

Antimatter Mysteries

Rolf Landua

Research physicist

CERN

Angels + Demons: The Movie



TOM HANKS
ANGELS & DEMONS
A RON HOWARD FILM
IN THEATERS MAY 15

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[Flags: Denmark, Brazil, Canada, Spain, France]

ENTER THE ANGELS & DEMONS
Path of Illumination
Contest ON msn

BASED ON THE BEST SELLING NOVEL
BY THE AUTHOR OF
THE DAVINCI CODE

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The Da Vinci Code Extended Cut, available for the first time on Blu-ray™ April 28

COLUMBIA PICTURES AND IMAGINE ENTERTAINMENT PRESENT A BRIAN GRAZER/JOHN CALLEY PRODUCTION
A RON HOWARD FILM "ANGELS & DEMONS" EWAN MCGREGOR AYELET ZURER STELLAN SKARSGÅRD PIERFRANCESCO FAVINO NIKOLAJ LIE KAAS AND ARMIN MUELLER-STAHL
MUSIC BY HANS ZIMMER ASSOCIATE PRODUCERS KATHLEEN MCGILL LOUISA VELLIS WILLIAM M. CONNOR EXECUTIVE PRODUCERS TODD HALLOWELL DAN BROWN BASED UPON THE NOVEL BY DAN BROWN
PRODUCED BY BRIAN GRAZER RON HOWARD JOHN CALLEY SCREENPLAY BY DAVID KOEPP AND AKIVA GOLDSMAN DIRECTED BY RON HOWARD
IMAGINE ANGELS AND DEMONS COLUMBIA PICTURES
AngelsAndDemons.com

Angels + Demons: The Cast @ CERN

Tom Hanks

Aliyet Zurer

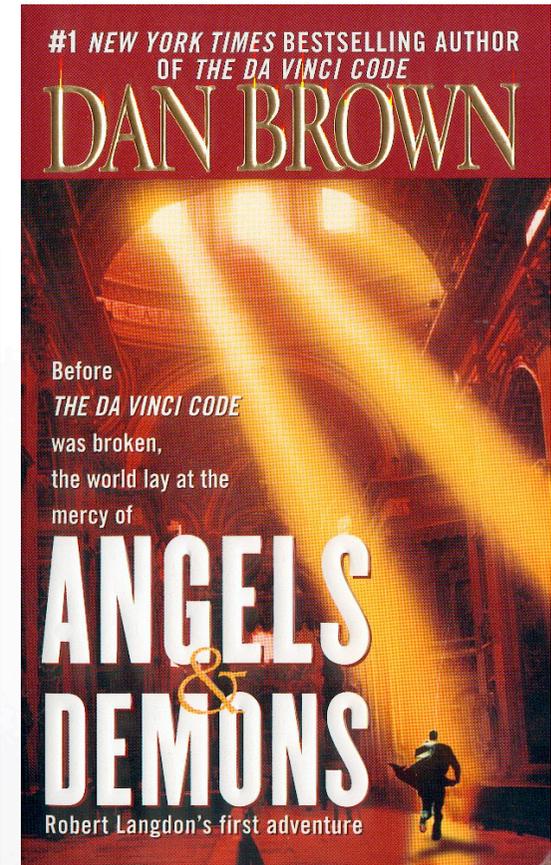
Ron Howard



Antimatter Mysteries

Angels + Demons: The Book

The story line of ...



What's true ?
What's false ?

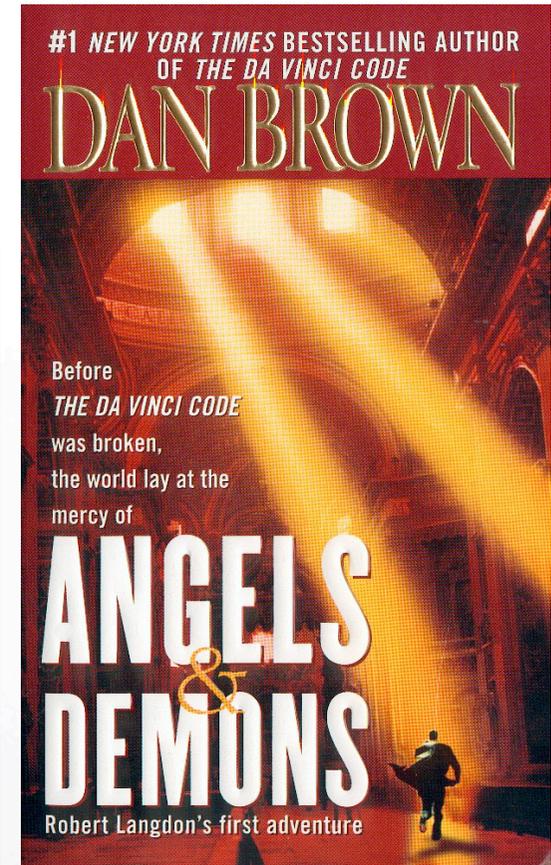
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Wuminati

Detective story about a secret society which ...



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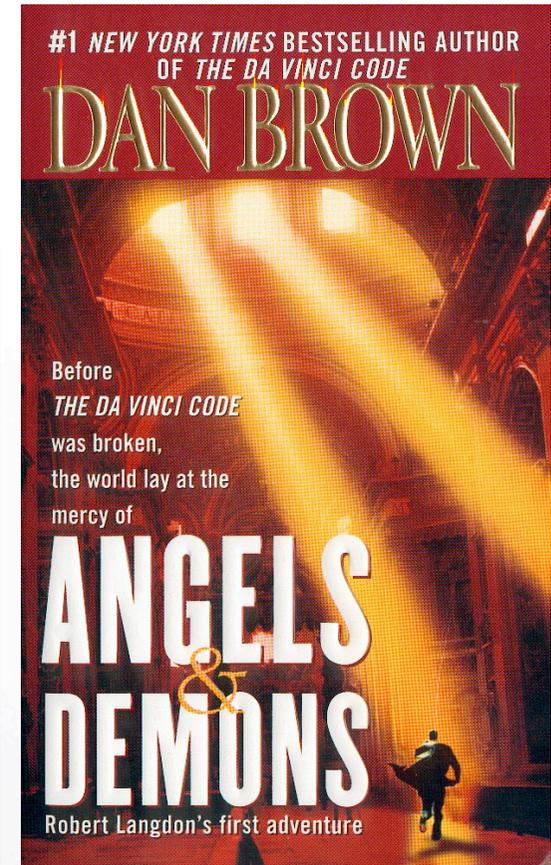


Wuminati

Detective story about a secret society which ...



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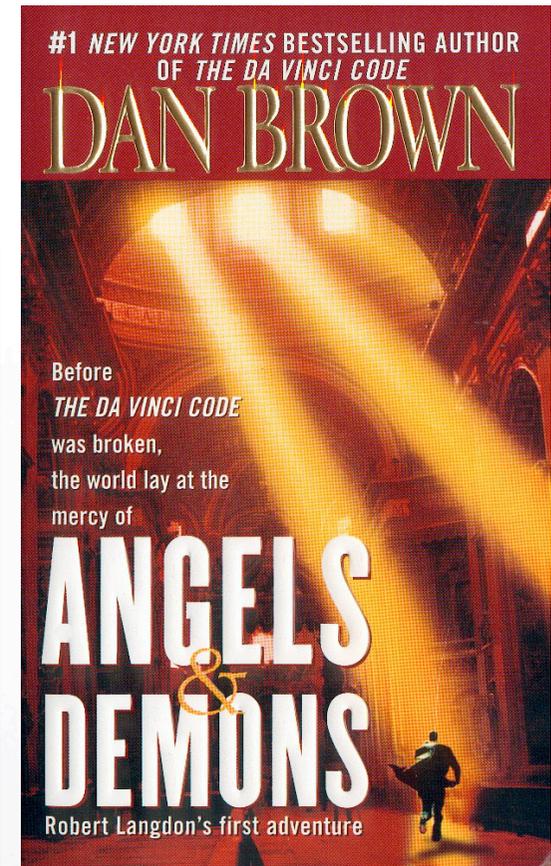
Detective story about a secret society which ...



... steals 1 g of antimatter from a physicist at the 'LHC' in a place called "CERN" ...



... to blow up the Vatican, an old "enemy of science and CERN".



What's true ?
What's false ?

Angels + Demons: The Movie

The 'Angels and Demons' movie is being made (release 2009).



***Da Vinci Code, Apollo 13, Beautiful mind, ...**

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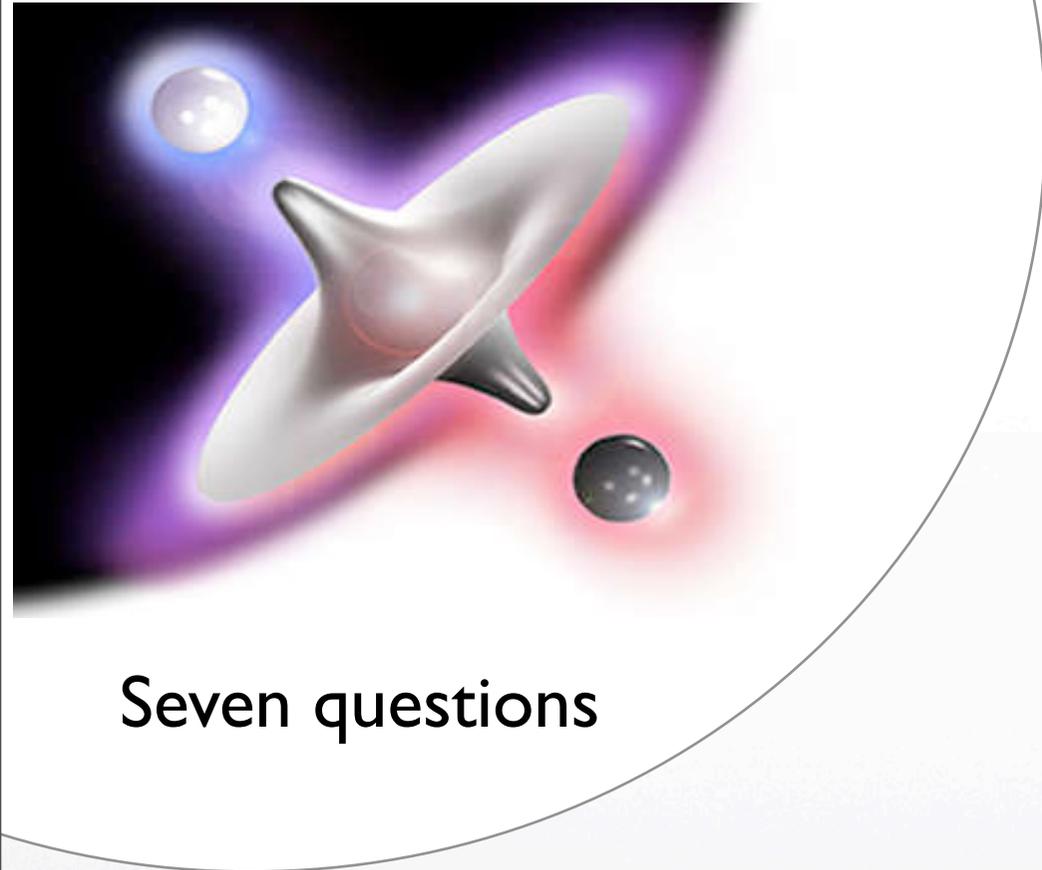
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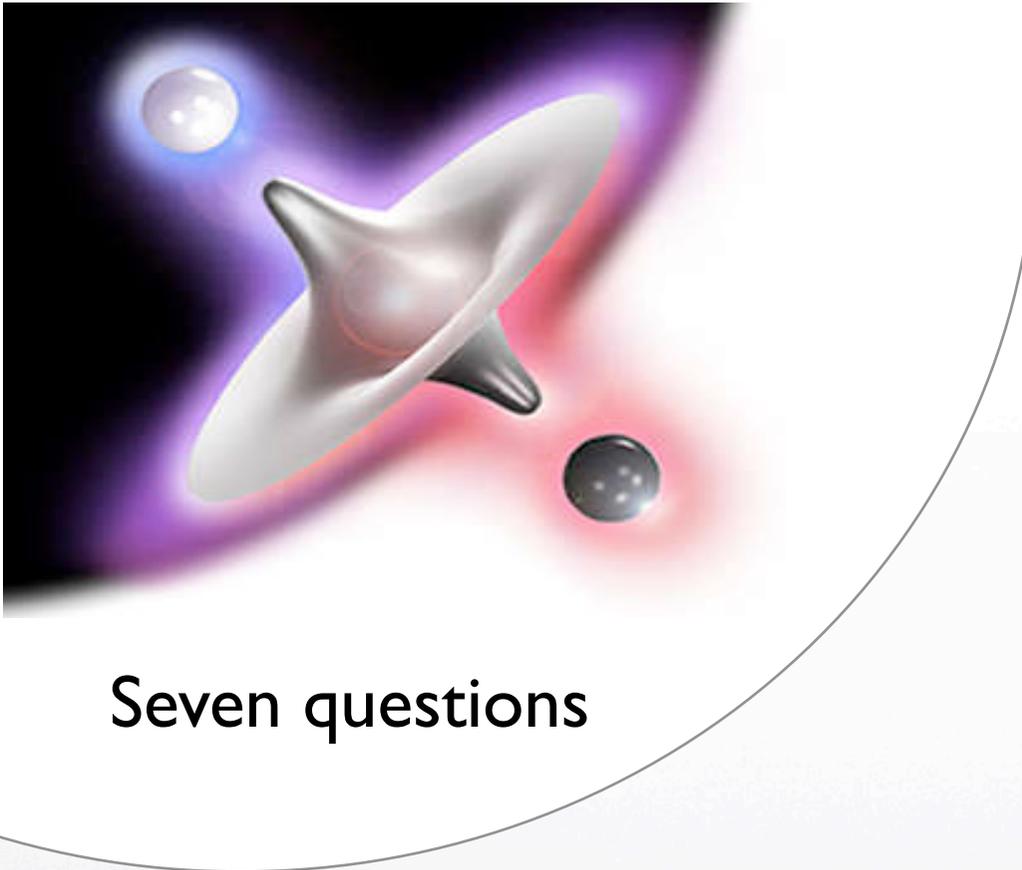
This is what Dan Brown understands about antimatter

*Da Vinci Code, Apollo 13, Beautiful mind, ...



