



The University of Texas at Austin
Environmental Science Institute

Hot Science - Cool Talk # 64

***Angels & Demons: Physics,
Antimatter, and Armageddon***

**Dr. Sacha Kopp
February 19, 2010**

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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

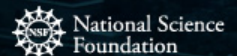
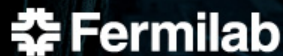
Angels & Demons

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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THE SCIENCE REVEALED



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THE SCIENCE REVEALED

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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THE SCIENCE REVEALED

Hollywood's CERN



photo credit: Sony Motion Pictures

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THE SCIENCE REVEALED

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)

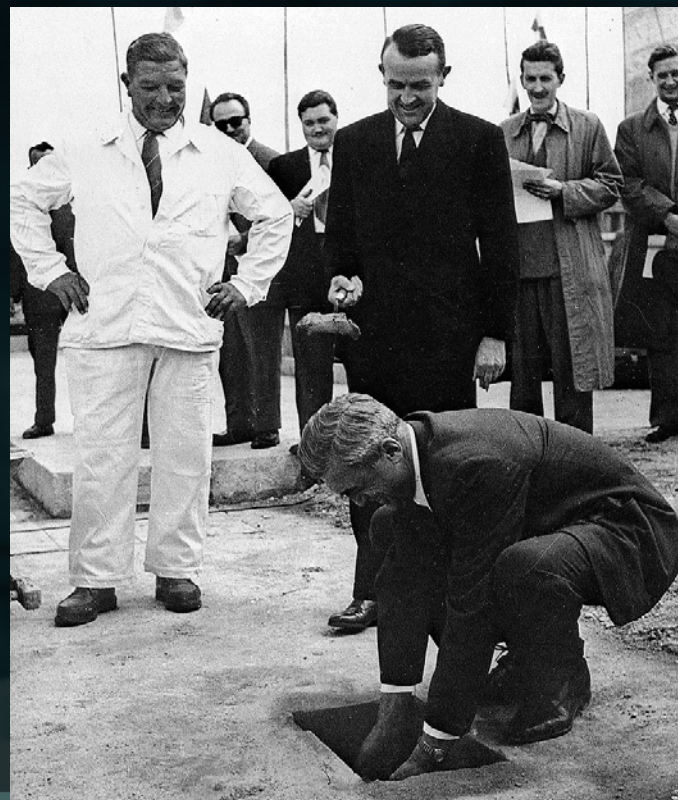


photo credit: CERN

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THE SCIENCE REVEALED

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

© CERN

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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

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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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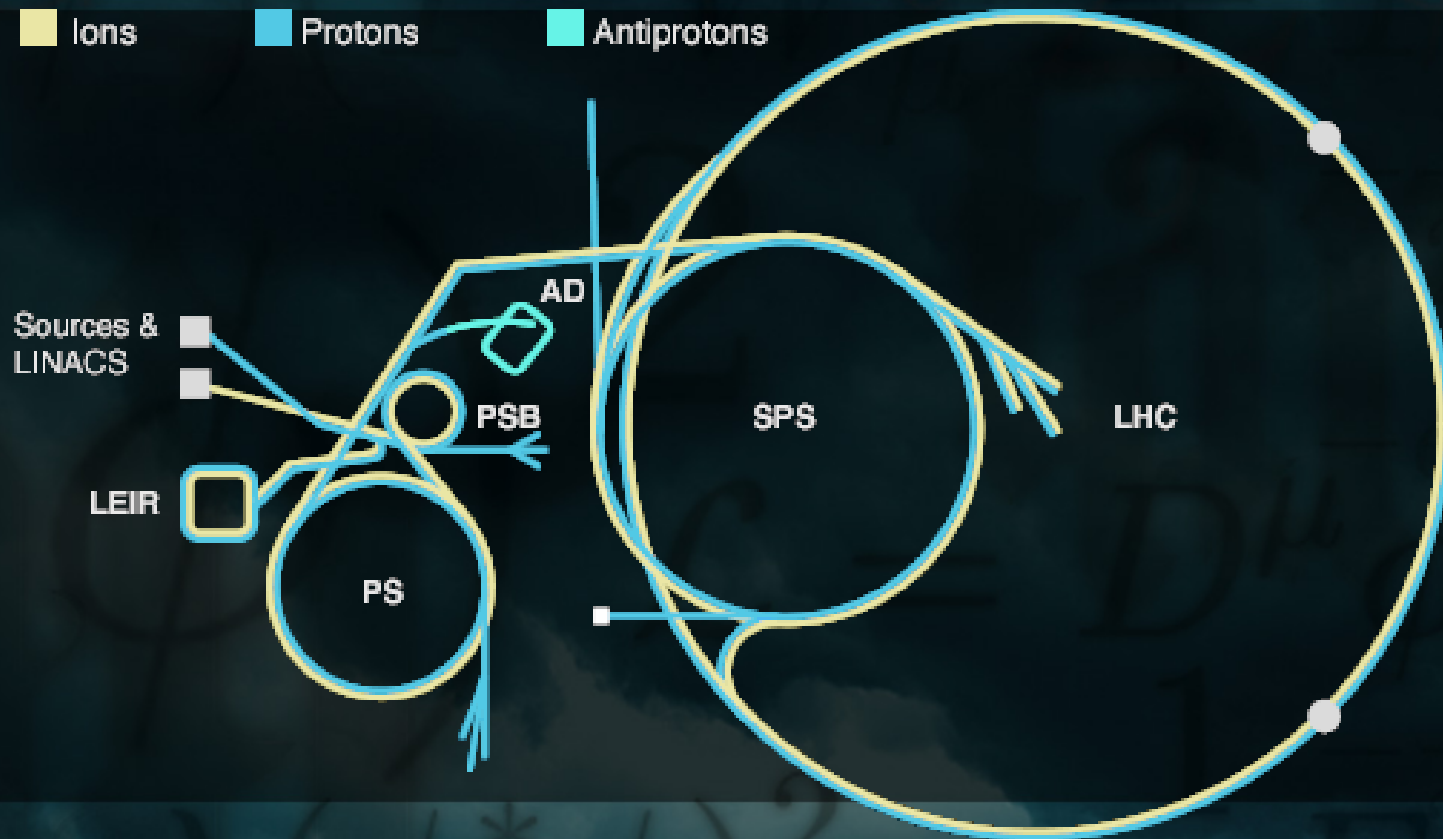
THE SCIENCE REVEALED

The real LHC

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



The CERN accelerator complex



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THE SCIENCE REVEALED

The Large Hadron Collider...



photo credit: CERN

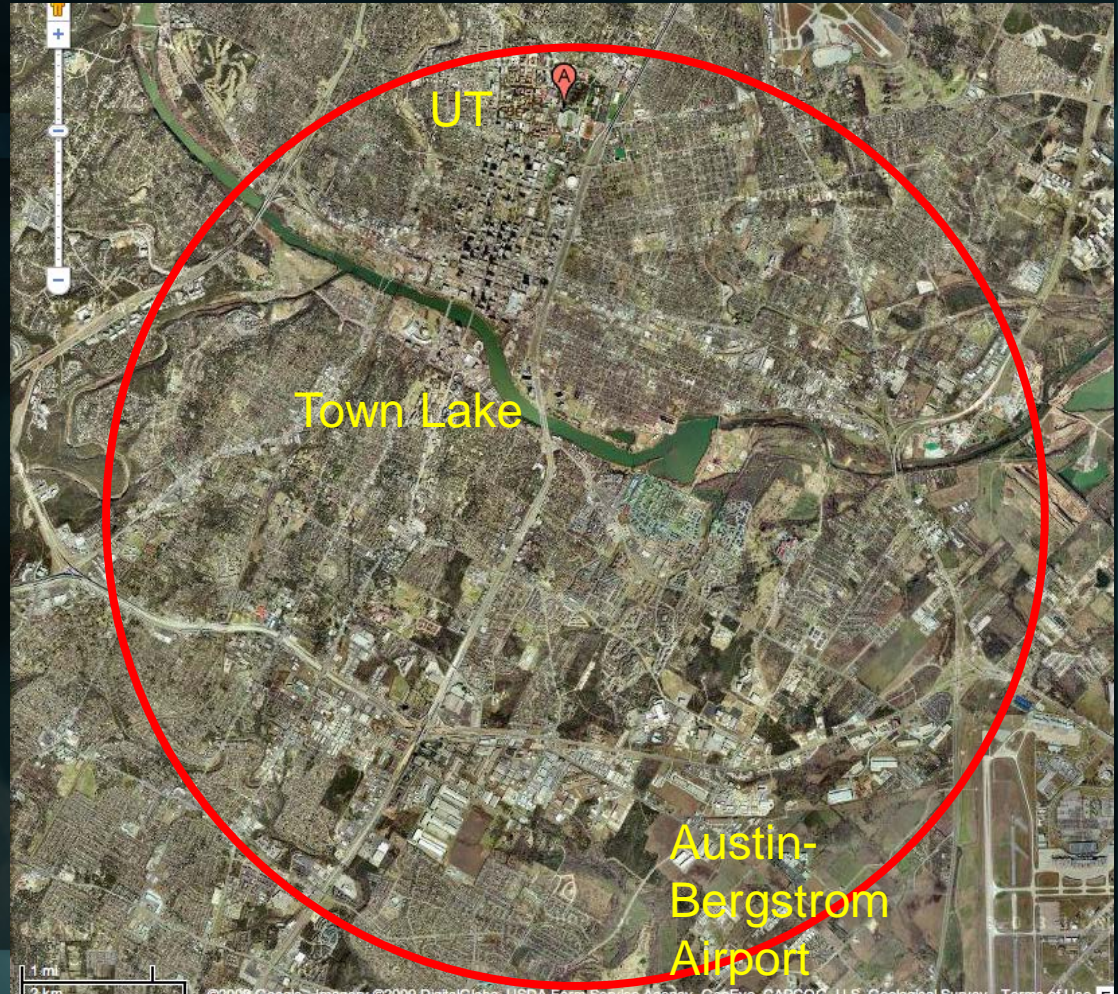
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... is really LARGE!!

