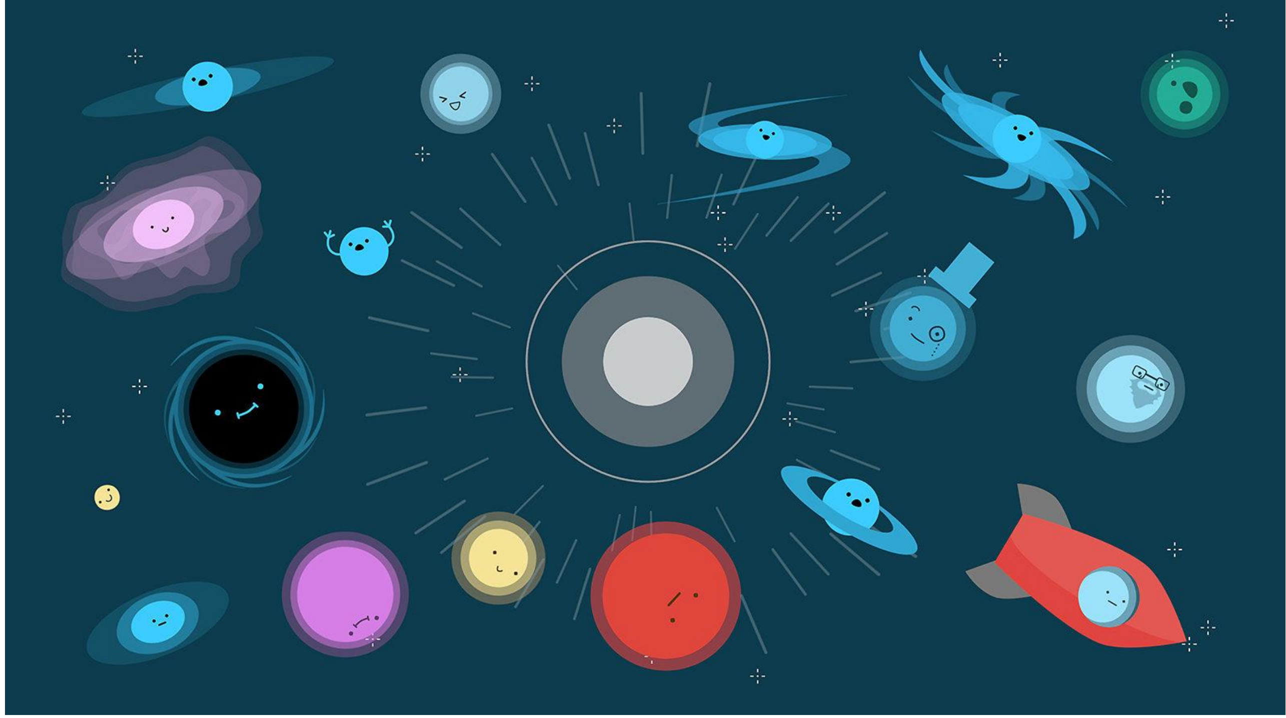
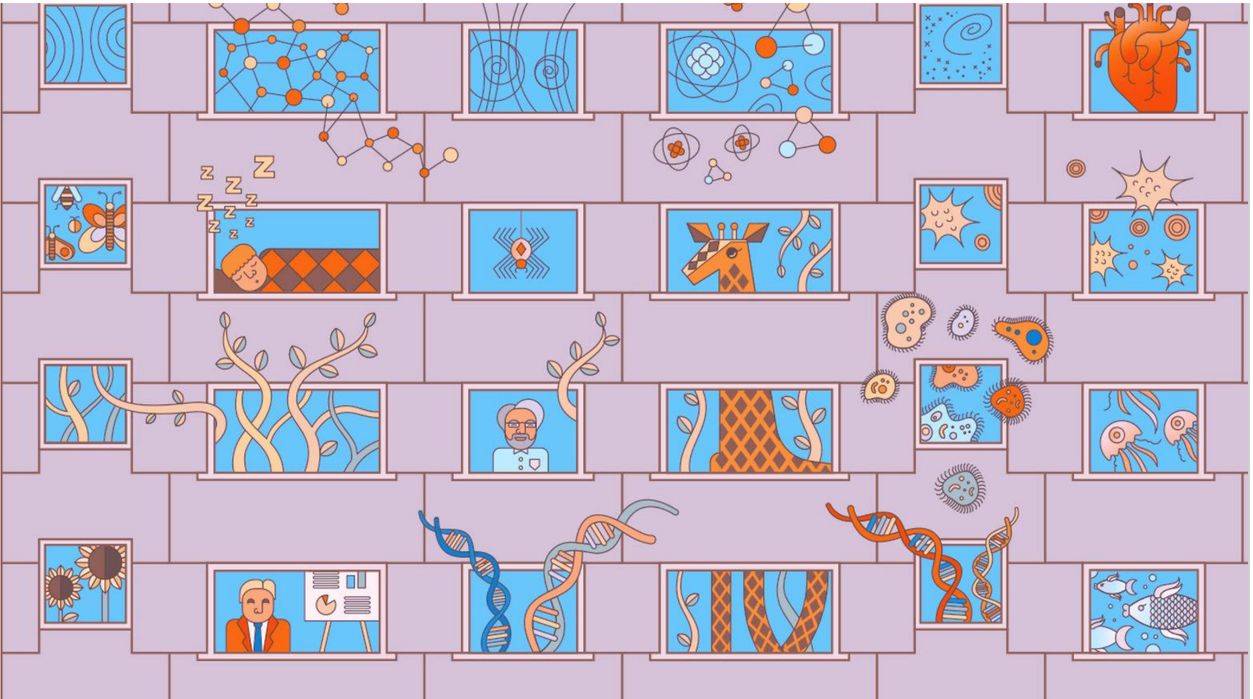
PhysQuiz Tutorial

Particles	Neutrinos	Forces	Accelerators	Symmetry
100	100	100	100	100
200	200	200	200	200
300	300	300	300	300
400	400	400	400	400
500	500	500	500	500

