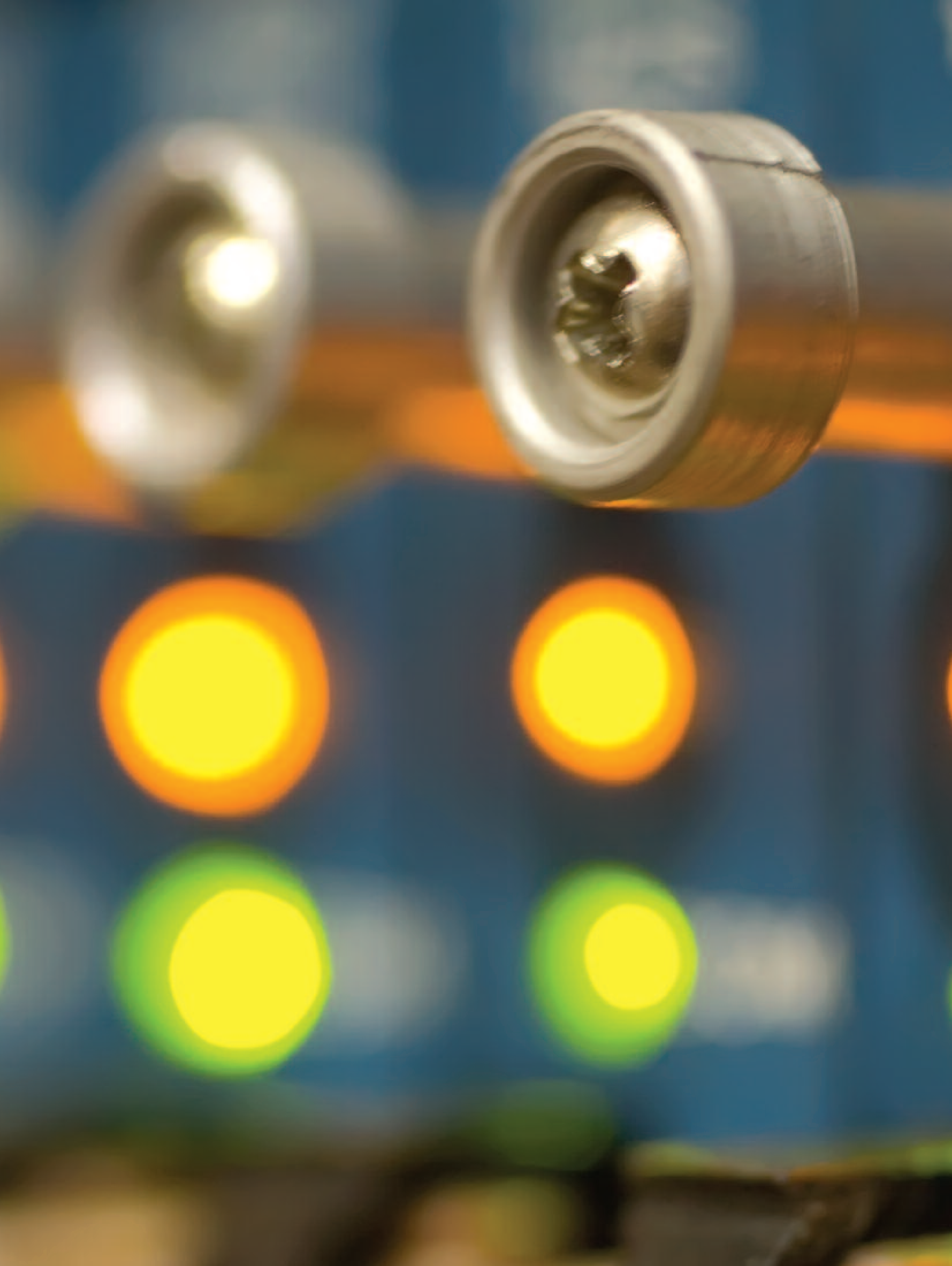


Frank DiMeo

CESR and CLEO

COLLISIONS MATTER

The Ultimate Building Blocks of Matter

For more than 25 years CESR and the CLEO experiment have maintained the Laboratory for Elementary-Particle Physics (LEPP) at the forefront of the field of elementary-particle physics, the study of the ultimate building blocks of matter. With CESR, electrons and their antiparticles, positrons, collide at high energies in the CLEO detector to produce other elementary particles. Some of these elementary particles are fundamental particles called leptons (the electron is a lepton), while others—called mesons and baryons—are composed of yet more fundamental particles called quarks and antiquarks. Quarks and leptons are collectively the smallest particles known to physicists today and are the constituents of all observed matter.

