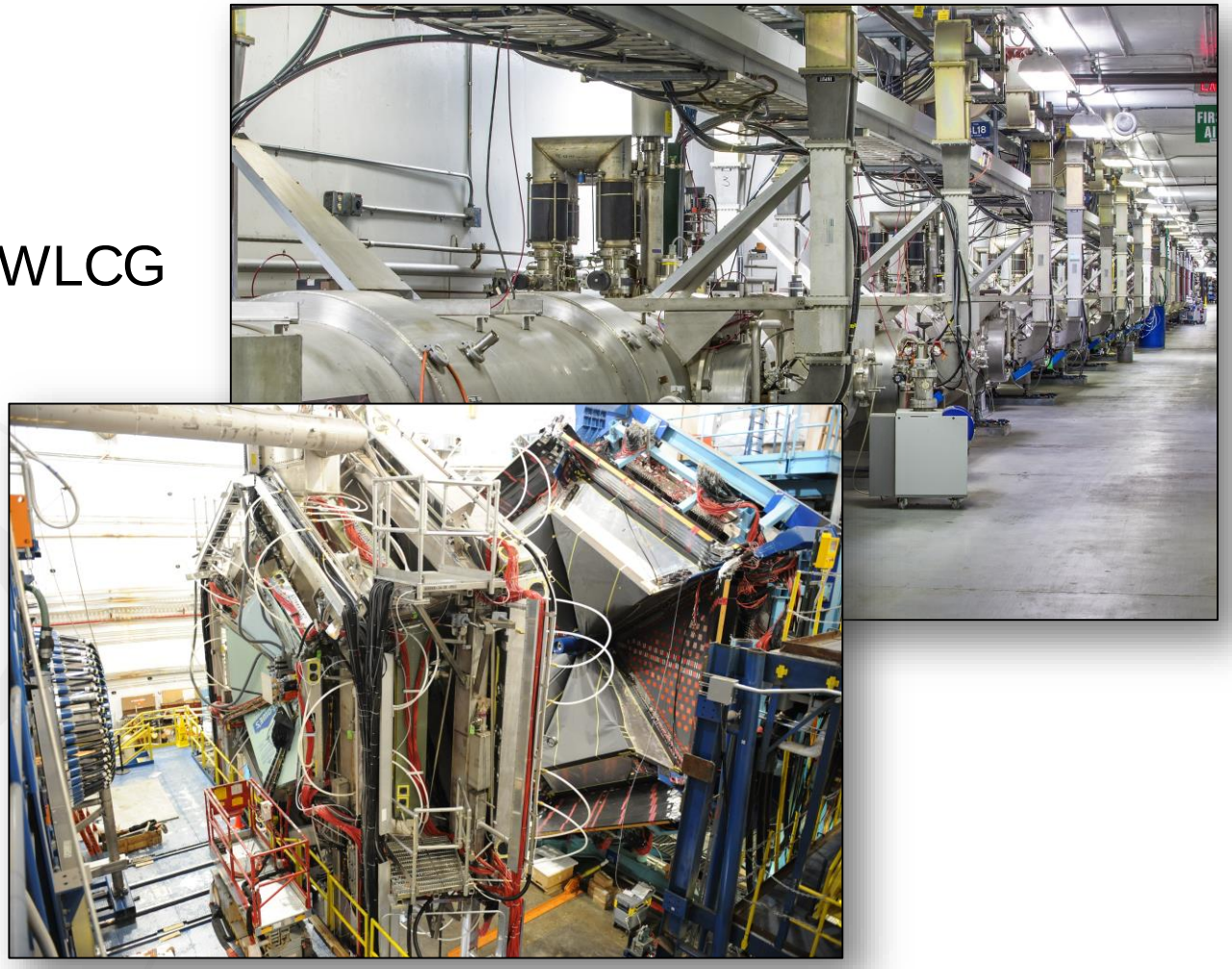
Overview of Jefferson Lab



2019 Joint HSF/OSG/WLCG Workshop

Stuart Henderson
Laboratory Director

March 18, 2019

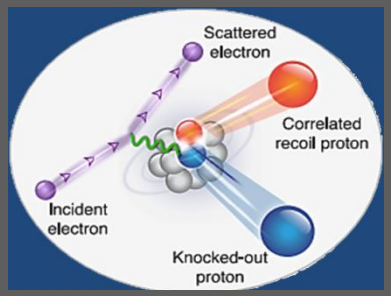
Jefferson Lab Overview

- U.S. Department of Energy National Lab: Single program focus 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
- In operation since 1995
- **Managed for DOE by Jefferson Science Associates, LLC (JSA)**

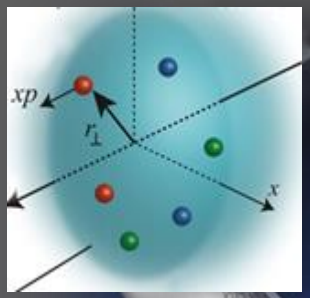
Jefferson Lab by the numbers:

- 700 employees
- 169 acre site
- 1,600 Active Scientist Users
- 27 Joint faculty
- 608 PhDs granted to-date (211 in progress): ~1/3 of US PhDs in Nuclear Physics
- K-12 programs serve ~12,000 students and ~1000 teachers annually

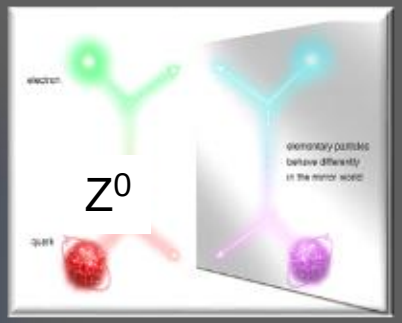
Jefferson Lab: A Laboratory For Nuclear Science



Nuclear Structure



Structure of Hadrons



Fundamental Forces & Symmetries

Medical Imaging Technology

Nuclear Astrophysics

Cryogenics

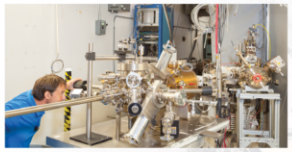
Accelerator S&T

Theory & Computation

Jefferson Lab

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.

