Electro-weak production of pseudovector C-even heavy quarkonia in electron-positron collisions on Belle II and BES III

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OUTLINE

The $X(3872) = \chi_{c1}(3872)$ meson, a patriarch of the XYZ spectroscopy, was appointed to be the $D^0\bar{D}^{*0} + c.c.$ molecule with a radius greater than 3 fermi from the very beginning despite the fact that $X(3872) = \chi_{c1}(3872)$ is produced in hard processes with a radius less than one fermi as intensively as the compact charmonium $\psi(2S)$.

We reviewed the scenario in detail where $X(3872)$ resonance is the $c\bar{c} = \chi_{c1}(2P)$ charmonium which "sits on" the $D^0\bar{D}^{*0}$ threshold. We explained all known data on $X(3872)$ and suggested clear program of verification of our scenario.

We predicted a significant number of decay channels via two gluons: $X(3872) \to gluon\, gluon \to light\, hadrons$.

OUTLINE

It means that two virtual gluons can produced $X(3872)$

$e^+e^- \to \psi(m_i) \to \gamma\, gluon\, gluon \to \gamma X(3872)$,

here $\psi(m_k)$: $I^G(J^{PC}) = 0^-(1^{--})$, $m_i > m_{X(3872)}$.

N.N. Achasov and E.V. Rogozina,
JETP Lett. 100, 227(2014);
Mod. Phys. Lett. A 30, 1550181 (2015);
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EPJ Web Conf. 191, 04002 (2018).
N.N. Achasov, Phys. Part. Nucl. 48, 839 (2017).

BES III put if not a point, then a fat comma in disputes on the $X(3872)$ nature.

OUTLINE

BES III found $X(3872)$ in $e^+e^- \to \gamma X(3872)$ at center-of-mass energies for 4.009 to 4.420 GeV:

$$e^+e^- \to \sum_i \psi(m_i) \to \gamma\, gluon\, gluon \to \gamma X(3872) =$$
$$= \psi(4040) + \psi(4160) + \psi(4230) + \psi(4260) + \psi(4360) +$$
$$+ \psi(4390) + \psi(4415) \to \gamma\, gluon\, gluon \to \gamma\, X(3872) \to$$
$$\to \gamma\pi^+\pi^- J/\psi.$$

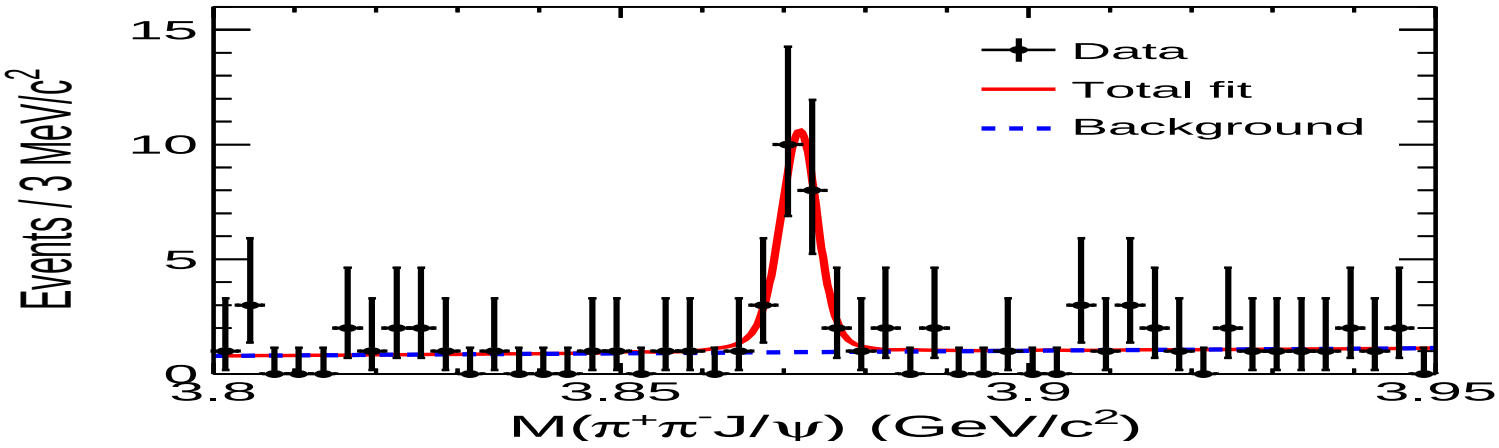
M. Ablikim *et al.*, Phys. Rev. Lett. 112, 092001 (2014).

