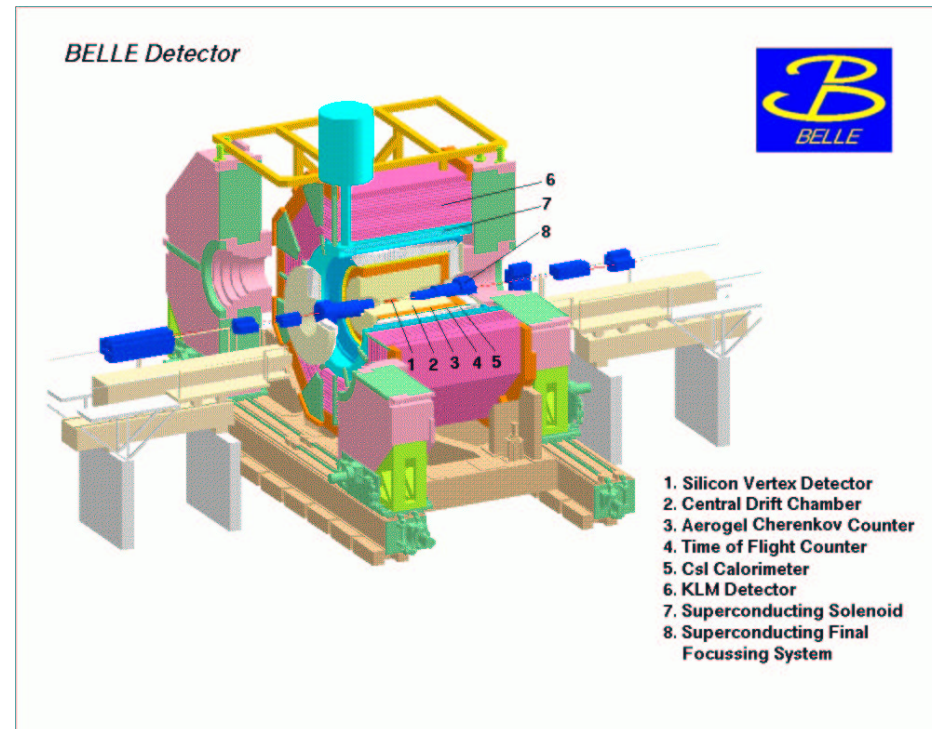


$$B^{\pm} \rightarrow D_{CP}K^{\pm} \text{ and } B^{\pm} \rightarrow D_{CP}^{*}K^{\pm}$$

Nick Kent
University of Hawai'i
Belle Collaboration

August 2004

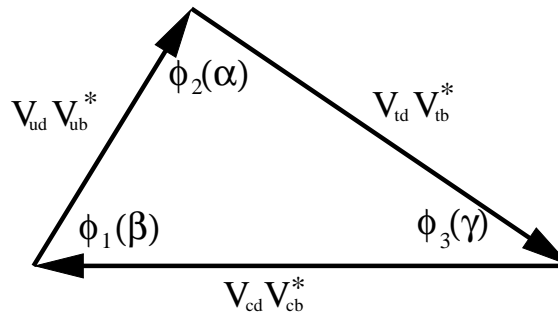
KEKB Accelerator and Belle



- $\sim 900 \text{ pb}^{-1}/\text{day}$ (~ 1 million $B\bar{B}$ /day), $\sim 280 \text{ fb}^{-1}$ on tape
- These results use all available data
274 million $B\bar{B}$ events

Theory Background

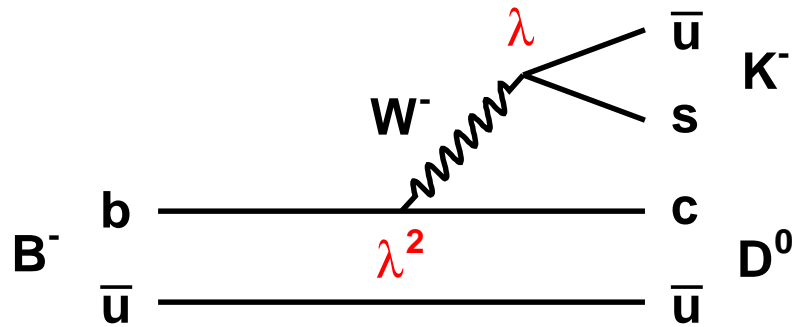
- use unitarity of CKM matrix and obtain two expressions



