Beam Stability and Life Time in Low Energy Storage Rings

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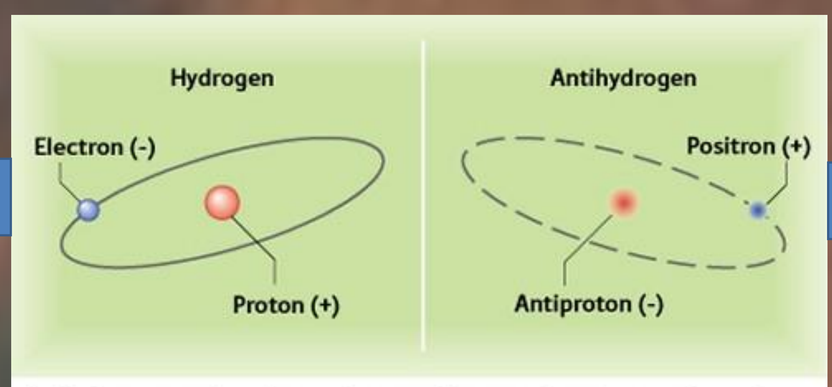
Antimatter

In 1928 Paul Dirac predicted the existence of particles with negative energy solution: they called them *antiparticle*s. They are 'mirror images' of particles: same mass but opposite electric charge (and other quantum numbers). For example the positively charged positron is the antiparticle to the negatively charged electron.

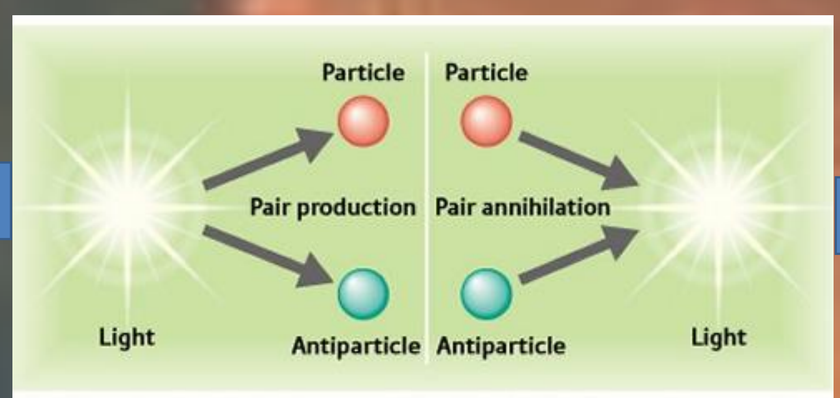
In the heart of an atom of matter, called the nucleus, are protons (which have a positive electrical charge) and neutrons (which have a neutral charge). Electron occupy orbits around the nucleus



Antihydrogen consists of an antiproton with a negative charge and a positron with a positive charge.

Antimatter instead is made up of antiprotons, positrons and antineutrons

Pairs of particles and their antimatter counterparts can be produced from high-energy collisions, in which the excess of energy is converted into mass. Positrons are commonly produced in radioactive processes



Particle and antiparticle pairs are produced from light. Conversely, upon collision of a particle and an antiparticle, pair annihilation occurs to produce light.

When a particle and its antiparticle meet, the two annihilate each other and all their mass is converted into energy

