Experimental status and prospects of the "Kπ puzzle"

Yuuji Unno
Hanyang university
On behalf of the Belle collaboration

CKM2010 @ Univ. of Warwick, UK

Contents

- Introduction
- Analysis overview
- Br(B→Kπ)
- A_{CP}(B→Kπ)
- CPV in $B^0 \to K^0\pi^0$
- Summary

All results(

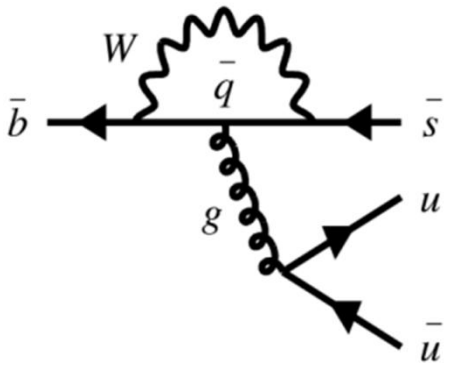
, 
, 

, CLEO) from HFAG 2010
http://www.slac.stanford.edu/xorg/hfag/

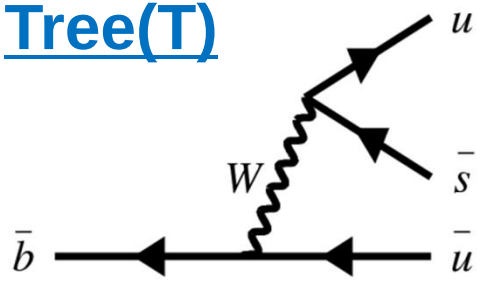
Introduction (Why is B→Kπ interesting?)

- **Charmless two-body B decays**
  - **CKM angles, CPV, search for new physics(NP).**
- **B→Kπ amplitudes are dominated by P and/or T**

Penguin(P)



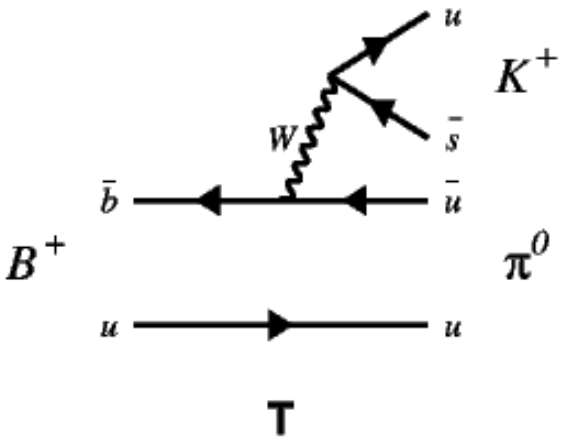
Tree(T)



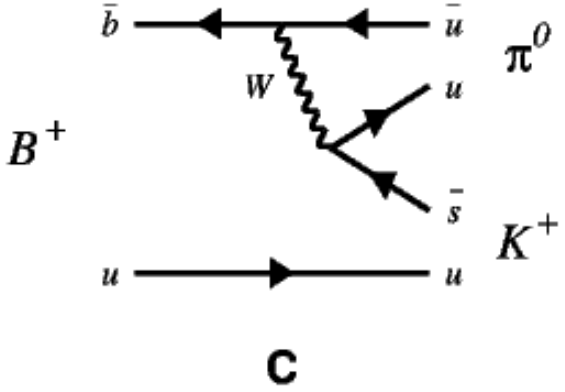
  - **Direct CPV through interference of P & T**
  - **ϕ_3 through b→u (but theoretically challenging…)**
  - **New physics hints in Br/CPV from loop in P**
- **Many theoretical calculations with different factorization approaches: QCDF, PQCD, SCET**
- **Deviation from expectation in SM→ puzzle/NP hints**

Introduction(diagram decomposition)

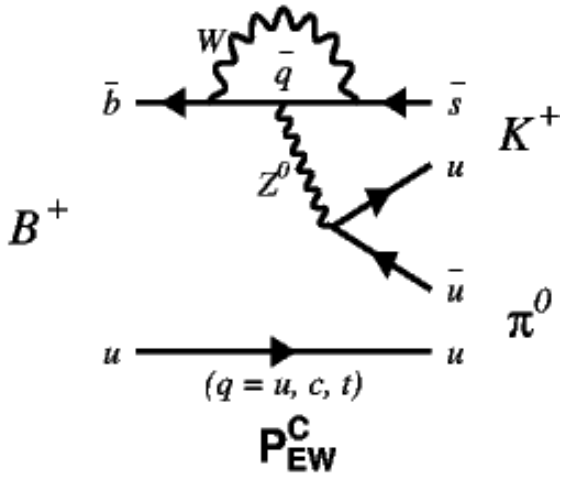
Some of the 6 processes can contribute to B→Kπ



