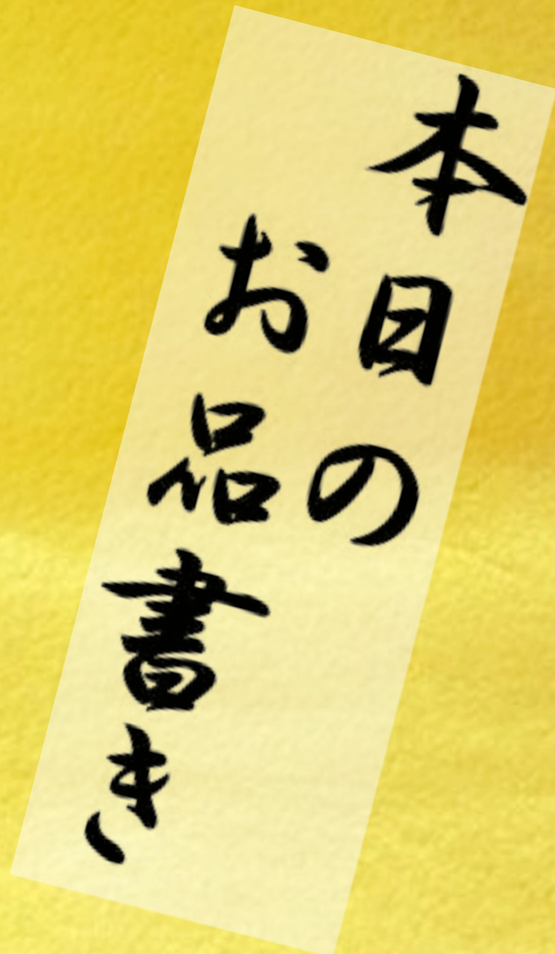
Study of the suppressed decay $B^- \rightarrow DK^-$ and $B^- \rightarrow D^{(*)}_{CP}K^-$ decays at Belle

Naoki Kikuchi
(Tohoku Univ)
on behalf of Belle collaboration

Today's menu

1. CKM model
2. ϕ_3 measurement
3. GLW method
   & $B^- \rightarrow D^{(*)}_{CP} K^-$ result
4. ADS method
   & $B^- \rightarrow D_{ADS} K^-$ result
5. Summary



1. CKM model

- **Weak interaction**

$$L = -\frac{g}{\sqrt{2}} \overline{U_L} \gamma^{\mu} V_{CKM} D_L W_{\mu}$$

$$\lambda \equiv \sin\theta_c \approx 0.22$$

$$|A| \approx |\rho| \approx |\eta| \approx O(1)$$

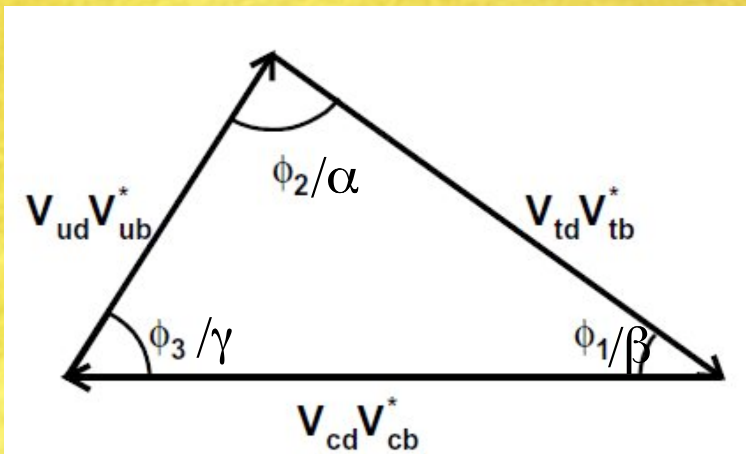
$$V_{CKM} \equiv \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \approx \begin{pmatrix} 1-\frac{\lambda^2}{2} & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\frac{\lambda^2}{2} & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix}$$

Complex component

- **Unitarity condition**

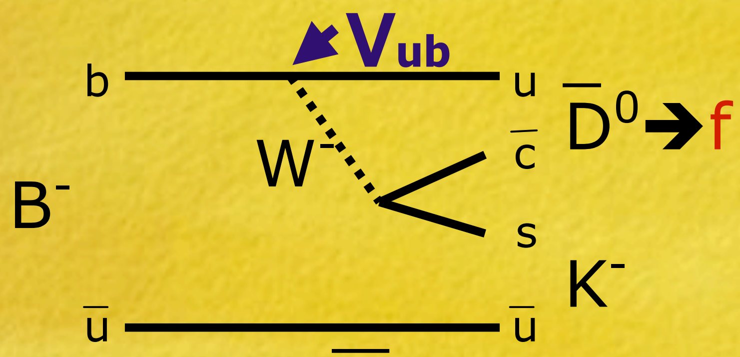
$$V_{CKM}{}^{+} V_{CKM} = 1$$

$$\Rightarrow V_{ud} V_{ub}{}^{*} + V_{cd} V_{cb}{}^{*} + V_{td} V_{tb}{}^{*} = 0$$

