Hadronic b $\rightarrow$ c decays

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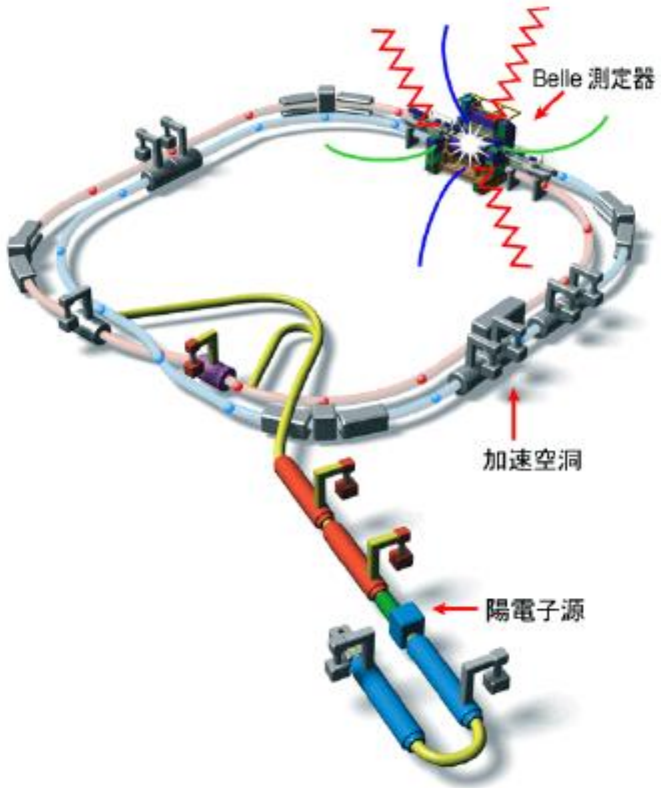
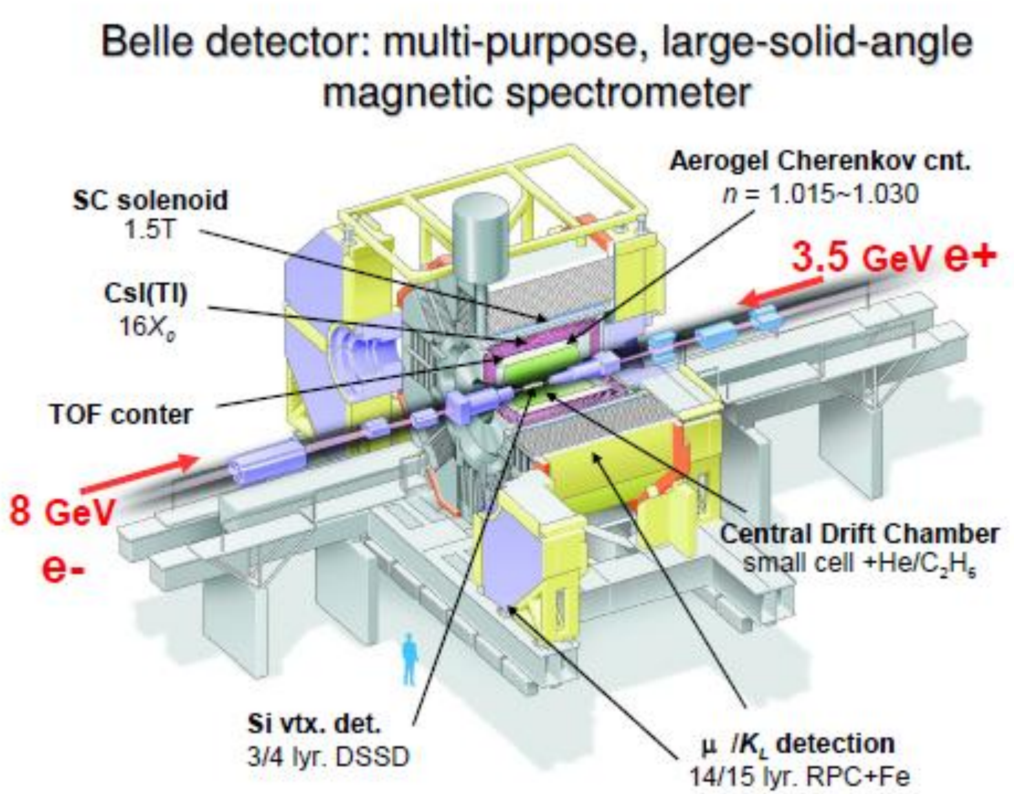
Outline:

- introduction
- $B^0 \rightarrow D_s^{*}h$ decays
- $B \rightarrow D_s^{(*)} K \pi$ decays
- conclusions

KEKB B-factory and Belle detector





$e^+e^- \to \Upsilon(4S) \to B\overline{B}$ clean source of exclusive B meson pairs

Main selection criteria

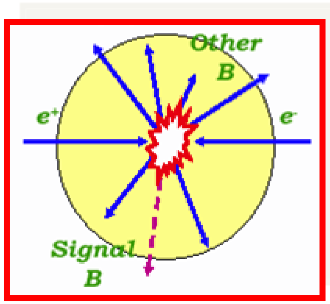
- Hadron identification

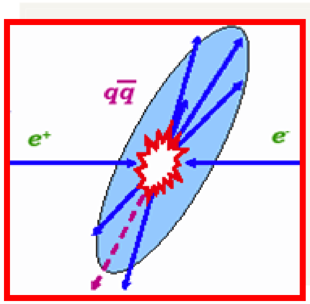
 - $\mathcal{L}_K \ (\mathcal{L}_\pi)$ - likelihood for being K(π) is assigned to each charged track based on the information from CDC, ToF and ACC

e.g. $\mathcal{L}_K/(\mathcal{L}_K+\mathcal{L}_\pi)$ > 0.6 applied for Kaons

- Continuum suppression

  - separate $B\bar{B}$ events from $q\bar{q}$ events (q=u,d,s,c)





- Requirements on intermediate resonances distributions:

masses of D_s, ϕ, K^{*0} etc.

