The TJNAF Facility and the SBIR/STTR Program

Fulvia Pilat

DoE-NP SBIR/STTR Exchange Meeting Aug 6-7 2015

Jefferson Lab

Thomas Jefferson National Accelerator Facility

Outline

Jefferson Lab intro and program

- 12 GeV Project
- 12 GeV Operations
- WFO: LCLS-II and FRIB
- MEIC

FY16 STTR/SBIR topics and JLAB

Highlights of R&D opportunities

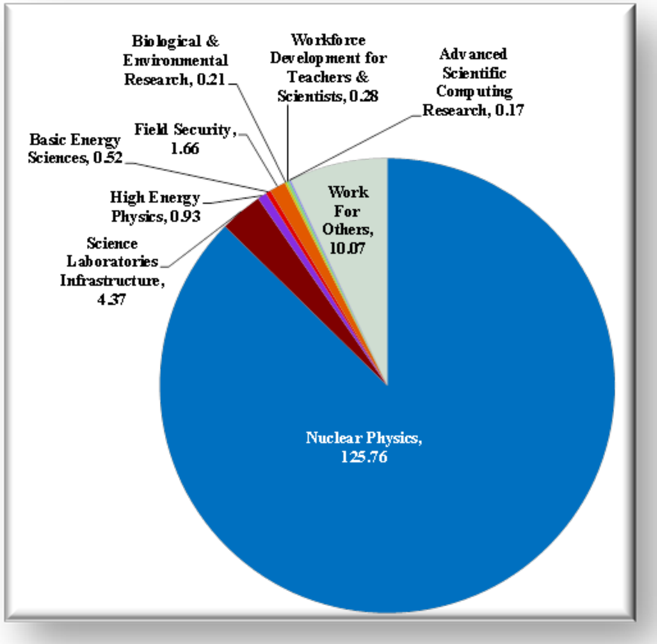
- Accelerator Technology
  MEIC focused Accelerator R&D (overview, magnet, SRF, sources…)
  General Accelerator R&D (Injectors, SRF R&D, CASA….)
- Instrumentation, Detection Systems and Techniques
- Nuclear Physics Isotope Science and Technology
- Software and Data Management
- Electronics Design and Fabrication

Jefferson Lab At-A-Glance

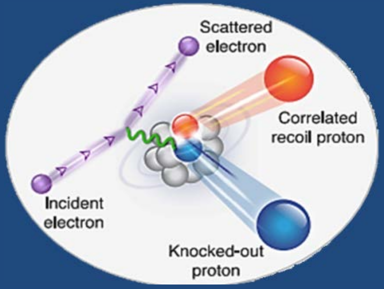
- **Created to build and Operate the Continuous Electron Beam Accelerator Facility (CEBAF), world-unique user facility for Nuclear Physics:**
  - Mission is to gain a deeper understanding of the structure of matter
    - Through advances in fundamental research in nuclear physics
      - Through advances in accelerator science and technology
  - In operation since 1995
  - 1,380 Active Users
  - 178 Completed Experiments to-date; 70 have been approved for the future 12 GeV program
  - Produces ~1/3 of US PhDs in Nuclear Physics (504 PhDs granted to-date; 200 in progress)
- **Managed for DOE by Jefferson Science Associates, LLC (JSA)**
- **Human Capital:**
  - 673 FTEs
  - 26 Joint faculty; 24 Post docs; 4 Undergraduate, 34 Graduate students
- **K-12 Science Education program serves as national model**
- **Site is 169 Acres, and includes:**
  - 81 Buildings & Trailers; 890K SF
  - Replacement Plant Value: $384M

FY 2014:

Total Lab Operating Costs:	$144.0M
Total DOE Costs:	$134.0M
SPP (inc. DOE non-NP) Costs:	$10.1M



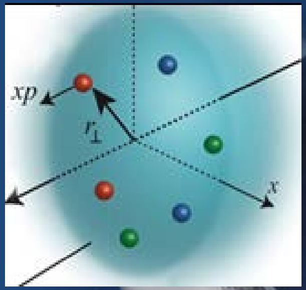
JLab: A Laboratory for Nuclear Science



Nuclear Structure

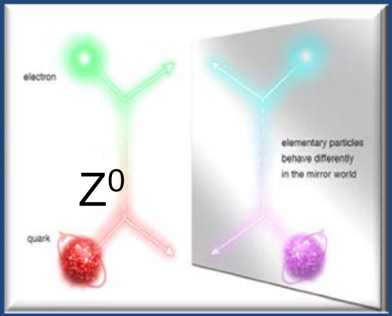
Medical Imaging

Cryogenics



Structure of Hadrons

Accelerator S&T



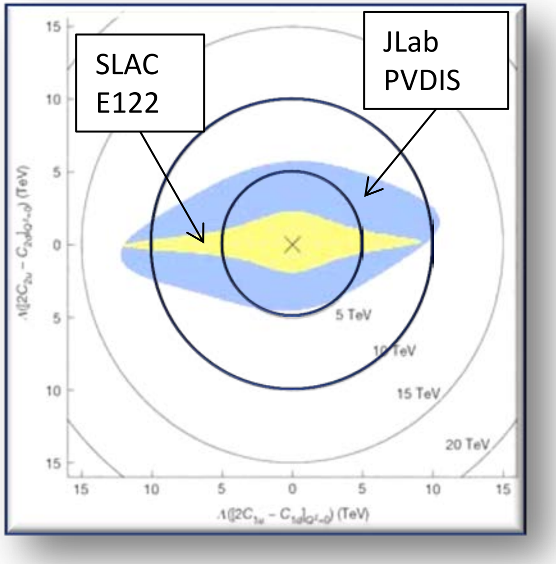
Fundamental Forces & Symmetries

Nuclear Astrophysics

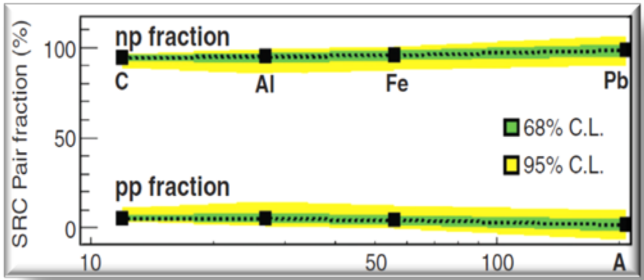
Theory & Computation

JLab 2014

Nature 506, 67 (6 February 2014)
Parity Violating DIS

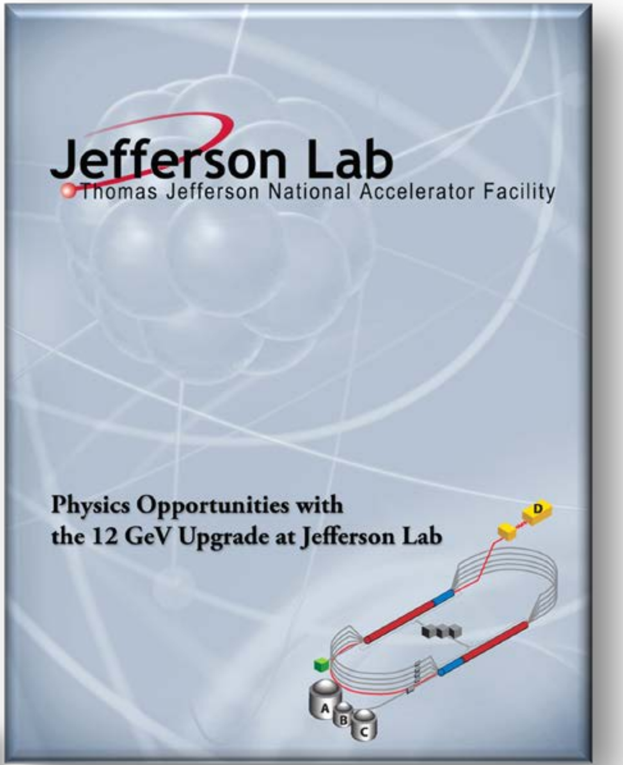


Science 346, 614 (October 2014)
Short Range NN Correlations



Near-Future

Decade of Experiments Approved
Eager to Start 12 GeV Science!



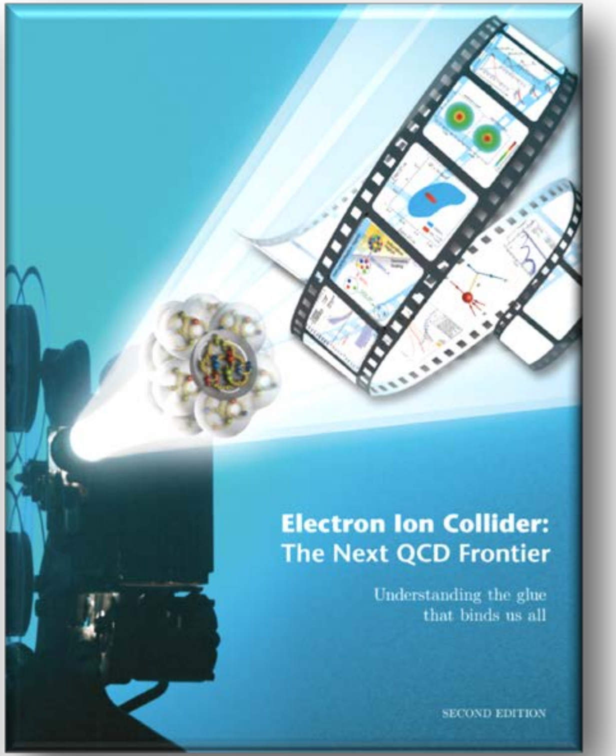
Jefferson Lab
Thomas Jefferson National Accelerator Facility

Physics Opportunities with
the 12 GeV Upgrade at Jefferson Lab

- **Confinement**
- **Hadron Structure**
- **Nuclear Structure and Astrophysics**
- **Fundamental Symmetries**

Future

Electron Ion Collider
The Next QCD Frontier



Electron Ion Collider:
The Next QCD Frontier

Understanding the glue
that binds us all

SECOND EDITION

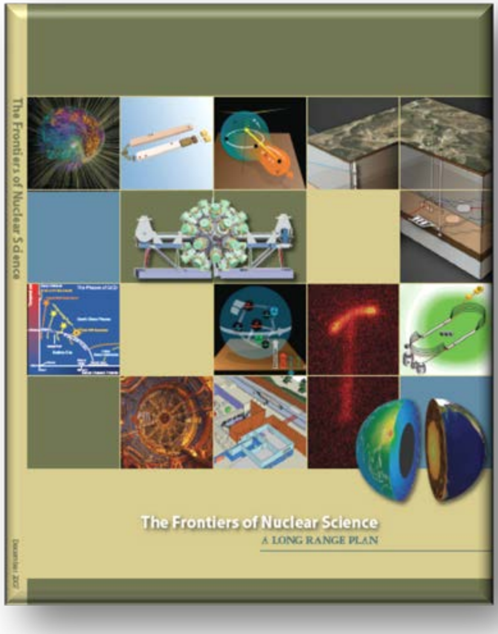
Role of Gluons in Nucleon and Nuclear Structure

Director’s Perspective

This is an exciting time for the lab, poised to embark on a major new scientific program. The management team is strong and the staff are highly skilled and talented. We continually work to improve our safety record. And the user community is very active and engaged.

- Continued emphases:
  - Finish the 12 GeV upgrade project, safely, on time, and within budget.
  - Restore full-time operations with all Halls operational at the performance levels to produce outstanding physics. Operations budgets are a concern here.
  - Advance new NP projects to exploit the scientific capability of the upgrade (MOLLER and SoLID)
  - Manage the large projects, like FRIB and LCLS-II, for success while ensuring the health of all aspects of the core NP program.
  - Develop MEIC to provide the international NP community with a viable path to a future physics era.

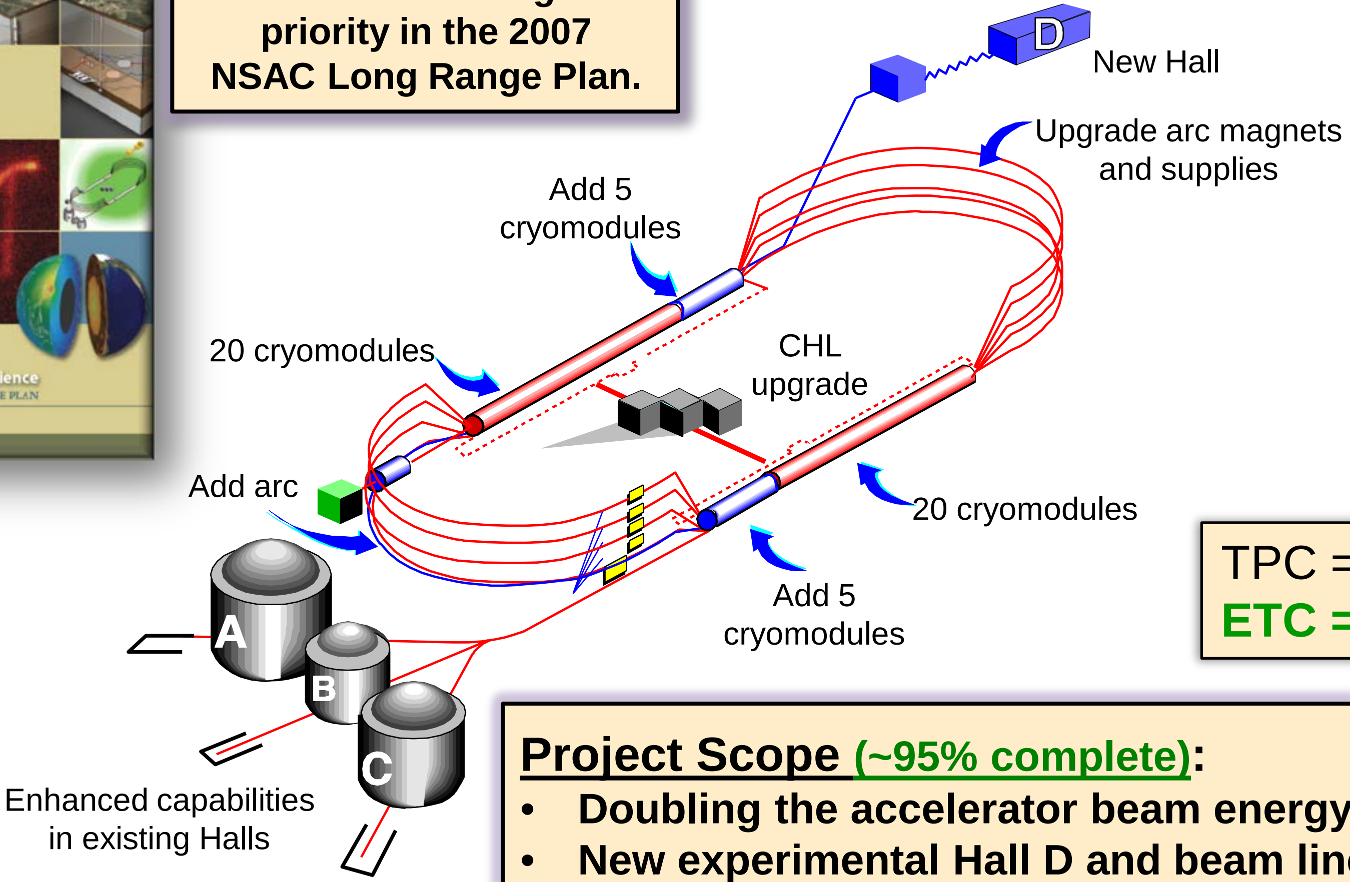
12 GeV Upgrade Project


The Frontiers of Nuclear Science

A LONG RANGE PLAN

Completion of the 12 GeV CEBAF Upgrade 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.



TPC = $338M

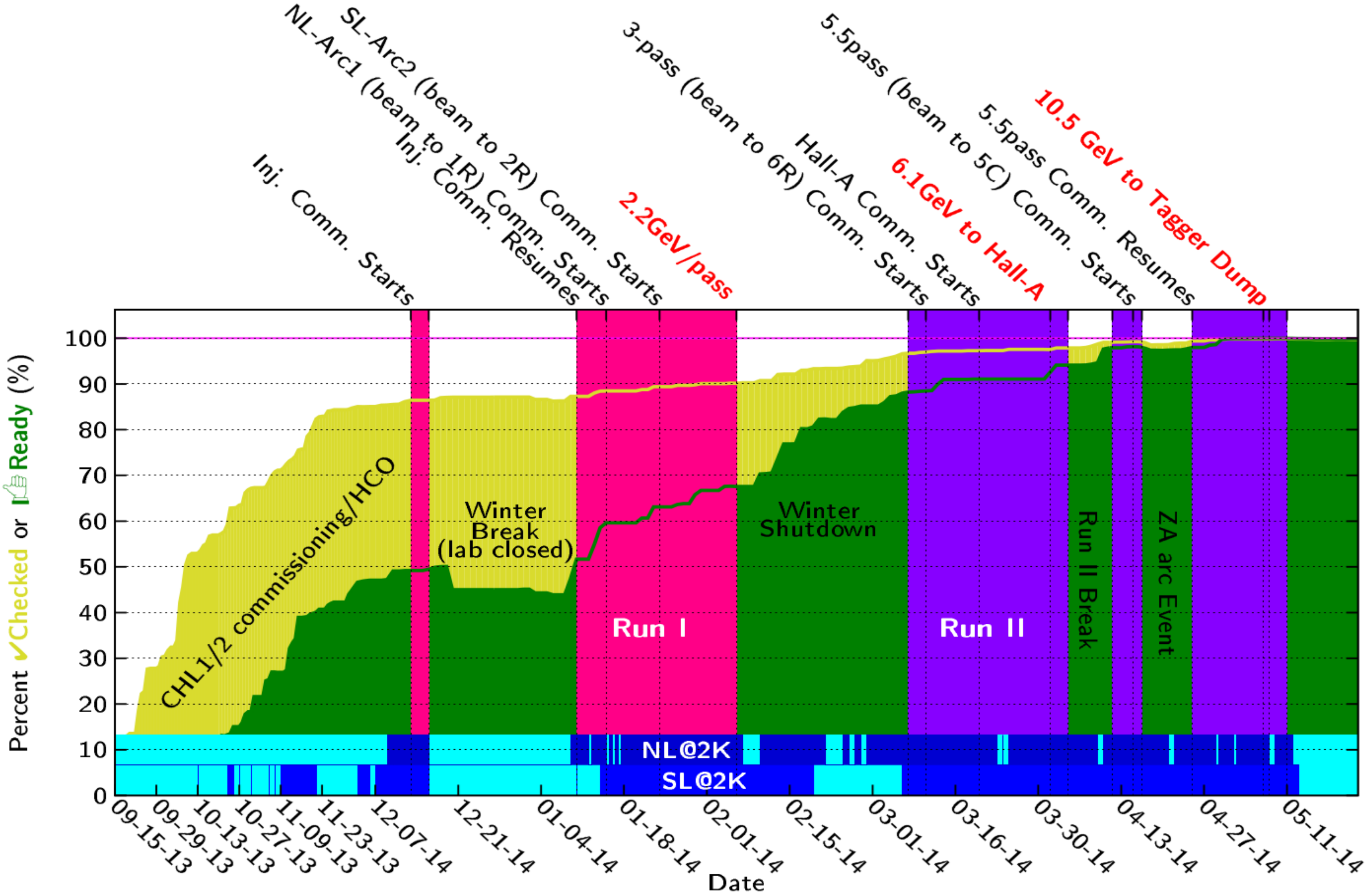
ETC = ~$18M

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

Project Scope (~95% complete):

- **Doubling the accelerator beam energy - DONE**
- **New experimental Hall D and beam line - DONE**
- **Civil construction including Utilities - ~99%**
- **Upgrades to Experimental Halls B & C - ~87%**

