

Hall-B Status Report

- News from Hall-B Group and Collaborations
- Research Output from Hall B

Patrick Achenbach

July 21, 2025



News from Hall-B Group and Collaborations



Hall-B Group

NEW APPOINTMENTS

- **New Bridge Appointment with Lamar University**
 - 5-year assistant professor position with Hall B

GROUPS IN HALL B

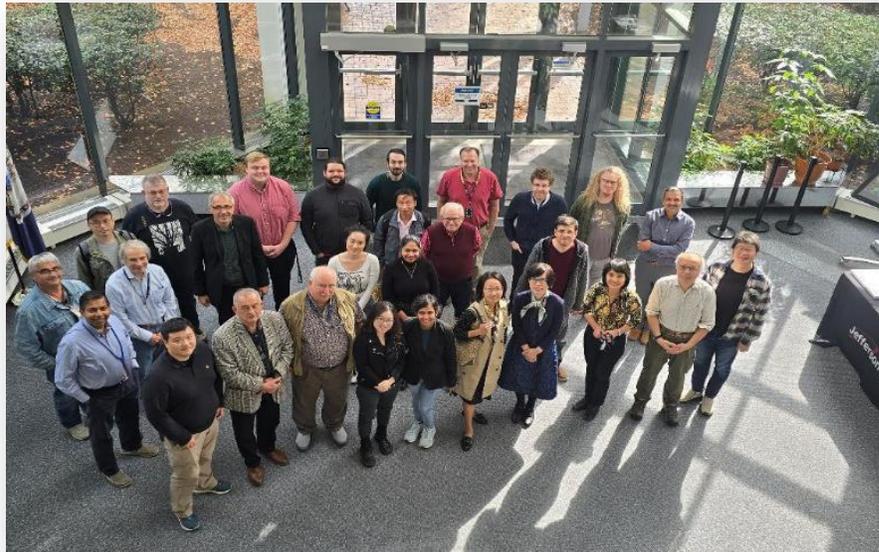
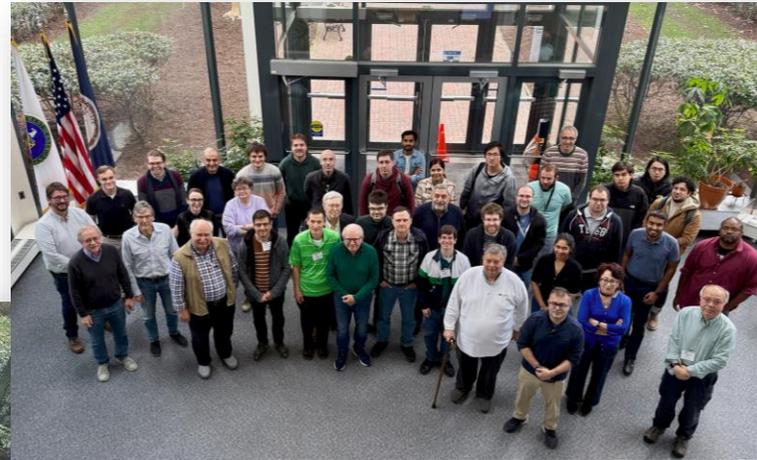
CLAS Collaboration:

HPS Collaboration (*not pictured*)

PRad Collaboration:

POSTDOCS

- **Pierre Chatagnon** left for CEA in Paris-Saclay
- **Bhawani Singh** started in Feb 2025
- **Richard Tyson** will leave in mid October



News from Hall-B Collaborations

CLAS COLLABORATION

- Collaboration meetings in Nov 2024, Mar 2025 and July 2025
- More than 200 members and new institutions joined
- **Bryan McKinnon from Glasgow U** elected as next chair
- **ALERT** detector installation in Nov 2024
- **~46 of 55 PAC days of DIS data taken** on track to complete in July
- **Expected to complete SRC data taking** by end of run



The ALERT detector is transported to its new home in Hall B.

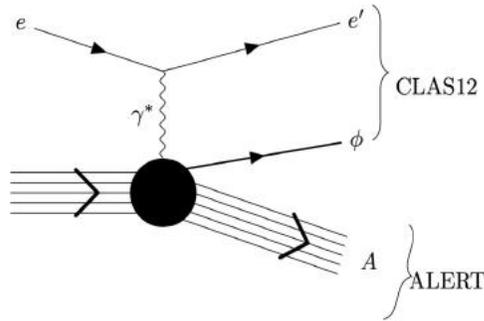
Proposal	Physics	Exp. Contact	Rating	Days	PAC	Jeop.	Group Days	Equipment	Energy	Group Contact	Target	Complete
E12-17-012	Partonic structure of light nuclei	Z. Meziani	A-	55	45		55	CLAS12; Forward Tagger; ALERT	11	L R. Dupré	Gaseous H, D, ⁴ He	completed
E12-17-012A	Tagged EMC measurements on light nuclei	R. Dupré			45							
E12-17-012B	Spectator-tagged DVCS on light nuclei	W. Armstrong			45							
E12-17-012C	Other physics opportunities with ALERT	R. Dupré			45							
E12-23-013	Measuring short-range correlations with ALERT	F. Hauenstein	A	17	51		17		6.6	F. Hauenstein (RG-T)		15 d scheduled

Physics Opportunities with ALERT

A Low Energy Recoil Tracker (ALERT)

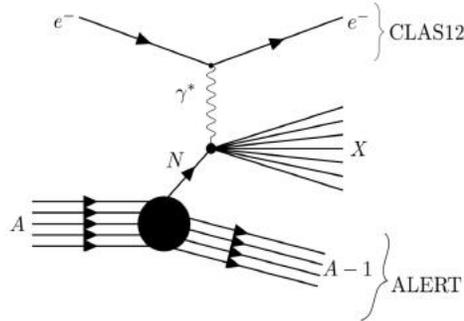
- Hyperbolic drift chamber
- Time-of-Flight array
- Target straw for H₂, D₂, and ⁴He

Measurement	Particles detected	p range	θ range
Nuclear GPDs	⁴ He	$230 < p < 400 \text{ MeV}/c$	$\pi/4 < \theta < \pi/2$ rad
Tagged EMC	p, ³ H, ³ He	$70 < p < 250 \text{ MeV}/c$	As close to π as possible
Tagged DVCS	p, ³ H, ³ He	$70 < p < 250 \text{ MeV}/c$	As close to π as possible



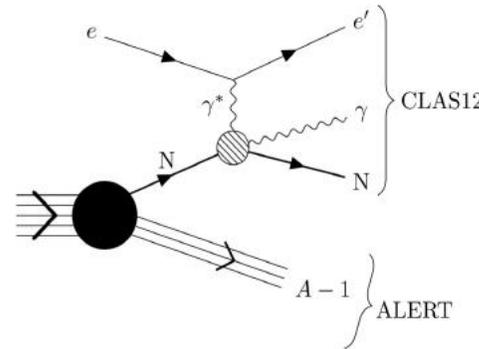
Coherent Processes on ⁴He

- ⁴He(e, e' γ)⁴He
- ⁴He(e, e' ϕ)⁴He



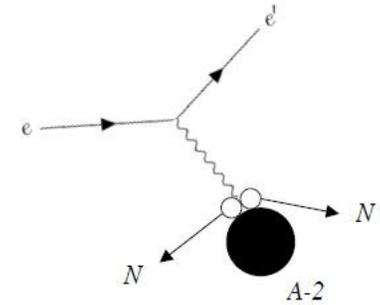
DIS on ⁴He and ²H:
Tagged EMC Effect

- ⁴He(e, e'³H)X
- ⁴He(e, e'³He)X
- ²H(e, e'p)X



Incoherent Processes
on ⁴He and ²H

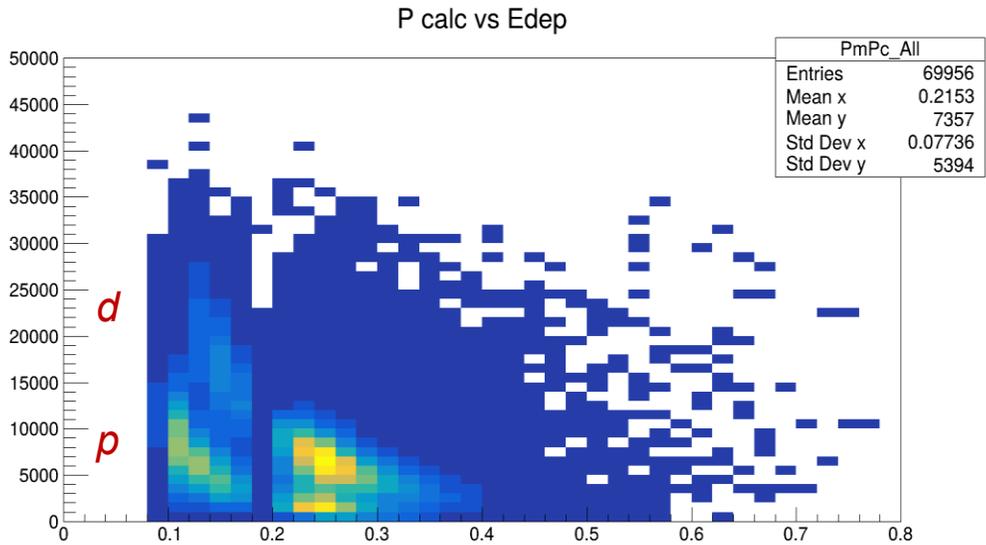
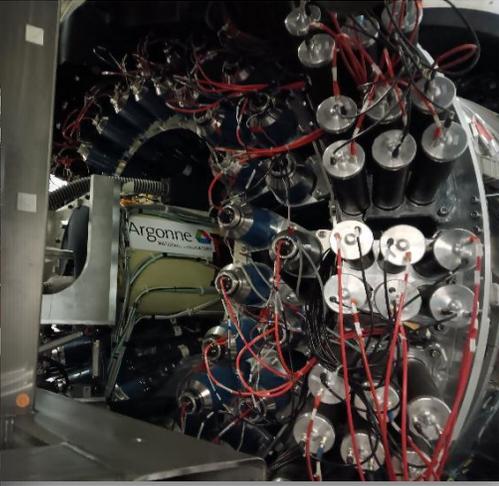
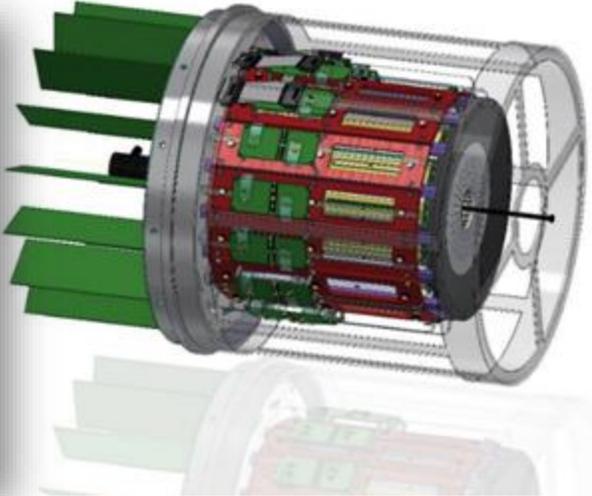
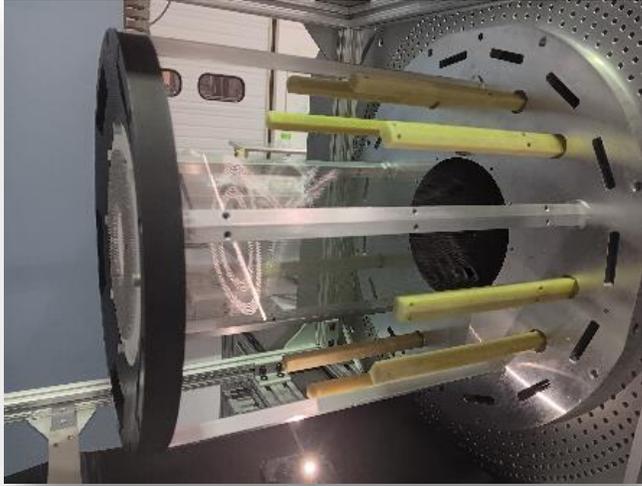
- ⁴He(e, e' γ p³H)
- ⁴He(e, e' γ ³He)n
- ²H(e, e' γ p)n



