Status of Hall B

Volker D. Burkert

CLAS Collaboration Meeting
February 23-26, 2016
Hall B Overview

- **Personnel:** Nathan Harrison, new Postdoctoral Research Associate 1/19/2016
- **Solid flow of PhD theses, publications in refereed journals and conference talks**
  - 156 PhD theses completed on CLAS results (32 in progress)
  - 174 physics papers published/accepted in refereed journals (incl. higher level analysis papers based on CLAS data)
  - 38 technical papers published in NIM (25 CLAS, 12 CLAS12, 1 HPS)
  - > 1,875 talks at conferences (11 talks for every published physics paper)
- **Non-CLAS experiments**
  - HPS – Spring/2016 run started 2/5/2016
  - PRad – Preparations ongoing – March/April setup and tests, run scheduled for May 2016.
- **12 GeV upgrade project**
  - All base detector construction completed, CTOF undergoing final testing. Slow controls efforts strengthened.
  - Torus assembly nearly complete – survey & alignment ongoing, cryogenics next, plan for (limited) field mapping
  - Solenoid coil #5 (shielding) winding started
- **CLAS12 upgrades with collaboration driven equipment**
  - CND on site, to be tested this spring, FT assembly in EEL, MM - First barrel layers integrated with SVT
  - RICH detector on track for 2017 completion (1 sector)
  - Event reconstruction, calibration/commissioning effort making immense progress using cosmic rays for validation and detector calibration.
## Hall B  
### Physics Publications in refereed Journals

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<td>SUM</td>
<td>81</td>
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[updated 19 Feb 2016]
Conference Presentations

Source: CSC
updated 19 Feb 2016

Total: 1,875
PRad Status

- Mechanical design work is complete. Main installation to begin in March.

- The collimator box and windowless gas target installed on the beam line. (HPS beam passes through)

- Two GEM chambers have been built at UVA and delivered to JLAB. Readout is integrated into CODA.

- HyCal ready to run.

- Focus is development of software tools

- The final ERR is scheduled for 3/25

- The first commissioning beam scheduled for 4/8-10 followed by accelerator configuration change

- Physics run scheduled for May 1-28, contingent on non-interference with CLAS12
Physics run May 4 - 18, 2015 with 1.05 GeV beam energy

- Collected 2 PAC-days of physics data with SVT Layer-I at 0.5 mm from the beam plane ($\theta_{\text{min}} = 15$ mrad) at proposed run conditions - 50 nA beam current and 0.125 r.l W-target
- Pass4 processing of 10% of unblinded data for calibration and analysis is complete
- Analysis of benchmark reactions ($e^-e^-, e^-\gamma, e^-e^+, e^-A$) shows remarkable agreement with expected performance from simulations
- Ready for final processing of 100% of data.

### Mass Resolution

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<td>SVT occupancy</td>
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<td>Ecal rates</td>
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<tr>
<td>Pair vertex res.†</td>
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</table>

* At 34 MeV
† At 40 MeV
2016 Running

Physics Run on Weekends at 2.3 GeV
February 4 - March 14, 2016

- HPS Detector and Beamline are Fully Commissioned
  * Beam spot $\sigma_x \sim 200 \, \mu m$, $\sigma_y < 50 \, \mu m$
  * Ecal calibrated on Coulomb scattered electrons
  * Trigger/DAQ at 250 nA: 25 kHz, 85% Live Time
  * SVT commissioned and positioned 500 $\mu m$ from beams

- CEBAF delivers good beam stability

- Physics Production Running has begun February 21, 2016.
- Goal: 7 PAC Days at 2.3 GeV
CLAS12

Forward Detector (FD)
- TORUS magnet
- HT Cherenkov Counter
- Drift chamber system
- LT Cherenkov Counter
- Forward ToF System
- Pre-shower calorimeter
- E.M. calorimeter

Central Detector (CD)
- SOLENOID magnet
- Silicon Vertex Tracker
- Central Time-of-Flight

Beamline
- Cryo Target
- Moller polarimeter
- Shielding
- Photon Tagger

Upgrade to the baseline
- Central Neutron Detector
- MicroMegas
- Forward Tagger
- RICH detector
- Polarized target
Hall B in February 2016
Status of Hall B

