Limiting velocity-light speed and special relativity

Riferimento alle Indicazioni nazionali e al programma

Nelle Indicazioni nazionali del liceo scientifico, relativamente alla Fisica per il quinto anno, è specificato che: *"Lo studio della teoria della relatività ristretta di Einstein porterà lo studente a confrontarsi con la simultaneità degli eventi, la dilatazione dei tempi e la contrazione delle lunghezze; l'aver affrontato l'equivalenza massa-energia gli permetterà di sviluppare un'interpretazione energetica dei fenomeni nucleari…"*; nel decreto ministeriale in riferimento al colloquio orale e al progetto CLIL è specificato che "*per quanto concerne le conoscenze e le competenze della disciplina non linguistica (DNL), veicolata in lingua straniera attraverso la metodologia CLIL, il colloquio può accertarle in lingua straniera qualora il docente della disciplina coinvolta faccia parte della commissione di esame in qualità di membro interno*"; nella relazione di lavoro annuale svolto, che è parte integrante del documento del consiglio di classe, è indicato il tema della relatività speciale di Einstein, trattato con il dovuto rigore matematico e con moduli CLIL in lingua inglese.

LIMITING VELOCITY-LIGHT SPEED

The *Large Hadron Collider* (LHC), at the CERN facility close to Geneva, Switzerland, is the largest and most **powerful particle accelerator** in the world. The LHC is an enormous 27 km **ring** that is a maximum of 175 m under the mountains on the French/Swiss **border**.

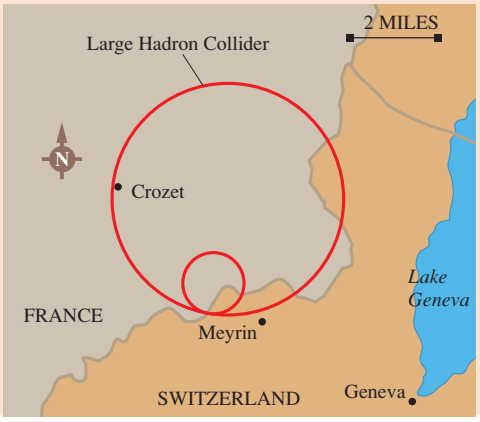
What happens at this **facility**?
Two beams of very high energy (7 TeV) **protons** circulate around the 27 km of tunnels in opposite directions. When they **collide**, scientists study the many other particles that are produced. The velocity (vLHC) of the protons in the LHC is very close to the speed of light, c. In fact, it is:

$$v_{LHC} = 0.999\ 999\ 991c$$

The difference between vLHC and c is around 10 kilometres per hour; very, very small. However, the proton will never move at the same velocity as light.

No machine will ever be able to give the proton the necessary extra 10 km an hour. Why? Well, we know the answer. According to the *theory of relativity*, a body with a mass of more than 0 cannot be accelerated to the speed of light. The speed of light is the *universal limiting velocity*. This simple fact is a crucial part of the theory of relativity.

Many experiments have tested this theory. One of the most precise tests studied **cosmic rays**. The observation of very high energy electrons in cosmic rays allows us to discover if they travel faster than c.
This analysis concluded that **electrons** in cosmic rays travel almost exactly at c. This result was observed with a precision of one part in one million billion. Scientists have also studied *neutrinos* to test the theory of relativity. Neutrinos have almost zero mass and they can travel very long distances because they do not react with other particles.

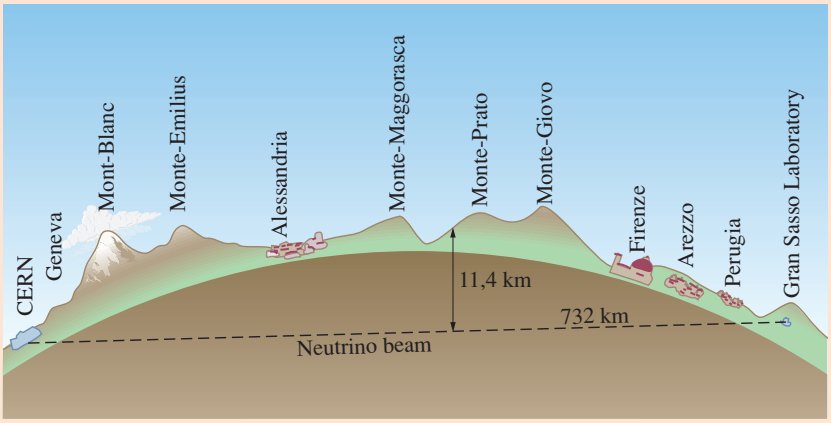


A map to show the position and size of the LHC. The 27 km of tunnels are mostly in France.

In theory, we can calculate a neutrino's speed by measuring the distance that it travels and in a certain time. We could then compare this velocity with the speed of light.
A similar experiment has been performed by a collaboration between two important scientific groups; CERN in Geneva and Laboratori Nazionali del Gran Sasso in Italy. This is called the OPERA collaboration. In this experiment, neutrinos were fired from a source at CERN and **detected** by scientists at Gran Sasso. That's a distance of 732 km and the neutrons arrived after only 2.43928 ms. That's very fast! Initially the scientists thought that the neutrinos travelled faster than the speed of light; however, they did the calculations again and **realised** that they made a **mistake**.

The neutrinos were travelling very close to the speed of light, but not faster!

We have also observed neutrinos that are not on Earth. In 1987, scientists observed the explosion of a supernova in another galaxy (called the *Large Magellanic Cloud*) which is 150 000 light years away.
This means that the explosion happened 150 000 years before 1987! The explosion produced an enormous number of neutrinos. Around 20 of those neutrinos arrived at three observation stations on Earth. Their calculations showed that the neutrinos travelled at the same speed as light, with a precision of one part in a billion.



A graphical representation of the OPERA experiment.

The Large Magellanic Cloud galaxy which is 150 000 light years away.

Competenze da sviluppare, conoscenze di base, eventuali collegamenti

Starting from the provided document, the candidate should present a complete analysis regarding the impossibility for a particle to travel faster than the speed of light. Appropriate scientific language and correct mathematical formalism are required. The candidate may expand the dissertation with a brief explanation of the theory of special relativity and its implications.