Hot Science Cool Talks

UT Environmental Science Institute

64

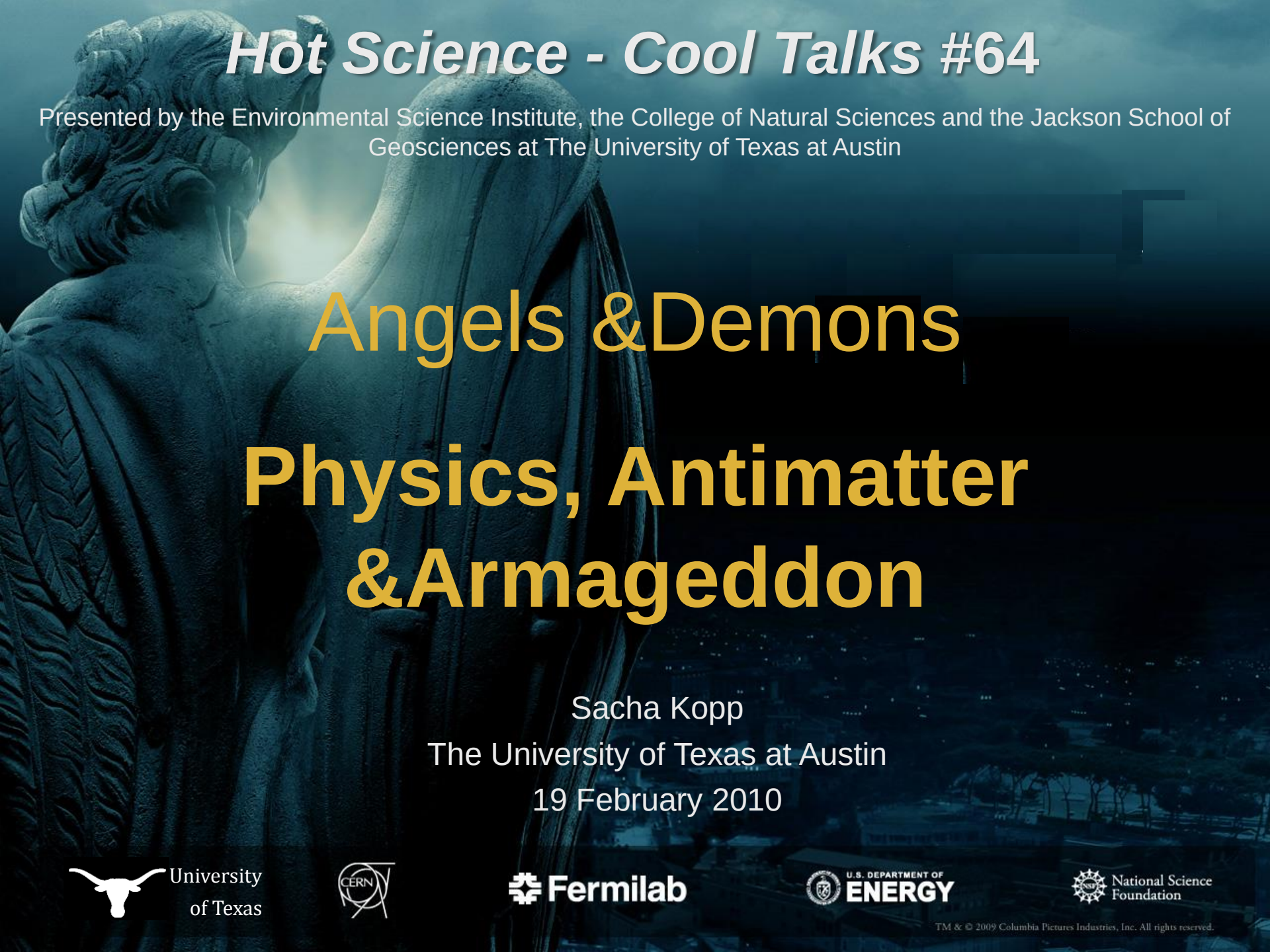
Angels & Demons: Physics, Antimatter, and Armageddon

Dr. Sacha Kopp

February 19, 2010

Hot Science - Cool Talks #64

Presented by the Environmental Science Institute, the College of Natural Sciences and the Jackson School of Geosciences at The University of Texas at Austin



Angels &Demons

Physics, Antimatter &Armageddon

Sacha Kopp
The University of Texas at Austin
19 February 2010

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Lecture Night

THE SCIENCE REVEALED

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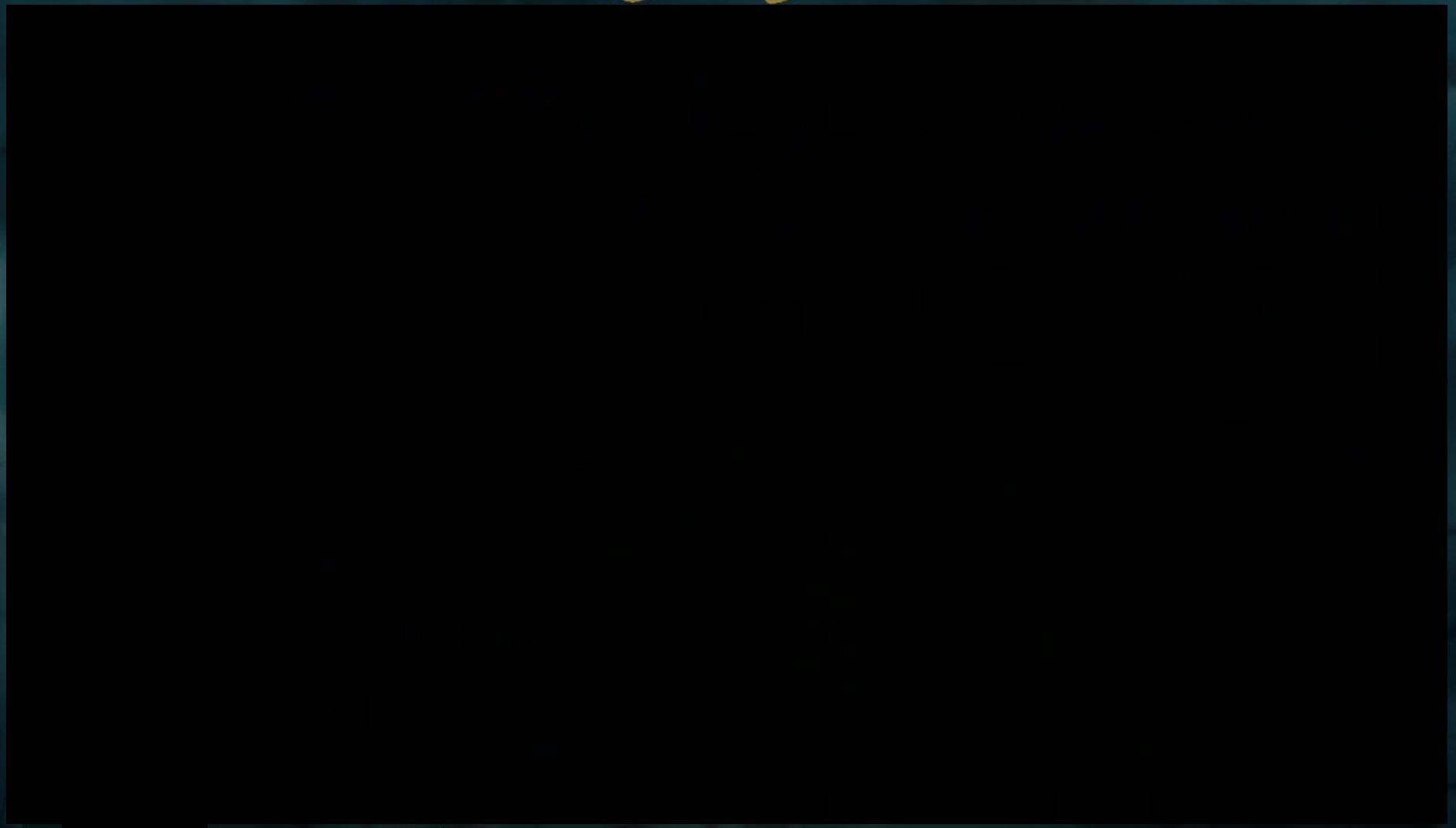

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The Plot

- 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.

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Hollywood's CERN

photo credit: Sony Motion Pictures

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Real-life CERN

Near Geneva, Switzerland

Not top secret

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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)

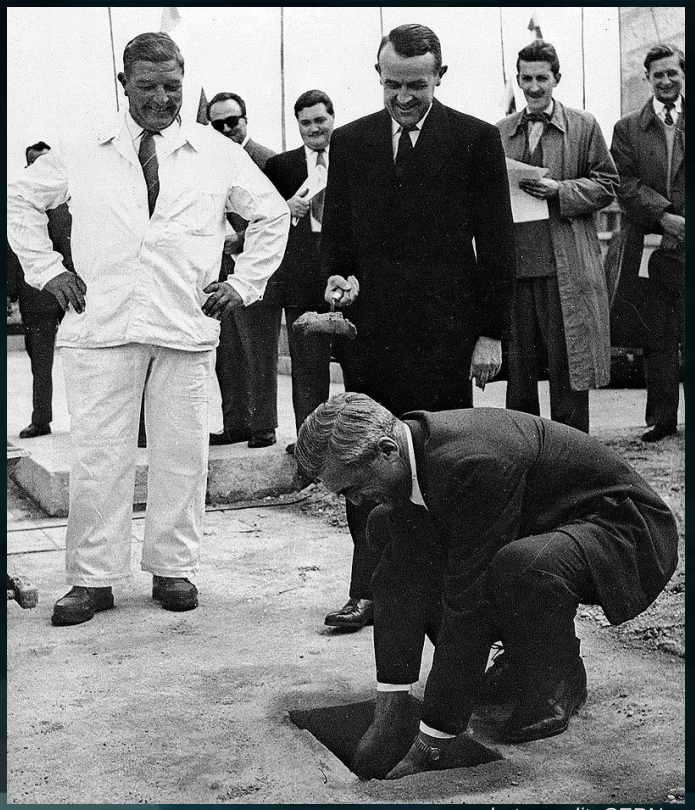

photo credit: CERN

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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

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Hollywood's Large Hadron Collider

photo credit: Sony Entertainment

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The Real LHC Control Room

TRUE: large array of computers, links to experiments

FALSE: not right next to LHC detectors

photo credit: CERN

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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

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The real LHC

- The world's most powerful particle accelerator – 14 TeV
- 16.8 miles around, 330 feet underground

