Strong Interactions

• Nuclear physics
• Many hadronic bound states and resonances:
  – Baryons \((N, \Delta, \ldots)\)
  – Mesons
  – Discover symmetries:
    * Baryon number: exactly conserved
    * “Strangeness” broken by weak interactions only
    * Flavor SU(2) (“isospin”) and SU(3). Somewhat broken (later understood to be by quark masses)
• Initial idea: particles and fields are in one-to-one correspondence
• Later: quark model: \(u, d\) and \(s\) flavors, spin 1/2
• Success: magnetic moments of proton and neutron

Getting uniquely to quantum chromodynamics (QCD)

• Problem of quark statistics (e.g., \(\Delta^{++}\), symmetric \(uuu\))
• Suggestion: “quark statistics” (para-fermions of rank 3+ . . . )
• Current algebra and broken chiral symmetry.
• Deep-inelastic scattering and parton model
• Fritzsch and Gell–Mann (1972) [hep-ph/0208010]:
  – SU(3) “color” group
  – observed states are color singlet
  – suggests Yang–Mills theory of quarks and gluons
• Then Gross & Wilczek and Politzer (1973): asymptotic freedom
• Resulting theory is QCD
• Combines with Weinberg-Salam theory easily to give Standard Model
• Need representation theory of SU(3) to understand all this
Symmetries, conservation laws in Standard Model and QCD

- Residual unbroken gauge symmetry $U(1)_{\text{em}} \otimes SU(3)_{\text{color}}$
- Baryon number, lepton number conservation
- Separate lepton numbers, $L_e, L_\mu, L_\tau$ if neutrinos massless
- Separate quark numbers ($u, d, s$, etc) in QCD + QED
- Flavor SU(2) and flavor SU(3) of QCD are broken by unequal masses of the $u, d, s$ quarks
- Chiral SU(2) $\otimes$ SU(2) broken by non-zero $m_u, m_d$
- $P, C, T$ separately symmetries of QCD + QED, but not of rest of SM.
- $CP$ and $T$ almost exact.