Rare B decays

Fourth Workshop on
Mass Origin and Supersymmetry Physics

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Hidekazu Kakuno

(Univ. of Tokyo)

Introduction: rare B-meson decays

Major B meson decays:

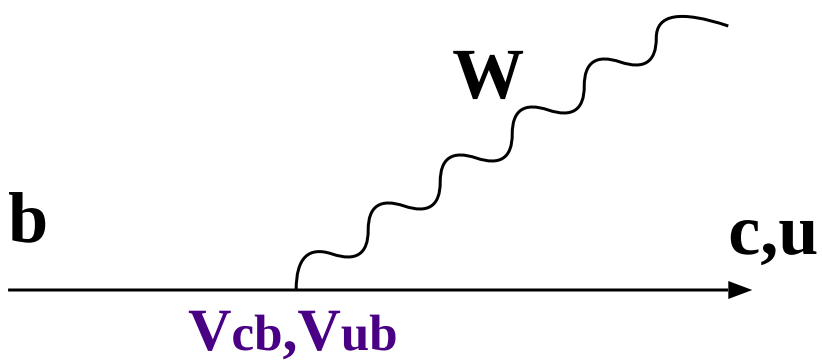
supressed by the CKM matrix element V_{cb}

For some rare B-meson decays:

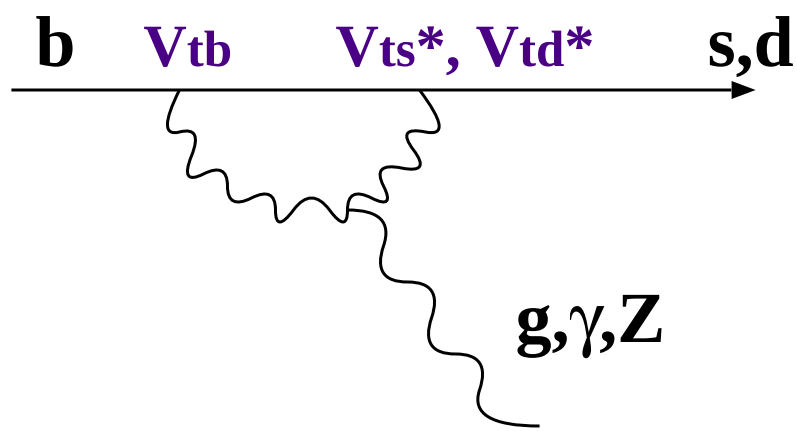
Tree diagram is highly suprresed by the CKM matrix element V_{ub}

Non-negligible contribution of the one loop (penguin) diagram

1. **Decays from tree and penguin diagram**
   -> **search for the direct CP violation**
2. **Decays from penguin diagram**
   -> **search for the new physics that may appear in the loop**



Tree diagram



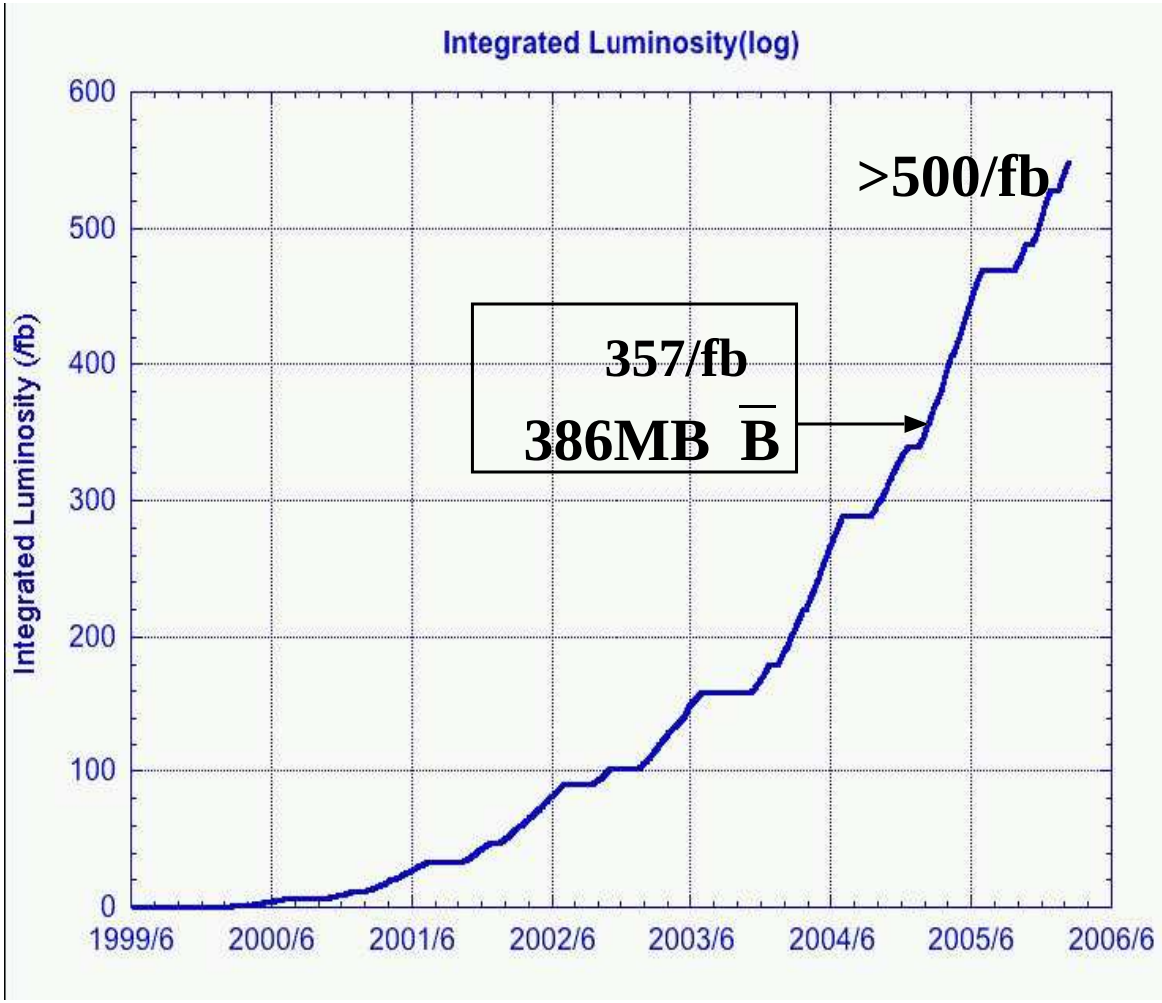
penguin diagram

Introduction: Belle experiment

Integrated luminosity

Belle /KEKB accumulate more than 500/fb data

Many exciting analysis results of the rare B meson decays



This talk includes:

1. **measurement of the direct CP Violation in B→ Kπ**
2. **search for b→d processes**
   b→dγ
   B→KK
3. **Forward-backward asymmetry in B →K*ll**

analyses using 357/fb data

1. measurement of the direct CP Violation in $B \rightarrow K\pi$

Introduction: Direct CP violation

Direct CP violation: $\Gamma(\ \bar{B}\to\ \bar{f}\ ) \neq \Gamma(\ B\to f)$

two diagrams are required to contribute to the decay

Direct CP Asymmetry:

$$A_{cp} = \frac{\Gamma(\ \bar{B}\to\ \bar{f}\ ) - \Gamma(\ B\to f)}{\Gamma(\ \bar{B}\to\ \bar{f}\ ) + \Gamma(\ B\to f)}$$