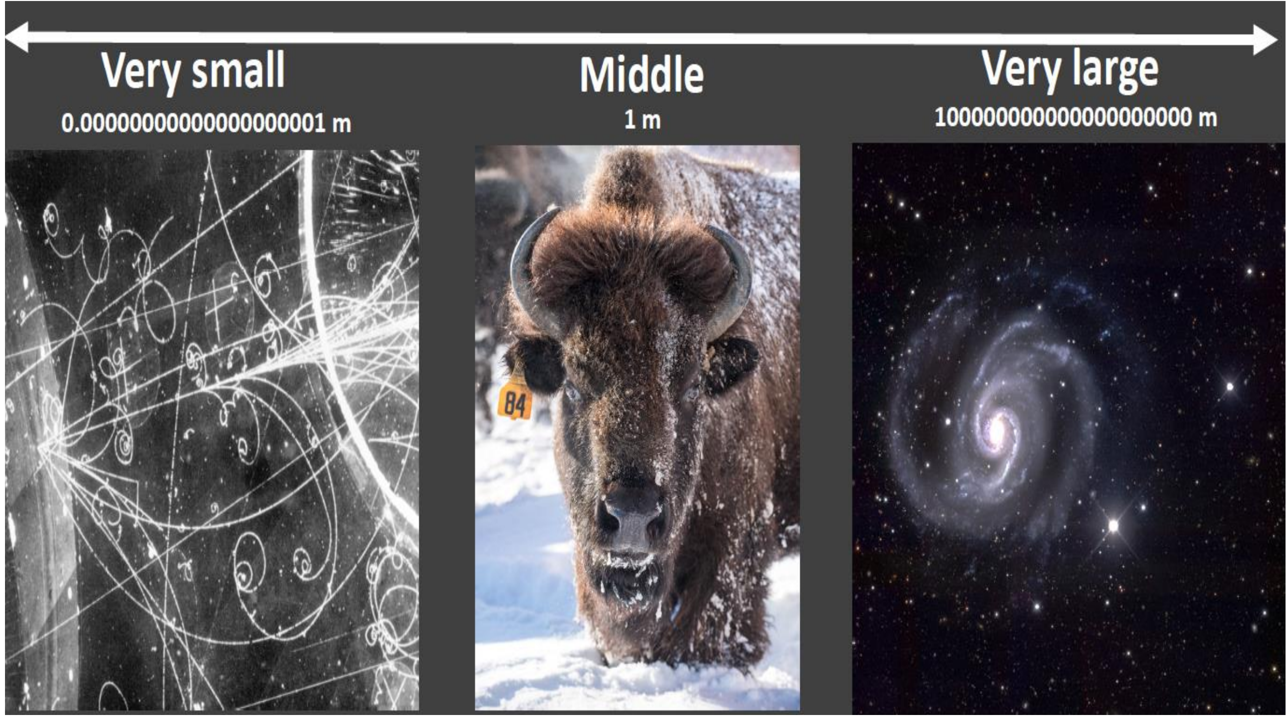
The universe is a big place and getting bigger, but there is a whole world of small objects, like cells, atoms and quarks, which can’t be seen with the naked eye. Particle physicists discover and study elementary particles—the basic building blocks of matter. They invent special tools to observe them.





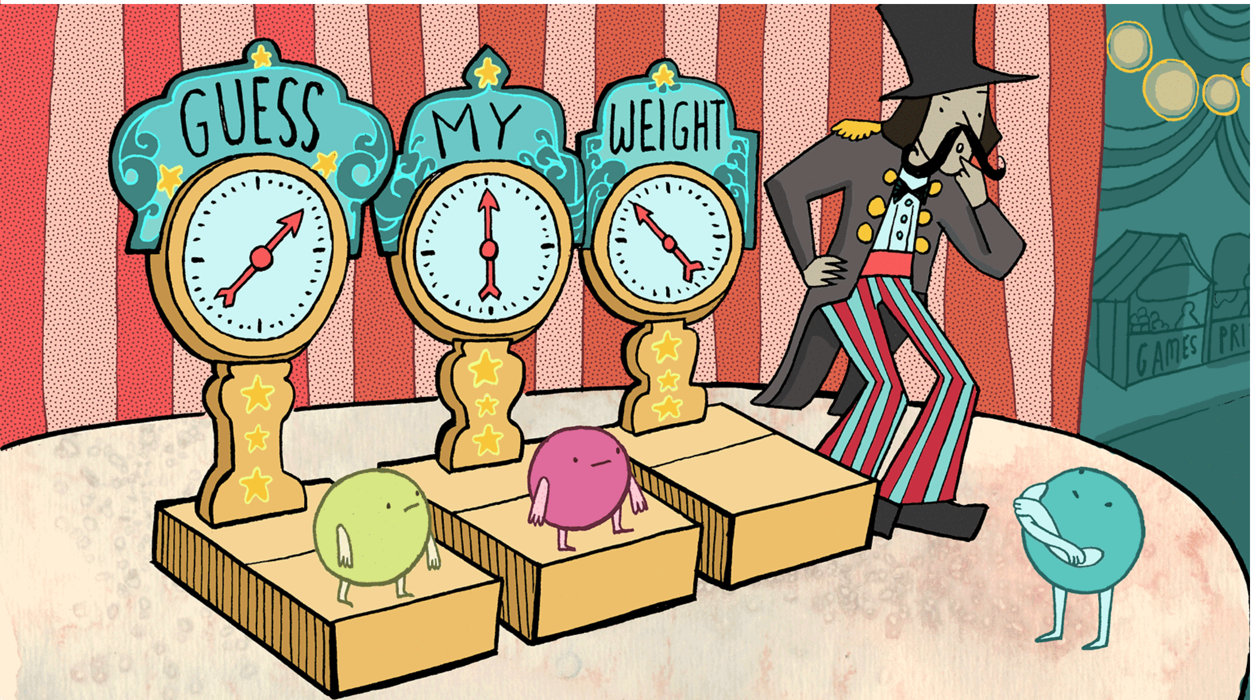
Neutrinos, quarks, and electrons are the smallest pieces of matter known. How small are they? Imagine a single grain of sand. A proton is a trillion times smaller than this grain of sand, and quarks are a quadrillion (1,000,000,000,000,000) times smaller than a single grain of sand.

So, how small is very small? Imagine a bison. Quarks and neutrinos are at least as much smaller compared to a bison, as a galaxy is larger. At Fermilab, scientists explore nature at these extreme scales.