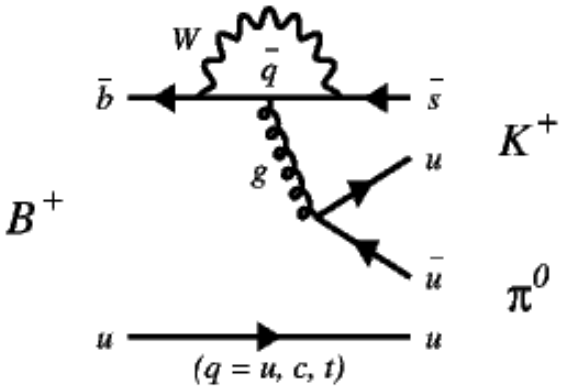
T



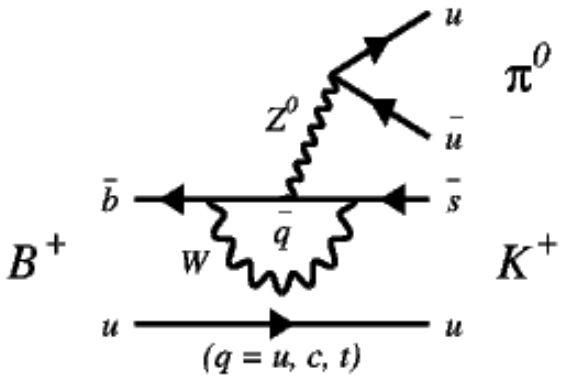
C



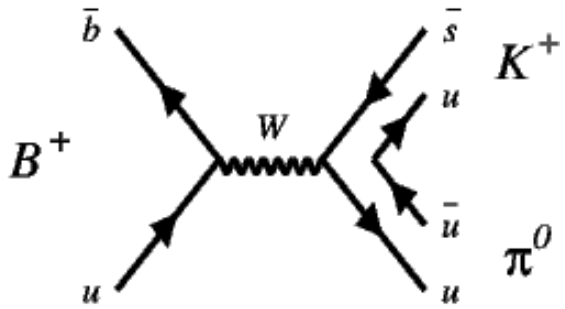
P_{EW}^{C}



P



P_{EW}



A

Introduction(diagram decomposition)

Mode	Feynman diagram
$B^0 \to K^+\pi^-$	$T+P+P^C_{EW}$
$B^+ \to K^+\pi^0$	$T+P+C+P_{EW}+P^C_{EW}+A$
$B^+ \to K^0\pi^+$	$P+P^C_{EW}+A$
$B^0 \to K^0\pi^0$	$P+C+P_{EW}+P^C_{EW}$

Some predictions can be made:

- **By assuming P and/or T are dominant**
  - **DCPV in $K^+\pi^-$ and $K^+\pi^0$**
  - **no DCPV in $K^0\pi^+$ and $K^0\pi^0$**
- **From Isospin relation** (M.Gronau, et al., PRD52,6374-6382(1995))

$$\Gamma(K^+\pi^-) - \sqrt{2}\Gamma(K^+\pi^0) - \Gamma(K^0\pi^+) + \sqrt{2}\Gamma(K^0\pi^0) = 0$$

  - **We can test isospin sum rules in Br and A_{CP}**

Where are puzzles(NP hints) ?

