BaBar Results on the D_s System

R. Cahn

LBNL

Hadron 2003

Aschaffenburg, Sept. 4, 2003

Event Selection

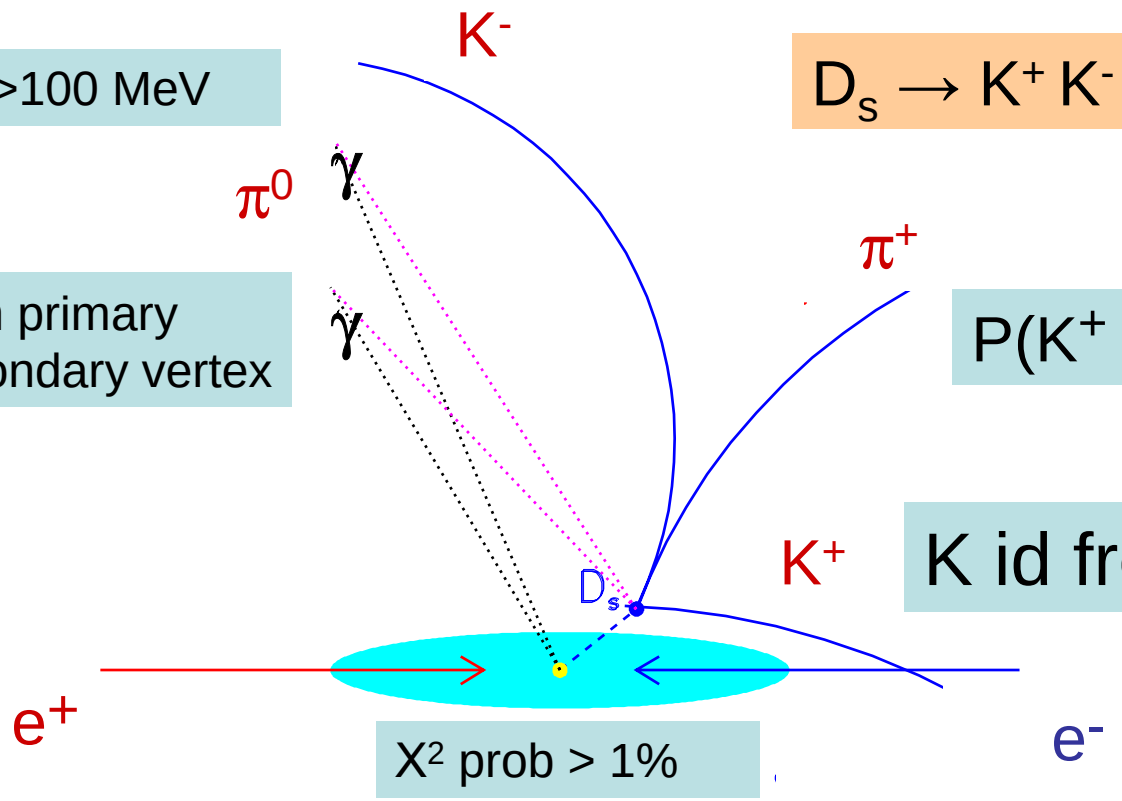
E_γ >100 MeV

$D_s \rightarrow K^+ K^- \pi^+$

π^0 from primary or secondary vertex

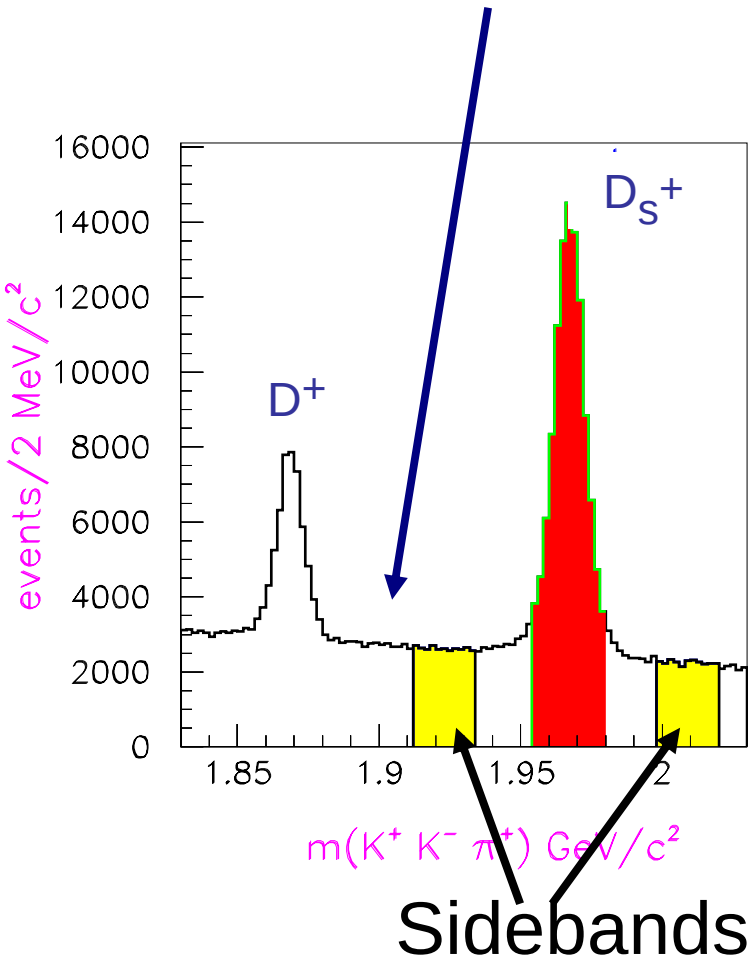
$P(K^+ K^- \pi^+\pi^0)$>2.5 GeV

K id from DIRC, dE/dx



X^2 prob > 1%

Suppress background

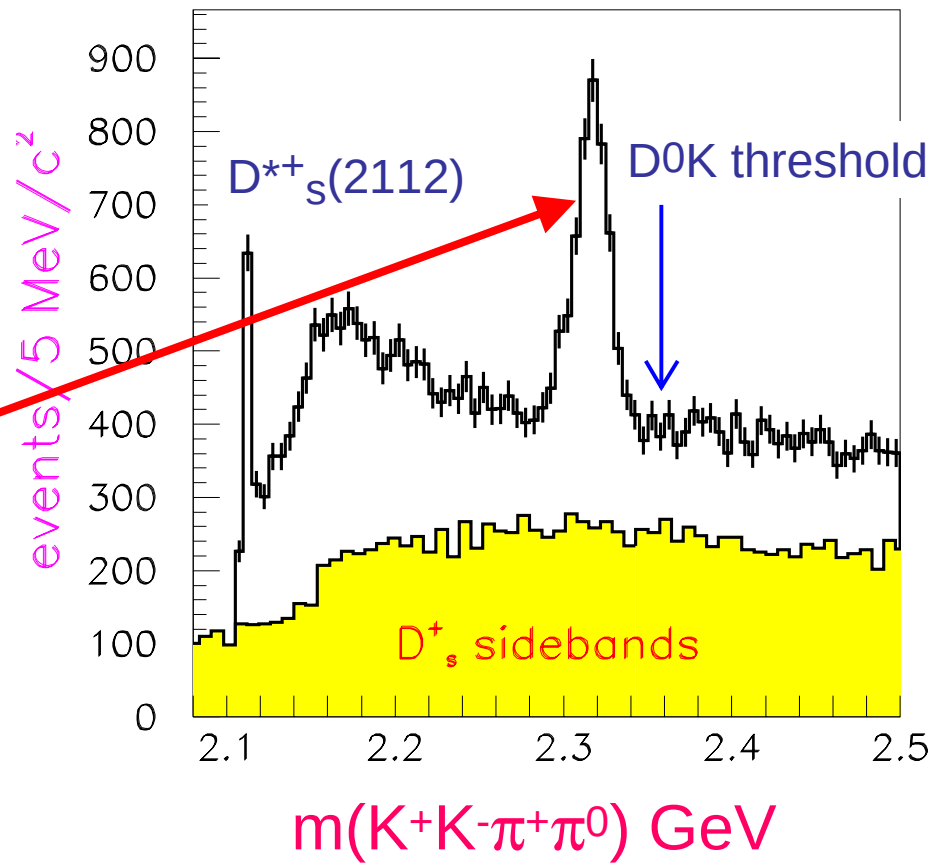


