Charm Spectroscopy and Search for New States at BaBar

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Europhysics Conference on High Energy Physics
Manchester
19th – 25th July 2007

Outline

BaBar: not only a b-factory, but also a rich source for charmed hadrons!

$$N(b\bar{b}) = 469 \cdot 10^6$$
$$N(c\bar{c}) = 581 \cdot 10^6$$

Charm spectroscopy

- High precision measurements: $D_{s1}(2536)$
- New charm-strange meson states: $D_{sJ}(2860)$ $X(2690)$
- New charmed baryon states: Ω_c^{*0} $\Lambda_c(2940)^+$ $\Xi_c(3055)^+$ $\Xi_c(3123)^+$

Charmed-strange Mesons

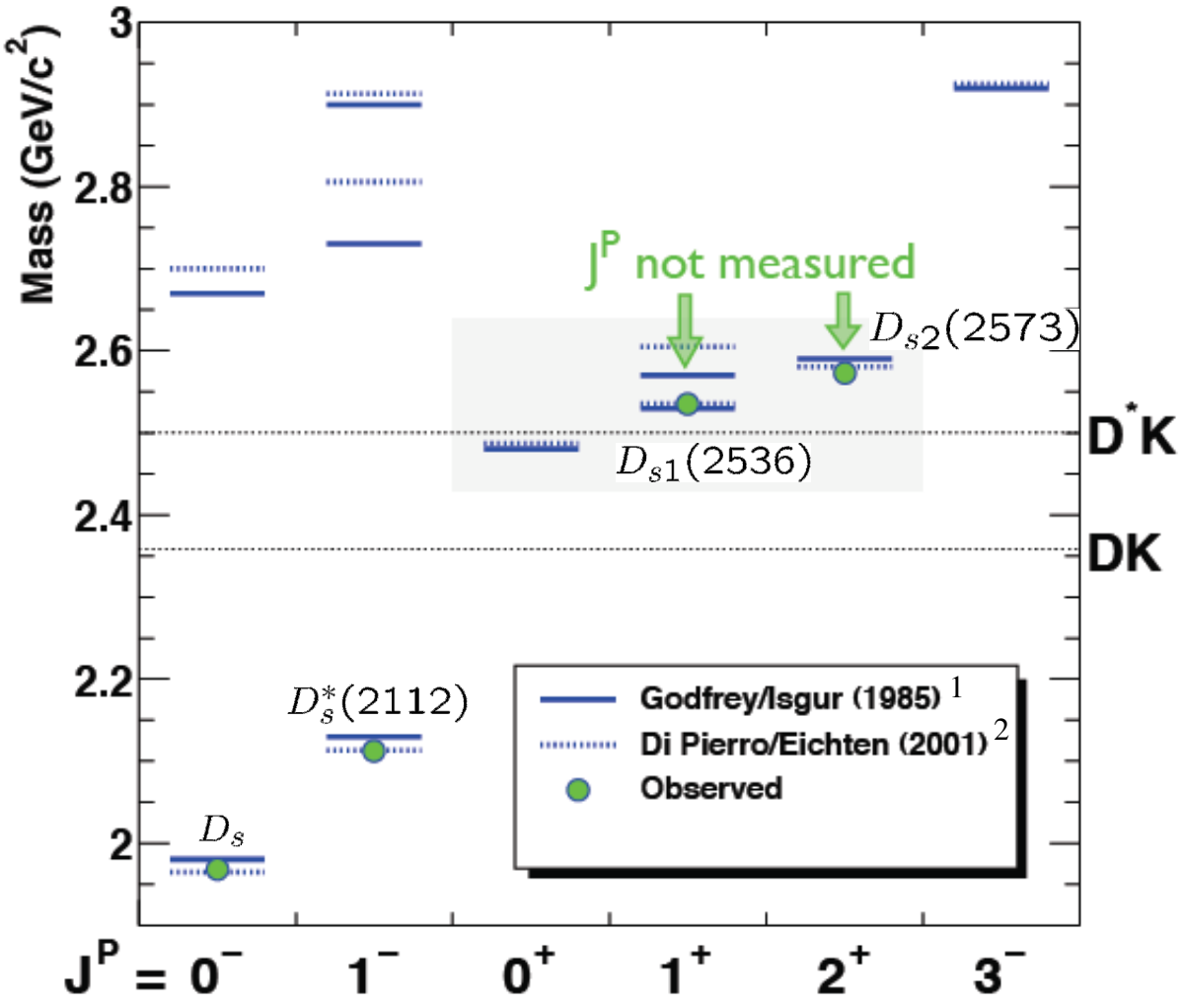
$D^{(*)}_{s(J)}$: $c\bar{s}$ mesons

D_s

$D_s^*(2112)$

$D_{s1}(2536)$

$D_{s2}(2573)$



1) Phys. Rev. D32, 189
2) Phys. Rev. D64, 114004

Charmed-strange Mesons

$D^{(*)}_{s(J)}$: $c\bar{s}$ mesons

D_s

$D^*_s(2112)$

$D_{s1}(2536)$

$D_{s2}(2573)$

last four years...

