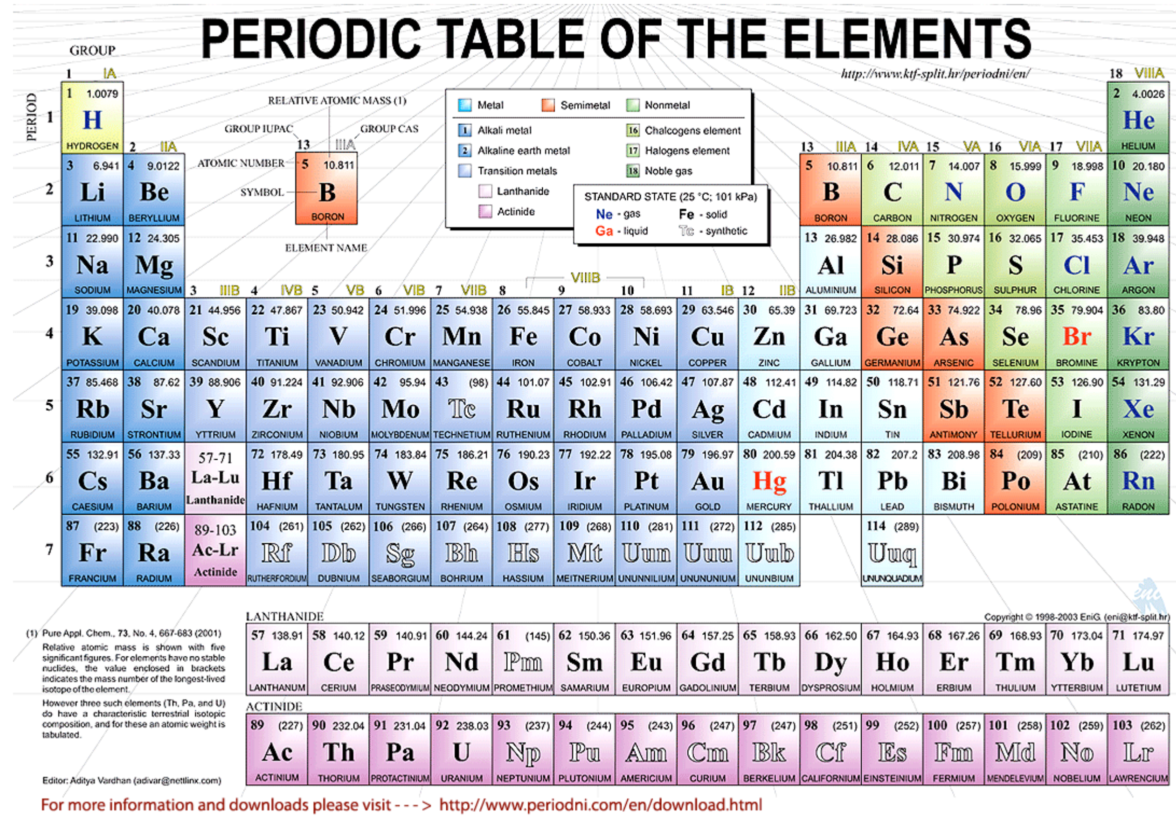
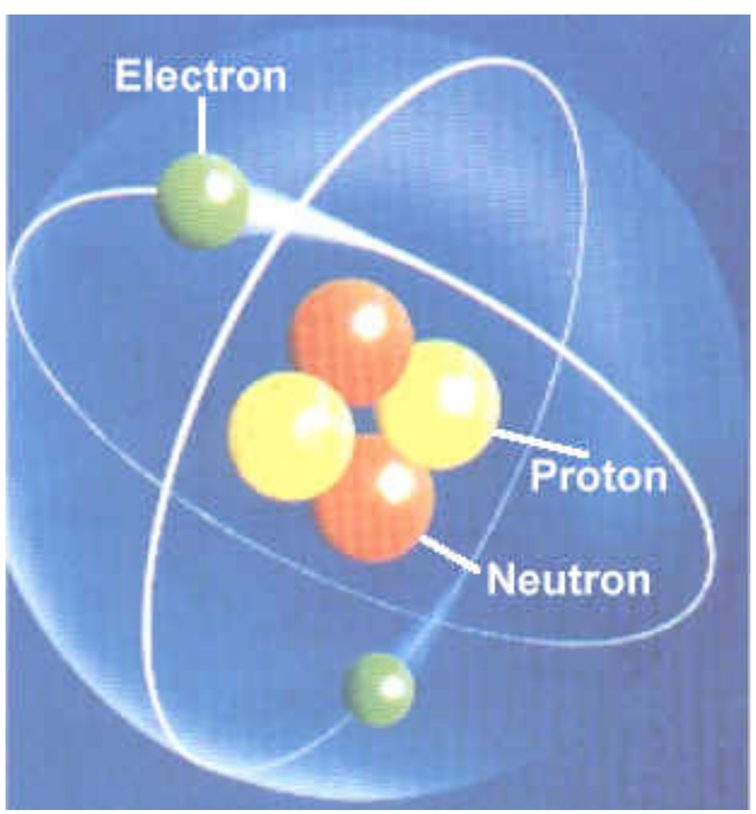
From Quarks to the Cosmos

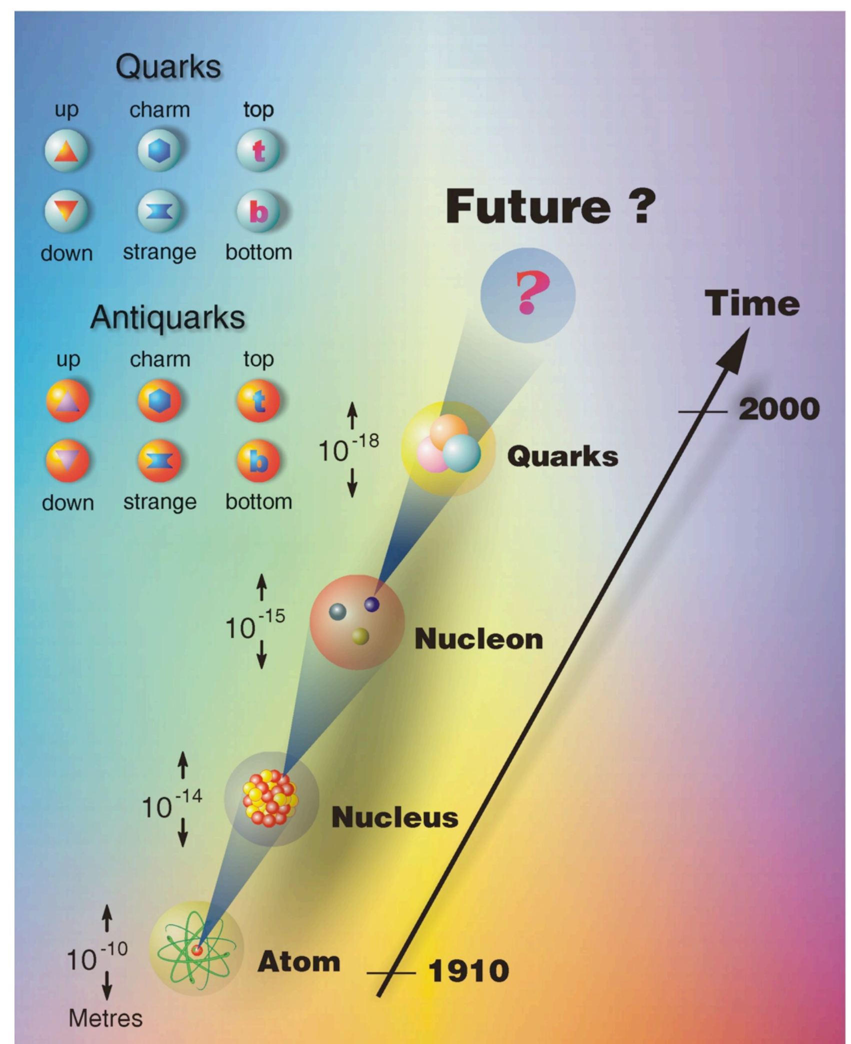
Patrick Fox

Fermilab

Particles (Fermions)







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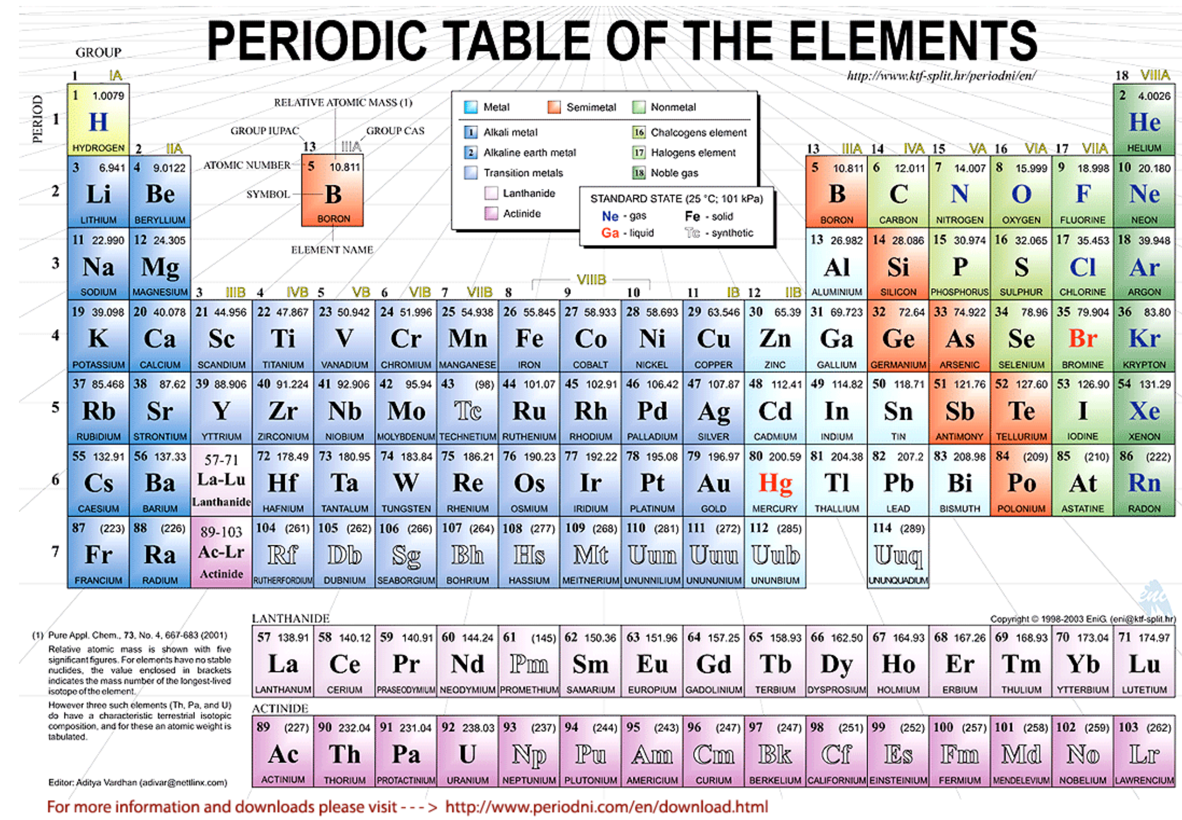

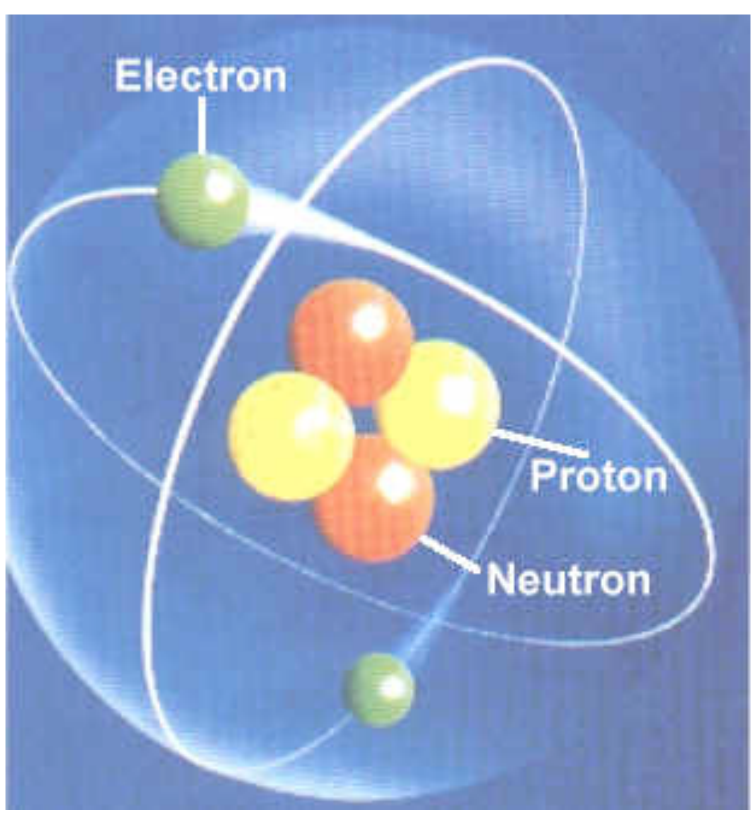

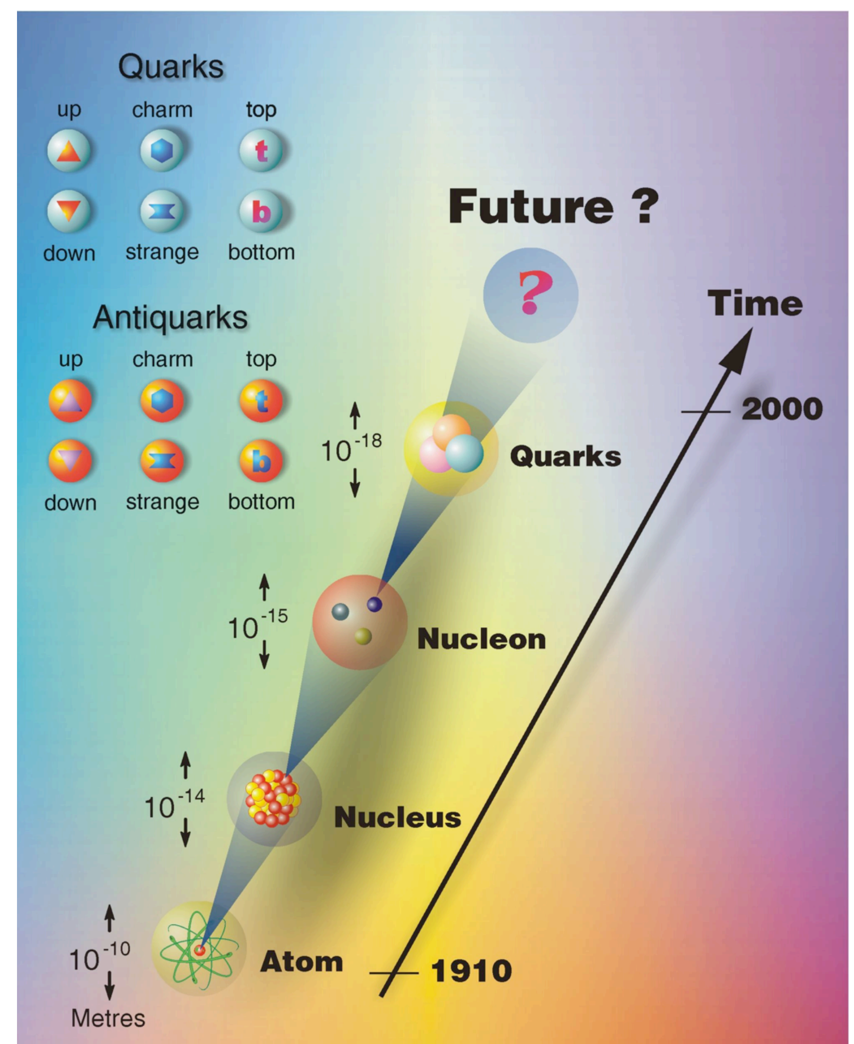

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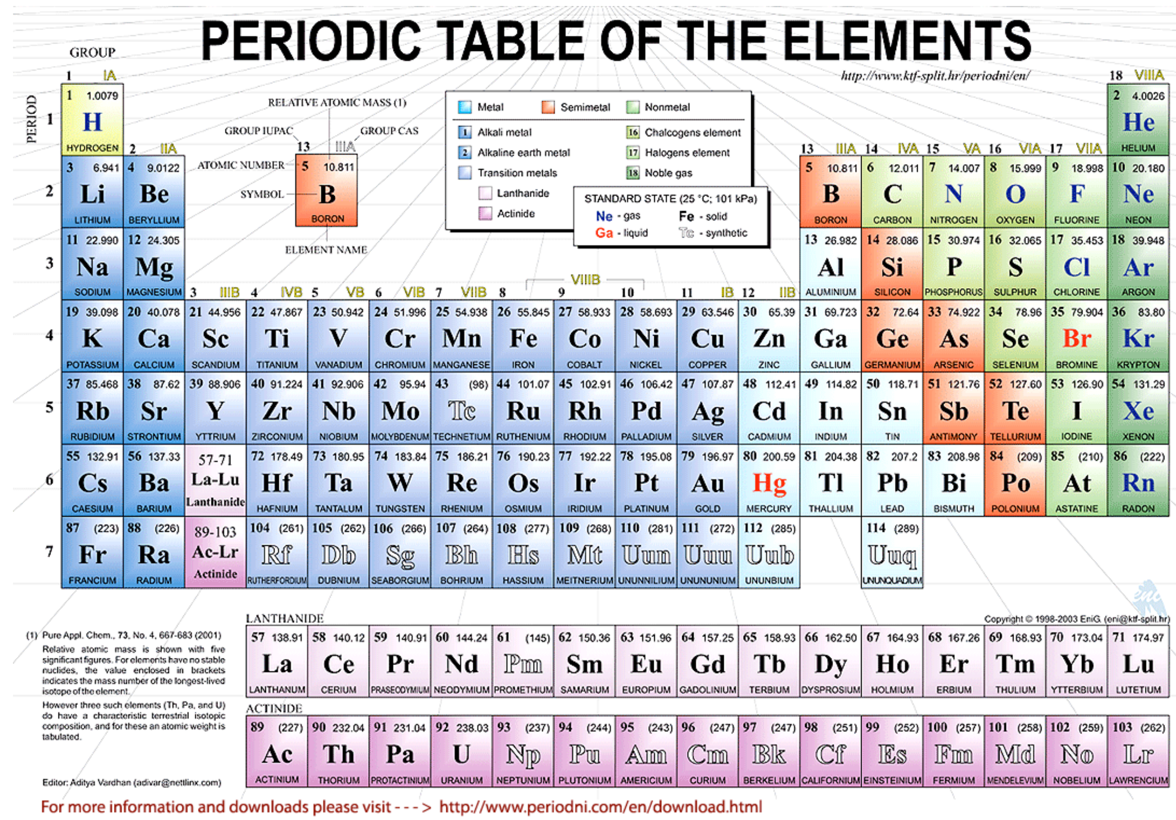

