Discriminating among interpretations for $X(2900)$ states

Tim Burns (Swansea University)
29 October 2020

[T.B. & E.Swanson, 2008.12838]
[T.B. & E.Swanson, 2009.05352]

Experimental properties

Two $X(2900)$ states in $B^+ \to D^+ X, X \to D^- K^+$

Their minimal flavour content is $ud\bar{s}\bar{c}$

$X_0(2900)$	$2.866 \pm 0.007 \pm 0.002$ GeV	0^+
$X_1(2900)$	$2.904 \pm 0.005 \pm 0.001$ GeV	1^-

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Models

Tetraquark

Tetraquark interpretations:

- [Karliner & Rosner, 2008.05993]
- [He, Wang & Zhu, 2008.07145]
- [Zhang, 2008.07295]

But

- Mass inconsistent with variational quark model [Lu, Chen, Dong, 2008.07340]
- Analogy with *bound* lattice $ud\bar{b}\bar{b}$ is questionable
- If $X(2900)$ are orbital/radial excitations, where are ground states?
- No evidence for *bound* $ud\bar{s}\bar{c}$ in lattice [Hudspith et al 2006.14294], quark model [Zouzou et al 1986], QCD sum rules [Agaev et al 1907.04017]
- 1^- state awkward (P-wave)

Molecule

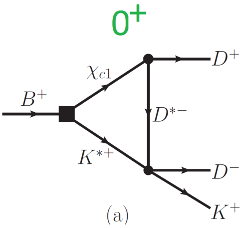
Many models for 0^+ $X_0(2900)$:

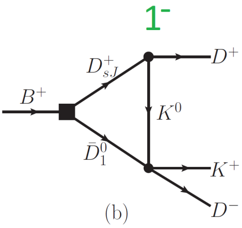
- isoscalar $\bar{D}^* K^*$ with vector hidden gauge [Molina et al 1005.0355, 2008.11171]
- isoscalar $\bar{D}^* K^*$ with effective Lagrangian [Liu et al 2008.07389]
- isovector $\bar{D}^* K^*$ with effective Lagrangian [He and Chen 2008.07782]
- isoscalar $\bar{D}^* K^*$ with heavy quark symmetry [Hu et al 2008.06894]
- isoscalar $\bar{D}^* K^*$ with molecular and diquark d.o.f. [Chen et al 2008.07516, Xue et al 2008.09516]

The 1^- $X_1(2900)$ is more difficult:

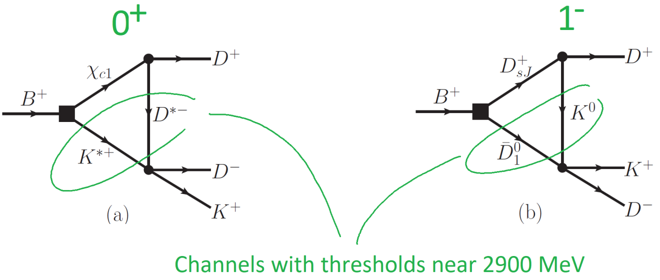
- virtual state from $\bar{D}_1(2420)K$ [He and Chen 2008.07782]

Triangle [Liu et al 2008.07190]

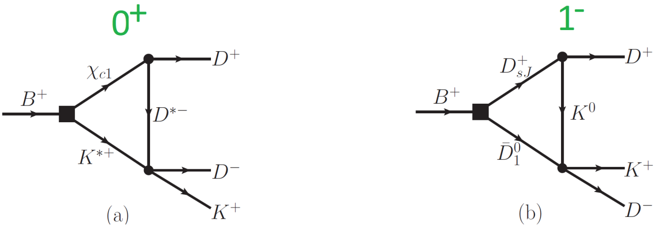




Triangle [Liu et al 2008.07190]



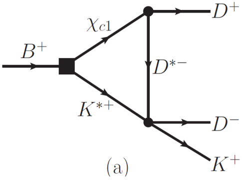
Triangle [Liu et al 2008.07190]



colour-suppressed!

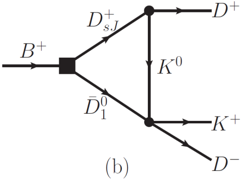
Triangle [Liu et al 2008.07190]

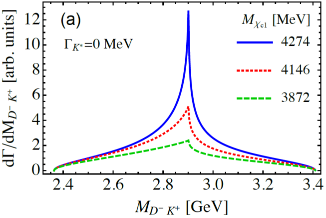
0+



colour-suppressed!

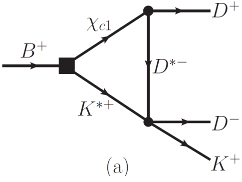
1-





Triangle [Liu et al 2008.07190]

0^+



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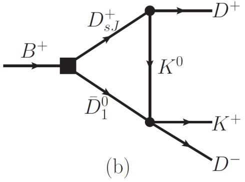
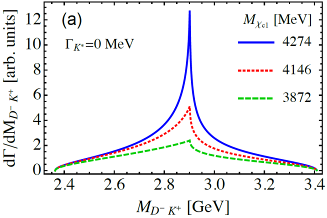
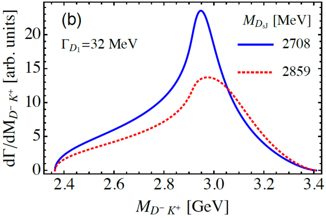
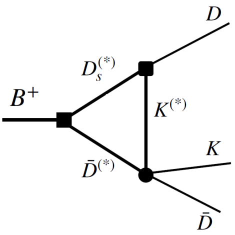
1^-

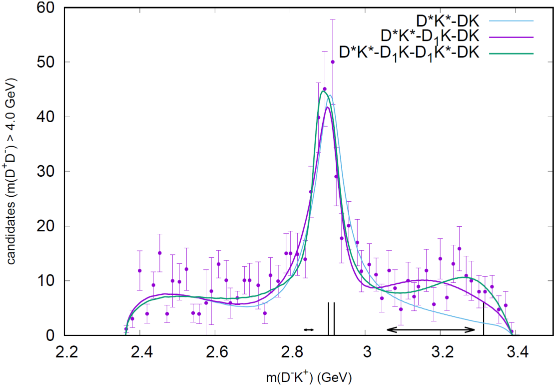






Triangle with FSIs [T.B. & Swanson 2008.12838]





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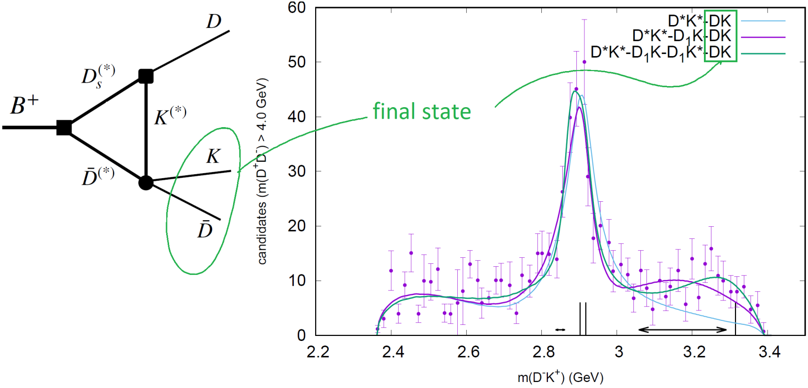

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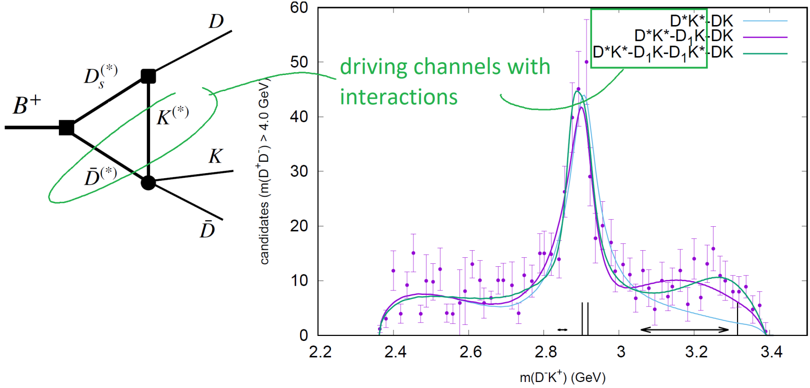

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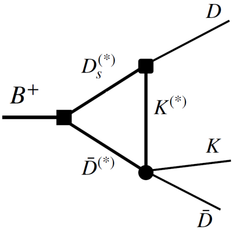
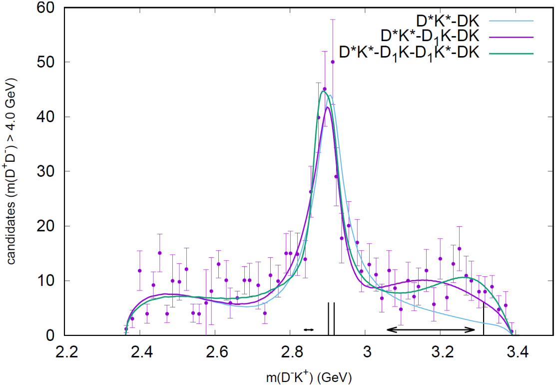


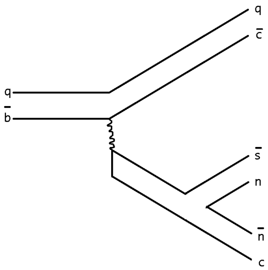


This is an example fit.

