Matthew L. Strait

Curriculum Vitae

Physics and Astronomy
University of Minnesota
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Experienced researcher in neutrino physics with emphases on long-baseline oscillations, particle astrophysics, and reduction of systematic errors, primarily through improved particle simulations.

Positions

Associate Lab Director, NOvA Far Detector, University of Minnesota — NOvA, DUNE 2023 –
"Researcher 7", grant-eligible position equivalent to research professor

Postdoc, University of Minnesota — NOvA, DUNE 2015 – 2022
Supervisors: Prof. Marvin Marshak, Prof. Greg Pawloski

Post-doctoral Scholar, University of Chicago — Double Chooz, SNO+ 2010 – 2015
Supervisor: Prof. Ed Blucher

Research Assistant, University of Minnesota — MINOS, NOvA 2006 – 2010
Supervisor: Prof. Dan Cronin-Hennessy

Leadership Roles

NOvA Operations Manager 2023 –
NOvA Exotics Group Convenor (astrophysics and beyond-the-Standard-Model) 2017 –
NOvA Speakers Committee 2019 –
NOvA/T2K Joint Analysis, Detector Simulation Convenor 2019 –
NOvA Run Coordinator 2016 – 2017
SNO+ Code Integrity Committee, Chair 2014 – 2015
SNO+ Supernova Group, Deputy Convenor 2015
SNO+ Event Viewer Selection Committee, Chair 2013
University of Chicago HEP Lunch Seminar Series Organizer 2011 – 2012

Education

Ph.D. Physics, University of Minnesota, Twin Cities 2010
B.A. Physics (magna cum laude), Carleton College 2003

Grants

Universities Research Association Visiting Scholar, $2000 2021 – 2022
Measurements of liquid argon stopping power for DUNE

Fermilab Intensity Frontier Fellowship, $10,000 2019 – 2020
NOvA oscillation and astrophysics data analysis and measurements of LAr properties for DUNE

Universities Research Association Visiting Scholar, $3000 2019 – 2020
NOvA oscillation and astrophysics data analysis and measurements of LAr properties for DUNE

Fermilab Neutrino Physics Center Fellowship, $3000 2018 – 2019
Travel Support for NOvA Analysis and ProtoDUNE DAQ
Universities Research Association Visiting Scholar, $7000 2018 – 2019
Travel Support for NOvA Analysis and ProtoDUNE Cosmic Ray Tracker
Fermilab Neutrino Physics Center Scholar, $4000 2017 – 2018
Travel Support for NOvA Collaboration on Astrophysical Analyses and ProtoDUNE Cosmic Ray Tracker
Universities Research Association Visiting Scholar, $8000 2017 – 2018
Travel Support for NOvA Exotics Group and ProtoDUNE Cosmic Ray Tracker
Universities Research Association Visiting Scholar, $9000 2016 – 2017
Travel Support for NOvA Electron Neutrino Selection, Run Coordination, Meetings and Workshops

Research Activities

NOvA Collaboration, University of Minnesota **2015 – present**

Astrophysics

Convene the "Exotics" group, which covers all astrophysical topics as well as all searches for new physics beyond neutrino oscillations (2017 – present) [3] [14] [16].

Designed and commissioned trigger to respond to signals of gravitational waves from the LIGO/Virgo Collaboration. Published analysis searching for coincident signals in the NOvA detectors, expanding NOvA's multi-messenger astronomy program [2] [4].

Developed background rejection techniques for supernova neutrino self-trigger. Tested longer readout windows for supernova triggers, allowing NOvA to observe more late-time physics [14].

Wrote shifter GUI for KamLAND pre-supernova significance. Alerts shifters when a high significance of an impending supernova is reported. In use by NOvA and SNO+.

Spearheaded effort to reconstruct data for astrophysical triggers immediately, making them available to offline analysis within days rather than months or years.

Electron neutrino appearance

Demonstrated that NOvA's deep-learning convolutional neural network event selection for ν_e could achieve very significantly improved discrimination by taking into account information from delayed activity in the detector from muon decay and neutron captures *if* we could model the detector response with more precision.