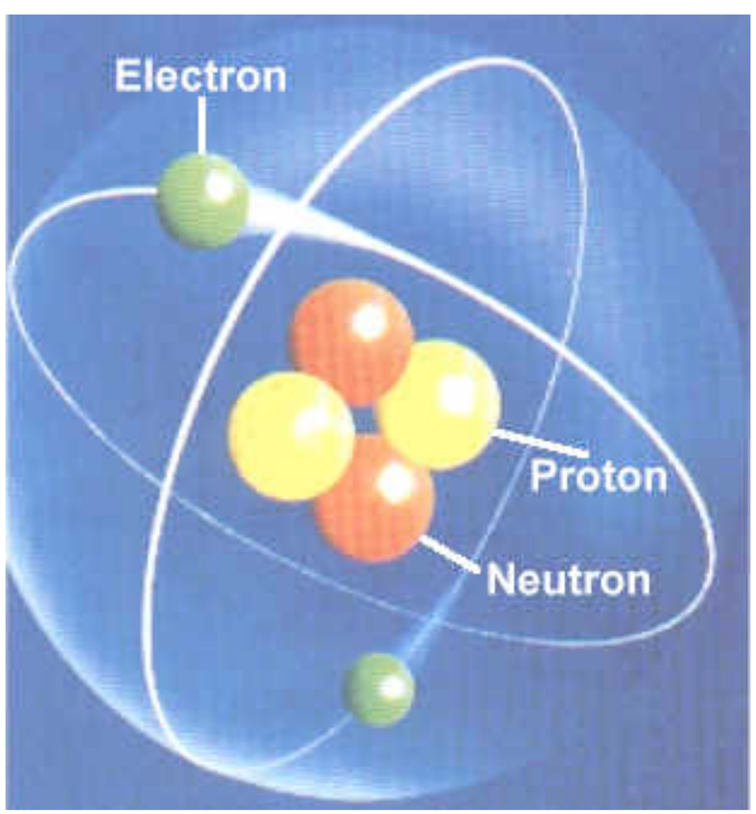

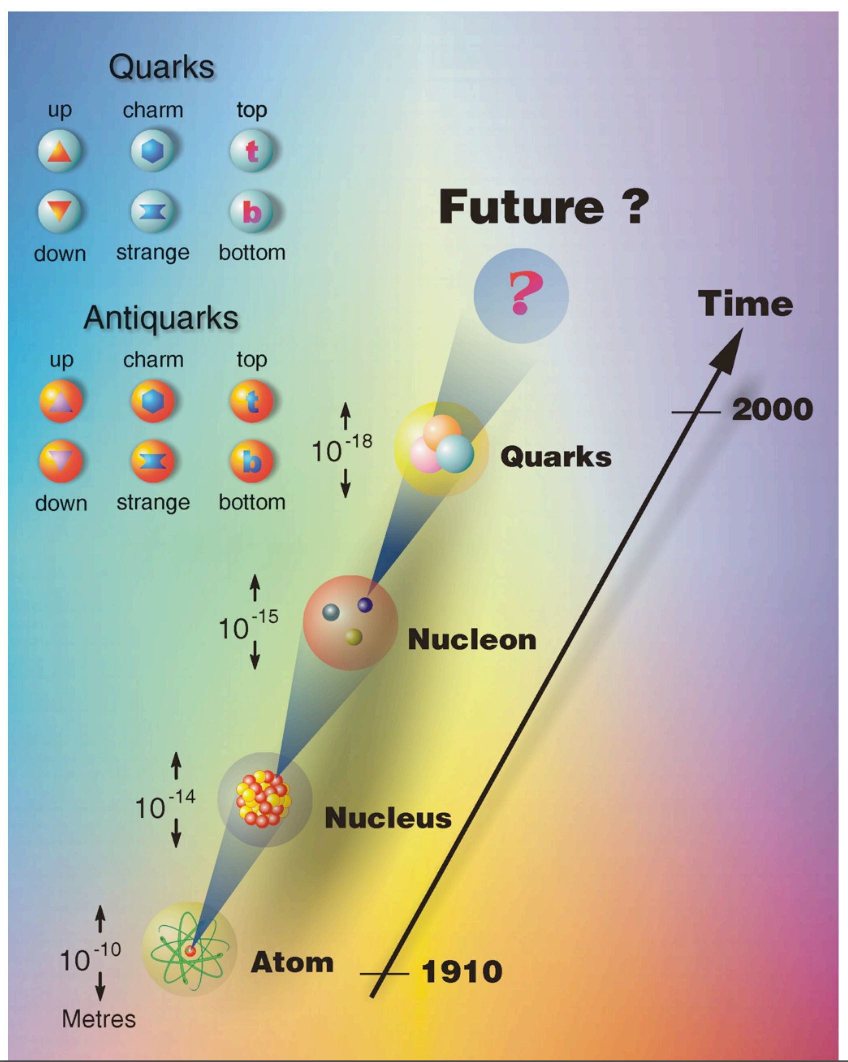

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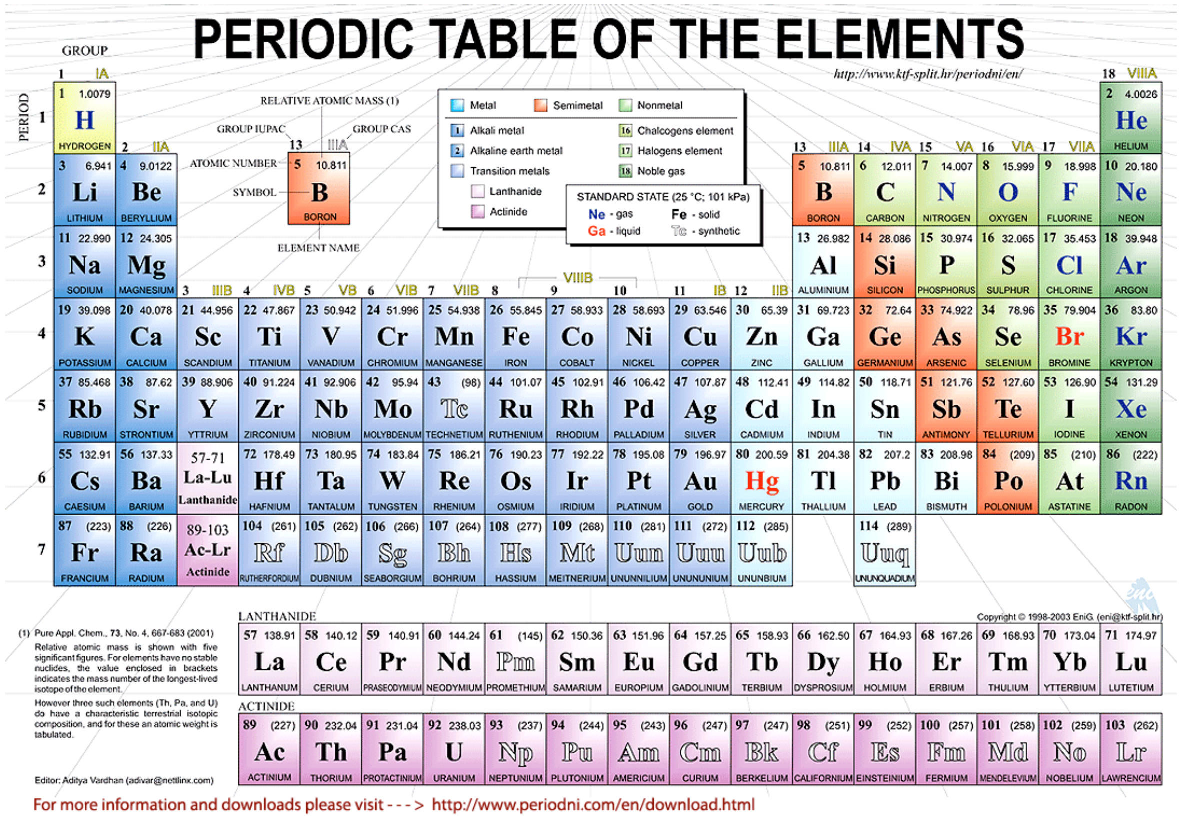
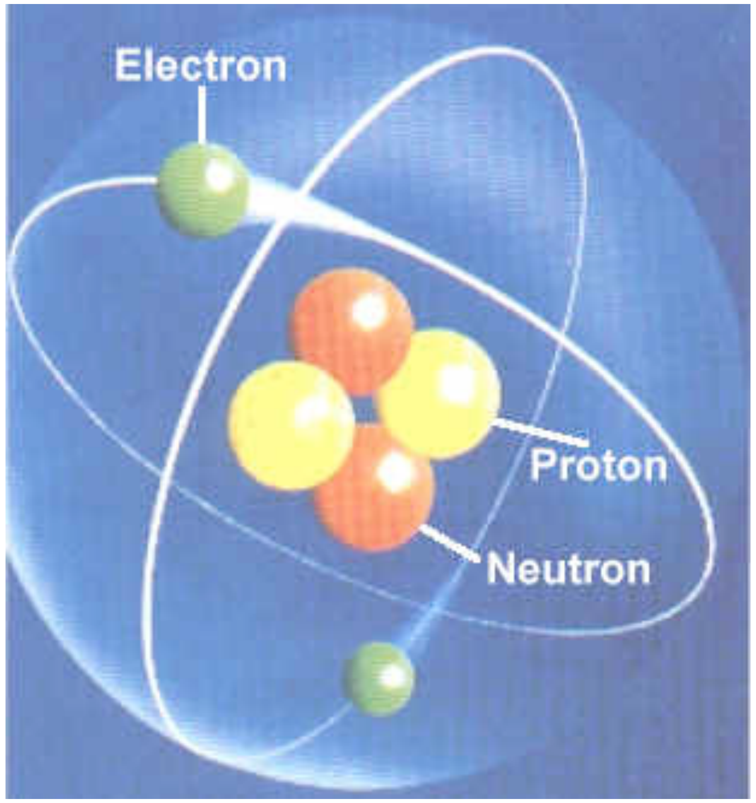
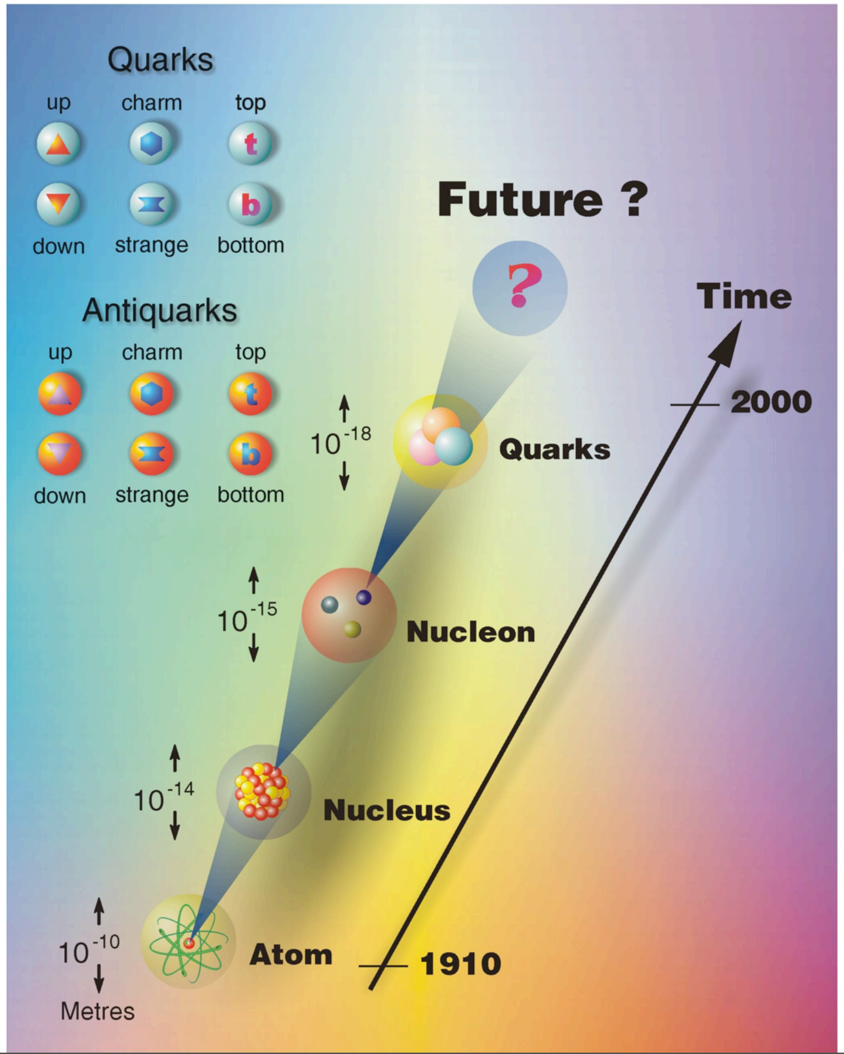
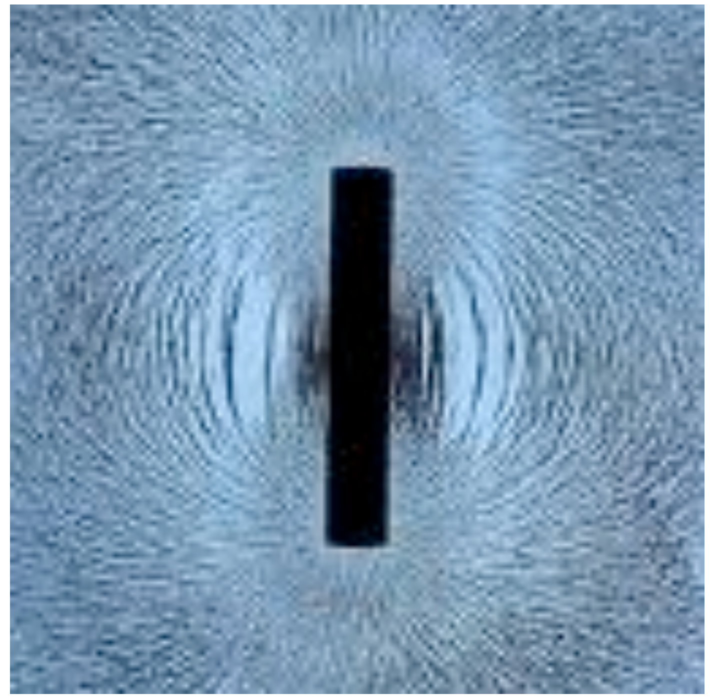
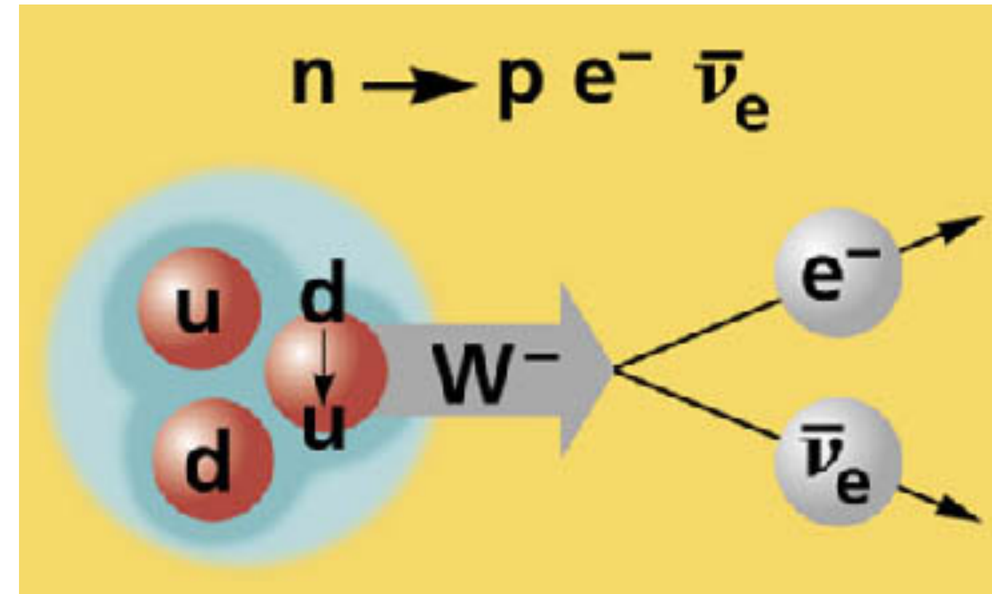


