the purpose of the station and view it as a way point toward something else," says Robert Richardson, vice president for research at Cornell University in Ithaca, New York. "The vision issue was the most heated part" of panel discussions, recalls Silver. Before they can focus on the long term, however, NASA's new leaders must first survive the current national crisis and the resulting tight fiscal constraints. –ANDREW LAWLER

QUANTUM PHYSICS

Spooky Twins Survive Einsteinian Torture

It's a nagging truth that all physicists must face: Relativity and quantum mechanics don't mix, and when they square off, Einstein loses. Now Swiss physicists have brought the two great theories into the arena again. In an experiment that turns commonsense notions of causality on their head, the scientists showed that relativity's tools for dealing with the flow of time are irrelevant in the submicroscopic realm of quantum processes.

The experiment, conducted at the University of Geneva, explored the properties of pairs of particles whose fates are linked through a mechanism called entanglement. As long as physicists don't examine them, such so-called Einstein-Podolsky-Rosen (EPR) pairs enjoy a wishy-washy existence, not committing themselves to any particular states of properties such as polarization. But jolt one of the particles into choosing—say, by noting its existence with a detector—and the other instantly feels the tweak, even if it's millions of light-years away. If one particle is detected with horizontal polarity, for instance, the other might instantly assume vertical polarity.

Lab experiments have repeatedly confirmed that this "spooky action at a distance" operates faster than light, although physicists have shown that it doesn't violate relativity because it can't be used to send faster-than-light messages. In the mid-1990s, however, Swiss physicists Antoine Suarez and Valerio Scarani realized that EPR pairs pose a different sort of relativistic problem, because it's not always clear which particle is tweaking which. The reason is that according to Einstein, observers in different reference frames can disagree about the order in which events occur.

In a classic thought experiment, for instance, physicists like to imagine a person with a 15-meter-long pole running into a 15-meter-long barn at four-fifths the speed of light (see figure). To an observer looking down from the rafters of the barn, the streaking pole seems to be contracted to 9 meters, so it fits entirely within the barn. This means an electronic sensor can (a) shut the front door and then (b) open the back door. But from the pole's point of view, the *barn* is moving. It shrinks to 9 meters long, while the pole retains its full length of 15 meters. Why doesn't it smash into the barn door? Because the order of events is different from the runner's point of view. The pole carrier clearly sees (b) the back door open before (a) the front door shuts, the opposite of what a stationary observer sees.

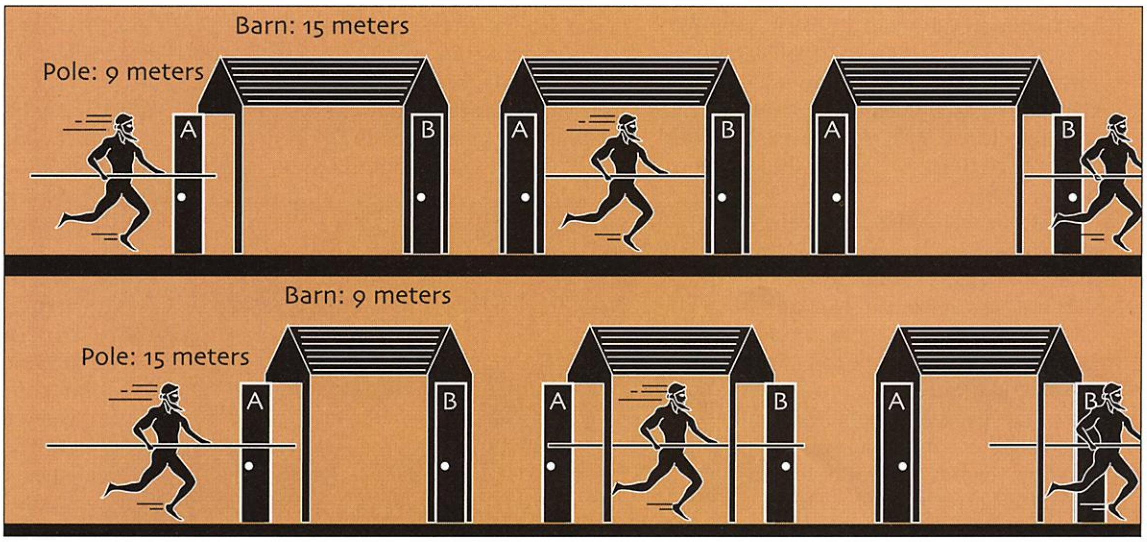
Likewise, if two scientists are moving with respect to each other when they measure each half of an EPR pair, they might disagree about who measured the particle first. How could the twins be "communicating" if both scientists think that their twin is the sender and the other is the receiver? In such a "before-before" situation, Suarez and Scarani argued, the two particles can't be communicating at all. The spooky action must fall apart.

The Suarez-Scarani theory suffered a setback last year, when Nicolas Gisin of the University of Geneva and his colleagues put it to an ingenious test (*Science*, 17 March 2000, p. 1909). They set up an experiment in which a laser spat out entangled pairs of photons. After zipping through fiber-optic cables, each entangled photon struck a beam splitter, which gave the entangled photons a "choice" of paths leading to different particle detectors.

To bring relativity into play, Gisin used a whirling drum as a stand-in for one of the device's stationary photon detectors. The drum's motion created an Einsteinian before-before situation, in which each detector thought that it had measured the photon before the particle's twin struck the other detector. Contrary to Suarez and Scarani's theory, the particles stayed entangled. The refutation wasn't quite airtight: Skeptics pointed out that the Suarez-Scarani interpretation could still be true if the particles made their "choices" of path before they struck the detector—at the beam splitters, for example.

The new experiment closes that loophole by showing that the particles still communicate even if they make their choice at the beam splitters. Using nearly the same setup, Gisin's team—with Scarani added—replaced the moving detector with a stationary one and made the stationary beam splitters into moving ones by pumping sound waves through crystals. In a paper submitted to *Physical Review Letters*, Gisin and his team describe how they set the speeds of the beam splitters to create a before-before situation. As in the earlier experiment, the particles remained entangled. Although each particle hit the beam splitter "first," and thus thought it was the sender rather than the receiver, the particles were communicating just as well as when the beam splitters were stationary.

The results, Suarez says, leave the theory he and Scarani proposed no wiggle room. "The notion of time makes sense only in Einstein's world," he says. "It doesn't make sense in the [quantum world]. It cannot be described in terms of before and after." And for those who prefer to live in a world of cause and effect, spooky action at a distance just got even spookier. –CHARLES SEIFE



What next? Quantum experiment's relativistic quirks resemble those of a pole moving through a barn at near the speed of light. An observer in the barn would see a short pole and both doors closed at once, but the runner carrying the pole sees a foreshortened barn with at least one door always open.

ILLUSTRATION: A. STONEBRAKER