PHYS 1441 – Section 001
Lecture #1

Tuesday, May 27, 2008
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
- Uncertainties
- Dimensional Analysis

Today's homework is homework #1, due 9pm, Friday, May 30!!

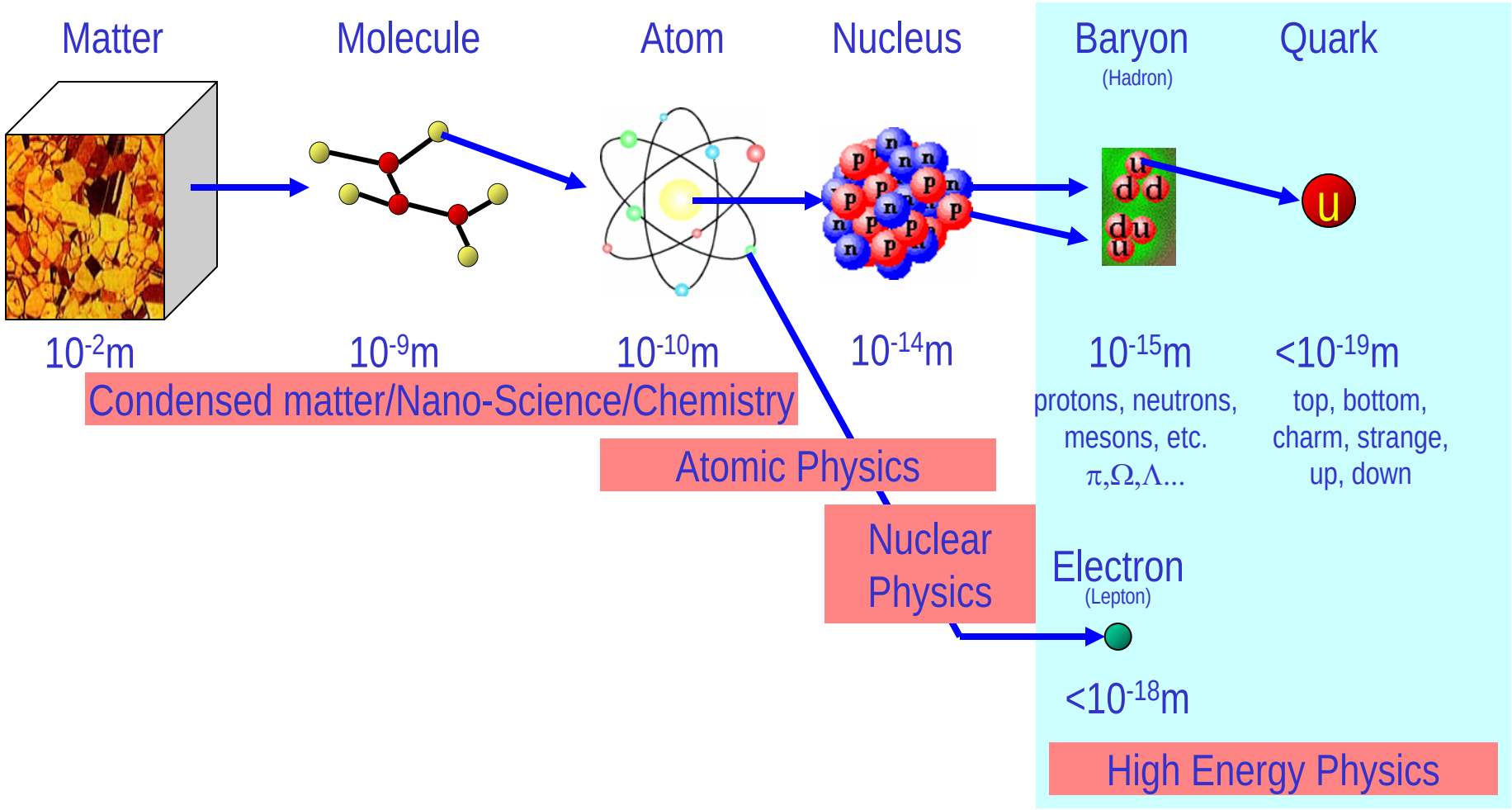
Announcements

- Reading assignment #1: Read and follow through all sections in appendices C, D and E by Thursday, May 29
  - There will be a quiz on Monday, June 2, on this reading assignment
- Reading assignment #2: Read CH1.1 – 1.4 by this Thursday, May 29
- First term exam
  - 8 – 10am, Next Wednesday, June 4
  - SH103
  - Covers CH1 – what we finish next Tuesday + appendices

Who am I?

