Jefferson Lab and SBIR/STTR Program

Drew Weisenberger

DOE-NP SBIR/STTR Exchange Meeting   Aug 9-10 2016

Outline

- Jefferson Lab Overview and Mission
- Scientific and Technical Capabilities
- JLab and the NP SBIR/STTR Program-
  A Synergistic Involvement

JLab Overview

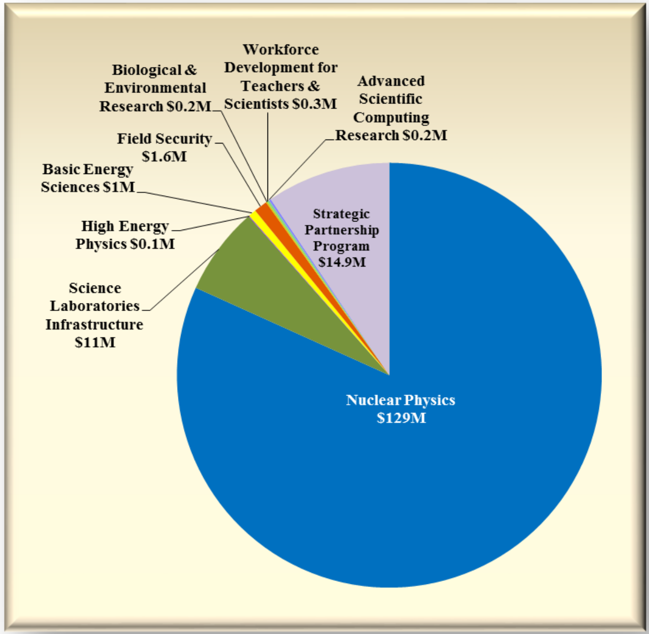
Jefferson Lab At-A-Glance

- **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
  - 1,510 Active Users
  - 178 Completed Experiments to-date
  - Produces ~1/3 of US PhDs in Nuclear Physics (531 PhDs granted to-date; 195 in progress)
- **Managed for DOE by Jefferson Science Associates, LLC (JSA)**
- **Human Capital:**
  - 686 FTEs
  - 24 Joint faculty; 21 Post docs; 7 Undergraduate students; 37 Graduate students
- **K-12 Science Education program serves as national model**
- **Site is 169 Acres, and includes:**
  - 70 Buildings & Trailers: 876K SF
  - Replacement Plant Value: $397M

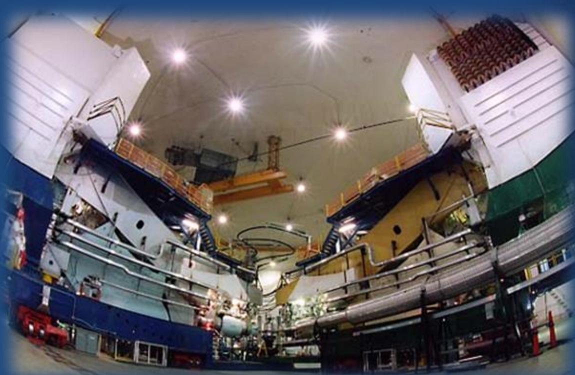
FY 2015:

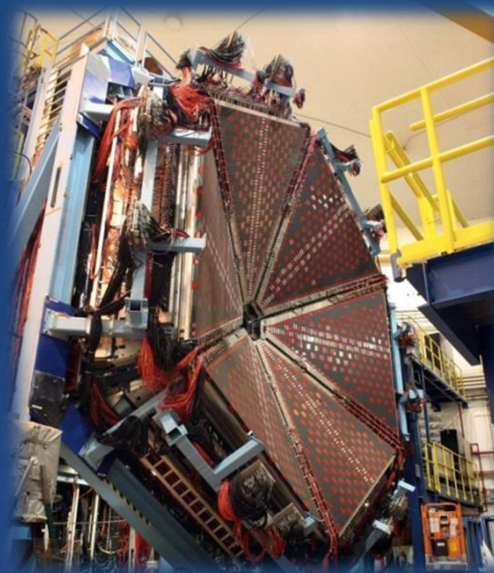
Total Lab Oper. Costs: $158M

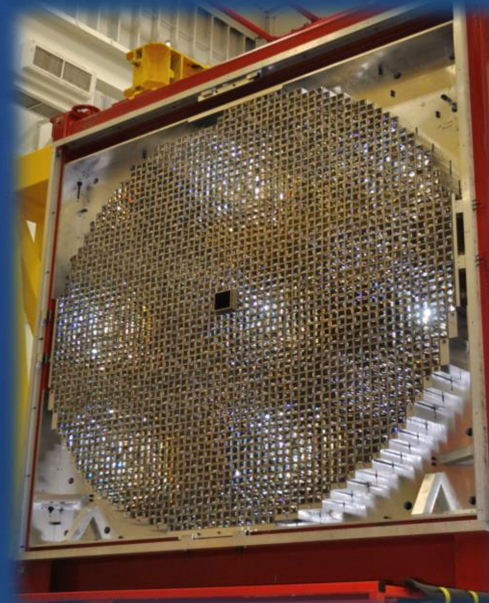
Non-DOE Costs: $14.9M



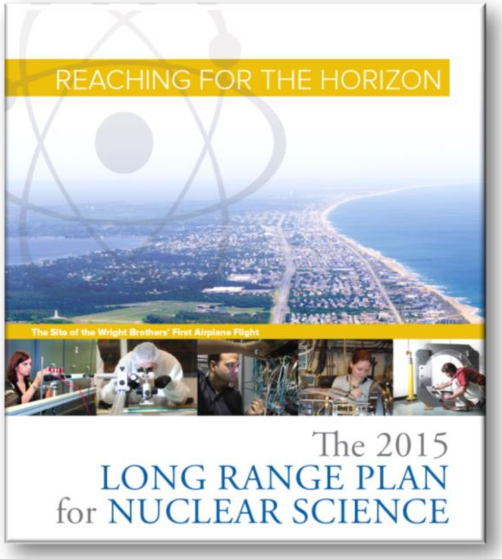
Science and Technology

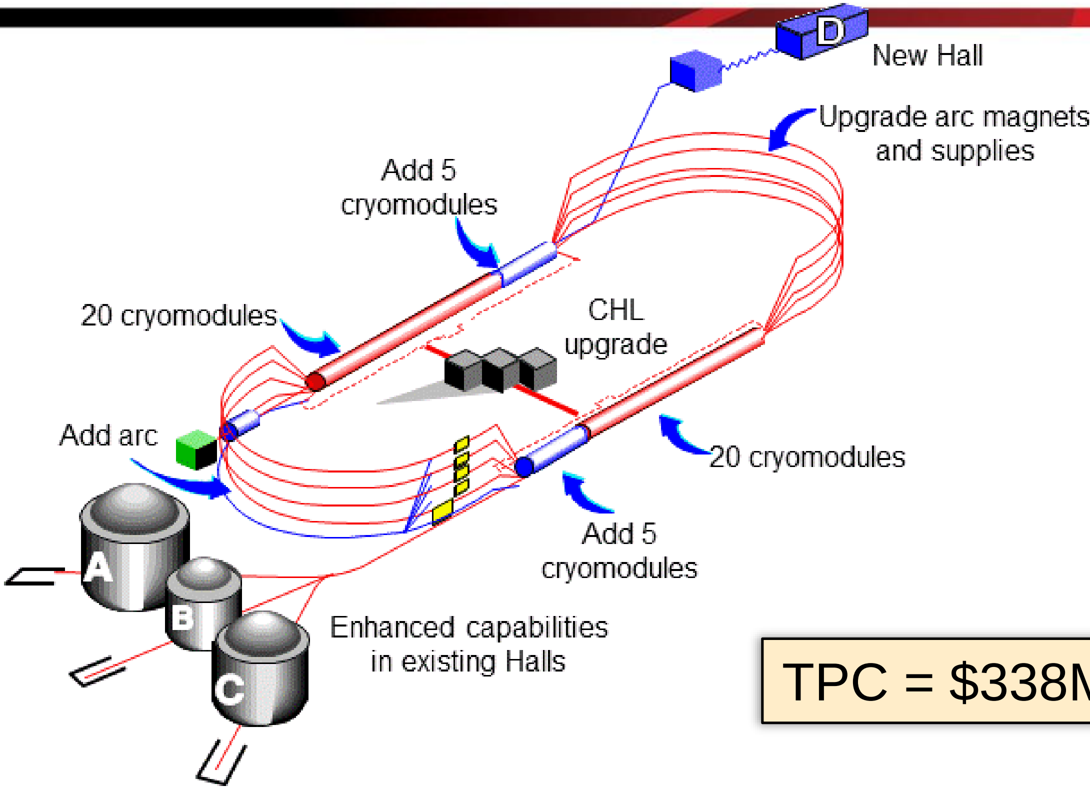






CEBAF Upgrade





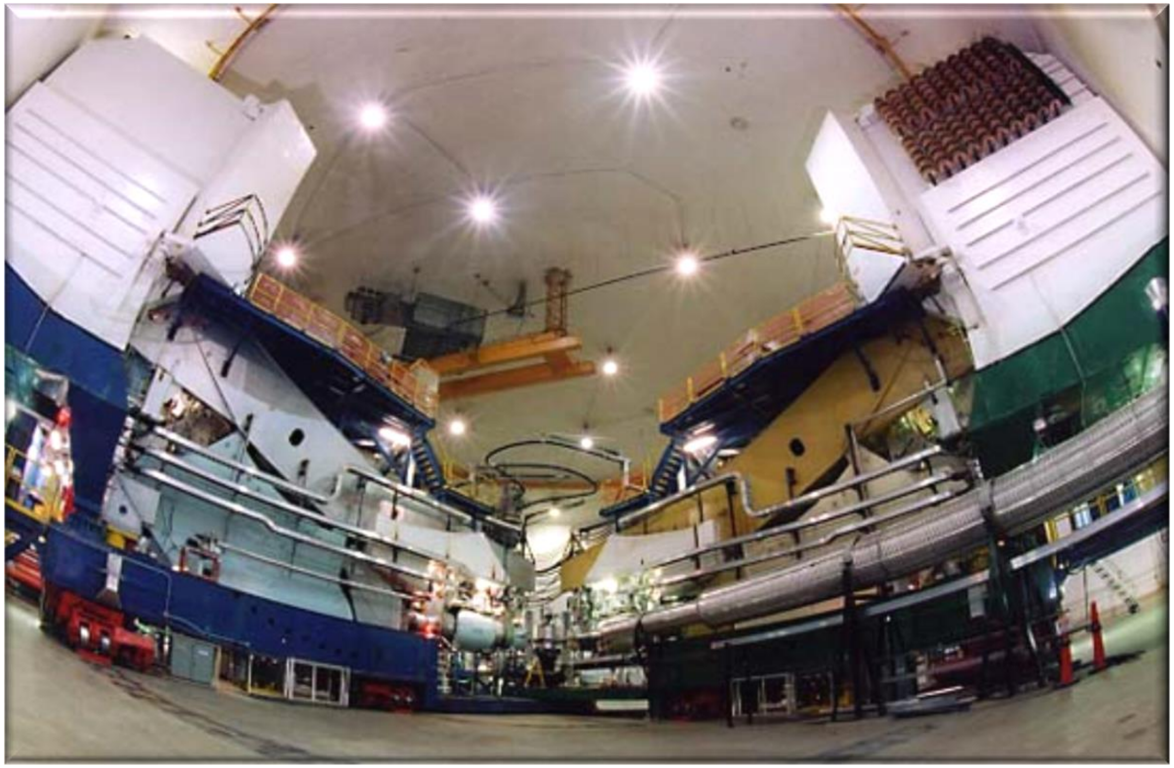
TPC = $338M

"With the imminent completion of the CEBAF 12-GeV Upgrade, its forefront program of using electrons to unfold the quark and gluon structure of hadrons and nuclei and to probe the Standard Model must be realized"

Project Scope (complete FY17):

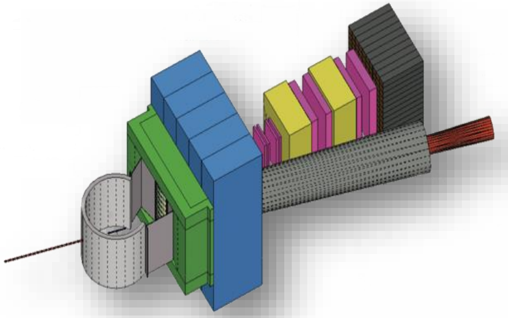
- **Doubling the accelerator beam energy - DONE**
- **New experimental Hall D and beam line - DONE**
- **Civil construction including utilities - DONE**
- **Upgrades to Experimental Halls B & C - FY17**
  - **Halls B & C Detectors – DONE**

Hall A

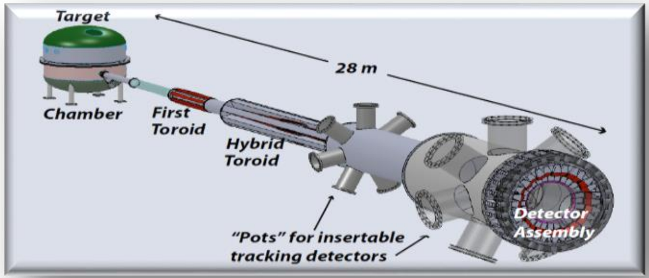


Two High Resolution Spectrometers (HRSs)
Commissioning started: February 2014

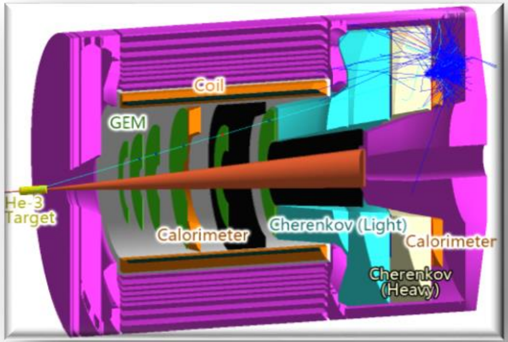
- Super BigBite Spectrometer



- 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

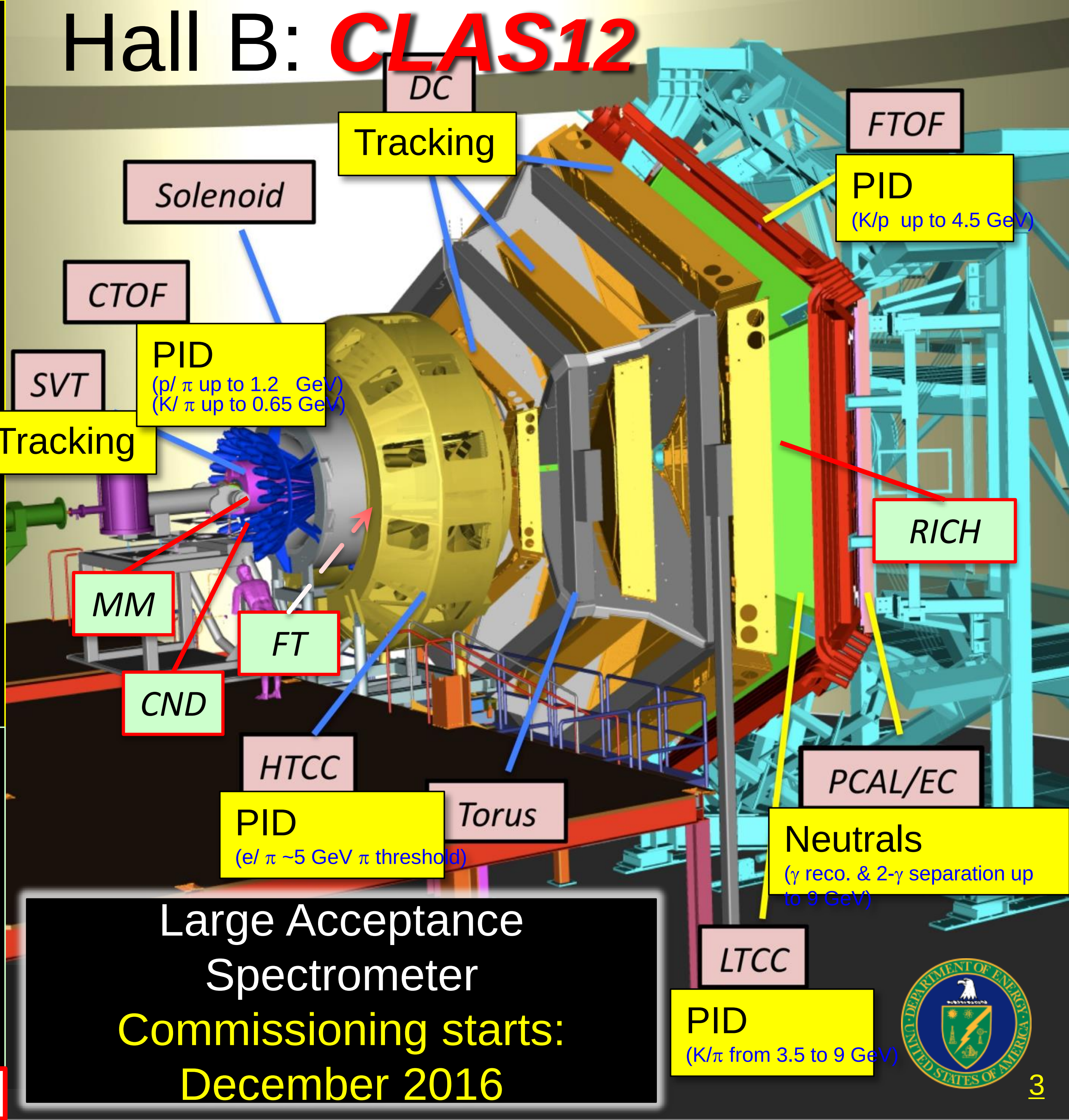
Beamline

- Targets
- Moller polarimeter
- Photon Tagger

Upgrade to base equipment

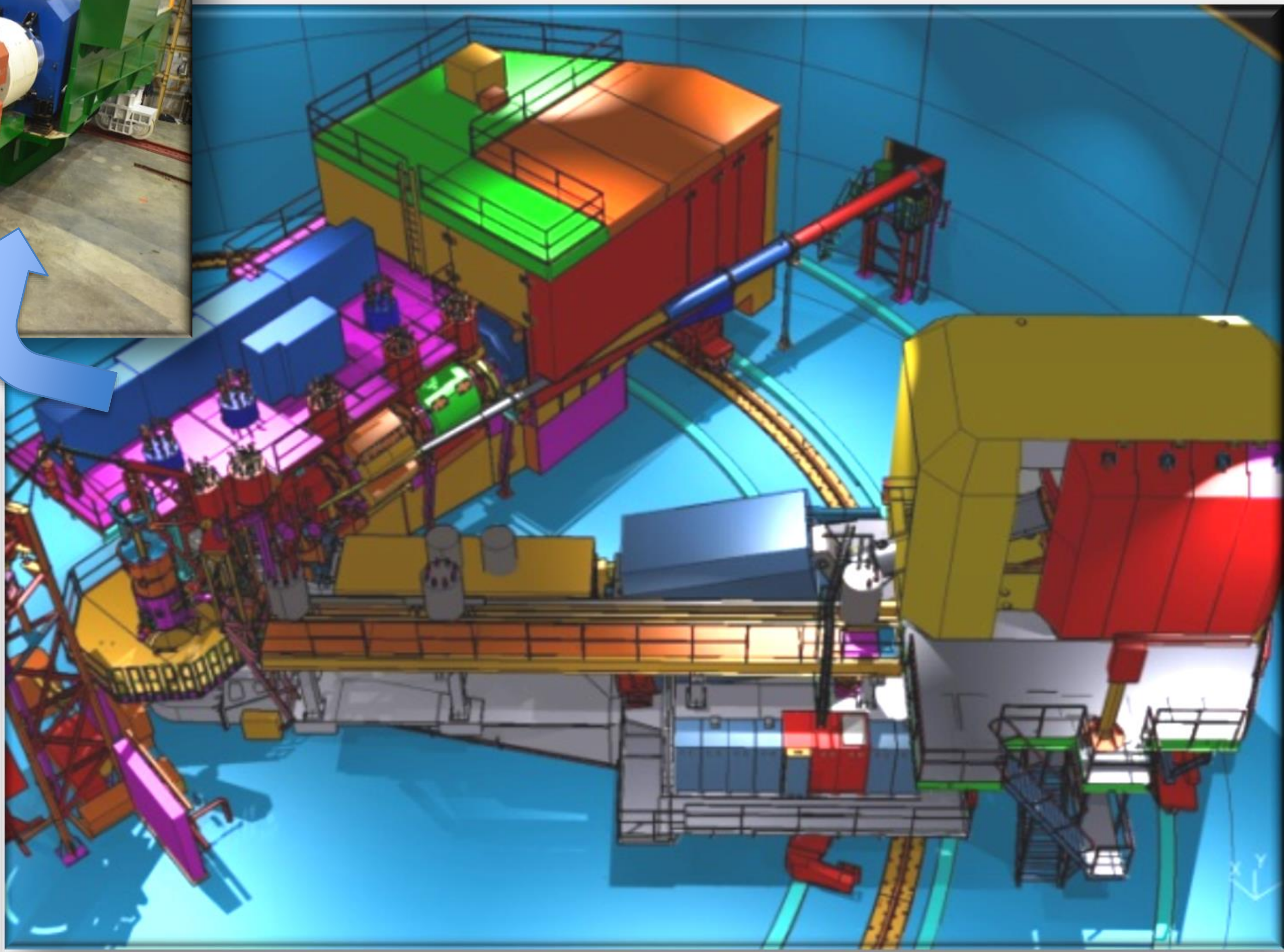
- MicroMegas
- Central Neutron Detector
- Forward Tagger
- RICH detector (1 sector)
- Polarized target (long.)

