Role of $D^{0**}_{0,2}$ in $B^- \rightarrow D_s^+ K^- \pi^-$

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Oleg Antipin, Iowa State University
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Notation: D-meson excited states (D**)

In the heavy quark limit, the heavy quark spin decouples from the other degrees of freedom and the total angular momentum of the light quark is a good quantum number.

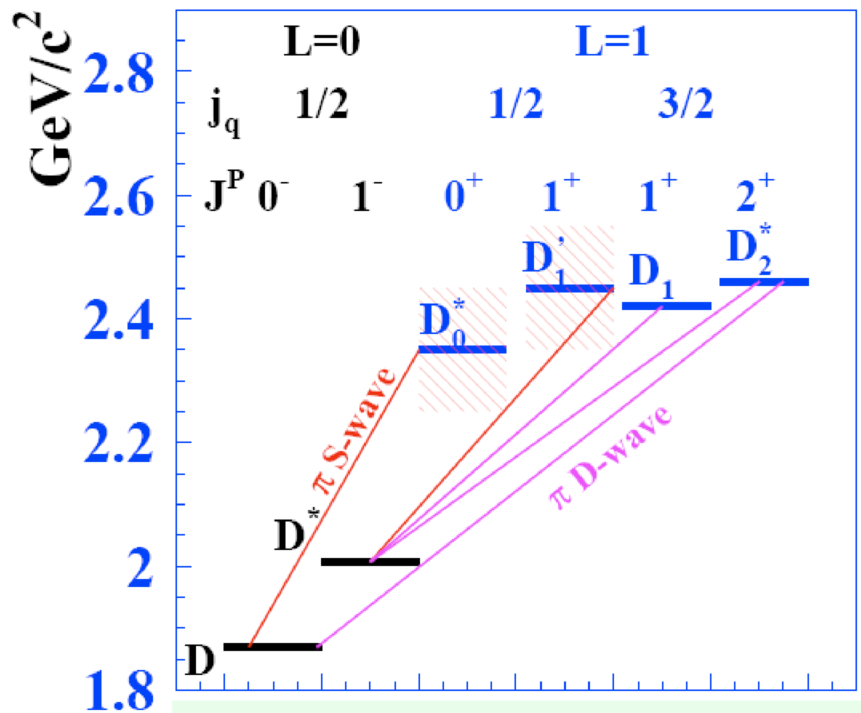


Figure is taken from hep-ex/0307021

FIG. 1: Spectroscopy of D-meson excitations. The lines show possible single pion transitions.

Motivation

Babar report for ICHEP06 –Moscow: $Br(B^- \to D_s^+ K^- \pi^-) = (1.88 \pm 0.13 \pm 0.41) \cdot 10^{-4}$

The Babar collaboration has recently reported the observation of the decay mode $B^- \to D_s^+ K^- \pi^-$.

Motivation

- We investigate the role played by D** resonances which are very close to the $D_s^+K^-$ production threshold and therefore play an important role.

$$m_{D_0^{**}} = (2308 \pm 17 \pm 15 \pm 28)\ MeV$$
$$m_{D_2^{**}} = (2461.6 \pm 2.1 \pm 0.5 \pm 3.3)\ MeV,$$

are sufficiently close to the $D_s^+ K^-$ system threshold at 2.462GeV

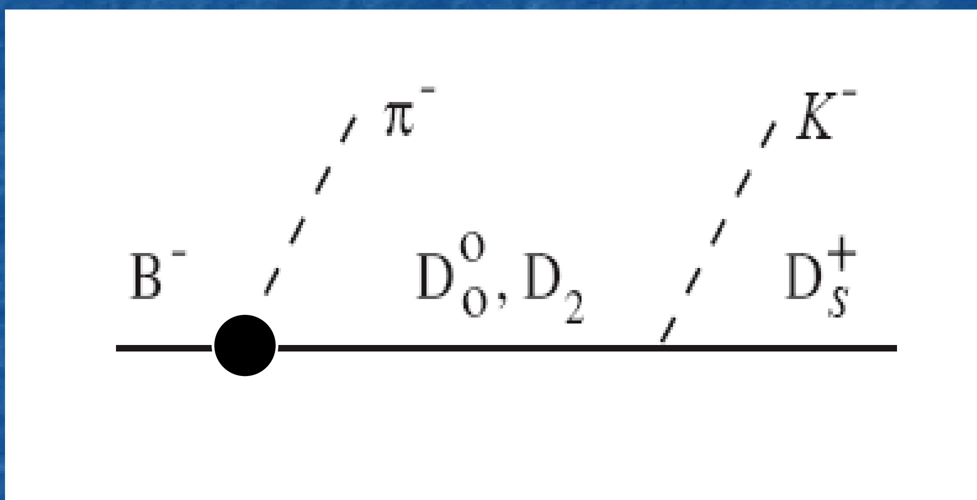
→ they are "quasi-resonances"

- There is a possibility to extract the $D^{**}D_s^+ M$ strong coupling (if decay process factorizes).