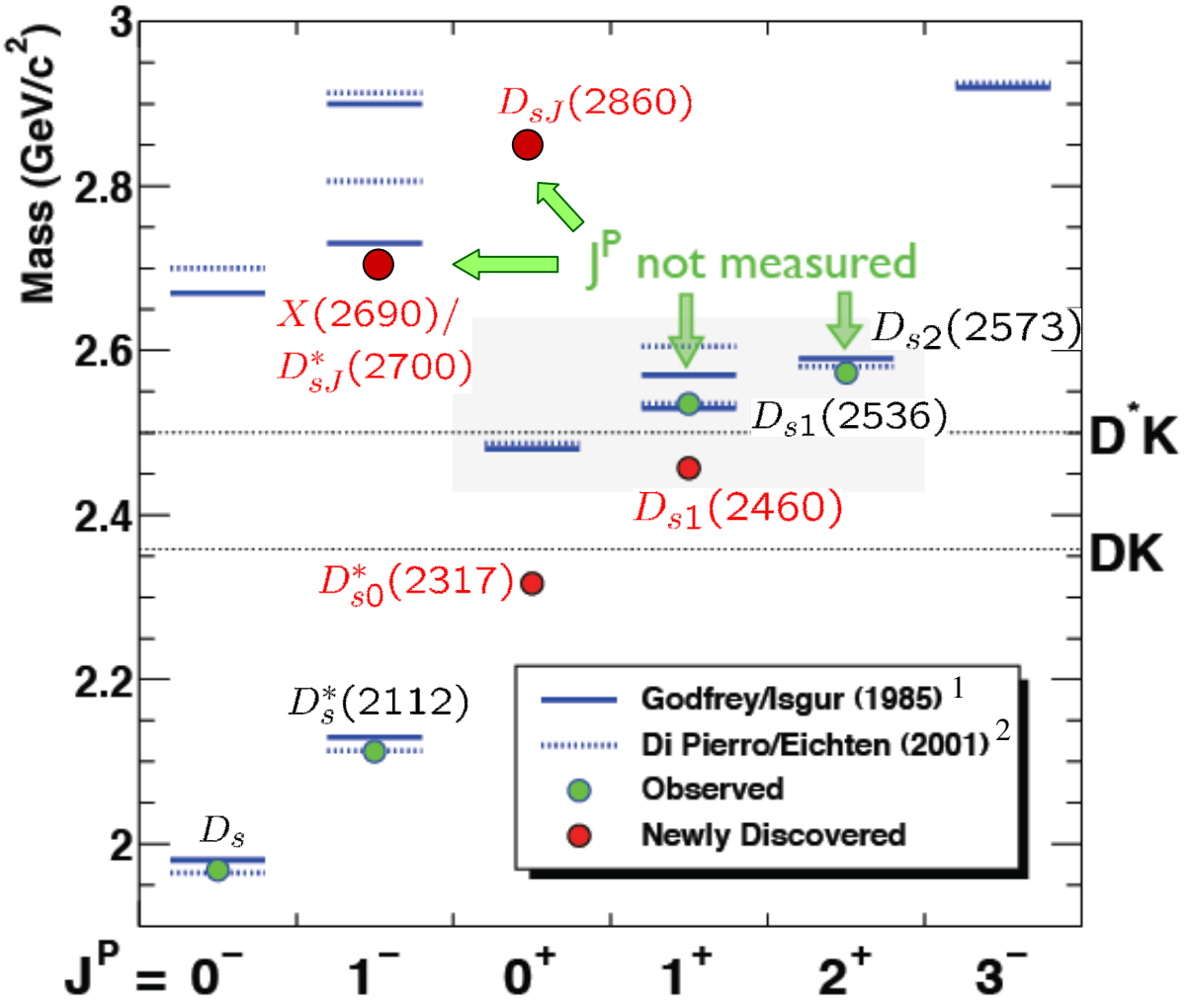
$D^*_{s0}(2317)$ BaBar

$D_{s1}(2460)$ Cleo

$D_{sJ}(2860)$ BaBar

? $X(2690)/D^*_{sJ}(2700)$

Babar Belle



1) Phys. Rev. D32, 189

2) Phys. Rev. D64, 114004

Analysis of $D_{s1}(2536) \to D^*K_S$

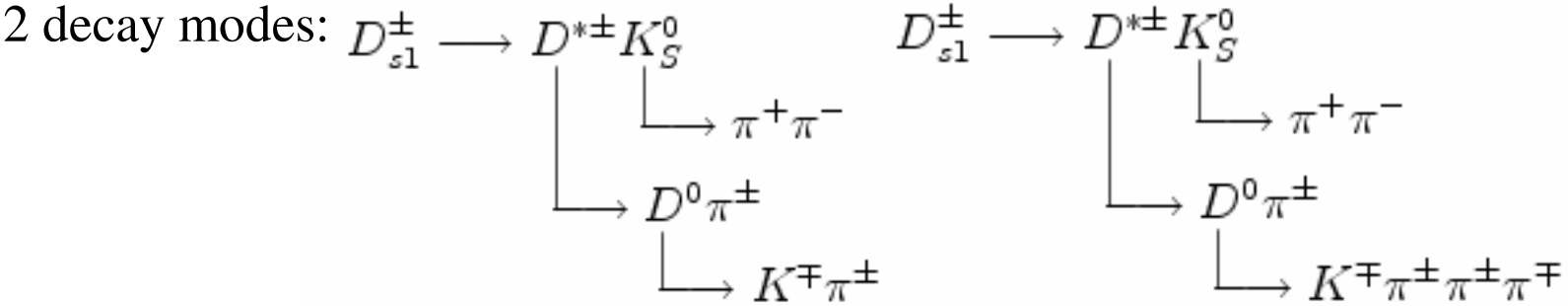
- High precision measurement of $D_{s1}(2536)$ mass and decay width

PDG 06: $m(D_{s1}) = 2535.35 \pm 0.34 \pm 0.5 \mathrm{MeV}/c^2$

$m(D_{s1}) - m(D^*) = 525.3 \pm 0.6 \pm 0.1 \mathrm{MeV}/c^2$

$\Gamma(D_{s1}) < 2.3 \mathrm{MeV}/c^2$

- 2 decay modes:



- measure $\Delta m(D_{s1}) = m(D_{s1}) - m(D^*) - m(K_S^0)$
  to reduce systematics and improve resolution
- Systematic studies

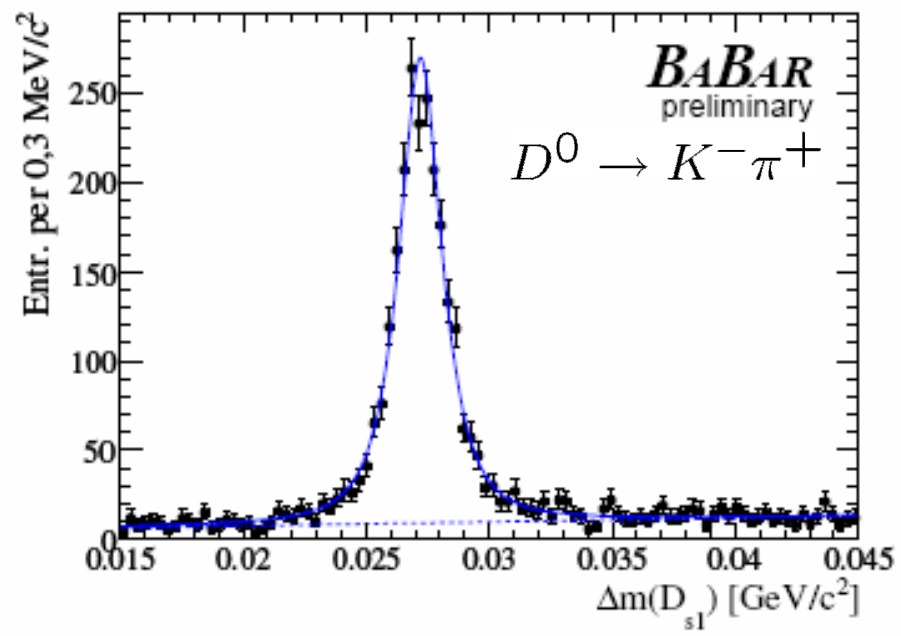
  Detector: tracking, momentum and angular dependence

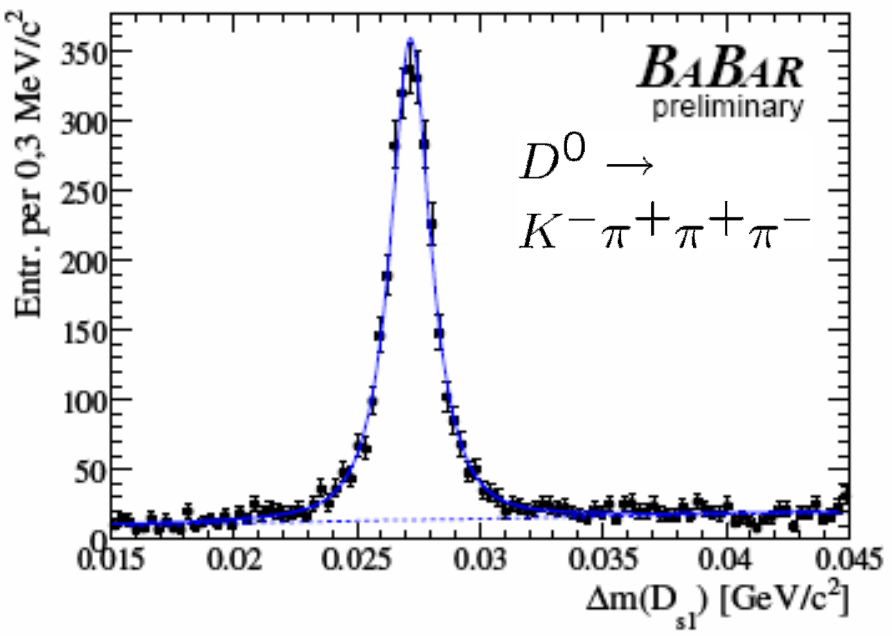
  MC, fit model

Data: 232 fb^{-1}

hep-ex/0607084 (preliminary)

Analysis of $D_{s1}(2536) \to D^*K_S$





$$m(D_{s1}) = 2534.85 \pm 0.02 \pm 0.40 \text{MeV}/c^2$$
$$m(D_{s1}) - m(D^*) = 524.85 \pm 0.02 \pm 0.04 \text{MeV}/c^2$$

mass difference: improvement by factor of 14 compared with PDG value

First measurement of $D_{s1}(2536)$ decay width:

$$\Gamma(D_{s1}) = 1.03 \pm 0.05 \pm 0.12 \text{MeV}/c^2$$

Data: 232 fb^{-1}

next: measure J^P

hep-ex/0607084 (preliminary)

Inclusive study of DK

$e^+e^- \to D^0K^+X/D^+K^0_SX$

$p^*(DK) > 3.5\text{GeV}/c$

- reduce background
- reject candidates from B decays

PRL 97, 222001 | Data: 240 fb^{-1}

final state DK $\to$ natural spin-parity

$\to J^P = 0^+, 1^-, 2^+ \ldots$

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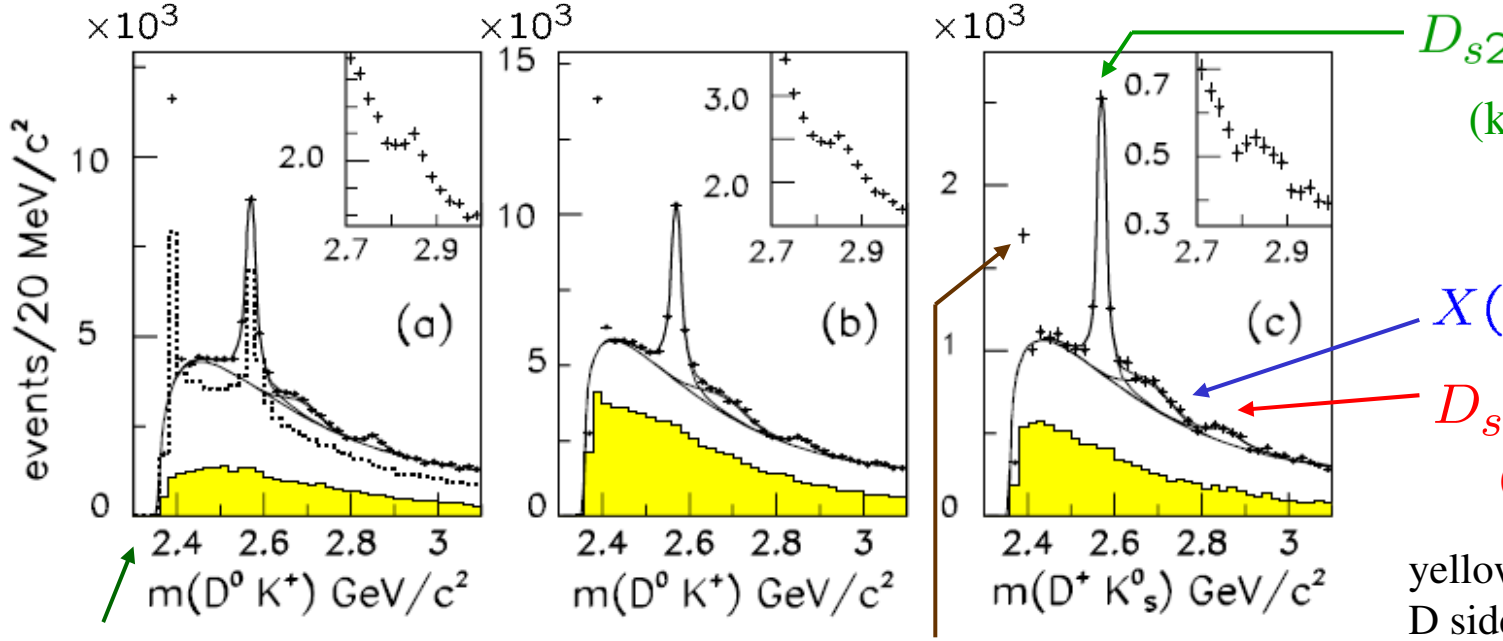
$p^*(DK) > 3.5\text{GeV}/c$

