JLab Upgrade Projects Status
CEBAF 12 GeV Upgrade
TEDF

C. Reece

Material drawn heavily from Leigh Harwood & John Hogan

OUTLINE

- **Where we are**
  - CEBAF now
- **Where we want to go**
  - 12 GeV Science + National SRF Support
- **What it takes to get there**
  - New equipment and facilities
  - Budget and schedule
- **How far we are "down the road"**
  - 12 GeV Construction Status
  - TEDF plans and schedule
- **Summary**

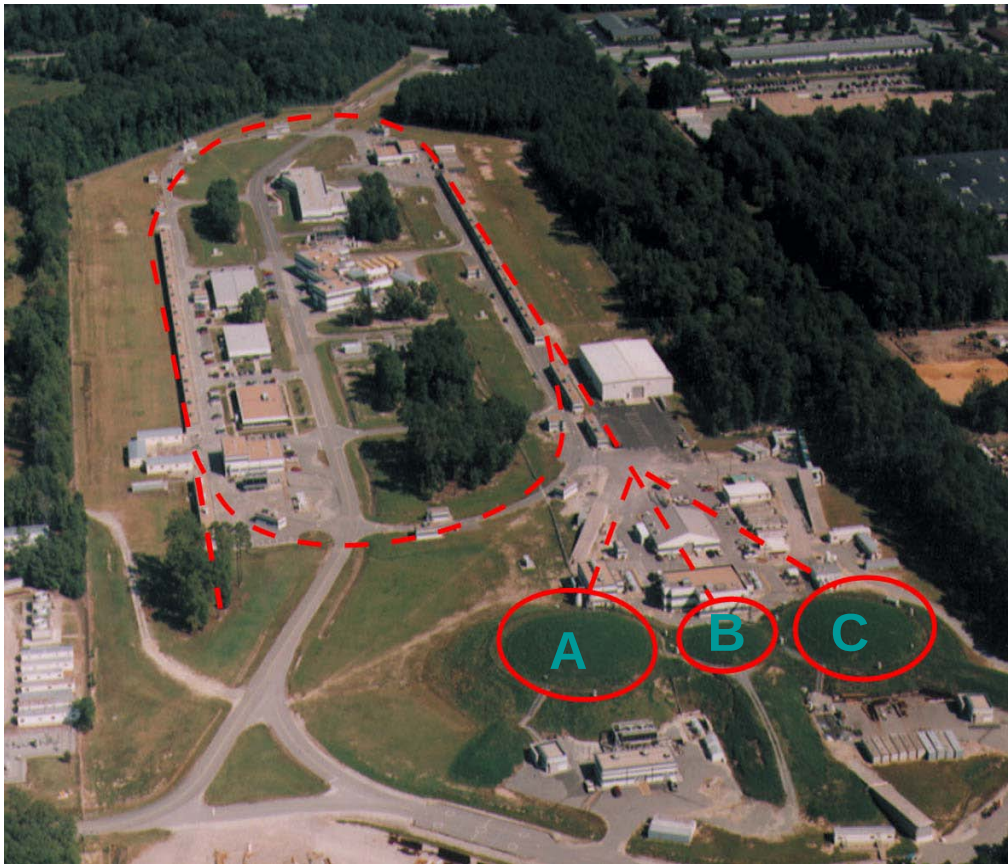
JEFFERSON LAB TODAY

Office of Science
U.S. DEPARTMENT OF ENERGY

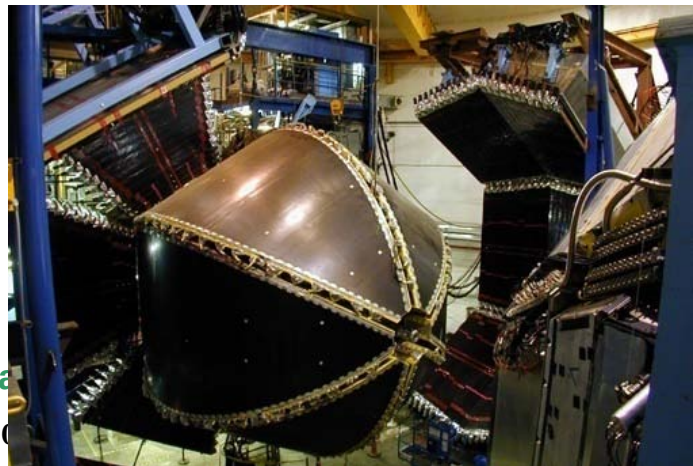
>1300 active member international user community engaged in exploring quark-gluon structure of matter.

Superconducting electron accelerator provides 100% duty factor beams of unprecedented quality, with high polarization at energies up to 6 GeV.

Newport News, VA

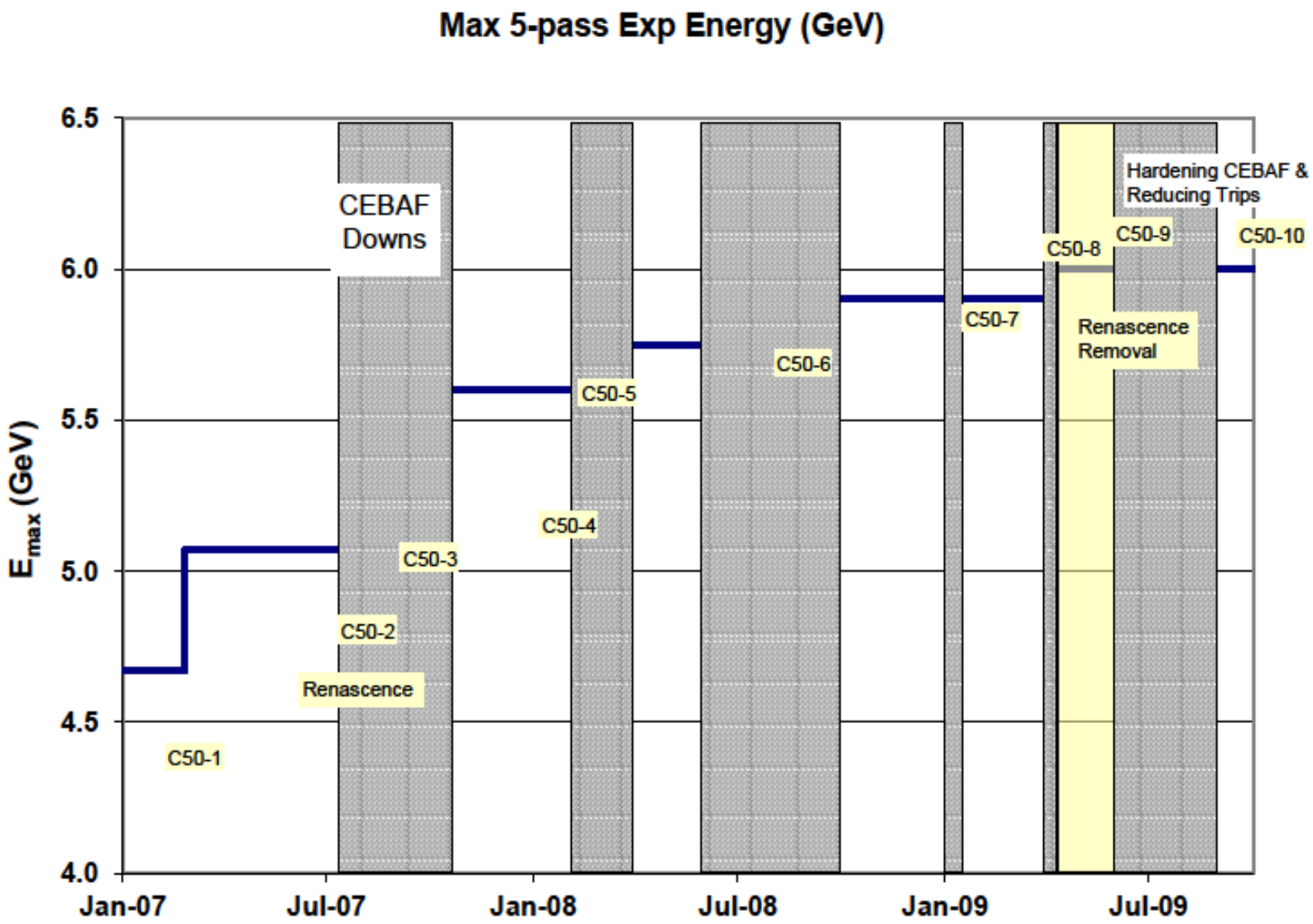


CEBAF's delivery of beam with unique properties to three experimental halls simultaneously. Each hall offers complementary capabilities.



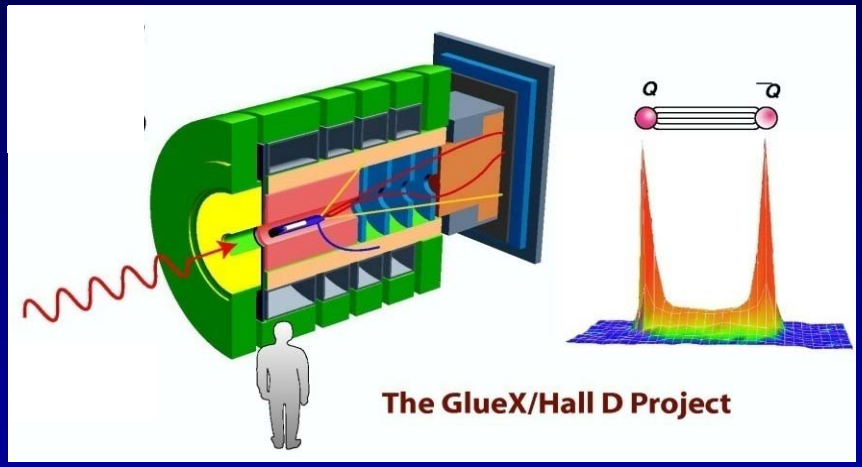
JEFFERSON LAB TODAY

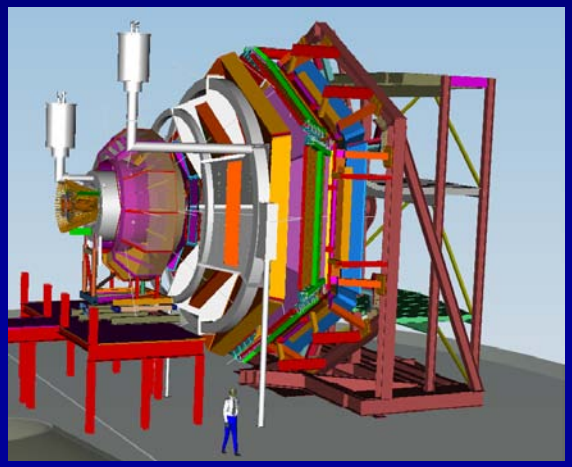
"C50" program reworked 10 CEBAF CMs to 50 MV



Target 12 GeV Scientific Capabilities

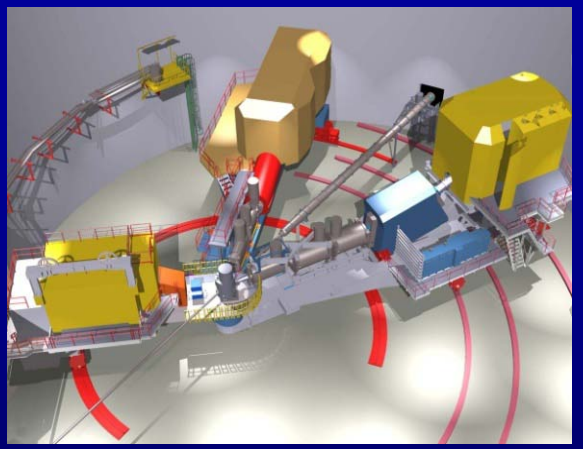
Hall D **– exploring origin of confinement by studying exotic mesons**

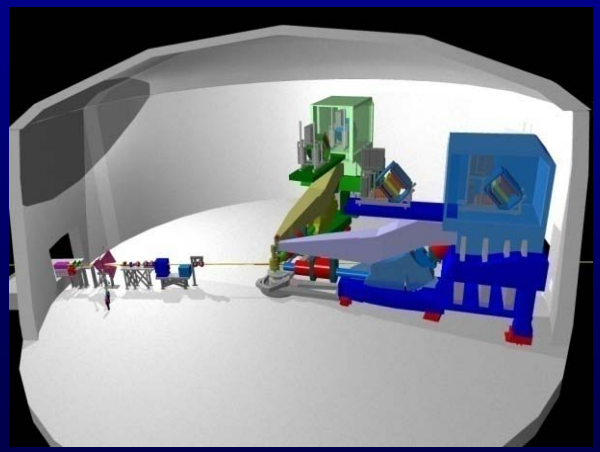




Hall B **– understanding nucleon structure via generalized parton distributions**

