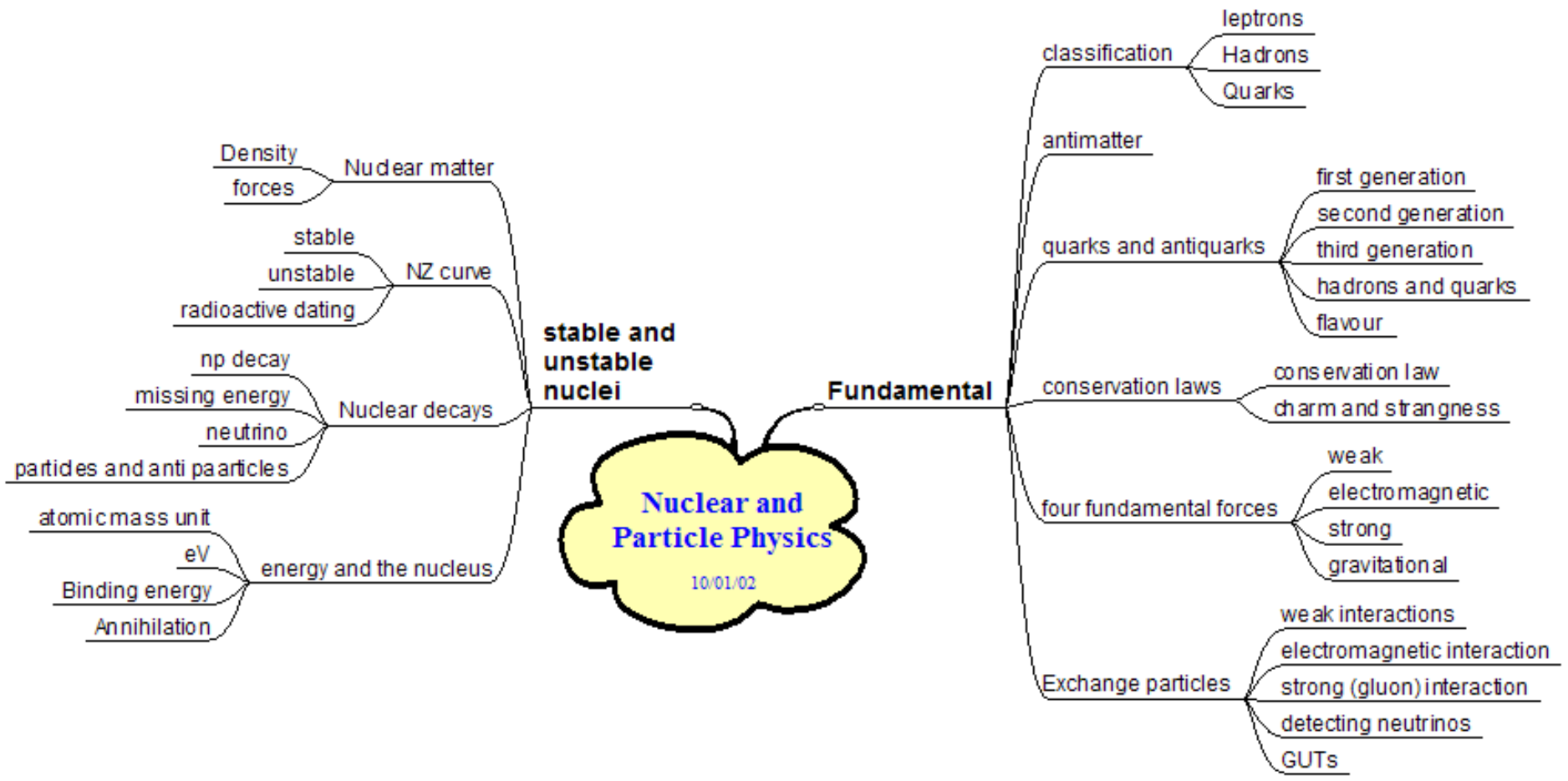
Nuclear and Particle Physics

Dr P Lawson


Nuclear and Particle Physics
10/01/02
stable and unstable nuclei
Nuclear matter
Density
forces
NZ curve
stable
unstable
radioactive dating
Nuclear decays
np decay
missing energy
neutrino
partides and anti paarticles
energy and the nucleus
atomic mass unit
eV
Binding energy
Annihilation
Fundamental
classification
leptrons
Hadrons
Quarks
antimatter
quarks and antiquarks
first generation
second generation
third generation
hadrons and quarks
flavour
conservation laws
conservation law
charm and strangness
four fundamental forces
weak
electromagnetic
strong
gravitational
Exchange particles
weak interactions
electromagnetic interaction
strong (gluon) interaction
detecting neutrinos
GUTs

