PHYS 3313 – Section 001
Lecture #4

Monday, Jan. 30, 2017
Dr. Jaehoon Yu

- Conservation Laws and Fundamental Forces
- Atomic Theory of Matter
- Unsolved Questions of 1895 and the New Horizon
- Unsolved Questions Today!
- Galilean Transformation
- Do we need Ether?

Announcements

- Reading assignments: CH 2.10 (special topic), 2.13 and 2.14
  - Please go through eq. 2.45 through eq. 2.49 and example 2.9
- Homework #1
  - chapter 2 end of the chapter problems
  - 17, 21, 23, 24, 32, 59, 61, 66, 68, 81 and 96
  - Due is by the beginning of the class, Wednesday, Feb. 8
  - Work in study groups together with other students but PLEASE do write your answer in your own way!
- Quiz #1 results
  - Class average: 22/100
  - Top score: 73/100

Research Projects

1. Each of the 9 research groups has an assigned research topic

Research Topics

1. Blackbody radiation
2. Michelson–Morley Experiment
3. The Photoelectric Effect
4. The Brownian Motion
5. Compton Effect
6. Discovery of Electron
7. Rutherford Scattering
8. Super-conductivity
9. The Discovery of Radioactivity

Research Projects

1. Each of the 9 research groups has an assigned research topic
2. Study the topic as a group, looking up references
   - Original theory or Original observation
   - Experimental proofs or Theoretical prediction + subsequent experimental proofs
   - Importance and the impact of the theory/experiment
3. Each member of the group writes a 5 – 7 page report, including figures (must not copy!!)
   - 10% of the total grade
   - Can share the theme and facts but you must write your own!
   - Due beginning of the class Wed. Apr. 26, 2017
4. Each group presents a 10+2min power point talk
   - 5% of the total grade
   - Date and time will be announced close to the end of the semester

Reminder: Research Project Report

1. Must contain the following at the minimum
   - Original theory or Original observation
   - Experimental proofs or Theoretical prediction + subsequent experimental proofs
   - Importance and the impact of the theory/experiment
   - Conclusions and future prospects
   - The reference to the original paper must be included!
   - Bibliography referring to web site must be minimized (<20%)

Project Report Template

Title Goes Here Like This with The First Letter of Each Word Capital

PHYS-3313, Spring 2017
MM DD, 2017

Author Name
Department of XYZ
The University of Texas at Arlington

Abstract

Describe briefly and to the point the content of the note in about a paragraph or so, including the brief conclusion. The font of the main body must be Times New Roman 12pt. Tables and figures must be numbered in sequence as they appear as Table 1 or Figure 1. Each has its own numbering system. They must be placed as close to the text in which they are referred. They must have associated captions attached to them. These explain what the contents of the figure or table are. Captions must be Times New Roman 11pt. References must be placed to where the reference is relevant in a square bracket with a number counted in sequence as they appear but only in the main body not in the abstract.

1. **Introduction**
   Describe what this paper is all about and how this note is organized [1] and motivate the readers.