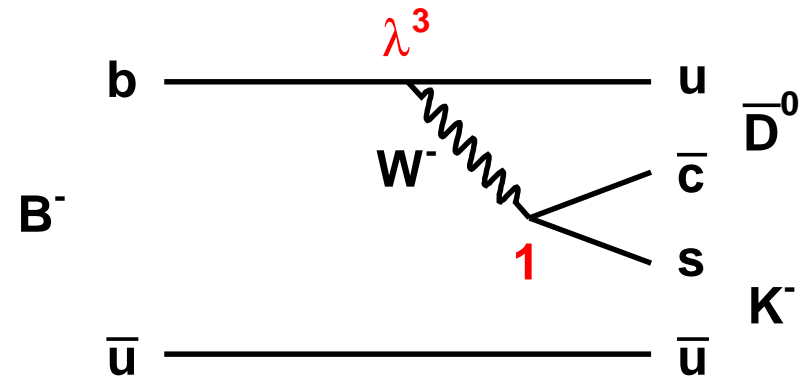
- $V_{ud} V_{ub}^* + V_{cd} V_{cb}^* + V_{td} V_{tb}^* = 0$
- $\phi_3(\gamma) = \arg(V_{ub}^*)$
- this study focuses on $B^\pm \rightarrow D_{CP}^{(*)0} K^\pm$ [M. Gronau and D. London, Phys. Lett. B **253**, 483 (1991) and M. Gronau and D. Wyler, Phys. Lett. B **265**, 172 (1991)]
 - need a common final state
 - $A(B^- \rightarrow D_{CP} K^-) \simeq |A(B^- \rightarrow D^0 K^-)| + |A(B^- \rightarrow \bar{D}^0 K^-)| e^{i\phi_3} e^{i\delta}$
 - $A(B^+ \rightarrow D_{CP} K^+) \simeq |A(B^+ \rightarrow D^0 K^+)| + |A(B^+ \rightarrow \bar{D}^0 K^+)| e^{-i\phi_3} e^{i\delta}$
 - CP even(D_1), $K^+ K^-$, $\pi^+ \pi^-$
 - CP odd(D_2), $K_s \pi^0$, $K_s \omega$, $K_s \phi$, $K_s \eta$

Coupling Strengths for $B^\pm \rightarrow DK^\pm$ versus $B^\pm \rightarrow D\pi^\pm$

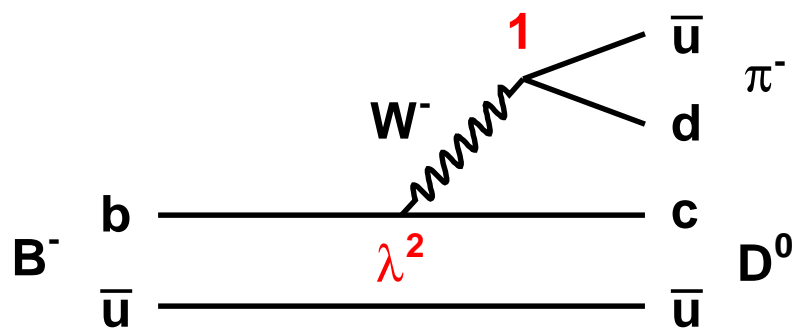
$B^- \rightarrow D^0 K^-$



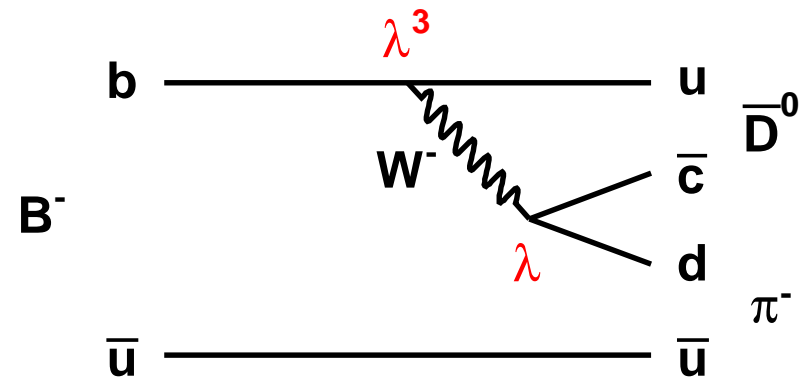
$B^- \rightarrow \bar{D}^0 K^-$



$B^- \rightarrow D^0 \pi^-$



$B^- \rightarrow \bar{D}^0 \pi^-$



Observables in $B^\pm \rightarrow D_{CP}K^\pm$

- easier to measure double ratio ($R_{1,2} = R_{+,-}$ and $\mathcal{A}_{1,2} = \mathcal{A}_{CP+,CP-}$)