Stable and unstable nuclei we have done
REMEMBER ITS IN THE TOPICS SECTION

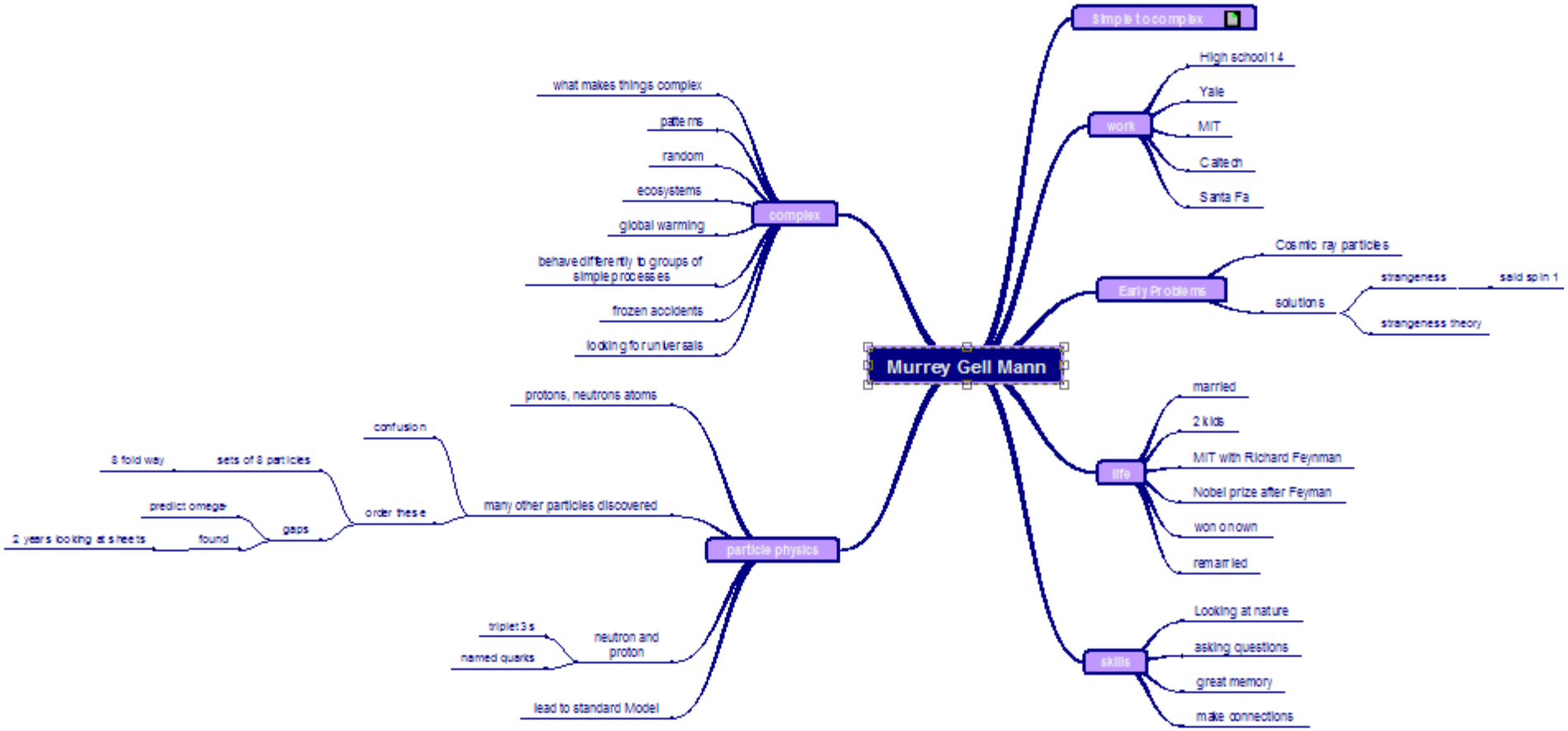
Check

STUDENT FORUM \Dr Lawson\A'Level\Physics

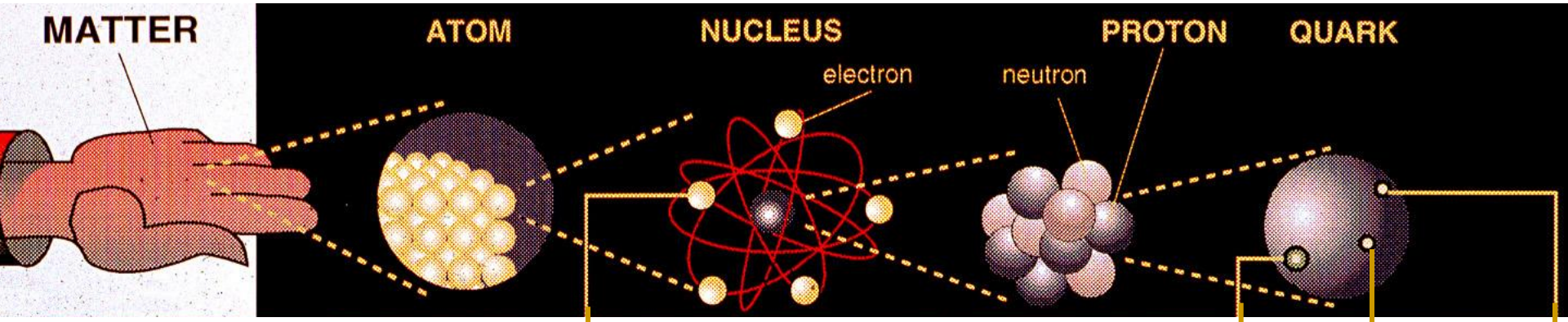
physics spec.pdf

Edexcel physics student guide.pdf

Murry Gell-Mann



