PHY294H

- Professor: Joey Huston
- email:huston@msu.edu
- office: BPS3230
- textbook: Knight, Physics for Scientists and Engineers: A Strategic Approach,

  Vol. 4 (Chs 25-36), 3/E + MasteringPhysics

  0321844297

  MasteringPhysics (complete ebook) access card stand alone

  0321753054
- Homework will be with Mastering Physics (and an average of 1 hand-written problem per week)
  - first MP assignment due Wed Jan. 20; first hand-written problem as well
- Quizzes by iclicker (sometimes hand-written)
- Lectures: MTWTh 11:30-12:20
- Course website: www.pa.msu.edu/~huston/phy294h/index.html
  - lectures will be posted frequently, mostly every day if I can remember to do so

- Occasionally there will be guest lecturers, as for example Wednesday and Thursday this week

Get Started with MasteringPhysics

- **Email:** The email you use for school.
- **Course ID:** A Course ID looks something like MCprofessor12345. Ask your instructor for your Course ID!
- **Access code or credit card**: The required access code comes either with your book or by itself at your bookstore. Alternatively, you can buy instant access with a credit card or PayPal account during registration.

Purchase Access

Bookstore:

An Access Code is included in a package available for purchase at the bookstore. You will redeem the code during the registration process.

<insert package ISBN and price>

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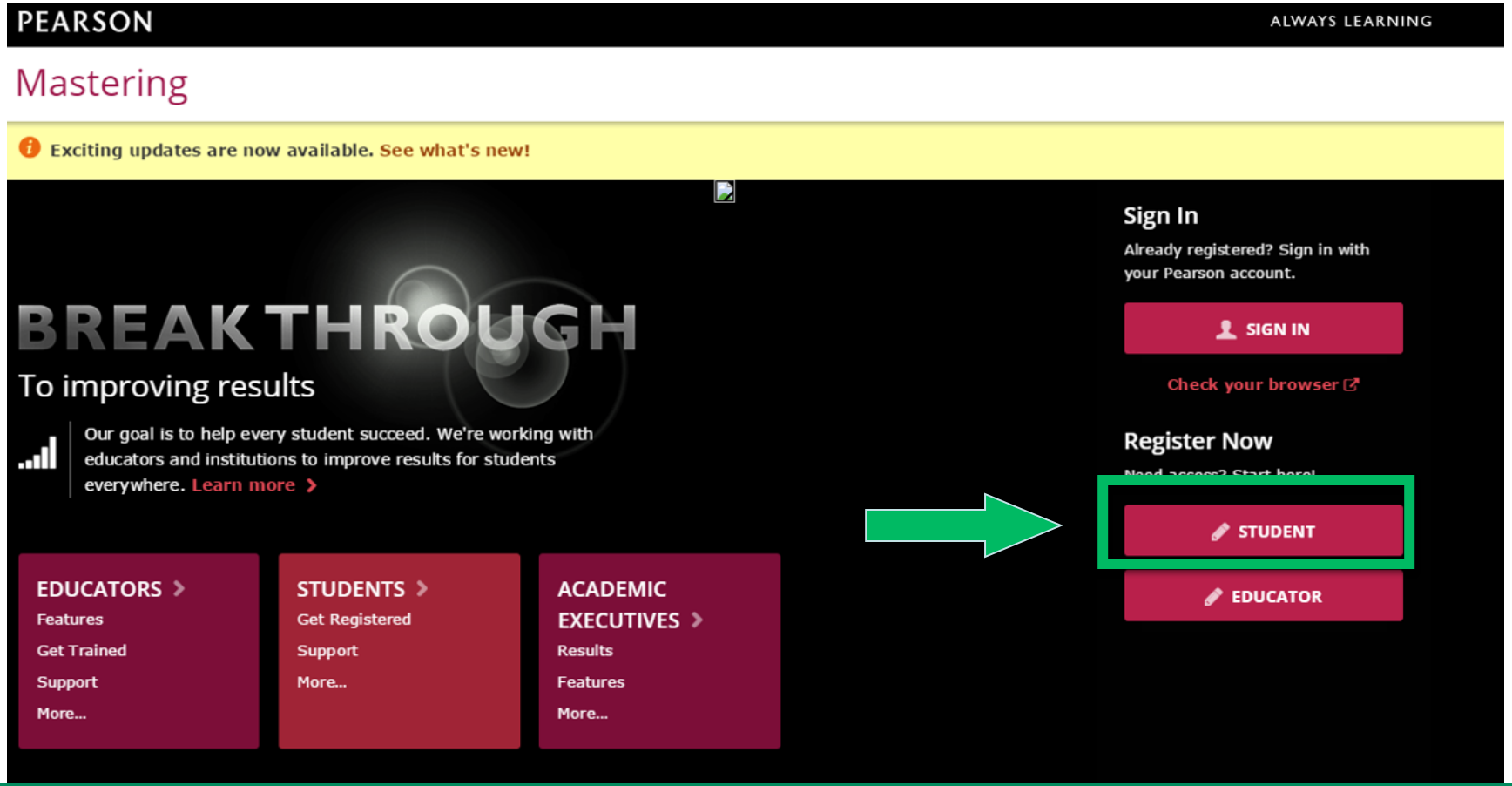
Use a Credit Card or PayPal account to purchase instant access online during the registration process.

Step 1

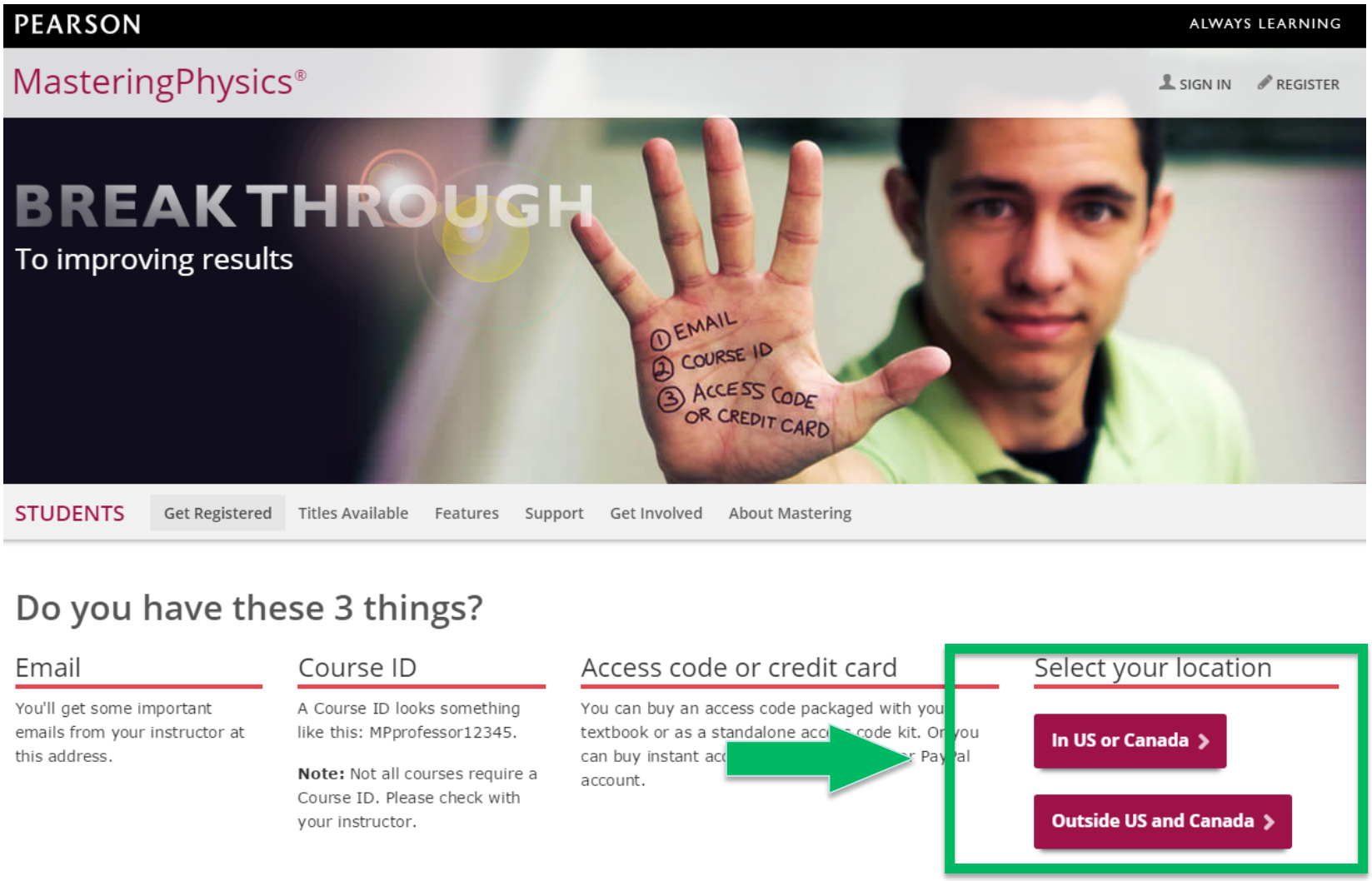
Go to www.MasteringPhysics.com

Under the large Register Now section on the right side of the page, click the **Student**