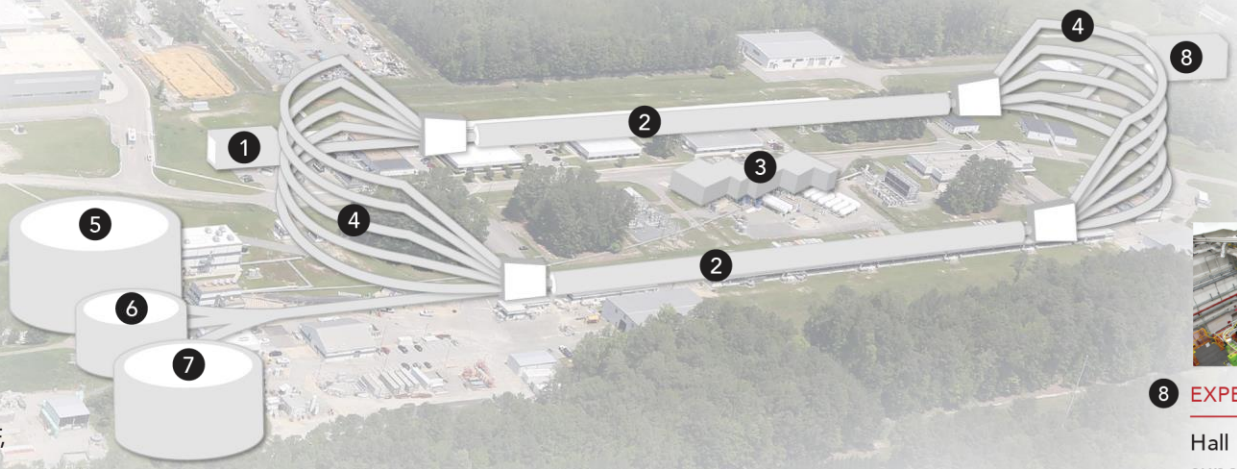
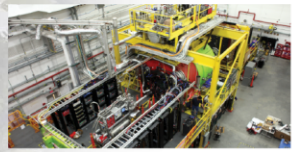


Diagram representational of below ground structure



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

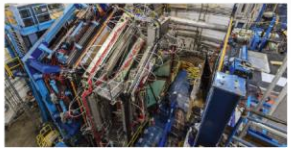
The Central Helium Liquefier keeps the accelerator cavities at -456 degrees Fahrenheit.

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.



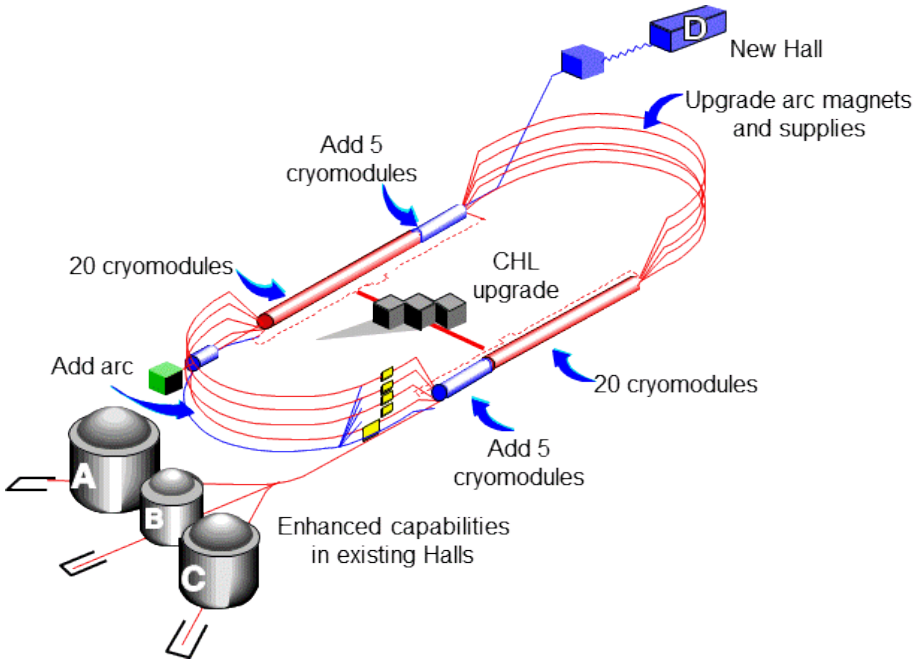
6 EXPERIMENTAL HALL B

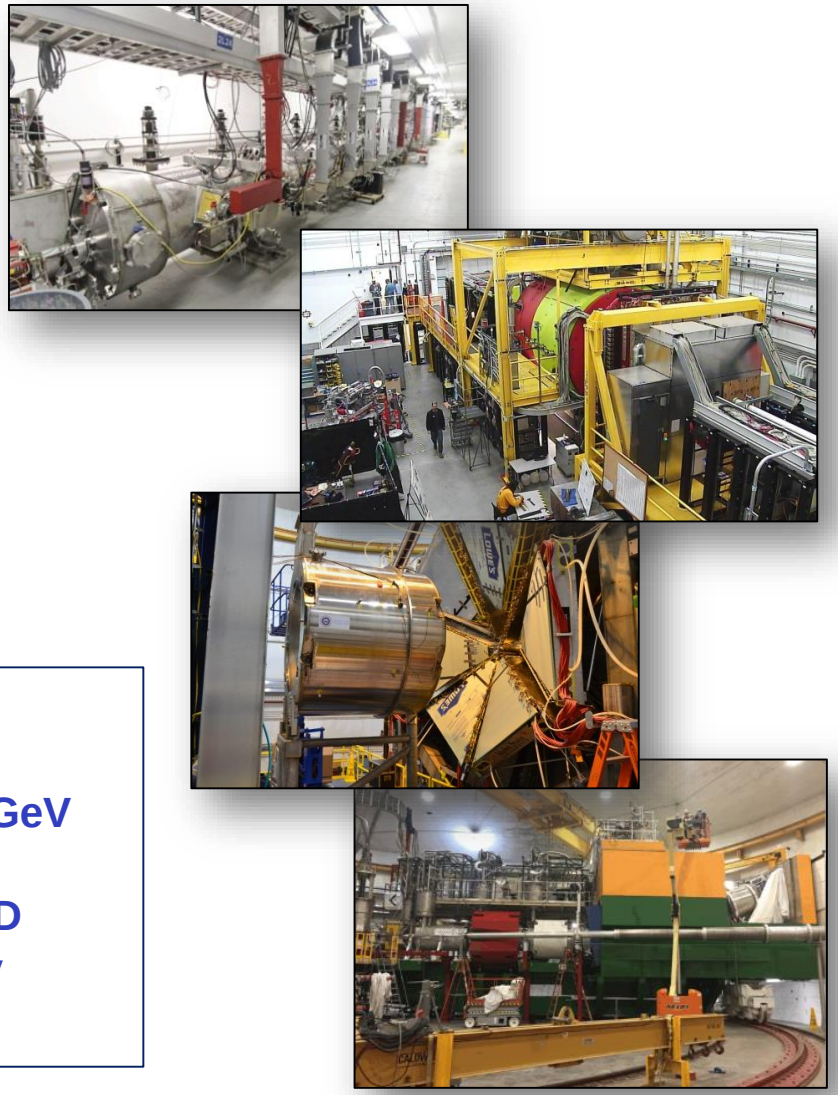
The CEBAF Large Acceptance Spectrometer surrounds the target, permitting researchers to measure simultaneously many different reactions over a broad range of angles.

