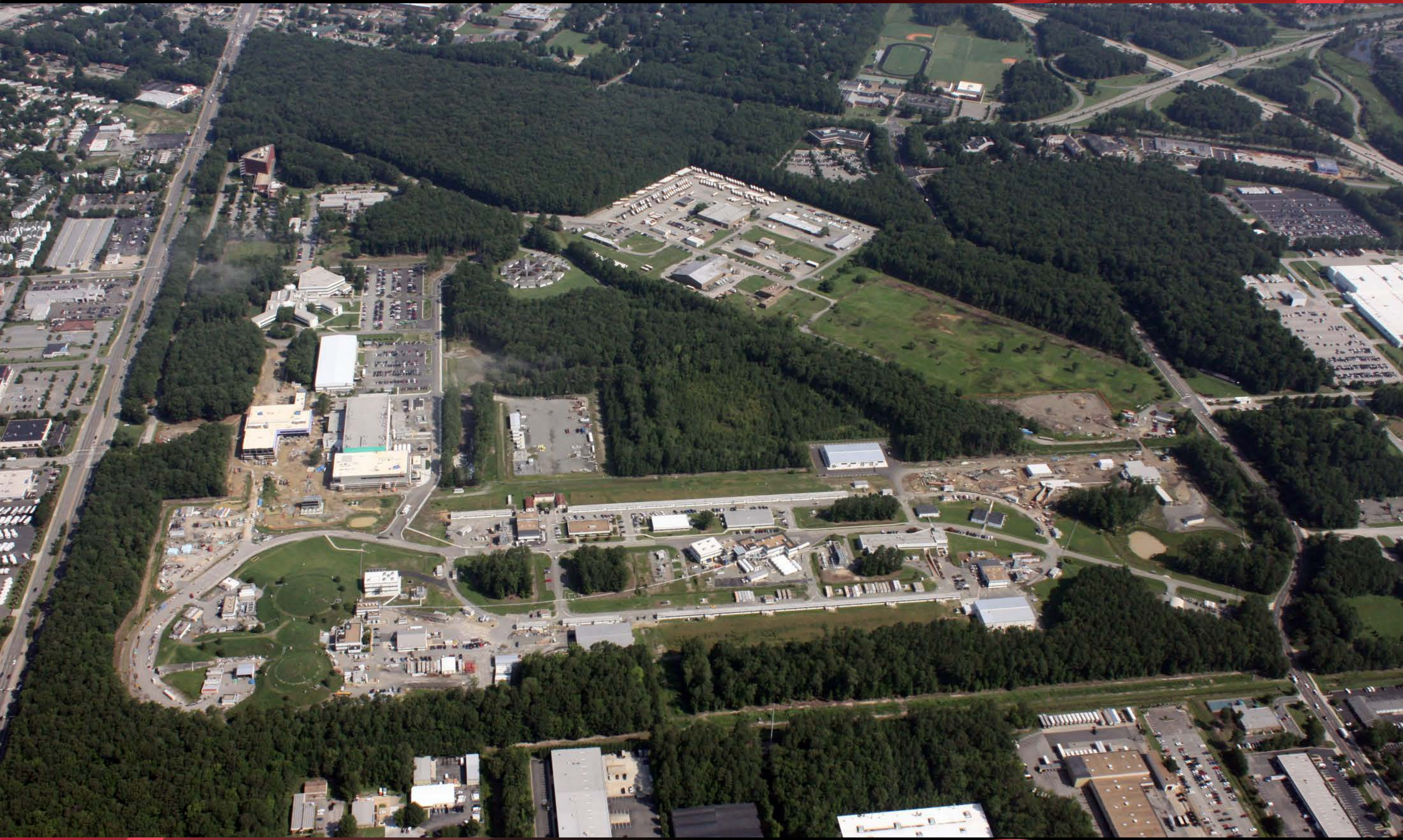
DOE Nuclear Physics SBIR-STTR



Roy Whitney, CIO & CTO
November 6, 2013

Jefferson Lab
Thomas Jefferson National Accelerator Facility

Outline

- **Overview of Jefferson Laboratory**
- **Scientific and technical capabilities** (CEBAF, Upgrade, MEIC, FEL, Gun/Injector, SRF, Cryogenics, Detectors, Computing, Energy)
- **SBIR/STTR opportunities at Jefferson Lab**
- **SBIR/STTR → Changes coming from DEO Tech Transfer**

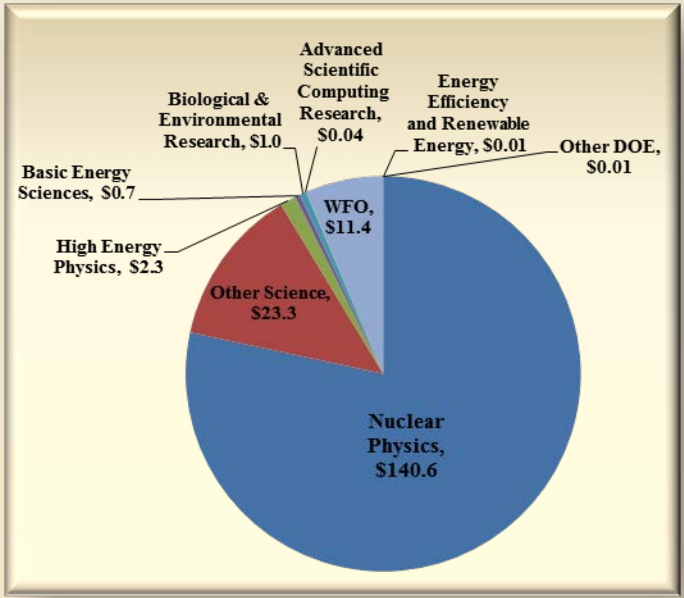
Jefferson Lab At-A-Glance

- **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
  - 1,385 Active Users
  - 178 Completed Experiments to-date
  - Produces ~1/3 of US PhDs in Nuclear Physics (444 PhDs granted, 186 in progress)
- **Managed for DOE by Jefferson Science Associates, LLC (JSA)**
- **All work is unclassified**
- **Human Capital:**
  - 759 FTEs
  - 22 Joint faculty; 25 Post docs; 10 Undergraduate, 33 Graduate students
- **K-12 Science Education program serves as national model**
- **Site is 169 Acres, and includes:**
  - 88 SC Buildings & Trailers; 899K SF
  - Replacement Plant Value: $384M

FY 2012:

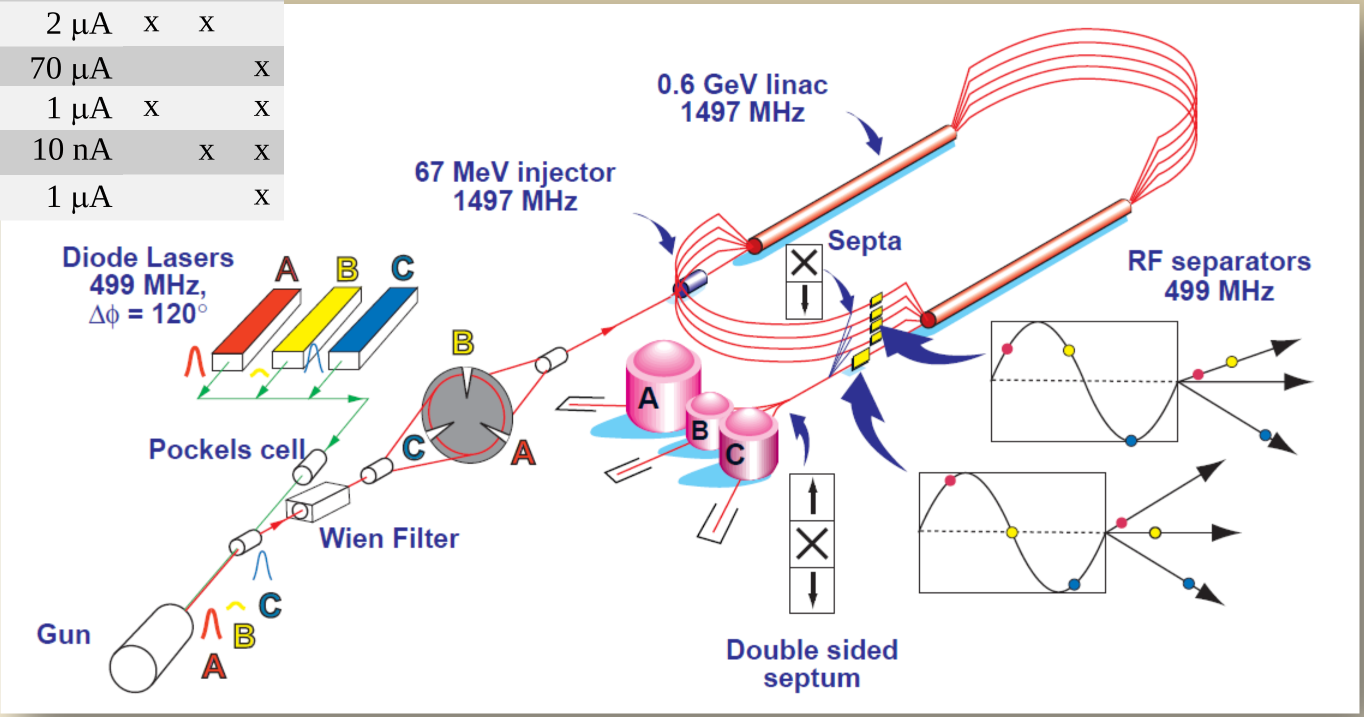
Total Lab Operating Costs: $179M

Non-DOE Costs: $11M



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

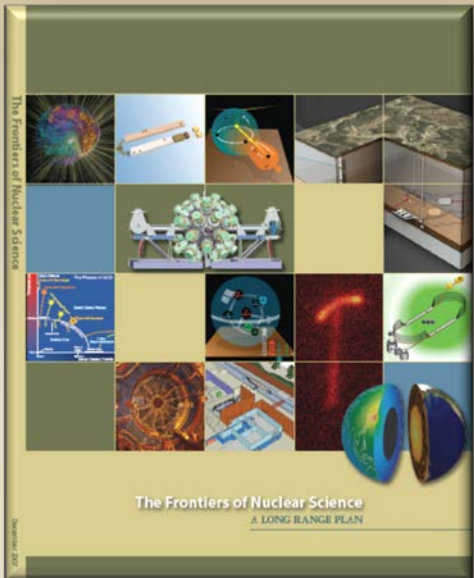
In operations since **1995** → served 1400+ nuclear physics users

