Phenomenology of spin-orbit potential for charmonium.

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29 de noviembre de 2021

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Abstract.

- A simple exploration to the physics of charmonium, i.e., mesonic states which are not simply charm - anticharm configurations.
- A review of the states for the potential Spin-Orbit, $\mathbf{V}_{L,S}$. It is described phenomenologically for charmonium. The description extended to spin-dependent interactions to be added to the nonrelativistic interaction.

Introduction.

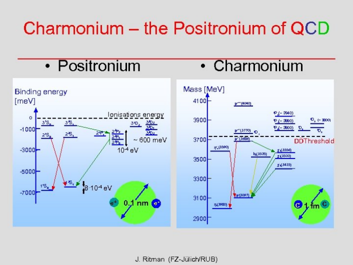
- In 1974, an unusual resonance found simultaneously at BNL [1] and at SLAC [2].
- The new J/Ψ resonance was the first to have been observed state of a system containing previously unknown (but anticipated) charmed quark and its antiquark: $c\bar{c}$.
- The new system, charmonium, was expected to contain a spectrum of resonances, corresponding to various excitations of the heavy quark pair.

BNL and SLAC.

Picture of `https://www6.slac.stanford.edu/about`.

Introduction.

- The newly found system was, in a way, the simplest object for a study of the strong interactions.
- The development of many methods in QCD is directly related to analyses of the properties of charmonium and of its heavier sibling bottomonium.



Charmonium.

Picture of `https://present5.com/precision-spectroscopy`.

Spin-orbit potential.

The potential description extended to spin-dependent interactions results in three types of interaction terms that are to be added to the discussed leading nonrelativistic interaction:

$$\begin{aligned} V_1(r) &= V_{L,S}(r)(\vec{L}\cdot\vec{S}) + V_T(r)\left[S(S+1) - 3\frac{3(\vec{S}\cdot\vec{r})(\vec{S}\cdot\vec{r})}{r^2}\right] \\ &+ V_{SS}(r)\left[S(S+1) - \frac{3}{2}\right] \end{aligned} \tag{1}$$

Spin-orbit potential.

The interaction in Eq. (1) arises among the v^2/c^2 effects in the nonrelativistic expansion and it generally requires additional model-dependent assumptions about the structure of the interquark forces.
The spin-dependent terms in Eq. (1) can be written in terms of the vector, $V_V(r)$, and scalar, $V_S(r)$, parts of the static potential by the standard Breit–Fermi expansion to order v^2/c^2:

$$\begin{aligned} V_{L,S} &= \frac{1}{2m_c^2 r}\left(3\frac{dV_V}{dr} - \frac{dV_S}{dr}\right), \\ V_T &= \frac{1}{6m_c^2}\left(\frac{d^2V_V}{dr^2} - \frac{1}{r}\frac{dV_V}{dr}\right), \\ V_{SS} &= \frac{1}{3m_c^2}\Delta V_V, \end{aligned} \tag{2}$$

con $\Delta = \nabla^2$.

Bibliografía

1 J.J. Aubert, et al., Phys. Rev. Lett. 33 (1974) 1404.

2 J.E. Augustin, et al., Phys. Rev. Lett. 33 (1974) 1406.

3 M.B. Voloshin / Progress in Particle and Nuclear Physics 61 (2008) 455–511.

Thanks! :)