The energy upgrade to 12 GeV at Jefferson Lab

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Jefferson Lab
Thomas Jefferson National Accelerator Facility

Outline

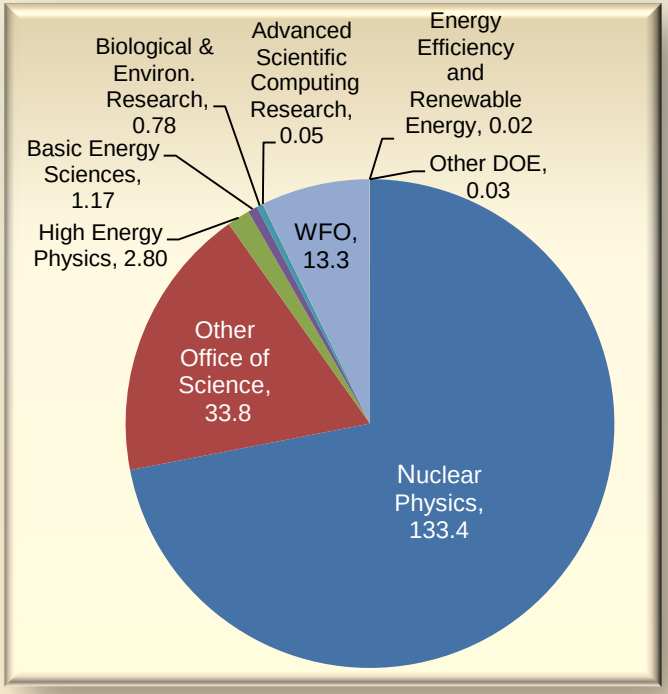
- Introduction to **JLAB** and the **12 GeV Upgrade**
- **Timeline** and present **status**

- **C100 cryomodule**: design, production, performance
- **Magnet** rework program
- **Cryogenics**

- **JLAB future plans**:
  - 12 GeV commissioning and physics running
  - Electron-ion Collider

Jefferson Lab At-A-Glance

- **Created to build and Operate the Continuous Electron Beam Accelerator Facility (CEBAF), world-unique user facility for Nuclear Physics:**
  - Mission is to gain a deeper understanding of the structure of matter
    - Through advances in fundamental research in nuclear physics
      - Through advances in accelerator science and technology
  - In operation since 1995
  - 1,376 Active Users
  - 178 Completed Experiments to-date
  - Produces ~1/3 of US PhDs in Nuclear Physics (406 PhDs granted, 180 more in progress)
- **Managed for DOE by Jefferson Science Associates, LLC (JSA)**
- **Human Capital:**
  - 769 FTEs
  - 22 Joint faculty; 27 Post docs; 14 Undergraduate, 33 Graduate students
- **K-12 Science Education program serves as national model**
- **Site is 169 Acres, and includes:**
  - 83 SC Buildings & Trailers; 749K SF
  - Replacement Plant Value: $331M



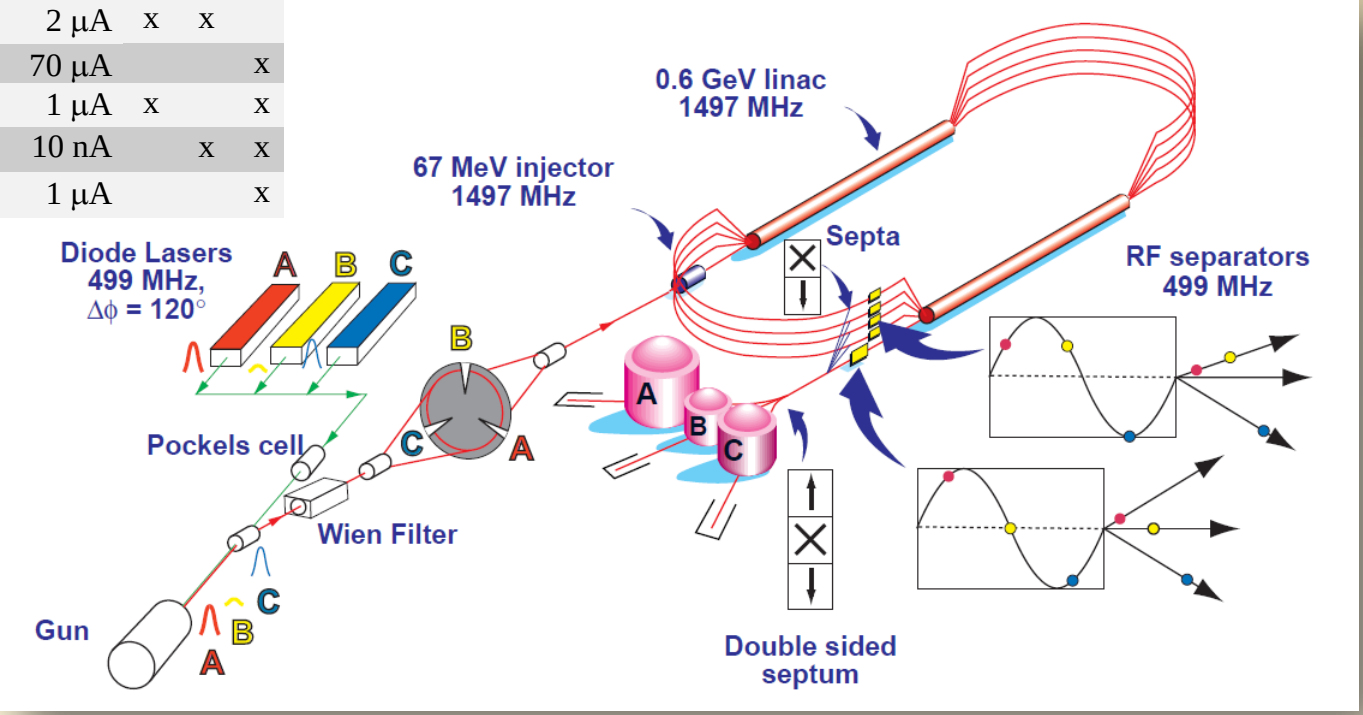
FY 2011:

Total Lab Operating Costs: $185M

Non-DOE Costs: $13M

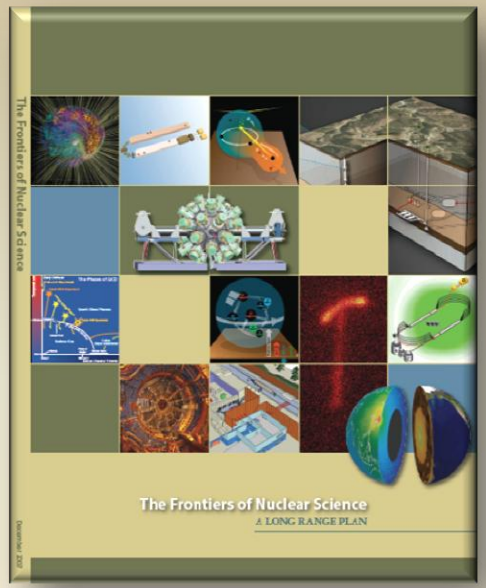
CEBAF overview

Polarimeter	I_{ave}	P_x	P_y	P_z
Injector Mott	2 μA	x	x	
Hall A Compton	70 μA			x
Hall A Moller	1 μA	x		x
Hall B Moller	10 nA		x	x
Hall C Moller	1 μA			x