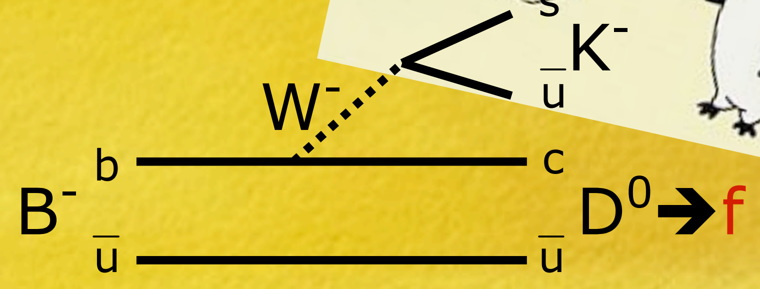


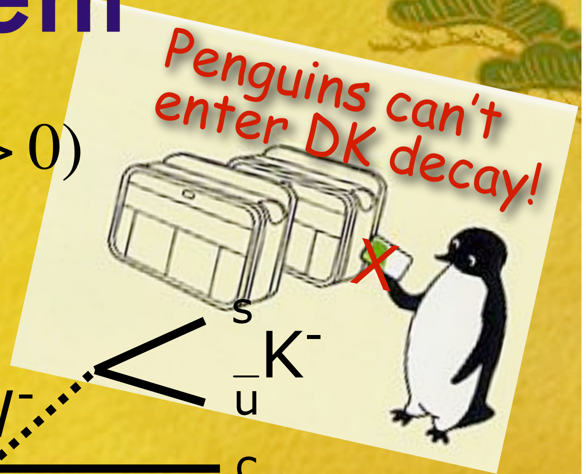
2. ϕ_3 measurement

$$\phi_3 \equiv \arg\left(\frac{V_{ud}V_{ub}{}^*}{-V_{cd}V_{cb}{}^*}\right) \approx \arg(V_{ub}{}^*) \quad (\because -V_{cd}V_{cb}{}^* > 0)$$



$B^- \to \overline{D}{}^0 K^-$





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

- D^0 and $\overline{D}{}^0$ decay into common final state, f.
  →Determine ϕ_3 through interference term.
- r_B determines the size of interference by ϕ_3.

$$r_B \equiv \left|\frac{A(B^- \to \overline{D}{}^0 K^-)}{A(B^- \to D^0 K^-)}\right|$$

- Choice of final state
  - f=[$K_S\pi^+\pi^-$] : Dalitz analysis → P.Krokovny's talk
  - f=D_+ [K^+K^-, $\pi^-\pi^-$], D_-[$K_S\pi^0$, $K_S\omega$, $K_S\phi$…] : GLW method
  - f=D_{ADS} [$K^+\pi^-$] / suppressed decay: ADS method

3. GLW method

M.Gronau and D. London, PLB **253**, 483 (1991)
M. Gronau and D. Wyler, PLB **265**, 172 (1991)

- Direct CPV

$$A_{\pm} = \frac{\Gamma(D_{\pm}K^{-}) - \Gamma(D_{\pm}K^{+})}{\Gamma(D_{\pm}K^{-}) + \Gamma(D_{\pm}K^{+})} = \frac{\pm 2 r_B \sin\phi_3 \sin\delta}{R_{\pm}}$$

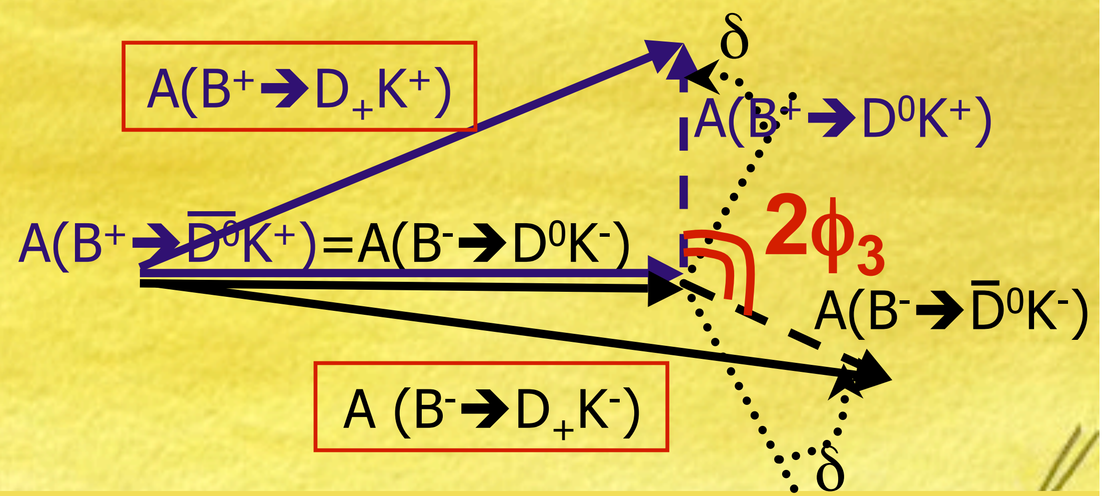
$$D_{\pm} \equiv \frac{D^0 \pm \overline{D^0}}{\sqrt{2}}$$