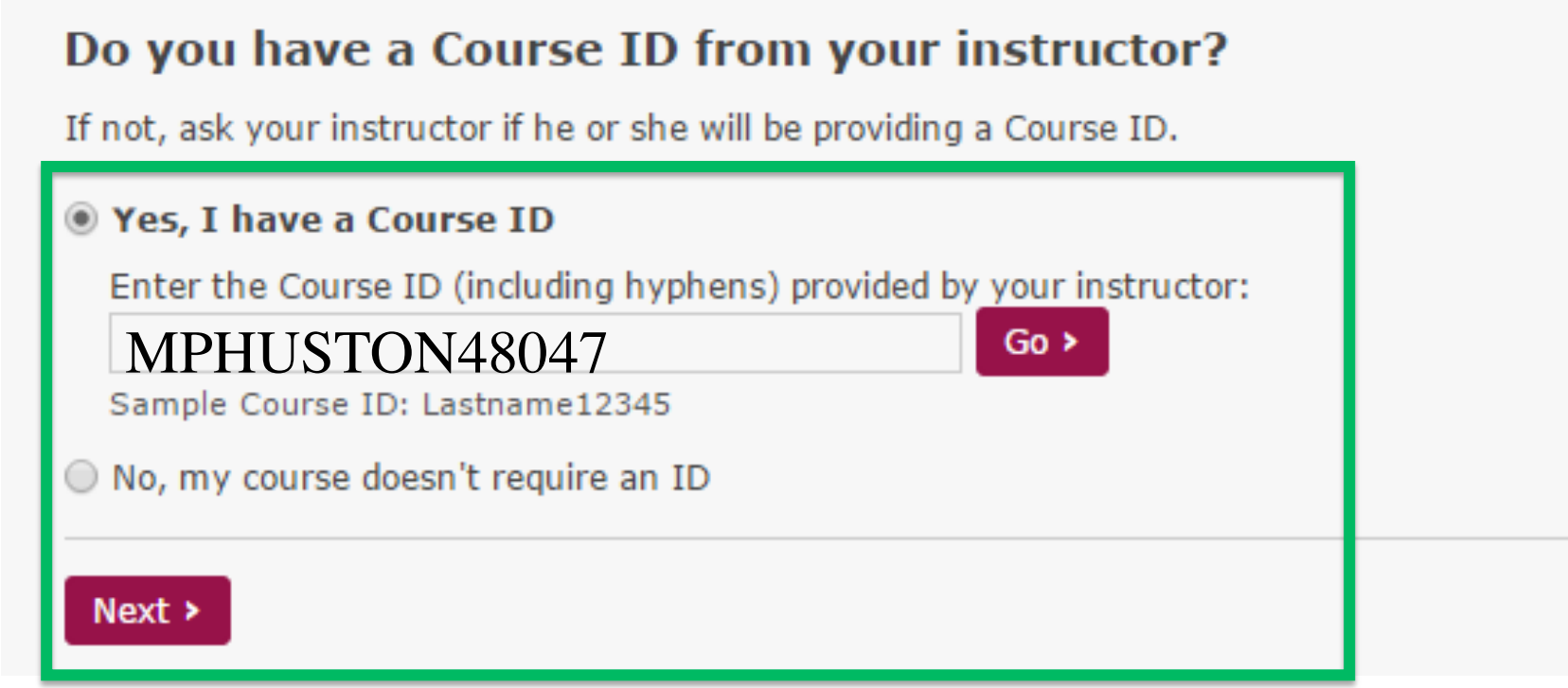
Step 2

Read through the onscreen instructions and select your **location.**



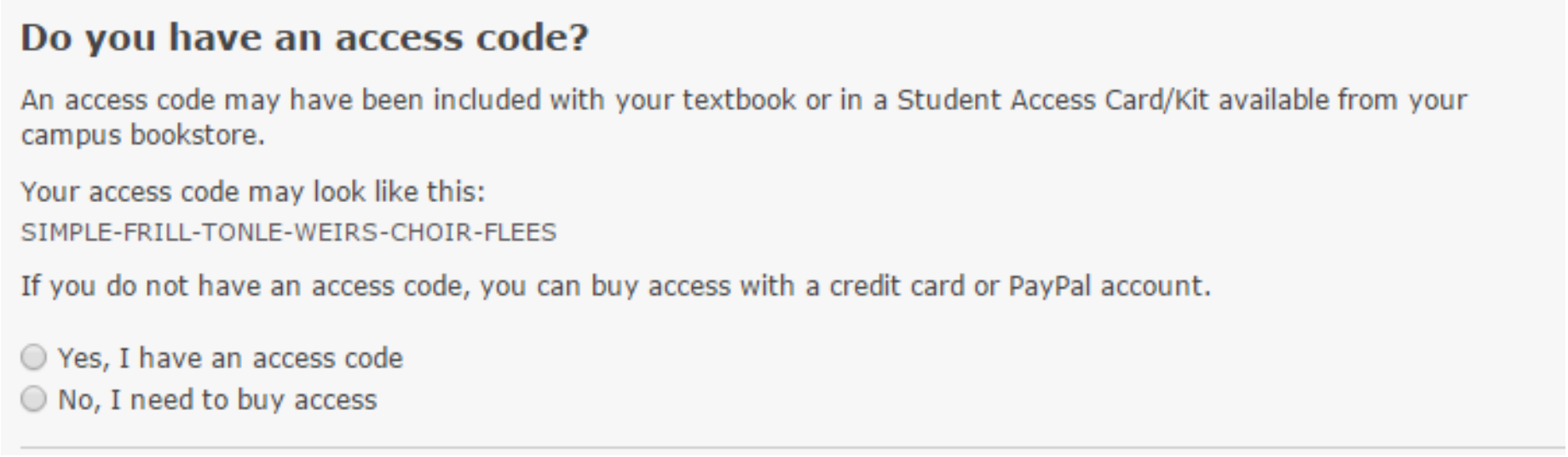
Step 3

Check off whether or not you have a **Course ID**. If you have a **Course ID** provided by your instructor, type it in and press **Go**. If your course does not require an ID, click on the radio button below and click **Next**. *Check with your professor to be sure!*



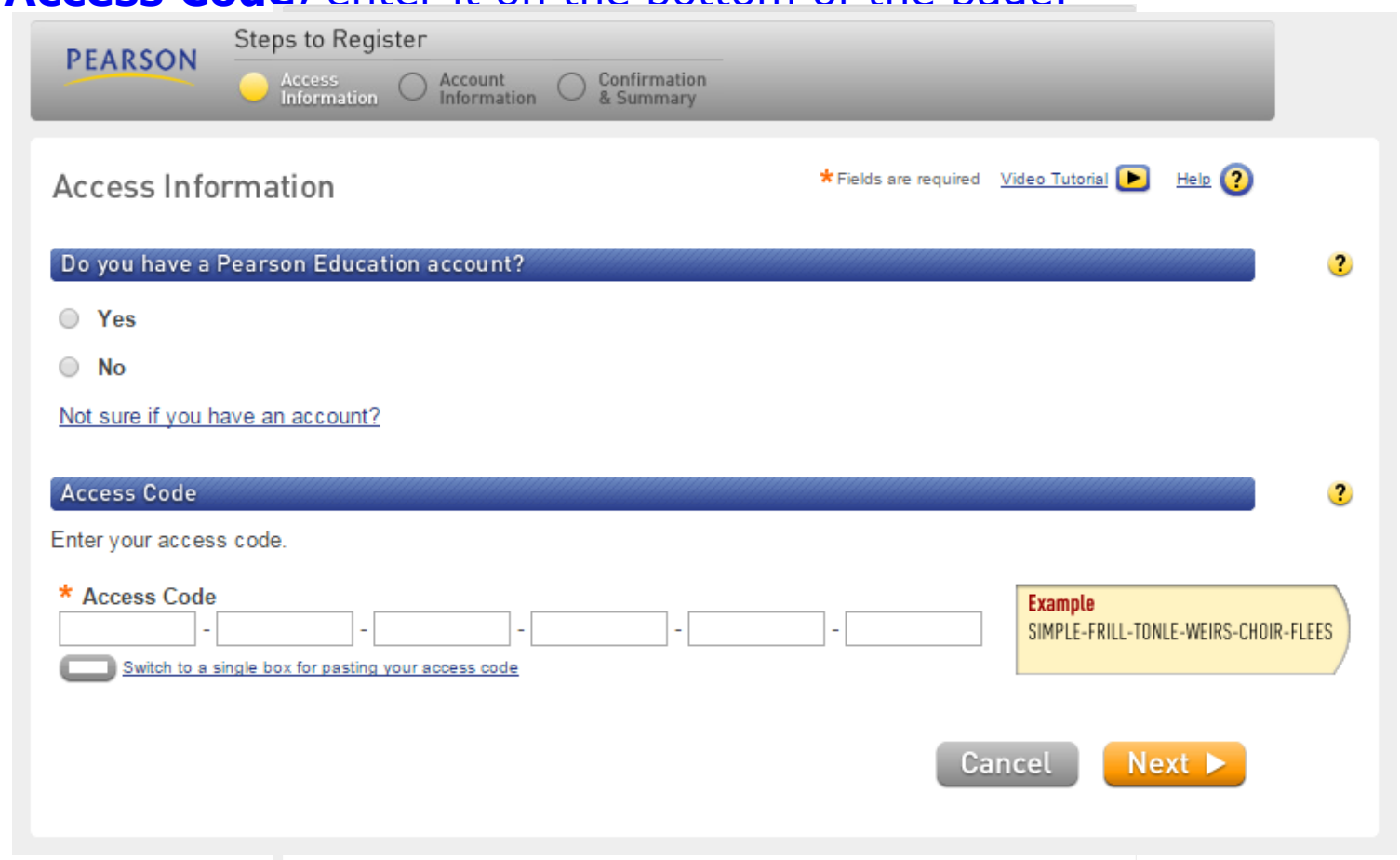
Step 4

Check off whether or not you have an **Access Code**. If you don't have one, you can purchase access online. You will need the correct textbook title, author, and edition. Check with your professor to get this information or your course syllabus.



Step 5

Before continuing, make sure you read & accept the License Agreement. After this, either **Create** a new Pearson username/password, or, if you've already registered for another Pearson product, enter that username/password. If you have an **Access Code**, enter it on the bottom of the page.



Step 6

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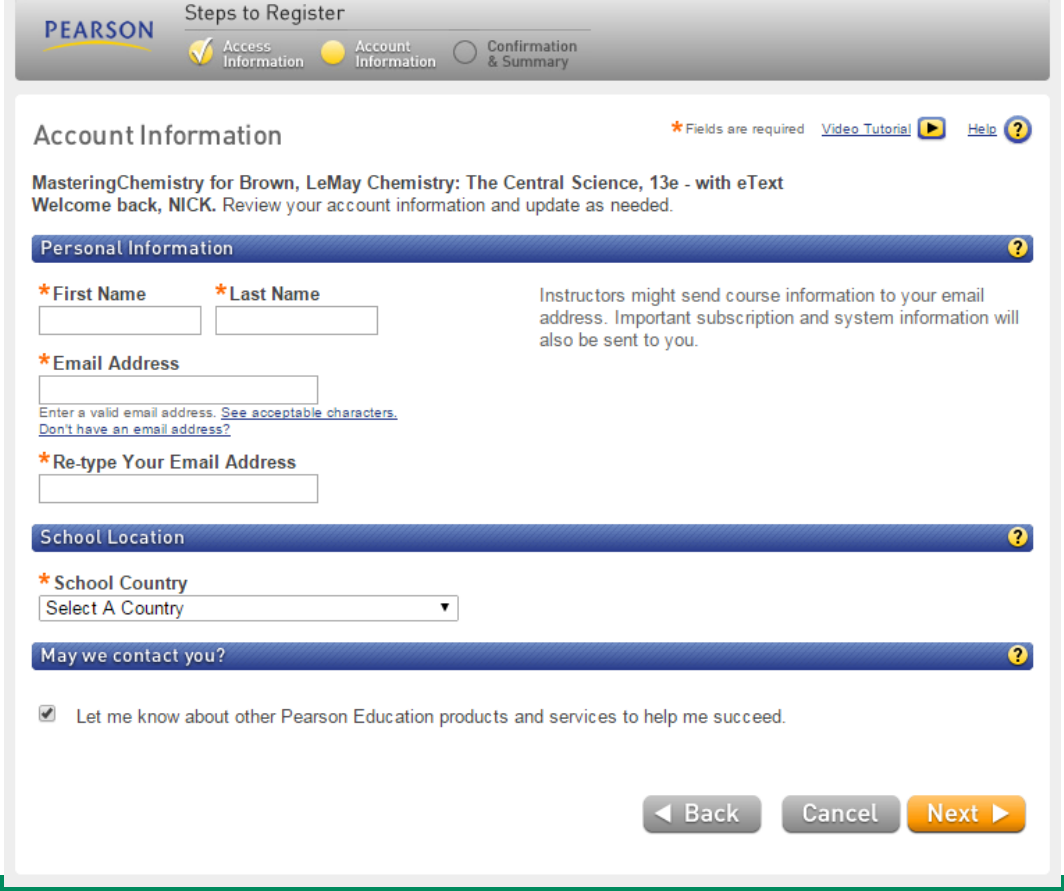
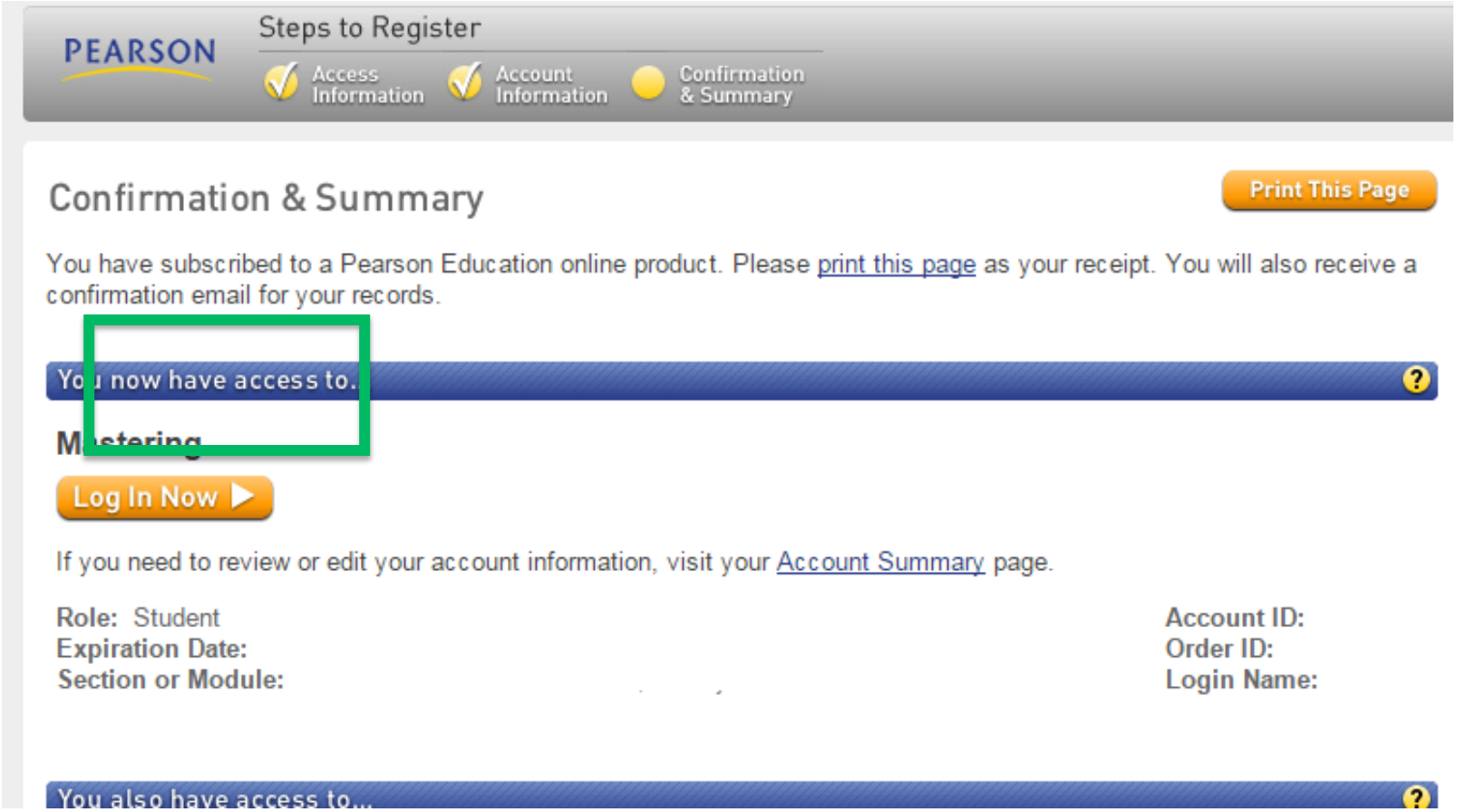


Step 7

You're now registered! Click **Log In Now.** If prompted, enter your Student ID. That's it!



