

ANGELS & DEMONS™
Lecture Night
THE SCIENCE REVEALED

Mark Neubauer
Kevin Pitts
University of Illinois
MAY 29, 2009

 ILLINOIS



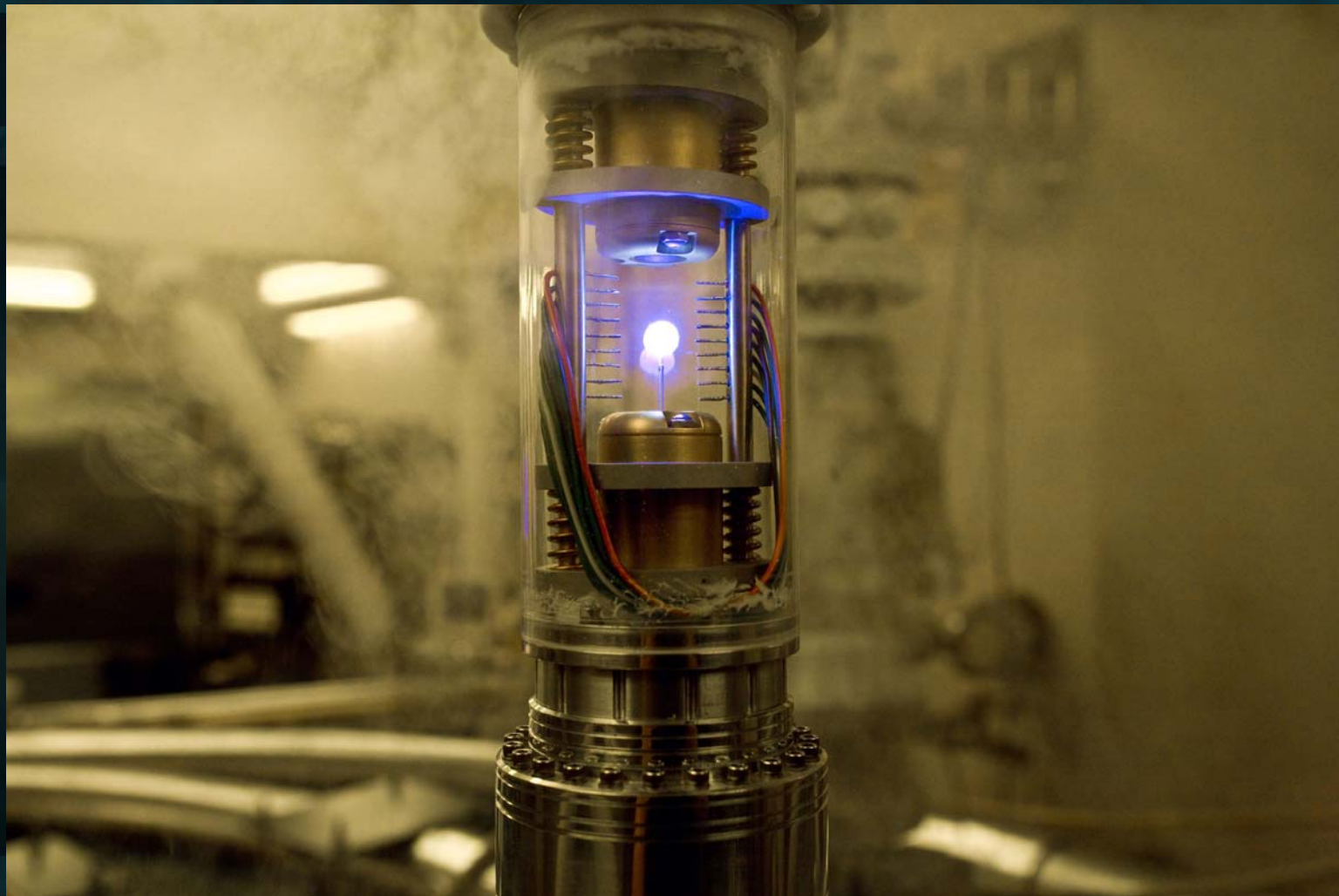
 Fermilab



ANGELS & DEMONS™

Lecture Night

THE SCIENCE REVEALED



ILLINOIS



Fermilab



U.S. DEPARTMENT OF
ENERGY



National Science
Foundation

ANGELS & DEMONS™

Lecture Night

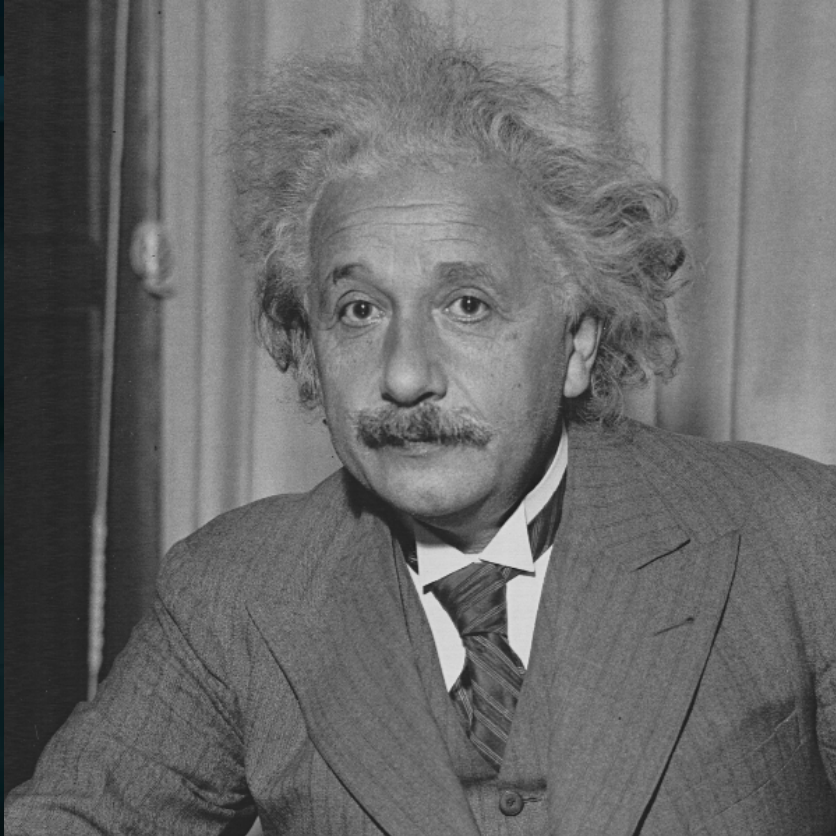
THE SCIENCE REVEALED

THE PLOT

- Antimatter is stolen from CERN's Large Hadron Collider (LHC) and hidden in Vatican City.
- Countdown to Vatican annihilation begins.
- Race through Rome to avert death and destruction.



