



What is a particle?

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Plan

- *General overview of Standard Model (Ivan)*
- *History of Standard Model (Michael)*
- *Contributions from Karlsruhe -
«The Many Faces of a Particle» (Manuel)*

***We will try to answer
this very difficult question!***

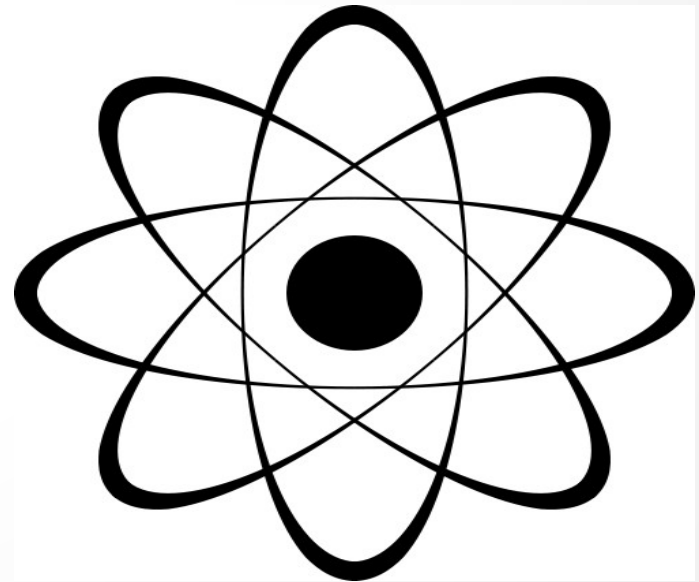
Average person:

- 65% oxygen
- 18 % carbon
- 10 % hydrogen
- 3 % nitrogen



Atoms

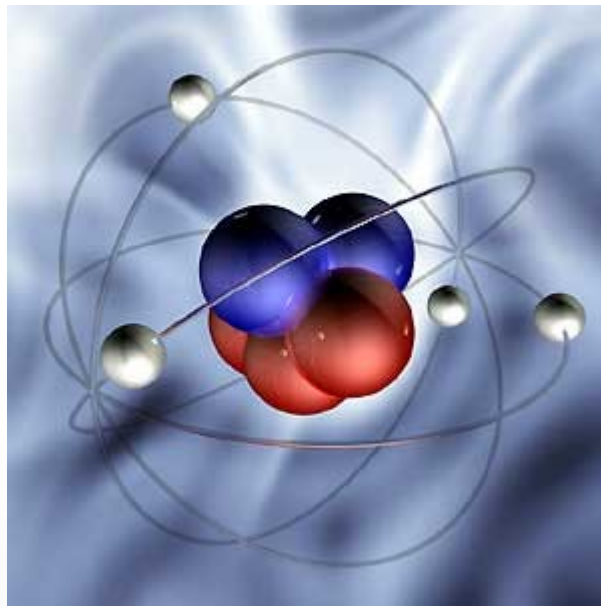
- We all consist of atoms!
- Average person consists of
~ **10^{27} atoms**



Atoms

- Atom consists of **electrons** and **nucleus**

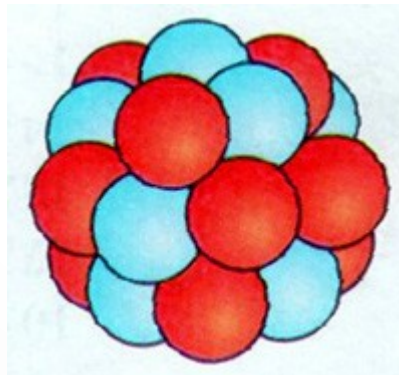
$\sim 10^{-10}$ cm



Atomic nucleus

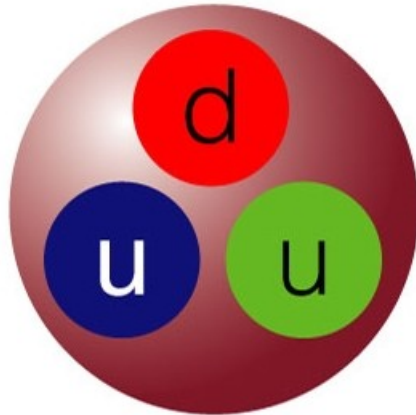
- Atomic nucleus consists of protons and neutrons

