INFN
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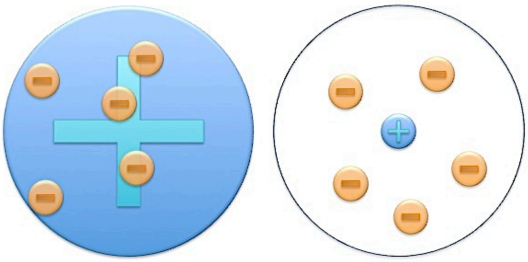
THE NA62 EXPERIMENT

MODELS OF THE PHYSICAL WORLD

The goal of physics is to discover the principles that give rise to the phenomena observed in nature.



Atomic models of Thomson and Rutherford

Sometimes, in the quest to reach this goal, it is useful to summarize what we already know about a given phenomenon by a simplified representation, or model.
One of the most famous models ever used in physics is Rutherford's model of the atom, in which the atom is depicted as having a tiny nucleus of positive charge, with a cloud of negatively charged electrons orbiting around it. This model superseded Thomson's model of the atom, in which the electrons were represented as wandering around inside a positively charged cloud. This came about because of Rutherford's 1911 experiment, the results of which could not be explained by Thomson's model. The models used to describe the atom were visual representations of objects too tiny to be directly observed.

THE STANDARD MODEL

The most basic constituents of matter and their interactions are described by the so-called Standard Model (SM). The SM postulates the existence of a small number of elementary particles, which interact via three of the fundamental forces to give rise to the universe as we know it. Moreover, the Standard Model can predict quantitatively the probability for a certain phenomenon to occur. Like all models hypothesized to date, the Standard Model only explains some of the phenomena that occur in nature. It does not, for example, describe gravity. Nor does it explain the existence of the so-called *dark matter* that seems to make up much of the universe.
On the other hand, the SM has furnished extremely precise predictions for the results of many, many experiments. A very important example is the prediction of the masses of the particles that mediate the weak nuclear interaction (W^+, W^-, Z^0), the discovery of which led to the award of the Nobel Prize to Carlo Rubbia (together with Simon van der Meer) in 1984.

THE LIMITS OF MODELS

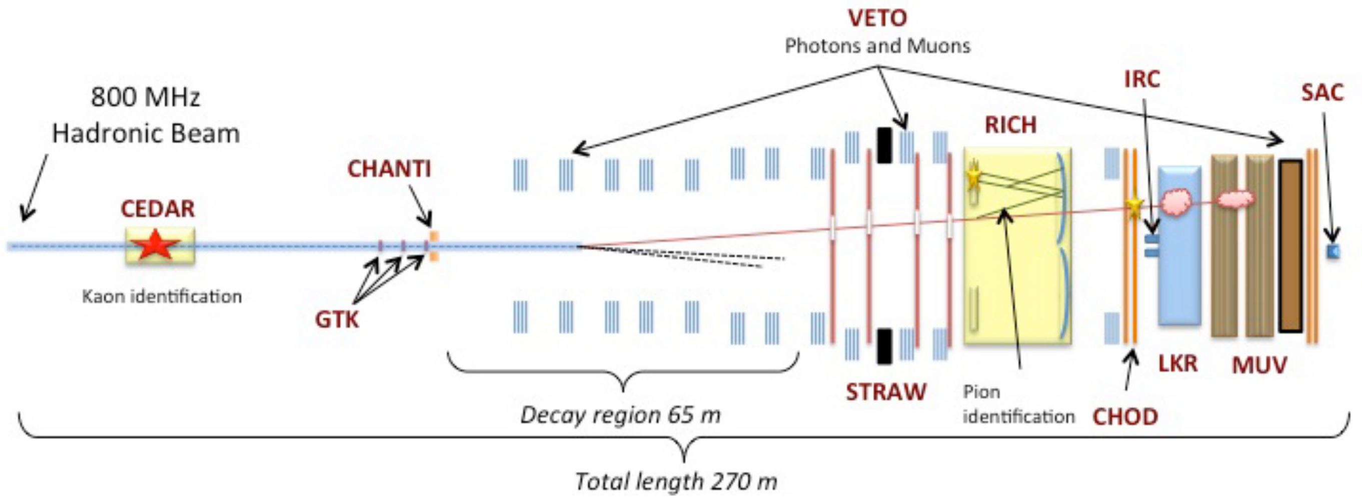
The physicist's job is to improve on the existing models of nature to obtain predictions of higher and higher precision. To that end, theoretical physicists create ever more intricate models, while experimental physicists devise ever more stringent tests to find the weaknesses of those models. Paradoxically, the weak points of a given model are usually searched for by probing the strongest claims that the model can make the results that the model most accurately predicts.