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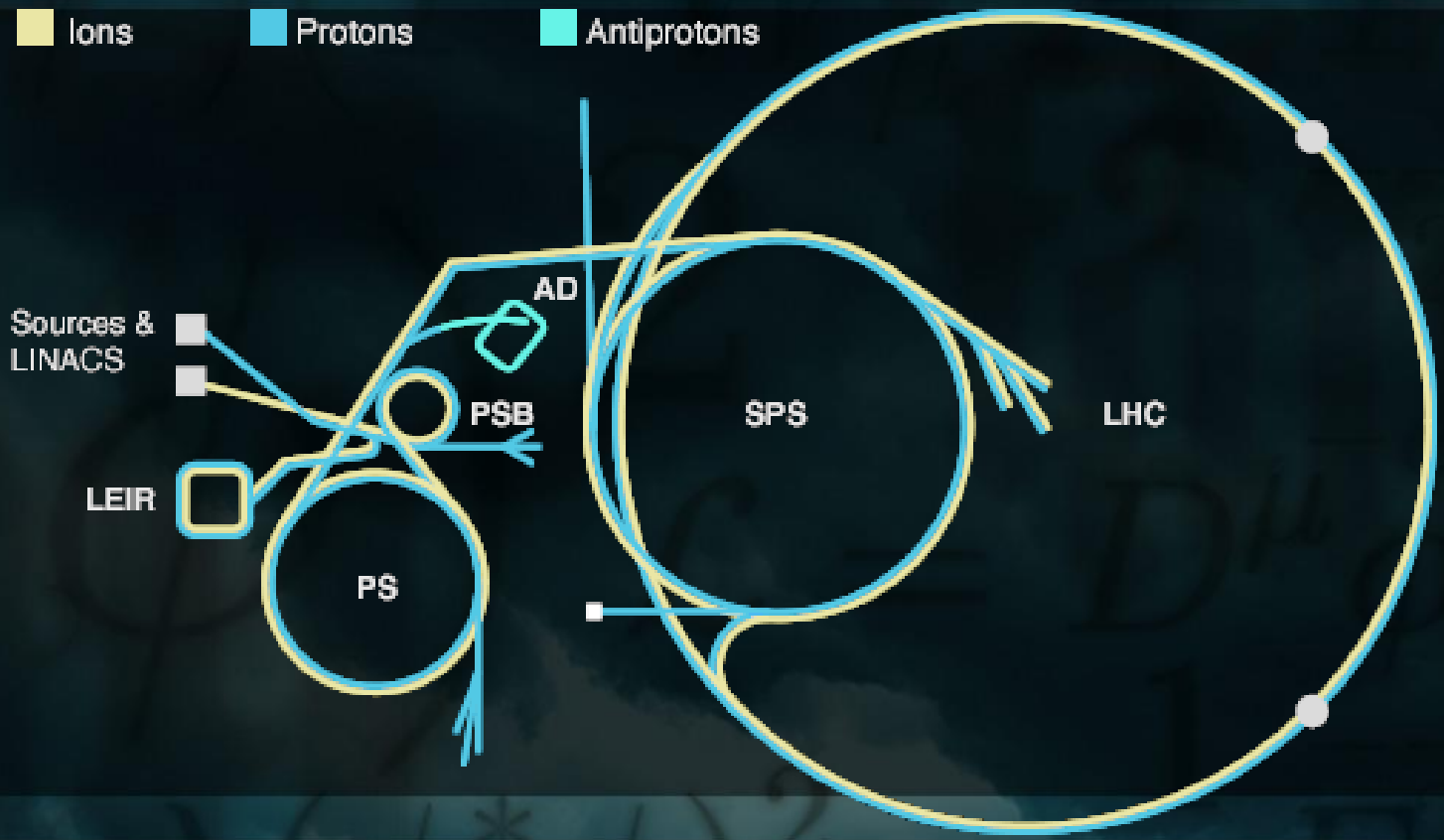
The CERN accelerator complex



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The Large Hadron Collider…

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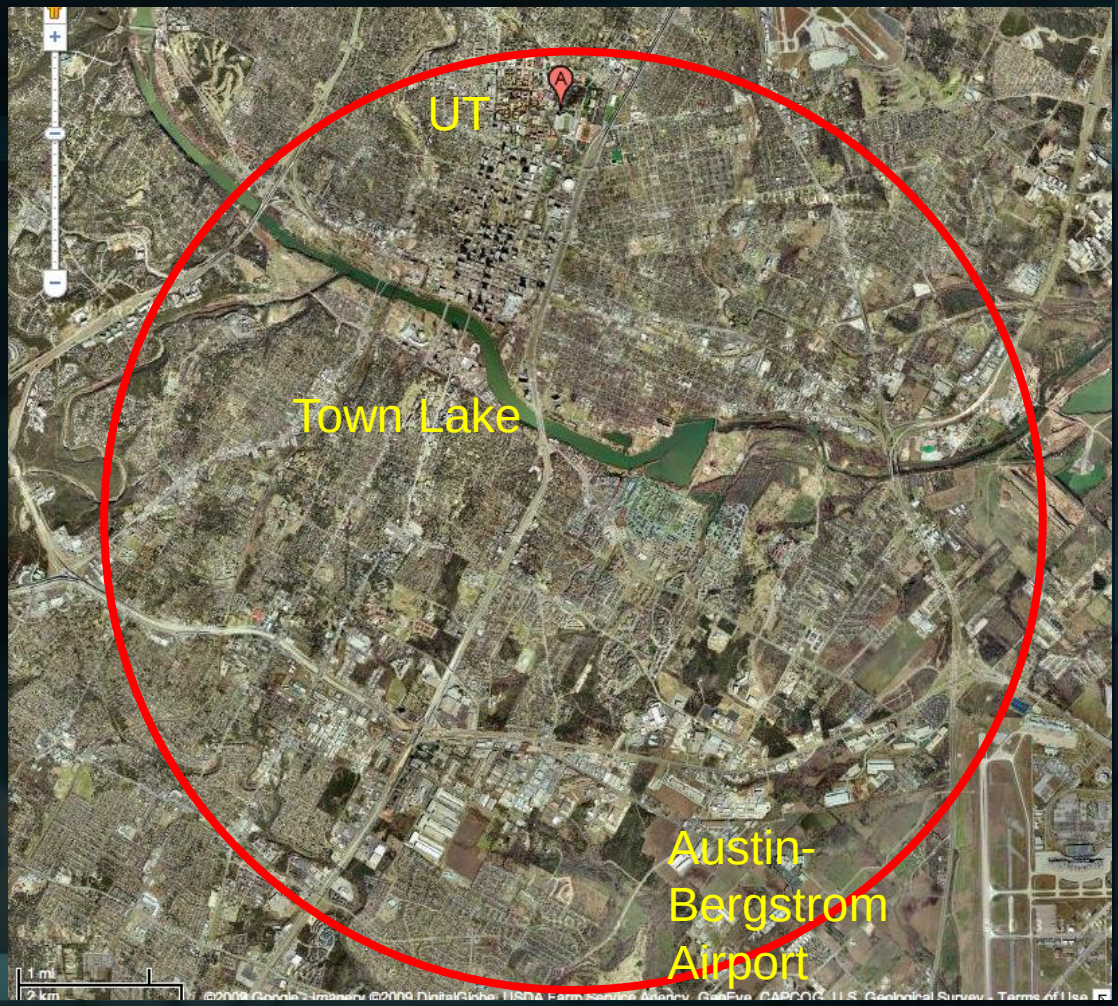
… is really LARGE!!

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



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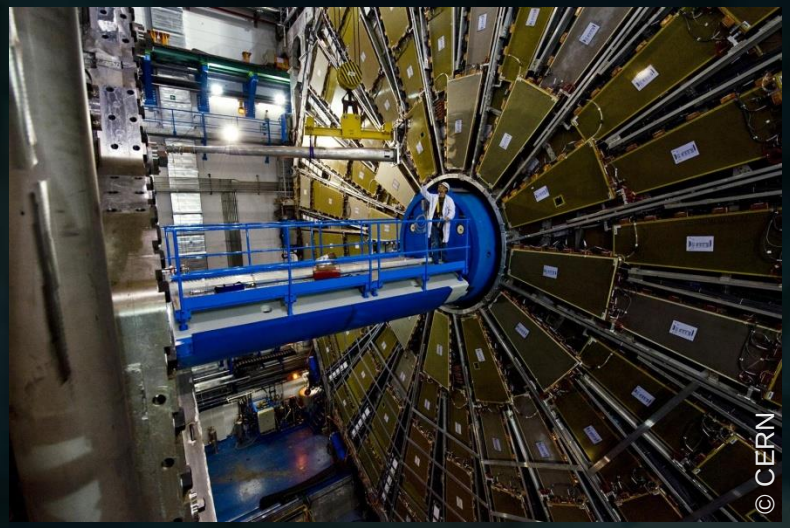
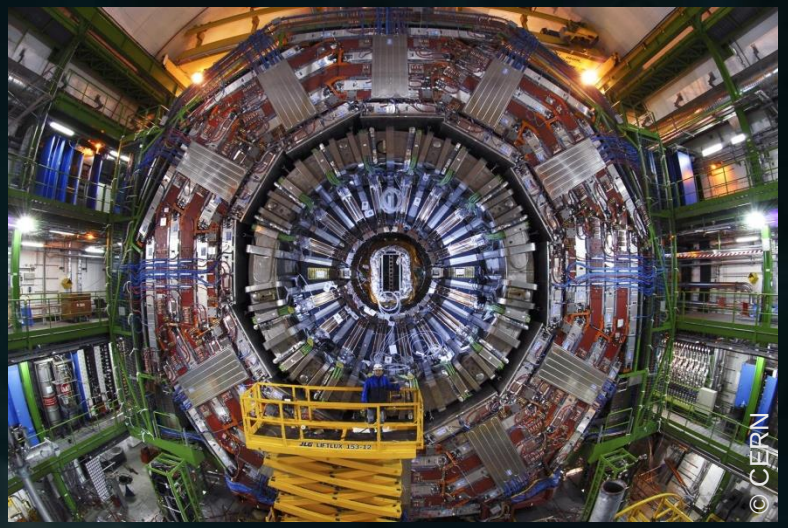
The LHC

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!