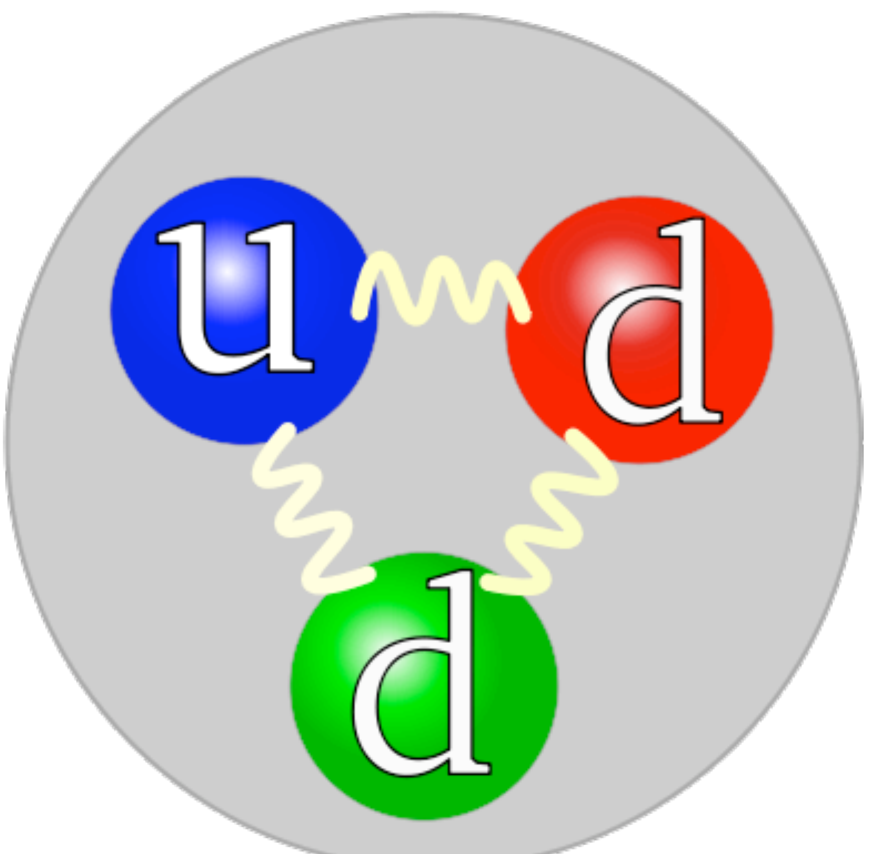




Forces (Bosons)





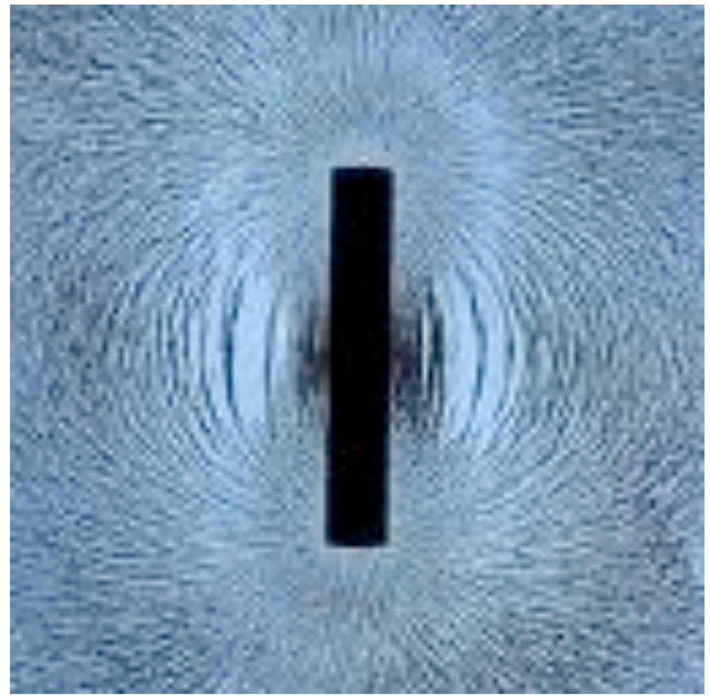


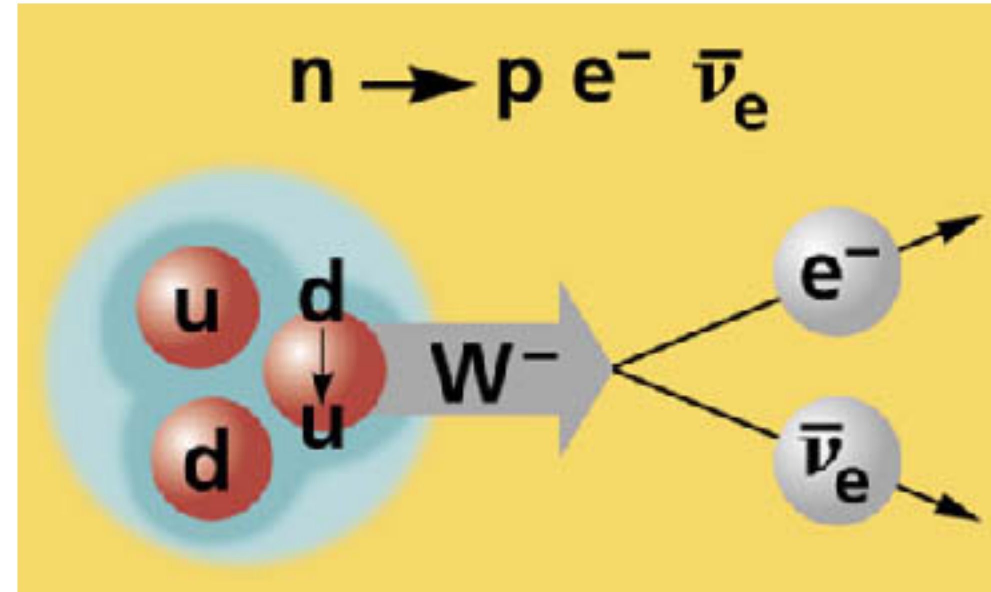
$$W^{\pm}\ Z^0$$

$$\gamma$$

gluon

Forces (Bosons)





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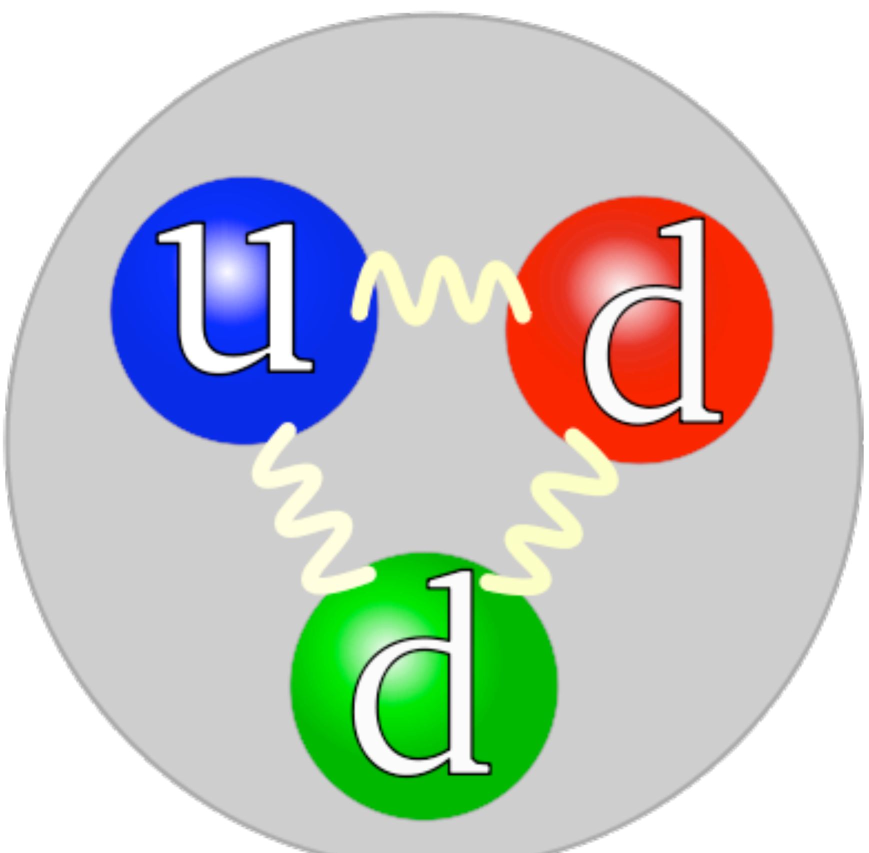

gluon

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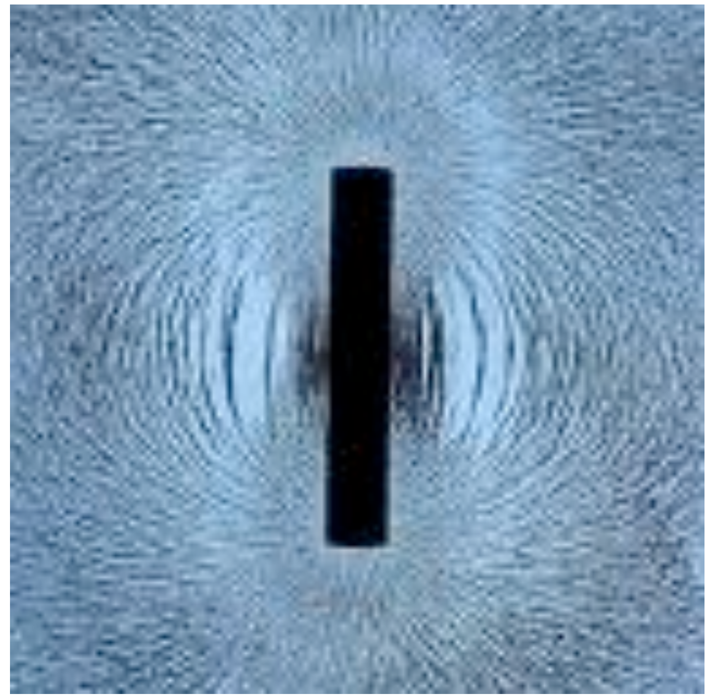

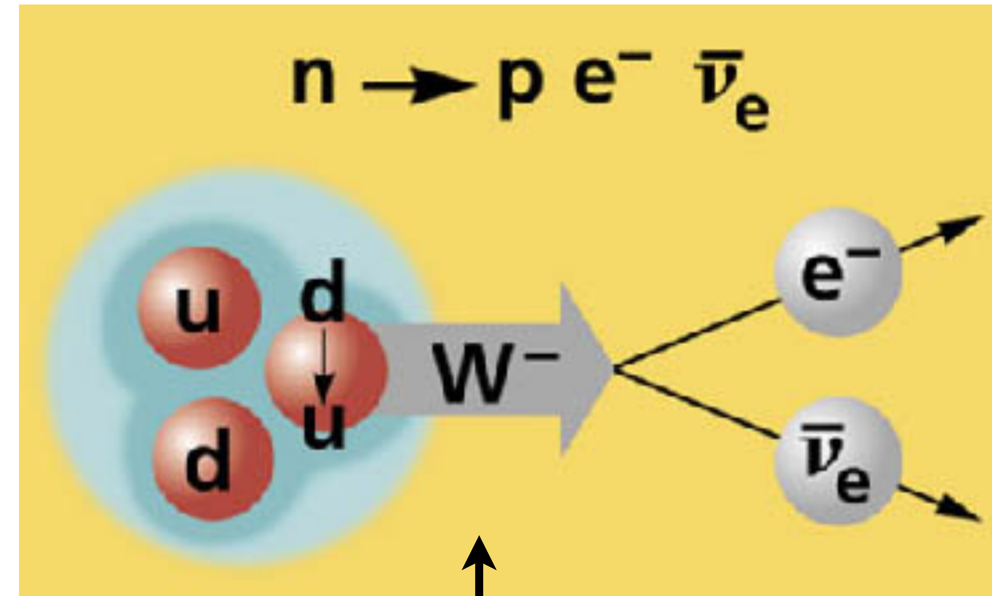

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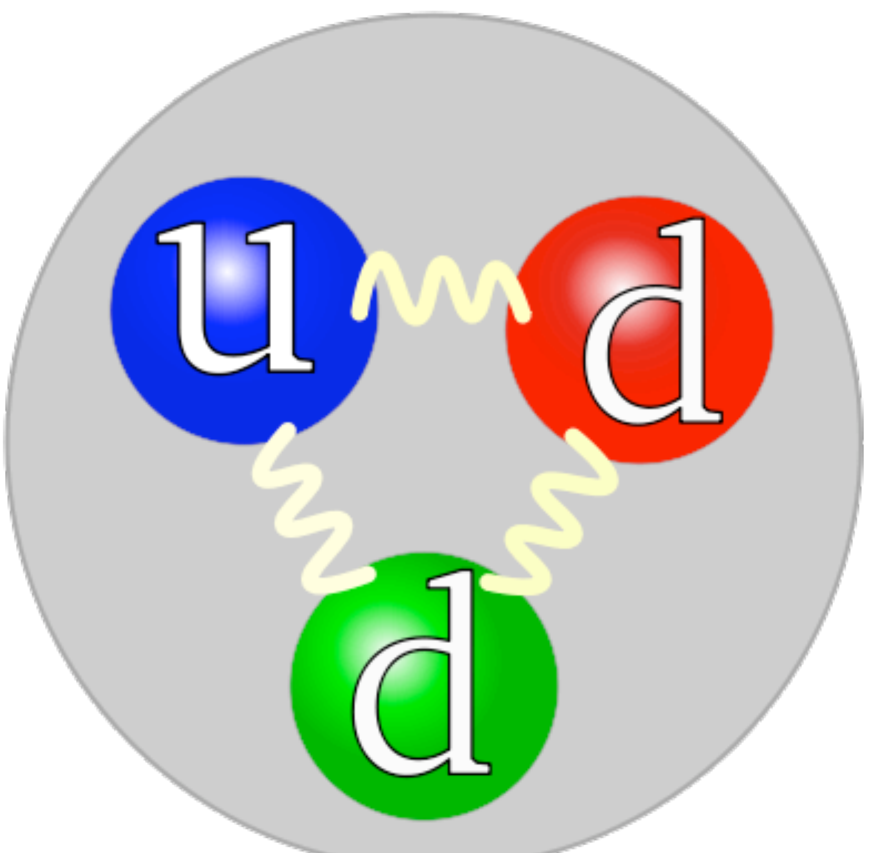

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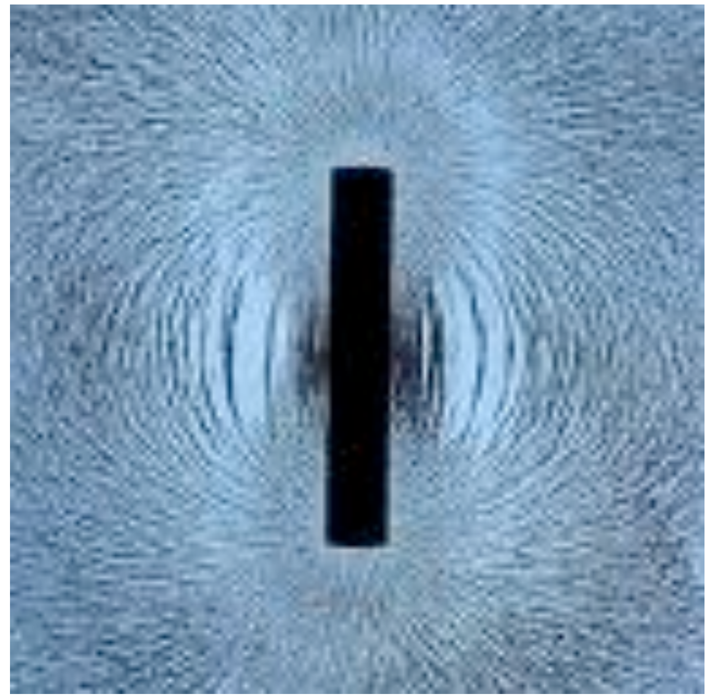
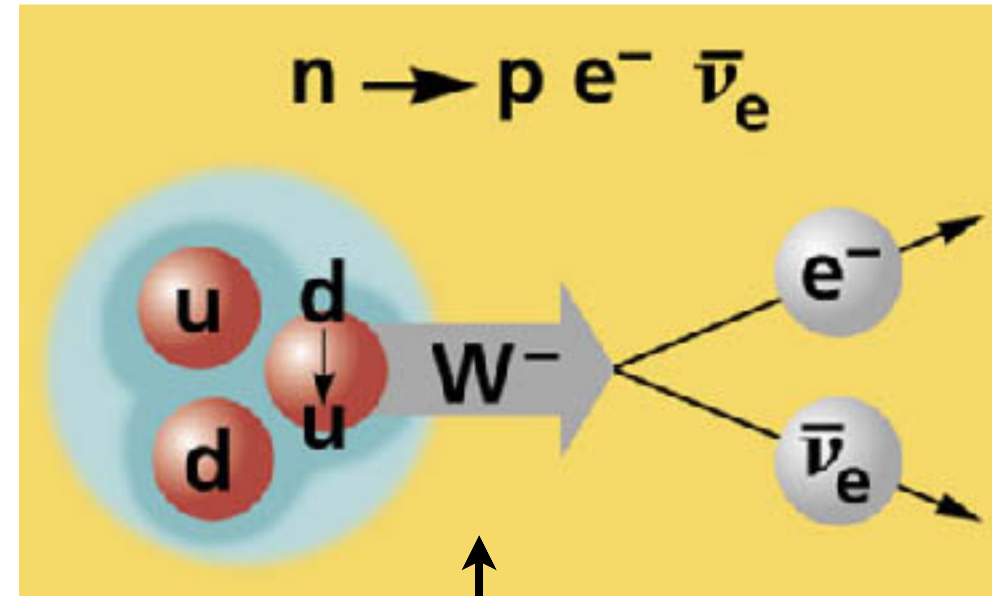
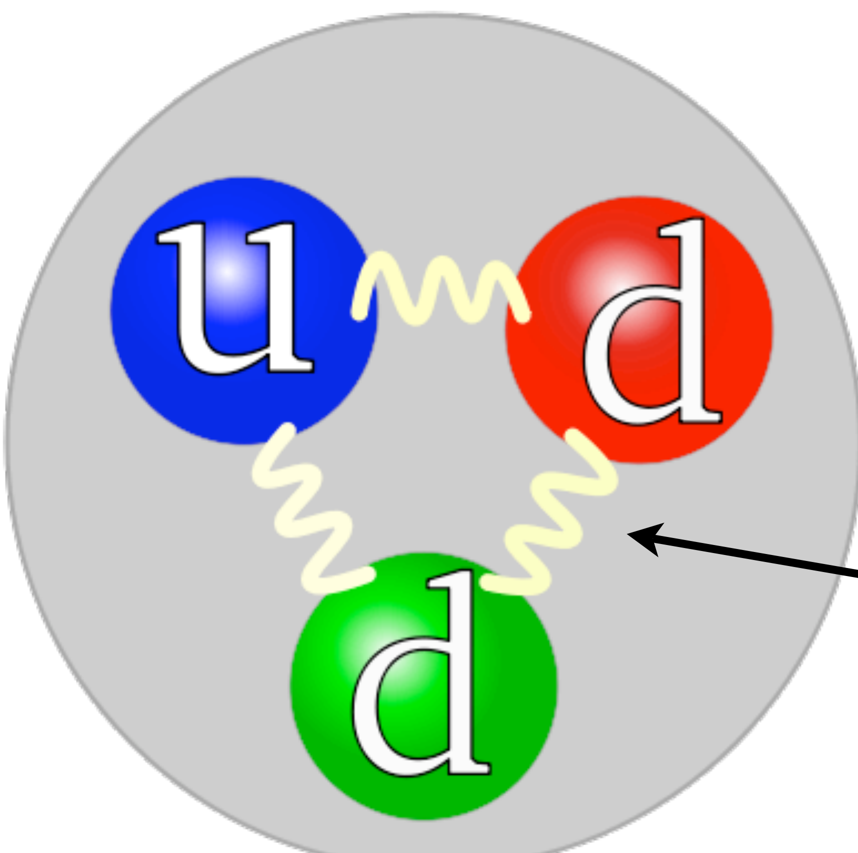