From you to the quark



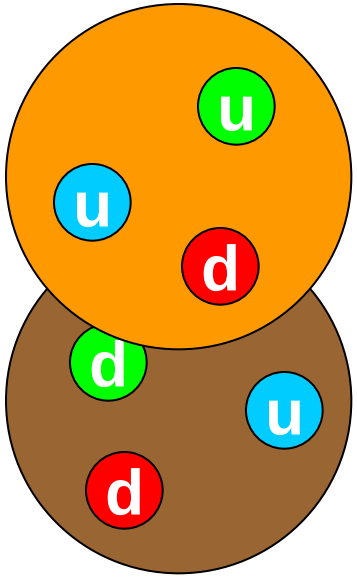
Electrons orbiting nucleus

d type quark

u type quarks

The Matter Particles

Proton



Mass: 1.7 10^{-27} kg
charge: +1

Neutron

Charge: 0

Electron

e

Mass: 0.0005 proton mass
charge: -1

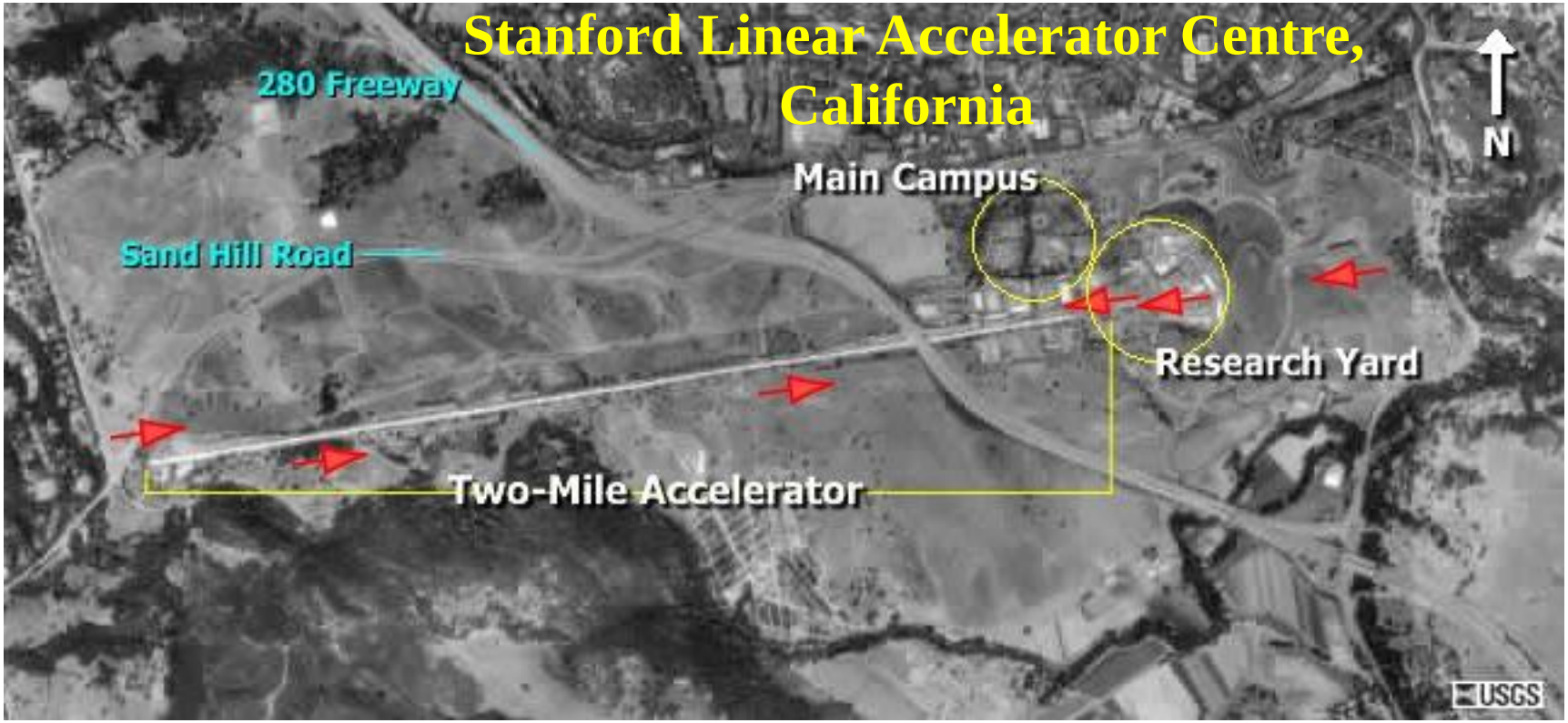
Neutrino

ν

Mass: ~<10^{-9} proton mass?
Charge: 0

How do we know about quarks?

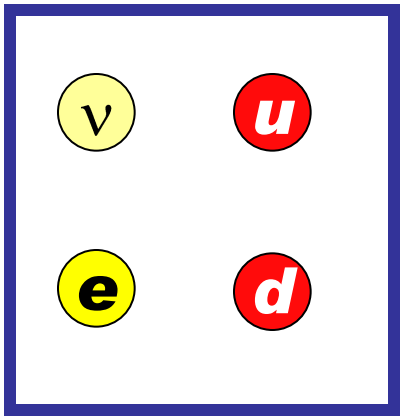
Rutherford found a nucleus in the atom by firing alpha particles at gold and seeing them bounce back



Fire electrons at protons: See big deflections!

