PHY397K - NUCLEAR PHYSICS

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Spring 2015, Unique numbers: 57115
RLM 5.116, TTH 12:30 - 2:00 pm

Christina Markert
Office: RLM: 10.305
Phone: 512 471 8834
Email: cmarkert@physics.utexas.edu

Syllabus

Bookmark these URLs:
Website: https://web2.ph.utexas.edu/~cmarkert/home/Teaching.html
Root: https://root.cern.ch/drupal/
Inspires: https://inspirehep.net/

INSTRUCTOR:
Name: Christina Markert, Associate Professor Physics
Email: cmarkert@physics.utexas.edu (NOTE: cmarkert !!! (not markert))
Office phone: 512-471-8834

HOMEWORK: There will be reading assignments for the topics covers in class + prepared questions. A few homework assignments will be announced in class (Root-software exercise)

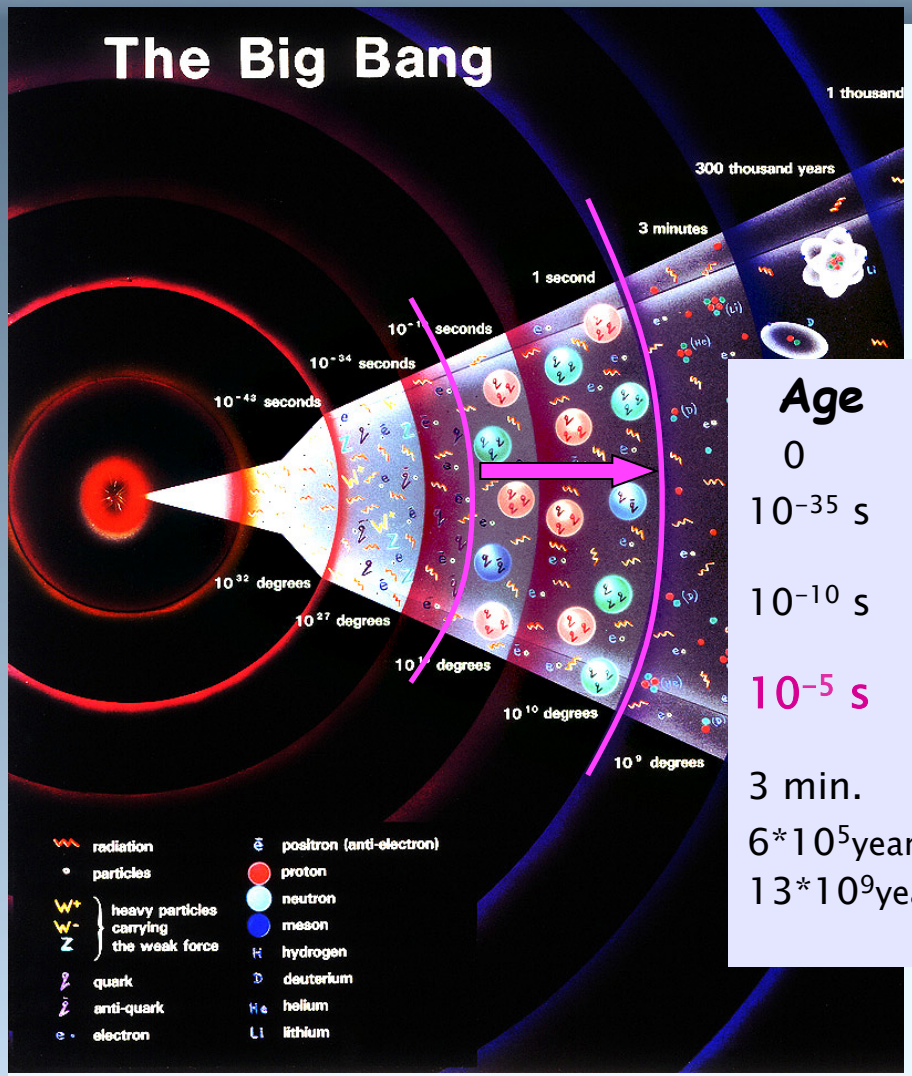
CLASSWORK: Students must be seated by 12:30 am. Attendance is required and will be documented.