Capabilities: 5 passes, multiple energies, beam characteristics, polarization

3 Halls running simultaneously

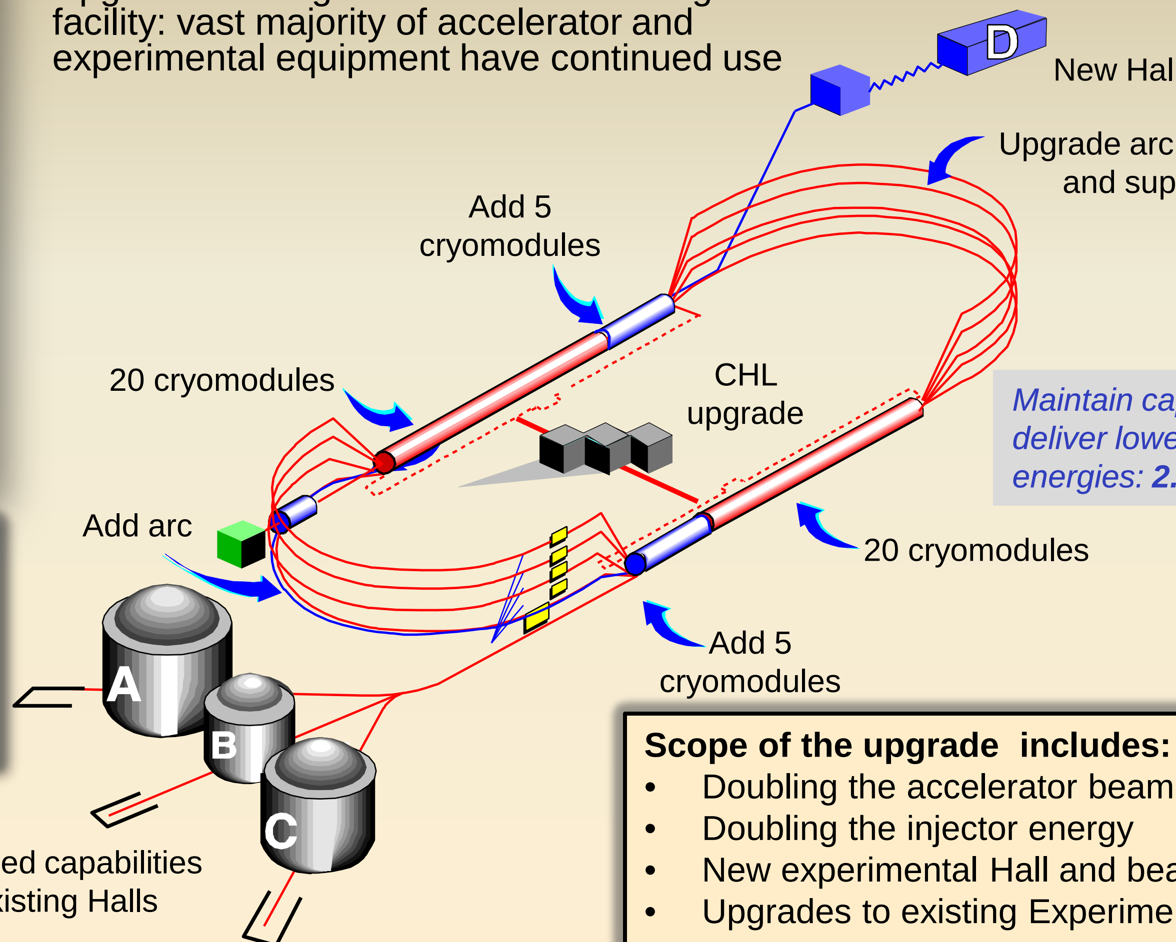
Upgrade to 12 GeV: proposal late 1990's → approved and funded in 2004

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

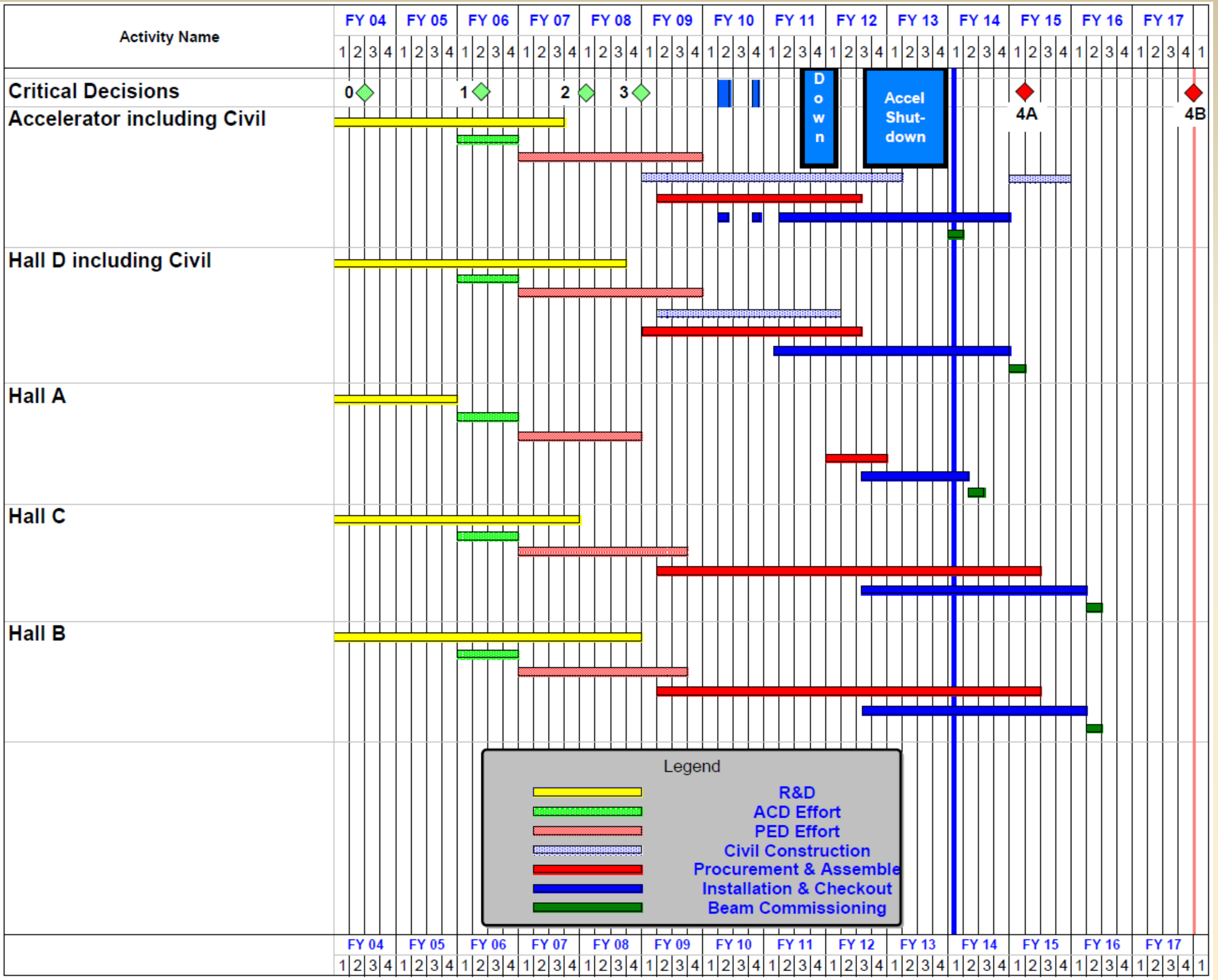


*Maintain capability to deliver lower pass beam energies: **2.2, 4.4, 6.6….***

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

12 GeV Upgrade Project Schedule



Rebaseline complete Sept 2013

16-month installation
May 2012 - Sept 2013 DONE

Accelerator commissioning start
Oct 2013 IN PROGRESS

Hall A commissioning start
Feb 2014

Hall D commissioning start
Oct 2014

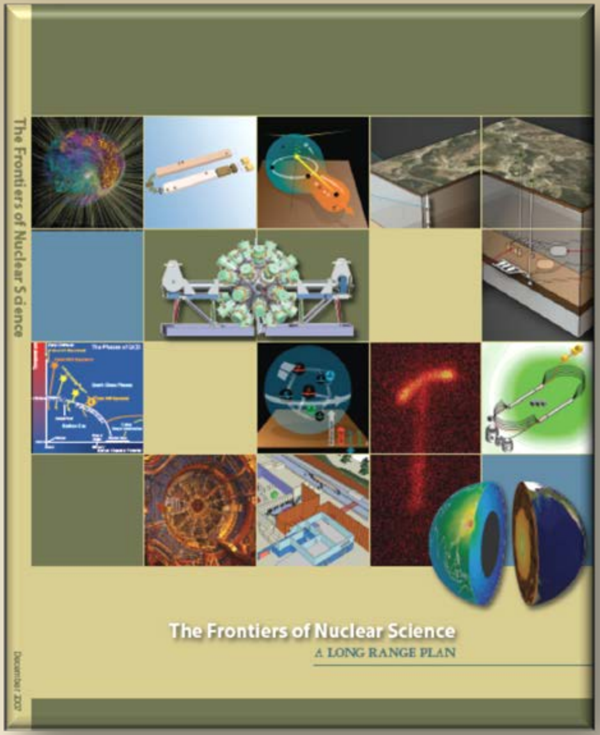
Halls B & C commissioning start
Jan/Feb 2016

Project Completion
September 2017

Electron Ion Collider

NSAC 2007 Long-Range Plan:

"An **Electron-Ion Collider (EIC)** with **polarized** beams has been **embraced by the U.S. nuclear science community** as embodying the vision for **reaching the next QCD frontier**. EIC would provide unique capabilities for the study of QCD well beyond those available at existing facilities worldwide and complementary to those planned for the next generation of accelerators in Europe and Asia."

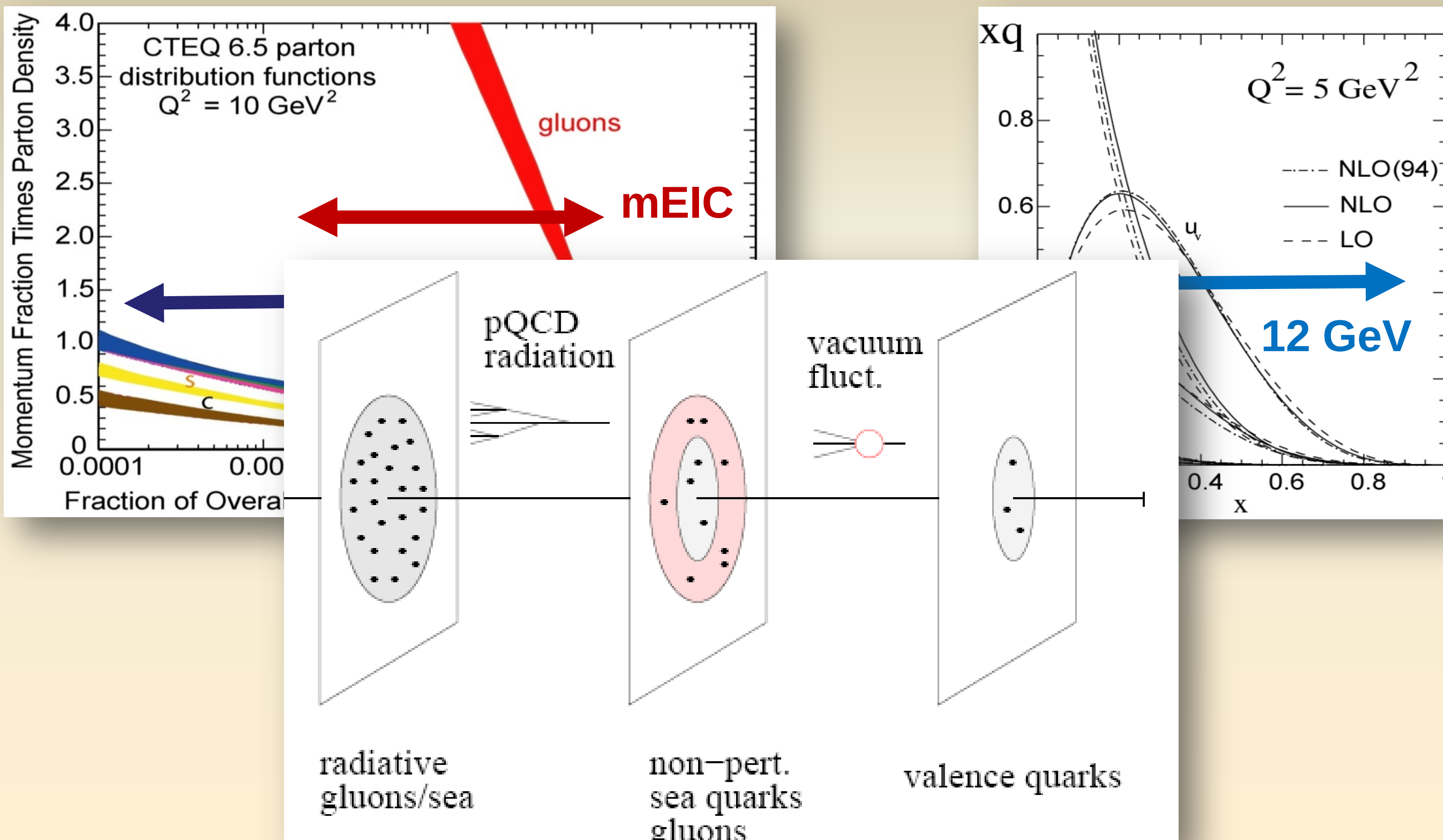


- **Jefferson Lab and BNL developing facility designs**
- **Joint community efforts to develop science case → white paper (2013)**

