Studies of D_{sJ} mesons at BaBar

Loredana Lopez
University of Bari & INFN
For the BaBar Collaboration

Joint Meeting of Pacific Region Particle Physics Communities
(DPF2006+JPS2006…)
October 29 - November 3, 2006

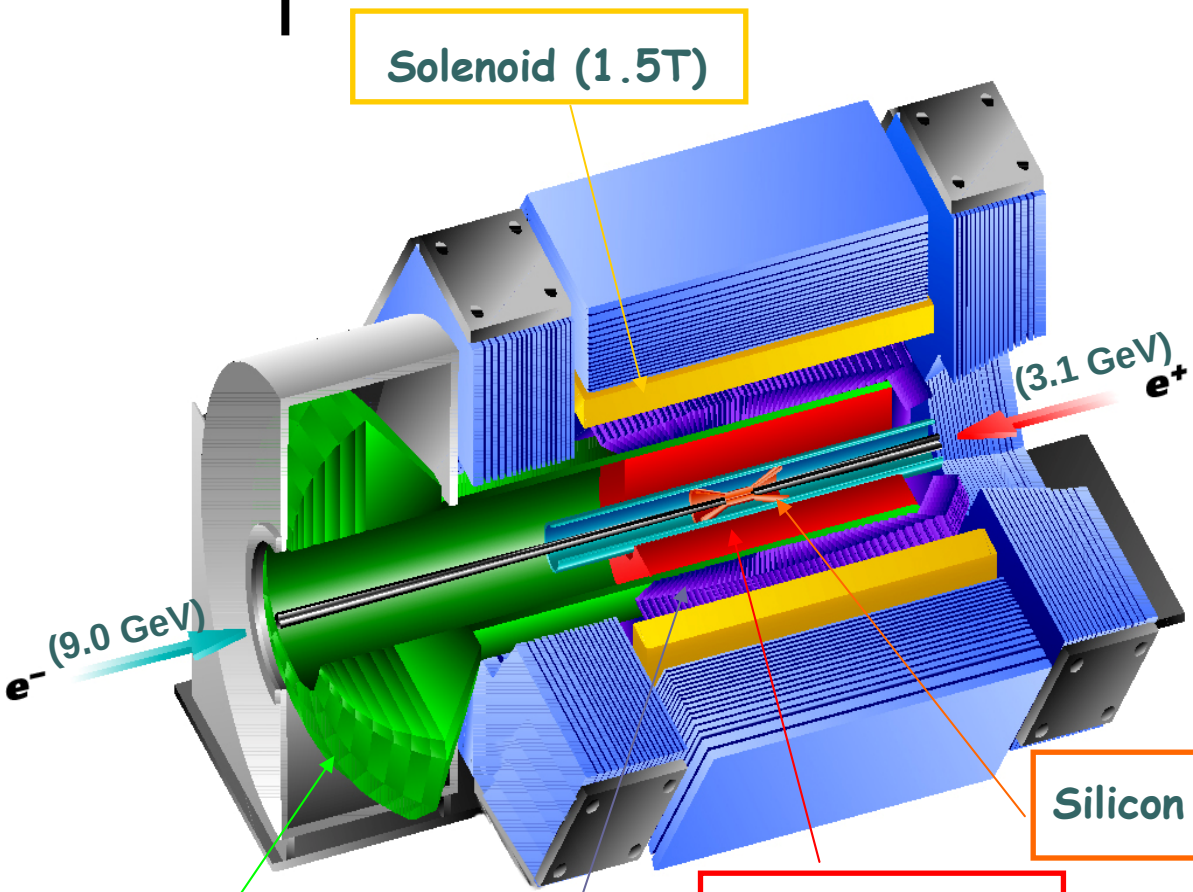
Outline

- Charm spectroscopy:
  - Precise measurements of $D_{s1}(2536)$ parameters
  - New results in charmed-strange mesons: $D_{s0}^*(2317)$ and $D_{s1}(2460)$
  - Observation of a ***new D_s meson*** with mass of ~2.86 GeV/c^2 and a wide structure at ~2.69 GeV/c^2

BABAR

In every analysis charge conjugation is implied

The BaBar Detector



L_{peak} = 12.06 x 10^{33} cm^{-1} s^{-1}
$L_{recorded}$ ~ 391 fb^{-1}

N($b\bar{b}$) ~ 400 M
N($c\bar{c}$) ~ 500 M

BaBar is also a charm factory

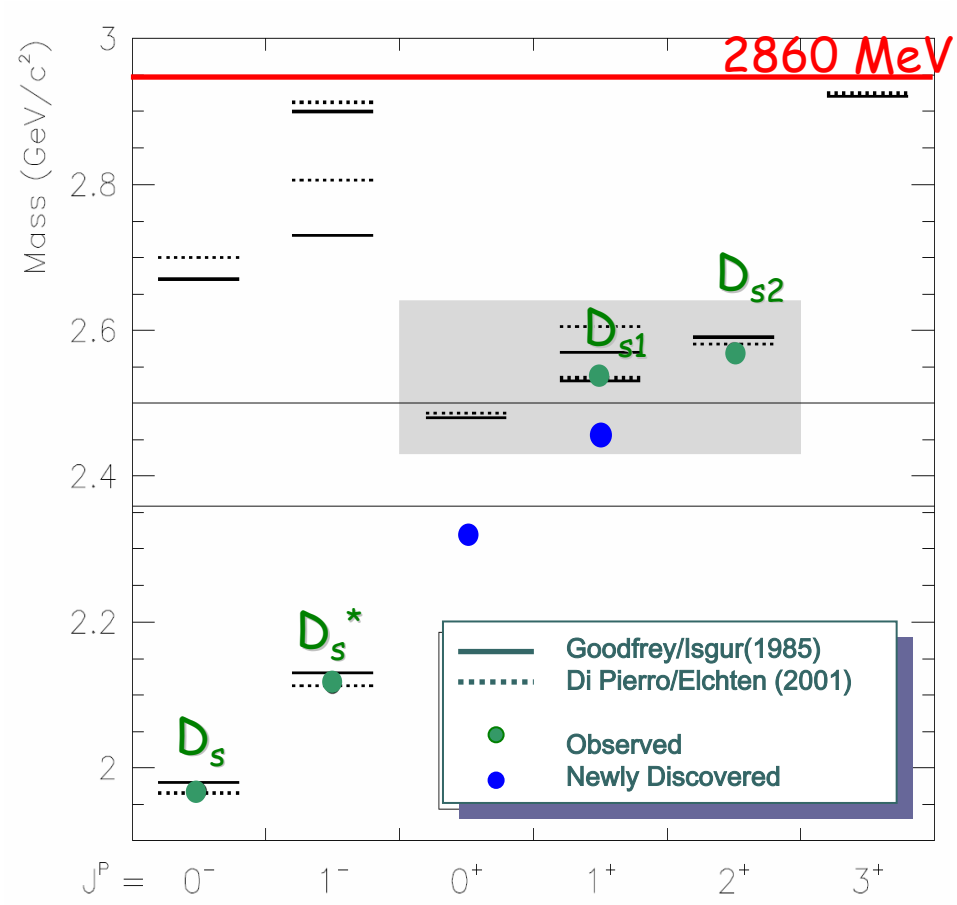
Charmed-strange meson Spectrum

- The $c\bar{s}$ spectrum is still incomplete
- Discovered in 2003 two new states:

