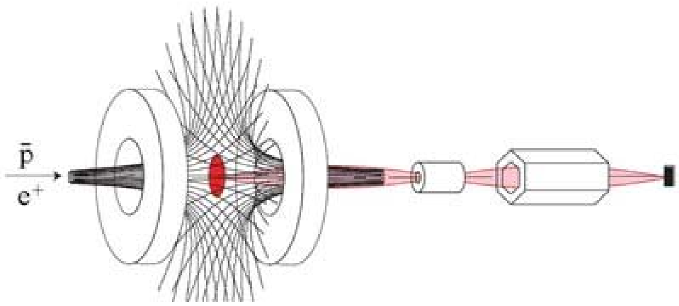
CERN moves closer to antihydrogen spectroscopy

Dec 9, 2010 14 comments



Antihydrogen on the cusp

Physicists at CERN have taken a big step towards making the first spectroscopic measurements on a beam of antihydrogen atoms. The antihydrogen atoms, which consist of an antielectron orbiting an antiproton, were made by members of the lab's ASACUSA group. The beams could be used to carry out the first detailed studies of the energy levels in antihydrogen.

Measuring in detail the energy levels in antihydrogen is important because the Standard Model of particle physics says they should be identical to those of hydrogen. Any slight differences in the "fine structure" of the levels compared to ordinary hydrogen could shed light on why there is so much more matter than antimatter in the universe.

The breakthrough comes just weeks after researchers in the ALPHA collaboration at CERN succeeded in trapping 38 antihydrogen atoms for about 170 ms. This was the first time antimatter atoms had been stored for long enough to measure their properties in detail and, taken together, the two results represent major advances in studies of antimatter.

Trapped in a cusp

The ASACUSA researchers, however, used an alternative technique for creating antihydrogen. Led by Yasunori Yamazaki of the RIKEN laboratory in Japan, they created their antiatom beams by combining antiprotons with positrons in a "cusp trap".

The trap comprises 17 successive ring-shaped electrodes and two magnetic coils, which are wired to create magnetic fields in opposite directions (see figure). A cloud of antielectrons (also called positrons) from a radioactive source is first sent into the trap, where it is held as a plasma. A cloud of antiprotons – created in a nearby accelerator – is then fired into the plasma to create the antihydrogen atoms.

Charged particles remain stuck in the trap, while neutral antihydrogen atoms are able to move further along the apparatus to a "field ionization trap". At this point, antihydrogen atoms in highly excited Rydberg states, in which the positron lies very far from the antiproton, are ionized and their antiprotons are trapped.

Detecting pions

The trapped antiprotons are then released and quickly annihilate upon contact with the walls of the trap. Each annihilation event creates pions, which are easily spotted by a bank of detectors surrounding the trap. By comparing the number of antiprotons injected into the trap with the number of annihilations detected, the team estimated that about 7% of antiprotons combine to form antihydrogen.

The team is now trying to improve the way in which antihydrogen is extracted from the trap before passing it through a microwave cavity in which hyperfine transitions between atomic energy states should occur. Making precise measurements of these transitions, which have not yet been carried out, could be used to study a fundamental quantum transformation known as the charge-parity-time (CPT) operation.

When applied to a physical system, a CPT transformation converts every particle to its antiparticle, reflects each spatial co-ordinate, and reverses time. Although is currently no experimental evidence that the CPT symmetry is violated, it could show up as a slight difference in the frequency of hyperfine transitions in hydrogen and antihydrogen atoms. The discovery of such a violation could also help physicists understand why there is much more matter than antimatter in the universe.

The work is reported in *Phys. Rev. Lett.* **105** 243401.

About the author

Hamish Johnston is editor of *physicsworld.com*

14 comments

Comments on this article are now closed.

1 **dratman**
Dec 10, 2010 1:03 AM
cherry Hill, United States

This would be a triumph

What a feat of science and engineering this experiment will represent! Kudos to all involved.

I have two questions:

1) Why is the lifetime of the anti-hydrogen been limited at all? Don't get me wrong -- 170 ms is an impressively long time, but in the absence of contamination of the apparatus with unwanted matter, shouldn't anti-hydrogen be as stable as hydrogen?

2) Are there any specific theories riding on the outcome of this experiment?

Thank you.

Ralph Dratman

Edited by dratman on Dec 10, 2010 1:05 AM.

2 **psycherevolt**
Dec 10, 2010 3:53 AM
Houghton, United States
Quote:

> *Originally posted by* ***dratman***
>
> 1) Why is the lifetime of the anti-hydrogen been limited at all? Don't get me wrong -- 170 ms is an

> impressively long time, but in the absence of contamination of the apparatus with unwanted matter, shouldn't anti-hydrogen be as stable as hydrogen?

The trap isn't perfect, so they get released due to thermal fluctuations and imperfect vacuums I think. It might be as stable as hydrogen, but perhaps antimatter reacts via the weak force differently causing it to interact with neutrinos and WZ bosons differently. Any inherent mass/charge differences will become apparent through experiments.

Quote:

> *Originally posted by **dratman***
>
> 2) Are there any specific theories riding on the outcome of this experiment?