GRADS:
Homework assignments, participation in discussions in class**,** attendance.

Suggested Course Layout

	DAY	DATE	Subject and Comments	
1	T	Jan 20	Introduction 1	
2	TH	Jan 22	Introduction 2	
3	T	Jan 27	Hadron, quark interactions, parton model, QCD,	
4x	TH	Jan 29	Hadron, quark interactions, parton model, QCD,	
5x	T	Feb 2	Collision, Participant, Spectator, Centrality	
6x	TH	Feb 4	Global Variables	
7x	T	Feb 10	Particle Detectors	
8	TH	Feb 12	Particle Detectors	
9	T	Feb 17	Tracking, Particle Reconstruction,	
10	TH	Feb 19	Particle Spectra, PID	
11	T	Feb 24	Strangeness	
12	TH	Feb 26	Strangeness	
13	T	Mar 2	Space time picture of Heavy Ion Collision	
14	TH	Mar 4	Freeze-outs	
15	T	Mar 10	Root - Installation	
16	TH	Mar 12	Root – Macro - Decay	
	T	Mar 17	Spring Break	
	TH	Mar 19	Spring Break	
17	T	Mar 24	Root - Pythia	
18	TH	Mar 26	Root – Pythia/Hijing	
19	T	Mar 31	Thermal and hydrodynamical models	
20	TH	Apr 2	Thermal and hydrodynamical models	
21	T	Apr 7	Charmonium	
22	TH	Apr 9	Charmonium	
23	T	Apr 14	Open heavy Flavor	
24	TH	Apr 16	Open heavy Flavor	
25	T	Apr 21	Jets	
26	TH	Apr 23	Jets	
27	T	Apr 28	Literature - Higgs	
28	TH	Apr 30	Literature - Higgs	
29	T	May 5	Future Experiments	
30	TH	May 7	Future Experiments	