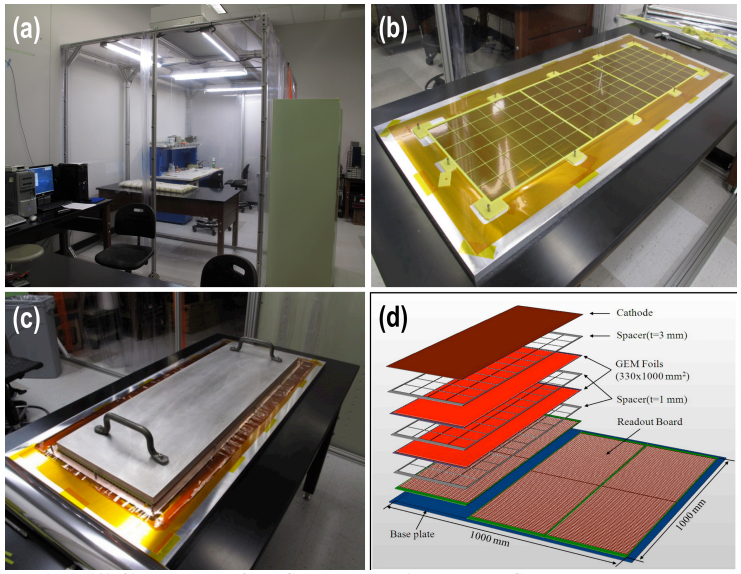


Figure. 1 (a) 12'x8' clean room for LGEM construction (b) An LGEM layer on an assembly jig held by alignment pins throughout the sides (c) glue curing process with heavy flattening pressing plane (d) Layout of a full $100\text{cm} \times 100\text{cm}$ **GEM DHCAL active layer.**

2. **Original Theory or Experiment**
   Describe the original theory or experiment that prompted this particular paper here.
3. **Theoretical predictions and/or experimental proofs**
   Describe the subsequent experimental proof of the theory or of the paper.
4. **Importance and the impact of the theory/experiment of the paper**
   Describe in detail the importance and impact of the paper. What did we do with the knowledge of the paper?
5. **Conclusions and Future Work**
   Describe what your conclusions are on this paper and what can be done more.

Bibliography← your references go here and in the text with the same reference numbers in order as they appear in the paper. They get assigned the ref. number just once. You then use them throughout the paper.

1. D. Decamp et al., ALEPH Collaboration, Nucl. Inst. Meth. **A360**, 481 (1995).
2. R. Bouclier, *et al.*, "The Gas Electron Multiplier (GEM)," IEEE Trans. Nucl. Sci. **NS-44**, 646[1] (1997).

1

Research Presentations

- Each of the 9 research groups makes a 10+2min presentation
  - 10min presentation + 2min Q&A
  - All presentations must be in power point
  - I must receive all final presentation files by 8pm, Sunday, Apr. 23, 2017
    - No changes are allowed afterward
  - The representative of the group makes the presentation followed by all group members' participation in the Q&A session
- Date and time:
  - In class Monday and Wednesday, Apr. 24 and 26, 2017
- Important metrics
  - Contents of the presentation: 60%
    - Inclusion of all important points as mentioned in the report
    - The quality of the research and making the right points
  - Quality of the presentation itself: 15%
  - Presentation manner: 10%
  - Q&A handling: 10%
  - Staying in the allotted presentation time: 5%
  - Judging participation and sincerity: 5%

Conservation Laws and Fundamental Forces

- Conservations laws are the guiding principles of physics
- Recall the fundamental conservation laws:
  - Conservation of energy
  - Conservation of linear momentum
  - Conservation of angular momentum
  - Conservation of electric charge
- In addition to the classical conservation laws, two modern results include:
  - The conservation of the number of baryons and leptons
  - The fundamental invariance principles for time reversal, distance, and parity

Also in the Modern Context…

- The three fundamental forces are introduced
  - **Gravitational**: $\vec{F}_g = -G\frac{m_1 m_2}{r^2}\hat{r}$
    - Responsible for planetary motions, holding things on the ground, etc
  - **Electroweak (unified at high energies)**
    - **Weak**: Responsible for the nuclear beta decay and effective only over distances of ~10^{-15} m
    - **Electromagnetic**: Responsible for all non-gravitational interactions, such as all chemical reactions, friction, tension….
    - $\vec{F}_C = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}\hat{r}$ (Coulomb force)
  - **Strong**: Responsible for "holding" the nucleus together and effective in the distance less than ~10^{-15} m

