Hall B Status

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Jefferson Lab

CLAS Collaboration Meeting
July 24, 2003

Run status
Publication status
PAC24, S&T Review
Hall B Run Plan
Status of equipment projects
2003/2004 Run Schedule
CLAS – The first 5 years
Energy upgrade
Hall B Status Overview

- Completed 5+ years of physics running

- 20 major CLAS production runs completed
  - e1a/b, g1a/b, g6a, e1c, e2a, g6b, g2a, g1c, g3, e1d, e5, eg1b, g8a, g6c, e1-6, e6, e2b, g7, e1e, e1f/g (in progress) (+2 non-CLAS experiments: g5, radphi)

- Publications
  - 15 technical papers published (latest: NIM paper on CLAS)
  - 20 physics papers published/accepted in PRL, PRC, PRD
  - 5 submitted
  - 5 in collaboration review

- Major effort to repair on-board electronics for all six region 3 axial super layers (suffering from corrosion). Problem recurring in areas where electronics have been partially replaced only.

- Preparations for approved experiments
  - PrimEx ($\pi^0$ lifetime measurement)
  - Deeply Virtual Compton Scattering (Probing GPDs)
  - BoNus Experiment (Neutron Structure Functions with proton tagging)
  - Frozen Spin Target (Needed to search for missing resonances in hyperon production)
  - New Cerenkov counter for one CLAS sector (for small $Q^2$ GDH)
  - Polarimeter for linearly polarized photons
# Technical Publications

- **Torus Magnet**  
  IEEE Mag. 25 (1989) 1902

- **Drift Chambers**
  - construction: Mac Mestayer  
    NIM A323 (1992) 191
  - update: Mac Mestayer  
    NIM A367 (1995) 316
  - Region I: Dan Carman  
    NIM A419 (1998) 315
  - Region II: L.M. Qin  
    NIM A411 (1998) 265
  - Summary: Dan Carman  
    NIM A449 (2000) 81

- **Cerenkov Counter**  
  Paul Stoler  
  NIM A465 (2001) 414

- **TOF Counters**  
  Elton Smith  
  NIM 432 (1999) 265

- **Start Counters**  
  Simon Taylor  
  NIM A462 (2001) 484

- **Forward Cal.**  
  Cole Smith  
  NIM A460 (2001) 239

- **Large Angle Cal.**  
  Mauro Taiuti  
  NIM A447 (2000) 431

- **Tagging System**
  - window: Jim O’Brien  
    NIM 421 (1999)
  - tagger: Jim O’Brien  
    NIM 440/2 (2000) 263

- **Polarized target**  
  Chris Keith  
  NIM A501 (2003) 327

- **CLAS Overview**  
  Bernhard Mecking  
  NIM A503 (2003) 513
Hall B Physics Publications (PRL/PRC/PRD)

- 20 - published/accepted
- 5 - submitted
- 5 - in collaboration review

N* program – Exclusive Processes (15)

- η-Electroproduction in the S11(1535) region, PRL86 (2001) 1702
- Double Spin Asymmetry in ep->eπ^+n, PRL88 (2002) 082001
- N->Δ(1232) Multipoles from π^0 Electroproduction, PRL88 (2002) 122001
- η-Photoproduction on the Proton, PRL89, (2002) 222002-1
- Polarisation transfer in ep->eK^+Λ, PRL90,131804 (2003),
- Single Quark Transition Analysis of N* Excitations in [70,1-], PRC67, 035204 (2003)
- First measurement of beam-target spin asymmetry in ep->epp0, PRC accepted
- Measurement of σ_{LT^*} in the Δ(1232) region, PRC submitted , nucl-ex/0301012
- Evidence for an Exotic Baryon State with S=+1, PRL submitted, hep-ex/0307018
- Electroproduction of ep -> eπ^+ in the first and second resonance region, CLAS review
- Single Spin Asymmetry in ep -> eπ^+n, in the Δ(12232) region, CLAS review
- Electroproduction of K^+Λ/Σ from protons

N* program - Inclusive Processes (3)

- Inclusive double polarisation asymmetry, g_1, Γ_{1p}, PRL submitted
Hall B Physics Publications – cont’d

Hard Processes (8)

