Angels & Demons
Physics, Antimatter & Armageddon

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University of Texas
Suggest inserting the movie "International Trailer C"
The Plot

- Antimatter is stolen from CERN’s Large Hadron Collider and hidden in Vatican City.
- Countdown to Vatican annihilation begins.
- Race through Rome to avert death and destruction.
Hollywood’s CERN
Real-life CERN

Near Geneva, Switzerland

Not top secret
Towards international collaboration

- First proposed by Louis deBroglie, Neils Bohr, Pierre Auger, and others
- Founded 1954
- Bring together nations of Europe in spirit of scientific collaboration (aftermath of World War II)
CERN

- European Laboratory for Particle Physics
- 20 member countries
- More than 9,000 scientists
- Over 100 nationalities
- More than 1,000 from U.S. universities and labs
Hollywood’s Large Hadron Collider

photo credit: Sony Entertainment
The Real LHC Control Room

TRUE: large array of computers, links to experiments

FALSE: not right next to LHC detectors

photo credit: CERN
Remote LHC Control Room in U.S.A.

Sun will never set on LHC. Daytime USA = night in Switzerland

Modern internet and computing ==> remote monitoring of LHC.

photo credit: Fermilab
The real LHC

- The world’s most powerful particle accelerator – 14 TeV
- 16.8 miles around, 330 feet underground
The CERN accelerator complex
The Large Hadron Collider...
… is really LARGE!!

- Time for fast marathon runner to sprint around once: 2 hours?
- Time for the proton beam: $1/10,000^{th}$ of a second
The LHC

Will smash particles into each other... …to re-create the conditions of the early Universe

Info. from LHC detectors will equal ENTIRE world telecommunications traffic!
Computer simulation of proton-proton collision
Just how much energy …

Blast Furnace $\sim \frac{1}{4} \text{ eV}$

Tesla coils – 250,000 eV
...is 14 TeV anyway??

Van de Graaf – 5,000,000 eV

Fermilab – 1,000,000,000,000 eV
Can the LHC really destroy the world …
As seen on the “Daily Show”
Antimatter

- It’s real
- It’s produced at the Large Hadron Collider
- Enough of it could destroy Rome
- What is it?

photo credit: Sony Motion Pictures
What is matter?

Particles in various combinations

**Quarks**
- up
- charm
- top
- down
- strange
- bottom

**Leptons**
- electron
- muon
- tau
- electron neutrino
- muon neutrino
- tau neutrino
Building a universe

Multiply by billions and billions and billions and billions...
For every particle there is an antiparticle. Particles and antiparticles have opposite electric charge.
Matter vs. Antimatter

But were they to meet...

$E=mc^2$
Our first introduction to Antimatter
K$^{40}$ is antimatter producer

KCl is salt substitute

K$^{40}$ is 0.012% of all Potassium
Has too many neutrons compared to stable K$^{39}$.

Transmutes one proton by ejecting a positron from nucleus:

$$K^{40} \rightarrow Ar^{39} + e^+ + \nu_e$$
Antimatter can be used for PET Scans
Making isotopes for PET (C$^{11}$, N$^{13}$, O$^{15}$, F$^{18}$)

Harvard cyclotron, 1955
Detecting simultaneous gamma rays
Assessing brain activity

Normal Sleep

REM Sleep
Reduced blood flow to organs of smokers

Assessing CHEMO effectiveness

Before chemotherapy

After chemotherapy
Hat: If I have one more PET scan I think I'll glow!

Basic Flexfit Wool Cap

6 panel, mid-profile fitted cap. Fused hard buckram sewn into front of 3 1/2" crown. 6 sewn eyelets, 8 rows of stitching on a Permacurv® visor, silver undervisor and taped seams. This classic Flexfit cap comes in two sizes and stretches to fit comfortably.

Color: Khaki

Size: L/XL, 7 1/8" - 7 5/8"
“CAT SCANS ARE FOR FELINES.

I’LL GIVE YOUR DOG A PET SCAN.”
YOU DIDN’T WASH THE MATTER WITH THE ANTI-MATTER AGAIN, DID YOU?
CAN WE MAKE ANTIMATTER?

Nature does, all the time!
Example of cosmic rays: *Aurora Borealis*
Incoming cosmic ray breaks up a nucleus
QUANTUM OF ENERGY SPLITS INTO MATTER-ANTIMATTER
CAN WE MAKE ANTIMATTER?

We can, and do ...

In particle accelerators
Proton-antiprotons at 2 TeV: make t quark
• Rome is threatened by \( \frac{1}{4} \) gram of antimatter
• Annihilation of \( \frac{1}{4} \) g matter + \( \frac{1}{4} \) g antimatter = 10 kilotons of TNT
• More than enough to destroy the Vatican
• Hiroshima atomic bomb was equivalent to 15kton of TNT

• To actually haul 10 kton of TNT would require a cargo train with 100 cars.
ANTIMATTER’S NO THREAT

- We make very little antimatter
- Fermilab creates 2.3 nanograms of antiprotons per year

- It would take 109 million yrs to make ¼ gram (longer @ CERN)
- Energy required to make ¼ gram would equal entire world’s energy consumption for 30 years!
Fermilab: the anti-matter factory!

Image credit: Fermilab
ACTUAL TRAPPING OF PARTICLES

- Laser-trapping of atoms
- Nobel prize 1997 (Steven Chu, current Secretary of Energy!)
- Research here at UT! (Profs. Dan Heinzen, Mark Raizen)

photo American Physical Society/NIST
ANTIMATTER’S NO THREAT

- It’s not portable
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photo American Physical Society/NIST
ANTIMATTER CAN’T BE USED FOR

- **Power**
  - Have to make every single antiparticle
  - More energy goes in than is produced – 1 in $10^6$

- **Spaceships**
  - need an amount of antimatter like your fist
BOOK SUGGESTS CERN HAS X33 SPACECRAFT
More typical of a “Mr. Bean” television episode than of space vehicle.

Image credit: Prof. Trisha Vahle
THE MYSTERY OF ANTIMATTER

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

NASA/STScI/G.Bacon
14 billion years ago, the Big Bang produced equal amounts of matter and antimatter.

Everything should have annihilated.

Instead…

Hitoshi Murayama
Particle accelerators produce matter (quarks) and antimatter (anti-quarks).

Study the difference between them.

Prof. Jack Ritchie and Roy Schwitters
SOLVING THE MYSTERY

With neutrinos

- Neutrinos come in three types
- They can spontaneously switch
- Could provide answers to diff in matter, antimatter
- Prof. Karol Lang and S.K.
The search is on

Tevatron

Large Hadron Collider
Phrase coined by Leon Lederman

- Nobel prize winner in 1988
- Former director of Fermilab
- Actually called it the “goddamned particle” because it’s difficult to find
- Higgs boson gives other particles their mass (predicted 1964!)
- Central goal of the LHC!
So Why do ‘Big science’

<table>
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<th>The thrill of discovery</th>
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<td>International collaboration</td>
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<td>Seeing your own ideas brought to life</td>
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<td>“Game changers” of science that re-write the textbooks</td>
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THANK YOU

For more information
www.uslhc.us
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RESOURCES FROM
DEPARTMENT OF PHYSICS

Request a visit from the
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Come to a Saturday
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Hands-On-Science™
Inquiry-Based Curriculum
Dr. Sacha Kopp’s research is in the field of elementary particle physics. He studies the collision of subatomic particles at accelerator laboratories at Cornell University and the Fermi National Accelerator Laboratory. His current research addresses the question: Do particles known as neutrinos have mass?