Require K*K or ϕ π

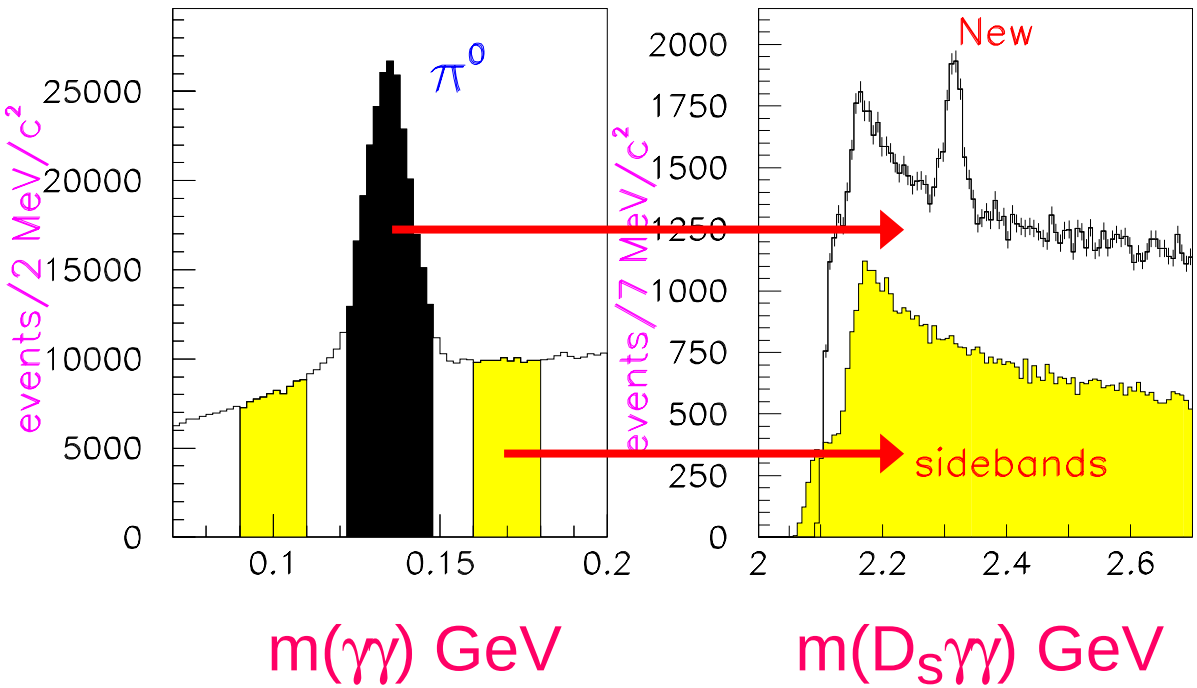
Cut on decay angle: $|\cos\theta|>0.5$

Add π^0 to D_s:

$D_{sJ}^*(2317)$



Not there for fake π^0

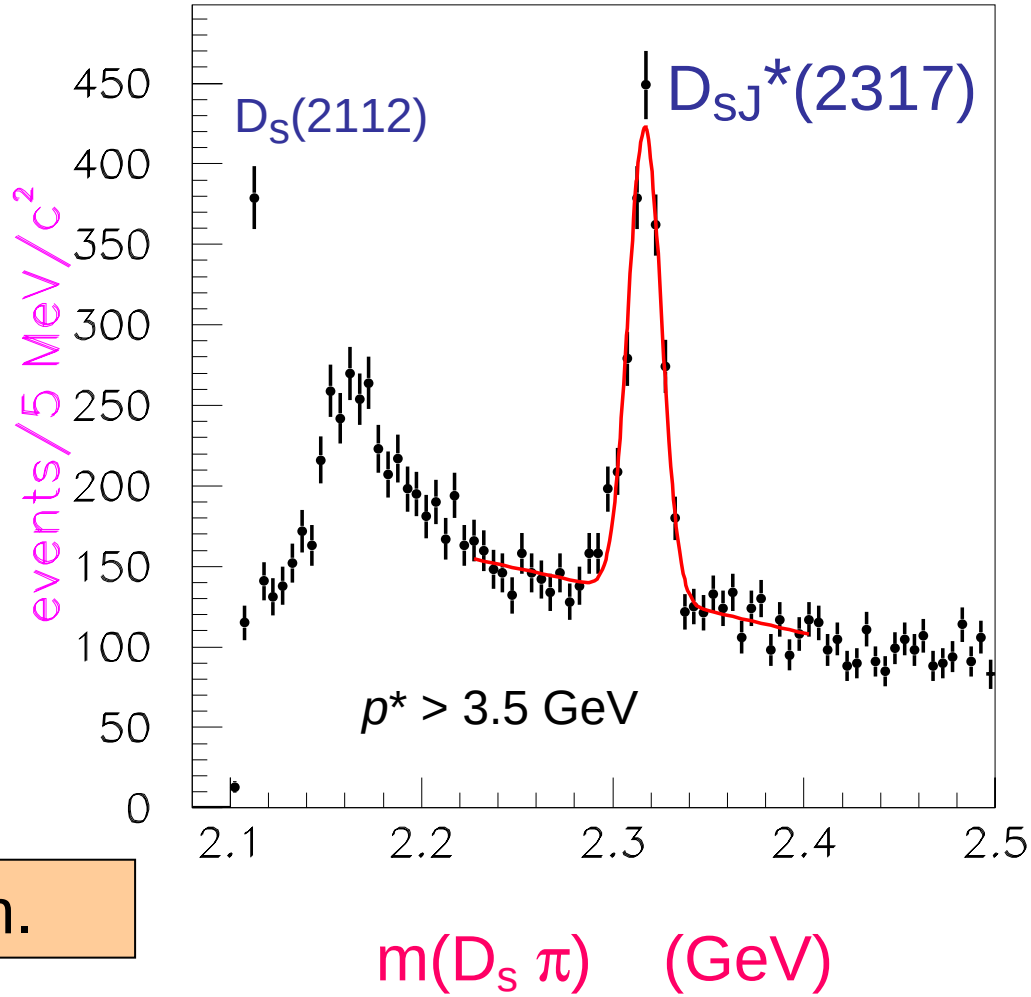


Fit to mass, width:

M = 2316.8 ± 0.4 MeV

σ = 8.6 ± 0.4 MeV

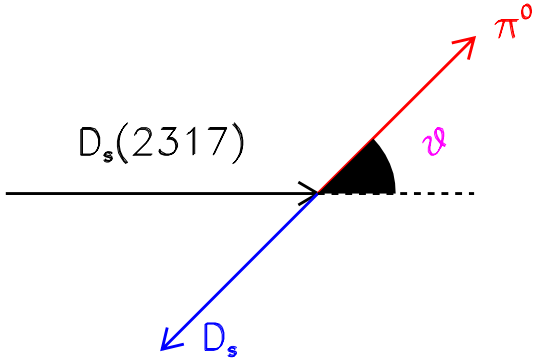
(Statistical errors only)

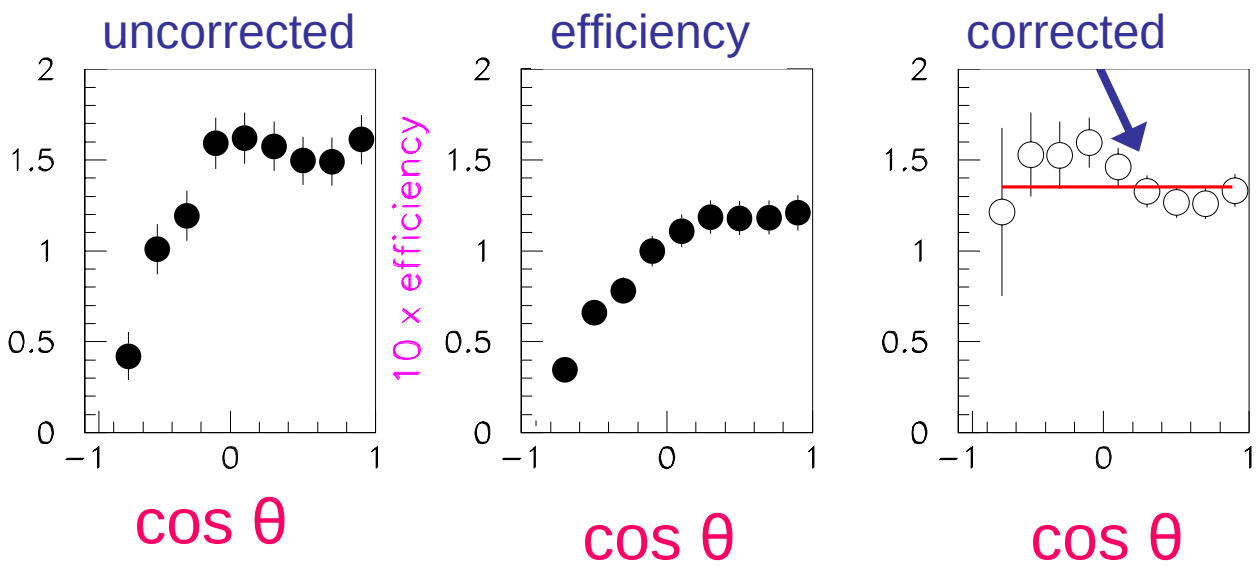


σ consistent with resolution.

