Physics in Ξ_c - baryon

문태진

2017-02-08

Why?

- Why baryon with heavy quark, i.e. heavy baryon?
- Why charmed quark?
- Why Ξ - baryon?

Perturbation

$$\mathcal{L}_{\mathrm{QCD}} = \bar{\psi}_i \left(i(\gamma^\mu D_\mu)_{ij} - m\,\delta_{ij} \right) \psi_j - \frac{1}{4} G^a_{\mu\nu} G_a^{\mu\nu}$$

QCD Lagrangian

- Quantum process를 loop expansion (Feynman diagram)한 후 각 loop에서 계산된 값을 더하게 된다.

$$\boxed{\Gamma = \hbar^{-1} \times \text{0-loop} + \hbar^{0} \times \text{1-loop} + \hbar^{1} \times \text{2-loop} + \cdots}$$

- Each term in the Γ expansion has an additional power of coupling constant, α.

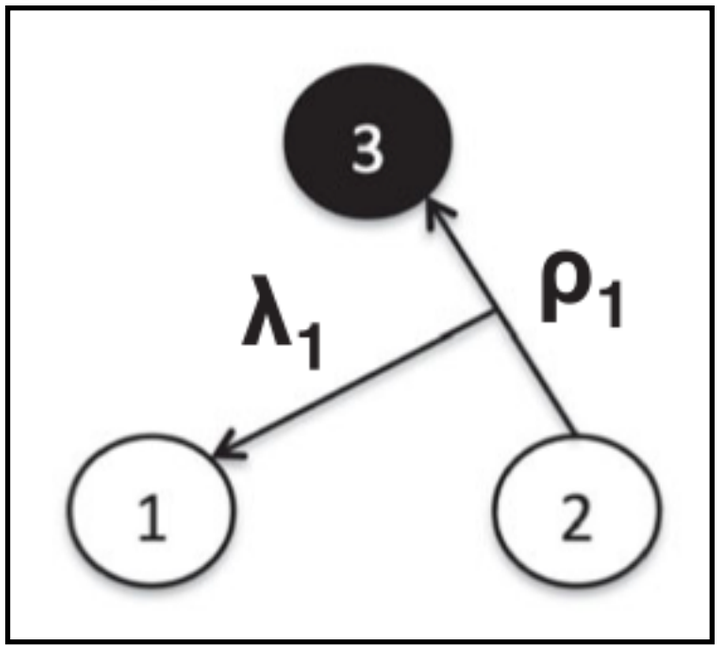
Coupling Constant

- QED
  - $\alpha \sim 1/137 \sim 0.007$
- QCD
  - $\alpha \rightarrow 0.1$ as $E \sim 100\text{GeV}$
    - **perturbative**, asymptotic freedom, ultraviolet regime
  - $\alpha > 1$ when $E \sim \Lambda_{QCD}$ (217MeV)
    - **non-perturbative**, confinement, infrared regime

QCD

- Perturbative
  - 이 경우도 계산이 간단하지 않음. (QED와 비교하였을때)
- Non-perturbative
  - 1st principle에서 출발하기 보다 phenomenological.
  - Effective theory에 의존할 수 밖에 없음.

Example
- Three Body Problem -



- Harmonic Oscillator

$$H = \sum_i \frac{\boldsymbol{p}_i^2}{2m_i} + \sum_{i<j} \frac{k}{2} |\boldsymbol{r}_i - \boldsymbol{r}_j|^2$$

$$= \frac{\boldsymbol{p}_\rho^2}{2m_\rho} + \frac{\boldsymbol{p}_\lambda^2}{2m_\lambda} + \frac{m_\rho \omega_\rho{}^2}{2}\boldsymbol{\rho}^2 + \frac{m_\lambda \omega_\lambda{}^2}{2}\boldsymbol{\lambda}^2$$

- More complicated potential

$$H = K + V_{\text{con}} + V_{\text{short}}$$

$$K = \sum_i \left(m_i + \frac{\boldsymbol{p}^2{}_i}{2m_i} \right) - K_G$$

$$V_{\text{con}} = \sum_{i<j} \frac{b r_{ij}}{2} + C$$

$$V_{\text{short}} = \sum_{i<j} \Bigg[-\frac{2\alpha^{\text{Coul}}}{3r_{ij}} + \frac{16\pi\alpha^{\text{ss}}}{9m_i m_j} \boldsymbol{s}_i \cdot \boldsymbol{s}_j \frac{\Lambda^2}{4\pi r_{ij}} \exp(-\Lambda r_{ij}) + \frac{\alpha^{\text{so}}(1-\exp(-\Lambda r_{ij}))^2}{3r_{ij}{}^3}$$
$$\times \left[\left(\frac{1}{m_i^2} + \frac{1}{m_j^2} + 4\frac{1}{m_i m_j} \right) \boldsymbol{L}_{ij} \cdot (\boldsymbol{s}_i + \boldsymbol{s}_j) + \left(\frac{1}{m_i^2} - \frac{1}{m_j^2} \right) \boldsymbol{L}_{ij} \cdot (\boldsymbol{s}_i - \boldsymbol{s}_j) \right]$$
$$+ \frac{2\alpha^{\text{ten}}(1-\exp(-\Lambda r_{ij}))^2}{3m_i m_j r_{ij}{}^3} \left(\frac{3(\boldsymbol{s}_i \cdot \boldsymbol{r}_{ij})(\boldsymbol{s}_j \cdot \boldsymbol{r}_{ij})}{r_{ij}{}^2} - \boldsymbol{s}_i \cdot \boldsymbol{s}_j \right) \Bigg].$$

Why charmed quark?

- Lightest heavy quark!!
- Heavy Quark Symmetry
  - qqQ로 이루어진 heavy baryon의 spectrum이 Q의 flavor에 independent

Why Ξ-baryon?

- Charmed Baryon: s → c
- S=-1: Σ^+(uus), Σ^0(uds), Σ^-(dds), Λ(uds)
- S=-2: Ξ^0(uss), Ξ^-(dss)
- S=-3: Ω^-(sss)
- ex) Ω^-(sss) → ssc, scs, css가 적당히 symmetrized된 총 3개의 Ω_c^0 state들이 존재.