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It's an exciting time for physics. We are currently exploring the universe at larger and smaller scales than ever before. Astrophysical probes let us see out into the Universe at the largest observable scales. Particle experiments set to investigate the fundamental nature of matter smaller distances and higher energies than ever before.

Admittedly, the questions we ask can be very abstract in their detailed formulation-so much so that people sometimes question the merit of our enterprise, which doesn't have the obvious and immediate impact of other more applied or more people-oriented research. But at the root of what we explore are questions as basic as what are the fundamental building blocks of matter? What is out there in the universe that we cannot yet see? And how did the universe evolve into its current state? The ability to ask—and to answer these questions—and to formulate them precisely enough that we know answers should exists—is what makes people, and up to this point Americans, special.

Some of the very features that make the field so esoteric and so challenging are also what makes it critical as a way of maintaining leadership in scientific, technical, and creative fields. If you want to attract the best people to do the most creative things, challenges are vital. We've maintained the best universities and had the most innovative companies for the last half century for a reason.

So what are the questions we ask and what will it take to answer them? We want to understand matter's most basic elements and the forces through which they interact. We'd like to connect observed particles, interactions, and phenomena to underlying theoretical frameworks. That might be string theory, which posits fundamental underlying vibrating strings at the heart of all matter. Or these studies might yield a deeper understanding of spacetime. Are the three dimensions of space that we see all there are? Or are there dimensions to the universe that are different and so far completely hidden from view? It could be that there are parallel universes less than a centimeter away that we have not yet seen. It would be revolutionary to discover that the Universe is so much richer than we have so far observed.

We want to connect what we learn about fundamental particles to how the universe has evolved. And we'd like to understand the implications of cosmological observations for particle physics. Can we understanding the origin of the universe and structures that we see?

The chief particle physics questions today center around the origin of the masses of fundamental particles and why they are at the scale we have observed them to be. This is no small questions since quantum mechanics and special relativity tell us that it is extremely unlikely without something very interesting going on to maintain the hierarchy of mass scales that is necessary to develop interesting physical theories—and the world as we know it. Without what we call “fine-tuning” of parameters-or something new and profound—it seems that masses would be nothing like what we have seen. We want to understand both where mass comes from and what protects the mass scale.

That latter question has led to explorations as profound and admittedly speculative as the search for additional dimensions of space. It could be that spacetime is distorted in a way that keeps gravity weak and masses as they should be.

And most remarkably we should soon be able to test these ideas. The Large Hadron Collider, the giant machine colliding together two beams of protons at seven times higher energy than has yet been achieved on Earth, should be able to explore what physical theory accounts for the phenomena we have observed. For example, when protons collide they can turn into energy, and that energy (through E=mc2) can turn into particles that travel in the extra dimensions. Those particles might escape, or they might decay into the detectors which are specially designed to identify these decay products and piece together what was originally there.

By studying the energy scales that the LHC will explore, we might also understand what accounts for dark matter, the matter in the universe whose gravitational effects we observe but which don’t emit or absorb light. In addition to the LHC, this is an interesting experimental era for the study of cosmology and dark matter in particular. Many particle theorists currently explore the cosmological implications of physical theories that might underlie the Standard Model. Dark matter will be tested directly, in experiments on earth where the small probability that dark matter will interact is enhanced by providing big vats of target material. Dark matter will also be tested through the possibility that dark matter particles can annihilate with each other and give rise to photons or antiparticles that we can measure astronomically.

Our job as theorists is to understand experimental implications and suggest what might be present so that we won’t miss it when it is produced in the laboratory or in space. Experiments are complicated and the many subtle ways to find what lies beyond the Standard Model challenges us all to rise to the occasion.

There are many new ideas and results in theoretical physics that follow from our better understanding of the implications of Einstein’s theory of gravity and our particle physics models. There are intriguing possibilities to explore and test, both with theory and experiments. Many of these ideas center on the scales that the LHC will explore. These ideas—ones as exotic as extra dimensions or as relatively straightforward as the so-called Higgs mechanism for generating msas—could soon be tested. Given that we are at the cusp of this new understanding of the nature of the universe, how can we choose not to explore?