PHYS 1441 – Section 002
Lecture #1

Monday, Jan. 14, 2013

Dr. Jaehoon Yu

- Who am I?
- What is High Energy Physics?
- What is the Higgs Particle?
- How is this class organized?
- What do we want from this class?

Today's homework is homework #1, due 11pm, Friday, Jan. 18!!

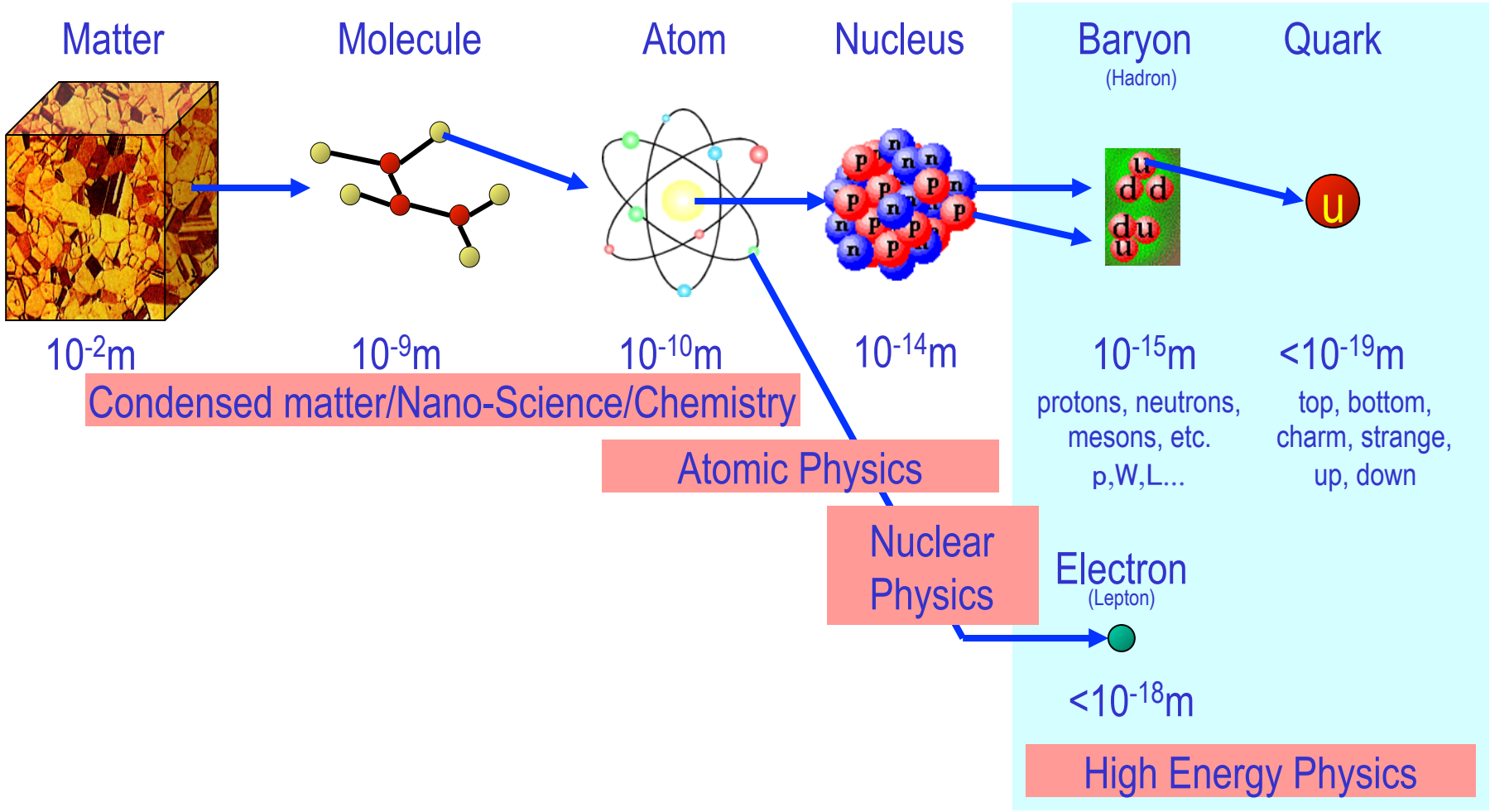
Announcements

- 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 Monday, Jan. 21
  - A-1 through A-8
- There will be a quiz on this and what we cover this Wednesday in the class Wednesday, Jan. 23.

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
    - 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

Structure of Matter

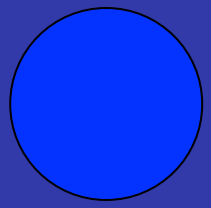


We always wonder…

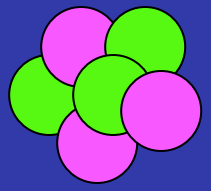
- What makes up the universe?
- How does the universe work?
- What holds the universe together?
- How can we live in the universe well?
- Where do we all come from?

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)

