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A COUPLE OF NEW CHARMED, STRANGE MESONS AT BaBar*

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The BaBar Collaboration has observed two new narrow invariant mass states in the D_s sector near 2.32 and 2.46 GeV/c^2decaying respectively in $D_s^+\pi^0$ and $D_s^+\pi^0\gamma$; naturally interpreted as $c\overline{s}$ mesons, they have been denoted as the $D_{sJ}^*(2317)^+$ and the $D_{sJ}(2458)^+$. Their masses, widths and dominant decay modes differ considerably from expectations in current Heavy Quark potential models. Both states have been also observed by Belle and CLEO in the same decay modes and with comparable properties. The observation of these two new mesons has started a very large activity in this sector, both on the experimental and theoretical side.

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1. Introduction

This year there has been a big surprise in the Charm Physics with BaBar announcing the discovery of a new charmed meson at a mass ~ 2.32 GeV/c^2 [1], which was very soon confirmed both by CLEO [2] and Belle [3, 4]. Later this year CLEO observed another new meson in the same sector at a mass ~ 2.46 GeV/c^2 [2], successively confirmed by Belle [4] and BaBar [5]. These two new states have been observed to decay respectively in $D_s^+\pi^0$ and $D_s^+\pi^0\gamma$ and, naturally interpreted as $c\overline{s}$ mesons, have been denoted (according to the PDG rules) as the $D_{sJ}^*(2317)^+$ and the $D_{sJ}(2458)^+$.[1]

Since the discovery of the first of these two new mesons there has been a big excitement on the theoretical side, since both of these particles do not fit

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[1] Charge conjugation is implied throughout, where not explicitly noted otherwise.

well in the existing Heavy Quarks potential model, till now very successful in describing the masses and widths of the observed states in the D, B and D_s sectors. This has produced a large number of theoretical speculations about these states being either a four-quark state, or a "DK" molecule-like or other exotic objects, as we will document more in detail in Section 6.

The spectroscopy of $c\bar{s}$ states is simple in the limit of large charm-quark mass [6, 7]: that is the reason why up to now quark potential models have been successful in describing the properties of $c\bar{s}$ mesons [8, 9]. Four states had been observed at the predicted mass values: the $D_s(1968)^+$, the $D_s^*(2112)^+$, the $D_{s1}(2536)^+$ and the $D_{s2}(2573)^+$ [10]. Two of the missing states were predicted at masses between 2.4 and 2.6 GeV/$c^2$with expected decays to DK and D^*K respectively. With these hadronic decays the expected line shape width was of a few hundred MeV, making the observation of these states against the combinatorial background rather problematic. However Cho and Wise [11] had predicted that a state with mass below the $D(^*)K$ threshold would have an isospin-violating decay and hence be much narrower and easier to observe. The experimental and theoretical status of the P-wave $c\bar{s}$ states thus can be summarized by stating that experiments have provided good candidates for the states that the theory predicts could be easily observable, but have turned up with unexpectedly lighter and narrow mesons for the two states that should have been more difficult to observe.

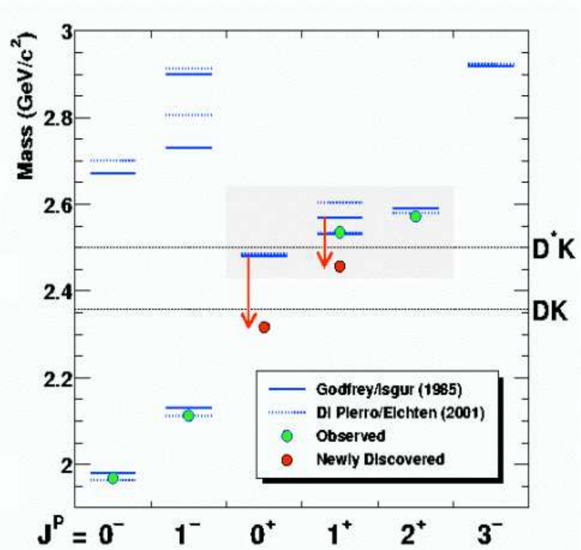

Fig. 1. A sketch of the foreseen (lines) and experimentally observed (grey dots) D_s states with their masses *vs* their quantum numbers. In black dots the newly observed states. The DK and D^*K thresholds have been shown.

The first of the new mesons, decaying to $D_s^+\pi^0$, with a mass of 2317 MeV/c^2 (below the DK threshold) and a width less than 10 MeV, has been observed by Prof. Antimo Palano, of the BaBar Collaboration, at the beginning of 2003. While studying other possible decay channels, another state has been observed in the $D_s^+\pi^0\gamma$ channel with a mass of 2458 MeV/c^2 (below the D^*K threshold) and a small width.

2. The BaBar experiment and the data event selection

The BaBar detector is a general purpose, solenoidal, magnetic spectrometer, described in detail in [12], located at the PEP-II asymmetric-energy e^+e^- storage ring.