Puzzle in Ratio of Brs

Buras, Fleischer,et. al EPJC45,701(2006), Cheng,Chua arXiv/0909.5229

$$R_c = \frac{2Br(B^+ \to K^0\pi^+)}{Br(B^+ \to K^+\pi^0)} = 1.15 \pm 0.03$$

$$R_n = \frac{Br(B^0 \to K^+\pi^-)}{2Br(B^0 \to K^0\pi^0)} = 1.12 \pm 0.03$$

$$R_c - R_n = 0.03 \pm 0.04 \approx 0$$

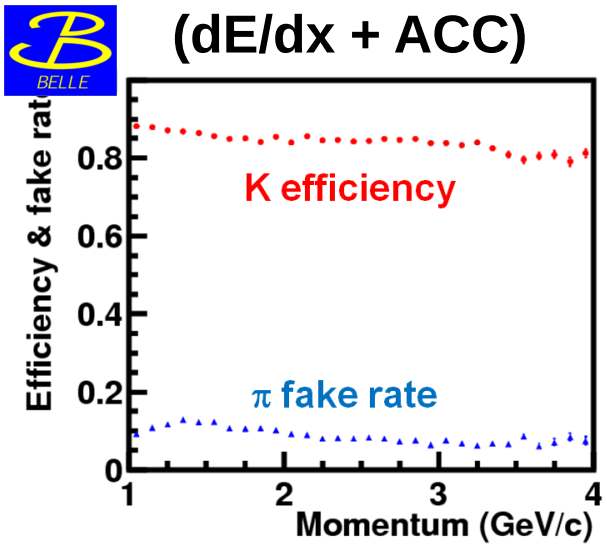
- In theory, hadronic uncertainties cancel out
- In experiment, some systematics cancel out

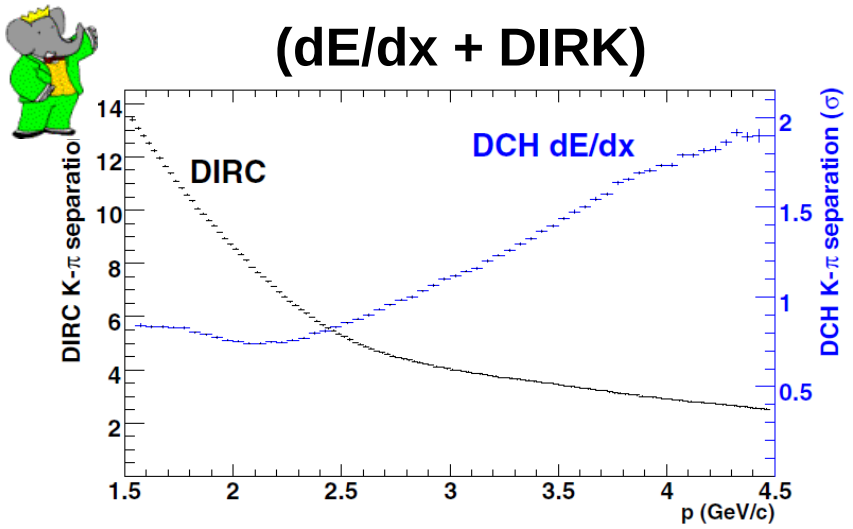
Puzzle in CPV

- ΔA_{CP} puzzle

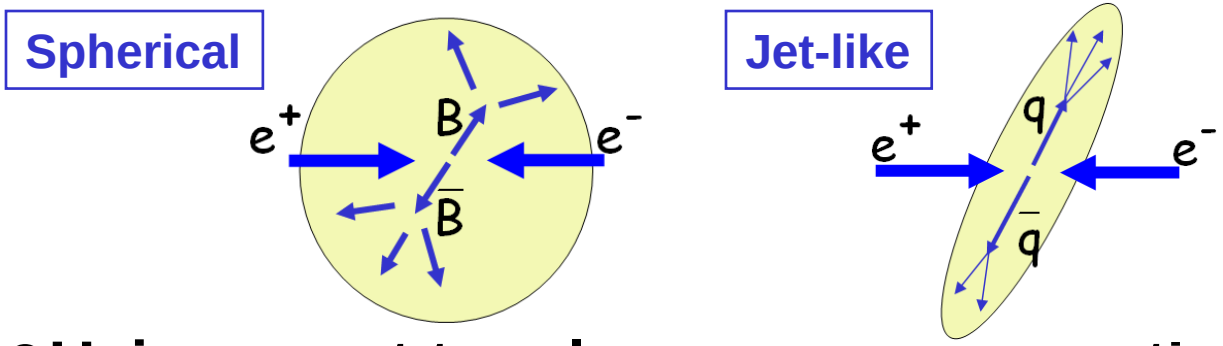
Analysis overview

- Good high momentum Kπ separation is required





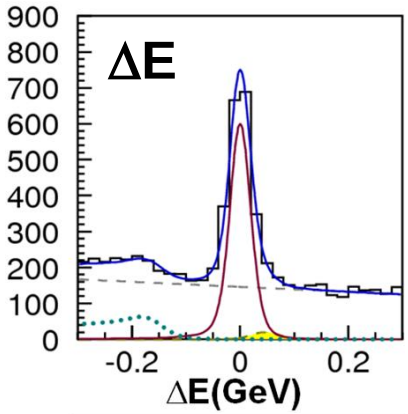
- Main bkg is from $e^+e^- \rightarrow q\bar{q}(q=u,d,s,c)$ continuum



