PHYS 1441 – Section 001
Lecture #1

Monday, June 8, 2015

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
- Standards and units

Today's homework is homework #1, due 11pm, this Wednesday, June 10!!

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 of appendix A by Wednesday, June 10
  - There will be a quiz next Wednesday, June 10, on this reading assignment

Who am I?

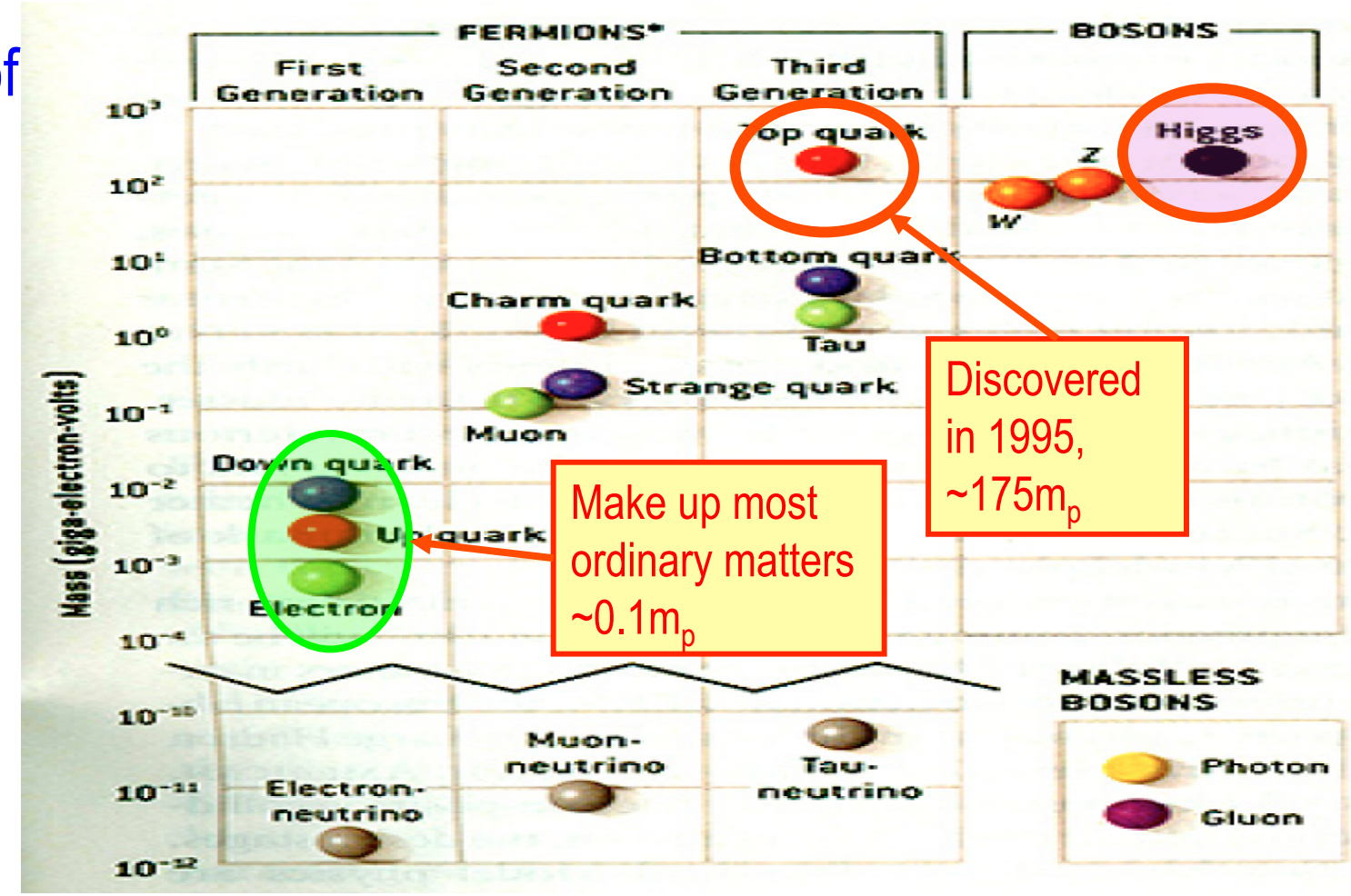
- Name: Dr. Jaehoon Yu (You can call me **Dr. Yu**)
- Office: Rm 342, Chemistry and Physics Building
- Extension: x22814, E-mail: *jaehoonyu@uta.edu*
- My profession: High Energy Particle Physics (HEP)
  - Collide particles (protons on anti-protons or electrons on anti-electrons, positrons) at the energies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

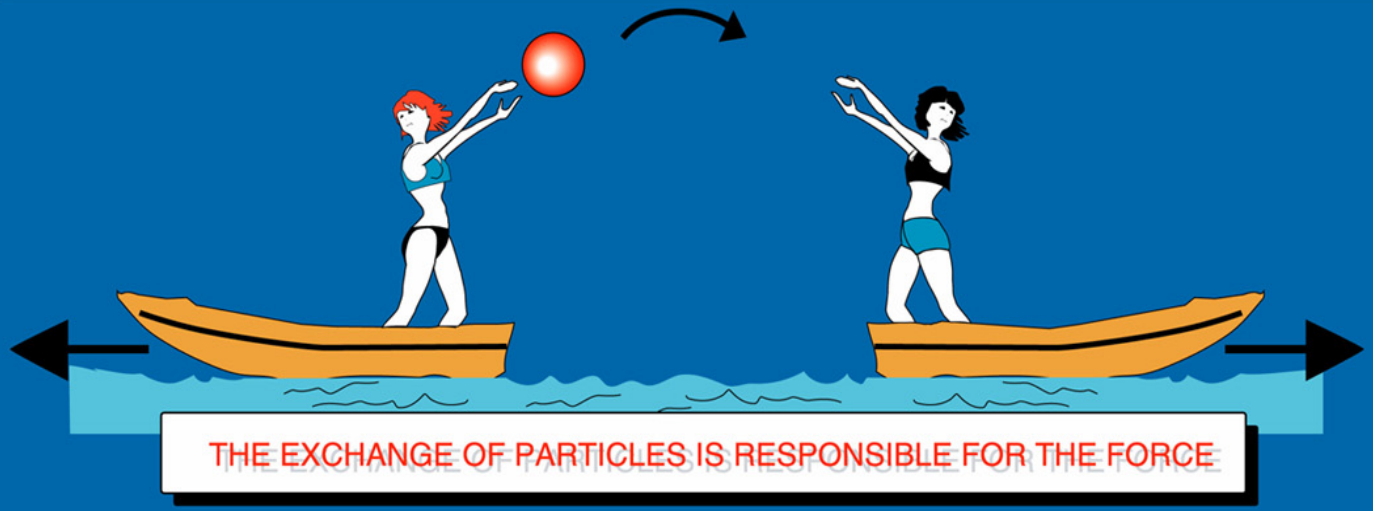
HEP: A field of physics that studies the fundamental constituents of matter and basic principles of interactions between them.



