# Jefferson Lab and the NP SBIR/STTR Program

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**Deputy Associate Director**

**Accelerator Operations and R&D**

# Outline

- **Jefferson Lab Overview**
- **Accelerator Facilities**
  - *Continuous Electron Beam Accelerator Facility (CEBAF)*
  - *Low Energy Recirculator Facility (LERF)*
  - *LERF Gun Test Stand (GTS)*
  - *Upgraded Injector Test Facility (UITF)*
  - *SRF Production and R&D Facility*
- **Accelerator R&D Major Directions**
  - *SRF technology*
  - *Sources*
  - *EIC*
  - *Advanced Computing Initiatives*
- **SBIR Engagement**
  - *Internal Process*
  - *Ongoing Partnerships*
- **Summary**

# Jefferson Lab Overview

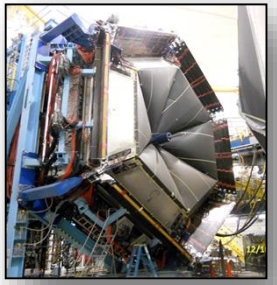
- DOE Office of Science Laboratory with a program focused on Nuclear Physics.
- Created to build and operate the Continuous Electron Beam Accelerator Facility (CEBAF), world-unique user facility for Nuclear Physics.
- Mission is to gain a deeper understanding of the structure of matter:
  - Through advances in fundamental research in nuclear physics
  - Through advances in accelerator science and technology
- In operation since 1995

**Jefferson Lab by the numbers:**

- 725 employees
- Annual Costs: $160M
- 169 acre site
- 1,690 Active Scientist Users
- ~2,100 publications and > 182,000 citations
- 24 Joint faculty
- 658 PhDs granted to-date (195 in progress)
- K-12 programs serve more than 12,000 students and ~1000 teachers annually

# Vision for Jefferson Lab

**Jefferson Lab supports the DOE Office of Science and serves the Nuclear Physics user community as a world-leading center for fundamental nuclear science and associated technologies**

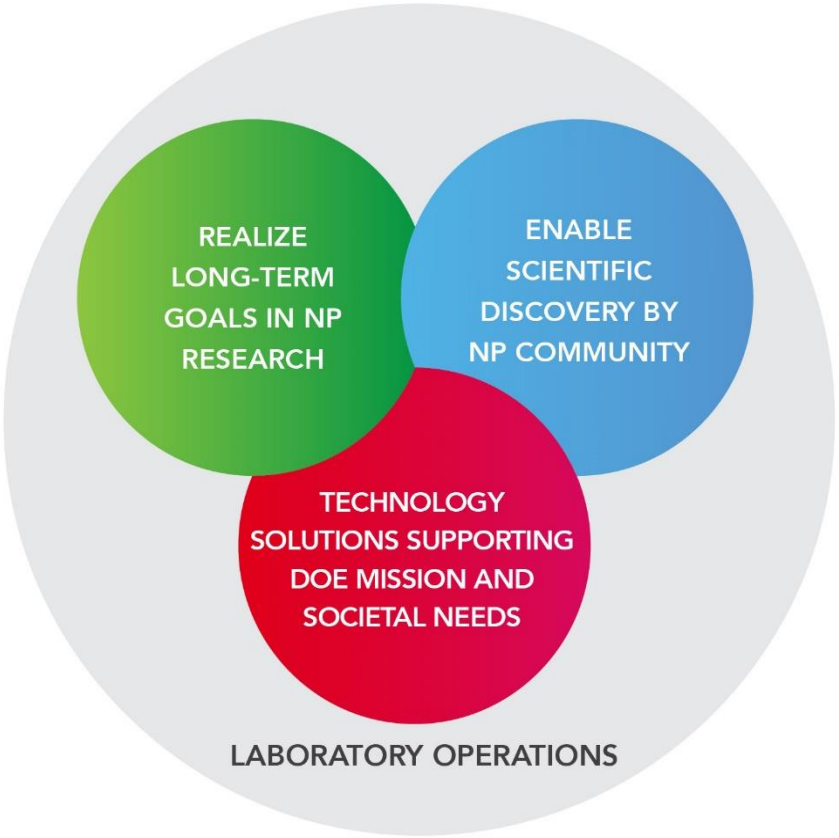


**1. Deliver on 12 GeV Scientific Program**


**2. Support long-term goals in nuclear physics**

**3. Provide technology solutions supporting DOE mission**

**4. Enable world-class science through excellence in Laboratory Operations**



# Mission and Strategic Plan

**MISSION**

We support the DOE Office of Science and serve the Nuclear Physics User Community as a world-leading center for fundamental nuclear science and associated technologies

## SCIENCE & TECHNOLOGY

### STRATEGIC OUTCOMES

| Enable scientific discoveries by the Nuclear Physics User Community through our unique, world leading facilities and capabilities | Plan for future facilities and capabilities to realize the long-term scientific goals in Nuclear Physics research | Provide technology solutions that support the NP community, the larger DOE mission and societal needs |
|---|---|---|

### MAJOR INITIATIVES

| | | |
|---|---|---|
| 1 Operate CEBAF accelerator and experimental facilities to execute the FY20 experimental nuclear physics program | 1 Continue to develop the MOLLER and SoLID initiatives | 1 Plan and execute projects to construct equipment for facilities (DOE and possibly others) beyond Jefferson Lab. |
| 2 Prepare CEBAF accelerator and experimental equipment for future 3-5 year experimental physics program | 2 Perform Accelerator R&D towards an Electron Ion Collider | 2 Perform R&D to enable other future (non-CEBAF, non-EIC) accelerator capabilities and enhance the reputation of JLab in SRF and large-scale cryogenics |
| 3 Perform R&D to enable enhanced performance and future new capabilities for CEBAF and experimental halls | 3 Perform Detector R&D towards an Electron Ion Collider | 3 Develop and promote technology transfer activities that align with the lab's research portfolio, further DOE missions, and promote national and economic security. |
| 4 Perform theoretical research in support of the CEBAF 12 GeV program | 4 Pre-project design and planning for an Electron Ion Collider | |
| 5 Perform theoretical and experimental research in support of the broader NP research community | 5 Engage with the EIC user community and further develop the anticipated scientific program for a future Electron Ion Collider | |
| 6 Provide software and computational resources for theoretical and experimental nuclear physics research | 6 Develop and expand expertise in Scientific Computation and Data Science | |

## OPERATIONS

### STRATEGIC OUTCOMES

Provide, protect, and improve the human, physical and information resources that enable world class science

### MAJOR INITIATIVES

| | | |
|---|---|---|
| 1 Business Process Streamlining | 4 Learning Management | 7 Management Information Systems |
| 2 Talent Management | 5 Science Education | 8 Facilities Engineering and Reliability Program |
| 3 Diversity and Inclusion | 6 Performance Assurance | 9 Internal Communications |