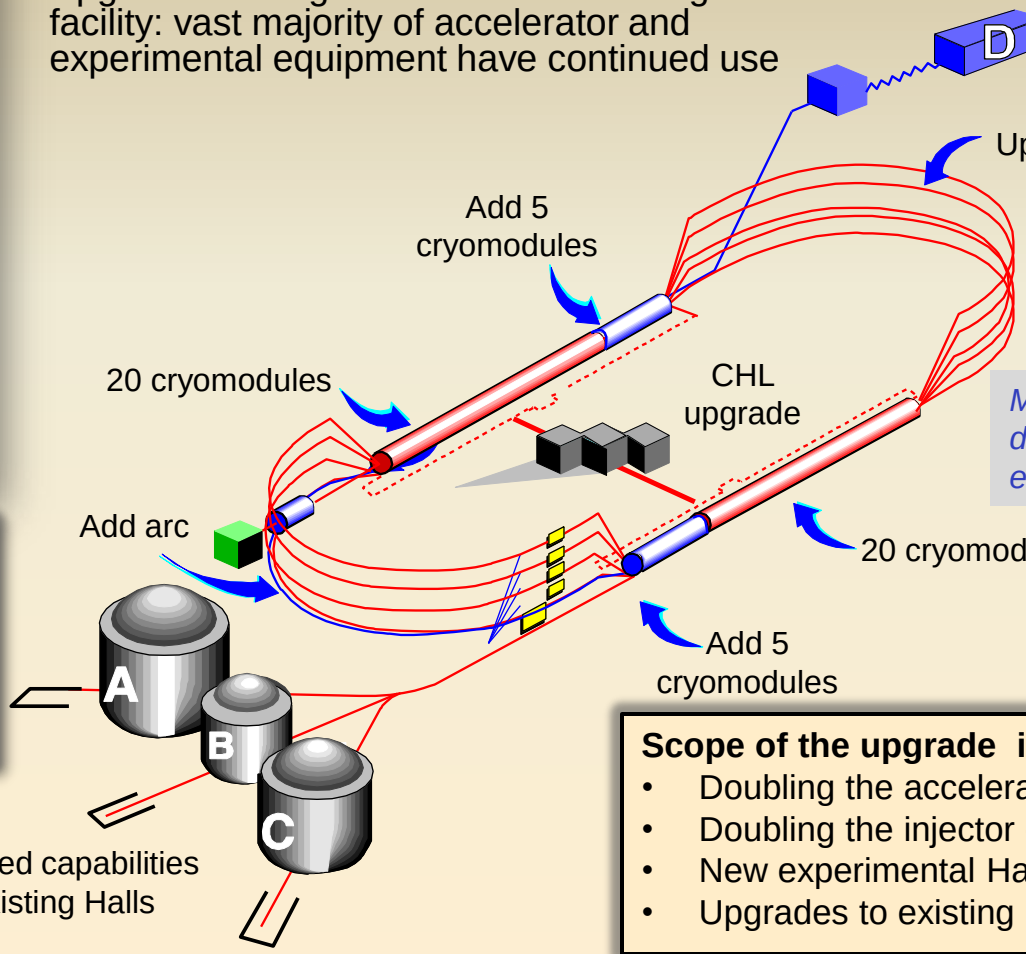
First large high-power CW recirculating e-linac based on SRF technology
In operations since **1995** → served ~1400 nuclear physics users
Capabilities: 5 passes, multiple energies, beam characteristics, polarization
3 Halls running simultaneously
Upgrade to 12 GeV: proposal late 1990's → approved and funded in 2004

The 12 GeV Upgrade



The completion of the 12 GeV Upgrade of CEBAF was ranked the highest priority in the 2007 NSAC Long Range Plan.

Upgrade is designed to build on existing facility: vast majority of accelerator and experimental equipment have continued use

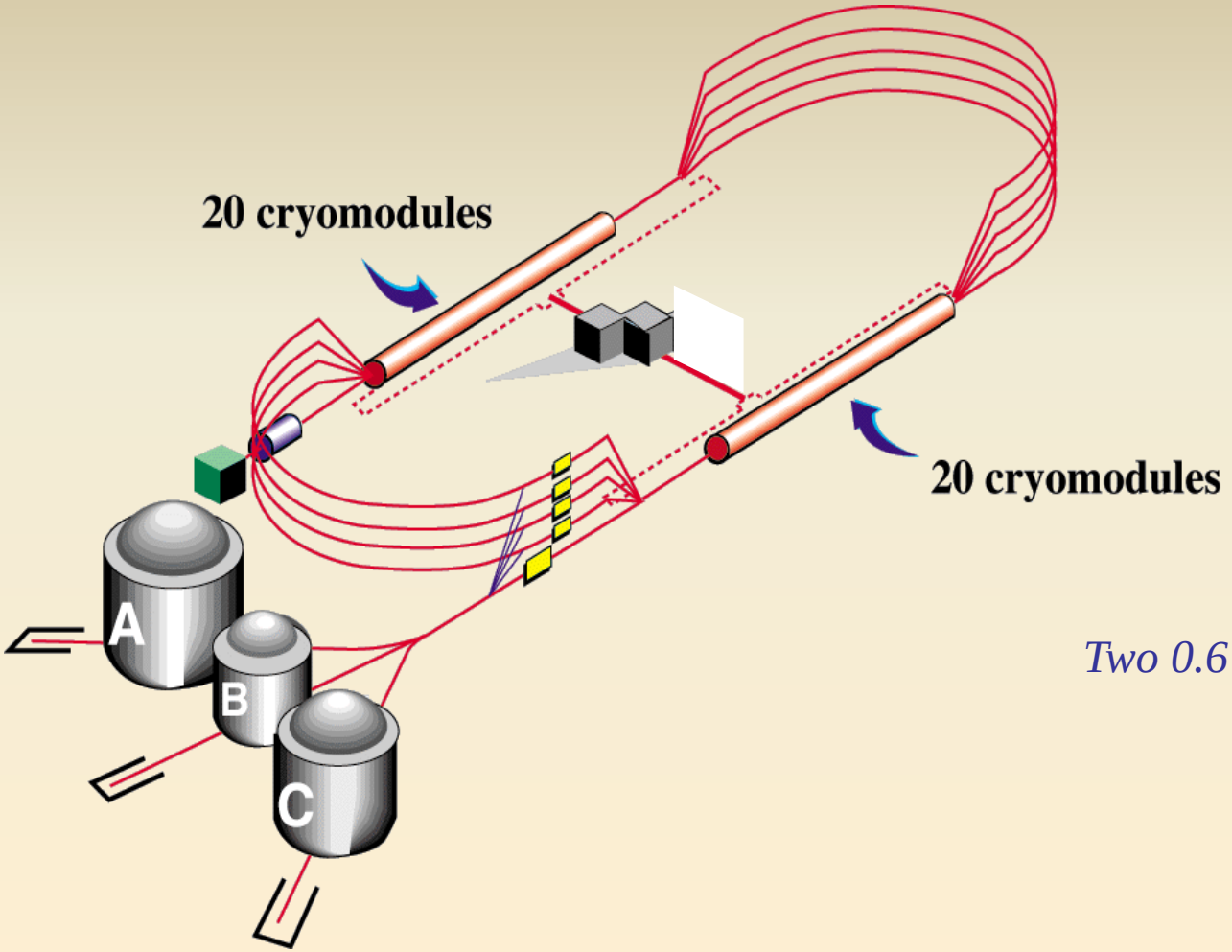


*Maintain capability to deliver lower pass beam energies: **2.2, 4.4, 6.6….***

Scope of the upgrade includes:

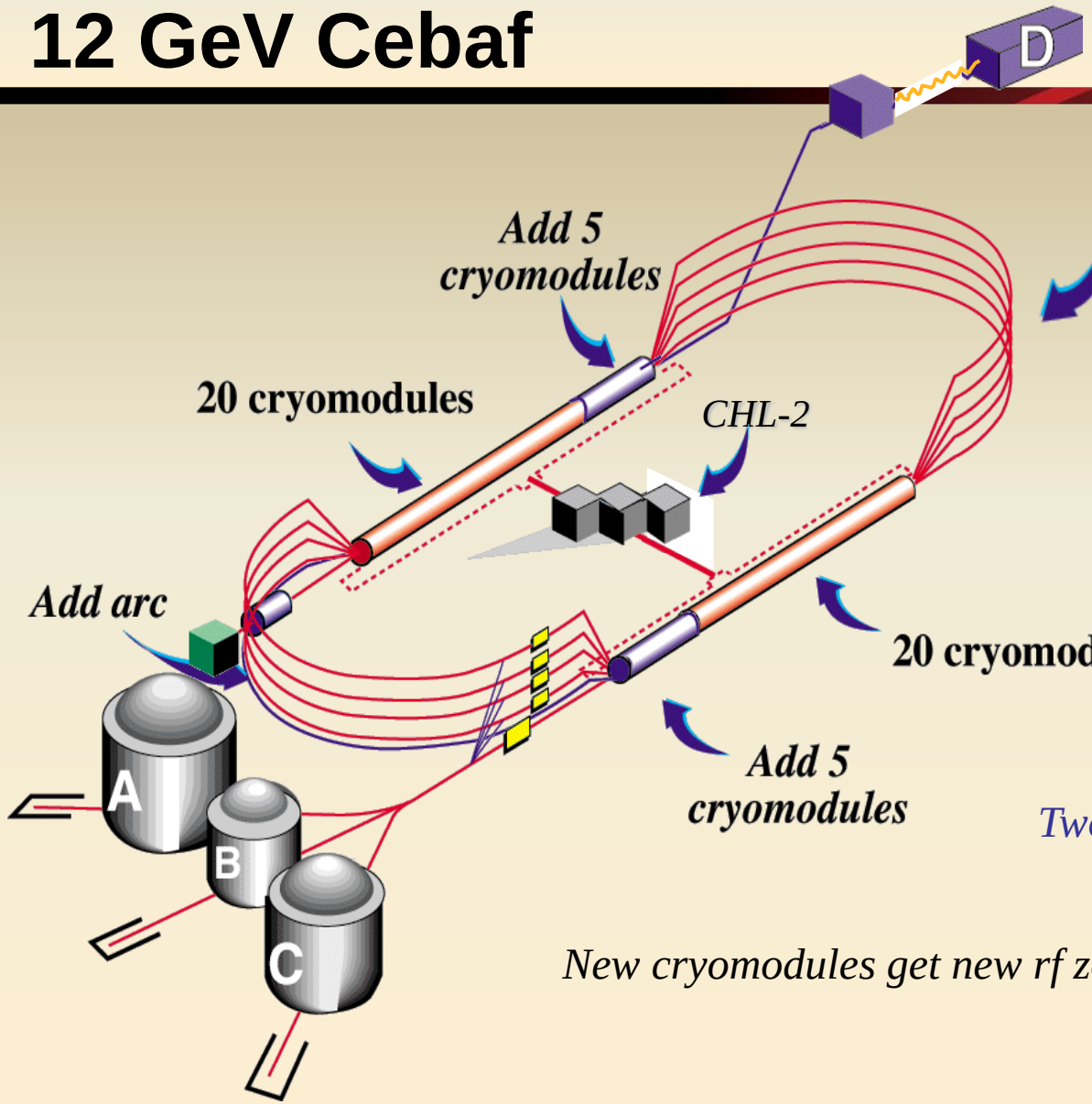
- Doubling the accelerator beam energy
- Doubling the injector energy
- New experimental Hall and beam-lines
- Upgrades to existing Experimental Halls