- 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!

The forces in Nature

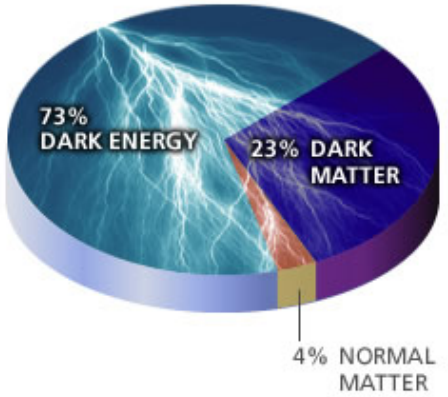
TYPE	INTENSITY OF FORCES (DECREASING ORDER)	BINDING PARTICLE (FIELD QUANTUM)	OCCURS IN :
STRONG NUCLEAR FORCE	~ 1	GLUONS (NO MASS)	ATOMIC NUCLEUS
ELECTRO -MAGNETIC FORCE	~ 10^{-3}	PHOTONS (NO MASS)	ATOMIC SHELL ELECTROTECHNIQUE
WEAK NUCLEAR FORCE	~ 10^{-5}	BOSONS Z^{o} , W+ , W- (HEAVY)	RADIOACTIVE BETA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



CERN AC _Z04_ V25/8/1992

So what's the problem?

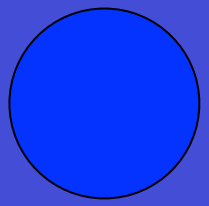
- Why is the mass range so large ($0.1m_p$ – $175\ m_p$)?
- How do matters acquire mass?
  - Higgs mechanism, did we find the Higgs?
- Why is the matter in the universe made only of particles?
- Neutrinos have mass!! What are the mixing parameters, particle-anti particle asymmetry and mass ordering?
  - The nature of neutrinos, Majorana, Dirac?
- Why are there only four apparent forces?
- Is the picture we present the real thing?
  - What makes up the ~95% of the universe?



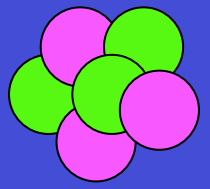
- Are there any other theories that describe the universe better?
  - Does the super-symmetry exist?
- How is the universe created? The BIG BANG?
- How can we live well in the universe as an integral partner?

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.

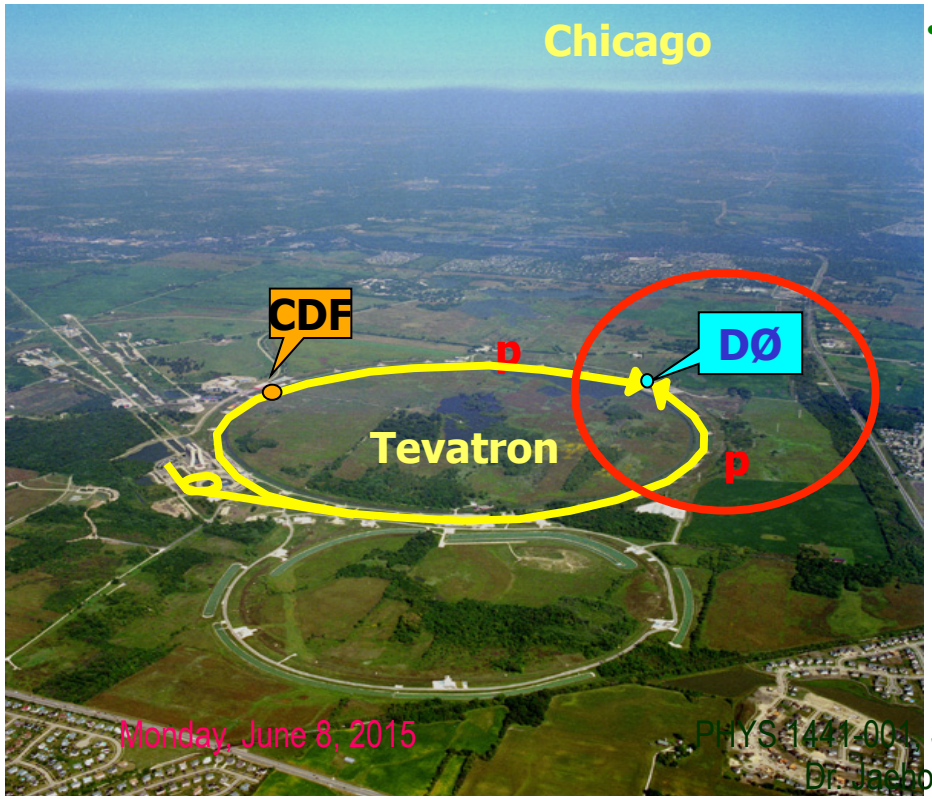
They make particles last seen
in the earliest moments of the universe.

Particle and anti-particle annihilate.

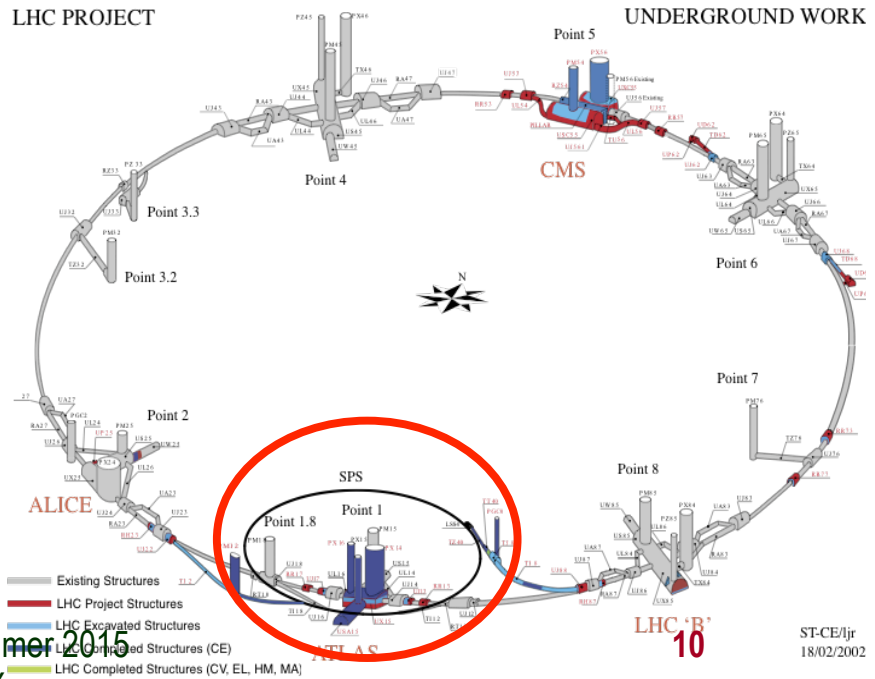
$$E = mc^2$$

Fermilab Tevatron and LHC at CERN

- World's Highest Energy proton-anti-proton collider
  - 4km (2.5mi) 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
  - **Tevatron was shut down in 2011**
  - **Vibrant other programs running, including the search for dark matter with beams!!**