PRL 97, 222001 | Data: 240 fb^{-1}

final state DK → natural spin-parity
→ $J^P = 0^+, 1^-, 2^+ \ldots$

a) $D^0 \to K^-\pi^+$ b) $D^0 \to K^-\pi^+\pi^0$ c) $D^+ \to K^-\pi^+\pi^+$



$D_{s2}(2573)$ (known)

$X(2690)$ (?)

$D_{sJ}(2860)$ (new state)

yellow area:
D sideband regions

dotted line:
$c\bar{c}$-MC

reflection from
$D_{s1}(2536) \to D^*K$

Inclusive study of DK - $D_{s2}(2573)$

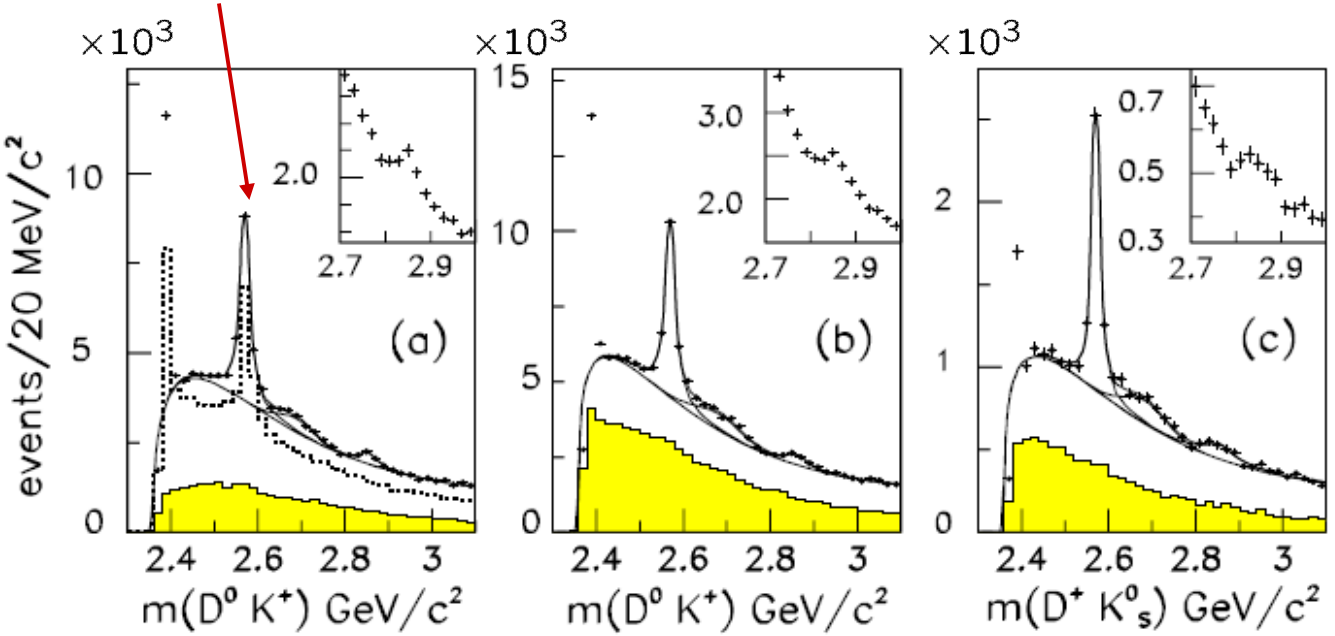
D^0K^+ / $D^+K^0_S$

PDG: $m(D_{s2}(2573)) = 2573.5 \pm 1.7 \text{MeV}/c^2$
$\Gamma(D_{s2}(2573)) = 15 \pm 5 \text{MeV}/c^2$

- Improvement for $D_{s2}(2573)$

$$m(D_{s2}(2573)) = 2572.2 \pm 0.3 \pm 1.0 \text{MeV}/c^2$$
$$\Gamma(D_{s2}(2573)) = 27.1 \pm 0.6 \pm 5.6 \text{MeV}/c^2$$

(fit to all decay modes)



Data: 240 fb^{-1}

PRL 97, 222001

Inclusive study of DK - $D_{sJ}(2860)$

D^0K^+ / $D^+K^0_S$

final state DK → natural spin-parity

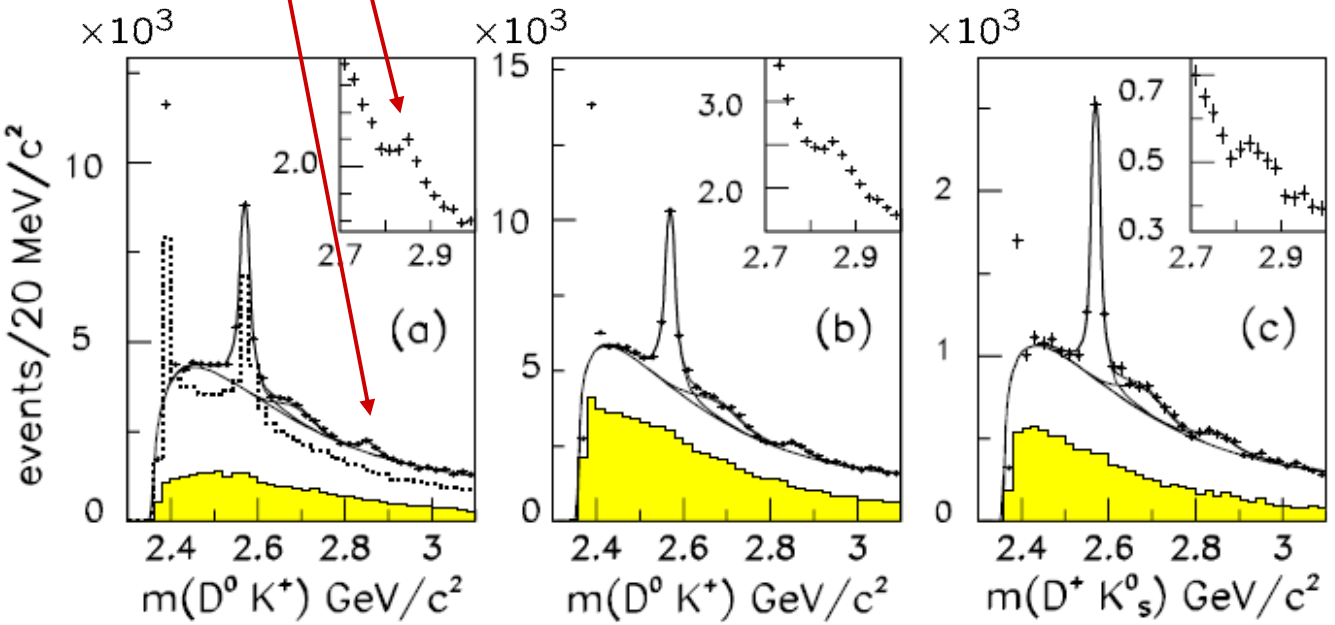
$J^P = 0^+, 1^-, 2^+ \ldots$

- New resonance:

$m(D_{sJ}(2860)) = 2856.6 \pm 1.5 \pm 5.0 \mathrm{MeV}/c^2$

$\Gamma(D_{sJ}(2860)) = 47 \pm 7 \pm 10 \mathrm{MeV}/c^2$

(fit to all decay modes)



-no signal in MC and sidebands
-no reflection from D*K
-checked K/π K/p misident.

