Is 2^{-+} for X(3872) compatible with radiative transition data?

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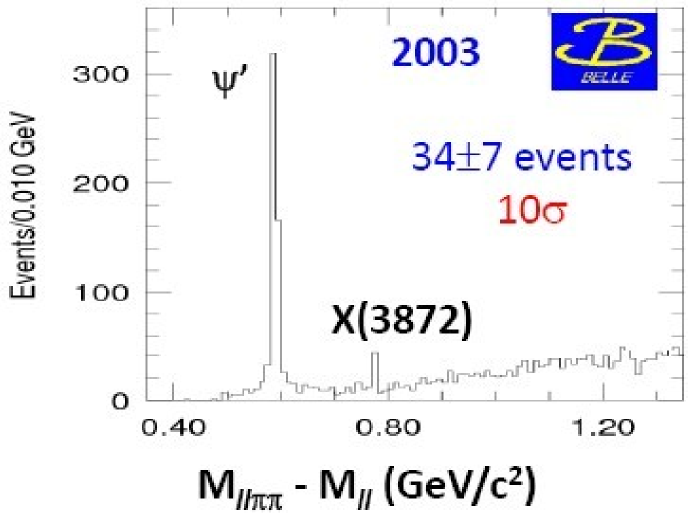
Outline

- Introduction and motivation
- Charmonium $^1D_2$ decay width in pNRQCD
- Results and discussions
- Summary

Introduction and Motivation

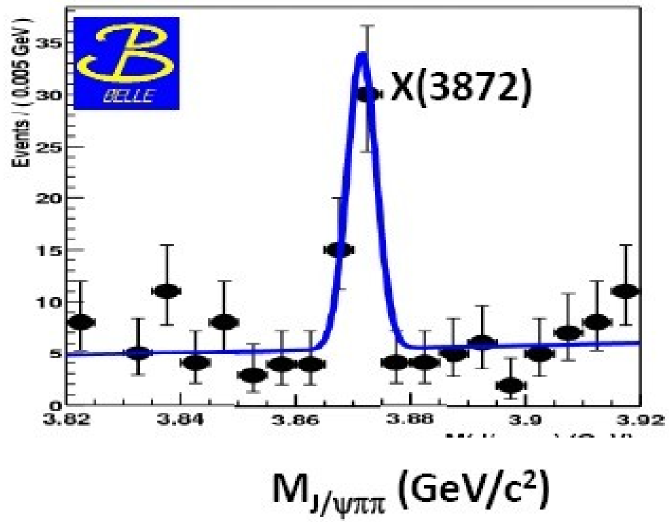
2003 Belle observed X(3872)

Discovered by Belle in $J/\psi\pi\pi$ decay mode PRL 91,262001(2003)

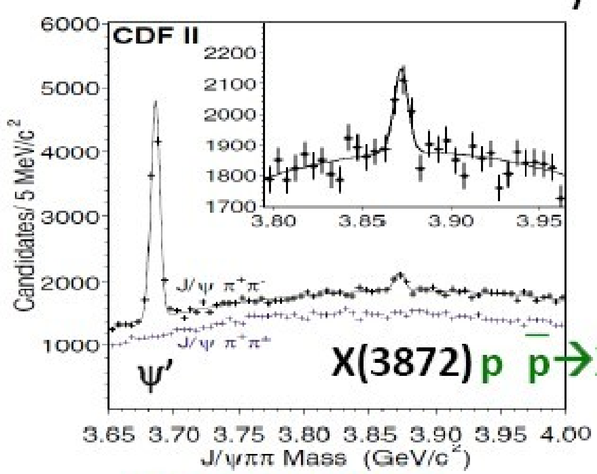


$B^+ \to X(3872)\,K^+$,
$X(3872) \to J/\psi\pi^+\pi^-$

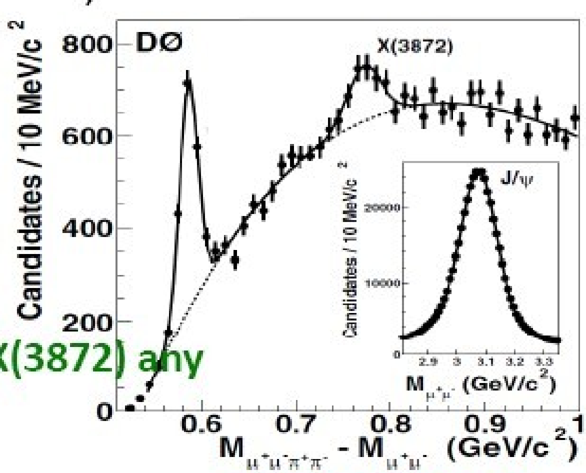
$\Gamma < 2.3$ MeV
(90%CL)

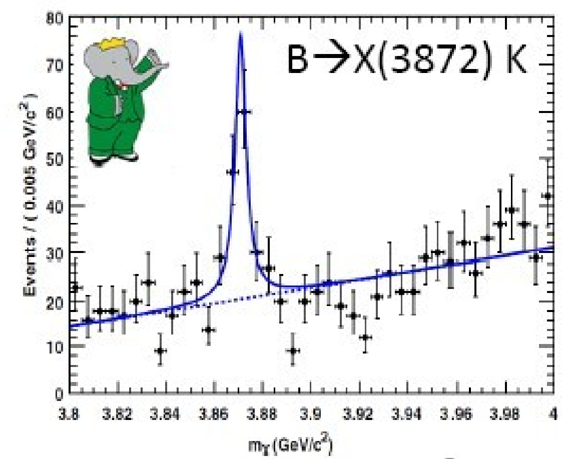


Soon confirmed by CDF, DO & BaBar



X(3872) $p\bar{p} \to X(3872)$ any





PRL 93,072001(2004) PRL 93,162002(2004) PRD 71,071103(2005)

X(3872) is an interesting particle

- Its mass is nearly at the $D^0\,\bar{D}^{*0}$ threshold

X(3872) found in $J/\psi\pi\pi$,

similar to ψ'

Another charmonium ?