$$R_{1,2} = \frac{R^{D_{CP}}}{R^{D_f}} = 1 + r^2 \pm 2r \cos(\delta) \cos(\phi_3)$$

where

$$R^{D_{CP}} = \frac{\mathcal{B}(B^- \rightarrow D_{1,2}K^-) + C.C.}{\mathcal{B}(B^- \rightarrow D_{1,2}\pi^-) + C.C.}$$

$$\mathcal{A}_{1,2} = \frac{\mathcal{B}(B^- \rightarrow D_{1,2}K^-) - \mathcal{B}(B^+ \rightarrow D_{1,2}K^+)}{\mathcal{B}(B^- \rightarrow D_{1,2}K^-) + \mathcal{B}(B^+ \rightarrow D_{1,2}K^+)}$$

$$r^2 = (R_1 + R_2)/2$$

and

$$A_1 R_1 = -A_2 R_2$$

so we have 3 independent measurements and 3 unknowns

- if we add another decay mode D_{CP}^*K we get another 3 independent observables
- but these depend on ϕ_3 , R_{D^*K} and δ_{D^*}
- R and δ can be different
- now there are 6 observables and 5 quantities so should be solvable

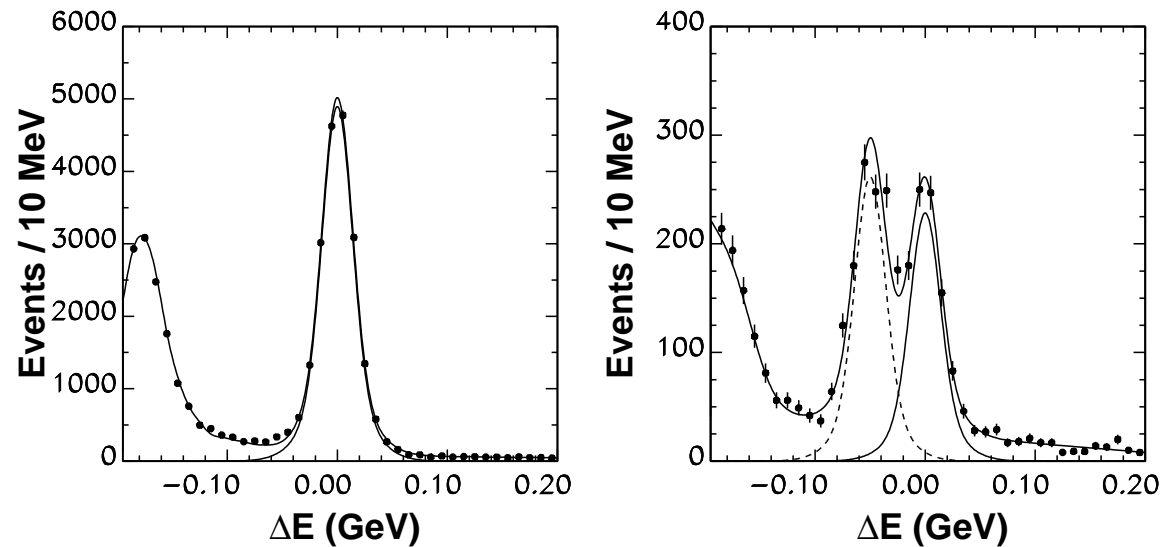
Event Selection

All cuts tuned on $D\pi$ mode, then same used for DK

- D^0 mass cut
 - $K\pi, KK, \pi\pi \pm 3\sigma (5 \text{ MeV}/c^2)$
 - other modes have asymmetric cuts based on exp. distributions, around $1.84 - 1.89 \text{ GeV}/c^2$
- Particle IDentification, $KK \text{ PID} > 0.2, \pi\pi \text{ PID} < 0.55$
- intermediate states
 - $M(K_s^0)$ within $\pm 8.5 \text{ MeV}/c^2$
 - $118 \text{ MeV}/c^2 < M(\gamma\gamma) < 150 \text{ MeV}/c^2, E_\gamma > 0.03 \text{ GeV}$
 - $0.757 \text{ GeV}/c^2 < M(\omega) < 0.807 \text{ GeV}/c^2, \pi \text{ PID} < 0.9$
 - $1.000 \text{ GeV}/c^2 < M(\phi) < 1.035 \text{ GeV}/c^2$
 - $0.495 \text{ GeV}/c^2 < M(\eta) < 0.600 \text{ GeV}/c^2$
- for $P \rightarrow PV$ modes, helicity angle cuts are applied
- likelihood ratio optimised for each $D\pi$ and each DK mode
- D^* modes, $|\Delta m - 0.14201| < 3 \times 0.9 \text{ MeV}$
- fast π or K PID, $< 0.8 (> 0.8)$

