Jefferson Lab Users Organization Board of Directors Visit

Dec 14th, 2018

Lamiaa El-Fassi (MSU), Or Hen (MIT), Kent Paschke (UVA), and Julie Roche (Ohio U).
Jefferson Lab Overview

• One of 17 U.S. Department of Energy National Laboratories with a single focus on 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

• Created to build and operate the Continuous Electron Beam Accelerator Facility (CEBAF). In operation since 1995

• Recently upgraded to 12 GeV maximal energy. Upgrade complete as of Spring 2018

• Managed for DOE by Jefferson Science Associates, LLC (JSA)

JLAB by the numbers

✓ nominally 35 weeks of operation/year
✓ 100% duty cycle accelerator thanks to superconducting RF cavities
✓ 4 experimental hall simultaneous operation
✓ 100 uA beam on target
✓ ultra-high luminosities, up to $10^{39}$ electrons nucleons /cm$^2$/s
✓ 85% polarized electrons
Enthusiastic and Growing Users Organization

1597 Users, 568 International Users [FY17]

- Recent growth shows strong interest in the 12 GeV program
- Largest users organization worldwide among nuclear physics labs.
JLab affiliated institutions in the US

- 425 Physics Letters and Physical Review Letters publications; 1,459 in other refereed journals
- 608 PhDs granted; 211 more in-progress
- JLab produces ~1/3 of US PhDs in Nuclear Physics

JEFFERSON LAB USER INSTITUTIONS
- 1029 Users in 120 institutions from 32 states
- 7 HBCU institutions
- 7 HSI institutions
JLab physics is an integral part of the NSAC LRP

RECOMMENDATION I
The progress achieved under the guidance of the 2007 Long Range Plan has reinforced U.S. world leadership in nuclear science. The highest priority in this 2015 Plan is to capitalize on the investments made.

- 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.

<table>
<thead>
<tr>
<th>Topic</th>
<th>Hall A</th>
<th>Hall B</th>
<th>Hall C</th>
<th>Hall D</th>
<th>Other</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>24</td>
<td>23</td>
<td>23</td>
<td>5</td>
<td>3</td>
<td>78</td>
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<tr>
<td>Total Experiments Completed</td>
<td>4.6</td>
<td>2.7</td>
<td>2.1</td>
<td>0.8</td>
<td>0</td>
<td>10.2</td>
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<tr>
<td>Total Experiments Remaining</td>
<td>19.4</td>
<td>20.3</td>
<td>20.9</td>
<td>4.2</td>
<td>3.0</td>
<td>67.8</td>
</tr>
</tbody>
</table>
Exciting 12 GeV Physics Questions

- Hadron spectra as probe of QCD
  *What is the role of glue in the spectroscopy of mesons?*

- The transverse structure of the hadrons

- The longitudinal structure of the hadrons

- The 3D structure of the hadrons
  *What is the correlation between space and momentum distribution of partons? Julie*

- Hadrons and cold nuclear matter
  *How do quarks interact with a dense nuclear medium? Lamiaa*
  *What is the relationship between short range NN correlations and the QCD structure of nuclei? Or*

- Low-energy tests of the Standard Model and Fundamental Symmetries
  *Can we discover evidence for physics beyond the standard model? Kent*
3D Spatial Imaging

\[ \frac{1}{2} = \text{Spin of all Quarks} + \text{Spin of Gluons} + \text{Angular Momentum of all Quarks} + \text{Angular Momentum of Gluons} \]

\( \gamma \) production (JLab 6)

\( \pi^0 \) production (JLab 6)

\( Q^2 \) vs \( x_B \) coverage in Halls A and C

- Hall C 11 GeV
- Hall C 8.8 GeV
- Hall C 6.6 GeV
- Hall A 11 GeV
- Hall A 8.8 GeV
- Hall A 6.6 GeV
- Hall A 5.75 GeV

Nature Comm. 2017
PRL, 2016
Nuclear QCD Signatures and 3-D Partonic Structure

- Study hard processes in nuclei to probe the QCD confinement dynamics:
  - Color propagation and fragmentation – **Hadronization process**
  - Creation and evolution of small size hadrons - **color transparency (CT)**
- Use hard probe on light nuclei (\(^4\)He nucleus) to
  - Study partonic structure with GPDs via coherent processes
  - Explore DVCS, DVMP, SIDIS with spectator tagging
  - ALERT - A Low Energy Recoil Tracker - comprehensive program for \(^4\)He
- A high-impact studies with CLAS-12: \(^4\)He through \(^{208}\)Pb
Short Range Correlations and EMC effect

- How does the nucleus arise from QCD?
- How do short range correlated pairs form?
- How are nucleons modified in the nucleus?
  - How is this related to SRC pairing?
- Are 3N correlations measurable?

Many 12 GeV experiments!