$D_{s0}^*(2317)$ ($\rightarrow D_s\pi^0$)
m=2317.4±0.9 MeV, Γ<4.6 MeV (PDG)
J^P consistent with 0^+

$D_{s1}(2460)$ ($\rightarrow D_s^*\pi^0, D_s\gamma, D_s\pi^+\pi^-$)
m=2459.3±1.3 MeV, Γ<5.5 MeV (PDG)
J^P consistent with 1^+

- $c\bar{s}$ assignment in conflict with expectations: masses lower than predicted, widths very small



- June 2006: a new $c\bar{s}$ state found in Babar
$D_{sJ}(2860) \rightarrow D\ K$

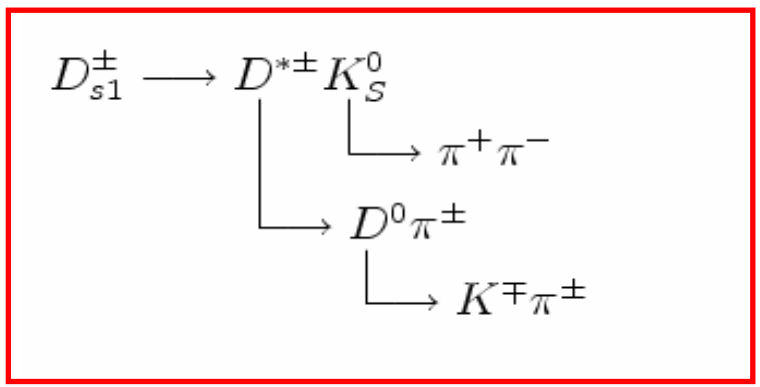
Determination of mass and width for $D_{s1}(2536)$

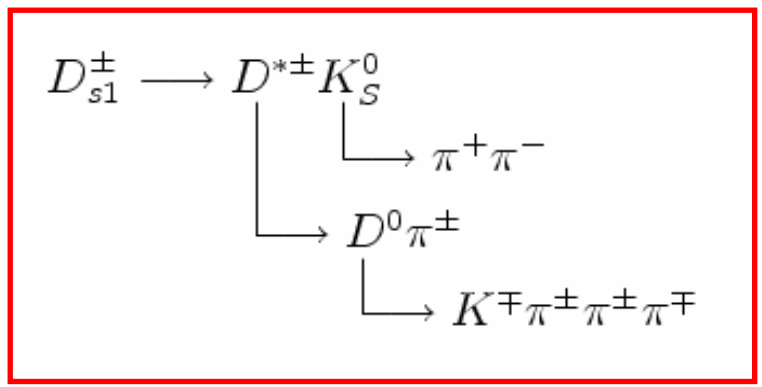
Submitted to PRL: hep-ex/0607084

- Values of mass and width from PDG:

  $m = 2535.35 \pm 0.34 \pm 0.5$ MeV/c^2 and $\Gamma < 2.3$ MeV

- Decay modes used:





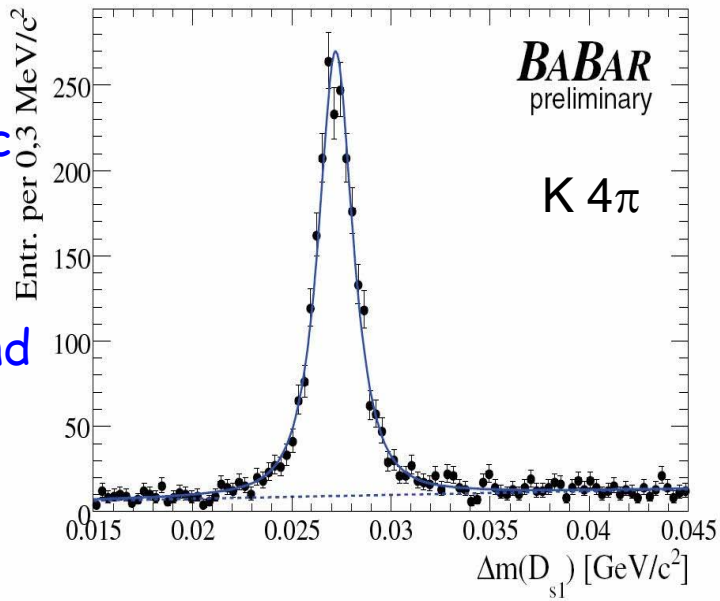
- Only charged tracks → good mass resolution
- Measure of: $\Delta m = m(D_{s1}^{+}) - m(D^{*+}) - m(K_S^0)$ to reduce the systematics and improve resolution

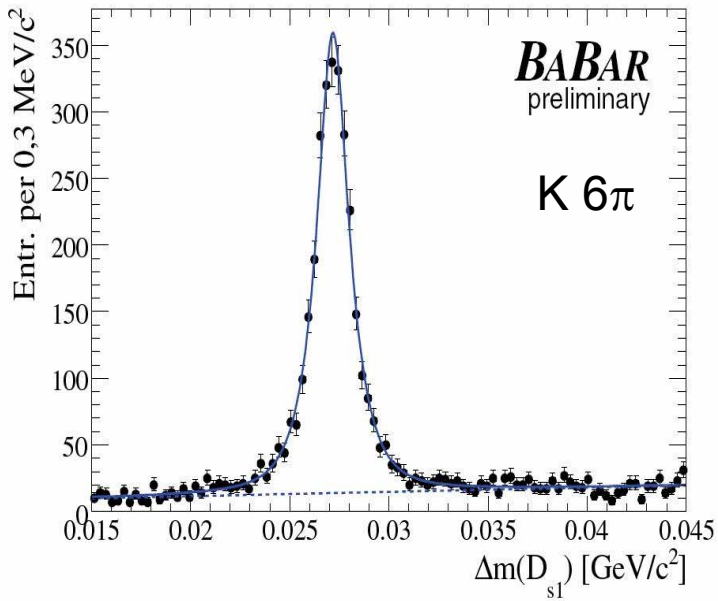
Fit to the data

BaBar:232 fb^{-1}
hep-ex/0607084

$p^*(D^0 K_s) > 2.7$ GeV/c

Signal:
rel. Breit-Wigner and
Gaussian resolution





For a combined sample the results are:

$m(D_{s1}^+) = (2534.85 \pm 0.02 \pm 0.40)$ Mev/c^2

$\Gamma(D_{s1}^+) = (1.03 \pm 0.05 \pm 0.12)$ MeV

$\Delta m = m(D_{s1}^+) - m(D^{*+}) = (524.85 \pm 0.02 \pm 0.04)$ MeV/c^2

Improvement by a factor of 14 compared to the current PDG value

Update on D_{sJ} states

- Comprehensive study of decays to D_s^+, plus one or two $\pi^\pm$,π^0 or γ's;
- Decay pattern if $J^P=0^+$ and $J^P=1^+$, respectively

