Jefferson Lab
12 GeV UPGRADE

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OUTLINE

• Existing Jefferson Lab Facility
• Scientific Opportunities
• Jefferson Lab in 12 GeV Era
• Project – Cost & Schedule
• Construction Highlights & Status
• Summary
>1300 active member international user community engaged in exploring quark-gluon structure of matter.

Superconducting electron accelerator provides 100% duty factor beams of unprecedented quality, with high polarization at energies up to 6 GeV.

CEBAF’s delivery of beam with unique properties to three experimental halls simultaneously. Each hall offers complementary capabilities.
Highlights of the 12 GeV Science Program

• Explore the physical origins of quark confinement (GlueX)
• New and revolutionary access to the spin and flavor structure of the proton and neutron
• Discovering the quark structure of nuclei
• Probe potential new physics through high precision tests of the Standard Model
Gluonic Excitations and the Origin of Confinement

Does confinement occur through formation of string-like flux tubes between quarks? Test this via spectrum of gluonic excitations of exotic mesons.

With the 12 GeV CEBAF, a linearly polarized photon beam, and the GlueX detector, JLab will be uniquely poised to:

- discover these states,
- map out their spectrum, and
- measure their properties

FOM \((P^2 N_\gamma)\) peaks for \(M=2.5\) GeV and \(E_0=12\) GeV
New, comprehensive view of hadronic structure

Elastic Scattering
transverse quark distribution in Coordinate space

DIS
longitudinal quark distribution in momentum space

GPDs
The fully-correlated Quark distribution in both coordinate and momentum space

GPDs connect the charge and parton distribution
Quark Structure of Nuclei

- (Nucleons and Pions) or (Quarks and Gluons)?
- Not a simple convolution of free nucleon structure with Fermi motion
- In nuclear deep-inelastic scattering, we look directly at the quark structure of nuclei

12 GeV Upgrade Provides Substantially Enhanced Access to the DIS Regime with enough luminosity to reach the high-$Q^2$, high-$x$ region!
Measuring High-x Structure Functions

REQUIRES:

- High beam polarization
- High electron current
- High target polarization
- Large solid angle spectrometers

12 GeV will access the regime \(x > 0.3\), where valence quarks dominate.

Does \(A_1^n \rightarrow 1\) as \(x \rightarrow 1\) ?
Defining 12 GeV PHYSICS Program

Four Reviews: Program Advisory Committees (PAC) 30, 32, 34, 35

• 2006 through 2010

• Recent Charge:
  – Review proposals that will use base equipment for 12 GeV Upgrade
    – in top half of priority list for first 5 years of 12 GeV Operations
  – Review proposals that will require major new apparatus

• Results:
  – 32 experiments approved
  – 13 conditionally approved

  *Exciting slate of experiments for 4 Halls planned for initial five years of operation!*

• Future Plans:
  – 12 GeV PACs (a) Proposals, (b) Ranking
12 GeV SCIENCE CATEGORIES

- The Hadron spectra as probes of QCD
  (GlueX and heavy baryon and meson spectroscopy)

- The transverse structure of the hadrons
  (Elastic and transition Form Factors)

- The longitudinal structure of the hadrons
  (Unpolarized and polarized parton distribution functions)

- The 3-D structure of the hadrons
  (Generalized Parton Distributions and Transverse Momentum Distributions)

- Hadrons and cold nuclear matter
  (Medium modification of the nucleons, quark hadronization, N-N correlations, hypernuclear spectroscopy, few-body experiments)

- Low-energy tests of the Standard Model and Fundamental Symmetries
  (Møller, PVDIS, PRIMEX, .....)

12 GeV CEBAF

Add 5 cryomodules

20 cryomodules

Add arc

20 cryomodules

Add 5 cryomodules

Two 1.1 GeV linacs

Upgrade magnets and power supplies

Enhanced capabilities in existing Halls

new Hall
Acceleration & Beam Transport

- Eight cavities are packaged into each cryomodule
  - 42 cryomodules in CEBAF today
  - 10 new ones will be added
    - high-performance, quadruple the gradient
- Each cavity has dedicated microwave source
  - 338 in CEBAF today
  - 80 new ones will be added
- Duplicate the existing cryogenics plant