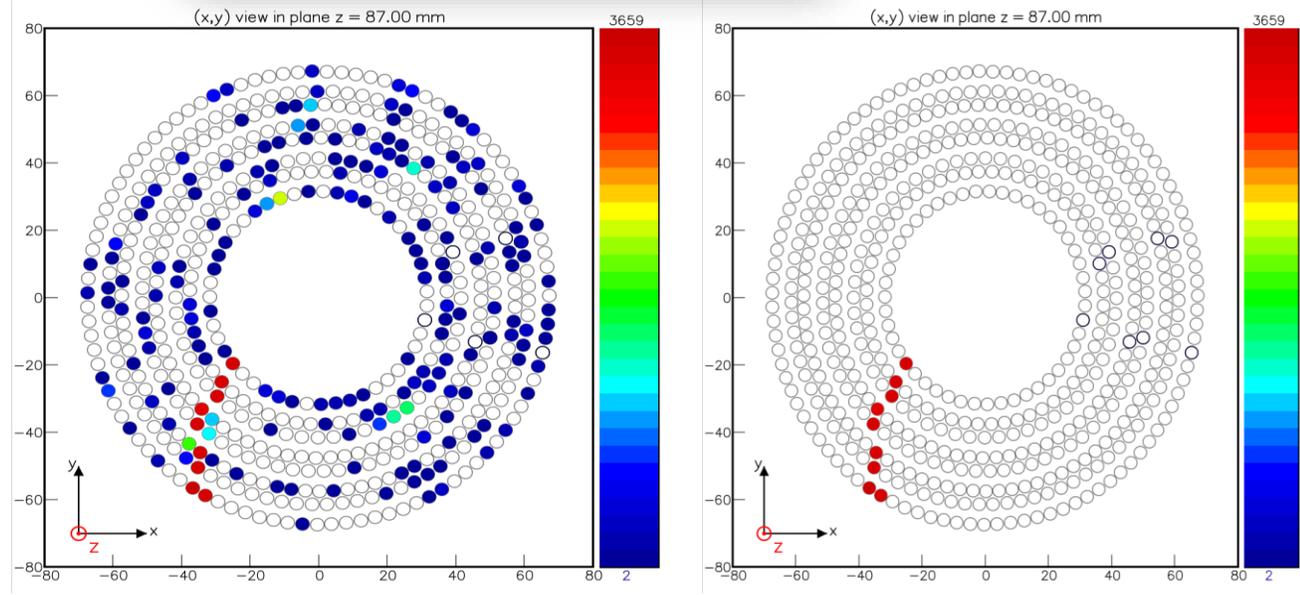
Short Range Correlations
on ⁴He

- ⁴He(e, e'pd)n
- ⁴He(e, e't)p
- ⁴He(e, e'p)

ALERT Detector Operation



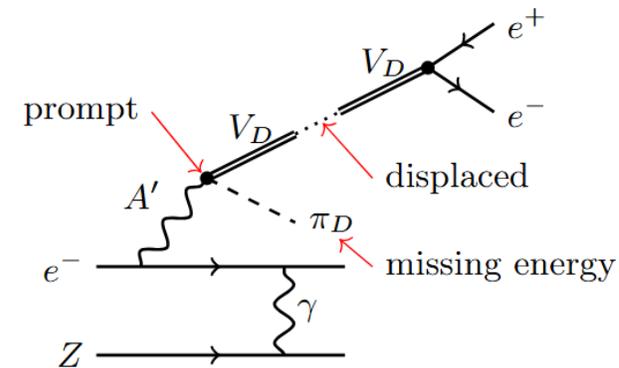
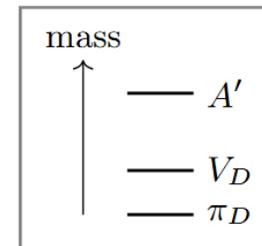
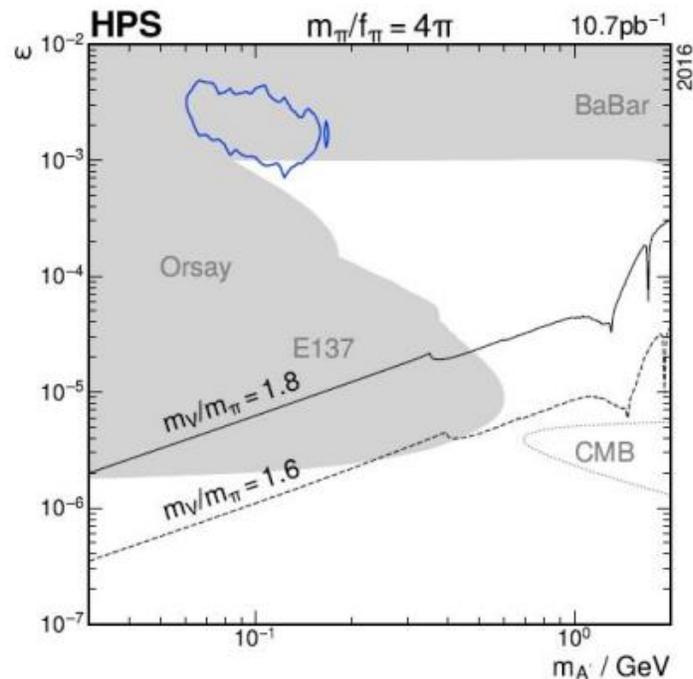
Energy loss vs. calculated momentum in ALERT



Hits with large ionization energy loss in AHDC

HPS COLLABORATION

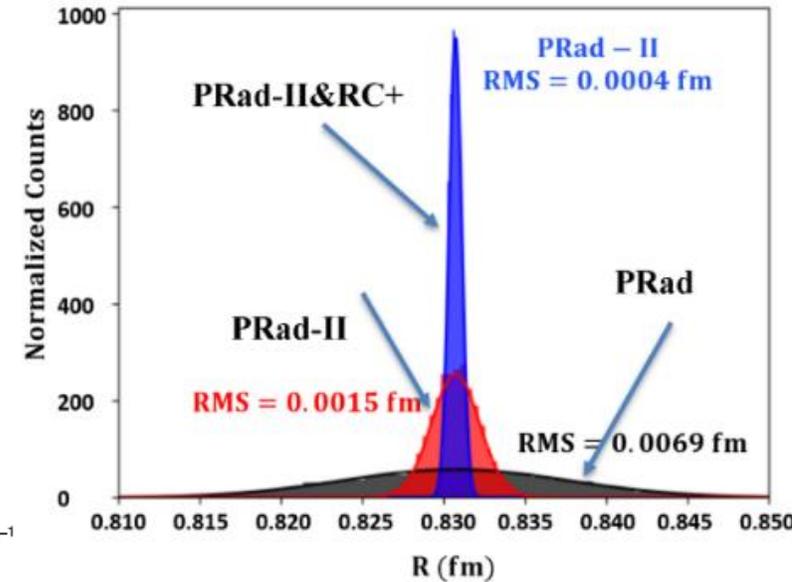
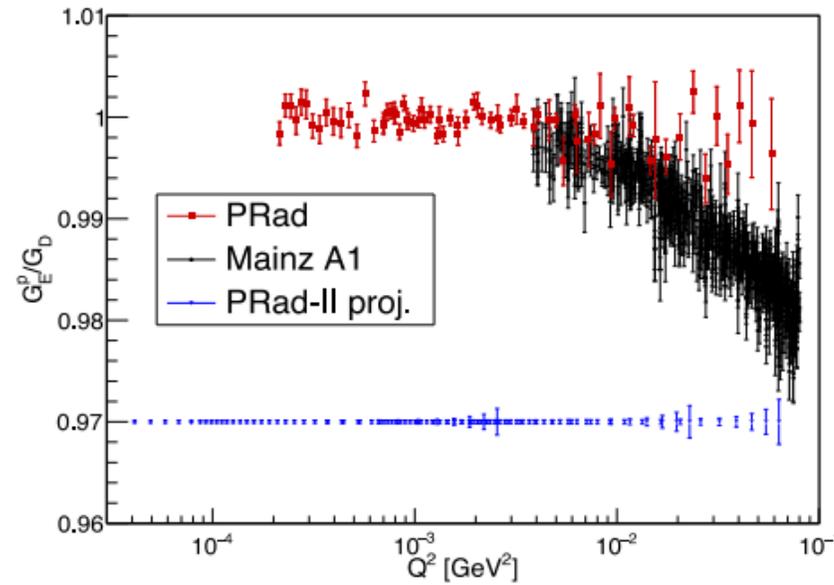
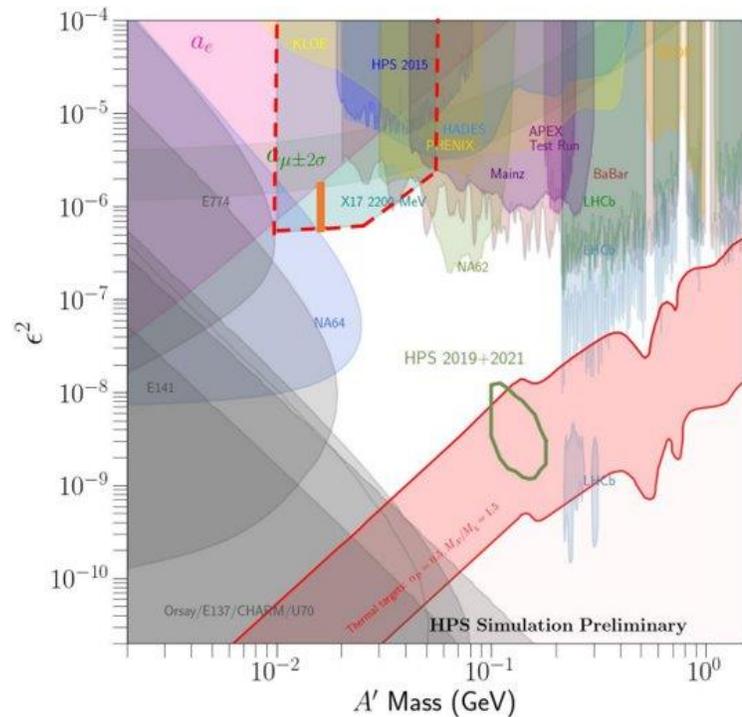
- Semi-annual collaboration meetings in Nov 2024 and June 2025
- **Reapproved in jeopardy hearing of PAC 52** with “A” rating and all originally approved 180 PAC days
- **Requested and planning 60 out of remaining 105 PAC days of 4.4 GeV running**
- Draft “*Displaced Vertex Searches for Electroproduced Strongly Interacting Massive Particles with the 2016 HPS Dataset*” based on analysis notes from **Alec Spellmann** and **Tom Eichlersmith**:



First search for strongly interacting dark sector particles

PRAD COLLABORATION

- Semi-annual collaboration meetings in Nov 2024 and March 2025
- Collaboration charter adopted in November 2024
- More than 60 members including new U.S. and international collaborators
- **Experimental Readiness Review for PRad-II/X17 on May 8–9, 2025**
- Updated projections for PRad-II/X17 runs:



PRad-II / X17 Instrumentation

- Preparations on track for the **installation of PRad-II/X17 setup during SAM 2025**
- **PRad-II** scheduled for completion of the experiment including non-standard beam energies
- **X17 Search** scheduled for ~50% of the experiment with one of two planned beam energies

HyCal:



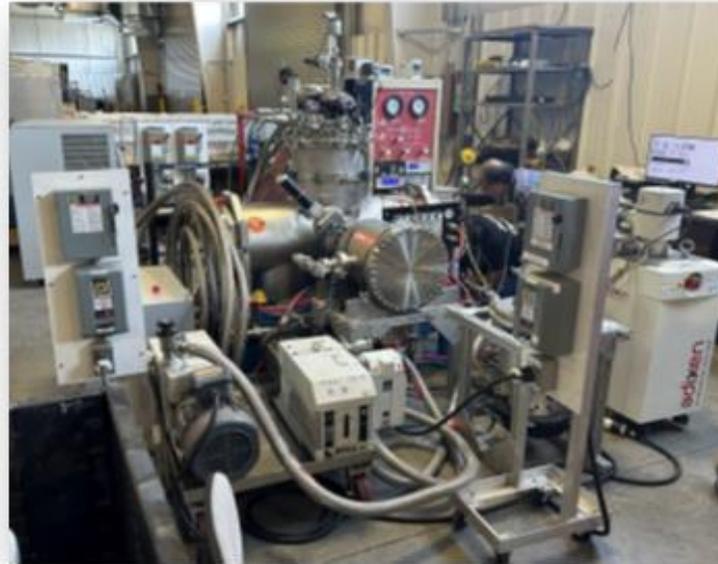
X17 foil targets:



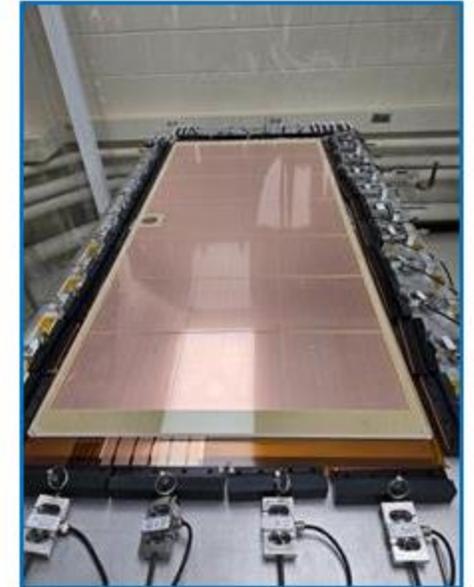
Beamline:



PRad gas target:



GEMs:





Completed Theses in CLAS Collaboration

MEASURING CLAS12 $D(E, E''^{\pm})$ CROSS SECTIONS FOR $EANU$

by

Caleb Fogler

B.S. December 2016, Old Dominion University
M.S. May 2019, Old Dominion University

A Dissertation Submitted to the Faculty of
Old Dominion University in Partial Fulfillment of the
Requirements for the Degree of

DOCTOR OF PHILOSOPHY

PHYSICS

OLD DOMINION UNIVERSITY
December 2024

Timelike Compton Scattering from a Longitudinally Polarised
Target with CLAS12 at Jefferson Lab

Kayleigh Gates

Submitted in fulfilment of the requ
Degree of Doctor of Phil

THE STRUCTURE FUNCTION OF THE FREE NEUTRON AT

HIGH X -BJORKEN

by

Madhusudhan Pokhrel

B. Sc. December 2013, Tribhuvan University, Nepal
M. Sc. December 2016, Tribhuvan University, Nepal
M. S. May 2019, Old Dominion University, USA

A Dissertation Submitted to the Faculty of
Old Dominion University in Partial Fulfillment of the
Requirements for the Degree of

DOCTOR OF PHILOSOPHY

PHYSICS

OLD DOMINION UNIVERSITY
May 2025

Approved by:

Stephen Bueltmann (Director)

Sebastian Kuhn (Member)

Raul Briceno (Member)

Yuan Zhang (Member)

Sylvain Marsillac (Member)

université
PARIS-SACLAY

Nucleon Structure Studies at
Jefferson Lab and the Electron Ion
Collider

UNIVERSITY OF CALIFORNIA
SANTA CRUZ
SEARCHING FOR STRONGLY-INTERACTING DARK MATTER
WITH THE HEAVY PHOTON SEARCH EXPERIMENT

A dissertation submitted in partial satisfaction of the
requirements for the degree of

DOCTOR OF PHILOSOPHY

in

université Paris-Saclay

FIRST CLAS12 DOUBLE-PION ($N\pi\pi$) ELECTROPRODUCTION ANALYSIS

by

Krishna Chandra Neupane

Bachelor of Science
Tribhuvan University, 2011

Master's Degree in Physics
Tribhuvan University, 2014

Submitted in Partial Fulfillment of the Requirements

for the Degree of Doctor of Philosophy in

Physics

College of Arts and Sciences

University of South Carolina

2025

Accepted by:

Ralf Gothe, Major Professor

Fred Myhrer, Committee Member

Steffen Strauch, Committee Member

Viktor Mokeev, Committee Member

Ann Vail, Dean of the Graduate School

CLAS: since Oct 2024

- Valerii Klimenko
- Caleb Fogler
- Kayleigh Gates
- Noémie Pilleux
- Madhusudhan Pokhrel
- Krishna Neupane

HPS: December 2025

- Alec Spellman

Publications

*Only listings because of limited time,
more information available in the backup*



Publications using CLAS Data

- A.V. Golda, ..., V.I. Mokeev *et al.*, “Cross Section Evaluation for Exclusive Channels of $K^+\Lambda$ and $K^+\Sigma^0$ Electroproduction off Protons Using CLAS Detector Data”, **Moscow Univ. Phys. 79, 450 (Aug 2024)**, DOI: <https://doi.org/10.3103/S0027134924700577>
- L. Clark *et al.* (CLAS Collaboration), “Photo-production of the Σ^+ hyperon using linearly polarized photons with CLAS”, **Phys. Rev. C 111, 025204 (Feb 2025)**, DOI: <https://doi.org/10.1103/PhysRevC.111.025204>
- A. Deur *et al.* (CLAS Collaboration), “Measurement of the nucleon spin structure functions for $0.01 < Q^2 < 1$ GeV^2 using CLAS”, **Phys. Rev. C 111, 035202 (Mar 2025)**, DOI: <https://doi.org/10.1103/PhysRevC.111.035202>
- A.V. Sarantsev *et al.* (CLAS Collaboration), “Photoproduction of two charged pions off protons in the resonance region”, **Phys. Rev. C 111, 035203 (Mar 2025)**, DOI: <https://doi.org/10.1103/PhysRevC.111.035203>
- A.V. Sarantsev, E. Klempt, K.V. Nikonov, T. Seifen, U. Thoma, Y. Wunderlich, P. Achenbach, V.D. Burkert, V. Mokeev, V. Crede, “Decays of N^* and Δ^* Resonances into $N\rho$, $\Delta\pi$, and $Nf_0(500)$ ”, **Phys. Rev. C 112, 015202 (July 2025)**, DOI: <https://doi.org/10.1103/qfpp-tcs3>
- P. Roy *et al.* (CLAS Collaboration), “Measurement of Single- and Double-Polarization Observables in the Photoproduction of $\pi^+\pi^-$ Pairs off the Proton Using CLAS at Jefferson Laboratory”, arXiv:2504.21119, DOI: <https://doi.org/10.48550/arXiv.2504.21119>, **submitted to Phys. Rev. C**
- T. Mineeva *et al.* (CLAS Collaboration), “Suppression of Neutral Pion Production in Deep-Inelastic Scattering of Nuclei with the CLAS Detector”, arXiv:2406.04512, <https://doi.org/10.48550/arXiv.2406.04513>, **submitted to Phys. Rev. C**

Publications using CLAS12 Data

- A. Hobart *et al.* (CLAS Collaboration), “*First Exclusive Measurement of Deeply Virtual Compton Scattering on the Neutron*”, **Phys. Rev. Lett.** **133**, 211903 (Nov 2024) , DOI: <https://doi.org/10.1103/PhysRevLett.133.211903>
- V. Klimenko *et al.* (CLAS Collaboration), “*Inclusive Electron Scattering in the Resonance Region off a Hydrogen Target with CLAS12*”, **accepted in Phys. Rev. C (June 2025)**
- D.S. Carman *et al.* (CLAS Collaboration), “*Recoil Polarization in K^+Y Electroproduction in the Nucleon Resonance Region with CLAS12*”, arXiv: 2505.12030, DOI: <https://doi.org/10.48550/arXiv.2505.12030>, **submitted to Phys. Rev. C**
- A. Kripko *et al.* (CLAS Collaboration), “*Multi-dimensional Measurements of Beam Single Spin Asymmetries in Semi-Inclusive Deep-Inelastic Charged Kaon Electroproduction off Protons in the Valence Region*”, arXiv: 2504.0858, DOI: <https://doi.org/10.48550/arXiv.2504.08580>, **submitted to Phys. Rev. Lett.**

Other Publications

- V. Burkert, G. Eichmann, E. Klempt, “*The impact of γN and $\gamma^* N$ interactions on our understanding of nucleon excitations*”, arXiv: 2506.16482, DOI: <https://doi.org/10.48550/arXiv.2506.16482>, **submitted to Prog. Part. Nucl. Phys.**
- P. Achenbach, D.S. Carman, R.W. Gothe, K. Joo, V.I. Mokeev, C.D. Roberts, “*Electroexcitation of Nucleon Resonances and the Emergence of Hadron Mass*”, **Symmetry 17, 1106 (July 2025)**, DOI: <https://doi.org/10.3390/sym17071106>
- V. Kubarovsky, J. Rittenhouse West, and S.J. Brodsky, “*Quantum chromodynamics resolution of the ATOMKI anomaly in ^4He nuclear transitions*”, **Phys. Rev. C 111, 024320 (Feb 2025)**, DOI: <https://doi.org/10.1103/PhysRevC.111.024320>
- V. Burkert, S. Diehl, P. Schweitzer, “*Quarks unter Hochdruck im Proton*”, **Phys. Unserer Zeit 55, 298–306 (Nov 2024)**, <https://doi.org/10.1002/piuz.202401699>
- R. De Vita, “*The CLAS12 Experiment at Jefferson Lab*”, **to appear in Encyclopedia of Particle Physics (2026)**
- P. Achenbach, “*Experiments at Jefferson Lab*”, **to appear in Encyclopedia of Particle Physics (2026)**

