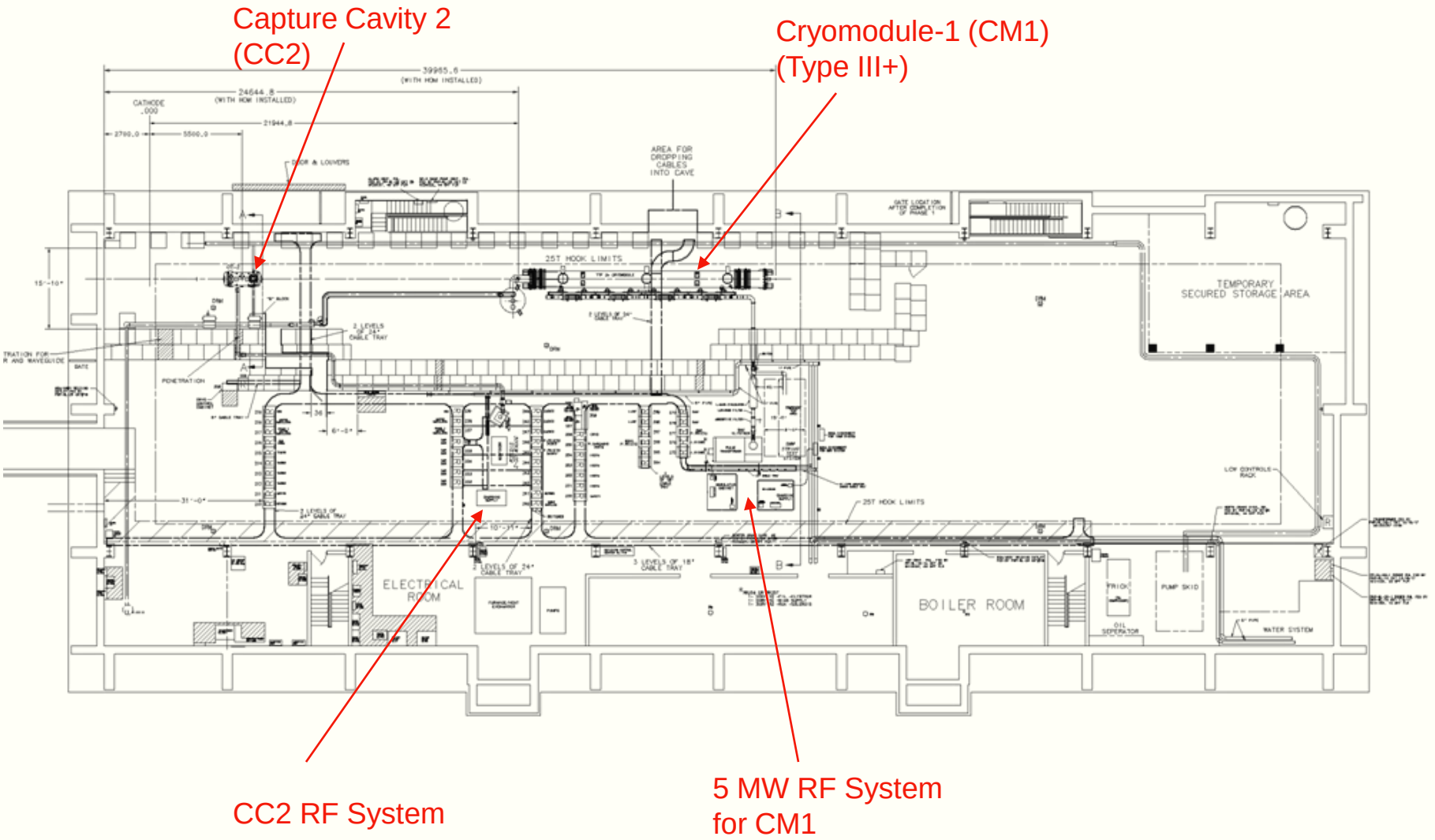

Phase 2/3 Layout of NML Building

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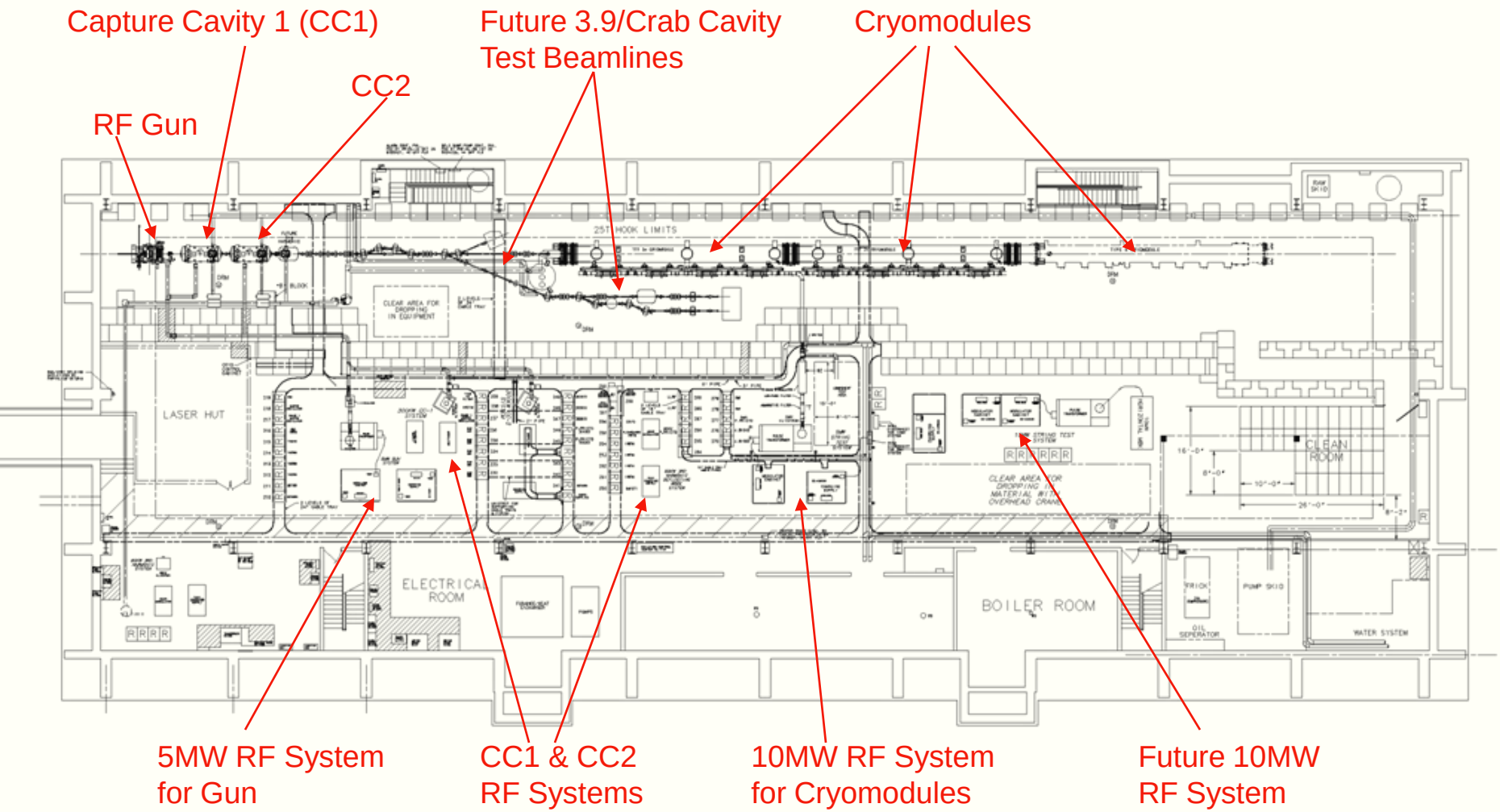