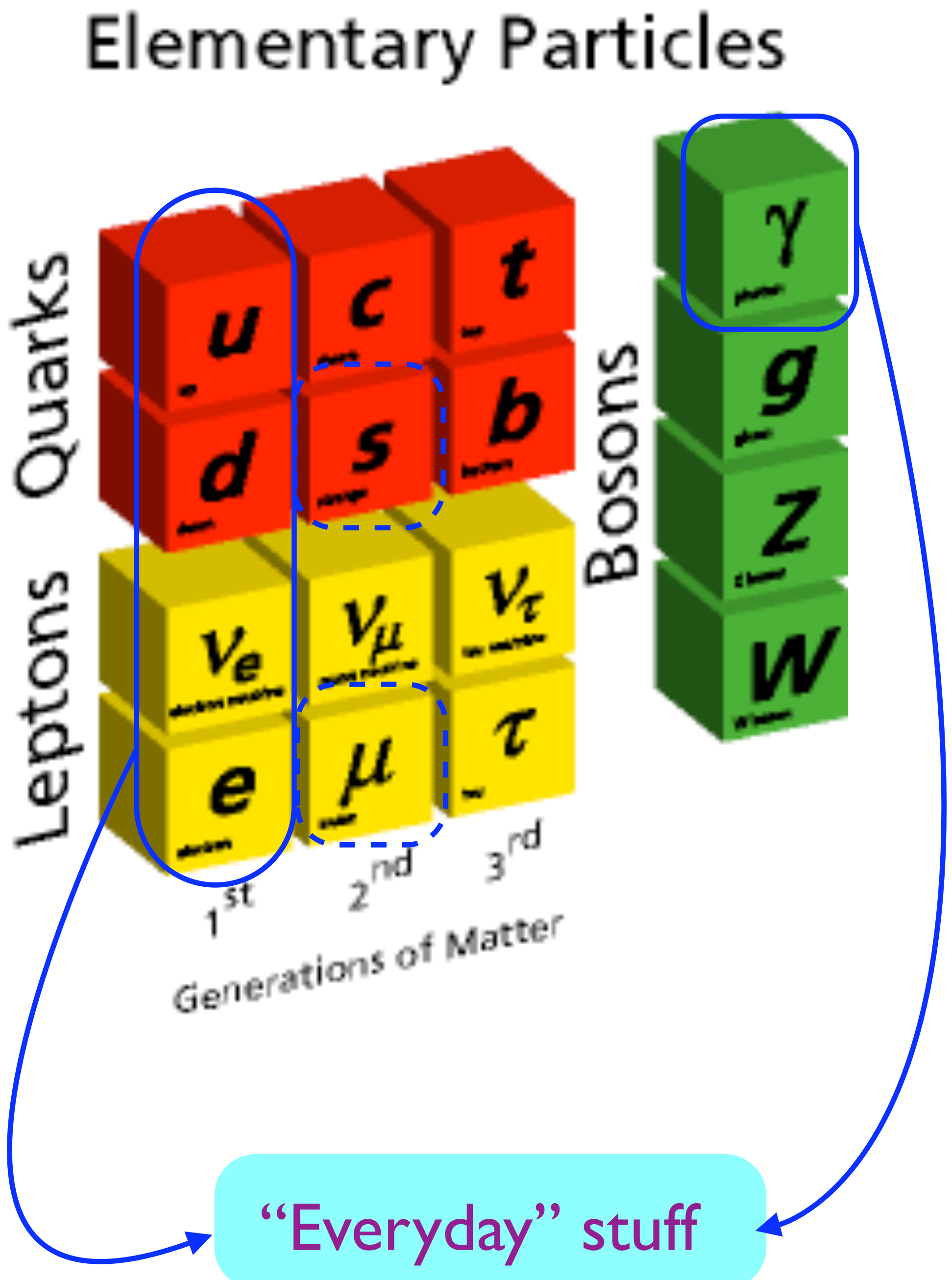
$W^\pm\ Z^0$

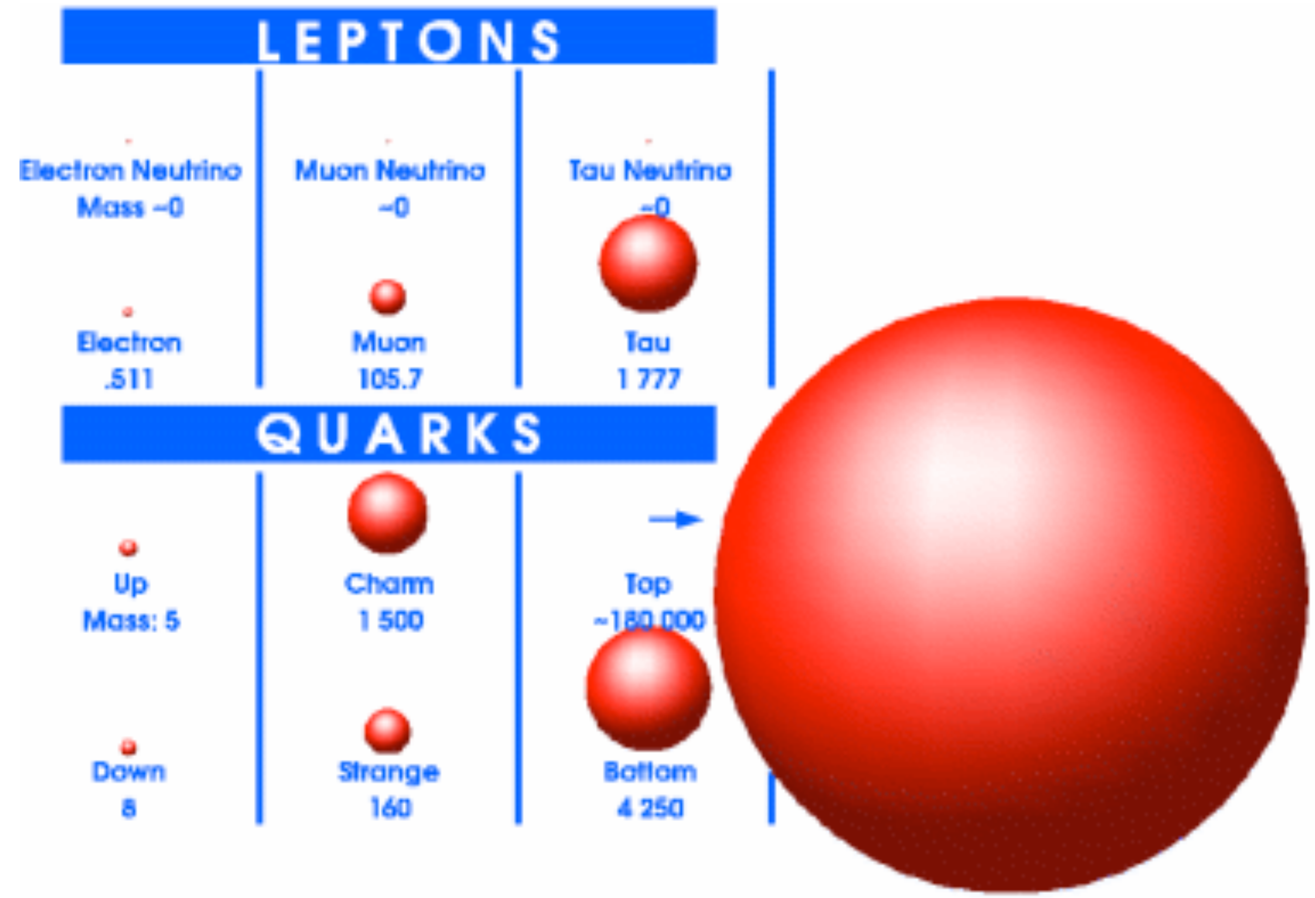
γ



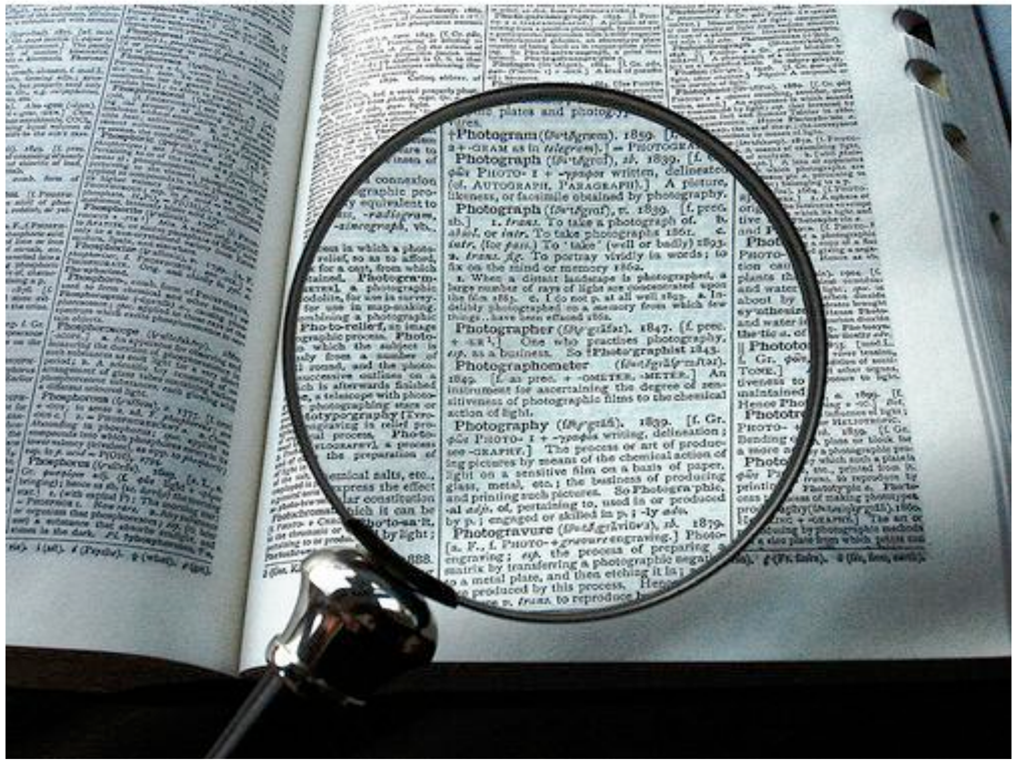
gluon

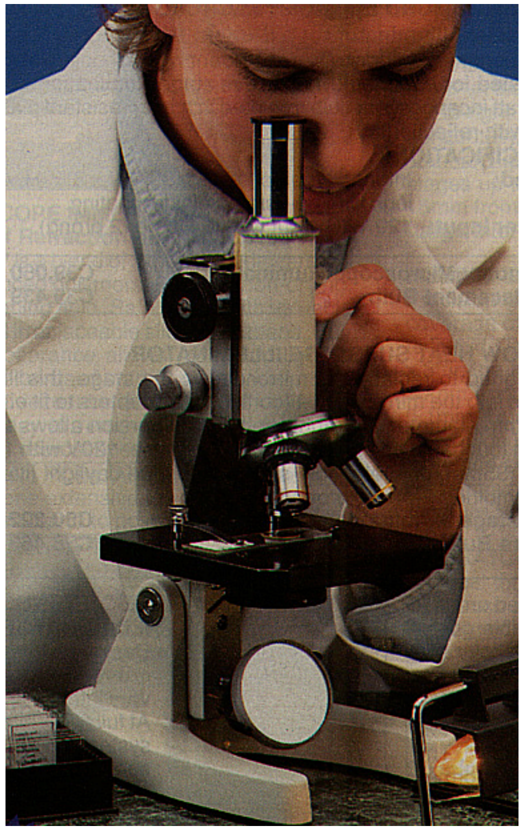
Finally arrive at the Standard Model

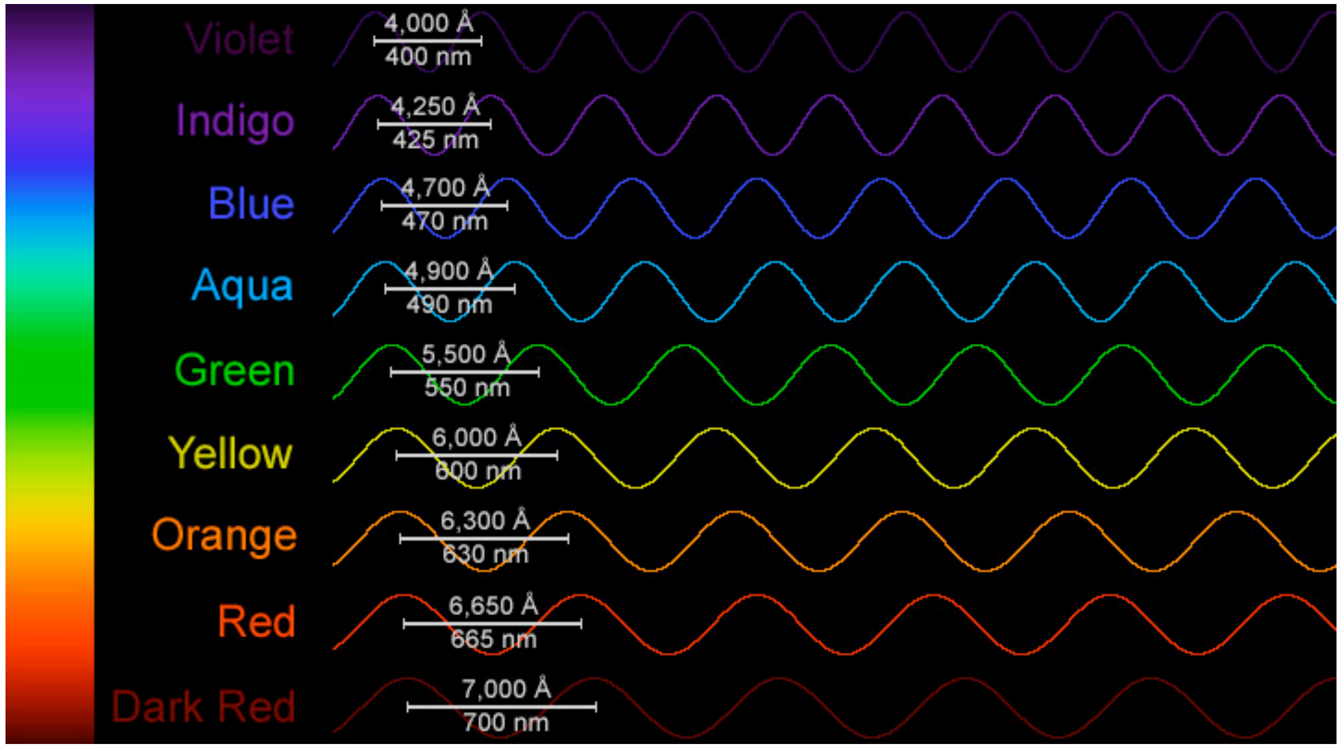


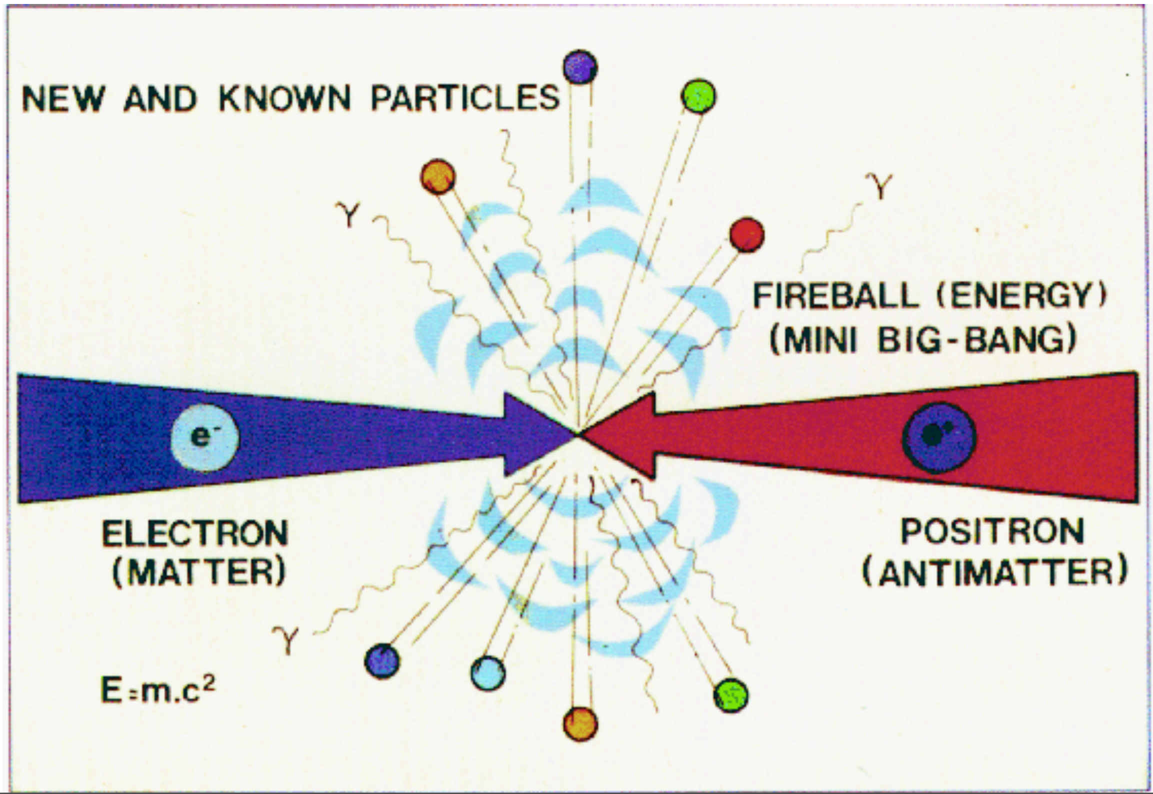


How do we find all these particles?









