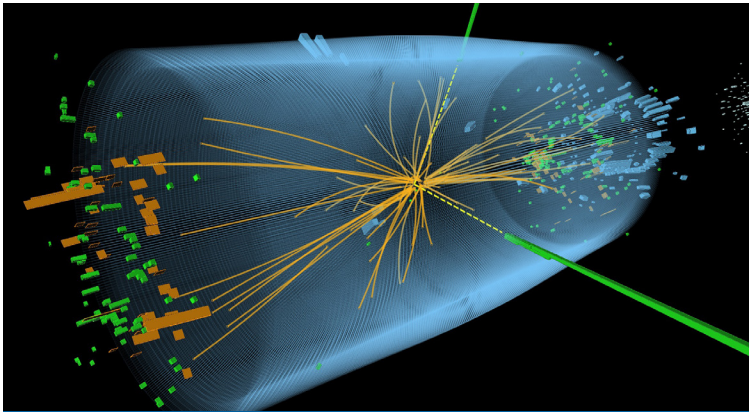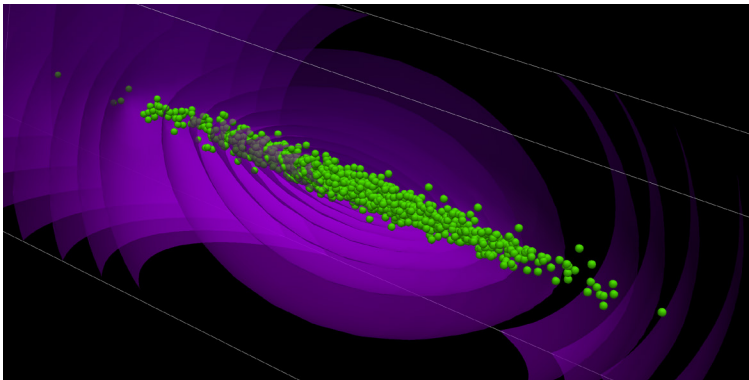# Scientific computing

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 500 petabytes of storage capability. The lab is growing the tape facilities to meet expected demands of over 100 petabytes of additional data per year. Fermilab also has the technology and computing power to quickly process these data to facilitate scientific discoveries, which often lead to applications in other areas of society. Our 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 500 petabytes of storage capability at Fermilab. One of the largest systems available today, it could store about 6,500 years of HD TV on tape cartridges.

Supercomputing and computing in the cloud

Particle physics requires copious computing resources in order to get scientific results. Fermilab is pursuing 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 consume available computing resources—whether these resources are local to Fermilab or available via worldwide computing grids, national supercomputing centers and commercial clouds.

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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 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 created a framework that enables physicists to develop their own experiment-specific code as needed while reusing the foundational code that is common across many experiments. Building on this framework, computational scientists at Fermilab and around the world are developing an additional physics software package for neutrino experiments. Scientists across multiple collaborations use the common physics algorithms included in this package. Sharing software has allowed reduced development time and easy transfer of knowledge across experiments.
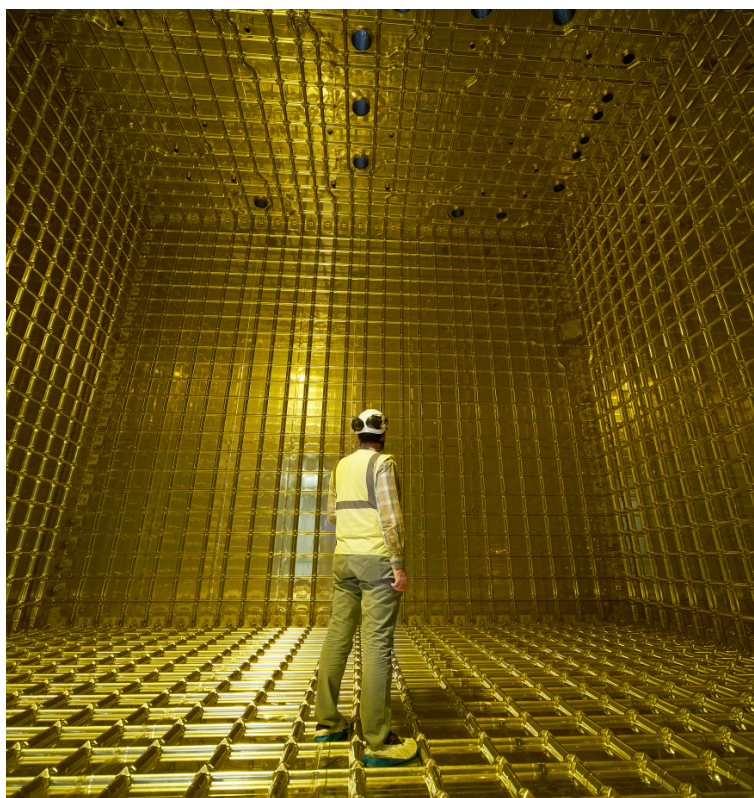
The international Deep Underground Neutrino Experiment, hosted by Fermilab, will come online in the mid-2020s. It will probe the fundamental nature of neutrinos. The Fermilab Scientific Computing Division will acquire, monitor and analyze the data to extract the science from the DUNE detector.
Photo: Maximilian Brice/CERN

Plans for the future

In a fast-moving, high-tech global economy, any country that wants to remain a leading economic power will have to out-compute to out-compete. Fermilab, along with several partnerships and collaborations, is investigating the use of artificial intelligence and quantum computing to ramp up computing power. 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.
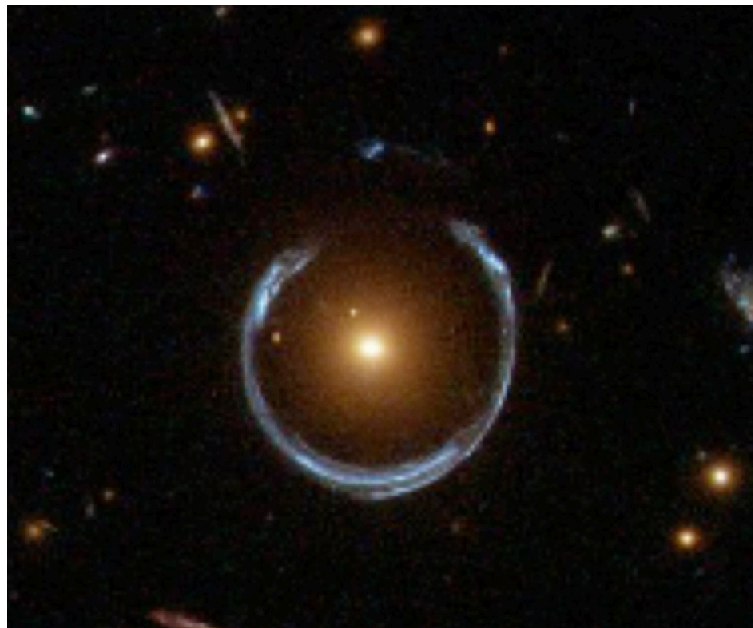
Example of a strong gravitational lens, a complex astrophysical system that we can locate within data sets generated from projects in which we lead or collaborate, such as the Dark Energy Survey and the Large Synoptic Survey Telescope. We used to use human visual scanning to look for these systems. Now we 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.

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