

# $B \rightarrow DDX$ at BaBar/Belle

Koji Hara (KEK)

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# B → DDX BG in hadronic B → D\* $\tau$ nu

- Largest BG source in analyses using hadronic tau decays
  - About 40 % of BG events in MC are two-D modes for Belle hadronic B → D\* $\tau$ nu analysis of PRL118, 211801 (2017)
- One of most significant systematic error source

Two-D mode BG composition for B → D\* $\tau$ nu,  $\tau \rightarrow \pi\nu, \rho\nu$  modes in MC

Decay	Fraction	Br in PDG2017	Relative uncertainty
$B^- \rightarrow D^{*0} D_{sJ}(2460)^-$	24.8%	1.20 +/- 0.30 %	25%
$B^- \rightarrow D^{*0} D_s^{*-}$	42.4%	1.71 +/- 0.24 %	14%
$B^- \rightarrow D^{*0} D_s^-$	3.9%	$8.2 \pm 1.7 \times 10^{-3}$	21%
$B^- \rightarrow D^{*0} D^{*-}$	0.4%	$3.9 \pm 0.5 \times 10^{-4}$	21%
$B^- \rightarrow D^{*0} D^{*-} K^0$	6.6%	$9.2 \pm 1.2 \times 10^{-3}$	15%
$B^- \rightarrow D^{*0} D^- K^0$	7.5%	$2.1 \pm 0.5 \times 10^{-3}$	16%
$B^- \rightarrow D^{*0} \bar{D}^{*0} K^-$	0.8%	1.12 +/- 0.13 %	25%
$B^- \rightarrow D^{*0} \bar{D}^0 K^-$	2.5%	6.3 +/- 0.5 %	8%
Remaining/unmeasured	11.1%		(100%)
<b>Sum</b>	<b>100%</b>		

From S. Hirose and T. Iijima, Belle note 1377 for [PRL118, 211801 \(2017 May 26\)](#)

\* B → D\*Ds is suppressed by requirement of  $q^2 > 4$  (GeV)<sup>2</sup> in this analysis

- Significant in this order : B → D\*Ds\*, B → D\*DK, B → D\*D\*
- Significant contribution of D\*D<sub>sJ</sub> → excited state of D<sub>s</sub> is also important
- Relative uncertainty of Br measurement 10 ~ 30 %
- Remaining/unmeasured decays in MC are produced based on rough theoretical assumptions or un-tuned PYTHIA generator (B → D\*Dpi etc) → assigned +/- 100 % syst. err.

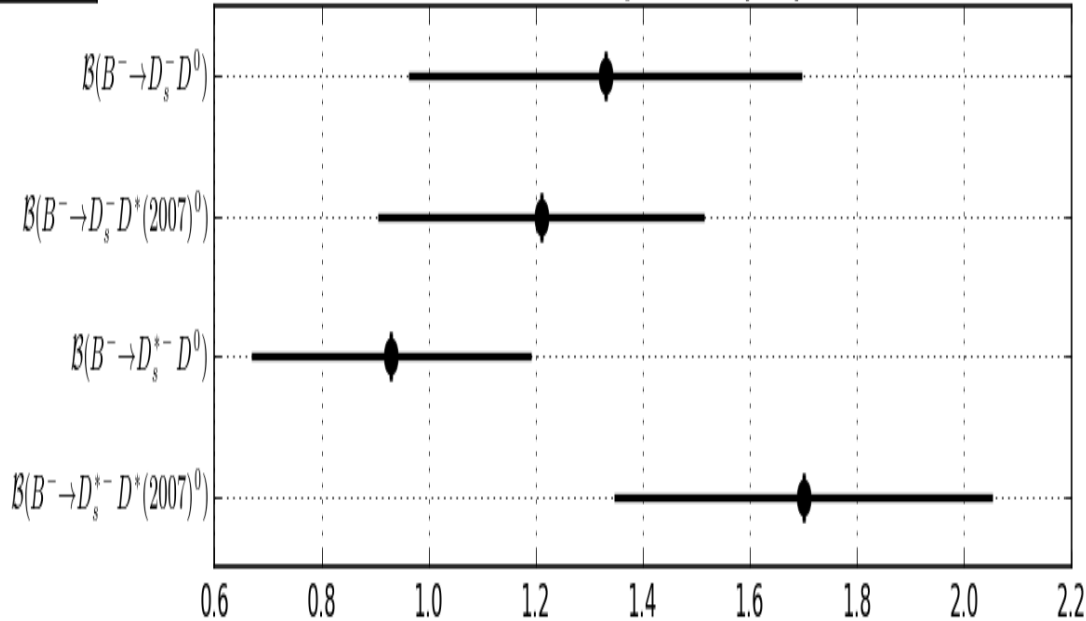
# Status of $B \rightarrow DDX$ measurement at Belle and BaBar

- Summarized by HFAG
- Details are available on

<http://www.slac.stanford.edu/xorg/hflav/btocharm/index.html>

# $B^- \rightarrow D_s(^*)^- D(^*)^0$

Decays to  $D_s(^*)^- D(^*)^0$  [ $10^{-2}$ ]



Experiment	Measurement	Reference
BaBar	$[1.21 \pm 0.23 \text{ (stat)} \pm 0.20 \text{ (syst)}] \times 10^{-2}$	<a href="#">PRD 74 (2006) 031103</a>
<b>Average</b>	<b><math>[1.21 \pm 0.30 \text{ (combined)}] \times 10^{-2}</math></b>	

Experiment	Measurement	Reference
BaBar	$[1.21 \pm 0.23 \text{ (stat)} \pm 0.20 \text{ (syst)}] \times 10^{-2}$	<a href="#">PRD 74 (2006) 031103</a>
<b>Average</b>	<b><math>[1.21 \pm 0.30 \text{ (combined)}] \times 10^{-2}</math></b>	

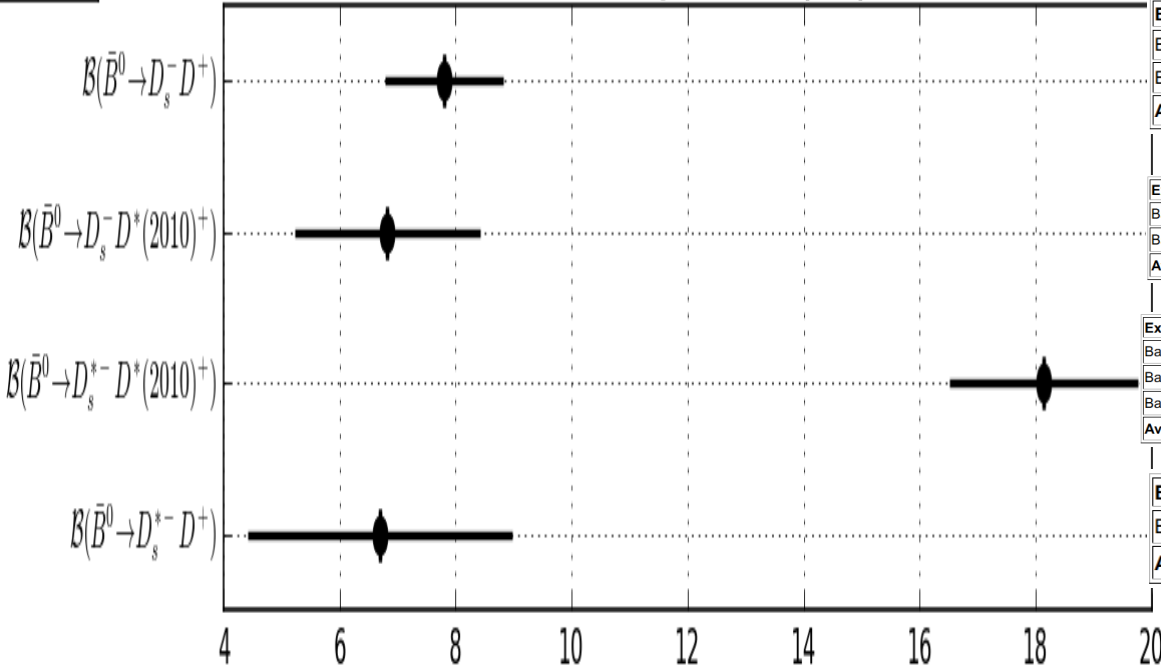
Experiment	Measurement	Reference
BaBar	$[0.93 \pm 0.18 \text{ (stat)} \pm 0.19 \text{ (syst)}] \times 10^{-2}$	<a href="#">PRD 74 (2006) 031103</a>
<b>Average</b>	<b><math>[0.93 \pm 0.26 \text{ (combined)}] \times 10^{-2}</math></b>	

Experiment	Measurement	Reference
BaBar	$[1.70 \pm 0.26 \text{ (stat)} \pm 0.24 \text{ (syst)}] \times 10^{-2}$	<a href="#">PRD 74 (2006) 031103</a>
<b>Average</b>	<b><math>[1.70 \pm 0.35 \text{ (combined)}] \times 10^{-2}</math></b>	

- BaBar PRD74 (2006) 031103
  - $210.5 \text{ fb}^{-1}$ , Full-reconstruction tag and recoil of  $B_{\text{sig}} \rightarrow D_{(s)}(^*) + X$

# $B^0 \rightarrow D_s(^*) D(^*)$

Decays to  $D_s^{(*)-} D^{(*)+} \times 10^{-3}$



Experiment	Measurement	Reference
Belle	$[7.5 \pm 0.2 \text{ (stat)} \pm 0.8 \text{ (syst)} \pm 0.8 \text{ (brs)}] \times 10^{-3}$	<a href="#">PRD 75, 091102 (2007)</a>
BaBar	$[0.90 \pm 0.18 \text{ (stat)} \pm 0.14 \text{ (syst)}] \times 10^{-2}$	<a href="#">PRD 74 (2006) 031103</a>
<b>Average</b>	<b><math>[7.8 \pm 1.0 \text{ (combined)}] \times 10^{-3}</math></b>	CL=0.5569