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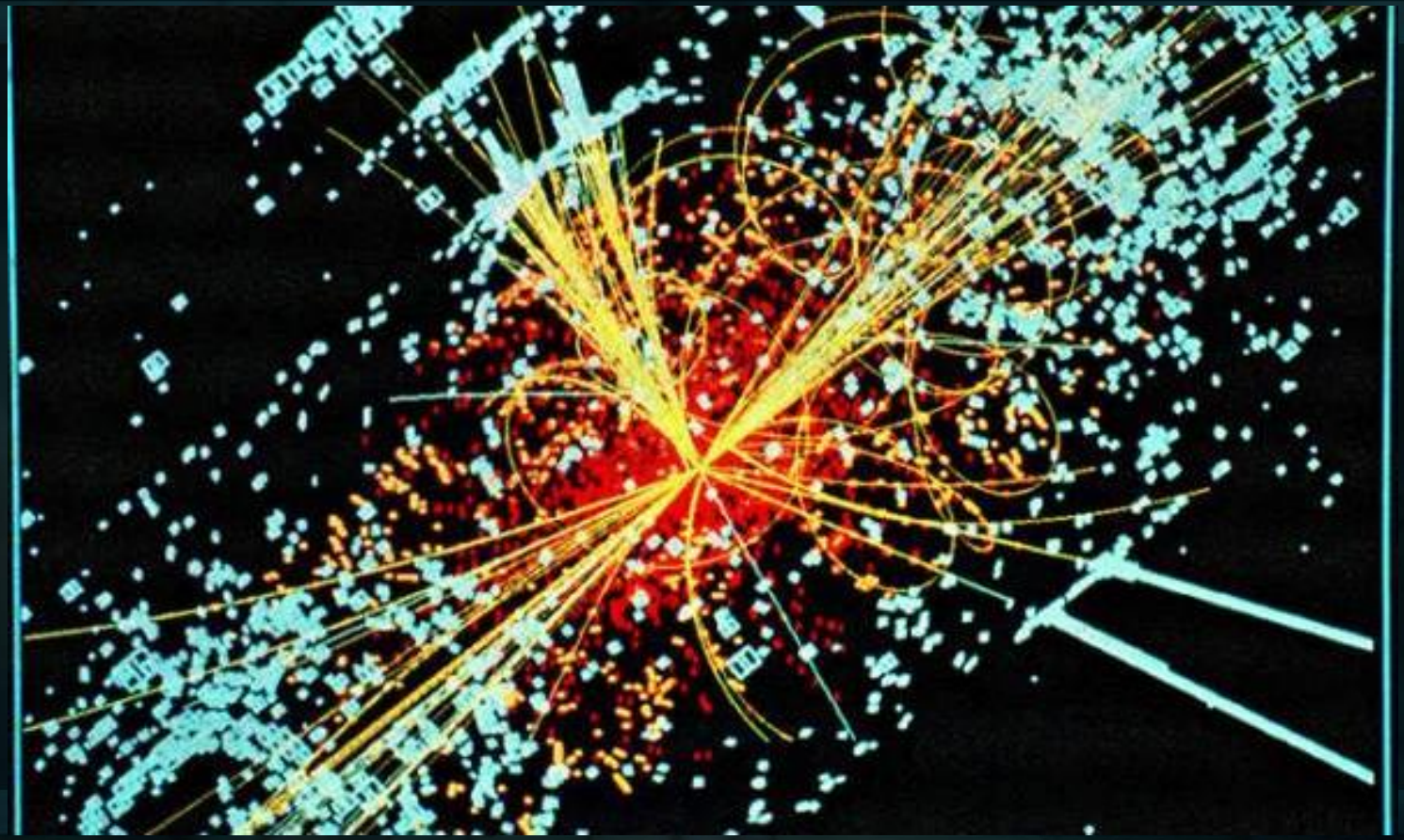
Computer simulation of proton-proton collision



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Just how much energy …

Blast Furnace ~ ¼ eV

Tesla coils – 250,000 eV

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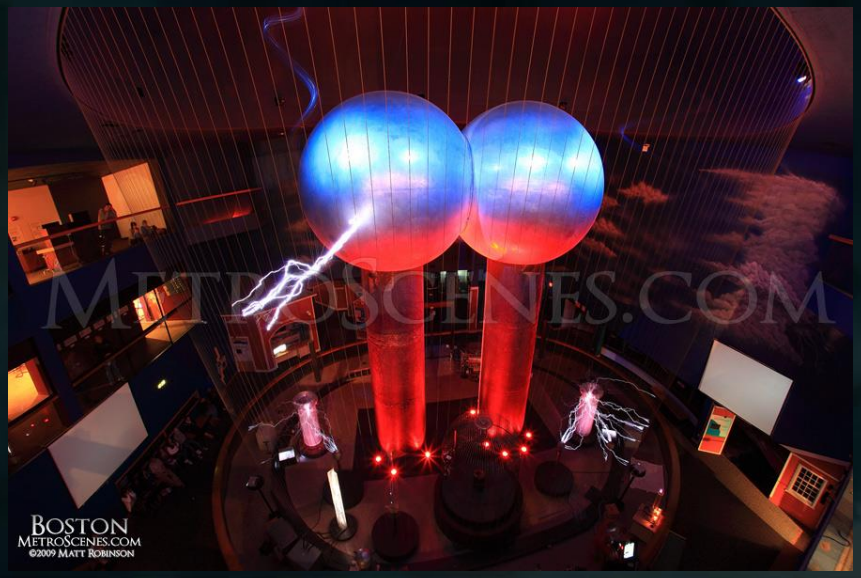
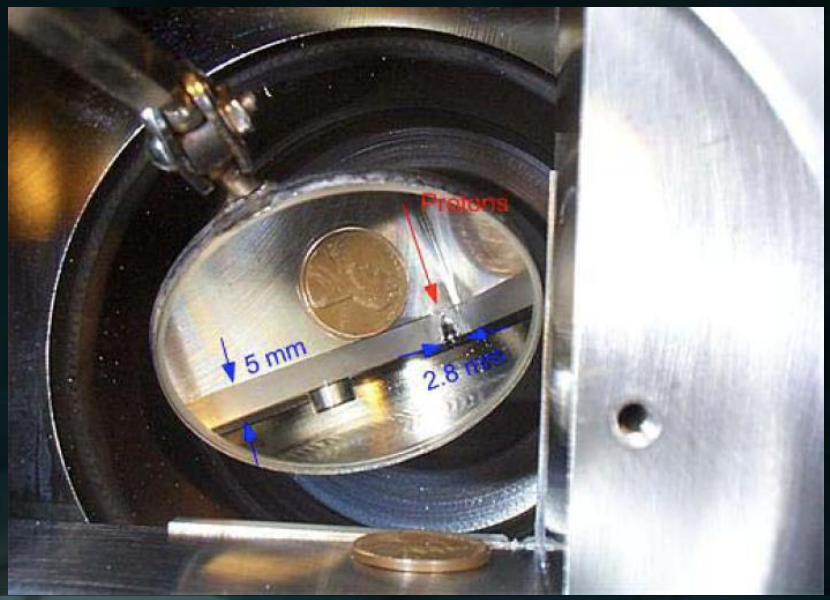
…is 14 TeV anyway??

Van de Graaf – 5,000,000 eV



Fermilab – 1,000,000,000,000eV



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Can the LHC really destroy the world …

Atom-smasher fears spark lawsuit - Science- msnbc.com

http://www.msnbc.msn.com/id/23844529/

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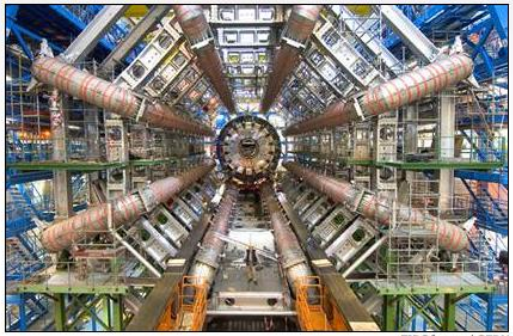
Doomsday fears spark lawsuit over collider

Critics worry about mini-black holes, strangelets; experts reject clain



EIROforum / CERN

A hardhat worker is dwarfed by the inner workings of the Large Hadron Collider's ATLAS detector, deep beneath the French-Swiss border.

By Alan Boyle
Science editor

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Asking a Judge to Save the World, and Maybe a Whole Lo

http://www.nytimes.com/2008/03/29/science/29collider.html

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No Competition. The Only

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… As seen on the “Daily Show”

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Antimatter

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

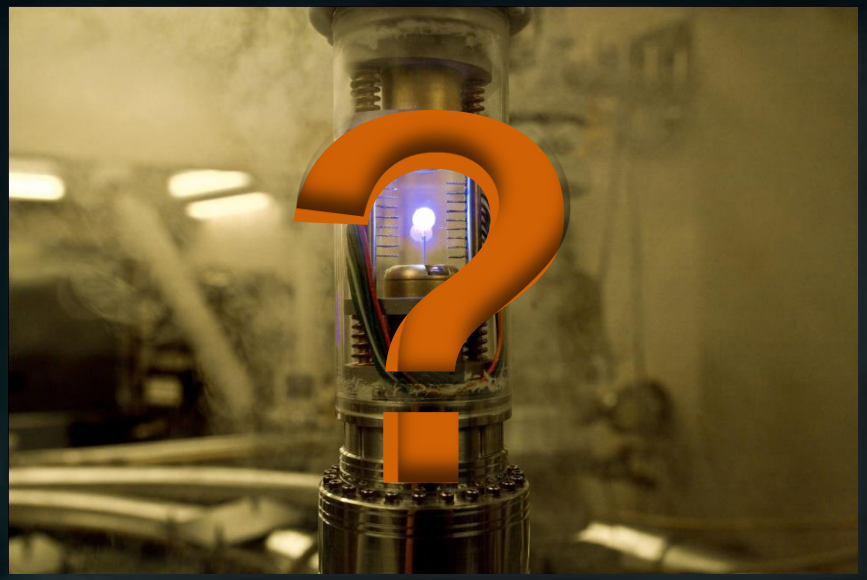

photo credit: Sony Motion Pictures

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What is matter?

Particles in various combinations

Quarks


up


charm


top


down


strange


bottom

Leptons


electron


muon


tau


electron neutrino


muon neutrino


tau neutrino

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Building a universe

electron

proton

neutron

Multiply by billions and billions and billions and billions…

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Where does antimatter fit?

For every particle


up


electron


down


electron neutrino

There is an antiparticle


anti-up


positron


anti-down


Anti-electron neutrino

Particles and antiparticles have opposite electric charge

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Matter vs. Antimatter

Anti-Tom Hanks

Would look very much like

Tom Hanks

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Matter vs. Antimatter

But were they to meet…

$E=mc^2$

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Our first introduction to Antimatter

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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:

$K^{40} \rightarrow Ar^{39} + e^{+} + \nu_e$

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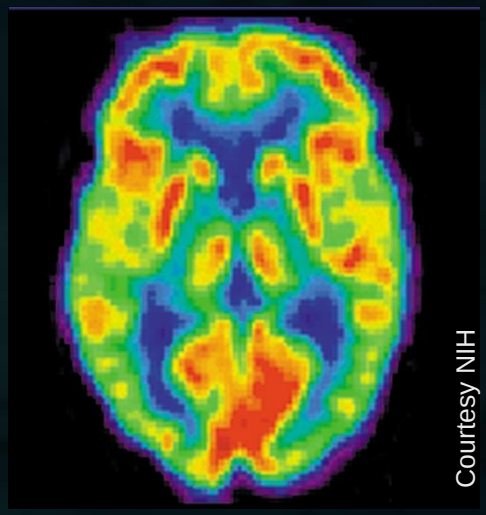
Antimatter can be used for

PET Scans



Courtesy NIH

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Making isotopes for PET (C^{11}, N^{13}, O^{15}, F^{18})