Hall C **– precision determination of valence quark properties in nucleons and nuclei**



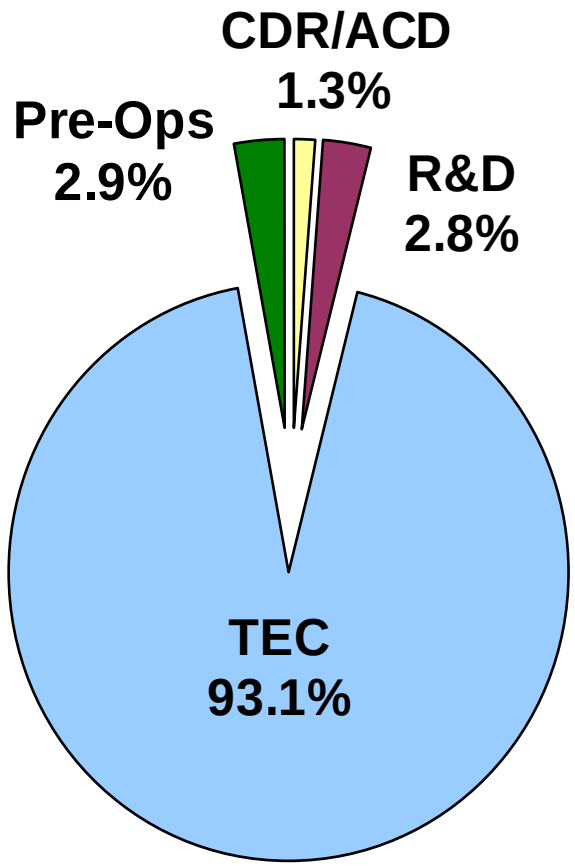


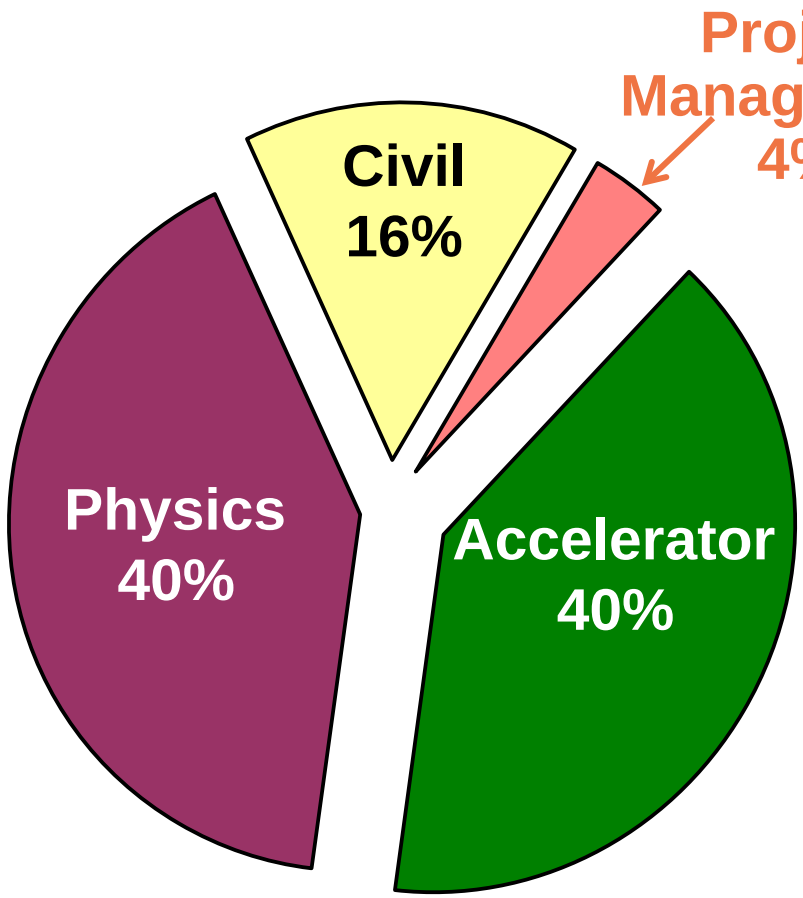
Hall A **– short range correlations, form factors, hyper-nuclear physics, future new experiments (e.g. PV and Moller)**

Getting There: Accelerator Upgrade

	Present	12 GeV
Max. Energy ABC/D	6 GeV	11 GeV / 12 GeV
Passes ABC/D	5	5/5.5
Duty Factor	CW	CW
Max. Current at Full Energy A&C / B&D	165 μA / 50 nA	85 μA / 5 μA
Maximum Beam Power	1 MW	1 MW
Max. Bunch Charge	0.2 pC	0.2 pC

12 GeV TPC and Construction



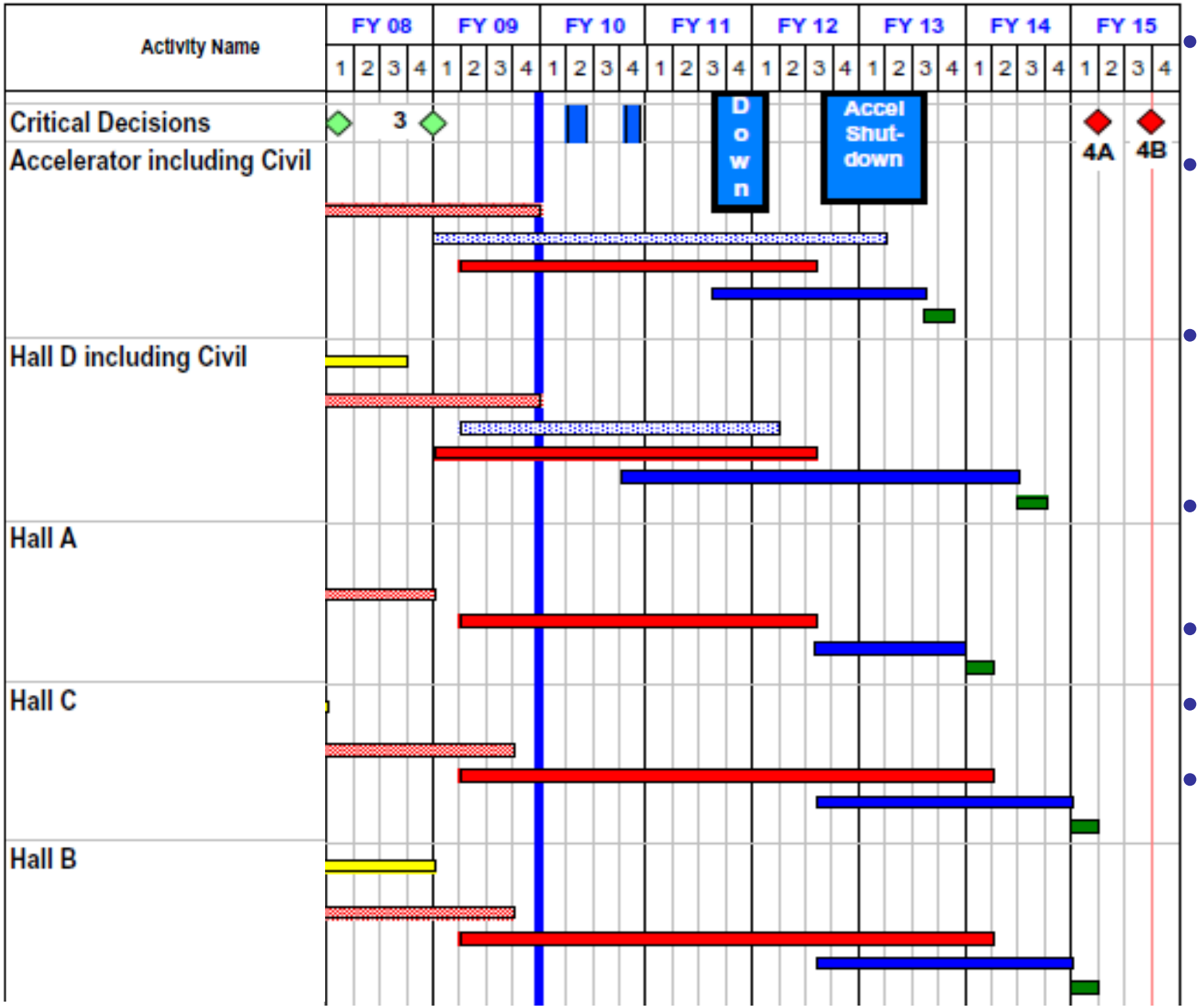


Construction
$266M

Total Project Cost= $310M
Total Equipment Cost=$287.5M

All numbers are AY$ and include contingency

Schedule



- **2Q10: Begin Accel. installation**
- **3Q11-4Q11: 6-month "down" for major Accel. installation**
- **3Q12-3Q13: 1-year "down" for major installation**
- **3Q13: Accelerator commissioning**
- **1Q14: Hall A**
- **3Q14: Hall D**
- **1Q15: Halls B and C**

Project Complete: June, 2015

This is the baseline schedule. We will be working ahead of it.

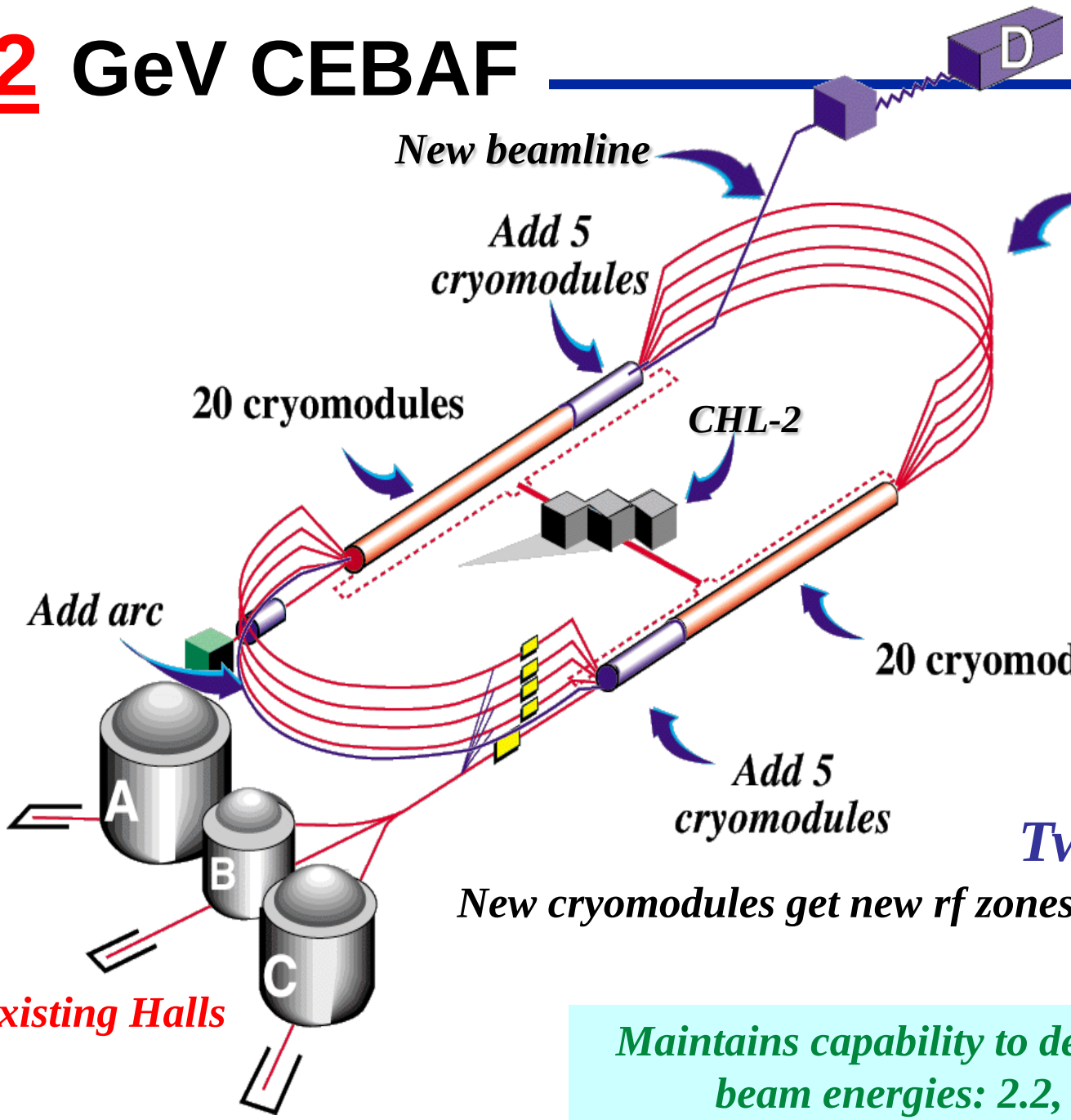
Paradigm for Accelerator Systems

It's about the physics!