THE PHYSICS OF RARE PROCESSES

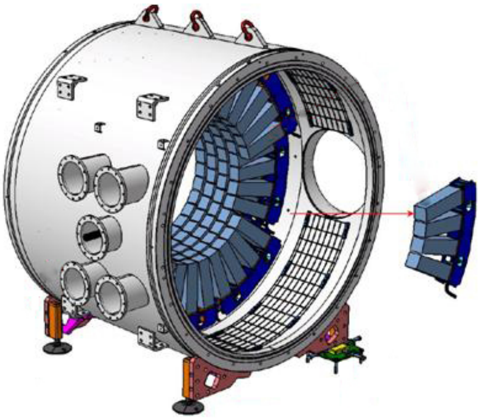
The SM is based on existing particle physics data, so to challenge it, processes predicted to occur but which are as yet unseen must be witnessed, in the hopes of measuring the parameters that describe them and obtaining values different from those predicted. The term "new physics" is used to describe phenomena that current models cannot explain. There are two ways to search for new physics. One way is to make available higher and higher energies for the production and observation of new particles. A famous example of physics at the "energy frontier" is the search for the Higgs boson at the LHC at CERN. The other way is to look for physical processes so rare that they have never before been observed, or alternately, to measure with higher and higher precision the parameters that describe known processes. For this second approach to be useful, the processes must be predicted precisely by the SM, so that a deviation from the prediction constitutes an unambiguous sign of new physics.

THE NA62 EXPERIMENT

NA62 is the 62nd experiment to be conducted in the North Area of the Super Proton Synchrotron at CERN, in Geneva. The goal of the experiment is to measure the branching ration, or probability of occurrence, of an extremely rare decay: that of a positively charged kaon into a positive pion, a neutrino, and an anti-neutrino $K^+ \rightarrow \pi^+ \nu \bar{\nu}$. This probability is predicted very precisely by the Standard Model, in part using the results of very-high-precision measurements of other decays



made in the past. NA62 will collect data from 2014 to 2016. During these two years, 5000 billion kaons will decay in the experiment, but of these, only 1000 will decay into a pion, a neutrino, and an anti-neutrino. Meanwhile, the vastly larger number of kaons decaying into other particles will most often produce at least one photon (γ) or muon (μ). By spotting these other particles, the scientists of NA62 will be able to recognize and count the interesting kaon decays.



The NA62 charged kaon beam has a mean energy of 75 GeV, which means that on average, kaons in the beam decay after 600 m of flight. To enclose as many kaon decays as possible, the NA62 experiment is very long—270 meters. Powerful pumps maintain the inside of the decay tube at high vacuum (10^{-6} mbar). The NA62 experiment is comprised of many different detectors (see figure above), each of which serves a different purpose in distinguishing $K^+ \to \pi^+ \nu\bar{\nu}$ decays from the others. The primary kaon is identified using the CEDAR, a detector that makes use of the Cherenkov effect (the emission, under special conditions, of light in traversing a material), and tracked by the Gigatracker (GTK), a silicon pixel detector. Kaons may interact in the GTK to produce spurious particles; these are seen and rejected by the CHANTI. The secondary particles are tracked in the STRAW chambers and identified as pions by another Cherenkov detector, the RICH. In addition, all decays containing at least one photon (γ) must be rejected with a high degree of confidence by the LAV, LKR, IRC, and SAC detectors. Likewise, redundancy for the precise rejection of the enormous number of decays containing muons (μ) is provided by the muon vetoes (MUV) and the charged-particle hodoscope (CHOD).

The researchers and technicians of the NA62 group at the Frascati Laboratories are responsible for the construction of one of these detector systems: the large-angle photon vetoes.

THE LARGE ANGLE VETOS (LAVs)

The LAV system consists of 12 different detectors. Each detector is a cylindrical steel vacuum vessel lined with four or five rings of lead-glass blocks, with each block coupled to a photomultiplier tube, as seen in the figure. The different detectors contain from 160 to 256 blocks, are from 2.2 to 3.1 m in diameter (the downstream detectors are larger) and weigh from 10 to 15 tons. The lead-glass blocks were obtained from OPAL, a decommissioned LEP experiment at CERN.

How does a lead-glass photon detector work? When a charged particle passes through the lead glass, it emits light via the Cerenkov effect. This light is reflected onto the photomultiplier tube and converted into an electrical signal. The signals from all 2496 tubes are converted into digital signals by specialized electronic circuits. Finally, these signals are recorded and processed by a high-speed computer network, and combined with information from the other NA62 detectors.

When a sufficient number of events has been acquired, the NA62 scientists will analyze them, and using advanced computing techniques, will determine the branching ratio for the decay $K^+ \to \pi^+ \nu\bar{\nu}$, hopefully shedding new light on physics beyond the Standard Model.