Curriculum Vitae

Dr. Nathaniel James Tagg

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Education

Ph.D: University of Guelph, Ontario, Canada, 2001.
(Guelph-Waterloo Program for Graduate Studies in Physics)
Thesis supervisor: J. J. Simpson.
Thesis: "The ^{8}Li Calibration Source and Through-Going Muons in the Sudbury Neutrino Observatory"

M.Sc: University of Guelph, Ontario, Canada. 1996.
(Guelph-Waterloo Program for Graduate Studies in Physics)

B.Sc: University of Lethbridge, B.Sc. (Great Distinction) 1993.

Employment

2019-2021: Professor at Otterbein University

2015-2020: Physics Department Chair at Otterbein University

2013-2019: Associate Professor of Physics at Otterbein University

2008-2013: Assistant Professor of Physics at Otterbein University

2005-2008: Visiting Scientist at Tufts University

2006-2008: Research Assistant at Brookhaven National Laboratory

2001-2005: Postdoctoral research assistant at Oxford University, UK

Awards

Co-recipient of the 2016 Breakthrough Prize in Fundamental Physics (along with many other collaborators)

Notable Projects

These are projects in which I was solo developer or team lead.

"Sietch" DUNE APA Database - 2020-21 Authored a web application and RESTful interface for storing data related to Anode Plane Assembly production for the DUNE experiment, including QA, QC, inventory, component relationships, checklists, and work instructions. It is a full-stack node.js application along with formio.js to create a dynamic front-end form system. The MongoDB backend allowed extreme schema flexibility during rapid evolution of production processes. I deployed development servers on AWS and production servers on container-based on Fermilab's OpenShift Kubernates container cluster.

"Otternet" Schedule browser 2017-20 As faculty member and department chair, I saw a need for software that would allow for easy navigation of course and student-level academic data. I wrote this web application to let advisors easily find student pictures and records, list class rosters, find free times in calendars, and track program enrollments. Added to this was a system for doing Just In Time Teaching responses by students, and a system to interface with the Google Sheets API to allow easy and secure display of student scores by instructions without use of an LMS. Widely lauded as an important tool by administrators and faculty.

DUNE trigger study, 2019 As a short sabbatical project, I analyzed use of Single-phase ProtoDUNE data to examine how induction wires could be used in conjunction with collection wires to increase trigger efficiency for low-energy neutrino events.

"Argo" Event Display for MicroBooNE and DUNE – 2013-19 I authored a web application for visualizing neutrino data from high-resolution liquid argon time projection chambers. First versions were based on Arachne (see below) but eventually evolved into a full-stack node.js application using a custom C++ back-end to read LarSoft files. Notable innovations included encoding raw data into custom PNG files and using real-time false-color LUTs with WebGL to dynamically render images, along with 2D and 3D reconstruction. Non-expert users could display events from live data streams or stored files with latencies well under 10 seconds, which is orders of magnitude faster than any other system. It is used for data monitoring, education, outreach, and reconstruction evaluation.

Michel electron study MicroBooNE -2016 Provided alternate event selection and analysis of Michel electrons from cosmic-ray muons. Used as a cross-check on standard analyses of electron response.

"RunCat" MicroBooNE run conditions catalog - 2013- Python application that monitored data acquisition system to catalog all runs, and interfaced with multiple database systems to provide useful summary data on run conditions, beam exposure, running time. Evolved into a system for doing shift checklists for detector monitoring and ensuring good uptime.

MicroBooNE "Supernova" Stream Reconstruction - 2017-2020 Constructed a system to synchronize, build, and reconstruct data taken in "continuous readout" or "supernova" mode from the MicroBooNE detector, along with monitoring software to characterize data integrity. This system scans local data files from multiple DAQ nodes, build the data streams into time-synchronized event records, and compose those records to disk like the DAQ. I then wrote the software that allowed LarSoft, the C++ analysis framework, to decompress the data and build them into ROIs usable by downstream analysis just like the regular triggered data. This project included an extensive campaign to identify and characterize subtle bit-level errors introduced by front-end FPGAs.