Data: 240 fb^{-1}

PRL 97, 222001

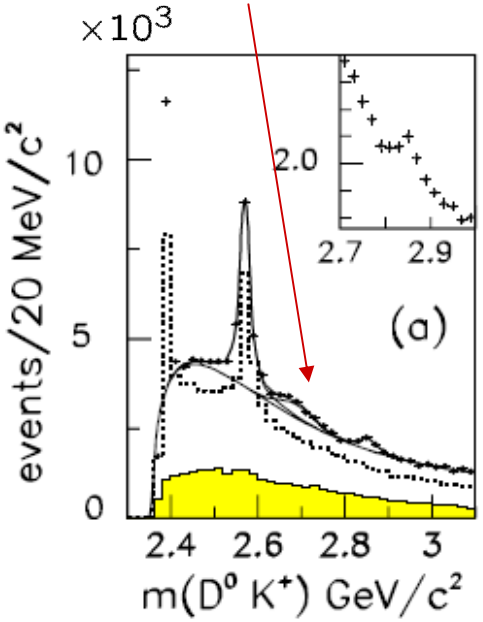
Inclusive study of DK - X(2690)

D^0K^+ / $D^+K^0_S$

$m(X(2690)) = 2688 \pm 4 \pm 3\,\mathrm{MeV}/c^2$

$\Gamma(X(2690)) = 112 \pm 7 \pm 36\,\mathrm{MeV}/c^2$

(fit to all decay modes)



Another new resonance at 2690 MeV/c²?
Or just a reflection?
- no signal in sidebands and $c\bar{c}$-MC
- also seen in other places...

Data: 240 fb^{-1}

PRL **97**, 222001

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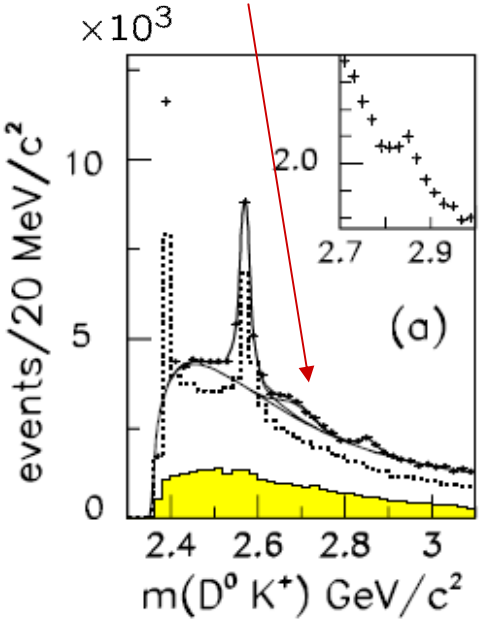

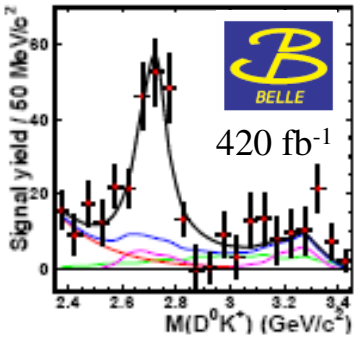

Belle observation, J =1

$B^+ \to \bar{D}^0 X, X \to D^0 K^+$

hep-ex/0608031

$m(X) = 2715 \pm 11 \pm 13\text{MeV}/c^2$

$\Gamma(X) = 115 \pm 20 \pm 34\text{MeV}/c^2$

Data: 240 fb^{-1}

PRL **97**, 222001

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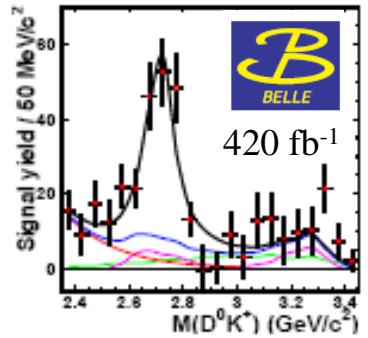

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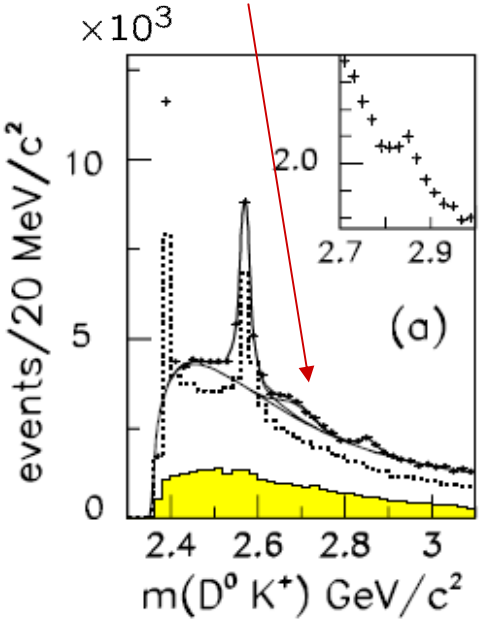
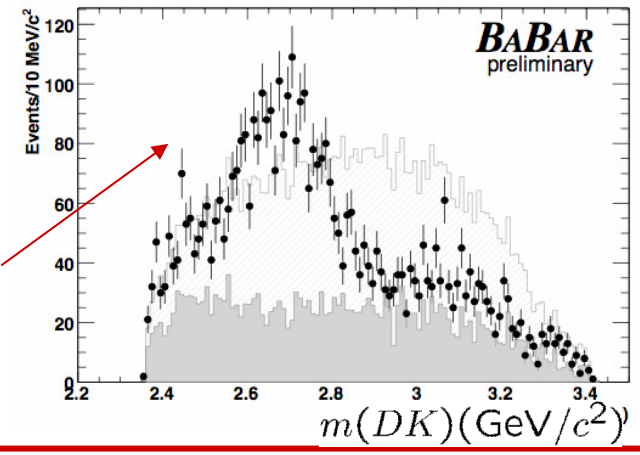
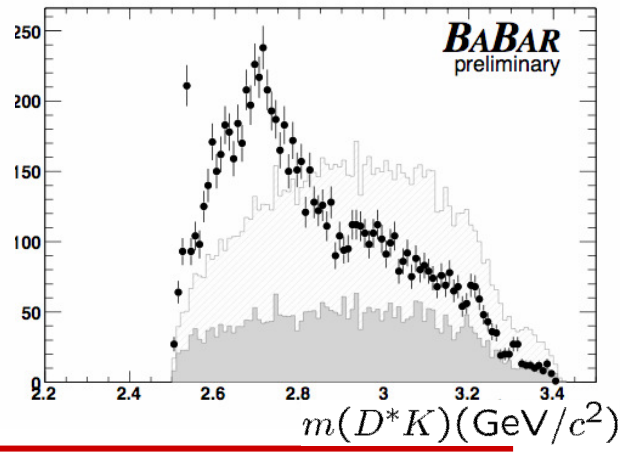