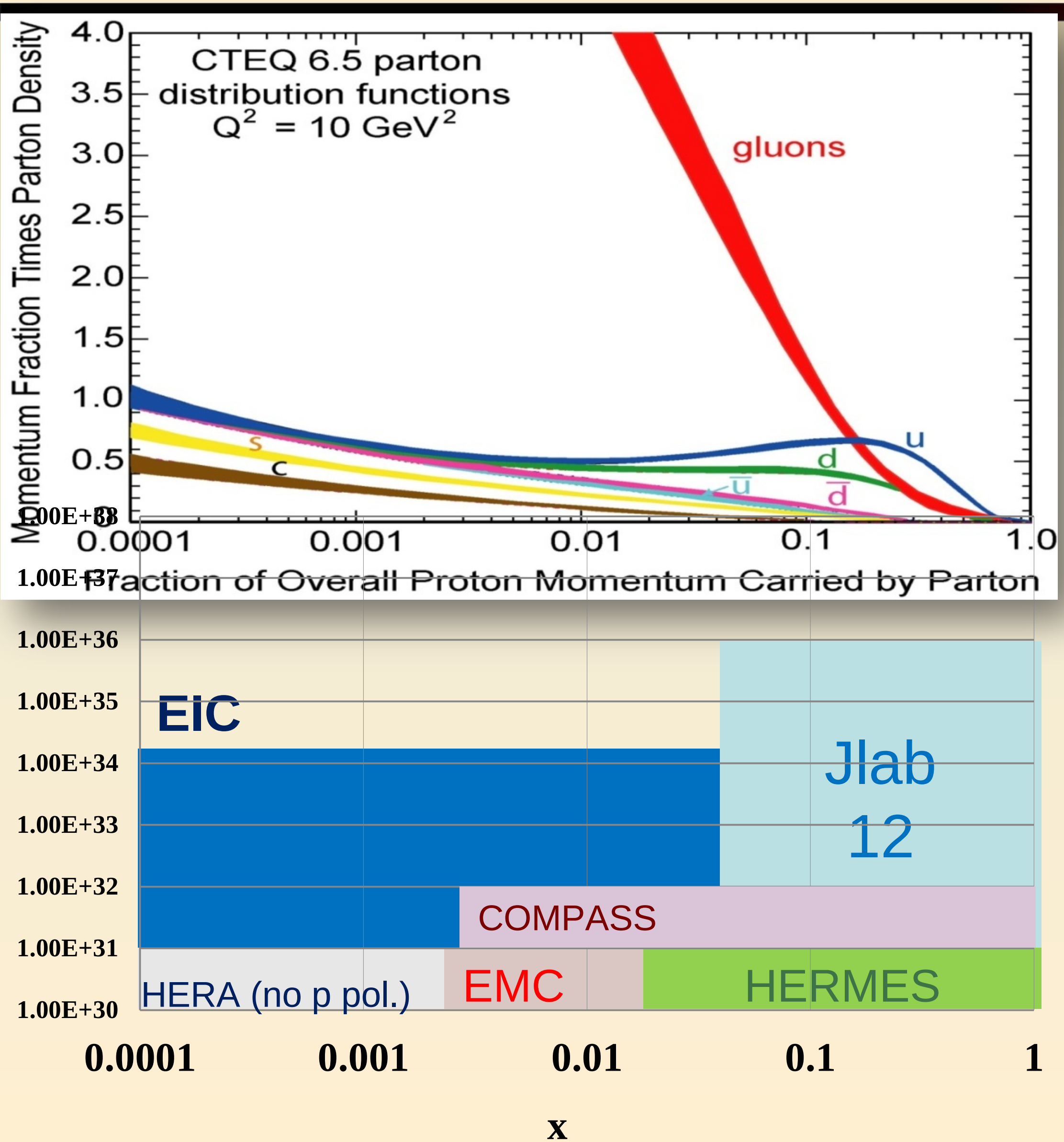
Into the “sea”: EIC

EIC aims to study gluon dominated matter.

With 12 GeV we study mostly the valence quark component



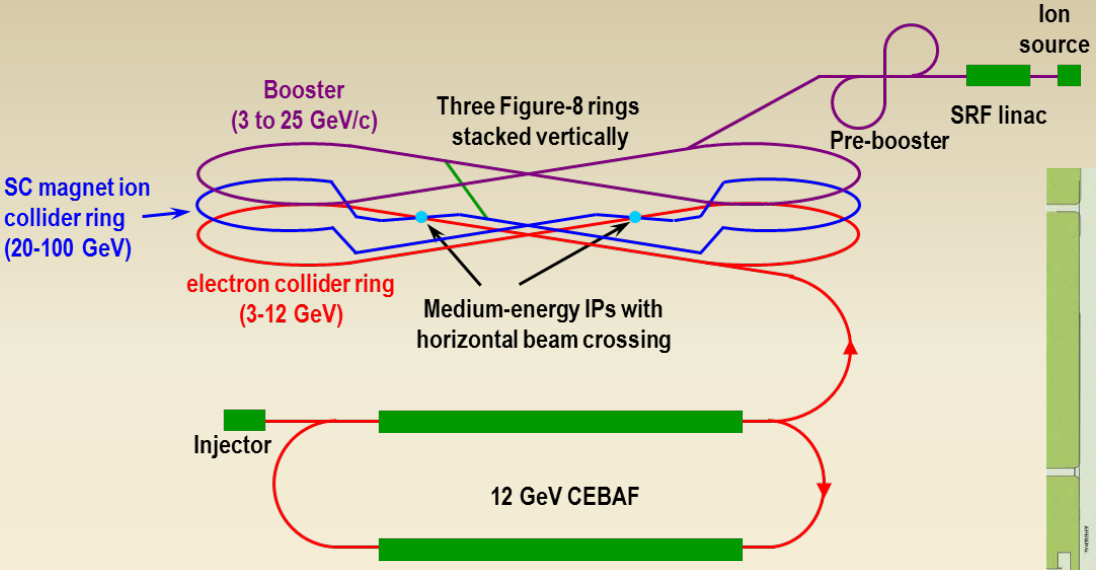
The Reach of EIC



- **High Luminosity**
  → $10^{34} cm^{-2}s^{-1}$
- **Low x regime**
  x → 0.0001
- **High Polarization**
  → 70%

Discovery Potential!

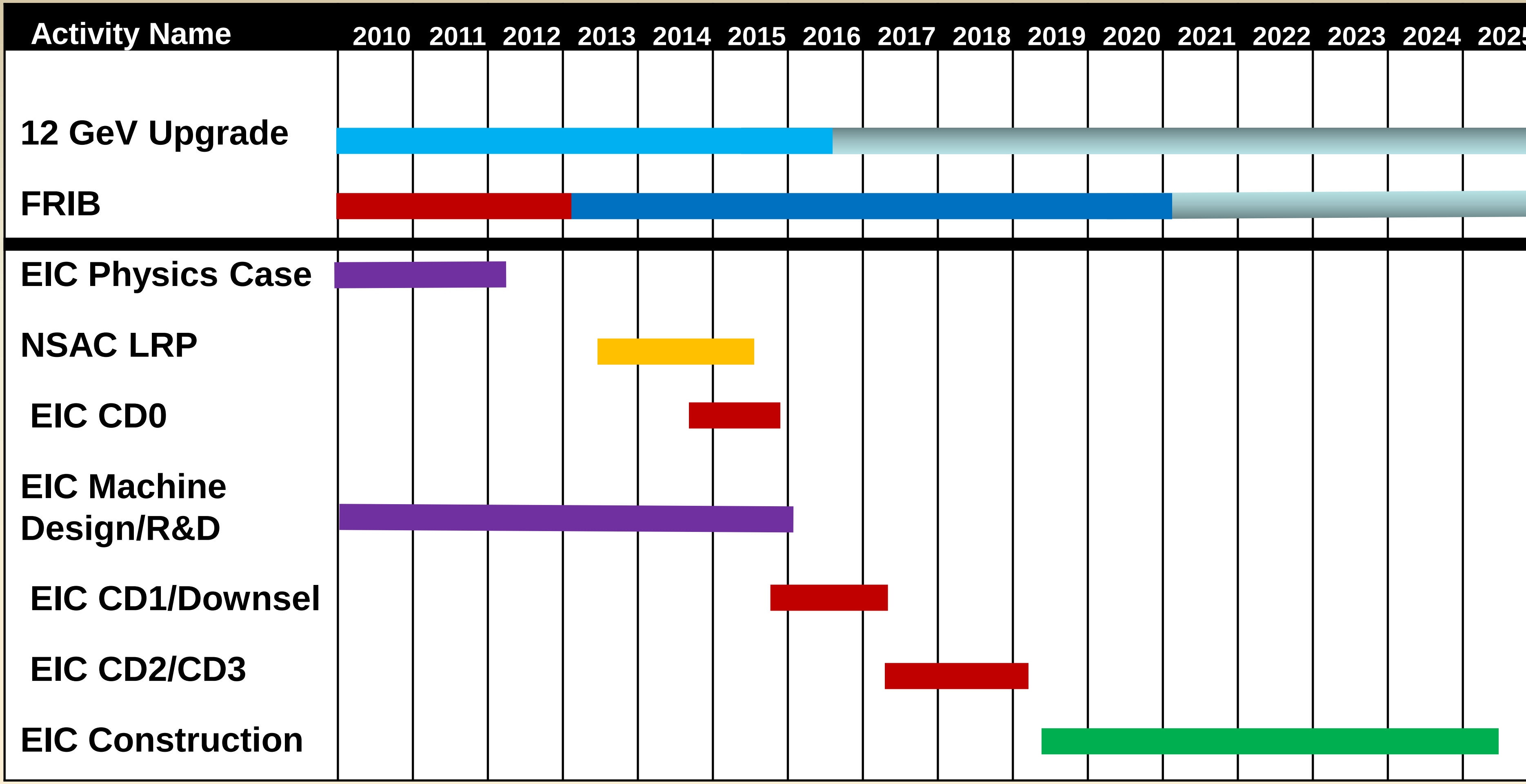
Medium Energy EIC@JLab



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}
- Upgradable to higher energies
  250 GeV protons + 20 GeV electrons