Angular distribution featureless

$D_{sJ}(2317)$ spinless or unaligned



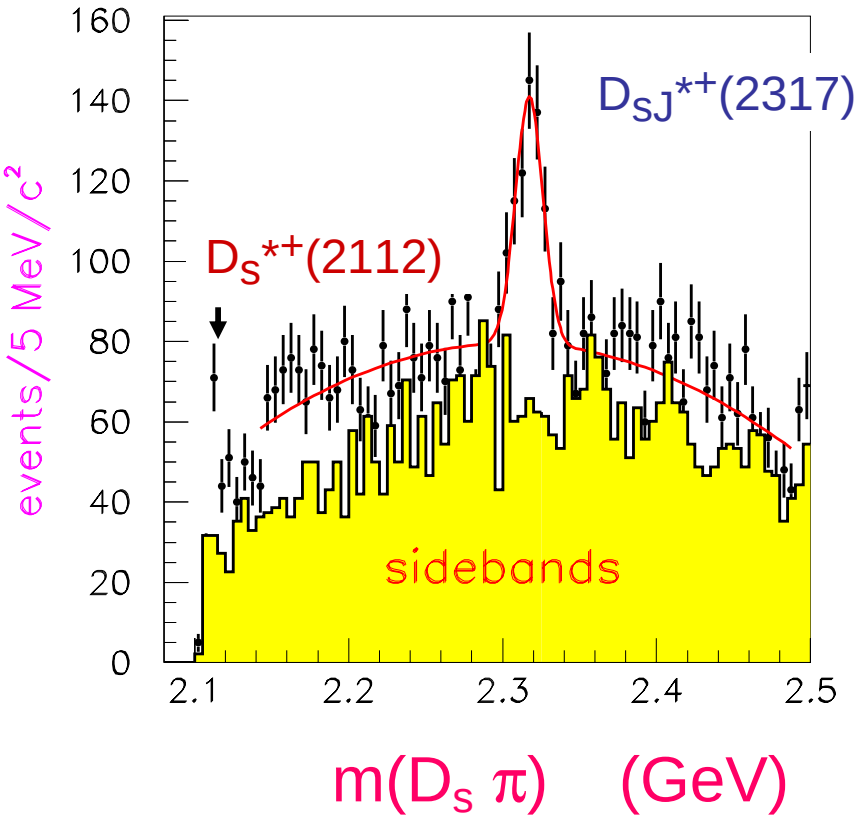


Consistent results in second mode: $D_s \rightarrow K^+K^-\pi^+\pi^0$

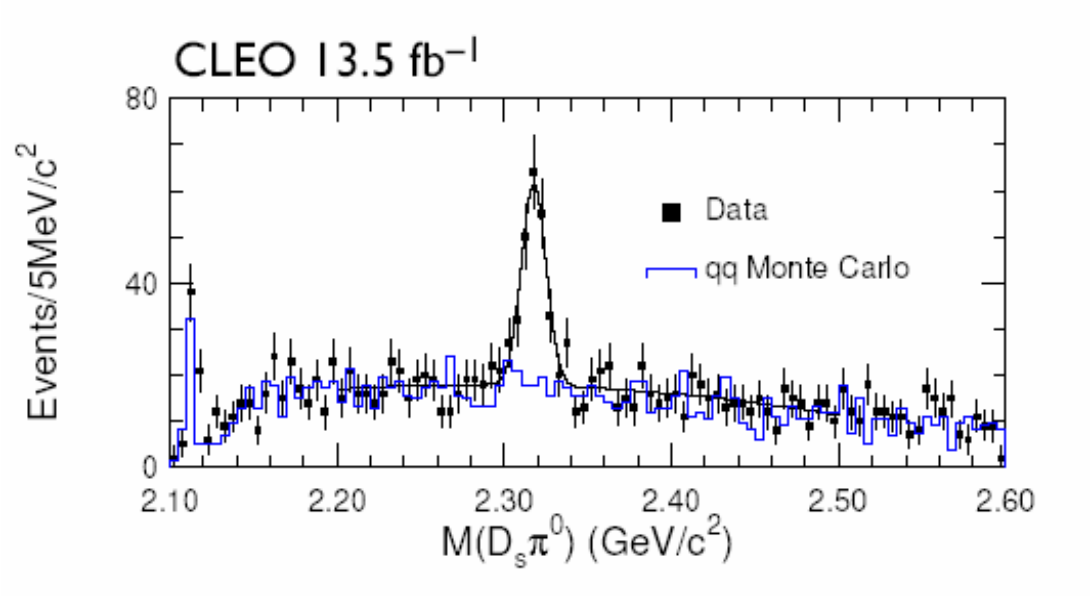
M = 2317.6 ± 1.3 MeV

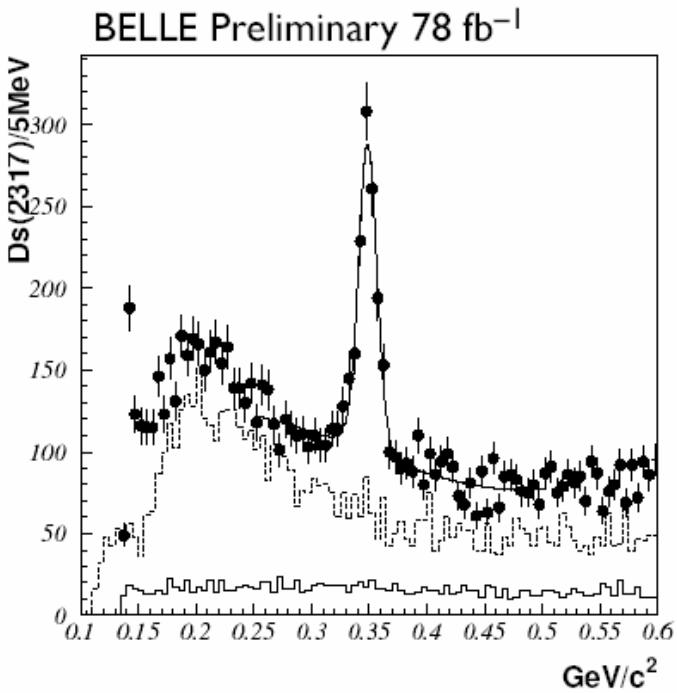
σ = 8.8 ± 1.1 MeV

(Statistical errors only)



State Confirmed by CLEO and Belle





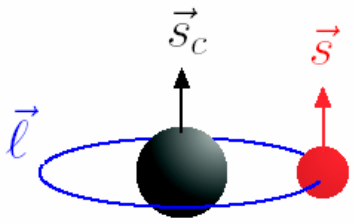
$D_s(2317)$: Immediate conclusions

- $D_s\ \pi^0$ has charm, strangeness, isospin.
- If initial state is c-sbar, strong isospin-violating decay.
- Explains narrowness.
- Must be natural spin-parity.

