

Richard W. Gran

Professor

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Professional Preparation

Institution	Location	Area	Degree	Year
University of Minnesota Duluth	Duluth, MN	Particle Physics		2005 - present
University of Washington	Seattle, WA	Particle Physics		2002-2005
KEK Accelerator Laboratory	Tsukuba, Japan	Particle Physics		Winter 2003
University of Minnesota	Minneapolis, MN	Physics	Ph.D.	2002
Carleton College	Northfield, MN	Physics, Music	B.A.	1994

Appointments

Professor	University of Minnesota	Duluth, MN	2016 - present
Visiting Researcher	Institut de Fisica d'Altes Energies	Barcelona, Spain	Winter 2013
Associate Professor	University of Minnesota	Duluth, MN	2011-2016
Assistant Professor	University of Minnesota	Duluth, MN	2005-2011
Research Associate	University of Washington	Seattle, WA	2002-2005
JSPS Fellow	KEK Accelerator Laboratory	Tsukuba, Japan	Winter 2003
Research Assistant	University of Minnesota	Minneapolis, MN	1994-2002
Visiting Instructor	Carleton College	Northfield, MN	1999-2000
Teaching Assistant	University of Minnesota	Minneapolis, MN	1994-1997

Honors and awards

Nominated for fellow in American Physical Society, March 2018, in review.

Nominated for MINERvA collaboration spokesperson, January 2017.

(The minimum two nominations were received, but then declined to stand for election.)

Co-winner (with entire K2K and other neutrino collaborations) of 2016 Breakthrough Prize

Selected publications

Also coauthor and contributor on additional MINERvA, MINOS, K2K, Super-K, and Soudan2 papers, 112+ total listed as “published only” on inspirehep.net for Richard.W.Gran.1 . Names marked with * are UMD M.S. student co-lead authors.

- [1] *Neutrons from low momentum transfer anti-neutrino hydrocarbon reactions*, M. Elkins*, *et al.* (MINERvA collaboration), in preparation for *Phys. Rev. D*, in internal collaboration review.

- [2] *Measurement of final-state correlations in neutrino muon-proton mesonless production on hydrocarbon at $E_\nu = 3$ GeV*,
X.-G Lu, M. Betancourt, T. Walton, *et al.* (MINERvA collaboration), *Phys. Rev. Lett.*, vol. 121, p. 022504, 2018.
- [3] *Anti-neutrino reactions on scintillator with low momentum transfer*,
R. Gran, M. Betancourt, M. Elkins*, P.A. Rodrigues, *et al.* (MINERvA collaboration), *Phys. Rev. Lett.*, vol. 120, p. 221805, 2018.
- [4] *Deuterium target data for precision neutrino-nucleus cross sections*,
A.S. Meyer, M. Betancourt, R. Gran, R.J. Hill, *Phys. Rev. D*, vol. 93, p. 113015, 2016.
- [5] *Measurement of single π^0 production by coherent neutral-current neutrino-iron interactions in the MINOS Near Detector*, P. Adamson, *et al.* (MINOS collaboration), *Phys. Rev.*, vol. D94, p. 072006, 2016.
- [6] *GENIE implementation of IFIC Valencia model for QE-like 2p2h neutrino-nucleus cross section*, J. Schwehr, D. Cherdack, R. Gran, public technical note, not peer-reviewed, arXiv:1606.02038
- [7] *Identification of nuclear effects in neutrino-carbon interactions at low three-momentum transfer*, P.A. Rodrigues, J. Demgen*, E. Miltenberger*, *et al.* (MINERvA collaboration), *Phys. Rev. Lett.*, vol. 116, p. 071802, 2016.
- [8] *MINERvA neutrino detector response measured with test beam data*, L. Aliaga, *et al.* (MINERvA collaboration), *Nucl. Instrum. Meth.*, vol. A789, pp. 28-42, 2015.
- [9] *Measurement of muon plus proton final states in ν_μ Interactions on Hydrocarbon at $\langle E_\nu \rangle = 4.2$ GeV*, T. Walton, M. Betancourt, *et al.* (MINERvA collaboration), *Phys. Rev.*, vol. D91, p. 071301, 2015.
- [10] *Study of quasielastic scattering using charged-current ν_μ -iron interactions in the MINOS Near Detector*, P. Adamson *et al.* (MINOS collaboration), *Phys. Rev.*, vol. D91, p. 012005, 2015.
- [11] *The Long-Baseline Neutrino Experiment: Exploring Fundamental Symmetries of the Universe*, C. Adams, *et al.* (LBNE collaboration) arXiv:1307.7335 and printed by Fermilab April 2014. [unrefereed publication]
- [12] *Neutrino-nucleus quasi-elastic and 2p2h interactions up to 10 GeV*,
R. Gran, J. Nieves, F. Sanchez, and M. J. Vicente Vacas, *Phys. Rev.*, vol. D88, p. 113007, 2013.
- [13] *Measurement of muon neutrino quasielastic scattering on a hydrocarbon target at $E_{\nu\mu} \sim 3.5$ GeV*, G.A. Fiorentini, D. Schmitz, P. Rodrigues, *et al.* (MINERvA collaboration), *Phys. Rev. Lett.*, vol. 111, p. 022502, 2013.
- [14] *Measurement of muon antineutrino quasielastic scattering on a hydrocarbon target at $E_{\nu\mu} \sim 3.5$ GeV*, L. Fields, J. Chvojka, *et al.* (MINERvA collaboration), *Phys. Rev. Lett.*, vol. 111, p. 022501, 2013.