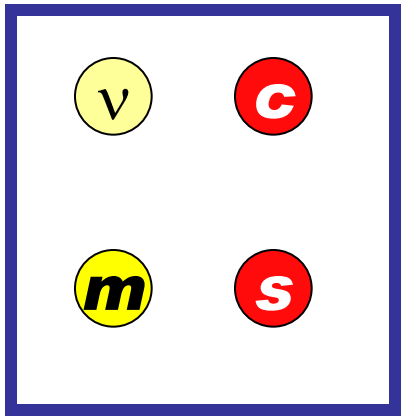
Late 1960's

The Matter particles



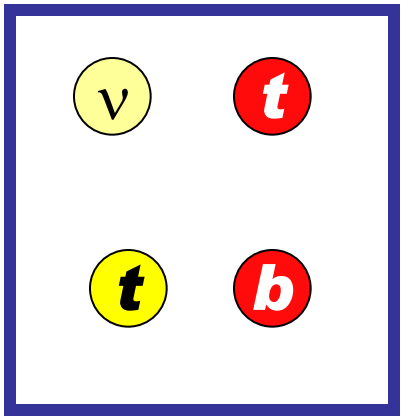
1st Generation

Ordinary matter



2nd Generation

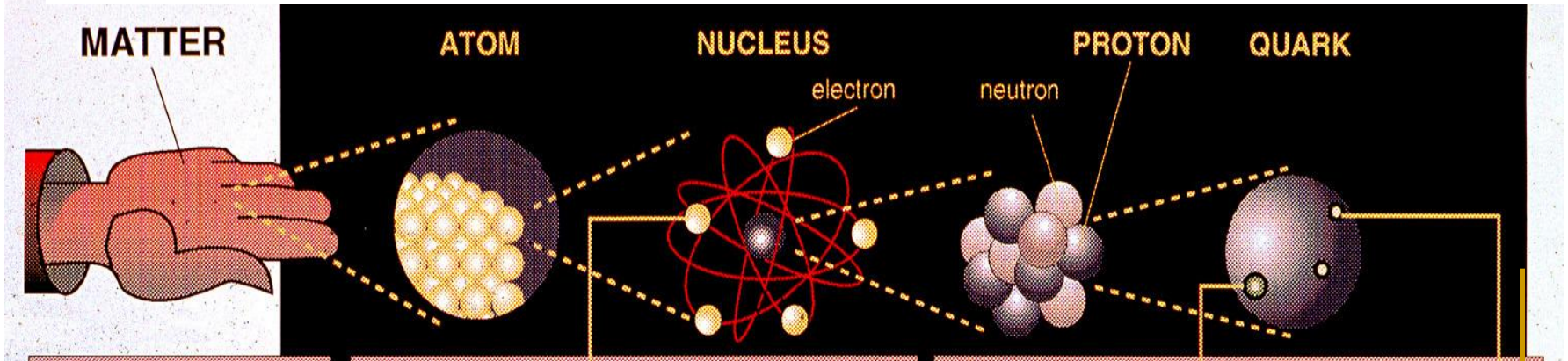
Cosmic rays



3rd Generation

Accelerators

From you to the quark



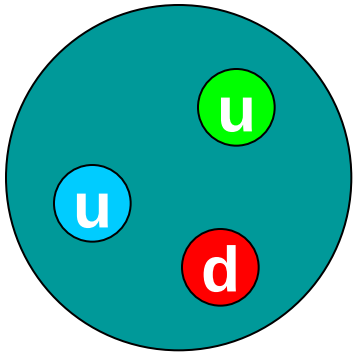
ALL ORDINARY MATTER BELONGS TO THIS GROUP.

THESE PARTICLES EXISTED JUST AFTER THE BIG BANG.

NOW THEY ARE FOUND ONLY IN COSMIC RAYS AND ACCELERATORS.

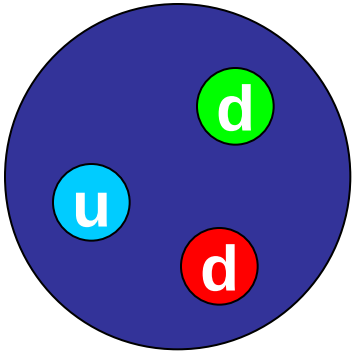
LEPTONS		QUARKS	
electron Electric charge –1. Responsible for electricity and chemical reactions	**electron neutrino** Electric charge 0. Rarely interacts with other matter.	**up** Electric charge + 2/3. Protons have 2 up quarks Neutrons have 1 up quark	**down** Electric charge –1/3. … and one down quark. … and two down quarks.
muon A heavier relative of the electron.	**muon neutrino** Created with muons when some particles decay.	**charm** A heavier relative of the up.	**strange** A heavier relative of the down.
tau Heavier still.	**tau neutrino** Not yet observed directly.	**top** Heavier still, recently observed.	**bottom** Heavier still.

How do quarks combine?



A proton:

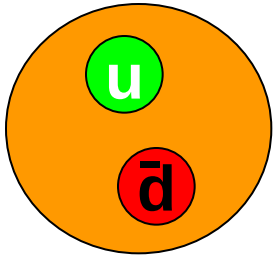
two ‘u’ quarks and one ‘d’ quark



A neutron:

2 ‘d’ quarks and 1 ‘u’ quark

With 6 quark types there are hundreds of combinations



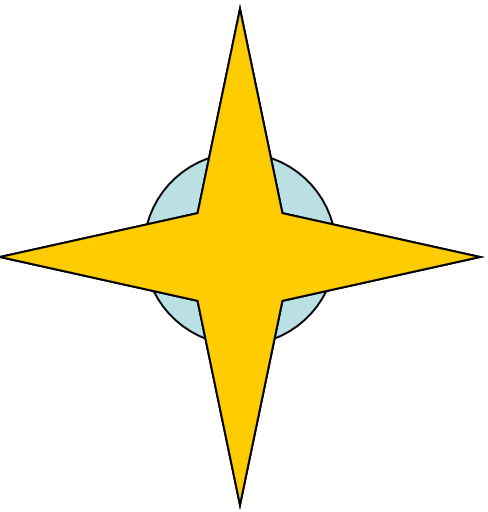
Mesons have a quark and an anti-quark

Many created, not stable

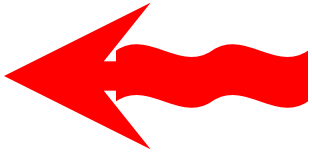
Forces in Particle Physics

High energies and small distances ⇔ quantum mechanics

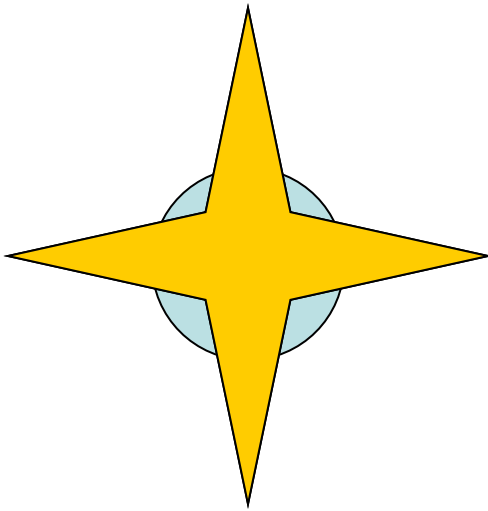
Continuous field → exchange of quanta



For Electromagnetism

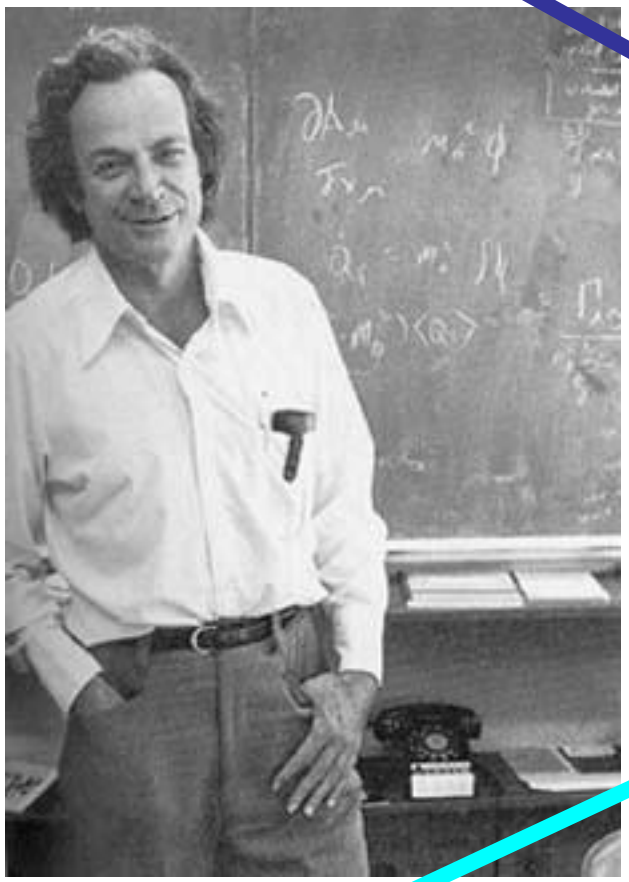


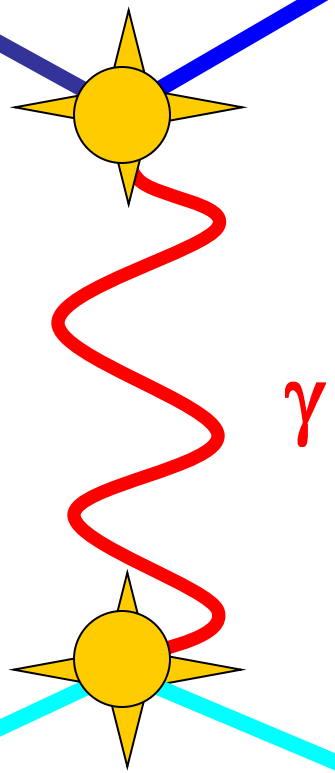
The quanta are photons, γ



Mediation of the Forces

Electron





At each 'vertex' charge is conserved. Heisenberg Uncertainty allows energy borrowing.

Positron
(anti-electron)