Deja Vu

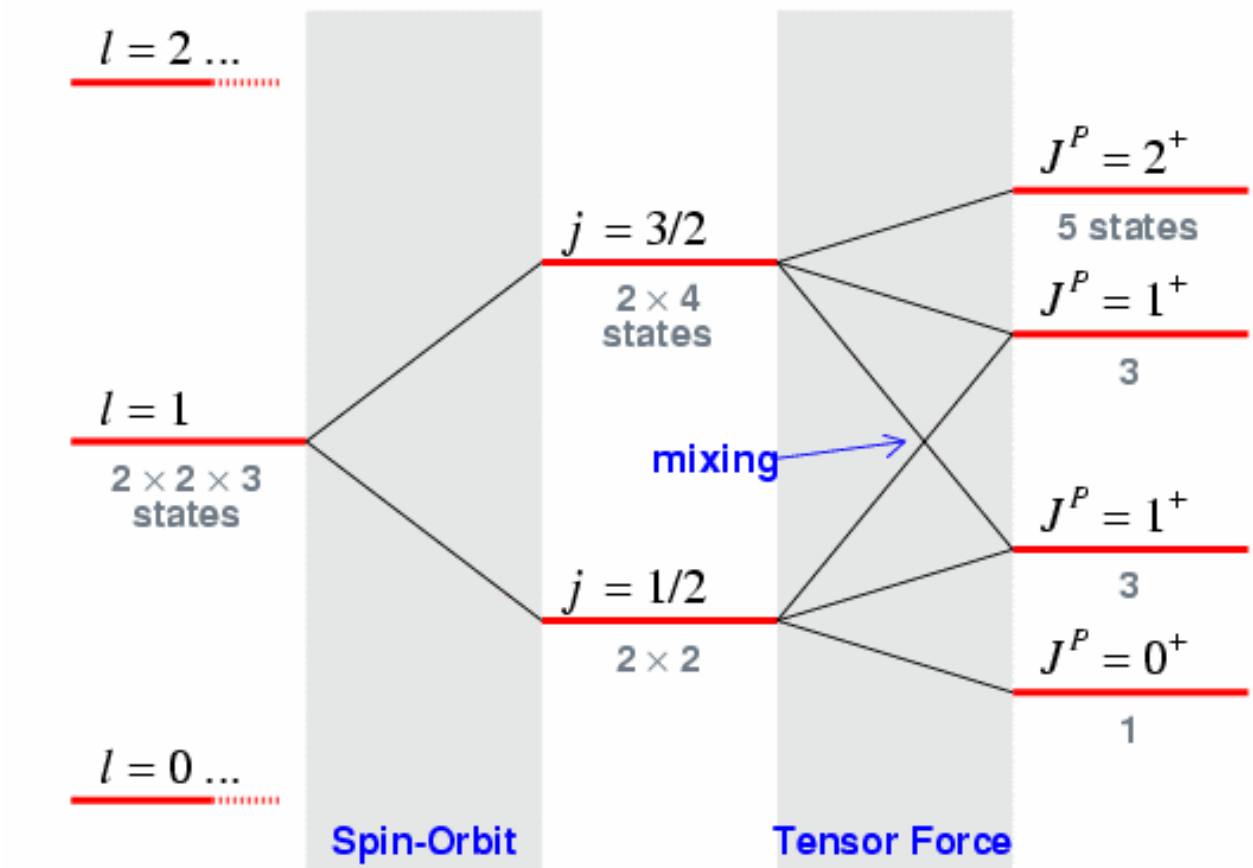
- Heavy-quark light-quark = the hydrogen atom!
  - DeRujula, Georgi, Glashow 1975
- Heavy quark's spin doesn't matter much
- Add light quark's spin $\boldsymbol{s}$, orbital $\boldsymbol{l}$ angular momentum: $\boldsymbol{j} = \boldsymbol{l} + \boldsymbol{s}_{light}$
- $\boldsymbol{j}$ nearly conserved
- $\boldsymbol{J} = \boldsymbol{j} + \boldsymbol{s}_{heavy}$ really conserved