- $\phi$-Photoproduction at large t, PRL85 (2000) 4682
- $\phi$-Electroproduction, PRC63 (2001) 065205-1
- $K^+\Lambda(1520)$ Electroproduction, PRC63 (2001) 044601
- $\rho^0$-Photoproduction, PRL87 (2001) 172002
- Beam Asymmetry in DVCS PRL87 (2001) 182002
- Photoproduction of $\omega$ mesons at high t, PRL90, 022002-1 (2003)
  - Beam Single Spin Asymmetry in $ep\rightarrow e\pi^+X$ in the DIS kinematics, PRL submitted, nucl-ex/0301012
  - Deeply exclusive $\rho^0$ production, CLAS review

Nuclear Processes (4)

- Photofission of Heavy Nuclei, PRL84 (2000) 5740
- Photofission of Heavy Nuclei, PRC65, 044622 (2002)
- Nuclear Scaling in $A(e,e')$ at $x>1$, PRC accepted, nucl-ex/0301008
  - Two-Nucleon Momentum Distributions Measured in $^3$He(e,e’pp)n, CLAS review
<table>
<thead>
<tr>
<th>Paper</th>
<th>Physics</th>
<th>#citations &gt;20 (as of 07/22/03)</th>
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<tr>
<td>PRL 85 (2000) 4682</td>
<td>$\phi$-Photoproduction at high $t$</td>
<td>29</td>
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<tr>
<td>PRL 86 (2001) 1702</td>
<td><strong>Study of $S_{11}(1535)$ in $\eta$ electroproduction</strong></td>
<td>21</td>
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<tr>
<td>PRL 87 (2001) 182002</td>
<td><strong>Deeply Virtual Compton Scattering</strong></td>
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<tr>
<td>PRL 88 (2002) 182002</td>
<td>*<em>Multipoles from $\gamma^<em>N\Delta(1232)$ transition</em></em></td>
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<tr>
<td>Paper</td>
<td>Physics</td>
<td>#spires citations per month&gt;0.5</td>
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<td>PRL 85 (2000) 4682</td>
<td>$\phi$-Photoproduction at high t</td>
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<td>PRL 86 (2001) 86, 1702</td>
<td>$S_{11}(1535)$ in $\eta$ electroproduction</td>
<td>0.6</td>
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<tr>
<td>PRL 87 (2001) 172002</td>
<td>$\rho^0$-Photoproduction at high t</td>
<td>0.6</td>
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<td>PRL 87 (2001) 182002</td>
<td>Deeply Virtual Compton Scattering</td>
<td>3.5</td>
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<tr>
<td>PRL 88 (2002) 182002</td>
<td>Multipoles from $\gamma^*N\Delta(1232)$ transition</td>
<td>1.1</td>
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<tr>
<td>PRL 90 (2003) 22002</td>
<td>$\omega$-Photoproduction at high t</td>
<td>0.6</td>
</tr>
<tr>
<td>hep-ex/ 0301005 (2003)</td>
<td>SSA in SI DIS $ep \rightarrow e\pi^+X$</td>
<td>0.8</td>
</tr>
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</table>
Hall A, B, C: requested/awarded beam time ~ 3:1

**New CLAS Proposals:**

<table>
<thead>
<tr>
<th>Proposal</th>
<th>Physics</th>
<th>PAC days (48 days)</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>E-03-105</td>
<td>Pion photoproduction on polarized target</td>
<td>18</td>
<td>B+</td>
</tr>
<tr>
<td>E-03-113</td>
<td>Search for the Exotic S=+1 Baryon</td>
<td>30</td>
<td>A</td>
</tr>
</tbody>
</table>
Annual review of the laboratory performance

- Physics (including Hall B) received very high marks especially in the area of hadron structure

- Noted slower than hoped for results of the N* program => emphasizes need for stronger theory support in phenomenology

- Pre-proposal for N* Analysis Center to DOE received favorably
## Hall B Run Plan

<table>
<thead>
<tr>
<th>Run group</th>
<th>Run time</th>
<th>PAC rating</th>
<th>Target</th>
<th>Energy (GeV)</th>
<th>Electron polar.</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>e1g</td>
<td>10</td>
<td>A-</td>
<td>H₂</td>
<td>3</td>
<td>High</td>
<td>completes original e1</td>
</tr>
<tr>
<td>eg2a</td>
<td>33</td>
<td>B⁺</td>
<td>nuclear</td>
<td>4 - 6</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>PrimEx</td>
<td>22</td>
<td>A</td>
<td>nuclear</td>
<td>6.0</td>
<td>No</td>
<td>ECALs, ..</td>
</tr>
<tr>
<td>g2c</td>
<td>30</td>
<td>A</td>
<td>D2</td>
<td>3-4</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>e1-DVCS</td>
<td>60</td>
<td>A</td>
<td>H₂</td>
<td>6.0</td>
<td>High</td>
<td>Solenoid, crystal EC</td>
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</tbody>
</table>