Experiment	Measurement	Reference
BaBar	$[0.57 \pm 0.16 \text{ (stat)} \pm 0.09 \text{ (syst)}] \times 10^{-2}$	<a href="#">PRD 74 (2006) 031103</a>
BaBar	$[1.03 \pm 0.14 \text{ (stat)} \pm 0.13 \text{ (syst)} \pm 0.26 \text{ (correlated systematic)}] \times 10^{-2}$	<a href="#">PRD 67, 092003 (2003)</a>
<b>Average</b>	<b><math>[0.68 \pm 0.16 \text{ (combined)}] \times 10^{-2}</math></b>	CL=0.2153

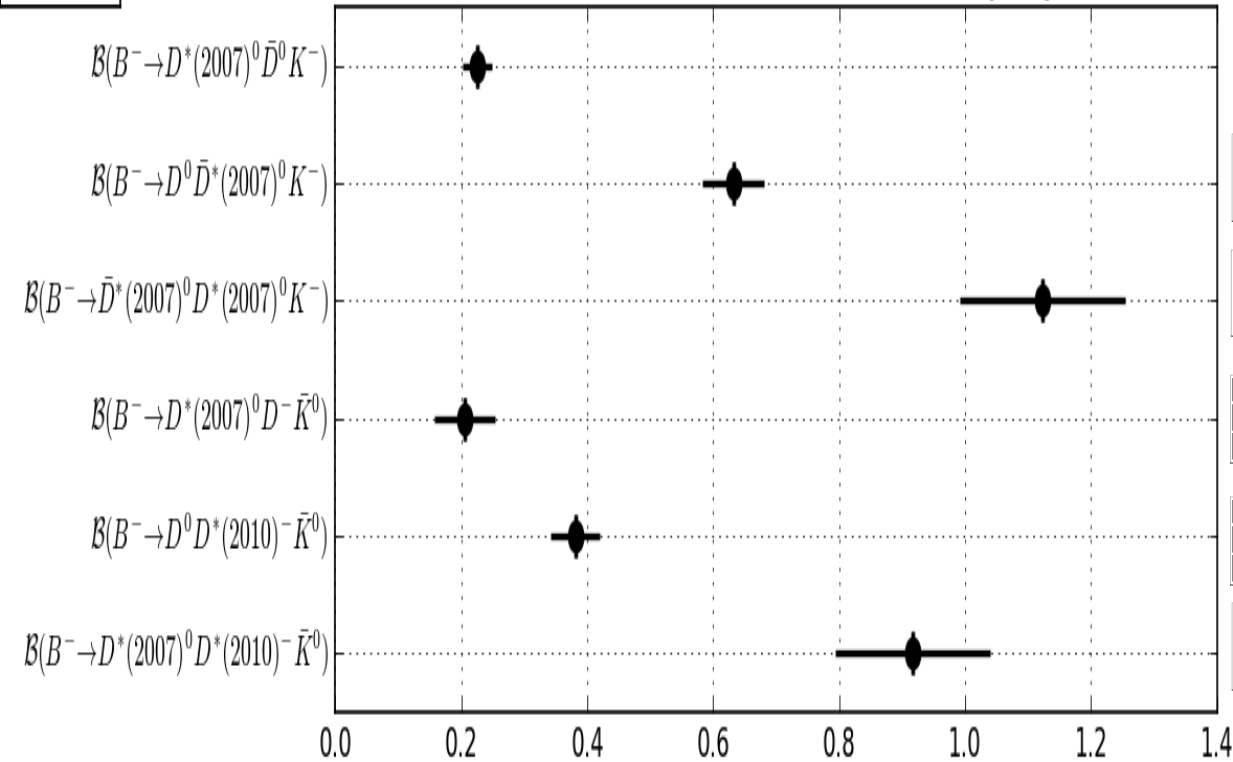
Experiment	Measurement	Reference
BaBar	$[1.65 \pm 0.23 \text{ (stat)} \pm 0.19 \text{ (syst)}] \times 10^{-2}$	<a href="#">PRD 74 (2006) 031103</a>
BaBar	$[1.88 \pm 0.09 \text{ (stat)} \pm 0.16 \text{ (syst)} \pm 0.06 \text{ (correlated syst)}] \times 10^{-2}$	<a href="#">PRD 71, 091104 (2005)</a>
BaBar	$[1.97 \pm 0.15 \text{ (stat)} \pm 0.30 \text{ (syst)} \pm 0.49 \text{ (correlated systematic)}] \times 10^{-2}$	<a href="#">PRD 67, 092003 (2003)</a>
<b>Average</b>	<b><math>[1.81 \pm 0.16 \text{ (combined)}] \times 10^{-2}</math></b>	CL=0.7978

Experiment	Measurement	Reference
BaBar	$[0.67 \pm 0.20 \text{ (stat)} \pm 0.11 \text{ (syst)}] \times 10^{-2}$	<a href="#">PRD 74 (2006) 031103</a>
<b>Average</b>	<b><math>[0.67 \pm 0.23 \text{ (combined)}] \times 10^{-2}</math></b>	

- BaBar PRD74 (2006) 031103:  $210.5 \text{ fb}^{-1}$ , Full-reconstruction tag, recoil analysis of  $B_{\text{sig}} \rightarrow D_{(s)}(^*) + X$
- BaBar PRD67, 092003 (2003):  $20.8 \text{ fb}^{-1}$
- BaBar PRD71, 0911104 (2005):  $1.23 \text{ M BBbar}$ , partial reconstruction
- Belle PRD75 (2007), 091102 :  $449 \text{ fb}^{-1}$

# $B^- \rightarrow D\bar{D}K$ (1)

Decays to two  $D$  mesons and a kaon I [ $10^{-2}$ ]



Experiment	Measurement	Reference
BaBar	$2.26 \pm 0.16$ (stat) $\pm 0.17$ (syst) $\times 10^{-3}$	<a href="#">PRD 83, 032004 (2011)</a>
Average	$2.26 \pm 0.23$ (combined) $\times 10^{-3}$	

Experiment	Measurement	Reference
BaBar	$6.32 \pm 0.19$ (stat) $\pm 0.45$ (syst) $\times 10^{-3}$	<a href="#">PRD 83, 032004 (2011)</a>
Average	$6.32 \pm 0.49$ (combined) $\times 10^{-3}$	

Experiment	Measurement	Reference
BaBar	$11.23 \pm 0.36$ (stat) $\pm 1.26$ (syst) $\times 10^{-3}$	<a href="#">PRD 83, 032004 (2011)</a>
Average	$11.23 \pm 1.31$ (combined) $\times 10^{-3}$	

Experiment	Measurement	Reference
BaBar	$2.06 \pm 0.38$ (stat) $\pm 0.30$ (syst) $\times 10^{-3}$	<a href="#">PRD 83, 032004 (2011)</a>
Average	$2.06 \pm 0.48$ (combined) $\times 10^{-3}$	

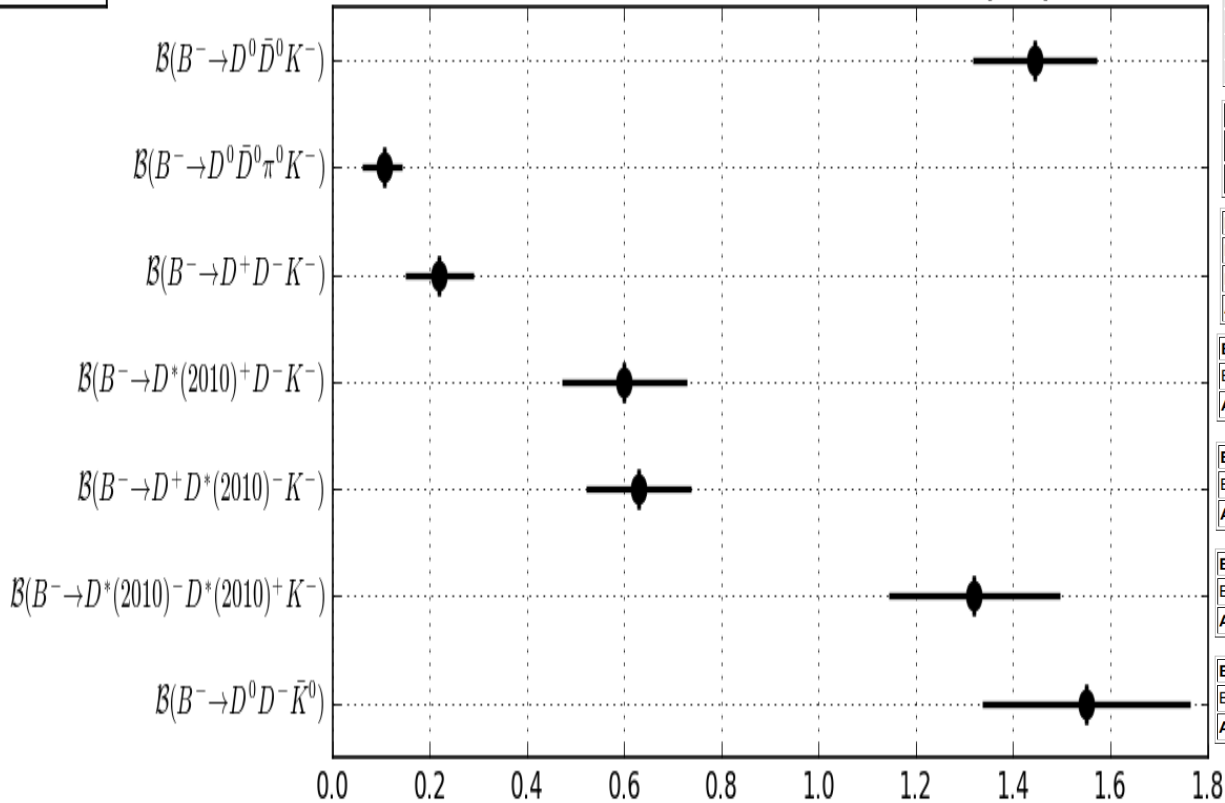
Experiment	Measurement	Reference
BaBar	$3.81 \pm 0.31$ (stat) $\pm 0.23$ (syst) $\times 10^{-3}$	<a href="#">PRD 83, 032004 (2011)</a>
Average	$3.81 \pm 0.39$ (combined) $\times 10^{-3}$	