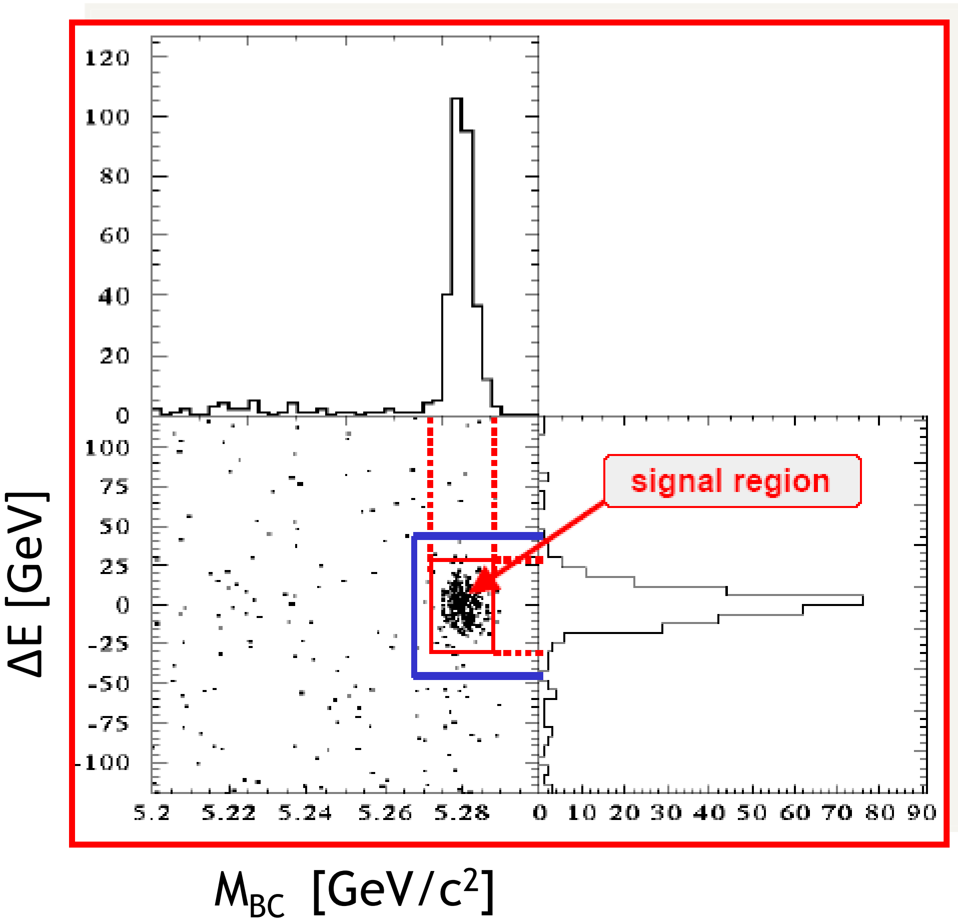
e.g.

$|m_{K+K-} - m_{\phi\_WA}| < 10\text{-}15$ MeV

- Requirements on: - photon energy (E_γ > 100 MeV)

  - K^0_s decay length > 0.5 cm from the IP

Belle kinematic variables ΔE and M_{BC}



$$\Delta E = \sum_i E_i^* - E_{beam}^*$$

$$M_{bc} = \sqrt{E_{beam}^{*2} - (\sum_i p_i^*)^2}$$

E_{beam} - beam energy in the CM frame

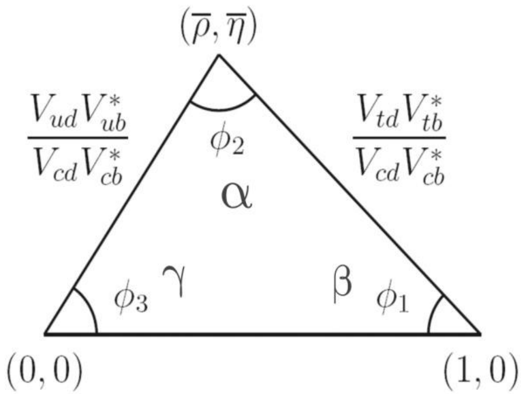
$\Sigma_i E_i$ - total energy of the B products

$\Sigma_i p_i$ - total momentum of the B products

$B^0 \rightarrow D_s^* h$ (h= K, π)

(Abstract no *597*)

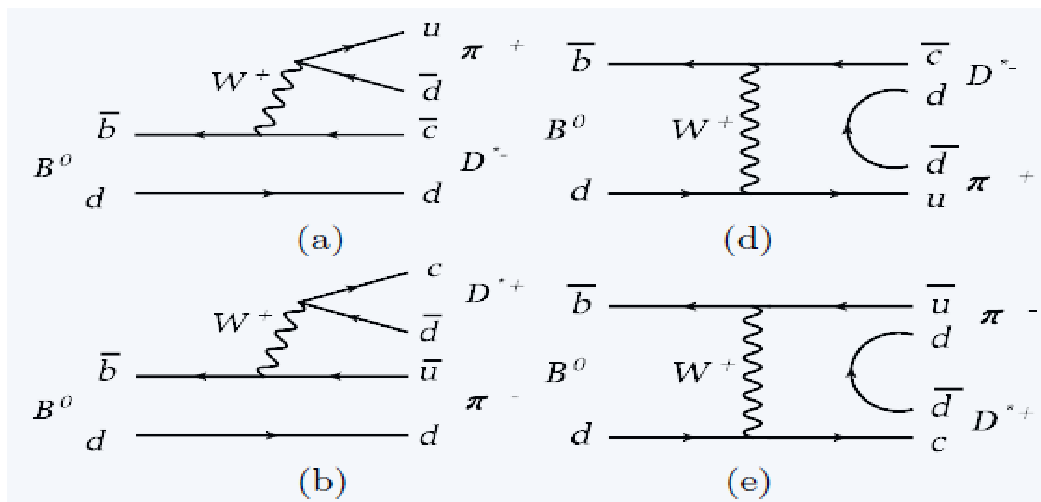
Motivation:



- Experimental measurement of unitary triangle angles – test for the explanation of CP violation in SM
- Extracting ϕ_3 parameter is experimentally challenging issue
- $R_{D^*\pi}\sin(2\phi_1 + \phi_3)$ can be extracted from the time-dependent CP violation analysis of the $B^0(\bar{B}^0) \rightarrow D^{*\mp}\pi^{\pm}$

Cabibbo Favored Decay (CFD)

Doubly Cabibbo Suppressed Decay (DCSD)



$R_{D^*\pi}$ - ratio of the DSCD/CFD amplitudes

W-exchange contribution

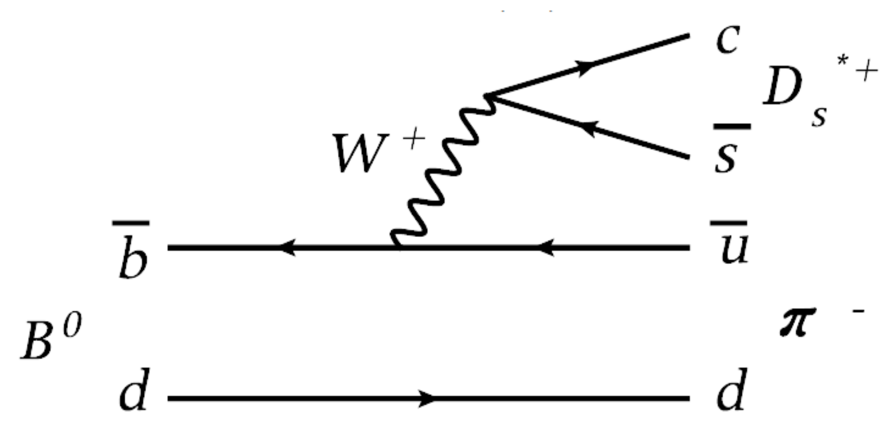
To extract ϕ_3 we need independent measurement of $R_{D^*\pi}$!!!

