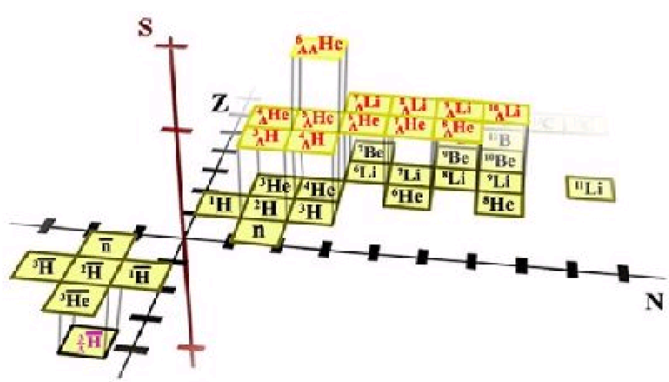
RHIC nets strange antimatter

Mar 5, 2010 17 comments



Extending the nuclear terrain

Physicists working in the STAR collaboration at the Relativistic Heavy Ion Collider (RHIC) at the Brookhaven Laboratory in the US have detected antimatter nuclei containing strange quarks for the first time. The antihypertriton – consisting of an antiproton, an antineutron and an antilambda particle – is the heaviest antinucleus yet produced and opens up a new realm of strange antinuclei. It could also shed light on a number of problems in astrophysics and cosmology, including the dominance of matter over antimatter in the universe.

RHIC collides gold ions at high energies, recreating what are believed to have been the conditions in the universe just a few microseconds after the Big Bang. The enormous energy density that existed at that time would have kept quarks separate from one another, in what theory predicts would have been a very hot gas of free quarks, antiquarks and gluons known as a quark–gluon plasma. As the plasma expanded and cooled these quarks would have bound to one another to form a range of different hadrons, including protons and neutrons (consisting solely of up and down quarks), hyperons (which contain strange quarks) and all of the associated antiparticles.

Introducing antihypertriton

With further expansion a small fraction of these hadrons would then have combined to form light nuclei and their antiparticles. Physicists have previously generated antiprotons, anti-deuterium, anti-tritium and anti-helium-3 in particle collisions but the STAR collaboration, led by Declan Keane at Kent State University in the US, Jinhui Chen of the Shanghai Institute of Applied Physics in China and Zhangbu Xu of Brookhaven, have seen the first ever antimatter hypernucleus: antihypertriton. In addition to an antiproton and an antineutron, this nucleus contains an antilambda hyperon, which is made up of an up quark, a down quark and a strange quark.

Identifying the new particle required painstakingly sifting through the debris of some 100 million collisions. All of the charged particles within this debris left their mark by ionizing the gas inside RHIC's time projection chamber but the antihypertritons revealed themselves through a unique decay signature – the two tracks left by a charged pion and an antihelium-3 nucleus, the latter being heavy and so losing energy rapidly with distance in the gas.

Below the N-Z plane

One of the collaboration members, Lee Barnby of the University of

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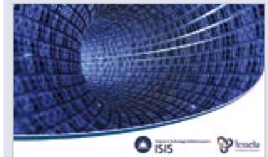
Science DOI: 10.1126/science.1183980



Birmingham in the UK, says that this result "opens up a new area of study" because it shows that "any very light bound nucleus or antinucleus can be formed in heavy-ion collisions". Indeed, the discovery extends graphically our knowledge of the nuclear terrain. Physicists represent this terrain by placing each kind of nucleus on a three-dimensional graph with the three axes being Z, the number of protons in a nucleus; N, the number of neutrons; and S, the degree of strangeness. Each of these three axes has positive and negative sections, allowing for the representation of both particles and antiparticles. As illustrated in the diagram, this latest result extends the nuclear terrain below the N–Z plane for the first time.

The STAR collaboration's production of hypernuclei could also help us better understand the structure of the massive-star remnants known as neutron stars. That is because the kind and extent of strange-matter content within these stars depends on how strongly hyperons interact with nucleons (protons and neutrons), and this interaction strength in turn can be worked out by measuring the lifetime of hypernuclei. The current experiment yielded a value of around 2×10^{-10} s for hypertritons.