Nature 2018

PRL 2018

Science 2014
Parity-Violating Electron Scattering

**Qweak - precise measure of proton weak charge**
- New physics in electron-proton parity-violating coupling excluded to 27 TeV mass scale
- Highest precision electron-nuclear scattering measurement, demonstrating new potential for future experiments

**State of the Art**
- \( \leq 1 \times 10^9 \) Statistical reach and systematics control
- \( \leq 1\% \) Normalization precision

**PREX-2 and CREX**
- Scheduled to run summer/fall 2019,
  - Measure neutron skin thickness to precision of 0.06 fm in \(^{208}\text{Pb}\). Important bound on nuclear equation of state. Compare to results on neutron star observations such as gravity waves.
  - Neutron skin thickness to 0.02 fm in \(^{48}\text{Ca}\), testing new technology for computing nuclear structure

**12 GeV Era (next decade):**
- **MOLLER CD-0**: broad interest within Fundamental Symmetries and related fields for this unique search for physics beyond the Standard Model
- **SoLID**: unique next generation PVDIS measurement also enabling broad SIDIS program

**Steady Improvements in JLab polarized source, accelerator, and detector technology**

**Continuous interplay:** hadron physics vs electroweak physics
HALL D: ANALYSIS AS OF FALL 2018

**J/ψ production at threshold**

- **Production Asymmetries**
  - Production asymmetry of the reaction $γp \rightarrow p η'$
  - Preparing for internal review
  - Production asymmetry of the reaction $γp \rightarrow π^- Δ^{++}$
  - Preparing for internal review

**J/ψ cross section at threshold and limit on charm pentaquark photoproduction**
- GlueX-I is complete
- 25% of data analyzed
- 3 papers in preparation
- Getting ready for Primex-η and GlueX-II (with DIRC)

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Slide from R. Mckeown, Nov 2018
JLab Community Enthusiasm for the Electron Ion Collider

- JLab 12 GeV Science leads naturally into EIC Science
  - June’18 JLUO meeting: “From JLab 12 to the EIC”

- 60 JLab experimental groups in EIC Users Group

- Taking initiatives in developing EIC Science with multiple topical workshops

- Strong support for the specific features of the JLEIC concept:
  - Maximal luminosity; Path to energy upgrades; Polarized deuterons;
  - Total acceptance detector with far-forward electron and hadron detection;

- Strong interest in expanded participation in Accelerator and Detector R&D:
  - 20 user groups active in design of JLEIC Detector and/or Generic Detector R&D (limited funding), request increase of Detector R&D funds in addition to Accelerator R&D funds
  - **Building the right machine and detector for the desired science**

- Pleased to see the Center for Nuclear Femtography and the EIC² creation
JLab is a user driven facility

- Good Idea
- Proposal Development
- PAC Presentation
- Detector & Experiment Optimization
- Experiment Readiness Review (ERR)
- Scheduling
- Data-Taking
- Analysis and Publication
Main issue with the process: (from a funding perspective)

Schedule available for 18 months while grants follow 3 year cycles => challenging for reviewers.

Relevant information that can help:

- Scheduling is only possible following successful completion of an ERR => Passing an ERR is a good indication that scheduling is foreseen.

- PAC significantly raised its bar and approves a very small number of proposals => Experiments recently approved by the PAC have very high physics-merit and are likely to be scheduled soon. Same is true for experiments passing jeopardy.
MRIs provide support for non-standard DOE equipment on projects lead by users.

- NPS on SHMS platform
- Detector
- Magnet
- NPS in Hall C (CUA, ODU and OU)
- Polarized target for Hall B (ODU, UVA, CNU)
- PCAL in Hall B (OU, W&M, JMU, NSU)
CROSS-DISCIPLINARY EXAMPLE I: JLAB-FRIB

Understanding NN interaction and short-distance and its effect on spectroscopic factors quenching

=> (new) Consistent view of high- and low-energy nuclear structure
CROSS-DISCIPLINARY EXAMPLE II: JLAB-LIGO

Using weak interaction to select neutrons

$A = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L} \propto |\gamma Z^0/2|$

=> Constrain the slope of the symmetry energy

\[symmetric EoS E_0(n): DD2\]

\[symmetry energy E_s(n):\]

\[\begin{array}{c}
DD2-\\
DD2+\\
DD2++\\
\gamma=1/6\\n\gamma=1/3\\n\gamma=1/2\\n\gamma=2/3\\n\gamma=4/5\\n\gamma=9/10\\n\gamma=1
\end{array}\]

\[R [\text{km}]\]

\[M [M_{\odot}]\]

\[\begin{array}{c}
\text{Galileo cosmology}\\n34, 1,584, 2010.7
\end{array}\]

\[\begin{array}{c}
\text{Probing extreme redshift galaxies in the Hubble Ultra Deep Field}\\n31, 2,415, 2010.3
\end{array}\]

\[\begin{array}{c}
\text{Sterile neutrinos at the eV scale}\\n41, 2,472, 2010.2
\end{array}\]

\[\begin{array}{c}
\text{Herschel Space Observatory and initial performance}\\n9, 1,456, 2010.2
\end{array}\]

\[\begin{array}{c}
\text{Kepler Mission and the search for extra-solar planets}\\n47, 4,211, 2010.0
\end{array}\]

\[\begin{array}{c}
\text{Neutron star observations and nuclear symmetry energy}\\n18, 1,536, 2009.9
\end{array}\]

\[\begin{array}{c}
\text{Evolution of massive early-type galaxies}\\n18, 1,724, 2009.6
\end{array}\]

\[\begin{array}{c}
\text{Gamma-ray sources detected by the Fermi Large Area Telescope}\\n8, 1,531, 2009.5
\end{array}\]

\[\begin{array}{c}
\text{Data from Hinode (Solar-B) Solar Optical Telescope and Solar Dynamics Observatory (SDO)}\\n24, 3,023, 2009.4
\end{array}\]

\[\begin{array}{c}
\text{Supernova Type Ia light curves and dark energy}\\n19, 5,920, 2009.2
\end{array}\]

