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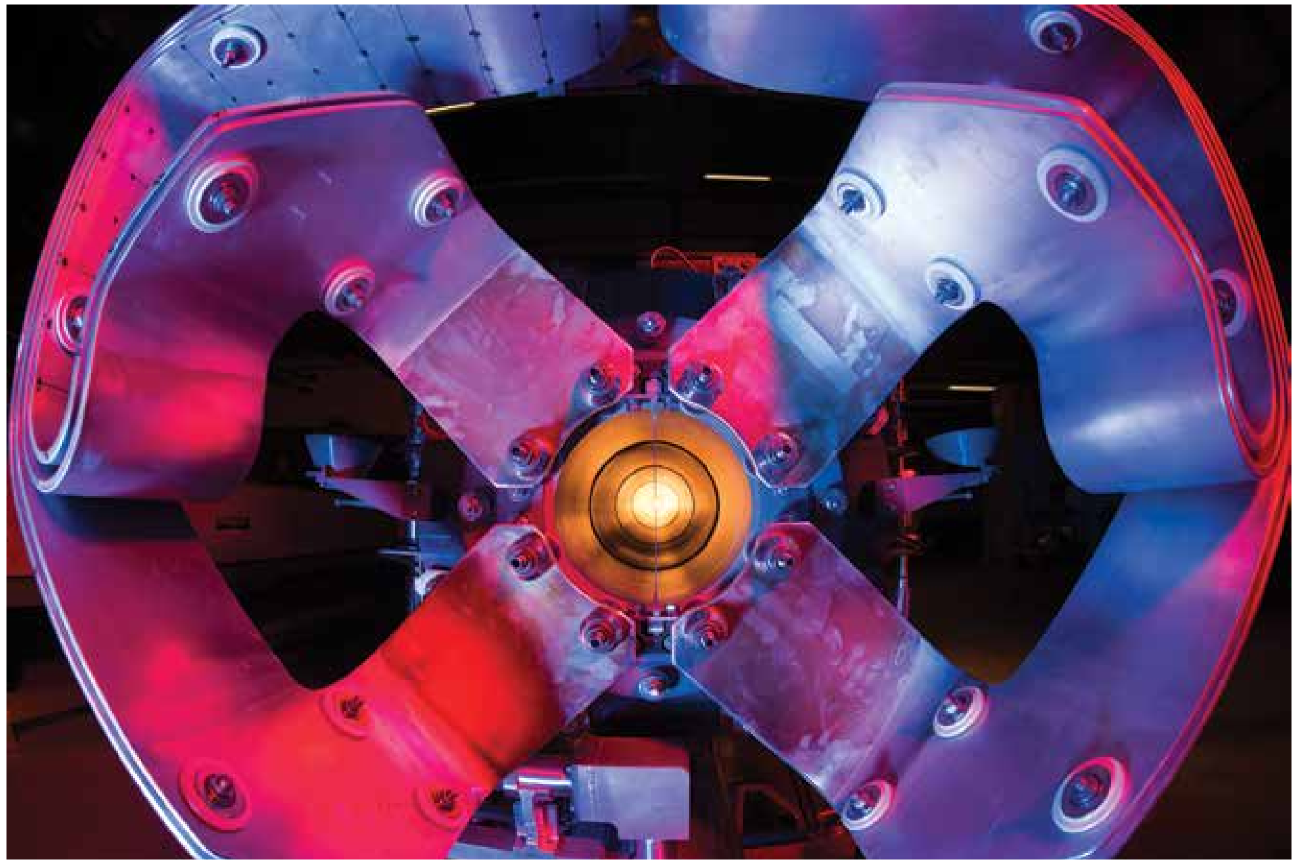
FERMILAB

Situated on a 6,800-acre site, home to a herd of bison and almost 300 species of bird, Fermi National Accelerator Laboratory (Fermilab) in Illinois has been working to enhance our understanding of the universe since 1967. From investigating the properties of the tiniest elemental particles to probing the nature of dark matter and dark energy in the farthest reaches of the universe, scientists and engineers at Fermilab are busy untangling the mysteries of our physical reality. Here we speak to **Dr Katie Yurkewicz,** who tells us all about the organisation, and gives us an overview of some interesting projects that are currently ongoing.

'Together we all seek answers to the deep questions that remain about the nature of matter, energy, space and time'



To start, could you please give our readers a brief introduction to Fermilab, and tell us a little bit about its history and mission?

Fermilab is a particle physics laboratory located outside Chicago, Illinois. It is one of 17 U.S. Department of Energy national laboratories, and it was founded in 1967. Fermilab builds cutting-edge particle accelerators and detectors to unravel the biggest mysteries of our universe, and to study it at the smallest and largest scales. We do this by creating particles in the laboratory using accelerators and measuring them using detectors. We also use particle detectors to search for naturally occurring particles of dark matter, and place detectors on telescopes to learn more about the mysterious phenomenon of dark energy. We build and operate world-leading facilities for the use of scientists from around the world.

How many different countries are involved in the research conducted at Fermilab, and who are your biggest collaborators?