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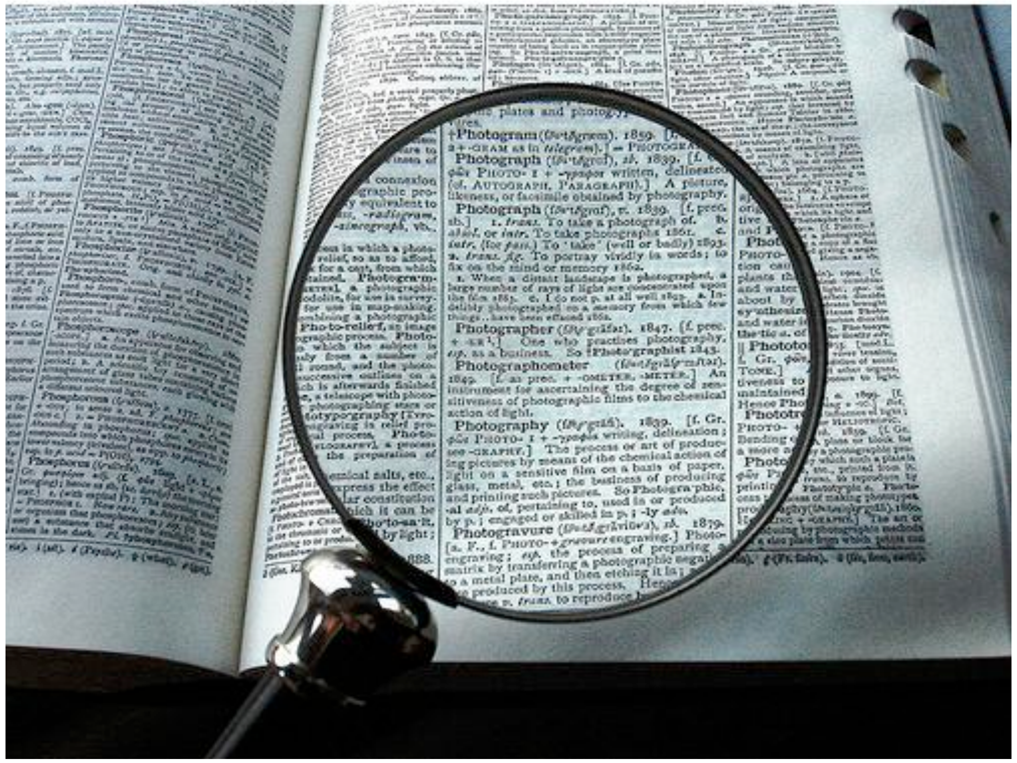
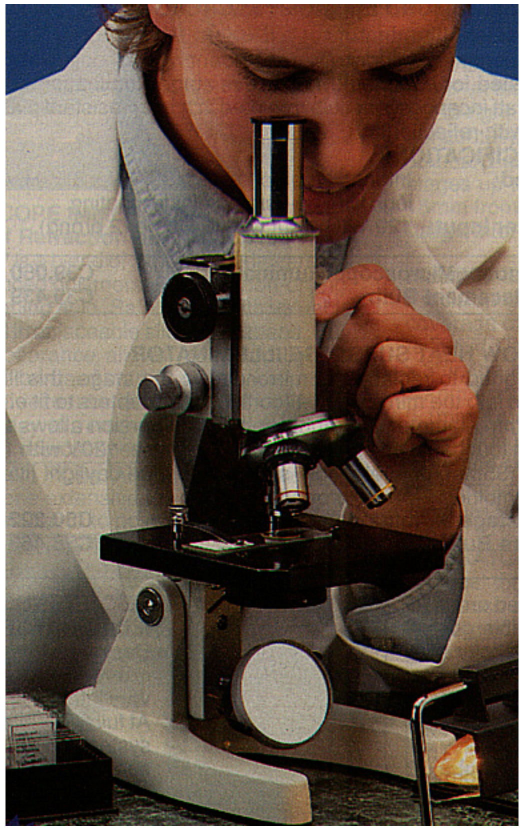
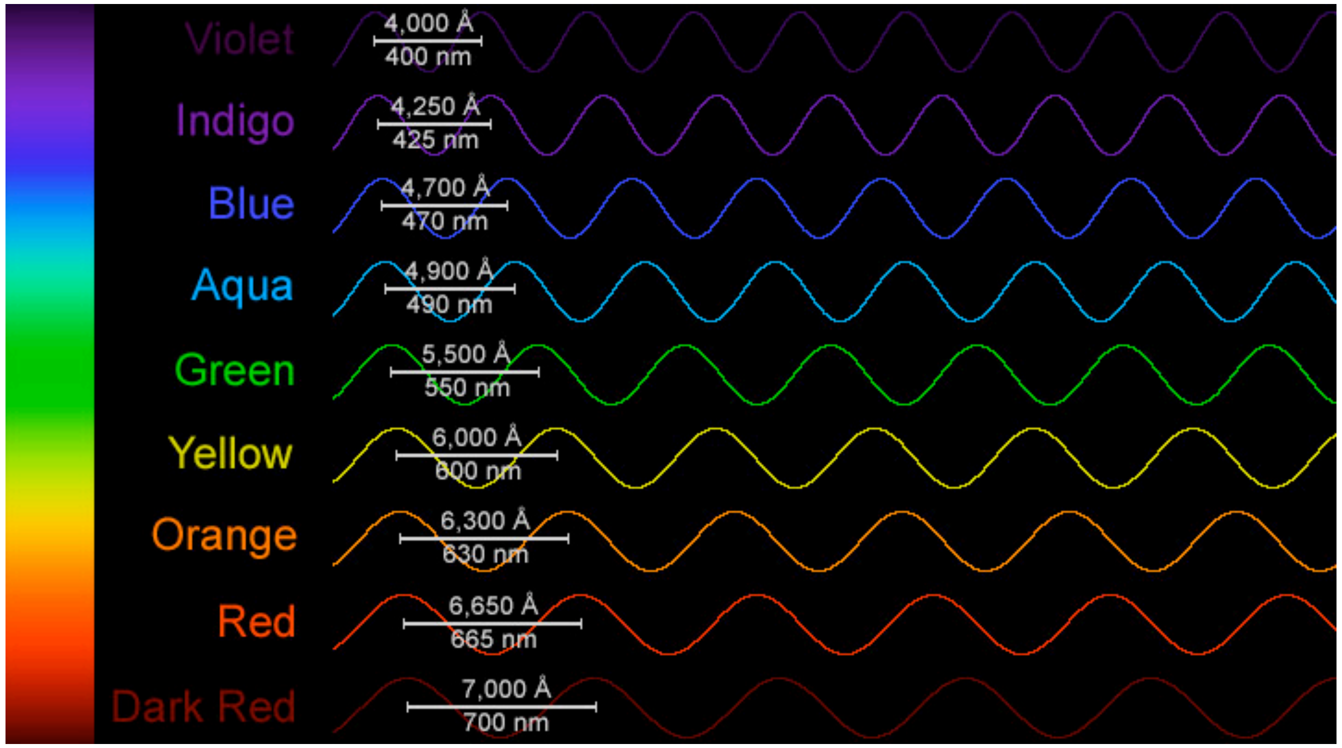
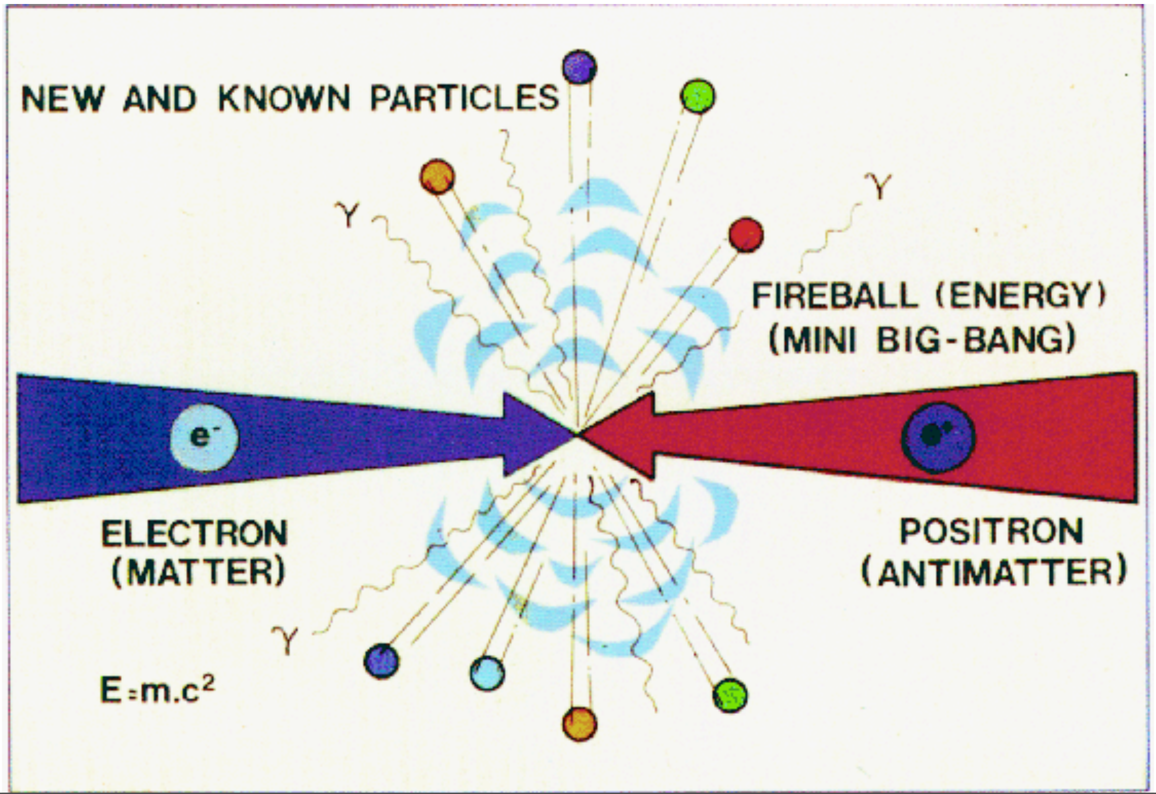