Publications on Detectors and Methods

- K. Gnanvo, F. Hauenstein, S. Liyanaarachchi, N. Liyanage, H. Nguyen, R. Paremuzyan and S. Stepanyan, “*μRWELL detector developments at Jefferson Lab for high luminosity experiments*”, **PoS QNP2024, 014 (Mar 2025)**, <https://pos.sissa.it/465/014>
- G. Gavalian, P. Thomadakis, A. Angelopoulos and N. Chrisochoides, “*Charged Track Reconstruction with Artificial Intelligence for CLAS12*”, **EPJ Web of Conferences 295, 09038 (May 2024)**, DOI: <https://doi.org/10.1051/epjconf/202429509038>
- R. Tyson, G. Gavalian, B. McKinnon and D. Ireland, “*Level-3 Trigger for CLAS12 with Artificial Intelligence*”, **EPJ Web of Conferences 295, 02018 (May 2024)**, DOI: <https://doi.org/10.1051/epjconf/202429502018>
- G. Gavalian, “*High-performance data format for scientific data storage and analysis*”, **Comp. Phys. Comm 315, 109732 (Oct 2025)**, <https://www.sciencedirect.com/science/article/pii/S0010465525002346>
- F. Rossi, M. Battaglieri, E. Ragusa, P. Gastaldo, G. Gavalian, “*Artificial Intelligence Data Reduction Algorithm for Streaming Readout in High Energy Physics Experiment*”, **Commun. Comput. Inf. Sci. 2253, 50–58 (Apr 2025)**, https://doi.org/10.1007/978-3-031-85856-7_5
- G. Gavalian, “*Real-Time Charged Track Reconstruction for CLAS12*”, **JINST 19, C05050 (May 2024)**, DOI: <https://doi.org/10.1088/1748-0221/19/05/C05050>

Publications on Methods

- D.I. Glazier, R. Tyson, “*Converting sWeights to Probabilities with Density Ratios*”, arXiv: 2409.08183, DOI: <https://doi.org/10.48550/arXiv.2409.08183>, **submitted to Comput. Phys. Commun.**
- G. Gavalian and R. Tyson, “*Online Electron Reconstruction at CLAS12*”, , arXiv: 2507.05274, DOI: <https://doi.org/10.48550/arXiv.2507.05274>, **submitted to Comput. Phys. Commun.**
- G. Matousek and A. Vossen, “*AI-Assisted Object Condensation Clustering for Calorimeter Shower Reconstruction at CLAS12*”, arXiv: 2503.11277, DOI: <https://doi.org/10.48550/arXiv.2503.11277>
- V.D. Burkert, A. Camsonne, P. Chatagnon, K. Cichy, M. Constantinou, H. Dutrieux, I. M. Higuera-Angulo, C. Mezrag, D. Richards, P. Sznajder, “*Open database for GPD analyses*”, arXiv: 2503.18152, DOI: <https://doi.org/10.48550/arXiv.2503.18152>

Concluding Remarks

- Hall B is scheduled to **complete all ALERT experiments** in this run period
- **Installation of PRad-II/X17 setup** is planned for this SAM
- **CLAS Collaboration in Hall B** continues to **deliver high-level physics results**

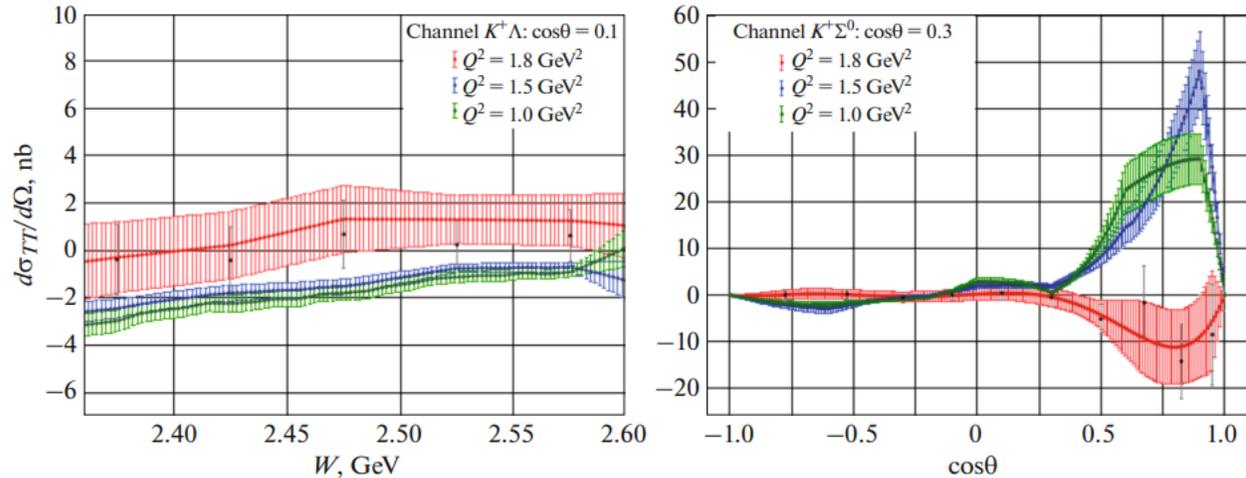
- **CLAS-approved proposals to PAC53:**
 - Stepan Stepanyan *et al.*: “*Electro- and photo-production of muon pairs with μ CLAS12: Double Deeply Virtual Compton Scattering, Timelike Compton Scattering, and J/ψ production*”
 - Marco Contalbrigo *et al.* (Run Group H): “*Experiments with a Transversely Polarized Target*”
 - Harut Avakian *et al.* (Run Group H addition): “*Measurements of Single Spin Asymmetries in exclusive production of hadrons with RGH*”
 - Sangbaek Lee *et al.*: “*Measurement of the Coherent J/ψ Electroproduction off ^4He* ”

BACKUP



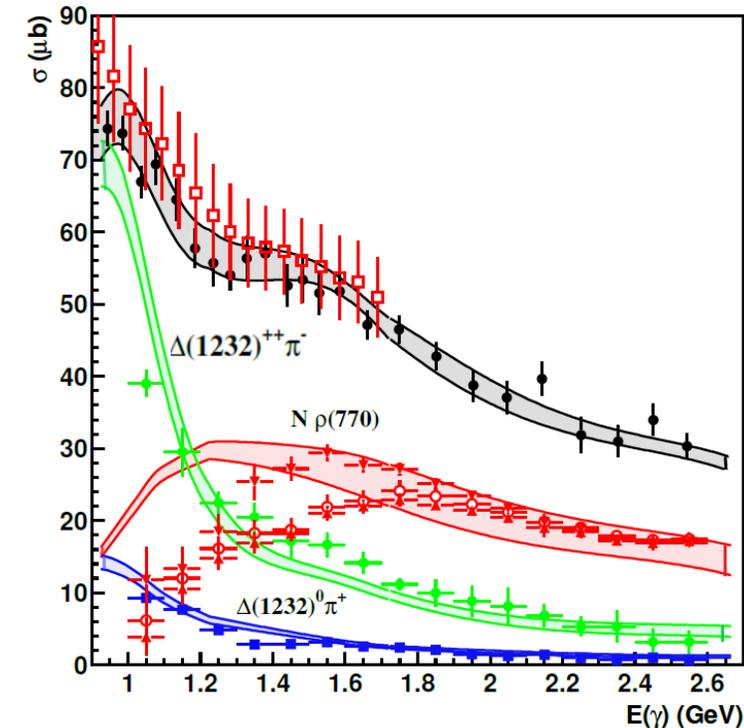
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Estimates of the structure function $d\sigma_{TT}/d\Omega_K$ for $K^+\Lambda$ channels (left) and $K^+\Sigma^0$ channels (right)

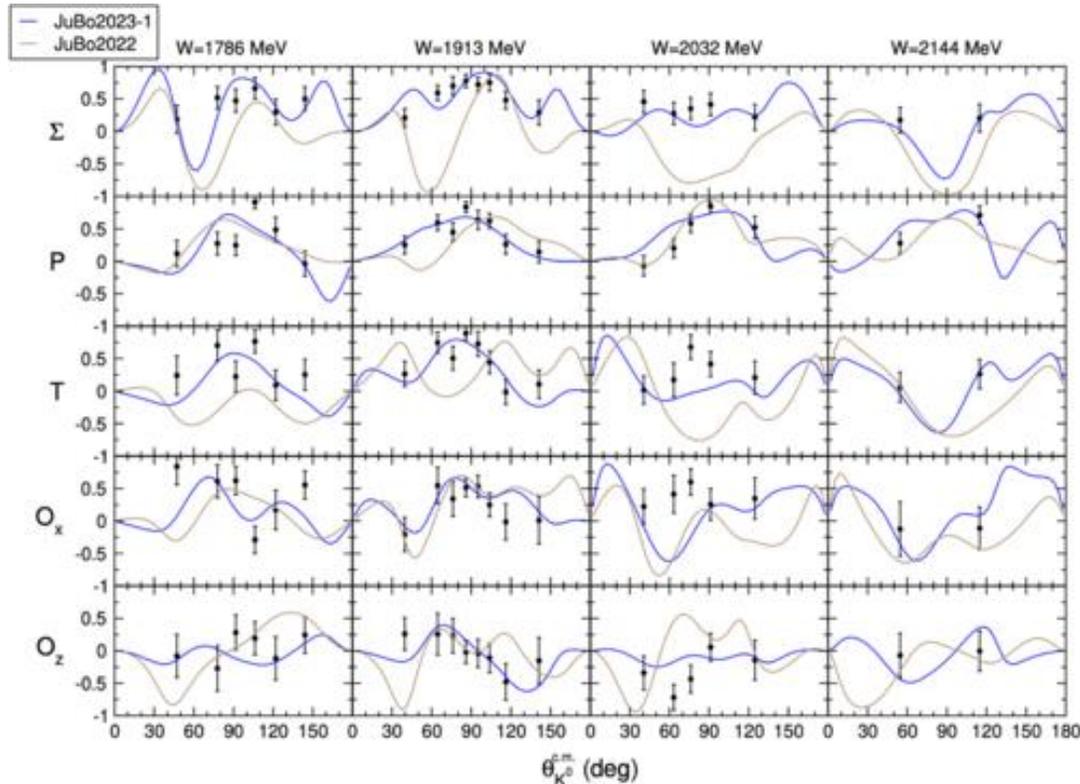
A.V. Sarantsev *et al.* (CLAS Collaboration), “Photoproduction of two charged pions off protons in the resonance region”, **Phys. Rev. C 111, 035203 (Mar 2025)**, DOI: <https://doi.org/10.1103/PhysRevC.111.035203>



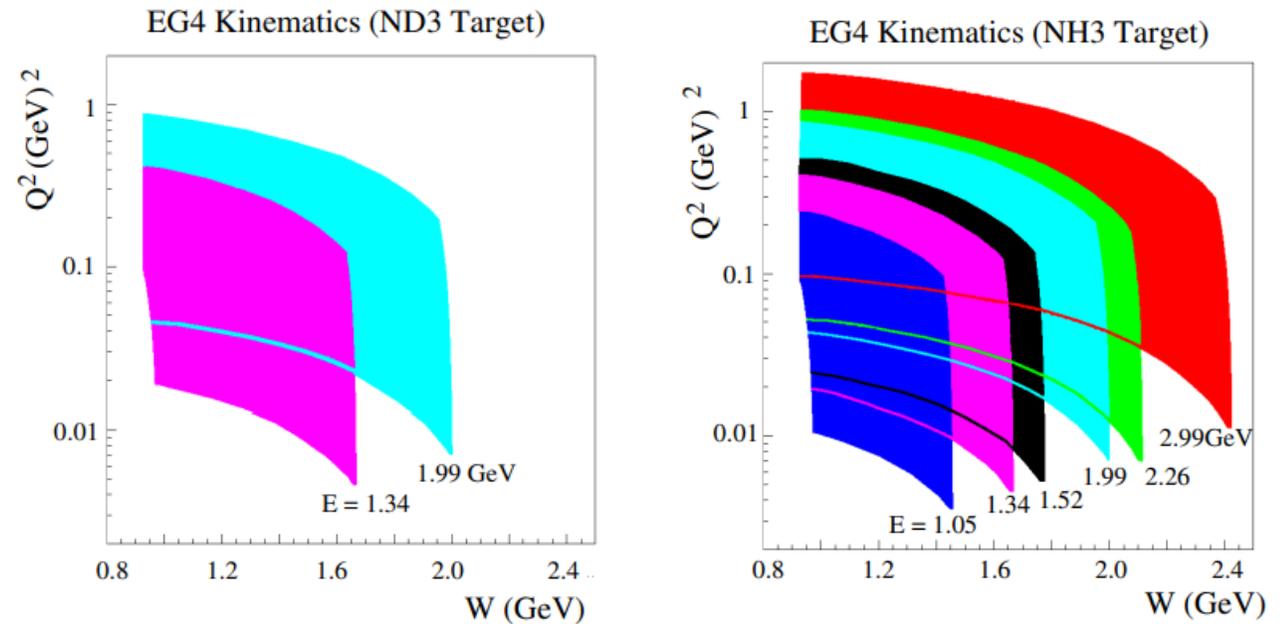
Total cross section for the reaction $\gamma p \rightarrow p\pi^+\pi^-$ including different isobar contributions