EIC Realization Imagined

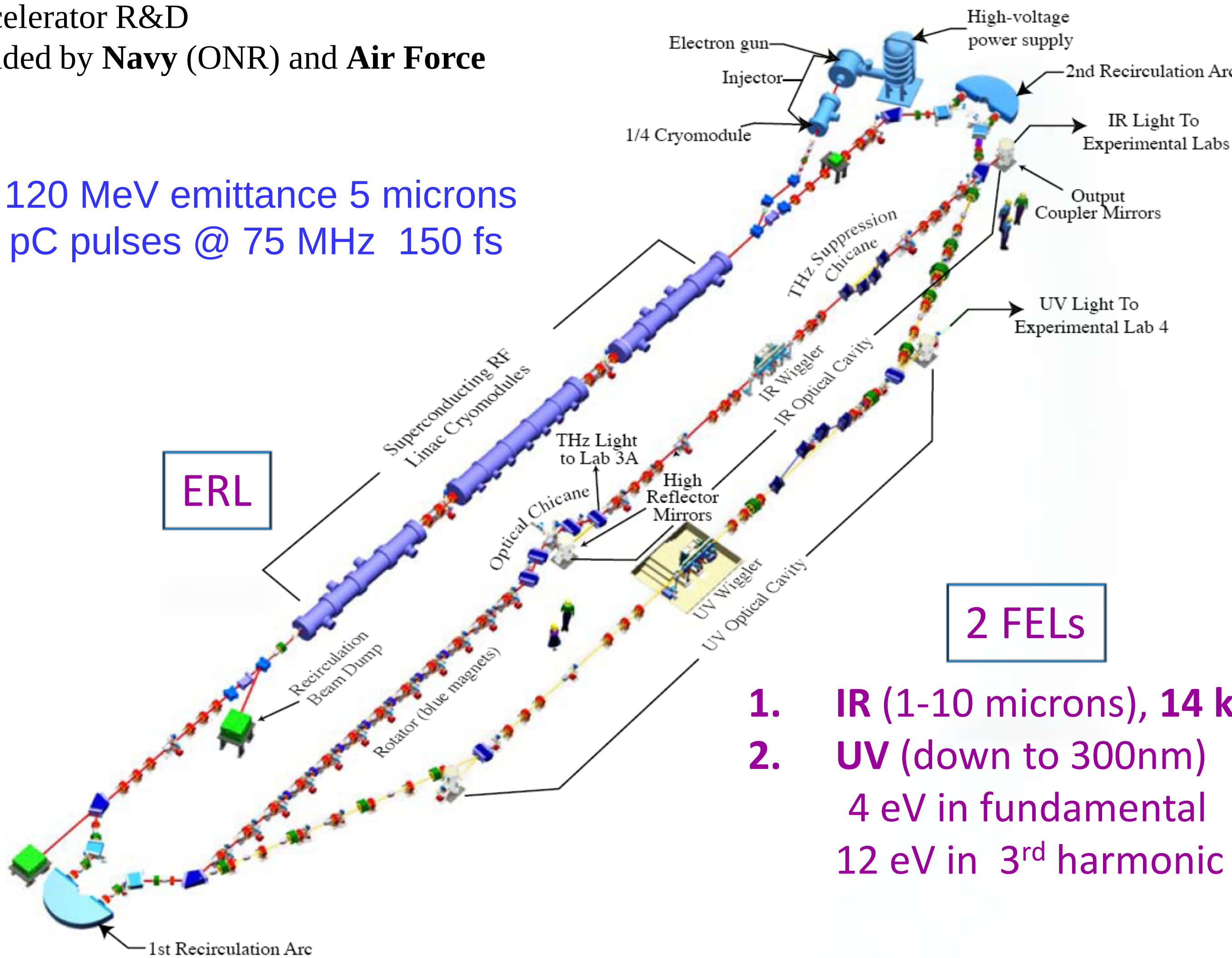


Assumes endorsement for an EIC at the next NSAC Long Range Plan
Assumes relevant accelerator R&D for down-select process done around 2016

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



ERL

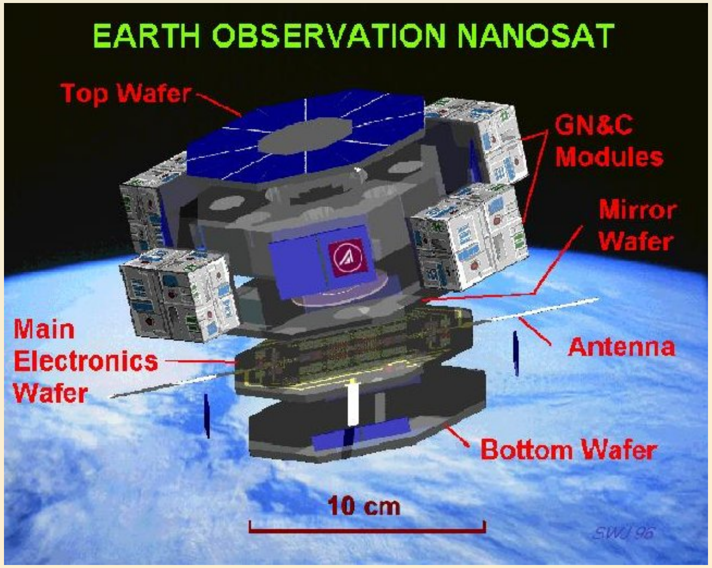
2 FELs

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

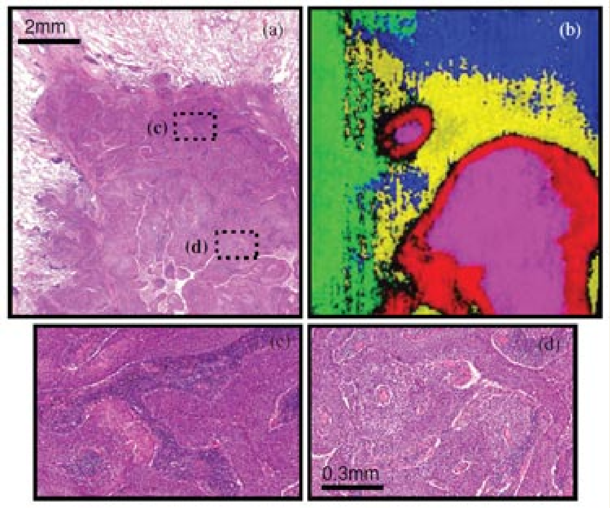
Free Electron Laser - Applications

- JLab Free Electron Laser (FEL) started in 1997, mostly DoD funded at total cost of > $110M, built on NP technology to stay on the frontier of FEL technology
  - Developing 100 kW class laser in partnership with Office of Naval Research
  - THz, IR and UV beam lines

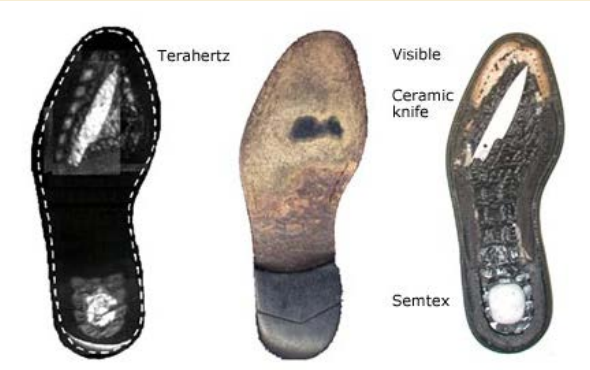
Micro Fabrication



THz Medical



THz Security



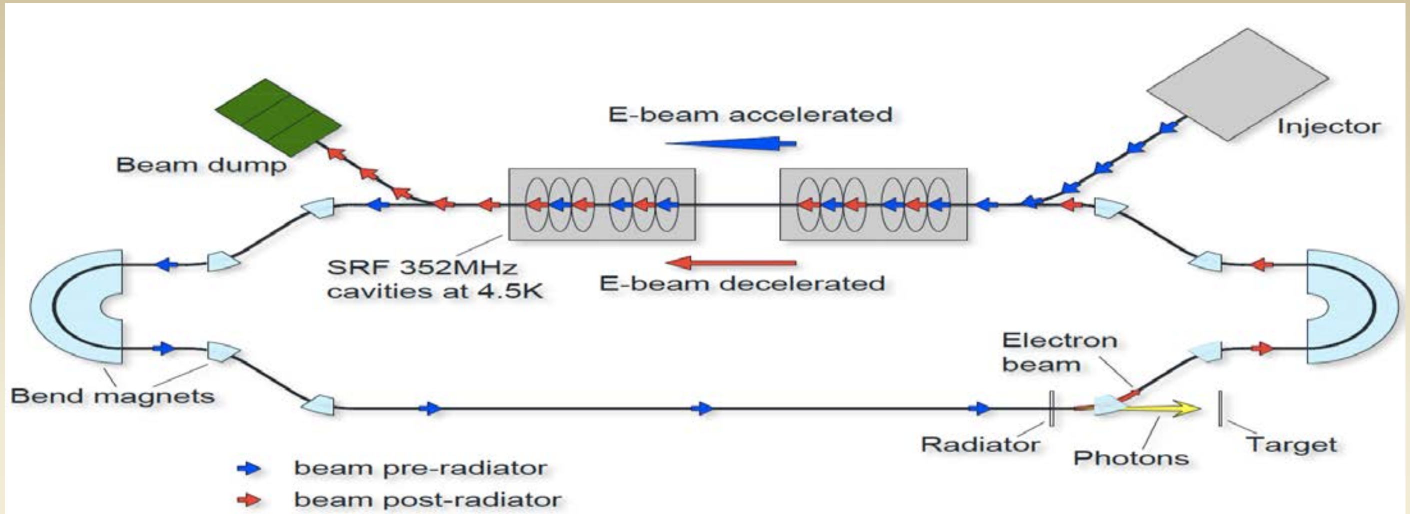
Images courtesy of Teraview Inc.

THz Visible Sole removed

Jefferson Lab

Energy Recovery Linac-Based Isotope Production

^{67}Cu

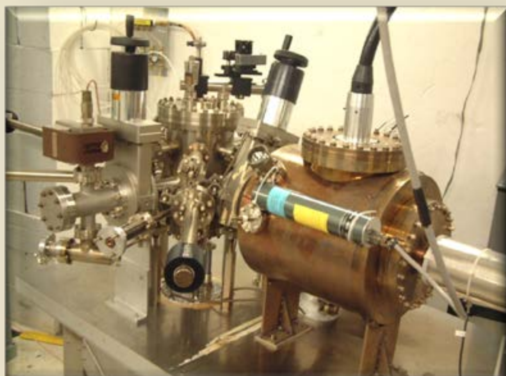


- Can be built in a hospital basement or in a distribution center within an hour or two of tens of hospitals and research establishments for production of isotopes such as ^{67}Cu (useful for both therapy and imaging)
- ERL technique is energy efficient because it enables the recovery of energy of the electrons that do not produce gammas in the radiator
- Superconducting Radio Frequency accelerator rather than copper structures means that the integrated costs (construction plus operation) are significantly lower
- At 50 MeV electron energy and 3 mA current, it takes 2.5 mins to produce 1 mCi of ^{67}Cu at a cost of $1.25 not including include separation costs

Polarized Electron Source

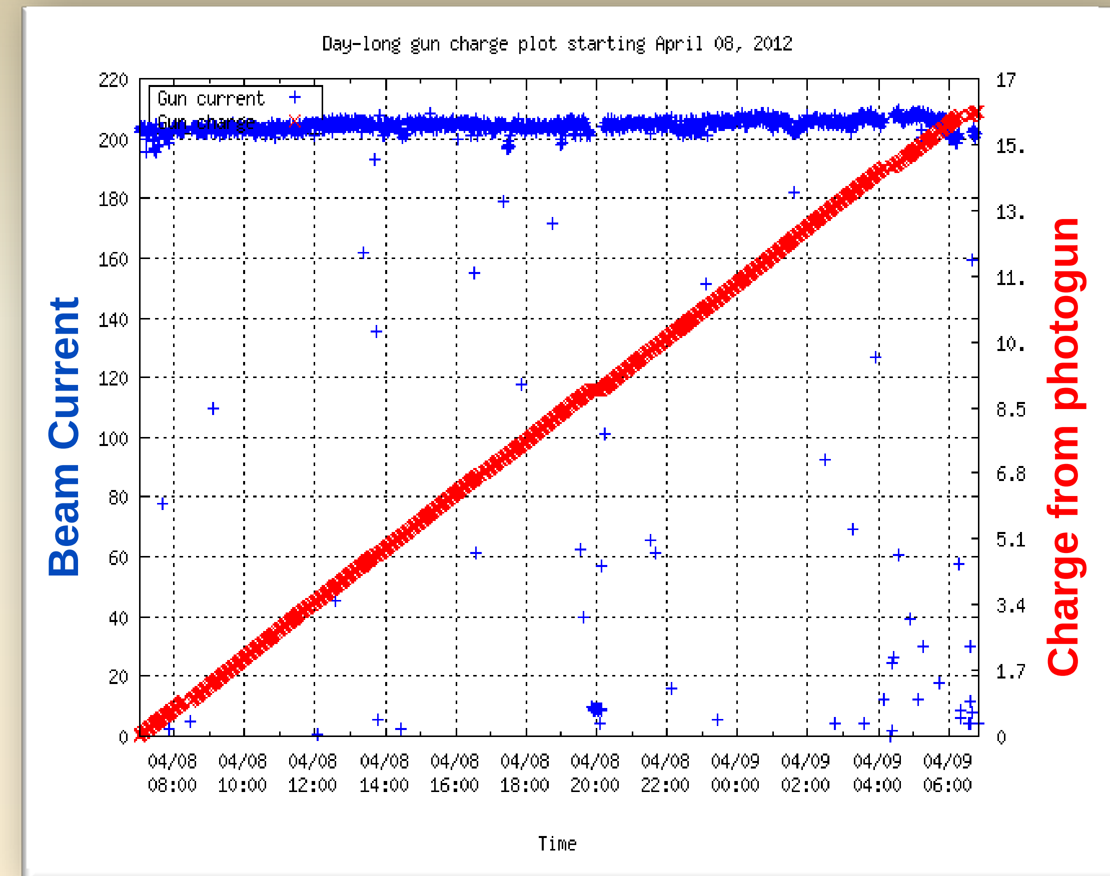
B. Matthew Poelker
2011 E. O. Lawrence Award

