



Antimatter Mysteries

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Research physicist

CERN

Angels + Demons: The Movie



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

ENTER THE SITE
ENTER THE ANGELS & DEMONS
Path of Illumination
Contest on msn

BASED ON THE BEST SELLING NOVEL
BY THE AUTHOR OF
THE DA VINCI CODE

REGISTER FOR UPDATES WORLDWIDE RELEASES DATES

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 SKARSGARD PIERFRANCESCO FAVINO NIKOLAJ LIE KAAS AND ARMIN MUELLER-STAHN
MUSIC BY HANS ZIMMER EXECUTIVE PRODUCERS KATHLEEN MCGILL LOUISA VELIS WILLIAM M. CONNOR PRODUCED BY 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
AngelsAndDemons.com

Angels + Demons: The Book

The story line of ...



Wuminati

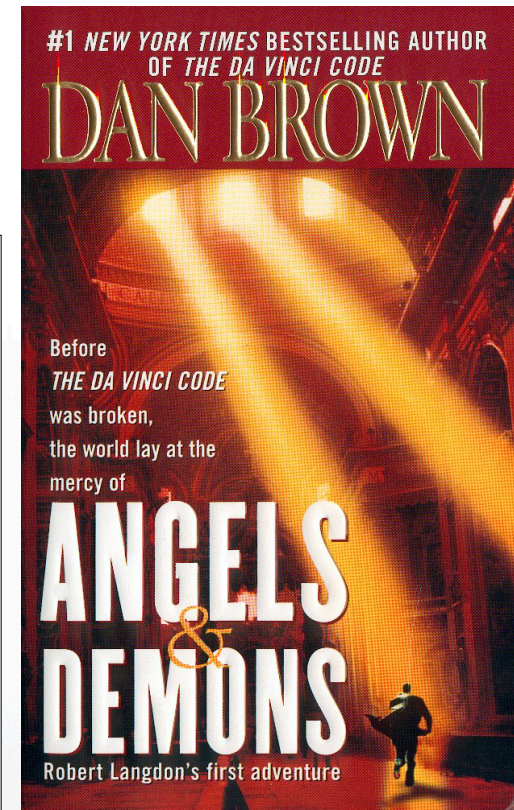
Detective story about a secret society which ...



... 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 Cast @ CERN

Tom Hanks Aliyet Zurer

Ron Howard



Antimatter Mysteries

Angels + Demons: The Director

The 'Angels and Demons' movie preparation started in 2007. The Director, Ron Howard, visited CERN on a weekend.

What did Ron Howard* say after he had seen CERN?



That's how small I feel after seeing the huge machines ...

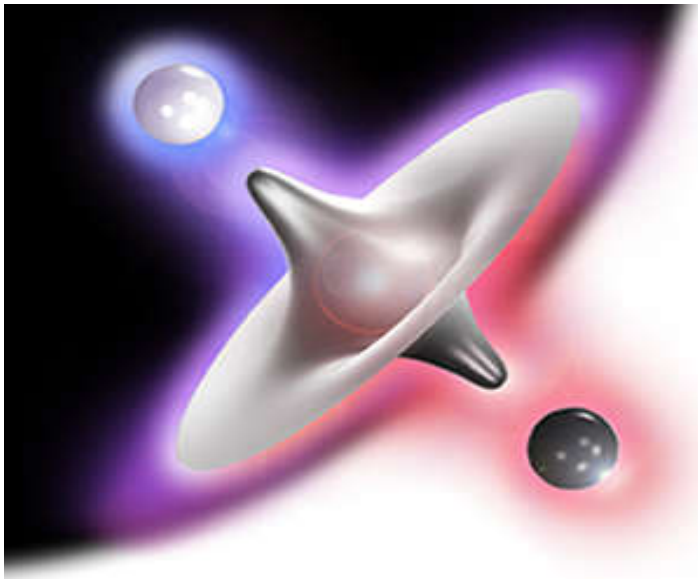
That's the budget of my new movie "Angels and Demons"

This much science will be in the "Angels and Demons" movie ...

This is what Dan Brown understands about antimatter

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

Antimatter Questions



Seven questions

What is antimatter

Where is antimatter made

How is antimatter made

The mystery of antimatter

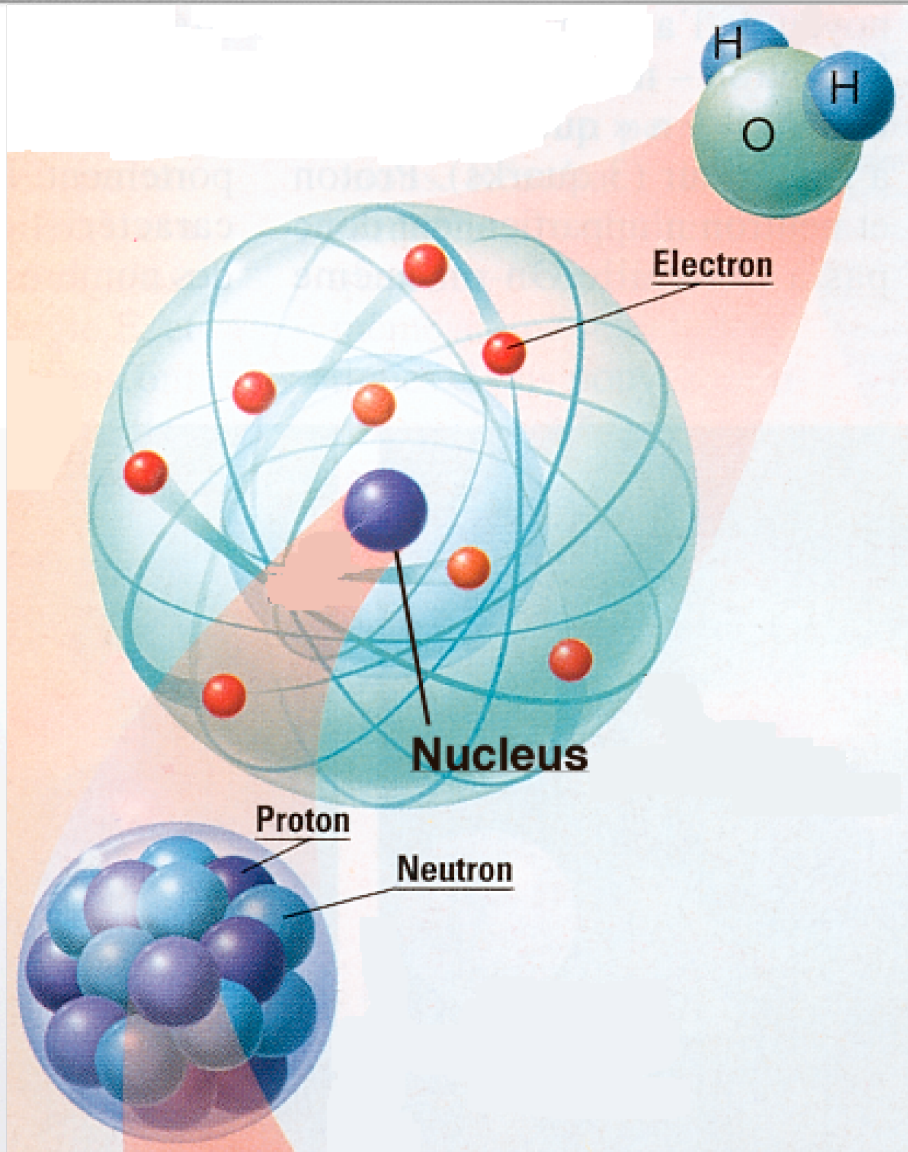
How to study antimatter

Energy source, weapon, Star Trek ?

Applications in medicine

I What is antimatter ?

I 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**

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

I What is antimatter ?