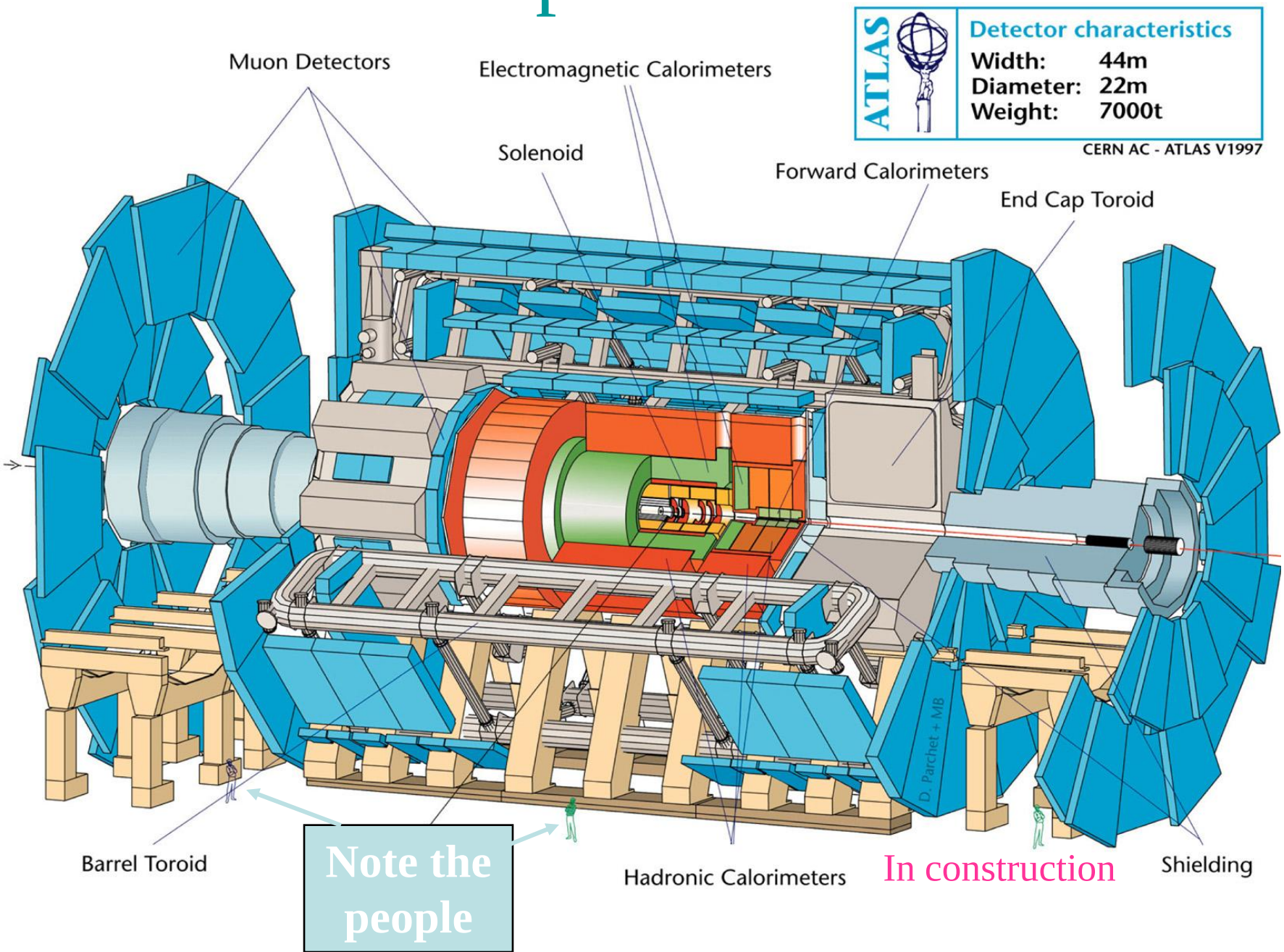
Feynman Diagram

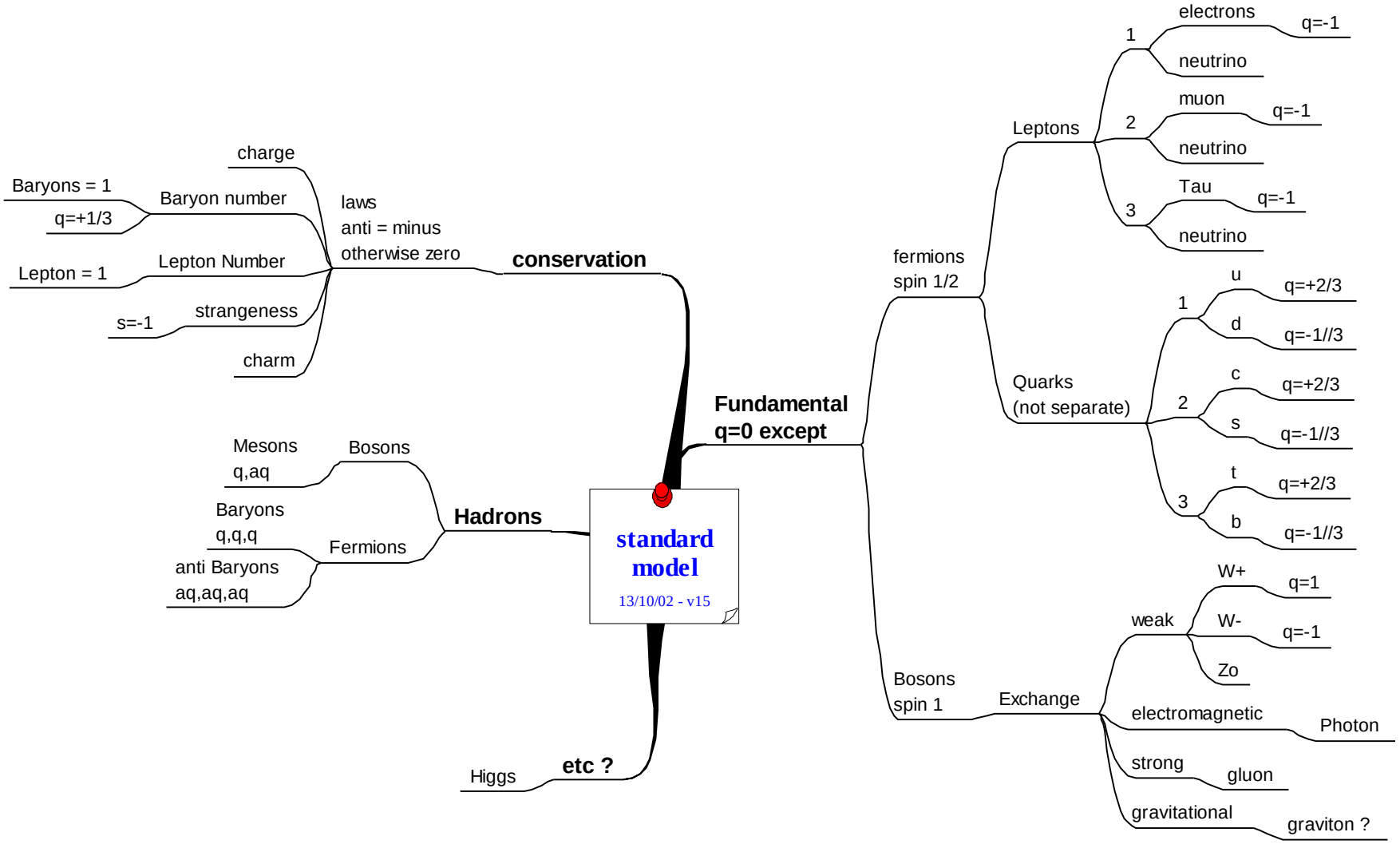
Particles and forces

	‘u’ quarks	‘d’ quarks	electron	neutrino
E.M. charge	+2/3	–1/3	–1	0
Strong force	yes	yes	no	no
Weak force	yes	yes	yes	yes

Heavier generations have identical pattern

An LHC experiment: ATLAS




standard model
13/10/02 - v15
conservation
laws
anti = minus
otherwise zero
charge
Baryon number
Baryons = 1
q=+1/3
Lepton Number
Lepton = 1
strangeness
s=-1
charm
Fundamental
q=0 except
fermions
spin 1/2
Leptons
1
electrons
q=-1
neutrino
2
muon
q=-1
neutrino
3
Tau
q=-1
neutrino
Quarks
(not separate)
1
u
q=+2/3
d
q=-1//3
2
c
q=+2/3
s
q=-1//3
3
t
q=+2/3
b
q=-1//3
Bosons
spin 1
Exchange
weak
W+
q=1
W-
q=-1
Zo
electromagnetic
Photon
strong
gluon
gravitational
graviton ?
Hadrons
Bosons
Mesons
q,aq
Fermions
Baryons
q,q,q
anti Baryons
aq,aq,aq
etc ?
Higgs

FERMIONS

matter constituents
spin = 1/2, 3/2, 5/2, ...