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



Large Acceptance Spectrometer
Commissioning starts: December 2016

Hall C

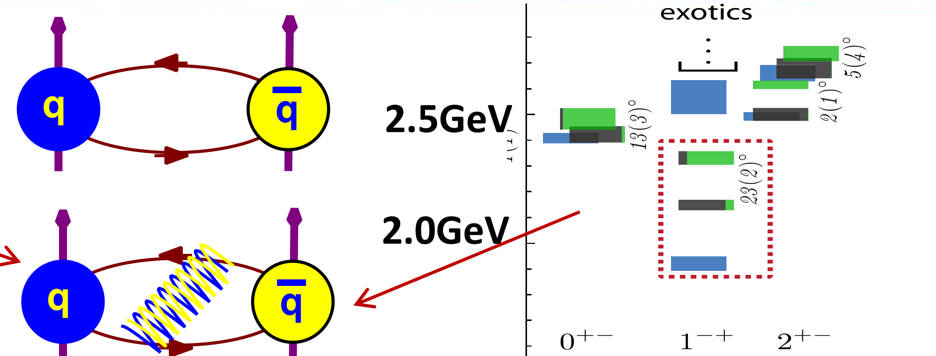


High **M**omentrum **S**pectrometer (**HMS**)+ **S**uper **H**igh **M**omentum **(SHMS)**

Commissioning starts: September 2016

Hall D: Experiments with Photon Beam

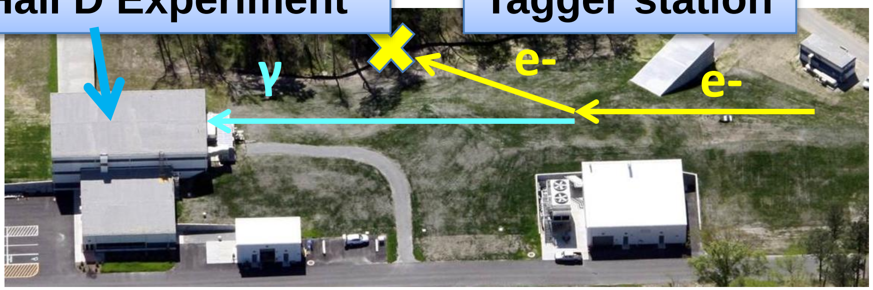
- Linearly polarized photon beam ~9 GeV
- Experiment GlueX: Search for gluonic excitations in light meson spectra
- Commissioning completed June 2016



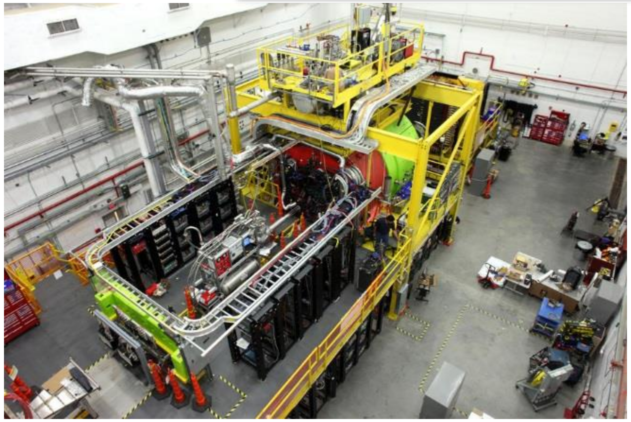
LQCD predictions

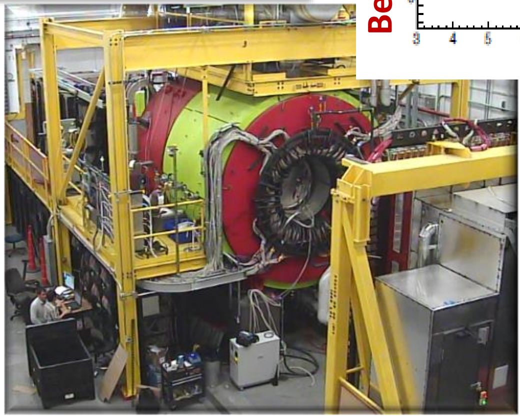
Hall D Experiment

Tagger station

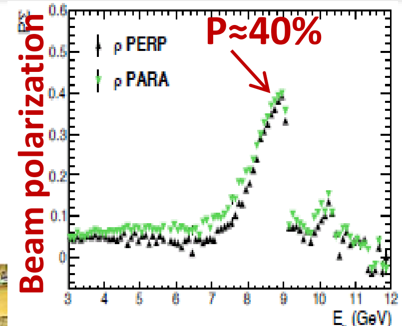


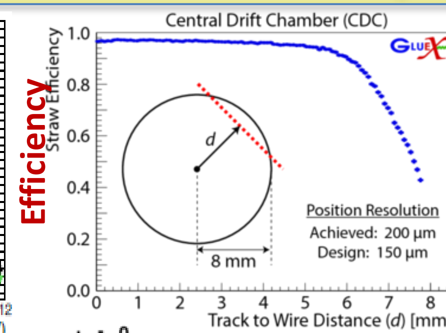
Large-acceptance spectrometer



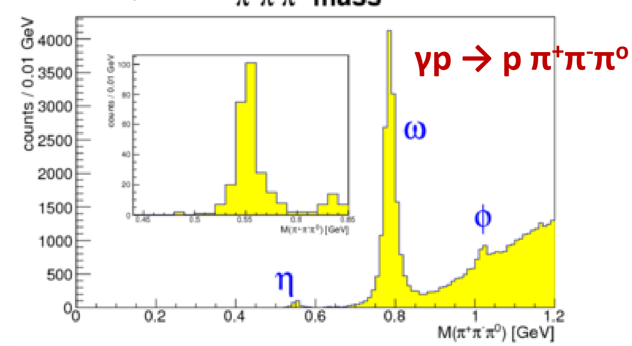


Preliminary results of the commissioning





$\pi^+\pi^-\pi^0$ mass



CEBAF Commissioning Highlights

Spring 2015:
- First simultaneous Hall A/D operations
- Successful commissioning runs:
  Hall B (Heavy Photon Search) and Hall D (GlueX)

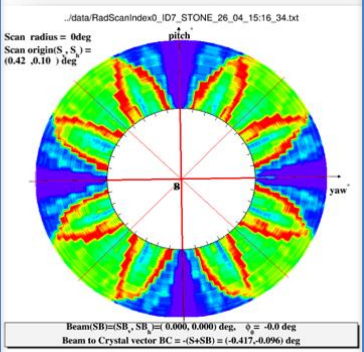
Fall 2015:
- First operation of CEBAF at design energy

Spring 2016:
- Hall D engineering run complete
- Hall A commissioning and early physics run
- Hall B HPS on weekends, extended run

Summer 2016:
- Proton Radius Experiment (PRad)
- First completed experiment in 12 GeV era!

Accelerator ready for 12 GeV physics program

D: 1st production polarized photons

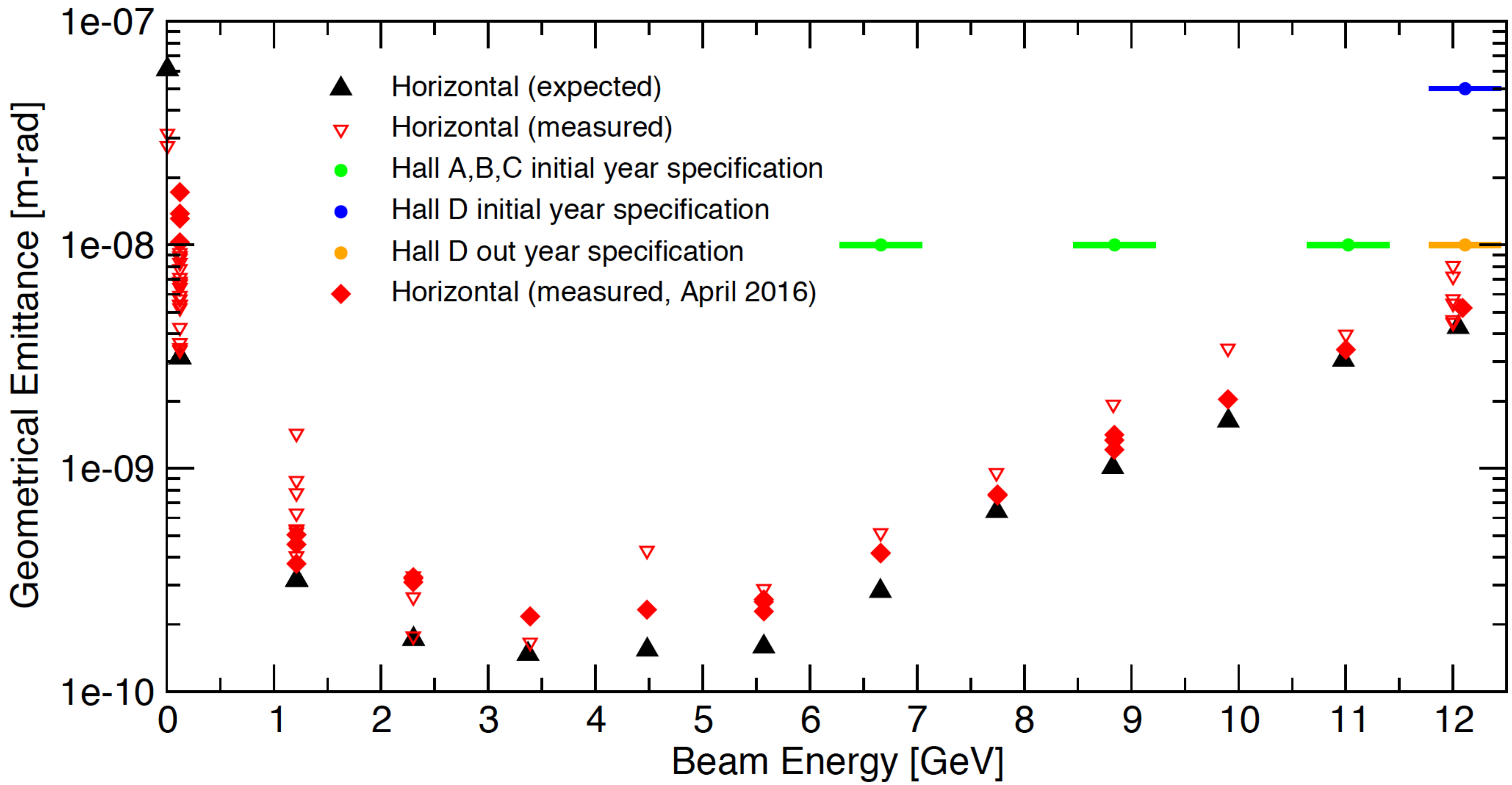


Jefferson Lab

Fall 2015 Run Highlights

2015-November-09 to 2015-December-21

- E=2.2 GeV/pass
- High beam polarization measured at high energy
- Measured horizontal emittance after every pass



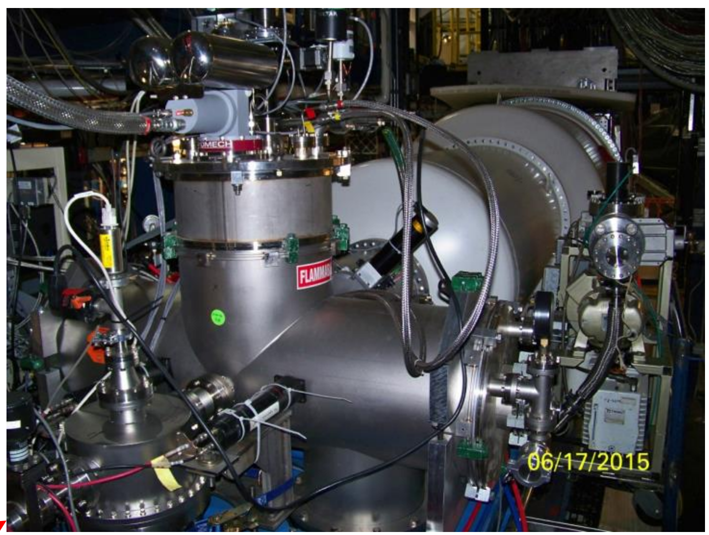
Spring 2016 Run: Hall B Short Experiment

2016-January-28 to 2016-April-25

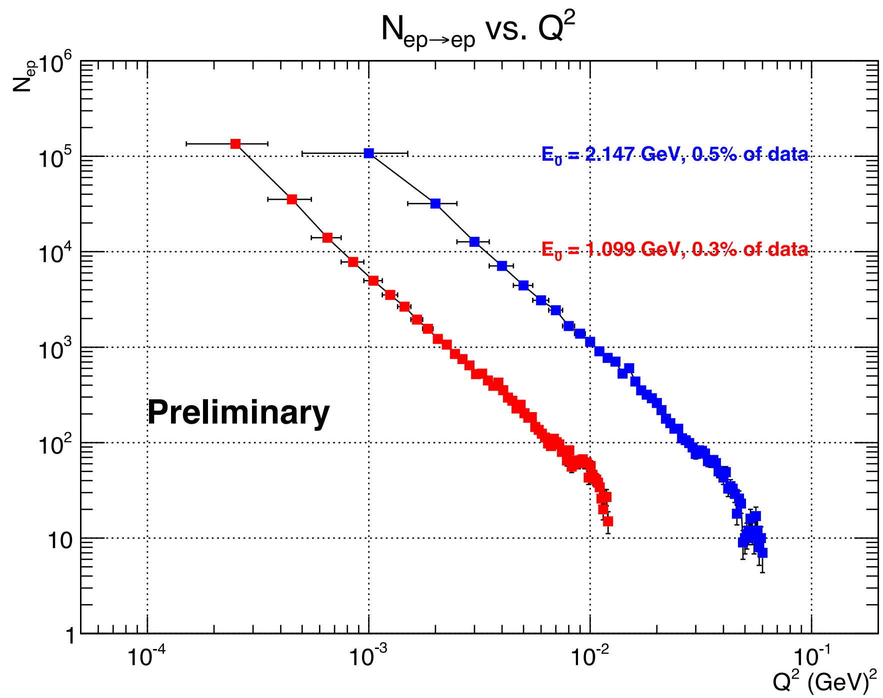
- Hall B: Approved PRad (1 and 2 pass) Experiment
  - Precision Proton Radius Measurement
  - Data Taking Complete
- First “Windowless” Hydrogen Gas Target
- Ran CEBAF on one CHL

Beginning of 12 GeV Era!

e - beam



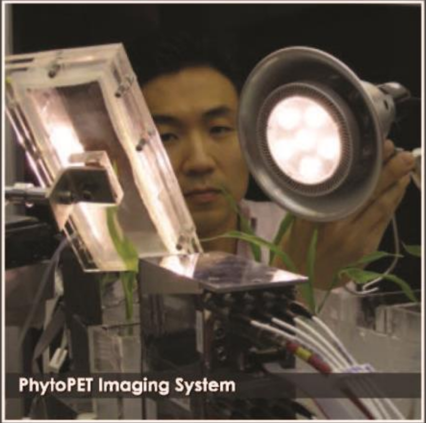
Windowless H2 Target Installed



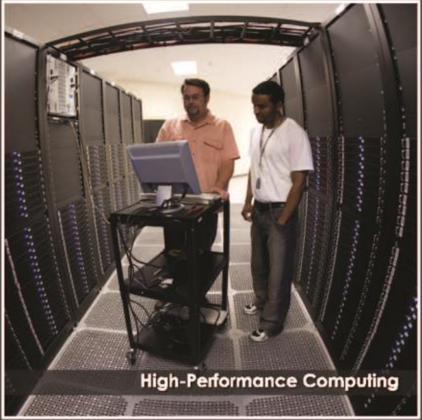
Scientific & Technical Capabilities

Jefferson Lab

FACILITIES EXPERTISE & EQUIPMENT FUEL INNOVATION, FEED BUSINESS



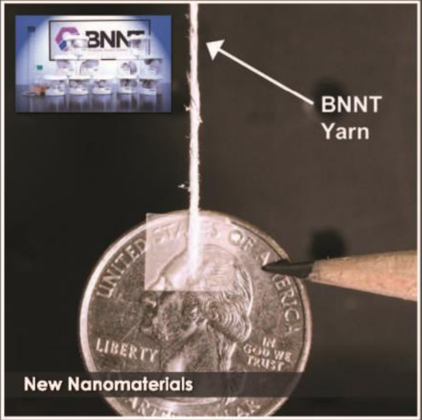
PhytoPET Imaging System



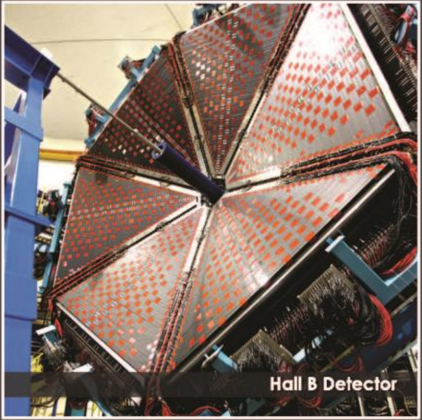
High-Performance Computing

EXPERTISE

- Cryogenics
- High-Performance Computing
- High-Power RF
- Radiation Testing of Materials
- Ultra-High Vacuum
- Radiation Shielding
- Industrial-Scale Control Systems
- Sophisticated Simulation Capabilities
- Safety Systems
- Biological and Medical Imaging



New Nanomaterials

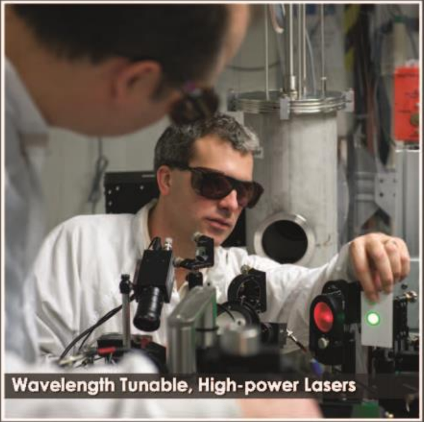


Hall B Detector

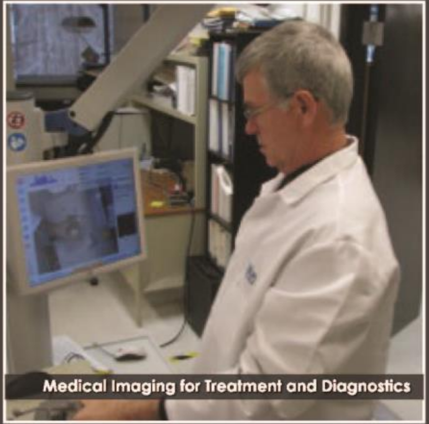
FACILITIES AND EQUIPMENT

- Cleanrooms
- Magnetically Shielded Room
- Electron Accelerators
- Wavelength Tunable, High-power Lasers
- Electron Beam Welder
- < 4 Kelvin Dewars
- Nuclear Radiation Detectors
- Surface Analysis Equipment
- CW Free Electron Laser *(world record power)*
- TeraHertz beam *(world record power)*

Crab Cavity



Wavelength Tunable, High-power Lasers



Medical Imaging for Treatment and Diagnostics

Cleanrooms

JLab Technology → Commercial Apps

3D Micro Machining
Controls
Cryo Engineering
Detectors
Electron Accelerators
Energy Recovery Linacs
Fast Electronics
Free Electron Laser
High Perform Computing
High Power Optics
Light – THz
Light – IR
Light – UV
Light – Soft X-ray
Nuclear Physics
Rad Shield & Model
SRF (2°K)
SRF (4°K)

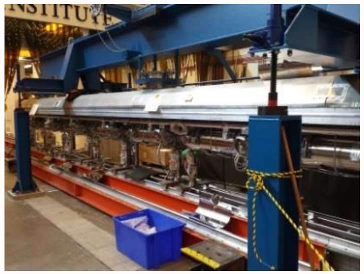
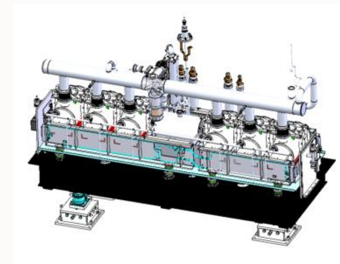
Accelerator Driven Systems
Bio Med 3D Imaging
Bio Med Surface Imaging
Bio Med - Nanoscale
Isotope Production
Laser Chemistry
Laser Materials Treatment
Materials Testing
Nano Satellites
Radiation Shielding
Security Screening
Univ Compact Light Source

