Jefferson Lab and SBIR/STTR Program

Drew Weisenberger

DOE-NP SBIR/STTR Exchange Meeting Aug 8-9 2017

Jefferson Lab
Thomas Jefferson National Accelerator Facility

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

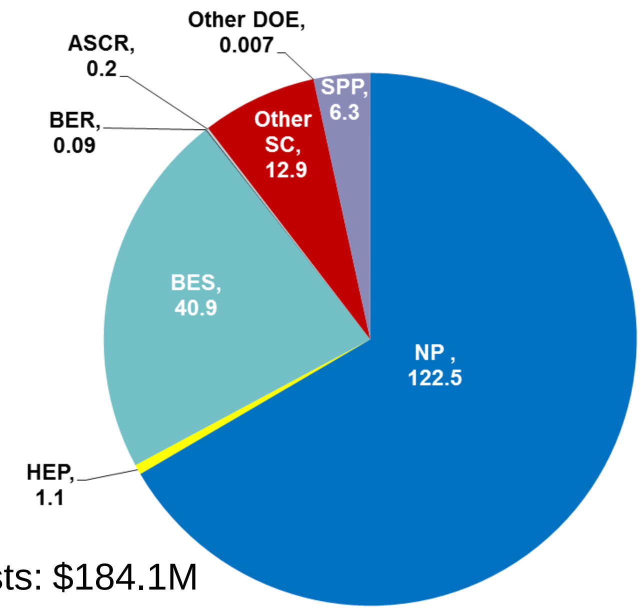
- **Created to build and Operate the Continuous Electron Beam Accelerator Facility (CEBAF), world-unique user facility for Nuclear Physics:**
  - **Mission is to gain a deeper understanding of the structure of matter**
    - Through advances in fundamental research in nuclear physics
      - Through advances in accelerator science and technology
  - In operation since 1995
  - 1,530 Active Users
  - 181 Completed Experiments to-date(3 full, 3 partial from 12 GeV era)
  - 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:**
  - 699 FTEs
  - 26 Joint faculty; 28 Post docs; 9 Undergraduate students; 39 Graduate students

- **K-12 Science Education program serves as national model**

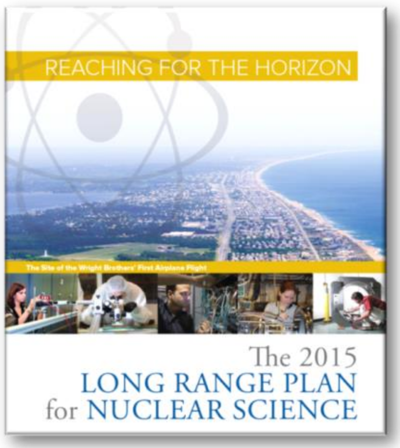
- **Site is 169 Acres, and includes:**
  - 72 Buildings & Trailers: 880K SF
  - Replacement Plant Value: $415M

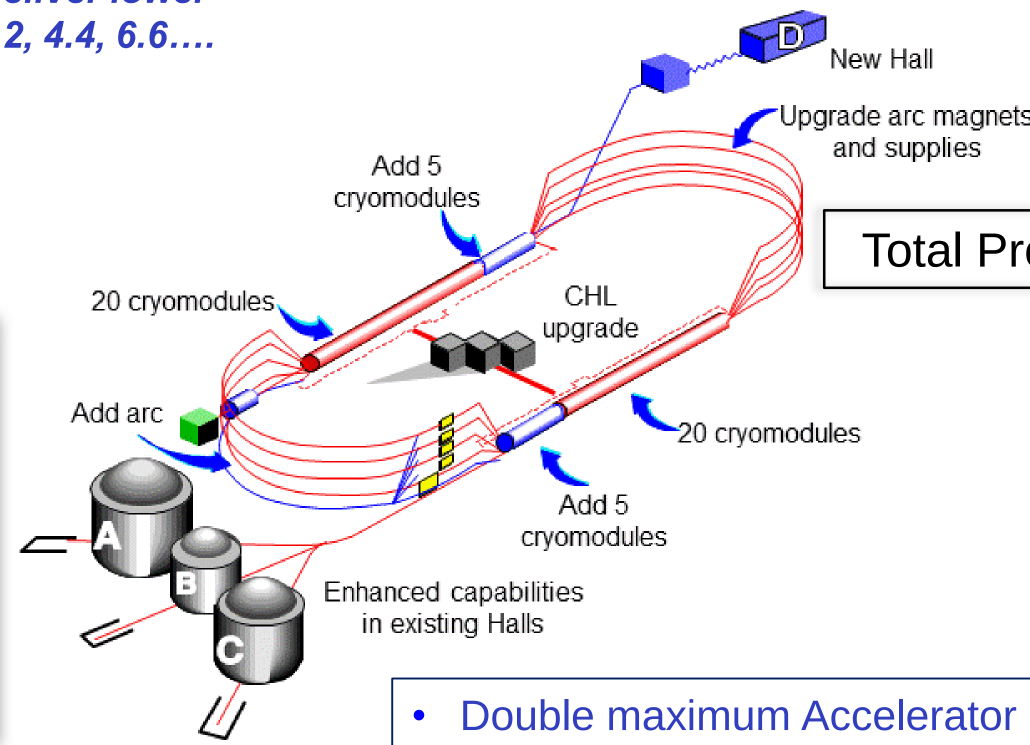


FY 2016:
Total Lab Operating Costs: $184.1M
Non-DOE Costs: $6.3M

12 GeV CEBAF Upgrade

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



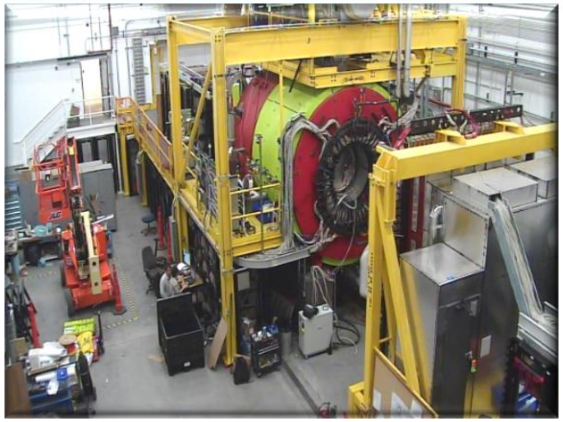


Total Project Cost = $338M

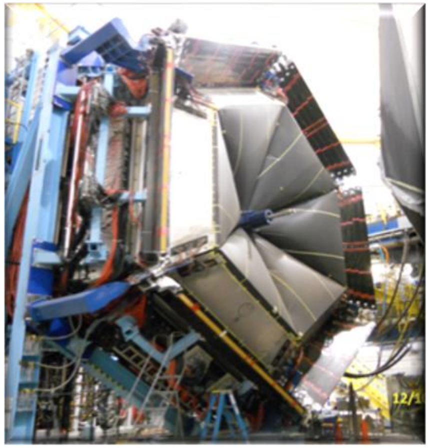
"With the imminent completion of the CEBAF 12-GeV Upgrade, its forefront program of using electrons to unfold the quark and gluon structure of hadrons and nuclei and to probe the Standard Model must be realized"

- Double maximum Accelerator energy to 12 GeV
  - Ten new high gradient cryomodules
  - Double Helium refrigerator plant capacity
  - Civil construction and upgraded utilities
- Add 10^{th} arc of magnets for 5.5 pass machine
- Add 4^{th} experimental Hall D
- New experimental equipment in Halls B, C, D

12 GeV Scientific Capabilities

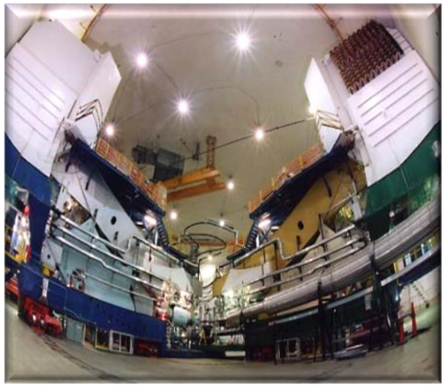


Hall D – exploring origin of confinement by studying exotic mesons



Hall B – understanding nucleon structure via generalized parton distributions and transverse momentum distributions

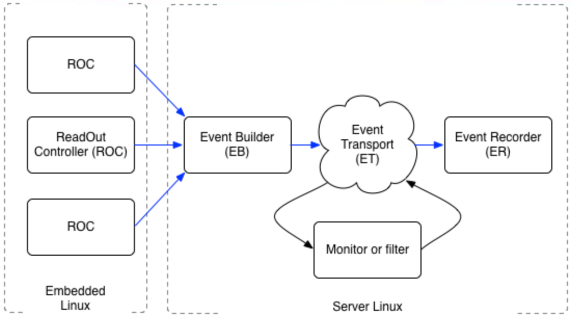
Hall C – precision determination of valence quark properties in nucleons and nuclei

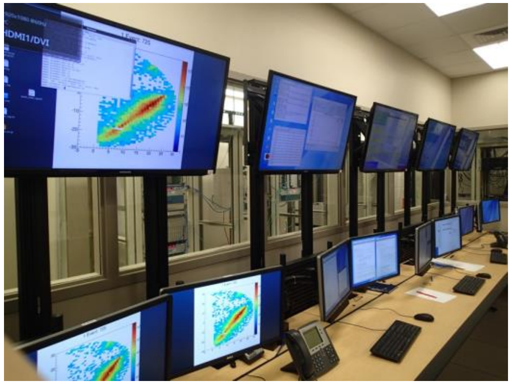


Hall A – short range correlations, form factors, hyper-nuclear physics, future new experiments (e.g., MOLLER and SoLID)

NP Data Acquisition

- All four halls base their DAQ off CODA (CEBAF Online Data Acquisition) - a suite of software and hardware components for building DAQ systems
- Data is read from the detector by embedded VME CPUs running Linux.
- Switched network transfers data to servers running Linux.
  - Use “high end” multi-core servers to maximize throughput per server.
  - Network for Event Builder is 40 Gbit/s InfiniBand.
  - CODA can Run multiple EB and ER in parallel.
- GLUEX in hall-D high luminosity running (2019 onward)
  - 16 kByte events at 90 kHz ~ 1.5 GByte/s
  - GLUEX DAQ tested at 2.7 GByte/s with two Event Builders
  - GLUEX will generate 7 Pbyte of raw data in 2019.





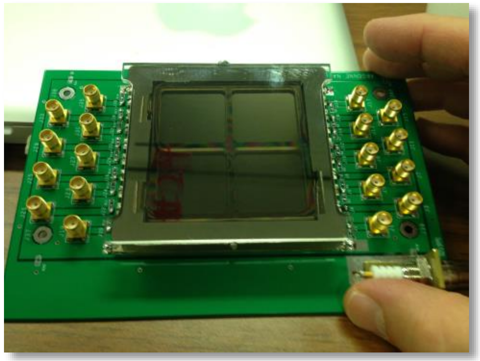
Scientific & Technical Capabilities

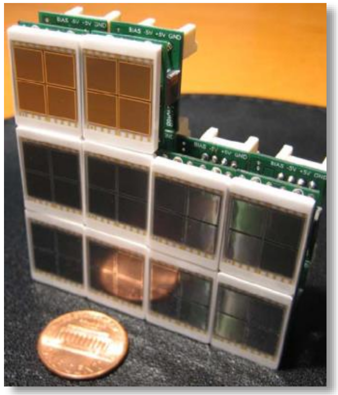
Instrumentation, Detection Systems & Techniques

Jefferson Lab

Photon Detector Characterizations

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



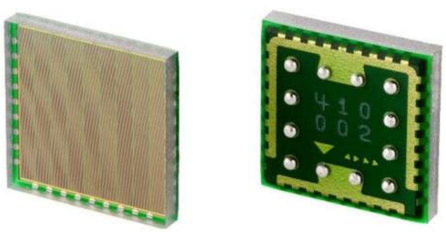


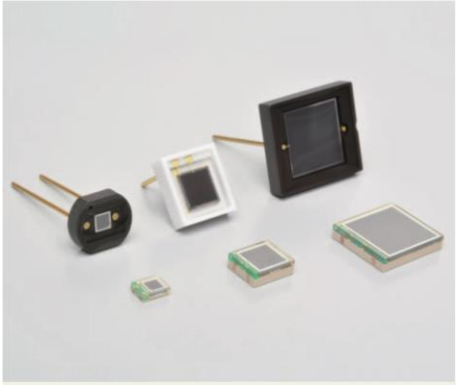
-Microchannel plate based photomultiplier tubes (MCP/PSPMT)
-Large area picosecond photon detector (LAPPD)
-Silicon photo multipliers (SiPM)
-Single Photon Avalanche Photo Diodes (SPADs)

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

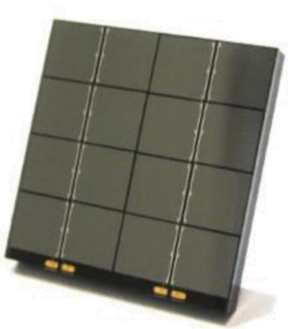
Silicon Photomultipliers & Radiation Hardness

- Silicon Photomultipliers (SiPMs) offer the advantage of high B field immunity
- But have key disadvantages at present
  - Do not have the *single photon* timing resolution offered by MCP-PMTs
  - Numerous studies indicate damage threshold ~ 10^{10} n_{eq}/cm^2
  - Some alleviation possible through low temperature operation and offline high temperature annealing
- For EIC applications, latest studies indicate that dose levels are tolerable (~10^{10}-10^{11} n_{eq}/cm^2)
- Commercial SiPMs continue to improve in higher photodetection efficiency and lower noise, but radiation damage data is for discontinued models in most cases
- Need to re-evaluate current commercial models to assess suitability of SiPMs


Ketek WB


Hamamatsu S13360

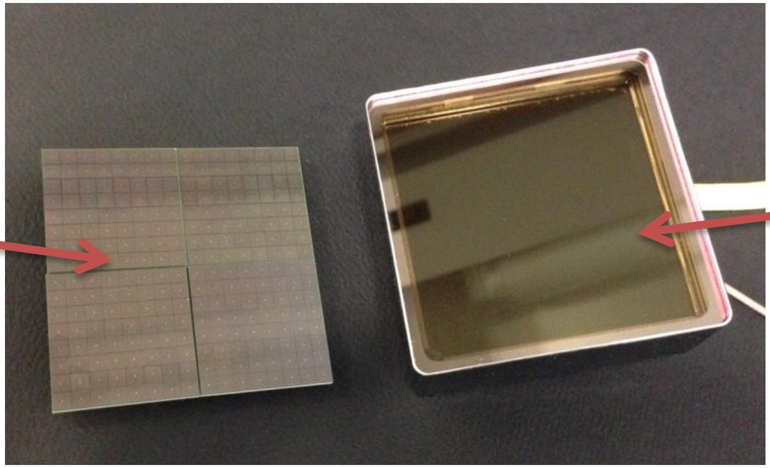

SensL J


Advansid NUV

Multichannel ASIC-based Readout

Microchannel PMTs & SiPM arrays

SiPM array
3x3 mm^2 pixels
256 channels
5x5 cm^2 area



MCP-PMT
6x6 mm^2 pixels
64channels
5x5 cm^2 area

Both sensors and ASIC chips on site

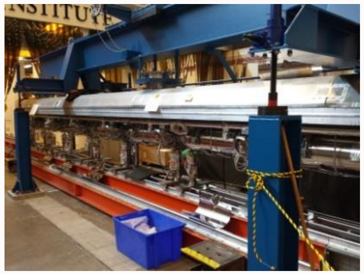
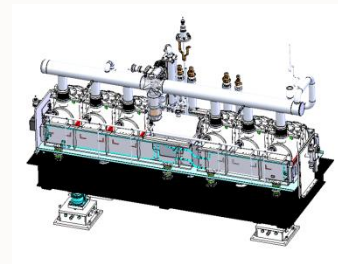
- Address needs of modern detector setups involving high channel counts and small pixel readout – extend success with MaPMT (CLAS12 RICH) to microchannel PMTs (giving high timing precision) and SiPMs (compactness, low voltage operation, magnetic-field immunity)
- In collaboration with **Fast Electronics Group** (F. Barbosa, B. Raydo, C. Dickover), will adapt existing solutions to these photodetectors
- Use results to ***leverage*** further development to address unique capabilities and challenges imposed by these detectors