Experiment	Measurement	Reference
BaBar	$9.17 \pm 0.83$ (stat) $\pm 0.90$ (syst) $\times 10^{-3}$	<a href="#">PRD 83, 032004 (2011)</a>
Average	$9.17 \pm 1.22$ (combined) $\times 10^{-3}$	

- BaBar PRD83, 032004 (2011):  $429 \text{ fb}^{-1}$

# $B^- \rightarrow D\bar{D}K$ (2)

Decays to two  $D$  mesons and a kaon II [ $10^{-3}$ ]



Experiment	Measurement	Reference
Belle	$22.2 \pm 2.2$ (stat) $^{+2.6}_{-2.4}$ (syst) $\times 10^{-4}$	PRL 100,092001, 2008
Belle	$1.17 \pm 0.21$ (stat) $\pm 0.15$ (syst) $\times 10^{-3}$	PRL 93,051803(2004) (superseded)
BaBar	$1.31 \pm 0.07$ (stat) $\pm 0.12$ (syst) $\times 10^{-3}$	PRD 83, 032004 (2011)
Average	$14.4 \pm 1.3$ (combined) $\times 10^{-4}$	CL=0.0117

Experiment	Measurement	Reference
Belle	$1.07 \pm 0.31$ (stat) $^{+0.19}_{-0.33}$ (syst) $\times 10^{-4}$	PRL 97, 162002 (2006)
Average	$1.07^{+0.36}_{-0.45}$ (combined) $\times 10^{-4}$	

Experiment	Measurement	Reference
Belle	$< 0.90 \times 10^{-3}$	PRL 93,051803(2004)
BaBar	$0.22 \pm 0.05$ (stat) $\pm 0.05$ (syst) $\times 10^{-3}$	PRD 83, 032004 (2011)
Average	$0.22 \pm 0.07$ (combined) $\times 10^{-3}$	

Experiment	Measurement	Reference
BaBar	$0.60 \pm 0.10$ (stat) $\pm 0.08$ (syst) $\times 10^{-3}$	PRD 83, 032004 (2011)
Average	$0.60 \pm 0.13$ (combined) $\times 10^{-3}$	

Experiment	Measurement	Reference
BaBar	$0.63 \pm 0.09$ (stat) $\pm 0.06$ (syst) $\times 10^{-3}$	PRD 83, 032004 (2011)
Average	$0.63 \pm 0.11$ (combined) $\times 10^{-3}$	

Experiment	Measurement	Reference
BaBar	$1.32 \pm 0.13$ (stat) $\pm 0.12$ (syst) $\times 10^{-3}$	PRD 83, 032004 (2011)
Average	$1.32 \pm 0.18$ (combined) $\times 10^{-3}$	

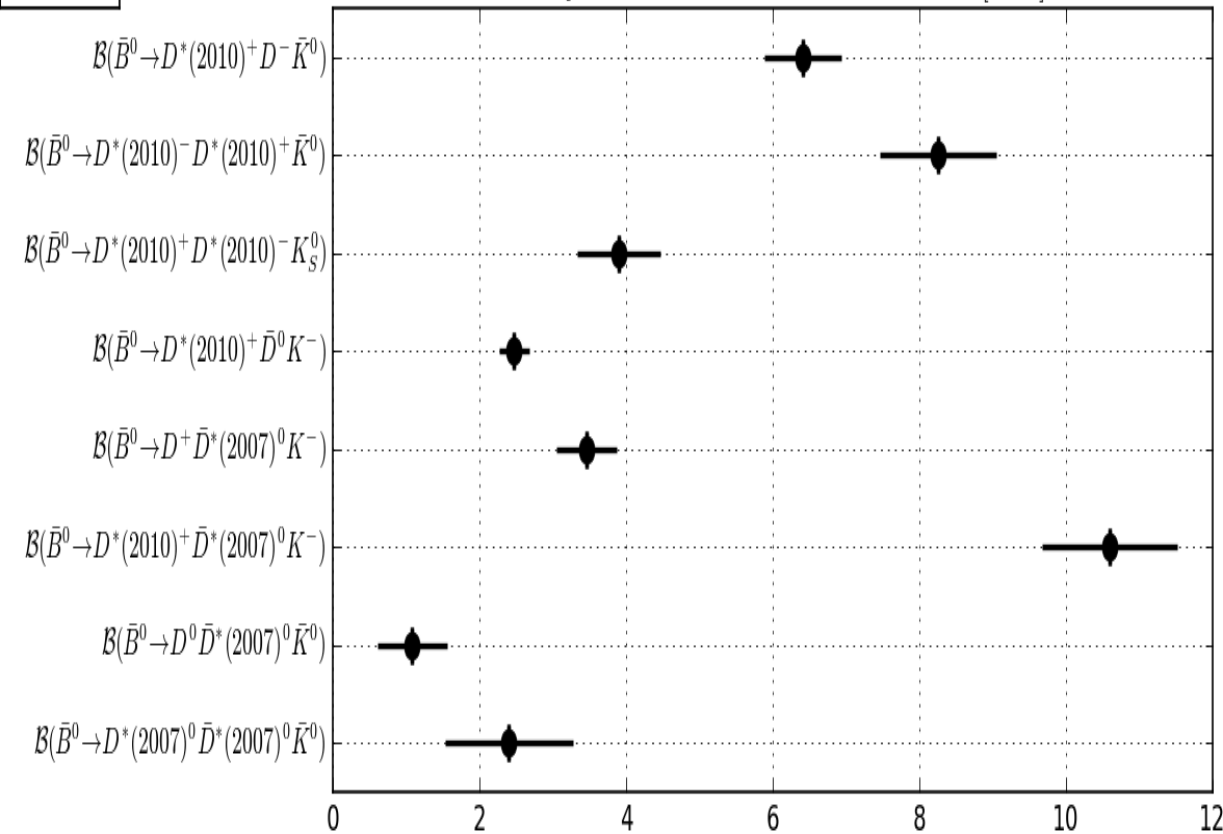
Experiment	Measurement	Reference
BaBar	$1.55 \pm 0.17$ (stat) $\pm 0.13$ (syst) $\times 10^{-3}$	PRD 83, 032004 (2011)
Average	$1.55 \pm 0.21$ (combined) $\times 10^{-3}$	

- Belle PRL 100, 092001(2008): 414 fb<sup>-1</sup>
- Belle PRL 97, 162002(2006): 414 fb<sup>-1</sup>
- 2017 BaBar PRD83, 032004: 429 fb<sup>-1</sup>

# $B^0 \rightarrow D\bar{D}K$ (1)

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Decays to two  $D$  mesons and a kaon I [ $10^{-3}$ ]



Experiment	Measurement	Reference
BaBar	$[6.41 \pm 0.36$ (stat) $\pm 0.39$ (syst)] $\times 10^{-3}$	<a href="#">PRD 83, 032004 (2011)</a>
Average	$[6.41 \pm 0.53$ (combined)] $\times 10^{-3}$	

Experiment	Measurement	Reference
BaBar	$[8.26 \pm 0.43$ (stat) $\pm 0.67$ (syst)] $\times 10^{-3}$	<a href="#">PRD 83, 032004 (2011)</a>
Average	$[8.26 \pm 0.80$ (combined)] $\times 10^{-3}$	

Experiment	Measurement	Reference
Belle	$[3.4 \pm 0.4$ (stat) $\pm 0.7$ (syst)] $\times 10^{-3}$	<a href="#">PRD 76, 072004, 2007</a>
BaBar	$[4.4 \pm 0.4$ (stat) $\pm 0.7$ (syst) $\pm 0.0$ (correlated syst.)] $\times 10^{-3}$	<a href="#">PRD 74, 091101 (2006)</a>
Average	$[3.9 \pm 0.6$ (combined)] $\times 10^{-3}$	CL=0.3807

Experiment	Measurement	Reference
BaBar	$[2.47 \pm 0.10$ (stat) $\pm 0.18$ (syst)] $\times 10^{-3}$	<a href="#">PRD 83, 032004 (2011)</a>
Average	$[2.47 \pm 0.21$ (combined)] $\times 10^{-3}$	

Experiment	Measurement	Reference
BaBar	$[3.46 \pm 0.18$ (stat) $\pm 0.37$ (syst)] $\times 10^{-3}$	<a href="#">PRD 83, 032004 (2011)</a>
Average	$[3.46 \pm 0.41$ (combined)] $\times 10^{-3}$	

Experiment	Measurement	Reference
BaBar	$[3.46 \pm 0.18$ (stat) $\pm 0.37$ (syst)] $\times 10^{-3}$	<a href="#">PRD 83, 032004 (2011)</a>
Average	$[3.46 \pm 0.41$ (combined)] $\times 10^{-3}$	

Experiment	Measurement	Reference
BaBar	$[1.08 \pm 0.32$ (stat) $\pm 0.36$ (syst)] $\times 10^{-3}$	<a href="#">PRD 83, 032004 (2011)</a>
Average	$[1.08 \pm 0.48$ (combined)] $\times 10^{-3}$	

Experiment	Measurement	Reference
BaBar	$[2.40 \pm 0.55$ (stat) $\pm 0.67$ (syst)] $\times 10^{-3}$	<a href="#">PRD 83, 032004 (2011)</a>
Average	$[2.40 \pm 0.87$ (combined)] $\times 10^{-3}$	