- Decay rate average

$$R_{\pm} = 2\frac{\Gamma(D_{\pm}K^{-}) + \Gamma(D_{\pm}K^{+})}{\Gamma(D^0K^{-}) + \Gamma(\overline{D}^0K^{+})} = 1 + r_B^2 \pm 2 r_B \cos\phi_3 \cos\delta$$

- D decay mode
  - CP=+ mode
    - K^+K^-, $\pi^+\pi^-$
  - CP=- mode
    - $K_S\pi^0$, $K_S\omega$, $K_S\phi$

3 unknowns r_B, δ, ϕ_3



- Features
  - Model independent
  - High statistics
  - Low sensitivity for r_B

3.1. Analysis procedure

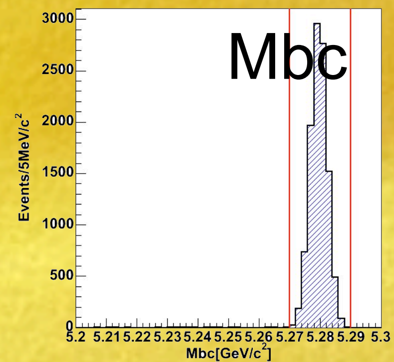
- 2 independent kinematic variables
  - ΔE : Energy difference

$$\Delta E \equiv E_D{}^* + E_K{}^* - E_{beam}{}^*$$

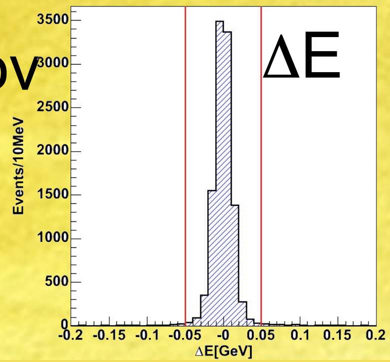
  - Mbc : Beam energy constrained mass

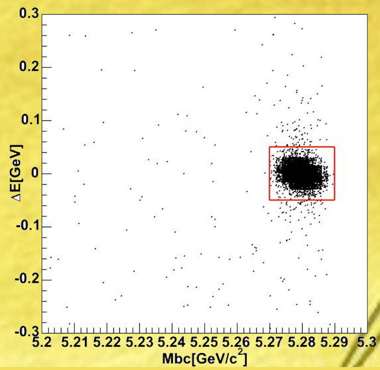
$$M_{bc} \equiv \sqrt{E_{beam}{}^{*2} - (\vec{p}_D{}^* + \vec{p}_K{}^*)^2}$$

Variables with * are evaluated in CM system



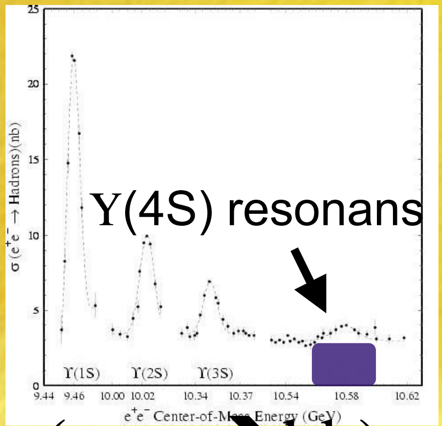
- D reconstruction
  - $|M_{rec}-M_D|<2.5\sigma$
  - PID ← dE/dx+TOF+Cherenkov
    For K, LR(K/π)>0.4
    For π, LR(K/π)<0.7





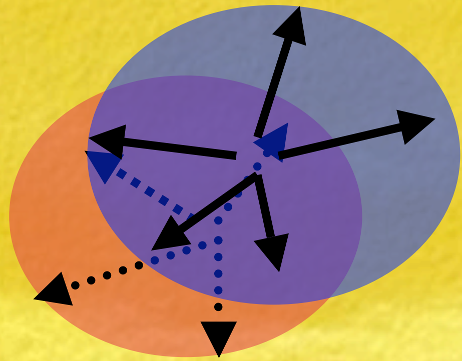
3.1. Analysis procedure (cont'd)

- Continuum background suppression

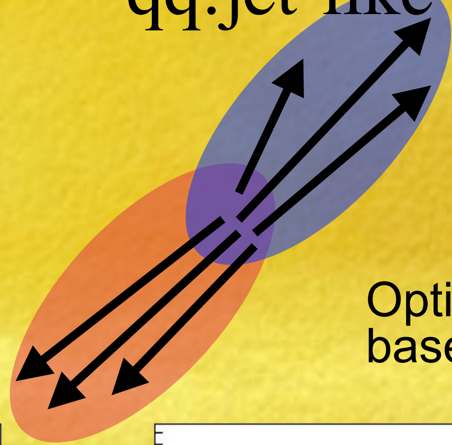


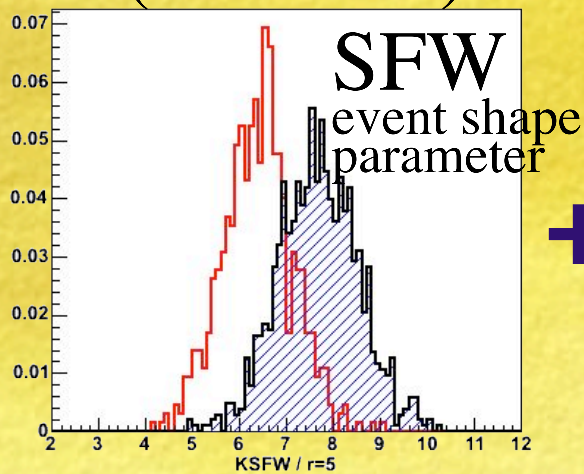
σ(e+e-➔hh)