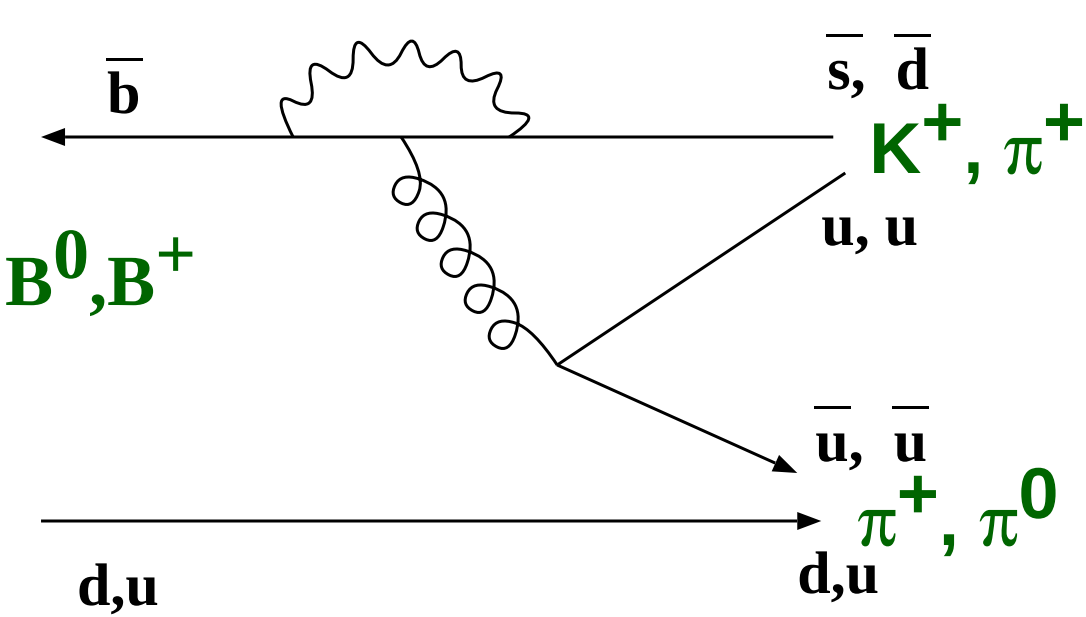
$$= \frac{2|A_1/A_2|\ \sin(\Delta\phi)\sin(\Delta\delta)}{1+|A_1/A_2|^2+2|A_1/A_2|\ \cos(\Delta\phi)\ \cos(\Delta\delta)}$$

Large direct CP violation if:

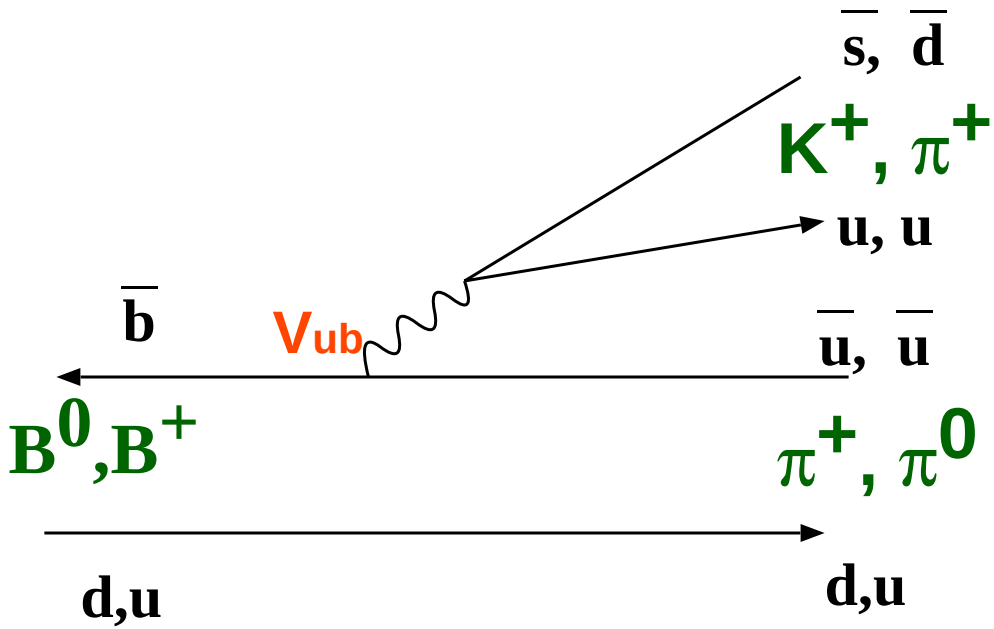
- the ratio of the two amplitudes $|A_1/A_2| \sim 1$
- the difference of the weak phase $\Delta\phi$ is large
- the difference of the strong phase $\Delta\delta$ is large

Introduction: B → K π / π π

penguin diagram and tree diagram contribute to the decay



Penguin diagram



Tree diagram

tree diagram is supressed by Vub

Amplitudes of Penguin and Tree diagram are comparable

→ possiblity to observe a large CP violation

Analysis tools: Continuum background suppression

Major background: continuum q $\bar{q}$ events

- B $\bar{B}$ events ~1nb

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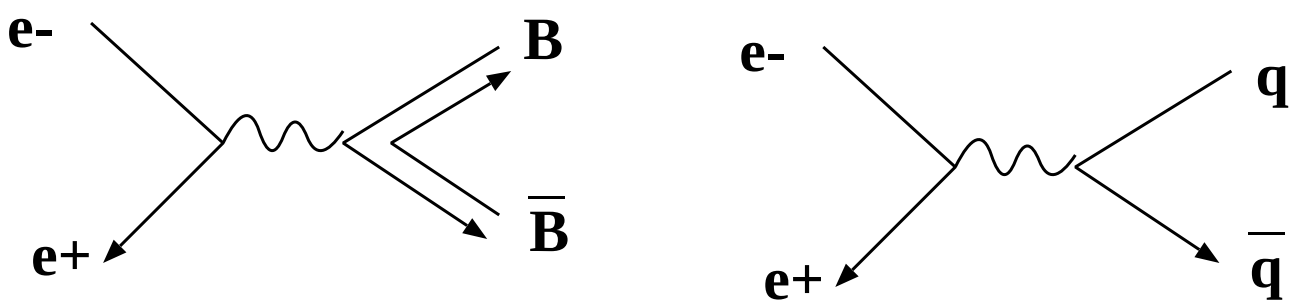
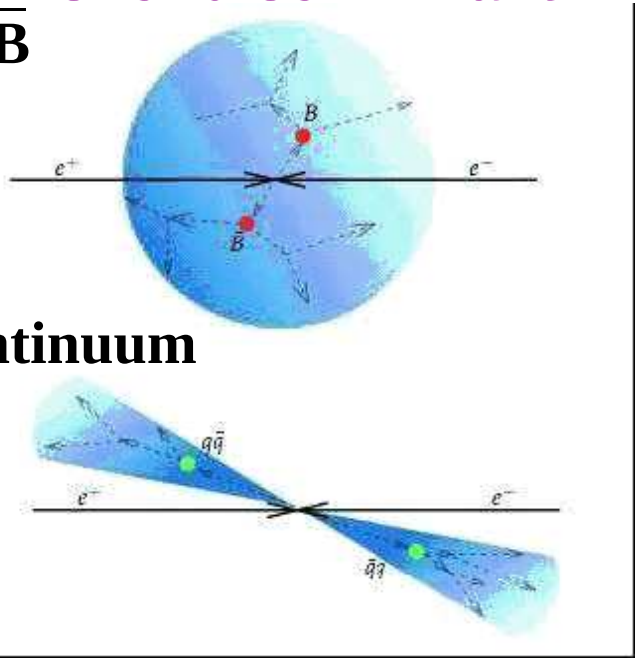
- continuum q $\bar{q}$ events (q = u, d, s, c) ~ 3nb