Given parametric freedom, can't really distinguish triangle scenario (weak FSIs) from resonance scenario (strong FSIs)

Discriminating among models

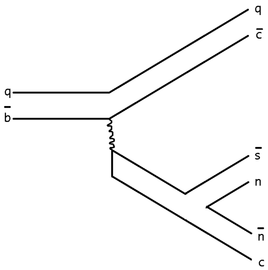
[T.B. & E.Swanson, 2009.05352]

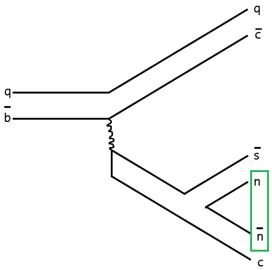


$\bar{b} \rightarrow \bar{c}(c\bar{s})$ Cabibbo-favoured

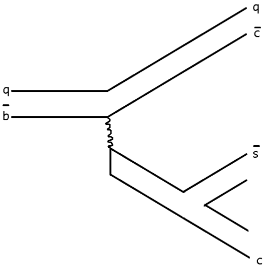
colour-favoured

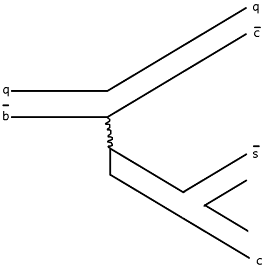
Other diagrams gives wrong flavours and/or are colour suppressed

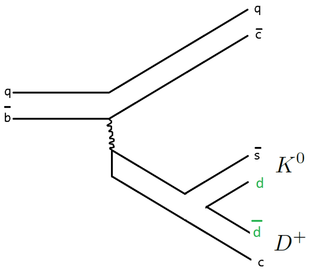

q
c̄
q
b̄
s̄
n
n̄
c

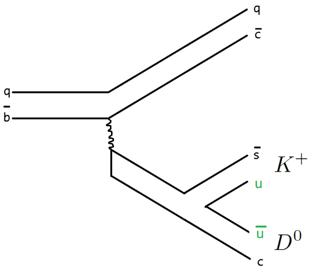


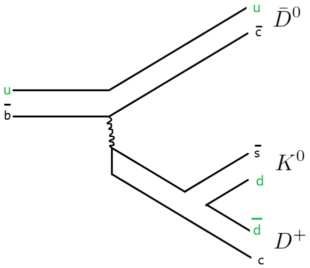
$$n\bar{n} = (u\bar{u} + d\bar{d})/\sqrt{2}$$


q
$\bar{c}$
q
$\bar{b}$
$\bar{s}$
c


q
$\bar{c}$
q
$\bar{b}$
$\bar{s}$
c


q
$\bar{c}$
q
$\bar{b}$
$\bar{s}$
K^0
d
$\bar{d}$
D^+
c


q
$\bar{c}$
q
$\bar{b}$
$\bar{s}$
K^+
u
$\bar{u}$
D^0
c


u
$\bar{c}$
$\bar{D}^0$
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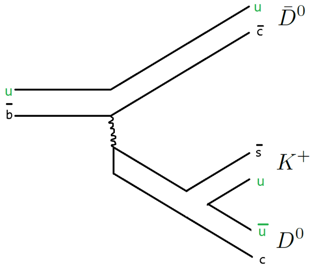
$\bar{b}$
$\bar{s}$
K^0
d
$\bar{d}$
D^+
c


u
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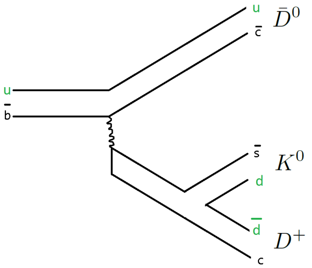
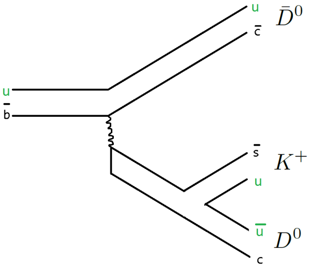
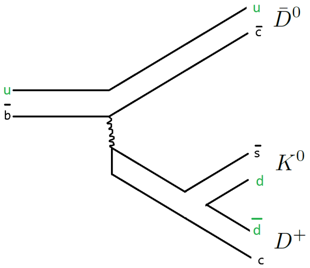
u
$\bar{b}$
$\bar{s}$
K^+
u
$\bar{u}$
D^0
c





Note the absence of

$$B^+ \to D^+ D^- K^+$$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$\bar{b}$
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$\bar{c}$
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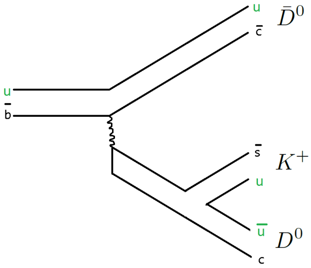
K^0
d
$\bar{d}$
D^+
c


u
$\bar{b}$
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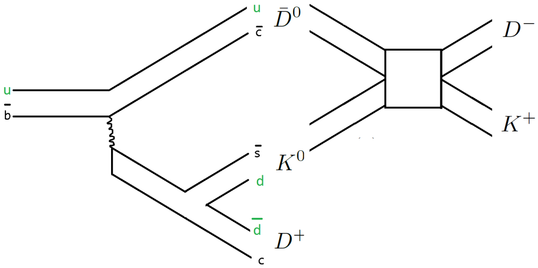
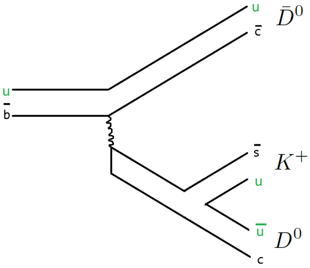
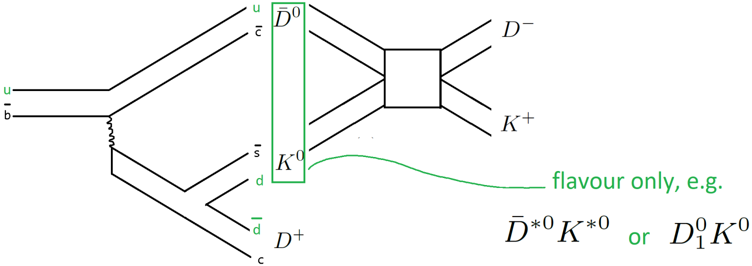
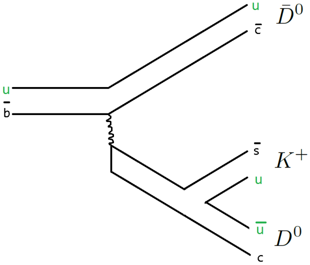
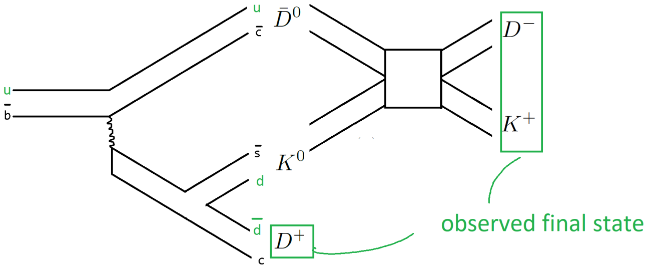
K^+
u
$\bar{u}$
D^0
c