Publications Using CLAS Data

L. Clark *et al.* (CLAS Collaboration), “*Photo-production of the Σ^+ hyperon using linearly polarized photons with CLAS*”, **Phys. Rev. C 111, 025204 (Feb 2025)**, DOI: <https://doi.org/10.1103/PhysRevC.111.025204>



A. Deur *et al.* (CLAS Collaboration), “*Measurement of the nucleon spin structure functions for $0.01 < Q^2 < 1 \text{ GeV}^2$ using CLAS*”, **Phys. Rev. C 111, 035202 (Mar 2025)**, DOI: <https://doi.org/10.1103/PhysRevC.111.035202>

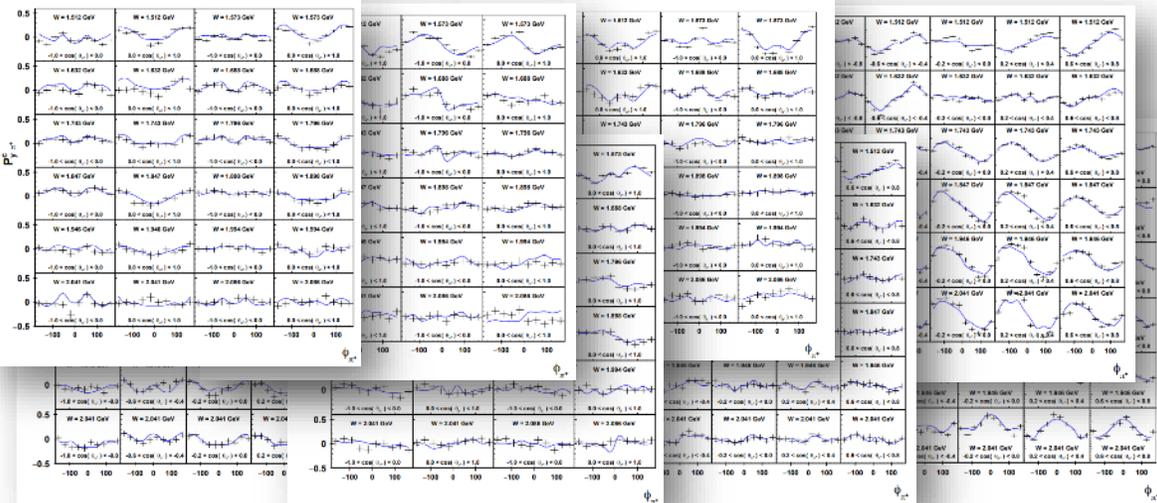


Archival paper with details of the CLAS EG4 experiment from 2006 and final results for **proton and deuteron spin structure function data**

Publications Using CLAS Data

P. Roy *et al.* (CLAS Collaboration), “*Measurement of Single- and Double-Polarization Observables in the Photoproduction of $\pi^+\pi^-$ Pairs off the Proton Using CLAS at Jefferson Laboratory*”, arXiv:2504.21119, DOI: <https://doi.org/10.48550/arXiv.2504.21119>, submitted to Phys. Rev. C

- Beam and target asymmetries, and beam-target double-polarization observables measured using a transversely polarized target (FROST)



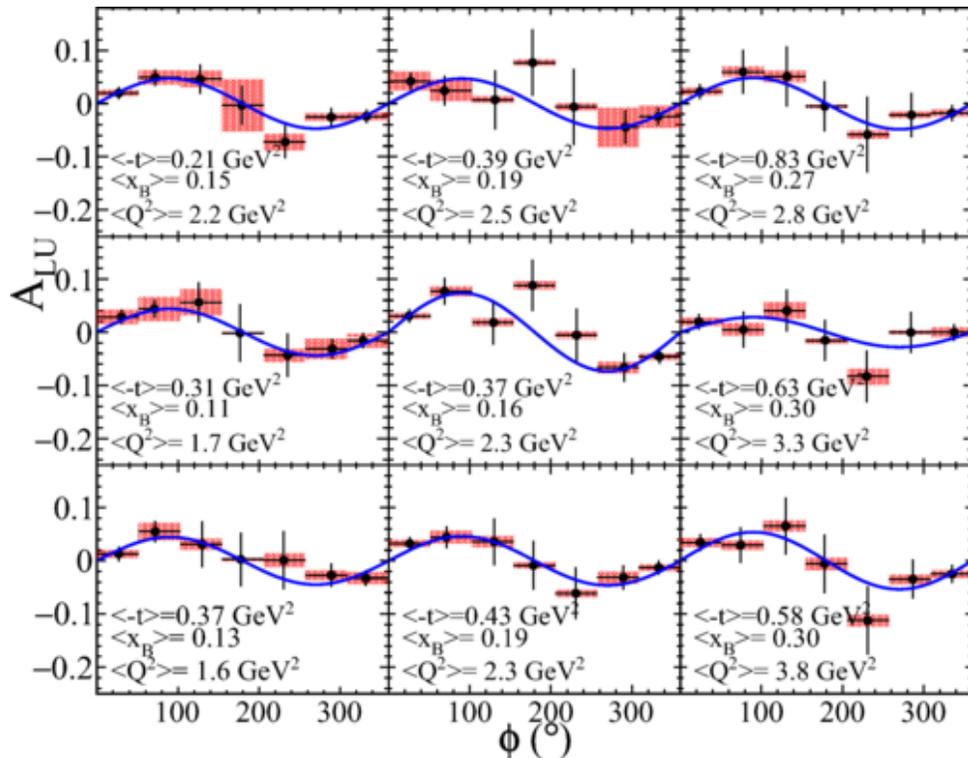
A.V. Sarantsev, E. Klempt, K.V. Nikonov, T. Seifen, U. Thoma, Y. Wunderlich, P. Achenbach, V.D. Burkert, V. Moiseev, V. Crede, “*Decays of N^* and Δ^* Resonances into $N\rho$, $\Delta\pi$, and $Nf_0(500)$* ”, Phys. Rev. C **112**, 015202 (July 2025), DOI: <https://doi.org/10.1103/physrevc.112.015202>