# Jefferson Lab Plays a Vital SRF Stewardship Role

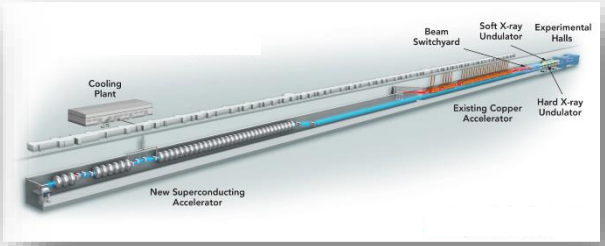
*CEBAF - 1994*
*12 GeV Upgrade - 2017*

*Spallation Neutron Source (ORNL) - 2006*

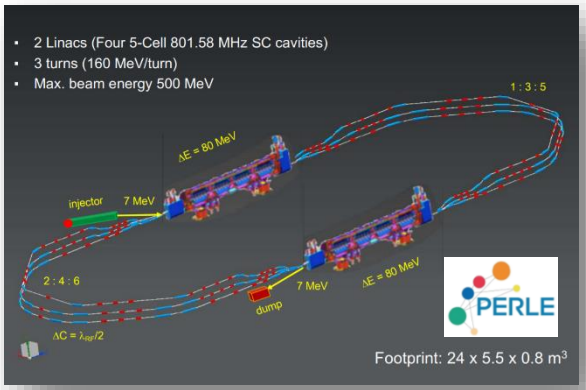
*Facility for Rare Isotope Beams (MSU) - 2021*


*Linac Coherent Light Source II (SLAC) 2021*

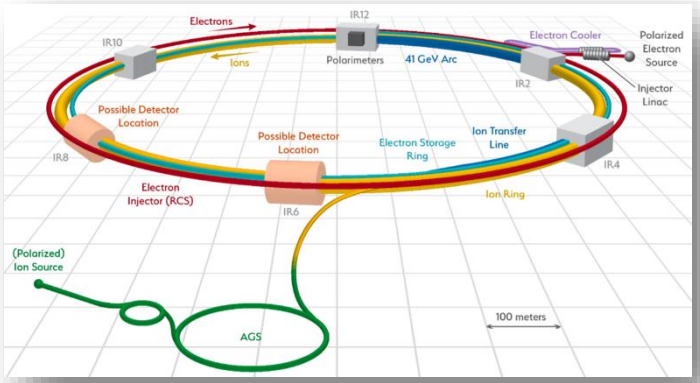
*SNS Proton Power Upgrade 2023*




*LCLS-II High Energy Upgrade 2024*




*PERLE@Orsay - End Date TBD*




*Electron Ion Collider - End Date TBD*



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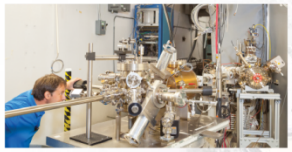
# CEBAF AT JEFFERSON LAB

Jefferson Lab's Continuous Electron Beam Accelerator Facility (CEBAF) enables world-class fundamental research of the atom's nucleus. Like a giant microscope, it allows scientists to "see" things a million times smaller than an atom.



## 1 INJECTOR

The injector produces electron beams for experiments.

## 2 LINEAR ACCELERATOR

The straight portions of CEBAF, the linacs, each have 25 sections of accelerator called cryomodules. Electrons travel up to 5.5 passes through the linacs to reach 12 GeV.

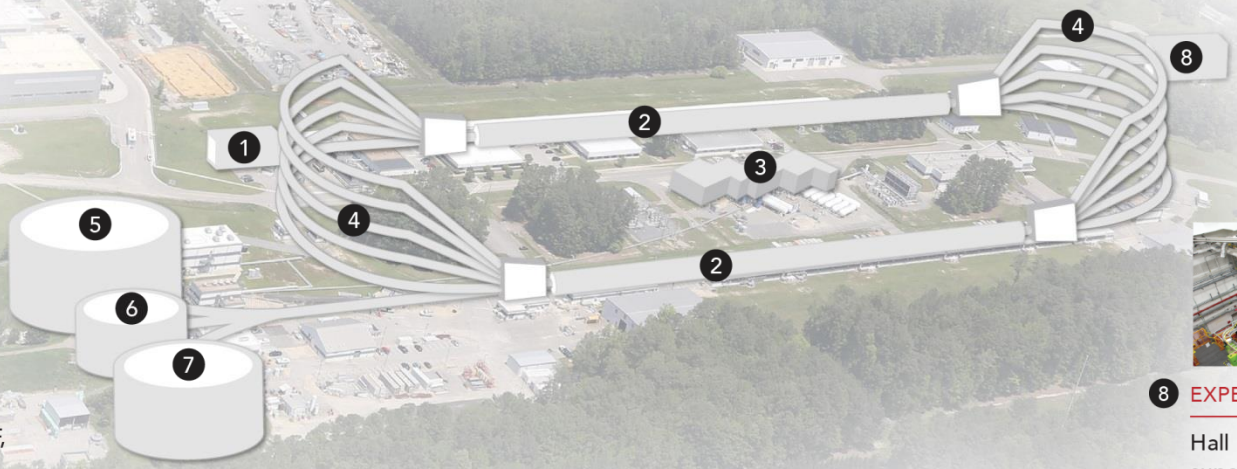
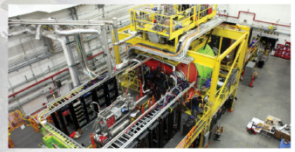



*Diagram representational of below ground structure*



## 8 EXPERIMENTAL HALL D

Hall D is configured with a superconducting solenoid magnet and associated detector systems that are used to study the strong force that binds quarks together.

## 3 CENTRAL HELIUM LIQUEFIER

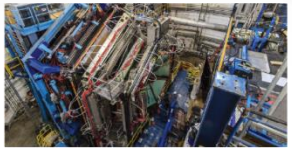
The Central Helium Liquefier keeps the accelerator cavities at -456 degrees Fahrenheit.

## 4 RECIRCULATION MAGNETS

Quadrupole and dipole magnets in the tunnel focus and steer the beam as it passes through each arc.

## 5 EXPERIMENTAL HALL A

Hall A is configured with two High Resolution Spectrometers for precise measurements of the inner structure of nuclei. The hall is also used for one-of-a-kind, large-installation experiments.



