Jefferson Laboratory Overview

Fulvia Pilat

NP SBIR/STTR Exchange Meeting, Gaithersburg

October 1-2, 2012

Jefferson Lab

Thomas Jefferson National Accelerator Facility

Outline

- **Overview** of Jefferson Laboratory
- **Mission**
- **Status** and **plans**

- **Scientific and technical capabilities** (CEBAF, Upgrade, FEL, SRF (TEDF/TLA), Cryogenics, Detectors, Energy)
- **SBIR/STTR opportunities** at Jefferson Lab in the programmatic areas:

  Software and Data Management
  Electronics Design and Fabrication
  Accelerator Technology
  Instrumentation, Detection Systems and Techniques
  Nuclear Physics Isotope Science and Technology
- Past and present programs
- Future

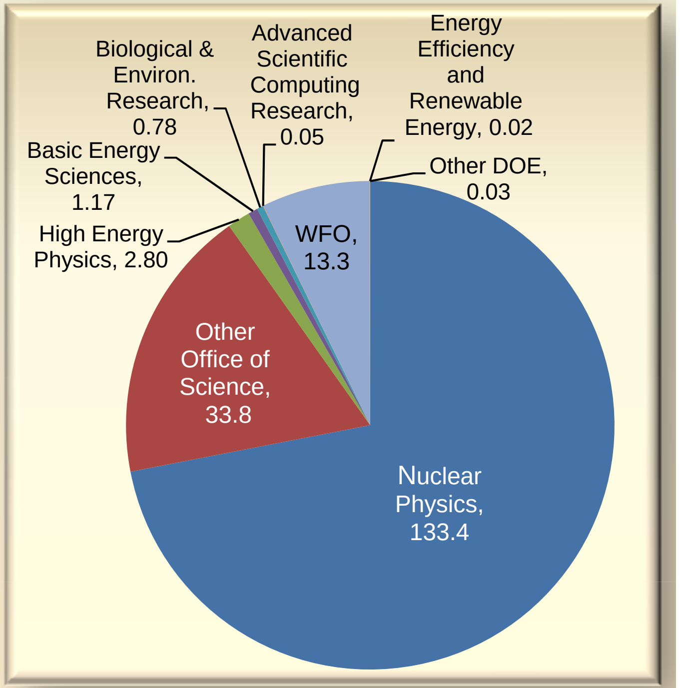
Jefferson Lab At-A-Glance

- **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

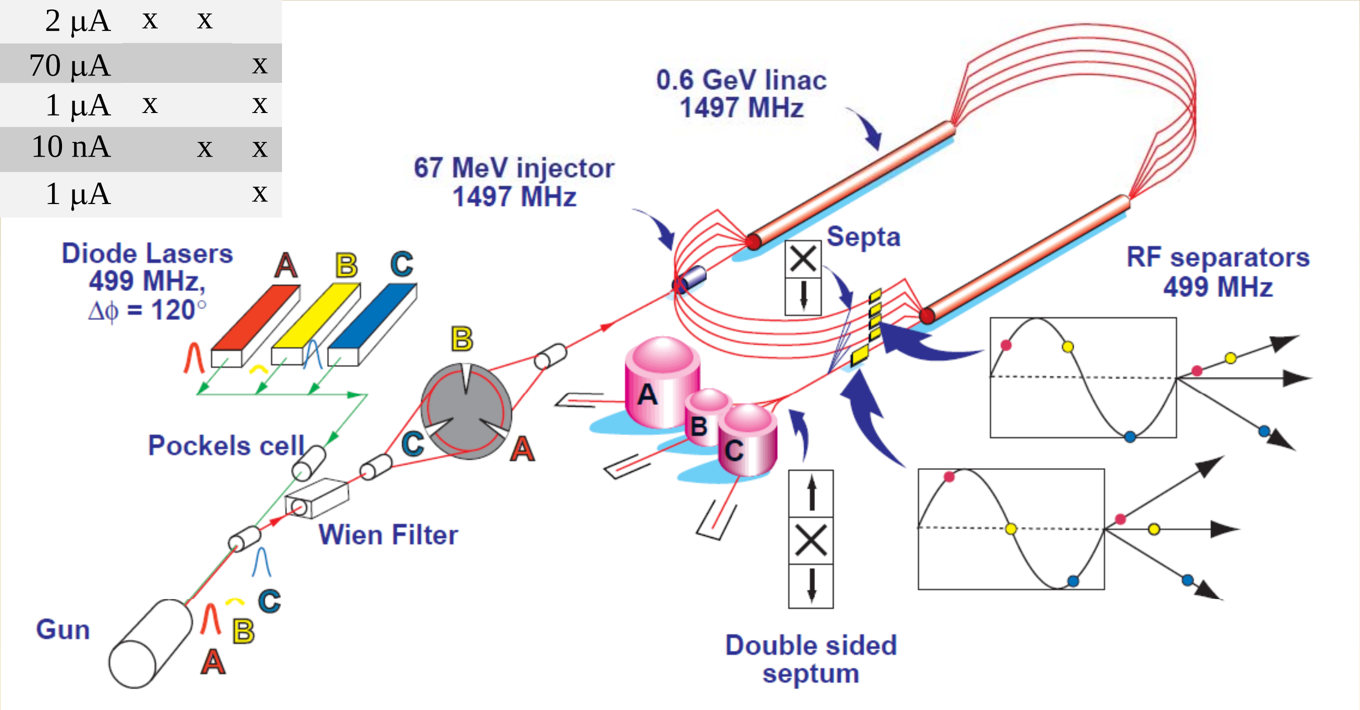


JLAB Mission

- Deliver discovery-caliber **research** by exploring the atomic nucleus and its fundamental constituents, including precise tests of their interactions
- **Apply** advanced particle accelerator, detector and other technologies to address challenges of modern society
- Advance knowledge of science and technology through **education** and **public outreach**, and
- Provide responsible and effective **stewardship** of resources