Harvard cyclotron, 1955

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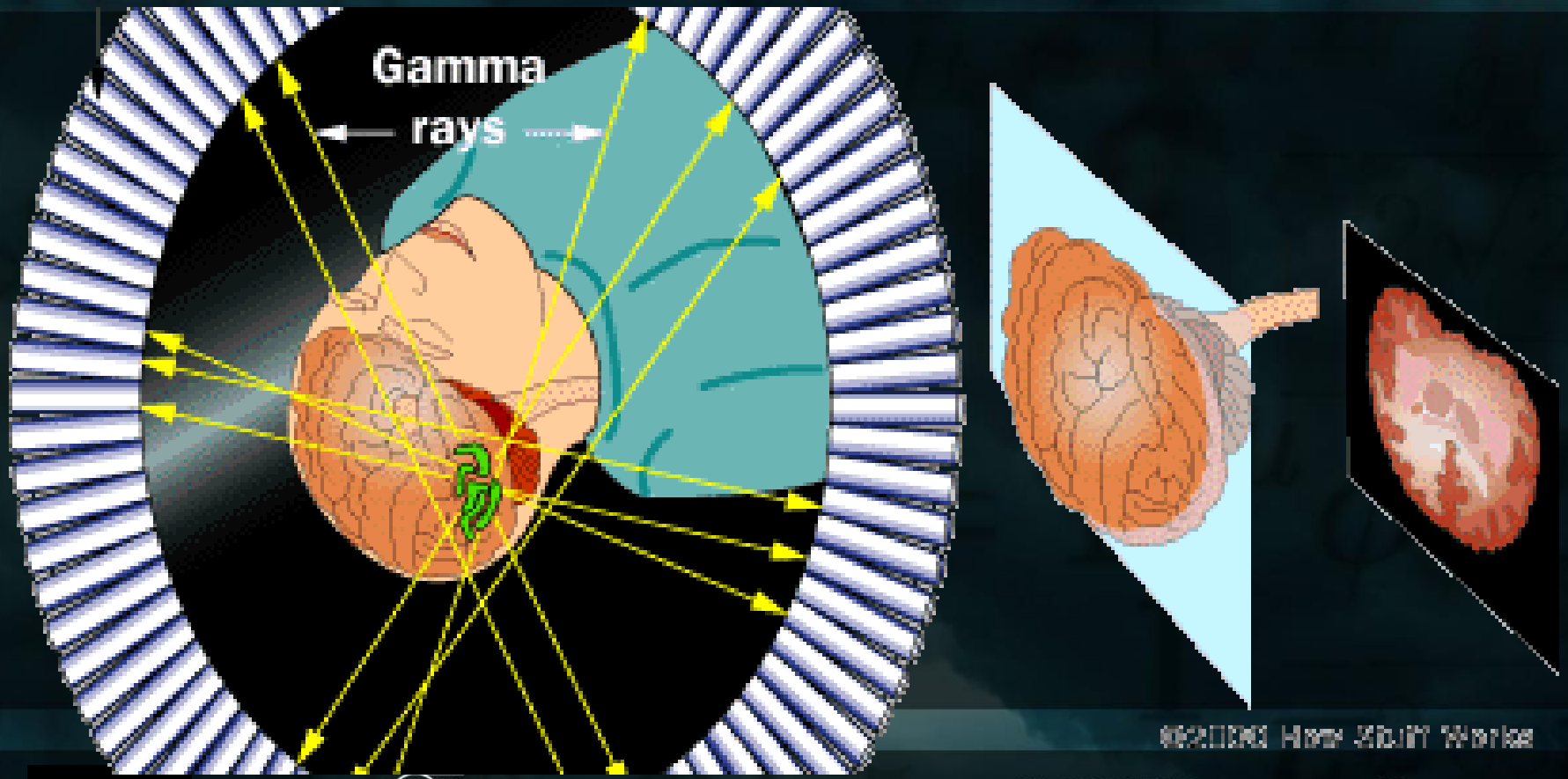
Detecting simultaneous gamma rays



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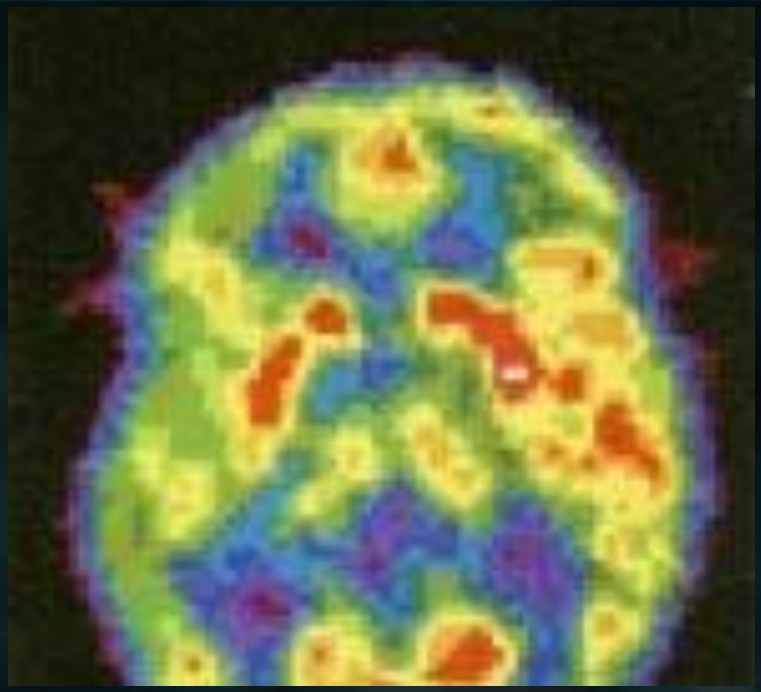
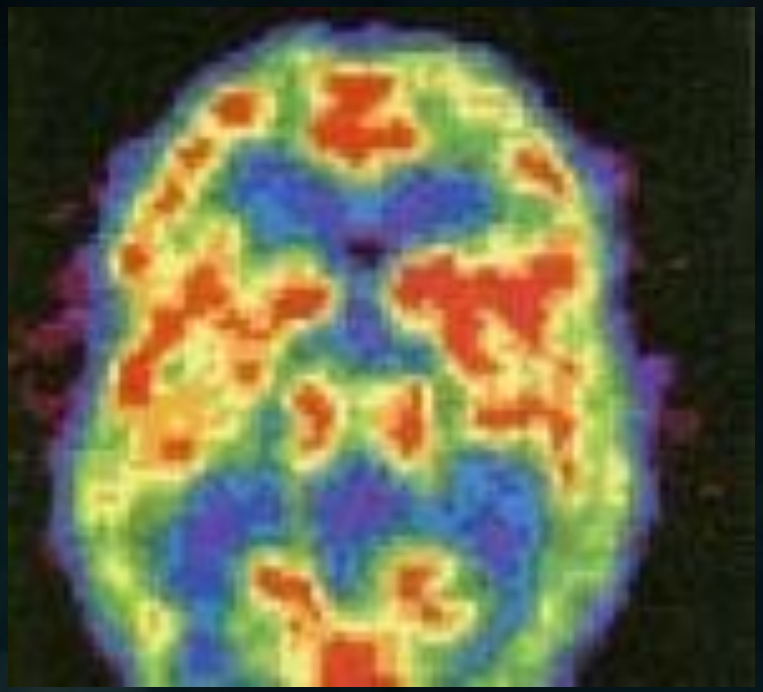
Assessing brain activity



Normal Sleep



REM Sleep

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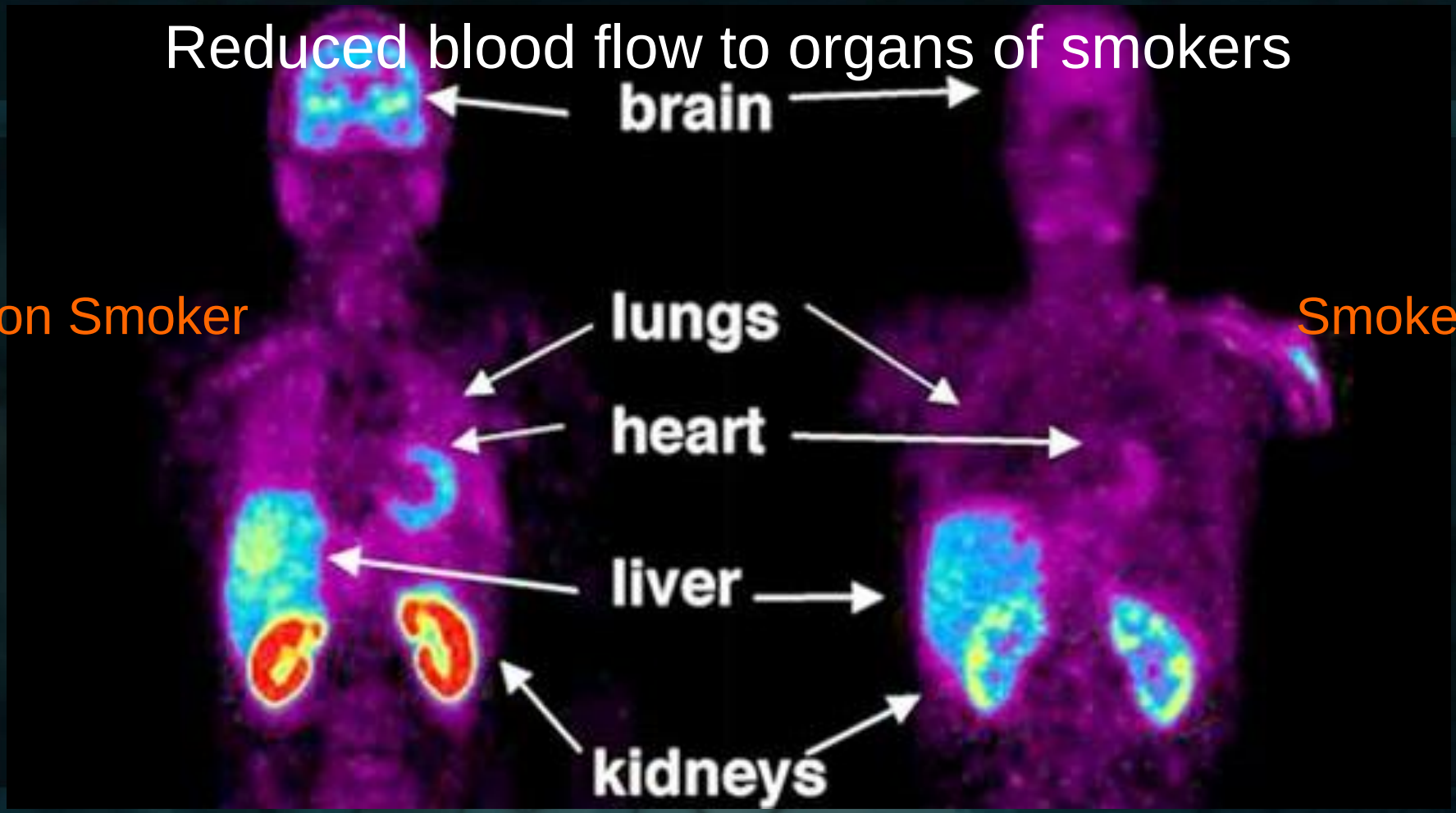
Reduced blood flow to organs of smokers



Proc. Nat'l Acad. of Sciences, 9/28/03, "Low Monoamine Oxidase B in Peripheral Organs in Smokers."