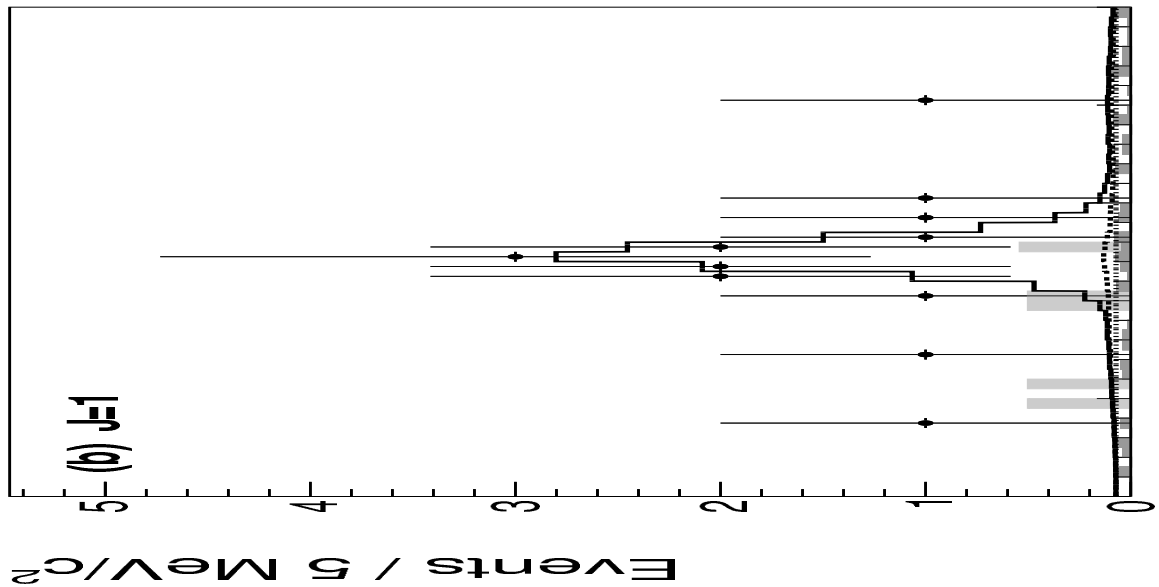
Recently BES III found $X(3872)$ in $e^+e^- \to \gamma X(3872)$ at center-of-mass energies for 4.15 to 4.3 GeV:

$$e^+e^- \to \psi(4160) + \psi(4230) + \psi(4260) \to$$
$$\to \gamma\, gluon\, gluon \to \gamma\, X(3872) \to \gamma\pi^0\chi_{c1}(1P).$$

M. Ablikim *et al.*, arXiv: 1901.03992 v1 [hep-ex] 13 Jan 2019.

OUTLINE


Data
Total fit
Background
Events / 3 MeV/c^2
M($\pi^+\pi^-$J/ψ) (GeV/c^2)


(b) J=1
Events / 5 MeV/c^2
$M(\pi^0\chi_{c1})$ [GeV/c^2]

OUTLINE

So, BES III close the molecular model of $X(3872)$. The giant colourless molecule does not connected with gluons! Its colourless constituents D^0 , $\bar{D}^{*0}$ do not connected with gluons also!

As for the tetraquark model, the two-gluon production of $X(3872)$ is possible

$e^+e^- \to \gamma\, gluon\, gluon \to \gamma q\bar{q}c\bar{c} \to \gamma X(3872), q = u, d.$

But, such a process is described by nonplanar diagrams, which are depressed always.

