PHYS 3313 – Section 001
Lecture #1

Monday, Aug. 27, 2012

Dr. Jaehoon Yu

- Who am I?
- How is this class organized?
- What do we want from this class?
- What is Physics?
- Brief history of modern physics

Announcements

- Plea to you: Please turn off your cell-phones, pagers and computers in the class
- Reading assignment #1: Read and follow through appendices 3, 5, 6 and 7 by Tuesday, Sept. 4
  - There will be a quiz next Wednesday, Sept. 5, on this reading assignmentå

Who am I?

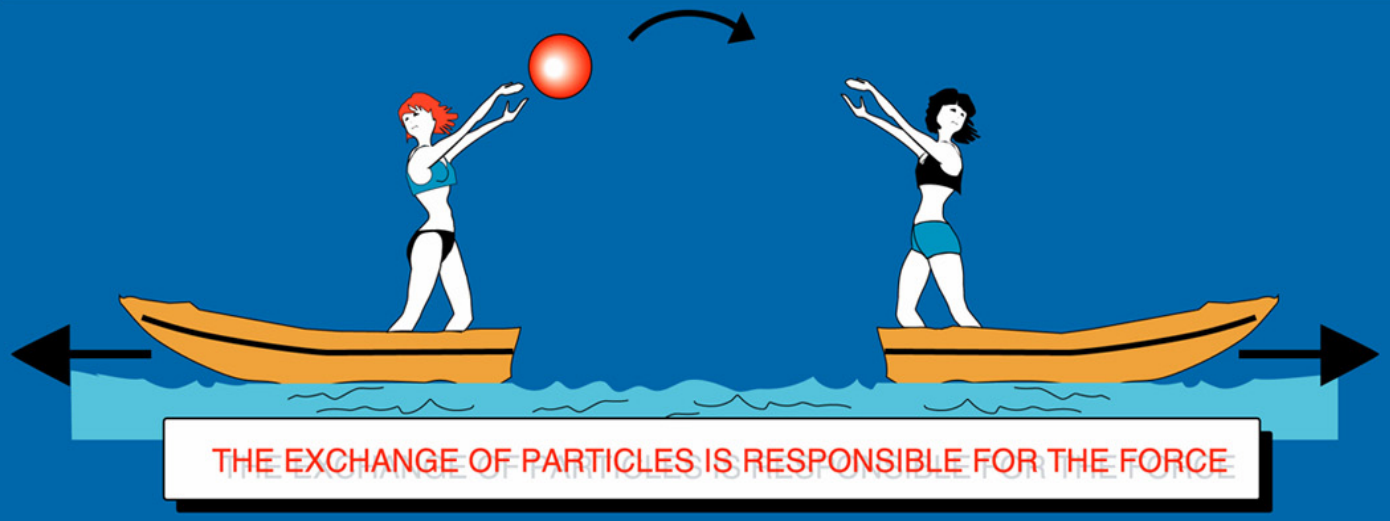
- Name: Dr. Jaehoon Yu (You can call me **Dr. Yu**)
- Office: Rm 342, Chemistry and Physics Building
- Extension: x22814, E-mail: *jaehoonyu@uta.edu*
- My profession: High Energy Particle Physics (HEP)
  - Collide particles (protons on anti-protons or electrons on anti-electrons, positrons) at the energies 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

High Energy Physics

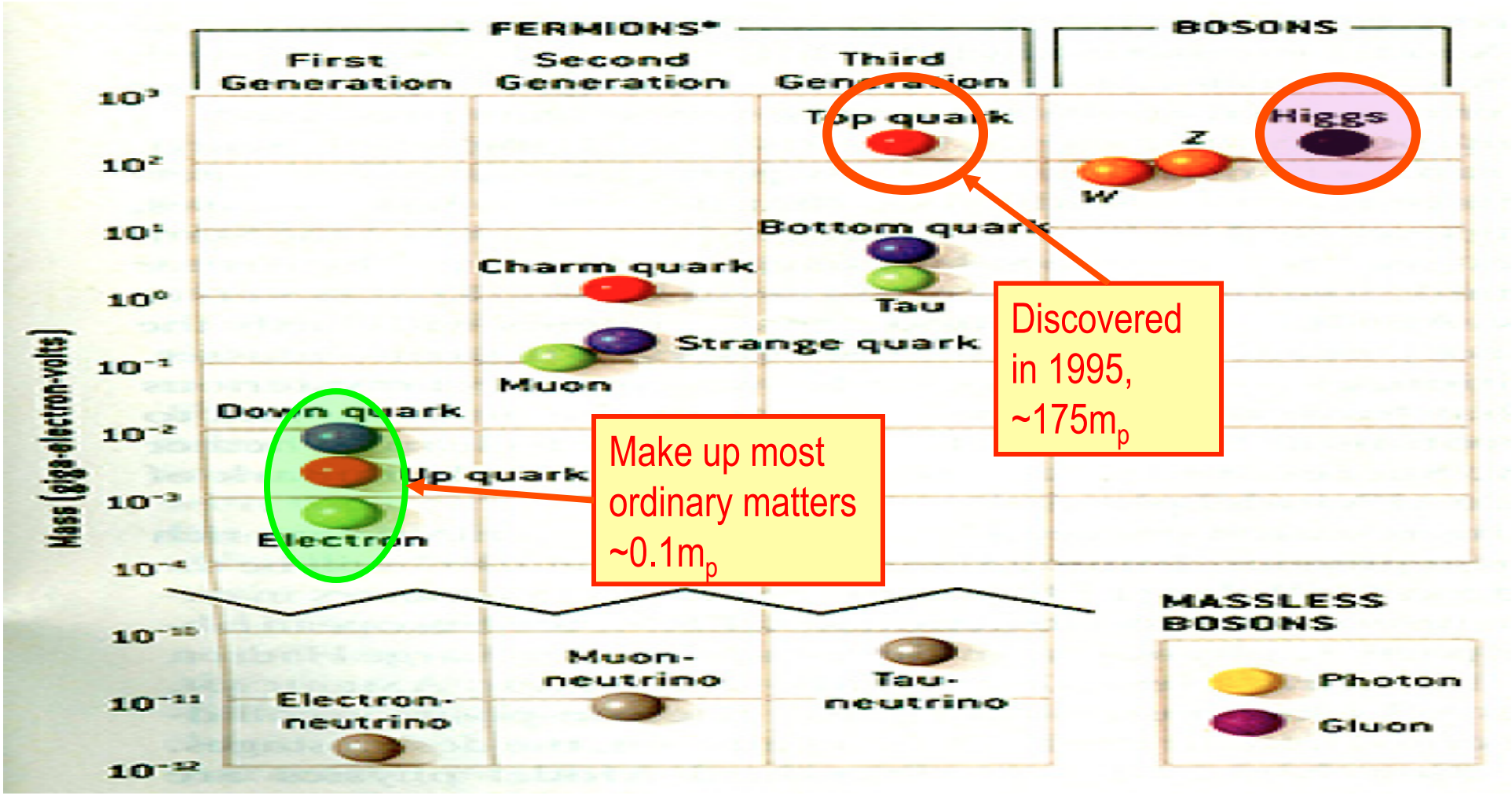
- Definition: A field of physics that pursues understanding the fundamental constituents of matter and basic principles of interactions between them.
- Known interactions (forces):
  - Gravitational
  - Electro-Weak
  - Strong
- Current theory: The Standard Model of Particle Physics
  - Unified Weak and Electromagnetic: SU(2)xU(1)
  - Strong Interaction: SU(3)
  - Currently:SU(3)xSU(2)xU(1)
  - Meaning: 8+4 mediators for forces

The forces in Nature

TYPE	INTENSITY OF FORCES (DECREASING ORDER)	BINDING PARTICLE (FIELD QUANTUM)	OCCURS IN :
STRONG NUCLEAR FORCE	~ 1	GLUONS (NO MASS)	ATOMIC NUCLEUS
ELECTRO -MAGNETIC FORCE	~ 10^{-3}	PHOTONS (NO MASS)	ATOMIC SHELL ELECTROTECHNIQUE
WEAK NUCLEAR FORCE	~ 10^{-5}	BOSONS Z^{o} , W^{+} , W^{-} (HEAVY)	RADIOACTIVE BETA DESINTEGRATION
GRAVITATION	~ 10^{-38}	GRAVITONS (?)	HEAVENLY BODIES



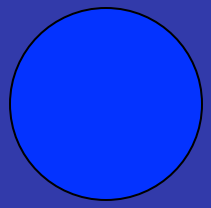
The Standard Model



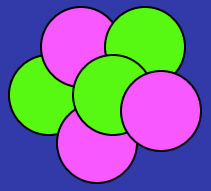
- Total of 16 particles make up the matter in the universe! ➔ Simple and elegant!!!
- Tested to a precision of 1 part per million!

Accelerators are Powerful Microscopes.

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



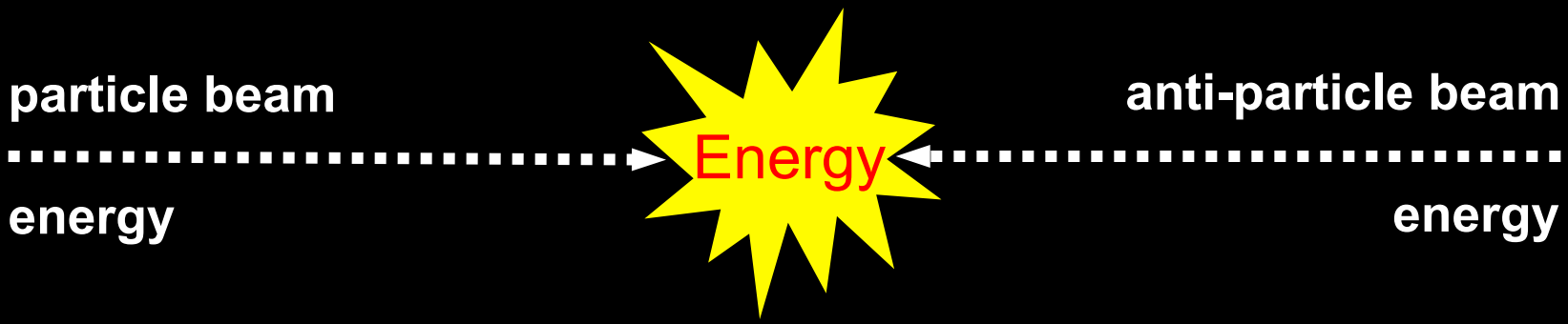
seen by
low energy beam
(poorer resolution)



seen by
high energy beam
(better resolution)

Accelerators are also Time Machines.