**TORUS Magnet Installation**
All coils and connections installed in Hall B
- Pump down: Mar 2016
- Cool down (after ERR): April 2016
- Magnet ramp up: May 2016
- Field mapping: June 2016
- Drift Camber installation start: Aug 2016

**SOLENOID Magnet**
- 4 of 5 coils winding/potting complete,
- Shielding coil being wound
- Delivery of Magnet to JLab: 09/2016
- Expected to be operational: 12/2016
- Detector (CND, CTOF, SVT, MM): 12/2016

**Beam Line Instrumentation**
Commissioned during HPS run up to Faraday cup,
BPMs, harps, halo counters.
Moeller quad moved in position for 12GeV operation
Beamline shielding in final design stage

**Forward Carriage**
- FTOF1a, FTOF1b, PCAL and EC operational
- LTCC installation completed 2/23/2016
- FTOF Panel 2 installation is next
**High Threshold Cherenkov Counter**

**Purpose:** e/π sep.

**Radiator Gas (18.8 m³):** CO₂ (1 atm)

**Mirror thickness:** 135 mg/cm²

**Pion threshold:** 4.9 GeV/c

**Number of Channels:** 48

**Light readout:** 5” PMTs (Quartz)

**Construction completed:** 6/2015

**Calibration w/ LMS:** s.p.e.

**Coverage in θ & φ:** 5° – 35°, 360°

**Ready for installation:** ~7/2016
Purpose: Separate charged π’s from K/p
All 6 sectors completed, installed in CLAS12
- refurbished boxes, increase C₄F₁₀ volume
- recoated mirrors & Winston cones
- PMT windows coated w/ waveshifter

Typical before / after reflectivity of mirrors, WC

q.e. improvement with p-terphenyl
Knowledge of Tmax useful in monitoring DC conditions and performance, e.g. if gas density changes, Tmax will change.

Fit function:

\[ f(t) = (1 - \text{sigmoid}) \times \text{exponential} + \text{constant} \]

\[ f(t) = \left(1 - \frac{1}{1 + e^{A-Bt}}\right) \times e^{C-Dt} + E \]
Silicon Vertex Tracker

- SVT is integrated with Micromegas
- Both systems calibrated, no extra noise observed integration
- Cosmic alignment sample: 100M SVT and 20M SVT/MVT tracks collected

- Central tracker commissioning, taking cosmic 24/7
- Developing data validation and monitoring suite
- Validation of local and track reconstruction
- Monte Carlo tuning on the cosmic data
- SVT alignment using Monte Carlo and cosmic data
The two layers of the MicroMegas Vertex Tracker designed and built by the CEA team have been assembled at JLab for integration with the Silicon Vertex Tracker.
Micromegas Vertex Tracker

- Shipment of 2-layer barrel and 3-layer forward in 11/2015 at Jefferson Lab
- Integration with SVT (2x4 layers) went flawlessly
- Cosmic ray data taken since
- Analyzed barrel data so far
- Preliminary results encouraging (no optimization yet)

- Rest of the detector design is finished, all ordered from CERN
- Expect all detectors integrated at Saclay by the end of summer
- Mechanical structure for 6-layers expected before summer
- Final gas system expected before summer
- All electronics/cables are here
**Forward Tagger (FT)**

Detect electrons at small angle to perform quasi-real photo-production experiments.

**Calorimeter:** electron energy/momentum
Photon energy ($\nu = E - E'$), Polarization $\varepsilon^{-1} \approx 1 + \nu^2 / 2EE'$
PbWO$_4$ crystals with APD/SiPM readout

**Scintillation Hodoscope:** veto for photons, Scintillator tiles with WLS

**Tracker:** electron angles, polarization plane, MicroMegas detectors

- FT-Cal and FT-Hodo assembled and under cosmic ray test at JLab
- FT-Trk tested at JLab
- Full FT integration at JLab in spring 2016
- Developing common tools for monitoring and data analysis

**Energy distribution of cosmic muons in PbWO FT-Cal crystal**
CTOF Status

Counter Assembly:
- All counters assembled on storage carts
- Fiber mounting blocks for Light Monitoring System (LMS) installed