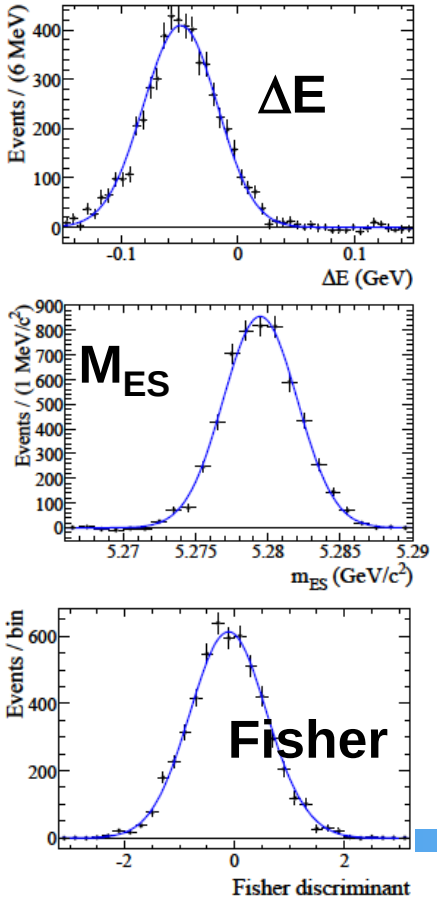
- Using event topology, suppress continuum bkg.

Analysis overview(signal extraction)

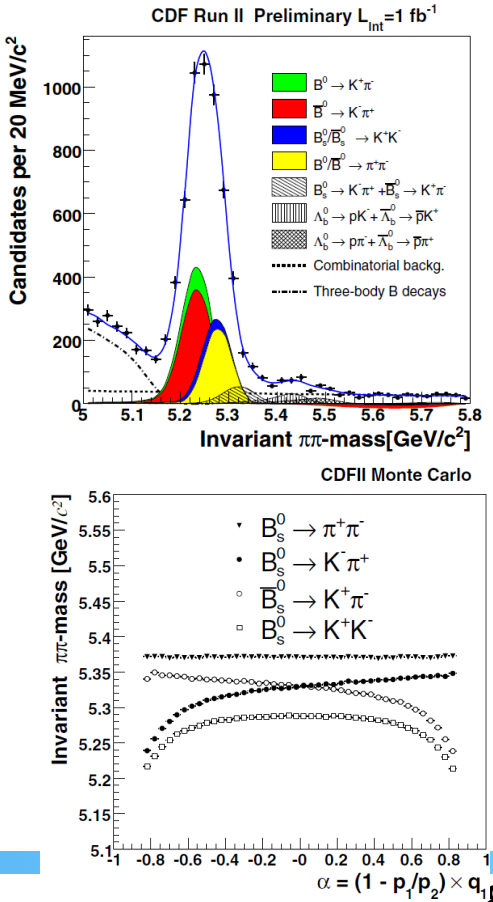
Fit on ΔE, M_{bc} after cut on Fisher & PID



Fit on ΔE, M_{ES}, PID, and Fisher



Fit on $M(\pi\pi)$, PID, and Kinematic info.



Br(B→Kπ)

(x10^{-6})	$K^+\pi^-$	$K^+\pi^0$	$K^0\pi^+$	$K^0\pi^0$
Belle	$19.9\pm0.4\pm0.8$	$12.4\pm0.5\pm0.6$	$22.8^{+0.8}_{-0.7}\pm1.3$	$8.7\pm0.5\pm0.6$
Babar	$19.5\pm0.6\pm0.6$	$13.6\pm0.6\pm0.7$	$23.9\pm1.1\pm1.0$	$10.1\pm0.6\pm0.4$
CLEO	$18.0^{+2.3}_{-2.1}{}^{+1.2}_{-0.9}$	$12.9^{+2.4}_{-2.2}{}^{+1.2}_{-1.1}$	$18.8^{+3.7}_{-3.3}{}^{+2.1}_{-1.8}$	$12.8^{+4.0}_{-3.3}{}^{+1.7}_{-1.4}$
Avg.	19.4 ± 0.6	12.9 ± 0.6	23.1 ± 1.0	9.5 ± 0.5

- All results are well consistent between 3 experiments.
- *All results are already systematics dominanted !!!*
- Exp. results are consistent with theoretical calculations

(Unit is 10^{-6}, Table from H.Y.Cheng,C.K.Chua arXiv/0909.5229)