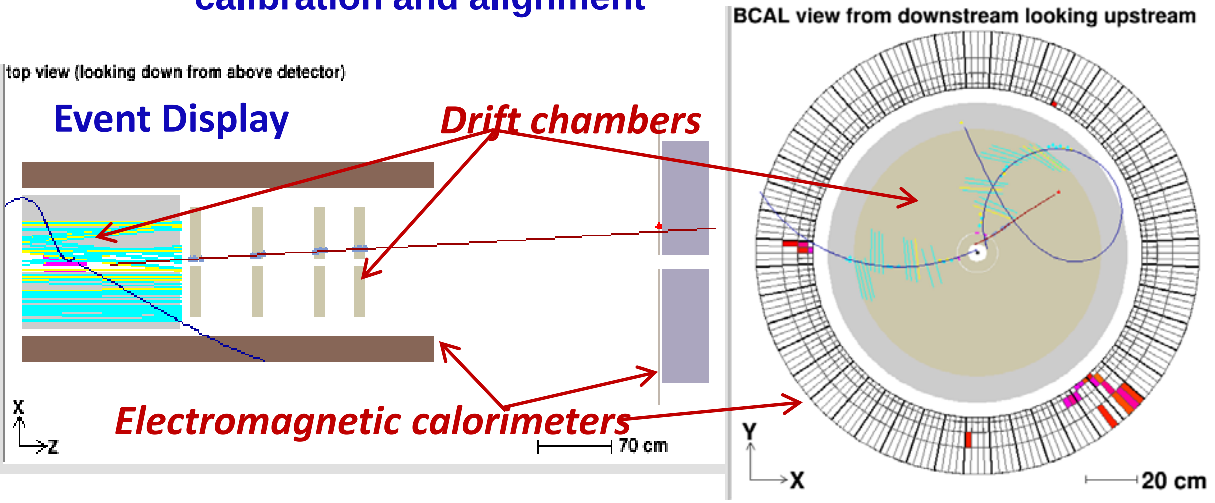
CEBAF Operations: Run I and II Progression



Run III: Hall D Commissioning

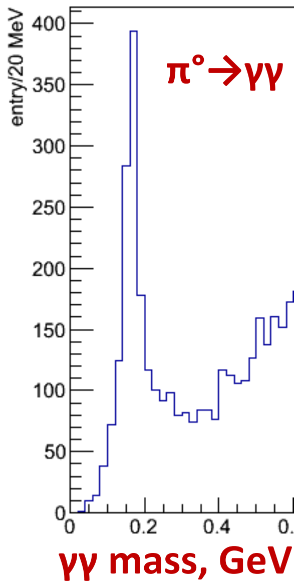
- Hall D: facility for experiments using linearly polarized photon beam
- Main goal: search for gluonic excitations in light meson spectra (GlueX experiment)
- Photon beam line + large acceptance spectrometer for charged particles & photons
- Commissioning with beam **Nov. & Dec. 2014**

Results with preliminary detector calibration and alignment

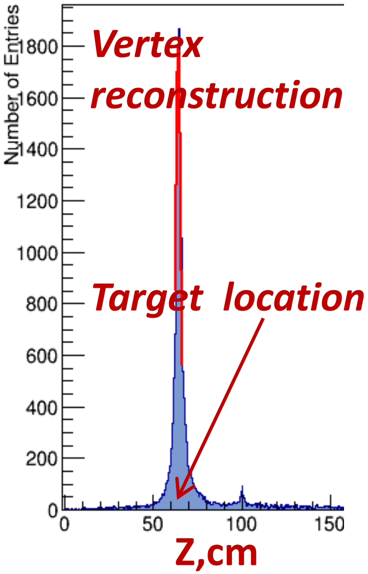


Spectrometer in solenoidal magnetic field

Neutral particles reconstruction



Charged particles tracking

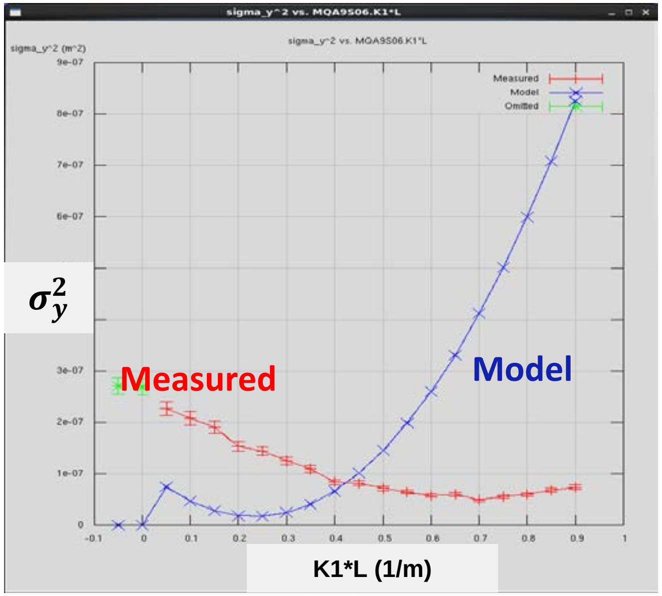


Run IV Highlights

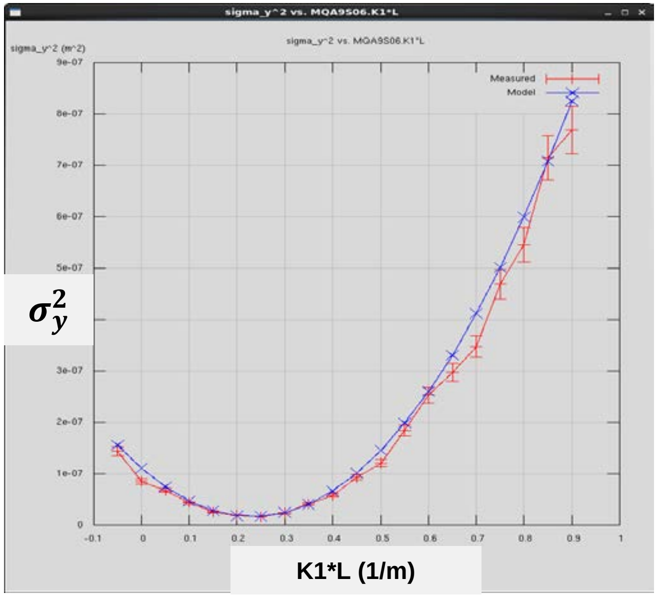
2015-Feb-13 to 2015-May-18

- E=1.9GeV/pass
- Commission new 249.5 MHz laser/injector configuration
- Commission new 750 MHz 5-pass separators
- Exercise new setup process and associated tools: New **beam matching process**
- Establish baseline emittance and bunch length evolution
- Support ~5wk "early Physics" Operation

Quad Scan: Before match



Quad Scan: **After** match



12GeV Operations: Future

- Complete the **Summer 2015 shutdown** tasks.
- Operate RF systems 24/7 for two weeks prior beam operations.
  - Optimize C100 LLRF to **achieve design gradients** (or beyond).
  - Collect data on C20 trip rates, used to optimize gradient distribution with minimal trip rate.
  - Decrease the gap between the commissioning and operations gradients for all cavity types.

Fall2015 (E_{linac} = 1100 MeV):

2015-Oct-26 to 2015-Dec-21

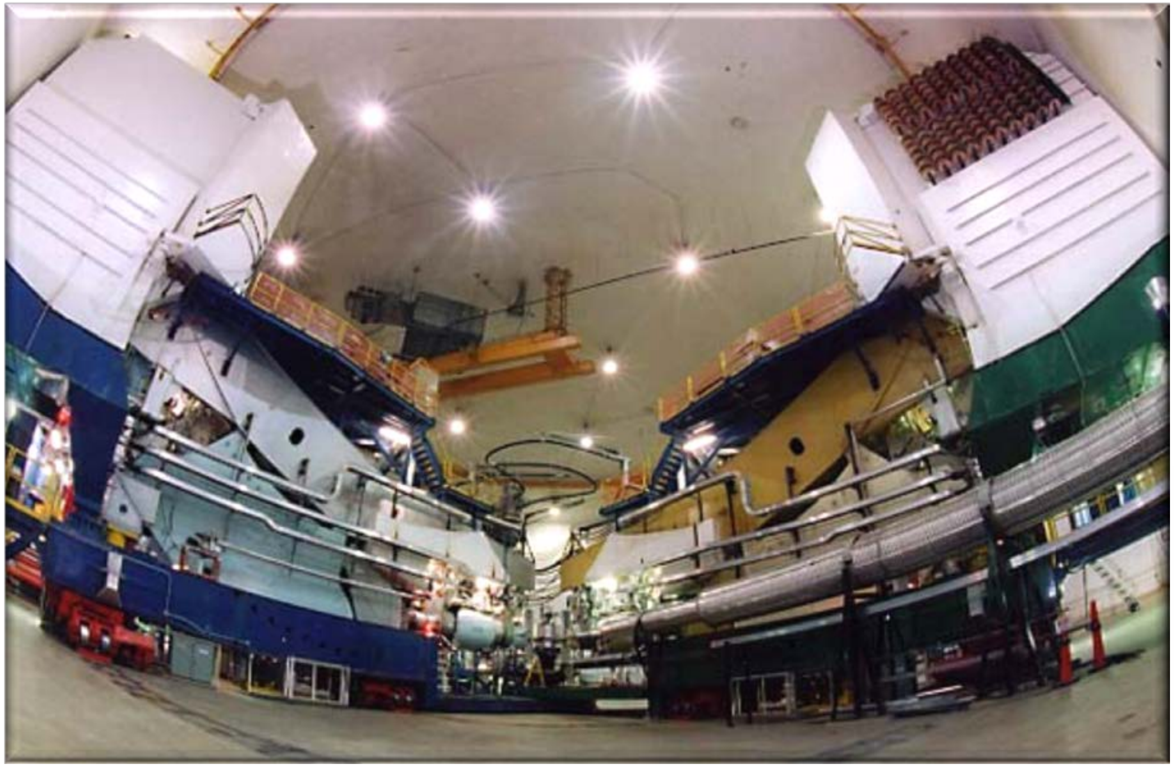
- Emittance/energy spread growth studies.
- SRF performance optimization at full energy.
  - Minimize trip rate
  - Minimize recovery time
  - Maximize gradient
- Detector commissioning at full energy.
- Opportunistic beams for Physics.

Spring2016 (E_{linac} = 1100 MeV):

2016-Jan-28 to 2016-Mar-31

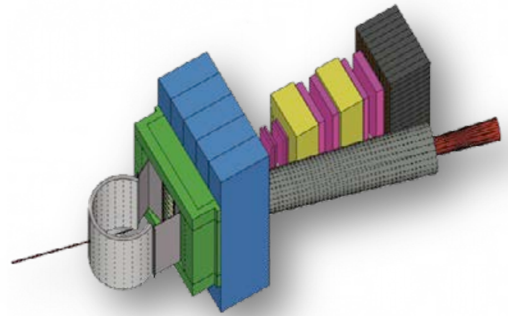
- **First Physics runs with CEBAF at 12 GeV energy: Halls A&D**

Hall A

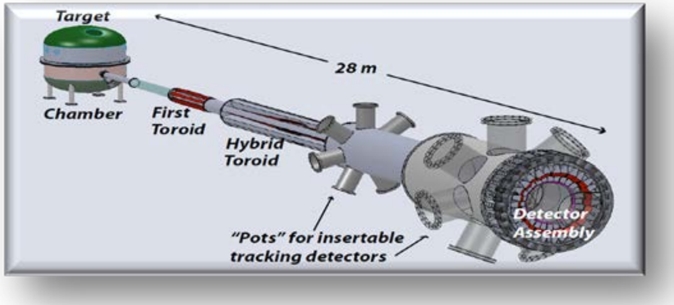


Two High Resolution Spectrometers (HRSs)
Commissioning started: February 2014

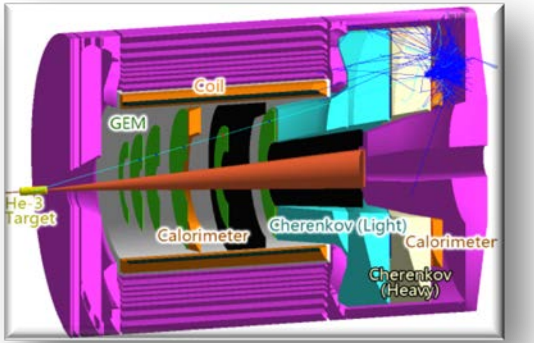
- Super BigBite Spectrometer



- Moller detector



- SoLID detector



Hall B: ***CLAS12***

Base equipment

Forward Detector (FD)

- TORUS magnet (6 coils)
- HT Cherenkov Counter
- Drift Chamber system
- LT Cherenkov Counter
- Forward ToF system
- Pre-shower Calorimeter
- E.M. Calorimeter

Central Detector (CD)

- SOLENOID magnet
- Silicon Vertex Tracker
- Central ToF system

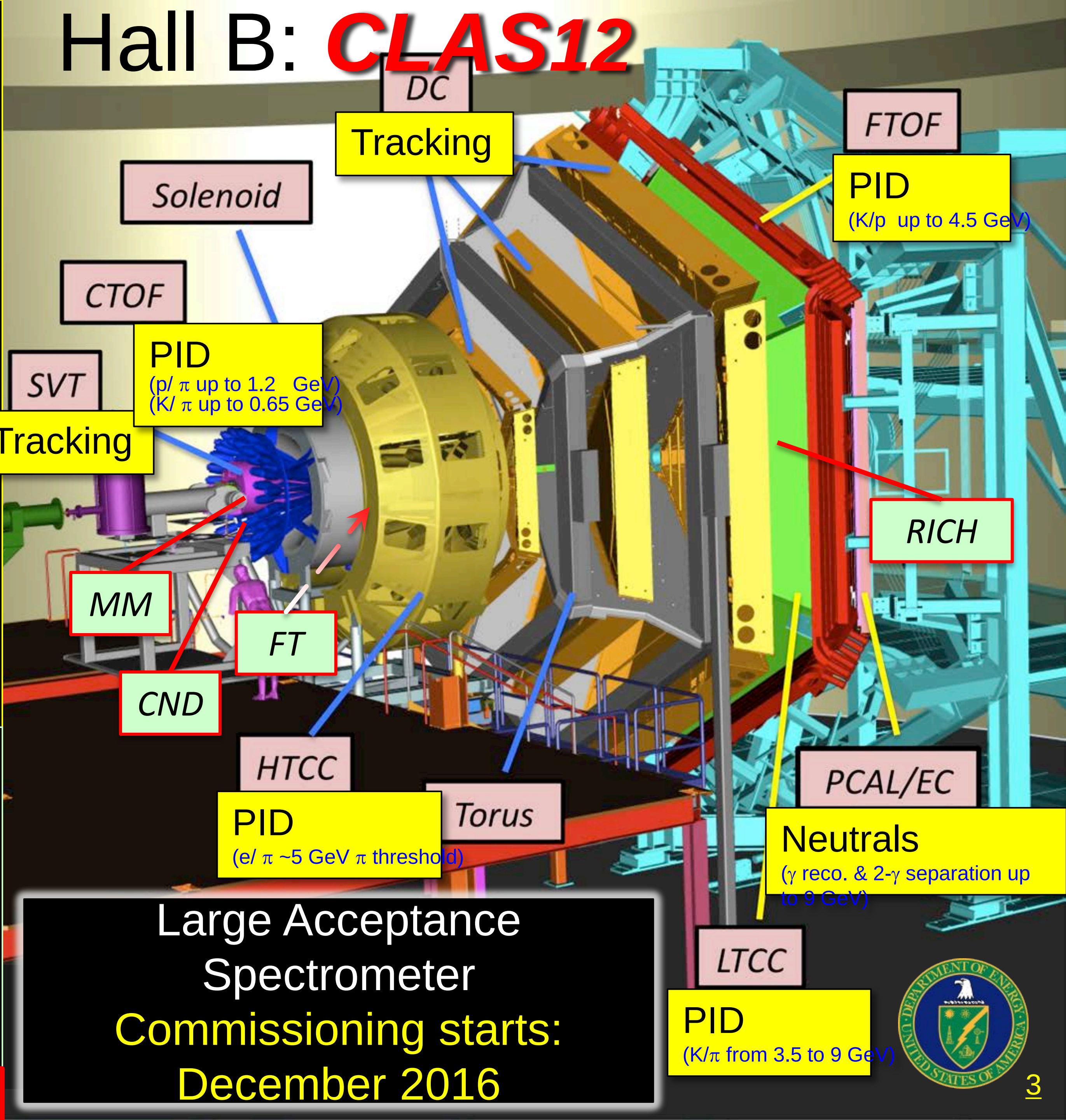
Beamline

- Targets
- Moller polarimeter
- Photon Tagger

Upgrade to base equipment

- MicroMegas
- Central Neutron Detector
- Forward Tagger
- RICH detector (1 sector)
- Polarized target (long.)