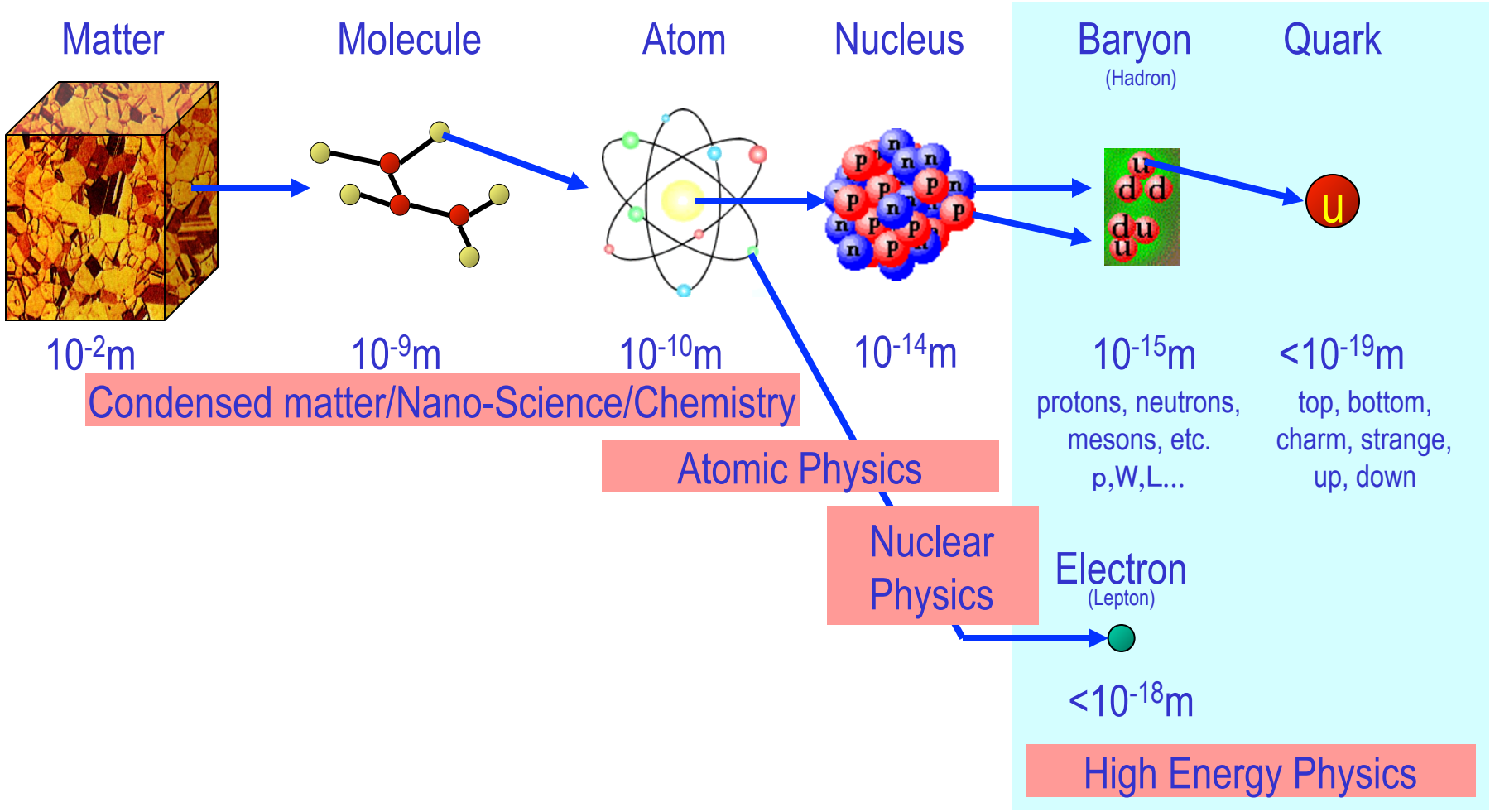
They make particles last seen
in the earliest moments of the universe.



Particle and anti-particle annihilate.

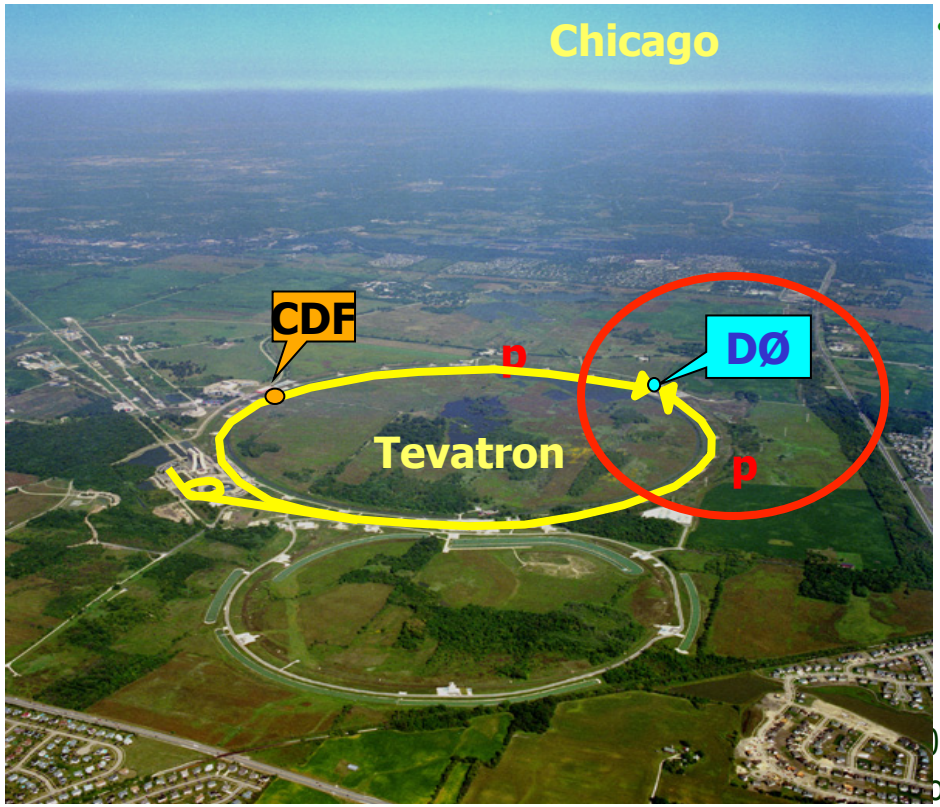
$$E = mc^2$$

Structure of Matter

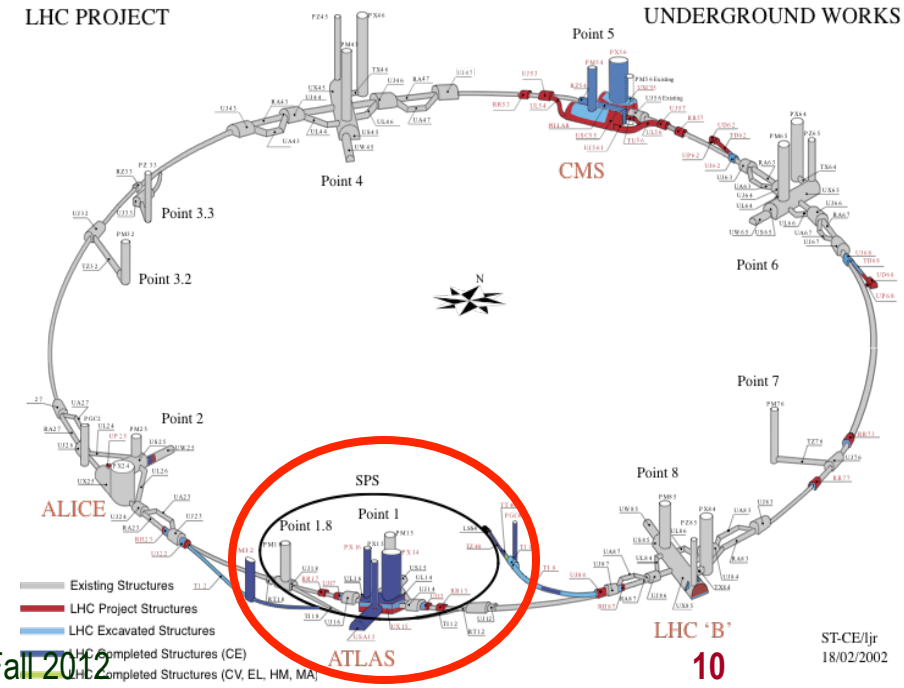


Fermilab Tevatron and LHC at CERN

- 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!!**

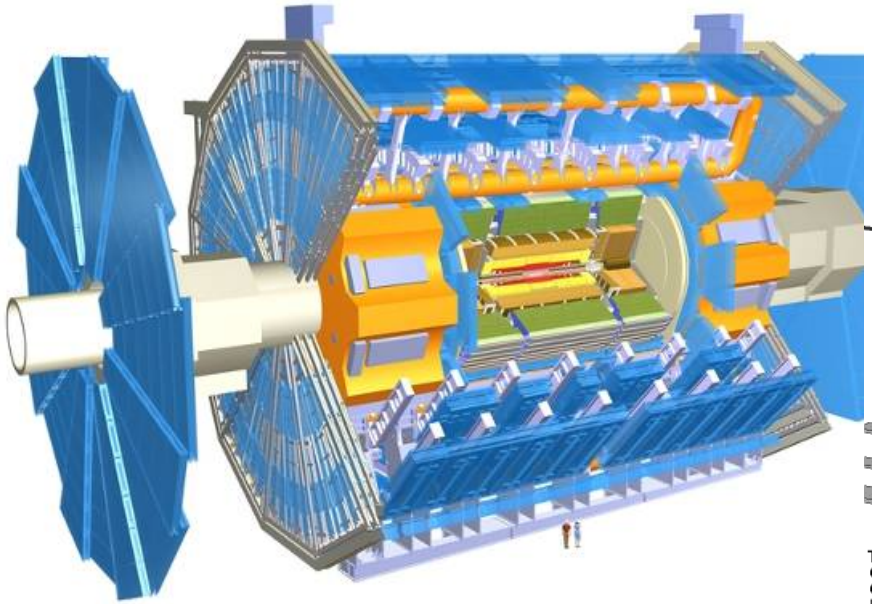


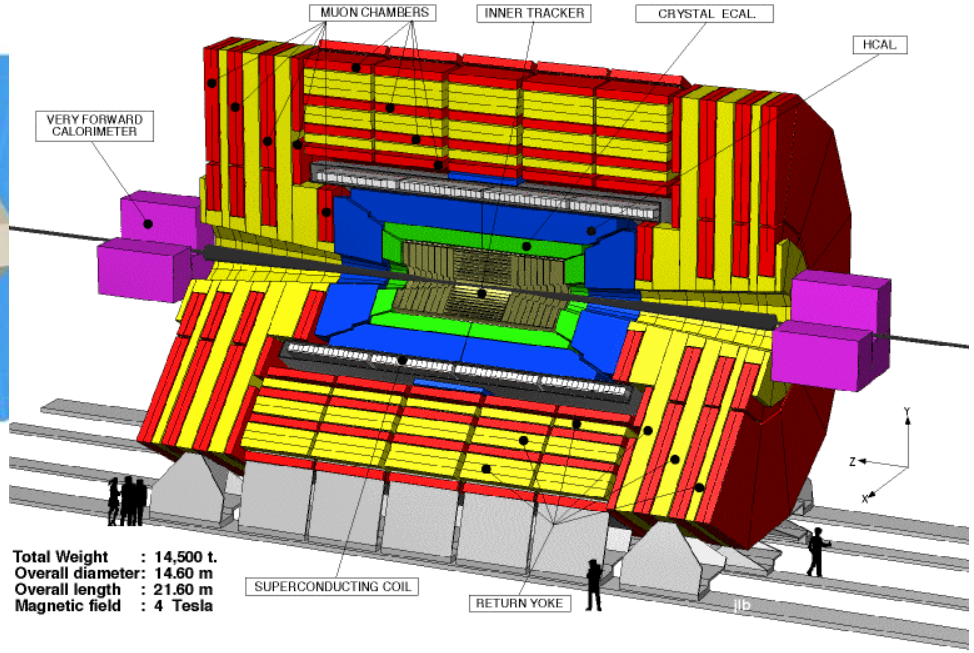
- World's Highest Energy p-p collider
  - 27km circumference, 100m underground
  - Design E_{cm}=14 TeV (=44x10^{-7}J/p➔ 362M Joules on the area smaller than 10^{-4}m^2)
  - ➢ Equivalent to the kinetic energy of a B727 (80tons) at the speed 193mi/hr ➔ 312km/hr
    - ➢ ~3M times the energy density at the ground 0 of the Hiroshima atom bomb
- First 7TeV collisions on 3/30/10 ➔ The highest energy humans ever achieved!!
- **First 8TeV collisions in 2012 on April 5, 2012**