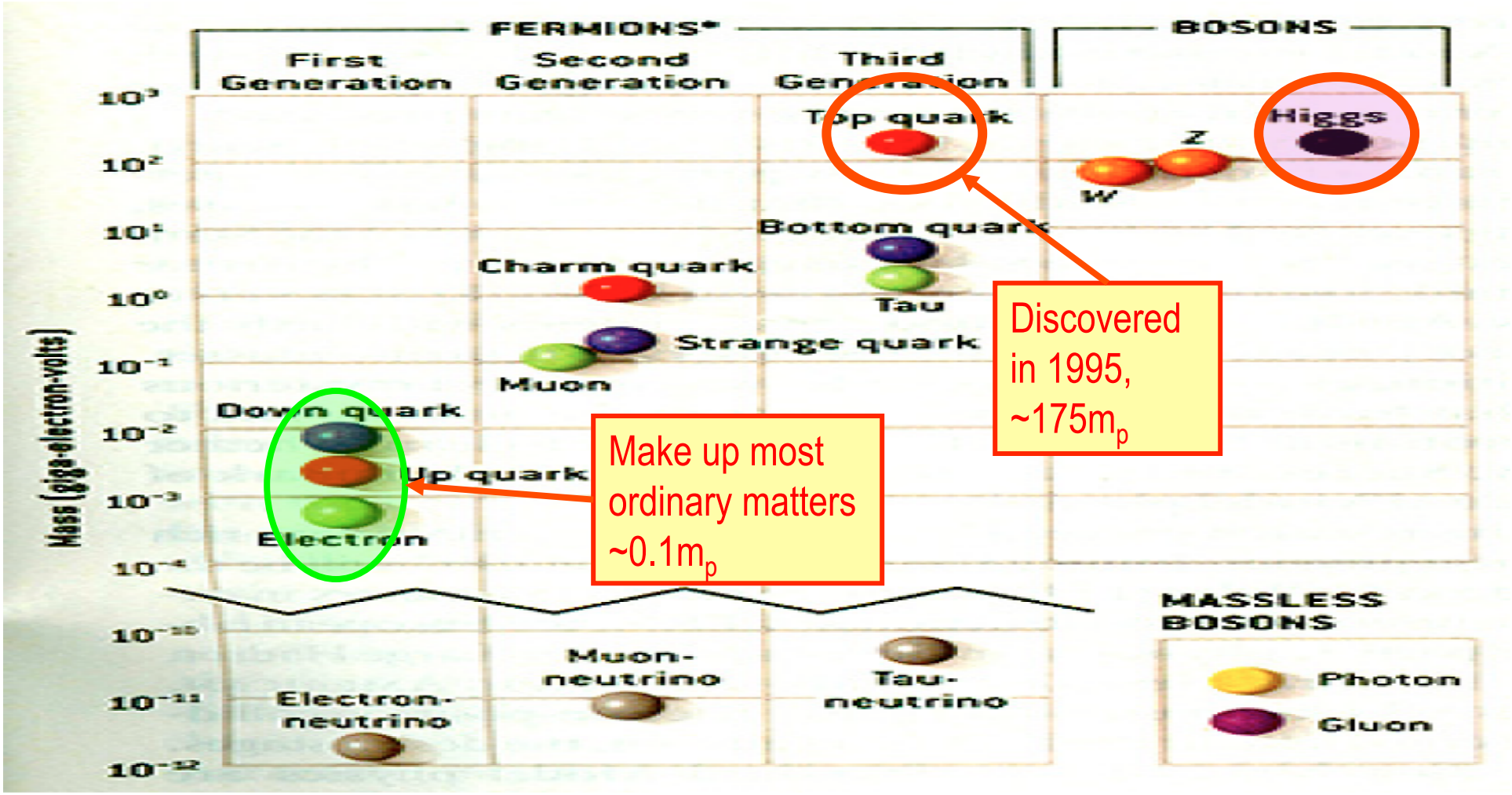
Accelerators are also Time Machines.

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

Particle and anti-particle annihilate.

$$E = mc^2$$

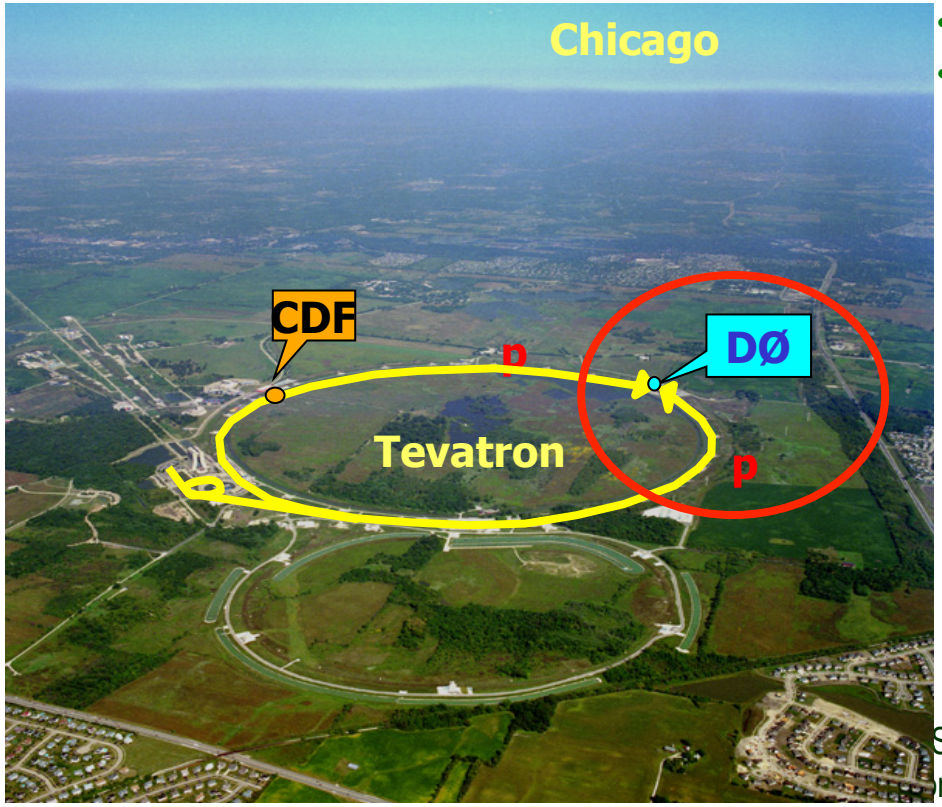
The Standard Model



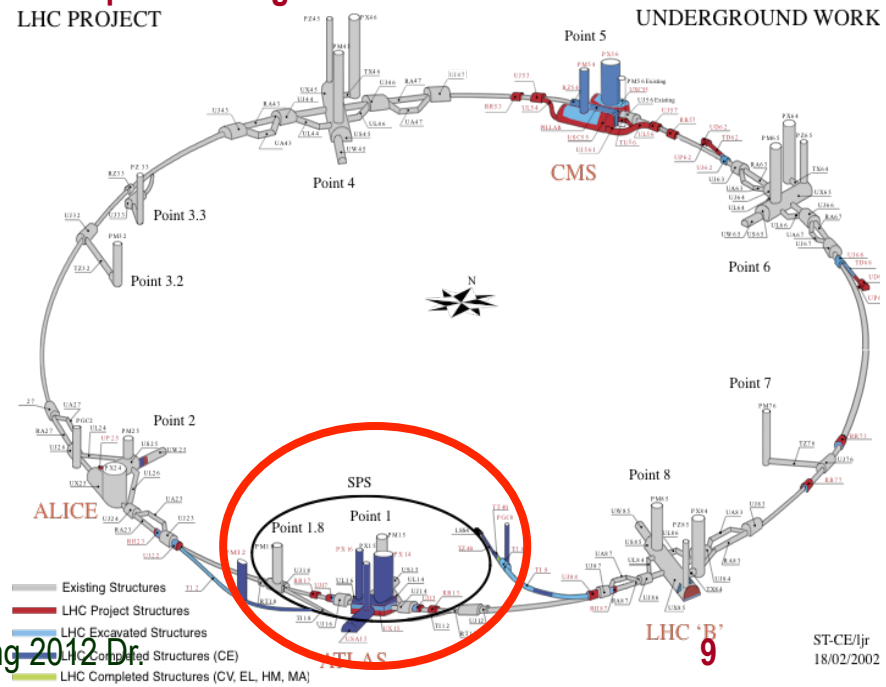
- Total of 16 particles make up the matter in the universe! ➔ Simple and elegant!!!
- Tested to a precision of 1 part per million!

