# The Accelerators and the Big Bang


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TABLE I
BASIC FORCES AND ITS MEDIATORS

| force | mediator | mass (GeV/c$^2$) |
|---|---|---|
| strong | gluons | 0 |
| electromagnetic | foton | 0 |
| weak | $W^+$, $W^-$, $Z^0$ | 80,4; 80,4; 91,2 |
| gravitation | graviton | 0 |

TABLE II
THE THREE GENERATIONS OF THE ELEMENTARY PARTICLES

| 1. | 2. | 3. |
|---|---|---|
| $u$ | $c$ | $t$ |
| $d$ | $s$ | $b$ |
| $e$ | $\mu$ | $\tau$ |
| $\nu_e$ | $\nu_\mu$ | $\nu_\tau$ |

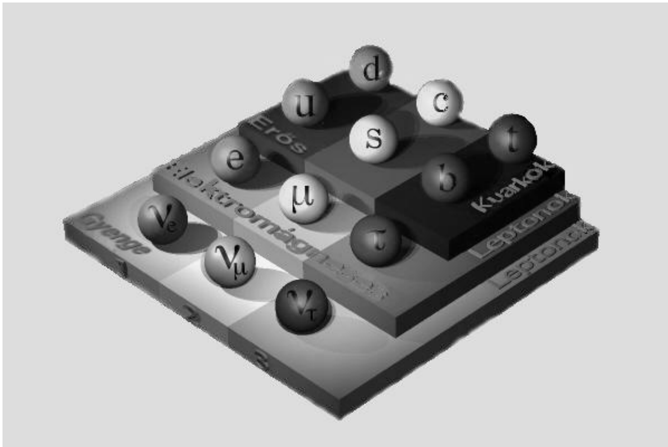


Fig. 1. The connection between the particles and forces.


***Abstract*—**


## I. The basic forces and the Standard Model

All the forces come from the four forces: strong, electromagnetic, weak and gravitation. For example the force of the the spring is derived from the electromagnetic forces between the atoms of the spring. These four forces acts between elemantary particles by mediator particles. According to the Standard Model of the particle physics there are 12 types of elementary particles. Elementary means they can't be break into smaller parts. From the 12 particles there is 6 leptons and 6 quarks, and all the 12 particles has antiparticles.

In the Table I we see the elementary particles. We can sort them into three generations. In the upper two rows we can see the quarks, in the other two rows the leptons. In all the rows the particles are heaviest from left to right. The two easiest from the 6 quarks are the *u* and the *d* (up and down) quarks. They builds up the protons and the neutrons. There are no free quarks, they are confined into particles called hadrons. The electron and its two heaviest 'relatives': muon ($\mu$) and the tau-lepton ($\tau$) belongs to the leptons, and the three types of neutrino, too.

On the Figure I we can see what sort of force on what types of particles acts. The strong force acts between the quarks, and the hadrons built up from quarks, and is mediated by gluons. The electromagnetic forces acts between the particles in the first three lines. The weak force and the gravity acts on all 12 particles.

## II. The Big Bang and the Accelerators

Once upon the time the Universe was very hot and high density. And at about 13.8 billion years ago the time and the Universe was born, and the Universe began to expand. There is more evidences of this event, the so called Big Bang.

How can we investigate the earlier state of the Universe. It was hotter than now. Higher temperature means that the particles moved faster, and collided with higher energies. How can we reach such a high energies. We have two possibility. We can investigate the cosmic ray. Sometimes we get very energetic particles but not many. The other way, to build accelerators, and give the particles energy.

If an electron goes through 1 V potential from the negative cathode to the positive anode it get some energy, called one electronvolt abbreviated as 1 eV. We can't reach more than millions of Volts of potential, so one could think, that we can't reach more energy, than some million (=mega) electronvolts, some MeVs. But in the syncrotrons – and some other accelerators – the electron or other charged particle goes through this potential many times.

Synchrotron is a particle accelerator in which the particles goes in circular vacuum tubes, so it can goes through the potencial as many times, as many circles it take (we ought to use alternating current to that). So one could think we can reach as high energy, as we want; we can calculate how many times must the particles goes through the potential to get a given energy.