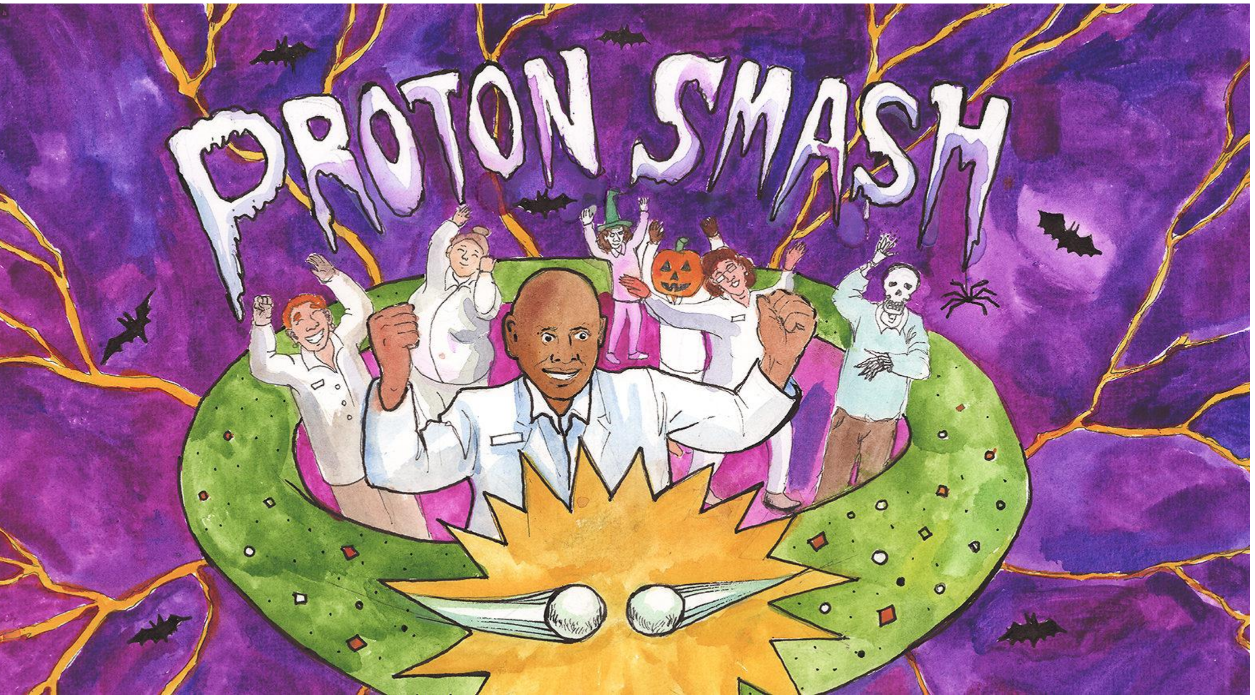
Why are quarks and neutrinos called fundamental particles? This is because scientists do not think they are made up of anything smaller. Everything is made of fundamental particles.

Neutrinos are the tiniest pieces of matter, and they go through you in trillions every second. Out of those trillions of neutrinos, only one may interact with your atoms during your lifetime! There are three different types of neutrinos known to scientists.



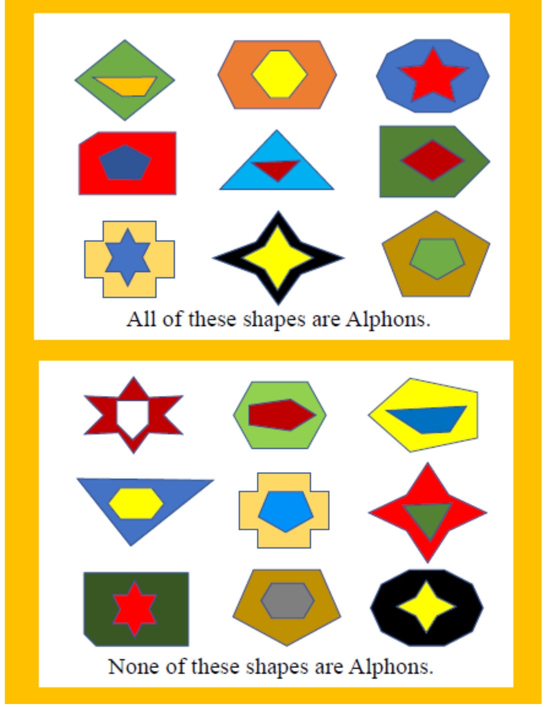
Neutrinos are also the lightest particles of matter. A neutrino is at least 10 billion, billion, billion times lighter than a grain of sand. Scientists don’t know the exact masses of the different neutrino types, nor do they know which neutrino is lightest and which is heaviest.

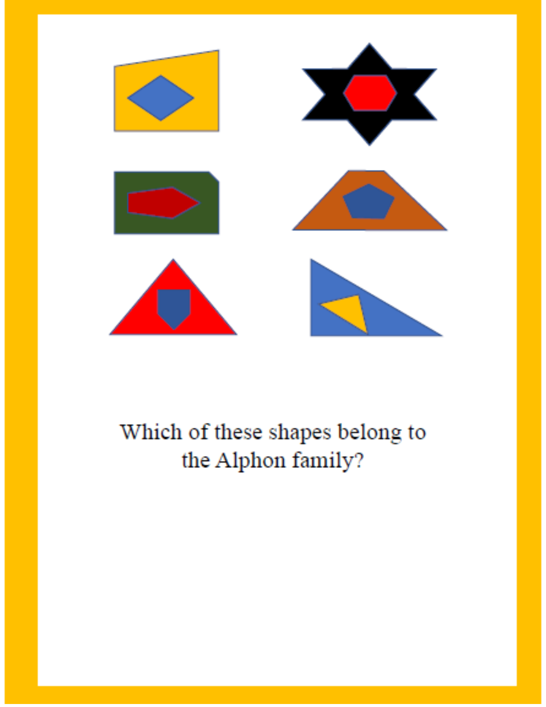
Even though neutrinos are the tiniest and lightest particles of matter, they may help explain some of the biggest mysteries of our universe. Fermilab scientists use accelerators to make the world’s most intense neutrino beams.