"Inverted" Insulator Design



Electron Gun Requirements

- Ultrahigh vacuum
- No field emission
- Maintenance-free



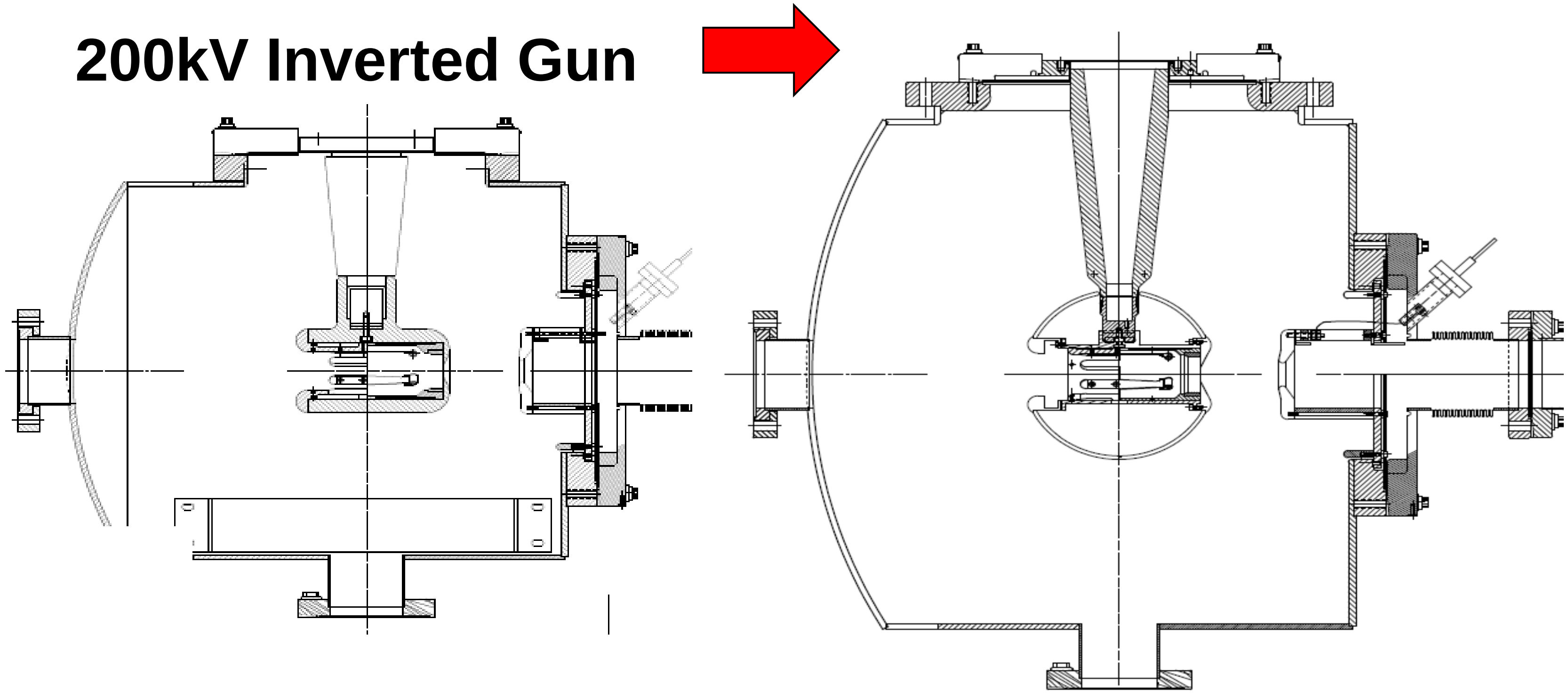
24 Hours

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

500 kV Inverted Gun – Path Forward Idea

Goals: Current, Brightness, Lifetime & Polarizaation

200kV Inverted Gun

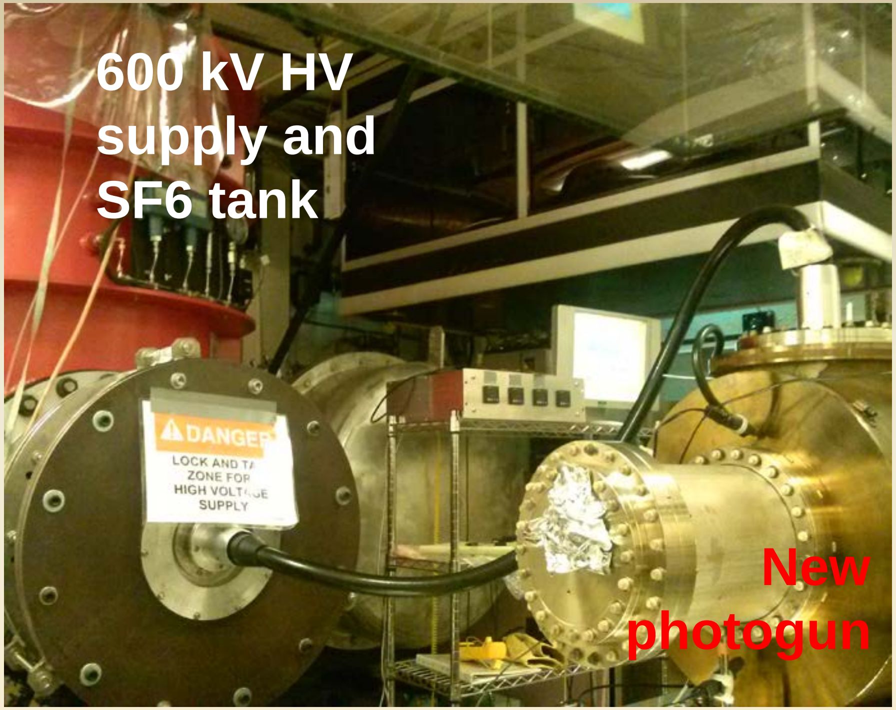


Benefits of Inverted Design

- Less metal biased at high voltage
- Fewer regions of high field strength
- Insulator not exposed to field emission

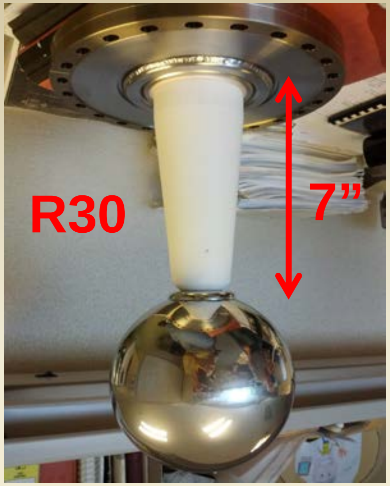
- Longer insulator “R30”
- Spherical electrode
- Thin NEG sheet to move ground plane further away

500 kV Inverted Gun Tests



Tests Underway at FEL Gun Test Stand

- Glassman 600 kV HV supply, inside SF6 tank at 10 psi
- Commercial HV receptacle and cable to attach to photogun



Pure alumina insulator, arced to ground at 330kV, atmosphere side of insulator

Short partially conductive insulator, happy at 330kV

Work of C. Hernandez-Garcia, J. Hansknecht

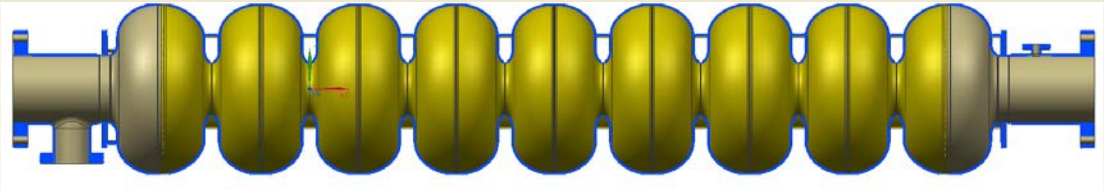
12 GeV Upgrade – C100 Cryomodule Status

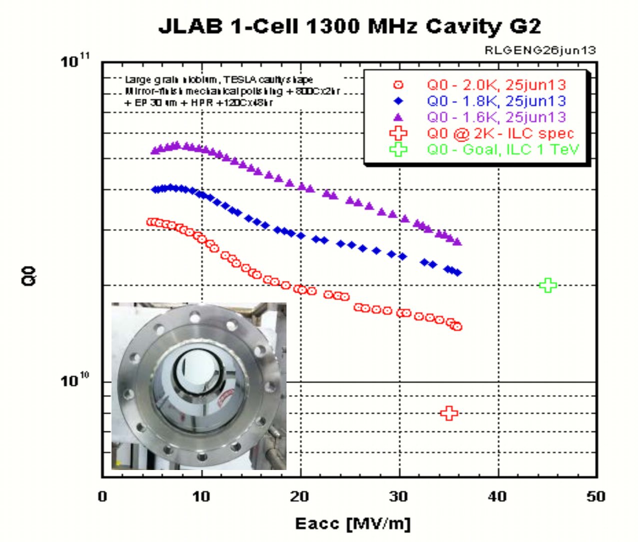
- **The C100 Cryomodule Project which began in 2009 is nearing its end.**
  - Nine of the Ten Installed C100 Cryomodules have been Successfully Commissioned:
  - **Average Max Operating Gradient = 19.6 MV/m (Design goal = 19.2 MV/m)**
  - **Average Q_0 at 19.2 MV/m = 8.1E9 (Design goal = 7.2E9)**
  - **Average Energy Gain = 110 MV (Design goal = 108 MV)**

- **Two of these Cryomodules have been Operated with Beam**
- **One has Successfully Operated at 108 MV with full beam loading of 465 μA**

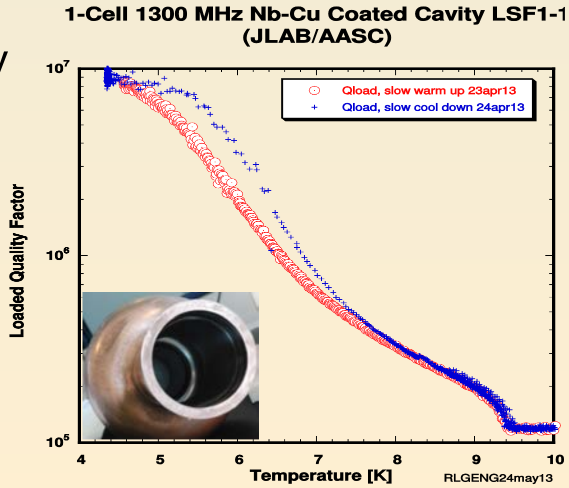
High Gradient SRF R&D

- Push for <u>ultra-high-gradient, high-Q_0</u> cavity (Goal: 50 MV/m at Q_0=1E10, 2K)
  - Reduce field emission
    - X-ray mapping for field emitter localization
    - Mirror-finish mechanical polishing (inset photo at right)
  - New Low-Surface-Field shape 9-cell cavity (model below)
    - 18 half-cells formed, heat treated and weld-prep machined