But there are some limits. First of all we should make clear, how can we get a circular path. It is easy. The path of a charged particle in homogen magnetic field is circle, if the velocity of the particle is peripendicular to the $\bar{B}$ vector of the field. The $r$ radius of the path is depends on the $p$ momentum of the particle and on the value of the $B$ and from the $q$ charge of the particle.

The centripetal force is given by the Lorentz force, so

$$m\frac{v^2}{r} = qvB, \Rightarrow p = Mv = qBr,$$

where $M$ is the relativistic mass of the particle, which depends on the $v$ velocity of the particle and the $m$ rest mass (or invariant mass) as

$$M = \frac{m}{\sqrt{1-\frac{v^2}{c^2}}}$$

With superconducting technology we can reach some teslas magnetic field and we can create tens of kilometers long tunnel for the synchrotrons. $B$ and $r$ are limited, so the $p$ momentum and the energy as well.

The Large Hadron Collider will be the more energetic accelerator ever built. Proton will collide with proton in four point of it, in the four experiments. It will begin its work next year, in 2007. Its bending magnets has $B = 8.33$ maximum value, and its circumference is 27 kilometers. In it the protons will reach the 7 TeV=7000 GeV=7000000000000 eV. We can calculate, how high temperature is it mean. In a gas of $T$ absolute temperature each molecule of gas have the

$$\varepsilon = \frac{1}{2}kT$$

energy in average in all degrees of freedom (3 for the movement in the 3 directions $(x,y,z)$ and can be maximum 3 for rotation and some for vibration), $k$ is the Boltzman constant. With 7 TeV energy is about $1.6\times10^{17}$ kelvins of temperature, the Universe coold down to this temperature circa in $10^{-6}$ seconds after the Big Bang.

## III. The stages of the Big Bang

First of all lets see what happens if we increase the temperature of the water. At 100 $^{O}$C the water becomes gas, at more higher temperature the molecules will broken then atoms will loose their electrons, like gases in the energy saving (phosphorescent) lamps. After that there are stranger processes, the protons and the neutrons break into quarks and other changes (other phase transitions) happen which needs a lot of knowledge, what are more difficult to mention here, but we have well established model which describes this.

TABLE III

General Parameters of LHC

| | |
|---|---|
| Circumfrence | 26.659 km |
| Proton energy at collisions | 7 TeV |
| Dipole field at 7 TeV | 8.33 T |
| Protoncurrent | 0.56 A !! |
| Number of bunches (each directions) | 2835 |
| Protons/beam | $1,1\cdot10^{11}$ |
| Lifetime of luminosity (reduce to 1/e) | 10 hours |
| Losted energy /cycle | 6.7 keV |
| Energy of the beam | 350 MJ !! |

In the process of the Big Bang the state of the matter changes in the opposite direction. We have well established model which describes what have happed after the $10^{-43}$-th second of the Big Bang. For earlier states we need the theory of the quantumgravity – the unified theory of the quantum mechanics and the general relativity, what we have not yet. The later stages of the Big Bang we can describe quite good. From the $10^{-6}$-th second the quarks are closed into bigger particles, such as protons and neutrons. To the 3-rd minute the atomic nuclei are formed, mainly hydrogen, helium and deuterium. 300000 years after the Big Bang the nuclei catched the electrons to form atoms, the Universe got transparent for the photons. In 1948 George Gamow realised that the “light” of it could be visible on the night sky as a 2.7-kelvin blackbody radiaton described by Planck law. Some years later Arno Penzias and Robert Woodrow Wilson found it and got Nobel Prize for their discovery of that cosmic microwave background radiation. This was the first evidence of the Big Bang theory. From that time stars and galaxies are formed, and in the stars haviest atoms are formed in the process of nuclear fusion.

We have not speak about an important thing. Why is more matter in the Universe as antimatter? It is an important thing for astrophysicists and particle physicists.

The accelerators are help us to test our models and answer some basic questions, such as the previous one.

## Bibliography


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