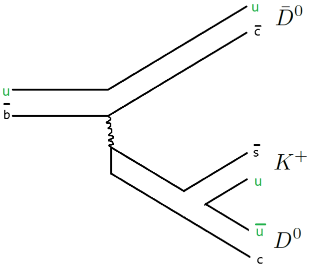

u
$\bar{b}$
u
$\bar{c}$
$\bar{D}^0$
$\bar{s}$
K^0
d
$\bar{d}$
D^+
c
D^-
K^+


u
$\bar{b}$
u
$\bar{c}$
$\bar{D}^0$
$\bar{s}$
K^+
u
$\bar{u}$
D^0
c


u
b
u
c
$\bar{D}^0$
s
K^0
d
d
D^+
c
D^-
K^+
flavour only, e.g.
$\bar{D}^{*0} K^{*0}$ or $D_1^0 K^0$


u
b
u
c
$\bar{D}^0$
s
K^+
u
u
D^0
c


u
c̄
D̄⁰
u
b̄
s̄
K⁰
d
d̄
D⁺
c
D⁻
K⁺
observed final state


u
c̄
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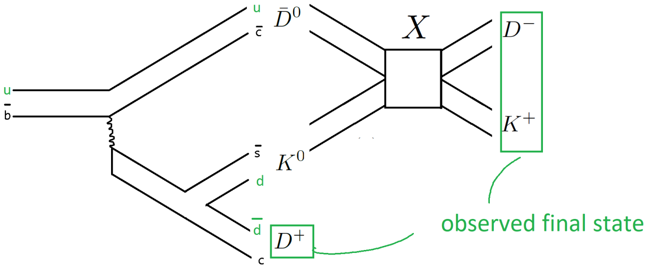
K⁺
u
ū
D⁰
c



u
c̄
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X
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K^+
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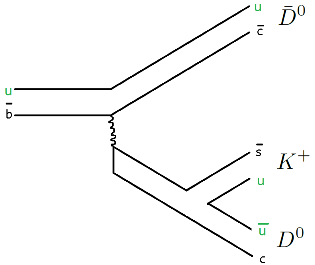
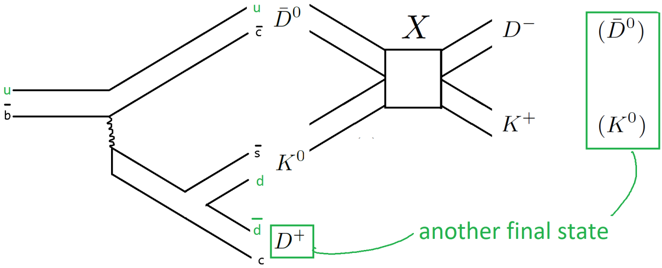
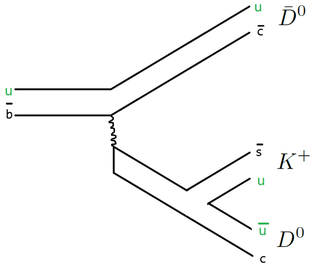
b̄
s̄
K^0
d
d̄
D^+
c
observed final state



u
c̄
$\bar{D}^0$
u
b̄
s̄
K^+
u
ū
D^0
c


u
$\bar{D}^0$
$\bar{c}$
X
D^-
$(\bar{D}^0)$
u
$\bar{b}$
K^+
(K^0)
$\bar{s}$
K^0
d
$\bar{d}$
D^+
another final state
c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$\bar{u}$
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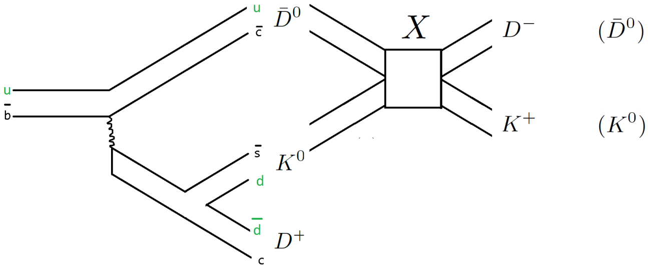
u
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K^+
(K^0)
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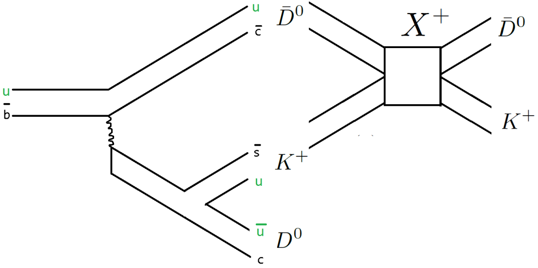
d̄
D^+
c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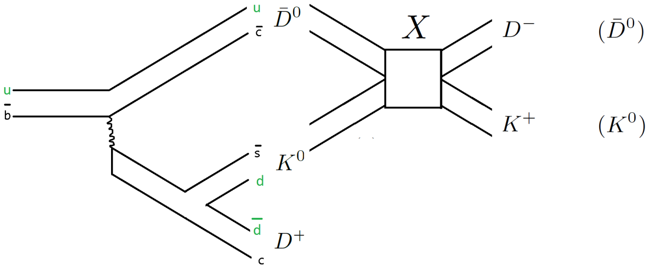

u
$\bar{c}$
$\bar{D}^0$
X
D^-
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u
$\bar{b}$
K^+
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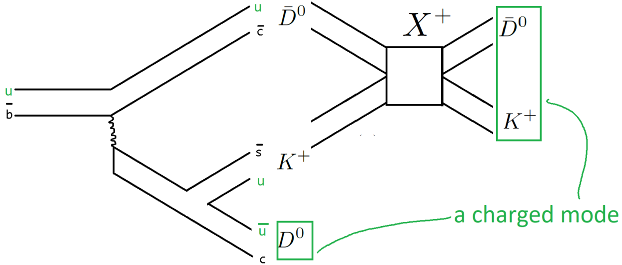
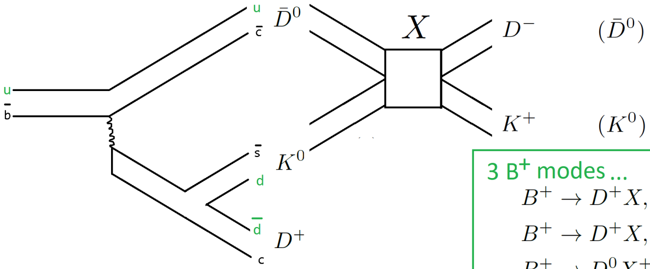
d
$\bar{d}$
D^+
c

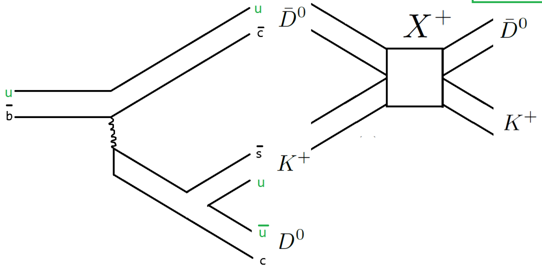


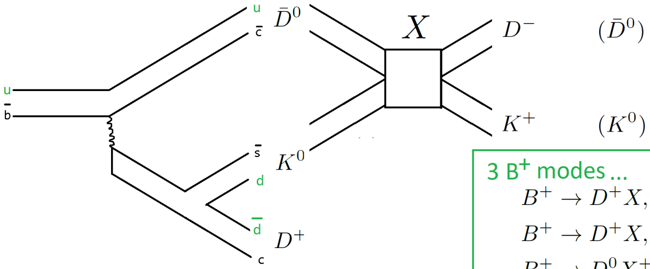
u
$\bar{c}$
$\bar{D}^0$
X^+
$\bar{D}^0$
u
$\bar{b}$
K^+
$\bar{s}$
K^+
u
a charged mode
$\bar{u}$
D^0
c



3 B^+ modes ...

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

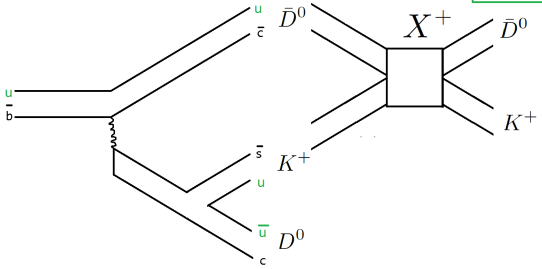


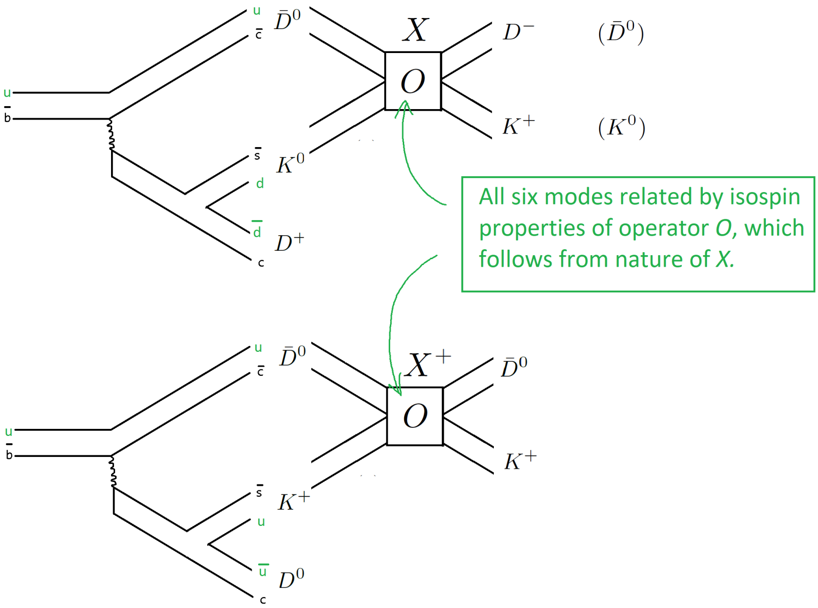


3 B⁺ modes ...

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

... and another 3 for B⁰





u
b
u
c
$\bar{D}^0$
s
d
K^0
d
D^+
c
X
O
D^-
K^+
$(\bar{D}^0)$
(K^0)
All six modes related by isospin properties of operator *O*, which follows from nature of *X*.
u
b
u
c
$\bar{D}^0$
s
u
K^+
u
D^0
c
X^+
O
$\bar{D}^0$
K^+