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

Name	Electric Charge [e]	Mass	Electric Charge [e]	Name
Electron	- 1	0.0005	+ 1	Positron
Proton	+ 1	0.938	- 1	Antiproton
Neutron	0	0.941	0	Antineutron



Particles

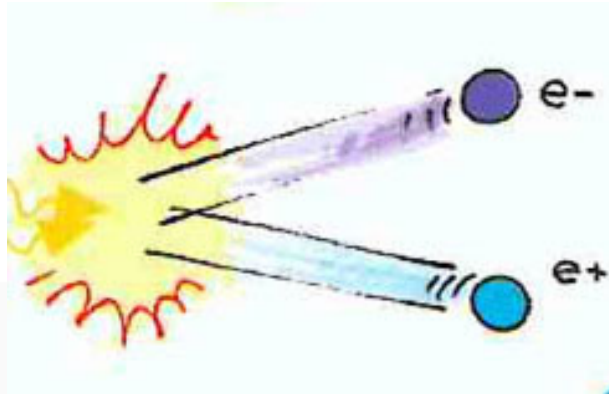


Anti-Particles

I What is antimatter ?

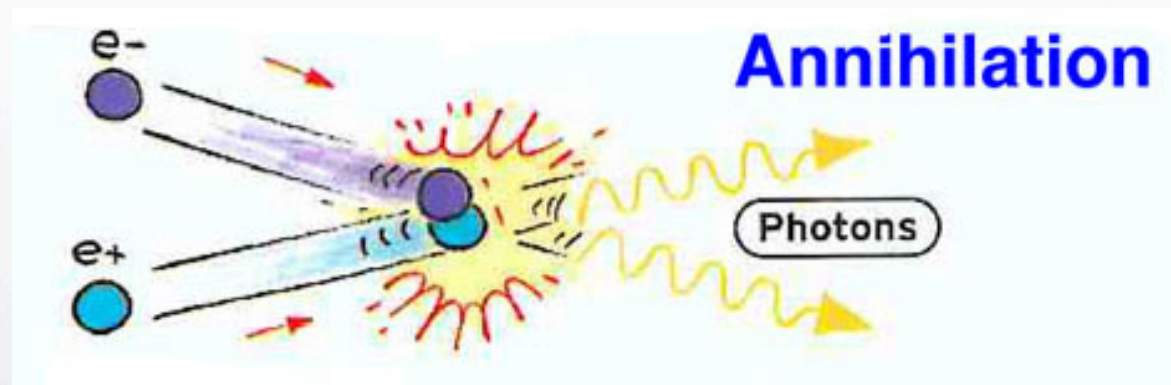
Particles and antiparticles are always **created in pairs** ...

Energy to mass:



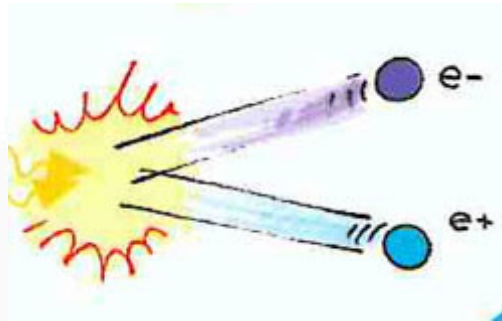
... and they can also **annihilate** each other

Mass to energy:



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.” !



2 Where is antimatter made ?

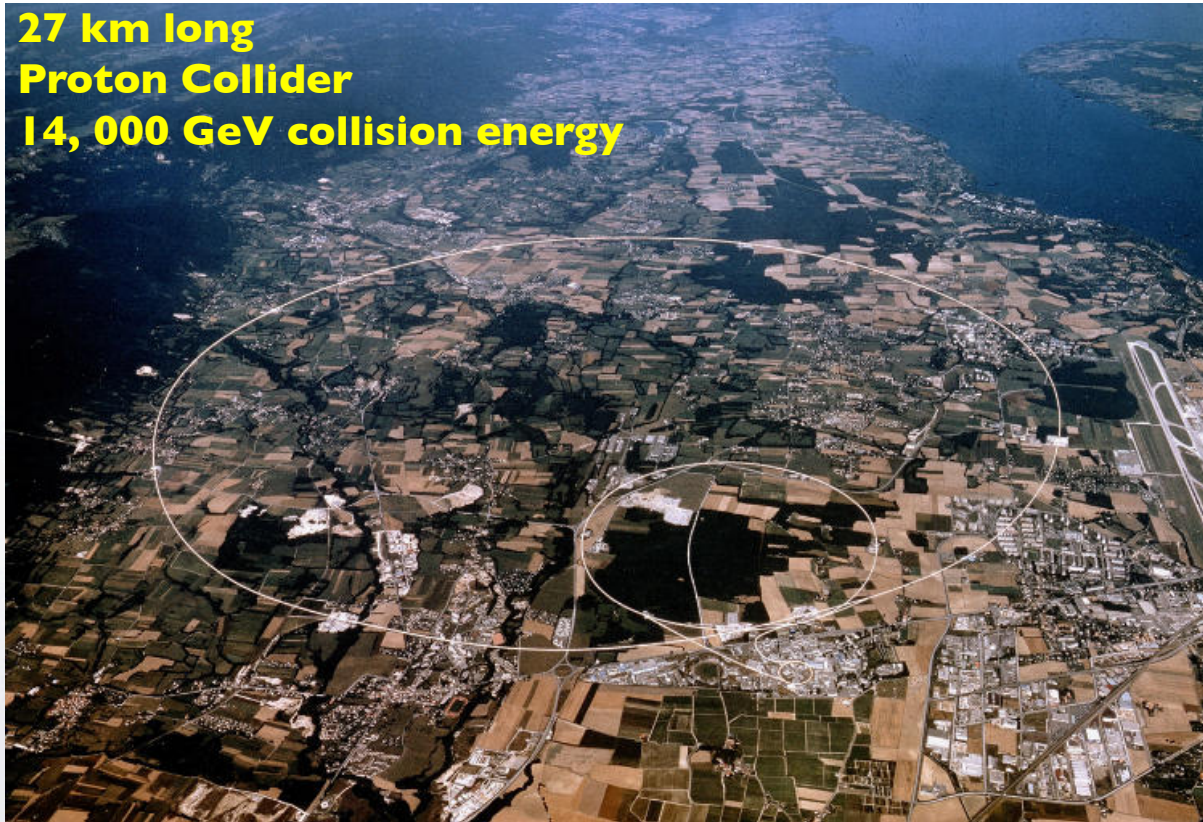
2 Where is antimatter made ?

Antiparticles are produced using accelerators

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

CERN = 'Conseil Européen pour la Recherche Nucléaire'

27 km long
Proton Collider
14, 000 GeV collision energy



10000+ physicists from
104 countries

2 Where is antimatter made ?

CERN = 'Conseil Européen pour la Recherche Nucléaire'
European Laboratory for Particle Physics