Some of the detector components employed in this analysis are here briefly discussed. Charged particles are detected and their momenta measured by a combination of a cylindrical drif chamber (DCH) and a silicon vertex tracker (SVT), both operating inside a 1.5 T solenoidal magnetic field. A ring-imaging Cherenkov detector (DIRC) is used for charged particle identification (π/K) in the range of interest ($p \sim 1 \div 2$ GeV/c) together with the dE/dx measurements from both trackers. Electrons are identified and photons measured by a CsI electromagnetic calorimeter (EMC).

The data consist of a sample of 91.5 fb^{-1}(equivalent to $\sim$ 120 millions of events) collected in e^+e^- collision at center of mass energies near 10.58 GeV, on and off the $\Upsilon(4s)$ resonance peak, at the PEP-II asymmetric-energy e^+e^- storage ring. We remind that, under the resonance peak, we have a huge contribution of $c\bar{c}$ events due to a production cross section of 1.3 nb.

We look first for the inclusive production of $D_s(1968)^+$ via its decays into $K^+K^-\pi^+$ and $K^+K^-\pi^+\pi^0$, accompanied by at least one more π^0. This way we select events with at least three charged tracks (2 of them with opposite charge and satisfying the kaon identification criteria, the other being NOT identified as a kaon, muon or electron and thus assigned to a pion) and at least two calorimetric clusters with energy greater that 100 MeV.

The charged tracks are fitted to a common vertex with probability $> 0.1\%$ and required to be consistent with production at the interaction region. A candidate π^0 is obtained by constraining two calorimetric clusters, considered as a $\gamma\gamma$ pair, to emanate from the same vertex and to have an invariant mass $122 < m_{\gamma\gamma} < 148$ MeV/c^2 fixed by a 1-C fit with probability $> 1\%$. Each π^0 is fit twice: once to the interaction vertex, and the other to the charged track vertex, to take into account the two $D_s(1968)^+$ decay modes.

To reduce background from combinatorial and from B meson decays we require:

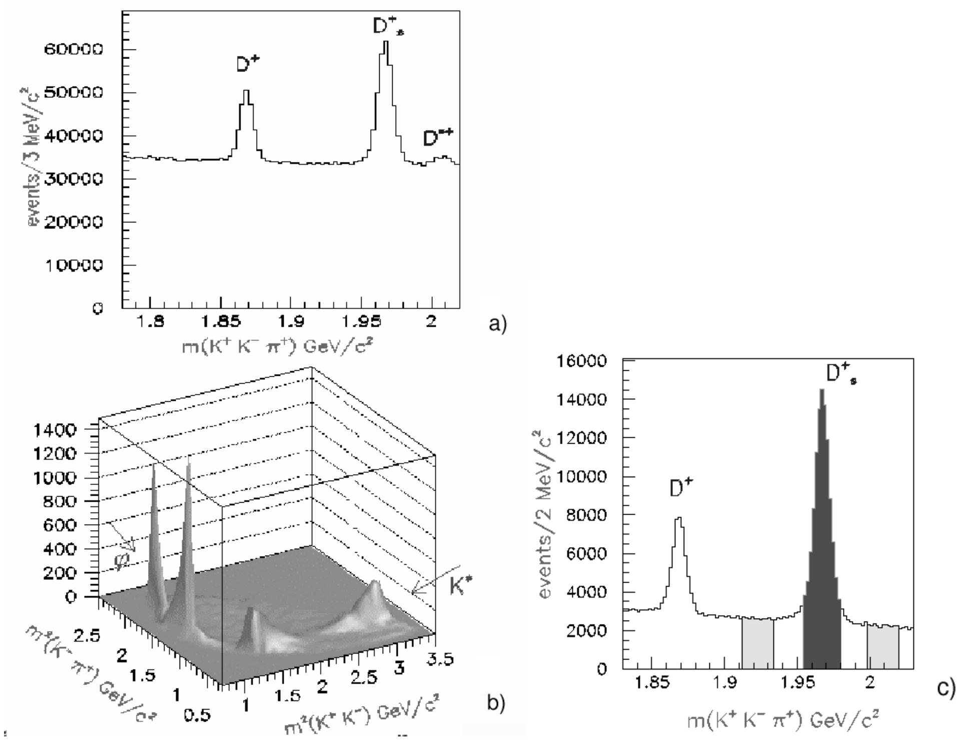

Fig. 2. (a): the 3 observed states in the $K^+K^-\pi^+$ mass spectra. (b): Dalitz plot for the $K^-\pi^+$ *vs* K^+K^- with the observed lines due to $\phi\pi$ and $\bar{K}^*K$ decays with the valley due to the $|\cos\theta_h|$ decay angle distribution. (c): final distribution for the selected $D_s(1968)^+$ signal region and sidebands.

(a) each $K^+K^-\pi^+$ candidate to have a momentum in the e^+e^- center of mass system $p^* > 2.5$ GeV/c (suppresses $b\bar{b}$ decays);

(b) to remove the D^{*+} observed peak (see Fig. 2(a)) each event must have $m(K^+K^-) < 1.84$ GeV/c^2;

(c) to select only $\phi\pi^+$ ($|m(K^+K^-) - m(\phi)| < 10$ MeV/c^2) and $\bar{K}^{*0}K^+$ ($|m(K^-\pi^+) - m(\bar{K}^{*0})| < 50$ MeV/c^2) decay mode candidates (see Fig. 2(b));

(d) due to the nature of a $P \to PV$ decay to ϕ and $\bar{K}^{*0}$ we cut on the K decay helicity angle $|\cos\theta_h| > 0.5$ (exhibits expected $\cos^2\theta_h$).

