

## Journey from Bottle to Bang

Insignificant though this bottle of compressed hydrogen gas looks, it marks the beginning of the world's largest and most powerful particle accelerator chain, culminating in CERN's spectacular "LARGE HADRON COLLIDER"

4 gentle little eruptions of particle tracks.

Hydrogen atoms from this gas cylinder are fed at a precisely controlled rate into the source chamber of a linear accelerator – CERN's Linac 2 – where their electrons are stripped off

### WIND RUSH

to leave hydrogen nuclei. These are protons and have a positive charge, enabling them to be accelerated by an electric field. Their journey to eventually take part in ultra high energy collisions, similar to those following the Big Bang, can now begin.

This initial acceleration has caused Linac 2 has been likened to the lumbering first stage of a huge rocket.

By the time this packet of protons leaves Linac 2 it will be travelling at 1/3 the speed of light.

It's about to enter the BOOSTER – stage two of the rocket, if you will. In order to maximise the intensity of the beam, the packet is divided up into 4 – one for each of the booster's rings.

Straight acceleration is now impractical and the booster is circular – 157 metres in circumference.

In order to accelerate the packets they are repeatedly circulated, and the electric field is now pulsed in the same way that you push a child on a swing each time they reach a certain point.

Magnets exert a force on the passing protons at right angles to their direction of motion and so powerful electromagnets are used to bend the beam of protons round the circle.

The booster accelerates the protons up to 91.6% of the speed of light and squeezes them closer together.

Recombining the packet from the 4 rings, its then flung on into the Proton Synchrotron – by analogy, stage 3 of our rocket.

Let's just follow two such proton packets.

The Proton Synchrotron is 628 metres in circumference and they circulate for 1.2 seconds, reaching over 99.9% of the velocity of light.

It's here that the "Point of Transition" is reached – a point where the energy added to the protons by the pulsating electric field cannot translate into increased velocity as they are already approaching the limiting speed of light.

Instead the added energy manifests itself as increasing mass of the protons.

In short: the protons can't go faster so they get heavier.

The microscopic kinetic energy of each proton is measured in units called electron volts and now the energy of each proton has risen to 25 Giga electron volts – or "GeV" The protons are now 25

times heavier than they are at rest.

The packets of protons are now channelled into stage 4, the Super Proton Synchrotron a huge ring 7 km in circumference designed specifically to accept protons at this energy and increase it to 450 GeV .

Soon, the packets of protons will be energised sufficiently to be launched into the orbit of the gigantic Large Hadron Collider or LHC which lies between the Jura mountains and the Alps and straddles both France and Switzerland.

Lying deep underground it has a circumference of 27 kilometres.

There are two vacuum pipes within the LHC containing proton beams travelling in opposite directions.

Using ultra-sophisticated “Kickers” to synchronise incoming packets with those already circulating, one vacuum pipe has injected into it protons which will circulate clockwise, and the other - protons which will circulate anti-clockwise.

The counter rotating beams cross over in the four detector caverns, where they can be made to collide. The energy of the collision is DOUBLE that of the individual opposing protons and it is the debris from these collisions that is tracked in the detectors

For half an hour the SPS injects protons. Finally, there are 2808 packets.

During this time, the LHC adds extra energy to each proton whose velocity is now so near the speed of light that it goes round the 27 km ring over 11,000 times each second getting a boost of energy at each revolution from the pulsed electric field.

Finally each proton has an energy of 7 terra electron volts. And they're 7000 times heavier than at rest.

The magnetic force needed to keep the beams bending to the ring is so enormous that nearly 12,000 amps must flow through its electromagnets.

This is achieved by making the LHC colder than outer space so that its magnets become super-conducting.

Now the protons are ready to collide in the detectors.

A steering magnet finally brings them onto a collision course.

Quiet noise

The total energy of two protons colliding in the LHC is 14 TeV and reproduces similar states to moments after the big bang.

Particle tracks from these collisions will be analysed by computers connected to the detectors and it's hoped these tracks will give a new insight into the very birth of our universe, how our universe has evolved, what governs its behaviour today, and where it is going in the future.