Interactions split energy levels of p-wave states

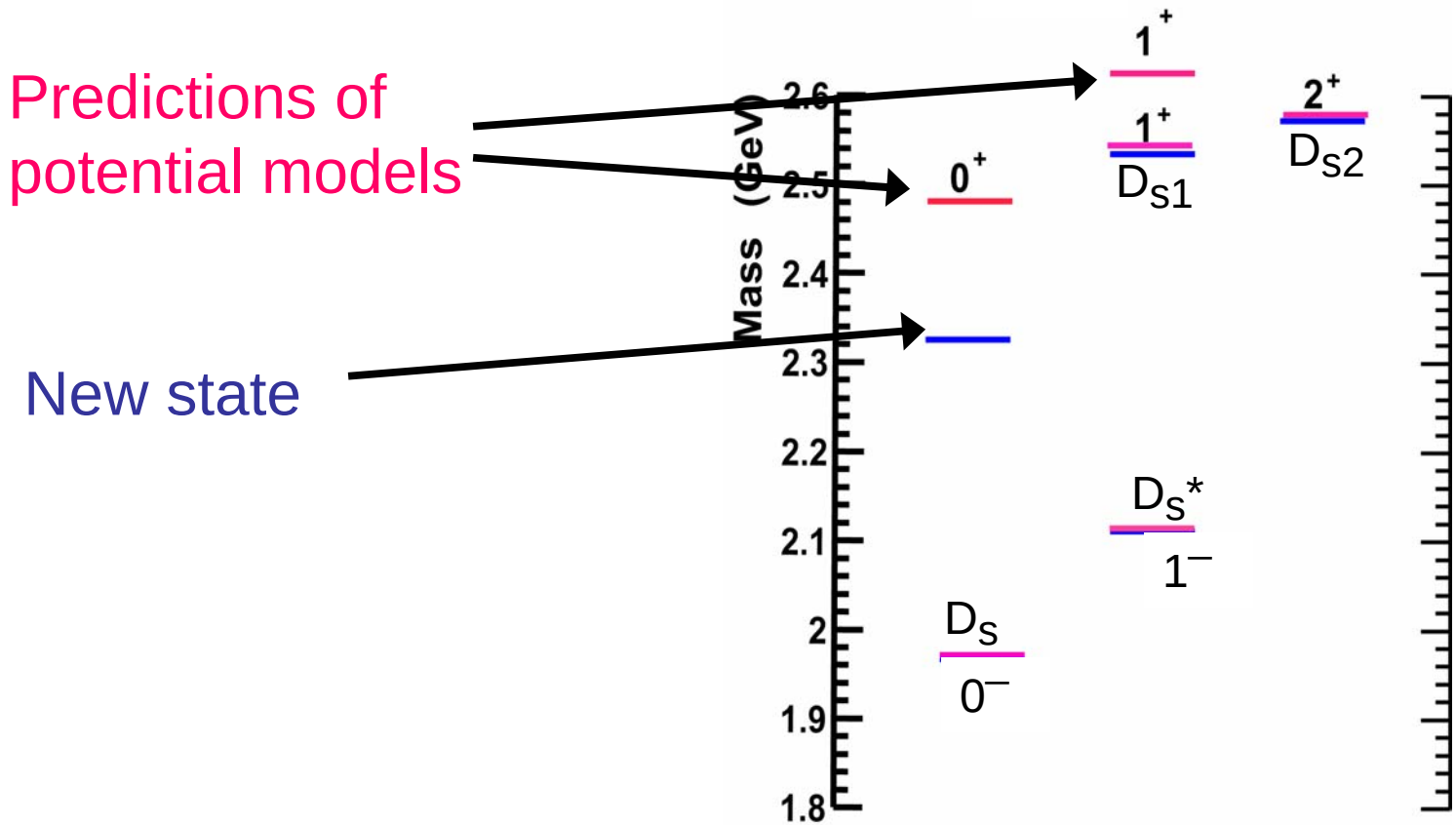


$$\vec{j} = \vec{\ell} + \vec{s}$$

$$\vec{J} = \vec{j} + \vec{s}_c$$



New State 170 MeV Below Potential Model Predictions



Looking in other channels

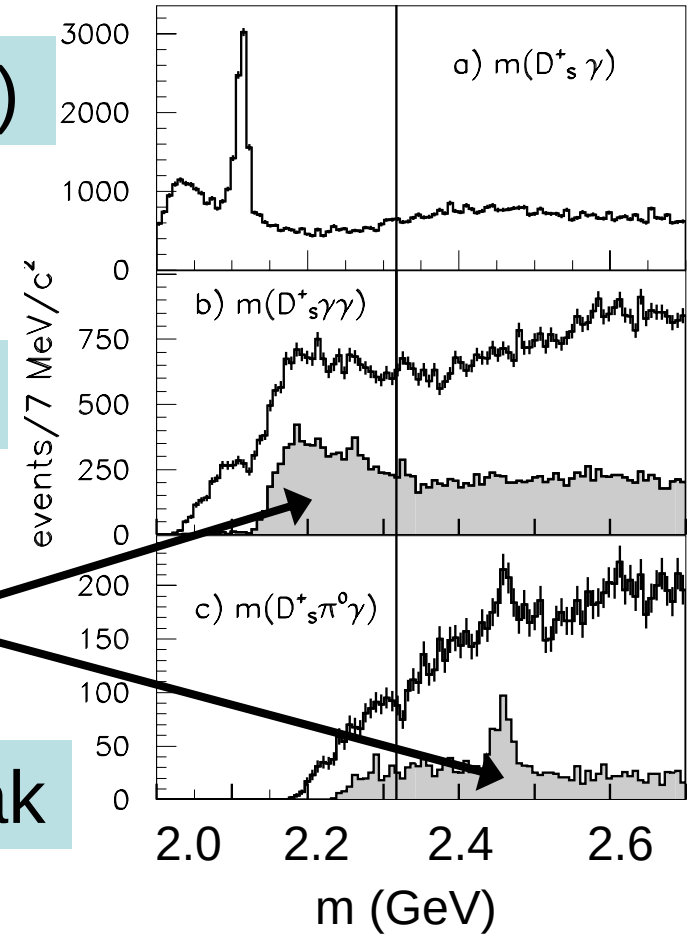
BaBar PRL90,242001(2003)

