Outline

- Relativistic Kinematics
  - (4-momentum)2 invariance, invariant mass
  - Hypothesis testing, production thresholds
  - Cross-sections, flux and luminosity, accelerators
  - Particle lifetime, decay length, width
- Classification of particles
  - Fermions and bosons
  - Leptons, hadrons, quarks
  - Mesons, baryons
- Quark Model
  - Meson and baryon multip
  - Isospin, strangeness, c,
- Particle Interactions
  - Colour charge, QCD, gluons
  - Virtual particles and range of forces
  - Strong and weak decays, conservation rules
  - Parity, charge conjugation, CP
  - Weak decays of quarks
  - Charmonium and upsilon systems
- Electroweak Interactions
  - Charged and neutral currents
  - W, Z, LEP experiments
  - Higgs and the future
- LHC Experiments
- Future – introduction to accelerator physics

Today

- Lecture 9 (4 slides/page) - colour charge
  - Griffiths, pp. 181-188
  - Perkins (3rd edition), pp. 283-285

- Lecture 9 (4 slides/page) - colour charge
  - Griffiths, pp. 181-188
  - Perkins (3rd edition), pp. 283-285

Previous lecture

- Lecture 8 (4 slides/page) - baryon wavefunction and colour charge
  - Griffiths, pp. 176-181
  - Perkins (3rd edition), pp.150
  - Perkins (3rd edition), pp 283-284

Baryon wavefunction and colour

- Baryon wavefunction

$$\Psi_{baryon} = \Psi_{spin}\ \Psi_{space}\ \Psi_{flavour}\ \Psi_{colour}$$

has to be overall antisymmetric (Pauli Exclusion Principle) under interchange of any 2 quarks

- For J=3/2, uuu (Δ^{++}), ddd(Δ^-), sss(Ω^-) states exist
  - Ψ_{spin}, Ψ_{space} and $\Psi_{flavour}$ are all symmetric
  - Therefore ψ_{colour} has to be antisymmetric
  - We extend this assertion to be true for all baryons
- Colour wavefunction for baryons (qqq) is always antisymmetric and is

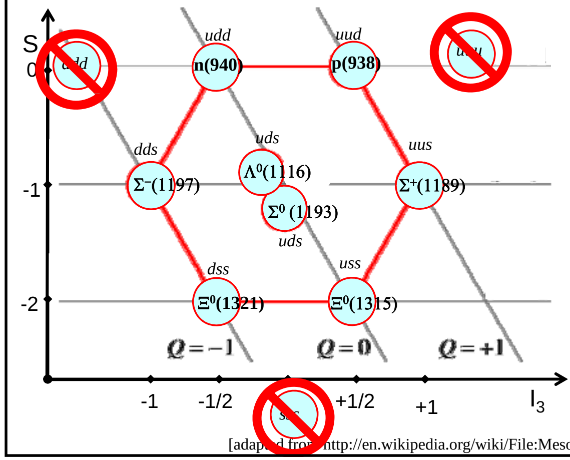
$$|rgb - grb + brg - rbg + gbr - bgr\rangle/\sqrt{6}$$

  - This is the colour singlet state and only this one is allowed (of all 3^3 combinations)
  - Subtle detail: identical particles are the quarks, contrast with meson case

Baryon wavefunction and colour

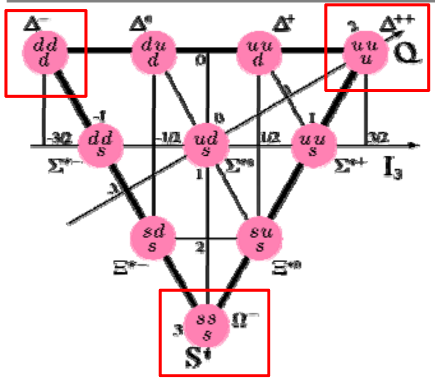
- For J=1/2 baryon case, Ψ_{space} is still symmetric, so $\Psi_{spin}\ \Psi_{flavour}$ must also be symmetric
  - In J=1/2, states, $|\uparrow\uparrow\downarrow\rangle$ etc., clearly symmetry is "mixed" – neither fully symmetric or antisymmetric – depending on which quarks are interchanged
  - To ensure overall symmetric behaviour of $\Psi_{spin}\ \Psi_{flavour}$, need $\Psi_{flavour}$ to have complementary mixed symmetry to Ψ_{spin}
  - As $\Psi_{flavour}$ is perfectly symmetric for uuu, ddd, sss states
  - … and spin states such as $|\uparrow\uparrow\downarrow\rangle$ are mixed symmetry,
  - … PEP excludes existence of these combinations in J=1/2 states.
- This agrees with the observed baryon states
  - Further evidence for colour quantum number
  - In uud, etc. cases, there is one possibility for $\Psi_{flavour}$ to complement mixed symmetry spin wavefunction
  - In uds case, two options for $\Psi_{flavour\ corresponding}$ to $\Lambda^0(1116)$ and Σ^0 (1193)
- Further details, see course web page references, esp. Griffiths pp. 187-188.

J=1/2 Baryon Octet



[adapted from http://en.wikipedia.org/wiki/File:Meson_nonet_-_spin_1.svg]

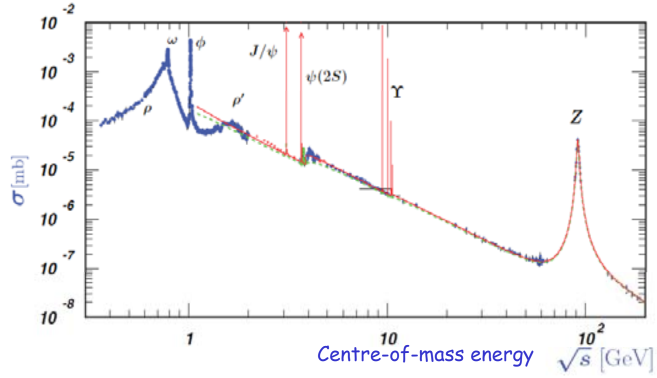
J=3/2 Baryon Decuplet



Same valence quark as in J=1/2 octet, with new members

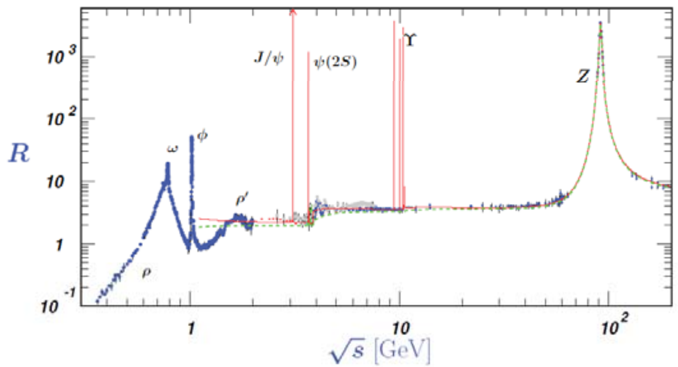
[from http://en.wikipedia.org/wiki/File:Baryon-decuplet-small.svg]

cross-section ($e^+e^- \rightarrow$ hadrons)



http://pdg.lbl.gov/2008/reviews/hadronicrpp.pdf

cross-section ratio: ($e^+e^- \rightarrow$ hadrons)/ ($e^+e^- \rightarrow \mu^+\mu^-$)



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