Mode	QCDF (this work)	pQCD	SCET
$B^- \to \bar{K}^0\pi^-$	$21.7^{+9.2+9.0}_{-6.0-6.9}$	$23.6^{+14.5}_{-\ 8.4}$	$20.8\pm7.9\pm0.6\pm0.7$
$B^- \to K^-\pi^0$	$12.5^{+4.7+4.9}_{-3.0-3.8}$	$13.6^{+10.3}_{-\ 5.7}$	$11.3\pm4.1\pm1.0\pm0.3$
$\bar{B}^0 \to K^-\pi^+$	$19.3^{+7.9+8.2}_{-4.8-6.2}$	$20.4^{+16.1}_{-\ 8.4}$	$20.1\pm7.4\pm1.3\pm0.6$
$\bar{B}^0 \to \bar{K}^0\pi^0$	$8.6^{+3.8+3.8}_{-2.2-2.9}$	$8.7^{+6.0}_{-3.4}$	$9.4\pm3.6\pm0.2\pm0.3$

Ratio of Br(B→Kπ)

Naïve world avg.

$$R_c = \frac{2Br(B^+ \to K^0\pi^+)}{Br(B^+ \to K^+\pi^0)} = 1.12 \pm 0.07$$

$$R_n = \frac{Br(B^0 \to K^+\pi^-)}{2Br(B^0 \to K^0\pi^0)} = 1.02 \pm 0.06$$

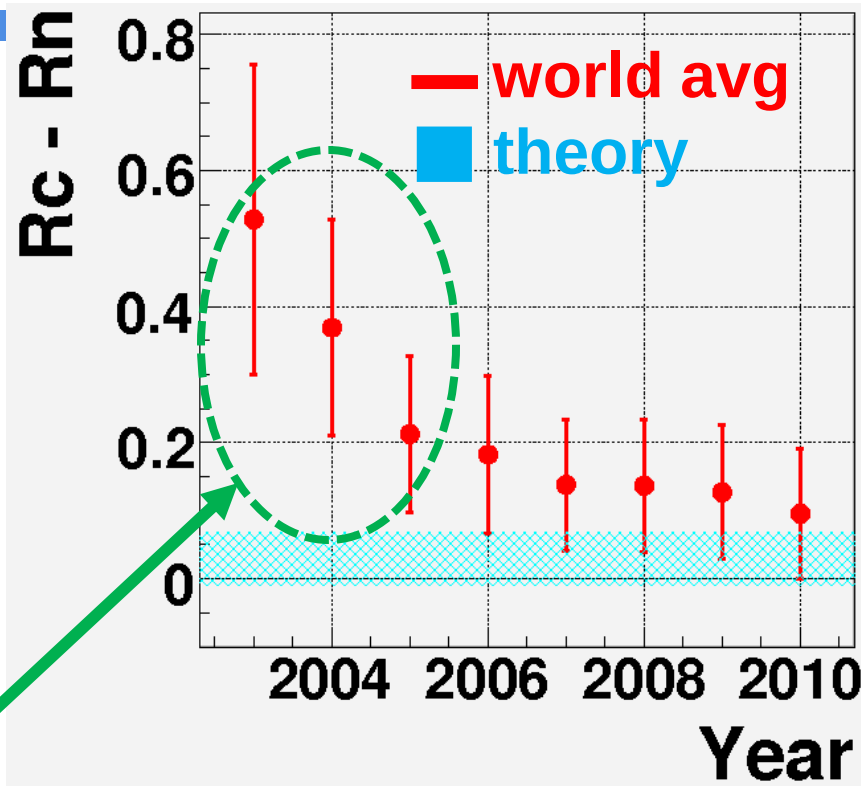
$$R_c - R_n = 0.10 \pm 0.09$$

World avg. are consistent with theory:

$$R_c = 1.15 \pm 0.03$$

$$R_n = 1.12 \pm 0.03$$

$$R_c - R_n = 0.03 \pm 0.04$$



- **Puzzle** appears to have disappeared
- For a more precise check, we have to reduce:
  - syst. errors in exp.
  - theory errors.

