Powerful New Detectors Spy On Strange Spinning Nuclei

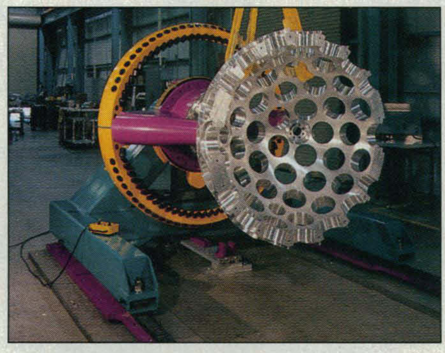
Late last month, physicists from all over Western Europe gathered at the Centre de Recherches Nucléaires (CRN) in Strasbourg to inaugurate the Vivitron, France's new linear heavy ion accelerator, which will ramp up over the next few years to be the most powerful facility of its kind. The Vivitron's first experimental array, a joint French-British sensor called Eurogam II, billed as "the world's most advanced" gamma ray detector, is also ready and waiting. But Eurogam II doesn't have the field to itself. While the Europeans were celebrating in Strasbourg, an equally enthusiastic group of scientists was standing by in California while the Lawrence Berkeley Laboratory's rival to Eurogam II, Gammasphere, undergoes an upgrade that will make it—according to a Berkeley press release—"the world's most powerful gamma ray detector."

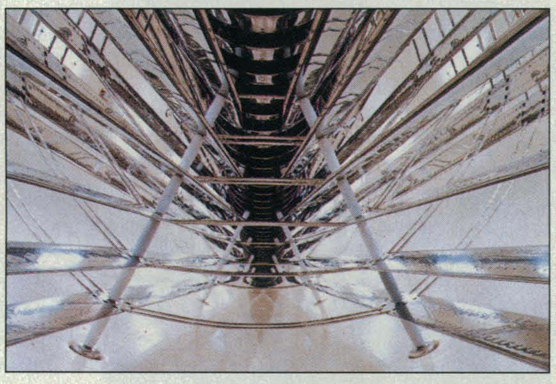
Physicists don't despair at these conflicting claims. In fact, the claims reflect "a good healthy competition" between the two detectors, says Liverpool University physicist Peter Twin, who leads the Eurogam effort with CRN director Francis Beck. Nor is this a zero-sum game: In the end, physicists on both sides of the Atlantic will come out winners, says Twin. The biggest winners will be physicists studying the fine structure of the atomic nucleus by measuring the gamma rays it gives off when it is driven into unusual excited states. This already hot field promises to get even hotter with the almost 100-fold increase in sensitivity that the new generation of detectors will eventually achieve.

The new gamma ray detectors are basically spherical metal structures which hold in place a multitude of germanium crystal detectors. The impact of a gamma ray on the germanium creates an electric charge which can then be monitored electronically. Although the two detectors share these basic principles, they have different histories and designs. Eurogam II is a completely redesigned version of the earlier Eurogam I, which operated until March 1993 at Britain's Daresbury Laboratory. The new array has almost three times as many individual germanium detectors as its predecessor, giving it 10 times the resolving power.

Gammasphere runs on Berkeley's 88-inch cyclotron, which accelerates ions in a spiral and has been in operation since 1962. Gammasphere was first used early last year, but with only 36 of the 110 detectors it will eventually house. The current upgrade, which should be completed by Christmas, will boost it to 55 detectors and make it roughly equivalent in sensitivity to Eurogam II. And in a year's time, with 110 detectors in place, Gammasphere will pull ahead—but only until 1997, when a more powerful European detector, Euroball, will bring the two sides roughly even again.

This race for sensitivity among the detector builders is paying real dividends for researchers. "Our chances of grabbing a gamma ray when it comes along will be much better," says physicist Robert Janssens of the Argonne National Laboratory in Illinois. "For many years we studied the most common things that happen, and that's basically what we know about nuclear structure," says Gammasphere director Frank Stephens. "[Now] we will be able to study things that occur much less frequently." These rare events often correspond to the more subtle structural changes that nuclei can undergo, and give off much weaker signals.


LAWRENCE BERKELEY LABORATORY


STRASBOURG CENTER FOR NUCLEAR RESEARCH

Sensitivity race. Berkeley's Gammasphere detector *(top)* head to head with France's Vivitron *(bottom)* and Eurogam II.

During the past several years, important new insights into the structure of the atomic nucleus have come from the study of short-lived nuclear states collectively called "superdeformation," discovered by Twin in 1986. Superdeformation occurs when a fast-moving beam of heavy ions hits a target made up of another heavy ion species, causing some of the projectile nuclei to fuse with target nuclei (*Science*, 10 May 1991, p. 778). Because the nuclei seldom collide head-on, the angular momentum from the collision sets them spinning at up to 10^{20} rotations per second, thereby modifying the arrangement of protons and neutrons and causing the nuclei to assume unusual shapes—including rugby balls or even pancakes.

The laws of quantum mechanics prevent the spinning nuclei from slowing down smoothly to their normal states. Instead, they must hop from one energy level down to the next, giving off a gamma ray with each energy jump—up to 25 gamma rays in the larger nuclei. Although this deformed shape lasts only about 50 trillionths of a second, it can reveal information not obtainable from nuclei in their normal spherical state. The reason, says Stephens, is that from the point of view of quantum physics, "a spherical nucleus cannot rotate, because to rotate something you have to be able to orient it in space and keep track of its orientation." Once a nucleus takes on an oblong shape, however, researchers can "watch" it spin. "A superdeformed nucleus is the most perfect rotor of any nucleus we have seen," Stephens says. Detailed analysis of these rotors is "telling us things we didn't know before."

One surprising early observation was the detection of seemingly identical energy levels in different superdeformed nuclei. This phenomenon, called band twinning, was entirely unexpected, because the different arrangement of particles in different nuclei would normally be expected to give unique spectra. Although squads of theoreticians immediately set to work on this problem, few physicists are satisfied with what they have come up with so far. "I'd say we're not there yet," says Twin. But the band twinning results seem to be consistent with more recent data suggesting that some superdeformed nuclei give gamma ray bands in which the energies are shifted slightly up or down. The currently favored interpretation of this result is that the rugby ball–shaped nuclei also form bulges or ridges along their long axes, giving them a cross section akin to a four-leafed clover. If this is correct, says Stephens, quantum calculations "will teach us more about how [protons and neutrons] interact with each other in these systems."

In the meantime, says Twin, the new generation of detectors "will enable us to solve a lot of the intriguing questions" that have been raised by previous studies. "There is going to be a lot of data coming out in the next 6 months."

–Michael Balter