The BaBar Experiment

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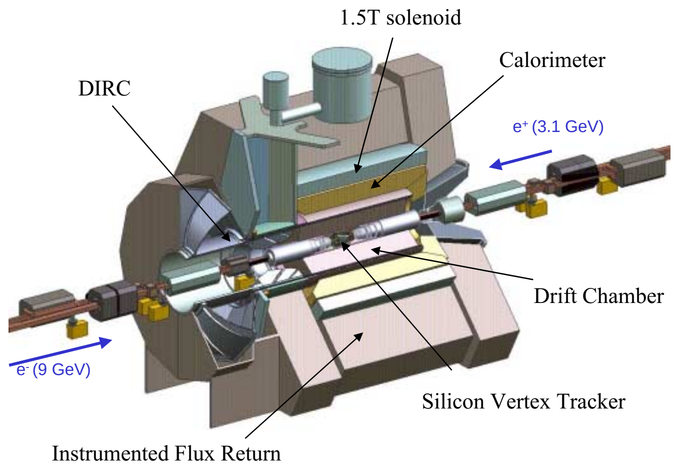
When most people think of antimatter - if they think of it at all - it is in terms of Star Trek and warp drive. In fact, antimatter is not purely science fiction - scientists regularly make it in the laboratory. But this attitude reflects the observation that as far as we can tell, the entire universe appears to be made of matter.

This asymmetry between matter and antimatter is mysterious. The Big Bang should have produced equal amounts of matter and antimatter, which would subsequently mutually annihilate, producing a universe filled with photons and nothing else. This is close to what actually happened: almost all matter did annihilate with antimatter, producing the flood of photons that form the 2.7K cosmic microwave background. But a tiny excess of matter over antimatter - one part in ten billion - ensured that some matter survived to form stars, planets and us.

This asymmetry indicates that the laws of physics must also be asymmetry; that the "Charge-Conjugation Parity" (CP) symmetry, which relates matter and antimatter, must be violated. In the laboratory, a small CP violation effect was first observed in 1964 in the decay of neutral K mesons. The theoretical interpretation, however, remained unclear.

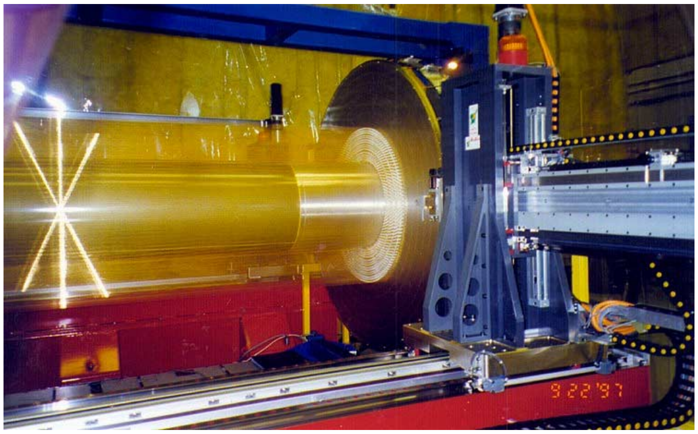
To clarify this situation, TRIUMF has joined with more than 400 collaborators in Canada, the United States and in Europe to form the BaBar experiment. Its goal is to precisely understand CP violation in a second particle, the B meson. The detector



The three-story-tall, 1000 tonne BaBar detector will collect information about B mesons and their decay products

built by the collaboration, together with the PEP-II e+e- particle collider, make up the "B-Factory" located at the Stanford Linear Accelerator Center. Seven Canadian faculty members, located at UBC, Victoria, Montreal and McGill, collaborate on BaBar.

PEP-II is a new facility built specifically for this measurement. It collides bunches of electrons and their antimatter equivalent, positrons, approximately 100 million times per second. A tiny fraction of the time - about 30 times per second - an



Robots assisted with the construction of the BaBar drift chamber at TRIUMF

electron and a positron annihilate to create a pair of leptons or quarks. A B meson is produced together with its antimatter equivalent , an anti-B, an average of three times per second.

The energies of the colliding electron and positron determine the speed of the B meson, approximately one-half the speed of light. The distance a meson travels before decaying (0.25 mm on average), is therefore directly related to its lifetime. CP violation will reveal itself as subtle differences between the lifetimes of the B and anti-B meson when decaying to certain selected final states. The B meson can decay many different ways (to many different final states), but less than 0.01% of all decays are useful for the study of CP violation. This low fraction required that PEP-II be designed to produce huge numbers of B mesons.

The BaBar detector surrounds the PEP-II collision point. Because of their short lifetime, the B mesons themselves do not enter the detector, so BaBar reconstructs their properties by examining the decay products. To do this, BaBar is assembled from five subsystems, each optimized to measure a different property of the decay particles.

