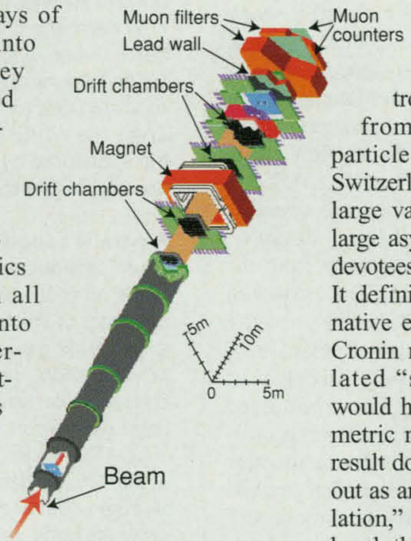
PARTICLE PHYSICS

Surprising Asymmetry Seen in Kaon Decays

CHICAGO—Once again, nature is teasing particle physicists. The Standard Model of subatomic particles, a body of theory that has survived several close shaves over the past few years, suggests that a lopsidedness in the laws of physics called direct CP violation should be small. Now data from millions of particle decays in the Tevatron particle accelerator at the Fermi National Accelerator Laboratory (Fermilab) near here point to a much larger asymmetry. Either the Standard Model is showing a crack—something theorists have long hoped for—or they have been applying the model incorrectly.

Either way, "it's a shocking result," says Bruce Winstein, a University of Chicago physicist on the experiment, called KTeV. For more than 30 years, CP violation has been known in a so-called indirect form, first observed by the University of Chicago's James Cronin and Princeton University's Val Fitch at Brookhaven National Accelerator Laboratory. Fitch and Cronin studied the decays of particles called kaons into the lighter pions. They showed that a long-lived kaon, called K-long, decayed about once out of 500 times into two pions instead of three, which would be forbidden if the laws of physics were unchanged when all particles are changed into their antimatter counterparts and space is reflected about all three of its axes. It was a new and unexpected asymmetry, and its discovery won Fitch and Cronin the 1980 Nobel Prize in physics. [Hints of similar asymmetry were recently seen in the decay of particles called B mesons at Fermilab (*Science*, 18 December 1998, p. 2169).]



Direct detection. Fermilab researchers tracked millions of decays of neutral kaons for signs of asymmetry.

Theorists later came up with an explanation for CP violation within the Standard Model by assuming that a K-long consists of a slightly lopsided mixture of an ordinary neutral kaon and its antiparticle, which added a kind of CP "impurity" in an otherwise symmetrical state. The same explanation predicted that CP violation would still be evident, but smaller, in decays of the neutral kaons themselves. So experimenters went looking for such "direct" CP violation.

But that would require keeping track of many more decays at once, including some that went to neutral pions, which are much more difficult to pick out than the mostly charged pions of the original experiment. It took decades of improvements in detector technology—and the design of a clever experiment—to pick out slight differences in the way kaons and antikaons decayed into several combinations of pions, says Sunil Somalwar, a KTeV collaborator at Rutgers University in Piscataway, New Jersey.

Because the team did a blind analysis of the data—eliminating any human bias by adding an unknown offset that was removed at the very end—they themselves did not know the answer until a few days before the University of Chicago's Peter Shawhan gave a seminar at Fermilab on 24 February. "It was one of the most remarkable moments I've ever experienced in a physics seminar," says Chris Quigg, a Fermilab theorist who is not a member of KTeV. "When he ripped the Post-It off" a viewgraph, revealing the value, "there was a quarter-note rest in the whole audience during which nobody breathed; and then a big gasp, collectively."

The number was far larger than suggested by earlier, sketchier results from the Tevatron, although some results from CERN, the European particle physics lab in Geneva, Switzerland, had also suggested a large value. In one respect, the large asymmetry offers solace to devotees of the Standard Model: It definitively rules out an alternative explanation of the Fitch-Cronin results based on a postulated "superweak" force that would have stirred up the asymmetric mixture. "What this new result does is basically throw that out as an explanation for CP violation," says Fitch. On the other hand, the asymmetry, about 300 times smaller than in the Fitch-Cronin experiment, is also several times larger than the Standard Model had suggested.

Still, theorists should not give in just yet to the temptation to look beyond the Standard Model, says Quigg. The calculations that predict a value for direct CP violation involve poorly known quantities like the mass of the strange quark. If, as some theorists have recently proposed, the strange quark is much lighter than has been assumed, all could be well again, he says. More data are on the way from CERN and the Tevatron, so particle physicists should soon know whether the new results are more tease than promise.

–JAMES GLANZ

BIG SCIENCE

Panel Backs Next-Generation Synchrotron

GAITHERSBURG, MARYLAND—A key federal panel last week recommended continued research toward a "fourth-generation" synchrotron, a machine capable of creating x-ray pulses billions of times more intense than current designs. The instrument could revolutionize many fields of science, from figuring out protein structures to understanding the physics of materials, by providing more detailed snapshots and movies of the atomic structures of molecules and materials. It's unlikely to be built in the next decade, however.

Last summer, the Department of Energy (DOE) asked the panel—made up primarily of university and industry-based scientists—for advice on how to proceed with novel synchrotrons. The panel's go-ahead is expected to prompt DOE to spend up to $8 million a year this year and next on research and design ideas for the machine. If given another go-ahead in 2001, DOE would likely ask Congress for about $100 million to build a test-bed facility at the Stanford Linear Accelerator Center. A full-scale facility, designed to accommodate around 1000 users a year, is expected to cost $1 billion to $2 billion.

While several different designs have been proposed for a fourth-generation synchrotron, the panel threw its initial support behind a so-called "hard x-ray free-electron laser," which would use gyrating beams of electrons traveling through a linear accelerator to create its x-ray pulses. The synchrotron would produce much higher intensity pulses than existing third-generation machines can, and the x-ray light waves in each pulse would be "coherent," with the crests and troughs of the waves traveling in lockstep. That property, the panel concluded, "has the potential to open new areas of science that are likely to be well beyond what can be anticipated by current scientific knowledge and predictions." One likely beneficiary is the nascent field of x-ray holography, where the blast of coherent x-rays triggers the emission of additional x-rays from atoms in a sample. By tracking how these waves interfere with one another, researchers can determine the location of nearby atoms in a three-dimensional sample in one step rather than the complex multistep approach used today.

The panel's endorsement "is a major event for the synchrotron community," says David Moncton, director of the Advanced Photon Source, a third-generation synchrotron at Argonne National Laboratory in Illinois. But to justify the enormous expense, "a more effective case for the science must still be made," says panel chair Stephen Leone of JILA—formerly known as the Joint Institute for Lab-

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