6 GeV CEBAF



Two 0.6 GV linacs

12 GeV Cebaf



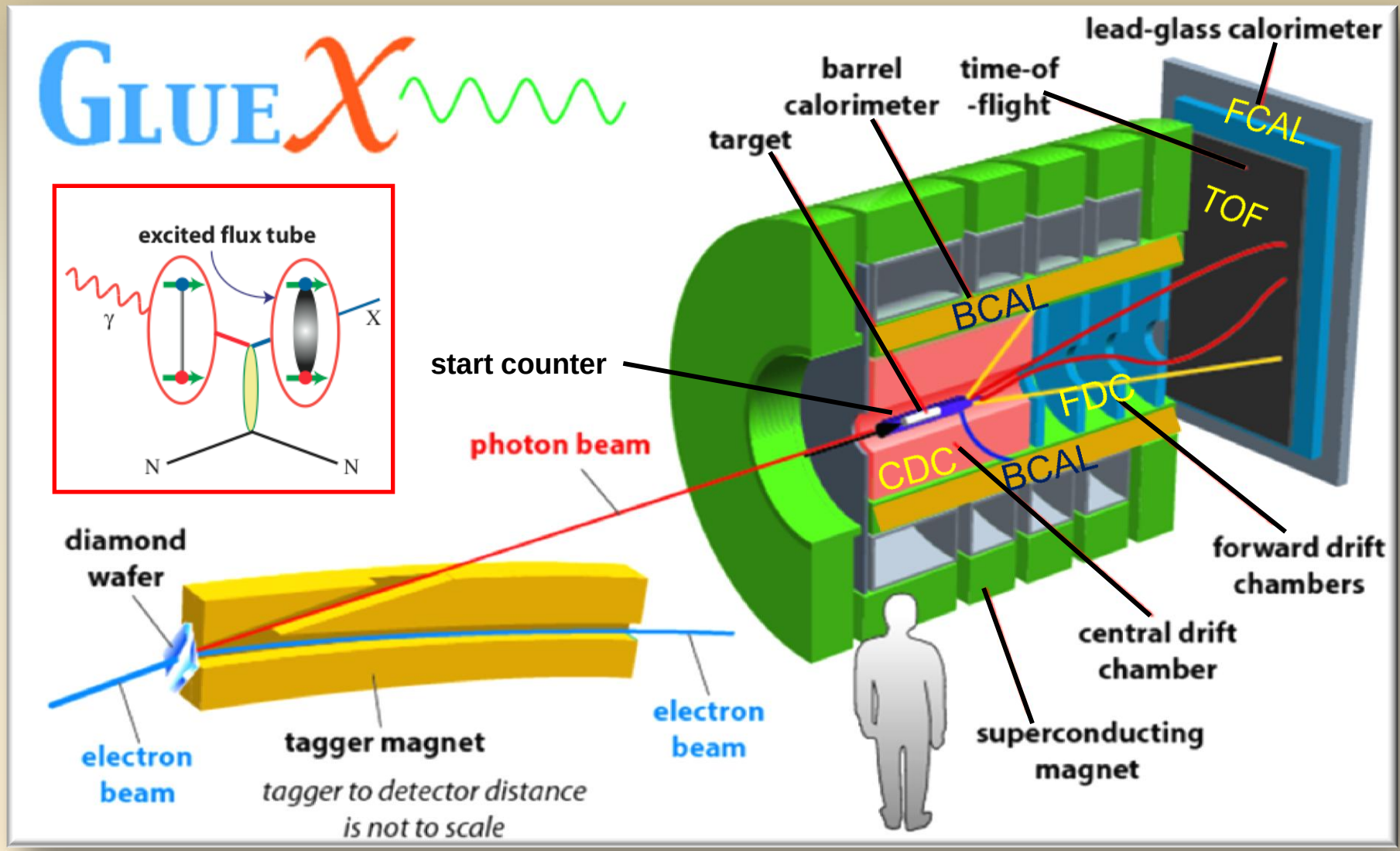
Two 1.1 GV linacs

New cryomodules get new rf zones

6 and 12 GeV CEBAF

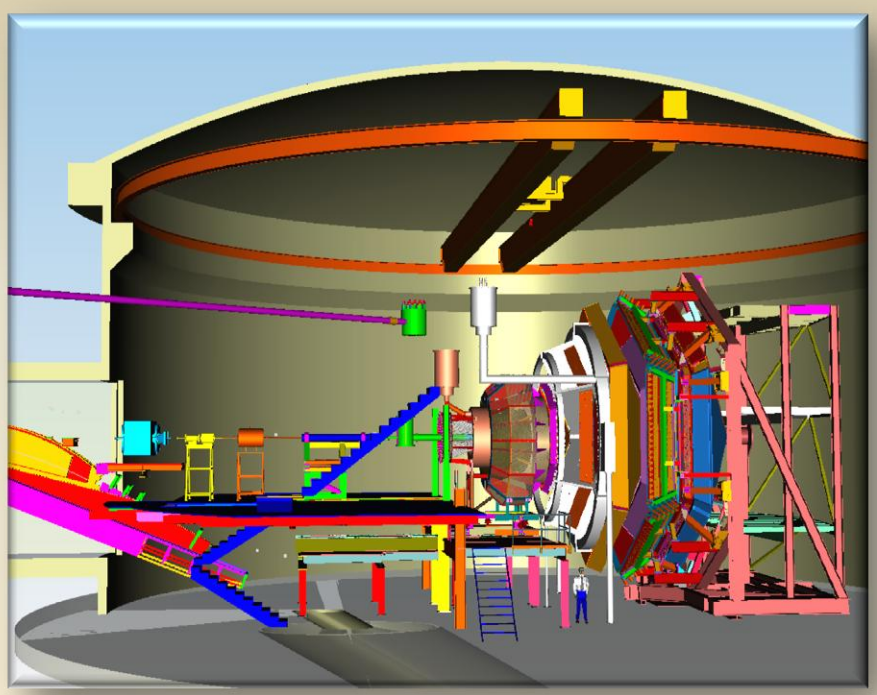
Parameter	Unit	6 GeV	12 GeV
Maximum energy to Halls A, B, C /D	GeV	6	12
Number of passes for Halls A, B, C / D		5	5 / 5.5
Maximum current to Halls A, C / B	μA	200 / 5	85 / 5
Emittance at max energy H / V	nm-rad	1 / 1	10 / 2
Energy spread at max energy	10^{-5}	2.5	50 at 11 GeV 500 at 12 GeV
Bunch length (rms)	ps	0.2	~1
Polarization	%	80	80

Hall D


GLUEX
excited flux tube
γ
X
N
N
lead-glass calorimeter
barrel calorimeter
time-of -flight
target
FCAL
TOF
BCAL
start counter
FDC
photon beam
CDC
BCAL
diamond wafer
forward drift chambers
central drift chamber
electron beam
tagger magnet
electron beam
superconducting magnet
tagger to detector distance is not to scale