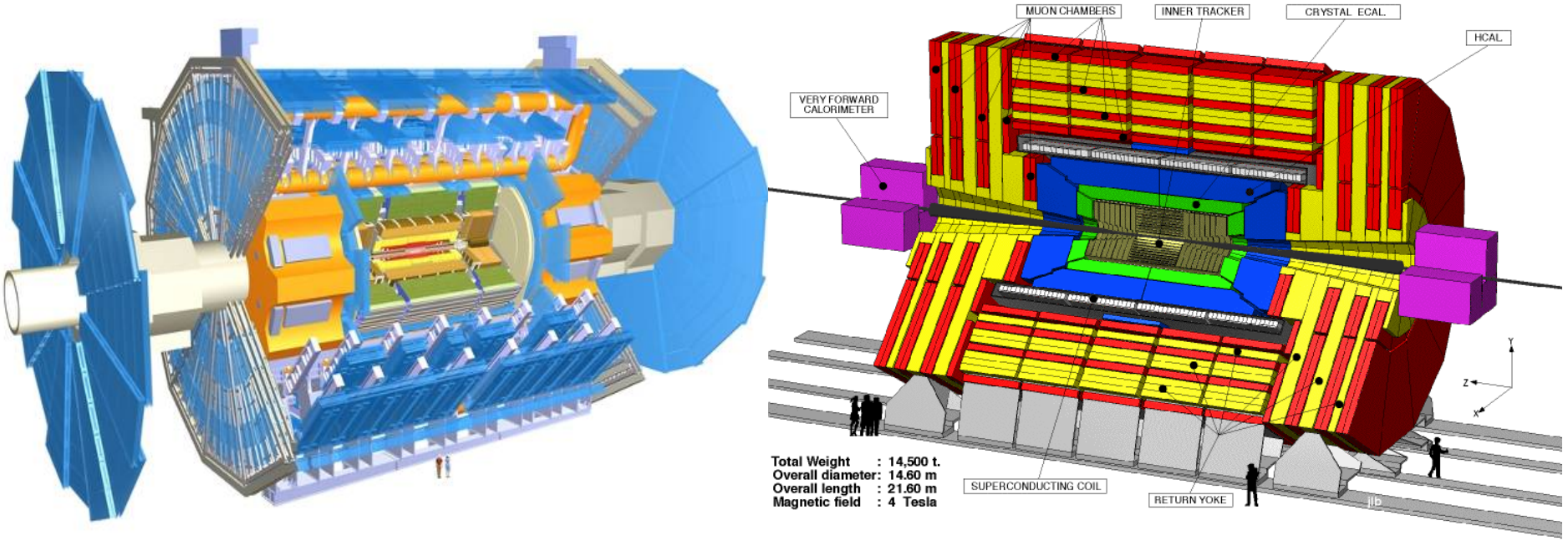


- World's Highest Energy p-p collider
  - 27km (17mi) circumference, 100m (300ft) underground
  - Design E_{cm}=14 TeV (=44x10^{-7}J/p➔ 362M Joules on the area smaller than 10^{-4}m^2)
  - ➢ Equivalent to the kinetic energy of a B727 (80tons) at the speed 193mi/hr (312km/hr)
    - ➢ ~3M times the energy density at the ground 0 of the Hiroshima atom bomb
- **Large amount of data accumulated in 2010 – 2013**
- **Beam returned after a 2 yr shutdown, data taking begun**



LHC @ CERN Aerial View

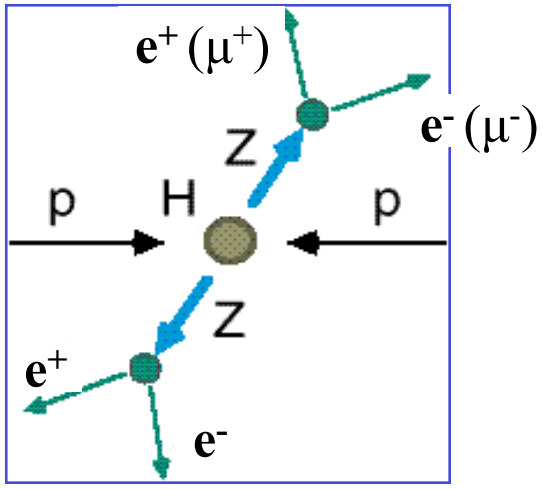
The ATLAS and CMS Detectors



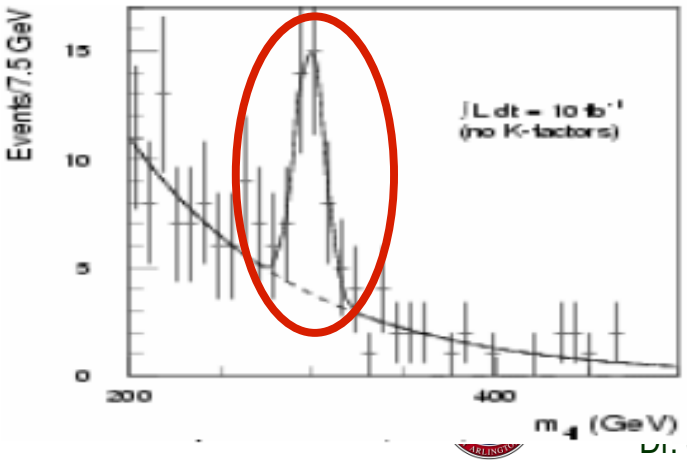
- **Fully multi-purpose detectors with emphasis on lepton ID & precision E & P**
- **Weighs 7000 tons and 10 story tall**
- Records **200 – 400 collisions/second**
- Records approximately **350** MB/second
- Record ~2 PB per year ➔ **200*Printed material of the US Lib. of Congress**

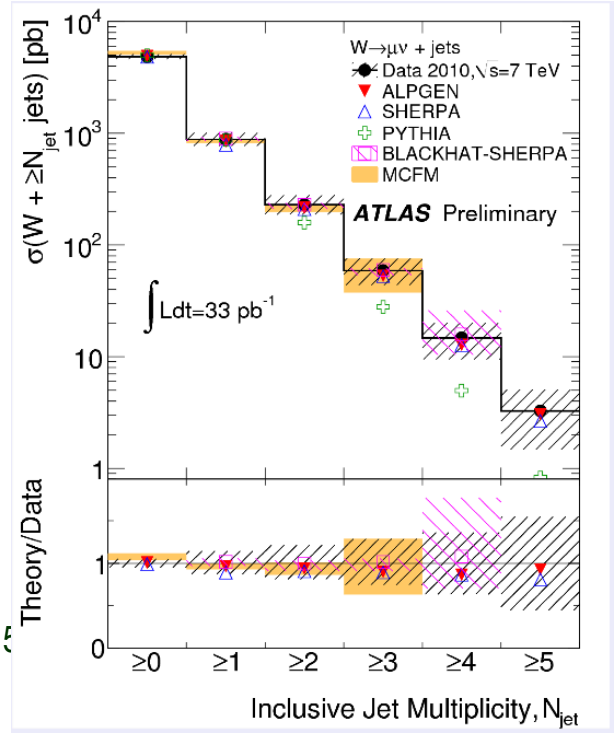
How do we look for the Higgs?