$\sim 10^{-13}$ cm



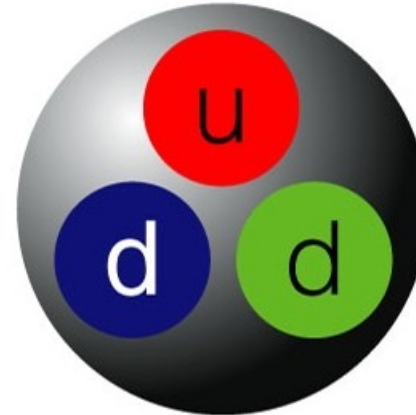
Proton and neutron

A proton is composed of 2 up quarks (u) and 1 down quark (d).



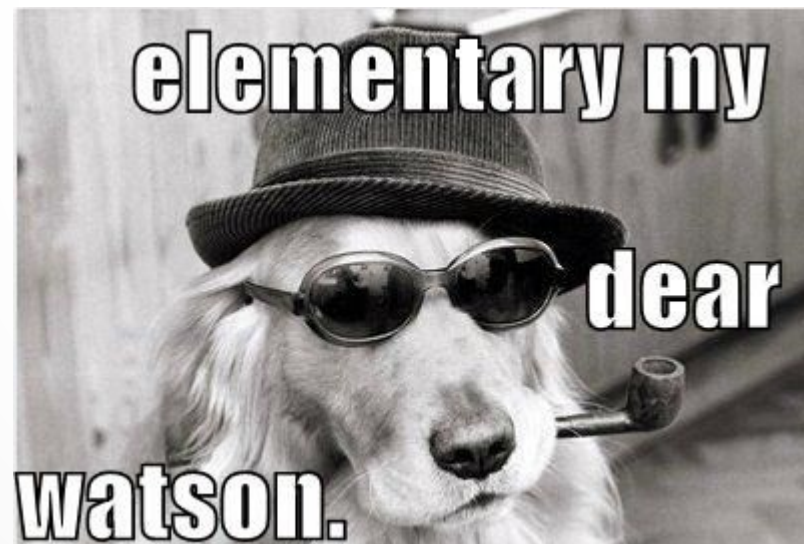
Total charge:
 $+ 2/3 + 2/3 - 1/3 = +1$

A neutron is composed of 1 up quark (u) and 2 down quarks (d).