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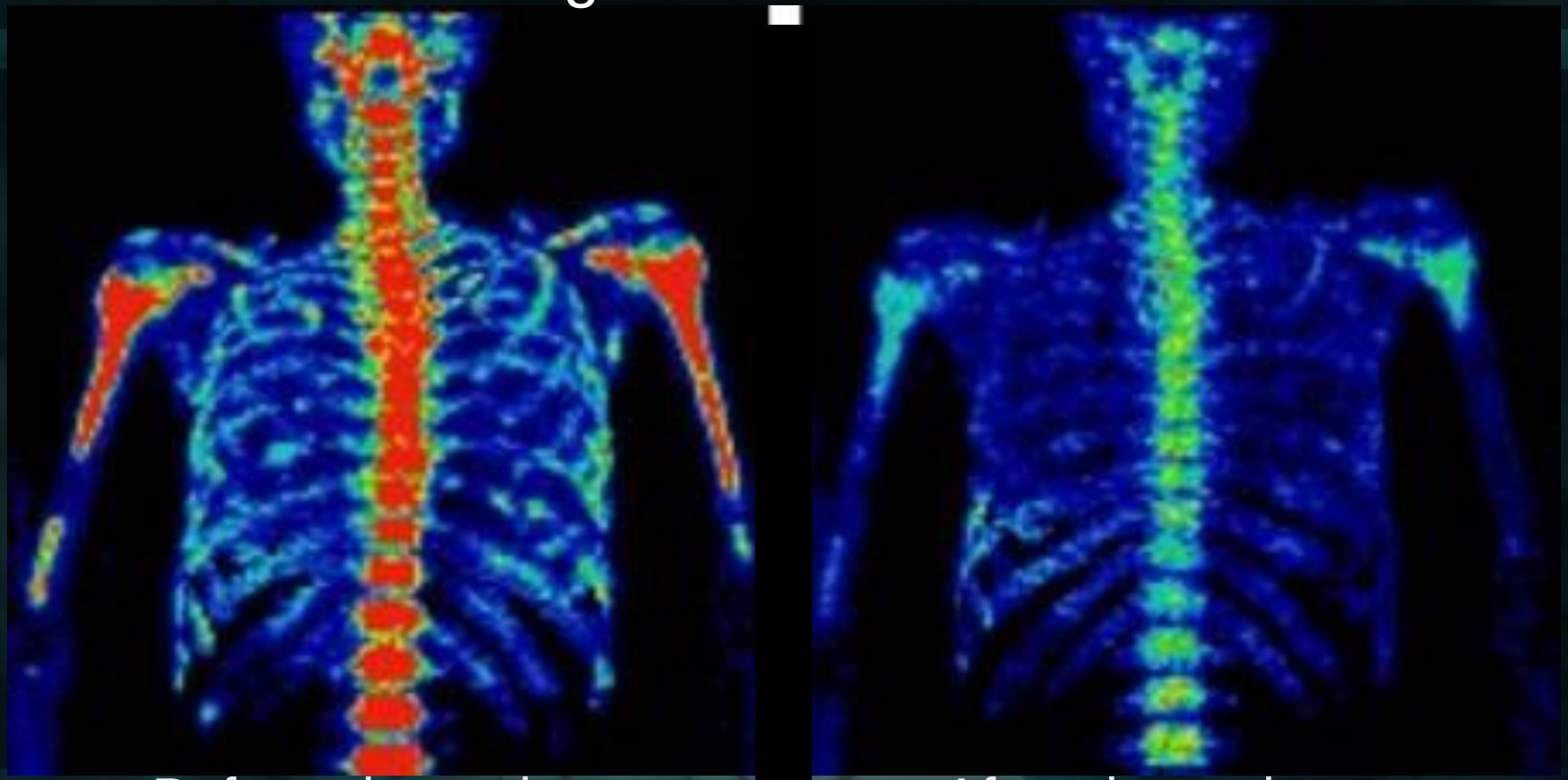
Assessing CHEMO effectiveness



Before chemotherapy

After chemotherapy

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

Views: Model | Product | Design

View stitch

Basic Flexfit Wool Cap (starting at **$22.95**)

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.


Basic Flexfit Wool Cap


Basic Adjustable Cap


Distressed Chino Twill Cap

Color: Khaki

Size: L/XL, 7 1/8" - 7 5/8"

S/M | L/XL

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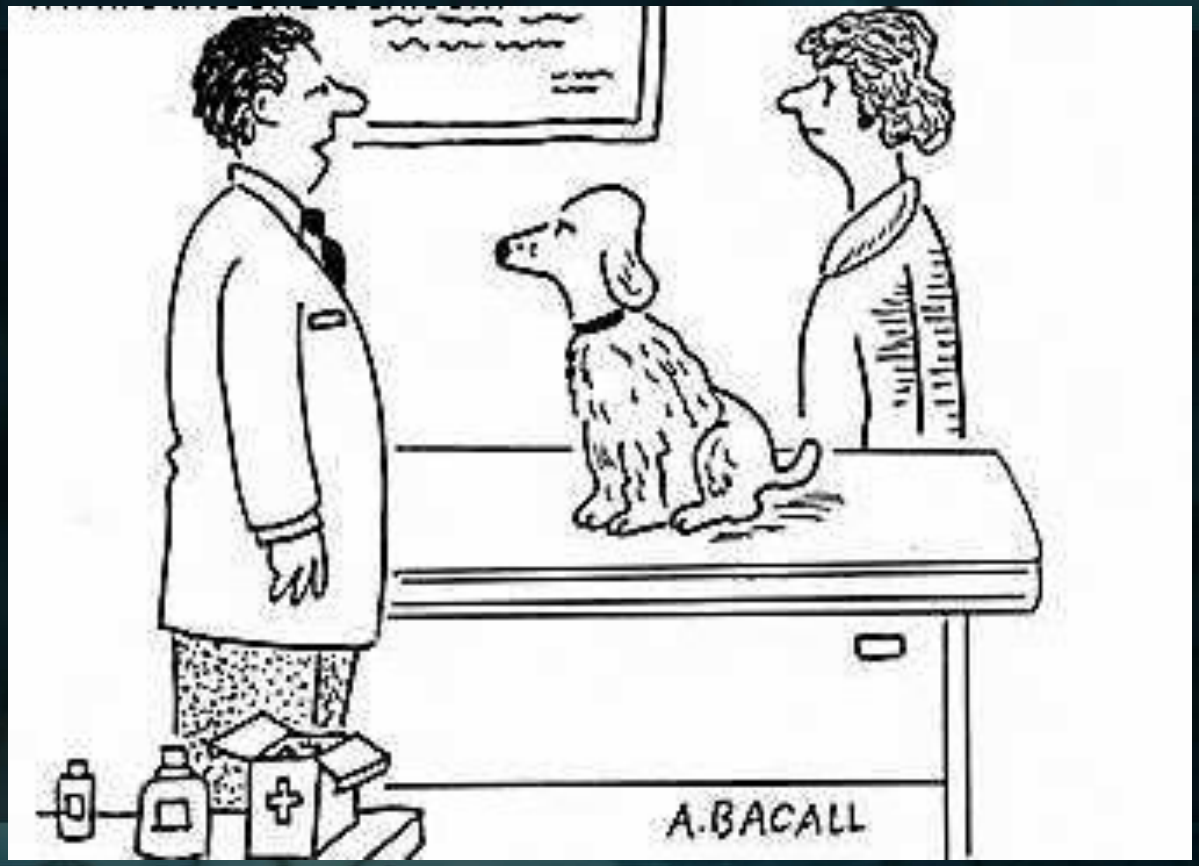
"CAT SCANS ARE FOR FELINES.

I'LL GIVE YOUR DOG A PET SCAN."



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YOU DIDN'T WASH THE MATTER WITH THE ANTI-MATTER AGAIN, DID YOU?

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CAN WE MAKE ANTIMATTER?

Nature does, all the time!

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Example of cosmic rays: *Aurora Borealis*

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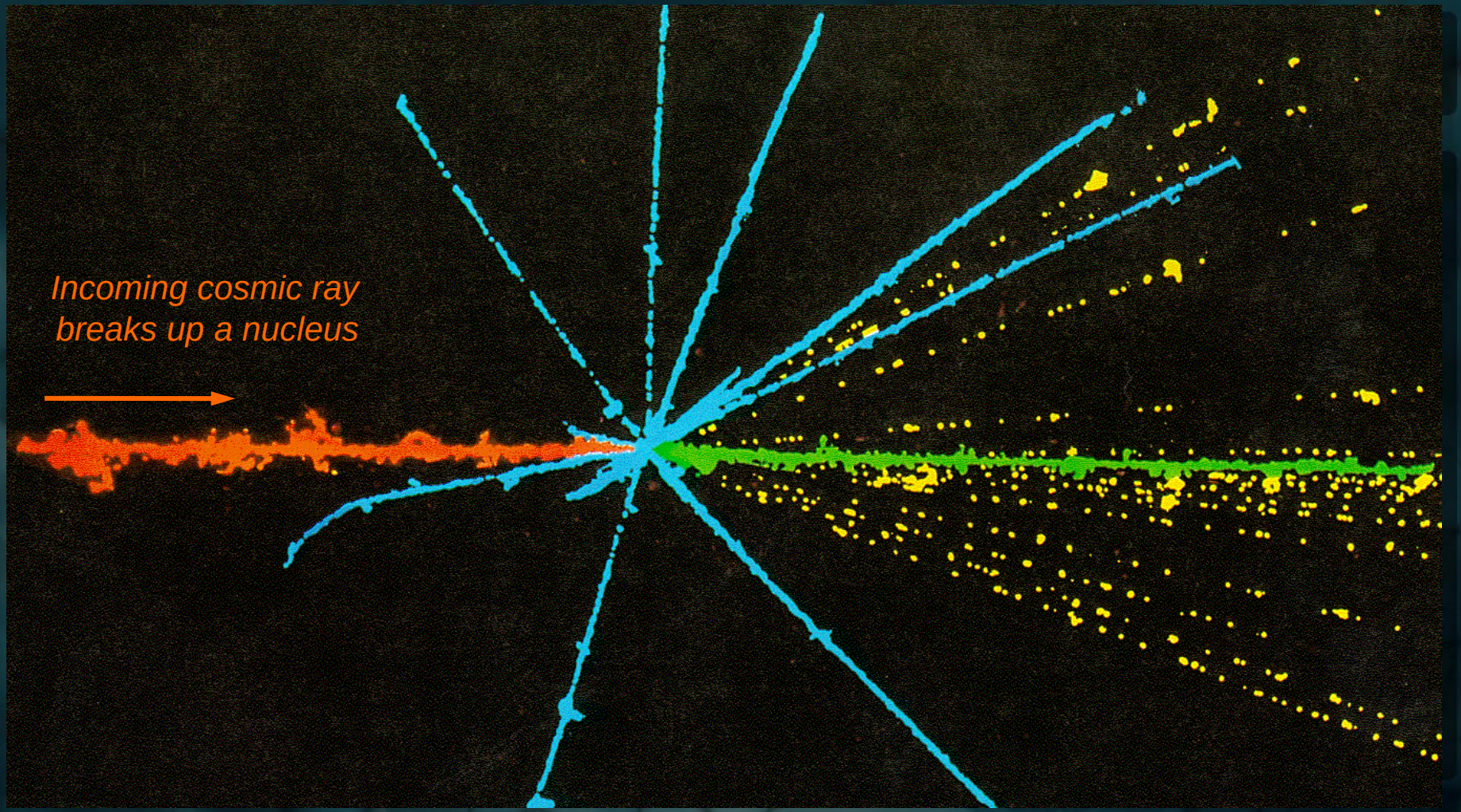

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QUANTUM OF ENERGY SPLITS INTO MATTER-ANTIMATTER

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CAN WE MAKE ANTIMATTER?

