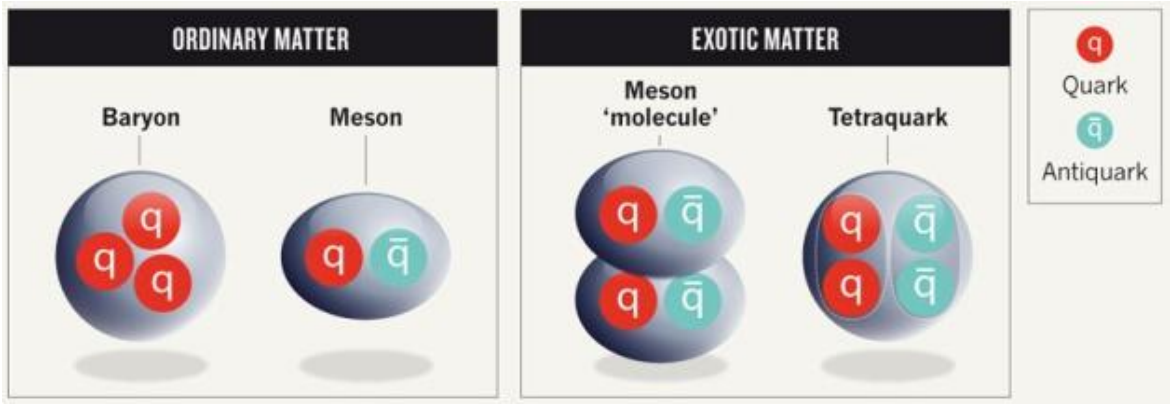
Determination of the Spin and Parity of the $Z_c(3900)$

JC29

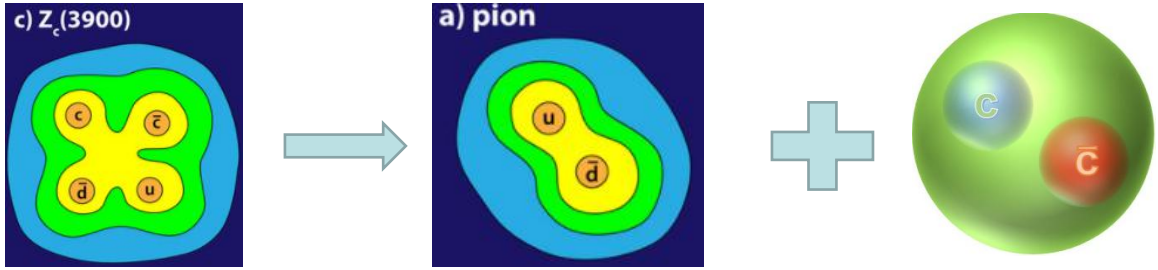
Outline

- Introduction
- Part I, determination of J^P of Zc(3900)
- Part II, search for Zc(4020) in pi pi Jpsi final state

Quark model of hadrons



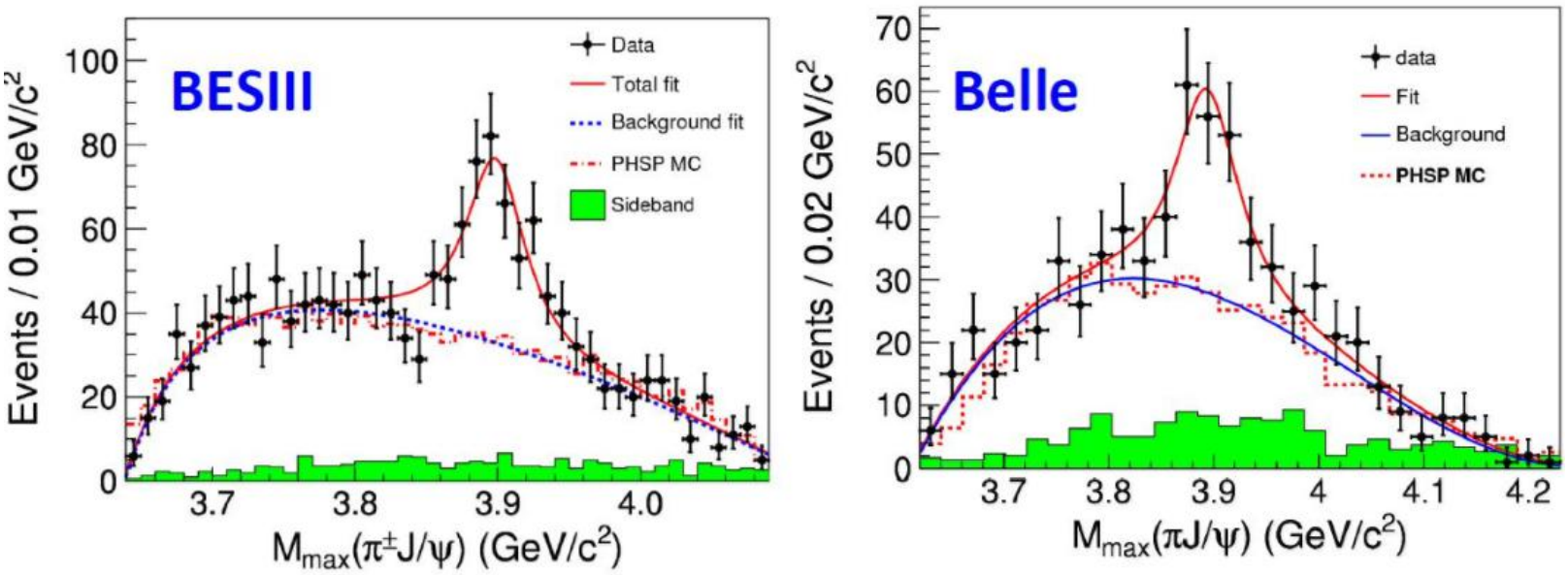
possible quark assignment of Zc(3900)