$B^0 \to D_s^* h$ (h= K, π)

Motivation cd:

We can measure $R_{D^*\pi}$ basing on
SU(3) flavor symmetry between D^* and D_s^* :

$$R_{D^*\pi} = \tan\theta_c \left(\frac{f_{D^*}}{f_{D_s^*}}\right) \sqrt{\frac{\mathcal{B}(B^0 \to D_s^{*+}\pi^-)}{\mathcal{B}(B^0 \to D^{*-}\pi^+)}}$$

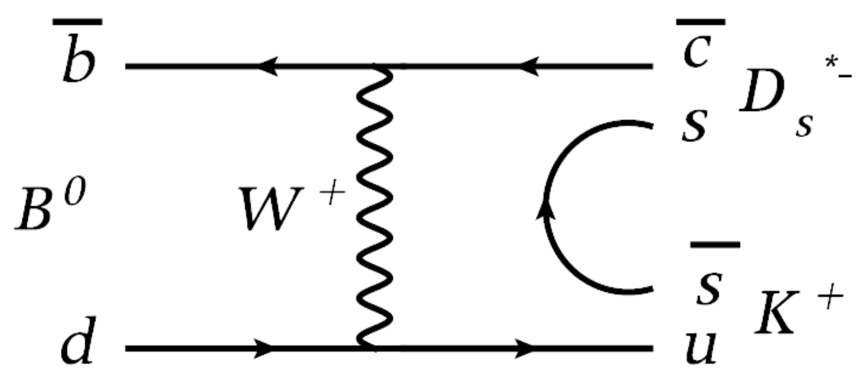


→ We need to measure $B^0 \to D_s^{*+}\pi^-$ --→ no $\overline{B}^0$ contribution to the same final state
↘ no W-exchange contribution

→ W-exchange amplitudes contribution for $B^0 \to D^{*\mp}\pi^\pm$ modes should be negligible

Measurement of $\mathcal{B}(B^0 \to D_s^{*-}K^+)$

proceeds only via W-exchange
so it can give estimation of the size of the W-exchange diagram



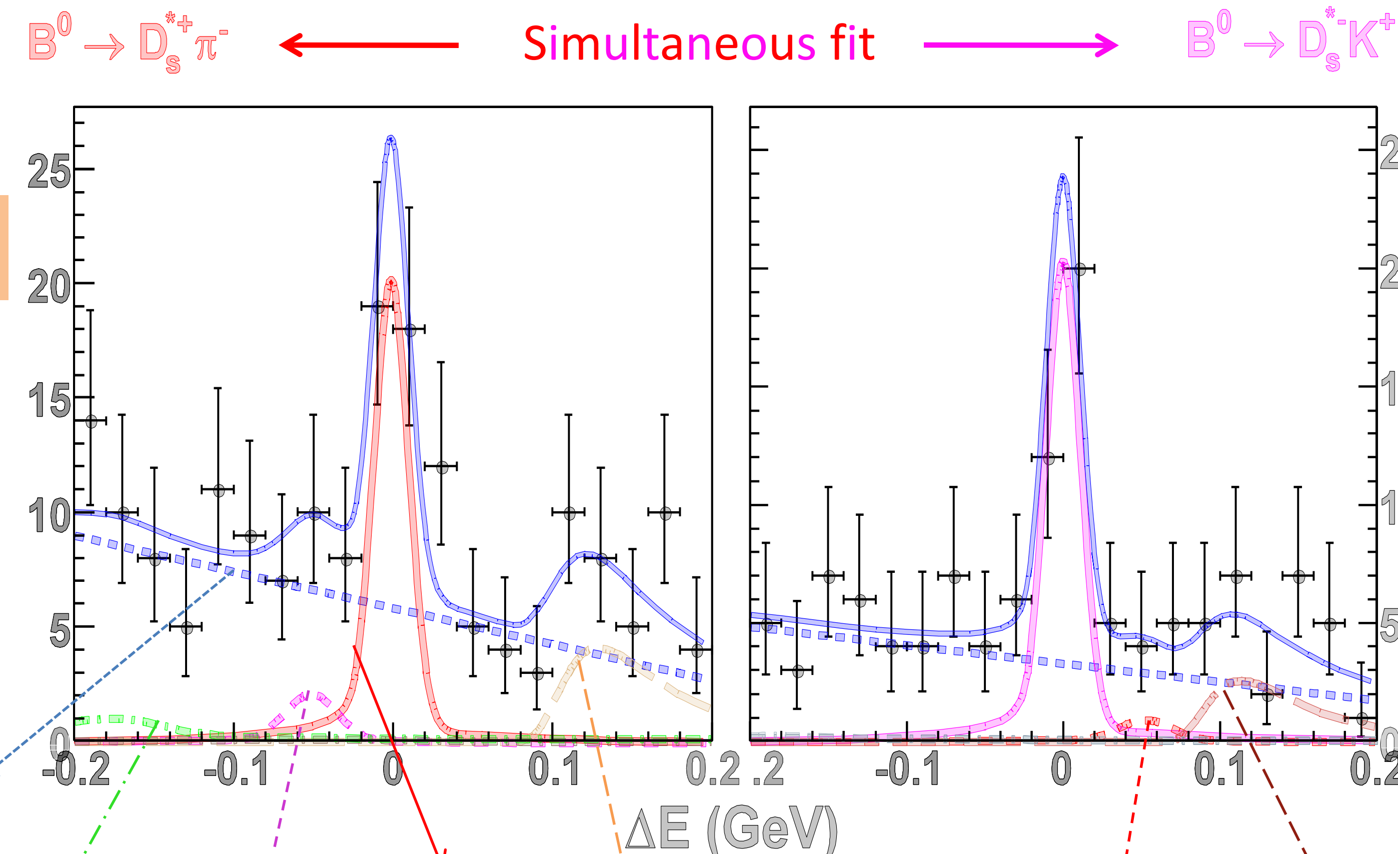
Data sample: 657×10^6 $B\overline{B}$ pairs