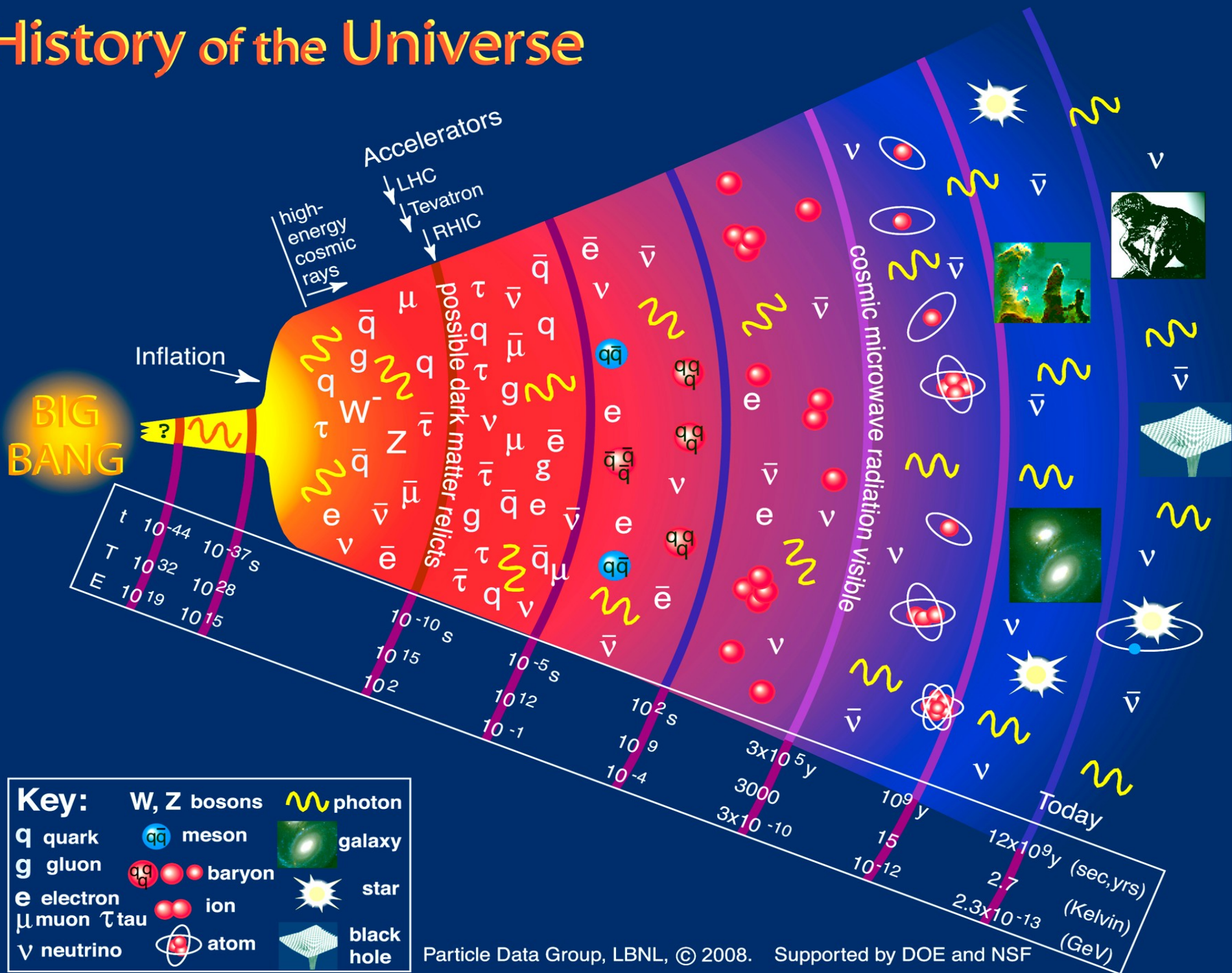
Total charge:
 $+ 2/3 - 1/3 - 1/3 = 0$

- *u-* and *d-* quarks are **elementary particles - objects** that has no structure
- At least up to distances 10^{-17} cm