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

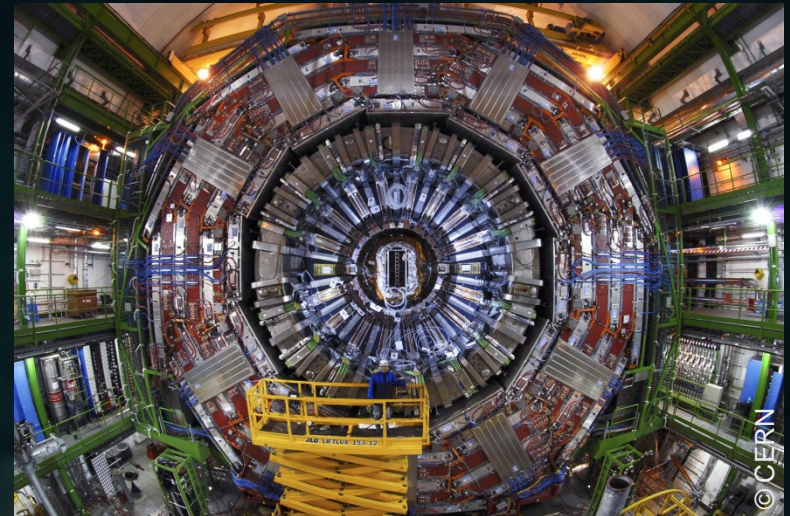
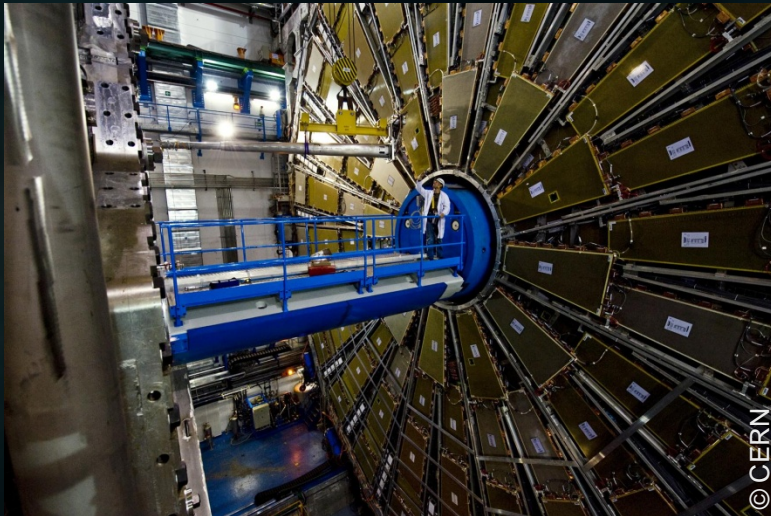


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THE SCIENCE REVEALED

The LHC

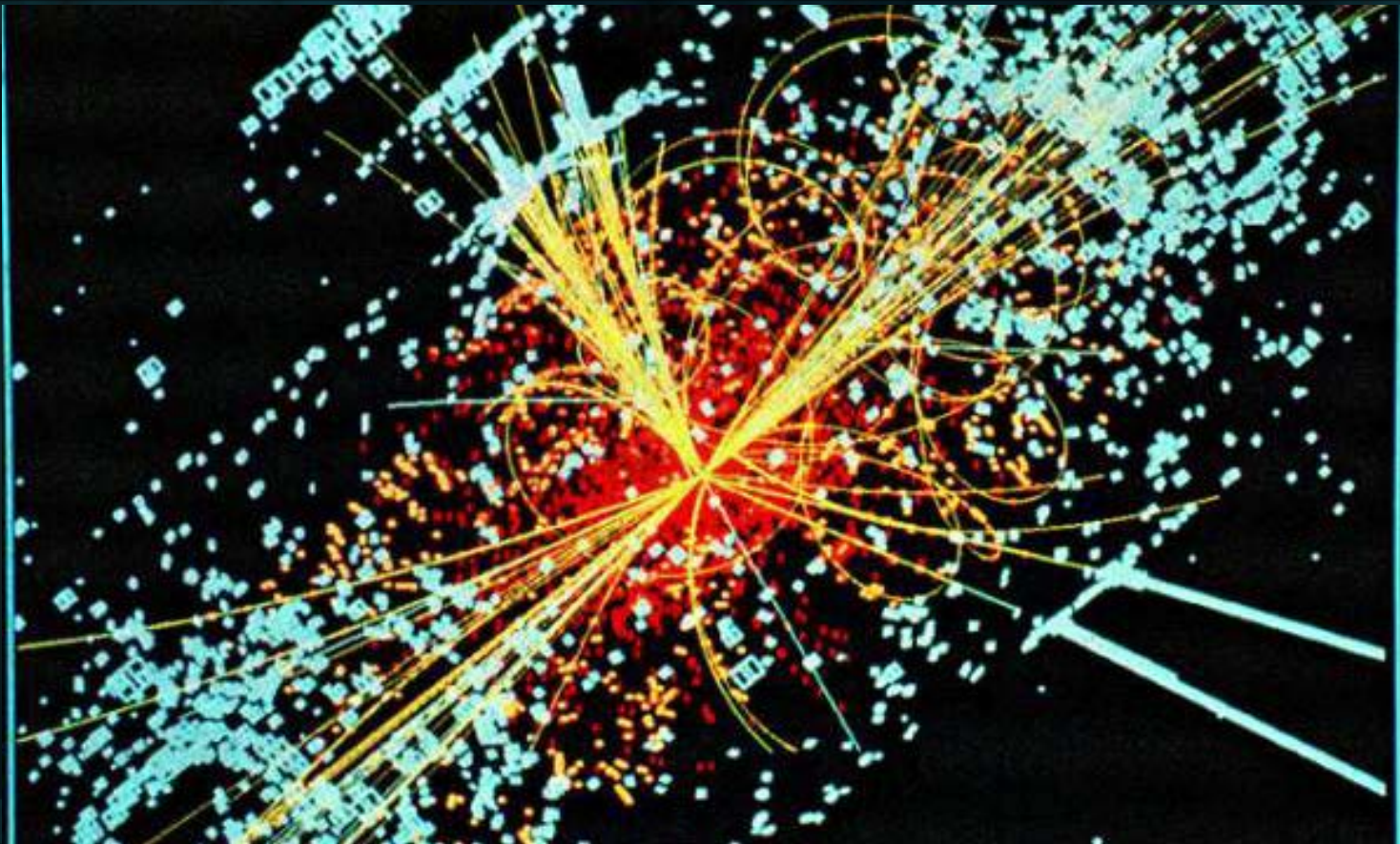
Will smash particles into
each other...

...to re-create the conditions
of the early Universe



Info. from LHC detectors will equal ENTIRE world telecommunications traffic!

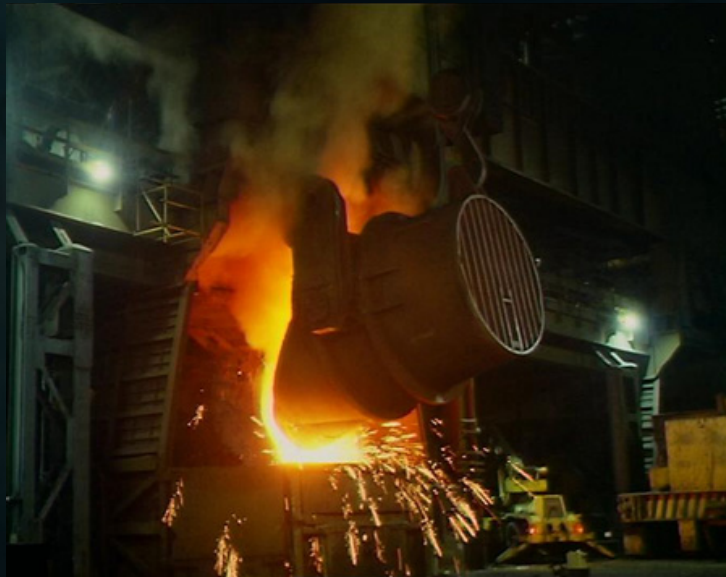
Computer simulation of proton-proton collision



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Just how much energy ...

Blast Furnace ~ $\frac{1}{4}$ eV



Tesla coils – 250,000 eV



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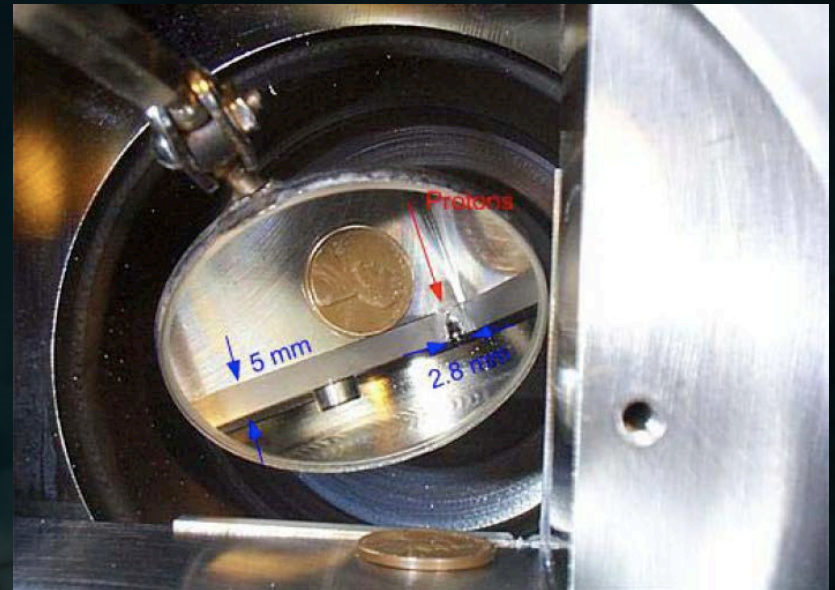
THE SCIENCE REVEALED

...is 14 TeV anyway??

