PHYS 1442 – Section 001
Lecture #1

Monday, June 3, 2013

Dr. Jaehoon Yu

- Who am I?
- How is this class organized?
- What is Physics?
- What do we want from this class?
- Brief history of physics
- Some basics …
- Chapter 16
  - Static Electricity and Charge Conservation
  - Charges in Atom, Insulators and Conductors & Induced Charge

Today's homework is homework #1, due 11pm, this Thursday!!

Announcements

- Plea to you: Please turn off your cell-phones, pagers and computers in the class
- Reading assignment #1: Read and follow through all sections in appendix A by Wednesday, June 5
  - A-1 through A-8
- There will be a quiz on this and Ch. 16 on Thursday, June 6.

Who am I?

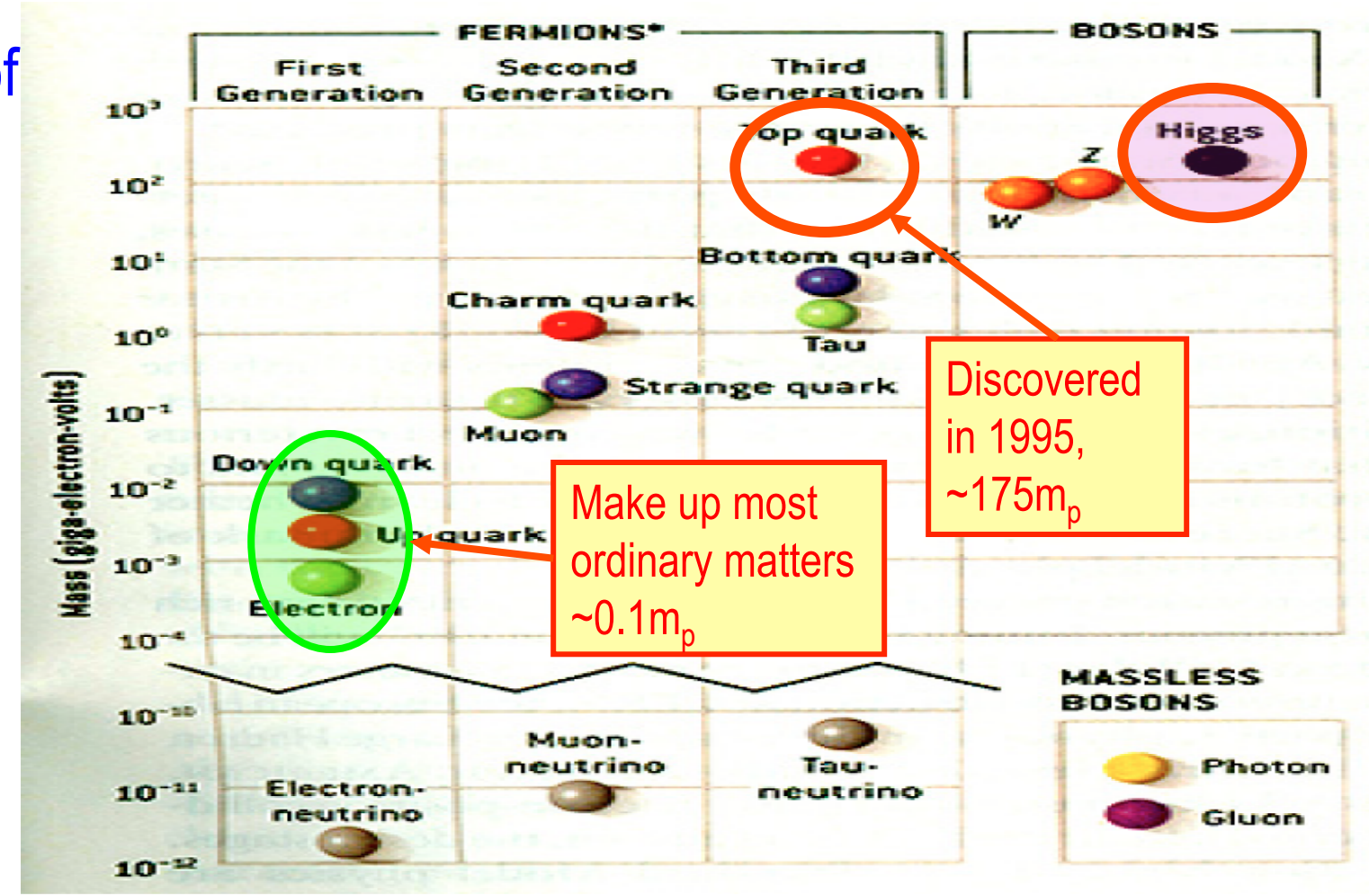
- Name: Dr. Jaehoon Yu (You can call me **Dr. Yu**)
- Office: Rm 342, Chemistry and Physics Building
- Extension: x22814, E-mail: *jaehoonyu@uta.edu*
- My profession: High Energy Particle Physics (HEP)
  - Collide particles (protons on anti-protons or electrons on anti-electrons, positrons) at the energies equivalent to 10,000 Trillion degrees
  - To understand
    - Fundamental constituents of matter
    - Forces between the constituents (gravitational, electro-magnetic, weak and strong forces)
    - Origin of Mass
    - Search for Dark Matter
    - Creation of Universe (**Big Bang** Theory)
  - A pure scientific research activity
    - Direct use of the fundamental laws we find may take longer than we want but
    - Indirect product of research contribute to every day lives; eg. WWW
  - Why do we do with this?
    - Make our everyday lives better to help us live well as an integral part of the universe

We always wonder…

- What makes up the universe?
- How does the universe work?
- What holds the universe together?
- How can we live in the universe well?
- Where do we all come from?

HEP and the Standard Model

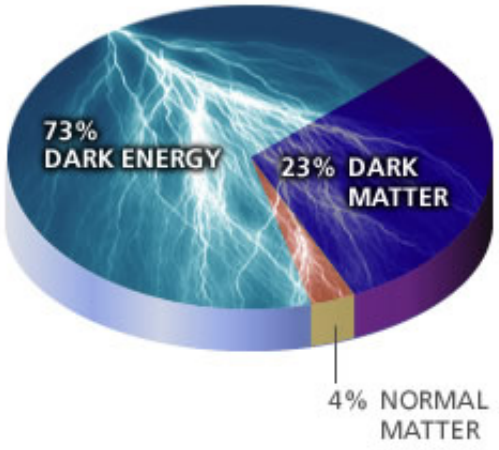
HEP: A field of physics that studies the fundamental constituents of matter and basic principles of interactions between them.



- Total of 16 particles (12+4 force mediators) make up all the visible matter in the universe! ➔ Simple and elegant!!!
- Tested to a precision of 1 part per million!

So what's the problem?

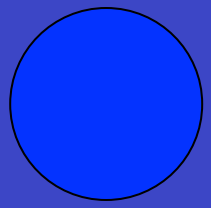
- Why is the mass range so large ($0.1m_p$ – $175\ m_p$)?
- How do matters acquire mass?
  - Higgs mechanism, did we find the Higgs particle?
- Why is the matter in the universe made only of particles?
- Neutrinos have mass!! What are the mixing parameters, CP violations and mass ordering?
- Why are there only three apparent forces?
  - Can the forces be unified?
- Is the picture we present the real thing?
  - What makes up the 96% of the universe?
  - What is the dark matter and dark energy?



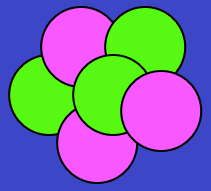
- Are there any other theories that describe the universe better?
  - Does the super-symmetry exist?
- How is the universe created, the Big Bang?

Accelerators are Powerful Microscopes.

They make high energy particle beams that allow us to see small things.



seen by
low energy beam
(poorer resolution)



seen by
high energy beam
(better resolution)

Accelerators are also Time Machines.