Leptons spin = 1/2

Flavor	Mass GeV/c^2	Electric charge
ν_e electron neutrino	$<1\times10^{-8}$	0
e electron	0.000511	–1
ν_μ muon neutrino	<0.0002	0
μ muon	0.106	–1
ν_τ tau neutrino	<0.02	0
τ tau	1.7771	–1

Quarks spin = 1/2

Flavor	Approx. Mass GeV/c^2	Electric charge
u up	0.003	2/3
d down	0.006	–1/3
c charm	1.3	2/3
s strange	0.1	–1/3
t top	175	2/3
b bottom	4.3	–1/3

BOSONS

force carriers
spin = 0, 1, 2, ...

Unified Electroweak spin = 1		
Name	Mass GeV/c^2	Electric charge
γ photon	0	0
W^-	80.4	–1
W^+	80.4	+1
Z^0	91.187	0

Strong (color) spin = 1		
Name	Mass GeV/c^2	Electric charge
g gluon	0	0

Mesons $q\bar{q}$

Mesons are bosonic hadrons.
There are about 140 types of mesons.

Symbol	Name	Quark content	Electric charge	Mass GeV/c^2	Spin
π^+	pion	$u\bar{d}$	+1	0.140	0
K^-	kaon	$s\bar{u}$	–1	0.494	0
ρ^+	rho	$u\bar{d}$	+1	0.770	1
B^0	B-zero	$d\bar{b}$	0	5.279	0
η_c	eta-c	$c\bar{c}$	0	2 .980	0

History of the Universe