$B\bar{B}$:spherical

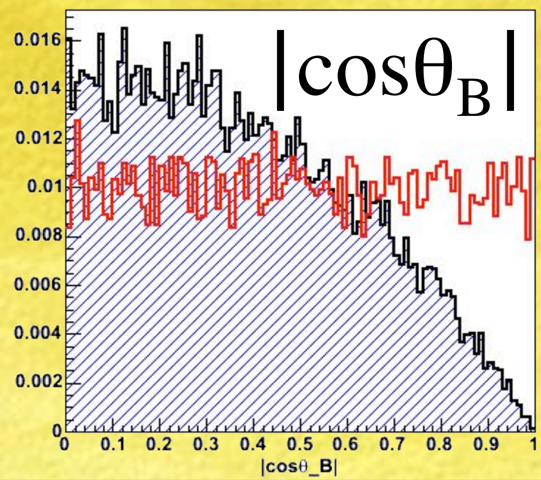


$q\bar{q}$:jet-like



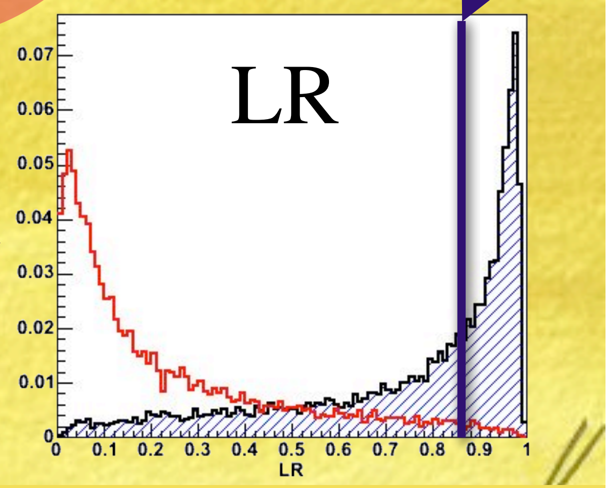


+



➔

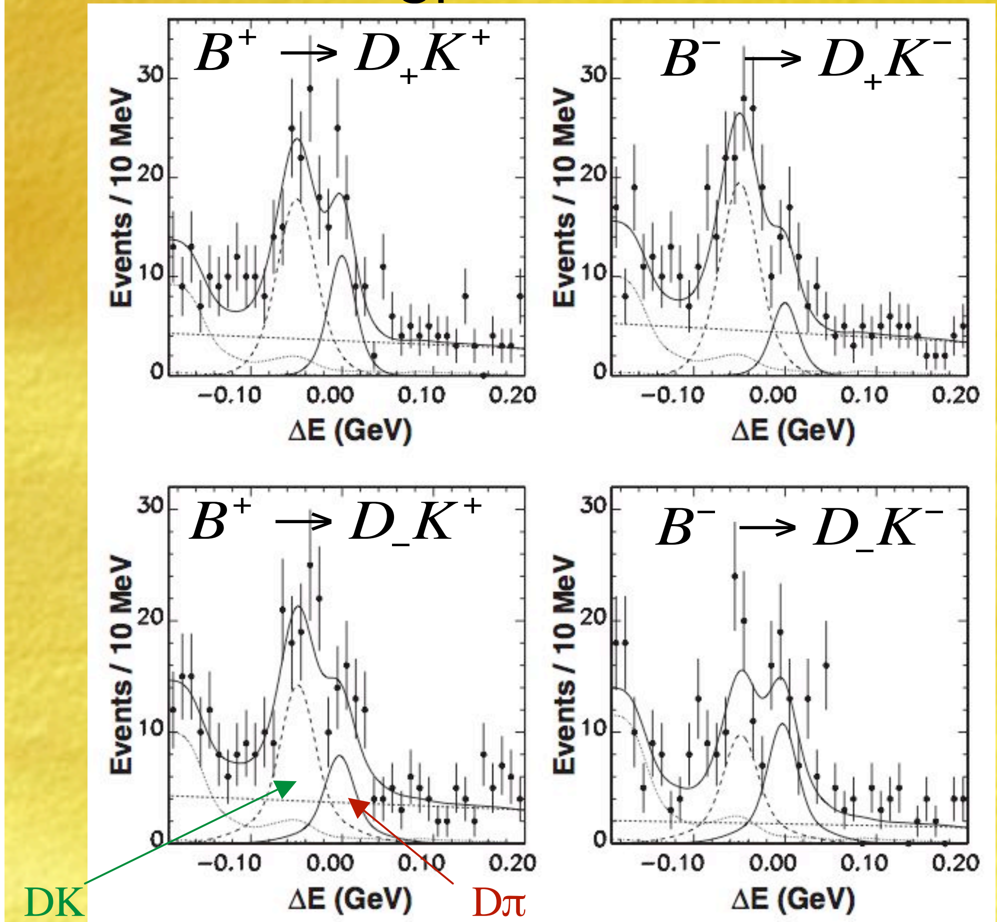
Optimized cut based on FOM



3.2. Result on $D_{CP}K$

- $B^- \rightarrow D_{CP}K^-$ w/Belle 274M BB

PRD 73, 051106 (2006)