MicroBooNE Online Monitor "Lizard" - 2013-present I authored a system to continuously sample and monitor from the MicroBooNE detector data stream, which reads out approximately 8000 wire channels with 2 MHz sampling, plus triggered data from PMTs. This system samples data directly out of the DAQ circular buffers by shared memory, and dispatches it over local network to a high parallel C++ process for near-time analysis. Error checking, unpacking, pulse-finding, FFT power analysis, and other specialized analyses are performed, creating a live archive ∼50,000 histograms. Plots can be displayed with the use of web-based data visualization tools derived from Arachne (below), allowing easy access to both high- and low-level diagnostic information. The tool is used for automatic data checks, manual monitoring of data quality, expert analysis of detector issues, and long-term detector trend analysis. I have been sole on-call support for this system, which has had $> 99.\%$ uptime 24/7 for more than five years.

Physics simulations for education 2013-21 Wrote several JavaScript-based web sites ("physlets") for teaching various physics properties. This included a dynamic, responsive system for diagramming electric field lines in 2D, an animated display of fields in an electromagnetic wave, a simulation of linear polarizers, a more advanced version which showed the relationship between linear and circular polarizers, and a full 2D wave simulation by differential equations that runs via WebGL on the client GPU.

"Arachne " Event Display for MINERvA - 2008-2013 Authored CGI-based web application that used a C++ backend to serve data from ENSTORE ROOT files to a browser-based event viewer, allowing users to see live or reconstructed data from the MINERvA experiment. This was one of the first systems that allowed dynamic interaction rather than static rendering of particle physics data, which enabled a large range of hand-scan based analyses and reconstruction checks widely distributed across the international collaboration. I developed the underlying graphics engine, which used HTML5 Canvas types to do graphs, histograms, and a 3D vector diagrams.

"Glaucus" Shift Scheduler and Collaboration Management Tool - 2008-2012 A web site based on PERL and MySQL is used to track collaborators on the MINERvA experiment, and allow easy sign-ups for continuous shifts for detector monitoring.

Student laboratory experiments - 2008-21 As the sole resident experimentalist at Otterbein during most of this time, I created many laboratory exercises for students at both the introductory and advanced levels. Examples include a twofold coincidence gamma ray detector for observing Na-24 positron annihilations, and a safe liquid-scintillator-based cosmic ray detector that could accurately measure the Michel electron time distribution.

Daya Bay DatabaseInterface - 2007 I adapted the MINOS database interface system to work in the multi-site multi-detector system of the Daya Bay experiment.

MINOS Calibration, 2003-2006 Lead designer and task force lead on calibration of MINOS detectors. Designed software that allowed for multistage calibration of data, and de-calibration of Monte Carlo simulation (used in conjunction with my tools that simulated the optical and electronic properties of the readout system).

MINOS timing - 2002-2005 Worked in team that created MINOS detector timing systems. These systems used GPS to synchronize distant multiple sites with clocks precise to the nanosecond level and accurate to within 200 ns in hardware, and NTP level accuracy in software.

MINOS Blinding - 2003-5 Built and successfully advocated use of a blind analysis scheme in MINOS, which introduced systematically blind data from the the detector stream to hide oscillation signals.

PMT characterization - 2001-2003 Lead a campaign to characterize each of several hundred multi-channel photomultiplier tubes used in the MINOS near detector, to understand gain curves, optical and electronic cross-talk between channels.

8-Li Calibration source for SNO - 1998-2001 (PhD thesis.) Designed, built, and deployed a system that used rapid transport of aerosol-laden gases to carry short-lived radioactive isotopes from a neutron generator target to a decay volume placed within the Sudbury Neutrino Observatory, and to use gas scintillation to tag candidate decays. This system was used to verify electron response of the Cherenkov imager.

Analysis of through-going muons in SNO - 1998-2001 (PhD thesis.) First analysis of high-energy muons at the Sudbury Neutrino Detector. Able to analyze both upward-going and downward-going muons in the same analysis to put limits on certain cosmic-ray-induced neutrino oscillation scenarios.

