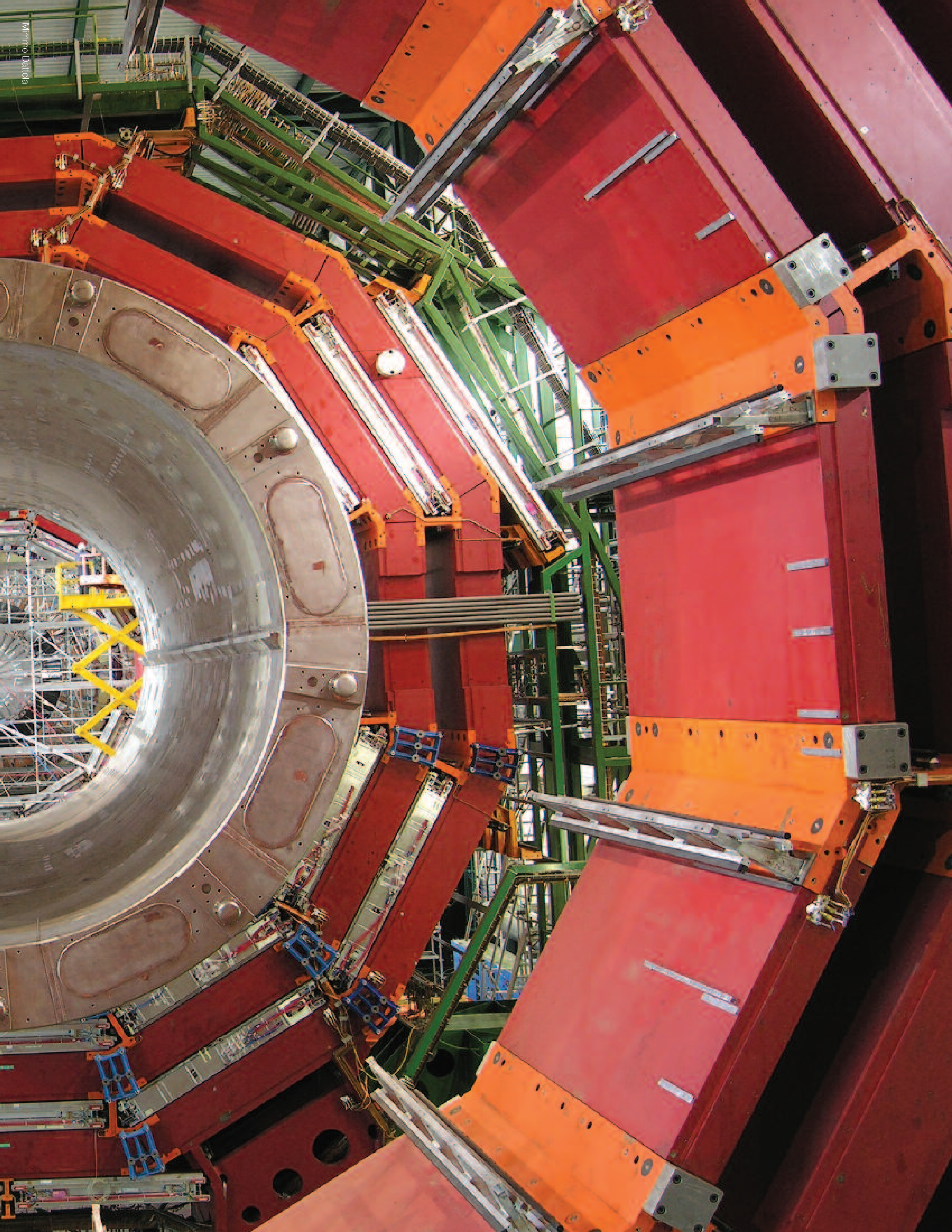


Mimmo Dattola

Cornell Theorists

TO TEST THEORIES OF PHYSICS

What Is the Origin of Inertia?

The standard model of strong, electromagnetic, and weak interactions is the crowning achievement of twentieth-century physics. The model combines insights from quantum mechanics and relativity theory to provide a theoretical description of physics at the subatomic scale. Over the past three decades, a series of experiments has confirmed the predictions of the theory, often with exquisite precision.

Satisfying as this success is, it by no means represents the end of the quest to understand nature at its most fundamental, microscopic level. Rather, it brings into focus a new set of questions that are not addressed by the standard model. Some of the questions are these: What is the origin of mass, inertia, and matter? How does gravity, the only known force left outside the scope of the standard model, fit in? Why are there so many (16 at the latest count) different kinds of elementary particles in nature? Recent cosmological observations indicate that only about five percent of the energy in the universe is in the form of known particles included in the standard model; of what is the remaining 95 percent made? Members of the LEPP theory group are actively engaged in the search for answers.