Results for $X_1(2900)$ and its charged partners
(For $X_0(2900)$ scale by 5.6 / 30.6)

	$B^+ \to D^+ X$, $X \to D^- K^+$	$B^0 \to D^0 X$, $X \to \bar{D}^0 K^0$	$B^+ \to D^+ X$, $X \to \bar{D}^0 K^0$	$B^0 \to D^0 X$, $X \to D^- K^+$	$B^+ \to D^0 X^+$, $X^+ \to \bar{D}^0 K^+$	$B^0 \to D^+ X^-$, $X^- \to D^- K^0$
$\mathcal{B}(B \to D\bar{D}K)$	2.2 ± 0.7	2.7 ± 1.1	15.5 ± 2.1	10.7 ± 1.1	14.5 ± 3.3	7.5 ± 1.7
$f(B \to DX, X \to \bar{D}K)$						
Triangle, QE	30.6	23.2	0	0	4.6	8.3
Triangle, OPE	30.6	23.2	1.1	1.5	1.2	2.1
Triangle, EFT	30.6	23.2	$1.1\left(1-\frac{C_0}{C_1}\right)^2$	$1.5\left(1-\frac{C_0}{C_1}\right)^2$	$1.2\left(1+\frac{C_0}{C_1}\right)^2$	$2.1\left(1+\frac{C_0}{C_1}\right)^2$
Resonance, $I=0$	30.6	23.2	4.3	5.8	0	0
Resonance, $I=1$	30.6	23.2	4.3	5.8	18.6	33.4
Resonance, I mixed	30.6	23.2	$4.3\tan^2\left(\theta+\frac{\pi}{4}\right)$	$5.8\tan^2\left(\theta-\frac{\pi}{4}\right)$		
$\Delta f/f$	0.1	0.53	0.36	0.35	0.41	0.41

Results for $X_1(2900)$ and its charged partners

(For $X_0(2900)$ scale by 5.6 / 30.6)

neutral X modes

	$B^+ \to D^+ X$, $X \to D^- K^+$	$B^0 \to D^0 X$, $X \to \bar{D}^0 K^0$	$B^+ \to D^+ X$, $X \to \bar{D}^0 K^0$	$B^0 \to D^0 X$, $X \to D^- K^+$	$B^+ \to D^0 X^+$, $X^+ \to \bar{D}^0 K^+$	$B^0 \to D^+ X^-$, $X^- \to D^- K^0$
$\mathcal{B}(B \to D\bar{D}K)$	2.2 ± 0.7	2.7 ± 1.1	15.5 ± 2.1	10.7 ± 1.1	14.5 ± 3.3	7.5 ± 1.7
$f(B \to DX, X \to \bar{D}K)$						
Triangle, QE	30.6	23.2	0	0	4.6	8.3
Triangle, OPE	30.6	23.2	1.1	1.5	1.2	2.1
Triangle, EFT	30.6	23.2	$1.1\left(1-\frac{C_0}{C_1}\right)^2$	$1.5\left(1-\frac{C_0}{C_1}\right)^2$	$1.2\left(1+\frac{C_0}{C_1}\right)^2$	$2.1\left(1+\frac{C_0}{C_1}\right)^2$
Resonance, $I=0$	30.6	23.2	4.3	5.8	0	0
Resonance, $I=1$	30.6	23.2	4.3	5.8	18.6	33.4
Resonance, I mixed	30.6	23.2	$4.3\tan^2\left(\theta+\frac{\pi}{4}\right)$	$5.8\tan^2\left(\theta-\frac{\pi}{4}\right)$		
$\Delta f/f$	0.1	0.53	0.36	0.35	0.41	0.41

Results for $X_1(2900)$ and its charged partners

(For $X_0(2900)$ scale by 5.6 / 30.6)

charged X modes

	$B^+ \to D^+ X$, $X \to D^- K^+$	$B^0 \to D^0 X$, $X \to \bar{D}^0 K^0$	$B^+ \to D^+ X$, $X \to \bar{D}^0 K^0$	$B^0 \to D^0 X$, $X \to D^- K^+$	$B^+ \to D^0 X^+$, $X^+ \to \bar{D}^0 K^+$	$B^0 \to D^+ X^-$, $X^- \to D^- K^0$
$\mathcal{B}(B \to D\bar{D}K)$	2.2 ± 0.7	2.7 ± 1.1	15.5 ± 2.1	10.7 ± 1.1	14.5 ± 3.3	7.5 ± 1.7
$f(B \to DX, X \to \bar{D}K)$						
Triangle, QE	30.6	23.2	0	0	4.6	8.3
Triangle, OPE	30.6	23.2	1.1	1.5	1.2	2.1
Triangle, EFT	30.6	23.2	$1.1\left(1-\frac{C_0}{C_1}\right)^2$	$1.5\left(1-\frac{C_0}{C_1}\right)^2$	$1.2\left(1+\frac{C_0}{C_1}\right)^2$	$2.1\left(1+\frac{C_0}{C_1}\right)^2$
Resonance, $I=0$	30.6	23.2	4.3	5.8	0	0
Resonance, $I=1$	30.6	23.2	4.3	5.8	18.6	33.4
Resonance, I mixed	30.6	23.2	$4.3\tan^2\left(\theta+\frac{\pi}{4}\right)$	$5.8\tan^2\left(\theta-\frac{\pi}{4}\right)$		
$\Delta f/f$	0.1	0.53	0.36	0.35	0.41	0.41

triangle diagram with quark-exchange (QE), one-pion exchange (OPE) or effective field theory (EFT) interactions

	$B^+ \to D^+X$, $X \to D^-K^+$	$B^0 \to D^0X$, $X \to \bar{D}^0K^0$	$B^+ \to D^+X$, $X \to \bar{D}^0K^0$	$B^0 \to D^0X$, $X \to D^-K^+$	$B^+ \to D^0X^+$, $X^+ \to \bar{D}^0K^+$	$B^0 \to D^+X^-$, $X^- \to D^-K^0$
$\mathcal{B}(B \to D\bar{D}K)$	2.2 ± 0.7	2.7 ± 1.1	15.5 ± 2.1	10.7 ± 1.1	14.5 ± 3.3	7.5 ± 1.7
$f(B \to DX, X \to \bar{D}K)$						
Triangle, QE	30.6	23.2	0	0	4.6	8.3
Triangle, OPE	30.6	23.2	1.1	1.5	1.2	2.1
Triangle, EFT	30.6	23.2	$1.1\left(1-\frac{C_0}{C_1}\right)^2$	$1.5\left(1-\frac{C_0}{C_1}\right)^2$	$1.2\left(1+\frac{C_0}{C_1}\right)^2$	$2.1\left(1+\frac{C_0}{C_1}\right)^2$
Resonance, $I=0$	30.6	23.2	4.3	5.8	0	0
Resonance, $I=1$	30.6	23.2	4.3	5.8	18.6	33.4
Resonance, I mixed	30.6	23.2	$4.3\tan^2\left(\theta+\frac{\pi}{4}\right)$	$5.8\tan^2\left(\theta-\frac{\pi}{4}\right)$		
$\Delta f/f$	0.1	0.53	0.36	0.35	0.41	0.41