Bob Rimmer

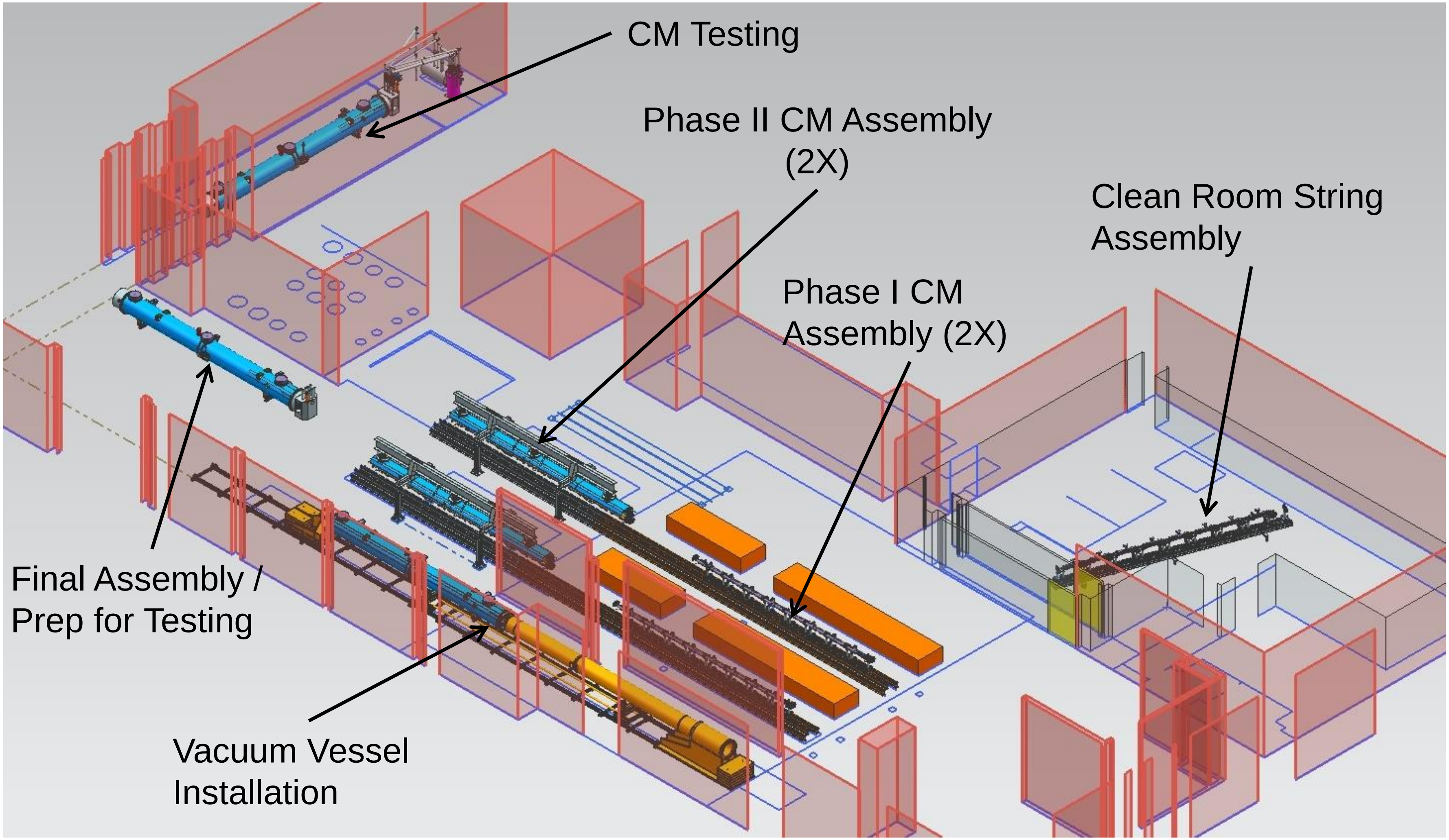
SRF R&D Activities

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

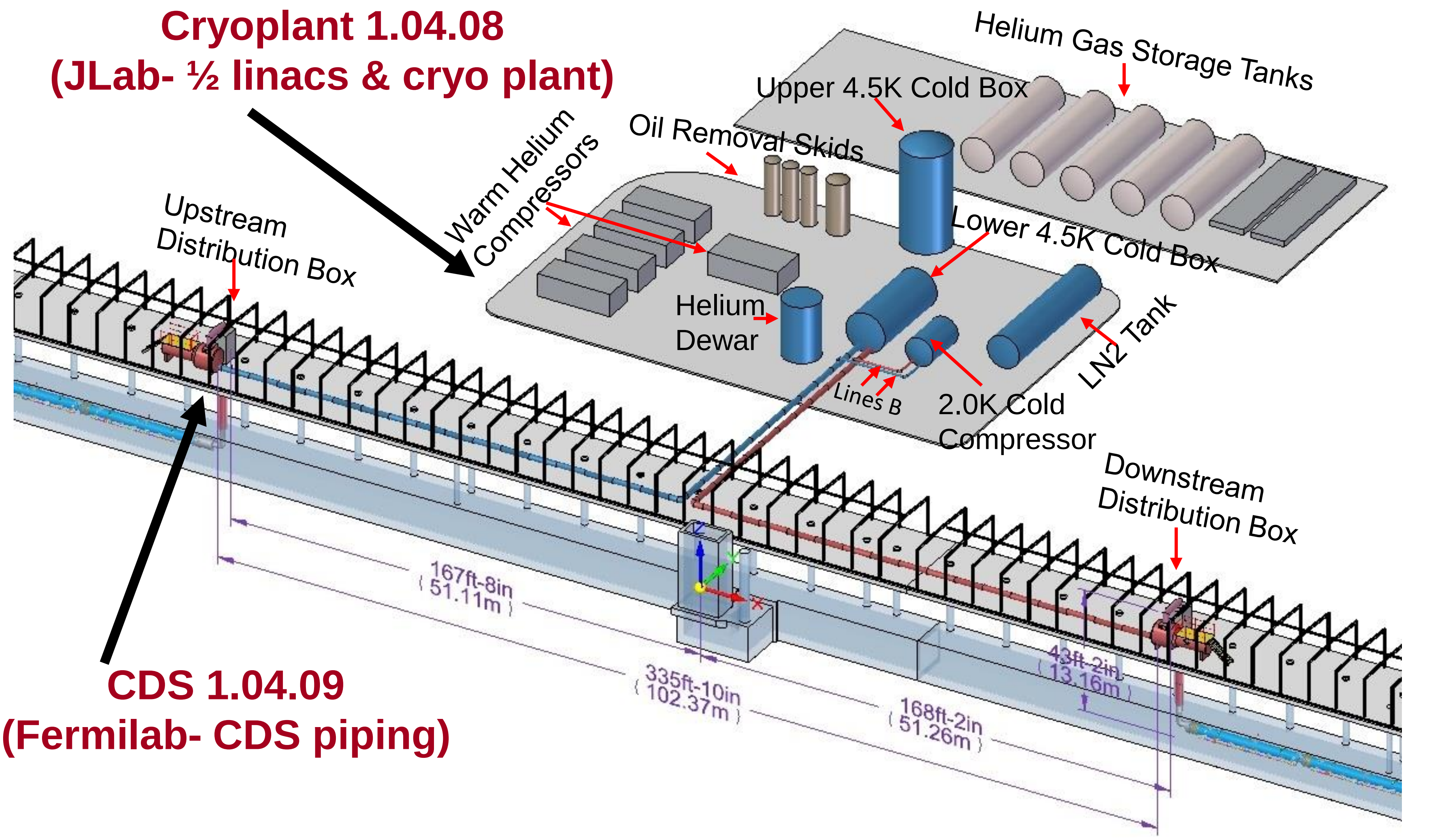
Major Projects Underway

	LCLS II	FRIB
	 Prototype Cavity String	 β=0.29 Cryomodule
Description	4 GeV superconducting linac in existing SLAC tunnel	New user facility at MSU for rare isotope studies
Collaboration	ANL, Cornell, FNAL, LBNL, SLAC, Jefferson Lab	MSU, State of Michigan, DOE SC, Jefferson Lab
Jefferson Lab Scope	• Cryoplant design and acquisition • Cryomodule and cavities for half of linac • Qo R&D, LLRF, machine physics	• Cryogenic system design, procurement, fabrication, and integration • Cryomodule engineering and design finalization
Status	✓ CD 2/3A complete ✓ First two cryoplant procurements placed ✓ Several SRF contracts placed including cavities - vendors performing well ✓ All procurements for prototype cryomodule complete, assembly started	✓ FDR for 2K cold compressors complete ✓ Beta 0.041 design complete - Beta 0.29 design underway

JLab Layout for LCLS-II CM Production

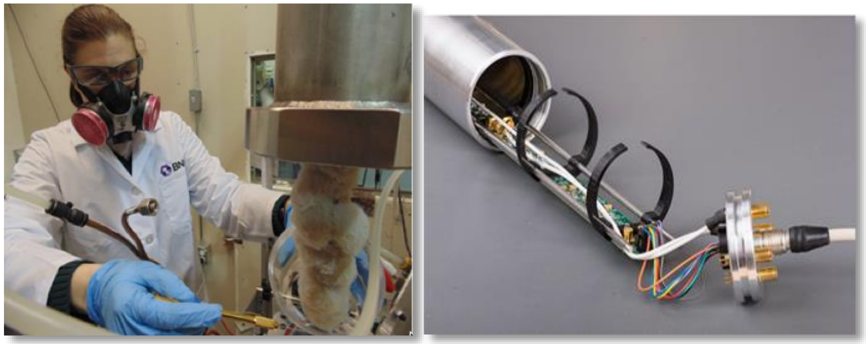


LCLS-II Cryoplant Schematic showing Cryogenic Distribution System (CDS)



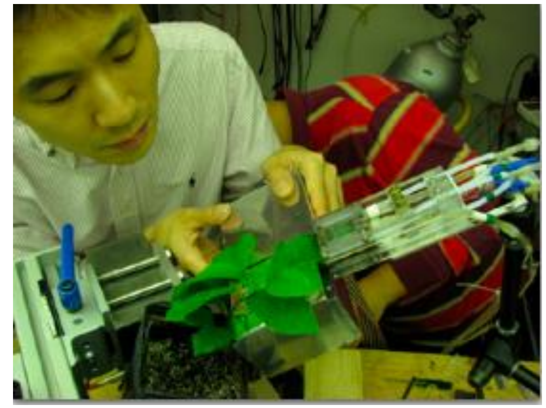
Technology Transfer

Boron Nitride Nanotubes (BNNT) based Neutron Detector



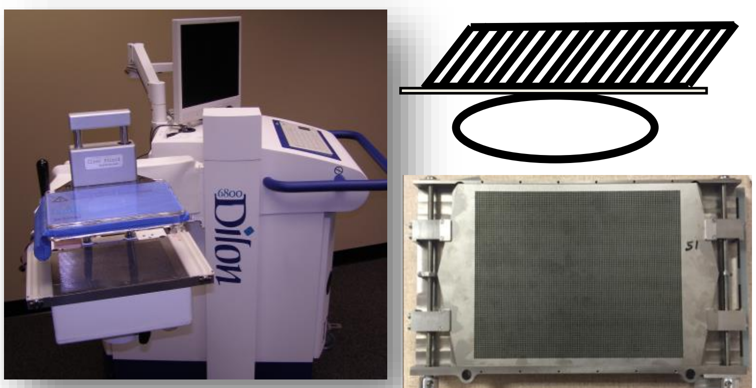
BNNT based neutron detector

Radioisotope Based Molecular Imaging for Plant Biology



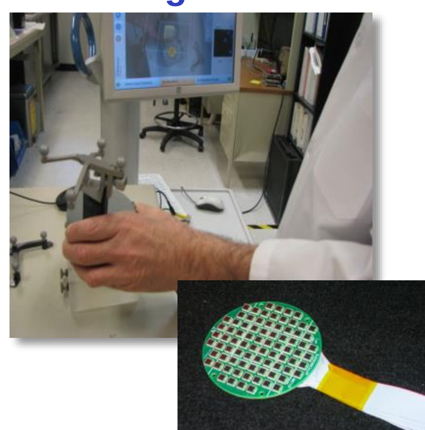
Plant biology studies with $C^{11}O_2$

3-D Breast Cancer Detector



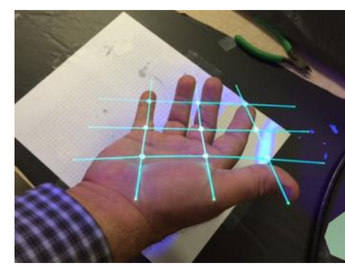
VASH installed on Dilon Technologies gamma camera

Handheld Gamma Camera for Surgeons

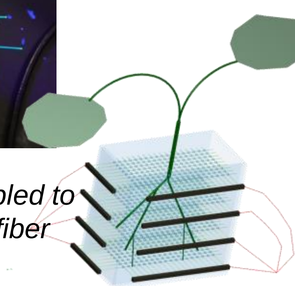


SiPM based detector

Scintillation Web Detector for Radioisotope Imaging of 32P Uptake in Plant Roots

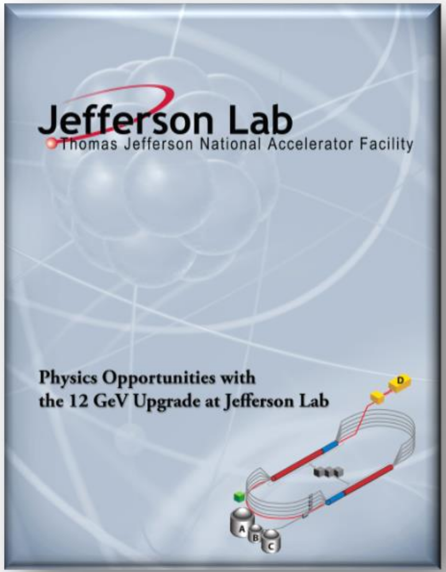


Plastic scintillator coupled to wavelength shifting fiber

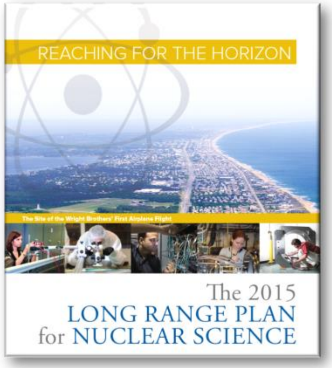


Looking to the Future

Decade of Experiments Approved
First 12 GeV Science Experiment Complete!

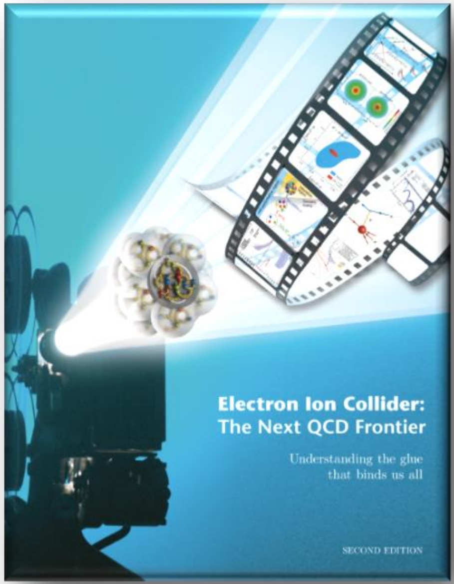


- **Confinement**
- **Hadron Structure**
- **Nuclear Structure and Astrophysics**
- **Fundamental Symmetries**



2015 NSAC Long Range Plan
Strong support for TJNAF program

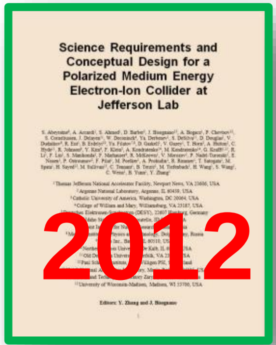
Electron Ion Collider
The Next QCD Frontier



- **Role of Gluons in Nucleon and Nuclear Structure**

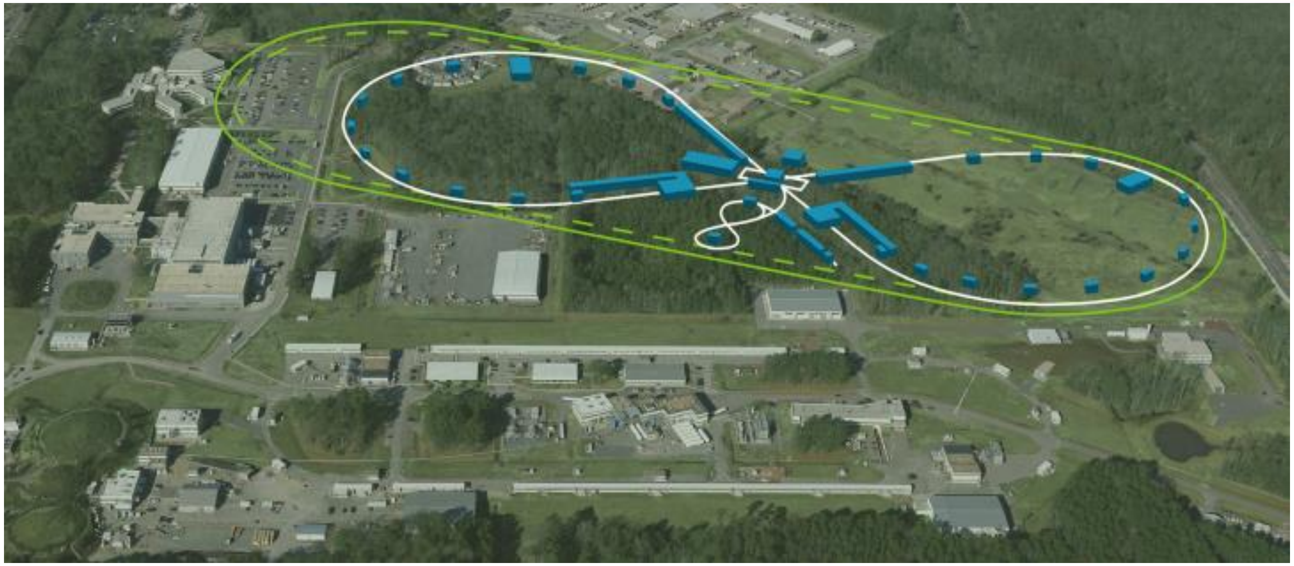
Exploring the Glue that Binds Us All

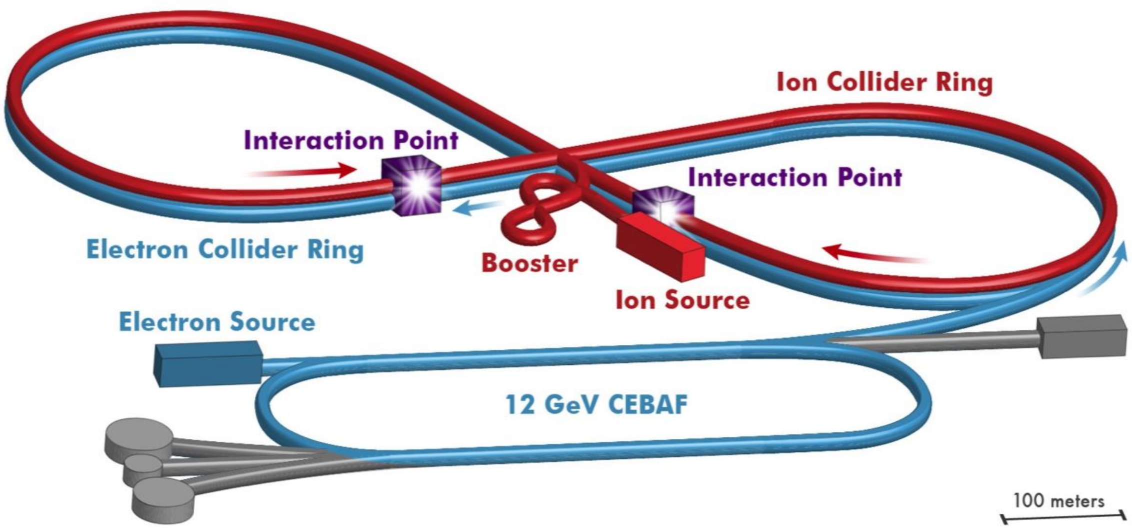
JLab Electron Ion Collider



arXiv:1209.0757

arXiv:1504.07961





energy range:
e-: 3-10 GeV
p : 20-100 GeV

Cooling strategy:
- **DC cooler** in booster
- **Bunched beam cooler** in Ion collider ring

JLab & the NP SBIR/STTR Program

Synergistic involvement

- Accelerator Technology
- Software and Data Management
- Nuclear Physics Isotope Science & Technology
- Instrumentation, Detection Systems & Techniques

Accelerator Technology

SRF R&D

Bob Rimmer

JLab SRF has benefitted from various SBIR collaborations, including RF source development, new **SRF processes**, **new materials**, new **tuners** and other cavity fabrication-related activities and **EM simulation tools.**

What we need now:

- High efficiency RF sources (>70%), including magnetrons, for JLEIC (952.6MHz) and as replacement for the old CEBAF klystrons (1497 MHz)
- SRF compatible microwave absorbing materials for HOM loads at cryogenic temperatures.
- Low loss, reliable RF windows and couplers, capable of 13 kW to 500 kW operation.
- Low-impedance, particle free bellows for high currents.
- Novel fabrication techniques for seamless cavities.
- Novel support structures or vibration isolation techniques to counter microphonics.
- New materials or process especially for high Q' and HF(acid)-free recipes
- New high Tc SRF materials.
- New cavity diagnostics and inspection methods.
- Novel crab (deflecting mode) cavity designs.

