Jefferson Lab

3rd Topical Workshop on Lattice Hadron Physics (LHP06)

Roy Whitney, CIO
Operation of a Unique User Facility Enables Forefront Science

Superconducting radiofrequency (SRF) cavities undergo vertical testing.

Cryomodules in the accelerator tunnel

An aerial view of the recirculating linear accelerator and 3 experimental halls.

CEBAF Large Acceptance Spectrometer (CLAS) in Hall B
Jefferson Lab at a Glance – Basic Facts

• Managed for DOE by new M&O contractor, Jefferson Science Associates under a cost reimbursable award-fee contract (awarded April 2006)
• ~630 employees, with 37% having advanced degrees, including 134 with Ph.D.s
• International community of more than 2,000 users
• Program-dedicated laboratory with funding of ~$90.7M as follows (FY06):

  - DOD $8M (FEL)
  - State of VA $1.6M
  - ILC $1.4M
  - Safeguards & Security $1.1M
  - SciDAC (LQCD, PPDG) $0.7M
  - Nuclear Physics $77M
  - Other (Imaging, Education, etc.) $0.9M
Since Inception

• Form factors
  - $G_E/G_M$, other n and p form factors
  - Modification of proton form factor in $^4\text{He}$.... new measurements to come

• Measurement of spin dependent structure functions, including:
  - $g_{1n}$ zero crossing seen for the first time
  - Measurement of Bjorken sum-rule vs $Q^2$ - conformal behavior at low $Q^2$

• Studies of precocious scaling/duality to low $Q^2$

• Confirming strong short distance correlations in nuclei

• High energy resolution in a new approach to hyper-nuclear spectroscopy.... new types of states can be studied

• Semi-inclusive deep inelastic scattering in Hall C, a tool to explore flavor dependence of spin dependent parton distributions
The Future - The 12 GeV Upgrade Will Enable Breakthrough Research in Four Areas

• The experimental study of the confinement of quarks – one of the outstanding questions for 21st century science – why are quarks never found alone?

• Increase knowledge of the fundamental quark-gluon structure of the nuclear building blocks: the proton and neutron (3-D tomography of the nucleon and valence quark structure)

• Increase understanding of nuclei in terms of nucleons and the $N-N$ force and the QCD basis for that understanding

• Allow precision experiments with sensitivity to new physics beyond the Standard Model
Scope of the proposed project includes doubling the accelerator beam energy, a new experimental Hall and associated beamline, and upgrades to the existing three experimental Halls.

<table>
<thead>
<tr>
<th>Description</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of passes for Hall D</td>
<td>5.5 (add a tenth arc)</td>
</tr>
<tr>
<td>Max. Energy to Hall D</td>
<td>12 GeV (for 9 GeV photons)</td>
</tr>
<tr>
<td>Number of passes for Halls A/B/C</td>
<td>5</td>
</tr>
<tr>
<td>Max. Energy to Halls A/B/C</td>
<td>11 GeV</td>
</tr>
<tr>
<td>New Cryomodules</td>
<td>10 (5 per linac)</td>
</tr>
<tr>
<td>Central Helium Liquefier upgrade</td>
<td>9 kW (from present 4.5 kW)</td>
</tr>
</tbody>
</table>

Enhanced capabilities in existing Halls
New Capabilities in Halls A, B, & C, and a New Hall D

A

High Resolution Spectrometer (HRS) Pair, and specialized large installation experiments

B

CLAS upgraded to higher luminosity and coverage

C

Super High Momentum Spectrometer (SHMS) at high luminosity and forward angles

D

9 GeV tagged polarized photons and a $4\pi$ hermetic detector

JEFFERSON LAB

THOMAS JEFFERSON NATIONAL ACCELERATOR FACILITY

Operated by Jefferson Science Associates, LLC

for the U. S. Department of Energy

Office of Science

U.S. Department of Energy
Lattice QCD at Jefferson Lab

- Lattice QCD at Jefferson Lab is both a theory program and a platform (hardware and software) development program
- SciDAC is a key R&D vehicle

Develop infrastructure and tools
- Machine abstraction – enable portable code between clusters and custom and commercial hardware
- Numerical kernel optimization for high performance on specific platforms
- Libraries and tools for data analysis and sharing
- Prototype hardware for code development and architecture evaluation

- R&D Effort feeds greater LQCD Computing Project
## SciDAC Prototyping

Under the SciDAC-1 project, JLab evaluated and deployed a series of commodity technologies for optimized clusters for Lattice QCD.

<table>
<thead>
<tr>
<th>Year</th>
<th>Nodes Type</th>
<th>TF</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>16 node DEC Alpha + myrinet</td>
<td>0.015</td>
</tr>
<tr>
<td>2002</td>
<td>128 node Xeon + myrinet cluster</td>
<td>0.08</td>
</tr>
<tr>
<td></td>
<td>(64 nodes funded by JLab as matching)</td>
<td></td>
</tr>
<tr>
<td>2003</td>
<td>256 node Xeon + gigE mesh cluster</td>
<td>0.19</td>
</tr>
<tr>
<td></td>
<td>(128 nodes funded by JLab as matching)</td>
<td></td>
</tr>
<tr>
<td>2004</td>
<td>384 node Xeon + gigE mesh cluster</td>
<td>0.46</td>
</tr>
<tr>
<td></td>
<td>(128 nodes funded by JLab for theory group)</td>
<td></td>
</tr>
<tr>
<td>2005-6</td>
<td>140 node Pentium-D + infiniband</td>
<td>0.34</td>
</tr>
<tr>
<td></td>
<td>(70 nodes funded by JLab for theory group)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(this cluster later expanded to 280 nodes)</td>
<td>0.67</td>
</tr>
</tbody>
</table>
Current Clusters at Jlab

2003 – 3G Cluster
3D Gigabit Ethernet
fabric
256 2.67 GHz Xeons
190 Gflops sustained

2004 – 4G Cluster
5D Gigabit Ethernet
fabric
384 x 2.8 GHz Xeons
460 Gflops Sustained

2006 – 6N Cluster
Infiniband fabric
280 2.8 GHz Pentium-D
dual core nodes
670 Gflops Sustained

Over 1 Tflop/s Computational Capacity for Science
Performance per Dollar for Lattice QCD Applications

**Optimized LQCD Clusters**
- Commodity compute nodes (leverage marketplace & Moore’s law)
- Low latency, high bandwidth network to exploit full I/O capability

**Future clusters** will significantly extend scientific reach

- QCDSP
- JLab SciDAC Prototype Clusters
- BlueGene/L
- Vector Supercomputers, including the Japanese Earth Simulator

**Cluster Performance**

- 1990
- 2000
- 2010

- Mflops / $
National Lattice QCD Computing Project

This HEP + NP funded activity complements the SciDAC project by deploying large scale resources in support of Lattice QCD for a national user community.

2006 Analysis cluster at JLab

2006 Large cluster at FNAL (deploying Sept 06)

2007 Large cluster at JLab

2008+9 Large cluster at FNAL

The Lattice QCD Computing Project also funds the operation of the QCDOC and SciDAC prototype clusters as a coherent resource, with a single allocations committee.