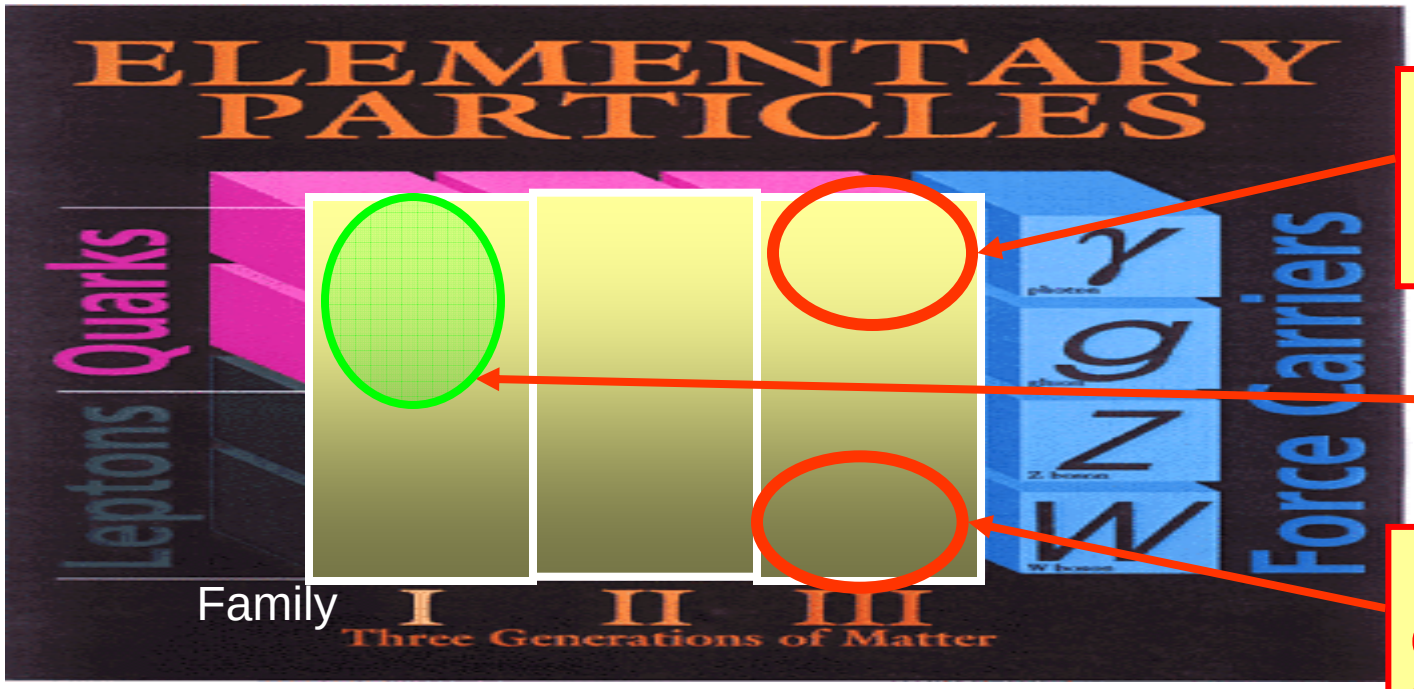
- Name: Dr. Jaehoon Yu (You can call me Dr. Yu)
- Office: Rm 342, Chemistry and Physics Building
- Extension: x22814, E-mail: *jaehoonyu@uta.edu*
- My profession:High Energy Physics (HEP)
  - Collide particles (protons on anti-protons or electrons on anti-electrons, positrons) at the energies equivalent to 10,000 Trillion degrees
  - To understand
    - Fundamental constituents of matter
    - Interactions or forces between the constituents
    - Origin of Mass
    - Creation of Universe (The **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

Structure of Matter



The Particle Physics Standard Model

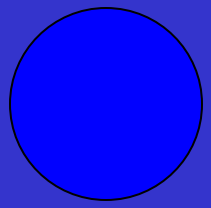
- Assumes the following fundamental structure:



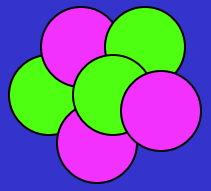
- Three families of leptons and quarks together with 12 force mediators ➔ Simple and elegant!!!

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.