Improved efficiency: Ti and N doping for Q_0

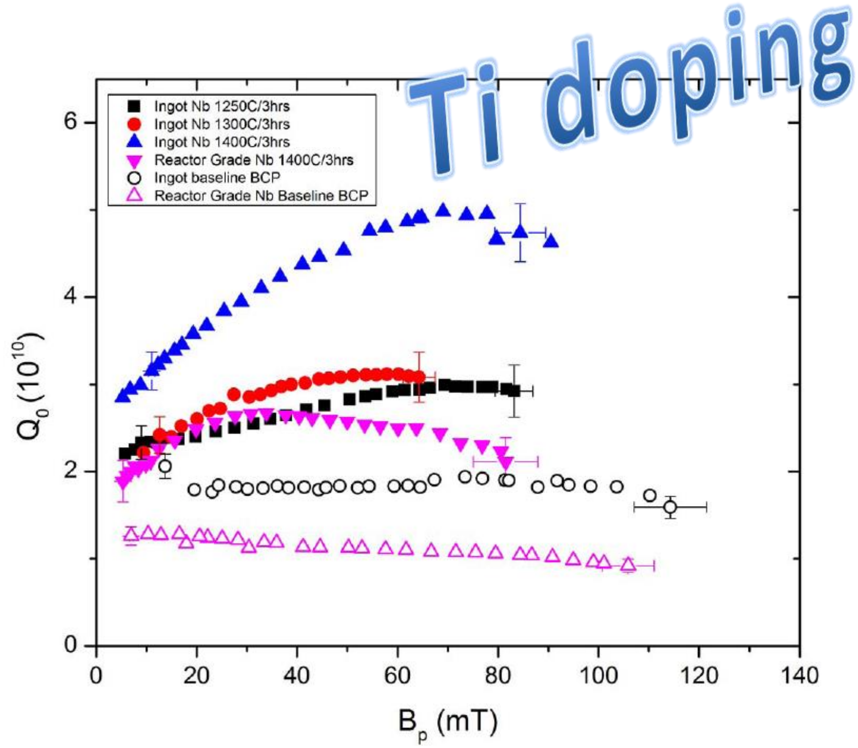


Fig. 1. Q_0(2 K) versus B_p for the ingot and reactor grade Nb 1.5 GHz ($B_p/E_{acc} = 4.43$ mT/(MV/m)) SRF cavities heat treated in titanium environment in temperature range of 1250–1400 °C. These rf tests were limited by cavity quench. About 20 μm inner surface of ingot cavity was removed by BCP before each heat treatment.

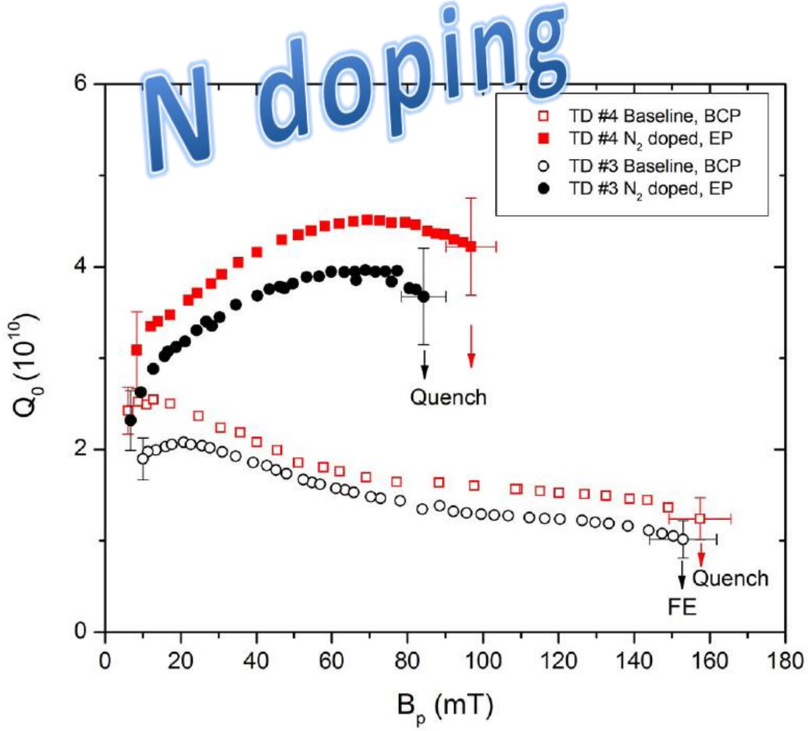


Fig. 3. Q_0(2 K) versus B_p for ingot Nb with RRR > 300 1.3 GHz ($B_p/E_{acc} = 4.33$ mT/(MV/m)) cavities heat treated in the presence of nitrogen gas followed by ~10 μm EP.

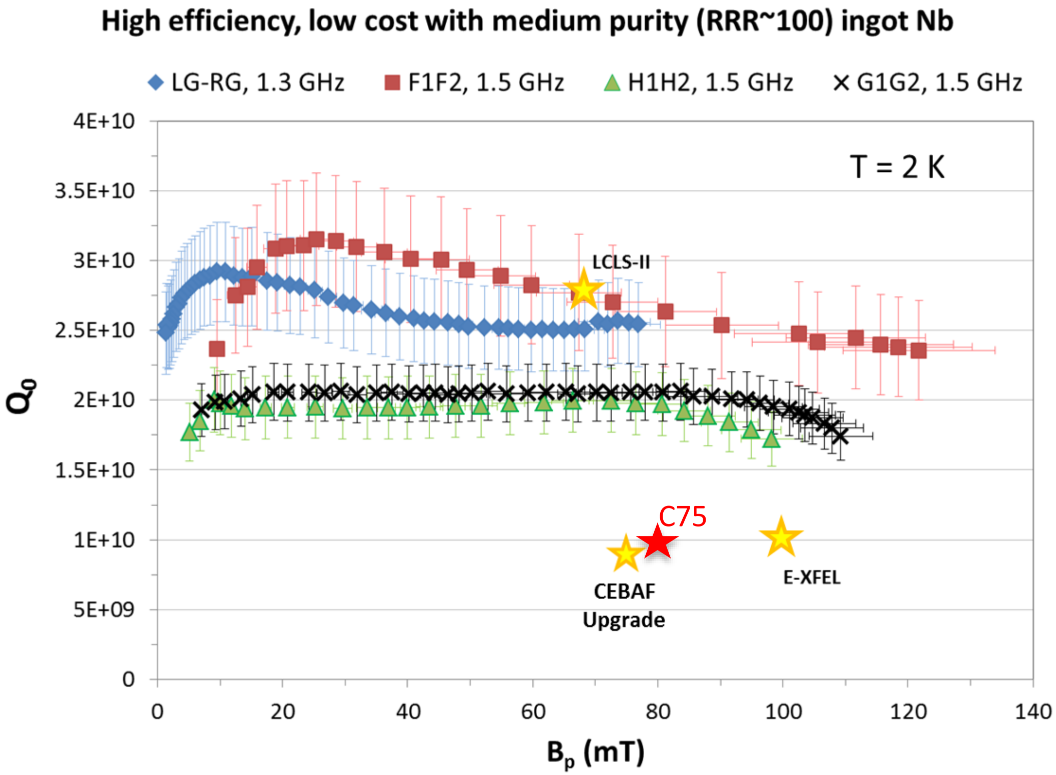
- Q_0 improved by up to a factor of 2 at medium fields by doping
- N-doping recipe more "robust" than Ti-doping

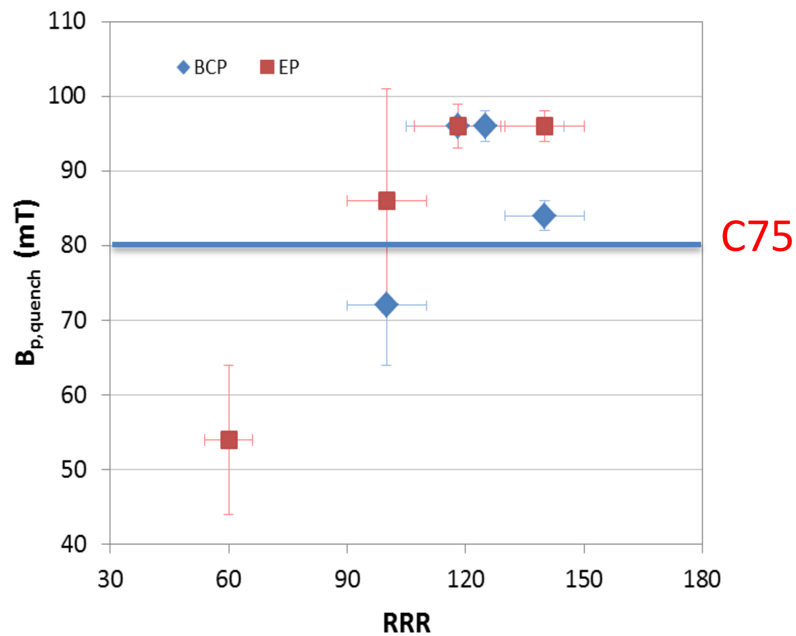
P. Dhakal et al., IEEE Trans. Appl. Supercond. **25**, 3500104 (2015)

High efficiency at low cost: ingot Nb

Medium-purity ingot Nb is a good material to build SRF cavities operating at medium gradients with higher efficiency and potentially lower cost (~1/3) than standard high-purity, fine-grain cavities.

Chosen for new "C75" cells

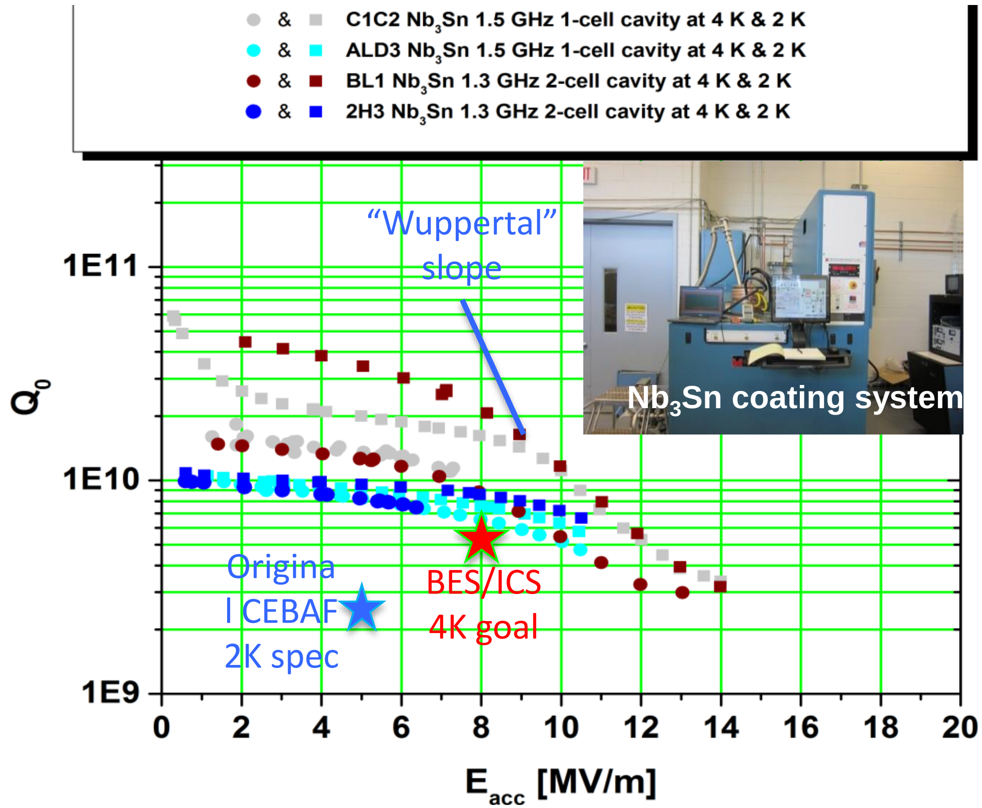




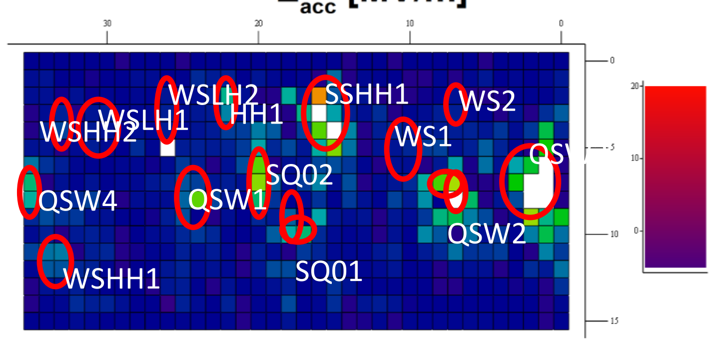
G. Ciovati et al., SRF'15, MOPB001 (2015).

Improved efficiency: Nb_3Sn

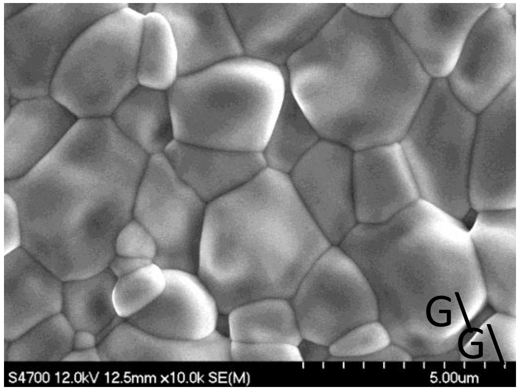
G. Eremeev



T-map



- 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.
- Grigory Eremeev recognized with DOE Early Career Award



Injectors and sources R&D

Matt Poelker

CEBAF Injector R&D

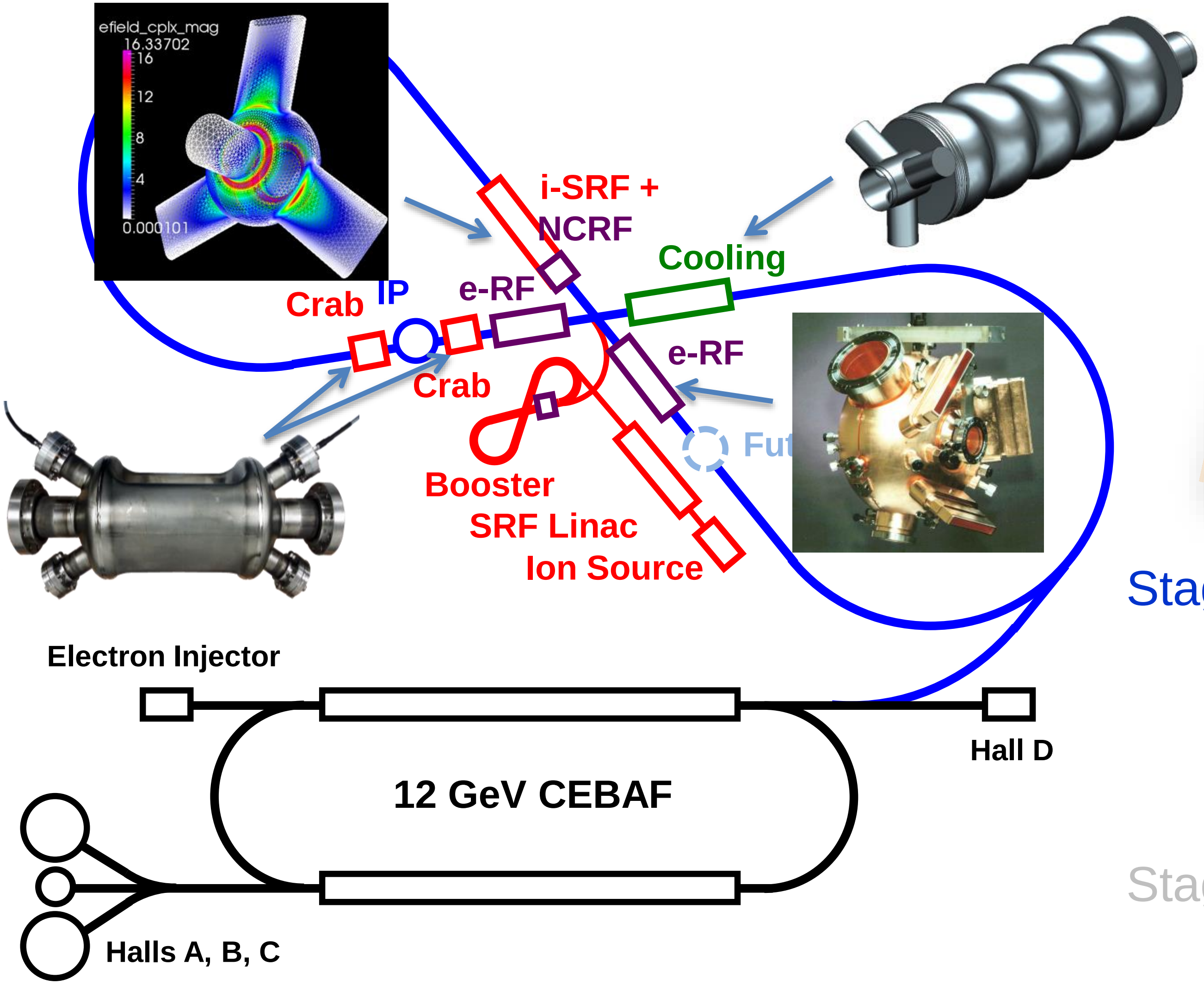
- Bunchlength monitor and fast kicker using harmonically-resonant cavity (SBIR-related)
- High Polarization and High QE Photocathodes (SBIR-related)
- Improving vacuum (funded via *Research and Development for Next Generation Nuclear Physics Accelerator Facilities*)
- Preparing for new parity-violation 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*)

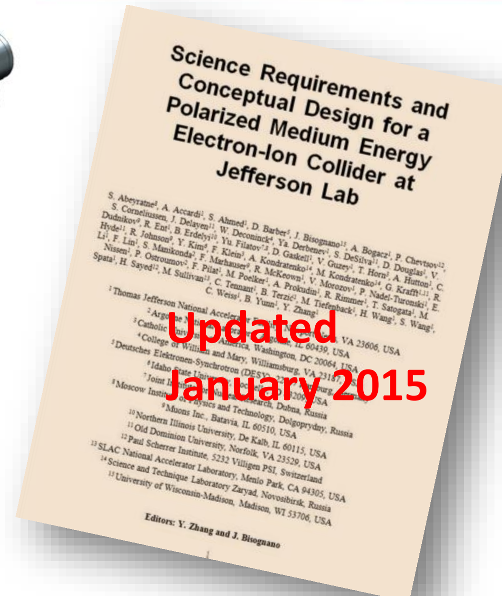
EIC R&D Areas Ripe for SBIR

- Magnetized electron sources
- Polarized proton sources and polarimeters
- Charge Strippers for heavy Ions
- Magnet R&D for: fast cycling 3-4 T SC magnets, high field-high aperture IR magnets, 1-2T long solenoid (20m) for e-cooling
- Advanced simulations and modeling for: bunched beam electron cooling, beam-beam, space-charge, spin tracking

Bob Rimmer

JLEIC SRF R&D




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

Updated January 2015

Editors: Y. Zhang and J. Bisognano

Stage I JLEIC

- 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

EIC present design and R&D program focus

Bunched beam electron cooling	
▪ERL Cooler design	(JLAB)
▪Magnetized source for e-cooler	(JLAB LDRD, Cornell SBIR)
▪Bunched beam cooling experiment	(JLAB, IMP)
▪Fast kicker for re-circulator cooler	(JLAB)
Magnets for the ion booster and collider	
▪Super-ferric magnet R&D for 3T , prototype	(Texas A&M, JLAB)
▪Super-conducting magnets design for 3T	(LBL)
▪IR magnets design	(Texas A&M, LBL)
SRF cavities and crab cavities	
▪952 MHz crab cavity design, integration, prototype	(ODU-JLAB)
▪952 MHz SRF cavities for cooler and ion collider:	(JLAB)
Ion injector	
▪SRF linac design, stripping, simulations	(ANL, JLAB)
▪Evaluation warm vs. cold linac	(MSU)
Interaction Regions and beam dynamics	
▪IR design, detector interface, backgrounds, collimation	(SLAC, JLAB)
▪Non-linear dynamics, corrections, DA	(SLAC, JLAB)
▪**Beam physics and modeling**	(JLAB, ODU, LBL, ANL, SLAC)

Software and Data Management

SBIR Topics in Modeling/Simulations

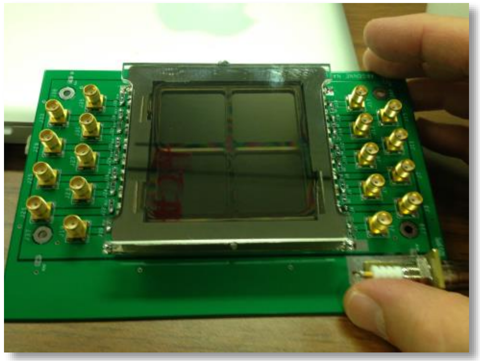
Yves Roblin

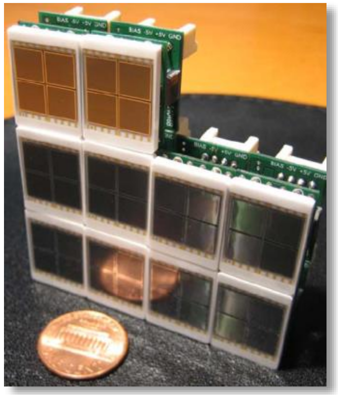
- Study of non linear dynamics in the presence of beam beam interactions
  - Effect of beam beam in the presence of non-linearities
  - Effect of coherent and incoherent beam beam on the working point
  - Implications of utilizing a multi bunch scheme (gear changing) for synchronization
  - Effect of crab crossing in the presence of beam beam, synchro-betatron resonances
- chromaticity compensation and dynamic aperture optimizations in the presence of higher order multipoles and magnet non-linearities
- Ion beam generation, acceleration, injection into the booster ring in the presence of space charge
- Estimation of electron cloud effects in the ion ring
- Simulation of the bunch splitting scheme in the ion ring
- Design of a cooler for bunched beam cooling for the ion beam
- Development of a GPU accelerated high order symplectic tracking and beam collision code for evaluating long term beam beam effects
- Development of a GPU accelerated code for beam cooling simulation