Large
Hadron
Collider

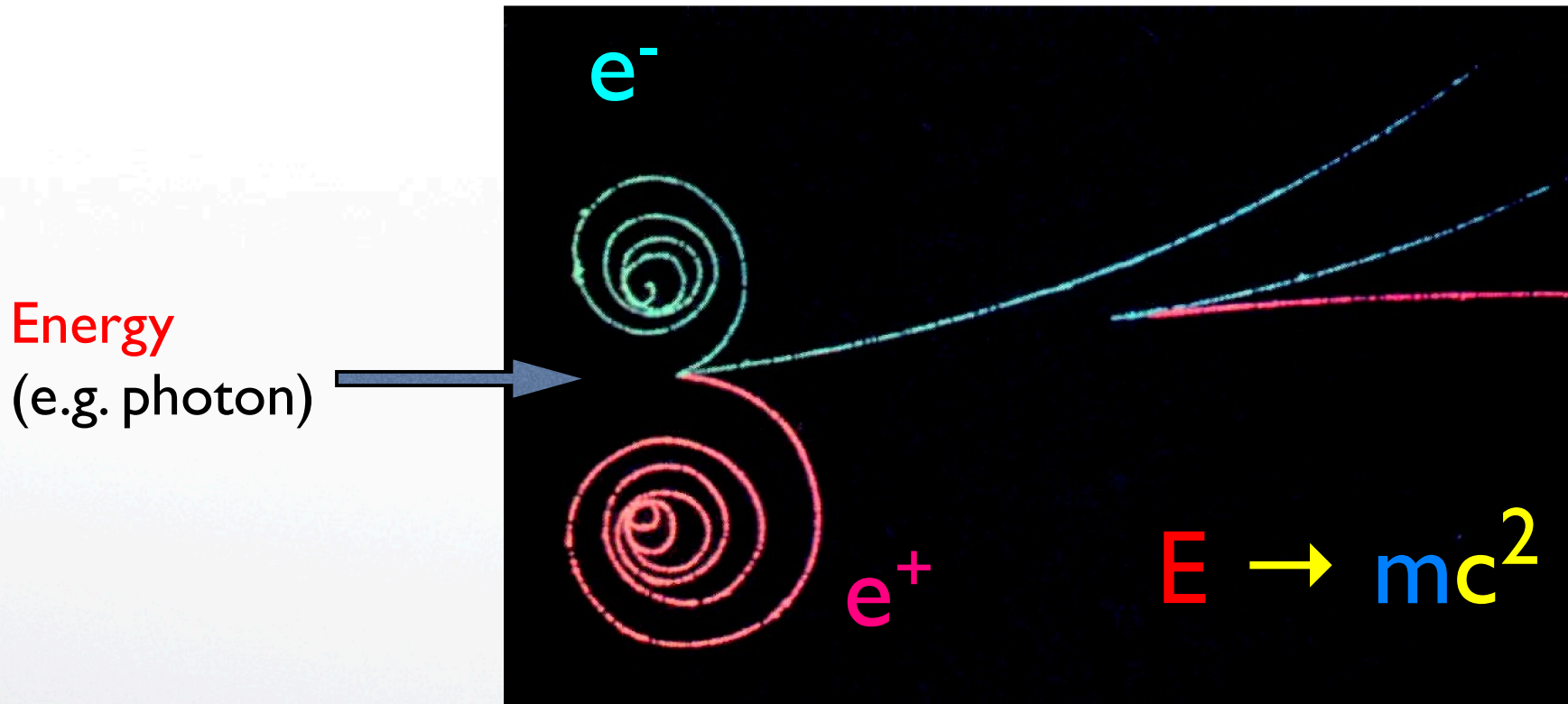
The most powerful
particle accelerator
in the world

3 How is antimatter made ?

$$E = mc^2$$

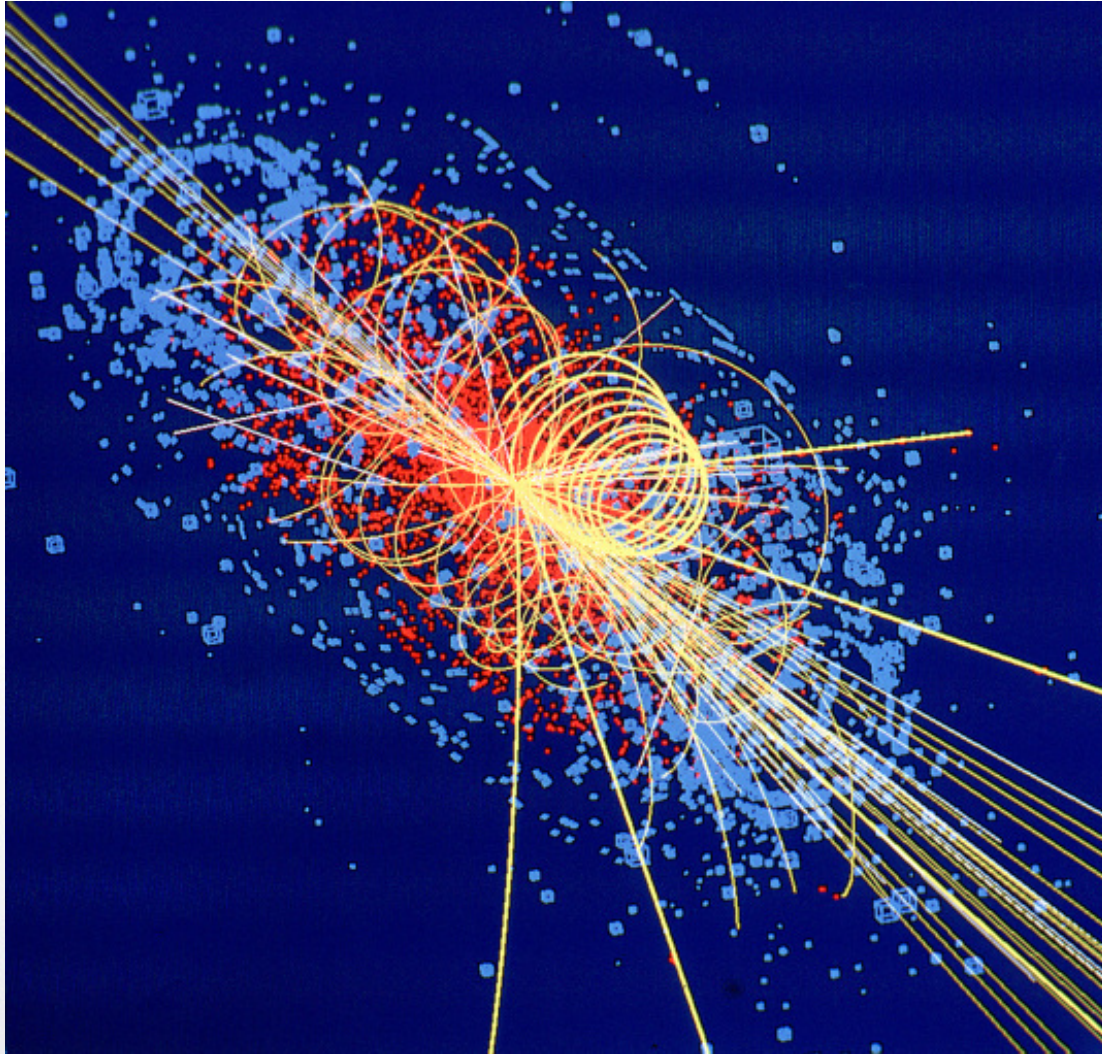
3 How is antimatter made ?

Energy is converted to mass



Mass of electron and positron

3 How is antimatter made ?



New particles will be created that only existed shortly after the Big Bang; 50 % antiparticles!

Dark Matter ?