$$E = mc^2$$

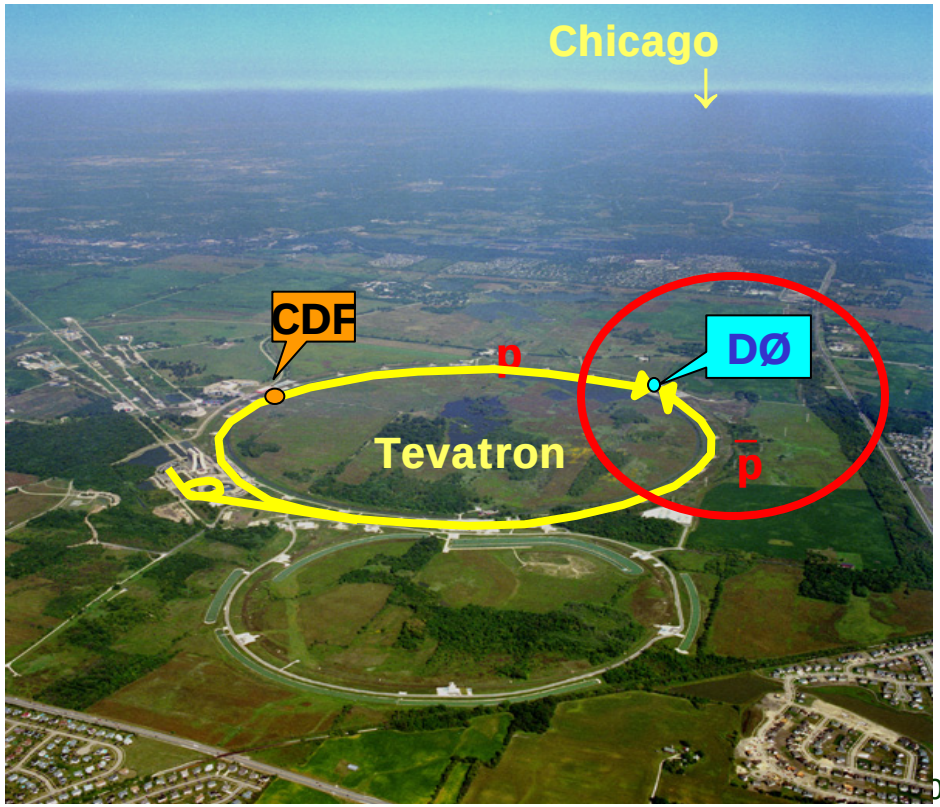
Fermilab Tevatron and LHC at CERN

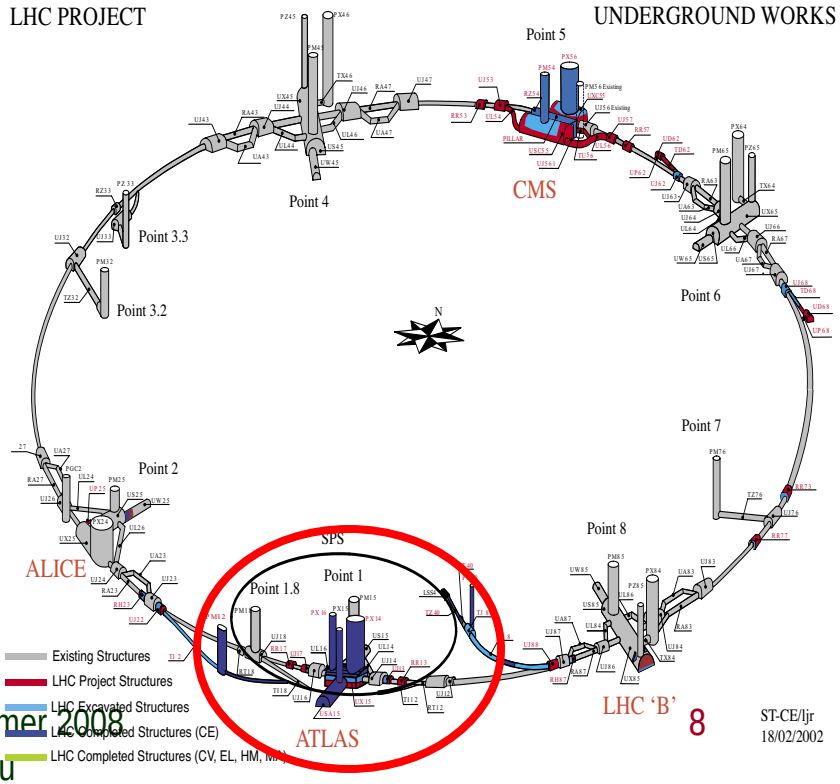
- Present world's Highest Energy proton-anti-proton collider
  - 4km circumference
  - E_{cm}=1.96 TeV (=6.3x10^{-7}J/p➔ 13M Joules on 10^{-4}m^2)

  ⇒ Equivalent to the kinetic energy of a 20t truck at a speed 81mi/hr➔ 130km/hr

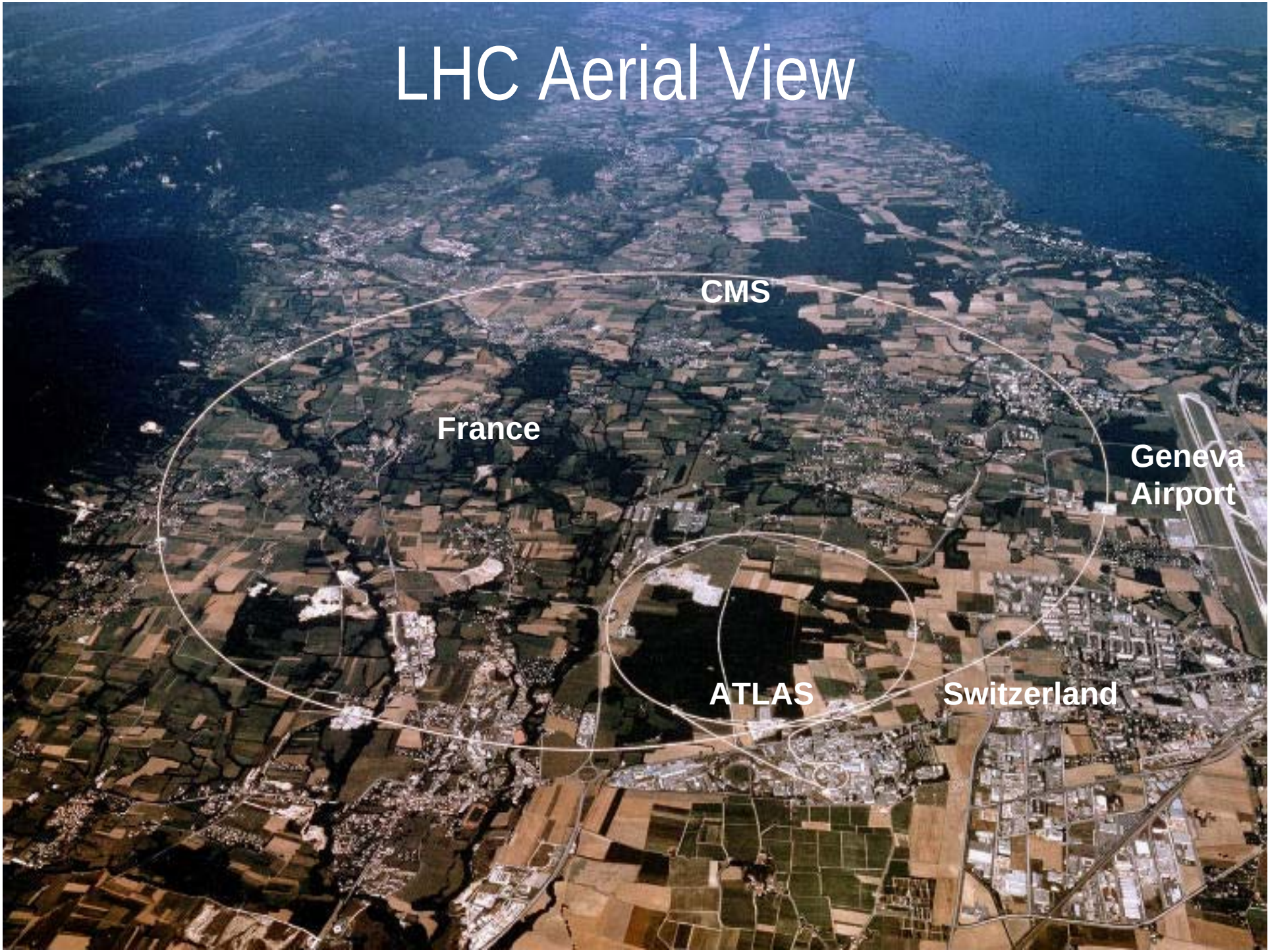
- World's Highest Energy proton-proton collider end of this year
  - 27km circumference
  - E_{cm}=14 TeV (=44x10^{-7}J/p➔ 1000M Joules on 10^{-4}m^2)