Muon neutrino disappearance

Developed novel method to measure the flux of ν_μ background ("wrong sign") in the $\bar{\nu}_\mu$-mode of the NuMI beam in an unmagnetized detector, exploiting the fact that μ^- are captured by nuclei, releasing neutrons, but μ^+ are not. The count of neutron captures near track ends gives us our only data-driven estimate of the wrong-sign rate [5].

Extensively studied the systematic error on determining muon energy from range, leading to a factor of three reduction in this uncertainty, and a more sophisticated treatment of correlations between the Near and Far detectors [6] [7].

Investigated systematic error on energy reconstruction from the Coulomb effect and implemented a treatment of it in the NOvA analysis.

Detector simulation

Improved Geant4 modeling of the Fermi density effect which modifies energy loss and is particularly relevant at typical NOvA energies. Modifies $\mathrm{d}E/\mathrm{d}x$ by up to 2%, improving modeling for all Geant4 users, and in particular giving NOvA a better estimate of muon energy.

Overhauled Monte Carlo model of NOvA detectors. Added important geometrical details. Overhauled chemical compositions, substantially improving the correct Monte Carlo predictions for neutrino cross-sections, particle ranges, neutron capture cross sections, etc. Reduces calibration systematic errors, which are among our largest.

Studied thermal neutron properties in NOvA, uncovering modeling problems in Geant4 affecting the mean lifetime and propagation distances. Allowed for better discrimination between Michel electrons and neutron.

Investigated modeling of delayed electronics behavior following large energy depositions. Found large data/Monte Carlo discrepancies in electronics "flasher" hits, hampering my efforts to use delayed hits in ν_e identification.

Studied the effect of differing rock compositions surrounding the Near Detector on the rate of beam-related charged particles and neutrons arriving from outside the detector. Improved modeling of rock, leading to a factor of three reduction in expectation for thermal neutron flux, among other changes, primarily by including rock water content.

Studied light propagation in NOvA cells. Built a lab benchtop model and wrote simulation code. Uncovered calorimetric biases in previous model. Wrote new Monte Carlo routine to account for these effects, significantly reducing our largest systematic error.

Run coordinator

First run coordinator after commissioning; led effort to transform procedures into those needed for increasingly stable running. Coordinated work for detector and DAQ upgrades. On-call for all detector problems. Gave weekly summary of data-taking status.

Event display

Wrote new event display from scratch which allows much faster access to events by loading events in milliseconds, 1000× faster than the existing event display. Displays information complementary to the existing event display.

Software

Made major efficiency improvements to reconstruction software, sufficient to make time for additional studies bolstering our oscillation analysis.

DUNE Collaboration, University of Minnesota **2017 – present**

LAr Stopping Power

Liquid argon stopping power is only known through measurements on gaseous argon. Phase is known to have significant effect on stopping power, but there are no measurements of this effect for argon. I am developing a test beam experiment, to run at the Fermilab ITA, that will make the first measurement of the mean ionization energy of liquid argon; the target is a higher precision than has been achieved for gaseous argon.

ProtoDUNE Cosmic Ray Tracker

Wrote and tested DAQ software, including back-end code and *artdaq* "board reader" interface. Collaborated with timing system group to integrate our internal system with the rest of ProtoDUNE. Participated in early mechanical tests. Assembled and installed panels at CERN.

NuSOL, University of Minnesota **2021 – present**

Feasibility studies

Monte Carlo studies to determine what could be learned by putting a space-based neutrino detector into close solar orbit. Studying whether the solar core could be imaged in ^{8}B neutrinos with a realistic detector mass. Also considering possibility of detecting extra-solar neutrinos by using the Sun as a gravitational lens.

SNO+ Collaboration, University of Chicago **2012 – 2015**

Online monitoring/data flow working group

Developed level-2 trigger and supernova data buffer. Designed hardware and software to optimize supernova capabilities. Prepared for data storage solutions at Fermilab [20].

Supernova working group

Deputy convenor: Organized group meetings, coordinated work, reported to collaboration.

On-site construction shifts

Worked to prepare our underground areas for installation of scintillator processing plant.

Nucleon decay

Investigated various modes of invisible nucleon and di-nucleon decay that could result in low-background delayed-coincidence signals in the water phase of the SNO+ program [17].