World average mass → 3871.5 ± 0.2 MeV/c^2

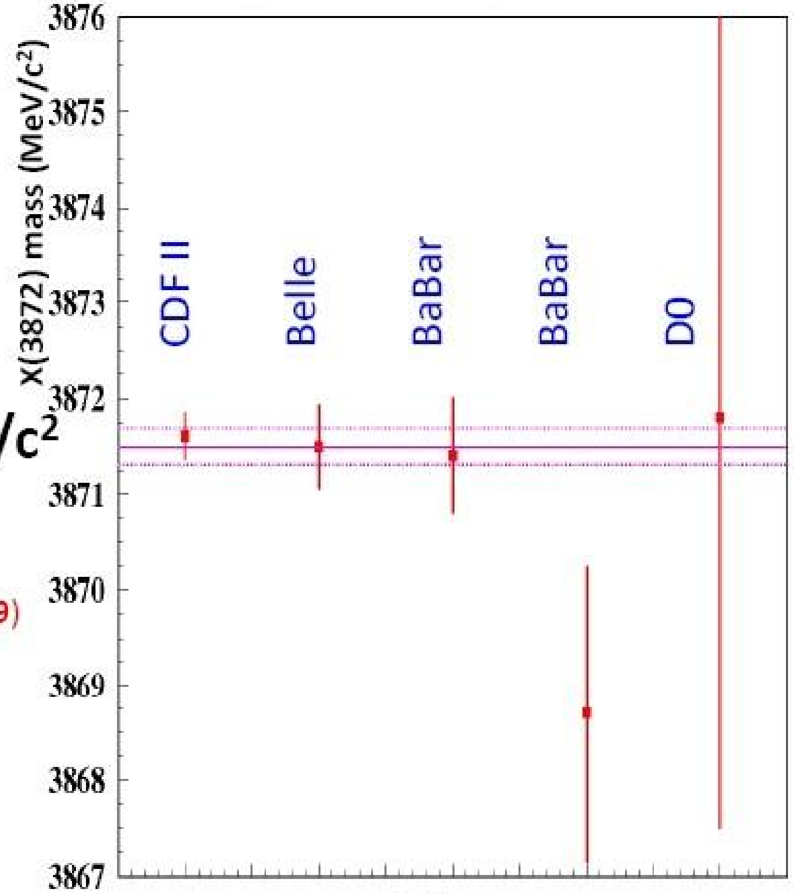
$X(3872) \rightarrow J/\psi\pi\pi$

CDF II $3871.61 \pm 0.16 \pm 0.19$

PRL, 103, 152001 (2009)

Belle $3871.50 \pm 0.40 \pm 0.19$

arXiv:0809.1224



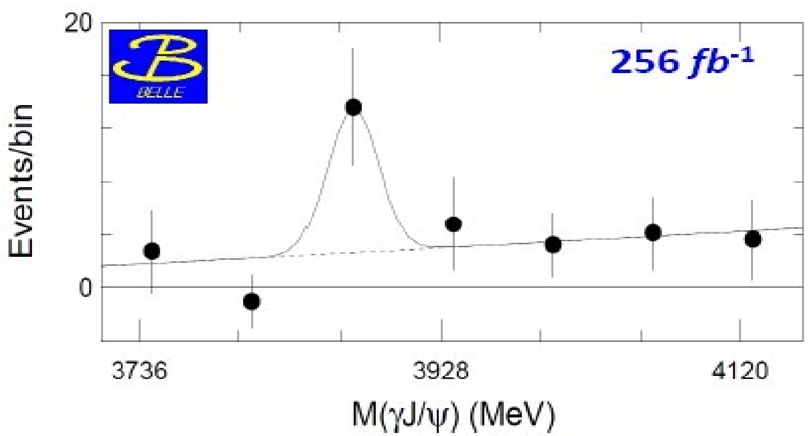
Mass near D^0 and $\bar{D}^{*0}$ threshold → 3871.8 ± 0.4 MeV/c^2 PDG

- X(3872) has much narrower decay width (Γ< 2.3 MeV @ 90% CL) than other charmonium states above $D^0 \bar{D}^{*0}$ threshold. (BELLE PRL 2003)

- Strong evidence for large isospin violation in its decay pattern. (CDF PRL 2006)

J^{PC} of X(3872)

The even C-parity has been established.



Belle found evidence for $X(3872) \rightarrow J/\psi\gamma$ in $B^+ \rightarrow X(3872)\, K^+$ decay mode

arXiv:0505037

13.6±4.4 events

$$\mathcal{BR}(B^+ \rightarrow XK^+) \cdot \mathcal{BR}(X \rightarrow J/\psi\gamma) = (1.8 \pm 0.6 \pm 0.1) \times 10^{-6}$$

+ve C parity

Confirmed by BaBar

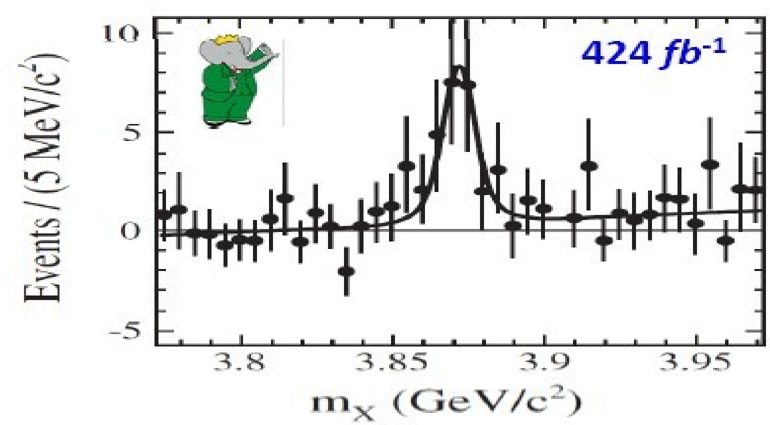
PRD 74, 071101 (2006)

Recent update

23.0±6.4 events

$$\mathcal{BR}(B^+ \rightarrow XK^+) \cdot \mathcal{BR}(X \rightarrow J/\psi\gamma) = (2.8 \pm 0.8 \pm 0.1) \times 10^{-6}$$

PRL 102, 132001 (2009)



Results of CDF

J^P of X(3872) has been narrowed down to 1^+ or 2^-.