Definitely, there are many. If the fine and hyperfine structure have any anomalies we will learn insight on spin in antimatter also. There are many concepts of symmetry in particle physics models and any potential asymmetries must be inspected to find inherent differences between real matter and antimatter.

Edited by psycherevolt on Dec 10, 2010 3:54 AM.

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3 **reader01**
Dec 10, 2010 8:47 AM

trap

Maybe in such trap can be catch positrons and antiprotons. Why not to try to get there also antineutrons. It may arise more complicated structures than antihydrogen.

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4 **reader01**
Dec 10, 2010 10:21 AM

I think

that production of energy from annihilation of matter and antimatter is now real thing. Such time of storage of antimatter is enough long and if we deliver constant amount of antimatter we can have the most useful change of matter to energy that can be.

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5 **aivasilis**
Dec 10, 2010 1:39 PM

Magnetic fields are good at trapping charged particles but not neutral atoms. This is why antihydrogen atoms eventually escape, as would hydrogen atoms do.

The energy needed to create antimater is enormous compared to the mass of the antiparticles. There is no way one can improve this for antimater to become an efficient energy storage. But even if one could, what would then happen, if there was a power failure and the trap stopped working?

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6 **mikki**
Dec 10, 2010 1:49 PM

Please understand Hydrogen (H atom) cannot survive by itself without neutron. So, when they say they trapped anti-hydrogen for a limited time- that could possibly meant they created few neutrons that make proton-electron in each neutron orbit opposite to the orbit of H in the matter.. I will be surprized if this magic is anything more than that- at what Cost? Quote:

> *Originally posted by **reader01***
> Maybe in such trap can be catch positrons and antiprotons. Why not to try to get there also antineutrons. It may arise more complicated structures than antihydrogen.

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7 **reader01**
Dec 10, 2010 2:30 PM

Quote:

> *Originally posted by **mikki***

> Please understand Hydrogen (H atom) cannot survive by itself without neutron. So, when they say they trapped anti-hydrogen for a limited time- that could possibly meant they created few neutrons that make proton-electron in each neutron orbit opposite to the orbit of H in the matter.. I will be surprized if this magic is anything more than that- at what Cost? Quote:
>
> > *Originally posted by **reader01***
> > Maybe in such trap can be catch positrons and antiprotons. Why not to try to get there also antineutrons. It may arise more complicated structures than antihydrogen.

According to the statistic there are most atoms of H without neutron, so I suppose that at usual condition it is the same with antihydrogen. But there is also possibility that antihydrogen can make molecules of H2 and also hydrogen bridges between these antihydrogen molecules. The scientist also say that only 7% of all antiprotons makes antihydrogen. So we can count down how many of them will be antihydrogen 1H and how many of them 2H.

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8 **reader01**
Dec 12, 2010 8:43 AM
Such trap is like motor that use an energy of anihilation. But why not to use this trap also for study of ionizied matter? I think that also ionizied matter have the energy for this kind (trap) of ion motor.

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9 **reader01**
Dec 12, 2010 10:31 AM
Quote:

> *Originally posted by **reader01***
> Such trap is like motor that use an energy of annihilation. But why not to use this trap also for study of ionized matter? I think that also ionized matter have the energy for this kind (trap) of ion motor.

Is it possible to study in this trap electrons and positrons and also protons and anti protons as one two parts particals (atoms)?
And as concerned anti hydrogen spectroscopy we can study anti hydrogen with different polarized photons... Photons do not change (they interact but not annihilate) with antimatter.

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10 **reader01**
Dec 12, 2010 10:46 AM
I think that we can measure entropy of the antihydrogen system.

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11 **reader01**
Dec 12, 2010 12:24 PM
Quote:

> *Originally posted by **reader01***
> I think that we can measure entropy of the antihydrogen system.

Maybe antihydrogen can be suitable for capture of neutrinos or antineutrinos. If it capture neutrinos then it decays and if it capture electron antineutrinos then it can create antineutrons.

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12 **reader01**
Dec 12, 2010 1:03 PM
as photons do not interact with antihydrogen atoms (not all photons make antihydrogen exciting), we can make antihydrogen trap from laser beams or combination of magnetic field and laser beams. But we must use the beams that has needed width. And also magnetic field can make laser beam suitable for different width of this beam (suitable magnetic field can it spread). For example if we have changing magnetic field it should make wave from this beam.

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13 **reader01**
Dec 12, 2010 1:11 PM
As concerned anti hydrogen spectroscopy we can study anti hydrogen with different polarized photons... Photons do not change (they interact but not annihilate) with antimatter. Also we can use photons to interact with

antiprotons to exciting them and make more antihydrogen then it is possible without such exciting (they say only 7% of antiprotons creates antihydrogen).

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14 **m.a.king**
Dec 12, 2010 10:11 PM
Toronto, Canada

Neutrinos

As mentioned by others, the interaction of this new 'bulk' antimatter with the neutrino environment must be taken into account. Perhaps with more accessible antimatter systems we could see novel types of neutrino telescopes?
mk