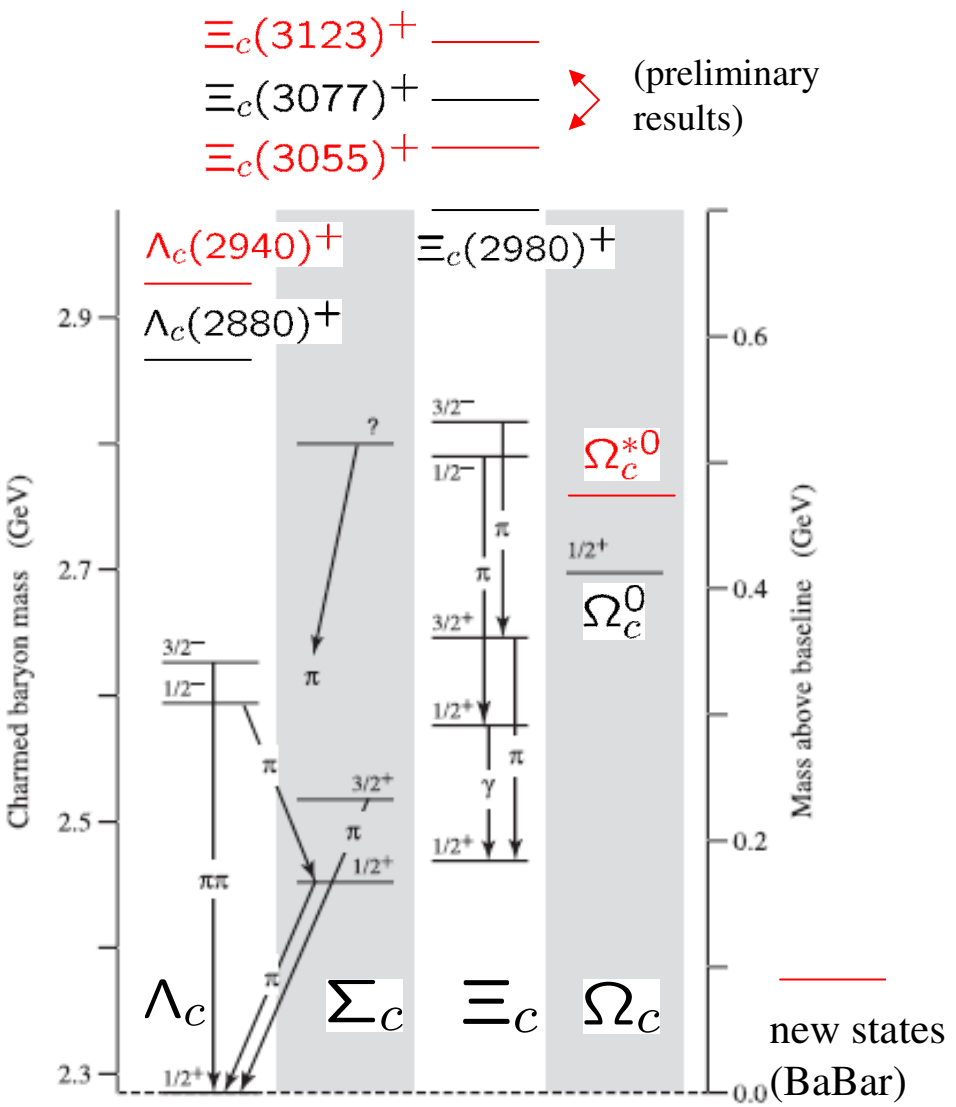
BaBar

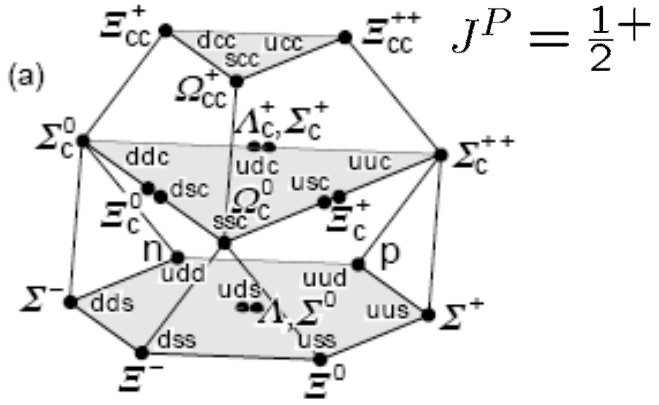
$B \to D^{(*)} D^{(*)} K^+$

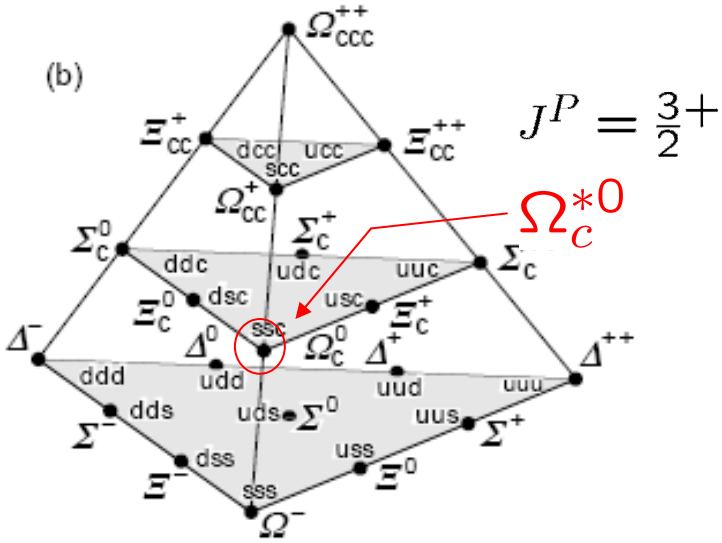




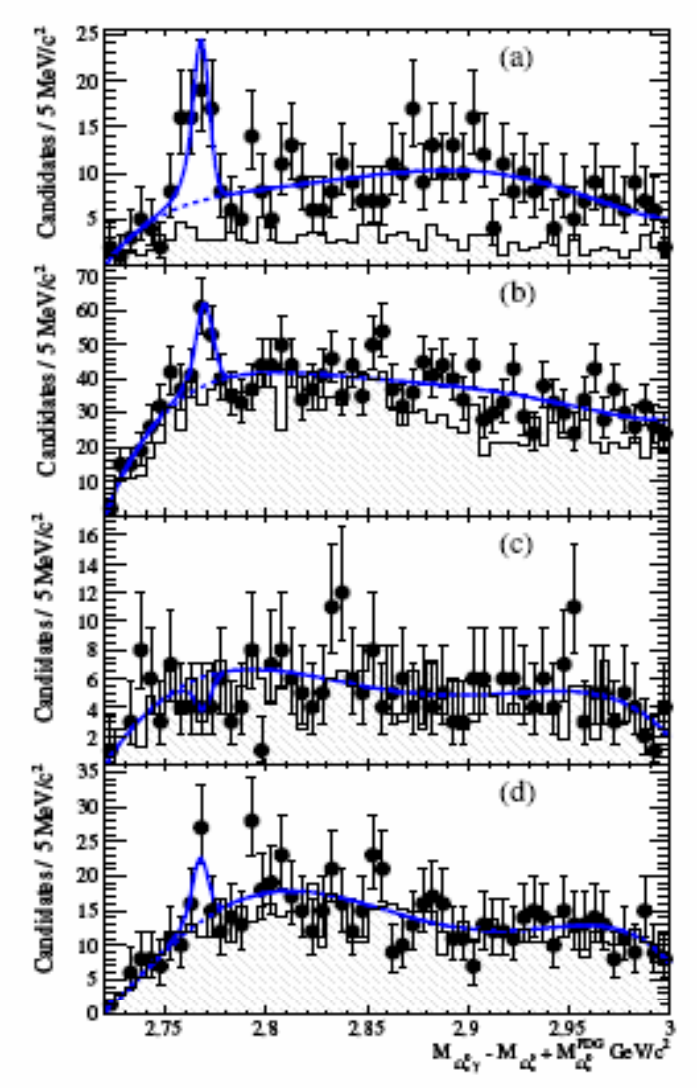
Charmed Baryons







Discovery of Ω_c^{*0}



$\Omega_c^{*0} \to \Omega_c^0 \gamma$ css baryon $J^P = \frac{3}{2}^+$

last remaining css ground state to be discovered (no orbital/radial excitation)

a) $\Omega_c^0 \to \Omega^- \pi^+, \Omega^- \to \Lambda K^-$

b) $\Omega_c^0 \to \Omega^- \pi^+ \pi^0, \Omega^- \to \Lambda K^-$

c) $\Omega_c^0 \to \Omega^- \pi^+ \pi^+ \pi^-, \Omega^- \to \Lambda K^-$

d) $\Omega_c^0 \to \Xi^- K^- \pi^+ \pi^+, \Xi^- \to \Lambda \pi^-$

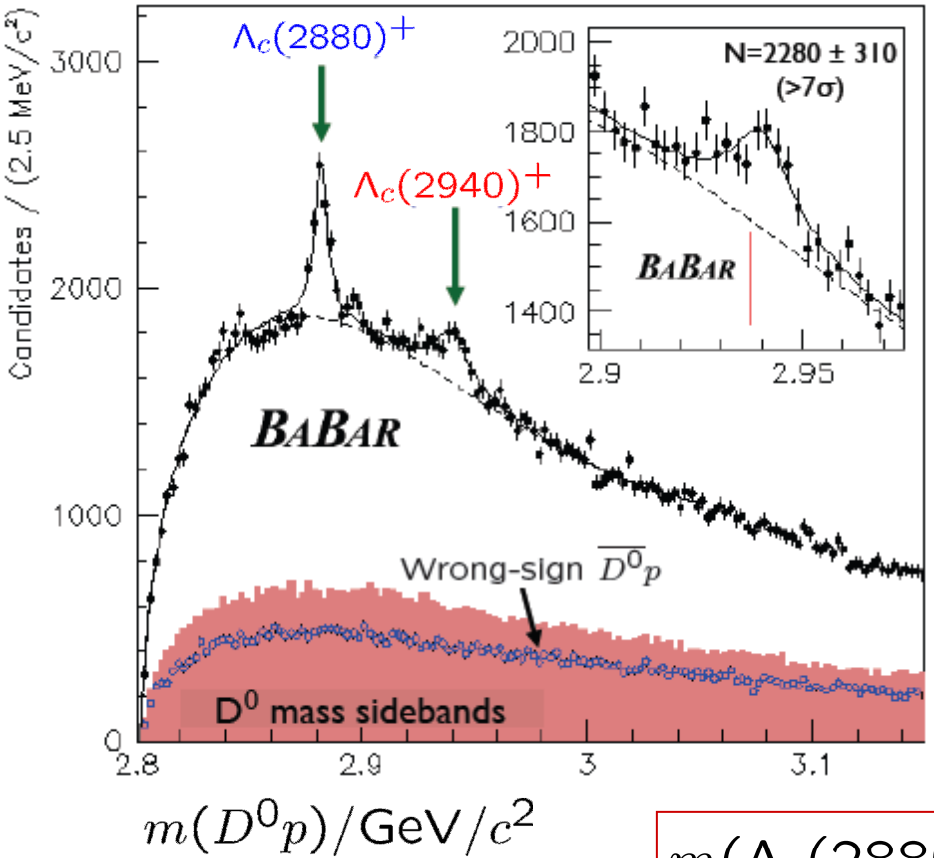
$$m(\Omega_c^{*0}) - m(\Omega_c^0) = 70.8 \pm 1.0 \pm 1.1 \text{MeV}/c^2$$

$$\frac{\sigma(e^+e^- \to \Omega_c^{*0})}{\sigma(e^+e^- \to \Omega_c^0)} = 1.01 \pm 0.23 \pm 0.11$$