Need help?

Visit www.MasteringPhysics.com
and click the "Student" button under "Register Now" for:

-Helpful videos
-Frequently Asked Questions
-System Requirements
-Other helpful "getting started" info!

Or visit our 24/7 Technical Support site at http://247pearsoned.custhelp.com.

Send us a Tweet at @PearsonSupport

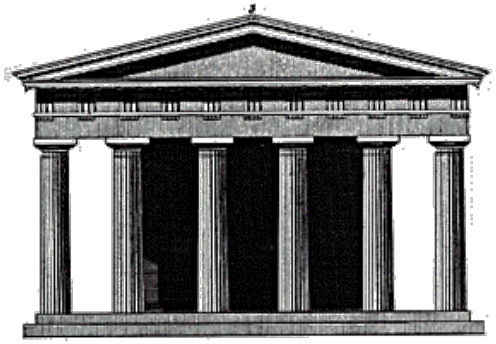
Introduction

What is fundamental?

- The TWO most fundamental questions about the universe are:
  - What is it made of?
  - How is it all held together?

Four Fundamental Elements

- The Hunt for the answers to those two questions has been going on for a very long time.
- It really started with the Greeks.



…and Two Fundamental Forces

- There were two fundamental forces:
  - Love
  - Strife
- This picture is a tad too simple….

Let's jump ahead 2000 years or so

- Four fundamental forces (that we know about):

(1) strong

(2) weak → electroweak (70's and 80's)

electrostatics (1700's)

magnetism (1700's, 1800's) → (3) electromagnetic

(4) gravity

TABLE 30.1 Particle Interactions

Interaction (Force)	Relative Strength[a]	Range of Force	Mediating Field Particle
Strong	1	Short ($\sim$1 fm)	Gluon
Electromagnetic	10^{-2}	Long ($\propto 1/r^2$)	Photon
Weak	10^{-6}	Short ($\sim 10^{-3}$ fm)	$W^{\pm}$ and Z^0 bosons
Gravitational	10^{-43}	Long ($\propto 1/r^2$)	Graviton

[a] For two quarks separated by 3×10^{-17} m

What am I trying to do in my research?

(1) strong

(2,3)electroweak

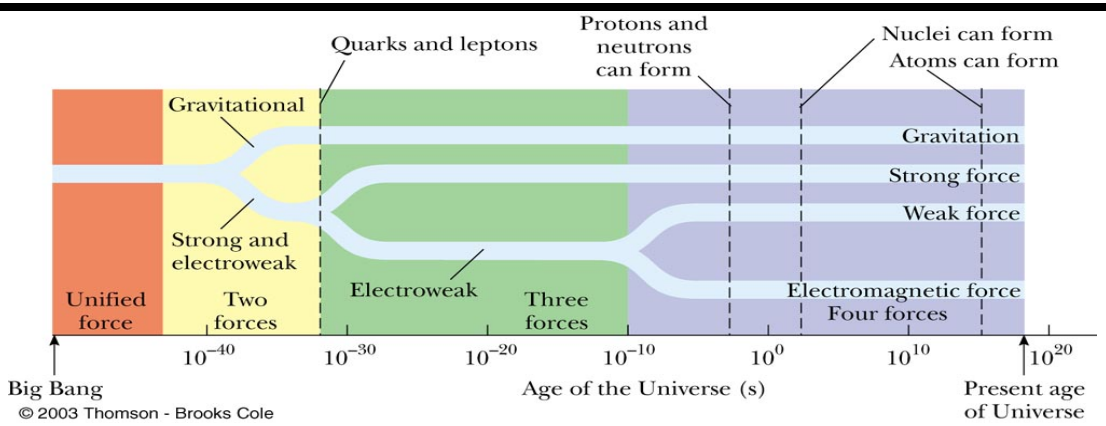
GUT

TOE

(4) gravity

+ Grand Unified Theory = Theory of Everything

Big Bang

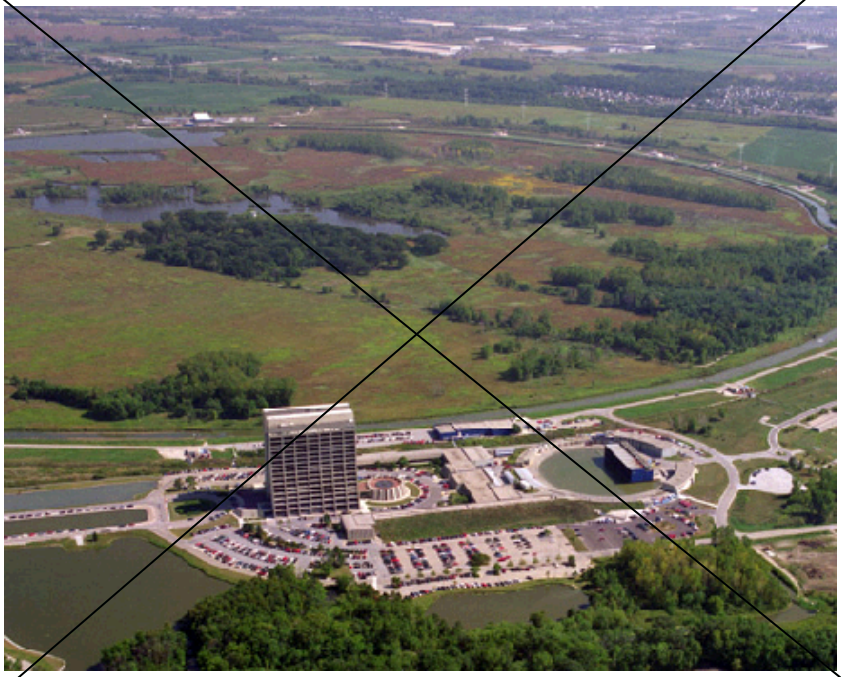


What is high energy physics all about?

- In high energy physics, we are attempting to understand the fundamental laws and forces which govern the universe, as well as to discover all of its fundamental constituents
- …and pretty neat questions as to how many dimensions the universe really has
- …and whether for high energy collisions whether gravity can be strong enough to create black holes

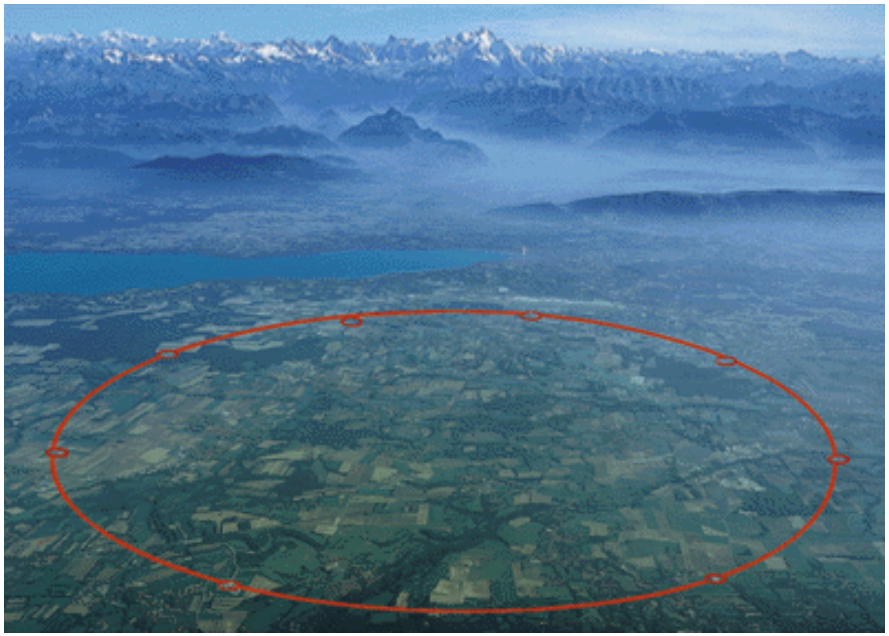
To do so takes big accelerators

Fermilab, near Chicago



Fermilab is still running but the Tevatron (protons colliding with anti-protons) shut down in 2012

CERN, near Geneva, Switzerland



The CERN LHC started running in 2008, took data in 2010, 2011,2012 and 2015 (protons colliding with protons) and is now starting up again.