- [15] *An improved measurement of muon antineutrino disappearance in MINOS*,
P. Adamson, *et al.* (MINOS Collaboration), *Phys. Rev. Lett.*, vol. 108, p. 191801, 2012.
- [16] *Neutrino and antineutrino inclusive charged-current cross section measurements with the MINOS Near Detector*,
P. Adamson, *et al.*, (MINOS Collaboration), *Phys. Rev.*, vol. D81, p. 072002, 2010.
- [17] *Search for muon-neutrino to electron-neutrino transitions in MINOS*,
P. Adamson, *et al.*, (MINOS Collaboration), *Phys. Rev. Lett.*, vol. 103, p. 261802, 2009.
- [18] *Measurement of neutrino oscillations with the MINOS Detectors in the NuMI Beam*,
P. Adamson, *et al.*, (MINOS Collaboration), *Phys. Rev. Lett.*, vol. 101, p. 131802, 2008.
- [19] *Study of muon neutrino disappearance using the Fermilab Main Injector neutrino beam*,
P. Adamson, *et al.*, (MINOS Collaboration), *Phys. Rev.*, vol. D77, p. 072002, 2008.
- [20] *Measurement of neutrino oscillation by the K2K experiment*,
M.H. Ahn, *et al.* (K2K Collaboration), *Phys. Rev.*, vol. D74, p. 072003, 2006.
- [21] *Measurement of the quasi-elastic axial vector mass in neutrino oxygen interactions*,
R. Gran, E.J. Jeon, *et al.* (K2K Collaboration), *Phys. Rev.*, vol. D74, p. 052002, 2006.

Public technical notes, not refereed

- [i] *Magnetic field map for T977 tertiary beam*
R. Gran, FERMILAB-TM-2628-ND, 2018.
- [ii] *Model uncertainties for Valencia RPA effect for MINERvA*
R. Gran, FERMILAB-FN-1030-ND, arXiv:1705.02932, 2017.
- [iii] *Experiment simulation configurations used in DUNE CDR*
T. Alion, FERMILAB-FN-1020-ND, arXiv:1606.09550, 2016.
- [iv] *GENIE implementation of IFIC Valencia model for QE-like 2p2h neutrino-nucleus cross section*
J. Schwehr, D. Cherdack, R. Gran, arXiv:1601.02038, 2016.