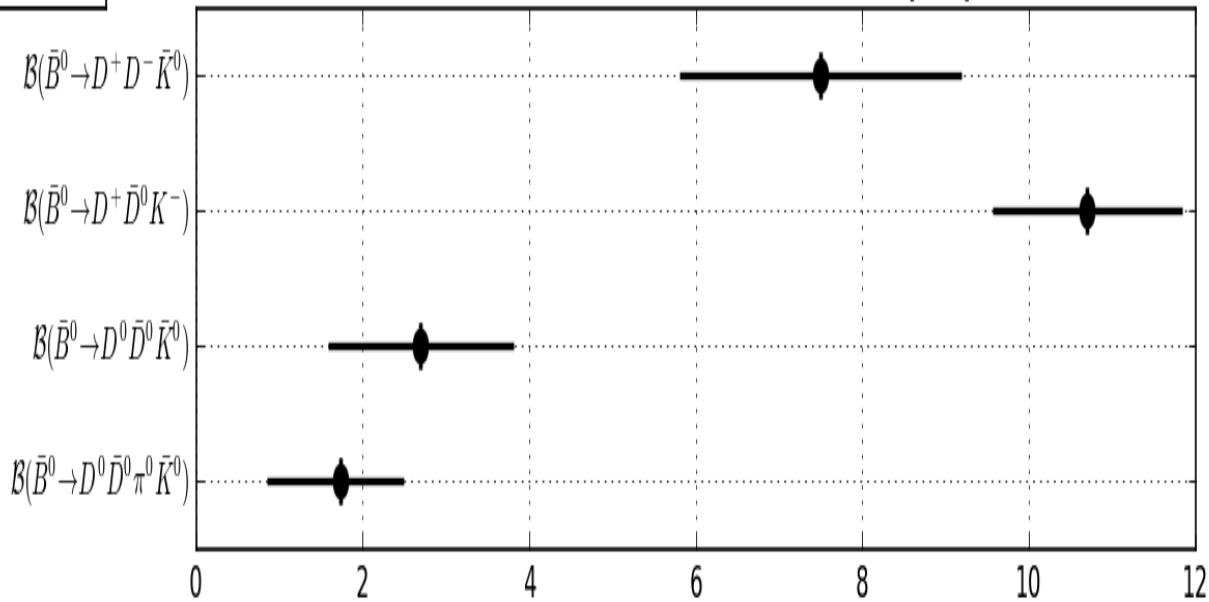
- BaBar PRD83, 032004 (2011):  $429 \text{ fb}^{-1}$
- Belle PRD76, 072004 (2007) :  $414 \text{ fb}^{-1}$
- <sup>2017/11/14</sup> BaBar PRD74, 091101 (2006): 2.30 M BBbar



# $B^0 \rightarrow D\bar{D}K$ (2)

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Decays to two  $D$  mesons and a kaon II [ $10^{-4}$ ]



Experiment	Measurement	Reference
BaBar	$[0.75 \pm 0.12$ (stat) $\pm 0.12$ (syst)] $\times 10^{-3}$	<a href="#">PRD 83, 032004 (2011)</a>
Average	$[0.75 \pm 0.17$ (combined)] $\times 10^{-3}$	

Experiment	Measurement	Reference
BaBar	$[1.07 \pm 0.07$ (stat) $\pm 0.09$ (syst)] $\times 10^{-3}$	<a href="#">PRD 83, 032004 (2011)</a>
Average	$[1.07 \pm 0.11$ (combined)] $\times 10^{-3}$	

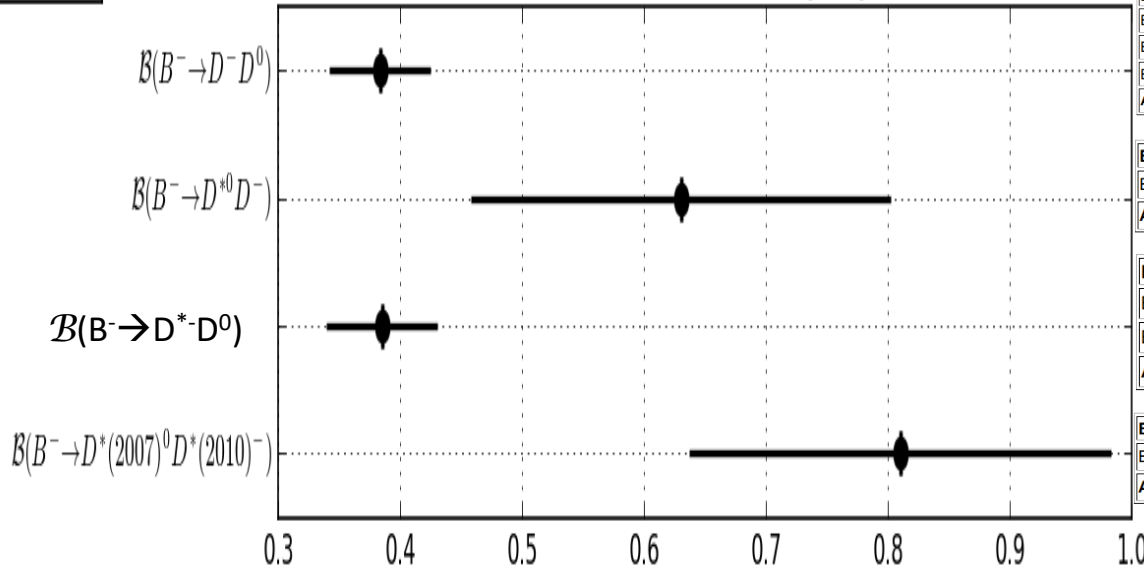
Experiment	Measurement	Reference
BaBar	$[0.27 \pm 0.10$ (stat) $\pm 0.05$ (syst)] $\times 10^{-3}$	<a href="#">PRD 83, 032004 (2011)</a>
Average	$[0.27 \pm 0.11$ (combined)] $\times 10^{-3}$	

Experiment	Measurement	Reference
Belle	$[1.73 \pm 0.70$ (stat) $^{+0.31}_{-0.53}$ (syst)] $\times 10^{-4}$	<a href="#">PRL 97, 162002 (2006)</a>
Average	$[1.73^{+0.77}_{-0.88}$ (combined)] $\times 10^{-4}$	

- BaBar PRD83, 032004 (2011): 429 fb<sup>-1</sup>
- Belle PRL 97, 162002(2006): 414 fb<sup>-1</sup>

# $B^- \rightarrow D^{(*)} D^{(*)}$

Decays to  $D^{(*)-} D^{(*)0} [10^{-3}]$



Experiment	Measurement	Reference
Belle	$[5.62 \pm 0.82 \text{ (stat)} \pm 0.65 \text{ (syst)}] \times 10^{-4}$	<a href="#">PRL 95, 041803 (2005) (superseded)</a>
Belle	$[3.85 \pm 0.31 \text{ (stat)} \pm 0.38 \text{ (syst)}] \times 10^{-4}$	<a href="#">PRD 77:091101,2008</a>
BaBar	$[3.8 \pm 0.6 \text{ (stat)} \pm 0.4 \text{ (syst)} \pm 0.3 \text{ (correlated syst)}] \times 10^{-4}$	<a href="#">PRD 73(2006) 112004</a>
Average	$[3.84 \pm 0.42 \text{ (combined)}] \times 10^{-4}$	CL=0.9567

Experiment	Measurement	Reference
BaBar	$[6.3 \pm 1.4 \text{ (stat)} \pm 0.8 \text{ (syst)} \pm 0.6 \text{ (correlated syst)}] \times 10^{-4}$	<a href="#">PRD 73(2006) 112004</a>
Average	$[6.3 \pm 1.7 \text{ (combined)}] \times 10^{-4}$	

