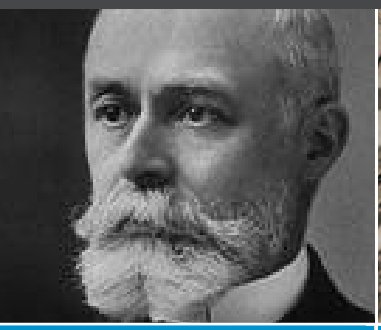
Cornell's Accelerator-Based Sciences



A Timeline

…TO WATCH THE MASSIVE PROTEIN COMPLEXES THAT FUNCTION AS CELLULAR MACHINES PRODUCE THE SIGNALS THAT FORM THE VERY ESSENCE OF LIFE … WITH THE APPLICATION OF NEW METHODS—FOR EXAMPLE, THROUGH THE DEVELOPMENT OF THE ERL—WILL SOON BECOME REALITY.



1800s

1895

Wilhelm Roentgen discovers x-rays.

1896

Henri Becquerel discovers natural radioactivity.

Wilhelm Roentgen

Early 1900s

Early 1900s–mid-1940s

Scientists discover the structure of the atom and nuclear energy and develop quantum mechanics.

1940s (World War II)

Cornell physicists serve on the Manhattan Project.

After World War II

Hans Bethe persuades Cornell to found the Laboratory of Nuclear Studies, now LEPP, and to build Newman Laboratory to house the lab's activity.

1947

General Electric laboratory in Schenectady, New York, chances upon visible light emanating from a room-sized betatron.

1949

Julian Schwinger publishes a theoretical explanation for the light, now known as synchrotron radiation.

1950s

1952

The world's first synchrotron radiation (SR) beamline, on the 300 MeV accelerator in the basement of Newman Lab, is created. Cornell physics faculty Paul Hartman, Diran Tomboulian, and Dale Corson publish their first investigations of SR, ushering in a new era of radiation science, one of Cornell's most important research tools.

(r.) Hans Bethe, (c.) Kenneth Wilson, and (l.) Boyce McDaniel

1960s

1965

Maury Tigner proposes that energy recovery is possible in superconducting radio frequency (RF) cavities—the basis for current ERL light source proposals.

1967

A new 10 GeV synchrotron accelerator is constructed—a half-mile–circumference tunnel under Alumni Fields.

Wilson Lab's new building—Robert R. Wilson Synchrotron Laboratory—is constructed to house experiments.

IN JULY 2006,
TO BECOME C
ACCELERATO

Above, from left to right: Henri Becquerel, Hans Bethe and Boyce McDaniel (1968) on bicycles, first synchrotron built in 1955 in Newman Lab, Robert R. Wilson, Wilson Lab, Karl Berkelman, protein crystallography, Maury Tigner and Sol Gruner. Credits: CU; Wilson Lab; Frank DiMeo

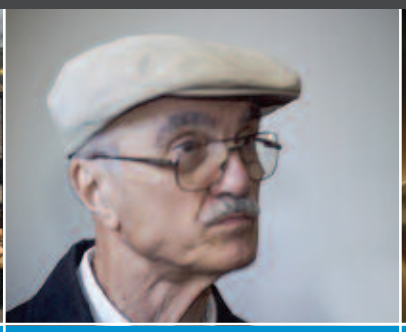
1970s

1977

CHESS is funded by NSF to build the first high energy x-ray beamlines in the U.S. for materials research.

1979

The Cornell Electron Storage Ring (CESR) is added to the synchrotron tunnel to store countercirculating electrons and positrons for collisions inside the CLEO particle detector.



1980s

1982

The first storage ring superconducting cavity test is constructed.

1983

NIH funds the MacCHESS resource for protein x-ray research.

1985

The first x-ray structure of a mammalian virus is solved.

1985–2000

The “golden years” of B-meson physics reign at Cornell under LEPP director Karl Berkelman.

1990s

1990s

One out of seven papers published in *Physical Review D* is based on data from Wilson Lab.

One out of five of the most important protein and virus structures is based on data acquired at CHESS.

1999

The first fully powered superconducting RF x-ray storage ring is completed.

2000s

2000

Construction of a new x-ray beamline, the G-line, begins with Cornell and NSF funding.

2001

The first microsecond x-ray pixel array detectors are used at CHESS.

2003

The Nobel Prize in Chemistry is awarded to CHESS user Rod MacKinnon (Rockefeller University) for work done in part at CHESS.

2004

CLEO begins c quark studies.

2005

NSF funds an ERL prototype with an $18M grant, and development of key technologies begins.

2006

New York State grants $12M to help support the engineering design of the ERL during the prototype period.