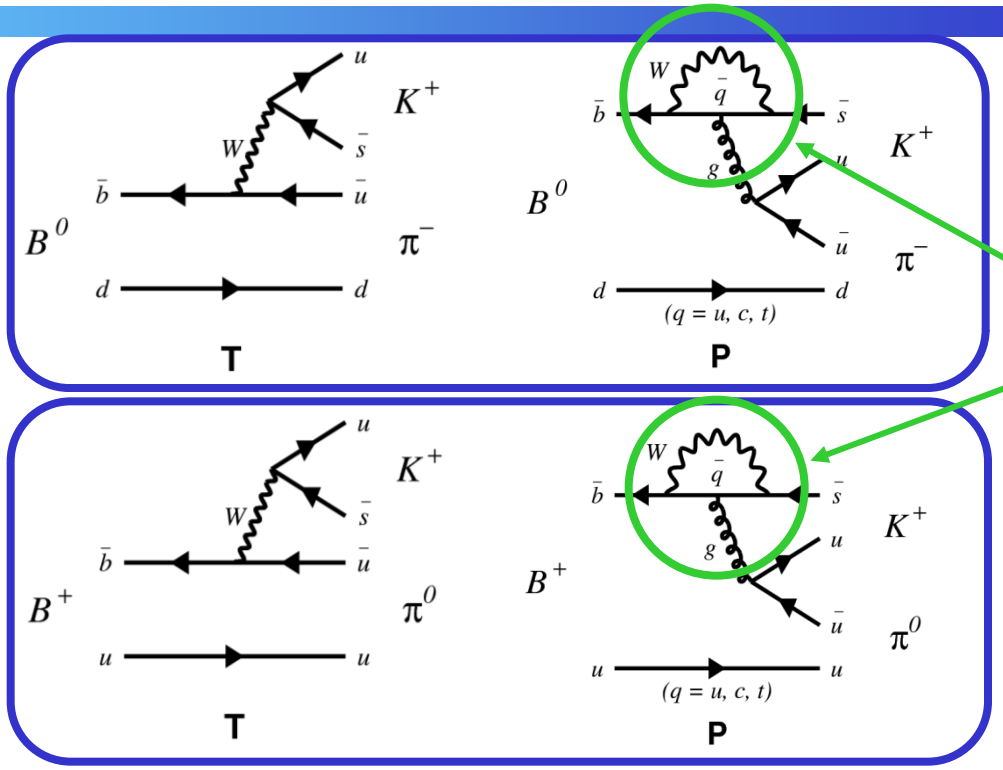
Ratio of Br(B→Kπ)

	$K^+\pi^-$	$K^+\pi^0$	$K^0\pi^+$	$K^0\pi^0$
Sig PDF	±0.2	±0.4	±0.2	±0.4
Charmless B bkg	±0.1	±0.4	-0.1	±0.1
Feed-across bkg	±0.4	±0.7	$^{+0.2}_{-0.4}$	±0.0
$q\bar{q}$ suppression	±1.0	±1.3	±1.1	±1.5
Tracking	±2.0	±1.0	±1.0	±0.0
KID	±2.9	±1.5	±1.3	±0.0
K^0_S rec.	±0.0	±0.0	±4.9	±4.9
π^0 rec.	±0.0	±4.0	±0.0	±4.0
# of $B\bar{B}$	±1.3	±1.3	±1.3	±1.3
Sig MC statistics	±0.6	±0.4	±0.8	±0.7
Total(%)	±4.0	±4.9	±5.5	±6.7

Need to improve a method to estimate systematics.
Now, Belle is trying to reduce these systematics.

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

- **$B^0 \to K^+\pi^-$ (T+P)**



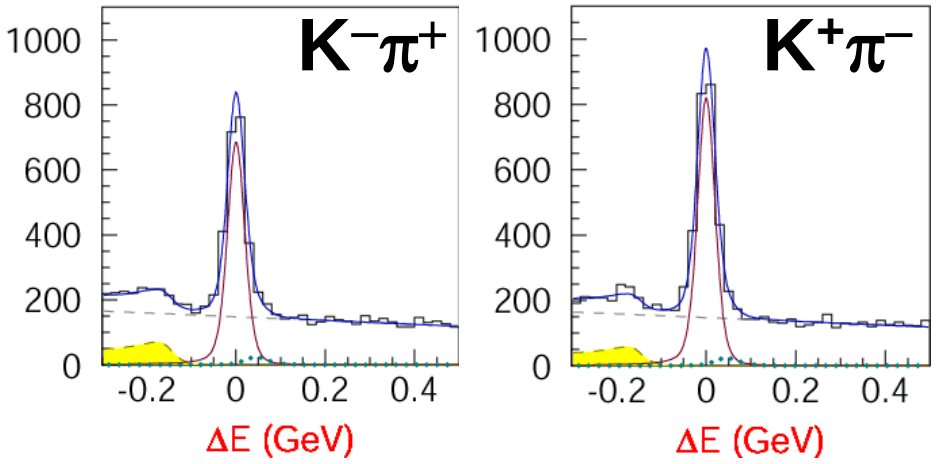
- **$B^+ \to K^+\pi^0$ (T+P)**

- DCPV through interference of T and P
- Naïve expectation $A_{CP}(K^+\pi^-) \sim A_{CP}(K^+\pi^0)$
- **$A_{CP}(K^+\pi^-) \neq A_{CP}(K^+\pi^0)$ ➔ might indicate NP**
- $K^0\pi^+$ is P dominant → null A_{CP} in SM