SRF R&D Activities

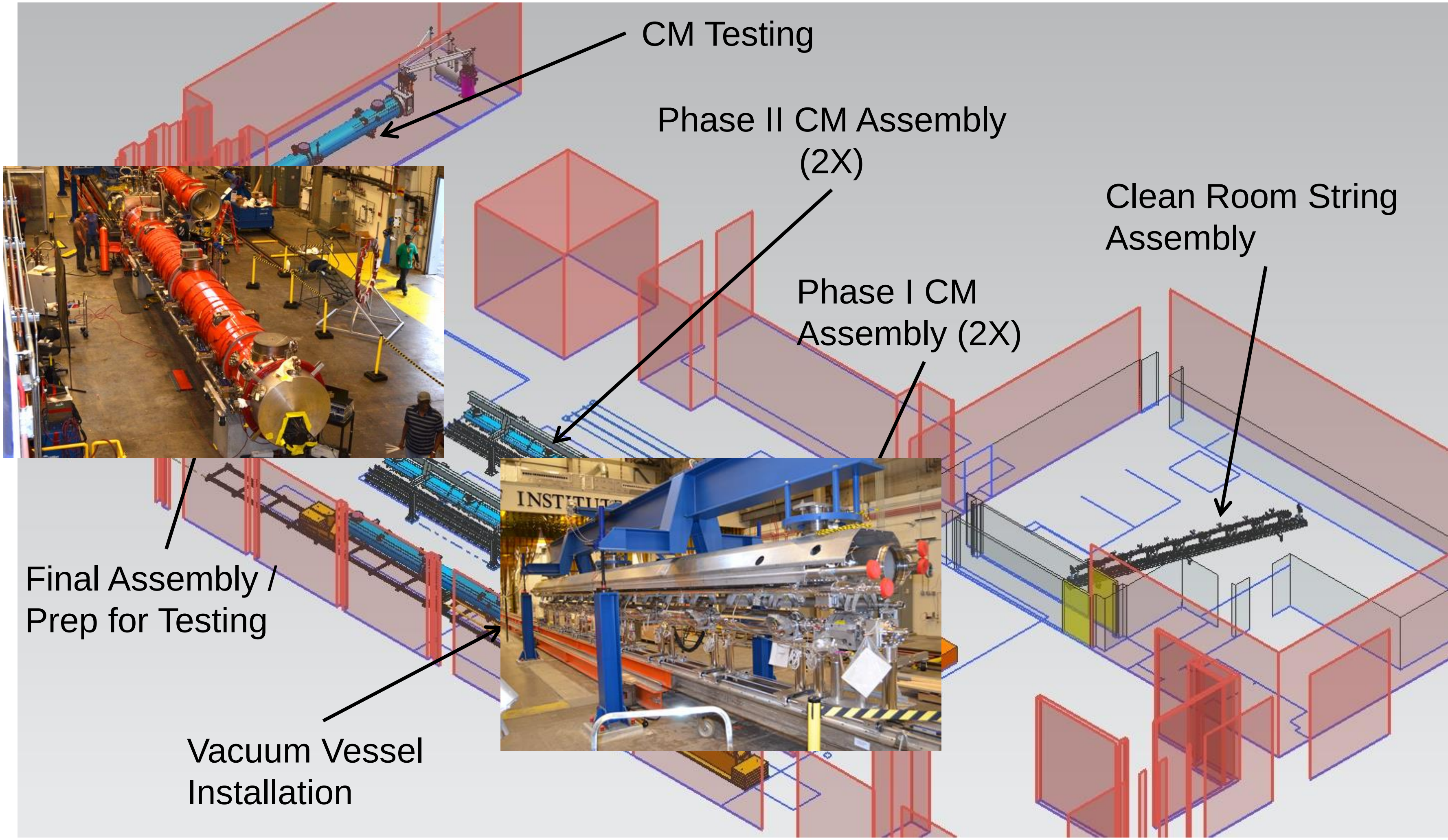
- SRF R&D
  - High Q0
  - High gradient
  - Surface doping
  - Thin films

- SPP
  - LCLS-II
  - FRIB
  - HZB
  - CERN

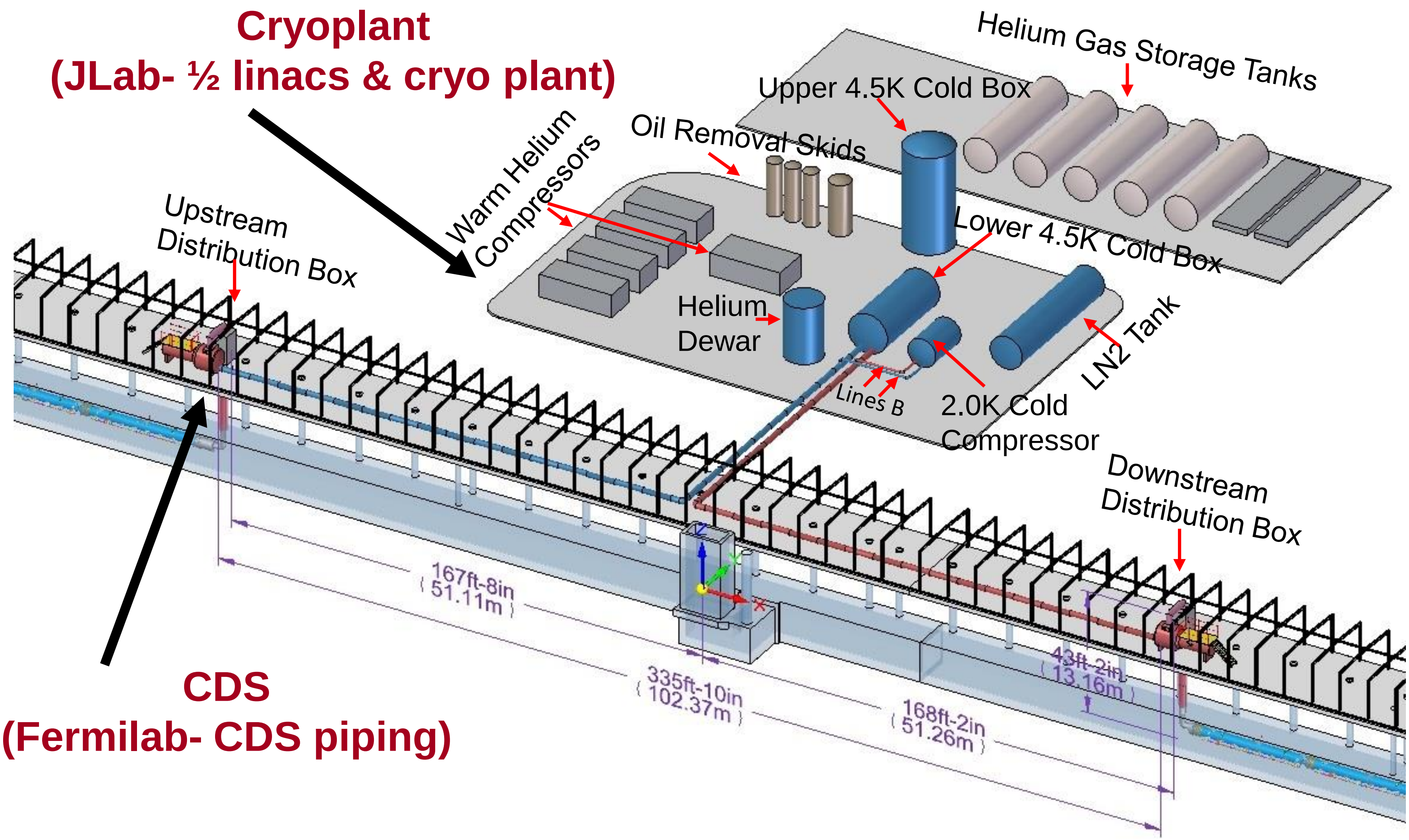
Major Projects Underway

	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 ✓ Prototype cryomodule complete and tested, ✓ Production cryomodule assembly started, string 6 completed.	✓ FDR for 2K cold compressors complete ✓ Beta 0.041 design complete ✓ Beta 0.29 design complete

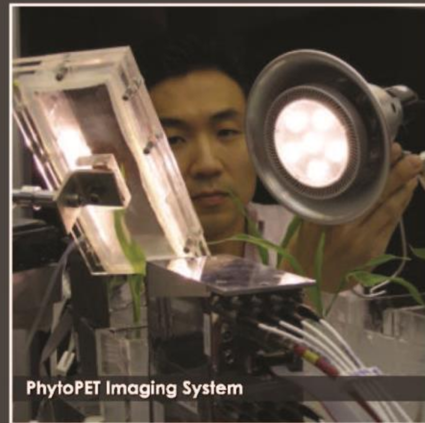
JLab Layout for LCLS-II CM Production



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



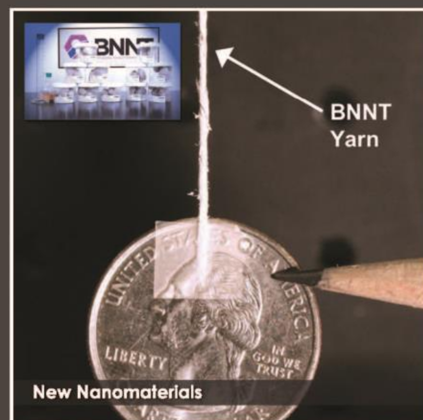
Jefferson Lab FACILITIES EXPERTISE & EQUIPMENT FUEL INNOVATION, FEED BUSINESS


PhytoPET Imaging System

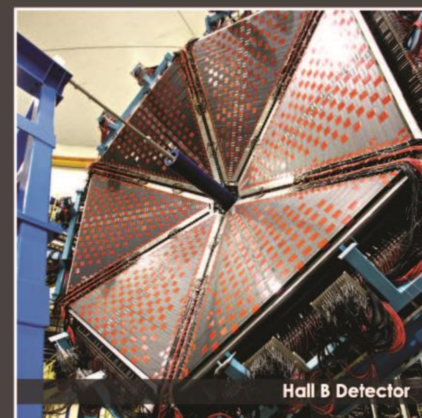

High-Performance Computing

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



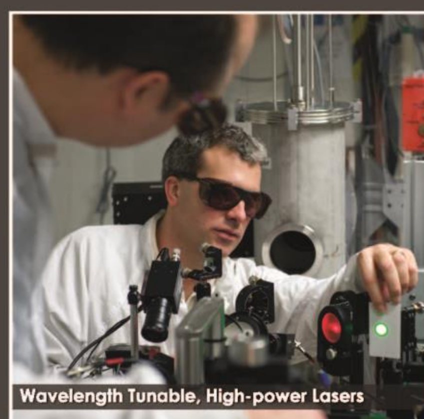
New Nanomaterials


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

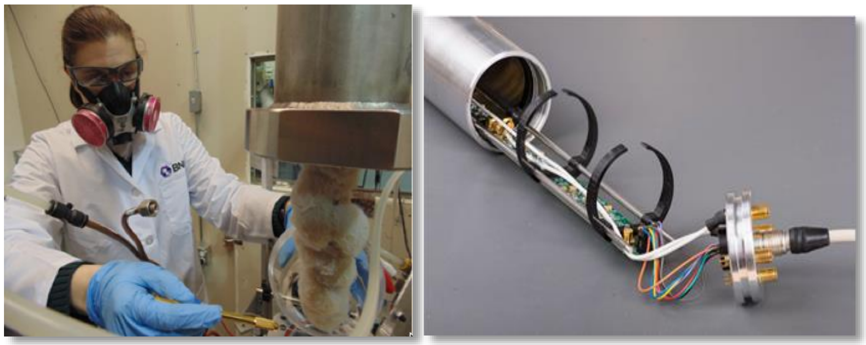

Wavelength Tunable, High-power Lasers


Medical Imaging for Treatment and Diagnostics


Cleanrooms

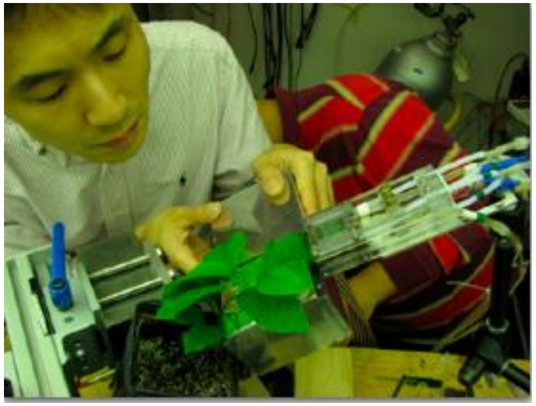
Technology Transfer Advances

Boron Nitride Nanotubes (BNNT) based Neutron Detector



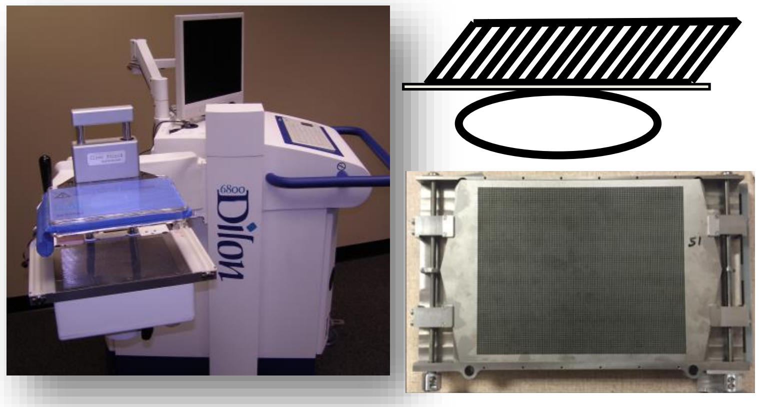
BNNT based neutron detector

Radioisotope Based Molecular Imaging for Plant Biology



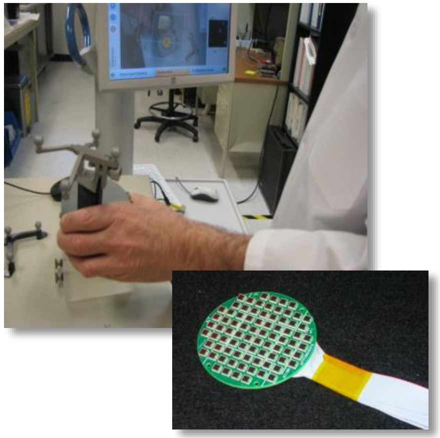
Plant biology studies with $C^{11}O_2$

3-D Breast Cancer Detector



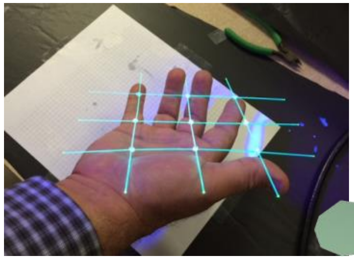
VASH installed on Dilon Technologies gamma camera

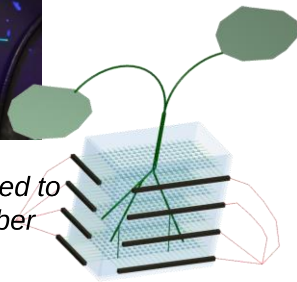
Handheld Gamma Camera for Surgeons



SiPM based detector

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

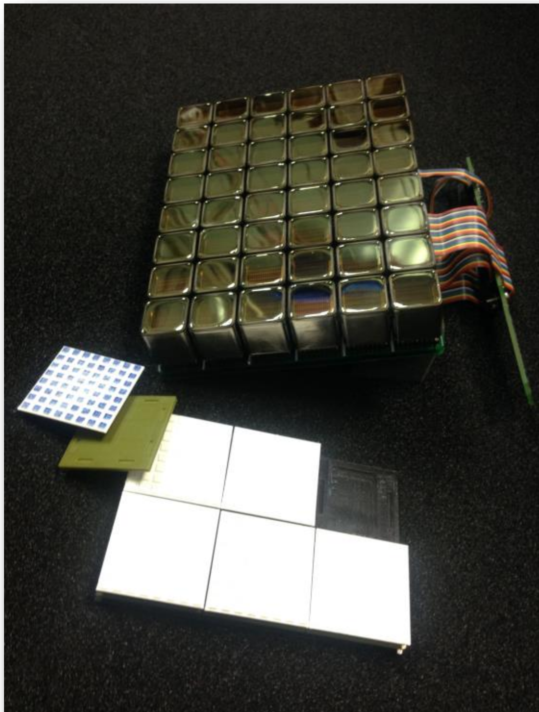




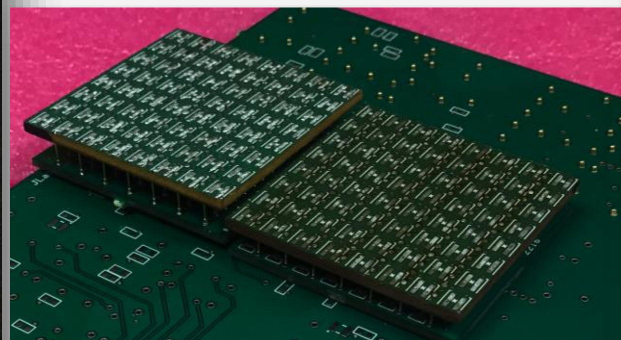
Plastic scintillator coupled to wavelength shifting fiber

Novel Gamma Camera Development: SiPM Based

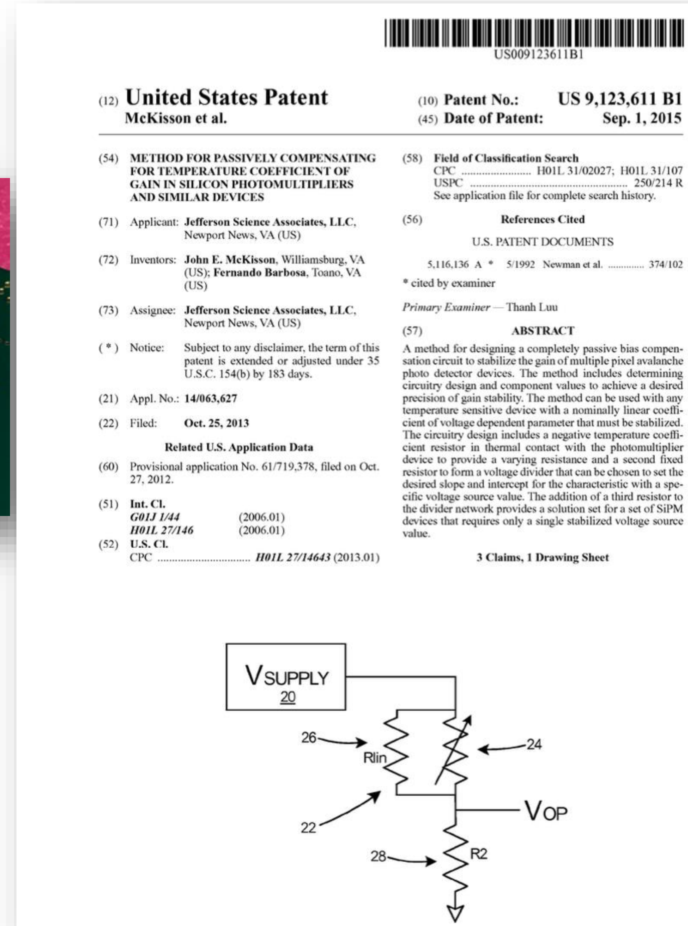
SiPM based Low Profile Imager in collaboration with Dilon Technologies



Allows for thinner lighter cameras. Facilitates a dual headed system and advanced collimators



Two of twelve SiPM Arrays with passive temperature compensation on mother board. Total height ~ 1.0 cm



US009123611B1

(12) **United States Patent**
McKisson et al.