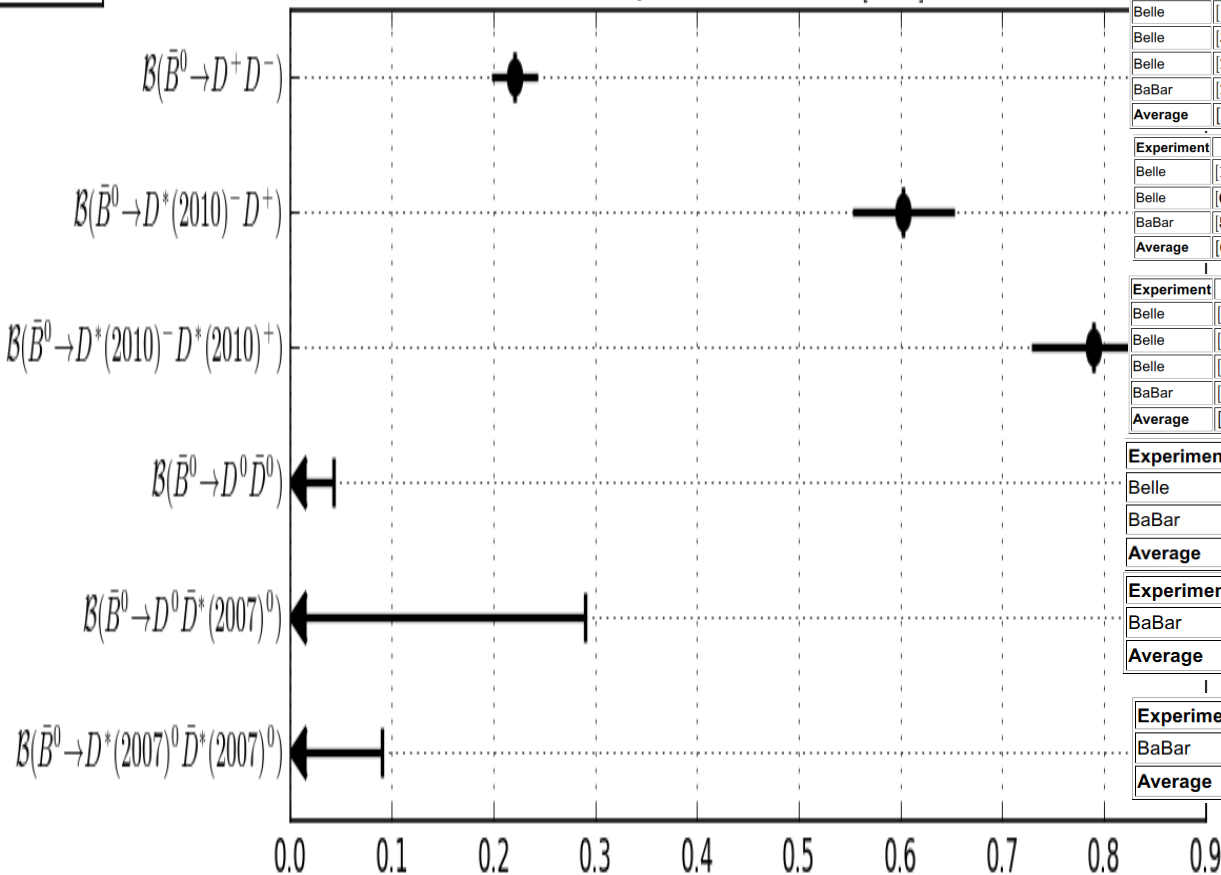
Experiment	Measurement	Reference
Belle	$[4.59 \pm 0.72 \text{ (stat)} \pm 0.56 \text{ (syst)}] \times 10^{-4}$	<a href="#">PRL 95, 041803 (2005)</a>
BaBar	$[3.6 \pm 0.5 \text{ (stat)} \pm 0.4 \text{ (syst)} \pm 0.2 \text{ (syst)}] \times 10^{-4}$	<a href="#">PRD 73(2006) 112004</a>
Average	$[3.85 \pm 0.46 \text{ (combined)}] \times 10^{-4}$	CL=0.3476

Experiment	Measurement	Reference
BaBar	$[8.1 \pm 1.2 \text{ (stat)} \pm 1.1 \text{ (syst)} \pm 0.6 \text{ (correlated syst)}] \times 10^{-4}$	<a href="#">PRD 73(2006) 112004</a>
Average	$[8.1 \pm 1.7 \text{ (combined)}] \times 10^{-4}$	

- BaBar PRD73, 112004 (2006) : 210.5 fb<sup>-1</sup>
- Belle PRD77, 091101 (2008) : 657 M BBbar
- Belle PRL95, 041803 (2005) : 140 fb<sup>-1</sup>

# $B^0 \rightarrow D(*)D(*)$

Decays to  $D^{(*)+}D^{(*)-}$  [ $10^{-3}$ ]



Experiment	Measurement	Reference
Belle	$1.97 \pm 0.20$ (stat) $\pm 0.20$ (syst) $\times 10^{-4}$	<a href="#">PRL 98, 221802 (2007) (superseded)</a>
Belle	$3.21 \pm 0.57$ (stat) $\pm 0.48$ (syst) $\times 10^{-4}$	<a href="#">PRL 95, 041803 (2005) (superseded)</a>
Belle	$2.12 \pm 0.16$ (stat) $\pm 0.18$ (syst) $\times 10^{-4}$	<a href="#">PRD 85 (2012) 091106</a>
BaBar	$2.8 \pm 0.4$ (stat) $\pm 0.3$ (syst) $\pm 0.4$ (correlated syst) $\times 10^{-4}$	<a href="#">PRD 73(2006) 112004</a>
<b>Average</b>	<b><math>2.20 \pm 0.23</math> (combined) <math>\times 10^{-4}</math></b>	CL=0.3215

Experiment	Measurement	Reference
Belle	$1.17 \pm 0.26$ (stat) $^{+0.20}_{-0.24}$ (syst) $\pm 0.08$ (D br (correlated)) $\times 10^{-3}$	<a href="#">PRL 89, 122001 (2002) (superseded)</a>
Belle	$6.14 \pm 0.29$ (stat) $\pm 0.50$ (syst) $\times 10^{-4}$	<a href="#">PRD 85 (2012) 091106</a>
BaBar	$5.7 \pm 0.7$ (stat) $\pm 0.6$ (syst) $\pm 0.4$ (correlated syst) $\times 10^{-4}$	<a href="#">PRD 73(2006) 112004</a>
<b>Average</b>	<b><math>6.03 \pm 0.50</math> (combined) <math>\times 10^{-4}</math></b>	CL=0.7014

Experiment	Measurement	Reference
Belle	$7.82 \pm 0.38$ (stat) $\pm 0.60$ (syst) $\times 10^{-4}$	<a href="#">Belle (superseded)</a>
Belle	$7.82 \pm 0.38$ (stat) $\pm 0.60$ (syst) $\times 10^{-4}$	<a href="#">PRD 86 (2012) 071103</a>
Belle	$0.81 \pm 0.08$ (stat) $\pm 0.11$ (syst) $\times 10^{-3}$	<a href="#">PLB 618.34 (2005) (superseded)</a>
BaBar	$8.1 \pm 0.6$ (stat) $\pm 0.9$ (syst) $\pm 0.5$ (correlated syst) $\times 10^{-4}$	<a href="#">PRD 73(2006) 112004</a>
<b>Average</b>	<b><math>7.90 \pm 0.61</math> (combined) <math>\times 10^{-4}</math></b>	CL=0.8373

Experiment	Measurement	Reference
Belle	$< 0.43 \times 10^{-4}$	<a href="#">PRD 77:091101,2008</a>
BaBar	$< 0.6 \times 10^{-4}$	<a href="#">PRD 73(2006) 112004</a>
<b>Average</b>	<b><math>&lt; 0.43 \times 10^{-4}</math></b>	

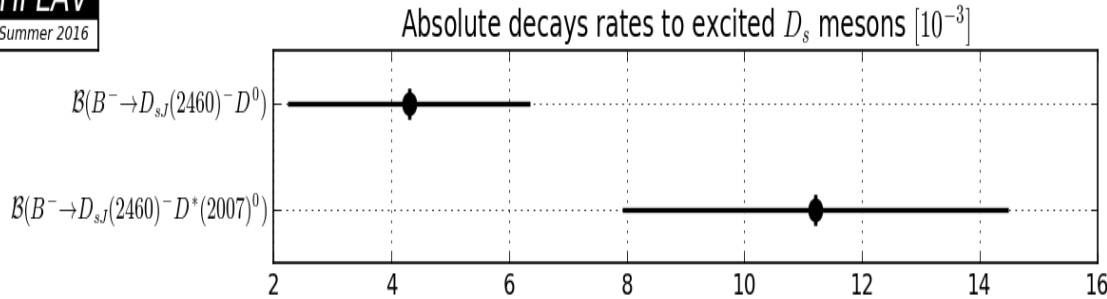
Experiment	Measurement	Reference
BaBar	$< 2.9 \times 10^{-4}$	<a href="#">PRD 73(2006) 112004</a>
<b>Average</b>	<b><math>&lt; 2.9 \times 10^{-4}</math></b>	

Experiment	Measurement	Reference
BaBar	$< 0.9 \times 10^{-4}$	<a href="#">PRD 73(2006) 112004</a>
<b>Average</b>	<b><math>&lt; 0.9 \times 10^{-4}</math></b>	

- Belle PRD 85 091106 (2012): 772 M BBbar
- BaBar PRD73, 112004 (2006) : 210.5 fb<sup>-1</sup>
- Belle PRD 86, 071103 (2012) : 772 M BBbar
- Belle PRD 77, 091101 (2008) : 657 M BBbar

# $B \rightarrow D_{s1}(2460)D(*)$

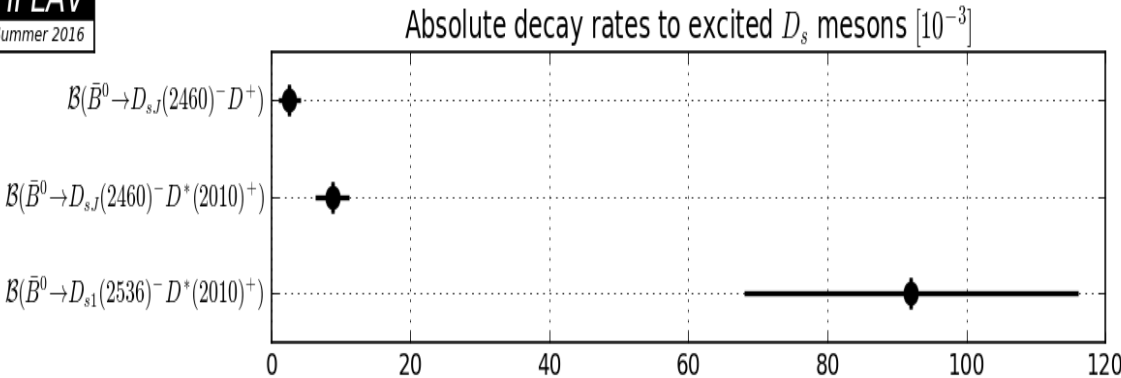
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Experiment	Measurement	Reference
BaBar	$[0.43 \pm 0.16 \text{ (stat)} \pm 0.13 \text{ (syst)}] \times 10^{-2}$	<a href="#">PRD 74 (2006) 031103</a>
<b>Average</b>	<b><math>[0.43 \pm 0.21 \text{ (combined)}] \times 10^{-2}</math></b>	