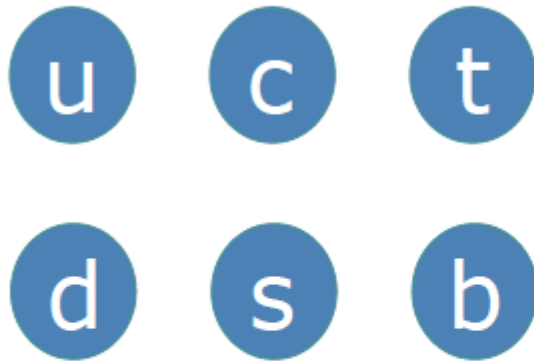


Let's stop
and go back
~13 billions years ago

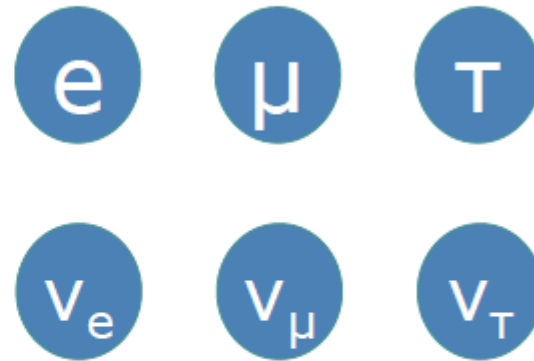
History of the Universe



Matter



quarks



leptons

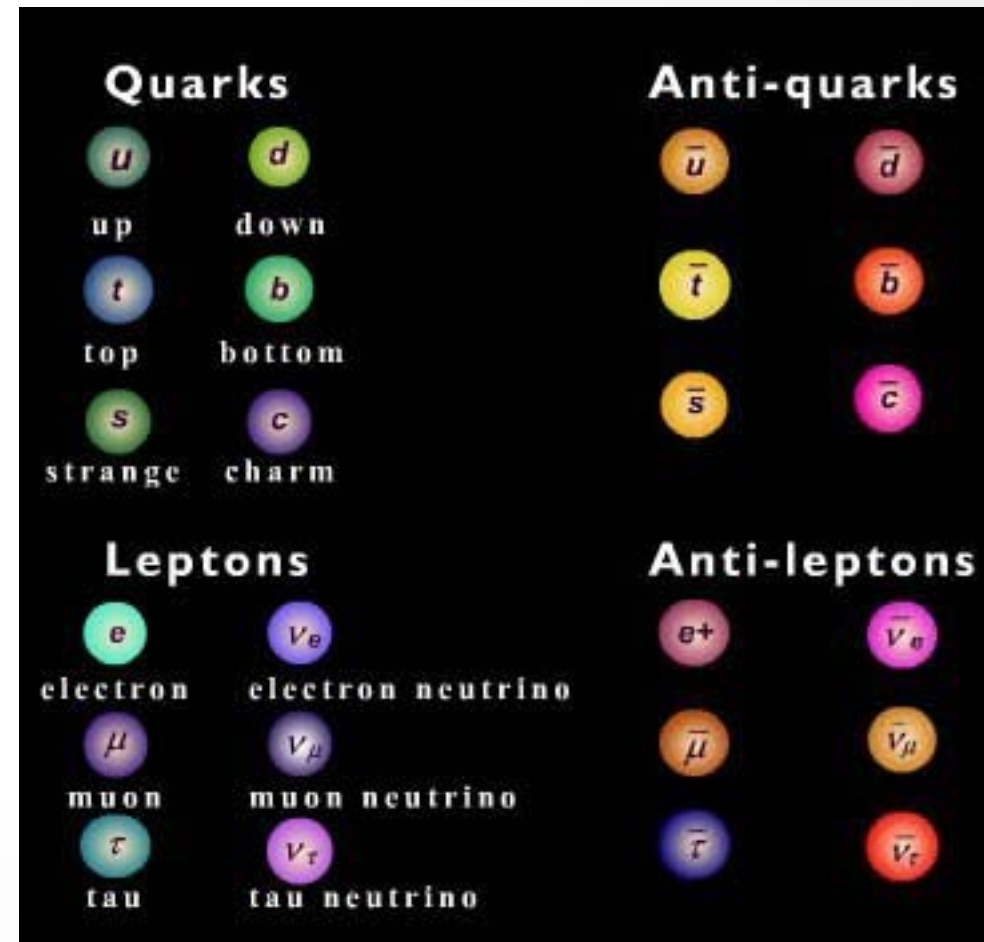
Matter

Mass	→	2.4 MeV/c ²	1.27 GeV/c ²	171.2 GeV/c ²		
Charge	→	2/3	2/3	2/3		
Spin	→	1/2	1/2	1/2		
		u	c	t	quarks	
		up	charm	top		
		4.8 MeV/c ²	104 MeV/c ²	4.2 GeV/c ²		
		-1/3	-1/3	-1/3		
		1/2	1/2	1/2		
		d	s	b		
		down	strange	bottom		
		0.511 MeV/c ²	105.7 MeV/c ²	1.777 GeV/c ²		
		-1	-1	-1		
		1/2	1/2	1/2		
		e	μ	τ	leptons	
		electron	muon	tau		
		< 2.2 eV/c ²	< 0.17 MeV/c ²	< 15.5 MeV/c ²		
		0	0	0		
		1/2	1/2	1/2		
		ν_e	ν_μ	ν_τ		
		e neutrino	μ neutrino	τ neutrino		