Van de Graaf – 5,000,000 eV



Fermilab – 1,000,000,000,000eV



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THE SCIENCE REVEALED

Can the LHC really destroy the world ...

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

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

Atom-smasher fears spark lawsuit...

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MSNBC

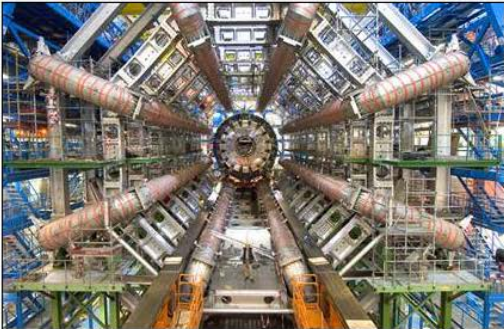
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Doomsday fears spark lawsuit over collider

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



By Alan Boyle
Science editor

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

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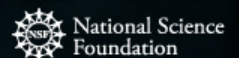
Asking a Judge to Save the World, and Maybe a Whole Lot More



Loading "http://www.nytimes.com/2008/03/29/science/29collider.html", completed 26 of 27 items

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National.Citysearch.com

Business Opportunity
No Competition. The Only



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THE SCIENCE REVEALED

... As seen on the “Daily Show”


Video: Large Hadron Collider | The Daily Show | Comedy Central

http://www.thedailyshow.com/watch/thu-april-30-2009/large-hadron-collider

Video: Large Hadron Collider | Th...

April 30, 2009: Large Hadron Collider

Video paused...



00:06:05:58 SHARE

Large Hadron Collider
John Oliver visits the doomsday machine threatening to destroy our planet.

Tags: John Oliver, science, on location, lawsuits, space, doomsday, Hawaii, Switzerland, media, safety

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Posted: 04/30/09
Comments: 8
Thumbs Up: 15

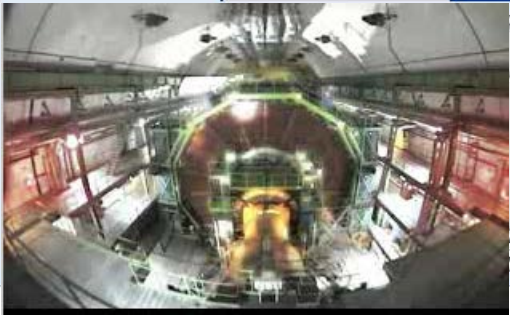
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Antimatter

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

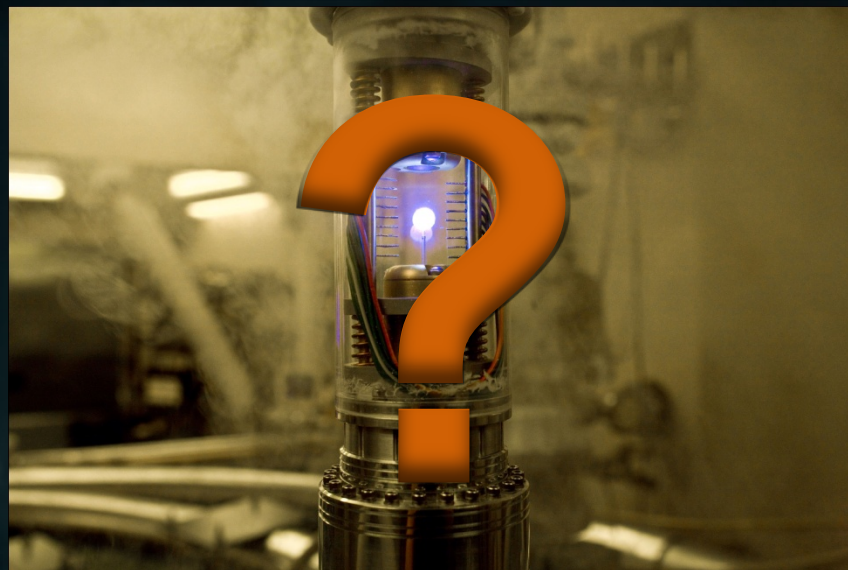


photo credit: Sony Motion Pictures



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THE SCIENCE REVEALED

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



proton



electron



neutron

Multiply by billions and billions and billions and billions...

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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THE SCIENCE REVEALED

Matter vs. Antimatter

Anti-Tom Hanks



Would look
very much
like

Tom Hanks



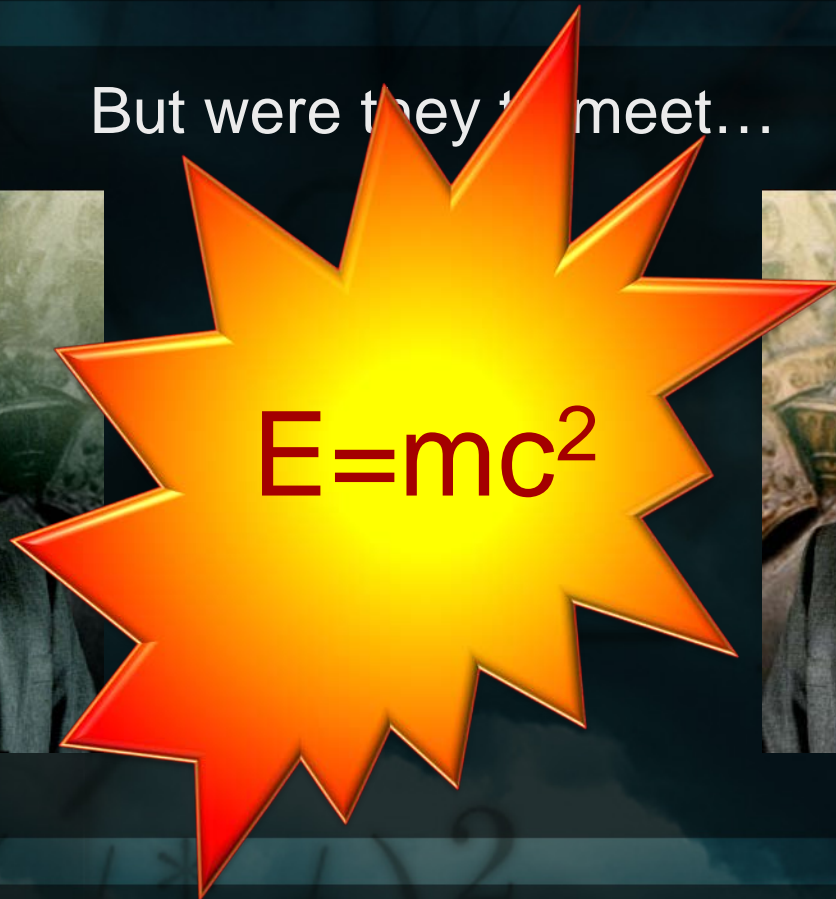
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Matter vs. Antimatter

But were they to meet...



Our first introduction to Antimatter



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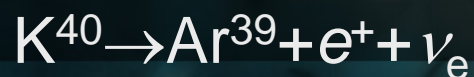
K^{40} is antimatter producer

KCl is salt substitute

K^{40} is 0.012% of all Potassium

Has too many neutrons
compared to stable K^{39} .

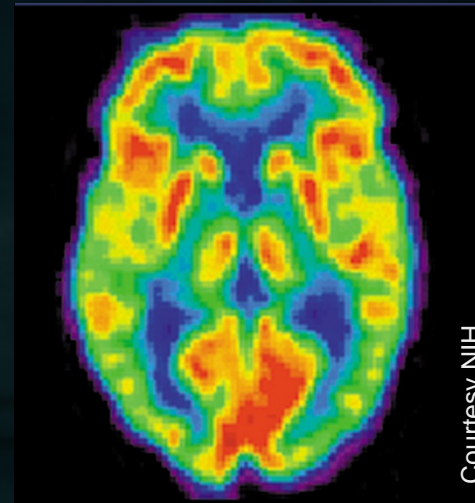
Transmutes one proton by
ejecting a positron from
nucleus:



Copyright © 2008 Theodore W. Gray

Antimatter can be used for

PET Scans



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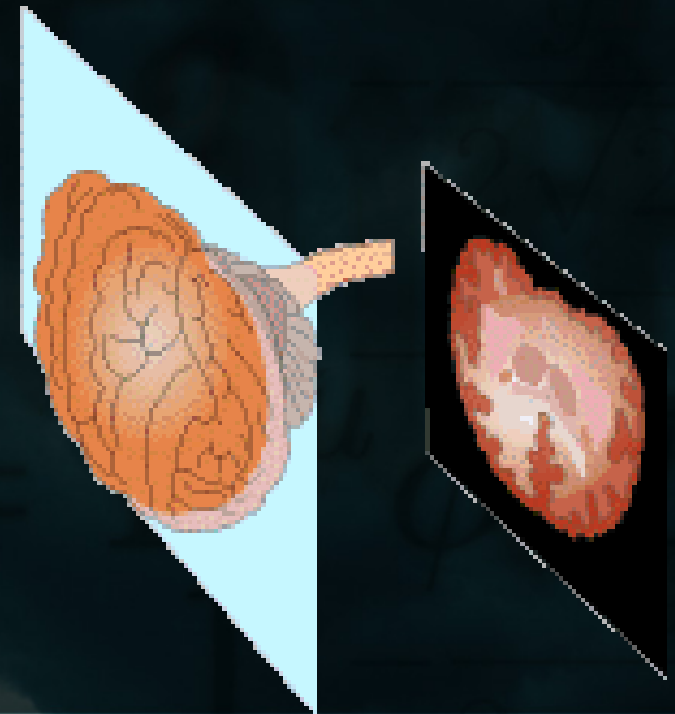
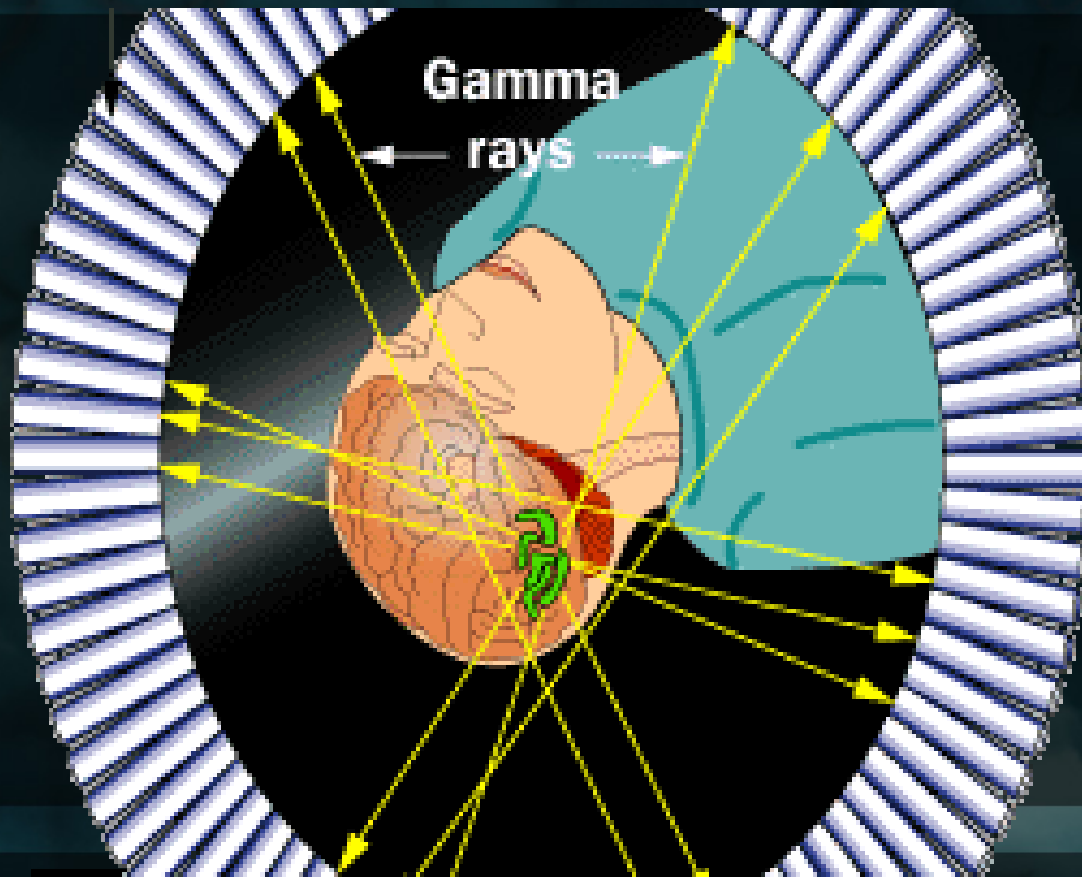
THE SCIENCE REVEALED