Re-use almost all

- Upgrade or replace existing recirculation & transport elements
  - 357 major Dipoles (1-3m long)
  - 730 Quads (30x30x30cm)
  - >2000 power supplies
  - >700 beam diagnostics
  - >5 km of vacuum line

New

- Arc 10
  - 32 major dipoles (4m long)
  - 40 quads (35x30x30cm)
  - 81 power supplies
  - 32 beam diagnostics
  - 0.3 km of vacuum line
Hall D – exploring origin of **confinement** by studying **exotic mesons**

Hall B – understanding **nucleon structure** via **generalized parton 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. PV and Moller)
### SCOPE OF 12 GeV UPGRADE

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Present JLab</th>
<th>Upgraded JLab</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Halls</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Number of passes Halls A/B/C</td>
<td>5 (for max energy)</td>
<td>5 (for max energy)</td>
</tr>
<tr>
<td>Max Energy to Halls A/B/C</td>
<td>up to ~6 GeV</td>
<td>up to ~11 GeV</td>
</tr>
<tr>
<td>Number of passes to Hall D</td>
<td>New Hall</td>
<td>5.5</td>
</tr>
<tr>
<td>Energy to Hall D</td>
<td>New Hall</td>
<td>12 GeV</td>
</tr>
<tr>
<td>Current – Hall A &amp; C</td>
<td>max ~180 μA combined</td>
<td>max ~85 μA combined</td>
</tr>
<tr>
<td></td>
<td>(higher at lower energy)</td>
<td></td>
</tr>
<tr>
<td>Current – Hall B &amp; D</td>
<td>(B) Up to 5 μA max</td>
<td>(B, D) Up to ~5 μA max</td>
</tr>
<tr>
<td></td>
<td></td>
<td>each</td>
</tr>
<tr>
<td>Central Helium Liquefier (CHL)</td>
<td>4.5 kW</td>
<td>9 kW</td>
</tr>
<tr>
<td># of cryomodules in LINACS</td>
<td>40</td>
<td>50</td>
</tr>
<tr>
<td>Accelerator energy per pass</td>
<td>1.2 GeV</td>
<td>2.2 GeV</td>
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</table>

Routinely provide beam polarization of ~85% now, same in 12 GeV era
## DOE CRITICAL DECISION SCHEDULE

<table>
<thead>
<tr>
<th>Decision Point</th>
<th>Date</th>
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<tbody>
<tr>
<td>CD-0 Mission Need</td>
<td>MAR-2004 (A)</td>
</tr>
<tr>
<td>CD-1 Preliminary Baseline Range</td>
<td>FEB-2006 (A)</td>
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<tr>
<td>CD-2 Performance Baseline</td>
<td>NOV-2007 (A)</td>
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<tr>
<td>CD-3 Start of Construction</td>
<td>SEP-2008 (A)</td>
</tr>
<tr>
<td>CD-4A Accelerator Project Completion and Start of Operations</td>
<td>DEC-2014</td>
</tr>
<tr>
<td>CD-4B Experimental Equipment Project Completion and Start of Operations</td>
<td>JUN-2015</td>
</tr>
</tbody>
</table>

~15 months into 5.5 year construction period

CD-4 split to ease transition into operations phase
12 GeV TPC and Construction

Total Project Cost= $310M
Total Equipment Cost=$287.5M
12 GeV - $310M Total Project Cost

Start Construction
Oct 2008

ARRA
Advance Funding
$65M included

CD-4A
Dec 2014

CD-4B
June 2015
12 GeV Total Project Performance

(Budgeted Cost of Work Scheduled)
(Budgeted Cost of Work Performed)
(Actual Cost of Work Performed)

Corresponds to 1 month behind schedule.
Project has 12 months of remaining float.
12 GeV UPGRADE SCHEDULE

- 6-month installation May-Oct 2011
- 12-month installation May 2012-May 2013
- Hall A commissioning start October 2013
- Hall D commissioning start April 2014
- Halls B and C commissioning start October 2014
- Project Completion June 2015
CONSTRUCTION HIGHLIGHTS

• Accelerator Major Procurements:
  – cryomodule cavities; beam transport magnets; helium refrigerator

• Accelerator Installation Start: Dec ‘09 to Jan ‘10
  – Prep work:
    • RF zones
    • baseplates
    • stands
    • alignment

