PHYS 1444 – Section 002
Lecture #1

Wednesday, Jan. 22, 2020

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, Monday, Jan. 27!!

Announcements

- Plea to you: Please turn off all your electronic devices, including cell-phones and all types of computers before the start of each class!
- Reading assignment #1: Read and follow through all sections in appendix A by Wednesday, Jan. 29
  - A-1 through A-8
- There will be a quiz on this and what we've learned in CH21 and 22 on Monday, Feb. 3

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
    - Fundamental forces between the constituents
    - Origin of Mass
    - Search for Dark Matter and Making of Dark Matter Beams
    - Creation of Universe (**Big Bang** Theory)
  - A pure scientific research endeavor
    - 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 in the first place?
    - Make everyday lives better to help the whole humanity live well as an integral part of the universe

We always wonder…

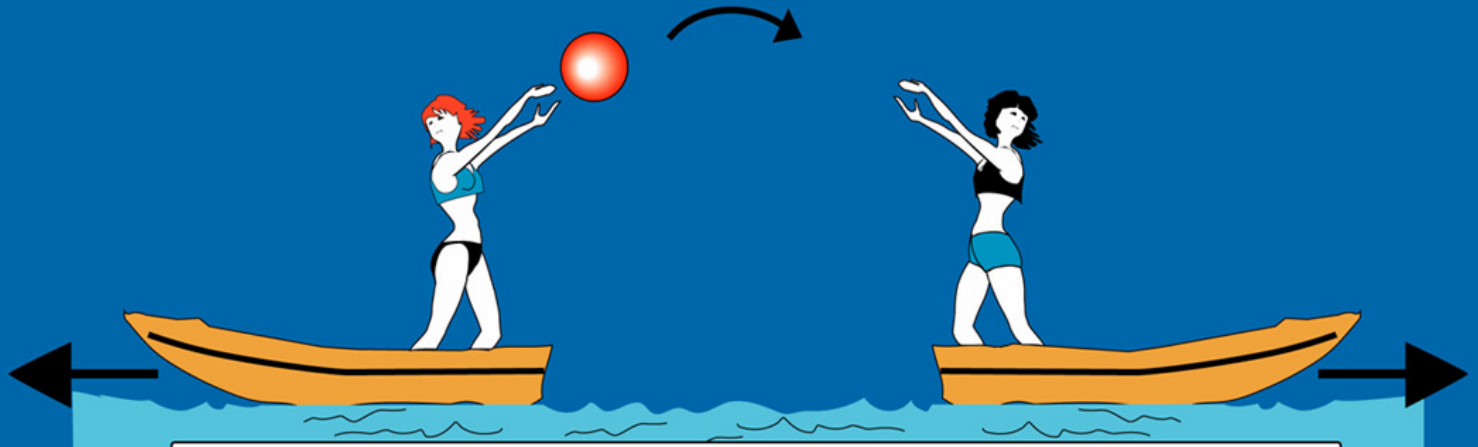
- What makes up the universe?
- How does the universe work?
- What holds the universe together?
- How can we live in the universe well?
- Where do we all come from?

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

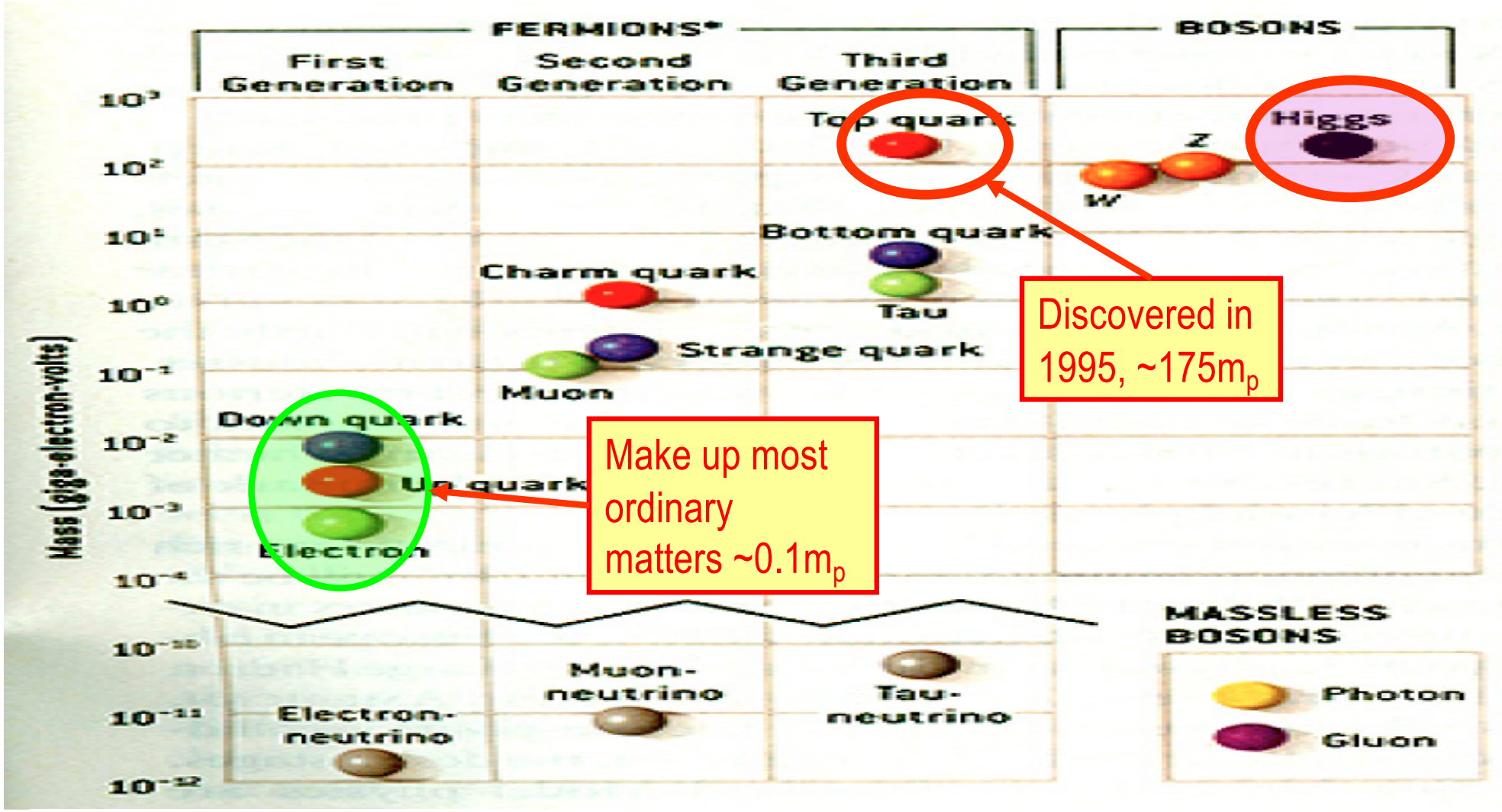
The forces in Nature

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



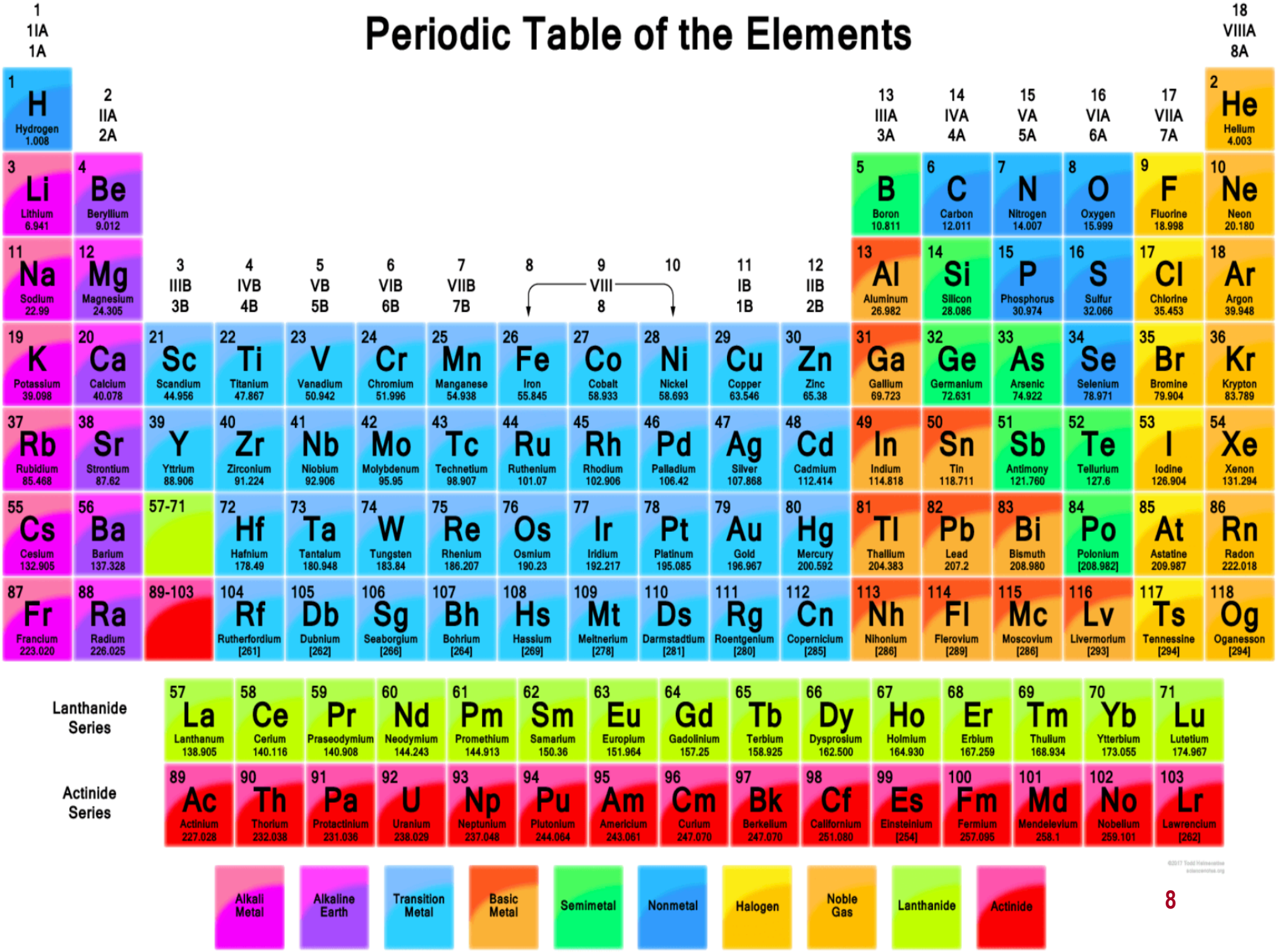
THE EXCHANGE OF PARTICLES IS RESPONSIBLE FOR THE FORCE

HEP and the Standard Model



- 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!