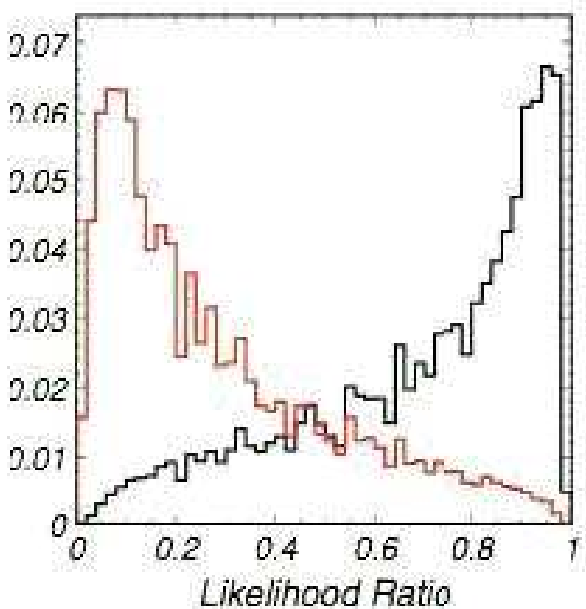


Event topology -> Fisher discriminant

B $\bar{B}$

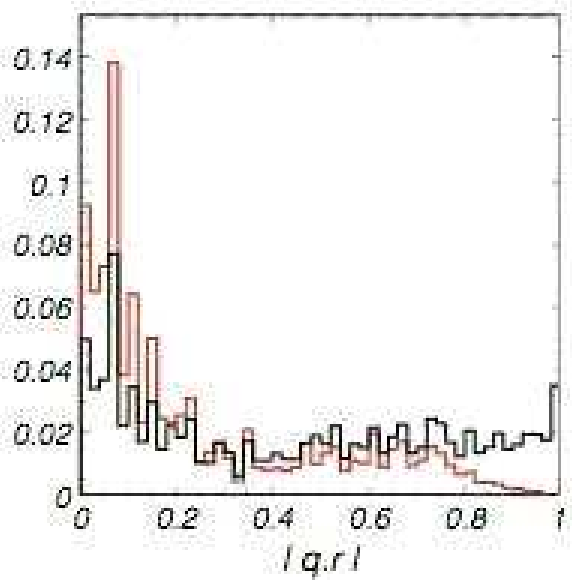


B flight direction



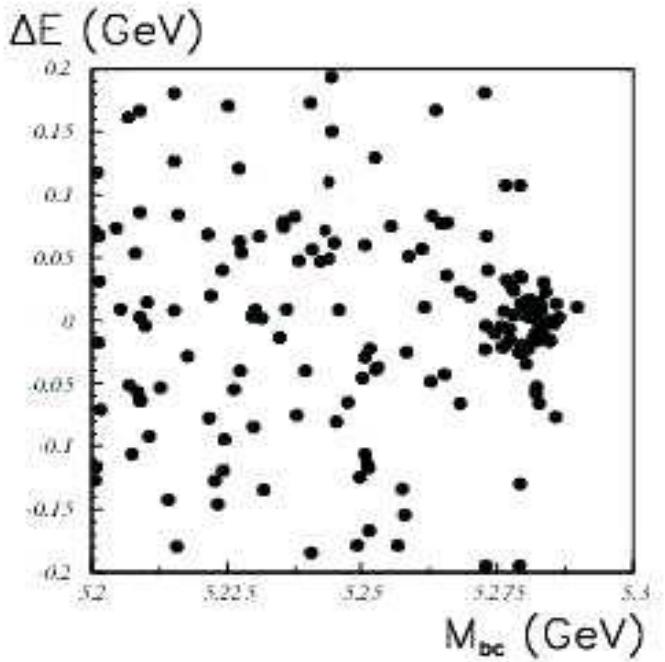
B-Flavor tagging info.

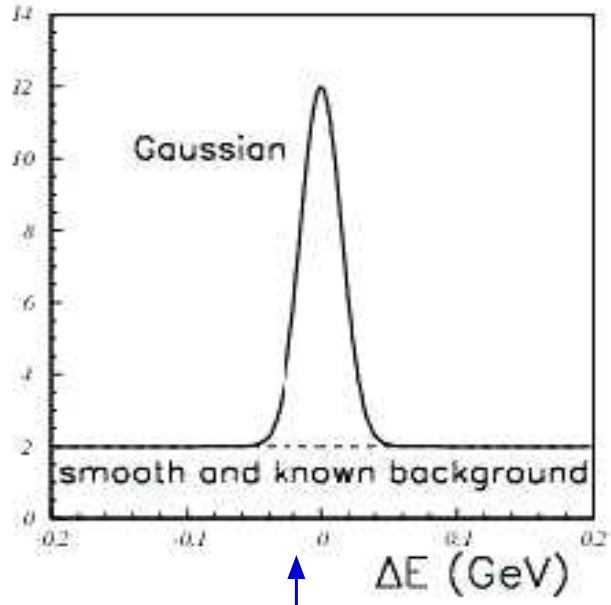
- particle species in the rest of the events



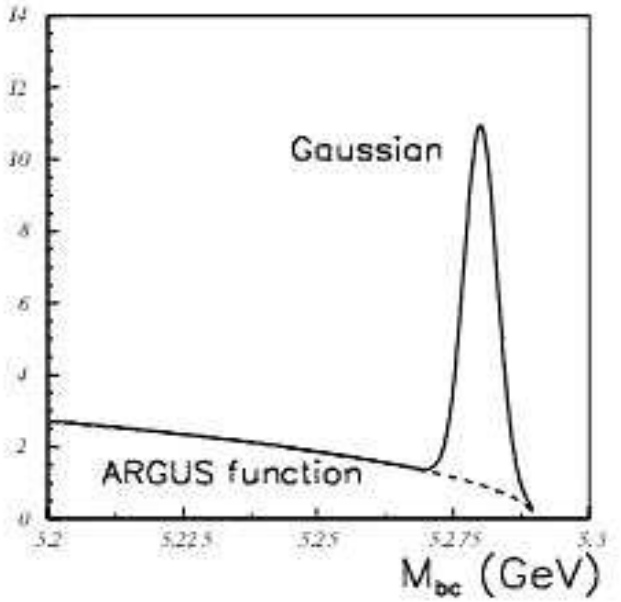
Analysis tools: B reconstruction

Use two variables to reconstruct B mesons from $\Upsilon(4S)$ decay:





$$\Delta E = \Sigma E_i - E_{CM}/2$$



$$M_{bc} = \sqrt{(E_{CM}/2)^2 - |\Sigma p_i|^2}$$

$A_{CP}(B^0 \to K^+\pi^-)$

Unbinned maximum likelihood fit to (Mbc, ΔE) distribution

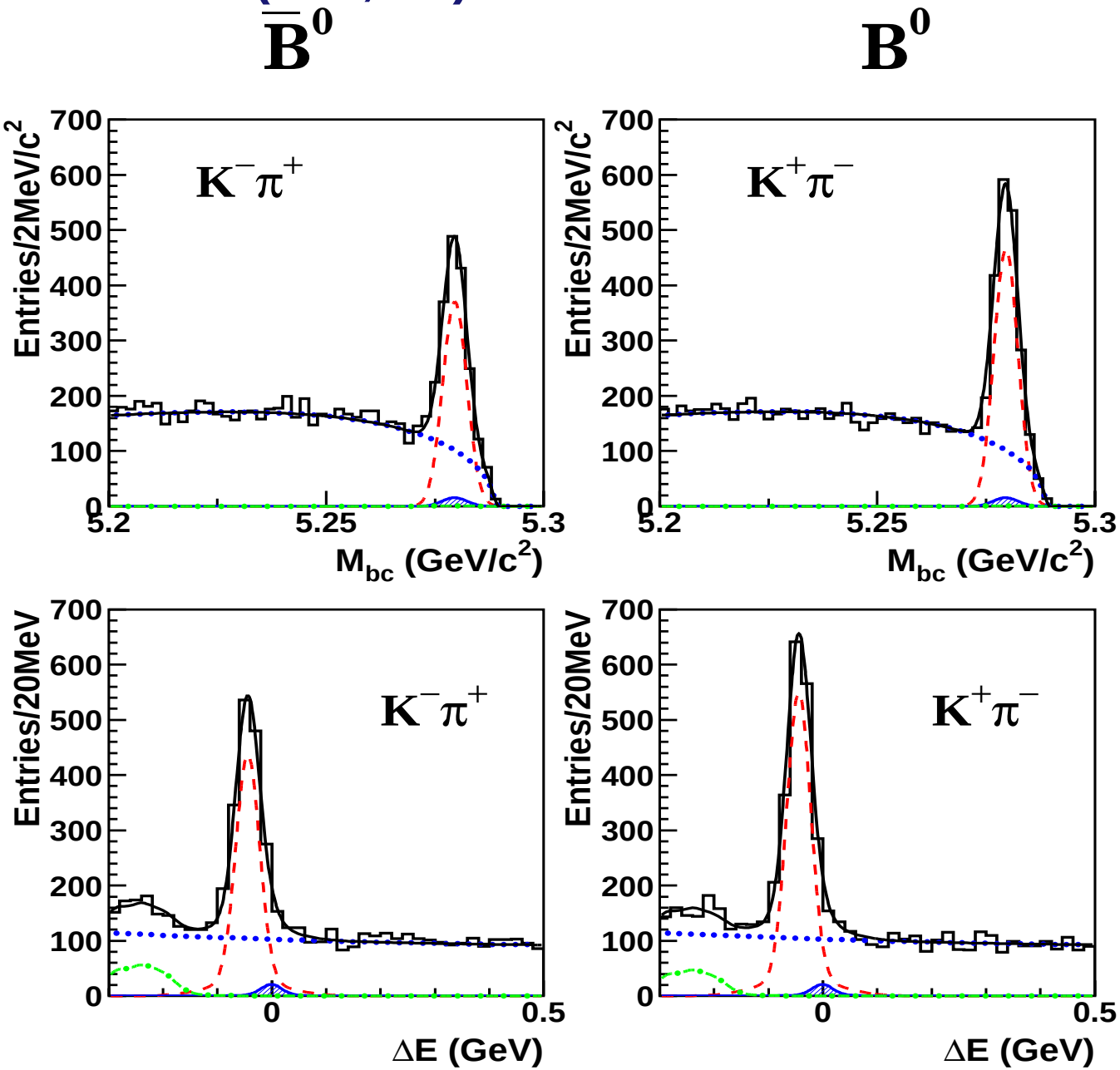
Signal yields: 3026 ± 53

$$A_{CP}(B^0 \to K^+\pi^-) = -0.113 \pm 0.022_{stat} \pm 0.008_{syst}$$

5.0σ

preliminary

(including syst. uncertainty)



consistent with the value reported by BaBar:

A_{CP}=-0.113±0.022±0.008

(4.2σ; PRL 93, 131801(2004))

hepex/0507045

$A_{CP}(B^+ \to K^+\pi^0)$

$A_{CP}(B^+ \to K^+\pi^0) =$

$+0.04 \pm 0.04 \pm 0.02$

preliminary

No DCPV observed

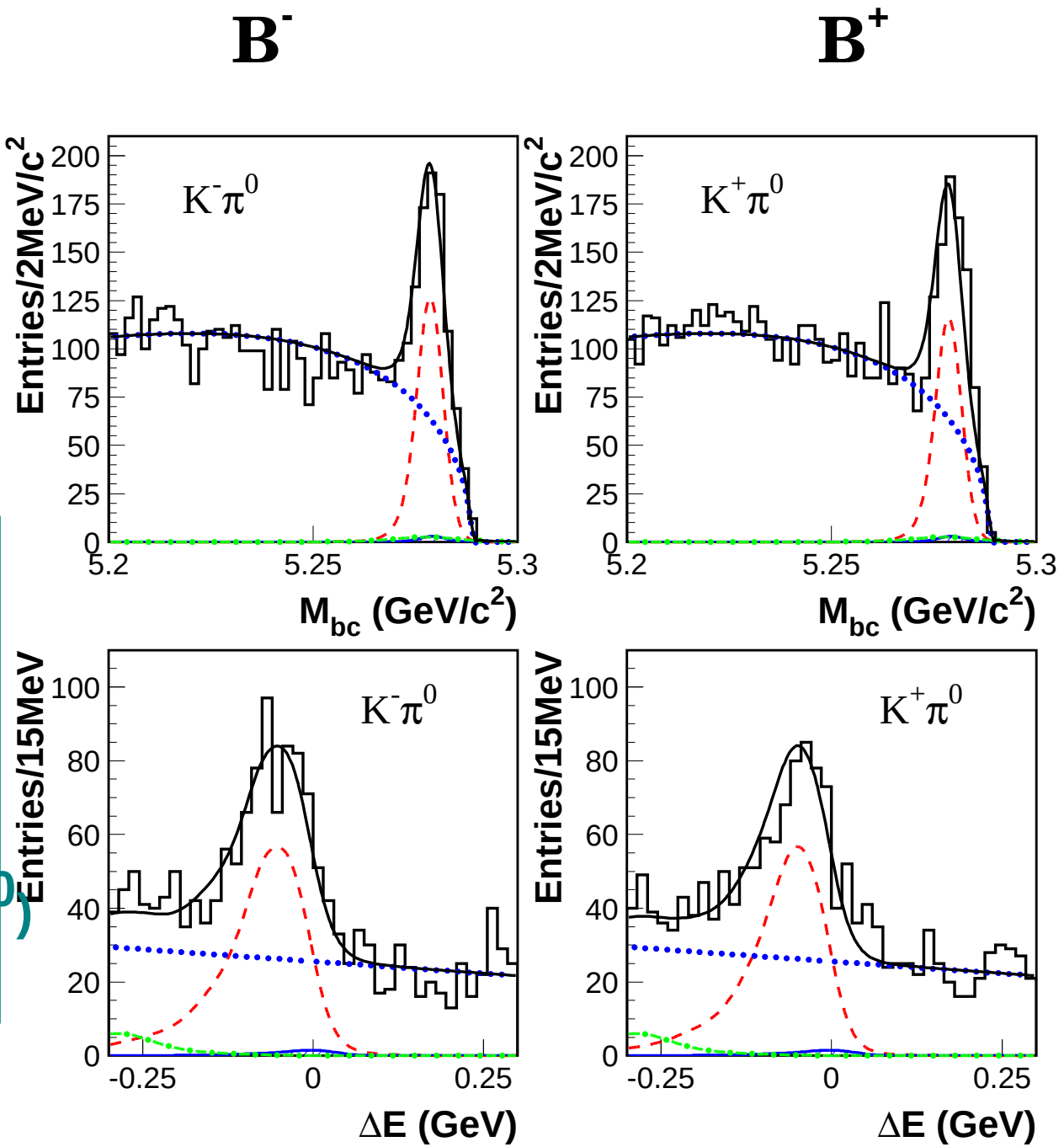
3.1σ difference from

$A_{CP}(B^0 \to K^+\pi^-)$

puzzling

Naive expectation from SM:

$A_{CP}(B^0 \to K^+\pi^-) \sim A_{CP}(B^+ \to K^+\pi^0)$



2. search for $b \to d$ process

$b \to d\gamma$

$B \to KK$

Introduction: search for b→d

b→d transition

- loop diagram -> sensitive to the new physics

- highly suppressed compared to the b→s transition ($|V_{td}/V_{ts}|^2 \sim 1/100$)

the decay modes with pure b→d processes:

posibility to observe the CP violation through the interference between SM and NP processes in the loop

increase of
the integrated luminosity

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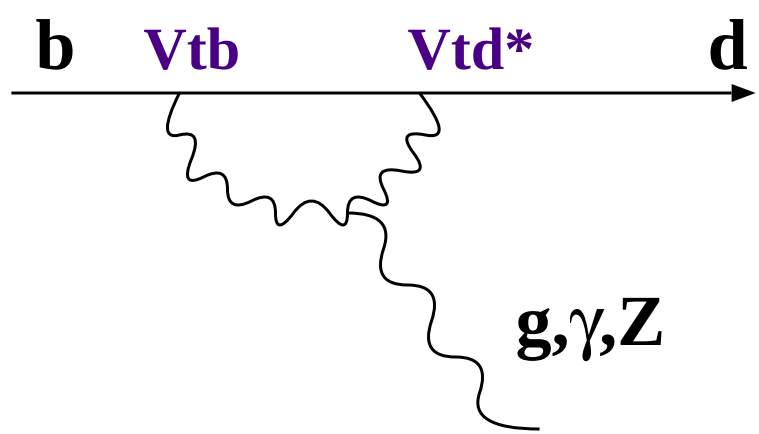
decays with pure b→d processes
become accesible!