Data: 231 fb^{-1}

PRL97, 232001

Discovery of $\Lambda_c(2940)$



Decay mode D^0p

Known state $\Lambda_c(2880)^+$

New state $\Lambda_c(2940)^+$

First observation of charmed baryon decay to D and light baryon

no signal in D^+p
→ Isospin 0
→ both Λ_c

Data 287 fb^{-1}

PRL 98, 012001

$$m(\Lambda_c(2880)^+) = 2881.9 \pm 0.1 \pm 0.5 \text{MeV}/c^2$$
$$\Gamma(\Lambda_c(2880)^+) = 5.8 \pm 1.5 \pm 1.1 \text{MeV}/c^2$$
$$m(\Lambda_c(2940)^+) = 2939.8 \pm 1.3 \pm 1.0 \text{MeV}/c^2$$
$$\Gamma(\Lambda_c(2940)^+) = 17.5 \pm 5.2 \pm 5.9 \text{MeV}/c^2$$

Excited charm-strange baryons

$\Lambda_c^+ K_S^0$ $\quad$ $\Lambda_c^+ K^- \pi^+$

$\Lambda_c^+ K^-$ $\quad$ $\Lambda_c^+ K_S^0 \pi^-$

$\Lambda_c^+ K^- \pi^+ \pi^-$

$\Lambda_c^+ K_S^0 \pi^+ \pi^-$

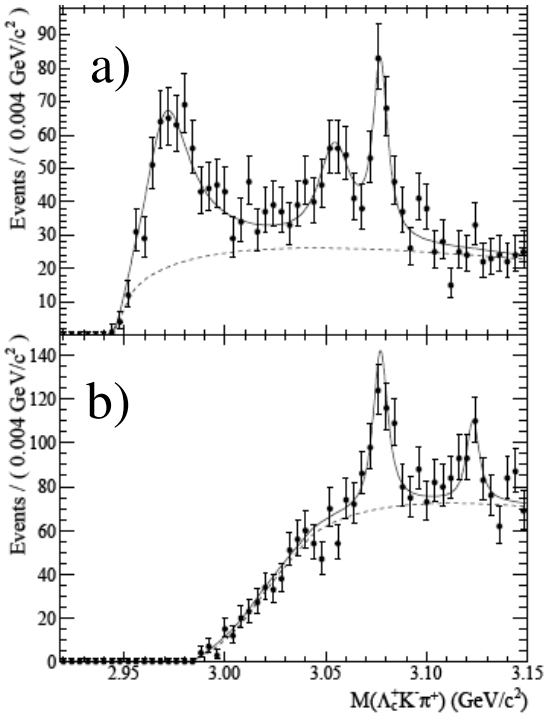
} significant signals

search for decays through intermediate resonant states:

$\Sigma_c(2455)^{++} K^- / \Sigma_c(2455)^0 K_S^0$

$\Sigma_c(2520)^{++} K^- / \Sigma_c(2520)^0 K_S^0$

$\Sigma_c \to \Lambda_c \pi$



⇦ a) $m(\Lambda_c^+ \pi^+)$ within $\pm 6.7 \mathrm{MeV}/c^2$ around $\Sigma_c(2455)^{++}$ mass (3 natural widths)

⇦ b) $m(\Lambda_c^+ \pi^+)$ within $\pm 30 \mathrm{MeV}/c^2$ around $\Sigma_c(2520)^{++}$ mass (2 natural widths)

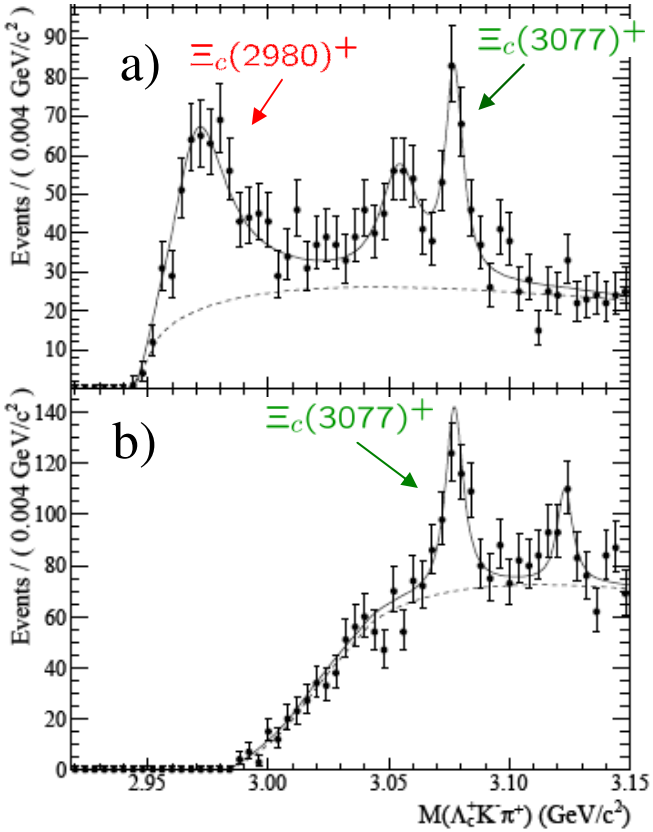
(same for neutral modes)

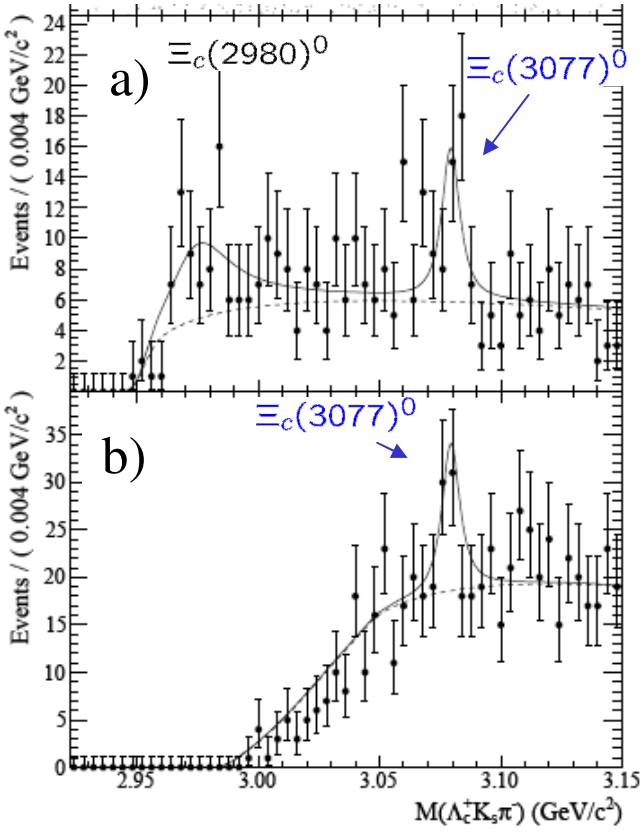
$p^* > 2.9 \mathrm{GeV}/c$

Data 384 fb^{-1}

hep-ex/... (preliminary)

Excited charm-strange baryons





Confirmation of
$\Xi_c(2980)^+$,
$\Xi_c(3077)^+$,
$\Xi_c(3077)^0$

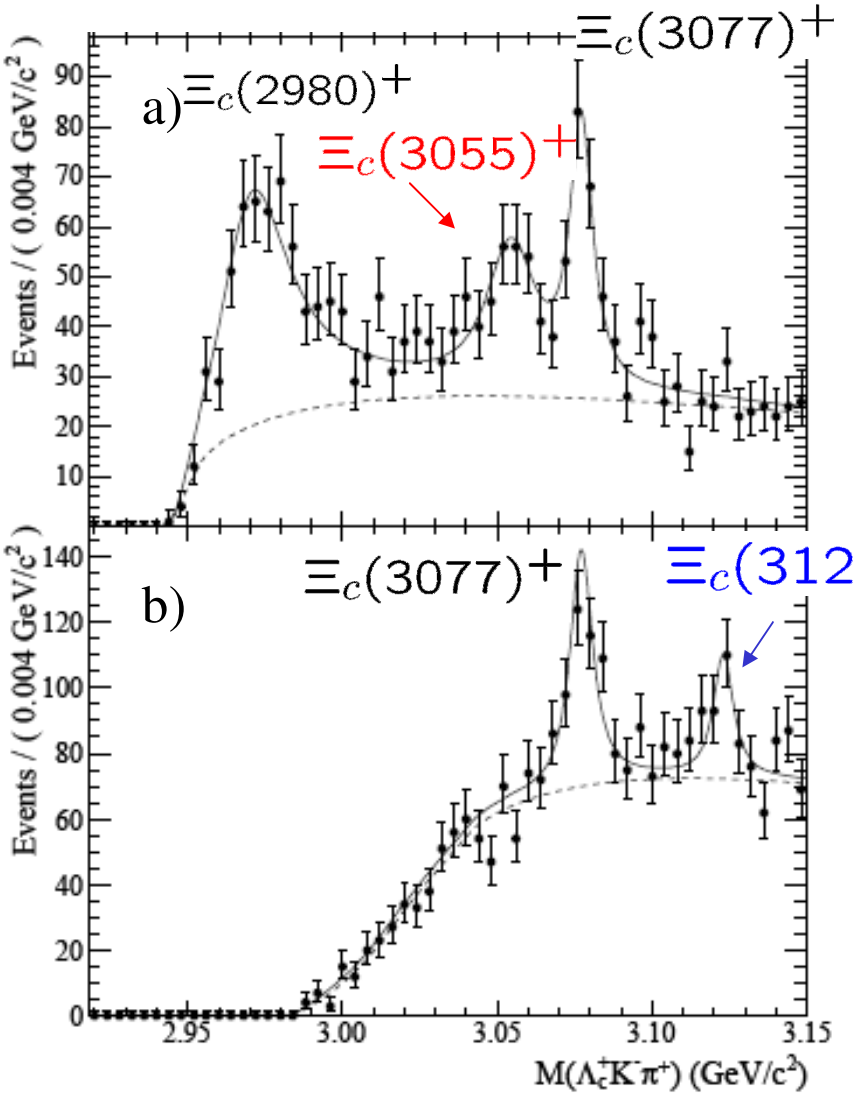
first observed by Belle

$$m(\Xi_c(2980)^+) = 2969.3 \pm 2.2 \pm 1.7 \mathrm{MeV}/c^2$$

Data 384 fb^{-1}

hep-ex/... (preliminary)