2007–8

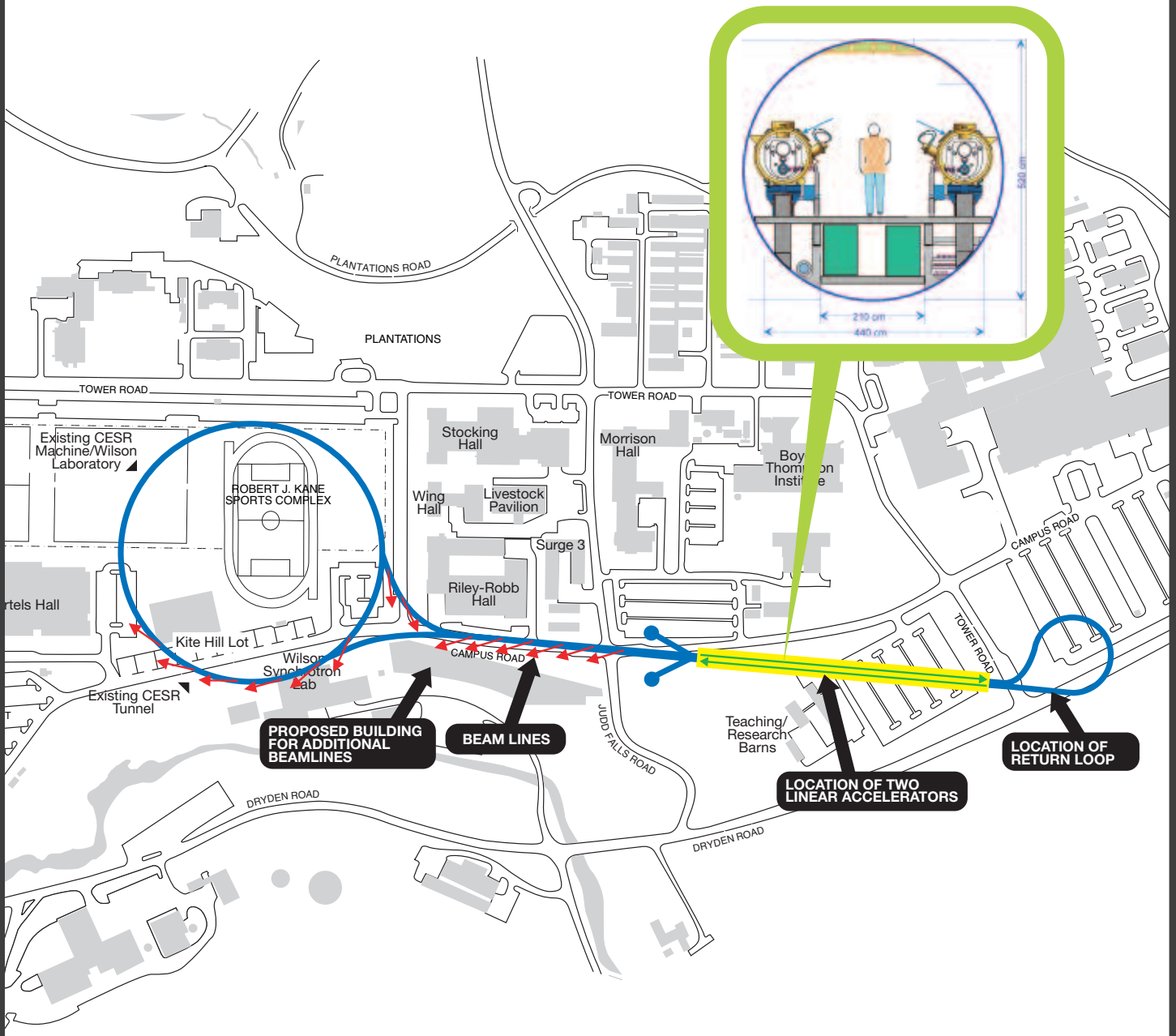
A full ERL x-ray source is proposed as an upgrade to CESR.