(10) **Patent No.: US 9,123,611 B1**
(45) **Date of Patent: Sep. 1, 2015**

(54) **METHOD FOR PASSIVELY COMPENSATING FOR TEMPERATURE COEFFICIENT OF GAIN IN SILICON PHOTOMULTIPLIERS AND SIMILAR DEVICES**

(71) Applicant: **Jefferson Science Associates, LLC**, Newport News, VA (US)

(72) Inventors: **John E. McKisson**, Williamsburg, VA (US); **Fernando Barbosa**, Toano, VA (US)

(73) Assignee: **Jefferson Science Associates, LLC**, Newport News, VA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 183 days.

(21) Appl. No.: **14/063,627**

(22) Filed: **Oct. 25, 2013**

Related U.S. Application Data

(60) Provisional application No. 61/719,378, filed on Oct. 27, 2012.

(51) **Int. Cl.**
G01J 1/44 (2006.01)
H01L 27/146 (2006.01)

(52) **U.S. Cl.**
CPC *H01L 27/14643* (2013.01)

(58) **Field of Classification Search**
CPC H01L 31/02027; H01L 31/107
USPC .... 250/214 R
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,116,136 A * 5/1992 Newman et al. 374/102

* cited by examiner

Primary Examiner — Thanh Luu

(57) **ABSTRACT**

A method for designing a completely passive bias compensation circuit to stabilize the gain of multiple pixel avalanche photo detector devices. The method includes determining circuitry design and component values to achieve a desired precision of gain stability. The method can be used with any temperature sensitive device with a nominally linear coefficient of voltage dependent parameter that must be stabilized. The circuitry design includes a negative temperature coefficient resistor in thermal contact with the photomultiplier device to provide a varying resistance and a second fixed resistor to form a voltage divider that can be chosen to set the desired slope and intercept for the characteristic with a specific voltage source value. The addition of a third resistor to the divider network provides a solution set for a set of SiPM devices that requires only a single stabilized voltage source value.

3 Claims, 1 Drawing Sheet

Leveraging original SiPM development for Hall D

Nuclear Physics Emerging Initiatives

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.

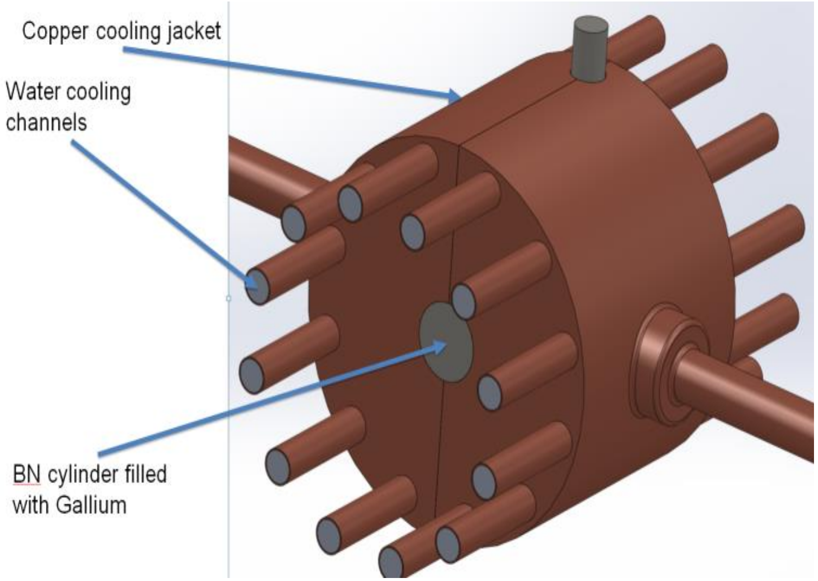
- LERF at Jefferson Lab (FEL) can deliver >100 kW of beam power
- Electron beam energy & current are tunable
- Use it to produce ^{67}Cu with the bremsstrahlung

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

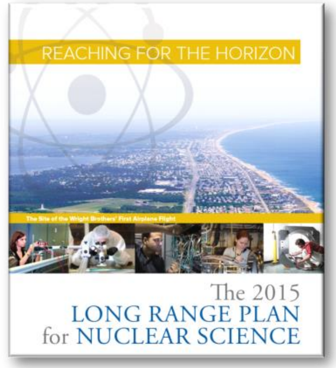


VCU will perform separation of ^{67}Cu from irradiated gallium

Looking to the Future

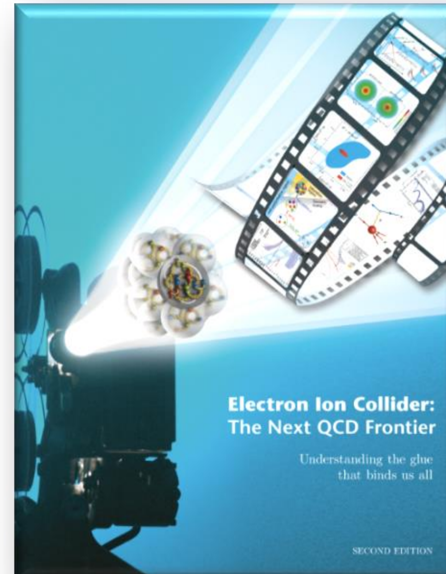
Decade of Experiments Approved
First 12 GeV Science Experiment Complete!

- 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

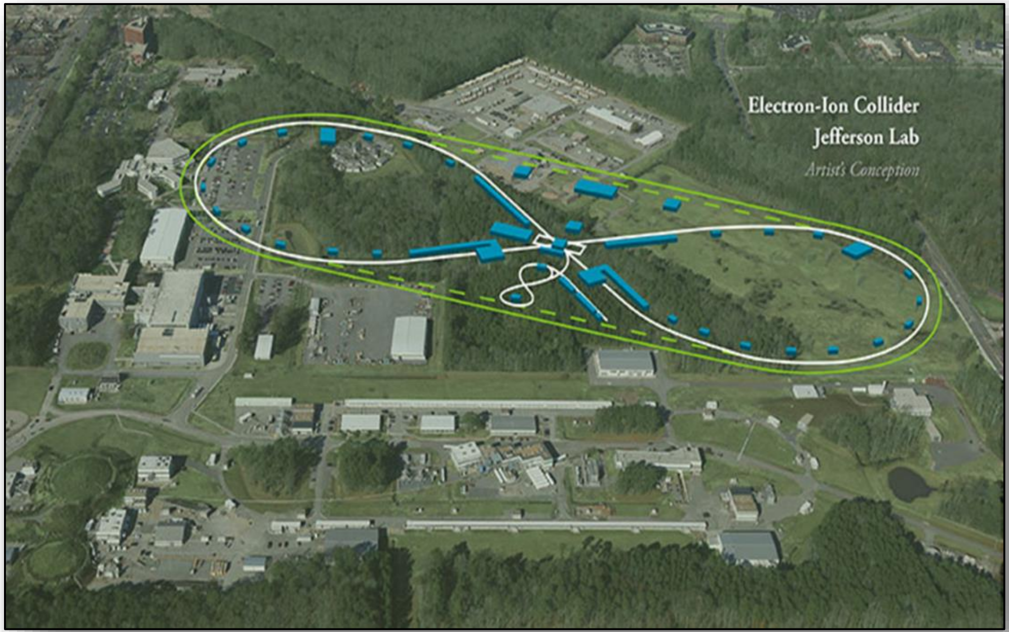
Exploring the Glue that Binds Us All

JLab Electron Ion Collider

JLab EIC Figure 8 Concept

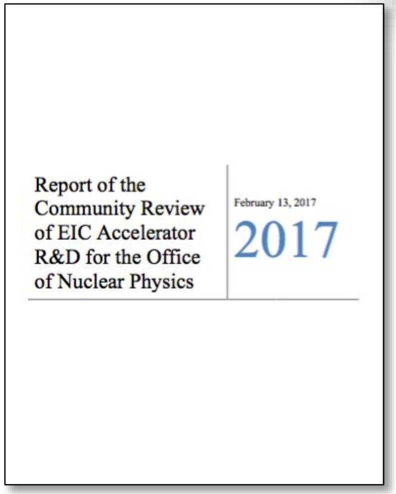
- High Polarization
- High Luminosity
- Low technical risk
- Flexible timeframe for construction consistent w/running 12 GeV CEBAF
- Cost effective operations

➢ Fulfills White Paper Requirements



Jones Report:

EIC R+D lead to SBIR call for simulation of spin tracking, beam-beam effects, EIC


Report of the Community Review of EIC Accelerator R&D for the Office of Nuclear Physics

February 13, 2017

2017

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

Collaboration with SLAC, LBNL, ANL, BNL

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

JLab and the NP SBIR/STTR Program

JLab & the NP SBIR/STTR Program

Synergistic involvement

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

SBIR Partners

Partner	Project	PI
Black Laboratories	Processing Methods for Superconducting Materials	Charlie Reece
Microdynamics Inc	Continued evolution of the operational performance characteristics of the “CYCLOPS” cavity internal inspection and topography characterization system	Charlie Reece
MuPlus	Design and Optimization of Muon Cooling Channel	Mike Spata
SVT	GaAsSb/AlGaAs Superlattice High-Polarization electron source	Matt Poelker
	Construct and operate a compact photocathode preparation chamber with a microMott polarimeter, with true load-lock capability	Matt Poelker
Alameda	Nb-on-Cu cavities for 700-1500 MHz SRF accelerators	Charlie Reece
	Viability of Cathodic Arc Nb coatings on electro-hydro-formed copper cavities	Charlie Reece
Faraday	Investigate and accelerate the development of the FARADAYIC HF-FREE Electro-Polishing process (aka cathodic electropolishing (CEP) for SRF Niobium cavities	Charlie Reece

SBIR Partners

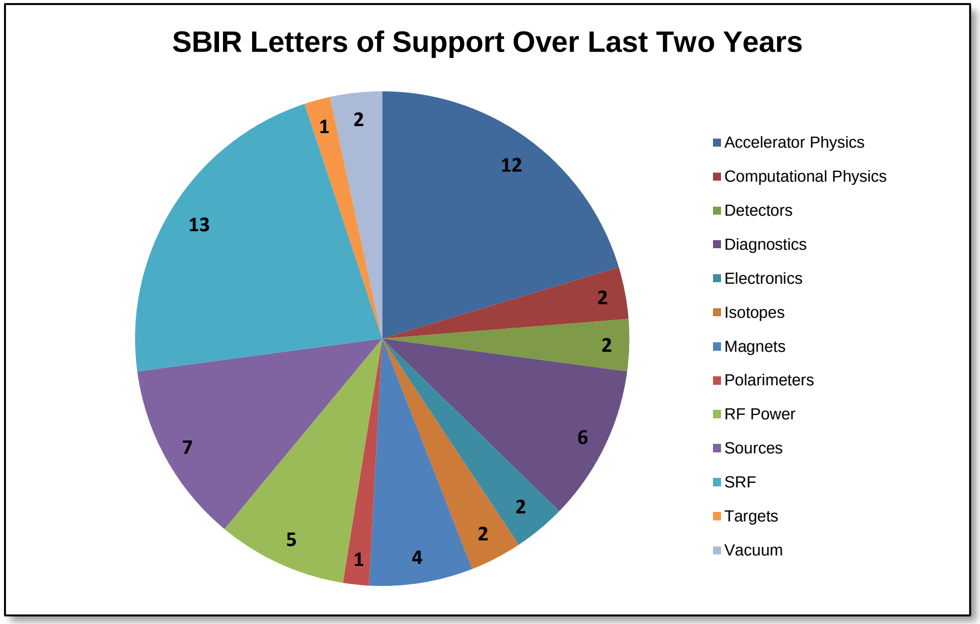
Partner	Project	PI
Radiabeam	Nb Nano-Patterned Cathode	Fay Hannon
	BNNT Wire Scanner	Joe Gubeli
Muons Inc	Test two 13kW, CW magnetrons built by Muons Inc	Haipeng Wang
	Lossy Beam Pipe HOM Load Ceramics with DC Conductivity	Frank Marhauser
Surmet	Provide cryogenic testing of ten (10) wedge samples to be provided by SURMET for testing	Jiquan Guo
Electrodynamic	Non-Invasive Spin Polarization Monitoring	Matt Poelker
Xelera Research*	A Magnetized Electron Source for Ion Beam Cooling	Fay Hannon
Q-Peak*	High Power, High Repetition Rate, 700-850nm Pulsed Laser	Shukui Zhang

* At DOE for Approval

Accelerator Technology

SBIR Program Support

- Jefferson Lab actively seeks opportunities with **Industrial Partners** to conduct research that is aligned with our Strategic Plan
- Laboratory staff work with the **SBIR Program Manager** to edit topical areas for the different Funding Opportunity Announcements
- Solicitations received from Industry cover a broad spectrum of potential opportunities →
- Jefferson Lab provides a **prioritized list of supported proposals** to the SBIR Program Manager
- We then monitor awards for potential synergies with our Strategic Plan



SRF R&D

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.**

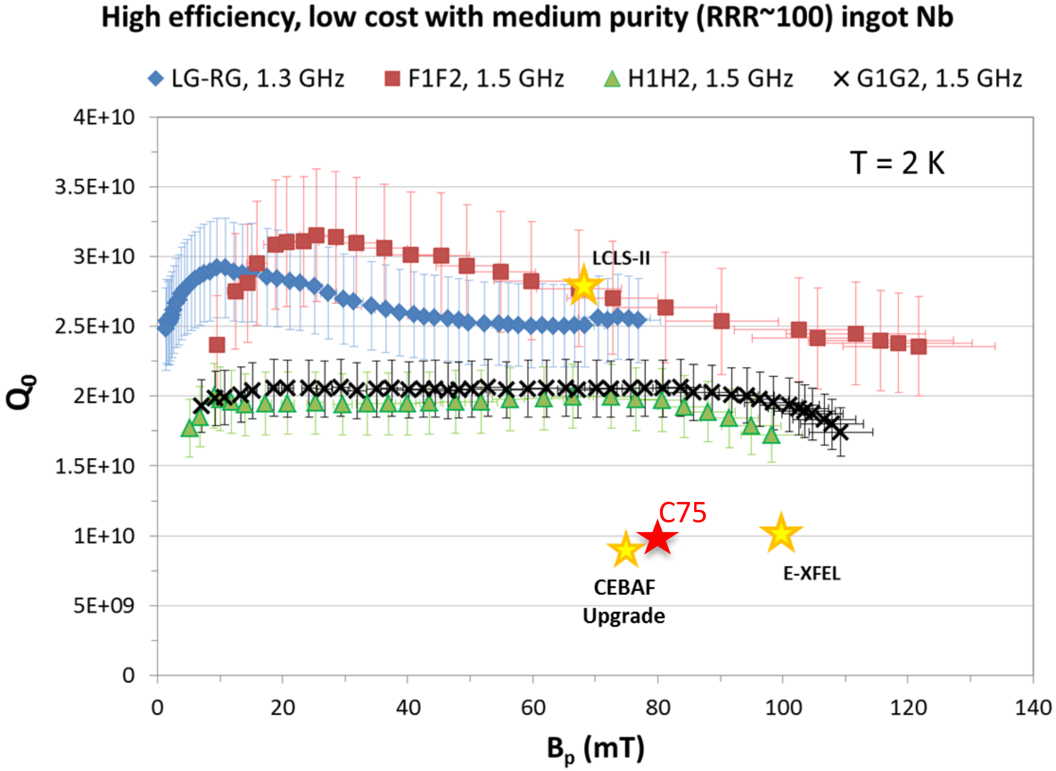
What we need now:

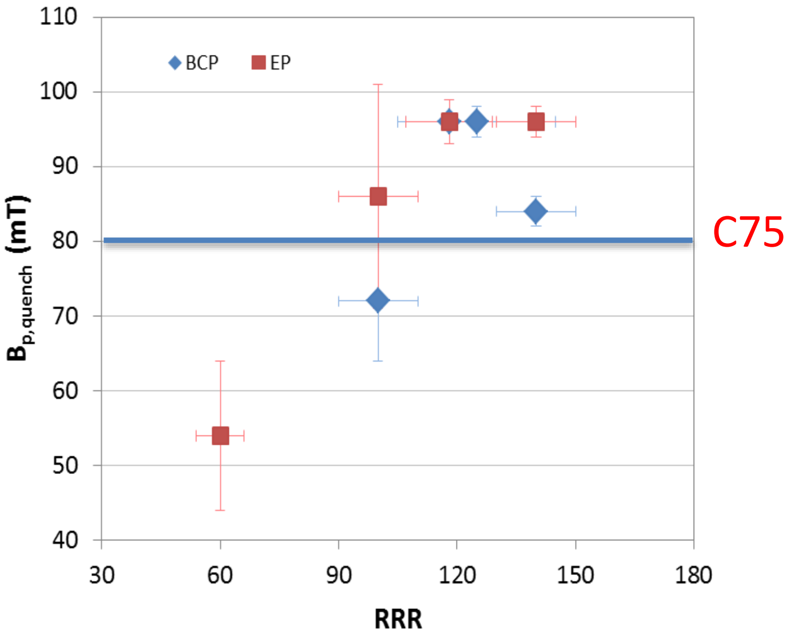
- High efficiency RF sources (>70%), including magnetrons, for JLEIC (952.6MHz) and as replacement for the old CEBAF klystrons (1497 MHz)
- SRF compatible microwave absorbing materials for HOM loads at cryogenic temperatures.
- Low loss, reliable RF windows and couplers, capable of 13 kW to 500 kW operation.
- 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.