$B^0 \to D_s^{*+}\pi^-$ and $B^0 \to D_s^{*-}K^+$ - fit parameterization

unbinned extended maximum likelihood fit to the ΔE variable

preliminary

$D_s \to \phi\pi$



Combinatory background: 1st order polynomial

Contribution from $B^0 \to D_s^{(*)+}\rho^-$ with missing π^0

Contribution from $B^0 \to D_s^{*-}K^+$ (misidentified K)

Signal yield: broad Gaussian + Crystal Ball

Contribution from $B^0 \to D_s^{+}\pi^-$ (additional γ)

Contribution from $B^0 \to D_s^{*-}\pi^+$ (misidentified π)

Contribution from $B^0 \to D_s^{-}K^+$ (additional γ)

PDF shapes for peeking background fixed from the large MC samples

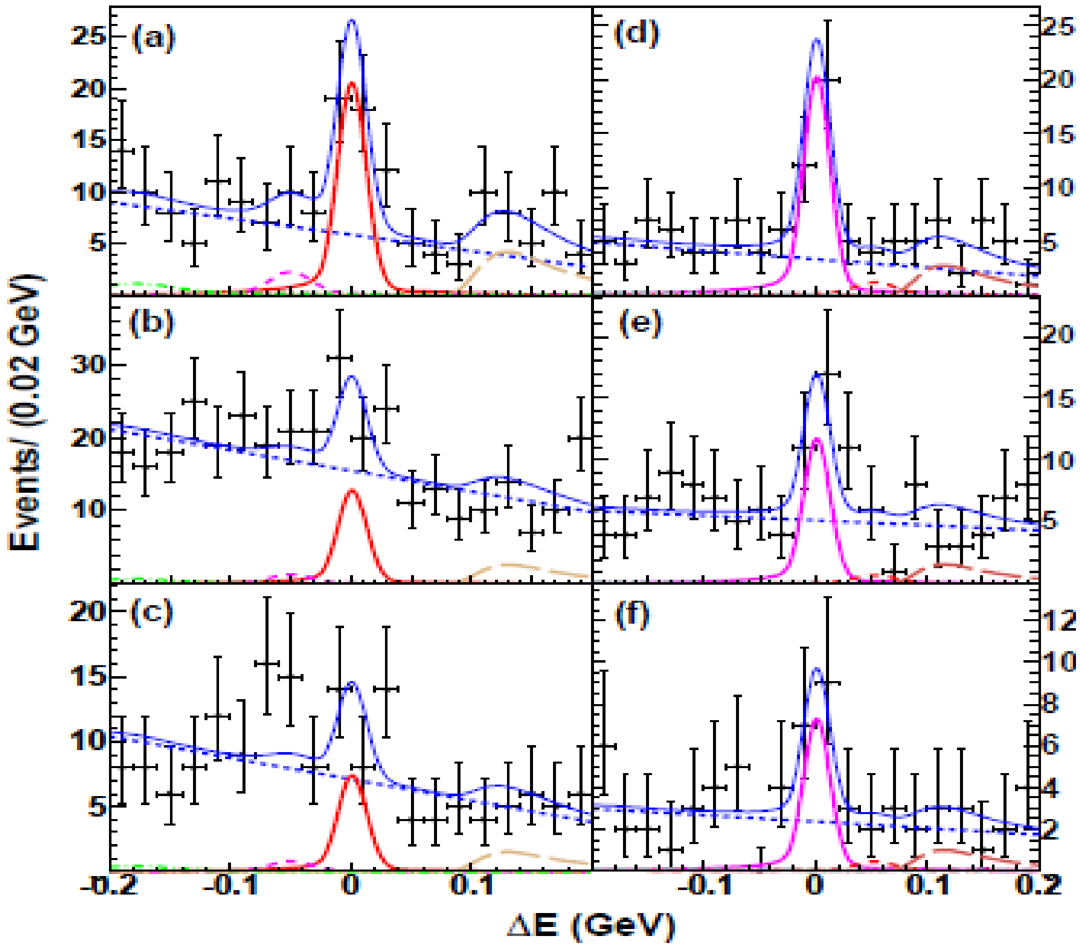
Fit results for $B^0 \to D_s^{*+}\pi^-$ and $B^0 \to D_s^{*-} K^+$

Signal yield extraction: unbinned extended maximum likelihood fit to the ΔE variable

Results of the simultaneous fit to the three D_s modes: $\phi\pi^-$, $K^{*0}K$, K^0_sK

preliminary

$B^0 \to D_s^{*+}\pi^-$ $B^0 \to D_s^{*-} K^+$



Signal yields:

	$B^0 \to D_s^{*+}\pi^-$	$B^0 \to D_s^{*-} K^+$
$D_s \to \phi\pi$	32 ± 8	33 ±8
$D_s \to K^{*0}K$	29 ± 10	23 ±7
$D_s \to K^0_sK$	13 ± 7	14 ±5

$B^0 \to D_s^{*+}\pi^-$ and $B^0 \to D_s^{*-} K^+$

Main sources of systematic uncertainties:

- Uncertainty in the branching fraction of the D_S decays (~10%)
- Tracking efficiency (~4%)
- Particle identification efficiency (~3%)
- Photon /K^0_s detection efficiency (7%/1.1%)
- Uncertainty in the branching fraction of the peeking background modes (~2%)
- Uncertainty in the determination of the signal PDF shape (3.5%)

Results for $B^0 \to D_s^{*+}\pi^-$ and $B^0 \to D_s^{*-} K^+$

Preliminary results:

B^0 mode	D_s^+ mode	Efficiency (%)	$N_{\rm sig}$	$\mathcal{B}(10^{-5})$	Σ (σ)
$B^0 \to D_s^{*+}\pi^-$	$D_s^+ \to \phi\pi^+$	15.2	32 ± 8	$1.58 \pm 0.40 \pm 0.24$	3.2
	$D_s^+ \to \bar{K}^*(892)^0 K^+$	7.9	29 ± 10	$2.30 \pm 0.76 \pm 0.35$	2.6
	$D_s^+ \to K_S^0 K^+$	8.0	13 ± 7	$1.78 \pm 0.92 \pm 0.11$	2.2
	Simultaneous	-	-	$1.75 \pm 0.33 \pm 0.20$	6.6
$B^0 \to D_s^{*-}K^+$	$D_s^+ \to \phi\pi^+$	13.4	33 ± 8	$1.81 \pm 0.41 \pm 0.27$	3.2
	$D_s^+ \to \bar{K}^*(892)^0 K^+$	6.4	23 ± 7	$2.22 \pm 0.66 \pm 0.34$	2.8
	$D_s^+ \to K_S^0 K^+$	6.9	14 ± 5	$2.14 \pm 0.80 \pm 0.13$	3.1
	Simultaneous	-	-	$2.02 \pm 0.33 \pm 0.23$	8.6