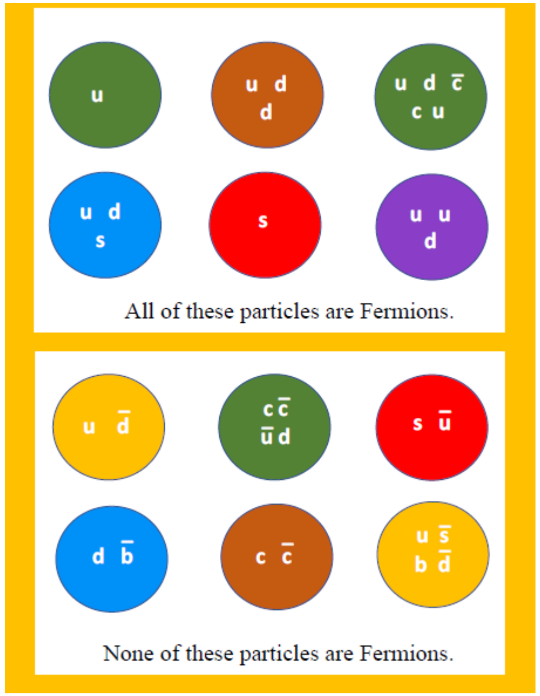


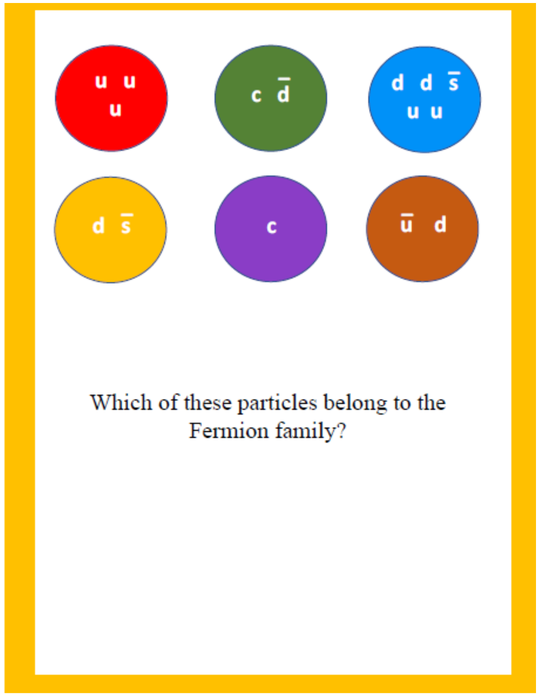
Neutrinos interact with matter very rarely and they can go through almost anything. Because of this, Fermilab scientists need to create and send intense beams of neutrinos to different detectors to be able to study their properties.

Particle physicists explore the properties of the fundamental elementary particles and group them in different families. Try to find patterns in the made up Alphons family (on the right) and find out which shapes belong to this family.



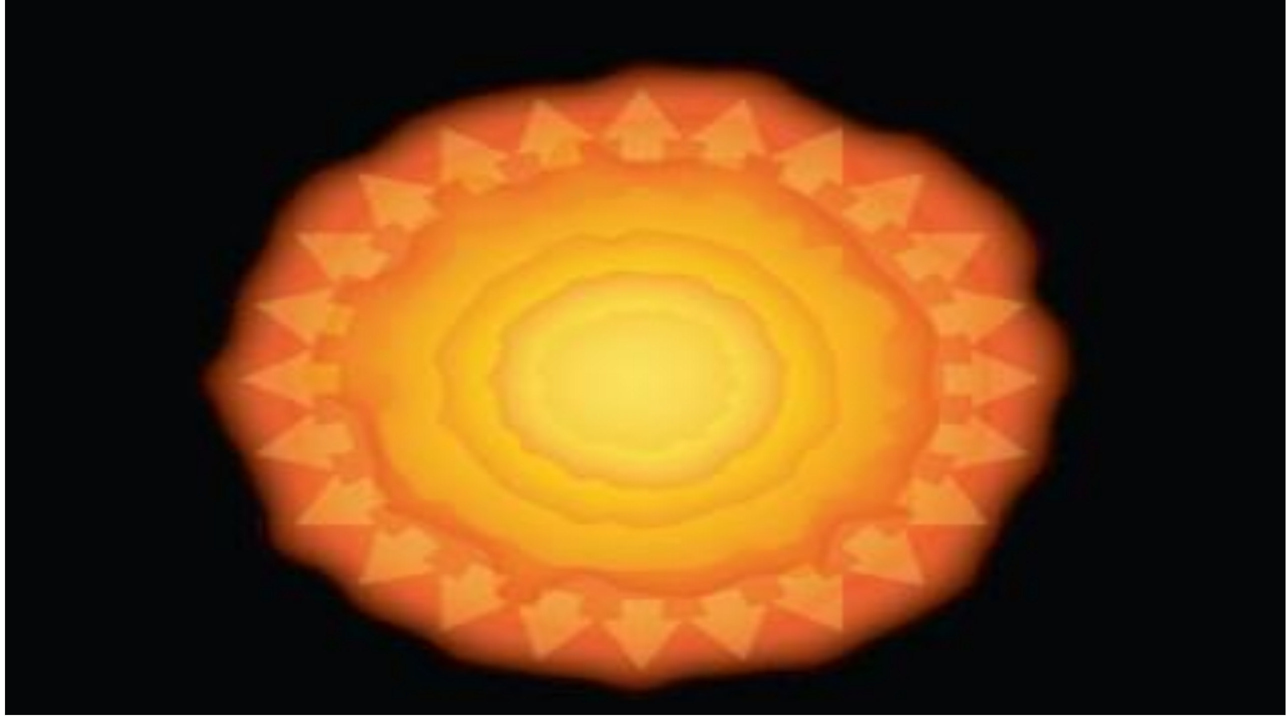






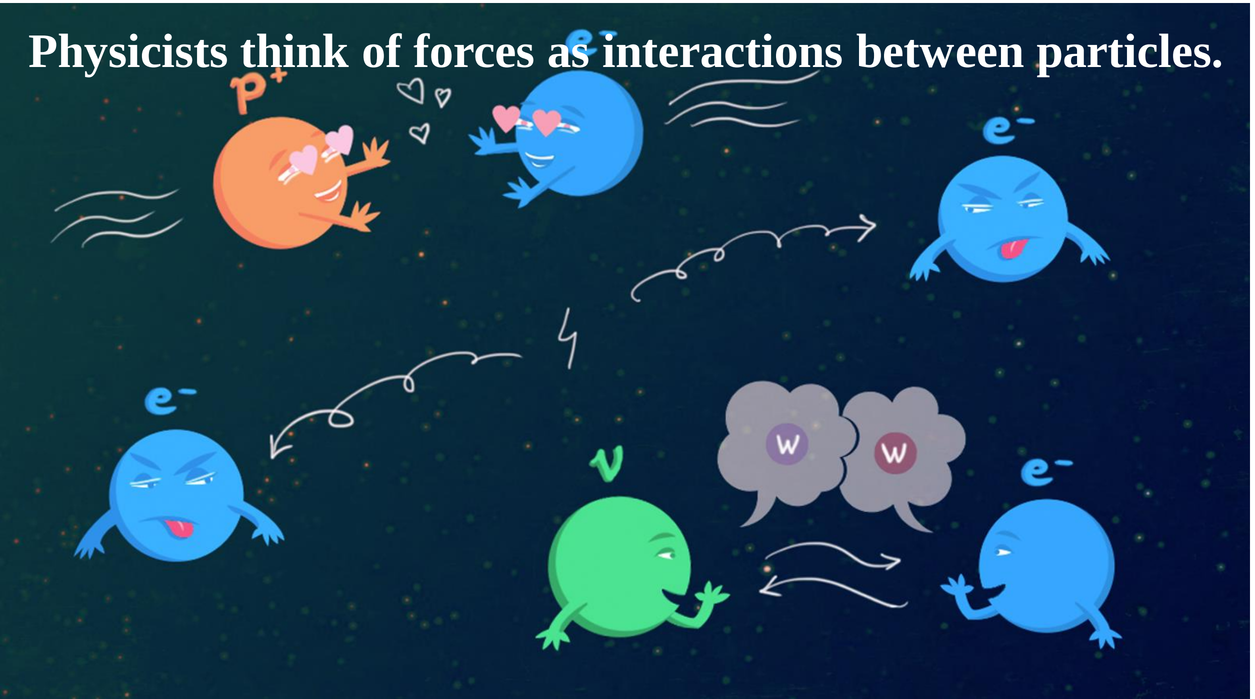
Two basic particle families are Fermions and Bosons. Try to find patterns in the Fermions family (on the left) and find out which particles belong to this family.