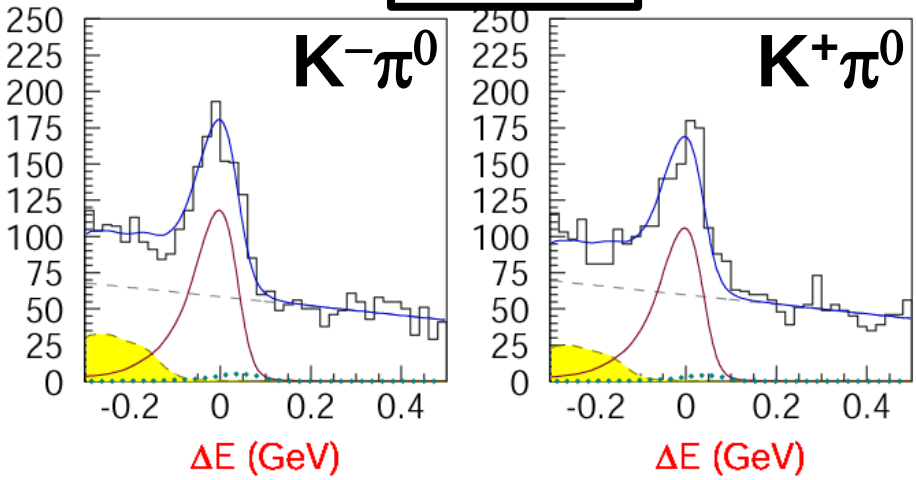
$A_{CP}(B \to K\pi)$

Nature452,332-335(2008)
PRL98,181804(2007)