Selected talks and posters

- [a] *No-pion 2p2h implementations in GENIE*,
R. Gran, invited talk at ECT* workshop “Modeling neutrino-nucleus interactions”, Trento, Italy, July 2018.
- [b] *Anti-neutrino reactions with low momentum transfer*,
R. Gran, Fermilab Joint Theoretical Experiment Seminar, 3 November 2017.
- [c] *Systematics related to q_0 - q_3 determination*,
R. Gran, invited talk at 11th international workshop on neutrino-nucleus reactions (NuInt17), 25 June 2017.

- [d] website www.neutrino-classroom.org [outreach website], went live 2015. With N. Tagg (Osterbein) and K. McFarland (Rochester) and high school teachers in northern Minnesota and Rochester, NY.
- [e] “Next generation QE and resonance models, and lessons from MINERvA” contributed talk at the CETUP* workshop on systematics in neutrino oscillation experiment held in Lead, SD, July 2014.
- [f] “Public outreach at the Soudan Underground Laboratory”, contributed poster at the 37th International Conference on High Energy Physics (ICHEP 2014, Valencia, Spain), July 2014.
- [g] “MINERvA measurement of neutrino charged-current cross section ratios of nuclei C, Fe, and Pb to CH at energies of a few GeV”, contributed talk at the 37th International Conference on High Energy Physics (ICHEP 2014, Valencia, Spain), July 2014.
- [h] “QE and 2p2h up to 10 GeV” invited talk at the ninth international workshop on neutrino-nucleus interactions in the few-GeV region (NuInt14, London), May 2014.
- [i] “The MINERvA testbeam preliminary results”, poster presented at NuInt12 conference, Rio de Janeiro, October 2012.
- [j] “Neutrino resonance production at very low momentum transfer” Invited talk at the seventh international workshop on neutrino-nucleus interactions (NuInt11), Dehradun, India, March 2011.
- [k] “MINERvA” Invited talk at the Workshop on the Next Generation Nucleon Decay and Neutrino Detectors (NNN09), Estes Park, CO, 8 October 2009.
- [l] “Quasi-elastic scattering results at a few GeV” Invited parallel session talk given at the Eleventh International Workshop on Neutrino Factories (NuFact09), Chicago, IL, 21 July 2009.
- [m] “Neutrino experiment review, needs from theory and models” Invited talk given at the Sixth International Workshop on Neutrino-Nucleus Interactions (NuInt09) Sitges, Barcelona, Spain, 18 May 2009.
- [n] “The MINERvA Neutrino Interaction Experiment” Contributed poster given at the XXIII International Conference on Neutrino Physics and Astrophysics (Neutrino 2008), Christchurch, New Zealand, 25 May 2008.
- [o] “The MINERvA Neutrino Interaction Experiment” Invited parallel session talk at the Ninth International Workshop on Neutrino Factories (NuFact07), in Okayama, Japan, 8 August 2007.
- [p] “Progress in measuring neutrino quasielastic interactions” Invited talk at Fifth International Workshop on Neutrino-Nucleus Interactions (NuInt07), at Fermilab, Batavia, IL, 31 May 2007.

- [q] “MINOS and MINERvA in the NuMI Beam”
 Contributed talk at Workshop on Neutrino Response Functions from Threshold to 10 GeV, INT-06-2b workshop, Institute for Nuclear Theory, U. Washington, Seattle, WA, August 2006.
- [r] “K2K Cross Sections”
 Contributed talk at Workshop Neutrino Response Functions from Threshold to 10 GeV, INT-06-2b workshop, Institute for Nuclear Theory, University of Washington, Seattle, WA, 31 July 2006.
- [s] “K2K Cross Section Studies”
 Invited talk at XXII International Conference on Neutrino Physics and Astrophysics (Neutrino 2006), Santa Fe, NM, 17 June 2006.

Selected physics and leadership contributions within DUNE, MINERvA, and MINOS

The narratives indicate leadership and specific physics contributions to long-term collaborative efforts, especially when details are not clear from the above publication record.