- Distribution with respect to the angle between the pion and kaon momenta can constrain the D_2^0 tensor couplings (h')

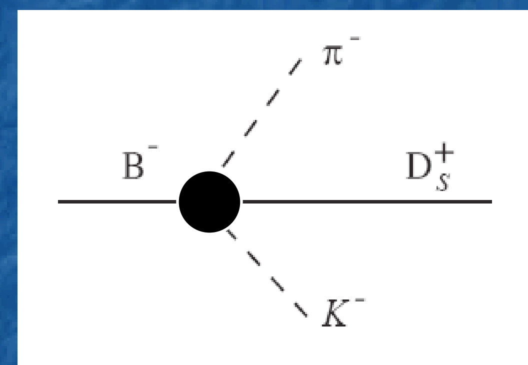
$B^- \to D_s^+ K^- \pi^-$ schematically

Quasi-resonant



+

Non-resonant

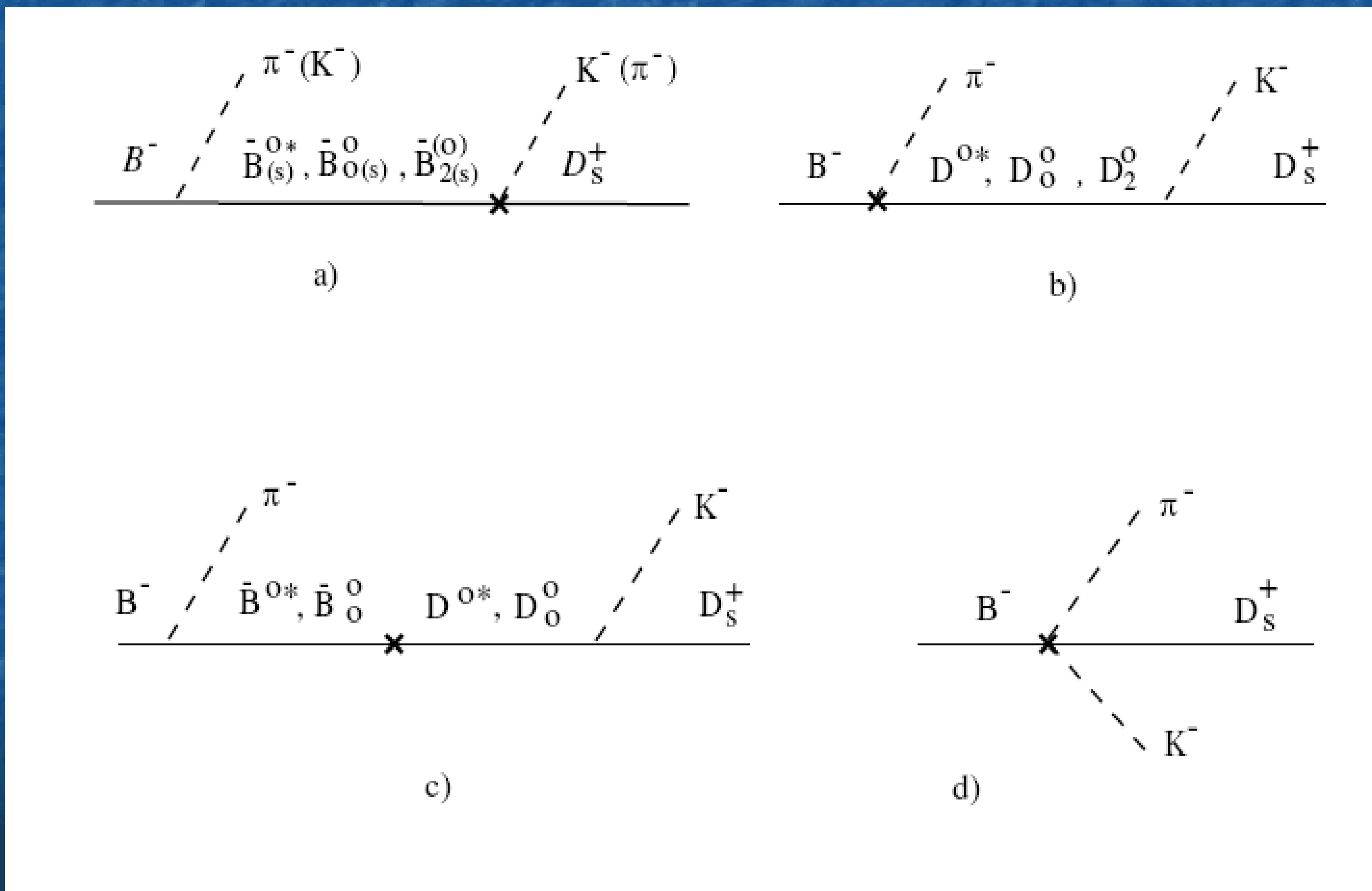


$$R = \frac{Br(B^- \to D^+ \pi^- \pi^-)}{Br(B^- \to D_s^+ K^- \pi^-)}$$

⇒ If quasi-resonant contribution dominates, residual dependence on the weak vertex parameterization cancels out in R

Calculation of $B^- \rightarrow D^+ K_s^- \pi^-$ in chiral perturbation theory

Calculation consists of evaluation of 13 diagrams :



"X" stands for the weak transition

Results. Parameterization of the amplitude.

Working in the $D_s^+ K^-$ center of mass frame ** we write the amplitude as a linear superposition of Legendre polynomials:

$$\mathcal{M}(B^- \to D_s^+ K^- \pi^-) = \mathcal{M}_0 P_0(\cos\theta_{K^-\pi^-}) + \mathcal{M}_1 P_1(\cos\theta_{K^-\pi^-}) + \mathcal{M}_2 P_2(\cos\theta_{K^-\pi^-}) + \cdots$$

In terms of this components the differential decay rate is:

$$\frac{d\Gamma(B^- \to D_s^+ K^- \pi^-)}{dm_{D_s^+ K^-}} = \frac{E_{D_s^+} |\vec{p}_K^{\,*}| |\vec{p}_\pi|}{4(2\pi)^3 m_B} \left[|\mathcal{M}_0|^2 + \frac{1}{3}|\mathcal{M}_1|^2 + \frac{1}{5}|\mathcal{M}_2|^2 + \cdots \right]$$

** This frame would correspond to the rest frame of the D** if it were produced as a physical intermediate state and, thus, this angular analysis would normally be used to determine the spin of the resonance

Results. Plots of the partial amplitudes.