Calibration and Testing Status:
- Cosmic ray testing in progress since June 2015
  - Counter performance stable since extensive surface re-polishing last summer
- HV gain matching completed; detailed counter characterization in progress (PAW/FORTRAN)
  - Time resolutions measured (70 → 75 ps)
- Calibration suite (JAVA) under development
- Testing, optimization, controls, and calibration of the LMS to be completed this winter/spring
- Preparation of technical paper in progress

Design and Procurements:
- Upstream support structure delivered; test assembly/survey this spring
- Downstream support structure design in progress – completion by March 31
- Installation tooling/fixtures design in progress – completion by March 31
- LMS fiber bundle assembly ordered
Central Neutron Detector

Recent achievements:
• Construction completed
• Detector at JLab (ESB building) since 6/2015
• HV calibrations of PMTs completed
• Cosmic data analysis: $\sigma_t \sim 150$ ps for all blocks
• Assembly in mechanical structure done
• Development of calibration and reconstruction software ongoing

Plan for 2016:
• March-April: Cosmic rays tests at JLab to check time resolution and characterize the block using CLAS12 electronics
• June: ERR
• December: scheduled installation in the CD

Photos of the CND:
[Link to photos]
MAPMTs and ELECTRONICS
All 430 Hamamatsu MAPMTs delivered and tested at JLab. Procurement of the front-end electronics started.

MIRRORS
Production of the spherical and planar mirrors started. Delivery of the first mirrors is expected in March.

AEROGEL
Production of the first layer of large angle section is in progress. Completion is expected in March. Order of the second layer started.

MECHANICS
Construction of the RICH mechanical structure and of the frontal and electronic panels started. Assembling and installation procedures established.
**Main Team (Glasgow & JLab):** N. Baltzell, K. Livingston, B. McKinnon, W. Moore

- Biweekly meetings (8:30 on Fridays in L210A), minutes posted on wiki
- Gantt chart: [https://userweb.jlab.org/~baltzell/CLAS12/SC/SlowControlsPlan.oplx](https://userweb.jlab.org/~baltzell/CLAS12/SC/SlowControlsPlan.oplx)
- KPP, Full baseline support by summer’s end

**Framework:**
- UI: java-based CS-Studio
- OS: RHEL7
- Lots of sharing with Hall-D
- JLab Mya EPICS archiver and viewer
- BEAST alarm system inside CS-Studio
- Porting & improving/replacing CLAS6 software

**Recent Highlights:**
- Detector specific GUIs developed and in use (CTOF/FTOF/ECAL/PCAL/FTC)
- Hierarchical system, now navigable via tree view
- Hardware purchases this month (e.g. MYA Server, Cameras, Weather)
- Alarm system tested at end of 2015, to be deployed spring 2016
- Gas/Torus/Solenoid/Cryo EPICS interfaces in progress with DSG
- FTC Flasher support and GUI

**Upcoming:**
- Finish/deploy controls for next installed detectors (LTCC, DC, HTCC)
- Moller system, DAQ Integration, (selected) DISC/FADC scalers
- Off-site access in a web browser, etc.
- En route to KPP by end of summer 2016
**Central Vertex Tracker:** Development of central tracker package with new algorithms to employ micromegas hit information. SVT validation package to analyze cosmic and helical tracks at advanced stage.

**DC:** Hit-based tracking used to analyze cosmic data. Realistic inefficiencies in MC. Code optimization & ongoing validation tests using simulated physics events.

**HTCC:** Plugin now in full reconstruction chain (e-ID). Clustering and timing validated on MC.

**FTOF:** Matching of DC track to TOF panels. Updating time calculation to read TDC values from the database. Ongoing validation tests.

**EC/PCAL:** Implementation of attenuation correction. Calibration constants from database. Code optimization for iterations and calibration.

**FT:** FT-Calorimeter & FT-Hodoscope services available. Improved hodoscope clustering algorithm.

**Event Builder:** ~ realistic forward carriage detectors digitization allows for improved PID assignment and photon reconstruction.