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 at 2pm CDT, Sept. 30, 2011**
  - **Vibrant other programs running!!**



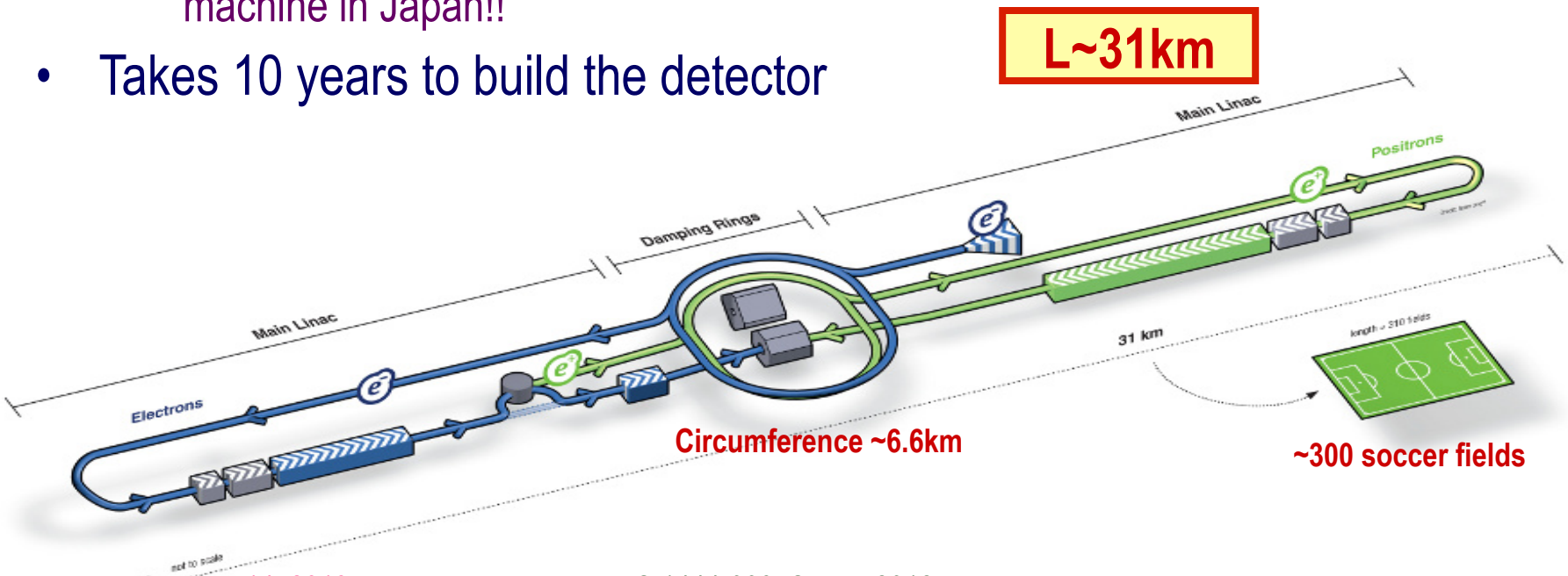
- World's Highest Energy p-p collider
  - 27km circumference, 100m underground
  - Design E_{cm}=14 TeV (=44x10^{-7}J/p➔ 362M Joules on the area smaller than 10^{-4}m^2)
  - ➢ Equivalent to the kinetic energy of a B727 (80tons) at the speed 193mi/hr ➔ 312km/hr
    - ➢ ~3M times the energy density at the ground 0 of the Hiroshima atom bomb
- First 7TeV collisions on 3/30/10 ➔ The highest energy humans ever achieved!!
- **Large amount of data accumulated in 2011 and 2012**
- **2013 operation begun**



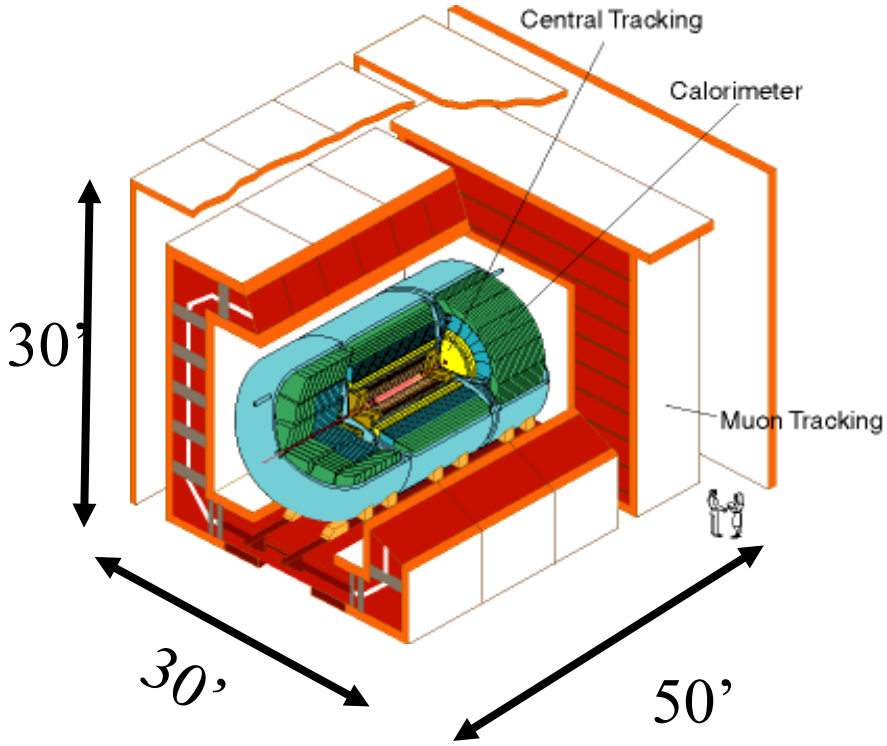
LHC @ CERN Aerial View

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)
  - our Japanese colleagues have declared that they will bid for building a 250GeV machine in Japan!!
- Takes 10 years to build the detector