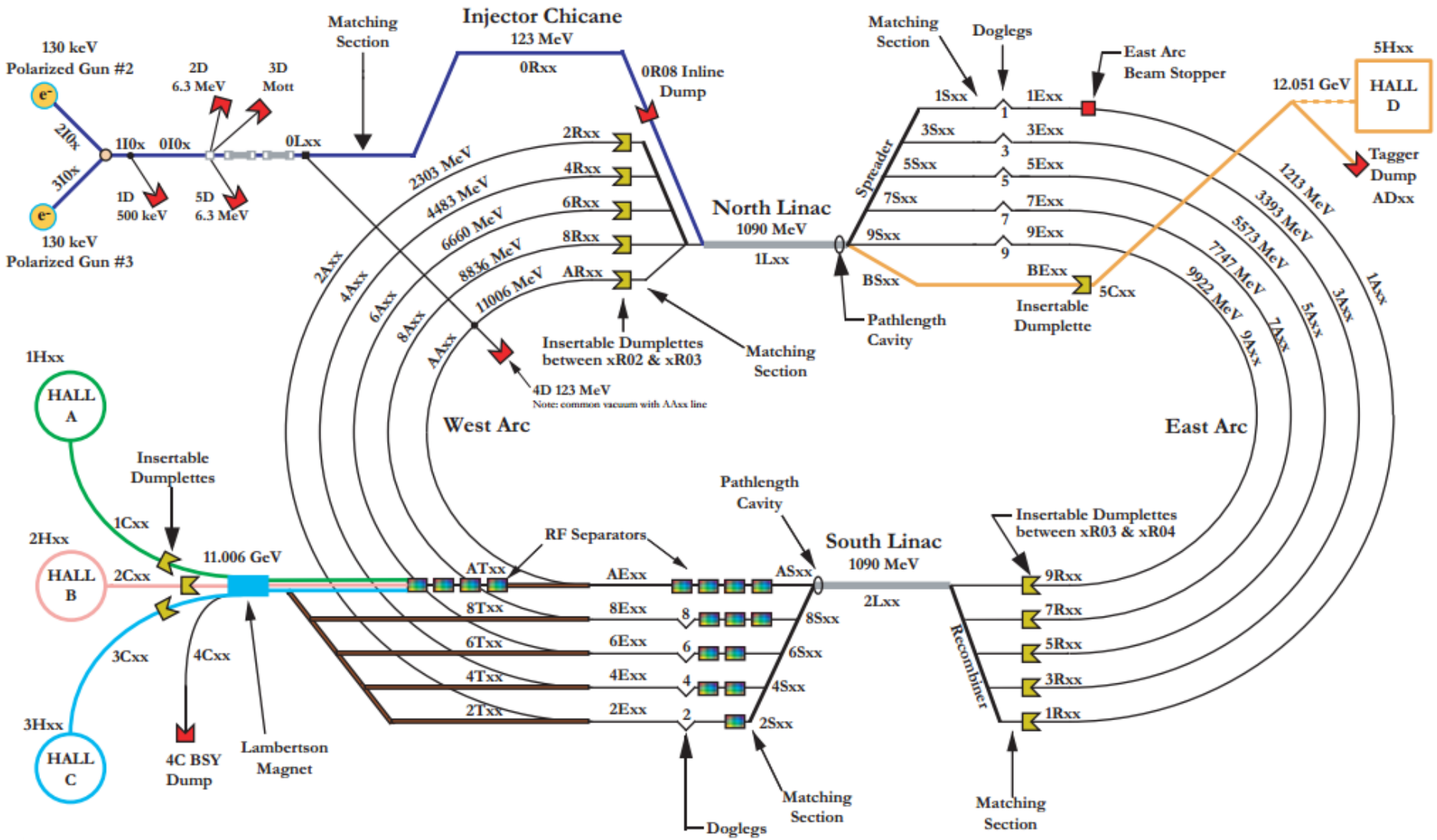
## 6 EXPERIMENTAL HALL B

The CEBAF Large Acceptance Spectrometer surrounds the target, permitting researchers to measure simultaneously many different reactions over a broad range of angles.

## 7 EXPERIMENTAL HALL C

The Super High Momentum Spectrometer and the High Momentum Spectrometer make precise measurements of the inner structure of protons and nuclei at high beam energy and current.

# Continuous Electron Beam Accelerator Facility



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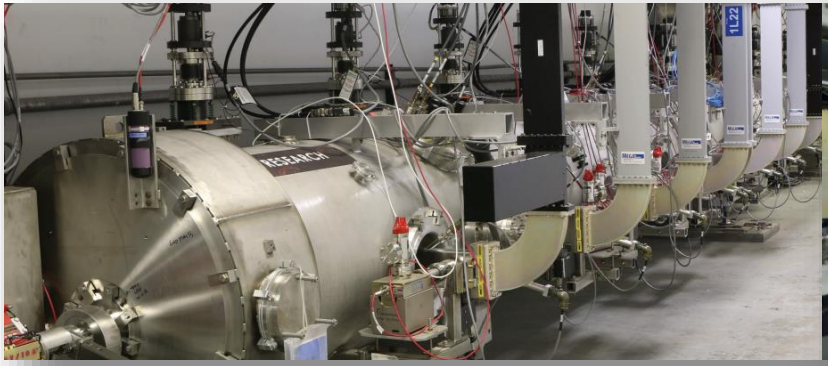
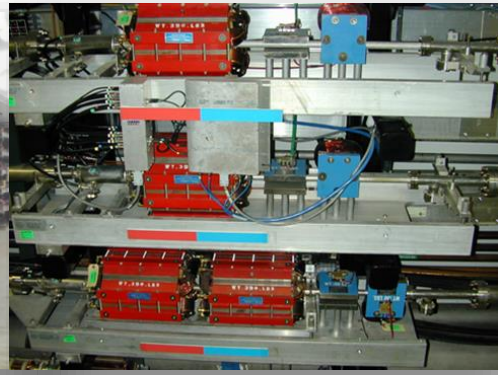
# CEBAF Accelerator – Technical Scope

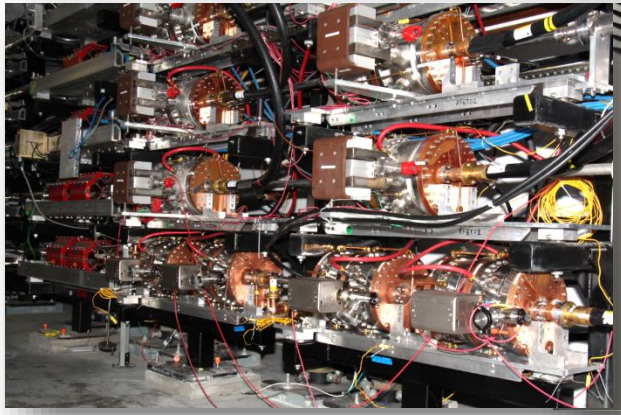


52-1/4 Cryomodules with 418 SRF Cavities

~500 Large Dipoles powered by >40 HVPS

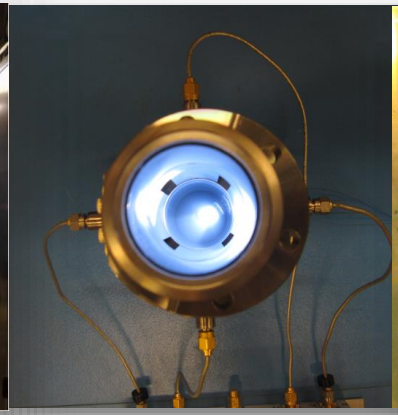


>2800 Trim Magnets



16 RF Deflectors for Extracting Beams


RF Gallery



Beam Position Monitor


High Power Beam Dump

- Capable of delivering 4 independent CW polarized electron beams simultaneously to experiment Halls.
- Over 7 km of beamline ~800 BPMs, 60 harps, 150 viewers, and 7 synchrotron light monitors.
- >580,000 data channels on a distributed network of over 600 local computers with 200 kHz data rate.

# LERF Overview

- LERF facility initially funded through DOD (Navy) program to develop high power Free Electron Lasers ($140M investment).
- Program ended in 2014
- Conducted a workshop in 2017 to explore potential for research and workforce development activities at LERF.
- Subset of topics covered:
  - Isotope R&D
  - EIC R&D
  - Source and Laser R&D
  - Diagnostics development
  - Detector R&D
  - Cryomodule R&D, Commissioning
  - Low current fixed target experiments
  - Medium current internal target experiments
- LERF is available to support R&D under a full cost recovery model for activities aligned with the Lab Agenda.
- Gun Test Stand and User Labs available to be used in support of SC R&D programs.