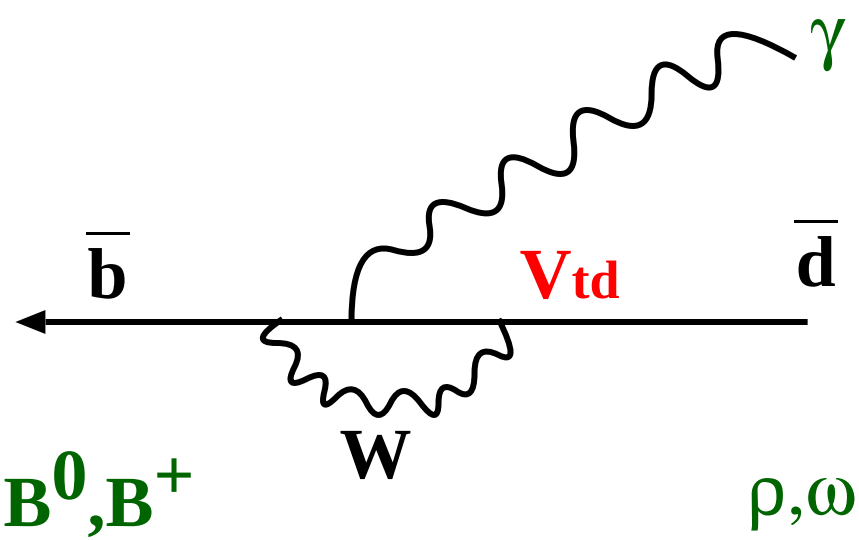


b->d γ

pure b→d (radiative penguin) process

Strong supression from V_{td}

-> sensitive to the new physics



- also important for the constraint on a CKM matrix element |Vtd|

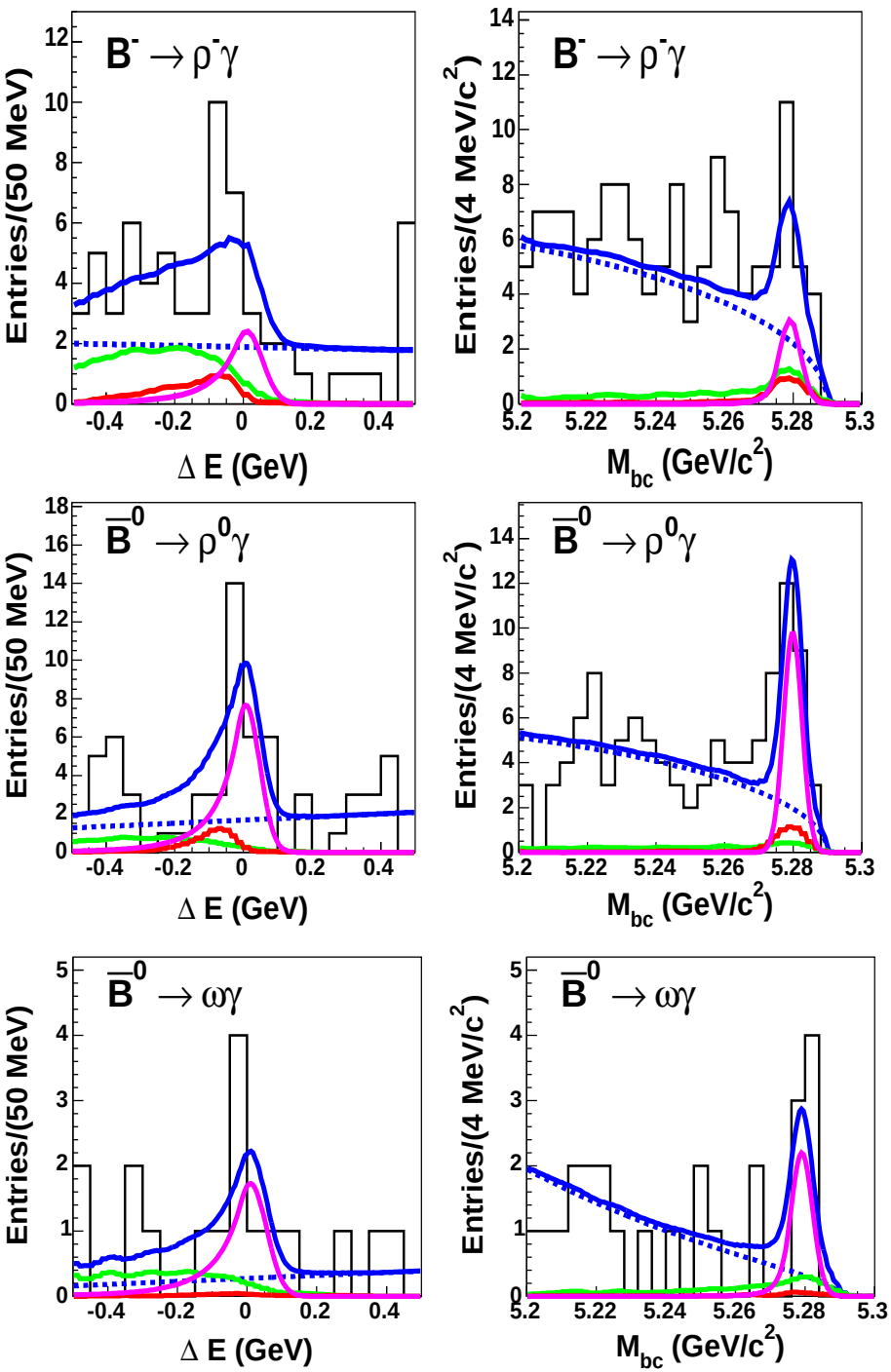
$$\frac{\mathcal{B}(B \to (\rho,\omega)\gamma)}{\mathcal{B}(B \to K^*\gamma)} \propto \left|\frac{V_{td}}{V_{ts}}\right|^2$$

where

$$\mathcal{B}(B \to (\rho,\omega)\gamma) = \mathcal{B}(B^+ \to \rho^+\gamma) = 2\frac{\tau_B^+}{\tau_B^0}\mathcal{B}(B^0 \to \rho^0\gamma, \omega\gamma)$$

(Isospin relation)

B->d γ : result



386MB $\overline{B}$

	BR($\times 10^{-6}$)	
$B^+ \to \rho^+ \gamma$	$0.55^{+0.43+0.12}_{-0.37-0.11}$	1.5σ
$B^0 \to \rho^0 \gamma$	$1.17^{+0.35+0.09}_{-0.31-0.08}$	5.1σ
$B^0 \to \omega \gamma$	$0.58^{+0.35+0.07}_{-0.27-0.08}$	2.6σ
combined		
$B \to (\rho, \omega)\gamma$	$1.34^{+0.34+0.31}_{-0.14-0.10}$	5.5σ

Observation of the b→dγ process

Constraint on the CKM matrix element |Vtd/Vts|

$$\frac{\mathcal{B}(B \to (\rho,\omega)\gamma)}{\mathcal{B}(B \to K^*\gamma)} = S_\rho \left|\frac{V_{td}}{V_{ts}}\right|^2 \left(\frac{1 - m_\rho^2/M_B^2}{1 - m_{K^*}^2/M_B^2}\right)^3 \zeta^2 \left[1 + \Delta R\right]$$

$\zeta = 0.85 \pm 0.10$ **form factor ratio**

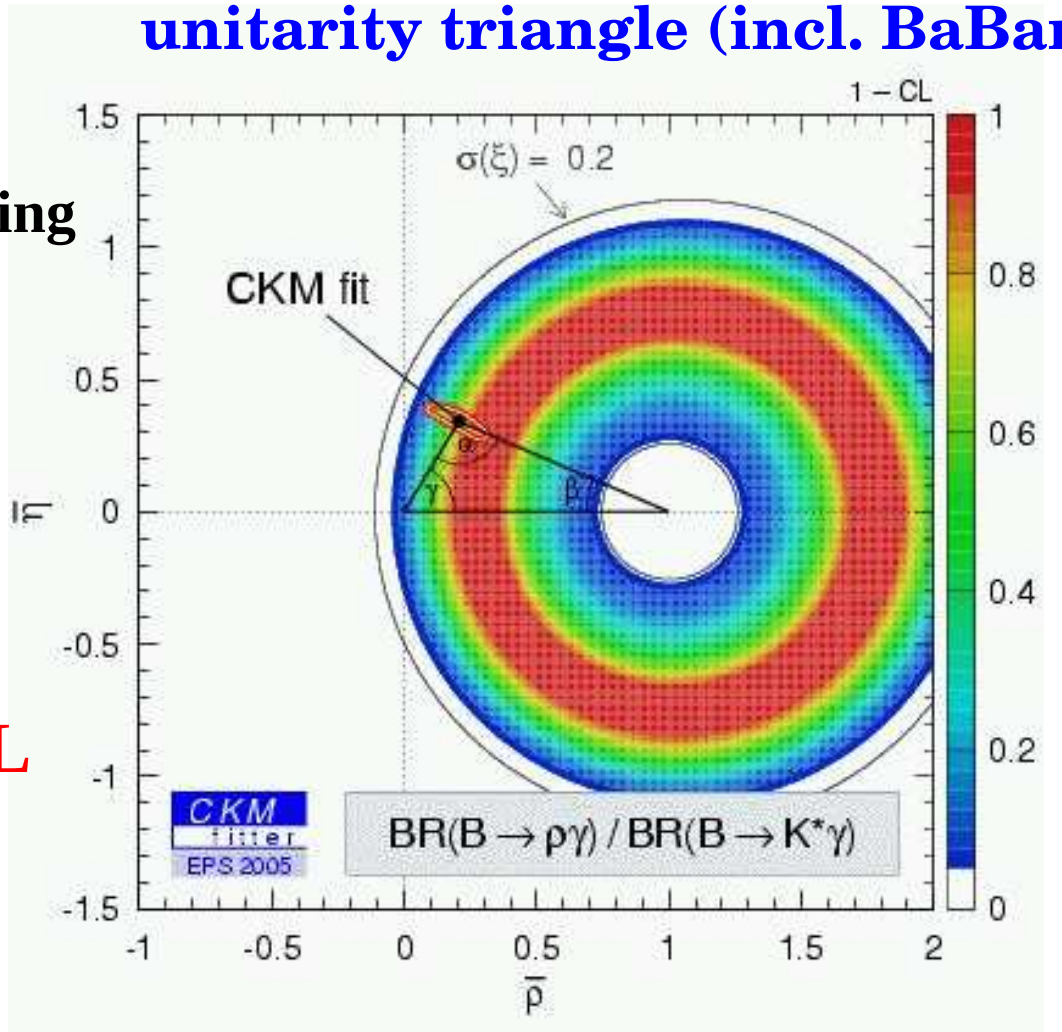
$\Delta R = 0.1 \pm 0.1$ **effect of SU3 breaking**

