RECENT HIGHLIGHTS

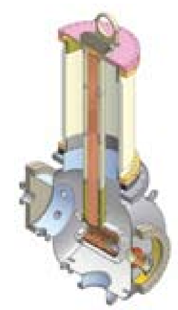
CHESS X-ray: The Invisible Art

CHESS scientists are engaged in collaborative research projects with the North Carolina Museum of Art, the Getty Museum in California, the Museum of Modern Art in New York, and the Winterthur Museum in Delaware. A special 3-D scanner, developed at CHESS, mounts paintings up to 1.4 meters and then probes them with a tiny x-ray beam. The beam measures the chemical makeup of paint layers buried beneath the surface without damaging the valuable surface work. Visit www.chess.cornell.edu

Jennifer Maas (Winterthur Museum and University of Delaware) shows the 17th century Flemish painting, "**The Armorer's Shop**," under study.

ERL: The Prototype Succeeds

On July 8, 2008, the first beam of electrons was accelerated through the prototype injector of the Energy Recovery Linac (ERL) at Cornell University. The ERL is a proposed new accelerator dedicated to x-ray science. The ERL will produce x-rays from extremely intense and very short pulses of electrons. The photocathode gun creates the electrons which are then accelerated in 5 superconducting RF cavities. When in full operation, the cavities will be unique in that they will sustain the accelerating field continuously and will be capable of handling exceptionally high beam current and power. Visit erl.chess.cornell.edu



This photocathode gun, which is part of the ERL injector, is where the electrons are created.

SRF: World Record Superconducting Cavity

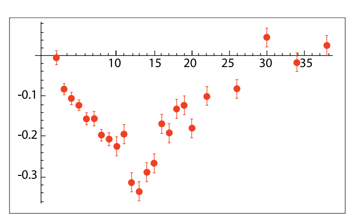
New cavity shape developed by LEPP to reach 50 million volts per meter.

In 2005, CLASSE researchers, as part of a world effort, designed and built an accelerating cavity that established a new record for the electric field gradient. The electric field gradient of superconducting niobium cavities, which is responsible for beam acceleration, has more than quintupled over the last two decades, making projects such as the ILC plausible. As a next step, CLASSE sent a cavity similar to the record-breaking one to the KEK laboratory in Japan, where they repeated and soon bettered the record to 50 million electron volts per meter. Future SRF developments at Cornell will push accelerating gradients even higher.

Visit www.lepp.cornell.edu/public/CESR/SRF/

CESR: Testing Accelerator Science

In November 2008, CESR scientists began studies of tight beams of electrons and anti-electrons (positrons), with the aim of improving the design of future ultra-high energy electron colliders such as the ILC. The first tests probed the cloud of electrons that tends to accumulate around intense positron beams and ultimately destabilize them - and revealed a startling phenomenon, the accumulation of clouds around electron beams as well. These effects could have important implications for collider design.

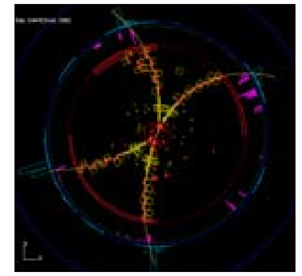


The graph shows the growth of the electron cloud as a beam passes by (first 12 dots), and its subsequent decay. The lower the dot, the bigger the cloud.

Visit www.lepp.cornell.edu/Research/AP/CESR/SRF/

CLEO: A Standard Candle for the Strong Force

In a meson, two quarks are bound through the strong force into an atom-like bundle. In rare cases, the two quarks can overlap in space and annihilate. By measuring this rate, CLEO physicists have measured the strength of the strong force.



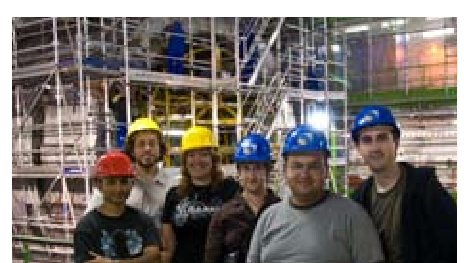
In this event, two mesons were produced, one of which annihilated, producing a single electron (downward trajectory).