…and big detectors

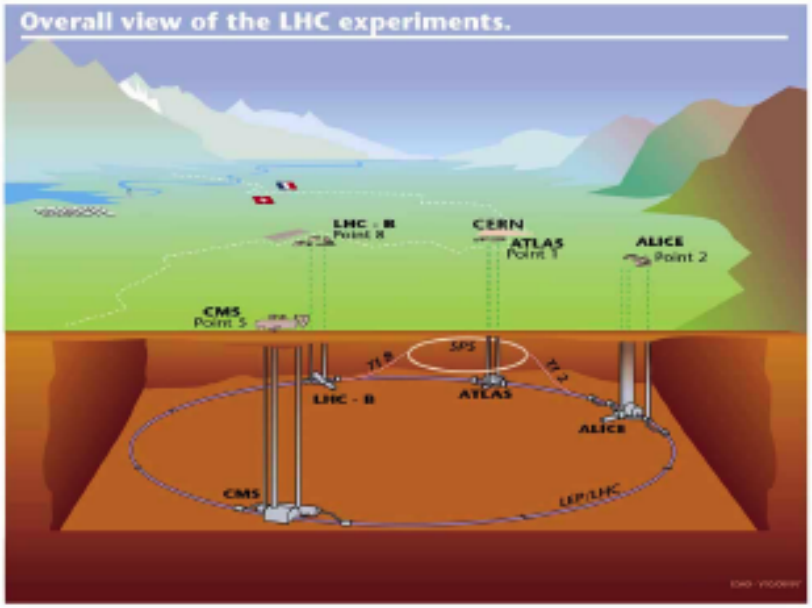
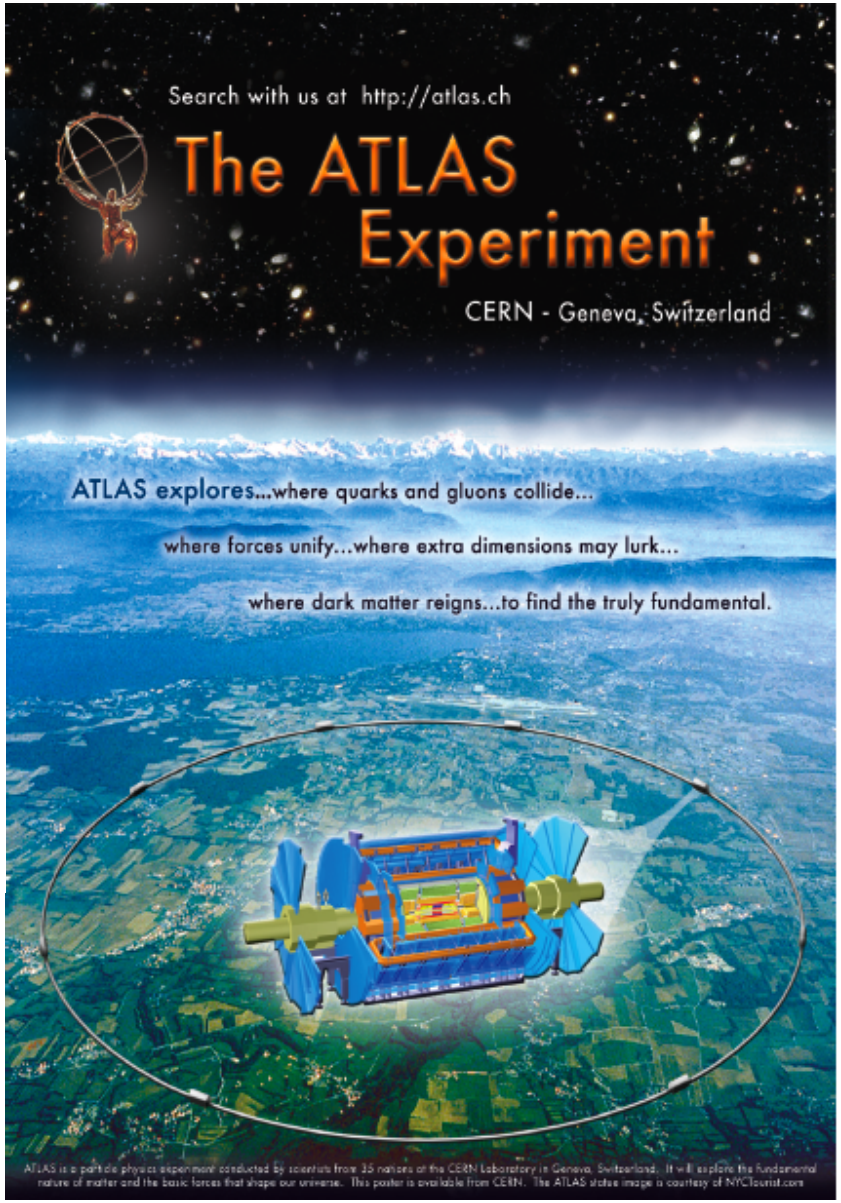
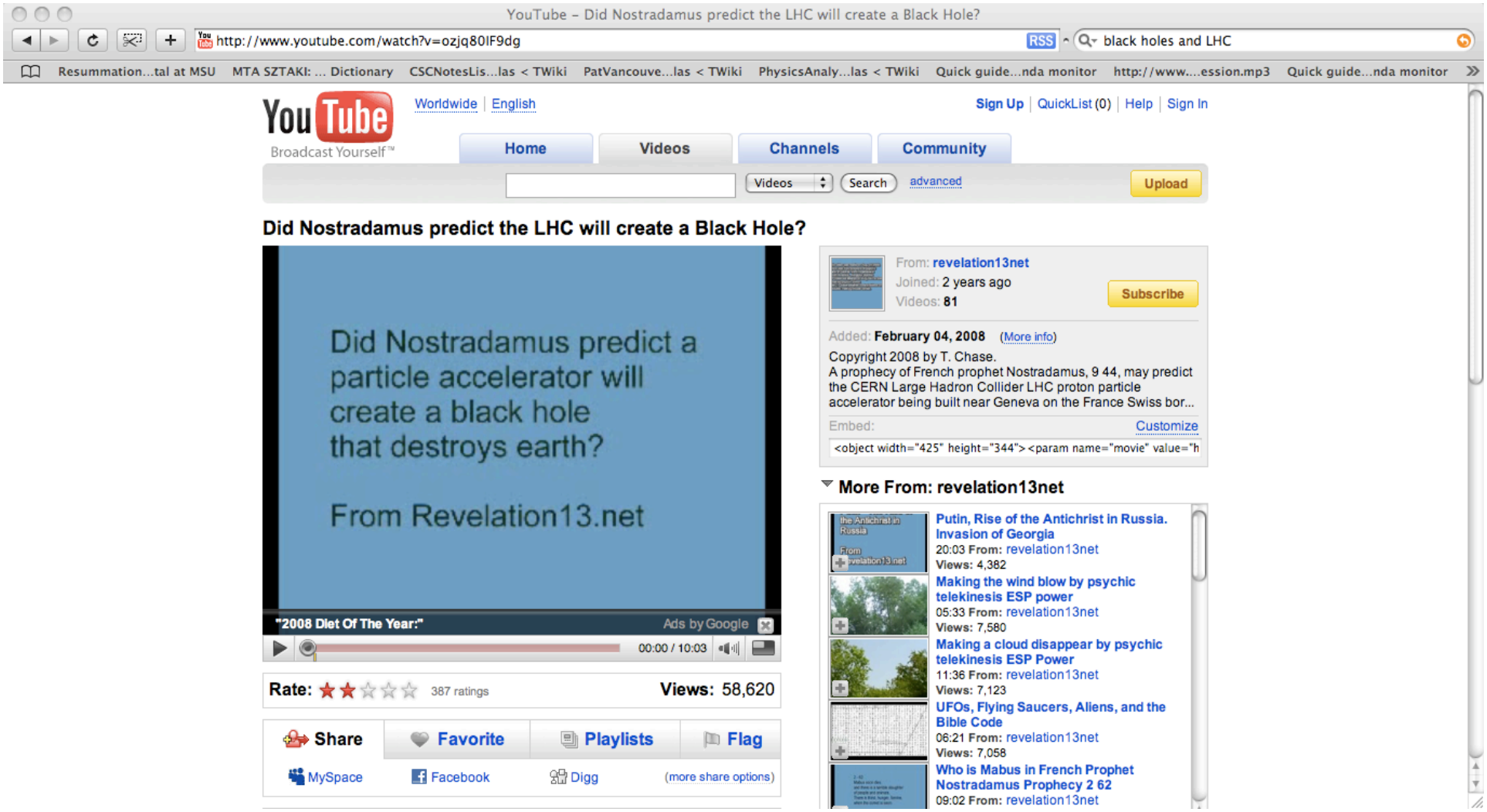


Figure 1: A Schematic diagram of the LHC complex, the smaller ring is the SPS which feeds protons into the LHC for further acceleration [2]



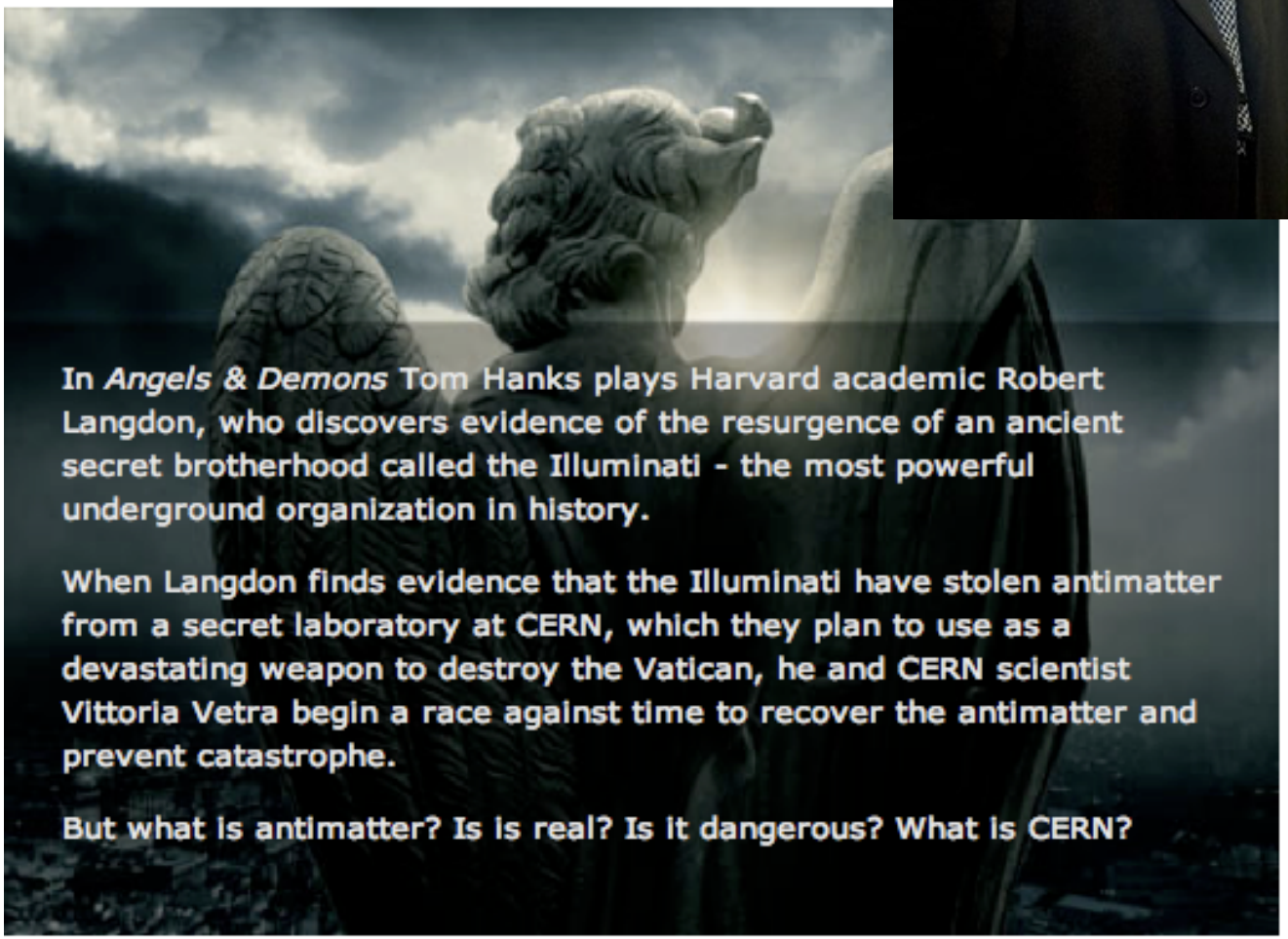
…we did not



…and unfortunately no evidence of black holes so far

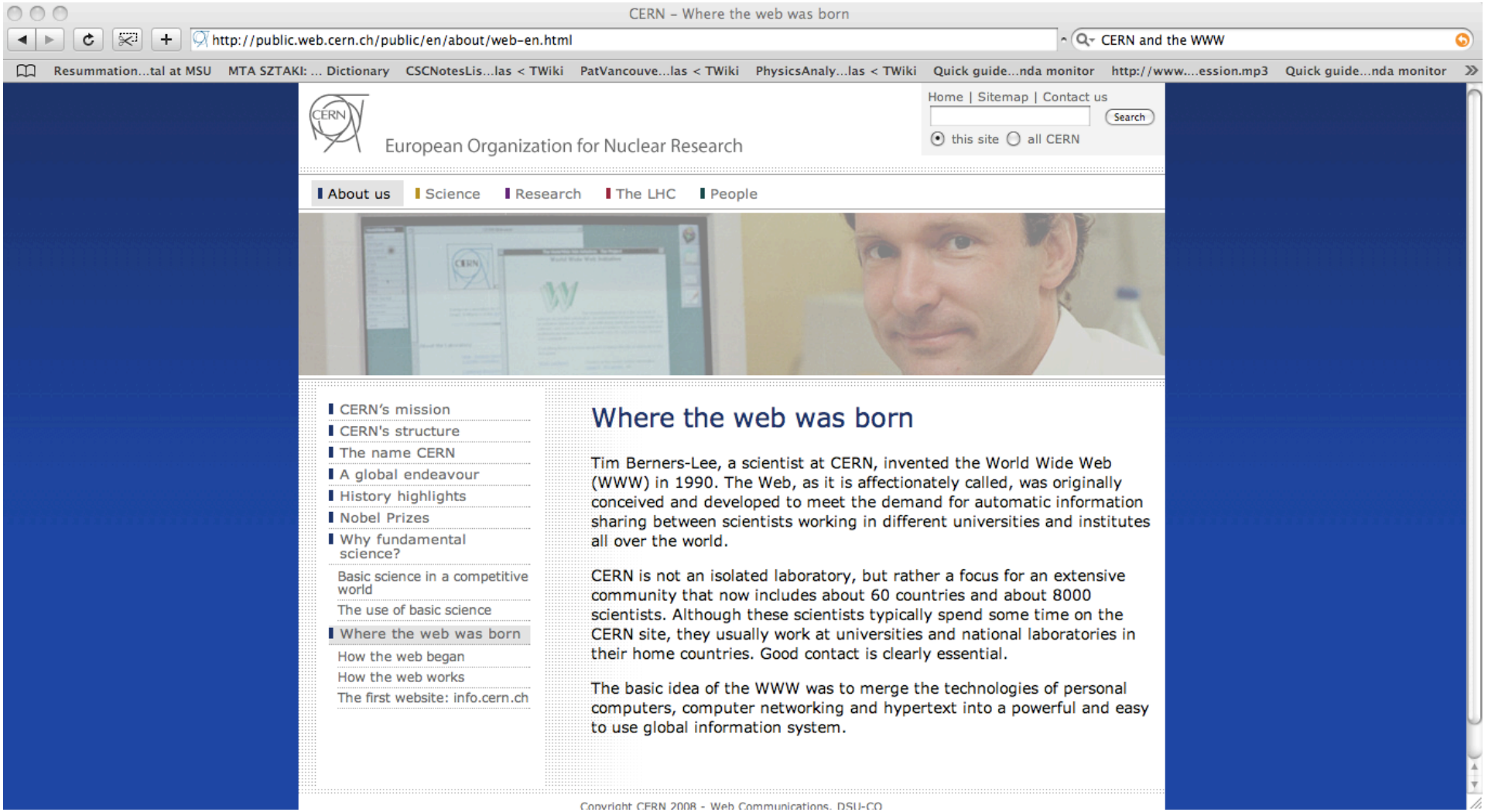
Tom Hanks at CERN

- We produce anti-matter, but not enough to blow up the Vatican



http://angelsanddemons.cern.ch/

…but we did


CERN – Where the web was born
http://public.web.cern.ch/public/en/about/web-en.html
CERN and the WWW
Resummation...tal at MSU
MTA SZTAKI: ... Dictionary
CSCNotesLis...las < TWiki
PatVancouve...las < TWiki
PhysicsAnaly...las < TWiki
Quick guide...nda monitor
http://www....ession.mp3
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About us
Science
Research
The LHC
People
CERN's mission
CERN's structure
The name CERN
A global endeavour
History highlights
Nobel Prizes
Why fundamental science?
Basic science in a competitive world
The use of basic science
Where the web was born
How the web began
How the web works
The first website: info.cern.ch
Where the web was born
Tim Berners-Lee, a scientist at CERN, invented the World Wide Web (WWW) in 1990. The Web, as it is affectionately called, was originally conceived and developed to meet the demand for automatic information sharing between scientists working in different universities and institutes all over the world.
CERN is not an isolated laboratory, but rather a focus for an extensive community that now includes about 60 countries and about 8000 scientists. Although these scientists typically spend some time on the CERN site, they usually work at universities and national laboratories in their home countries. Good contact is clearly essential.
The basic idea of the WWW was to merge the technologies of personal computers, computer networking and hypertext into a powerful and easy to use global information system.
Copyright CERN 2008 - Web Communications, DSU-CO