**unscheduled (alphabetical order):**

<table>
<thead>
<tr>
<th>Run group</th>
<th>Run time</th>
<th>PAC rating</th>
<th>Target</th>
<th>Energy (GeV)</th>
<th>Electron polar.</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coherent ρ</td>
<td>50</td>
<td>A-</td>
<td>D₂</td>
<td>6.0</td>
<td>High</td>
<td>uses DVCS solenoid</td>
</tr>
<tr>
<td>eg1(γ)</td>
<td>22</td>
<td>B⁺</td>
<td>p</td>
<td>1.6-4.0</td>
<td>High</td>
<td>Frozen spin target</td>
</tr>
<tr>
<td>eg2</td>
<td>11</td>
<td>B⁺</td>
<td>nuclear</td>
<td>&gt; 5</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>g8</td>
<td>29</td>
<td>A-</td>
<td>H₂</td>
<td>4.2-4.5</td>
<td>No</td>
<td>Photon polarimeter</td>
</tr>
<tr>
<td>GDH (Low Q²)</td>
<td>20</td>
<td>A</td>
<td>p</td>
<td>1.2-4.0</td>
<td>High</td>
<td>New Cerenkov counter</td>
</tr>
<tr>
<td>Missing N*</td>
<td>38</td>
<td>A-</td>
<td>p</td>
<td>No</td>
<td>Frozen spin target</td>
<td></td>
</tr>
<tr>
<td>Neutron S.F.</td>
<td>25</td>
<td>A-</td>
<td>D₂ gas</td>
<td>4-6</td>
<td>No</td>
<td>Radial TPC</td>
</tr>
<tr>
<td>Σ unscheduled</td>
<td>195</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
DVCS Experiment

Superconducting solenoid: needed for shielding Möller electrons
PbWO₄ e.m. calorimeter needed for photon detection

- Solenoid under construction at SACLAY

![Diagram of solenoid and calorimeter](image)
DVCS - 100 crystal prototype for test run

Connexion board
APD / Preamplifier

Back frame
Support frame
Mother board + preamplifier
Connectors

Optical fiber system mounted on the front frame
Alignement system + / - 5 mm
Fixing plate on the CLAS support

General view of the calorimeter

Ph. Rosier, Orsay
DVCS Experiment

- **PbWO₄ crystal calorimeter**
  - 440 tapered crystals, APDs, on site (ITEP, JLab)
  - Mechanical structure in final design stage (Orsay)
  - Preamps - designs being evaluated (ITEP, Orsay)
  - 5 x 5 crystal prototype built and being tested
PrimEx Experiment

Purpose: Precise measurement of the $\pi^0$ lifetime using the Primakoff process.

Hybrid Calorimeter (HyCal)
Needed to reconstruct $\pi^0 \rightarrow \gamma\gamma$ events

Status:
- Engineering design completed
- All PbWO$_4$ crystals and Pb-glass blocks at JLab, being assembled
- Plan for cosmic ray testing in August
- Readiness review in 11/03
- Installation in Hall B in 01/2004

Test stacking of PbWO$_4$ crystals
PbWO₄ crystal channel

Electron beam test results

Energy Resolution

- 1X1 $\Delta E/E = 3.4\%$
- 3X3 $\Delta E/E = 1.6\%$
- 6x6 $\Delta E/E = 1.3\%$

Energy Resolution Table:
- $\chi^2$/ndf: 86.02 / 31
- Constant: 194.4
- Mean: 4.290
- Sigma: 0.557E-01
Frozen Spin Target

- Needed for Search for missing N* in pion and kaon photoproduction, Experiment E-02-112, F. Klein et al., E-03-105, S. Strauch et al.

Work by Target group (Chris Keith, et al.)

- Polarizing magnet ordered, estimated delivery: Feb. 2004
- Longitudinal holding magnet; prototype constructed – being tested
- Transverse holding magnet: prototype for “racetrack” design completed
- Design for dilution refrigerator 50% completed, construction underway.
BoNuS Detector

- **Radial Time Projection Chamber (RTPC)**
  
  (needed for experiment E03-012; S. Kuhn, et al.)
  Goal: detect spectator protons with momenta as low as 70 MeV/c

- Cylindrical prototype with GEM readout being developed by Howard Fenker
- Flat GEM prototype has been built and is being tested
Gas Cherenkov Counter, INFN Genova

- Needed for E-03-106 (GDH Integral at very low $Q^2$), M. Ripani, et al.
Photon Beam Polarimeter

Needed for g8 run group, and follow-up measurements with linearly polarized photon beams.