$A_+ = 0.06 \pm 0.14 \pm 0.05$

$A_- = -0.12 \pm 0.14 \pm 0.05$

$R_+ = 1.13 \pm 0.16 \pm 0.05$

$R_- = 1.17 \pm 0.14 \pm 0.05$

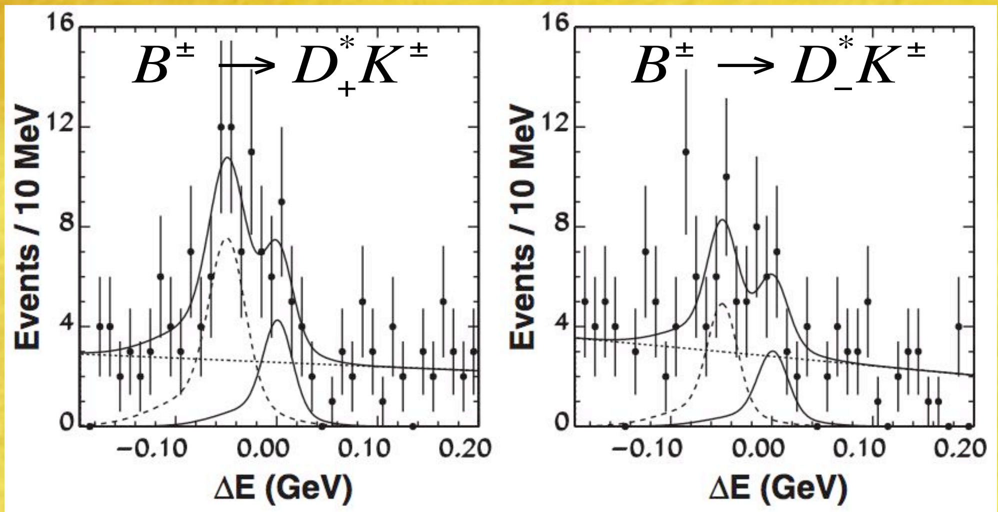
Yield:
D_+K : 143.3±21.9 (12.4σ)
D_-K : 149.5±19.0 (9.2σ)

Signals are established!
Significant deviations of $A_\pm \sim 0, R_\pm \sim 1$ are not seen.

3.2. Result on $D^*_{CP}K$

PRD 73, 051106 (2006)

- $B^- \rightarrow D^*_{CP}K^-$ w/Belle 274M BB
  Using $D^* \rightarrow D\pi^0$ mode



$A_+ = -0.2 \pm 0.22 \pm 0.04$

$A_- = 0.13 \pm 0.3 \pm 0.08$

$R_+ = 1.41 \pm 0.25 \pm 0.06$

$R_- = 1.15 \pm 0.31 \pm 0.12$

Yield:
D^*_+K : 43.9±10.2 (5.2σ)
D^*_-K : 32.7±10.0 (3.3σ)

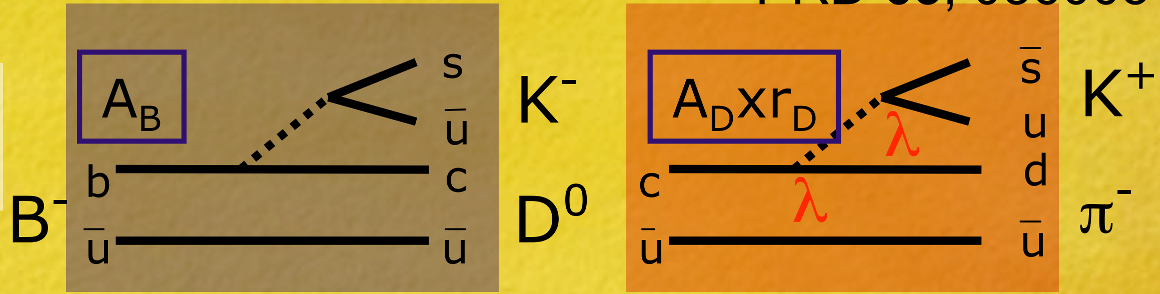
Signals are established!
Significant deviations of
A±~0,R±~1 are not seen.