Long Axis Length 64 meters

https://www.jlab.org/indico/event/199/



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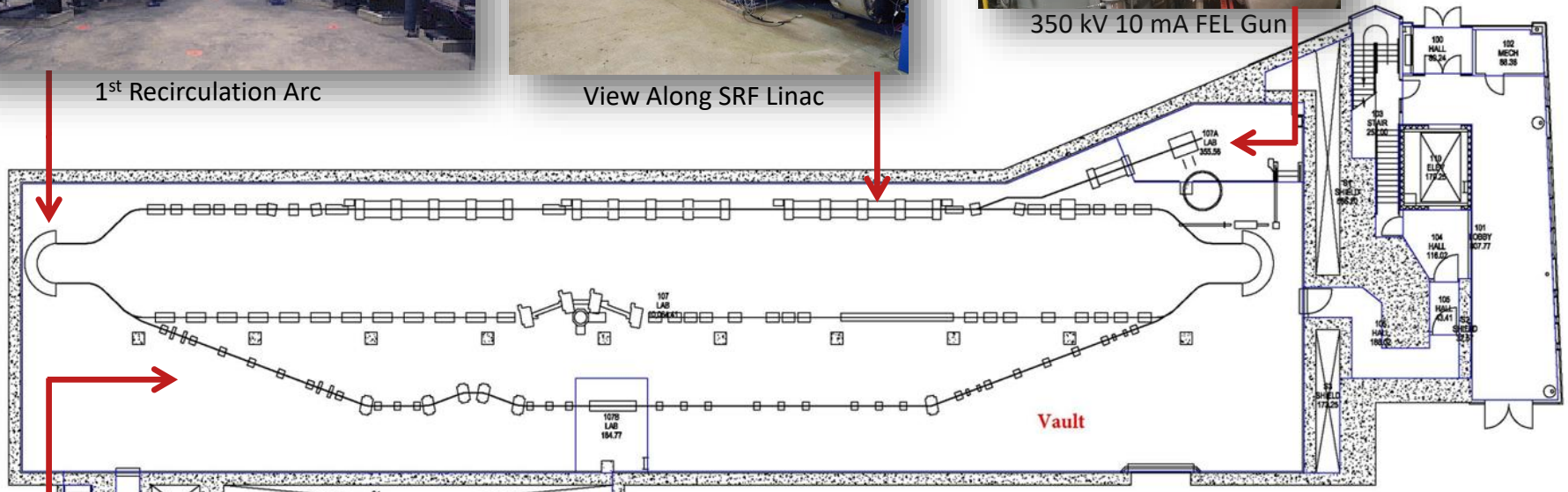
# LERF Vault and Gun Test Stand

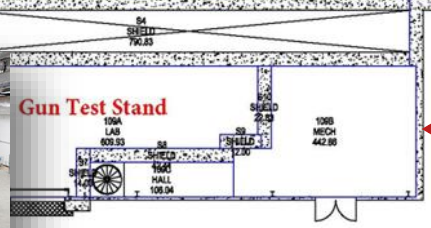
1st Recirculation Arc

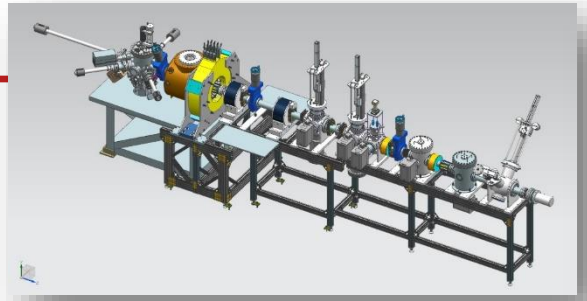
View Along SRF Linac

350 kV 10 mA FEL Gun

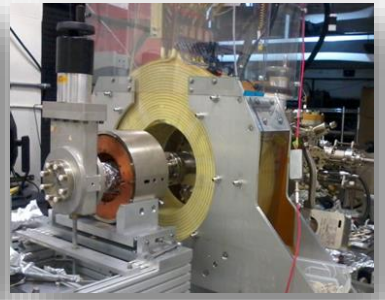



IR and UV Beamlines



Magnetized Beam Experiment



Magnetized Gun Solenoid



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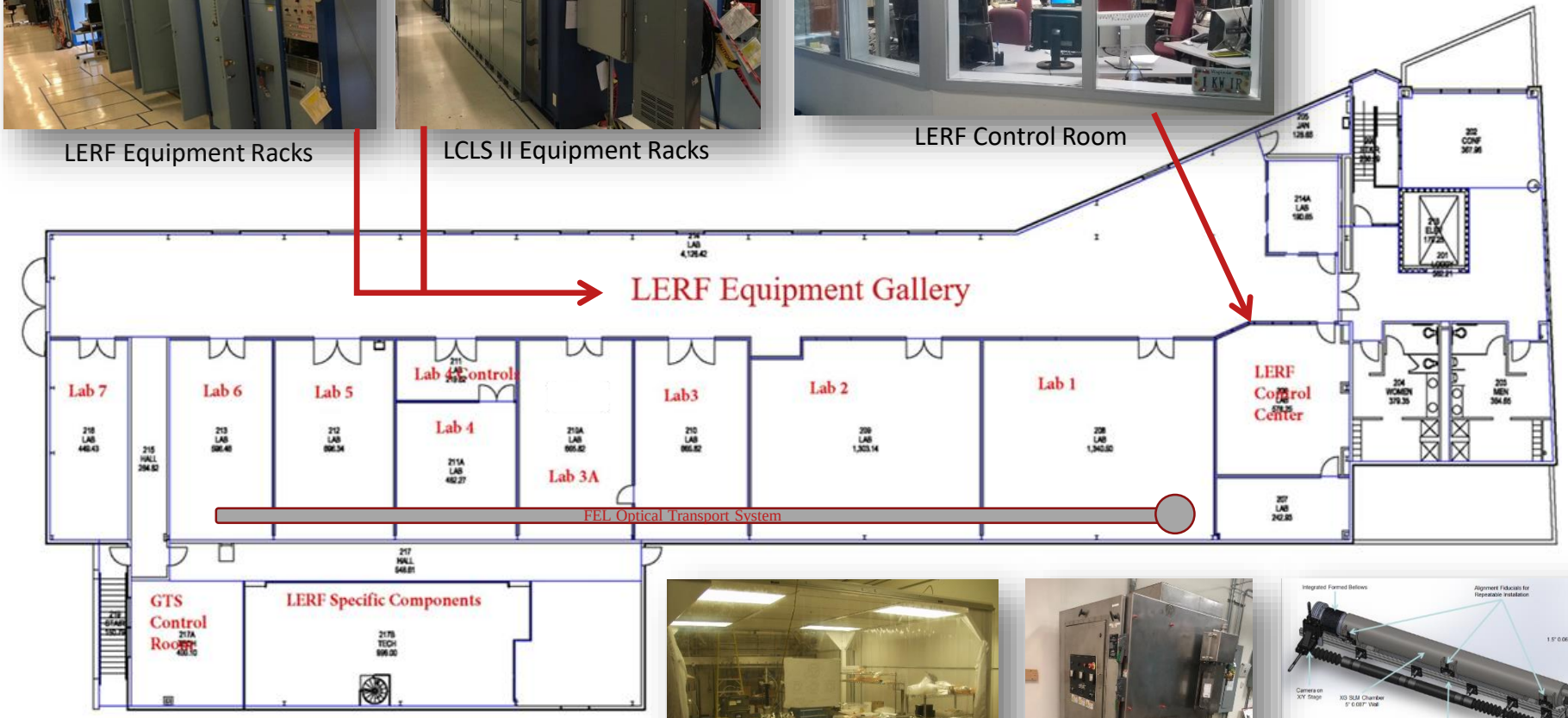
# LERF Gallery, User Labs and Control Center


LERF Equipment Racks

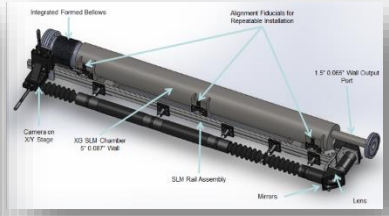
LCLS II Equipment Racks

LERF Control Room




Vacuum Cleanroom Assembly

Magnetron R&D



Diagnostics R&D



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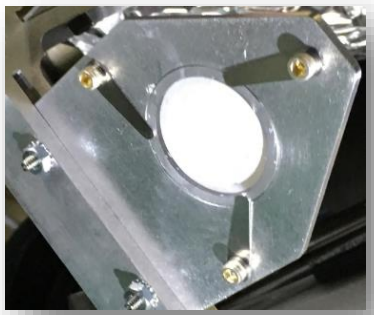
# LERF User Labs