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.

12 GeV CEBAF Upgrade is Complete and in Full Operation





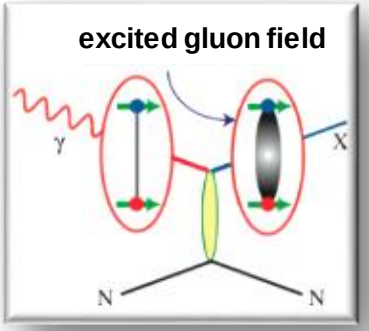
- **12 GeV Upgrade Project Complete:**
  - **Total Project Cost of $338M**
  - **Double maximum accelerator energy to 12 GeV**
  - **Add 4th experimental Hall D**
  - **New experimental equipment in Halls B, C, D**
- **In full operation now with simultaneously beam deliver to all 4 experimental halls**

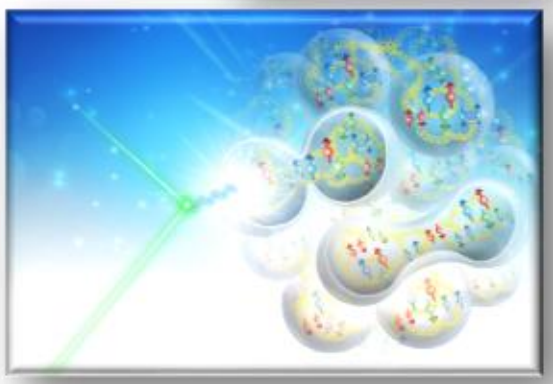
Project Completion Approved September 27, 2017

Jefferson Lab

Jefferson Lab @ 12 GeV Science Questions

- What is the role of gluonic excitations in the spectroscopy of light mesons?
- Where is the missing spin in the nucleon? Role of orbital angular momentum?
- Can we reveal a novel landscape of nucleon substructure through 3D imaging at the femtometer scale?
- What is the relation between short-range N-N correlations, the partonic structure of nuclei, and the nature of the nuclear force?
- Can we discover evidence for physics beyond the standard model of particle physics?