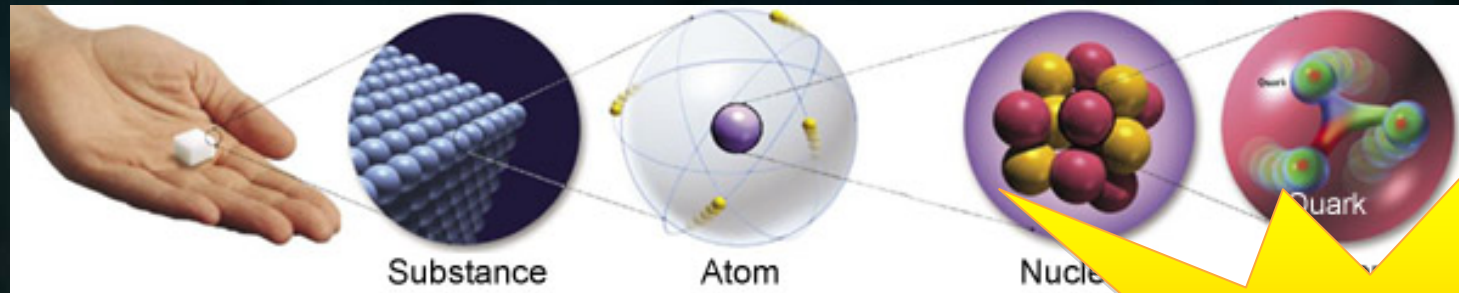
ANGELS & DEMONS™
Lecture Night
THE SCIENCE REVEALED



**"The most
incomprehensible
thing about the
world is that it is
comprehensible."**

ATOMS & THE “SUBATOMIC” WORLD

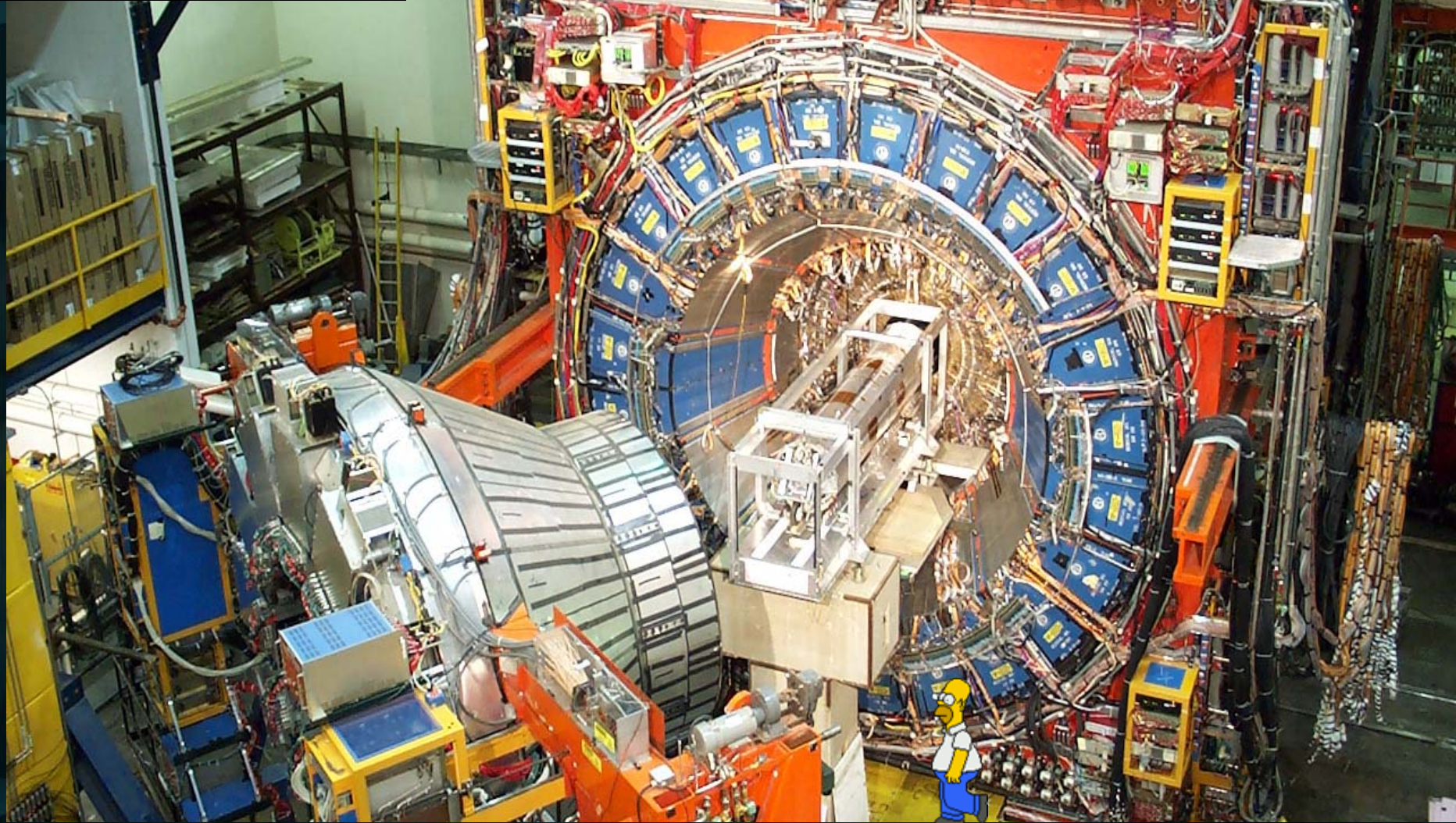
- Everything familiar to us is made of billions and billions of atoms.
- Atoms consist of protons, neutrons and electrons.



- Our job is to peer inside the atom, and even inside the proton!

**particle
accelerators are
big microscopes!**

We need **BIG**
tools for this job!