Seven Fully Equipped User Labs for R&D

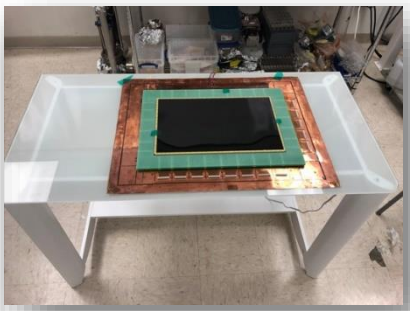
- Magnetron development (Stewardship)
- Diagnostics development (NP Ops, SBIR)
- GEM Detector development (NSF)
- High Power Lasers for Polarizing $^{3}He$ Targets (SBIR)
- Precise Laser Polarization Control for Polarized Electron Beam Generation (SBIR)
- Vacuum Assembly Lab (NP Ops, SBIR)
- Many graduate students involved

Laser Table for Generic R&D

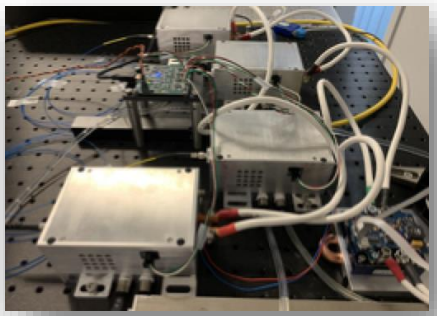
915 MHz Magnetron Power Supply



BNNT Viewer Flag



GEM Detector

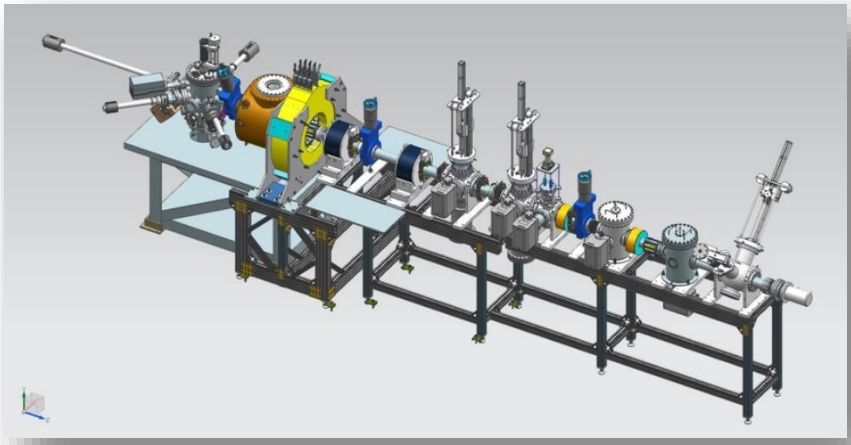


High Power Laser Hardware

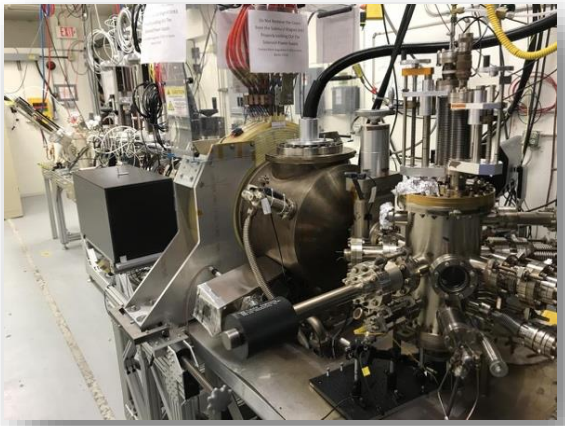
# Gun Test Stand

Active R&D facility for Source development

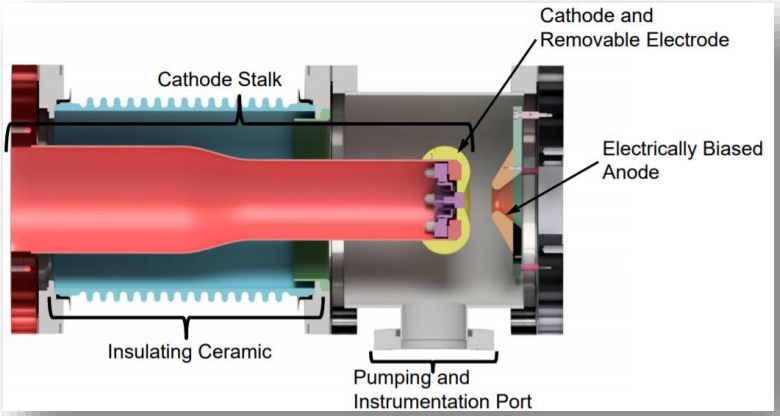
- Magnetized Source for EIC (LDRD)
- Resonant Polarimetry and Magnetometry (SBIR)
- Gridded Thermionic Magnetized Source for Ion Beam Cooling (SBIR)
- Diagnostics R&D (NP-Ops, SBIR)
- Many graduate students involved



Gun Test Stand Layout



Gun Test Stand Photo




Gridded Thermionic Cathode for EIC

XELERA Electrode



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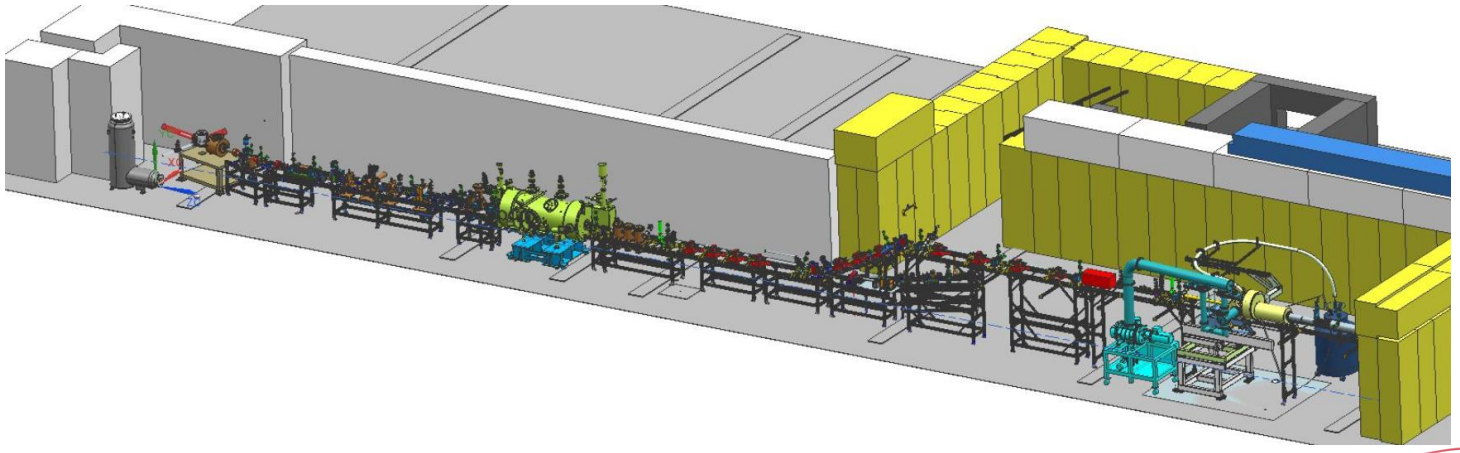
# Upgraded Injector Test Facility (UITF)