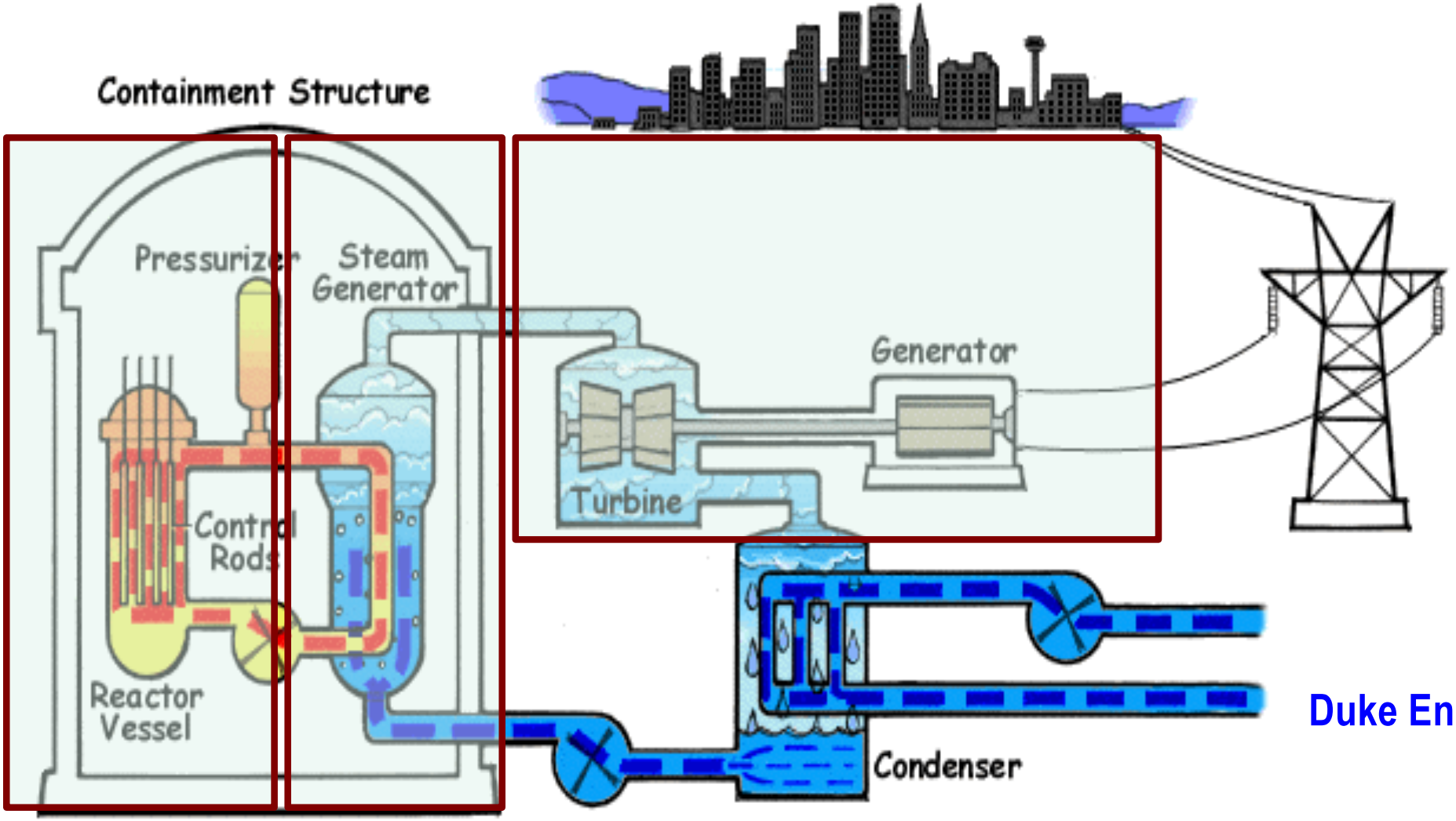
Periodic Table of the Elements



What are some issues in HEP?

- Why is the mass range so large ($0.1m_p$ – $175\ m_p$)?
- Is the particle discovered at the LHC really the Higgs particle?
- Why is the matter in the universe made only of particles?
- Neutrinos have mass!! (**OMG!! The SM is broken!!!**)
  - What are the mixing parameters, particle-anti particle asymmetry and the neutrino mass ordering?
- Why are there only four apparent forces?
  - Were they all unified at the Big Bang?

How does a nuclear power plant work?



Duke Energy

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 ($0.1m_p$ – $175\ m_p$)?
- Is the particle we discovered really the Higgs particle?
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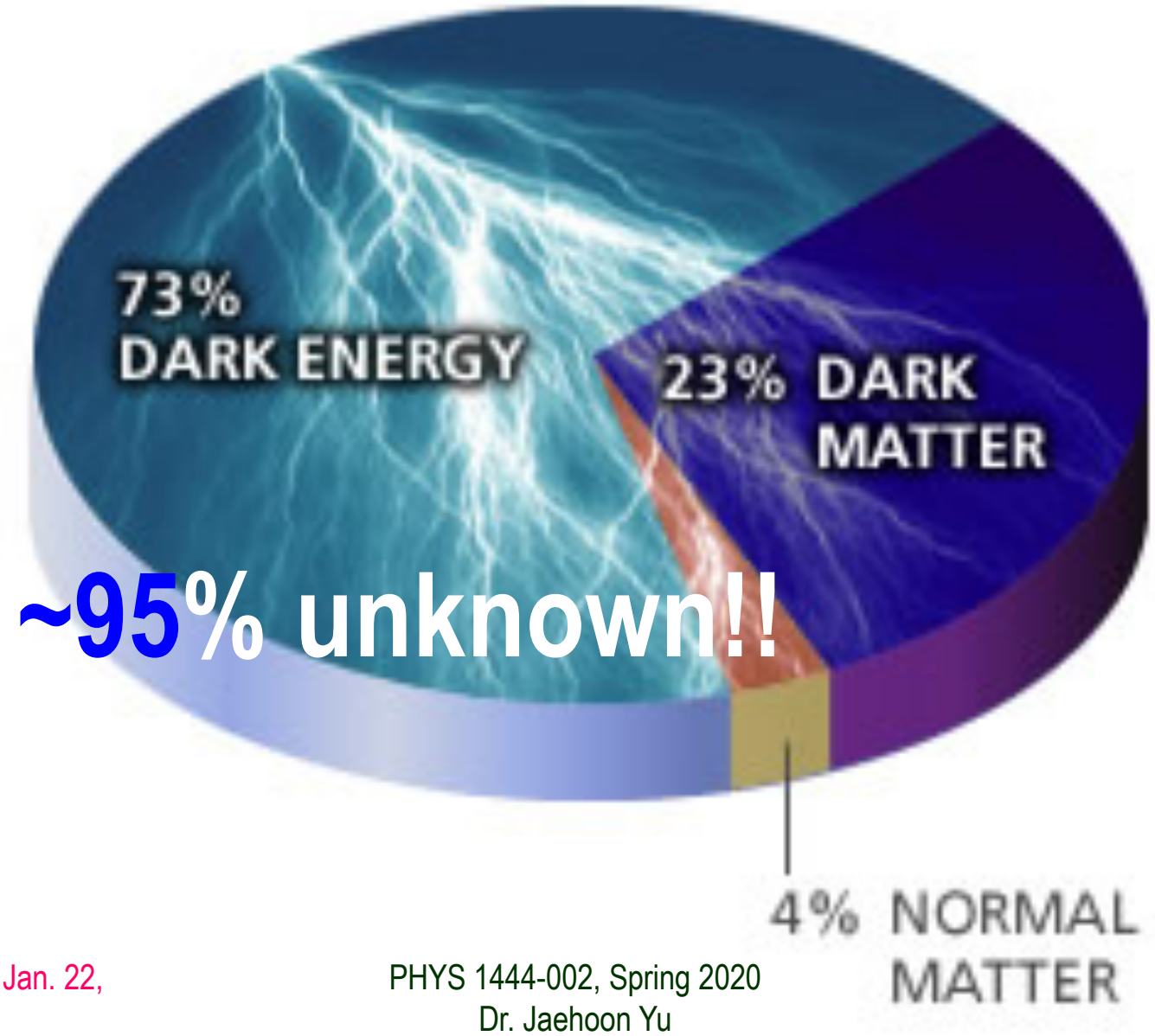
  - Were they all unified at the Big Bang?
- Is the picture we present the real thing?

What makes up the universe?



~95% unknown!!

So what's the problem?