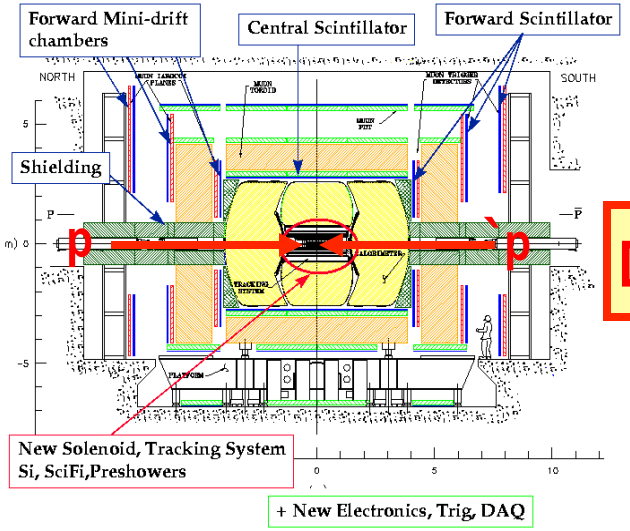
LHC @ CERN Aerial View

The ATLAS and CMS Detectors





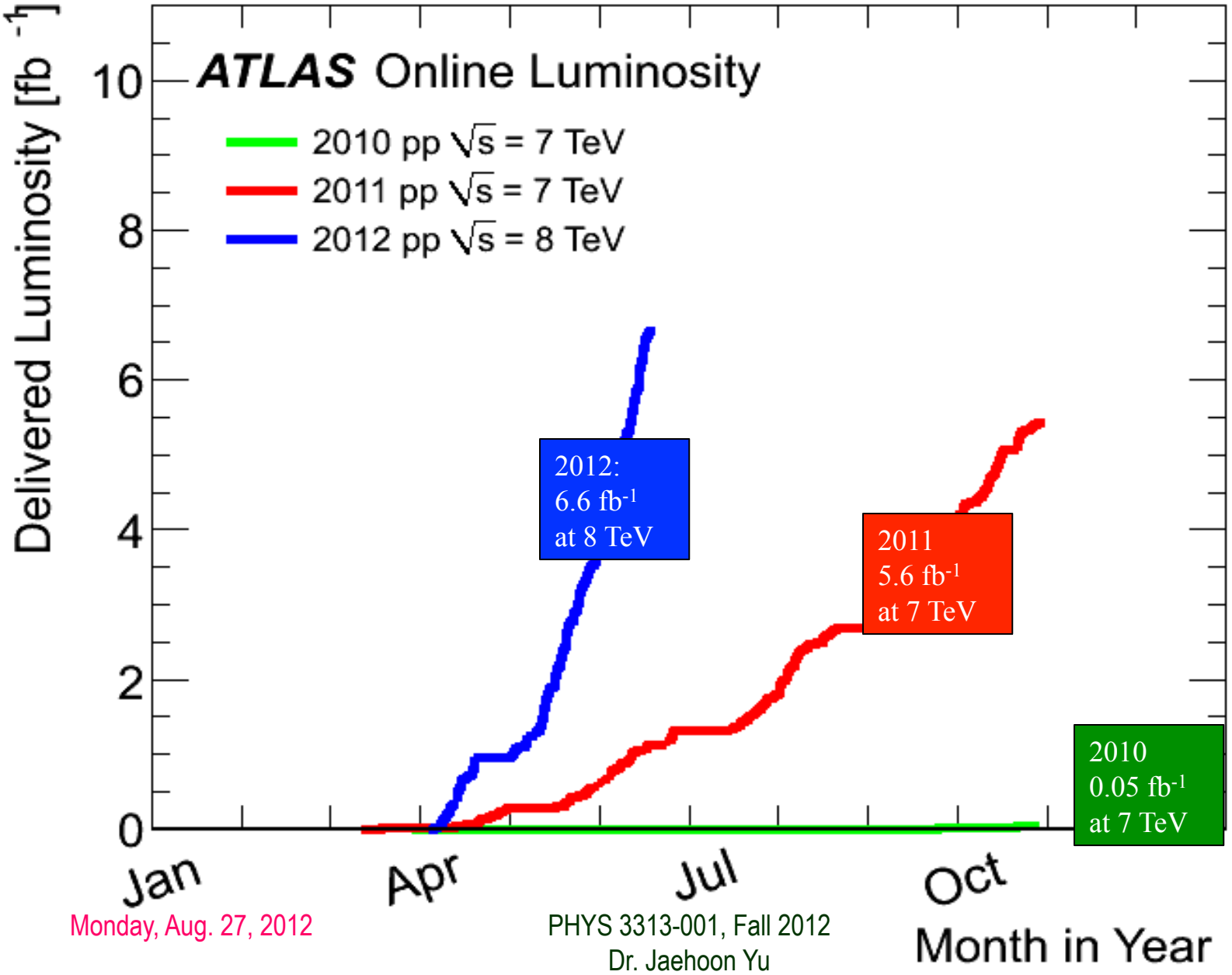
- **Fully multi-purpose detector with emphasis on lepton ID & precision E & P**
- **Weighs 7000 tons and 10 story tall**
- Records **200 – 400 collisions/second**
- Records approximately **350** MB/second
- Record over 2 PB per year ➔ **200*Printed material of the US Lib. of Congress**



Digital data

Data Reconstruction

Amount of ATLAS Data



What is the Higgs and What does it do?

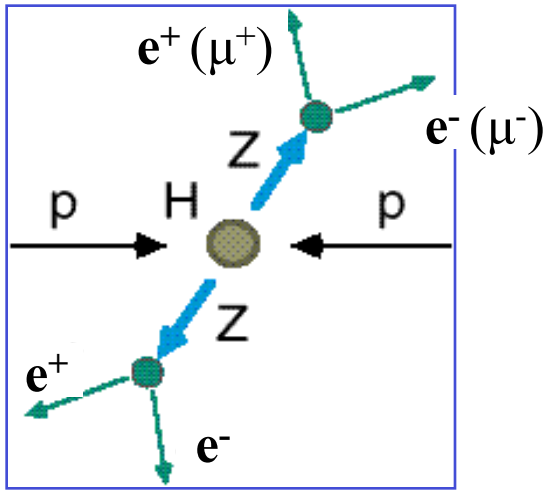
- When there is perfect symmetry, one cannot tell directions!
- Only when symmetry is broken, can one tell directions
- Higgs field works to break the perfect symmetry and give mass
  - This field exists right now amongst us so that we have mass
- Sometimes, this field spontaneously generates a particle,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

How do we look for the Higgs?

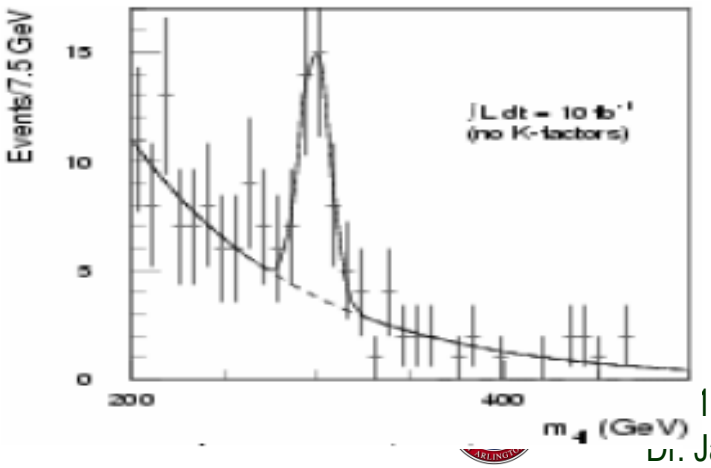
- Higgs particle is so heavy they decay into some other particles very quickly
- When one searches for a new particle, you look for the easiest way to get at them
- Of these many signatures of the Higgs, some states are much easier to find, if it were the Standard Model one
  - $H \rightarrow \gamma\gamma$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

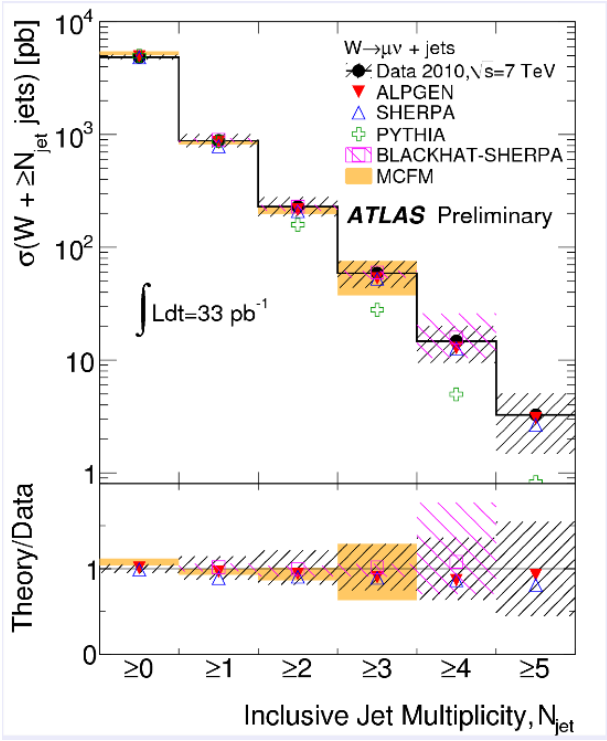
How do we look for the Higgs?