- The Injector Test Facility was established in the very early days of Jefferson Lab to build and commission the CEBAF warm injector while tunnel construction was underway. The facility was recently upgraded with cryogenics capabilities.
- Ongoing and planned R&D include:
  - Full Injector Upgrade: 200 kV gun, Wien filters, new Quarter Cryomodule
  - Polarize solid targets for the Physics Program and commissioning the HDIce target system for a future experiment in Hall B
  - Magnetized beam tests for EIC
  - R&D in support of Environmental Applications of Accelerators
  - Advanced polarized source R&D
  - Polarized positron source development for CEBAF and EIC

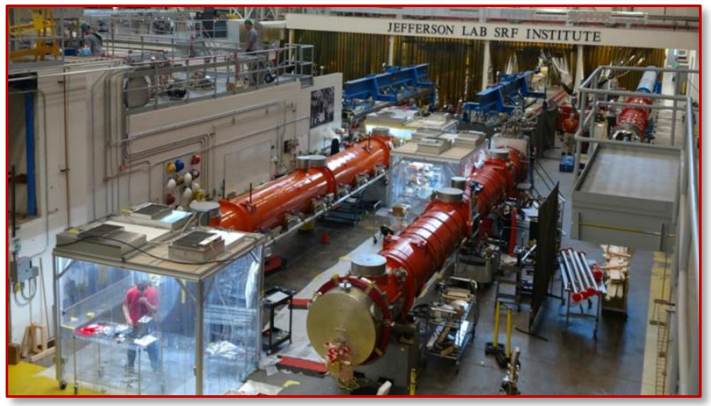


# SRF Production Facility

Jefferson Lab's SRF Facility has the capability to meet the needs of CEBAF and simultaneous DOE R&D, assembly and refurbishment projects

## Infrastructure

- Large capacity cavity preparation and test facilities
  - Fully equipped cavity processing centers
  - ISO 4 configurable clean room
  - Cavity RF test (VTA) with (6) large and (2) small dewars
- Multiple cryomodule assembly bays
  - (2) bays dedicated for LCLS II/ILC style
  - (1) dedicated for SNS PPU
  - (1) dedicated for CEBAF
  - Others dedicated for final assemblies
- Dedicated cryomodule test facility (CMTF)
  - Tested C20, C50, C75, C100, SNS and LCLS II

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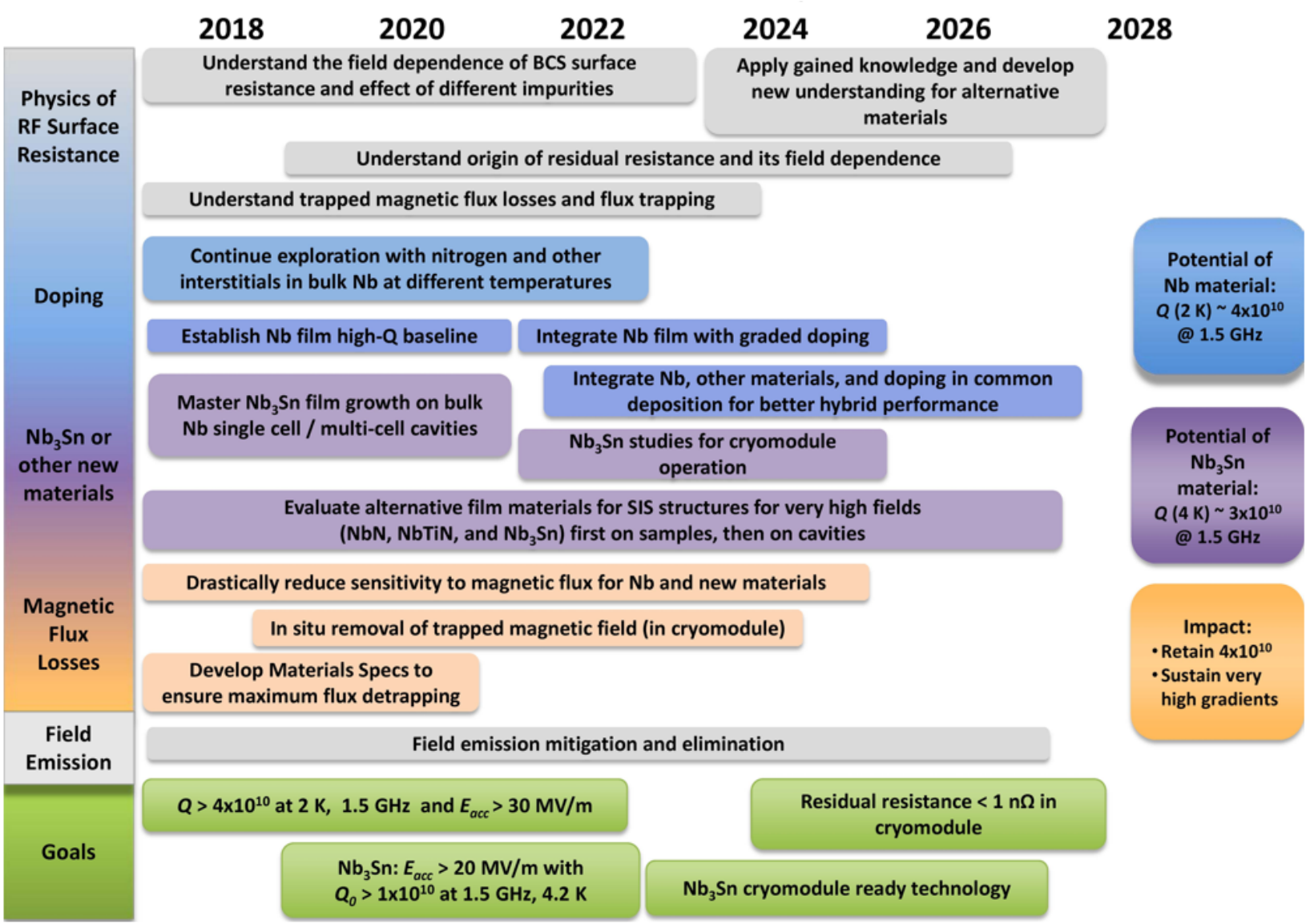
# SRF R&D Roadmap