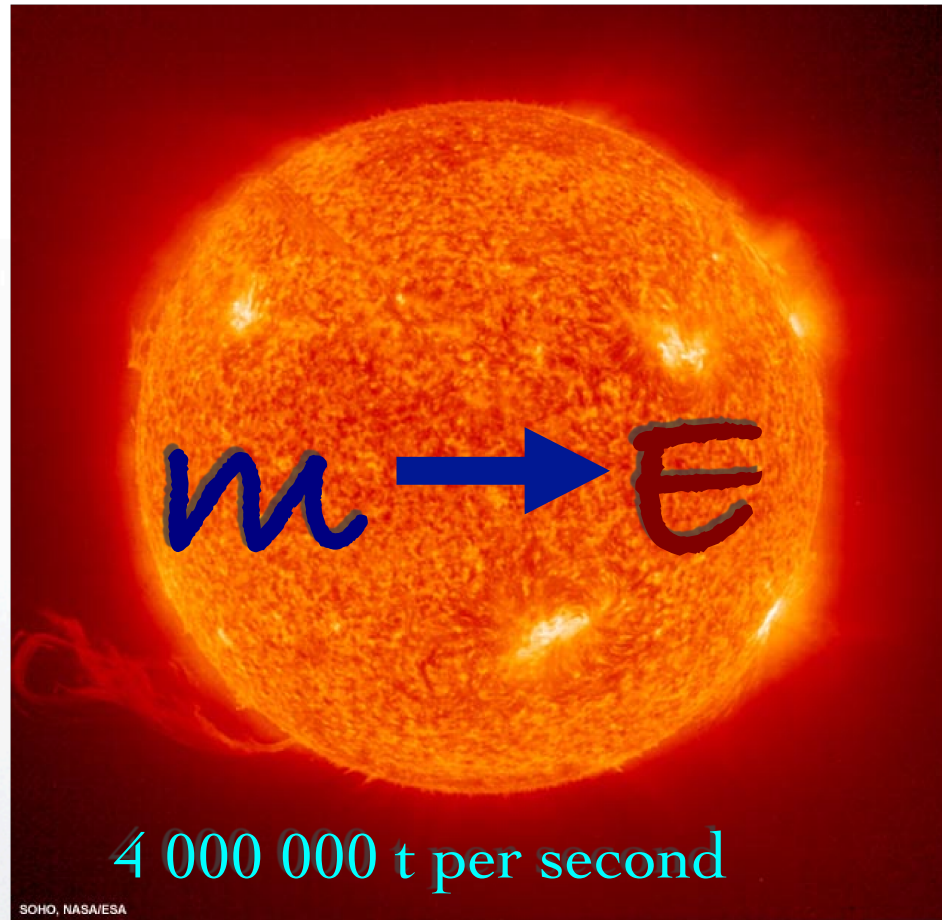
The “Higgs” particle ?

Mini-Black holes ?

But: antiparticles made in the LHC are far too fast to be trapped !

3 How is antimatter made ?

In contrast, in the Sun, mass is converted to energy



3 How is antimatter made ?



New particles and antiparticles are created in collisions

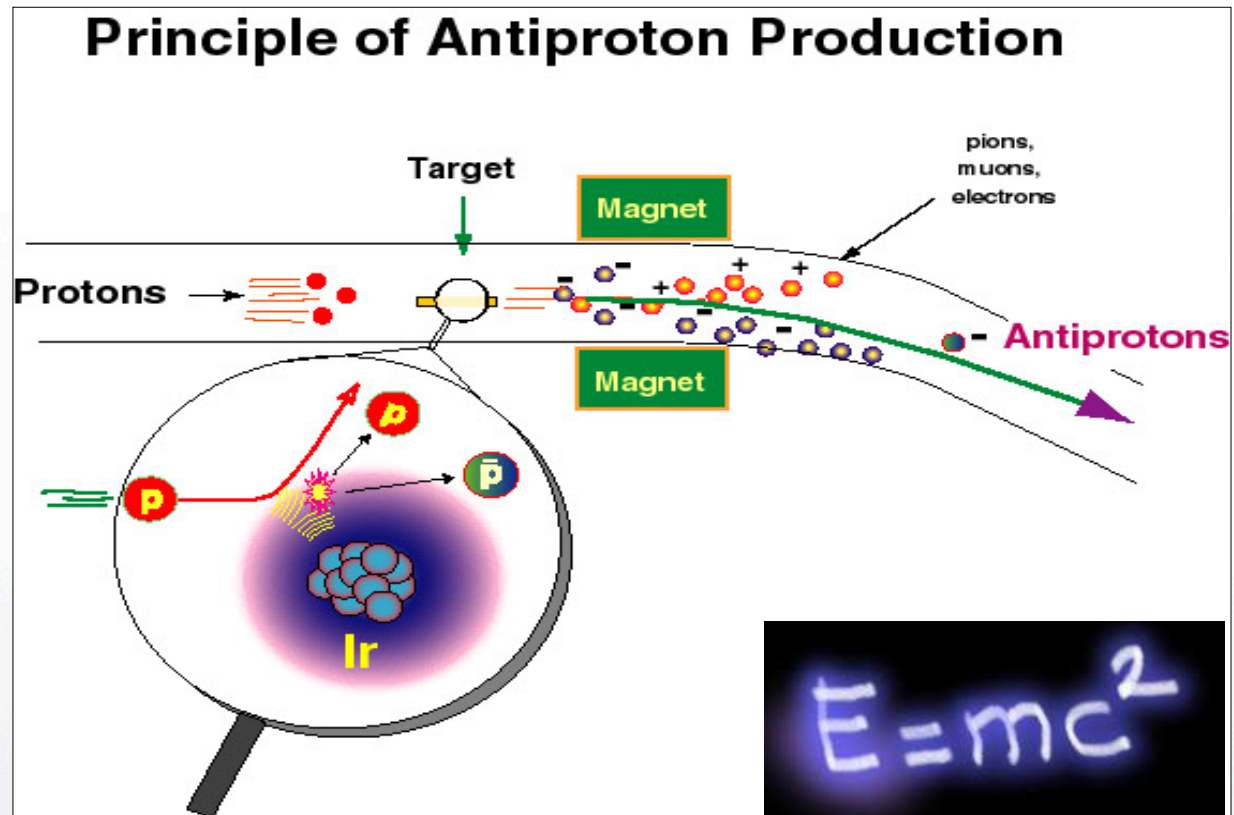
What did Hollywood think of that?

The ATLAS experiment is hijacked to make antimatter

Movie Clip “LHC collisions”

3 How is antimatter made ?

Energy is carried by **accelerated** particles



Energy is converted to mass in **collisions**

The true 'antimatter factory' - the Antiproton Decelerator

AD Movie Clip

4 The mystery of antimatter

Tom Hanks explains the research at CERN

Movie Clip “Antimatter trap in Vatican”