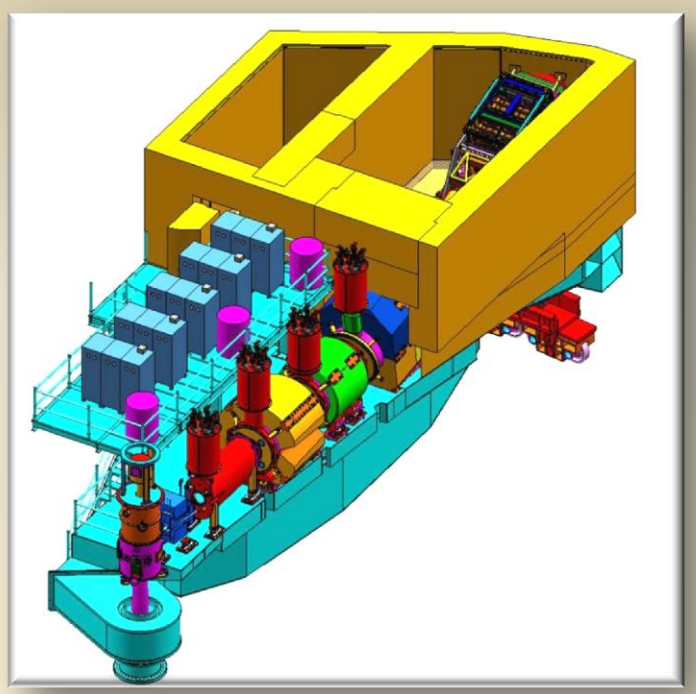
Halls B and C

Hall B
CLAS12 = CEBAF Large Acceptance Spectrometer



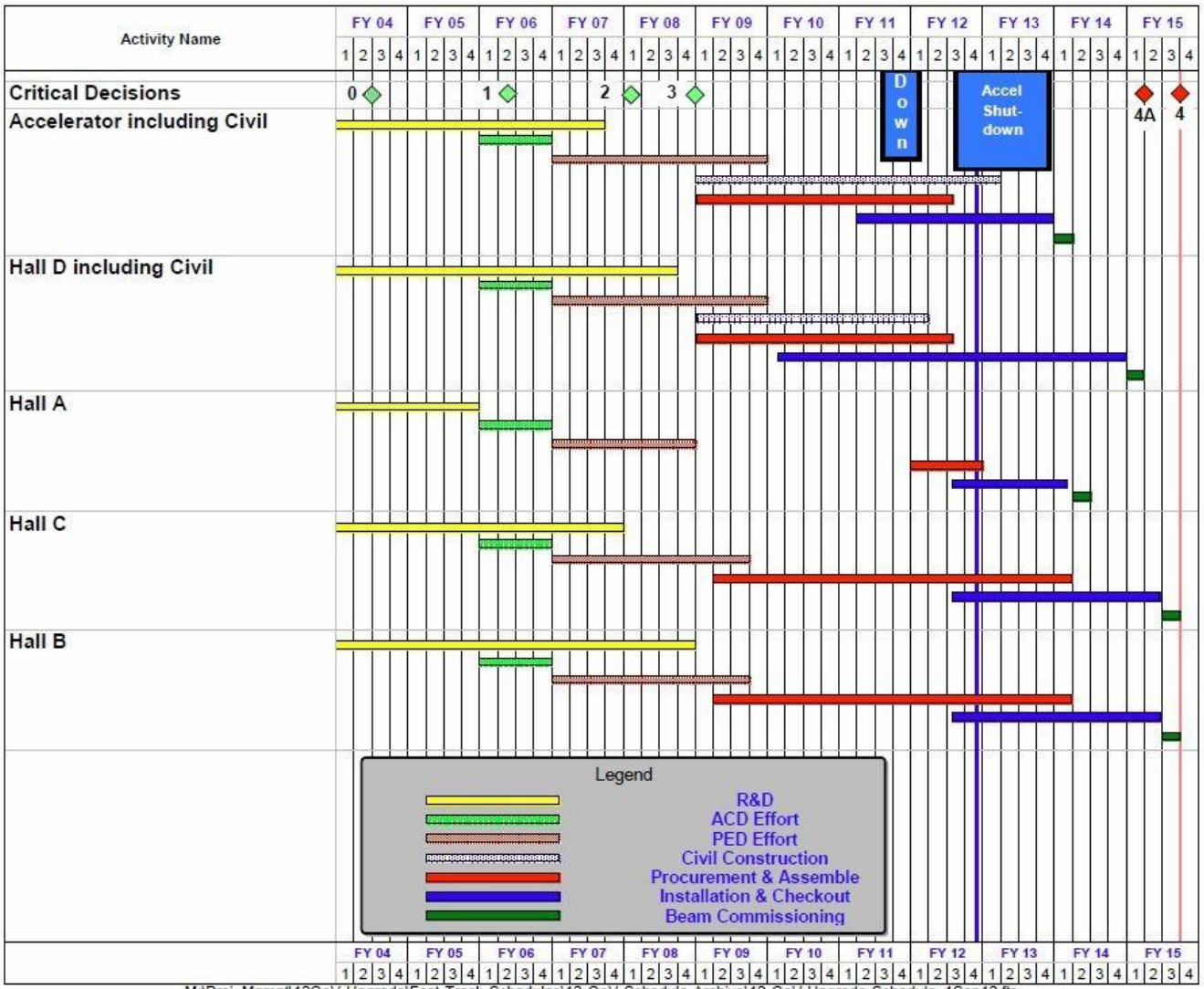
- **Key Features:**
  - 1 torus & 1 solenoid magnet
  - new detectors: Cerenkovs, calorimeters, drift chambers, silicon vertex tracker
  - -- re-use some existing detectors
  - hermetic device, low beam current, high luminosity

Hall C
SHMS = "Super High Momentum Spectrometer"



- **Key Features:**
  - 3 quadrupole & 1 dipole & 1 horizontal bend magnet
  - new 6 element detector package
  - complementary to existing spectrometer (HMS)
  - rigid support structure
  - well-shielded detector enclosure

12 GeV Upgrade Schedule



FY12: reduction of $16M
FY13: Pres Request – no restoration

16-month installation
May 2012 - Sept 2013

Hall A commissioning start
Feb 2014

Hall D commissioning start
Oct 2014

Halls B & C commissioning
Apr 2015

Project Completion June 2015

12 GeV Upgrade organization and status

12 GeV Project, with project management structure and practices

Total Project Cost: **310 M$** (Injector Upgrade off project)

Project **68% complete**, 79% obligated

Upgrade to 12GeV planned over **2 operations shutdowns**:

6 months (May-Nov 2011) and 16 months (May 2012 – Sep 2013)

→ Run last 6 GeV physics run (Nov 2011-May 2012)

→ Test in operations critical upgrade components (C100 cryo-module and reworked and new magnets)

Vast scope of work ongoing concurrently at JLAB during shut-downs (12 GeV upgrade, running of FEL, construction of a 30 M$ Facility, 2 buildings to integrate engineering capabilities and doubling the SRF infrastructures **[Reece, MOPB061]**

→ **Lab-wide coordination of shutdown activities**

6- month shutdown a success, exceeded scope of work in magnet upgrade

The C100 cryomodule

- Cavity production
- Cryomodule production
- Cryomodule test and performance

C100 SRF cavities

C100: string of **8 7-cell cavities**, **1497 MHz**, produced by RI (Research Instruments)

80 cavities + 8 pre-production tested and assembled at JLAB

18-step qualification process

EP derived from **ILC R&D**

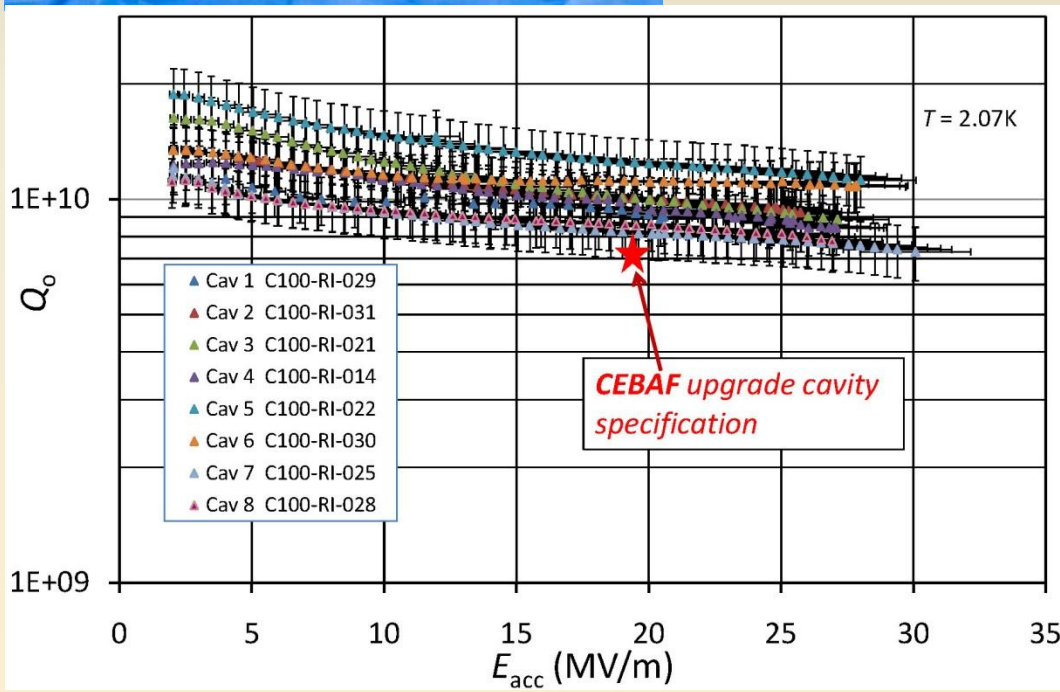
The cavity tests are performed at the Vertical Test Area (VTA)