The Origin of Mass

For years, physicists speculated that the origin of mass is the so-called Higgs boson, a particle that so far eludes experimental discovery. This nondiscovery motivated some theorists to look for alternative explanations: for example, Cornell's Csaba Csaki, Physics, and his colleagues have recently suggested that there is no Higgs boson, and the origin of mass is instead related to the existence of a fifth dimension of space curled up to a tiny size. Even if the Higgs exists, it is very likely that the actual mechanism of mass generation is more complicated, involving other new particles and interactions. Theorists have proposed numerous candidate models. In the near future, the experiments at the frontier of next-generation accelerator facilities, the LHC and the ILC, will provide a definitive test of these ideas. Considerations of theoretical consistency guarantee that the new physics involved in the mechanism of mass generation—whatever it is—will be discovered in the new round of experiments. The new experimental data should enable the construction of a definitive theory of the origin of mass, and Cornell theorists look forward to participating in the exciting quest for such a theory.

Maxim Perelstein

Frank DiMeo

MY COLLABORATORS AND I HAVE RECENTLY USED THE COSMOLOGICAL DATA ON DARK MATTER ABUNDANCE TO PREDICT THE RATE AT WHICH THESE PARTICLES SHOULD BE PRODUCED IN ACCELERATORS.

Dark Matter

Understanding the origin of mass may also shed light on one of the biggest puzzles in cosmology, the mystery of dark matter. Judging by its effects on the motion of visible galaxies, dark matter is ubiquitous in the universe. It seems to be much more common than the ordinary matter of which stars, planets, and humans are made. It must consist of particles that have not yet been observed in the laboratory, probably due to the extreme weakness of their interactions with ordinary matter. Such particles are predicted by many models of the origin of mass, and may be discovered by the experiments at the LHC and the ILC. My collaborators and I have recently used the cosmological data on dark matter abundance to predict the rate at which these particles should be produced in accelerators. Producing and studying the dark matter particles on Earth will allow my group to understand their properties in detail.

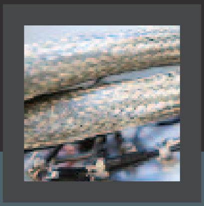
LEPP

One potential signature, identified by Henry Tye, Physics, and his coworkers, is that some of the strings may have been stretched out by the expansion of the universe to become extremely large, spanning galactic and extragalactic scales.

The leading candidate for a unified theory of gravity and other forces is string theory, which postulates that all elementary particles, rather than being point-like objects with no size, are extended in one dimension like tiny fragments of a string. This hypothesis has yielded the first self-consistent quantum theory of gravity, providing interesting insights into the microscopic nature of black holes, for example. Obtaining experimental evidence for string theory is a difficult task, since the typical size of the string is only a tiny fraction of the proton's diameter. Studying physics at such small scales is beyond the reach of even the most powerful terrestrial accelerators. Nonetheless, if true, string theory must have played a role in the initial moments of the universe's existence—in the first nanoseconds after the Big Bang. The strings then may have left an imprint on the universe that could be observed today. One potential signature, identified by Henry Tye, Physics, and his coworkers, is that some of the strings may have been stretched out by the expansion of the universe to become extremely large, spanning galactic and extragalactic scales. While not luminous, such cosmic strings could still be detected, since they would affect the light emitted by the surrounding stars and emit gravitational waves. Tye and his students are working with colleagues in Cornell's astronomy department to identify the most promising signatures.

Maxim Perelstein
Physics

MASS, ENERGY, AND LENGTH



Frank DiMeo

Modern physics has uncovered several amazing relations between seemingly different concepts. Perhaps the most famous one is the Einstein's formula, $E=mc^2$, which connects mass and energy: any object, even if it is not moving, has latent energy. Under the right circumstances, some of this "mass energy" can be converted into other, more familiar kinds of energy. For example, in a nuclear power plant, the liberated mass energy of decaying uranium nuclei is converted into electricity. The connection between energy and mass is so close that today's physicists frequently use the two words interchangeably.

Another interesting relation is between energy and length. According to quantum mechanics, high energy particles can be thought of as waves, and particles of higher energies have shorter wavelengths. Optics teaches us that the maximal size of the object that a wave can "see" is roughly equal to its wavelength: this is why atoms cannot be made visible to the eye, even with the most powerful microscope. Energetic particles from accelerators allow physicists to study the structure of matter at tiny distances. In physicists' language, "high energy" is synonymous with "short distance."

For example, in a nuclear power plant, the liberated mass energy of decaying uranium nuclei is converted into electricity.

For more information:

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