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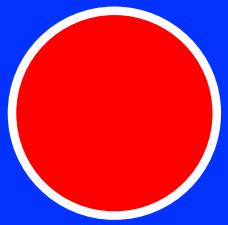
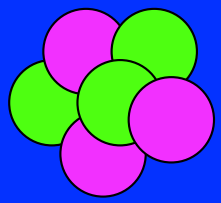
- Is the particle we discovered really the Higgs particle?
- Why is the matter in the universe made only of particles?
- Neutrinos have mass!! What are the mixing parameters, particle-anti particle asymmetry and mass ordering?
- Why are there only four apparent forces?
  - Were they all unified at the 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.

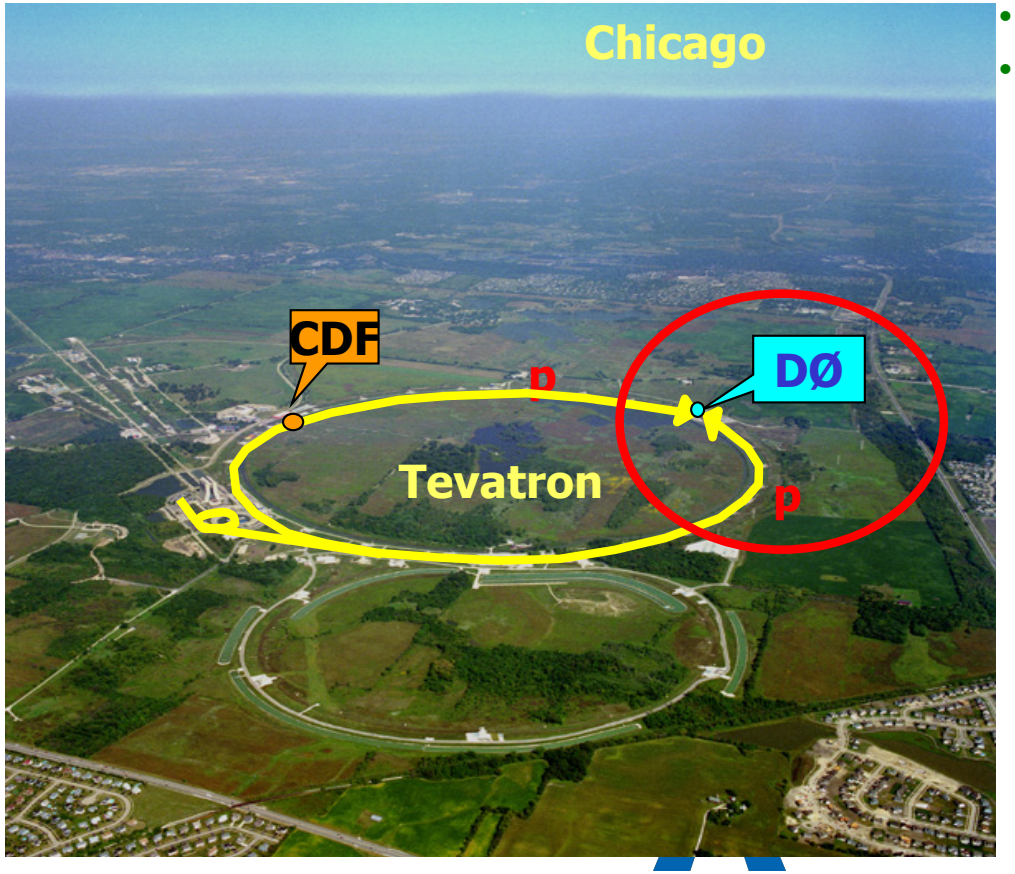
They make particles last seen
in the earliest moments of the universe.

Particle and anti-particle annihilate.

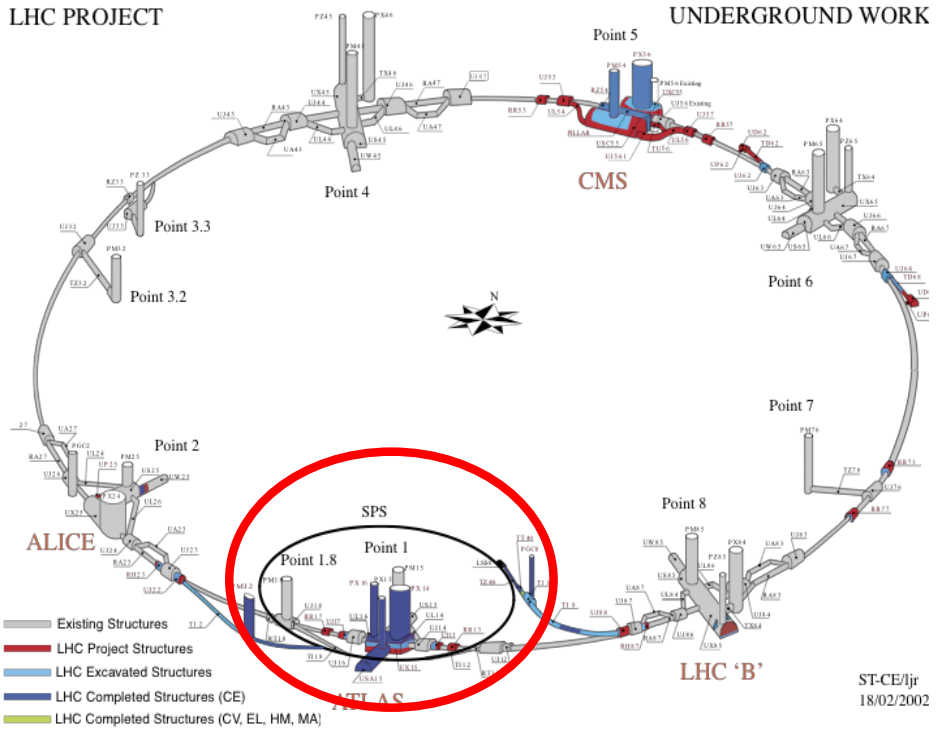
$$E = mc^2$$

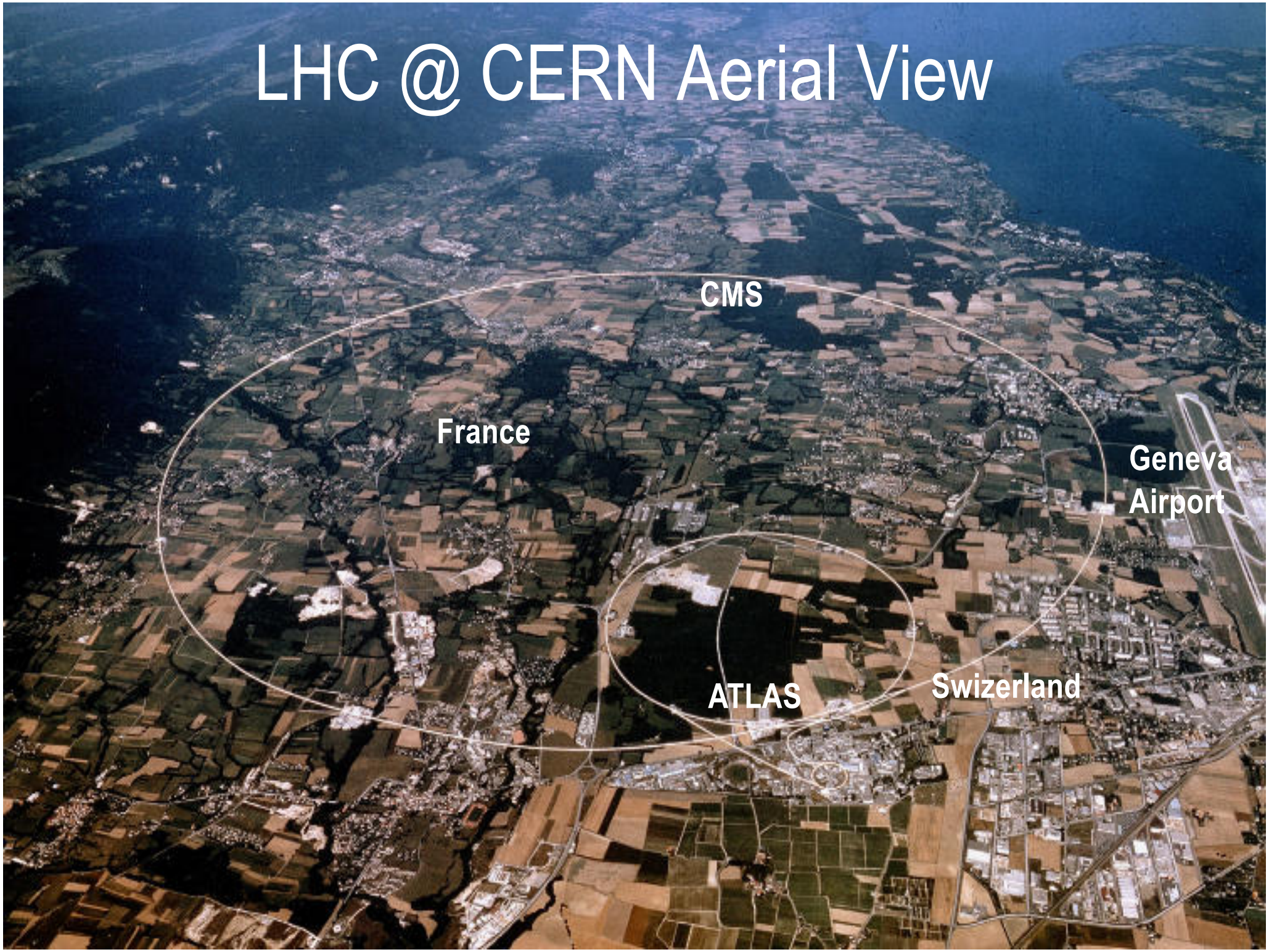
Fermilab Tevatron and LHC at CERN

- World's Highest Energy proton-anti-proton collider
  - 4km (2.5mi) circumference
  - E_{cm}=1.96 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 130km/hr
    - ~100,000 times the energy density at the ground 0 of the Hiroshima atom bomb
  - **Tevatron was shut down in 2011**
  - **New frontiers with high intensity proton beams including the search for dark matter with beams!!**