Part I

determination of J^P of Zc(3900)

Discovery of Zc(3900)



- The charged Zc(3900) were discovered by BESIII and Belle almost at the same time, in the pi pi J/psi channel.
- confirmed by CLEOc experiment
- couples to c cbar and has nonzero charge, at least four quarks in it.

discovery of Zc(3885)

- another charged Zc was discovered in a different channel

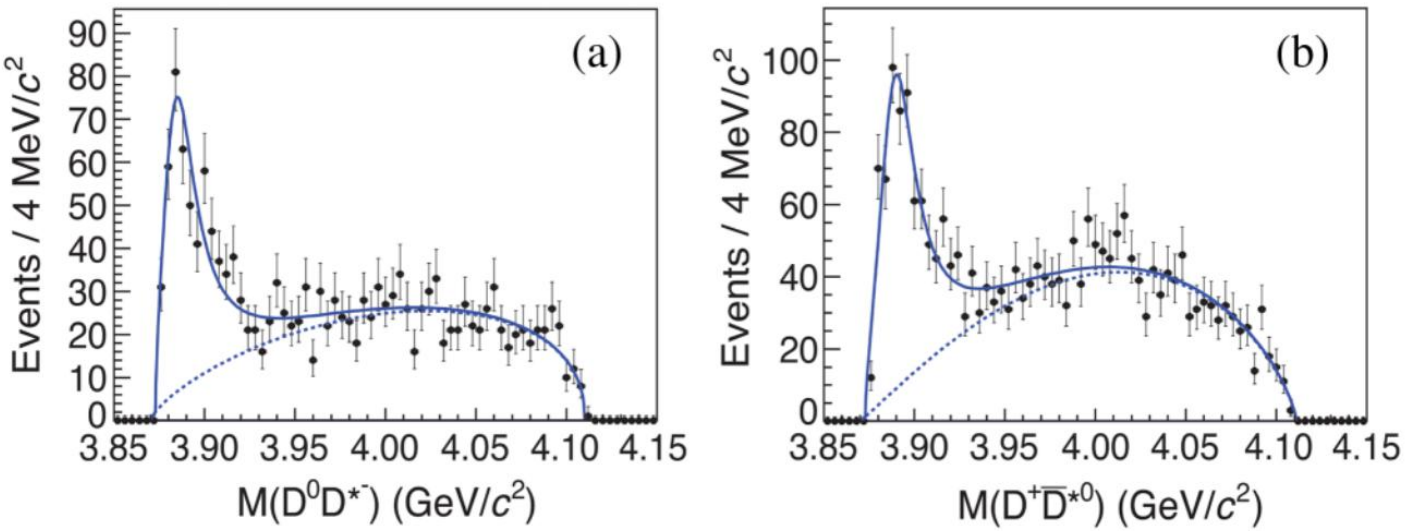


FIG. 2 (color online). The (a) $M(D^0D^{*-})$ and (b) $M(D^+\bar{D}^{*0})$ distributions for selected events. The curves are described in the text.

spin-parity of Zc(3885)