Why more matter than antimatter?

The findings may also help us understand why the universe appears only to contain matter, whereas equal quantities of matter and antimatter were believed to have been created in the Big Bang. Quarks and antiquarks are generated in equal measure by the heavy-ion collisions at RHIC and this equal abundance of matter and its antimatter partner is observed to persist as the hot gas cools.

In addition, the number of hypertritons and antihypertritons produced in the RHIC collisions (about 160 and 70 respectively) very closely matched the number of helium-3 and antihelium-3 nuclei generated. Mike Charlton of Swansea University in the UK, who is not a member of the STAR collaboration, points out that this implies that the hot gas must have contained similar amounts of strange quarks and up and down quarks. This, he says, is an indication that the gas is indeed a true quark–gluon plasma, as physicists believe. "The research is a *tour-de-force* of analysis and highlights the immense power of modern particle physics detector technologies and techniques," he adds.

> The research is a *tour-de-force* of analysis and highlights the immense power of modern particle physics detector technologies and techniques
>
> **Mike Charlton, Swansea University**

The STAR collaboration has restarted its antimatter observations at a higher collision rate, hoping to increase their collected data by a factor of 10 over the next few years. Keane says that this should allow them to discover yet heavier antinuclei, both strange and non-strange.

The work is described in *Science* DOI: 10.1126/science.1183980.

About the author

Edwin Cartlidge is a science writer based in Rome

17 comments

Add your comments on this article

1 **Ragtime**
Mar 6, 2010 3:20 PM
Prague, Czech Republic

Why more matter than anti-matter?

During BigBang vacuum foam was formed by tiny dense bubbles with double surface gradients, which differed by their surface curvature a much more, then after inflation by now. Because particles and antiparticles are formed by density gradients of inner and outer walls of this foam, the formation of particles was greatly enhanced during Big Bang, while antiparticles expanded by pressure of radiation into streaks of dark matter.

Surprisingly, the question of matter-antimatter ratio is relevant to question of chirality of life, which was formed by tiny liposomes in its very beginning as well. At the case of such tiny bubbles the inner and outer surface are of different curvatures. Because these surface differ by helicity of adsorbed molecules, the less polar L-proteins were attached into super-hydrophobic surface of liposomes, while chiral D-sugars with hydrophilic groups were attracted to interior of liposomes preferably.

In this model L-proteins are analogy of observable matter and D-sugars are symbols of energy transferring medium, i.e photons.

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2 **Ivan Gorelik**
Mar 7, 2010 8:57 AM

Proton, p = (uud).
Neutron, n = (udd).
Lambda, l = (uds).
Antiproton, p~ = (u~u~d~).
Antineutron, n~ = (u~d~d~).
Antilambda, l~ = (u~d~s~).
Hypertriton, T = (pnl).
Antihypertriton, T~ = (p~n~l~).

RHIC collides ions. That creates HOT quark gluon plasma.
Now LHC collides protons. In non-central inelastic collisions it can tear out of a Dirac sea a COLD crystals of strange matter and antimatter:

p + p = p + p + N(uds) + N(u~d~s~).

N is a number of lambda and antilambda in "strange nucleus or antinucleus".
The number of nucleons in usual matter is limited, because of electric repulsion between protons. The periodic system is limited by uranium.
The number of lambda (strange nucleons) in strange matter can be not limited and it is possible that neutron stars are in fact are big strange nuclei.

The strange matter can transform a usual matter into strange matter because under big N the binding energy per nucleon in strange nucleus is bigger than in usual matter under the same number of nucleons.

The binding energy can be find through the mass differences of nucleons in free state and inside the nucleus.

Usual matter:

Mass of a free proton is 938.272 MeV/c^2.
Mass of a proton in deuteron is several MeV/c^2 less.
Mass of a proton in He is several MeV/c^2 less.
Mass of a proton in C is several MeV/c^2 less.
Mass of a proton in Fe is several MeV/c^2 less, and minimal.

These mass differences say us about binding energy.

Strange droplet consisting of a several (uds) is unstable and decay.