Software

Headed the "Code Integrity Committee," which oversaw development of Monte Carlo, reconstruction, calibration and analysis software. Chaired committee tasked with deciding which of two existing event display packages would be supported by the collaboration. Maintained event display, and integrated it with SNO+ software. Optimized speed of reconstruction algorithms.

Double Chooz Collaboration, University of Chicago **2010 – 2015**

Outer Veto

Installed the UChicago Outer Veto, wrote its event viewer, and contributed to calibration and reconstruction software. Evaluated impact of different designs for Near Detector Outer Veto. Reduced background in oscillation analysis [22].

High-precision muon reconstruction

Wrote a high-resolution muon reconstruction that aids in suppression of cosmogenic backgrounds. Includes new energy estimator for GeV-scale events. Documented in NIM A article [9] [19].

Nuclear muon capture

Using my muon reconstruction, performed analysis of isotope production via nuclear muon capture. Made most precise measurement to date of ^{12}B production, including the exclusive rate into several nuclear states and the total rate. Measured three previously unobserved reactions. Set limits on 15 other reactions. Results published in PRC [8].

Software

Made major efficiency improvements to reconstruction software.

MINOS Collaboration, University of Minnesota **2006 – 2010**

Partially contained event analysis

My thesis work, which was used to extend the sensitivity of the standard MINOS analysis [10], was to analyze the sample of beam events that occur in the exterior of the detector and in the surrounding rock.

Study of $\bar{\nu}_\mu$ disappearance using rock events

Developed $\bar{\nu}_\mu$ selection for Far Detector rock events, allowing a cross-check to MINOS's surprising 2011 results showing a 2σ tension between ν_μ and $\bar{\nu}_\mu$. Published results include this cross-check [23].

Contributions to detector Monte Carlo

Identified and corrected mismatch between rock density in two parts of the simulation, leading to incorrect rock muon flux. Improved modeling of Far Detector rock based on published rock compositions. Measured density of rock from core samples and incorporated into simulation. Identified and corrected incorrect modeling of scintillator strip lengths in the MINOS Far Detector.

Reconstruction batch processing working group

Member of two-person group responsible for reconstructing all MINOS data and official Monte Carlo samples. Managed batch queue, determined quality of output, and organized file sets.

NOvA Collaboration, University of Minnesota **2005 – 2010**

Fiber aging studies

Performed materials compatibility study between wavelength-shifting fibers and NOvA scintillator, including an accelerated aging test using fibers immersed in scintillator at 45°C, demonstrating a large safety margin at NOvA pseudocumene concentrations. Published study in NIM A [11].

Stringing machine R&D

Designed and built a machine to insert the fibers into NOvA cells during construction. Studied the effect of the physical stresses involved in this process on fiber cladding and determined minimal risk of cracks causing loss of light transmission efficiency [24].

Selected Publications

My role for each paper is given **in bold** following the reference.

1. M. Strait, *Evaluation of the mean excitation energies of gaseous and liquid argon*, JINST **19**(01), P01009 (2024), arXiv:2212.06286 (phys.ins-det). **Single author. New recommendations based on extensive literature review.**

2. M. A. Acero et al. (NOvA Collaboration), *Extended search for supernovalike neutrinos in NOvA coincident with LIGO/Virgo detections*, Phys. Rev. D **104**, 063024 (2021), arXiv:2106.06035. **Primary author: all analysis and writing.**

3. M. A. Acero et al. (NOvA Collaboration), *Search for slow magnetic monopoles with the NOvA detector on the surface*, Phys. Rev. D **103**, 012007 (2021), arXiv:2009.04867. **One of two primary authors.**

4. M. A. Acero et al. (NOvA Collaboration), *Search for multi-messenger signals in NOvA coincident with LIGO/Virgo detections*, Phys. Rev. D **101**(11), 112006 (2020), arXiv:2001.07240. **Primary author: all analysis and writing.**

5. M. A. Acero et al. (NOvA Collaboration), *First measurement of neutrino oscillation parameters using neutrinos and antineutrinos by NOvA*, Phys. Rev. Lett. **123**, 151803 (2019), arXiv:1906.04907. **Measurement of ν_μ background in $\bar{\nu}_\mu$ beam, using novel neutron capture technique in a non-magnetized detector, allowing reliable CP-violation measurements.**