- Identify Higgs candidate events

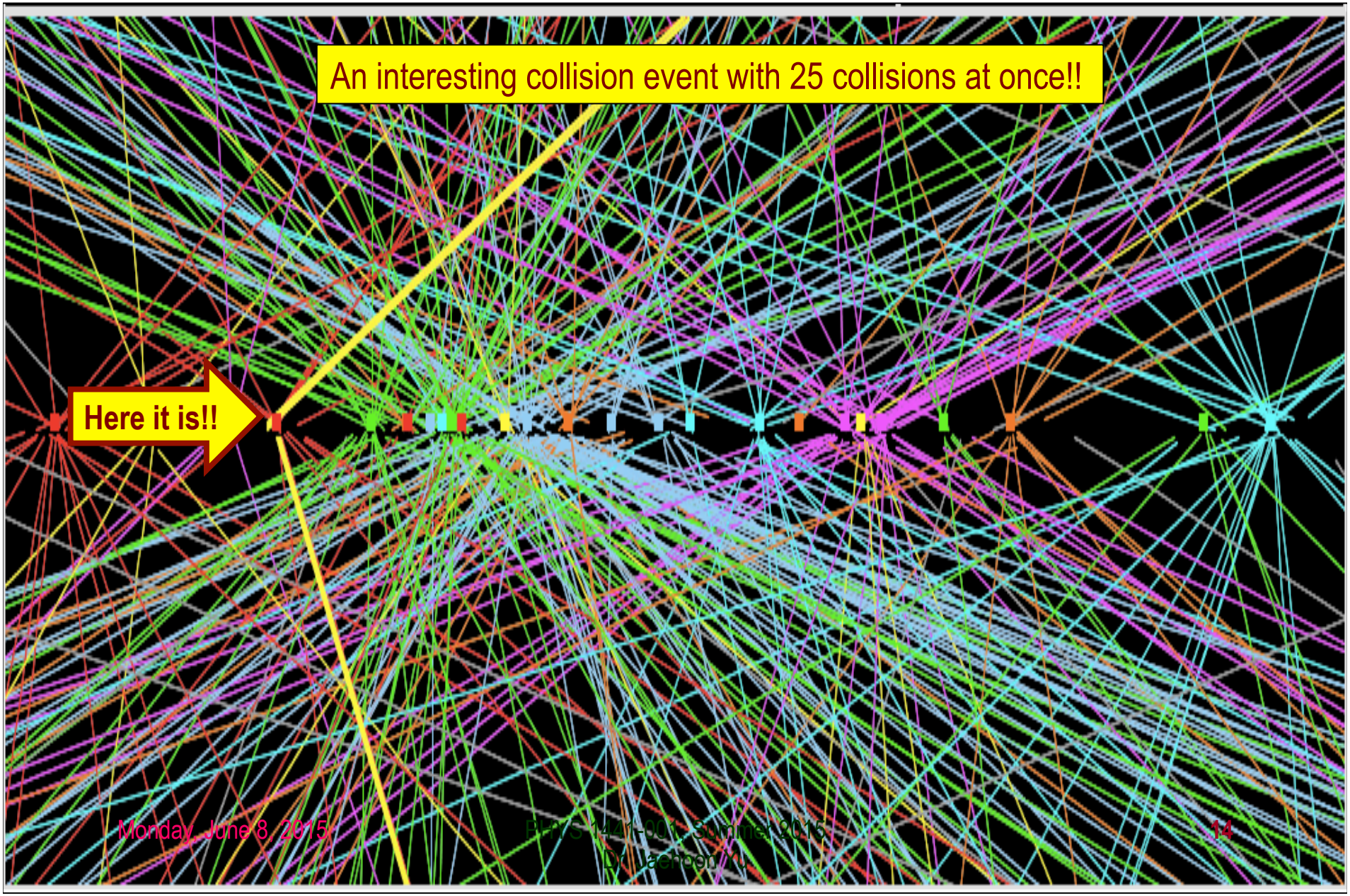


- Understand fakes (backgrounds)
- Look for a bump!!
  - Large amount of data absolutely critical