- Masses, widths and branching ratios of N^* and Δ^*

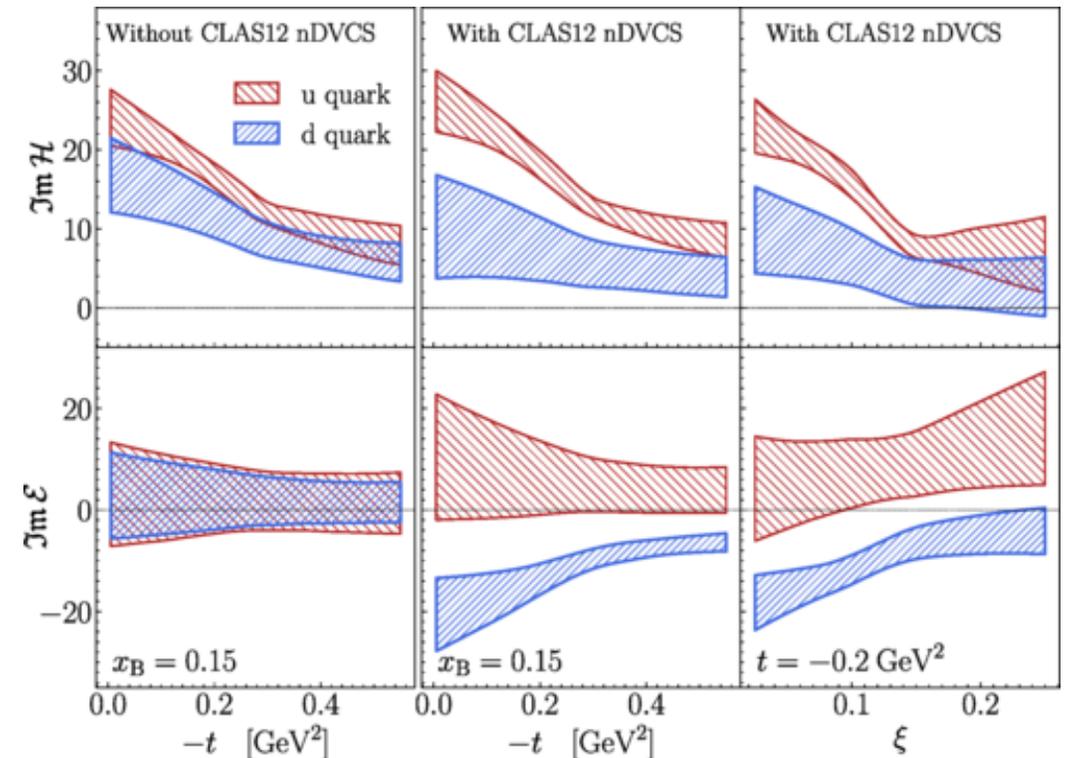
N^*, Δ^*, J^P	M_{pole}	Γ_{pole}	M_{fit}	Γ_{fit}	$\mathcal{B}^{N\rho}$	$\mathcal{B}^{\Delta\pi}$	$\mathcal{B}^{Nf_0(500)}$	$\mathcal{B}^{N\rho}$	$\mathcal{B}^{\Delta\pi}$	$\mathcal{B}^{Nf_0(500)}$
$N(1440) 1/2^+$	1396(23)	192(24)	1402(20)	206(13)	-0.078(10.006)	-0.011(0.006)	-0.011(0.006)	-0.078(10.006)	-0.011(0.006)	-0.011(0.006)
$N(1520) 3/2^-$	1506(22)	122(23)	1515(23)	114(24)	-0.028(0.006)	-0.17(1.8)	0.18(0.007)	-0.028(0.006)	-0.17(1.8)	0.18(0.007)
$N(1650) 1/2^-$	1694(17)	115(20)	1717(24)	113(27)	0.101(0.006)	0.2(1.0)	0.101(0.006)	0.101(0.006)	0.2(1.0)	0.101(0.006)
$N(1675) 3/2^-$	1664(10)	106(16)	1670(26)	102(27)	0.021(0.004)	0.30(1.0)	0.021(0.004)	0.021(0.004)	0.30(1.0)	0.021(0.004)
$N(1680) 5/2^-$	1692(25)	130(18)	1688(24)	130(28)	0.021(0.004)	0.30(1.0)	0.021(0.004)	0.021(0.004)	0.30(1.0)	0.021(0.004)
$N(1700) 5/2^-$	1676(16)	117(24)	1689(25)	122(25)	0.016(0.004)	0.35(1.5)	0.18(0.005)	0.016(0.004)	0.35(1.5)	0.18(0.005)
$N(1720) 3/2^-$	1745(14)	109(16)	1750(23)	104(20)	0.035(0.011)	0.30(1.0)	0.100(0.003)	0.035(0.011)	0.30(1.0)	0.100(0.003)
$N(1730) 5/2^-$	1696(17)	109(16)	1694(26)	109(20)	0.045(0.012)	0.30(1.0)	0.045(0.012)	0.045(0.012)	0.30(1.0)	0.045(0.012)
$N(1750) 3/2^-$	1710(20)	101(16)	1716(28)	101(23)	0.100(0.025)	0.5(1.0)	0.045(0.003)	0.100(0.025)	0.5(1.0)	0.045(0.003)
$N(1800) 5/2^-$	1870(15)	100(16)	1870(25)	100(23)	0.008(0.006)	0.5(1.0)	0.007(0.005)	0.008(0.006)	0.5(1.0)	0.007(0.005)
$N(1875) 3/2^-$	1850(17)	200(22)	1860(21)	210(22)	0.022(0.006)	0.10(1.0)	0.014(0.006)	0.022(0.006)	0.10(1.0)	0.014(0.006)
$N(1880) 5/2^-$	1840(25)	270(30)	1860(25)	270(30)	0.015(0.005)	0.10(1.0)	0.014(0.006)	0.015(0.005)	0.10(1.0)	0.014(0.006)
$N(1890) 1/2^-$	1890(18)	100(16)	1890(26)	100(20)	0.021(0.006)	0.10(1.0)	0.021(0.006)	0.021(0.006)	0.10(1.0)	0.021(0.006)
$N(1900) 5/2^-$	1920(25)	270(30)	1930(25)	270(30)	0.050(0.012)	0.4(1.0)	0.044(0.012)	0.050(0.012)	0.4(1.0)	0.044(0.012)
$N(1975) 3/2^-$	1935(10)	60(10)	1935(10)	60(10)	0.075(0.025)	0.7(1.0)	0.075(0.025)	0.075(0.025)	0.7(1.0)	0.075(0.025)
$N(2000) 5/2^-$	2000(15)	270(30)	2020(22)	280(13)	0.011(0.006)	0.4(1.0)	0.011(0.006)	0.011(0.006)	0.4(1.0)	0.011(0.006)
$N(2040) 1/2^-$	2030(10)	40(10)	2030(10)	40(10)	0.035(0.008)	0.2(1.0)	0.035(0.008)	0.035(0.008)	0.2(1.0)	0.035(0.008)
$N(2090) 5/2^-$	2030(10)	40(10)	2030(10)	40(10)	0.005(0.015)	0.3(1.0)	0.005(0.015)	0.005(0.015)	0.3(1.0)	0.005(0.015)
$N(2100) 5/2^-$	2055(25)	430(25)	2070(25)	430(25)	0.008(0.008)	0.5(1.0)	0.008(0.008)	0.008(0.008)	0.5(1.0)	0.008(0.008)
$N(2130) 3/2^-$	2130(10)	30(10)	2130(10)	30(10)	0.020(0.015)	0.4(1.0)	0.045(0.015)	0.020(0.015)	0.4(1.0)	0.045(0.015)
$N(2190) 5/2^-$	2190(10)	30(10)	2190(10)	30(10)	0.009(0.013)	0.5(1.0)	0.009(0.013)	0.009(0.013)	0.5(1.0)	0.009(0.013)
$N(2200) 5/2^-$	2165(30)	440(40)	2165(30)	440(40)	0.015(0.010)	0.6(1.0)	0.015(0.010)	0.015(0.010)	0.6(1.0)	0.015(0.010)
$N(2250) 5/2^-$	2250(10)	30(10)	2250(10)	30(10)	0.008(0.010)	0.5(1.0)	0.008(0.010)	0.008(0.010)	0.5(1.0)	0.008(0.010)
$\Delta(1232) 3/2^+$	1230(11)	101(12)	1230(11)	101(12)	-0.133(0.003)	-0.17(1.7)	-0.255(0.003)	-0.133(0.003)	-0.17(1.7)	-0.255(0.003)
$\Delta(1600) 3/2^+$	1610(15)	240(22)	1620(11)	240(22)	0.040(0.008)	0.2(1.0)	0.040(0.008)	0.040(0.008)	0.2(1.0)	0.040(0.008)
$\Delta(1620) 5/2^+$	1620(17)	130(12)	1608(13)	130(10)	0.047(0.007)	0.10(1.0)	0.047(0.007)	0.047(0.007)	0.10(1.0)	0.047(0.007)
$\Delta(1700) 5/2^+$	1690(15)	300(25)	1690(15)	300(25)	0.104(0.020)	0.30(1.0)	0.104(0.020)	0.104(0.020)	0.30(1.0)	0.104(0.020)
$\Delta(1720) 5/2^+$	1710(10)	200(15)	1710(10)	200(15)	0.020(0.007)	0.5(1.0)	0.020(0.007)	0.020(0.007)	0.5(1.0)	0.020(0.007)
$\Delta(1900) 5/2^+$	1815(30)	540(35)	1815(30)	540(35)	0.075(0.015)	0.5(1.0)	0.075(0.015)	0.075(0.015)	0.5(1.0)	0.075(0.015)
$\Delta(1905) 5/2^+$	1795(30)	200(20)	1815(30)	215(30)	0.030(0.007)	0.5(1.0)	0.072(0.010)	0.030(0.007)	0.5(1.0)	0.072(0.010)
$\Delta(1910) 5/2^+$	1840(30)	400(40)	1890(30)	230(40)	0.000(0.009)	0.4(1.0)	0.000(0.009)	0.000(0.009)	0.4(1.0)	0.000(0.009)
$\Delta(1920) 5/2^+$	1880(30)	200(20)	1890(30)	200(20)	0.040(0.025)	0.3(1.0)	0.005(0.025)	0.040(0.025)	0.3(1.0)	0.005(0.025)
$\Delta(1930) 5/2^+$	1812(10)	620(25)	1812(10)	620(25)	0.008(0.008)	0.10(1.0)	0.008(0.008)	0.008(0.008)	0.10(1.0)	0.008(0.008)
$\Delta(1940) 5/2^+$	2010(10)	400(30)	2000(30)	400(30)	0.045(0.025)	0.4(1.0)	0.000(0.000)	0.045(0.025)	0.4(1.0)	0.000(0.000)
$\Delta(1950) 5/2^+$	1801(25)	350(10)	1810(25)	350(10)	0.070(0.006)	0.10(1.0)	0.070(0.006)	0.070(0.006)	0.10(1.0)	0.070(0.006)
$\Delta(2200) 5/2^+$	2200(10)	30(10)	2180(30)	220(10)	0.120(0.015)	0.3(1.0)	0.070(0.012)	0.120(0.015)	0.3(1.0)	0.070(0.012)
$\Delta(2310) 5/2^+$	2300(15)	340(40)	2300(15)	340(40)	0.057(0.012)	0.7(1.0)	0.091(0.010)	0.057(0.012)	0.7(1.0)	0.091(0.010)

Publications Using CLAS12 RG-B Data

A. Hobart et al. (CLAS Collaboration), “First Exclusive Measurement of Deeply Virtual Compton Scattering on the Neutron”, *Phys. Rev. Lett.* **133**, 211903 (Nov 2024), DOI: <https://doi.org/10.1103/PhysRevLett.133.211903>



Beam-spin asymmetry for nDVCS versus ϕ for 3 bins in $-t$, 3 bins in x_B , and 3 bins in Q^2



Extraction of up and down quark contributions to the Compton Form Factors $\Im m H$ and $\Im m E$

Media Coverage of this Publication

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Революционный детектор открывает новые возможности изучения внутренней структуры нейтрона через первые измерения глубокого виртуального комптоновского рассеяния

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Протоны и нейтроны, известные под общим названием нуклоны, являются основополагающими элементами материи. Тем не менее в ядерной физике нейтронам традиционно уделялось меньше внимания по сравнению с протонами. В недавно опубликованной статье в Physical Review Letters описывается новаторский подход к изучению внутренней структуры нейтрона, достигнутый благодаря созданию специального детектора, разработка которого потребовалась 10 лет.

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SCIENCE

A reaction that only measured protons detected neutrons for the first time

For the last 10 years, scientists have been working on a neutron detector. Finally, they tested it, and it worked like magic.

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NEWS RELEASE 22-NOV-2024

Accessing the lesser known nucleon

An inaugural measurement of the neutron will help physicists learn about nucleon structure and spin

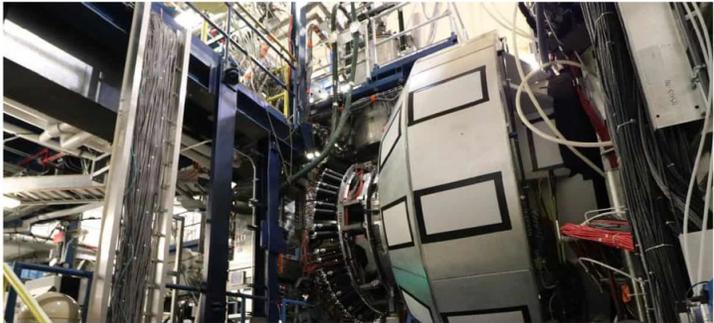
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physicsworld

PARTICLE AND NUCLEAR RESEARCH UPDATE

Inner workings of the neutron illuminated by Jefferson Lab experiment

17 Dec 2024



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NOVEMBER 22, 2024 Editors' notes

Accessing the lesser known nucleon: New neutron measurement can help physicists learn about nucleon structure and spin

by Chris Patrick, Thomas Jefferson National Accelerator Facility

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PHYSICS

Inside the Neutron: Scientists Discover Hidden Layers of Matter

BY THOMAS JEFFERSON NATIONAL ACCELERATOR FACILITY – NOVEMBER 24, 2024 NO COMMENTS 9 MINS READ

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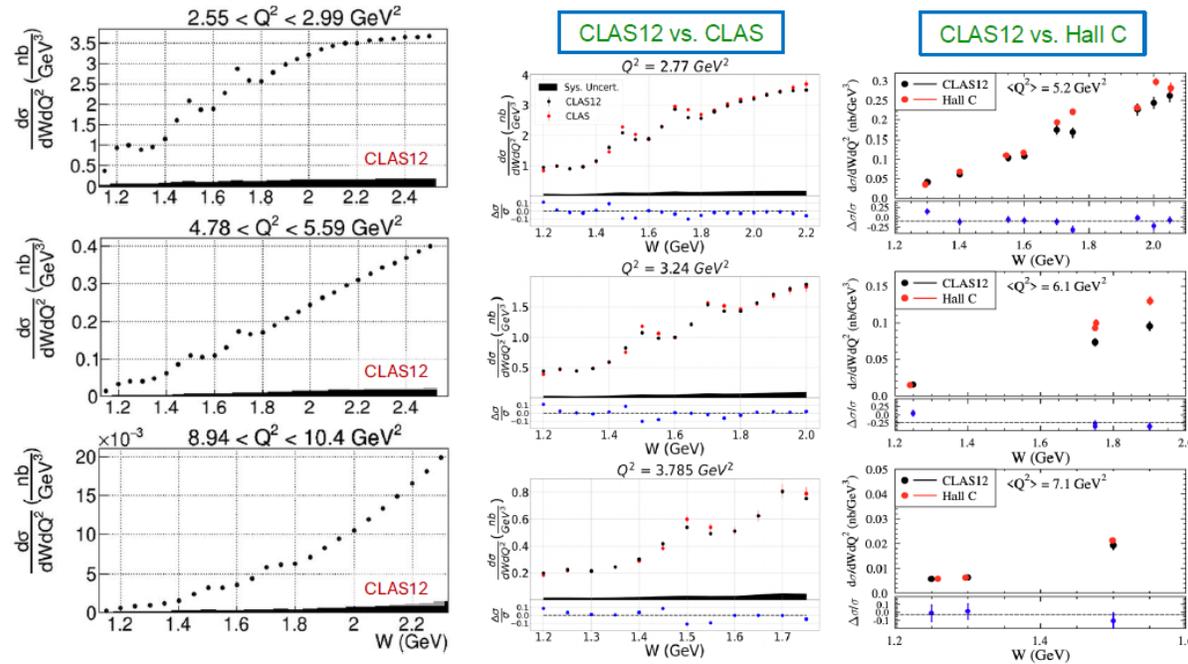
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Publication Using CLAS12 RG-A Data