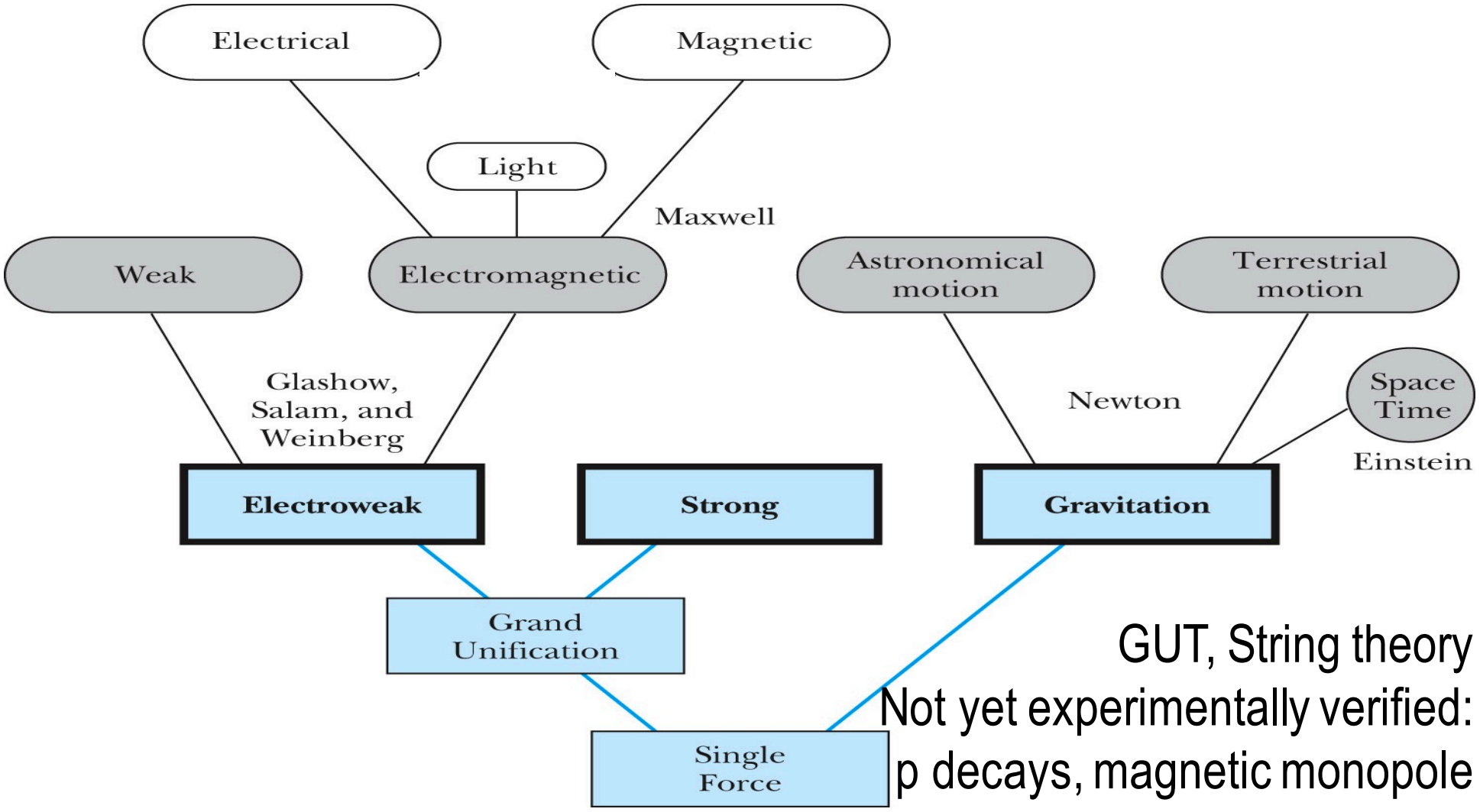
Relative Strength of Fundamental Forces

Table 1.1 Fundamental Forces

Interaction		Relative Strength*	Range
Strong		1	Short, $\sim 10^{-15}$ m
Electroweak	Electromagnetic	10^{-2}	Long, $1/r^2$
	Weak	10^{-9}	Short, $\sim 10^{-15}$ m
Gravitational		10^{-39}	Long, $1/r^2$

*These strengths are quoted for neutrons and/or protons in close proximity.