	$B^+ \to D^+ X$, $X \to D^- K^+$	$B^0 \to D^0 X$, $X \to \bar{D}^0 K^0$	$B^+ \to D^+ X$, $X \to \bar{D}^0 K^0$	$B^0 \to D^0 X$, $X \to D^- K^+$	$B^+ \to D^0 X^+$, $X^+ \to \bar{D}^0 K^+$	$B^0 \to D^+ X^-$, $X^- \to D^- K^0$
$\mathcal{B}(B \to D\bar{D}K)$	2.2 ± 0.7	2.7 ± 1.1	15.5 ± 2.1	10.7 ± 1.1	14.5 ± 3.3	7.5 ± 1.7
$f(B \to DX, X \to \bar{D}K)$						
Triangle, QE	30.6	23.2	0	0	4.6	8.3
Triangle, OPE	30.6	23.2	1.1	1.5	1.2	2.1
Triangle, EFT	30.6	23.2	$1.1\left(1-\frac{C_0}{C_1}\right)^2$	$1.5\left(1-\frac{C_0}{C_1}\right)^2$	$1.2\left(1+\frac{C_0}{C_1}\right)^2$	$2.1\left(1+\frac{C_0}{C_1}\right)^2$
Resonance, $I=0$	30.6	23.2	4.3	5.8	0	0
Resonance, $I=1$	30.6	23.2	4.3	5.8	18.6	33.4
Resonance, I mixed	30.6	23.2	$4.3\tan^2\left(\theta+\frac{\pi}{4}\right)$	$5.8\tan^2\left(\theta-\frac{\pi}{4}\right)$		
$\Delta f/f$	0.1	0.53	0.36	0.35	0.41	0.41

Resonance, either molecular or tetraquark

Mixed isospin case relevant for molecule

$$f(B \to DX, X \to \bar{D}K) = \frac{\mathcal{B}(B \to DX, X \to \bar{D}K)}{\mathcal{B}(B \to D\bar{D}K)}$$

	$B^+ \to D^+X$, $X \to D^-K^+$	$B^0 \to D^0X$, $X \to \bar{D}^0K^0$	$B^+ \to D^+X$, $X \to \bar{D}^0K^0$	$B^0 \to D^0X$, $X \to D^-K^+$	$B^+ \to D^0X^+$, $X^+ \to \bar{D}^0K^+$	$B^0 \to D^+X^-$, $X^- \to D^-K^0$
$\mathcal{B}(B \to D\bar{D}K)$	2.2 ± 0.7	2.7 ± 1.1	15.5 ± 2.1	10.7 ± 1.1	14.5 ± 3.3	7.5 ± 1.7
$f(B \to DX, X \to \bar{D}K)$						
Triangle, QE	30.6	23.2	0	0	4.6	8.3
Triangle, OPE	30.6	23.2	1.1	1.5	1.2	2.1
Triangle, EFT	30.6	23.2	$1.1\left(1 - \frac{C_0}{C_1}\right)^2$	$1.5\left(1 - \frac{C_0}{C_1}\right)^2$	$1.2\left(1 + \frac{C_0}{C_1}\right)^2$	$2.1\left(1 + \frac{C_0}{C_1}\right)^2$
Resonance, $I = 0$	30.6	23.2	4.3	5.8	0	0
Resonance, $I = 1$	30.6	23.2	4.3	5.8	18.6	33.4
Resonance, I mixed	30.6	23.2	$4.3\tan^2\left(\theta + \frac{\pi}{4}\right)$	$5.8\tan^2\left(\theta - \frac{\pi}{4}\right)$		
$\Delta f/f$	0.1	0.53	0.36	0.35	0.41	0.41

$$f(B \to DX, X \to \bar{D}K) = \frac{\mathcal{B}(B \to DX, X \to \bar{D}K)}{\mathcal{B}(B \to D\bar{D}K)}$$

relations among matrix elements and small correction (B lifetime)

	$B^+ \to D^+X$, $X \to D^-K^+$	$B^0 \to D^0X$, $X \to \bar{D}^0K^0$	$B^+ \to D^+X$, $X \to \bar{D}^0K^0$	$B^0 \to D^0X$, $X \to D^-K^+$	$B^+ \to D^0X^+$, $X^+ \to \bar{D}^0K^+$	$B^0 \to D^+X^-$, $X^- \to D^-K^0$
$\mathcal{B}(B \to D\bar{D}K)$	2.2 ± 0.7	2.7 ± 1.1	15.5 ± 2.1	10.7 ± 1.1	14.5 ± 3.3	7.5 ± 1.7
$f(B \to DX, X \to \bar{D}K)$						
Triangle, QE	30.6	23.2	0	0	4.6	8.3
Triangle, OPE	30.6	23.2	1.1	1.5	1.2	2.1
Triangle, EFT	30.6	23.2	$1.1\left(1-\frac{C_0}{C_1}\right)^2$	$1.5\left(1-\frac{C_0}{C_1}\right)^2$	$1.2\left(1+\frac{C_0}{C_1}\right)^2$	$2.1\left(1+\frac{C_0}{C_1}\right)^2$
Resonance, $I=0$	30.6	23.2	4.3	5.8	0	0
Resonance, $I=1$	30.6	23.2	4.3	5.8	18.6	33.4
Resonance, I mixed	30.6	23.2	$4.3\tan^2\left(\theta+\frac{\pi}{4}\right)$	$5.8\tan^2\left(\theta-\frac{\pi}{4}\right)$		
$\Delta f/f$	0.1	0.53	0.36	0.35	0.41	0.41

$$f(B \to DX, X \to \bar{D}K) = \frac{\mathcal{B}(B \to DX, X \to \bar{D}K)}{\mathcal{B}(B \to D\bar{D}K)}$$

matrix elements equal in pairs

	$B^+ \to D^+X$, $X \to D^-K^+$	$B^0 \to D^0X$, $X \to \bar{D}^0K^0$	$B^+ \to D^+X$, $X \to \bar{D}^0K^0$	$B^0 \to D^0X$, $X \to D^-K^+$	$B^+ \to D^0X^+$, $X^+ \to \bar{D}^0K^+$	$B^0 \to D^+X^-$, $X^- \to D^-K^0$
$\mathcal{B}(B \to D\bar{D}K)$	2.2 ± 0.7	2.7 ± 1.1	15.5 ± 2.1	10.7 ± 1.1	14.5 ± 3.3	7.5 ± 1.7
$f(B \to DX, X \to \bar{D}K)$						
Triangle, QE	30.6	23.2	0	0	4.6	8.3
Triangle, OPE	30.6	23.2	1.1	1.5	1.2	2.1
Triangle, EFT	30.6	23.2	$1.1\left(1-\frac{C_0}{C_1}\right)^2$	$1.5\left(1-\frac{C_0}{C_1}\right)^2$	$1.2\left(1+\frac{C_0}{C_1}\right)^2$	$2.1\left(1+\frac{C_0}{C_1}\right)^2$
Resonance, $I=0$	30.6	23.2	4.3	5.8	0	0
Resonance, $I=1$	30.6	23.2	4.3	5.8	18.6	33.4
Resonance, I mixed	30.6	23.2	$4.3\tan^2\left(\theta+\frac{\pi}{4}\right)$	$5.8\tan^2\left(\theta-\frac{\pi}{4}\right)$		
$\Delta f/f$	0.1	0.53	0.36	0.35	0.41	0.41

$$f(B \to DX, X \to \bar{D}K) = \frac{\mathcal{B}(B \to DX, X \to \bar{D}K)}{\mathcal{B}(B \to DDK)}$$

enhancement if 3-body small

	$B^+ \to D^+X$, $X \to D^-K^+$	$B^0 \to D^0X$, $X \to \bar{D}^0K^0$	$B^+ \to D^+X$, $X \to \bar{D}^0K^0$	$B^0 \to D^0X$, $X \to D^-K^+$	$B^+ \to D^0X^+$, $X^+ \to \bar{D}^0K^+$	$B^0 \to D^+X^-$, $X^- \to D^-K^0$
$\mathcal{B}(B \to D\bar{D}K)$	2.2 ± 0.7	2.7 ± 1.1	15.5 ± 2.1	10.7 ± 1.1	14.5 ± 3.3	7.5 ± 1.7
$f(B \to DX, X \to \bar{D}K)$						
Triangle, QE	30.6	23.2	0	0	4.6	8.3
Triangle, OPE	30.6	23.2	1.1	1.5	1.2	2.1
Triangle, EFT	30.6	23.2	$1.1\left(1-\frac{C_0}{C_1}\right)^2$	$1.5\left(1-\frac{C_0}{C_1}\right)^2$	$1.2\left(1+\frac{C_0}{C_1}\right)^2$	$2.1\left(1+\frac{C_0}{C_1}\right)^2$
Resonance, $I=0$	30.6	23.2	4.3	5.8	0	0
Resonance, $I=1$	30.6	23.2	4.3	5.8	18.6	33.4
Resonance, I mixed	30.6	23.2	$4.3\tan^2\left(\theta+\frac{\pi}{4}\right)$	$5.8\tan^2\left(\theta-\frac{\pi}{4}\right)$		
$\Delta f/f$	0.1	0.53	0.36	0.35	0.41	0.41

$$f(B \to DX, X \to \bar{D}K) = \frac{\mathcal{B}(B \to DX, X \to \bar{D}K)}{\mathcal{B}(B \to D\bar{D}K)}$$