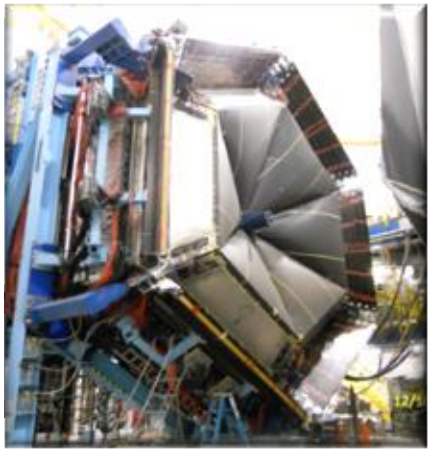




Jefferson Lab

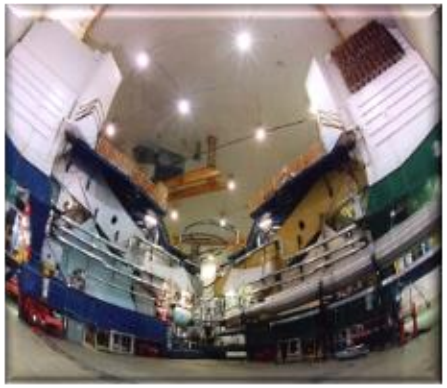
12 GeV Scientific Capabilities

Hall D – exploring origin of confinement by studying exotic mesons



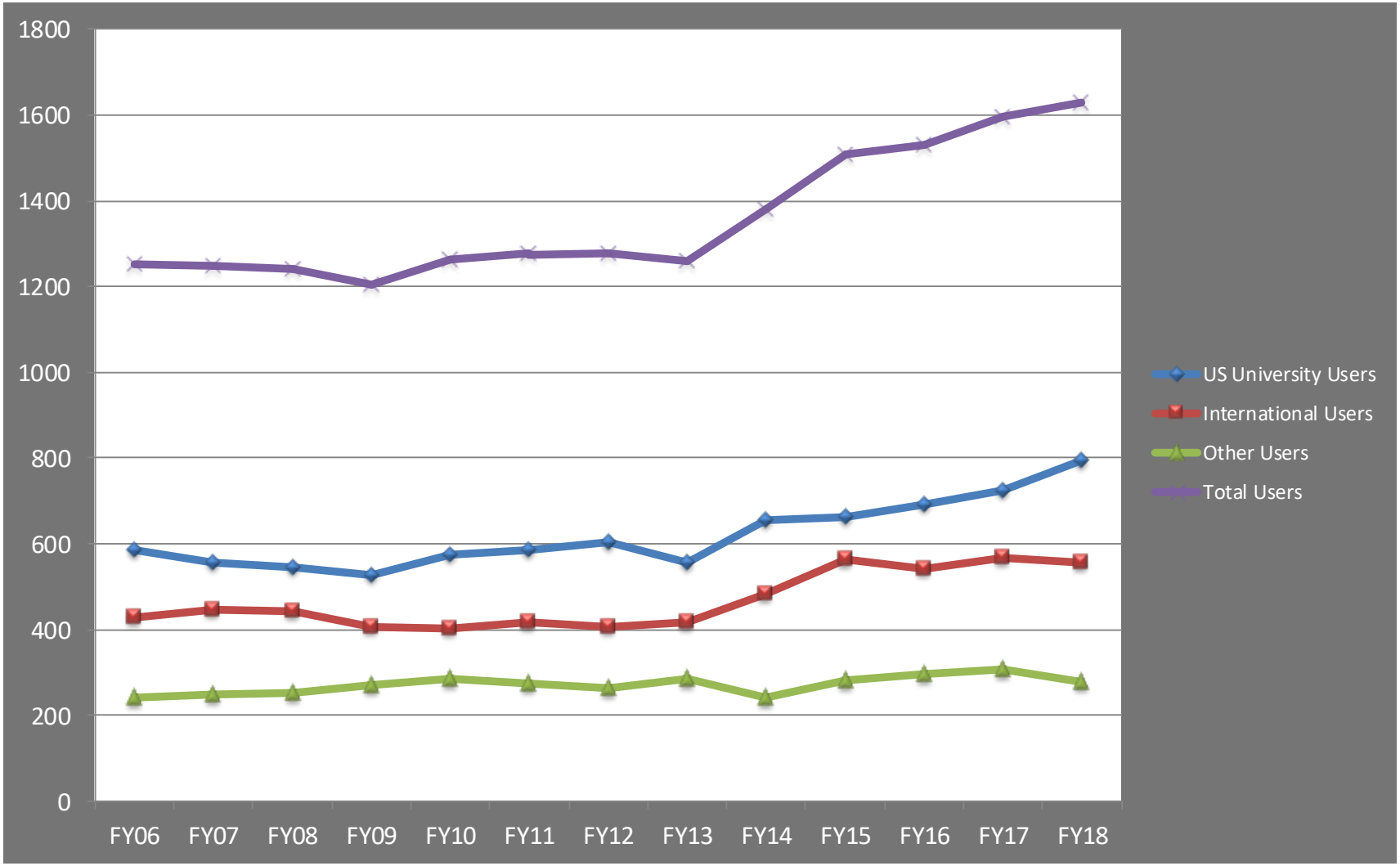
Hall B – nucleon imaging ("femtography") via generalized parton distributions and transverse momentum distributions

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., SoLID and MOLLER)

Jefferson Lab's User Community Continues to Grow

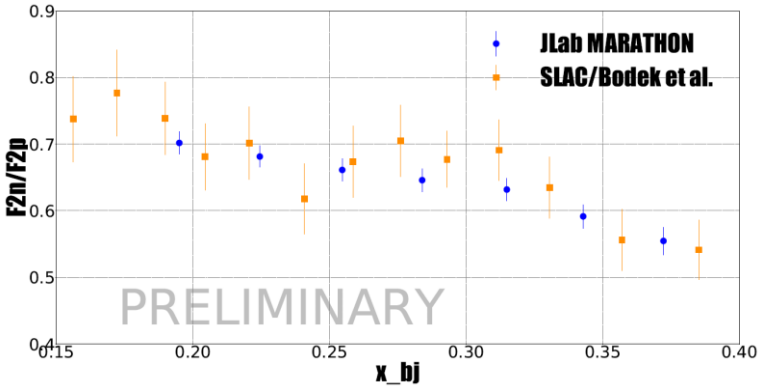


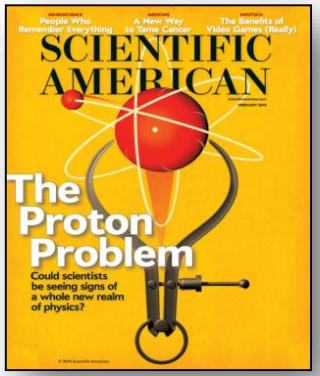
More than 1600 users from 278 institutions in 39 countries

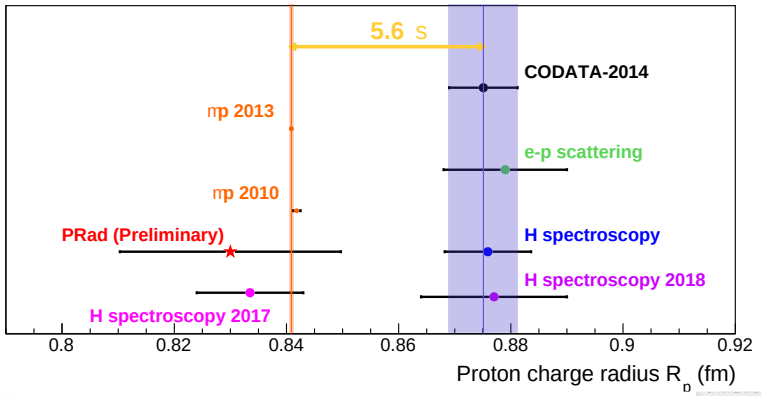
Jefferson Lab

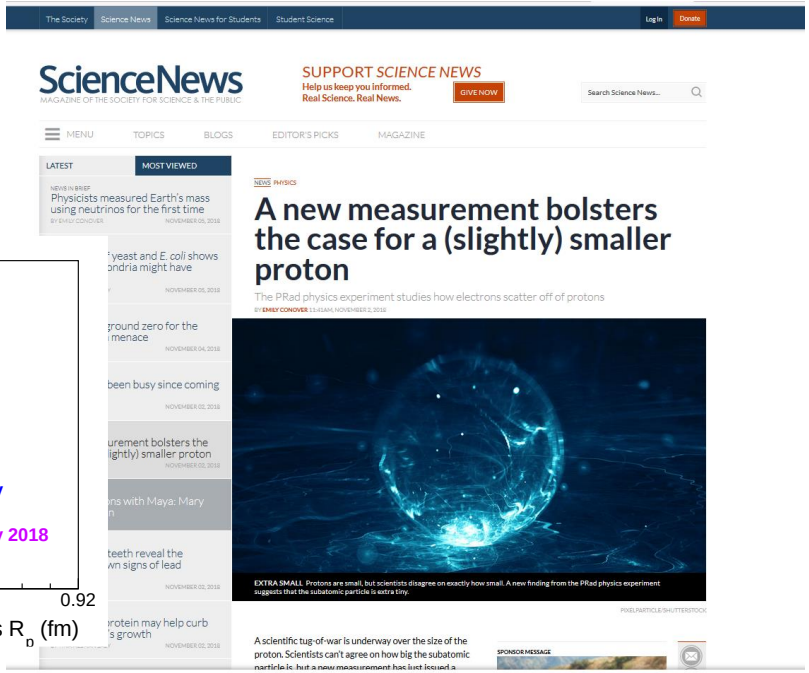
12 GeV Science Era is Here!