Experiment	Measurement	Reference
BaBar	$[1.12 \pm 0.26 \text{ (stat)} \pm 0.20 \text{ (syst)}] \times 10^{-2}$	<a href="#">PRD 74 (2006) 031103</a>
<b>Average</b>	<b><math>[1.12 \pm 0.33 \text{ (combined)}] \times 10^{-2}</math></b>	

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Experiment	Measurement	Reference
BaBar	$[0.26 \pm 0.15 \text{ (stat)} \pm 0.07 \text{ (syst)}] \times 10^{-2}$	<a href="#">PRD 74 (2006) 031103</a>
<b>Average</b>	<b><math>[0.26 \pm 0.17 \text{ (combined)}] \times 10^{-2}</math></b>	

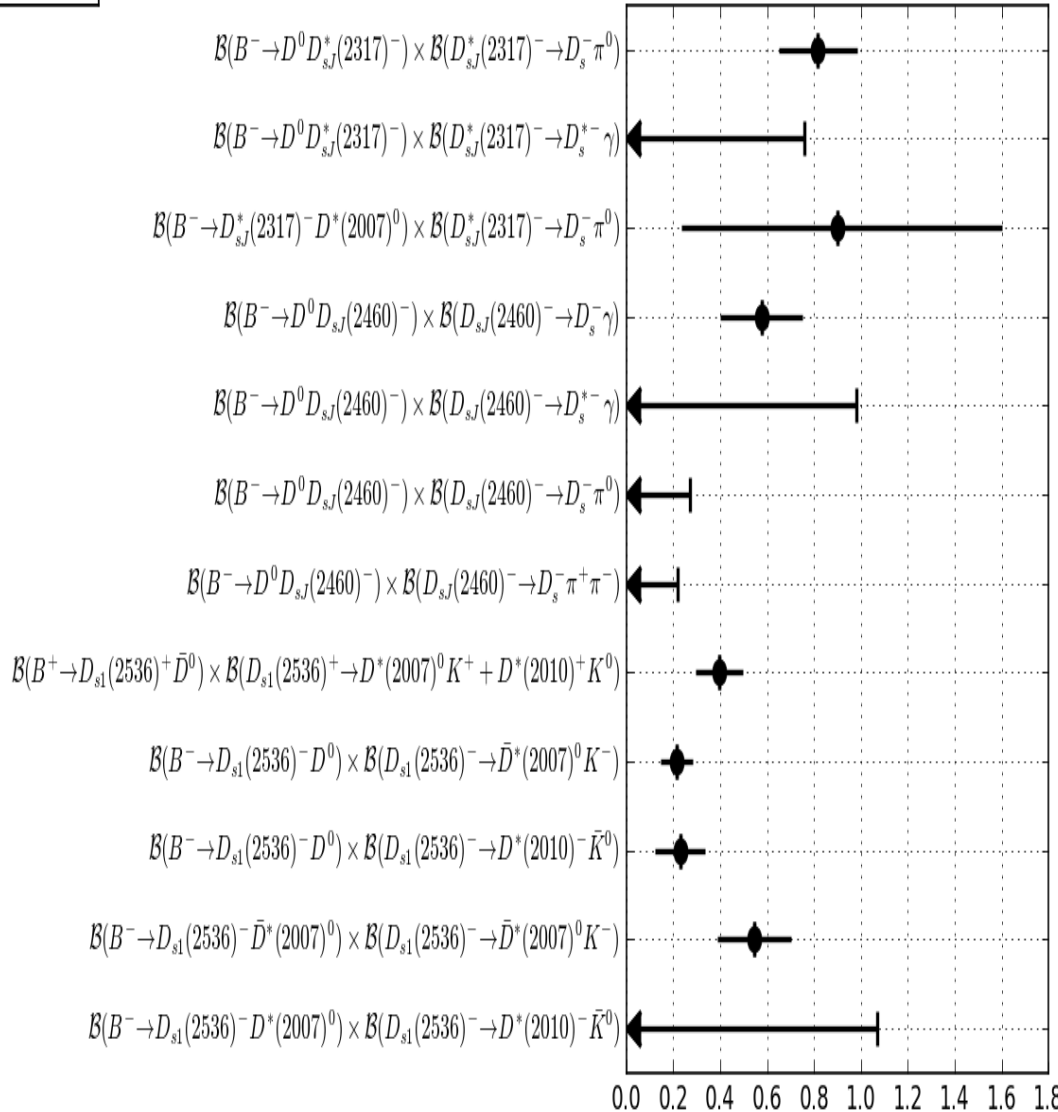
Experiment	Measurement	Reference
BaBar	$[0.88 \pm 0.20 \text{ (stat)} \pm 0.14 \text{ (syst)}] \times 10^{-2}$	<a href="#">PRD 74 (2006) 031103</a>
<b>Average</b>	<b><math>[0.88 \pm 0.24 \text{ (combined)}] \times 10^{-2}</math></b>	

Experiment	Measurement	Reference
BaBar	$[0.092 \pm 0.024 \text{ (stat)} \pm 0.001 \text{ (syst)}] \times 10^0$	<a href="#">PRD 74 091101 (2006)</a>
<b>Average</b>	<b><math>[0.092 \pm 0.024 \text{ (combined)}] \times 10^0</math></b>	

- BaBar PRD74, 031103 (2006) :  $210.5 \text{ fb}^{-1}$ , Full-reconstruction tag, recoil analysis of  $B_{\text{sig}} \rightarrow D_{(s)}(*) + X$
- BaBar PRD74, 091101 (2006) : 230 M BBbar

# Product Br of B- to excited Ds states

Product decays rates to excited  $D_s$  mesons II



Experiment	Measurement	Reference
Belle	$[8.1^{+3.0}_{-2.7} \text{ (stat)} \pm 2.4 \text{ (syst)}] \times 10^{-4}$	<a href="#">PRL 91,262002 (2003) (superseded)</a>
Belle	$[8.0^{+1.3}_{-1.2} \text{ (stat)} \pm 1.1 \text{ (syst)} \pm 0.4 \text{ (correlated systematic)}] \times 10^{-4}$	<a href="#">Phys. Rev. D 91, 092011 (2015)</a>
BaBar	$[1.0 \pm 0.3 \text{ (stat)} \pm 0.1 \text{ (syst)}^{+0.4}_{-0.2} \text{ (correlated systematic)}] \times 10^{-3}$	<a href="#">PRL 93,181801 (2004)</a>
Average	$[8.2 \pm 1.7 \text{ (combined)}] \times 10^{-4}$	CL=0.6579

Experiment	Measurement	Reference
Belle	$< 7.6 \times 10^{-4}$	<a href="#">PRL 91,262002 (2003)</a>
Average	$< 7.6 \times 10^{-4}$	

Experiment	Measurement	Reference
BaBar	$[0.9 \pm 0.6 \text{ (stat)} \pm 0.2 \text{ (syst)}^{+0.3}_{-0.2} \text{ (correlated systematic)}] \times 10^{-3}$	<a href="#">PRL 93,181801 (2004)</a>
Average	$[0.9^{+0.7}_{-0.7} \text{ (combined)}] \times 10^{-3}$	

Experiment	Measurement	Reference
Belle	$[5.6^{+1.6}_{-1.5} \text{ (stat)} \pm 1.7 \text{ (syst)}] \times 10^{-4}$	<a href="#">PRL 91,262002 (2003)</a>
BaBar	$[0.6 \pm 0.2 \text{ (stat)} \pm 0.1 \text{ (syst)}^{+0.2}_{-0.1} \text{ (correlated systematic)}] \times 10^{-3}$	<a href="#">PRL 93,181801 (2004)</a>
Average	$[5.8 \pm 1.8 \text{ (combined)}] \times 10^{-4}$	CL=0.9110

Experiment	Measurement	Reference
Belle	$< 9.8 \times 10^{-4}$	<a href="#">PRL 91,262002 (2003)</a>
Average	$< 9.8 \times 10^{-4}$	

Experiment	Measurement	Reference
Belle	$< 2.7 \times 10^{-4}$	<a href="#">PRL 91,262002 (2003)</a>
Average	$< 2.7 \times 10^{-4}$	

Experiment	Measurement	Reference
Belle	$< 2.2 \times 10^{-4}$	<a href="#">PRL 91,262002 (2003)</a>
Average	$< 2.2 \times 10^{-4}$	

Experiment	Measurement	Reference
Belle	$[3.97 \pm 0.85 \text{ (stat)} \pm 0.56 \text{ (syst)}] \times 10^{-4}$	<a href="#">PRD 83, 051102(R) (2011)</a>
Average	$[3.97 \pm 1.02 \text{ (combined)}] \times 10^{-4}$	

Experiment	Measurement	Reference
BaBar	$[2.16 \pm 0.52 \text{ (stat)} \pm 0.45 \text{ (syst)}] \times 10^{-4}$	<a href="#">PRD 77 011102 (2008)</a>
Average	$[2.16 \pm 0.69 \text{ (combined)}] \times 10^{-4}$	