- Identify the Higgs candidate events

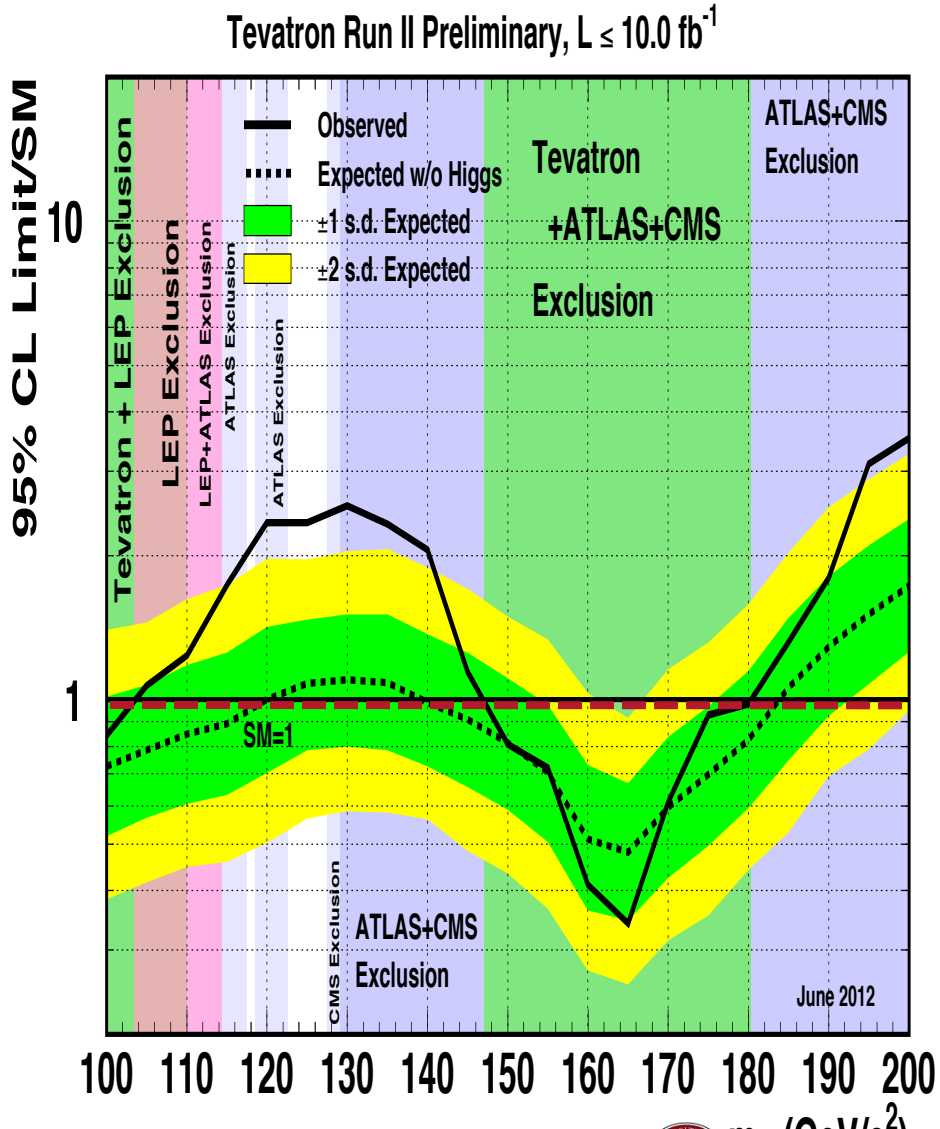


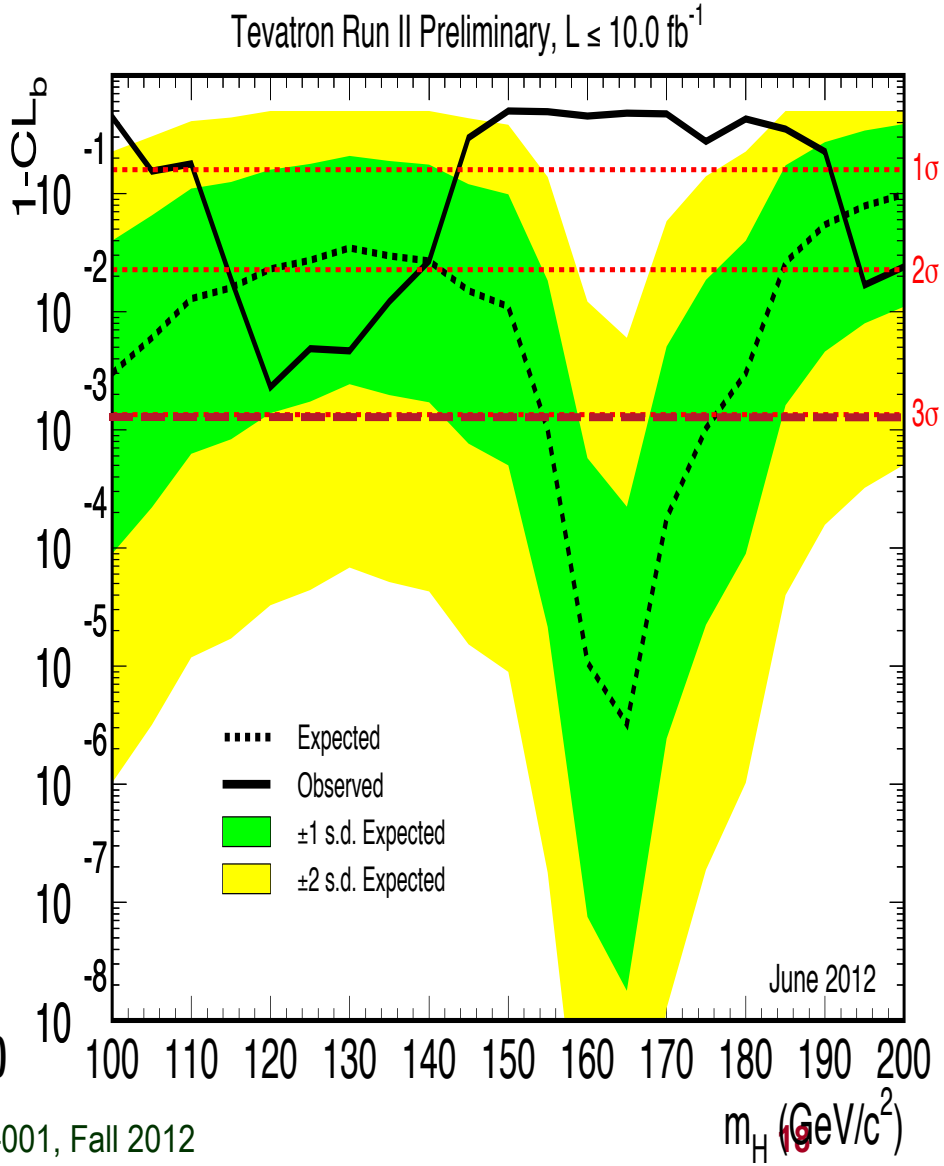
- Understand fakes (backgrounds)
- Look for a bump!!



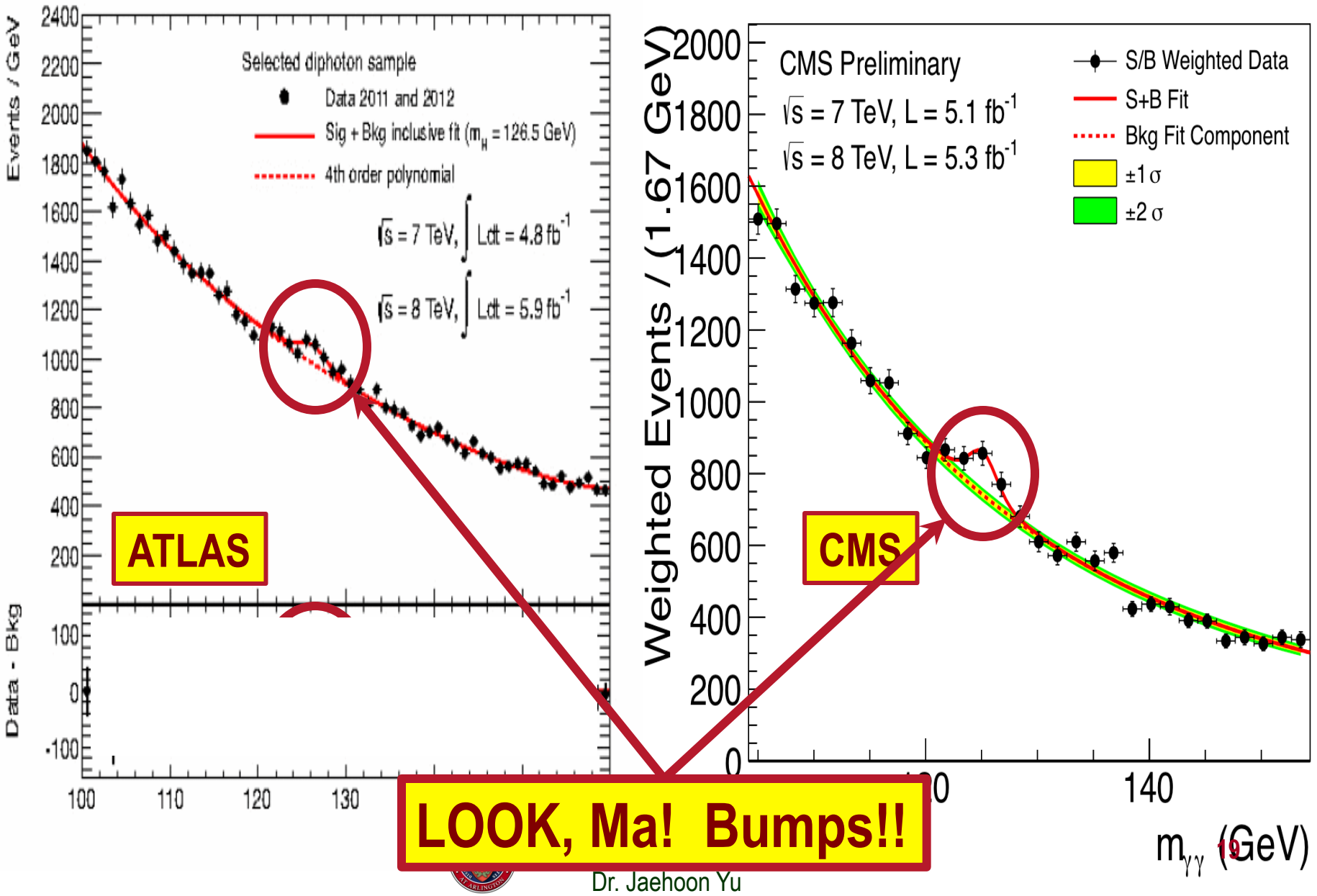


What does Tevatron tell us on Higgs?