"Accelerator costs must be minimized while ensuring delivery of required beams so available funding can be maximally devoted to nuclear physics research program."

- Meet the requirements and a few "design goals" (for robust operation) but no "wouldn't it be nice….."
- Leverage available parts
  - 6 GeV CEBAF accelerator
  - Tunnel
  - Service buildings
  - Cryogenic plant components
- Must ensure reliable operation

12 GeV CEBAF



Two 1.1 GeV linacs

New cryomodules get new rf zones

11GeV to existing Halls

Maintains capability to deliver lower pass beam energies: 2.2, 4.4, 6.6….

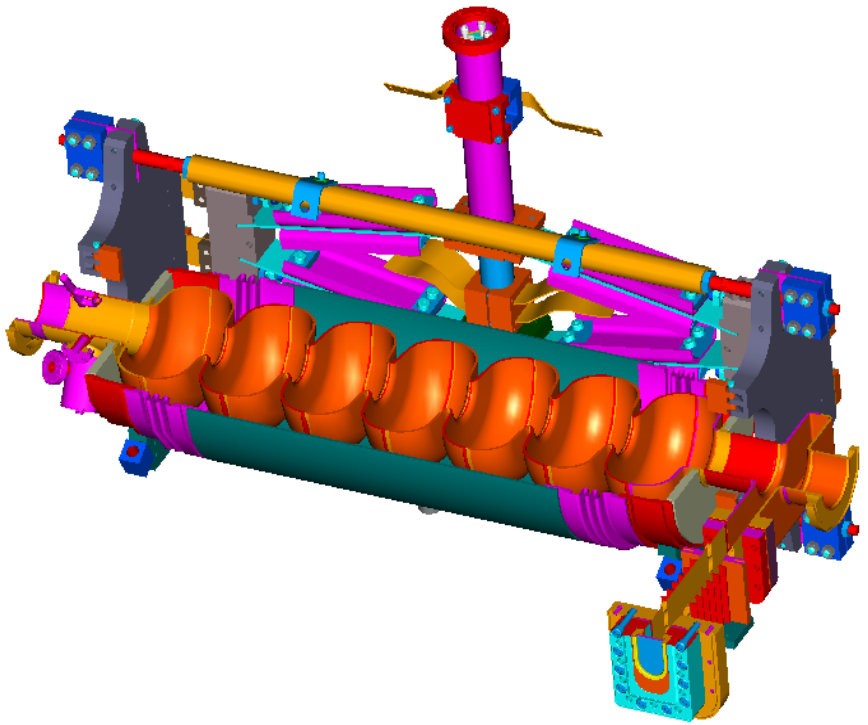
Acceleration
(Cryomodules, RF, Cryogenics)

- **Eight cavities are packaged into a cryomodule**
  - **–40 cryomodules are installed in CEBAF linacs today (600 MV/linac)**
  - **–10 new ones will be added**
    - **Average of 98MV/module needed in each linac**
    - **Add 10% for operational headroom**
- **Each cavity has a dedicated microwave source**
  - **–338 of these are installed in CEBAF today**
    - **5-8 kW**
  - **–80 new ones will be added**
    - **13 kW**
- **The new cryomodules result in a ~100% increase in the cryogenics load**
  - **–Will build a 2nd plant that replicates of the existing cryogenics plant's capacity.**
    - **4.5 kW @ 2K**

Cavity Performance

Measured cavity performance is better than requirements.

	E_{acc} (max usable)	E_{acc} @ heat load spec*
Target	≥ 21.2 MV/m	≥ 19.2 MV/m**
12 GeV Cavity-1	22.8 MV/m	21 MV/m
12 GeV Cavity-2	25.2 MV/m	22 MV/m

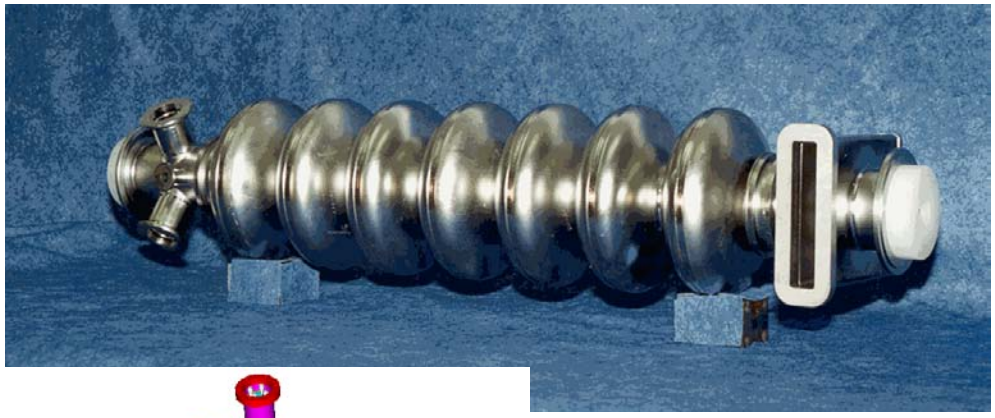


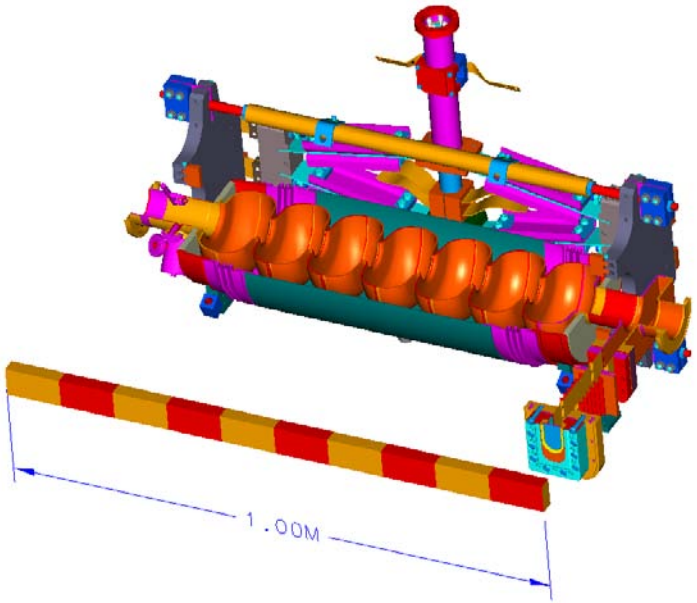
* 29W

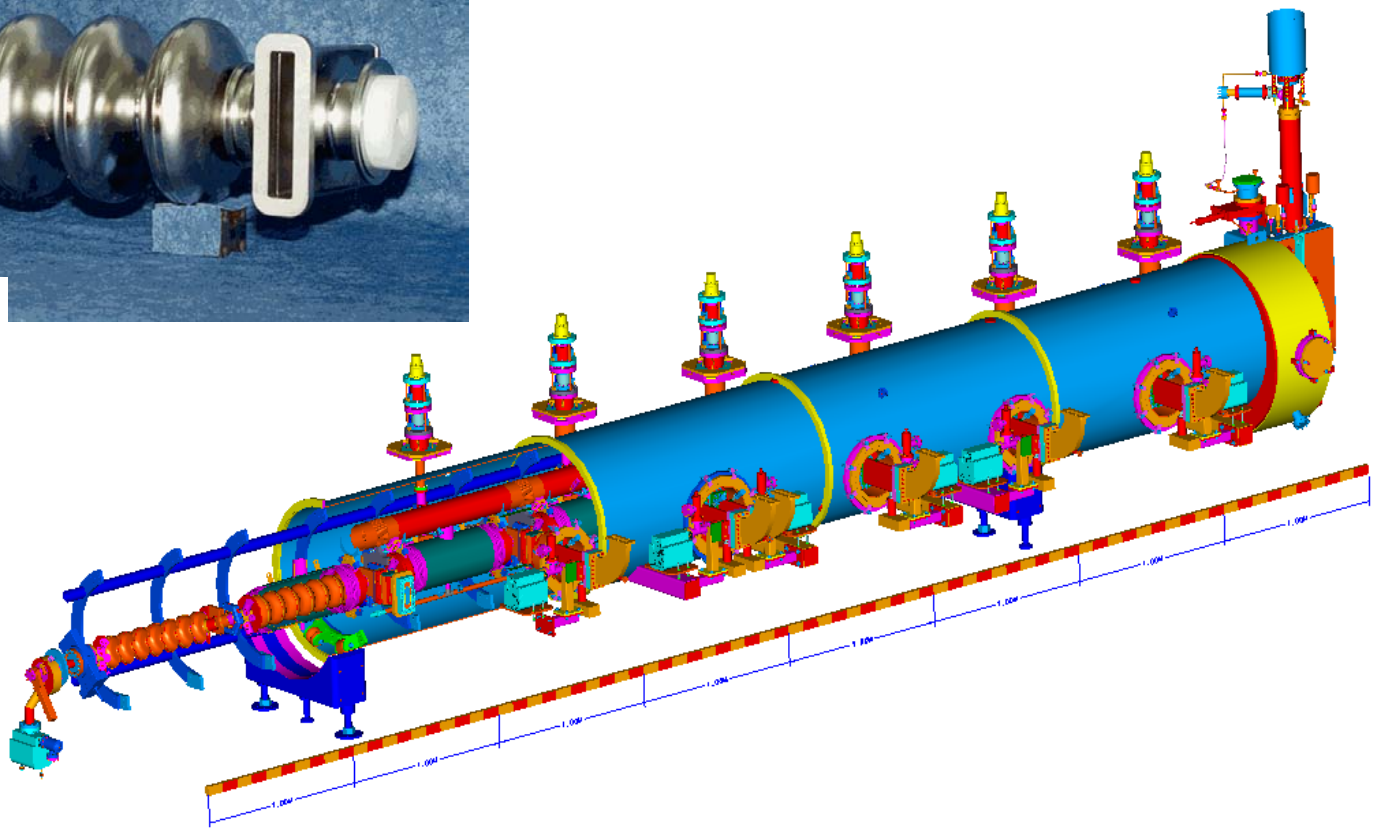
**Meets 540MV/linac (10% reserve above requirement to deliver 12 GeV)

Accelerator Construction Status: Cryomodules

- **All major contracts have been placed**
- **Cavities are being fabricated by vendor**
- **First cavity string will be complete at JLab in ~September**







Beamlines
(magnets, power supplies, beam diagnostics, vacuum lines)

- **Existing recirculation and transport to existing halls**
  - 357 major Dipoles (1-3m long)
  - 730 Quads (30x30x30cm)
  - >2000 power supplies
  - >700 beam diagnostics
  - >5 km of vacuum line

Reuse almost all

- **Arc 10**
  - 32 major dipoles (4m long)
  - 40 quads (35x30x30cm)
  - 81 power supplies
  - 32 beam diagnostics
  - 0.3 km of vacuum line
- **Transport to Hall D**
  - 4 major dipoles (4m long)
  - 32 quads (35x30x30cm)
  - 97 power supplies
  - 44 beam diagnostics
  - 0.3 km of vacuum line