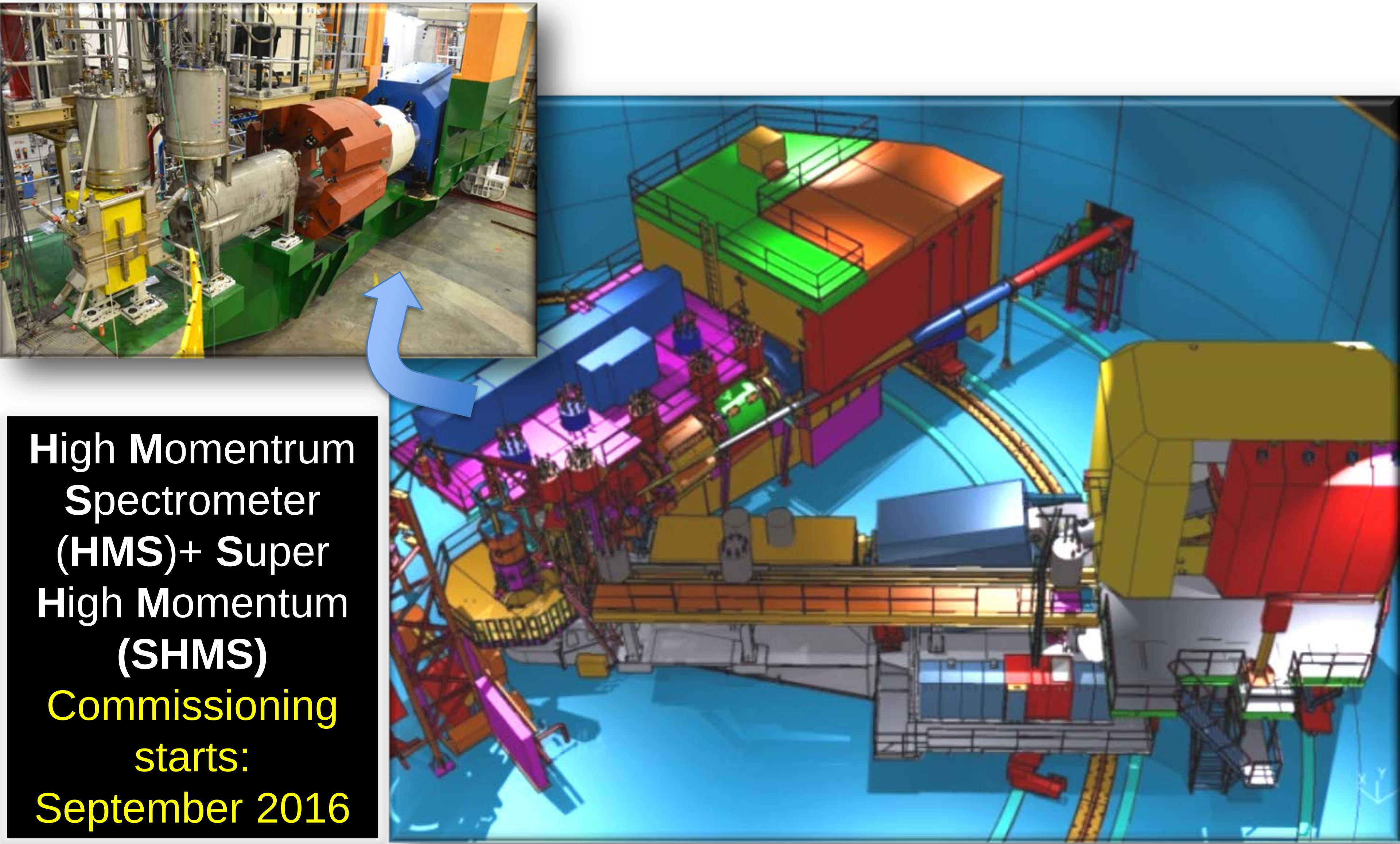
http://www.jlab.org/Hall-B/clas12-web/



Large Acceptance Spectrometer

Commissioning starts: December 2016

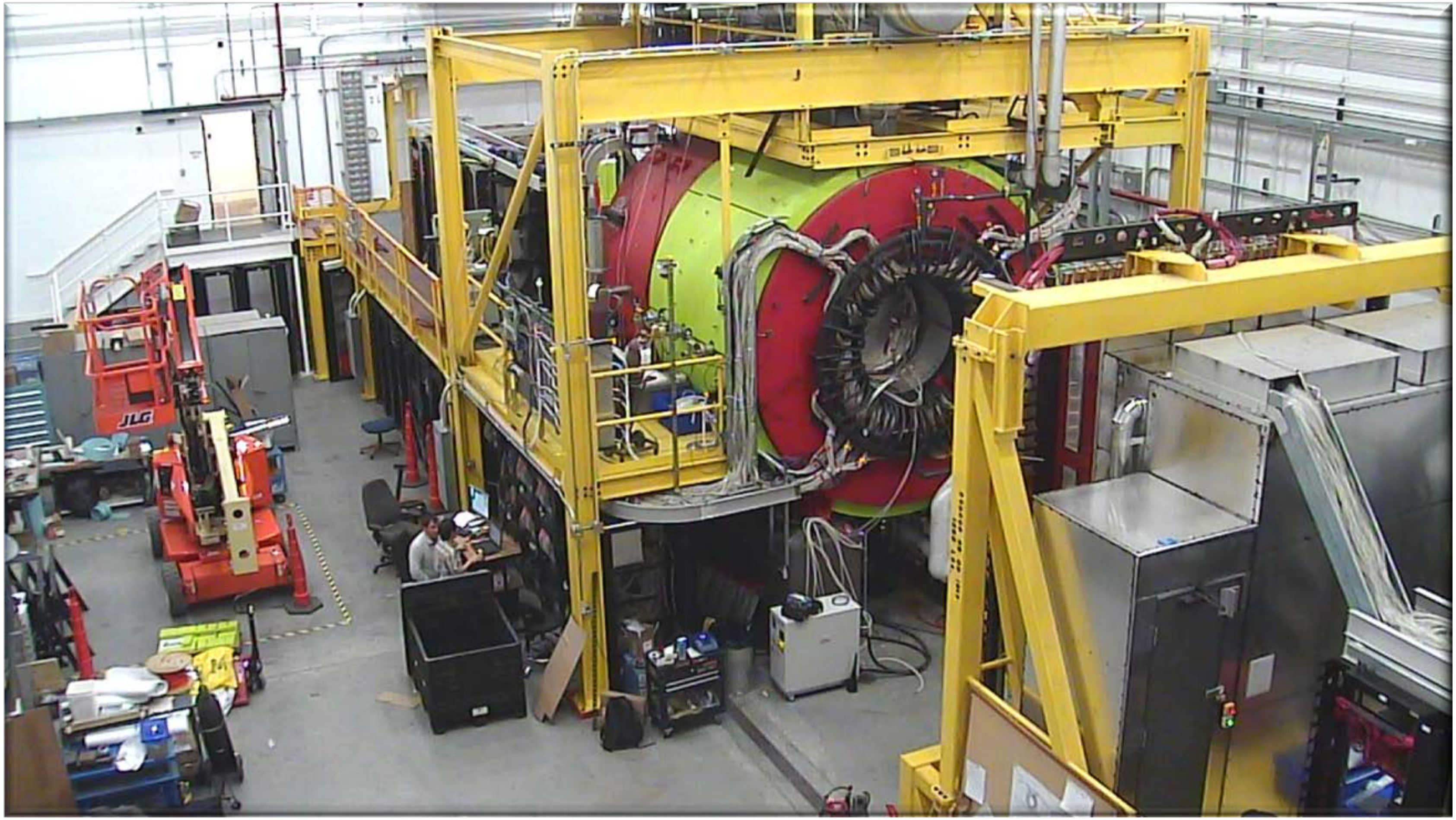
Hall C



High Momentrum Spectrometer (HMS)+ **Super High Momentum (SHMS)**

Commissioning starts: September 2016

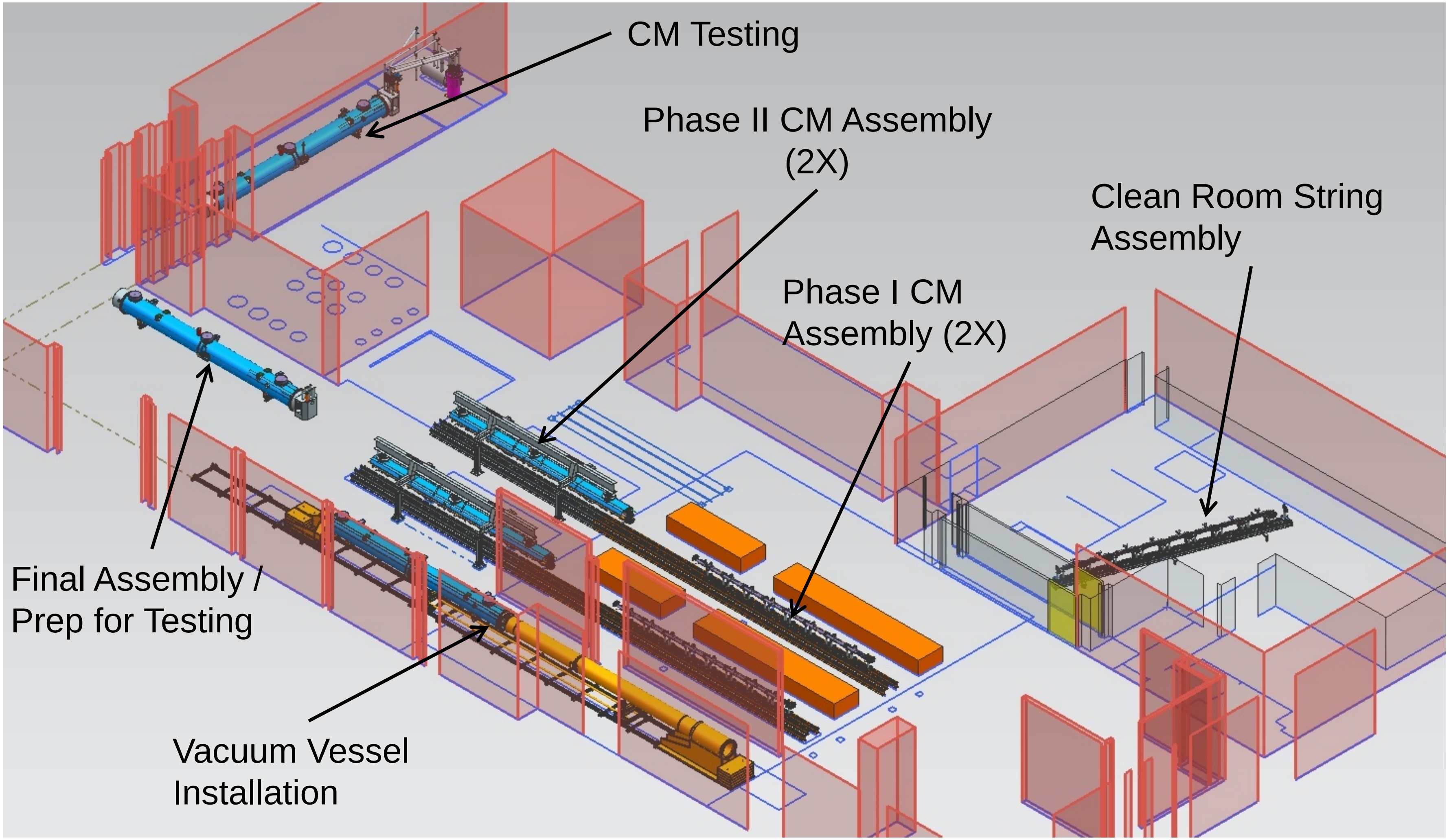
Hall D



GlueX detector:

Commissioning started: May 2014

JLab Layout for LCLS-II CM Production



CM Testing

Phase II CM Assembly (2X)

Clean Room String Assembly

Phase I CM Assembly (2X)

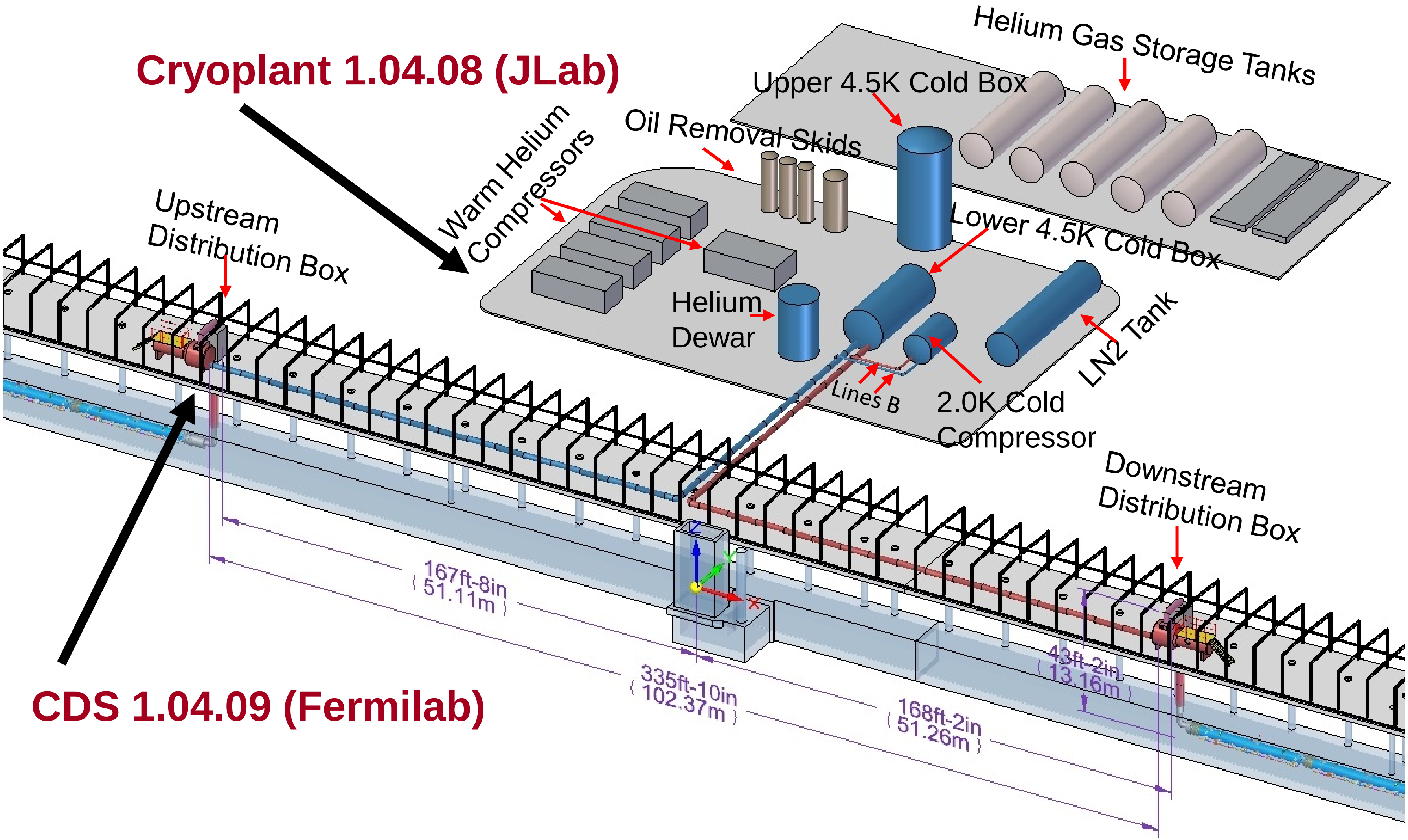
Final Assembly / Prep for Testing

Vacuum Vessel Installation

Cryoplant Schematic showing Cryogenic Distribution System (CDS)

Cryoplant 1.04.08 (JLab)

CDS 1.04.09 (Fermilab)



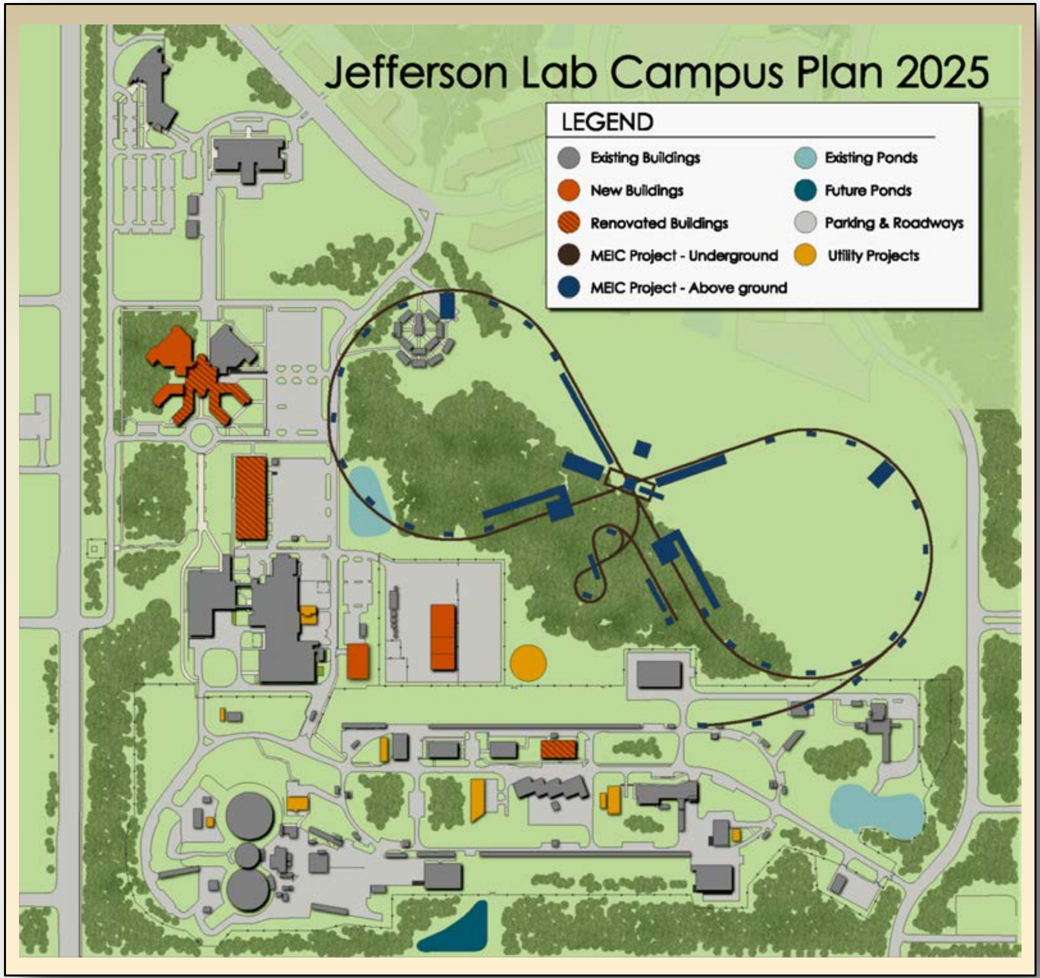
Jefferson Lab Future: MEIC

JLab MEIC Figure 8 Concept

- **Initial configuration:**
  - 3-10 GeV on 20-100 GeV ep/eA collider
  - Optimized for high ion beam polarization:
    - polarized deuterons
  - Luminosity:
    - up to few x 10^{34} e-nucleons cm^{-2} s^{-1}
- **Low technical risk**
- **Upgradable** to higher energies
  250 GeV protons on 20 GeV electrons
- **Flexible** timeframe for Construction
  consistent w/running 12 GeV CEBAF
- Thorough cost estimate completed

  presented to NSAC EIC Review
- Cost effective **operations**

→ Fulfills White Paper Requirements



Current Activities

- Site evaluation (VA funds)
- Accelerator, detector R&D
- Design optimization
- Cost reduction

MEIC Baseline

Baseline for the cost estimate

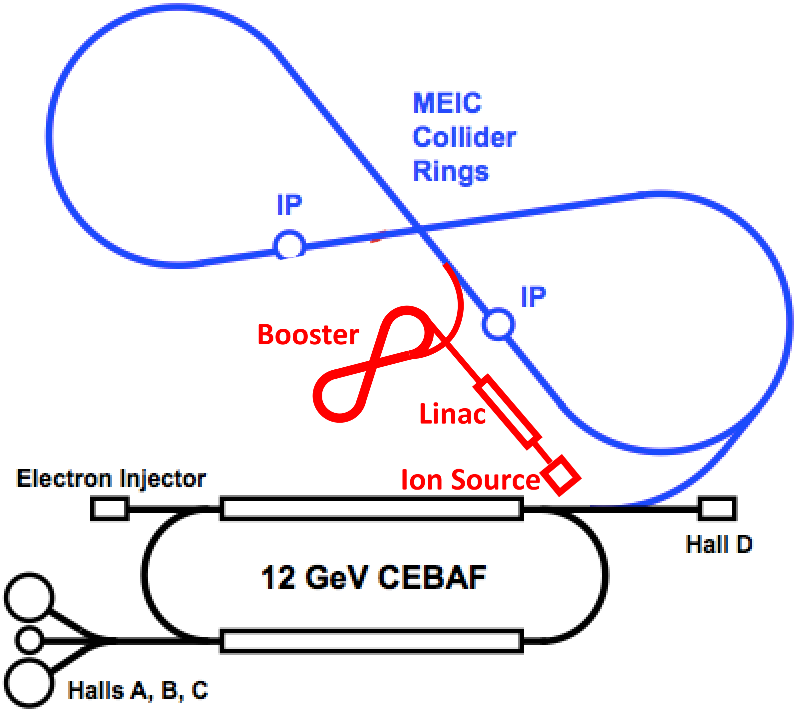
- Collider ring circumference: ~2200 m
- Electron collider ring and transfer lines : PEP-II magnets, RF (476 MHz) and vacuum chambers
- Ion collider ring: super-ferric magnets
- Booster ring: super-ferric magnets
- SRF ion linac

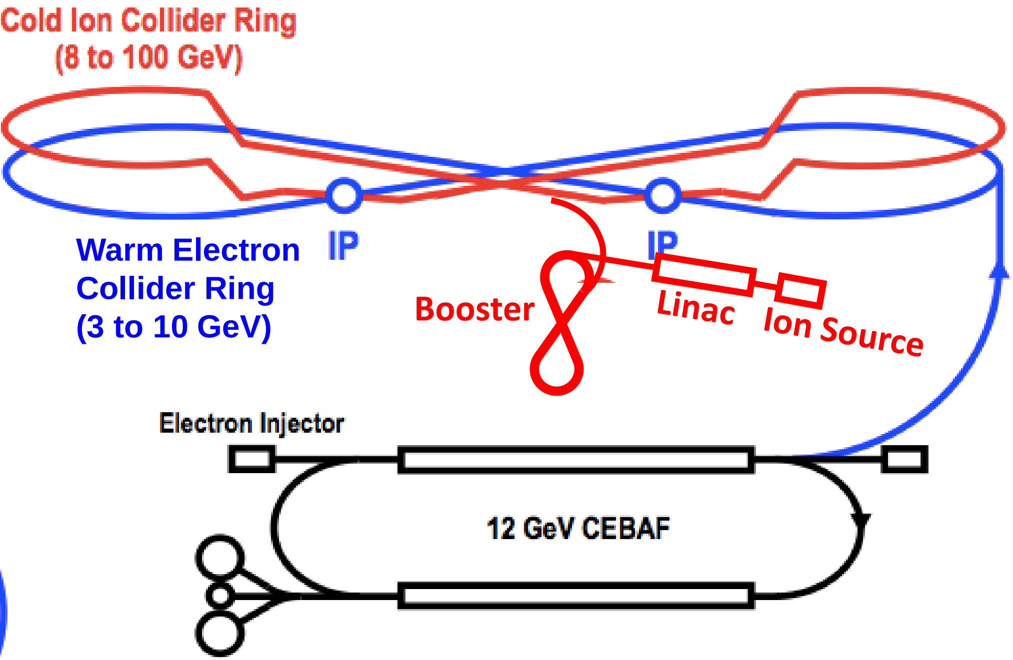
Energy range

- Electron: 3 to 10 GeV
- Proton: 20 to 100 GeV
- Lead ions: up to 40 GeV

Design point	p energy (GeV)	e- energy (GeV)	Main luminosity limitation
low	30	4	space charge
medium	100	5	beam beam
high	100	10	synchrotron radiation

Baseline Layout





CEBAF is a full energy injector.
Only minor gun modification is needed

MEIC Update since last SBIR Meeting

- Established a **MEIC Organization** at JLAB by the Lab Director (July 2014)
- MEIC went through a significant **performance and cost optimization** (July – December 2014)
  - ***Adopted PEP-II electron ring (magnets, vacuum chambers, RF)***
  - ***Adopted super-ferric magnets for ion and booster ring***
  - ***Consolidated pre-booster and high-energy booster in 1 ring***
- MEIC Design Report was prepared (August 2012), updated with a **Design Update Report** (January, 2015)
- MEIC was extensively **reviewed** for technical viability, reviews were positive
- Baseline design and cost estimate presented at the **EIC Cost review** (January 2015), costs were accepted
- Organized EIC14, The International Workshop on Accelerator Science and Technology for Electron-Ion Colliders at Jefferson Lab in with over 100 participants (March 2015)
- Held the **1st MEIC Collaboration Meeting** with collaborating institutions and industry (March 2015)
- Developed integrated plan for design, pre-project R&D, Pre-CDR (August 2015)
- **2nd MEIC Collaboration Meeting** planned for **October 5-7, 2015**