Expansion of NML Facility

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New Cryoplant & CM Test Facility

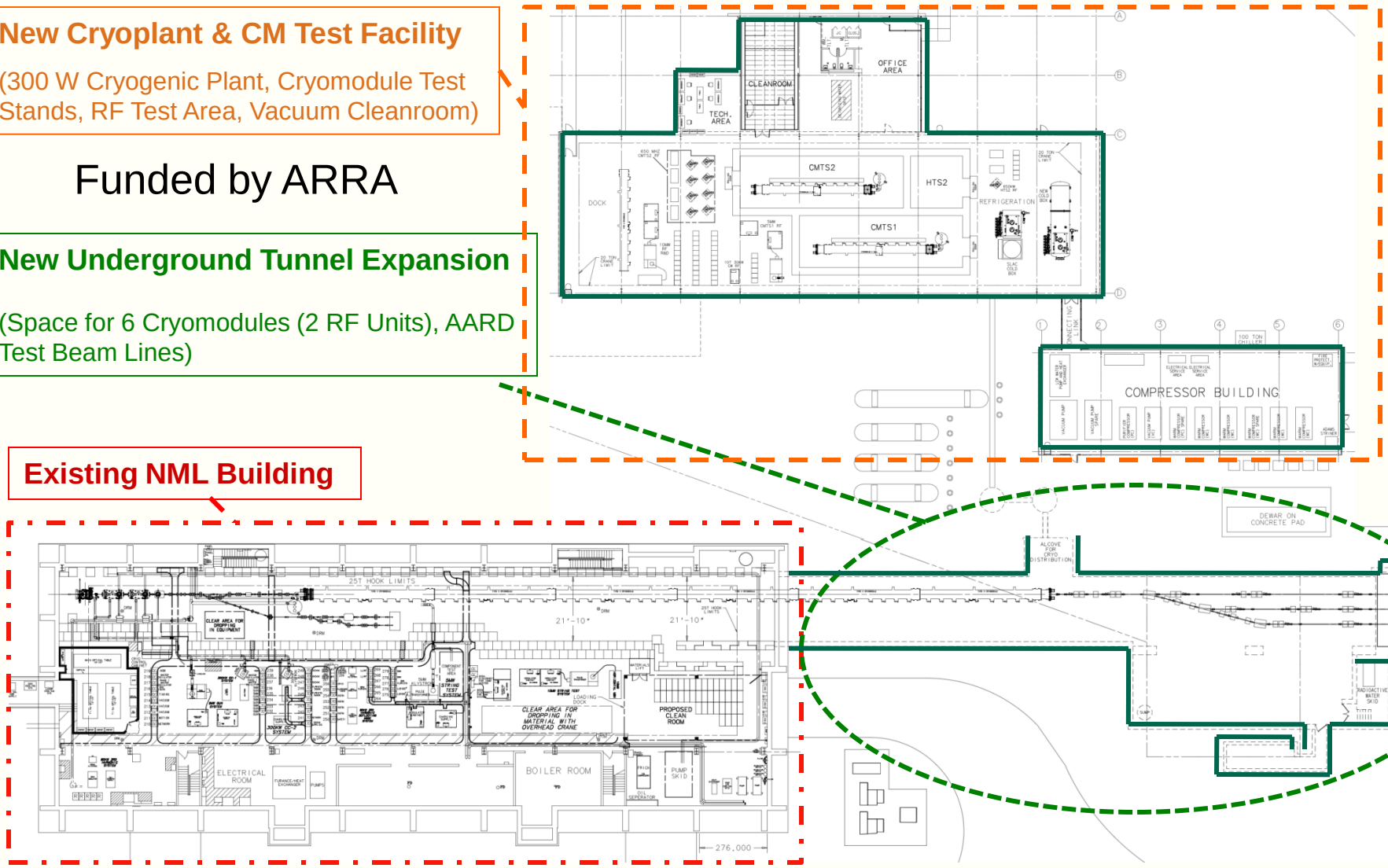
(300 W Cryogenic Plant, Cryomodule Test Stands, RF Test Area, Vacuum Cleanroom)

Funded by ARRA

New Underground Tunnel Expansion

(Space for 6 Cryomodules (2 RF Units), AARD Test Beam Lines)

Existing NML Building



Future NML Complex

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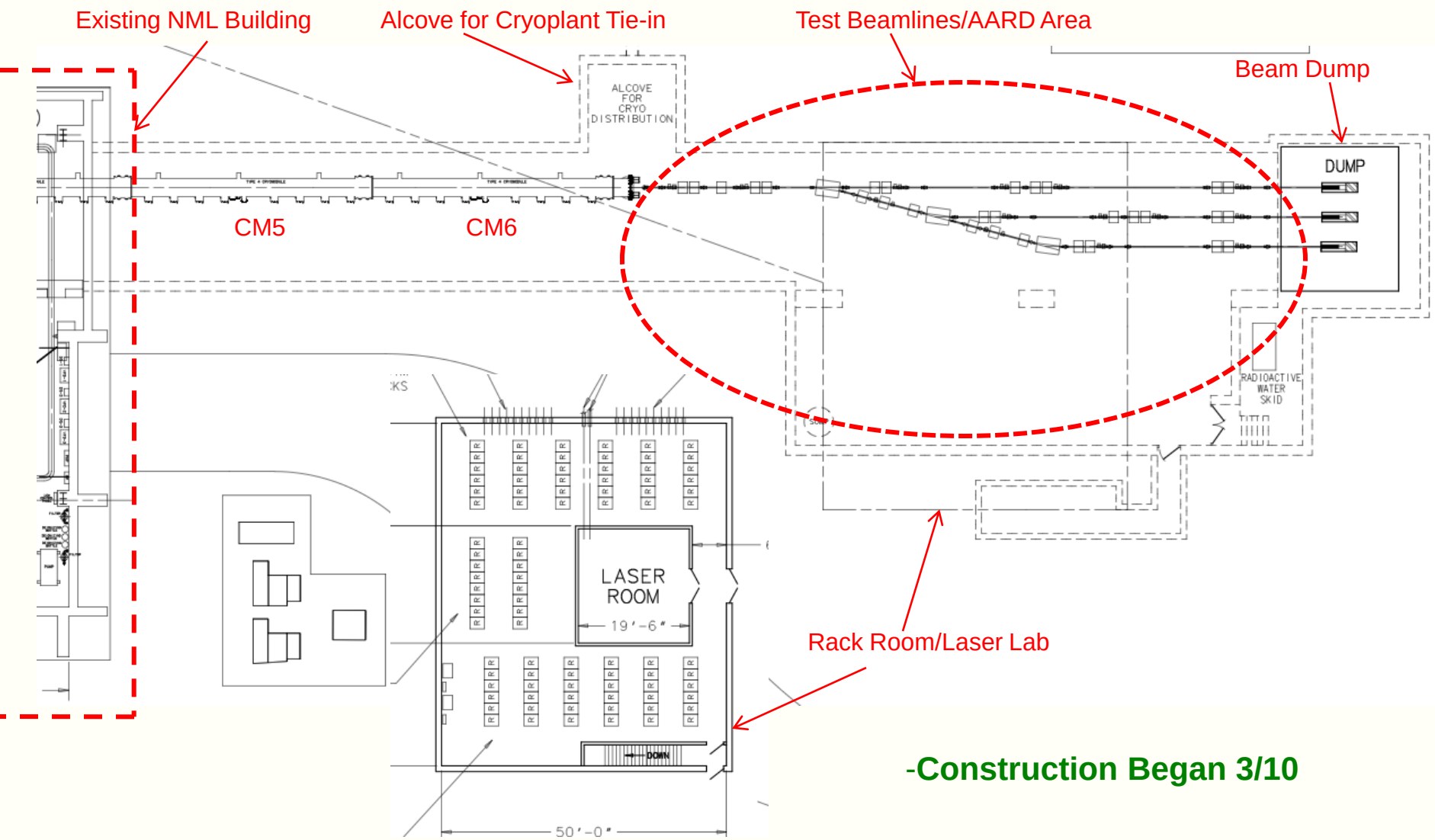
NML Expansion