$D_s^+\pi^0$ only decay mode observed for $D_{s0}^*(2317)^+$

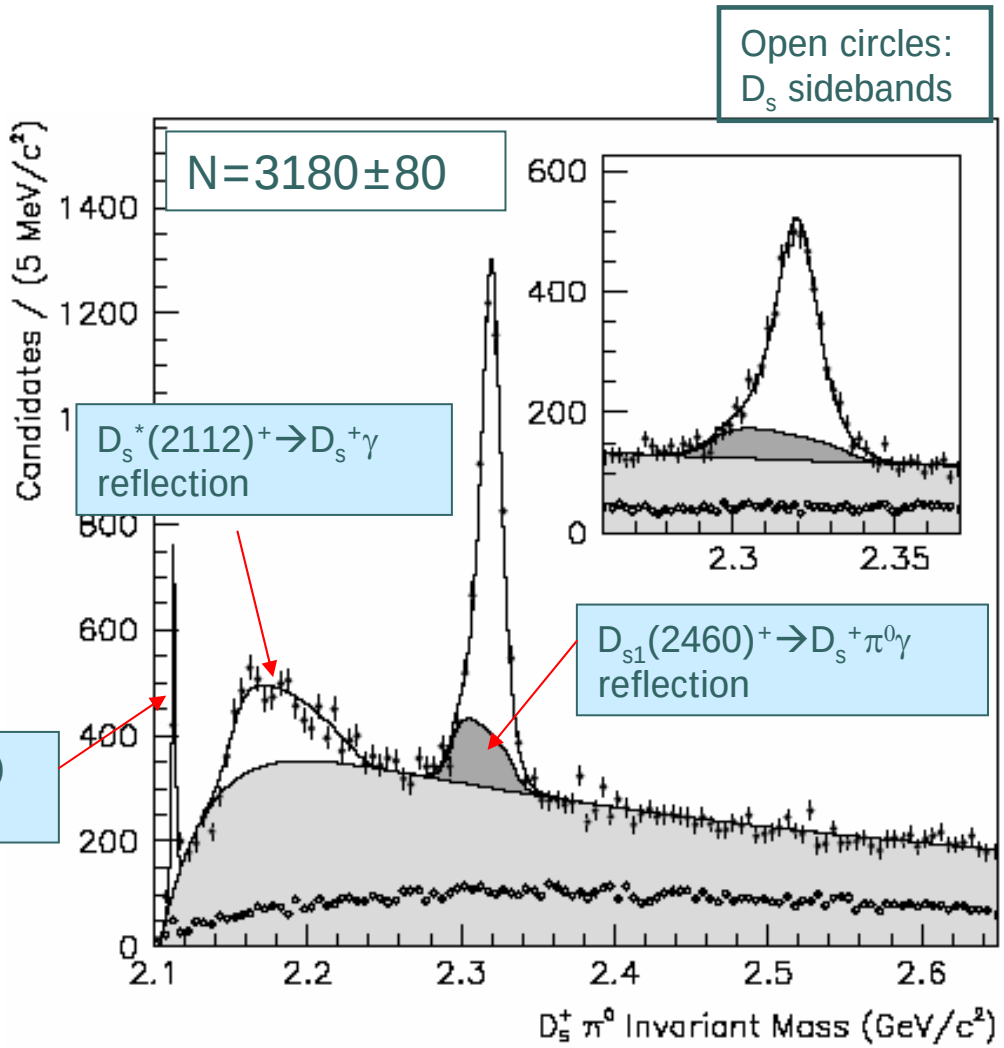
Decay Channel	$D_{s0}^*(2317)^+$	$D_{s1}(2460)^+$
$D_s^+\pi^0$	Seen	Forbidden
$D_s^+\gamma$	Forbidden	Seen
$D_s^+\pi^0\gamma$ (a)	Allowed	Allowed
$D_s^*(2112)^+\pi^0$	Forbidden	Seen
$D_{sJ}^*(2317)^+\gamma$	—	Allowed
$D_s^+\pi^0\pi^0$	Forbidden	Allowed
$D_s^+\gamma\gamma$ (a)	Allowed	Allowed
$D_s^*(2112)^+\gamma$	Allowed	Allowed
$D_s^+\pi^+\pi^-$	Forbidden	Seen

(a) Non-resonant only

$D_{s0}^*(2317)^+ \to D_s^+ \pi^0$

BaBar:232 fb^{-1}
PRD74, 032007 (2006)

- Only decay mode observed is:
  $D_{s0}^*(2317)^+ \to D_s^+ \pi^0$
- Maximum Likehood fit accounting for:
  signals, reflection and combinatorial background

