# 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-born 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 M$\mu$LAN 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.
- 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 (M$\mu$LAN) 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