Visit www.lepp.cornell.edu/Research/EPP/CLEO/

LHC: First Beam in the Large Hadron Collider

On September 10, 2008, the Large Hadron Collider (LHC) at the CERN Laboratory in Geneva, Switzerland, circulated beams of protons in preparation for collisions in 2009. These collisions will have energy far beyond any previous accelerator, and may reveal new forms of matter or forces never seen before, but that influenced the universe as it evolved from the Big Bang to the current day. Cornell experimentalists work on CMS, one of two general-purpose experiments at the LHC. Cornell theorists hope to predict the phenomena revealed by LHC collisions.

Visit www.lepp.cornell.edu/Research/EPP/CMS/



Cornell graduate students and Research Associates prepare the CMS particle detector for LHC data. CMS, the size of a 6-story building and weighing 14,000 tons, is visible under the scaffolding in the background.

WWW.LEPP.CORNELL.EDU I WWW.CHESS.CORNELL.EDU

SCIENCE @ CLASSE

CORNELL LABORATORY FOR ACCELERATOR-BASED SCIENCES AND EDUCATION

CLASSE's primary source of support is the National Science Foundation (NSF).

| ACCELERATOR TECHNOLOGY | X-RAY SCIENCE | ELEMENTARY PARTICLE PHYSICS |

THE BREADTH OF SCIENCE

The Cornell Laboratory for Accelerator-based Sciences and Education (CLASSE), explores the structure of matter and its origins in the evolution of the universe. Through our research, we strive to understand objects as diverse as subatomic particles, innovative materials, and biological structures. CLASSE educates the next generation of world-leading scientists and engineers. All of this work relies on a common tool: the particle accelerator. Particle accelerators produce beams of particles - usually electrons or protons - and then ramp up their energy to near the speed of light. The beams can be collided to study nature at very high energies and small length scales; or, electron beams, in particular, can be used to produce x-rays useful for studying biological structures, specialized materials, and matter under a host of different conditions.

CLASSE THEMES:

Accelerator Technology

For over 30 years CLASSE has been a source of innovations in accelerator design that have led to performance advances and powered accelerators around the world.

Cornell is developing a revolutionary accelerator that will make it possible for scientists to witness chemical and biological processes as they occur in real time!

X-ray Sciences

Built as the first high-energy x-ray source in the U.S., CLASSE now supports almost a thousand scientists each year who study materials at the scale of atoms and molecules.

Elementary Particle Physics

CLASSE physicists explore matter at its tiniest scale in order to learn about how particles and their interactions shaped the universe today.

RESEARCH ACHIEVEMENTS

Cornell's superconducting accelerator cavities are such perfect resonators that if a bell had a similar quality, it would ring continuously for more than three years!

Difficult membrane proteins can be crystallized and studied using x-rays. X-ray diffraction techniques were utilized by Nobel Prize winner Rod Mackinnon at CHESS to determine the structure and function of ion channel proteins.

The Large Hadron Collidor (LHC) will duplicate conditions less than a second after the Big Bang!

THE RANGE OF SCALE FROM SMALLEST TO LARGEST...

A remarkable aspect of these investigations is that they span scales from the subatomic, to atoms and molecules, to the expanse of the universe. Elementary particle physicists examine the smallest building blocks of matter - the fundamental particles - with the ultimate goal of explaining the origin and history of the universe. X-ray research is conducted at the molecular level with the immediate aim of understanding the structure of the material world. This knowledge, in turn, contributes to progress in fields such as medicine, chemistry, biology and material science. At left is a protein nanotube that is less than 100 microns in diameter ($1x10^{-6}$m). At right is the Andromeda galaxy, an estimated $1x10^{21}$m in diameter, comprised mostly of dark matter which is being studied at the LHC.