Seven questions

What is antimatter

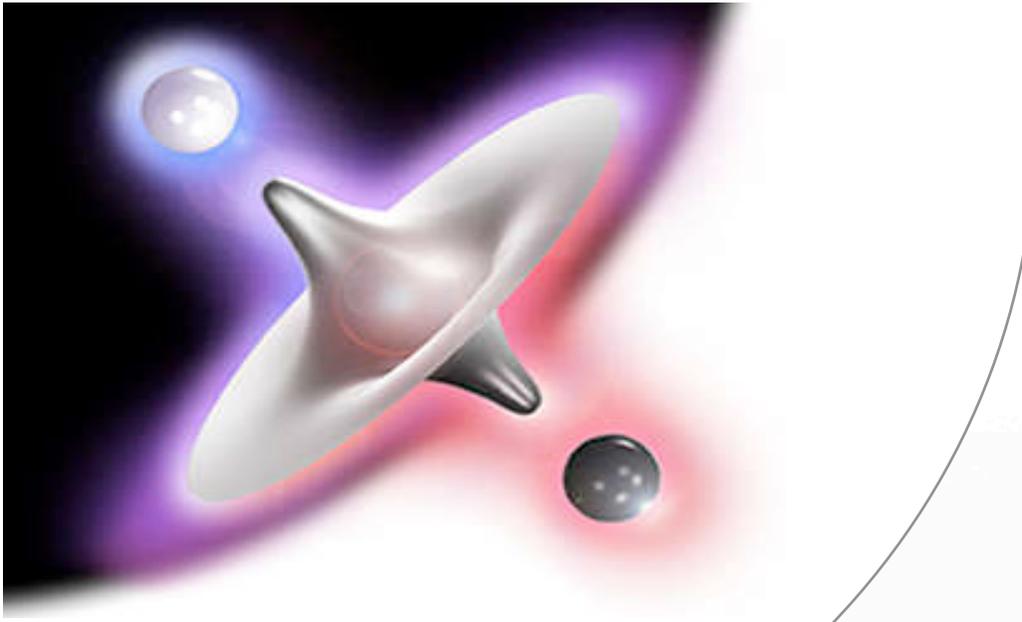


Seven questions

Antimatter Questions

What is antimatter

Where is antimatter made



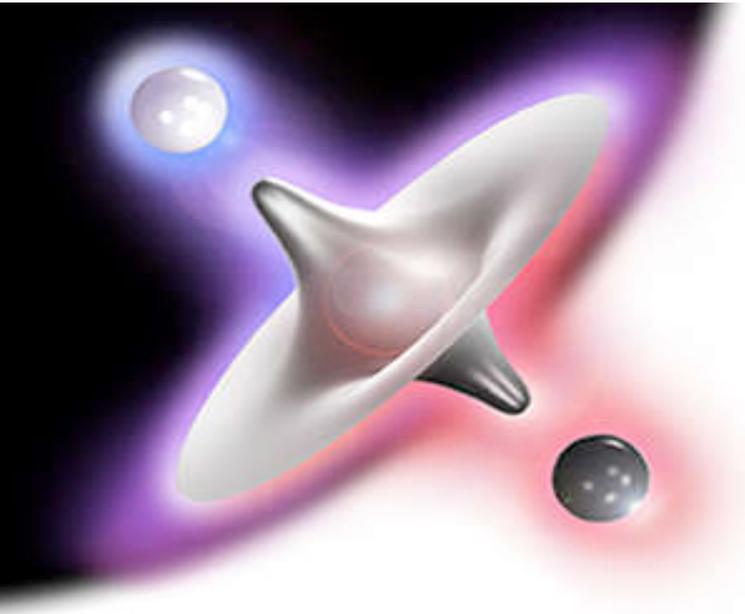
Seven questions

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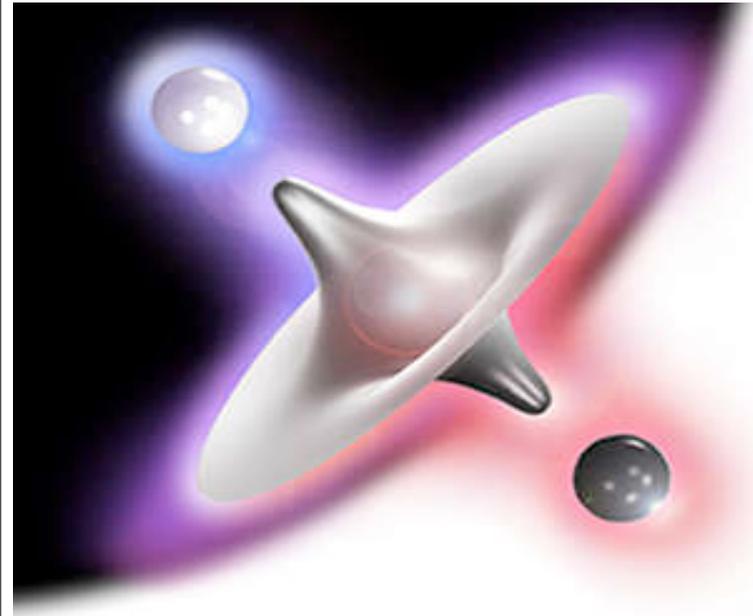
Where is antimatter made

How is antimatter made



Seven questions

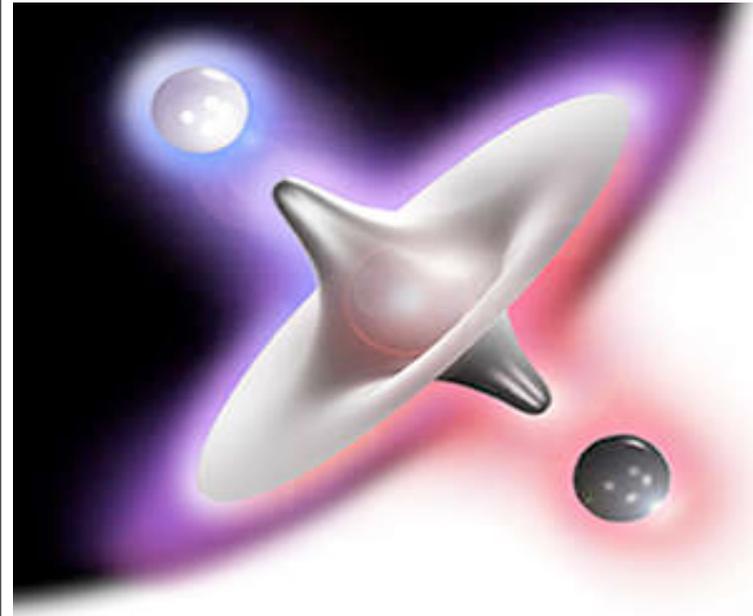
Antimatter Questions



Seven questions

- What is antimatter
- Where is antimatter made
- How is antimatter made
- The mystery of antimatter

Antimatter Questions



Seven questions

What is antimatter

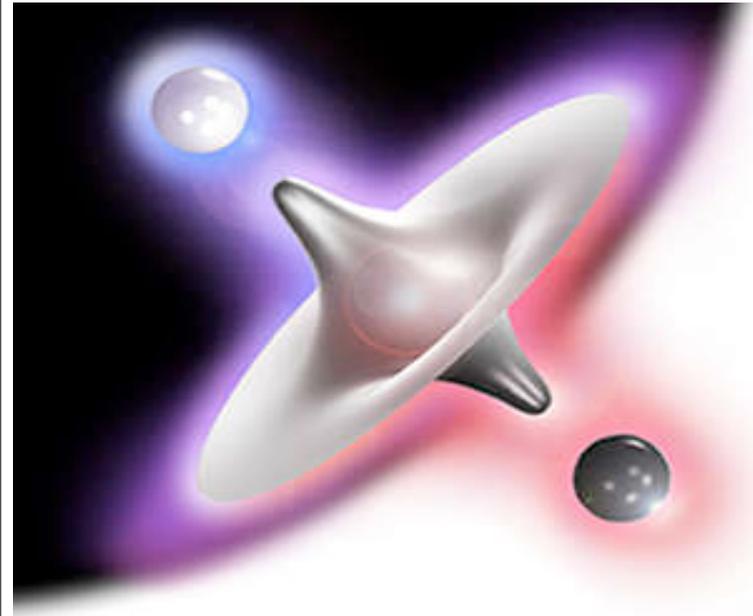
Where is antimatter made

How is antimatter made

The mystery of antimatter

How to study antimatter

Antimatter Questions



Seven questions

What is antimatter

Where is antimatter made

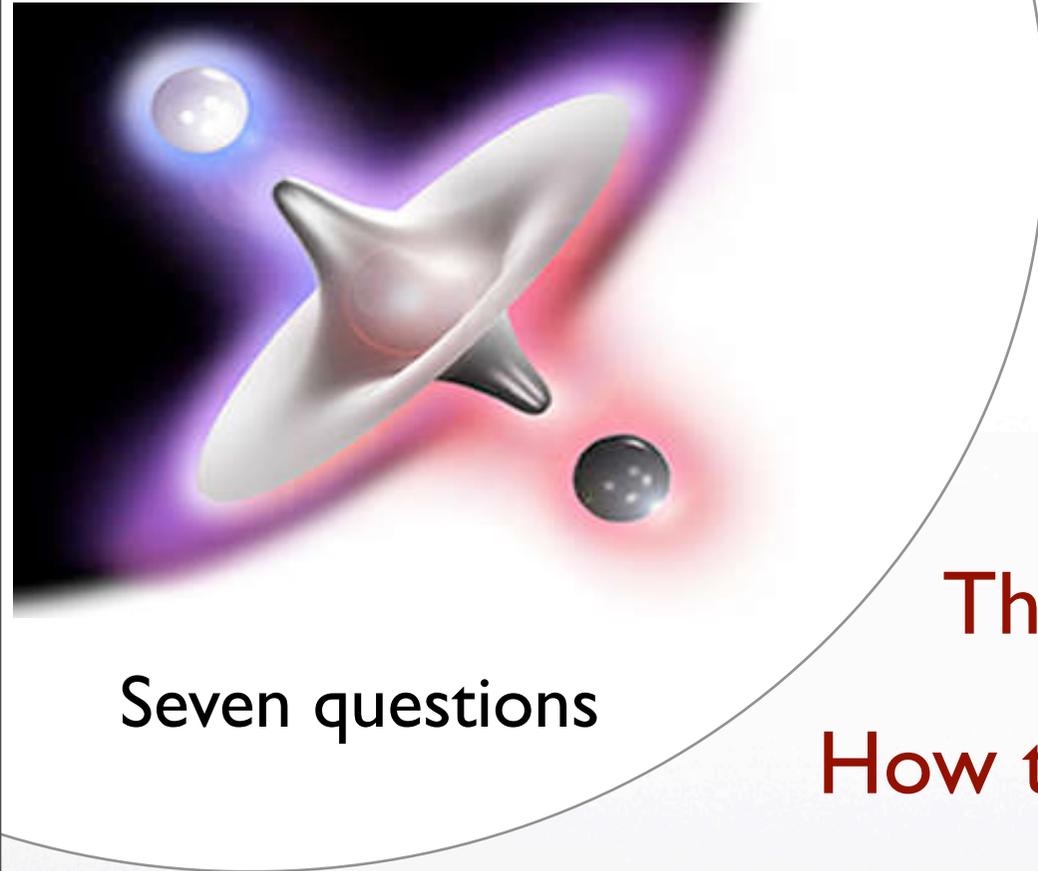
How is antimatter made

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Energy source, weapon, Star Trek ?

Antimatter Questions



Seven questions

What is antimatter

Where is antimatter made

How is antimatter made

The mystery of antimatter

How to study antimatter

Energy source, weapon, Star Trek ?

Applications in medicine

I What is antimatter ?

| What is antimatter ?