-Construction Began 3/10

Cryomodule Test Facility (CMTF)

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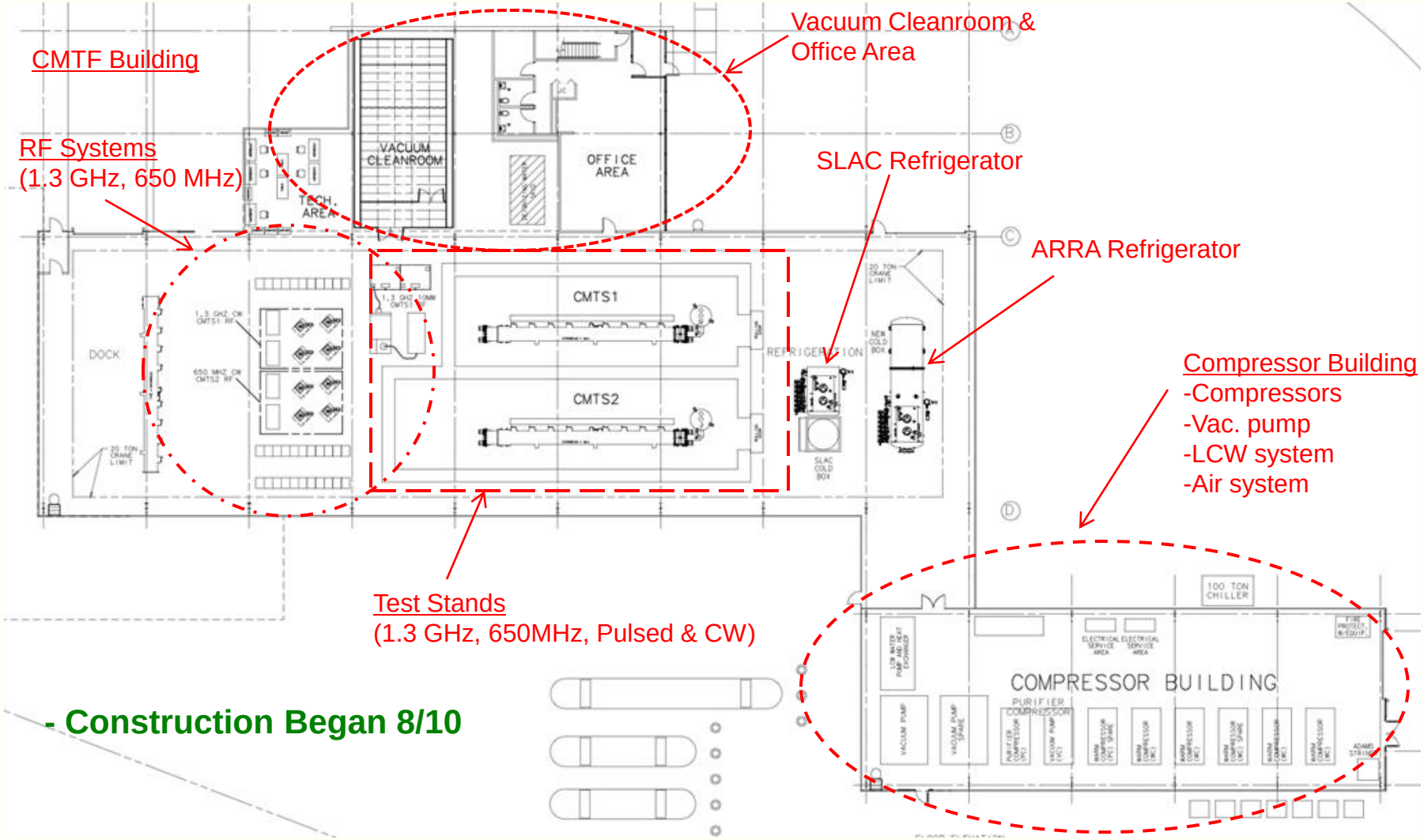
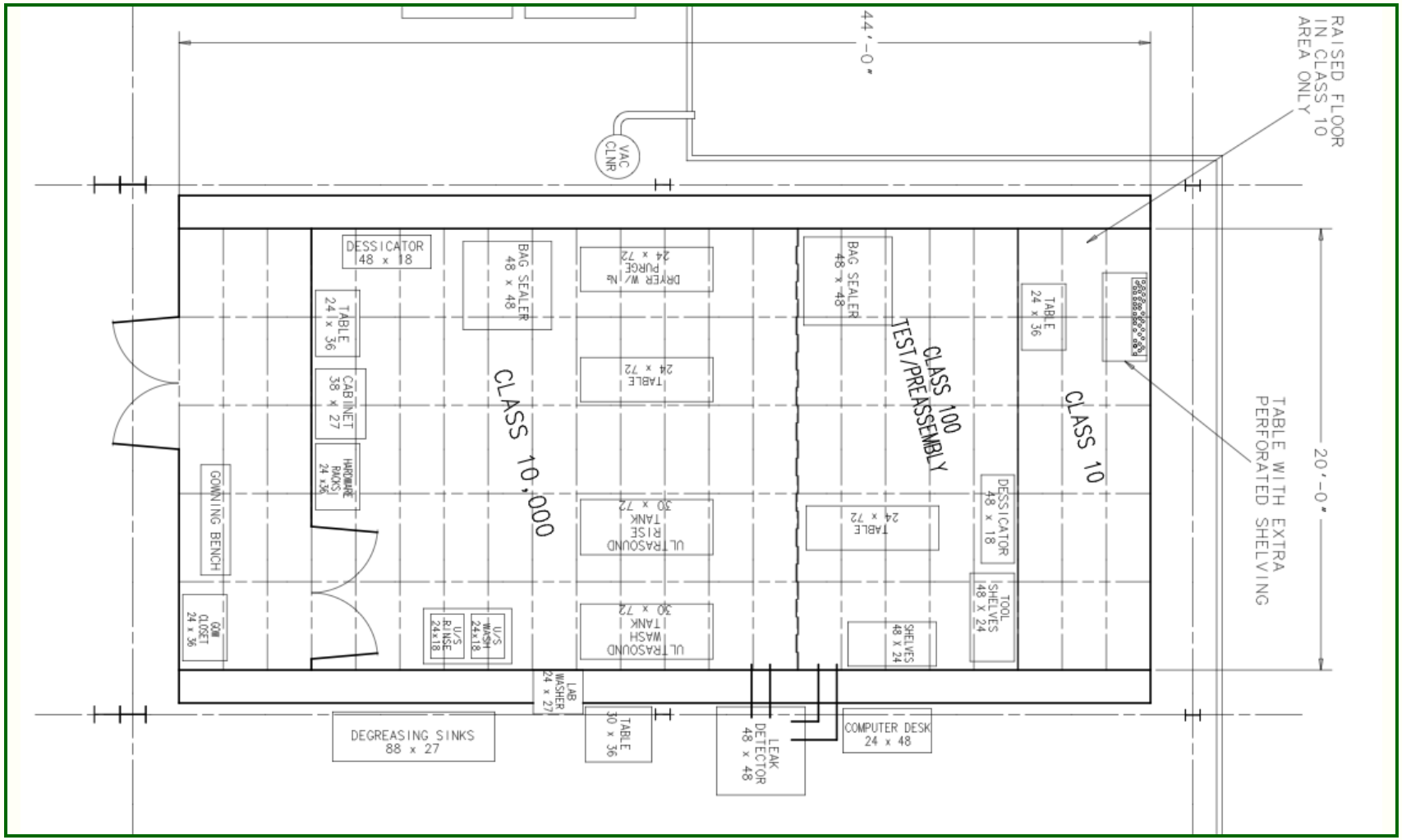