Excited charm-strange baryons



New state: $\Xi_c(3055)^+$

Evidence for $\Xi_c(3123)^+$

$\Xi_c(3055)^+$	
Mass (MeV/c^2)	$3054.2 \pm 1.2 \pm 0.5$
Width (MeV/c^2)	$17 \pm 6 \pm 11$
Yield	$218 \pm 53 \pm 79$
Significance	6.4σ

$\Xi_c(3123)^+$	
Mass (MeV/c^2)	$3122.9 \pm 1.3 \pm 0.3$
Width (MeV/c^2)	$4.4 \pm 3.4 \pm 1.7$
Yield	$101 \pm 34 \pm 9$
Significance	3.6σ

Data 384 fb^{-1}

hep-ex/... (preliminary)

Summary

- New open charm meson discovered: $D_{sJ}(2860)$
- Next: Confirm $X(2690)$ (= Belle $D^*_{sJ}(2700)$?)
- Precise measurement of D_{sJ} parameters:

  $D^*_{s0}(2317), D_{s1}(2460)$ mass

  $D_{s1}(2536)$ mass, decay width
- New charmed baryons discovered: Ω_c^{*0} $\Lambda_c(2940)^+$

  $\Xi_c(3055)^+$ $\Xi_c(3123)^+$ (prelim.)
- Confirmation / Improvement of $\Xi_c(3077)^0$ $\Xi_c(3077)^+$

  $\Xi_c(2980)^+$ $\Lambda_c(2880)^+$

⇨ see other talks on Babar charm/charmonium physics:

- Charm decays, A. Oyanguren
- D0 Mixing, J. Coleman
- Quarkonium spectroscopy, G. Cibinetto