FY16 SBIR/STTR Topics

NUCLEAR PHSICS SOFTWARE AND DATA MANAGEMENT

- Large Scale Data Processing and Distribution
- Software-Driven Network Architecture for Data Acquisition
- Heterogeneous Concurrent Computing

NUCLEAR PHSICS ELECTRONIC DESIGN AN FABRICATION

- Advances in Digital and High-density Analog Electronics
- Circuits
- Advance Devices and systems
- Next Generation Pixel Sensors
- Manufacturing and Advanced Interconnection Techniques

NUCLEAR PHYSICS ACCELERATOR TECHNOLOGY
- **Material and Components for Radio-Frequency Devices**
- **Radio-Frequency Power Sources**
- **Design and Operations of RF Beam Accelerator Systems**
- **Particle Beam Sources and Techniques**
- **Polarized Beam Sources and Polarimeters**
- **Charge Strippers Heavy Ion Accelerators**
- **Rare Isotope Beam Production Technology**
- **Accelerator Control and Diagnostics**
- **Magnet Development for Future Electron-Ion Colliders**
- Accelerator systems Associated with the capability to deliver Heavy-Ion beams to multiple users

FY16 SBIR/STTR Topics con’t

NUCLEAR PHYSICS INSTRUMENTATION< DETECTION SYSTEMS AND TECHNIQUES

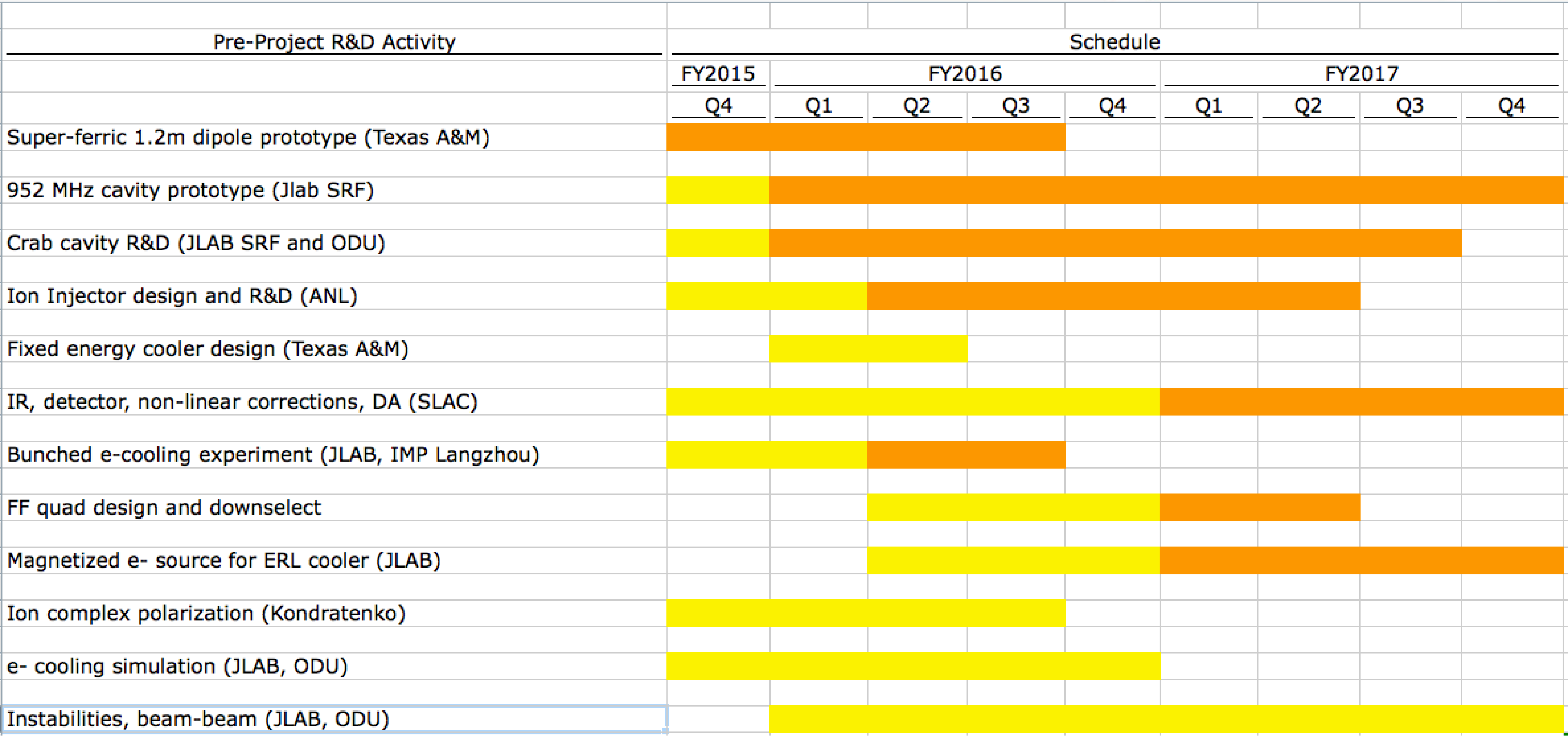
- **Advances in in Detector and Spectrometer Technology**
- Development of Novel Gas and Solid-State Detectors
- Technology for Rare Decay and Rare Particle Detection
- **High Performance Scintillators, Cherenkov Materials and other Optical Components**
- **Specialized Targets for Nuclear Physics Research**
- **Technology for High Radiation Environments**

NUCLEAR PHYSICS ISOTOPE SCIENCE AND TECHNOLOGY

- **Novel or Improved Production Techniques for Radioisotopes or Stable Isotopes**
- Improved Radiochemical Separation Methods for Preparing High-Purity Radioisotopes

MEIC R&D

Fulvia Pilat
Yuhong Zhang



Pre-Project R&D Activity	Schedule								
	FY2015	FY2016				FY2017			
	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Super-ferric 1.2m dipole prototype (Texas A&M)	🟧	🟧	🟧	🟧					
952 MHz cavity prototype (Jlab SRF)	🟨	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧
Crab cavity R&D (JLAB SRF and ODU)	🟨	🟧	🟧	🟧	🟧	🟧	🟧	🟧	
Ion Injector design and R&D (ANL)	🟨	🟨	🟧	🟧	🟧	🟧	🟧		
Fixed energy cooler design (Texas A&M)		🟨	🟨						
IR, detector, non-linear corrections, DA (SLAC)	🟨	🟨	🟨	🟨	🟨	🟧	🟧	🟧	🟧
Bunched e-cooling experiment (JLAB, IMP Langzhou)	🟨	🟨	🟧	🟧					
FF quad design and downselect			🟨	🟨	🟨	🟧	🟧		
Magnetized e- source for ERL cooler (JLAB)			🟨	🟨	🟨	🟧	🟧	🟧	🟧
Ion complex polarization (Kondratenko)	🟨	🟨	🟨	🟨					
e- cooling simulation (JLAB, ODU)	🟨	🟨	🟨	🟨	🟨				
Instabilities, beam-beam (JLAB, ODU)		🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨

Total proposed pre-project R&D estimate < 5 M$

Reviews

Super-Ferric magnets (external)	June 4 2015
•Crab cavity R&D (internal)	June 9 2015
•SRF R&D (internal)	June 18 2015
•MEIC engineering	August 4 2015
•Overall MEIC R&D review	Aug 12 2015

MEIC Magnet R&D

Fulvia Pilat
Yuhong Zhang

- Existing collaboration with Texas A&M for the design and prototyping of super-ferric magnets for the ion collider ring and for the booster
- Design and prototyping of high field, large aperture, compact super-conducting magnets for the collider Interaction Regions and Final Focus
- Design of long solenoids (15-30m) for bunched beam cooling

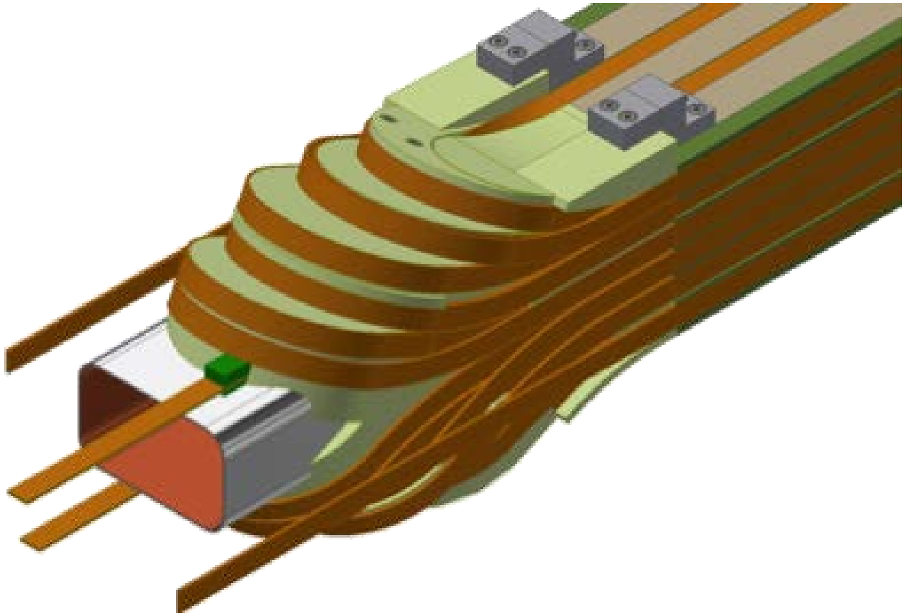
Example: design of a large-aperture high-pole-tip-field superconducting quadrupole with modest yoke thickness

Type:	Quadrupole
Length	2.4 m
Max Field Gradient	51 T/m
Aperture/bore radius	11.8-17.7
Max outer size	43 cm (on one side)
Field uniformity	$<10^{-4}$ at 25mm radius

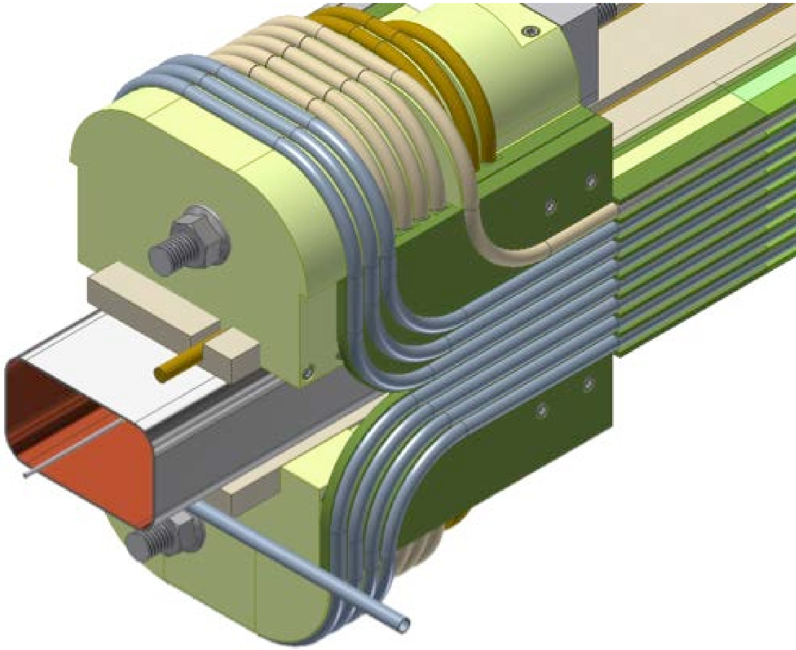
MEIC super-ferric magnet R&D

TexasA&M developed 2 approaches to winding cable:

NbTi Rutherford cable



NbTi Cable-in-Conduit



Pros: Uses mature cable technology (LHC).

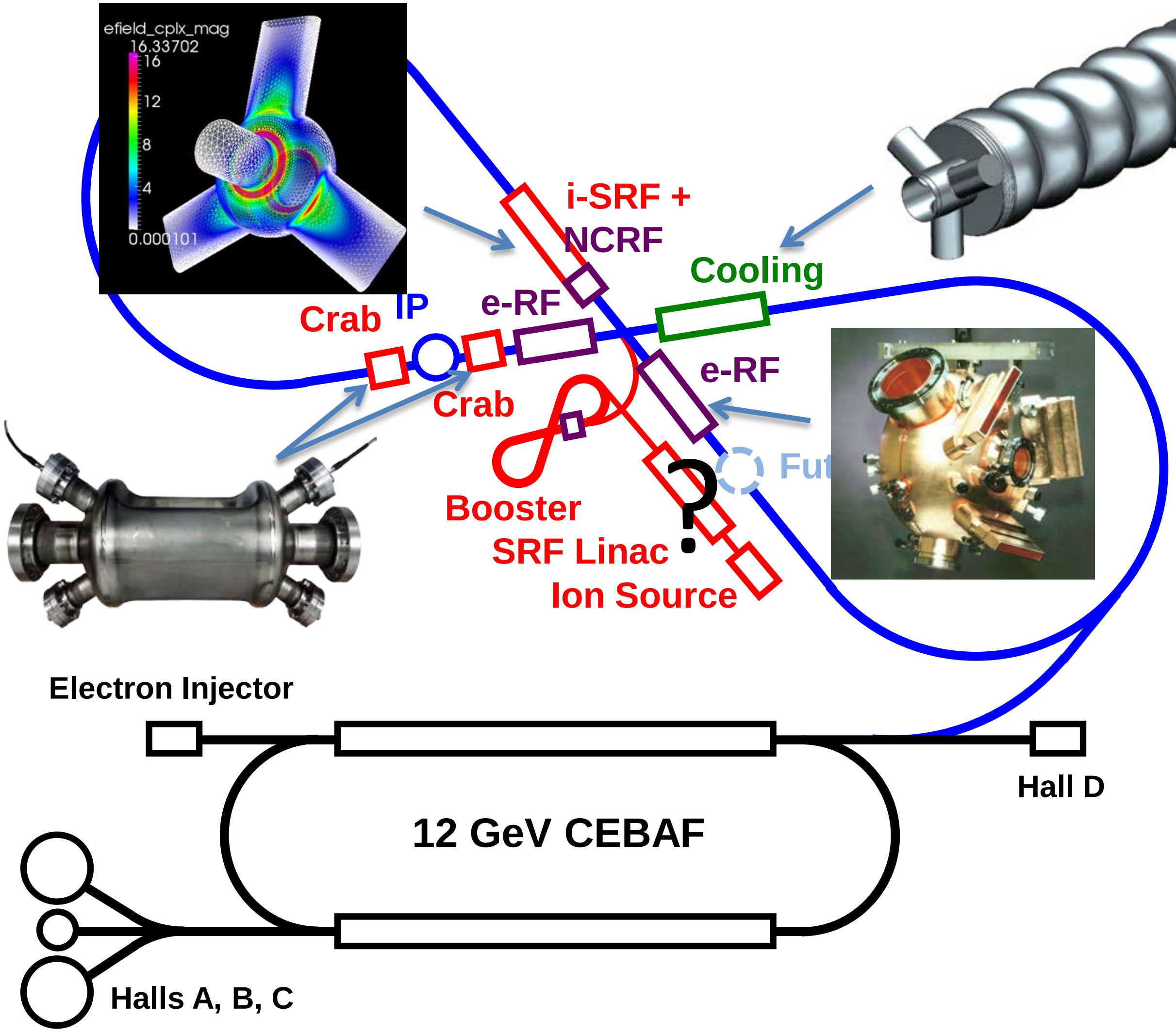
Semi-rigid cable makes simpler end winding.
Semi-rigid round cable can be precisely located.
Cryogenics contained within cable.

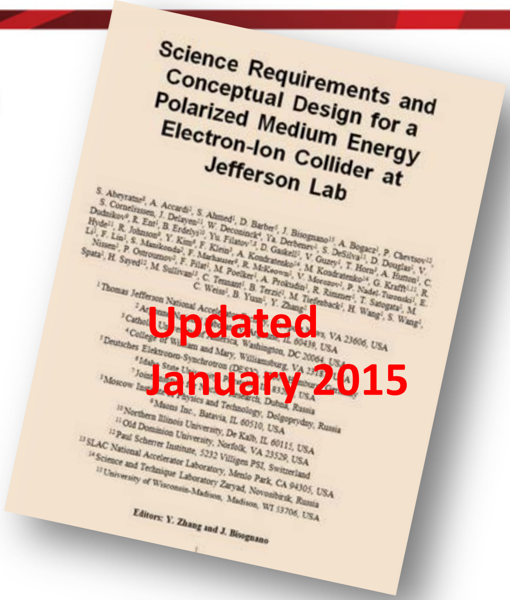
Cons: Ends tricky to support axial forces.

Cable requires development and validation.

MEIC SRF R&D

Bob Rimmer





Science Requirements and Conceptual Design for a Polarized Medium Energy Electron-Ion Collider at Jefferson Lab

Editors: Y. Zhang and J. Bisognano

Updated January 2015

Stage I MEIC

- CEBAF as full-energy e^-/e^+ injector
- 3-10 GeV e^-/e^+
- 8-100 GeV protons
- <40 GeV/u ions

Stage II EIC

- up to 20 GeV e^-/e^+
- up to 250 GeV protons
- up to 100 GeV/u ions

Matt Poelker

Injectors and sources R&D

CEBAF Injector R&D

- Bunch-length monitor using harmonically-resonant cavity (SBIR-related)
- High Polarization Photocathodes (SBIR-related)
- **Polarized Positron** Production ("PEPPo" – a PAC approved Experiment)
- Bubble Chamber Experiment (photo-disintegration of oxygen into helium and carbon – a PAC approved experiment)
- **Improving vacuum** (funded via Research and Development for Next Generation Nuclear Physics Accelerator Facilities)
- Preparing for new parity-violation experiments:
  - Precision Mott Polarimeter, striving for accuracy at ~ 1% level
  - 200 kV gun + new "booster" to eliminate x/y coupling, providing better beam envelope matching, and smaller helicity correlated position asymmetries
- **350 kV load-locked gun** and related field emission studies (funded in part via Research and Development for Next Generation Nuclear Physics Accelerator Facilities)

Bunch-length monitor at CEBAF

- Near real-time bunch-length monitor for bunches > ~ 35 ps
- Can be used to accurately set phases of lasers and pre-buncher