[SVT:DC:HTCC:FTOF:ECRec:FT:EB chain of services in the next release (2.3)]
Data R/W development: raw data decoder & pulse fitter used to analyze cosmics
Advances in calibration (tools & implementation), plotting & fitting packages

Event monitoring SVT + BMT GUI connected to ET ring & currently running in SVT cleanroom

EC calibration GUI showing ADC profiles for strips and pixels. Each strip object contains pixels relevant for the calibration of that strip

Forward Tagger Calorimeter GUI used for commissioning with cosmic rays showing problematic channels that needs preamp replacement (black squares)
• Forward carriage DAQ electronics installation is almost complete, remaining electronics (VTPs) are ordered and will be installed within few months.
• Space Frame and Subway DAQ electronics installation in progress.
• Fiber Ethernet and trigger network complete.
• Counting room complete.
• DAQ software is operational, development continues.
• ECAL, PCAL and FTOF detectors are taking data; CTOF, DCRB, SVT, etc. tests.

DAQ rate in current HPS run. Expect similar performance for CLAS12 > 180MBytes/sec.
Design and engineering of the cryogenic system is ongoing by the JLab Target Group.

Procurement of the NMR, microwave, and pumping systems has been completed by CNU, UVa and ODU.

Optimization of the microwave cavity and waveguide for single and double cell designs is underway at JLab, CNU, and UVa.

Microwave sensitive film. Approximate size and location of proposed target samples.
Preparations for e+HD at the Upgraded Injector Test Facility

UITF ⇔ 10 MeV accelerator in the TestLab
- polarized, parity quality e⁻ beams
- energy deposition in HD ~ as with 10 GeV ⇔ testbed for transverse e+HD
- 1ˢᵗ MeV beams to Cave 2 by Sept/16
- beam on polarized HD by April/17

- e⁻ beam ionizes/unpairs 1s electrons of HD
  - should be inert if polarized
- UITF conditions adjusted to produce the same polarization of residual unpaired electrons (0.998) as in CLAS-12
- multiple scattering, $\vartheta \sim 1/\gamma$
  - power density not as uniform ~ 3 x higher than Hall B
## Run Group Schedule – Tentative

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CLAS12 assembly
SUMMARY

• CLAS data continue to deliver important science in many areas

• Heavy Photon Search experiment is taking data on weekends. Proton Radius experiment preparing for May 2016 run.

• All CLAS12 base detectors are complete, in testing with cosmic rays. CTOF in final testing.

• Superconducting Torus magnet on track for operation in June 2016. Solenoid expected to arrive in Sept/Oct 2016 for assembly with the cryogenic service tower.

• CLAS12 upgrade led by European collaborators (Central Neutron Detector, Forward Tagger (ECAL,HODO,MM), MVT, RICH) are well on-track, several detector components being assembled and tested at JLab.

• Software development on track to be ready on “Day 1” (9/2016). Planning for engineering and first physics run in 2017 underway (CLAS12 workshop 2/23)
Plans for first years of Beam in Hall B

Construction & Installation

< 6 GeV beam

Installation

Commissioning & early 11 GeV Experiments

5 A-rated experiments in early running: HPS, PRad, pDVCS, nDVCS, pSIDIS, $g_1^p/g_1^n$

pDVCS & GPDs
pSIDIS & TMDs
$N^*s$ & $M_q(p)$

nDVCS & GPDs
nSIDIS & TMDs
$F_2^n$

$g_1^p$, $g_1^n$ - large x spin structure

QCD in nuclei

CY 2015

CY 2016

CY 2017

CY 2018

CY 2019
M. McCracken et al., Search for baryon-number and lepton-number violating decays of Λ hyperons using the CLAS detector at JLab, PRD 92 (2015) 7, 072002.

D. Adikaram et al., Towards a resolution of the proton form factor problem: new electron/positron scattering data, PRL 114 (2015) 6, 062003

C. Colle et al., Mass dep. and Q.N. of SRC pairs from A(e,e'p) and A(e,e'pp), PRC 92, 024604, 2015

Or Hen, et al., Symmetry energy of nucleonic matter with tensor correlations, PRC 91, 025803, 2015

I. Senderovich et al., First measurement of the helicity asymmetry $E$ in η photoproduction on the proton, Phys.Letts. B755 (2016) 64

N. Guler et al., Precise determination of the deuteron spin structure at low to moderate Q2 with CLAS and extraction of the neutron contribution, PRC 92 (2015) 5, 055201.