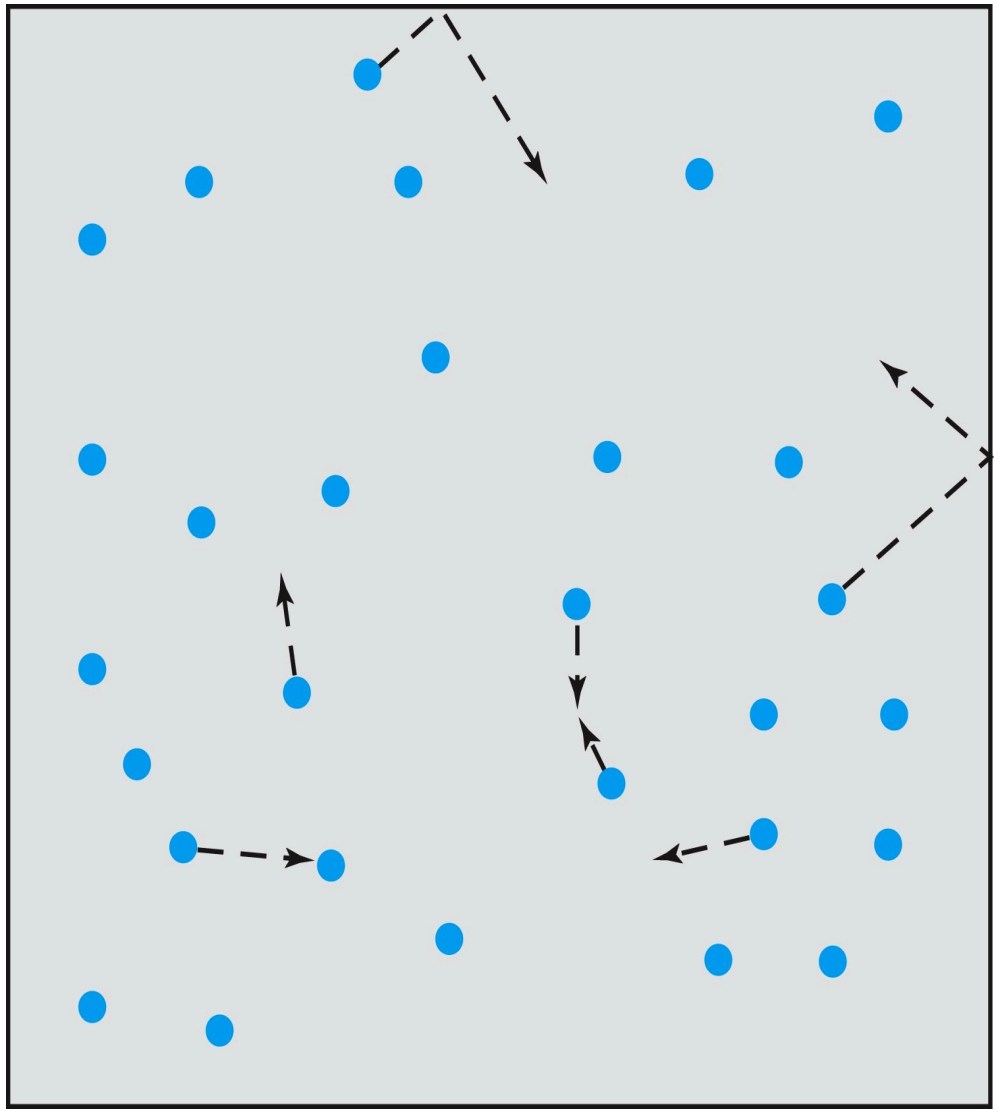
Unification of Forces



GUT, String theory
Not yet experimentally verified:
p decays, magnetic monopole

Relevance of Gas Concept to Atoms

- The idea of gas (17th century) as a collection of small particles bouncing around with kinetic energy enabled the concept of small, unseen objects
- This concept formed the bases of existence of something small that makes up matter