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

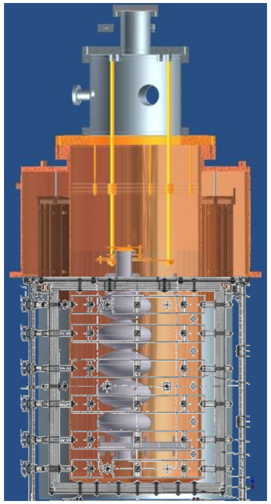




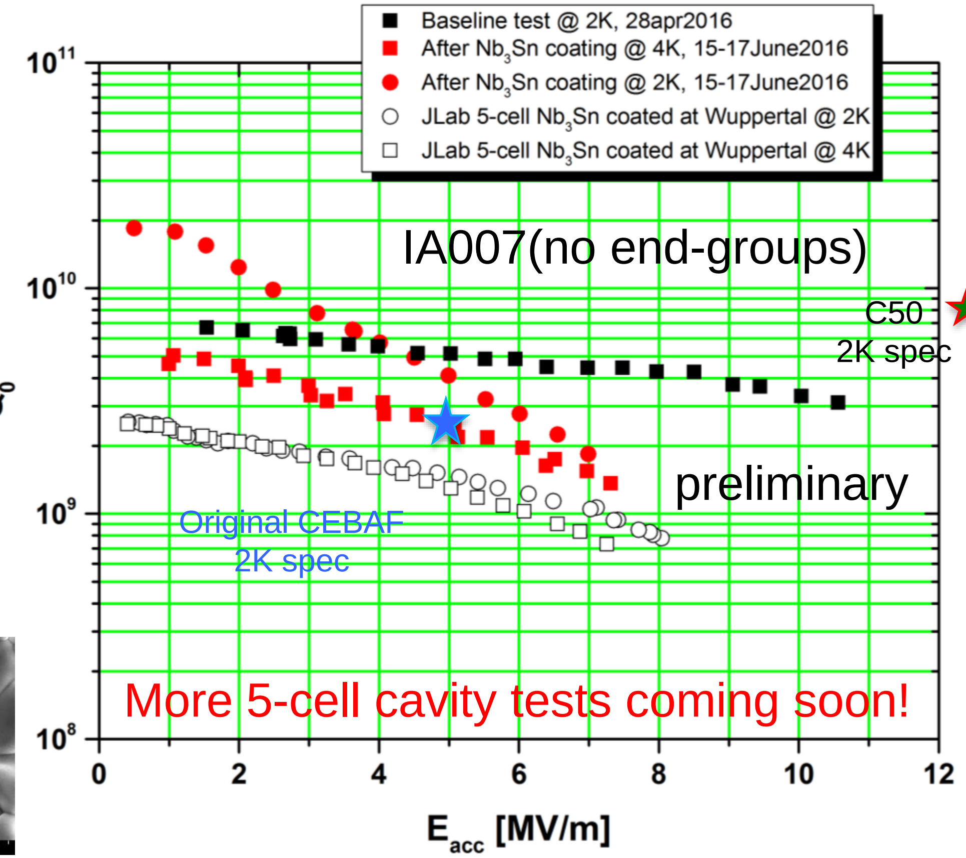
G. Ciovati et al., SRF'15, MOPB001 (2015).

Improved efficiency: JLab Nb_3Sn 5-cell progress

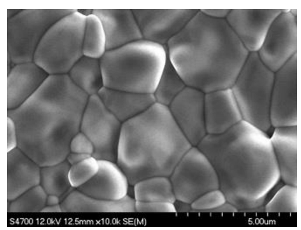
G. Eremeev early career award



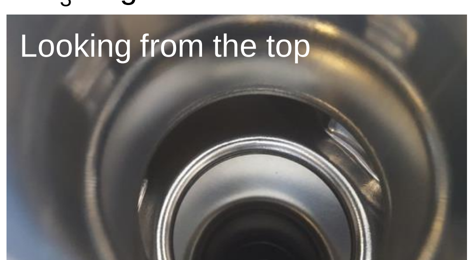
The new configuration was commissioned up to 1250 °C on May 4, 2017.



New 17” OD x 40” furnace insert



Nb_3Sn grain structure



Looking from the top

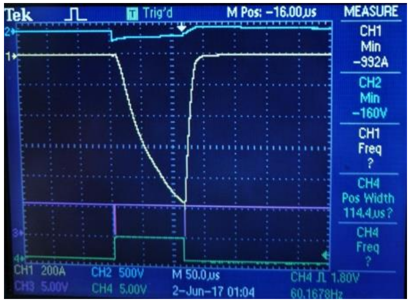
Reasonable low-field Q_0, but a strong Q-slope, similar to the one measured in 5-cell cavity coated at Wuppertal University. Medium field Q-slope is likely due to equator features.

Nb_3Sn coating is present, but is not uniform. The top of the cavity seems “shinier” than the bottom

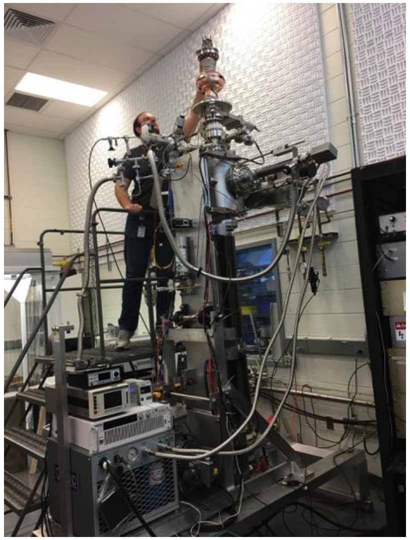
Nb/Cu Thin Film Cavity - HIPIMS

Upgraded Deposition System

- Tripled Pulse Power Capability
- Permanent Vertical System Operation



Updated pulse profile

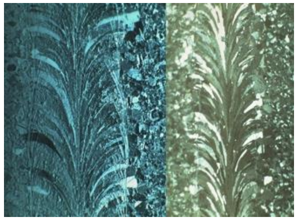


Vertical coating system

Small Samples

- Very low surface roughness
- Bulk-like crystal structure
- Hetero-epitaxial Growth

Cu cavity



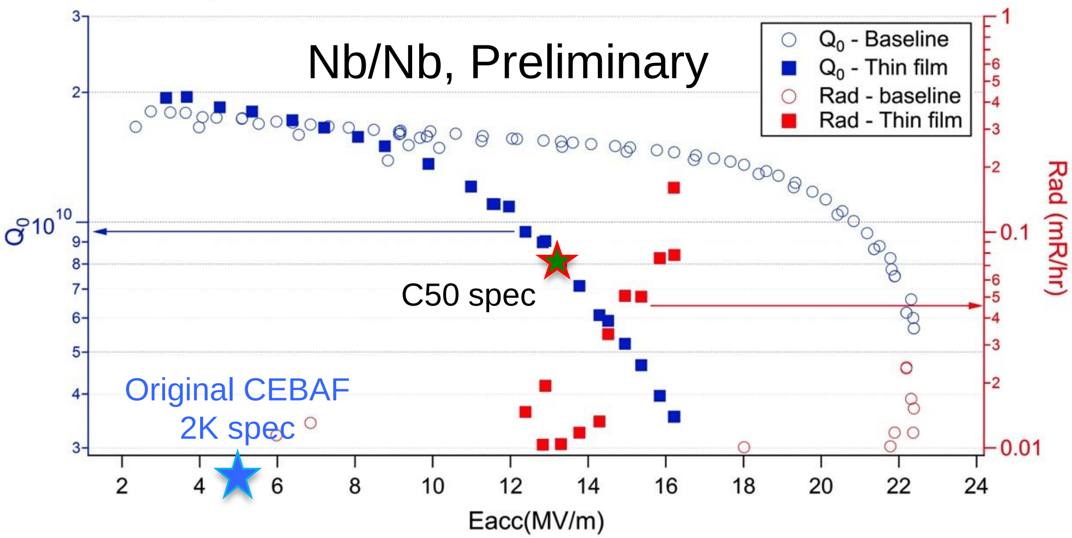
Weld seam

HIPIMS discharge

Cavities

- Cavity RF performance shows larger Q than bulk at low field
- Excellent film adhesion
- Continuing to converge on a high quality copper surface for film deposition

PE-01 - Niobium single cell (C100 end Cell type)



More Cu cavity tests coming soon!

Matt Burton, Larry Phillips, et. al.

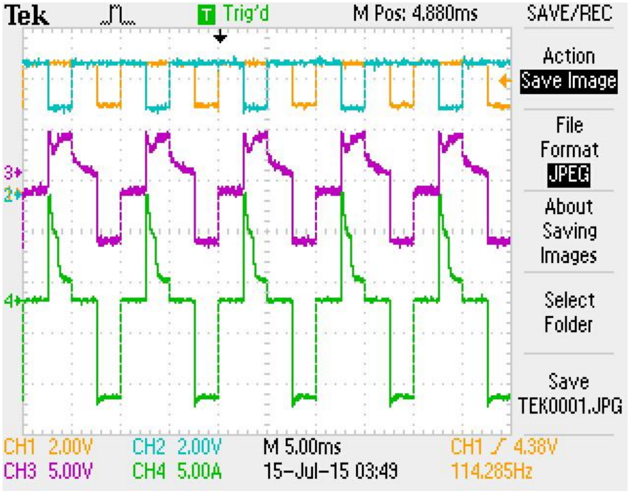
HF-Free Electropolishing Niobium

Pulse-reversed process demonstrated effective on single cell cavity by Faraday Technology using sulfuric acid alone

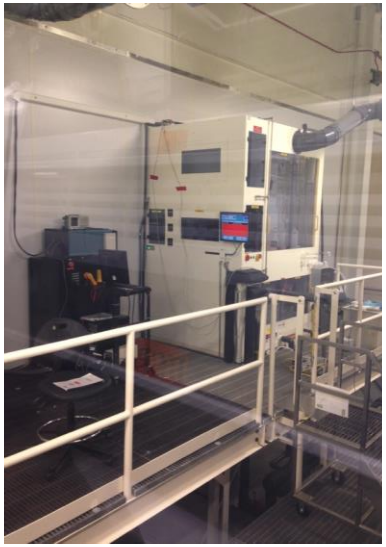
E.J. Taylor et al., SRF2013
A.M. Rowe et al., SRF2013

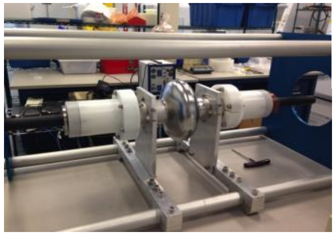
JLab is providing detailed electrochemical analysis and process characterization with varied concentration and pulse structure

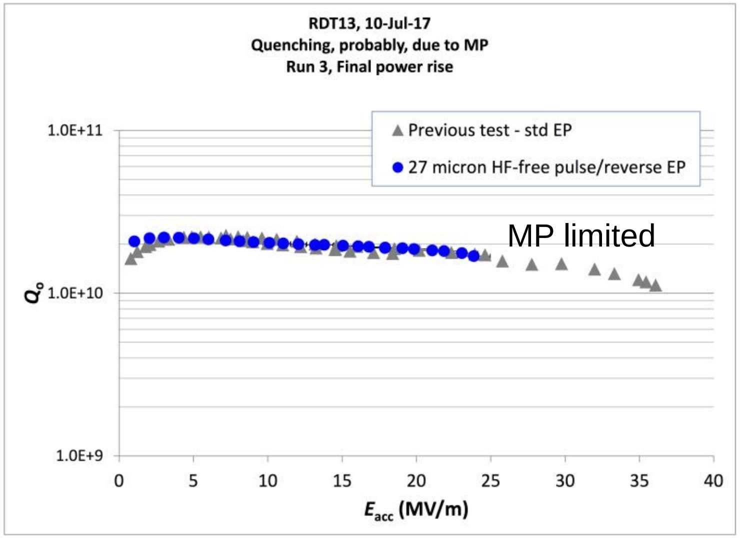
Completed setup of first vertical EP cabinet for HF-free cavity processing



H. Tian, et. al.







First cavity processed this way somewhere other than Faraday Technology. 10% sulfuric acid

Injectors and sources R&D

CEBAF Injector and JLEIC R&D

- Bunchlength monitor and fast kicker using harmonically-resonant cavity, harmonic arbitrary waveform generator and amplifier (SBIR-related)
- Non-invasive electron beam polarimeter, RF-cavity to detect polarization, and/or to monitor Stern-Gerlach deflection (SBIR-related)
- High Polarization and High QE Photocathodes (SBIR-related)
- Improving vacuum to -13 Torr (funded via *Research and Development for Next Generation Nuclear Physics Accelerator Facilities*)
- Thermionic gun with RF time structure, for generating magnetized beam (SBIR-related, JLEIC)
- Powerful drive laser for photoguns, wavelength near 532 and/or 780 nm, with variable repetition rate, ~ 50ps laser pulses via gain-switching (SBIR-related)

BENEFITS OF DISTRIBUTED BRAGG REFLECTOR

- non-DBR Photocathode : absorption in the GaAs/GaAsP superlattice < 5%
  - Most light passes into the substrate leading to unwanted heating
- DBR photocathode : absorption in the GaAs/GaAsP superlattice > 20%
  - Less light required to make required beam, less light means less heat
- Great for high current initiatives like polarized positrons at CEBAF and EIC

GaAs	5 nm	p=5E19 cm^{-3}
GaAs/GaAsP SL	(3.8/2.8 nm) ×14	p=5E17 cm^{-3}
$GaAsP_{0.35}$	2750 nm	p=5E18 cm^{-3}
Graded $GaAsP_x$ ($x = 0\sim0.35$)	5000 nm	p=5E18 cm^{-3}
GaAs buffer	200 nm	p=2E18 cm^{-3}
p-GaAs substrate (p>1E18 cm^{-3})		

Photocathode without DBR
Non-DBR photocathode

GaAs	5 nm	p=5E19 cm^{-3}
GaAs/GaAsP SL	(3.8/2.8 nm) ×14	p=5E17 cm^{-3}
$GaAsP_{0.35}$ spacer	750 nm	p=5E18 cm^{-3}
$GaAsP_{0.35}$/ $AlAsP_{0.4}$ DBR	(54/64 nm) ×12	p=5E18 cm^{-3}
$GaAsP_{0.35}$	2000 nm	p=5E18 cm^{-3}
Graded $GaAsP_x$ ($x = 0\sim0.35$)	5000 nm	p=5E18 cm^{-3}
GaAs buffer	200 nm	p=2E18 cm^{-3}
p-GaAs substrate (p>1E18 cm^{-3})		

Photocathode with DBR (57 layers!)
DBR photocathode

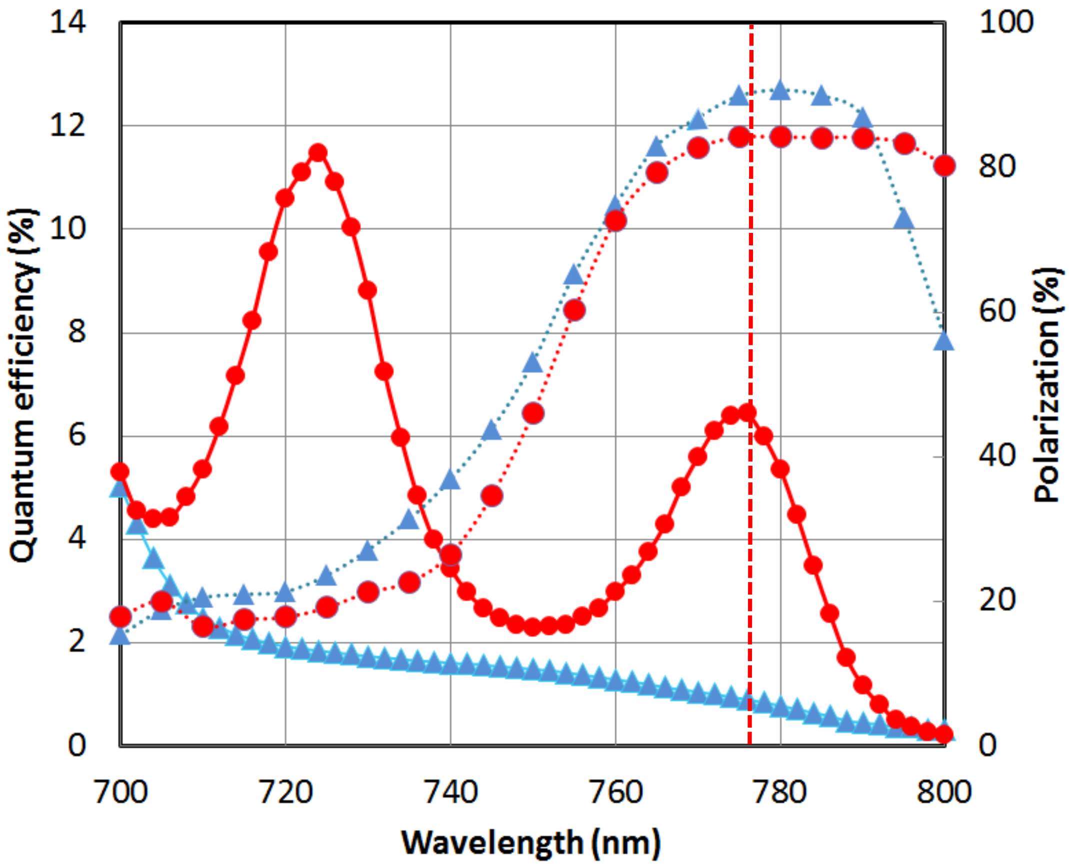
SVT Associates phase 2

Jefferson Lab

World Record: QE from High Polarization Photocathode

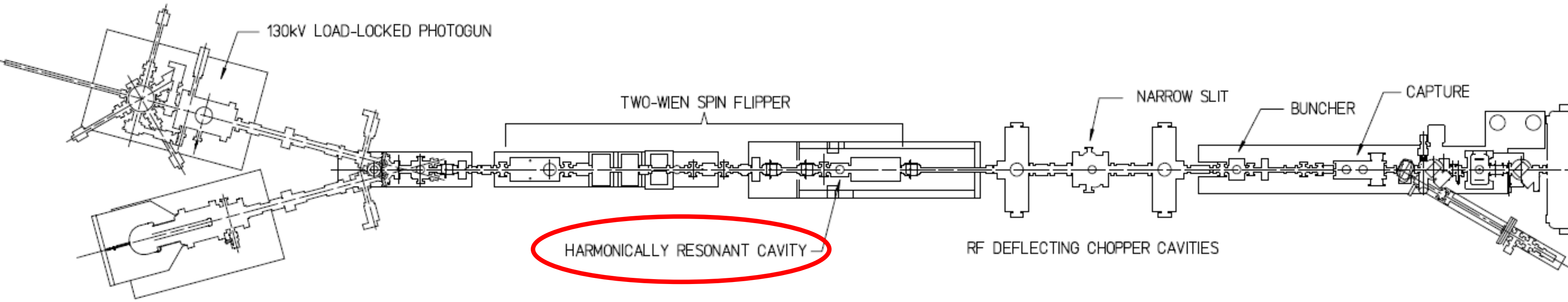
Others have tried…but very difficult to obtain QE enhancement at the laser wavelength that also provides high polarization, CEBAF lasers operate at ~ 776 nm (doubled-telecom lasers)