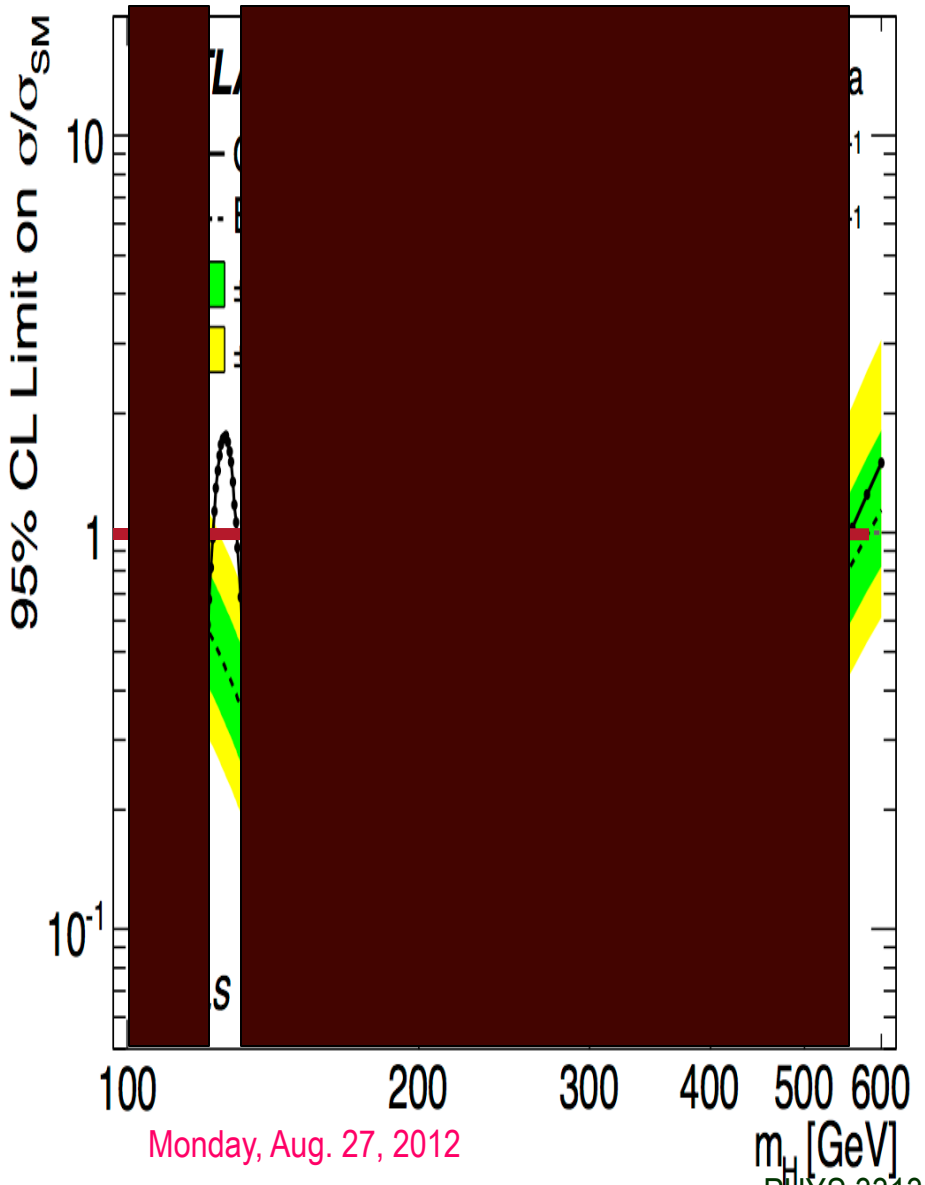


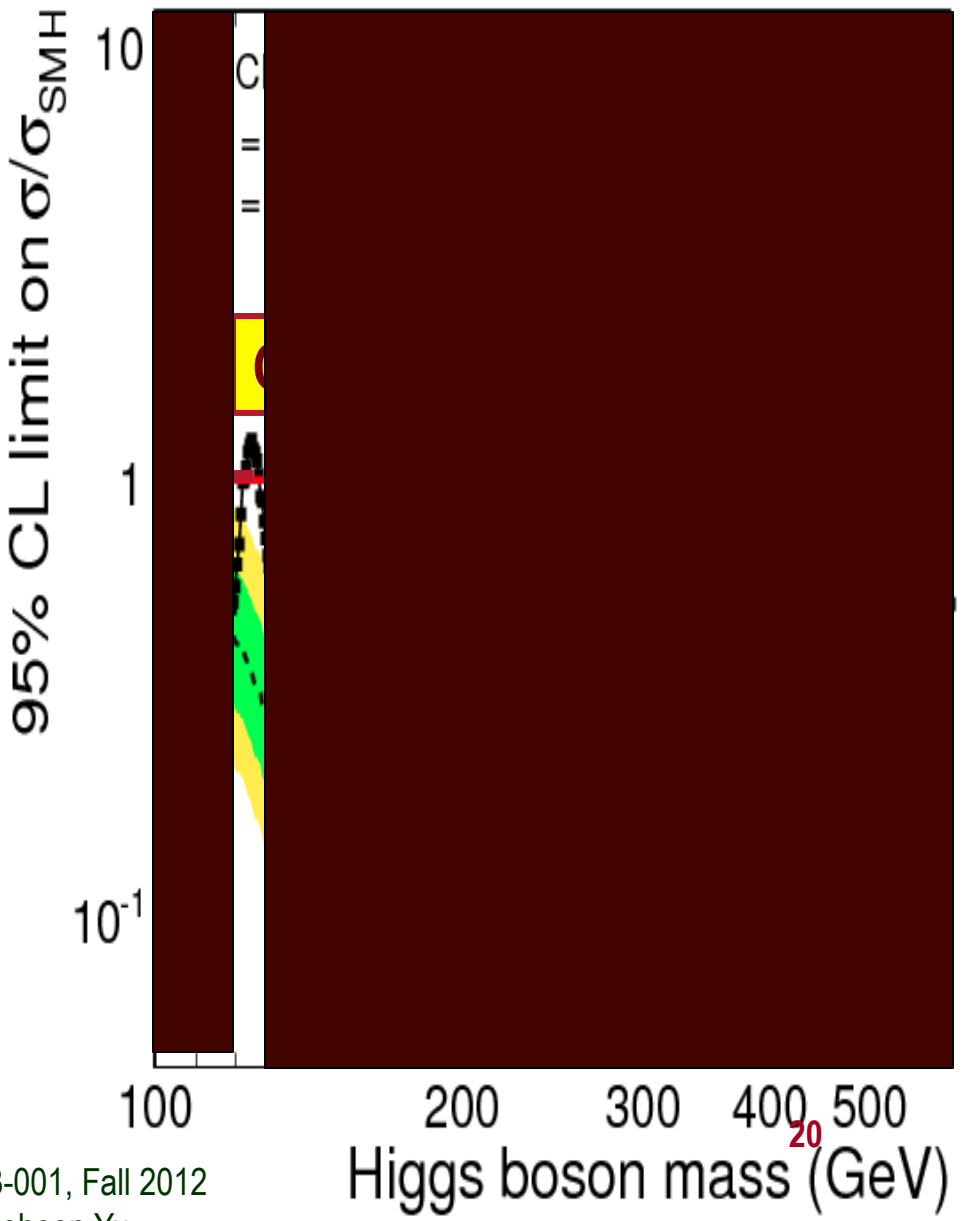


ATLAS and CMS Mass Bump Plots

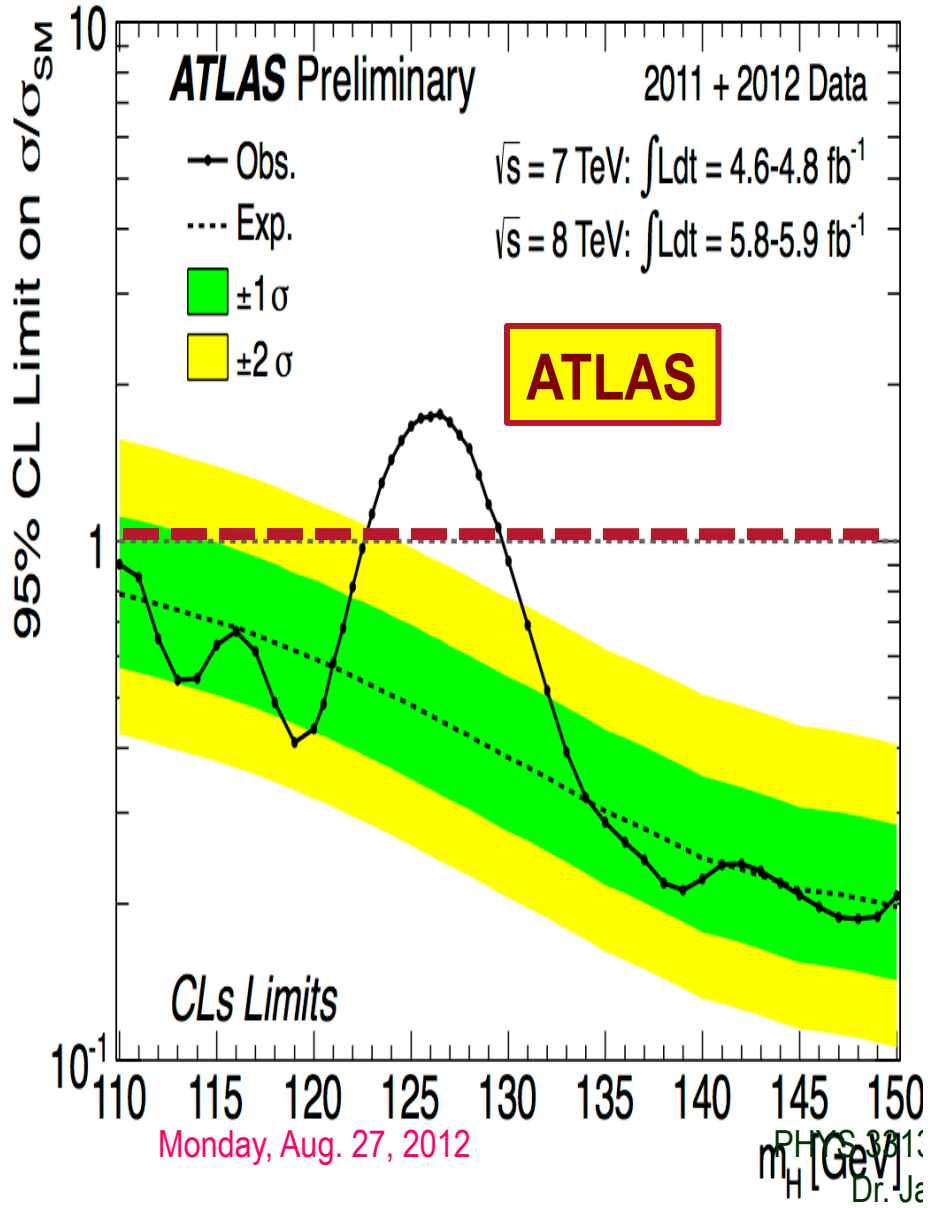


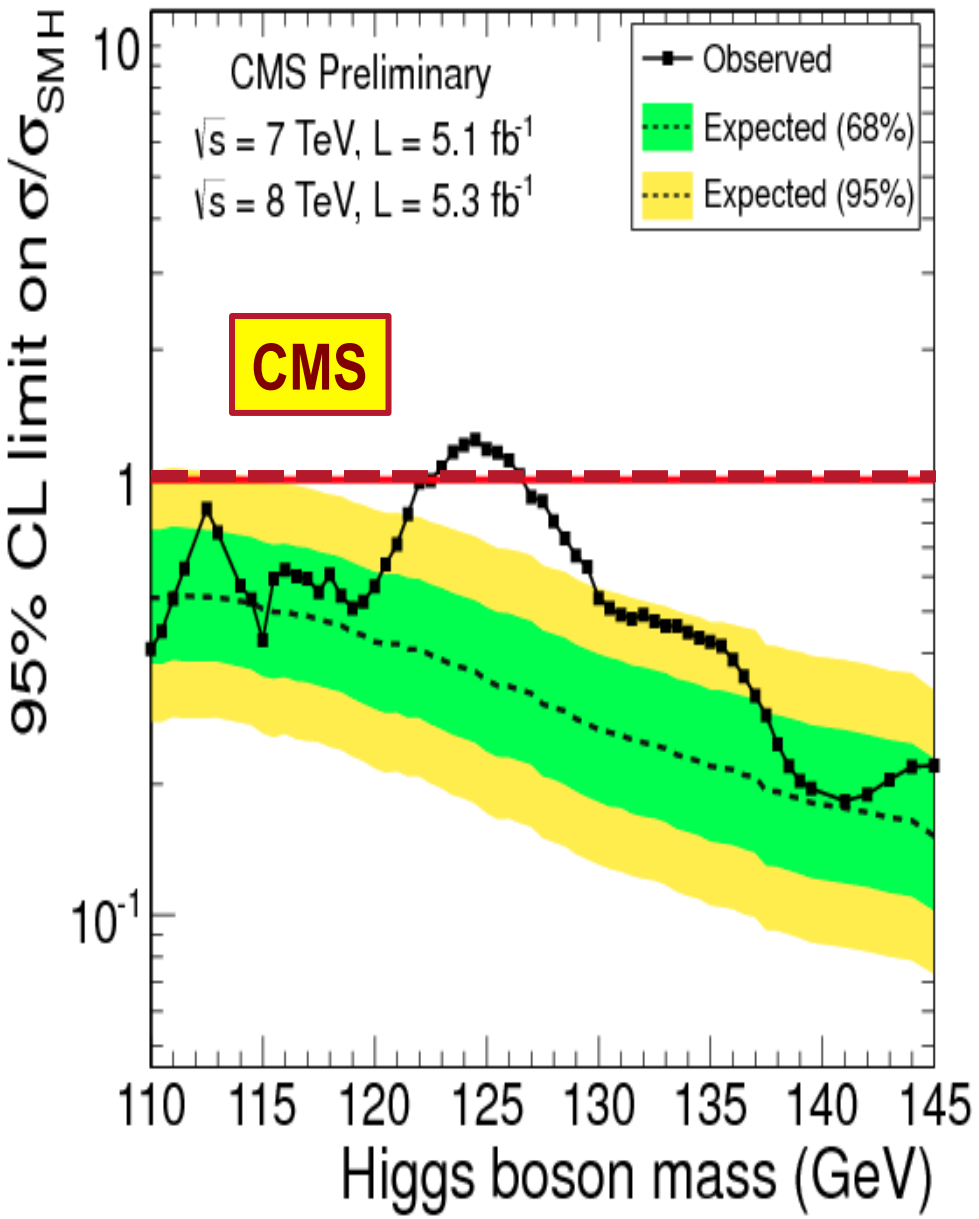
ATLAS Higgs – All M_H