All items are copies of or variations on existing hardware

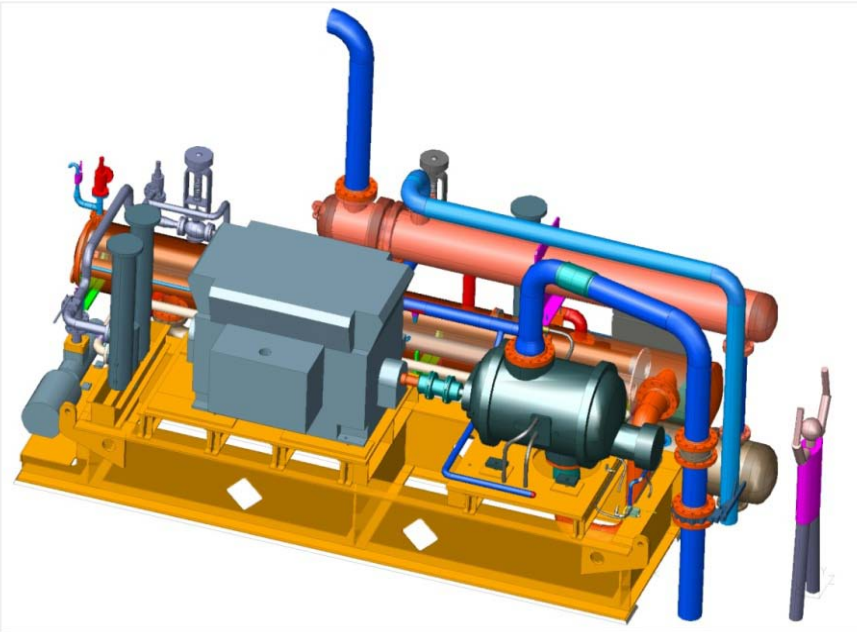
Accelerator Construction Status: Power

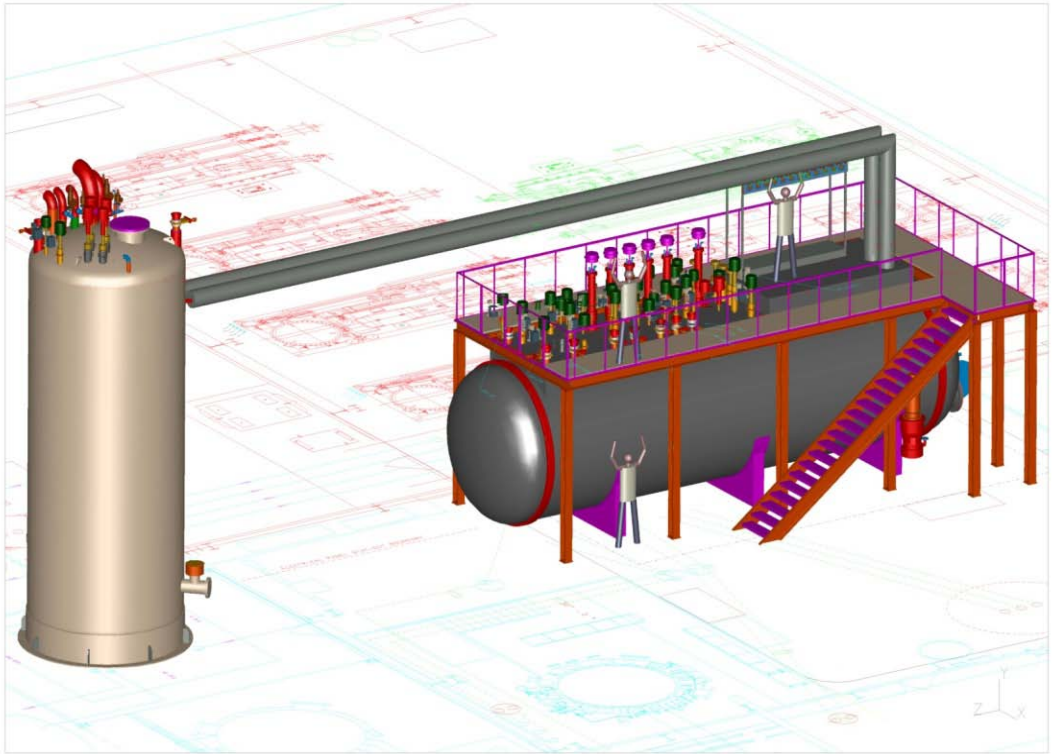
- **RF:**
  - Using world's first digital self-excited-loop controls
  - Klystrons ordered (1st article due in April)
  - Assembly of low-level RF controls has started
  - Installation has begun
- **Power supplies for large dipoles have been ordered**

	Amplitude	Phase
Required	4.5×10^{-4}	0.5°
Achieved	1.3×10^{-4}	0.14°

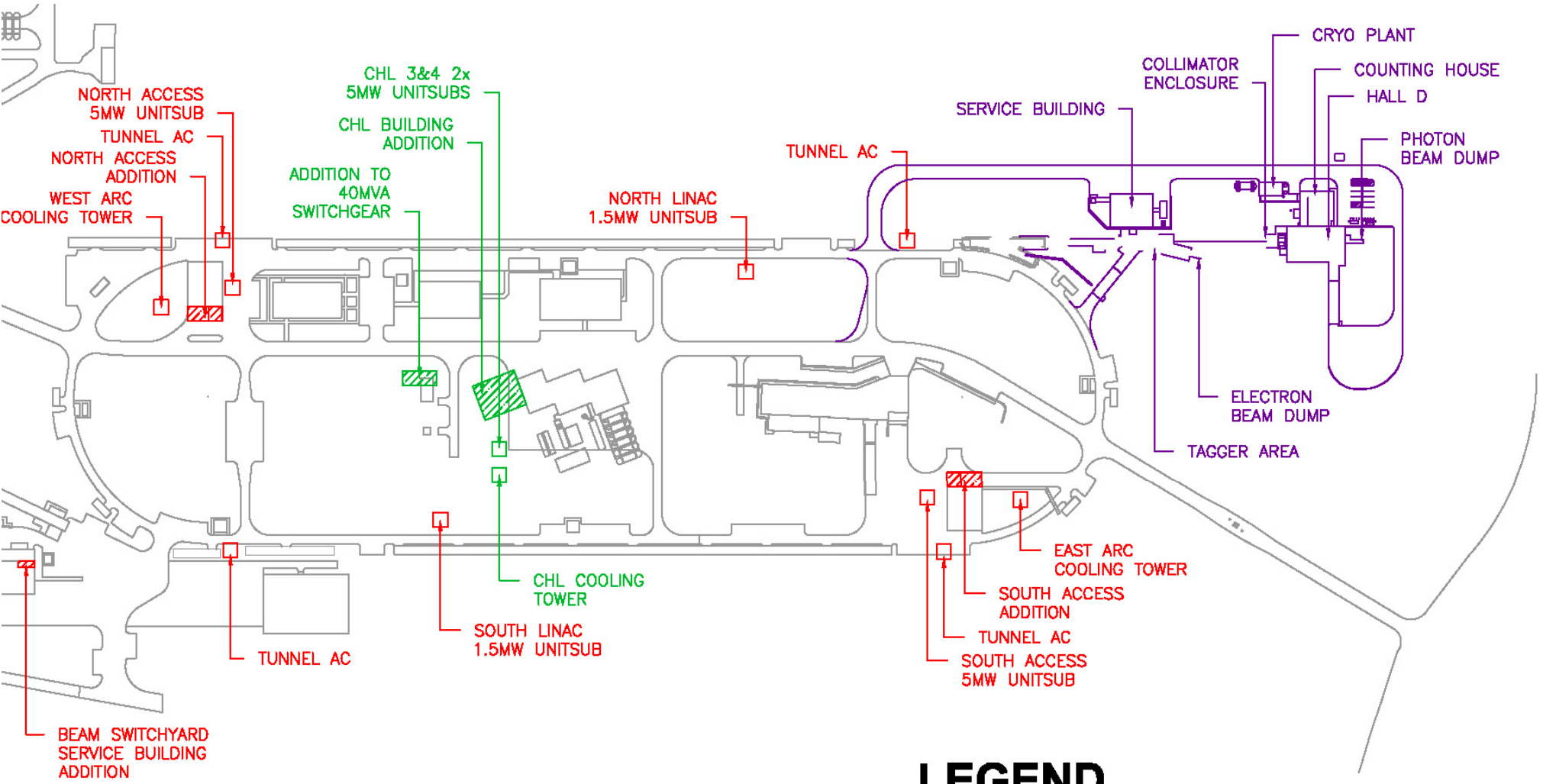
Accelerator Construction Status: Cryogenics

- **All major contracts are placed**
  - **Coldbox vendor successfully passed the design review**
- **Installation of piping is about to begin**





CONVENTIONAL FACILITIES SCOPE – MASTER PLAN VIEW



LEGEND

- WBS 1.6.1 ACCELERATOR FACILITIES
- WBS 1.6.2 CHL ADDITION
- WBS 1.6.3 HALL D COMPLEX

Groundbreaking

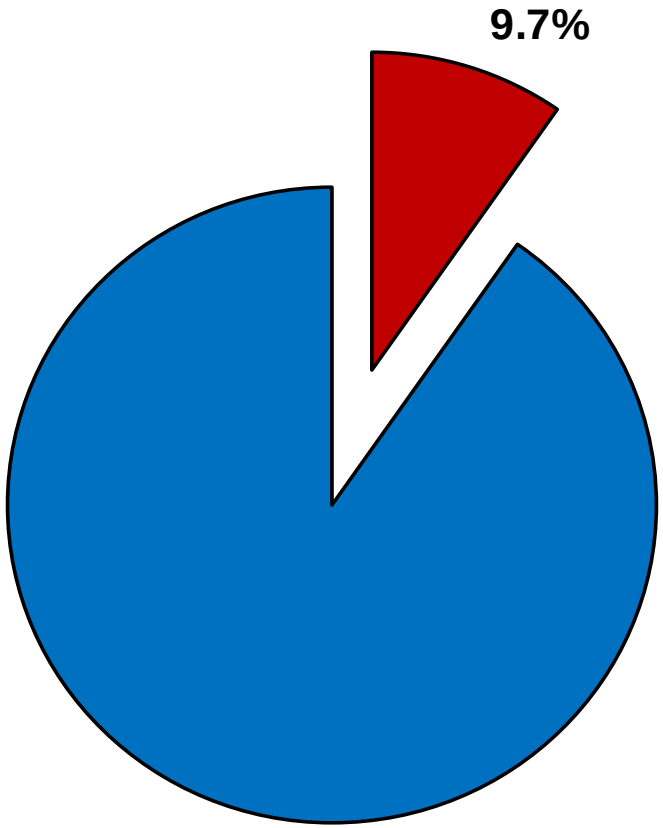
Excavation

Civil Construction: Hall D Complex 2009-2010

Floor Slab

Walls

WBS 1.3.1 Construction Cost

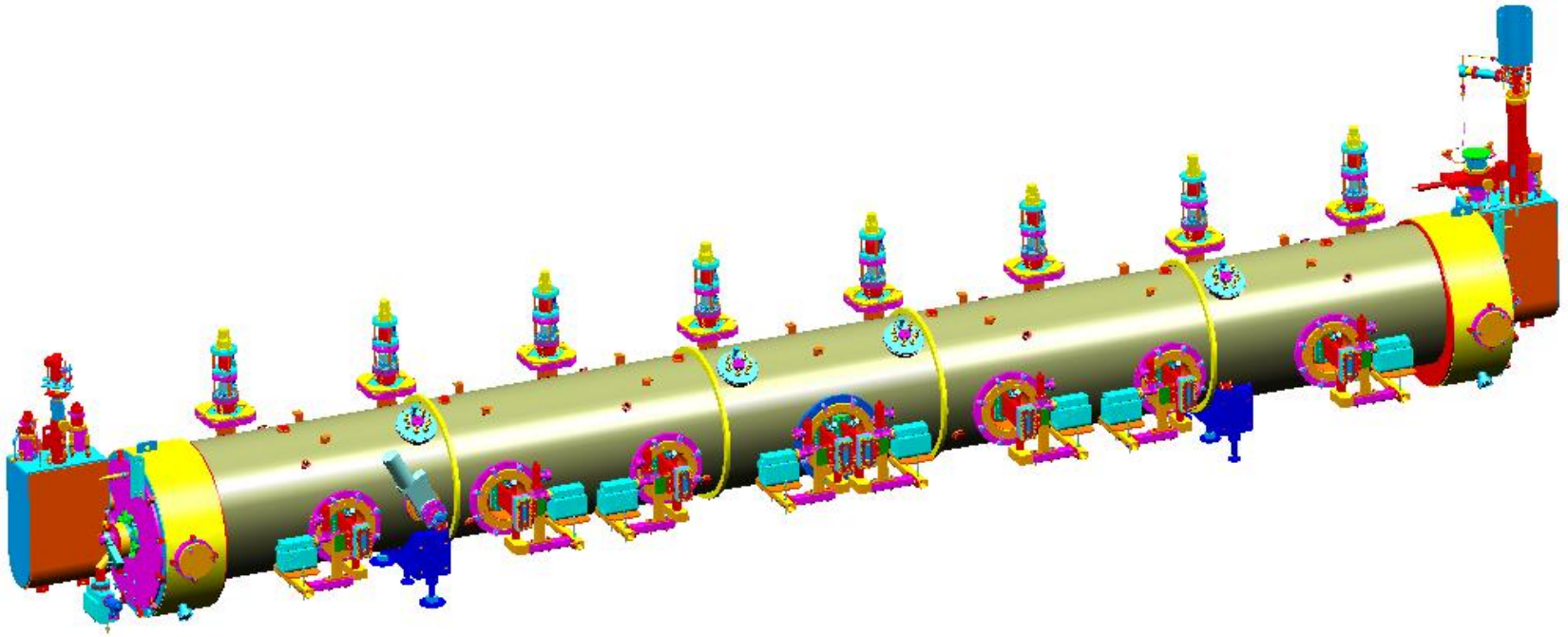


(FY09$K Direct)