  ⇒ Equivalent to the kinetic energy of a 20t truck at a speed 711mi/hr➔1140km/hr



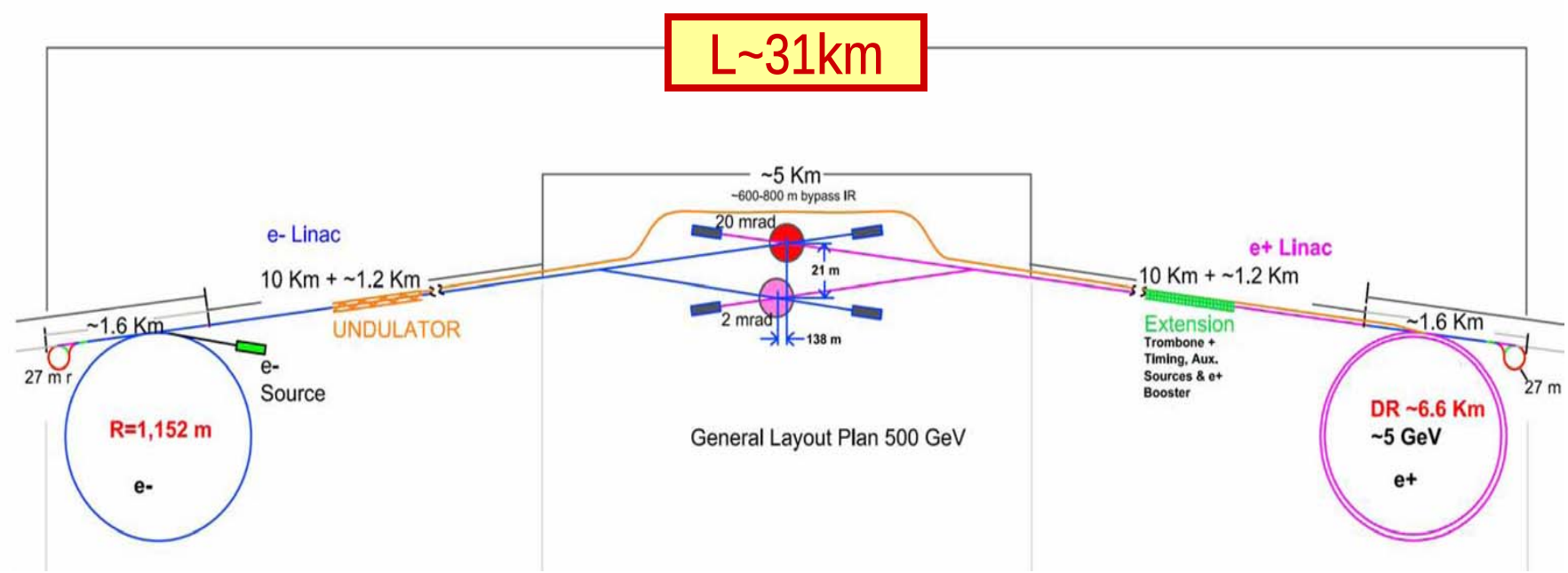


LHC Aerial View

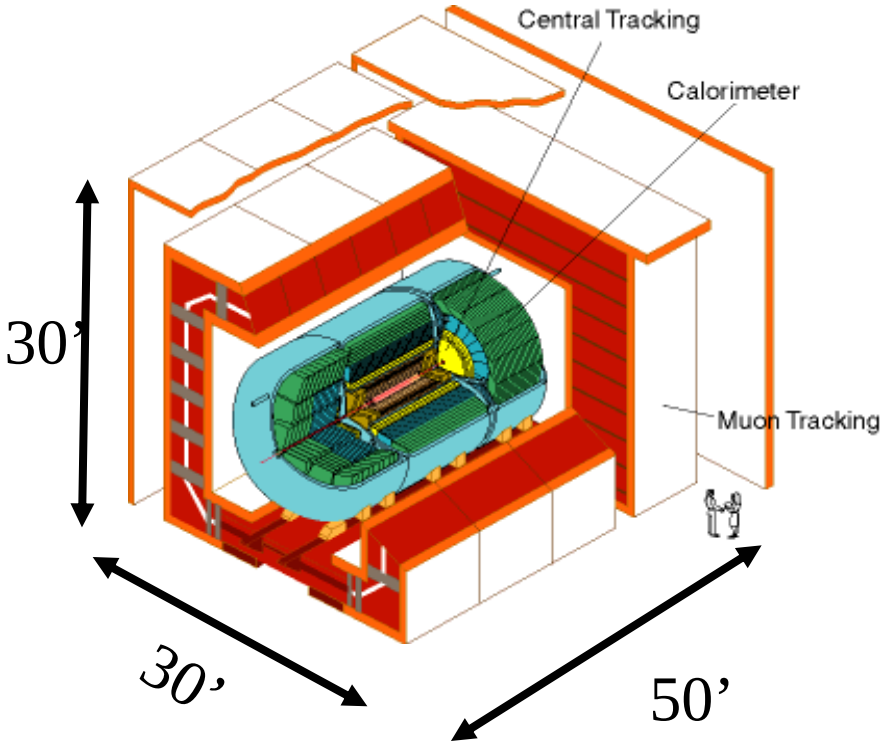


The International Linear Collider

- An electron-positron collider on a straight line
- CMS Energy: 0.5 – 1 TeV
- 10~15 years from now
- Takes 10 years to build the accelerator and the detector