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

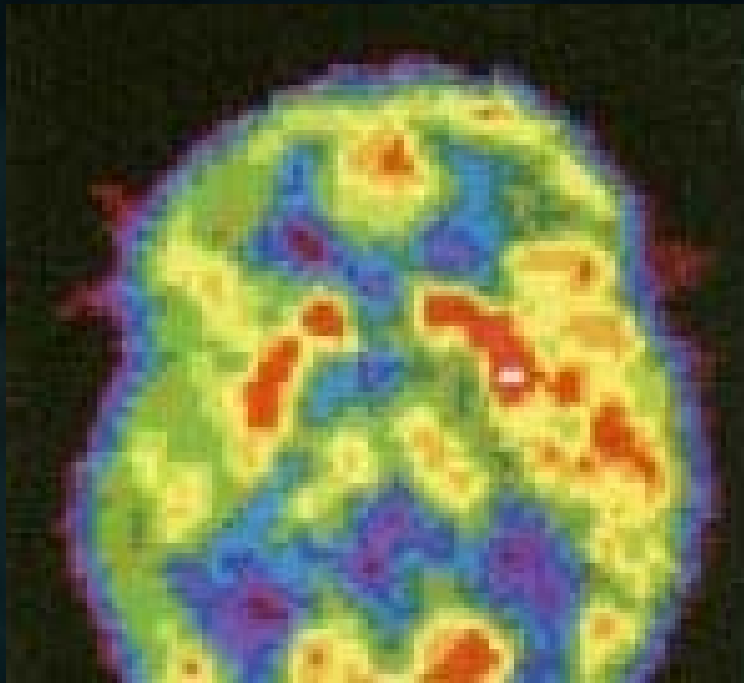


Harvard cyclotron, 1955

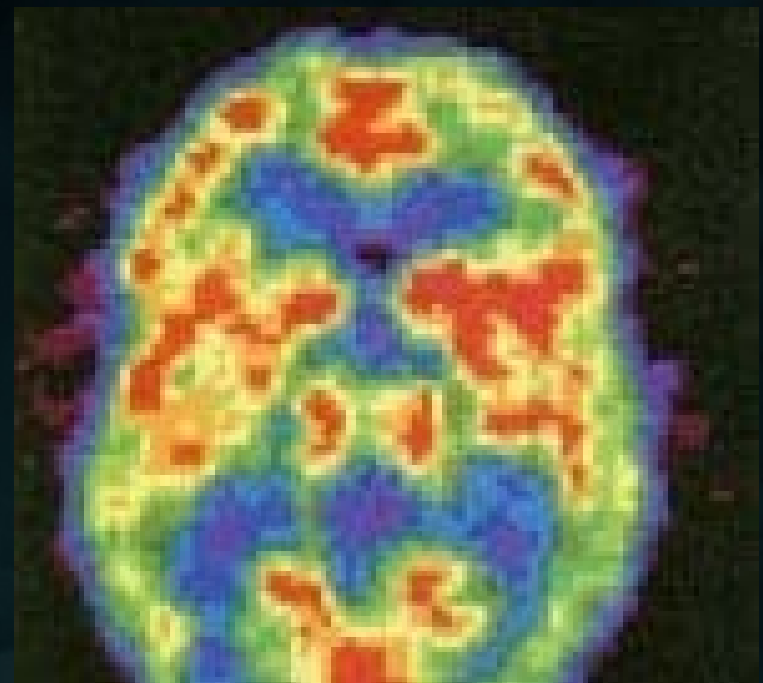
Detecting simultaneous gamma rays



Assessing brain activity



Normal Sleep



REM Sleep



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THE SCIENCE REVEALED

Reduced blood flow to organs of smokers

brain

lungs

heart

liver

kidneys

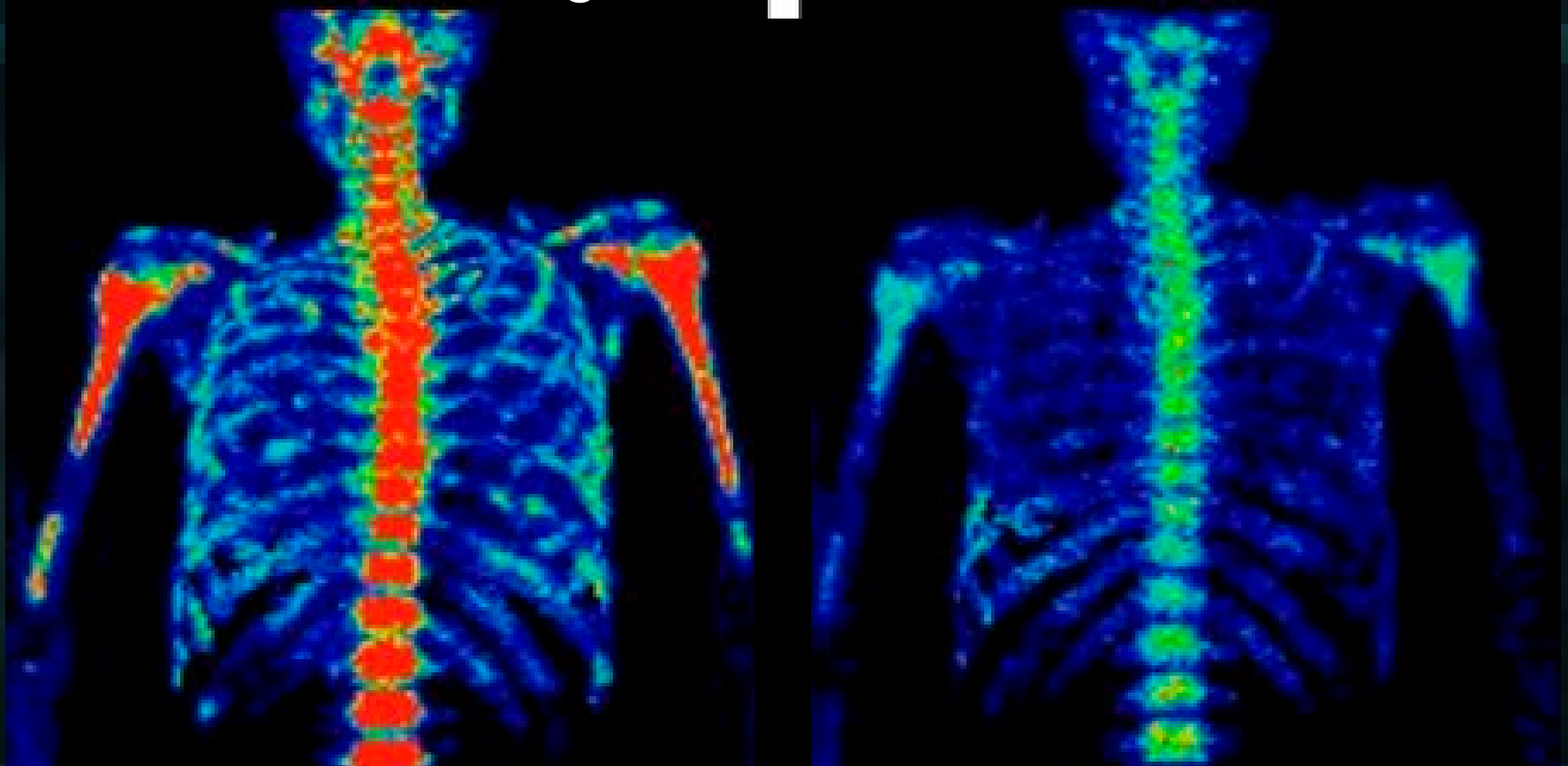
Non Smoker

Smoker

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



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



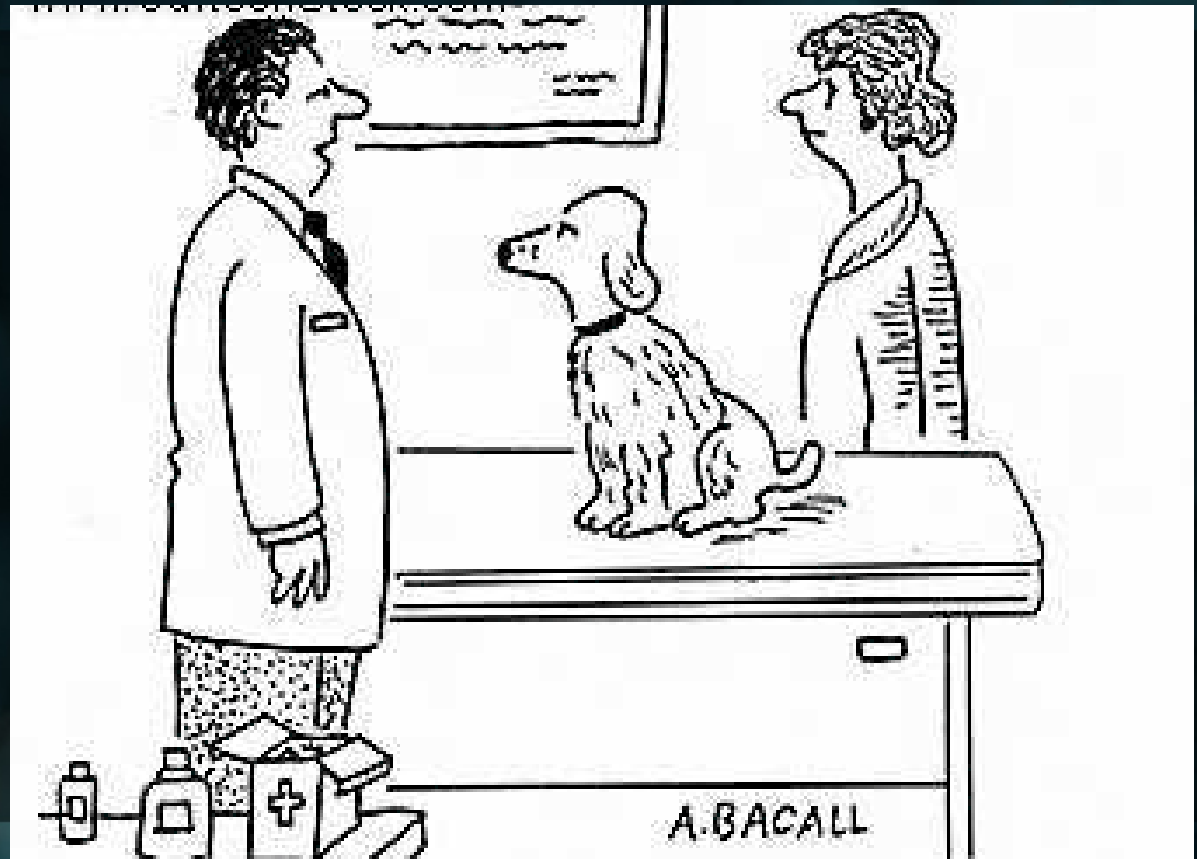
Size: L/XL, 7 1/8" - 7 5/8"



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“CAT SCANS ARE
FOR FELINES.

I’LL GIVE YOUR
DOG A PET SCAN.”



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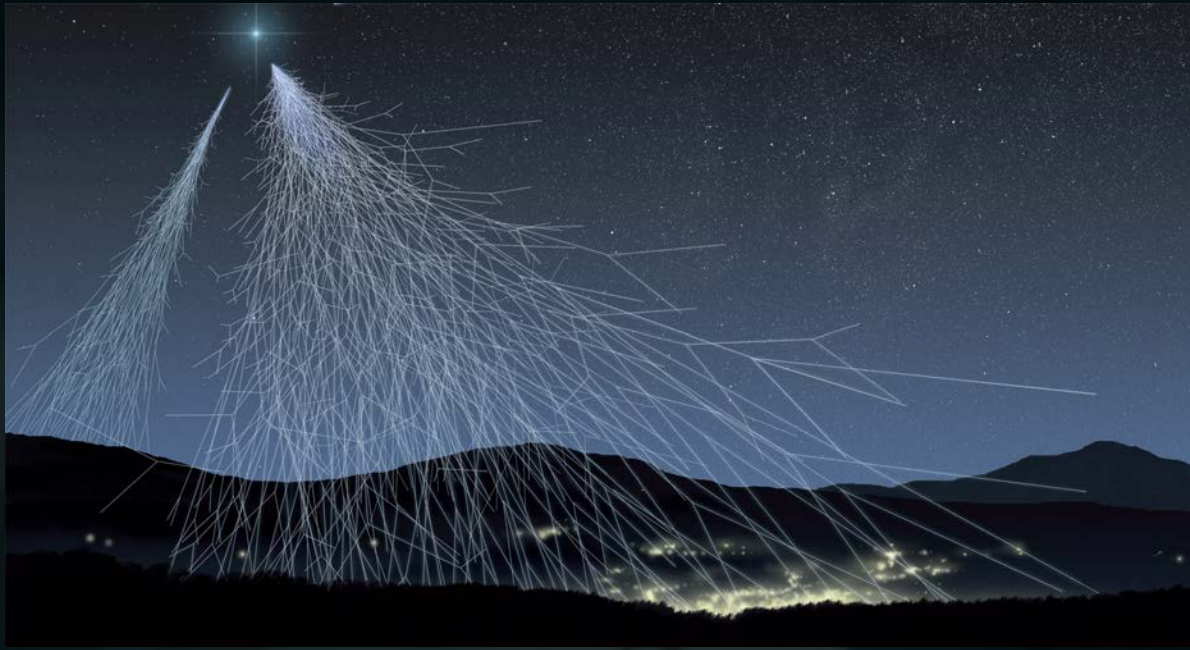
THE SCIENCE REVEALED

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



CAN WE MAKE ANTIMATTER?

Nature does, all the time!



© L. Bret / Novapix / ASPERA



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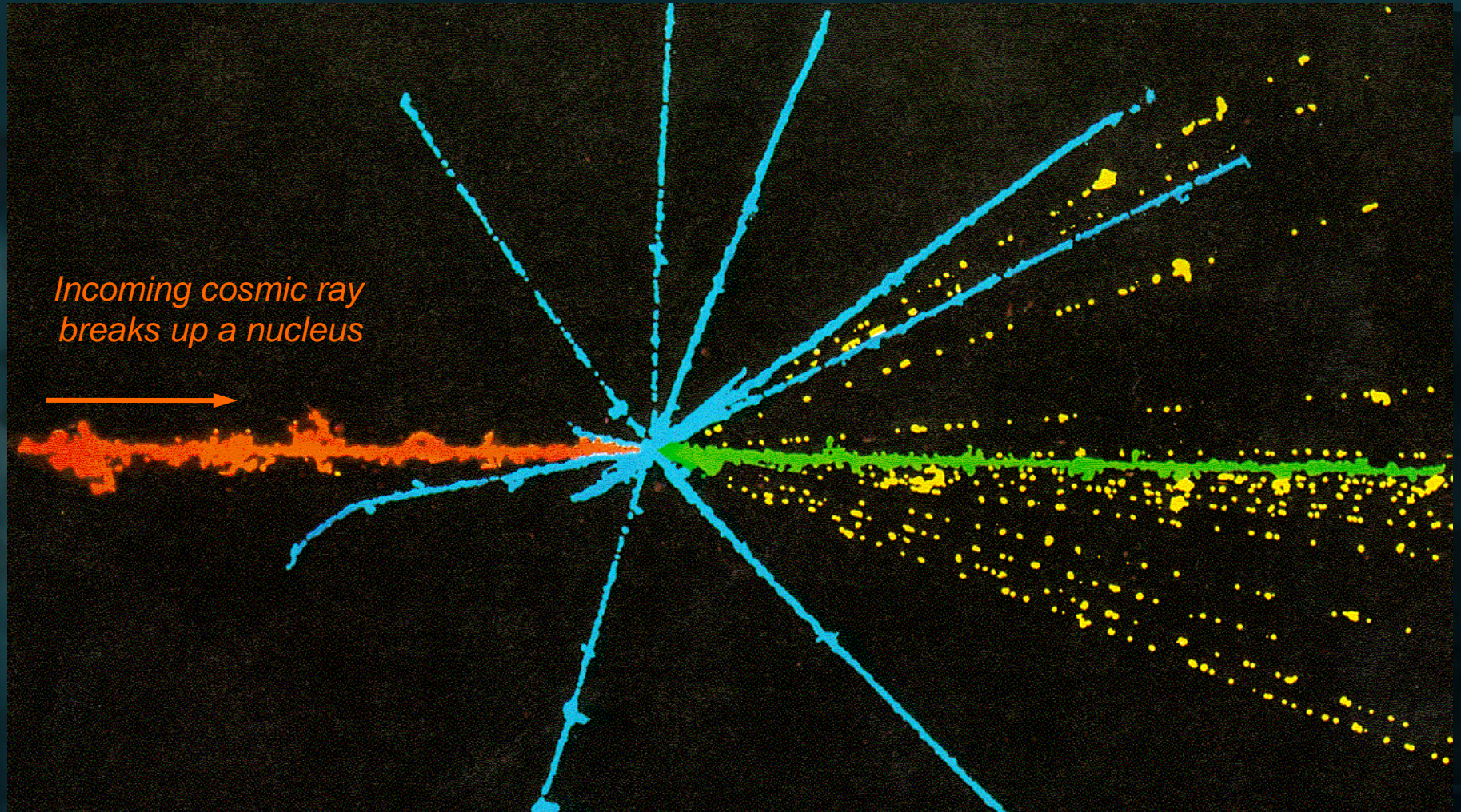