3. The D_s^+ selection and signal/background improvements

In Fig. 2(c) we see the final distribution for the $D_s(1968)^+$ candidates: there are about 80000 events on background with a purity $\sim 70\%$.

All candidates in the signal region

$$1.955 < m(K^+K^-\pi^+) < 1.979 \text{ MeV}/c^2$$

and in the sidebands

$$1.912 < m(K^+K^-\pi^+) < 1.934 \text{ and } 1.998 < m(K^+K^-\pi^+) < 2.020 \text{ MeV}/c^2$$

are then combined with a signal π^0 candidate, eliminating any candidate which shares either photon with another π^0, using the candidate with higher probability.

The resulting mass distribution (with the additional constraint of using the PDG mass for the $D_s(1968)^+$ to improve resolution) is shown in Fig. 3(b)).

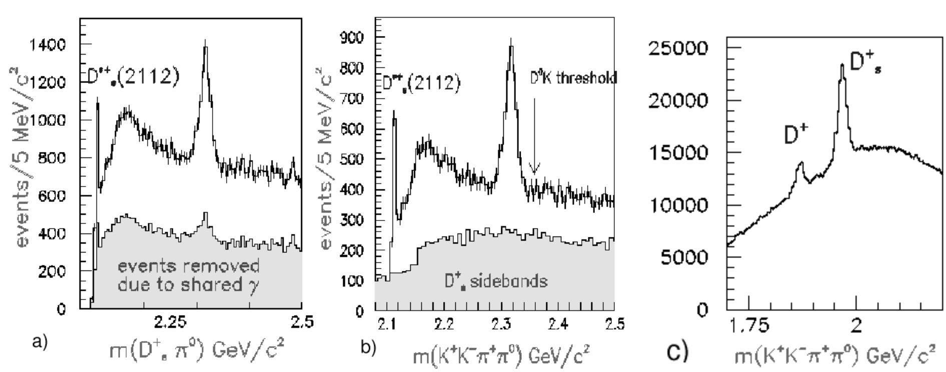

Fig. 3. (a): total $D_s(1968)^+\pi^0$ mass distribution with the (shaded) part to be removed by taking off events with shared γ. (b) shows the previously subtracted distribution for the D_s signal region and its sidebands. (c): $K^+K^-\pi^+\pi^0$ mass distribution for the other D_s decay channel.

Here we clearly observe the narrow peak of the $D_s^*(2112)^+$ and an unknown narrow peak near 2.32 GeV/c^2. The shaded histogram from the D_s sideband does not exhibit the same peak and shows that the signal is associated with the $D_s\pi^0$ channel. The same has been observed using $\gamma\gamma$ combinations not coming from the π^0 peak. To further reduce the background we have studied the CMS momentum p^* dependence of the $D_s(1968)^+\pi^0$ candidates: the signal is present in all p^* intervals and, as expected for production from $c\bar{c}$, the signal/background ratio improves at higher momenta. As a final improvement we decide then to apply a cut at $p^* > 3.5$ GeV/c.

Let us look also at the distribution for the other decay channel

$$D_s(1968)^+ \rightarrow K^+K^-\pi^+\pi^0$$

obtained with all cuts as above, except that the 2-body invariant mass selection is extended to the $\bar{K}^{*\pm}, \bar{K}^{*0}, \phi, \rho^+$ to improve the purity of the sample. We clearly see in Fig. 3(c) also for this channel the two signals from D_s^+ and D^+. With the same mass selection previously used for the D_s^+ signal and sidebands, we now combine these candidates with a π^0 candidate with momentum greater than 300 MeV/c.

4. The $D_s(2317)$ signal

The distribution for the $D_s\pi^0$ invariant mass for both decays are shown in Fig. 4(a) and (b) and both clearly exhibit both the $D_s^*(2112)^+$ and the new peak near 2.32 GeV/c^2. The broad peak in Fig. 4(a) centered at 2.16 GeV/c^2 is due to random $D_s^*(2112)^+\gamma$ events where $D_s^*(2112) \rightarrow D_s^+\gamma$. A fit to the resonance shape has been performed in both modes with a single Gaussian for the signal and a polynomial for the background. The results of the Gaussian fit for both distributions are given in Table I.

We clearly see that the fits for both modes are very well consistent with each other. The errors in the table are statistical only, and BaBar conservatively estimates the systematic uncertainty on the mass as less than 3 MeV/c^2. The fitted width are perfectly consistent with the experimental resolution and the intrinsic width should therefore be below 10 MeV.