We can, and do …


SLAC National Accelerator Laboratory


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In particle accelerators

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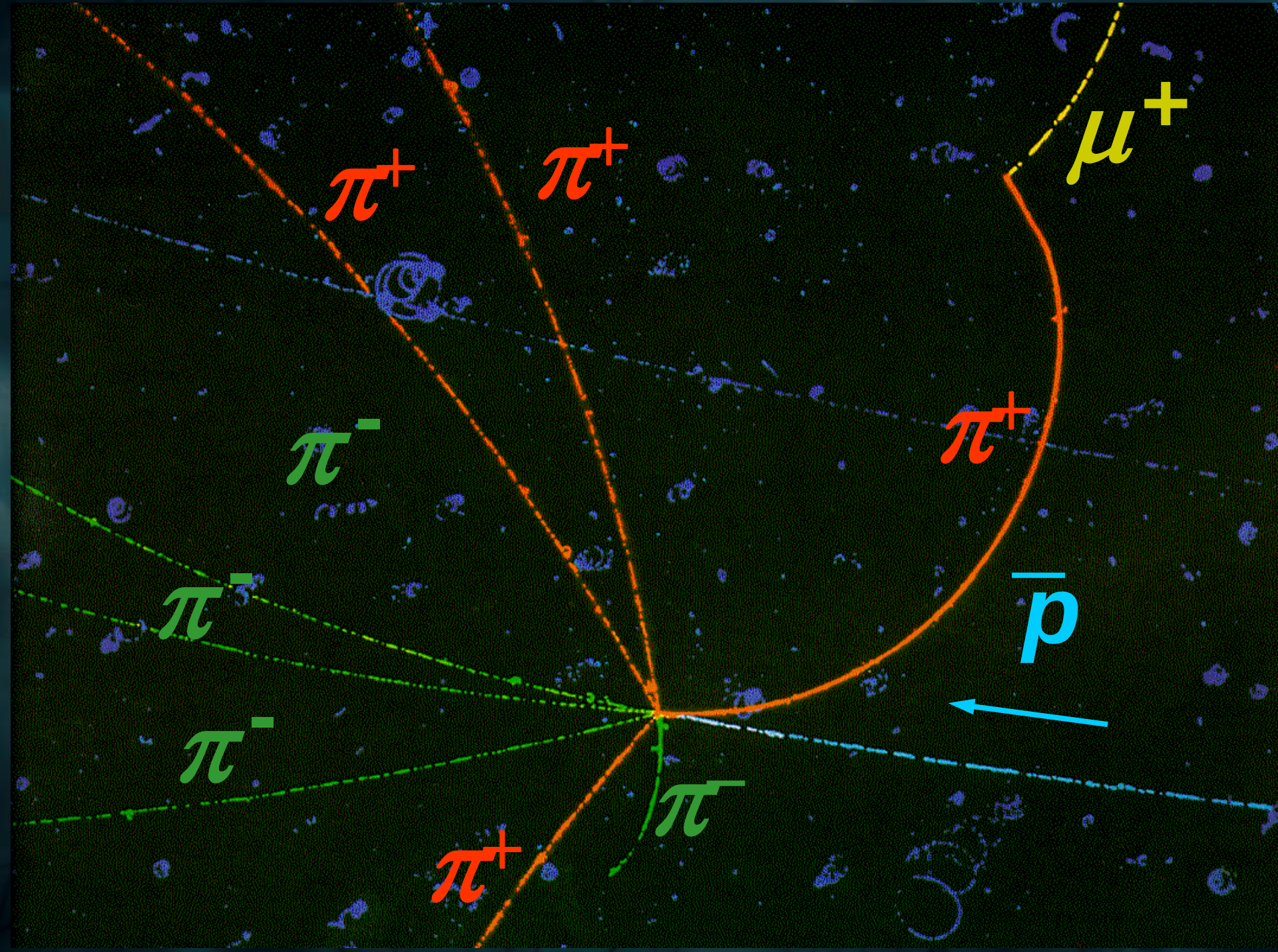
π^+
π^+
μ^+
π^-
π^+
π^-
$\bar{p}$
π^-
π^-
π^+

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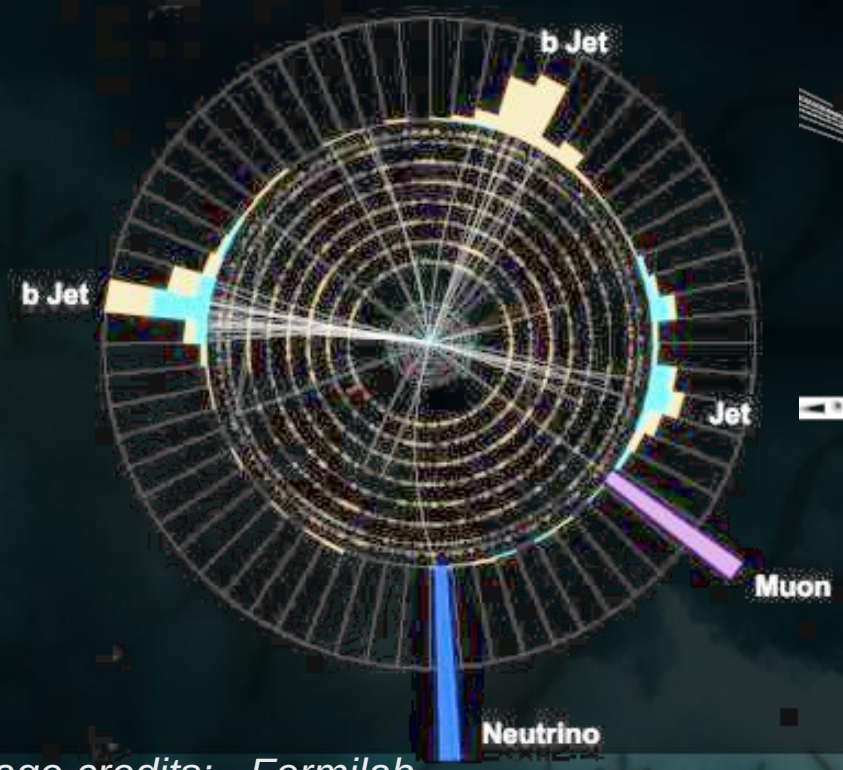
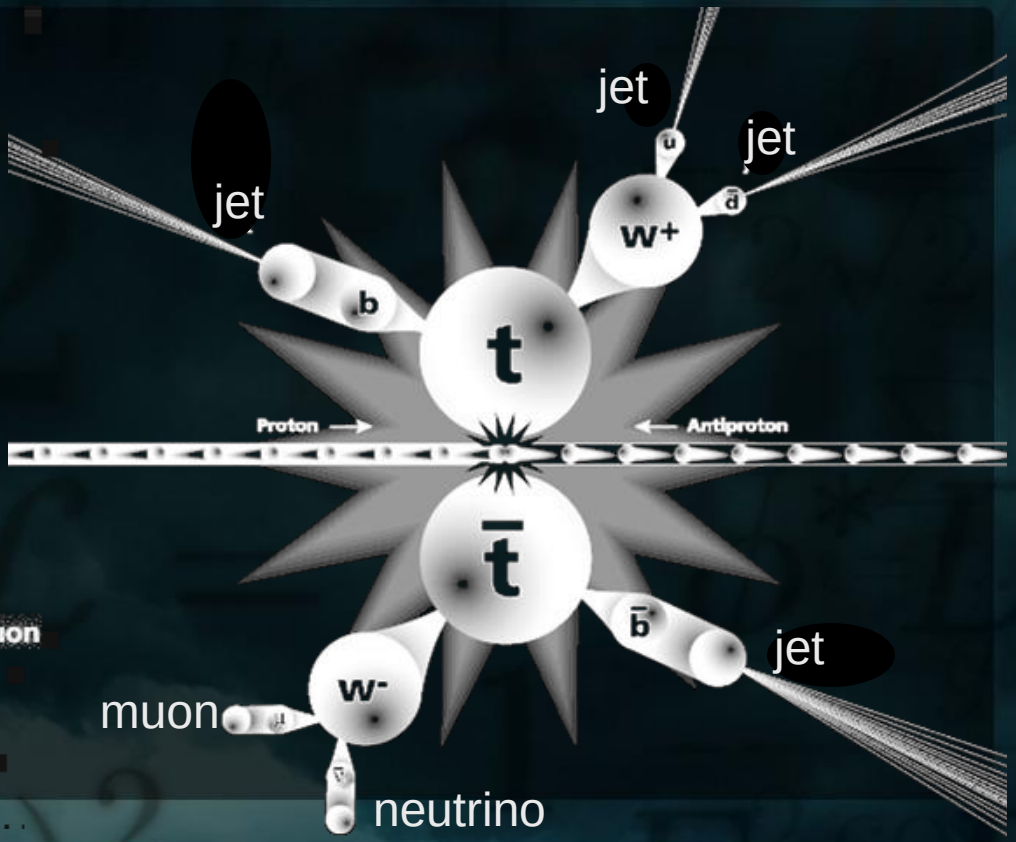
Proton-antiprotons at 2 TeV: make t quark





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ANGELS & DEMONS & ANTIMATTER

- Rome is threatened by ¼ gram of antimatter
- Annihilation of ¼ g matter + ¼ g antimatter = 10 kilotons of TNT
- More than enough to destroy the Vatican

¼ gram

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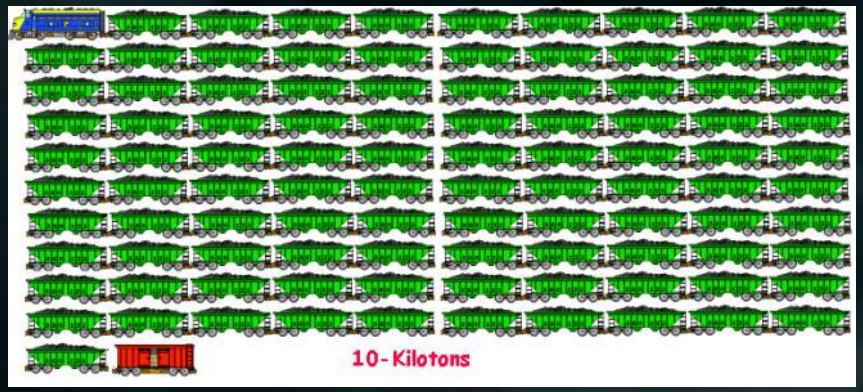
- Hiroshima atomic bomb was equivalent to 15kton of TNT
- To actually haul 10 kton of TNT would require a cargo train with 100 cars.



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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!