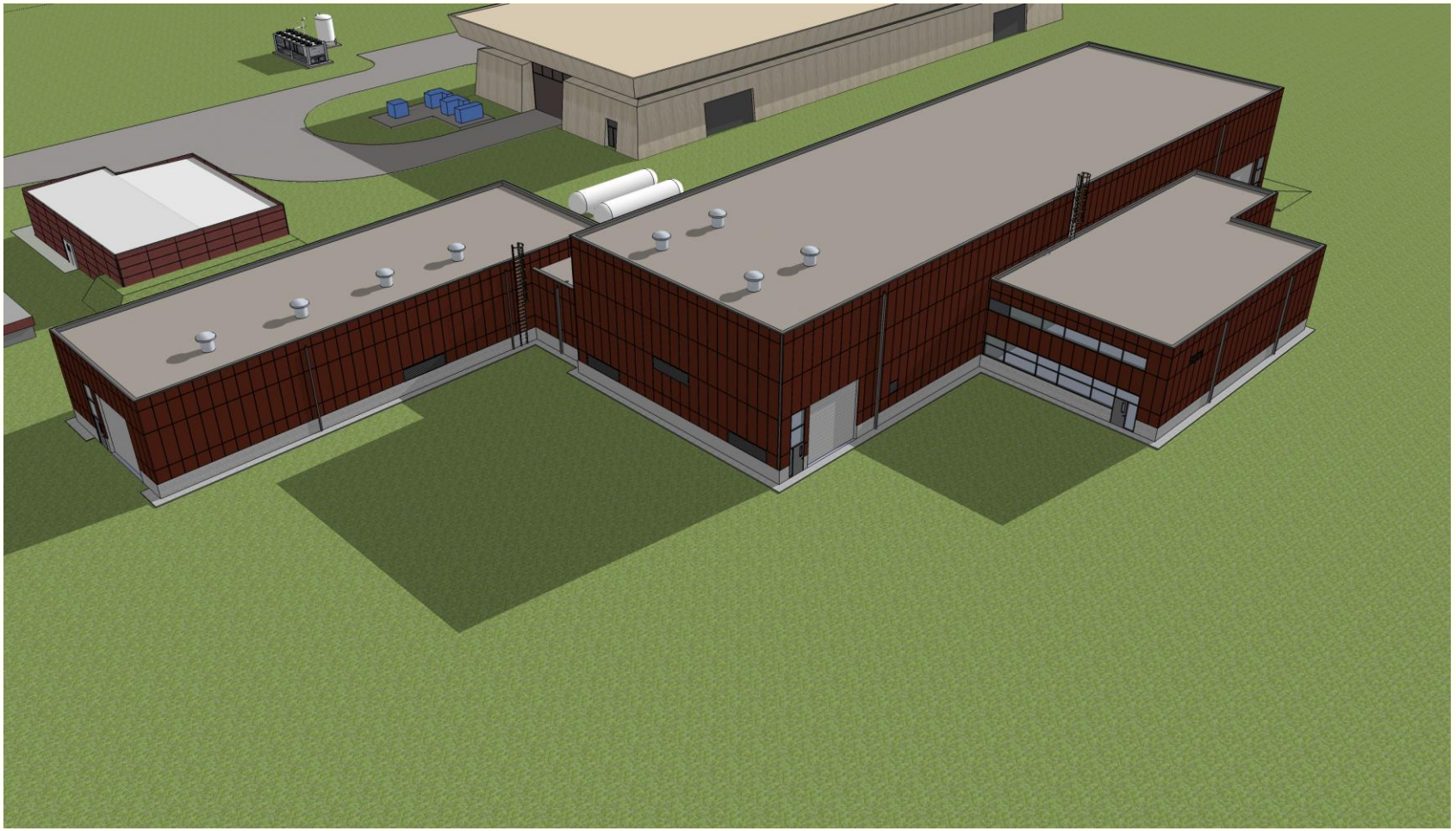
- Construction Began 8/10

Vacuum Cleanroom



Future NML Complex

Fermilab



NML Technical Progress

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NML Infrastructure (FY07-08)

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- Completed Removal of Chicago Cyclotron Magnet
- Prepared Building Infrastructure
  - AC power, network cabling, piping, cable tray, air ducts
  - Cleaned out building, epoxy coated floor, alignment network
  - Cave for Phase-1 (~3/4 of full cave), electrical racks
  - Reused existing equipment (tray, racks, piping, shield blocks, gas storage tanks, cryo heat exchangers & refrigerator components)

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

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

Recent Picture of NML Facility

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View From North

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NML Expansion Construction

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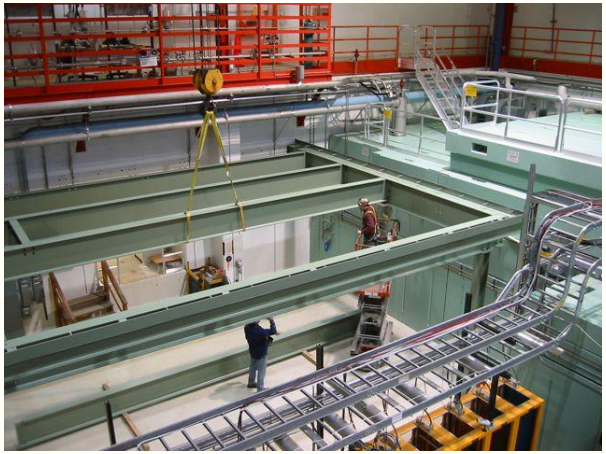
Loading Dock Demolition