ILLINOIS



Fermilab



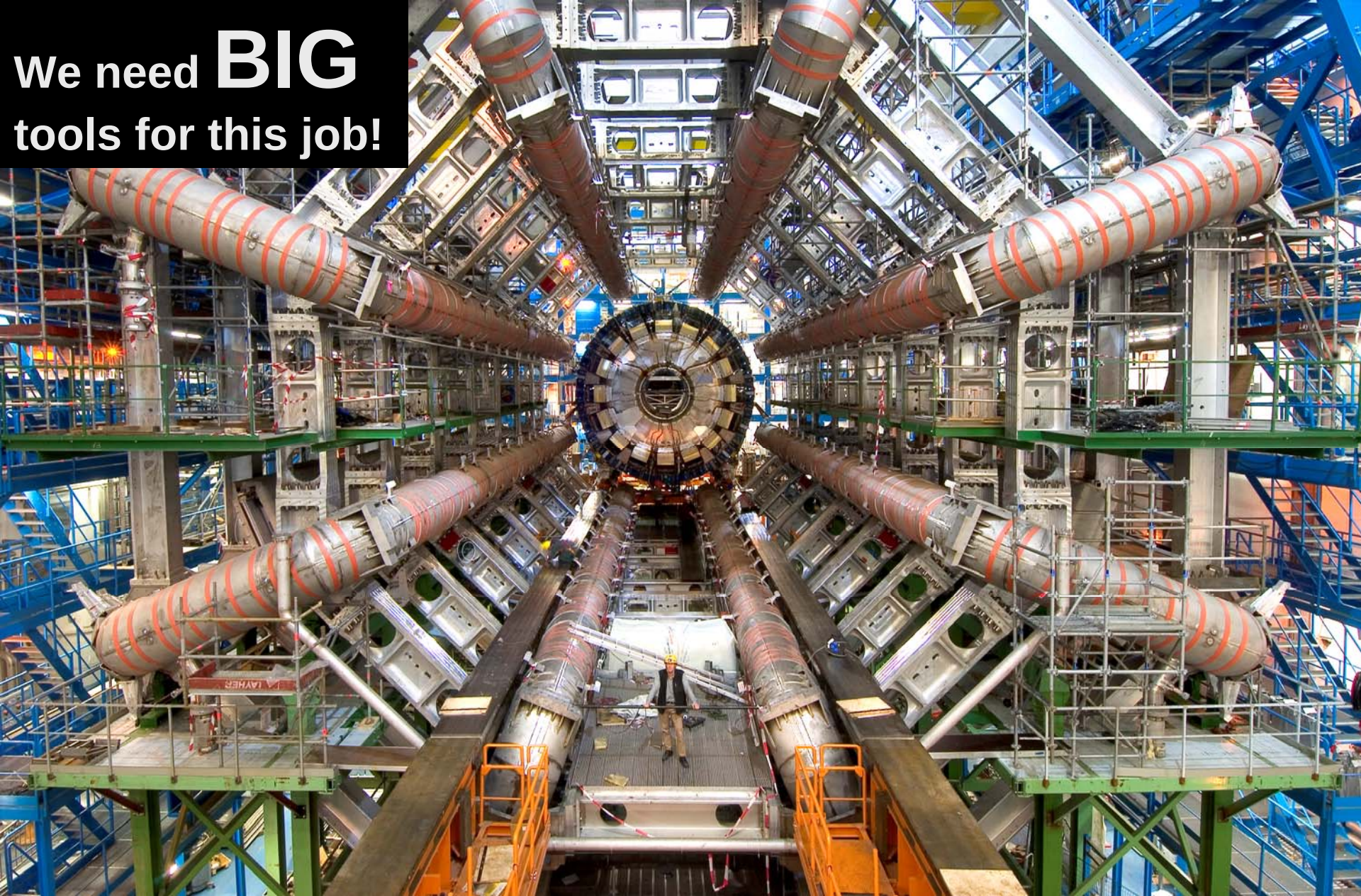
**U.S. DEPARTMENT OF
ENERGY**



**National Science
Foundation**

TM & © 2009 Columbia Pictures Industries, Inc. All rights reserved.

We need **BIG**
tools for this job!



ILLINOIS



Fermilab



U.S. DEPARTMENT OF
ENERGY



National Science
Foundation

ANTIMATTER REALLY EXISTS

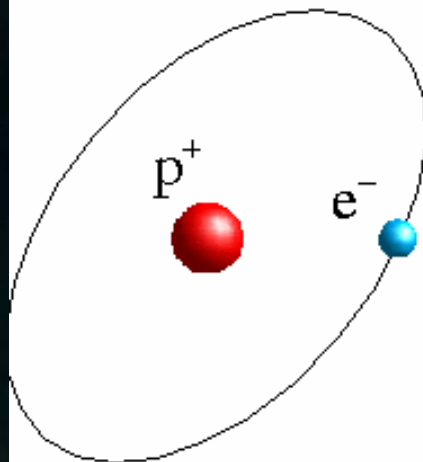
- All material familiar to us (Earth, people, atmosphere) is matter (made up of protons, neutrons and electrons)
- For every type of matter particle, there is also an antimatter particle. It has the same mass and opposite charge as matter.

ANGELS & DEMONS™

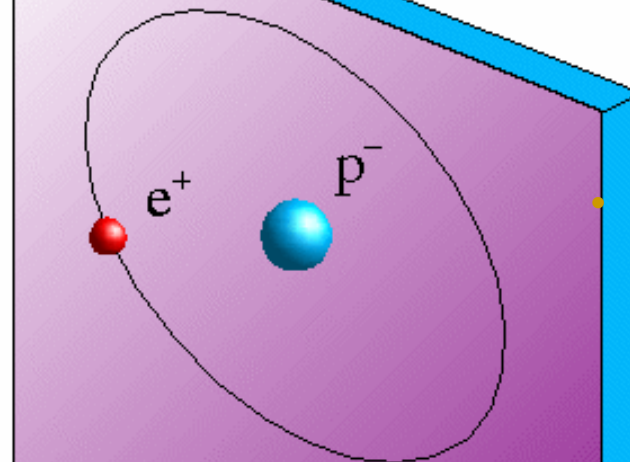
Lecture Night

THE SCIENCE REVEALED

Hydrogen



Antihydrogen



Matter:

p^+ = proton

e^- = electron

Antimatter:

p^- = antiproton

e^+ = antielectron
(positron)

ANGELS & DEMONS™
Lecture Night
THE SCIENCE REVEALED

CAN WE MAKE ANTIMATTER?

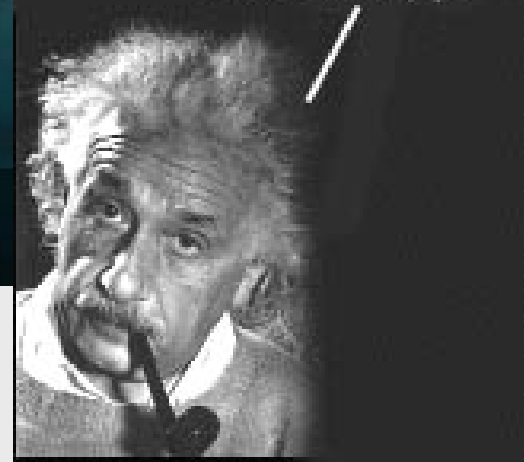
We can, and do



in particle accelerators

ANTIMATTER QUESTIONS

- **How much of it occurs naturally?**
Answer: tiny, tiny, tiny amounts (more on this later)
- **How do you make it and why did you let the illuminati steal it?**
- **Can you really make an antimatter bomb?**



Professor Einstein had it right

$$E=mc^2$$

energy mass Speed of light = **constant!!**

- Use a large particle accelerator to give particles enormous energy. (big, big E)
- Smash those particles into other particles (convert E to m!!)
- Some of the mass created is matter, some is antimatter!

HOW MUCH CAN WE MAKE?

- At Fermilab, we make about
200,000,000,000
antiprotons per hour.
- That sounds like a lot, but it takes:
150,000,000,000,000,000,000,000,000,000,000
antiprotons to make $\frac{1}{4}$ gram of antimatter
(i.e. the antimatter bomb)

ANTIMATTER'S NO THREAT

- We make *very* little antimatter
- Fermilab creates 2 nanograms of antiprotons per year



- It would take 100 million years to make $\frac{1}{4}$ gram

ANGELS & DEMONS™
Lecture Night
THE SCIENCE REVEALED

MATTER VS. ANTIMATTER

Anti-Tom Hanks



Would look
very much
like

Tom Hanks



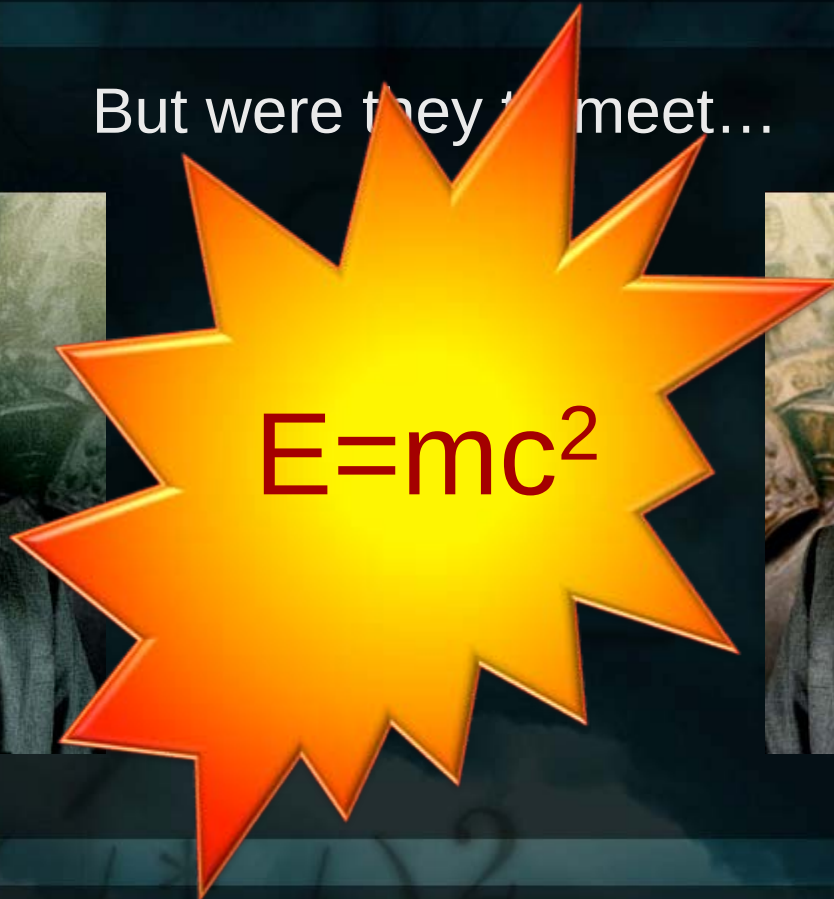
ANGELS & DEMONS™

Lecture Night

THE SCIENCE REVEALED

MATTER VS. ANTIMATTER

But were they to meet...