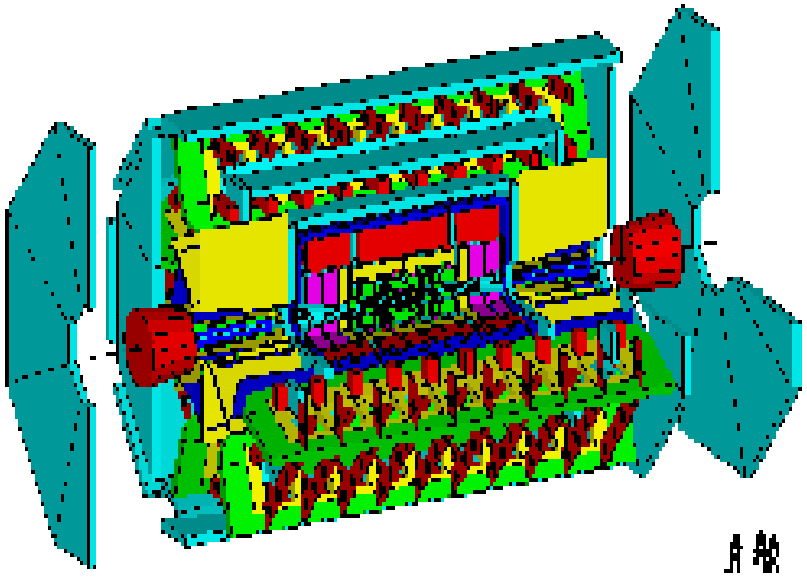


DØ Detector



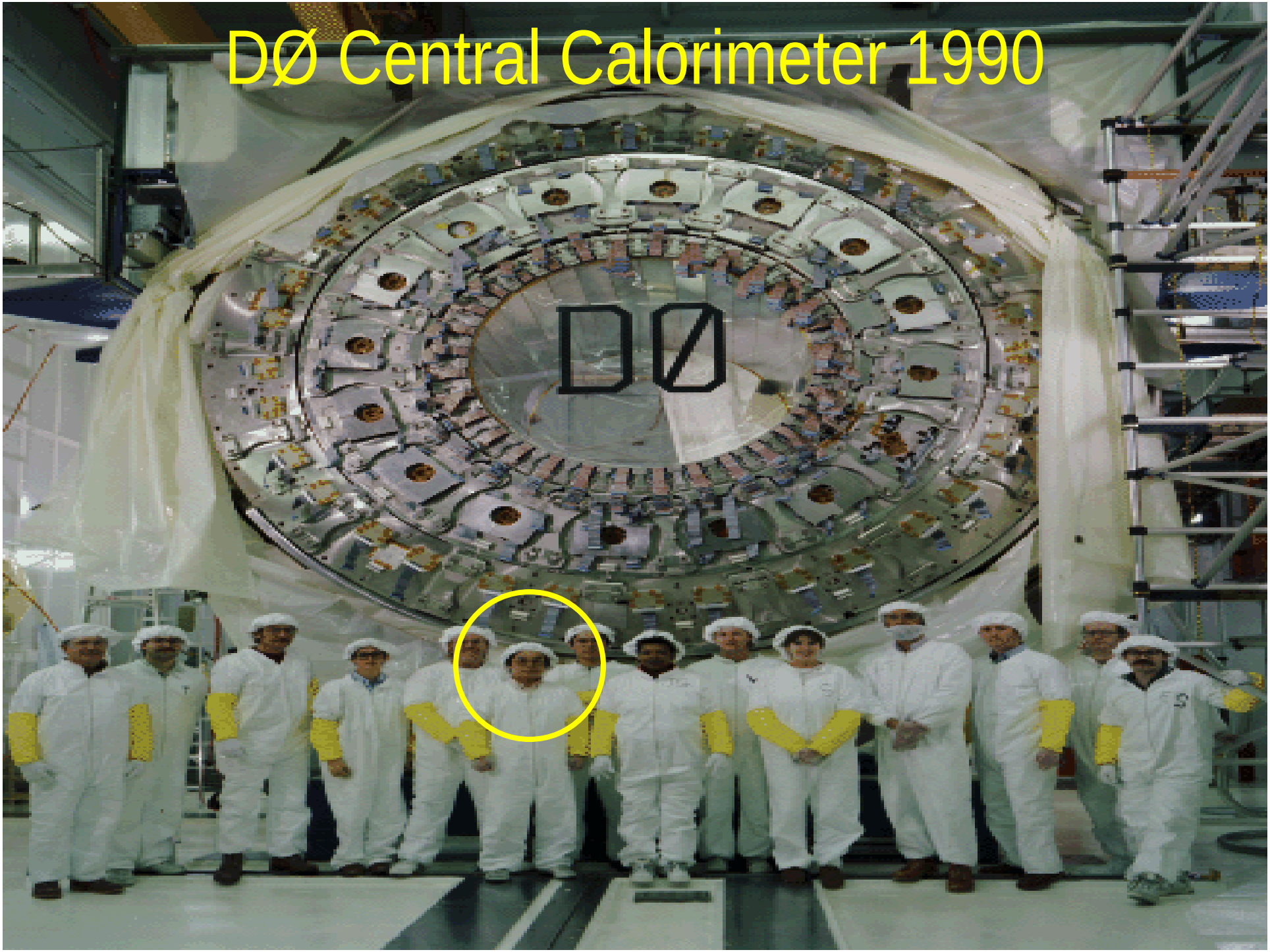
- Weighs 5000 tons and 5 story tall
- Can inspect 3,000,000 collisions/second
- Record 75 collisions/second
- Records approximately 10,000,000 bytes/second
- Records 0.5×10^{15} (500,000,000,000,000) bytes per year (0.5 PetaBytes).

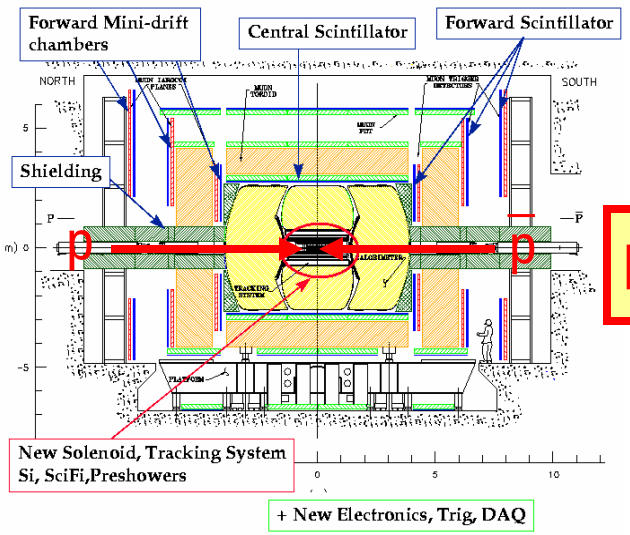
ATLAS Detector



- Weighs 10000 tons and 10 story tall
- Can inspect 1,000,000,000 collisions/second
- Will record 100 – 200 collisions/second
- Records approximately 300,000,000 bytes/second
- Will record 1.5×10^{15} (1,500,000,000,000,000) bytes each year (1.5 PetaByte).