Core of 4m Dipole Magnet at Vendor

Beam Transport Quadrupole Magnets at JLab
PHYSICS EQUIPMENT

• Major contracts awarded:
  – 3 superconducting spectrometer magnets
  – Hall D Barrel Calorimeter detector construction (Univ of Regina)

• Major contracts in progress
  – Hall C Horizontal Bend spectrometer magnet (MSU NSCL)
  – Hall D Central Drift Chamber (Carnegie Mellon)
  – Hall D Forward Calorimeter (Indiana University)
  – Hall B Drift Chambers (Old Dominion; Idaho State)
PHYSICS EQUIPMENT CONSTRUCTION

Hall B – PCAL Test Extrusions w/ Optical Fibers

Hall C Superconducting Magnet Coil

Hall D – Forward Drift Chamber in Test Stand
PHYSICS EQUIPMENT CONSTRUCTION

Hall B – Region II Drift Chamber Frame Assembly

Hall D – Barrel Calorimeter Module

Hall C – Wire Stringing Jig for Drift Chamber
CONSTRUCTION HIGHLIGHTS

PHYSICS EQUIPMENT

Strong university User involvement

Two NSF MRI grants
- Hall B pre-shower calorimeter detector
  - William&Mary, James Madison, Norfolk State, Ohio Univ

- Hall C detectors
  - William&Mary, James Madison, Hampton Univ, NCA&T

International contributions/collaborators
- Hall C lead glass: NIKHEF and Yerevan
- Hall D: Univ of Regina (Canada); Santa Maria (Chile)
# Hall B CLAS12 International Collaborators

<table>
<thead>
<tr>
<th>COUNTRY</th>
<th>INSTITUTION</th>
<th>FOCUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>UK</td>
<td>Edinburgh Univ</td>
<td>Software</td>
</tr>
<tr>
<td>UK</td>
<td>Glasgow Univ</td>
<td>Central Detector</td>
</tr>
<tr>
<td>France</td>
<td>Grenoble Univ</td>
<td>Central Detector</td>
</tr>
<tr>
<td>France</td>
<td>Orsay – IN2P3</td>
<td>Central n Detector</td>
</tr>
<tr>
<td>France</td>
<td>CEA Saclay</td>
<td>Central Tracker</td>
</tr>
<tr>
<td>Italy</td>
<td>Bari</td>
<td>Future RICH</td>
</tr>
<tr>
<td>Italy</td>
<td>Catania</td>
<td>tbd</td>
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<tr>
<td>Italy</td>
<td>Frascati &amp; Fermi Ctr</td>
<td>Central n Detector</td>
</tr>
<tr>
<td>Italy</td>
<td>Genoa</td>
<td>Central n Detector</td>
</tr>
<tr>
<td>Italy</td>
<td>ISS/Rome</td>
<td>Future RICH</td>
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<tr>
<td>Italy</td>
<td>Rome Tor Vergata</td>
<td>Central n Detector</td>
</tr>
<tr>
<td>Russia</td>
<td>ITEP</td>
<td>Magnets</td>
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<tr>
<td>Russia</td>
<td>Moscow State HEP &amp; SINP</td>
<td>Silicon Tracker</td>
</tr>
<tr>
<td>Korea</td>
<td>Kyungpook Nat’l Univ</td>
<td>CD TOF</td>
</tr>
<tr>
<td>Armenia</td>
<td>Yerevan Physics Institute</td>
<td>Central Tracker</td>
</tr>
</tbody>
</table>

*as of September 2009*
Groundbreaking

Excavation

Civil Construction: Hall D Complex 2009-2010

Floor Slab

Walls
12 GeV Upgrade

• An exciting scientific opportunity
  – Explore the physical origins of quark confinement (GlueX)
  – New access to the spin and flavor structure of the proton and neutron
  – Discovering the quark structure of nuclei
  – Probe potential new physics through high precision tests of the Standard Model

• Cost effective plan re-uses most of existing facility

• Strong User community involvement
  – NSF MRI funding to universities for detector elements
  – Strong international collaborations

• Project performance within DOE thresholds

• Construction is well underway!
  – Accelerator commissioning will start May 2013
  – Hall commissioning starts Oct 2013 through Oct 2014
  – Project completion by June 2015