Example of cosmic rays: *Aurora Borealis*

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QUANTUM OF ENERGY SPLITS INTO MATTER-ANTIMATTER



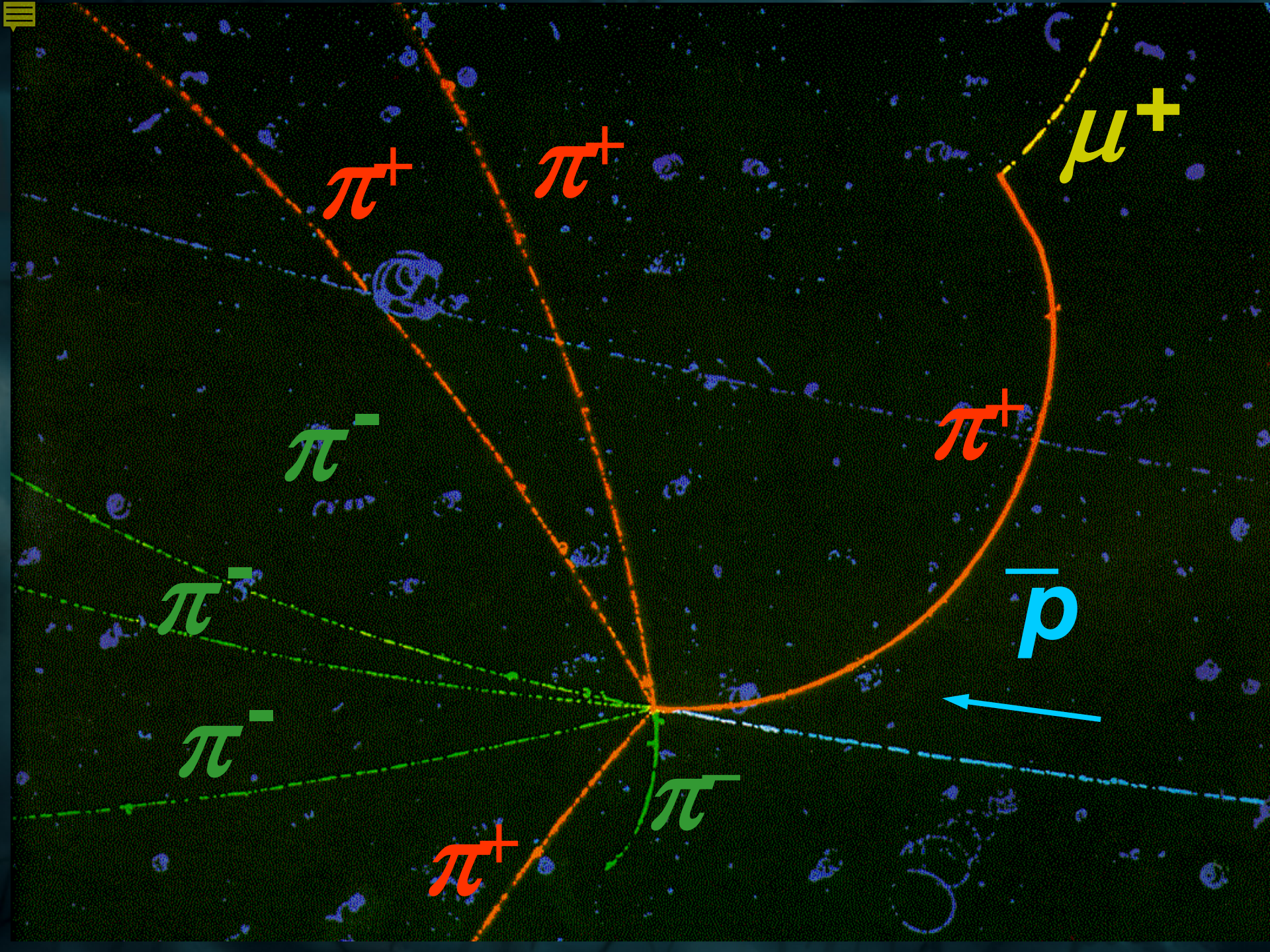
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CAN WE MAKE ANTIMATTER?

We can, and do ...



In particle accelerators



π^+

π^+

μ^+

π^-

π^+

π^-

\bar{p}

π^-

π^+

π^-

Proton-antiprotons at 2 TeV: make t quark

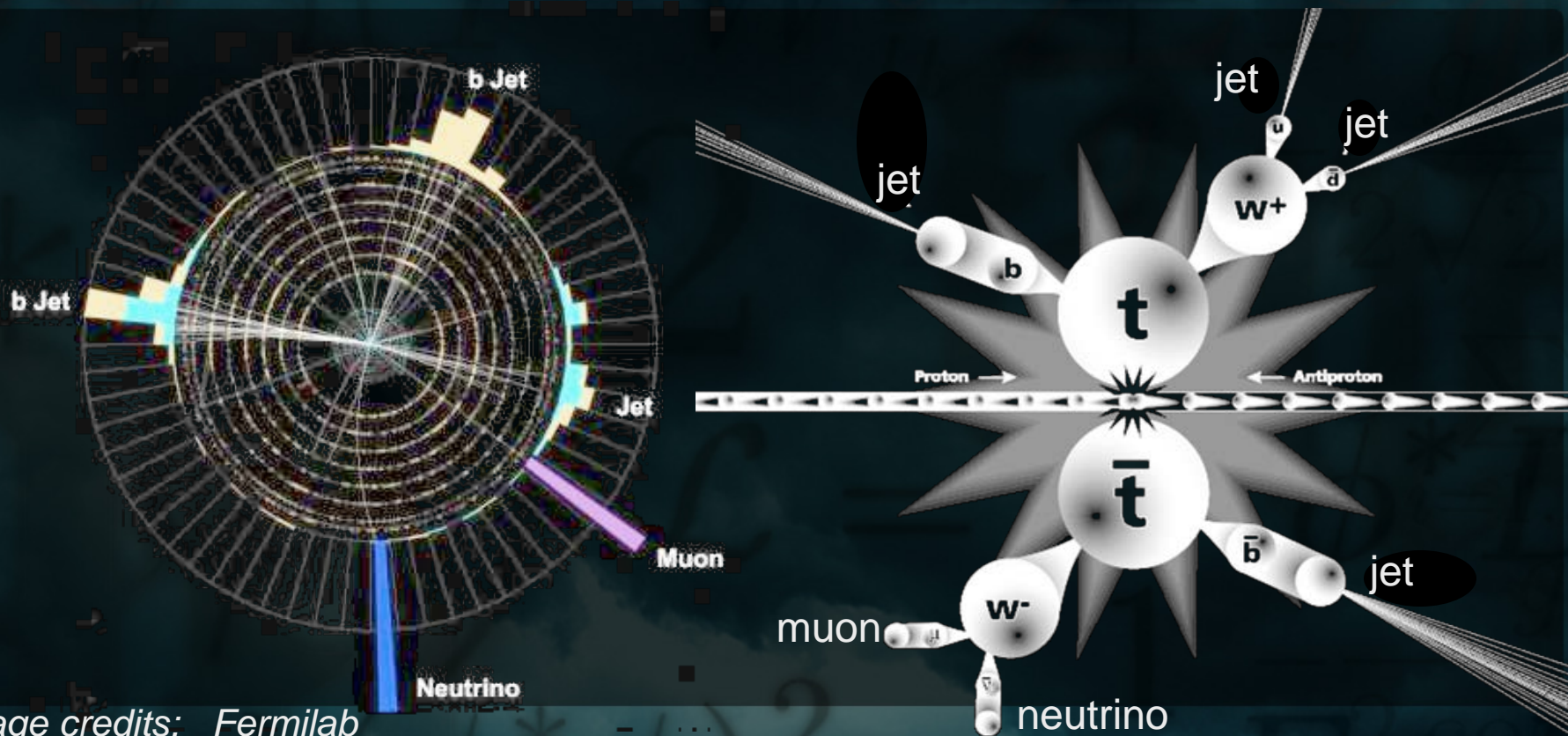


Image credits: Fermilab

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 kilotons of TNT
- More than enough to destroy the Vatican



$\frac{1}{4}$ gram

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THE SCIENCE REVEALED

- 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 $\frac{1}{4}$ gram (longer @ CERN)
- Energy required to make $\frac{1}{4}$ gram would equal entire world's energy consumption for 30 years!