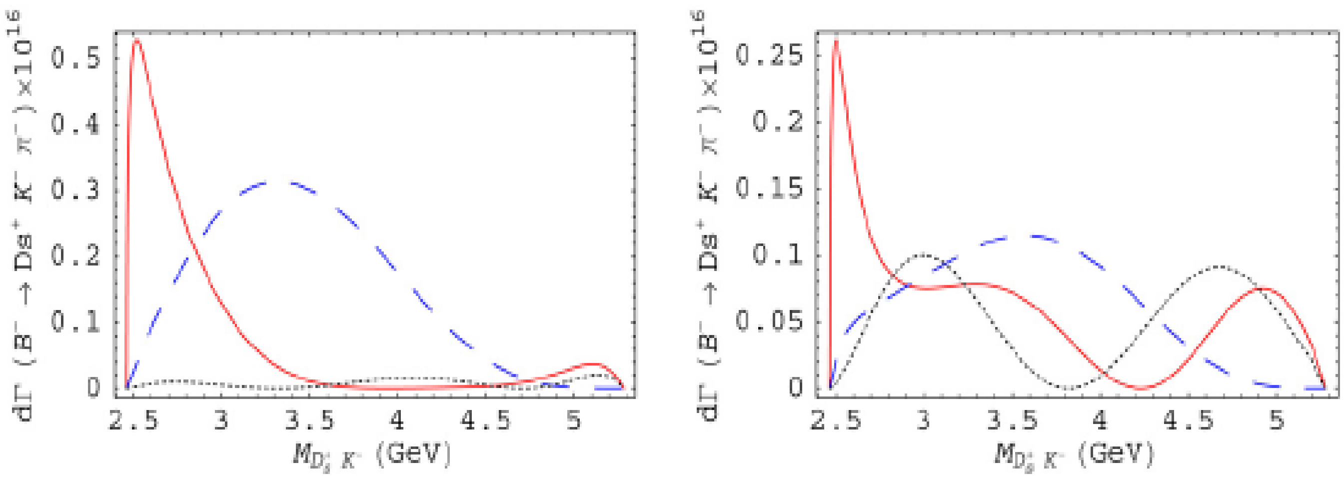


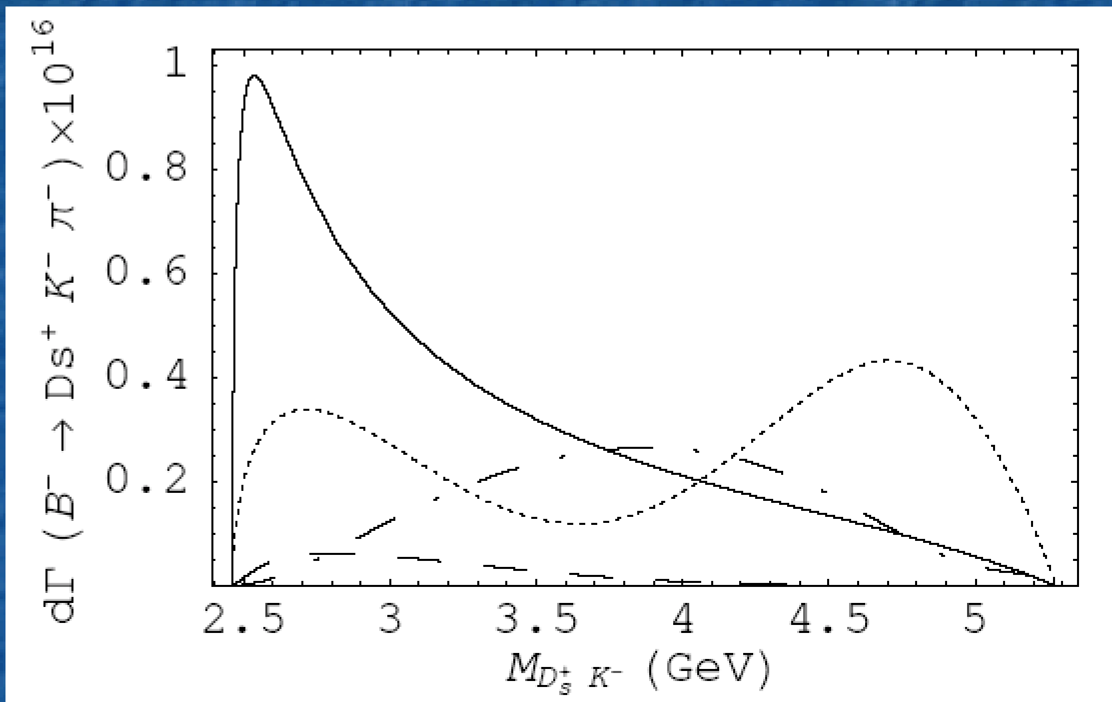
Fig. 5. Contributions to the decay rate from different spin amplitudes for $B_1 = 1$, $B_2 = 1.13$ with: (a) $h' < 0$, (b) $h' > 0$. In both cases the solid line corresponds to M_0, the dotted line to M_1 and the dashed line to M_2. Higher spin contributions are negligible and are not shown.

Branching ratios for the partial wave amplitudes are:

Table 1
Partial branching ratios for spin amplitudes

	$h' > 0$	$h' < 0$
$\mathcal{B}_0(B^- \to D_s^+ K^- \pi^-)$	4.4×10^{-5}	5.3×10^{-5}
$\mathcal{B}_1(B^- \to D_s^+ K^- \pi^-)$	3.6×10^{-5}	5.6×10^{-6}
$\mathcal{B}_2(B^- \to D_s^+ K^- \pi^-)$	4.3×10^{-5}	1.0×10^{-4}
$\mathcal{B}_{J>2}(B^- \to D_s^+ K^- \pi^-)$	4.2×10^{-8}	5.4×10^{-7}

Results. Resonant vs. non-resonant diagrams



Solid: scalar

Dashed: tensor

The rest: dotted and dash-dotted

$Br_{scalar} \approx 2 \cdot 10^{-4}$

$Br_{tensor} \approx 1.3 \cdot 10^{-5}$

→ Large contribution to these partial waves from non-resonant diagrams

Results. Total decay rate.

