Decay Widths of X(1835) as $\overline{N}N$ Bound State

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- Interpretations of $X(1835)$
- Two-Body Decays of $X(1835)$ as $\overline{N}N$ Bound State
- $X(1835)$ to $\eta\pi\pi$ and $\eta'\pi\pi$
- Remark

Interpretations of $X(1835)$

BES Collaboration (PRL91:022001):
$J/\psi \to \gamma X$, $X \to \overline{p}p$

Decay Modes	$J^{PC}(X)$	l between γ and X
$\gamma X(^1S_0)$	0^{-+}	1
$\gamma X(^3P_0)$	0^{++}	0
$\gamma X(^3P_1)$	1^{++}	0

Interpretations of $X(1835)$

BES Collaboration (PRL95:262001):
$J/\psi \to \gamma X$, $X \to \pi^+\pi^-\eta'$

$$\Downarrow$$

- $I^G(X) = 0^+$
- $I^G(J^{PC}(X)) = 0^+(0^{-+})$, ($\pi^+$, π^- and η produced in relative S wave
- X likely $^{11}S_0$

Interpretations of $X(1835)$

- $\overline{N}N$ bound state: arXiv:1006.2000, PRC80:045207, JPG36:055004, JPG34:505, CTP46:291
- Baryonium with sizable gluon content: EPJA28:351
- η' second radial excitation: PRD73:014023
- Glueball: PRD74:034019, EPJC49:731
- η_c - glueball: PRD72:097502, PLB633:283

Two-Body Decays of $X(1835)$ as $\overline{N}N$ Bound State

$$T_{X\to M_1M_2} = \langle M_1M_2|V(^3P_0)|\overline{N}N\rangle\langle\overline{N}N|X\rangle$$
$$= \int \frac{d\vec{p}}{(2\pi)^{3/2}}\ \Phi_X(\vec{p})\ T_{\overline{N}N\to M_1M_2}(\vec{p},\vec{k}) \qquad (1)$$

$$\int \frac{dp^3}{(2\pi)^3}|\Phi_X(\vec{p})|^2 = 1 \qquad (2)$$

At zero momentum approximation

$$T_{X\to M_1M_2} = \Psi_X(0)\ T_{\overline{N}N\to M_1M_2}(0,\vec{k}) \qquad (3)$$

$\Psi_X(0)$: r-space wave function at origin.

Two-Body Decays of $X(1835)$ as $\overline{N}N$ Bound State

Partial decay widths normalized to $\omega\omega$ channel for a $^{11}S_0$ $X(1835)$ in $^3P_0$ model, with baryon size parameter being 2.0 GeV^{-1} and meson size parameter being 2.5 GeV^{-1}

- $\rho\rho$: 3.1
- $a_0(890)\pi$: 5.5×10^{-2}
- $\eta f_0(600)$: 1.3×10^{-2}
- $\eta f_0(980)$: 2.1×10^{-4}
- $\eta' f_0(600)$: 4.8×10^{-3}

η and η' Mixing

$$\begin{aligned} |\eta'\rangle &= \cos\theta_g \left(\sin\theta_q |\eta_n\rangle + \cos\theta_q |\eta_s\rangle\right) + \sin\theta_g |\eta_g\rangle \\ |\eta\rangle &= \cos\theta_q |\eta_n\rangle - \sin\theta_q |\eta_s\rangle \end{aligned} \quad (4)$$

in the base

$$\begin{aligned} |\eta_n\rangle &= \frac{1}{\sqrt{2}}\left(|u\overline{u}\rangle + |d\overline{d}\rangle\right), \\ |\eta_s\rangle &= |s\overline{s}\rangle, \\ |\eta_g\rangle &= |\text{gluonium}\rangle \end{aligned} \quad (5)$$

with $\theta_q = (40.4 \pm 0.6)^o$ and $\sin^2\theta_g = 0.12 \pm 0.04$ (JHEP0907:105).

$X(1835)$ to $\eta\pi\pi$ and $\eta'\pi\pi$

$$\frac{T(X \to a_0(890)\pi)}{T(X \to \eta f_0(600)\pi)} = -\sqrt{3} \tag{6}$$

Remark

The work has not been completed

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