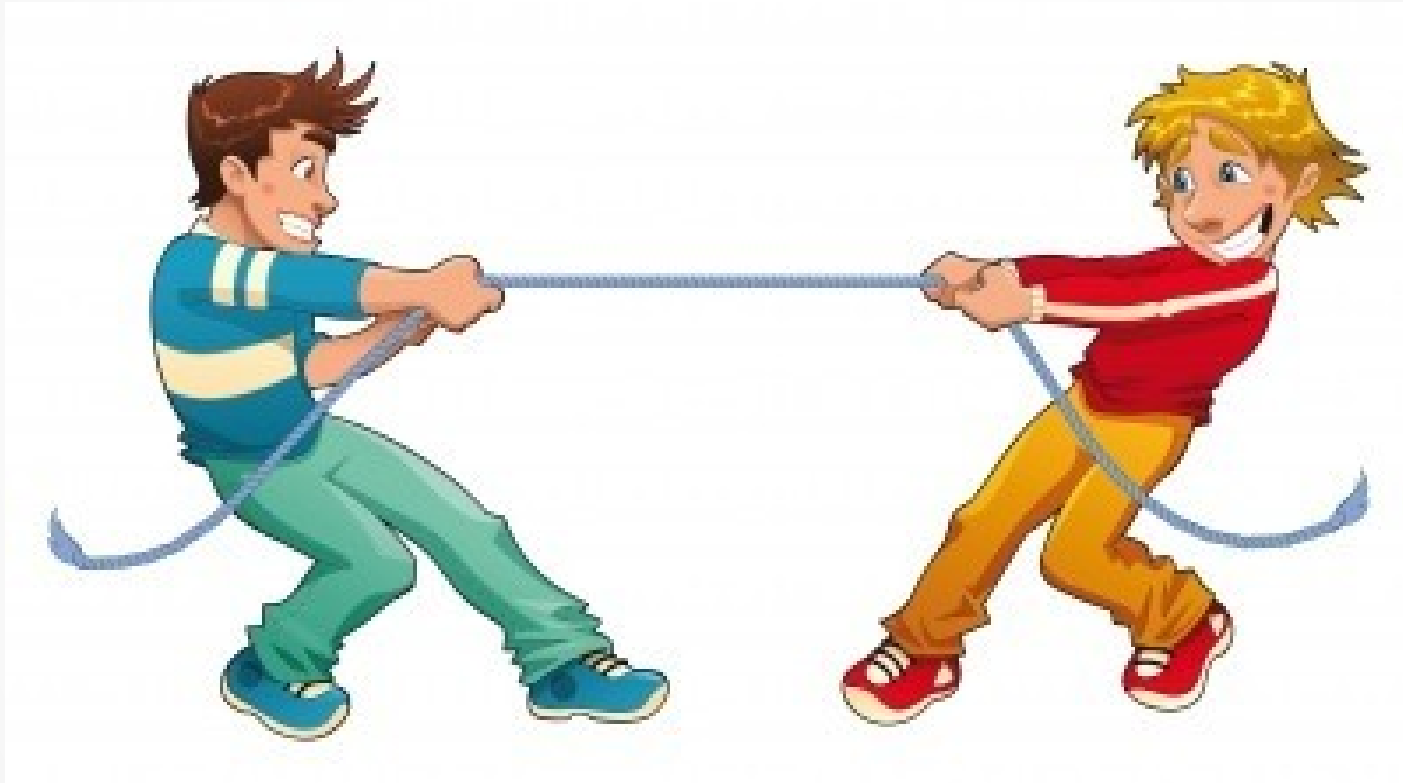
Antimatter

$$E^2 = p^2 c^2 + m_0^2 c^4$$

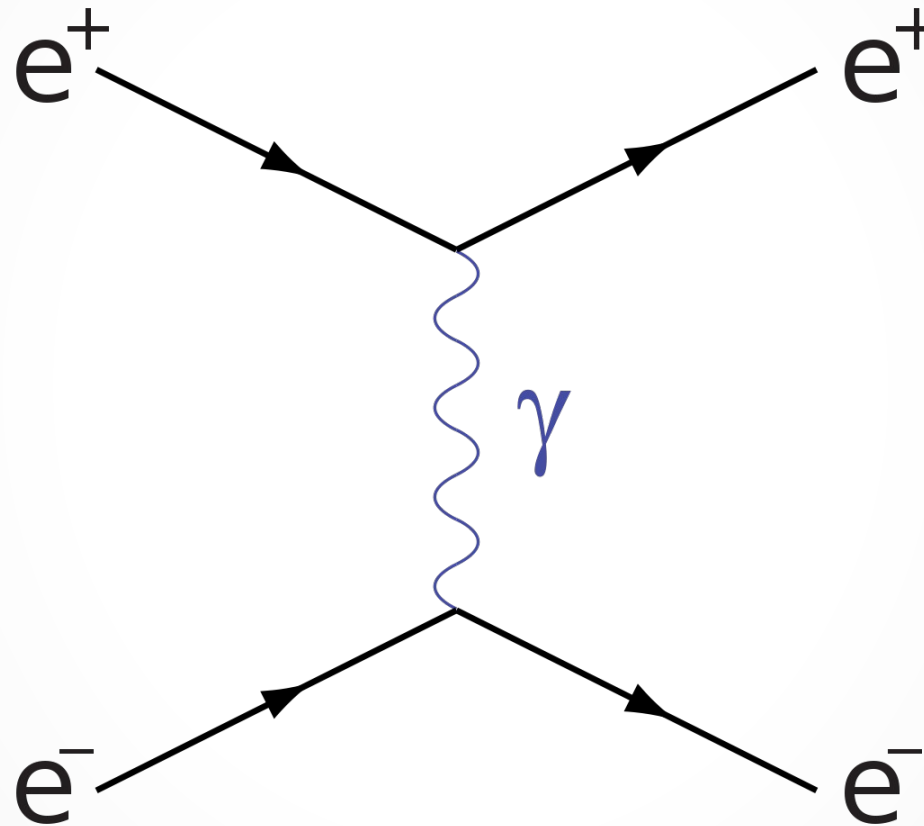
- 2 energy solutions
- Every particle has its own particle
- Antiparticle has opposite charge



Matter is hold together by forces



Forces are mediated by bosons



Forces

EM force

Electric charge (1)

Massless photon

Coupling g

Weak force

Weak charge (2)

Massive W^\pm, Z

Coupling g_w

Strong force


Colour charge (3)

8 massless gluons

Coupling g_s

Electromagnetic

$0 \text{ eV}/c^2$
0
1
photon



U(1)

Strong (QCD)

$0 \text{ eV}/c^2$
0
1
gluon

8 x





SU(3)

Weak

$80.4 \text{ GeV}/c^2$
 ± 1
1
W boson

$91.2 \text{ GeV}/c^2$
0
1
Z boson

2 x



SU(2)

Higgs boson

- Special place in particle world
- Every massive particle gets its mass interacting with Higgs field



Lots of unknowns

- Dark matter, dark energy
- Gravity
- Antimatter
- +Unknown unknowns