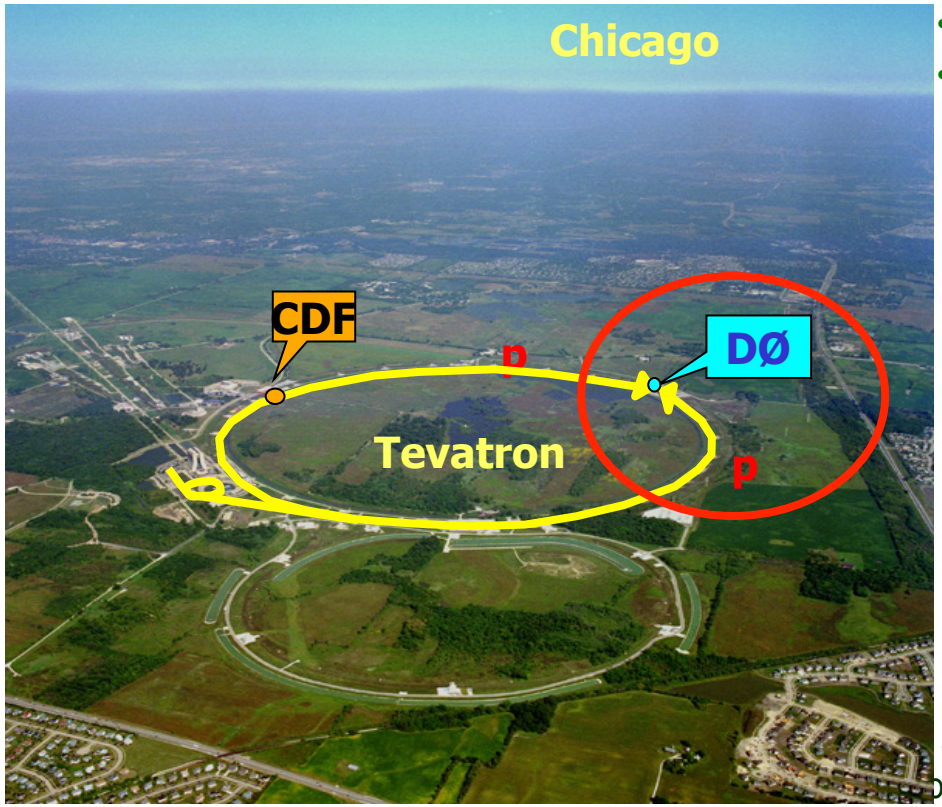
They make particles last seen
in the earliest moments of the universe.

Particle and anti-particle annihilate.

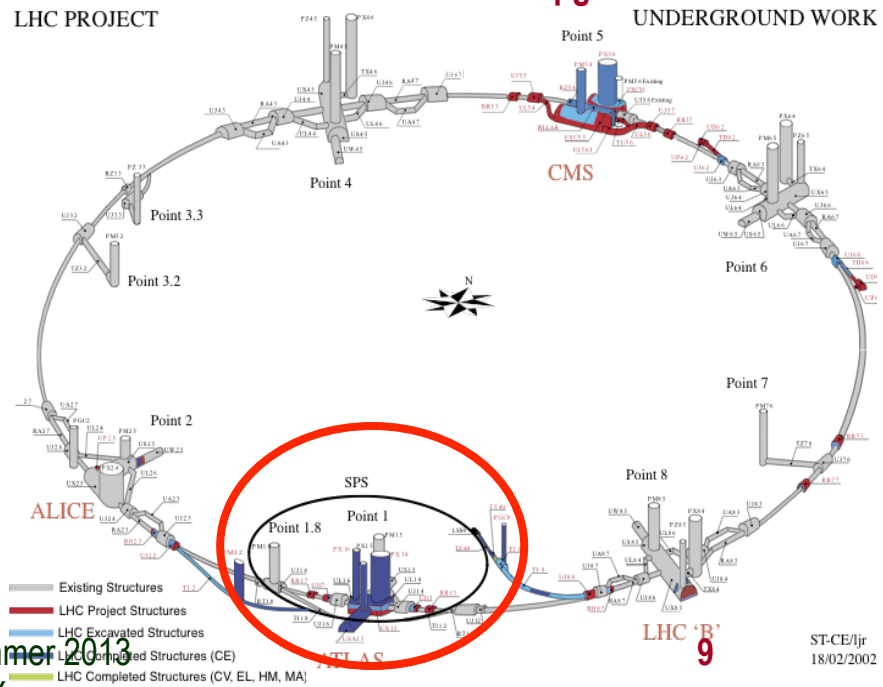
$$E = mc^2$$

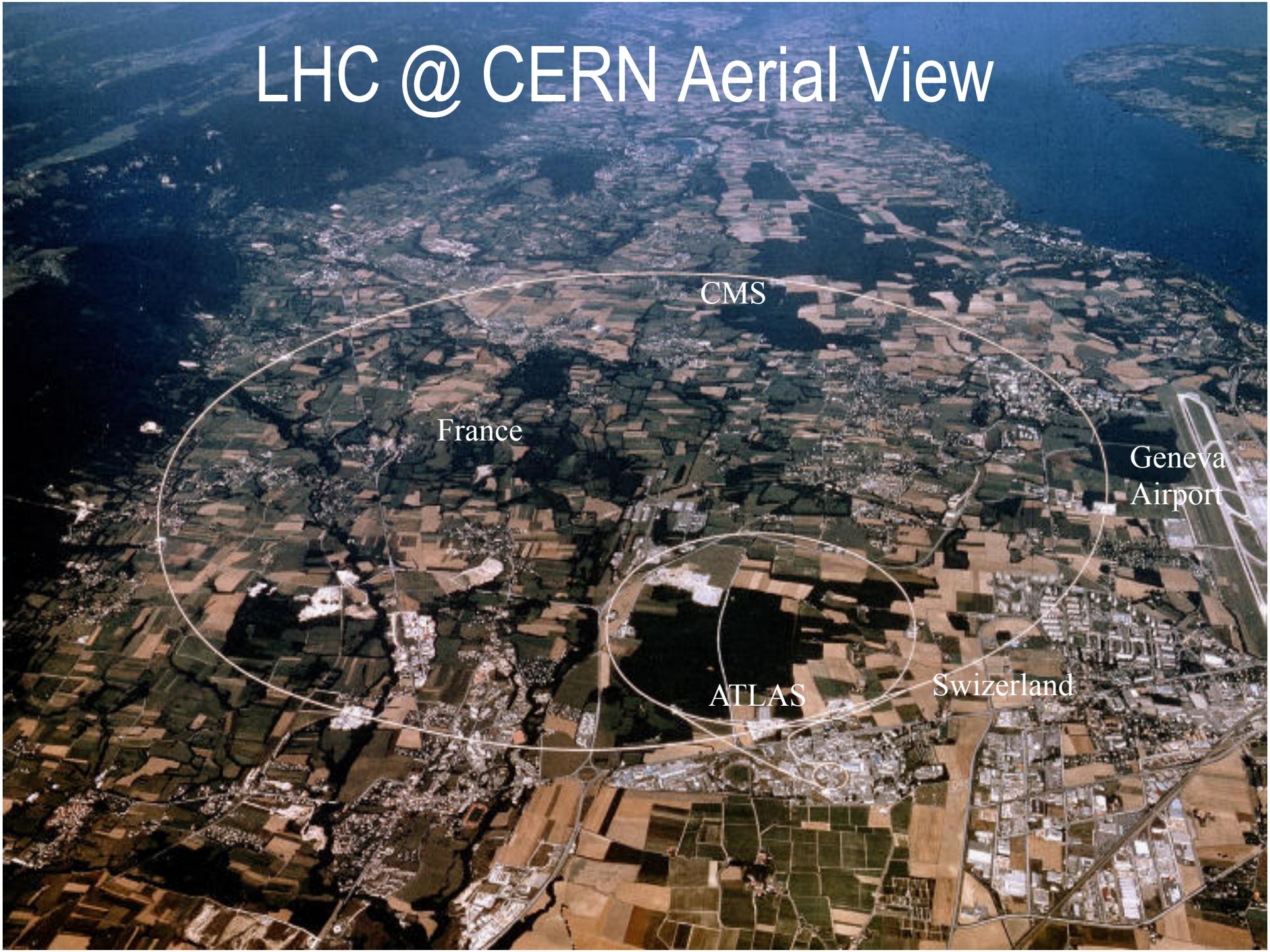
Fermilab Tevatron and LHC at CERN

- World's Highest Energy proton-anti-proton collider
  - 4km circumference
  - E_{cm}=1.96 TeV (=6.3x10^{-7}J/p➔ 13M Joules on the area smaller than 10^{-4}m^2)
  - Equivalent to the kinetic energy of a 20t truck at the speed 81mi/hr➔ 130km/hr
    - ~100,000 times the energy density at the ground 0 of the Hiroshima atom bomb
  - **Was shut down on Sept. 30, 2011**
  - **Vibrant other programs running, including the search for dark matter!!**