Instrumentation, Detection Systems & Techniques

Photon Detector Characterizations

- **Temperature effects**
- **B-field effects**
- **Rad hard (AmBe 10^{11} n/cm^2)**
- **Timing**
- **Linearity**
- **Spatial uniformity of response**
- **Crosstalk**





-Microchannel plate based photomultiplier tubes (MCP/PSPMT)
-Large area picosecond photon detector (LAPPD)
-Silicon photo multipliers (SiPM)
-Single Photon Avalanche Photo Diodes (SPADs)

Hamamatsu- Japan
Photonis- France
Photek- UK
ANL/Incom (Boston)
Voxtel

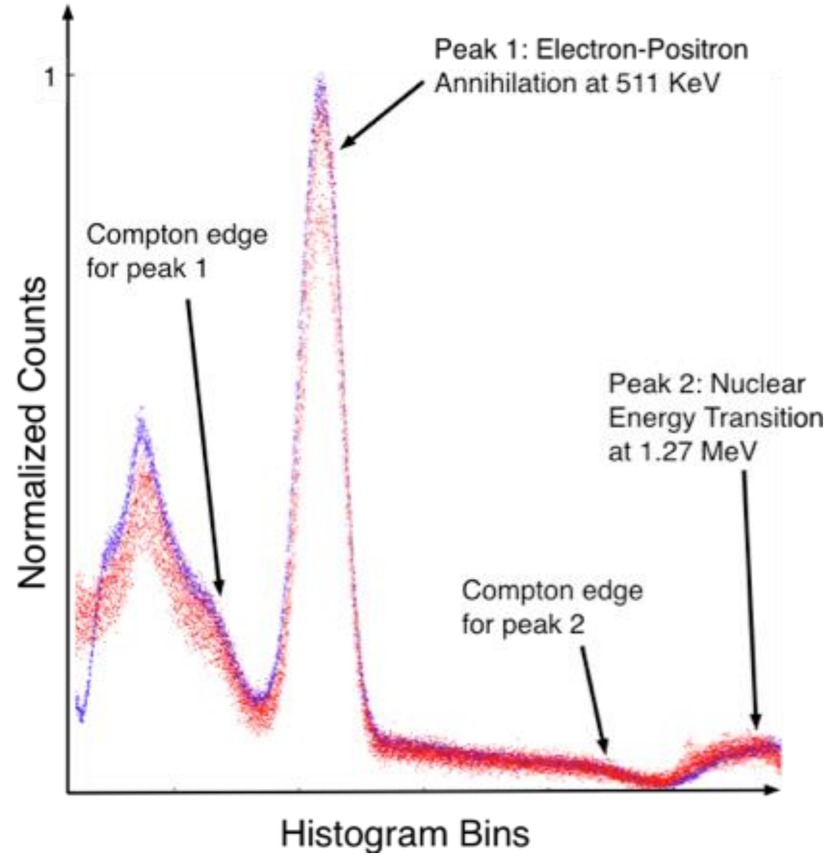
A Radiation Tolerant High-Magnetic Field Immune High-Signal Fidelity Electro-Optically Coupled Detector (EOCD) for Nuclear Physics

Applications:

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

EOCD

- analog electrical pulses from multiple detector channels (e.g. PMTs, SiPMs) drive the output of LED lasers of various wavelengths
- multi-wavelength analog laser pulses transmitted down communications grade single mode fiber optics allow multiplexed channels
- 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**: >100 analog channels/fiber
- high-radiation and high-magnetic field tolerant



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

W. Xi, et al, "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.

Nuclear Physics Isotope Science & Technology

Electron Accelerators for Radioisotope Production

High power (~100 kW) electron accelerators are well suited for the production of some important isotopes for medical and industrial applications.

Method: generate bremsstrahlung photons, using a radiator, which in turn irradiates the target.

- LERF at Jefferson Lab (FEL) can deliver >100 kW of beam power
- Electron beam energy & current are tunable
- Use it to produce ^{67}Cu with the bremsstrahlung

Isotope Photo-production

- Need for a self contained, compact, cooled bremsstrahlung radiator system able to 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 radiator can handle, the better. 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. Need for self contained 'turn-key' systems with **low maintenance**. Need to be **compact** so isotope target can be placed close to the radiator system (<5 cm) to intercept a large fraction of the photon beam.

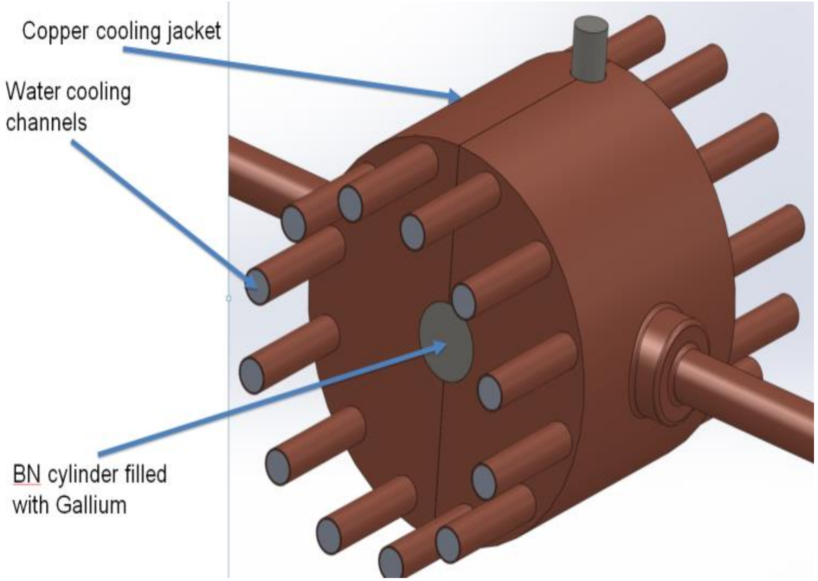
- Need a design for the isotope conversion target. Able to handle >50 kW continuous beam power.

Technical Challenge

Target system which can handle high power (50 kW)

For ^{67}Cu production, gallium is a potential isotope target

- Solid below ~30^0 C
- Boiling Point ~2200^0 C



VCU will perform separation of ^{67}Cu from irradiated gallium

New SBIR/STTR Activity

Radiabeam	Nano-Patterned Cathode Surfaces For High Efficiency Photoinjector BNNT Wire Scanner
Surmet	ALON®Components with Tunable Dielectric Properties for High Power Accelerator Applications
Muons	A novel injection-locked amplitude-modulated magnetron at 1497 MHz
Faraday	Electro-Polishing Niobium Cavities in an HF Free Electrolyte
Euclid	Flat Field Emitter Based on Ultrananocrystalline Diamond (UNCD) Film for SRF Technology
Alameda	Nb-on-Cu cavities for 700-1500 MHz SRF accelerators
Radiasoft	Integrated Simulations for a High Energy, High Power Energy Recovery Linac

Conclusions

- Successful track record of synergy between the SBIR program and JLab

- JLab is committed in to continuously supporting & enhancing the SBIR/STTR program at JLab especially in Accelerator, Detector & Isotope R&D

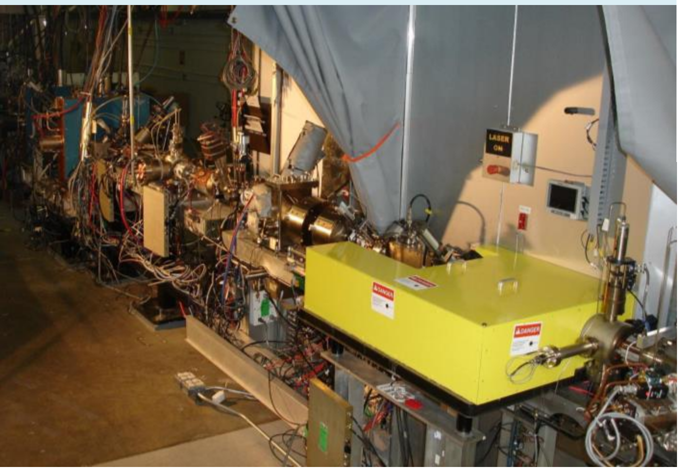
- We are in particularly interested in exploring the SBIR/STTR opportunities towards **EIC directed R&D**, and we welcome the opportunity to support future proposals.

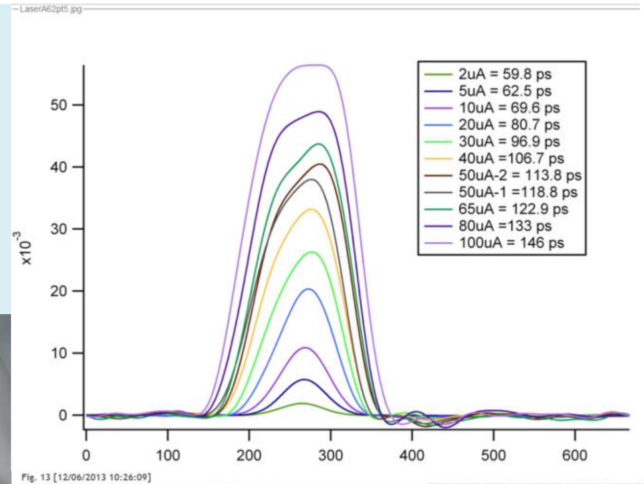
Thank You

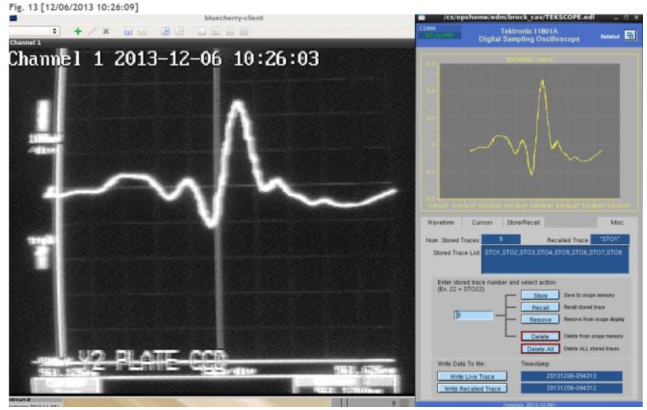
BACK-UP SLIDES

Bunch-length monitor at CEBAF

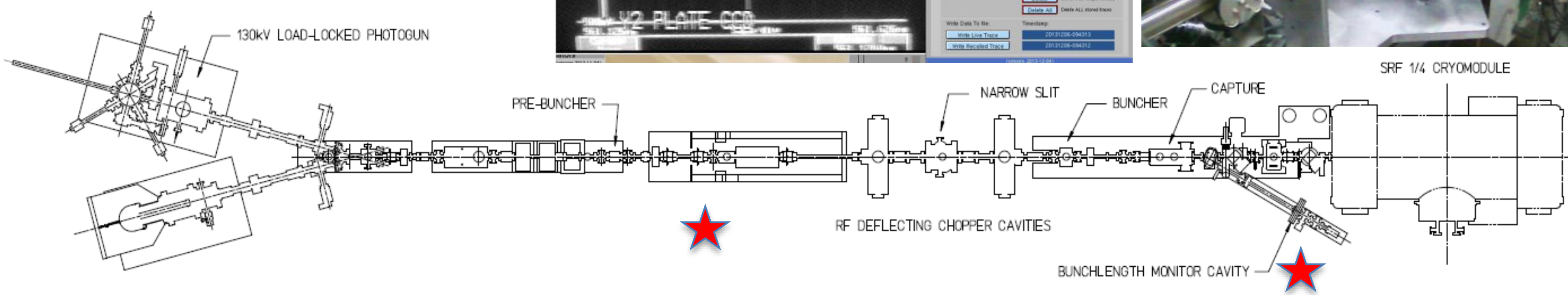
- Near real-time bunch-length monitor for bunches > ~ 35 ps
- Can be used to accurately set phases of lasers and pre-buncher







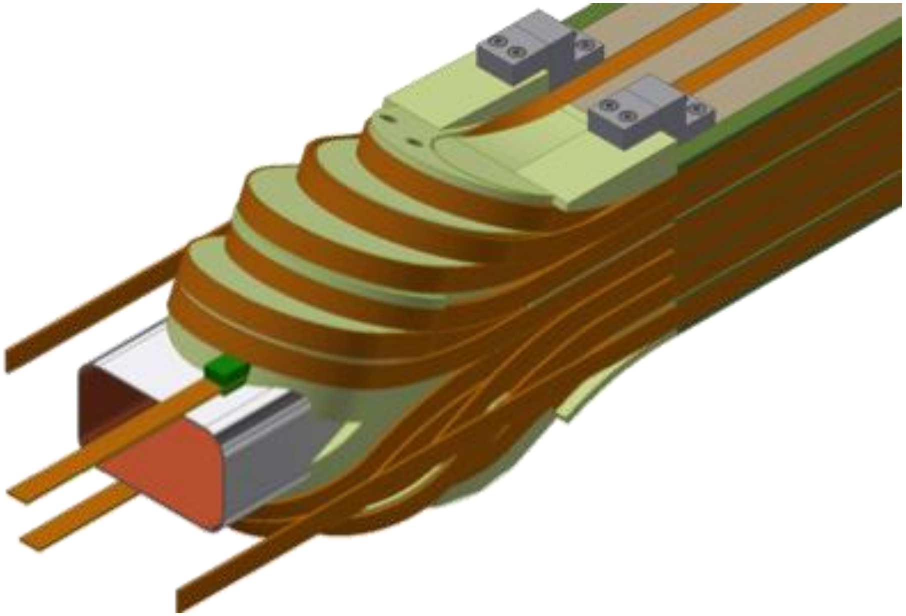
- Simple tool to help validate our particle tracking code models
- Fast Kicker?
- Useful when placed at higher energy locations of machine?



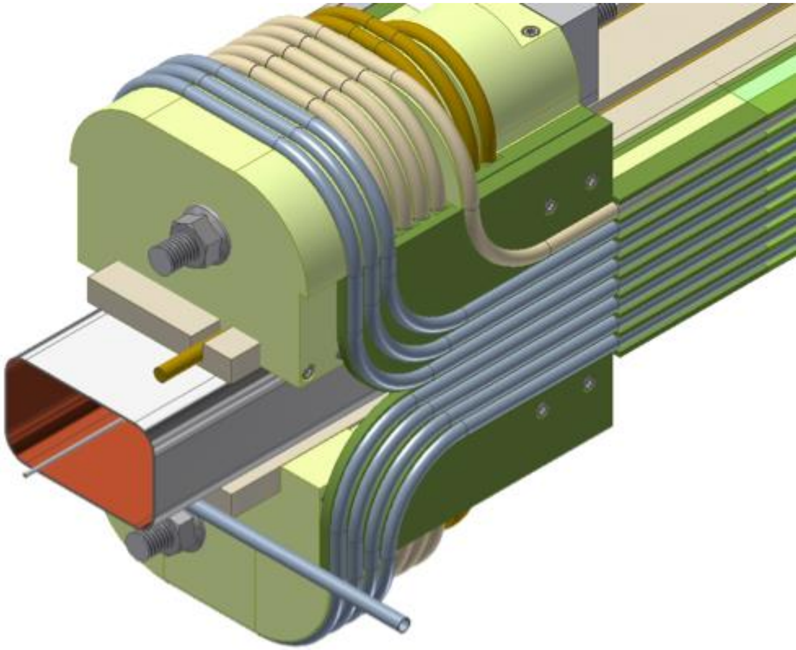
JLEIC super-ferric magnet R&D

Texas A&M developed 2 approaches to winding cable:

NbTi Rutherford cable



NbTi Cable-in-Conduit

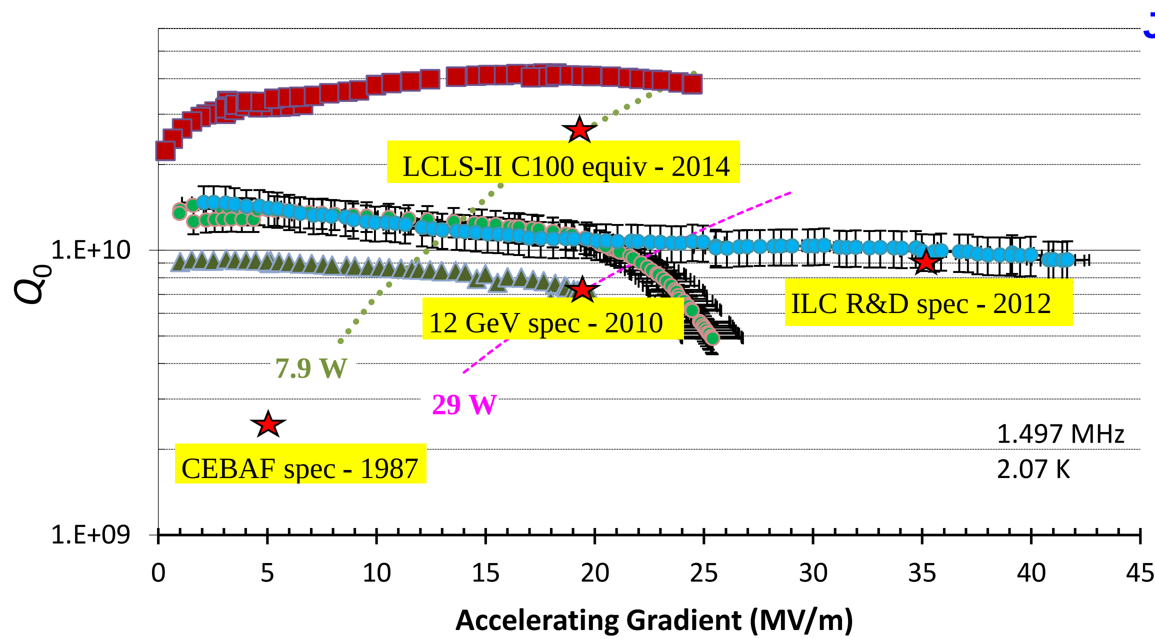


	NbTi Rutherford cable	NbTi Cable-in-Conduit
Pros:	Uses mature cable technology (LHC).	Semi-rigid cable makes simpler end winding. Semi-rigid round cable can be precisely located. Cryogenics contained within cable.
Cons:	Ends tricky to support axial forces.	Cable requires development and validation.