$$|V_{td}/V_{ts}| = 0.200^{+0.026+0.038}_{-0.025-0.029}$$

exp. theory

0.143 < |Vtd/Vts| < 0.260 @95%CL

constraint on the unitarity triangle (incl. BaBar



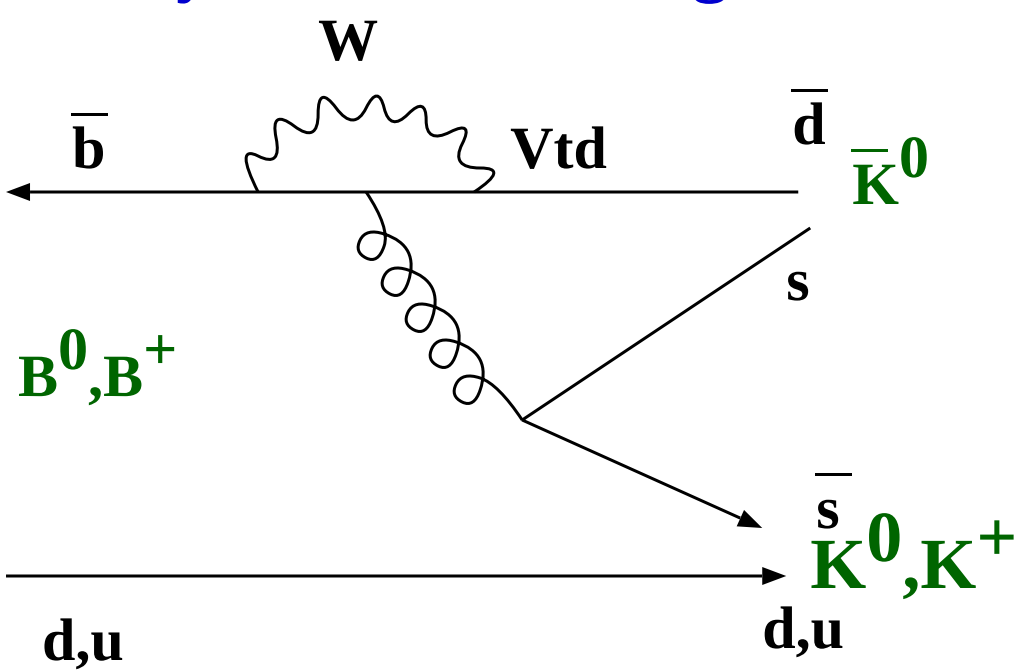
$B^+ \to \overline{K^0} K^+, B^0 \to \overline{K^0} K^0$ decays :

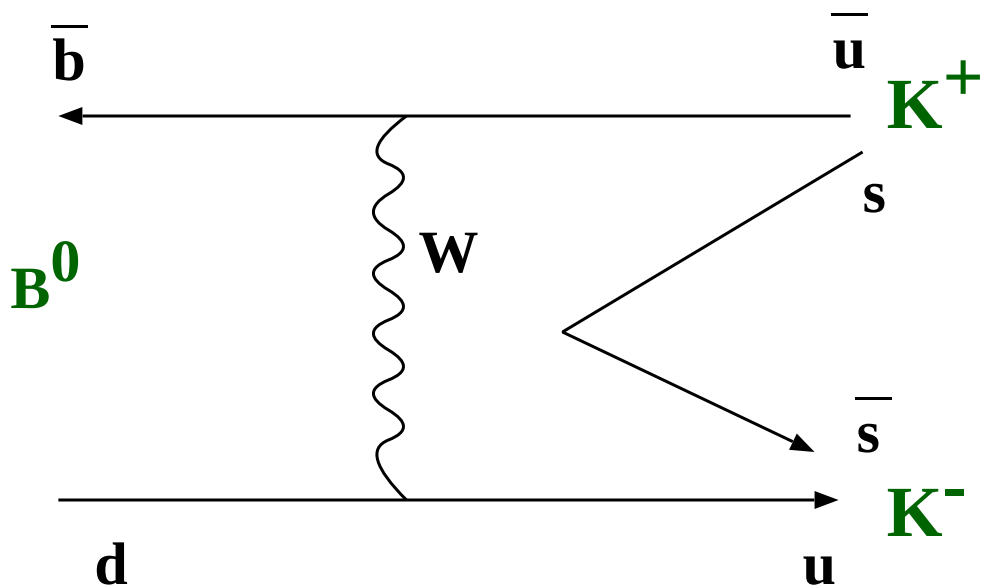
pure b→d process

strong suppression by V_{td} -> sensitive to the new physics

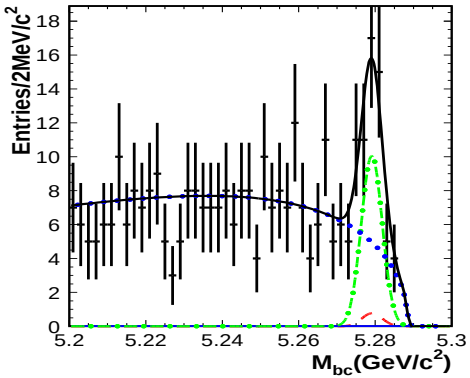
$B^0 \to K^+ K^-$ decays :

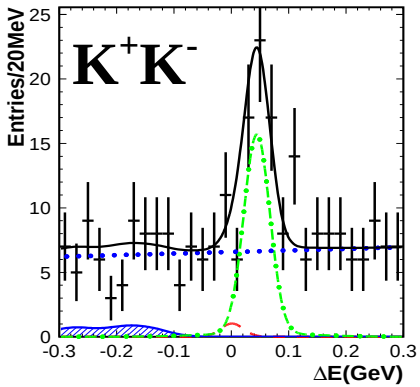
W exchange, final state interaction, ...
vary small branching fraction is expected

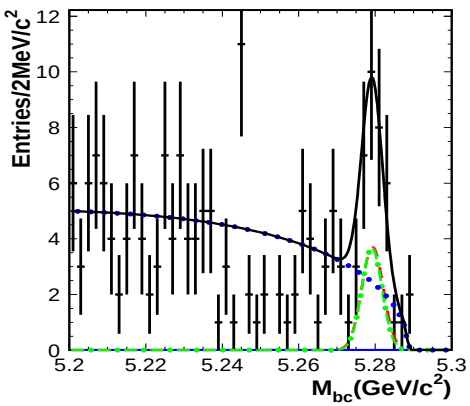


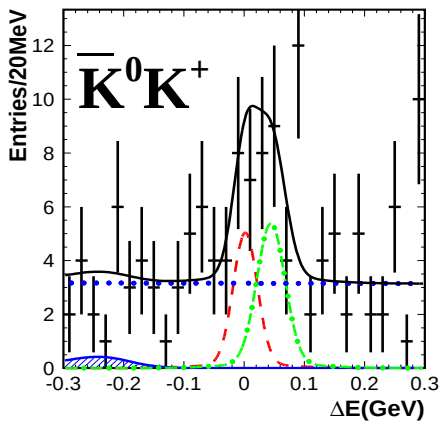


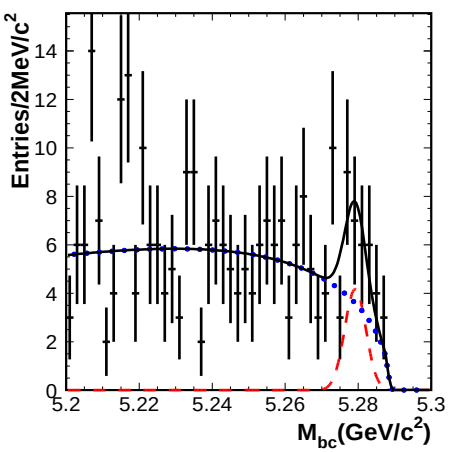
B-> KK: result

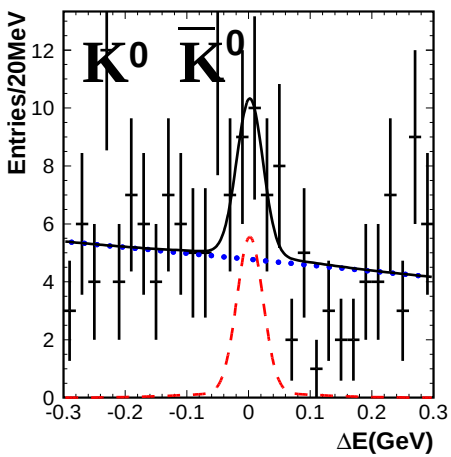












386MB $\overline{B}$

	BR(x10^{-6})	
$B^0 \to K^+K^-$	< 0.37	0.5σ
$B^+ \to \overline{K^0}K^+$	$1.0 \pm 0.4 \pm 0.1$	3.0σ
$B^0 \to K^0\overline{K^0}$	$0.8 \pm 0.3 \pm 0.1$	3.5σ