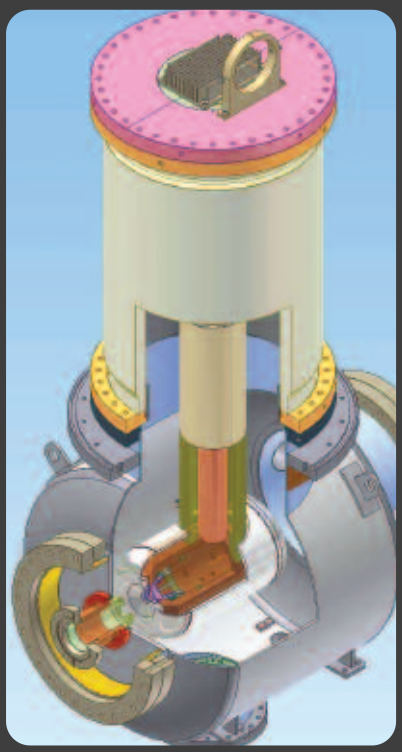
2008

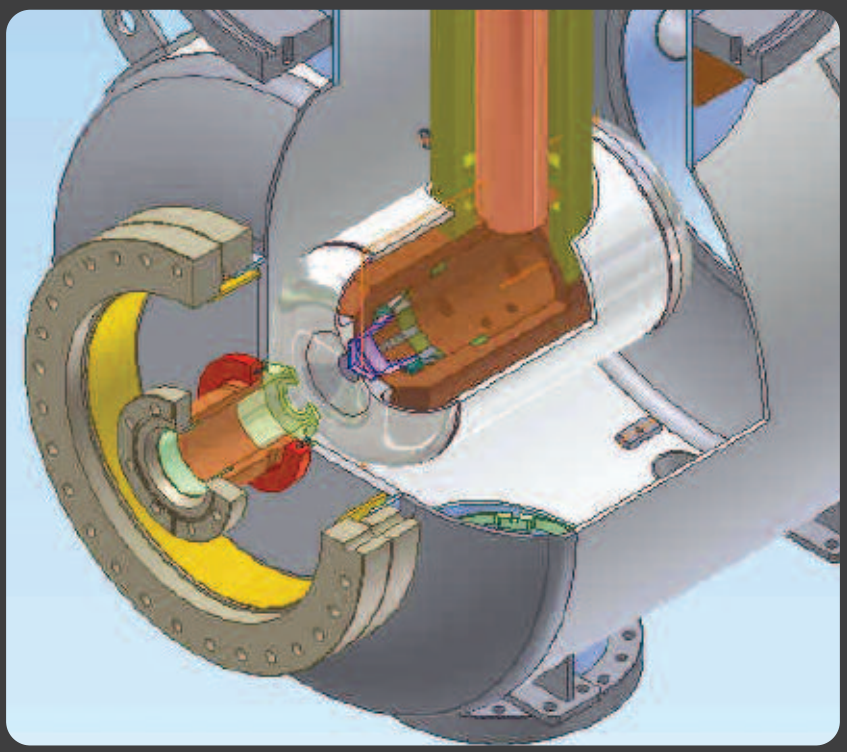
The focus of high energy physics experiments shifts from Wilson Lab to the Large Hadron Collider (LHC) in Switzerland.

LEPP AND CHESS JOINED TOGETHER
CLASSE—CORNELL LABORATORY OF
R-BASED SCIENCES AND EDUCATION.

The Proposed ERL

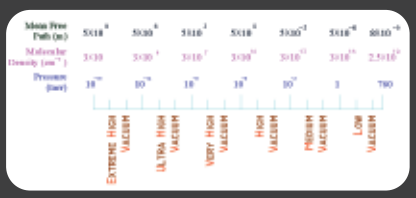






A Brand-New Parade: Vacuum Technology

Unlike existing x-ray synchrotron sources, an ERL is like a parade of brand-new electron bunches. Each bunch of electrons makes only a single pass through the machine—making x-rays. Then, it gives back its energy and a new bunch of high energy electrons is born.



Vacuum Scales: A vacuum is the state of a gas where the density of the particles is lower than atmospheric pressure at the earth's surface. The mean free path is the mean distance a gaseous atom or molecule travels before it collides with another particle.

Creating this parade, however, is a challenge for the ERL scientists. The Cornell plan calls for an amazing 1.3 billion electron bunches created every second! Each bunch needs to be as large as possible because the number of x-rays produced is directly proportional to the number of electrons in each bunch.

The true workhorse in the ERL is a special device called a photocathode injector. The cathode is a piece of single crystal semiconductor, made of gallium and arsenic, that is blasted by an intense laser beam 1.3 billion times each second. The laser beam accelerates electrons away from the surface and forms them into bunches, which join the electron parade.

One of the key technologies needed to make all of this work is vacuum. Not just good vacuum, nor high vacuum, nor ultra-high vacuum. This photocathode needs 1,000 times cleaner than ultrahigh, a regime referred to as "extreme high vacuum," explains LEPP scientist and vacuum group lead Yulin Li. Any particles of gas that get near the cathode or in the powerful laser beam will contaminate and "poison" the painstakingly cleaned electron-emitting source.

High vacuum environments are of paramount importance. For instance, at an ultrahigh vacuum pressure of 10-10 torr, where there are one trillion times fewer atoms per volume than in the atmosphere we breath, the cathode surface would be hit by 1,000 atoms per second in square millimeter. Another surprise is that at these extreme vacuum levels, there is the problem of atoms "outgassing" from all natural materials. Small atoms can diffuse right through the stainless steel walls of the vacuum chambers and contaminate the surrounding gas.

How is great vacuum achieved? It takes careful selection of materials, diligent attention to possible contaminants, discipline in working with equipment, and the utmost care when preparing the components for installation. Staff, when assembling the ERL photocathode, wear gloves, face masks, and cloth booties over shoes to minimize dust and debris. Before installation, parts are baked at a very high temperature of 450 C for several days to boil off water absorbed deep inside metal and ceramic parts. In addition, the inner surfaces of the chamber walls are coated with special "getter" materials that actually absorb contaminants rather than outgas. Multiple vacuum pumps work to achieve the ultimate environment for generating electrons.