- Standard strained-superlattice
  - QE = 0.89%
  - Polarization = 92%
- DBR
  - QE = 6.4%
  - Polarization = 84%
- The highest reported QE of any high polarization photocathode
- Excellent candidate for mA operations, will test at CEBAF this shutdown
- SBIR partnership



SVT Associates phase 2

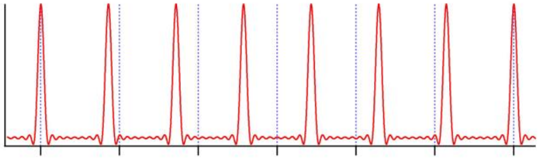
Harmonically resonant cavity as selective energy booste

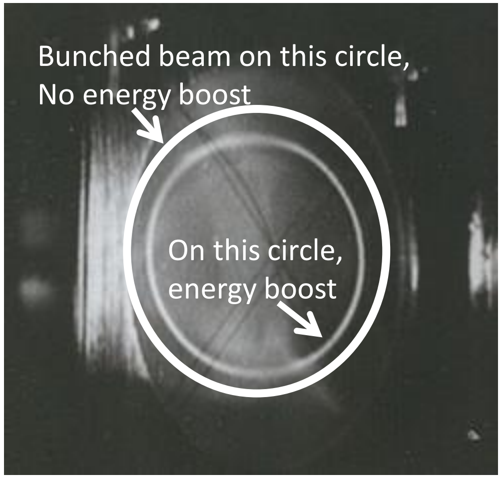


- Drive **harmonically resonant cavity** with RF to create powerful, short-lived E-field
- Set laser rep rate to 1247.5 MHz, kicker driven at 1497 MHz plus harmonics
- Use, Wien filter, chopper and/or 1D spectrometer to measure energy boost

Electrodynamic, Phase 2 SBIR

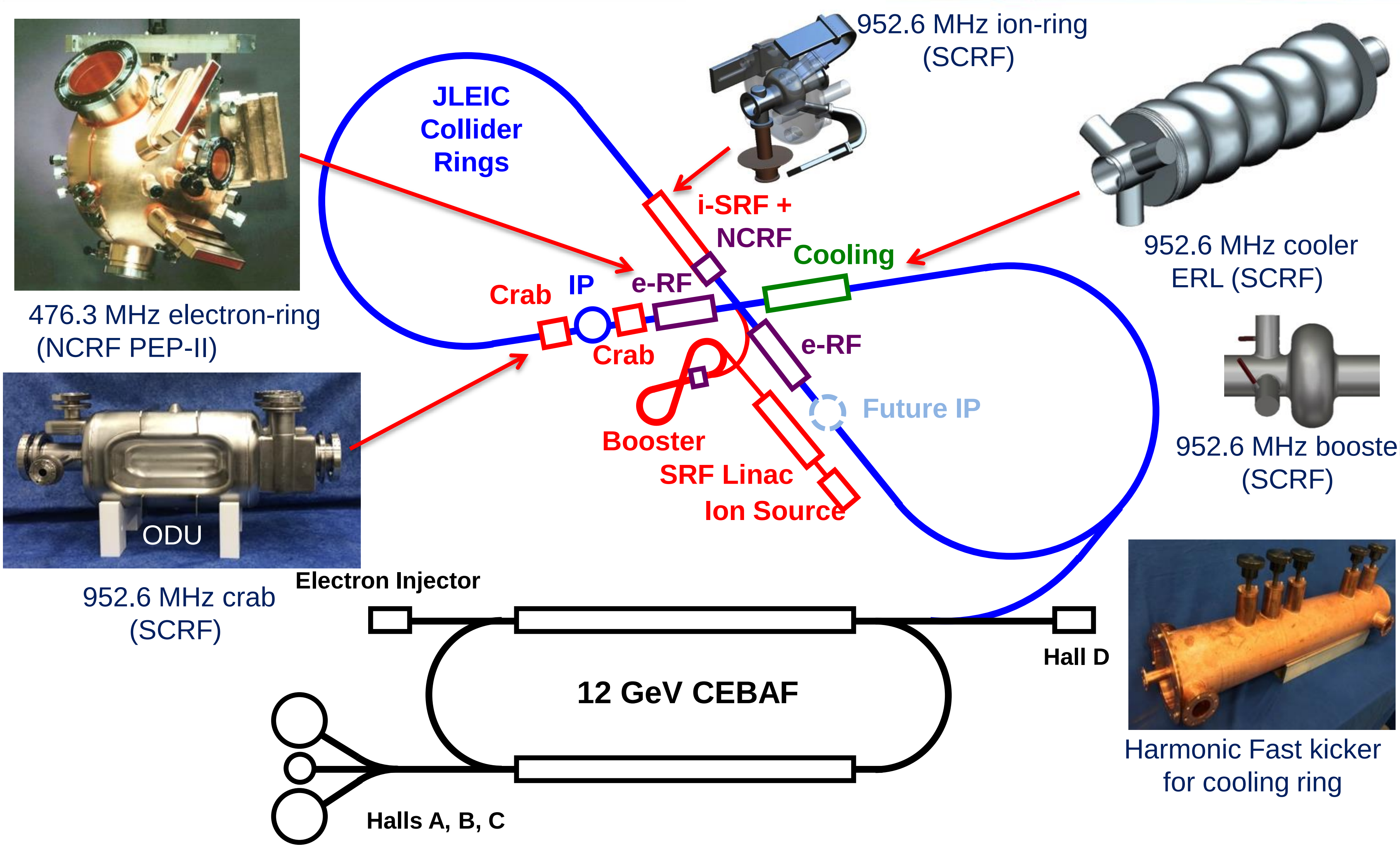
Harmonically resonant cavity





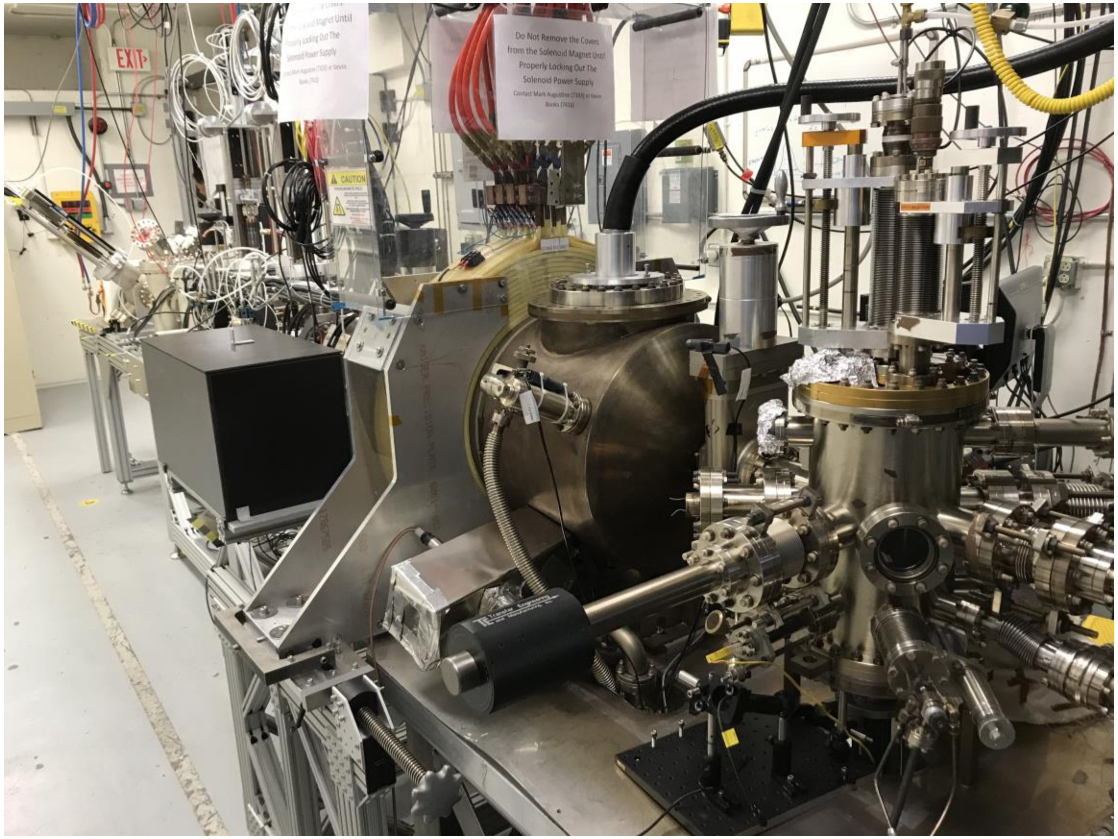
Chopper viewer as spectrometer

RF cavities for JLEIC



LDRD Magnetized Electron Source

- K_2CsSb Photocathode Preparation Chamber, Gun, Solenoid and Beamline are all operational



- Replace photogun with rf-pulsed thermionic gun (Xelera phase2)

EIC R&D Areas Ripe for SBIR

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

Jefferson Lab

Simulations and Data Management

SBIR Topics in Modeling/Simulations

- 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
- Design of a cooler for bunched beam cooling for the ion beam
- Development of a GPU accelerated code for beam cooling simulation

Detector Related SBIR Projects of Interest to JLab

Design and Fabrication of the ASoC: a System-on-Chip Data Acquisition System

Nalu Scientific LLC
2800 Woodlawn Drive, Suite 298, Honolulu, HI, 96822-1864

Awarded Phase II - $1M funding

Principal Investigator
Name: Isar Mostafanezhad
Phone: (808) 343-9204
Email: isar@naluscientific.com

a) Experiments in nuclear, high energy and astrophysics require hundreds to thousands of recording channels capable of fast data acquisition and signal processing.

b) Proposal to design and make commercially available the “ASoC”: a low-cost, low power and high density System-on Chip (SoC) capable of analog signal conditioning, 4 Gigasample/sec waveform sampling and integrated readout and signal processing capabilities.

c) The ASoC device will also have a deep sampling buffer making it suitable for large nuclear physics experiments with potentially long trigger delays. Design and development of the advanced ASoC chip which is built based on the existing IRSX chip by integrating into one SoC (i) analog signal conditioning circuits, (ii) an optimized version of IRSX, and (iii) digital readout and signal processing block capabilities (triggering, sparsification and data reduction).

New Tech Center Adjacent to Jefferson Lab

- 80,000 square feet available
- Entrance to the park located at the intersection of Jefferson Avenue & Hogan Drive
- Situated next to Marketplace at Tech Center featuring over 250,000 SF of retail, restaurants, and Crunch Fitness, and the Venture Apartments [iN] Tech Center
- Walking and biking trails
- Access to VT KnowledgeWorks, a business acceleration program at Virginia Tech Corporate Research Center
- Access to videoconferencing and conference rooms
- World leading research grade internet speeds available
- Co-working space available in the building
- Plus, career boards; U.S. mail pick up; personal housekeeping in suites; Newport News Enterprise Zone; networking events, maintenance and after hours assistance

AERIAL MAP

TECH CENTER is adjacent to the Jefferson Lab and minutes from NASA's Langley Research Center. Tech Center is a partnership between W. M. Jordan Development Company, Virginia Tech Corporate Research Center, retail developer S. J. Collins Enterprises, and residential apartment developer Venture Realty, and the City of Newport News. The current development includes 250,000 SF of retail and restaurants, over 250 upscale apartment homes, and at completion, nearly 1 million square feet of research and office space.

- **Located on 50 acres adjacent to Jefferson Lab**
- **Follows the proven business model at Virginia Tech Corporate Research Center (VTCRC)**
- **1 million square feet of research and office space**

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

Jefferson Lab

Detector-Related SBIR Projects of Interest to JLab cont.

Design and fabrication of the "SiREAD"- Silicon photomultiplier REadout, Automated calibration and Detection: A low power, low noise and high performance waveform sampling chip for high channel

NaLu
Awarded Phase I - $150k funding

1. Proposal to design and make commercially available the "SiREAD": a low-cost, low power and high density System-on Chip (SoC) capable of analog signal conditioning, fast waveform sampling and integrated readout and signal processing capabilities.

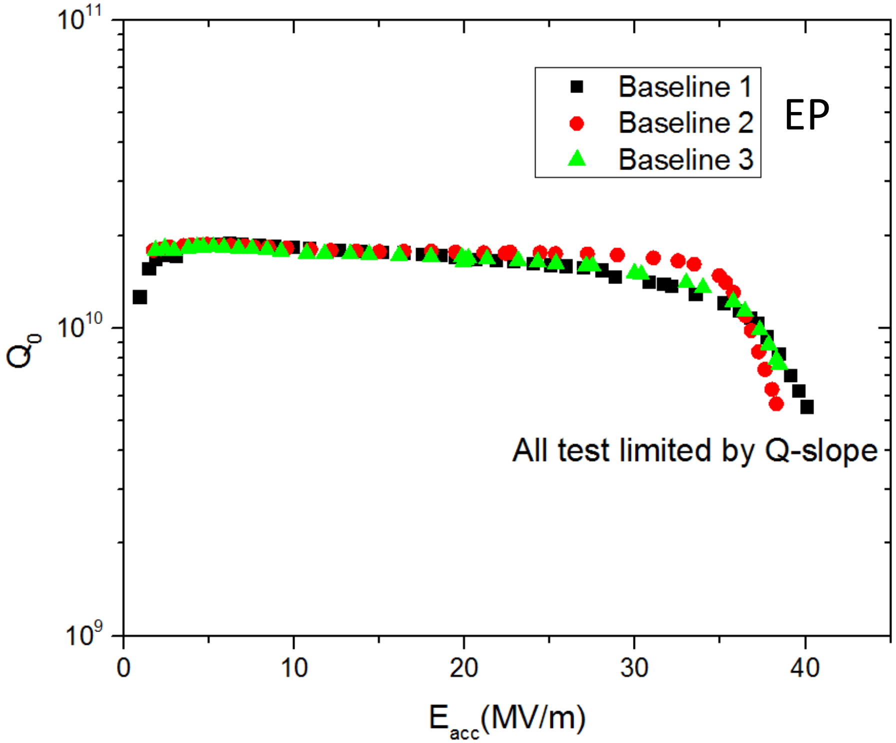
2. The SiREAD device will also have calibration and monitoring circuitry in addition to a deep sampling buffer making it suitable for large Nuclear Physics experiments with potentially long trigger delays.

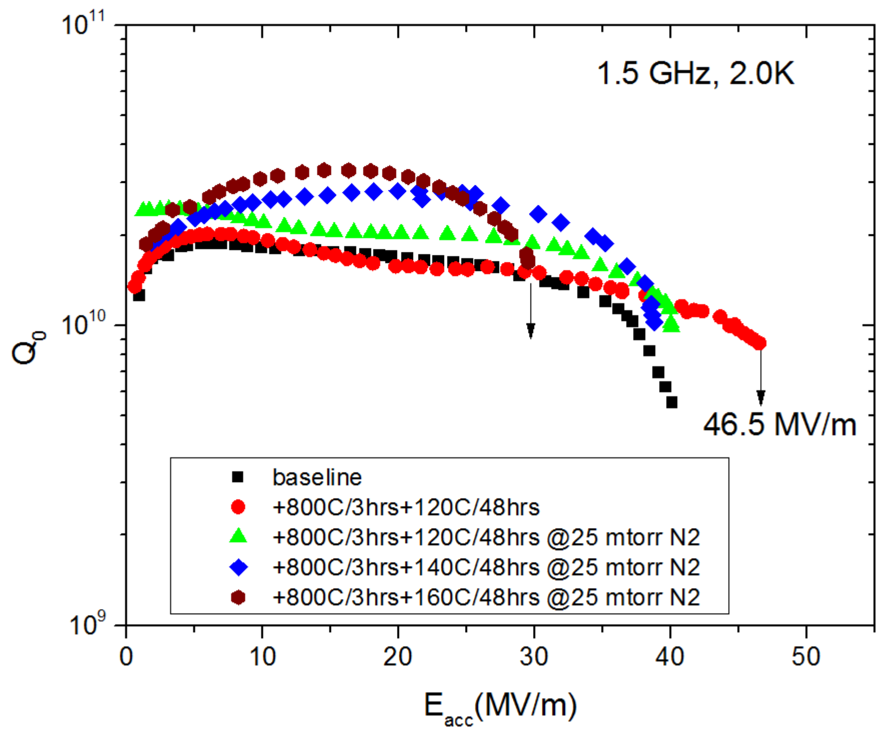
3. Design and development of the advanced SiREAD chip which is built based on the existing TARGET chip by integrating into one SoC (i) analog signal conditioning circuits and bias monitoring, (ii) an optimized version of TARGET, and (iii) digital readout and signal processing block capabilities (triggering, sparsification and data reduction).