ANGELS & DEMONS & ANTIMATTER

- Rome is threatened by $\frac{1}{4}$ gram of antimatter
- Annihilation of:

$\frac{1}{4}$ g matter + $\frac{1}{4}$ g antimatter = 10,000 kilotons of TNT

- More than enough to destroy the Vatican



$\frac{1}{4}$ gram

ANGELS & DEMONS™

Lecture Night

THE SCIENCE REVEALED

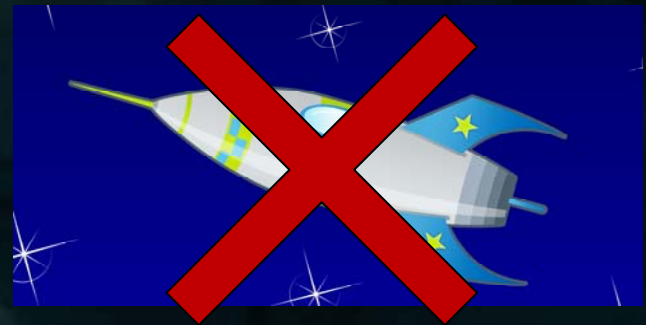
ANTIMATTER'S NO THREAT

- It's not portable



ANTIMATTER CAN'T BE USED FOR:

- **Power**
 - Have to make every single antiparticle
 - Not an energy source: much more energy goes in than is produced
- **Bombs**
- **Spaceships**



...BUT ANTIMATTER CAN BE (& IS BEING) USED FOR:

- Medicine & Diagnostic Imaging
 - Positron Emission Tomography (PET)
 - Particle accelerators routinely used in cancer treatment
- Solving some of the biggest mysteries of the Universe
 - Why do we exist?
 - Why do we have mass?
 - What is most of the Universe made of?

SEARCHING FOR ANSWERS

- At high energy physics laboratories around the world



ANGELS & DEMONS™

Lecture Night

THE SCIENCE REVEALED

CERN

CERN is a real-life laboratory near Geneva, Switzerland



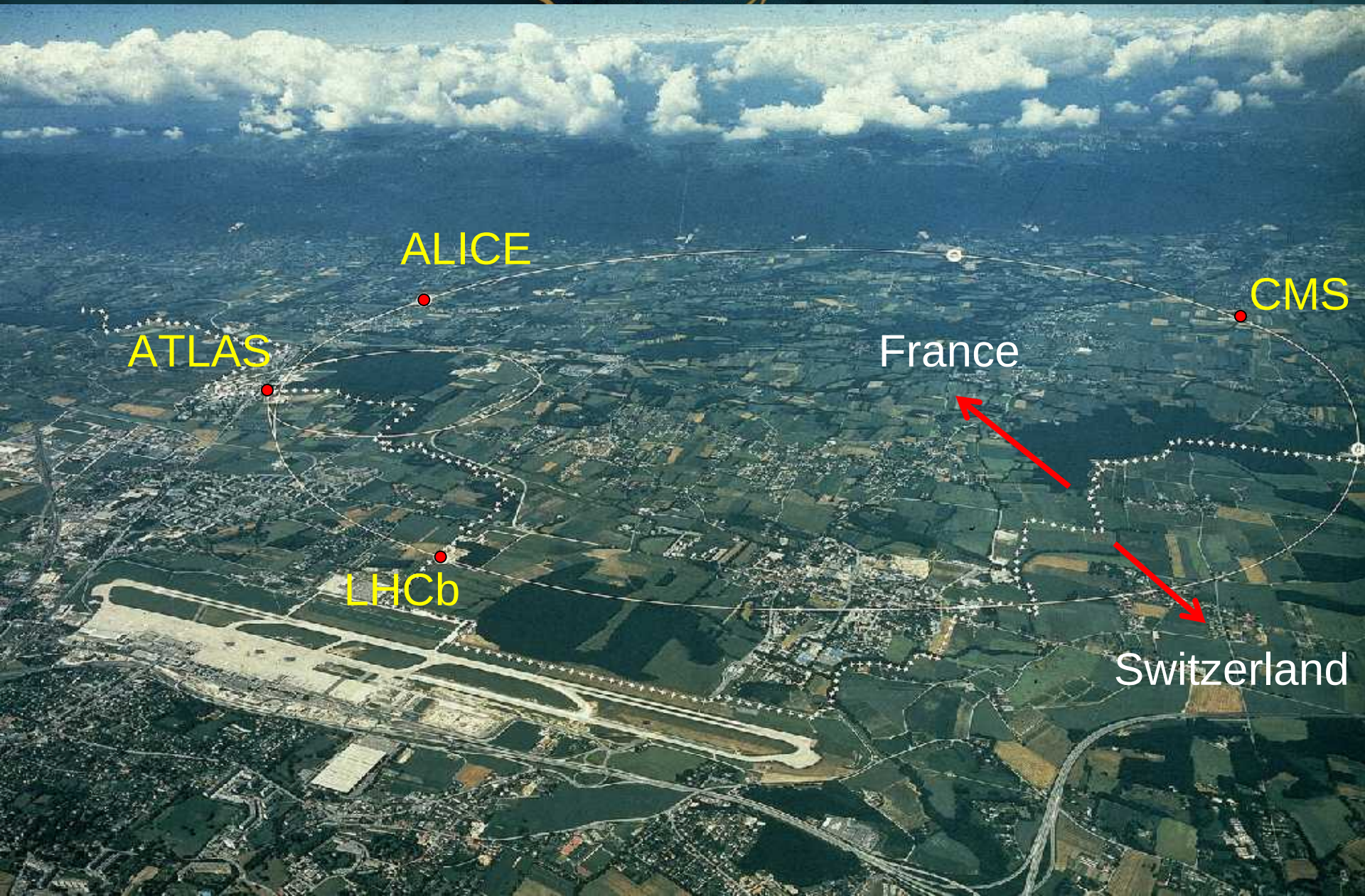
LARGE HADRON COLLIDER (LHC)

- Located at CERN
- The world's most powerful particle accelerator
- 16.8 miles around, 330 feet underground



ANGELS&DEMONS™

Lecture Night



ANGELS & DEMONS™
Lecture Night
THE SCIENCE REVEALED

HOLLYWOOD'S LHC CONTROL ROOM





ANGELS & DEMONS™

Lecture Night

THE SCIENCE REVEALED

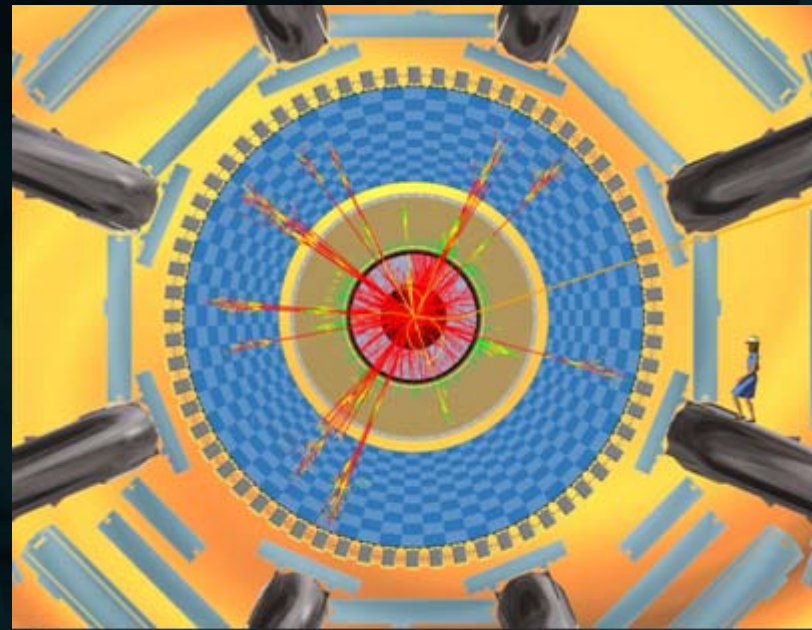


real scientists,
no lab coats!