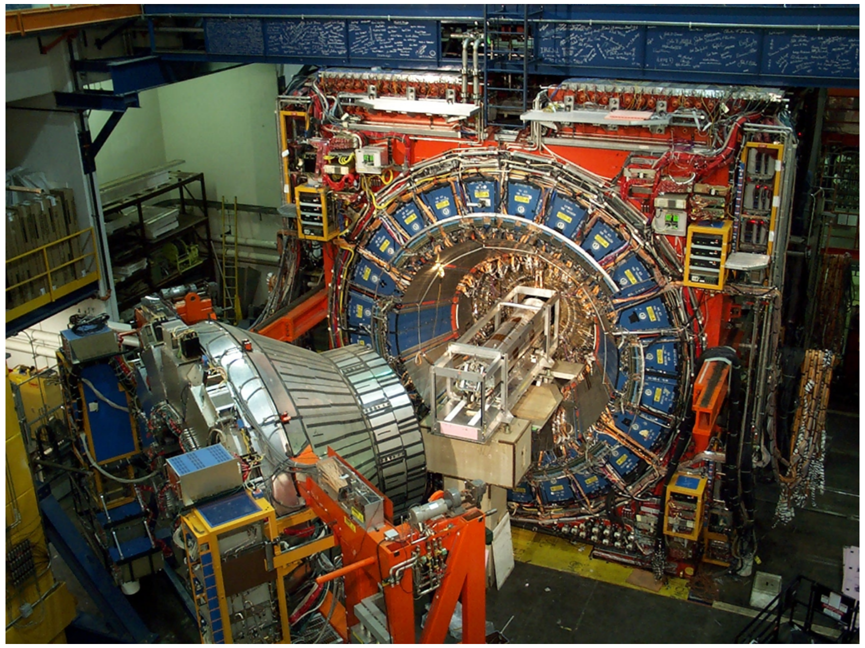
Experimental physicist in the lab







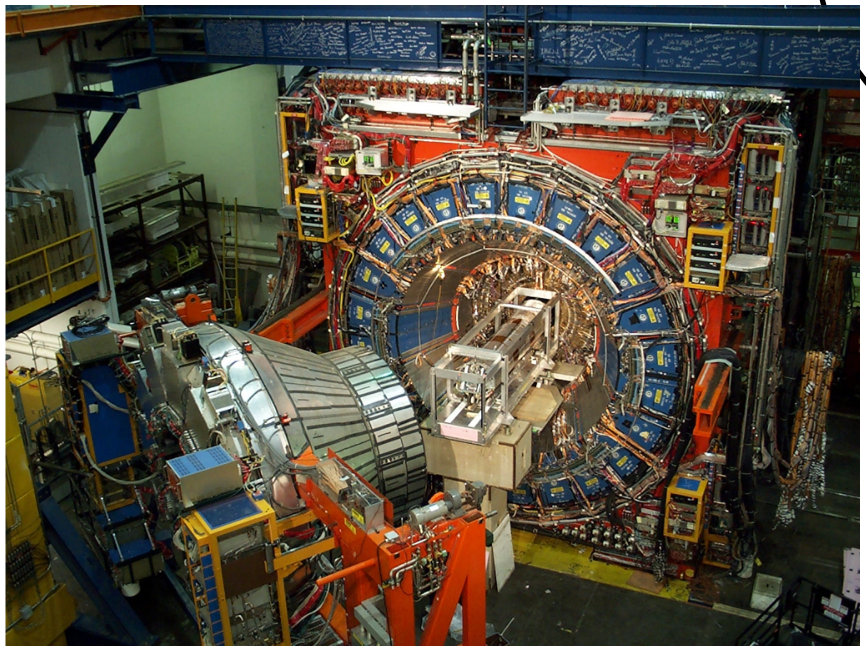
The TeVatron



Discovered the top quark, 1995

The TeVatron

I work here

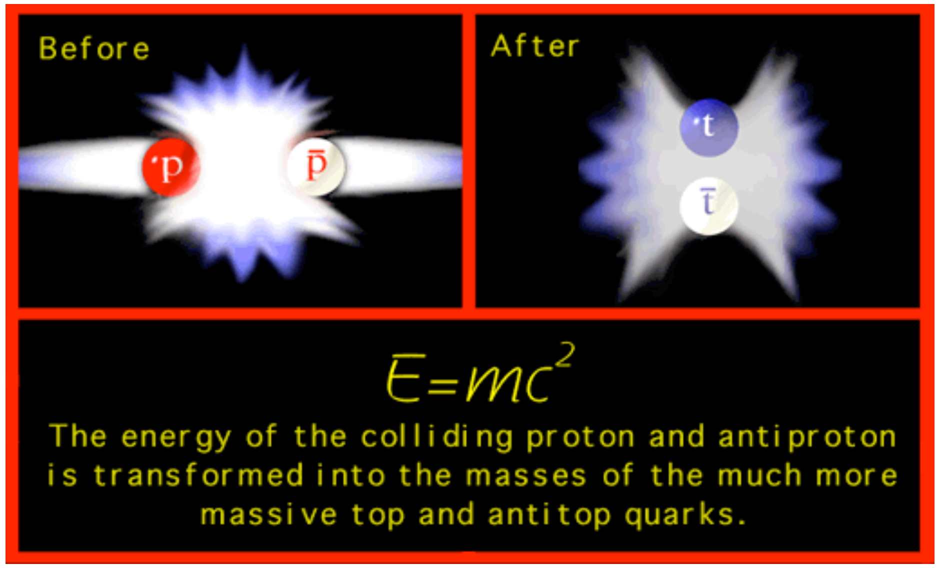


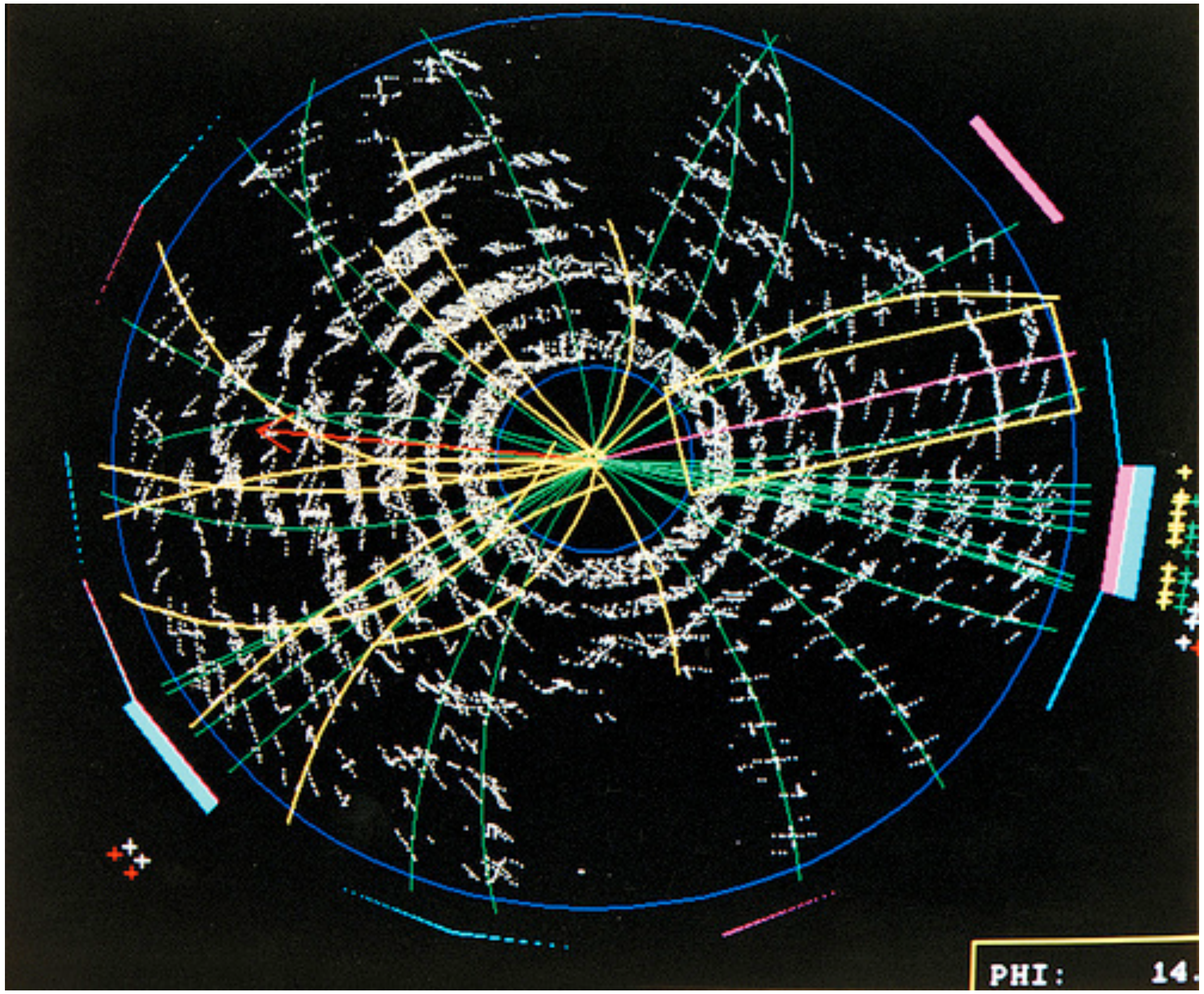
Discovered the top quark, 1995

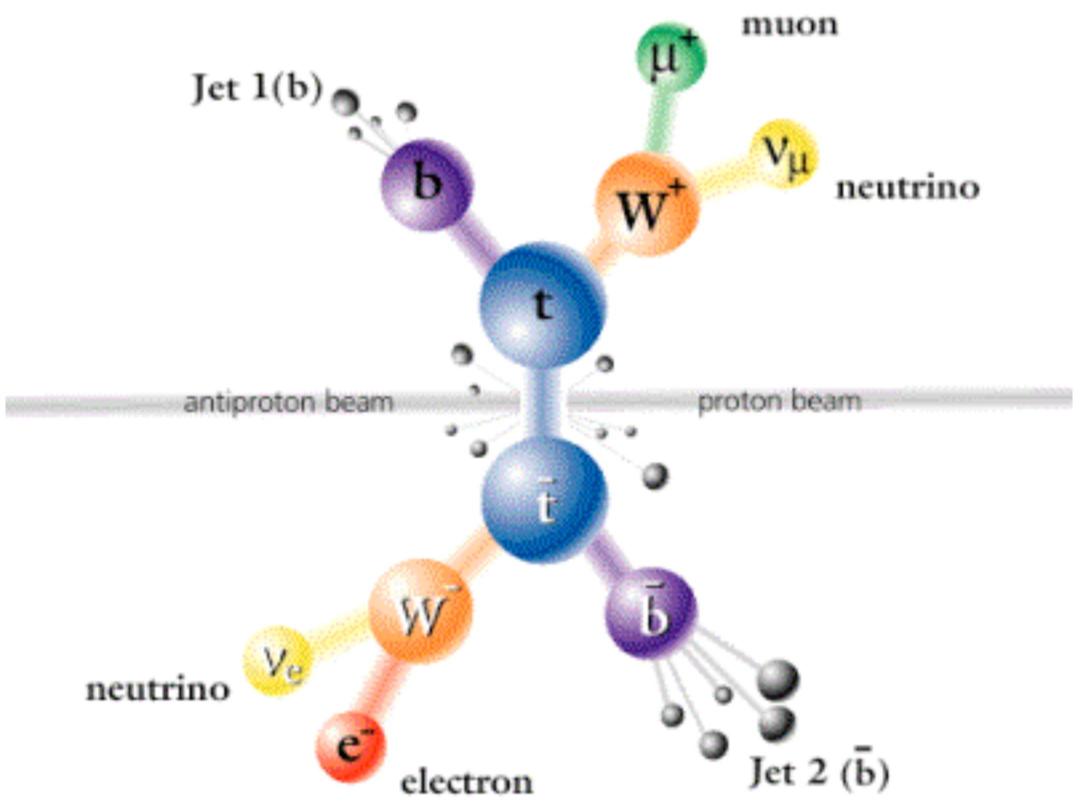
The TeVatron

- 4 miles around
- Collides protons and anti-protons
- World's highest energy machine, ~2 TeV
- Two experiments: D0, CDF
- Superconducting magnets
- Running brilliantly, delivering new results all the time e.g. Ω_b B_s

Top quark (~170 x proton mass!)

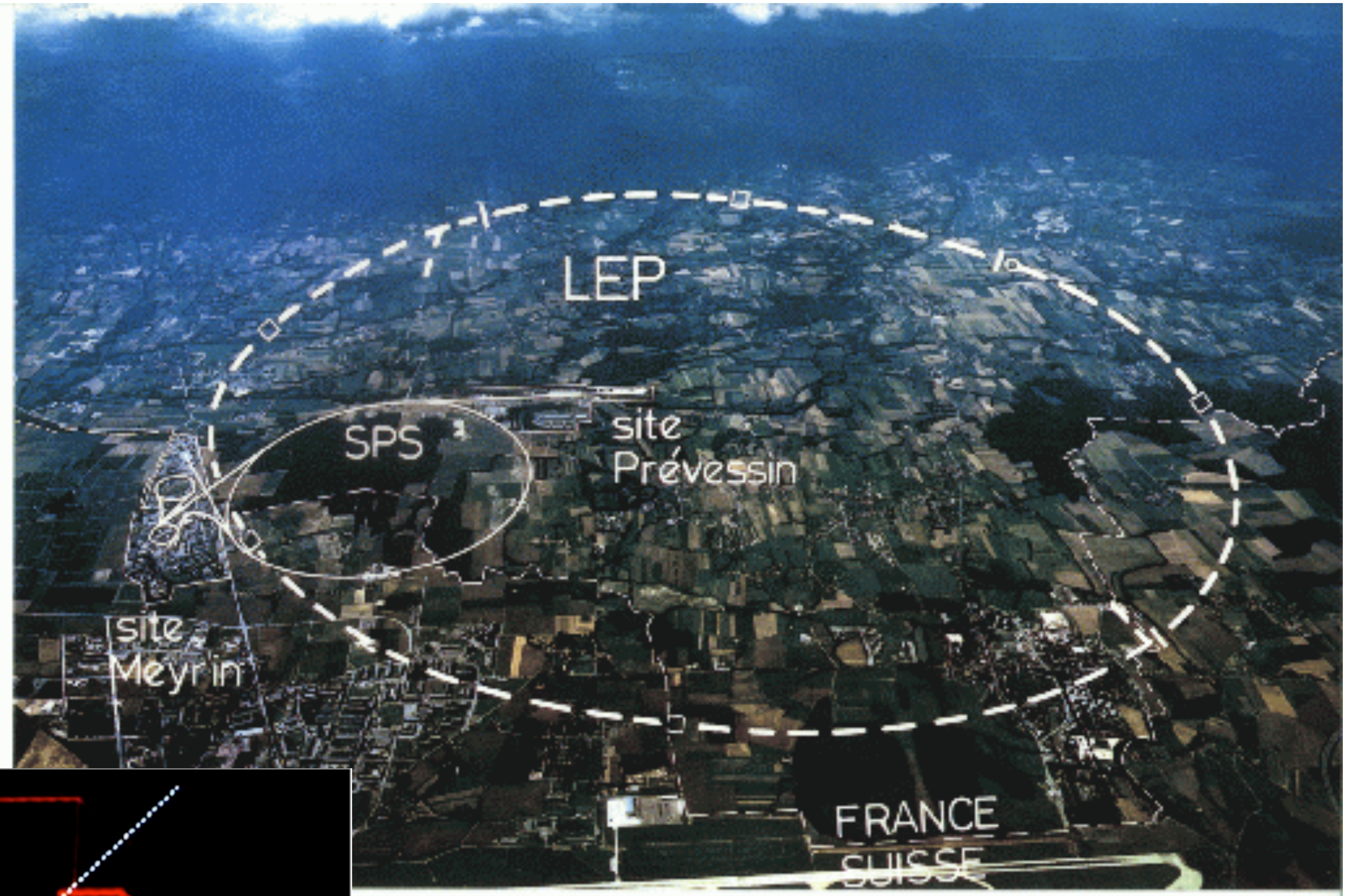


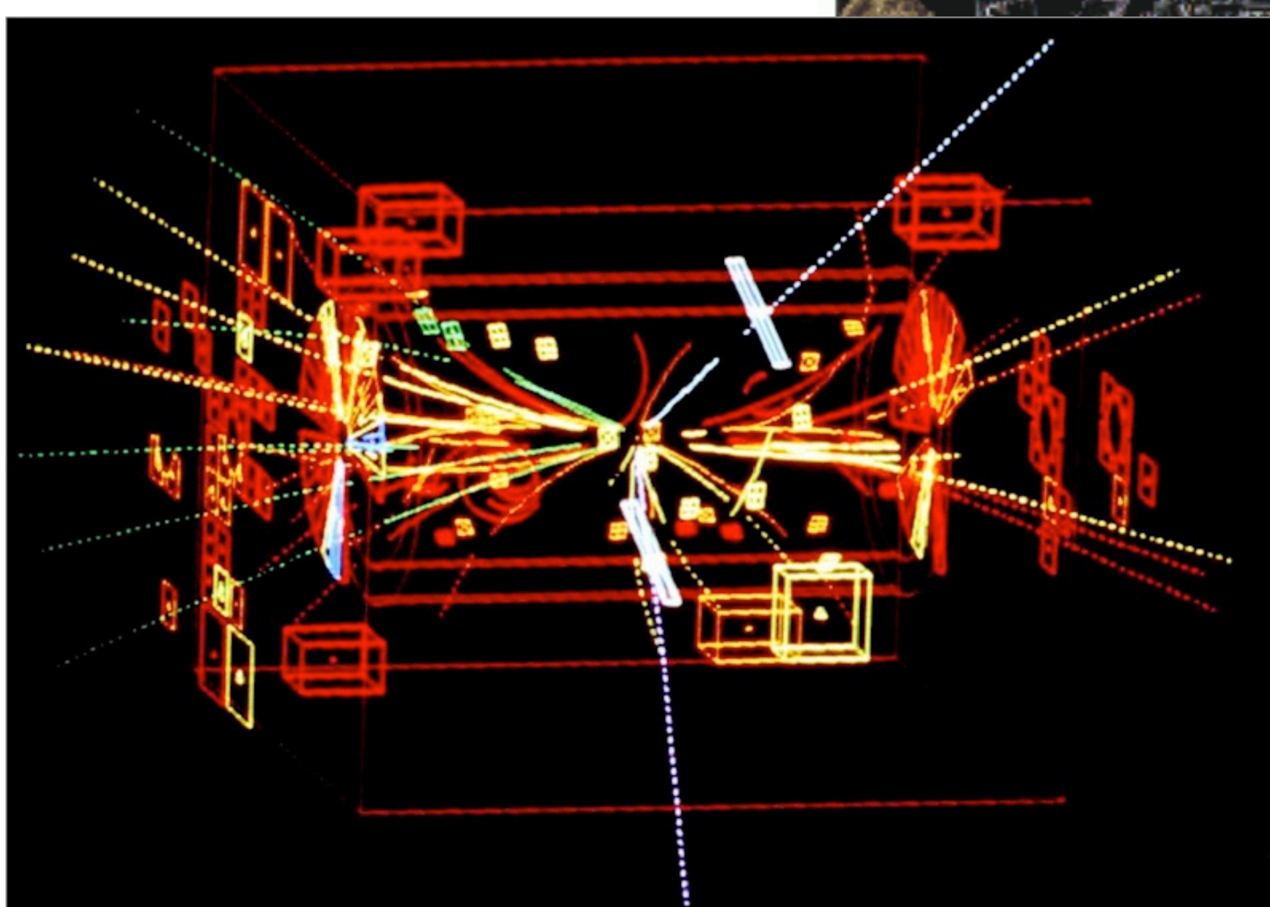




CERN

Discovered the W and Z, 1983





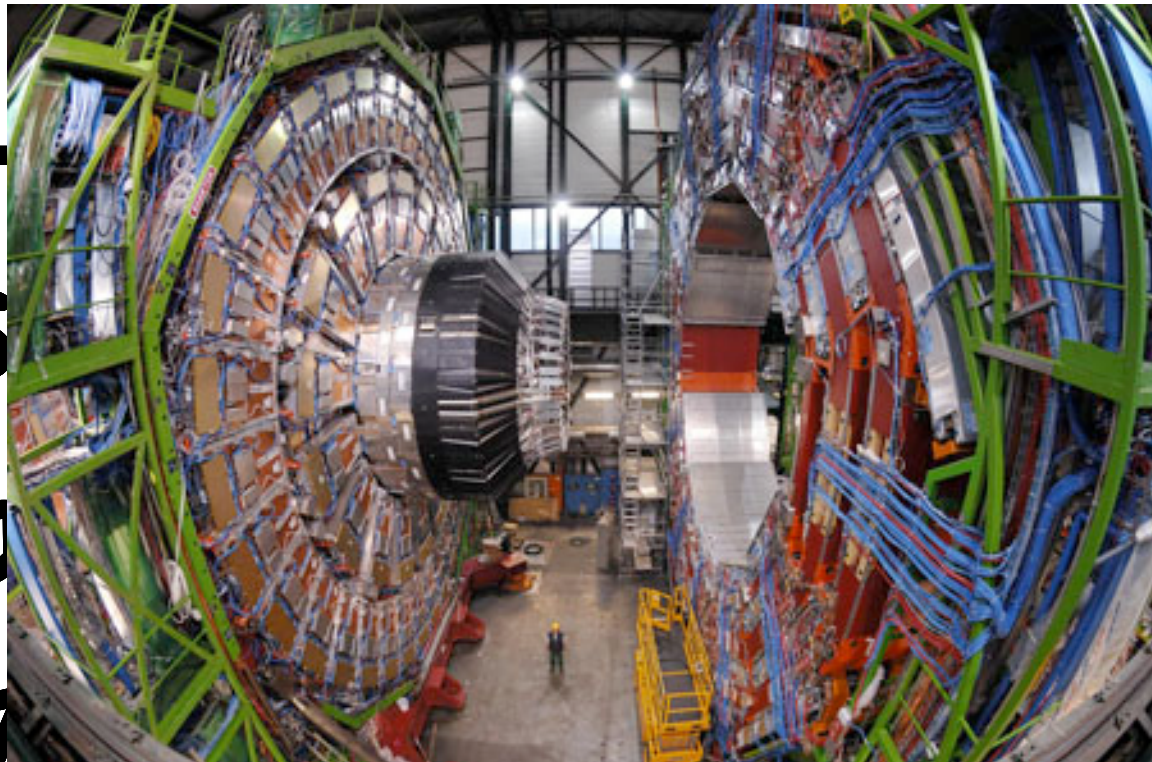
LEP → **LHC**

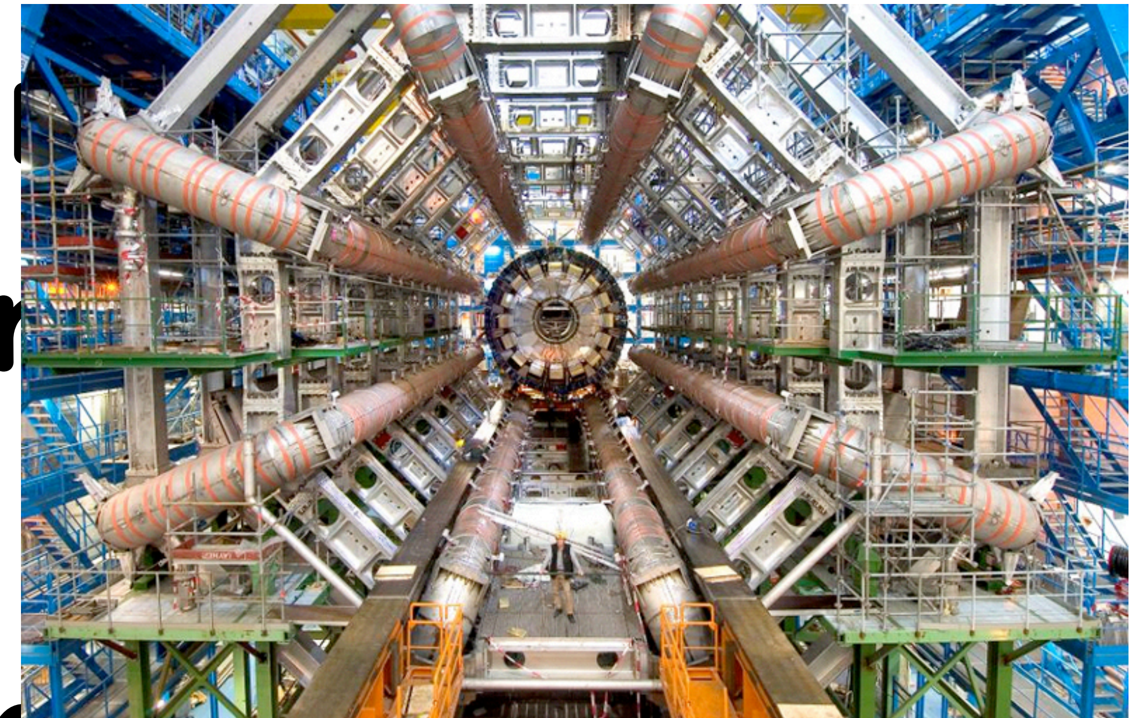
Large Hadron Collider (LHC)

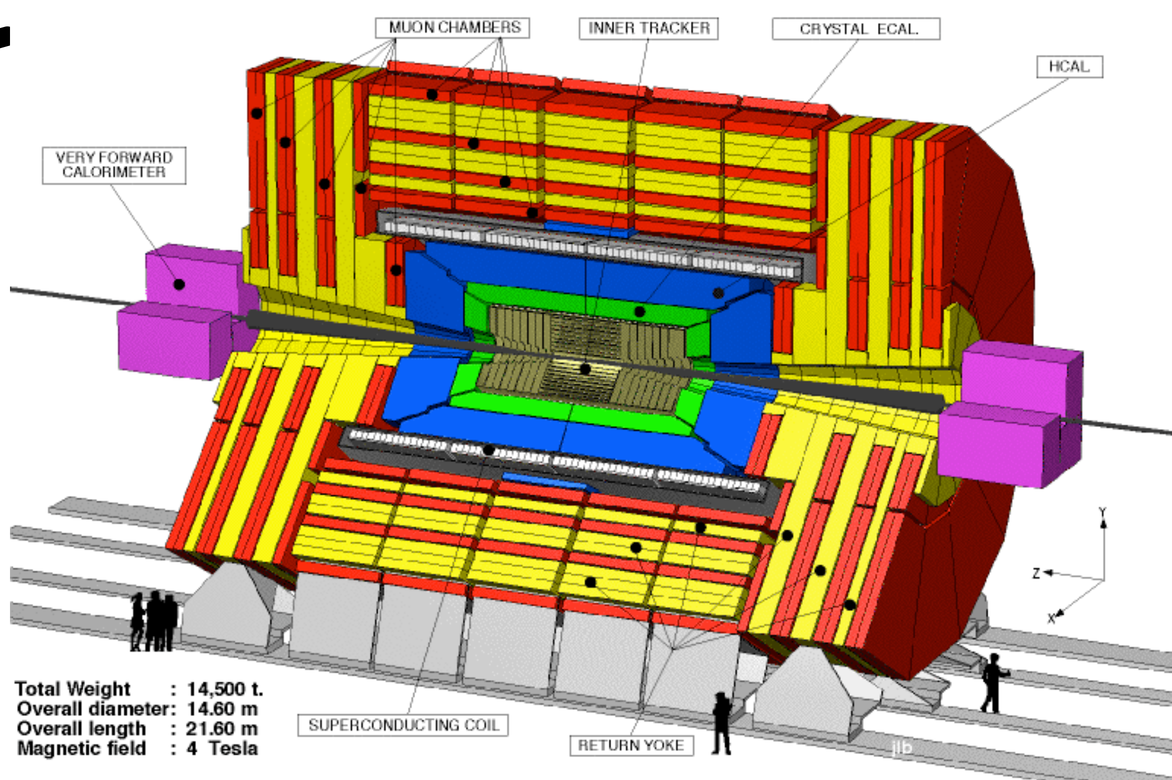
Largest, most complicated science experiment ever attempted.