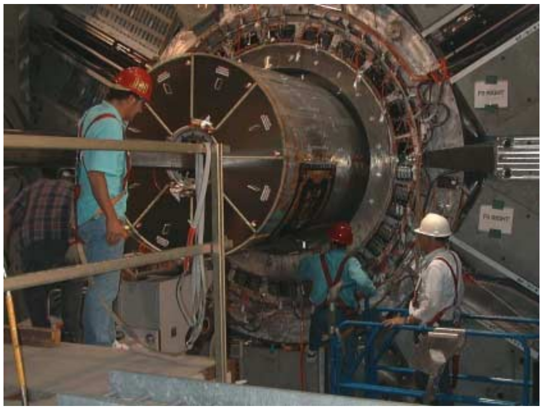
The silicon vertex tracker (SVT), in conjunction with the drift chamber (DCH), measures the direction and location of electrically charged particles. The information from all the charged particles in an event is combined to derive the decay points of the two B mesons and hence their lifetimes.

The DCH measures the momentum of charged particles. To achieve this, the DCH (as well as the SVT, DIRC and calorimeter) is immersed in a 1.5 T magnetic field that induces charged particles to follow a curved trajectory. The DCH measures this curvature, which depends on the momentum of the particle.

TRIUMF scientist Robert Henderson finalizes the construction of the BaBar drift chamber.

The remaining systems - the DIRC, the calorimeter, and the muon detector - measure the speed of charged particles and the energy of photons and electrons, and distinguish muons (heavy cousins of the electron) from other charged particles.

The DCH was constructed at TRIUMF, with the assistance of American and Italian collaborators, as the Canadian contribution

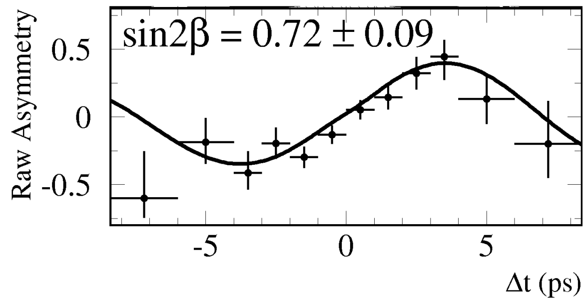


The drift chamber being integrated with the rest of the BaBar detector.

to the BaBar detector. It consists of 28,768 fine wires strung between two endplates that precisely locate the wires. Inner and outer cylinders support the wire tension , align the endplates, and contain the helium-based gas used in the chamber.

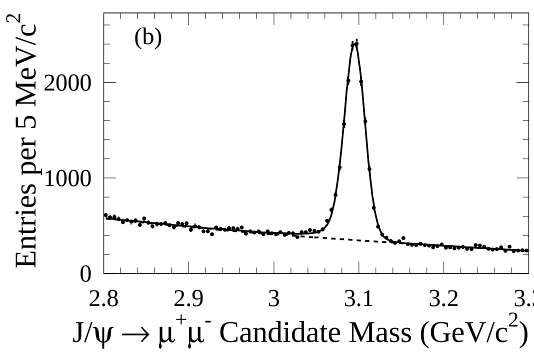
The wires were installed with the assistance of two robots supplied by Italian collaborators. The work took place in a large clean room originally built for the Hermes experiment, and now used by the ATLAS collaboration. Construction took one year and was followed by the shipment of the chamber to SLAC and its integration with the rest of BaBar. The DCH is performing to specifications and is expected to do so for the life of the project. The construction of the DCH has been a tremendous success for TRIUMF's program to provide infrastructure support for particle physics infrastructure in Canada.

PEP-II has been operating very well, producing 30% more data per year than designed. The degree of CP violation is characterized by a non-zero value for a parameter called sin(2beta). BaBar has unambiguously measured CP violation in B decay with the value sin(2beta) = 0.72 +/- 0.09.



The asymmetry in decay rates of B mesons and anti-B mesons unambiguously indicates CP violation.

BaBar has produced many other exciting results as well. One analysis, led by the Canadian group, has studied the production in the decay of B mesons of "charmoniums" mesons, which consist of a c quark paired with an anti-c quark. The momentum distribution of the charmonium mesons is surprising, and may indicate that the B meson has a different internal structure than suspected.



Charmonium mesons are studied by examining the decay products of B mesons.

Although it is now clear that the K meson is not unique, the issue of CP violation is not closed. The next steps for BaBar are to study CP violation in other decay modes, where the results should be predictable from current measurements. And the huge data set that BaBar is accumulating is allowing the Canadian group is undertake sensitive searches for rare B decays that could point the way to new physics.