4 The mystery of antimatter

The Universe started 13 700 million years ago



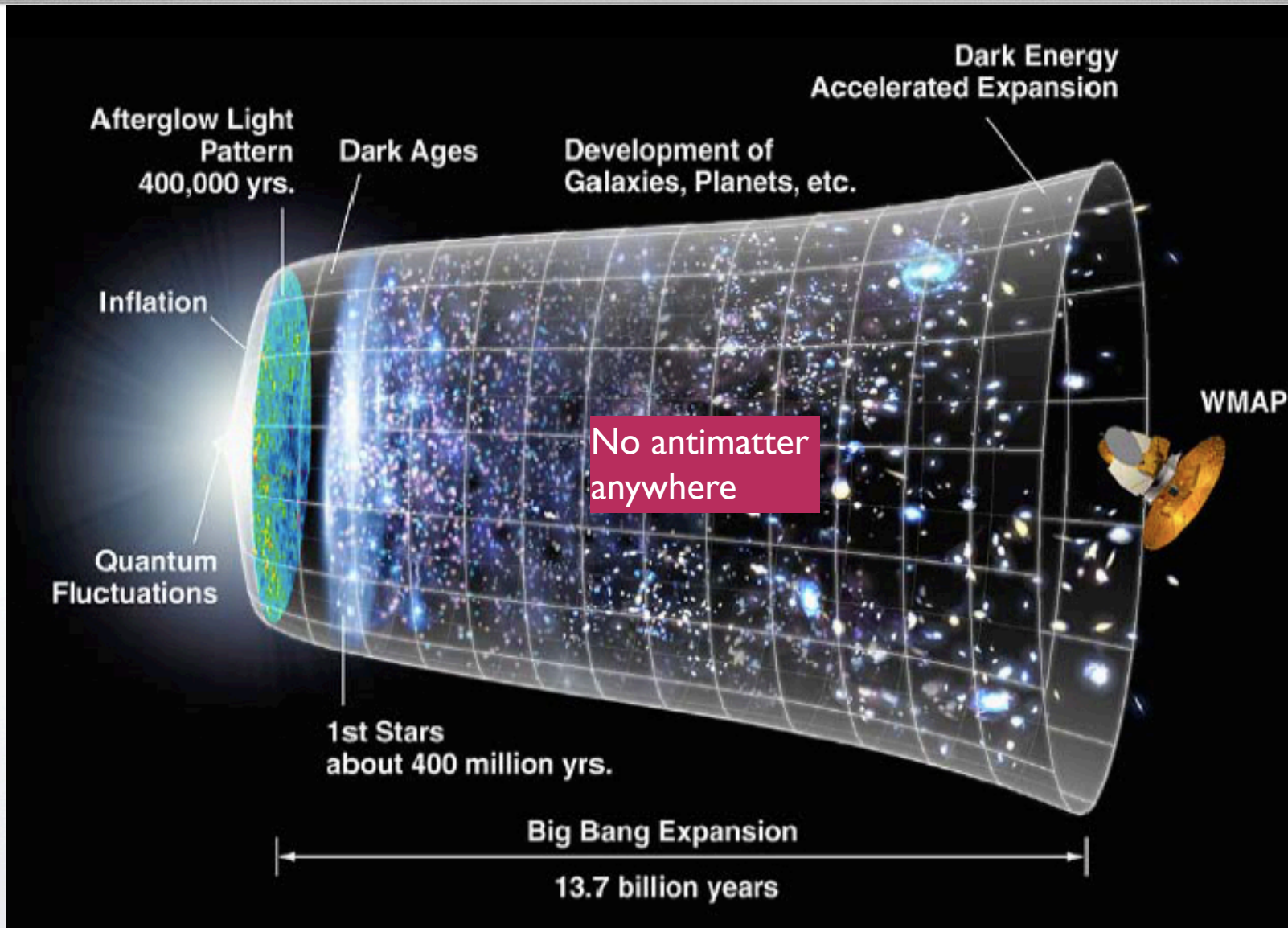
$\sim 10^{72}$ Joule



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

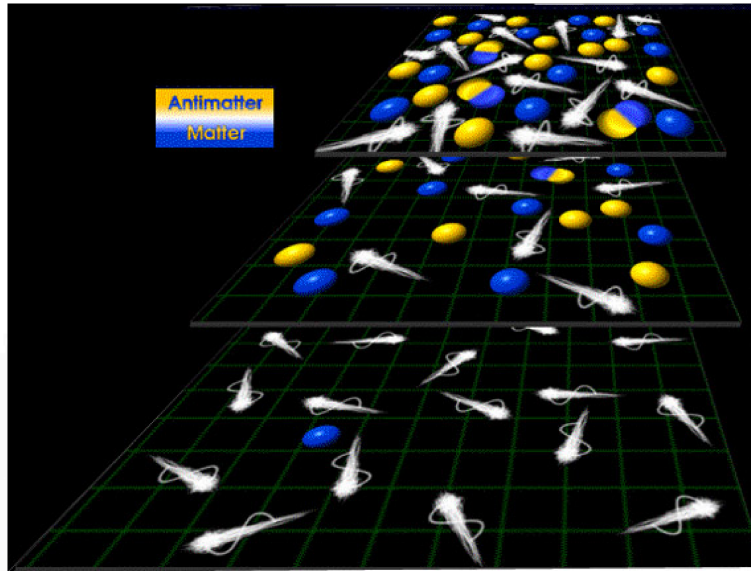


4 The mystery of antimatter

No antimatter in the Universe ?????

Why not ?

4 The mystery of antimatter



The first instants of the Universe:

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

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

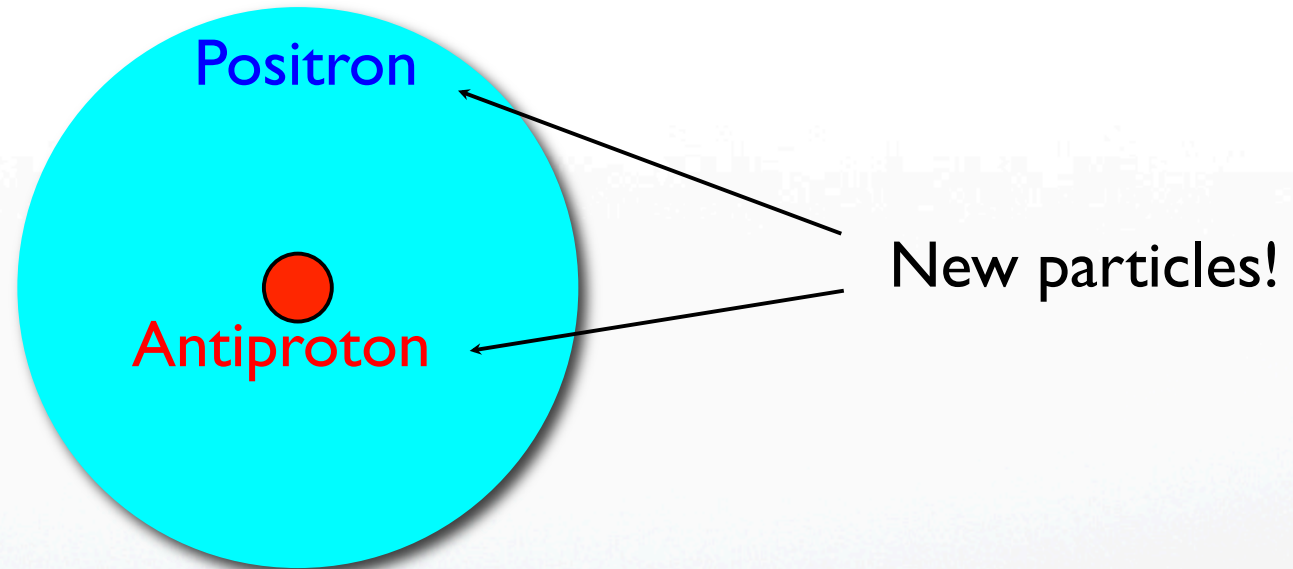
Why is there something and not nothing (but radiation?)

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



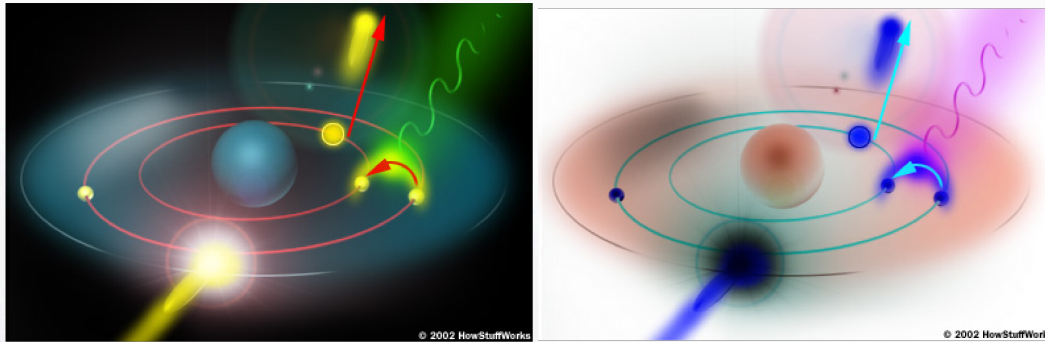
Measure possible differences to a precision of 0.000 000 000 000 001 %

5 How to study antimatter ?

We have learned how to make antimatter atoms*

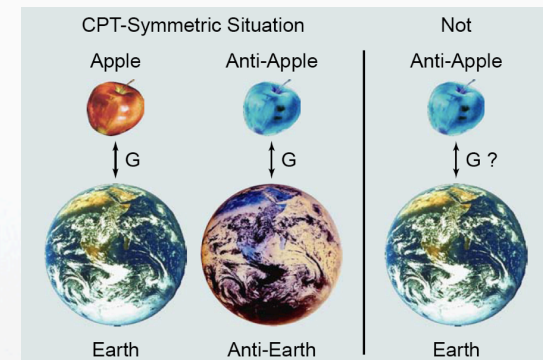
- 1) Produce **antihydrogen atoms** from antiprotons and positrons
- 2) Trap antihydrogen atoms
- 3) Measure their properties

Different energy levels ?