	$B^+ \to D^+X$, $X \to D^-K^+$	$B^0 \to D^0X$, $X \to \bar{D}^0K^0$	$B^+ \to D^+X$, $X \to \bar{D}^0K^0$	$B^0 \to D^0X$, $X \to D^-K^+$	$B^+ \to D^0X^+$, $X^+ \to \bar{D}^0K^+$	$B^0 \to D^+X^-$, $X^- \to D^-K^0$
$\mathcal{B}(B \to D\bar{D}K)$	2.2 ± 0.7	2.7 ± 1.1	15.5 ± 2.1	10.7 ± 1.1	14.5 ± 3.3	7.5 ± 1.7
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Triangle, QE	30.6	23.2	0	0	4.6	8.3
Triangle, OPE	30.6	23.2	1.1	1.5	1.2	2.1
Triangle, EFT	30.6	23.2	$1.1\left(1-\frac{C_0}{C_1}\right)^2$	$1.5\left(1-\frac{C_0}{C_1}\right)^2$	$1.2\left(1+\frac{C_0}{C_1}\right)^2$	$2.1\left(1+\frac{C_0}{C_1}\right)^2$
Resonance, $I=0$	30.6	23.2	4.3	5.8	0	0
Resonance, $I=1$	30.6	23.2	4.3	5.8	18.6	33.4
Resonance, I mixed	30.6	23.2	$4.3\tan^2\left(\theta+\frac{\pi}{4}\right)$	$5.8\tan^2\left(\theta-\frac{\pi}{4}\right)$		
$\Delta f/f$	0.1	0.53	0.36	0.35	0.41	0.41

fractional uncertainty

$$f(B \to DX, X \to \bar{D}K) = \frac{\mathcal{B}(B \to DX, X \to \bar{D}K)}{\mathcal{B}(B \to D\bar{D}K)}$$

	$B^+ \to D^+X$, $X \to D^-K^+$	$B^0 \to D^0X$, $X \to \bar{D}^0K^0$	$B^+ \to D^+X$, $X \to \bar{D}^0K^0$	$B^0 \to D^0X$, $X \to D^-K^+$	$B^+ \to D^0X^+$, $X^+ \to \bar{D}^0K^+$	$B^0 \to D^+X^-$, $X^- \to D^-K^0$
$\mathcal{B}(B \to D\bar{D}K)$	2.2 ± 0.7	2.7 ± 1.1	15.5 ± 2.1	10.7 ± 1.1	14.5 ± 3.3	7.5 ± 1.7
$f(B \to DX, X \to \bar{D}K)$						
Triangle, QE	30.6	23.2	0	0	4.6	8.3
Triangle, OPE	30.6	23.2	1.1	1.5	1.2	2.1
Triangle, EFT	30.6	23.2	$1.1\left(1-\frac{C_0}{C_1}\right)^2$	$1.5\left(1-\frac{C_0}{C_1}\right)^2$	$1.2\left(1+\frac{C_0}{C_1}\right)^2$	$2.1\left(1+\frac{C_0}{C_1}\right)^2$
Resonance, $I=0$	30.6	23.2	4.3	5.8	0	0
Resonance, $I=1$	30.6	23.2	4.3	5.8	18.6	33.4
Resonance, I mixed	30.6	23.2	$4.3\tan^2\left(\theta+\frac{\pi}{4}\right)$	$5.8\tan^2\left(\theta-\frac{\pi}{4}\right)$		
$\Delta f/f$	0.1	0.53	0.36	0.35	0.41	0.41

existing channel is largest

$$f(B \to DX, X \to \bar{D}K) = \frac{\mathcal{B}(B \to DX, X \to \bar{D}K)}{\mathcal{B}(B \to D\bar{D}K)}$$

	$B^+ \to D^+X$, $X \to D^-K^+$	$B^0 \to D^0X$, $X \to \bar{D}^0K^0$	$B^+ \to D^+X$, $X \to \bar{D}^0K^0$	$B^0 \to D^0X$, $X \to D^-K^+$	$B^+ \to D^0X^+$, $X^+ \to \bar{D}^0K^+$	$B^0 \to D^+X^-$, $X^- \to D^-K^0$
$\mathcal{B}(B \to D\bar{D}K)$	2.2 ± 0.7	2.7 ± 1.1	15.5 ± 2.1	10.7 ± 1.1	14.5 ± 3.3	7.5 ± 1.7
$f(B \to DX, X \to \bar{D}K)$						
Triangle, QE	30.6	23.2	0	0	4.6	8.3
Triangle, OPE	30.6	23.2	1.1	1.5	1.2	2.1
Triangle, EFT	30.6	23.2	$1.1\left(1-\frac{C_0}{C_1}\right)^2$	$1.5\left(1-\frac{C_0}{C_1}\right)^2$	$1.2\left(1+\frac{C_0}{C_1}\right)^2$	$2.1\left(1+\frac{C_0}{C_1}\right)^2$
Resonance, $I=0$	30.6	23.2	4.3	5.8	0	0
Resonance, $I=1$	30.6	23.2	4.3	5.8	18.6	33.4
Resonance, I mixed	30.6	23.2	$4.3\tan^2\left(\theta+\frac{\pi}{4}\right)$	$5.8\tan^2\left(\theta-\frac{\pi}{4}\right)$		
$\Delta f/f$	0.1	0.53	0.36	0.35	0.41	0.41

neutral mode is comparable

general prediction, same for all models

$$f(B \to DX, X \to \bar{D}K) = \frac{\mathcal{B}(B \to DX, X \to \bar{D}K)}{\mathcal{B}(B \to D\bar{D}K)}$$

	$B^+ \to D^+X$, $X \to D^-K^+$	$B^0 \to D^0X$, $X \to \bar{D}^0K^0$	$B^+ \to D^+X$, $X \to \bar{D}^0K^0$	$B^0 \to D^0X$, $X \to D^-K^+$	$B^+ \to D^0X^+$, $X^+ \to \bar{D}^0K^+$	$B^0 \to D^+X^-$, $X^- \to D^-K^0$
$\mathcal{B}(B \to D\bar{D}K)$	2.2 ± 0.7	2.7 ± 1.1	15.5 ± 2.1	10.7 ± 1.1	14.5 ± 3.3	7.5 ± 1.7
$f(B \to DX, X \to \bar{D}K)$						
Triangle, QE	30.6	23.2	0	0	4.6	8.3
Triangle, OPE	30.6	23.2	1.1	1.5	1.2	2.1
Triangle, EFT	30.6	23.2	$1.1\left(1-\frac{C_0}{C_1}\right)^2$	$1.5\left(1-\frac{C_0}{C_1}\right)^2$	$1.2\left(1+\frac{C_0}{C_1}\right)^2$	$2.1\left(1+\frac{C_0}{C_1}\right)^2$
Resonance, $I=0$	30.6	23.2	4.3	5.8	0	0
Resonance, $I=1$	30.6	23.2	4.3	5.8	18.6	33.4
Resonance, I mixed	30.6	23.2	$4.3\tan^2\left(\theta+\frac{\pi}{4}\right)$	$5.8\tan^2\left(\theta-\frac{\pi}{4}\right)$		
$\Delta f/f$	0.1	0.53	0.36	0.35	0.41	0.41

remaining predictions discriminate among models

uncertainties are large but predictions still discriminate

$$f(B \to DX, X \to \bar{D}K) = \frac{\mathcal{B}(B \to DX, X \to \bar{D}K)}{\mathcal{B}(B \to D\bar{D}K)}$$

	$B^+ \to D^+X$, $X \to D^-K^+$	$B^0 \to D^0X$, $X \to \bar{D}^0K^0$	$B^+ \to D^+X$, $X \to \bar{D}^0K^0$	$B^0 \to D^0X$, $X \to D^-K^+$	$B^+ \to D^0X^+$, $X^+ \to \bar{D}^0K^+$	$B^0 \to D^+X^-$, $X^- \to D^-K^0$
$\mathcal{B}(B \to D\bar{D}K)$	2.2 ± 0.7	2.7 ± 1.1	15.5 ± 2.1	10.7 ± 1.1	14.5 ± 3.3	7.5 ± 1.7
$f(B \to DX, X \to \bar{D}K)$						
Triangle, QE	30.6	23.2	0	0	4.6	8.3
Triangle, OPE	30.6	23.2	1.1	1.5	1.2	2.1
Triangle, EFT	30.6	23.2	$1.1\left(1-\frac{C_0}{C_1}\right)^2$	$1.5\left(1-\frac{C_0}{C_1}\right)^2$	$1.2\left(1+\frac{C_0}{C_1}\right)^2$	$2.1\left(1+\frac{C_0}{C_1}\right)^2$
Resonance, $I=0$	30.6	23.2	4.3	5.8	0	0
Resonance, $I=1$	30.6	23.2	4.3	5.8	18.6	33.4
Resonance, I mixed	30.6	23.2	$4.3\tan^2\left(\theta+\frac{\pi}{4}\right)$	$5.8\tan^2\left(\theta-\frac{\pi}{4}\right)$		
$\Delta f/f$	0.1	0.53	0.36	0.35	0.41	0.41

same production mode

$$f(B \to DX, X \to \bar{D}K) = \frac{\mathcal{B}(B \to DX, X \to \bar{D}K)}{\mathcal{B}(B \to D\bar{D}K)}$$