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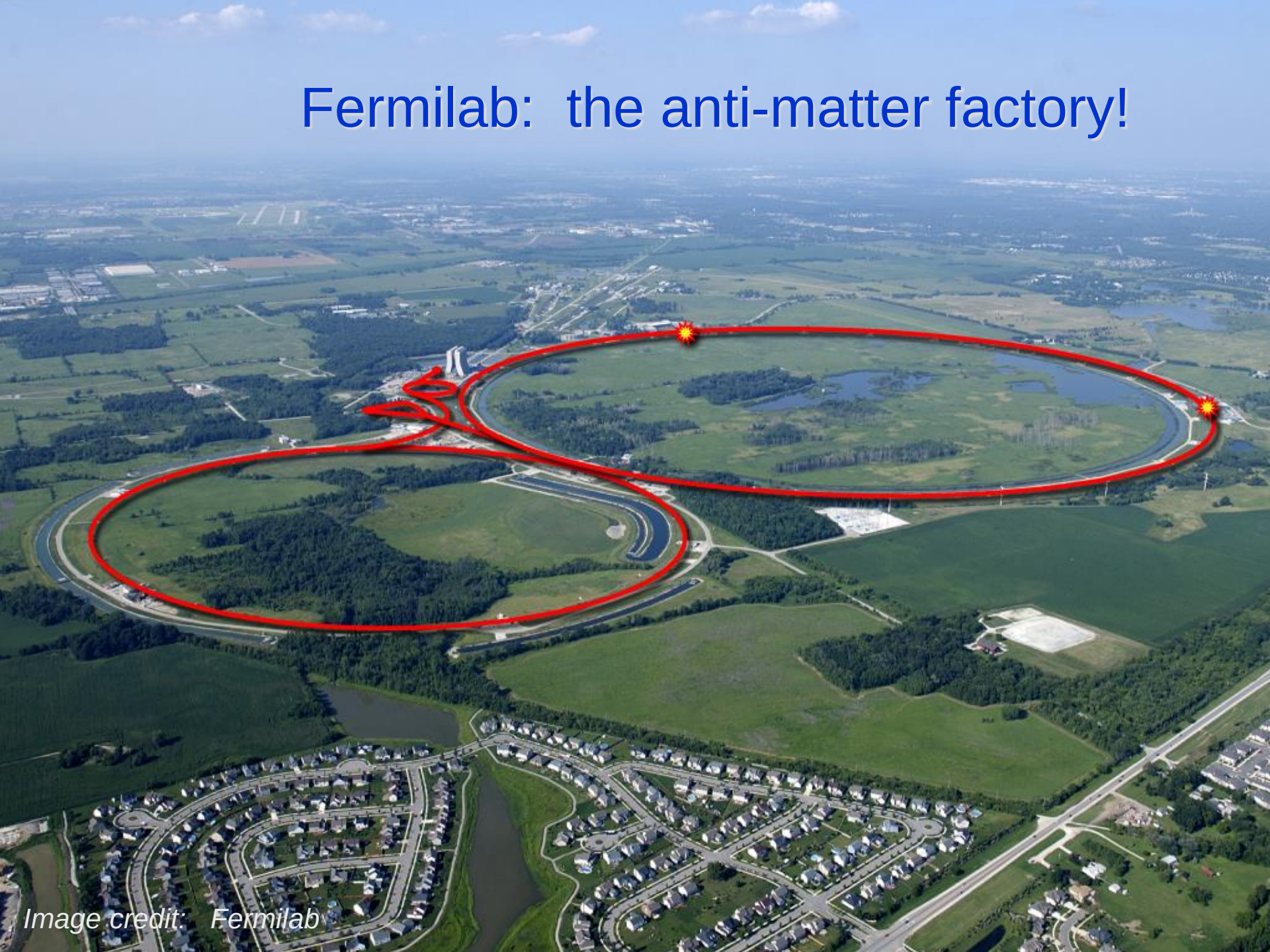
Fermilab: the anti-matter factory!



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ACTUAL TRAPPING OF PARTICLES

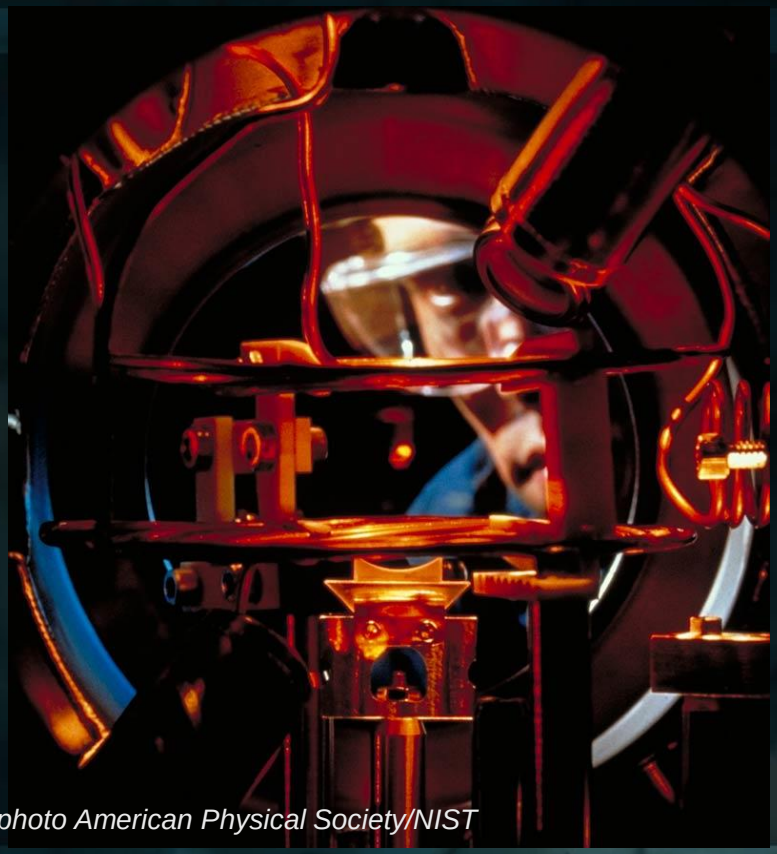

photo American Physical Society/NIST

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

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ANTIMATTER'S NO THREAT

- It's not portable

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ACTUAL TRAPPING OF PARTICLES

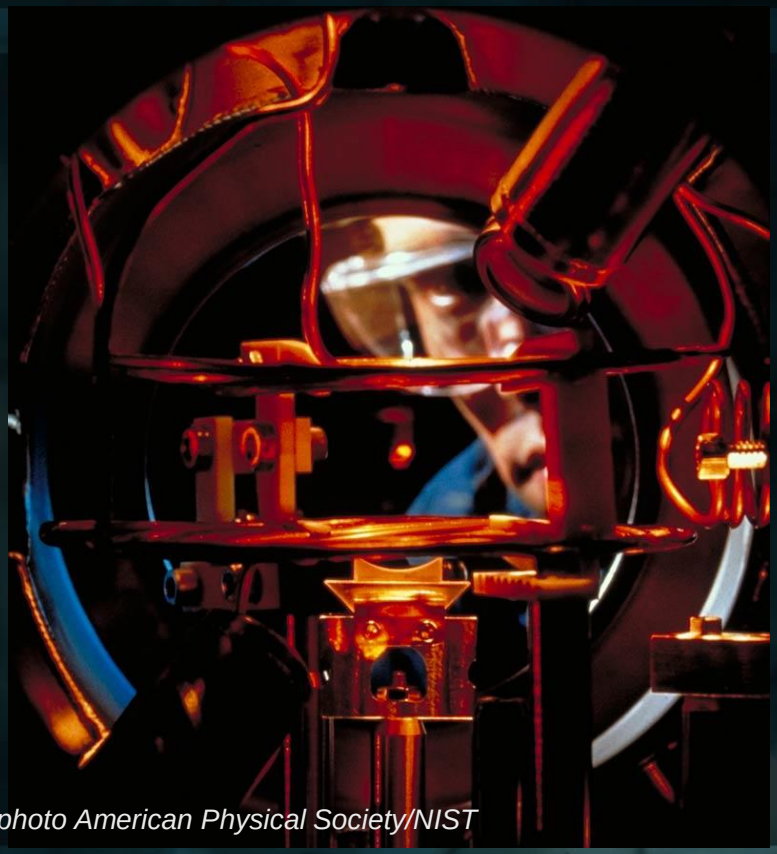

photo American Physical Society/NIST

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

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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**

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BOOK SUGGESTS CERN HAS X33 SPACECRAFT

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MORE TYPICAL CERN VEHICLE

Image credit: Prof. Trisha Vahle

More typical of a “Mr. Bean” television episode than of space vehicle.

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THE MYSTERY OF ANTIMATTER

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

NASA/STScI/G.Bacon

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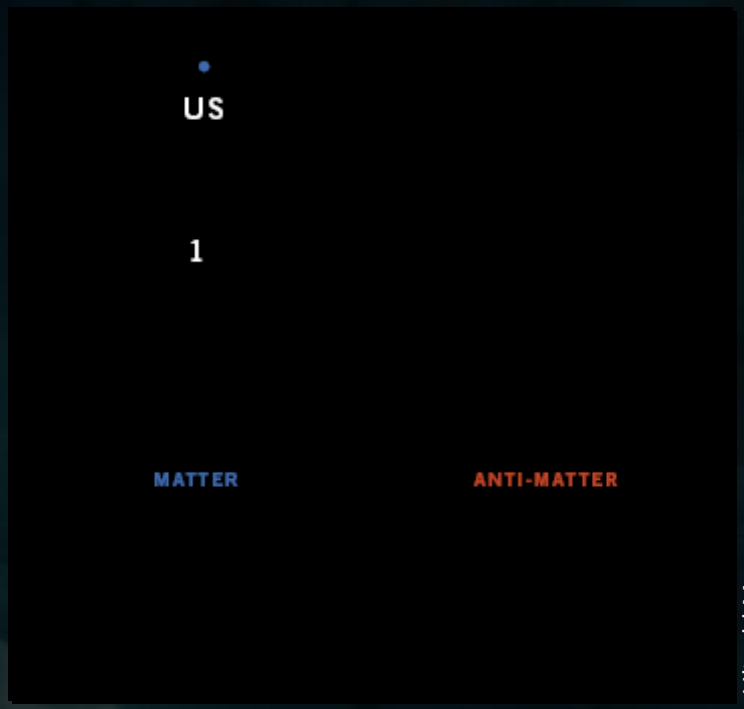
THE BIG BANG

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



Hitoshi Murayama

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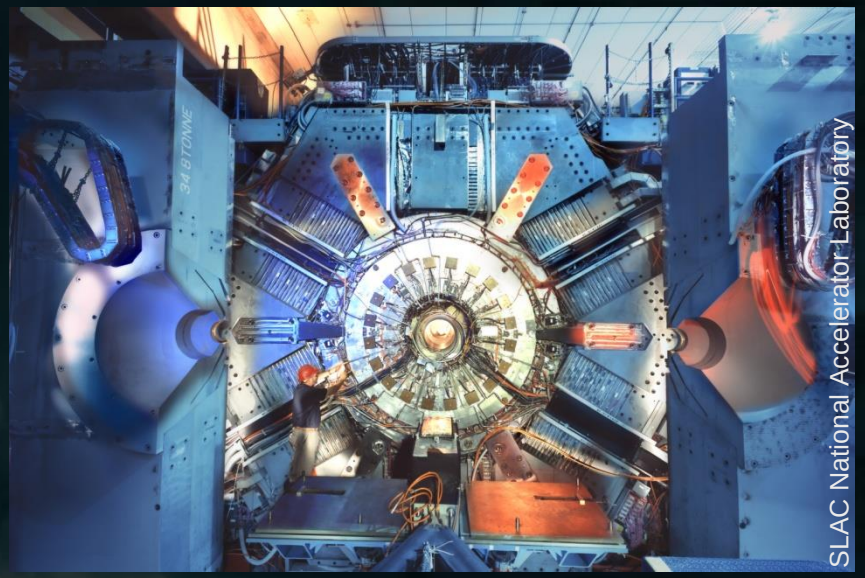
SOLVING THE MYSTERY

With quarks

- Particle accelerators produce matter (quarks) and antimatter (anti-quarks)
- Study the difference between them
- Prof. Jack Ritchie and Roy Schwitters



SLAC National Accelerator Laboratory

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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.