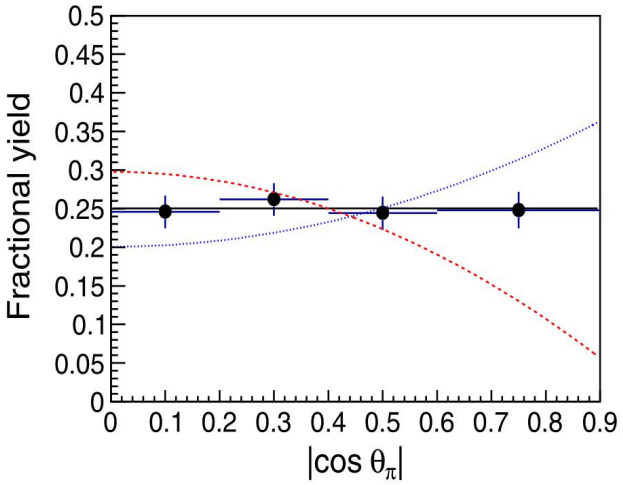


FIG. 3 (color online). $(1/N_{\rm tot})dN/d|\cos\theta_\pi|$ versus $|\cos\theta_\pi|$ for $Z_c(3885)$ events in data. The solid, dashed, and dotted curves show expectations for $J^P = 1^+$, 0^-, and 1^-, respectively.

If the $Z_c(3885)$ quantum numbers are $J^P = 1^+$, the π-$Z_c(3885)$ system produced via $Y(4260) \to \pi Z_c(3885)$ can be in an S and/or a D wave. Since the process occurs near threshold, the D wave should be suppressed and $dN/d|\cos\theta_\pi| \simeq$ constant, where θ_π is the pion's polar angle relative to the beam direction in the e^+e^- rest frame. For $J^P = 0^-$ (1^-), the π-$Z_c(3885)$ would be in a P wave with an expected distribution of $dN/d|\cos\theta_\pi| \propto \sin^2\theta_\pi$ $(1 + \cos^2\theta_\pi)$. Parity conservation excludes $J^P = 0^+$.

Figure 3 shows the efficiency-corrected fractional $Z_c(3885)$ signal yield for four bins of $|\cos\theta_\pi|$ with curves that show fit results for the $J^P = 1^+, 0^-$ and 1^- hypotheses. The data strongly prefer $J^P = 1^+$, with $\chi^2/\text{ndf} = 0.44/3$, and disagree with expectations for $J^P = 0^-$ $(\chi^2/\text{ndf} = 32/3)$ and 1^- $(\chi^2/\text{ndf} = 16/3)$.

determining the spin-parity of Zc(3900)

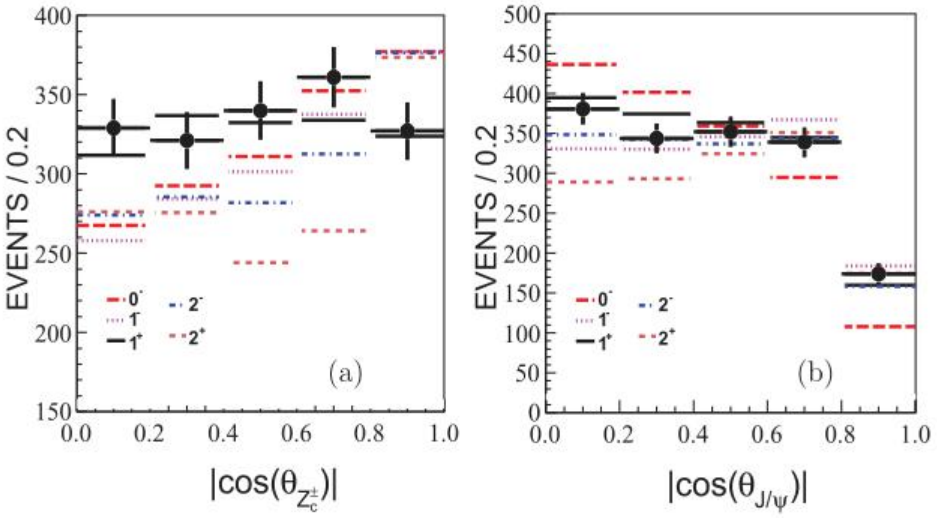


FIG. 2. (a) Polar angle distribution of $Z_c^\pm$ in the process $e^+e^- \to Z_c^+\pi^- + \text{c.c.}$; (b) helicity angle distribution of J/ψ in the $Z_c^\pm \to \pi^\pm J/\psi$. The dots with error bars show the combined data with the requirement $m_{J/\psi\pi^\pm} \in (3.86, 3.92)$ GeV/c^2 and compared to the total fit results with different J^P hypotheses.

determining the spin-parity of Zc(3900)