4. ADS method

D. Atwood, I. Dunietz and A. Soni, PRL **78**, 3357 (1997)
PRD **63**, 036005 (2001)

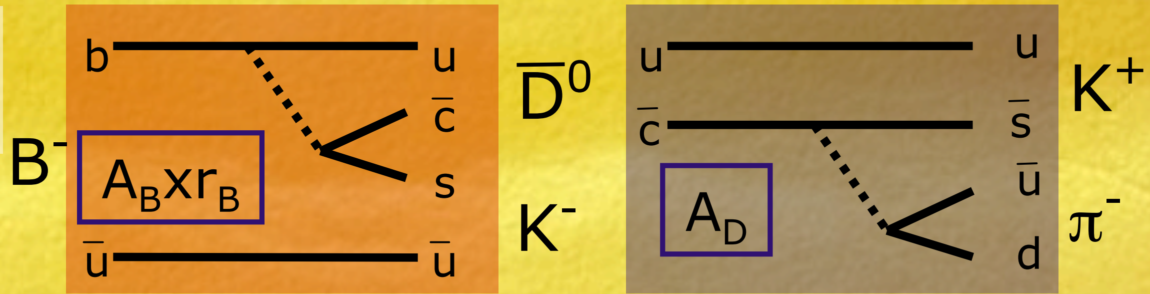
- **Decay mode**

$B^- \to D^0 K^-$
 ↳ $K^+\pi^-$



Color allowed x Doubly-Cabibbo sup.

$B^- \to \bar{D}^0 K^-$
 ↳ $K^+\pi^-$



Color sup. x Cabbibo allowed

- **CP asymmetry**

$$\Gamma(B^- \to [K^+\pi^-]K^-) = (r_B^2 + r_D^2 + 2r_B r_D \cos(\delta - \phi_3)) \,|\, A_B \,|^2 |\, A_D \,|^2$$

$$\Gamma(B^+ \to [K^-\pi^+]K^+) = (r_B^2 + r_D^2 + 2r_B r_D \cos(\delta + \phi_3)) \,|\, A_B \,|^2 |\, A_D \,|^2$$

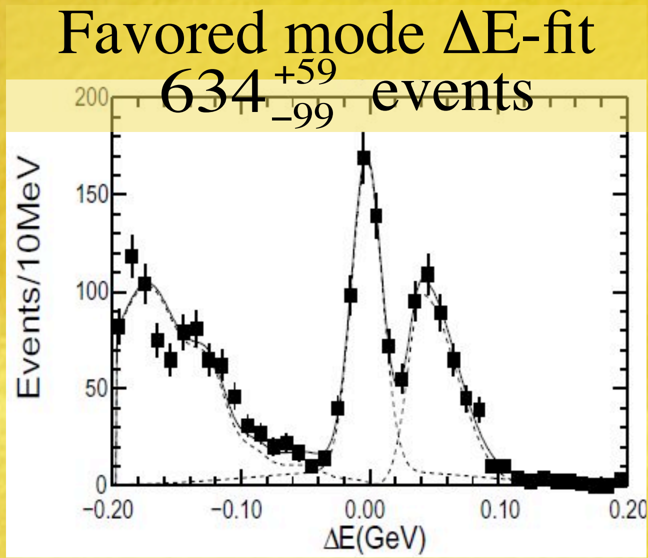
- **Features**
  - Low statistics
  - High sensitivity

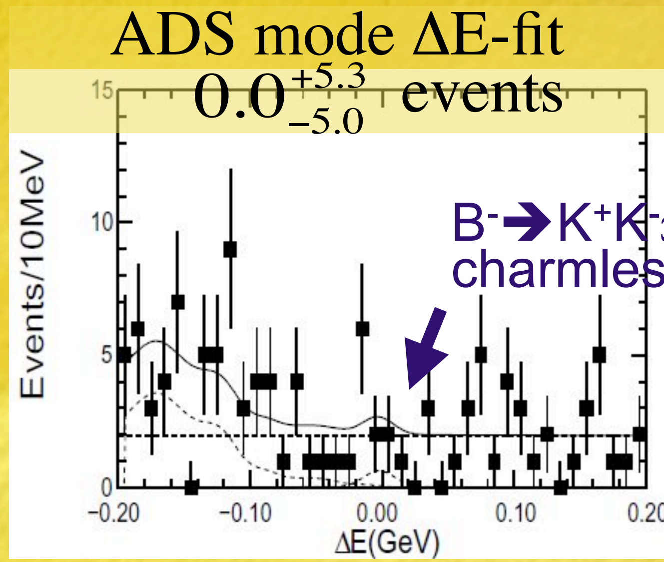
3 unknowns r_B, δ, ϕ_3
well measured r_D, A_B, A_D

4.1. Result on $D_{ADS}K$

- $B^- \rightarrow D_{ADS}K^-$ w/Belle 386M BB

hep-ex/0508048(2005)





Favored mode

$$\Gamma(B^{\mp} \rightarrow D_{fav}[K^{\mp}\pi^{\pm}]K^{\mp}) \approx |A_B|^2 |A_D|^2$$

$$R_{DK} \equiv \frac{\Gamma(B^{\pm} \rightarrow D_{ADS}K^{\pm})}{\Gamma(B^{\pm} \rightarrow D_{fav}K^{\pm})}$$