Improving SRF Cavity Efficiency via Doped Materials

<u>Learning how to minimize SRF losses (maximize cavity Q) via Nitrogen Doping of Niobium</u>

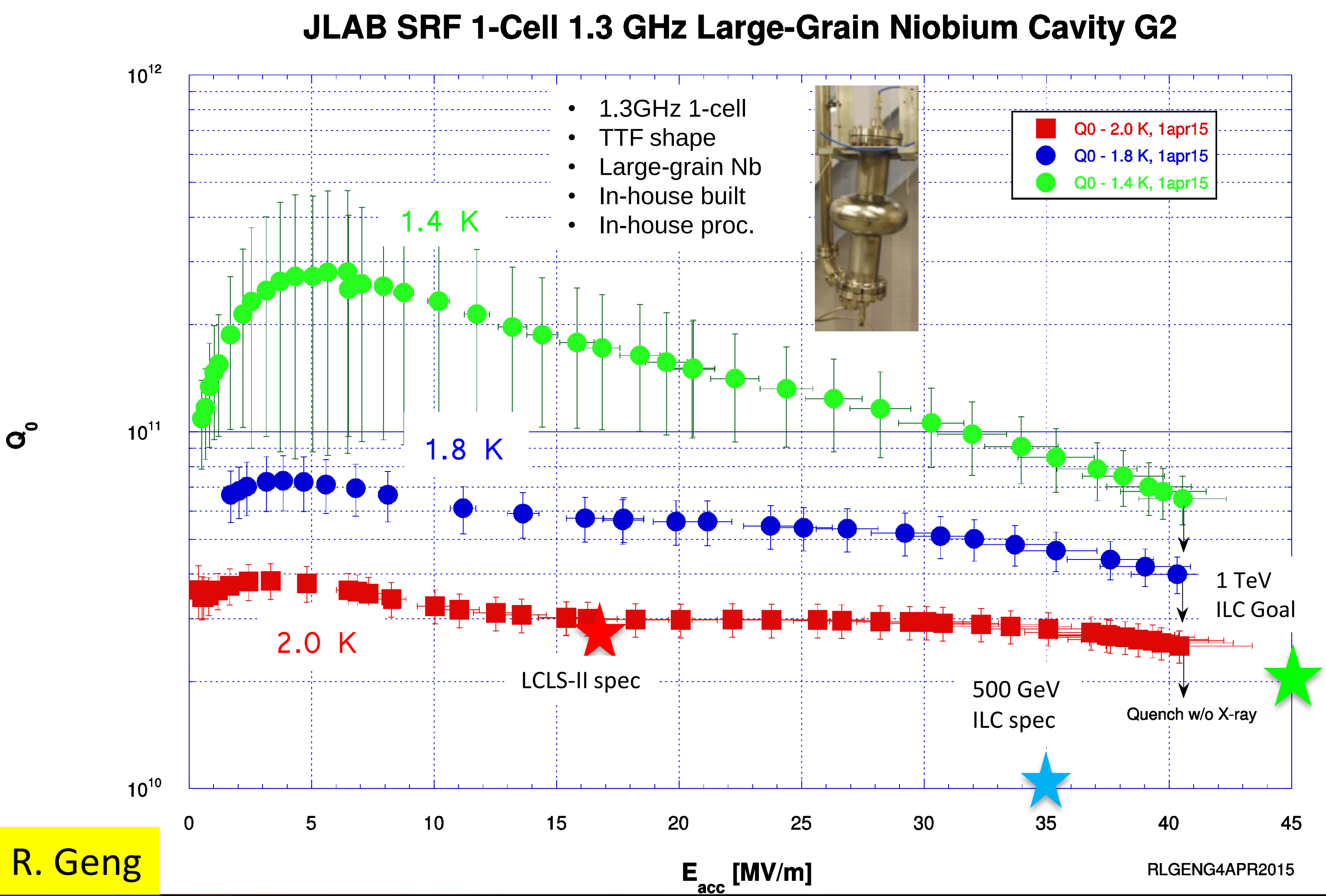
- Collaborated with FNAL and Cornell to **validate High-Q process for LCLS-II**
  - Enabled >50% reduction in cryo-load compared with previous methods
  - Now transferring the protocols to vendors
- Systematically studying the doping protocols, material effects, and SRF properties
  - Involving university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



Ari Palczewski
Charles Reece

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



Future cavities: LSF cavity

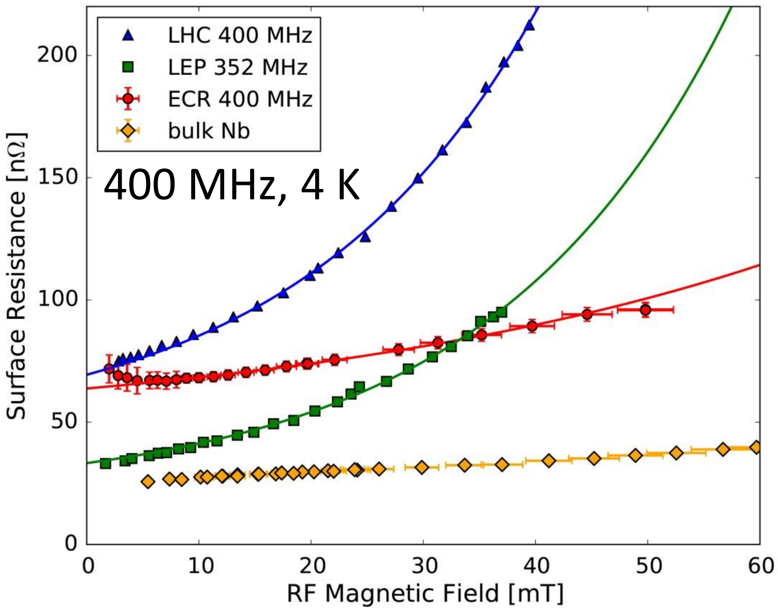
Prototypes:

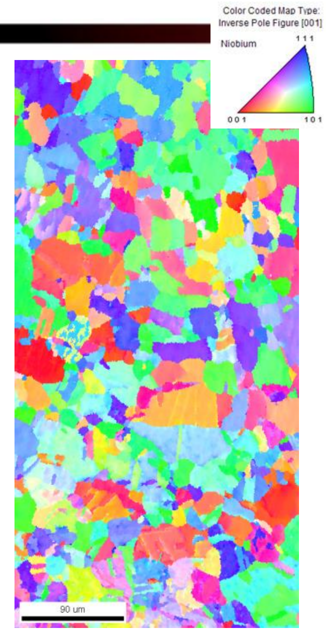
- Two each 1-cell built and tested
- Two each 3-cell and one each 9-cell in process of fabrication.

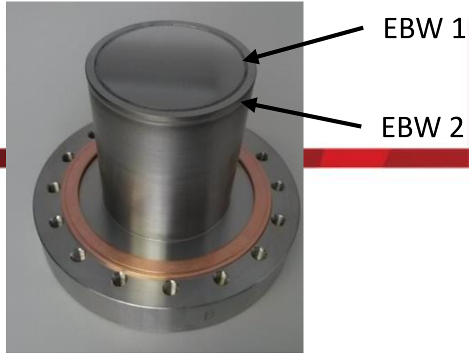
R. Geng

Jefferson Lab

Nb/Cu films by Energetic Condensation







	R_{res} [nΩ]	λ(0K) [nm]
400 MHz	46.6 ± 0.8	40 ± 2
800 MHz	79 ± 2	38 ± 1
1200 MHz	156 ± 11	38 ± 1

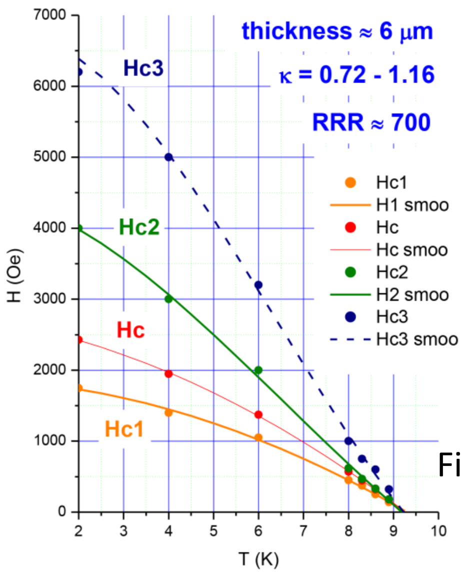
ℓ* [nm]	RRR
144 ± 20	53 ± 7

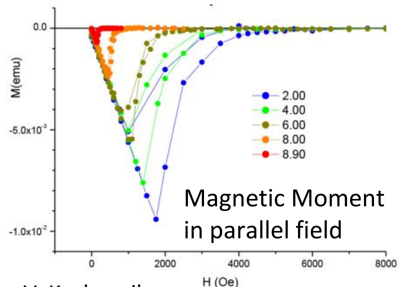
* with λ_L = 32 nm and ξ_0 = 39 nm

ECR Nb/Cu film shows a much reduced slope compared to sputtered Nb/Cu cavities.

The residual resistance is high due to the post-coating e-beam welding (EBW 2) to the support structure.

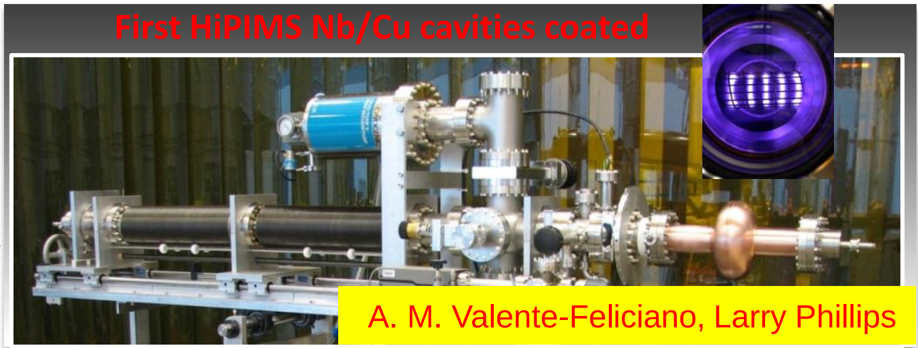
Series of QPR sample coating/measurement underway





V. Kozhevnikov

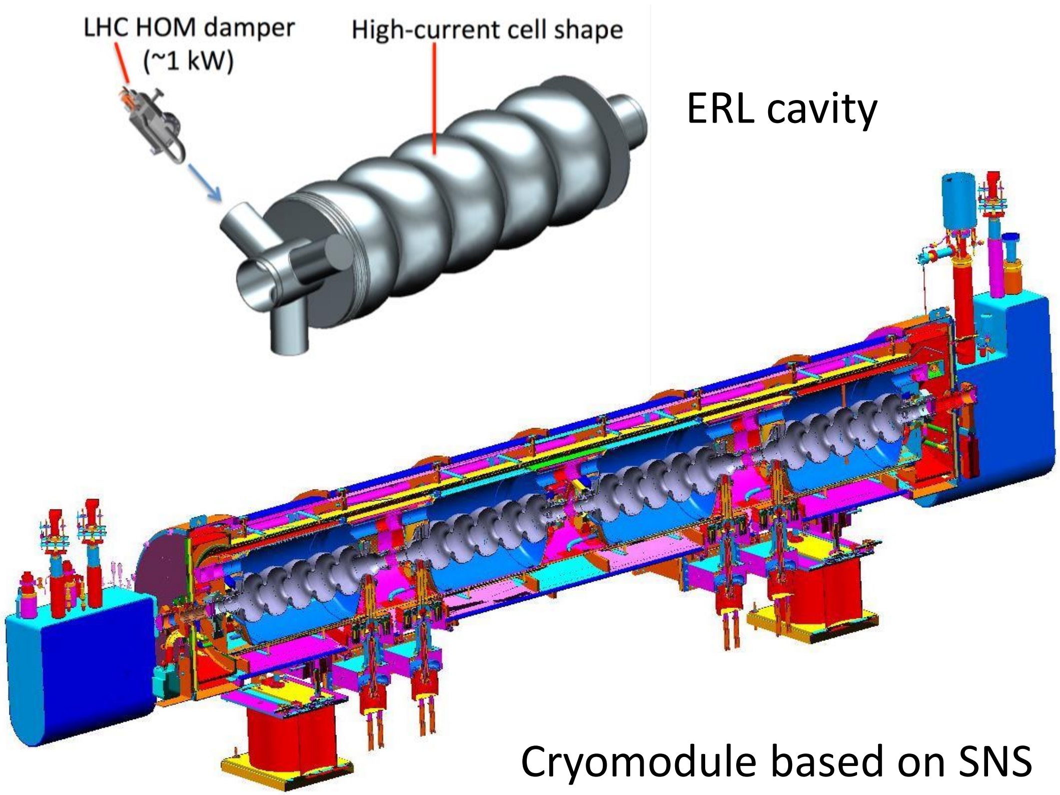
Magnetic field phase diagram
for ECR Nb/ (1-120) Al_2O_3
First flux Penetration @ 2 K ~ 180 mT,
showing superior behavior
to measured bulk Nb (130 mT)

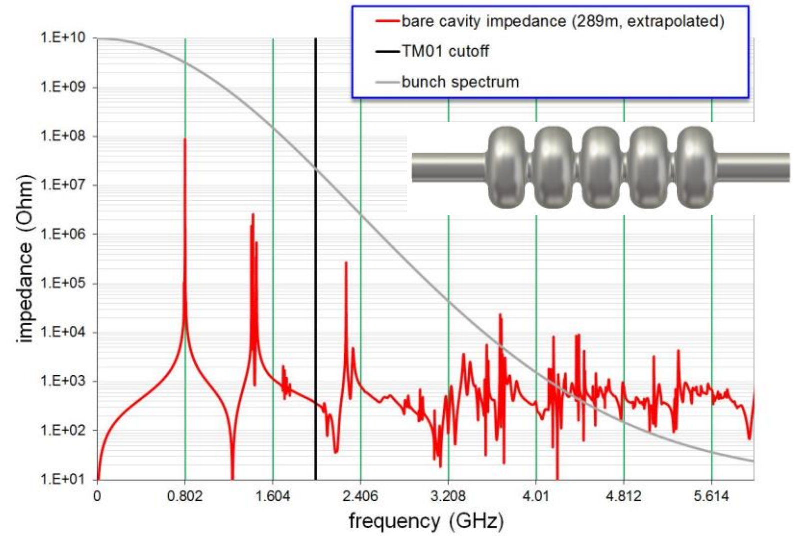


Collaboration with CERN on SRF for FCC

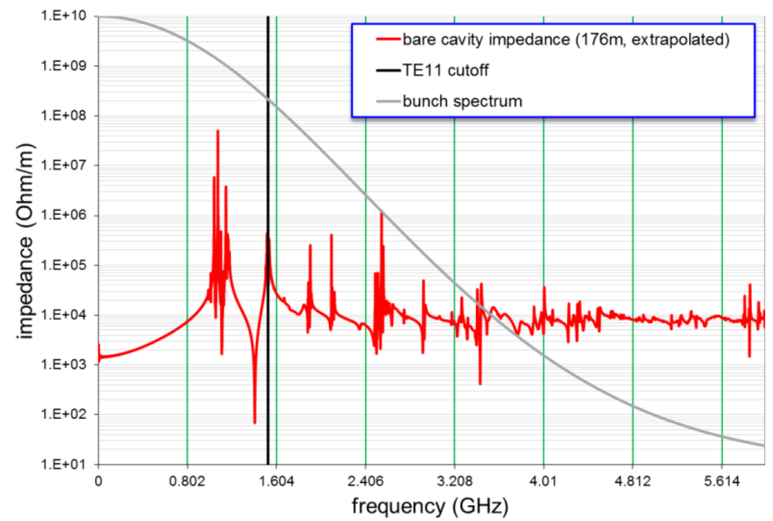
Collaboration on 802 MHz SRF for FCC-eh (CERN's electron-ion option)

- Cavity design and prototype
- Joint study on cryomodule

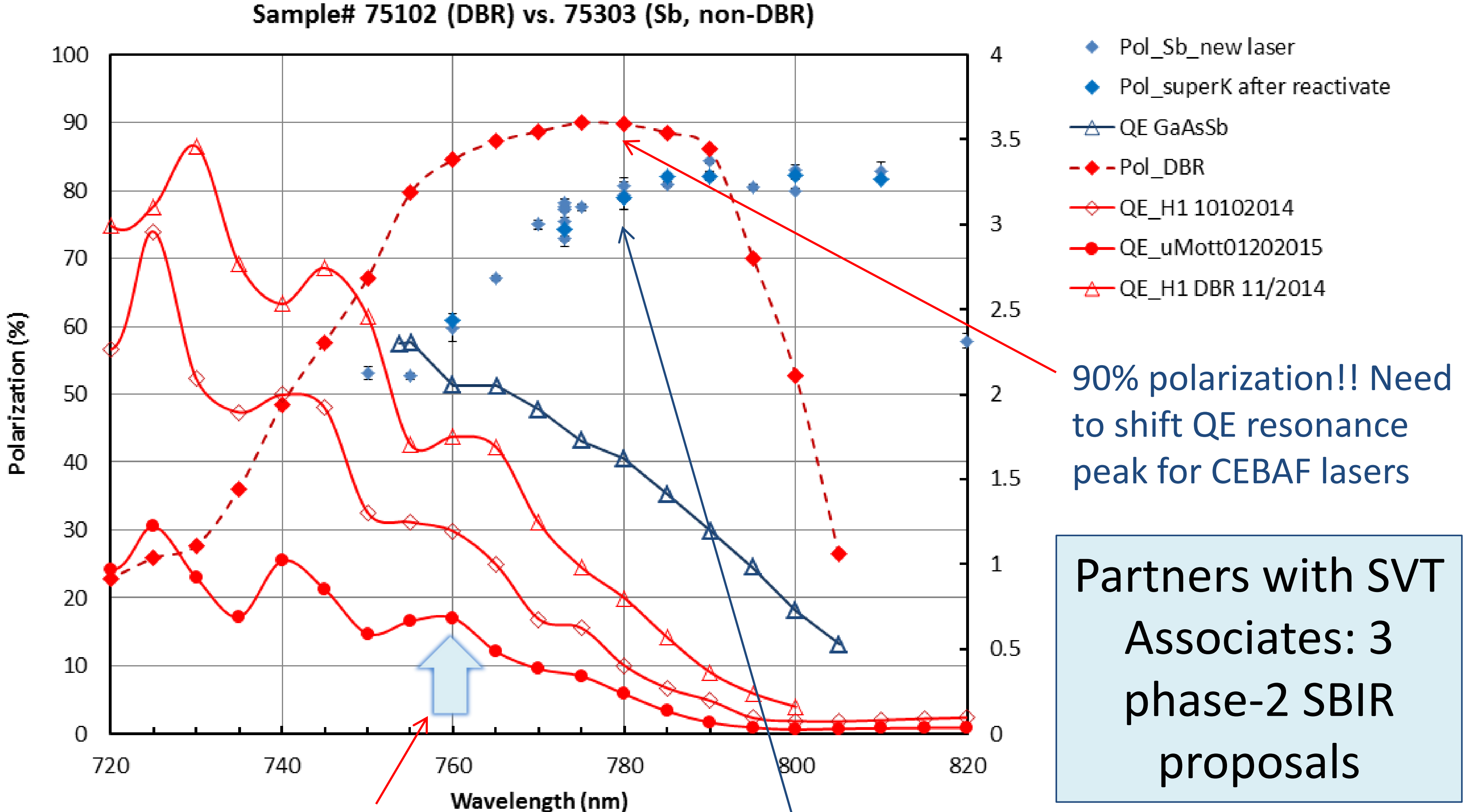




HOM spectrum looks good



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 !

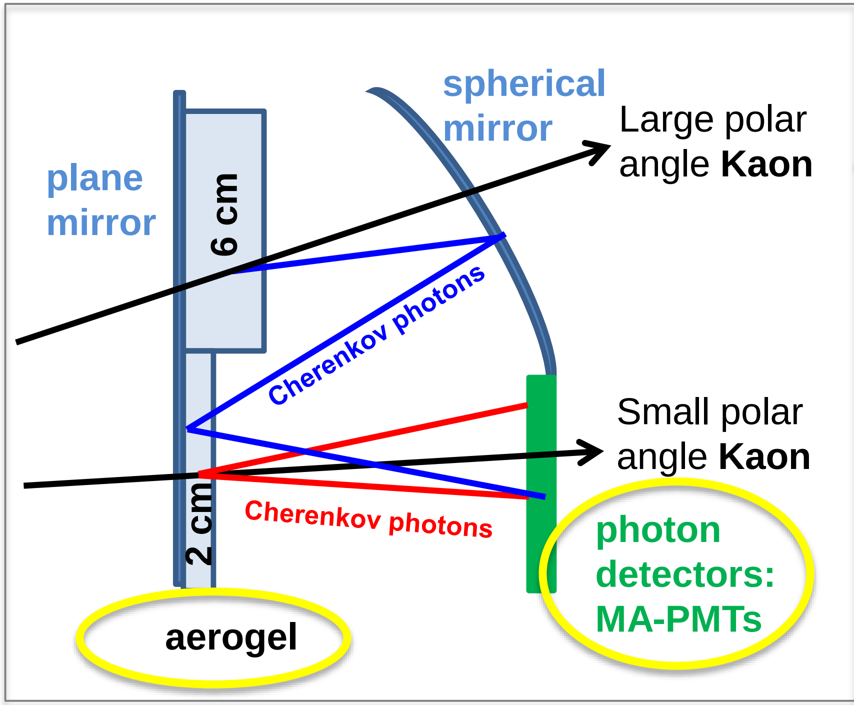
GaAsSb/AlGaAsP not bad, need to test at high voltage

