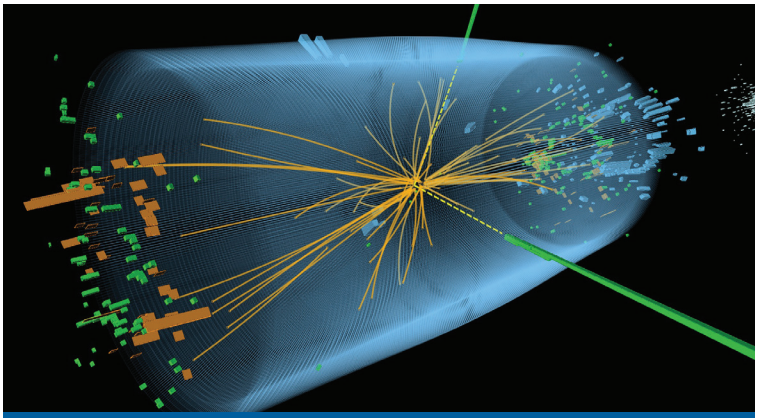
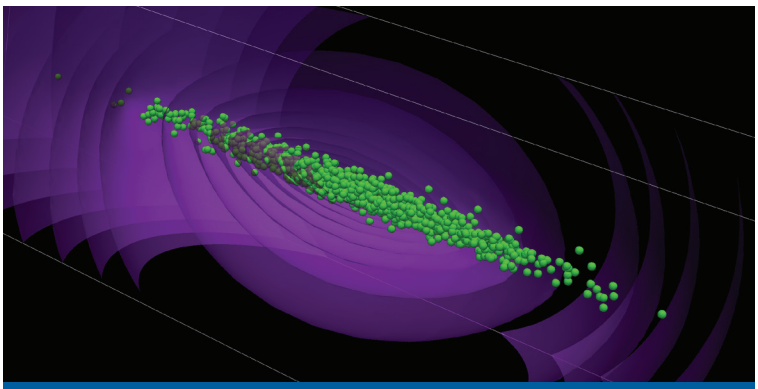
Scientific computing

Scientists, engineers and programmers at Fermilab are tackling today's most challenging computational problems. Their solutions, motivated by the needs of worldwide research in particle physics and accelerators, help America stay at the forefront of innovation.



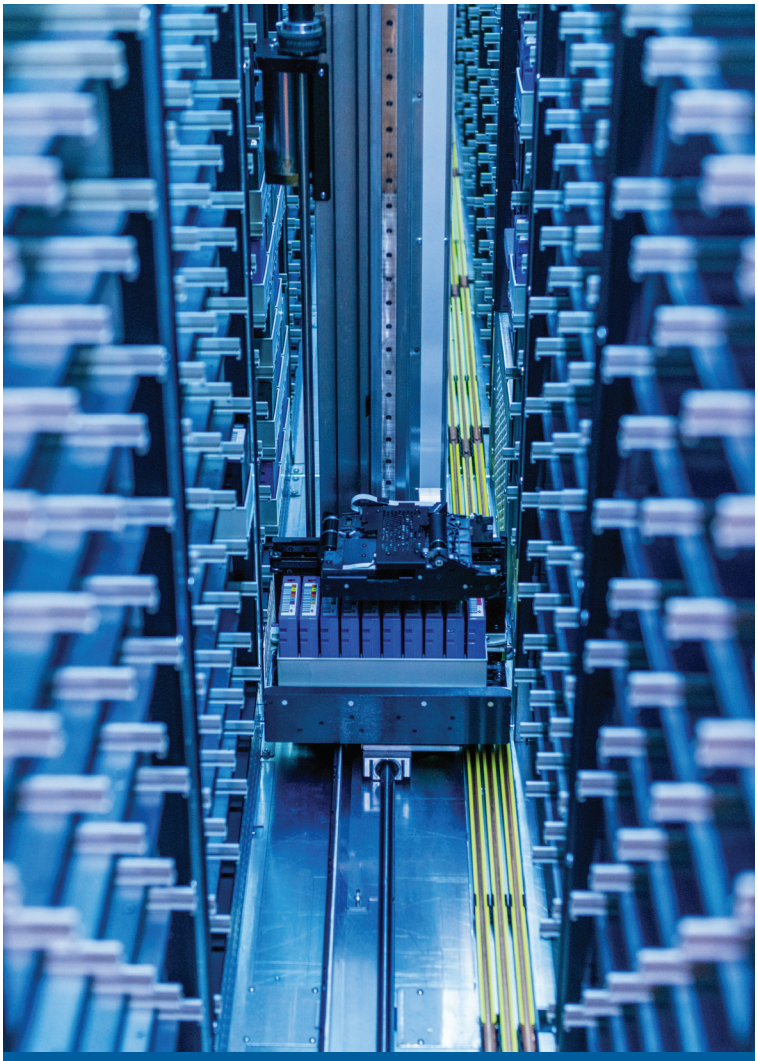
The discovery of the Higgs boson was reported all over the world. Fermilab contributed a large fraction of the distributed computing resources, data storage and software infrastructure necessary to achieve this breakthrough.



