Zachary S. Hartwig, Ph.D.

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Research Interests

Development and application of radiation detectors, radiation sources, and particle transport simulation to solve complex problems in nuclear science and engineering

- Radiation and particle detector development
- Satellite-based detectors and energy sources
- Accelerator-based nuclear and material science
- Fusion energy nuclear science and device design
- Monte Carlo particle transport simulations
- Digital data acquisition and analysis systems
- Active and passive detection in nuclear security
- Fusion plasma-material interaction science

Education

Ph.D. in Nuclear Science, MIT. February 2014.

- Concentration: Fusion nuclear science
- GPA: 4.7 / 5.0
- Thesis: *An accelerator-based in-situ diagnostic for plasma-material interactions science on magnetic fusion devices*

B.A. in Physics, Boston University. May 2005.

- Concentration: Experimental particle physics
- GPA: 3.7 / 4.0
- Degree awarded *summa cum laude*
- Recipient of Alumni Award in Physics
- Dean's List all 8 semesters

Notable Achievements

- *Recipient*, U.S. Department of Energy ORISE Postdoctoral Fellowship, Jan 2015.
- *Recipient*, MIT NSE Del Favero Prize in Nuclear Science and Engineering, May 2014.
- *Fellow*, 2013 Kavli Frontiers of Science.
- *Invited speaker*, Kavli Frontiers of Science Meeting, November, 2013.
- *USA Cycling National Champion*, Collegiate Track Division II Team Omnium. September 2012.
- *Recipient*, MIT NSE Special Award, Excellence in Science Communication and Policy. May 2012.
- *Recipient*, MIT Plasma Science and Fusion Center Award, Science Education and Outreach. July 2012.
- *Recipient*, MIT International Science and Technology Initative Global Seed Fund Grant. May 2011.
- *Recipient*, Boston University Alumni Prize for Excellence in Physics. May 2005.

Research Experience

- **Postdoctoral associate/fellow, MIT (2013-present)**: Initiated and lead a number of diverse research efforts. Lead data acquisition, analysis, and computation efforts for two nuclear security projects (Low-dose monoenergetic gamma radiography system; Zero knowledge warhead verification system). Conducted on-going efforts to bring an ultracompact superconducting cyclotron to MIT for nuclear security and materials research. Proposed and lead a collaboration with MIT Aeronautics and Astronautics Engineering department on novel low-cost satellite-based particle spectrometers and dosimeters. Established a new accelerator science and detector development laboratory with collaborators. Co-founded a design group at MIT Plasma Science and Fusion Center to pursue a new approach to fusion energy with private funding and advanced technology. Continued development of the AIMS diagnostic for plasma-material interaction science on the Alcator C-Mod tokamak.
- **Advisor, Tokamak Energy U.K. (2013-2014)**: Advised a private company on Monte Carlo neutronics simulations for magnetic fusion applications. The work involved training team members on advanced fusion neutronics and improving existing in-house simulation capabilities.
- **Ph.D student, MIT (2007-2013)**: Designed and demonstrated an innovative accelerator-based materials diagnostic for magnetic fusion devices. The research involved creating advanced particle transport simulations, applying radiation detection in a challenging environment, implementing a custom digital data acquisition system, and creating data analysis tools.
- **Advisor, Neotron Inc. (2009-2010)**: Collaborated on development of an innovative lithium-6-based detector for homeland security. The research involved using particle transport simulations to optimize the design and cost of the final detector.
- **Advisor, Cyclotron Group, MIT (2010)**: Predicted the impact of nuclear heating on superconducting magnets in a proposed ultracompact superconducting cyclotron during various operational scenarios using particle transport simulations.
- **Research Assistant, Boston University (2004-2006)**: Developed a particle physics simulation for the Muon g-2 Experiment, previously at Brookhave National Lab and now at Fermi National Lab. The simulation is presently used as a leading computational design tool for the next generation of the experiment. Performed experimental work on particle detection and data acquisition for the MμLAN muon lifetime experiment at Paul Sherrer Institute, Switzerland, 2005.

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Doctoral Dissertation

MIT Department of Nuclear Science and Engineering Ph.D. Dissertation

- Z.S. Hartwig (2013). *An In-situ Accelerator-based Diagnostic for Plasma-Material Interactions on Magnetic Fusion Devices.* Doctoral Dissertation, MIT, Cambridge MA, USA.
  Available for download here

Research Publications

Accelerator-based In-situ Materials Surveillance (AIMS)

- Z.S. Hartwig *et al. Fuel retention measurements in Alcator C-Mod using Accelerator-based In situ Materials Surveillance.* J. Nucl. Mat. **263** (2015) 73. doi:10.1016/j.jnucmat.2014.09.056
- Z.S. Hartwig *et al. An in-situ accelerator-based diagnostic for plasma-material interactions on magnetic fusion devices.* Rev. Sci. Instr. **84** (2013) 123503. doi:10.1064/1.4832420
- Z.S. Hartwig and D.G. Whyte. *Simulated plasma-facing component measurements for an in-situ surface diagnostic on Alcator C-Mod.* Rev. Sci. Instr. **81** (2010) 10E106. doi:10.1063/1.4832420