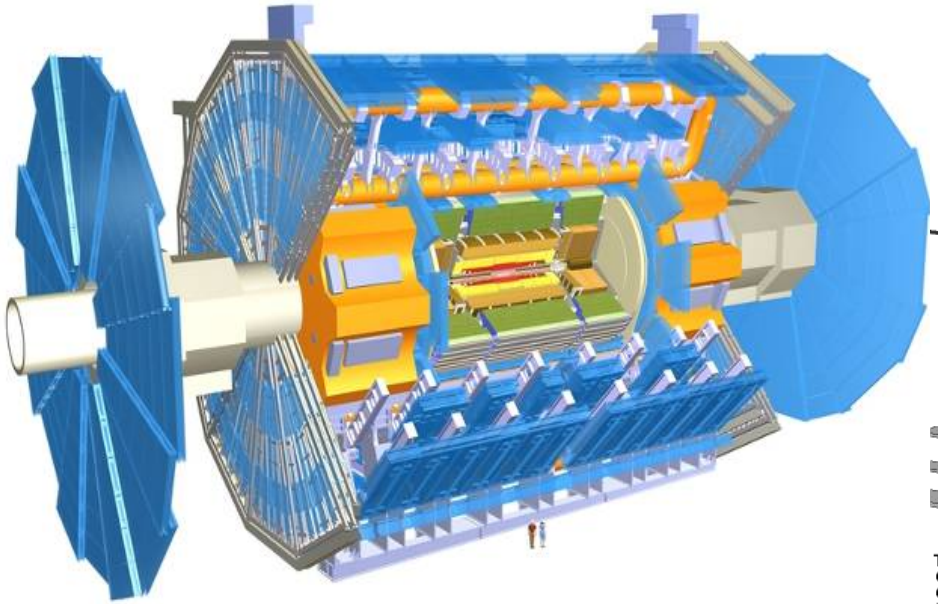


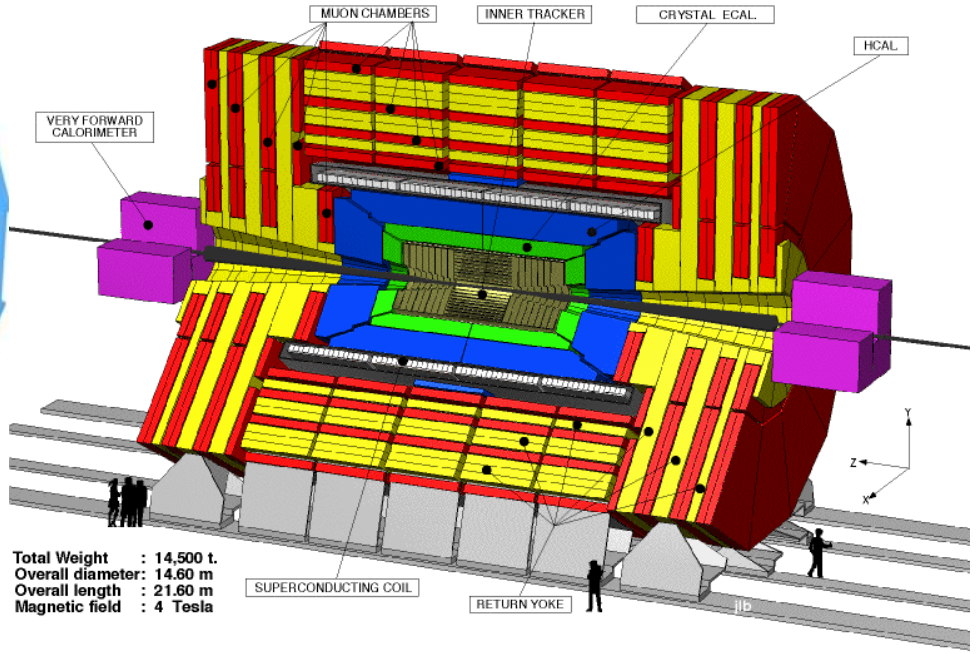
- World's Highest Energy p-p collider
  - 27km circumference, 100m underground
  - Design E_{cm}=14 TeV (=44x10^{-7}J/p➔ 362M Joules on the area smaller than 10^{-4}m^2)
  - ➢ Equivalent to the kinetic energy of a B727 (80tons) at the speed 193mi/hr ➔ 312km/hr
    - ➢ ~3M times the energy density at the ground 0 of the Hiroshima atom bomb
- First 7TeV collisions 2010 ➔ The highest energy humans ever achieved!!
- **Large amount of data accumulated in 2011 – 2013**
- **Shutdown in Feb. 2013 for 18mo for upgrade**



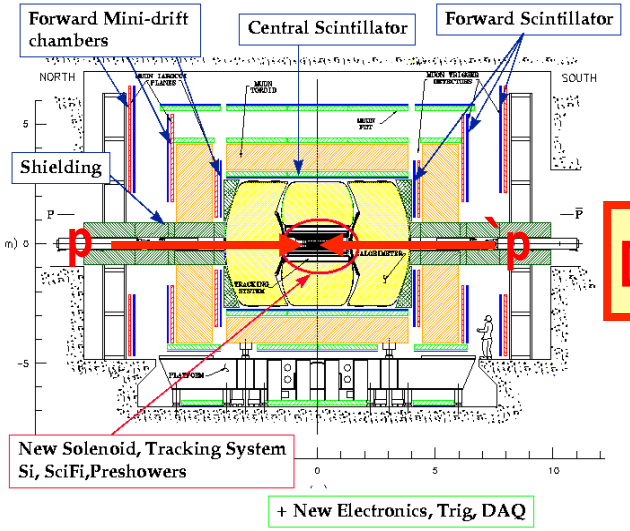

LHC @ CERN Aerial View
CMS
France
Geneva
Airport
ATLAS
Swizerland

The ATLAS and CMS Detectors





- **Fully multi-purpose detectors with emphasis on lepton ID & precision E & P**
- **Weighs 7000 tons and 10 story tall**
- Records **200 – 400 collisions/second**
- Records approximately **350** MB/second
- Record ~2 PB per year ➔ **200*Printed material of the US Lib. of Congress**



Digital data

Data Reconstruction

What is the Higgs and What does it do?

- When there is perfect symmetry, one cannot tell directions!
- Only when symmetry is broken, can one tell directions
- Higgs field works to break the perfect symmetry and gives mass to all fundamental particles
- In this process, this field spontaneously generates a particle, the Higgs particle
- So the Higgs particle is a piece of evidence of the existence of the Higgs field!

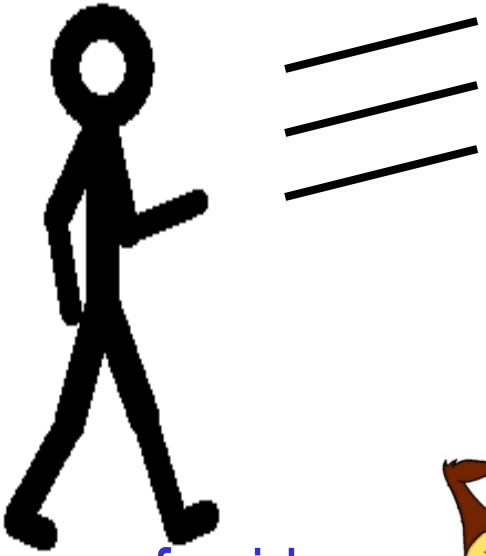
What? What's the symmetry?

- Where is the head of the table?
- Without a broken symmetry, one cannot tell directional information!!

So how does Higgs Field work again?

- Person in space ➔ no symmetry breaking

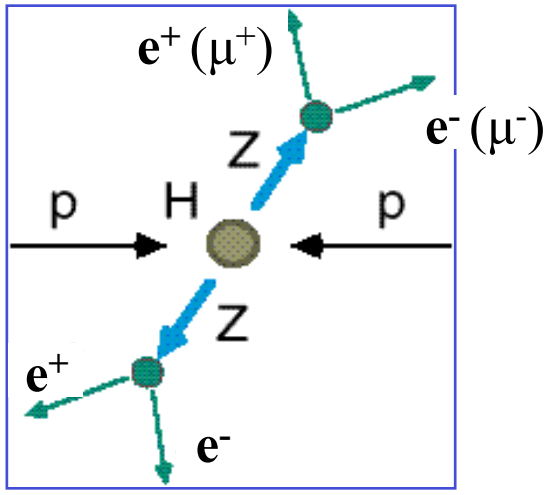
- Person in air ➔ symmetry can be broken
- Sometimes, you get