Simulation of particles moving through an accelerator: The development of the Synergia package is part of the ComPASS project, a multilab and university effort funded by the DOE's Scientific Discovery through Advanced Computing program.

Mastering the big data challenge

Our research generates a vast amount of data that scientists must gather, store, analyze and interpret. These activities require expertise and the right tools. Fermilab is home to one of the largest tape robotic systems available today, providing more than 800 petabytes of storage capability. The lab is growing the tape facilities to meet expected demands of over 1,000 petabytes of additional data per year by the end of the decade. Fermilab also has the technology and computing power to efficiently process these data to facilitate scientific discoveries. Our computational experts work closely with experimenters and the scientific community at large to provide and facilitate the use of the cutting-edge computing tools necessary for these discoveries. .



Tape robotic systems provide more than 800 petabytes of storage capability at Fermilab. One petabyte, or 1000 terabytes, of storage could store about 13 years of high-definition streaming video or approximately 250 million books. Photo: Ryan Postel, Fermilab

Supercomputing and computing in the cloud

Particle physics requires massive computing resources in order to get scientific results. Fermilab has deployed a new paradigm in particle physics through HEPCloud, the next step in the evolution of scientific computing. HEPCloud provides a single managed portal for scientists to utilize available computing resources—whether these resources are local to Fermilab or located at national supercomputing centers, commercial clouds, or, HEP computing grids worldwide.

Simulations for science and society

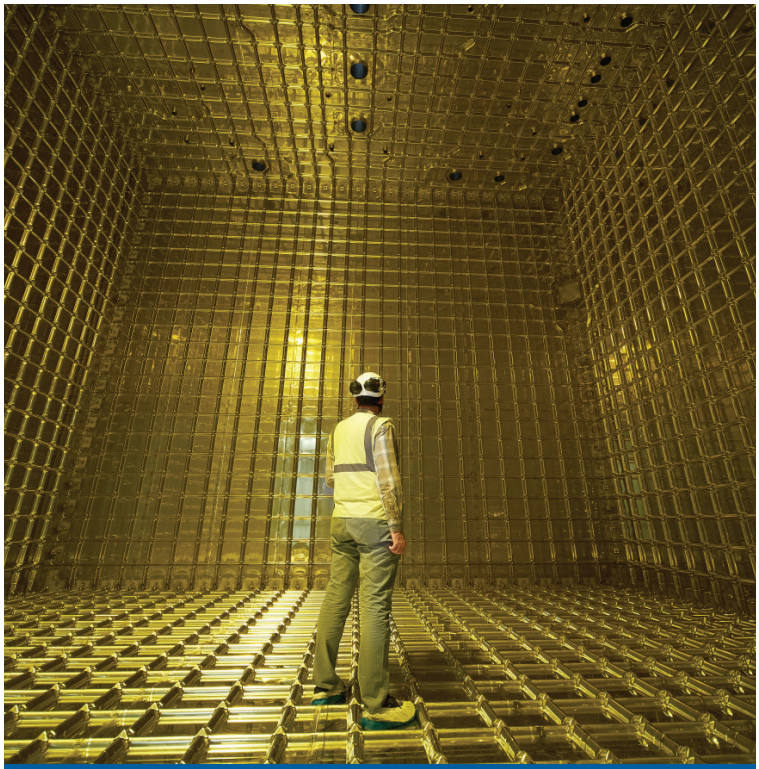
Particle accelerators enable scientists to explore the nature of matter and energy, and they also have applications in medicine, industry and national security. The ability to accurately model their performance using high-performance computers has had major implications for U.S. competitiveness and leads to benefits for people's daily lives.