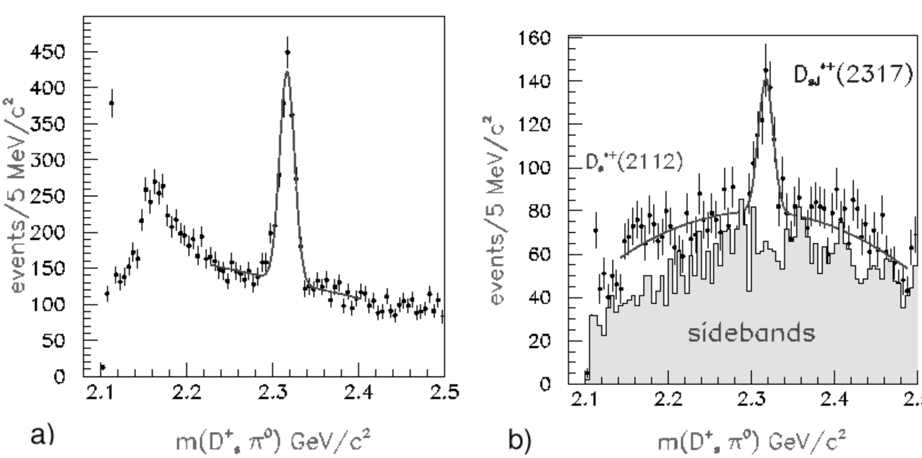

Fig. 4. (a) and (b) show the final cut $D_s^+\pi^0$ mass distribution with the fit to the $D_s(2317)$ signal respectively for $D_s \rightarrow K^+K^-\pi^+$ and $D_s \rightarrow K^+K^-\pi^+\pi^0$ channels.

TABLE I

Mode	Yeld (events)	Mass (MeV/c^2)	Sigma (MeV/c^2)
$D_s^+ \to K^+K^-\pi^+$	1267 ± 53	2318.6 ± 0.4	8.6 ± 0.4
$D_s^+ \to K^+K^-\pi^+\pi^0$	273 ± 33	2317.6 ± 1.3	8.8 ± 1.1

The new state seems therefore well established and has been named (after the PDG convention) the $D_{sJ}^*(2317)^+$. BaBar has used large statistics Monte Carlo calculations to investigate the possibility that the $D_{sJ}^*(2317)^+$ signal could be due to reflection from other charmed states. The simulation used included $e^+e^- \to c\bar{c}$ events and all known charm states and decays. The generated events were processed by a detailed detector simulation and passed to the same reconstruction and analysis chain as used for the data. No peak has been found in the 2.32 GeV/c^2 $D_s^+\pi^0$ region . In addition, no signal peak has been produced also when the $K^\pm$ and the $\pi^\pm$ assignment have been deliberately exchanged.

One expects that the decay to 2 pseudoscalars implies a natural spin-parity, so we looked at the distribution of the π^0 angle in the $D_s^+\pi^0$ rest frame with respect to the flight direction in the center of mass system. This distribution is shown in the rightmost plot of Fig. 5 and, once corrected for efficiency, is compatible (at the 43% probability level) with being flat, as would be expected for a $J^{\rm PC} = 0^+$ state or with a higher spin state, if produced unpolarized.

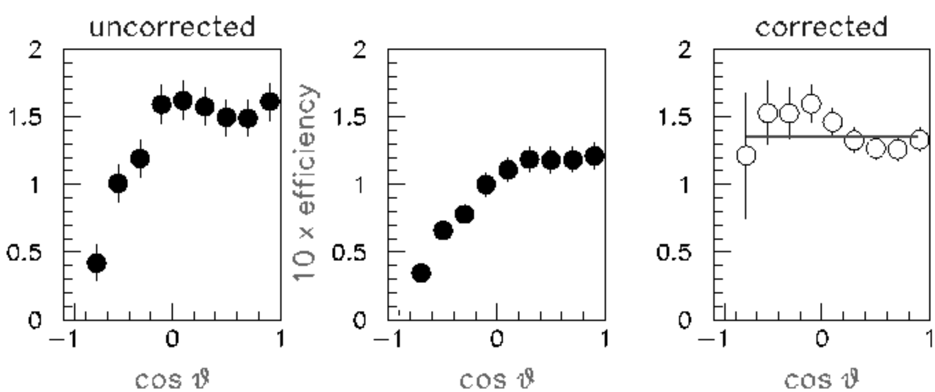

Fig. 5. From the left: uncorrected angular distribution, efficiency and corrected angular distribution for the helicity angle $\cos\theta_h$ of the π^0 in the $D_{sJ}^*(2317)^+$ decay.

5. Other decay modes search and the $D_s(2458)$ signal

A rather extensive search for other decay modes has also been performed. Figures 6(a) to (c) show respectively the mass spectra for the following decay modes: $D_s^+\gamma$, $D_s^+\gamma\gamma$ *and* $D_s^*(2112)^+\gamma$, $D_s^+\pi^0\pi^0$. No significant signal near 2.32 GeV/c^2 is visible with the current statistics in any of these distributions.