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

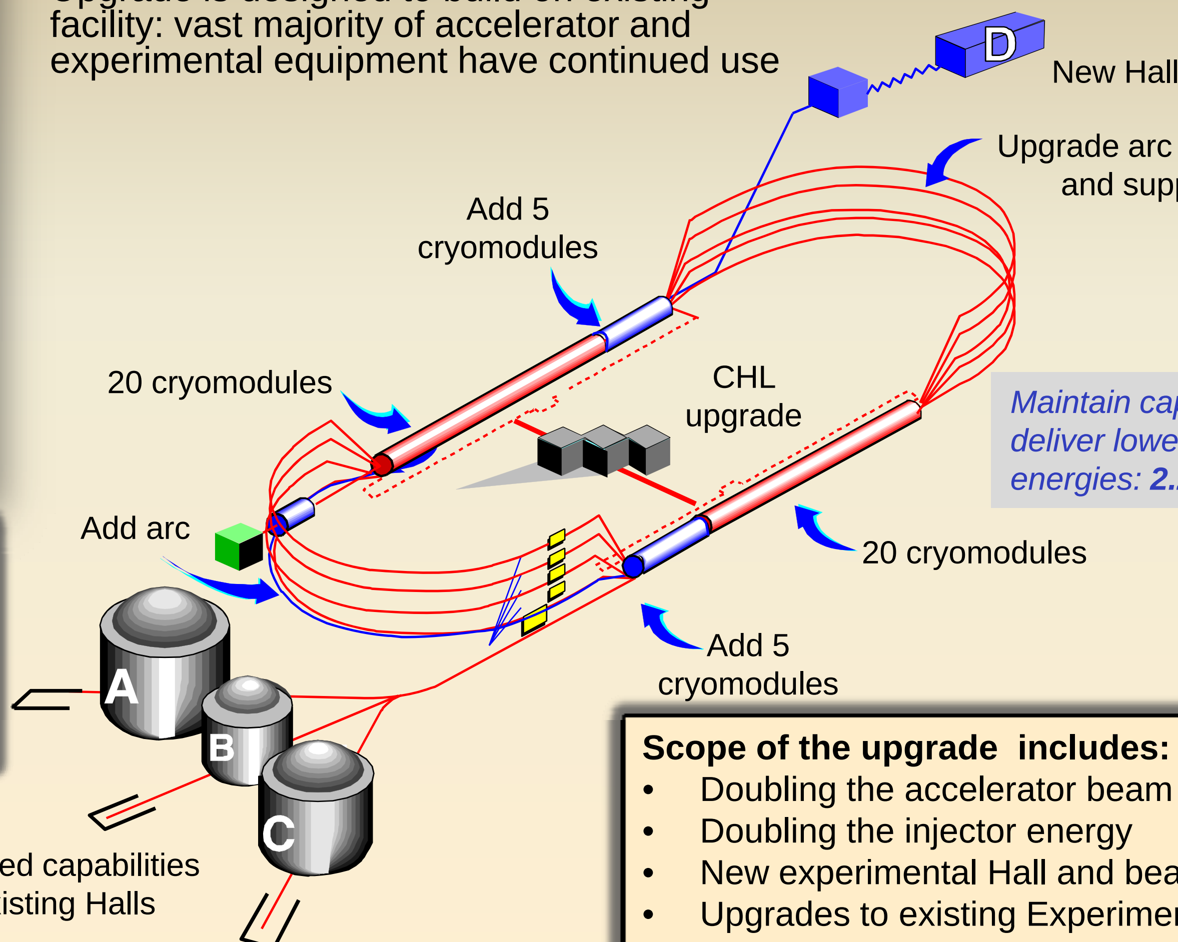
3 Halls running simultaneously

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

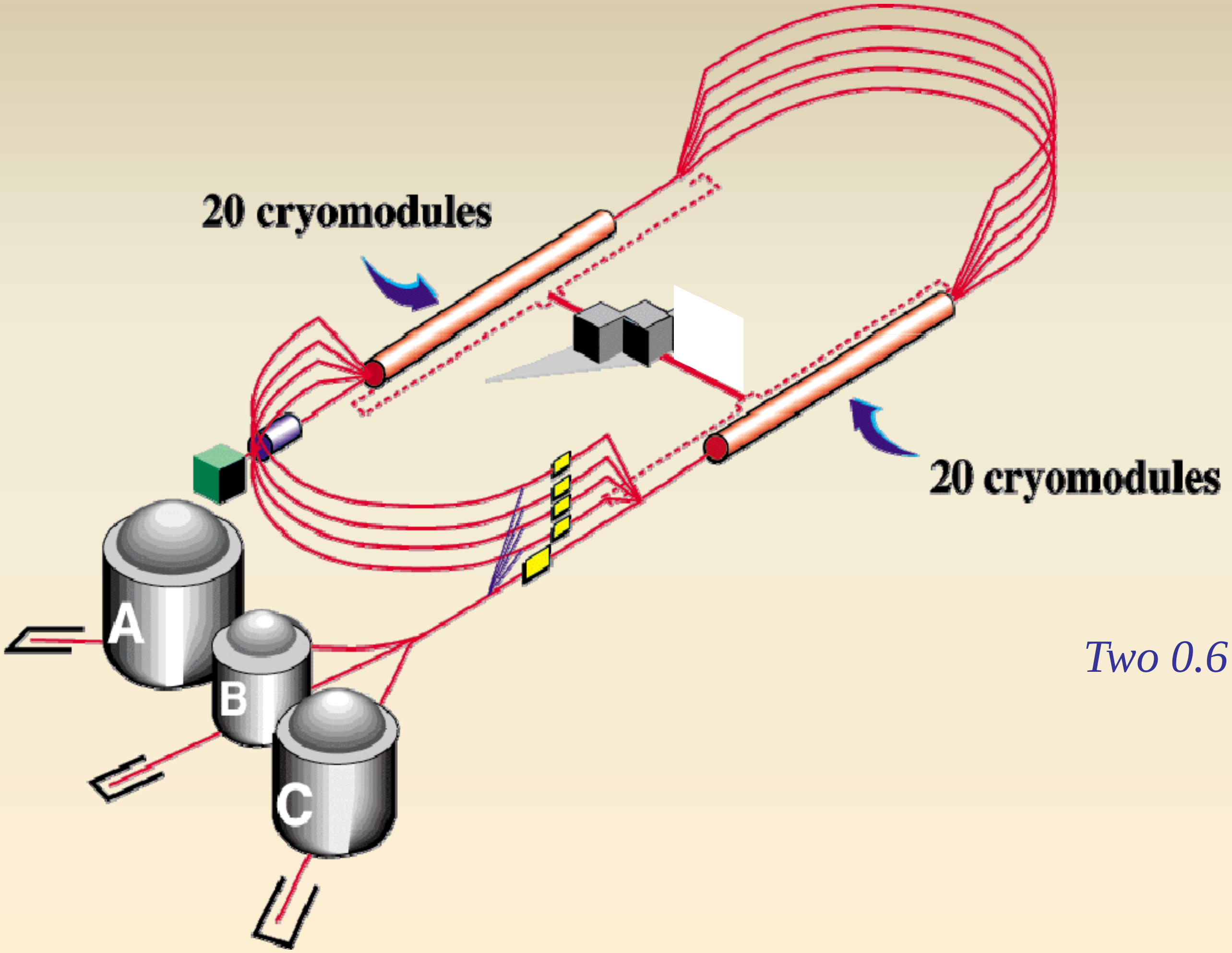


*Maintain capability to deliver lower pass beam energies: **2.2, 4.4, 6.6….***

Scope of the upgrade includes:

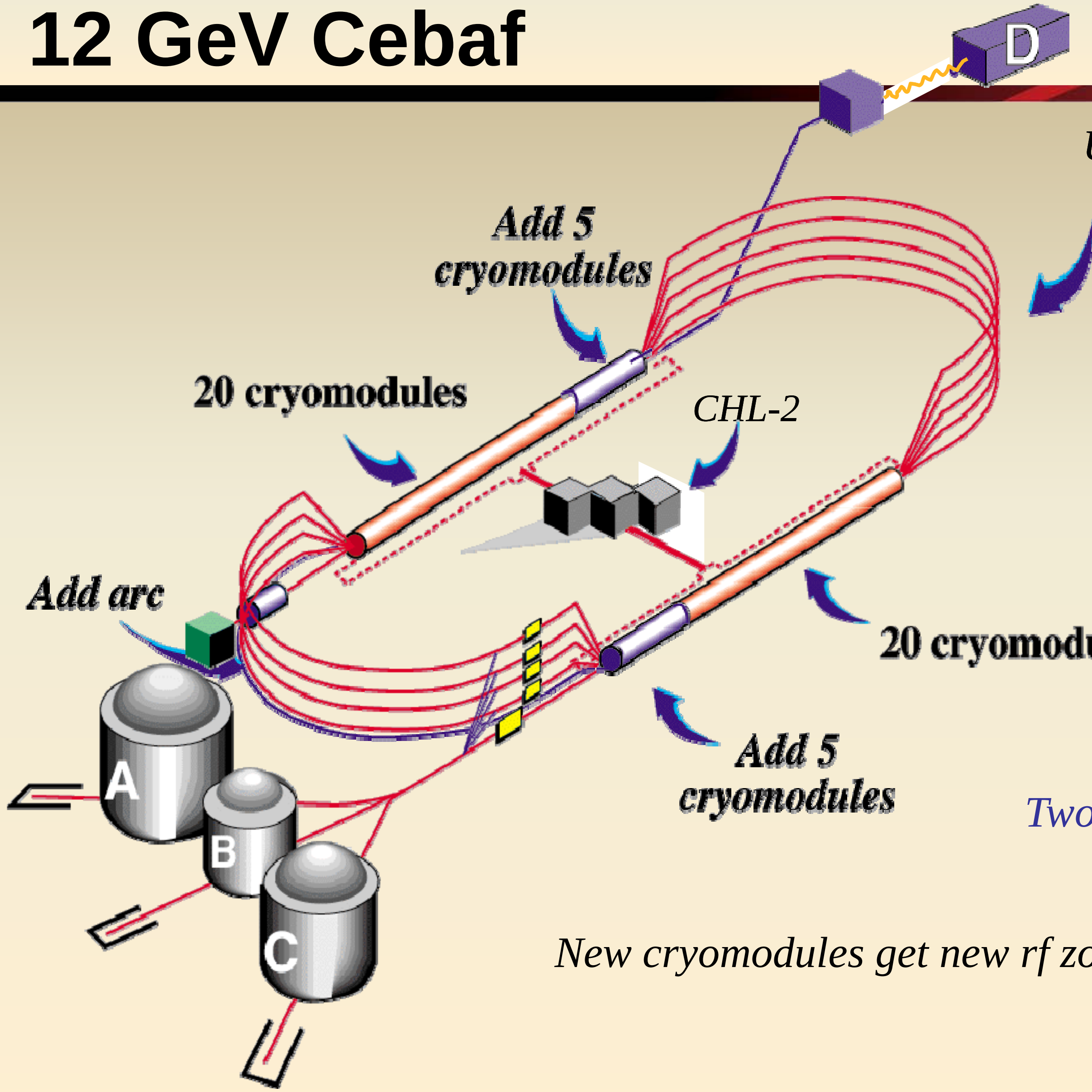
- Doubling the accelerator beam energy
- Doubling the injector energy
- New experimental Hall and beam-lines
- Upgrades to existing Experimental Halls