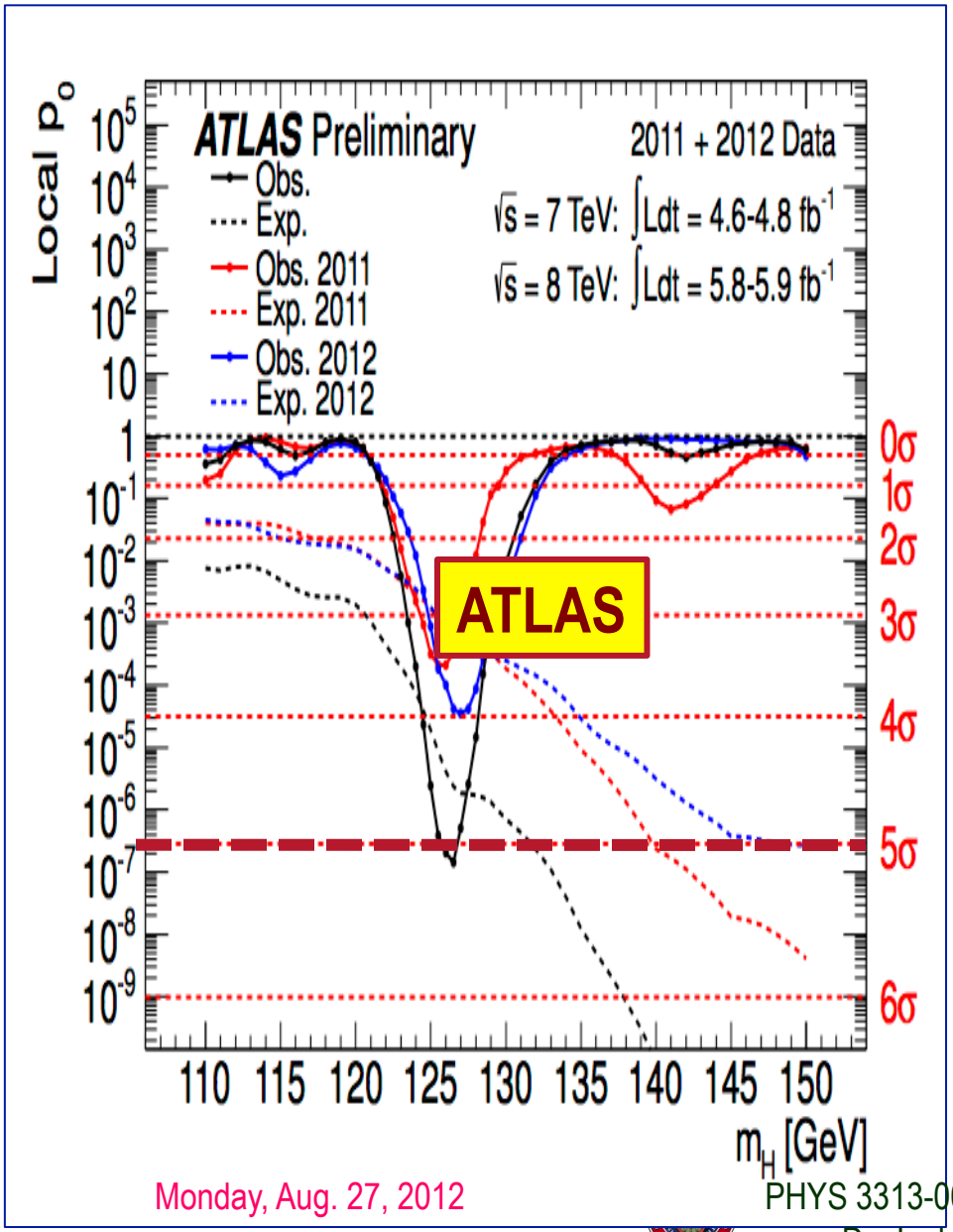


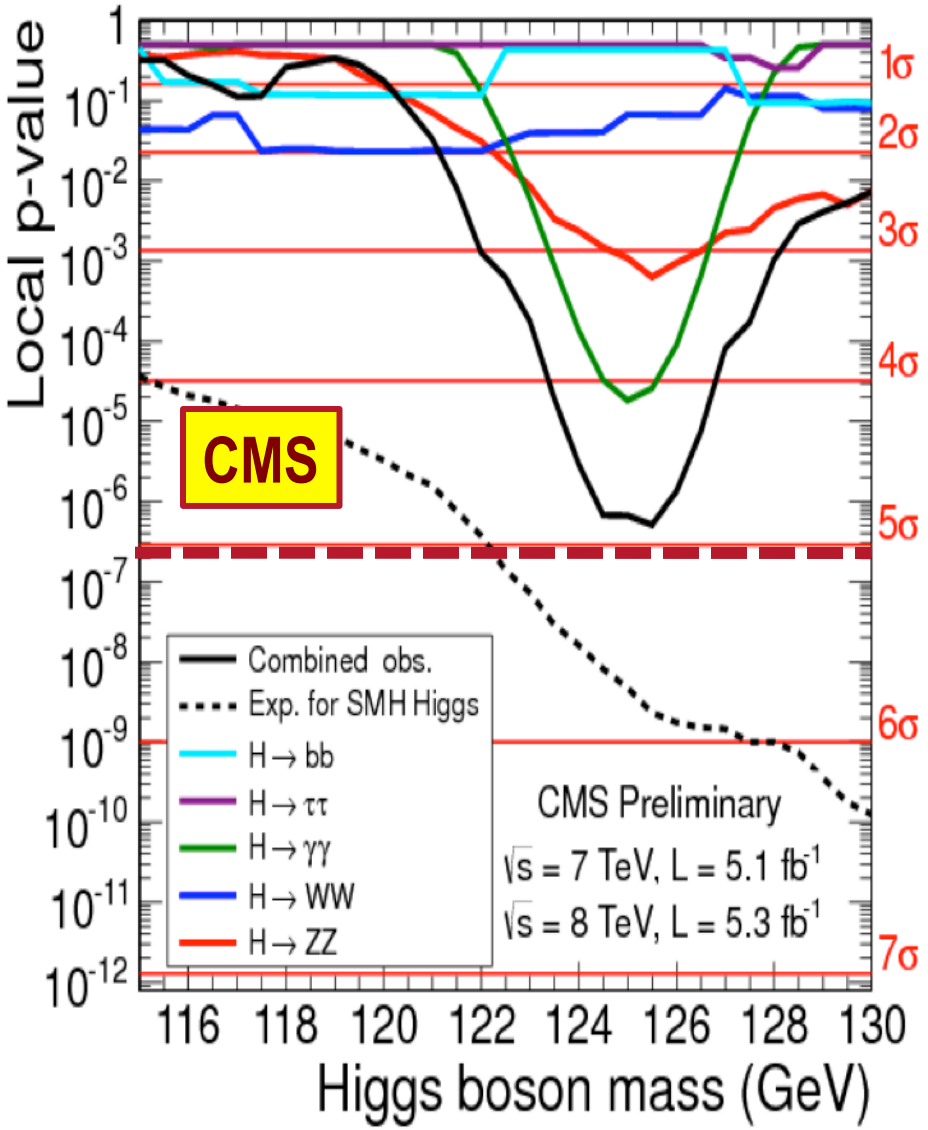
ATLAS and CMS Higgs – low M_H



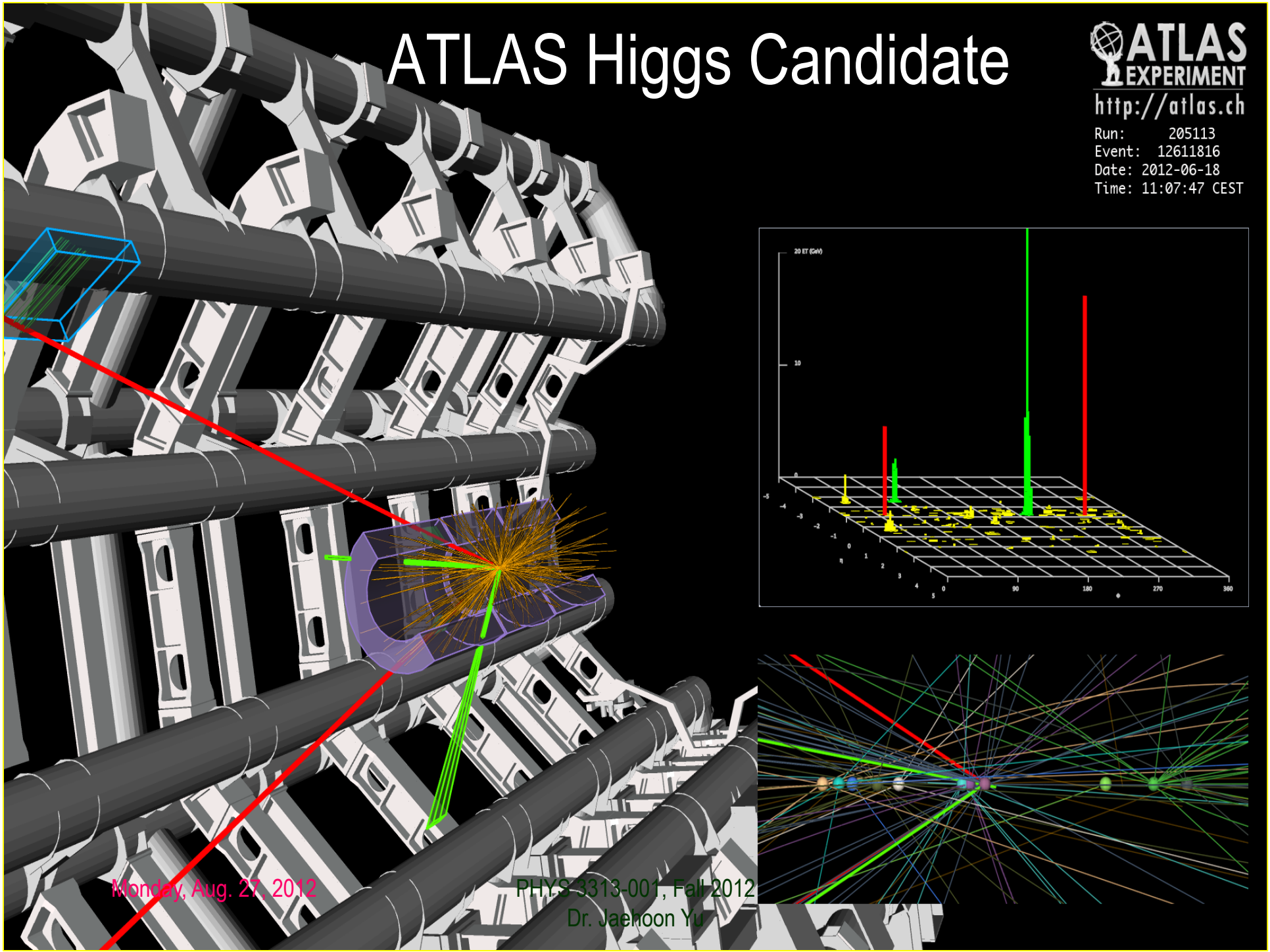


ATLAS and CMS Higgs – Prob.





ATLAS Higgs Candidate



So have we seen the Higgs particle?