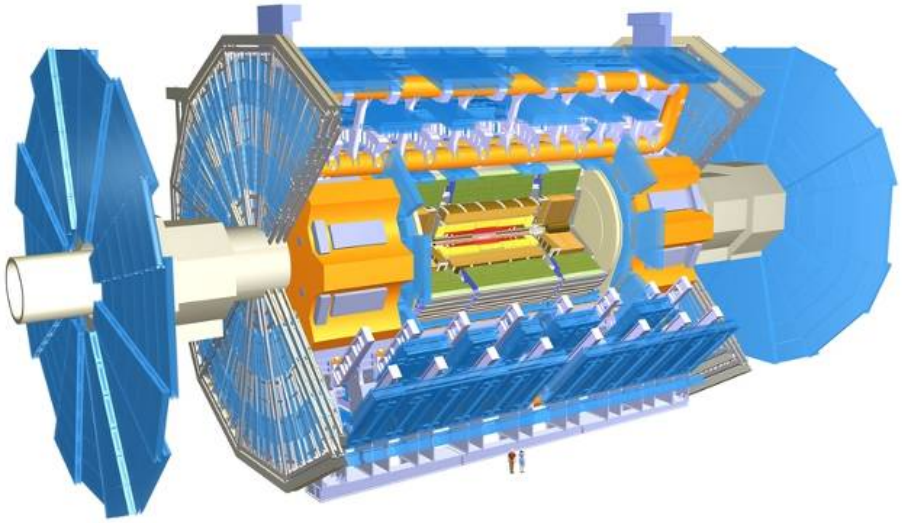


DØ Detector



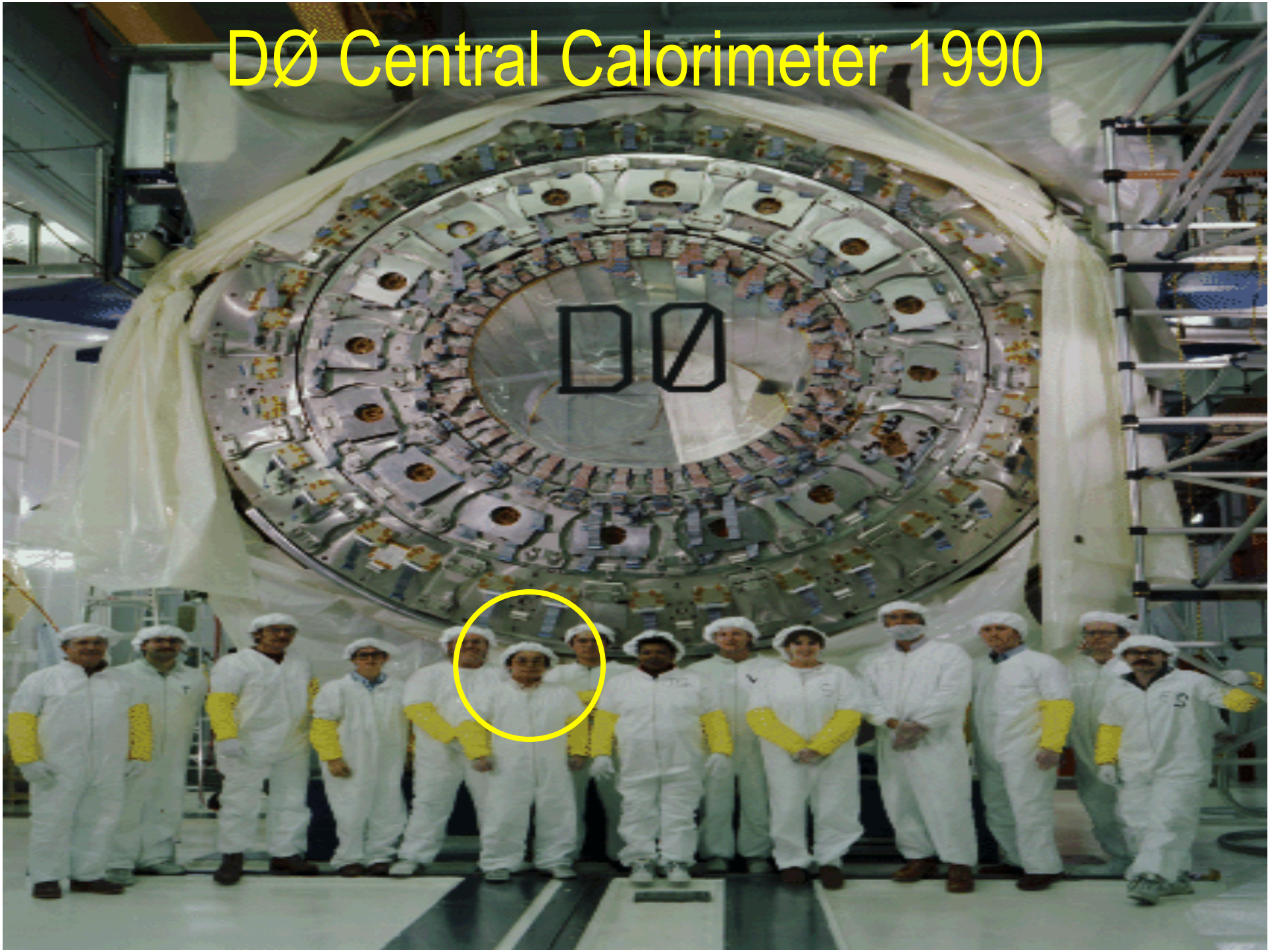
- **Weighs 5000 tons and 5 story tall**
- Can inspect **3,000,000** collisions/second
- Record **100 collisions/second**
- Records approximately **10,000,000** bytes/ second
- Records **0.5x10^{15}** (500,000,000,000,000) bytes per year (0.5 PetaBytes).

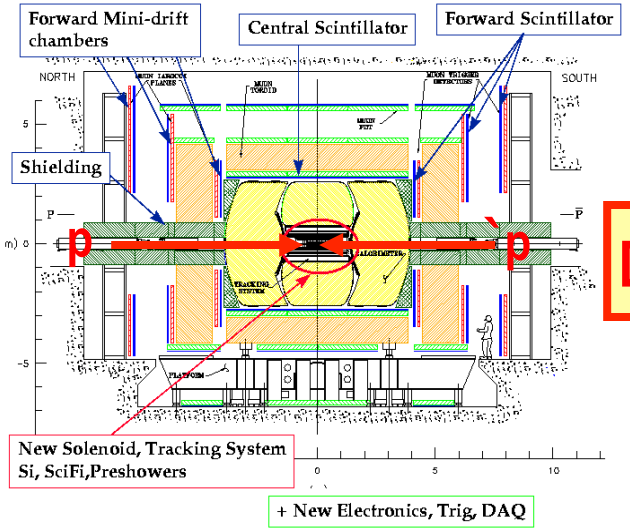
ATLAS Detector



- **Weighs 7000 tons and 10 story tall**
- Can inspect **1,000,000,000** collisions/second
- Records **200 – 400 collisions/second**
- Records approximately **350,000,000** bytes/ second
- Record **2x10^{15}** (2,000,000,000,000,000) bytes each year (2 PetaByte). ➔ **200*Printed material of the US Lib. of Congress**