H.S. Jo et al., Cross sections for the exclusive photon electro-production on the proton and GPDs, PRL 115 (2015) 21, 212003

S. Pisano, et al., Single and double spin asymmetries for deeply virtual Compton scattering measured with CLAS and a longitudinally polarized proton target, PRD 91 (2015) 5, 052014

E. Seder et al., Longitudinal Target-Spin Asymmetries for Deeply Virtual Compton Scattering, PRL 114, 089901 (2015)

I. Niculescu et al., Direct observation of $q$-$h$ duality in the F2n structure function, PRC 91, 055206 (2015).

G. Aznauryan et al., Electroexcitation of the $Δ(1232)3/2^-$ and $Δ(1600)3/2^+$ in a light-front relativistic quark model, PRC 92 (2015) 3, 035211

S. Strauch et al., First Measurement of the Polarization Observable $E$ in the $p(γ,π^+)n$ Reaction up to 2.25 GeV, PLB 750 (2015) 53

I.G. Aznauryan et al., Extracting meson-baryon contributions to the excitation of the $N(1675)5/2^-$ nucleon resonance, PRC 92 (2015) 1, 015203

K. Park et al., Measurements of $ep→e'π+n$ at $W = 1.6 - 2.0$ GeV and nucleon resonance electro-couplings at CLAS, PRC 91 (2015)
FTOF Calibration Update

Known Problems:
- S4b #7R (high PMT current)
- S5a #4L (bad dynode)
- S6a #21L (bad voltage divider)
- S6b #54L (high PMT current)

Calibration Runs: (S1 → S6)
- Check signal connectivity
- Check signal inverters (panel-1b)
- Complete HV gain matching
- Check for swapped cables
- Check counter functionality
- Test DAQ and electronics
- Collect data for calibration suite development
- Completed final functionality checks after torus spit removal and LTCC support install
- Check functionality after LTCC installation
- Preparing for FTOF panel-2 installation in Feb. 2016

Recent/Current Work:
- (4 out of 1080 channels) CLAS12

(4 out of 1080 channels)
• All trigger electronics installed except first stage boards (VTPs)
• Trigger algorithms development is in progress, primary goal is to deliver electron trigger (ECAL+PCAL+HTCC) by summer, with other detectors following
• Currently available: hit-based ECAL/PCAL trigger (used in cosmic runs in the hall), drift chamber hit-based segment finder (used in drift chamber test setup)
• TO DO: new VTP board production and commissioning (Ben Raydo, Sergey Boyarinov); VTP-based ECAL/PCAL algorithms development (Ben Raydo, Cole Smith, Sergey Boyarinov); all electronics testing (with Fast Electronics Group and CODA group involvement)
• DAQ+Trigger whole system commissioning during summer
• Forward Carriage DQA crates installed

• CLAS12 Trigger Fiber-Optic cabling installed in FWCR and Pie Tower

• Subway rack installation for DCs completed

• All DC boards received and all boards pass acceptance testing

• 20 VXS crates received
CLAS PhD Theses

Completed: 156  In progress: 32

updated 29 Dec 2015
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<td>Proton's quark dynamics in SIDIS pion production</td>
<td>Avakian</td>
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<td>E12-09-003</td>
<td>Excitation of nucleon resonances at high Q²</td>
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<td>Exclusive ϕ meson electroproduction with CLAS12</td>
<td>Stoler, Weiss</td>
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<td>Dihadron studies on long. polarized target</td>
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**TOTAL run time**: 1466 (1586) days
### C1 approved proposals & non-CLAS12

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<td>C12-11-006</td>
<td>Heavy Photon Search at Jefferson Lab (HPS)</td>
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<td>Beam time from approved CLAS12 experiments (from previous page)</td>
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<td>TOTAL Beam time for all Hall B experiments</td>
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Optimistically, we may run 90 PAC days per year. To run all experiments as run groups with full beam time will require 936/90 ≈ 10 years.
Run Group Publications

- **published / accepted**
- **submitted**

E1 (a-g) (26):