Previous results from BaBar : $BF(B^0 \to D_s^{*+}\pi^-) = (2.6 \pm 0.5 \pm 0.3) \times 10^{-5}$

$BF(B^0 \to D_s^{*-}K^+) = (2.4 \pm 0.4 \pm 0.2) \times 10^{-5}$

Phys. Rev. Lett. **98**,081801 (2007)
Phys. Rev. D**78**,032005 (2008)

$$R_{D^*\pi} = \tan\theta_c \left(\frac{f_{D^*}}{f_{D_s^*}}\right) \sqrt{\frac{\mathcal{B}(B^0 \to D_s^{*+}\pi^-)}{\mathcal{B}(B^0 \to D^{*-}\pi^+)}}$$

$= (2.76 \pm 0.13) \times 10^{-3}$ (PDG 2008)

$= 1.10 \pm 0.02$ (arXiv:**hep-lat/0011075**)

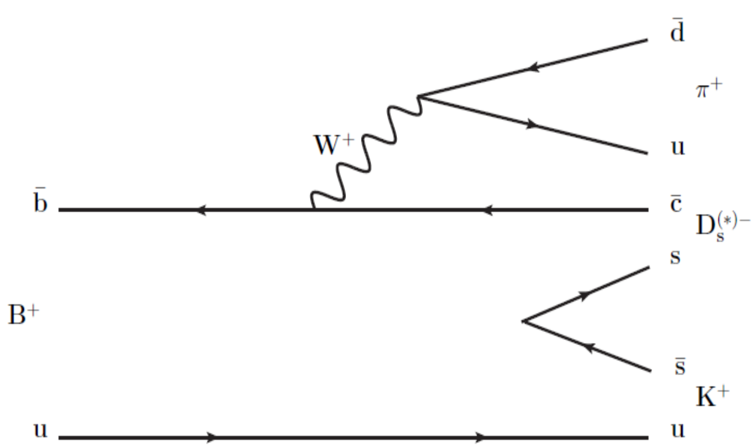
$\dashrightarrow$ obtained the most precise measurement of $R_{D^*\pi}$ so far :

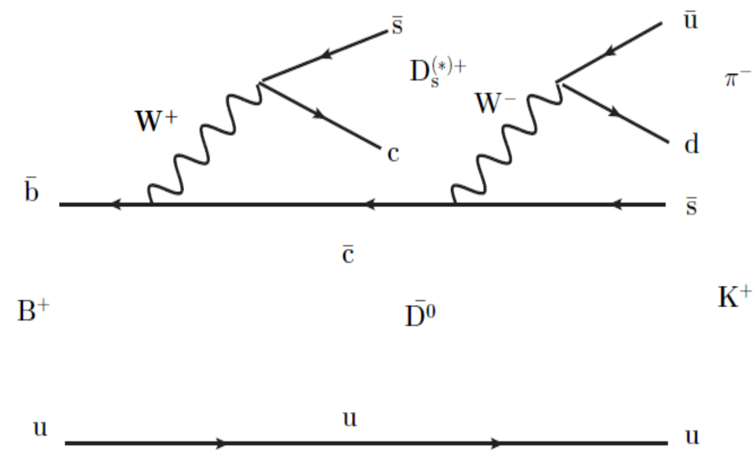
$$R_{D^*\pi} = 1.63 \pm 0.16\,(\text{stat}) \pm 0.10\,(\text{syst}) \pm 0.03\,(\text{th})\ \%$$

$\rightarrow$ W-exchange processes seem to be negligible in the $R_{D^*\pi}$

$B \to D_s^{(*)} K \pi$

submitted to PRD, hep-ex: arXiv:0903.4956v1





$B^+ \to D_s^{(*)-} K^+ \pi^+$ process mediated by the $b \to c$ quark transition and includes the production of an additional $s\bar{s}$ pair

already observed by BaBar

B. Aubert *et al.* (BaBar Collaboration), Phys. Rev. Lett. **100**, 171803 (2008)

Reference channel $B^+ \to D_s^{(*)+} \bar{D}^0$ ($\bar{D}^0 \to K^+ \pi^-$) – two-body decay with the similar final state

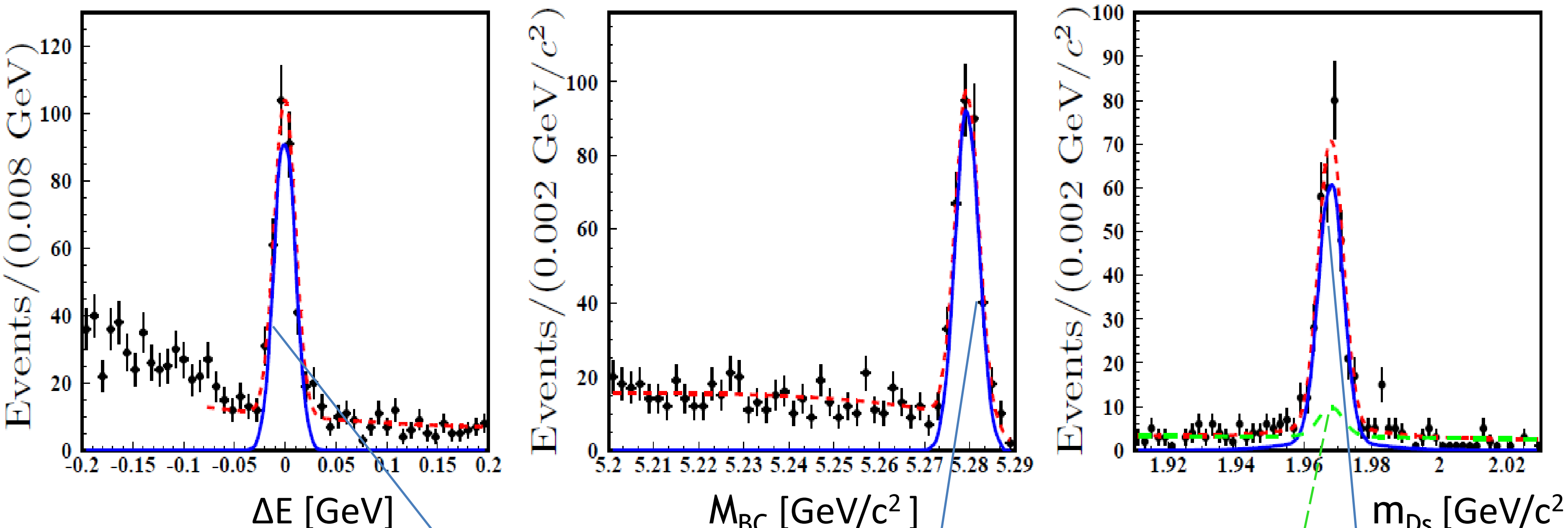
The intermediate resonances could be formed from the three final-state particles

Possible studies of the invariant mass distributions for the two-body subsystems to search for new resonances.