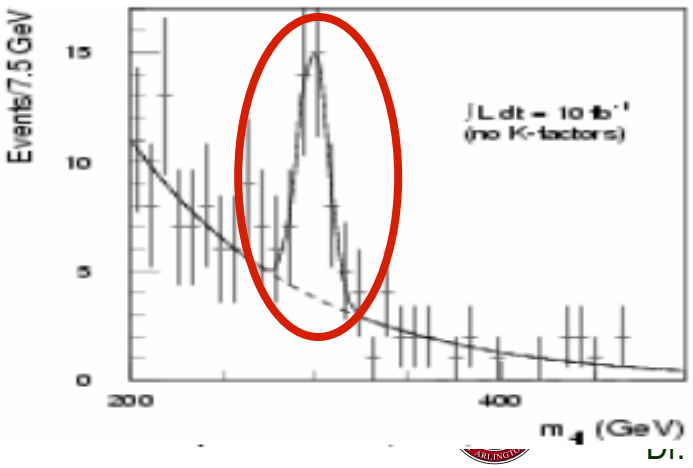
Just like a tornado is a piece of evidence of the existence of air, Higgs particle is a piece of evidence of Higgs mechanism

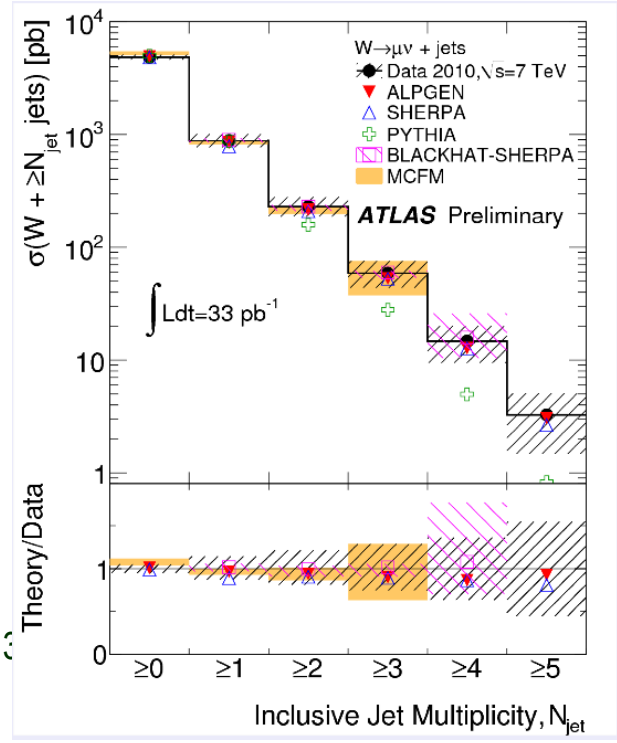
How do we look for the Higgs?

- Identify Higgs candidate events

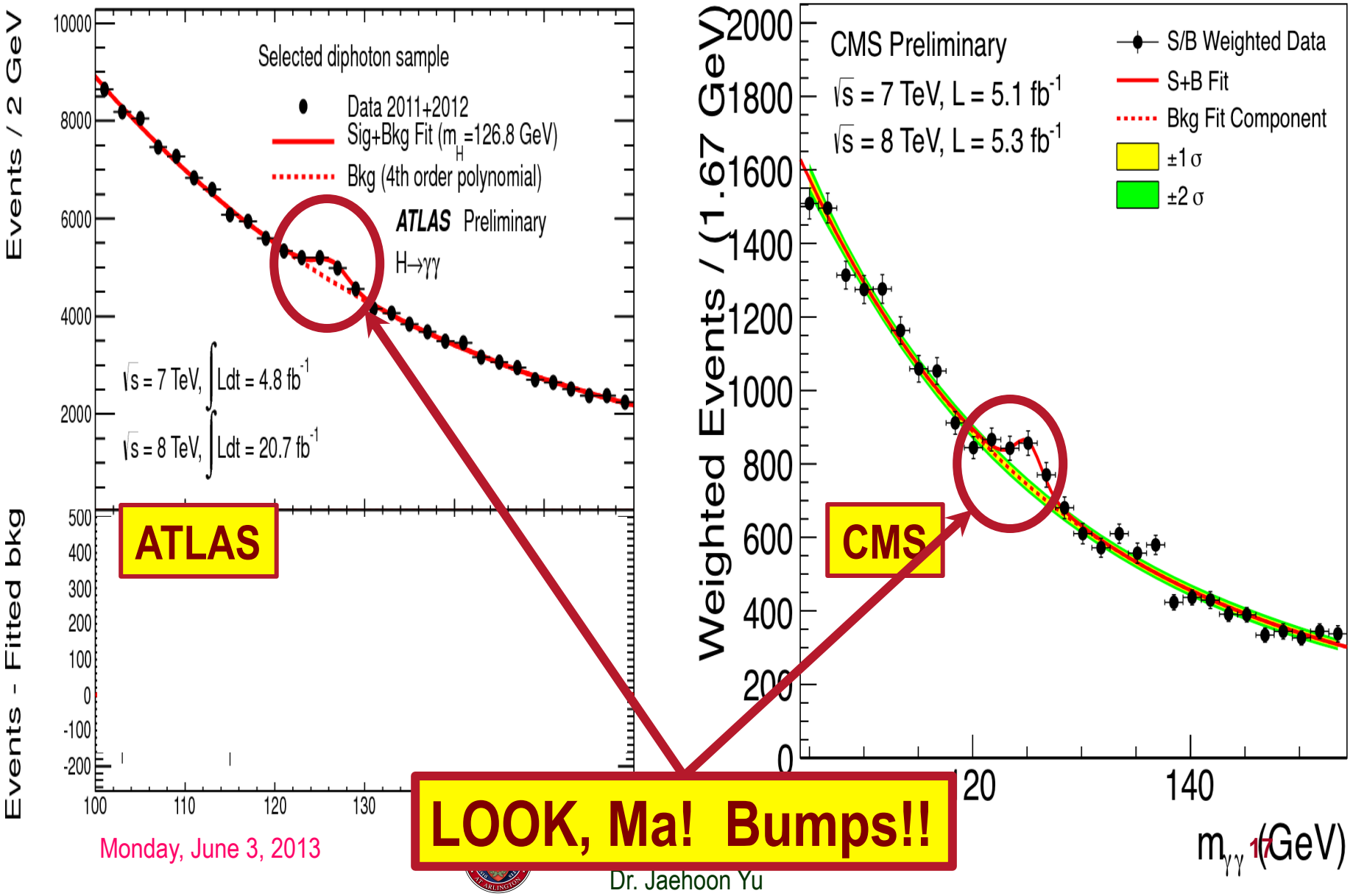


- Understand fakes (backgrounds)
- Look for a bump!!
  - Large amount of data absolutely critical