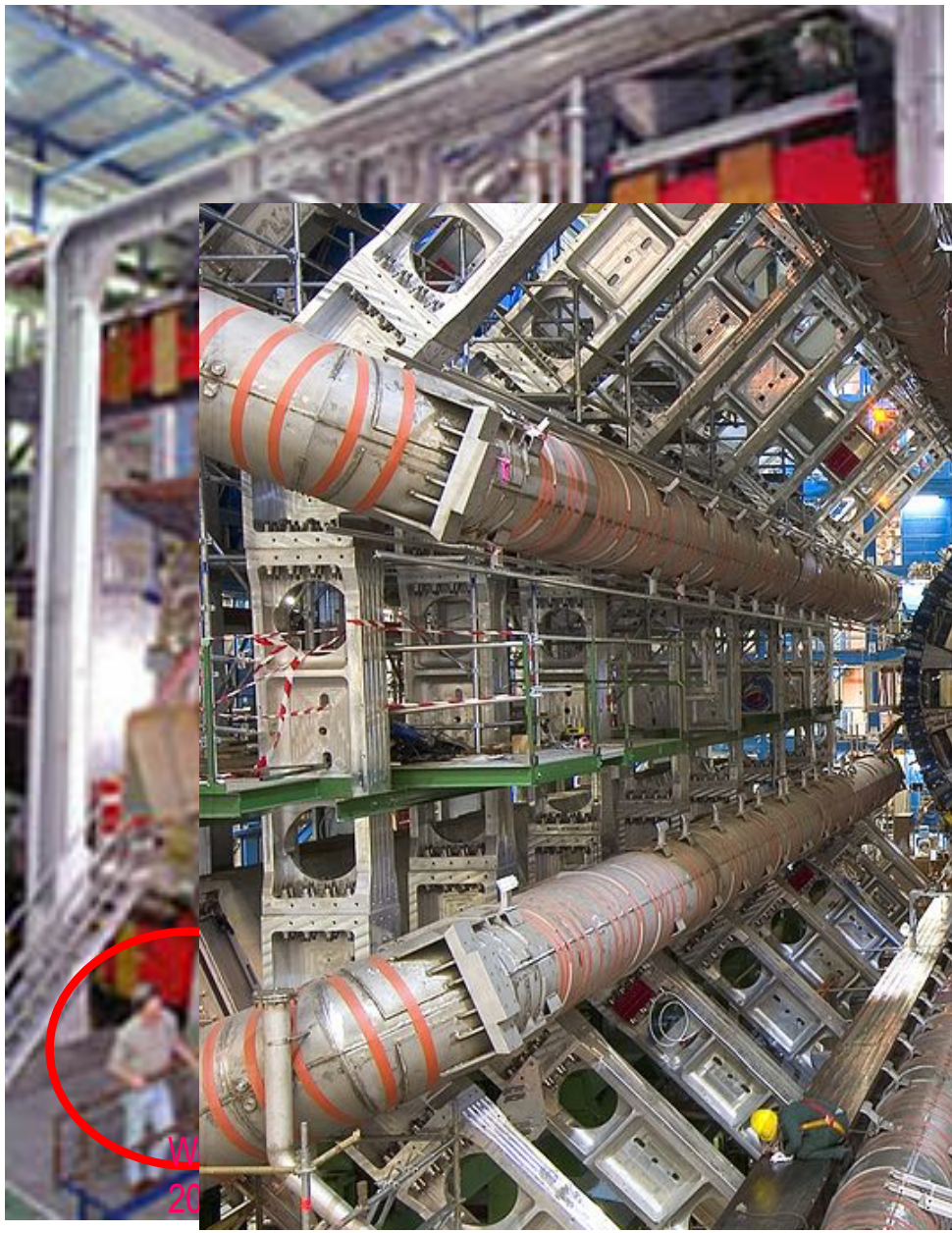


- World's Highest Energy p-p collider
  - 27km (17mi) circumference, 100m (300ft) underground
  - Design E_{cm}=14 TeV (=44x10^{-7}J/p➔ 362M Joules on the area smaller than 10^{-4}m^2)
  - ➢ Equivalent to the kinetic energy of a B727 (80tons) at the speed 310km/hr
    - ➢ ~3M times the energy density at the ground 0 of the Hiroshima atom bomb
- **Discovered a new heavy particle that looks Higgs in 2012**
- **Search for new particles has been ongoing!!**
- **Shut down for two years begun for high stat. upgrade!**