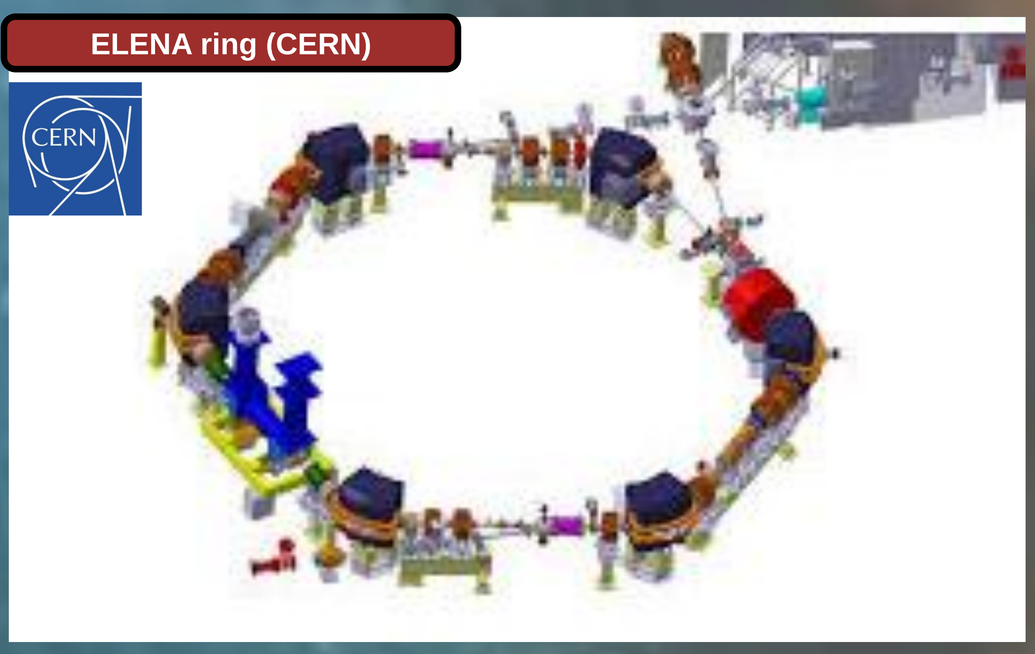
The matter-antimatter asymmetry problem

Physics' standard model says that when the universe came into being at the Big Bang there should have being created matter and antimatter in equal amounts. The interaction between the two should have led them to annihilate, leaving nothing but energy behind. But today, everything we see from the smallest life forms on Earth to the largest stellar objects is made almost entirely of matter.
There are two plausible solutions to this mystery.

Annihilation could not have been total in those first few seconds: somehow, some matter and antimatter were prevented from interacting. The residual antimatter could be somewhere far away completely isolated from the universe we observe.

The more popular explanation is that there might be some subtle difference in the physics of matter and antimatter that left the early universe with a surplus of matter.

ELENA ring (CERN)



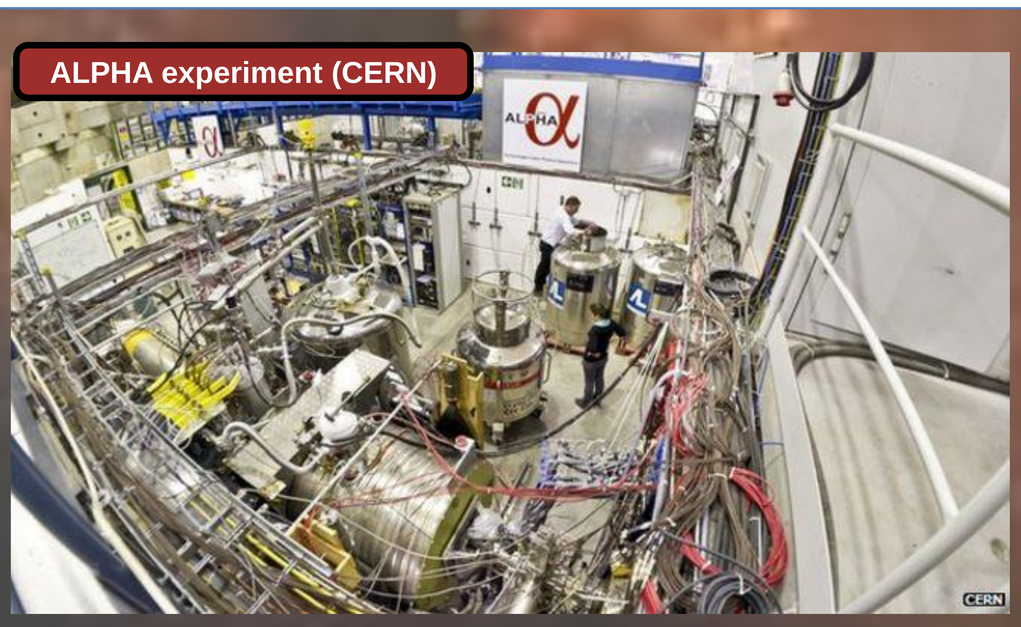
Why low energy storage rings?

In order to be able to produce antihydrogen and compare its behaviour with the regular hydrogen and possibly find the source of the asymmetry, antiprotons with very low energy are needed. The slower they are, the easier it is for the CERN antimatter experiments to study and manipulate them. The small **E**xtra **L**ow **EN**ergy **A**ntiproton (ELENA) decelerating ring will provide a large number of very slow antiprotons to numerous experiments (like ACE, ASACUSA, ALPHA), sensibly increasing the efficiency of the antihydrogen production and trapping.

Antimatter → Antigravity?

The Standard Model predicts that gravity should have the same effect on matter and antimatter; however, this has yet to be seen. Experiments such as **AEGIS**, **ALPHA** and **GBAR** are hard at work trying to find out.
In fact antimatter might fall up!

ALPHA experiment (CERN)



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