$D_s\ \gamma$: only the $D_s(2112)$

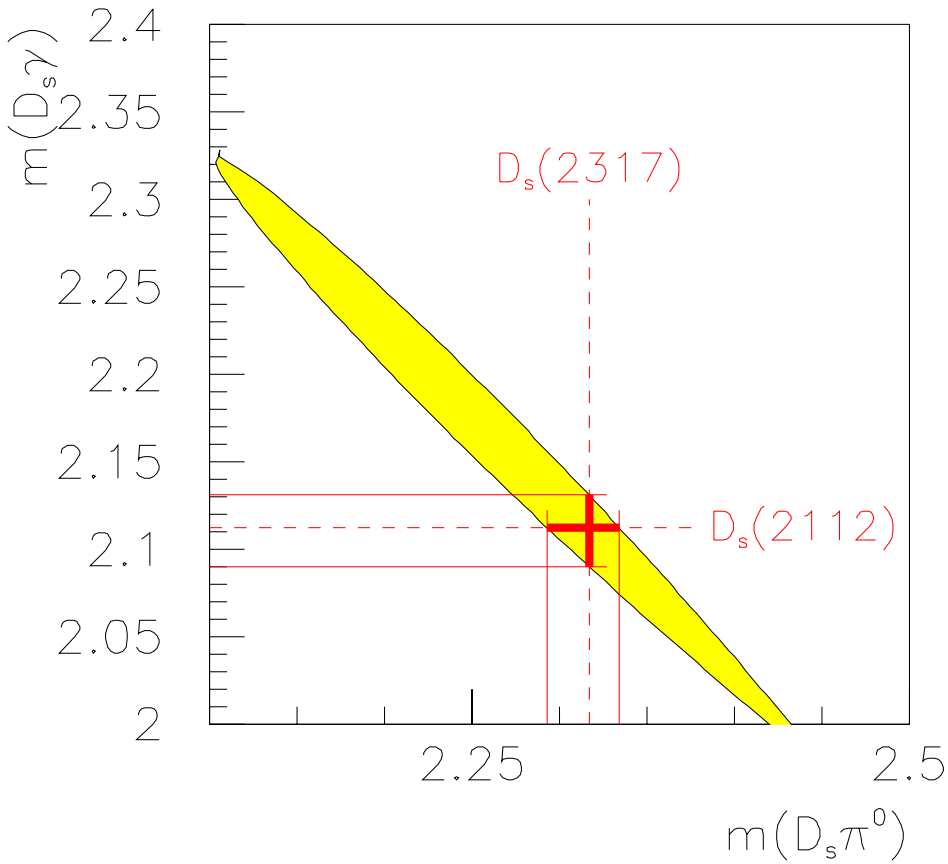
$D_s\ \gamma\gamma$: nothing

Events with a $D_s\ \gamma = D_s^*$

$D_s\ \pi^0\ \gamma$: some sort of peak



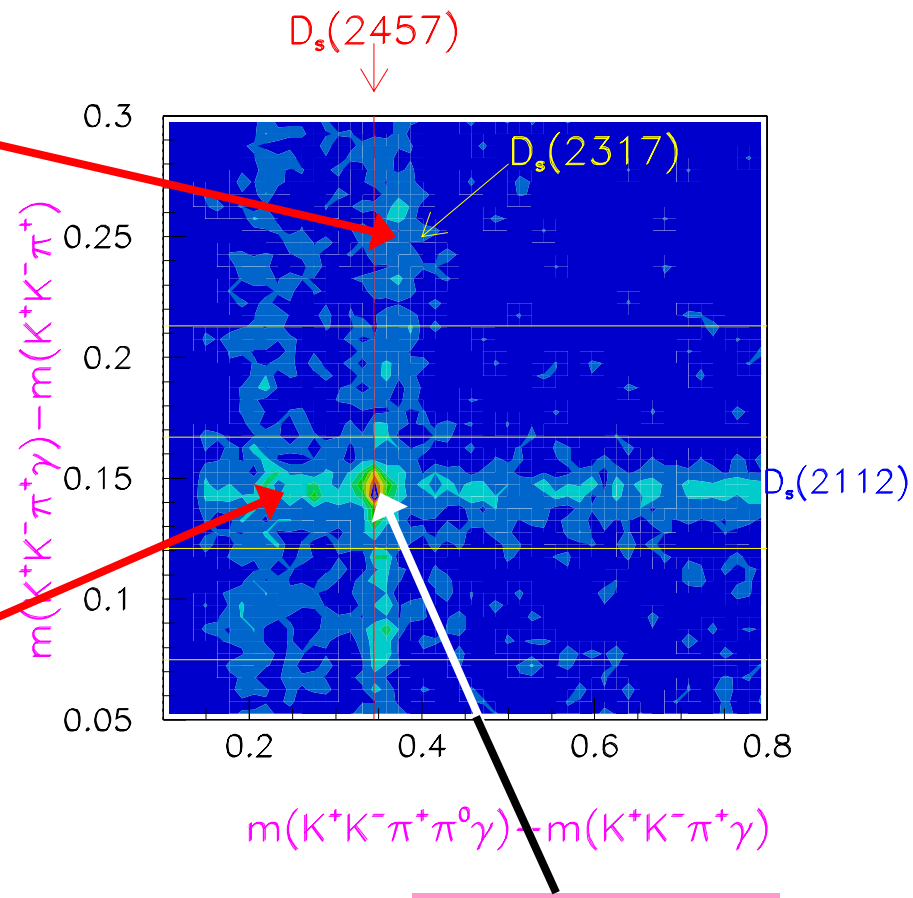
Crossing of bands complicates analysis



Overlapping Bands in $D_s^+ \pi^0 \gamma$

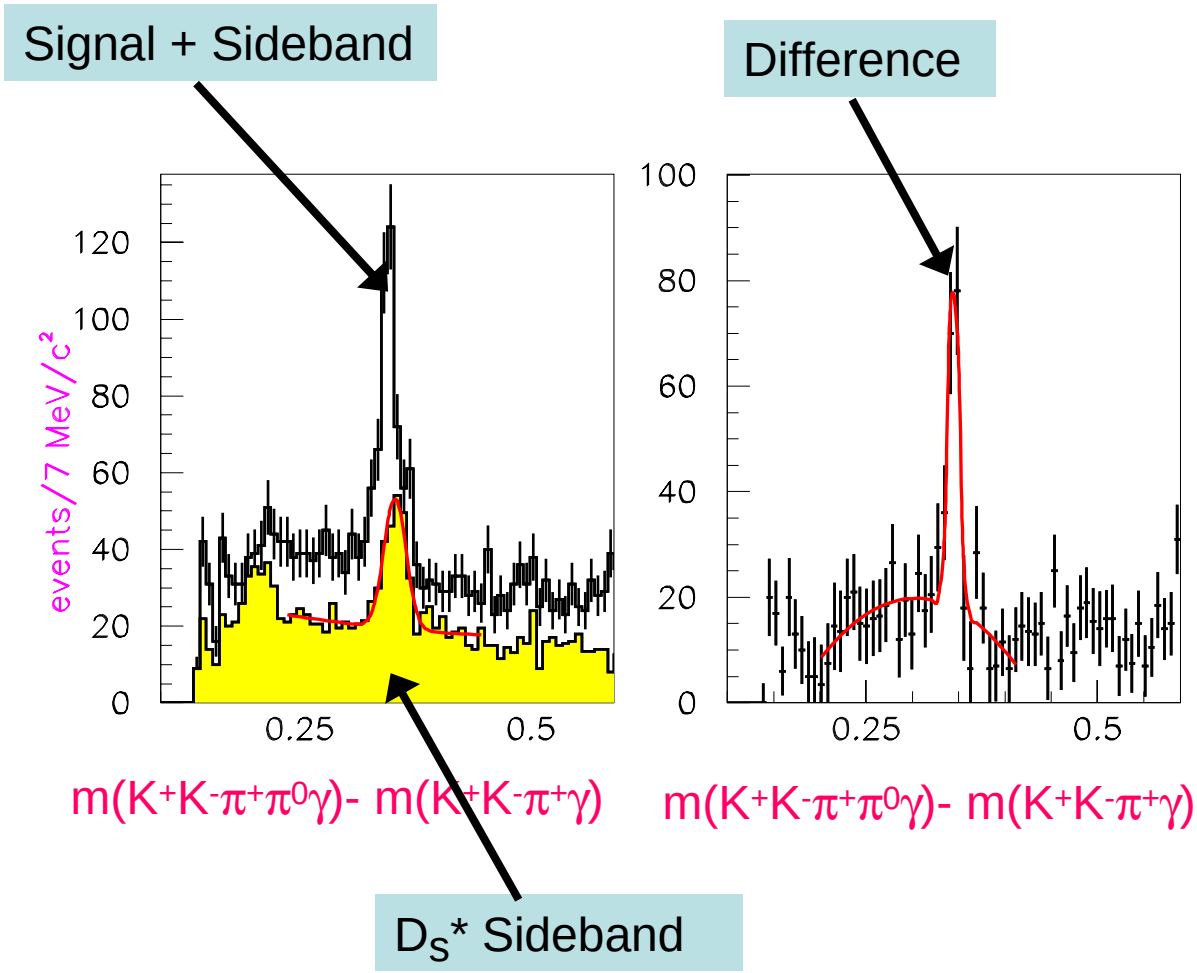
$D_s(2317)$ + random γ

D_s^* + random π^0



Excess ?