The mass of free lambda is 1116 MeV/c^2 and is almost 200 MeV/c^2 bigger than the mass of free proton or free neutron.
This is the cause of lambda decay.
Some authors said that strange nucleus, consisting of 10 lambdas, can be stable.
The binding energy of one lambda in big strange nucleus can be, for example, of about 500 MeV/c^2.
That means that strange nucleus can grow transforming usual nuclei into strange ones.
The value 500 TeV, as a binding energy of (uds) in a strangelet N(uds), can easily be received from comparison with the rest energy of kaons K+ and K0, which are correspondingly 493 MeV and 497 MeV.
Kaons (K+=us~; K0=ds~) can be side products, occurring at the time of proton (p=uud) and neutron (n=udd) capture by strange matter N(uds):
N(uds) + p = (N+1)(uds) + K+ = (N+1)(uds) + e+ + 500 MeV.
(N+1)(uds) + n = (N+2)(uds) + K0 = (N+2)(uds) + 500 MeV.
...
...
...
Extremely powerful explosion.
This explosion has specific energy output, which is hundred times bigger than under the nuclear explosion.

By the way, at the time of November-December collisions there were more Kaons output that it was theoretically predicted. That means that we are very close to creation of this dead droplet, which can transform the whole Earth into 10-meterr lump of strange\dead matter.
Space observations says us that periods of pulsars are almost do not change. That means that strange matter is very stable.

Read about strange matter, strangelets, and strange stars in Wikipedia. I think that our civilization is crazy.

From one hand, it already knows about a deadly dangerous strange matter; from the other hand, it tries to create that dead droplet at colliders. I do not understand you, people. I wish you to become mentally healthy and STOP all powerful colliders.

At LHC two COLD crystals can be created from Dirac's quark sea. That is absolutely different state. That is not hot quark gluon plasma, but cold crystals, torn out of Dirac's quark sea. Density of those crystals can be hundred times bigger than the density of nuclear matter and by hundred millions times more than the density of usual solid matter.

Strange crystal, which can be made tomorrow at LHC, can kill us all.
p + p + 2*3.5 TeV= 6000(usd) + 6000(u~s~d~)

Strange crystal 6000(usd) is extremely stable and deadly dangerous! This is a droplet of strange matter, embryo of a "neutron star". The whole Earth can be transformed into such strange matter in a 1000 of seconds or slightly more.

Reply to this comment   Offensive? Unsuitable? Notify Editor

3 **Ragtime**
Mar 7, 2010 12:09 PM
Prague, Czech Republic

Quote:

> *Originally posted by **Ivan Gorelik***
> ..Strange crystal 6000(usd) is extremely stable and deadly dangerous! This is a droplet of strange matter, embryo of a "neutron star". The whole Earth can be transformed into such strange matter in a 1000 of seconds or slightly more.

I can fully agree with this estimation. After all, the formation of stable black holes at LHC was predicted by many other theories www.iop.org...S52 and recently confirmed by computer simulation news.sciencemag.org...22-01.html . The existence of stable micro-black holes follows from Sundrum-Randall theory, too. The LHC experiments should be stopped ASAP, until physicists will not learn to respect their own theories.

Edited by Ragtime on Mar 7, 2010 12:11 PM.

Reply to this comment   Offensive? Unsuitable? Notify Editor

4 **kasuha**
Mar 8, 2010 10:51 AM
Prague, Czech Republic

LHC is not going to create anything that has not yet been created millions of times in collisions of cosmic ray particles with earth atmosphere or surface. If these didn't destroy the universe or Earth yet, LHC is not going to either.

Reply to this comment   Offensive? Unsuitable? Notify Editor

5 **psycherevolt**
Mar 8, 2010 3:12 PM
Houghton, United States

Proton mass + mass equiv. of kinetic energy = total mass
2*938*(3e8)^2 MeV + 7000000MeV = 1.6884e20 MeV

Hyperon(assuming equal mass for anti/normal) + 0 kinetic = total mass
12000*1116*(3e8)^2 MeV + 0 MeV = 1.205e24 MeV

Even assuming no kinetic energy for reaction products... where's the extra 1.204e24 MeV coming from? Show me papers.