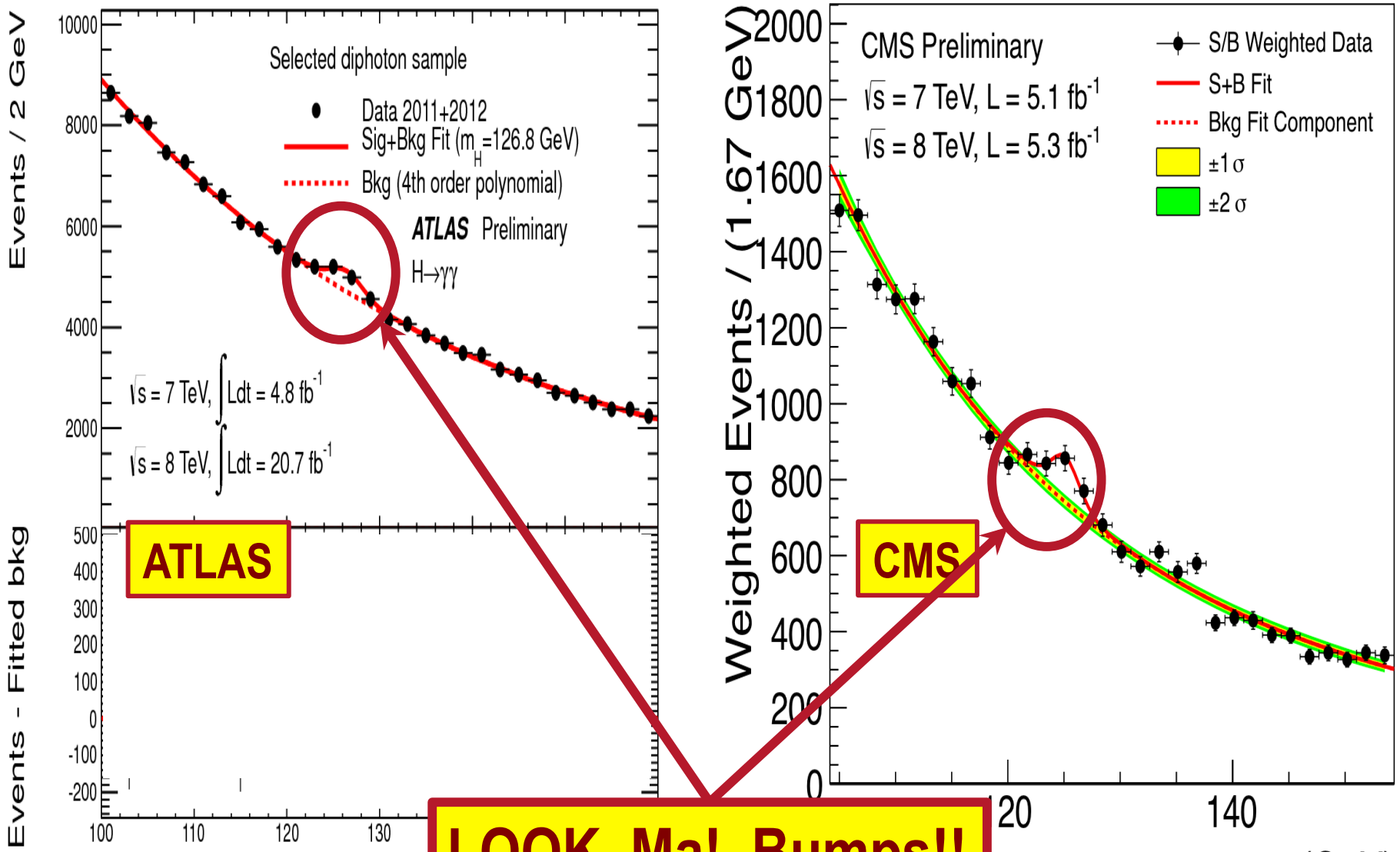




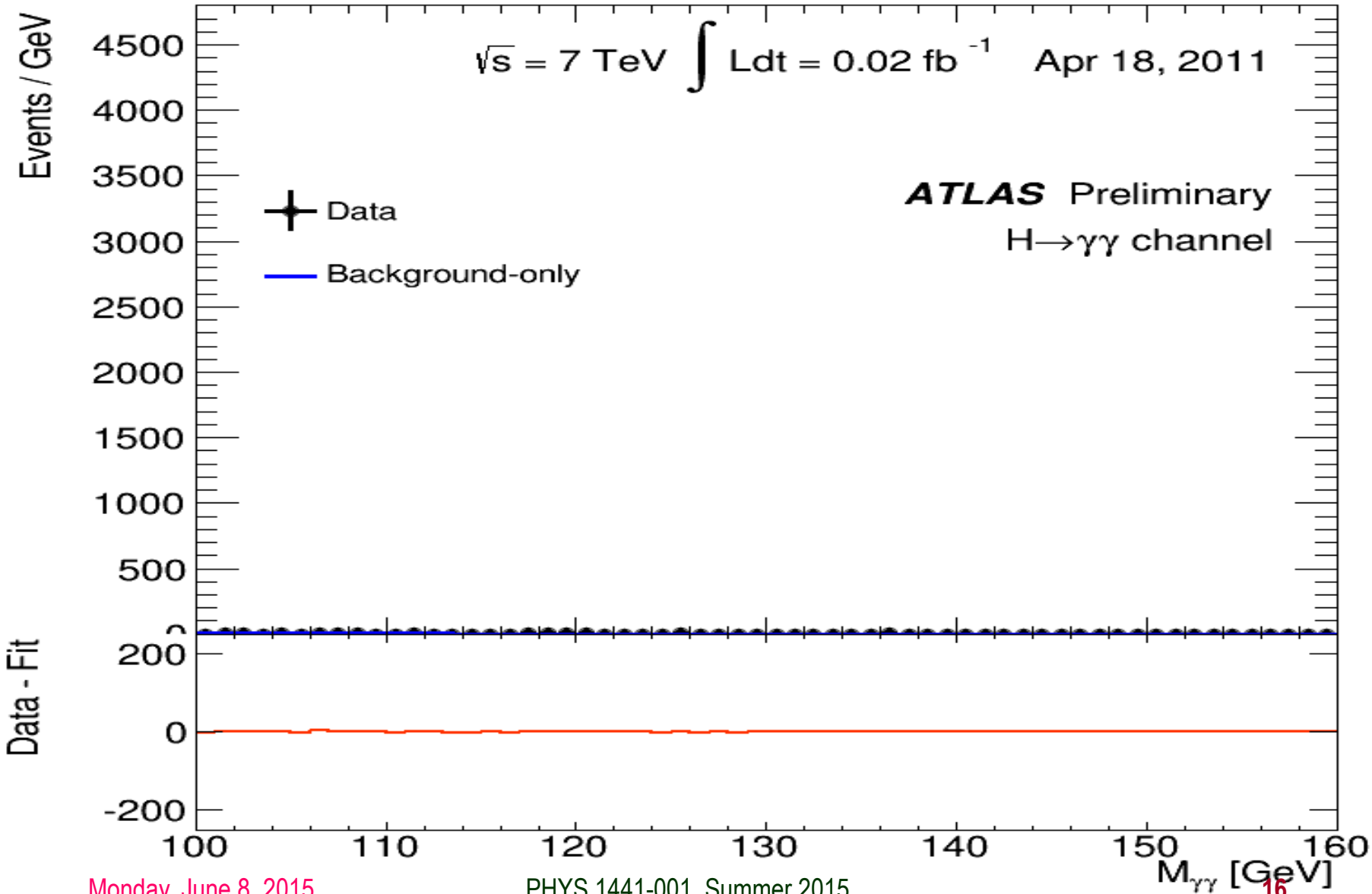
Challenges? No problem!



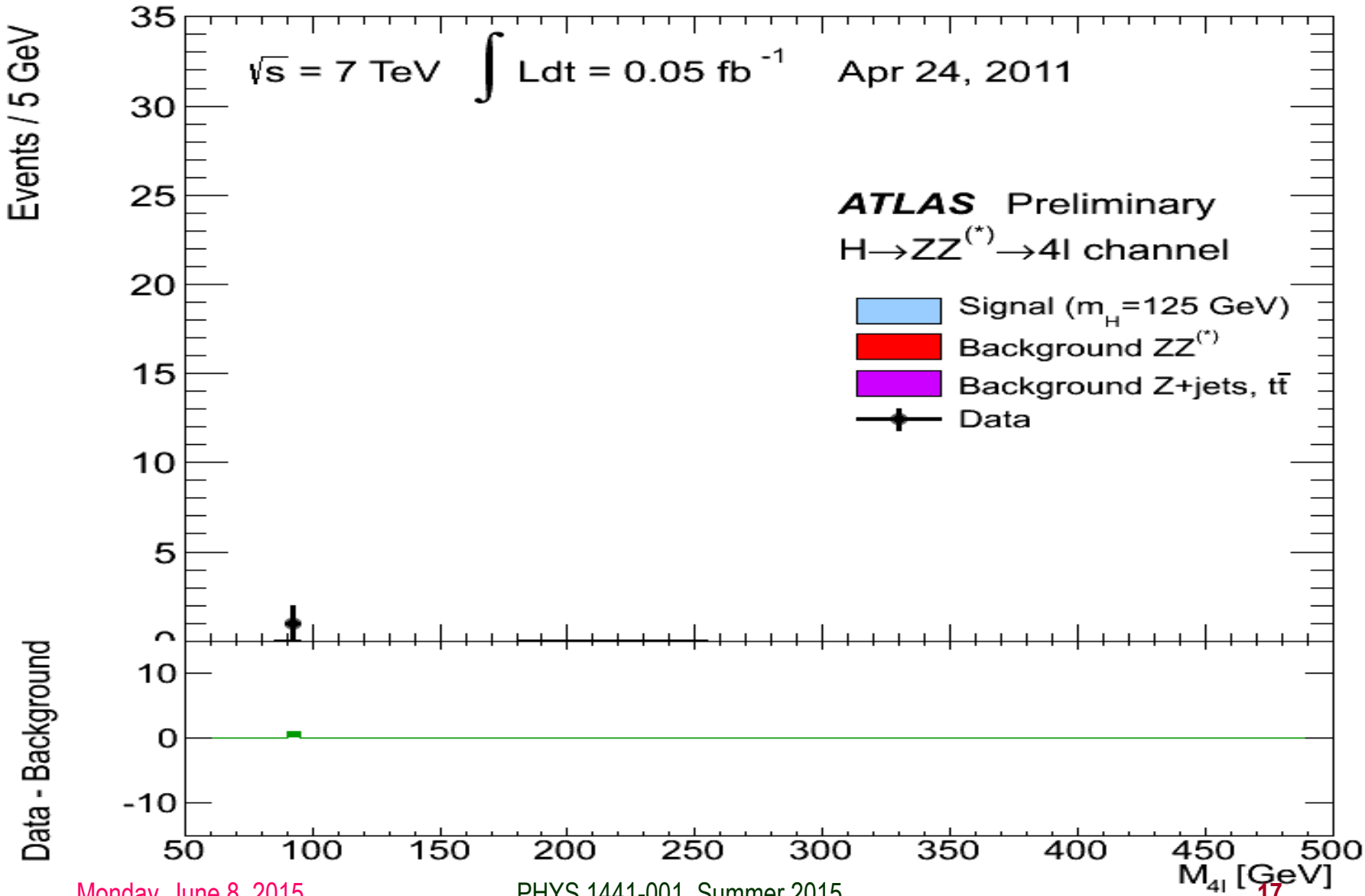
ATLAS and CMS Mass Bump Plots ($H \rightarrow \gamma\gamma$)