Data sample: 657×10^6 $B\bar{B}$ pairs

$B^+ \rightarrow D_s^{(*)-} K^+ \pi^+$ - fit parametrization

3D unbinned extended maximum likelihood fit to the (ΔE, M_{BC}, $m_{Ds(*)}$) variables



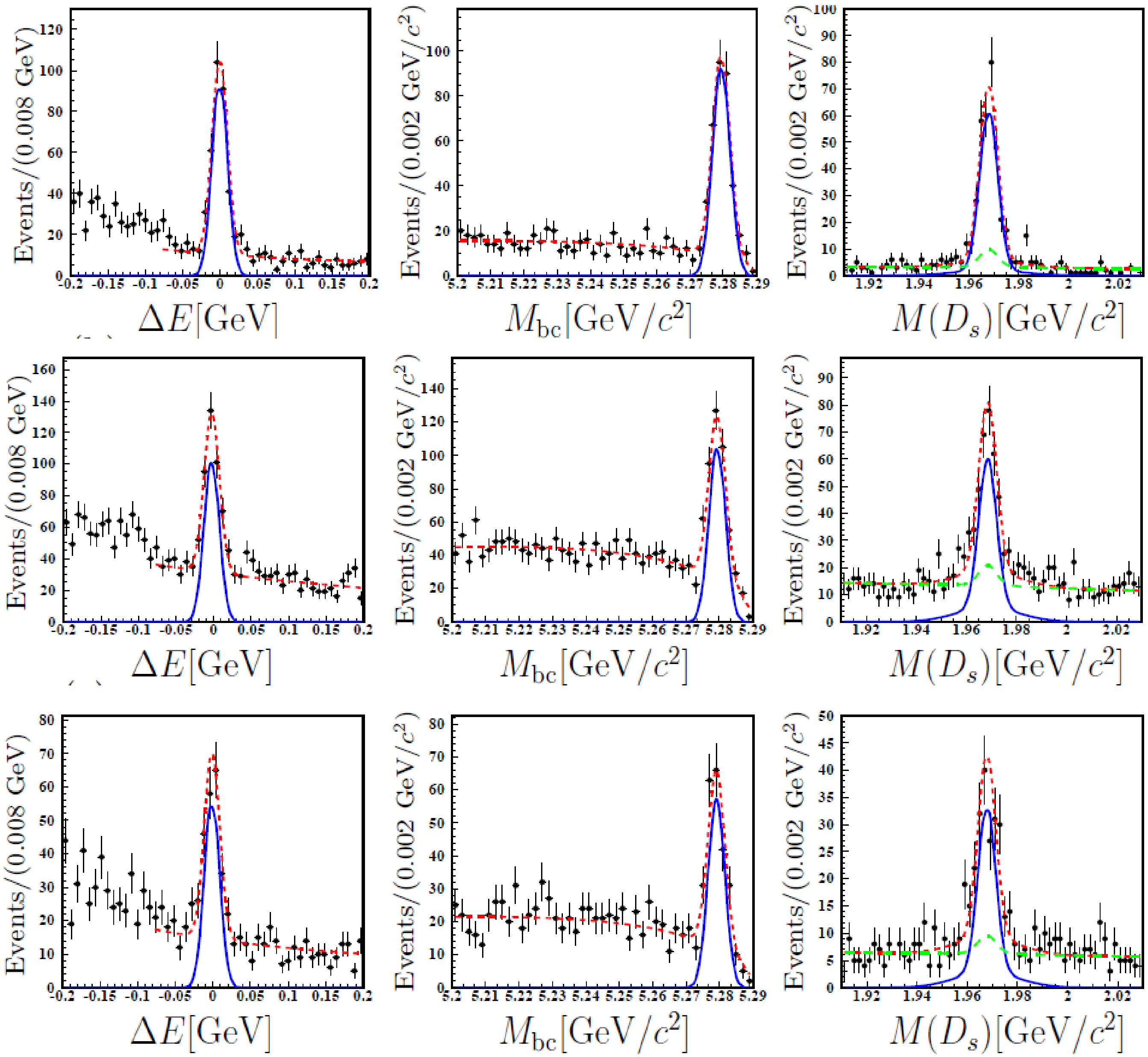
Signal parametrization: Gaussian Gaussian Double Gaussian

Peeking background in $M(D_s^{(*)})$ - $D_s^{(*)}$ randomly combined with K, π -- Double Gaussian

Comb. background parametrization: 2nd order polynomials (ΔE, m_{Ds}) and Argus function (M_{BC})

Fit results for $B^+ \to D_s^- K^+ \pi^+$

3D unbinned extended maximum likelihood fit to the (ΔE, M_{BC}, m_{Ds}) variables