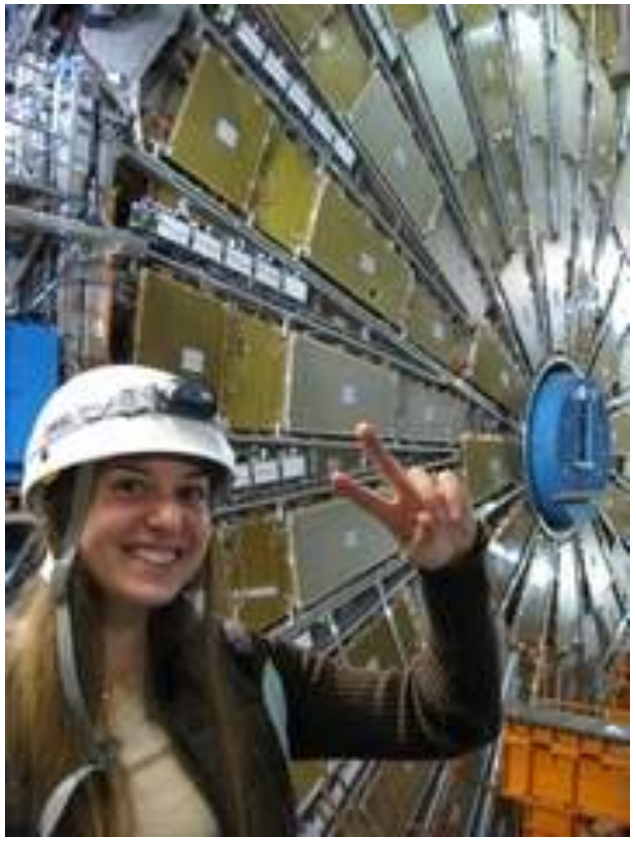
…and this is the home of

First picture ever posted on the web

I may play some of their music this semester

…and we do have a rap song

- MSU grad's particle physics rap is YouTube hit
  - Katie McAlpine
  - With an intro from MC Hawking



…in front of my experiment

…and we did

- Discover the Higgs bosons

Physicists Find Elusive Particle Seen as Key to Universe

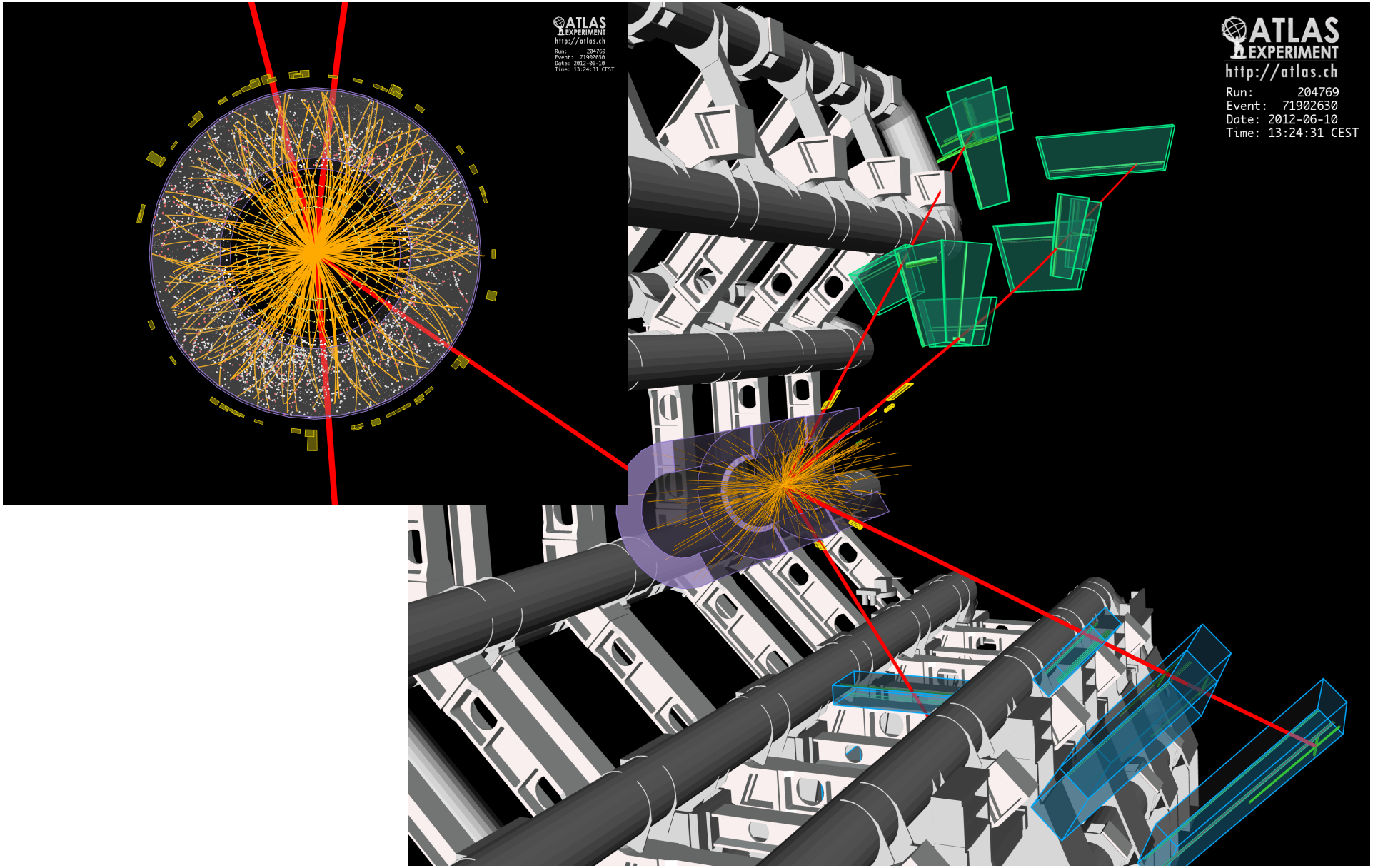
Pool photo by Denis Balibouse

Scientists in Geneva on Wednesday applauded the discovery of a subatomic particle that looks like the Higgs boson.

By DENNIS OVERBYE
Published: July 4, 2012 | 122 Comments

I didn't get there early enough for a seat.