Creation through Annihilation

When electrons and positrons collide, they can annihilate each other, producing an unstable state with energy equal to the total energy of the two particles before the collision. This state disappears extremely quickly and produces new particles—mostly, but not always, mesons. Many of these particles live long enough to travel uninterrupted through the CLEO detector, leaving a trail of signals that can be utilized to observe them and measure properties such as their directions and energies. Particles that decay in the detector produce longer-lived particles that can also be observed in the same manner. The signals are produced in about 125,000 individual detector elements; most of them are contained in a cylindrical volume that is about 10 feet in diameter and 11 feet long. Within this volume is a very strong magnetic field, about 2,400 times the earth's magnetic field. Approximately 1,000 tons of iron—the CLEO detector is a 20-foot cube—shape and contain the field.

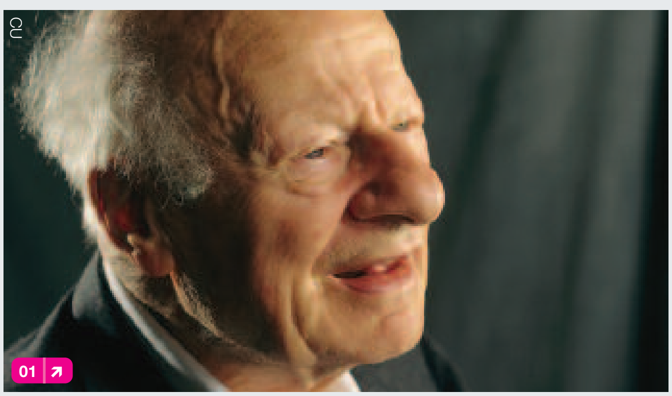
The six types of quarks that exist have been given fanciful names: up (u), down (d), strange (s), charm (c), bottom (b), and top (t). All except the t quark, which is too heavy, have been produced routinely by CESR. For their first 20 years, CESR and CLEO dominated the study of the b quark, which is heavier than all others except the t quark. Understanding the properties of this quark is especially important because it is believed to hold the key to one of the deepest mysteries of the universe: we do not observe equal amounts of matter and antimatter. What is always observed is this: when matter is

QUARKS AND LEPTONS ARE COLLECTIVELY THE SMALLEST PARTICLES KNOWN TO PHYSICISTS TODAY AND ARE THE CONSTITUENTS OF ALL OBSERVED MATTER.

produced from energy, an equal amount of antimatter is also produced. This implies that equal amounts of matter and antimatter must have been produced in the Big Bang. A phenomenon called CP violation is one of the theoretical ingredients required to explain the disappearance of the antimatter that must have been produced in the Big Bang, and decays of b quarks and b antiquarks are the ideal environment in which to seek the source of CP violation.

Three Nobel Prizes in Physics have been awarded for theoretical work done in the laboratory: to Hans Bethe (1967) for understanding the carbon cycle for production of energy in stars, to Richard P. Feynman (1965) for his contributions to the development of quantum electrodynamics, and to Kenneth G. Wilson (1982) for findings that simultaneously provided significant new insight to the theories of elementary particles and to phase transitions in condensed matter.

CU



American Institute of Physics

CU

01. Hans Bethe
02. Richard P. Feynman
03. Kenneth G. Wilson

Frank DiMeo

CLEO researcher Hubert Schwarthoff at the CLEO Counting Room

From B Quarks to C Quarks

About five years ago it became clear that CESR's capacity to study the b quark had been fully utilized. Researchers' complete grasp of many experimental results was also limited by their understanding of the properties and decays of the c quark. B quarks are usually observed as they decay to c quarks, and the precision of b-quark measurements exceeded the precision of c-quark measurements required to interpret fully the b-quark data. This impasse led to a decision to reconfigure CLEO for the study of c quarks, reducing the energy of CESR from that used to study b quarks to a lower energy more favorable for c-quark production. The reorientation of the laboratory program is now complete, and CESR and CLEO are producing a host of significant new results in c-quark physics.