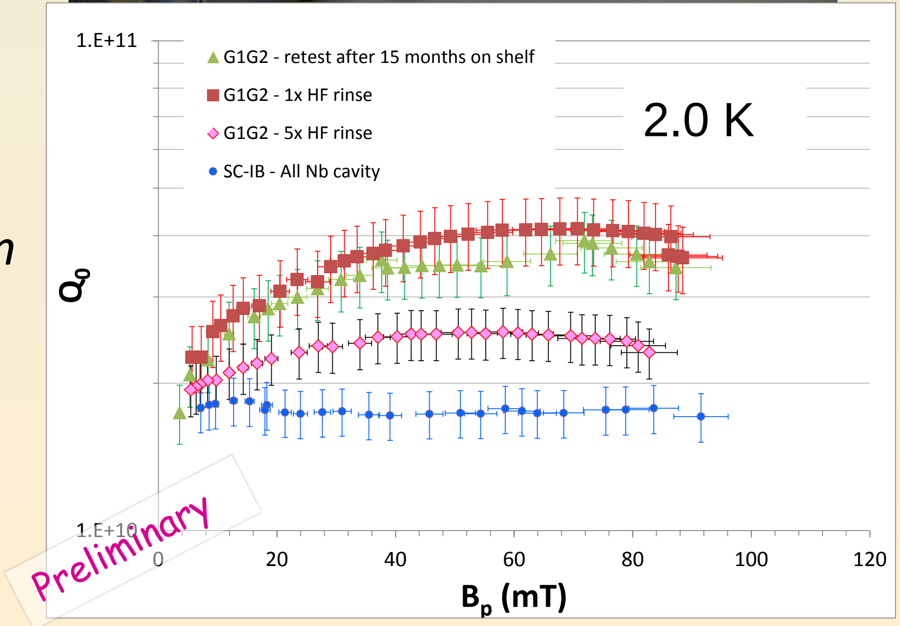
- Push for inexpensive SRF
  - Niobium coated copper cavity in collaboration with US industry
    - 1st 1-cell niobium coated copper cavity coated (inset photo at right)
    - Excellent coating adhesion to copper cavity inner surface
      - Mirror finish mechanical polished before coating
      - No delamination at standard HPR rinse or after 450C baking
    - High residual resistance (~ 9 μΩ) under investigation
      - Hydrogen removal by vacuum furnace heat treatment
      - Film structure analysis from cut-out samples



High Q_0 R&D

G. Ciovati et. al.

- Induction furnace successfully re-commissioned in Test Lab North Annex
  - *New Ultra-High Purity gas delivery system (H_2, O_2, Ar, N_2)*
  - *New ISO 4 soft-wall clean room*
  - *New water cooling system*
- Investigation of "low-field Q-rise" by sequential nanoremoval and heat-treatment of "all Nb" cavity
  - *The effect is confined to the top ~10 nm*
  - *~1 at.% Ti within the RF penetration depth seems necessary*

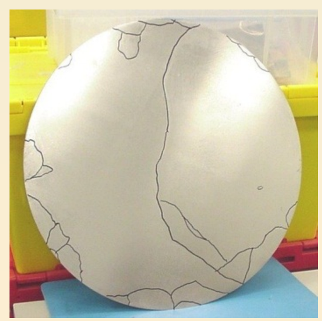


Ingot and Low RRR Niobium

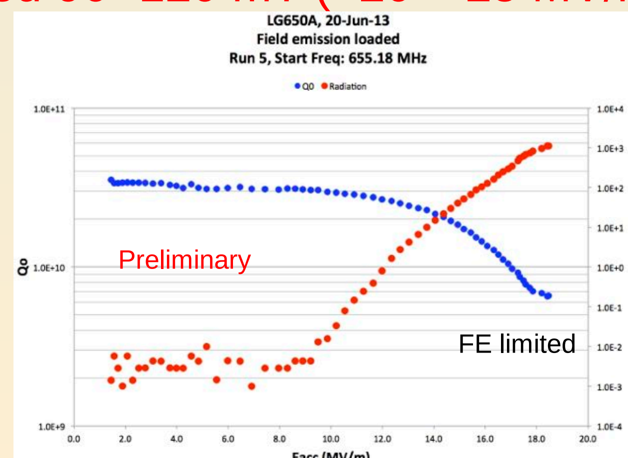
Peter Kneisel

- With the limited capabilities due to the refurbishing of the test lab the material studies concentrated on two aspects:
  - Investigate cavities from large grain niobium, which had been enlarged for low frequency (650 MHz) cavities
  - Investigate the performance capabilities of lower RRR material (~70), both large grain and fine grain, for less demanding projects for cost savings reasons
- Three 650 MHz single cell cavities have been fabricated from enlarged high RRR material (1) and reactor grade Nb (2)
- Three CEBAF type single cell cavities were also fabricated: one large grain with RRR~140; two fine grain from RG niobium. All reached 90- 120 mT (~20 – 25 MV/m)
- The 650 MHz cavities are under investigation

Three 650 MHz test cavities



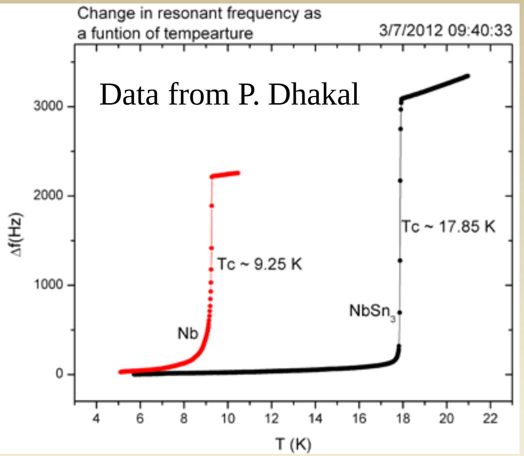
19” disk made by enlarging smaller slice



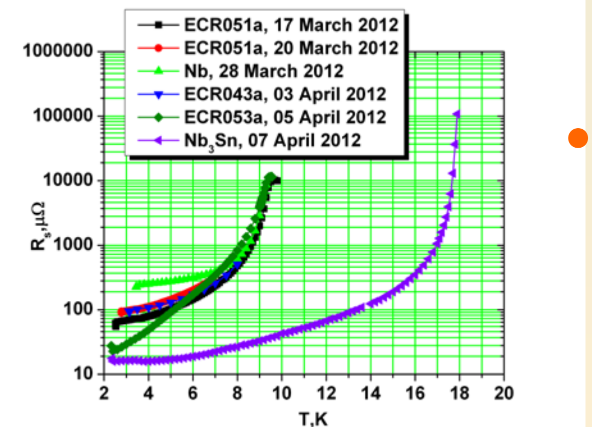
First test of 650 MHz cavity made from enlarged ingot slice

Nb_3Sn Progress

Grigory Eremeev



Transition temperature is ~ 17.85 K. The best of three samples shows very smooth surface with no residual tin contamination



Recent measurements of surface resistance of several ECR films, bulk Nb sample, and Nb_3Sn sample as a function of temperature at 7.4 GHz.

- Preliminary studies with samples have been done. RF measurements on a sample indicated the transition temperature of 17.9 K and RF surface resistance of about 30 $\mu\Omega$ at 9 K and 7.4 GHz.
- The horizontal insert has been built and inserted in the furnace. The first furnace run has been done at 1,200 °C for 2 hours.
- R&D furnace for Nb_3Sn development has been delivered.

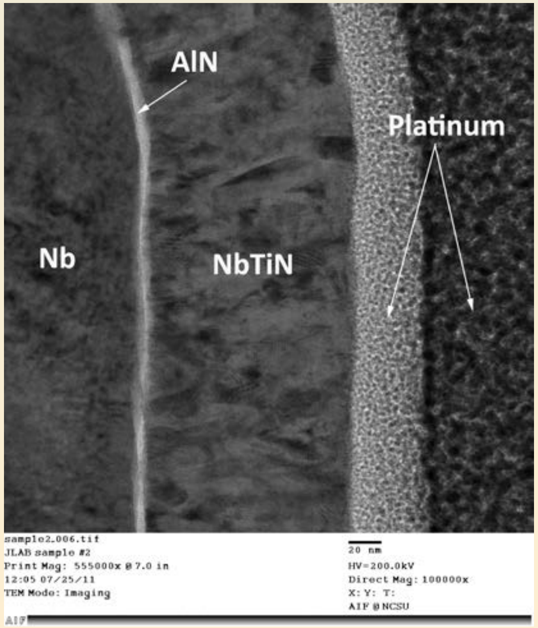
SRF Thin Film Development

Charlie Reece et. al.

JLab continues to lead a multi-lab collaboration to integrate analysis of growth modes and material characterization (JLab, W&M, NSU, ODU, ANL, LBNL, MIT, UMD, UIL, NCSU).

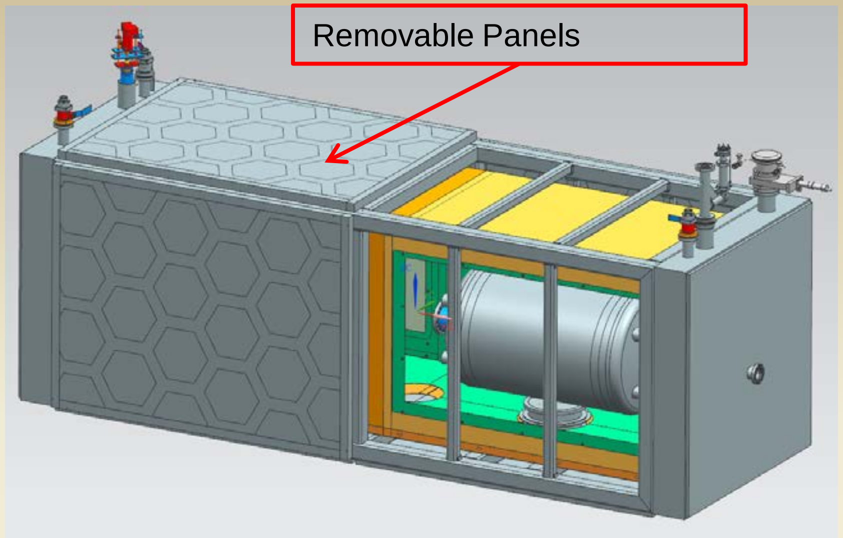
- Systematic study of Nb ion deposition energy affect on film quality distinguished optimum energy for film nucleation (first few monolayers) from optimum energy for film growth – yields very high quality Nb on Cu substrate.

- Multi-layer SRF films demonstrated enhanced magnetic flux penetration field. RF characterization coming in the next year.
- Developing techniques for NbTiN/AlN multilayer film growth.
- SBIR collaboration with AASC guiding evaluation and interpretation of test cavities coated by AASC.
- New Nb cavity deposition system under construction to exploit lessons learned to date from small samples.