Status:
- mechanical layout on the beam line completed
- detector box constructed
- target box which holds the microstrip and motion mechanism on order
- VME/PC part of readout, software is operational
<table>
<thead>
<tr>
<th>Date Range</th>
<th>Experiment</th>
<th>Energy Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>07/09 - 07/29/03</td>
<td>e1g p(e,e’X)</td>
<td>3.3 GeV</td>
</tr>
<tr>
<td>08/01 - 08/29/03</td>
<td>eg2 A(e,e’X), A(γ,X)</td>
<td>4.7-5.5 GeV</td>
</tr>
<tr>
<td>09/02 - 10/16/03</td>
<td>Accelerator and Hall maintenance, DC electronics repair Region 3, PRIMEX installation, Polarized target magnet installation for DVCS test</td>
<td></td>
</tr>
<tr>
<td>10/17 - 10/26/03</td>
<td>DVCS Tests</td>
<td>5.0 GeV</td>
</tr>
<tr>
<td>10/26 – 10/30/03</td>
<td>Remove polarized target magnet</td>
<td></td>
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<tr>
<td>10/31 - 12/24/03</td>
<td>eg2 continued</td>
<td>4-5 GeV</td>
</tr>
<tr>
<td>01/04 - 02/12/04</td>
<td>PRIMEX Installation &amp; commissioning</td>
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<tr>
<td>02/18 – 04/25/04</td>
<td>g2c</td>
<td>4.0 GeV</td>
</tr>
<tr>
<td>04/27 – 05/24/04</td>
<td>PRIMEX</td>
<td>5.5 GeV</td>
</tr>
<tr>
<td>05/25 – 06/30/04</td>
<td>DVCS Installation &amp; DC maintenance</td>
<td></td>
</tr>
<tr>
<td><strong>Tentative</strong></td>
<td></td>
<td></td>
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<tr>
<td>07/</td>
<td>PRIMEX</td>
<td>5.5 GeV</td>
</tr>
<tr>
<td>08/ -</td>
<td>DVCS</td>
<td>6.0 GeV</td>
</tr>
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</table>
CLAS
the first
5 years
- Establish relevance of the 2-gluon exchange contribution for $\phi$ production at high transverse momentum

- $u$-channel contributions near kinematic limit
The first 5 years

The pS11(1535) transition form factor shows a very slow fall off with $Q^2$.

Indicative of a resonance transition involving a small quark core.
The first 5 years

DVCS and GPDs

Charge density distributions for u-quarks at different quark momentum fractions $x$
Nucleon pion cloud responsible for large part of $\Delta$ deformation.
The scaling behavior in the $Q^2$-dependence observed for different orders $n$ in the Nachtmann moments, is interpreted as “elastic” scattering off CQs with radius ~ 0.2-0.3 fm.
The first 5 years  N*’s in $2\pi$ production

Do you discover a missing N* state or drastically change our understanding of a known state?

|Q^3>

or

|Q^2Q>

$Q^2=0.65\text{ GeV}^2$

$0.95\text{ GeV}^2$

$1.3\text{ GeV}^2$
The first 5 years

Nuclear Scaling

Ratio of inclusive cross sections for C-12 and He-3 at high $x_B$ show nuclear Scaling for the involvement of one, two, or three nucleons in the interaction.
The first 5 years

Good News about “Nothing”

The transferred $\Lambda$ polarization is maximal along the photon direction

CERN Courier On Target
$\Gamma_{1p}(Q^2)$ showing the importance of resonance contributions to the spin structure functions at medium and low $Q^2$. 

The first 5 years  

Nucleon spin structure
The first 5 years

N-N Correlations

2-nucleon knockout shows evidence for correlations in the np pair, which is not involved in the initial interaction. Correlations are evident at high relative momentum of the pair.
The first 5 years

Pentaquark

\[ \gamma D \rightarrow pK^-K^+(n) \]

\[ M_\Theta = 1542 \text{ MeV} \]
\[ \Gamma_\Theta < 20 \text{ MeV} \]

Co-discovery of a 5-quark Baryon with exotic quantum number, \( S = +1 \).
CLAS in the News

Jefferson Lab experiment yields evidence of exotic 5-quark particle

At the Conference on the Intersections of Particle and Nuclear Physics (CIPANP) held from May 19 to 24 in New York City, researcher Stephan Sopanen from the Department of Energy's Thomas Jefferson National Accelerator Facility (Jefferson Lab), located in Newport News, Va., revealed the most convincing evidence yet of a subatomic particle consisting of five quarks. He was representing his CLAS (CEBAF Large Acceptance Spectrometer) collaboration, a multi-national group of researchers, as he presented Jefferson Lab research supporting the existence of the "pentaquark."