6. M. Strait et al., *NOvA muon energy scale systematic*, Fermilab technical publication FERMILAB-FN-1061-ND (2019), arXiv:1902.02805. **Primary author, Monte Carlo updates, Monte Carlo sample generation, judgments, large majority of studies, some physical detector measurements.**

7. M. A. Acero et al. (NOvA Collaboration), *New constraints on oscillation parameters from ν_e appearance and ν_μ disappearance in the NOvA experiment*, Phys. Rev. D **98**, 032012 (2018), arXiv:1806.00096. **Uses my improved Monte Carlo geometry. Large reduction of previously dominant systematic uncertainty on muon energy. Maintained detector uptime in role of run coordinator.**

8. Y. Abe et al. (Double Chooz Collaboration), *Muon capture on light isotopes measured with the Double Chooz detector*, Phys. Rev. C **93**, 054608 (2016), arXiv:1512.07562. **Primary author: all data analysis.**

9. Y. Abe et al. (Double Chooz Collaboration), *Precision muon reconstruction in Double Chooz*, Nucl. Instrum. Methods **A764**, 330 (2014), arXiv:1405.6227 **Primary author: describes my reconstruction work.**

10. P. Adamson et al. (MINOS Collaboration), *Measurement of the neutrino mass splitting and flavor mixing by MINOS*, Phys. Rev. Lett. **106**, 181801 (2011), arXiv:1103.0340. **Thesis work: partially contained events.**

11. M. Strait, D. Cronin-Hennessy and K. Arms, *Interaction rate of polystyrene fiber optics with pseudocumene-based liquid scintillator*, Nucl. Instrum. Methods **A615**, 33 (2010), doi:10.1016/j.nima.2010.01.002. **Primary author: Design of procedures, bench work, paper writing.**

Further Publications

12. M. A. Acero et al. (NOvA Collaboration), *Seasonal variation of multiple-muon cosmic ray air showers observed in the NOvA detector on the surface*, Phys. Rev. D **104**(1), 012014 (2021), arXiv:2105.03848. **Publication of NOvA Exotics group, which I convene.**

13. S. Al Kharusi et al. (SNEWS Collaboration), *SNEWS 2.0: a next-generation SuperNova Early Warning System for multi-messenger astronomy*, New J. Phys. **23**(3), 031201 (2021), arXiv:2011.00035. **Analyzed latency requirements.**

14. M. A. Acero et al. (NOvA Collaboration), *Supernova neutrino detection in NOvA*, JCAP **10**, 014 (2020), arXiv:2005.07155. **Publication of NOvA Exotics group.**

15. M. A. Acero et al. (NOvA Collaboration), *Measurement of neutrino-induced neutral-current coherent π^0 production in the NOvA Near Detector*, Phys. Rev. D **102**(1), 012004 (2020), arXiv:1902.00558. **NOvA paper committee reviewer.**

16. M. A. Acero et al. (NOvA Collaboration), *Observation of seasonal variation of atmospheric multiple-muon events in the NOvA Near Detector*, Phys. Rev. D **99**, 122004 (2019), arXiv:1904.12975. **First publication of NOvA Exotics group.**

17. M. Anderson et al. (SNO+ Collaboration), *Search for invisible modes of nucleon decay in water with the SNO+ detector*, Phys. Rev. D **99**, 032008 (2019), arXiv:1812.05552. **Early work on characterizing signals of di-nucleon decay.**

18. P. Adamson et al. (NOvA Collaboration), *First measurement of electron neutrino appearance in NOvA*, Phys. Rev. Lett. **116**, 151806 (2016), arXiv:1601.05022, P. Adamson et al. (NOvA Collaboration), *First measurement of muon-neutrino disappearance in NOvA*, Phys. Rev. D **93**, 051104 (2016), arXiv:1601.05037. **First NOvA papers, authorship represents my graduate work on R&D.**

19. Y. Abe et al. (Double Chooz Collaboration), *Improved measurements of the neutrino mixing angle θ_{13} with the Double Chooz detector*, JHEP **10**, 086 (2014), arXiv:1406.7763, [Erratum: JHEP02,074(2015)]. **My muon reconstruction reduced ^{9}Li background by half.**