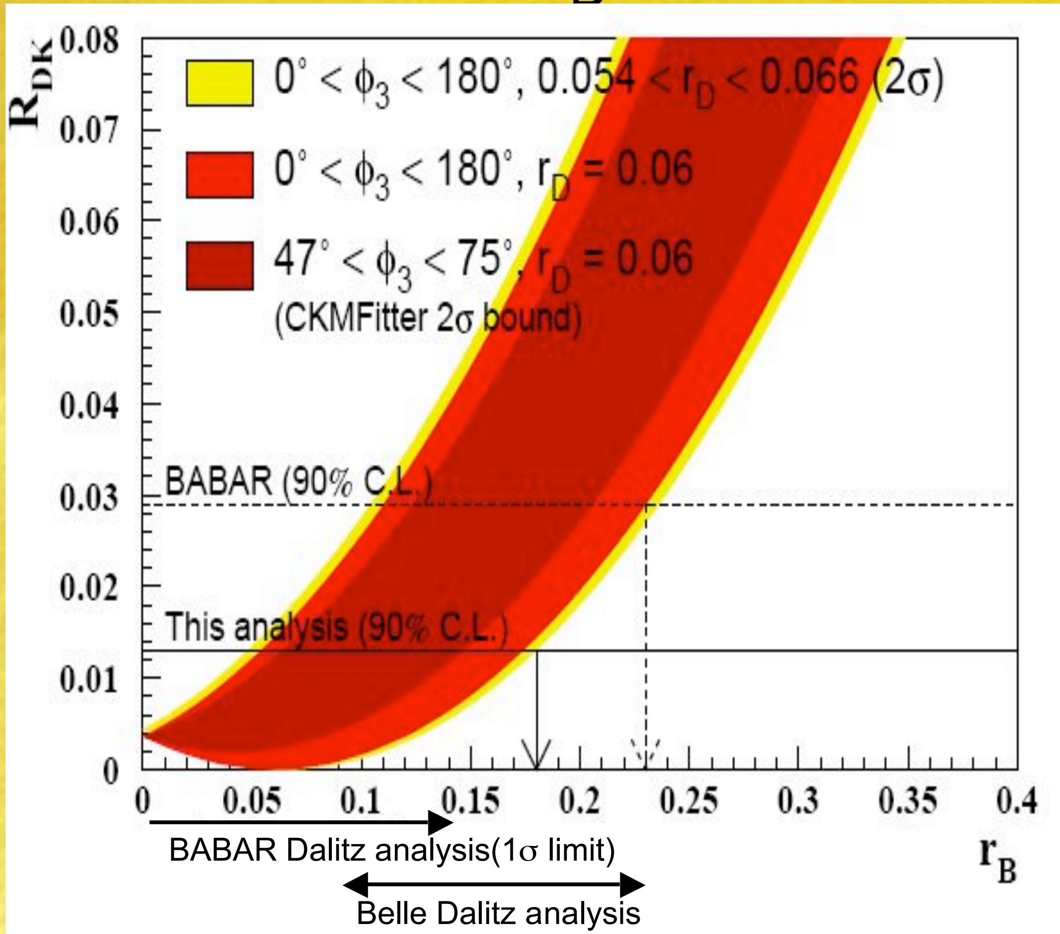
$$= r_B^2 + r_D^2 + 2r_B r_D \cos\phi_3 \cos\delta$$

$$= (0.0^{+8.4}_{-7.9}(stat) \pm 1.0(syst)) \times 10^{-3}$$

$$< 0.014(90\%C.L.)$$

4.1. Result (cont'd)

- Constraint for r_B with $B^- \to DK^-$ decay



hep-ex/0508048(2005)

Varying $0<\phi_3,\delta<\pi$, $\pm 2\sigma$ for r_D,

$$r_B < 0.18$$

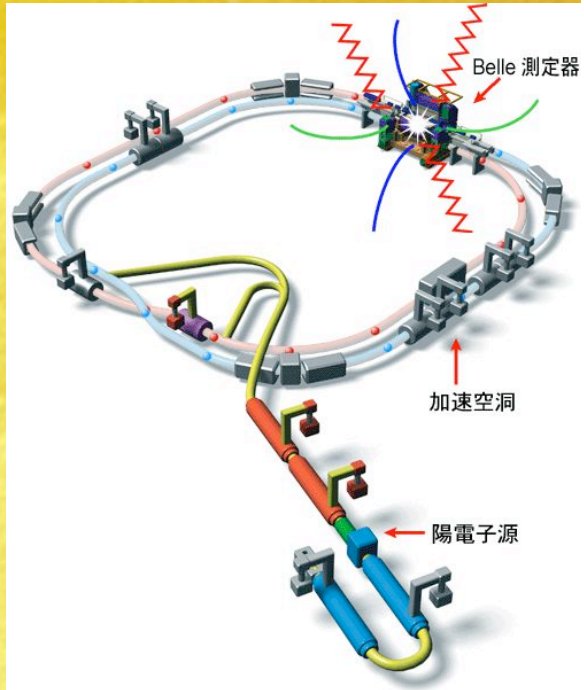
(90% C.L.)

BABAR Dalitz analysis
hep-ex/0607104(2006)
Belle Dalitz analysis
PRD 73, 112009(2006)

5. Summary

- GLW & ADS method are model independent methods to extract ϕ_3.
- GLW
  - Measurement for $B^- \rightarrow D_{CP}K^- / D^*_{CP}K^-$
  - Signals are established
  - DCPV is not seen yet.
- ADS
  - Search for $B^- \rightarrow D_{ADS}K^-$
  - Signal is not seen yet
  - But we give a constraint on r_B.