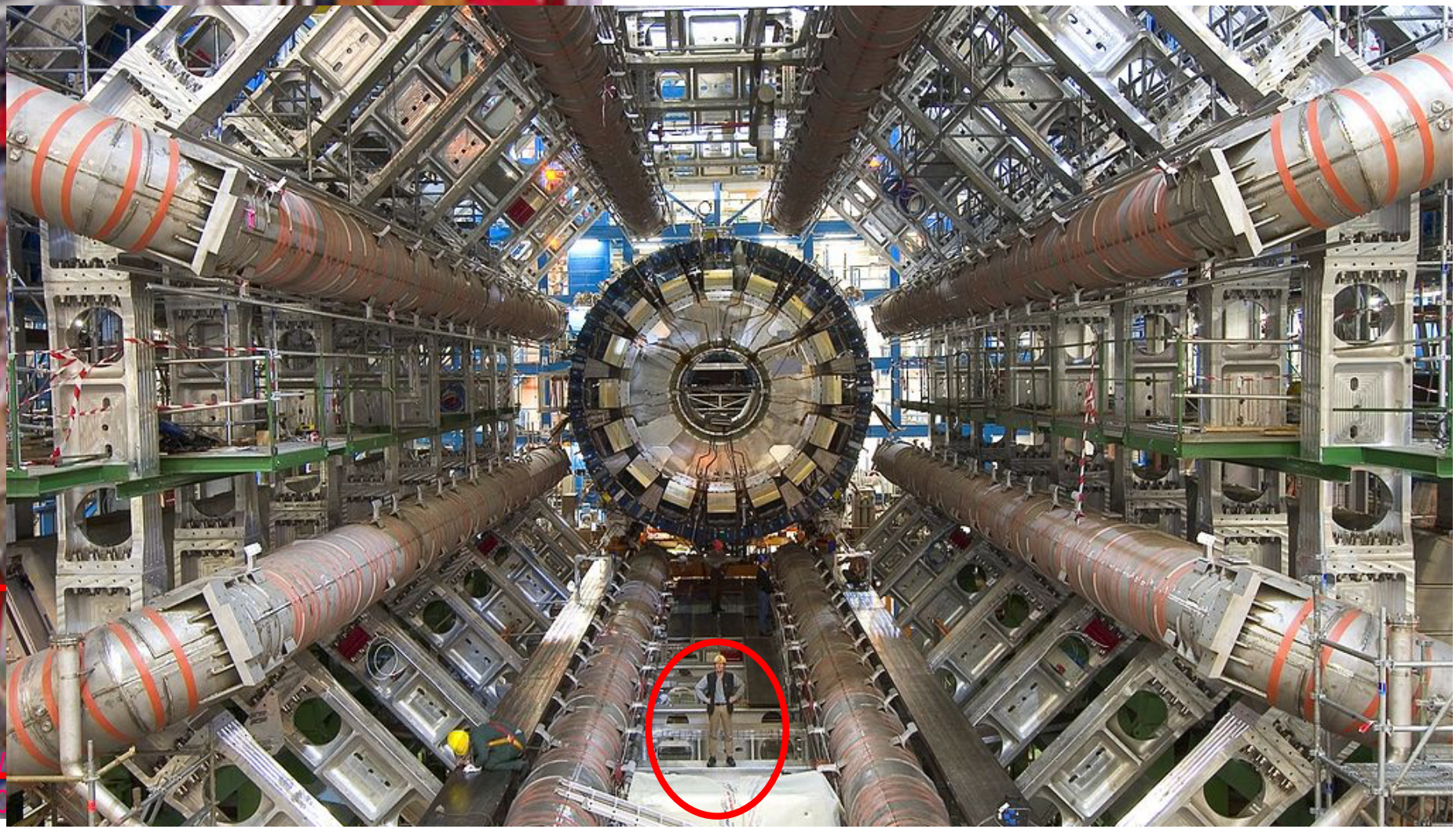



LHC @ CERN Aerial View
CMS
France
Geneva
Airport
ATLAS
Swizerland

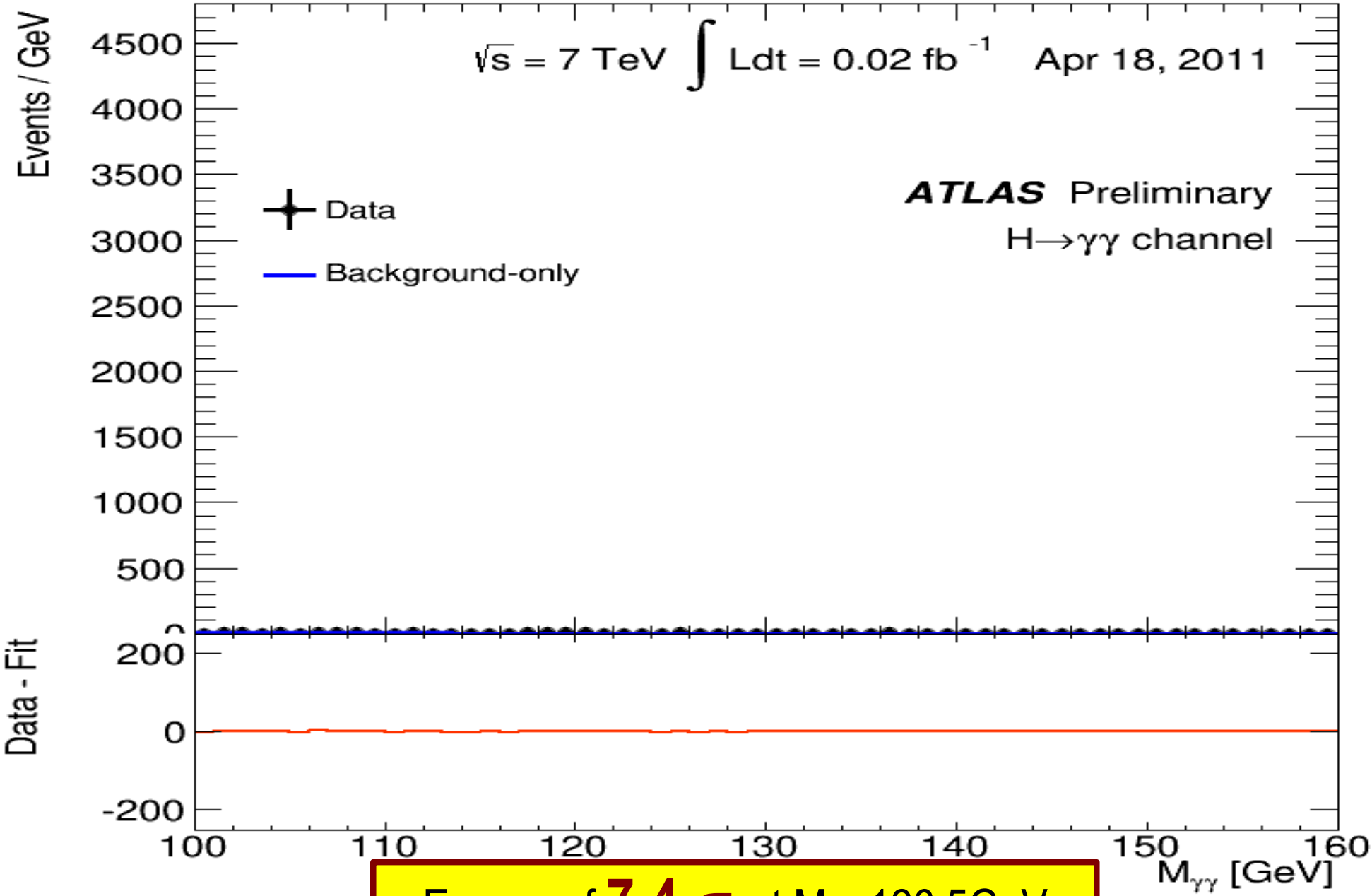
DZero Detector at Fermilab near Chicago



ATLAS Detector in Geneva Switzerland



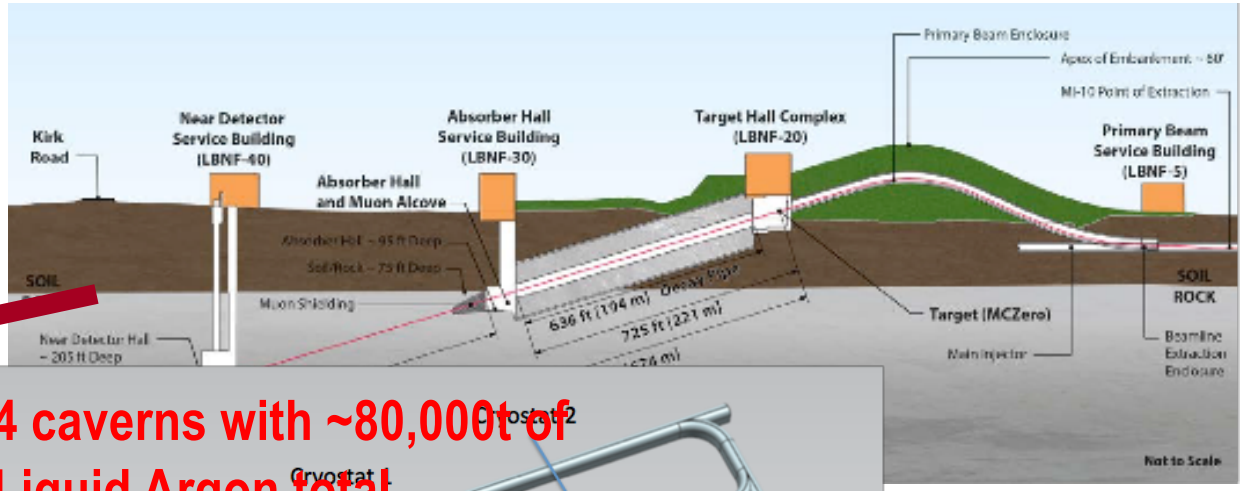
What did statistics do for Higgs→ γγ?

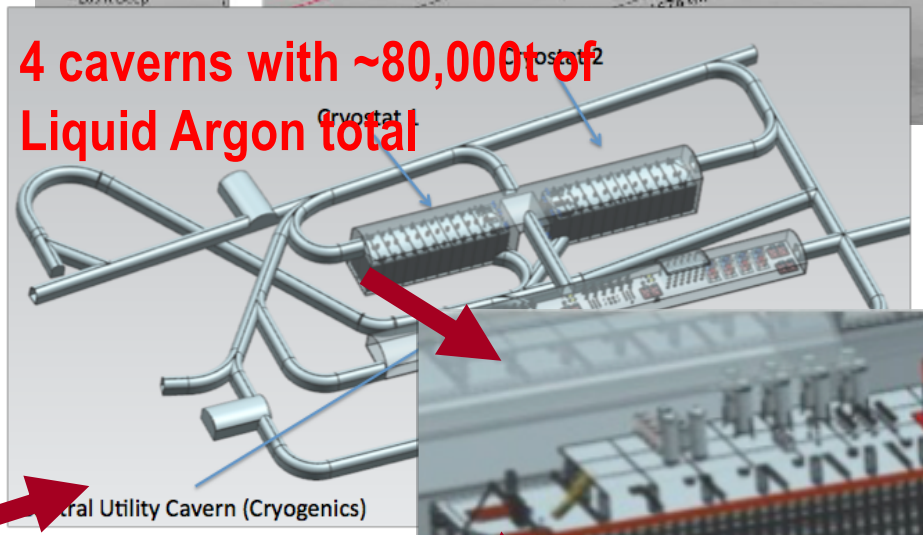


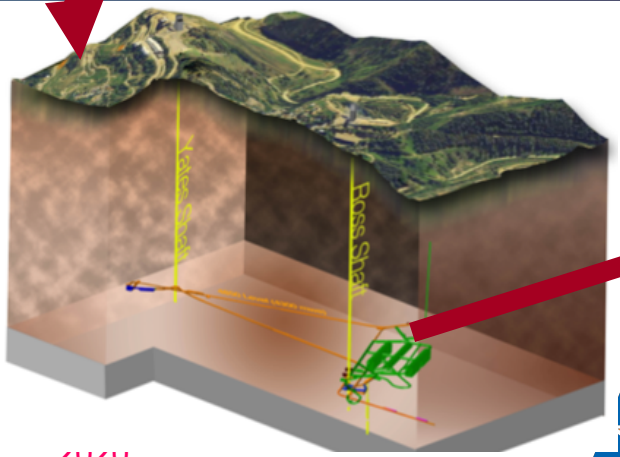
Excess of **7.4 σ** at M_H=126.5GeV

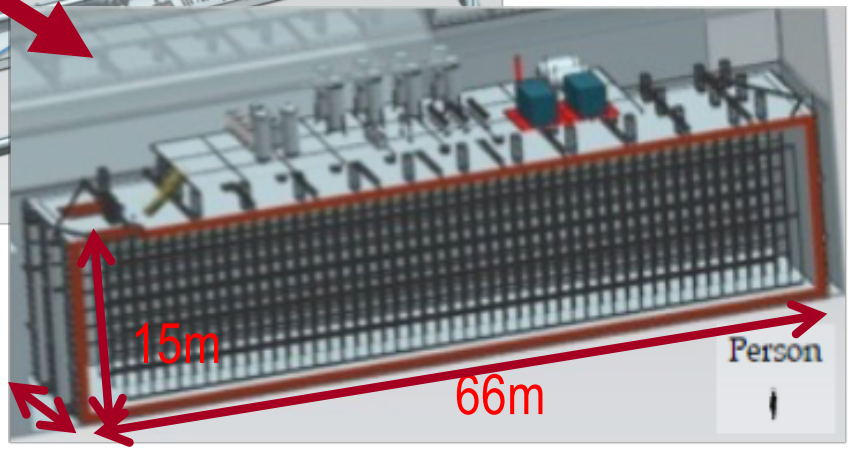
The Next Big Thing - DUNE Experiment

- Stands for Deep Under Ground Neutrino Experiment
- The $1.5B flagship long baseline (1300km) ν experiment
  - 1500m underground in South Dakota