CDF PRL (2007)

TABLE I. Result of the $X(3872)$ particle angular analysis. Listed are the state, the decay mode, the L and S quantum numbers of the J/ψ-$(\pi^+\pi^-)$ system, the χ^2 with 11 degrees of freedom and the χ^2 probability.

J^{PC}	decay	LS	χ^2 (11 d.o.f.)	χ^2 prob.
1^{++}	$J/\psi\rho^0$	01	13.2	0.28
2^{-+}	$J/\psi\rho^0$	11,12	13.6	0.26
1^{--}	$J/\psi(\pi\pi)_S$	01	35.1	2.4×10^{-4}
2^{+-}	$J/\psi(\pi\pi)_S$	11	38.9	5.5×10^{-5}
1^{+-}	$J/\psi(\pi\pi)_S$	11	39.8	3.8×10^{-5}
2^{--}	$J/\psi(\pi\pi)_S$	21	39.8	3.8×10^{-5}
3^{+-}	$J/\psi(\pi\pi)_S$	31	39.8	3.8×10^{-5}
3^{--}	$J/\psi(\pi\pi)_S$	21	41.0	2.4×10^{-5}
2^{++}	$J/\psi\rho^0$	02	43.0	1.1×10^{-5}
1^{-+}	$J/\psi\rho^0$	10,11,12	45.4	4.1×10^{-6}
0^{-+}	$J/\psi\rho^0$	11	104	3.5×10^{-17}
0^{+-}	$J/\psi(\pi\pi)_S$	11	129	$\leq 1 \times 10^{-20}$
0^{++}	$J/\psi\rho^0$	00	163	$\leq 1 \times 10^{-20}$

Interpretations

- S wave $D^0 \bar{D}^{*0}$ Molecule

Close, Page PLB (2004) Voloshin PLB (2004)

Braaten, Kusunoki PRD (2004) Tornqvist PLB (2004)

Swanson PLB (2004), etc.

- Tetra quark

Maiani, Piccinini, Polosa, Riquer PRD (2005)