Erection of Laser Deck

New Loading Dock

NML Expansion Construction

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Digging Tunnel

Pouring Concrete

Finished Tunnel

CMTF Construction

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NML Cryogenic System

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- **NML Cryogenic System Plan**
  - Start with two 625 W (4 K) Tevatron satellite Refrigerators and large vacuum pump (~ 60 W at 1.8 K)
  - Move 1000 W (4 K) BABAR refrigerator from SLAC
  - Add new 250 W (2 K) refrigerator
- **Status**
  - Installed Refrigerator room & helium storage tanks
  - Tevatron Satellite Refrigerator #1 operational - 8/07
  - Tevatron Satellite Refrigerator #2 operational – 4/10
  - Distribution system - Feedbox, Feed Cap & End Cap installed
  - Vacuum pump and Frick compressor
  - Capture Cavity-2 (CC2) Cooled to 2K – 10/09
  - Cryomodule-1 (CM1) Cool down to 2K – Fall 2010

NML Cryogenic System

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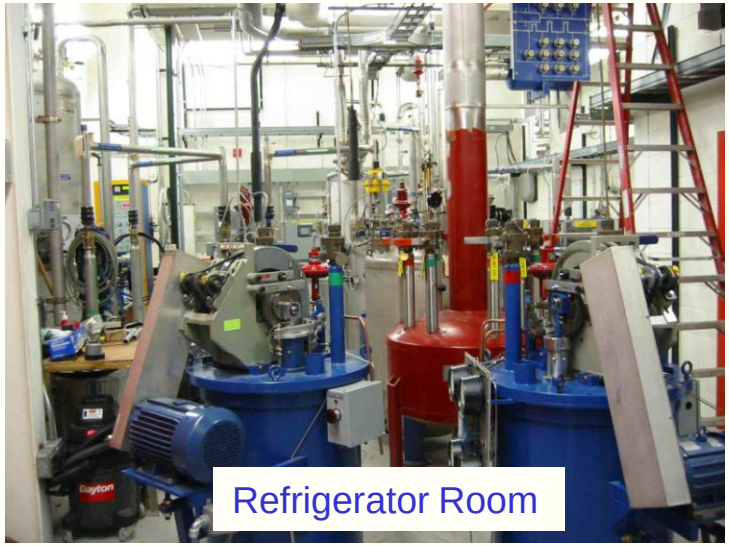

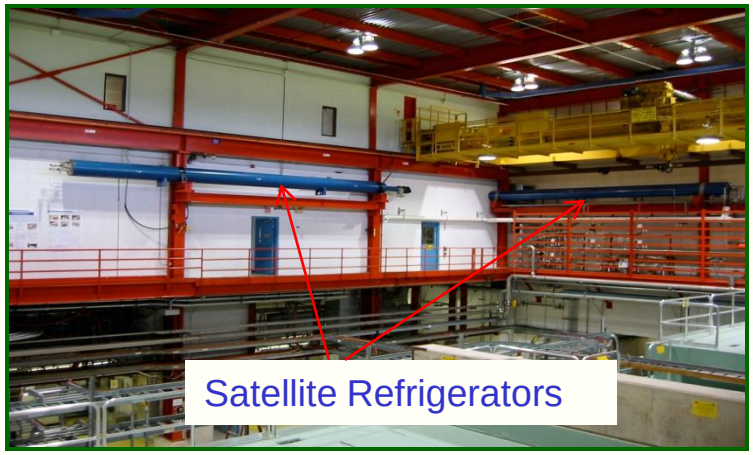

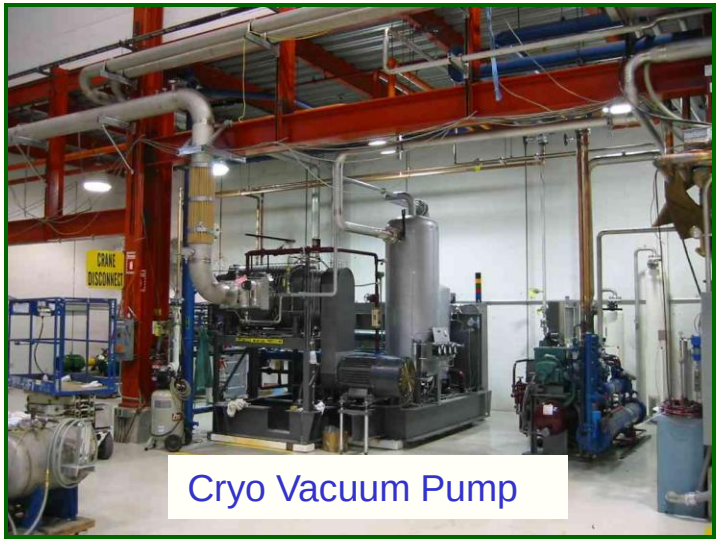

NML RF Systems

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- **RF System**
  - **5 MW for CM1**
    - **Fully Operational**
  - **300 KW for CC2**
    - **Fully Operational**
  - **Distribution**
    - **CM1 distribution from SLAC (in-house)**


5 MW RF


300 KW RF


CC2 RF


Waveguide (SLAC)

CM1 moving to NML

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NML Accelerator

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- **Injector**
  - Detailed Lattice designed
  - New gun system being installed
    - Collaboration with DESY, KEK & INFN
  - CC2 (single 9-cell cavity) operational - 10/09

- **Accelerator**
  - CM1 installed, aligned, and under vacuum
  - Cable pulls & cryo interconnects
- **Test Beamline**
  - Beamline layout complete
  - Beam Absorber analysis complete

CC2 Operation At NML

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- Moved from MDB to NML – 2/09
- Installation complete (vacuum, cryo., alignment) – 6/09
- First warm RF powering – 6/09
- Coupler conditioning complete – 7/09
- CC2 operated at 2 Kelvin – 10/09
- 24 MV/m gradient (limited by Coupler PM Tube trips) – 2/10
  - Similar to performance in MDB
- Studies of Low Level RF system and tuner, microphonics and Lorentz Force Detuning Compensation

