QCD

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Master-level course

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Introduction

$$\mathcal{L}_{QCD} = \sum_{i=1}^{f} \bar{\psi}_i (i\not{D} - m_i)\psi_i - \frac{1}{2}\mathrm{tr}\left[G_{\mu\nu}G^{\mu\nu}\right] + \theta\frac{g^2}{16\pi^2}\mathrm{tr}\left[G_{\mu\nu}\tilde{G}^{\mu\nu}\right]$$

$D_\mu = \partial_\mu - igA_\mu$ — matrix! $N_c \times N_c$

N_c: colors...

f: flavors

ψ_i: vector of N_c fermion fields

$G_{\mu\nu} = \frac{i}{g}[D_\mu, D_\nu]$

θ-term breaks P, T, CP

$\tilde{G}^{\mu\nu} = \frac{1}{2}\varepsilon^{\mu\nu\rho\sigma}G_{\rho\sigma}$

* The "crown jewel" of the SM...
* A model for a theory of everything?
  - Beautiful, simple structure
  - few parameters

- well defined up to arbitrarily high energies! ("Asymptotic freedom")

* Interesting low-E dynamics

  - Strong coupling, colour confinement: color-neutral hadrons, instead of quark & gluon states! "$E = mc^2$"

    Remarkable that QCD was discovered!
    "The correct theory will not be found in the next 100 years!" Dyson 1960

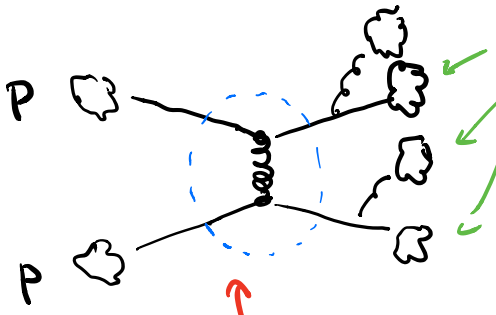
    ⇝ Nonperturbative

    ⇝ Lattice QCD

  - Spontaneous breaking of (approximate) chiral symmetry. $\pi^\pm, \pi^0$ are (pseudo-) Goldstone bosons.

⇝ CHPT (chiral perturbation theory)

* Complicated scattering dynamics



hadrons

nonperturbative

...

Interplay of long- & short-distance physics

short-distance reaction, perturbative

no factorization

SCET

(soft collinear effective theory