Low Cost Box Cryostat Design

John Mammosser

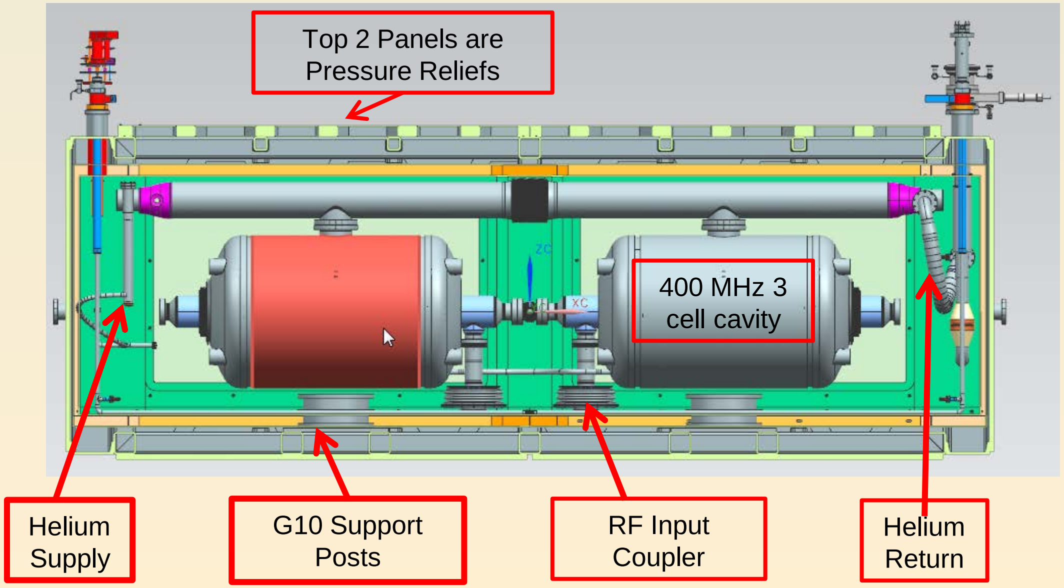


Basic concept is a simple box:

- Structure is square tube stainless steel frame
- Removable panels for servicing and upgrading
  - Removable support struts
  - Removable thermal shield panels
  - Vacuum sealing o-ring fabricated in face
- Bottom and ends are stainless steel plate

Panel Options:

- Honeycomb sandwich
- Stainless sandwich



Jefferson Lab

New SRF Infrastructure

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

TEDF (Technology Engineering Development Facility)

TLA (Test Lab Addition- 14,000 sft addition to Test Lab)

(8,600 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

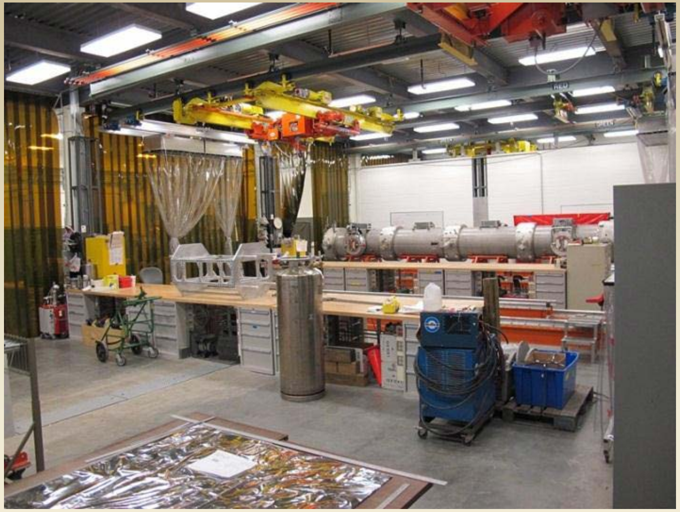
- Completely new infrastructures
- Phase 1: existing equipment and tools
- Phase 2: incremental acquisition of new equipment and tools

TLA occupancy: summer 2012

Test Lab renovation: Completed summer 2013

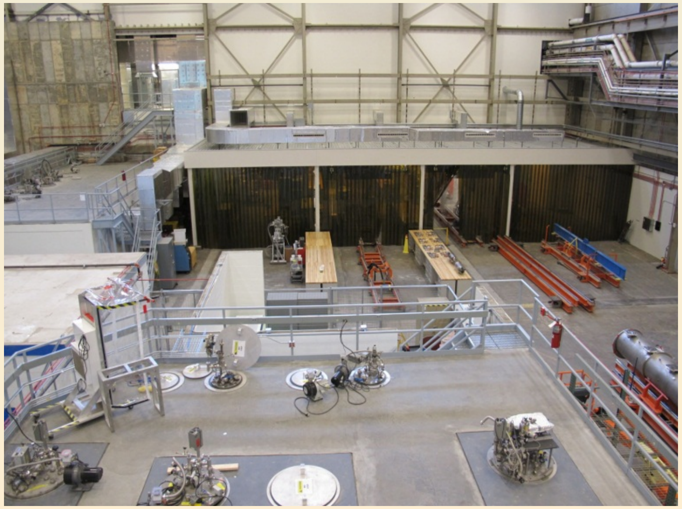
Renovated Test Lab Facilities

VTA with expanded service area



Cryomodule assembly area

New Thin films lab

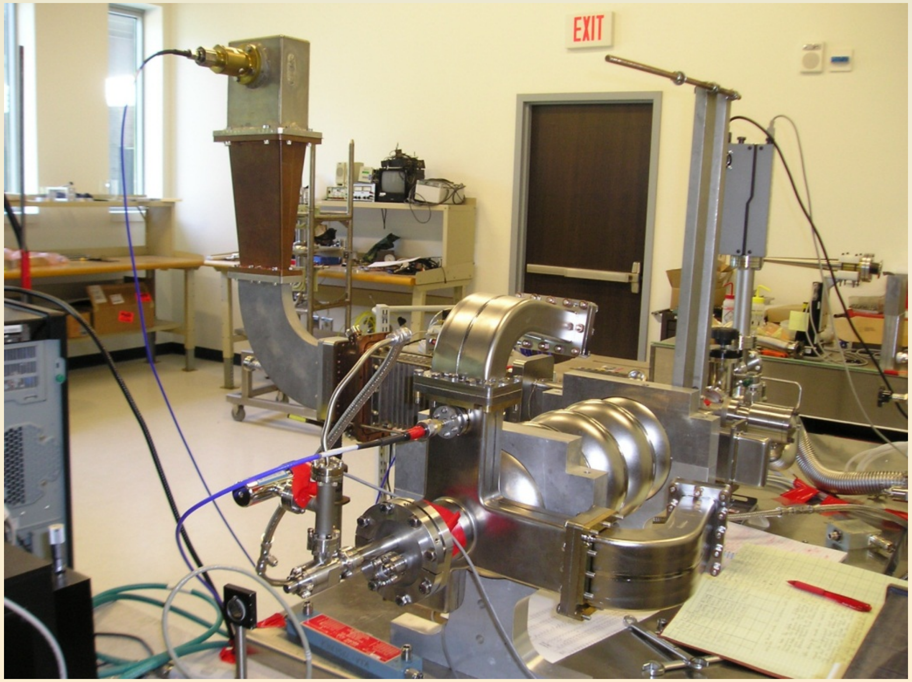


Renovated high bay area

Plasma Processing Setup

Shahid Ahmed
John Mammosser

- Plasma processing using active gasses (e.g. O_2, Cl)
  - Can remove surface hydrocarbons and other contaminants
  - Can be done in 5-cell cavity with standard FPC coupling
  - Could significantly reduce cryogenic load from FE in CEBAF



5-cell cavity test set up

View of microwave glow discharge inside the cavity

Cryogenic Plant Doubling

CHL Compressors are installed and commissioned

Cryogenic Plant Doubling

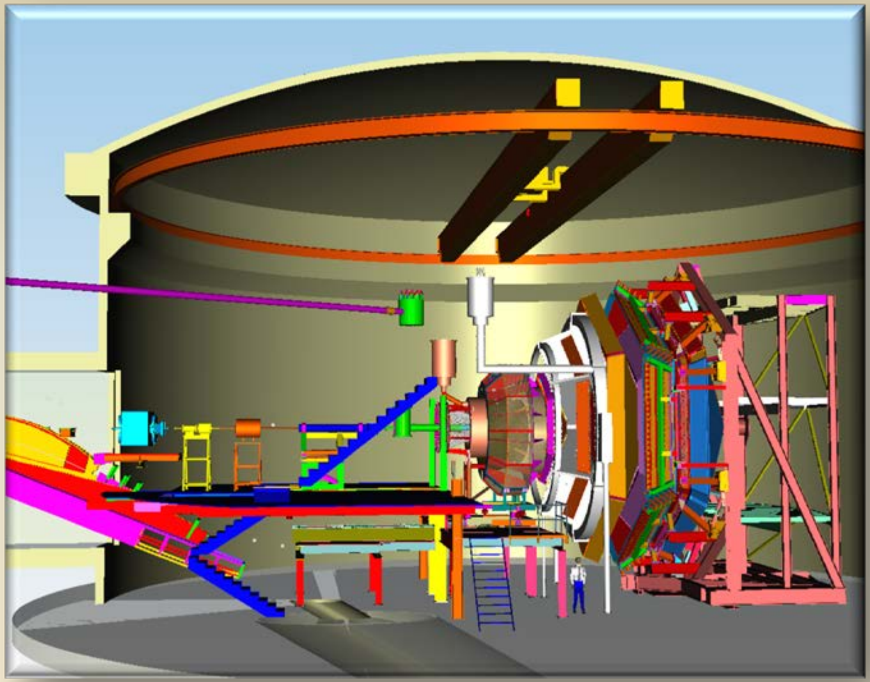
Installation of Cold Boxes complete

UPPER COLDBOX

LOWER COLDBOX

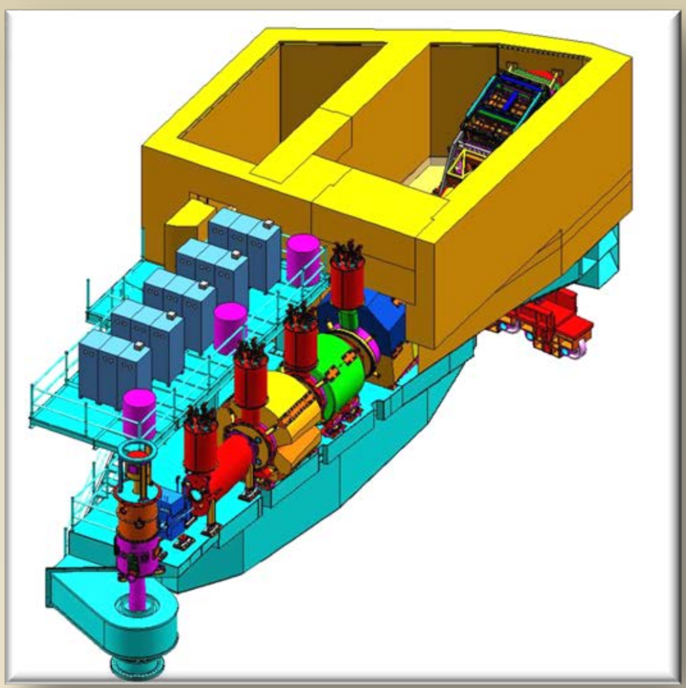
Physics Detectors and Experimental Halls

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

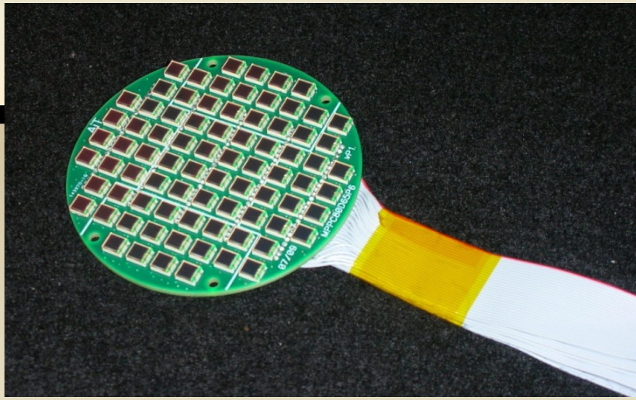
- gas based detectors
- standard and position-sensitive photomultiplier tubes (PSPMTs)
- silicon photomultipliers (SiPMs)
- scintillation and light guide techniques
- fast analog readout electronics and data acquisition
- on-line image formation and analysis
- 3D image reconstruction algorithm development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