CC2 Operations at NML

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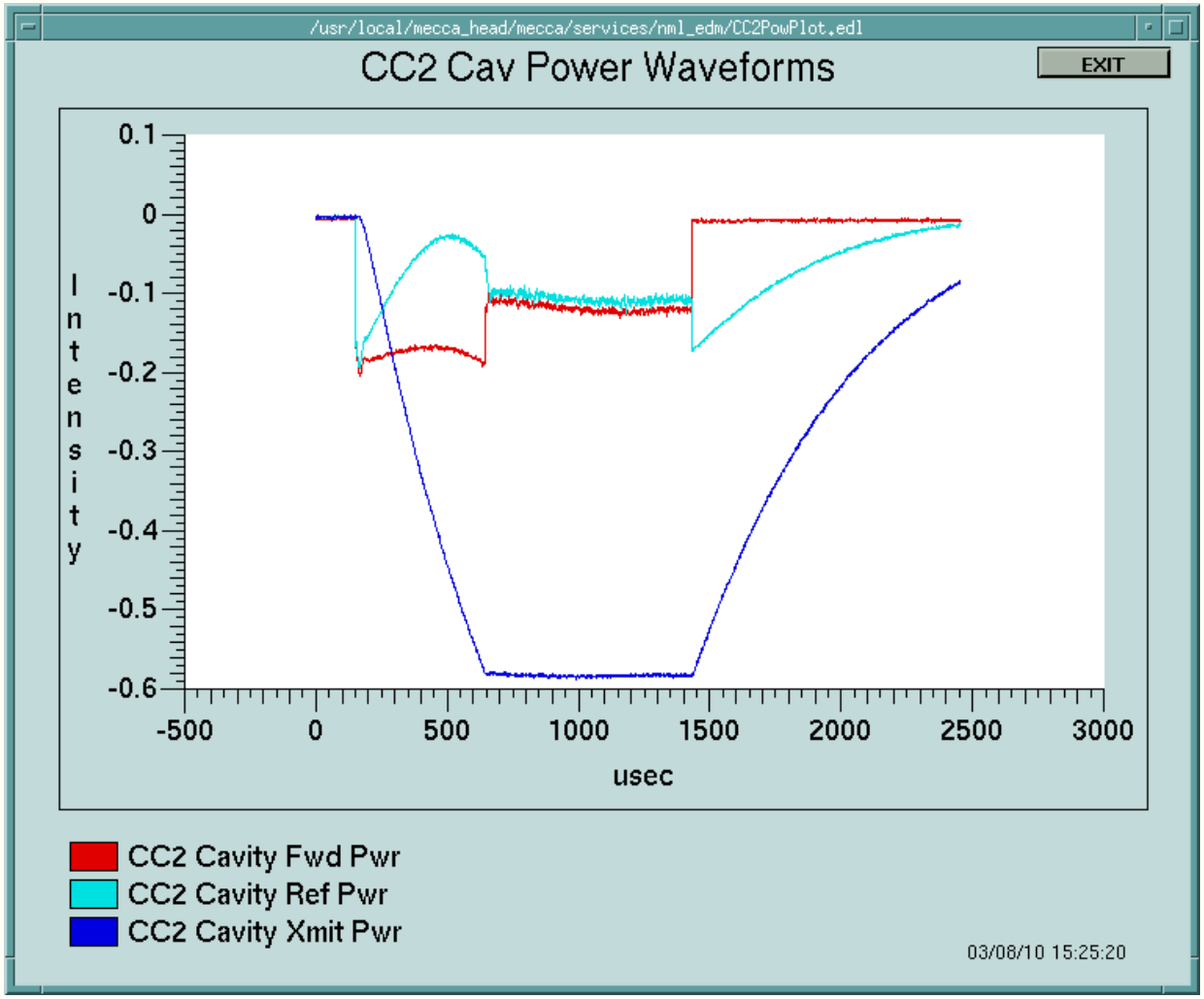
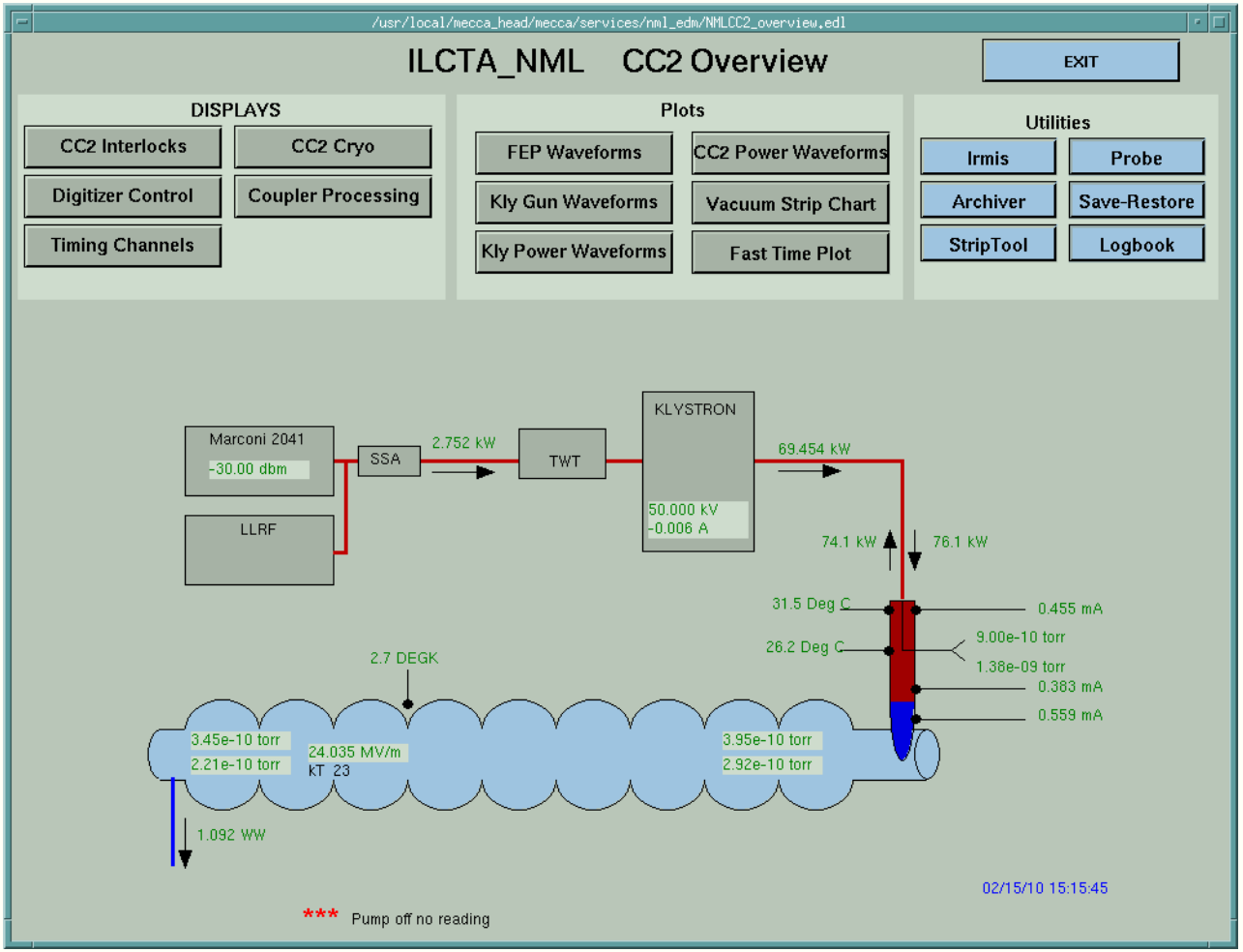
- **Regulated operation**
  - **LLRF feedback and feedforward enabled**
  - **1.3 ms pulse width**
  - **5 Hz**
  - **20 MV/m**
  - **Limitation is Coupler**