Fermilab works with 44 different countries, and roughly 3,500 scientists from around the world collaborate with us on our experiments. Fermilab collaborates closely with the CERN particle physics laboratory in Europe, other laboratories in Europe, North America and Asia, and scientists and students from universities around the world.

Can you tell us a little bit about the neutrino experiments that are currently ongoing at Fermilab?

Neutrinos are nearly massless fundamental particles that interact so rarely with other matter that trillions of them pass through our bodies each second without leaving a trace. They are the most abundant matter particles in the universe, but we know very little about them. For example, we know that there are at least three different types of neutrinos. But we don't know their masses – or even which one is the lightest and which is the heaviest – we don't know if there are more than three, we don't know if neutrinos and antineutrinos behave differently, and we don't know whether the neutrino is its own antiparticle. There are also theories that say that neutrinos played a big role in the evolution of the universe, but we can't say yet whether those theories are true.

All of these questions are very tantalizing to physicists, and today the study of neutrinos is a very competitive field of physics. There are experiments to study neutrinos in North America, Europe, Asia and Antarctica. At Fermilab, we currently operate neutrino experiments on our site and in northern Minnesota. We have plans to create a suite of three new on-site neutrino experiments, which will search for signs of a long-theorized fourth type of neutrino, and we are steadily working toward building our new flagship, the Deep Underground Neutrino Experiment, which will be the largest long-distance neutrino experiment ever constructed. We will send a beam of neutrinos 1,300 kilometers through the earth to South Dakota to study neutrino oscillations.

Additionally, our readers would love to hear about Fermilab's dark energy and dark matter research, please highlight one or two key projects that are currently underway.

The main project Fermilab is involved with in that realm is called the Dark Energy Survey. Scientists built and tested one of the world's most powerful digital cameras at Fermilab and then mounted it on a telescope in Chile, and they are spending five years taking extraordinarily detailed snapshots of the cosmos. They will use this data to study dark energy's effect on the universe over time, as it has pushed galaxies and cosmic structures away from one another. The Dark Energy Survey is also using this data to make a map of dark matter concentrations in the survey area.

We are also involved in several next-generation experiments to search for particles of dark matter, including a next-generation experiment being built in the SNOLAB underground research facility in Canada.

In 2008, scientists at Fermilab discovered a new sub-atomic particle – the bottom Omega baryon. Please could you explain to us why this finding was so significant?

Every newly discovered particle is an important piece of information leading to a clearer picture of how the universe works. The bottom Omega baryon is a composite particle, containing different combinations of quarks. By discovering different types of composite particles and measuring their properties, we learn more about how fundamental particles come together to make up everything we see (and don't see) in the universe. Fermilab has also been the place that three truly fundamental particles were first observed, including the top quark, the bottom quark and the tau neutrino.

How was Fermilab involved in the discovery of the Higgs boson in 2012?

Fermilab is the US hub for the Compact Muon Solenoid (CMS) experiment, one of the two that discovered the Higgs. Fermilab scientists made vital contributions to the construction of the Large Hadron Collider, including the superconducting magnets that focus particle beams into collision. Fermilab also make major contributions to the construction of the CMS detector, and roughly 100 Fermilab employees work on the CMS experiment itself. Fermilab also serves more than 500 US scientists who work on the CMS experiment through its remote operations centre that lets US scientists and students monitor scientific data as it is collected in real-time thousands of miles away in Europe, and through its computing centre that is one of the top in the world for LHC data, processing and analysing millions of collisions a second in real time. Fermilab scientists, technology and expertise were a major part of making the Higgs discovery happen.

On a different note, is it true that the Fermilab site is open to members of the public? Please tell us a little bit about Fermilab's position on public engagement.

Fermilab is strongly committed to public engagement. Much of our 6,800-acre site is open to the public every day. We offer free public tours once a week, and a free 'Ask a Scientist' event on the first Sunday of each month. We offer public events regularly, from our well-attended Family Open House to our public arts and lecture series to our work with every school in our local area. Fermilab also has a Community Advisory Board made up of local citizens who offer their perspectives on our interactions with the community.

Also, could you please tell our readers about Fermilab's efforts in wildlife conservation?

Fermilab's site contains about 1,000 acres of restored tall grass prairie and a further 1,000 acres of woodland and wetland, and it is home to many different varieties of wildlife. We employ an ecologist and work with a non-profit group called Fermilab Natural Areas to keep those areas diversified and beautiful. We also have a (fenced-in) herd of bison on site, which is quite an attraction for the local community.

Finally, can you please share your thoughts on the future of fundamental physics research, and the ongoing role of Fermilab in that future?

For nearly 50 years, Fermilab has been a world leader in discovery science, seeking out answers to the fundamental questions about our universe. Interest in our particular type of science (particle physics) is very high right now, with the discovery of the Higgs boson and last year's Nobel Prize in physics being awarded for neutrino research. The future of physics is very bright, and it is also highly international – all of the world's major particle physics projects are being built through international collaboration and cooperation. As we work toward the future flagship Deep Underground Neutrino Experiment we are becoming a truly international laboratory. More than 25 countries are already on board with DUNE and we are actively seeking to engage more partners. Together we will all seek answers to the deep questions that remain about the nature of matter, energy, space and time.

All photos courtesy of Fermilab

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