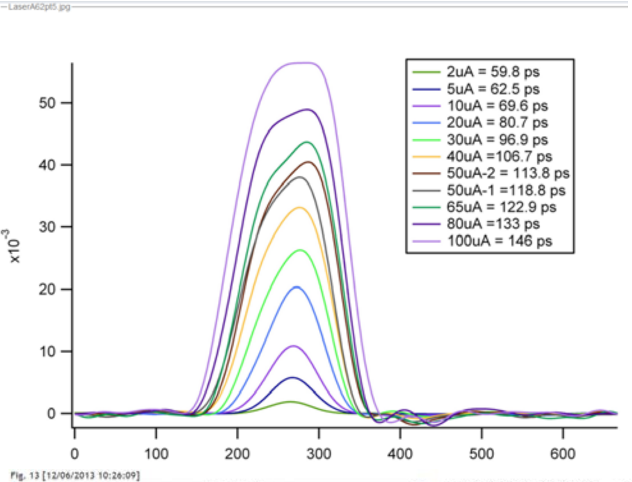
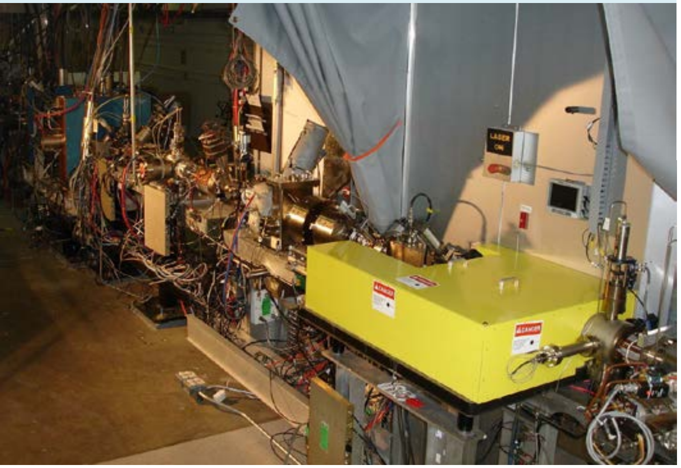
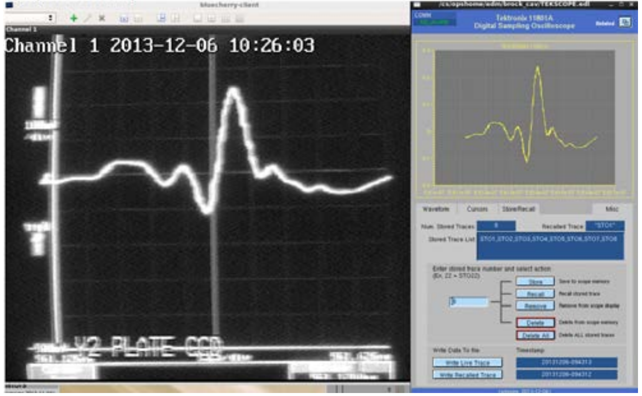
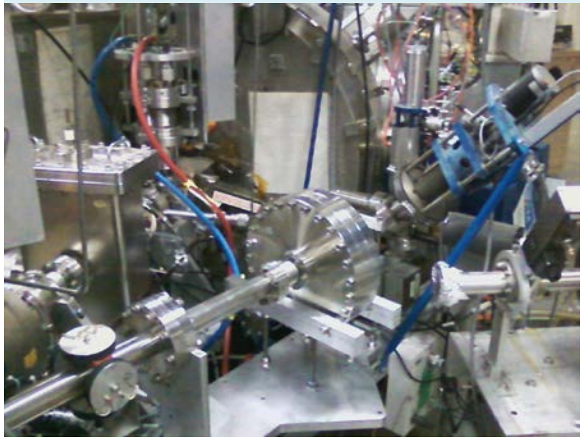


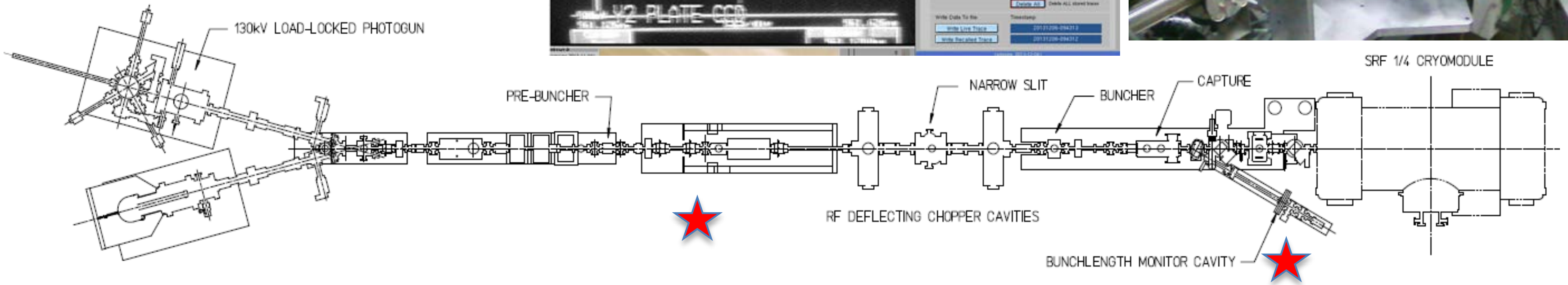
Fig. 13 [12/06/2013 10:26:09]



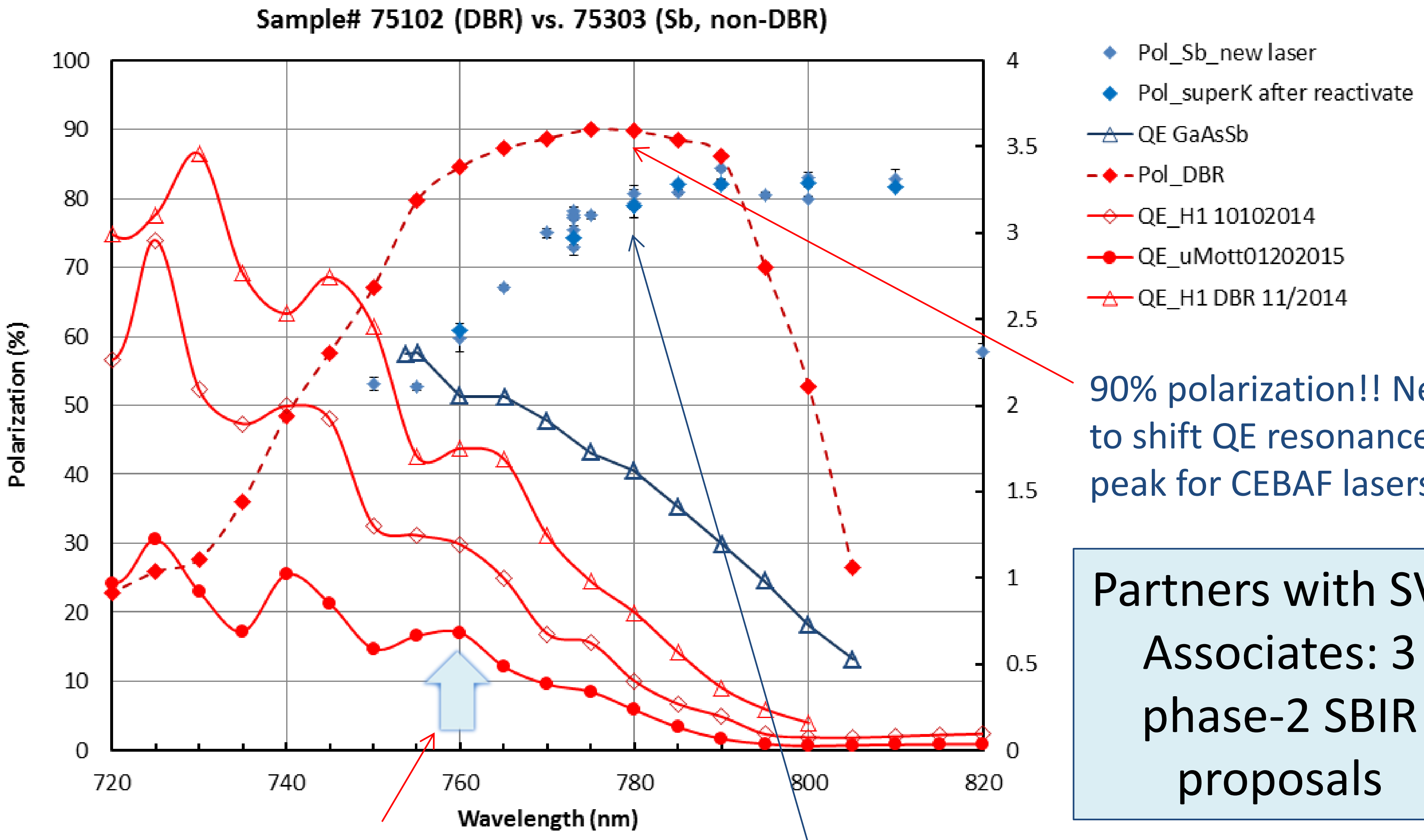


- Simple tool to help validate our particle tracking code models
- Fast Kicker?
- Useful when placed at higher energy locations of machine?





High Polarization Photocathodes



90% polarization!! Need to shift QE resonance peak for CEBAF lasers

Partners with SVT Associates: 3 phase-2 SBIR proposals

Distributed Bragg Reflector (DBR) enhancement designed @760nm

Need to shift DBR resonance to 780nm !

GaAsSb/AlGaAsP not bad, need to test at high voltage

SRF R&D Activities

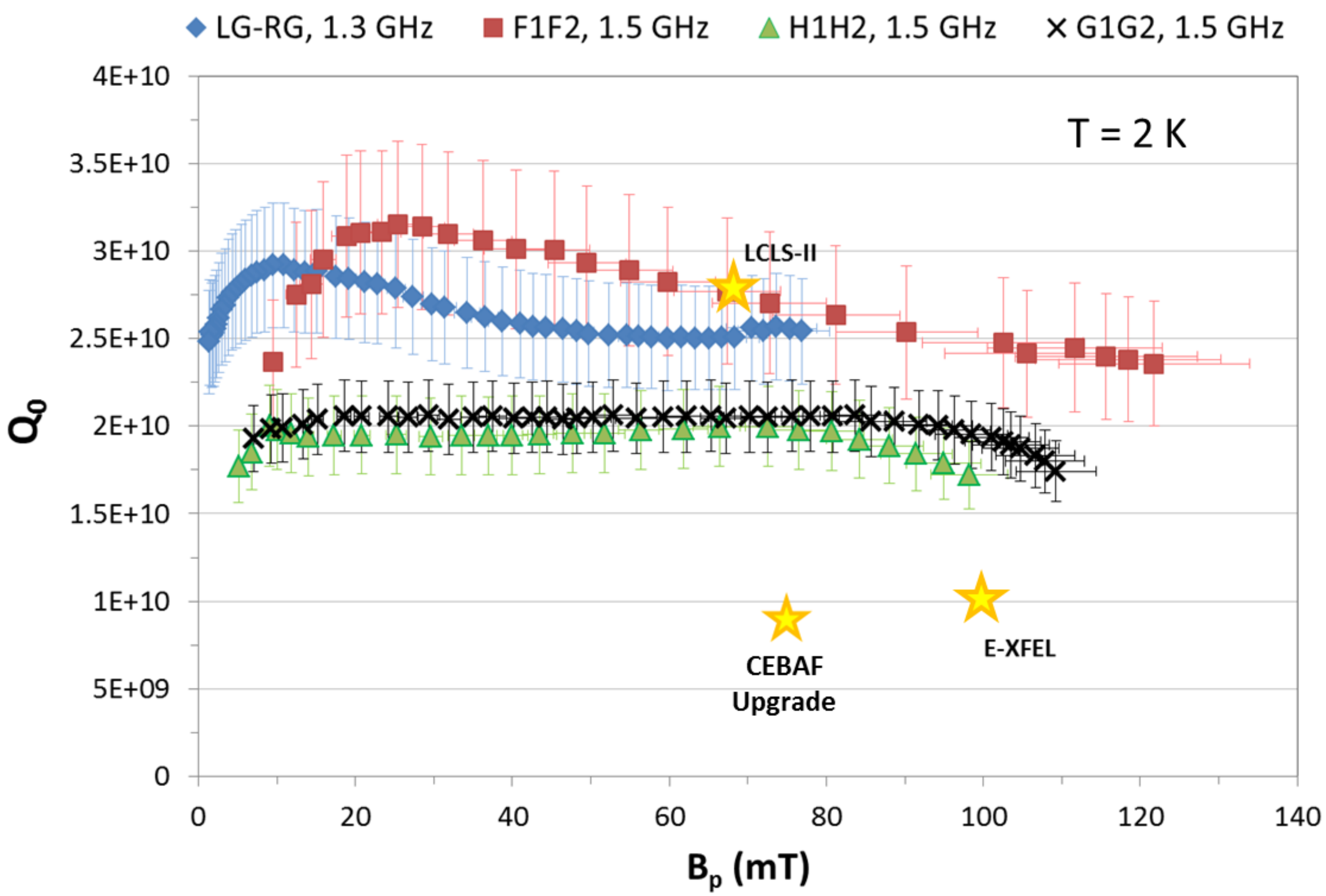
Bob Rimmer
Charlie Reece

- SRF R&D
  - High Q0
  - High gradient
  - Surface doping
  - Thin films
- WFO
  - HZB
  - CERN
  - LCLS-II
  - FRIB

High efficiency at low cost: ingot Nb

Gigi Ciovati

High efficiency, low cost with medium purity (RRR~100) ingot Nb

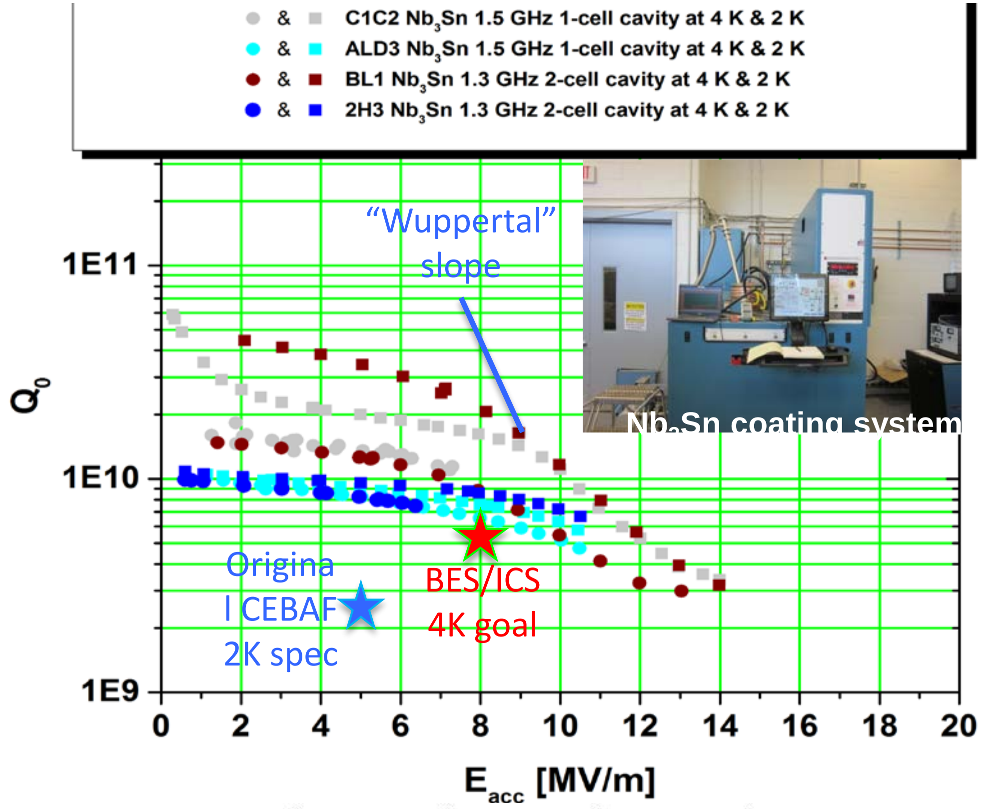


Performance of four single-cell cavities made of different ingots after standard processes (Electro-polishing and 120°C bake)

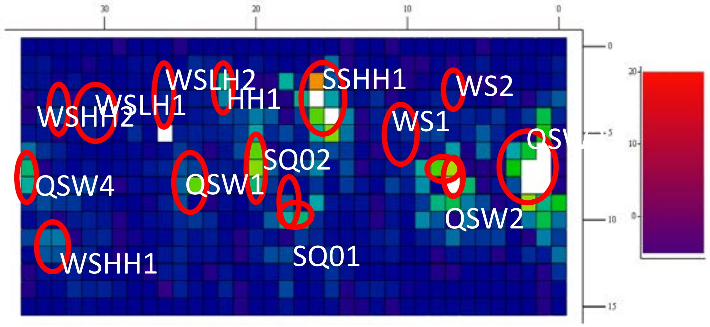
Cost may be 50-60% of fine-grain high RRR in project scale

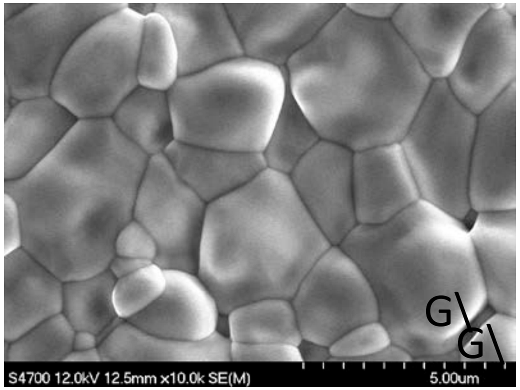
Nb_3Sn progress

G. Eremeev



- 1.5 GHz 1-cell, 1.3 GHz 1-cell, and 1.3 GHz 2-cell seamless cavities have been **coated**.
- All cavities had the transition temperature of about 18 K with the low field **Q_0 of about 10^{10} at 4.3 K**.
- The best cavities reached **E_{acc} above 10 MV/m** limited by localized defects and "Wuppertal" slope.
- Small coated samples and cutouts from a 1.5 GHz cavities are being analyzed towards understanding of present limitations.





Bob Rimmer

SRF R&D “wishlist”

JLAB SRF have benefitted over the years from various SBIR collaborations although the flow has reduced significantly since the commercialization emphasis.

These have included **magnetron** and other RF source development, new **SRF processes** such as the bipolar "HF-free" EP, **new materials** such as high Tc thin films (e.g. MgB2) and alternative processes for Nb on copper, new kinds of fast **tuner** and other cavity fabrication-related activities such as **hydro-forming**, **3D printing** etc., and **EM simulation tools** and software.

What we need now:

- High efficiency RF sources, including magnetrons, for MEIC and as a drop in replacement for the old CEBAF klystrons
- Microwave absorbing materials that might be used as HOM loads at cryogenic temperatures.
- Low loss and reliable RF windows and couplers.
- Low-impedance bellows for high currents.
- Novel fabrication techniques for seamless cavities.
- Novel support structures or vibration isolation techniques to counter microphonics.
- New materials or process for high Q's.
- New High Tc SRF materials.
- New cavity diagnostics and inspection methods.
- Surface melting or preparation techniques and HF-free recipes.
- Novel crab cavity designs.
- Improved LLRF systems.

Mike Spata

Accelerator Physics Group R&D

- Accelerator Physics
  - Detailed design studies for next generation **Energy Recovery Linacs**
  - Lattice, interaction region and bunched beam cooler design for **MEIC**
- Computational Physics
  - Numerical code development for simulating **field emission** in waveguides (SLAC)
  - Study of **bunched beam electron cooling** (LDRD)
  - Study of suppression of **Coherent Synchrotron Radiation** driven effects (LDRD)
  - **Model development** related to beam parity quality (CEBAF)
  - **Collective effects** and tracking studies for MEIC (ODU Collaboration)
- Diagnostics Development
  - **Laser-wire Beam Profile Monitor** (BES Early Career Award)
  - **Large Dynamic Range Diagnostic System** (BES Early Career Award)
  - **Bunch Length Interferometer**
- Research Experience for Undergraduates
  - Supported 4 summer students

Isotope photo-production

Hari Areti
Geoff Krafft

- The biggest challenge is the **target**. The photon flux at >10 MeV, and possibly up to 50 is crucial for isotope production. Since the desired isotope is only a small fraction of the target, ideally **one would concentrate the photon flux in a small target**, making the ratio of the desired isotope to target higher. What this means is that the **photon beam size at the isotope target should be as small as possible**. This means two things:
- the electron beam should also be small. (small electron beam size and the resulting power density can destroy the bremsstrahlung radiator)
- the isotope target should be close to the radiator in order that the most of the energetic photon beam hits the isotope target. (good to sweep away as much of the electron beam exiting from the radiator as possible so that the electron beam does not hit the isotope target)

- It would be a welcome contribution if a company can develop a self contained, compact, cooled bremsstrahlung radiator system that can handle >10 KW of electron beam power dumped in a radiator area whose radius is of the order of 200 microns. (The higher the power this target can handle the better it is. The radiator thickness is between 0.5 and 1 radiation lengths)

- People have come up with **liquid bremsstrahlung radiator** ideas. They could be expensive and may not be easy to maintain. If they can be made self contained 'turn-key' systems with **low maintenance**, that would be fine. They do have to be **compact** in order that the isotope target can be placed close to the radiator system (<5 cm) to intercept a large fraction of the photon beam.