6 GeV CEBAF



Two 0.6 GV linacs

12 GeV Cebaf

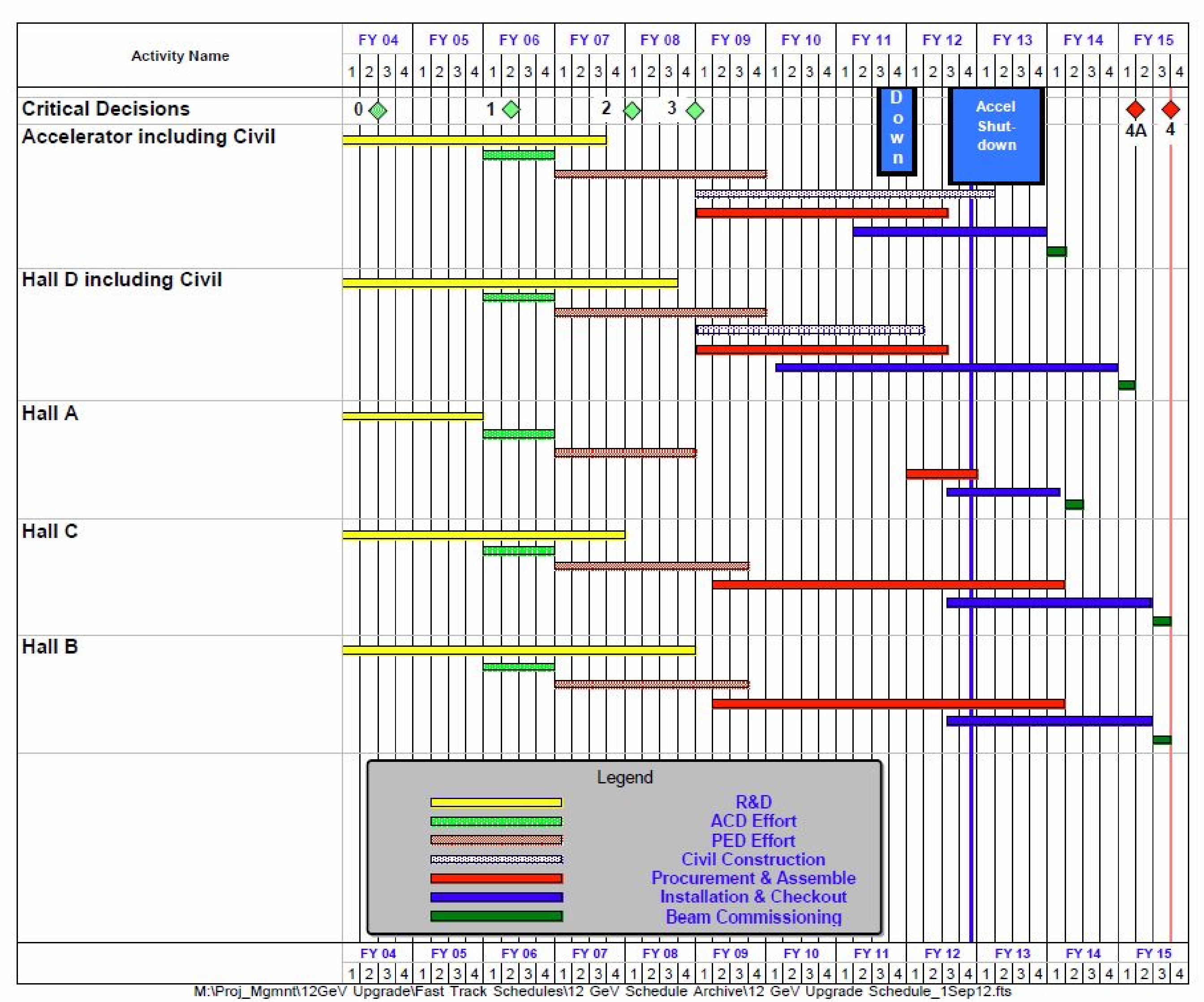


Upgrade magnets and power supplies

Two 1.1 GV linacs

New cryomodules get new rf zones

12 GeV Upgrade Schedule



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

16-month installation May 2012 - Sept 2013

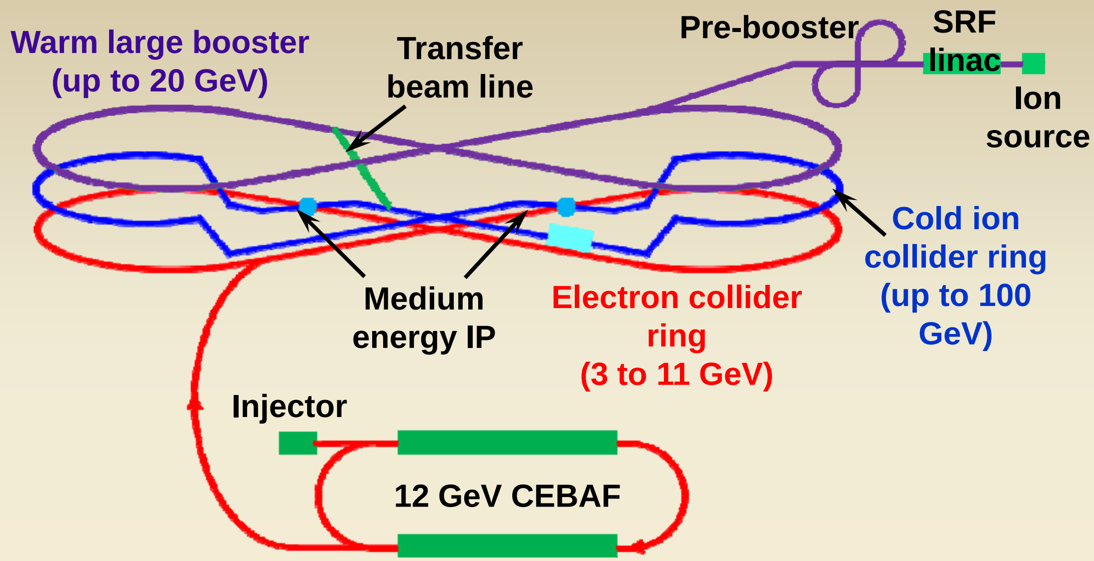
Hall A commissioning start Feb 2014

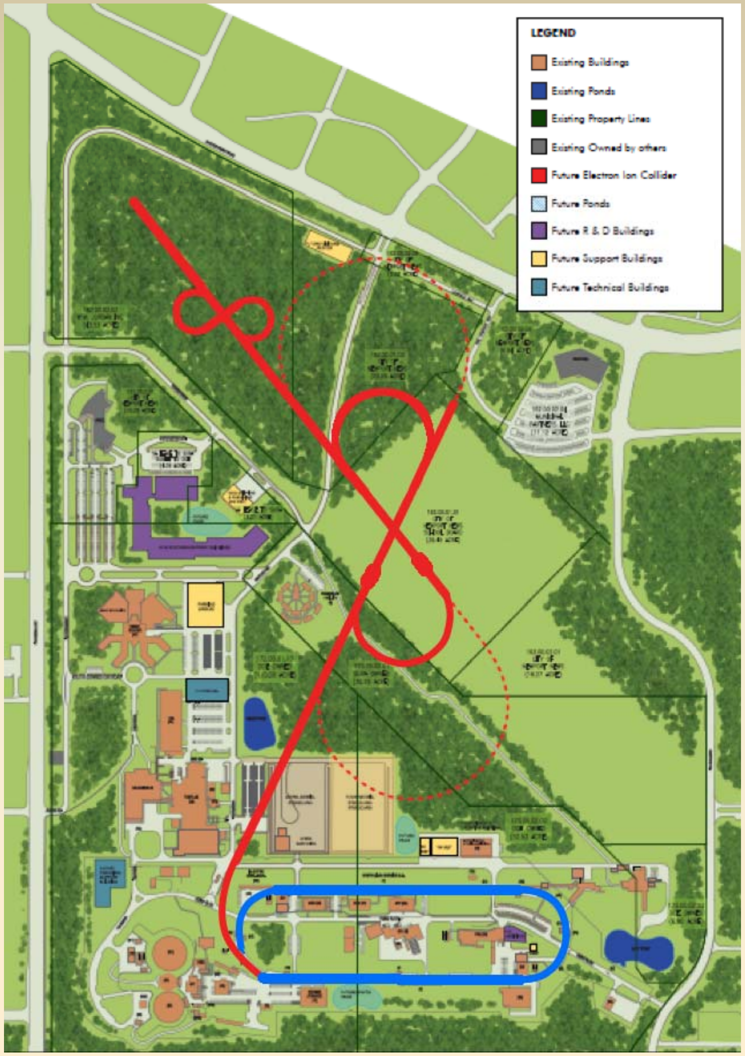
Hall D commissioning start Oct 2014

Halls B & C commissioning Apr 2015

Project Completion June 2015

Medium Energy EIC@JLab

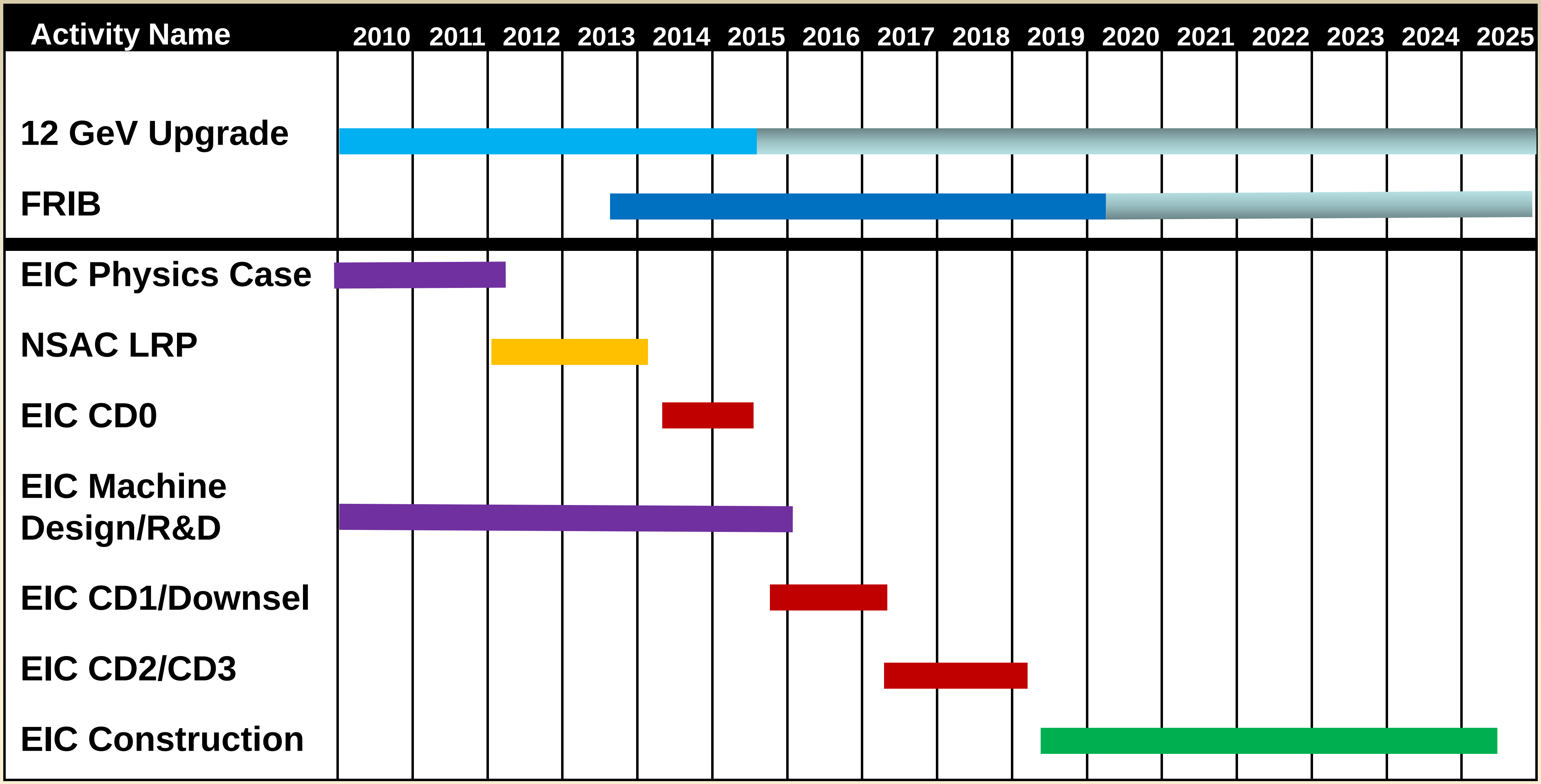