Everything is made of matter

(We, animals, plants, rocks)

Matter is made of **particles**

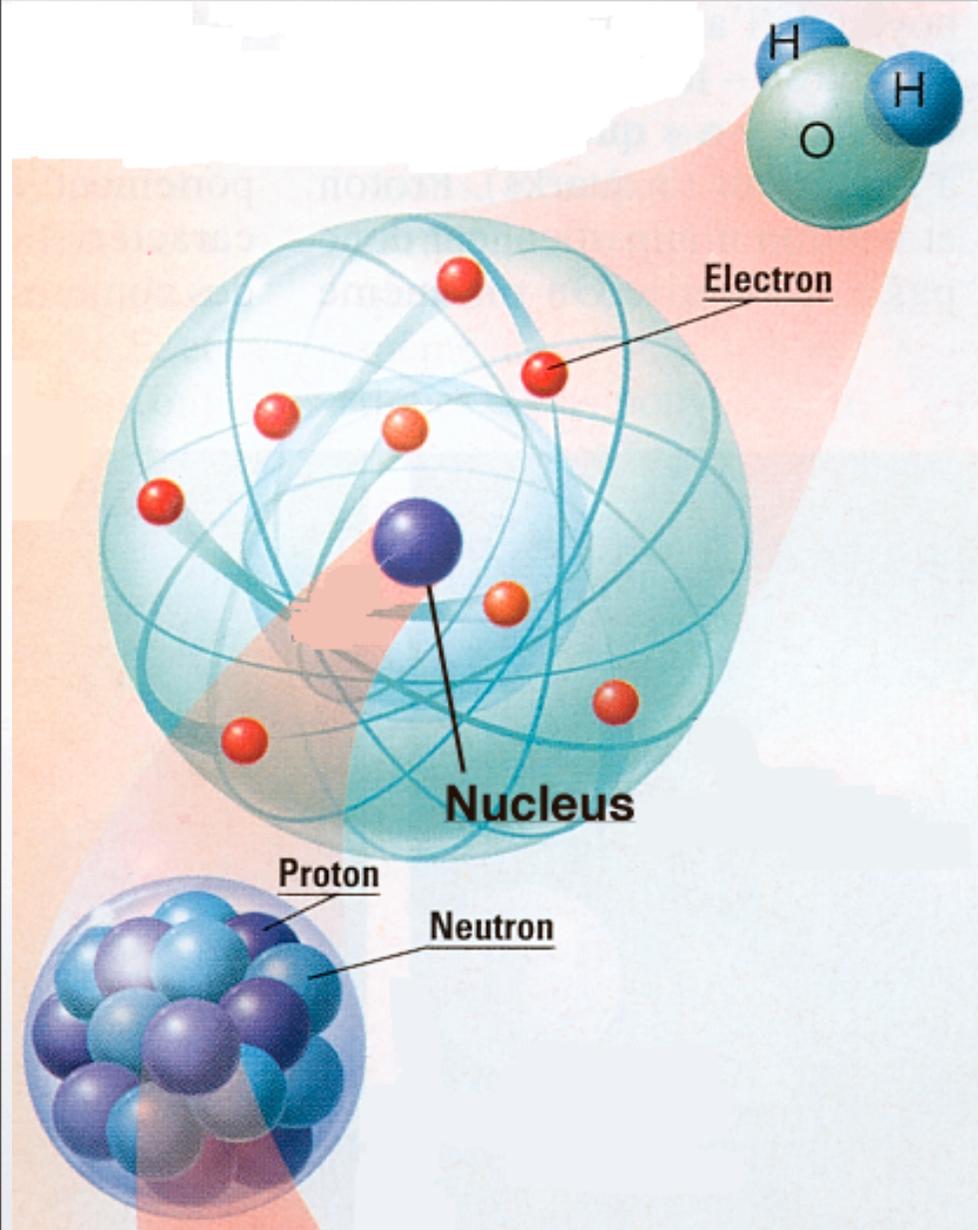
Electrons

Protons

Neutrons

} Quarks

The whole (visible) Universe can be explained with 4 building blocks



I What is antimatter ?

Particles have specific **masses** and **charges**

I What is antimatter ?

Particles have specific **masses** and **charges**

Name	Electric Charge [e]	Mass [GeV*]
Electron	- 1	0.0005
Proton	+ 1	0.938
Neutron	0	0.941

*GeV = Giga-Electron Volt = 1,000,000,000 Electron-Volt = $1.8 \cdot 10^{-27}$ kg

| What is antimatter ?

Anti-Particles have the **same mass**, but **opposite charge**

Particles



Anti-Particles

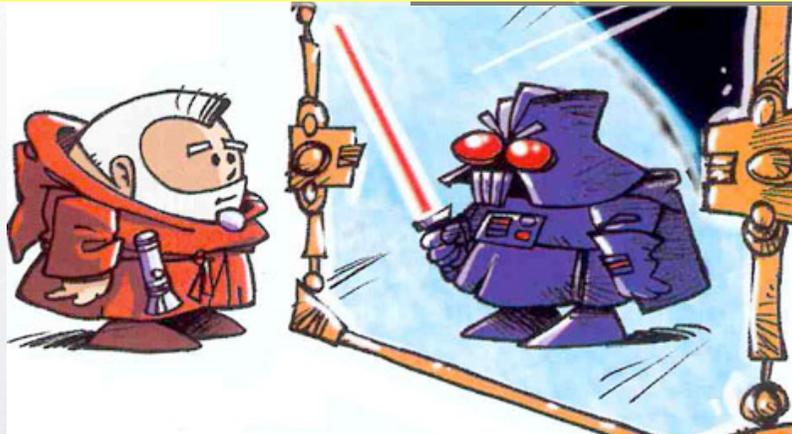
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Name	Electric Charge [e]	Mass [GeV ^{c²}]	Electric Charge [e]	Name
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Proton	+ 1	0.938	- 1	Antiproton
Neutron	0	0.941	0	Antineutron



Particles



Anti-Particles

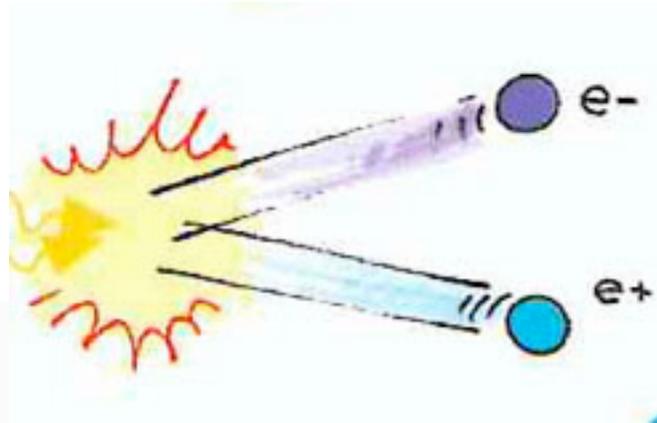
I What is antimatter ?

Particles and antiparticles are always **created in pairs** ...

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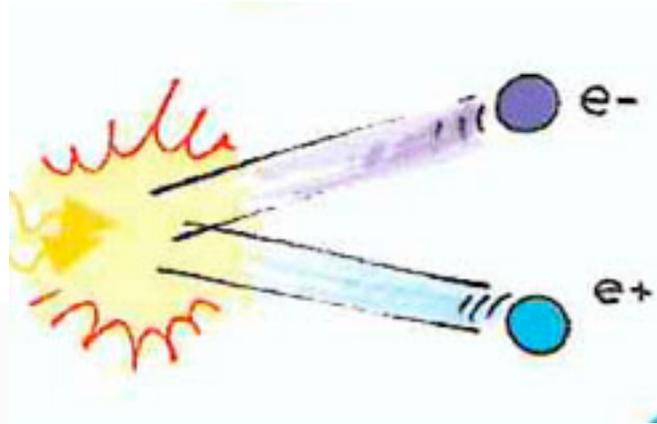
Energy to mass:



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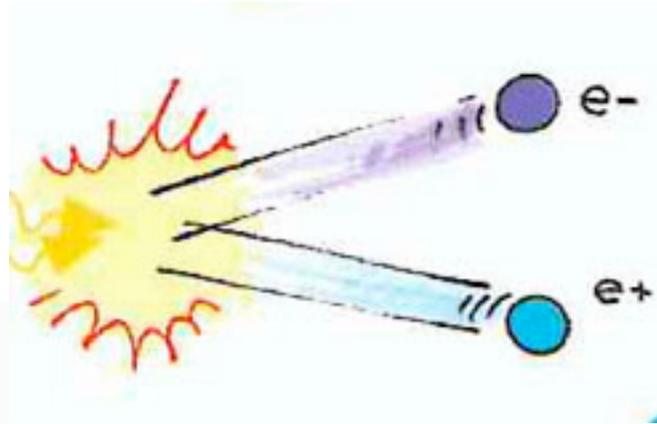


... and they can also **annihilate** each other

I What is antimatter ?

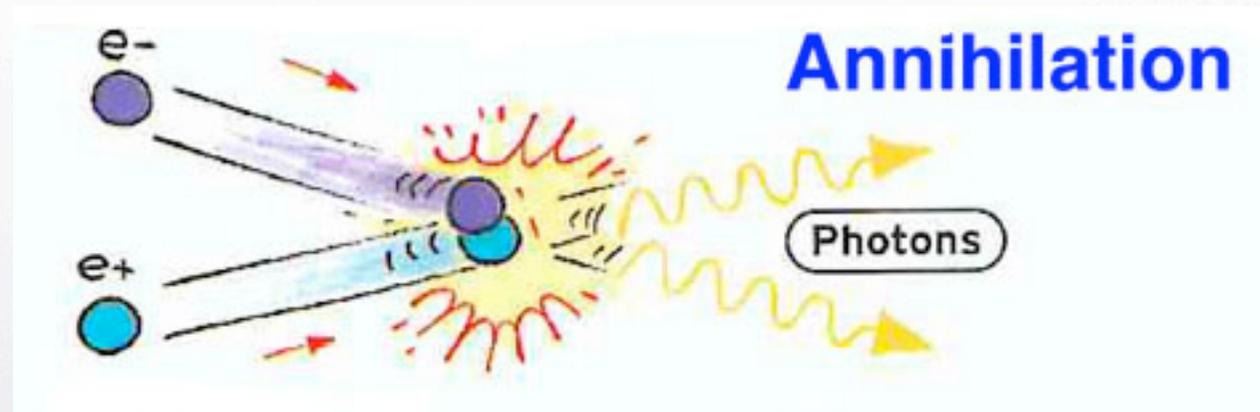
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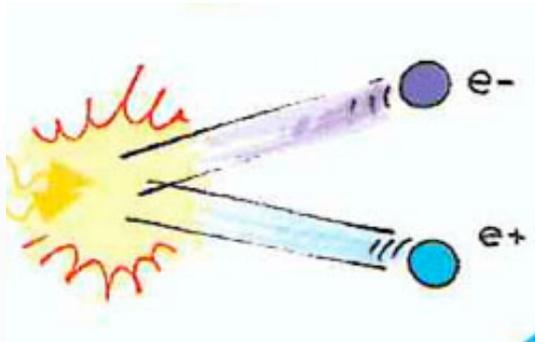
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Mass to energy:



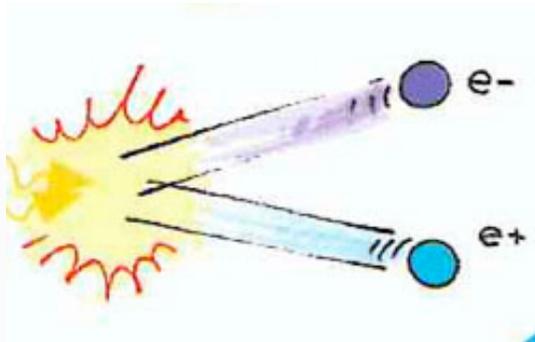
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What is an anti-particle?



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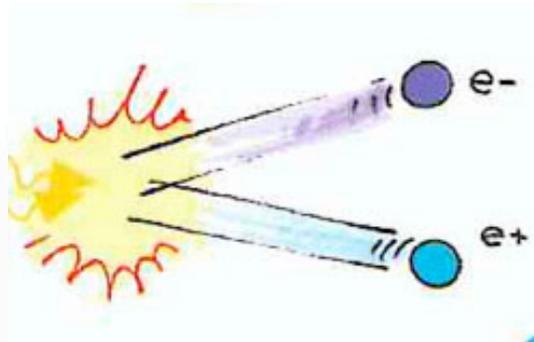


Anti-Particles are
as real as particles



I What is antimatter ?

What is an anti-particle?



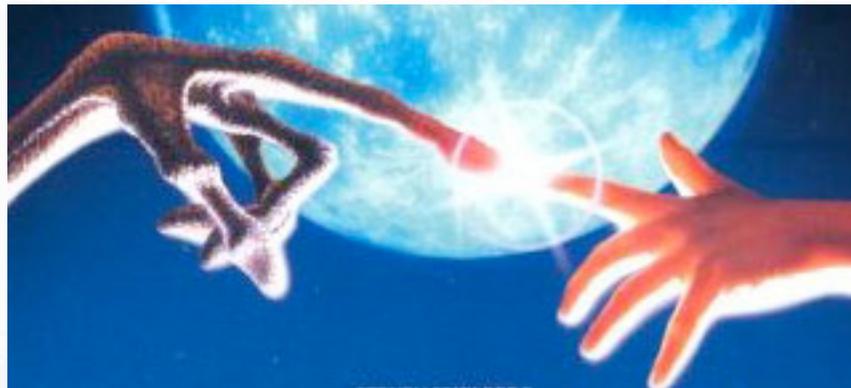
Anti-Particles are
as real as particles



*A world made of antiparticles could exist -
and it would look the same as our world.*

I What is antimatter ?