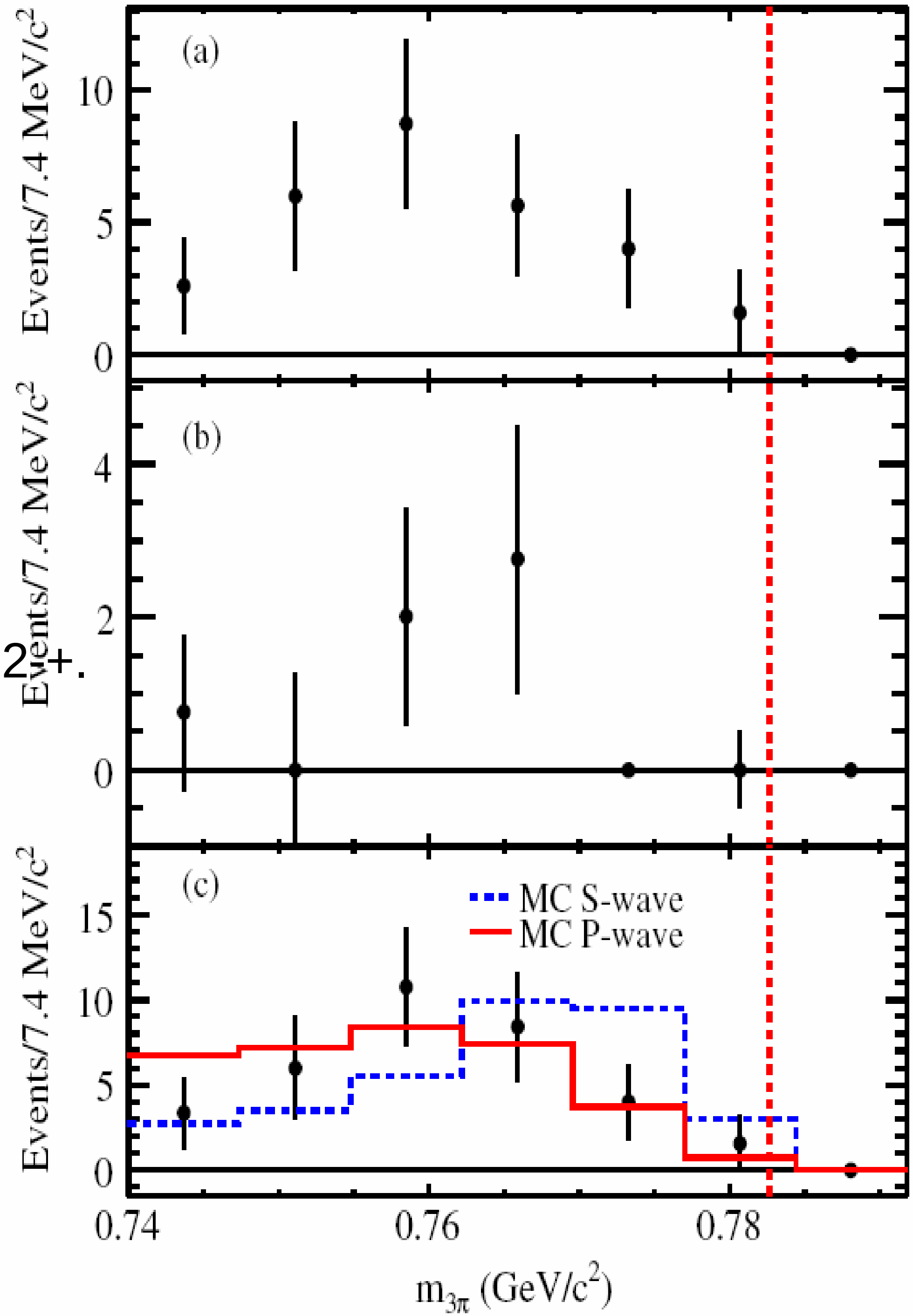
- Hybrid

B. A. Li PLB (2005)

However, very recently experiment analysis by BABAR indicates that the J^{PC} of X(3872) would more favor 2^{-+} rather than 1^{++} .

BABAR PRD (2010)

$$X \to J/\psi\omega$$



motivation

One of strongest objection of $^1D_2$ assignment for X(3872) is perhaps from it radiative transitions to J/ψ and ψ' . Such parity-conserving transitions flip the quark spin and change the orbital angular momentum by two units, so there must be strong multipole suppression which usually corresponds a rather small branching fraction.

- BABAR have given the following results:

BABAR PRL (2009)

$$\mathcal{B}[B^{\pm} \to X(3872)K^{\pm}]\,\mathcal{B}[X(3872) \to J/\psi + \gamma] = (2.8 \pm 0.8 \pm 0.1) \times 10^{-6},$$
$$\mathcal{B}[B^{\pm} \to X(3872)K^{\pm}]\,\mathcal{B}[X(3872) \to \psi' + \gamma] = (9.5 \pm 2.7 \pm 0.6) \times 10^{-6},$$

From this data we can deduce:

$$\frac{\mathcal{B}[X(3872) \to \psi' + \gamma]}{\mathcal{B}[X(3872) \to J/\psi + \gamma]} = 3.4 \pm 1.4.$$

BABAR also have given the data:

$$\mathcal{B}[B^{\pm} \to X(3872)K^{\pm}] < 3.2 \times 10^{-4},$$ 90% CL

BABAR PRL (2006)

Combining this inequality and the former equality, we can deduce:

$$\mathcal{B}[X(3872) \to J/\psi + \gamma] > 5.9 \times 10^{-3}, \quad \mathcal{B}[X(3872) \to \psi' + \gamma] > 1.9 \times 10^{-2},$$

If the J^{PC} of X(3872) is 2^{-+}, then the most natural candidate for X(3872) would be η_{c2} ($^1D_2$) meson.

So a study for the radiative transition processes $\eta_{c2} \rightarrow J/\psi(\psi') + \gamma$ is necessary.

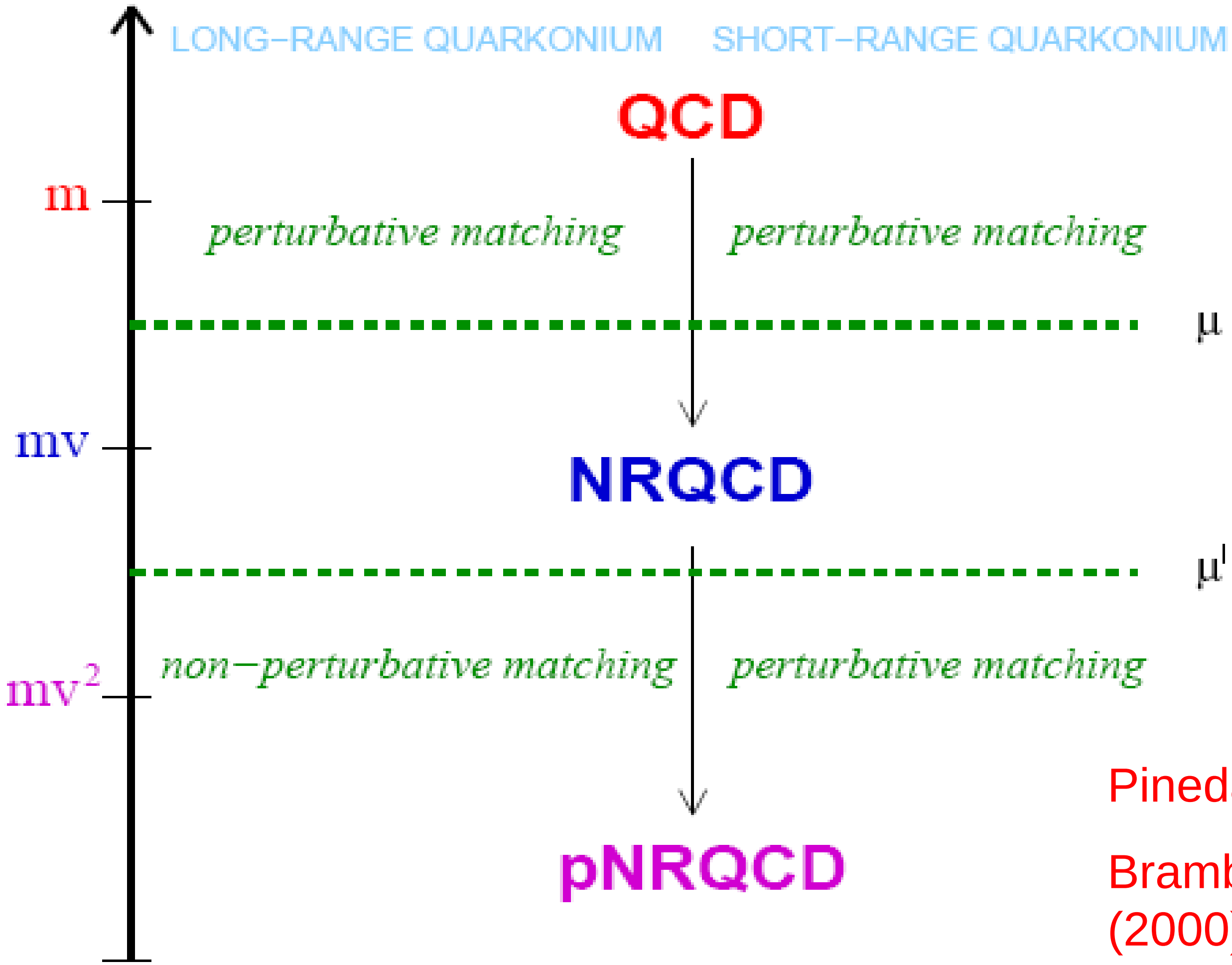
Charmonium $^1D_2$ Decay Width in potential NRQCD (pNRQCD)