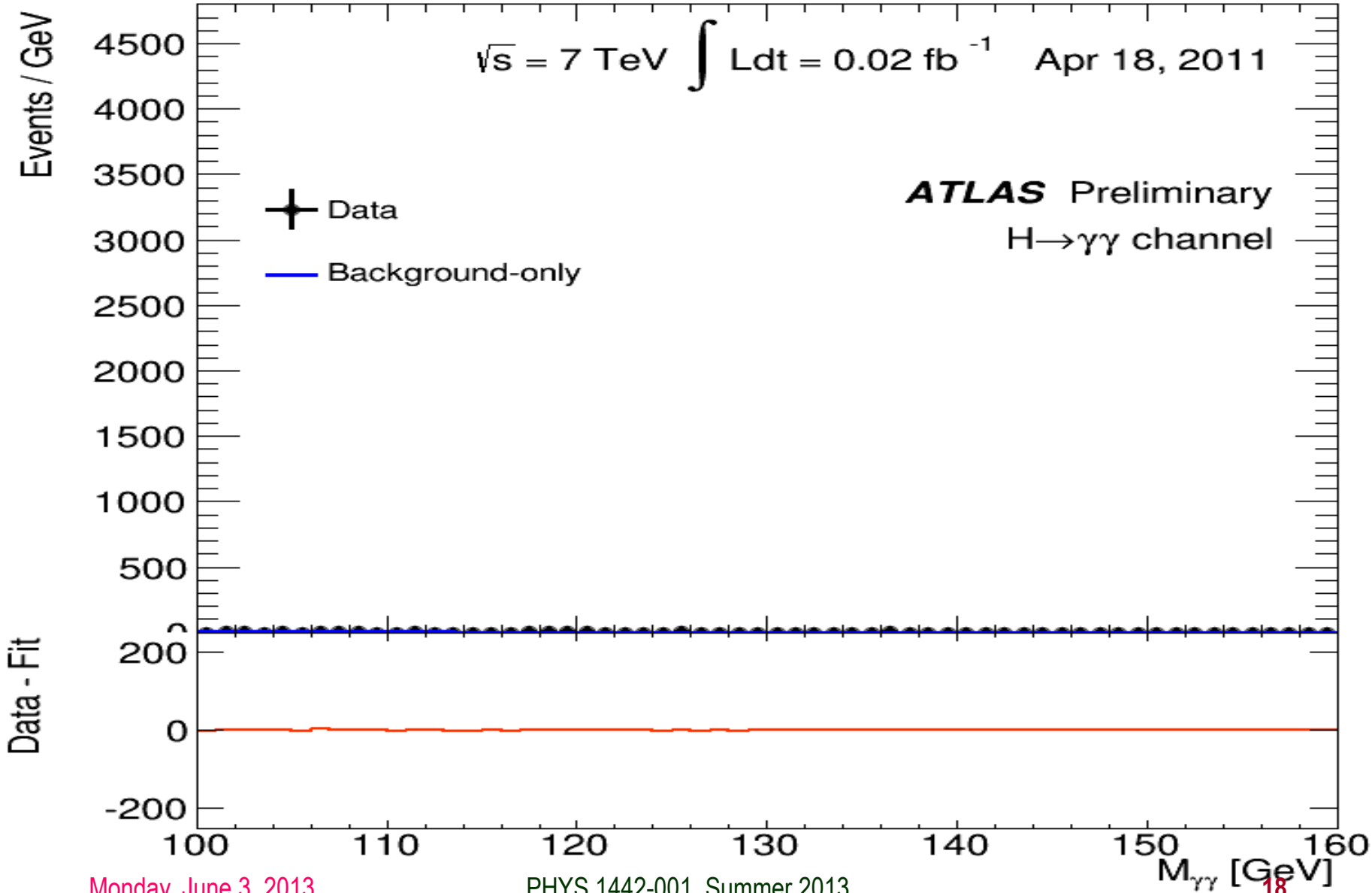


ATLAS and CMS Mass Bump Plots ($H \rightarrow \gamma\gamma$)



LOOK, Ma! Bumps!!

What did statistics do for Higgs?



So have we seen the Higgs particle?

- The statistical significance of the finding is way over 7 standard deviations

Statistical Significance Table

zσ	Percentage within CI	Percentage outside CI	Fraction outside CI
0.674 490σ	50%	50%	1 / 2
0.994 458σ	68%	32%	1 / 3.125
1σ	68.268 9492%	31.731 0508%	1 / 3.151 4872
1.281 552σ	80%	20%	1 / 5
1.644 854σ	90%	10%	1 / 10
1.959 964σ	95%	5%	1 / 20
2σ	95.449 9736%	4.550 0264%	1 / 21.977 895
2.575 829σ	99%	1%	1 / 100
3σ	99.730 0204%	0.269 9796%	1 / 370.398
3.290 527σ	99.9%	0.1%	1 / 1,000
3.890 592σ	99.99%	0.01%	1 / 10,000
4σ	99.993 666%	0.006 334%	1 / 15,787
4.417 173σ	99.999%	0.001%	1 / 100,000
4.891 638σ	99.9999%	0.0001%	1 / 1,000,000
5σ	99.999 942 6697%	0.000 057 3303%	1 / 1,744,278
5.326 724σ	99.999 99%	0.000 01%	1 / 10,000,000
5.730 729σ	99.999 999%	0.000 001%	1 / 100,000,000
6σ	99.999 999 8027%	0.000 000 1973%	1 / 506,797,346
6.109 410σ	99.999 9999%	0.000 0001%	1 / 1,000,000,000
6.466 951σ	99.999 999 99%	0.000 000 01%	1 / 10,000,000,000
6.806 502σ	99.999 999 999%	0.000 000 001%	1 / 100,000,000,000
7σ	99.999 999 999 7440%	0.000 000 000 256%	1 / 390,682,215,445

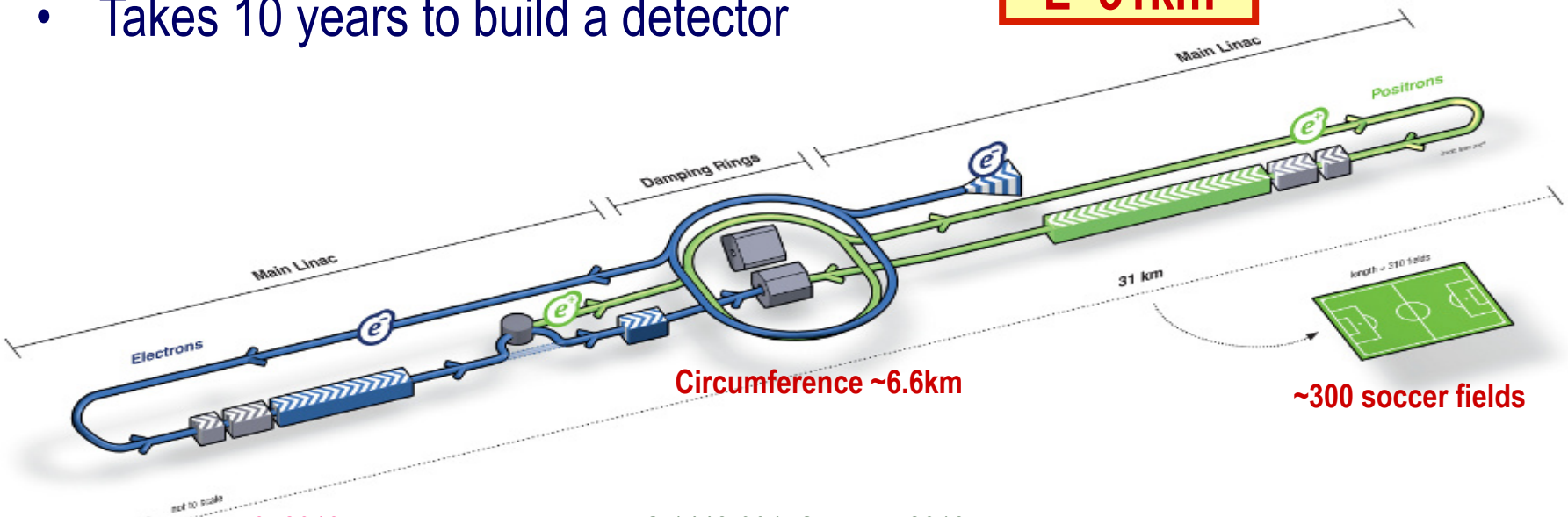
So have we seen the Higgs particle?

- The statistical significance of the finding is over 7 standard deviations
  - Level of significance: 99.999 999 999 7% (eleven 9s!!)
  - We can be wrong once if we do the same experiment 391,000,000,000 times
- So did we find the Higgs particle?
  - We have discovered a new particle, the heaviest boson we've seen thus far
  - It has many properties consistent with the Standard Model Higgs particle
  - We, however, do not have enough data to precisely measure all the properties – mass, lifetime, the rate at which this particle decays to certain other particles, etc – to definitively determine
- UTA had a lecture by Nobel Laureate, prof. Steven Weinberg, which was attended by 1200 people!!

What next? Future Linear Collider

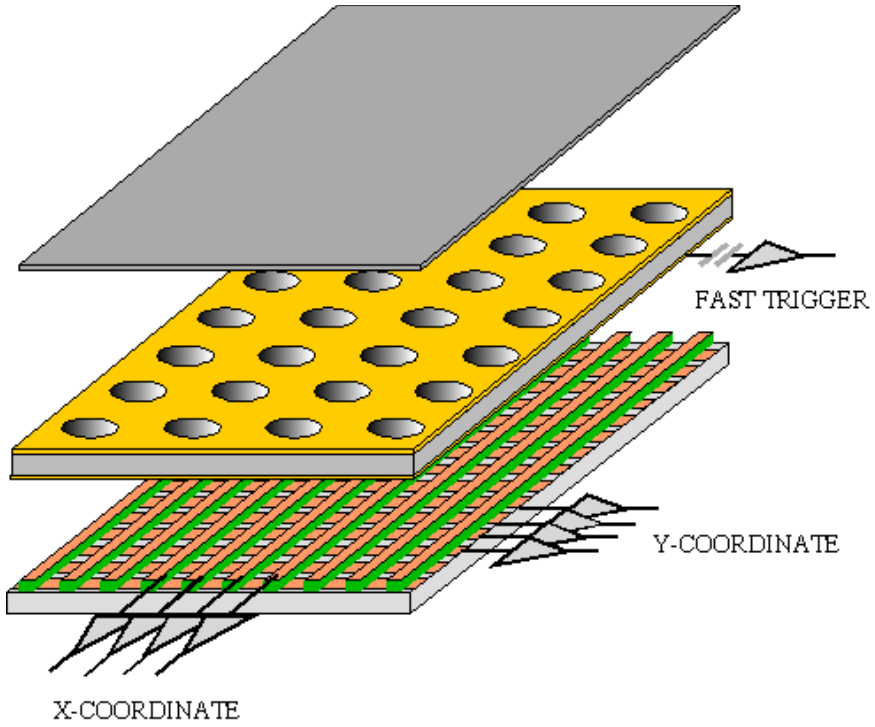
- Now that we have found a new boson, precision measurement of the particle's properties becomes important
- An electron-positron collider on a straight line for precision measurements
- 10~15 years from now (In Dec. 2011, Japanese PM announced that they would bid for a LC in Japan and reaffirmed by the new PM in 2013
  - Our Japanese colleagues have declared that they will bid for building a 250GeV machine in Japan!!
- Takes 10 years to build a detector