3σ evidence for K^0K^+ and $K^0\ \bar{K}^0$

red: signal
green: B->Kπ BG

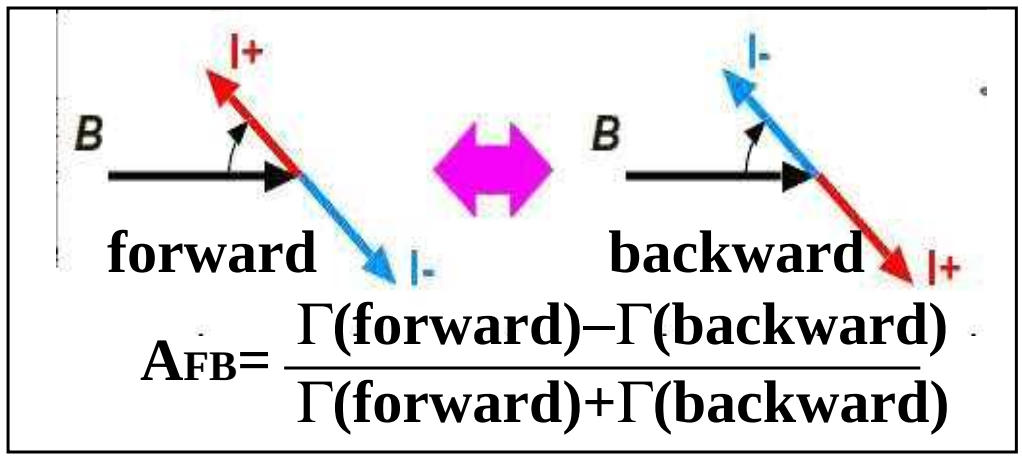
3. Forward-Backward asymmetry in $B \to K^* ll$

A_{FB} in B->K*ll: Introduction

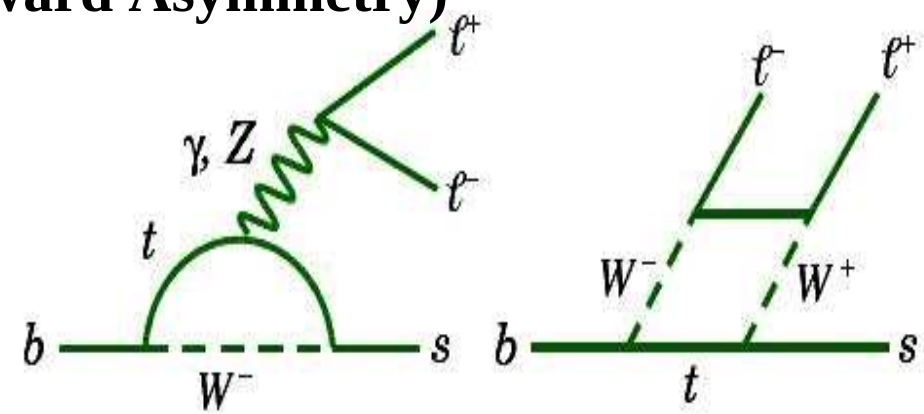
B→K*ll: Sensitive to the Wilson coefficients C_7, C_9 and C_{10}

A_7(q^2 independent term of C_7): $|A_7|$ is constrained by B→Xsγ
sign of A_7? A_9,A_{10} values?

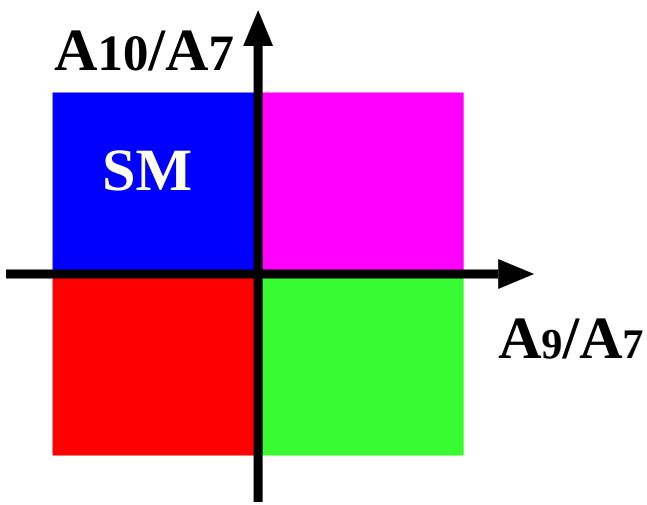
new measurement：A_{FB}(Forward-Backward Asymmetry)



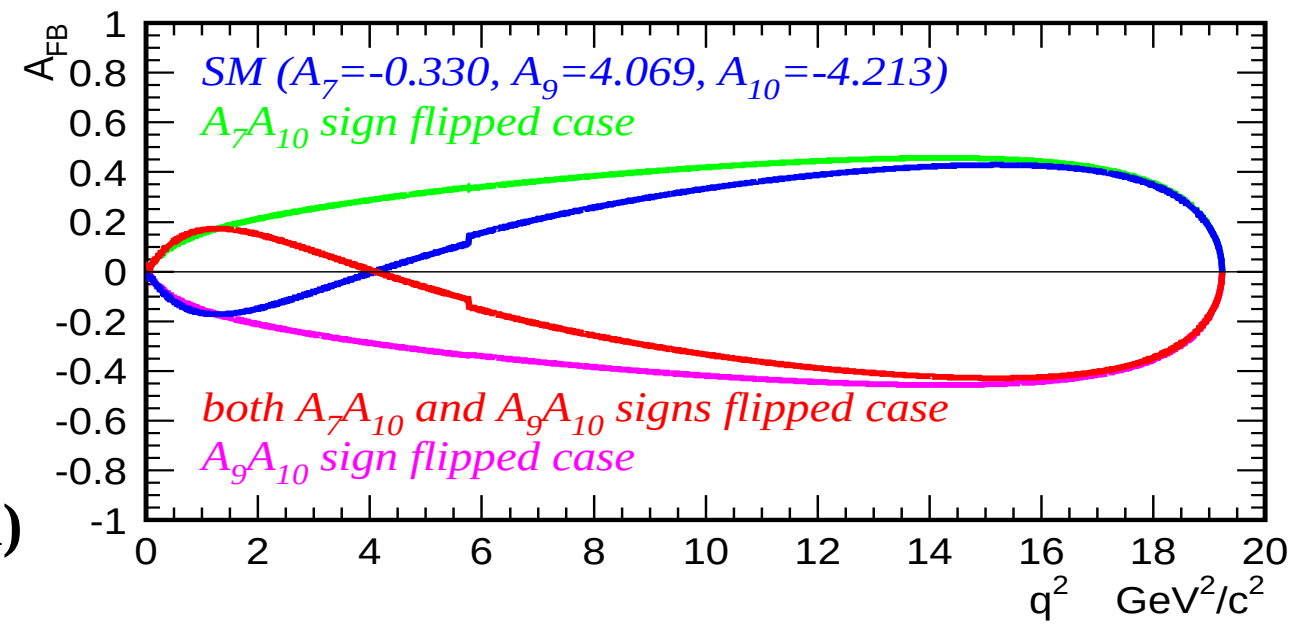
$$A_{FB}=\frac{\Gamma(\text{forward})-\Gamma(\text{backward})}{\Gamma(\text{forward})+\Gamma(\text{backward})}$$



determine the relative sign between A_7 and A_{10}, and between A_9 and A_{10}



(Ai: q^2 independent term of Ci)