	$B^+ \to D^+X$, $X \to D^-K^+$	$B^0 \to D^0X$, $X \to \bar{D}^0K^0$	$B^+ \to D^+X$, $X \to \bar{D}^0K^0$	$B^0 \to D^0X$, $X \to D^-K^+$	$B^+ \to D^0X^+$, $X^+ \to \bar{D}^0K^+$	$B^0 \to D^+X^-$, $X^- \to D^-K^0$
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Triangle, EFT	30.6	23.2	$1.1\left(1-\frac{C_0}{C_1}\right)^2$	$1.5\left(1-\frac{C_0}{C_1}\right)^2$	$1.2\left(1+\frac{C_0}{C_1}\right)^2$	$2.1\left(1+\frac{C_0}{C_1}\right)^2$
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$\Delta f/f$	0.1	0.53	0.36	0.35	0.41	0.41

same production mode

different final state

$$f(B \to DX, X \to \bar{D}K) = \frac{\mathcal{B}(B \to DX, X \to \bar{D}K)}{\mathcal{B}(B \to D\bar{D}K)}$$

selection rule

	$B^+ \to D^+X$, $X \to D^-K^+$	$B^0 \to D^0X$, $X \to \bar{D}^0K^0$	$B^+ \to D^+X$, $X \to \bar{D}^0K^0$	$B^0 \to D^0X$, $X \to D^-K^+$	$B^+ \to D^0X^+$, $X^+ \to \bar{D}^0K^+$	$B^0 \to D^+X^-$, $X^- \to D^-K^0$
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Triangle, OPE	30.6	23.2	1.1	1.5	1.2	2.1
Triangle, EFT	30.6	23.2	$1.1\left(1-\frac{C_0}{C_1}\right)^2$	$1.5\left(1-\frac{C_0}{C_1}\right)^2$	$1.2\left(1+\frac{C_0}{C_1}\right)^2$	$2.1\left(1+\frac{C_0}{C_1}\right)^2$
Resonance, $I=0$	30.6	23.2	4.3	5.8	0	0
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Resonance, I mixed	30.6	23.2	$4.3\tan^2\left(\theta+\frac{\pi}{4}\right)$	$5.8\tan^2\left(\theta-\frac{\pi}{4}\right)$		
$\Delta f/f$	0.1	0.53	0.36	0.35	0.41	0.41

same production mode

different final state

$$f(B \to DX, X \to \bar{D}K) = \frac{\mathcal{B}(B \to DX, X \to \bar{D}K)}{\mathcal{B}(B \to D\bar{D}K)}$$

discriminates, despite large uncertainties

	$B^+ \to D^+X$, $X \to D^-K^+$	$B^0 \to D^0X$, $X \to \bar{D}^0K^0$	$B^+ \to D^+X$, $X \to \bar{D}^0K^0$	$B^0 \to D^0X$, $X \to D^-K^+$	$B^+ \to D^0X^+$, $X^+ \to \bar{D}^0K^+$	$B^0 \to D^+X^-$, $X^- \to D^-K^0$
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Triangle, OPE	30.6	23.2	1.1	1.5	1.2	2.1
Triangle, EFT	30.6	23.2	$1.1\left(1-\frac{C_0}{C_1}\right)^2$	$1.5\left(1-\frac{C_0}{C_1}\right)^2$	$1.2\left(1+\frac{C_0}{C_1}\right)^2$	$2.1\left(1+\frac{C_0}{C_1}\right)^2$
Resonance, $I=0$	30.6	23.2	4.3	5.8	0	0
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same production mode

different final state

$$f(B \to DX, X \to \bar{D}K) = \frac{\mathcal{B}(B \to DX, X \to \bar{D}K)}{\mathcal{B}(B \to D\bar{D}K)}$$

constraint on contact terms

	$B^+ \to D^+X$, $X \to D^-K^+$	$B^0 \to D^0X$, $X \to \bar{D}^0K^0$	$B^+ \to D^+X$, $X \to \bar{D}^0K^0$	$B^0 \to D^0X$, $X \to D^-K^+$	$B^+ \to D^0X^+$, $X^+ \to \bar{D}^0K^+$	$B^0 \to D^+X^-$, $X^- \to D^-K^0$
$\mathcal{B}(B \to D\bar{D}K)$	2.2 ± 0.7	2.7 ± 1.1	15.5 ± 2.1	10.7 ± 1.1	14.5 ± 3.3	7.5 ± 1.7
$f(B \to DX, X \to \bar{D}K)$						
Triangle, QE	30.6	23.2	0	0	4.6	8.3
Triangle, OPE	30.6	23.2	1.1	1.5	1.2	2.1
Triangle, EFT	30.6	23.2	$1.1\left(1 - \frac{C_0}{C_1}\right)^2$	$1.5\left(1 - \frac{C_0}{C_1}\right)^2$	$1.2\left(1 + \frac{C_0}{C_1}\right)^2$	$2.1\left(1 + \frac{C_0}{C_1}\right)^2$
Resonance, $I = 0$	30.6	23.2	4.3	5.8	0	0
Resonance, $I = 1$	30.6	23.2	4.3	5.8	18.6	33.4
Resonance, I mixed	30.6	23.2	$4.3\tan^2\left(\theta + \frac{\pi}{4}\right)$	$5.8\tan^2\left(\theta - \frac{\pi}{4}\right)$		
$\Delta f/f$	0.1	0.53	0.36	0.35	0.41	0.41

same production mode

different final state

$$f(B \to DX, X \to \bar{D}K) = \frac{\mathcal{B}(B \to DX, X \to \bar{D}K)}{\mathcal{B}(B \to D\bar{D}K)}$$

constraint on isospin mixing angle

	$B^+ \to D^+X$, $X \to D^-K^+$	$B^0 \to D^0X$, $X \to \bar{D}^0K^0$	$B^+ \to D^+X$, $X \to \bar{D}^0K^0$	$B^0 \to D^0X$, $X \to D^-K^+$	$B^+ \to D^0X^+$, $X^+ \to \bar{D}^0K^+$	$B^0 \to D^+X^-$, $X^- \to D^-K^0$
$\mathcal{B}(B \to D\bar{D}K)$	2.2 ± 0.7	2.7 ± 1.1	15.5 ± 2.1	10.7 ± 1.1	14.5 ± 3.3	7.5 ± 1.7
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Triangle, EFT	30.6	23.2	$1.1\left(1-\frac{C_0}{C_1}\right)^2$	$1.5\left(1-\frac{C_0}{C_1}\right)^2$	$1.2\left(1+\frac{C_0}{C_1}\right)^2$	$2.1\left(1+\frac{C_0}{C_1}\right)^2$
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$$f(B \to DX, X \to \bar{D}K) = \frac{\mathcal{B}(B \to DX, X \to \bar{D}K)}{\mathcal{B}(B \to D\bar{D}K)}$$

	$B^+ \to D^+X$, $X \to D^-K^+$	$B^0 \to D^0X$, $X \to \bar{D}^0K^0$	$B^+ \to D^+X$, $X \to \bar{D}^0K^0$	$B^0 \to D^0X$, $X \to D^-K^+$	$B^+ \to D^0X^+$, $X^+ \to \bar{D}^0K^+$	$B^0 \to D^+X^-$, $X^- \to D^-K^0$
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$\Delta f/f$	0.1	0.53	0.36	0.35	0.41	0.41

similar patterns for neutral X in neutral B decays

$$f(B \to DX, X \to \bar{D}K) = \frac{\mathcal{B}(B \to DX, X \to \bar{D}K)}{\mathcal{B}(B \to D\bar{D}K)}$$

triangle selection rule opposite

	$B^+ \to D^+X$, $X \to D^-K^+$	$B^0 \to D^0X$, $X \to \bar{D}^0K^0$	$B^+ \to D^+X$, $X \to \bar{D}^0K^0$	$B^0 \to D^0X$, $X \to D^-K^+$	$B^+ \to D^0X^+$, $X^+ \to \bar{D}^0K^+$	$B^0 \to D^+X^-$, $X^- \to D^-K^0$
$\mathcal{B}(B \to D\bar{D}K)$	2.2 ± 0.7	2.7 ± 1.1	15.5 ± 2.1	10.7 ± 1.1	14.5 ± 3.3	7.5 ± 1.7
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$$f(B \to DX, X \to \bar{D}K) = \frac{\mathcal{B}(B \to DX, X \to \bar{D}K)}{\mathcal{B}(B \to D\bar{D}K)}$$

charged partners discriminate among models

	$B^+ \to D^+X$, $X \to D^-K^+$	$B^0 \to D^0X$, $X \to \bar{D}^0K^0$	$B^+ \to D^+X$, $X \to \bar{D}^0K^0$	$B^0 \to D^0X$, $X \to D^-K^+$	$B^+ \to D^0X^+$, $X^+ \to \bar{D}^0K^+$	$B^0 \to D^+X^-$, $X^- \to D^-K^0$
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charged partners discriminate among models