Our universe emerged about 13.8 billion years ago from a hot, dense soup of particles. Quarks and gluons followed nature’s rules and clumped together to form protons and neutrons, which then began to form nuclei.



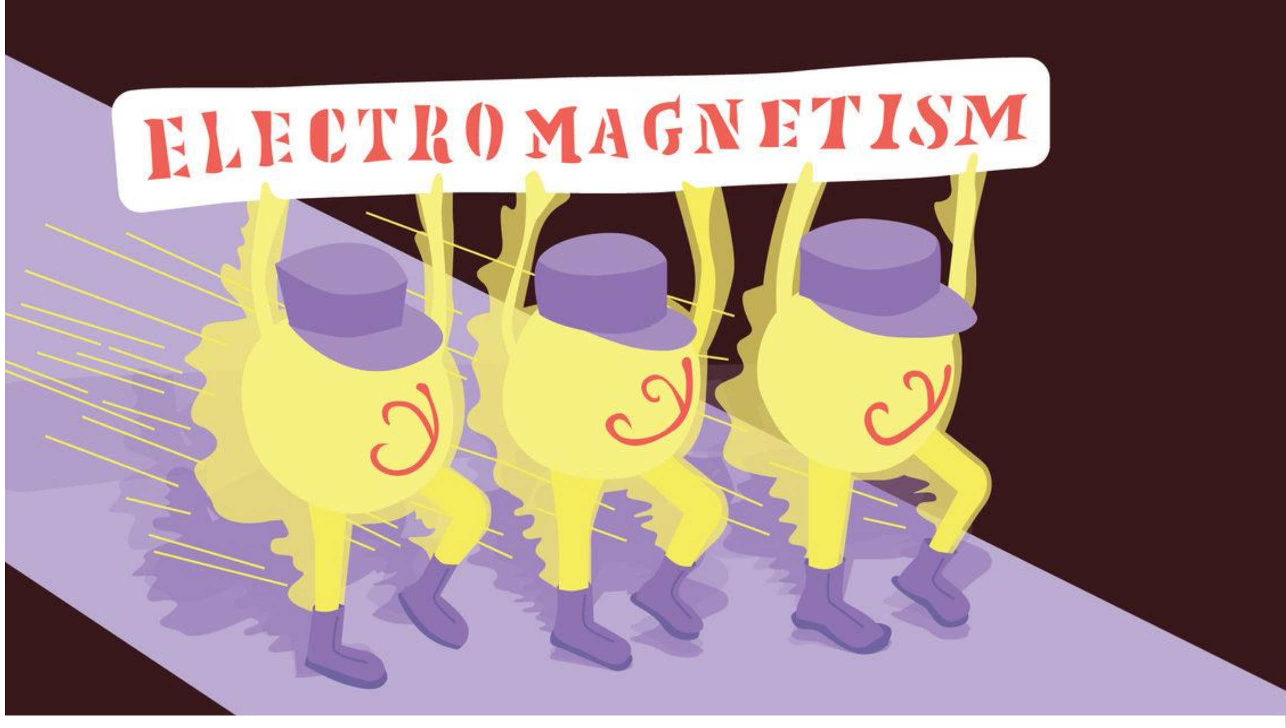
Why is it important to know the rules of how quarks combine in ordinary matter? This is because these rules define how ordinary matter is created in our universe. Fermilab scientists study not only particles but also the forces that govern our universe.

Interactions between objects produce forces. You may think of forces as pushes and pulls. All interactions can be explained by four fundamental forces: gravity, electromagnetism, the weak nuclear force, and the strong nuclear force.



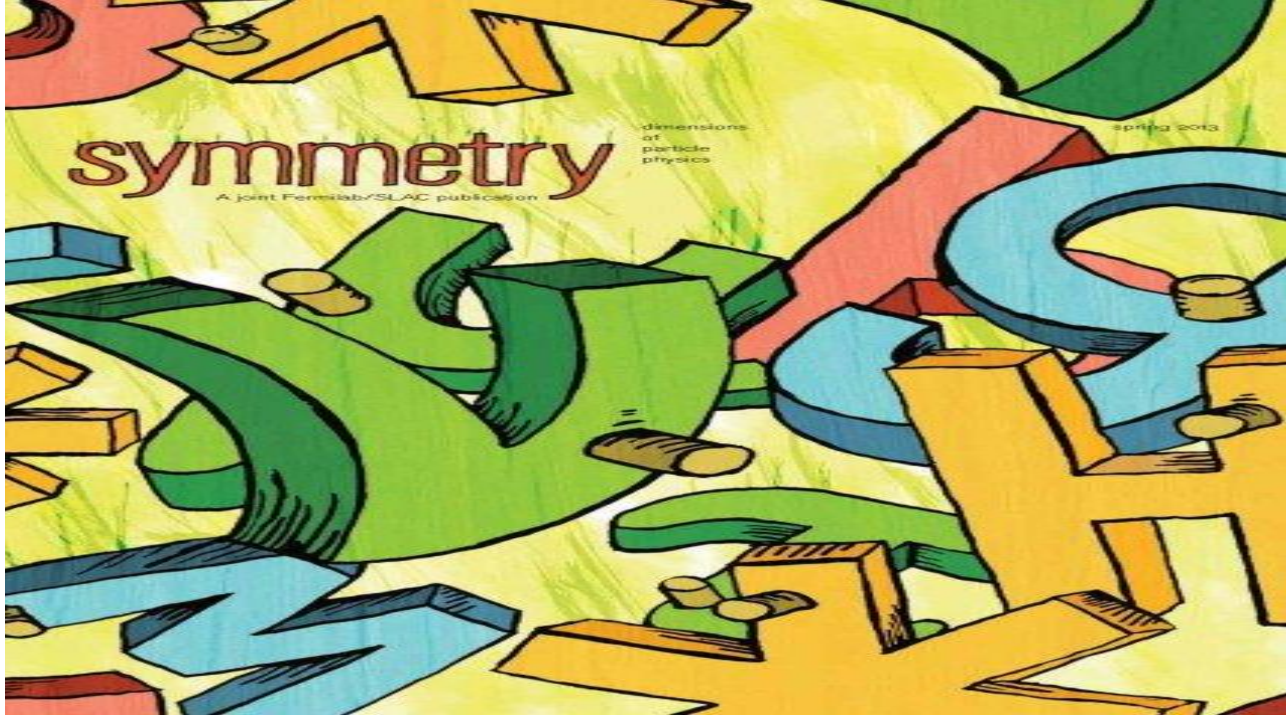
Gravity is caused by the curvature of space around a massive object and it is the weakest force. The electromagnetic force acts between charged particles. Neutrinos are affected only by gravity and weak nuclear forces.