Hall	Capital Equipment Under DOE guidance	FY13	FY14	FY15	FY16	FY17	FY18	FY19
A	SBS Basic	🟩	🟩	🟩				
	SBS Neutron		🟩	🟩	🟩	🟩		
	SBS Proton	🟩	🟩	🟩	🟩	🟩		
	Solid Magnet relocated/refurb.				🟩	🟩	🟩	🟩
	^{3}H target	🟩	🟩	🟩				
	HRS magnet Controls				🟩	🟩		
	High Luminosity Polarized 3He				🟩	🟩	🟩	
	Tagged DIS							🟩
B	Polarized Target			🟩	🟩	🟩	🟩	
	HD Ice Transverse Target				🟩	🟩	🟩	🟩
	RICH detector	🟩	🟩	🟩	🟩			
	DC Readout		🟩		🟩	🟩		
	Beam Line Upgrade				🟩			
C	Beamline/Compton Upgrade	🟩	🟩	🟩	🟩			
	^{3}He Polarized Target	🟩	🟩	🟩	🟩	🟩		
	Large Acceptance Detector							🟩
	GEn				🟩		🟨	🟨
D	Forward Calorimeter Upgrade					🟩	🟩	
	DIRC detector				🟩	🟩	🟩	
	Polarized Target for photon beam							🟥
ALL	High Resolution Calorimeter (NPS)						🟨	🟨
	Fast electronics	🟩					🟩	🟩

Patrizia Rossi

As compared to proposed

🟩 INCLUDED

🟨 DELAYED

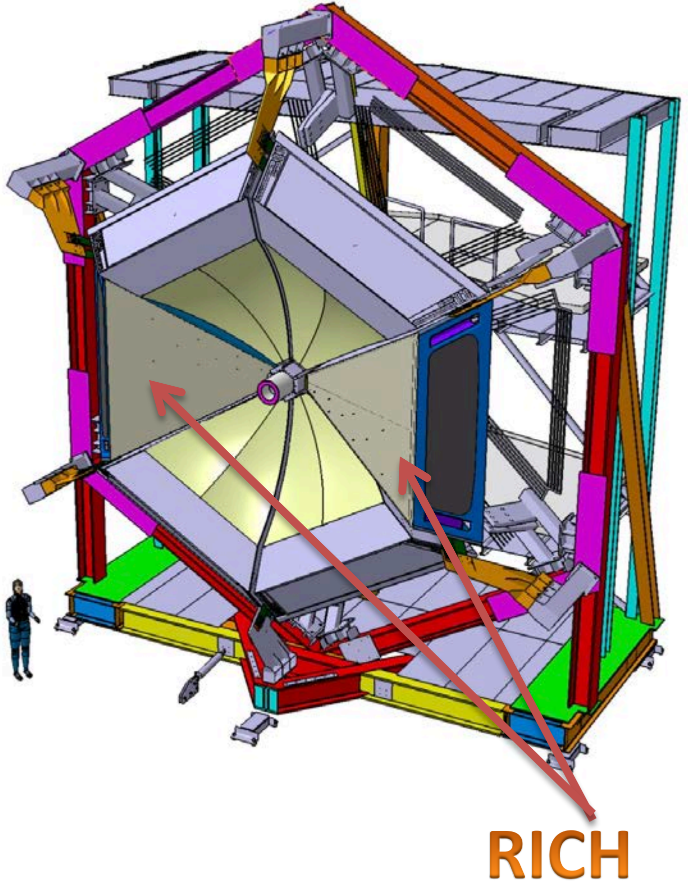
🟥 DESCOPED

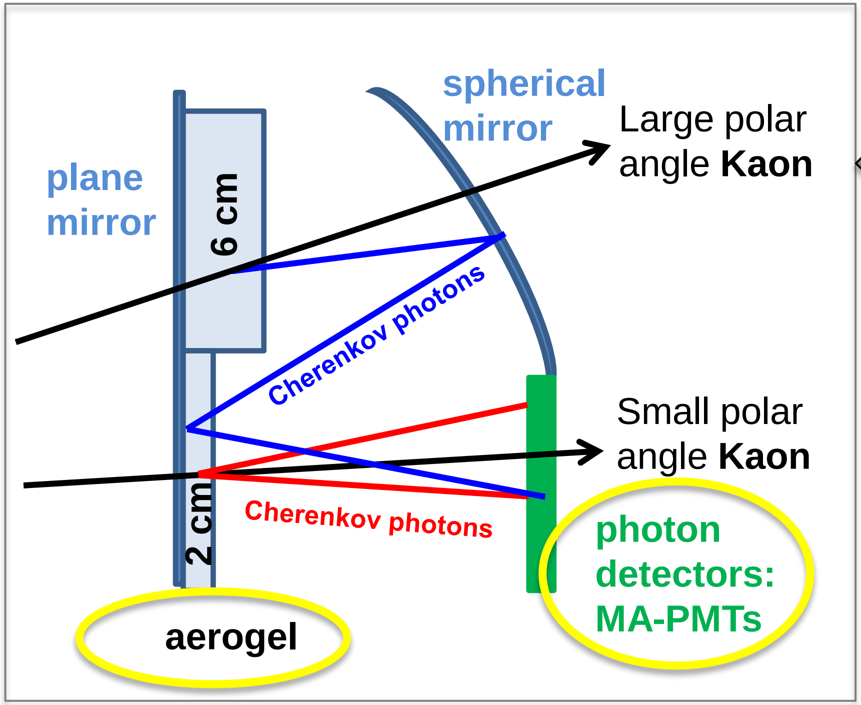
Patrizia Rossi

Hall B – RICH

Construction of a Ring Imaging Cherenkov (RICH) detector to replace two sectors of the LTCC in CLAS12. Each sector has an entrance window of ~ 4.5 m^2 and an exit windows of ~ 8m^2

Goal: ID of kaons vs π and p with momentum 3-8 GeV/c with a π/K rejection factor 1:500





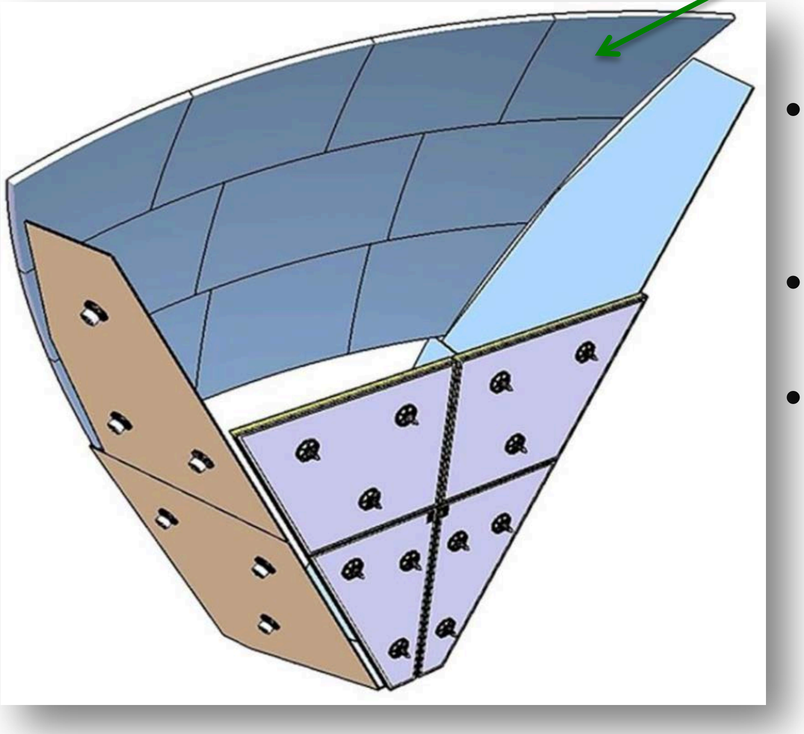
Hybrid solution: proximity gap plus focusing mirrors

Two elements extend the current "state-of-the-art" in the technology:

a) Spherical mirror

b) Aerogel

Hall B – RICH: The mirror system



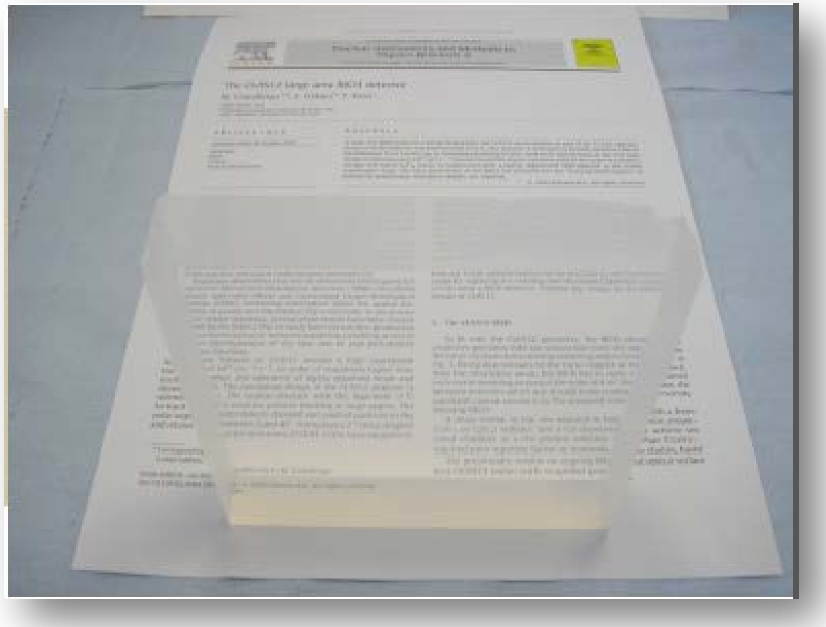
- Ten spherical mirror
  total surface ~3.6 m^2 mounted on a supporting structure attached to the RICH module
- Four frontal planar mirror
  total surface ~3 m^2 mounted on the frontal closing panel they hold the aerogel tiles
- Six lateral planar mirrors
  total surface ~1.4 m^2 mounted on the lateral panel
- One bottom mirror
  surface ~0.2 m^2 mounted on the lower panel

Spherical mirrors requirements:

- low material budget
- **surface roughness** below 3 nm RMS
- **surface accuracy** below 6 µm P-V
- **radius accuracy** better than 1%

Only one company within USA and Europe is able to fulfill the above requirements

Hall B – RICH: Aerogel



- Aerogel is the only known material whose index of refraction is correct for Kaon ID in the desired momentum range.
- One layer of 2cm thickness and n=1.05 radiator for $\theta<13^{o}$ and two layers of 3cm thickness and n=1.05 radiator for $\theta>13^{o}$ will be used.

Aerogel requirements:

- Rafractive index: 1.05
- Area: 20x20 cm^2 (large tiles)
- Thickness: 3 cm
- Scattering Length: greater than 50 mm (high transmission length)

Only one company in the world is able to fulfill the above requirements

Hall B – HDice Target for transverse configuration

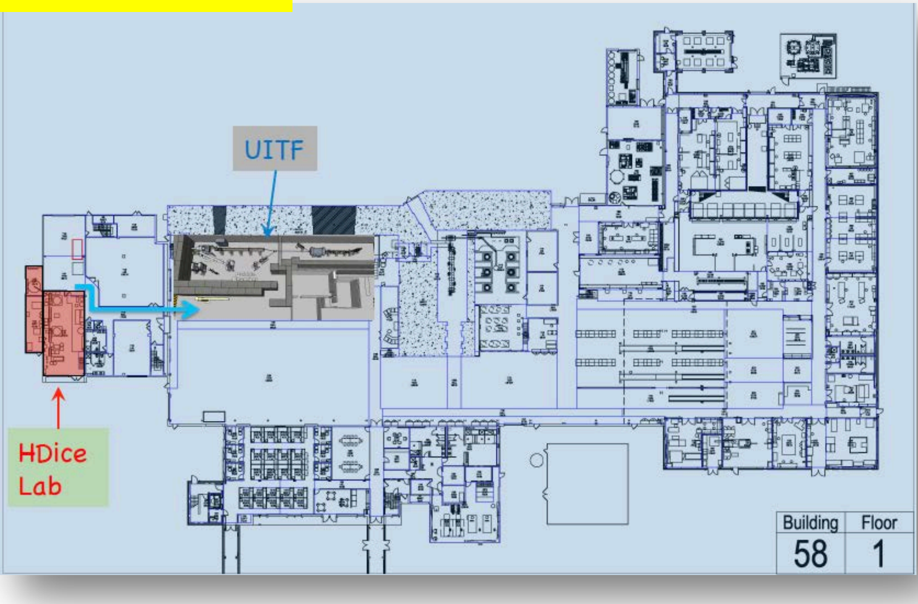
- Solid HD material placed into a frozen spin state
  - requires only modest (~1 T)•short (~15 cm) field to hold spin in-beam (MgB2 magnesium diboride)
- Operating performance with electrons beams requires further beam tests ➔plan to use upgrade of the injector test facility: E_e =5 – 10 MeV (~10 MeV beam will test the HD performance at 11 GeV!)

Modifications required to operate the target in transverse polarization mode in the CLAS12 Solenoid, whose strong long. magnetic field must be locally repelled.

Status of ongoing work:

- Transport design for 10 MeV rastered ITF beam
- R&D for a new “passive” SC *diamagnetic shield* to hold spin transverse to beam within solenoid
- Improving NMR system for target polarization measurement
- Design and build new HD gas purification factory

Patrizia Rossi



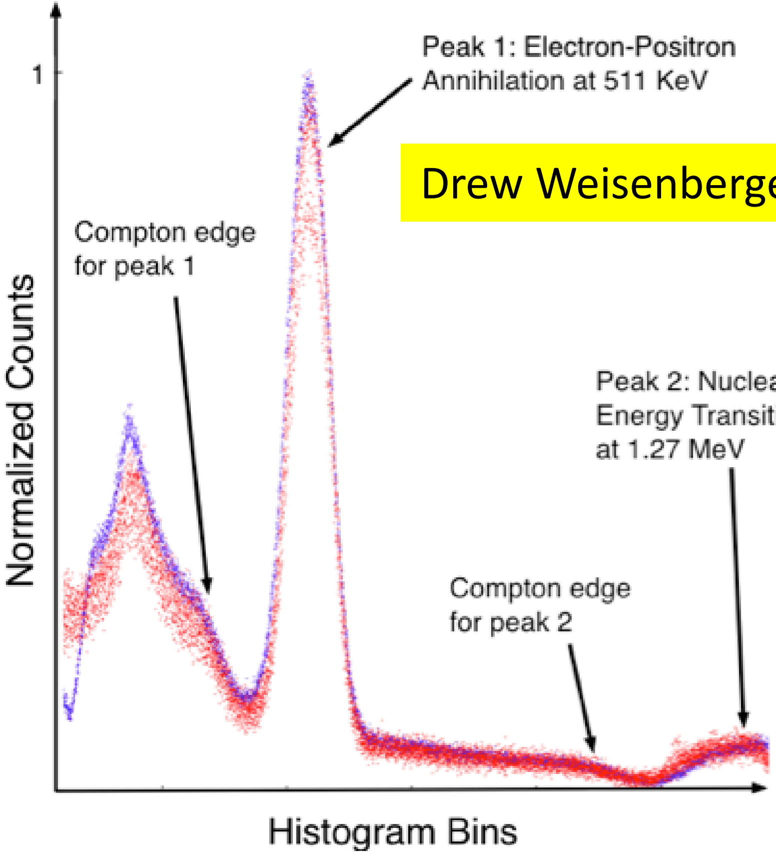
A Radiation Tolerant High-Magnetic Field Immune High-Signal Fidelity Electro-Optically Coupled Detector (EOCD) for Nuclear Physics

Applications:

- electromagnetic calorimeters (EMCs)
- detectors of internal-reflected Cerenkov light (DIRCs)

EOCD

- multiplexed channels of detector analog current pulses (e.g. PMTs, SiPMs) drive LED lasers of various wavelengths
- identical analog multi-wavelength laser pulses transmitted down communications grade single mode fiber optics
- laser detectors near remote DAQ convert/de-multiplex light pulses back to electrical for ADCs
- signal pulse preserved: shape, timing & phase
- reduced complexity
  - ✓**no copper**
  - ✓**fewer cables**: >200 analog channels/fiber
- high-radiation and high-magnetic field tolerant



Drew Weisenberger

SiPM-LYSO: ^{22}Na pulse spectra overlay- Red- pulse height spectrum via copper. Blue- Spectrum acquired with EOCD.

W. Xi, J.E. McKisson, A.G. Weisenberger, S. Zhang, C. Zorn, “Externally-Modulated Electro-Optically Coupled Detector Architecture for Nuclear Physics Instrumentation,” IEEE Trans. Of Nuclear Science, vol. 61, issue 3, pp 1333—1339, June 2014.

Gamma Camera for Breast Cancer Detection

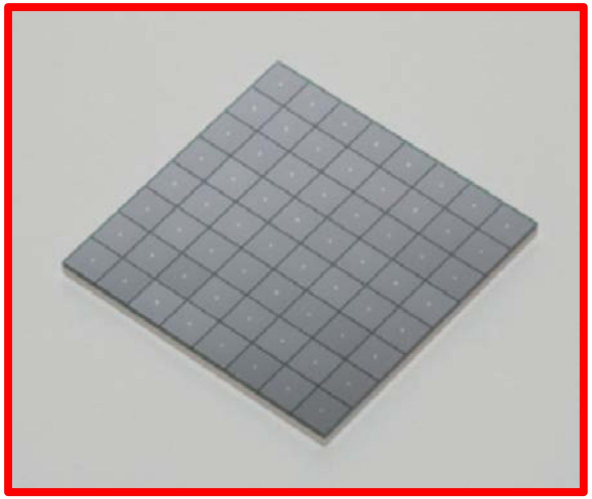
Drew Weisenberger

Several patents licensed from JLab.

Dilon Technologies, Inc. Newport News, VA
~20 employees, >250 units sold internationally
imaging performed on >250,000 patients

Nuclear physics detector technology used in the Dilon camera - helps detect breast cancers that conventional mammograms may miss, saving lives.

Recently: CRADA with Hampton University, Dilon & JLab initiated to enhance gamma camera performance using NP *silicon photomultiplier technology*.



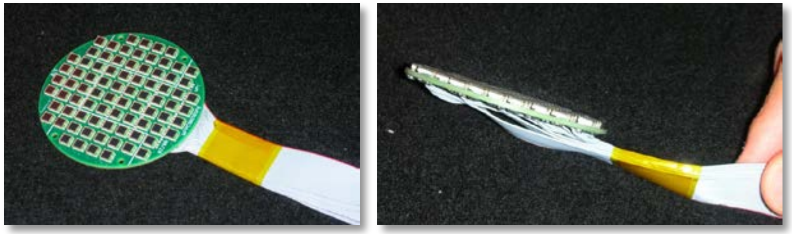
Technology Transfer: Nuclear Medicine Imaging For Real Time Surgery

Nuclear physics detector technology in a hand-held **gamma camera** through a CRADA with University of Virginia and Dilon Technologies, Inc now has 3D optical tracking ability to generate **“free-hand” SPECT images in real-time to aid cancer surgery.**

Drew Weisenberger

Silicon photomultiplier (SiPM) based detectors necessary for the experiments at Jefferson Lab have been developed for applications in medical imaging.

This technology is being further developed to allow **wireless operation**.