Grants and Support

- Nathaniel Tagg (PI): "RUI: Neutrino Experiments at Fermilab" 2019-2023. National Science Foundation, program for Research at Undergraduate Institutions. $196,000 to support research in experimental particle physics, including stipends and travel support for Otterbein students.
- Nathaniel Tagg (PI): NSF "RUI: Neutrino Experiments at Fermilab" (similar to above, $147,000) 2016-2018
- Nathaniel Tagg (PI): NSF "RUI: Neutrino Experiments at Fermilab" (similar to above, $137,000) 2013-2015.
- Nathaniel Tagg (PI): Visitor support for extended travel to Fermilab to work on MINERvA project. Roughly $6800 to supportPI and two undergraduate students for one month. Awarded and used June 2011.
- Nathaniel Tagg (PI): NSF "RUI: Neutrino Experiments with the NuMI Beam." (similar to above, $113,000) 2009-2012.
- National Sciences and Engineering Council Post Graduate Scholarship (NSERC PGS A), 1993-95

University Courses Taught

Introductory physics (calculus- and algebra-based), introductory lab, classical mechanics, nuclear and particle physics, electronics, advanced undergraduate laboratory, modern physics, optics, and general education courses for non-majors.

University Service

- Department chair (2015-2020)
- Hired, trained, mentored 2-3 undergraduate students/year as summer research interns. Supervised undergraduate thesis projects.
- Chair of Arts & Sciences Tenure/Promotion Committee (SPEC) (2017-2019), University Senator (2018-2021), Teaching/learning/technology committee (2011-12), Personnel/Curriculum hiring subcommittee (2011), Curriculum committee (2010-12), Institutional effectiveness committee (2009-11), Science lecture series committee (2009-2018)
- Supervised overhaul of physics curricula (2016) - change from 4-credit-hour model to 3-credit, also helped rebuild curriculum in 2010) change from quarters to semesters

Professional Memberships and Service

Grant reviewer; serving on panel for all National Science Foundation Investigator-Proposed grants in High-energy Experimental Physics. (Scheduled April 2021)

Referee: Nuclear Instruments and Methods A, American Journal of Physics

Member: American Physical Society, American Association of Physics Teachers

Member: American Association of University Professors

Research Affiliations

DUNE Experiment Collaboration (2017-)

MicroBooNE Experiment Collaboration (2014-)

MINERνA Experiment Collaboration (full author 2008-2015, limited author 2015-onward)

MINOS+ Experiment Collaboration (legacy author, 2001-)

Professional Development

Partnership for Integration of Computation into Undergraduate Physics (PICUP), 2017-2019

Member, Otterbein's Center for Teaching and Learning "STEM Professional Learning Community", 2014-15

Member, Otterbein's Center for Teaching and Learning "New Faculty Teaching and Learning Community", 2009-10

AAPT New Faculty Workshop, 2009

Publications

Papers in Refereed Journals

[1] P. Abratenko et al. "Measurement of the Longitudinal Diffusion of Ionization Electrons in the MicroBooNE Detector". In: (Apr. 2021). arXiv: 2104.06551 [physics.ins-det].

[2] P. Abratenko et al. "Measurement of differential cross sections for ν_μ -Ar charged-current interactions with protons and no pions in the final state with the MicroBooNE detector". In: *Phys. Rev. D* 102.11 (2020), p. 112013. DOI: 10.1103/PhysRevD.102.112013. arXiv: 2010.02390 [hep-ex].

[3] P. Abratenko et al. "Measurement of space charge effects in the MicroBooNE LArTPC using cosmic muons". In: *JINST* 15.12 (2020), P12037. DOI: 10.1088/1748-0221/15/12/P12037. arXiv: 2008.09765 [physics.ins-det].

[4] P. Adamson et al. "Precision Constraints for Three-Flavor Neutrino Oscillations from the Full MINOS+ and MINOS Dataset". In: *Phys. Rev. Lett.* 125.13 (2020), p. 131802. DOI: 10.1103/PhysRevLett.125.131802. arXiv: 2006.15208 [hep-ex].

[5] P. Abratenko et al. "First Measurement of Differential Charged Current Quasielastic-like ν_μ-Argon Scattering Cross Sections with the MicroBooNE Detector". In: *Phys. Rev. Lett.* 125.20 (2020), p. 201803. DOI: 10.1103/PhysRevLett.125.201803. arXiv: 2006.00108 [hep-ex].