Space Time Diagram of the Early Universe

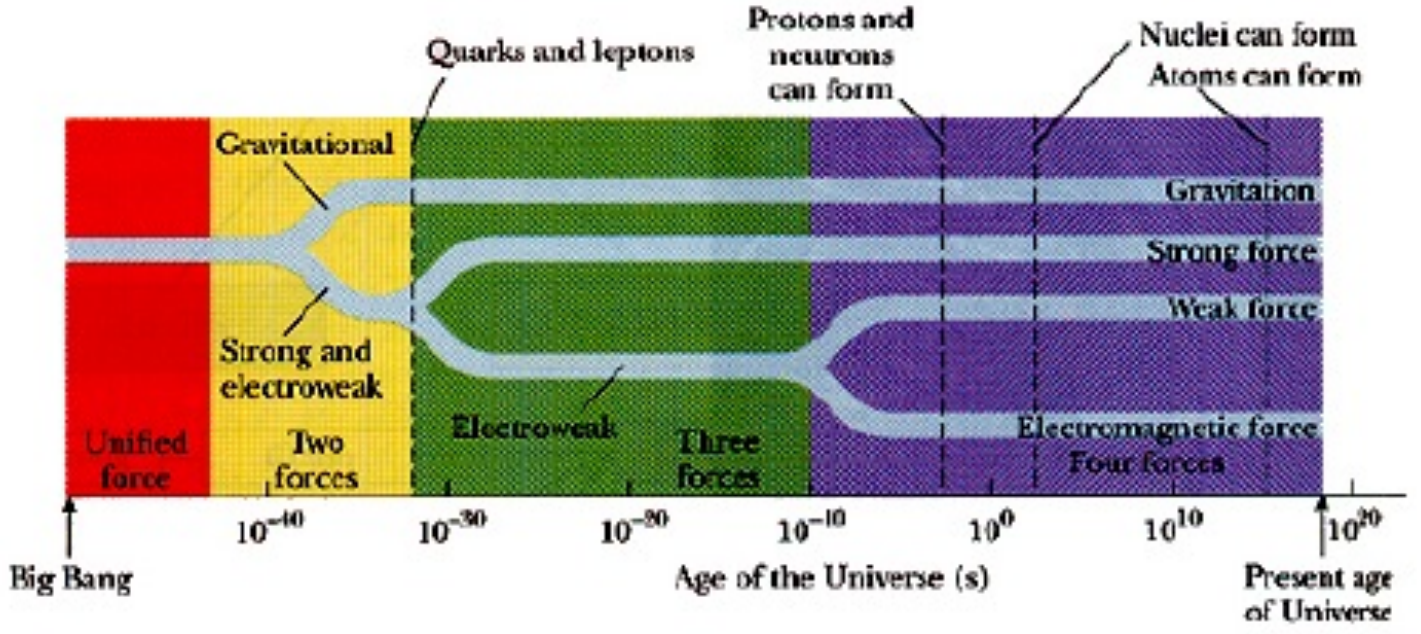


The Cosmic Timeline

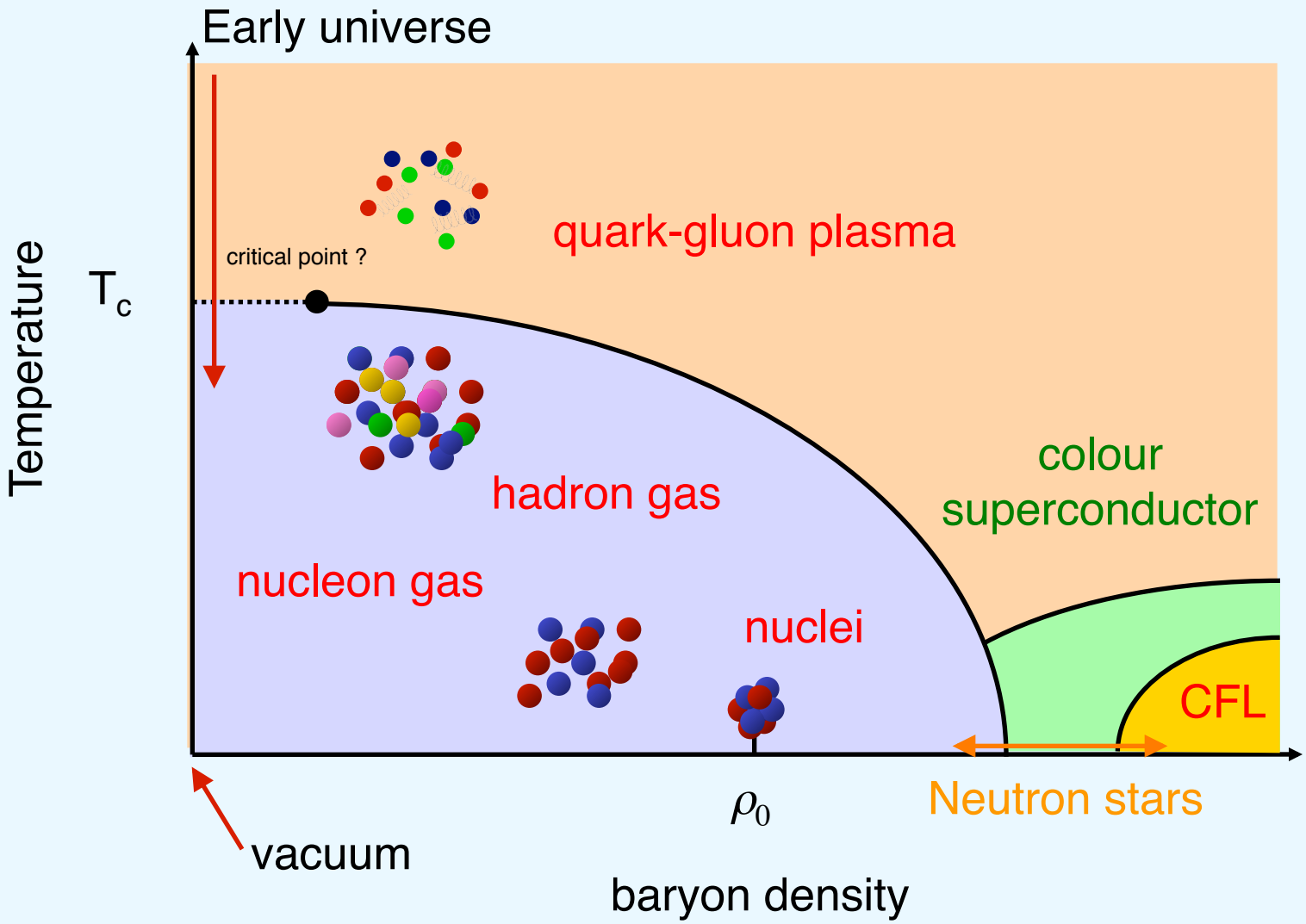
Age	Energy	Matter in universe
0	10^{19} GeV	grand unified theory of all forces
10^{-35} s	10^{14} GeV	1st phase transition (strong: q,g + electroweak: g, l,n)
10^{-10} s	10^{2} GeV	2nd phase transition (strong: q,g + electro: g + weak: l,n)
10^{-5} s	0.2 GeV	3rd phase transition (strong:hadrons + electro:g + weak: l,n)
3 min.	0.1 MeV	nuclei
$6*10^{5}$years	0.3 eV	atoms
$13*10^{9}$years	$3*10^{-4}$ eV	cosmic background radiation (now)