Careful with “antimatter E.T.” !



I What is antimatter ?

Careful with “antimatter E.T.” !



2 Where is antimatter made ?

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Antiparticles are produced using accelerators

The largest accelerator laboratory in the world is CERN in Geneva (CH)

CERN = '**C**onseil **E**uropéen pour la **R**echerche **N**ucléaire'

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CERN = 'Conseil Européen pour la Recherche Nucléaire'



7500 physicists from
104 countries

2 Where is antimatter made ?

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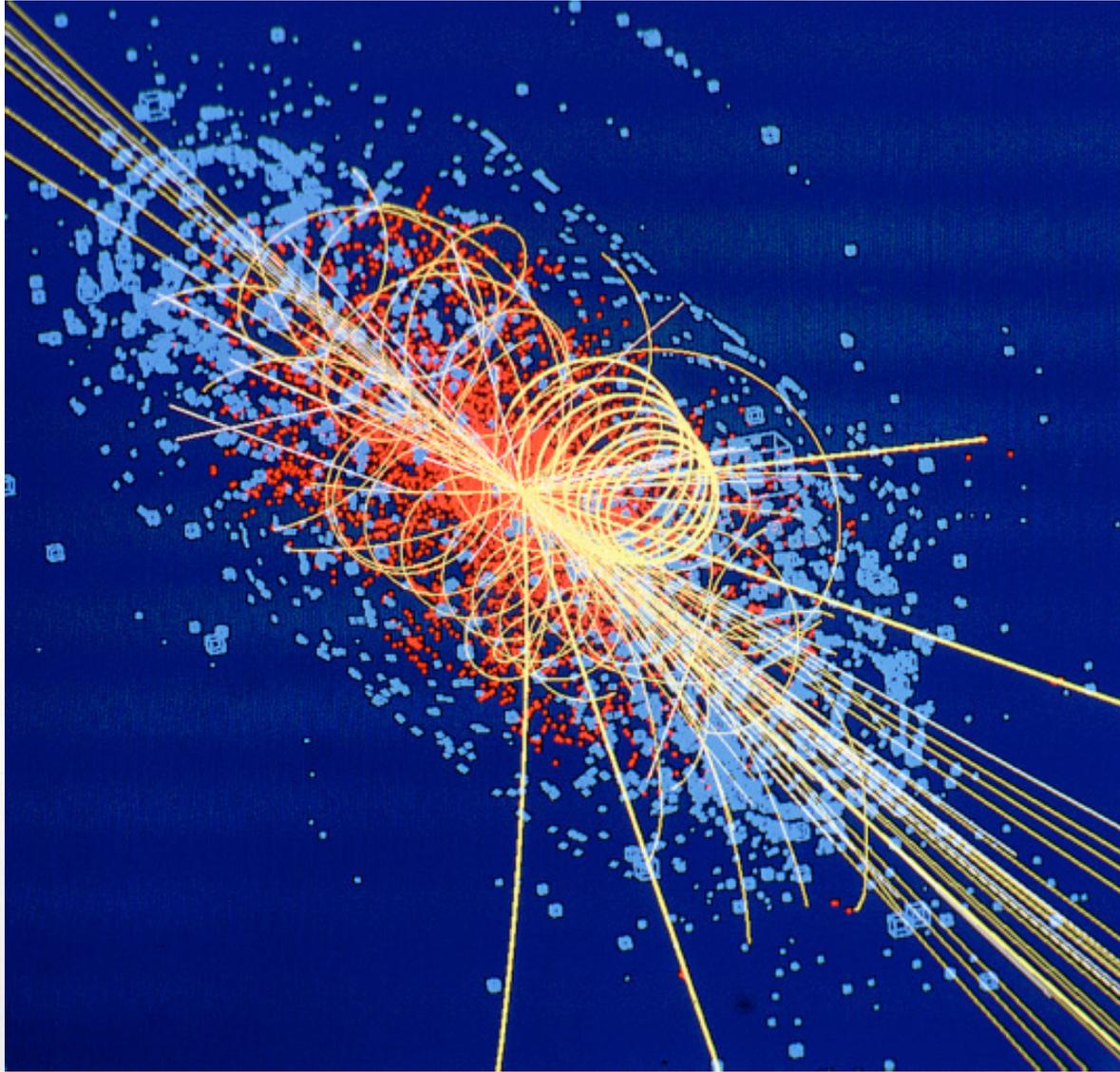
European Laboratory for Particle Physics



Large
Hadron
Collider

The most powerful
particle accelerator
in the world

2 Where is antimatter made ?



New particles will be created that only existed shortly after the Big Bang

Dark Matter ?
The “Higgs” particle ?
Mini-Black holes ?

3 How is antimatter made ?

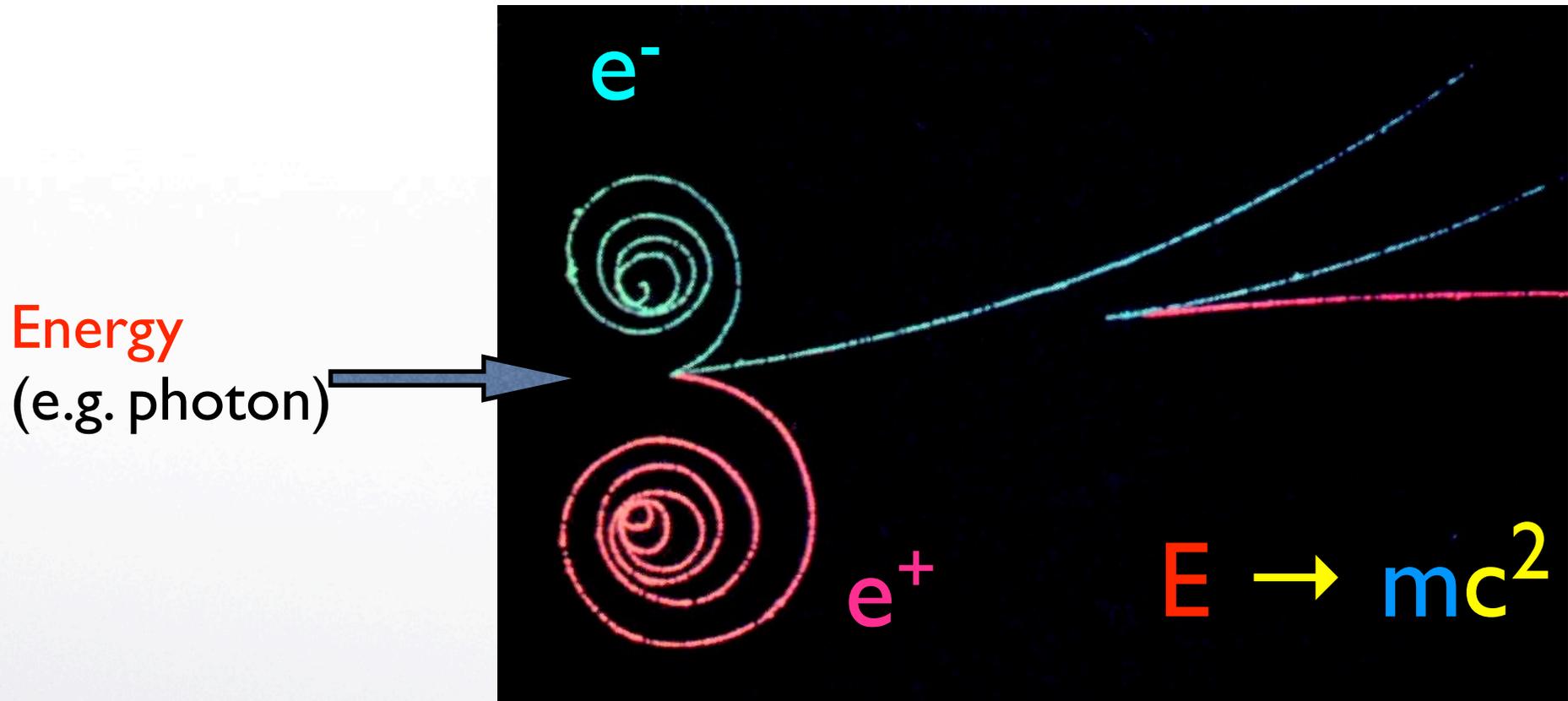
$$E = mc^2$$

2 How is antimatter made ?

Energy is converted to mass

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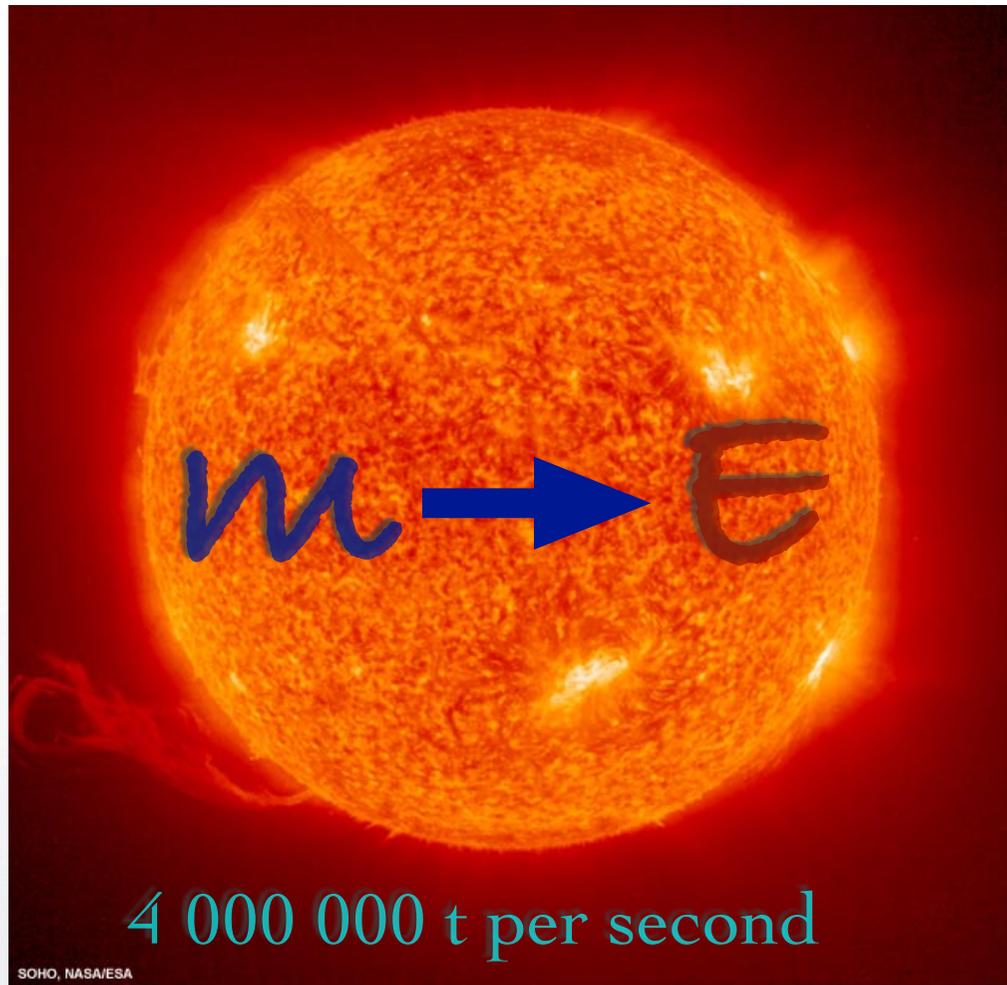
Energy is converted to mass