Research at the tiny and large scales

Simulations help scientists explore and understand complex systems, from the inner workings of a proton to the formation of galaxies in our universe. Specialized high-performance computing farms at Fermilab using traditional processors as well as specialized chips such as Graphics Processing Units (GPUs) help scientists solve the equations that govern the interactions of quarks and other elementary building blocks of matter and study the evolution of the cosmos.

Sharing scientific software

Each particle physics experiment requires specialized software to process its data. Fermilab software engineers create frameworks that enable physicists to develop their own experiment-specific code as needed while reusing foundational code that is common across many experiments. Building on these frameworks, computational scientists at Fermilab and around the world develop additional, shared physics software toolkits and algorithms used by scientists across multiple neutrino experiments. This innovative software sharing paradigm has allowed reduced development time and easy transfer of knowledge across experiments.

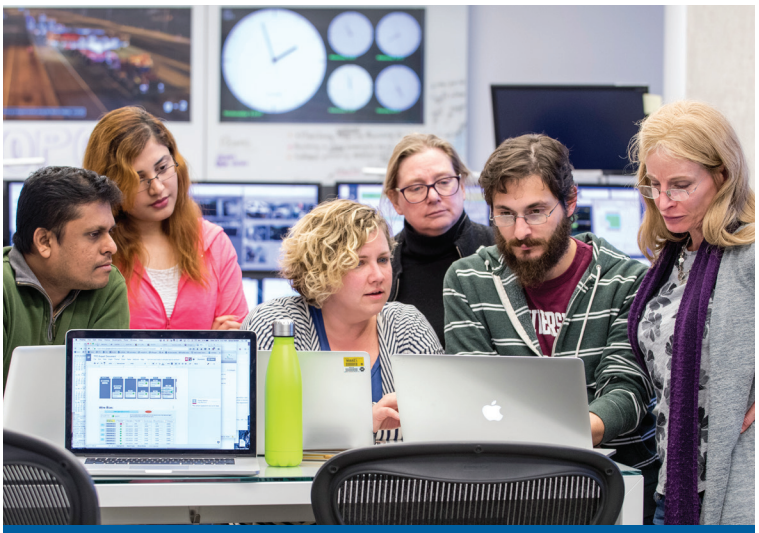


The international Deep Underground Neutrino Experiment, hosted by Fermilab, will come online at the end of this decade. It will probe the fundamental nature of neutrinos. The Fermilab Scientific Computing Division will acquire, monitor and analyze the data to extract the science from the DUNE detector. Photo: Maximilian Brice/CERN

Plans for the future

Fermilab, along with several partner institutions and collaborations, is investigating the use of artificial intelligence (AI) and quantum computing to ramp up computing power and possibilities. These technologies could revolutionize fields as disparate as medicine, space exploration and high-energy physics and greatly amplify our ability to do science research. We are using AI to enable computers to make observations in our experimental data, identifying patterns, and making better future decisions based on the examples that we provide. In addition, we are also using AI to improve the operations of our accelerator and computing facilities.

Example of a strong gravitational lens, a type of complex astrophysical system found within the large datasets of the Dark Energy Survey, the Vera Rubin Observatory Legacy Survey, and other projects we lead or with which we collaborate. Previously, identifying such systems required human visual scanning. We now use artificial intelligence.



Fermilab is building relationships with other laboratories and universities and industry through research partnerships in a variety of areas, including accelerator simulation, cloud computing, advanced networking and quantum computing.