Energy levels

Different gravitational attraction ?



Gravity

* 1 million anti-atoms ~ 1 billionth billionth gram

5 How to study antimatter ?



Antimatter factory at CERN

Antiproton Decelerator
produces antiprotons
and slows them down

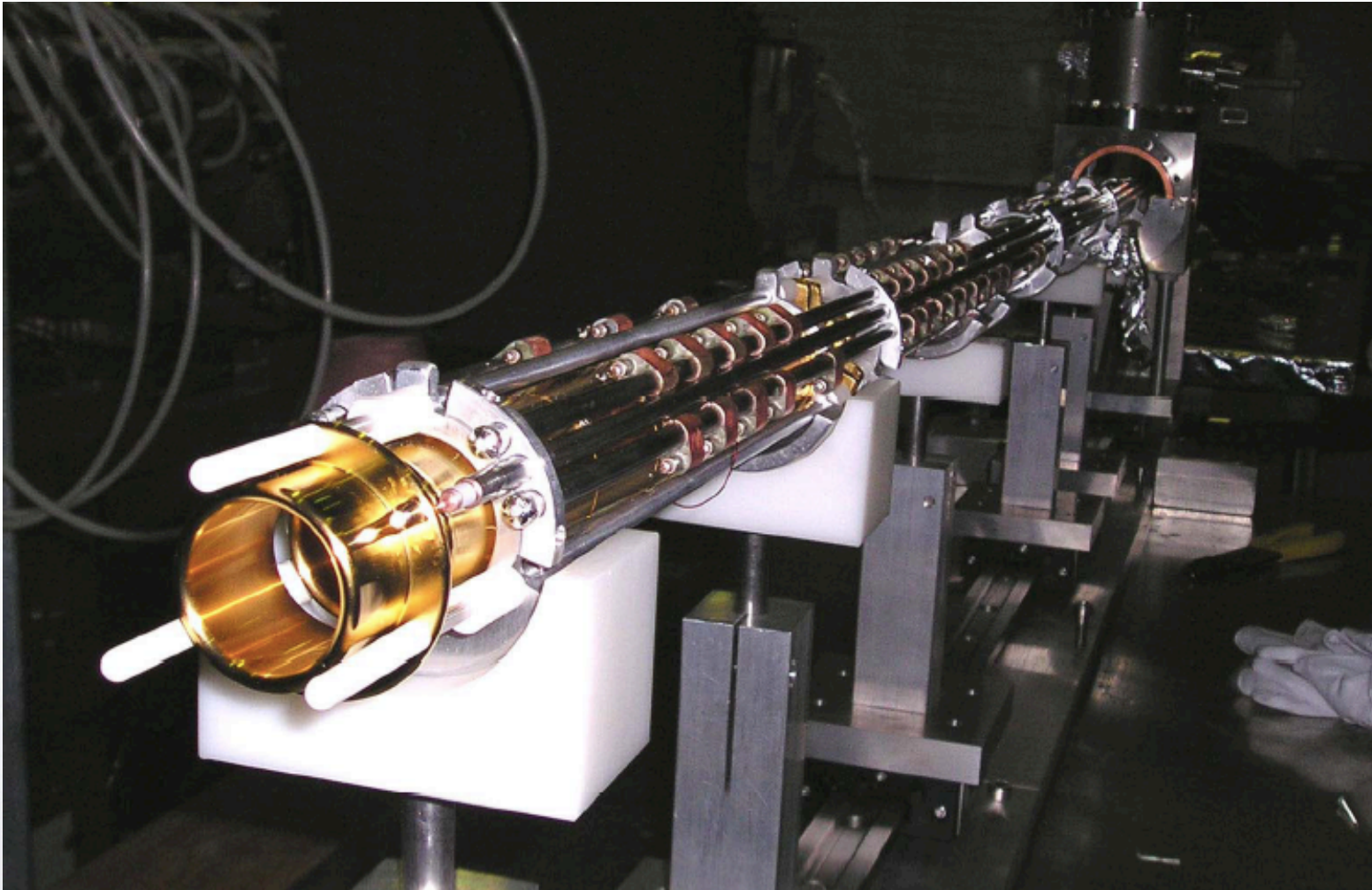
188 m long

Antiproton Production:
100,000,000 antiprotons per minute

Deceleration
96 % → 10 % speed of light

5 How to study antimatter ?

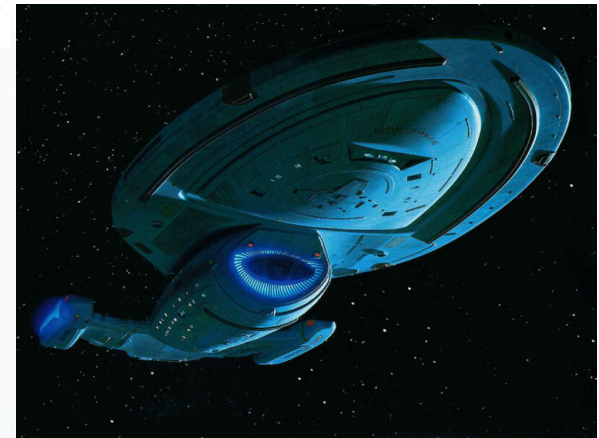
Then, antiprotons (and positrons) are trapped



The 'Angels&Demons' trap

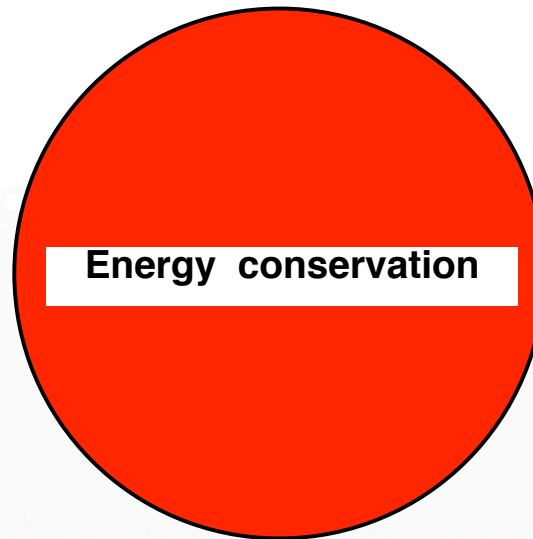


6 Energy source? Weapon? Star Trek?



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

A beautiful antimatter explosion

Movie Clip “Antimatter explosion”

6 Antimatter bombs ?



Dan Brown is right:

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

BUT:

0.5 g antimatter = $4.5 \cdot 10^{13}$ J

Total energy needed (efficiency = 10^{-9}) : $4.5 \cdot 10^{22}$ J

Electricity discount price CERN

[1 kWh = $3.6 \cdot 10^6$ J] = 0.1 €]