The Atomic Theory of Matter

- Concept initiated by Democritus and Leucippus (~450 B.C.) (first to use the Greek *atomos*, meaning "indivisible")
- In addition to fundamental contributions by Boyle, Charles, and Gay-Lussac, Proust (1754 – 1826) proposes the **law of definite proportions** ➔ For a compound of 2 or more elements, the weight proportion of the elements is always the same
- Dalton advances the **atomic theory of matter** to explain the law of definite proportions
- Avogadro proposed that all gases at the same temperature, pressure, and volume contain the ***same number of molecules (atoms)***; viz. 6.02×10^{23} atoms
- Cannizzaro (1826 – 1910) makes a distinction between atoms and molecules advancing the ideas of Avogadro.

Further Advances in Atomic Theory

- Maxwell derives the speed distribution of atoms in a gas
- Robert Brown (1753 – 1858), a botanist, observes microscopic "random" motion of suspended grains of pollen in water in 1811 (Brownian motion)
- Einstein in the 20th century explains this random motion using atomic theory (~100 year later!)

Opposition to the Atomic Theory

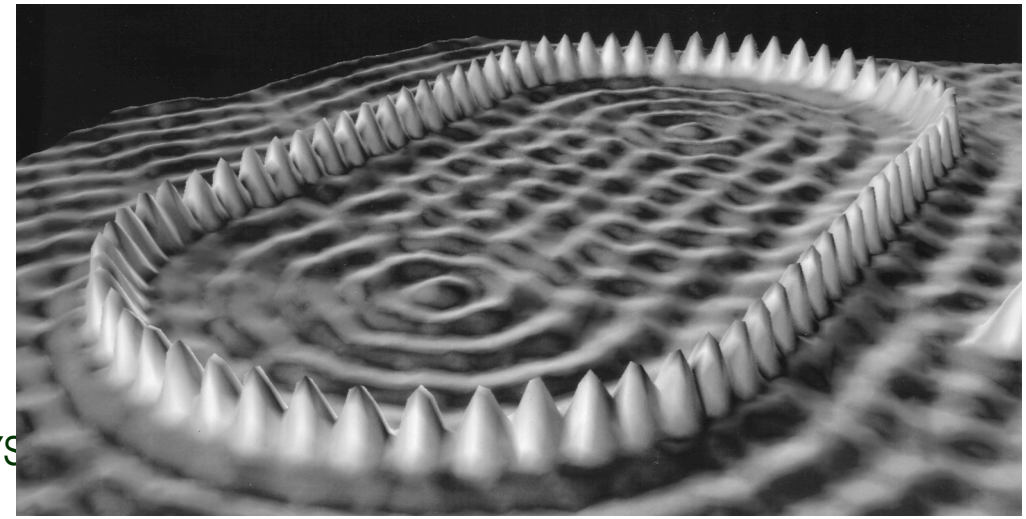
- Ernst Mach (1838 – 1916) opposes the theory on the basis of logical positivism, i.e., atoms being *"unseen" questions their reality*
- Wilhelm Ostwald (1853 – 1932) supports Mach's premise and called atoms hypothetical structures for bookkeeping based on experimental results of radioactivity, discrete spectral lines, and the formation of molecular structures

Overwhelming Evidence for Existence of Atoms

- Max Planck (1858 – 1947) advances the concept to explain blackbody radiation, using submicroscopic "quanta"
- Boltzmann requires existence of atoms for advances in statistical mechanics
- Albert Einstein (1879 – 1955) uses molecules to explain Brownian motion and determines the approximate value of their sizes and masses
- Jean Perrin (1870 – 1942) experimentally verifies Einstein's predictions