DØ Central Calorimeter 1990

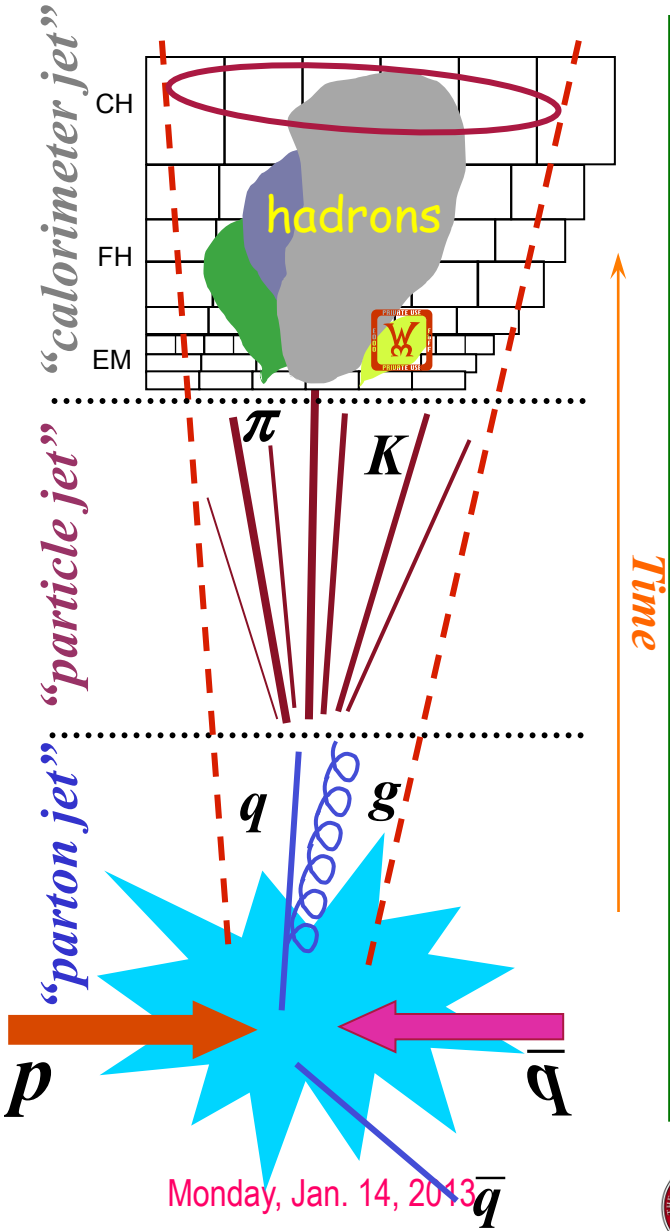


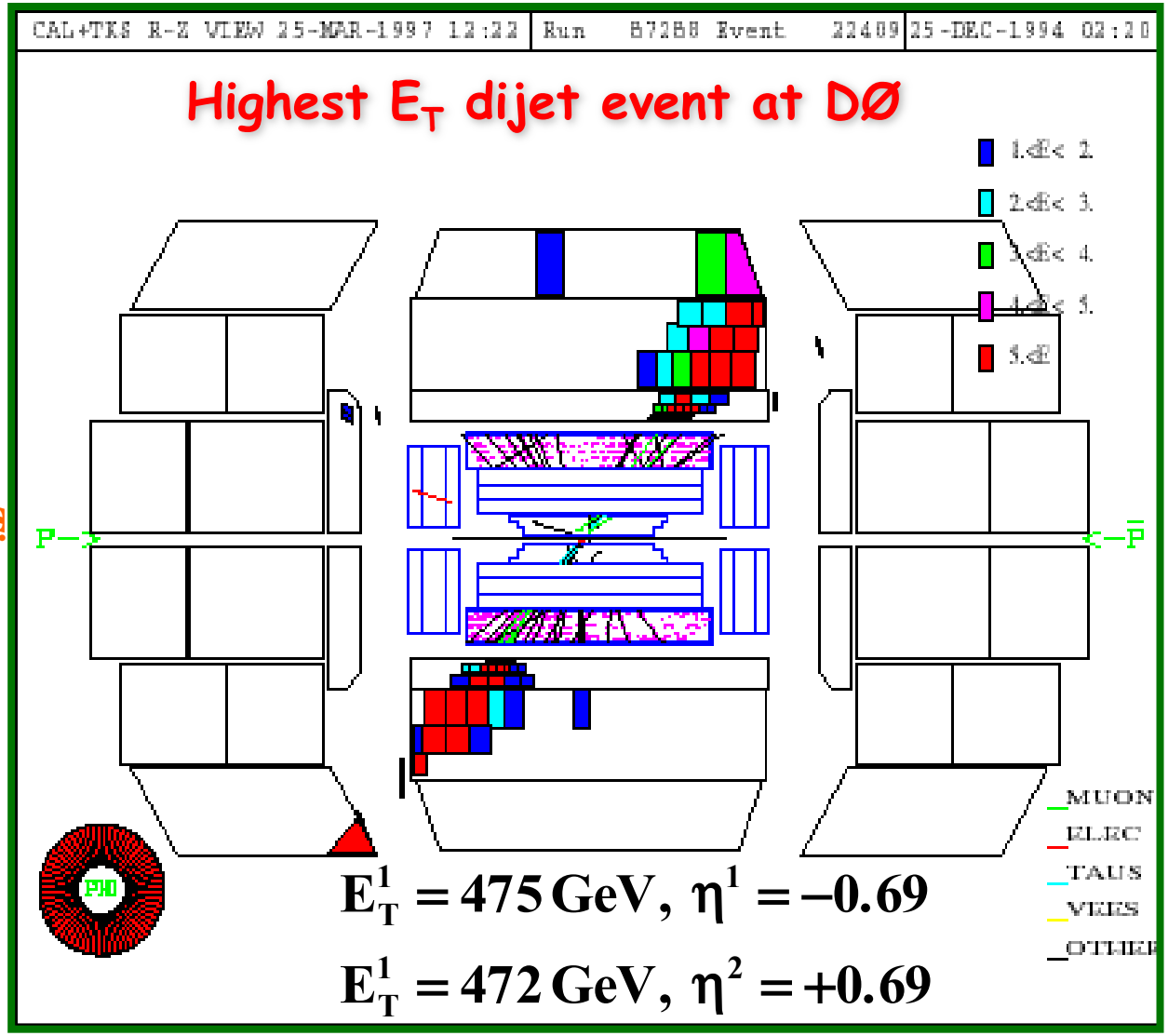


Digital data

Data Reconstruction

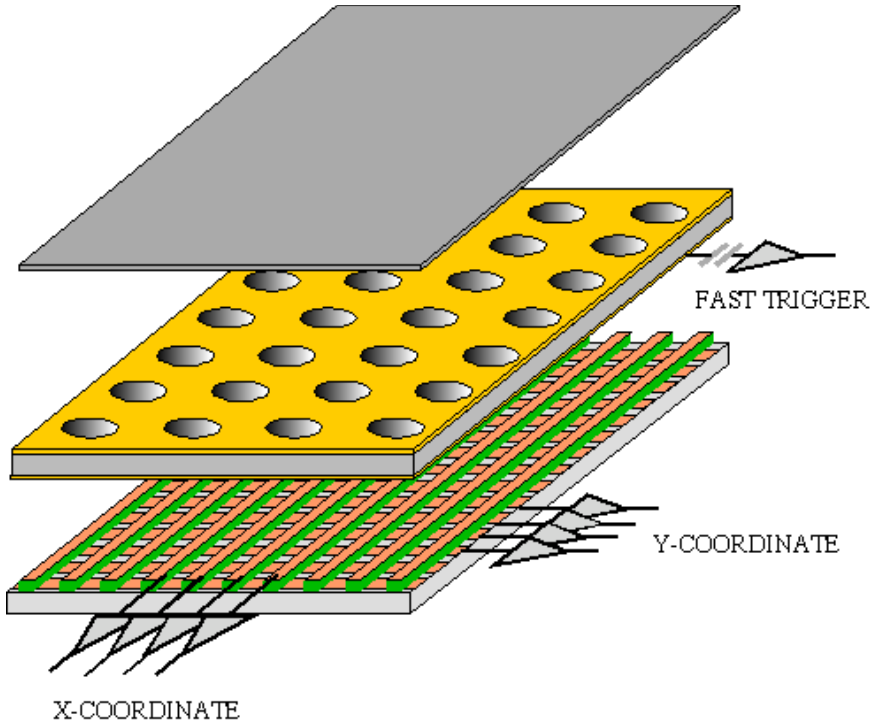
How does an Event Look in a Collider Detector?





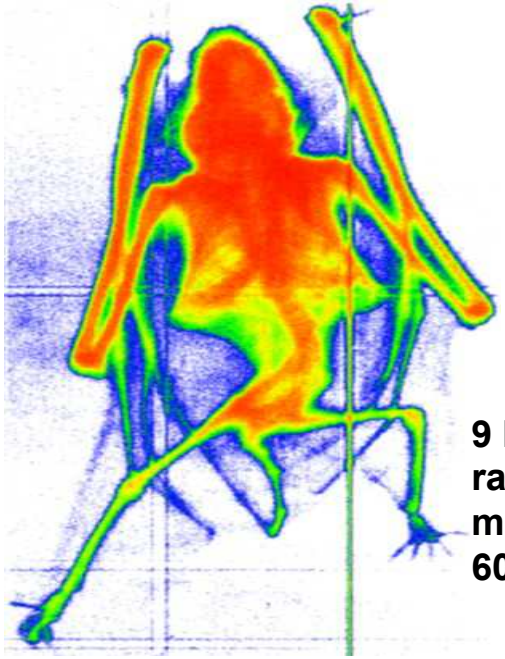
GEM Application Potential

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