$B\bar{B}$s are being mass-produced!

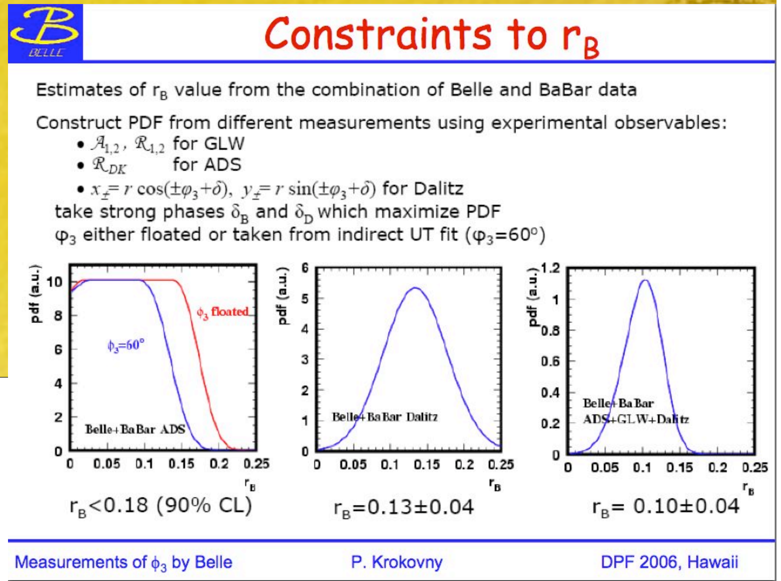


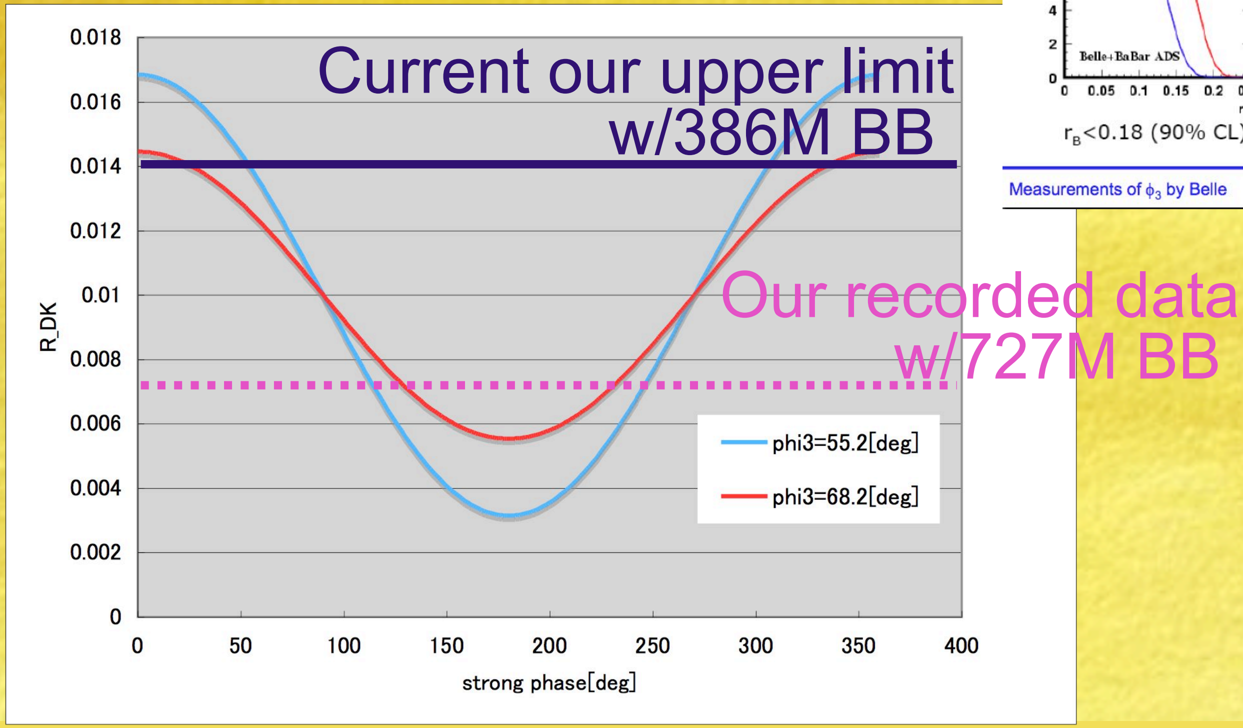
- We need more $B\bar{B}$s.

Backup

How much we need luminocity for $D_{ADS}K$?

- Assumptions
  - r_B=0.1 (Dalitz+ADS+Dalitz)
  - ϕ_3=55.2 ~ 68.2^{o}





$D^{(*)}_{CP}K$ systematics

R	Signal fraction	1.3%
	Yield extraction	6–8%
	Peaking background	1.3–2%
A	Intrinsic detector bias	1%
	Signal fraction	1.3%
	Yield extraction	2–4%
	Particle identification	1%