Isolate Signal



$\Delta m = 344.6 \pm 1.2$ MeV

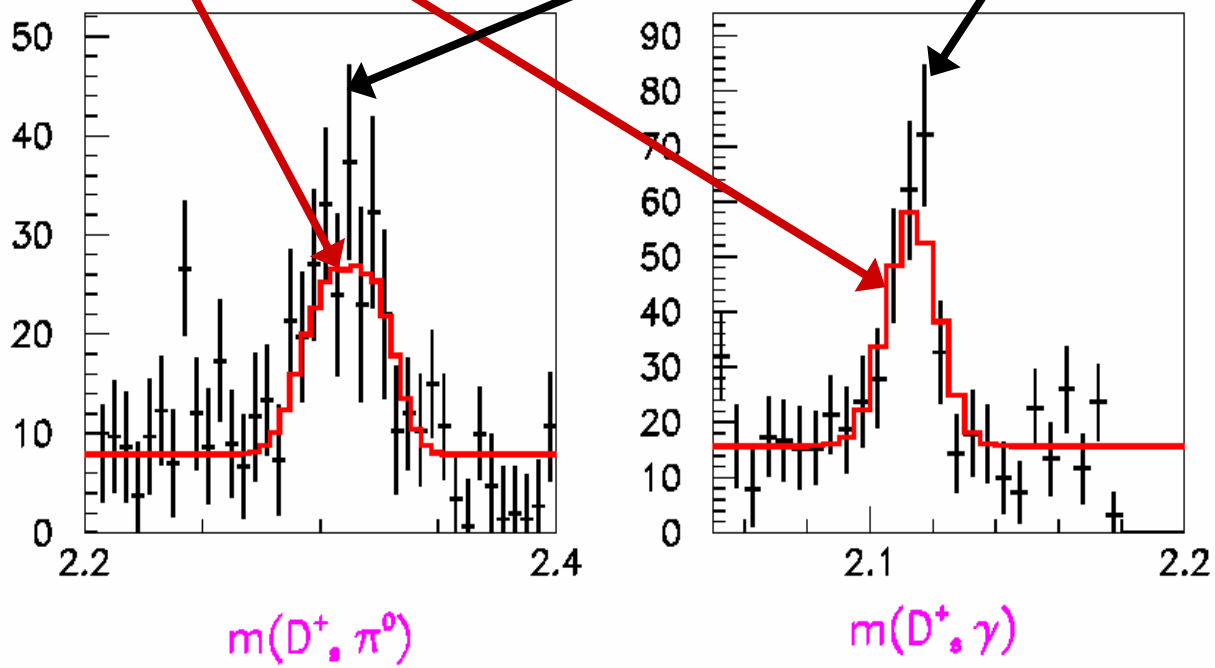
$N = 140 \pm 22$

$m = 2456.5 \pm 1.4$ MeV

Good fit with $D_s(2458) \rightarrow D_s^{*+} \pi^0$

MC with $D_s(2458) \rightarrow D^{+*}_s \pi^0$

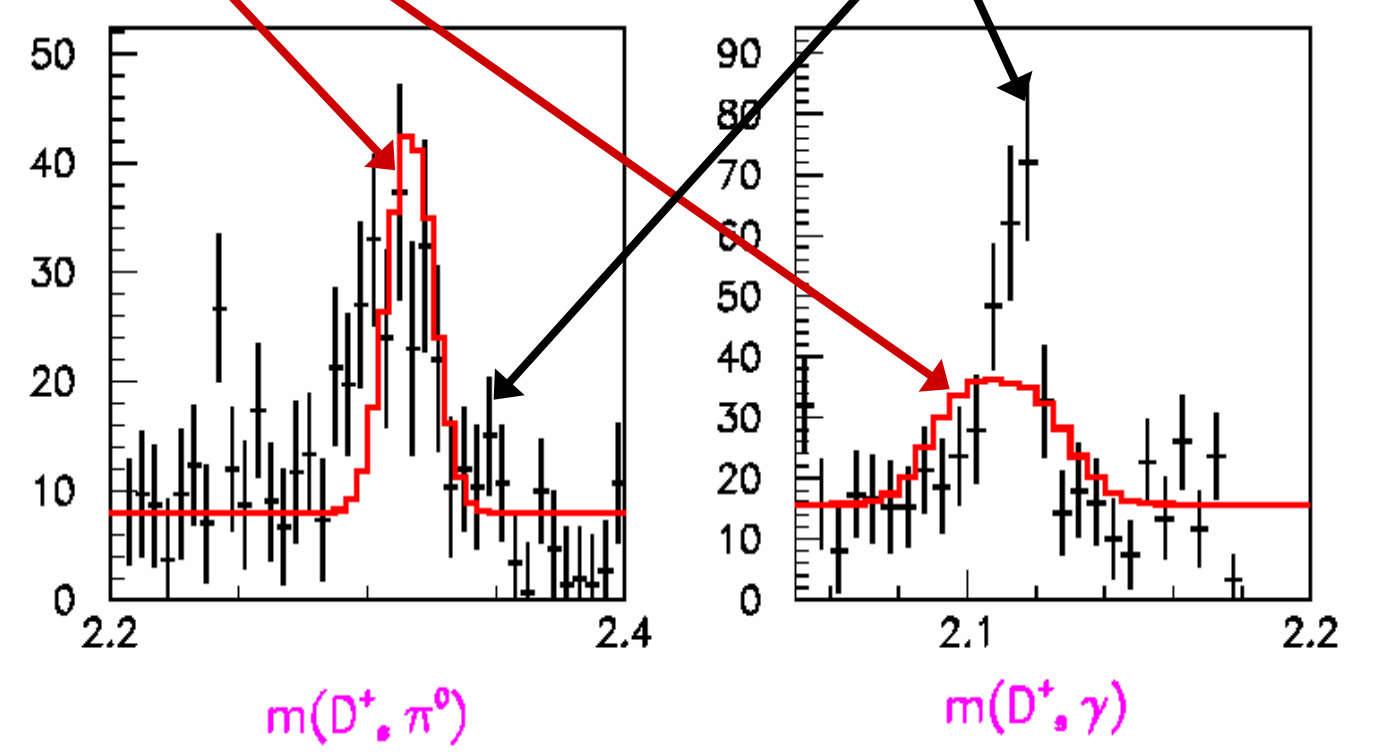
Sideband-subtracted data



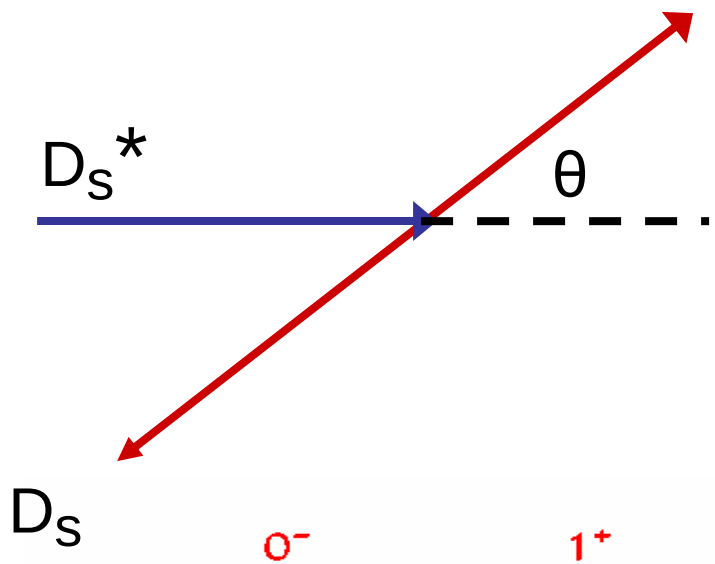
Poor fit with $D_s(2458) \rightarrow D_{sJ}^{*+}(2317)\,\pi^0$