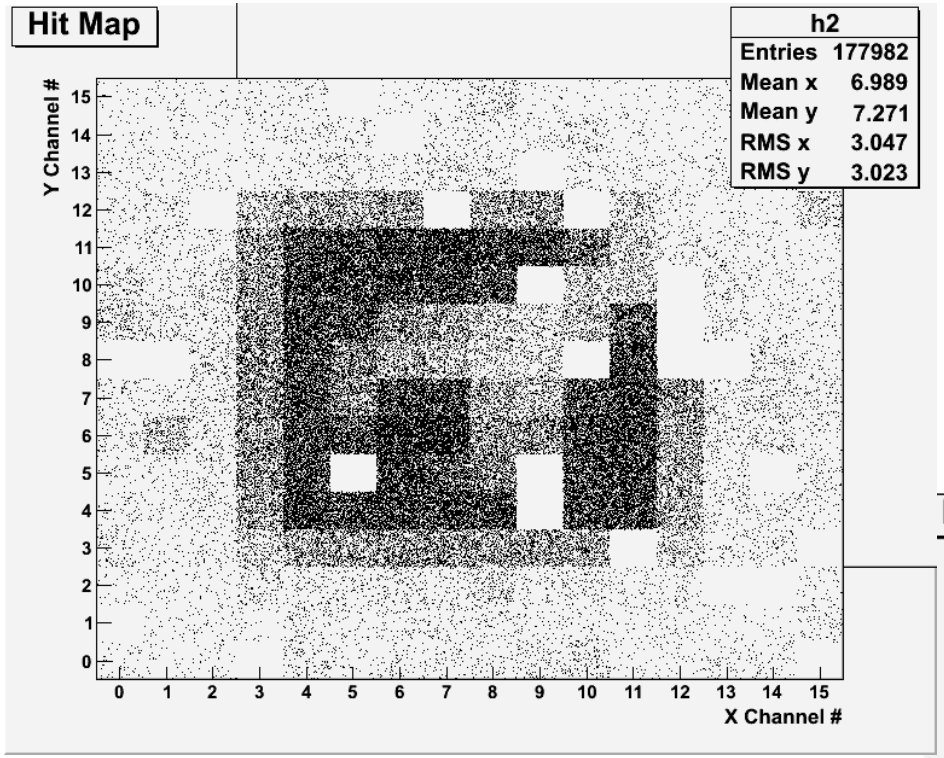
A. Bressan et al,
Nucl. Instr. and Meth. A 425(1999)254
F. Sauli, Nucl. Instr. and Meth.A 461(2001)47

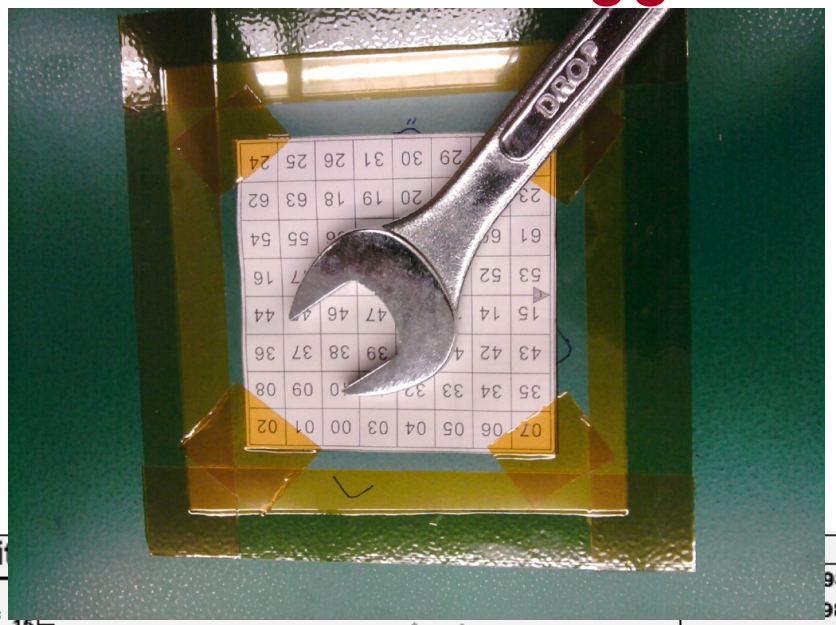
FAST X-RAY IMAGING



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

Radioactive Source Run with Internal Trigger





Can you see what the object is?