Magnetic fusion energy design and engineering

- Z.S. Hartwig *et al. An initial study of demountable, high-temperature superconducting magnets for the Vulcan tokamak conceptual design.* Fus. Eng. Design **87** (2012) 201. doi:10.1016/j.fusengdes.2011.10.002
- G.M. Olynyk, Z.S. Hartwig, *et al. Vulcan: a steady-state tokamak for reactor-relevant plasma-material interaction science.* Fus. Eng. Design **87** (2012) 224. doi:10.1016/j.fusengdes.2011.12.009
- G.M. Olynyk, Z.S. Hartwig, *et al. Assessing the feasibility of a high-temperature, helium-cooled vacuum vessel and first wall for the Vulcan tokamak conceptual design.* Fus. Eng. Design **87** (2012) 248. doi:10.1016/j.fusengdes.2011.12.018
- D.G. Whyte *et al. Reactor similarity for plasma–material interactions in scaled-down tokamaks as the basis for the Vulcan conceptual design.* Fus. Eng. Design **87** (2012) 234. doi:10.1016/j.fusengdes.2011.12.011
- Z.S. Hartwig and M. Zucchetti. *Neutronics studies for a compact, high-field tokamak neutron source.* Fus. Sci. Tech. **60** (2011) 725. Available online at http://www.ans.org/pubs/journals/fst/a_12471

Particle and radiation detector design, simulation, and data acquisition

- Z.S. Hartwig. *The ADAQ framework: An integrated toolkit for data acquisition and analysis with real and simulated radiation detectors.* Nucl. Instr. and Meth. A *In Press*, 2016. doi:10.1016/j.nima.2016.01.017
- Z.S. Hartwig and P. Gumplinger. *Simulating response functions and pulse shape discrimination for organic scintillation detectors with Geant4.* Nucl. Instr. and Meth. A **737** (2014) 155. doi:10.1016/j.nima.2013.11.027
- A. Inglis *et al. Glass panel Lithium-6 Detector.* IEEE Conference on Homeland Security (2012). doi:10.1109/THS.2012.6459887

Experimental particle physics (The Muon Lifetime Analysis (MμLAN) experiment)

- D.M. Webber *et al. Measurement of the positive muon lifetime and determination of the Fermi constant to part-per-million precision.* Phys. Rev. Lett. **106** (2011) 041803. doi:10.1103/PhysRevLett.106.041803
- V. Tishchenko *et al. Detailed report of the MuLan measurement of the positive muon lifetime and determination of the Fermi constant.* Phys. Rev. D. **87** (2013) 052003. doi:10.1103/PhysRevD.87.052003

Reference Publications

A comprehensive physics and mathematics reference for magnetic fusion

- Z.S. Hartwig and Y.A. Podpaly. *The Magnetic Fusion Energy Formulary.* Self-published, 2016. Available online at http://www-internal.psfc.mit.edu/research/MFEFormulary.

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Teaching Experience

- **UROP advisor**: Florent Sainct (2009), Jake Jurewicz (2011), Gabriel Ledoux (2012, 2013)
- **Undergraduate thesis mentor**: Lauren Chilton, MIT Class of 2012.
- **Teaching assistant**: 22.63: Engineering Principles for Fusion Reactors (Prof. D. Whyte). Spring 2012.
- **Teaching assistant**: 22.105 : Electromagnetic Interactions (Prof. D. Whyte). Fall 2010.
- **Private tutor**: High school physics for several Boston University Academy Students. 2005-2006.

Leadership Experience

- **Organizer**: U.S. fusion student advocacy trip to 30 Congressional offices in Washington DC. June 2012.
- **Mediator**: Conflict resolution, MIT Resistance for Easing Friction and Stress Program. January 2010.

Hardware Expertise

Detector Data Acquisition

- CAEN S.p.A. data acquisition systems, Tektronix digital oscilloscopes

Particle Detector Construction

- Scintillator crystals, photomultiplier tubes, silicon avalanche photodiodes, silicon photomultiplier, signal preamplifiers, microcontrollers, soldering, basic machining, vacuum hardware, detector test platforms

Computer expertise

Programming Languages

- C, C++, Python, IPython/IPython notebooks, Open MPI, Unix shell scripting, GNU make, Matlab, IDL, HTML

Particle Transport and Nuclear Physics Codes

- Geant4, MCNP6/5/X, DAGMC CAD-based neutronics, SRIM/TRIM, EASY, NJOY, TALYS, EMPIRE

Data acquisition, storage and analysis

- ROOT, MDSplus
- Lead developer of the ADAQ framework

Computer-Aided Design (CAD) and Analysis

- Solid Edge ST5, CUBIT Tool Suite, COMSOL Multiphysics

Cloud Computing

- Amazon Web Services (EC2 Cloud Compute Framework)

Productivity Software

- Windows OS, Linux OS (Fedora, RHEL, Ubuntu), Emacs, Subversion, Git, GitHub, LaTeX, GIMP, Inkscape