So, BES III puts in a difficult position the tetraquark model of X(3872).

So, BES III confirms the $c\bar{c}$ charmonium model of $X(3872)$.

$$X(3872) = \chi_{c1}(2P)\,!$$

OUTLINE

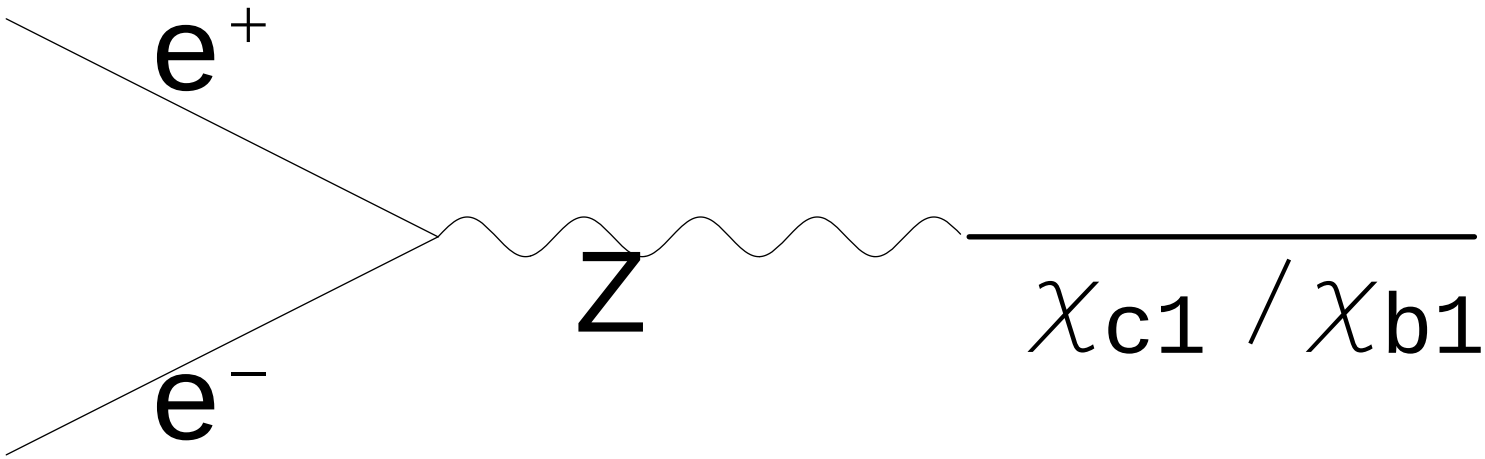
It is often thought that violations of isotopic invariance in the decays $X(3872) \to \pi^+\pi^- J/\psi$ and $X(3872) \to \pi^0\chi_{c1}(1P)$ are crucial for the $X(3872)$ nature.

However, this is a misunderstanding. These are the problems of the second row.

As for $X(3872) \to \pi^+\pi^- J/\psi$, this problem is discussed in detail in Refs. above. As for $X(3872) \to \pi^0\chi_{c1}(1P)$, it is possible a such scheme $X(3872) \to$
$gluon\, gluon\, \chi_{c1}(1P) \to \eta\chi_{c1}(1P) \to \pi^0\chi_{c1}(1P)$
via $\eta - \pi^0$ mixing.

I dare recommend looking for the decays $\chi_{b1}(2P) \to \rho^0 J/\psi$ and $\chi_{b1}(2P) \to \pi^0\chi_{b1}(1P)$.

OUTLOOK



In this energy region the weak interaction grows with energy increase $\propto G_F E^2$, here $G_F = 10^{-5} m_p^{-2}$ is the Fermi constant.

$G_F E^2 = 1.4 \times 10^{-4}$ for $\chi_{c1}(1P)$ and $G_F E^2 = 1.7 \times 10^{-4}$ for $\chi_{c1}(3872)$. That is, $G_F E^2 \sim \alpha^2$ in the BES III energy region.