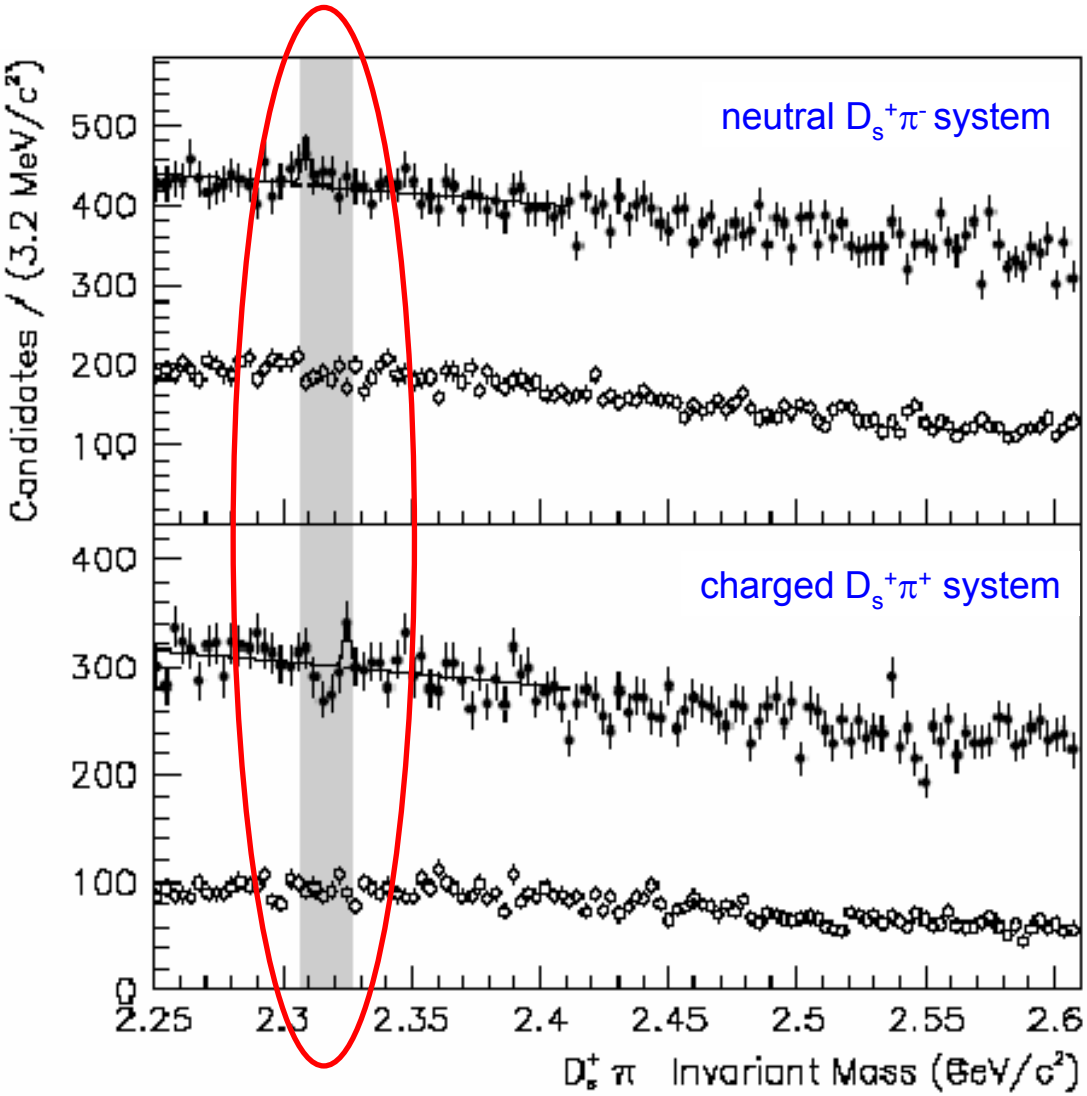


$$m = (2319.6 \pm 0.2 \pm 1.4)\ \mathrm{MeV/c^2}$$
$$\Gamma < 3.8\ \mathrm{MeV}\ @\ 95\%\ \mathrm{CL}$$

Search for neutral or doubly-charged partner of $D_{s0}(2317)$

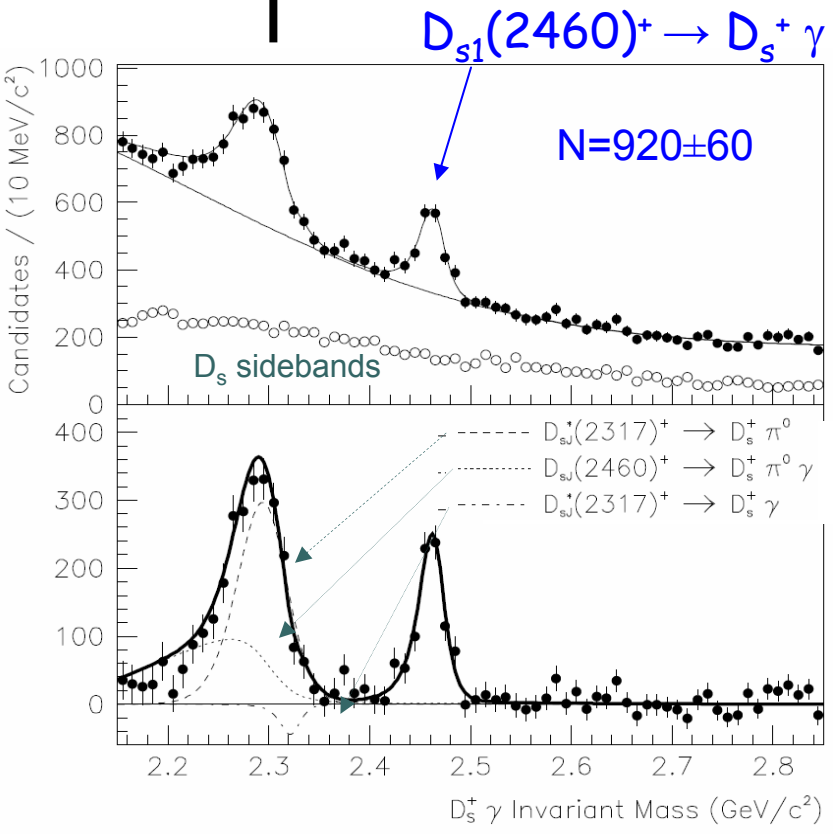
- Tetra-quark model allows neutral or doubly-charged partner

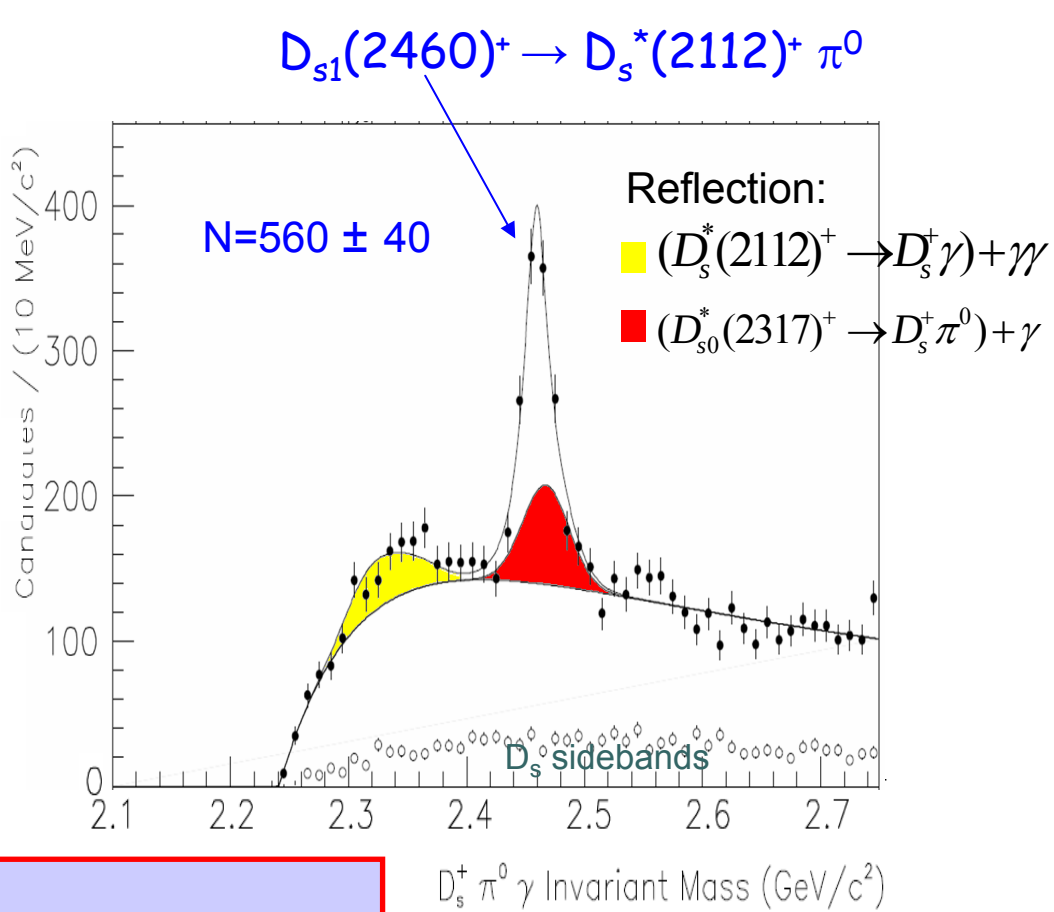
- However, no indication of such a states near 2317 MeV/c^2 ➞ I=0



BaBar:232 fb^{-1}
PRD74, 032007 (2006)

$D_{s1}(2460)^+ \to D_s^+ \gamma$ / $D_s^*(2112)^+ \pi^0$ $\hookrightarrow D_s^+ \gamma$





$$\frac{B(D_{s1}(2460)^+ \to D_s^+ \gamma)}{B(D_{s1}(2460)^+ \to D_s^+ \pi^0 \gamma)} = 0.337 \pm 0.036 \pm 0.038$$

