Abstract: Rutherford and Hess experiment, in the first years of the XX century, mark the beginning of the experimental Particle and Astroparticle Physics. In the next one hundred years many, many discoveries were made, and we have now a much deeper understanding of the elementary constituents and of the fundamental interaction of the Universe. However, we know now at the beginning of the XXI century that most of the Universe (~95%) is filled by mysterious entities, we have almost no idea about the dark matter and the dark matter energy.

The present and future experimental program of Particle and Astroparticle Physics is ambitious and we may hope for considerable progress in the years to come. A short review of the participation of the LIP Portuguese teams in such program is briefly described.

Key words: Particle Physics, Astroparticle, Cosmic Rays, LHC, Auger, Dark Matter, Dark Energy.

1. EXPERIMENTAL PARTICLE AND ASTROPARTICLE PHYSICS

Experimental Particle and Astroparticle Physics were born in the beginning in the XX Century. The Rutherford / Geiger / Marsdem experiment (1909-1912) can still be considered the paradigm of a Particle Physics Experiment: A beam of particles collides with a target and one’s
observes what and how get’s out! With such a simple scheme the structure of the atom was discovered. The beam was an $\alpha$ particle from a radioactive source; the target a thin gold sheet; and the detector a fluorescent screen. Nowadays the primary beams, mainly protons or electrons, are accelerated by, many kilometre devices and the detectors are huge and complex. But the principle still applies.

At the same time (1912-1914) Victor Hess, in a series of balloon flights, proved the existence of particles coming from the skies. In fact the intensity of the mysterious radiation that ionizes the air, increases with altitude and does not depend on the day or night. Some years later this radiation was named “Cosmic Rays” by Milikan.

All around the XX Century many, many discoveries were made. Just two striking examples: In 1933 Anderson discovered, in a cosmic ray experiment, the existence of a particle with the same mass and absolute charge of an electron, but curving in a magnetic field in the opposite direction. The antimatter, predicted just a few years before by Dirac, was discovered! In the 80’s, at CERN, the electroweak bosons, $Z^0$, $W^+$ and $W^-$, were first discovered and then hugely produced. A big step towards the unification dream of all the interactions was made.

In the last year of the XX century, for some physicists, Stephen Hawking on the top, the game seemed almost over. We know already that atoms are made of electrons, protons and neutrons, that protons and neutrons are made of quarks, that there are three families of quarks which can combine between themselves (and with its anti-partners – the antiquarks) to form a myriad of the so called elementary particles (hadrons and mesons). Besides the quarks, the framework of the constituents of the Standard Model also includes three lepton families (of electron type particles and neutrinos) and gauge bosons responsible for the fundamental interactions.

Three of these fundamental interactions (electromagnetic, weak and strong) can be described by elegant theories, based in symmetry principles which have the same mathematical structure, and thus can be unified in a single and final theory. The unification of gravitation with the other three interactions is not easy (no one knows yet how to build a realistic quantum gravity theory) but this aim is actively pursued namely by the string theoreticians.

But there are a few problems…

First of all the introduction of the particle masses in the theory. Particles do have mass and its values covers a extreme wide range (from zero, the photon, or just a few decimals or centesimal of electron Volts, the neutrinos, to the hundreds of giga-electron Volts, the top quark).

Peter Higgs, in the early 60’s created a mechanism to “give” effective masse to massless particles. These effective mass would be the result of the