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

What is the Higgs and What does it do?

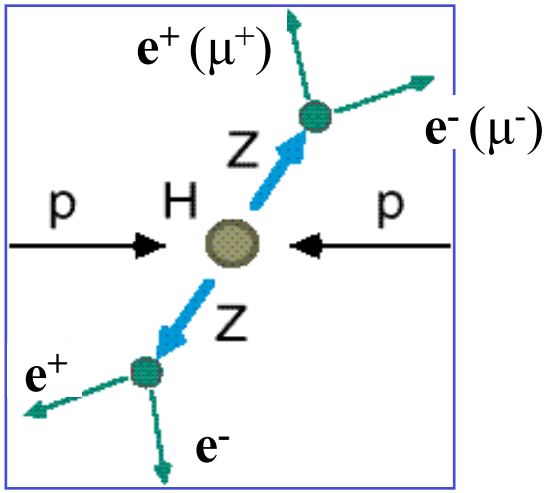
- When there is perfect symmetry, one cannot tell directions!
- Only when symmetry is broken, can one tell directions
- Higgs field works to break the perfect symmetry and give mass
  - This field exists right now amongst us so that we have mass
- Sometimes, this field spontaneously generates a particle, the Higgs particle
- So the Higgs particle is the evidence of the existence of the Higgs field!

How do we look for the Higgs?

- Higgs particle is so heavy they decay into some other particles very quickly
- When one searches for a new particle, you look for the easiest way to get at them
- Of these many signatures of the Higgs, some states are much easier to find, if it were the Standard Model one
  - $H \rightarrow \gamma\gamma$
  - $H \rightarrow ZZ^* \rightarrow 4e, 4\mu, 2e2\mu, 2e2\nu$ and $2\mu2\nu$
  - $H \rightarrow WW^* \rightarrow 2e2\nu$ and $2\mu2\nu$
  - And many more complicated signatures

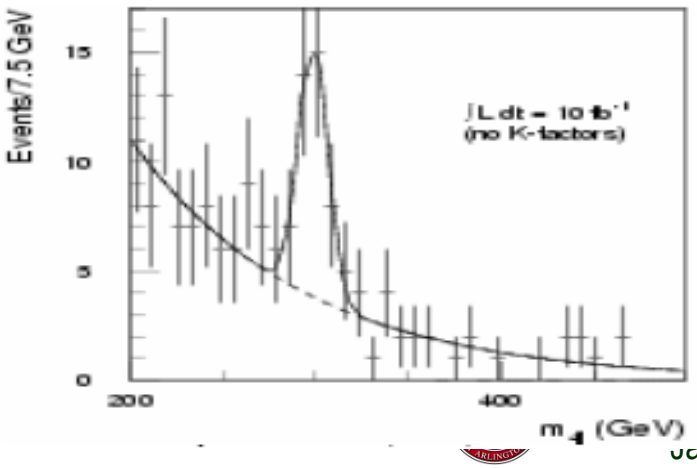
How do we look for the Higgs?