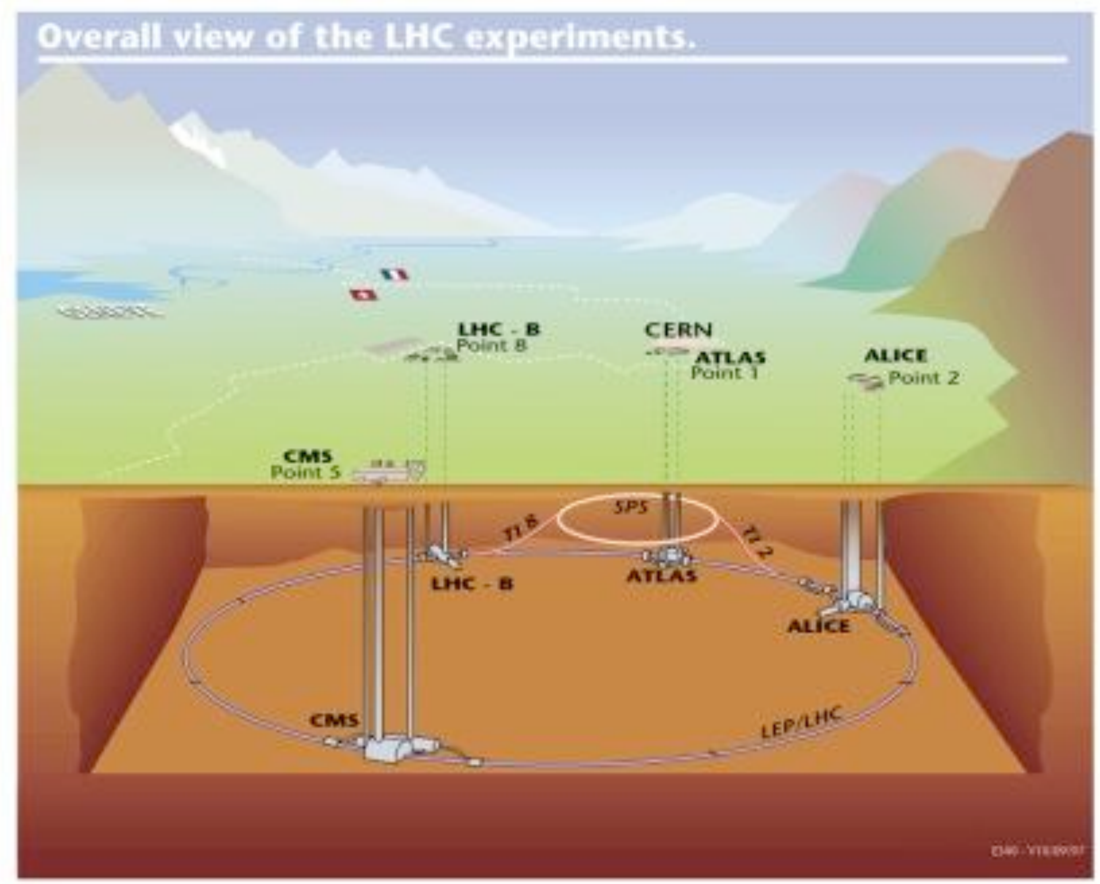
7 x the energy of the Tevatron (14 TeV)

Large Hadron Collider (LHC)









Large Hadron Collider (LHC)

- 17 miles around, cooled to 1.9K
- 120 ton of liquid He (1% annual production)
- Collides protons and protons
- Very high energy (14 TeV)
- Equivalent to 737 at landing (60kg TNT)
- 40M collisions/sec -> record 200/sec =2MB/s

30-40 countries

3000-4000 people

LHC pyjama party: 1am Sep 10, 2008

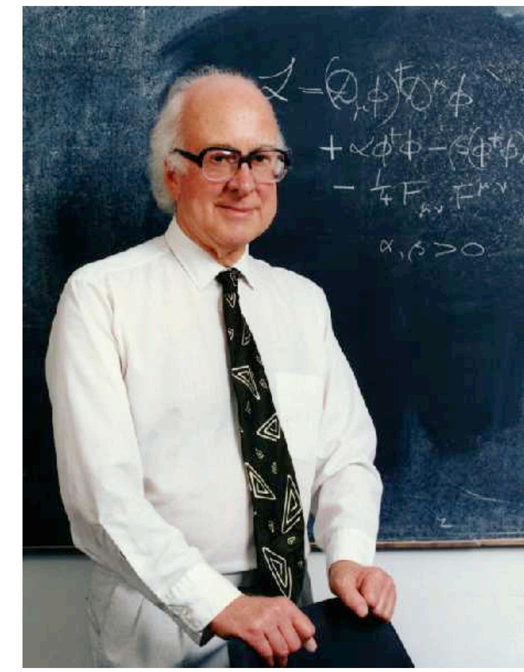
LHC will start-up again Oct, 09

The BIG questions

- What gives the particles their mass?
- Why 3 generations?
- Why is gravity so weak?
- Why 3 forces, are they really the same?
- Why do they have the masses they have?
- Why is there matter and no antimatter?
- What makes up the Universe?
- ....?

The hunt for the Higgs boson

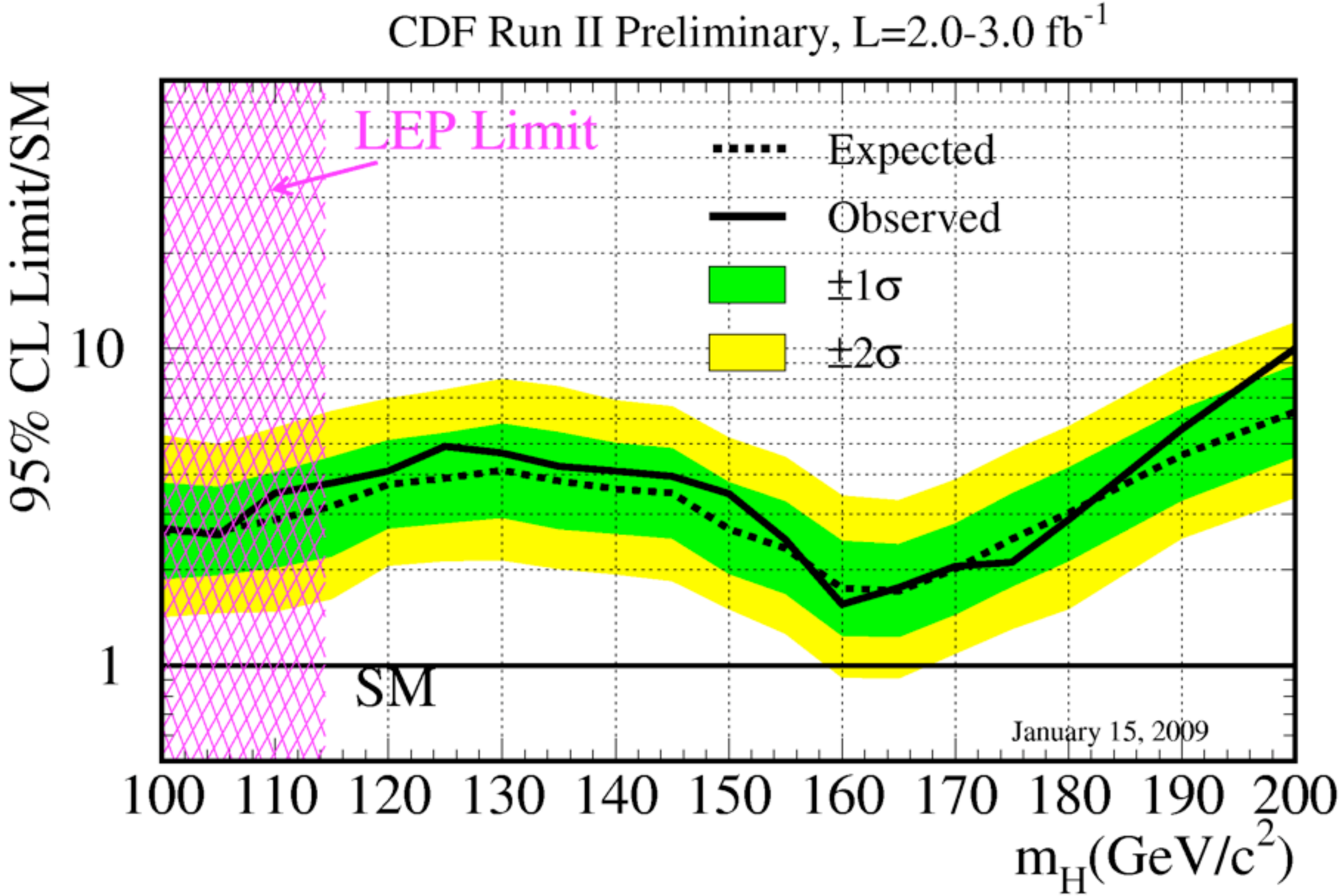
Higgs is responsible for mass of all the standard model particles



Still not seen

Higgs cocktail party analogy:

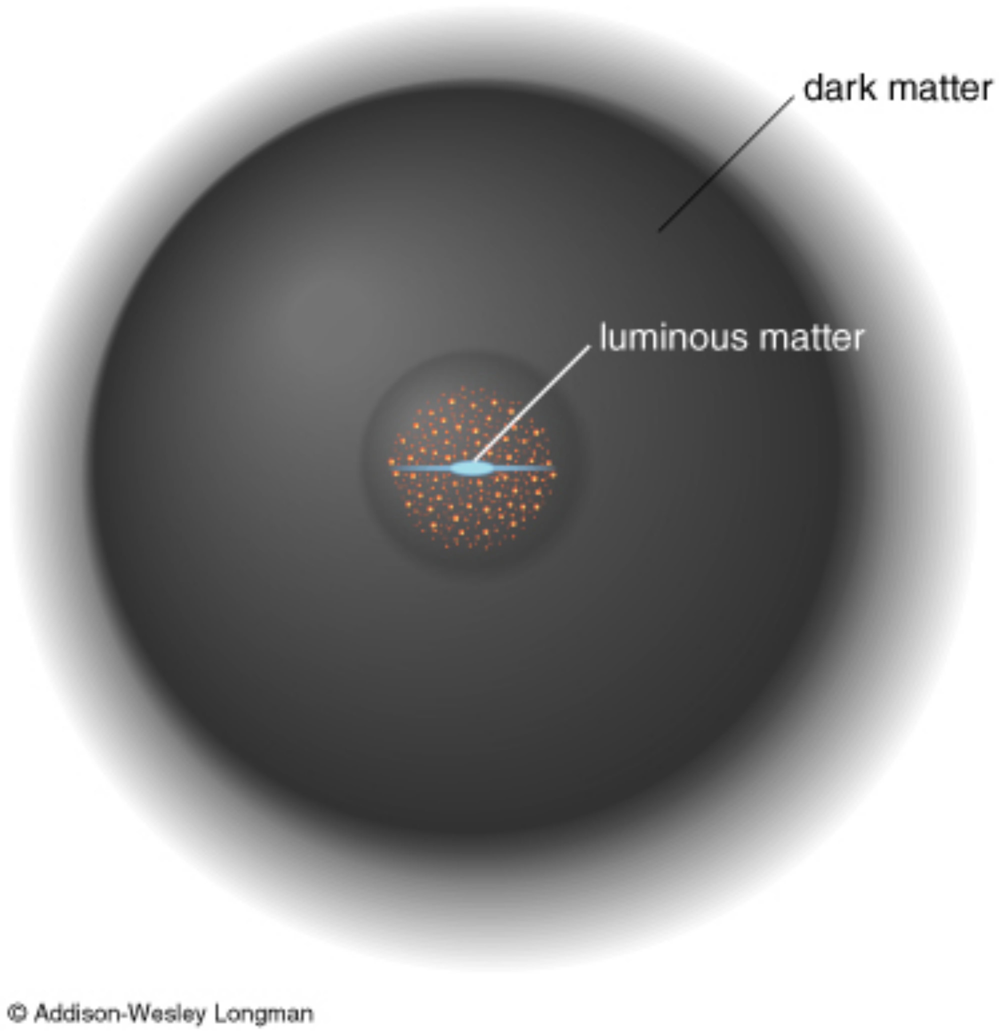
The TeVatron is getting close....