- K. Park et al., Measurement of \( p(e,e'\pi^+)n \) at \( 1.6<W<2.0\text{GeV} \) & \( N^* \) coupl. PRC 91 045203, 2015
- M. Mestayer et al., Flavor Dep. of \( \text{qq-bar} \) Creation Observed in the Exclusive Limit PRL 113, 152004, 2014
- M. Gabrielyan et al., Induced polarization of \( \Lambda(1116) \) in kaon electroproduction, PRC 90, 035203, 2014
- W. Gohn et al., Beam-spin asymmetries from semi-incl. pion elecvtprodution PRD89 072011, 2014
- H. Lu et al., First Observation of the \( \Lambda(1405) \) Line Shape in Electroproduction PRC 88, 045202, 2013
- M. Gabrielyan et al., Induced polarization of \( \Lambda(1116) \) in kaon electroproduction, PRC 90, 035203, 2014
- W. Gohn et al., Beam-spin asymmetries from semi-incl. pion elecvtprodution PRD89 072011, 2014
- H. Lu et al., First Observation of the \( \Lambda(1405) \) Line Shape in Electroproduction PRC 88, 045202, 2013
- D. Carman et al., Structure functions in \( K^+\Lambda \) and \( K^+\Sigma \) electroprod. at 5.5 GeV PRC87, 025204, 2013
- V. Mokeev et al., Study of P11(1440) and D13(1520) in \( p(e,ep\pi^+\pi^-) \) PRC86, 035203, 2012
- G. Gavalian et al., Beam Spin Asymmetries in DVCS with CLAS at 4.8 GeV PRC79, 015204, 2009
- G. Fedotov et al., Electroproduction of \( p\pi^+\pi^- \) at \( 0.2<Q^2<0.6, 1.3<W<1.57\text{GeV} \) PRC79, 015204, 2009
- H. Denizli et al., Polarized structure function \( \sigma_{LT}' \) for \( p(e,e'K^+)\Lambda \) in \( N^* \) region PRC77, 065208, 2008
- R. Nasseripour et al., Q\(^2\)-dependence of \( S_{11}(1535) \) & Evidence for P-wave resonance PRC76, 015204, 2007
- H. Denizli et al., Separated Structure Functions for \( ep\rightarrow e\Lambda/K\Sigma \) Final States PRC75, 045203, 2007
- P. Ambrozewicz et al., Electroproduction of single \( \pi^+ \) in \( ep \rightarrow ep^n \) PRC73, 025204, 2006
- H. Egiyan et al., \( \sigma_{LT}' \) for pion electroproduction in the Roper resonance PRC72, 058202, 2005
- K. Joo et al., \( \rho^0 \) electroproduction from hydrogen PL B 605, 256, 2005
- C. Hadjidakis et al., Measurement of \( \sigma_{LT}' \) for \( p(e,e'\pi^+)n \) in \( \Delta \) region PRC70, 042201, 2004
- K. Joo, et al., Beam spin asymmetry for \( p(e,e'\pi^+)X \) in DIS region PRD69, 112004, 2004
- H. Avakian et al., continues on next page
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### Run Group Publications