	$B^+ \to D^+X$, $X \to D^-K^+$	$B^0 \to D^0X$, $X \to \bar{D}^0K^0$	$B^+ \to D^+X$, $X \to \bar{D}^0K^0$	$B^0 \to D^0X$, $X \to D^-K^+$	$B^+ \to D^0X^+$, $X^+ \to \bar{D}^0K^+$	$B^0 \to D^+X^-$, $X^- \to D^-K^0$
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absent only in I=0 resonance scenario

$$f(B \to DX, X \to \bar{D}K) = \frac{\mathcal{B}(B \to DX, X \to \bar{D}K)}{\mathcal{B}(B \to D\bar{D}K)}$$

charged partners discriminate among models

	$B^+ \to D^+X$, $X \to D^-K^+$	$B^0 \to D^0X$, $X \to \bar{D}^0K^0$	$B^+ \to D^+X$, $X \to \bar{D}^0K^0$	$B^0 \to D^0X$, $X \to D^-K^+$	$B^+ \to D^0X^+$, $X^+ \to \bar{D}^0K^+$	$B^0 \to D^+X^-$, $X^- \to D^-K^0$
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$\Delta f/f$	0.1	0.53	0.36	0.35	0.41	0.41

enormous fit fractions in I=1 resonance scenario

Resonance scenarios only:

$$\mathcal{B}(B \to DX, X \to \bar{D}K) = \mathcal{B}(B \to DX)\mathcal{B}(X \to \bar{D}K),$$

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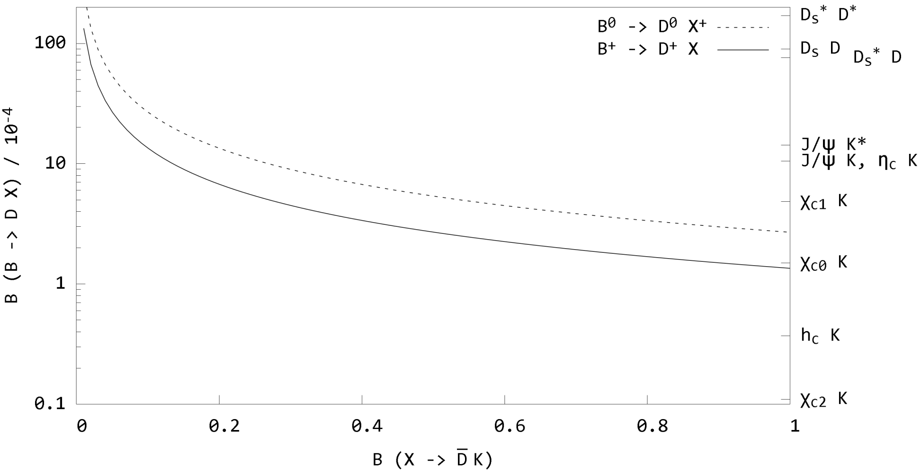
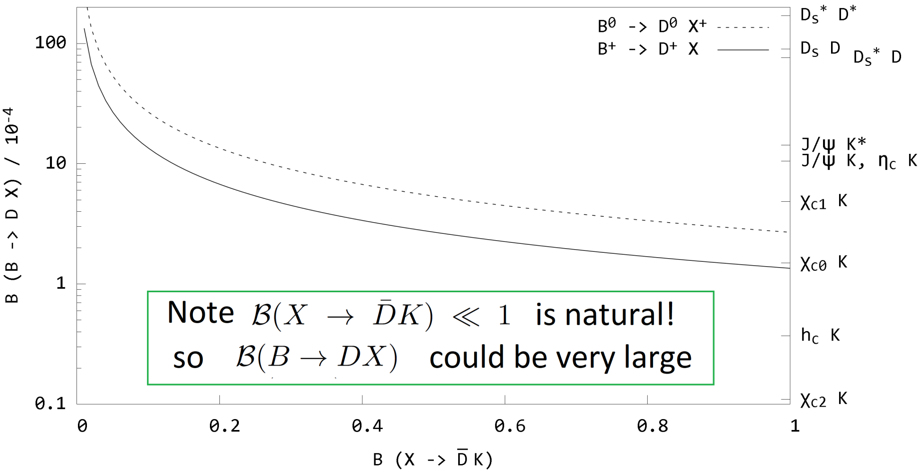
$$\mathcal{B}(B \to DX, X \to \bar{D}K) = \mathcal{B}(B \to DX)\mathcal{B}(X \to \bar{D}K)$$



Resonance scenarios only:

$$\mathcal{B}(B \to DX, X \to \bar{D}K) = \mathcal{B}(B \to DX)\mathcal{B}(X \to \bar{D}K),$$



Conclusions

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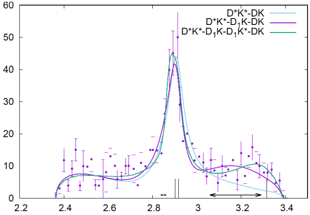
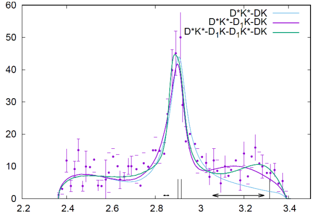
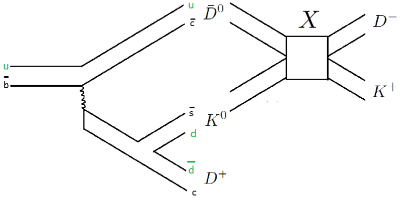


Triangle and resonance scenarios fit experimental data in amplitude model

Conclusions



Triangle and resonance scenarios fit experimental data in amplitude model

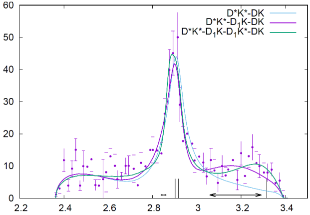


Assuming

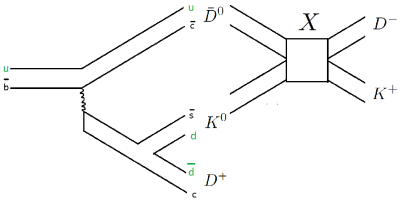
- dominance of colour-favoured transitions, and
- isospin

we get relations among fit fractions

Conclusions



Triangle and resonance scenarios fit experimental data in amplitude model



Assuming
- dominance of colour-favoured transitions, and
- isospin

we get relations among fit fractions

	$B^+ \to D^+X$, $X \to D^-K^+$	$B^0 \to D^0X$, $X \to \bar{D}^0K^0$	$B^+ \to D^+X$, $X \to \bar{D}^0K^0$	$B^0 \to D^0X$, $X \to D^-K^+$	$B^+ \to D^0X^+$, $X^+ \to \bar{D}^0K^+$	$B^0 \to D^+X^-$, $X^- \to D^-K^0$
$\mathcal{B}(B \to D\bar{D}K)$	2.2 ± 0.7	2.7 ± 1.1	15.5 ± 2.1	10.7 ± 1.1	14.5 ± 3.3	7.5 ± 1.7
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Triangle, QE	30.6	23.2	0	0	4.6	8.3
Triangle, OPE	30.6	23.2	1.1	1.5	1.2	2.1
Triangle, EFT	30.6	23.2	$1.1\left(1-\frac{C_0}{C_1}\right)^2$	$1.5\left(1-\frac{C_0}{C_1}\right)^2$	$1.2\left(1+\frac{C_0}{C_1}\right)^2$	$2.1\left(1+\frac{C_0}{C_1}\right)^2$
Resonance, $I=0$	30.6	23.2	4.3	5.8	0	0
Resonance, $I=1$	30.6	23.2	4.3	5.8	18.6	33.4
Resonance, I mixed	30.6	23.2	$4.3\tan^2\left(\theta+\frac{\pi}{4}\right)$	$5.8\tan^2\left(\theta-\frac{\pi}{4}\right)$		
$\Delta f/f$	0.1	0.53	0.36	0.35	0.41	0.41

absent only in I=0 resonance scenario

Six possible modes
- some new modes have very large fit fraction
- pattern can discriminate among models