Electricity and magnetism are two forms of a single force. Physicists unified them into the electromagnetic force in the 19th century. Experiments showed that electrical currents deflect magnetic compass needles, and moving magnets produce currents.



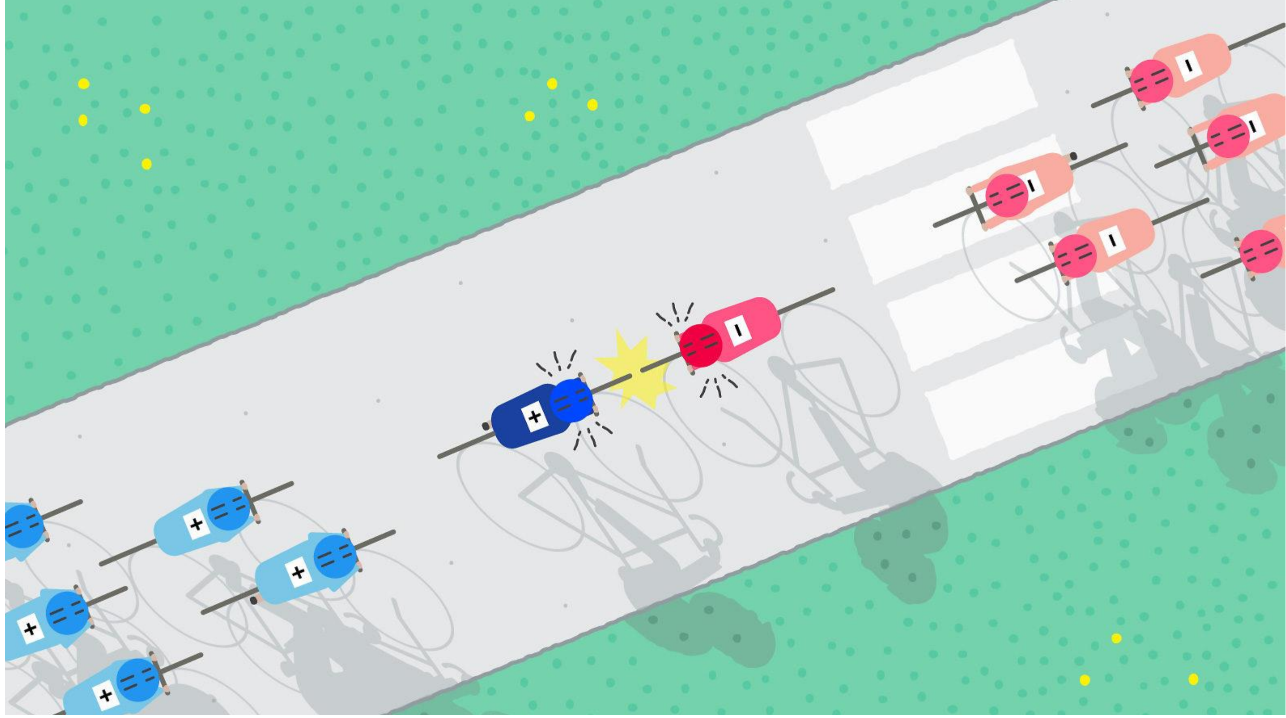
The electromagnetic force is responsible for holding electrons inside atoms and bonding atoms into molecules. Fermilab scientists make powerful electromagnets for particle accelerators. Without electromagnets, we would have no TVs, computers or telephones.

How do scientists reveal nature’s laws? There is an amazing beauty in nature. A snowflake, a daisy, a butterfly—the shapes of these and other natural objects—have underlying patterns and symmetries. This helps us organize our world conceptually.



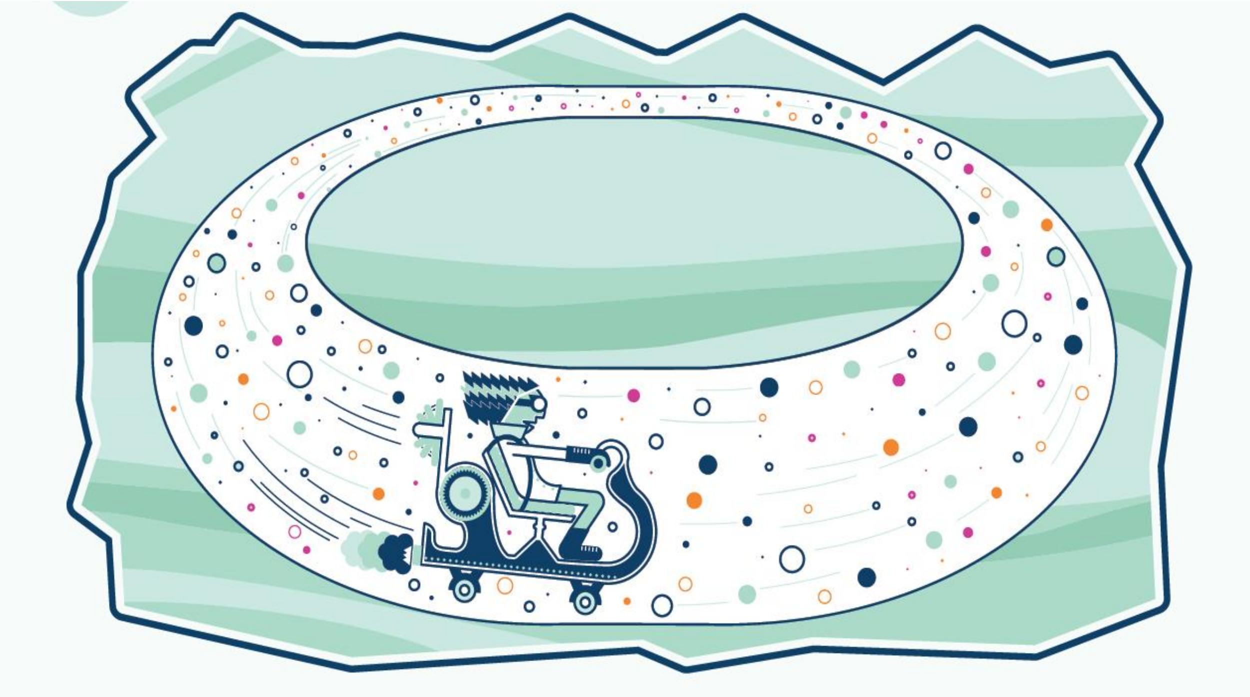
An object has symmetry if there is a change—transformation that takes this object onto itself. An object which does not change upon undergoing a reflection has mirror symmetry. Fermilab scientists use symmetry to understand the properties of matter and forces.

