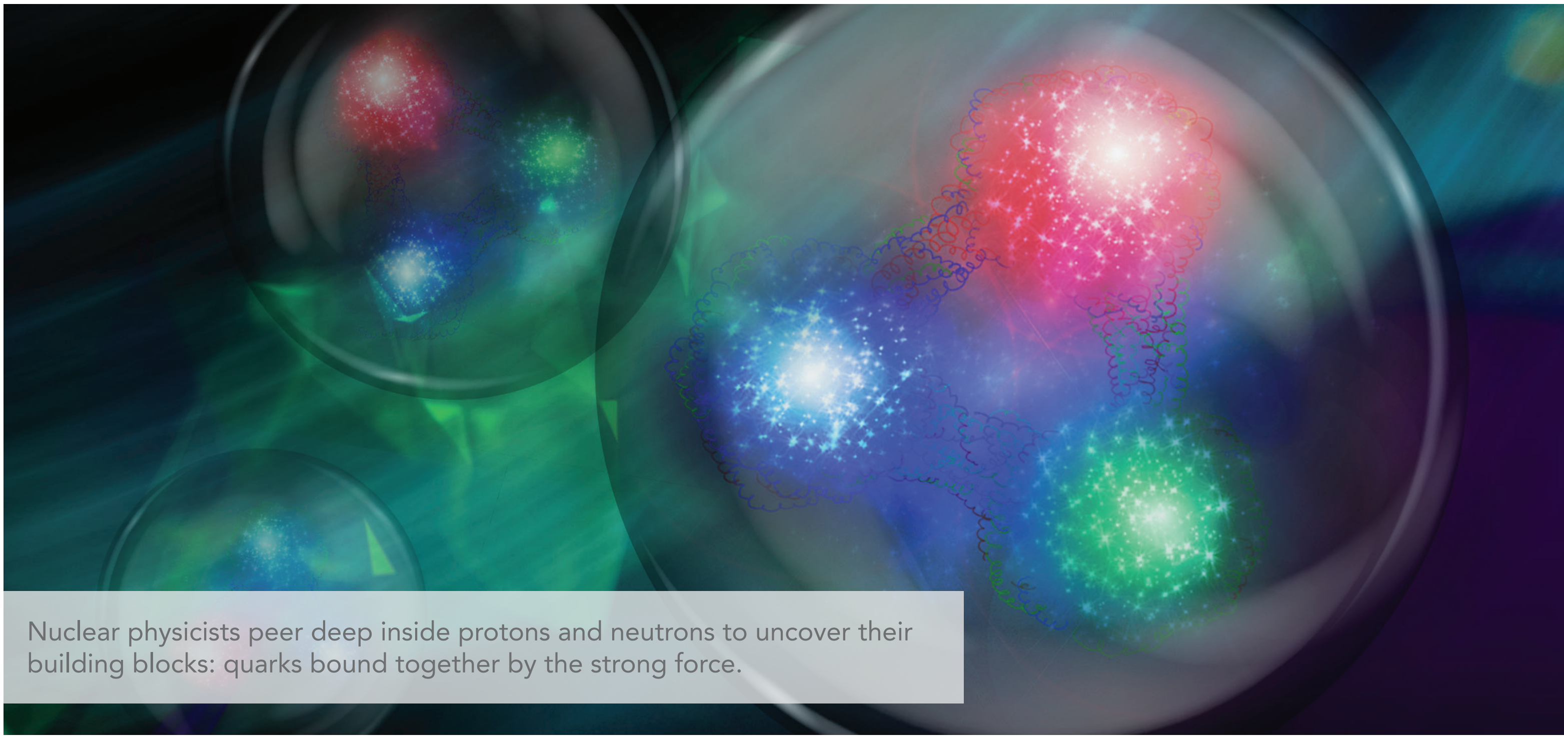
EXPLORING MATTER

Jefferson Lab

Working to understand the particles and forces that build our universe



Nuclear physicists peer deep inside protons and neutrons to uncover their building blocks: quarks bound together by the strong force.

Nature's real building block is the dynamic, mysterious strong force.

From the stars overhead to the atoms in our own DNA, all matter is composed of fundamental particles – particles that cannot be divided into smaller parts. Quarks are the smallest bits of matter we have found that, so far, cannot be split.

MATTER'S BUILDING BLOCKS

There are six types of quarks (up, down, charm, strange, top and bottom). The lightest two types – called up and down – are the most common. They stick together to make protons and neutrons.

Quarks are extremely small, taking up less than one billionth of a proton and only a few percent of its mass. So, what takes up the rest of the space and gives protons the rest of their mass? What's more, quarks and protons also have a property called spin, but the quarks' spin generates only 30% of the proton's. Where does the rest come from?