What did statistics do for Higgs?



How about this?



So have we seen the Higgs particle?

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

Statistical Significance Table

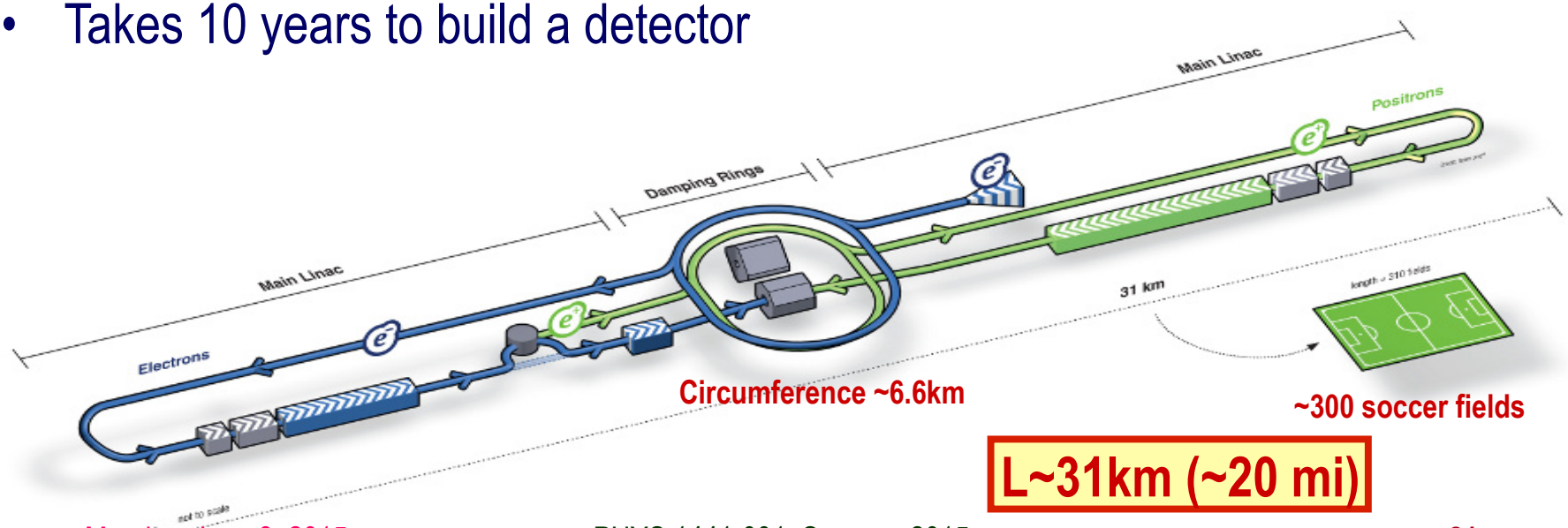
zσ	Percentage within CI	Percentage outside CI	Fraction outside CI
0.674 490σ	50%	50%	1 / 2
0.994 458σ	68%	32%	1 / 3.125
1σ	68.268 9492%	31.731 0508%	1 / 3.151 4872
1.281 552σ	80%	20%	1 / 5
1.644 854σ	90%	10%	1 / 10
1.959 964σ	95%	5%	1 / 20
2σ	95.449 9736%	4.550 0264%	1 / 21.977 895
2.575 829σ	99%	1%	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 much bigger than seven standard deviations
  - Level of significance: much better than 99.999 999 999 7% (eleven 9s!!)
  - We could be wrong once if we do the same experiment 391,000,000,000 times (will take ~13,000 years even if each experiment takes 1s!!)
- So did we find the Higgs particle?
  - We have discovered the heaviest new boson we've seen thus far
  - It has many properties consistent with the Standard Model Higgs particle
    - It quacks like a duck and walks like a duck but…
  - We 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 its nature
- Precision measurements and searches in new channels ongoing

What's 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)
  - Japan working hard to garner broad world-wide support of the ILC
  - Site has been selected and a design study on-going
- Takes 10 years to build a detector