Scientists invented different tools and methods to reveal nature's laws. Particle physicists use accelerators to study particles. Accelerators push beams of charged subatomic particles to very high speeds. In fact, they can accelerate particles to nearly the speed of light.



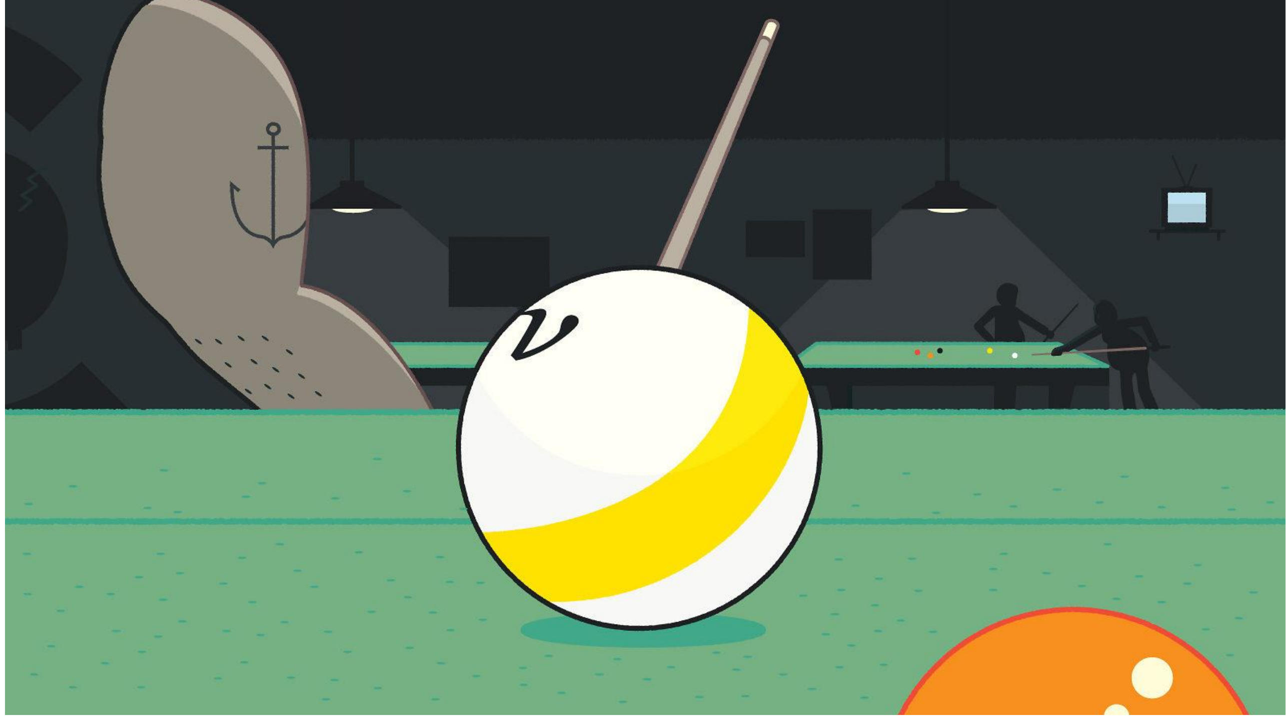
But what does acceleration mean in everyday life? You accelerate when you speed up, slow down, or change your direction.

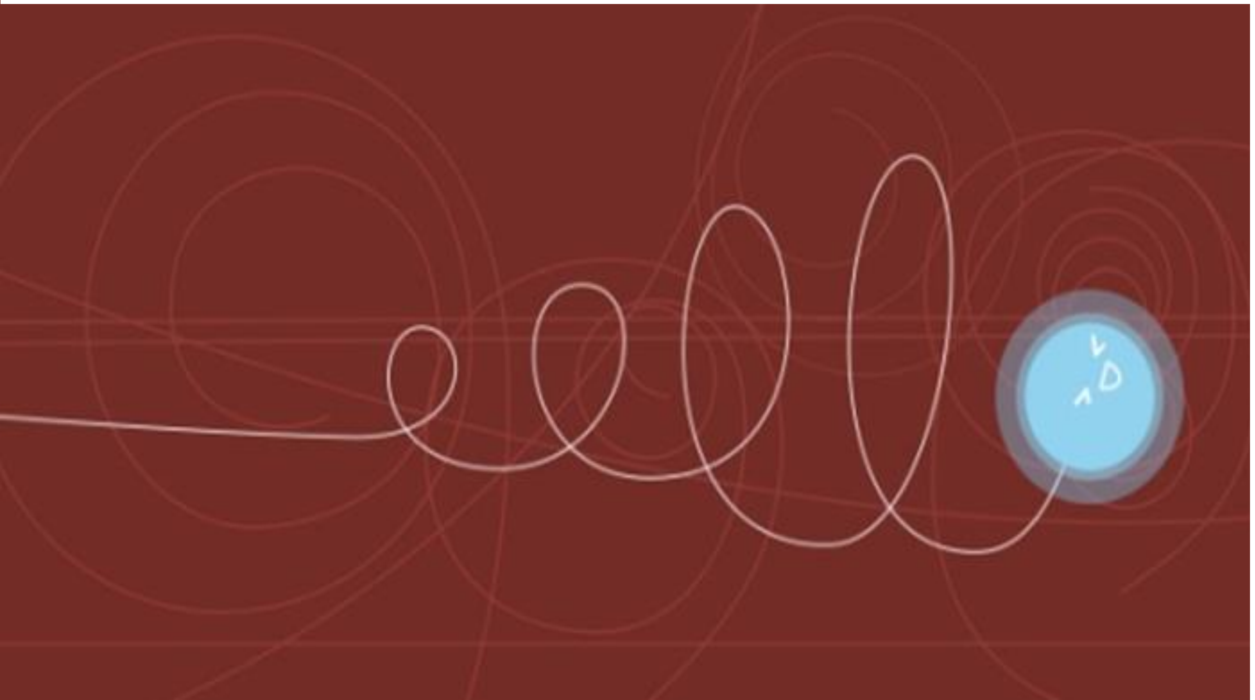
Two basic types of particle accelerators are linear and circular. Linear accelerators accelerate charged particles in a straight line. Fermilab is building a new superconducting linear accelerator to create the world’s most intense neutrino beam.



Circular accelerators take particles around a ring.
Inside circular accelerators, particles speed up by passing the same “kicking zones” several times until they reach the desired energy.