Readout implementations for EIC eRD14 PID Consortium from Nalu Scientific

- mRICH (Georgia State) prototype will use the 256 channel (3x3 mm^2 pixels) H13700 PMT (update to Hamamatsu H9500)
- Use available TARGETX ASIC – 16 channels - developed originally for SiPM readout in BELLE II
- Each H13700 will have adapter board that handles 8 plug-in cards (2 ASICS/card) + separate FPGA card for readout of one PMT – all 256 channels
- Goal is to eventually use SiREAD ASIC – now in SBIR Phase II development – as core ASIC for photodetector (MCP-PMT, SiPM, LAPPD) readout

Towards high Q and high gradient - doping

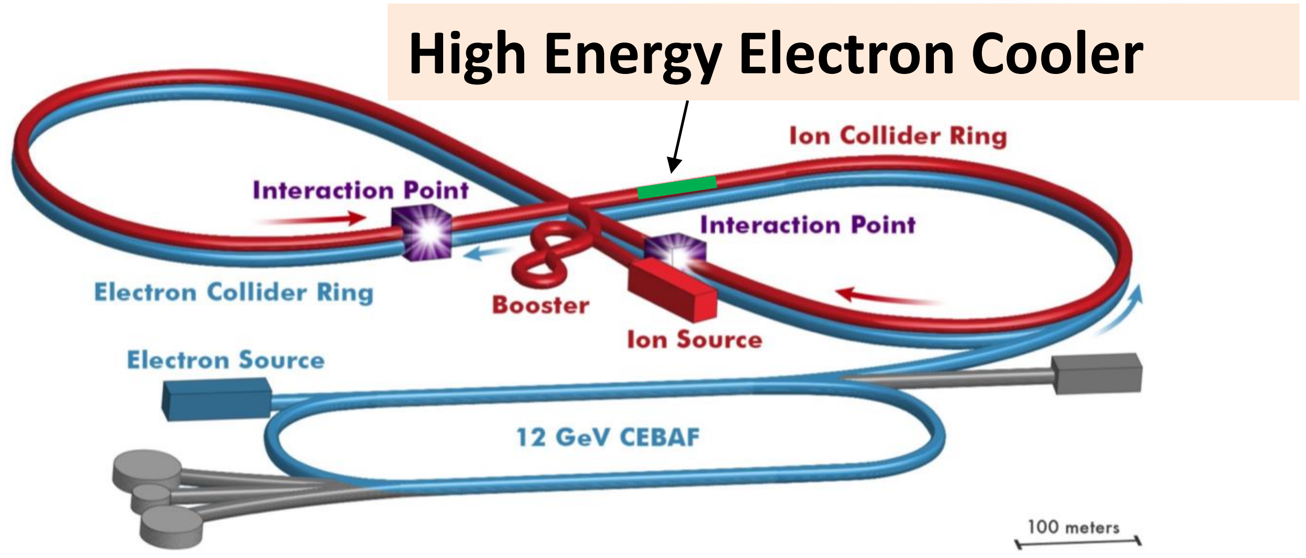


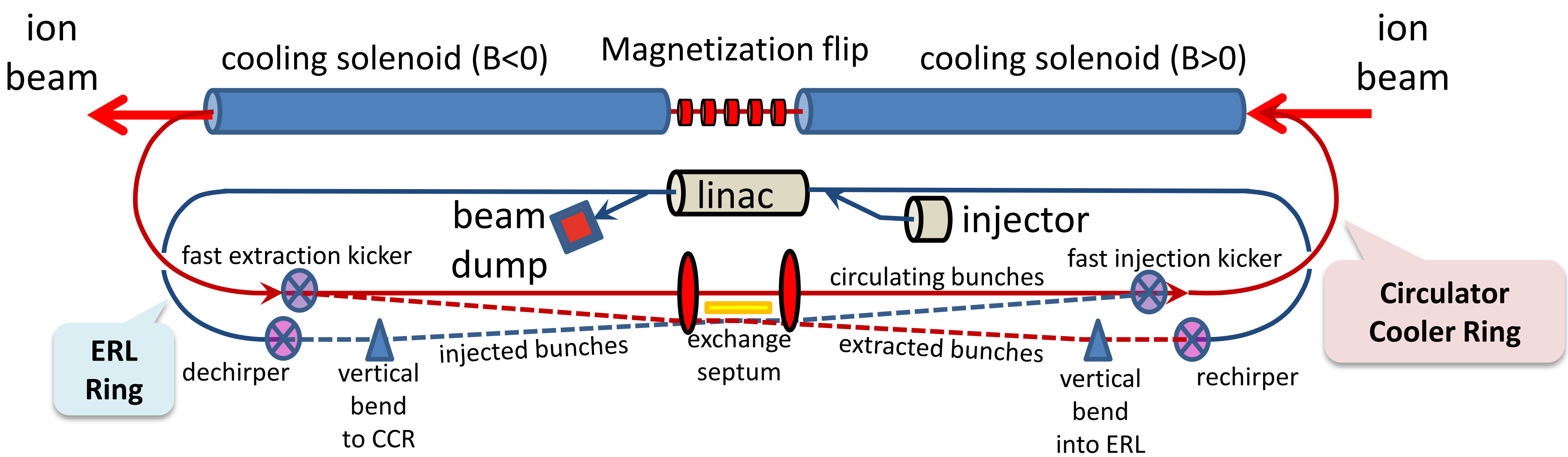


- One single cell cavity was use for the study to explore the **low temperature nitrogen infusion**. The baseline test is limited by Q-slope ~40MV/m and conventional 120 C bake improved the gradient and quenched at 46.5 MV/m.
- After low temperature N2 infusion, best result is observed with cavity baked at 140C/48hours in Nitrogen environment with $Q_0 = 2 \times 10^{10}$ at 35 MV/m.
- The study is ongoing...

P. Dhakal et. al.

JLEIC High Energy Electron Cooler

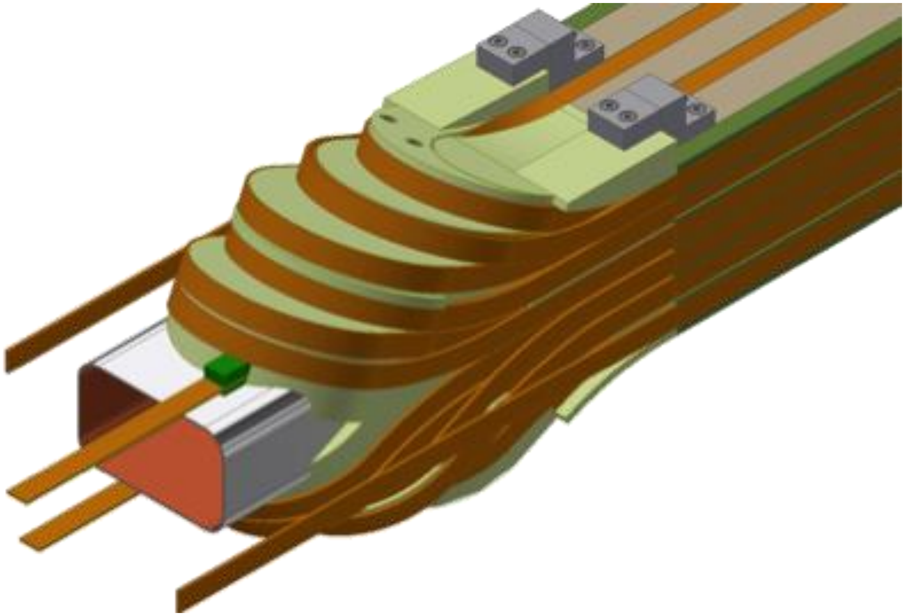




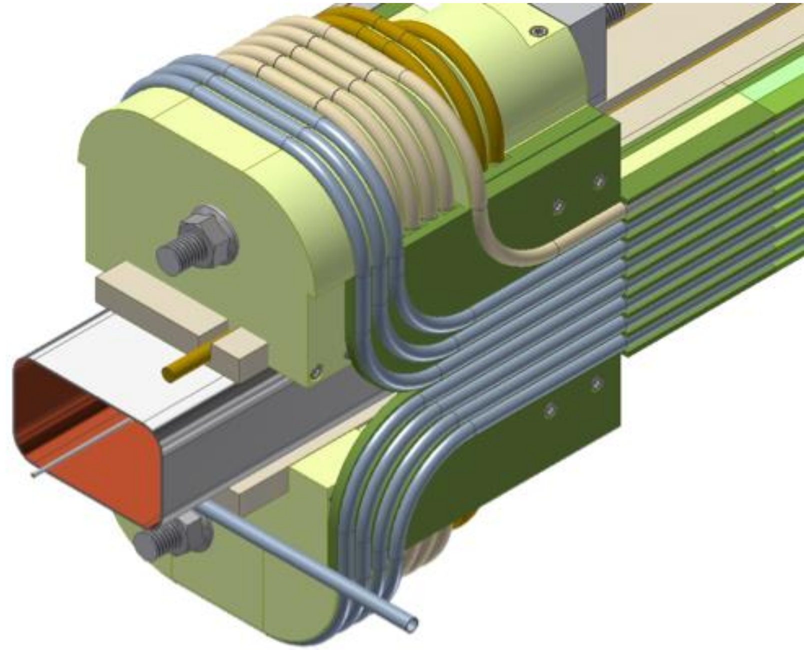
JLEIC super-ferric magnet R&D

Texas A&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.

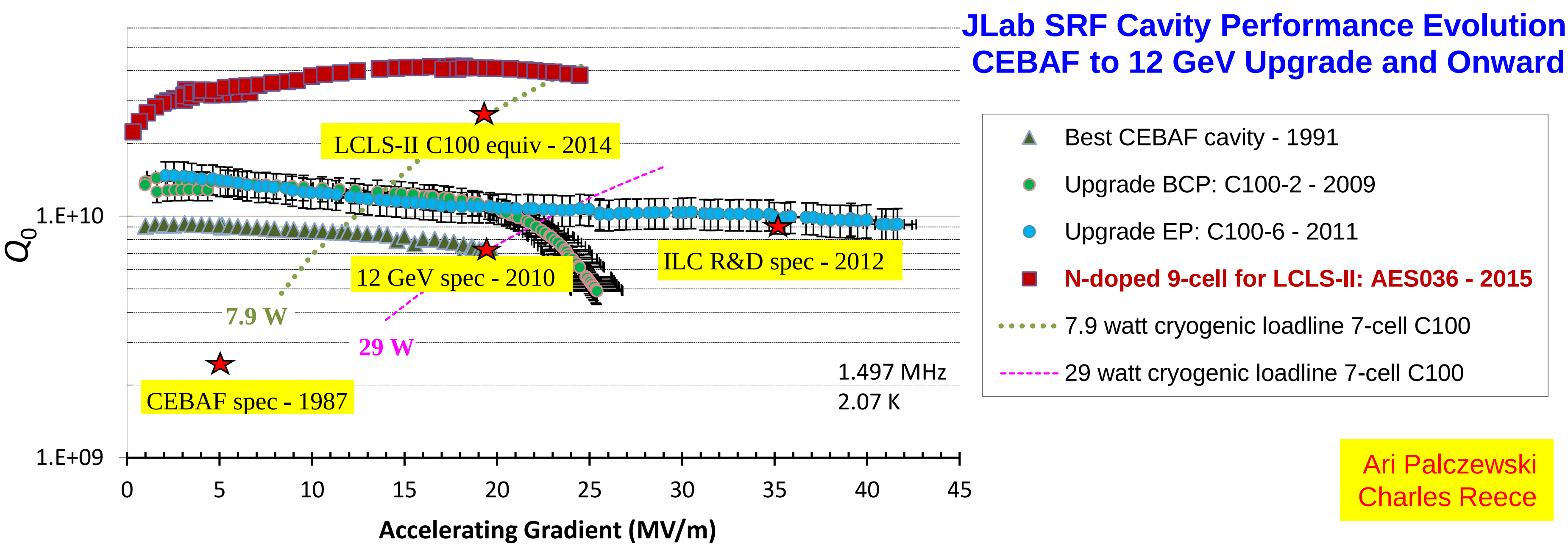
Cons: Ends tricky to support axial forces.

Cable requires development and validation.

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



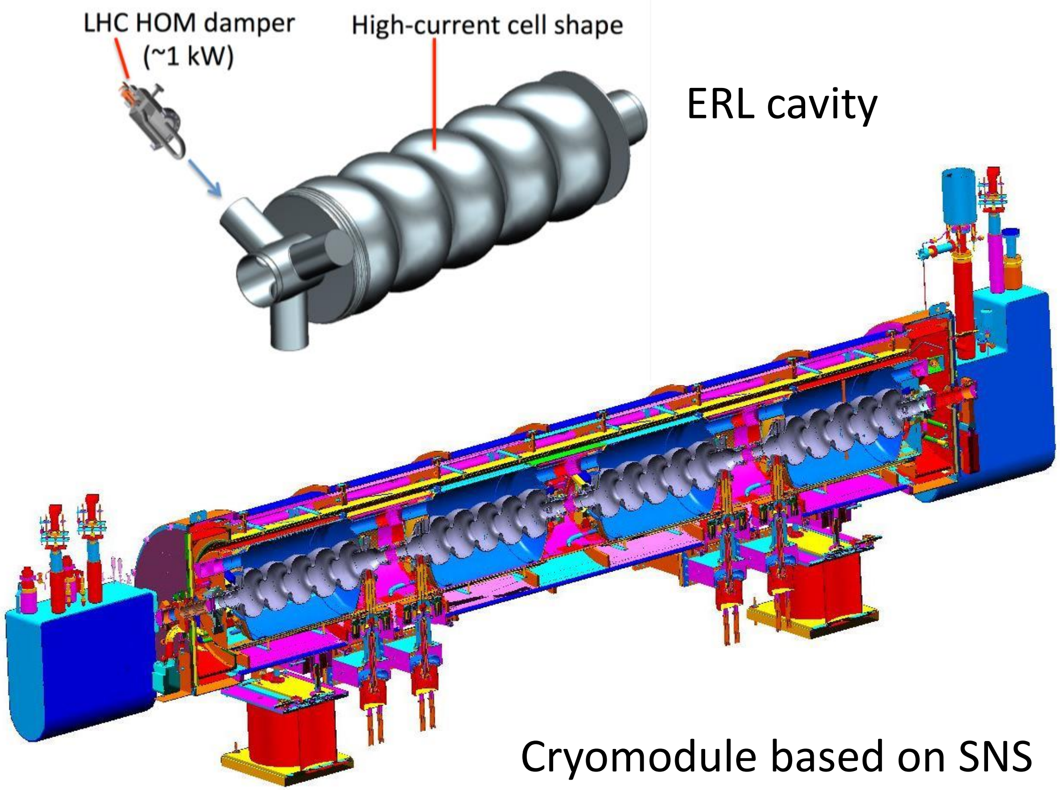
Ari Palczewski
Charles Reece

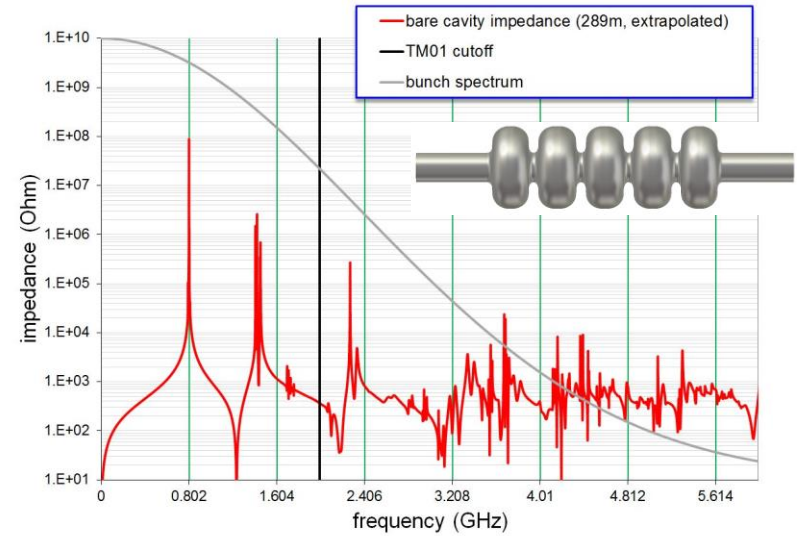
Jefferson Lab

Collaboration with CERN on SRF for FCC

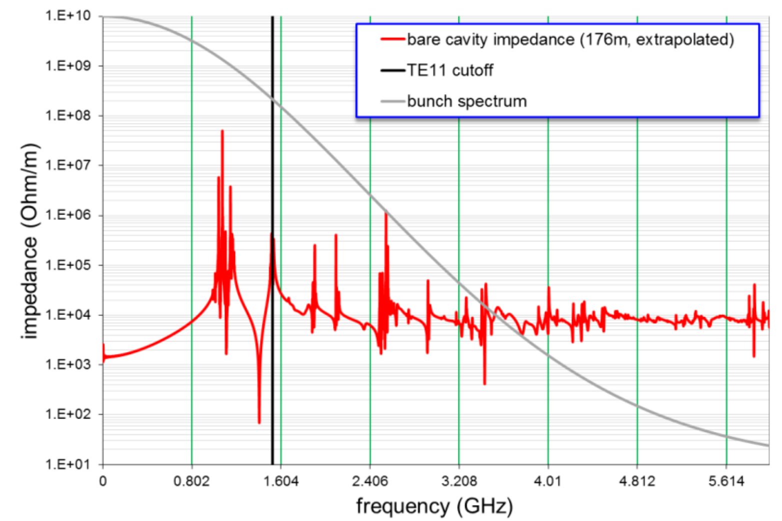
Collaboration on 802 MHz SRF for FCC-eh (CERN’s electron-ion option)