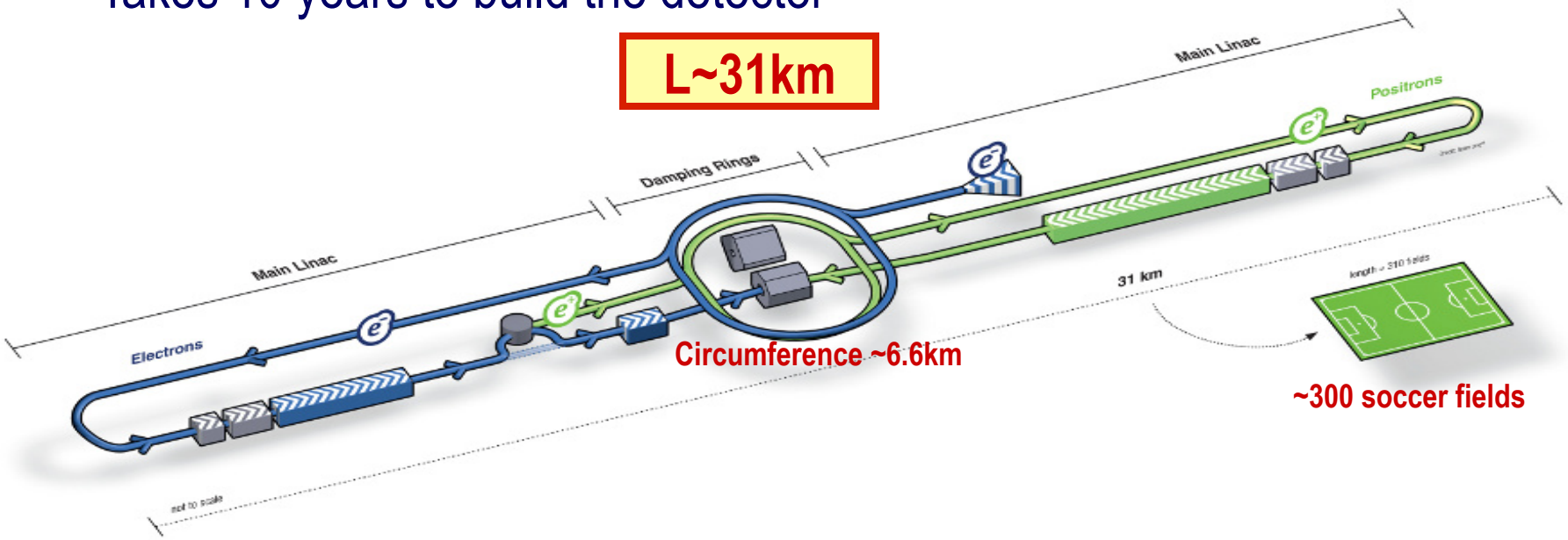
- The statistical significance of the finding is to 5 standard deviations
  - Level of significance: 99.99994%
  - We can be wrong once if we perform the same experiment 1,740,000 times
- So did we find the Higgs particle?
  - We have discovered a new particle, the heaviest boson we've seen thus far
  - 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

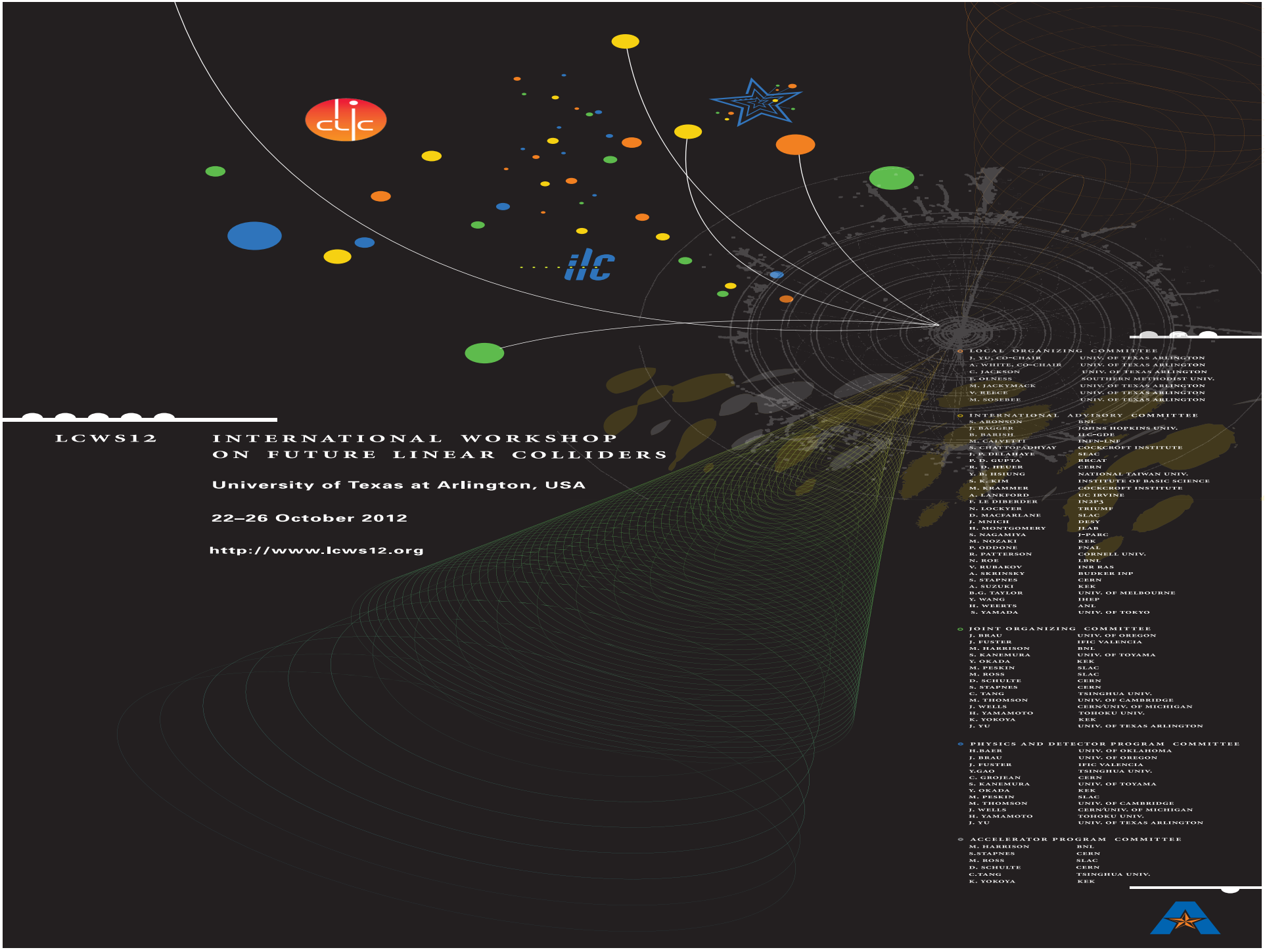
So why is this discovery important?

- This is the giant first 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

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)
- Takes 10 years to build the detector





LCWS12

INTERNATIONAL WORKSHOP ON FUTURE LINEAR COLLIDERS

University of Texas at Arlington, USA

22–26 October 2012

http://www.lcws12.org

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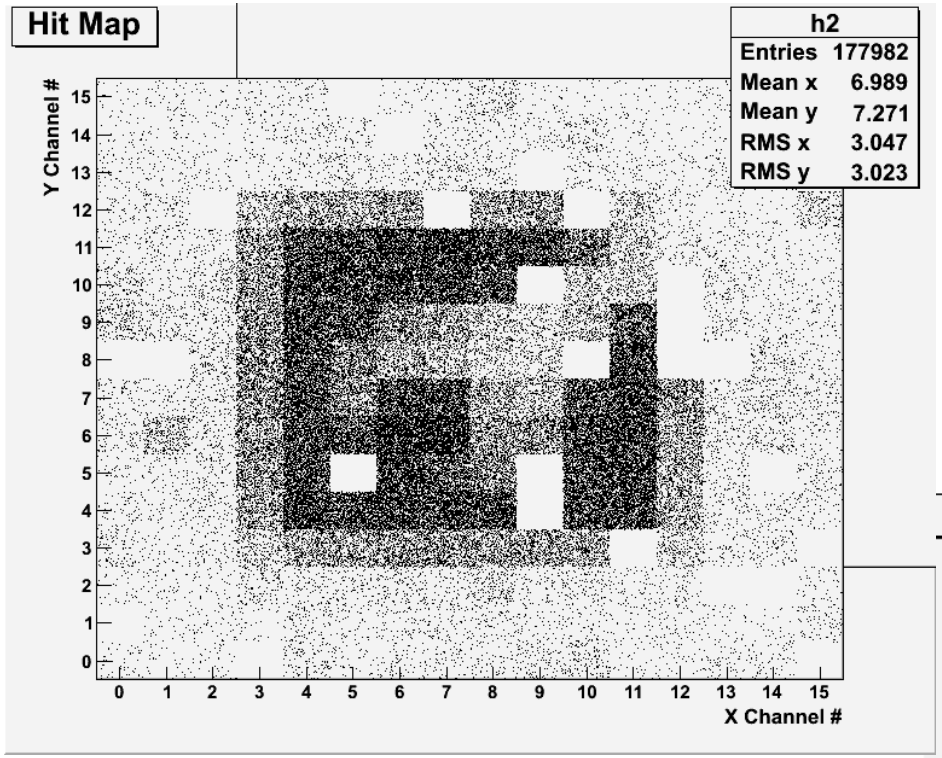
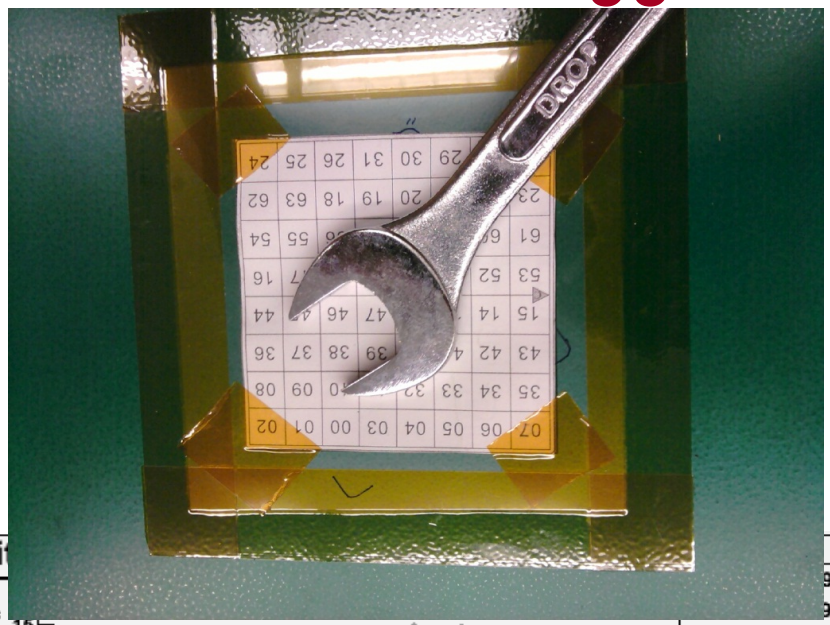
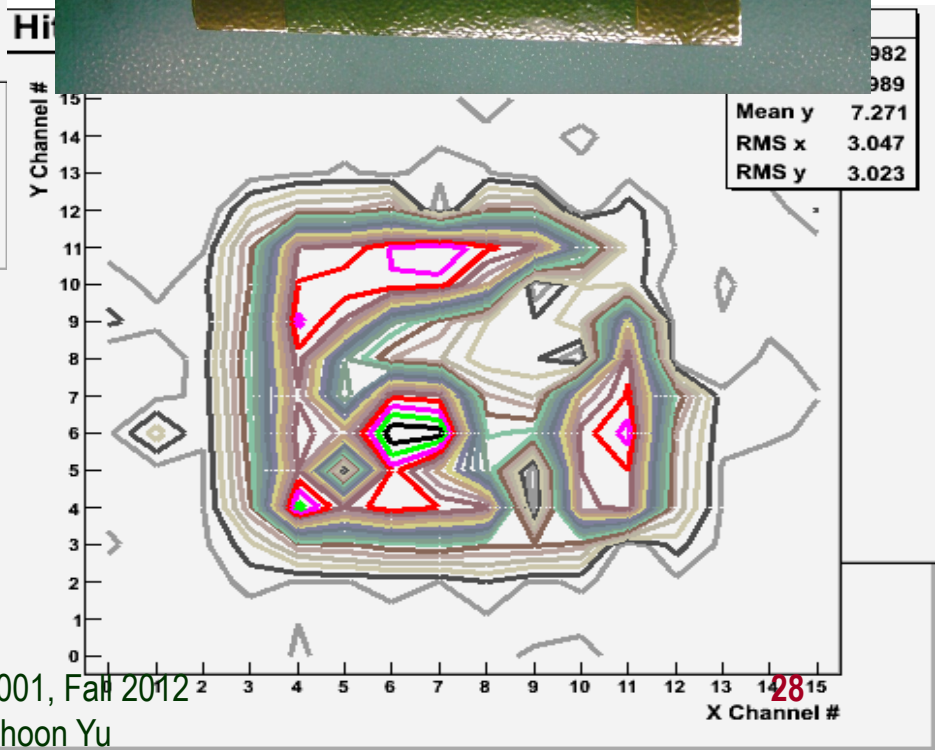
Radioactive Source Run with Internal Trigger