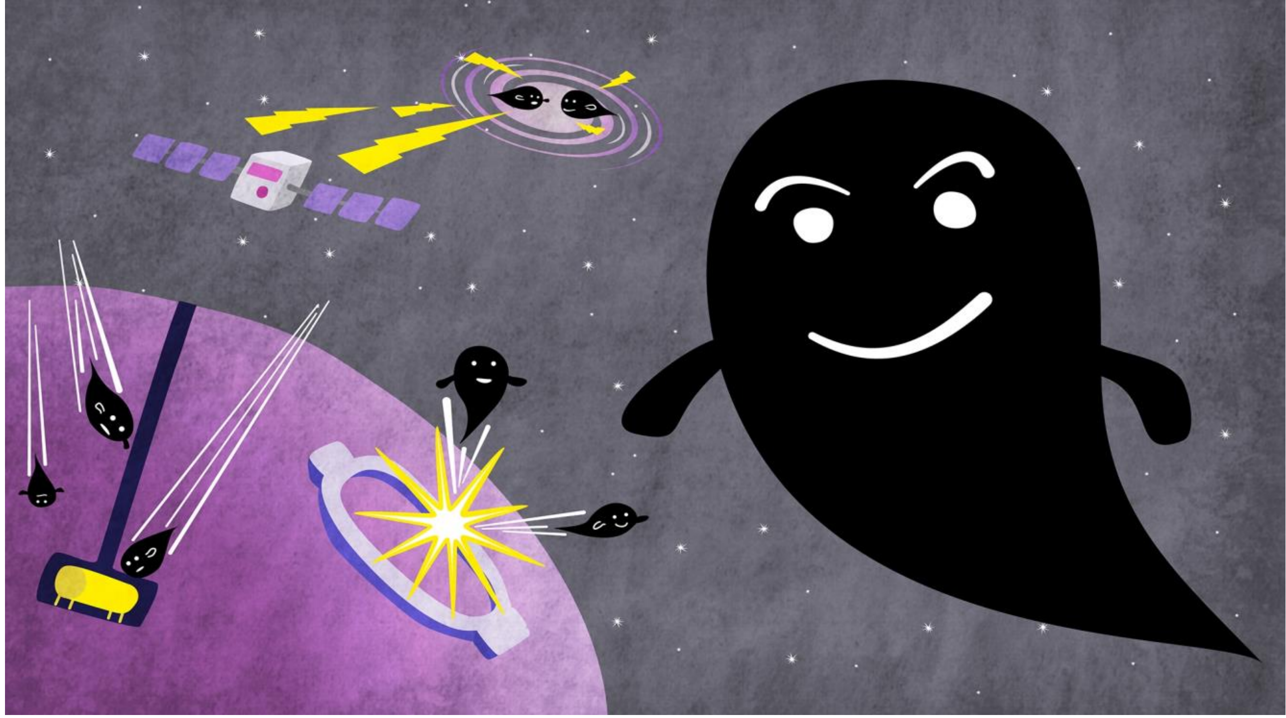
Physicists explore the invisible subatomic world by creating particle collisions. They collect data, analyze millions of different particle interactions, and gather information about the properties of particles.





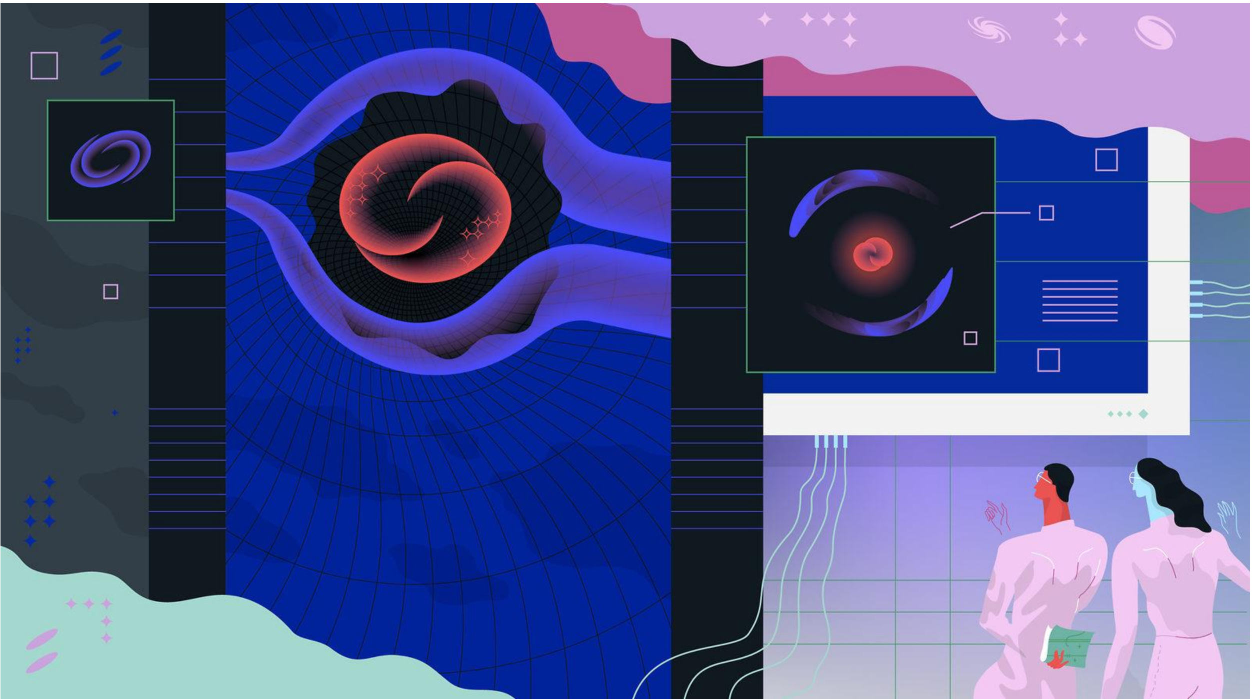
Physicists learn about particles by studying the tracks they leave inside detectors. The shape of a track can tell a scientist about a particle’s energy, direction, speed or electric charge.

Just like particle physicists use accelerators to study particles, particle astrophysicists use powerful telescopes to study galaxies. They make measurements, observe galaxy movements, and find patterns in their behavior.



Their measurements show that besides the ordinary matter, there must be some unknown dark matter and dark energy to explain how galaxies move. In fact, they think only 5% of our universe is made of ordinary matter and the rest is dark matter and dark energy.

We can see the universe through photons (particles of light). As the light emitted by distant stars passes by massive objects such as galaxies or black holes, the gravitational pull from these objects can bend the light. This is called gravitational lensing.



Gravitational lensing is caused by gravity and it is similar to how lenses bend light rays. Fermilab scientists use gravitational lensing to study the behavior and properties of different galaxies and to find out more about dark matter and dark energy.