ANTIMATTER & LHC

- Antimatter will be produced at the LHC
 - Half of everything produced in the collisions is antimatter!
- ... but, amount will be tiny (0.0000000002 grams / year)
 - 125 million years to create $\frac{1}{4}$ gram
- ... and it annihilates almost immediately in the detector

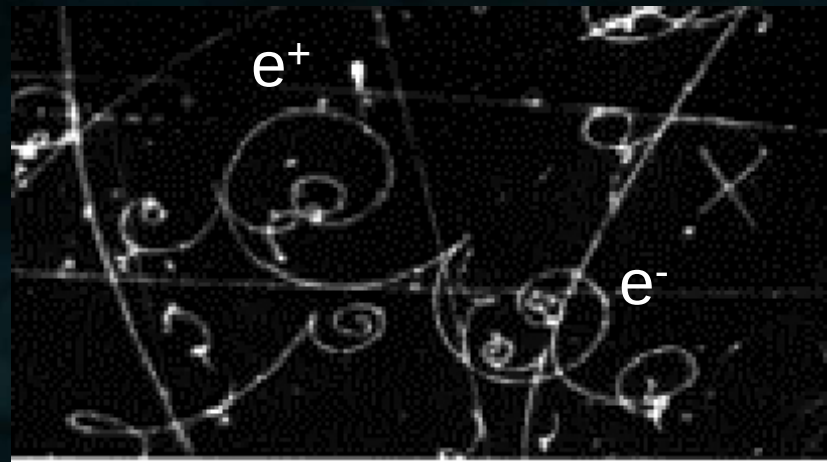


ANTIMATTER: WHERE ELSE?

Cosmic ray
showers



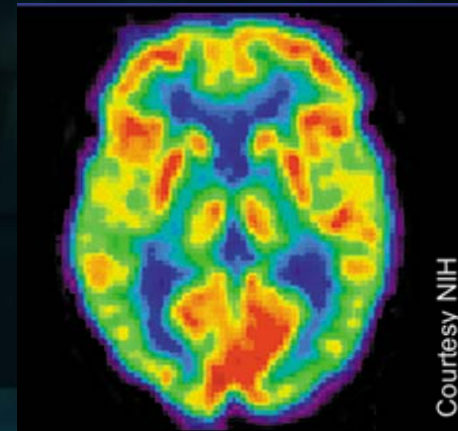
In fact, how antimatter was
discovered 75 years ago



Not a recent discovery

ANTIMATTER: WHERE ELSE?

- You!
- Radioactive decay of atoms (e.g. ^{40}K) in your body produce antimatter (positrons)
 - This antimatter annihilates into photons (light) in your body
- We have all have faint antimatter glow!
- In PET scans, similar radioactive atoms are placed in you to enhance this glow so that it can be analyzed



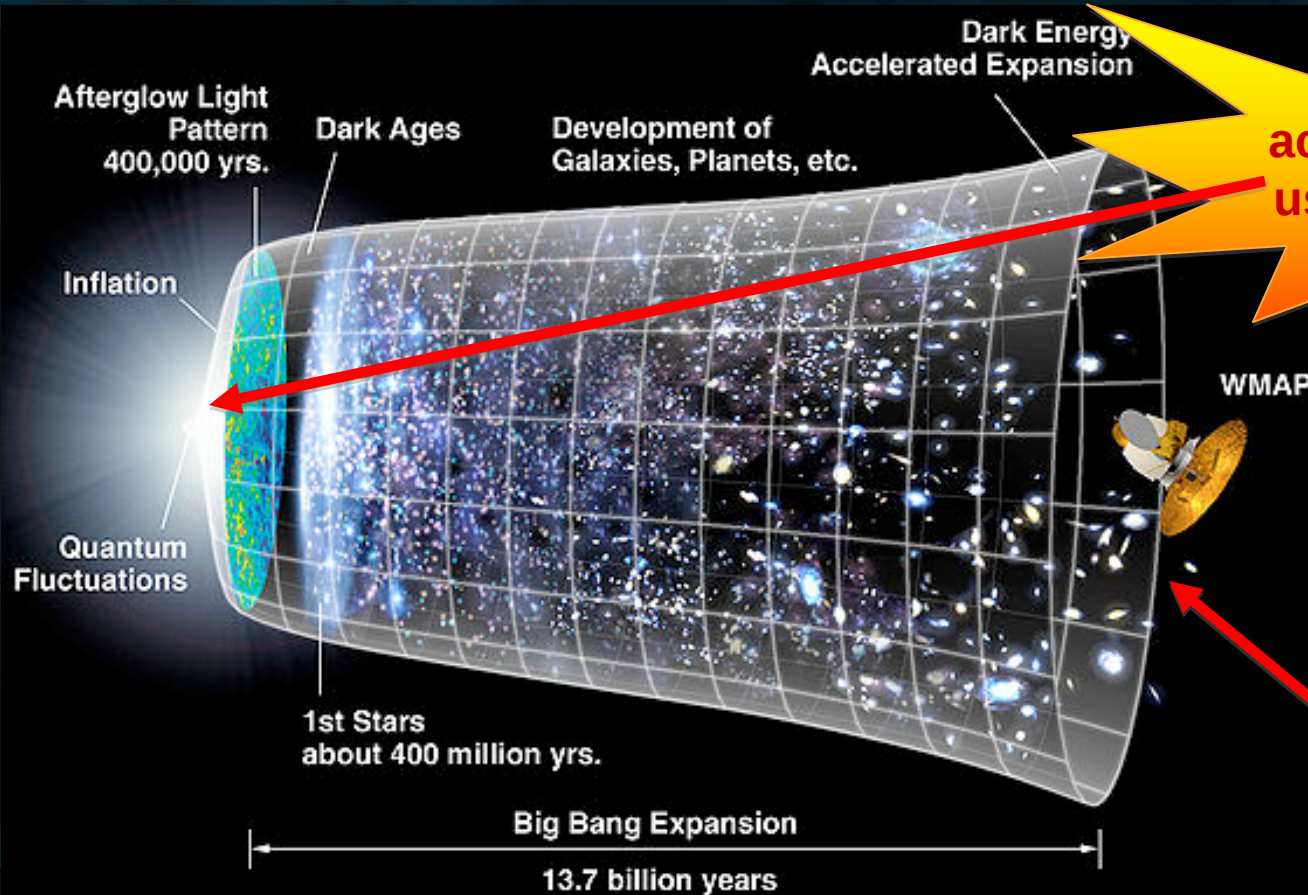
Courtesy NIH

ANGELS & DEMONS™

Lecture Night

THE SCIENCE REVEALED

A WINDOW INTO THE EVOLUTION OF OUR UNIVERSE



particle
accelerators allow
us to look back in
time!