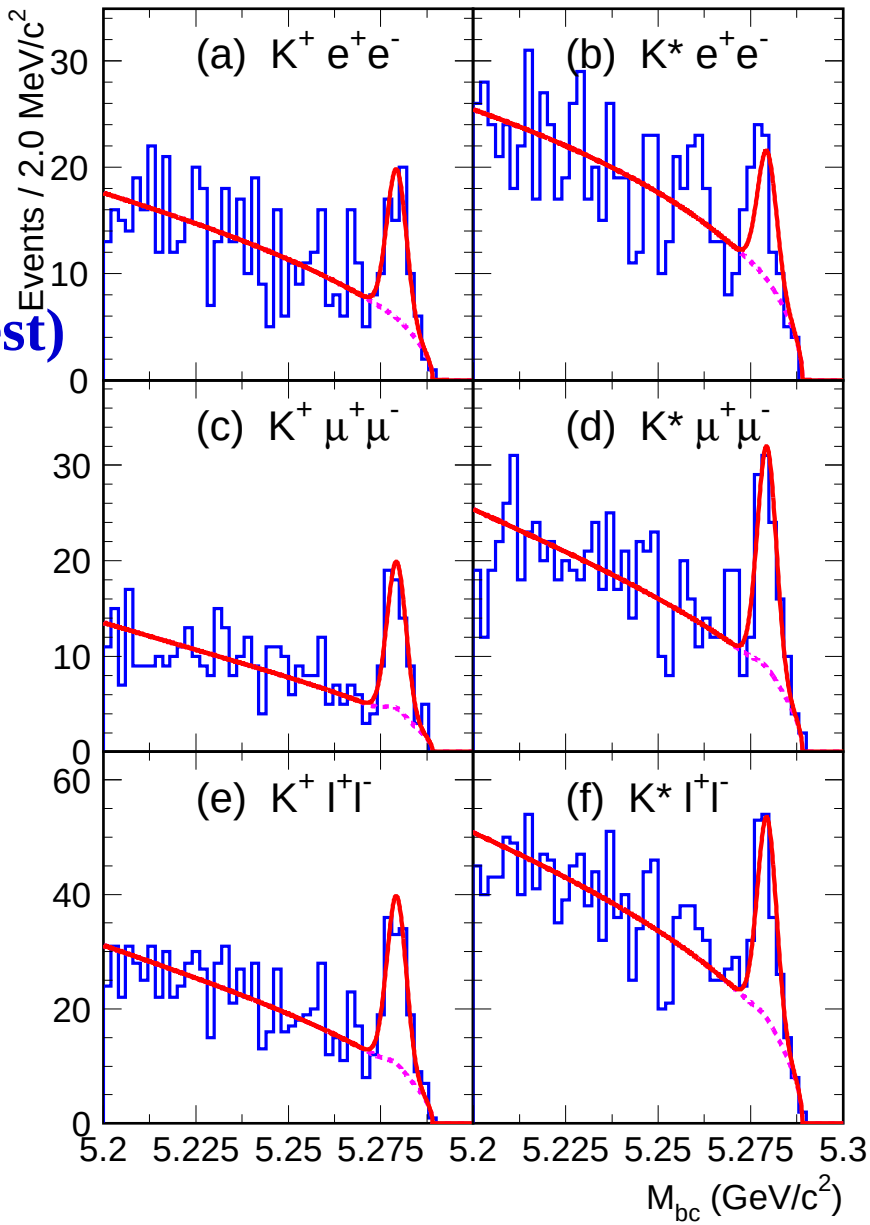
B->K*ll events

386M B $\overline{B}$

N(B→K*ll) = 114±14 (purity 44%)

N(B→Kll) = 96±12 (purity 57%)

(B→Kll: used for the null asymmetry test)



Maximum Likelihood fit to normalized double differential decay width $(1/\Gamma)d^2\Gamma/dsd\cos\theta$

($s=q^2$, θ: angle between l- and B)

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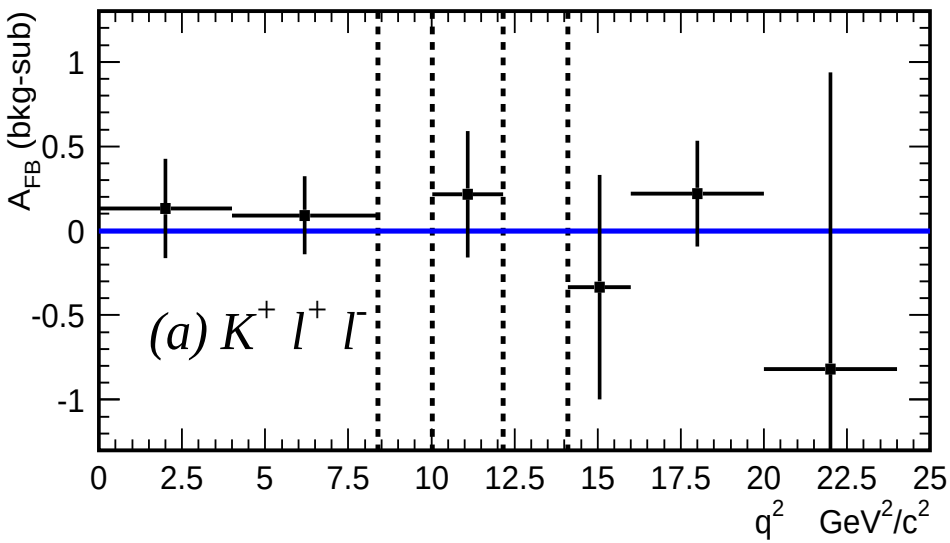
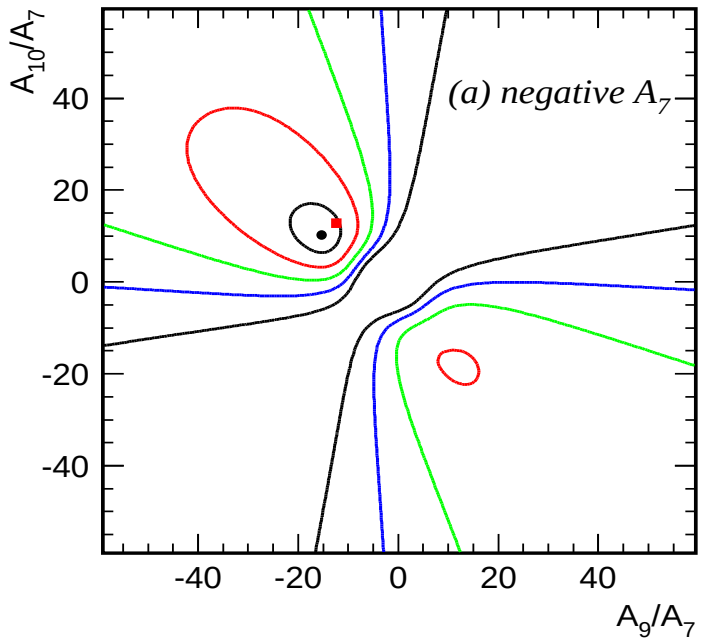
constrain A_9/A_7 and A_{10}/A_7

A_{FB} in B->K*ll



null asymmetry test

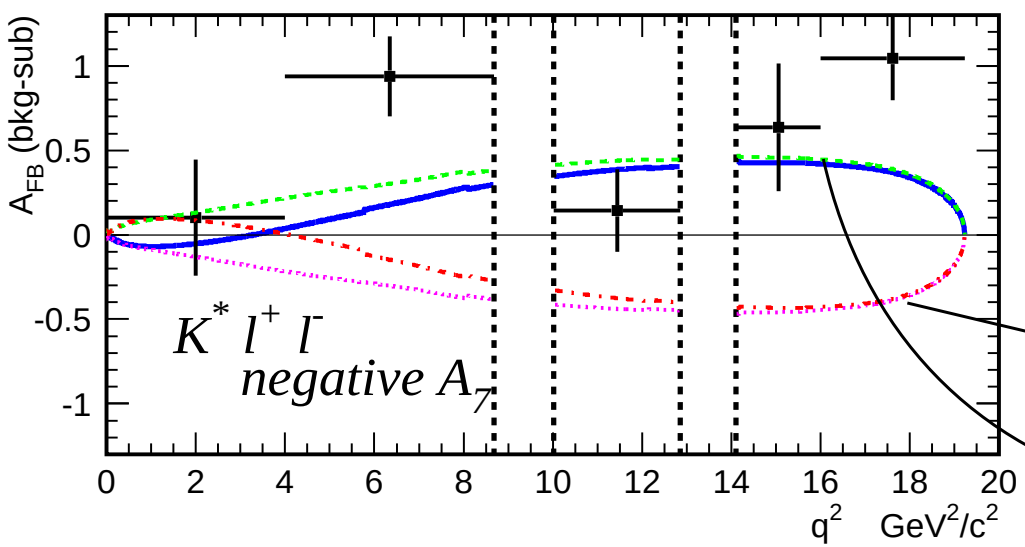


Best fit for negative A7(SM like)

$A_9/A_7 = -15.3^{+3.4}_{-4.8} \pm 1.1$

$A_{10}/A_7 = 10.3^{+5.2}_{-3.5} \pm 1.8$

c.f. SM: A_9/A_7 = -12.3,
A_{10}/A_7 = +12.8



sign-flipped A9A10 is excluded at 95%CL

sign of A7A10 is not determined (need more data)

Summary

Improved measurements

- Acp in $B \to K\pi$ decays

  Obervation of the Direct CP violation in $B^0 \to K^+\pi^-$

New measurements

- search for $b \to d$ process

  Observation of the $b \to d\,\gamma$ decay

  Evidence of $B^+ \to K^0 K^+$ and $B^0 \to K^0\ \overline{K}^0$

- meaurement of the forward-backward asymmetry in $B \to K^* ll$

↓

important tools for probing the new physics beyond the SM

Many other analyses that are not covered in this talk:
Acp measurements for many other rare B decays,
polalization measurements in $B \to VV$ decays, ...