PHYS 1441 – Section 001
Lecture #1

Monday, June 6, 2016
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 8!!
Announcements

• Plea to you: Please turn off all your electronic gadgets, including cell-phones, computers
• Reading assignment #1: Read and follow through all sections in appendix A by tomorrow, June 7
  – A-1 through A-7
• There will be a quiz on this and Ch. 21 on Wednesday, June 8.
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?
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 Force
  – Electromagnetic Force
  – Weak Nuclear Force
  – Strong Nuclear Force

• Current theory: The Standard Model of Particle Physics
## 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>$\sim 1$</td>
<td>GLUONS (NO MASS)</td>
<td>ATOMIC NUCLEUS</td>
</tr>
<tr>
<td>ELECTRO-MAGNETIC FORCE</td>
<td>$\sim 10^{-3}$</td>
<td>PHOTONS (NO MASS)</td>
<td>ATOMIC SHELL ELECTROTECHNIQUE</td>
</tr>
<tr>
<td>WEAK NUCLEAR FORCE</td>
<td>$\sim 10^{-5}$</td>
<td>BOSONS $Z^0, W^+, W^-$ (HEAVY)</td>
<td>RADIOACTIVE BETA DESINTEGRATION</td>
</tr>
<tr>
<td>GRAVITATION</td>
<td>$\sim 10^{-38}$</td>
<td>GRAVITONS (?)</td>
<td>HEAVENLY BODIES</td>
</tr>
</tbody>
</table>

THE EXCHANGE OF PARTICLES IS RESPONSIBLE FOR THE FORCE.
Discovered in 1995, ~175m_p

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)?
- Is the new particle we’ve discovered really the Higgs particle?
- 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?
- Why are there only four apparent forces?
  - Were they all unified at the Big Bang?
How does a nuclear power plant work?

My 1000 year dream: Skip the whole thing!

Make electricity directly from nuclear force!
So what’s the problem?

• Why is the mass range so large (0.1\(m_p\) – 175 \(m_p\))?
• Is the particle we discovered really the Higgs particle?
• 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?
• Why are there only four apparent forces?
  – Were they all unified at the Big Bang?
• Is the picture we present the real thing?
What makes up the universe?

~95% unknown!!
So what’s the problem?

• Why is the mass range so large (0.1m$_p$ – 175 m$_p$)?
• Is the particle we discovered really the Higgs particle?
• 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?
• Why are there only four apparent forces?
  – Were they all unified at the Big Bang?
• Is the picture we present the real thing?
  – What makes up the remaining ~95% of the universe?
• Are there any other particles we don’t know of?
  – Big deal for the new LHC Run!
• Where do we all come from?
• 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
  - $E_{cm} = 1.96 \text{ TeV} (=6.3 \times 10^{-7} \text{ J/p} \Rightarrow 13 \text{M Joules on the area smaller than } 10^{-4} \text{m}^2)$
  - Equivalent to the kinetic energy of a 20t truck at the speed 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 $E_{cm} = 14 \text{ TeV} (=44 \times 10^{-7} \text{ J/p} \Rightarrow 362 \text{M Joules on the area smaller than } 10^{-4} \text{m}^2)$
  - Equivalent to the kinetic energy of a B727 (80tons) at the speed 310km/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 2015 after a 2 yr shutdown
2017 data taking ongoing

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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 → no symmetry breaking
- Person in air → symmetry can be broken
- Sometimes, you get

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

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How do we look for the Higgs?

1. Identify Higgs candidate events

2. Understand fakes (backgrounds)

3. Look for a bump!!
   1. Large amount of data absolutely critical
What did statistics do for Higgs?

\[ \sqrt{s} = 7 \text{ TeV} \int \text{Ldt} = 0.02 \text{ fb}^{-1} \quad \text{Apr 18, 2011} \]

**ATLAS** Preliminary

H\(\rightarrow\gamma\gamma\) channel

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How about this?

\( \sqrt{s} = 7 \text{ TeV} \int Ldt = 0.05 \text{ fb}^{-1} \)  

**ATLAS** Preliminary 

\( H \to ZZ^{(*)} \to 4l \) channel

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

**Monday, June 6, 2016**

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So have we seen the Higgs particle?