L~31km

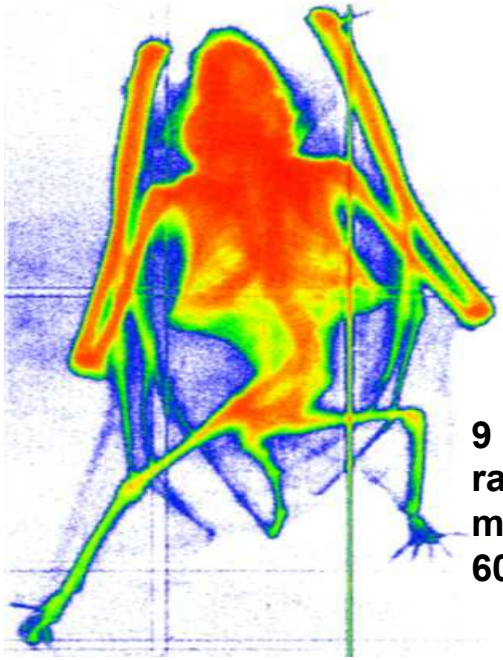


GEM Application Potential

Using the lower GEM signal, the readout can be self-triggered with energy discrimination:



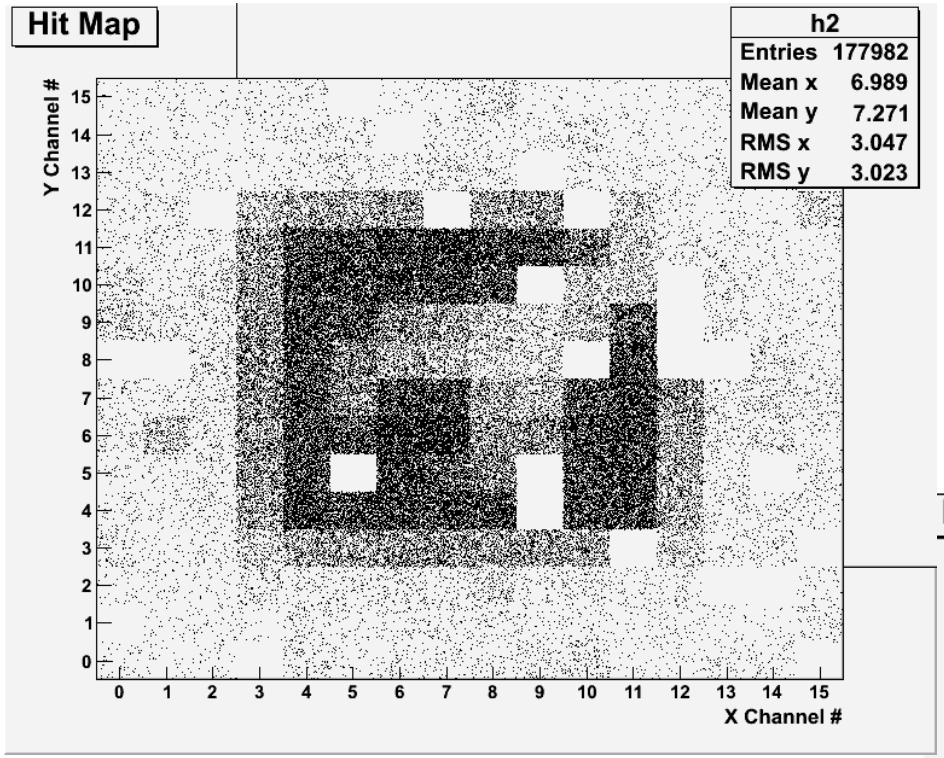
FAST X-RAY IMAGING

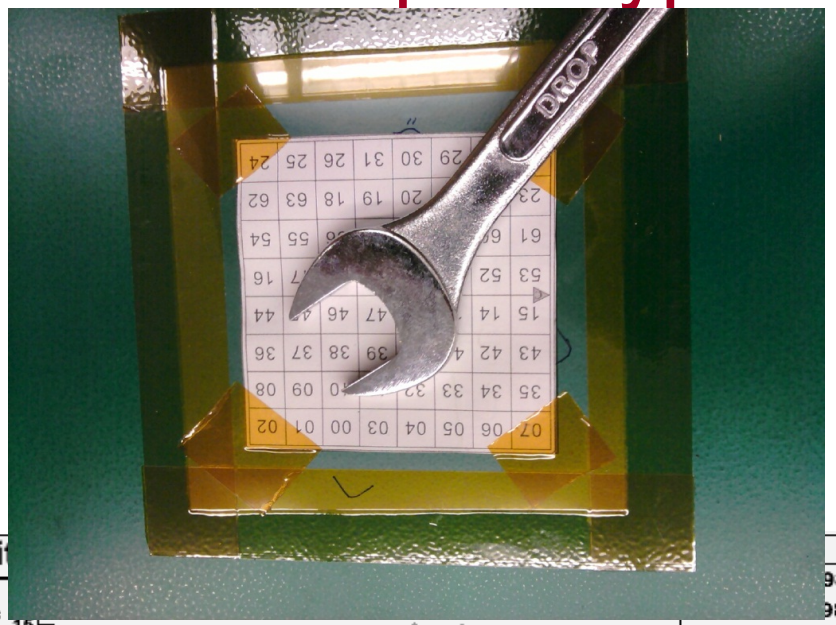


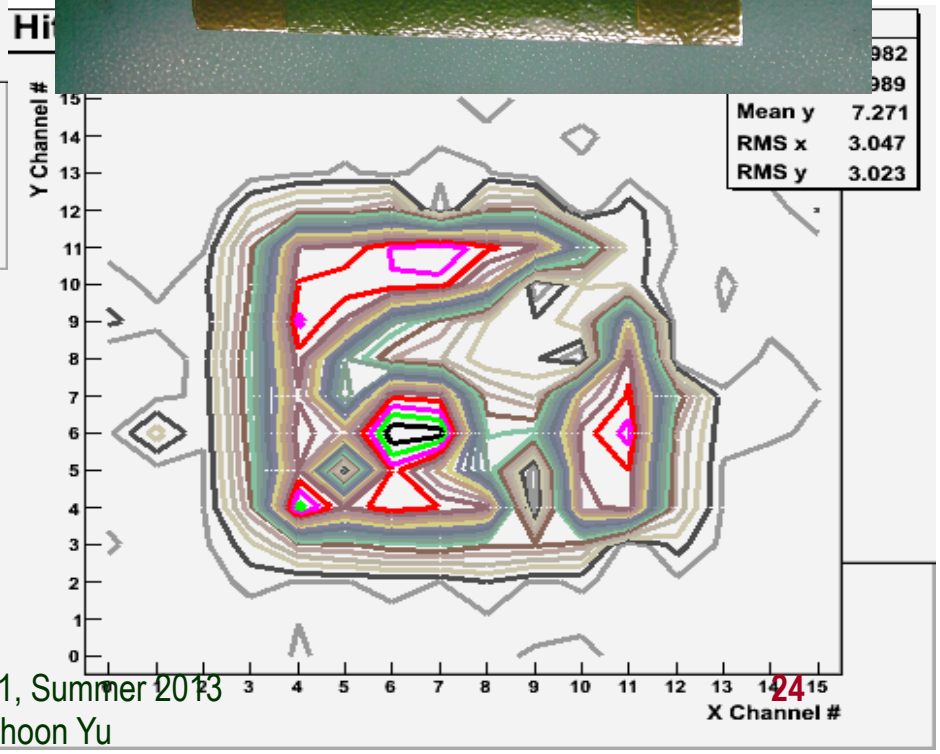
9 keV absorption radiography of a small mammal (image size ~ 60 x 30 mm^2)

A. Bressan et al,
Nucl. Instr. and Meth. A 425(1999)254
F. Sauli, Nucl. Instr. and Meth.A 461(2001)47

X-ray Image of an object with a prototype







Can you see what the object is?