Dynamical scales in quarkonium

- Labelle (1997), Pineda and Soto (1998)
- Beneke and Smirnov (1998), and among many others

- hard: $p^{\mu} \sim O(m)$
- soft: $p^{\mu} \sim O(m\,v)$
- potential: $p^{0} \sim O(m\,v^{2})$, $p^{i} \sim O(m\,v)$
- ultra-soft: $p^{\mu} \sim O(m\,v^{2})$

Introduction for pNRQCD



Caswell & Lepage (1986)

Bodwin, Braaten, Lepage (1994)

Pineda, Soto (1998)

Brambilla, Pineda, Soto, Vairo (2000)

NRQCD Lagrangian with $SU(3)_c \times U(1)_{em}$ gauge group

$$\mathcal{L}_{\rm NRQCD} = \psi^\dagger \left(iD_0 + \frac{\mathbf{D}^2}{2m} \right) \psi + \frac{c_F}{2m} \psi^\dagger \boldsymbol{\sigma} \cdot g\mathbf{B} \psi - \frac{c_s}{8m^2} \psi^\dagger \boldsymbol{\sigma} \cdot [-i\mathbf{D}\times, g\mathbf{E}] \psi$$
$$+ \frac{c_F^{\rm em}}{2m} \psi^\dagger \boldsymbol{\sigma} \cdot e e_Q \mathbf{B}^{\rm em} \psi - \frac{c_S^{\rm em}}{8m^2} \psi^\dagger \boldsymbol{\sigma} \cdot [-i\mathbf{D}\times, e e_Q \mathbf{E}^{\rm em}] \psi$$
$$+ \frac{c_{W1}^{\rm em}}{8m^3} \psi^\dagger \{\mathbf{D}^2, \boldsymbol{\sigma} \cdot e e_Q \mathbf{B}^{\rm em}\} \psi - \frac{c_{W2}^{\rm em}}{4m^3} \psi^\dagger \mathbf{D}^i \boldsymbol{\sigma} \cdot e e_Q \mathbf{B}^{\rm em} \mathbf{D}^i \psi$$
$$+ \frac{c_{p'p}^{\rm em}}{8m^3} \psi^\dagger \left(\boldsymbol{\sigma} \cdot \mathbf{D}\; e e_Q \mathbf{B}^{\rm em} \cdot \mathbf{D} + \mathbf{D} \cdot e e_Q \mathbf{B}^{\rm em}\; \boldsymbol{\sigma} \cdot \mathbf{D} \right) \psi$$
$$+ [\psi \to i\sigma^2 \chi^*, A_\mu \to -A_\mu^T, A_\mu^{\rm em} \to -A_\mu^{\rm em}]$$
$$+ \mathcal{L}_{\rm light} \,,$$

$$c_S^{\rm em} = 2c_F^{\rm em} - 1, \qquad c_{W12}^{\rm em} \equiv c_{W1}^{\rm em} - c_{W2}^{\rm em} = 1, \qquad c_{p'p}^{\rm em} = c_F^{\rm em} - 1.$$

$$c_F^{\rm em} \equiv 1 + \kappa_Q^{\rm em} = 1 + \frac{4}{3}\frac{\alpha_s}{2\pi} + \mathcal{O}(\alpha_s^2)$$

Reparameterization inv.

Manohar (1997)

Proceeds to pNRQCD

- Both the photon and dynamical gluons have ultrasoft momentum, $k^{\mu} \sim m v^{2}$,
- In radiative transition the wavelength of photon is much larger than the radius of the quarkonium so the EM field need be multipole-expanded.
- pNRQCD is the ideal formalism to deal with the radiative transition in quarkonium.
- Very similar to standard multipole expansion in quantum mechanics.

pNRQCD Lagrangian density with $SU(3)_c x U(1)_{em}$ gauge group

Brambilla, Jia and Vairo (2005)

$$\mathcal{L}_{\rm pNRQCD} = \int d^3r \; {\rm Tr}\left\{ {\rm S}^\dagger \left(i\partial_0 + \frac{\boldsymbol{\nabla}_R^2}{4m} + \frac{\boldsymbol{\nabla}_r^2}{m} - V_S^{(0)}(r) \right) {\rm S} \right\} + \mathcal{L}_{\rm light} + \mathcal{L}_{\gamma\,\rm pNRQCD}$$