[6] P. Adamson et al. "Improved Constraints on Sterile Neutrino Mixing from Disappearance Searches in the MINOS, MINOS+, Daya Bay, and Bugey-3 Experiments". In: *Phys. Rev. Lett.* 125.7 (2020), p. 071801. DOI: 10.1103/PhysRevLett.125.071801. arXiv: 2002.00301 [hep-ex].

[7] P. Abratenko et al. "Search for Heavy Neutral Leptons Decaying into Muon-Pion Pairs in the MicroBooNE Detector". In: *Phys. Rev. D* 101.5 (2020), p. 052001. DOI: 10.1103/PhysRevD.101.052001. arXiv: 1911.10545 [hep-ex].

[8] C. Adams et al. "Reconstruction and Measurement of $\mathcal{O}(100)$ MeV Energy Electromagnetic Activity from $\pi^0 \to \gamma\gamma$ Decays in the MicroBooNE LArTPC". In: *JINST* 15.02 (2020), P02007. DOI: 10.1088/1748-0221/15/02/P02007. arXiv: 1910.02166 [hep-ex].

[9] C. Adams et al. "A method to determine the electric field of liquid argon time projection chambers using a UV laser system and its application in MicroBooNE". In: *JINST* 15.07 (2020), P07010. DOI: 10.1088/1748-0221/15/07/P07010. arXiv: 1910.01430 [physics.ins-det].

[10] C. Adams et al. "Calibration of the charge and energy loss per unit length of the MicroBooNE liquid argon time projection chamber using muons and protons". In: *JINST* 15.03 (2020), P03022. DOI: 10.1088/1748-0221/15/03/P03022. arXiv: 1907.11736 [physics.ins-det].

[11] P. Abratenko et al. "First Measurement of Inclusive Muon Neutrino Charged Current Differential Cross Sections on Argon at $E_\nu \sim$0.8 GeV with the MicroBooNE Detector". In: *Phys. Rev. Lett.* 123.13 (2019), p. 131801. DOI: 10.1103/PhysRevLett.123.131801. arXiv: 1905.09694 [hep-ex].

[12] C. Adams et al. "Design and construction of the MicroBooNE Cosmic Ray Tagger system". In: *JINST* 14.04 (2019), P04004. DOI: 10.1088/1748-0221/14/04/P04004. arXiv: 1901.02862 [physics.ins-det].

[13] C. Adams et al. "Rejecting cosmic background for exclusive charged current quasi elastic neutrino interaction studies with Liquid Argon TPCs; a case study with the MicroBooNE detector". In: *Eur. Phys. J. C* 79.8 (2019), p. 673. DOI: 10.1140/epjc/s10052-019-7184-7. arXiv: 1812.05679 [physics.ins-det].

[14] C. Adams et al. "First measurement of ν_μ charged-current π^0 production on argon with the MicroBooNE detector". In: *Phys. Rev. D* 99.9 (2019), p. 091102. DOI: 10.1103/PhysRevD.99.091102. arXiv: 1811.02700 [hep-ex].

[15] C. Adams et al. "Deep neural network for pixel-level electromagnetic particle identification in the MicroBooNE liquid argon time projection chamber". In: *Phys. Rev. D* 99.9 (2019), p. 092001. DOI: 10.1103/PhysRevD.99.092001. arXiv: 1808.07269 [hep-ex].

[16] C. Adams et al. "Comparison of ν_μ-Ar multiplicity distributions observed by MicroBooNE to GENIE model predictions". In: *Eur. Phys. J. C* 79.3 (2019), p. 248. DOI: 10.1140/epjc/s10052-019-6742-3. arXiv: 1805.06887 [hep-ex].

[17] C. Adams et al. "Ionization electron signal processing in single phase LArTPCs. Part II. Data/simulation comparison and performance in MicroBooNE". In: *JINST* 13.07 (2018), P07007. DOI: 10.1088/1748-0221/13/07/P07007. arXiv: 1804.02583 [physics.ins-det].

[18] C. Adams et al. "Ionization electron signal processing in single phase LArTPCs. Part I. Algorithm Description and quantitative evaluation with MicroBooNE simulation". In: *JINST* 13.07 (2018), P07006. DOI: 10.1088/1748-0221/13/07/P07006. arXiv: 1802.08709 [physics.ins-det].