BaBar:232 fb^{-1}
PRD74, 032007 (2006)

$D_{s1}(2460)^+ \to D_s^+\pi^+\pi^-$

BaBar:232 fb^{-1}
PRD74, 032007 (2006)

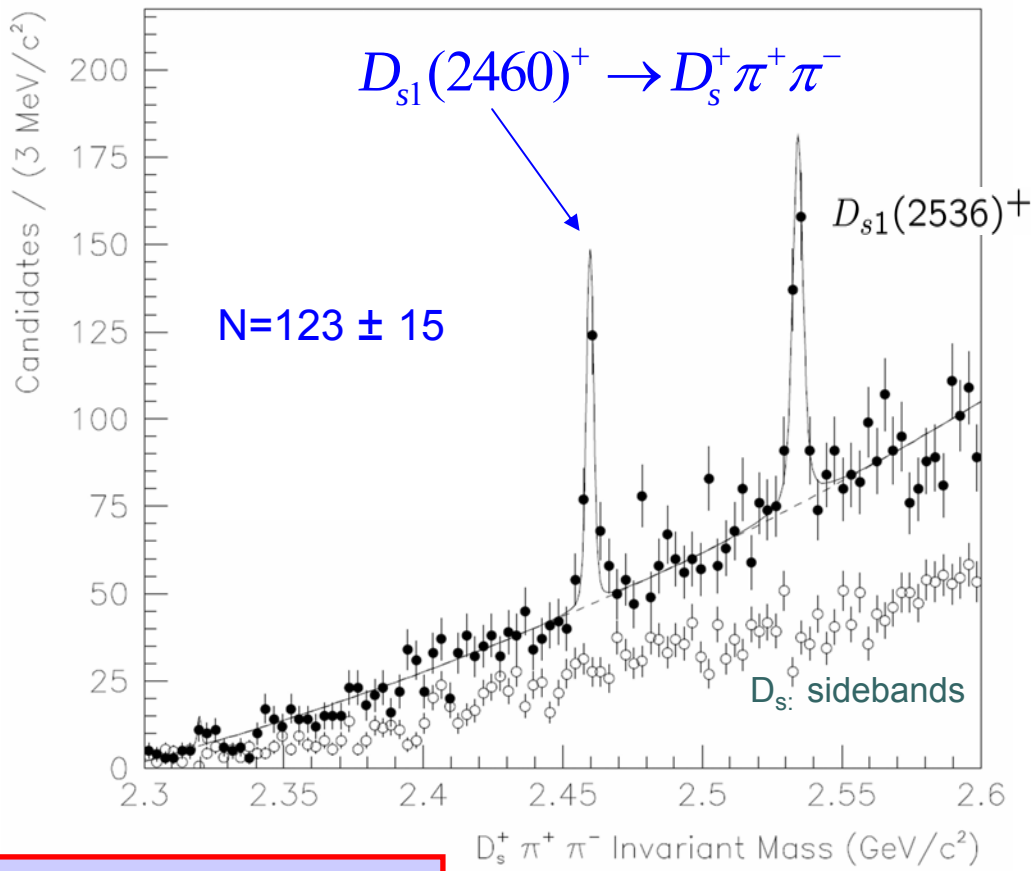
- No indication of $D_{s0}^*(2317)^+$
- Also observe $D_{s1}(2536)^+$

$D_{s1}(2460)$ parameters

$$m = (2460.2 \pm 0.2 \pm 0.8)\ \mathrm{MeV/c^2}$$
$$\Gamma < 3.5\ \mathrm{MeV}\ @\ 95\%\ \mathrm{CL}$$

$D_{s1}(2536)$ parameters

$$m = (2534.6 \pm 0.3 \pm 0.7)\ \mathrm{MeV/c^2}$$
$$\Gamma < 2.5\ \mathrm{MeV}\ @\ 95\%\ \mathrm{CL}$$

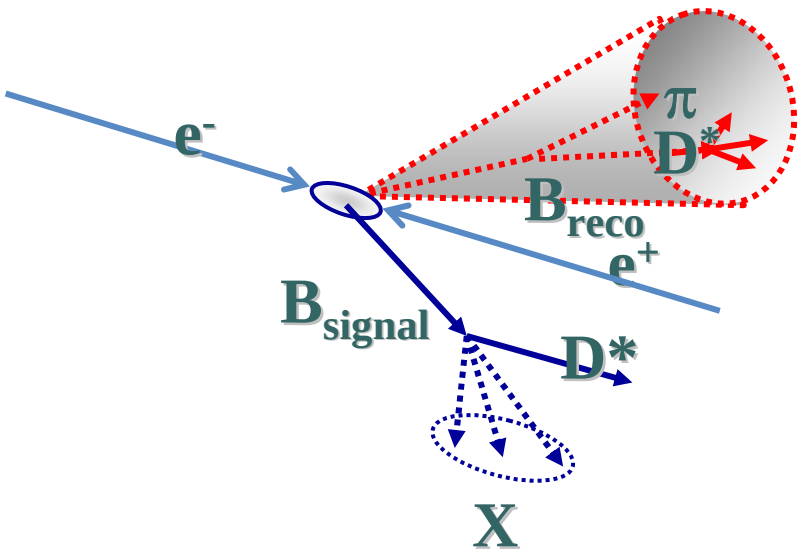


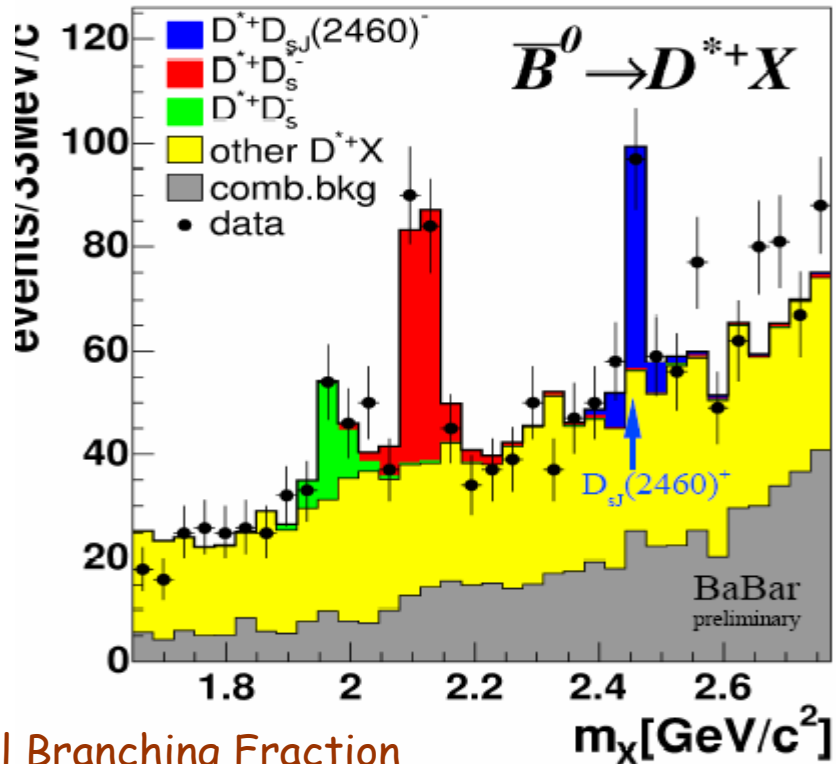
$$\frac{B(D_{s1}(2460)^+ \to D_s^+\pi^+\pi^-)}{B(D_{s1}(2460)^+ \to D_s^+\pi^0\gamma)} = 0.077 \pm 0.013 \pm 0.008$$