V. Klimenko *et al.* (CLAS Collaboration), “*Inclusive Electron Scattering in the Resonance Region off a Hydrogen Target with CLAS12*”, accepted in *Phys. Rev. C* (June 2025)

- First inclusive electron scattering cross sections
- JLab press release is prepared



CLAS12 Provides a New View of the Proton Spectrum

New data bring physicists closer to a full understanding of the proton's structure

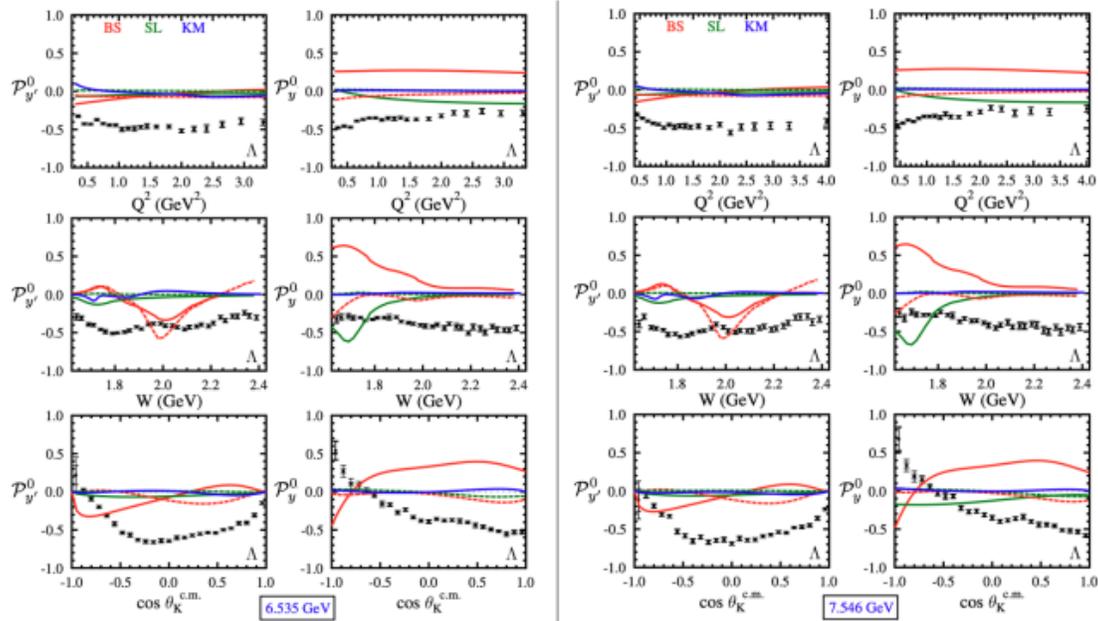
NEWPORT NEWS, VA – The small but mighty proton serves as a foundation for our universe. It abides at the very heart of matter, giving rise to everything we see around us as it anchors the nucleus of the atom. Yet, its own structure is unbelievably complex and the quest to understand the details of that structure has occupied theorists and experimenters alike since its discovery over a century ago.

“The visible universe is made of protons,” said Kyungseon Joo, a physics professor at the University of Connecticut. “And so, if you want to understand the universe, it’s important to understand how the proton is structured. We think we understand it quite well, but a lot of things are still missing.”

In 2018, an international team of researchers began taking new measurements of the proton in experiments conducted at the U.S. Department of Energy’s Thomas Jefferson National Accelerator Facility with a new apparatus called CLAS12. Now, the first results

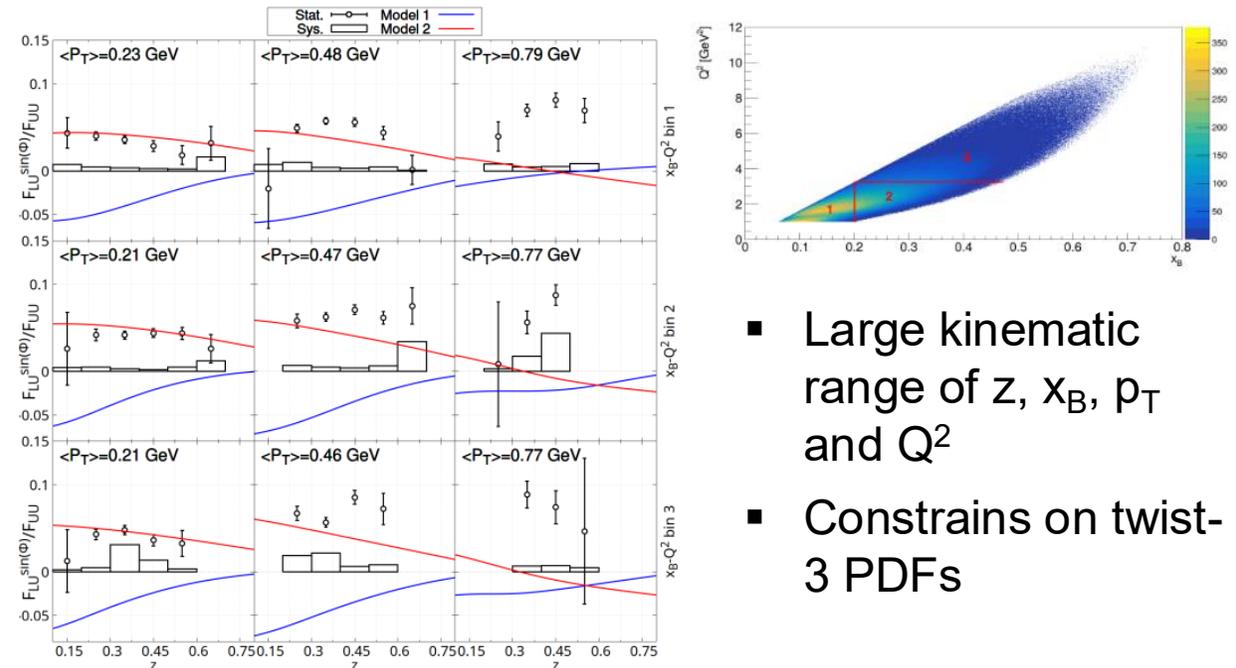
Publications Using CLAS12 Data

D.S. Carman *et al.* (CLAS Collaboration), “*Recoil Polarization in K^+Y Electroproduction in the Nucleon Resonance Region with CLAS12*”, arXiv: 2505.12030, DOI: <https://doi.org/10.48550/arXiv.2505.12030>, submitted to Phys. Rev. C



- Polarization observables extend existing data on Λ and first electroproduction measurements for Σ^0

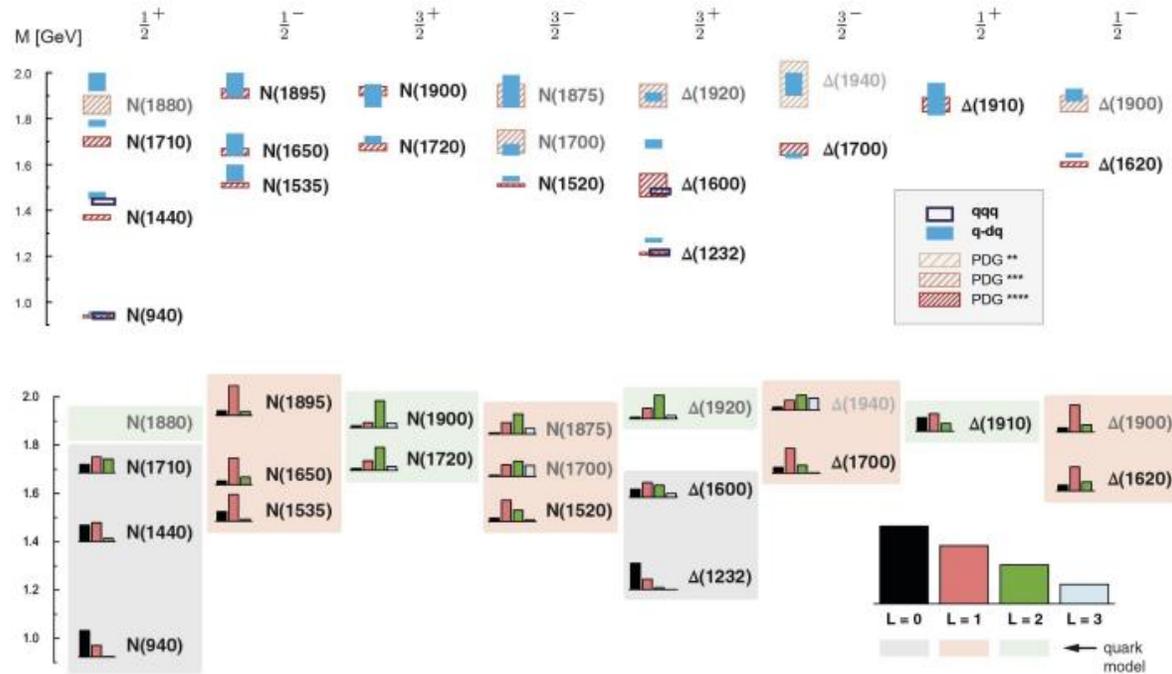
A. Kripko *et al.* (CLAS Collaboration), “*Multi-dimensional Measurements of Beam Single Spin Asymmetries in Semi-Inclusive Deep-Inelastic Charged Kaon Electroproduction off Protons in the Valence Region*”, arXiv: 2504.0858, DOI: <https://doi.org/10.48550/arXiv.2504.08580>, submitted to Phys. Rev. Lett.



