Observation of a neutral structure near the $D\bar{D}^{*}$ mass threshold in $e^+e^- \rightarrow (D\bar{D}^*)^0\pi^0$ at $\sqrt{s} = 4.226$ and 4.257 GeV

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Outline

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Motivation

- After the discoveries of the charged $Z_c^{\pm}$ states, BESIII reported studies of their neutral partners in the isospin symmetric channel of $e^+e^- \to Z_c^0\pi^0$,such as $Z_c(3900)^0$, $Z_c(4020)^0$ and $Z_c(4025)^0$.
- These measurements indicate that the $Z_c(3900)$, $Z_c(4020)$ and $Z_c(4025)$ are three different isospin triplet states.
- This motivates a search for the neutral partner of the $Z_c(3885)^{\pm}$ to identify its isospin.
- (PS: this is a strong interaction process of $Z_c(3885)^{\pm} \to (\mathrm{D}\bar{D}^*)^{\pm}$, strong interaction don't violate isospin symmetry .)

Reconstruction

- Choose the process $e^+e^- \rightarrow (\mathrm{D}\bar{D}^*)^0\pi^0 + c.c.$ to study if there is a neutral charmoniumlike structure $Z_c(3885)^0$, where $(\mathrm{D}\bar{D}^*)^0$ refers to D^+D^{*-} or $D^0\bar{D}^{*0}$.(PS c.c. represents the coupled channel)
- For the process $e^+e^- \rightarrow D^0\bar{D}^{*0}\pi^0$, $\bar{D}^{*0} \rightarrow \bar{D}^0\pi^0$, we just need to reconstruct the D^0, $\bar{D}^0$ and the primary π^0.
- The selection criteria
- A vertex fit of each D candidate and a mass-constrained kinematic fit to the nominal D mass are performed
- The primary π^0 candidates are reconstructed with pairs of photons, and their invariant mass $M(\gamma\gamma)$ must be in the range $(0.120{,}0.15)\mathrm{GeV}/c^2$

Background analysis

- For $e^+e^- \to D^0\bar{D}^{*0}\pi^0$ with $\bar{D}^{*0} \to \bar{D}^0\pi^0$, the process $e^+e^- \to D^0\bar{D}^{*0}\pi^0$ with $\bar{D}^{*0} \to \bar{D}^0\gamma$ is a major background. To reject this background, the way is ……
- The $e^+e^- \to (\mathrm{D}\bar{D}^*)^0\pi^0$ three body PHSP and inclusive MC background
- Some background events from high energy process, such as $e^+e^- \to D^{(*)}\bar{D}^{**} \to D^0\bar{D}^{*0}\pi^0$

Result

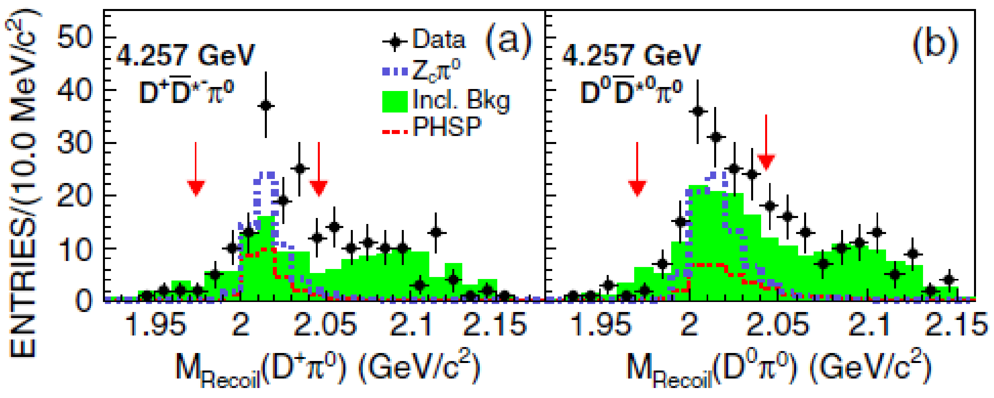

FIG. 1 (color online). Distributions of RM$(D\pi^0)$ at $\sqrt{s} = 4.257$ GeV. The signal and PHSP processes are overlaid with an arbitrary scale. The solid arrows indicate the selection criteria for the $(D\bar{D}^*)^0\pi^0$ candidates. Data at $\sqrt{s} = 4.226$ GeV show similar distributions and are omitted.