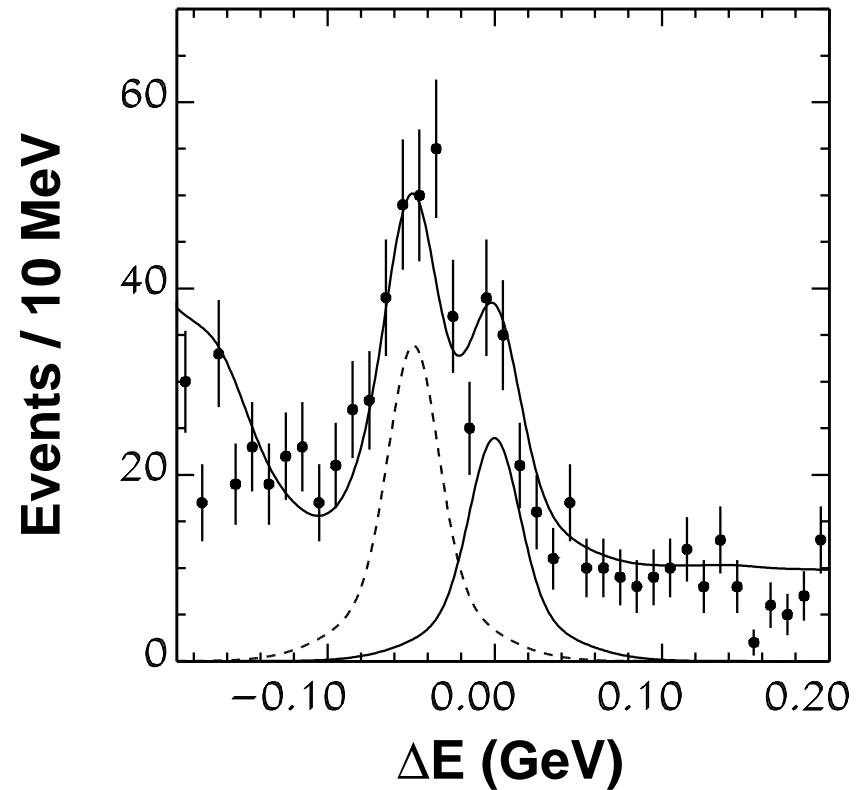
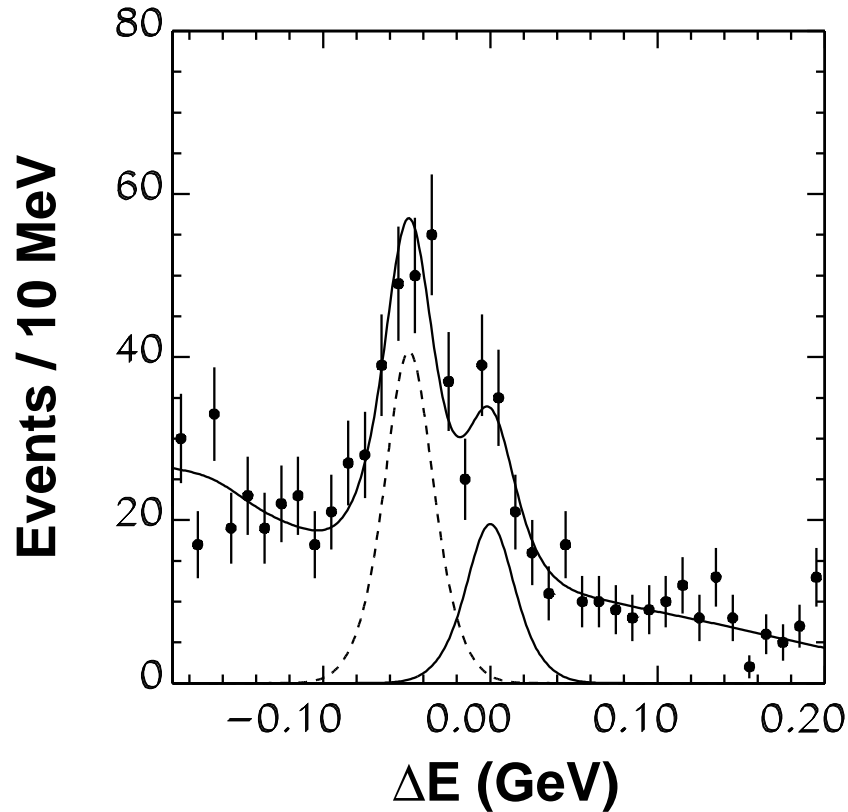
Non-CP mode $D^0 \rightarrow K^- \pi^+$ Control Sample