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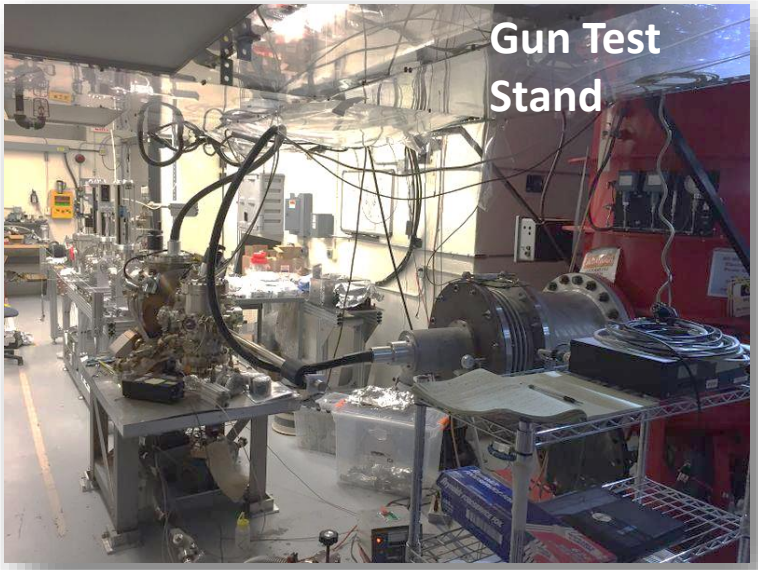
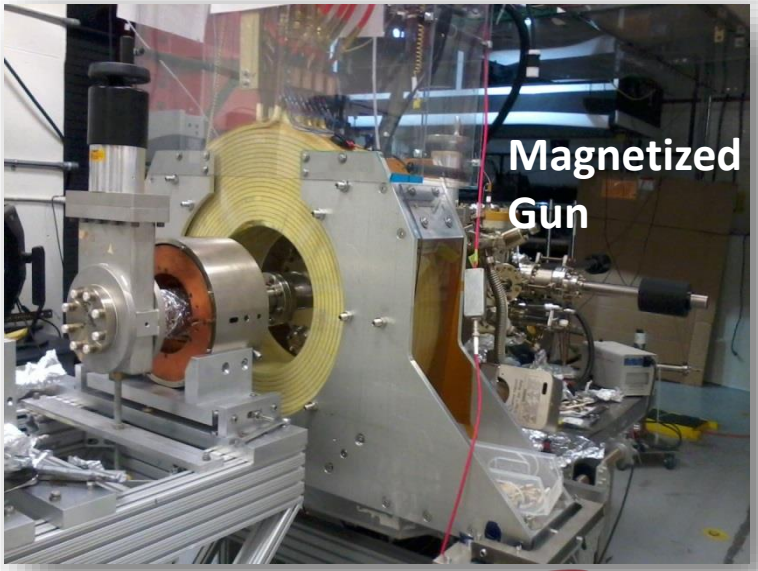
# Source Group R&D

- Magnetized beam transport (LDRD, NP-Ops)
- Bunchlength monitor and fast kicker using harmonically-resonant cavity, harmonic arbitrary waveform generator and amplifier (SBIR)
- Non-invasive electron beam polarimeter, RF-cavity to detect polarization (SBIR)
- High Polarization and High QE Photocathodes (SBIR)
- Improving vacuum to $10^{-13}$ Torr (NP-R&D)
- Thermionic gun with RF time structure, for generating magnetized beam (SBIR, NP-Ops)
- Powerful drive laser for photoguns, wavelength near 532 and/or 780 nm, with variable repetition rate, ~ 50ps laser pulses via gain-switching (SBIR)
- Improved lifetime in superlattice photocathodes with robust activated coatings for high current, highly spin-polarized beam production (Stewardship)



# Looking Towards the Future - EIC

- CD-0 approved Dec. 2019
- Site Selection at Brookhaven National Lab announced Jan. 2020
- From T. Hallman (NSAC 3/2/20):
  - *"An SC Prime Directive: The Project will be carried out as a full intellectual partnership between the BNL and JLAB teams (and other collaborators) with major participation by all"*
- From S. Binkley (NSAC 3/2/20):
  - *"Look to strengthen smaller/single purpose laboratories to be more multidiscipline"*

- Positive, constructive engagement with BNL leadership on EIC partnership
- Both labs firmly committed to EIC success
- That commitment formalized in BNL-JLAB Partnering Agreement, signed May 7, 2020
- Established JLAB EIC Project organization under leadership of A. Lung; Integrated BNL-JLAB team is being developed

*Jan 23, 2020 @ JLab*

*Feb 10, 2020 @ BNL*

*Feb 28, 2020 @ JLab*

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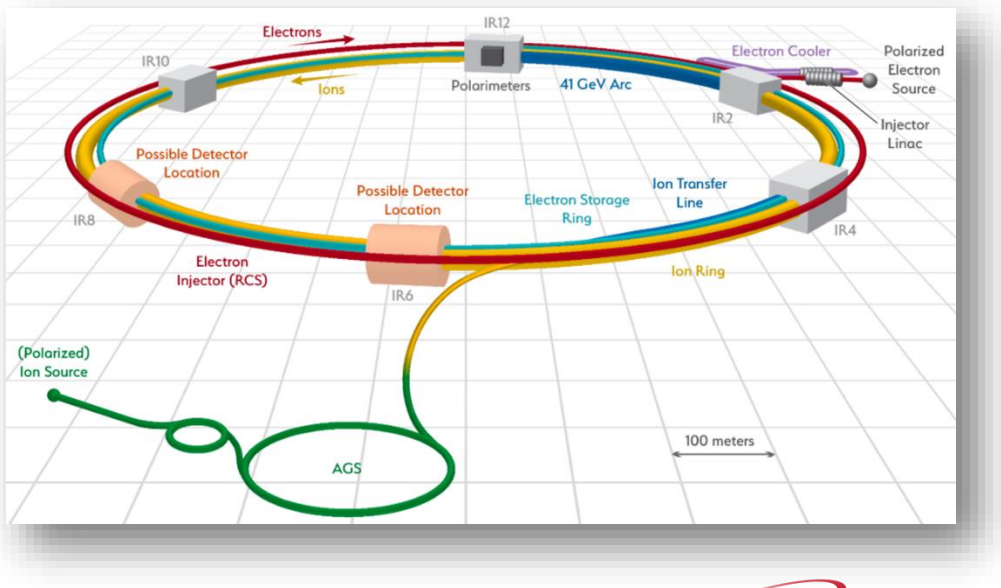
# Looking Towards the Future - EIC

- Jefferson Lab is a Major Partner for the EIC Project
- Project Management
- Physics Design
  - Accelerator Physics Task Forces (CDR)
  - Joint accelerator physics newsletter
  - CDR editorial committee membership
  - Change control board membership
- R&D
  - SRF and Cryomodule
  - Crab Cavities
- System Design
  - Detectors
  - Cryogenics
  - Spin Rotator Solenoids
  - Matching Magnets



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# EIC Accelerator Physics Task Forces

- ESR RF Beam Physics
- ESR Impedance-Driven Instabilities

ESR Dynamics

- ESR DA at 18 GeV

- RCS Beam Dynamics
- HSR Radial Shift

Other Machine Dynamics

- Beam-Beam
- Crabbing Cavity R&D

Collider Dynamics

- ESR Polarization

Spin/Polarization

- HSR Polarization
- RCS Polarization
- Novel ESR Spin Rotators

- Detector/Solenoid Compensation
- Second IR Design

Interaction Region

- Low Energy Lumi/Facility Optimization
- Low Energy Cooling
- Alternate Strong Cooling

Facility Optimization

- MPS and Collimation

JLab Driven/Led

Additional JLab S&T Expertise

ESR: Electron Storage Ring
RCS: Rapid Cycling (e-)Synchrotron
HSR: Hadron Storage Ring