$$\begin{aligned}
\mathcal{L}_{\gamma\,\rm pNRQCD} = \int d^3r \; {\rm Tr}\Bigg\{ & ee_Q {\rm S}^\dagger \mathbf{r}\cdot\mathbf{E}^{\rm em}{\rm S} + \frac{c_F^{\rm em} ee_Q}{2m} \left\{{\rm S}^\dagger, \boldsymbol{\sigma}\cdot\mathbf{B}^{\rm em}\right\}{\rm S} \\
& + \frac{c_F^{\rm em} ee_Q}{16m} \left\{{\rm S}^\dagger, \boldsymbol{\sigma}\cdot(\mathbf{r}\cdot\boldsymbol{\nabla}_R)^2\mathbf{B}^{\rm em}\right\}{\rm S} + \frac{ee_Q}{8m^2}\, rV_S^{(0)\prime} \left\{{\rm S}^\dagger, \boldsymbol{\sigma}\cdot\hat{\mathbf{r}}\times(\hat{\mathbf{r}}\times\mathbf{B}^{\rm em})\right\}{\rm S} \\
& - \frac{c_S^{\rm em} ee_Q}{16m^2} \left[{\rm S}^\dagger, \boldsymbol{\sigma}\cdot\left[-i\boldsymbol{\nabla}_R\times, \mathbf{E}^{\rm em}\right]\right]{\rm S} - \frac{c_S^{\rm em} ee_Q}{16m^2} \left[{\rm S}^\dagger, \boldsymbol{\sigma}\cdot\left[-i\boldsymbol{\nabla}_r\times, \mathbf{r}^i(\boldsymbol{\nabla}_R^i\mathbf{E}^{\rm em})\right]\right]{\rm S} \\
& + \frac{c_{W12}^{\rm em} ee_Q}{4m^3} \left\{{\rm S}^\dagger, \boldsymbol{\sigma}\cdot\mathbf{B}^{\rm em}\right\}\boldsymbol{\nabla}_r^2{\rm S} + \frac{c_{p'p}^{\rm em} ee_Q}{4m^3} \left\{{\rm S}^\dagger, \boldsymbol{\sigma}^i\,\mathbf{B}^{{\rm em}\,j}\right\}\boldsymbol{\nabla}_r^i\boldsymbol{\nabla}_r^j{\rm S} \Bigg\}
\end{aligned}$$

Vacuum to quarkonium pNRQCD matrix elements

$$\langle 0|S(\mathbf{R},\mathbf{r})|n^3S_1(\mathbf{P},\lambda)\rangle = \frac{1}{\sqrt{4\pi}} R_{n0}(r) \frac{\boldsymbol{\sigma}\cdot\mathbf{e}_{n^3S_1}(\lambda)}{\sqrt{2}} e^{i\mathbf{P}\cdot\mathbf{R}},$$

$$\langle 0|S(\mathbf{R},\mathbf{r})|n^1P_1(\mathbf{P},\lambda)\rangle = \sqrt{\frac{3}{4\pi}} R_{n1}(r) \frac{\mathbf{e}_{n^1P_1}(\lambda)\cdot\hat{\mathbf{r}}}{\sqrt{2}} e^{i\mathbf{P}\cdot\mathbf{R}},$$

$$\langle 0|S(\mathbf{R},\mathbf{r})|n^1D_2(\mathbf{P},\lambda)\rangle = \sqrt{\frac{15}{8\pi}} R_{n2}(r) \frac{\hat{r}^i\, h^{ij}_{n^1D_2}(\lambda)\, \hat{r}^j}{\sqrt{2}} e^{i\mathbf{P}\cdot\mathbf{R}},$$

$$\langle 0|S(\mathbf{R},\mathbf{r})|n^3D_1(\mathbf{P},\lambda)\rangle = \frac{3}{\sqrt{8\pi}} R_{n2}(r) \frac{\mathbf{e}(\lambda)\cdot\hat{\mathbf{r}}\boldsymbol{\sigma}\cdot\hat{\mathbf{r}} - \frac{1}{3}\mathbf{e}(\lambda)\cdot\boldsymbol{\sigma}}{\sqrt{2}} e^{i\mathbf{P}\cdot\mathbf{R}},$$

ψ' may not be a pure S-wave vector charmonium that maybe have some admixture of $^3D_1$ component :

$$|\psi'\rangle \;=\; \cos\phi|2^3S_1\rangle - \sin\phi|1^3D_1\rangle$$

Rosner PRD (2001)

Usually with ϕ taken to be around 12° .

Transition amplitude

$$\mathcal{M}[{}^1D_2 \to {}^3S_1 + \gamma] = \frac{ee_Q}{2m_Q}\sqrt{\frac{2}{15}}\left\{\frac{\mathbf{e}^* \cdot \mathbf{k} \times \varepsilon_\gamma^* \, k^i h^{ij} k^j}{|\mathbf{k}|^2} c_F^{\rm em} J_1 + k^i h^{ij} \left(\mathbf{e}^* \times \varepsilon_\gamma^*\right)^j \left(c_S^{\rm em} - 1\right) J_2 + e^{*i} h^{ij} \left(\mathbf{k} \times \varepsilon_\gamma^*\right)^j \left(J_2 + J_4 - c_{p'p}^{\rm em} J_3\right)\right\}$$

$$\mathcal{M}[{}^1D_2 \to {}^3D_1 + \gamma] = \frac{ee_Q}{2m_Q}\frac{6}{\sqrt{15}} e^{*i} h^{ij} \left(\mathbf{k} \times \varepsilon_\gamma^*\right)^j c_F^{\rm em} J_0$$

$$J_0 = \int_0^\infty dr\, R_{^3D_1}(r) R_{^1D_2}(r)\, r^2,$$

$$J_1 = -\frac{|\mathbf{k}|^2}{4}\int_0^\infty dr\, R_{n^3S_1}(r) R_{^1D_2}(r)\, r^4,$$

$$J_2 = \frac{|\mathbf{k}|}{2m_Q}\int_0^\infty dr\, R'_{n^3S_1}(r) R_{^1D_2}(r)\, r^3,$$

$$J_3 = -\frac{1}{m_Q^2}\int_0^\infty dr\, \left(R''_{n^3S_1}(r) - \frac{R'_{n^3S_1}(r)}{r}\right) R_{^1D_2}(r)\, r^2,$$

$$J_4 = \frac{1}{2m_Q}\int_0^\infty dr\, R_{n^3S_1}(r) V_S^{(0)\prime}(r) R_{^1D_2}(r)\, r^3.$$

$$R'' + \frac{2}{r}R' + \left[m(E - V(r)) - \frac{l(l+1)}{r^2}\right] R = 0$$

R is the solution of radial schroedinger equation. And *V(r)* is potential determined by potential model.