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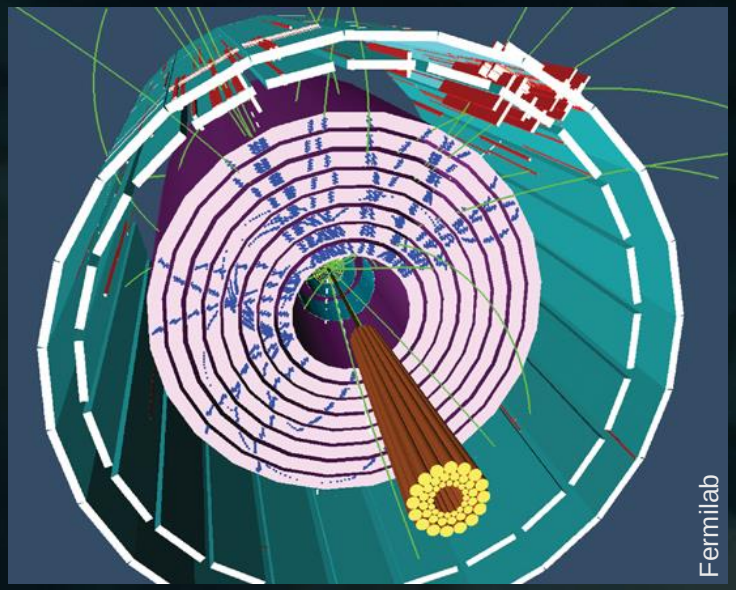
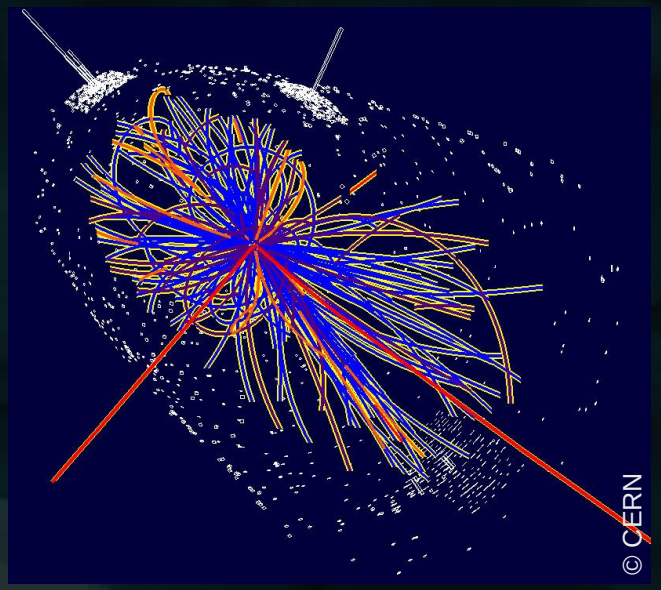
The search is on

Tevatron



Large Hadron Collider



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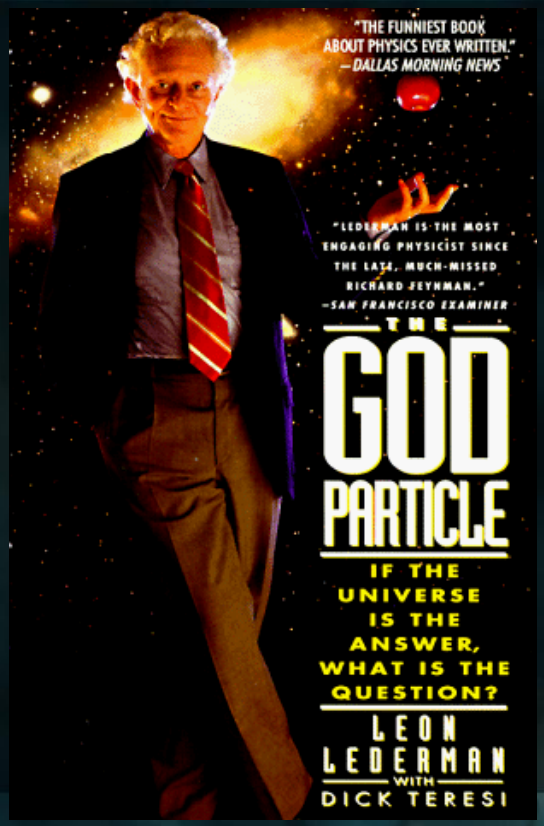
"THE GOD PARTICLE"



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!

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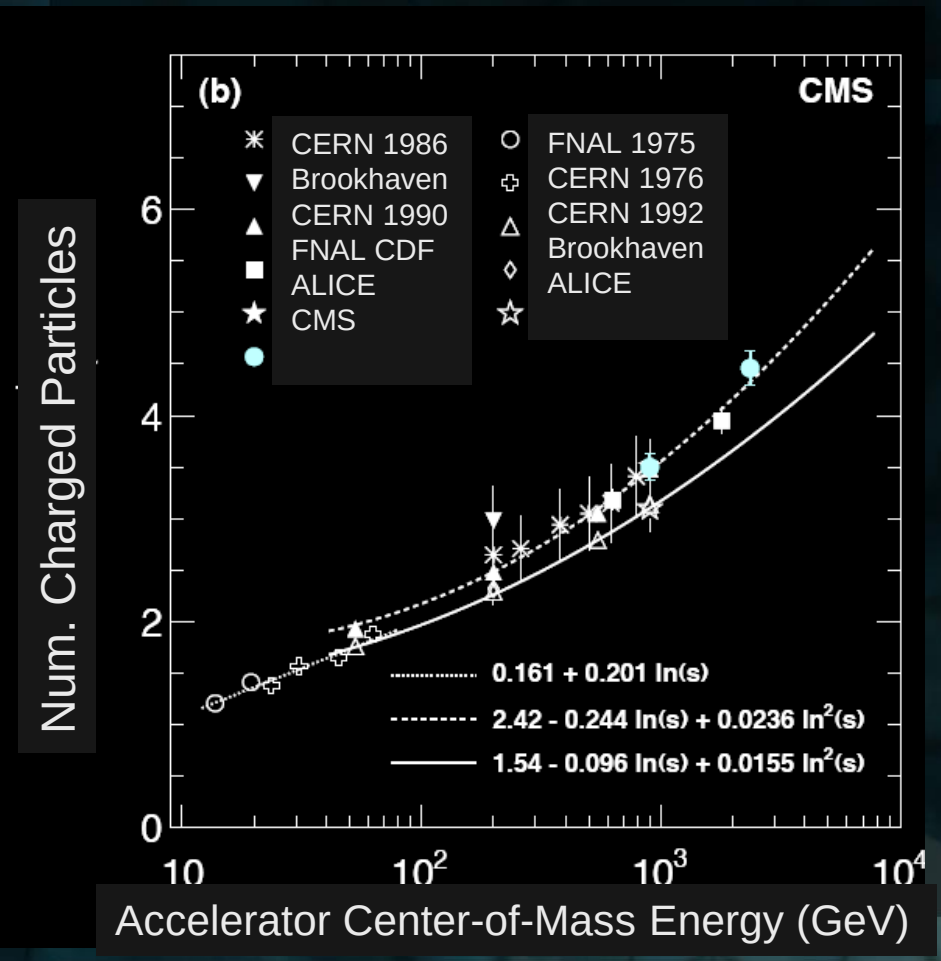

Presentation of Results

Dr. Fabiola Gianotti, 18 Dec. 2009

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So Why do 'Big science'

The thrill of discovery

- International collaboration
- Seeing your own ideas brought to life
- "Game changers" of science that re-write the textbooks

Today's science is tomorrow's technology

- PET imaging
- Proton accelerator cancer therapy
- High-speed computers
- World Wide Web
- Detectors for national security

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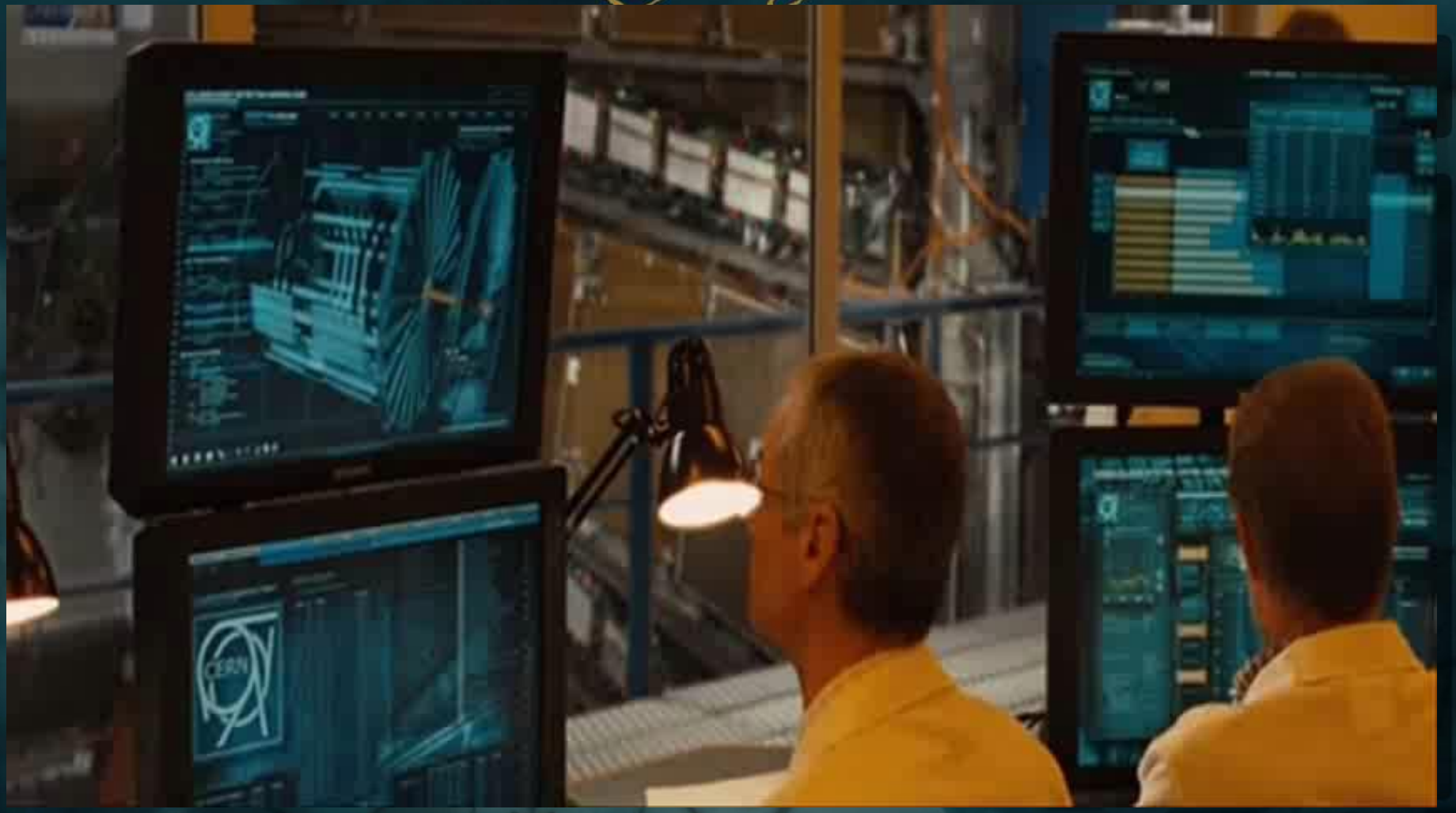

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THANK YOU

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Dr. Sacha Kopp

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?

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