Quarks are bound to each other by the strongest force in the universe. Surrounding and connecting the quarks, this strong force binding "glue" generates 98% of the universe's visible mass, and it may also be responsible for the extra spin and other properties of protons. It turns out that it's not just the matter that matters – Nature's real building block is the dynamic, mysterious strong force.

EXPLORING THE UNIVERSAL GLUE

Of the four fundamental forces in our universe, the strong force is perhaps the least understood.

Take its influence on quarks: when pried just one proton's width apart, the strong force exerts ten tons of force to pull quarks back together. It is so powerful, that if you expend an enormous amount of energy to pull the quarks apart, the strong force will convert that energy into a new quark/anti-quark pair, rather than allowing the original quarks to separate – a property called confinement.

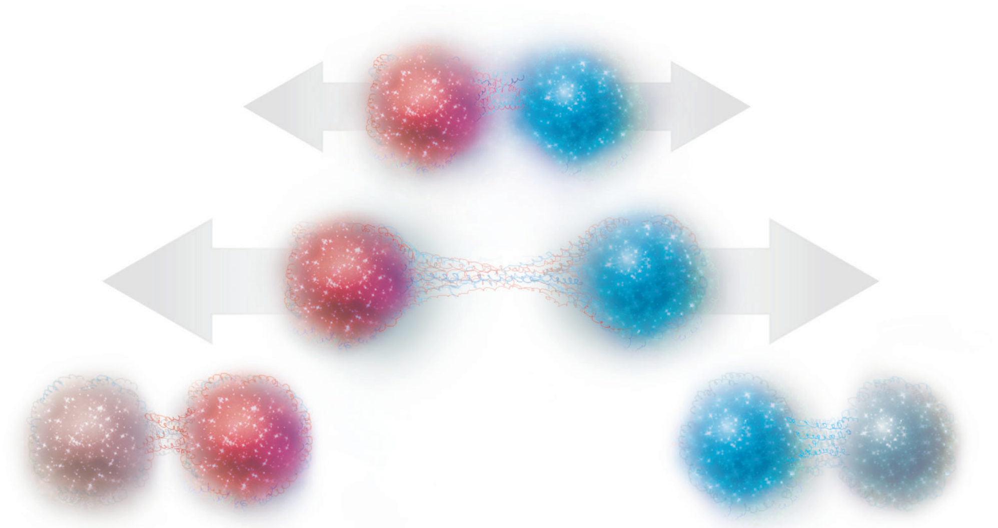
Confinement is one of the great mysteries of modern physics being studied by nuclear physicists at Jefferson Lab. They aim to produce an exotic meson – a particle built of a quark and anti-quark, and bound by a strong force that is more actively contributing to its properties.

Confinement is one of the great mysteries of modern physics studied at Jefferson Lab.

Although predicted by theory, there is only tentative experimental evidence for these exotic mesons, and it is essential that researchers produce and study them in detail to fully understand the strong force and how it confines quarks.

PROTONS AND NEUTRONS

There are still unanswered questions about what the insides of protons and neutrons look like. It's not possible to simply pry each quark out of the proton one-by-one. But recent theoretical advances are allowing physicists to patch together the first 3D snapshots of their internal structure using data from Jefferson Lab experiments.



If you try to pull two quarks apart, the energy to pull on the quarks will transform into two new quarks.

Another puzzle physicists aim to solve is how protons and neutrons bind together to form the atom's nucleus. Studying a wide range of distance scales within nuclei, from the minuscule quarks to the composite protons and beyond, allows scientists to explore the possibilities.

THE STANDARD MODEL

Jefferson Lab's Continuous Electron Beam Accelerator Facility (CEBAF) is also allowing physicists to study the limits of the Standard Model, a robust theory that describes the fundamental particles and their interactions in terms of the strong, weak and electromagnetic forces.

Scientists use CEBAF's accelerator to test the Standard Model in two ways: by testing its predictions for the structure of protons and neutrons, where the strong force is incredibly strong; and by testing its completeness with high-precision measurements at low energies, where discrepancies could reveal signatures of new forms of matter.

Discovering the limits of the Standard Model will provide deeper insights into the nature of the universe we live in.

THOMAS JEFFERSON
NATIONAL ACCELERATOR FACILITY

12000 Jefferson Avenue, Suite 15,
Newport News, Virginia 23606
(757) 269-7100
jlabinfo@jlab.org • www.jlab.org

Jefferson Lab is managed and operated by Jefferson Science Associates, LLC, a joint venture between Southeastern Universities Research Association, Inc., and PAE.