15m

2020

The Map of the DUNE Experiment

DEEP UNDERGROUND NEUTRINO EXPERIMENT

1106 collaborators
184 institutions
31 countries


Hector Carranza @ CERN

DUNE Prototype Detector @ CERN

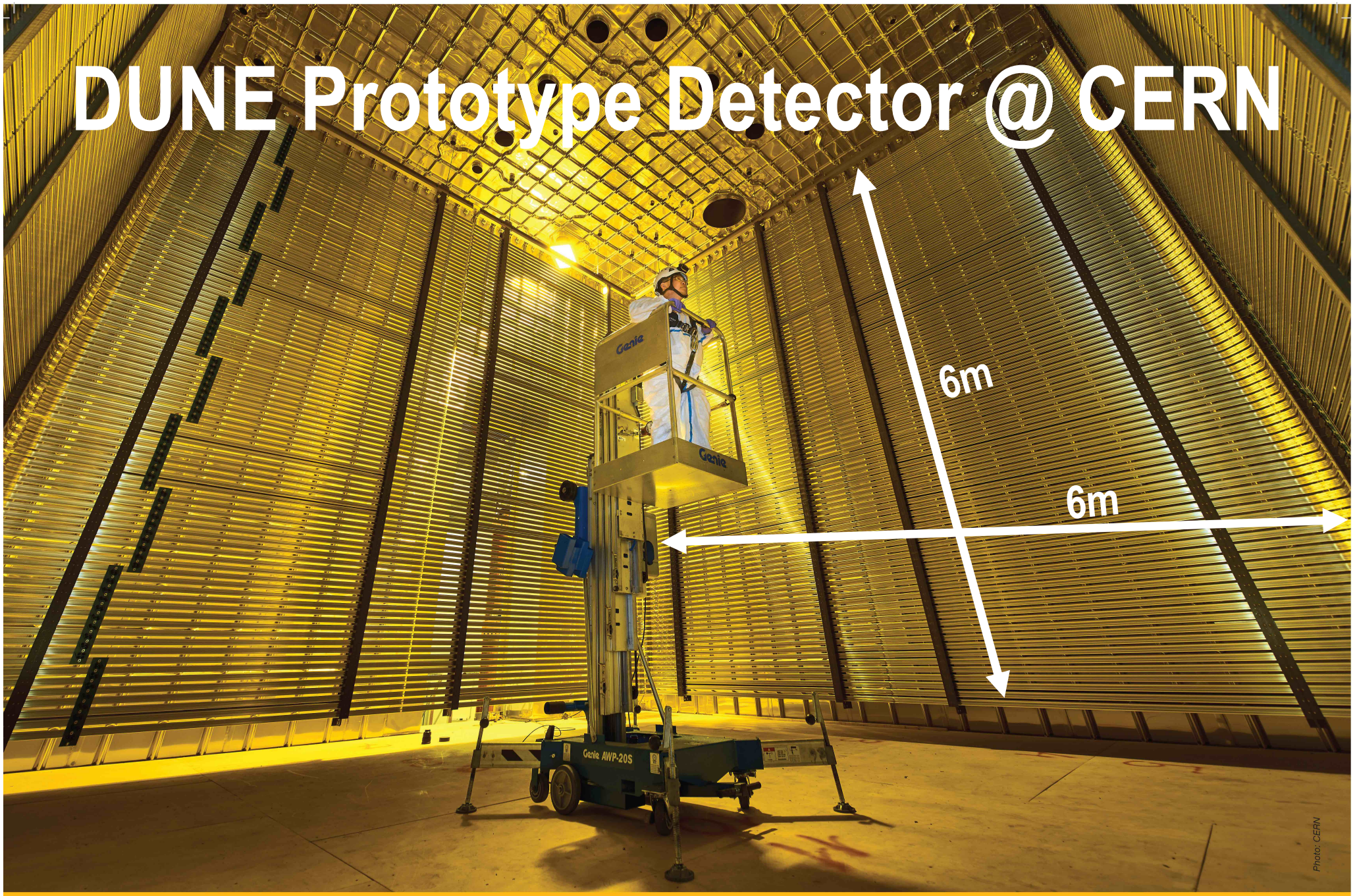


Photo: CERN

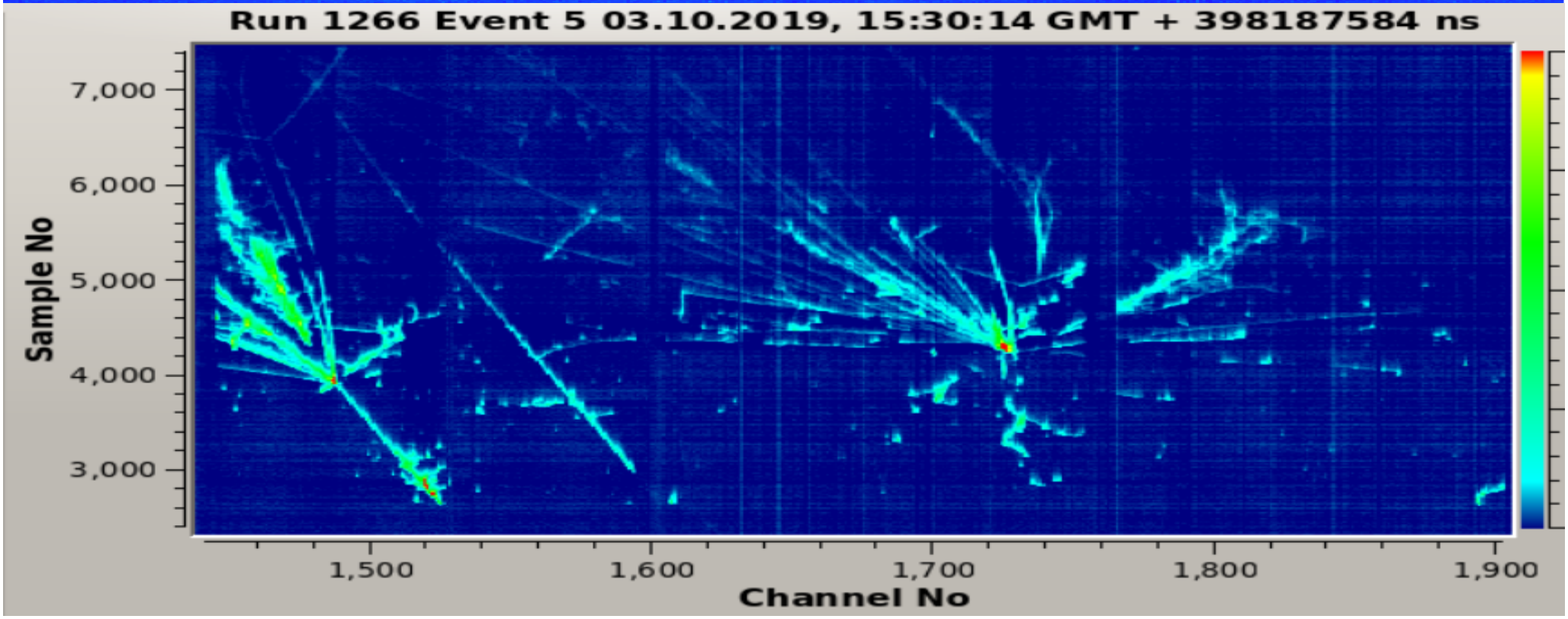
Prototype detector for the Deep Underground Neutrino Experiment

Fermilab

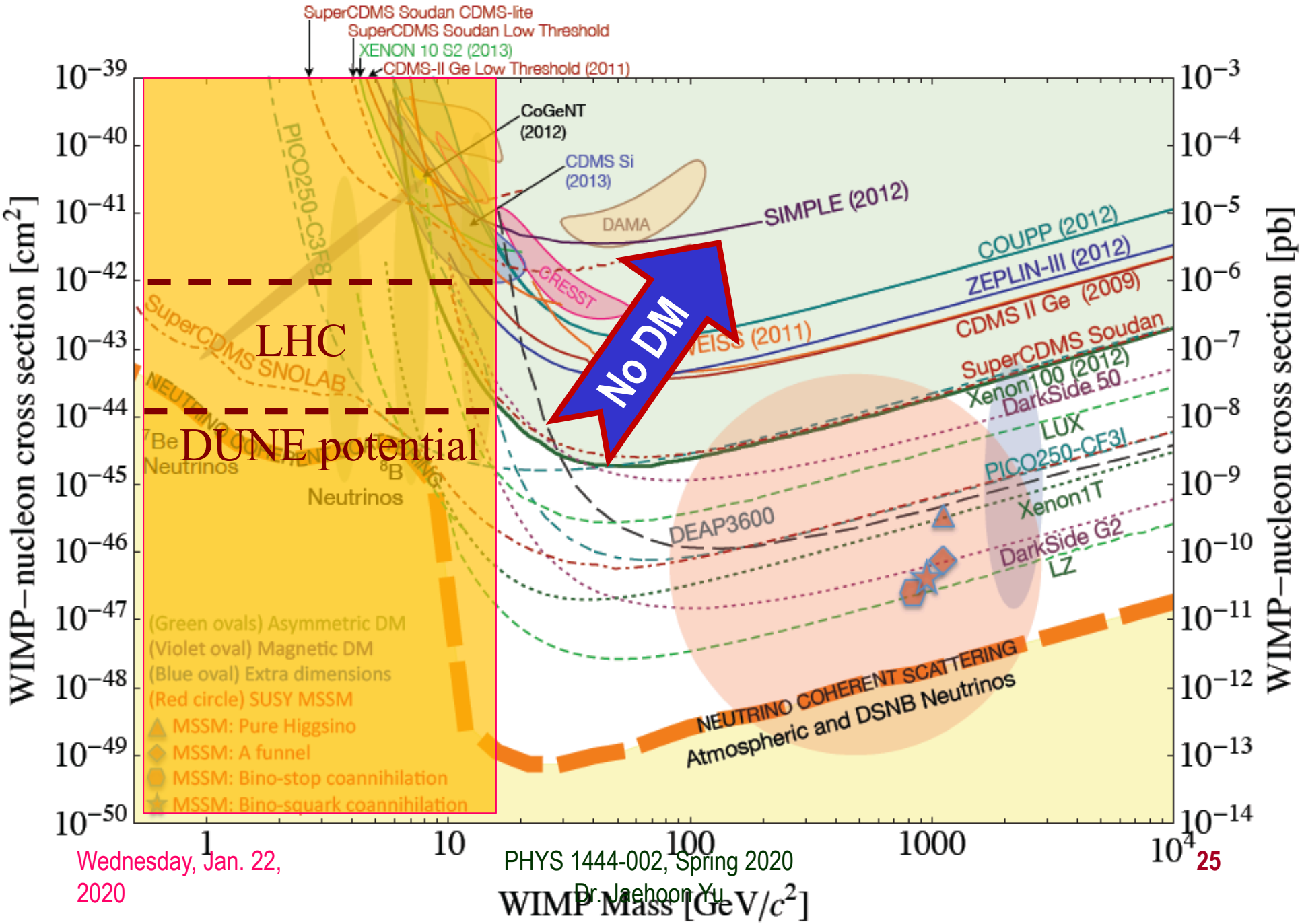
U.S. DEPARTMENT OF ENERGY

ProtoDUNE Event

Beam halo (high energy) muon with bremsstrahlung initiated E.M. shower



Let's Look for Dark Matter!!



