Today's homework is homework #1, due 11pm, this Thursday, Aug. 28!!
Announcements

• Plea to you: Please turn off your cell-phones, tablets and computers while class is in session
• Reading assignment #1: Read and follow through all sections in appendix A – D for units and unit conversions and E on math refresher by Thursday, Aug. 28
  – There will be a quiz next Thursday, Aug. 28, on this reading assignment
Who am I?

- **Name:** Dr. Jae hoon Yu (You can call me **Dr. Yu**)
- **Office:** Rm 342, Chemistry and Physics Building
- **Extension:** x22814, E-mail: jae hoonyu@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: 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 \((0.1 m_p – 175 m_p)\)?
- 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?
# The forces in Nature

<table>
<thead>
<tr>
<th>TYPE</th>
<th>INTENSITY OF FORCES (DECREASING ORDER)</th>
<th>BINDING PARTICLE (FIELD QUANTUM)</th>
<th>OCCURS IN:</th>
</tr>
</thead>
<tbody>
<tr>
<td>STRONG NUCLEAR FORCE</td>
<td>~ 1</td>
<td>GLUONS (NO MASS)</td>
<td>ATOMIC NUCLEUS</td>
</tr>
<tr>
<td>ELECTRO-MAGNETIC FORCE</td>
<td>~ 10^-3</td>
<td>PHOTONS (NO MASS)</td>
<td>ATOMIC SHELL ELECTROTECHNIQUE</td>
</tr>
<tr>
<td>WEAK NUCLEAR FORCE</td>
<td>~ 10^-5</td>
<td>BOSONS Z^0, W^+, W^- (HEAVY)</td>
<td>RADIOACTIVE BETA DESINTEGRATION</td>
</tr>
<tr>
<td>GRAVITATION</td>
<td>~ 10^-38</td>
<td>GRAVITONS (?)</td>
<td>HEAVENLY BODIES</td>
</tr>
</tbody>
</table>

**THE EXCHANGE OF PARTICLES IS RESPONSIBLE FOR THE FORCE.**
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
  - $E_{cm} = 1.96 \text{ TeV} (=6.3\times10^{-7} \text{J/p} \Rightarrow 13\text{M Joules on the area smaller than } 10^{-4}\text{m}^2$)
  - Equivalent to the kinetic energy of a 20t truck at the speed 81mi/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 $E_{cm} = 14 \text{ TeV} (=44\times10^{-7} \text{J/p} \Rightarrow 362\text{M Joules on the area smaller than } 10^{-4}\text{m}^2$)
  - Equivalent to the kinetic energy of a B727 (80tons) at the speed 193mi/hr
    - ~3M times the energy density at the ground 0 of the Hiroshima atom bomb

- Large amount of data accumulated in 2010 – 2013
- Shutdown in Feb. 2013 & on track to resume Mar. 2015
The ATLAS and CMS Detectors

- Weighs 7000 tons and ~10 story tall
- Records 200 – 400 collisions/second (out of 50 million)
- Records approximately 350 MB/second
- Records ~2 PB per year ➔ 200*Printed material of the US Lib. of Congress

200x

Tuesday, Aug. 26, 2014

PHYS 1443-004, Fall 2014
Dr. Jaehoon Yu
What is the Higgs and What does it do?

• When there is perfect symmetry, one cannot tell directions!
What? What’s the symmetry?

- Where is the head of the table?
- Without a broken symmetry, one cannot tell directional information!!
A broken symmetry
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
- Sometimes, this field spontaneously generates a particle, the Higgs particle
- So the Higgs particle is the evidence of the existence of the Higgs field!
So how does Higgs Field work again?

- Person in space $\Rightarrow$ no symmetry breaking
- Person in air $\Rightarrow$ 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
Challenges? No problem!

An interesting collision event with 25 collisions at once!!

Here it is!!
ATLAS and CMS Mass Bump Plots ($H \rightarrow \gamma\gamma$)

**ATLAS**

- Data 2011+2012
- Sig+Bkg Fit ($m_H = 126.8$ GeV)
- Bkg (4th order polynomial)

**CMS**

- S/B Weighted Data
- S+B Fit
- Bkg Fit Component
- $\pm 1 \sigma$
- $\pm 2 \sigma$

Selected diphoton sample

$\sqrt{s} = 7$ TeV, $L = 4.8$ fb$^{-1}$

$\sqrt{s} = 8$ TeV, $L = 20.7$ fb$^{-1}$

**LOOK, Ma! Bumps!!**

Dr. Jaehoon Yu
What did statistics do for Higgs?
How about this?

\[ \sqrt{s} = 7 \text{ TeV} \quad \int Ldt = 0.05 \text{ fb}^{-1} \quad \text{Apr 24, 2011} \]

**ATLAS** Preliminary

\[ H \rightarrow ZZ^{(*)} \rightarrow 4l \text{ channel} \]

- Signal (\( m_H = 125 \text{ GeV} \))
- Background \( ZZ^{(*)} \)
- Background \( Z + \text{jets, } t\bar{t} \)
- Data

Tuesday, Aug. 26, 2014

PHYS 1443-004, Fall 2014

Dr. Jaehoon Yu
So have we seen the Higgs particle?