$B^\pm \rightarrow D^0 \pi^\pm$ left, $B^\pm \rightarrow D^0 K^\pm$ right



- $\Delta E = \sum_i E_i - E_{beam}$
- using shape from generic mc, straight line fitted to 0.1 \rightarrow 0.2 and double gaussian for each peak
- $D\pi$ yield: 19283 ± 150
- DK yield: 1031 ± 39

$$B^\pm \rightarrow D_1^0 K^\pm, B^\pm \rightarrow D_2^0 K^\pm$$



- D_1K yield: 114 ± 21
- D_2K yield: 167 ± 21

Peaking Backgrounds in D_1

- background in $B^\pm \rightarrow D(K^+K^-)K^\pm$, from $B^\pm \rightarrow K^+K^-K^\pm$
 - 37 ± 6 events observed, consistent with [Belle-conf-0410 @ ICHEP]
- background in $B^\pm \rightarrow D(\pi^+\pi^-)K^\pm$, from $B^\pm \rightarrow \pi^+\pi^-K^\pm$
 - 15 ± 10 events observed, consistent with [Belle-conf-0410 @ ICHEP]
- yields also consistent with BaBar hep-ex/0408082
- subtracted from yields and asymmetries for D_1
- no peaking backgrounds observed for D_2

Preliminary $B^\pm \rightarrow D^0 K^\pm$ yields

D mode	total	+	-	\mathcal{A}
$D_f K$	1031 ± 39	484 ± 27	549 ± 28	0.06 ± 0.04
$D_1 K$	114 ± 21	49 ± 15	63 ± 14	0.07 ± 0.14
$D_2 K$	167 ± 21	94 ± 17	75 ± 16	-0.11 ± 0.14

$$\mathcal{A}_1 = 0.07 \pm 0.14(stat) \pm 0.06(sys)$$

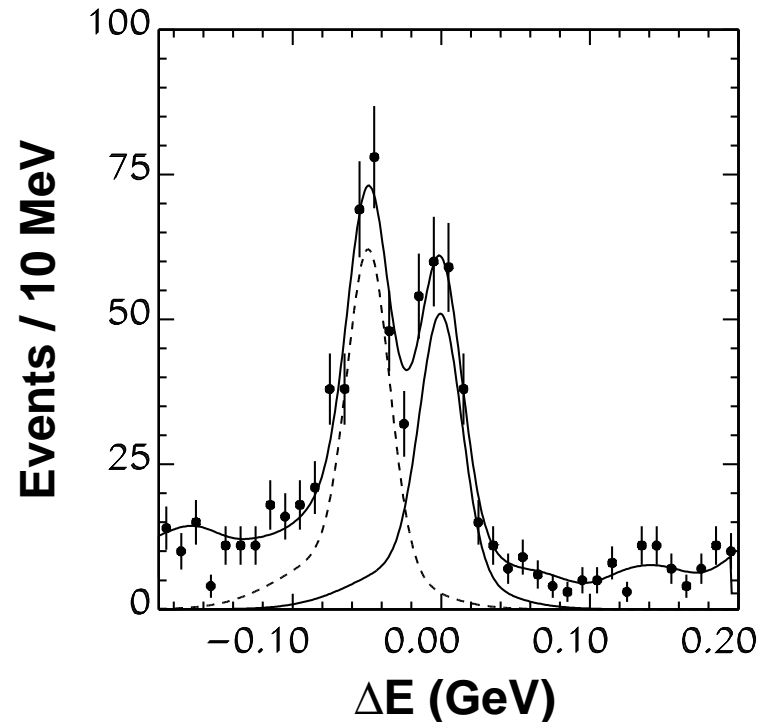
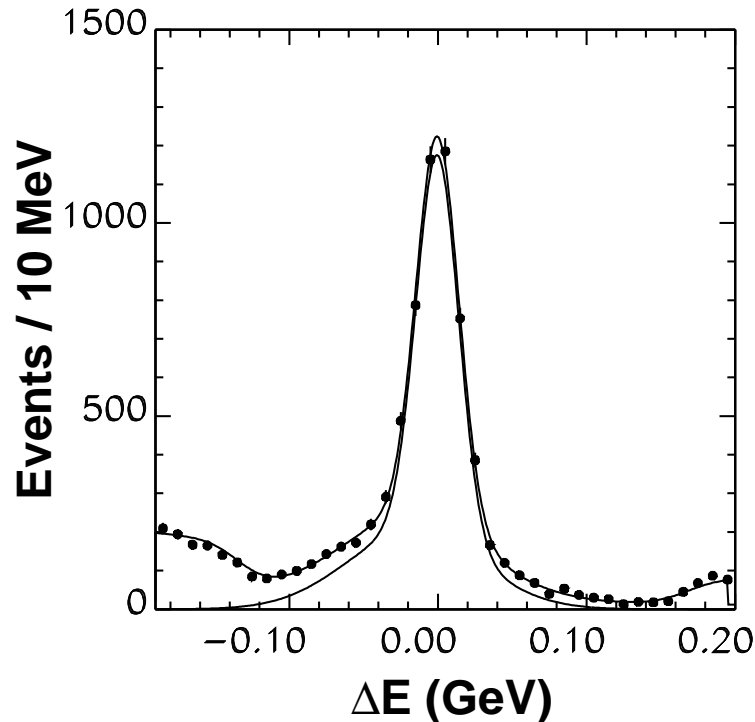
$$\mathcal{A}_2 = -0.11 \pm 0.14(stat) \pm 0.05(sys)$$