JLab Concept

- 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)
- **Design Report published in August 2012**

Jefferson Lab Electron Ion Collider



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

Scientific and technical core capabilities

- High power CW **linacs** (CEBAF)
- Theoretical and experimental **nuclear physics**
- **Free Electron Lasers**
- **e- sources**
- **SRF** science and technology:

  R&D

  Production (new TLA facility)
- **Cryogenics** technology
- **Detectors** and imaging

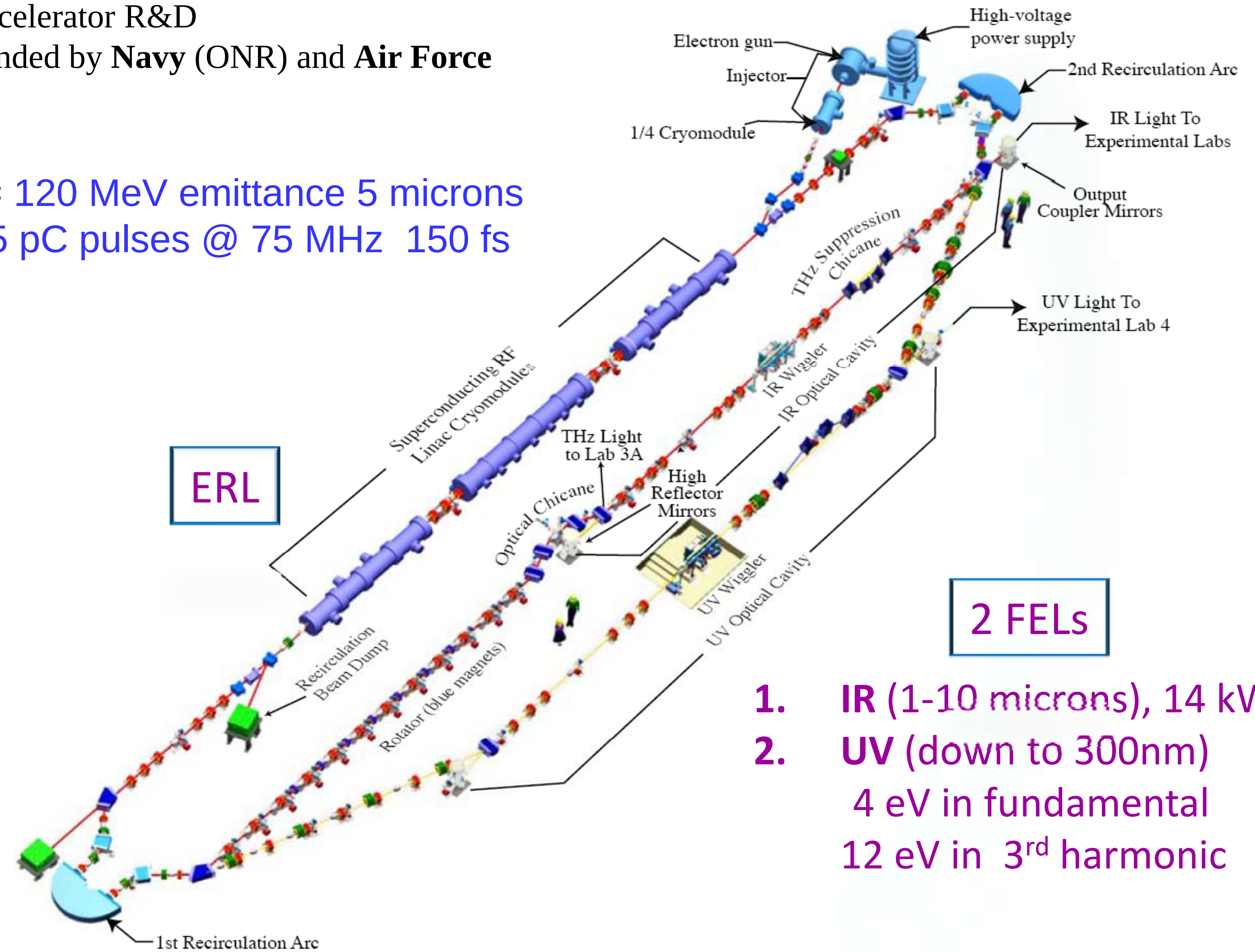
Developing:

- **Energy** applications (sustainability, ADS)

Jefferson Lab FEL

Accelerator R&D
funded by **Navy** (ONR) and **Air Force**

E = 120 MeV emittance 5 microns
135 pC pulses @ 75 MHz 150 fs

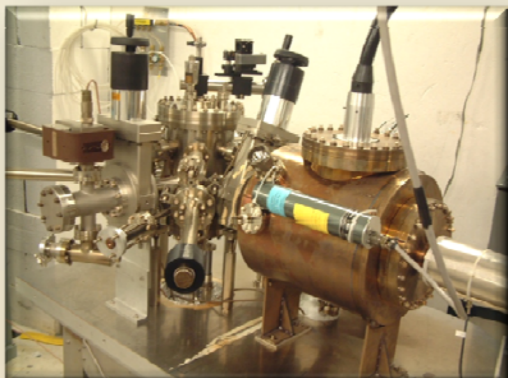


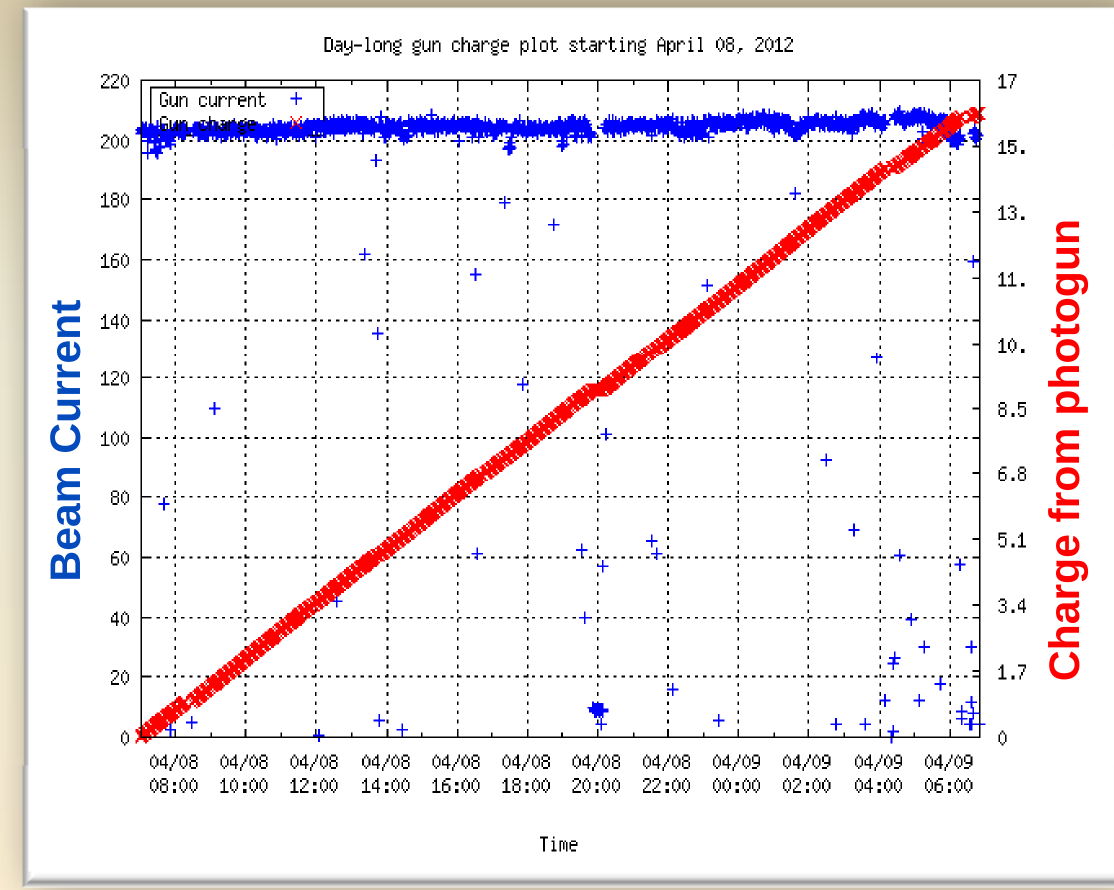
1. **IR** (1-10 microns), 14 kW
2. **UV** (down to 300nm)
   4 eV in fundamental
   12 eV in 3rd harmonic

Jefferson Lab

Polarized Electron Source

B. Matthew Poelker
2011 E. O. Lawrence Award





24 Hours

Electron Gun Requirements

- Ultrahigh vacuum
- No field emission
- Maintenance-free

Record Performance (2012): 180 µA at 89% polarization

SRF at JLAB

- Cavity & Cryomodules for 12 GeV
- R&D program
- The new TLA production facility

C100 SRF cavities

C100: string of **8 7-cell cavit**ies, **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**

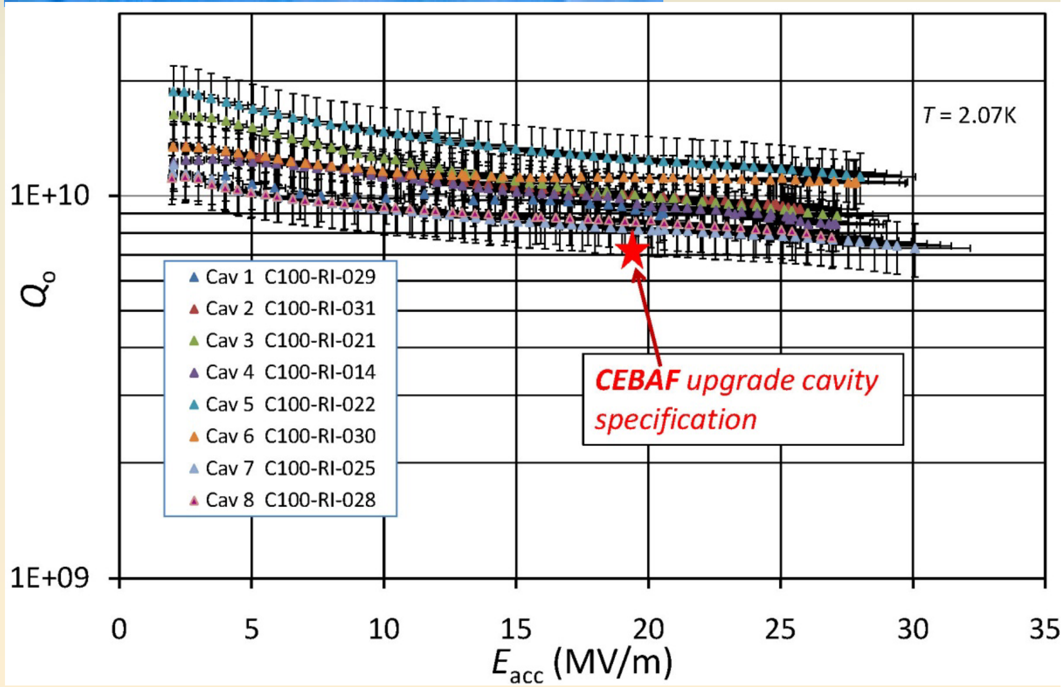
The cavity tests are performed at the Vertical Test Area (VTA)