Source: Thomson Reuters Essential Science Indicators
CROSS-DISCIPLINARY EXAMPLE III: JLAB-NEUTRINO

Using electron scattering to assess bias and inform base-line calculations for oscillations and new-physics searches

$\nu_{\mu}$ Flux - DUNE Far Detector

$E_{\nu}$ [GeV]

Oscillated $\nu_{\mu} / n_{\mu} / n_{\mu}^2$ POT (GeV)

$56^{\text{Fe}}$

$E_{\text{rec}}$ [GeV]

$E_{\text{Cal}}(e,e'p)$

$E_{\text{QE}}(e,e')$

$E_{\text{QE}}(e,e'p)$

$2.26 \text{ GeV}$

DUNE oscillation prediction
Training the next generation of scientists (undergraduates)

**Derek Boylan** – construction of test setup and characterization of large diameter PMTs, now project engineer at Cerillo, developing biomedical instrumentation

**Katya Gilbo** – conceptual design studies for the Neutral Particle Spectrometer, now graduate student in biomedical engineering

**Salim Roustom, Abigail McShane, Dannie Griggs** – Neutral Particle Spectrometer component characterization (NSF MRI) and simulation studies for pion and kaon structure function experiments (NSF REU)

“Working with CUA’s Nuclear Physics group as a summer intern was an absolutely amazing experience…and I came out with much more knowledge of nuclear physics than I came in with. My love for nuclear physics has been solidified in the past few weeks, and I can’t wait to learn more about it during my college education.”

It has been a privilege to work with you and the Nuclear Physics Group. I never would have imagined that I would have had the opportunity to work on the front lines of Physics research just out of high school. I am thankful for not only the hands-on experience of both the experimentation and simulation aspects of the research, but also for the chances to present my own work at the APS conferences.
Recent JLab Alumni Benefiting Society

Steven Avery
PhD 2002, Hampton
Based on JLab/Hall C project
Associate Professor of Radiation Oncology

Rebecca Bradford
PhD 2005, CMU
Based on JLab/Hall B project
Postdoc at U. of Rochester
ANL Staff Scientist

Hospital of the University of Pennsylvania.
Works on small animal radiation research and on quality assurance and safety in proton therapy treatment delivery. Also works as adjunct professor at the Physics Department, and on D&I of underrepresented groups in physics.

National Oceanic and Atmospheric Administration (NOAA). Works on terrestrial gravity measurements, used both for geodesy and for practical applications like mineral locations and elevation measurements, correcting for general relativity effects on earth. Member of the National Geodetic Survey.

Advanced Photon Source at Argonne National Lab. Leads ANL efforts to develop specialized x-ray detectors for scientific applications. The synchrotron x-ray sources provide intense x-ray beams, facilitating a host of investigational techniques for nearly every field in science and engineering. While a postdoc, managed construction and installation of MINERvA detector at Fermi National Lab.

Derek Van Westrum
PhD 1998, Colorado
Based on JLab/Hall C project
Geodesy Subject Matter Expert

Rebecca Bradford
PhD 2005, CMU
Based on JLab/Hall B project
Postdoc at U. of Rochester
ANL Staff Scientist
Jefferson Lab Users Organization - Perspective on the status of the lab

- 12 GeV Science fully operational
  - Completed 12 GeV Upgrade Project
  - Commissioned Hall B
  - All four Halls are running physics simultaneously
  - 12 GeV papers are being published
  - Large cohort of students, post-docs, and faculty ready to run. Years of detectors and analysis prep-work.

- Very positive developments in FY18
  - 16 weeks of beams in FY17, 22 weeks in FY18 and 28 weeks in FY19: more topics not just more statistics.
  - Improved beam delivery and execution of the lab Reliability Plan
  - Proposal for investment in cryogenic infrastructure
How can NSF continue to support research at JLab

- Strengthen research budget to support careers of graduate students, post-docs, young faculty and user groups at JLab.

- Provide flexibility and support for creative projects that are not part of DOE long term plans.

- Support R&D through MRIs and NSF Career Awards.

- Provide undergraduates and the community at large with exposure to research performed locally, nationally and internationally thanks to its support of local university groups.
Spare
JLUO Board of Directors (JLUO BoD)

- **Community building**: Encourage and assist scientists and engineers in the use of the Continuous Electron Beam Accelerator Facility

- **Representation the JLab Users** in front of JSA, the JLab Management, and outside stakeholders

- **Outreach**: promote the most effective utilization of CEBAF for the common good and welfare of society