



Matthias Heinz

Eugene P. Wigner Fellow

Where and when did you earn your PhD?

I earned my doctorate degree from the Institute for Nuclear Physics at the Technische Universität (TU) Darmstadt in 2024, working with Achim Schwenk.

What was the subject of your dissertation?

My dissertation developed and explored ab initio or first-principles nuclear structure calculations. There are a few key challenges in such calculations: (1) our understanding of nuclear interactions is still uncertain; (2) the methods we use to simulate nuclei are necessarily approximate, with errors that are challenging to quantify; and (3) the calculations, especially in heavy nuclei, are tremendously computationally expensive. Despite these challenges, ab initio calculations provide a robust, global description of nuclei as heavy as lead-208, making important predictions for the structure of extremely exotic nuclei and for the interpretation of ongoing searches for physics beyond the standard model.

What was your dissertation's major contribution to your field?

I developed high-precision ab initio nuclear structure calculations using a method known as the IMSRG(3). I calculated the structure of ytterbium isotopes, where high-precision laser spectroscopy had measured an anomalous signal, possibly induced by a new particle interacting with electrons and neutrons. Our ab initio calculations showed that this signal was due to the complicated, deformed structure of the ytterbium nuclei, not new physics—highlighting the importance of nuclear structure calculations to interpret the signals measured in ongoing searches for physics beyond the standard model.

Who is your ORNL mentor, and which group and division are you working in?

I am working in both the Advanced Computing for Nuclear, Particles, and Astrophysics Group at the National Center for Computational Sciences and the Theoretical and Computational Physics Group in the Physics Division. As a result, I have two mentors, Gustav Jansen and Gaute Hagen.

What will your fellowship research focus on?

My research will focus on nuclear structure predictions for ongoing and planned new physics searches including neutrinoless double-beta decay, a process where two neutrons would decay to two protons and two electrons with no antineutrinos; coherent elastic neutrino-nucleus scattering, a low-energy process measured at ORNL that can provide stringent tests of the standard model; and permanent electric dipoles in radioactive molecules. My nuclear structure input (including nuclear matrix elements, weak-scattering form factors, and Schiff moments) will be essential to interpret the experiments and refine our understanding of possible physics beyond the standard model.

What is your project's expected contribution to your field?

As part of my work, I will develop ORNL's leadership computing capacities in ab initio calculations to tackle heavy, deformed nuclei. This will refine our understanding of how complex deformation phenomena arise from basic nuclear forces. Additionally, it will provide crucial input to interpret the results from new physics searches. Furthermore, our improved understanding of heavy nuclei will put us in a position to address open questions on the synthesis of heavy elements in astrophysical environments.

What are your research interests?

I am interested in computational many-body physics—the workhorse of ab initio calculations—and also nuclear forces and uncertainty quantification. I like to work at the interface of theoretical developments, high-performance computing, and statistical methods, where a lot of exciting work can be done.

What led you to science and your specific discipline?

My initial motivation to pursue science was simply my affinity for science, math, and engineering in school. In engineering projects and math challenges, I found that open questions with no clear path to the answer—and often no right answer—excited me. Through my undergraduate research with Richard J. Furnstahl at The Ohio State University (OSU), I grew to enjoy research, especially the computational side of modern nuclear theory research, leading me to settle in nuclear theory.

What did you do before coming to ORNL?

Before coming to ORNL, I completed my master's and doctorate studies at TU Darmstadt. Before that, I obtained my bachelor's degree at OSU.

Could you share an interesting fact or two about yourself?

I am trilingual, speaking English, German, and French, as I moved around from Regensburg, Germany, to Geneva, Switzerland, to Columbus, Ohio, when I was young.

What nonscience topic or activity is important to you and why?

I am passionate about travel. I cherish the opportunity to get to know new cultures and understand how different my life could be elsewhere, but I also have found that travel is a good way to get to know yourself and your companions better. It also combines well with my enjoyment of running, hiking, nature, food, and beer.