MAJOR FACILITIES

Wilson Lab is home to several important CLASSE facilities that enable scientists to carry out their research.

CESR: Cornell Electron Storage Ring CESR is a particle accelerator that allows scientists and students to study the dynamics of electron beams. These beams are the heart of x-ray science and particle physics programs. Current accelerator research is focused on the International Linear Collider (ILC), a proposed electron accelerator that will succeed the Large Hadron Collider (LHC). CESR is uniquely suited to this work, as its features are similar to those of an important and especially challenging component of the ILC. By helping make the ILC a reality, CESR-TA is fostering scientific discovery and world-wide collaboration.

CHESS: Cornell High Energy Synchrotron Source CESR is an intense source of high-energy x-ray beams, with intensities a thousand to a million times greater than those from medical x-ray equipment. Scientists visit the CHESS National User Facility to investigate the detailed atomic structure of solids and liquids in both biological and non-biological systems. Experimental stations support research in chemistry, physics, biology and environmental sciences, and materials research. A National Institutes of Health (NIH) supported group, MacCHESS, supports special facilities for studying super-large protein macromolecules. Scientists use instruments such as the automounter to hunt for answers and cures for the common cold, HIV-AIDS, and cancer. Over 600 students have obtained their doctoral degree through research at CHESS.

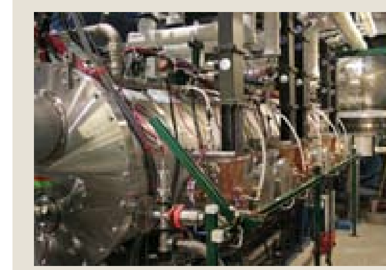
ERL: Energy Recovery Linac Cornell physicists are developing a revolutionary accelerator for .x-ray science. The electrons will make a single trip around the accelerator ring, return to the superconducting cavities that accelerated them, and return their energy back to these cavities - hence an "energy recovery linac" (ERL). Because of the single trip, the electron beams remain much more tightly bunched and produce beams that are a factor of 1000 times brighter and more coherent than current sources while conserving energy. The ERL will be a crucial resource to the world, propelling scientific and biomedical advancement as well as economic development.

CLEO: Particle Physics Experiment For 40 years, CESR collided beams of electrons and anti-electrons in order to study the physics of quarks, two species of which make up the proton and neutron. The spray of particles produced in each collision was detected by CLEO, a particle detector built and operated by a multi-institutional collaboration. Today, CESR and CLEO data are revealing the important properties of quarks and leptons and the forces that bind protons and neutrons, and make the sun shine, In parallel, LEPP theorists are developing methods for calculating these and other phenomena. Over its history, more than 200 students have obtained their doctoral degree through research on CLEO.

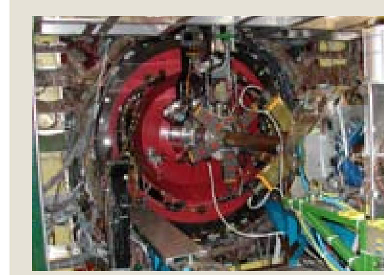
SRF: Superconducting Radio Frequency (RF) Technology CLASSE physicists are developing technology for accelerating particle beams using devices known as Superconducting RF (SRF) cavities. These are large devices able to support standing electro-magnetic waves, similar to sound waves in a pipe organ. The electric field in the cavity accelerates the passing beam. The use of superconducting cavities increases efficiency and reduces disruption of the beam. SRF cavities provide the basis for the ILC and the ERL, and other accelerators.

The existing particle accelerator (left side of picture) and synchrotron (right side of picture) are being modified for CESR-TA studies.

The Huber 6-circle diffractometer used for conducting crystallographic and diffraction studies at CHESS.



The five meter long cylindrical cryomodule keeps the ERL accelerating components at 1.8 degree K.



CLEO is a high-energy physics instrument that detects, measures and analyzes electron-positron colision events.