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

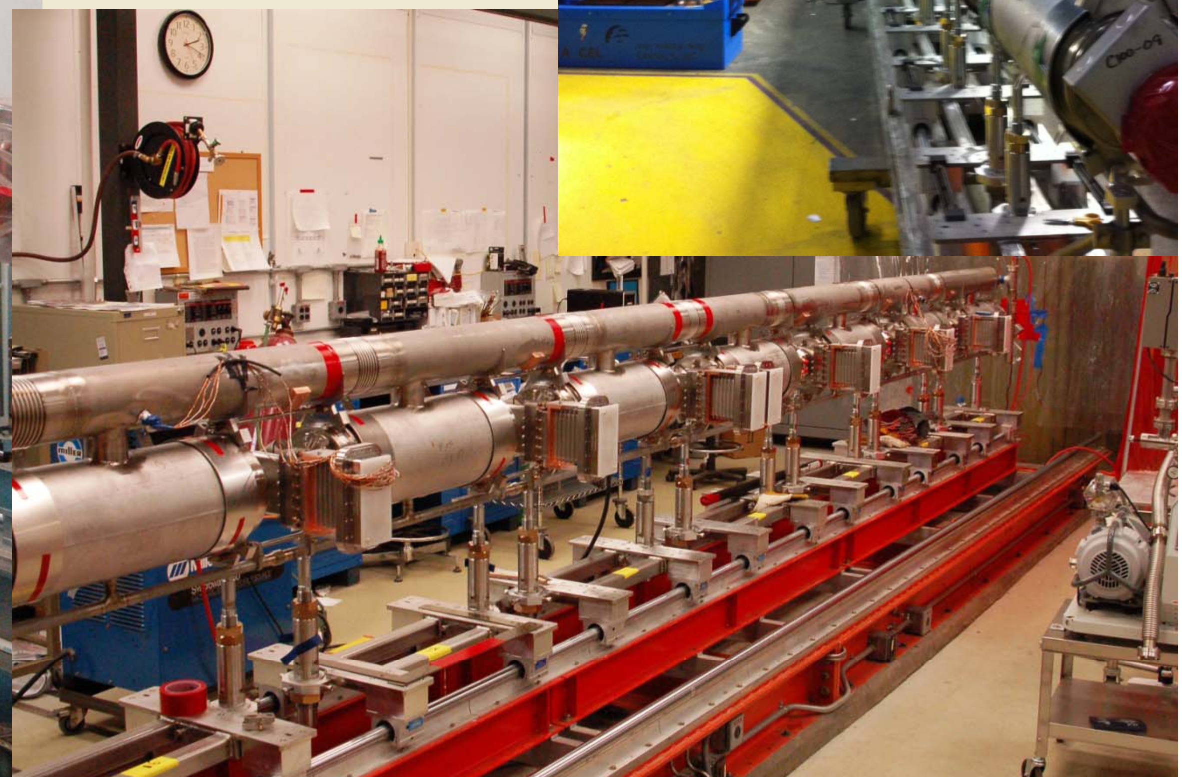
Cryomodule design and production

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 commissioning and operations

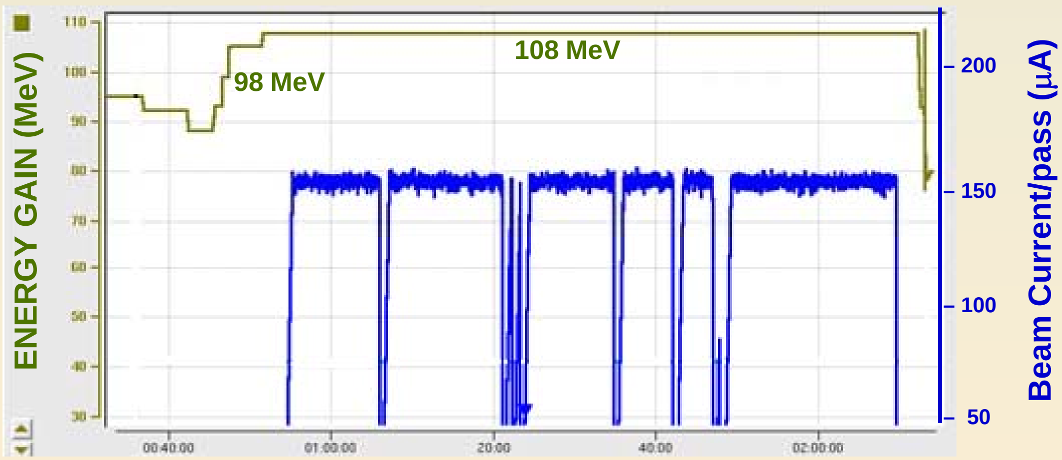
2 C100 installed during the 6 months shutdown

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

Challenges: narrower bandwidth, higher gradient, coupling

Learning curve (LLRF, trip recovery, etc.)

C100 Cryomodule Energy Gain – May 18th



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.

SRF R&D activities at JLAB

Goals: high cryogenics efficiency (**Qo**), **high gradient**

Activities:

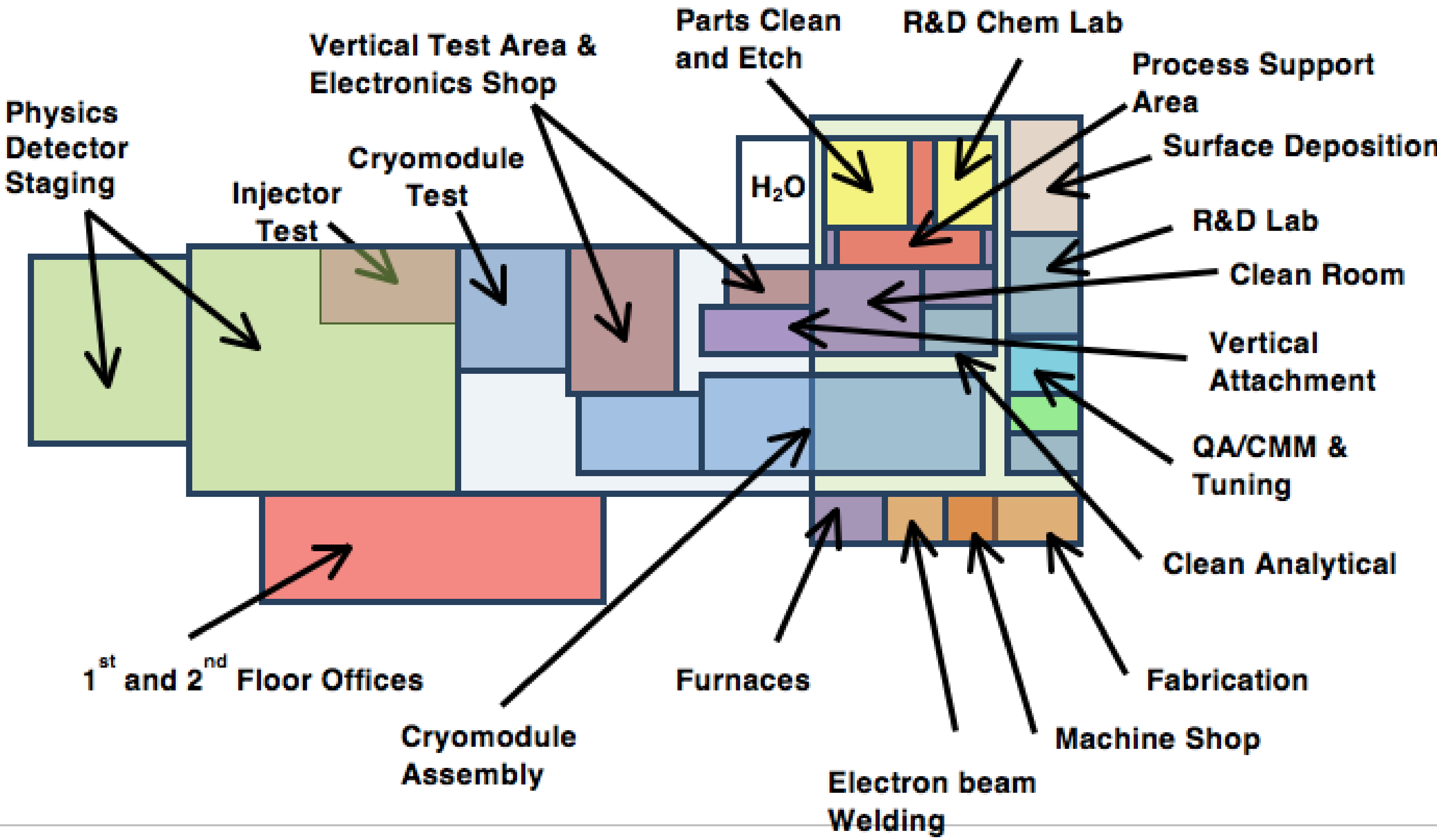
- Novel SRF cavity structures (crab cavities, spokes)
- High Qo R&D
- Ingot niobium technology
- Compact SLS (inverse Compton scattering)
- Cost effective modular cryomodules
- Thin film technology
- High gradient elliptical cavities

Examples of WFO and 'WWO':