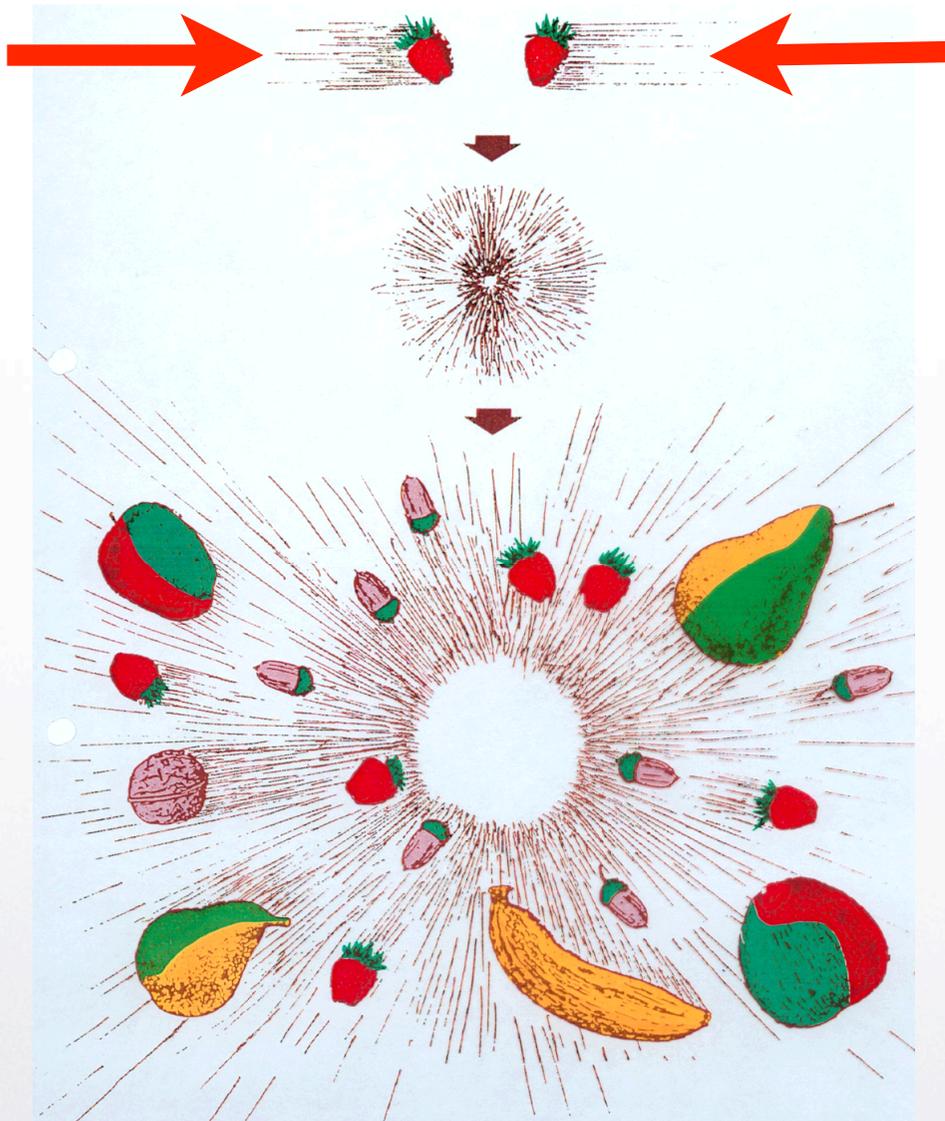
Mass of electron and positron

2 How is antimatter made ?

In the Sun, mass is converted to energy



2 How is antimatter made ?



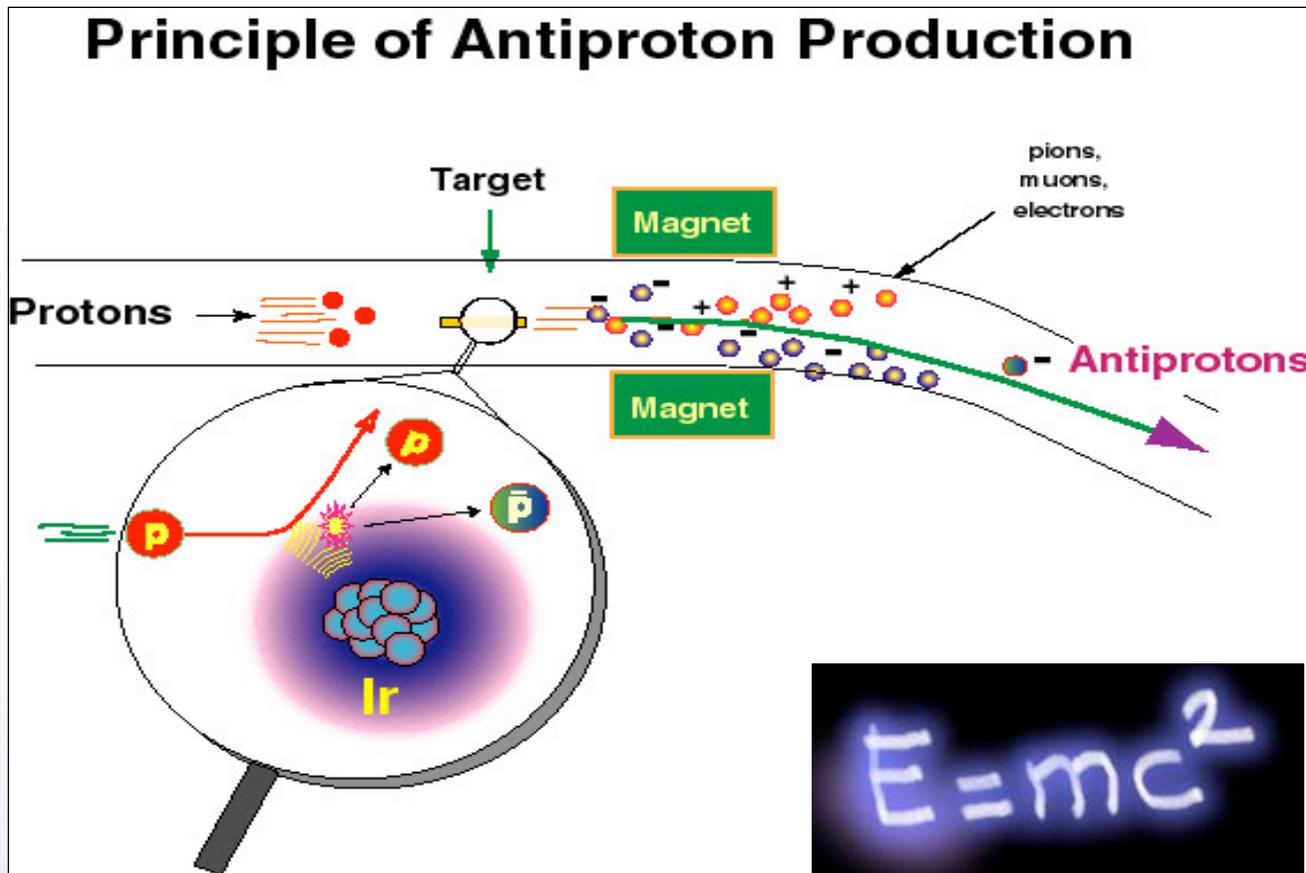
New particles and antiparticles are created in collisions

2 How is antimatter made ?

Energy is carried by **accelerated** particles

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Energy is carried by **accelerated** particles



Energy is converted to mass in **collisions**

4 The mystery of antimatter

4 The mystery of antimatter

The Universe started 13 700 million years ago



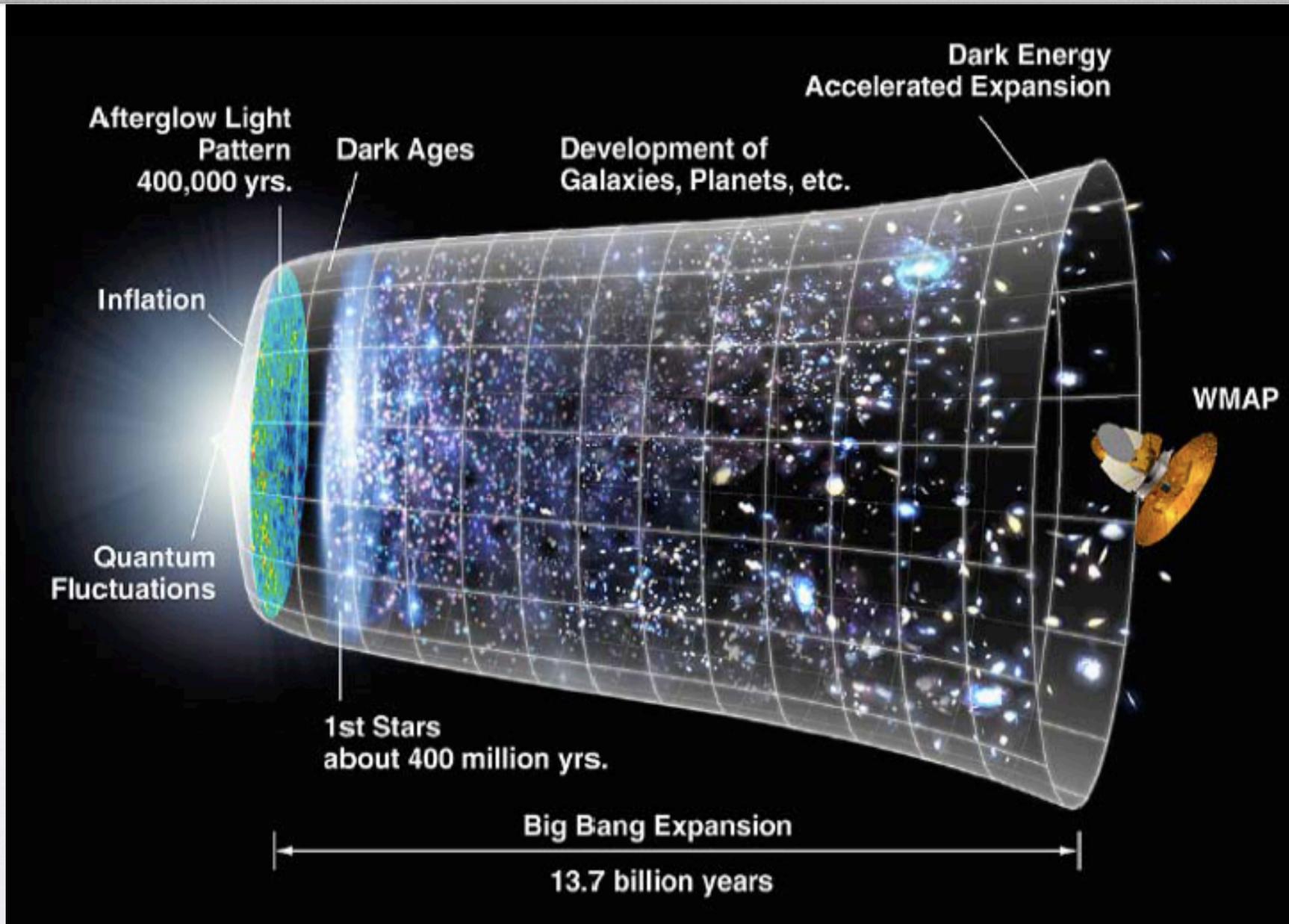
~ 10^{72} Joule



Size (x 100) of the visible Universe at the 'Planck' time

Space and time came into existence. The space expanded, while the energy converted into mass

4 The mystery of antimatter

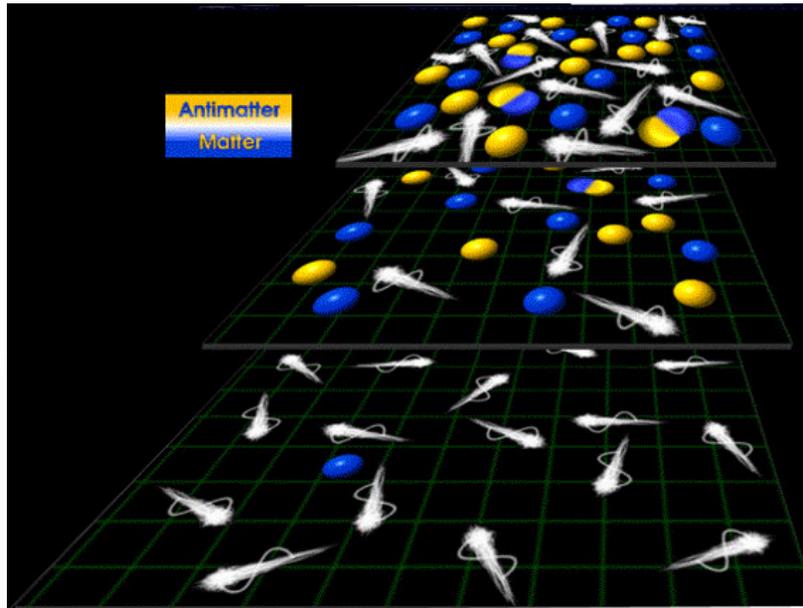


4 The mystery of antimatter

No antimatter in the Universe ?????

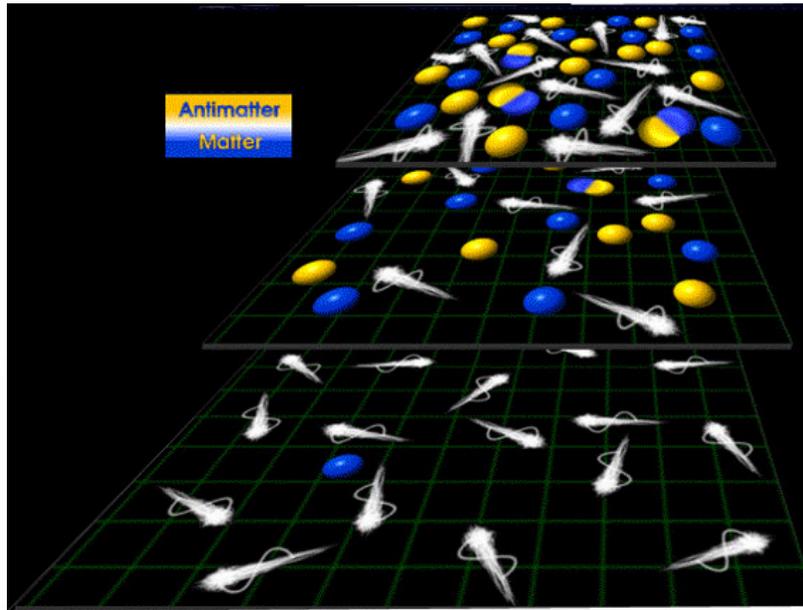
Why not ?