Charm spectroscopy in B decays

BABAR: 210.5M $B\bar{B}$
PRL 93,181801(2004)

- $B\bar{B}$ sample with one B fully reconstructed
  → Study decays of $B \to D^{(*)+/0}(D_s^{(*)-})$ X
  - Observe $D_{s1}^*(2460)$ signal in the recoil mass, m_x
    - Mass and momentum of X inferred from the kinematics of the two body B-decay





Absence of $D_{s1}^*(2317)$ expected due to the small Branching Fraction

$D_{s1}^*(2460)$ Absolute Branching Fractions, cont.

BABAR: 210.5M BB
PRL 93,181801(2004)

- First measurement of absolute BF's for $B \to D^{(*)+/0} D_{s1}(2460)^-$ decays, e.g.
  - $\mathcal{B}(B^0 \to D^{*+} D_{s1}(2460)^-) = (0.88 \pm 0.0.2 \pm 0.14)\%$
- Combine with previously measured, exclusive product BF's
  - $B \to D^{(*)} D_{s1}(2460)^+$, $D_{s1}(2460)^+ \to D_s^+ \gamma$ / $D_s^*(2112)^+ \pi^0$ to obtain absolute BFs:

$\mathcal{B}(D_{s1}(2460)^+ \to D^*_s(2112)^+ \pi^0) = 0.56 \pm 0.13 \pm 0.09$ $(D_s^{*+} \to D_s^+ \gamma)$
$\mathcal{B}(D_{s1}(2460)^+ \to D_s^+ \gamma) = 0.16 \pm 0.04 \pm 0.03$

Sum of BFs for $D_{s1}(2460)^+$ decaying to $\pi^0/\gamma = 72 \pm 19\%$

$\mathcal{B}(D^+_s \to \phi\pi^+) = (4.62 \pm 0.36 \pm 0.51)\%$
as determined in this analysis

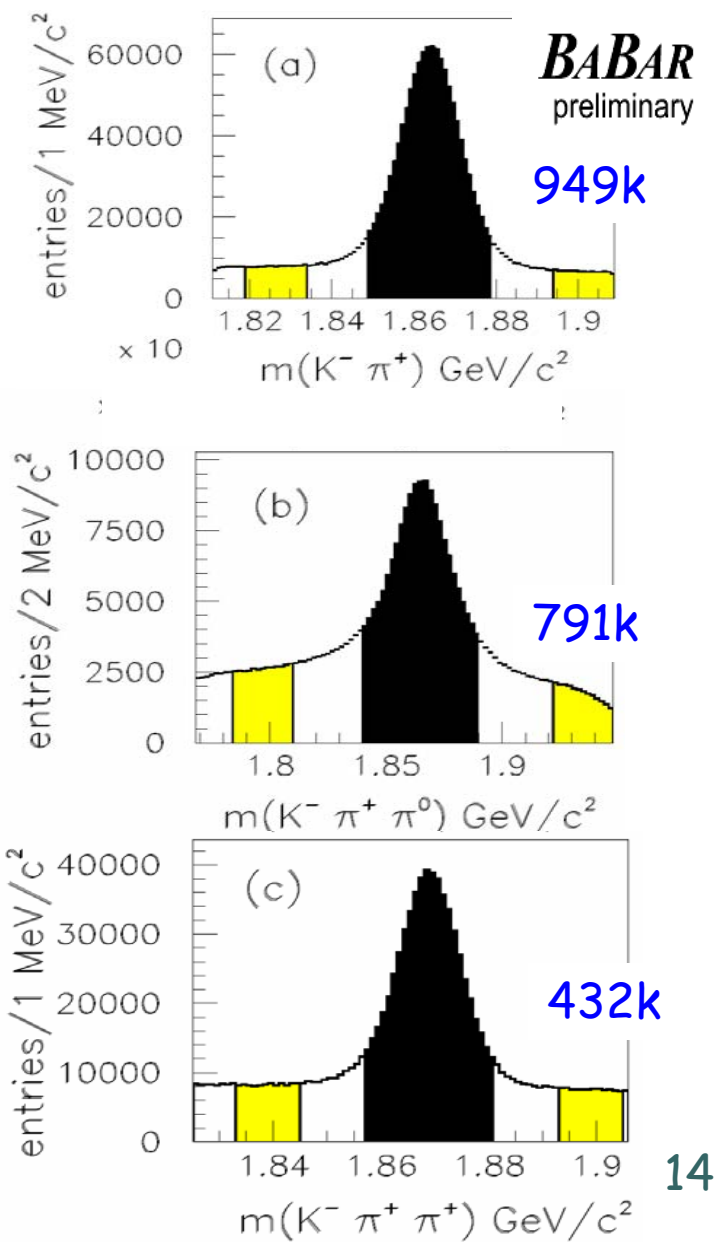
Inclusive study in the DK system

- Inclusive study in the DK system in $e^+e^- \to c\bar{c}$ system:

$$e^+e^- \to (D^0K^+)X \hookrightarrow K^-\pi^+, K^-\pi^+\pi^0$$

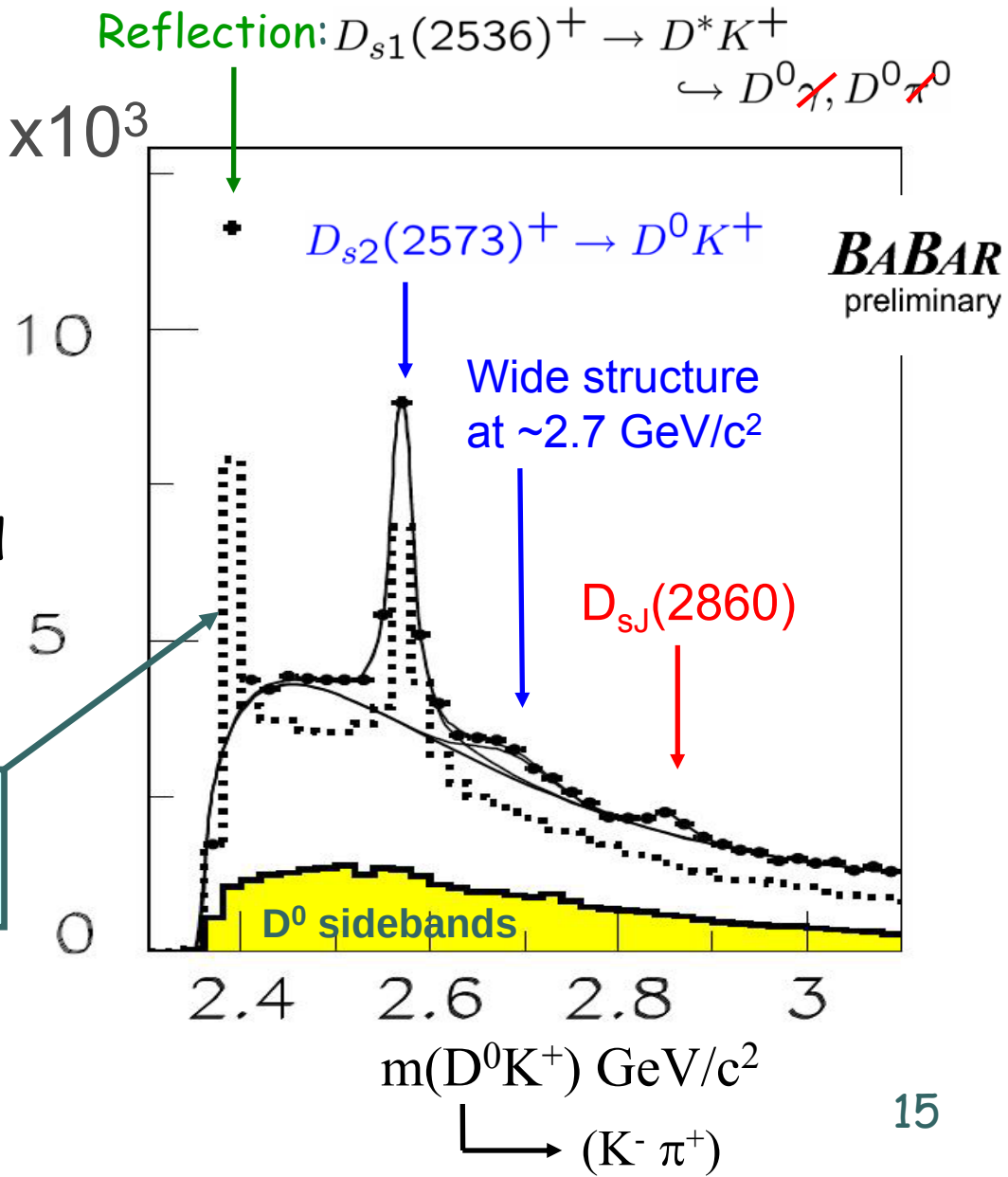
$$e^+e^- \to (D^+K_S^0)X \hookrightarrow K^-\pi^+\pi^+$$

- Pions/Kaons positively identified
- CM momentum p*(DK)>3.5 GeV/c



Observation of a new resonance at 2.86 GeV

- New structure at 2.86 GeV
  - absent in D^0 sidebands
  - absent in $e^+e^- \to c\bar{c}$ MC events
  - not due to kaon/pion and proton misidentification



Dotted line: Monte Carlo simulation with arbitrary scale

BaBar:240 fb^{-1}
hep-ex/0607082

Other observations of $D_{sJ}(2860)$

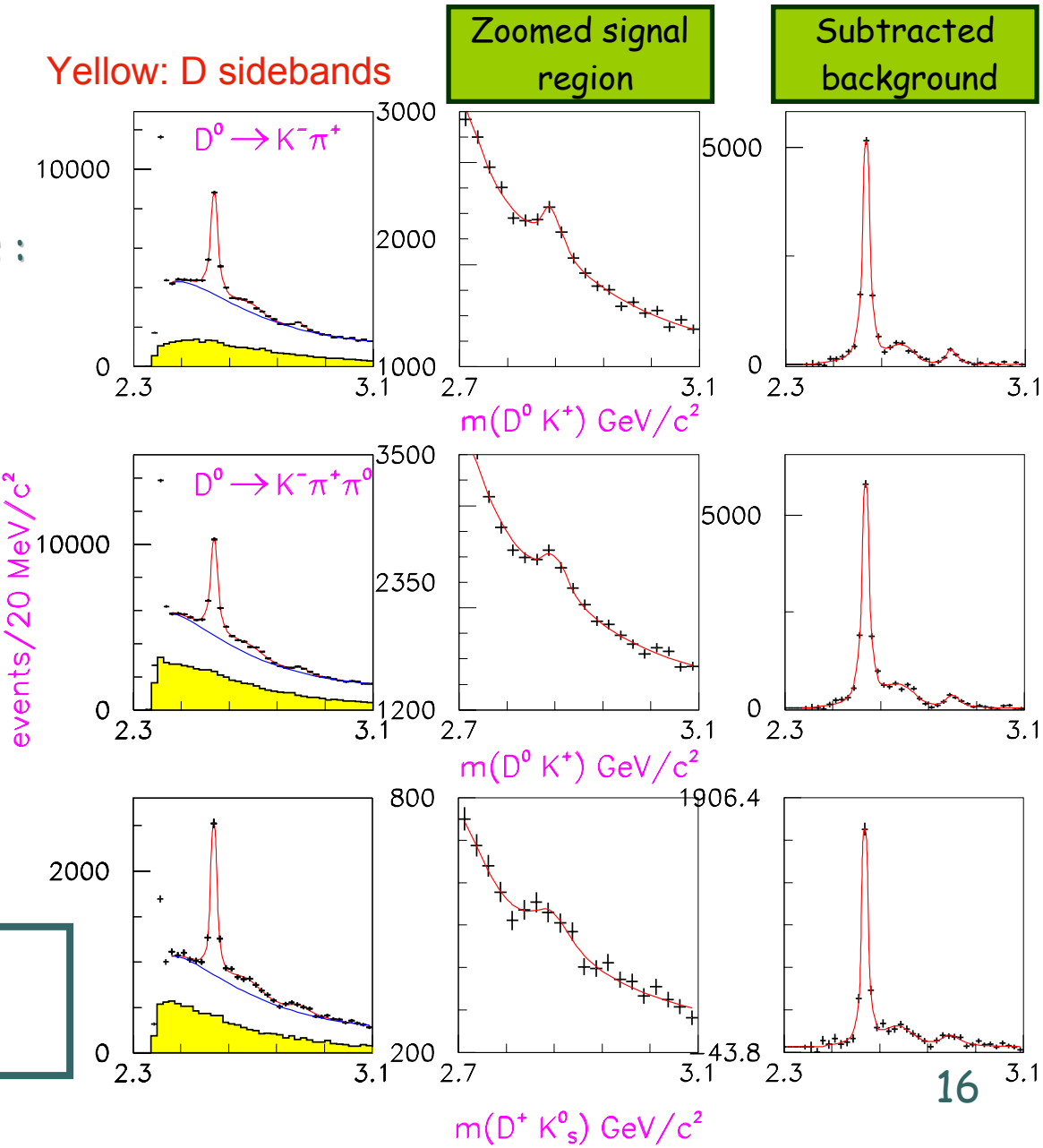
Three different decay channels :

1. $D^0 K^+$, $D^0 \to K^- \pi^+$:
   886±134 events (6.2σ)

2. $D^0 K^+$, $D^0 \to K^- \pi^+ \pi^0$:
   1146±157 events (6.5 σ)

3. $D^+ K_s$, $D^+ \to K^- \pi^+ \pi^+$:
   371 ±84 events (3.7 σ)