ANL crab cavities, FRIB cavities/cryomodules

NGLS (cavities, cryogenics), CERN (LHeC ERL), ESS, …

New TLA production facility



TLA - continued

2 buildings (SLI program, 30 M$ investment):

TEDF (Technology Engineering Development Facility)

TLA (Test Lab Addition- 14000 sft addition to TestLab)

(8600 sft chemroom / cleanroom)

- Energy efficiency
- Life-safety code compliance
- **Work-flow efficiency**
- Facility sustainability
- Human work environment
- Technical quality of facilities for future work

Cavity fabrication and **cryomodule assembly**

- Completely new infrastructures
- Phase 1: existing equipment and tools
- Phase 2: incremental acquisition of new equipment and tools

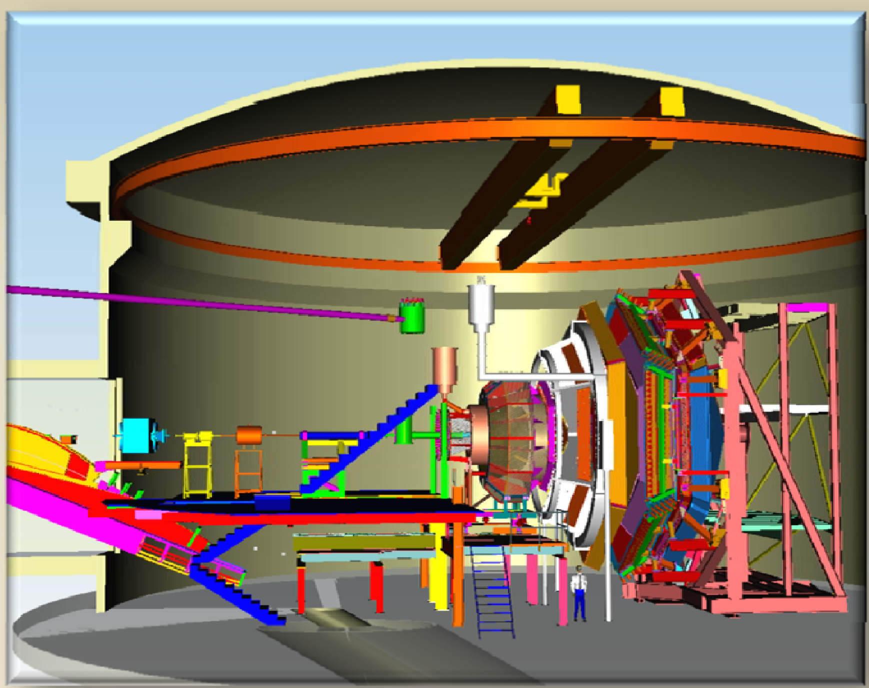
TEDF occupancy: **beginning 2012**

TLA occupancy: **summer 2012**

TestLab renovation: **summer 2013**

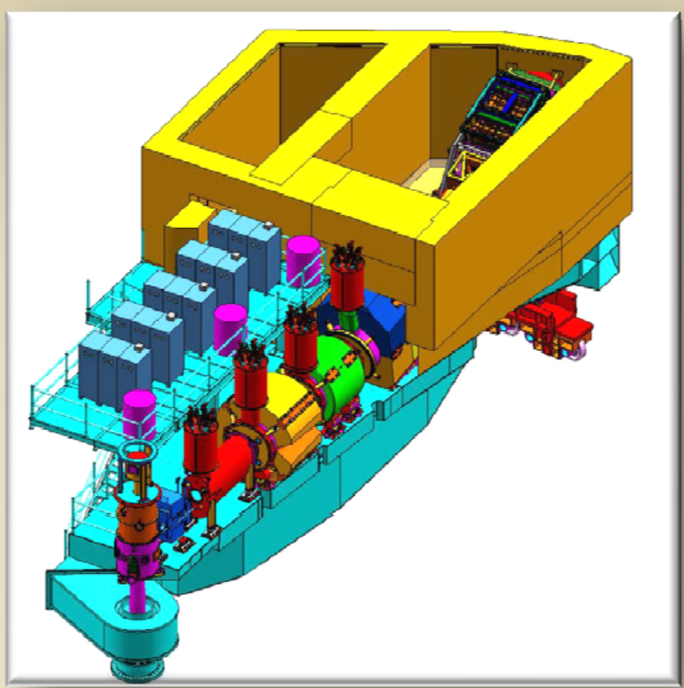
Physics detectors and experimental halls

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

Nuclear physics detector technology

Radiation Detector & Imaging Group- 7 Scientists and Engineers
Leader: Drew Weisenberger

Expertise in nuclear particle detection

- gas based detectors
- standard and position-sensitive photomultiplier tubes (PSPMTs)
- silicon photomultipliers (SiPMs)
- scintillation and light guide techniques
- fast analog readout electronics and data acquisition
- on-line image formation and analysis
- 3D image reconstruction algorithm development
- compact detectors

- Support design and construction of new detector systems-
  R+D detector components & systems for all Jefferson lab and others
- Technical consultants for the lab scientists and users
- Development and use of imaging and non-imaging detector systems

Tech Transfer: Leveraging the National Lab Strengths

Jefferson Lab provides a **unique technical environment** not found typically in one place in academia or industry.

Technical resources brought together to do basic nuclear physics research:

- advanced **radiation detection** methods
- state of the art **electronics**
- software development for **3D imaging**
- high performance **data acquisition**
- **optics**

Applying nuclear imaging detector techniques for challenges in other fields:

- **nuclear medicine** for improved patient care
- **bio-medical research** using radioisotopes
- **biological systems research** using radioisotopes

Jefferson Lab is a single purpose lab thus requiring **collaborations**

Nuclear Imaging 101

Radioisotopes that emit **high energy photons** and **beta particles** are incorporated into molecules that have a biological function of interest. The **tagged molecules** are then injected or introduced *in vivo* into biological systems:

- people
- animals
- plants
- microbes

Molecular Imaging: The bio-distribution of tagged molecules is imaged externally by devices capable of detecting the emitted particles. Typically the **high energy photons** are highly penetrating thus can be detected and imaged externally. Two molecular imaging techniques:

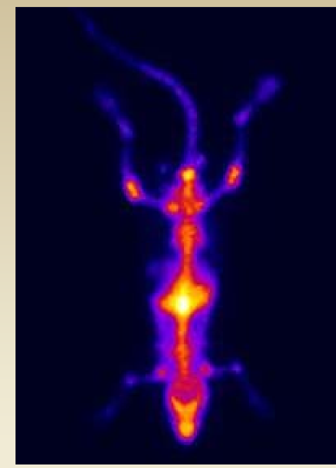
- Single Photon Emission Computed Tomography (**SPECT**)
- Positron Emission Tomography (**PET**)

Bio-Medical Imaging Modalities

Structural
- X-ray CT
- MRI

digital x-ray of mouse (JLab)

JLab/RD&I

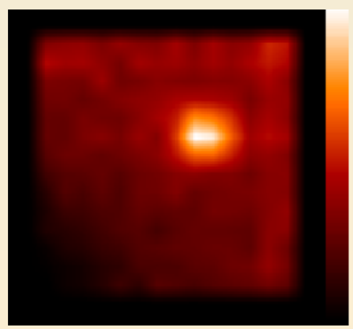


Tc99m- bone scan of live mouse (JLab)

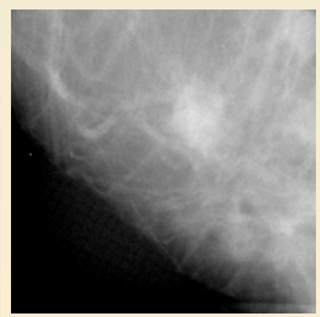
JLab/RD&I

Functional
- Single Photon Emission Computed Tomography (SPECT)
- Positron Emission Tomography (PET)

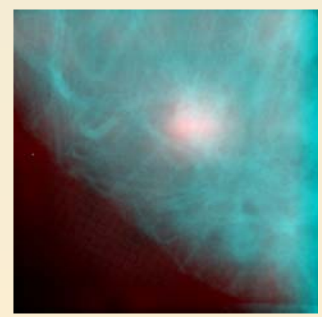
Multi Modality
- PET-CT
- PET-MRI
- SPECT-CT



Tc99m



mammogram



co-registered

JLab/RD&I

breast tumor imaged via Tc99m and digital x-ray then co-registered

Dilon 6800 Gamma Camera

Dilon Technologies, Inc.
Newport News, Virginia
~20 employees
Based on JLab/RD&I Group spin-off

Several patents licensed from JLab. Presently Dilon and JLab initiating a new CRADA agreement to enhance gamma camera performance.