Evolution of Forces in Nature

From the Big Bang to the Present



The phase diagram of QCD



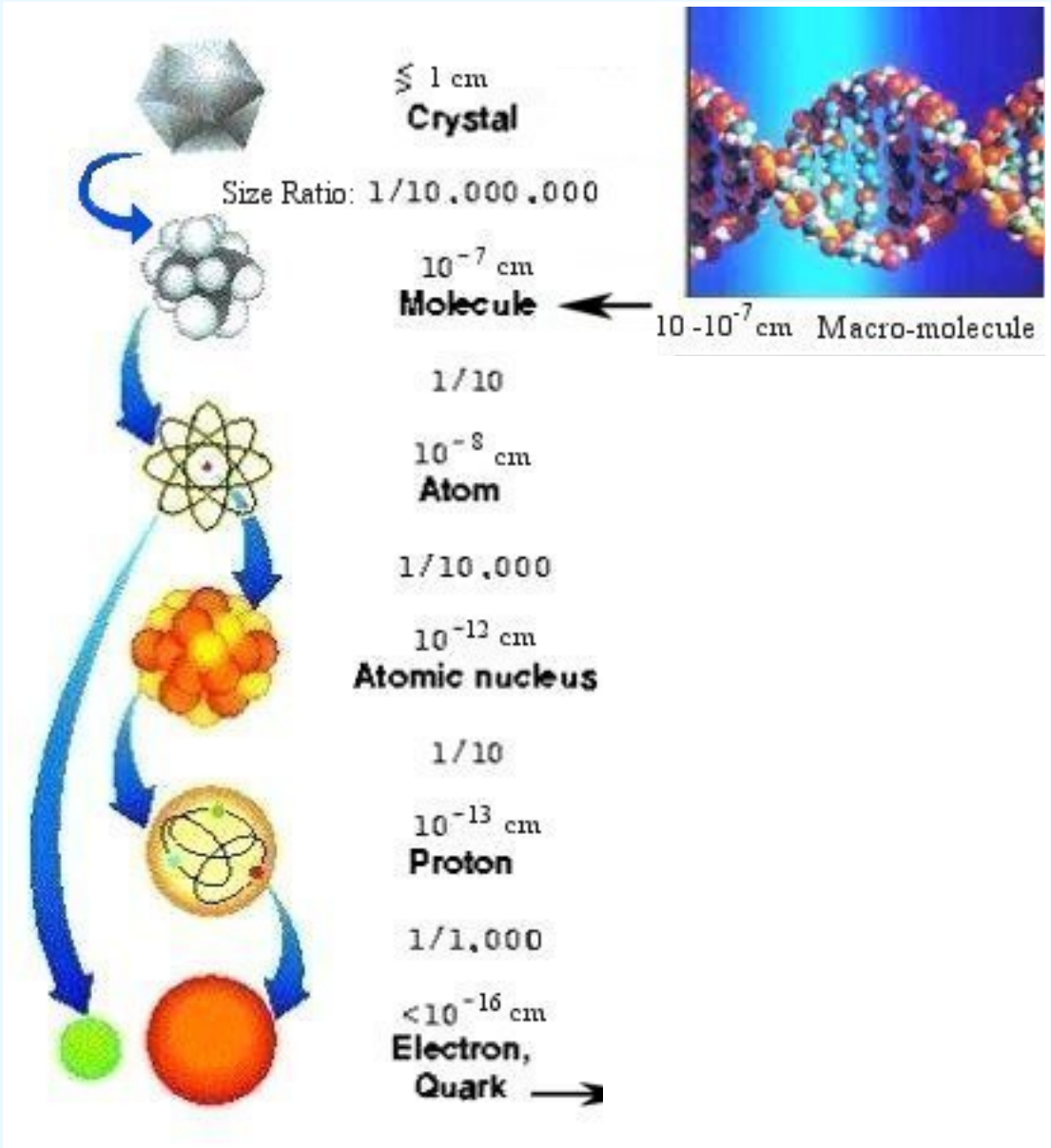
Temperature dependence

Higher temperature → elementary particles

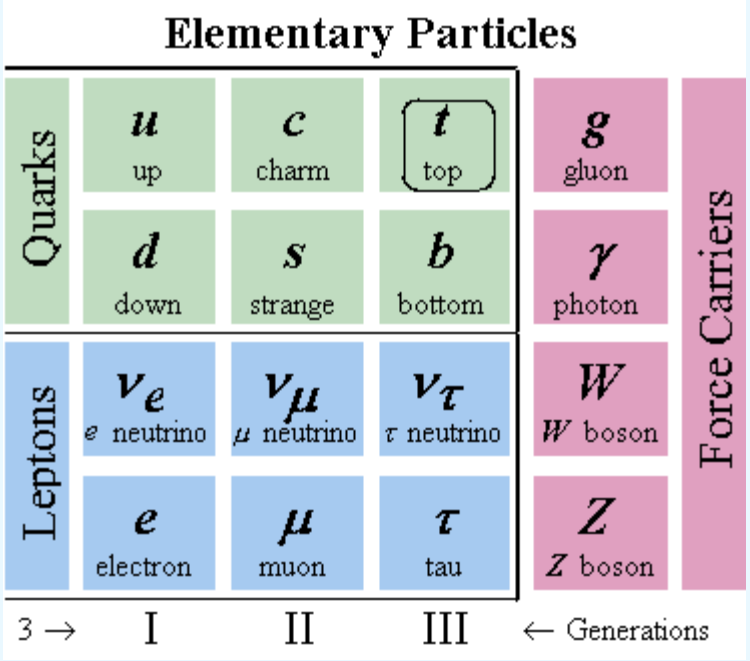
Lower temperature → more substructure

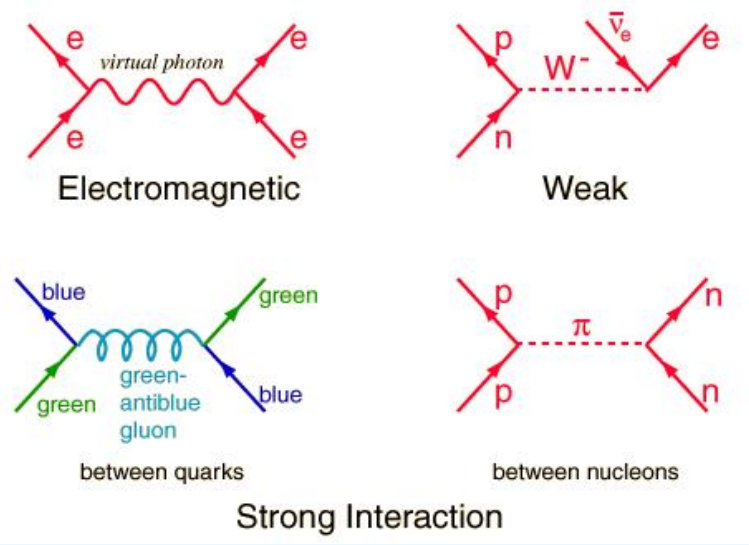
What do we know about atomic substructure ?