[19] A. Mislivec et al. "Measurement of total and differential cross sections of neutrino and antineutrino coherent $\pi^\pm$ production on carbon". In: *Phys. Rev. D* 97.3 (2018), p. 032014. DOI: 10.1103/PhysRevD.97.032014. arXiv: 1711.01178 [hep-ex].

[20] P. Adamson et al. "Search for sterile neutrinos in MINOS and MINOS+ using a two-detector fit". In: *Phys. Rev. Lett.* 122.9 (2019), p. 091803. DOI: 10.1103/PhysRevLett.122.091803. arXiv: 1710.06488 [hep-ex].

[21] R. Acciarri et al. "The Pandora multi-algorithm approach to automated pattern recognition of cosmic-ray muon and neutrino events in the MicroBooNE detector". In: *Eur. Phys. J. C* 78.1 (2018), p. 82. DOI: 10.1140/epjc/s10052-017-5481-6. arXiv: 1708.03135 [hep-ex].

[22] R. Acciarri et al. "Measurement of cosmic-ray reconstruction efficiencies in the MicroBooNE LArTPC using a small external cosmic-ray counter". In: *JINST* 12.12 (2017), P12030. DOI: 10.1088/1748-0221/12/12/P12030. arXiv: 1707.09903 [hep-ex].

[23] R. Acciarri et al. "Noise Characterization and Filtering in the MicroBooNE Liquid Argon TPC". In: *JINST* 12.08 (2017), P08003. DOI: 10.1088/1748-0221/12/08/P08003. arXiv: 1705.07341 [physics.ins-det].

[24] R. Acciarri et al. "Michel Electron Reconstruction Using Cosmic-Ray Data from the MicroBooNE LArTPC". In: *JINST* 12.09 (2017), P09014. DOI: 10.1088/1748-0221/12/09/P09014. arXiv: 1704.02927 [physics.ins-det].

[25] P. Abratenko et al. "Determination of muon momentum in the MicroBooNE LArTPC using an improved model of multiple Coulomb scattering". In: *JINST* 12.10 (2017), P10010. DOI: 10.1088/1748-0221/12/10/P10010. arXiv: 1703.06187 [physics.ins-det].

[26] R. Acciarri et al. "Design and Construction of the MicroBooNE Detector". In: *JINST* 12.02 (2017), P02017. DOI: 10.1088/1748-0221/12/02/P02017. arXiv: 1612.05824 [physics.ins-det].

[27] R. Acciarri et al. "Convolutional Neural Networks Applied to Neutrino Events in a Liquid Argon Time Projection Chamber". In: *JINST* 12.03 (2017), P03011. DOI: 10.1088/1748-0221/12/03/P03011. arXiv: 1611.05531 [physics.ins-det].

[28] P. Adamson et al. "Constraints on Large Extra Dimensions from the MINOS Experiment". In: *Phys. Rev. D* 94.11 (2016), p. 111101. DOI: 10.1103/PhysRevD.94.111101. arXiv: 1608.06964 [hep-ex].

[29] P. Adamson et al. "Measurement of single π^0 production by coherent neutral-current ν Fe interactions in the MINOS Near Detector". In: *Phys. Rev. D* 94.7 (2016), p. 072006. DOI: 10.1103/PhysRevD.94.072006. arXiv: 1608.05702 [hep-ex].

[30] P. Adamson et al. "Limits on Active to Sterile Neutrino Oscillations from Disappearance Searches in the MINOS, Daya Bay, and Bugey-3 Experiments". In: *Phys. Rev. Lett.* 117.15 (2016). [Addendum: Phys.Rev.Lett. 117, 209901 (2016)], p. 151801. DOI: 10.1103/PhysRevLett.117.151801. arXiv: 1607.01177 [hep-ex].

[31] P. Adamson et al. "Search for Sterile Neutrinos Mixing with Muon Neutrinos in MINOS". In: *Phys. Rev. Lett.* 117.15 (2016), p. 151803. DOI: 10.1103/PhysRevLett.117.151803. arXiv: 1607.01176 [hep-ex].