And in not too distant future, we could do ...

Information & Communication Source

- My web page: http://www-hep.uta.edu/~yu/
  - Contact information & Class Schedule
  - Syllabus
  - Homework
  - Holidays and Exam days
  - Evaluation Policy
  - Class Style & Communication
  - Other information
- Primary communication tool is e-mail: Make sure your e-mail address on your registration points to the most favorite one that you read at least once a day
- Office Hours: 12:30 – 1:30pm, Monday - Thursday or by appointments

Evaluation Policy

- Homework: 25%
- Exams
  - Final Comprehensive Exams (7/8): 23%
  - Mid-term Comprehensive Exam (6/19): 20%
  - One better of the two term Exams: 12%
    - Total of two non-comprehensive term exams (6/11 and 6/27)
    - One better of the two exams will be used for the final grade
  - Missing an exam is not permissible unless pre-approved
    - No makeup test
    - You will get an F if you miss any of the exams without a prior approval no matter how well you've been doing in class!
- Lab score: 10%
- Pop-quizzes: 10%

100%

- Extra credits: 10% of the total
  - Random attendances
  - Strong participation in the class discussions
  - Special projects (BIGGGGG!!!)
  - Planetarium shows and Other many opportunities
- Grading will be done on a sliding scale

Homework

- Solving homework problems is the only way to comprehend class material ➔ 2 homeworks per week
- An electronic homework system has been setup for you
  - Details are in the material distributed today and on the web
  - https://quest.cns.utexas.edu/student/courses/list
  - Choose the course **1442-Summer13**, unique number **42013**
  - Download homeworks, solve the problems and submit them online
  - Multiple unsuccessful tries will deduct points
  - Roster will close at tpm Wednesday, June 4
  - You need a UT e-ID: Go and apply at the URL https://idmanager.its.utexas.edu/eid_self_help/?createEID&qwicap-page-id=EA027EFF7E2DA39E if you don't have one.
- Each homework carries the same weight
- Home work problems will be slightly ahead of the class
- **No** homework will be dropped from the final grade!!
- Home work will constitute **25% of the total** ➔ A good way of keeping your grades high
- Strongly encouraged to collaborate ➔ Does not mean you can copy

Attendances and Class Style

- Attendances:
  - Will be taken randomly
  - Will be used for extra credits
- Class style:
  - Lectures will be on electronic media
    - The lecture notes will be posted on the web **AFTER** each class
  - Will be mixed with traditional methods
  - Active participation through questions and discussions are **STRONGLY** encouraged ➔ Extra credit….
  - Communication between you and me is extremely important
    - If you have problems, please do not hesitate talking to me

Lab and Physics Clinic

- Physics Labs:
  - Intro-labs on Wednesday and Thursday, June 5 and 6 (official beginning June 10)
  - Important to understand physical principles through experiments
  - 10% of the grade
  - Prelab questions can be obtained at www.uta.edu/physics/labs
  - Lab syllabus is available in your assigned lab rooms.
- Physics Clinic:
  - Free service
  - They provide general help on physics, including help solving homework problems
    - Do not expect solutions of the problem from them!
    - Do not expect them to tell you whether your answers are correct!
    - It is your responsibility to make sure that you have done everything correctly!
  - 11am – 6pm, Mon – Thu in SH 007
  - This service begins today!
  - Please take full advantage of this service!!

Extra credit

- 10% addition to the total
  - Could boost a B to A, C to B or D to C
- What constitute for extra credit?
  - Special projects (biggest!!)
  - Random attendances
  - Strong participation in the class discussions
  - Watch the valid planetarium shows
  - Many other opportunities

Valid Planetarium Shows

- Regular running shows
  - We Are Astronomers - Wednesdays at 2:00 and Saturdays at 5:30
  - Time Space – Fridays at 2:00 and Saturdays at 2:30
- Shows that need special arrangements
  - Astronaut; Bad Astronomy; Black Holes (can watch up to 2 times)
  - Experience the Aurora IBEX; Ice Worlds; Magnificent Sun; Mayan Prophecies
  - Nano Cam; Stars of the Pharaohs; Two Small Pieces of Glass
  - Unseen Universe: The Vision of SOFIA; Violent Universe
- How to submit for extra credit?
  - Obtain the ticket stub that is signed and dated by the planetarium star lecturer of the day
  - Collect the ticket stubs
  - Tape one edge of all of the ticket stubs on a sheet of paper with your name and ID written on it
  - Submit the sheet at the end of the semester at the final exam

What can you expect from this class?

- All A's?
  - This would be really nice, wouldn't it?
  - But if it is too easy it is not fulfilling or meaningful….
- This class is not going to be a stroll in the park!!
- You will earn your grade in this class.
  - You will need to put in sufficient time and sincere efforts
  - Exams and quizzes will be tough!!
    - Sometimes problems might not look exactly like what you learned in the class
    - Just putting the right answer in free response problems does not work!
- But you have a great control (up to 45%) of your grade in your hands
  - Homework is 25% of the total grade!!
    - Means you will have many homework problems
      - Sometimes much more than any other classes
      - Sometimes homework problems will be something that you have yet to learn in class
      - Exam's problems will be easier that homework problems but same principles!!
  - Lab 10%
  - Extra credit 10%
- I will work with you so that your efforts are properly rewarded

What do we want to learn in this class?

- Physics is everywhere around you.
- Skills to understand the fundamental principles that surrounds you in everyday lives…
- Skills to identify what laws of physics applies to what phenomena and use them appropriately
- Understand the impact of physical laws and apply them
- Learn skills to think, research and analyze observations.
- Learn skills to express observations and measurements in mathematical language
- Learn skills to express your research in systematic manner in writing
- But most importantly the confidence in your physics ability and to take on any challenges laid in front of you!!

Most importantly, let us have a lot of FUN!!

In this course, you will learn…

- Fundamentals of Electricity and Magnetism
- Electric and Magnetic Forces and Fields
- Electric charge and magnetic poles
- Electric and magnetic potential, energy and power
- Propagation of electric and magnetic fields
- Relationship between electro-magnetic forces and light
- Behaviors of light and optics
- Special relativity and quantum theories

How to study for this course?

- Keep up with the class for comprehensive understanding of materials
  - Come to the class and participate in the discussions and problems solving sessions
  - Follow through the lecture notes
  - Work out example problems in the book yourself without looking at the solution
  - Have many tons of fun in the class!!!!!
- Keep up with the homework to put the last nail on the coffin
  - One can always input the answers as you solve the problems. Do not wait till you are done with all the problems.
  - Form a study group and discuss how to solve problems with your friends, then work the problems out yourselves!
- Prepare for upcoming classes
  - Read the textbook for the material to be covered in the next class
- The extra mile
  - Work out additional problems in the back of the book starting the easiest problems to harder ones

Extra Credit Special Project #1

- Compare the Coulomb force to the Gravitational force in the following cases by expressing Coulomb force (F_C) in terms of the gravitational force (F_G)
  - Between two protons separated by 1m
  - Between two protons separated by an arbitrary distance R
  - Between two electrons separated by 1m
  - Between two electrons separated by an arbitrary distance R
- Five points each, totaling 20 points
- BE SURE to show all the details of your work, including all formulae, and properly referring them
- Please staple them before the submission
- Due at the beginning of the class Monday, June 10

Brief History of Physics

- AD 18th century:
  - Newton's Classical Mechanics: A theory of mechanics based on observations and measurements
- AD 19th Century:
  - Electricity, Magnetism, and Thermodynamics ➔ unification of forces
- Late AD 19th and early 20th century (Modern Physics Era)
  - Einstein's theory of relativity: Generalized theory of space, time, and energy (mechanics)
  - Quantum Mechanics: Theory of atomic phenomena
- Physics has come very far, very fast, and is still progressing, yet we've got a long way to go
  - What is matter made of?
  - How do matters get mass? ➔ Better than before since Higgs was found
  - How and why do matters interact with each other?
  - How is universe created?
  - What are Dark Matter and Dark Energy?

