they showed two basic behaviors. One was to totally ignore the infants. The other pattern, says Harlow, was grim and ghastly. When an infant attempted to make physical contact with its mother, she would literally scrape it from her body and abuse it by various sadistic devices. The mother would push the baby's face against the floor and rub it back and forth. Not infrequently, the mother would encircle the infant's head with her jaws, and in one case an infant's skull was crushed in this manner.

In most instances, the researchers were able to stop the sadism, but some mothers were so violent and vicious that a few infants were lost because the researchers had not anticipated the severity of the events in the reproduction of the battered child syndrome.

The motherless mothers, says Harlow, gave more to science than their offspring. They not only opened doors of understanding of the battered child syndrome but also provided two fringe benefits. First was confirmation of the power and persistence of infant love for the mother. If the infants were among those favored and fortunate enough to be just ignored by their mothers, or if they had survived the battering, they persisted in their intense efforts to make and maintain contact with the mother whether or not she scraped them away or engaged in maternal mayhem. The amount of punishment or banishment the infants would accept was a measure of their motivation.

The second bonus from the babies was that after they had continuously forced their mothers into accepting protracted contact, some of the contact comfort, softness and warmth seemed to rub off on the mothers. Furthermore, after the maternal contact had been achieved for a period of time, there tended to be a gradual but progressive maternal rehabilitation with partial or total submission to the infantile affection. The few mothers who succumbed were impressively more normal in the treatment of subsequent infants of their own. This finding has implications for therapies with humans.

"Research has shown," concludes Harlow, "that developmental timing and sequencing of the loves and of aggression are of vast significance in preventing or ameliorating aggression. When the development is out of normal sequence, aggression is uncontrolled and extremely difficult to alter or eliminate. New therapeutic techniques are making rehabilitation more of a reality, but the ideal solution is to prevent antisocial aggression through anticipation." □

# Quark theory: A prediction confirmed

Particle physicists invented the quark-parton theory of the structure of the class of particles called hadrons because it gave a relatively simple way of accounting for certain patterns among their important properties. But the test of a theory is not how well it explains what is already known but whether the unknown things it predicts can be found. The famous experiment at the SPEAR storage ring of the Stanford Linear Accelerator Center, operated by a consortium from SLAC and from the Lawrence Berkeley Laboratory, has now confirmed one of the significant predictions of the quark-parton theory.

The matter involved is one of the effects that happens when energetic electrons and positrons going in opposite directions collide with each other. Since this is a collision of matter and antimatter, the first thing that happens is an annihilation reaction that produces a virtual photon, a particle of light that has the property of being matter, antimatter and energy at the same time. The virtual photon then turns itself into other particles, depending on the amount of energy it has. These particles can often be hadrons.

The original electron and positron approach each other with equal and opposite momentum and so stop each other cold. The virtual photon, in strict principle, just sits there motionless. But the dynamics involved in producing hadrons from the virtual photon endow the hadrons with a certain momentum, and according to theory this should be directed transverse to the direction of the electron and positron beams. In short, the theory predicts jets of hadrons coming off in opposite directions from such an annihilation reaction. The experimental apparatus is a complicated array of detectors surrounding the point of impact that record particles coming off in all directions.

These jets have been found in the experiment, according to a report in the Dec. 15 PHYSICAL REVIEW LETTERS signed by Gail G. Hanson and 33 others. The theory requires fairly high energy for the jets to occur, and in fact, they appeared when the total energy of the electron and positron beams was 6.2 and 7.4 billion electron-volts. A rival model of the interaction predicts a more or less spherical distribution of off-coming particles, and this tends to fit the data at lower energies as well as the jet model, but the jet model is definitely a better fit at higher energies, the experimenters conclude.

Intermediate in the production of hadrons from the virtual photon is the decay of the photon into a quark-parton pair, which then produces the off-coming hadrons. The measured characteristics of the jets of hadrons allow a determination of their spin characteristics, and from that the spin characteristics of the partons themselves. The deduction supports those who say the partons must have one-half unit of spin rather than those who say zero spin. □

# Coloring crystals with light

Certain kinds of defects in the crystal lattices of alkali halide compounds can produce what are called color centers. These are locations that strongly absorb light passing through the crystal and give it a characteristic color. They are called F centers (from the German word *Farbe*), and they give each crystal a characteristic color ranging from yellow for lithium chloride to blue for cesium chloride.

According to a standard textbook, F centers are locations where an electron takes the place of a halogen ion in the crystal structure. They have been produced by illuminating the crystals with ultraviolet light or X-rays. Often the F center and the associated coloration of the crystal are transient. Now, in the Dec. 15 PHYSICAL REVIEW LETTERS three physicists from the Bell Telephone Laboratories in Holmdel, N.J., report a method for producing essentially permanent F centers. The experiment sheds light on the physics of the formation of F centers and, at the same time, produces essentially permanently colored crystals, which can have practical uses.

The experimenters, L.F. Mollenauer, G.C. Bjorklund and W.J. Tomlinson, began with potassium chloride crystals that contained a certain concentration of what are called U centers. (A U center is another kind of crystal defect, a negative hydrogen ion—a proton with two electrons attached, trapped at a vacancy where a negative halogen ion should be.) The technique is to transform U centers into F centers by making them absorb two photons of a particular wavelength of light.

The light wavelength is 266 nanometers and is the fourth harmonic of an yttrium-aluminum-garnet laser system. It fell on the crystal from one side. From another direction, monochromatic light at 586 nanometers was passed through the crystal. The amount of this light that was absorbed was the criterion for the production of F centers in the crystal. As the power of the 266-nanometer beam was raised, absorption of the 586-nanometer beam also rose.

The model that the three experimenters propose to explain what happens goes as follows: The crystal lattice absorbs two photons of 286-nanometer light, and this absorption generates an electron-hole pair. (A hole is a place where an electron should be but isn't. It has the effect of a positive charge, can move through the crystal and sometimes forms a bound pair with an electron.) Eventually the pair recombines; that is, the electron falls into the hole, producing a net neutrality. The recombination releases energy.

Recombination can occur at a U center, an F center or directly in the lattice. When