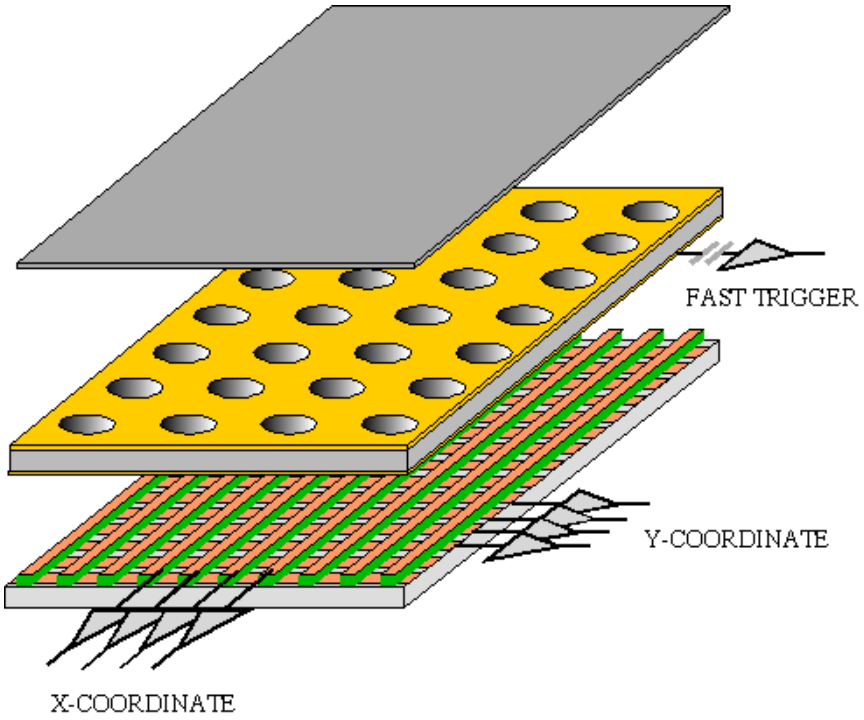


Dark Matter Searches at Fermilab

- Fermi National Accelerator Laboratory is turning into a lab with very high intensity accelerator program
- UTA group is part of three experiments
  - Long Baseline Neutrino Experiment (LBNE), an $850M flagship experiment, with data expected in 2025
    - High flux secondary beam and a near detector enables searches for DM
    - In addition to precision measurements of key neutrino param..
    - UTA playing very significant role in this experiment
- A rich physics program for the next 20 – 30 years!!
- If we see DM, we could use this to make DM Beam??

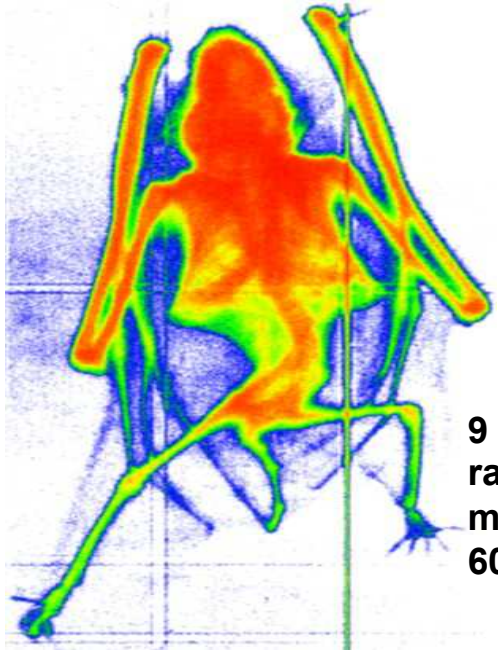
GEM Application Potential

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



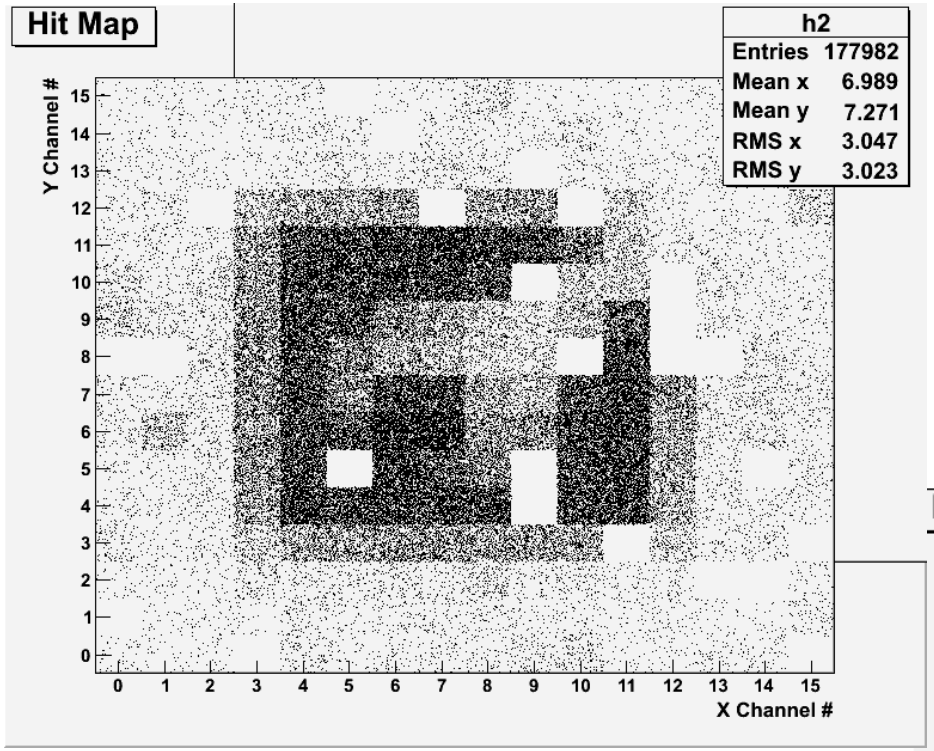
A. Bressan et al,
Nucl. Instr. and Meth. A 425(1999)254
F. Sauli, Nucl. Instr. and Meth.A 461(2001)47

