A hint of particles within quarks

The sight of a high-speed bullet tearing through a bale of hay without deviating from its path would come as no surprise to any onlooker. An occasional bullet that pierced the bale, then came shooting back toward the rifle would be a different matter, suggesting the presence of something small and hard inside the bale.

Physicists at the Fermi National Accelerator Laboratory (Fermilab) in Batavia, Ill., face an equally startling possibility in their analysis of the debris scattered from high-energy collisions between protons and antiprotons. They have observed a subtle effect—a small apparent deviation of the data from theoretical predictions—hinting that quarks themselves may be made up of still smaller building blocks.

"That quarks have a substructure is certainly a logical interpretation of the data," says Paul L. Tipton of the University of Rochester in New York. "But we're much more cautious than that."

"These are very difficult measurements," notes Andrew R. Baden of the University of Maryland at College Park. For example, researchers need to account properly for a wide variety of potential confounding effects due to the equipment and procedures used in the experiments.

Scientists have long employed scattering experiments to work out the structure of matter. Early in this century, the observation that gold atoms strongly deflect alpha particles led Ernest Rutherford to postulate the existence of the atomic nucleus. In the late 1960s, the strong scattering of electrons by protons provided experimental evidence of quarks as the building blocks of protons and other subatomic particles.

Fermilab's Tevatron collider accelerates protons and antiprotons to combined energies as high as 1.8 teraelectron-volts, more than 100,000 times the energy of the particles used by Rutherford. Such energies have enabled physicists to probe structures down to the level of quarks, confirming many aspects of the quark picture of matter and leading to the discovery of the top quark (SN: 7/1/95, p. 10).

At the highest possible collision energies, Fermilab researchers begin to see the effects of violent, extremely close encounters in which a quark inside a proton interacts with a quark inside an onrushing antiproton. These collisions can spray jets of subatomic particles sideways out of the interaction region. The jets can carry away different amounts of the original collision energy.

Members of the team operating the huge Collider Detector at Fermilab (CDF) found that the number of such events is significantly higher than expected for high-energy sideways jets. They report their results in a paper submitted to PHYSICAL REVIEW LETTERS.

"The data over the full [energy] range are very precise," the researchers say. "They . . . demand a reevaluation of theoretical predictions and uncertainties."

Preliminary data from the DZero detector at Fermilab hint at a similar, though smaller, deviation from theory. However, there are as yet too many uncertainties for a definitive answer.

The observed excess may indicate that quarks contain something smaller, representing a new level in the composition of matter. "But one would have to eliminate all other possibilities before reaching that conclusion," Tipton says.

For example, a problem could lie in the theoretical calculations used to make the predictions. These calculations involve approximations that may not be justified, Baden says. It's possible that small adjustments to the theory can eliminate the discrepancy.

The researchers also have more data to analyze. It takes years of effort to extract the crucial information, and the present results are based on observations made in 1992 and 1993.

So it remains a waiting game as members of both the CDF and DZero collaborations continue sifting through their bale of data. *— I. Peterson*

Need soldier ants? Just tell the nursemaid

Any military leader who has tried to recruit soldiers will envy the common ant *Pheidole pallidula.*

When these ants sense a possible threat, they increase the ratio of soldiers to workers in their colonies, report Luc Passera of Paul Sabatier University in Toulouse, France, and his colleagues.

Passera's team tested almost 40 large colonies of *P. pallidula* from southern France. The scientists removed all of the soldiers and decreased the number of workers to 1,100 in each colony.

The team then allowed worker ants from two colonies at a time to walk through a tunnel in search of a dinner of honey and mealworms. The tunnel was divided to keep the ants from different colonies apart. In some experiments, the partition was made of wire mesh, through which the ants poked their antennae and legs at each other. In other experiments, a plastic sheet kept the ants unaware of each others' presence.

In nature, ants from different colonies commonly pass each other when foraging and discriminate easily between foreigners and members of their group.

Over 7 weeks, the colonies whose workers traveled in the tunnel divided by mesh produced about twice as many soldiers, and fewer workers, as the other colonies, Passera and his colleagues report in the Feb. 15 NATURE.

Whether an ant larva grows into a worker or a soldier appears to depend on what it's fed, studies by other researchers indicate. Workers in the tunnel with the mesh alerted the larvae's nursemaids to the presence of foreigners, speculates coauthor Laurent Keller of the University of Lausanne in Switzerland. The nurses then probably beefed up the quality and quantity of some larvae's meals to produce soldiers, which are bigger than workers.

Since the late 1970s, many entomologists have thought that a healthy insect colony resembles an assembly line, with the number of animals in each job set to maximize efficiency, explains Deborah M. Gordon of Stanford University in an accompanying commentary. Scientists thought the numbers changed only over many generations, but few of them tested this theory.

Those who did test it failed to find evidence of ants altering the ratio of workers to soldiers in response to a threat because they did not reproduce the ants' environment, Keller asserts. For example, earlier researchers put ants from one colony into another, rather than simply letting them pass each other on the trail.

Few other animals can induce structural changes as a defensive measure, Gordon notes.

Colonies of *P. pallidula* are not extravagant with warrior production, however. The energy and time required to produce more soldiers may outweigh the advantages. *P. pallidula* increases the ratio of soldiers only when workers get a clear signal that foreigners are near but the attack has not yet begun. In other *Pheidole* species, workers simply change hats and help with the defense, Gordon notes. *— T. Adler*

Passera

Worker ants hold the legs of an intruder while one of their soldiers cuts it in half.