### E1(a-g) (26) cont’d:

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<th>Volume/Issue/Page</th>
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<tr>
<td>K. Joo et al.</td>
<td>Polarized structure function $\sigma_{LT}'$ in $\Delta(1232)$ region</td>
<td>PRC68</td>
<td>032201, 2003</td>
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<tr>
<td>M. Osipenko et al.</td>
<td>Kinematically complete measurement of $F_2$ in $N^*$ region</td>
<td>PRD67</td>
<td>092001, 2003</td>
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<tr>
<td>D. Carman et al.</td>
<td>First measurement of transferred polarization in $p(e,e'K^{+})\Lambda$</td>
<td>PRL90</td>
<td>131804, 2003</td>
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<tr>
<td>M. Ripani et al.</td>
<td>Measurement of $p(e,e'p\pi^+\pi^-)$ and baryon resonance analysis</td>
<td>PRL91</td>
<td>022002, 2003</td>
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<tr>
<td>K. Joo et al.</td>
<td>$Q^2$ dependence of quadrupole strength in $\Delta(1232)$ excitation</td>
<td>PRL88</td>
<td>122001, 2002</td>
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<tr>
<td>S. Barrow et al.</td>
<td>Electroproduction of the $\Lambda(1520)$ hyperon</td>
<td>PRC64</td>
<td>044601, 2001</td>
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<tr>
<td>S. Stepanyan et al.</td>
<td>First observation of exclusive DVCS in beam asymmetry</td>
<td>PRL87</td>
<td>182002, 2001</td>
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<tr>
<td>K. Lukashin et al.</td>
<td>Exclusive electroproduction of $\omega$ mesons at 4.2 GeV</td>
<td>PRC63</td>
<td>065205, 2001</td>
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<tr>
<td>R. Thompson et al.</td>
<td>The $p(e,e'p)\eta$ reaction at and above the $S_{11}(1535)$</td>
<td>PRL86</td>
<td>1702, 2001</td>
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<td>P. Khetarpal</td>
<td>Near threshold $\pi^0$ production at high $Q^2$ and generalized ff</td>
<td>PRC85</td>
<td>035208, 2012</td>
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<tr>
<td>K. Park et al.</td>
<td>Exclusive $n\pi^+$ production in the deep inelastic region</td>
<td>EPJA49</td>
<td>16, 2013</td>
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<tr>
<td>K. Park et al.</td>
<td>Generalized form factors at high $Q^2$ in $\gamma p\rightarrow n\pi^+$ near threshold</td>
<td>PRC85</td>
<td>035208, 2012</td>
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<td>I. Aznauryan et al.</td>
<td>Electroexcitation of $N^*$ in CLAS in pion electroproduction</td>
<td>PRC85</td>
<td>035208, 2012</td>
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<tr>
<td>D. Carman et al.</td>
<td>B-R Polarization Transfer in $N^*$ Region for $ep\rightarrow e'K^{+}\Lambda/\Sigma$</td>
<td>PRC79</td>
<td>065205, 2009</td>
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<tr>
<td>M. Osipenko et al.</td>
<td>Measurement of semi-inclusive $\pi^+$ electroproduction off protons</td>
<td>PRD 80</td>
<td>032004, 2009</td>
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<tr>
<td>S.A. Morrow et al.</td>
<td>Exclusive $\rho$ electroproduction on the proton at CLAS</td>
<td>EPJ A39</td>
<td>5-31, 2009</td>
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<td>J. Santoro et al.</td>
<td>Electroproduction of $\phi(1020)$ Mesons at High $Q^2$ with CLAS</td>
<td>PRC78:025210,2008</td>
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<tr>
<td>I. Aznauryan et al.</td>
<td>Electroexcitation of the Roper resonance in $ep\rightarrow e\pi^+$ at $Q^2&lt;4.5$</td>
<td>PRC78</td>
<td>045209, 2008</td>
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<tr>
<td>K. Park et al.</td>
<td>Cross section and beam asymmetries for $ep\rightarrow e\pi^+$ at $Q^2&lt;4.5$</td>
<td>PRC77</td>
<td>015208, 2008</td>
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<tr>
<td>M. Ungaro et al.</td>
<td>N$\Delta(1232)$ Transition at high Momentum Transfer</td>
<td>PRL97</td>
<td>112003, 2006</td>
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<tr>
<td>L. Morand et al.</td>
<td>Deeply virtual and exclusive electroproduction of $\omega$ mesons</td>
<td>EPJ A24</td>
<td>445, 2005</td>
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4/10/2016 CLAS collaboration meeting, JLab 2/23-26
### E2 (8):

- **H. Baghdasaryan et al.** Comparison forward/backward pp pair knockout in 3He(e,e’pp)n
  
  - PRL 85, 064318, 2012
- **H. Baghdasaryan et al.** Tensor correlations measured in 3He(e,epp)n
  
  - PRL105, 222501, 2010
- **M. Osipenko et al.** Nucleon structure function F2 in nuclear medium and moments
  
  - NPA 845, 1, 2010
- **K. Egiyan et al.** Measurement of 2-N and 3-N SRC Probabilities in Nuclei
  
  - PRL 96, 082501, 2006
- **D. Protopopescu et al.** $A_{LT}$’ in electron scattering on He-4 and C-12
  
  - NPA748, 357, 2005
- **A.V. Stavinsky et al.** Proton source size measurements in A(e,e’pp)X
  
  - PRL93, 192301, 2004
- **R. A. Niyazov, et al.** Two-nucleon momentum distribution in $^3$He(e,e’pp)n
  
  - PRL92, 052303, 2004
- **K. Egiyan et al.** Observation of nuclear scaling in A(e,e’) at $x_B > 1$
  
  - PRC68, 041313, 2003

### E1-DVCS (6):

- **H.S. Jo et al.** Exclusive Photon Electroproduction and GPDs
  
  - PRL 115, 212003, 2015
- **I. Bedluntsky et al.** Exclusive pi0 electroproduction at W>2 GeV with CLAS
  