Helicity and multipole amplitudes

$$A_0 \equiv A_{1,1} = -A_{-1,-1} = \frac{2c_F^{\rm em}J_1 - (2c_S - 1)J_2 + c_{p'p}^{\rm em}J_3 - J_4 + 3\sqrt{2}c_F^{\rm em}J_0 \sin\phi}{\sqrt{6}},$$

$$A_1 \equiv A_{0,1} = -A_{0,-1} = \frac{-c_S^{\rm em}J_2 + c_{p'p}^{\rm em}J_3 - J_4 + 3\sqrt{2}c_F^{\rm em}J_0 \sin\phi}{\sqrt{2}},$$

$$A_2 \equiv A_{-1,1} = -A_{1,-1} = -J_2 + c_{p'p}^{\rm em}J_3 - J_4 + 3\sqrt{2}c_F^{\rm em}J_0 \sin\phi,$$

The connection between helicity amplitude and multipole amplitude:

$$A_\nu = \sum_{J_\gamma} \sqrt{\frac{2J_\gamma + 1}{2J_{\eta_{c2}} + 1}}\, a_{J_\gamma} \langle J_\gamma, 1; 1, \nu - 1 | J_{\eta_{c2}}, \nu \rangle$$

Karl, Meshkov and Rosner: PRL (1980)

One can easily get the orthogonal transformation between helicity and multipole amplitudes

$$\begin{pmatrix} a_1 \\ a_2 \\ a_3 \end{pmatrix} = \begin{pmatrix} \frac{1}{\sqrt{10}} & \sqrt{\frac{3}{10}} & \sqrt{\frac{3}{5}} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{6}} & -\frac{1}{\sqrt{3}} \\ \sqrt{\frac{2}{5}} & -2\sqrt{\frac{2}{15}} & \frac{1}{\sqrt{15}} \end{pmatrix} \begin{pmatrix} A_0 \\ A_1 \\ A_2 \end{pmatrix},$$

And

$$\begin{aligned} a_1 &= \frac{2c_F^{\mathrm{em}} J_1 - 5(1 + c_S^{\mathrm{em}}) J_2 + 10 c_{p'p}^{\mathrm{em}} J_3 - 10 J_4 + 30\sqrt{2} c_F^{\mathrm{em}} J_0 \sin\phi}{2\sqrt{15}}, \\ a_2 &= \frac{2c_F^{\mathrm{em}} J_1 - 3(c_S^{\mathrm{em}} - 1) J_2}{2\sqrt{3}}, \\ a_3 &= \frac{2c_F^{\mathrm{em}} J_1}{\sqrt{15}}. \end{aligned}$$

a1, a2, a3 means M1, E2, M3 multipole amplitude respectively.

Decay Width

It's easy to get the decay width expression for the orthogonality between different helicity (multipole) amplitudes.

$$\Gamma[\eta_{c2} \to J/\psi(\psi') + \gamma] = \frac{2\alpha e_Q^2 |\mathbf{k}|^3}{75 m_c^2} \left(|A_0|^2 + |A_1|^2 + |A_2|^2 \right)$$

One also can express the decay width via multipole amplitudes:

$$\Gamma[\eta_{c2} \to J/\psi(\psi') + \gamma] = \frac{2\alpha e_Q^2 |\mathbf{k}|^3}{75 m_c^2} \left(|a_1|^2 + |a_2|^2 + |a_3|^2 \right)$$

Results and Discussions

Some input parameters

m_c=1.5 GeV, m($^1D_2$)=3872 MeV

$\kappa_c = 0.074$ by using $\alpha_s(m_c) = 0.35$.

Different Potential Models

TABLE I: The overlap integrals J_i for the electromagnetic transition $\eta_{c2} \to J/\psi(\psi')\gamma$ in various potential models. Since $J_0 = 1$, we have not listed its value.

J_i \ Potential Models	Cornell [34]		Screened [16]		NR [36]		BT [35]		Fulcher [37]	
	J/ψ	ψ'	J/ψ	ψ'	J/ψ	ψ'	J/ψ	ψ'	J/ψ	ψ'
J_1	0.600	-0.123	0.710	-0.180	0.728	-0.161	0.757	-0.153	0.763	-0.147
J_2	-0.376	0.051	-0.347	0.063	-0.365	0.056	-0.383	0.048	-0.390	0.044
J_3	-0.304	-0.256	-0.227	-0.160	-0.242	-0.191	-0.245	-0.212	-0.249	-0.225
J_4	0.136	-0.243	0.121	-0.218	0.128	-0.231	0.144	-0.244	0.173	-0.291

Cornell Potential: E.Eichten *et al.* (1978) (1980)

Screened Potential: B. Q. Li and K. T. Chao (2009)

NR Potential: T. Barnes, S. Godfrey and E.S. Wanson (1980)

BT Potential: W. Buchmuller and S. H. H. Tye (1981)

Fulcher Potential: L. P. Fulcher (1991)

Physical Predictions

TABLE I: The predictions of $\eta_{c2} \to J/\psi(\psi') + \gamma$ from various potential models. The mixing angle ϕ has been taken for both 12° and 0 for ψ'. We have taken $\alpha = 1/137$, and $\kappa_c = 0.074$ by using $\alpha_s(m_c) = 0.35$. In addition to the partial width, the helicity amplitudes and the (normalized) multipole amplitudes for each decay channel have also been given.