$$\mathcal{R}_1 = \frac{D_1 K / D_1 \pi}{DK / D\pi} = 0.98 \pm 0.18(stat) \pm 0.10(sys)$$

$$\mathcal{R}_2 = \frac{D_2 K / D_2 \pi}{DK / D\pi} = 1.29 \pm 0.16(stat) \pm 0.08(sys)$$

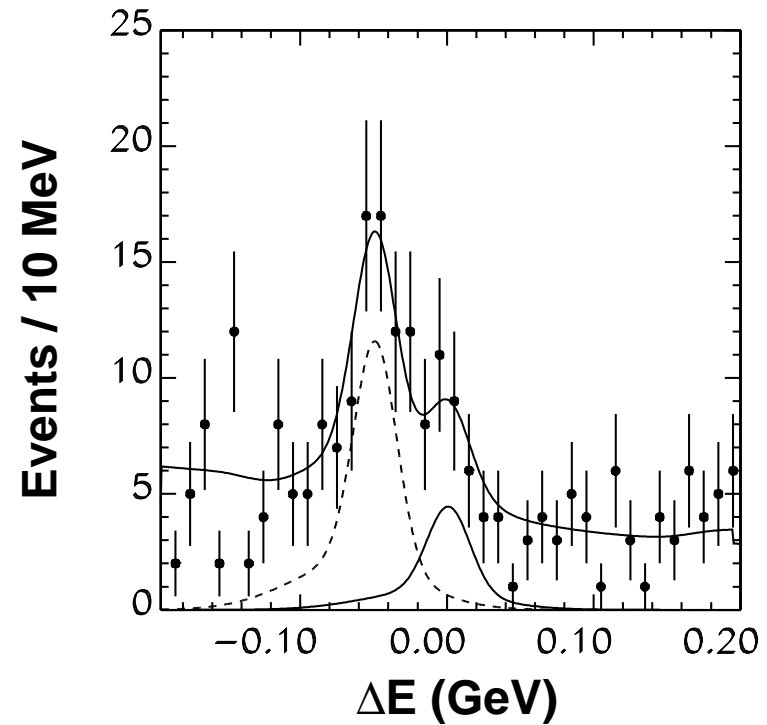
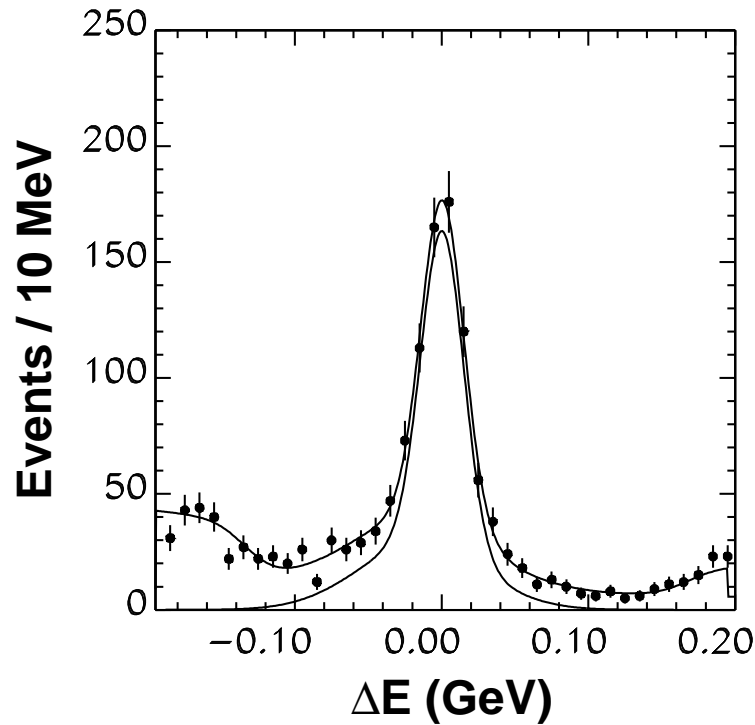
First look at D^*_{non-CP} Control Sample