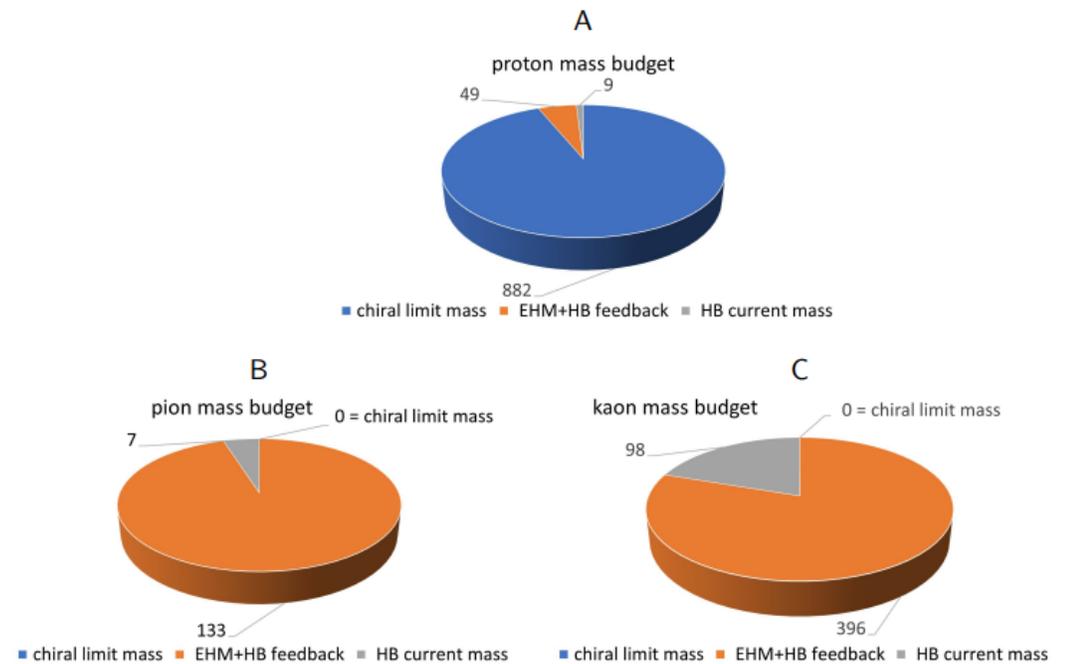
- Large kinematic range of z , x_B , p_T and Q^2
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Review Publications

V. Burkert, G. Eichmann, E. Klempt, “*The impact of γN and $\gamma^* N$ interactions on our understanding of nucleon excitations*”, arXiv: 2506.16482, DOI: <https://doi.org/10.48550/arXiv.2506.16482>, submitted to Prog. Part. Nucl. Phys.



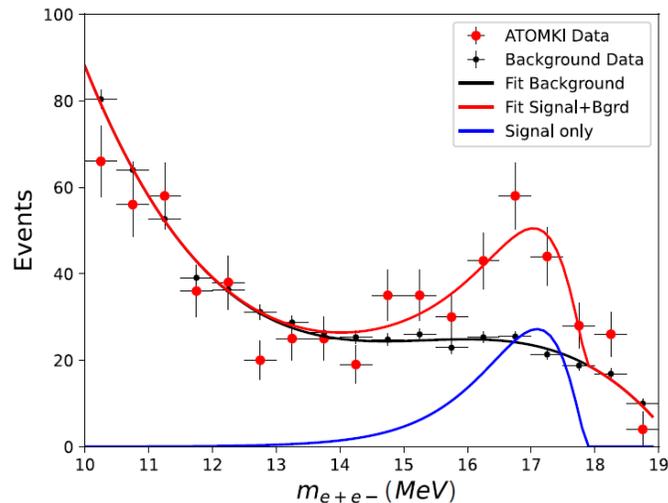
P. Achenbach, D.S. Carman, R.W. Gothe, K. Joo, V.I. Moiseev, C.D. Roberts, “*Electroexcitation of Nucleon Resonances and the Emergence of Hadron Mass*”, **Symmetry** 17, 1106 (July 2025), DOI: <https://doi.org/10.3390/sym17071106>



Other Publications

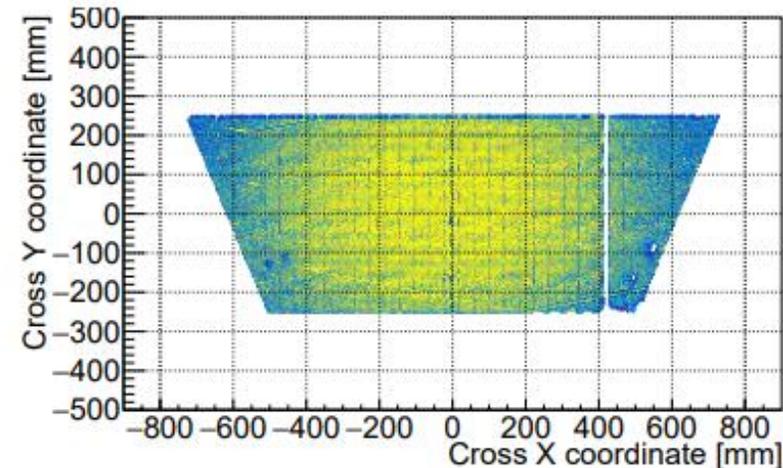
V. Kubarovsky, J. Rittenhouse West, and S.J. Brodsky, “Quantum chromodynamics resolution of the ATOMKI anomaly in ^4He nuclear transitions”, **Phys. Rev. C** **111**, **024320 (Feb 2025)**, DOI:

<https://doi.org/10.1103/PhysRevC.111.024320>



Description of ATOMKI invariant mass distribution with electromagnetic transition
 $\text{hexadiquark}^*(17.9) \rightarrow ^4\text{He} + (e^+e^-)$

K. Gnanvo, F. Hauenstein, S. Liyanaarachchi, N. Liyanage, H. Nguyen, R. Paremuzyan and S. Stepanyan, “ μRWELL detector developments at Jefferson Lab for high luminosity experiments”, **PoS QNP2024**, **014 (Mar 2025)**, <https://pos.sissa.it/465/014>



Distribution of hit coordinates on the detector surface from the cosmic rays

V. Burkert, S. Diehl, P. Schweitzer, “*Quarks unter Hochdruck im Proton*”, **Phys. Unserer Zeit** 55, 298–306 (Nov 2024), <https://doi.org/10.1002/piuz.202401699>

Mechanische Struktur des Protons

Quarks unter Hochdruck im Proton

VOLKER BURKERT | STEFAN DIEHL | PETER SCHWEITZER

Schon vor etwa 90 Jahren haben Experimente gezeigt, dass das Proton kein punktförmiges Elementarteilchen ist, wie das Elektron, sondern eine innere Struktur aufweist. Dies war der Beginn der Protonstrukturforschung, die vor Kurzem mit der Messung des Drucks im Innern des Protons

nen sind verantwortlich für mehr als 99,9% der Masse der Materie im sichtbaren Universum. Damit sind Nukleonen natürlich auch die am meisten experimentell untersuchten Objekte der Hadronenphysik. Im Folgenden beziehen wir uns auf das Proton, aber viele der diskutierten Fragen gelten gleichermaßen auch für das Neutron.

Ein wichtiger Meilenstein auf dem Gebiet der Proton-



Outreach Publications

R. De Vita, “*The CLAS12 Experiment at Jefferson Lab*”, to appear in Encyclopedia of Particle Physics (2026)

The CLAS12 Experiment at Jefferson Lab

R. De Vita^{1,2}
¹Thomas Jefferson National Accelerator Facility, Newport News, VA 23606, United States of America
²Istituto Nazionale di Fisica Nucleare, Sezione di Genova, Via Dodecaneso 33, 16146 Genova, Italy
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Chapter Article tagline: update of previous edition, reprint.

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Abstract

The CLAS12 experiment in Hall B at Jefferson Lab utilizes high-energy electrons produced by the CEBAF accelerator to probe the nuclear medium and understand its structure and the forces that govern it. The core of the experiment is a large acceptance spectrometer designed to detect, over broad kinematics, the particles emerging from the interaction of the electron beam with a fixed target. In operation since 2018, CLAS12 has already completed several measurements on different targets, from hydrogen to heavy nuclei, studying the microscopic structure of the proton and the neutron, the spectrum of hadrons produced in these reactions, and the behavior of the strong force in the nuclear medium. These measurements will shed light on fundamental questions about the properties of the strong force and the structure of ordinary matter.

Keywords: CLAS12, spectrometer, large acceptance, luminosity, electron beam, hadron physics



Fig. 1 The CLAS12 experiment in Hall B at Jefferson Lab. The photograph shows the CLAS12 detector complex. The overall extension of CLAS12 in the horizontal direction is about 13 m. Click on this link to view a video on the experiment.

CLAS12 Experiment at Jefferson Lab



Diagram shows the outer shell of the Drift Chamber (DC) and the

on a thin gold foil to generate plasmas via resonances (i.e., the excited states of the ions) by beginning the wide capabilities of ions when, over time, expanded the CLAS

is the basis for the operation of several of the CLAS12 subsystems. Particles carried to light. The light propagates through the scintillator and is detected by (a) the scintillator directly or via light guides or optical fibers. The top picture shows the plastic scintillator bars on the photomultiplier. An a demonstration of the all wire end. The light is reflected on the internal surface of the plastic light guide to the outside air and propagates through the bar, reaching the other end. Light particle crosses a material at a speed higher than the speed of light in the same produced by particles crossing aerogel tiles is reflected toward a matrix of multi-

P. Achenbach, “*Experiments at Jefferson Lab*”, to appear in Encyclopedia of Particle Physics (2026)

Experiments at Jefferson Lab

Patrick Achenbach^{1,*}
¹Thomas Jefferson National Accelerator Facility, Experimental Nuclear Physics Division, Newport News, Virginia 23606, USA

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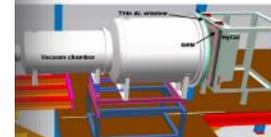
Abstract

This chapter presents experiments conducted at Thomas Jefferson National Accelerator Facility (Jefferson Lab), a U.S. Department of Energy national laboratory in Newport News, Virginia. There, physicists exploring the nature of matter make use of the Continuous Electron Beam Accelerator Facility (CEBAF), a DOE Office of Science user facility that enables the research of more than 1,650 scientists worldwide. CEBAF's precise electron beams can reach energies up to 12 billion electron-volts and exhibit high degrees of polarization. Jefferson Lab's first experiment began taking data in 1995. Since then, the facility has become a world leader in the study of quantum chromodynamics. Today, experiments are carried out simultaneously in four experimental halls, each with specialized capabilities. The primary instruments in use are focusing or large-acceptance magnetic spectrometers, many of which feature superconducting elements. Jefferson Lab's physics program provides unprecedented insight into the particles and forces that shape the visible universe.

Keywords: Jefferson Lab, electron scattering, magnetic spectrometer, quarks and gluons, hadron structure, hadron spectroscopy, Standard Model tests, nuclear structure, QCD spectroscopy

*patricka@jlab.org

Experiments at Jefferson Lab 13



of setup. Schematic of the experiment in Hall B see at top. After the gas flow target, followed by microchannel gas detectors for tracking and an electromagnetic calorimeter for the beamline, left, and the calorimeter, right.

a short decay time due to the short distance from target to the last detector plane, only

and collaborating institutions have developed a facility for hypernuclear spectroscopy. The High-Resolution Electron Spectrometer (HRES) and the High-Resolution Electron Spectrometer (HRES) are 2.5 m long with a momentum resolution of 2×10^{-4} (full width at half maximum). It is for the detection of kaons that have a decay length of only 3.7 m. Its central momentum resolution is particularly broad. Both spectrometers are enclosed with drift chambers, time-

of the detector in Hall B see at left, from Ref. [25], and a photo of

is located directly in front of a dipole magnet, in which a silicon micro-strip

is. An electromagnetic calorimeter and a scintillator hodoscope are placed

able of detecting scattered electrons with momenta up to 6 GeV/c, in a mo-

range from 10.5° to 90° . The HMS has four superconducting magnets, three

using decaying configurations followed by a momentum analyzing dipole with

between 1 and 1.5×10^{-4} . The angular acceptance is 4 steradians in plane and

achieved. The length of the HMS from target to detector has ~ 25 m. For the

(HRES) has been installed. Detecting reaction products with momenta up to

several new and momentum resolutions of the 0.1% level. They can be placed at

of the HMS and SHMS have well-thick detector bars, and a high-power cryogenic

and high beam currents, corresponding to

The SHMS was designed as a companion to the HMS so that they provide