- *DUNE: co-convenor of Near Detector Physics Working Group, Sep. 2015 to Sep. 2016.* Supported by a single semester leave spring 2016 from the university. Lead the group to a set of technical studies of different near detector design options in preparation for selection of final design in 2018. Builds off previous work with Dan Cherdack during my 2013 sabbatical to create a parameterized, fast Monte Carlo. This earlier effort provides DUNE a detailed set of particle responses for use in understanding oscillation sensitivities. It is documented in Appendix A.3 of the LBNE science document, Ref. [8] in the publication list.
- *Neutrino interaction analysis with MINERvA.* Physics work has focused on low-multiplicity final states from quasi-elastic scattering, resonance production, and 2p2h meson exchange current (MEC) contributions to the cross section. This has culminated in a sequence of innovative ways of expressing the data that reveals the need for two specific, long-anticipated nuclear model effects: MEC and another multi-nucleon effect known as RPA suppression. These are presented in Refs. [1] and [5] and M. Elkins* thesis (with journal publication in preparation), and all other recent MINERvA analyses use these results. M. Elkins* won best poster at NuInt17 workshop for her M.S. thesis results, the first ever use of time-of-flight neutrons to study anti-neutrino reactions.
- *Neutrino interaction analysis with model builders.* The sabbatical in 2013 was partially spent in Barcelona and Valencia. While there, an experimental colleague Federico Sanchez and I worked on models with theorists Juan Nieves and Manuel Vicente Vacas. They have one of the earliest models of the carbon nucleus for neutrino interactions, and were promoting the expected large effects of RPA suppression and MEC effects. Our work together, Ref. [9], confirmed that their results extend to MINERvA experiment energies, as long as it is limited to low momentum transfers. Another result of this work is code now available to the entire neutrino community, with a companion technical document Ref. [4]. An unrelated effort with other theory colleagues led to Ref. [2].

- *MINERvA: Leader of Fermilab T977 MINERvA Test Beam Experiment, Jan. 2006 to Jan. 2015.* Principal investigator and leader of this test beam experiment to obtain data and analyze the response of the MINERvA detector to single pions and protons. Led this experiment-in-itself effort from initial design to writing the publication. Approximate total cost 0.5M\$ not including facility use or reused/borrowed equipment. The effort included design of a low energy hadron tertiary beam and a miniature version of the MINERvA detector. The team included tens of students, faculty, technicians, and engineers on MINERvA and at Fermilab, Rochester, and William and Mary. Duluth M.S. student M. Lanari* did the first pion calorimetry analysis with preliminary calibrated data. Several Duluth undergraduates participated in the operations and analysis phase. Also helped modify the beam designed for MINERvA for use by the LArIAT liquid argon test beam experiment at Fermilab and which will soon be used for NOvA's test beam experiment. Results in Ref. [6] included a tuned Birks' suppression and detector material model tests with stopping protons, and comparisons to Geant4 to set the systematic uncertainty scale for pion, proton, and electron calorimetry.
- *Co-convenor of MINOS near detector physics analysis group, Dec. 2006 to Jan. 2013.* Leader and active contributor to the analysis of neutrino cross section measurements using the very high statistics MINOS Near Detector Data. The group produced three main measurements. Supported members of the group who produced Ref. [3] and [14]. Contributed directly to the quasi-elastic Q^2 distribution (Ref. [8]) which additionally included a close look at background processes, revealing model discrepancies with pion production. There were large contributions to Ref. [8] by myself and UMD students, and several conference proceedings along the way. Also contributions to development of interaction model systematic uncertainties for the early MINOS oscillation papers Ref. [13][15][16].
- *Co-leader of Soudan Lab summer intern and outreach program.* Organize the collection of high school teachers and undergraduate interns, usually five or six persons, who lead the summer tours of the Soudan Underground Lab, especially the MINOS and CDMS experiments. Supported by an NSF grant, over 1M\$ since 2007. Our undergraduate summer interns are recruited from all over Minnesota, not just Duluth. They have done numerous projects working on the experiments themselves, including support for the results in Refs. [1][5][8] and did the initial study of neutrons that became Elkins' thesis. One later did an internship at Fermilab, then Ph.D. student working on the MINERvA, and now holds a named postdoctoral fellowship at Berkeley.
- *Postdoctoral research on K2K experiment, 2002-2006.* Worked primarily with the Scintillating Fiber near detector analysis led by Makoto Sakuda, co-founder of the NuInt series of workshops. The resulting QE paper Ref. [19] is the first to demonstrate need for multi-nucleon effects to describe data. Simultaneously worked with the oscillation analysis to capture the systematic uncertainties, given the challenging state of the modeling. Played major role (with T. Nakaya, chair and M. Yokoyama) authoring the collaborations' final paper Ref. [18], cited for the Breakthrough Prize in 2016.

