Particle Detectors
KLOE

WHAT IS A PARTICLE DETECTOR?

A particle detector is an apparatus for capturing particles produced in collisions and measuring their characteristics.
Observing a particle is equivalent to detecting the effects of its interaction with the detection apparatus.

WHAT IS KLOE?

Kloe (K LOng Experiment) is a particle detector located at one of the **DAΦNE** accelerator's two interaction regions. Because it is designed to study rare phenomena with very high precision, the detector has extremely advanced technical characteristics.

HOW IS A PARTICLE DETECTOR MADE?

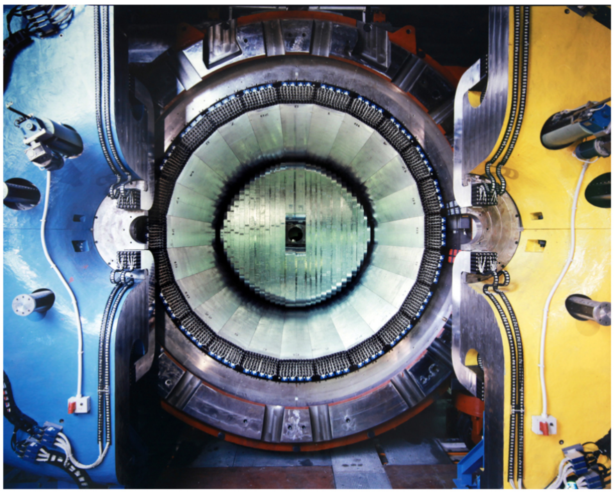
Since different types of particles interact with matter in different ways, the detection apparatus is generally comprised of several individual detectors, each with different characteristics according to the type of particle to be detected.
The quantities that are generally measured include:

- Energy
- Charge
- Velocity

A typical detector consists of a tracking system to reconstruct the interaction point and the trajectories of charged particles, as well as a device called a calorimeter to measure the energy released by both charged and neutral particles. The whole detector may be immersed in a magnetic field, which allows the charges of the particles to be determined based on how their trajectories are curved in the field. In addition, for charged particles, the curvature of the trajectory is proportional to the particle's velocity.
By combining the information obtained from these measured quantities, it is possible to identify the particles and reconstruct the event.
One type of tracking system consists of wires high voltage immersed in a gas.
When a passing particle strikes the atoms of the gas, it creates an electrical disturbance that is sensed on the closest wire. The measurement of the signals from the different wires allows the trajectory of the particle to be reconstructed.
A calorimeter is generally made of an active material that serves to measure the signal left by the passage of a particle, and of a passive material that helps to slow down the particle.

WHAT IS KLOE FOR?

Kloe is a typical "multipurpose" detector, that is a detector capable of performing several different measurements. With Kloe we can study in detail the invariance properties of the fundamental physics laws. Actually, the equations with which we describe the interactions among elementary particles have the property to remain unchanged if one applies on them well defined mathematical operations.
For instance the parity transformation (P), which changes the direction in space; charge conjugation (C), which transforms particles into antiparticles and vice versa; time reversal (T), which changes the direction of time.
All of the reactions of production and decay of the known elementary particles must respect this invariance property, which, in the practice, transforms in the fact that some specific reactions are allowed but others are not.



With Kloe we search for this kind of forbidden reactions, to measure at which level of precision the abovementioned invariance laws are respected. In nature it exists a small but very important exception to this rule, which has been observed in some specific decays of the K and B mesons that are not invariant under the simultaneous transformation of P and C. The latter is the so called CP symmetry violation, observed for the first time in 1964 and required to allow our Universe to be composed by matter and not by antimatter.
According to the theory of the Big Bang, our primordial Universe consisted of particles and antiparticles in equal amounts, that must behave symmetrically. If this is not the case, then there is a broken symmetry, which leads to the dominance of one type over the other. Each ϕ particle produced by DAΦNE in an electron-positron collision, decays, within an infinitesimal time, into two neutral particles called kaons, which, having different lifetimes, are referred to as K_L (K-long) and K_S (K-short).
It can be shown that, if the symmetry between matter and antimatter were perfect, K_L's would always decay into three pions, while K_S's would always decay into two. It has been observed, however, that about one time in a thousand, the K_L decays into two pions, and theory predicts that the K_S decays into three pions about one time in a billion. The goal of the Kloe experiment is to study this type of phenomenon. Since these types of decays are so rare, to study them, one needs a very large number of produced particles, as well as an extremely sensitive detector.
Kloe looks also for new hypothetical particles, the so called dark photons, which are required by some theories trying to explain the actual nature of dark matter, that is of that part of our Universe of which we infer the existence by astrophysics measurements, but that is not composed by any of the elementary particles observed in our laboratories so far. Since dark matter fills the Universe in a 5:1 ratio with respect to the ordinary matter, understanding its actual nature is one of the main goals of modern science.

HOW IS KLOE MADE?

Kloe is a cylindrical apparatus with a diameter of 7 m and a length of 6 m that surrounds the interaction point of electron and positron beams. The dimensions of the detector were chosen to allow the K_L's produced in the interactions to be captured.

The apparatus consists principally of two elements:

- Drift chamber (tracking system)
- Electromagnetic calorimeter.

Both are placed inside of a magnetic field.

The drift chamber, which has a diameter of 4 m and a length of 3.3 m and contains 52,000 wires, is the largest ever constructed. It can reconstruct particle trajectories with a precision of 0.3%.
The electromagnetic calorimeter is a cylinder 4 m in diameter and 4.5 m in length, and consists of alternate layers of scintillating fibers (active medium) – for a total of 15,000 km - and lead (passive medium) which measures the energy released by particles with a precision of about 15%.
The light signals left in the fibers are converted into electrical signals and amplified by 4880 photomultipliers. The fundamental characteristics of the calorimeter are related to its very high timing precision (0.0000000002 s), which is necessary for measuring the velocities of neutral particles.
Kloe can measures 2000 events each second.