- **Hall A: Completed Tritium Run**
  - December 15, 2017: First Beam on Tritium Target
  - Tritium experiment (Marathon) measures d/u at High x_B from ratio of 3H and 3He
- **Hall B: In physics operations**
  - Proton Radius and Heavy Photon Search results
  - CLAS12 program fully underway







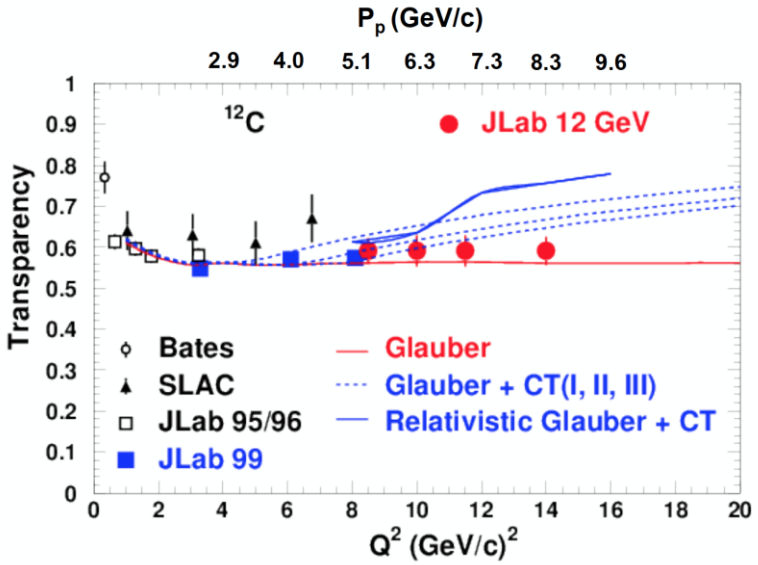


Jefferson Lab

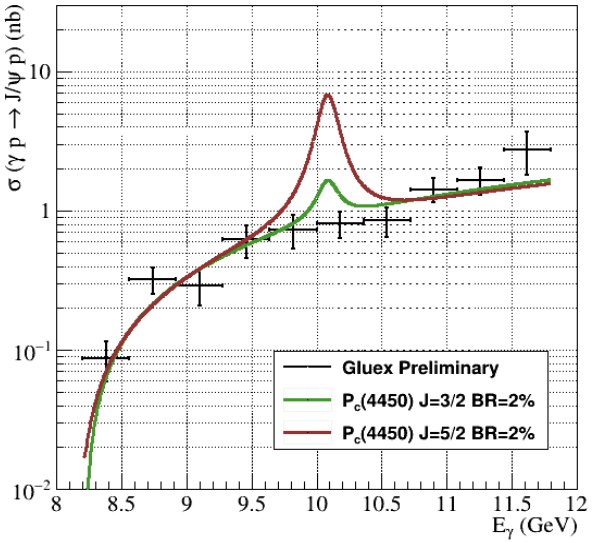
12 GeV Science Era is Here!

- **Hall C: In physics operations**
  - Spectrometer engineering run completed
  - Initial physics data acquired: EMC effect, $F_2^{H,D}$ structure functions, color transparency, TMD studies
- **Hall D: GlueX Phase 1 data-taking complete**
  - First 12 GeV era publication (April, 2017)
  - 25% data analyzed
  - Preparing Primex and GlueX-II

Projected Color Transparency errors



J/ψ production at threshold



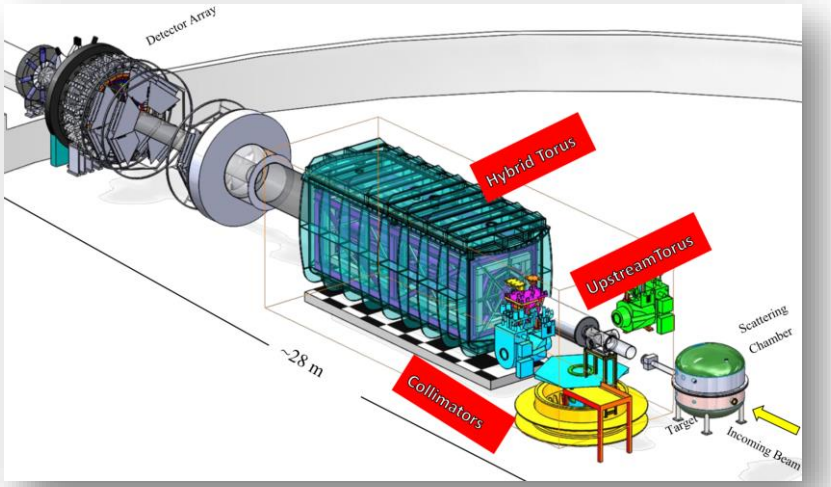
J/ψ cross section at threshold and limit on charm pentaquark photoproduction *(manuscript in preparation)*

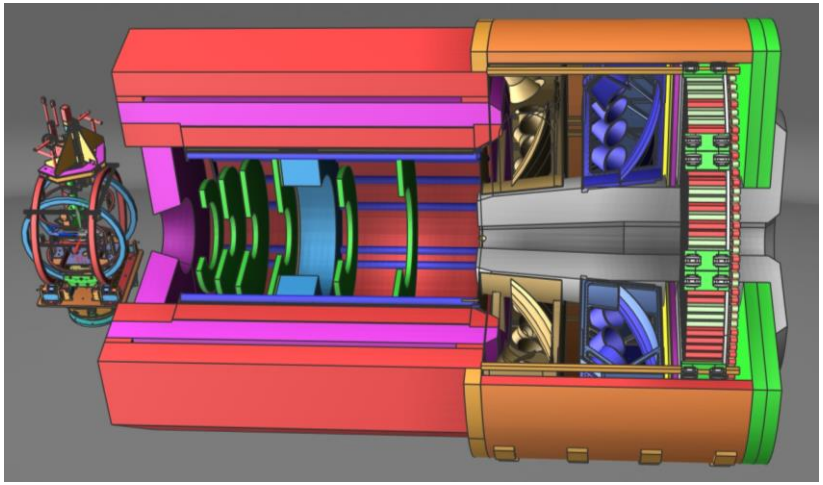
Jefferson Lab

MOLLER and SoLID

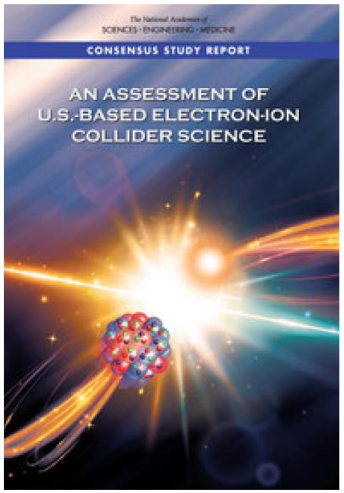
- Two projects that take advantage of 12 GeV CEBAF capabilities and will make the most of that investment