Collaborators and Other Affiliations

Current member of the following collaborations

- The DUNE deep underground neutrino experiment (formerly LBNE), which is proposing an experiment with a new beamline at Fermilab and a new detector in the Sanford Underground Lab at the Homestake Mine in South Dakota. Since 2009.
- The MINERvA neutrino interaction experiment, located at Fermilab in the NuMI neutrino beam. Since 2006.

Past member of the following collaborations

- The MINOS long-baseline neutrino oscillation experiment, uses the NuMI neutrino beam from Fermilab to Soudan, MN. 2005-2013.
- The K2K neutrino oscillation experiment, used a beam from the KEK accelerator in Japan to the Super Kamiokande detector. 2002-2006.
- The Super Kamiokande experiment, an underground detector in Kamioka, Japan for neutrino physics, particle astrophysics, and proton decay studies. 2002-2006.
- The Soudan-2 experiment, an underground detector in Soudan, Minnesota for neutrino physics, particle astrophysics, and proton decay studies. 1994-2004.

Past advisors and mentors

- Postdoctoral Sponsors: Prof. R. Jeffrey Wilkes, University of Washington and Dr. Makoto Sakuda, KEK Accelerator (now at Okayama University), Japan.
- Graduate Advisor: Prof. Keith Ruddick, University of Minnesota

Courses taught

- Phys 1001 Introduction to Physics I
- Phys 1002 Introduction to Physics II
- Phys 1021 Exploring Current Topics seminar
- Phys 1035 Energy
- Phys 2015 Physics II
- Phys 2018 Honors Physics II
- Phys 2021 Relativity and Quantum Physics
- Phys 2033 Relativity and Quantum Physics Lab
- Phys 3061 Instrumentation
- Phys 4011 Electrodynamics (Griffiths)
- Phys 4031 Thermal and Statistical Physics

- Phys 5053 Data Analysis Methods
- Phys 5511 Electrodynamics (Jackson)
- Phys 5090 Seminar
- At University of Washington, Phys 225 Modern Physics
- At Carleton College, Phys 343 Electronics, Phys 112 Introduction to Physics I, Phys 115 Gravity and the Cosmos (alternative to calc-based introductory course).

