ISAPP 2012 lecture
Cosmic ray detection

Victor Hess' balloon flight on 7 August 1912 was the beginning of one of the most extraordinary adventures in the history of science. Investigations of "the radiation of very great penetrating power entering our atmosphere from above" (known today as "cosmic rays") opened up the new world of high-energy physics and revealed new vistas in astrophysics and cosmology. In the effort to explain the origin of this radiation – whose spectrum covers more than 16 decades in energy -, physicists have developed not only a number of ideas about its nature, but also an arsenal of instruments, detectors, experimental techniques. The latter aspect will be the object of my lecture.

As a tribute to the centennial of Hess' discovery, the first part will be devoted to a historical review of the main detectors that have accompanied the growth of cosmic ray physics: from Wulf electroscopes that marked their discovery, to the time resolving single particle detectors (Geiger counters) and electronic circuits (Rossi coincidence). Tracking and high-resolution techniques (as cloud chambers, nuclear emulsions) represent examples of other families of detectors that have marked the development of cosmic ray physics (and also of particle physics). The electronic revolution, stimulated by the second World War, finally transformed cosmic ray detection, with the introduction of electronic methods of detecting particles by their electrical or light pulses (e.g., photomultipliers, scintillators, Cherenkov counters).

Besides the large extension in energy of the spectrum of cosmic rays, another "problem" is their paucity, increasing as their energy increases. Up to a certain energy and flux, detecting more particles is quite simply a matter of using larger apparatus for longer times. In the second part of my lecture I will show how airborne equipments in cosmic ray studies have evolved to long-duration balloon flights and satellite-borne hardware weighing many tons. These allow a direct identification of primary particles in terms of energy, mass and charge.

The "space-based" technique is well suited just up to about 10^{14} eV. At higher energies the rate of the primary radiation becomes simply too low. Fortunately, the Earth's atmosphere comes to our rescue. After a high-energy collision in atmosphere, a cascade develops until million (or even billions) of particles arrive at ground. All of these particles form what is known as an Extensive Air Shower (EAS). The final part of my lecture will be devoted to explain how the highest energy cosmic rays can be detected on Earth, even though only a handful of them arrive each year. It will also show the delicacy of this kind of indirect measurement. Inferring from an EAS the properties of the primary particle requires different detectors for the different EAS components, from the electromagnetic to the muonic and hadronic ones. Arrays of scintillators, Cherenkov counters or fluorescence telescopes are in widespread use, often all together. The Pierre Auger Observatory, the largest EAS array ever built in the world, will be used as an exemplary case, both from the point of view of detection and reconstruction principles.