SBIR/STTR program at JLAB

JLAB has 50+ open WFO and CRADA' s

SBIR/STTR (from NP and HEP) supports CRADA' s and WFO

2012: 21 letters of support, 13 companies

We expect a similar outcome for 2013

SBIR program at JLAB

CRADAs Supported by SBIR/STTR

Participant	Number	Project Description	Funds-In	Total Amount	Comments
Faraday Tech	2011S003	Electropolishing Niobium in an HF-Free Electrolyte	$ 19,000.00	$ 105,000.00	
Muons, Inc.	2005S005	Muon Beam Cooling Using Parametric Resonances	$ 60,000.00	$ 650,000.00	
Muons, Inc.	2008S010	Rugged Ceramic Window for RF Applications	$ 30,000.00	$ 100,000.00	SOW tasks include preparation of Phase II proposal
Muons, Inc.	2008S012	Pulsed Focusing Recirculating Linacs for Muon Acceleration	$ 30,000.00	$ 100,000.00	SOW tasks include preparation of Phase II proposal
Muons, Inc.	2009S013	High Power Co-Axial SRF Coupler	$ 27,000.00	$ 100,810.00	SOW tasks include preparation of Phase II proposal
Muons, Inc.	2009S014	Improved DC Gun Insulator Assembly	$ 28,000.00	$ 100,000.00	SOW tasks include preparation of Phase II proposal
Muons, Inc.	2010S002	Pulsed Focusing Recirculating Linacs for Muon Acceleration	$ 225,000.00	$ 750,000.00	Phase II
Muons, Inc.	2010S015	Epicyclic Helical Channels for Parametric References	$ 30,000.00	$ 99,999.00	SOW tasks include preparation of Phase II proposal
Muons, Inc.	2010S016	A Novel Crab Cavity RF Design	$ 27,000.00	$ 99,999.00	SOW tasks include preparation of Phase II proposal
Muons, Inc.	2011S009	High Power Co-Axial SRF Coupler- STTR	$ 209,760.00	$ 750,002.00	Phase II
Muons, Inc.	2011S020	Photoinjector Enhancements Using Surface Acoustical Waves	$ 30,000.00	$ 100,000.00	SOW tasks include preparation of Phase II proposal
Muons, Inc.	2011S021	Achromatic Low Beta Interaction Region Design	$ 30,000.00	$ 100,000.00	SOW tasks include preparation of Phase II proposal
Muons, Inc.	2011S025	Phase II SBIR- Alternating Dispersion Muon Cooling Channel	$ 225,000.00	$ 750,000.00	
MuPlus, Inc.	2012S005	Complete Muon Collider Cooling Channel Design and Simulations	$ 30,000.00	$ 100,000.00	SOW tasks include preparation of topics for Phase II
Radiabeam	2009S017	Devleop CW NCRF Photo-Injector Using Solid Freeform Fabrication (SFF)	$ 10,000.00	$ 93,596.00	
Radiabeam	2011S008	Phase II SBIR- Devleop CW NCRF Photo-Injector Using Solid Freeform Fabrication (SFF)	$ 74,520.00	$ 939,662.47	Phase II
Tech-X	2009S005	Simulation of Electromagnetic and Thermal Characteristics of SRF Structure	$ 29,978.00	$ 161,087.00	Final report notes funding from DOE Office of Nuclear Physics
Tech-X	2010S001	Simulation of Electromagnetic and Thermal Characteristics of SRF Structure	$ 119,999.00	$ 781,047.00	Phase II

WFO Supported by SBIR/STTR

Participant	Number	Project Description	Funding	Comments
Alameda Applied Sciences Corp.	2006W009	Evaluation of Coatings in Support of SBIR Award	$ 53,000.00	
Alameda Applied Sciences Corp.	2011W010	Thin-Films of Nb Deposited on Cu for Lower Cost SRF Accelerators	$ 25,000.00	

SBIR opportunity areas at JLAB

- *Software and Data Management*
  Simulations for CEBAF and EIC (accelerators and detectors)
- *Accelerator Technology*
  SRF R&D, RF power, e- sources, cryogenics, energy
- *Instrumentation, Detection Systems and Techniques*
- *Electronics Design and Fabrication*
  Nuclear imaging, detectors CEBAF, EIC
- *Nuclear Physics Isotope Science and Technology*
  CW e- linac based isotope production facilities

SRF: **B. Rimmer**
EIC: **G. Krafft**
e-sources: **M. Polker**
Imaging: **D. Weisenberger**

Conclusions

- There is a rich tradition at JLAB of work for others and with others (WFO, CRADA’ s)
- The SBIR/STTR program has consistently leveraged JLAB core capabilities in the past
- We intend to continue and strengthen this program as WFO becomes a central component of JLAB strategy and plans in the 12 GeV era.

BACK-UP SLIDES

External Partners

•Oak Ridge National Laboratory
•Triangle Universities Nuclear Laboratory

•West Virginia University
•Hampton University Proton Therapy Institute
•University of Virginia
•University of Maryland
•Johns Hopkins University
•Case Western Reserve University
•College of William and Mary
•Duke University
•Columbia University

•Dilon Technologies, Inc.

External Funding (beyond DOE NP)

•DOE BER
•NIH (WFO)
•DOD
•JSA

Tech Transfer

Business partnership opportunities for technology transfer:

Jefferson Lab Patents: 1991-present: 99
Radiation Detector & Imaging Group Patents: 1995-present: 31
several have been licensed

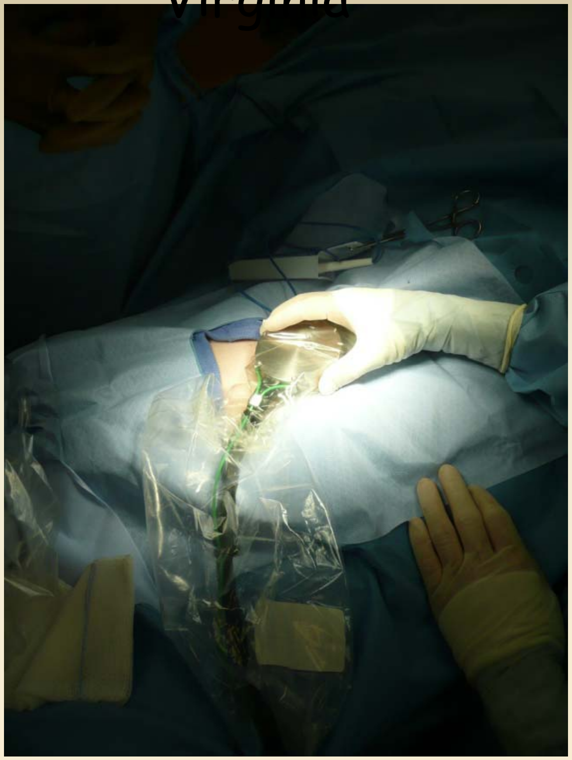
Clinical Application- Cancer Surgery

Problem: Need for compact handheld imaging gamma-ray detector to do lymphoscintigraphy for use in cancer surgery

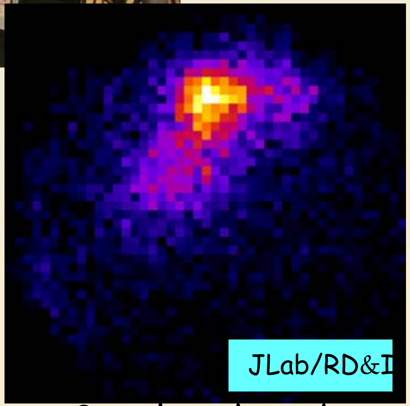
Solution: Use array of 80 silicon photomultipliers (SiPMs) to develop a compact detector with $LaBr_3$ (5 cm diam, 6 mm thick) scintillator and custom tungsten-polymer composite two-part collimator

"**Gamma Puck**": Handheld detector with tungsten shell and tungsten collimators

Clinical trials of Hand-Held Gamma Camera at the University of Virginia



radiopharmaceutical used to identify sentinel lymph nodes with cancer involvement during breast cancer surgery



~ 3cm lymph node

University of Virginia Cancer Center Technology Partnership Initiative: "Image-Guided Surgical Oncology Using a Hand-Held Gamma Camera Operated in Freehand SPECT Mode"

Dilon Technologies, Jefferson Lab and UVa awarded funds to facilitate R+D