Construction	17,615

Scope

Develop, Design, Fabricate, Install, and Commission 10 Cryomodules



Key Technical Parameters :

New cryomodules per linac: **5**

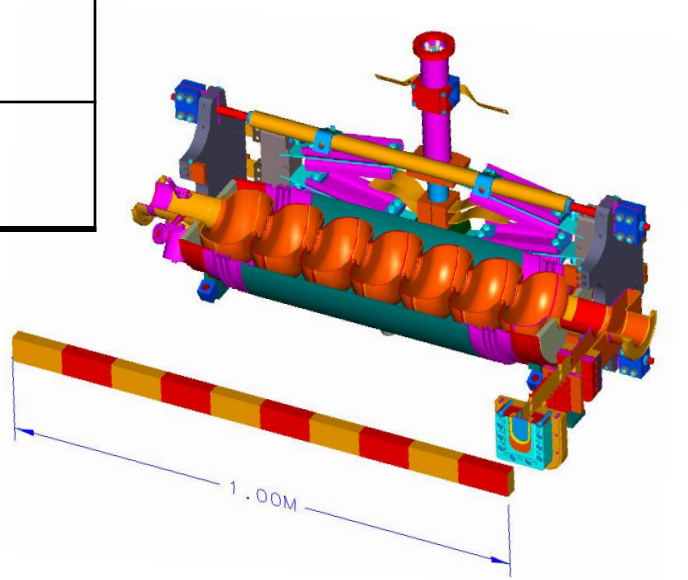
(Note: The following parameters are for each Cryomodule)

Voltage:	**≥ 108 MV** (ensemble average in each linac)
Heat budget: (Interface with Cryogenics)	
• 2 K	≤ 300 W
• 50 K	≤ 300 W
Slot Length:	**9.8 m**
Tuner resolution:	**≤ 2 Hz**
Fundamental Power Coupler (FPC):	**7.5/13 kW (Avg/Pk)**
Higher Order Mode (HOM) damping:	***Updated***
• Transverse (R/Q)Qk	$< 2.4 \times 10^{10}$ Ω/m
• Longitudinal (R/Q)Q	$< 6.5 \times 10^{11}$ Ω
Cryomodule Length (Physical)	**~8.5m**

Cavity Performance

Measured cavity performance exceeds requirements.

	E_{acc} (max usable)	E_{acc} @ Q_0 spec
Target	≥ 21.2 (MV/m)	≥ 19.2* (MV/m)
12 GeV Cavity-1	22.8 MV/m	22 MV/m
12 GeV Cavity-2	25.2 MV/m	22 MV/m



*Meets 540MV/linac (10% reserve above requirement to deliver 12 GeV)

Sub-system Design Evolution

Many major 12 GeV cryomodule sub-system designs and fabrication techniques plus alternatives were tested in 3 developmental cryomodules.

	Cavity end-group thermal design	HOM damping	Cavity cell shape	Helium header & primary circuit	Cavity tuner	Helium vessel	RF window config.	Space frame & Algnm't; Thermal Shield; Vacuum Vessel
SL21								
FEL03								
REN								

Key	
	Same as 12 GeV design
	Different from 12 GeV design

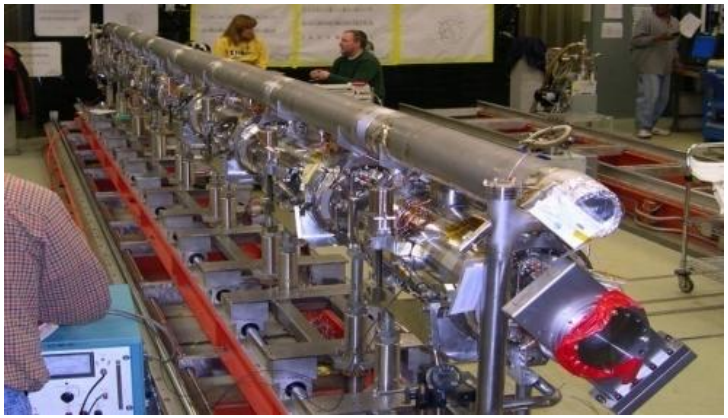
Lessons Learned

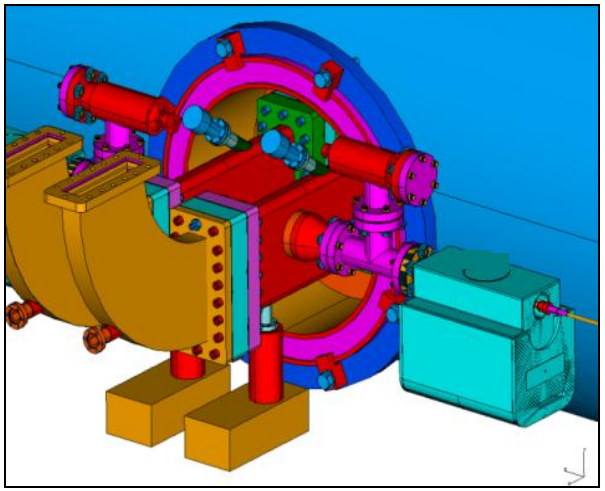
SL21 - First developmental cryomodule

- 7-cell cavities, tuners, spaceframe, etc.
  - Problem: Helium header riser limits heat flow to 2K
    - Response: Increase diameter of riser in FEL03

FEL03 - Second developmental cryomodule

- 7-cell cavities, tuners, spaceframe, etc. (with improved riser)
  - Problem: Warm window failure
    - Response: Add second window for 12 GeV

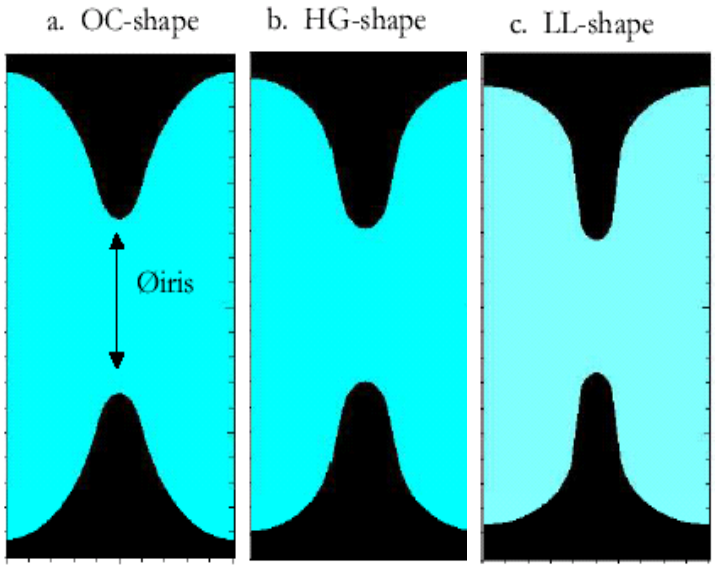




Lessons Learned (cont'd)

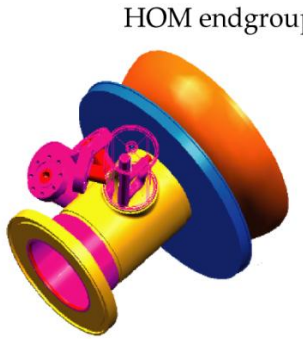
Renascence: Final developmental cryomodule for 12 GeV

- Used as testbed for design options
  - Two new cavity cell shapes
    - High-Gradient (reduced E_{max})
    - Low-Loss (reduced B_{max})
  - Down select to Low Loss (LL) cell shape for 12 GeV
- New cavity end-group design
  - Goal: Improved HOM damping
- New tuner design
  - Goal: Reduce cost



Lessons Learned (cont'd)

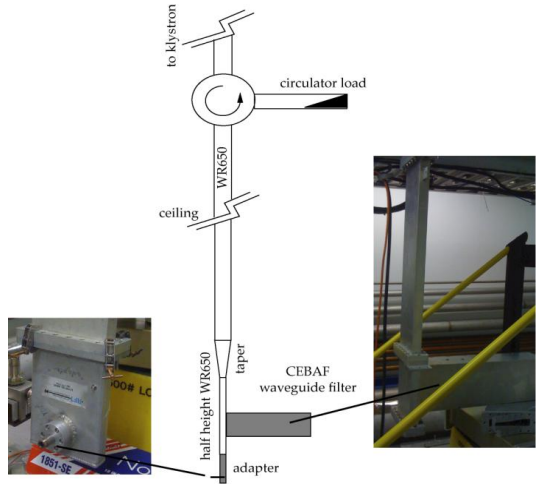
Renascence: Resolved Issues

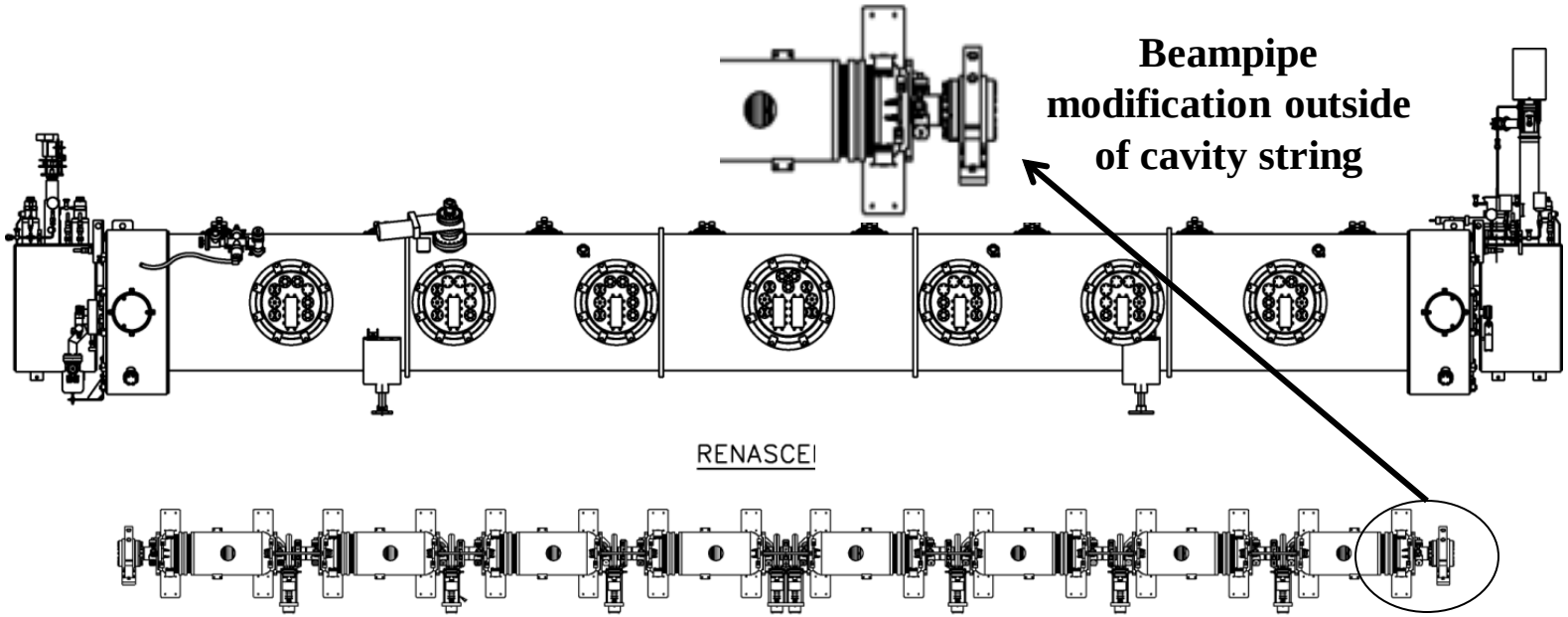


- Tuner Reliability
  - Response – Return to original design
- End-group heating
  - Response – Optimize end-group design
    - Reduce HOM couplers from 4 to 2
    - Reorient probe to reduce coupling to the fundamental
    - Add thermal anchoring for HOM feedthrough
- Beam Break Up (BBU) observed
  - Response – Detailed HOM damping analysis using measurements & modeling
    - Identified source of BBU (mis-shaped high-gradient cavity #2)
    - Comprehensive computational analysis (SLAC)
      - HOM damping is boundary condition dependent
    - Measured HOM damping of 12 GeV cavities for compliance (VTA & HTB) and confirmed they meet updated specification