So why is HEP relevant to me?

- HEP explores the most fundamentals of the Universe!
- Discoveries will realize our 1000 year dreams
- The discovery of the dark matter and making of dark matter beams will take us to the next Quantum level
- Outcome and bi-products of HEP research improves our daily lives directly and indirectly
  - WWW came from HEP


WHERE THE
WEB
WAS BORN

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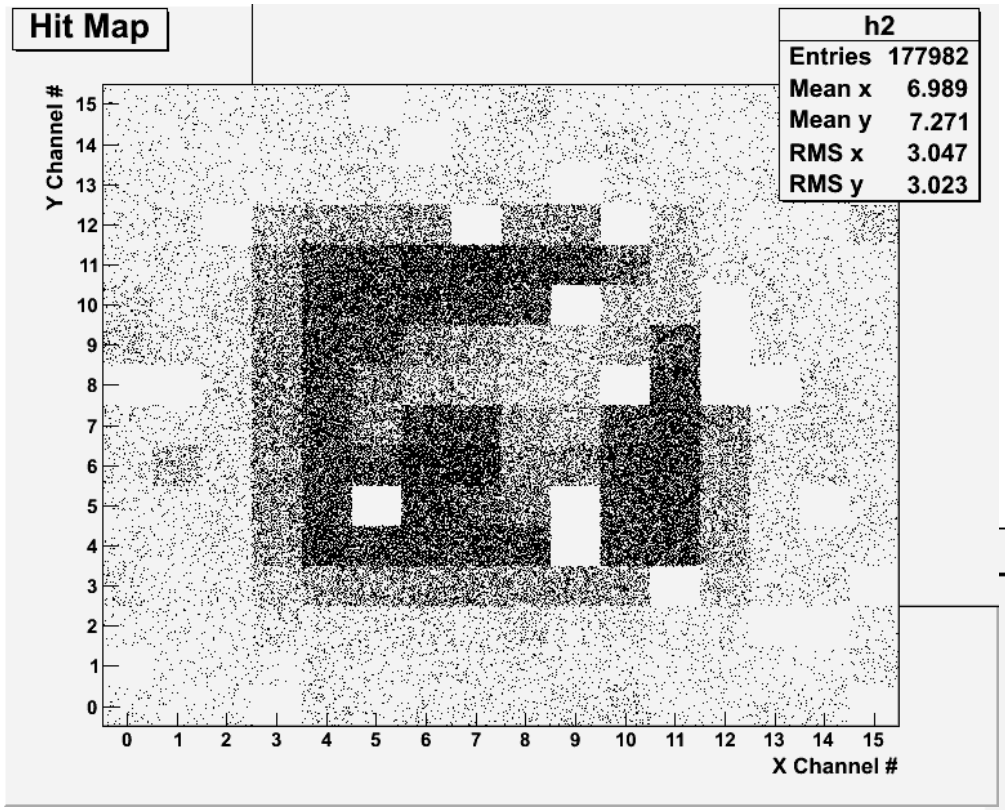
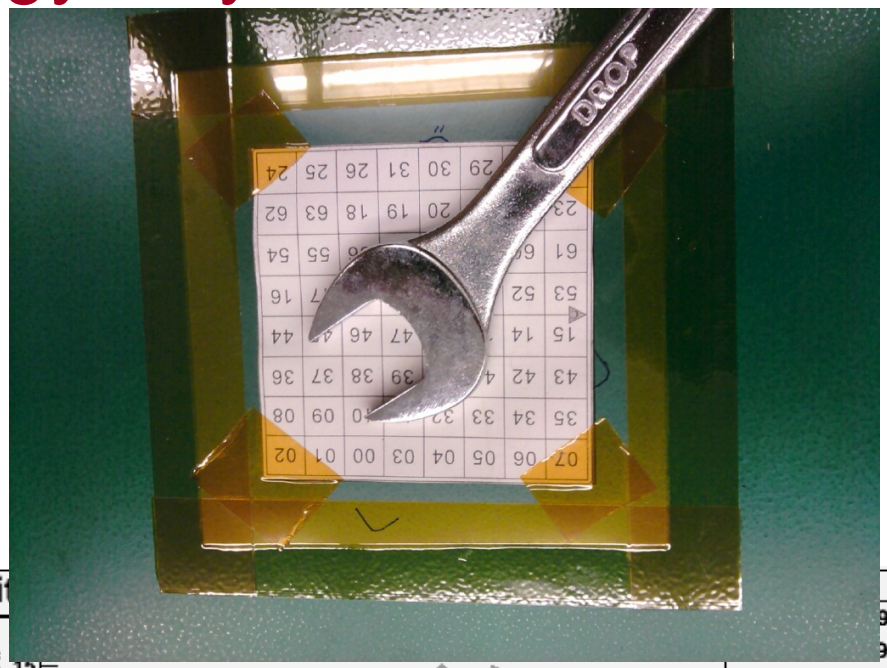
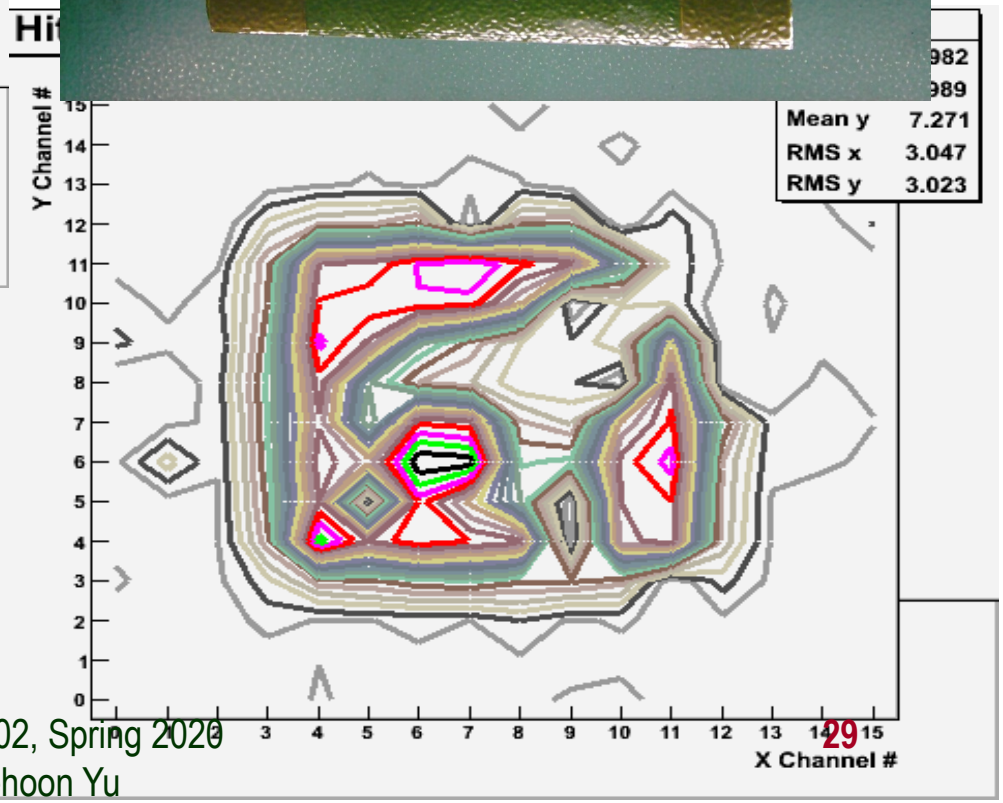
- Outcome and bi-products of HEP research improves our daily lives directly and indirectly
  - WWW came from HEP
  - Advanced detector technologies like GEM will make a large screen low dosage X-ray imaging possible