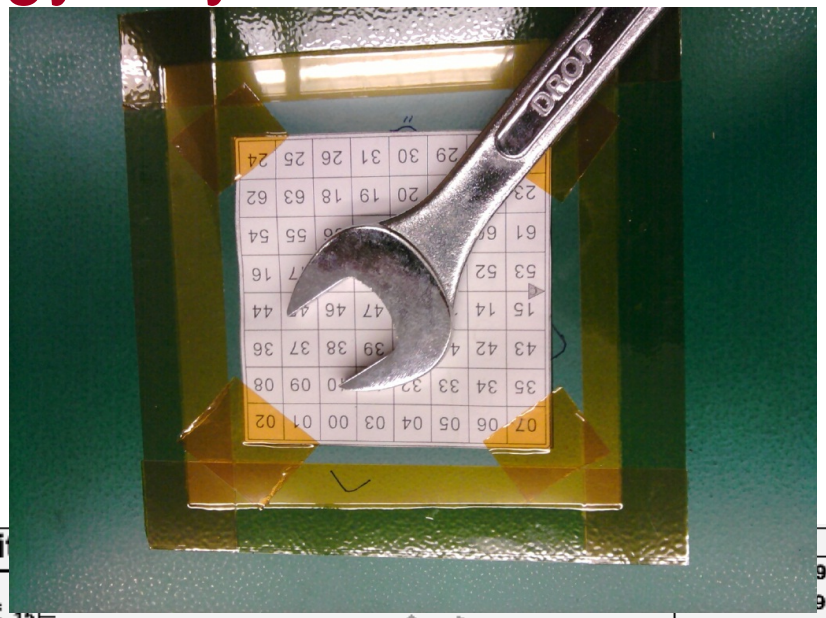
FAST X-RAY IMAGING

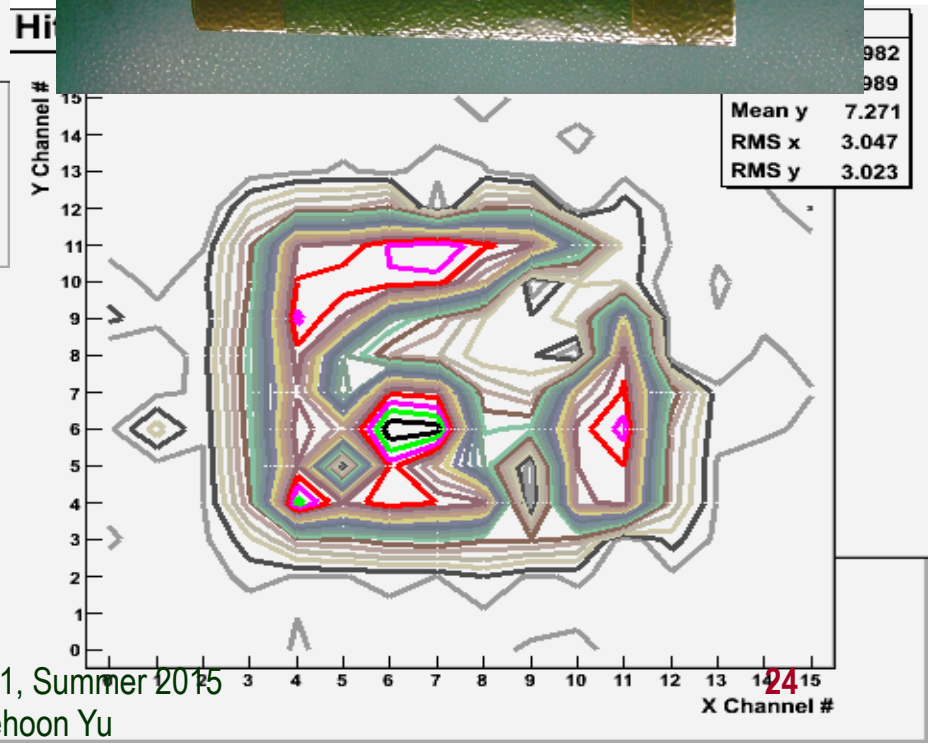


9 keV absorption radiography of a small mammal (image size ~ 60 x 30 mm^2)

Bi-product of High Energy Physics Research







Can you see what the object is?
(GEM Detector X-ray Image)


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

Dark Matter Searches at Fermilab

- Fermi National Accelerator Laboratory is turning into a lab with very high intensity accelerator program
- My group is part of three experiments at Fermilab
  - DUNE (data starts 2025), MiniBooNE (data now) and LArIAT (data now)
    - High flux secondary beam and a near detector enables searches for DM
    - In addition to precision measurements of key neutrino param
    - UTA playing leading roles in DM (We are the DM people!!
- A rich physics program for the next 20 – 30 years!!
- If we see DM, we could use this to make DM Beam??

Discovery of the God Particle in 2012

Information & Communication Source

- Course web page: http://www-hep.uta.edu/~yu/teaching/summer15-1441-001/summer15-1441-001.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: 12:30 – 1:30pm, M-Th or by appointments

Evaluation Policy

- Homework: 25%
- Exams
  - Final Comprehensive Exams (7/13): 23%
  - Mid-term Comprehensive Exam (6/23): 20%
  - One better of the two term Exams (6/15/15 and 7/1/15): 12%
    - Total of two non-comprehensive term exams (6/15 and 7/1)
    - 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 **PHYS1441-Summer15**, unique number **41015**
  - Download homeworks, solve the problems and submit them online
  - Multiple unsuccessful tries will deduct points
  - Roster will close at 11pm Wednesday, June 10
  - 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: Starts today, Monday, June 8
  - 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
  - Texas Stargazing – Tuesdays at 2:00 pm; Dynamic Earth – Wed. at 2:00 pm;
  - Stars of the Pharaohs – Fridays at 2:00pm and Saturdays at 5:30 pm
- Shows that need special arrangements
  - Astronaut; Bad Astronomy; Back to the Moon for Good, Black Holes (can watch up to 2 times)
  - Experience the Aurora IBEX; Ice Worlds; Magnificent Sun; Mayan Prophecies
  - Nano Cam; Stars of the Pharaohs; TimeSpace, Two Small Pieces of Glass
  - Unseen Universe: The Vision of SOFIA; Violent Universe, We are Astronomers
- 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 for 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 problems will be easier that 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
- Kinematic equations and description of motions
- Concepts of physical quantities that describe motions, such as velocity, speed, acceleration, etc
- Vector and scalar quantities and their operations
- Concepts of force, energy and momentum and the relationships between them and their conservation laws
- Techniques to use conservation laws for motions
- Rotational motions and Equilibrium conditions
- Fluid and wave motions and thermodynamics

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 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

Why do Physics?

Exp.
- To understand nature through experimental observations and measurements (**Research**)

Theory
- Establish limited number of fundamental laws, usually with mathematical expressions
- Predict the nature's course

⇒Theory and Experiment work hand-in-hand

⇒Theory works generally under restricted conditions

⇒Discrepancies between experimental measurements and theory are good for improvements

⇒Improves our everyday lives, even though some laws can take a while till we see them amongst us

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
- 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?
  - How and why do matters interact with each other?
  - How is universe created?

Models, Theories and Laws

- Models: An analogy or a mental image of a phenomena in terms of something we are familiar with
  - Thinking light as waves, behaving just like water waves
  - Often provide insights for new experiments and ideas
- Theories: More systematically improved version of models
  - Can provide quantitative predictions that are testable and more precise
- Laws: Certain concise but general statements about how nature behaves
  - Energy conservation
  - The statement must be found experimentally valid to become a law
- Principles: Less general statements of how nature behaves
  - Has some level of arbitrariness

Uncertainties

- Physical measurements have limited precision, however good they are, due to:

Stat.{ – Number of measurements

Syst.{ – Quality of instruments (meter stick vs micro-meter)
– Experience of the person doing measurements
– Etc

- In many cases, uncertainties are more important and difficult to estimate than the central (or mean) values

Significant Figures

- Denote the precision of the measured values
  - The number 80 implies precision of +/- 1, between 79 and 81
    - If you are sure to +/-0.1, the number should be written 80.0
  - Significant figures: non-zero numbers or zeros that are not place-holders
    - 34, 34.2, 0.001, 34.100
      - 34 has two significant digits
      - 34.2 has 3
      - 0.001 has one because the 0's before 1 are place holders to position "."
      - 34.100 has 5, because the 0's after 1 indicates that the numbers in these digits are indeed 0's.
    - When there are many 0's, use scientific notation for simplicity:
      - $31400000=3.14\text{x}10^{7}$
      - $0.00012=1.2\text{x}10^{-4}$

Significant Figures

- Operational rules:
  - Addition or subtraction: Keep the **smallest number of decimal place** in the result, independent of the number of significant digits: 12.001+ 3.1= 15.1
  - Multiplication or Division: Keep the **smallest number of significant digits** in the result: 12.001 x 3.1 = 37, because the smallest significant figures is ?.

What does this mean? **The worst precision determines the precision the overall operation!!**

In English? **Can't get any better than the worst measurement!**