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To Prove that Antiprotons Exist and that they are Produced When Protons Emerged from a Particle Accelerator are Collided with Nuclei in a Copper Target via the Reactions

Stuti Iyer*
XII High School Student, Department of Physics, Essar International School, Surat, India

***Abstract*: This paper examines to prove that antiprotons exist and that they are produced when protons emerged from a particle accelerator are collided with nuclei in a copper target via the reactions.**

***Keywords*: Antiprotons, particle accelerator, copper target.**

1. Introduction

A. Motivation

Our fascination to explore matter made us reach the captivating topic of antimatter and its subsets. Stars and galaxies appear to consist largely of matter. This is a perplexing observation because it means that when the universe began, some feature biased the conditions away from antimatter. This proposal concerns the discovery of basic information about antiprotons and an experiment that verifies their existence. The main character for our experiment is the antiprotons. In time, the electron reacts with the proton via its overlapping portion and disappears as it becomes part of the new neutron. Our motive to engage with this project is to study the observations after the collision and its consequences.

2. Apparatus Required

The aim was to produce and detect antiprotons by establishing the mass of negative particles originating at the Bevatron target. To determine it, they chose to measure the particles' momentum and velocity.

They planned an apparatus as follows:

The proton beam impinged on a copper target, then it described an orbit, going across several counters. It passed through the first magnet M1, a quadrupole-focusing magnet Q1, which brought the particles to a scintillation counter S1. It went through another quadrupole focusing magnet Q2, a second magnet M2, a second scintillation counter S2, a Cherenkov counter C1, and the special ˇ Cherenkov ˇ counter C2 and, finally, a third scintillation counter S3.

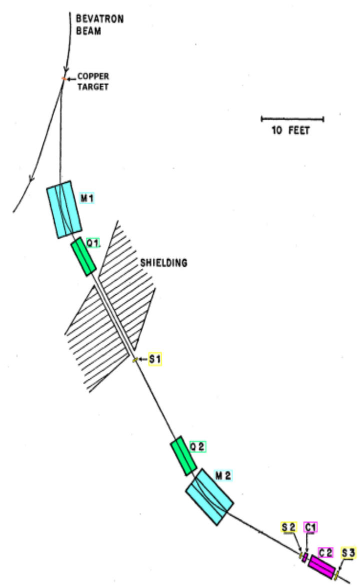

Fig. 1.

Let us now examine these elements of the apparatus:

M1 and M2:

These magnets were destined to deflect the proton beam (in this experiment, the particles were deflected three times: through an angle of 21◦ by the field of the Bevatron after the impact with the target, 32◦ by M1, and 34◦ by M2).

Q1 and Q2:

These Quadrupole focusing magnets were used to focus the beam. They consisted of three consecutive quadrupole magnets. Every quadrupole magnet consisted of four magnets with an alternatively reversed pole.

S1 and S2:

They were plastic scintillation counters and measured ionizing radiation. Because they could provide information very quickly, they were used to signal the passage of particles.

Cherenkov counters:

Sometimes during the experiment, there would be two

*Corresponding author: stuti.iyer05@gmail.com

different mesons passing through the two counters in such a way that a pulse from the second counter would be produced in just 51 milli microseconds after a pulse from the first

This gave accidental coincidences appearing like antiprotons (which may in reality be mesons or electrons).

To eliminate this difficulty faced during the experiments, the use of Cherenkov counters was introduced.

The Cherenkov counter C1 of chemical composition C8F160 and refractive index 1.28 was designed to respond to the particles with velocities greater than 0.79c (here c refers to the speed of light).

So, the second Cherenkov counter C2 of fused quartz and refractive index 1.46 was designed to respond to only those particles whose velocities were between 0.75c and 0.78c (as it can detect particles in a fixed velocity interval only)

Thus, due to the above-mentioned reasons, we can also say that the basic function of these Cherenkov Counters is Particle Identification which is further based on transition radiation, that is emitted by particles traveling in a medium with speeds faster than the speed of light (around 75%-78%).

In particular, it is possible to discriminate between two particles of the same momentum and different masses, because that particular angle provides a direct measurement of the velocity of each particle.

This will be further proved later with the help of the relativistic relationship between speed and momentum.