MC with $D_s(2458) \rightarrow D^{+*}_{sJ}(2317)\,\gamma$

Sideband-subtracted data



Spin of $D_s(2458)$



0^+: forbidden

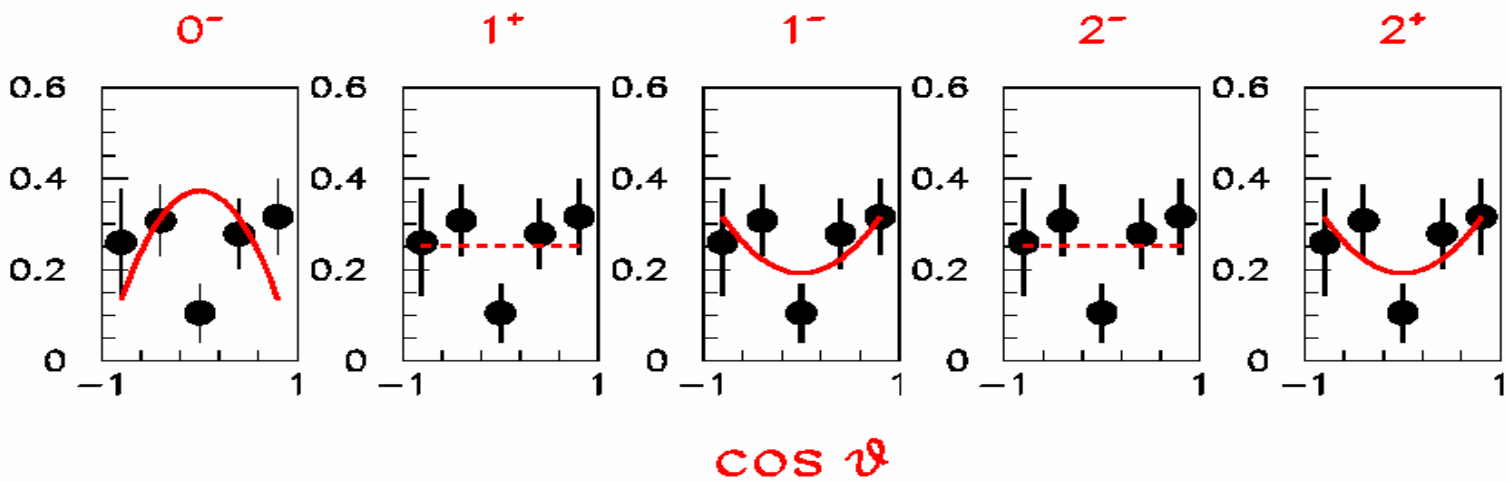
0^-: disfavored

1^+: can't say

1^-: ok

2^-: can't say

2^+: ok

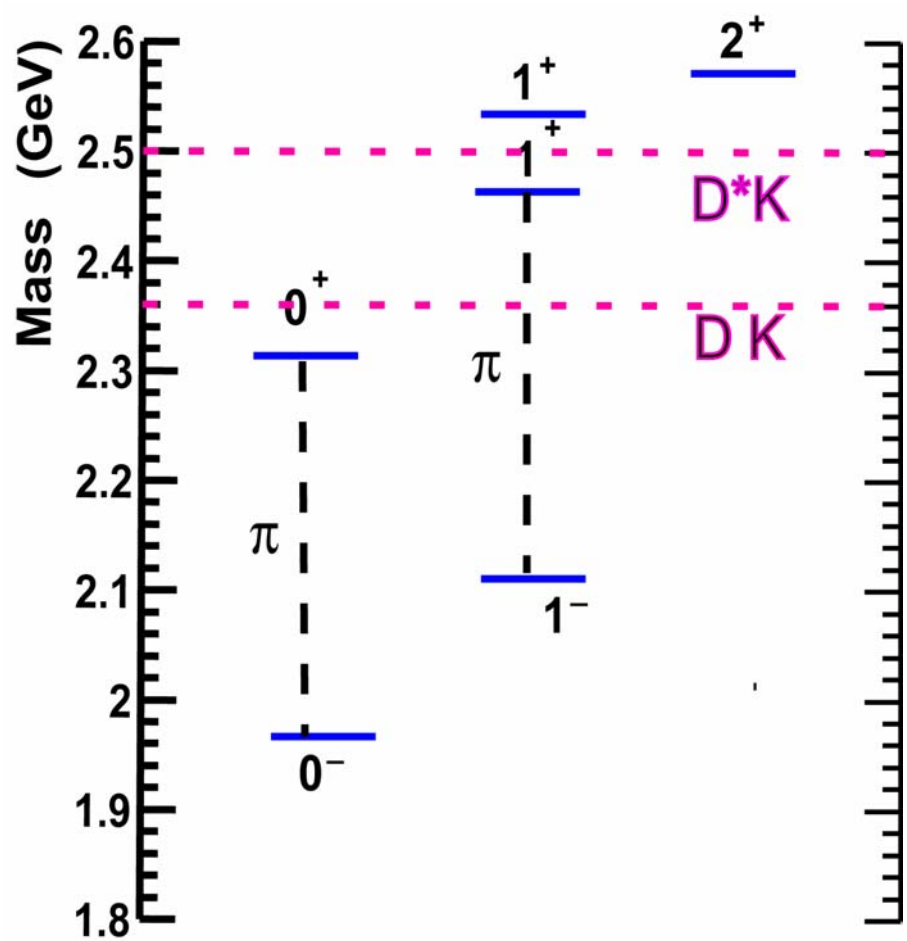


Consistent Picture of 2317 and 2458

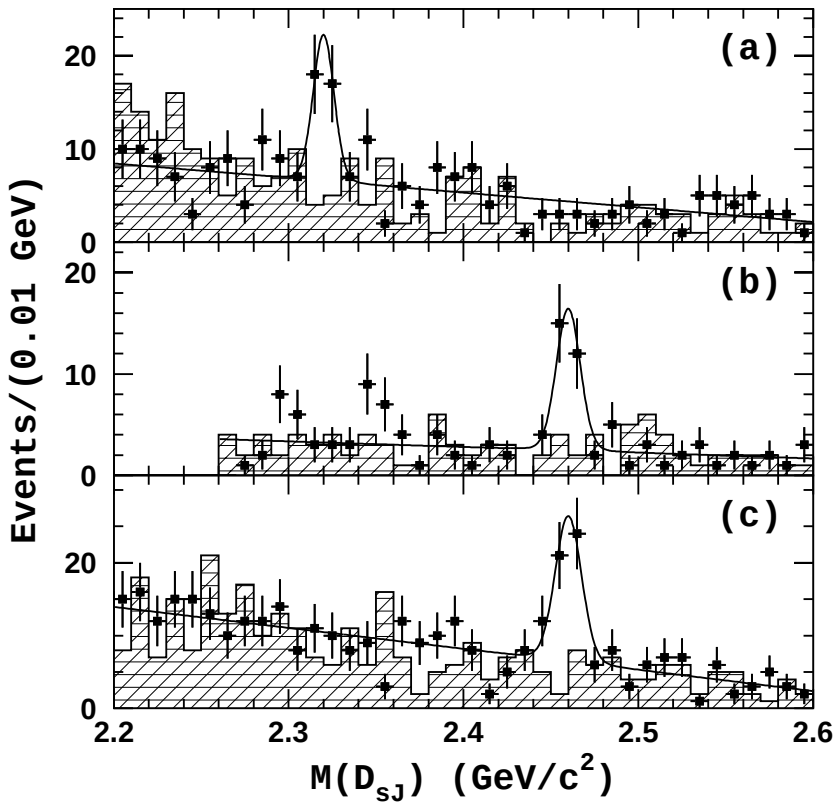
Isospin conserving decays to DK and D*K unavailable

Isospin violation:

View as η–π mixing.



Belle: Exclusive B Decays



$B \to D D_{SJ}^*(2317)$,

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

$B \to D D_{SJ}(2458)$,

$D_{SJ}(2458) \to D_s^*(2112) \pi^0$

$B \to D D_{SJ}(2458)$,

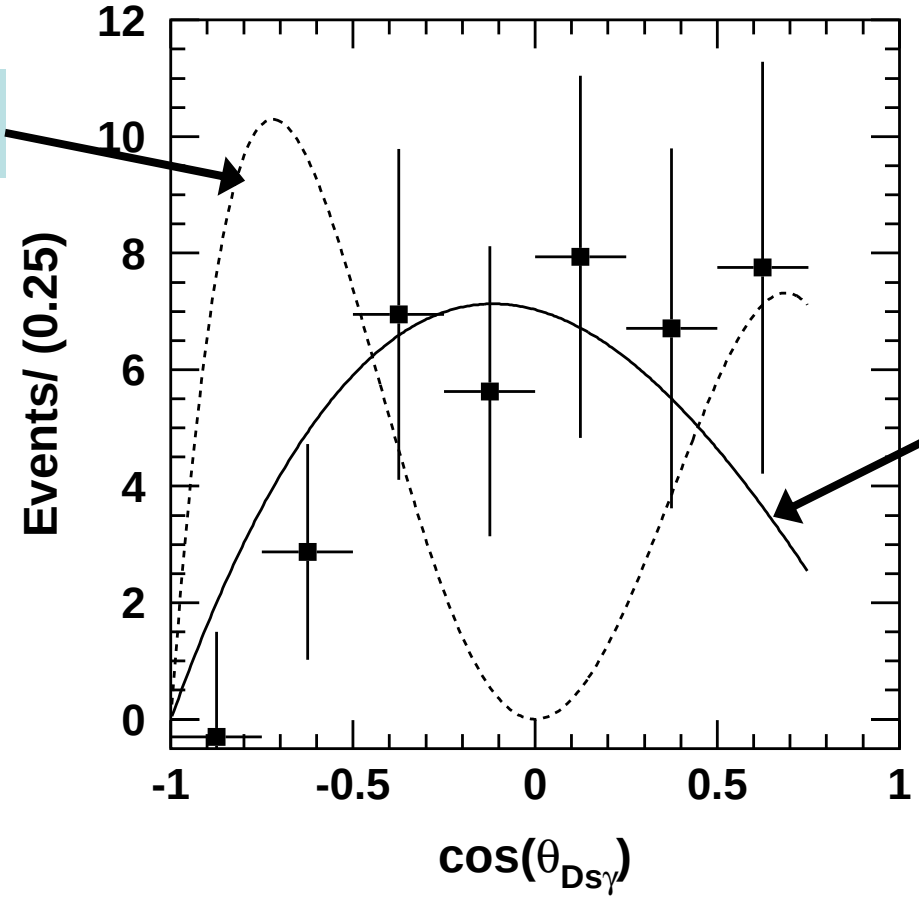
$D_{SJ}(2458) \to D_s \gamma$

Belle: $B \rightarrow DD_{sJ}(2458)$, $D_{sJ}(2458) \rightarrow D_s \gamma$

Spin-0 forbidden

Spin-2

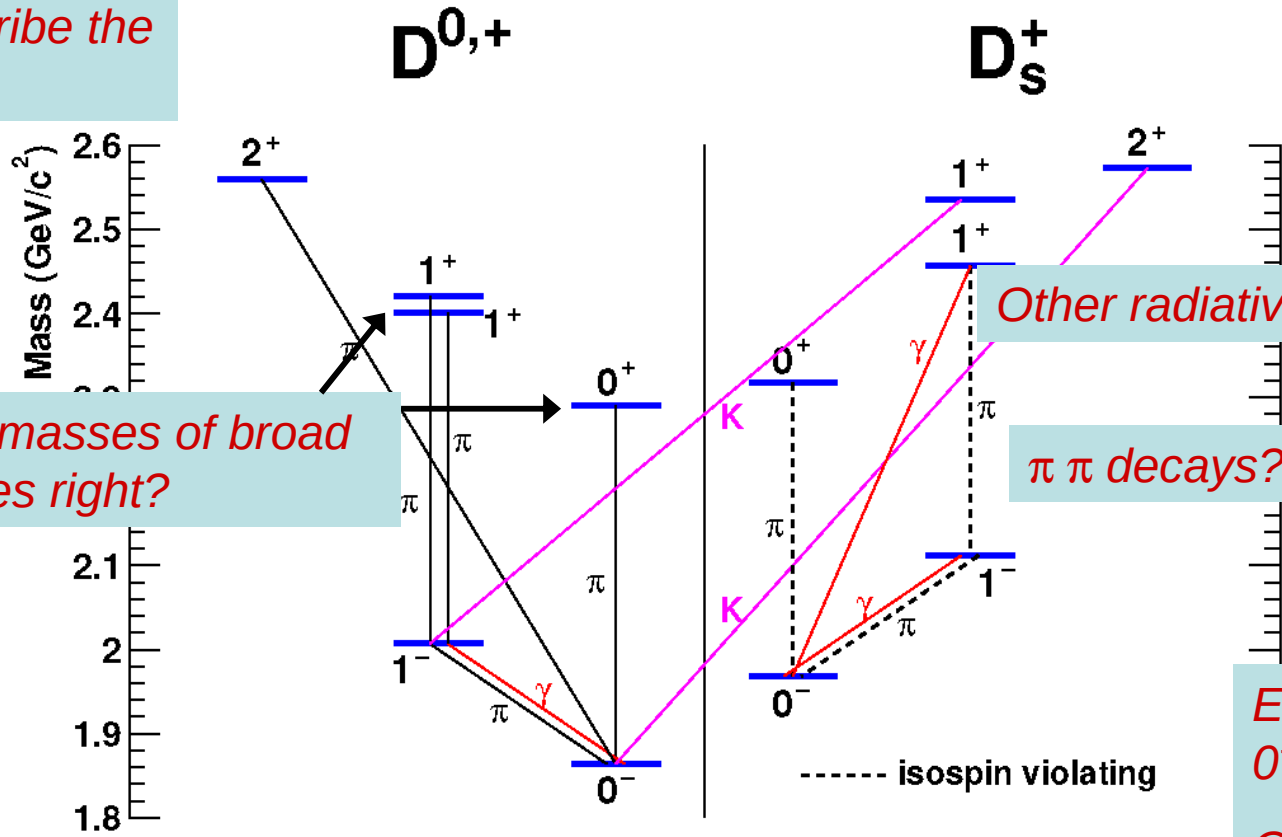
Belle
– hep-ex/0308019



Spin-1

Current Picture Challenges Experiment and Theory

Can any potential model describe the spectra?



Are masses of broad states right?

Other radiative decays?

$\pi\,\pi$ decays?

Equal 0^-1^- and 0^+1^+ splittings

Coincidental?