D^* plots, $D^{*0}\pi$ left, $D^{*0}K$ right but more interested in D_1^{*0} and D_2^{*0}



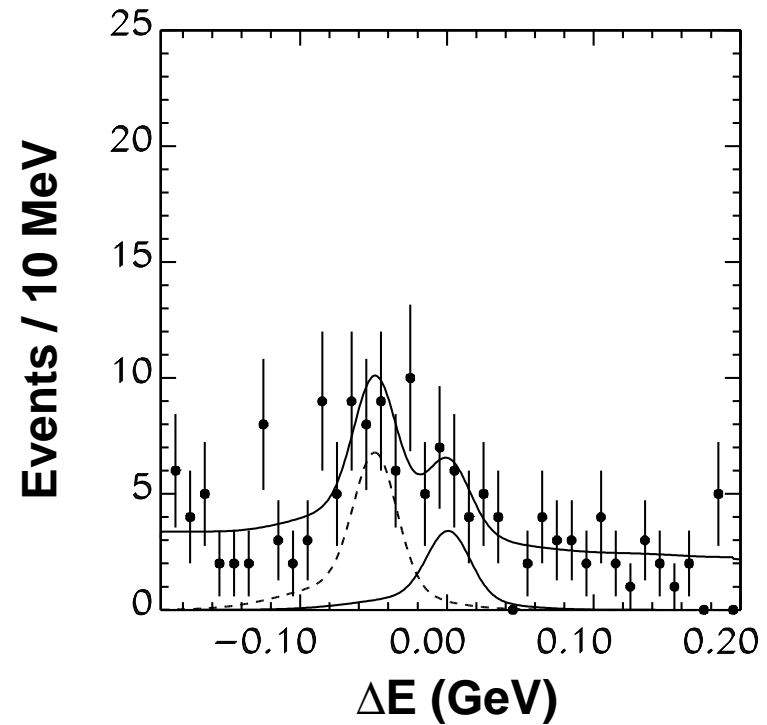
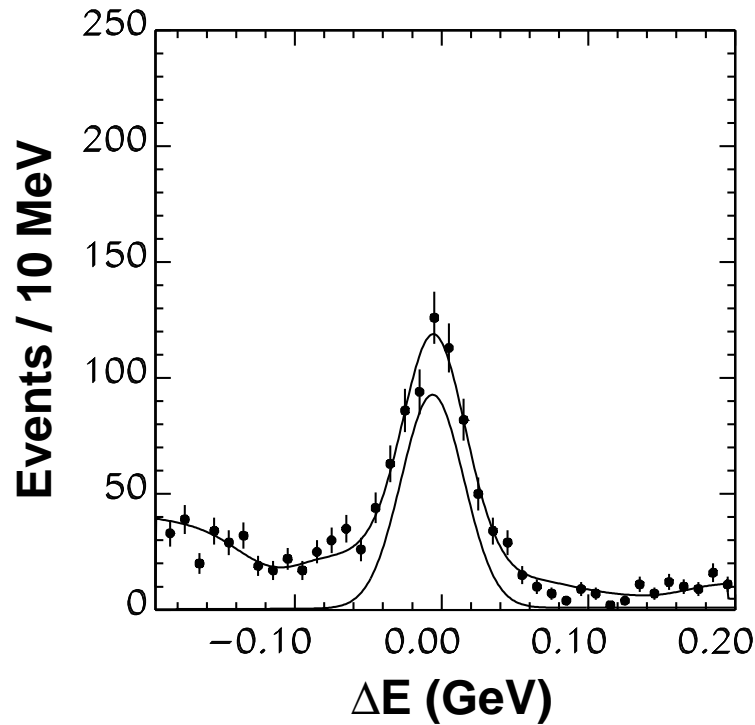
- $D^*\pi$ yield: 5762 ± 101
- D^*K yield: 284 ± 23