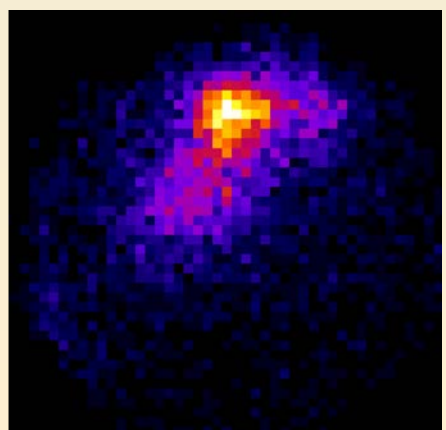
- Support design and construction of new detector systems-
  R+D detector components & systems for all Jefferson lab and others
- Technical consultants for the lab scientists and users
- Development and use of imaging and non-imaging detector systems

Dilon 6800 Gamma Camera
Breast-Specific Gamma Imaging

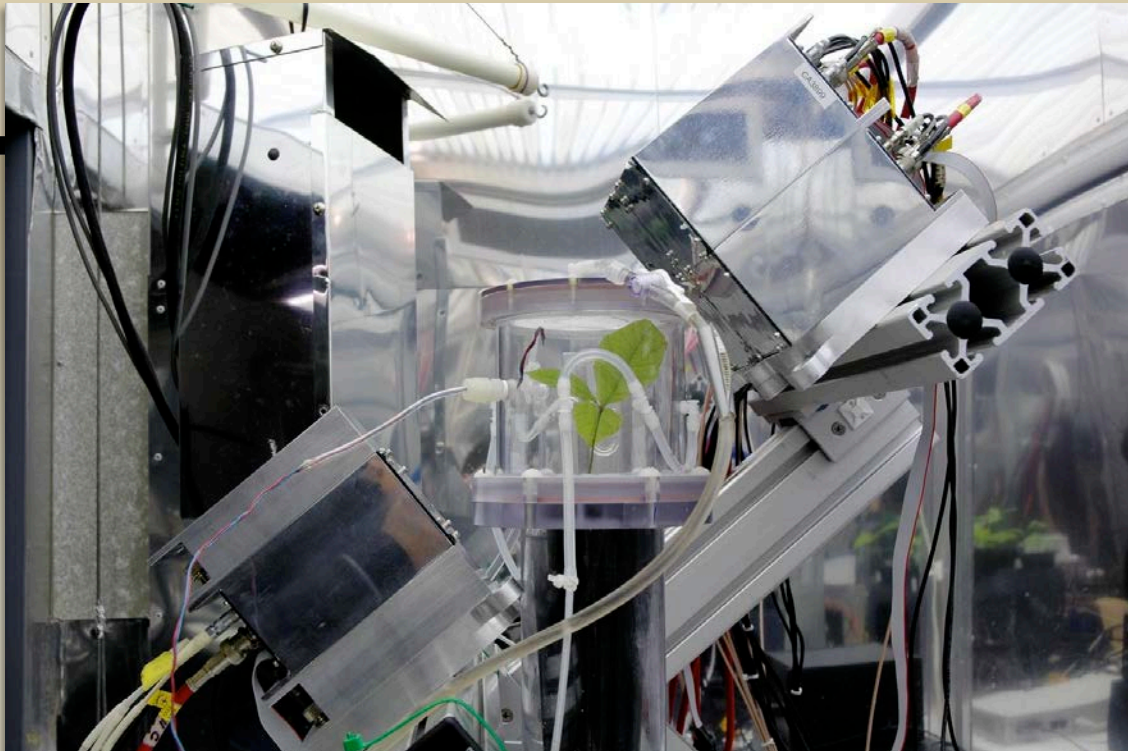
Dilon Technologies, Inc.
Newport News, Virginia
~20 employees

Several patents licensed from JLab



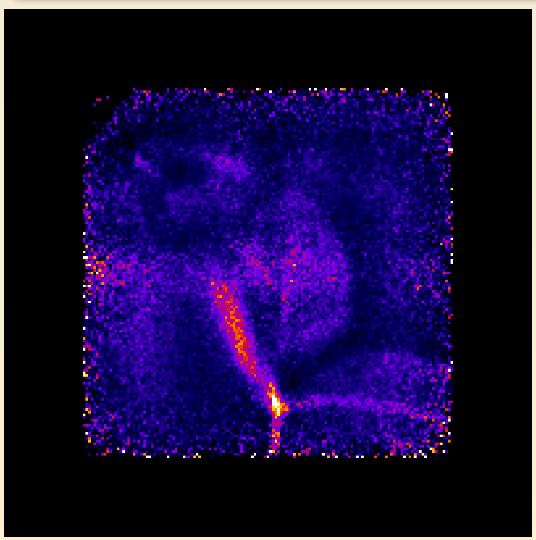


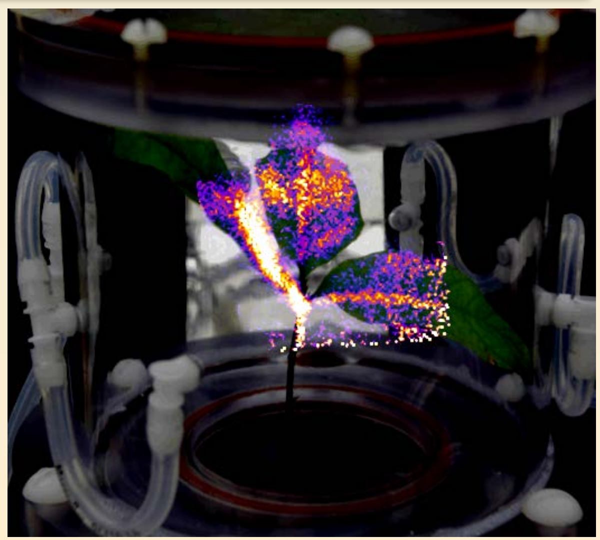
Compact JLab built handheld “gamma camera” used to assist surgery. Clinical trials at University of Virginia



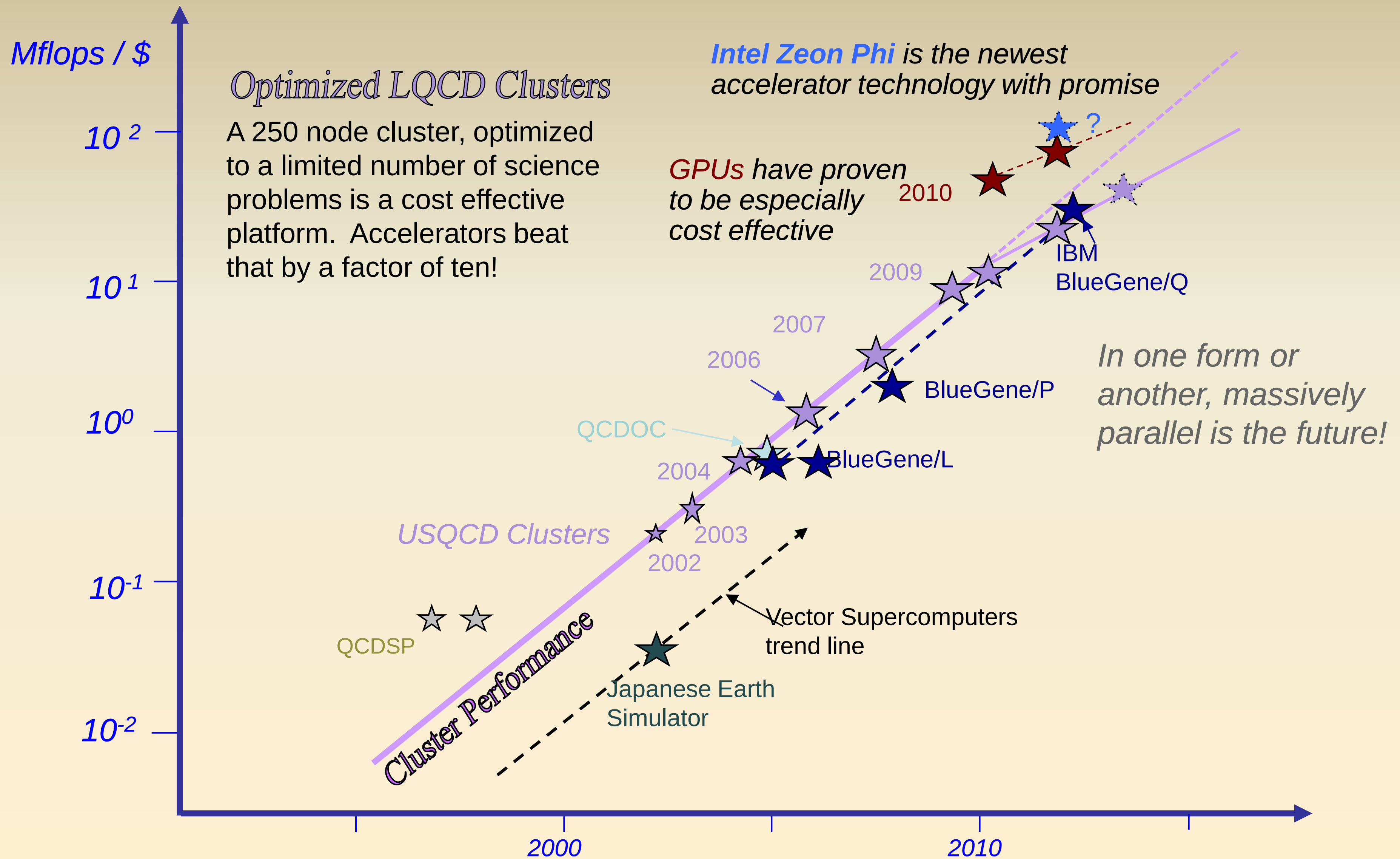
Photosynthesis studies at Duke University Phytotron

Carbon-11 tagged carbon dioxide imaged in live plants with JLab detectors





Science per Dollar for (some) LQCD Capacity Applications



SBIR/STTR Area Contacts

Computing	Chip Watson, Balint Joo, Jie Chen
Cryogenics	Dana Arenius, Kelly Dixon
e-sources	Matt Poelker, Carlos Hernandez-Garcia
EIC/MEIC	Rolf Ent, Geoffrey Krafft, Yuhong Zhang
Electronics, Data Acq	Chris Cuevas, Graham Heyes
Energy (ADS)	Andrew Hutton, Fulvia Pilat, Ganapati Myneni
ERL & FEL	George Neil, Steve Benson, David Douglas
Imaging	Drew Weisenberger
Instrumentation	John Musson, Omar Garza
Isotopes	Andrew Hutton, Fulvia Pilat, Hari Areti
Radcon	Vashek Vylet
RF	Curt Hovater, Rick Nelson, Tom Powers
SRF	Bob Rimmer, Charlie Reece, Joe Preble
CFO, CIO & CTO	Joe Scarcello, Roy Whitney

Letters of Support & Current CRADAs

SBIR/STTR letters of support provided in October 2013: 11 letters for 8 companies

Active CRADAs

Company	Title	Funds-in ($)	Funds-total ($)
Muons	High Power Co-Axial SRF Coupler	209,760	750,000
Muons	Alternating Dispersion Muon Cooling Channel	225,000	750,000
Muons	RF Power Source for Magnetron	50,000	200,000
Radiabeam	Advance Additive Manufacturing Method	106,086	1,000,000
MuPlus	Complete Muon Cooling Channel Design	300,000	1,000,000
BNNT	(IP being processed for patenting)	0	98,594

SBIR/STTR – Connecting to Tech Transfer

There are changes coming in the DOE Tech Transfer program

Much greater emphasis on successful commercialization

Prediction: These changes will impact SBIR/STTR

Conclusions

There is a rich tradition at JLab of working with others (CRADAs & WFOs)

The SBIR/STTR program consistently leverages JLab core capabilities

We intend to advance the JLab SBIR/STTR program including enhancing connections to Tech Transfer