MOLLER	SoLID
– Precision measurement of weak mixing angle via parity-violating Moller scattering – DOE CD-0 approved, Dec. 2016 (project paused due to budget) – Awaiting green light to proceed	– Large acceptance, high luminosity – Major experimental program of SIDIS and PVDIS emphasizing: • Standard model test • nucleon imaging





The community has identified the Electron-Ion Collider as the next major facility in Nuclear Physics

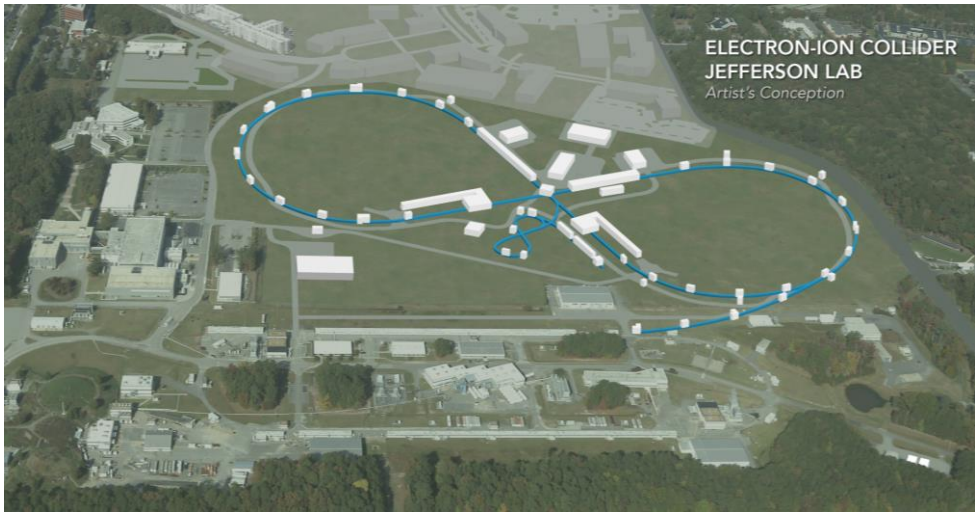


National Academy of Sciences – Assessment of U.S. Based Electron-Ion Collider Science (2018)

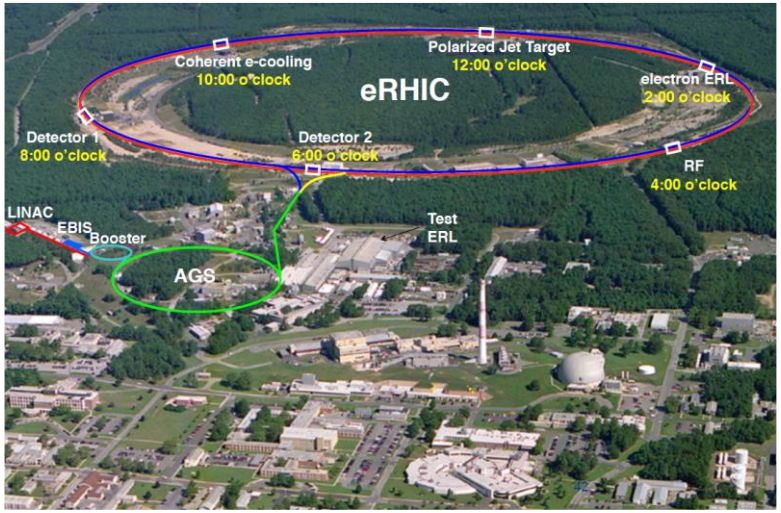
"…the committee finds a compelling scientific case for such a facility. The science questions that an EIC will answer are central to completing an understanding of atoms as well as being integral to the agenda of nuclear physics today."

JLEIC

JLEIC: Jefferson Lab Electron Ion Collider



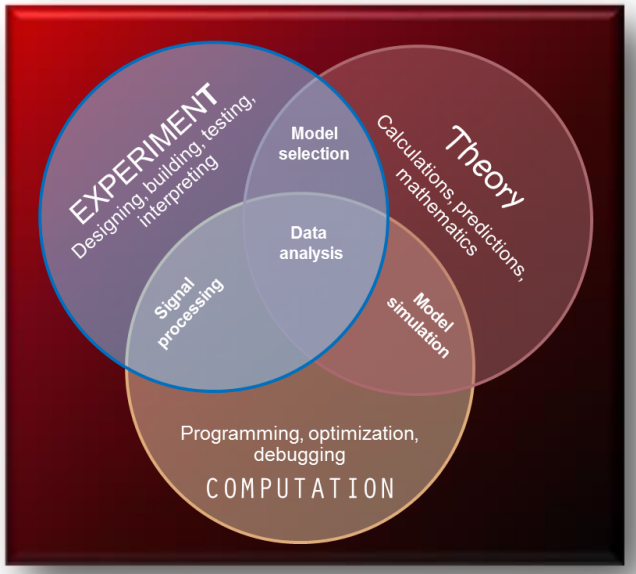
eRHIC: BNL Electron-Ion Collider



Jefferson Lab

Theory and Computation

- Progress in Nuclear Physics requires integrated effort in experiment, theory and computation
  - Essential to fully realizing the 12 GeV program
- High Performance Computing and the path to Exascale
  - World-class program at Jefferson Lab, leader in the USQCD Collaboration
  - Lattice QCD consumes ~10% of all US supercomputer resources
  - Key science driver for Exascale Computing; will enable a new era of precision studies with LQCD
- Advanced Computing Initiative Underway at Jefferson Lab
  - Integrated start-to-end experimental computing model for 12 GeV Physics program and future EIC
  - Computational/data sciences methodology for realize goals of femtography (nucleon imaging)
  - Machine learning for accelerator modeling and control



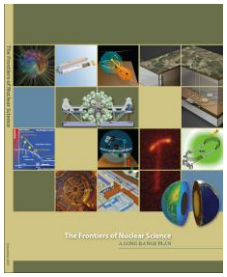
USQCD

EXASCALE COMPUTING PROJECT

Jefferson Lab

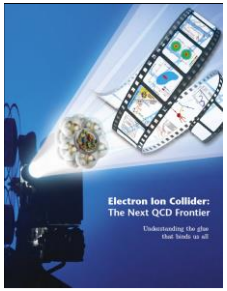
Welcome!