CC2 Performance at NML

- **Peak gradient - 24 MV/m**
- **Limited by Coupler activity**
- **Q_L = 2.92 X 10^6**
- **Similar performance as at MDB previously**



CC2 Performance at NML

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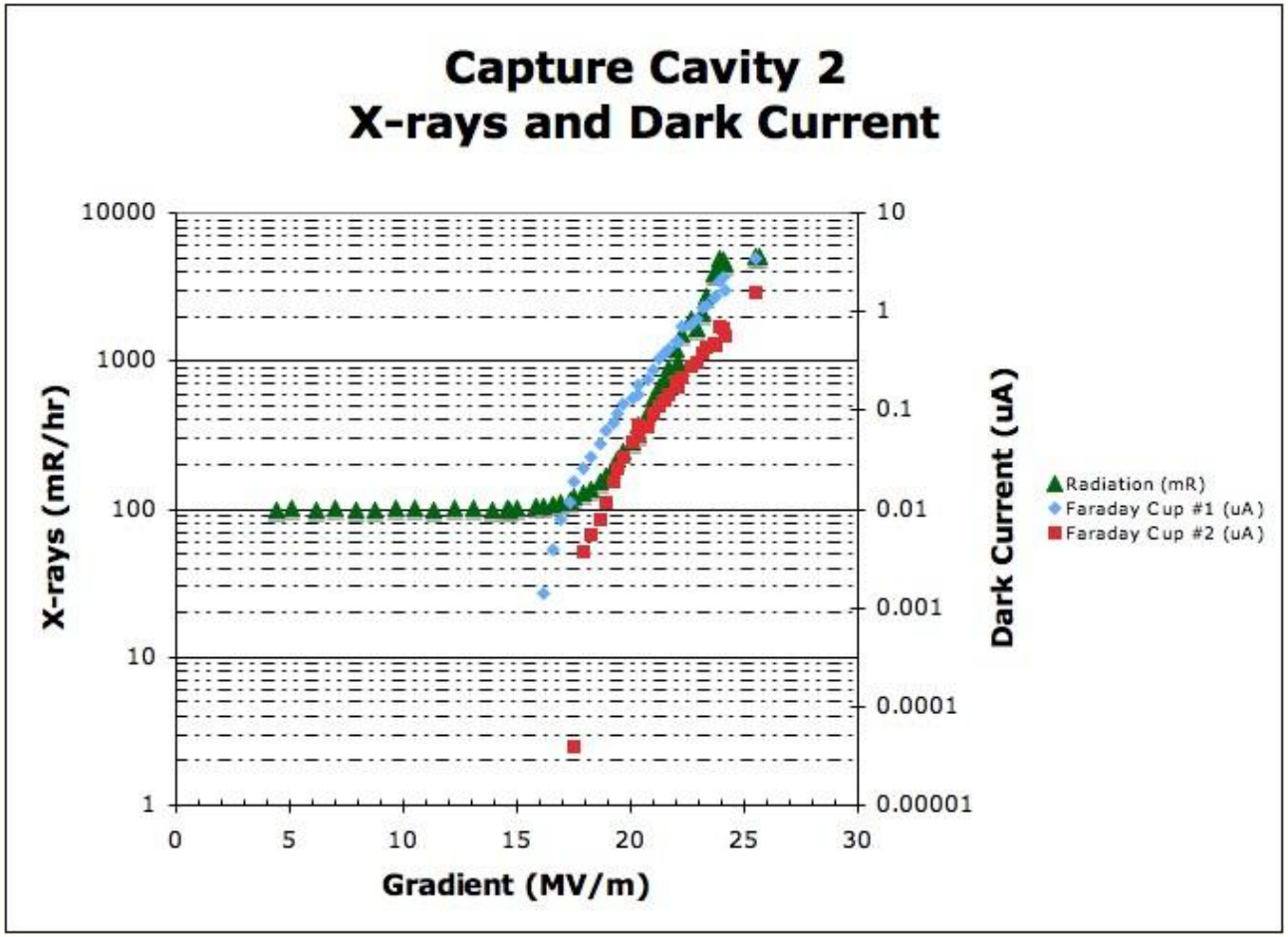
- Onset of field emission ~16 MV/m
- Similar threshold for dark current
- Largest amplitude at Coupler end



CM1 Testing

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- **Our first goal is to understand the performance of cavities in CM1 compared to HTS tests at DESY**
  - **We want to verify our assembly techniques in CAF**
- **Note that the dressed cavities provided by DESY for CM1 are NOT 35 MV/M cavities**
  - **We do not expect to meet the S1 goal of 31.5 MV/M**
  - **Average of Chechia tests is 23.5 MV/M**
  - **Anything close to this number will be a great success**

	Z89	AC75	AC 73	Z106	Z107	z91	z91	S33
Eacc max [MV/m]	23.5	22.5	30.6	33.5	36.5	31.1	28.5	26.6
Fe onset [MV/m]	> 23,5	>22,5	25.83	21	30.6	25.6	20	19.28
Eacc @ 1Exp-2 mGy/min	> 23,5	>22,5	28.6	27	32.4	29.7	24.41	23,48

- **It would be useful to understand what other tests might be useful for ILC with CM1**

CM1 Test Plan

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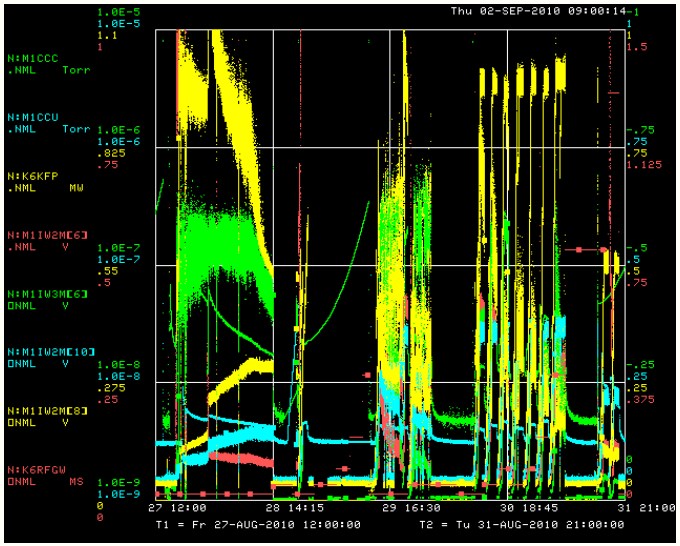
- **Virtually identical to DESY run plan for XFEL modules *(courtesy of Dennis Kostin)* and Fermilab experience at HTS and CC2**
- **TEST PROCEDURE:**
  - **1. RF Cable Calibration**
  - **2. Technical Interlock / Sensor checkout**
  - **3. RF source / Waveguides / LLRF**
  - **4. Warm Input RF Coupler Conditioning - in progress, 3/8 complete**
  - **5. Cooldown to 2K**
  - **6. Cavity Spectra measurements**
  - **7. Cavity Tuners Test and Tuning**
  - **8. Coupler Q_{load} measurement**
  - **9. Set Cavities On Resonance**
  - **10. Cold Input RF Coupler and Cavity Conditioning**
  - **11. Module Performance Measurement**
  - **12. Single Cavity Measurements**
  - **13. Cryo system performance test (if needed).**