Quote:

> *Originally posted by **Ivan Gorelik***
>
> Strange crystal, which can be made tomorrow at LHC, can kill us all.
> p + p + 2*3.5 TeV= 6000(usd) + 6000(u~s~d~)
>
> Strange crystal 6000(usd) is extremely stable and deadly dangerous! This is a droplet of strange matter, embryo of a "neutron star". The whole Earth can be transformed into such strange matter in a 1000 of seconds or slightly more.

Reply to this comment   Offensive? Unsuitable? Notify Editor

6 **Ragtime**
Mar 8, 2010 10:45 PM
Prague, Czech Republic

Quote:

> *Originally posted by **kasuha***
> If these didn't destroy the universe or Earth yet, LHC is not going to either.

Cosmic ray events never occur in form of dense, collimated proton jets with potentially zero momentum toward Earth. Anyway, strangeletes are believed to cause earthquakes, Lunar craters or even Solar flares.. BTW I didn't invented these theories.

www.telegraph.co.uk...evour-the-Earth.html

You can think about it like about cold fission mediated by cold neutrons. While these neutrons are fast, they're effectively inert to the nuclear reactions. The relatively slow speed or resulting products of LHC collisions is, what imay become dangerous there.

Edited by Ragtime on Mar 8, 2010 10:49 PM.

Reply to this comment Offensive? Unsuitable? Notify Editor

7 **kasuha**
Mar 9, 2010 8:08 AM
Prague, Czech Republic

Quote:

> *Originally posted by* ***Ragtime***
> Cosmic ray events never occur in form of dense, collimated proton jets

On particle scales these proton jets are about as dense as meteor showers. So far, the chance that they get a single p-p collision from two bunches meeting in experiment area is about 1:5000 (2 collisions per second from two bunches meeting about 11 thousand times per second in experiment area). So it's still one proton with one proton.

Quote:

> *Originally posted by* ***Ragtime***
> BTW I didn't invented these theories.

That doesn't mean they are valid.

Anybody concerned with LHC safety should read this:

cern.ch…LSAG-Report.pdf

Reply to this comment Offensive? Unsuitable? Notify Editor

8 **Ivan Gorelik**
Mar 9, 2010 8:23 AM

Quote:

> *Originally posted by* ***psycherevolt***
> Proton mass + mass equiv. of kinetic energy = total mass
> 2*938*(3e8)^2 MeV + 7000000MeV = 1.6884e20 MeV
>
> Hyperon(assuming equal mass for anti/normal) + 0 kinetic = total mass
> 12000*1116*(3e8)^2 MeV + 0 MeV = 1.205e24 MeV
>
> Even assuming no kinetic energy for reaction products... where's the extra 1.204e24 MeV coming from? Show me papers.

Two errors:
1. Do not multiply by (3e8)^2, but divide, or write in energies.
2. Do not use 1116 MeV as the rest energy of lambda. 1116 MeV is a rest energy of a free lambda. Inside nucleus, made of lambdas, containing 6000 strange nucleons, its total energy will be, for example, 583 MeV, or 500 MeV as a rest energy and 83 MeV as kinetic energy of moving lambda together with the whole strangelet.

I'll rewrite your formulae, with these corrections:

Two proton rest energies + kinetic energy of two protons = total energy.
2*938 MeV + 7000000MeV = 7,001,876 MeV = 7 TeV.

Total number of lambdas and antilambdas * (rest energy + kinetic energy) = total energy.
12000*(500 MeV + 83 MeV) = 7 TeV.

So, the formula p + p + 2*3.5 TeV= 6000(usd) + 6000(u~s~d~) does work.

But I made a typo in the last post. In fact, I wanted to write thusly:
p + p + 2*3.5 TeV= p + p + 6000(usd) + 6000(u~s~d~)

If you compute ones more, you would see, that the difference is not substantial.

By the way, today (March, 9, 2010) they'll try 1.2 TeV per beam.
Plan for a next month: lhc-commissioning.we…outline-20100308.pdf

Reply to this comment Offensive? Unsuitable? Notify Editor

9 **kasuha**
Mar 9, 2010 11:54 AM
Prague, Czech Republic

Quote:

> *Originally posted by* ***Ivan Gorelik***
> p + p + 2*3.5 TeV= p + p + 6000(usd) + 6000(u~s~d~)

Yes, this is about correct.