Fermilab: the anti-matter factory!



Image credit: Fermilab

ACTUAL TRAPPING OF PARTICLES

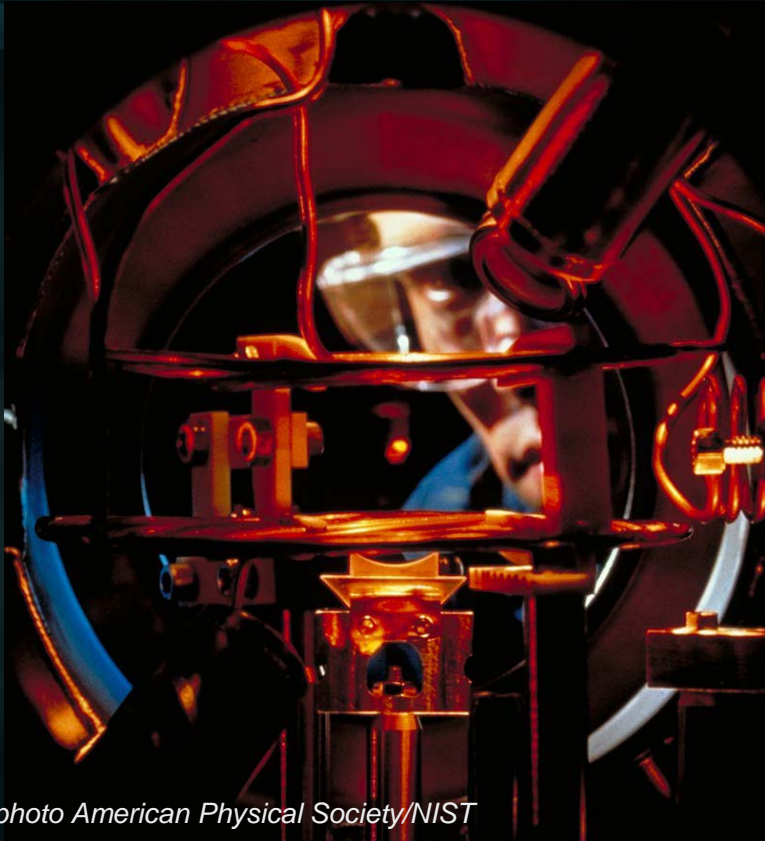


photo American Physical Society/NIST

- 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



ACTUAL TRAPPING OF PARTICLES

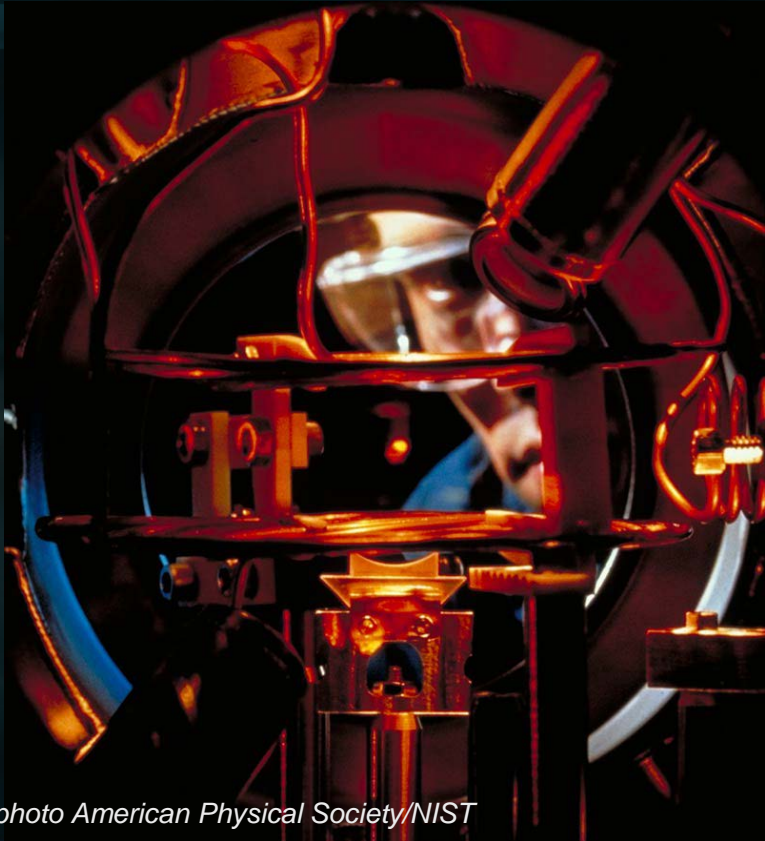


photo American Physical Society/NIST

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

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.

THE MYSTERY OF ANTIMATTER

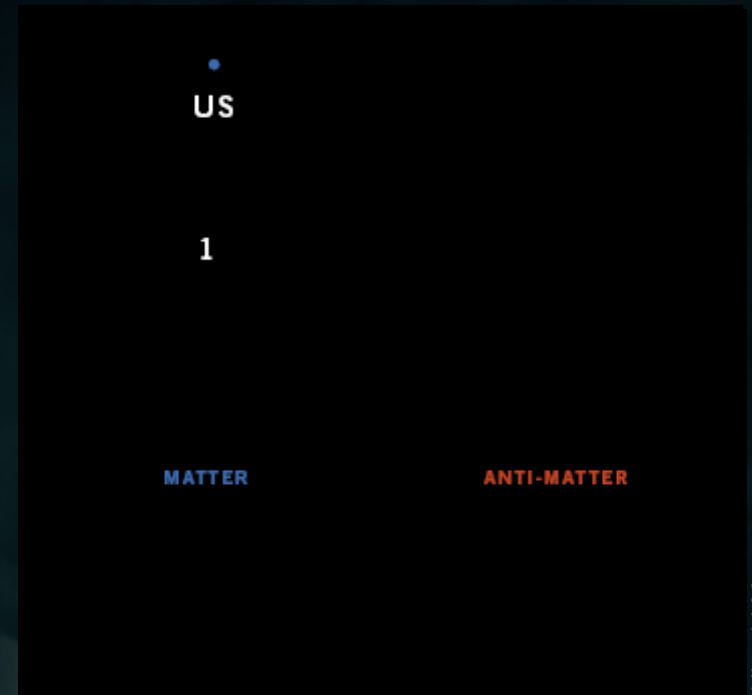
- We exist because there is almost no antimatter around
- It wasn't always that way



NASA/STScI/G. Bacon

THE BIG BANG

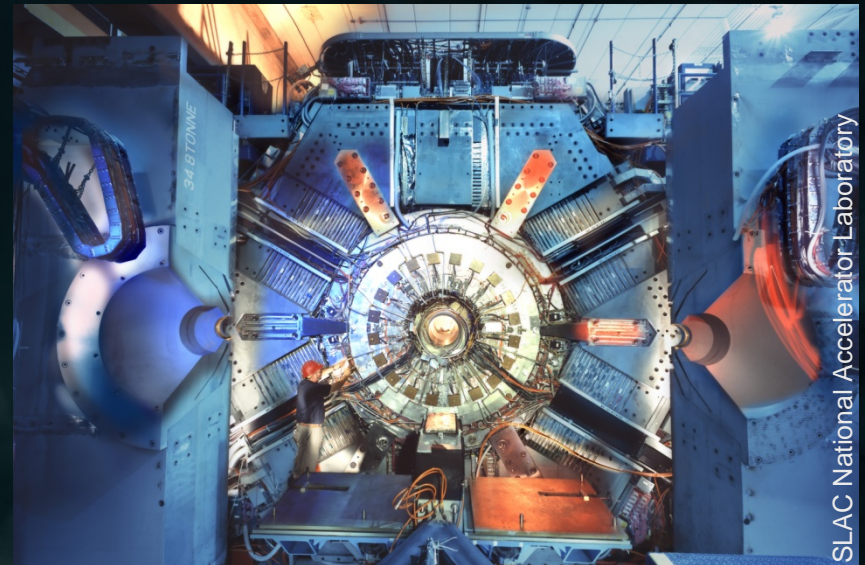
- 14 billion years ago, the Big Bang produced equal amounts of matter and antimatter
- Everything should have annihilated
- Instead...



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



SOLVING THE MYSTERY

With neutrinos

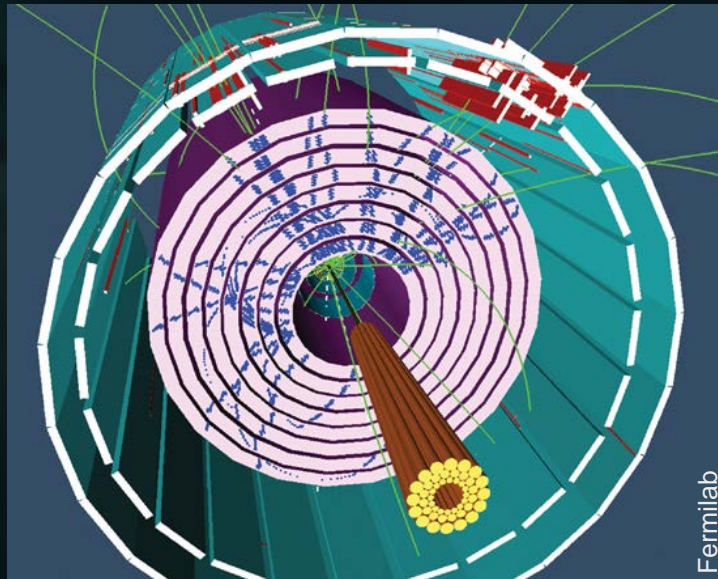
- Neutrinos come in three types
- They can spontaneously switch
- Could provide answers to diff in matter, antimatter
- Prof. Karol Lang and S.K.



