The Open University

The physical world: collisions
Collisions: the Hadron Collider

PRESENTER: They're building a new experiment, it won't be ready till 2005 and it's on an epic scale. It makes current particle physics look like child's play.

V/O: But it's got a very grown-up name: the Large Hadron Collider.

MAN: I think it's probably the biggest scientific instrument ever constructed and it's going to collide protons head on at the highest energies that have ever been achieved, and the idea is by colliding them at much energy than previously we can smash them apart into much smaller pieces, and get down to a deeper level of our understanding of the structure of matter.

FRANK CLOSE: By colliding the particles together at very high energy you are recreating for a brief moment in a very small volume the sort of energy or temperature that was present in the real Universe within a millionth of a millionth of a second of the original Big Bang.

V/O: Subatomic particles will be fired around a 27 kilometre ring and then smashed into each other at almost the speed of light. Huge detectors which act like enormous electronic eyes will capture the results of the collision. While the existing tunnel can be reused for the new experiment, the detectors will have to be bigger and better than anything ever built before.

TEJINDER VIRDEE: One of the two detectors on the Large Hadron Collider is going to have a diameter which is about twice as big and a length which is about three times as big, so in volume terms it'll be 6-10 times the volume of these detectors.

MAN: The data from one of these four big detectors in one year will be about a petabyte of data – what the hell's that? If you stored it on CD-rom, and each CD-rom's about sort of this thick, and then you stack them up they'll be three kilometres high, one year's worth of data. So just storing that, transmitting it, analysing, is going to be a big challenge. The energy of a proton of the LHC is about the energy, the kinetic energy, energy of motion of a mosquito buzzing around. Now that doesn't seem very much, but you've got to remember that a mosquito has in it something like a thousand billion, billion protons, so it's as if the mosquito which is made of these thousand billion, billion protons its energy was suddenly concentrated on one of them. So it's a huge amount of energy.

FRANK CLOSE: What's been going on at CERN in the last several years is smashing particles together at higher and higher energies, creating higher and higher temperatures, temperatures that are the equivalent of millions of millions of degrees, far hotter than anything in the Universe today, hotter than anything that has existed since the first millionth of a second. Now it might be surprising if I say and those temperatures are actually extremely cold compared to where we want to go to next, where we think there's something interesting happens. In a sense, all that we have done so far at CERN is seen the Universe when it was frozen like this. What we want to do next is to be able to melt the Universe, if you like, turn the ice into real water.

V/O: And what happens when the Universe melts? The Holy Grail for particle physicists, and the reason they're spending billions on this experiment, is to try to answer a simple but profound question: where does mass come from? A question you might have thought they'd have figured out by now.

MAN: One particular thing we're looking for is something called the Higgs boson which is associated with the mechanism by which particles acquire mass. We're in a very peculiar position that we know a lot of so-called elementary particles, we can organise them into certain families, as we go deeper the structure seems to be becoming simpler, but they have a very diverse range of masses, some of very light, even mass-less, some are heavier, and we don't understand the mechanism by which they get different masses. We have on paper theories of how particles get mass and they predict the existence of new particles called Higgs bosons, but we've never found one. We're pretty sure it exists but it's a generic idea, it could take different forms, and it's a roadblock actually to understanding more deeply the structure of matter, it's to try to find out this Higgs boson, or bosons, and what it or they are and how they operate. We'll unblock progress, I mean we know something is hiding the fact that all particles are trying to be mass-less, and generating mass for some but not others, and until we know the answer to that we can't get deeper into the structure of things.

V/O: If they discover the Higgs boson it will be one of the most exciting scientific developments of the New Millennium.

PRESENTER: But what if they don't find it?

FRANK CLOSE: Whether there will be a Higgs particle, or something more subtle along the same lines, is not yet known. But if nothing at all showed up then that might be even more interesting in a paradoxical sense because it would say that there is something fundamentally flawed somewhere in our present understanding of either relativity or quantum theory, the other great quote "laws", as we believe them to be. So it would be a signal that there is something missing and exactly whether that would be a profound re-evaluation of all of science or whether it would be a small thing something to be cooked up, who knows.

PRESENTER: Scientists have theories for the secrets they'll discover inside atomic particles although they can't be sure what's there. But whatever they do discover, scientists assume that the laws of conservation will still work, even at the smaller scale.

TEJINDER VIRDEE: Certainly when one gets the results, and one analyses the results, there are conservation laws which must be strictly satisfied. So when one says one gets the results right, these are the basic things which must be right, so we could not have something happening which is violating one of the cherished conservation laws.

MAN: Every law has to be continuously tested and try out the domain of validity and sometimes we found ah, it was only approximate, it works here, but when we really push things to very extreme energies or very extreme temperatures, the law doesn't work any more. So I think I will be very surprised if energy momentum conservation changed, but it's possible.