Unresolved Questions and New Horizons

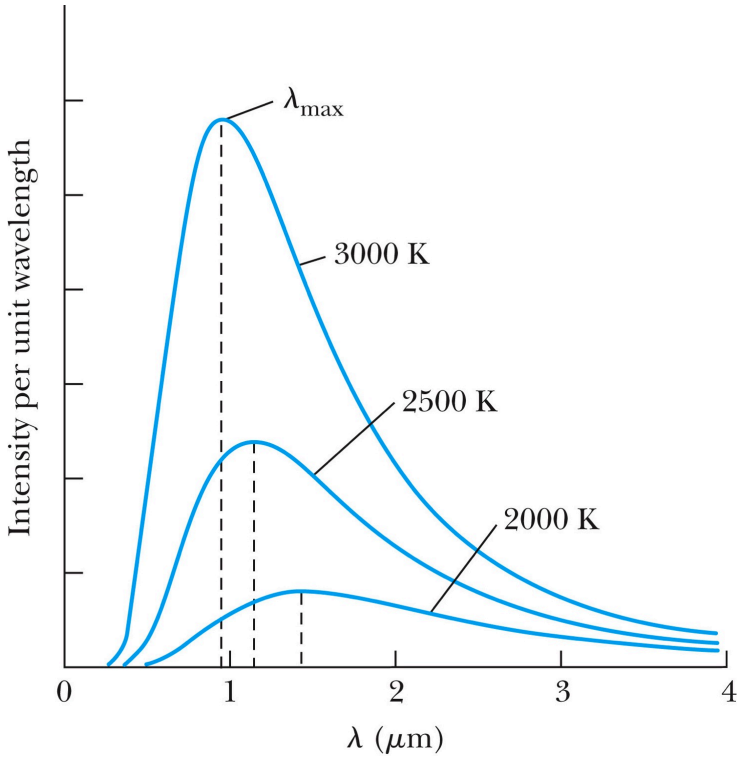
- The atomic theory controversy raises fundamental questions
  - It was not universally accepted
  - The constituents (if any) of atoms became a significant question
  - The structure of matter remained unknown with certainty
  - Experimental precisions were insufficient to discern this level of small scale



Further Complications

Three fundamental problems:

- The (non) existence of a medium that transmits light waves from the sun – the electromagnetic medium
- The observed differences in the electric and magnetic fields between stationary and moving reference systems
- The failure of classical physics to explain blackbody radiation in which characteristic spectra of radiation that cover the entire EM wavelengths were observed depending on temperature not on the body itself!!
  - Max Planck energy quantization