Backup Slides

The BaBar-Experiment

Electron-Positron Collider: PEP-II / SLAC

$\sqrt{(s)} = m(Y(4S))c^2 = 10.58\text{GeV}$

Peak Luminosity $1.21 \cdot 10^{34}\text{cm}^{-2}\text{s}^{-1}$

Integrated Luminosity (10/99-07/07) 447fb^{-1}

$\sigma(b\bar{b}) = 1.05\text{nb}$

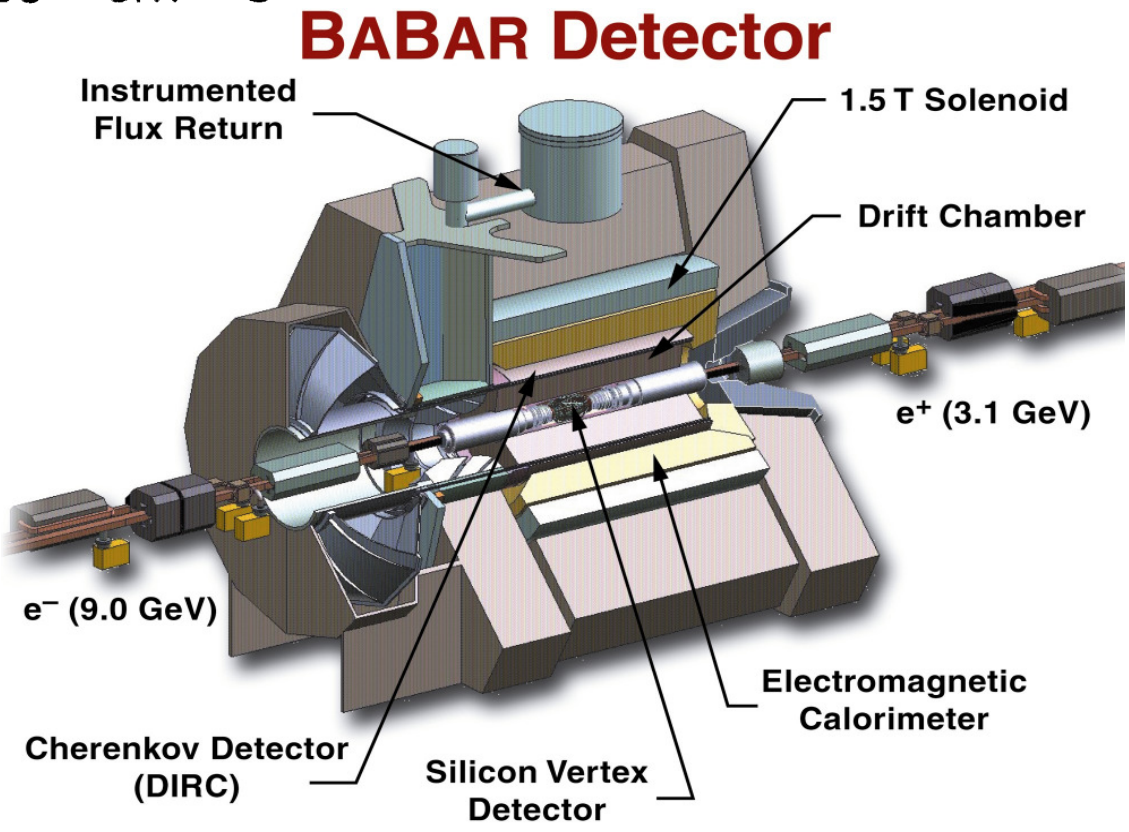
$\sigma(c\bar{c}) = 1.30\text{nb}$

$\Downarrow$

$N(b\bar{b}) = 469 \cdot 10^6$

$N(c\bar{c}) = 581 \cdot 10^6$

Good PID, Tracking and Vertexing

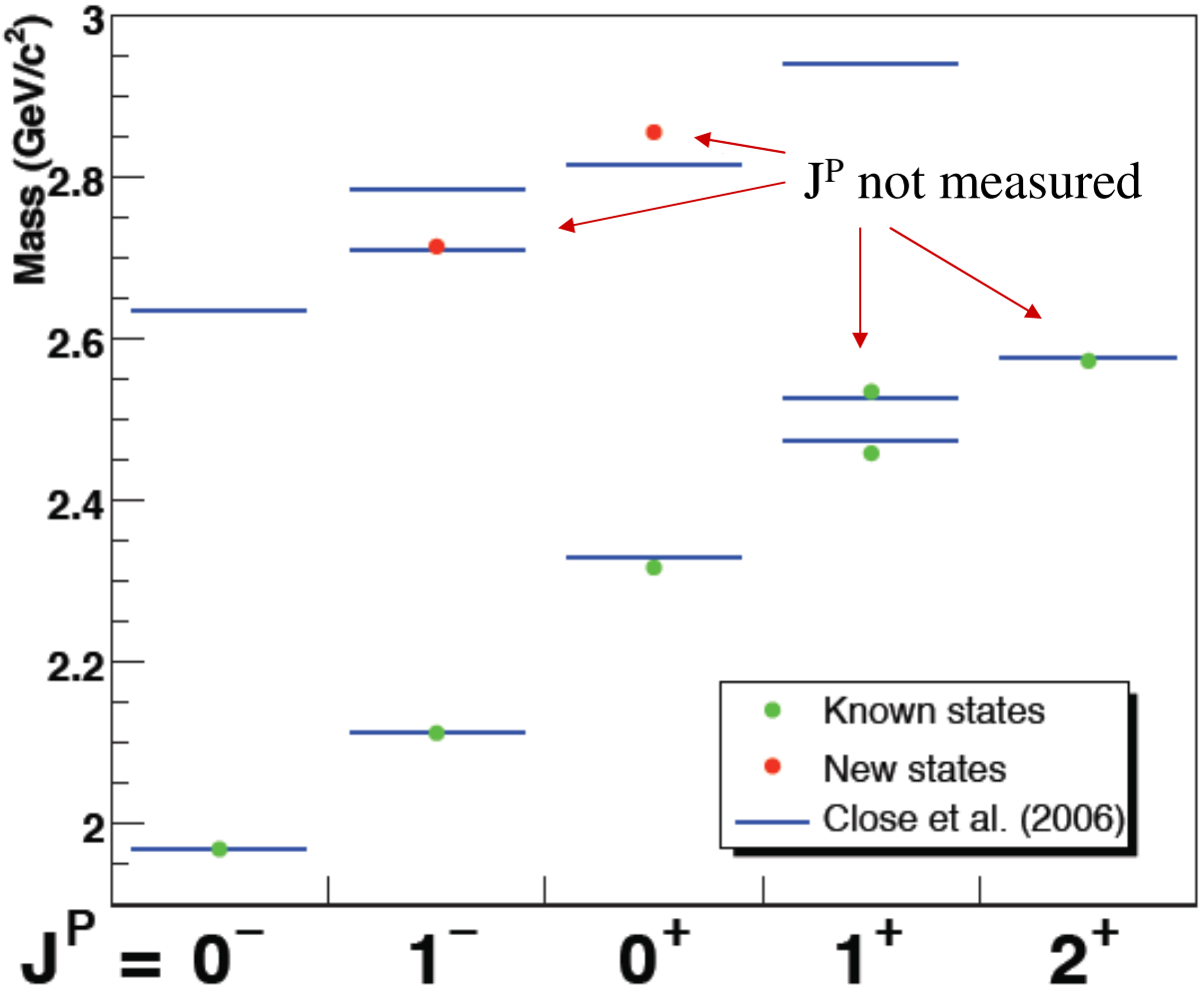


Charmed strange mesons

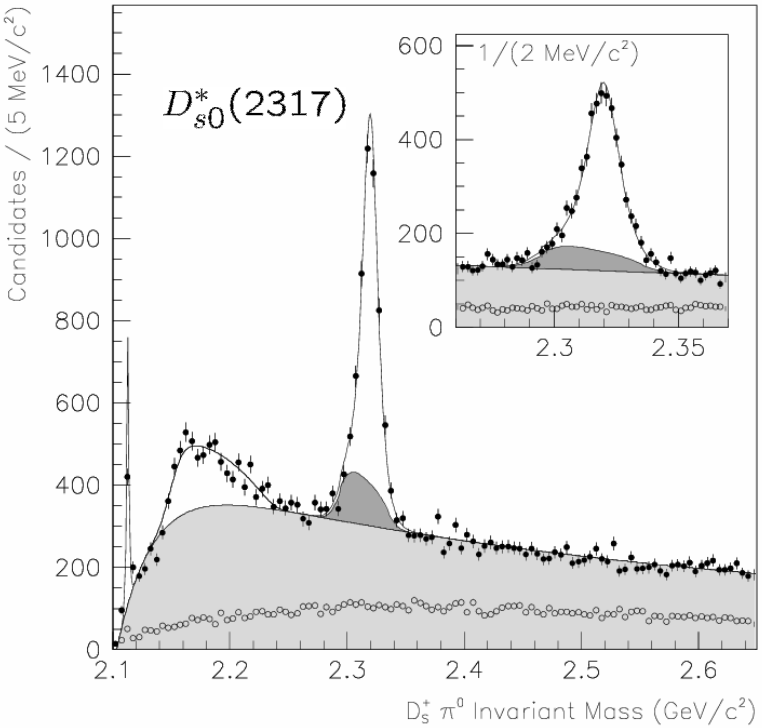
New potential model (2006) reproduces data better:

Close,Thomas, Lakina, Swanson (hep-ph/0608139)

other models:
van Beveren, Rupp (hep-ph/0606110)
Colangelo (hep-ph/0607245)



$D_{s0}^{*}(2317)$, $D_{s1}(2460)$



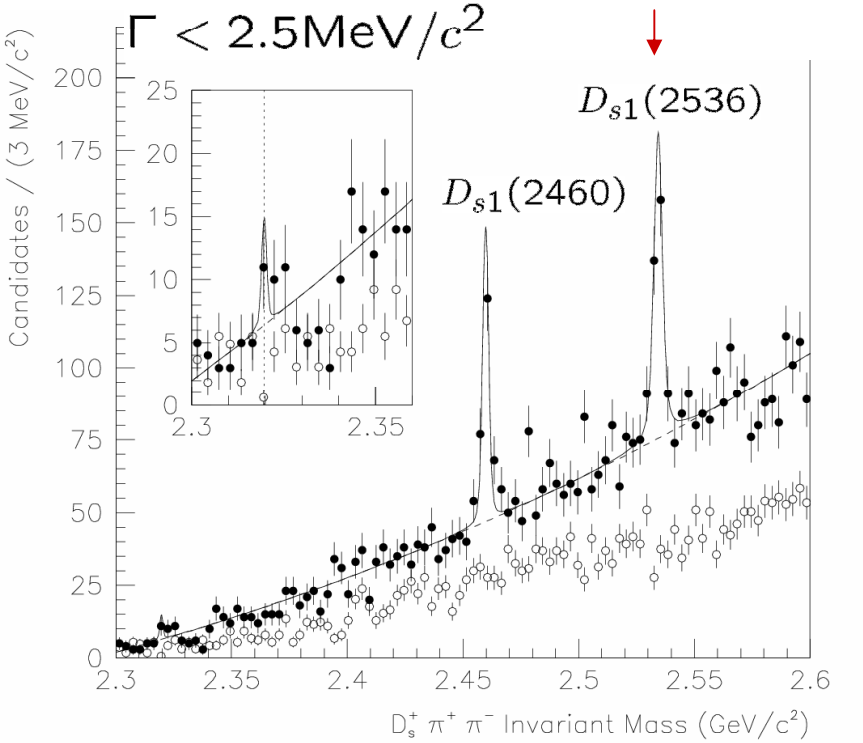
$\Gamma(D_{s0}^{*}) < 3.8\mathrm{MeV}/c^2$

$\Gamma(D_{s1}) < 3.5\mathrm{MeV}/c^2$

also $D_{s1}(2536)$

$m = 2534.6 \pm 0.3 \pm 0.7\mathrm{MeV}/c^2$

$\Gamma < 2.5\mathrm{MeV}/c^2$



$m(D_{s0}^{*}(2317)) = 2319.6 \pm 0.2 \pm 1.4\mathrm{MeV}/c^2$

$m(D_{s1}(2460)) = 2460.1 \pm 0.2 \pm 0.8\mathrm{MeV}/c^2$

Data: 232 fb^{-1}

PRD 74, 032007

Inclusive study of DK - $D_{sJ}(2860)$

D^0K^+ / $D^+K^0_S$

final state DK → natural spin-parity

$J^P = 0^+, 1^-, 2^+ \ldots$

- new resonance

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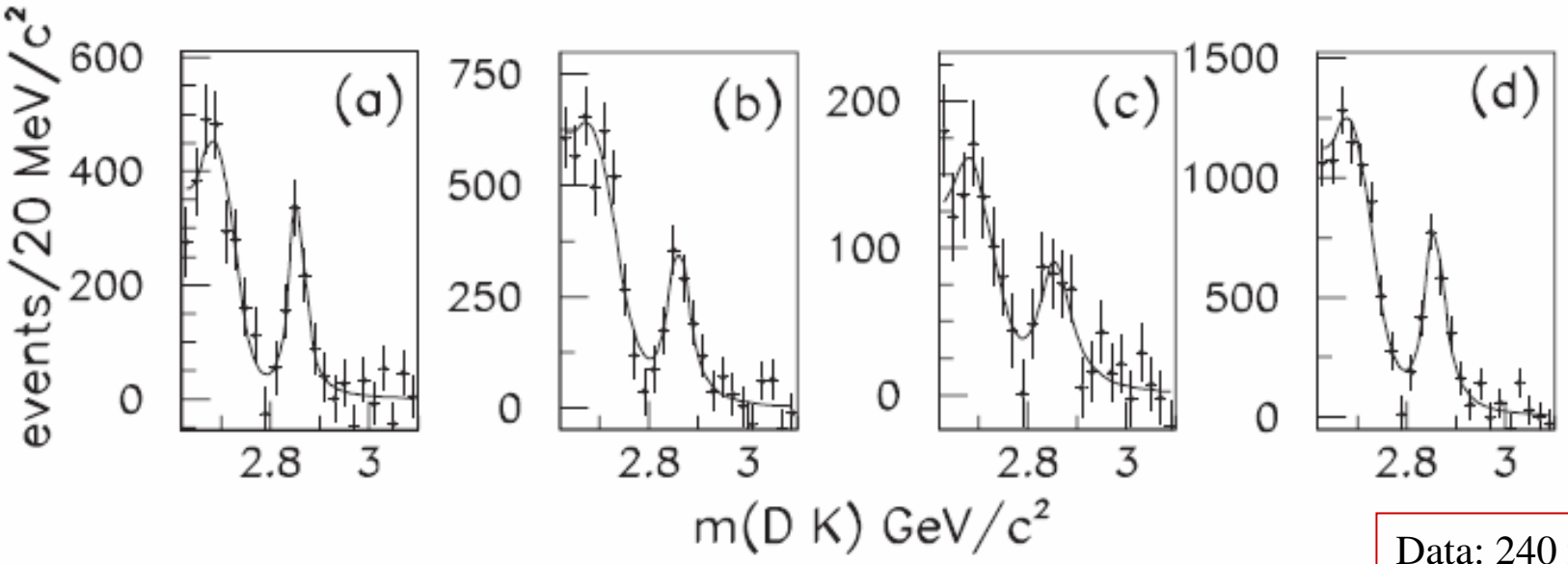
(fit to all decay modes)



background-subtracted spectra

Data: 240 fb^{-1}

PRL 97, 222001