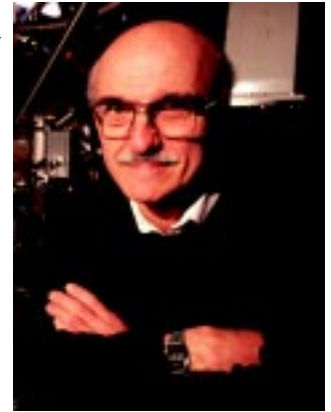


# LNS Director's Report

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Photo by - Robert Barker,  
Cornell University Photography



Karl Berkelman



Prototype section of a proposed dual-bore superconducting storage ring.

## The CESR - CLEO Program and Prospects

A few years back I contributed an article for the 1995 CHES Newsletter on "The CESR High Energy Physics Program". It's time now for an update and a fresh look at future prospects.

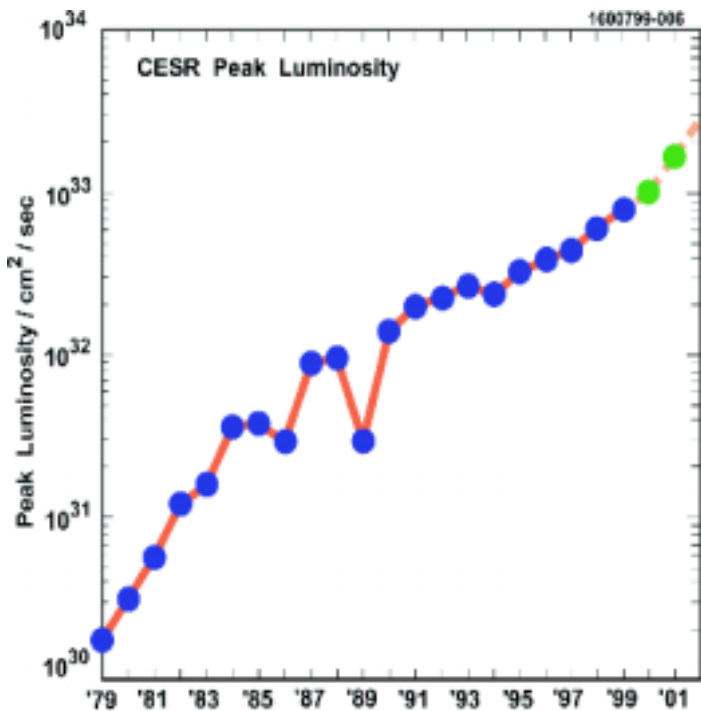
The Cornell Electron Storage Ring was built in the late 70's as an add-on to the existing Cornell 10 GeV synchrotron, sharing the same tunnel and extending the useful life of the synchrotron by putting it to good use as the injector for CESR. The original physics goal was to study electron-positron collisions in the energy range up to 8 GeV on 8 GeV. This maximum energy was determined by the circumference of the existing tunnel. By a wonderful accident of nature we learned after CESR construction started that the CESR energy would be just above the threshold for production of states containing the newly discovered  $b$  quark. This would make CESR the ideal facility for the study of the properties and interactions of the  $b$  quark and its bound states, the upsilons ( $b\bar{b}$ ) and the B mesons ( $b\bar{u}$  and  $b\bar{d}$ ).

The primary apparatus for this study is the CLEO detector, a general purpose detector surrounding the  $e^+e^-$  collision point, built and operated originally by a collaboration of six universities, and now upgraded and run by 25 collaborating universities. The detector is similar in concept to most state-of-the-art high energy collider detectors. Charged particle tracking takes place in a multiwire cylindrical drift chamber inside a 1 m radius superconducting solenoidal magnet with its axis parallel to the beam line. Tracking is supplemented by a silicon microstrip detector array packed around the 2 cm radius beryllium beam pipe.

Particle velocities are inferred from the ionization loss  $dE/dx$  in the drift chamber gas, measured from the anode wire pulse heights. Charged particles can then be identified ( $e, \pi, K, p$ ) from the calculated mass  $m = p/\gamma\beta$ . In the cylindrical shell between the drift chamber and the solenoid we have an array of 8000 CsI scintillation counters that record

electromagnetic showers from high energy photons, electrons, and positrons. Outside the solenoid coil is the iron flux return, interleaved with planar wire chamber detectors to register the passage of penetrating muons. In over 93% of the solid angle surrounding the beam-beam interaction point we identify and measure the energy of practically every particle emerging from an electron-positron annihilation event, except for the neutrinos.