Potential Models		ϕ	A_0	A_1	A_2	a_1	a_2	a_3	$\|a_2/a_1\|$	$\|a_3/a_1\|$	Width(keV)
Cornell	J/ψ	–	-0.39	0.19	0.22	0.31	-0.66	-0.68	2.15	2.21	3.11
	ψ'	0°	0.17	0.12	0.17	0.93	0.26	0.25	0.28	0.27	0.017
		12°	0.56	0.79	1.12	0.99	0.05	0.05	0.05	0.05	0.50
Screened	J/ψ	–	-0.50	0.18	0.21	0.19	-0.70	-0.70	3.72	3.70	4.22
	ψ'	0°	0.21	0.09	0.14	0.85	0.38	0.37	0.45	0.44	0.017
		12°	0.60	0.76	1.09	0.99	0.07	0.07	0.07	0.07	0.49
NR	J/ψ	–	-0.50	0.19	0.22	0.20	-0.69	-0.69	3.49	3.49	4.45
	ψ'	0°	0.20	0.11	0.16	0.89	0.33	0.32	0.38	0.36	0.018
		12°	0.59	0.78	1.11	0.99	0.06	0.06	0.06	0.06	0.50
BT	J/ψ	–	-0.53	0.20	0.22	0.18	-0.70	-0.69	3.76	3.76	4.78
	ψ'	0°	0.20	0.12	0.18	0.91	0.30	0.29	0.33	0.31	0.020
		12°	0.59	0.79	1.13	0.99	0.06	0.06	0.06	0.06	0.51
Fulcher	J/ψ	–	-0.54	0.18	0.20	0.14	-0.70	-0.70	5.16	5.16	4.77
	ψ'	0°	0.22	0.16	0.23	0.94	0.24	0.23	0.26	0.24	0.029
		12°	0.60	0.83	1.18	0.99	0.05	0.05	0.05	0.05	0.56

Comparison with earlier work

- Sebastian, Grotch, X. Zhang: PRD (1988)
- Sebastian: PRD (1994)
- Sebastian, X. G. Zhang: PRD (1997)

However, their work seems have some inconsistencies, for example:

1^1D_2 to $J/\psi\gamma$ have 2.13 keV (1988)

62.6 keV (1994)

0.69 keV (1997)

Discussion

Surveying the predicted partial widths from various potential models, one can place the following upper limit for the ratio of the two branching fractions:

$$\frac{\mathcal{B}[\eta_{c2} \to \psi' + \gamma]}{\mathcal{B}[\eta_{c2} \to J/\psi + \gamma]} < 0.16, (Cornell) \qquad \phi = 12^\circ$$

$$\frac{\mathcal{B}[\eta_{c2} \to \psi' + \gamma]}{\mathcal{B}[\eta_{c2} \to J/\psi + \gamma]} < 6.1 \times 10^{-3}. (Fulcher) \qquad \phi = 0^\circ$$

Contradictions

The ratio between two channel contradiction with the BABAR measurement no matter considering the mixing angle or not.

Theoretical:

$$\frac{\mathcal{B}[\eta_{c2} \to \psi' + \gamma]}{\mathcal{B}[\eta_{c2} \to J/\psi + \gamma]} < 0.16, (Cornell) \qquad \phi = 12^\circ$$

$$\frac{\mathcal{B}[\eta_{c2} \to \psi' + \gamma]}{\mathcal{B}[\eta_{c2} \to J/\psi + \gamma]} < 6.1 \times 10^{-3}. (Fulcher) \qquad \phi = 0^\circ$$

Experiment:

$$\frac{\mathcal{B}[X(3872) \to \psi' + \gamma]}{\mathcal{B}[X(3872) \to J/\psi + \gamma]} = 3.4 \pm 1.4.$$

The branch ratio for each channel

The total width of X(3872) in PDG(2008):

$$\Gamma = 3.0^{+2.1}_{-1.7}\ \mathrm{MeV}$$

For a conservative estimate we use the lower end of the PDG data: $\Gamma_X = 1.3$ MeV, and largest predicted patial width for each two channel, then we estimate:

$$\mathcal{B}[\eta_{c2} \to J/\psi + \gamma] < 3.7 \times 10^{-3}. \quad \text{(BT potential)}$$

$$\mathcal{B}[\eta_{c2} \to \psi' + \gamma] < 4.3 \times 10^{-4}, \text{(Fulcher)} \qquad \phi = 12^\circ$$

$$\mathcal{B}[\eta_{c2} \to \psi' + \gamma] < 2.2 \times 10^{-5}. \text{(Fulcher)} \qquad \phi = 0^\circ$$

Contrast with the experiment

Theoretical:

$$\mathcal{B}[\eta_{c2} \to J/\psi + \gamma] < 3.7 \times 10^{-3}. \quad \text{(BT potential)}$$

$$\mathcal{B}[\eta_{c2} \to \psi' + \gamma] < 4.3 \times 10^{-4}, \text{(Fulcher)} \qquad \phi = 12^\circ$$

$$\mathcal{B}[\eta_{c2} \to \psi' + \gamma] < 2.2 \times 10^{-5}. \text{(Fulcher)} \qquad \phi = 0^\circ$$

Experiment:

$$\mathcal{B}[X(3872) \to J/\psi + \gamma] > 5.9 \times 10^{-3}, \quad \mathcal{B}[X(3872) \to \psi' + \gamma] > 1.9 \times 10^{-2},$$

Contradiction!

Summary

- Our calculation indicates that if considering X(3872) as a pure charmonium, then its J^{PC} strongly disfavor 2^{-+}.
- Recently there are two papers also discussing the assignment of X(3872), and their work seem disfavor 2^{-+} too.

Burns, Piccinini, Polosa, Sabelli arXiv:1008.0018

Kalashnikova, Nefediev arXiv: 1008.2895

Thanks for your attention!