- Cavity design and prototype
- Joint study on cryomodule

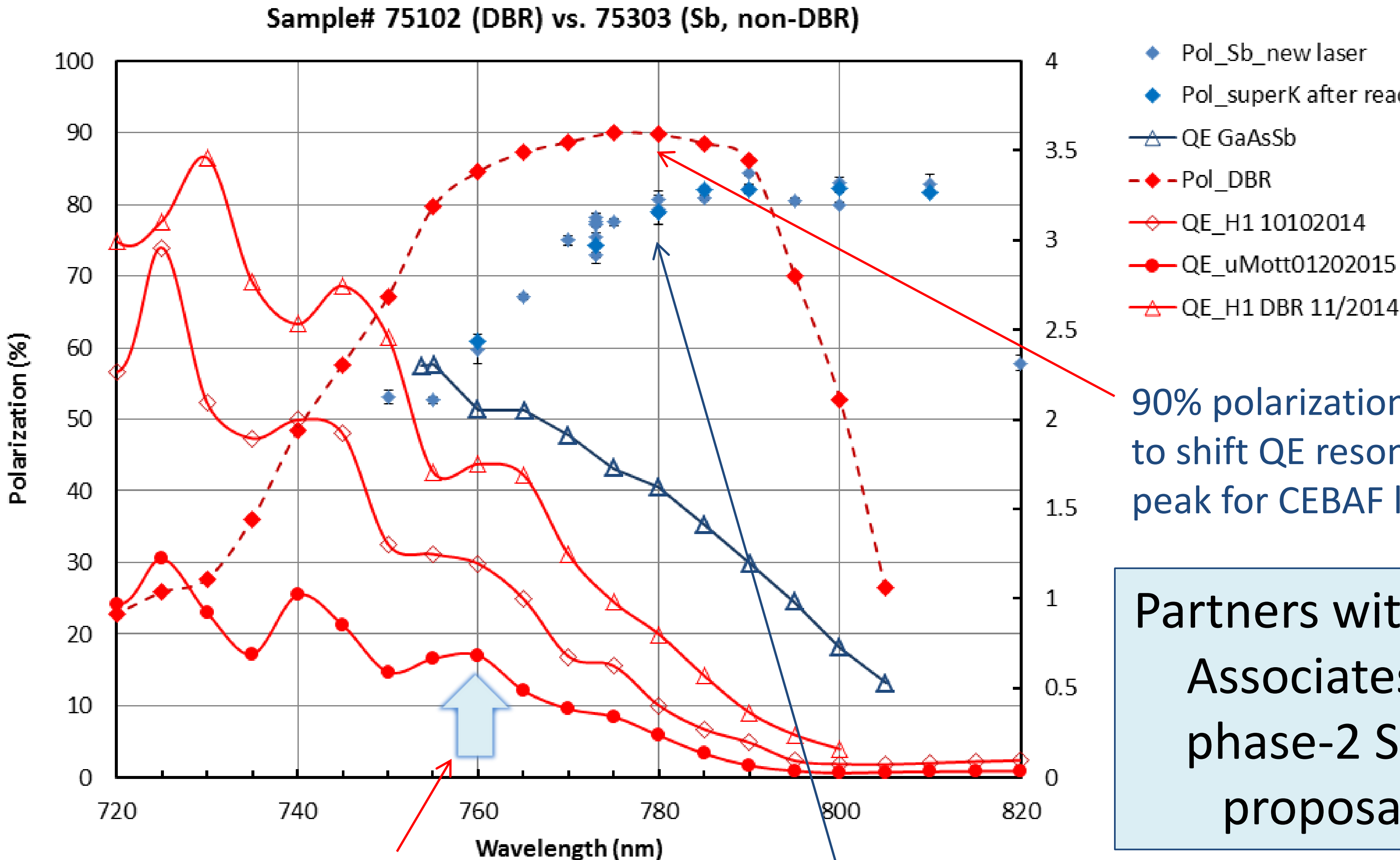




HOM spectrum looks good



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 !

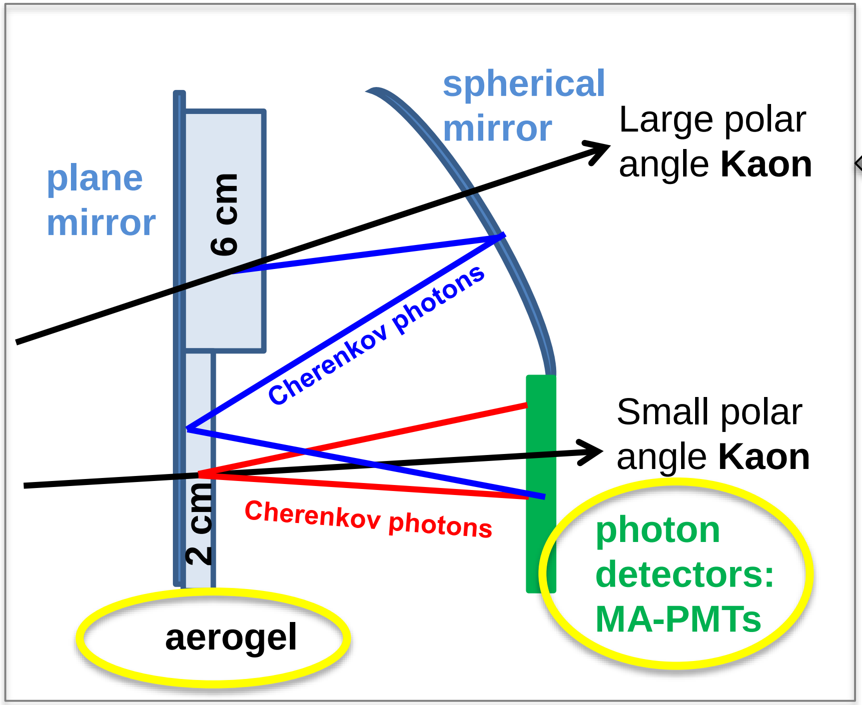
GaAsSb/AlGaAsP not bad, need to test at high voltage

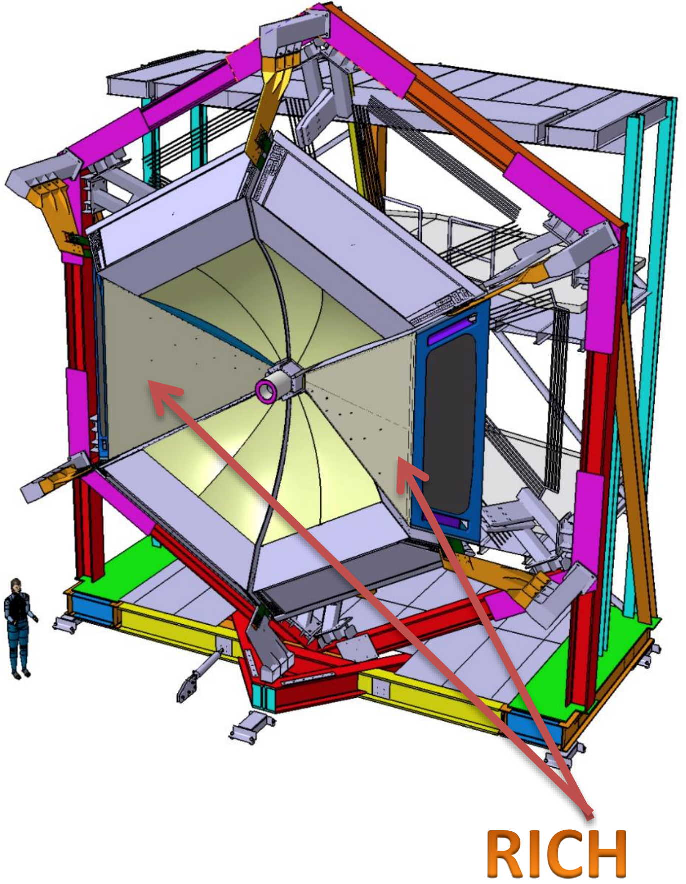
Patrizia Rossi

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



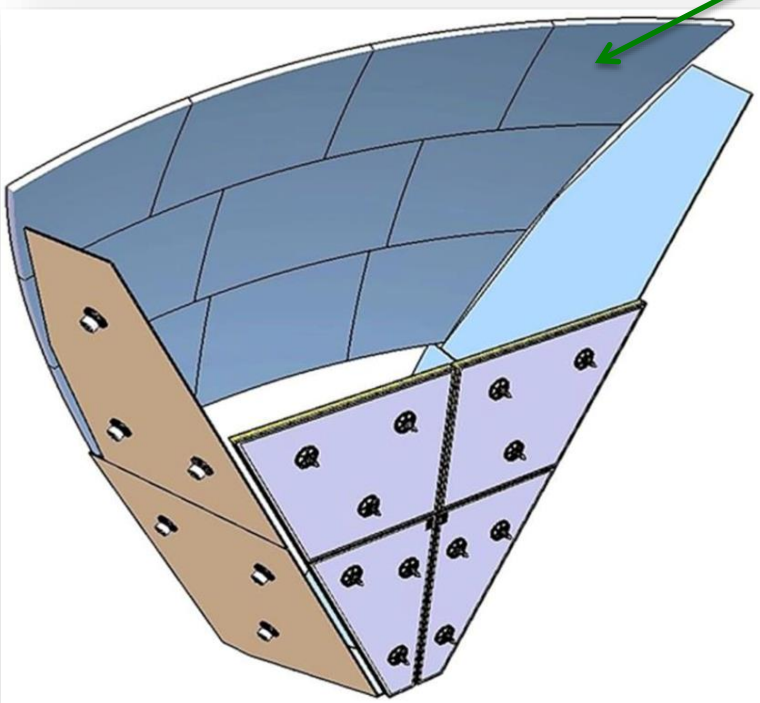


Hybrid solution: proximity gap plus focusing mirrors

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

a) Spherical mirror
b) Aerogel

Hall B – RICH: The mirror system



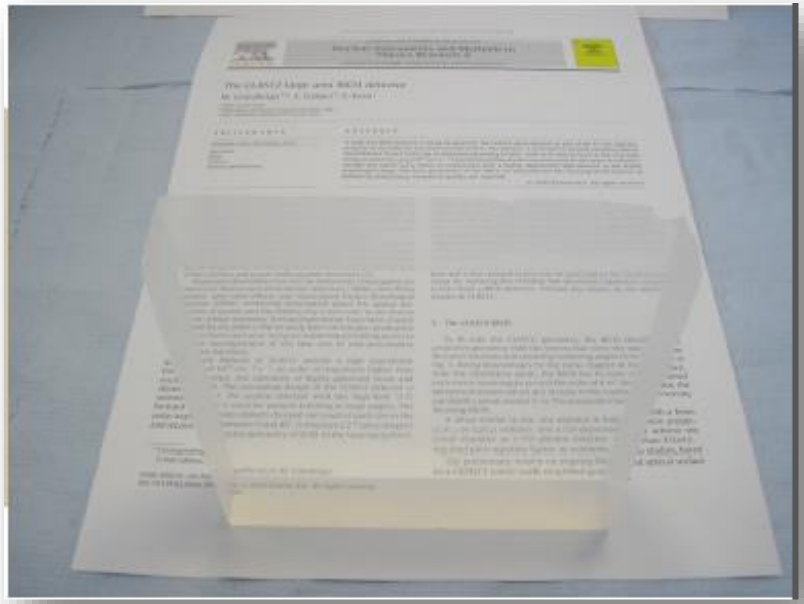
- Ten spherical mirror
  total surface ~3.6 m^2 mounted on a supporting structure attached to the RICH module
- Four frontal planar mirror
  total surface ~3 m^2 mounted on the frontal closing panel they hold the aerogel tiles
- Six lateral planar mirrors
  total surface ~1.4 m^2 mounted on the lateral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

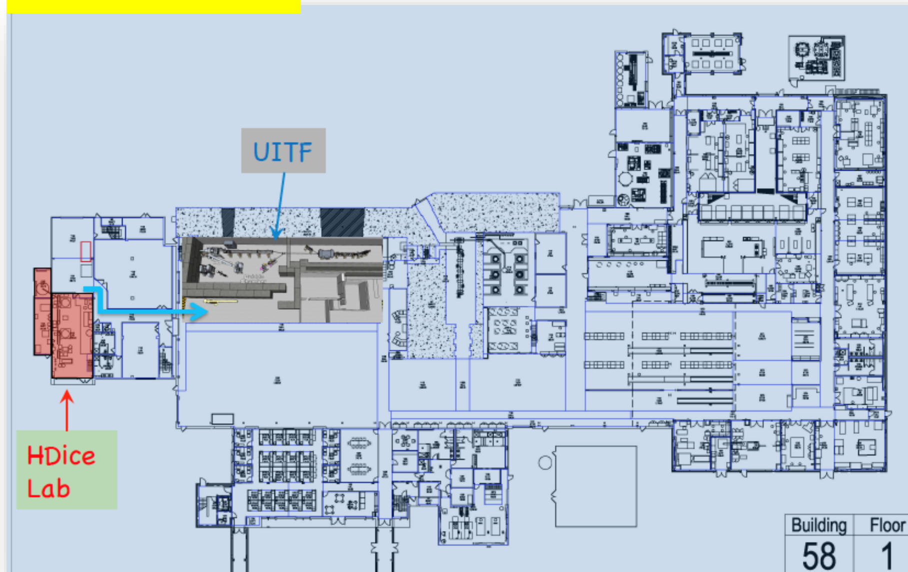
JSA Jefferson Lab

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

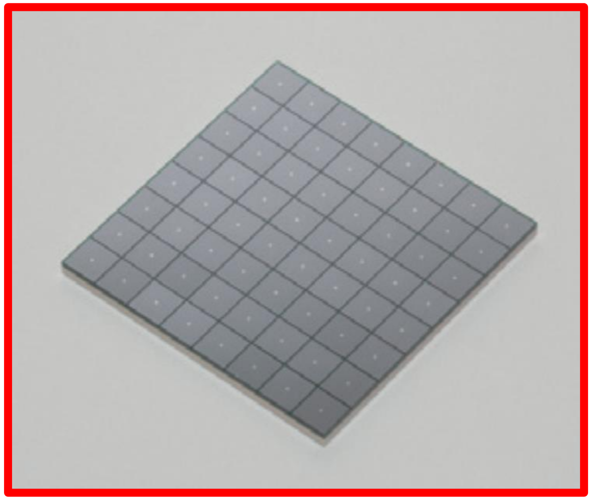
Drew Weisenberger

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.

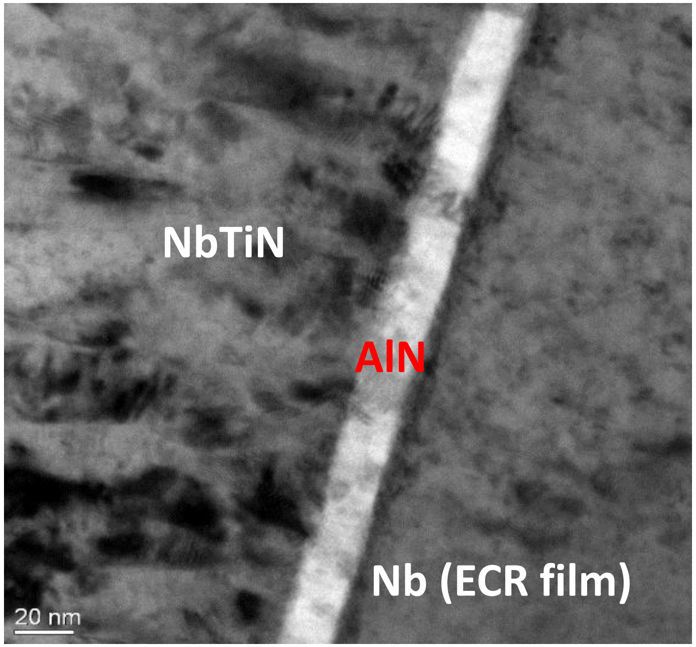
Recently: CRADA with Hampton University, Dilon & JLab initiated to enhance gamma camera performance using NP *silicon photomultiplier technology*.



Development of SIS NbTiN/AlN structures on Nb surfaces

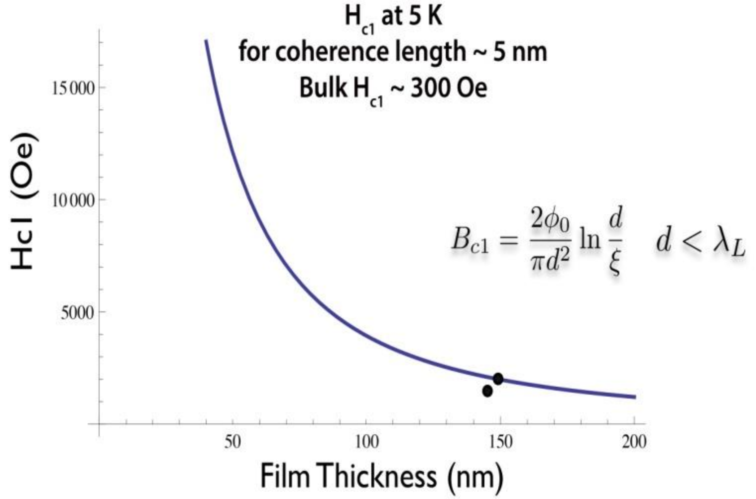
Learning how to grow high quality Superconductor/Insulator/Superconductor films