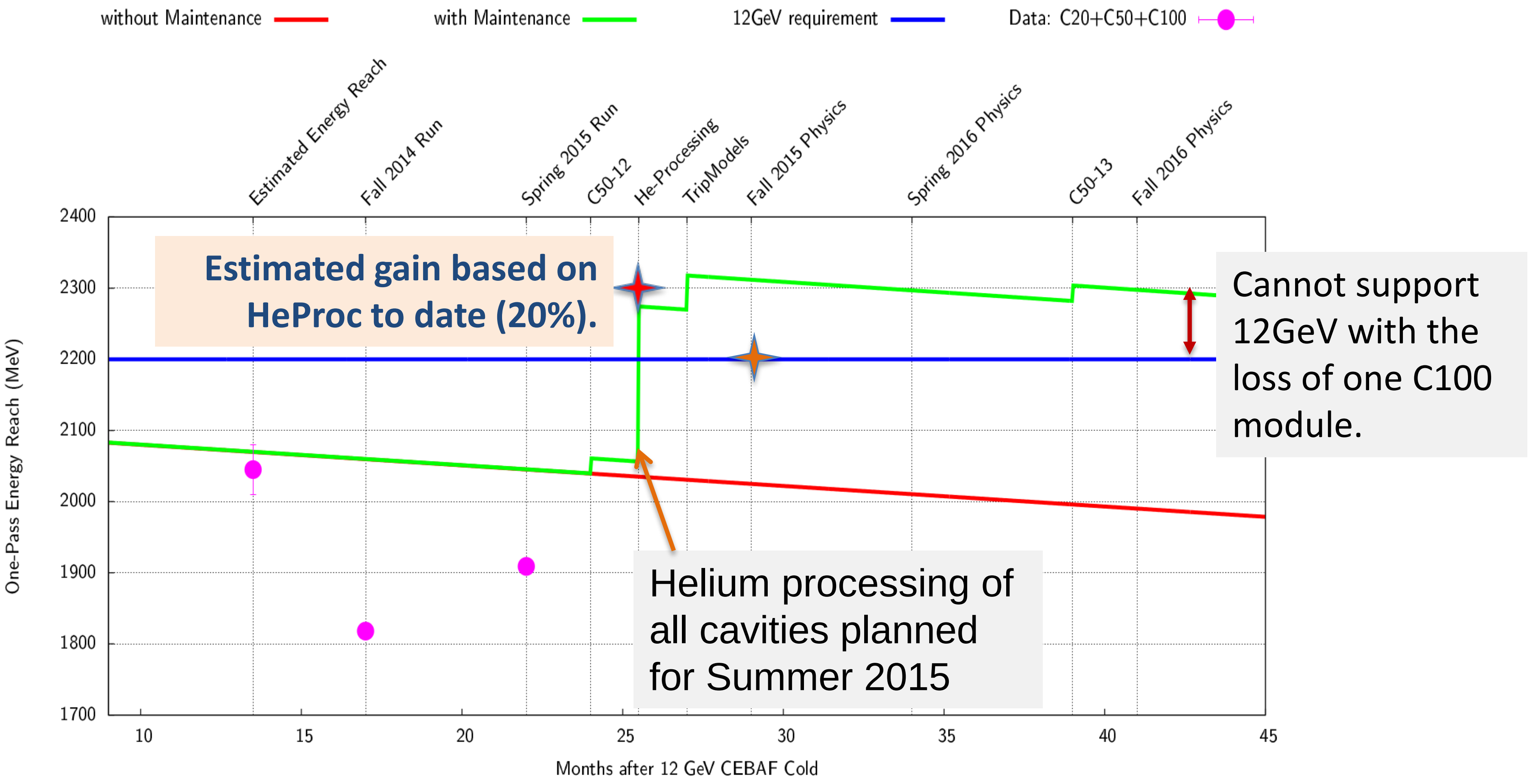
Array of 80 SiPMs

Conclusions

- Successful rack record of synergy between the SBIR program and JLAB
- The recent emphasis on SBIR commercialization has created some challenges in leveraging the SBIR program for mutual benefits
- JLAB is committed in continuously supporting and enhancing the SBIR/STTR program at JLAB especially in Accelerator, Detector and Isotope R&D
- We are in particular interested in exploring the SBIR/STTR opportunities towards **EIC directed R&D**, and we welcome the opportunity to support proposals for FY16.
- The **2nd MEIC Collaboration Meeting** on **October 5-7** will be a great opportunity to further discuss plans and finalize proposals: we strongly encourage interested parties to attend.

BACK-UP SLIDES

Energy Reach: Past and Future



Estimated gain based on HeProc to date (20%).

Cannot support 12GeV with the loss of one C100 module.

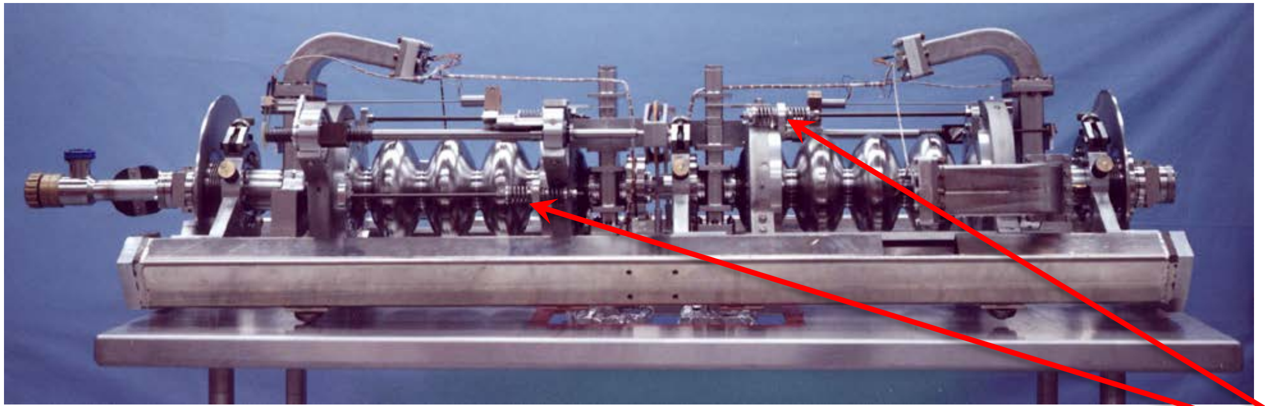
Helium processing of all cavities planned for Summer 2015

Energy Reach: Maximum CEBAF energy with less than 10 RF trips/h.

- 12GeV operations to Hall-D requires an energy reach of 2.2GeV/pass

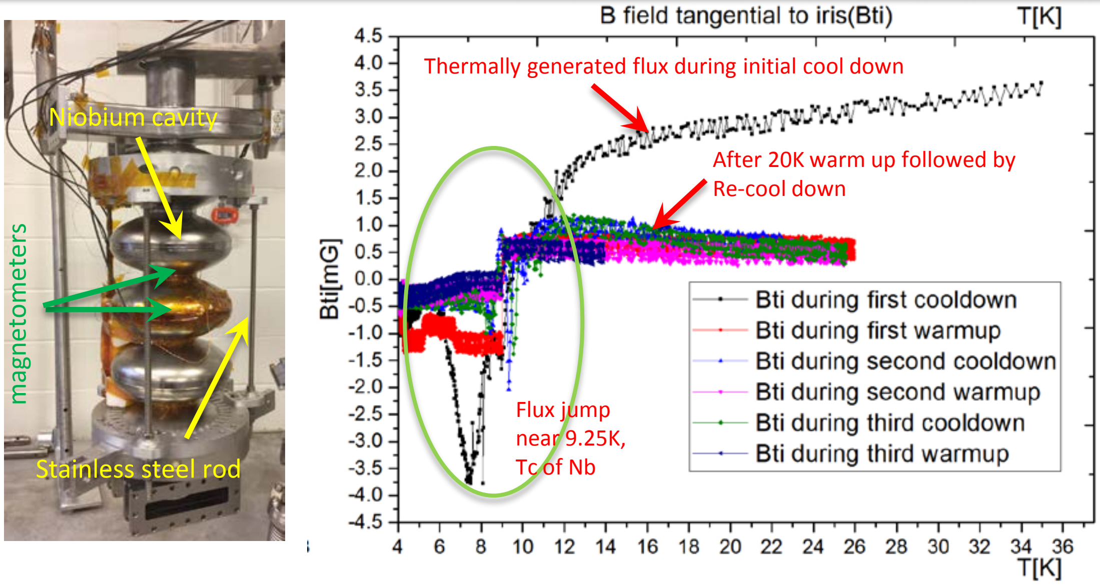
5-Cell CEBAF Cavities Low Q_0: Understanding, Cure

Purpose: Raise Q_0 of cavities installed in CEBAF, save operation cost and secure CEBAF energy reach



Previously:
- Identification of frozen-flux effect as the source of low Q_0 in 5-cell cavities installed in CEBAF tunnel (a factor of 2 degradation as compared to vertical test).
- “Discovery” of magnetized tuner components enclosed in the cold magnetic shield. The worst case is ***strut spring***: 6 Gauss at contact.
- Replacement strut springs implemented in C50-11.

  Two more recommended solutions to be implemented in C50-12.



Series test of thermal current and generated flux using a 5-cell CEBAF cavity

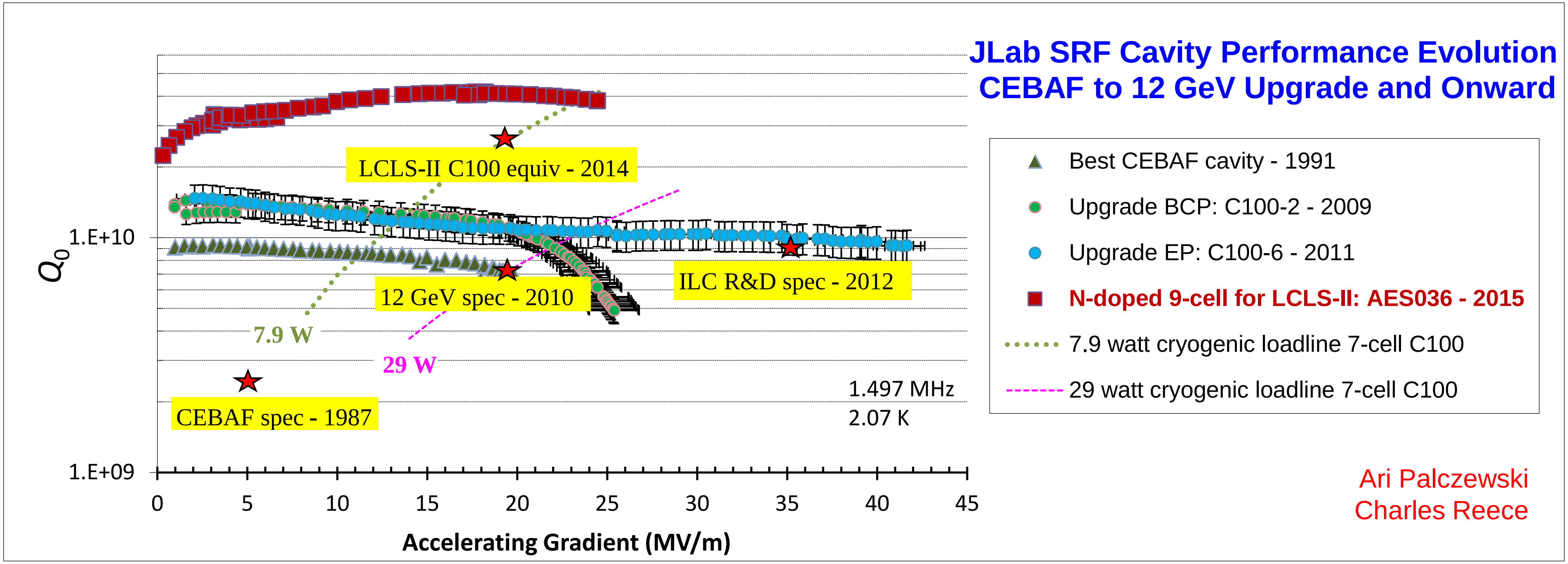
Presently:
- Examination of magnetic flux ***thermally generated*** inside the loop formed between niobium cavity and stainless steels rods
- A potential “thermal therapy” is being developed for zero out the thermally generated flux.

Rongli Geng

Improving SRF Cavity Efficiency via Doped Materials

Learning how to minimize SRF losses (maximize cavity *Q*) via Nitrogen Doping of Niobium

- Collaborated with FNAL and Cornell to **validate High-Q process for LCLS-II**
  - Enabled >50% reduction in cryo-load compared with previous methods
  - Now transferring the protocols to vendors
- Systematically studying the doping protocols, material effects, and SRF properties
  - Involving university collaborators (including graduate students) in **detailed material characterization**
  - Beginning to interpret new RF performance in terms of latest basic SRF theory



JLab SRF Cavity Performance Evolution CEBAF to 12 GeV Upgrade and Onward

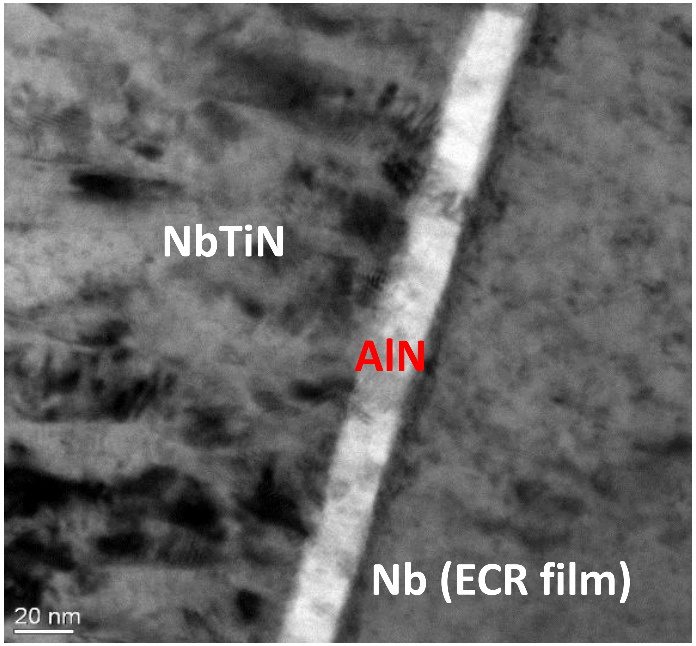
Ari Palczewski
Charles Reece

Development of SIS NbTiN/AlN structures on Nb surfaces

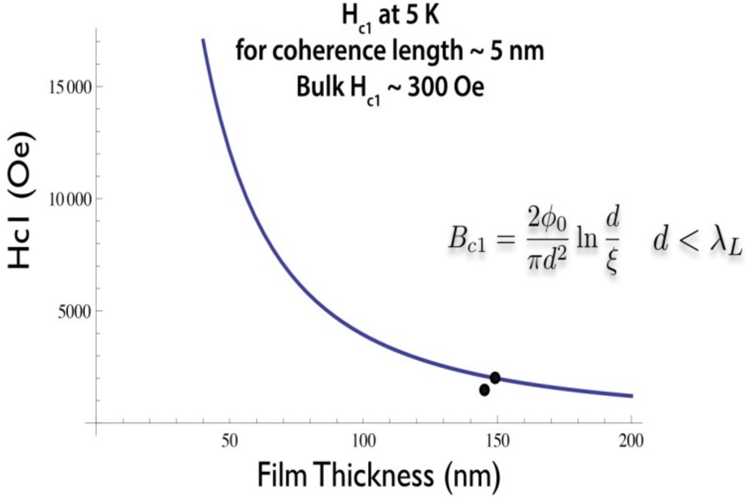
Learning how to grow high quality Superconductor/Insulator/Superconductor films

- ❑ Multi-layer SIS films may be a path to support very high surface RF fields
- ❑ Now producing high quality NbTiN/AlN/Nb films by multi-target sputter deposition
  - Candidate system to test the SIS SRF theory
  - Showing excellent progress in avoiding parasitic losses
  - Initial results are consistent with theory

	Thickness [nm]	H_{c1} [mT]	T_c [K]
NbTiN/MgO	2000	30	17.25
NbTiN/AlN/AlN ceramic	145	135	14.84
NbTiN/AlN/MgO	148	**200**	16.66

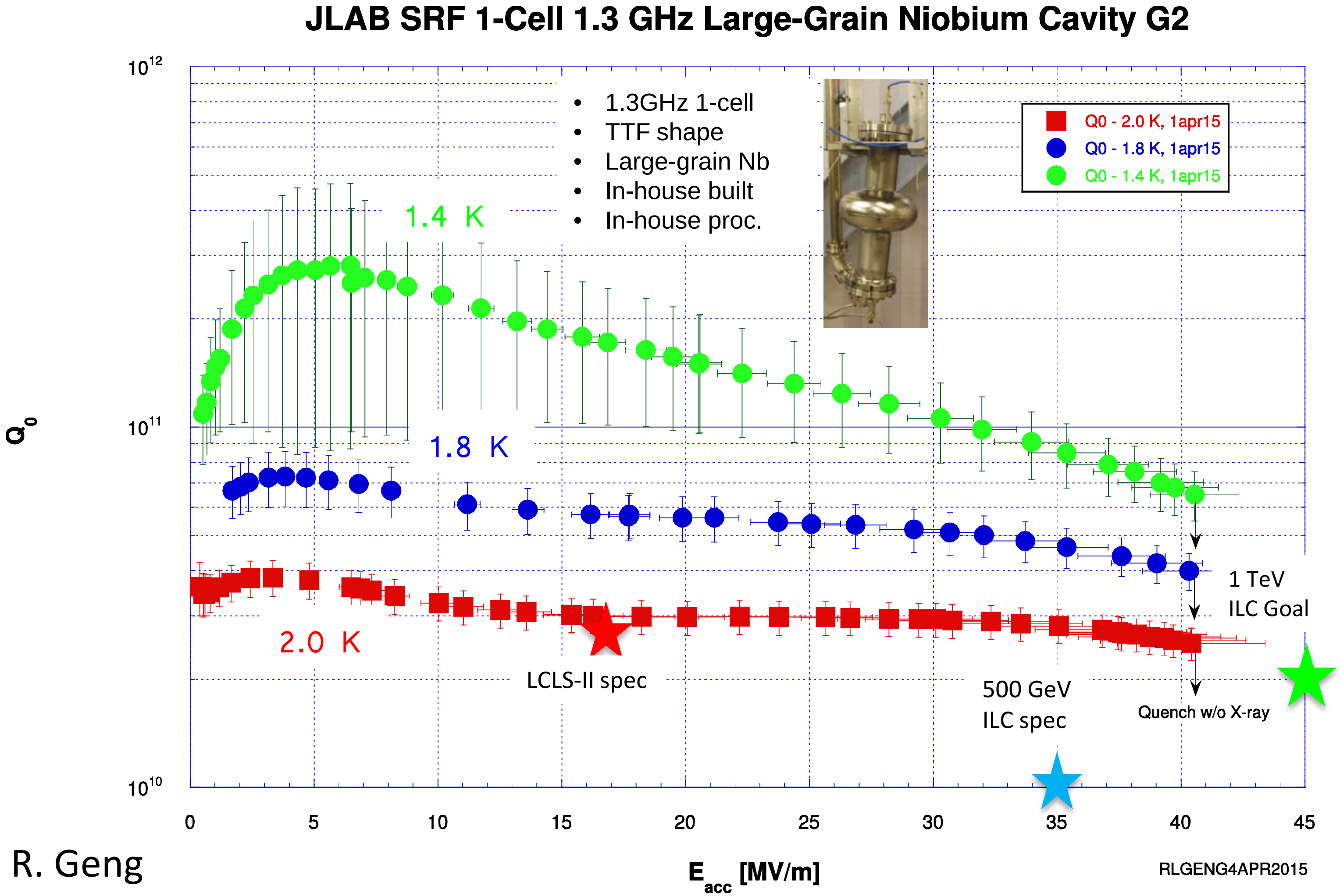


A-M Valente-Feliciano



High Gradient: New Results and Next Steps

Purpose: achieve high gradient with high efficiency, at a low cost and high reliability
Approach: Low-Surface-Field Shape + Large-grain Niobium material + advanced processing


JLAB SRF 1-Cell 1.3 GHz Large-Grain Niobium Cavity G2

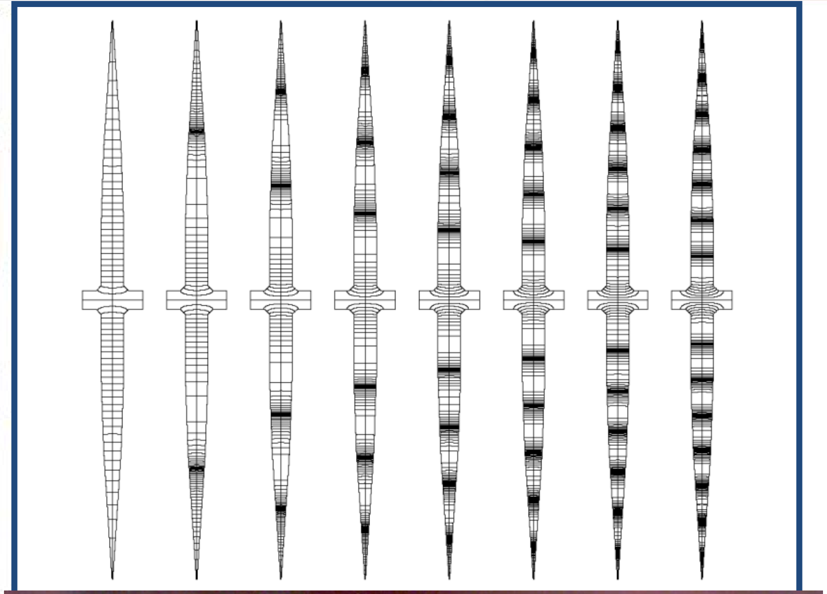
- 1.3GHz 1-cell
- TTF shape
- Large-grain Nb
- In-house built
- In-house proc.