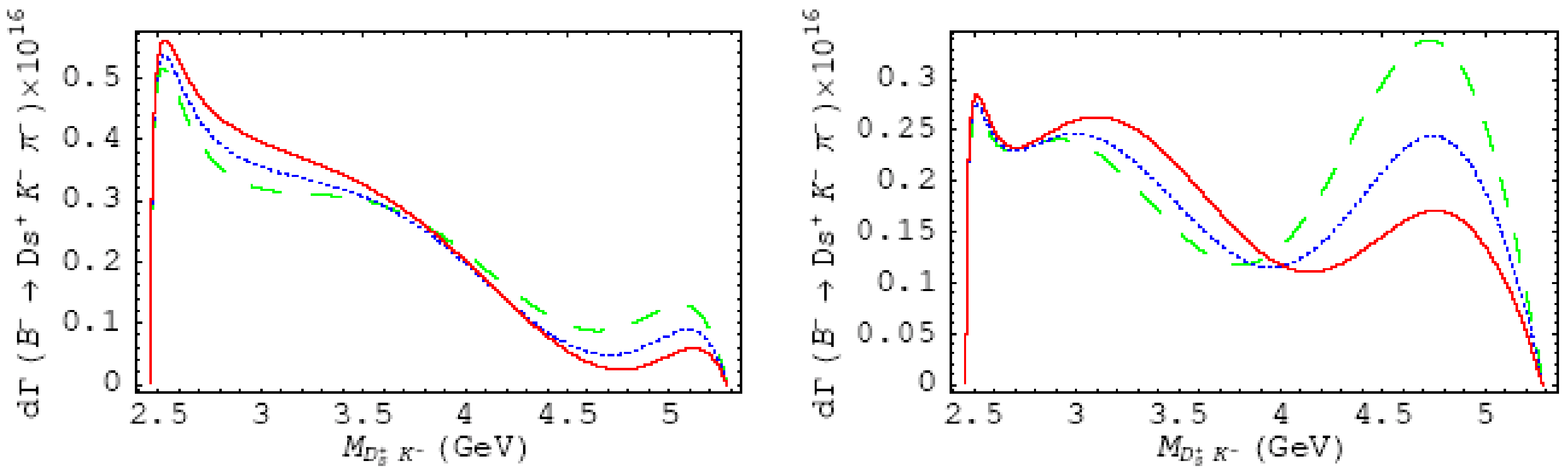
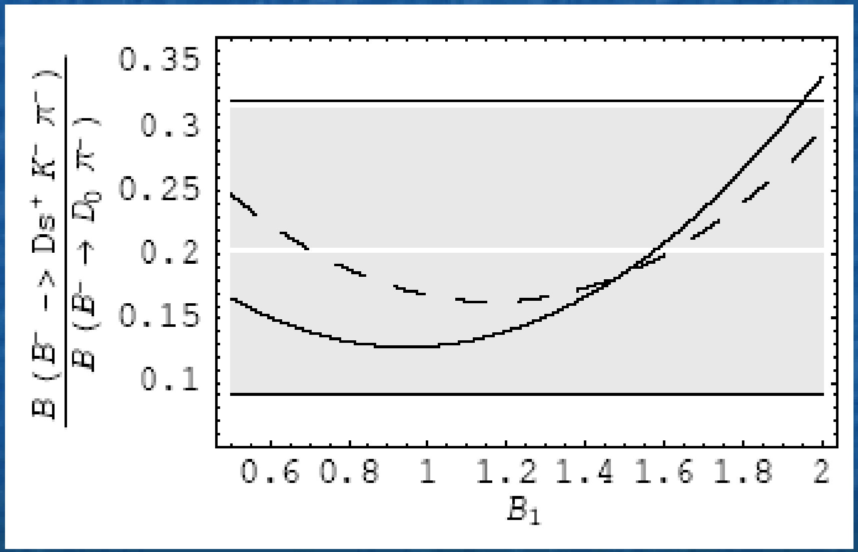


FIG. 4: $M_{D_s^+ K^-}$ invariant mass distributions with $B_1 = 1$, $B_2 = 1.13$ (solid), $B_1 = 1.15$, $B_2 = 1.06$ (dotted), $B_1 = 1.308$, $B_2 = 1$ (dashed) for (a) $h' = -0.5\ \mathrm{GeV}^{-1}$ and (b) $h' = 0.5\ \mathrm{GeV}^{-1}$.

Br ≈ $1\cdot 10^{-4}$ Experimental value is ≈ $2\cdot 10^{-4}$

Dependence on the parameterization of the weak vertex

We normalize the total decay rate shown above to the rate $B^- \to D_0^0 \pi^-$. We then plot this ratio as a function of the “bag factor” B1 while adjusting B2 in such a way that $B^- \to D_0^0 \pi^-$ remains fixed to its experimental central value



Again for both signs of unknown h’ strong tensor coupling constant

Conclusions

- The spin 0 partial rate receives a large but not dominant contribution from the D_0^{0**} intermediate state
- The spin 1 and 2 are large which forces the conclusion that D** resonances do not dominate this decay mode though play an important role.
- Contributions of spins higher than two are negligible
- Expect to give only qualitative description due to large Mb-Mc mass difference which breaks down the momentum expansion