A. Working with the Beam

As shown in the above figure, a beam of 6.2 GeV protons is made to emerge from the particle accelerator which collides with the nuclei in the copper target. According to theoretical predictions at the time, collisions between protons in the beam and the protons and neutrons in those nuclei should produce antiprotons via the reactions:

$$\mathrm{p} + \mathrm{p} \rightarrow \mathrm{p} + \mathrm{p} + \mathrm{p} + \bar{\mathrm{p}}$$
$$\mathrm{p} + \mathrm{n} \rightarrow \mathrm{p} + \mathrm{n} + \mathrm{p} + \bar{\mathrm{p}}.$$

However, even if these reactions did occur, they would be rare compared to the reactions:

Thus, most of the particles produced by the collisions between the 6.2 GeV protons and the copper target were pions. To prove that antiprotons exist and were produced by a limited number of collisions, particles leaving the target are sent into a series of magnetic fields and detectors. The first magnetic field (M1) curves the path of any charged particle passing through it; moreover, the field is arranged so that the only particles that emerged from it to reach the second magnetic field (Q1) have to be negatively charged (either an antiproton or pion$^-$) and have a momentum of 1.19 GeV/c.

Field Q1 is a special type of magnetic field (a quadrupole field) that focuses the particles reaching it into a beam, allowing them to pass through a hole in thick shielding to a scintillation counter S1. The passage of a charged particle through the counter triggers a signal, with each signal indicating the passage of either a 1.19 GeV/c pion$^-$ or (presumably) a 1.19 GeV/c antiproton.

After being refocused by magnetic field Q2, the particles are directed by magnetic field M2 through a second scintillation counter S2 and then through two Cherenkov counters C1 and C2. These latter detectors are manufactured so that they send a signal only when the particle passing through them is moving at a speed that falls within a specific range. In the experiment, a particle with a speed greater than 0.79c would trigger C1 and a particle with a speed between 0.75c and 0.78c would trigger C2.

There are 2 ways to distinguish the predicted rare antiprotons from the abundant negative pions. Both ways involve the fact that the speed of a 1.19 GeV/c antiproton and pion^{-} $^{\text{differ}}$ from each other.

To find the speed of antiproton and pion$^-$ with momentum 1.19GeV/c, we use the relativistic relation between speed and momentum:

$$p = \gamma m v = \frac{mv}{\sqrt{1-(v/c)^2}}$$

now we solve for 'v':

$$\frac{v}{c} = \sqrt{1 - \frac{1}{\left(pc/mc^2\right)^2 + 1}}\ .$$

For an antiproton mc^2 = 938.3 MeV and pc = 1.19 GeV = 1190 MeV, so

$$v = c\sqrt{1 - \frac{1}{(1190\,\mathrm{MeV}/938.3\,\mathrm{MeV})^2 + 1}} = 0.785c\ .$$

For the negative pion mc^2 = 193.6 MeV, and pc is the same. Therefore,

$$v = c\sqrt{1 - \frac{1}{(1190\,\mathrm{MeV}/193.6\,\mathrm{MeV})^2 + 1}} = 0.993c\ .$$

Since the speed of the antiprotons is about 0.78c but not over 0.79c, an antiproton will trigger C2. Since the speed of the negative pions exceeds 0.79c, a negative pion will trigger C1.

We use t = d/v, where d = 12 m. For an antiproton:

$$\Delta t = \frac{1}{0.785\left(2.998\times10^8\ \mathrm{m/s}\right)} = 5.1\times10^{-8}\,\mathrm{s} = 51\mathrm{ns}.$$

For a negative pion:

$$\Delta t = \frac{12\,\mathrm{m}}{0.993(2.998\times10^8\ \mathrm{m/s})} = 4.0\times10^{-8}\ \mathrm{s} = 40\,\mathrm{ns}\ .$$

Limitations:

Some of the problems that were encountered during the experiment are:

Other particles with characteristics similar to that of antiprotons were more likely to be mistaken as antiprotons.

In the case of a negative hydrogen ion, the scientists thought that it is possible to rule it out, (since it was extremely improbable for the ion to pass through all the counters without the stripping of its electrons). This was probably because the concept of heavy mesons wasn't known with the proper mass to explain these observations. Moreover, such particles did not have a meaningful life that was long enough to pass through the apparatus without a prohibitive amount of decay. However, this could not be completely ruled out; so, they considered the possibility of the existence of unknown negative particles of mass very close to 1840 electron masses, which also had to be singly charged.

3. Conclusion

This paper presented a study to prove that antiprotons exist and that they are produced when protons emerged from a particle accelerator are collided with nuclei in a copper target via the reactions.

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