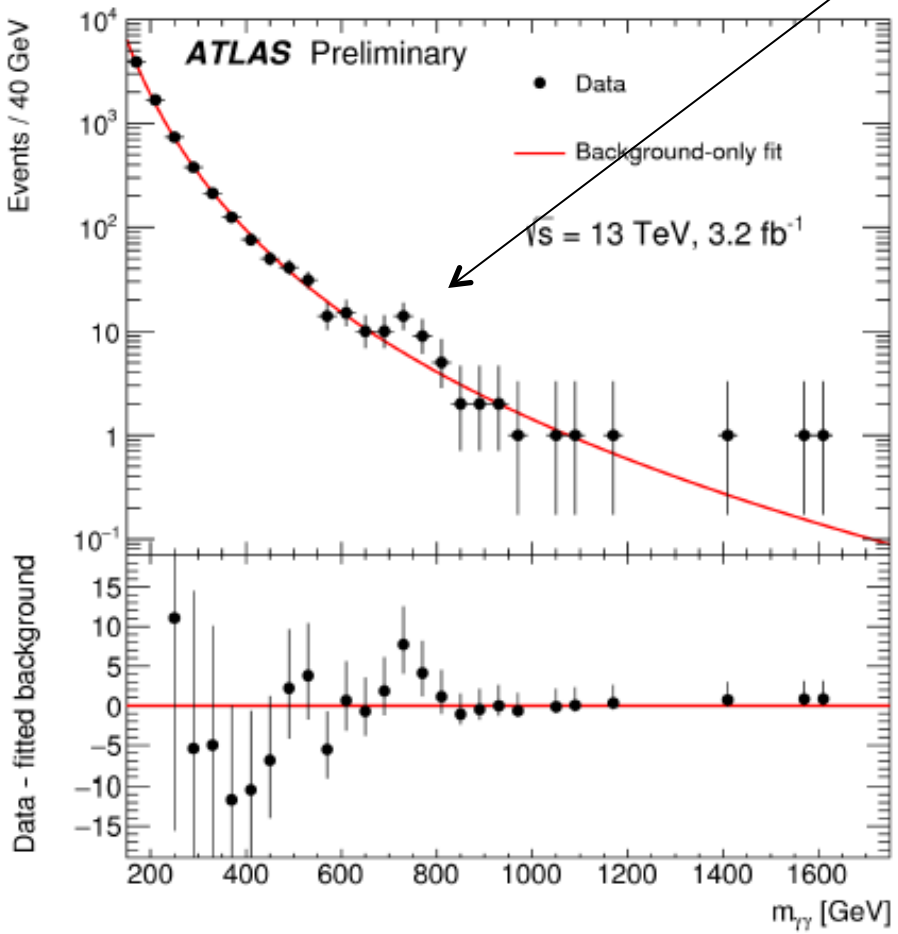
Higgs candidate event

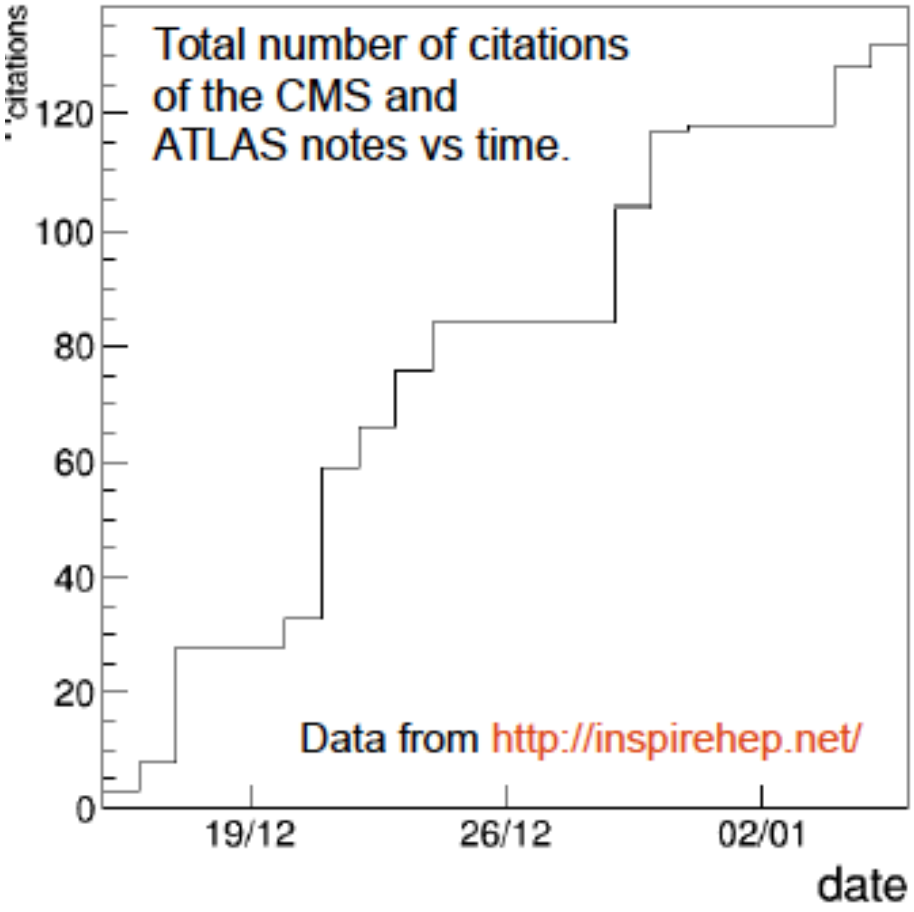


I'll keep you posted

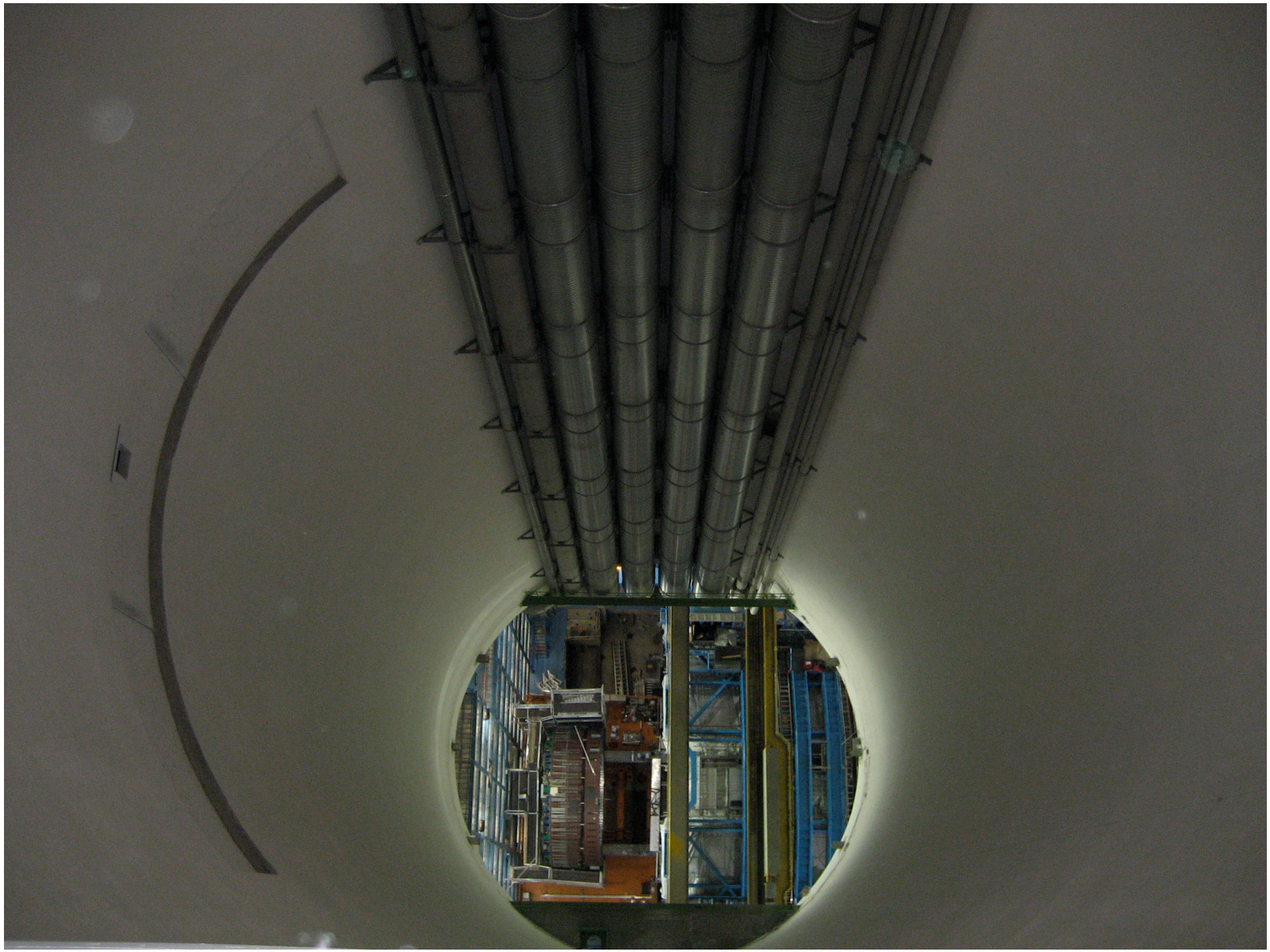
Physicists in Europe Find Tantalizing Hints of a Mysterious New Particle