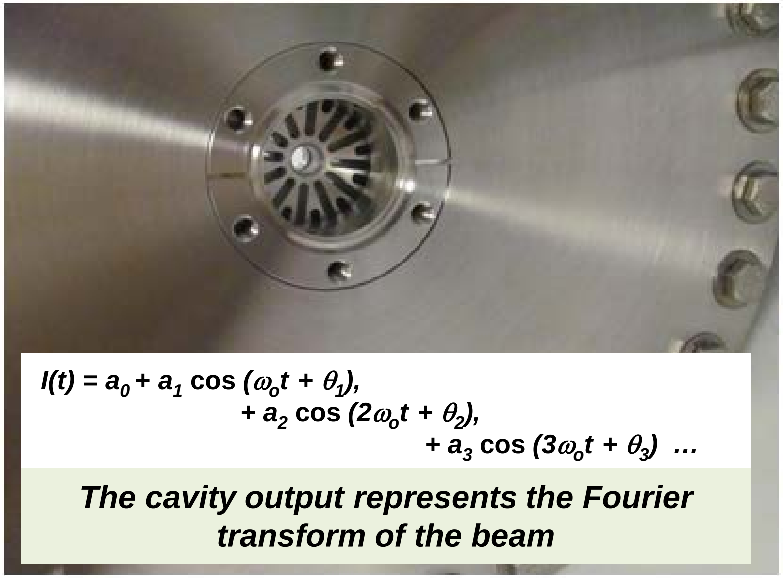
R. Geng

Future cavities: LSF cavity

Prototypes:
- Two each 1-cell built and tested
- Two each 3-cell and one each 9-cell in process of fabrication.

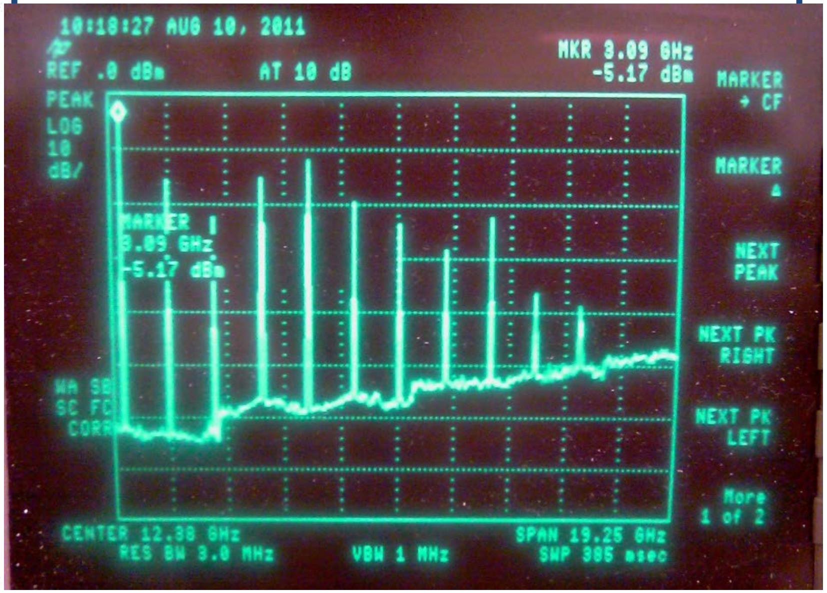
Harmonically-resonant cavity: only TM$_{ONO}$ modes!





$$I(t) = a_0 + a_1 \cos(\omega_o t + \theta_1),$$
$$+\, a_2 \cos(2\omega_o t + \theta_2),$$
$$+\, a_3 \cos(3\omega_o t + \theta_3) \;\ldots$$

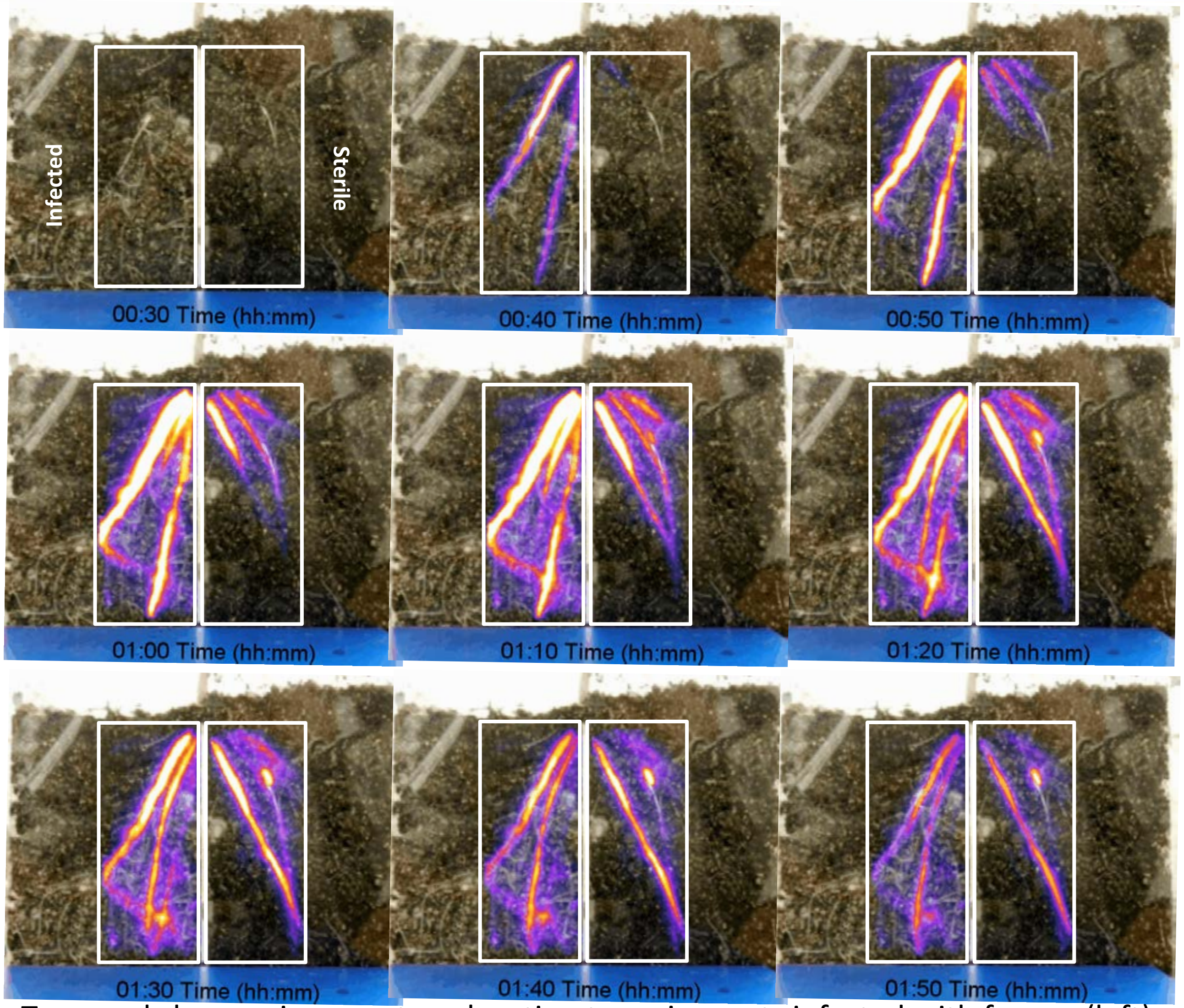
The cavity output represents the Fourier transform of the beam



PhytoPET to Measures ^{11}C Sugar Translocation

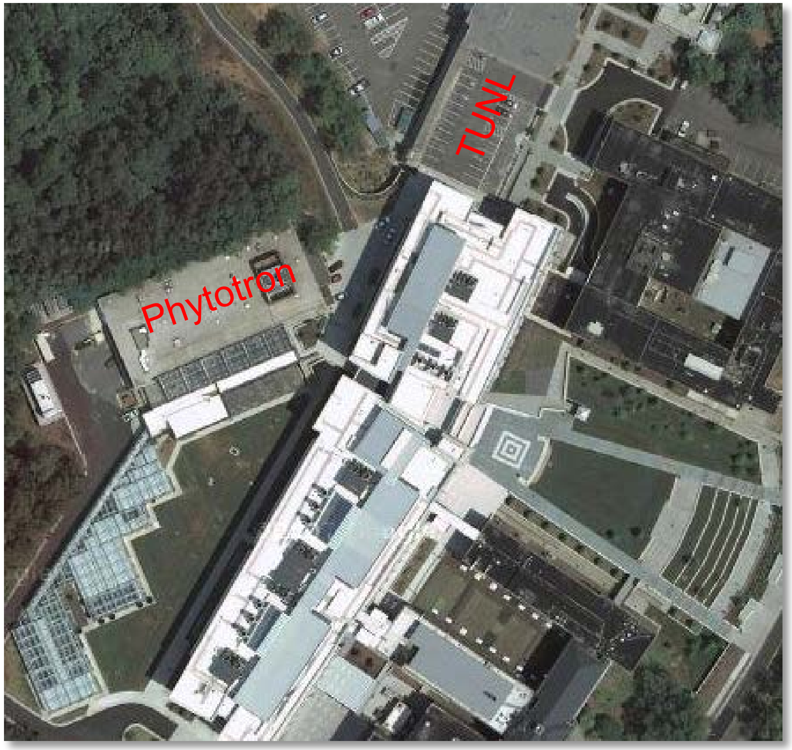
PhytoPET system (8 detector modules, 4 detectors on each side of cuvette) used for a **maize split root dynamic imaging of ^{11}C sugar uptake** down to roots from the leaf.

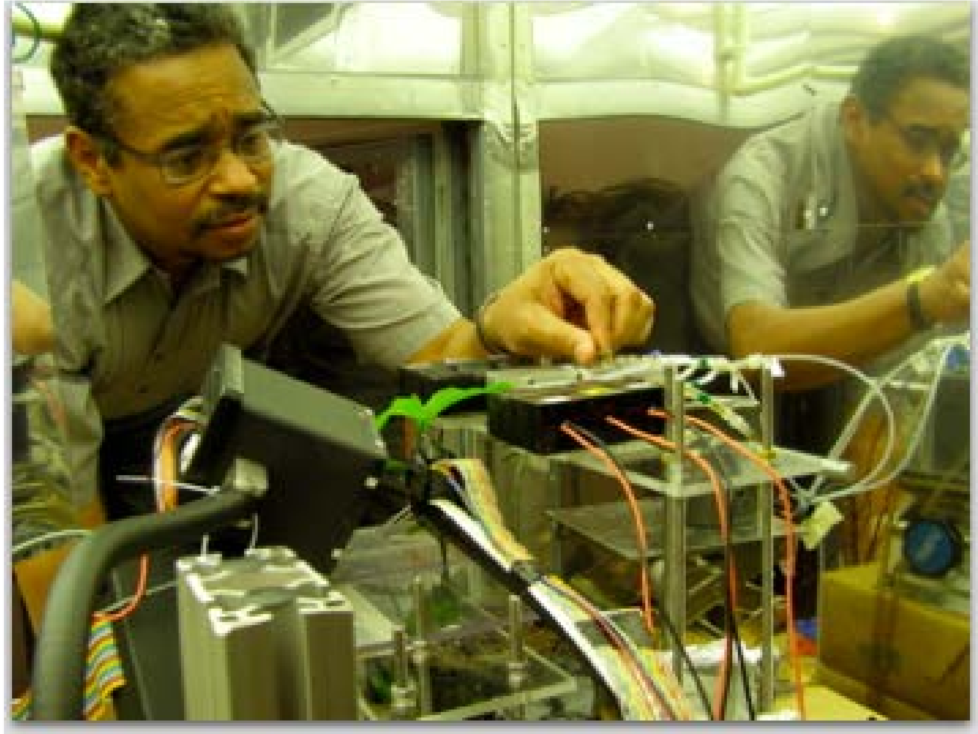
Exploring **soil/root/fungi** interaction. Identifying fungi that aid plant root growth.



Temporal changes in sugar translocation to maize roots infected with fungus (left) & sterile (right). Grown in a dual-chambered root cuvette using potting soil.

Detector Development for Plant Biology with Triangle Universities Nuclear Laboratory / Duke University



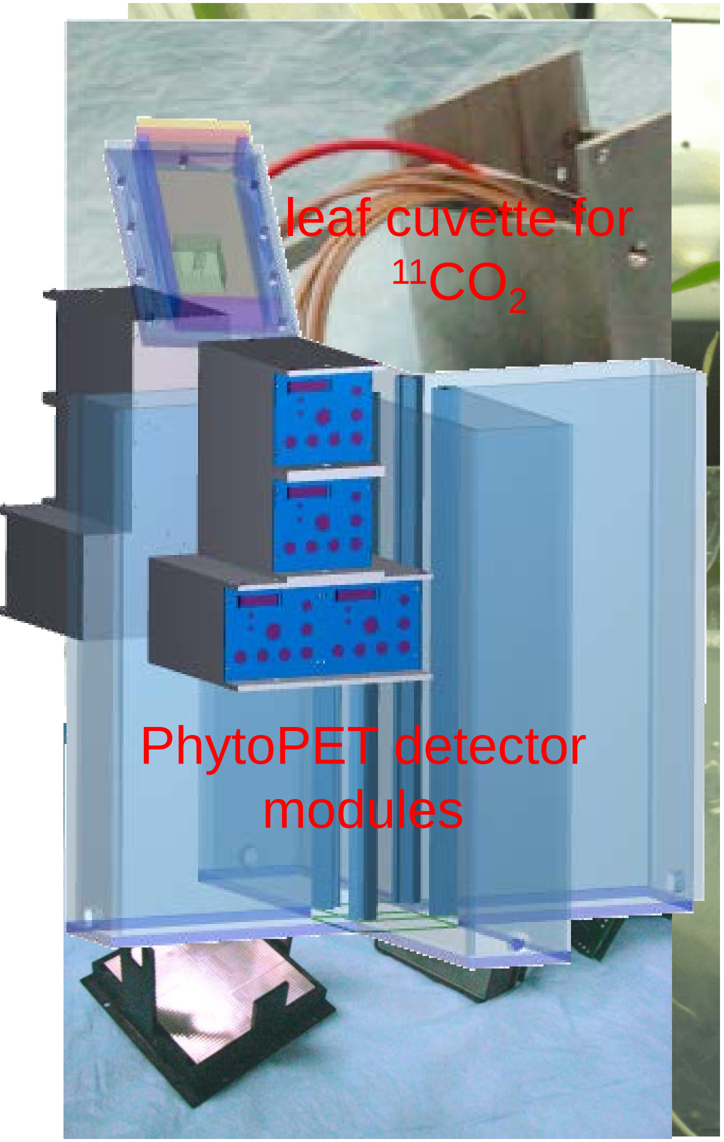


Drew Weisenberger

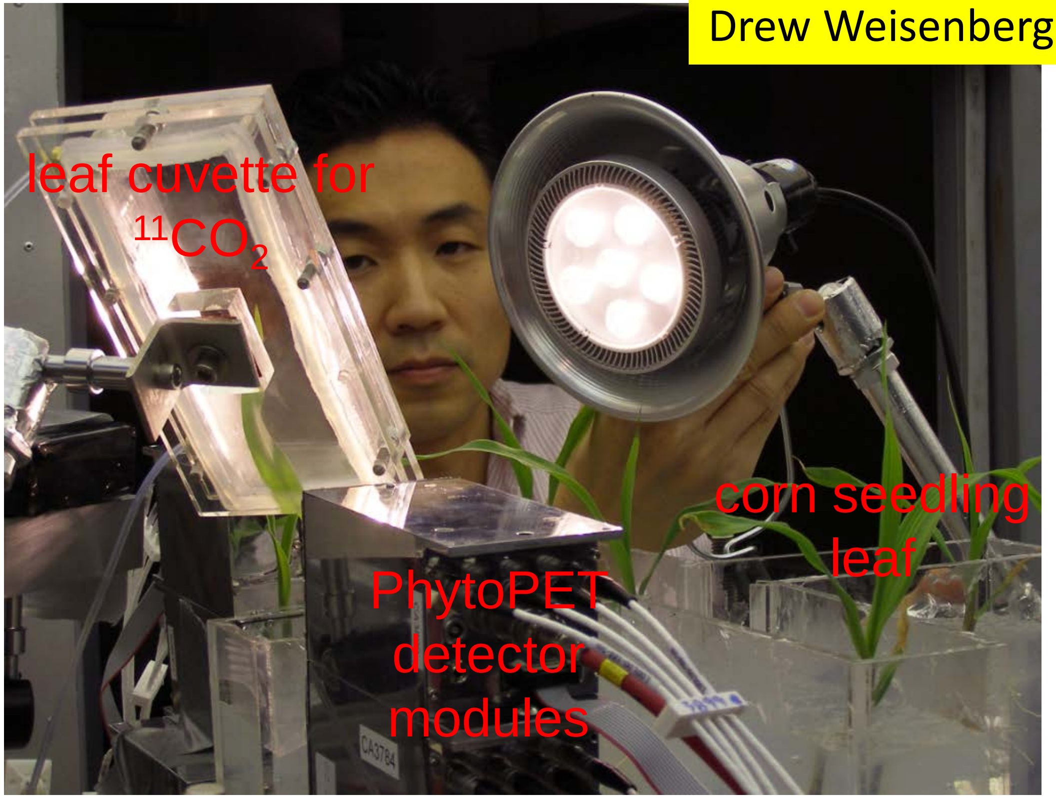
Duke University Phytotron plant research facility with environmentally controlled growth chambers for plant ecophysiological and microbial research using radionuclides

Radioisotope generation using TUNL tandem Van de Graaff

PhytoPET-Duke University/Jefferson Lab



Drew Weisenberger



Positron emission tomography (PET) detector systems to image the process of carbon transport through plants during photosynthesis under different conditions, using the PET radioisotope ^{11}C.

Technology Transfer: Nuclear Medicine Imaging
3D Brain Scans of Moving Mice

- **AwakeSPECT System** is based on technology developed by Jefferson Lab, with contributions from ORNL, Johns Hopkins University and University of Maryland. *It is presently being upgraded by JLab*.
  - Utilizes custom-built gamma cameras, image processing system, infrared camera motion tracking system and commercial x-ray CT system.
  - Acquires functional brain images of conscious, unrestrained, and un-anesthetized mice.
  - Documents for the first time the effects of anesthesia on the action of dopamine transporter imaging compound, and shows the drug was absorbed less than half as well in awake mice than in anesthetized mice: *Journal of Nuclear Medicine, vol. 54, no. 6, pp. 969-976, Jun. 2013*.
  - Can aid research into Alzheimer’s, dementia, Parkinson’s, brain cancers traumatic brain injury and drug addiction.

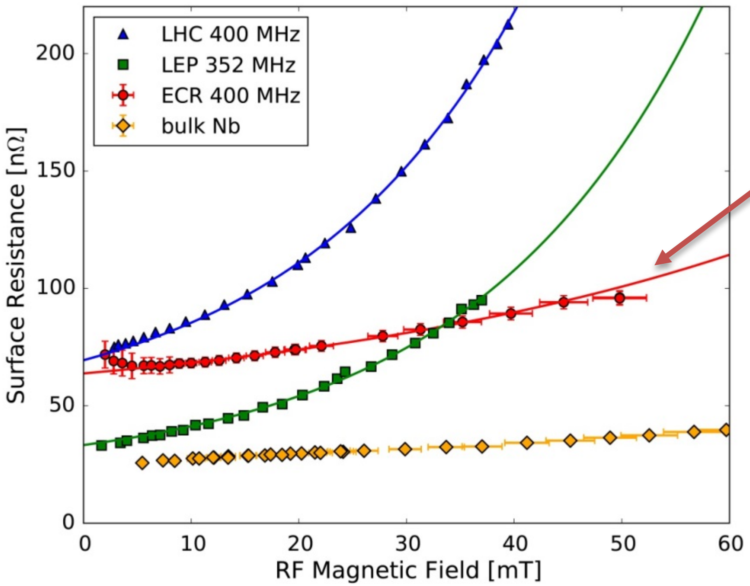
Three IR markers attached to the head of a mouse enable the AwakeSPECT system to obtain detailed, functional images of the brain of a conscious mouse as it moves around inside a clear burrow.

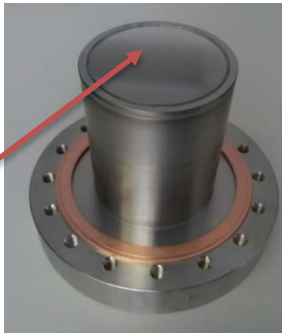
Drew Weisenberger

Development of Nb/Cu films by Energetic Condensation

Learning how to grow high quality crystalline Niobium films on Copper to replace bulk Niobium

- Now producing Niobium films with **higher purity and fewer defects than bulk Niobium**
- Collaborating with CERN for characterization of SRF properties
  - Demonstrated lowest-yet non-linear losses **(greatly reduced "*Q* slope")**
  - Best controlled samples now under test
- Migrating all lessons learned to new cavity deposition system with refinement/analysis of deposition conditions, film character, and RF performance
  - Involving DOE Office of Science **Graduate Student Research Award** winner





Sample configuration for CERN RF test system

Anne Marie Valente
Larry Phillips

First HiPIMS Nb/Cu cavity coated