Bi-product of High Energy Physics Research



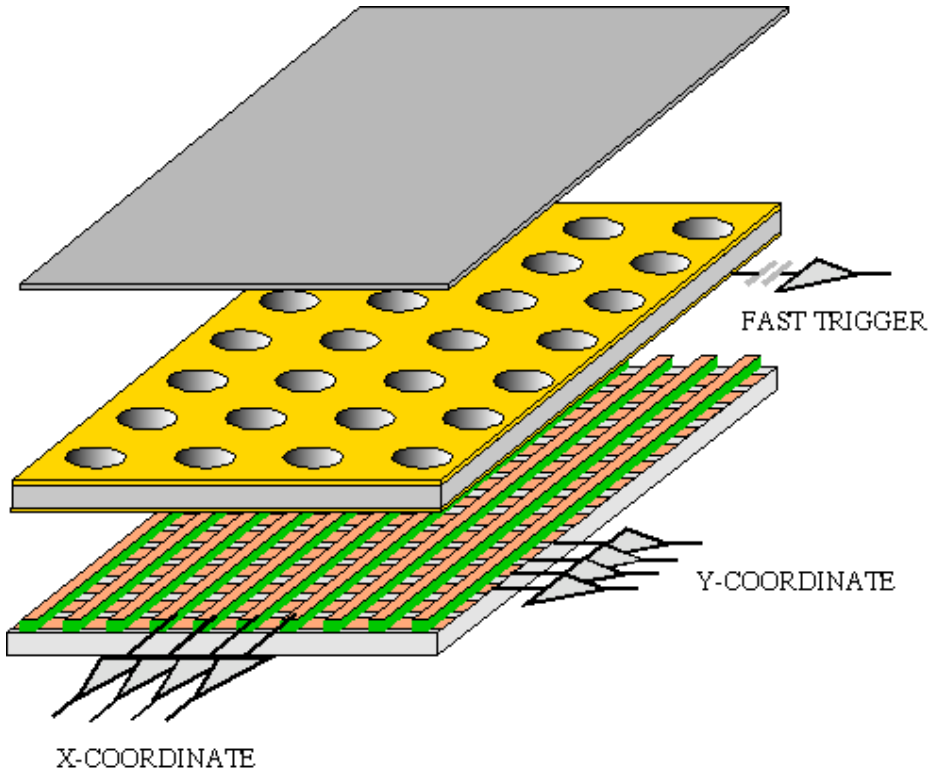




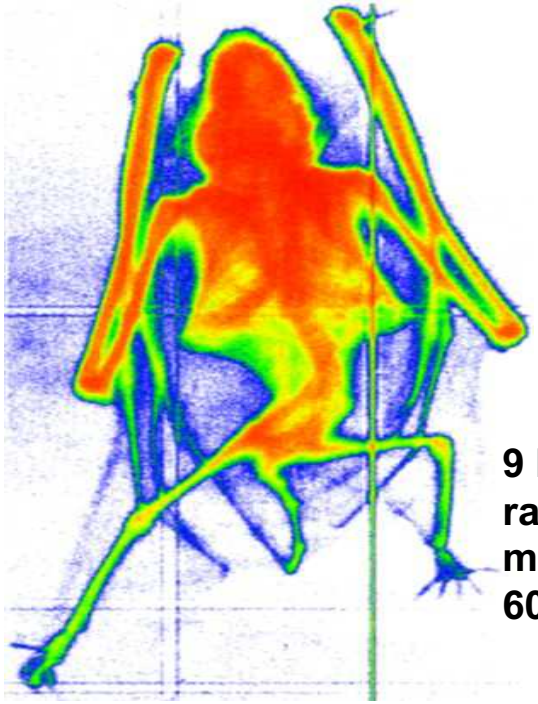
Can you see what the object is?
(GEM Detector X-ray Image)

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 mm^2)

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

Let's all dream,

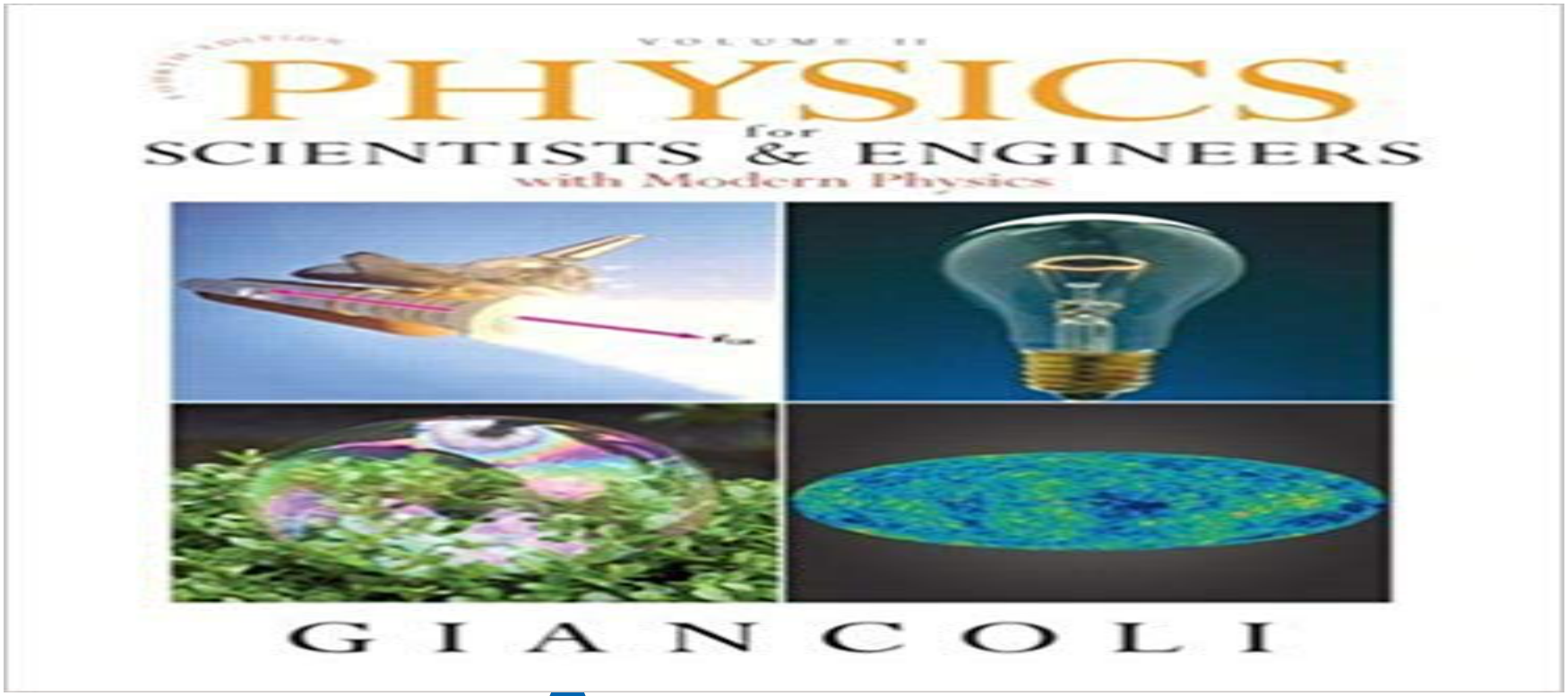
not just for tomorrow,

not just for the next year,

but for 1000 years into the future for the whole humanity!!

Textbook

- Title: Physics for Scientists and Engineers with Modern Physics
  - 4th edition
- Authors: D.C. Giancoli
- ISBN13: 978-0132273596
- ISBN10: 9780132273596



Information & Communication Source

- Course web page: http://www-hep.uta.edu/~yu/teaching/spring20-1444-002/spring20-1444-002.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 often read!!
- Office Hours for Dr. Yu: 2:30 – 3:30pm, MW or by appointments

Evaluation Policy

- Homework: 25%!!!
- Exams
  - Final Comprehensive Exam (5/6/20): 23%
  - Mid-term Comprehensive Exam (3/18/20): 20%
  - One better of the two term Exams (2/19/20 and 4/15/20): 12%
  - 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
  - Colloquium attendances
  - Special projects (BIGGGGG!!!)
  - 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
  - Choose the course **PHYS1444-Spring20**, unique number **44120**
  - Download homeworks, solve the problems and submit them online
  - Multiple unsuccessful tries will deduct points
  - Roster will close at 11pm next Monday, Jan. 27
  - You need a UT e-ID (NOT the UTA NetID): 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 and tough!
- **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 example problem work and discussions are **required!**
    - You take your own studies in your hands!
    - Your will be called out to give answers to examples and questions!!
  - 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: Begins in the week of Feb. 3
  - 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
  - Participating in the physics department colloquium
    - 4pm Wednesdays
    - Special colloquia already scheduled – **triple extra credit!!**
      - March 18: Dr. Pedro Machardo of Fermilab
  - Strong participation in the class discussions
  - Watching the valid planetarium shows
  - Many other opportunities

Valid Planetarium Shows

- Regular running show schedule: https://www.uta.edu/planetarium/shows/schedule.php
- Valid shows (some need special arrangements)
  - **Black Holes and Phantom of the Universe (Count up to 2 times!!)**
  - Astronaut; Bad Astronomy; Back to the Moon for Good; Cosmic Origins Spectrograph, Dark, Dynamic Earth, Europe to the Stars, From Earth to the Universe; Experience the Aurora; Ice Worlds;
  - Mayan Prophecies; Nano Cam; Stars of the Pharaohs; TimeSpace, Two Small Pieces of Glass; Unseen Universe; Violent Universe; Out there, Our Violent Planet; Rosetta; The Hot and Energetic Universe; The Sun: Our Living Star; Unseen Universe: Vision of SOFIA; We Are Astronomers
  - See https://www.uta.edu/planetarium/fieldtrips/showBook.php for more info
- How to submit for extra credit?
  - Obtain the ticket stub signed and dated by the planetarium star lecturer at the show
  - Collect the ticket stubs throughout the semester
  - Tape one edge of all of the ticket stubs on a sheet of paper with your name and ID on
  - Submit the sheet at the end of the semester on the day of the final examå

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
    - Show your work! 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%
- Play a proactive role in your own study and grades
- 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 a systematic manner in writing
- But most importantly the confidence in your physics ability and to take on any challenges laid in front of you!!

Even more 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 and fields
- 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 discussions and in solving example problems
  - Follow through lecture notes
  - Work out other example problems in the book yourself without the solutions
  - Have many tons of fun in the class, asking lots of questions!!!!!
- Keep up with the homework to put the last nail on the coffin
  - Do NOT wait till you are done with all the problems. One can always input the answers as you solve problems.
  - Form a study group and discuss how to solve problems with your friends, then work the problems out yourselves! ➔ Use physics clinic!!
- 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