HOM Damping Analysis

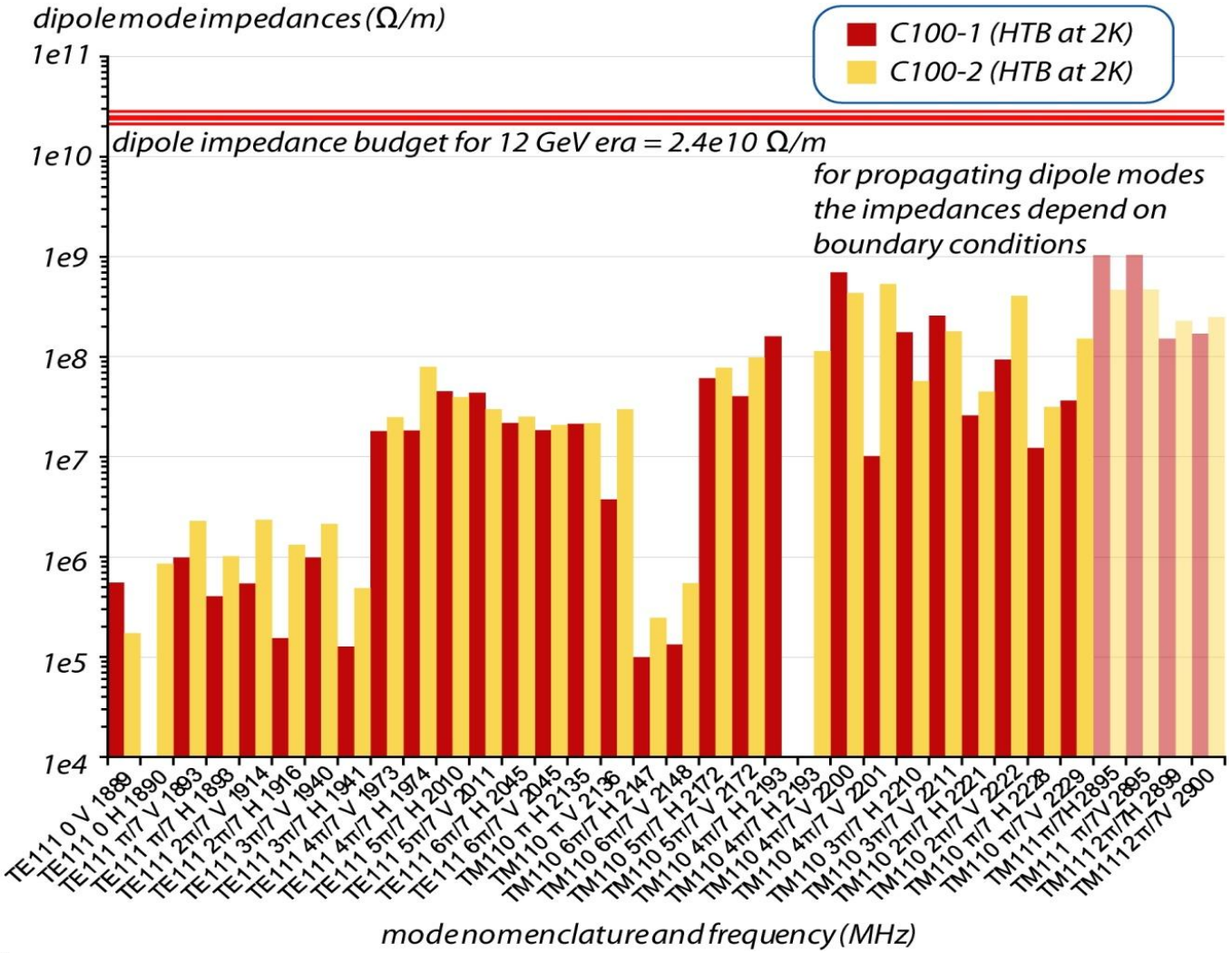
- FPC's contribute significantly to the damping of the HOM's in the region of 2.9GHz
  - May need to modify CEBAF warm waveguides filters
- Cavity positions one & eight lack the double FPC boundary condition
  - Warm-to-Cold beamtube is being modified in order to improve the HOM coupling of the end-groups for the end cavities





HOM Analysis (cont'd)

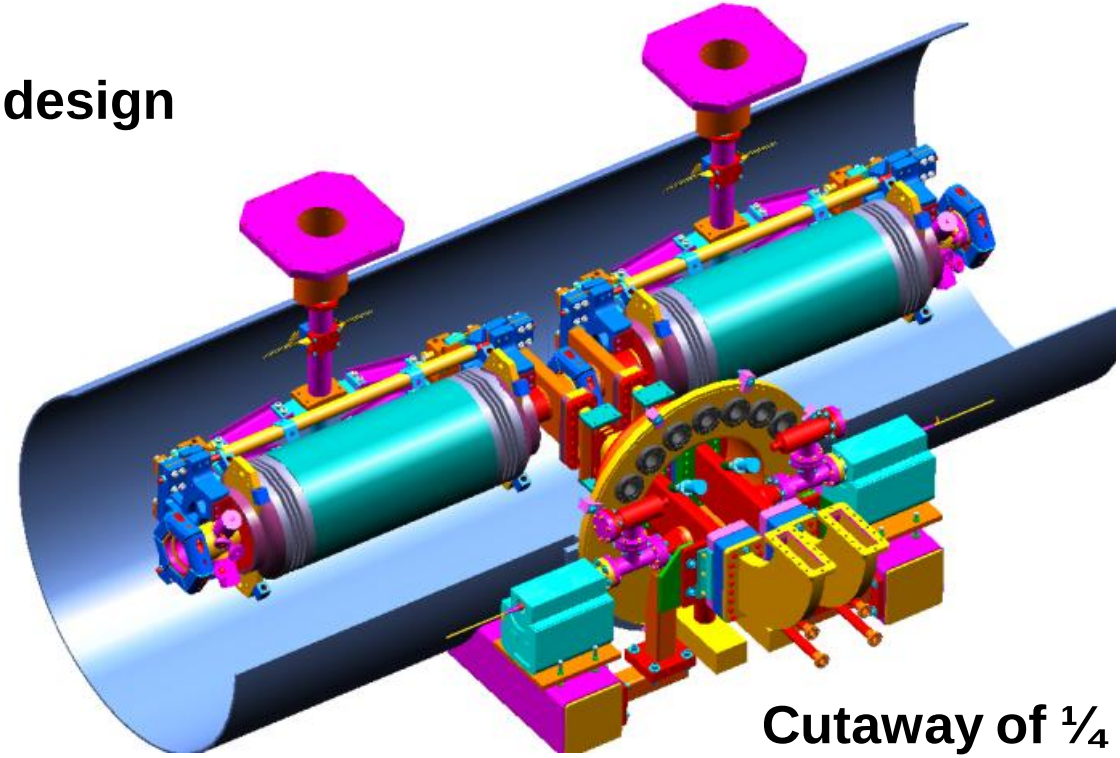
- **12 GeV cavity design is well below specification for *transverse* modes**



Validation of Design

Final design was tested in "1/4 cryomodule" which is referred to as the Horizontal TestBed (HTB)

- Functional verification of design
  - Cell shape
  - End-group thermal
  - HOM couplers
  - Helium vessels
  - Tuners
  - Double rf windows



Cutaway of ¼ Cryomodule

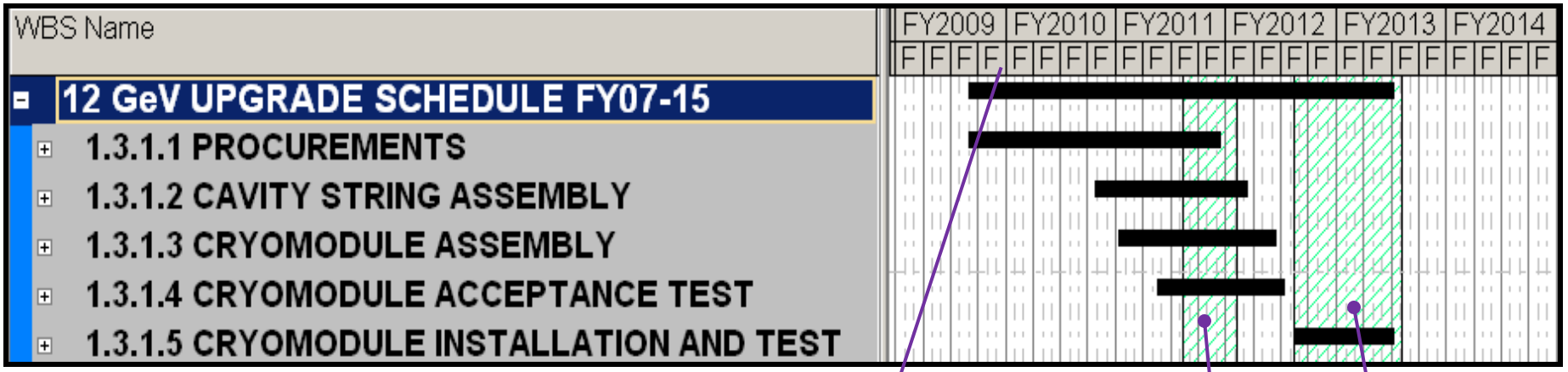
Sub-system Design Evolution: Conclusion

Final 12 GeV cryomodule sub-system designs and fabrication techniques have been thoroughly vetted in cryomodule environments.

	Cavity end-group thermal design	HOM damping	Cavity cell shape	Helium header & primary circuit	Cavity tuner	Helium vessel	RF window config.	Space frame & Algnm't; Thermal Shield; Vacuum Vessel
SL21								
FEL03								
REN								
HTB				NA				NA

Key	
	Same as 12 GeV design
	Different from 12 GeV design

WBS 1.3.1 Construction Schedule



Now

12-Month Down

6-Month Down

Opportunity to install cryomodules ahead of schedule

Key Dates

Activity	Baseline	Working Plan
• 1st procurement:	Complete	Complete
• 1st cavity string assembly:	September 2010	September 2010
• 1st cryomodule assembly complete:	February 2011	February 2011
• 1st cryomodule Installation:	May 2012	May 2011*
• Last cryomodule checked out:	April 2013	April 2013