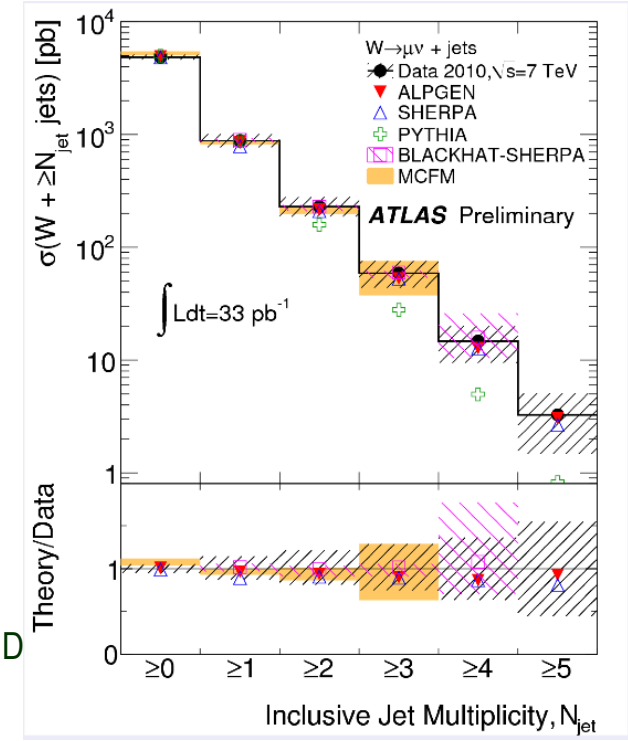
- Identify Higgs candidate events



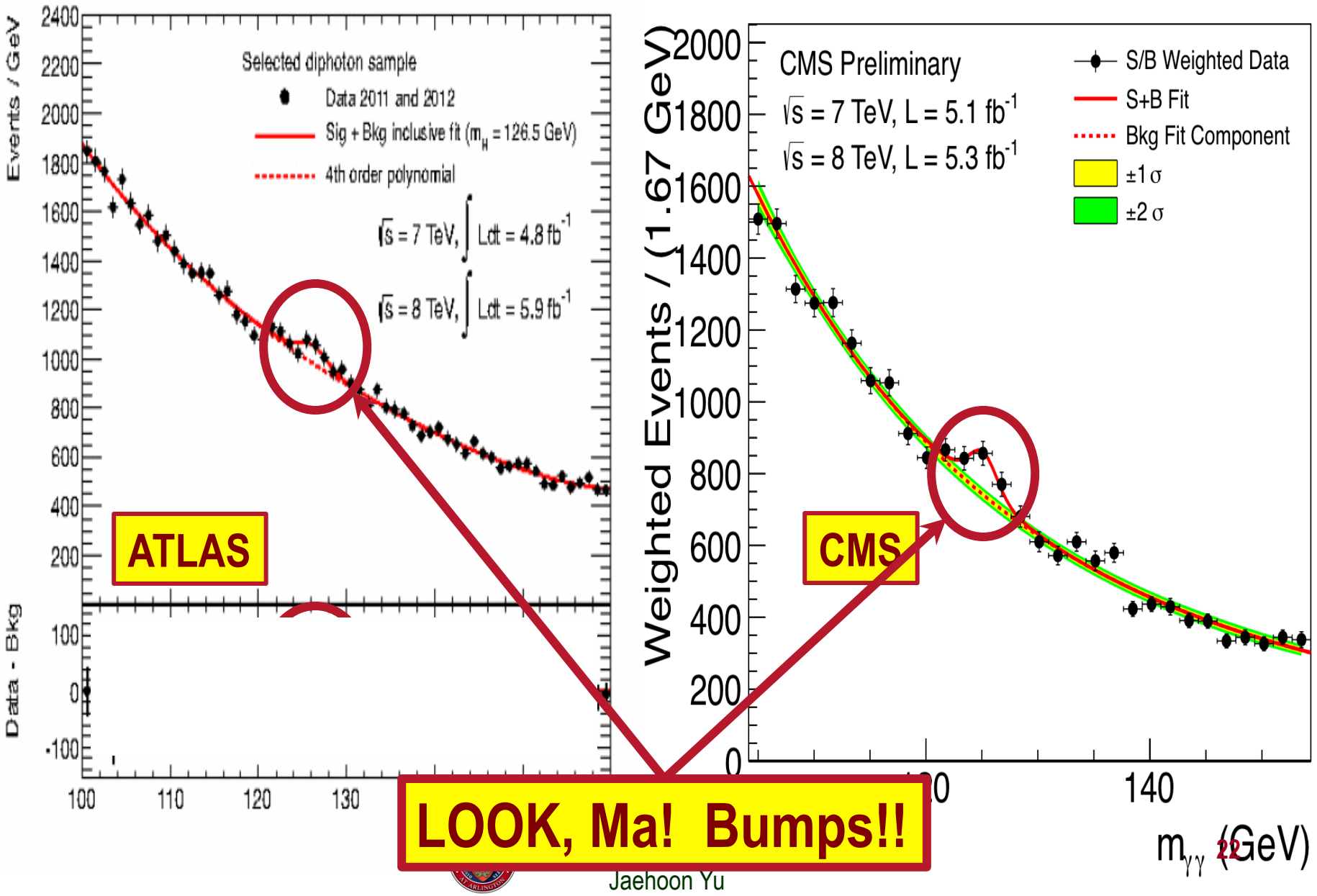
- Understand fakes (backgrounds)

- Look for a bump!!





ATLAS and CMS Mass Bump Plots



So have we seen the Higgs particle?

- The statistical significance of the finding is close to 6 standard deviations
  - Level of significance: 99.999 999 8% (seven 9s!!)
  - We can be wrong once if we do the same experiment 500,000,000 times
- So did we find the Higgs particle?
  - We have discovered a new particle, the heaviest boson we've seen thus far
  - It has some properties consistent with the Standard Model Higgs particle
  - We, however, do not have enough data to precisely measure all the properties – mass, life time, the rate at which this particle decays to certain other particles, etc – to definitively determine

So why is this discovery important?

- This is the giant first step in completing the Standard Model
- Will help understand the origin of mass and the mechanism at which mass is acquired
- Will help understand the origin and the structure of the universe and the inter-relations of the forces
- Will help us make our lives better
- Generate excitements and interests on science and train the next generation
  - A lecture at UTA by Nobel Laureate, prof. Steven Weinberg, was attended by 1200 people!!

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 to subscribe to the class e-mail distribution list **PHYS1441-002-SP13** by clicking on the link https://listserv.uta.edu/cgi-bin/wa.exe?A0=PHYS1441-002-SP13
  - 5 point extra credit if subscribed by Friday, Jan. 18.
  - 3 point extra credit if done by Tuesday, Jan. 22
  - A test message will be sent out Wednesday, Jan. 23
- Office Hours: 5:30 – 6:30pm, Mondays and Wednesdays or by appointments

Evaluation Policy

- Homework: 25%
- Exams
  - Final Comprehensive Exams (5/6): 23%
  - Mid-term Comprehensive Exam (3/20): 20%
  - One better of the two term Exams: 12%
    - Total of two non-comprehensive term exams (2/13 and 4/17)
    - 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
- Lab score: 10%
- Pop-quizzes: 10%

100%

- Extra credits: 10% of the total
  - Random attendances
  - Physics department colloquium participation
  - Strong participation in the class discussions
  - Special projects
  - 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
- A UT Quest 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 **1441-Spring13**, unique number **41302**
    - **You will be charged $25 for registration**
  - Download homework #1, solve the problems and submit them online by 11pm Friday, Jan. 18, for 100% credit
  - Multiple unsuccessful tries will deduct points
  - Roster will close 10pm, Monday, Jan. 21 (I have to approve your enrollment!!!)
  - 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
- **ALL** homework grades will be used for 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:
  - Starts Tuesday, Jan. 22
  - Important to understand physical principles through experiments
  - 10% of the grade
  - Lab syllabus is available in your assigned lab rooms.
    - Go by the lab room between 8am - 6pm M – F and pick up the syllabus
- 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 – Fri in SH 007
  - This service begins Wednesday, Jan. 15

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?
  - Random attendances
  - Physics department colloquium participation
    - 4pm Wednesdays
    - Some could even be double or triple credit
  - Strong participation in the class discussions
  - Special projects (BIGGGGG!!!)
  - Watch the valid planetarium shows
  - Many other opportunities

Valid Planetarium Shows

- Regular running shows
  - 2012: Mayan Prophecies – Fridays at 6:00, Saturdays at 2:30
  - Astronaut – Thursdays at 6:00, Saturdays at 5:30, Sundays at 1:30
- Shows that need special arrangements
  - Black Holes (can watch up to 2 times)
  - Experience the Aurora
  - IBEX
  - Magnificent Sun
  - Nano Cam
  - Stars of the Pharaohs
  - Time Space
  - Two Small Pieces of Glass
  - Unseen Universe: The Vision of SOFIA
  - Violent Universe
  - Wonders of the 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 all of them on a sheet of paper with your name and ID written on it
  - Submit the sheet at the end of the semester when asked

What can you expect from this class?

- All A's would be perfect for you, wouldn't it?
  - But easy come easy go
  - Must put in efforts to make it last and meaningful….
- This class is going to be challenging!!
- 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 of your grade in your hands, up to 45%!!!
  - Homework is 25% of the total grade!!
    - Means you will have many homework problems
      - Sometimes much more than any other classes
      - Some homework problems will be something that you have yet to learn in class
      - Exam problems will be easier than homework problems but the 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 mechanics
- Concepts of physical quantities that describe motions, such as velocity, speed, acceleration, etc
- Kinematic equations and description of motions
- Vector and scalar quantities
- Concepts of force, energy and momentum and the relationship between them
- Energy, momentum and angular momentum conservation laws
- Techniques to use conservation laws for motions
- Rotational motions and Equilibrium conditions
- Fluid and wave motions and thermodynamics