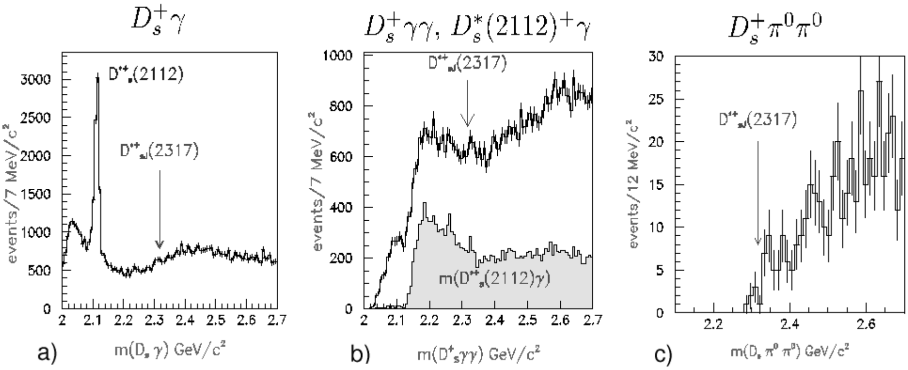

Fig. 6. Invariant mass spectra for various decay mode searched: no distribution shows any relevant signal for the $D_{sJ}^*(2317)^+$. (a): $D_s^+\gamma$ spectra showing the $D_s^*(2112)^+$ peak. (b): $D_s^+\gamma\gamma$ and (shaded) $D_s^*(2112)^+\gamma$ spectra. (c): $D_s^+\pi^0\pi^0$ spectra.

In Fig. 7(a) we show the mass distribution for $D_s^+\pi^0\gamma$ (shaded is the distribution for the D_s sidebands); for the study of this system each D_s^+ candidate has been combined with π^0 candidates with momentum greater

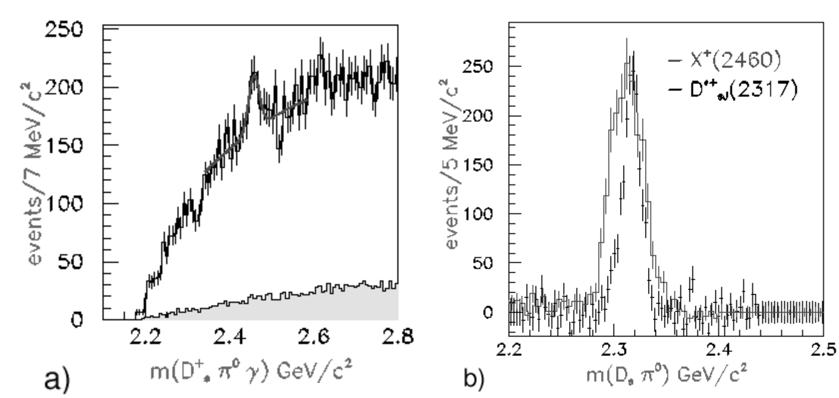

Fig. 7. (a): $D_s^+\pi^0\gamma$ and (shaded) D_s^+-sideband$\pi^0\gamma$ invariant mass distributions: a clear peak at ~ 2.46 GeV/c^2 is visible in the former. (b): the black points are the $D_{sJ}^*(2317)^+$ signal, the grey histogram is the faked signal from the $X(2460)$.

than 300 MeV/c and photons with energy greater than 100 MeV which do not belong to any signal π^0 candidate. In this distribution no peak is observed near 2.32 GeV/c^2, but a peak is observed at a mass near 2.46 GeV/c^2, and is particularly enhanced when subselecting the $D_s^*(2112)^+\pi^0$ channel. A naive Gaussian fit to the observed peak gives us a mass $m = 2458 \pm 4$ MeV/c^2 with $\sigma = 12.8 \pm 5.7$ MeV/c^2.

Can a narrow state near 2.46 GeV/c^2, decaying into $D_s^*(2112)^+\pi^0$, produce a peak in the $D_s^+\pi^0$ distribution near 2.32 GeV/c^2? After a Monte Carlo simulation of this decay (using the same parameters as observed in the data) we see that it has instead the wrong shape, an expected width $\sigma = 15$ MeV/c^2, and a peak central value shifted by some MeV, as shown in Fig. 7(b).

The observation of the peak in Fig. 7(a) hints at the production of a new state in the D_s sector decaying mostly to $D_s^*(2112)^+\pi^0$. However the study of a structure around 2.46 GeV/c^2 is quite challenging due to various background sources under the peak. Besides, we have to check first if this may not be a reflection of another state and also if, conversely, the state at 2317 MeV/c^2 may not be a reflection from this new state.

And besides, also if the observed $X(2460)$ signal decayed entirely into $D_s^*(2112)^+\pi^0$ it could only explain $\sim 1/6$ of the observed signal at 2.32 GeV/c^2. So, this new object cannot be the only source of the $D_{sJ}^*(2317)$ signal, but can surely contribute to part of the background under the signal: this will be discussed more in detail later.