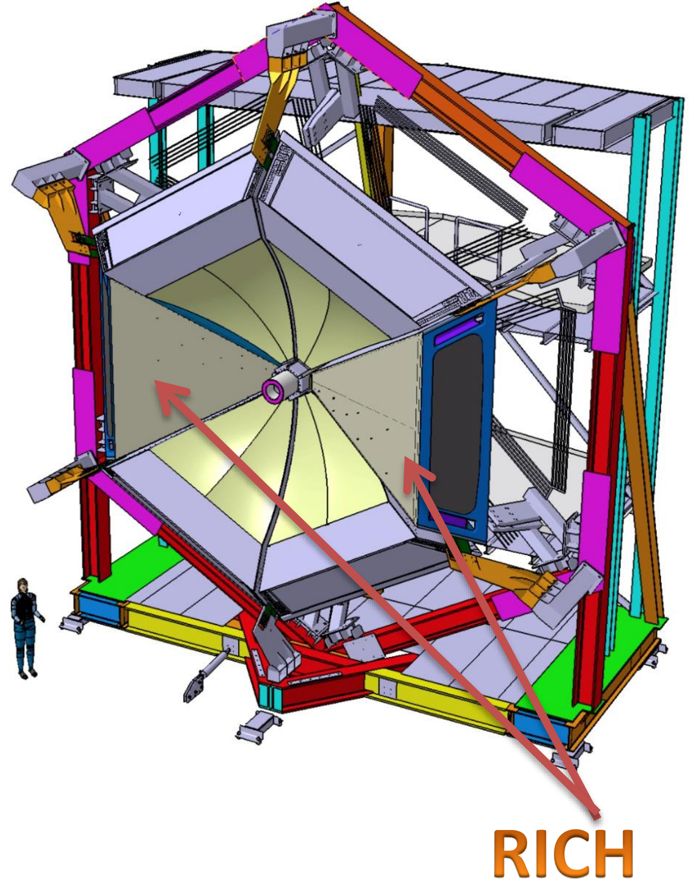
Patrizia Rossi

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



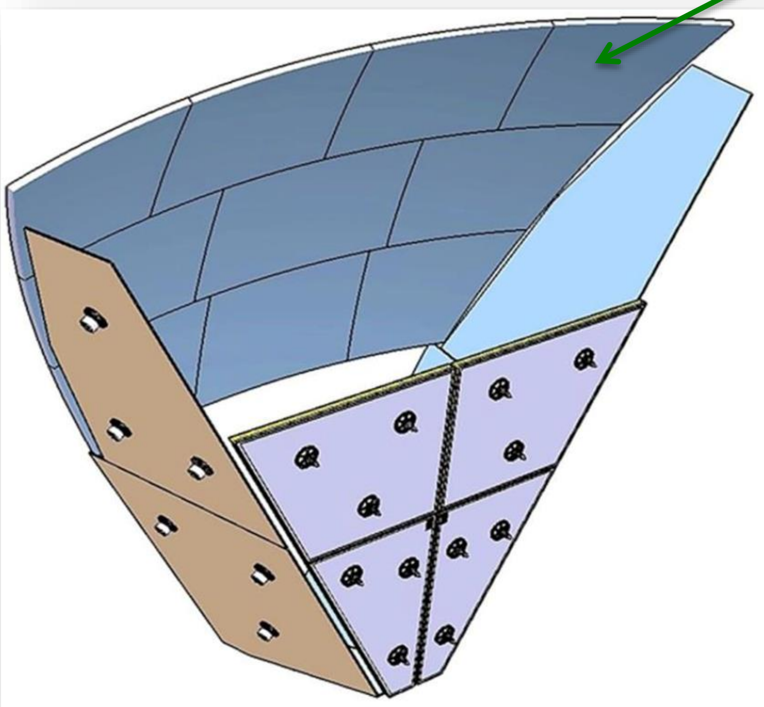


Hybrid solution: proximity gap plus focusing mirrors

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

a) Spherical mirror
b) Aerogel

Hall B – RICH: The mirror system



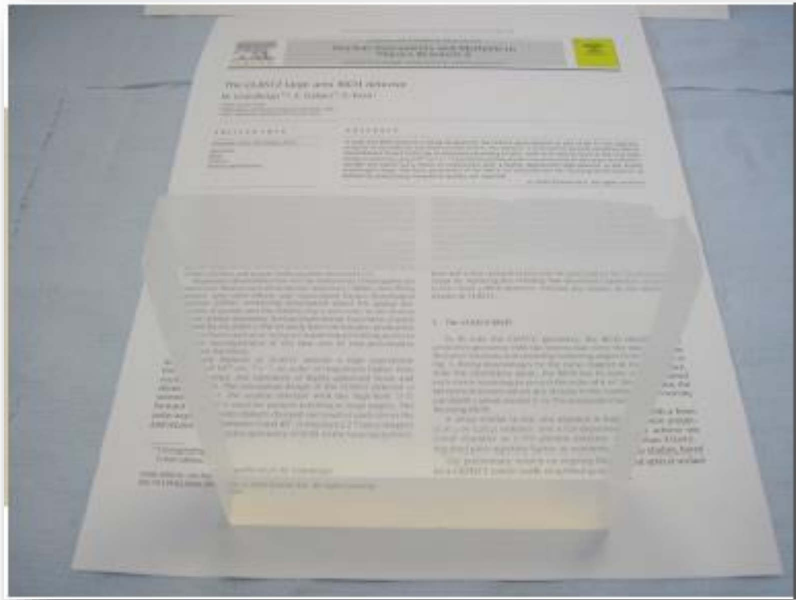
- Ten spherical mirror
  total surface ~3.6 m^2 mounted on a supporting structure attached to the RICH module
- Four frontal planar mirror
  total surface ~3 m^2 mounted on the frontal closing panel they hold the aerogel tiles
- Six lateral planar mirrors
  total surface ~1.4 m^2 mounted on the lateral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

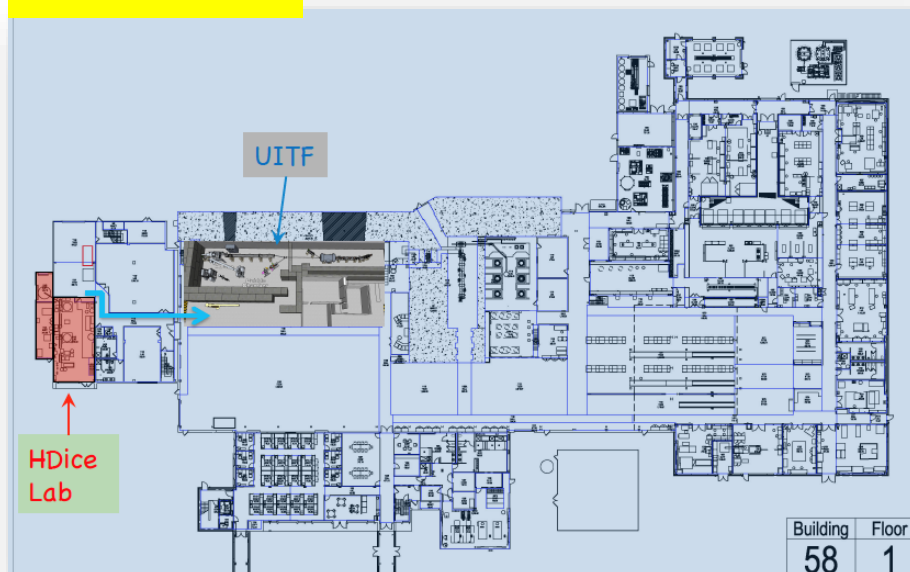
Only one company in the world is able to fulfill the above requirements

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.

Patrizia Rossi



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

Gamma Camera for Breast Cancer Detection

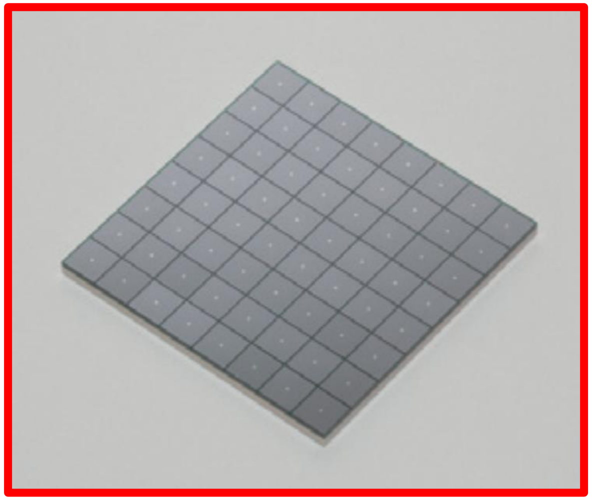
Drew Weisenberger

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.

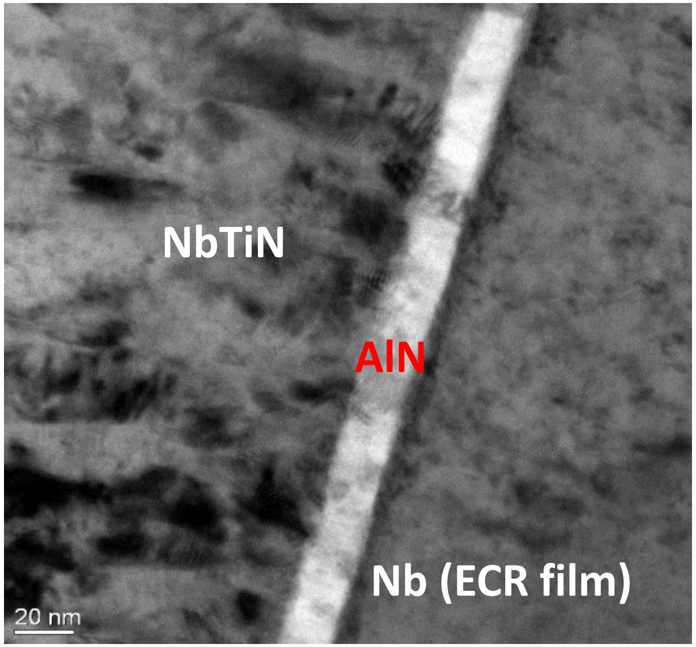
Recently: CRADA with Hampton University, Dilon & JLab initiated to enhance gamma camera performance using NP *silicon photomultiplier technology*.



Development of SIS NbTiN/AlN structures on Nb surfaces

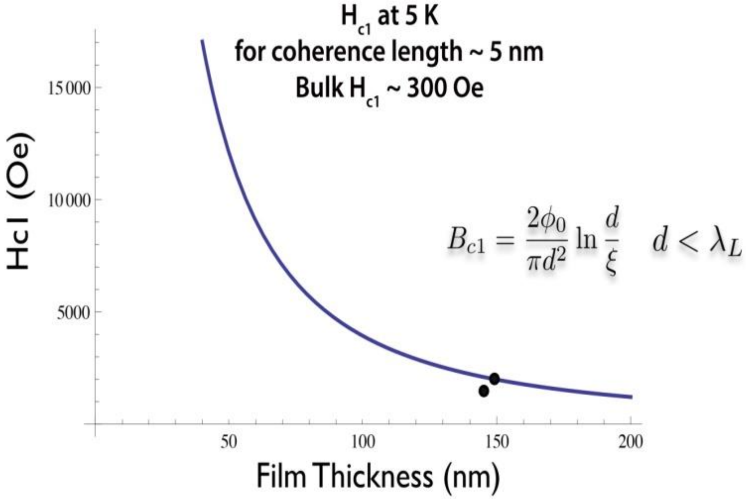
<u>Learning how to grow high quality Superconductor/Insulator/Superconductor films</u>

- 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



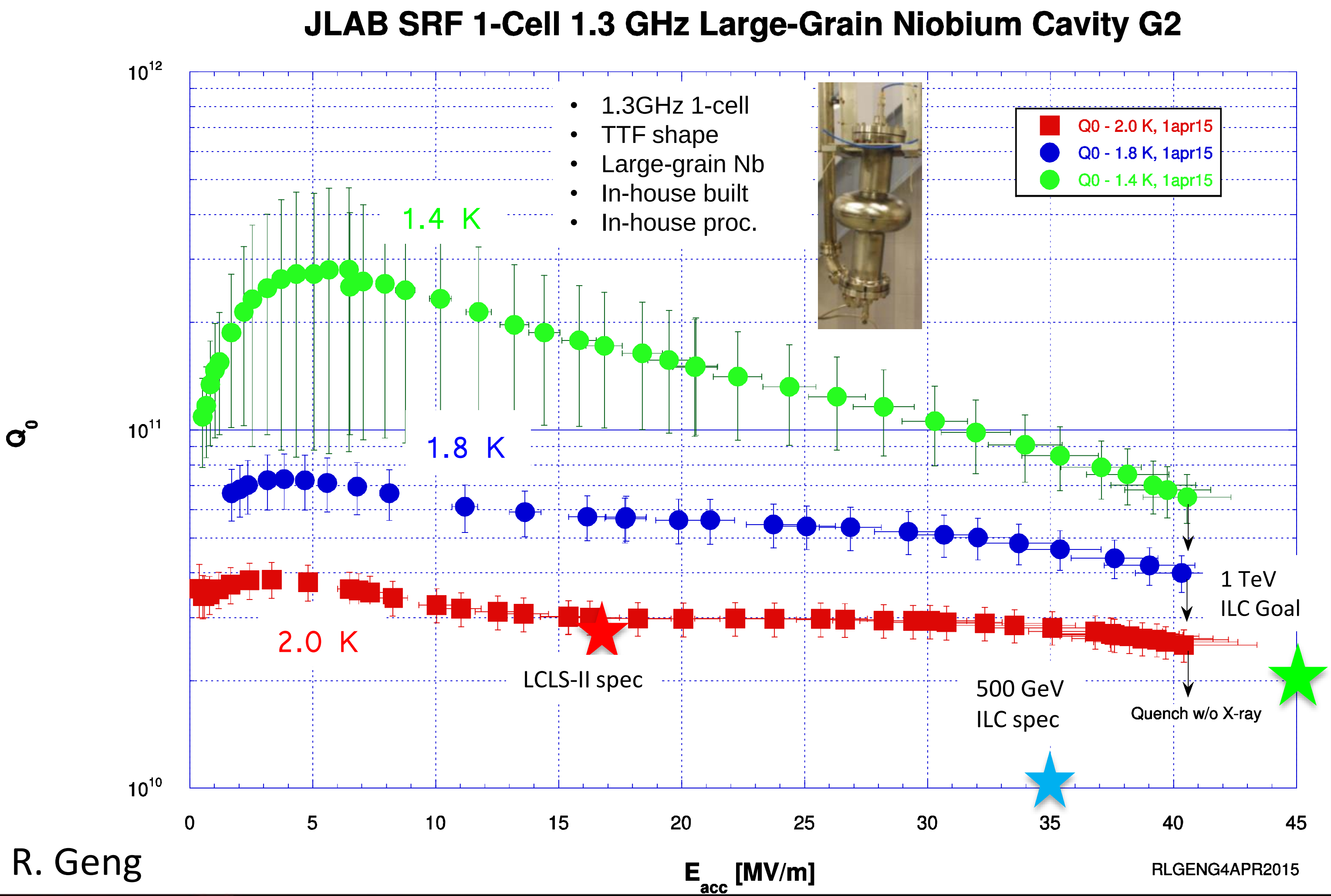
A-M Valente-Feliciano

	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



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

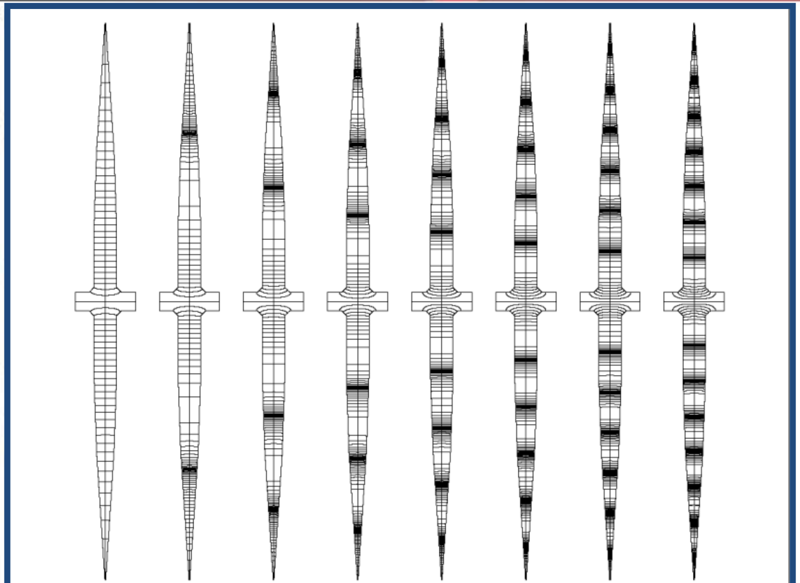


Future cavities: LSF cavity

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

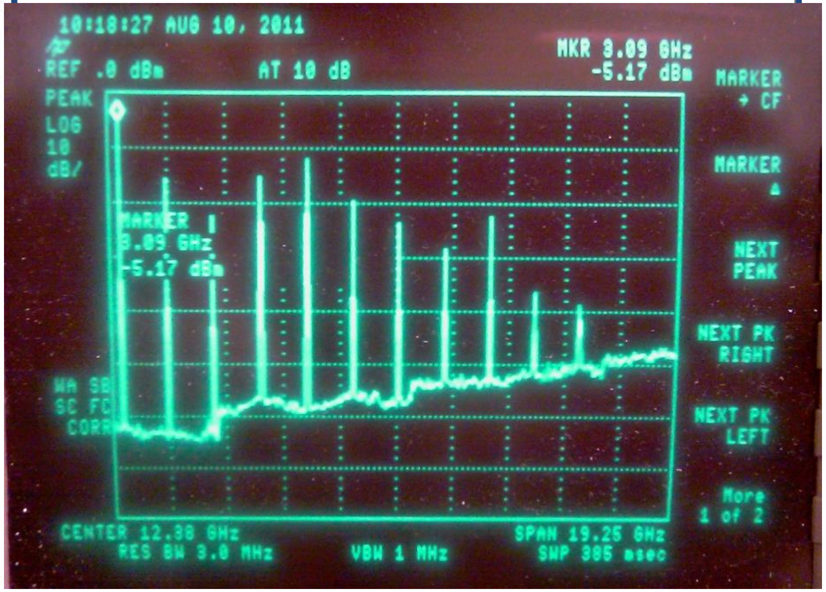
R. Geng

Harmonically-resonant cavity: only TM_{0N0} 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



JLEIC 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

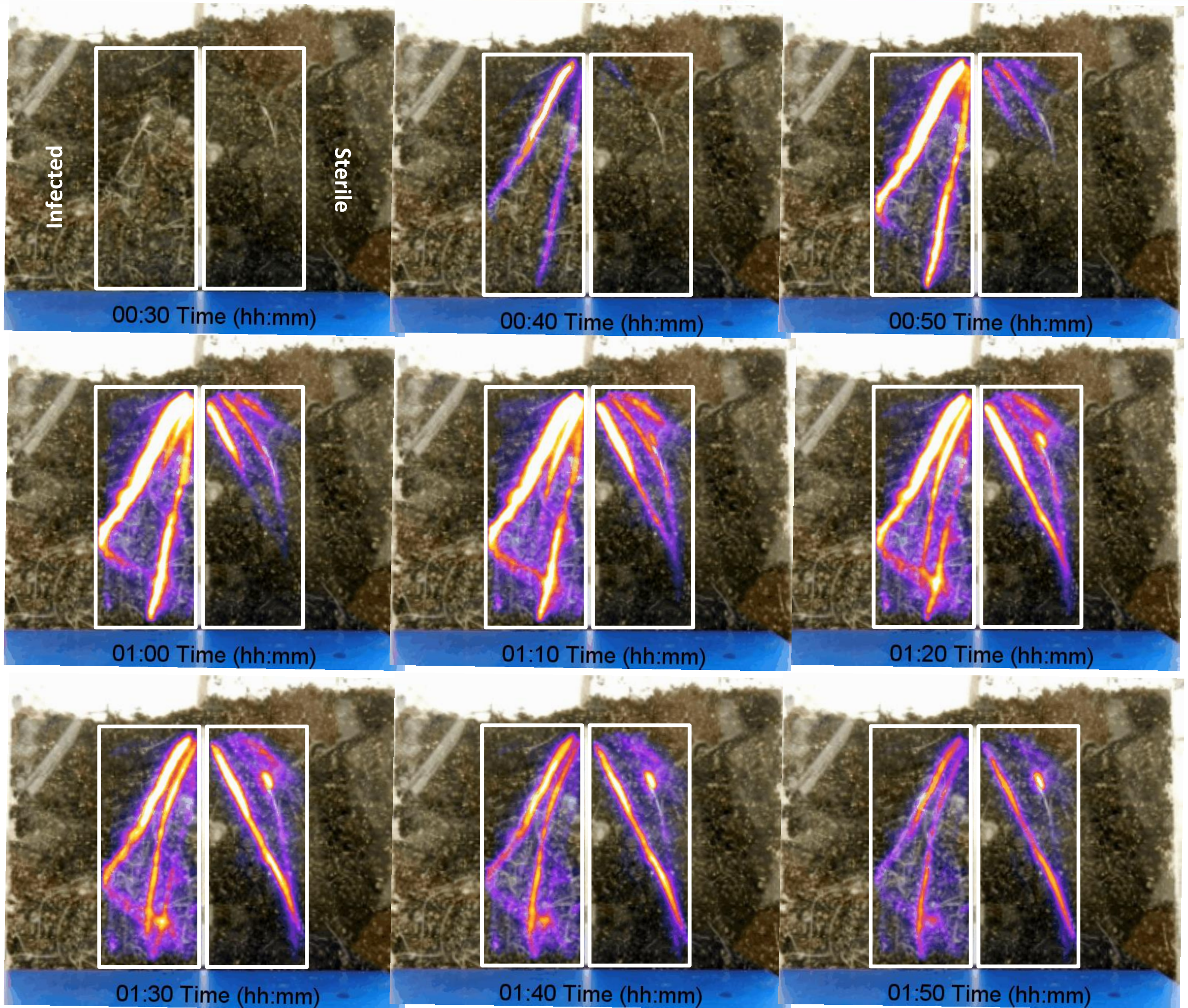
Example: design of a large-aperture high-pole-tip-field superconducting quadrupole with modest yoke thickness

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

PhytoPET to Measures ^{11}C Sugar Translocation

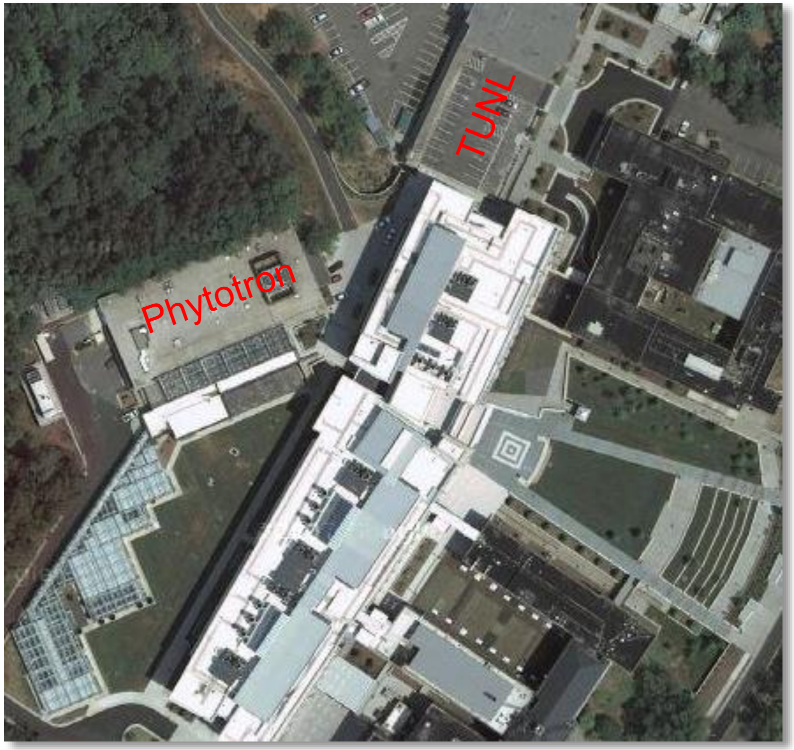
PhytoPET system (8 detector modules, 4 detectors on each side of cuvette) used for a **maize split root dynamic imaging of ^{11}C sugar uptake** down to roots from the leaf.