$D_s \to \phi\pi$

306.0 ± 19.4 signal events

$D_s \to K^{*0}K$

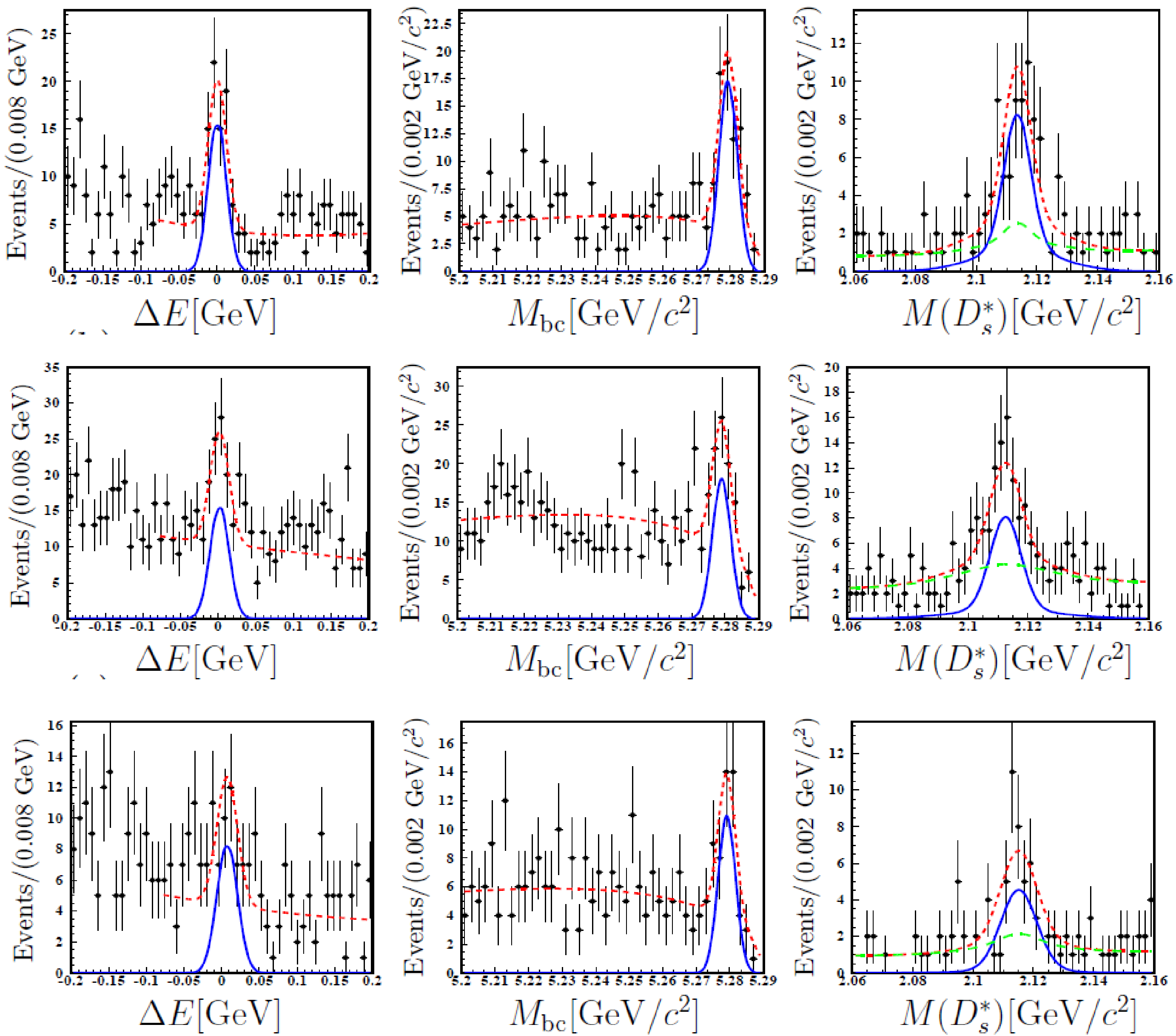
281.7 ± 24.0 signal events

$D_s \to K^0_s K$

179.4 ± 16.4 signal events

Fit results for $B^+ \rightarrow D_s^{*-} K^+ \pi^+$

3D unbinned extended maximum likelihood fit to the (ΔE, M_{BC}, m_{Ds^*}) variables



$D_s \rightarrow \phi\pi$

59.0 ± 9.0 signal events

$D_s \rightarrow K^{*0}K$

61.7 ± 10.2 signal events

$D_s \rightarrow K^0_s K$

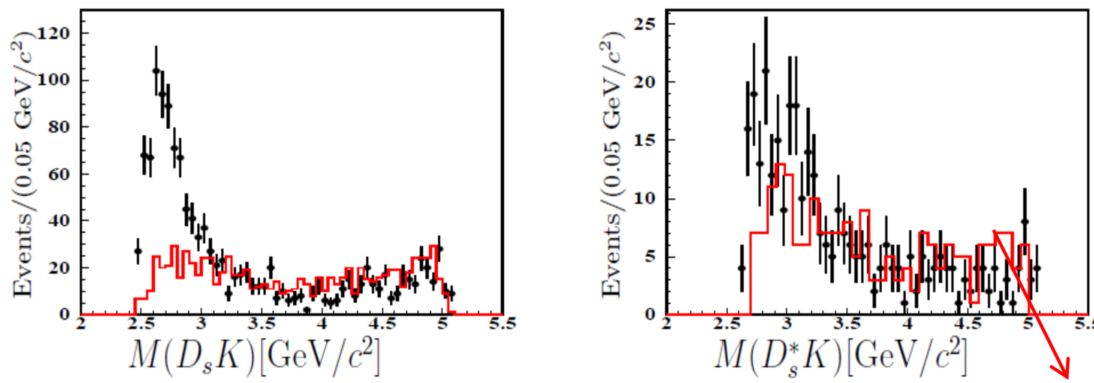
35.7 ± 6.4 signal events

$B \to D_s^{(*)} K \pi$

Main sources of systematics:

- Uncertainty in the efficiency calculation (~ 7% for $D_s K \pi$ and ~15% for $D_s^* K \pi$)

discrepancy between mass distributions of the $D_s^{(*)}$ K and expected distribution for three-body phase space production



Background from the M_{bc} sideband

$\to$ efficiency variation across $M(D_s^{(*)}K)$ distribution taken into account!

- Tracking efficiency (5%)
- Particle identification efficiency (5%)
- Photon /K^0_s detection efficiency (5%/4.5%)
- ucertainty in the determination of the signal PDF shape (~ 4% for $D_s K \pi$, ~7% for $D_s^* K \pi$)

Results for $B \to D_s^{(*)} K \pi$

Decay	Signal yield	Efficiency [%]	Statistical Signif. [σ]	Branching fraction [(10^{-4})]
$B^+ \to D_s^-(\to \phi\pi^-)K^+\pi^+$	$306.0^{+19.7}_{-19.1}$	13.09 ± 1.00	31.5	$1.63^{+0.11}_{-0.10}\ ^{+0.18}_{-0.18} \pm 0.25$
$B^+ \to D_s^-(\to K^{*0}K^-)K^+\pi^+$	$281.7^{+24.7}_{-23.6}$	9.48 ± 0.67	26.5	$1.74^{+0.15}_{-0.15}\ ^{+0.20}_{-0.20} \pm 0.27$
$B^+ \to D_s^-(\to K^0_S K^-)K^+\pi^+$	$179.4^{+16.7}_{-16.0}$	14.49 ± 1.11	20.4	$1.82^{+0.17}_{-0.16}\ ^{+0.24}_{-0.25} \pm 0.11$
$B^+ \to D_s^{*-}(\to \phi\pi^-)K^+\pi^+$	$59.0^{+9.3}_{-8.6}$	3.51 ± 0.52	11.0	$1.24^{+0.20}_{-0.18}\ ^{+0.23}_{-0.23} \pm 0.19$
$B^+ \to D_s^{*-}(\to K^{*0}K^-)K^+\pi^+$	$61.7^{+10.6}_{-9.8}$	2.88 ± 0.42	9.3	$1.33^{+0.23}_{-0.21}\ ^{+0.25}_{-0.25} \pm 0.21$
$B^+ \to D_s^{*-}(\to K^0_S K^-)K^+\pi^+$	$35.7^{+7.7}_{-6.9}$	4.02 ± 0.59	8.0	$1.39^{+0.30}_{-0.27}\ ^{+0.29}_{-0.28} \pm 0.08$