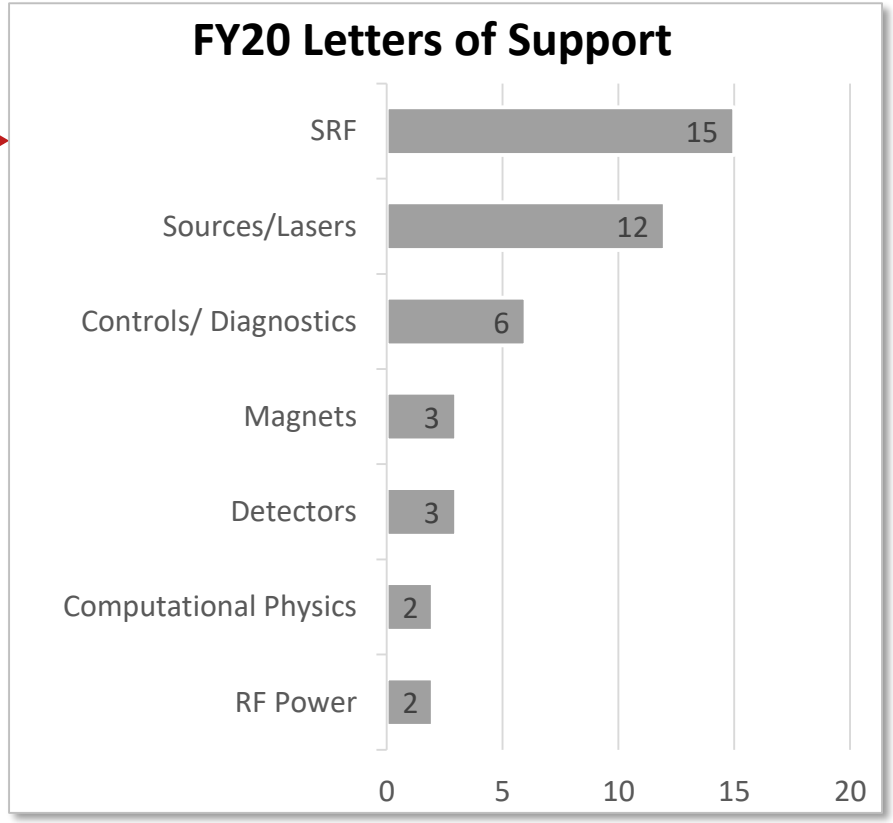
# Advanced Computing Initiatives

- Computational Sciences and Technology Division added to Lab Directorate
- Three major Advanced Computing Initiatives:
  - Develop Computing and Data Models for 12 GeV Physics Program and future EIC to insure experiment-theory integration
  - Develop computational and data science methodology and infrastructure to realize the scientific goals of the Center for Nuclear Femtography
  - Particle Accelerator Simulation and Operation
- Conducted an AI for Nuclear Physics Workshop: attended by 240 people

# JLAB SBIR Program Overview

- Jefferson Lab actively seeks opportunities with **Industrial Partners** to conduct research that is aligned with our Laboratory Agenda
- 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
- We monitor awards for potential synergies with our Strategic Plan
- Awards in FY20:
  - Eight of our industrial partners received Phase I awards totaling $1,598,780
  - Seven of our industrial partners received Phase II awards totaling $7,298,540
- The FY21 SBIR cycle has been launched at JLab




Jefferson Lab

# FY19 SBIR R&D at Jefferson Lab

| Topic | Title | Industrial Partner | Phase |
|---|---|---|---|
| Magnets | Micro-aligned 1 Tesla solenoid for high-energy bunched-beam electron cooling | Accelerator Technology Corp. | I |
| Magnets | Fast Beam-Switching Kickers | Electrodynamic | I |
| Magnets | Field Compensation in Electron-Ion Collider Magnets with Passive Superconducting Shield | Particle Beam Lasers Inc. | I |
| Magnets | Novel Design for High Field, Large Aperture Quadrupoles for Electron-Ion Collider | Particle Beam Lasers Inc. | I |
| Polarized Source | Precise and ultra-stable laser polarization control for polarized electron beam generation | Raytum Photonics LLC | I |
| RF Power | High-Efficiency 952.6-MHz Power Amplifier for JLEIC | Green Mountain Radio Research Company | I |
| SRF | HOM Load Development | Muons Inc. | I |
| SRF | Boron Nitride Nanotube Vibration Damping for SRF Structures | BNNT LLC | I |
| SRF | Modeling Plasma Discharge Cleaning of SRF Cavities | Tech-X Corp. | I |
| Beam Physics | Accurate Spin Tracking on Modern Computer Architectures for Electron-Ion Colliders | RadiaSoft LLC | II |
| Diagnostics | Radiation Hard High Speed Camera System for Accelerator Beam Diagnostics | Alphacore Inc. | II |
| Diagnostics | Resonant Polarimetry and Magnetometry | Electrodynamic | II |
| Diagnostics | Robust Wire-Scanner for High Intensity Beam Profile Diagnostics | RadiaBeam | II |
| Lasers | High Power Extremely Narrow Linewidth Diode Laser for Polarizing 3He Target | Raytum Photonics LLC | II |
| Lasers | High Power, High Repetition Rate 700-850 nm Pulsed Laser | Q-Peak Inc. | II |
| RF Power | Magnetron 1497 MHz RF Power Source | Muons Inc. | II |
| Source | A Magnetized Injector for Ion Beam Cooling | Xelera Research LLC | II |
| SRF | Low RF loss DC conductive Ceramic for High Power Input Coupler Windows for SRF Cavities | Euclid Techlabs LLC | II |
| SRF | Acid-Free Electropolishing of SRF Cavities | Faraday Technologies | II |

# FY20 SBIR R&D at Jefferson Lab

| Topic | Title | Company | Phase |
|---|---|---|---|
| Accelerator | Hydroformed Low Impedance Bellows for JLEIC | Bailey Tool | I |
| Accelerator | Fast Multi-Harmonic Kickers | Electrodynamic | I |
| Sources | A novel approach to production of highly spin polarized electrons from III-V semiconductor/half-metal hybrid multilayers | Euclid Beamlabs LLC | I |
| Detectors | Large Area Multi-Anode MCP-PMT for High Rate Applications | Incom LLC | I |
| Detectors | Design and fabrication of the “HDSoC”: High Density Digitizer System-on-Chip | Nalu Scientific LLC | I |
| SRF | Compact, low-cost higher order mode absorbers formed by cold spray of metal matrix composites | RadiaBeam Technologies, LLC | I |
| Accelerator | High Efficiency Low-Beta Accelerating Section | RadiaBeam Technologies, LLC | I |
| Accelerator | Magnetized Beam Transport Design Optimization for High Bunch Charge Beams | Xelera Research LLC | I |
| SRF | Cold Spray Technology Applications for SRF Cavity Thermal and Mechanical Stabilization | Euclid Beamlabs LLC | II |
| SRF | Low RF Loss DC Conductive Ceramic for High Power Input Coupler Windows for SRF Cavities | Euclid TechLabs LLC | II |
| Diagnostics | High Performance Scintillator and Beam Monitoring System | Integrated Sensors, LLC | II |
| Detectors | Low-cost and Efficient Cooling of on-Detector Electronics Using Conformal Thermoelectric Modules | Nanohmics, Inc | II |
| Accelerator | Ultrafast High Voltage Hardware for Ion Clearing Gap | RadiaBeam Systems, LLC | II |
| Controls | A Browser-based Toolkit for Improved Particle Accelerator Controls | RadiaSoft LLC | II |
| SRF | Large-Area, Conformal, Superconductive RF Coatings via HiPIMS with Positive Voltage Reversal | Starfire Industries LLC | II |

# Tech Center Coming Online


- **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**




Jefferson Lab

# Summary

- Jefferson Lab has multiple accelerator facilities spanning a broad range of parameter space that can be used to support R&D activities
- The SBIR program at Jlab has been growing over the last few years and covers a wide range of R&D topics
- The Laboratory is seeking to continue to grow the SBIR R&D program along topics that are consistent with the Lab Agenda and our Strategic Vision

Thank you!

# JLab SBIR Points of Contact

For more information about engaging with JLab on SBIR/STTR:

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