However, the rest of your assumptions, especially that the result is deadly, is not. They are just strong words aimed at scaring people who don't understand the matter. It has nothing to do with particle science, it's just psychology.

Again, all these scenarios have already been discussed and evaluated and the result can be found in CERN LHC safety report and related literature:

cern.ch…LSAG-Report.pdf

Reply to this comment   Offensive? Unsuitable? Notify Editor

10 **Ragtime**
Mar 9, 2010 1:12 PM
Prague, Czech Republic

Quote:

> *Originally posted by **kasuha***
> Anybody concerned with LHC safety should read this

The LHC safety report is parody to scientific analysis, because these guys never computed anything - they're only expecting money of tax payers.

The only computer models of particle collisions done so far predict formation of stable black holes clearly, in accordance with string theory models of micro-black holes and strangelets formation. For every single safety report of CERN we can find a dozens of peer-reviewed articles, openly proving the opposite:

arxiv.org…0908.1780
arxiv.org…0106295
www.unisci.com…1001012.htm
news.sciencemag.org…22-01.htm
cerncourier.com…28173
cerncourier.com…34938
adsabs.harvard.edu…2006hep.ph....6193B
www.iop.org…S52
www.risk-evaluation-…LHC_safety.pdf

Therefore your arguments regarding cosmic rays are irrelevant as well, because they're not supported by any calculations. In fact, scientists are taking grants for black holes search in stratosphere already - so you shouldn't convince us, they cannot be formed there.

focus.aps.org…st3

Reply to this comment   Offensive? Unsuitable? Notify Editor

11 **nick.evanson**
Mar 9, 2010 5:14 PM
United Kingdom

Quote:

> For every single safety report of CERN we can find a dozens of peer-reviewed articles, openly proving the opposite:
>
> adsabs.harvard.edu…2006hep.ph....6193B

The ranting your post quashed any real enthusiasm to explore your claims but I managed to muster a modicum of interest in the Harvard entry and found not a single use of the word 'saftey' in the entire article or, indeed, any reference to the safety (or lack of) of the LHC. Thus your claim that the indicated article 'openly proves the opposite' of CERN's safety report is clearly false - the only 'doom and gloom' comment in the entire article refers to how black hole production would put a limit on the examination of short scale structure for future particle accelerators.

Somehow I think the world would survive such an awful fate...

Reply to this comment   Offensive? Unsuitable? Notify Editor

12 **Ragtime**
Mar 9, 2010 10:31 PM
Prague, Czech Republic

Quote:

> *Originally posted by **nick.evanson***
> I think the world would survive such an awful fate..

Try to propose evidence, which would convince you to stop LHC experiments. You know, I don't waste my time with fanatists, who are deaf to every argument. Just show me the way...

Reply to this comment   Offensive? Unsuitable? Notify Editor

13 **Fundamental_science**
Mar 12, 2010 7:24 AM
Halstead, United Kingdom

An advanced knowledge of Quantum Gravity indicates the strong force to be comprised of the 'nature of antimatter': within atoms in quantity, less than needed to form a particle. When sufficient force is applied however to the strong force, the level of its energy is observed to increase. The splitting of an atom thus results in the fission of particles of antimatter so formed, with the nearest protons and neutrons. The action of the Large Hadron Collider has been designed to split protons: these comprise otherwise collectively, a significant proportion of the energy content of an atom. [Information in suitably greater detail was provided earlier for a number of scientists at CERN.]

Robert

Reply to this comment   Offensive? Unsuitable? Notify Editor

14 **Shturm**
Mar 14, 2010 10:12 AM

Comedy Gold!

I love seeing the ravings of armchair high energy physicists who have memorised papers they cannot comprehend!

Even better when they regurgitate the ravings of other clueless armchair HE physicists.

:-)

Reply to this comment Offensive? Unsuitable? Notify Editor

15 **biff_dawson**
Mar 16, 2010 2:46 PM
Letchworth, United Kingdom

:)

Quote:

> *Originally posted by* ***Shturm***
> I love seeing the ravings of armchair high energy physicists who have memorised papers they cannot comprehend!
>
> Even better when they regurgitate the ravings of other clueless armchair HE physicists.
>
> :-)

Welcome to the internets Shturm. Some of these guys comment on nearly every article here. One day they'll overturn the Establishment and be lauded as the geniuses they are. Until then, they'll just keep posting on the intertubes...