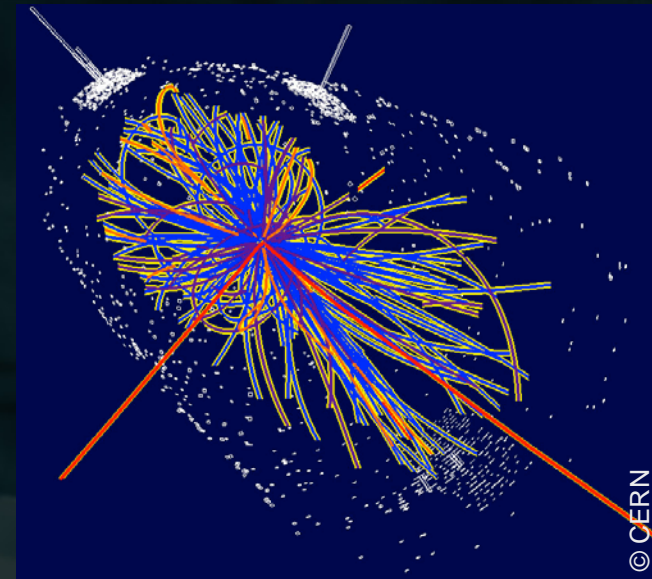
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The search is on

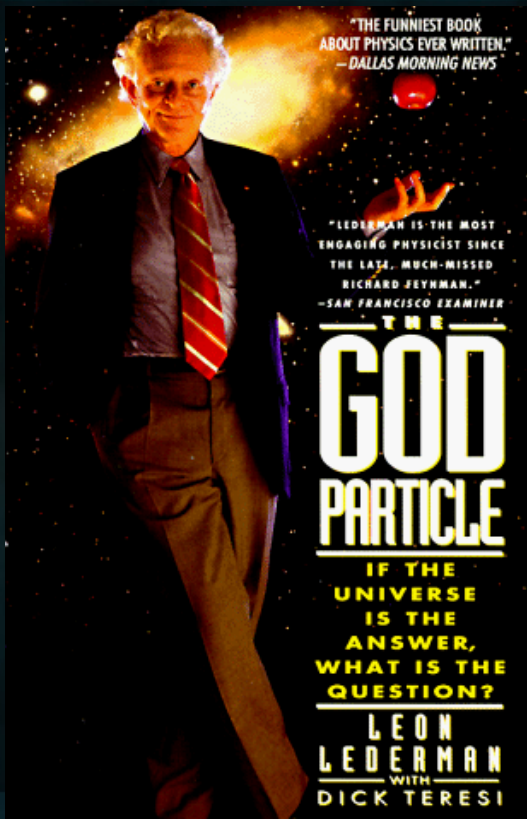
Tevatron



Large Hadron Collider



“THE GOD PARTICLE”



Phrase coined by Leon Lederman

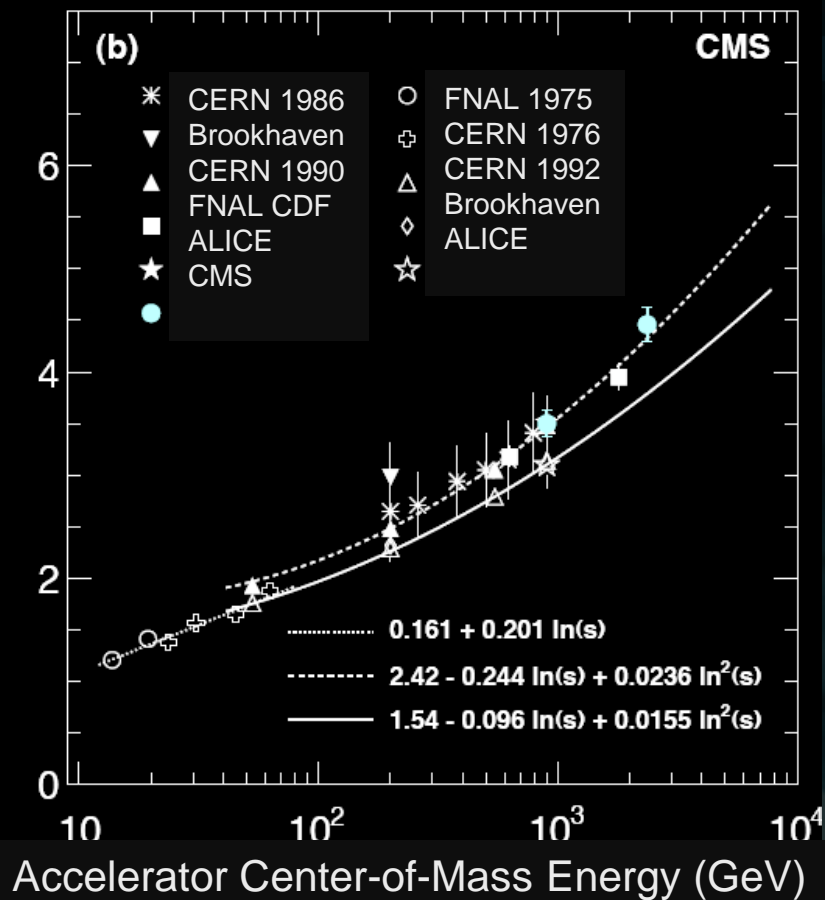
- Nobel prize winner in 1988
- Former director of Fermilab
- Actually called it the “goddamned particle” because it’s difficult to find
- Higgs boson gives other particles their mass (predicted 1964!)
- Central goal of the LHC!

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THE SCIENCE REVEALED

Num. Charged Particles



Presentation of Results



Dr. Fabiola Gianotti, 18 Dec. 2009

So Why do 'Big science'

The thrill of discovery

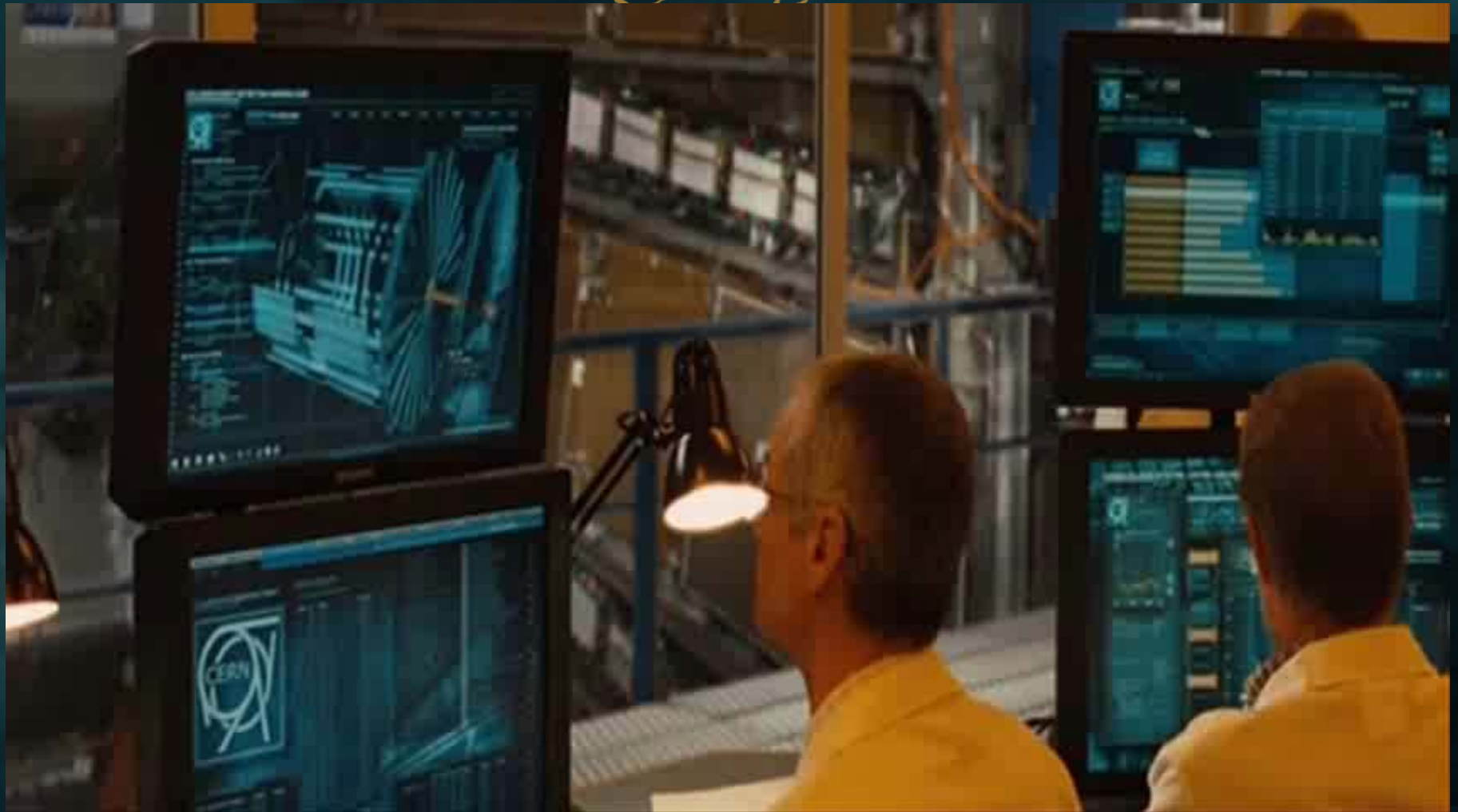
- International collaboration
- Seeing your own ideas brought to life
- “Game changers” of science that re-write the textbooks

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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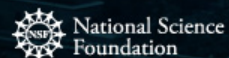
THANK YOU

For more information

www.uslhc.us

www.fnal.gov

www.cern.ch

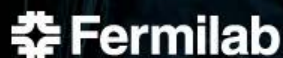


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Dr. Sacha Kopp



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?