[32] P. Adamson et al. "Search for flavor-changing nonstandard neutrino interactions using ν_e appearance in MINOS". In: *Phys. Rev. D* 95.1 (2017), p. 012005. DOI: 10.1103/PhysRevD.95.012005. arXiv: 1605.06169 [hep-ex].

[33] J. Wolcott et al. "Evidence for Neutral-Current Diffractive π^0 Production from Hydrogen in Neutrino Interactions on Hydrocarbon". In: *Phys. Rev. Lett.* 117.11 (2016), p. 111801. DOI: 10.1103/PhysRevLett.117.111801. arXiv: 1604.01728 [hep-ex].

[34] P. Adamson et al. "Measurement of the Multiple-Muon Charge Ratio in the MINOS Far Detector". In: *Phys. Rev. D* 93.5 (2016), p. 052017. DOI: 10.1103/PhysRevD.93.052017. arXiv: 1602.00783 [hep-ex].

[35] J. Mousseau et al. "Measurement of Partonic Nuclear Effects in Deep-Inelastic Neutrino Scattering using MINERvA". In: *Phys. Rev. D* 93.7 (2016), p. 071101. DOI: 10.1103/PhysRevD.93.071101. arXiv: 1601.06313 [hep-ex].

[36] J. Park et al. "Measurement of Neutrino Flux from Neutrino-Electron Elastic Scattering". In: *Phys. Rev. D* 93.11 (2016), p. 112007. DOI: 10.1103/PhysRevD.93.112007. arXiv: 1512.07699 [physics.ins-det].

[37] P. A. Rodrigues et al. "Identification of nuclear effects in neutrino-carbon interactions at low three-momentum transfer". In: *Phys. Rev. Lett.* 116 (2016). [Addendum: Phys.Rev.Lett. 121, 209902 (2018)], p. 071802. DOI: 10.1103/PhysRevLett.116.071802. arXiv: 1511.05944 [hep-ex].

[38] J. Wolcott et al. "Measurement of electron neutrino quasielastic and quasielasticlike scattering on hydrocarbon at $<E_\nu> = 3.6$ GeV". In: *Phys. Rev. Lett.* 116.8 (2016), p. 081802. DOI: 10.1103/PhysRevLett.116.081802. arXiv: 1509.05729 [hep-ex].

[39] F. P. An et al. "The Detector System of The Daya Bay Reactor Neutrino Experiment". In: *Nucl. Instrum. Meth. A* 811 (2016), pp. 133–161. DOI: 10.1016/j.nima.2015.11.144. arXiv: 1508.03943 [physics.ins-det].

[40] P. Adamson et al. "The NuMI Neutrino Beam". In: *Nucl. Instrum. Meth. A* 806 (2016), pp. 279–306. DOI: 10.1016/j.nima.2015.08.063. arXiv: 1507.06690 [physics.acc-ph].

[41] P. Adamson et al. "Precision Measurement of the Speed of Propagation of Neutrinos using the MINOS Detectors". In: *Phys. Rev. D* 92.5 (2015), p. 052005. DOI: 10.1103/PhysRevD.92.052005. arXiv: 1507.04328 [hep-ex].

[42] P. Adamson et al. "Observation of Seasonal Variation of Atmospheric Multiple-Muon Events in the MINOS Near and Far Detectors". In: *Phys. Rev. D* 91.11 (2015), p. 112006. DOI: 10.1103/PhysRevD.91.112006. arXiv: 1503.09104 [hep-ex].

[43] T. Le et al. "Single Neutral Pion Production by Charged-Current $\bar{\nu}_\mu$ Interactions on Hydrocarbon at $<E_\nu>$ =3.6 GeV". In: *Phys. Lett. B* 749 (2015), pp. 130–136. DOI: 10.1016/j.physletb.2015.07.039. arXiv: 1503.02107 [hep-ex].

[44] L. Aliaga et al. "MINERvA neutrino detector response measured with test beam data". In: *Nucl. Instrum. Meth. A* 789 (2015), pp. 28–42. DOI: 10.1016/j.nima.2015.04.003. arXiv: 1501.06431 [physics.ins-det].