  - PRC 90, 025205, 2014
- **I. Bedluntsky et al.** Exclusive pi0 electroproduction str. funct. and transversity GPDs
  
  - PRL 109, 112001, 2012
- **M. Aghasyan et al.** Precise measurements of beam spin asymmetries in $\pi^0$ SIDIS
  
  - PL B 704, 397, 2011
- **F. X. Girod, et al.** Deeply Virtual Compton Scattering Beam Asymmetries
  
  - PRL100, 162002, 2008
- **R. De Masi, et al.** Beam Asymmetries in Deeply Virtual $\pi^0$ Production
  
  - PRC77, 042201, 2008

### E5 (1):

- **J. Lachniet et al.** Precise measurement of the neutron magnetic form factor
  
  - PRL102, 192001, 2009

### E6 (3):

- **K. Egiyan et al.** Study of Exclusive d(e,e'p)n Reaction Mechanism at High $Q^2$
  
  - PRL98, 261502, 2007
- **A. Klimenko et al.** Deuteron s.f. with fast backward proton
  
  - PRC73, 035212, 2006
- **M. Osipenko et al.** Deuteron s.f. F2 in the resonance region & its moments
  
  - PRC73, 045205, 2006
EG1 (12):
- N. Guler et al., Deuteron Spin Structure and the Neutron Contribution
- H. Avakian et al., Spin asymmetries in SIDIS of pion prod. off long. pol. target
- Y. Prok et al., Moments of spin s.f. g_1^p and g_1^d for 0.05 < Q^2 < 3.0 GeV^2
- A. Biselli et al., First measurement of target asymmetry .. In the ep->epi0
- P. Bosted et al., N15/C12 Cross section ratios
- P. Bosted et al., Quark-Hadron Duality in Spin structure functions g_1^p and g_1^d
- V. Dharmawardane, Measurement of x- and Q^2 dependence of Asymmetry A1
- S. Chen, et al., Deeply Virtual Compton Scattering on Polarized Protons
- R. Fatemi et al, Proton spin structure function g_1(x, Q^2) for Q^2=0.15-1.6 GeV^2
- J. Yun et al., Measurement of inclusive spin S.F.’s of the deuteron
- A. Biselli et al., Polarized beam asymmetry for p(e,ep)π^0 in Δ(1232) region
- R. De Vita et al., First measurement of double spin asymmetry in p(e,e’π+)n

EG1-DVCS (3):
- A. Kim et al., Target and Double Spin Asymmetries for DVπ^0P on pol. target
- S. Pisano et al., Single and Double spin asymmetries for DVCS on pol. target
- E. Seder et al., Longitudinal target-spin asymmetries for DVCS
- Y. Prok, Precision measurement of g_1 of the proton and deuteron at 6 GeV

Run Group Publications

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- submitted
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<td></td>
<td>El Fassi, et al.</td>
<td>Onset of Color Transparency in $\rho^0$ production off nuclei</td>
<td>PLB 712, 326, 2012</td>
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<td>A. Daniel, et al.</td>
<td>Nuclear multiplicity ratio for $K^0_s$ hadronization at CLAS</td>
<td>PLB 706, 26, 2011</td>
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<td>EG3 (1):</td>
<td>H. Egiyan et al.</td>
<td>Upper limits for the $\phi^-(1860)$ production off the deuteron</td>
<td>PRC85,015205, 2012</td>
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### Run Group Publications

### E8-BoNuS (2):

- **S. Tkachenko et al.,** Measurement of nearly free neutron structure functions from ..
- **N. Baillie et al.,** Neutron F₂ structure function via spectator tagging

### G1 (14):

- **M. Dugger et al.,** π⁺ Photoproduction on protons at energies from 0.675 – 2.875
- **M. Dugger et al.,** π⁰ Photoproduction on protons at energies from 0.675 – 2.875
- **I. Hleiqawi et al,** Cross sections for γp→K*⁰Σ⁺ at E=1.7-3 GeV
- **R. Bradford et al,** Measurement of beam-recoil polarization in KΛ, KΣ
- **M. Dugger et al.,** η’ photoproduction on the proton
- **R. Bradford et al.,** Diff. cross sections of γp→ K⁺Y for Λ and Σ hyperons
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  - Region I: D. Carman, NIM A419 (1998) 315
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