You
are
here

SEARCHING FOR ANSWERS IN Champaign/Urbana

- University of Illinois high energy physics group
- 9 experimentalists, 6 theoreticians
- We participate in world-wide collaborations at laboratories in the U.S., Europe and South America
- Contact us or visit our web page to learn more
<http://www.hep.uiuc.edu/hepg/index.html>

A large, dark stone statue of William Shakespeare, shown from the back and side, looking towards the right. The statue is set against a dark, moody background with a bright light source behind it, creating a silhouette effect.

ANGELS & DEMONS™

Lecture Night
THE SCIENCE REVEALED

THANK YOU

For more information:

www.hep.uiuc.edu/hepg/index.html

www.uslhc.us

www.fnal.gov

www.cern.ch

 ILLINOIS



 **Fermilab**



ANGELS & DEMONS™
Lecture Night
THE SCIENCE REVEALED

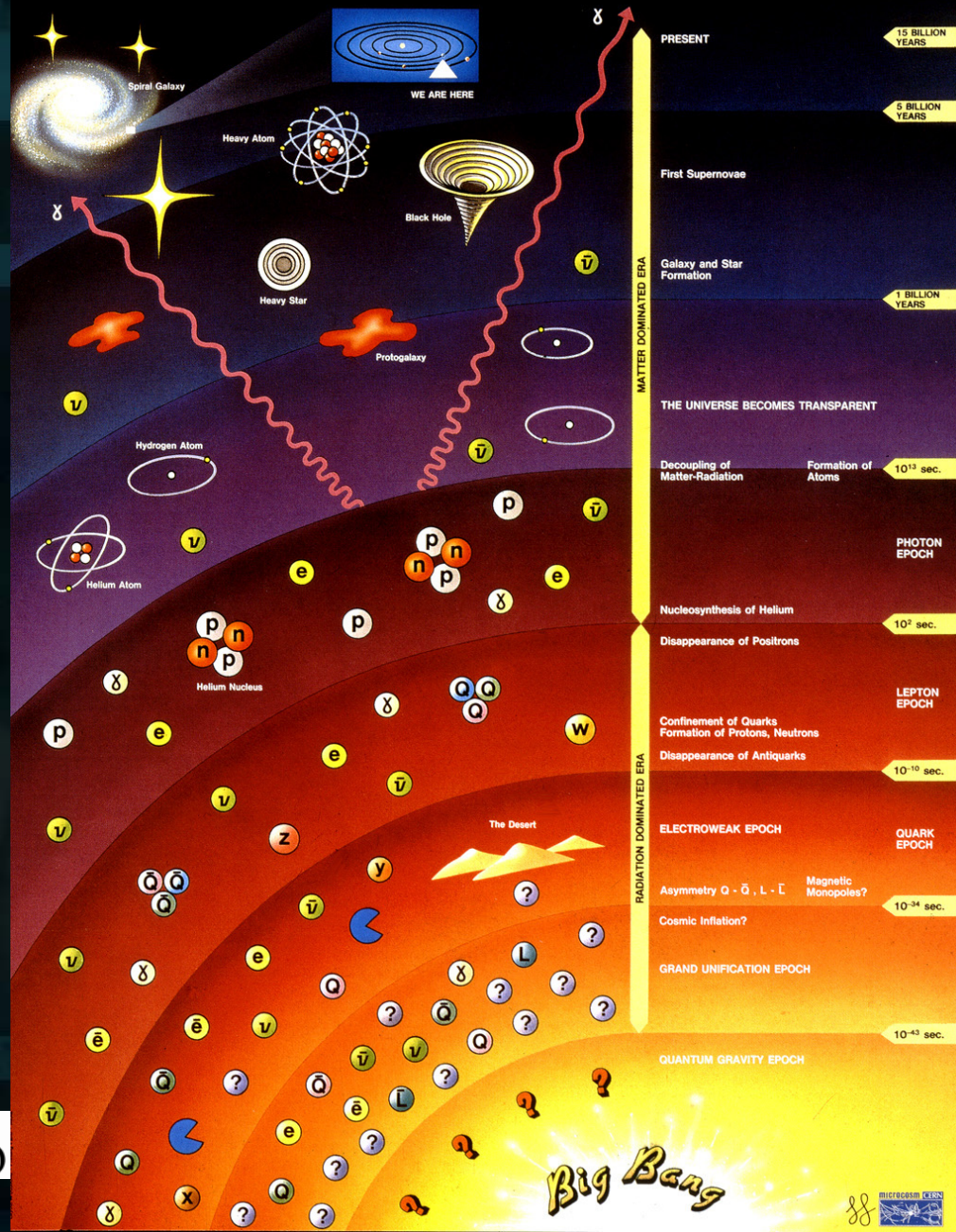
SUPPLEMENTAL SLIDES

THE MYSTERY OF ANTIMATTER

- We exist because there is almost no antimatter around
- It wasn't always that way



History of the Universe



THE BIG BANG

- 14 billion years ago, the Big Bang produced equal amounts of matter and antimatter
- Everything should have annihilated
- Instead...

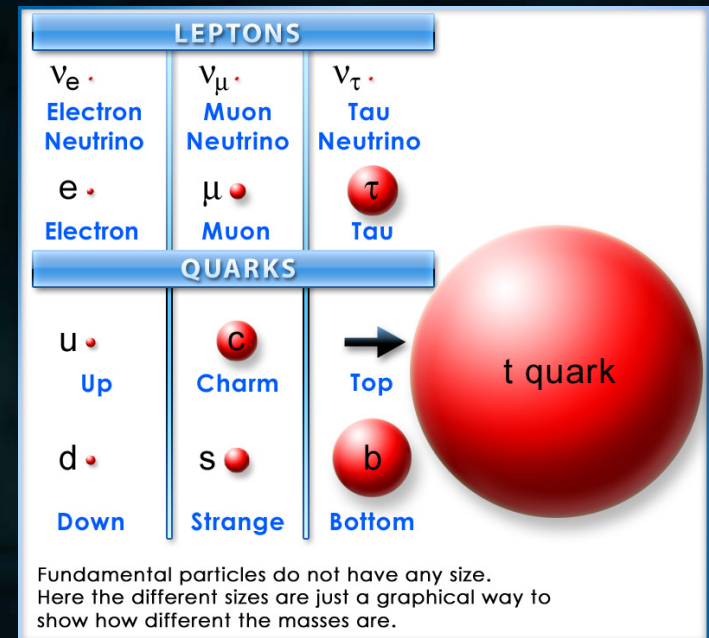


WHAT HAPPENED TO THE ANTIMATTER?

- After 40 years of research we know:
 - Some particles behave differently from their antiparticles
 - The difference is very slight – not enough to explain vast dominance of matter over antimatter
- There must be another explanation
 - Lots of ideas, but Nature gets the last word
 - Active area of current research at labs around the world, including Fermilab and CERN

GOD PARTICLE?!?

- Both Matter and Antimatter have mass
- But what is the origin of that mass?
- Why do different particles have such different masses?
- We believe that its due to an all-pervasive “Higgs field” that interacts with matter/antimatter particles



ANGELS & DEMONS™

Lecture Night

THE SCIENCE REVEALED

HIGGS FIELD?

- Imagine that a room full of physicists chattering quietly is like space filled with the Higgs field...



ANGELS & DEMONS™

Lecture Night

THE SCIENCE REVEALED



- A well-known scientist walks in, attracting a cluster of admirers with each step...

- ... this increases his resistance to movement, in other words, he acquires mass!