Removing the $D_{sJ}(2860)$ from the fit ⟶ $\Delta\chi^2/\Delta NDF = 108/5$



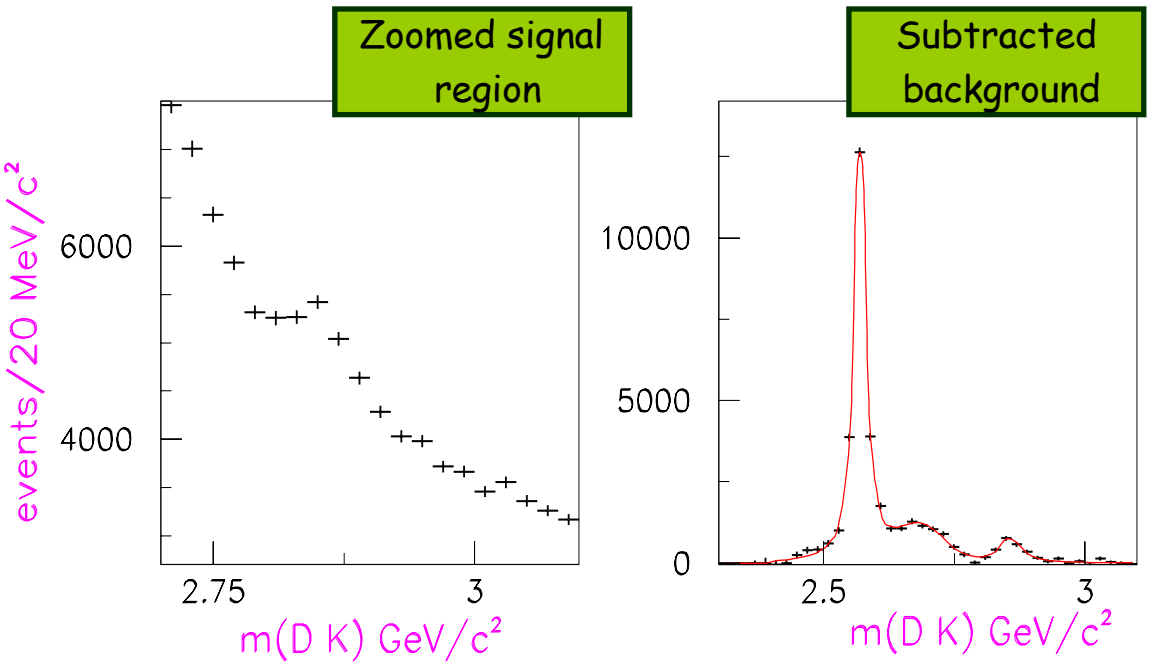
$D_{sJ}(2860)^+$ parameters

BaBar:240 fb^{-1}
hep-ex/0607082

$D_{s2}(2572)^+$ parameters:
$m=2572.2\pm0.3\pm1.0$ MeV/c^2
$\Gamma=27.1\pm0.6\pm5.6$ MeV

$D_{sJ}(2860)^+$ parameters:
$m=2856.6\pm1.5\pm5.0$ MeV/c^2
$\Gamma=48\pm7\pm10$ MeV

Sum of three mass spectra



Decay to DK implies natural spin-parity : is it a $D_{sJ}^*(2860)$ the missing $J^P=3^-$ $c\bar{s}$ state or is a scalar $J^P=0^+$ as suggested in hep-ph/0606110 ?

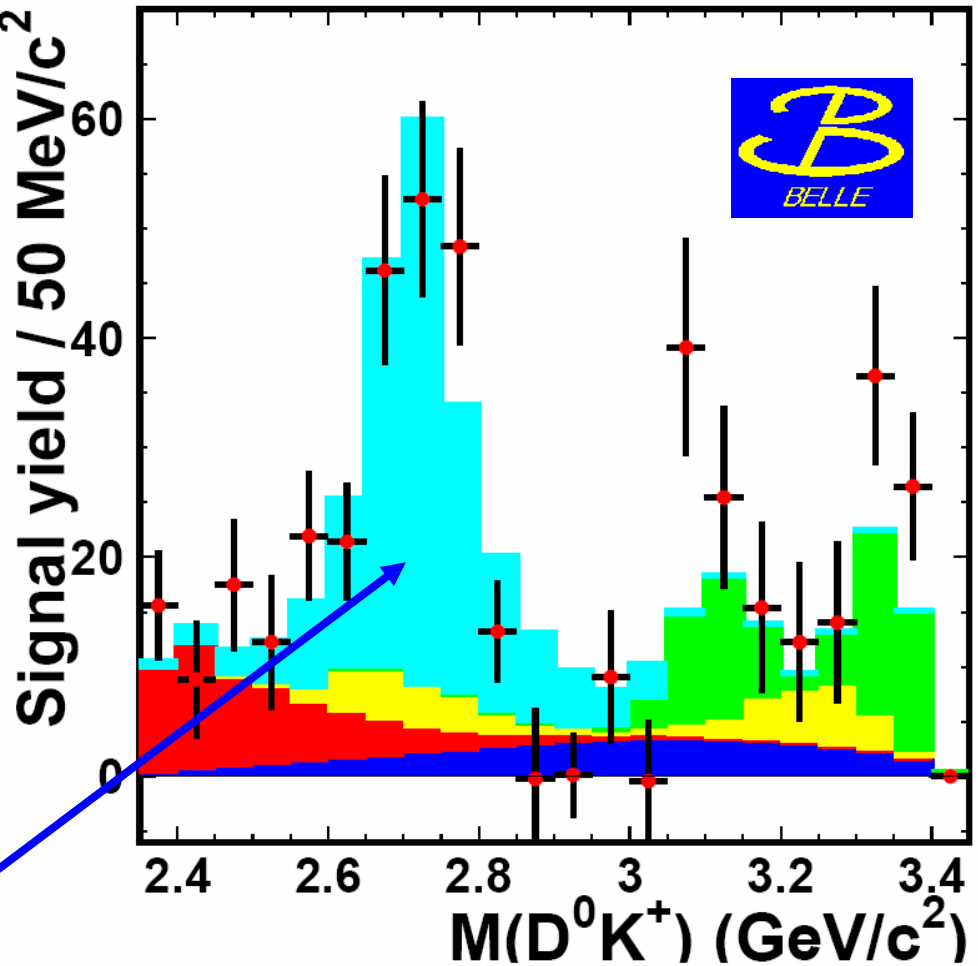
Possible resonance interpretation of X(2680)$^+$

If resonance: X(2680)$^+$ with a Breit Wigner parameterization

$$m = 2688 \pm 4 \pm 2 MeV/c^2$$
$$\Gamma = 112 \pm 7 \pm 36 MeV$$

A structure in the same mass region observed also by BELLE in $B \to \bar{D}^0 D^0 K^+$ system (BELLE-CONF-0643)

$$m = 2715 \pm 11^{+11}_{-14} MeV/c^2$$
$$\Gamma = 115 \pm 20^{+36}_{-32} MeV$$



Summary

- Precise measurements for the $D_{s1}(2536)^+$ mass and width
- Improvement in the measurements for the $D_{s0}(2317)^+$ and $D_{s1}(2460)^+$ parameters
- Observation of a new resonance $D_{sJ}(2860)$
- Possible observation of an other resonance $D_{sJ}(2680)$

BABAR