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16 **Novice_7**
Mar 25, 2010 2:05 PM

I have question--please--I am not physicist, but have interest.
I have read that the strange quark (s/) exists within the Proton, that is, within the boundary of the confinement of the uud quarks. Thus, seems logical that the anti-strange quark would be found within the anti-proton....correct ? Thus, would it be true that the anti-strange quark found in this experiment that is used to form the anti-lambda antimatter u/d/s/ was present within the gold atoms within anti-protons ? I need help here.

Reply to this comment Offensive? Unsuitable? Notify Editor

17 **jpivarski**
Mar 25, 2010 9:30 PM

Response to serious question about strange quarks

Quote:

> *Originally posted by* ***Novice_7***
> I have question--please--I am not physicist, but have interest.
> I have read that the strange quark (s/) exists within the Proton, that is, within the boundary of the confinement of the uud quarks.
>
> Thus, would it be true that the anti-strange quark found in this experiment that is used to form the anti-lambda antimatter u/d/s/ was present within the gold atoms within anti-protons ?

Hi,

A description of what quarks are actually "contained" in a proton is somewhat complicated. Quantum ChromoDynamics (QCD) is a quantum field theory, and in quantum field theories, all possible interactions between an initial state (e.g. before a collision) and a final state (after decay) take place simultaneously, superimposed like alternate histories. Each alternate history, however, comes with a weight called the amplitude, and in a more sedate quantum field theory like Quantum ElectroDynamics (QED), the possible paths with the most particle-antiparticle creations/annihilations have the least weight. Thus, when two electrons feel each others' presence and repel, the intermediate process is "mostly" the exchange of a single photon, with smaller contributions from two-photon exchanges, etc. Not so with QCD: when two quarks feel each others' presence and attract, a one-gluon exchange doesn't have much more weight than a two-gluon exchange, or a gluon that splits into a temporary quark-antiquark pair, or any number of these things. Some of those quark-antiquark pairs can include strange quarks, charm quarks, or even top quarks, suppressed only by their mass. (We *can* say, at least, that most of the loops are up-antiup and down-antidown. Strange-antistrange is more rare, but not exceedingly so; top-antitop is exceedingly rare.)

When you have a proton just sitting somewhere, its constituent quarks are always madly exchanging gluons, and those gluons are begetting more gluons and quark-antiquark pairs, etc., in a big complicated ball of quantum froth. About 98-99% of the mass of the proton is just the energy involved in this process--- the three "valence" up and down quarks are very light (several MeV, while the whole proton is ~1000 MeV). Standard field theory techniques (perturbation theory) are inadequate to describe this process; it needs to be modeled on a computer, a technique called Lattice Gauge Theory (because the discreteness of the computer description effectively creates a lattice of space-time points). (There are other techniques, like QCD Sum Rules.) Even on the computer, our description of the proton is limited by its complexity--- I've never seen a more precise Lattice Gauge Theory calculation of the proton's properties than the ~10% level. (The Lattice has had more success with simpler heavy mesons: J/psi, Upsilon, D, and B at the ~1% level.) Strange quark-antiquark pairs are an essential ingredient, however: the proton does "contain" some strange quarks, but always balanced by strange antiquarks and never permanant. Also, they're not present in all of the alternate histories: one history might have one strange/antistrange loop, another has zero, another has ten, and they're all happening at the same time.

When we say that the proton "contains" up, up, and down quarks, we're just saying that in all of the alternate histories, the sum of all quarks (counting the number of antiquarks with a minus sign) is 2 net up quarks and 1 net down quark.

When RHIC created nuclei with strange quarks in them, the strange quarks may have come from one of these temporary strange quarks already in the proton, or they might have been created in the collision. There isn't really a distinction between these two statements: they came from QCD interactions--- there are QCD interactions happening all the time inside protons, and QCD interactions also happened in the RHIC collision. It's all the same cloth.

Cheers,
-- Jim

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