Design gradient: **19.2 MV/m** average

Average heat/cavity: **29 W**

Operational limit: **25 MV/m**

(limited by the klystron RF power and possibly field emission)



Q is BCS-limited

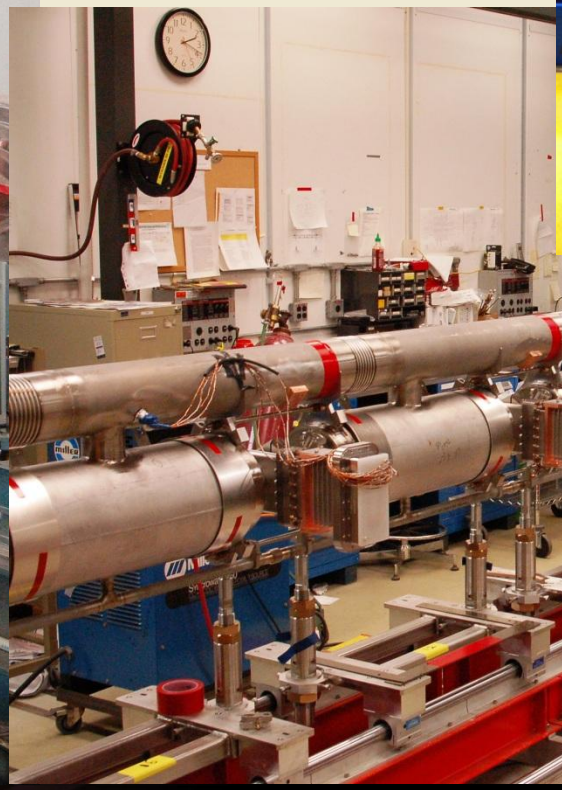
Cryomodule design and production

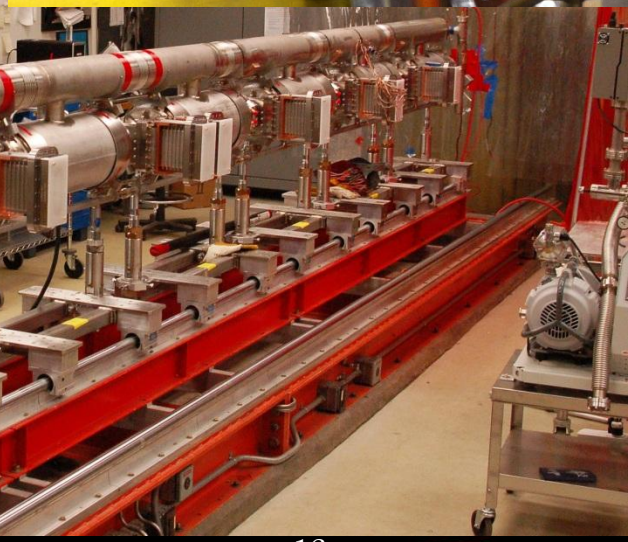
The design of the **C100** is an evolution from the **C20** CEBAF cryomodule Experience from the **C50 program** (*reduce field emission* and *raised gradient from 5.5 MV/m to 12.5 MV/m* for 10 of the weakest C20 cryomodules.

Output needed: **98 MV**, designed for **108 MV**

Primary components procured, assembly and qualification at JLAB

C-100 Cryomodule Assembly





Cryomodule tests and performance

Acceptance test (in CMTF, CryoModule Test Facility): every cavity is tested and **tuned** to 1497 MHz, **HOM** are characterized and **maximum gradient**, **field emission** and **Q_o** measured together with **microphonics** and static **heat loads**

Tunnel test: subset of acceptance tests **[M. Drury et al. MOPB030]**

Microphonics

Peak detuning budget is **35 Hz**

Measurements within specs but higher than expected (no stiffening rings in cavities?)

Modification of tuners from cryomodule 5 resulted in **42% decrease in microphonics** average peak

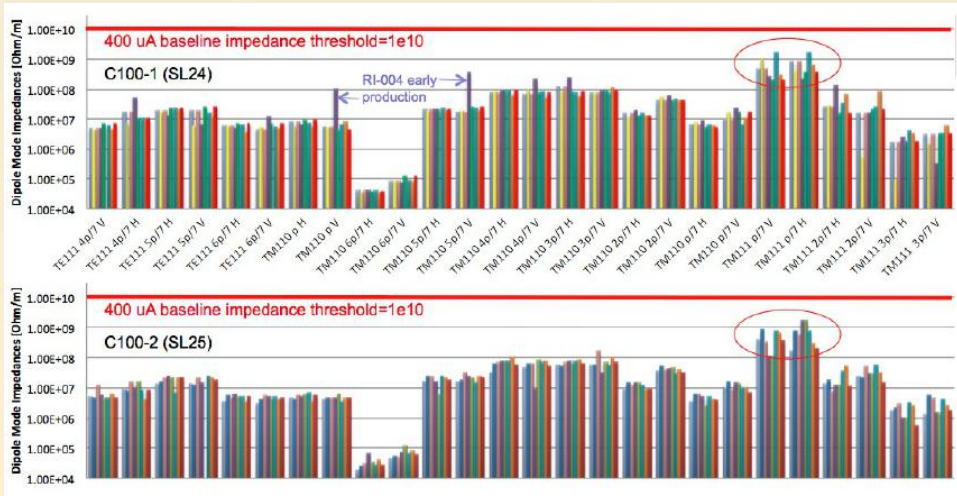
[K. Davis et al. MOPB031]

HOM measuments

The predicted **BBU** threshold is **26 mA** (nominal **465 μA** maximum beam loading)

Dedicated beam test at ½ energy and a special optics aimed at lowering threshold, BBU not detected.