We examine the kinematics underlying the peak observed at ~ 2.46 GeV/c^2 in Fig. 8(a): we have a better understanding of the physics involved by plotting the scatterplot in

$$\Delta m(D_s^*\pi^0) = m(D_s^+\pi^0\gamma) - m(D_s^+\gamma) \quad vs. \quad \Delta m((D_s^+\gamma) = m(D_s^+\gamma) - m(D_s^+).$$

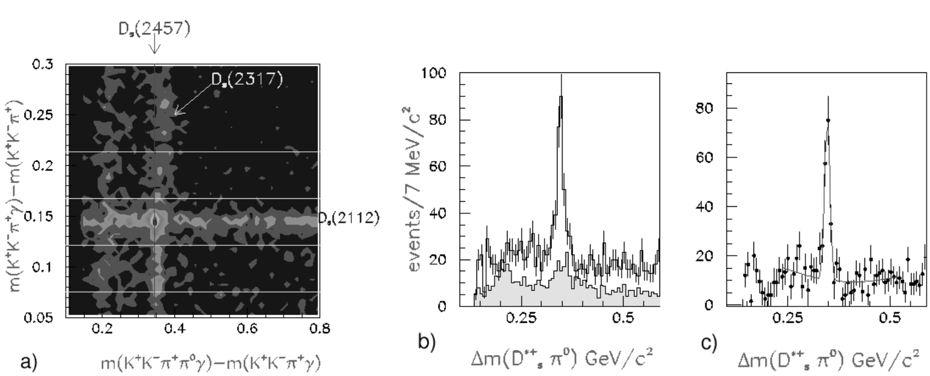

Fig. 8. (a): scatter plot $\Delta m(D_s^*\pi^0)$ *vs* $\Delta m((D_s^+\gamma)$. (b)$\Delta m(D_s^*\pi^0)$ for events in the $D_s^*(2112)^+$ signal region and (shaded) sideband. (c) difference between the 2 previous distributions showing the peak for the $D_{sJ}(2458)^+$.

In Fig. 8(a) we observe two prominent bands, the horizontal corresponding to the real $D_s^*(2112)^+ \to D_s^+\gamma$ decays combined with unrelated π^0's, and the vertical to real $D_{sJ}^*(2317)^+ \to D_s^+\pi^0$ decays combined with unrelated photons. Both these bands cross near the 2.46 GeV/c^2 signal. Fig. 8(b) shows $\Delta m(D_s^*\pi^0)$ for events in the $D_s^*(2112)^+$ signal region (upper line) and for its sideband (shaded). This indicates that a state decaying into $D_s^+\pi^0\gamma$ almost coincide with a background peak due to $D_{sJ}^*(2317)^+$ combined with an unrelated photon.

In Fig. 8(c) we plot the difference between the two previous distributions fitted by a Gaussian plus a polynomial background: the mean value of the Gaussian is $\Delta m(D_s^*\pi^0) = 346.2 \pm 0.9$ MeV/c^2 with a narrow width $\sigma = 8.5 \pm 1.0$ MeV/c, with a yeld of $N = 174 \pm 22$ events, thus confirming the observation of a new state. The shaded background in Fig. 8(b) peaks at $\Delta m(D_s^*\pi^0) = 353.1$ MeV/c^2, at a slightly higher mass than the signal.

Adding the PDG value for the $D_s^*(2112)^+$ mass we obtain a mass $m = 2458.2$ MeV/c^2 for the new object, which is then named $D_{sJ}(2458)^+$. This state may decay to $D_s^+\pi^0\gamma$ either via $D_s^*(2112)\pi^0$ or $D_{sJ}^*(2317)^+\gamma$: to disentangle these states we perform an unbinned channel likelihood analysis [13] simultaneously to the $D_s^+\pi^0\gamma$, $D_s^+\pi^0$, $D_s^+\gamma$ invariant masses for each signal event. Sources of background for the $D_s^+\pi^0\gamma$ spectrum in the fit are purely combinatorial. The fit determines the relative size of the background and signal contributions, the mass and width of the $D_{sJ}(2458)^+$ and of the $D_{sJ}^*(2317)^+$ and is validated using Monte Carlo simulations.

As shown in Fig. 9(a) to (c) the fit provides a good description of all the relative distributions observed in the data. The reconstructed $D_{sJ}(2458)^+ \to D_s^*(2112)^+\pi^0$ mass is $m = 2458.0 \pm 1.0(\text{stat}) \pm 1.0(\text{syst})$ MeV/c^2, while the $D_{sJ}^*(2317)^+\gamma$ amplitude is comparable with zero. Figures 9(b) and 9(c) clearly show that the first decay is clearly favored. Within this fit we also contemporarily consider the background from this channel in the $D_{sJ}^*(2317)^+$ mass distribution: Fig. 9(d) shows this contribution as the dashed curve under the $D_{sJ}^*(2317)^+$ signal. By remaking a binned fit explicitly including this contribution we obtain for the $D_{sJ}^*(2317)^+$ a yeld of $N = 1022 \pm 50$ events, a mass $m = 2317.3 \pm 0.4(\text{stat}) \pm 0.8(\text{syst})$ MeV/c^2 and a width $\sigma = 7.3 \pm 0.2$ MeV/c^2. These results are a new improvement over our previously published value [1].

The observed widths of both states are consistent with the detector resolution, as determined by Monte Carlo studies, so we may safely say that both widths are smaller than 10 MeV. The mass of $D_{sJ}^*(2317)^+$ lies below DK threshold and the $D_{sJ}(2458)^+$ lies above this and below the D^*K threshold; the narrow width and the isospin-violating decay to $D_{sJ}(2458)^+ \to D_s^*(2112)^+\pi^0$ indicate that the decay into DK is forbidden.