For almost 40 years, all subatomic particles have fit neatly into two categories: three-quark baryons, like protons and neutrons; or mesons, made up of one quark and one anti-quark. The new particle spotted at Jefferson Lab is a sort of baryon-meson hybrid with five quarks - or, more precisely, four quarks and one anti-quark. The pentaquark is a member of the baryon family, but it's said to be "exotic" because the anti-quark has a different "flavor" to the other quarks.

There are six known flavors of quarks, three of which are studied at Jefferson Lab's Continuous Electron Beam Accelerator Facility (CEBAF). They are called up, down and strange quarks, with symbols u, d and s, respectively. The other three known flavors are charm (c), top (t) and bottom (b) quarks. Each of these six quarks also has a corresponding anti-quark.

With six quarks and six anti-quarks to choose from, one could think of many possible combinations of quarks. But not all of them can exist, according to the rules of Quantum Chromodynamics (QCD), the theory that describes the strong interactions between quarks. For instance, QCD forbids four-quark configurations, while the pentaquark that left its signature on the Jefferson Lab data is an allowed state. Physicists know from conservation laws that the only possible configuration for this new particle, dubbed Theta-plus, is two up quarks, two down quarks and an anti-strange quark (uudds-bar).

Preprint of CLAS Results available at LANL
http://arxiv.org/abs/physics/0307014

Related Press Coverage

• Quark to Pentaquark
  (July 7, 2003, Brianne Carlin)

• Physicists discover new form of matter
  (July 7, 2003, W睫毛)

• Pentaquarks! New Matter Discovered
  (July 7, 2003, Science NOW!)

• Five Alive!
  (July 3, 2003, Ecosia.com)

• Pentaquark discovery confounds skeptics
  (July 2, 2003, NewScientist.com)

• Scientists Report Discovery of a New Kind of Subatomic Particle
  (July 2, 2003, The Chronicle)

• New subatomic species found: Collision debris yields five-quark particle
  (July 2, 2003, Nature)

• Behold the pentaquark
  (July 2, 2003, BBC News)

• Physicists discover particle with five quarks
  (July 2, 2003, PhysicsWeb)

• Subatomic breakthrough announced by physicists
  (July 2003, Dallas Morning News)

• A Subatomic Discovery Emerges From Experiments in Japan
  (July 1, 2003, New York Times)

• New Matter May Have Been Found
  (July 1, 2003, Los Angeles Times)

• Japanese physicists’ "pentaquark" hints at answers to makeup of matter
  (July 2003, USA Today)

• "Pentaquark" hints at answers to matter

• Elusive pentaquark captured
  (June 30, 2003, MSNBC News)

• A Five-Quark State Has Been Discovered
  (June 30, 2003, Physics News Update)
CEBAF 12 GeV Upgrade

Congress: E&W Appropriations Requests for Nuclear Physics

HOUSE: $399.4M, increase of 17.5M
SENATE: $389.4M, increase of 7.5M

HOUSE: Wants additional $7.5M to increase operating time and enhance user support for facilities at BNL and at JLab, and asks DOE to make a prompt CD0 decision.

SENATE: The Committee supports the CEBAF at the Thomas Jefferson National Accelerator Facility and encourages the Jefferson Lab to increase operational time.... and begin work toward the 12GeV upgrade. ..,the Committee urges the Department to grant approval and include adequate funds in its fiscal year 2005 request to continue this process.”
Conclusions

Hall B and CLAS are doing well:
- Science results with potentially high impact
- Physics scope is broadening, largely based on data “mining”
  - CAA’s give us an advantage, as e.g. in DVCS,
    SSA in SIDIS, Pentaquark
  With so much data already on tape, this source should be exploited more systematically!
- Interesting instrumentation developments provide basis for future experiments (DVCS, BoNuS, Frozen Spin Target, ..)

But:
- We have many exciting projects, but a shortage of PhD students.
  Need good ideas how to make CLAS more attractive to students.
- Need to tackle the extraction of physics from more complicated processes, as e.g. presented in the N* program, in a systematic fashion. This has become a high priority for us and for the laboratory!

- Hardware problem still not fully resolved: Drift chamber electronics board corrosion