By **DENNIS OVERBYE** DEC. 15, 2015

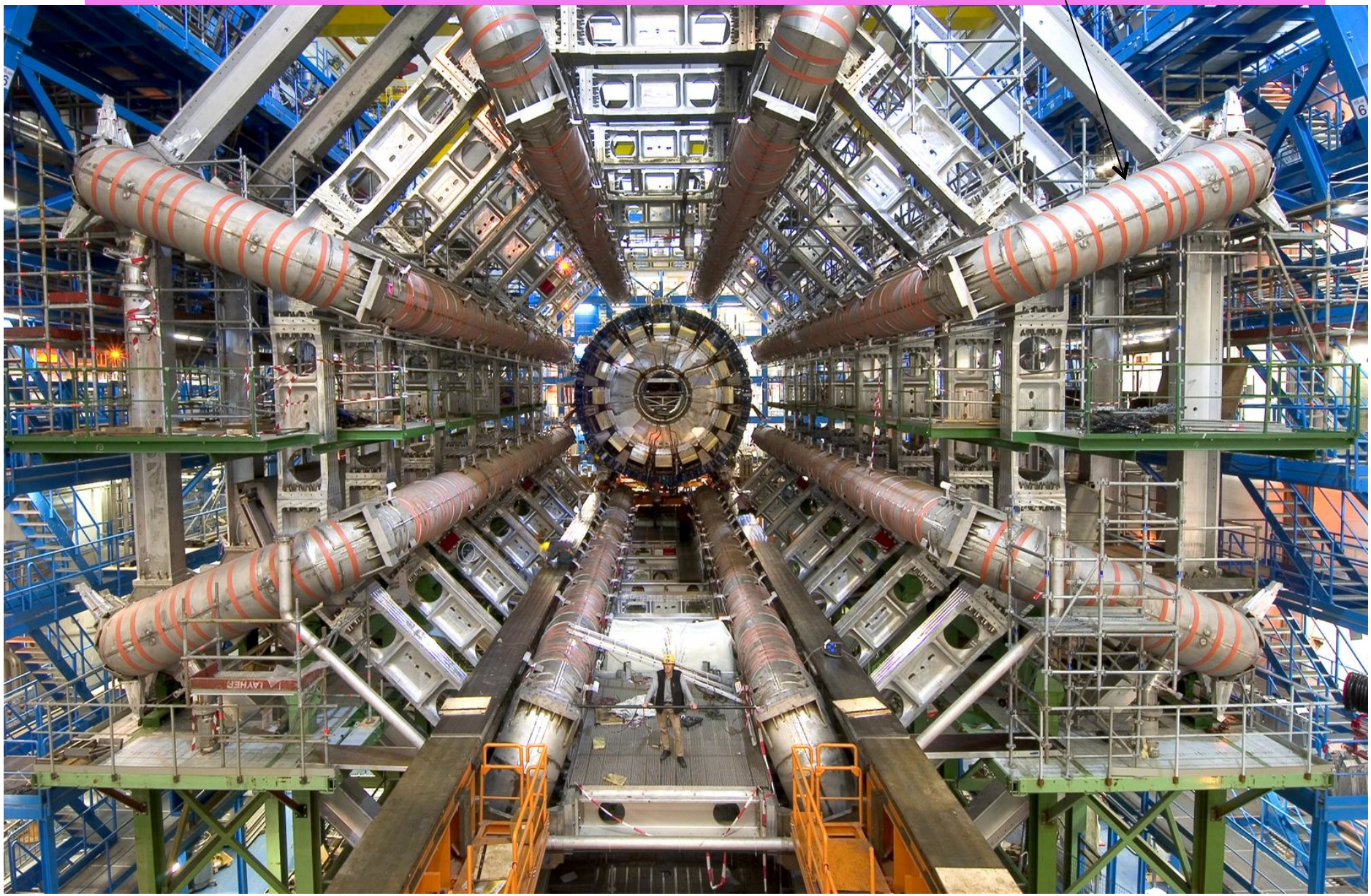




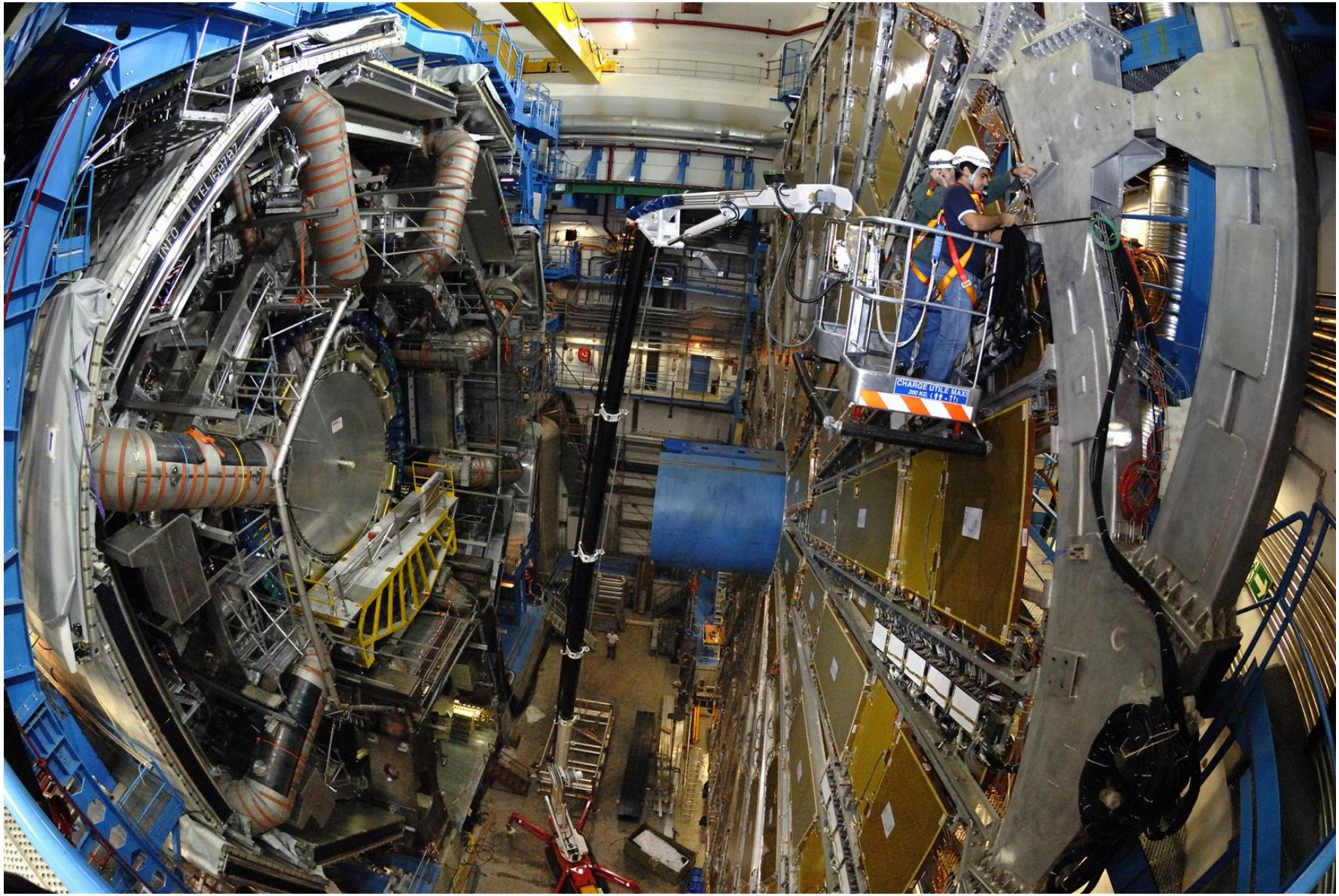
Looking down (100 m) into my experiment



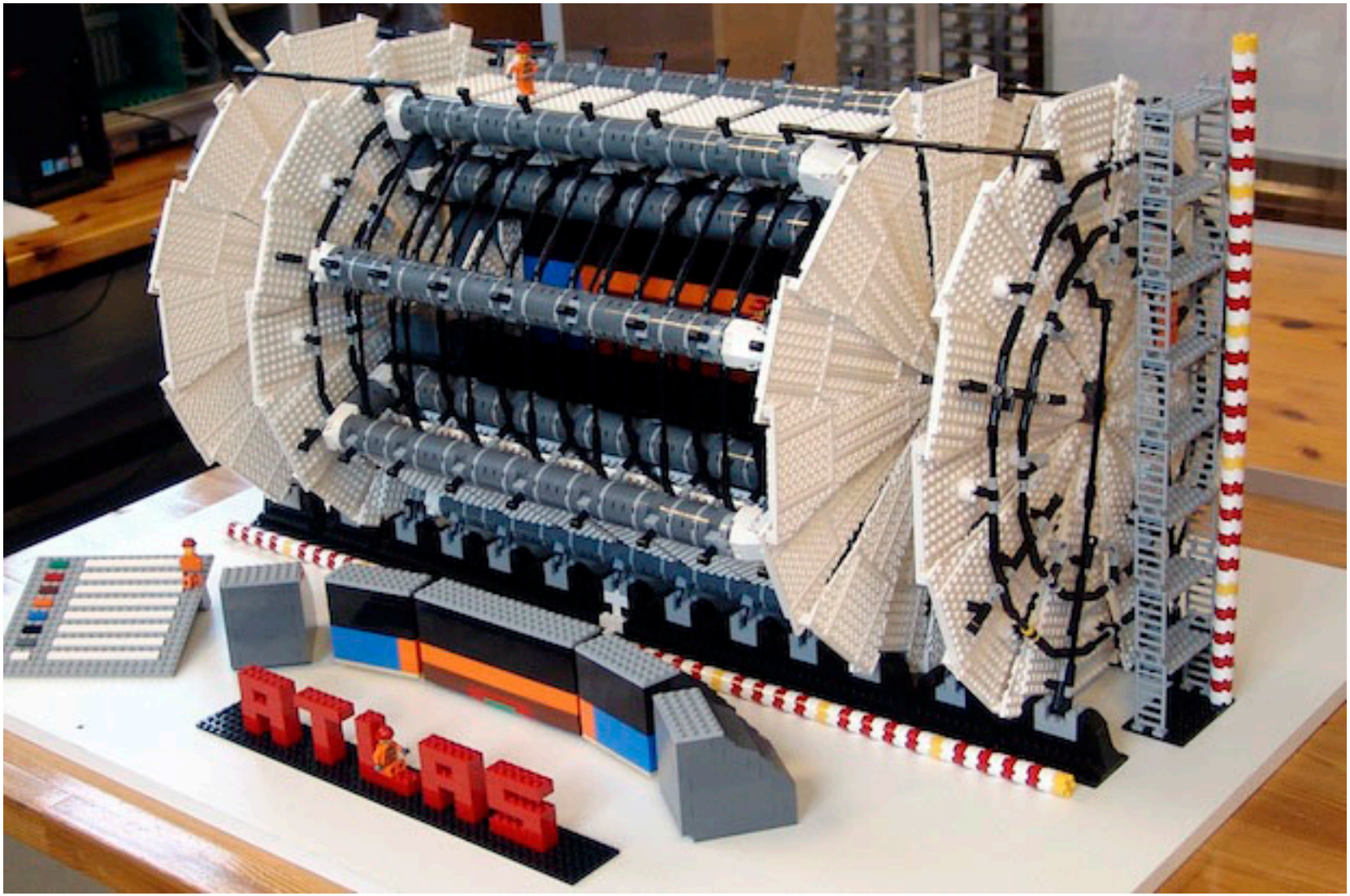
Toroid magnet



http://atlaseye-webpub.web.cern.ch/atlaseye-webpub/web-sites/pages/UX15_webcams.htm



Lego model of ATLAS



…still looking for a place to put it

Occasionally I will throw in stuff from BBT

Let's go back to electrostatics

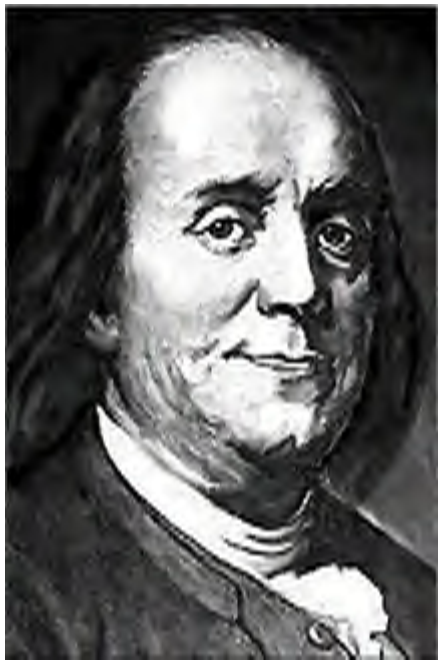
- …and thus back to the ancient Greeks
- The Greeks started the science of electrostatics (like almost everything else)
  - they observed that when amber was rubbed, it would attract small objects like feathers or straw
    - or like rubbing a balloon against your shirt
  - in fact our word for electricity comes from the Greek word for amber, *electron*

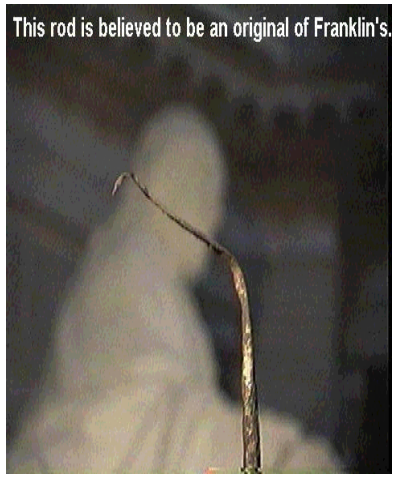
So not much happened for 2000 years or so

- In the 16th century, investigations revealed that there appeared to be two types of electricity
  - vitreous: from rubbed glass, animal hair
  - resinous: from rubbed amber, silk
- How is one different from the other?
  - 2 bodies charged with vitreous electricity repel each other, as do 2 bodies charged with resinous electricity
  - a body charged with resinous electricity will attract a body charged with vitreous

Is this the final story (should you write down vitreous and resinous)?

- No…and no
- In the mid-1700's, Benjamin Franklin proposed what he called a "one-fluid" theory of electricity. He proposed that every body had a normal amount of electricity.
- When a body is rubbed against another, some of the electricity is transferred from one body to another
- One body has an excess of electricity, the other a deficit
  - this is a great advance, one of the first conservation laws
- He described the excess as having a + charge and the deficit a -charge





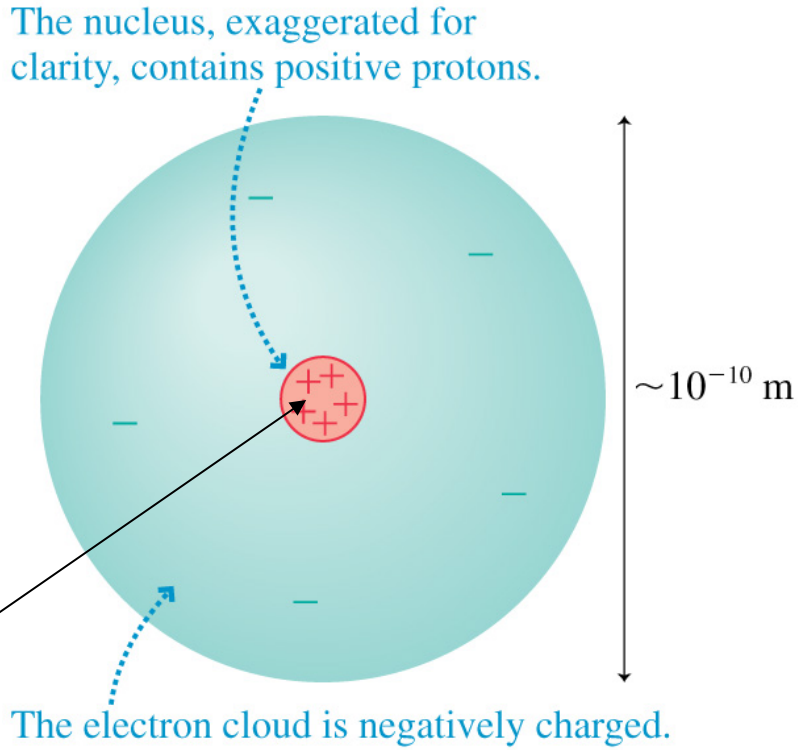
Can we stop now?

- Benjamin Franklin's theory was an advance
  - he unified the concepts of lightning and static electricity
- but not quite right
- In particular his choice of signs will come back to haunt us when we get to circuits
- Let's briefly review atomic structure

to give you an idea of the relative scale of the nucleus, Rutherford referred to it as the "fly in the cathedral"

The nucleus of the atom consists of protons + neutrons

Charge on proton = e = $+1.6X10^{-19}$ C



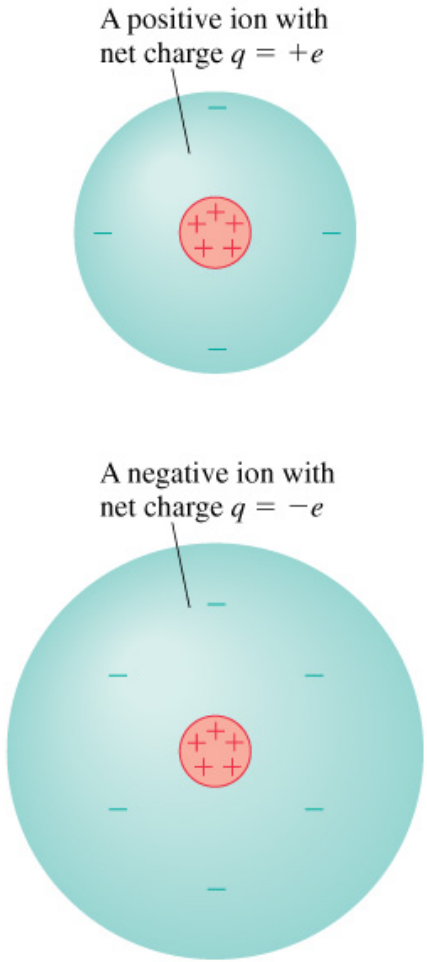
Each normal atom has as many electrons as protons

Charge on electron = -e = - $1.6X10^{-19}$ C

So every normal atom is neutral

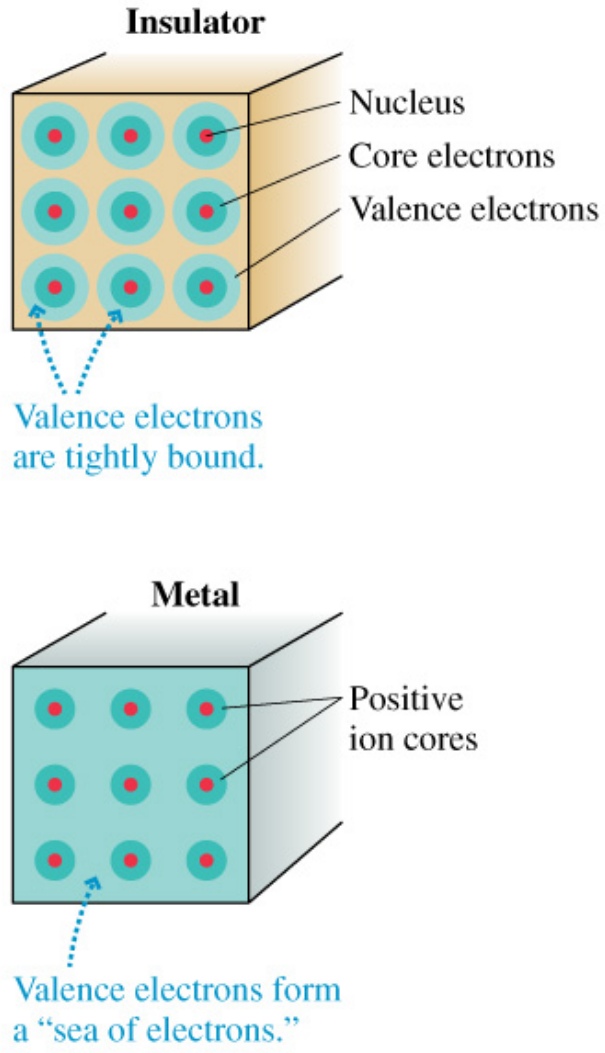
What do we know?