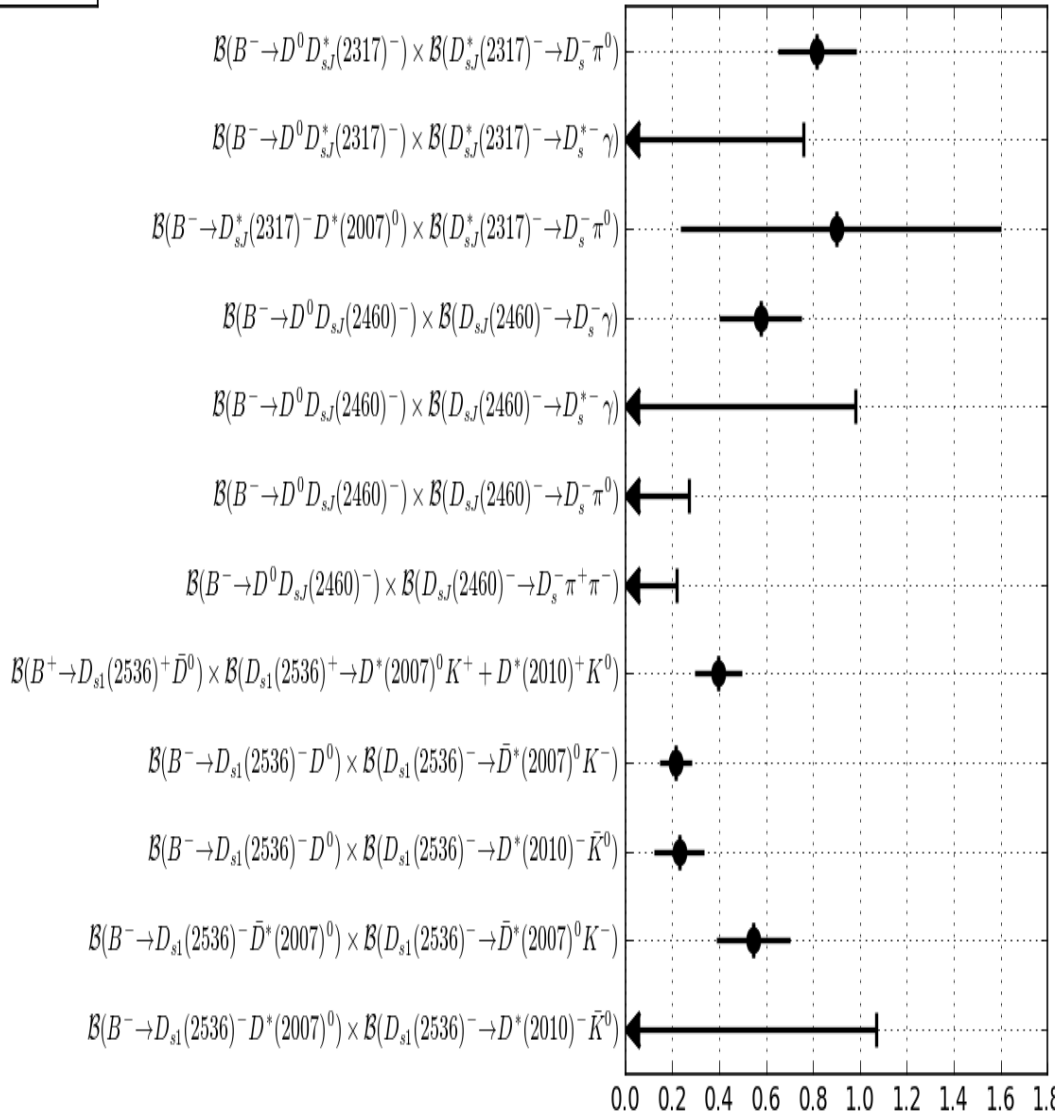
Experiment	Measurement	Reference
BaBar	$[2.30 \pm 0.98 \text{ (stat)} \pm 0.43 \text{ (syst)}] \times 10^{-4}$	<a href="#">PRD 77 011102 (2008)</a>
Average	$[2.30 \pm 1.07 \text{ (combined)}] \times 10^{-4}$	

Experiment	Measurement	Reference
BaBar	$[5.46 \pm 1.17 \text{ (stat)} \pm 1.04 \text{ (syst)}] \times 10^{-4}$	<a href="#">PRD 77 011102 (2008)</a>
Average	$[5.46 \pm 1.57 \text{ (combined)}] \times 10^{-4}$	

Experiment	Measurement	Reference
BaBar	$< 10.69 \times 10^{-4}$	<a href="#">PRD 77 011102 (2008)</a>
Average	$< 10.69 \times 10^{-4}$	

# Product Br of B- to excited Ds states

Product decays rates to excited  $D_s$  mesons



Experiment	Measurement	Reference
Belle	$[8.1^{+3.0}_{-2.7} \text{ (stat)} \pm 2.4 \text{ (syst)}] \times 10^{-4}$	<a href="#">PRL 91,262002 (2003) (superseded)</a>
Belle	$[8.0^{+1.3}_{-1.2} \text{ (stat)} \pm 1.1 \text{ (syst)} \pm 0.4 \text{ (correlated systematic)}] \times 10^{-4}$	<a href="#">Phys. Rev. D 91, 092011 (2015)</a>
BaBar	$[1.0 \pm 0.3 \text{ (stat)} \pm 0.1 \text{ (syst)}^{+0.4}_{-0.2} \text{ (correlated systematic)}] \times 10^{-3}$	<a href="#">PRL 93,181801 (2004)</a>
Average	$[8.2 \pm 1.7 \text{ (combined)}] \times 10^{-4}$	CL=0.6579

Experiment	Measurement	Reference
Belle	$< 7.6 \times 10^{-4}$	<a href="#">PRL 91,262002 (2003)</a>
Average	$< 7.6 \times 10^{-4}$	

Experiment	Measurement	Reference
BaBar	$[0.9 \pm 0.6 \text{ (stat)} \pm 0.2 \text{ (syst)}^{+0.3}_{-0.2} \text{ (correlated systematic)}] \times 10^{-3}$	<a href="#">PRL 93,181801 (2004)</a>
Average	$[0.9^{+0.7}_{-0.7} \text{ (combined)}] \times 10^{-3}$	

Experiment	Measurement	Reference
Belle	$[5.6^{+1.6}_{-1.5} \text{ (stat)} \pm 1.7 \text{ (syst)}] \times 10^{-4}$	<a href="#">PRL 91,262002 (2003)</a>
BaBar	$[0.6 \pm 0.2 \text{ (stat)} \pm 0.1 \text{ (syst)}^{+0.2}_{-0.1} \text{ (correlated systematic)}] \times 10^{-3}$	<a href="#">PRL 93,181801 (2004)</a>
Average	$[5.8 \pm 1.8 \text{ (combined)}] \times 10^{-4}$	CL=0.9110

Experiment	Measurement	Reference
Belle	$< 9.8 \times 10^{-4}$	<a href="#">PRL 91,262002 (2003)</a>
Average	$< 9.8 \times 10^{-4}$	

Experiment	Measurement	Reference
Belle	$< 2.7 \times 10^{-4}$	<a href="#">PRL 91,262002 (2003)</a>
Average	$< 2.7 \times 10^{-4}$	

Experiment	Measurement	Reference
Belle	$< 2.2 \times 10^{-4}$	<a href="#">PRL 91,262002 (2003)</a>
Average	$< 2.2 \times 10^{-4}$	

Experiment	Measurement	Reference
Belle	$[3.97 \pm 0.85 \text{ (stat)} \pm 0.56 \text{ (syst)}] \times 10^{-4}$	<a href="#">PRD 83, 051102(R) (2011)</a>
Average	$[3.97 \pm 1.02 \text{ (combined)}] \times 10^{-4}$	

Experiment	Measurement	Reference
BaBar	$[2.16 \pm 0.52 \text{ (stat)} \pm 0.45 \text{ (syst)}] \times 10^{-4}$	<a href="#">PRD 77 011102 (2008)</a>
Average	$[2.16 \pm 0.69 \text{ (combined)}] \times 10^{-4}$	

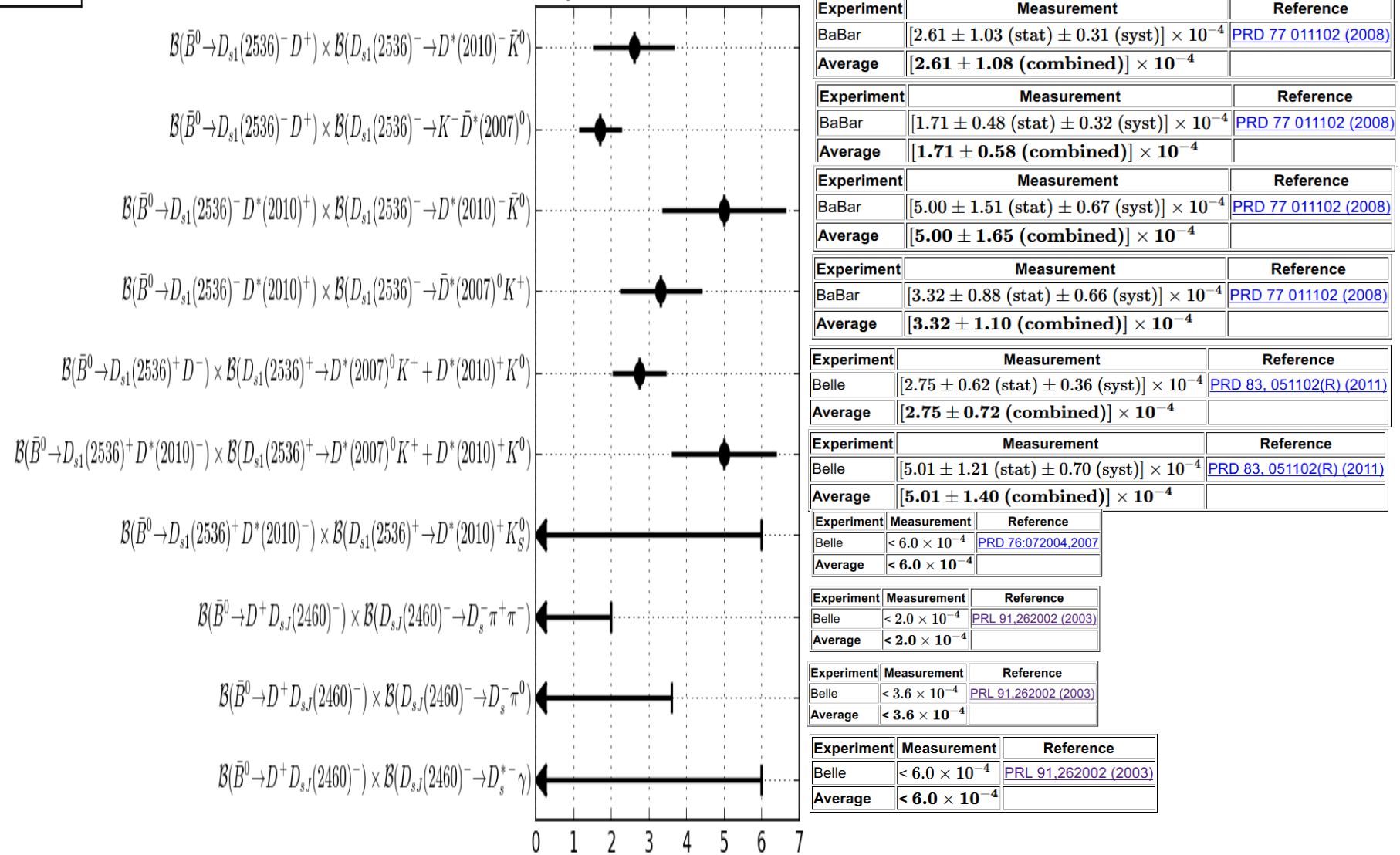
Experiment	Measurement	Reference
BaBar	$[2.30 \pm 0.98 \text{ (stat)} \pm 0.43 \text{ (syst)}] \times 10^{-4}$	<a href="#">PRD 77 011102 (2008)</a>
Average	$[2.30 \pm 1.07 \text{ (combined)}] \times 10^{-4}$	