In the two decades since the beginning of CESR operations, the CLEO experiment has been phenomenally successful. CLEO discovered and measured the masses of the  $B$  and  $B^*$  mesons, and co-discovered a host of  $b\bar{b}$  bound states. The weak decay transitions of the  $b$  quark,  $b \rightarrow c$ ;  $b \rightarrow u$ , and  $b \rightarrow s$ , and all of the known decay modes of the  $B$  meson down to the level of  $B \rightarrow \pi\pi$  branching fraction were first seen by CLEO. Most of what we know about the  $b$  quark has come from the CLEO experiment. CLEO also dominates the physics of the  $c$  quark and the  $\tau$  lepton. Prof. Ed Thorndike, one of our CLEO collaborators from the University of Rochester, was awarded the Panofsky Prize by the American Physical Society for his part in this work. Although much of this success has come through the hard work and ingenuity of the 200-odd members of the collaboration, I believe that most of the credit should go to the CESR accelerator staff. It has been the steadily improving performance of the collider that has paced the research potential of the CLEO experiment. The most important CESR parameter is the luminosity. This is defined as the number that you have to multiply any electron-positron interaction cross section by in order to calculate the corresponding reaction rate. Of course you also need high reaction rates to discover rare or forbidden processes or to look for small deviations from Standard Model predictions. Luminosity depends on the product of the beam currents divided by their overlap area at the collision point. CESR was originally designed to have a maximum luminosity (Fig. 1) of  $10^{31}$  at our usual 5.3 GeV per beam operating energy.



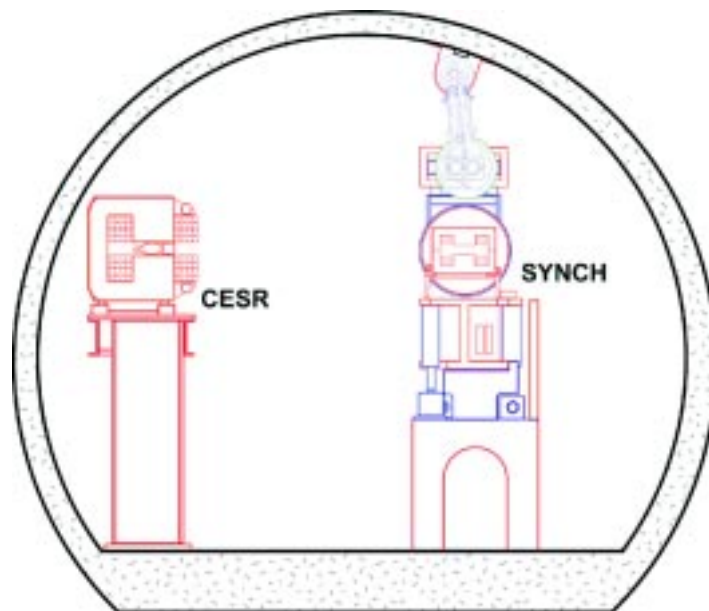
**Figure 1:** Peak Luminosity - Purple circles represent actual, green is projected.

Thanks to a number of tricks pioneered at CESR to raise the beam currents and focus them to a smaller overlap area, the luminosity has recently exceeded  $8 \times 10^{32} / \text{cm}^2 \cdot \text{s}$ . For a short while this was the world's record for colliding beams. The successes of CESR and CLEO have inspired competition. The Stanford Linear Accelerator Center and the KEK laboratory in Japan have now both modified their existing  $e^+e^-$  storage rings to produce  $B$  mesons efficiently. These “ $B$  Factory” designs incorporate the CESR luminosity tricks and their detectors are patterned after the CLEO detector. The novelty in the SLAC and KEK machines is asymmetric beam energies. This gives the new collider detectors an advantage in the measurement of certain  $CP$  violating  $B$  decays. Both facilities are now running at high luminosity and producing data.

With the prospect of this new competition, we decided several years ago that we would have to upgrade CESR to further increase the luminosity, and also upgrade the CLEO detector to make it more selective in identifying the rarer processes that the increased data rates would give us access to. Thanks to the generosity of the NSF Physics Division, this is now being accomplished. To increase the stability limit on the circulating beam currents we have replaced the copper rf cavities with superconducting niobium cavities, and to improve the focusing we will be installing superconducting quadrupole magnets in the interaction region. The CLEO detector has received a ring-imaging Cherenkov detector to improve the identification of  $\pi$ 's and  $K$ 's, a better radiation-hard silicon detector, and a new drift chamber to accommodate

the space required for the Cherenkov and the superconducting quadrupoles. Only the new quadrupoles remain to be installed. With these upgrades and the vast experience accumulated by CESR and CLEO personnel, these facilities will achieve new levels of performance. This will ensure that CESR and CLEO will continue to make significant contributions to accelerator and elementary particle physics.

Taking advantage of the upgrade installation shutdown of CESR, CHESS has built an experimental area to exploit G-line, a new wiggler beam line that will be instrumented in the coming year when the new quadrupoles are installed. Also in the coming year the anticipated doubling of the CESR circulating beam currents will translate directly into a doubling of the CHESS X-ray fluxes. So we expect the fruits of the next several years to be extremely beneficial for decades to come.



**Cross section of the existing CESR tunnel showing a sketch of a proposed dual-bore super conducting magnet installed on top of the synchrotron magnet system. If this were to be built, the current CESR ring could be operated as a dedicated synchrotron radiation source for CHESS.**

**Editors Note:** After three successful 5 year terms, Karl Berkelman retired from the LNS Directorship in June, 2000. The LNS is now in the capable hands of Prof. Maury Tigner, the recipient of the 2000 Robert R. Wilson Prize in accelerator physics from the *American Physical Society*.