External funding

- R. Gran “Neutrino Physics Center Fellowship,” Fermi National Accelerator Laboratory, funding for one course release spring 2017 to continue leading DUNE near detector effort, \$10,000. Funded, then declined due to lack of match.
- R. Gran “Fermilab URA Visiting Scholar,” Universities Research Alliance LLC, funding for one course release spring 2017 to continue leading DUNE near detector effort, \$16,000. Funded, then declined due to lack of match.
- R. Gran and A. Habig (Co-PIs), “RUI: Neutrino Physics Research at the University of Minnesota Duluth,” National Science Foundation. Funding three years 2016 to 2019, \$540,000. But NSF declined to match the above funded proposals.
- R. Gran, “Single semester leave, internal university grant,” To support service as DUNE near detector physics working group co-convenor, spring 2016.
- R. Gran and A. Habig (Co-PIs), “Education and Public Outreach at the Soudan Mine Underground Lab,” National Science Foundation. Funding two years 2015-2017, \$239,521
- A. Habig, R. Gran, M. Seigar (Co-PIs) “MINOS, MINERvA, and NOvA research and scholarships”, NASA/Minnesota Space Grant Consortium. Funding for first of five-year cycle FY 2015-2016, \$11,131
- R. Gran and A. Habig (Co-PIs), “RUI: Experimental Neutrino Research with NOvA, MINERvA, LBNE,” National Science Foundation. Funding three years 2013 to 2016, \$525,000.
- R. Gran, “Fermilab University Research Association Visiting Scholars Program” Funding for part of salary while on sabbatical, fall 2012, \$14,880.
- R. Gran and A. Habig (Co-PIs), “Education and Public Outreach at the Soudan Mine Underground Lab,” National Science Foundation. Funding three years 2012-2015, \$267,823
- R. Gran (PI), “Teaching buyout to support work on MINERvA,” subcontract from Fermilab, funded one course release fall 2011, \$22,281.
- A. Habig and R. Gran (Co-PIs), “MINOS, MINERvA, and NOvA research and scholarships”, NASA/Minnesota Space Grant Consortium. Funding for five-year cycle FY 2010-2015, \$107,852

- R. Gran and A. Habig (Co-PIs), “RUI: Experimental Neutrino Research with MINOS, NOvA, MINERvA,” National Science Foundation. Funding three years 2010 to 2013, \$490,000 (supplement added \$24,531 for Habig in 2013).
- R. Gran (PI), “Teaching buyout to support work on MINERvA test beam,” subcontract from Fermilab. Funded full teaching buyout fall 2009, \$37,123.
- R. Gran and A. Habig (Co-PIs), “Education and Public Outreach at the Soudan Mine Underground Lab,” National Science Foundation through a sequence of inter-related grants and subcontracts. Funding four years 2008-2012, \$256,194.
- A. Habig and R. Gran (Co-PIs), “MINOS, MINERvA, and NOvA research and scholarships,” NASA/Minnesota Space Grant Consortium, expanded scope from A. Habig’s existing grant includes work by R. Gran and students. Funded two years 2008-2010, \$58,959.
- R. Gran (PI) “Procure and test rack protection systems for the MINERvA neutrino experiment,” subcontract from Fermilab. Funded two years 2007-2008, \$11,270.
- R. Gran (Co-I) with Kevin McFarland, University of Rochester (PI) and others, “MRI: Collaborative Proposal for Development of Nuclear Targets and Calibration Systems for the MINERvA Neutrino Experiment,” National Science Foundation, subcontract from University of Rochester. Funded from 2006-2010, \$134,263 to Duluth.
- A. Habig and R. Gran (Co-PI’s), “RUI:Neutrino Studies in the NuMI Beam,” National Science Foundation. Funded three years 2007-2010, \$255,000.

Selected professional, university, and department service

- Reviewed five manuscripts for Physical Review Letters or PRD in past ten years.
- Member of NuSTEC board, 2015 - 2016
- Organizer and chair of oscillation systematics session for NuInt15 conference, 2015.
- MINERvA executive committee 2014-present (chair May 2015-present).
- College of Science and Engineering Executive Committee, 2014-2016.
- Director of Graduate Studies, Physics Department, 2014-2017.
- Hosted MINERvA experiment collaboration meeting at UM Duluth, June 2014.
- NSF review panel for Experimental Particle Physics, Spring 2014.
- Reviewed College of Science and Engineering UROP proposals 2009, 2010, 2016.
- College of Science and Engineering Technology Committee, 2011-2013.
- Organizer and chair of quasi-elastic session for NuInt07 conference, 2007.
- College of Science and Engineering Academic Standards Committee, 2006-2009.
- Advisor to UMD chapter of Society of Physics Students, 2006-2013.