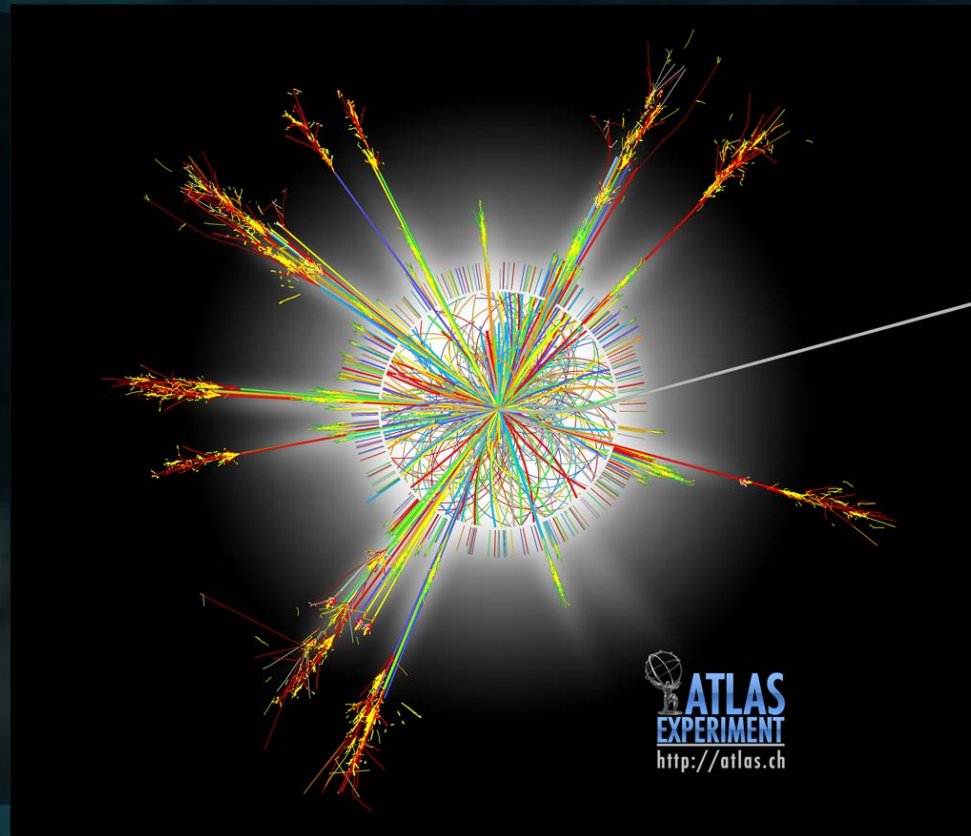
Black Holes ?

According to some speculative theories, tiny black holes could be produced in collisions at the LHC.

They would then very quickly decay and be detected by experiments (the tinier the black hole, the faster it evaporates).



Simulation of a Microscopic-Black Hole Event



Would Microscopic-Black Holes be Dangerous?

Cosmic rays are continuously bombarding Earth's atmosphere with far more energy than protons will have at the LHC

They have done so throughout the 4.5 billion years of the Earth's existence, and the Earth is still here!

So nobody should loose sleep over this

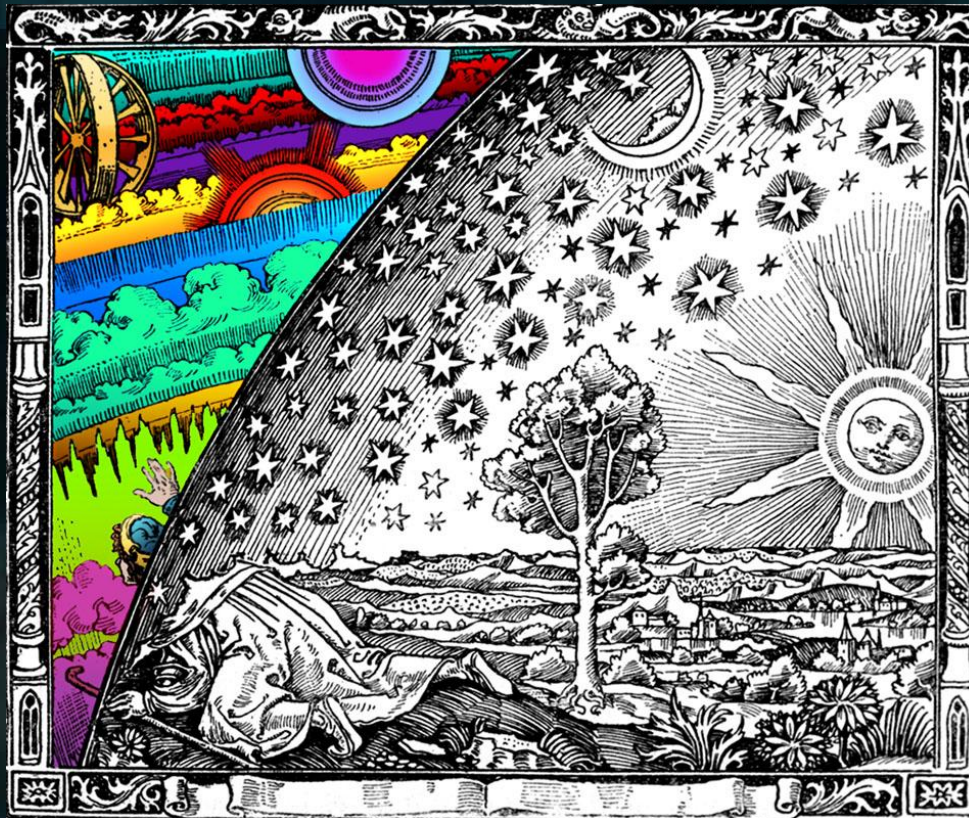


ANGELS & DEMONS™

Lecture Night

THE SCIENCE REVEALED

Extra Dimensions of Space!?!



Are There Extra Dimensions?



To understand why extra dimensions were proposed, consider:

Which is weaker:

Gravity or Electromagnetism?

Which is more powerful:

A small magnet or The entire massive Earth?

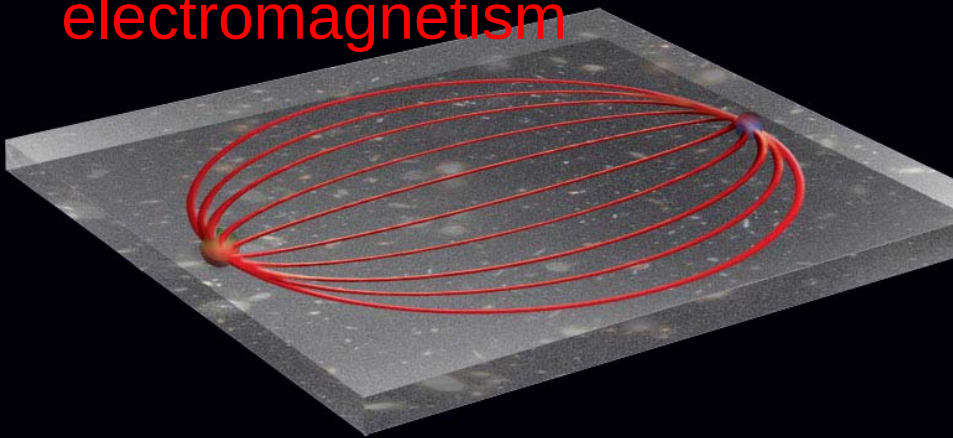


So gravity is extremely weak!
Why?

Why Is Gravity so Weak?

