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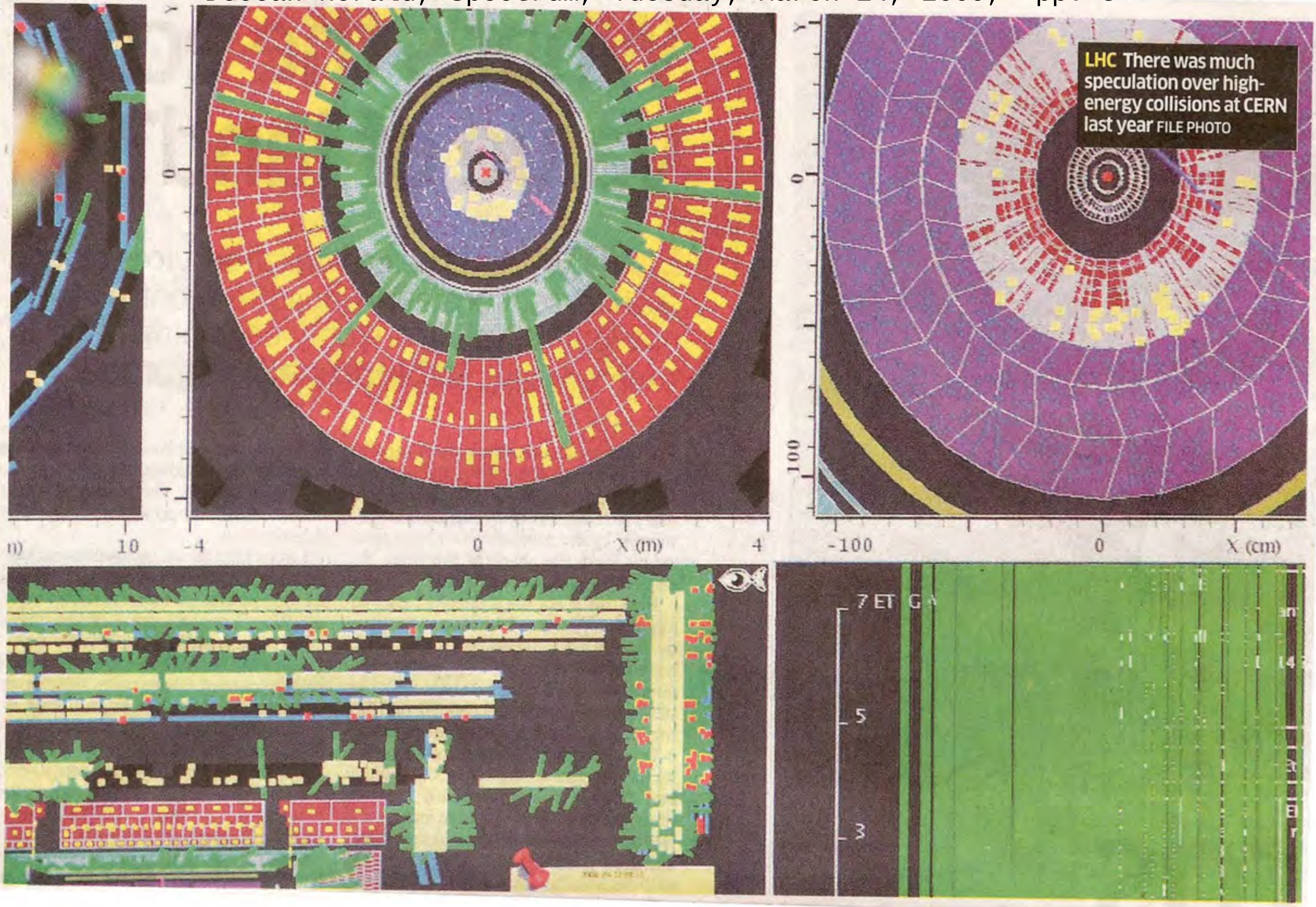

LHC There was much speculation over high-energy collisions at CERN last year FILE PHOTO

Dark matter of our vast universe

HIGH ENERGY COLLISIONS Even as scientists are running repairs on the Large Hadron Collider, **C Sivaram** dispels fears that a black hole produced out of the high energy collisions would actually accrete the earth. In fact, the energy produced would be too low for that, specially when it is confined to a localised 27-km region

The Large Hadron Collider created quite a buzz last year. There was much consternation, especially among the general public as to the possible disastrous consequences of such experiments. The first high energy beam of multi-TeV protons whizzed around the 27-km tunnel of the LHC. (One TeV is a terra electron volt, or the energy gained by an electron in an electric potential corresponding to a trillion volts.)