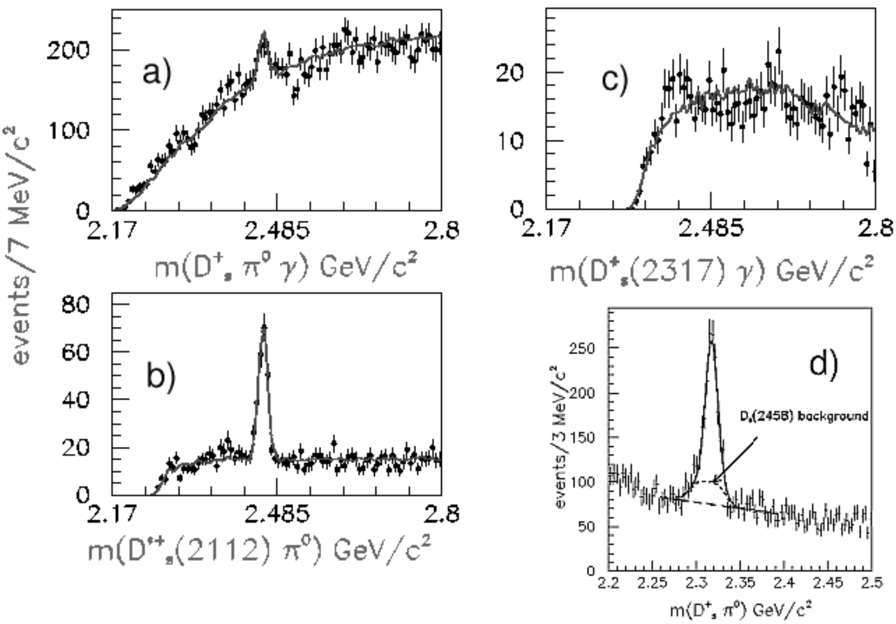

Fig. 9. Maximum likelihood fit results (continuous line) overlaid on the $D_s\pi^0\gamma$ mass distribution with (a) no weights and after applying weights corresponding to (b) the decay $D_s^*(2112)^+\pi^0$; (c) the decay $D_{sJ}^*(2317)^+\gamma$. In (d) the $D_s^+\pi^0$ mass distribution with the fit result contribution (dashed) under the $D_{sJ}^*(2317)^+$ (continuous) fitted signal.

Both the small width and the isospin-violating decay rule out $J^P = 0^+$ and, since the decay to D^0K^+, D^+K^0 is unobserved, also the natural spin-parity assignment $J^P = 1^-, 2^+, \ldots$ seems quite unlikely. Also the apparent absence of the $D_{sJ}^*(2317)^+\gamma$ decay seems to indicate that the electromagnetic decay cannot compete with the observed decay, which may be a strong, but isospin-violating process exploiting $\eta - \pi^0$ mixing [11].

BaBar has investigated the spin-parity assignment of the $D_{sJ}(2458)^+$ by looking at the distribution of the angle θ_h of the gamma from the decay $D_s^*(2112)^+ \rightarrow D_s^+\gamma$ in the $D_s^+\gamma$ center of mass frame respect to the $D_s^*(2112)^+$ line-of-flight. The efficiency corrected distribution of θ_h is shown in Fig. 10 in five bins of $\cos\theta_h$, where the likelihood fit has been separately applied to each of the five samples. This distribution is not consistent with a $\sin^2\theta_h$ distribution expected for $J^P = 0^+$; it is consistent however with a $(1 + \cos^2\theta_h)$ expected for the natural assignment, although as already explained this seems unlikely. We cannot draw any conclusion for $J^P = 1^+, 2^-, 3^+, \ldots$ because since at least 2 partial waves are allowed, we do not have a unique angular distribution.

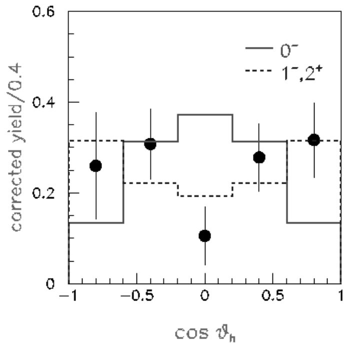

Fig. 10. The efficiency-corrected $D_{sJ}(2458)^+$ yeld as a function of $\cos\theta_h$. The solid [dashed] histogram corresponds to a $\sin^2\theta_h$ $[(1+\cos^2\theta_h)]$ distribution.