Experiment	Measurement	Reference
BaBar	$[5.46 \pm 1.17 \text{ (stat)} \pm 1.04 \text{ (syst)}] \times 10^{-4}$	<a href="#">PRD 77 011102 (2008)</a>
Average	$[5.46 \pm 1.57 \text{ (combined)}] \times 10^{-4}$	

Experiment	Measurement	Reference
BaBar	$< 10.69 \times 10^{-4}$	<a href="#">PRD 77 011102 (2008)</a>
Average	$< 10.69 \times 10^{-4}$	

# Product Br of $B^0$ to excited $D_s$ states

Product decay rates to excited  $D_s$  mesons II [10<sup>-4</sup>]



# Summary and Prospect

- Measurement of  $B \rightarrow DDX$  decays are important to improve understanding of BG in  $B \rightarrow D(*)\tau$  with hadronic tau decays
- Uncertainties are still large,  $20 \sim 30 \%$
- Not all decay modes are measured at both BaBar and Belle
  - Not enough  $B \rightarrow D_s(*)D(*)$  measurements at Belle
- Systematic errors are already comparable with stat. errors

Dominant systematic error sources:

- Mx shapes in the recoil analysis
- $D_s$  and  $D$  decay Br
- Tracking, PID efficiencies

not improved by simply increasing data

though need care to treat them, still possible to reduce

- Some analyses at Belle are on-going and will improve  $B \rightarrow DDX$  measurement

Systematics	$\overline{B}^0 \rightarrow D_s^- D^+ [\%]$
<i>B</i> 's of $D_s$ and $D$ mesons	10.1
Tracking	6.0
$PID(K^\pm/\pi^\pm)/K_S^0 \epsilon$	7.4
MC statistics	1.7
Signal window	1.0
Signal fraction ( $1 - r$ )	2.9
Fitting model	1.9
$N(B\overline{B})$	1.3
Total	14.5

Belle PRD75 (2007), 091102

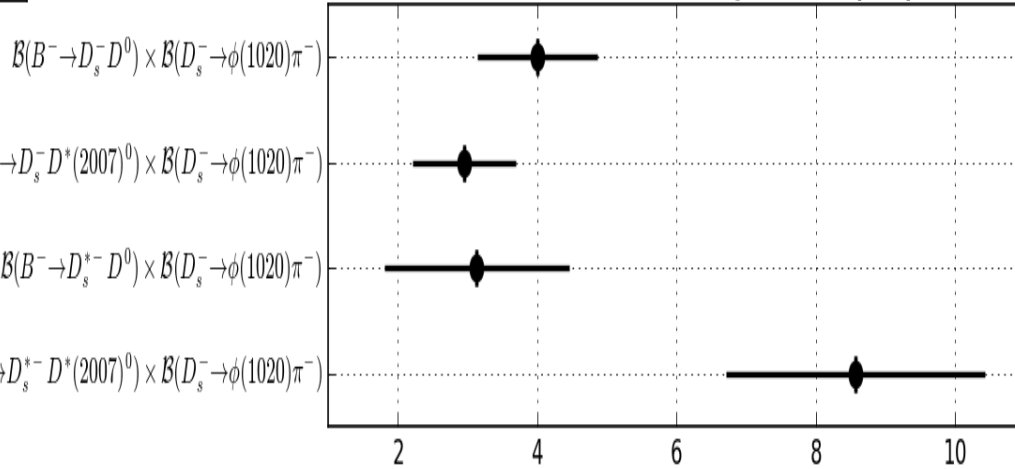




# Product Br of $B \rightarrow D_s(^*)D$

HFLAV  
Summer 2016

Product decays rates to  $D_s^{(*)-} D^{(*)+} [10^{-4}]$



Experiment	Measurement	Reference
BaBar	$[4.00 \pm 0.61$ (stat) $\pm 0.61$ (syst)] $\times 10^{-4}$	<a href="#">PRD 74 (2006) 031103</a>
<b>Average</b>	<b>[4.00 <math>\pm</math> 0.86 (combined)] <math>\times 10^{-4}</math></b>	

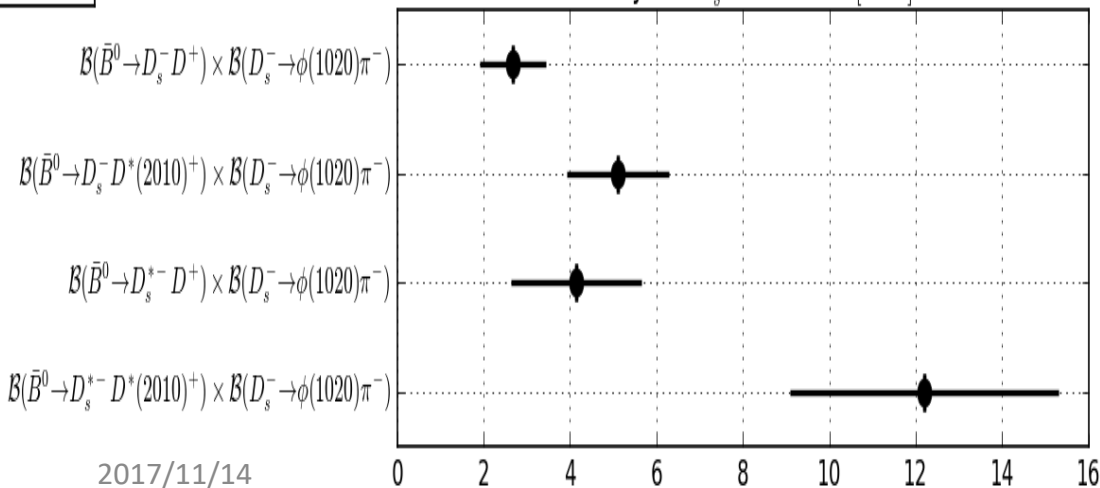
Experiment	Measurement	Reference
BaBar	$[2.95 \pm 0.65$ (stat) $\pm 0.36$ (syst)] $\times 10^{-4}$	<a href="#">PRD 74 (2006) 031103</a>
<b>Average</b>	<b>[2.95 <math>\pm</math> 0.74 (combined)] <math>\times 10^{-4}</math></b>	

Experiment	Measurement	Reference
BaBar	$[3.13 \pm 1.19$ (stat) $\pm 0.58$ (syst)] $\times 10^{-4}$	<a href="#">PRD 74 (2006) 031103</a>
<b>Average</b>	<b>[3.13 <math>\pm</math> 1.32 (combined)] <math>\times 10^{-4}</math></b>	

Experiment	Measurement	Reference
BaBar	$[8.57 \pm 1.48$ (stat) $\pm 1.12$ (syst)] $\times 10^{-4}$	<a href="#">PRD 74 (2006) 031103</a>
<b>Average</b>	<b>[8.57 <math>\pm</math> 1.86 (combined)] <math>\times 10^{-4}</math></b>	

HFLAV  
Summer 2016

Decays to  $D_s^{(*)-} D^{(*)+} \parallel [10^{-4}]$



Experiment	Measurement	Reference
BaBar	$[2.67 \pm 0.61$ (stat) $\pm 0.47$ (syst)] $\times 10^{-4}$	<a href="#">PRD 74 (2006) 031103</a>
<b>Average</b>	<b>[2.67 <math>\pm</math> 0.77 (combined)] <math>\times 10^{-4}</math></b>	

Experiment	Measurement	Reference
BaBar	$[5.11 \pm 0.94$ (stat) $\pm 0.72$ (syst)] $\times 10^{-4}$	<a href="#">PRD 74 (2006) 031103</a>
<b>Average</b>	<b>[5.11 <math>\pm</math> 1.18 (combined)] <math>\times 10^{-4}</math></b>	

Experiment	Measurement	Reference
BaBar	$[4.14 \pm 1.19$ (stat) $\pm 0.94$ (syst)] $\times 10^{-4}$	<a href="#">PRD 74 (2006) 031103</a>
<b>Average</b>	<b>[4.14 <math>\pm</math> 1.52 (combined)] <math>\times 10^{-4}</math></b>	

Experiment	Measurement	Reference
BaBar	$[12.2 \pm 2.2$ (stat) $\pm 2.2$ (syst)] $\times 10^{-4}$	<a href="#">PRD 74 (2006) 031103</a>
<b>Average</b>	<b>[12.2 <math>\pm</math> 3.1 (combined)] <math>\times 10^{-4}</math></b>	