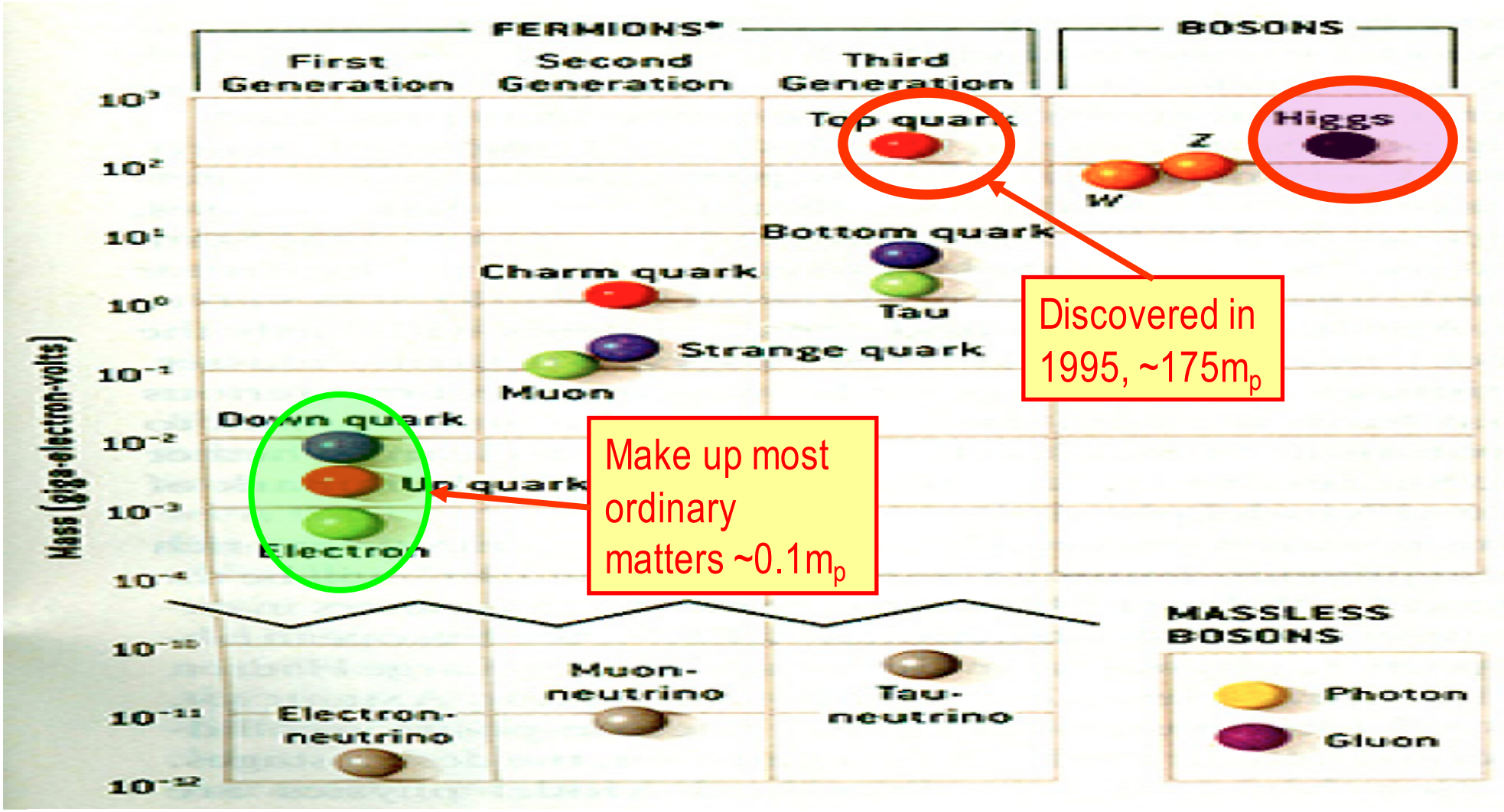
Additional Experimental Discoveries Contribute to the Complications

- Discovery of x-rays (1895, Röntgen)
- Discovery of radioactivity (1896, Becquerel)
- Discovery of the electron (1897, Thompson)
- Discovery of the Zeeman effect (1896, Zeeman), the dependence of spectral frequency on magnetic field

The Beginnings of Modern Physics

- These new discoveries and the many resulting complications required a revision of the fundamental physical assumptions culminated on the successes of the classical foundations
- To this end, the introduction of the modern theory of **relativity and quantum mechanics** becomes the starting point of this most fascinating revision
  - 1900 Max Planck's Radiation Law
  - 1905 Einstein's three papers: Brownian Motion, the Photo-electric effect, and the Special Relativity
  - Broadened the horizon of physics!!

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!

Unsolved Problems Today!

- Why are there three families of quarks and leptons?
- Why is the mass range so large ($0.1m_p$ – $175\ m_p$)?
- How do matters acquire mass?
  - Is the new particle we've discovered the Higgs particle?
- Why is the matter in the universe made only of particles?
  - What happened to anti-particles? Or anti-matters?
- Do neutrinos have mass & what are the mixing parameters?
- Why are there only three apparent forces?
- Is the picture we present the real thing?
  - What makes up the 95% of the universe?
  - How about extra-dimensions?
- How is the universe created?
- Are there any other theories that describe the universe better?
- Many more questions to be answered!!