$B^\pm \rightarrow D_1^{*0} \pi^\pm$ and $B^\pm \rightarrow D_1^{*0} K^\pm$



- $D_1^* \pi$ yield: 795 ± 41
- $D_1^* K$ yield: 56 ± 11
- $D_1^* K$ significance 5.6σ

$B^\pm \rightarrow D_2^{*0} \pi^\pm$ and $B^\pm \rightarrow D_2^{*0} K^\pm$



- $D_2^* \pi$ yield: 715 ± 37
- $D_2^* K$ yield: 33 ± 10
- $D_2^* K$ significance 4.5σ

Preliminary $B^\pm \rightarrow D^{*0}K^\pm$ yields

D mode	total	+	-	\mathcal{A}
D_f^*K	284 ± 23	158 ± 16	127 ± 16	-0.11 ± 0.08
D_1^*K	56 ± 11	33 ± 8	19 ± 8	-0.27 ± 0.25
D_2^*K	33 ± 10	13 ± 6	22 ± 7	0.26 ± 0.26

$$\mathcal{A}_1 = -0.27 \pm 0.25(stat) \pm 0.04(sys)$$

$$\mathcal{A}_2 = 0.26 \pm 0.26(stat) \pm 0.03(sys)$$

$$\mathcal{R}_1 = \frac{D_1^*K/D_1^*\pi}{D^*K/D^*\pi} = 1.43 \pm 0.28(stat) \pm 0.06(sys)$$

$$\mathcal{R}_2 = \frac{D_2^*K/D_2^*\pi}{D^*K/D^*\pi} = 0.94 \pm 0.28(stat) \pm 0.06(sys)$$

Other ϕ_3 analyses on Belle

- Dalitz analysis using $B^+ \rightarrow D^0 K^+$, $B^+ \rightarrow D^{*0} K^+$ with $D^0 \rightarrow K_s^0 \pi^+ \pi^-$
 - see [Belle-Conf-0445](#), (Yan-Pan Lau will also talk about BaBar's results)
 - first measurement of ϕ_3
 - $\phi_3 = 77_{-19}^{+17} \pm 13^\circ(\text{syst}) \pm 11^\circ(\text{model})$
 - $r_B = 0.26_{-0.14}^{+0.10} \pm 0.03(\text{syst}) \pm 0.04(\text{model})$
- ADS method, utilises the maximal interference for $B^+ \rightarrow D^0(K^+\pi^-)K^+$
 - [Belle-Conf-0444](#)
 - $B \rightarrow D_{ADS}\pi$ yield: 30.7 ± 8.8 events, significance 5.8σ
 - $B \rightarrow D_{ADS}K$ yield: 14.7 ± 7.6 events, significance 2.7σ
 - $r_B < 0.28(90\%C.L.)$
- $B^0 \rightarrow D^{(*)0} K^0$, first evidence of $D^{*0} K^0$
 - [Belle-Conf-0446](#)
 - update of $\bar{B}^0 \rightarrow D^0 \bar{K}^0$ and $\bar{B}^0 \rightarrow D^0 \bar{K}^{*0}$

Preliminary Conclusions

- update of $D_{CP}K$ with 3 times more data

DK

$$\mathcal{A}_1 = 0.07 \pm 0.14(stat) \pm 0.06(sys), \mathcal{A}_2 = -0.11 \pm 0.14(stat) \pm 0.05(sys)$$

$$\mathcal{R}_1 = 0.98 \pm 0.18(stat) \pm 0.10(sys), \mathcal{R}_2 = 1.29 \pm 0.16(stat) \pm 0.08(sys)$$

- first observation of D_1^*K (5.6σ) and D_2^*K (4.5σ)

D^*K

$$\mathcal{A}_1 = -0.27 \pm 0.25(stat) \pm 0.04(sys), \mathcal{A}_2 = 0.26 \pm 0.26(stat) \pm 0.06(sys)$$

$$\mathcal{R}_1 = 1.43 \pm 0.28(stat) \pm 0.03(sys), \mathcal{R}_2 = 0.94 \pm 0.28(stat) \pm 0.06(sys)$$

- with values of r_{DK}, r_{D^*K} with more statistics these measurements will constrain ϕ_3