4 The mystery of antimatter



The first instants of the Universe:

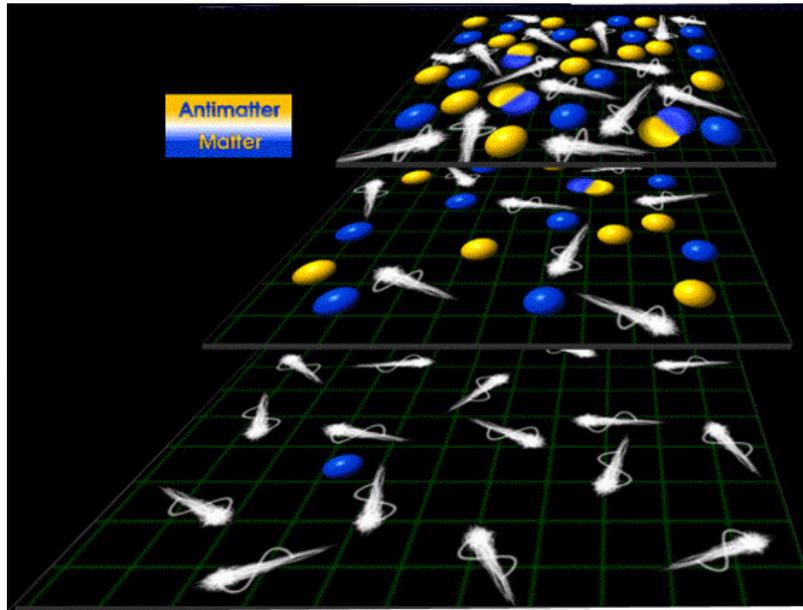
4 The mystery of antimatter



The first instants of the Universe:

- Transformation of energy into mass
- 50% matter - 50% antimatter
- should have destroyed each other
- leaving only radiation ... BUT:
- there's something left !

4 The mystery of antimatter



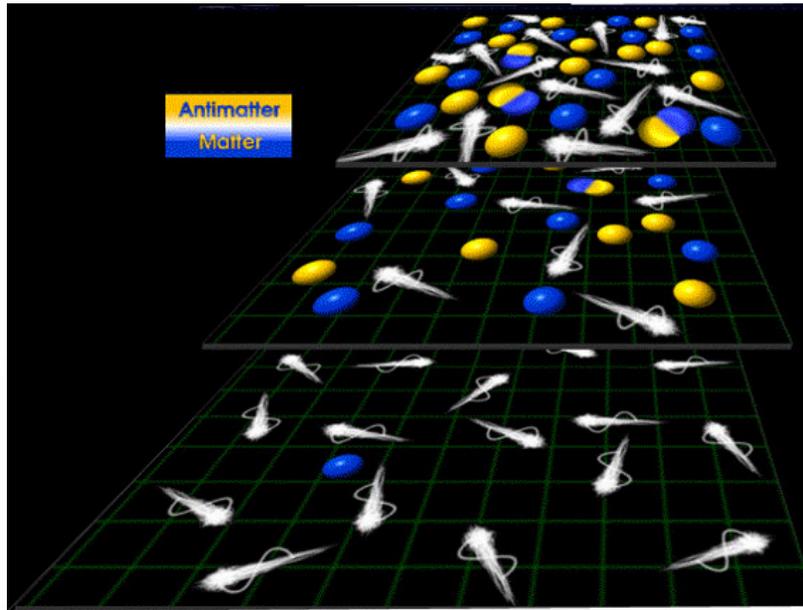
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Why does the Universe contain **only matter!**

Why is there something and not nothing (but radiation?)

4 The mystery of antimatter



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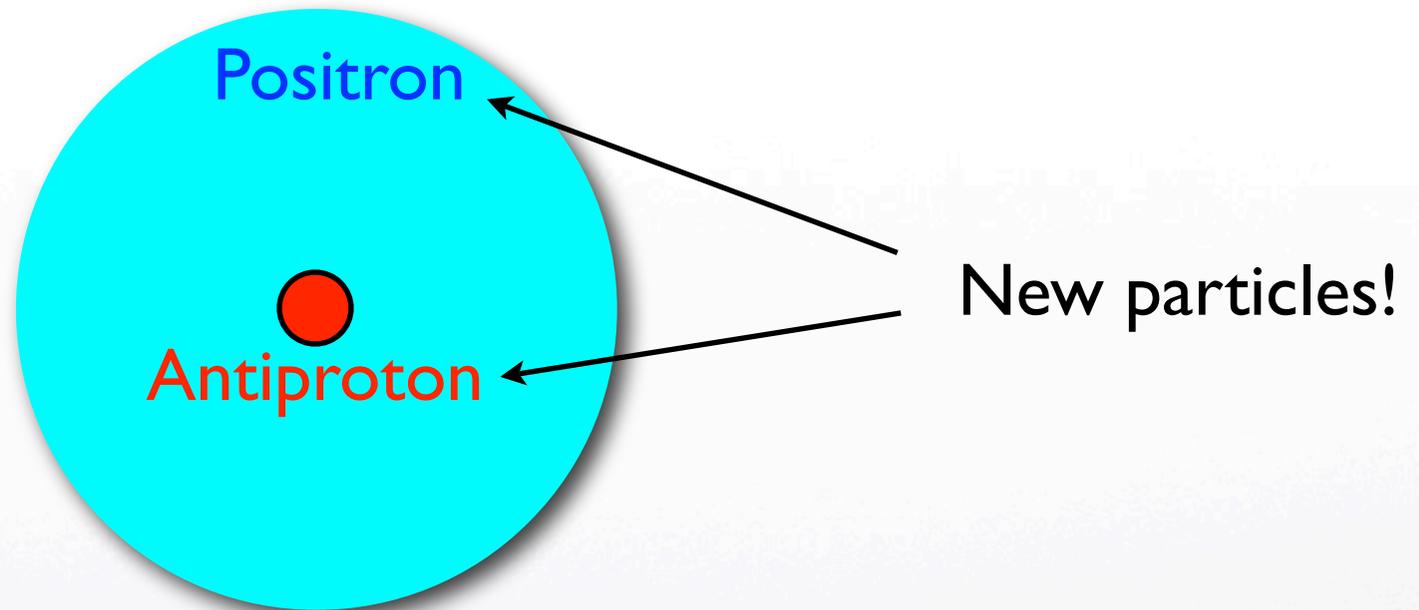
Why is there something and not nothing (but radiation?)

There must be a small difference between matter and antimatter -
but what exactly is it?

5 How to study antimatter ?

5 How to study antimatter ?

Make an antihydrogen atom and compare to a hydrogen atom



5 How to study antimatter ?

We have learned how to make antimatter atoms*

* 1 million anti-atoms ~ 1 billionth billionth gram

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We have learned how to make antimatter atoms*

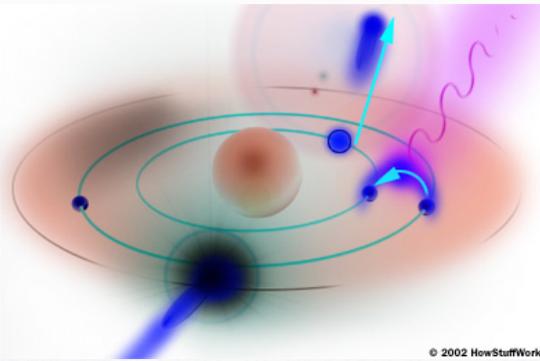
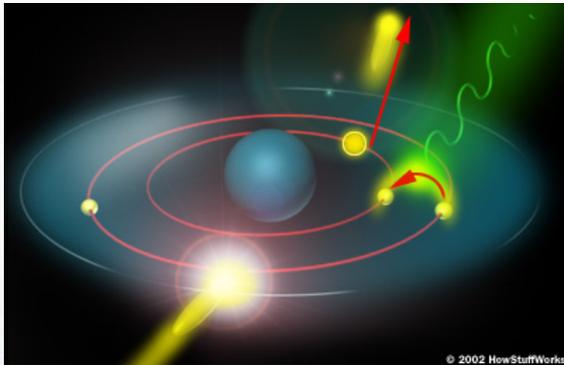
- 1) Produce **antihydrogen atoms** from antiprotons and positrons
- 2) Trap antihydrogen atoms
- 3) Measure their properties

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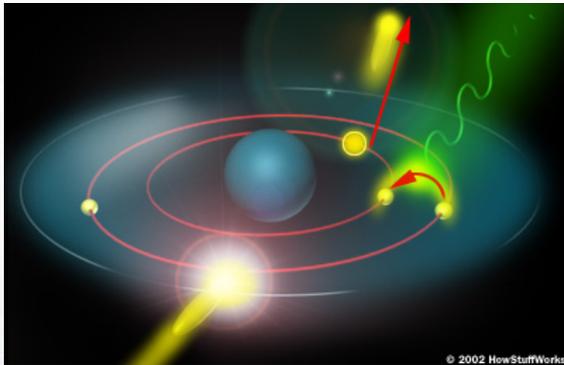
Energy levels

* 1 million anti-atoms ~ 1 billionth billionth gram

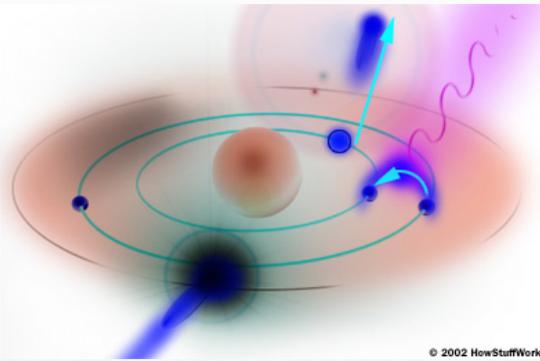
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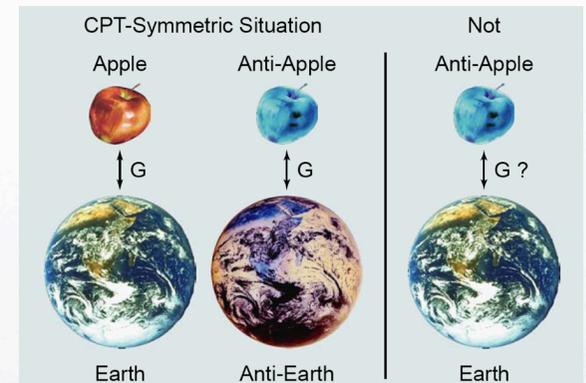
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Energy levels



© 2002 HowStuffWorks



Gravity

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5 How to study antimatter ?