Simultaneous fit
To three D_s modes:

$$\mathcal{B}(B^+ \to D_s^- K^+\pi^+) = (1.71^{+0.08}_{-0.07}(\text{stat})\ ^{+0.20}_{-0.20}(\text{syst}) \pm 0.15(\mathcal{B}_{int})) \times 10^{-4}$$

$$\mathcal{B}(B^+ \to D_s^{*-} K^+\pi^+) = (1.31^{+0.13}_{-0.12}(\text{stat})\ ^{+0.25}_{-0.25}(\text{syst}) \pm 0.12(\mathcal{B}_{int})) \times 10^{-4}$$

BaBar results:
$BF(B^+ \to D_s^- K^+\pi^+) = 2.02 \pm 0.13 \pm 0.38 \times 10^{-4}$
$BF(B^+ \to D_s^{*-} K^+\pi^+) = 1.67 \pm 0.16 \pm 0.35 \times 10^{-4}$

B. Aubert *et al.* (BaBar Collaboration), Phys. Rev. Lett. **100**, 171803 (2008)

Preliminary studies of two-body subsystems do not confirm existance of any new resonance !

conclusions

- $B^0 \to D_s^{*}h$

Preliminary measurements of

$BF(B^0 \to D_s^{*+}\pi^-) = (1.75 \pm 0.33\ (stat) \pm 0.17\ (syst) \pm 0.10\ (B_{int})\ ) \times 10^{-5}$
$BF(B^0 \to D_s^{*-}K^+) = (2.02 \pm 0.32\ (stat) \pm 0.18\ (syst) \pm 0.14\ (B_{int})\ ) \times 10^{-5}$

Improved measurement of the ratio of DCSD/CFD amplitudes

$R_{D^*\pi} = 1.63 \pm 0.16\ (stat) \pm 0.10\ (syst) \pm 0.03\ (th)\ \%$

-> improved capabilities of observing CP violation in the $D^{*\pm}\pi^{\mp}$ system

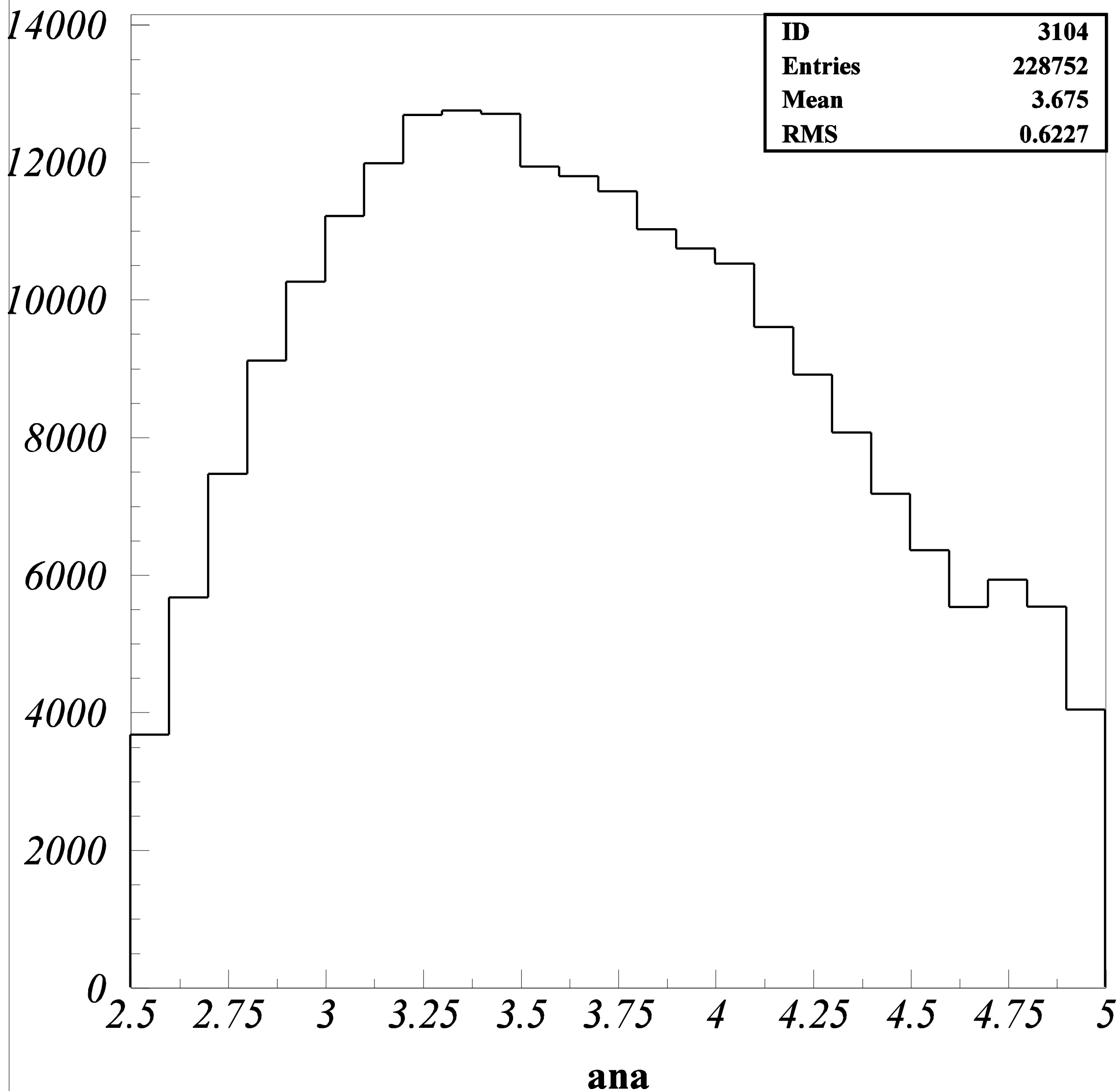
-> W-exchange processes seem to be negligible in the $R_{D^*\pi}$

- $B \to D_s^{(*)} K \pi$

Measurements of

$BF(B^+ \to D_s^- K^+\pi^+) = 1.71 \pm 0.08\ (stat) \pm 0.20\ (syst) \pm 0.15\ (B_{int}) \times 10^{-4}$
$BF(B^+ \to D_s^{*-} K^+\pi^+) = 1.31 \pm 0.13\ (stat) \pm 0.25\ (syst) \pm 0.12\ (B_{int}) \times 10^{-4}$

BACKUP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