- The statistical significance of the finding is way over 7 standard deviations
<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>
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<td>1.959 964$\sigma$</td>
<td>95%</td>
<td>5%</td>
<td>1 / 20</td>
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<td>4.550 0264%</td>
<td>1 / 21.977 895</td>
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<tr>
<td>2.575 829$\sigma$</td>
<td>99%</td>
<td>1%</td>
<td>1 / 100</td>
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<tr>
<td>3$\sigma$</td>
<td>99.730 0204%</td>
<td>0.269 9796%</td>
<td>1 / 370.398</td>
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<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>
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<td>4$\sigma$</td>
<td>99.993 666%</td>
<td>0.006 334%</td>
<td>1 / 15,787</td>
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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
A hint of something new?

\[ \sim 760 \text{GeV} \]

\[ \sim 4.6\sigma \text{ Excess!!} \]

ATLAS Preliminary

- Data
- Background-only fit

\( \sqrt{s} = 13 \text{ TeV}, 3.2 \text{ fb}^{-1} \) (2015 data)

Spin-2 Selection

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Not good enough yet!!
The Next Big Thing - DUNE Experiment

- Stands for Deep Under Ground Neutrino Experiment
- The flagship long baseline (1300km) $\nu$ experiment
  - 1500m underground in South Dakota

Yes, you are right!
Mount Rushmore!!

- Nobel Winning Neutrino Discovery by Ray Davis in 1960’s
- Many Dark Matter experiments in progress
- New DUNE area to be excavated shortly

Monday, June 6, 2016

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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 parameters...
    • 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??
The Components of the DUNE Experiment

1500m underground

4 caverns with ~20kt total each

14m

15m

62m

Monday, June 6, 2016
How BIG?

This is just for a 3mx1mx1m (42t) active volume baby prototype!!
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 mm²)
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 ...
Discovery of the God Particle in 2012
Information & Communication Source

- **Course web page:**
  [http://www-hep.uta.edu/~yu/teaching/summer16-1444-001/summer16-1444-001.html](http://www-hep.uta.edu/~yu/teaching/summer16-1444-001/summer16-1444-001.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 (7/11/16): 23%
  - Mid-term Comprehensive Exam (6/22/16): 20%
  - One better of the two term Exams (6/13/16 and 6/29/16): 12%
    - Total of two non-comprehensive term exams (6/13 and 6/29)
    - 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%
- Extra credits: 10% of the total
  - Random attendances
  - Strong participation in the class discussions
  - Special projects (BIGGGGGG!!!)
  - Planetarium shows and Other many opportunities
- Grading will be done on a sliding scale

Dr. Jaehoon Yu
Homework

- Solving homework problems is the only way to comprehend class material ➔ 2 homeworks per week
- An electronic homework system has been set up 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 PHYS1444-Summer16, unique number 44016
  - Download homeworks, solve the problems and submit them online
  - Multiple unsuccessful tries will deduct points
  - Roster will close at 11pm Wednesday, June 8
  - 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
- Homework problems will be slightly ahead of the class
- **No** homework will be dropped from the final grade!!
- Homework 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 6
  - Important to understand physical principles through experiments
  - 10% of the grade
  - Prelab questions can be obtained at [www.uta.edu/physics/labs](http://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;
  – We are astronomers– Fridays at 2:00pm and Saturdays at 5:30 pm

• Shows that need special arrangements
  – Black Holes (can watch up to 2 times)
  – Astronaut; Bad Astronomy; Back to the Moon for Good; From Earth to the Universe; Experience the Aurora; IBEX; Ice Worlds; Magnificent Sun
  – Mayan Prophecies; MicroCosm; Nano Cam; Stars of the Pharaohs; TimeSpace, Two Small Pieces of Glass; Unseen Universe; 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 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
      – 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!!
Specifically, in this course, you will learn…

- Concept of Electricity and Magnetism
- Electric charge and magnetic poles
- Electric and Magnetic Forces
- Electric and magnetic potential and energies
- 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 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