- 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



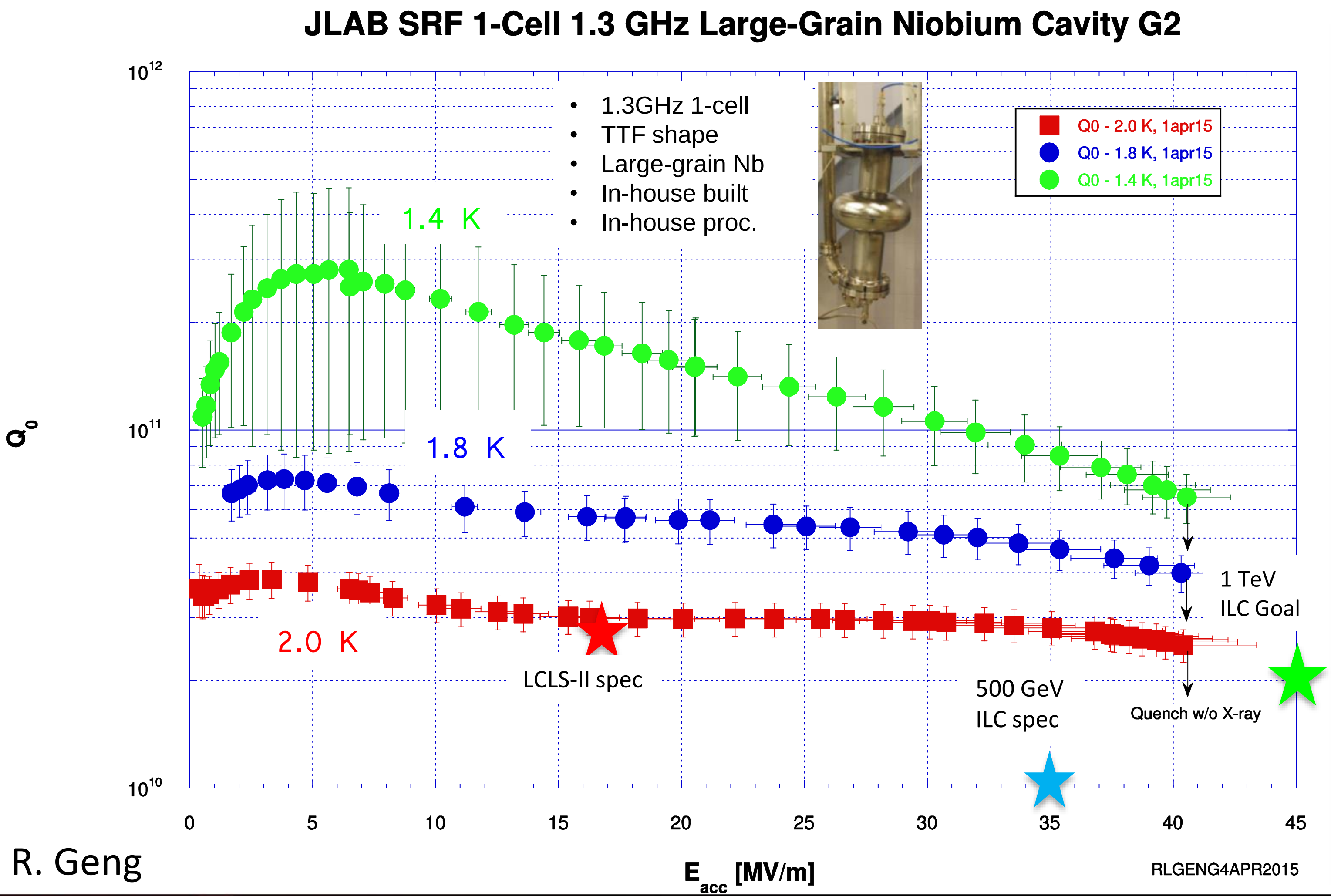
A-M Valente-Feliciano

	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

JLEIC Magnet R&D

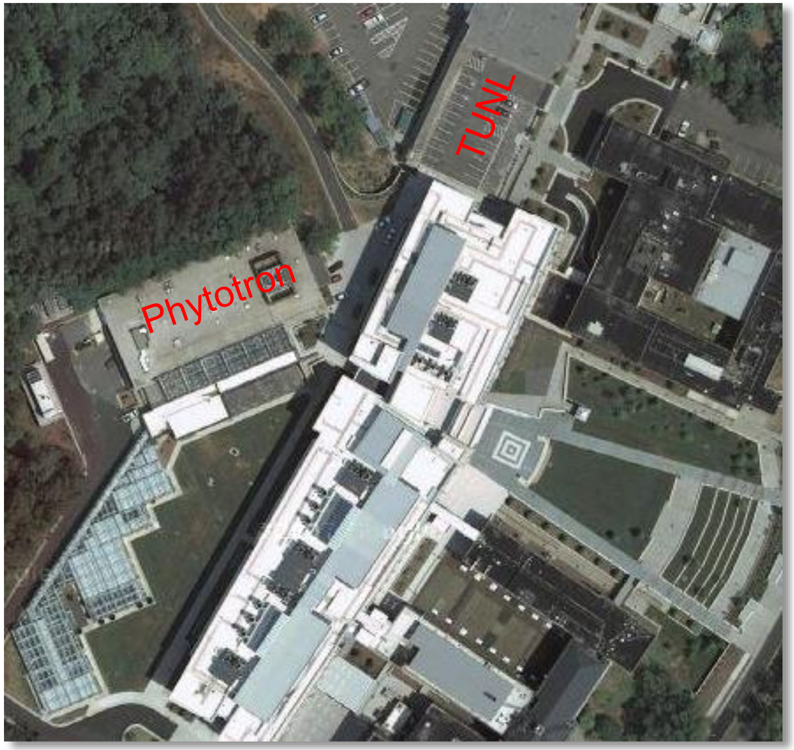
Fulvia Pilat
Yuhong Zhang

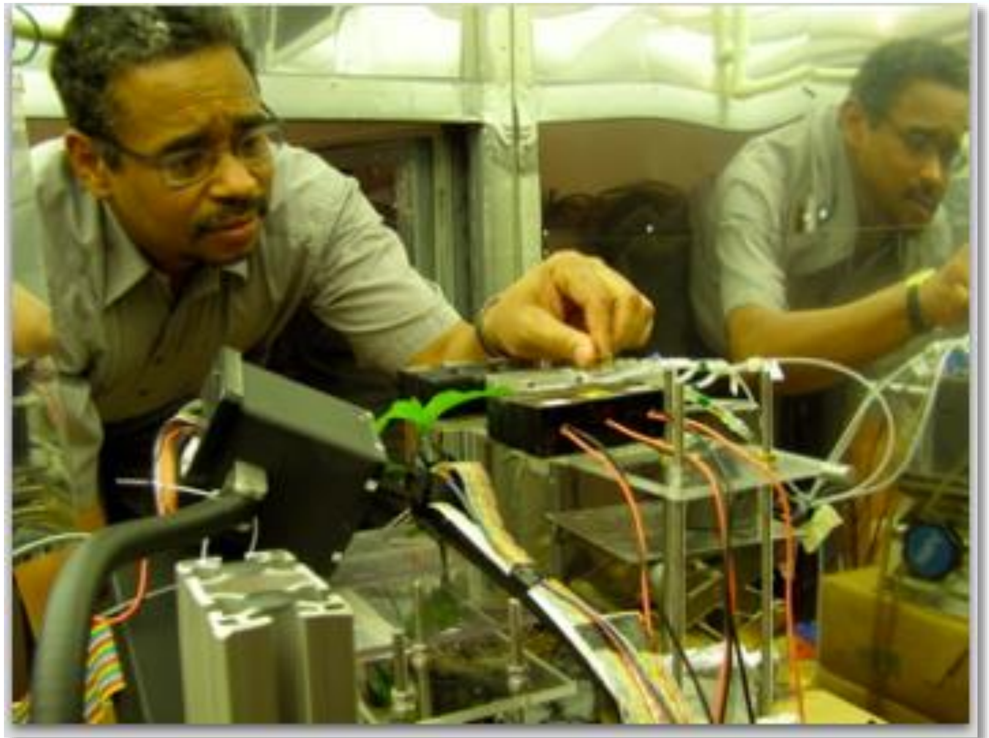
- Existing collaboration with Texas A&M for the design and prototyping of super-ferric magnets for the ion collider ring and for the booster
- Design and prototyping of high field, large aperture, compact super-conducting magnets for the collider Interaction Regions and Final Focus
- Design of long solenoids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

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



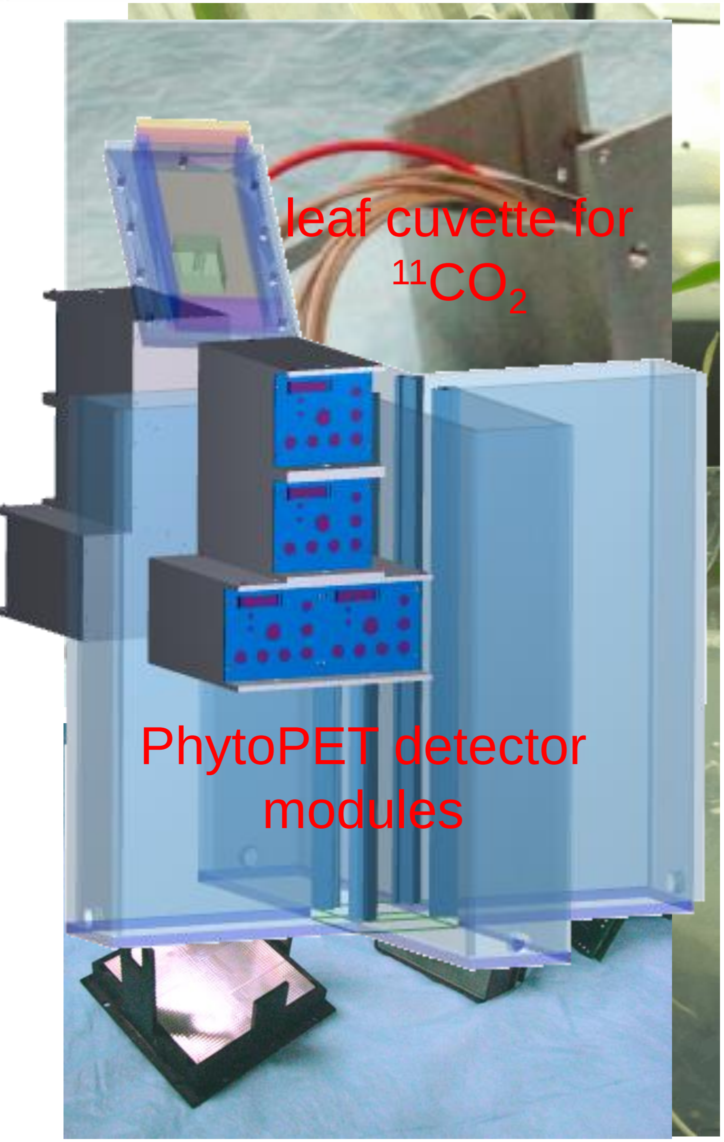


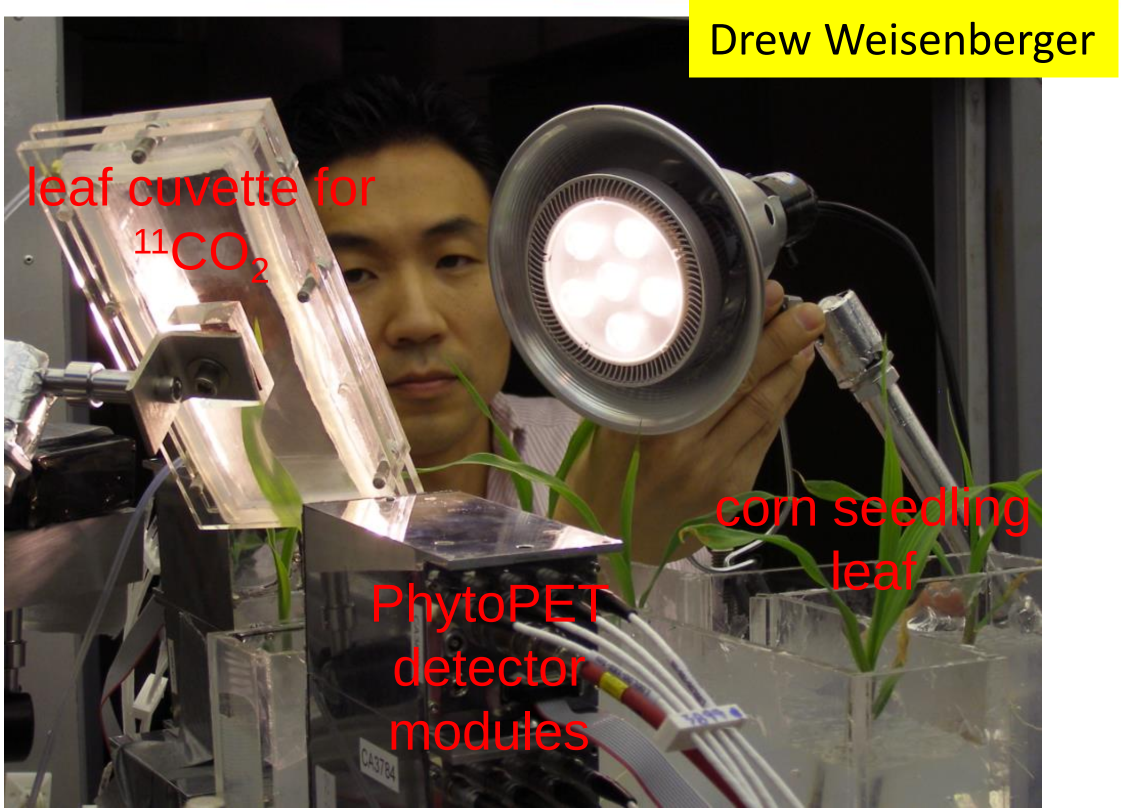
Drew Weisenberger

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

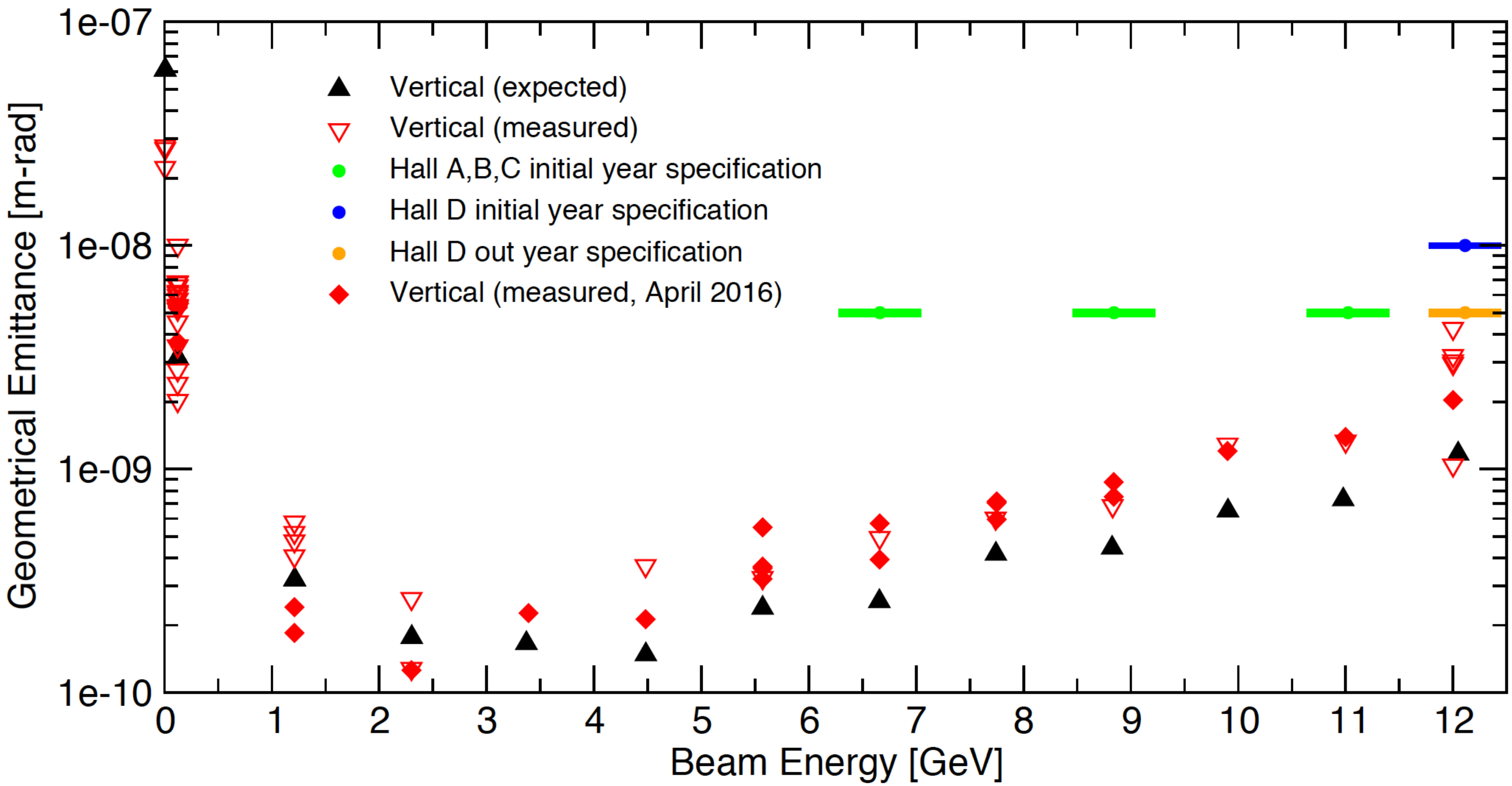
PhytoPET-Duke University/Jefferson Lab





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.

•Measured vertical emittance after every pass



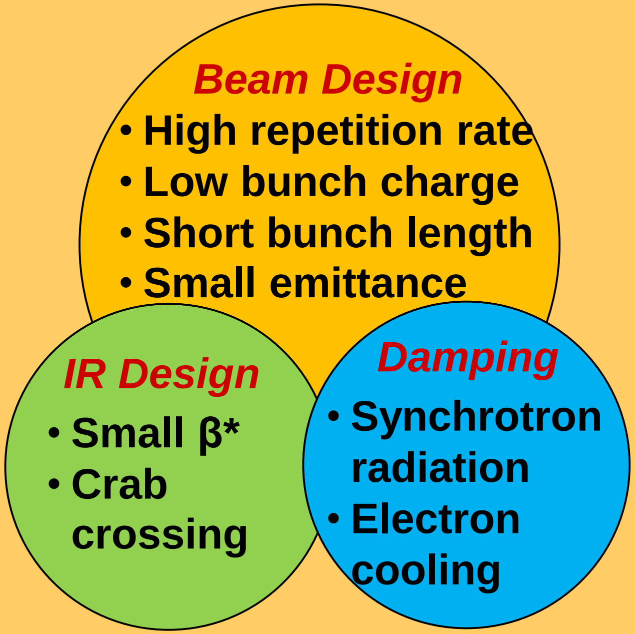
Strategy for High Luminosity and Polarization

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***

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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, γ)^{72}Ga	14.1h		43	63	8.7	49	71
^{70}Ga ^{71}Ga(γ,n)^{70}Ga ^{69}Ga(n, γ)^{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(γ, n)^{68}Ga	68 m	4.4×10^4	1.3×10^5	1.7×10^5		941	4770
^{67}Ga ^{69}Ga(γ, 2n)^{67}Ga	3.26 d	2.9×10^4	380	581		0.02	35
^{66}Ga ^{69}Ga(γ, 3n)^{66}Ga	9.5 h		6.2	121			29