6. Experimental confirmations and theory

We show in Fig. 11(a) to (d) the mass distributions for both new particles obtained by Belle and CLEO. As is evident from the figures, the BaBar findings and those of the other experiments are quite similar. The CLEO collaboration has claimed first the $D_{sJ}(2458)^+$ as a new state and confirms

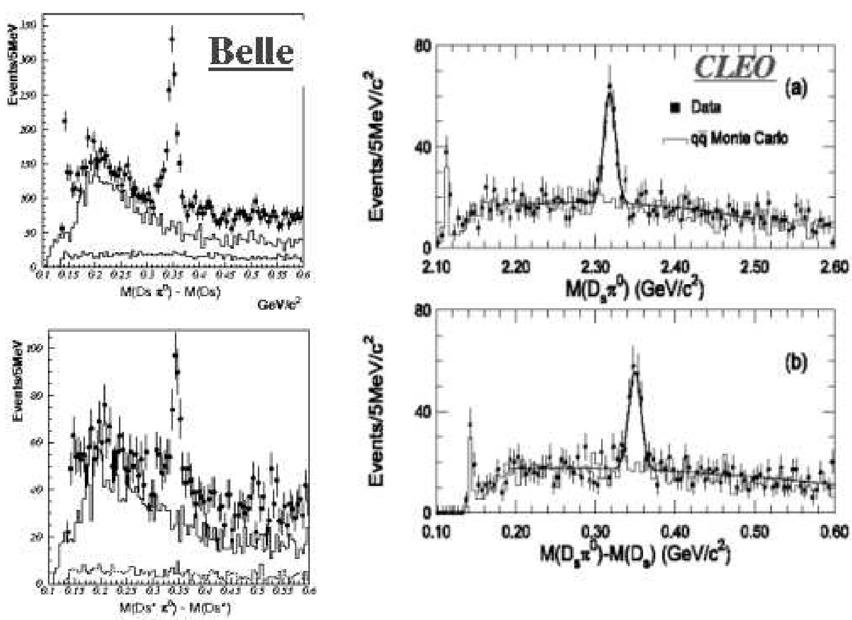

Fig. 11. Belle (left) and CLEO (right) published mass distributions for the $D^*_{sJ}(2317)^+$ (top) and the $D_{sJ}(2458)^+$ (bottom).

the $D^*_{sJ}(2317)^+$ [2]; Belle confirms both states [3, 4] reporting also the observation of the $D^*_{sJ}(2317)^+$ in $B \to DD^*_{sJ}(2317)^+$ decays and of the other decay $D_{sJ}(2458)^+ \to D_s^+\gamma$: this last results rules out $J = 0$ and favors a $J^P = 1^+$ interpretation.

So far all three experiments have shown a consistent picture for the new observed states. A lot of activity on the theoretical side has followed since the first BaBar observation: existing potential models [8, 9] and QCD simulations have trouble accomodating 0^+ and 1^+ $c\bar{s}$ states at such low masses and below DK and D^*K thresholds. An article by Cahn and Jackson [14] explicitely shows how, taking into account all known existing Heavy Quark potential model features, trying to fit the $D^*_{sJ}(2317)^+$ into the same picture raises quite a number of new problems.

In about 6 months since the first observation about 30 theoretical papers have been presented with widely different models: four-quark scalar states [15], DK molecule [16], chiral multiplets of Heavy-light mesons [17, 18], and many more. The models where an effective Lagrangian exploits light quark chiral symmetry [17,18] are quite interesting because they are able to predict the observed mass splittings and decay branching fractions quite well.

For a rewiew of most exotic interpretations see [19], while for a more general and recent review see [20].

The Charm Working Group of BaBar has set up a web-page where you may see an updated list of theoretical papers on the new mesons at [21].

7. Conclusions

BaBar has recently observed two new $c\bar{s}$ mesons: the $D^*_{sJ}(2317)^+$ and the $D_{sJ}(2458)^+$.

The first has been observed in the $D_s^+\pi^0$ decay channel with a mass $m = 2317.3 \pm 0.4(\text{stat}) \pm 0.8(\text{syst})$ MeV/c^2 and an observed Gaussian width $\sigma = 7.3 \pm 0.2$ MeV/c^2; it has been established as the $J^P = 0^+$ member of the D_s system. These particle has been independently confirmed by Belle and CLEO.

CLEO has first observed the $D_{sJ}(2458)^+$. BaBar and Belle have later confirmed it.

BaBar has observed it in the $D_s^*(2112)^+\pi^0$ decay channel and, using a full amplitude analysis to uncover the complex underlying kinematics of this system, has measured its mass at $m = 2458.0 \pm 1.0(\text{stat}) \pm 1.0(\text{syst})$ MeV/c^2 with an observed Gaussian width $\sigma = 8.5 \pm 1.0$ MeV/c^2. Its properties consistently indicate a $J^P = 1^+$ assignment. BaBar has not yet observed the connected e.m. decay channel $D_s^+\gamma$, which seems peculiarly suppressed.

The observed widths for both particle are fully consistent with the experimental resolution and consistent with intrinsic widths $\Gamma < 10$ MeV.

Both particles do not fit well into known existing HQT models and their small intrinsic widths may be explained by a known isospin-violating decay mechanism. These states are lighter respectively than the DK and D^*K thresholds, which were the main expected decay channels.

A lot of theoretical work has been spurred from the observation of these particles and several more or less exotic models have been proposed to explain them, and a lot of theorists are quite excited on the subject. The sector of D_s physics is now very alive both on the experimental and theoretical sides: there's a lot of work going on now and we expect to have interesting times ahead of us!

In particular BaBar is studying now these new states in great detail both in $c\bar{c}$ and B decays and expects to have more results in the next future.

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