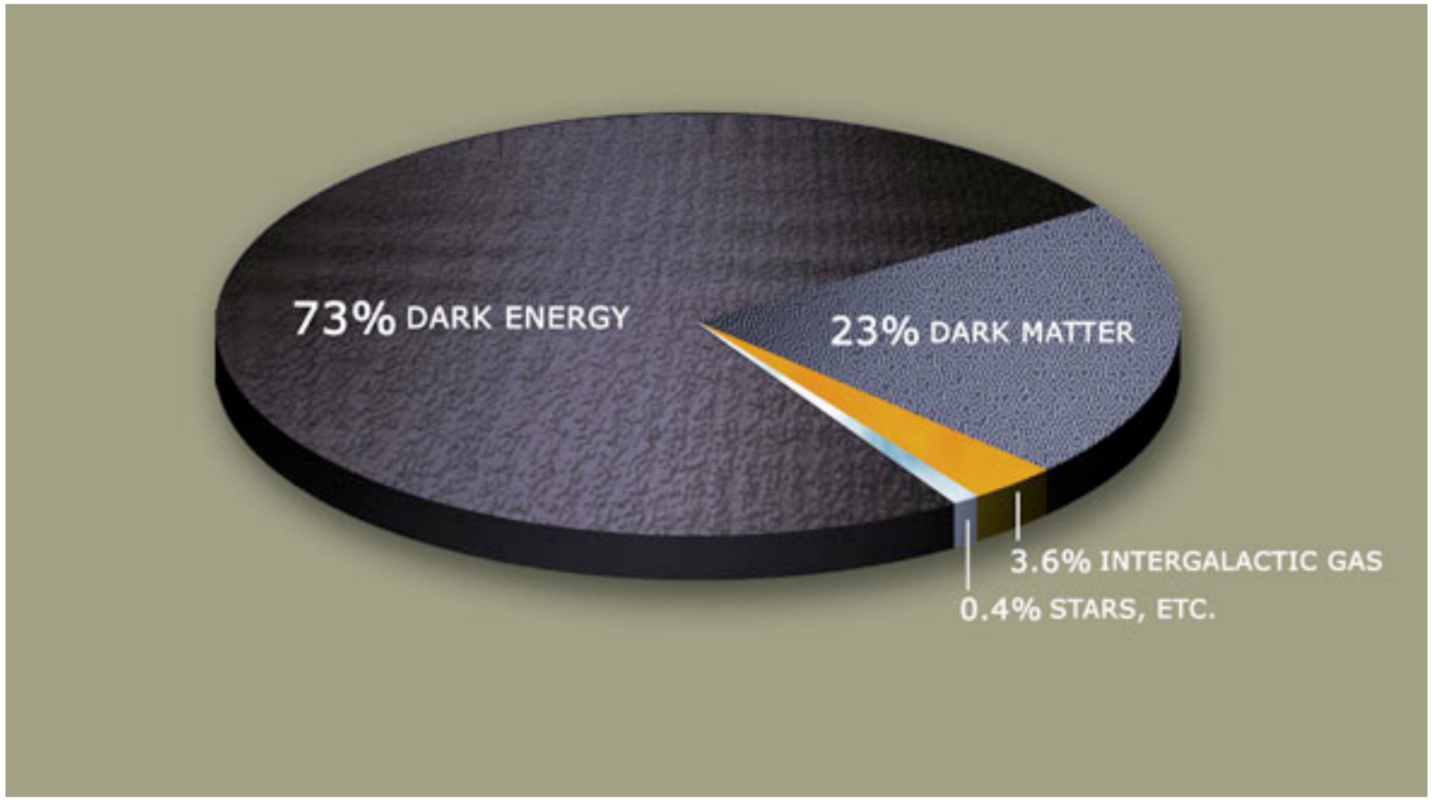


Beyond the Standard Model

The SM (with Higgs) is not complete

Observations of galaxies tell us





Beyond the Standard Model

The SM (with Higgs) is **not** complete

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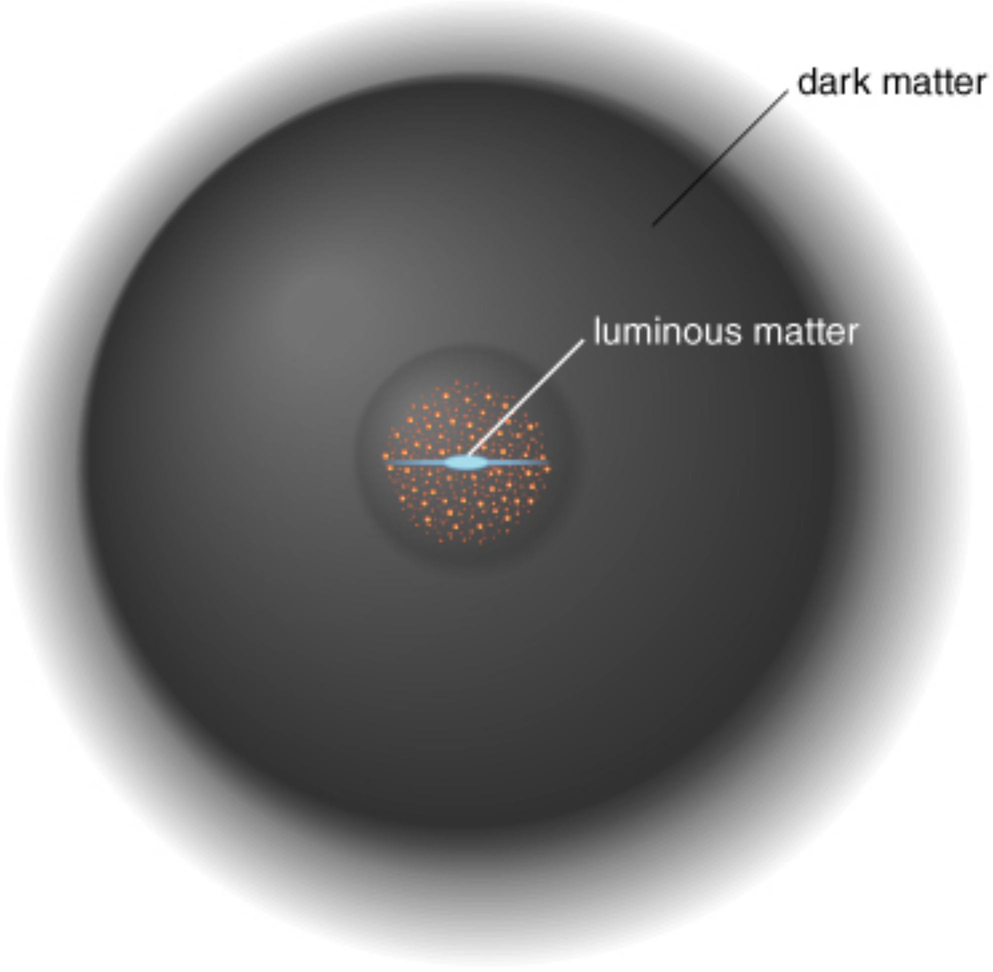

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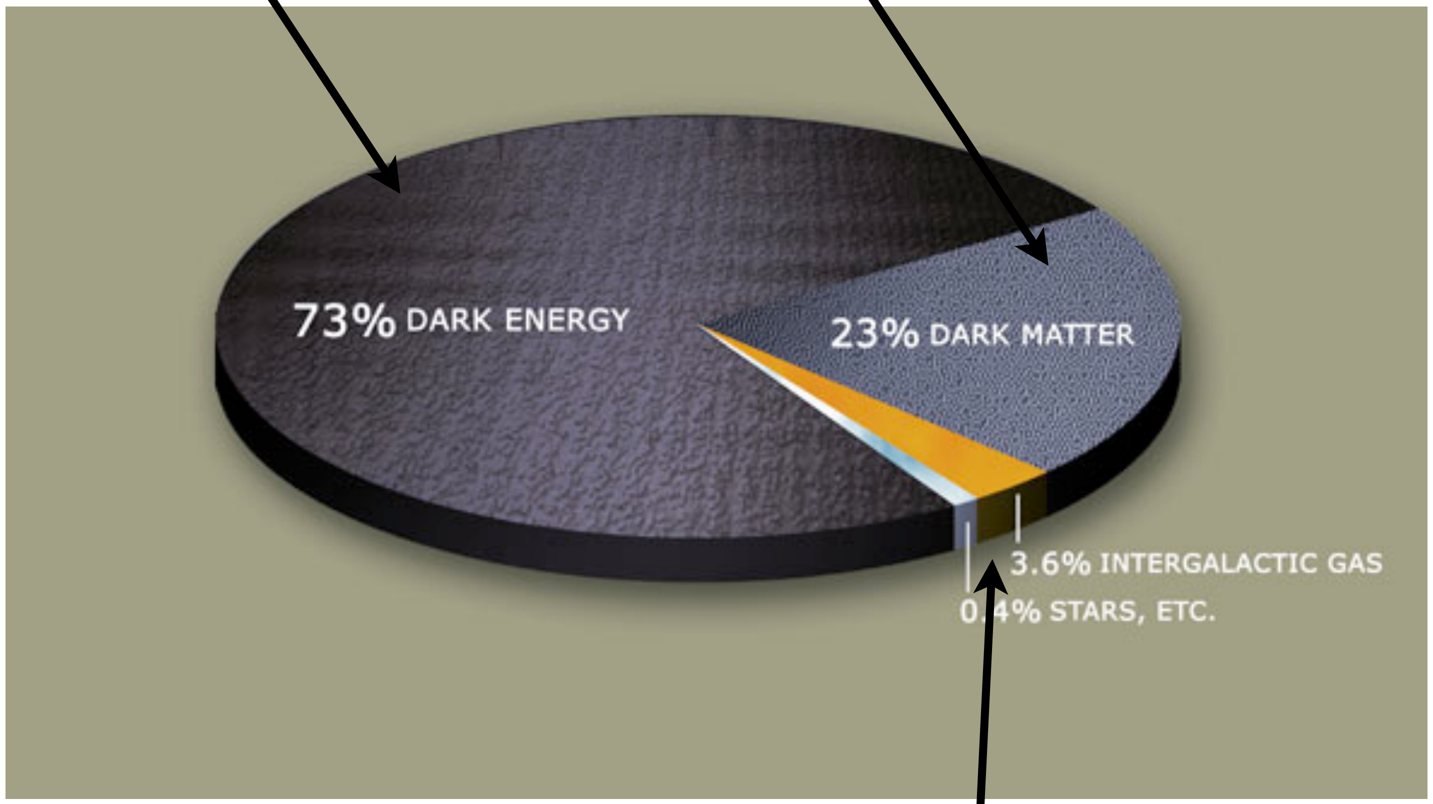

Standard Model

Beyond the Standard Model

The SM (with Higgs) is not complete

Observations of
gal

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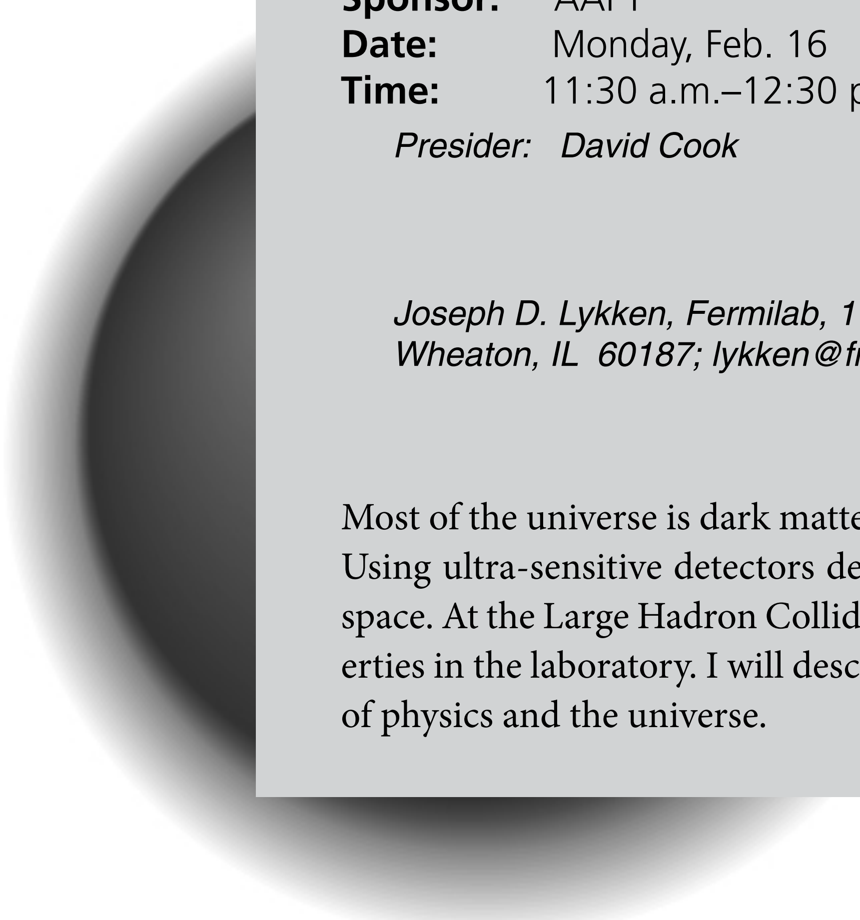


Session NA: AAPT Plenary – Dark Matter in the Laboratory

Location: H-Grand Ballroom EF
Sponsor: AAPT
Date: Monday, Feb. 16
Time: 11:30 a.m.–12:30 p.m.

Presider: David Cook

Joseph D. Lykken, Fermilab, 1707 E. Thomas Rd.,
Wheaton, IL 60187; lykken@fnal.gov

Joseph D. Lykken

Most of the universe is dark matter, whose composition is entirely unknown and may involve new forces or principles of nature. Using ultra-sensitive detectors deep underground, physicists are attempting to detect dark matter particles streaming in from space. At the Large Hadron Collider, physicists hope to manufacture large numbers of dark matter particles and study their properties in the laboratory. I will describe these efforts and how impending discoveries may change our fundamental understanding of physics and the universe.

Standard Model

Beyond the Standard Model

Other reasons to believe in new physics

e.g.

- Extra dimensions of space
- Second copy of SM - supersymmetry

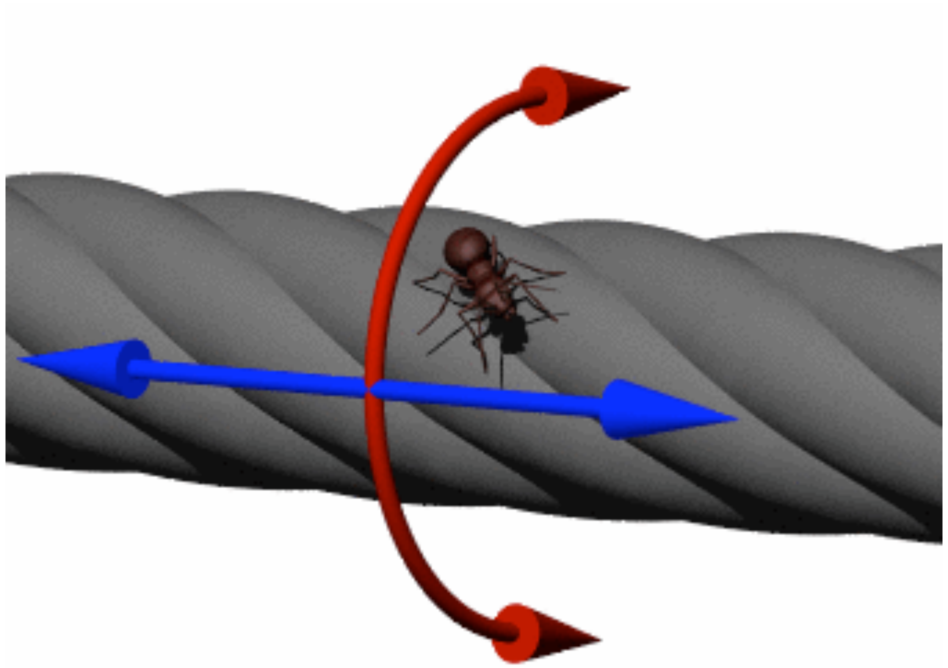
Both predict new particles and Dark Matter possibilities

Colliders and Cosmos

probing the same physics!

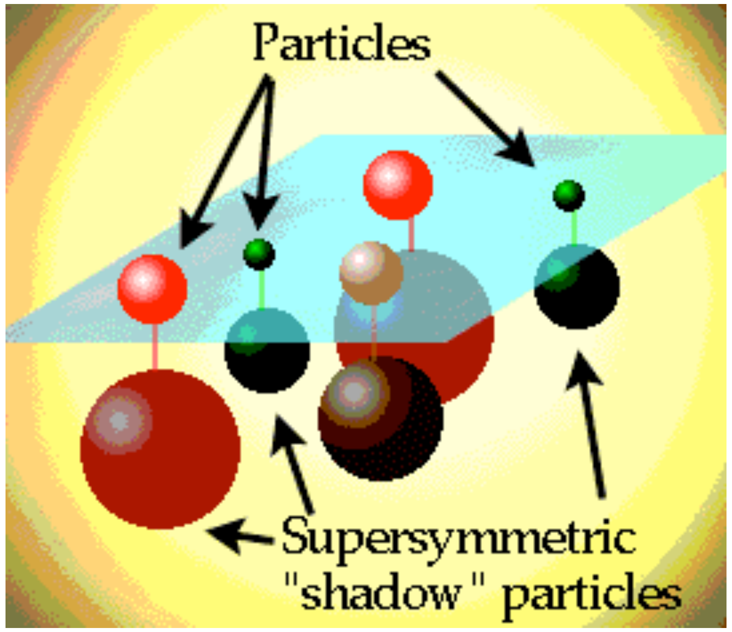
Extra dimensions of space, curled up very small

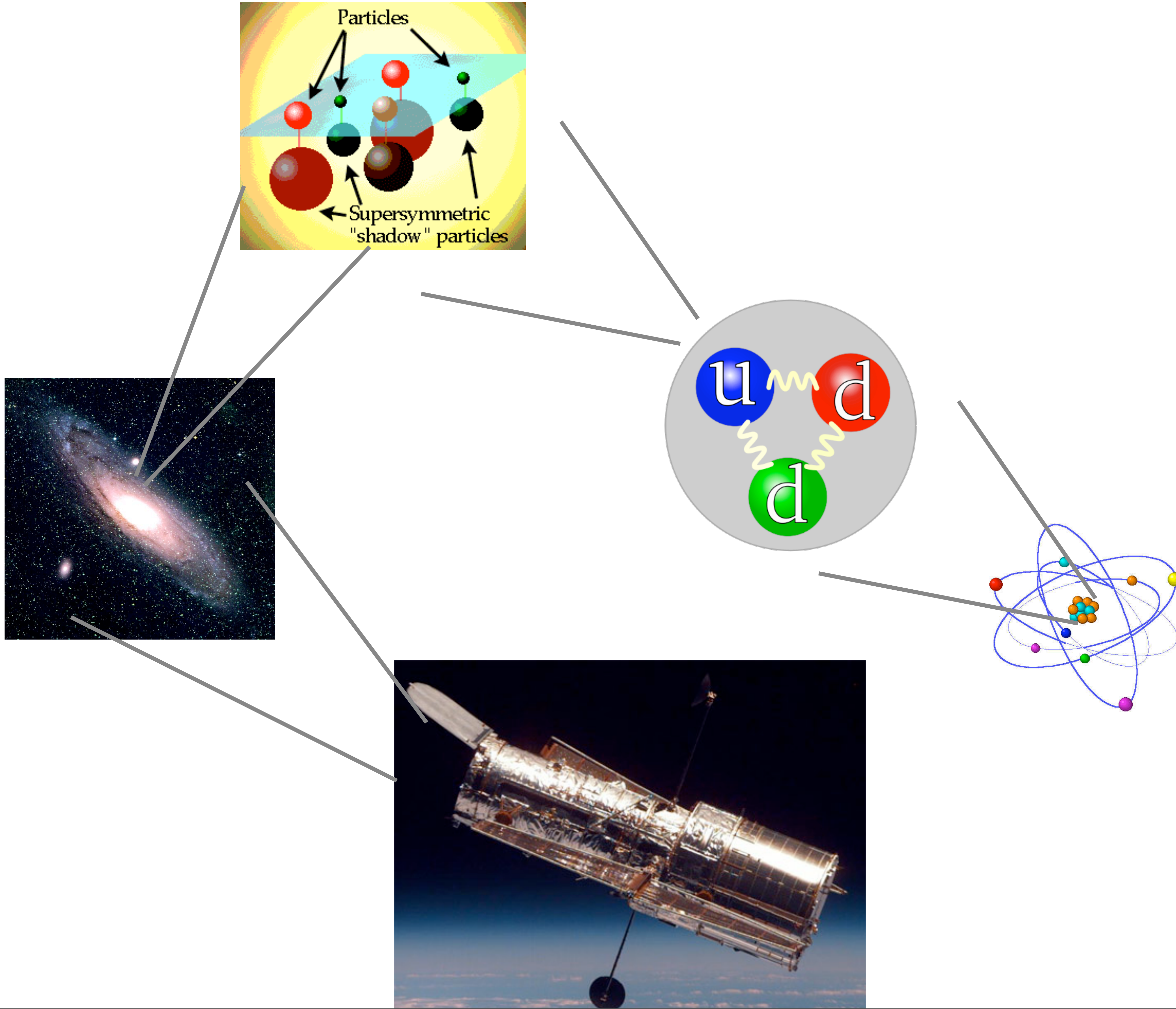
May be able to see them at TeVatron/ LHC!



Supersymmetry is a new symmetry of nature, only noticeable at short distances.

New particles made in collisions




Particles
Supersymmetric
"shadow" particles
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d
d

Keep your eye on the headlines!

- Very exciting times ahead
- Expect important discoveries impacting microscopic and macroscopic physics
- Many long standing mysteries may be solved:

Origin of mass, source of most of universe's matter, why not antimatter, unification of forces....

The BIG questions

- What gives the particles their mass?
- Why 3 generations?
- Why is gravity so weak?
- Why 3 forces, are they really the same?
- Why do they have the masses they have?
- Why is there matter and no antimatter?
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