U.S. Electron-Ion Collider Planning



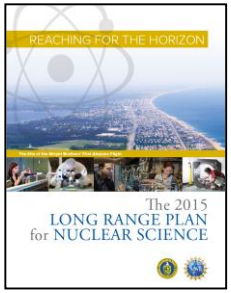
Federal Nuclear Science Advisory Cmte 2007 Long-Range Plan

"An Electron-Ion Collider (EIC) with polarized beams has been embraced by the U.S. nuclear science community as embodying the vision for reaching the next QCD frontier"



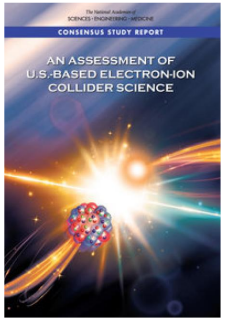
2013 Electron Ion Collider White Paper

(Writing committee convened by Jefferson Lab and BNL)



Federal Nuclear Science Advisory Cmte 2015 Long Range Plan

"We recommend a high-energy high-luminosity polarized EIC as the highest priority for new facility construction following the completion of FRIB."



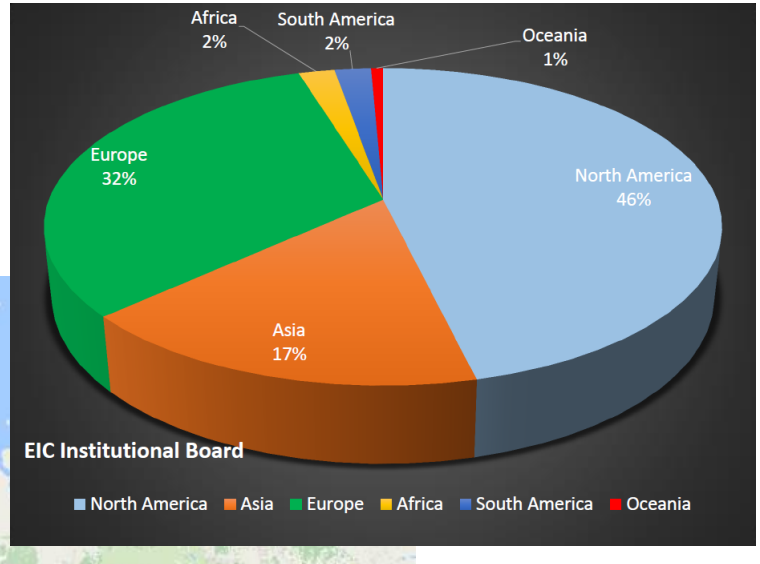
National Academy of Sciences – Assessment of U.S. Based Electron-Ion Collider Science (2018)

"…the committee finds a compelling scientific case for such a facility. The science questions that an EIC will answer are central to completing an understanding of atoms as well as being integral to the agenda of nuclear physics today."

EIC Users Group reflects growing international interest in EIC Physics

The EIC Users Group: EICUG.ORG

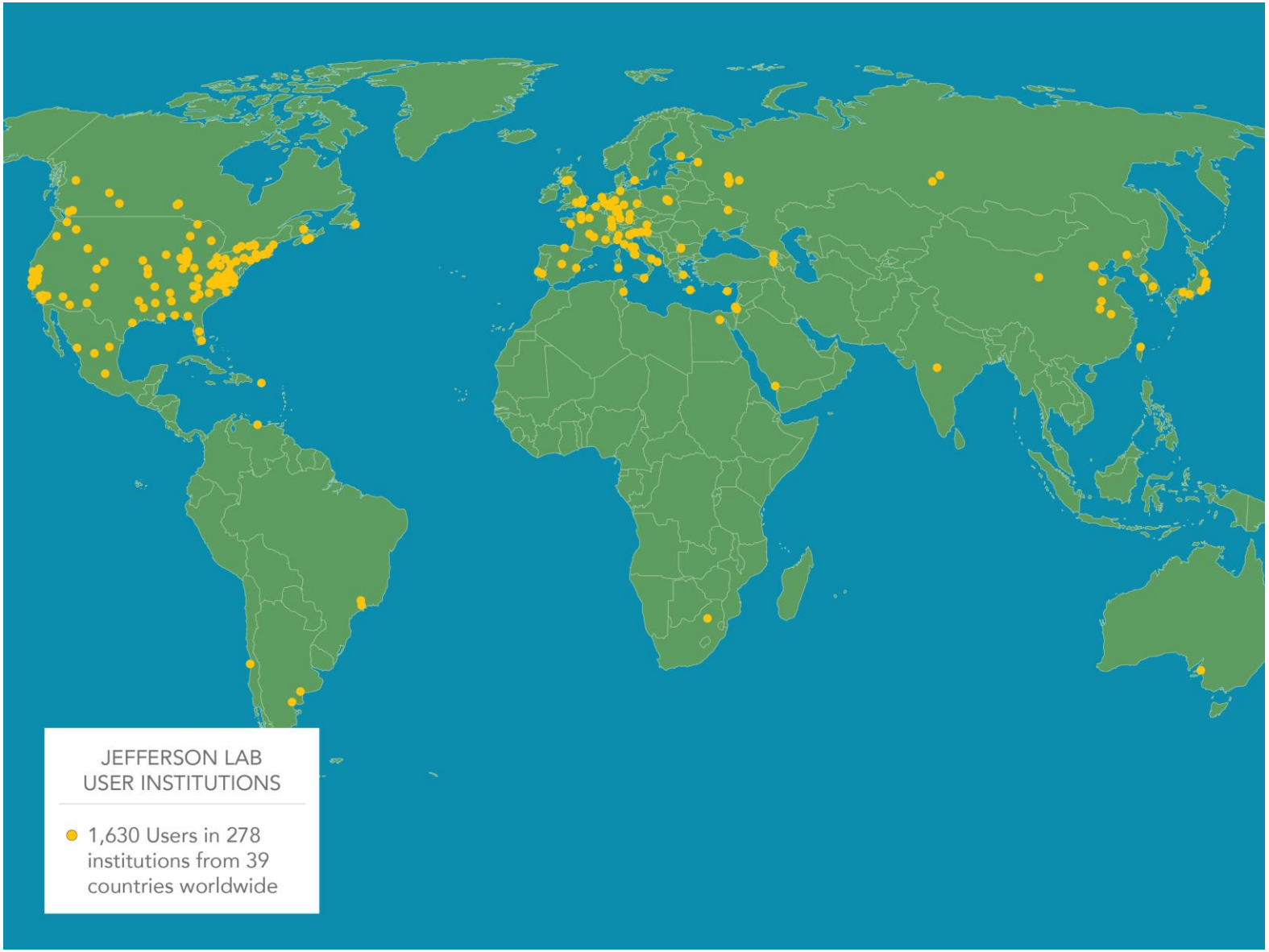
Formed 2016 – now 833 collaborators, 30 countries, 177 institutions... (Nov. 4, 2018)