***Working toward a stretch-goal with 1 year acceleration relative to baseline.**

Installation planning

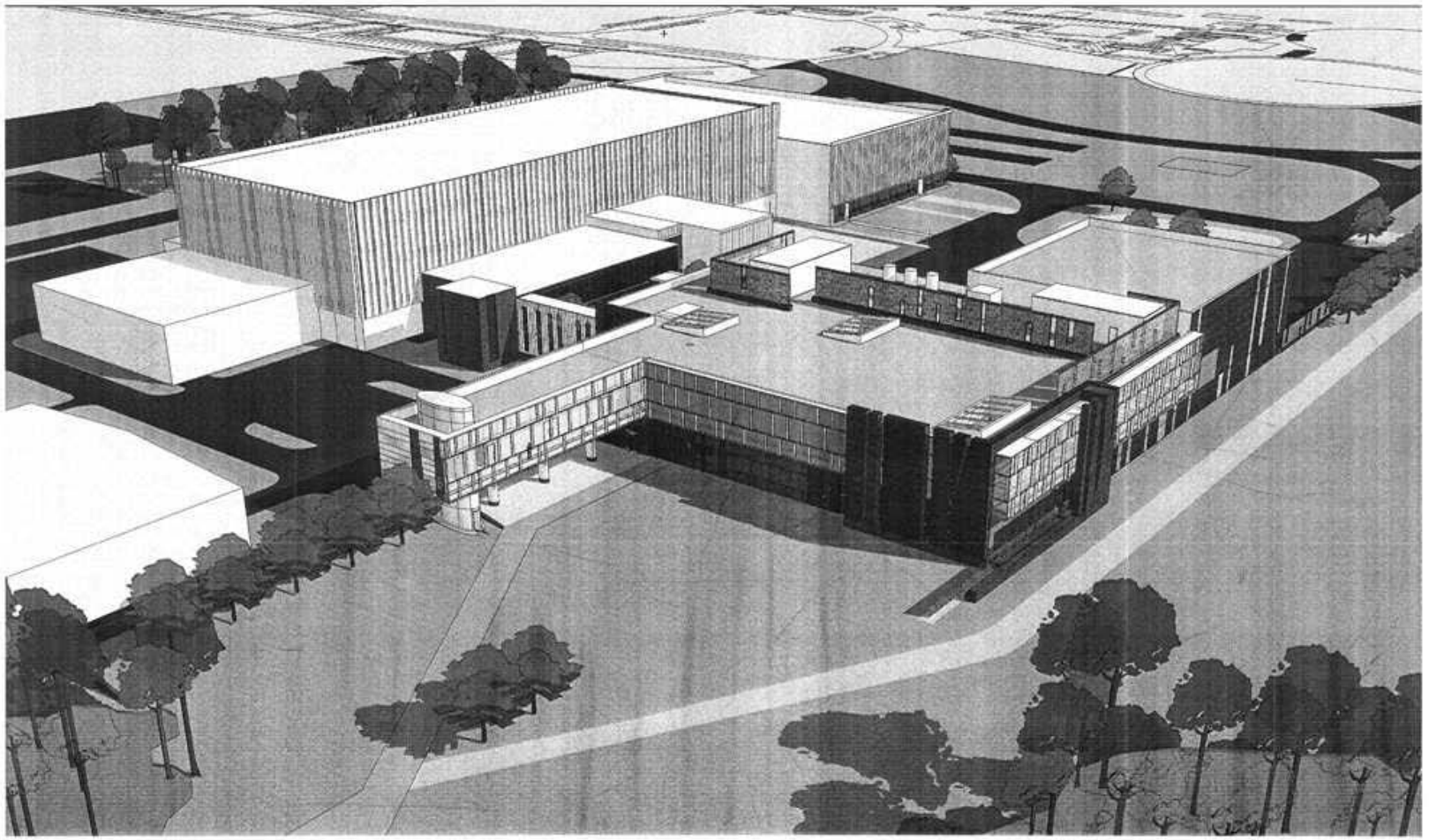
- Present procurement plans set stage for potential installation of first completed cryomodules during the six month down.
- Base plates installed into new zones ahead of 6-month down (CY2010).
- Baseline schedule for completion of acceptance testing of 1st cryomodule is March 2011.
- 6-Month down runs from May-Oct 2011.
  - Completed cryomodules will be staged and ready for opportunistic installation.
- Coordinating with other accelerator systems.

JEFFERSON LAB 2014

Jefferson Lab

Technology and Engineering Development Facility (TEDF)
Newport News, Virginia

Date: 01.08.2010 Issue No. 1 / EPP - FOR OWNER REVIEW



TEDF

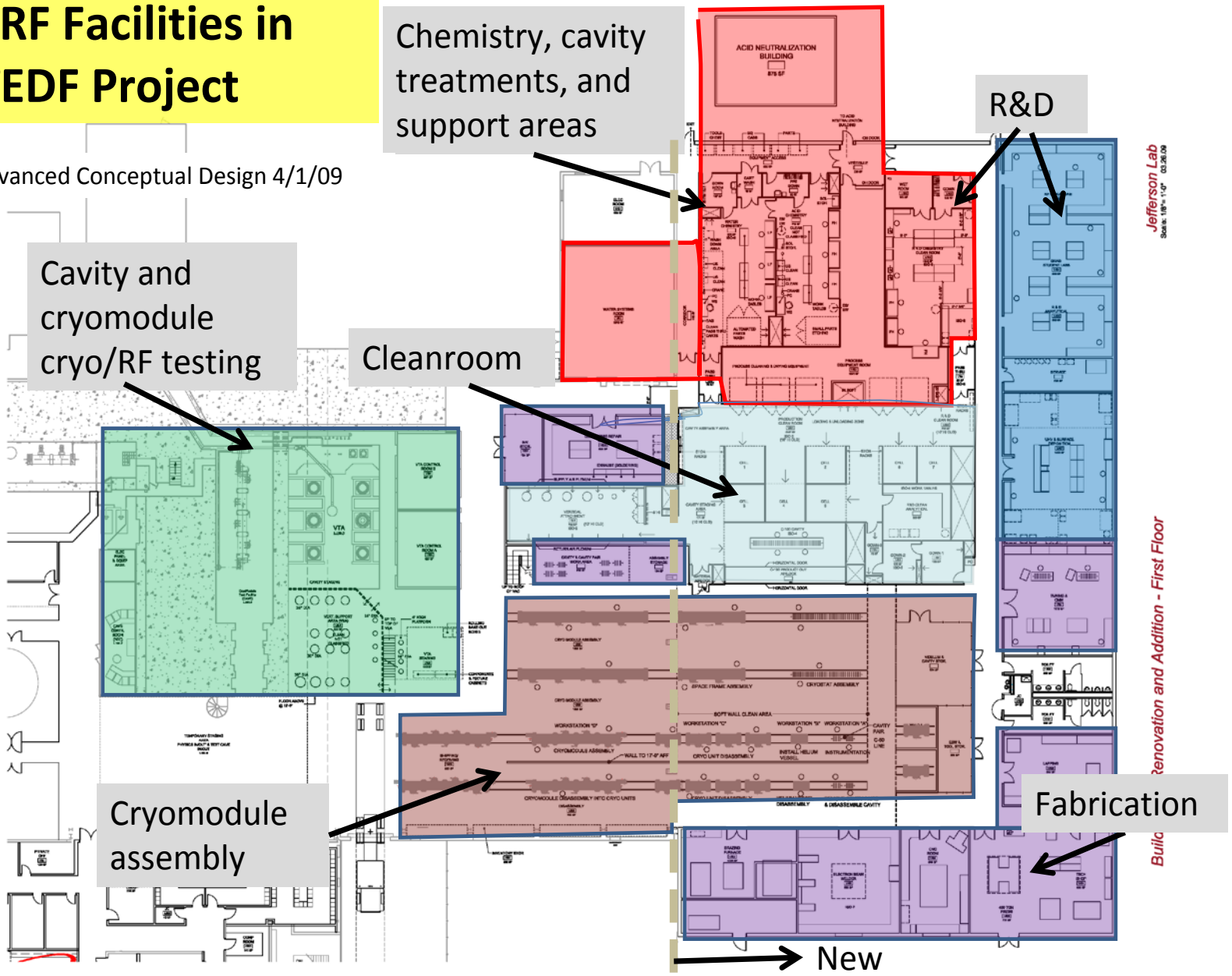
A major DOE infrastructure upgrade at JLab

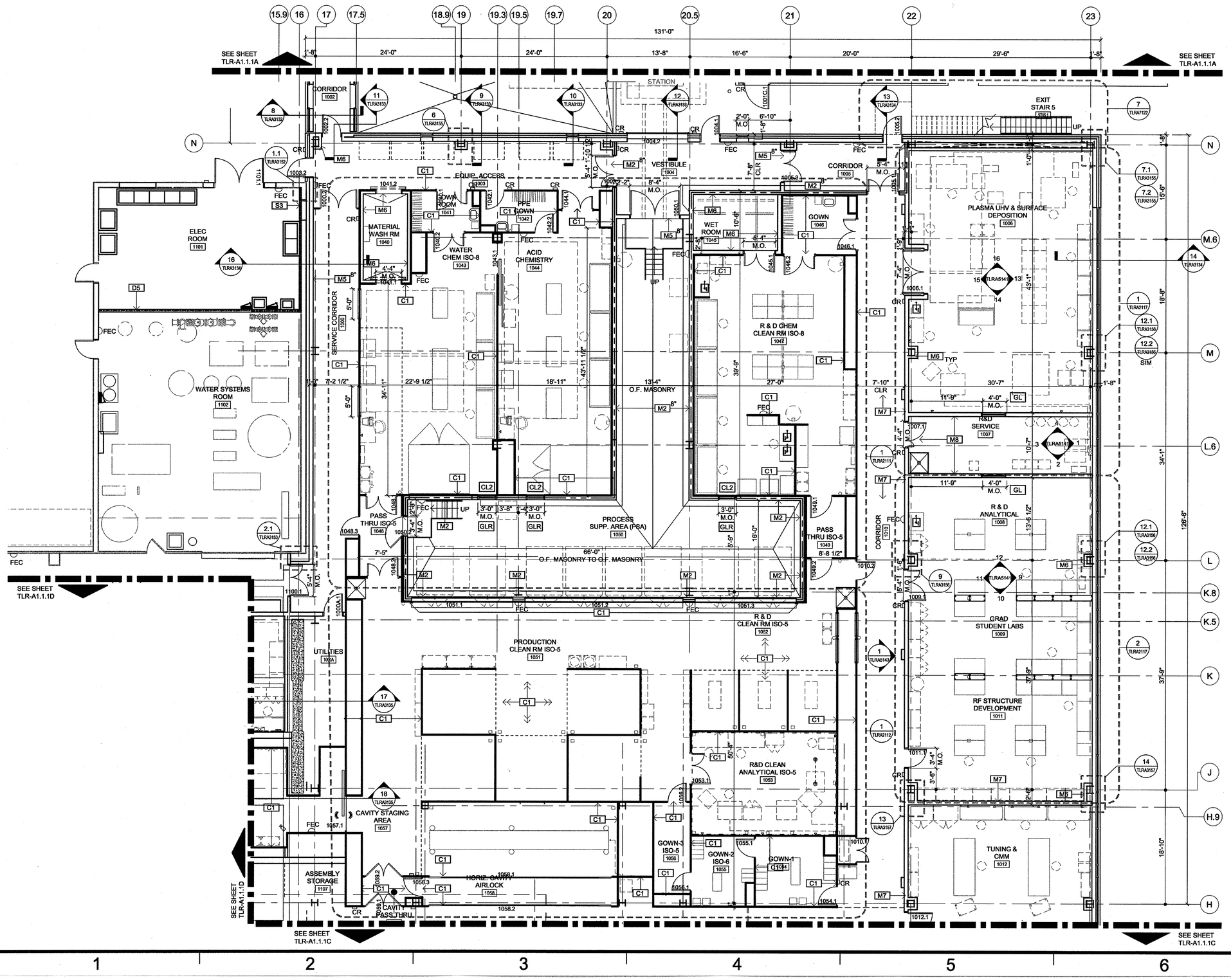
- New home for Engineering Division
- New home for Physics Div. detector development
- All new technical work areas for SRF
  - Restructured and upgraded -
    - Fabrication, chem, clean, and assembly facilities
- Full renovation of the Test Lab to LEED Gold standards

JEFFERSON LAB 2014

SRF Facilities in TEDF Project

Advanced Conceptual Design 4/1/09





EWING COLE

Federal Reserve Bank Building
100 North 6th Street
Philadelphia, PA 19106-1590
Tel: 215-923-2020 Fax: 215-574-0952

PLAN SYMBOLS KEY:

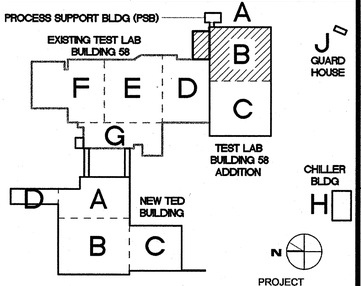
- EXISTING DOORS / NEW DOORS / DOOR NUMBER / FRAME TYPE FOR GLAZED OPNGS — SEE DOOR AND FRAME DRAWING A4.0.4.1 & A4.0.4.2 AND DOOR SCHEDULES FOR MORE INFORMATION
- PARTITION TYPE / FURRING TYPE — SEE PARTITION KEY ON DRAWING A4.0.1.1 FOR MORE INFORMATION

DIMENSION STANDARD:
- DIMENSION TO FACE OF FINISH
- DIMENSION TO CENTERLINE

GENERAL NOTES:
1. ALIGN ALL NEW PARTITIONS EDGE TO EDGE OF EXISTING PARTITIONS TO REMAIN.
2. ALL INTERIOR WALL PARTITIONS ARE NON-RATED 8" MASONRY WITH GROUTED CORES. UNO.

