Hi this is Steve Nerlich from Cheap Astronomy www.cheapastro.com and this is *The first three minutes revisited.*

There's a famous popular science book written by Steven Weinburg, who's a famous physicist and a Nobel prize winner, which is called *The First Three Minutes* and is a book about the first three minutes after the Big Bang. Three minutes is significant because the first hydrogen nuclei - the first box of the periodic table - formed out of what was previously just a quark-gluon soup.

Now, it's not the place of some cheap podcast to suggest it can improve upon such a master work. I just want a quick revisit of what goes on in that first three minutes - given we are now living in the age of the Large Hadron Collider - or LHC.

So, a quick recap of the Big Bang. Something happened - we are not really sure what - and seemingly out of nowhere gravity, followed by the strong nuclear force, began to exist resulting in a huge inflation of space-time. And within a ridiculously tiny proportion of the first second, the weak nuclear and electromagnetic forces also began to exist and suddenly there was a very hot and very dense baby universe.

This baby universe was born with a huge, but finite, level of energy - so that as it expanded, it cooled. After the first second, fermions - which are particles possessing mass - were able to form. Fermions include hadrons (which is where the LHC gets its name) and also leptons, which are small particles like electrons which aren't made up of quarks - they are their own fundamental particle. Hadrons, which are made up of quarks - include baryons (like protons and neutrons) and less stable particles called mesons.

The early (and the current) universe also contain bosons - which include the force-carrying particles - like photons which mediate the electromagnetic force – and gluons which mediate the strong nuclear force, the force that binds quarks together to form hadrons. There's also W and Z bosons, let's skip them for now - and at least theoretically there's also the Higgs boson, which we'll come back to later.

What is immediately puzzling about the early universe is that from the first second, up until three minutes had passed, our universe somehow became dominated by matter.

Just as soon as hadrons appeared, nearly as many anti-hadrons also formed - and these particles and anti-particles proceeded to annihilate each other. So, as hadrons came and then left just as quickly, the universe instead became dominated by leptons - which include electrons, but also their anti-particles, positrons - and they began to annihilate themselves.

But somehow at the end of all this annihilation - at about three minutes - there was left behind - a residue of hadrons, as well as a residue of leptons. And why? No idea. Well OK, there are ideas like symmetry breaking which sounds a lot more definitive than it really is, but otherwise nothing entirely convincing has been suggested to date.

After three minutes, the universe started behaving in a more conventional manner. It was still hot and dense enough for hydrogen nuclei to fuse to form helium nuclei - which kept going for the next seventeen minutes until the universe wasn't hot and dense enough anymore. We are pretty confident this first three to twenty minute period really happened since about 73% of all the universe's elements is just hydrogen, another 25% is just helium and all the other elements combined - which were subsequently formed in stars - make up the remaining 2%.

But the first three minutes does still remains a bit of a mystery. So what can instruments like the LHC tell us about the first three minutes? Particle accelerator technology dates back to the early 1960s, where a magnetic field has been used to propel positively charged ions, which are bare atomic nuclei without their electrons - one example being fairly large lead nuclei, which the LHC will propel. Although it will also propel the smallest atomic nuclei of all – which are hydrogen nuclei, or protons as they're better known.

Particle accelerators have carefully aligned electromagnets, which gather moving particles together into a tight beam and propel them forwards. The most powerful particle accelerators use more electromagnets to direct that beam into a circular path – so the particles are accelerated over many circular revolutions until they are going really, *really* fast.

Although the particles can never move faster than light does in a vacuum, if you keep accelerating them their momentum can still keep increasing. So, even if the particles never go faster that the speed of light c, they can still develop an $e=mc^2$ load more mass and hence more momentum energy - which is a product of mass and velocity.

So even though smaller particle accelerators than the LHC can also get particles up to around 99% of the speed of light, the LHC gives them that much more momentum energy. And when you direct one beam of really fast particles into a collision with another beam of really fast particles the combined momentum energy is translated into tremendous heat energy - bringing those particles momentarily into temperature ranges that existed early on in the first three minutes of the universe.

And from this new perspective we might be able to answer some important questions like:

1. What happened to all the antimatter?

This might have something to do with the differential decay rates of matter and anti-matter particles - which might have something to do with things like B mesons – or other mesons, which do generally have a very short lifetime and are largely only seen in particle accelerators – coming out of a particle collision before they decay (often into leptons and photons). Mesons are also known as bosonic hadrons if you really want to know.

2. Does the Higgs Boson – and hence the Higgs field actually exist?

The Higgs boson idea requires that the universe is filled with a Higgs field - similar in scope to the electromagnetic field that pervades the universe and that allows photons to relay electromagnetic energy - say from a supernova explosion all the way to your telescope.

Now, the Higgs boson would act like a tiny parachute that's attached to any massive particle - so that as that particle moves through the Higgs field, the little Higgs boson parachute creates drag on the massive particle giving it the quality of mass and of inertia. On the other hand, a photon – which has no rest mass, can be assumed not to have one of these little Higgs parachutes and can hence just zip through the Higgs field at the speed of light - which is just what photons are want to do

Theorists are confident that the LHC easily has the energy to split off a Higgs boson. So either we will see it and Peter Higgs gets a Nobel prize – or its existence will be essentially disproved - sending everyone back to the drawing board.

The breaking news at the end of 2011 was the discovery of the Chi-b 3P particle – which is a meson made up of a bottom quark and a bottom anti-quark - and hence could be called bottomonium if you felt so inclined. You might recall that mesons are also called bosonic hadrons, so the Chi-b 3P particle is technically a boson - but certainly nothing like the Higgs boson, which if it exists should be a fundamental particle. That is, it wouldn't be made up of quarks.

The Chi-b 3P particle was always predicted to exist, so its discovery is another indication that the Standard Model of sub-atomic particle physics works – and perhaps this makes it a bit more likely we will find the Higgs Boson, which is what the Standard Model also predicts should happen.

Thanks for listening. This is Steve Nerlich from Cheap Astronomy, www.cheapastro.com. Cheap Astronomy offers an educational website where we go around and around. No ads, no profit, just good science. Bye.