DØ Central Calorimeter 1990

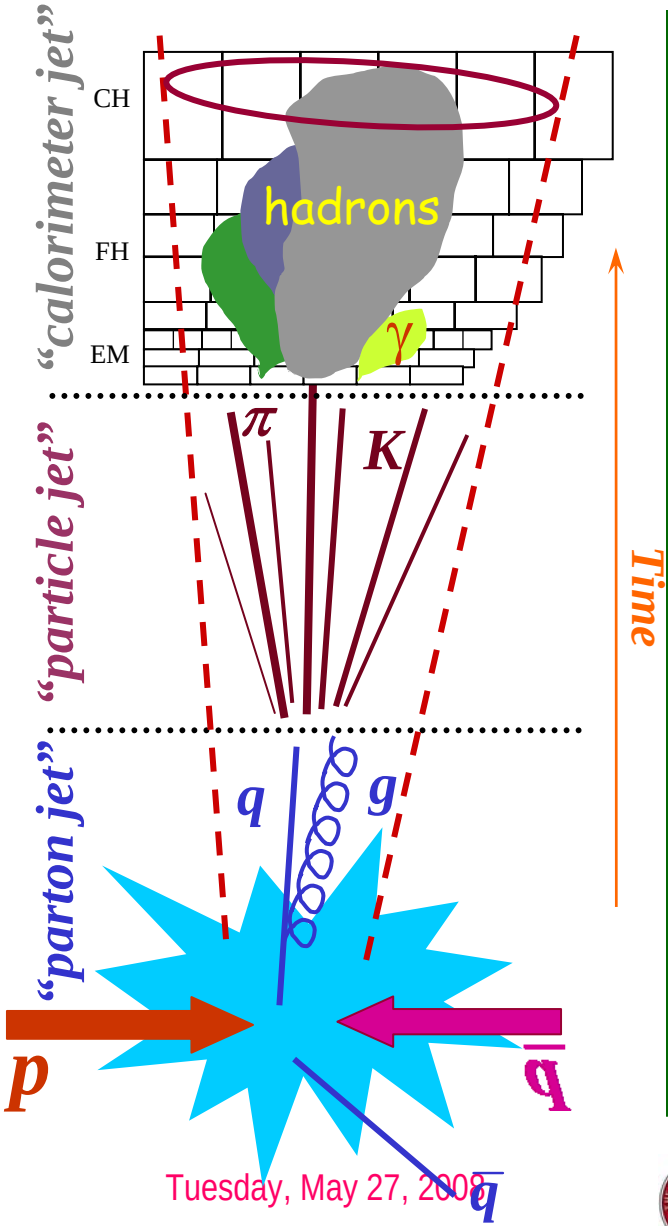


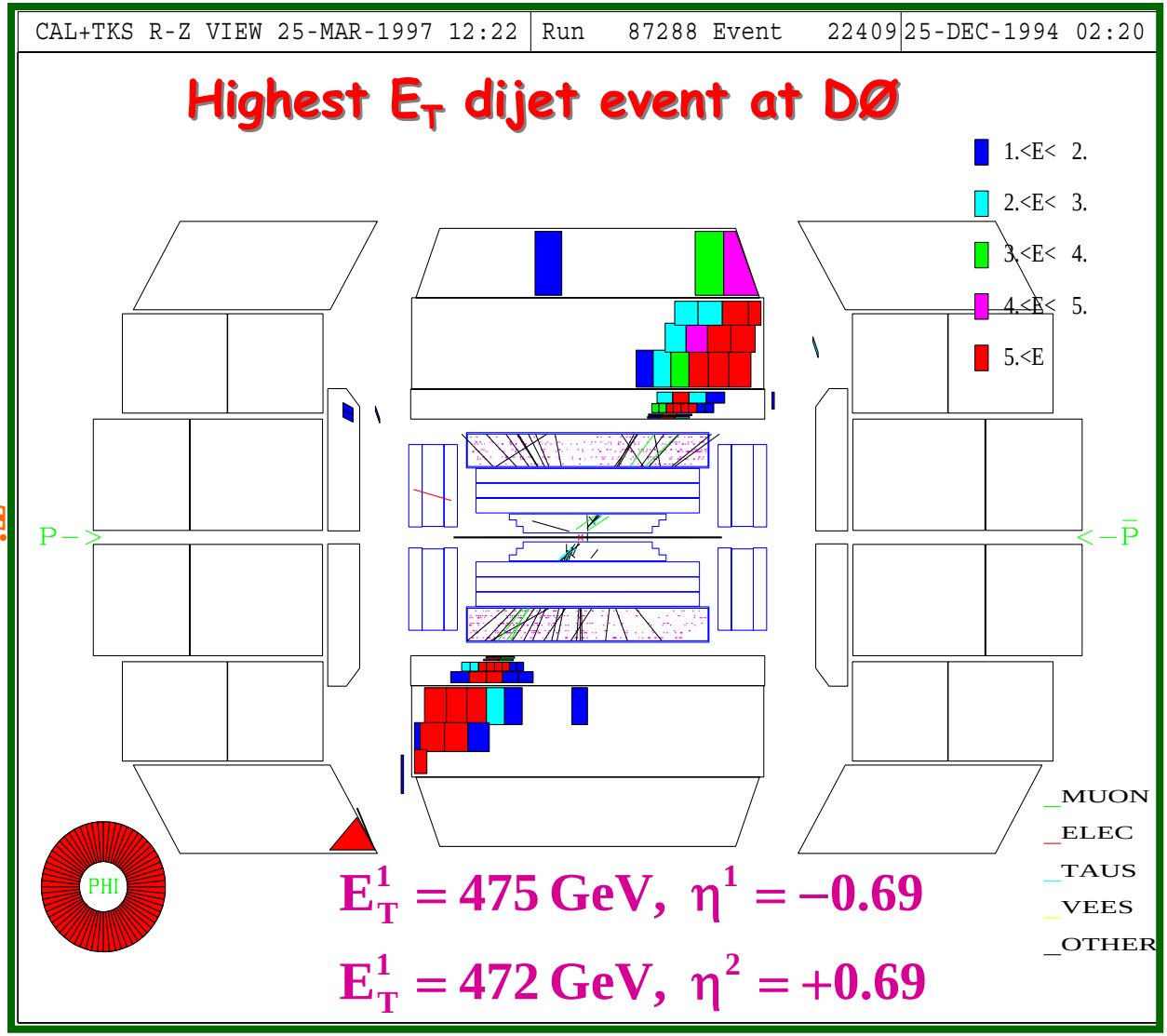


Digital data

Data Reconstruction

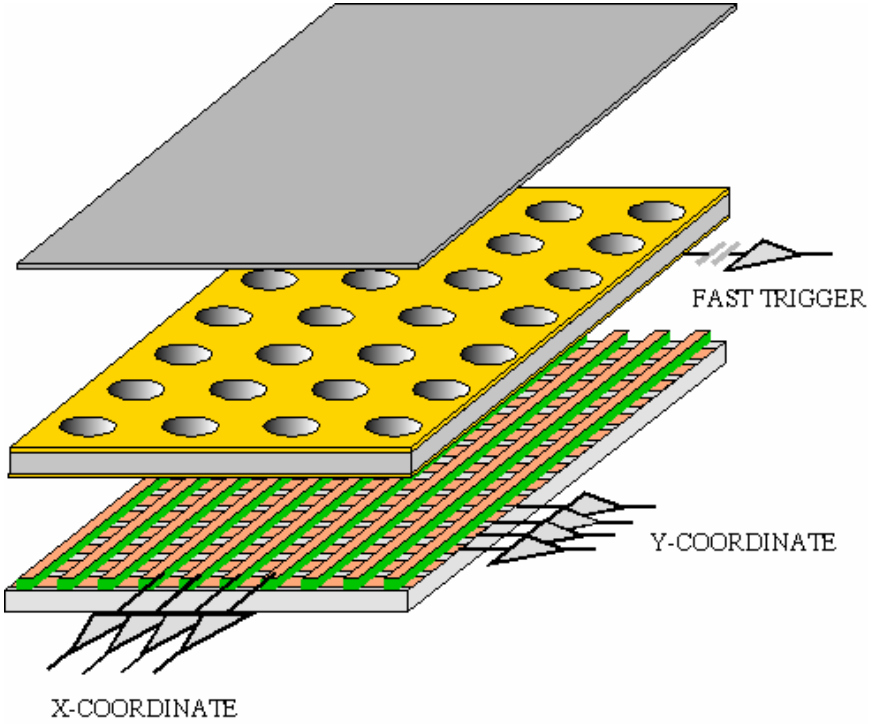
How does an Event Look in a Collider Detector?



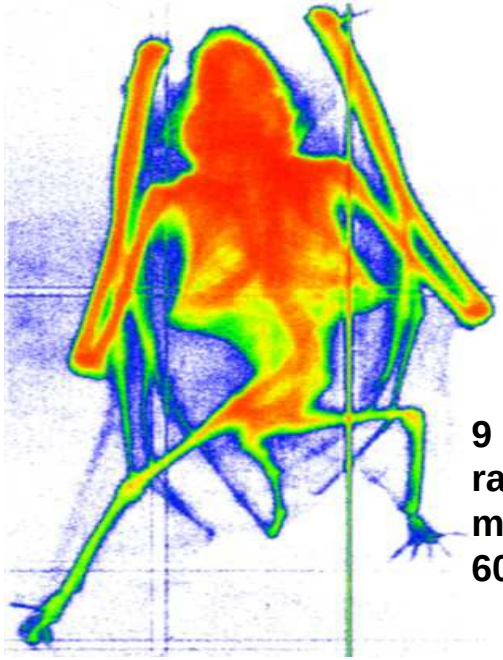


GEM Application Potential

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

Information & Communication Sources

- My web page: http://www-hep.uta.edu/~yu/
  - Contact information & Class Schedule
  - Syllabus
  - Homework
  - Holidays and Exam days
  - Evaluation Policy
  - Class Style & Communication
  - Other information
- Primary communication tool is e-mail: Register for PHYS1441-001-SUMMER08 e-mail distribution list as soon possible ➔ Instruction available in Class style & Communication
  - 5 points extra credit if done by Friday, May 30
  - 3 points extra credit if done by next Monday, June 2
- Office Hours: 10:00 – 11:00am, Mondays - Thursdays or by appointment

Evaluation Policy

- Homework: 30%
- Exams
  - Term Exams: 20%
    - Total of two exams (6/4 and 6/17)
    - One best of the two exams will be used for the final grade
    - Will constitute 20% of the total
    - 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
  - Final Comprehensive Exam (6/30): 25%
- Lab score: 15%
- Pop-quizzes: 10%

100%

- Extra credits: 10% of the total
  - Random attendances
  - Strong participation in the class discussions
  - Other many opportunities
- Grading will be done on 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://hw.utexas.edu/studentInstructions.html
  - Download homework #1, solve the problems and submit them online
  - Multiple unsuccessful tries will deduct points
  - Roster will close Friday, May 30
- 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 ➔ 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 Wednesday, May 28
  - Important to understand physical principles through experiments
  - 15% of the grade
- Physics Clinic:
  - Free service
  - They provide general help on physics, including help solving homework problems
  - 12 – 6pm, Mon-Thu
  - SH 224

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 effort
  - Exams and quizzes will be tough!
    - Sometimes problems might not look exactly like what you learned in class
- But you have a great control for grade in your hands
  - Homework is 30% od 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
  - Lab 15%
  - Extra credit 10%
- I will work with you so that your efforts are properly awarded

What do we want to learn in this class?