[45] P. Adamson et al. "Study of quasielastic scattering using charged-current $\nu\mu$ -iron interactions in the MINOS near detector". In: *Phys. Rev. D* 91.1 (2015), p. 012005. DOI: 10.1103/PhysRevD.91.012005. arXiv: 1410.8613 [hep-ex].

[46] T. Walton et al. "Measurement of muon plus proton final states in ν_μ interactions on hydrocarbon at $< E_\nu >=$ 4.2 GeV". In: *Phys. Rev. D* 91.7 (2015), p. 071301. DOI: 10.1103/PhysRevD.91.071301. arXiv: 1409.4497 [hep-ex].

[47] A. Higuera et al. "Measurement of Coherent Production of $\pi^\pm$ in Neutrino and Antineutrino Beams on Carbon from E_ν of 1.5 to 20 GeV". In: *Phys. Rev. Lett.* 113.26 (2014), p. 261802. DOI: 10.1103/PhysRevLett.113.261802. arXiv: 1409.3835 [hep-ex].

[48] P. Adamson et al. "Observation of Muon Intensity Variations by Season with the MINOS Near Detector". In: *Phys. Rev. D* 90.1 (2014), p. 012010. DOI: 10.1103/PhysRevD.90.012010. arXiv: 1406.7019 [hep-ex].

[49] B. Eberly et al. "Charged Pion Production in ν_μ Interactions on Hydrocarbon at $<E_\nu>=$ 4.0 GeV". In: *Phys. Rev. D* 92.9 (2015), p. 092008. DOI: 10.1103/PhysRevD.92.092008. arXiv: 1406.6415 [hep-ex].

[50] B. G. Tice et al. "Measurement of Ratios of ν_μ Charged-Current Cross Sections on C, Fe, and Pb to CH at Neutrino Energies 2-20 GeV". In: *Phys. Rev. Lett.* 112.23 (2014), p. 231801. DOI: 10.1103/PhysRevLett.112.231801. arXiv: 1403.2103 [hep-ex].

[51] P. Adamson et al. "Combined analysis of ν_μ disappearance and $\nu_\mu \rightarrow \nu_e$ appearance in MINOS using accelerator and atmospheric neutrinos". In: *Phys. Rev. Lett.* 112 (2014), p. 191801. DOI: 10.1103/PhysRevLett.112.191801. arXiv: 1403.0867 [hep-ex].

[52] L. Aliaga et al. "Design, Calibration, and Performance of the MINERvA Detector". In: *Nucl. Instrum. Meth. A* 743 (2014), pp. 130–159. DOI: 10.1016/j.nima.2013.12.053. arXiv: 1305.5199 [physics.ins-det].

[53] G. A. Fiorentini et al. "Measurement of Muon Neutrino Quasielastic Scattering on a Hydrocarbon Target at $E_\nu \sim 3.5$ GeV". In: *Phys. Rev. Lett.* 111 (2013), p. 022502. DOI: 10.1103/PhysRevLett.111.022502. arXiv: 1305.2243 [hep-ex].

[54] L. Fields et al. "Measurement of Muon Antineutrino Quasielastic Scattering on a Hydrocarbon Target at E$\nu\sim$3.5 GeV". In: *Phys. Rev. Lett.* 111.2 (2013), p. 022501. DOI: 10.1103/PhysRevLett.111.022501. arXiv: 1305.2234 [hep-ex].

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[56] P. Adamson et al. "Search for flavor-changing non-standard neutrino interactions by MINOS". In: *Phys. Rev. D* 88.7 (2013), p. 072011. DOI: 10.1103/PhysRevD.88.072011. arXiv: 1303.5314 [hep-ex].

[57] P. Adamson et al. "Electron neutrino and antineutrino appearance in the full MINOS data sample". In: *Phys. Rev. Lett.* 110.17 (2013), p. 171801. DOI: 10.1103/PhysRevLett.110.171801. arXiv: 1301.4581 [hep-ex].

[58] P. Adamson et al. "Comparisons of Annual Modulations in MINOS with the Event Rate Modulation in CoGeNT". In: *Phys. Rev. D* 87.3 (2013), p. 032005. DOI: 10.1103/PhysRevD.87.032005. arXiv: 1212.1776 [hep-ex].

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