M7 PARTITIONS ARE 14'-8" IN HEIGHT

M8 PARTITIONS ARE 22'-0" IN HEIGHT



TECHNICAL ENGINEERING & DEVELOPMENT FACILITY

(TEDF)

12000 JEFFERSON AVENUE, NEWPORT NEWS, VIRGINIA 23606

REV	ZONE	DESCRIPTION	APPR.	DATE
		ISSUE NO. 2 - OWNER REVIEW		02/26/10

REVISIONS

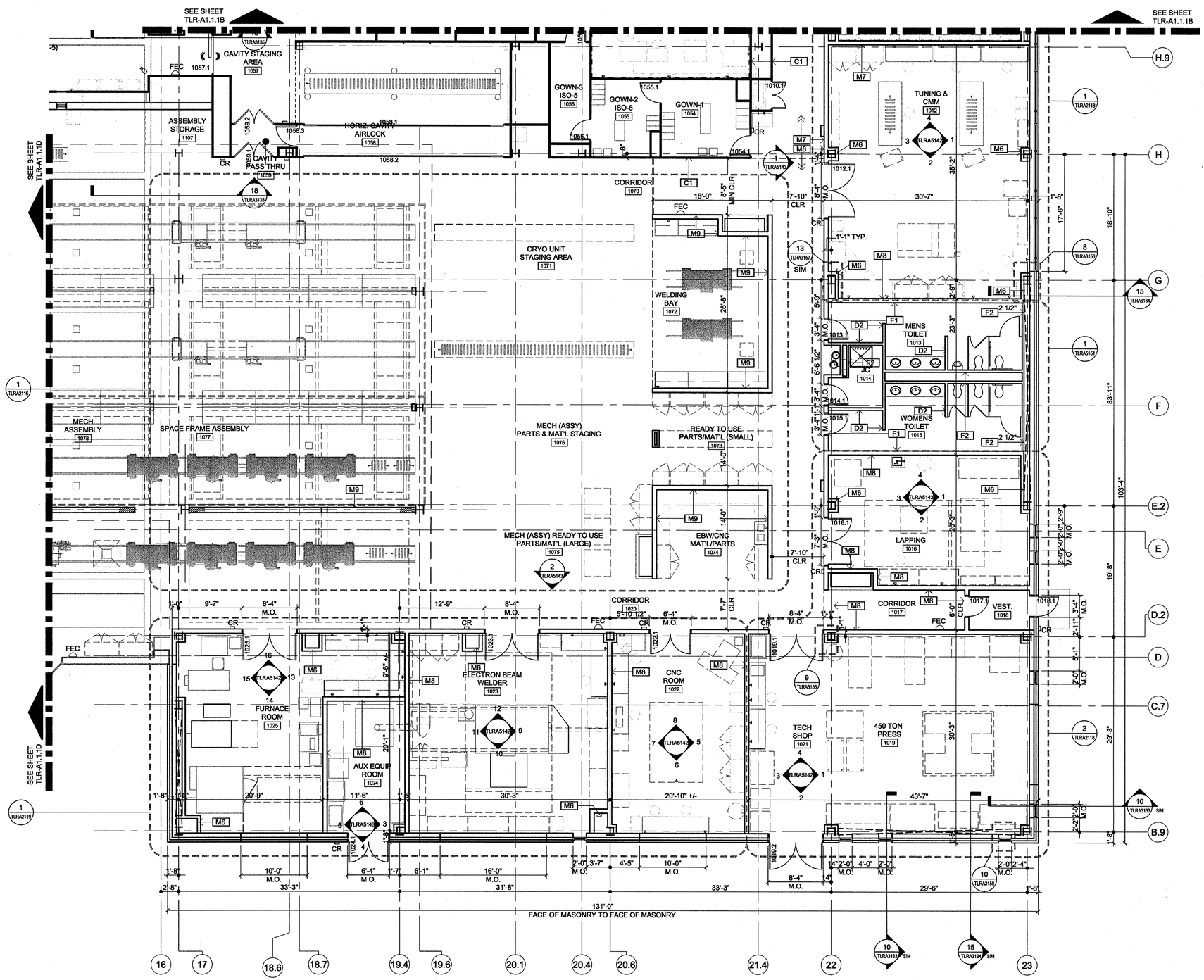
FACILITY USERS		FACILITIES & LOGISTICS	
APPROVED –	DATE –	DESIGNER –	DATE –
APPROVED –	–	DRAWN –	–
APPROVED –	–	CHECKED –	–
APPROVED –	–	APPROVED –	–

Jefferson Lab

TITLE:

TEST LAB ADDITION - BUILDING 58
FIRST FLOOR - SEGMENT B

SCALE	DRAWING NUMBER	SHEET	REV
1/8" = 1'-0"	–	TLR-A1.1.1B	–



NOTE: ALL INTERIOR WALL PARTITIONS ARE NON-RATED 8" MASONRY WITH GROUTED CORES. UNO.

EWING COLE

Federal Reserve Bank Building
100 North 6th Street
Philadelphia, PA 19106-1590
Tel: 215-923-2020 Fax: 215-574-0952

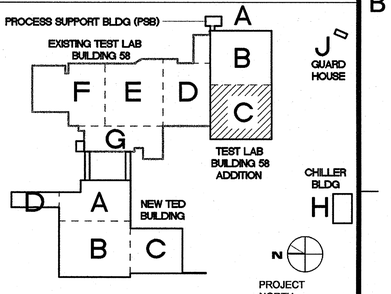
PLAN SYMBOLS KEY:

- EXISTING DOORS / NEW DOORS DOOR NUMBER / FRAME TYPE FOR GLAZED OPNGS — SEE DOOR AND FRAME DRAWING A4.0.4.1 & A4.0.4.2 AND DOOR SCHEDULES FOR MORE INFORMATION
- PARTITION TYPE / FURRING TYPE — SEE PARTITION KEY ON DRAWING A4.0.1.1 FOR MORE INFORMATION

DIMENSION STANDARD:
- DIMENSION TO FACE OF FINISH
- DIMENSION TO CENTERLINE

GENERAL NOTES:
1. ALIGN ALL NEW PARTITIONS EDGE TO EDGE OF EXISTING PARTITIONS TO REMAIN.

M7 PARTITIONS ARE 14'-8" IN HEIGHT
M8 PARTITIONS ARE 22'-0" IN HEIGHT
M9 PARTITIONS ARE 12'-0" IN HEIGHT



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–			

Jefferson Lab

TITLE:

TEST LAB ADDITION - BUILDING 58 FIRST FLOOR - SEGMENT C

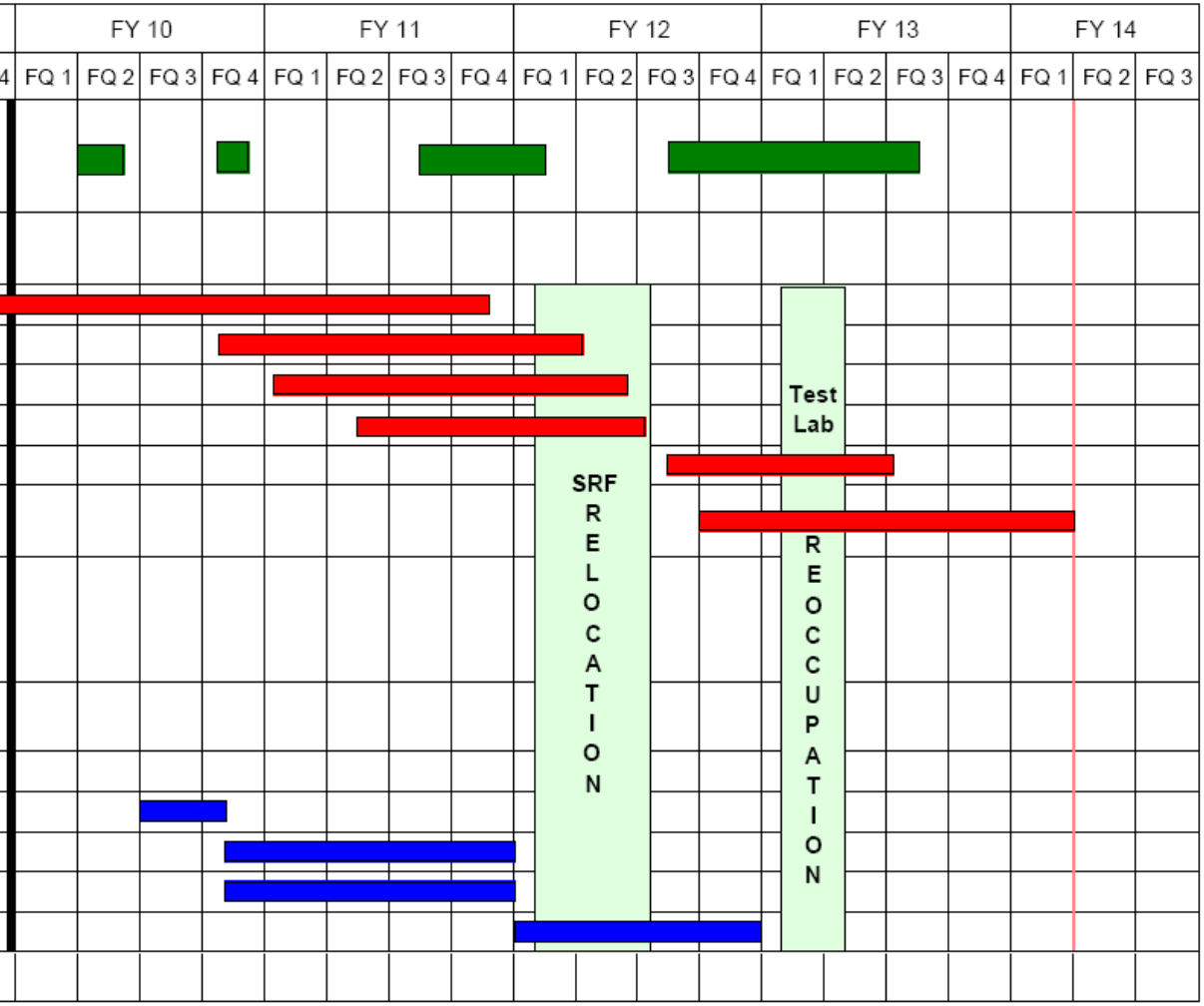
SCALE	DRAWING NUMBER	SHEET	REV
1/8" = 1'-0"	–	TLR-A1.1.1C	–

TEDF

- CD-3b is in hand
- Early site work has begun
- Reviewed 100% A/E drawing package last week
- General contractor/ construction manager is on site
  - Beginning disruption avoidance planning
  - Managing the interaction between projects will be very interesting
- Construction begins this summer

12 GeV and TEDF Schedules

Activity Name	Start Date	Finish Date
Accelerator Down Periods...	1/1/10 7/23/10 5/16/11 5/15/12	3/5/10 9/3/10 11/15/11 5/15/13
12 GeV Cryomodule Schedule		
1.3.1.1 Procurements	1/2/09	8/23/11
1.3.1.2 Cavity String Assembly	7/26/10	1/9/12
1.3.1.3 Cryomodule Assembly	10/14/10	3/13/12
1.3.1.4 Cryomodules Acceptance Test	2/16/11	4/9/12
1.3.1.5 Cryomodule Installation & Test	5/14/12	4/10/13
JLAMP Cyromodule Production	7/2/12	12/31/13
TEDF Schedule		
Early Start/Finish		
6.3.1.1 Civil/Site & Early Procurements	3/31/10	8/3/10
6.3.1.2 TED Building Construction	8/4/10	9/30/11
6.3.1.3 TL Addition Construction	8/4/10	9/30/11
6.3.1.4 TL Renovation	10/3/11	9/28/12



Summary

- The 12 GeV Upgrade provides exciting scientific opportunities
- TEDF Project promises new state-of-the-art SRF facilities for other national projects
- Construction is well underway of the equipment needed to exploit those opportunities
  - Most major contracts are awarded
  - Buildings are being built
  - Components are arriving
- There's a lot of work yet to do but we're on track to get it done.

It's an exciting time at Jlab!