20. S. Andringa et al. (SNO+ Collaboration), *Current status and future prospects of the SNO+ experiment*, Adv. High Energy Phys. **2016**, 6194250 (2016), arXiv:1508.05759. **Supernova and nucleon decay.**

21. J. R. Alonso et al., *Advanced Scintillator Detector Concept (ASDC): A concept paper on the physics potential of water-based liquid scintillator*, (2014), arXiv:1409.5864. **Supernova sensitivity.**

22. Y. Abe et al. (Double Chooz Collaboration), *Reactor electron antineutrino disappearance in the Double Chooz experiment*, Phys. Rev. D **86**, 052008 (2012), arXiv:1207.6632. **First Double Chooz analysis to use the UChicago Outer Veto.**

23. P. Adamson et al. (MINOS Collaboration), *Search for the disappearance of muon antineutrinos in the NuMI neutrino beam*, Phys. Rev. D **84**, 071103 (2011), arXiv:1108.1509. **Cross-check of surprising result using partially contained events.**

24. D. S. Ayres et al. (NOvA Collaboration), The NOvA technical design report, FERMILAB-DESIGN-2007-01, 2007. **Design of fiber stringing machine; fiber optical property measurements.**

Some collaboration papers omitted. The complete list is at inspirehep.net/literature?q=find a m strait and ps p

Students supervised

- Dmitrii Torbunov — Graduate student at University of Minnesota. Dissertation: "Improving Energy Estimation at NOvA with Recurrent Neural Networks," 2021.

- Vladimir Bychkov — Graduate student at University of Minnesota. Dissertation: "Escaping Events at the NOvA Far Detector," 2018.

- Andrew Vold — Graduate student at University of Minnesota. Dissertation: "Improving Physics Based Electron Neutrino Appearance Identification with a Long Short-Term Memory Network," 2018.
- Kevin Labe — Graduate student at University of Chicago. Supernova trigger and invisible nucleon decay in SNO+; Dissertation: "Tests of Lorentz Invariance at the Sudbury Neutrino Observatory," 2017.
- Emily Conover — Graduate student at University of Chicago. Dissertation: "Muon-induced backgrounds in the Double Chooz neutrino oscillation experiment," 2014.
- Keith Crum — Graduate student at University of Chicago. Dissertation: "A Measurement of $\sin^2\theta_{13}$ with the Double Chooz Experiment," 2014.
- Tony LaTorre — Graduate student at University of Chicago. Online monitoring, supernova trigger, solar neutrinos with SNO+.
- Jay Cushing — Undergraduate student at University of Chicago. Improvements to SNO+ offline software and databases; Double Chooz assembly.
- Alex Diaz — Undergraduate student at University of Chicago. Monte Carlo studies of supernova directionality with water volume of SNO+; Double Chooz assembly.
- Hadar Lazar — Undergraduate student at University of Chicago. Test stand studies of organic scintillator time structure.

Selected Talks

- Invited plenary talk: "The NOvA Neutrino Experiment and its Astrophysics Program," NuTEL 2021, Italy (virtual).
- Talk: "Measurement of the Atmospheric Neutrino Oscillation Parameters with NOvA," International Cosmic Ray Conference 2019, Madison, Wisconsin.
- Invited plenary talk: "Latest results from NOvA," NOW — The Neutrino Oscillation Workshop — 2018, Ostuni, Italy.
- Physics Colloquium: "Demystifying Neutrinos with the NOvA Experiment," University of Minnesota-Duluth, March 2017.
- Invited plenary talk: "NOvA: Status and Recent Results," MIAMI 2016, Fort Lauderdale, Florida.
- Invited plenary talk: "Status of SNO+," Lake Louise Winter Institute 2015.
- High Energy Physics Seminar: "Status and First Results from Double Chooz," University of Pittsburgh, February 2012.
- Physics Colloquium: "Neutrino Oscillations and the MINOS Experiment," St. Olaf College, March 2010.
- Invited plenary talk: "New Results from MINOS," PHENO 2010, Madison, WI.