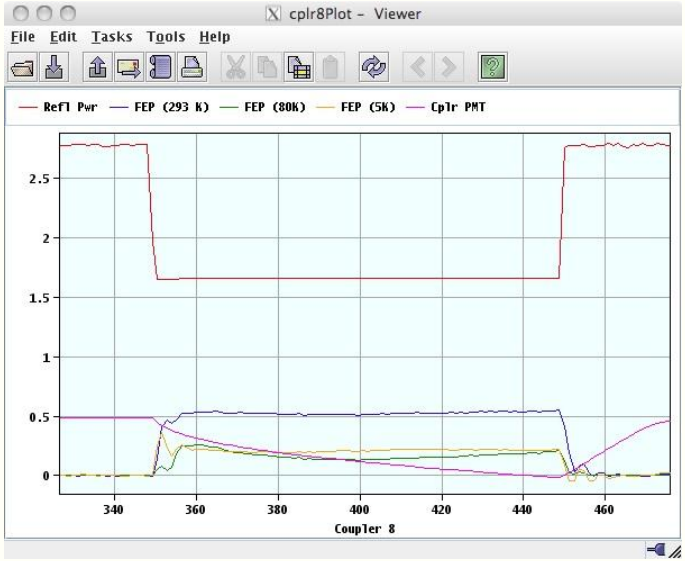
CM1 Test Plan

- **RF system is demonstrated good to ~3MW @ 2Hz, 1300 ms pulse**
- **Warm coupler conditioning**
  - **up to 1 MW for short (up to 400 us pulses)**
  - **600 kW for 800, 1300 us pulses**
  - **Using DESY results as the guide**



Conditioning Sequence for #6

FEP, PMT response during #8 conditioning



NML Auxiliary Systems

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- **Vacuum System**
  - Low-particulate vacuum cart built and tested
    - Leak detectors, RGA's, pumps, gauges, controls
  - (4) portable cleanrooms built (capable of achieving Class-10)
  - CM1 cavity string, and coupler systems under vacuum (10^{-9} Torr)
- **Water Cooling System (LCW)**
  - System design complete
  - New pumps and heat exchanger installed
  - Temporary skid (for Phase-1) operational
- **Safety Systems**
  - Radiation, ODH, Interlock, and Safety Assessment documentation complete

NML CM1 Vacuum Work

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NML Auxiliary Systems

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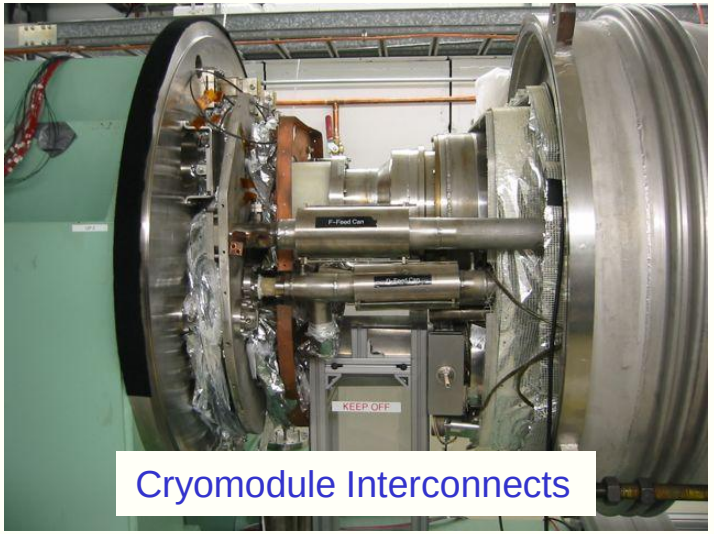
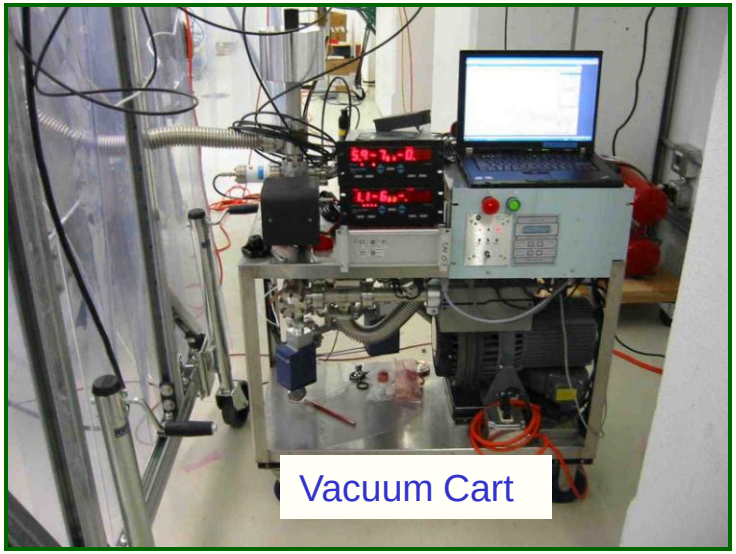
CC2 Installed



Cryomodule Interconnects


Vacuum Cart


Water System

NML Controls/Instrumentation

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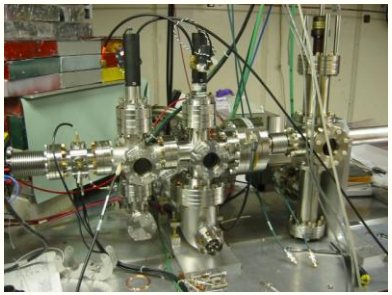
- **Controls**
  - **Control Room finished and operational**
  - **Modified (upgraded) ACNET control system in use**

Before

After

- **Instrumentation**
  - **Wire Position Monitors for CM1 tested and installed in Endcaps**
  - **Faraday Cups assembled**
  - **RF protection/interlock system complete**
  - **Beamline Instrumentation prototypes being Testing at A0 Photo Injector**



NML Schedule/Milestones

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- Phase-1 Cryogenic System Operational (August 2007)
- Delivery of First Cryomodule to NML (August 2008)
- Begin Civil Construction of NML Expansion (March 2010)
- Warm RF Testing of First Cryomodule (July 2010)
- Begin Construction of CMTF Building (August 2010)

- First Cryomodule Ready for Cooldown (Fall 2010)
- Cold RF Testing of First Cryomodule (Fall 2010)
- Delivery of 2nd Cryomodule to NML (S1) (2011)
- Install Injector & Test Beam Lines (2011)
- First Beam (2012)
- New Cryoplant Installation/Operation (2013-14)
- RF unit test with beam (S2) (2014)

NML Budget

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• SRF (18.2) - FY10	$1,917k
• Beamline/Facility Equipment (ARRA)	$10,765k
– FY10-FY11 (~ 60% obligated)	
• Expansion Construction (ARRA GPP)	$4,900k
– 80% complete	
• CMTF Construction (ARRA GPP)	$7,100k
– Began 8/10	
• Cryoplant Purchase (ARRA MIE)	$9,348k
– Place Order 9/10	
• RF Equipment for CMTF (ARRA)	$2,910k
– (~ 70% Obligated)	
• Total	$36,940k

Integrated SRF Plan (Cryomodules)

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