

PHYSICS OF HIGH-ENERGY PARTICLE DETECTORS

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1 PHYSICS OF HIGH-ENERGY PARTICLE DETECTORS

The basic philosophy of teaching elements of high-energy particle detectors is the inter-disciplinary character of this research. The physics of detectors is interesting because of several reasons:

- 1) It is an occasion to approach important disciplinary arguments (interaction of particles with matter, charge EM-interactions, relativity...)
- 2) The outcome of the research, i.e. discoveries in the field of elementary particles are one of the most fascinating, border-line research.

For example, the electromagnetic radiation and elementary particles interact with the matter in a complex way, at different energies causing different effects, as shown in the figure below.

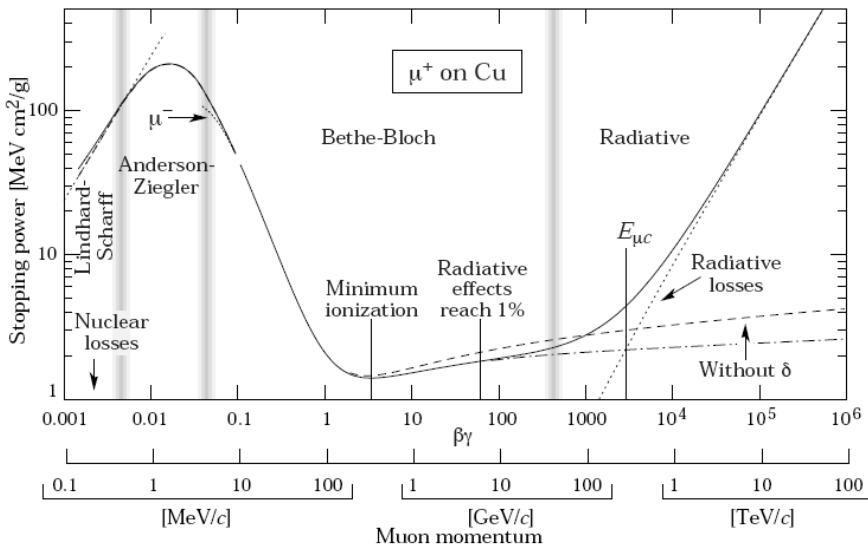


Figure 1 Interaction of the antimuon μ^+ with solid copper target vs. kinetic energy of colliding μ^+ .

This richness of physical phenomena makes the choice of the detector vast, specific to the kind of detected particles, their energy range, and the kind of the physical property of the particle we are interested in (energy, momentum).

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In gaseous detectors, an electric field is applied to a filling gas (usually a mixture argon – ethane). Charges produced by ionization in the gas, separate in order of their sign and migrate (drift) along the field lines toward the opposite sign electrodes (electrons drift faster and are used to define an electric signal).

A semiconductor detector is essentially a diode reverse-biased by applying an external voltage. A charged particle passing in the depletion region around the junction produce electron- hole pairs and the charged is collected at electrodes on surface of the semiconductor.

Scintillators have been in use since the beginning of 20th century, making use of the property of certain chemical compounds to emit short light pulses after excitation by the passage of charged particles or by photons of high energy. Scintillating materials can be *organic* (solid crystals, plastics, i.e. synthetic polymers, or liquids), or *inorganic* (crystals or glasses) and they are characterized by good signal linearity and fast response (down to 1ns). The light produced in the scintillation is collected by light guides and converted to an electric signal by photomultipliers, a device that uses the photoelectric effect to generate electrons, that are amplified by means a multiplier chain of secondary electron emission by absorbers and accelerating electric fields.

In modern research, all these methods are applied “in stack”, to track possibly complete information on the properties of detected particles, as shown on the picture below.

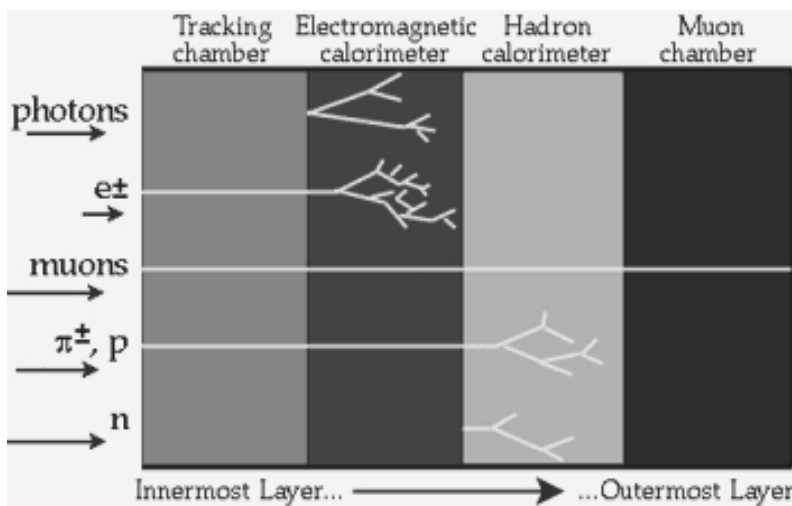


Figure 2 A stack of several detectors for tracing different particles produces in high-energy collisions.

Possible introducing elements of physics of particle detectors into school activity comes through collaboration with great research centers, like CERN, or virtually like FermiLab. All these projects offer “hands-on” not only on disciplinary arguments of HEP, but also on instruments, methods and technology involved in

the related research. We quote below just one example of such collaboration frameworks developed in Italy “Extreme Energy Events”.

EEE Extreme Energy Events

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EEE EXTREME ENERGY EVENTS

Antonio ZICHICHI
Università di Bologna, CERN, Centro Fermi, FCCSEM, VFS

The Project

The main task of the Project is to understand where, when and how the primary (protons or nuclei) cosmic rays form, as being the original ashes of the Big Bang and travel billions of years starting from the most remote regions of the Universe, much farther than the Moon, the Sun and the stars visible by naked eye. When a cosmic proton encounters a layer of matter, in particular the Earth's atmosphere, it interacts with the nuclei of which the matter itself is composed. During this interaction, particles of the Subnuclear Universe are produced, very short-living (fractions of billionth of a second). During such a short life they transform in other particles whose last stage are the so-called muons. At sea level, the most part of the electrically charged component of the cosmic rays is made of muons. The very high energy primary cosmic protons produce extensive "showers", made of numerous muons (more and more as the primary's

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Figure 3 Example of educational web-sites in the field of high-energy particle detectors.