Annual EICUG meeting
2016 UC Berkeley, CA
2016 Argonne, IL
2017 Trieste, Italy
2018 Washington, DC
2019 Paris, France

Jefferson Lab

Jefferson Lab is home to an international community of nuclear scientists



Jefferson Lab

Recent Nature Results

nature
International weekly journal of science

- *Precision measurement of the weak charge of the proton*, Qweak collaboration,
  Published: Nature 557, 207–211 (2018)
- *The pressure distribution inside the proton,* Burkert, Elouadrhiri, Girod,
  Published: Nature 557 (2018) no.7705, 396-399
- *A per-cent-level determination of the nucleon axial coupling for quantum chromodynamics*, Berkowitz et. al., Published: Nature 558, 91-94 (2018)
- *Ultrafast Nucleons in Asymmetric Nuclei,* M. Duer et. al., CLAS Collaboration,
  Published: Nature 560 (2018) no.7720, 617-621
- *A glimpse of gluons through deeply virtual compton scattering on the proton*, Dufurne et. al., Published: Nature Communications 8, 1408 (2017)

Jefferson Lab

CEBAF is in high-demand: approved experimental program will take better part of a decade to complete

Topic	Hall A	Hall B	Hall C	Hall D	Other	Total
The Hadron spectra as probes of QCD	0	2	1	3	0	**6**
The transverse structure of the hadrons	6	3	3	1	0	**13**
The longitudinal structure of the hadrons	2	3	6	0	0	**11**
The 3D structure of the hadrons	5	9	6	0	0	**20**
Hadrons and cold nuclear matter	8	5	7	0	1	**21**
Low-energy tests of the Standard Model and Fundamental Symmetries	3	1	0	1	2	**7**
Total	**24**	**23**	**23**	**5**	**3**	**78**
Total Experiments Completed	**4.6**	**2.7**	**2.1**	**0.8**	**0**	**10.2**
Total Experiments Remaining	**19.4**	**20.3**	**20.9**	**4.2**	**3.0**	**67.8**

INFN scientists are spokespersons for more than 20% of the approved experiments

Jefferson Lab Plays a Vital Stewardship Role for Big Science Projects Within the Department Of Energy

Jefferson Lab is a world-leader in Superconducting Radiofrequency particle accelerators and cryogenic technologies

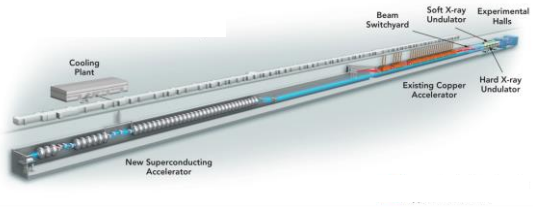
CEBAF - 1994
12 GeV Upgrade - 2017

Spallation Neutron Source (ORNL) - 2006

Facility for Rare Isotope Beams (MSU) - 2021

Linac Coherent Light Source II (SLAC) 2021

SNS Proton Power Upgrade



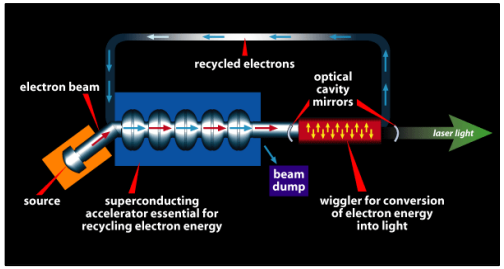
LCLS-II High Energy Upgrade

Jefferson Lab

Jefferson Lab's Technology Portfolio

Large scale Cryogenics (Ex: NASA James Webb Space Telescope)

Superconducting particle accelerators (Ex: LCLS-II Project)

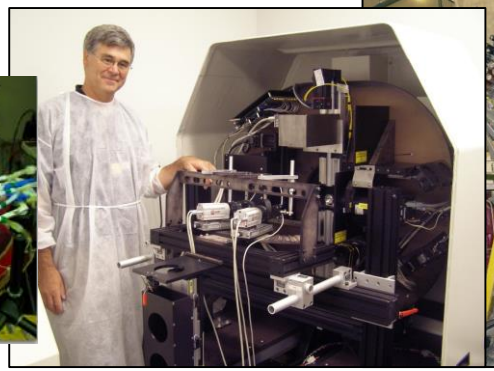


High-power Free electron lasers (Ex: Record power achieved in Office of Naval Research program at JLAB)

Big Data challenges (Ex: NASA Langley adoption of JLAB software framework for multi-satellite data processing)

High performance computation (Ex: first use of GPU hardware in HPC)

Particle Detector Technologies
(Ex: Compact gamma camera for breast cancer detection; AwakeSPECT for functional brain images of conscious, unrestrained mice; molecular imaging for plant biology



Jefferson Lab