• The statistical significance of the finding is way over 7 standard deviations
### Statistical Significance Table

<table>
<thead>
<tr>
<th>( z \sigma )</th>
<th>Percentage within CI</th>
<th>Percentage outside CI</th>
<th>Fraction outside CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.674 490( \sigma )</td>
<td>50%</td>
<td>50%</td>
<td>1 / 2</td>
</tr>
<tr>
<td>0.994 458( \sigma )</td>
<td>68%</td>
<td>32%</td>
<td>1 / 3.125</td>
</tr>
<tr>
<td>1( \sigma )</td>
<td>68.268 9492%</td>
<td>31.731 0508%</td>
<td>1 / 3.151 4872</td>
</tr>
<tr>
<td>1.281 552( \sigma )</td>
<td>80%</td>
<td>20%</td>
<td>1 / 5</td>
</tr>
<tr>
<td>1.644 854( \sigma )</td>
<td>90%</td>
<td>10%</td>
<td>1 / 10</td>
</tr>
<tr>
<td>1.959 964( \sigma )</td>
<td>95%</td>
<td>5%</td>
<td>1 / 20</td>
</tr>
<tr>
<td>2( \sigma )</td>
<td>95.449 9736%</td>
<td>4.550 0264%</td>
<td>1 / 21.977 895</td>
</tr>
<tr>
<td>2.575 829( \sigma )</td>
<td>99%</td>
<td>1%</td>
<td>1 / 100</td>
</tr>
<tr>
<td>3( \sigma )</td>
<td>99.730 0204%</td>
<td>0.269 9796%</td>
<td>1 / 370.398</td>
</tr>
<tr>
<td>3.290 527( \sigma )</td>
<td>99.9%</td>
<td>0.1%</td>
<td>1 / 1,000</td>
</tr>
<tr>
<td>3.890 592( \sigma )</td>
<td>99.99%</td>
<td>0.01%</td>
<td>1 / 10,000</td>
</tr>
<tr>
<td>4( \sigma )</td>
<td>99.993 666%</td>
<td>0.006 334%</td>
<td>1 / 15,787</td>
</tr>
<tr>
<td>4.417 173( \sigma )</td>
<td>99.999%</td>
<td>0.001%</td>
<td>1 / 100,000</td>
</tr>
<tr>
<td>4.891 638( \sigma )</td>
<td>99.9999%</td>
<td>0.0001%</td>
<td>1 / 1,000,000</td>
</tr>
<tr>
<td>5( \sigma )</td>
<td>99.999 942 6697%</td>
<td>0.000 057 3303%</td>
<td>1 / 1,744,278</td>
</tr>
<tr>
<td>5.326 724( \sigma )</td>
<td>99.999 99%</td>
<td>0.000 01%</td>
<td>1 / 10,000,000</td>
</tr>
<tr>
<td>5.730 729( \sigma )</td>
<td>99.999 999%</td>
<td>0.000 001%</td>
<td>1 / 100,000,000</td>
</tr>
<tr>
<td>6( \sigma )</td>
<td>99.999 999 8027%</td>
<td>0.000 000 1973%</td>
<td>1 / 506,797,346</td>
</tr>
<tr>
<td>6.109 410( \sigma )</td>
<td>99.999 9999%</td>
<td>0.000 0001%</td>
<td>1 / 1,000,000,000</td>
</tr>
<tr>
<td>6.466 951( \sigma )</td>
<td>99.999 9999 99%</td>
<td>0.000 000 01%</td>
<td>1 / 10,000,000,000</td>
</tr>
<tr>
<td>6.806 502( \sigma )</td>
<td>99.999 999 999%</td>
<td>0.000 000 001%</td>
<td>1 / 100,000,000,000</td>
</tr>
<tr>
<td>7( \sigma )</td>
<td>99.999 999 999 7440%</td>
<td>0.000 000 000 256%</td>
<td>1 / 390,682,215,445</td>
</tr>
</tbody>
</table>
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)
  • Our Japanese colleagues have declared that they will bid for building ILC
  • Japan announced the selection of the site for the ILC in Aug. 2013!!

• 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 and other experiments at Fermilab in Chicago!
• 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:

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

• Course web page:
  http://www-hep.uta.edu/~yu/teaching/fall14-1443-004/fall14-1443-004.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: 11:00am – 12:00pm, Tuesdays and Thursdays or by appointments
Grade Evaluation Policy

• Homework: 25%
• Exams
  – Midterm and Final Comprehensive Exams (10/21 and 12/11): 19% each
  – One better of the two term Exams: 12%
    • Total of two non-comprehensive term exams (9/23 and 11/23)
    • 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: 15%
• Pop-quizzes: 10%
• Extra credits: 10% of the total
  – Random attendances
  – Strong participation in the class discussions
  – Special projects (These are the biggest!!)
  – Planetarium shows and many other opportunities
• Grading will be done on a sliding scale
Homework

• Solving homework problems is the only way to comprehend class material

• 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](https://quest.cns.utexas.edu/student/courses/list)
  – Choose the course PHYS1443-004, unique number 43014
  – Download homework #1, solve the problems and submit them online
  – Multiple unsuccessful tries will deduct points
  – Roster will close Thursday, Aug. 27
  – 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](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 in the week of Sept. 1
  – Important to understand physical principles through experiments
  – 15% of the grade
  – Lab syllabus is available in your assigned lab rooms.
    • Go by the lab room 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 – Thu in SH 007
  – This service begins today, Tuesday, Sept. 2
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
  - Strong participation in the class discussions
  - Special projects
  - Watch the valid planetarium shows
  - Many other opportunities
Valid Planetarium Shows

• Regular running shows
  – Astronaut
  – Two Small Pieces of Glass
  – We are Astronomers

• Shows that need special arrangements
  – Back to the Moon for Good; 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; TimeSpace
  – 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 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?
  – 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 of your grade in your hands, up to 50%!!!
  – 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 the same principles!!
  – Lab 15%
  – 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
- Concepts of force, energy and momentum and relationship between them and their conservation laws
- Techniques to use conservation laws for motions
- Rotational motions and Equilibrium conditions
- Fluid and wave motions and thermodynamics