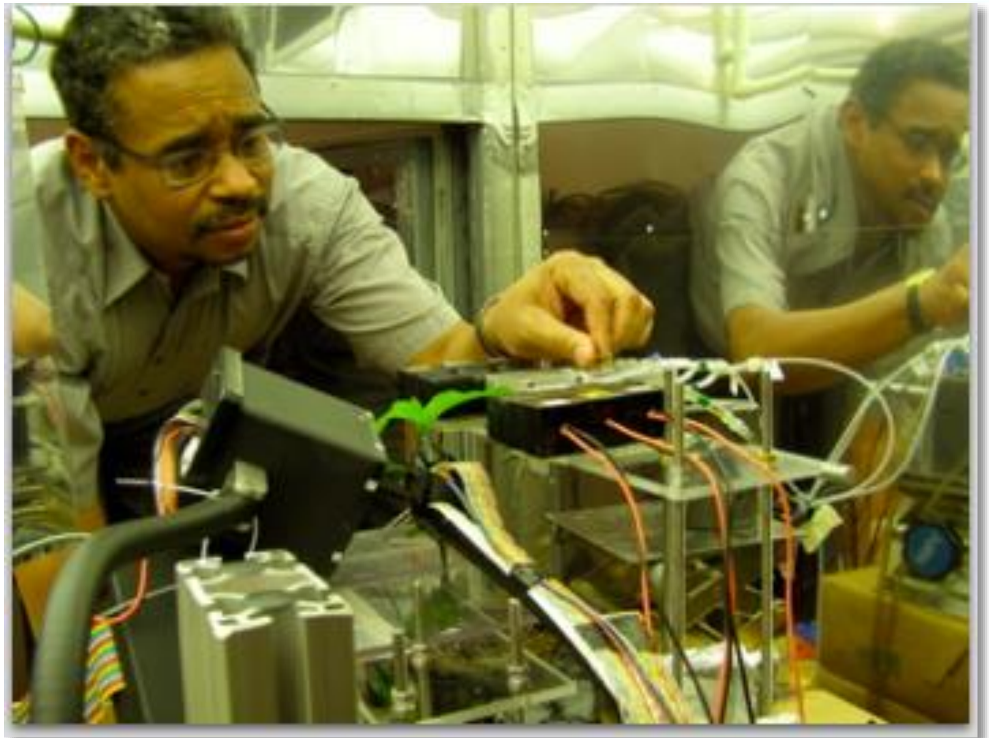
Exploring **soil/root/fungi** interaction. Identifying fungi that aid plant root growth.



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



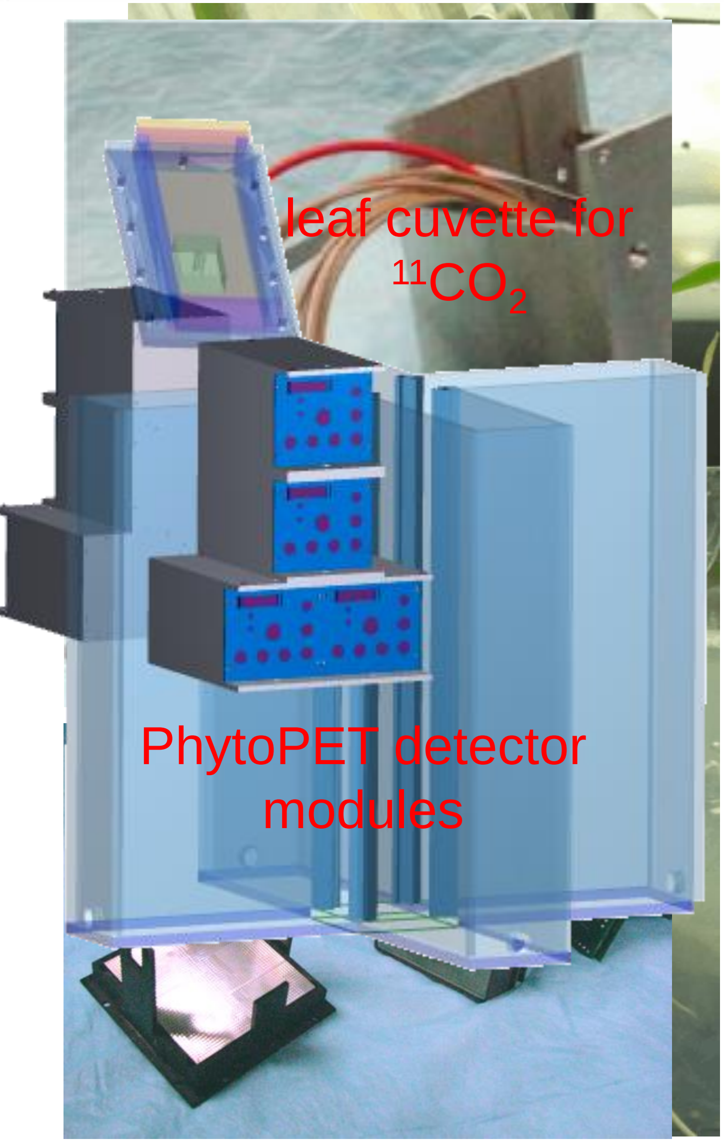


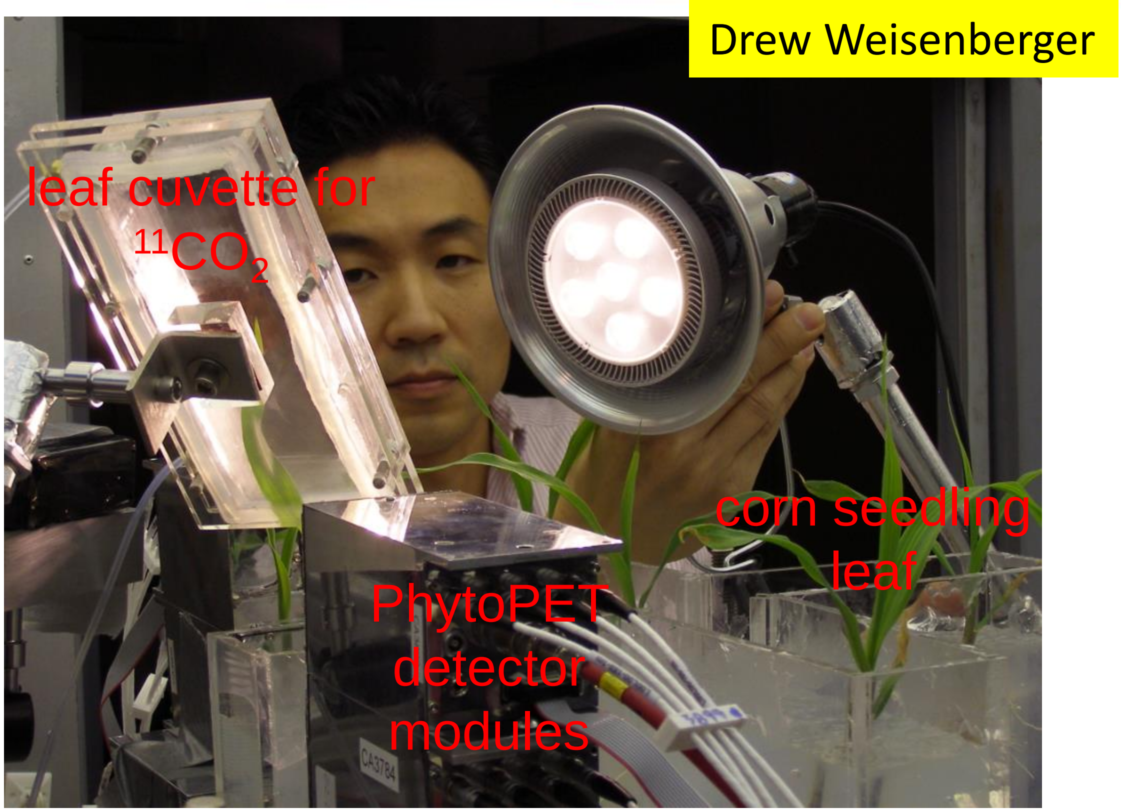
Drew Weisenberger

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





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.

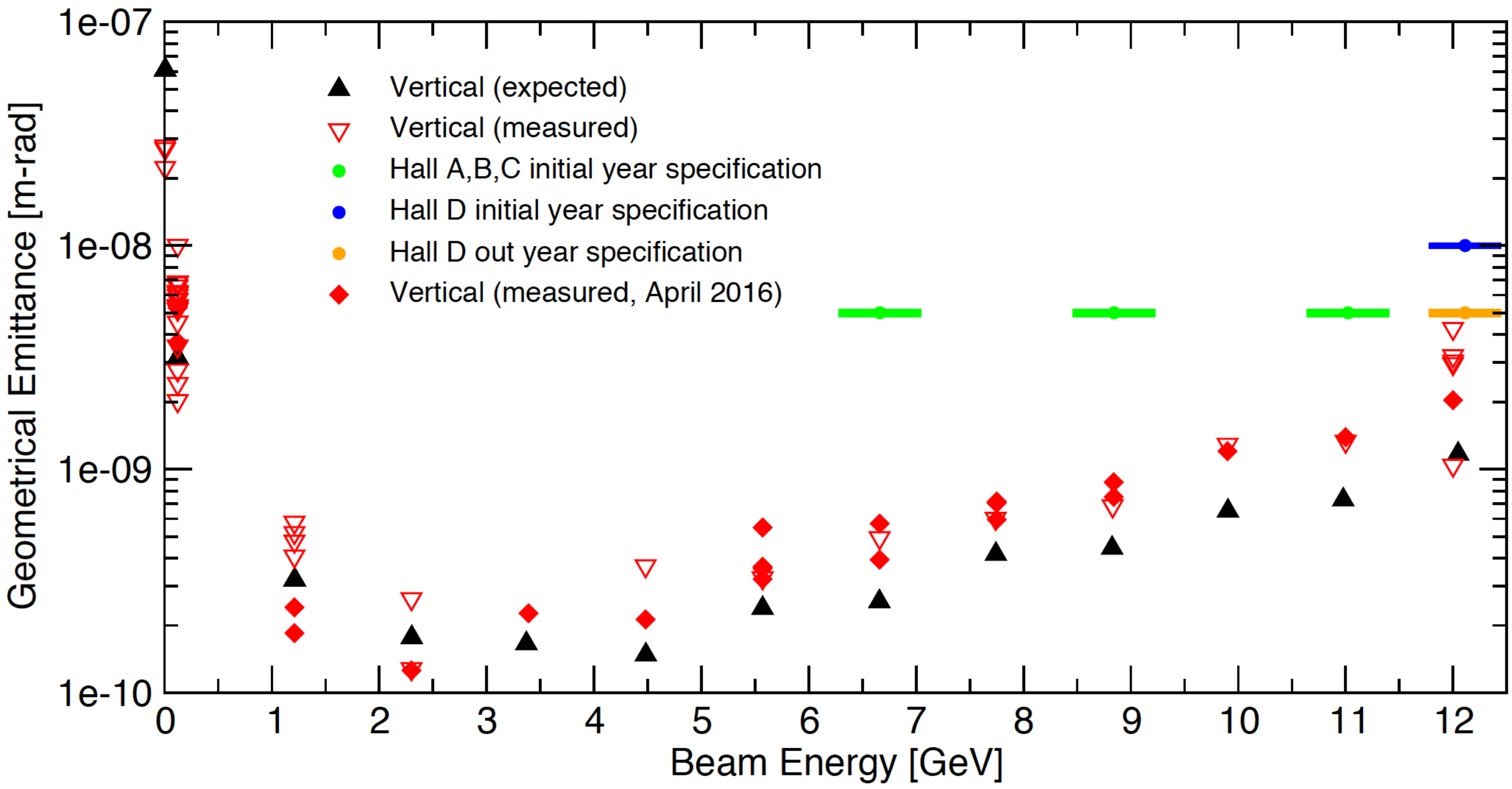
Technology Transfer: Nuclear Medicine Imaging
3D Brain Scans of Moving Mice

- **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

•Measured vertical emittance after every pass



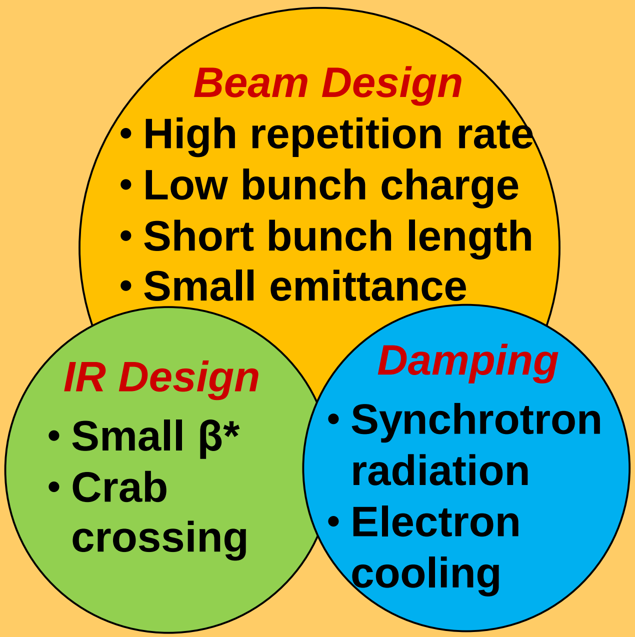
Strategy for High Luminosity and Polarization

High Luminosity

- Based on ***high bunch repetition rate CW colliding beams***

$$L = f\,\frac{n_1 n_2}{4\pi\sigma^*_x\sigma^*_y} \sim f\,\frac{n_1 n_2}{\varepsilon\beta^*_y}$$

- KEK-B reached > **2x10^{34} /cm^2/s**
- However new for proton or ion beams



High Polarization

All rings are in a figure-8 shape
➔ critical advantages for both beams

- Spin precessions in the left & right parts of the ring are ***exactly cancelled***
- Net spin precession (***spin tune***) is **zero**, thus ***energy independent***
- Spin can be ***controlled*** & ***stabilized*** by small solenoids or other compact spin rotators

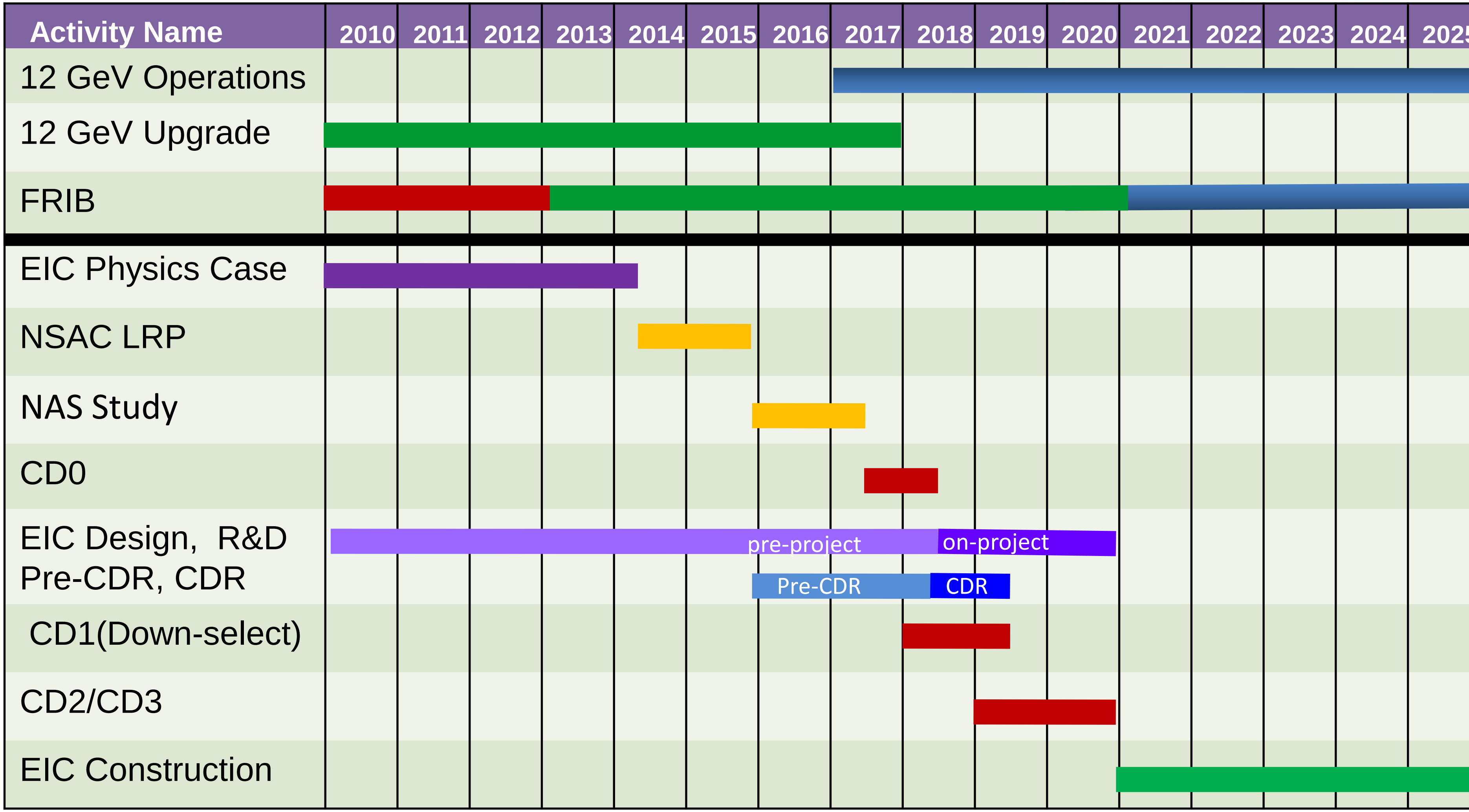
Excellent Detector integration

Interaction region is designed to support

- ***Full acceptance*** detection (including forward tagging)
- Low detector ***background***

68
Jefferson Lab

EIC Timeline



CD0 = DOE "Mission Need" statement; **CD1** = design choice and site selection (VA/NY)

CD2/CD3 = establish project baseline cost and schedule

Calculated Yields and Contaminants

(Full Absorption target)

		Natural Gallium Target			^{71}Ga Target		
Energy of Electron Beam [MeV]		18.5	40	100	18.5	40	100
Nuclide & dominant production reaction	$T_{1/2}$	Calculated Yield [mCi / (50 kW - h)]					
^{67}Cu ***^{71}Ga(γ,α)^{67}Cu***	***61.8 h***	***1.4***	***13***	***18***	***3.5***	***32***	***44***
^{64}Cu ^{69}Ga(γ,αn)^{64}Cu	12.7 h		298	521			72
^{71m}Zn ^{71}Ga(n,p)^{71m}Zn	4 h		0.1	0.8		0.2	1.1
^{69m}Zn ^{69}Ga(γ,np)^{69m}Zn ^{71}Ga(γ,np)^{69m}Zn	13.8 h	0.1	17	45	0.1	40	109
^{69}Zn ^{69}Ga(γ,np)^{69}Zn ^{71}Ga(γ,np)^{69}Zn	56 m	0.7	181	494	1	434	7

Calculated Yields and Contaminants

(Full Absorption target)

		Natural Gallium Target			^{71}Ga Target		
Energy of Electron Beam [MeV]		**18.5**	**40**	**100**	**18.5**	**40**	**100**
Nuclide & dominant production reaction	**$T_{1/2}$**	**Calculated Yield [mCi / (50 kW - h)]**					
^{72}Ga $^{71}Ga(n,\gamma)^{72}Ga$	14.1h		43	63	8.7	49	71
^{70}Ga $^{71}Ga(\gamma,n)^{70}Ga$ $^{69}Ga(n,\gamma)^{70}Ga$	21 m	8.5	1.7×10^5	2.1×10^5	1.1×10^5	4.1×10^5	5.2×10^5
^{68}Ga $^{69}Ga(\gamma,n)^{68}Ga$	68 m	4.4×10^4	1.3×10^5	1.7×10^5		941	4770
^{67}Ga $^{69}Ga(\gamma,2n)^{67}Ga$	3.26 d	2.9×10^4	380	581		0.02	35
^{66}Ga $^{69}Ga(\gamma,3n)^{66}Ga$	9.5 h		6.2	121			29