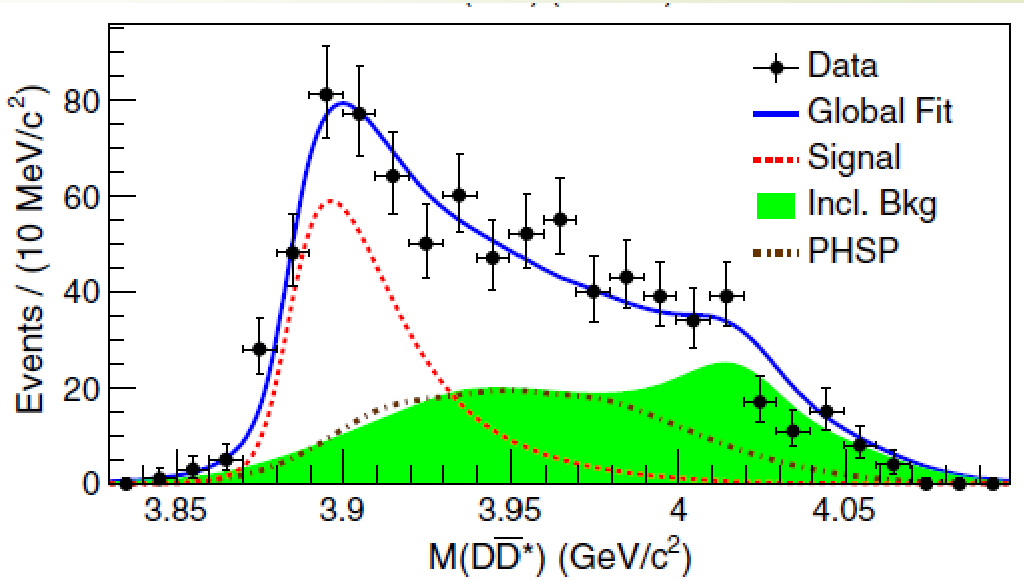

FIG. 2 (color online). (Upper) Projections of the simultaneous fit to the $M(D\bar{D}^*)$ spectra for $e^+e^- \to D^+D^{*-}\pi^0$ and $D^0\bar{D}^{*0}\pi^0$ at $\sqrt{s} = 4.226$ and 4.257 GeV. (Lower) Sum of the simultaneous fit to the $M(D\bar{D}^*)$ spectra for different decay modes at the different energy points above.

Fit result analysis

- An unbinned maximum likelihood fit is performed on the M($D\bar{D}^*$) spectra for $e^+e^- \to (D\bar{D}^*)^0\pi^0$. Three components are included in the fits: the $Z_c(3885)^0$ signal, the PHSP processes, and MC simulated backgrounds.
- The shape of PHSP process is derived from MC simulations. The signal shape is described as a mass-dependent-efficiency weighted Breit-Wigner function. The inclusive MC background distributions are modeled based on the kernel estimation.
- $\chi^2/d.o.f = 18.5/19$
- The statistical significance of the $Z_c(3885)^0$ signal is estimated to be more than 12σ.

Systematic uncertainties

TABLE I. Summary of systematic uncertainties for the resonance parameters, the Born cross sections, and the ratio of decay rates. Values outside the parenthesis represents uncertainties for $\sigma_{D\bar{D}^*}$ at $\sqrt{s} = 4.226$ GeV, while those inside are for $\sigma_{D\bar{D}^*}$ at $\sqrt{s} = 4.257$ GeV. The total systematic uncertainties are obtained by combining all the independent sources in quadrature.

Source	$m_{\text{pole}}(\text{MeV}/c^2)$	$\Gamma_{\text{pole}}(\text{MeV})$	$\sigma_{D\bar{D}^*}(\%)$	$\mathcal{R}(\%)$
Beam energy	1.0	3.0	4 (5)	1
Signal shape	3.5	8.2	5 (4)	2
Background	6.8	6.6	15 (15)	4
Fit range	0.3	0.3	3 (1)	1
Mass shift	3.0			
Resolution		9.5	11 (4)	1
Efficiency			11 (11)	11
Input-output check	1.6	2.5		
$(1+\delta^{\text{rad}})(1+\delta^{\text{vac}})$			5 (5)	
$\mathcal{B}_{\text{int}}$			5 (5)	5
$\mathcal{L}$			1 (1)	
Total	8.4	15	23 (21)	13

PS

- $e^+e^- \to Z_c^0\pi^0 \to (\mathrm{D}\bar{D}^*)^0\pi^0$
- π^0 has $J^P = 0^-$, e^+e^- has $J^P = 1^-$, if assuming that Z_c^0 has $J^P = 1^+$
- Since orbital parity $P = (-1)^l$, to ensure parity conservation, orbital angular momentum L must be 0,2,4……
- So using S-wave to simulate the process $e^+e^- \to Z_c^0\pi^0 \to (\mathrm{D}\bar{D}^*)^0\pi^0$ is reliable