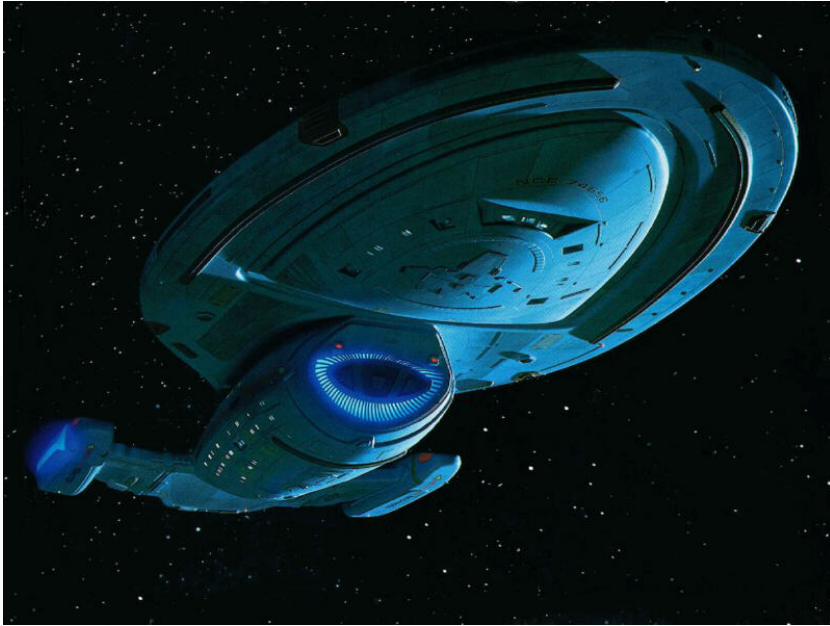
Price ~ 1,000,000,000,000,000 €

Delivery time ~ 1 000 000 000 years

20 kt TNT = $8.4 \cdot 10^{13}$ J

0.5 g antimatter + 0.5 g matter

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:

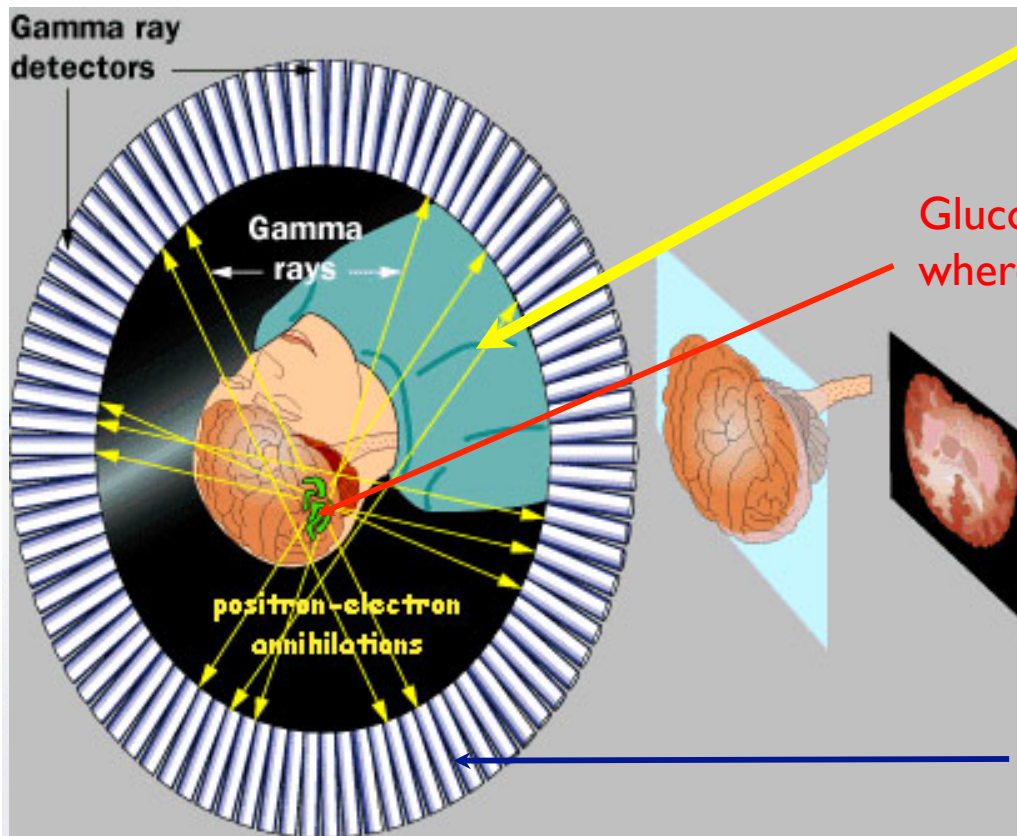
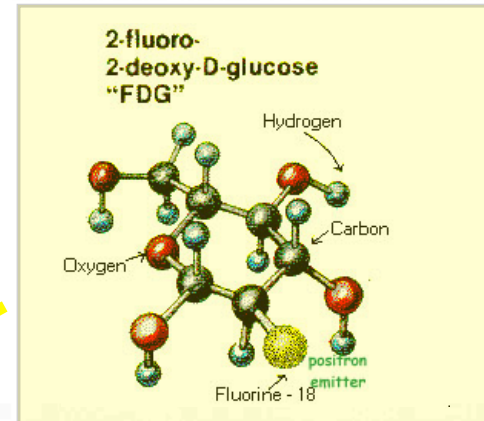
$$E = \gamma mc^2 \sim 10 \cdot 10^4 \text{ kg} =$$