Proton = 10^{-15} m
= 1 fm



Elementary Particles and Fields

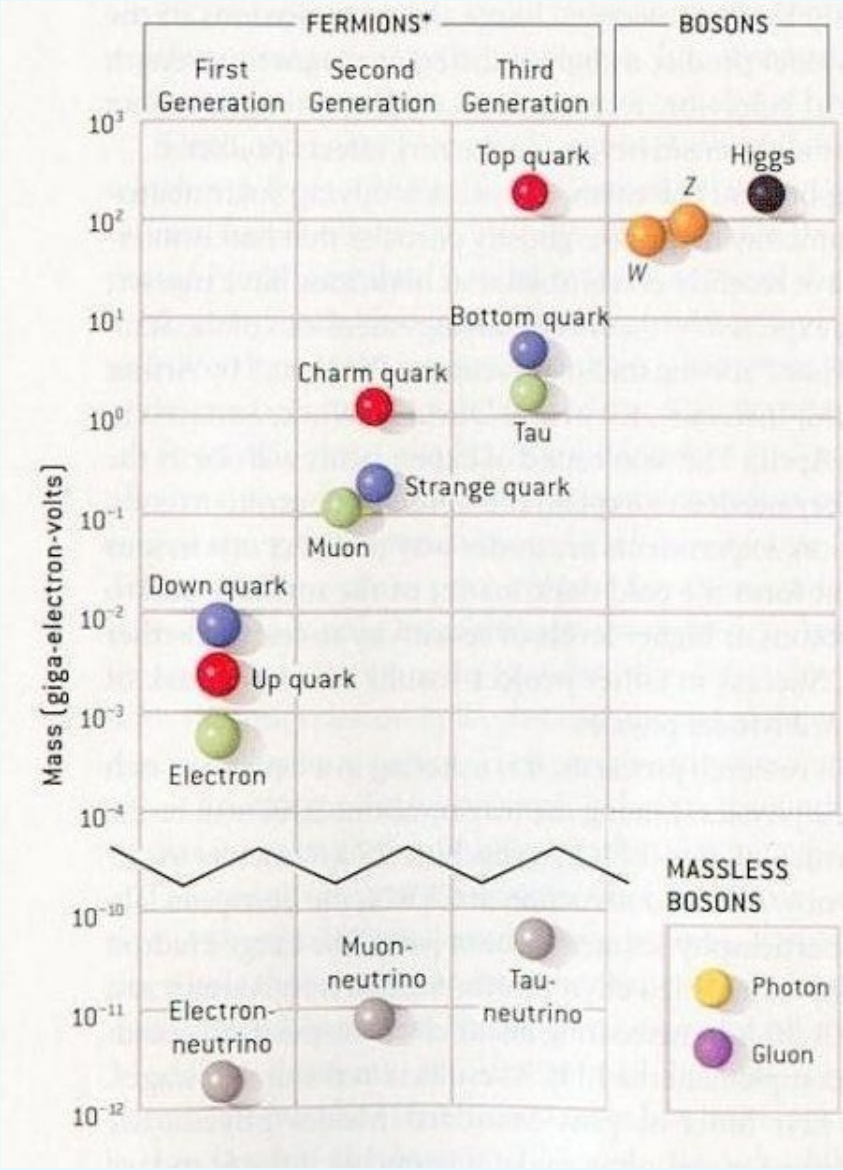




Interaction field	Boson
Gravitational	Gravitons –postulated
Weak	W^+, W^-, Z particles
Electromagnetic	Photons
Strong	Gluons –postulated

- **12 Elementary Particles**
  - Plus 4 field quanta
  - Plus antiparticles
- **3 Generations**
- Masses of (II) > (I)
- Masses of (III) > (II)
- (I) is for ordinary matter
- Q: Only three generations?
  - Only three ν observed (1991, CERN)
  - Therefore expect only three generations

What do we know about quark masses ?