The Cornell Style

CESR is the most recent of five electron accelerators built at Cornell since 1950. All were designed almost entirely by Cornell faculty and students, who participated actively in the construction and were ably supported by the laboratory's technical and administrative staffs. Other facilities have been designed primarily by much larger engineering staffs. Cornell faculty willingly meet the challenges of designing and constructing accelerators with active student participation, a distinctive approach that is often called the "Cornell Style." In the elementary-particle physics community, the Cornell Style is also understood to include a commitment to innovative and highly cost-effective design, construction, and operation of accelerator facilities.

Significant involvement of undergraduates in research is one of the unique advantages provided by the integration of LEPP and CESR into Cornell University. Every year approximately 50 Cornell undergraduates participate in the LEPP research program. Many are involved in sophisticated research activities, such as making measurements to understand the performance

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David Cassel

THE UNDERSTANDING OF ACCELERATOR PHYSICS AND INNOVATIONS THAT LED TO EVER-INCREASING LUMINOSITIES (COLLISION AND PRODUCTION RATES) AT CESR HAS ALSO PLAYED A SIGNIFICANT ROLE IN THE SUCCESS OF OTHER FACILITIES.

Frank DiMeo

In the elementary-particle physics community, the Cornell Style is also understood to include a commitment to innovative and highly cost-effective design, construction, and operation of accelerator facilities.

and limitations of devices developed in the laboratory, or help to develop computer programs for CESR, CLEO, and other experiments. This research experience is an excellent first step toward graduate school or a career in industry.

Although CESR owes its existence to Cornell faculty, students, and staff, the collaboration that designed, built, and utilizes CLEO detectors has always included other universities and colleges. From 8 to 25 institutions and from 60 to 250 faculty members, postdoctoral research associates, and graduate students have participated in the collaboration at any given time. Currently about 35 Cornell faculty members, postdoctoral research associates, and graduate students work with CLEO. The CLEO detector is the sixth in a series of distinct detectors with increasing capabilities and precision.

Frank DiMeo

(l.) David Cassel (r.) Ernie Fontes

Innovations Shared and Expanded

The LEPP accelerator physics program provides unique and innovative contributions to the scientific community. Studying the physics of b and c quarks requires precision measurements of rare processes that are always limited by the number of particles produced by the collider. The understanding of accelerator physics and innovations that led to ever-increasing luminosities (collision and production rates) at CESR has also played a significant role in the success of other facilities. LEPP has been a pioneer in the development of RF cavities, devices that increase the energies of the beams in accelerators, made of superconducting materials. These devices have little electrical resistance when operated at temperatures within a few degrees of absolute zero. In addition to offering significant savings in operating costs, superconducting RF cavities provide other technical advantages that enable accelerator innovations, including the Energy Recovery Linac, which is being designed in the laboratory. The design of the International Linear Collider (ILC), a high energy electron-positron collider envisioned as an essential future tool for the elementary-particle physics community, is based on superconducting RF technology that LEPP played a major role in developing.

Cornell scientists expect to complete the CLEO experimental program in 2008. The LEPP physicists involved in CLEO are beginning to turn some of their attention to the Compact Muon Solenoid (CMS) experiment at the Large Hadron Collider (LHC) in Geneva, Switzerland, and to the design of the ILC and detectors for that facility.

Frank DiMeo

CLEO graduate students

The Theoretical Physicists Abound

LEPP has always boasted a strong group—founded and nurtured by Hans Bethe—working on theoretical problems in elementary-particle physics. Three Nobel Prizes in Physics have been awarded for theoretical work done in the laboratory: to Hans Bethe (1967) for understanding the carbon cycle for production of energy in stars, to Richard P. Feynman (1965) for his contributions to the development of quantum electrodynamics, and to Kenneth G. Wilson (1982) for findings that simultaneously provided significant new insight to the theories of elementary particles and to phase transitions in condensed matter. Current principal theoretical efforts include the theory of mesons containing b or c quarks, string theory, and the theoretical basis for understanding the experimental results expected from experiments at the LHC and ILC.

LEPP HAS BEEN A PIONEER IN THE DEVELOPMENT OF RF CAVITIES, DEVICES THAT INCREASE THE ENERGIES OF THE BEAMS IN ACCELERATORS, MADE OF SUPERCONDUCTING MATERIALS.

David G. Cassel
Physics

Frank DiMeo

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