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

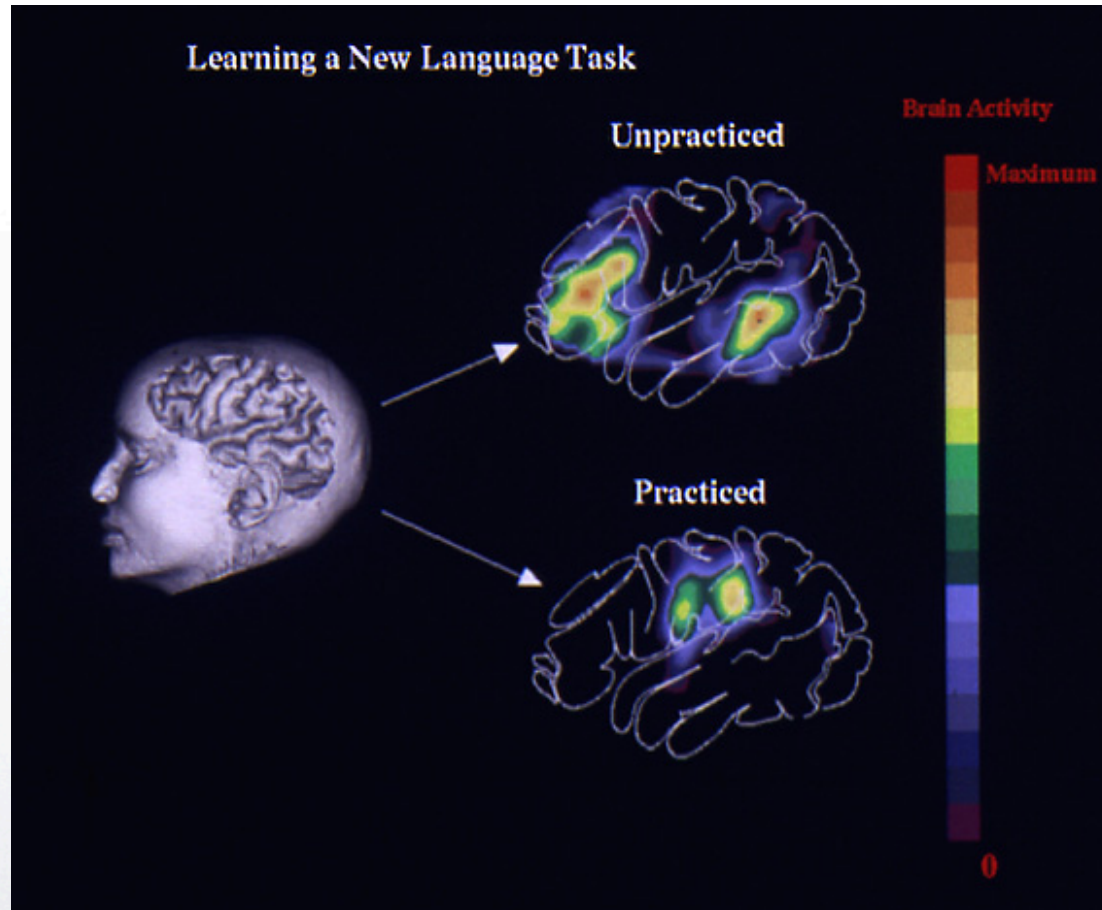


Glucose molecules accumulate (and decay) where energy is needed

Use detector to reconstruct place of positron annihilation

7 Positron Emission Tomography

Antimatter annihilations help to understand how the brain works



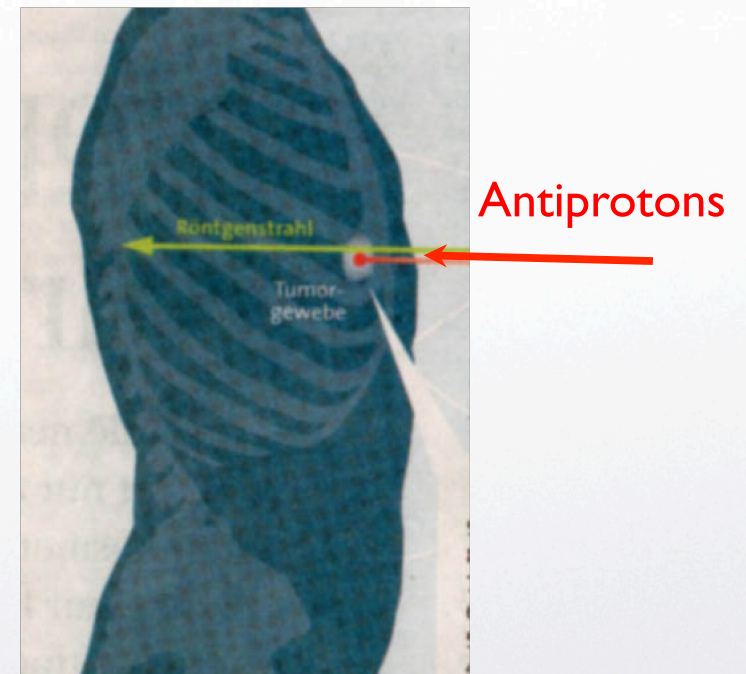
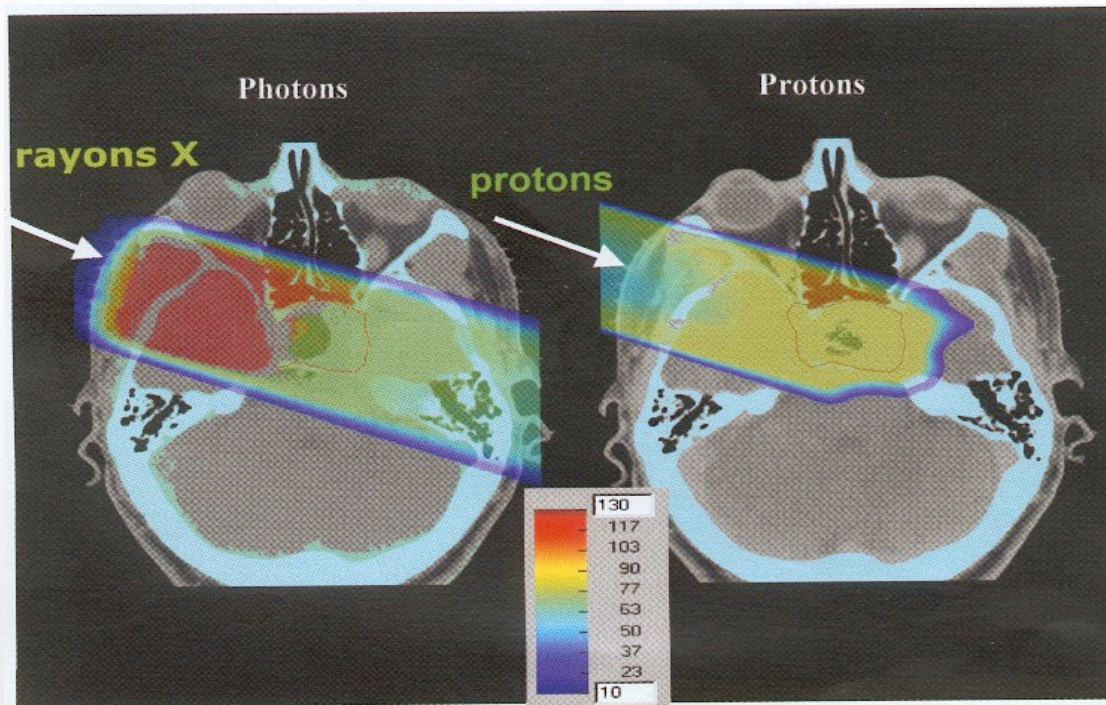
7 Tumour therapy with antiprotons ?

Radiation destroys tumour cells, but also healthy cells

Gamma radiation: more healthy than tumour cells destroyed

Protons deliver more energy in tumour cells

Antiprotons are 3x better than protons (but expensive)



Antimatter @ School

For Teaching

Antimatter Teaching Module

NEW

CERN

Particle Physics

Cosmology

Principles of Experimental Physics

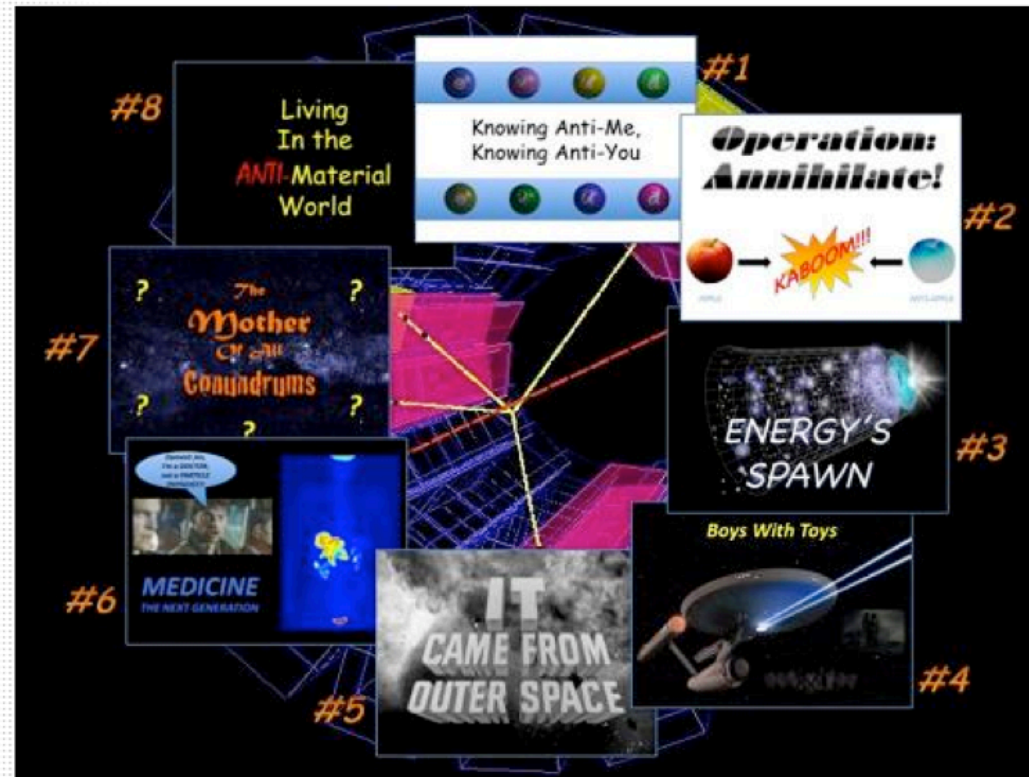
Introduction to Accelerators

Applications of CERN research

Multimedia material

Teaching Resources - Antimatter Teaching Module

>> Lesson Plans



[Back to Antimatter Teaching Module](#)

The 'Angels and Demons' antimatter movie

What did
Ron Howard
say after his
visit to CERN?

Movie Clip "Ron Howard at CERN"

Thank you for your attention.