Hypothesis	$\Delta(-2\ln L)$	$\Delta(\mathrm{ndf})$	Significance
1^+ over 0^-	94.0	13	7.6σ
1^+ over 1^-	158.3	13	10.8σ
1^+ over 2^-	151.9	13	10.5σ
1^+ over 2^+	96.0	13	7.7σ

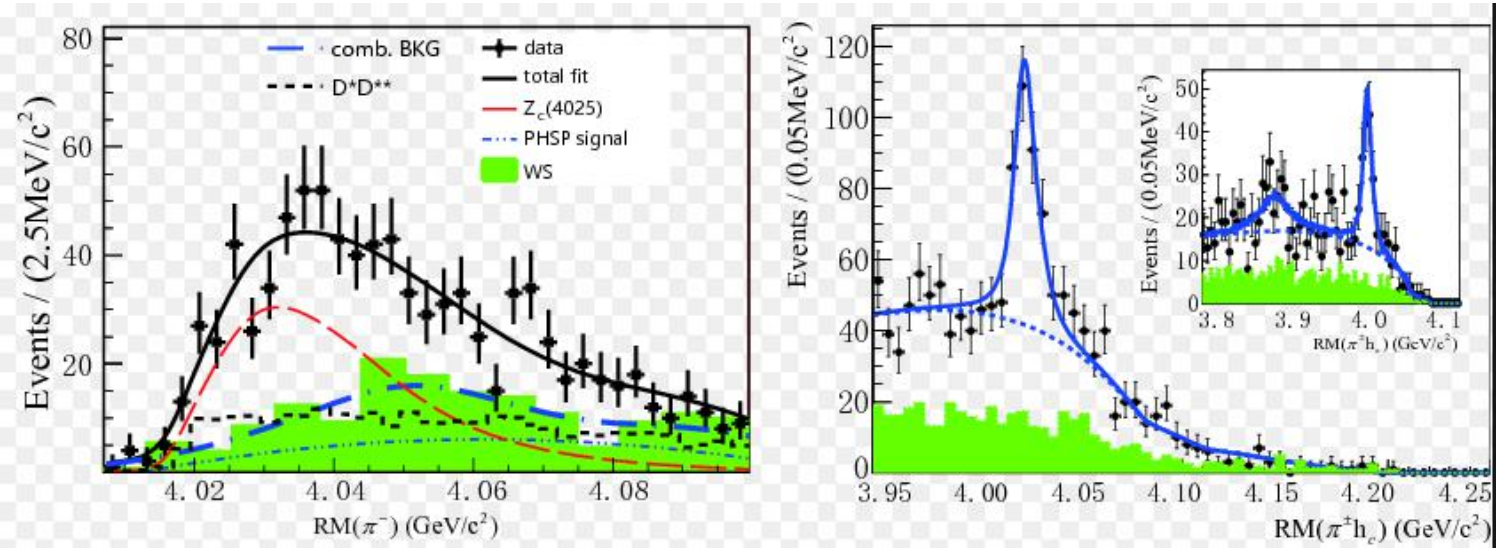
- The spin parity have been determined to be 1+
- with a statistical significance larger than 7\sigma over other quantum numbers.

- The result favors that, the socalled Zc(3900) and Zc(3885) are the same resonance.
- will deepen our undertanding of the structure of Zc(3900)

Part II

search for Zc(4020) in pi pi J/psi final state

Observation of Zc(4020) in different channels



- spin parity of hc(1P) is 1+, different with J/psi 1-
- Zc(4020) couples to two higher excited vector charm mesons.
- Zc(3900) couples to D D*, one psudoscalar and another vector.

- These facts indicate that
  - Zc(4020) may be higher excited state of Zc(3900)
  - Zc(4020) has different inner structure with Zc(3900)
  - search for pi J/psi channle will help us to have better understaning of the inner structure and the excitation mechanism of Zc(4020)

Search for Zc(4020) in this work

Using these two data sets, we also search for the process $e^+e^- \to Z_c(4020)^+\pi^- + \text{c.c.} \to \pi^+\pi^- J/\psi$, with the $Z_c(4020)^\pm$ assumed to be a 1^+ state. In the PWA, its mass is taken from Ref. [12], and its width is taken as the observed value, which includes the detector resolution. The statistical significance for $Z_c(4020)^\pm \to J/\psi\pi^\pm$ is found to be 3σ in the combined data. The Born cross sections are measured to be $(0.2 \pm 0.1_{\text{stat}})$ pb at 4.23 GeV and $(0.8 \pm 0.4_{\text{stat}})$ pb at $s = 4.26$ GeV, and the corresponding upper limits at the 90% confidence level are estimated to be 0.9 and 1.4 pb, respectively.

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