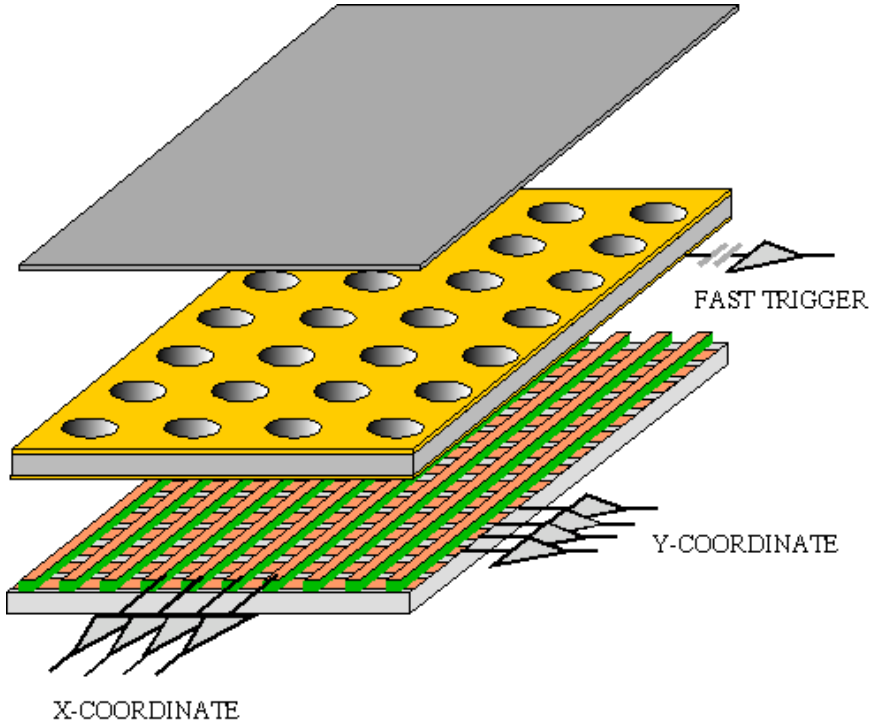


Noisy channels masked out!

Can you see what the object is?

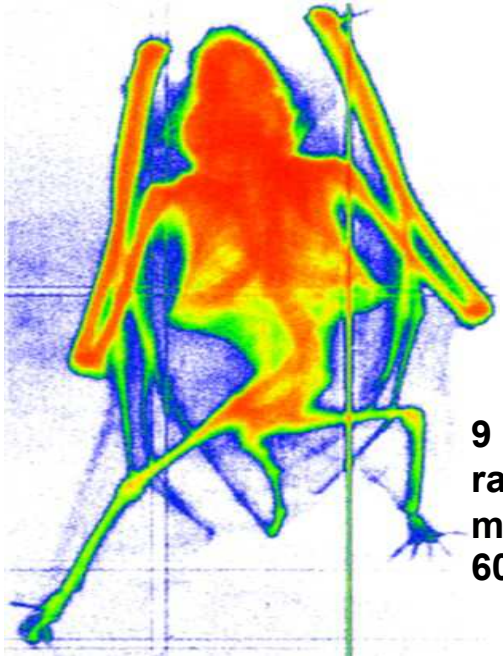
GEM Application Potential

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

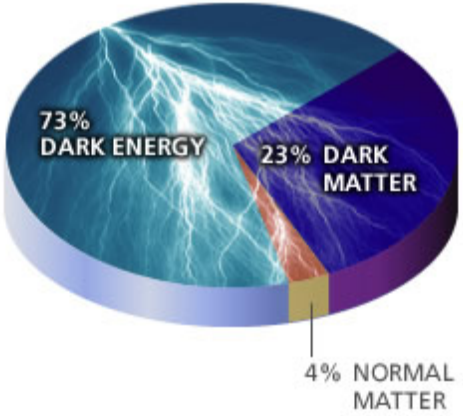


9 keV absorption radiography of a small mammal (image size ~ 60 x 30 mm^2)


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

So are we done yet?

- Why are there three families of quarks and leptons?
- Why is the mass range so large ($0.1m_p$ – $175\ m_p$)?
- How do matters acquire mass?
  - Higgs mechanism but where is the Higgs, the God particle?
- Why is the matter in the universe made only of particles?
  - What happened to anti-particles? Or anti-matters?
- Do neutrinos have mass& what are the mixing parameters?
- Why are there only three apparent forces?
- Is the picture we present the real thing?
  - What makes up the 96% of the universe?
  - How about extra-dimensions?
- How is the universe created?
- Are there any other theories that describe the universe better?
- Many more questions to be answered!!

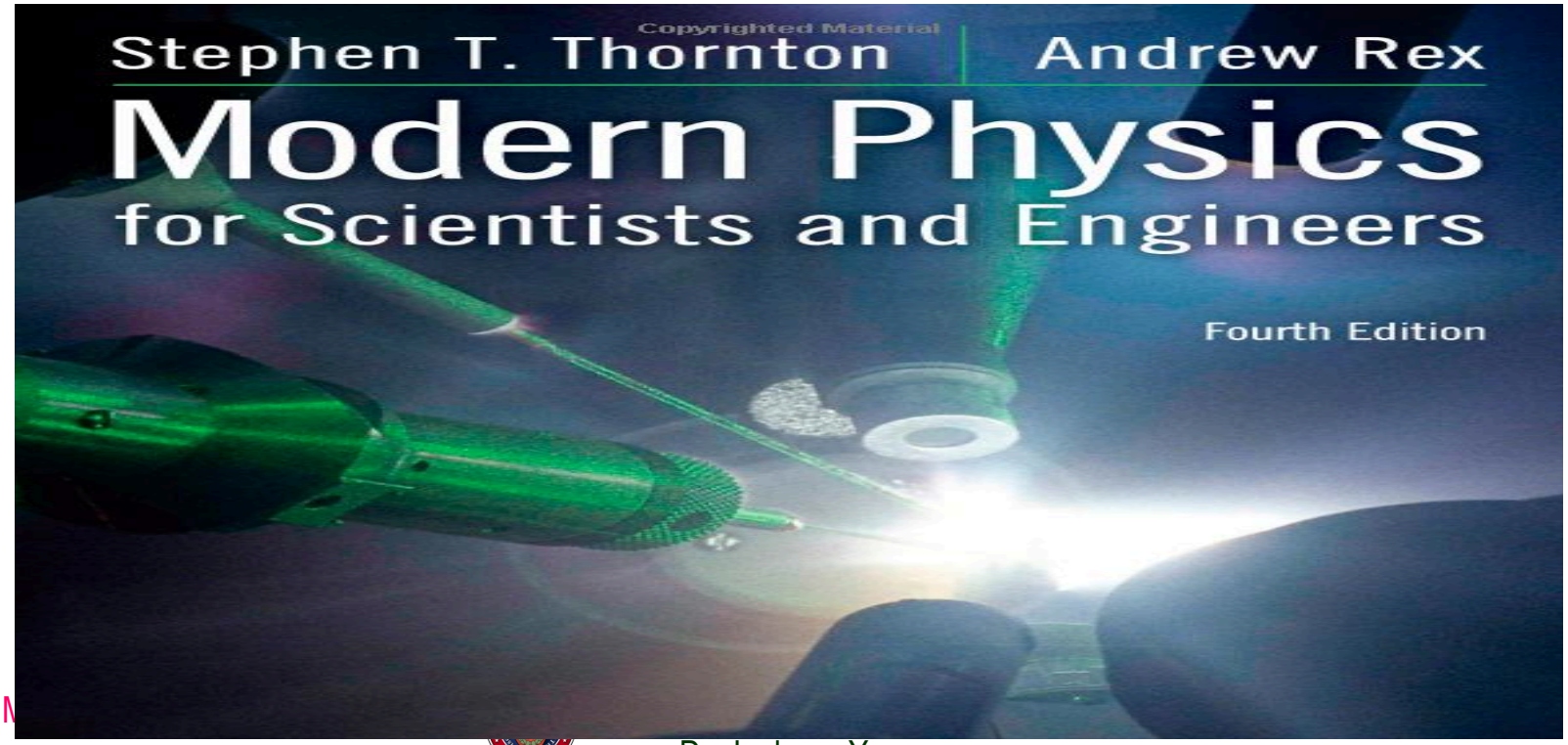


Information & Communication Source

- Course web page: http://www-hep.uta.edu/%7Eyu/teaching/fall12-3313-001/fall12-3313-001.html
  - 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 that your e-mail at the time of course registration is the one you most frequently read!!
- Office Hours for Dr. Yu: 2:30 – 3:40pm, Mondays and Wednesdays or by appointments

Textbook

- Title: Modern Physics for Scientists and Engineers
  - 4th edition
- Authors: S.T. Thornton and A. Rex
- ISBN: 978-1-133-10372-1



Evaluation Policy

- Homework: 30%
- Exams
  - Mid-term Exam (Wed., Oct. 10): 20%
  - Final Comprehensive Exam (Wed., Dec. 12): 25%
  - 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
- Group Research Project: 15%
- Pop-quizzes: 10%

100%

- Extra credits: 10% of the total
- Grading will be done on a sliding scale
- 55% of the grade is in your hand!!

Homework

- Solving homework problems is the only way to comprehend class material
- Consists of a lot of reading, deriving and writing
- Each homework carries the same weight
- **ALL** homework grades will be used for the final grade
- Home work will constitute **30% of the total**
  - A good way of keeping your grades high
- Strongly encouraged to collaborate
  - Just make sure to submit your own answers written in your OWN way!!

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

Extra credit

- Up to 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 Colloquium Participations
  - Strong participation in the class discussions
  - Special projects
  - Watch the valid planetarium shows
  - Many other opportunities

Valid Planetarium Shows

- Regular running shows
  - Experience the Aurora – Fridays at 6:00, Saturdays at 5:30
  - Violent Universe – Sundays at 1:30
  - Black Holes – Thursdays at 6:00, Saturdays at 2:30
- Shows that need special arrangements
  - IBEX
  - Magnificent Sun
  - Nano Cam
  - Stars of the Pharaohs
  - Time Space
  - Two Small Pieces of Glass
  - Unseen Universe: The Vision of SOFIA
  - 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 30% 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 the same principles!!
  - Extra credit 10%
- I will work with you so that your efforts are properly rewarded

What do we want to learn in this class?

- The physics that provided fundamentals to the technical progress for us
- Learn concepts of quantum theory for microscopic phenomena and relativity for phenomena with high speed
- Learn physical principles that we still exploit
- Learn skills to express observations and measurements in mathematical language
- Learn skills to research literatures and express your research in systematic manner in writing
- Build up confidence in your physics abilities 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…

- Concepts and derivation of many of the modern physics
  - Special relativity
  - Quantum theory
  - Atomic physics
  - Condensed Matter physics
  - Nuclear physics
  - Particle Physics
- Focus on learning about the concepts with less complicated math
- You will be able to understand what fundamental physics provides bases for the current technology