Needs for Standards and Units

- Three basic quantities for physical measurements
  - Length, Mass, and Time
- Need a language that everyone can understand each other
  - Consistency is crucial for physical measurements
  - The same quantity measured by one must be comprehendible and reproducible by others
  - Practical matters contribute
- A system of unit called **SI** (*System International*) established in 1960
  - Length in meters (m)
  - Mass in kilo-grams (kg)
  - Time in seconds (s)

SI Base Quantities and Units

Quantity	Unit	Unit Abbrevation
Length	Meter	m
Time	Second	s
Mass	Kilogram	kg
Electric current	Ampere	A
Temperature	Kelvin	k
Amount of substance	Mole	mol
Luminous Intensity	Candela	cd

- *There are prefixes that scales the units larger or smaller for convenience (see pg. 7)*

Prefixes, expressions and their meanings

- deca (da): 10^{1}
- hecto (h): 10^{2}
- kilo (k): 10^{3}
- mega (M): 10^{6}
- giga (G): 10^{9}
- tera (T): 10^{12}
- peta (P): 10^{15}
- exa (E): 10^{18}
- deci (d): 10^{-1}
- centi (c): 10^{-2}
- milli (m): 10^{-3}
- micro (μ): 10^{-6}
- nano (n): 10^{-9}
- pico (p): 10^{-12}
- femto (f): 10^{-15}
- atto (a): 10^{-18}

How do we convert quantities from one unit to another?

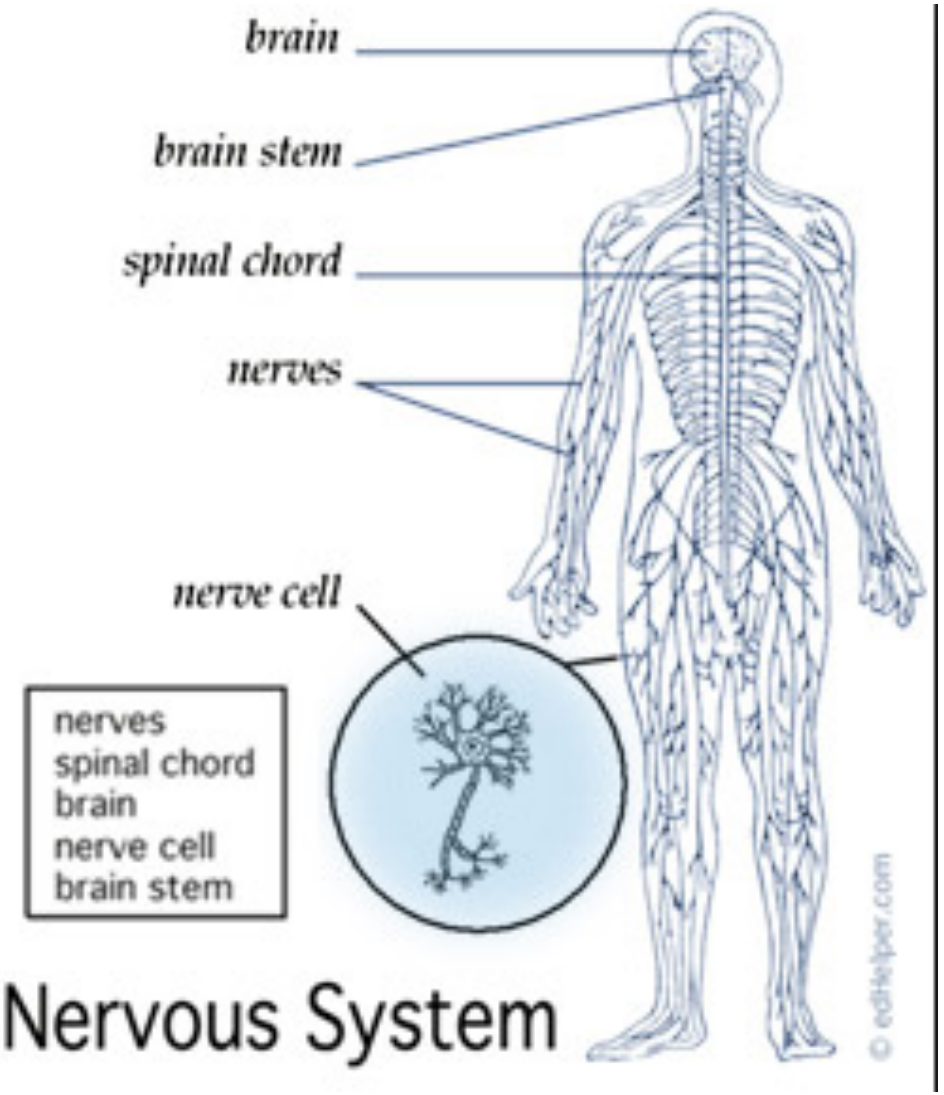
Unit 1 =	Conversion factor X	Unit 2
1 inch	2.54	cm
1 inch	0.0254	m
1 inch	2.54×10^{-5}	km
1 ft	30.3	cm
1 ft	0.303	M
1 ft	3.03×10^{-4}	km
1 hr	60	minutes
1 hr	3600	seconds
And many	More	Here….

What does the Electric Force do?

- Electric force froms the bases of modern technology
  - Virtually everything we use every day uses the electric force
    - Can you give a few examples?
- But this force also affects many others
  - Making up materials with atoms and molecules
  - Biological metabolic processes
    - Nerve signals, heart pumping, etc

Human Nerve System Wiring

- Nerve signals sent to the entire body via nerve wiring, just like any electronic gadgets we use



What does the Electric Force do?

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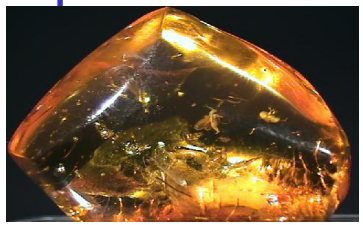
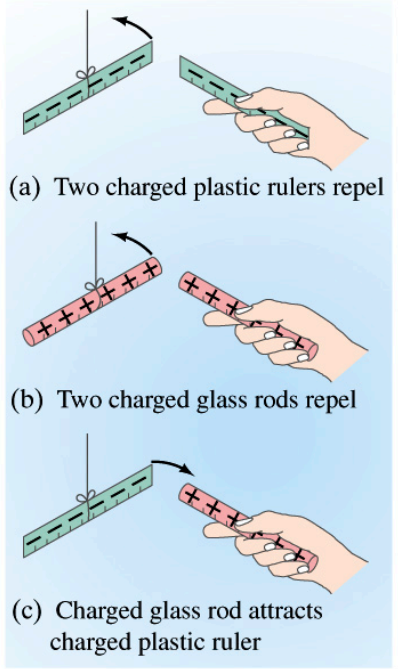
    - Can you give a few examples?
- But this force also affects many others
  - Making up materials with atoms and molecules
  - Biological metabolic processes
    - Nerve signals, heart pumping, etc
- Virtually all the forces we have learned in Physics I:
  - Friction, normal force, elastic force and other contact forces are the results of electric forces acting at the atomic level

Static Electricity; Electric Charge and Its Conservation

- Electricity is from Greek word *elecktron*=amber, a petrified tree resin that attracts matter when rubbed



- Static Electricity: an amber effect
  - An object becomes charged or "posses a net electric charge" due to rubbing
  - Can you give some examples?
- Two types of the electric charge
  - Like charges repel while unlike charges attract
  - Benjamin Franklin referred the charge on glass rod as the positive, arbitrarily. Thus the charge that attracts glass rod is negative. ➔ This convention is still used.



Static Electricity; Electric Charge and Its Conservation

- Ben Franklin argued that when a certain amount of charge is produced on one body in a process, an equal amount of opposite type of charge is produced on another body.
  - The positive and negative are treated algebraically so that at any time in the process the net change in the amount of produced charge is 0.
    - When you comb your hair with a plastic comb, the comb acquires a negative charge and the hair an equal amount of positive charge.
- This is the **law of conservation of electric charge.**
  - **The net amount of electric charge produced in any process is ZERO!!**
  - **No net electric charge can be created or destroyed**
    - If one object or one region of the space acquires a positive charge, then an equal amount of negative charge will be found in neighboring areas or objects.
    - No violations have ever been observed.
    - This conservation law is as firmly established as that of energy or momentum.

Electric Charge in the Atom

- It has been understood through the past century that an atom consists of
  - A positively charged heavy core ← What is the name?
    - This core is nucleus and consists of neutrons and protons.
  - Many negatively charged light particles surround the core ← What is the name of these light particles?
    - These are called electrons
    - How many of these?

As many as the number of protons!!

- So what is the net electrical charge of an atom?
  - Zero!!! Electrically neutral!!!
- Can you explain what happens when a comb is rubbed on a towel?
  - Electrons from towel get transferred to the comb, making the comb negatively charged while leaving positive ions on the towel.
  - These charges eventually get neutralized primarily by water molecules in the air.