Survey of HOM(TE111,TM110 and TM111) via BTF measurements



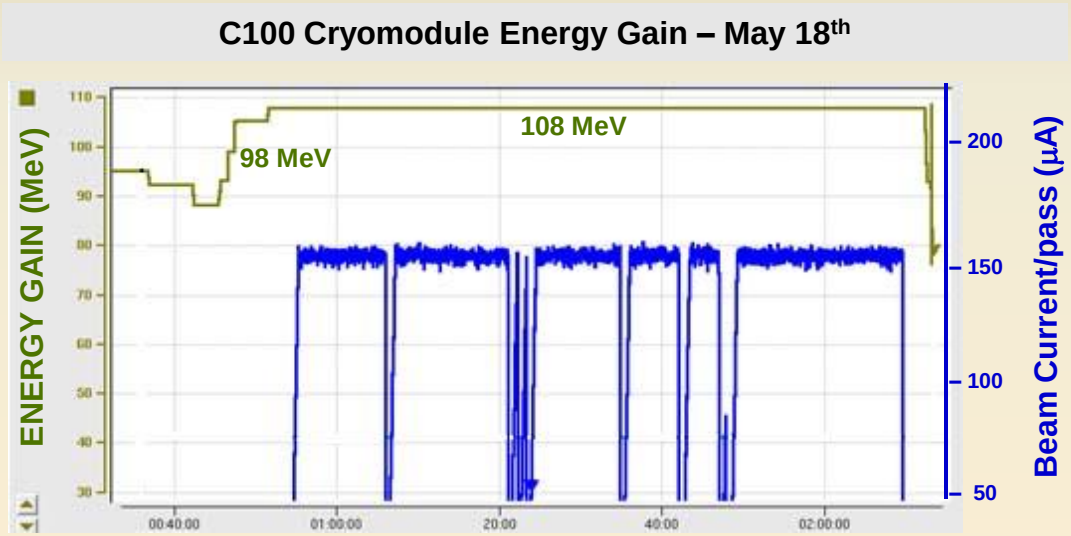
Cryomodule commissioning and operations

2 C100 installed during the 6 months shutdown

Commissioned and **in operations Nov 2011-May 2012**

Challenges: narrower bandwidth, higher gradient, coupling

Learning curve (LLRF, trip recovery, etc.)



C100 reached design energy gain (108 MeV) for the nominal 12 GeV current of 465 μA on May 17 2012.

Full validation of the C100 design.

Magnets for 12 GeV

Magnets in **existing arcs** (1-9) able to work saturated (low passes) or needed re-work (higher passes). **Add iron to turn C-magnets in H-magnets**

New **arc 10**, **spreaders and recombin**ers and **X-fer lines** need new magnets

Re-worked magnets, reinstalled in 2011, performed as predicted.

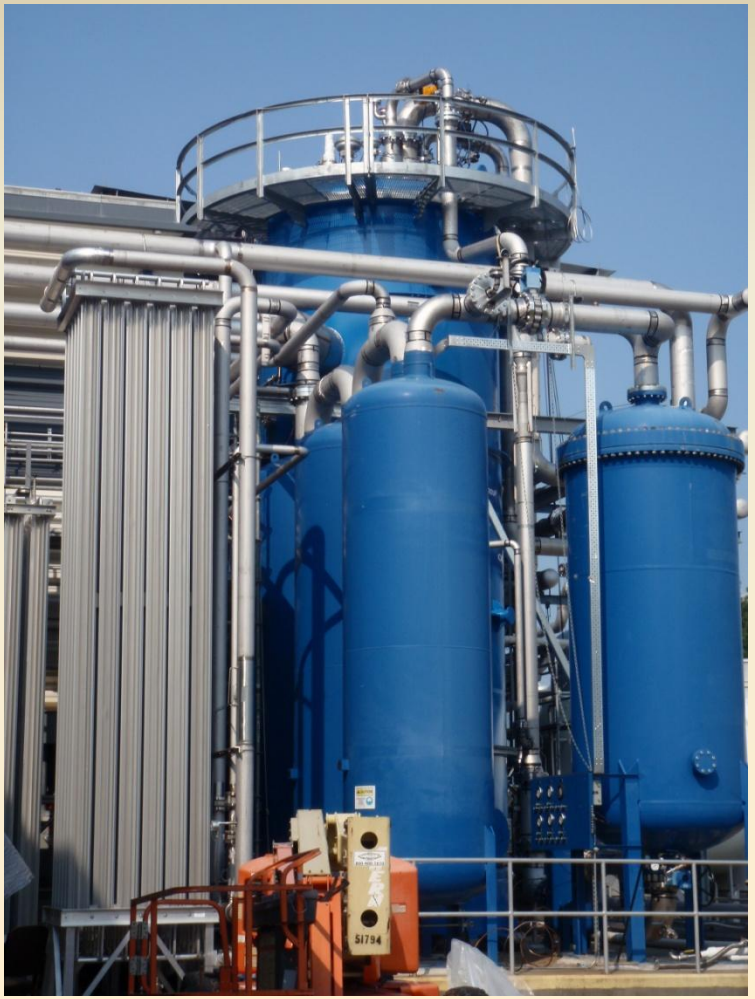
Cryogenic plant doubling

CHL Compressors are installed and are being commissioned.

Cryogenic plant doubling - 2

Installation of Cold Boxes nearing completion.

UPPER COLDBOX



LOWER COLDBOX

JLAB plans

Short (2012-2014)

- install and commission 12 GeV machine

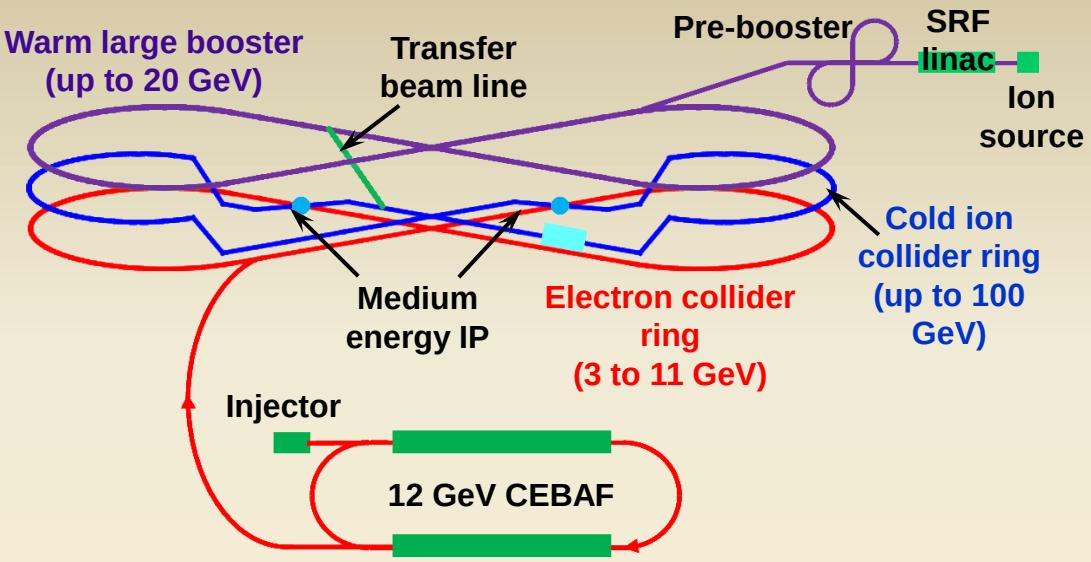
Medium (2015 – 2030)