Why are quark current masses so different ?

Basic Building Blocks ala Halzen and Martin

Building Blocks of Elementary Particles and Some of Their Quantum Numbers*

Name	Spin	Baryon Number B	Lepton Number L	Charge Q
Quarks				
u (up)	$\frac{1}{2}$	$\frac{1}{3}$	0	$+\frac{2}{3}$
d (down)	$\frac{1}{2}$	$\frac{1}{3}$	0	$-\frac{1}{3}$
Leptons				
e (electron)	$\frac{1}{2}$	0	1	-1
ν (neutrino)	$\frac{1}{2}$	0	1	0
Gauge bosons				
γ (photon)	1	0	0	0
$W^{\pm}, Z$ (weak bosons)	1	0	0	$\pm 1, 0$
g_i ($i = 1, \ldots, 8$ gluons)	1	0	0	0

*The spin is given in units of $\hbar$. The charge units are defined in such a way that the electron charge is -1. Not listed in the table are the antiparticles of the quarks and leptons [$\bar{u}$, $\bar{d}$ (antiquarks), e^+ (positron), $\bar{\nu}$ (antineutrino)]. Although they will not be carefully defined until Chapter 3, they are for present purposes identical to the corresponding particles except for the reversal of the sign of their B, L, and Q quantum numbers. For example, the $\bar{u}$ has $B = -\frac{1}{3}$, $L = 0$, $Q = -\frac{2}{3}$, and the e^+ has $B = 0$, $L = -1$, and $Q = +1$.

Particles

• **Fermions and Bosons:** spin statistics theorem (Pauli 1940) (spin = angular momentum)
Fermions = spin $1/2\hbar$ (e.g. electron) (constituent particle) ($\hbar$ = Plank constant, reduced)
Bosons = spin $1\hbar$ (e.g. photon) (force carriers)

•**Particle and Antiparticle:** opposite electromagnetic charge and magnetic momentum, $1\hbar$
Same mass
Fermoins and antifermions can only be created and destroyed in pairs.

•**Constituent Particle** (are fermions):
Quarks: flavor: u,d,s,c,d,t, electric charges: +2/3, -1/3, color charge: red, green, blue
Baryon (qqq) Meson (q anti-q)
Baryons: uud = p (proton) stable, udd = n (neutron), uds = Λ (Lambda)
Meson: $u\bar{d} = \pi^+$ (pion), $\bar{s}d = K^0$ (kaon), $\bar{s}s = \phi$ (meson)
Quantum numbers: baryon, strangeness, charm, bottom, top,

Leptons: e, μ, τ, ν electric charge +1,-1, 0
electron = stable, neutrino (ν)= stabile

Elementary Particles Summary

QUARK	CHARGE (e)	SPIN ($h/2\pi$)	MASS (MeV/c^2)
Up (u)	+2/3	½	2-8
Down (d)	-1/3	½	5-15
Strange (s)	-1/3	½	100-300
Charmed (c)	+2/3	½	1000-1600
Top (t)	+2/3	½	1.8×10^5
Bottom (b)	-1/3	½	4100-4500

LEPTONS	CHARGE (e)	SPIN ($h/2\pi$)	MASS (MeV/c^2)
Electron (e^-)	-1	½	0.511
Muon (μ^-)	-1	½	106
Tau (τ^-)	-1	½	1784
Electron Neutrino (ν_e)	0	½	<7.3 eV
Muon Neutrino (ν_μ)	0	½	<270 keV
Tau Neutrino (ν_τ)	0	½	<35 MeV

GAUGE BOSONS (Field Particles)	ELECTRIC CHARGE	SPIN ($h/2\pi$)	MASS (GeV/c^2)
Graviton	0	2	0
W±, Z°	±1, 0	1	80.41, 91.12
Photon (γ)	0	1	0
Gluon (g) – 8 varietie	0	1	0
Higgs Boson (H°)???	0	1	40-1000???