A theme that had then caught people's imagination was the possibility of black hole production in such high energy collisions. It was feared that once such a black hole was produced, it would quickly accrete all the surrounding matter including the whole earth!

Such notions are untenable and to explain this, a quantitative understanding of black hole formation and estimates of the energies involved are required. Even as scientists at CERN look forward to running the accelerator again in June, the reason to be excited about the very high collision energies of the protons in the oppositely moving beams is that it corresponds to the energies of the particle in the very early phase of the universe. To be precise, one picosecond after the universe started expanding (in the big bang) the temperature corresponded to a few TeV.

The LHC energies correspond to the particle energies about ten femtoseconds after the universe began expanding. Much of the universe seems to consist of dark matter (DM), believed to consist of particles produced due to breaking of super-symmetry (at energies of several TeV). The lightest such super-symmetric particles are expected to be stable and could constitute the DM in the present universe. If this picture has some truth, then such particles would be expected to be produced quite copiously in the LHC, when it goes into full swing. Then, we would know what constitutes the DM of our universe, six times more abundant than ordinary matter.

Black holes & their production

In the early universe, primordial black holes are formed when the gravitational potential equals the square of the velocity of light. This could happen, for example, if in the radiation dominated era, the external radiation pressure forced material inside the so-called gravitational radius provided it began with a density sufficiently in excess of ambient average density.

It turns out that the mass of the black hole that can form in the early universe depends on the epoch it is formed. This shows that primordial black holes of around the mass of the earth could have formed in the universe when the temperatures (energies) were several TeV.

Does this mean that the LHC can produce earth mass black holes? Let us consider the total energy required to form an earth mass black hole. We should remember that in the big bang when the temperature of the universe was a few TeV, the size of the universe (at that time) was hundred billion metres! This entire volume (of 10^{33} m^3 was at a temperature of 10^{17} K! (that is the volume of about the solar system was filled with quanta and particles of energy of many TeV, with a total energy content of $\sim 10^{82}$ J!). Whereas in the LHC, we have particles with individual energies confined to the vacuum tubes of a localised 27-km region.

LHC BUZZ

- The LHC was switched on, on September 10, 2008 amid much international attention.
- In the 1990s, scientists at Cern working with an older particle collider called LEP searched long and hard for the Higgs boson
- When LEP closed at the end of 2000, scientists knew the Higgs particle must weigh more than 114GeV, where 1 gigaelectron volt (GeV) is something like 1/6000 billion grams.

Black hole production

To produce a black hole of the earth mass, we would have to squeeze a total energy of $\sim 10^{41}$ J, in a volume of 10^{-5} m^3, that is an earth mass black hole would have a horizon radius of just a centimetre!

At the worst, the high energy beams in the LHC can go out of control and damage only the accelerator and surrounding structures. The total energy is just too low! The individual particle energies are high. (In a fluorescent lamp, the temperature of the individual particles is several thousand degrees, but the tube is cold to the touch, as the total heat content is low).

The energy required to form an earth mass black hole corresponds to our world's power production for years and all this has to be concentrated in a region of one cubic centimetre and to do that we have to squeeze it with a pressure of atmospheres.

The so-called Hawking black holes of asteroid mass ($\sim 10^{10}$ kg), were formed in the early universe when the temperatures were $\sim 10^{22}$ K, eight orders higher than the particle energies in the LHC. The only black holes which could perhaps be produced are the TeV mass black holes (weighing $\sim 10^{-21}$ g).

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