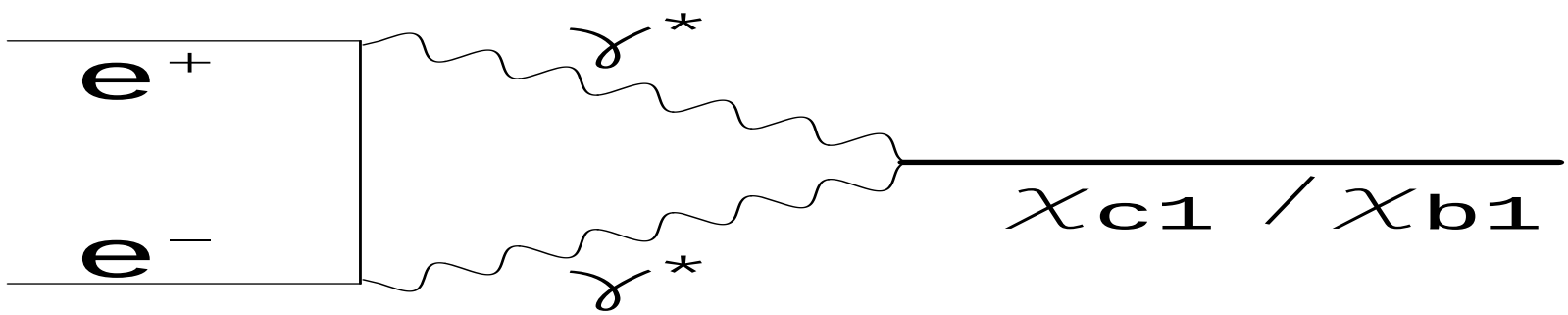
$G_F E^2 = 1.1 \times 10^{-3}$ for $\chi_{b1}(1P)$ and $G_F E^2 = 1.2 \times 10^{-3}$ for $\chi_{b1}(2P)$. That is, $G_F E^2 \gg \alpha^2$ in the Belle II energy region.

OUTLOOK

The BESS III luminosity $10^{33} cm^{-2} s^{-1}$ gives possibilities to register near hundred of events $e^+e^- \to Z \to \chi_{c1}(1P)$ per day and near thirty of them in the well-known channel $\chi_{c1}(1P) \to \gamma\psi(1S)$. If $\chi_{c1}(3872) = \chi_{c1}(2P)$, then also near hundred of events $e^+e^- \to Z \to \chi_{c1}(3872)$ per day may be registered and several of them in the channel $\chi_{c1}(3872) \to \gamma\psi(2S)$, several tens of them in the channel $\chi_{c1}(3872) \to D^0\bar{D}^{*0} + c.c.$.

The huge Belle II luminosity $8 \times 10^{35} cm^{-2} s^{-1}$ gives possibilities to register near hundred thousand of events each $e^+e^- \to Z \to \chi_{b1}(1P)$ and $e^+e^- \to Z \to \chi_{b1}(1P)$ per day and several tens of thousands of them in the well-known channels $\chi_{b1}(1P) \to \gamma\Upsilon(1S)$ and $\chi_{b1}(2P) \to \gamma\Upsilon(2S)$.

OUTLOOK



The $e^+e^- \to Z \to \chi_{c1}/\chi_{b1}$ and $e^+e^- \to \gamma^*\gamma^* \to \chi_{c1}/\chi_{b1}$ contributions do not interfere in the total cross sections. That is, the creation of longitudinally polarized electron-positron beams allows to study separately $e^+e^- \to Z \to \chi_{c1}/\chi_{b1}$ and $e^+e^- \to \gamma^*\gamma^* \to \chi_{c1}/\chi_{b1}$.

SUMMARY

The new elegant experimental probes appear. In particular, they could find out whether is $\chi_{c1}(3872) = \chi_{c1}(2P)$ and search out the $\chi_{b1}(2P) \to \rho^0\Upsilon(1S)$ and $\chi_{b1}(2P) \to \pi^0\chi_{b1}(1P)$.

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A lot of thanks

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