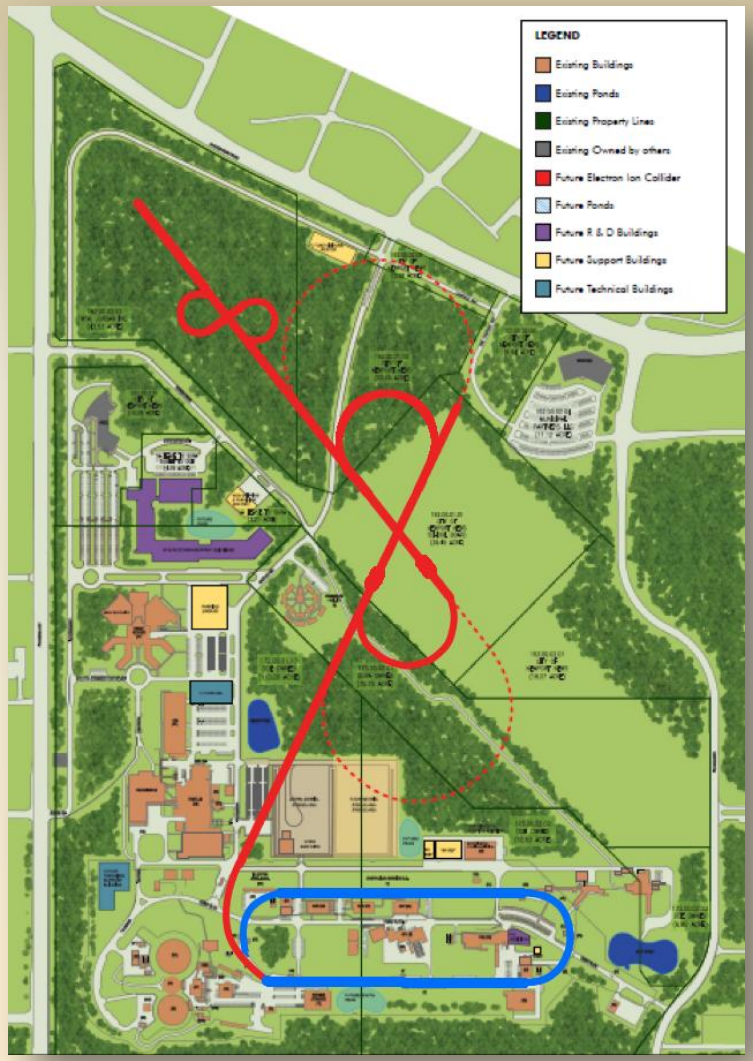
- Run 12 GeV physics program (50+ experiments approved)
- Exploit SRF core capabilities and new infrastructures →work for others
- Prepare EIC (Electron Ion Collider)

Long (2030+)

- “Bid for” and build a EIC at JLAB

Medium Energy EIC@JLab



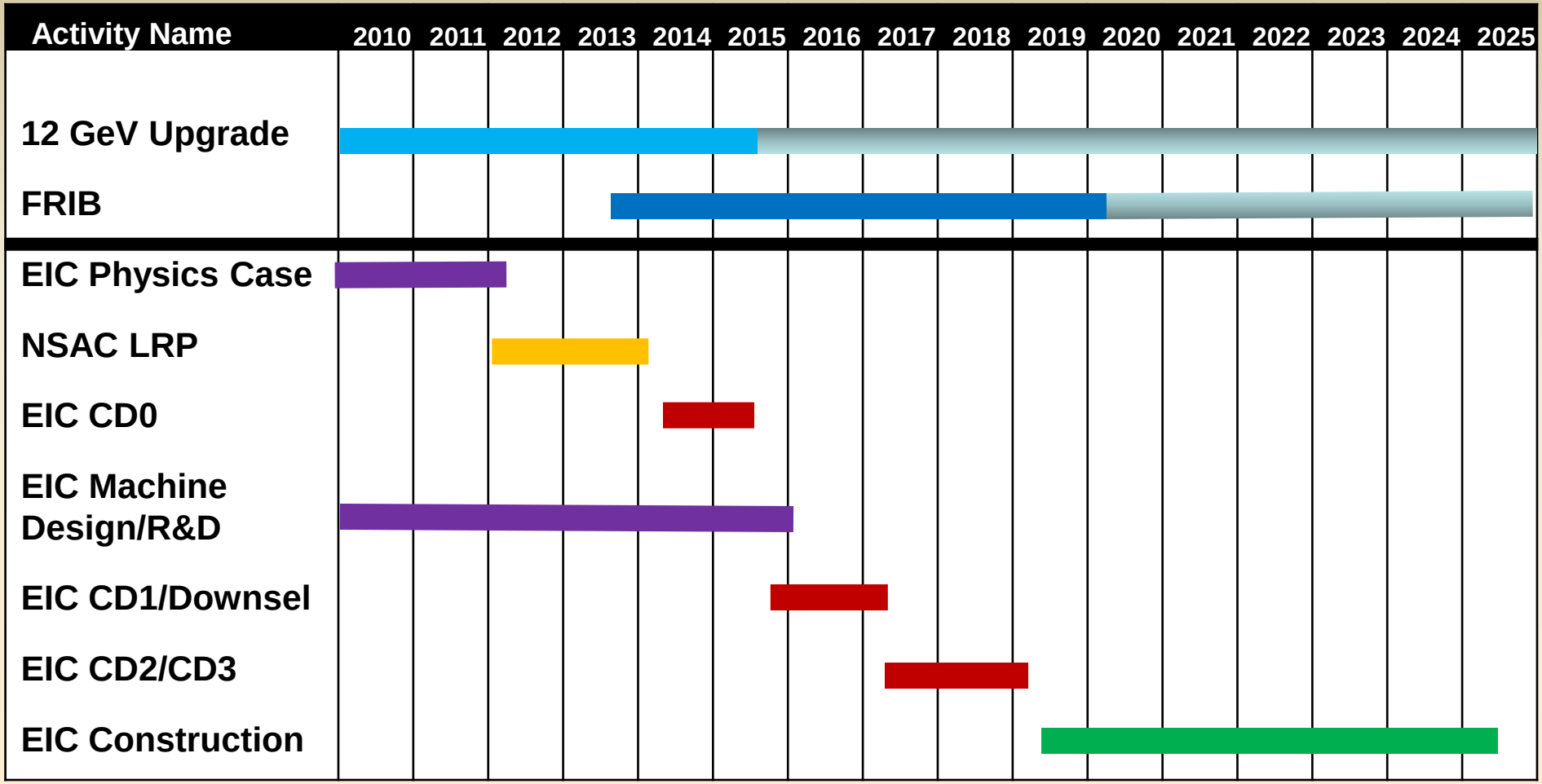


JLab Concept

- Initial configuration (MEIC):
  - 3-11 GeV on 20-100 GeV ep/eA collider
  - fully-polarized, longitudinal and transverse
  - luminosity: up to few x 10^{34} e-nucleons cm^{-2} s^{-1}
- Upgradable to higher energies (250 GeV protons)

Jefferson Lab Electro

- User Driven Physics Case
- Integrated Detector
- Cost Estimate in progress



Conclusions

- The 12 GeV Upgrade for CEBAF at JLAB is progressing well and the start of **commissioning** is planned for the fall of 2013.
- A robust program of **physics running** will follow.
- JLAB will complete a doubling of its SRF infrastructure in summer 2013 greatly enhancing its future **SRF R&D and production** capabilities.
- An **electron-ion collider** is the long-term strategic goal of the laboratory.

  The conceptual design for a MEIC at JLAB has been published in August 2012.