- Physics is everywhere around you.
- Understand the fundamental principles that surrounds you in everyday lives…
- Identify what laws of physics applies to what phenomena and use them appropriately
- Understand the impact of such physical laws
- Learn how to research and analyze what you observe.
- Learn how to express observations and measurements in mathematical language
- Learn how to express your research in systematic manner in writing
- I don't want you to be scared of PHYSICS!!!

Most importantly, let us have a lot of FUN!!

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, though some laws can take a while till we see them amongst us

Models, Theories and Laws

- Models: An analogy or a mental image of a phenomena in terms of something we are familiar with
  - 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 ➔ The statement must be found experimentally valid
- Principles: Less general statements of how nature behaves
  - Has some level of arbitrariness

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)
  - Discovery of radioactivity
  - 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?

Needs for Standards and Units

- Three basic quantities for physical measurements
  - Length, Mass and Time
- Need a language that everyone can understand each other
  - Consistency is crucial for physical measurements
  - The same quantity measured by one must be comprehendible and reproducible by others
  - Practical matters contribute
- A system of unit called SI (*System Internationale*) was established in 1960
  - Length in meters (m)
  - Mass in kilo-grams (kg)
  - Time in seconds (s)

Definition of Base Units

SI Units	Definitions
1 *m (Length) = 100 cm*	One meter is the length of the path traveled by light in vacuum during a time interval of 1/299,792,458 of a second.
1 *kg (Mass) = 1000 g*	It is equal to the mass of the international prototype of the kilogram, made of platinum-iridium alloy kept in International Bureau of Weights and Measure in France.
1 *s (Time)*	One second is the duration of 9,192,631,770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the Cesium 133 (C^{133}) atom.

- *There are prefixes that scales the units larger or smaller for convenience (see pg. 7)*
- *Units for other quantities, such as Kelvins for temperature, for easiness of use*

Prefixes, expressions and their meanings

- deca (da): 10^{1}
- hecto (h): 10^{2}
- kilo (k): 10^{3}
- mega (M): 10^{6}
- giga (G): 10^{9}
- tera (T): 10^{12}
- peta (P): 10^{15}
- exa (E): 10^{18}
- zetta (Z): 10^{21}
- yotta (Y): 10^{24}

- deci (d): 10^{-1}
- centi (c): 10^{-2}
- milli (m): 10^{-3}
- micro (μ): 10^{-6}
- nano (n): 10^{-9}
- pico (p): 10^{-12}
- femto (f): 10^{-15}
- atto (a): 10^{-18}
- zepto (z): 10^{-21}
- yocto (y): 10^{-24}

Table 1.2

International Standard Institutes

- International Bureau of Weights and Measure http://www.bipm.fr/
  - Base unit definitions: http://www.bipm.fr/enus/3_SI/base_units.html
  - Unit Conversions: http://www.bipm.fr/enus/3_SI/
- US National Institute of Standards and Technology (NIST) http://www.nist.gov/

How do we convert quantities from one unit to another?

Unit 1 =	Conversion factor X	Unit 2
1 inch	2.54	cm
1 inch	0.0254	m
1 inch	2.54×10^{-5}	km
1 ft	30.3	cm
1 ft	0.303	m
1 m	3.281	ft
1 hr	60	minutes
1 hr	3600	seconds
And many	More	Here….

Examples for Unit Conversions

- Ex 1: The highest waterfall in the world is Angel Falls in Venezuela, with a total drop of 979.0m. Express this drop in feet.

What do we need to know?

$$979.0m = 979.0m \times \left(\frac{3.281\,feet}{1\ m}\right)$$

$$= 979.0\cancel{m} \times \left(\frac{3.281\ \text{feet}}{1\ \cancel{m}}\right)$$

$$= 979.0 \times 3.281\ \text{feet} = 3212\ \text{feet}$$

- Ex 2 : Express the speed limit 65 miles per hour (mi/h or mph) in terms of meters per second (m/s).

$$1\ \text{mi} = (5280\ \text{ft})\left(\frac{12\ \text{in}}{1\ \text{ft}}\right)\left(\frac{2.54\ \text{cm}}{1\ \text{in}}\right)\left(\frac{1\ \text{m}}{100\text{cm}}\right) = 1609\ \text{m} = 1.609\ \text{km}$$

$$65\ \text{mi/h} = (65\ \text{mi})\left(\frac{1609\ \text{m}}{1\ \text{mi}}\right)\left(\frac{1}{1\ \text{h}}\right)\left(\frac{1\ \text{h}}{3600\ \text{s}}\right) = 29.1\ \text{m/s}$$

In km/hour? $65\ \text{mi/h} = (65\ \text{mi})\left(\frac{1.609\ \text{km}}{1\ \text{mi}}\right)\left(\frac{1}{1\ \text{h}}\right) = 104\ \text{km/h}$

Estimates & Order-of-Magnitude Calculations

- Estimate = Approximation
  - Useful for rough calculations to determine the necessity of higher precision
  - Usually done under certain assumptions
  - Might require modification of assumptions, if higher precision is necessary
- Order of magnitude estimate: Estimates done to the precision of 10s or exponents of 10s;
  - Three orders of magnitude: 10^3=1,000
  - Round up for Order of magnitude estimate; $8x10^7 \sim 10^8$
  - Similar terms: “Ball-park-figures”, “guesstimates”, etc

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

- Significant figures denote the precision of the measured value
  - Significant figures: non-zero numbers or zeros that are not place-holders
    - How many significant figures? 34, 34.2, 0.001, 34.001
      - 34 has two significant digits
      - 34.2 has 3
      - 0.001 has one because the 0's before 1 are place holders
      - 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:
      - $31400000=3.14x10^{7}$
      - $0.00012=1.2x10^{-4}$

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 significant figures in the result: 12.001 x 3.1 = 37, because the smallest significant figures is ?.