Antimatter factory at CERN

Antiproton Decelerator
produces antiprotons
and slows them down

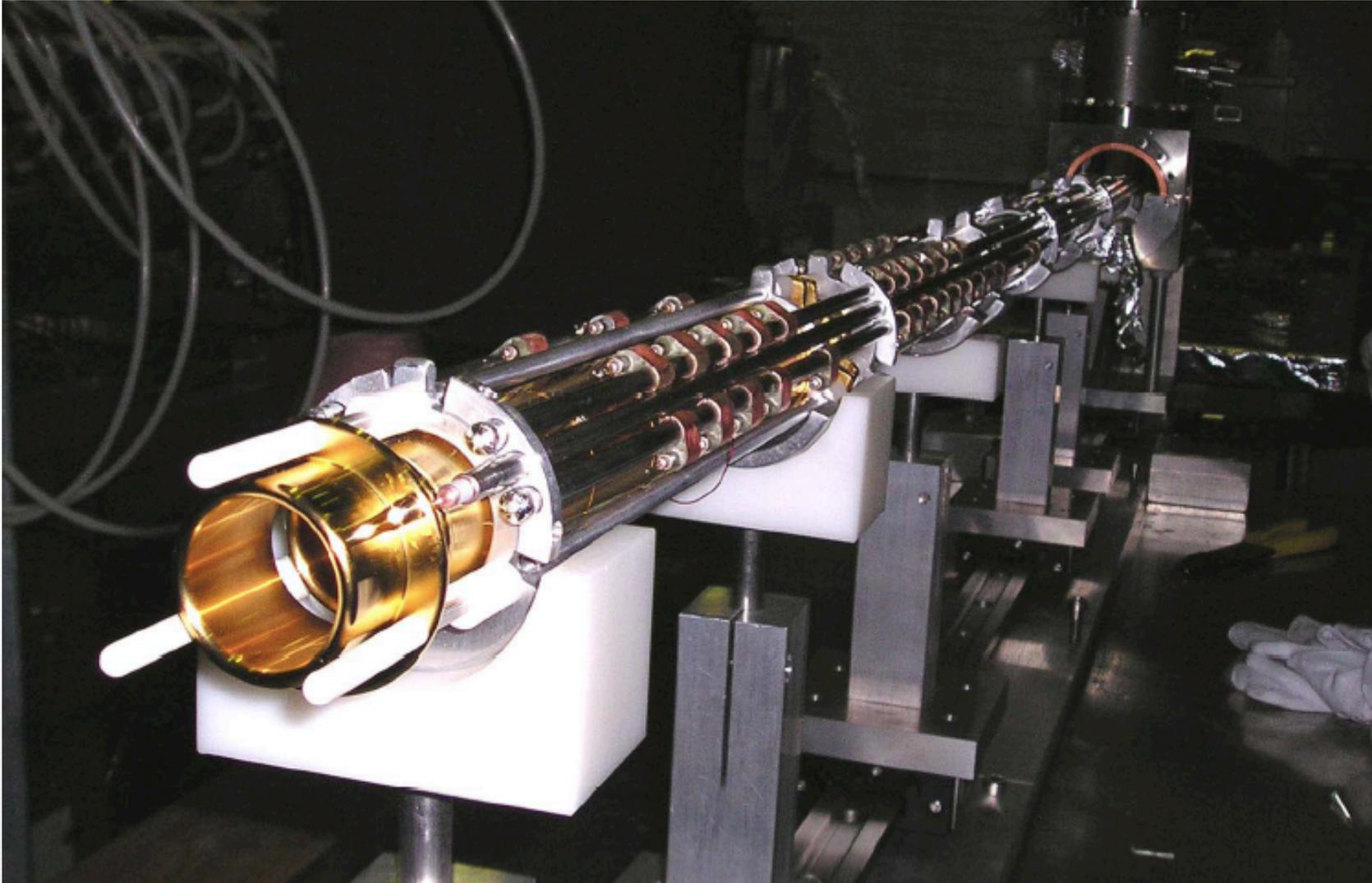
188 m long

Antiproton Production:
100,000,000 antiprotons per minute

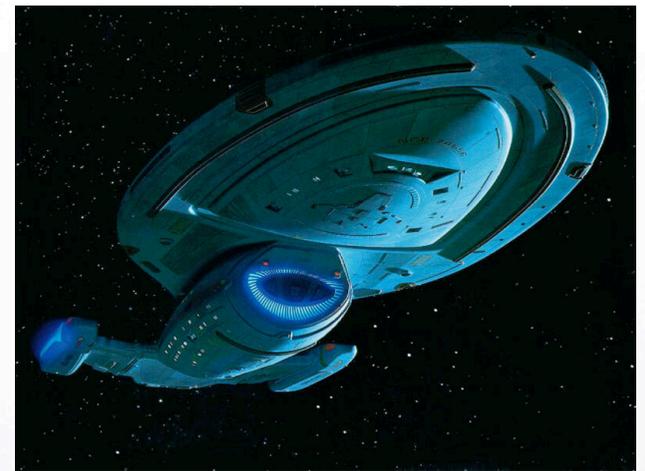
Deceleration
96 % \rightarrow 10 % speed of light

5 How to study antimatter ?

Then, antiprotons (and positrons) are trapped



6 Energy source? Weapon? Star Trek?

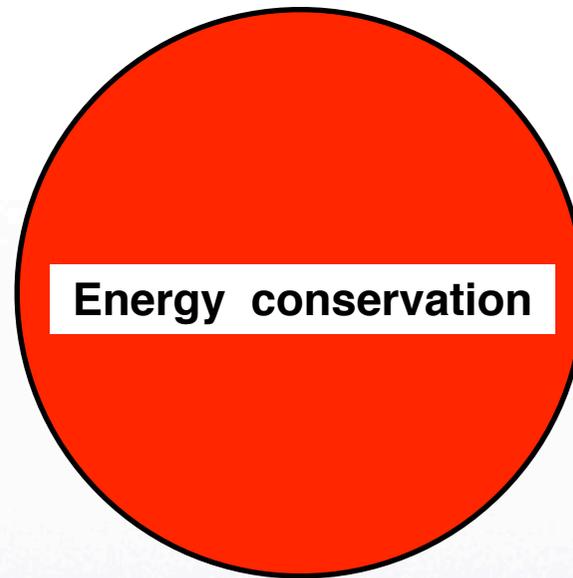


6 Energy source?

Dan Brown: Antimatter is the energy source of the future.

6 Energy source?

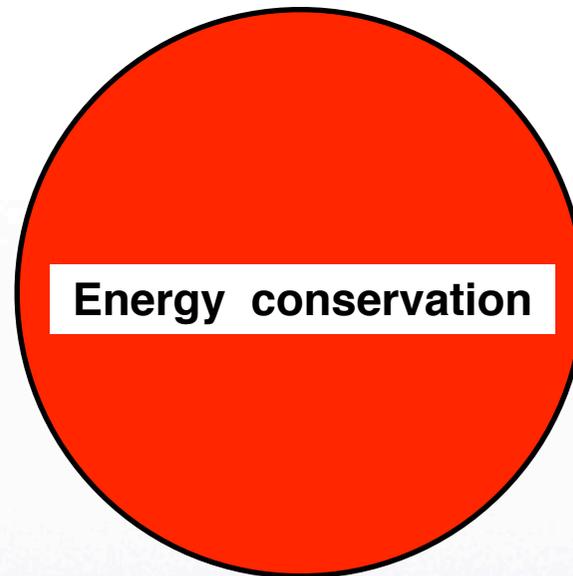
Dan Brown: Antimatter is the energy source of the future.



No

6 Energy source?

Dan Brown: Antimatter is the energy source of the future.



No

Antimatter production **requires energy**

1,000,000,000 times more energy invested than released by annihilation

6 Antimatter bombs ?



Dan Brown is right:

only 0.5 g antimatter makes an 'anti-atomic bomb'

BUT:

20 kt TNT = $8.4 \cdot 10^{13}$ J
0.5 g antimatter + 0.5 g matter

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Electricity discount price CERN

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Price ~ 1,000,000,000,000,000 €

Delivery time ~ 1 000 000 000 years

6 Star Trek?



Antimatter as fuel for space ships ?

No!

6 Star Trek?



Antimatter as fuel for space ships ?

No!

Energy needed to accelerate a 10-ton space ship to 95 % of the speed of light:

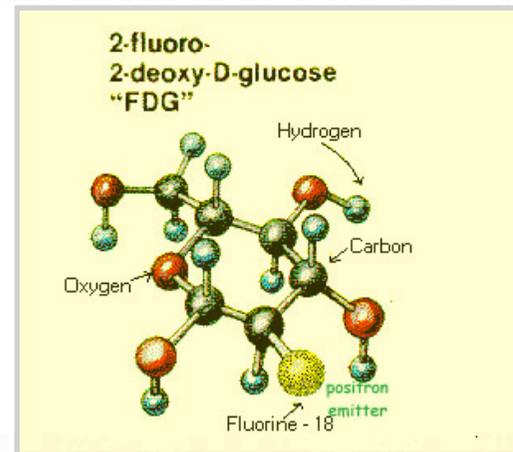
$$E = \gamma mc^2 \sim 10 \cdot 10^4 \text{ kg} =$$

Needs 50 tons of antimatter

7 Applications in medicine

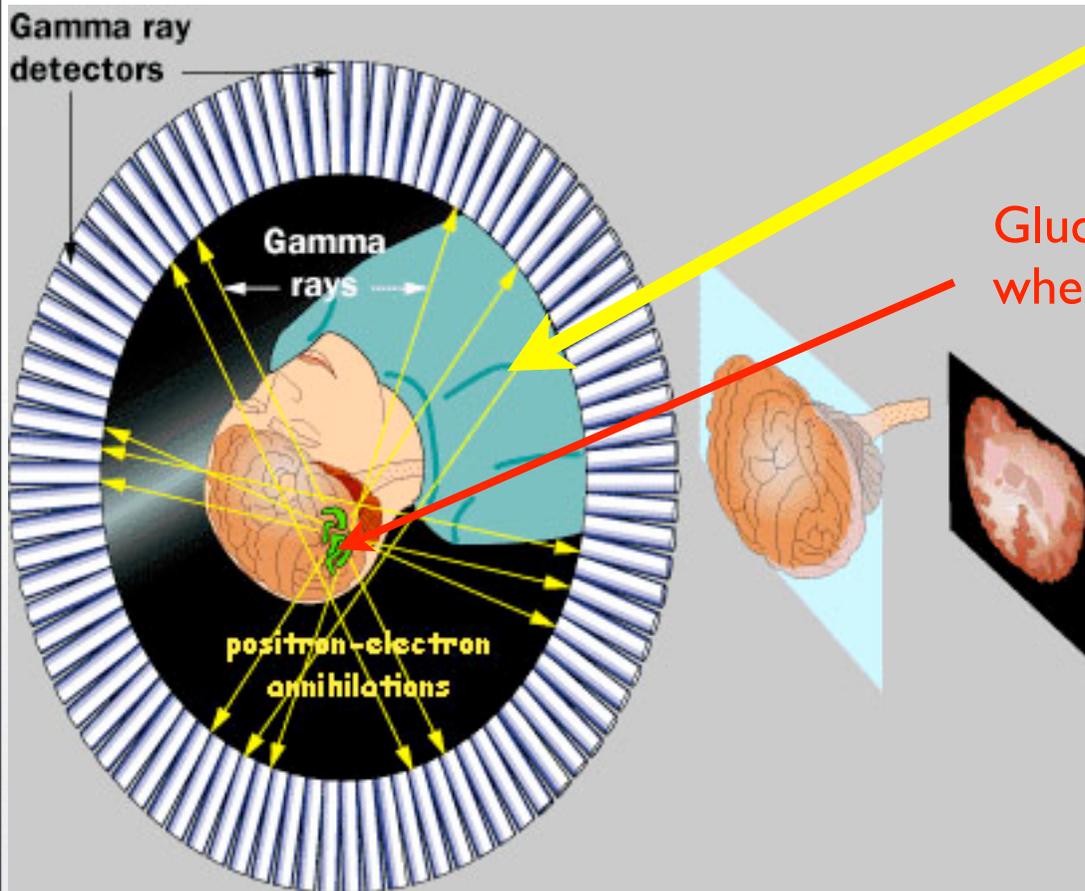
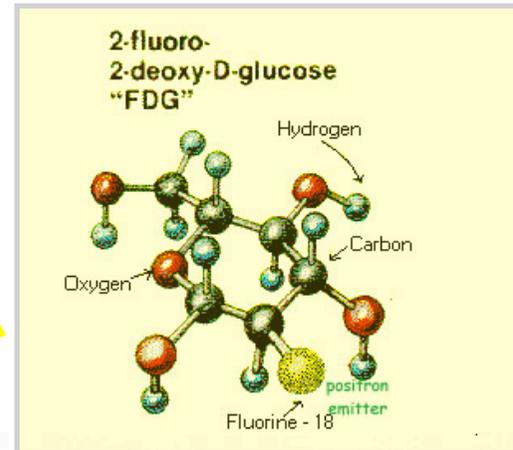
7 Positron Emission Tomography

Add **positron** emitting isotopes (e.g. F-18) to glucose molecule and inject into blood stream



7 Positron Emission Tomography

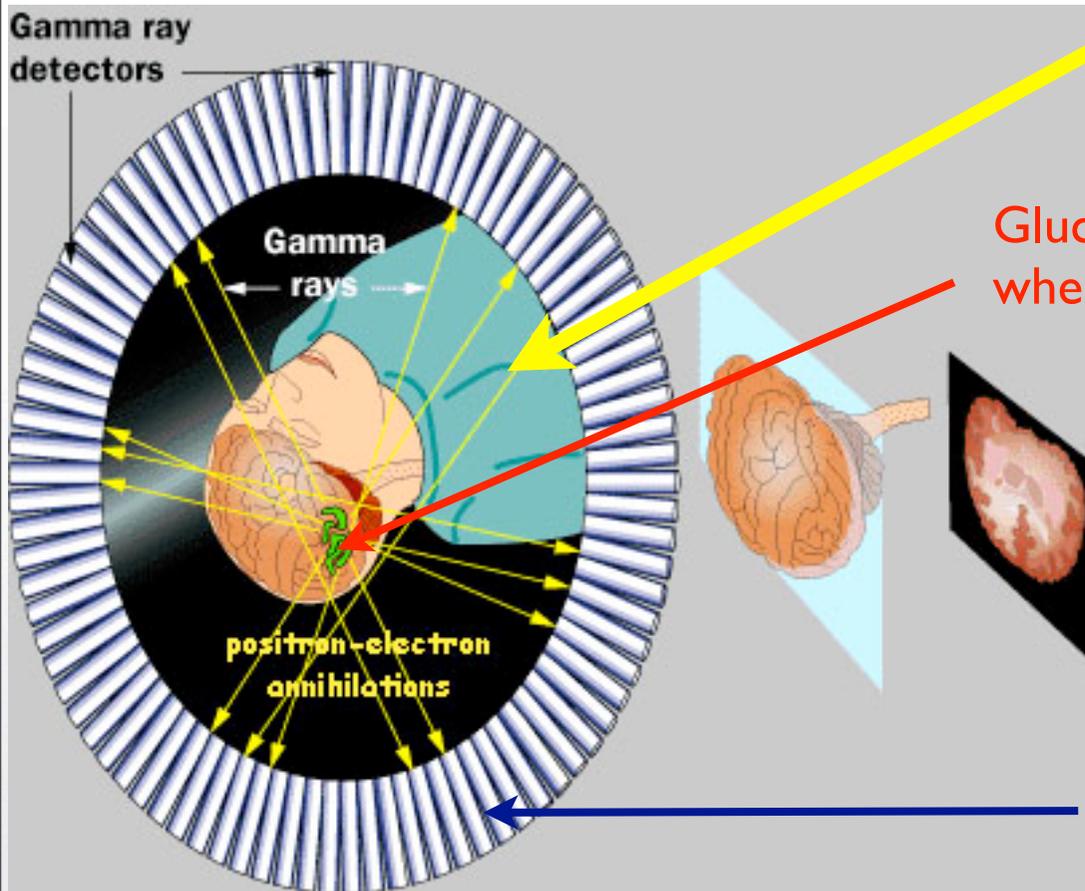
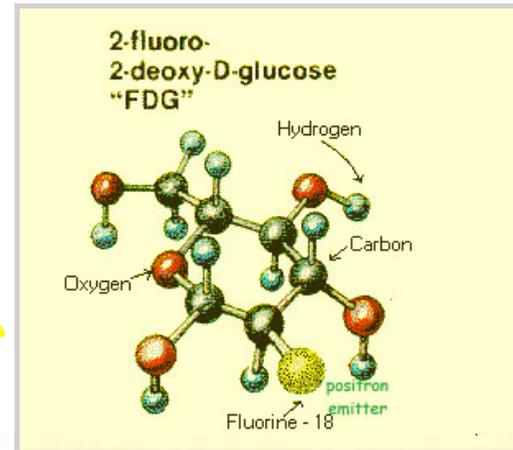
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Glucose molecules accumulate (and decay) where energy is needed

