First Matter

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A New Particle Detector Built at the Weizmann Institute of Science Will Help Probe the Primordial Universe

When the first matter came into being right after the Big Bang, what was it like? It may not have been quite as scientists have been describing it. That is one of the possibilities raised by four international teams of researchers that are about to publish important results three years into an experiment to recreate the primordial matter of the universe. Weizmann Institute scientists are among those who participated in the creation of matter that may be the "quark-gluon plasma" thought to be the first matter in the universe.

Scientists studying the unique physical properties of the quark-gluon plasma attempted to recreate the primordial matter using an accelerator, called RHIC, built especially for this purpose at the Brookhaven National Laboratory on Long Island, New York. The RHIC creates two beams of gold ions and accelerates them one towards the other, causing a head-on collision. The power of the collisions (about 40 trillion electron volts, also termed 40 tera electron volts) turns part of the beams' kinetic energy into various particles (a process described by Einstein's well-known equation $E=mc^2$).

The first stage in the creation of these new particles, like the first stage of the creation of matter in the Big Bang, is thought to be the quark-gluon plasma. In this stage, the jets of blazing matter that dispersed in all directions in the first few fractions of a second in the existence of the universe contained a mixture of free quarks and gluons. Later on, when

the universe cooled down a bit and became less dense, the quarks and gluons got “organized” into various combinations that created more complex particles called hadrons, a group that includes protons and neutrons. Since then, in fact, quarks or gluons have not existed as free particles in the universe.

But, while many of the experimental results fit in with predictions of how particles in the quark gluon plasma should behave, others have been a surprise. For instance, some analyses of the data show the plasma, created at a heat up to 150,000 times hotter than the center of the sun, behaves not as a super-hot gas, as expected, but more like a liquid. The Weizmann Institute scientists participated in the experiment known as “PHENIX,” carried out by an international team of 460 physicists from 12 countries. A number of the particle detectors installed for the original PHENIX experiment were designed and built by Prof. Itzhak Tserruya of the Weizmann Institute’s Particle Physics Department and his team. These detectors are capable of providing three-dimensional information on the precise location of the particles ejected from the collision area. The particles' direction, together with their energy and identity, help characterize the matter's properties within the collision area. The team is now working on an upgrade of the PHENIX set-up that entails the addition of a new detector, called the Hadron Blind Detector, which will allow scientists to focus on specific particle pairs. These particles are electrons and their antimatter opposites, called positrons. When they show up in pairs, they can give the scientists valuable clues as to the processes taking place in the matter. The new detectors are now in the construction phase, and Tserruya hopes to install them in time for the new experiments next year.