- All electrical charges are multiples of e
  - i.e. charge is quantized
- The protons are stuck inside the nucleus
- The outermost electrons are the ones that can come off by rubbing
  - i.e. electrostatic effects result from transfer of electrons and not of positive charges
- I can remove electrons from an object (ionization) in which case it becomes positive
- I can add electrons to an object in which case it becomes negative
- Total charge is always conserved

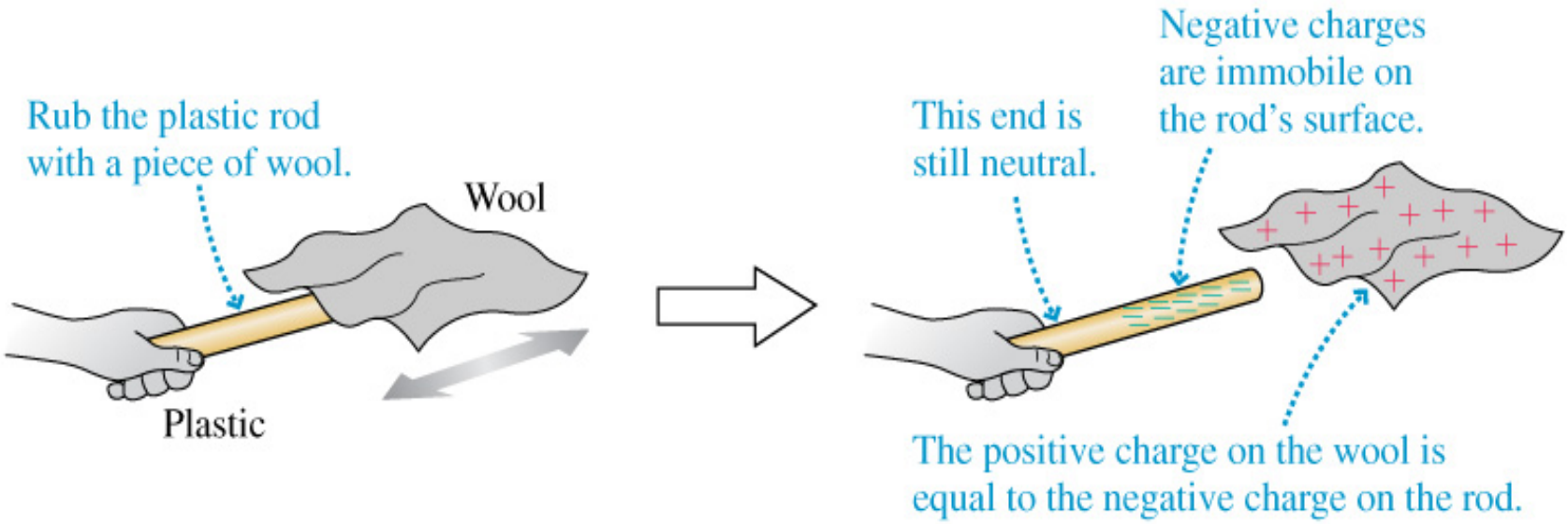


Conductors and insulators

- If outermost electrons are free to move within the material, we call the material a conductor
- If they're not free to move (but can still be rubbed off), we call the material an insulator
- Third possibility is that a material can be a semi-conductor
- Now what happened with the glass rod and silk, plastic rod and wool



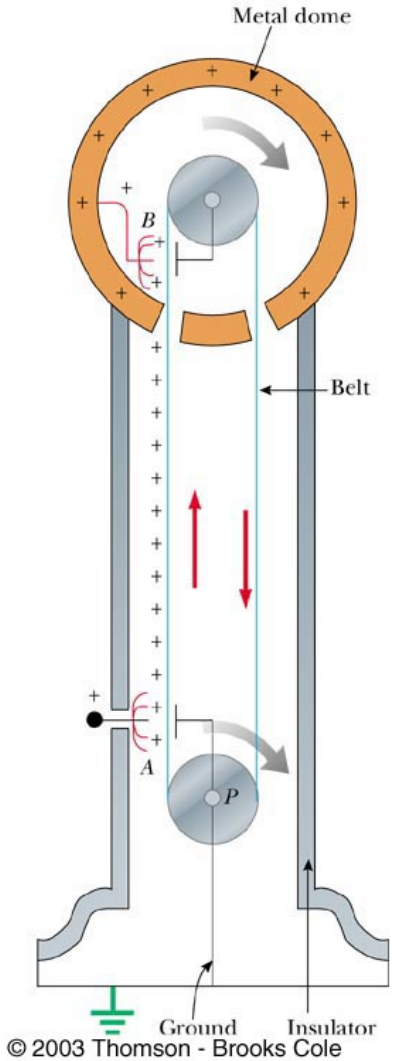
Charging insulators



…and the reverse for glass rod and silk

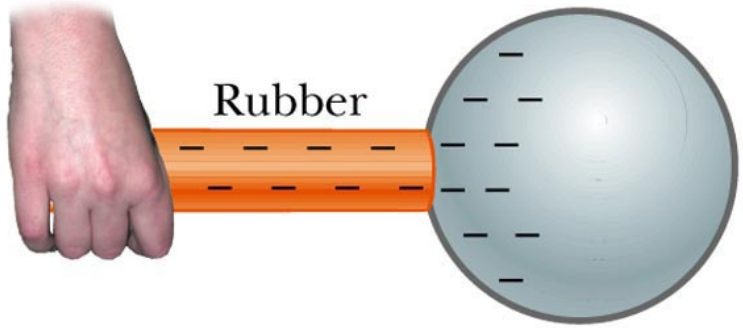
Another way of extracting charges

- The van de Graf machine
- Has a belt which transfers charge to the metal dome
- Does it take electrons up to the dome or transfer electrons away from the dome?

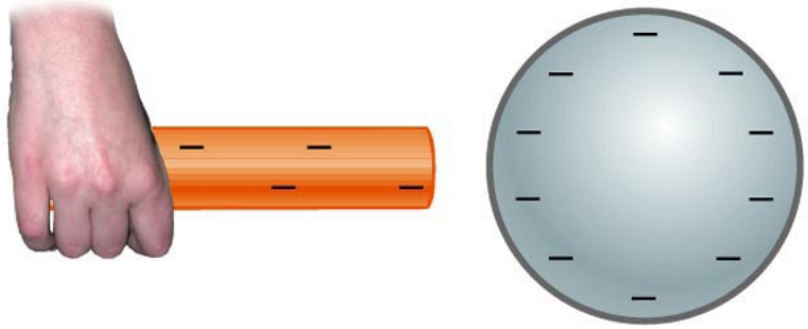


Charging an object (directly)

- Suppose I bring a rubber rod that has an excess negative charge in contact with a conductor; what happens?
- Some of the negative charge is transferred to the conductor
- Since the electrons are free to move inside the conductor, and since negative charges repel, they try to get as far away from each other as possible
- Charge is uniformly distributed over the surface of the conductor (none in the interior)



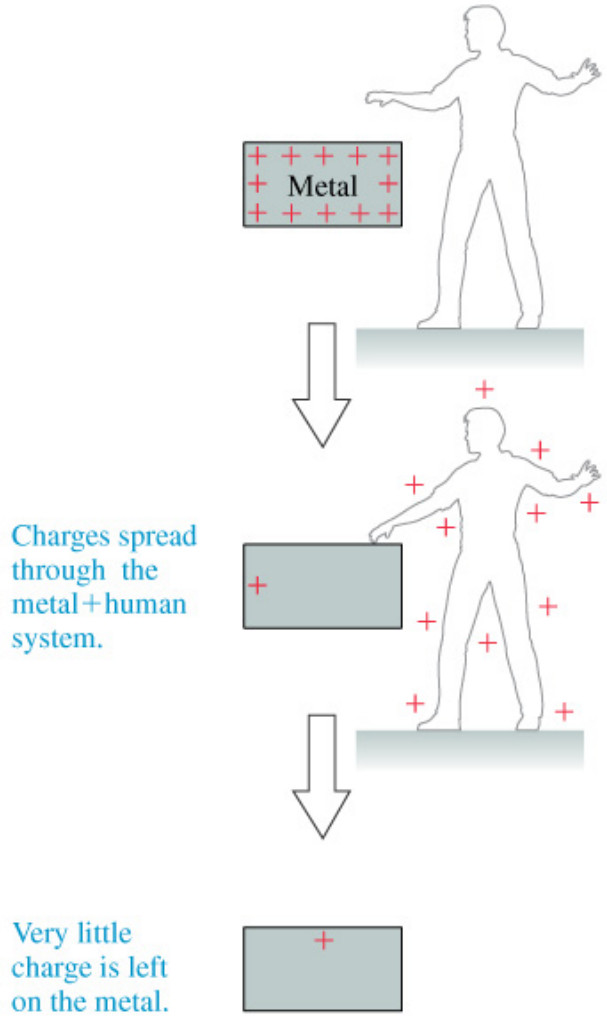
(a) Before



(b) After

Charging a human

- …or discharging a metal plate
- Body consists largely of salt water and thus is a reasonably good conductor
- When touching the metal, some of Cl^- ions on skin surface transfer extra electron to metal
- Leaving body with an excess of Na^+ ions, and thus a net positive charge
- By grounding objects, we are trying to prevent the buildup of any significant charge on them
- Excess charge shared with the earth
  - for example, by 3rd prong on electrical plug
- Moist air is a (relatively poor) conductor
  - that's why electrostatic demonstrations are always dangerous to do in late August



Let's try this with an electroscope

- Why do you think we would use gold leaf?

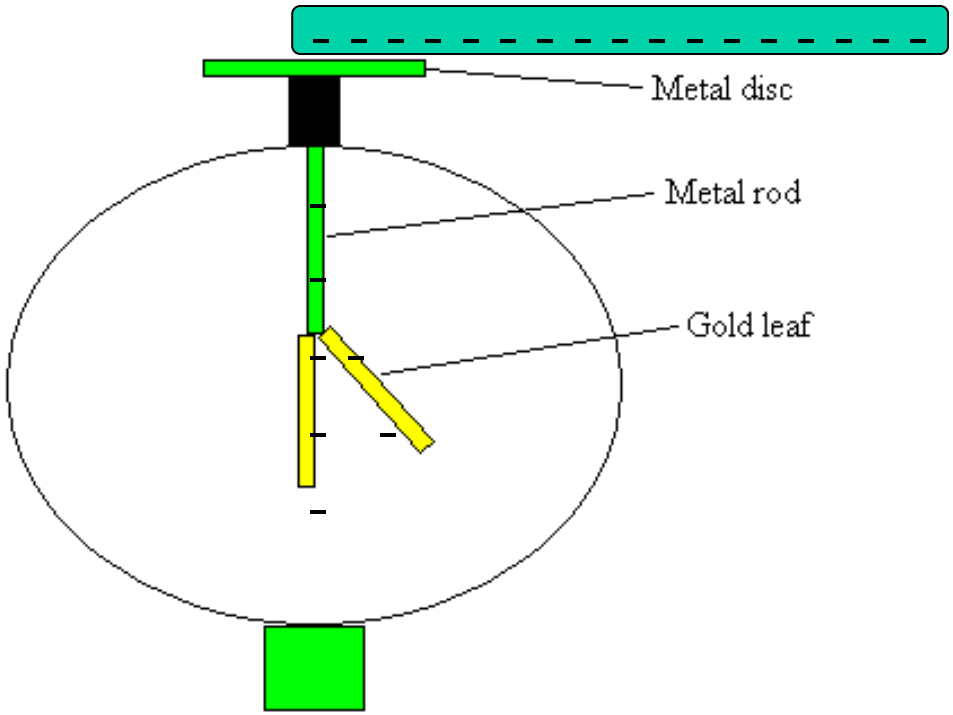


Figure 2: The classical electroscope

Charging by induction

- How can I see an effect when I haven't touched the electroscope?

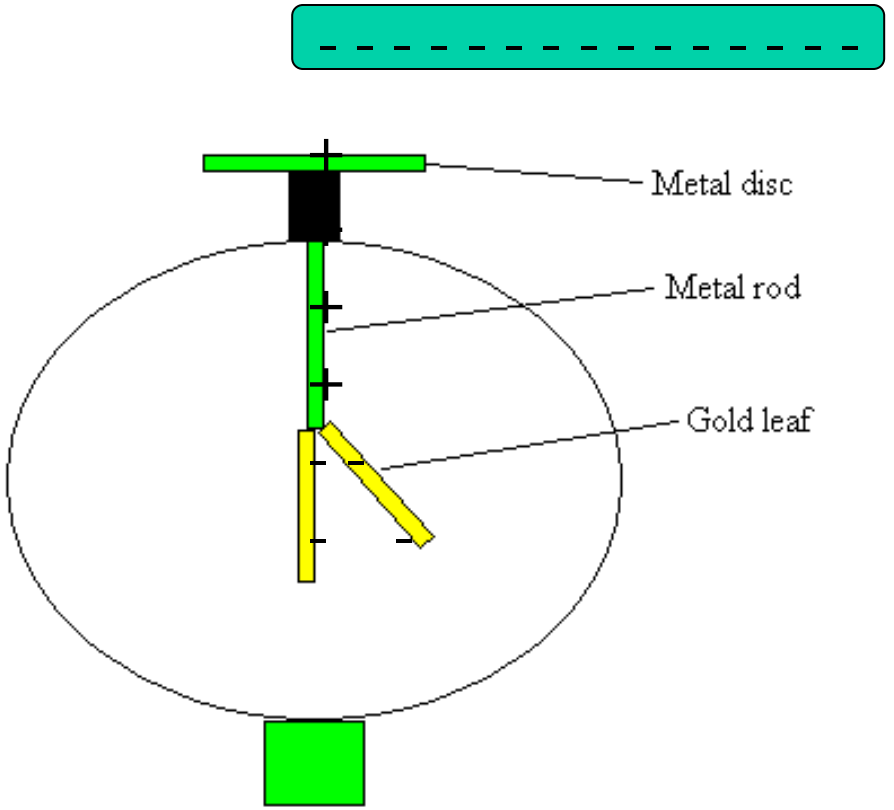


Figure 2: The classical electroscope