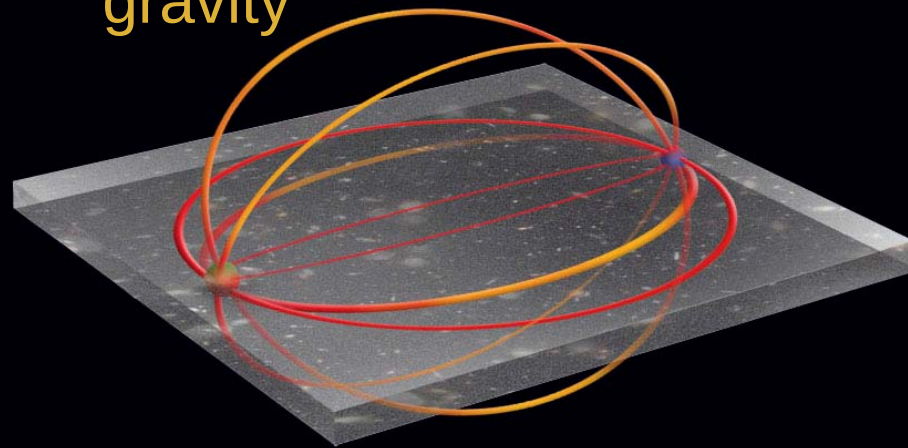
Electromagnetism is confined to our usual three dimensions of space

electromagnetism



Maybe Gravity sees the other dimensions of space.
As the force is spread out, it is weakened.

gravity



How can there be extra dimensions?

Think about an **acrobat** and a **flea** on a tight rope.

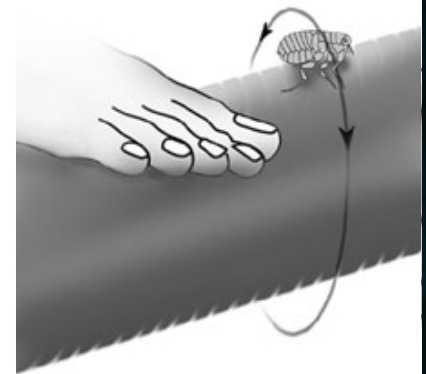
The **acrobat** can move forward and backward along the rope.

But the **flea** can also move sideways around the rope.

If the flea keeps walking to one side, it goes around the rope and winds up where it started.



An acrobat can only move in one dimension along a rope..



...but a flea can move in two dimensions.

How can there be extra dimensions?

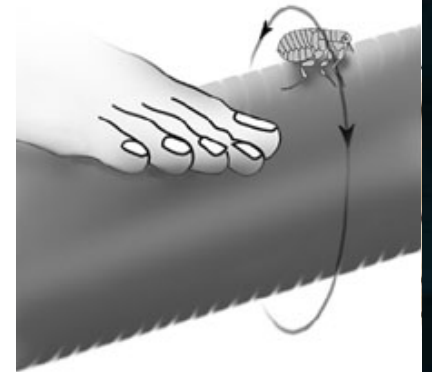
So the acrobat has **one** dimension, and the flea has **two** dimensions, but one of these dimensions is a small closed loop.

The acrobat can only detect the one dimension of the rope, just as we can only see the world in three dimensions, even though it might well have more.

This is impossible to visualize, precisely because we can only visualize things in three dimensions!



An acrobat can only move in one dimension along a rope..



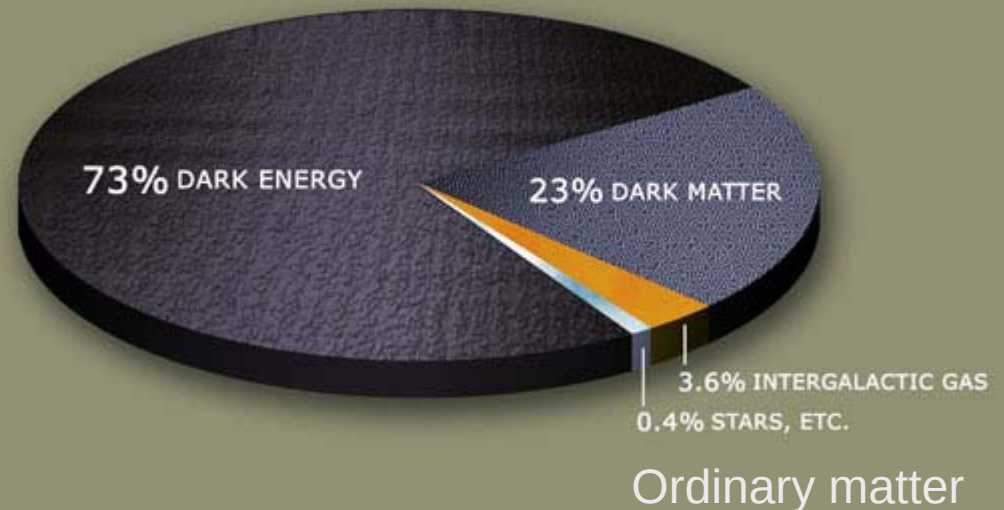
...but a flea can move in two dimensions.

But there is More than just Matter and Antimatter

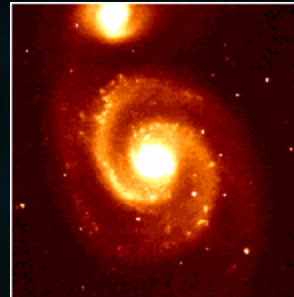
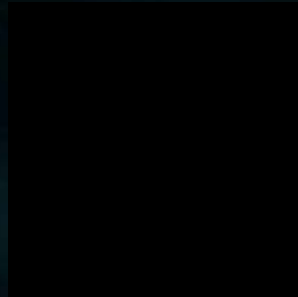
Looking at our Universe
we see much more than
ordinary matter (or
antimatter)

We call this extra stuff
“dark matter”
because we cannot
see it. But what is it?

Composition of our Universe



Dark Matter



Dark matter .. Not dark matter
... except that's not
really true

Much Evidence for its Existence

ANGELS & DEMONS

Lecture Night

THE SCIENCE REVEALED

In galaxies and galaxy clusters

There is not enough visible mass in rotating spiral galaxies to hold them together



Separation of dark matter and ordinary matter in the collision of two clusters of galaxies



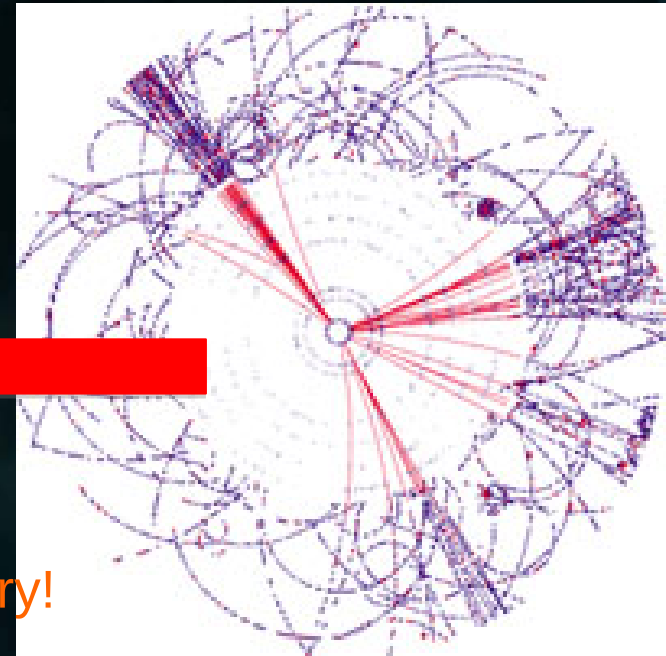
What is Dark Matter?

We don't know!

But we have ideas

If the constituents of dark matter are new particles, the LHC should discover them and elucidate the mystery of dark matter.

Dark Matter
produced in
the laboratory!



ANGELS & DEMONS™

Lecture Night

THE SCIENCE REVEALED

CERN

- European Laboratory for Particle Physics
- Founded in 1954
- 20 member countries
- More than 9,000 scientists
- Over 100 nationalities
- More than 1,000 from U.S. universities and labs