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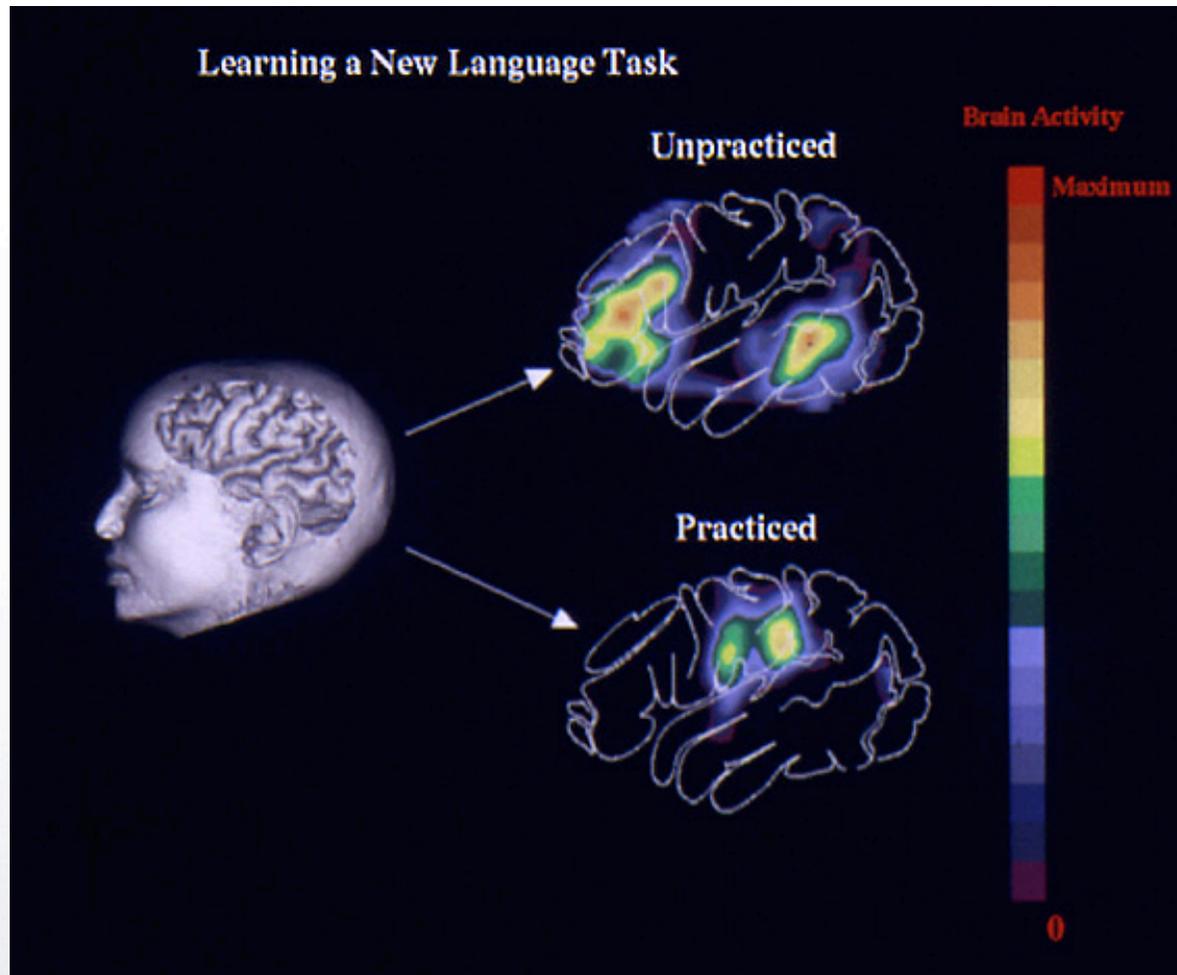


Glucose molecules accumulate (and decay) where energy is needed

Use detector to reconstruct place of positron annihilation

7 Positron Emission Tomography

Antimatter annihilations help to understand how the brain works

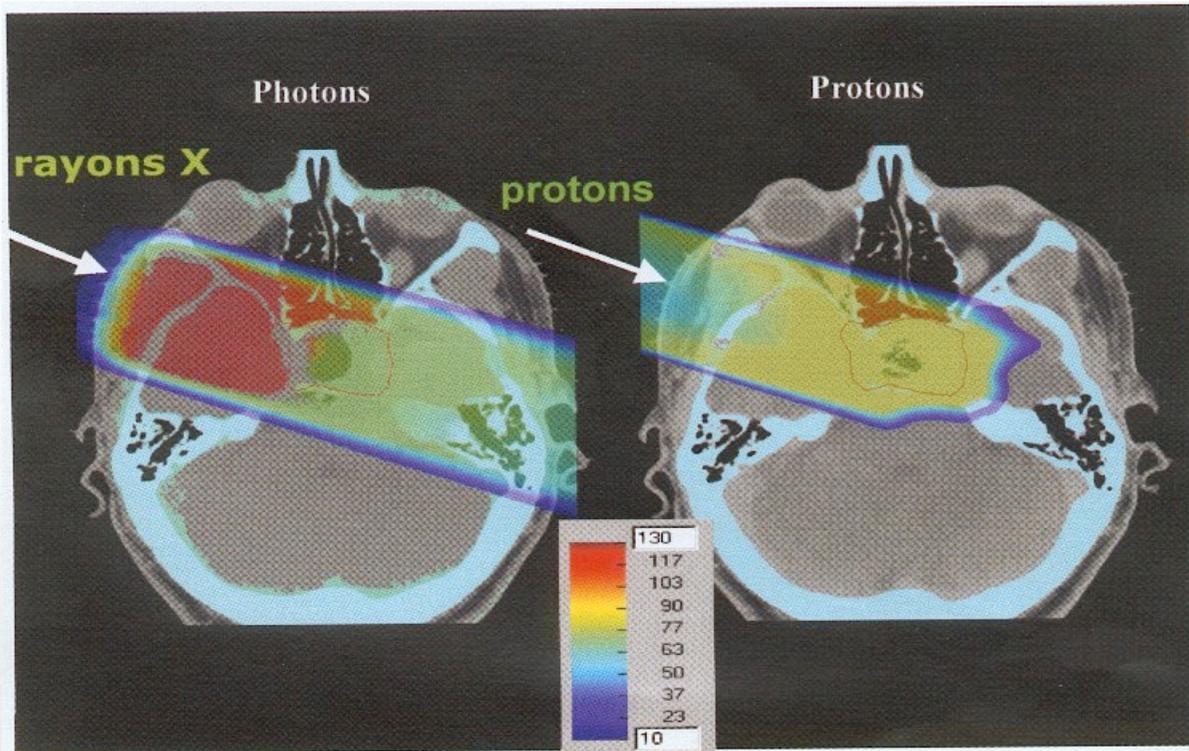


7 Tumour therapy with antiprotons ?

Radiation destroys tumour cells, but also healthy cells

Gamma radiation: more healthy than tumour cells destroyed

Protons deliver more energy in tumour cells



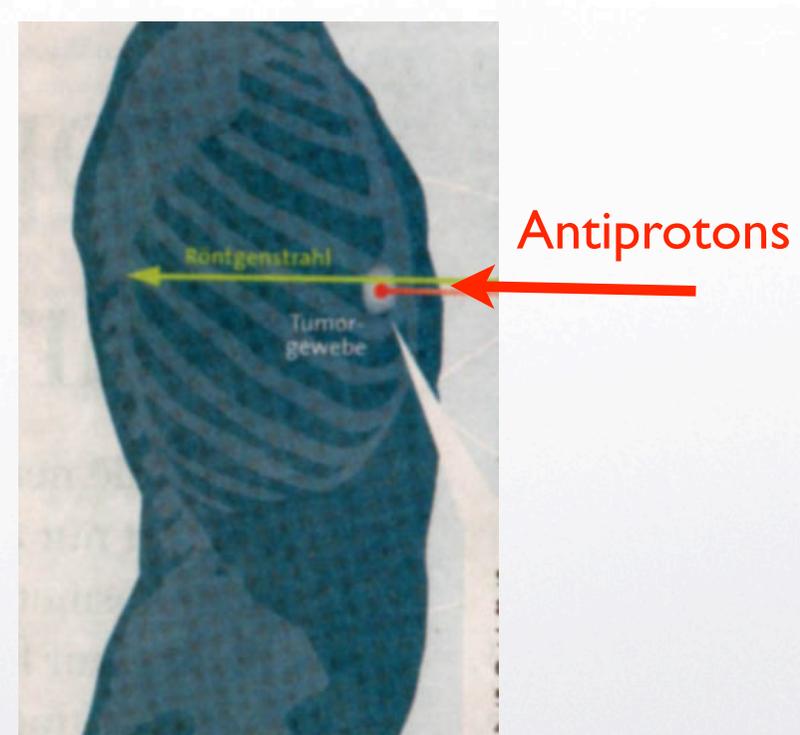
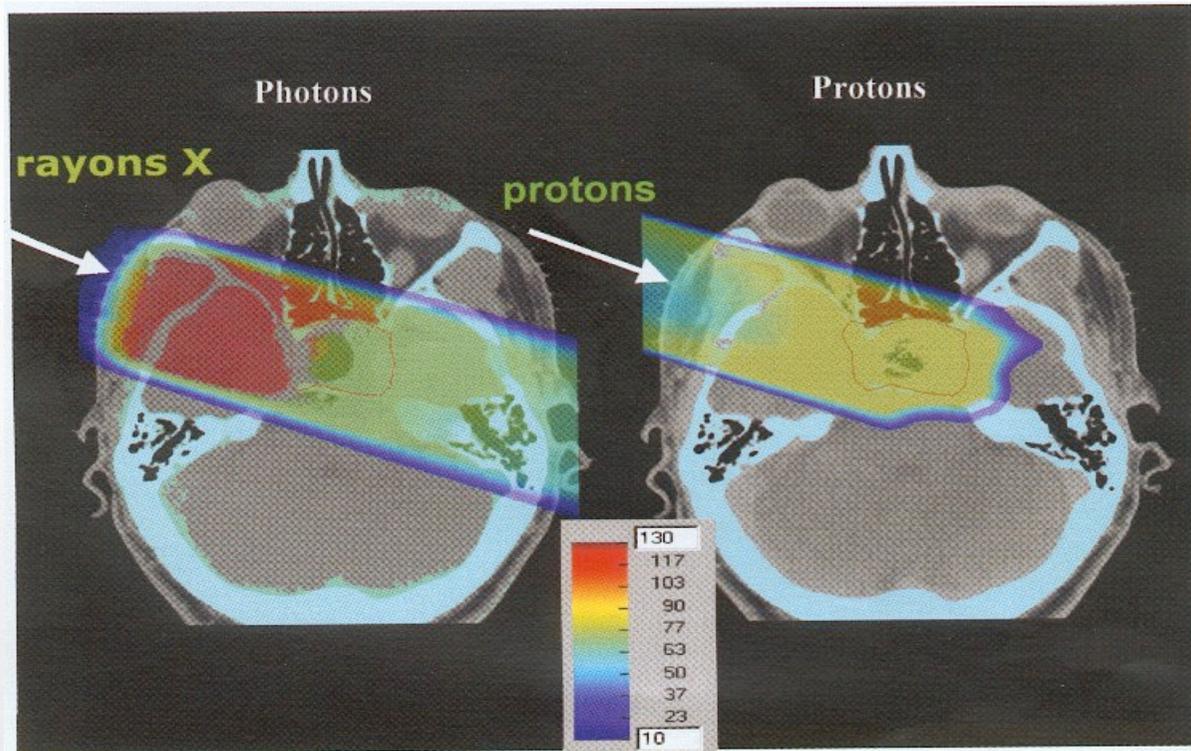
7 Tumour therapy with antiprotons ?

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Antiprotons are 3x better than protons (but expensive)



The 'Angels and Demons' antimatter movie

What did
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Thank you for your attention.