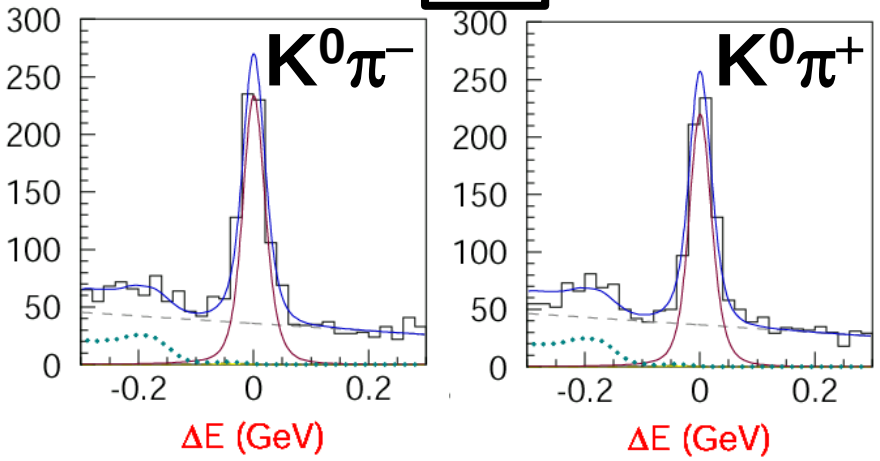
P+T



P+T



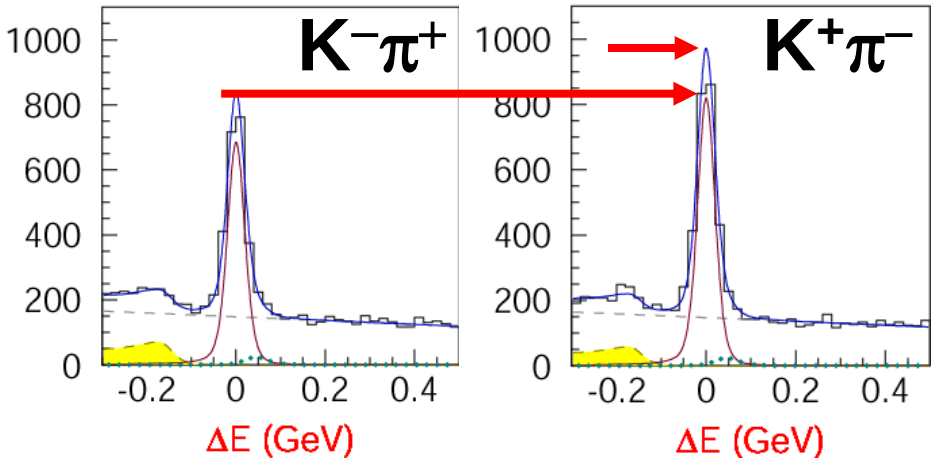
P



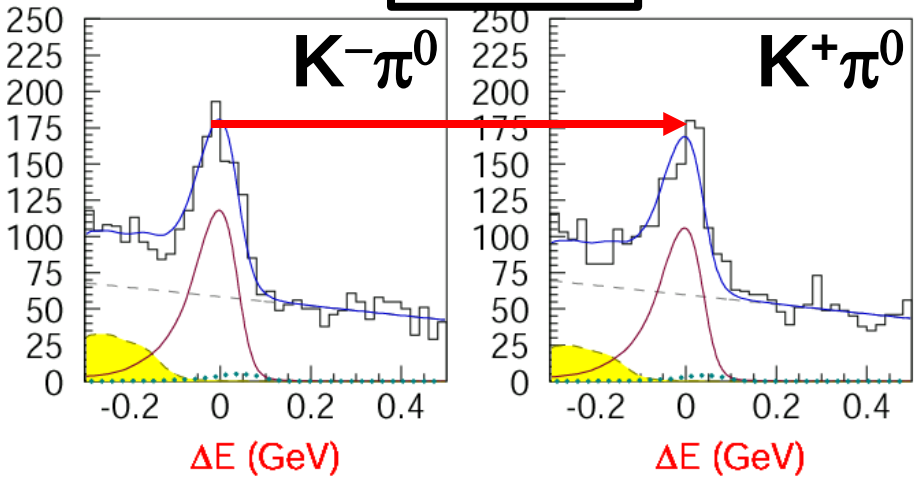
$A_{CP}(B \to K\pi)$

Nature452,332-335(2008)
PRL98,181804(2007)

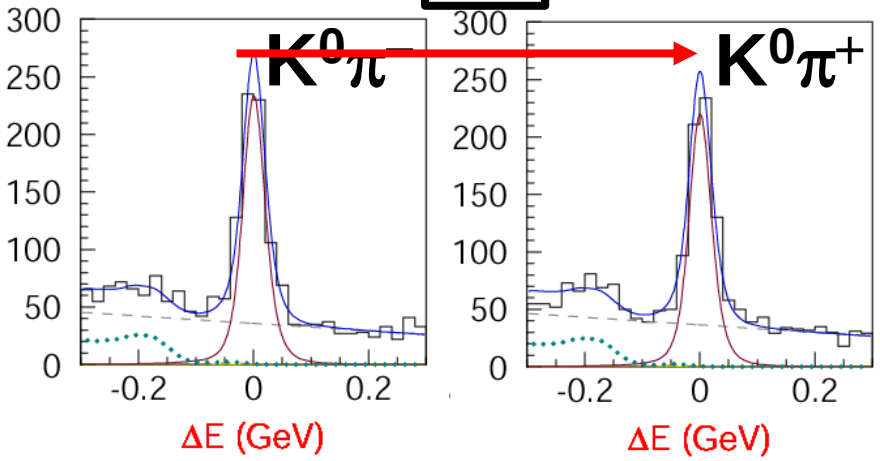
P+T



P+T



P



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

	$K^+\pi^-$	$K^+\pi^0$	$K^0\pi^+$
Belle	$-0.094 \pm 0.018 \pm 0.008$	$+0.07 \pm 0.03 \pm 0.01$	$+0.03 \pm 0.03 \pm 0.01$
Babar	$-0.107 \pm 0.016^{+0.006}_{-0.004}$	$+0.030 \pm 0.039 \pm 0.010$	$-0.029 \pm 0.039 \pm 0.010$
CDF	$-0.086 \pm 0.023 \pm 0.009$	---	---
CLEO	$-0.04 \pm 0.16 \pm 0.02$	$-0.29 \pm 0.23 \pm 0.02$	$+0.18 \pm 0.24 \pm 0.02$
Avg.	-0.098 ± 0.012 (8.1σ)	$+0.050 \pm 0.025$ (2.0σ)	$+0.009 \pm 0.025$

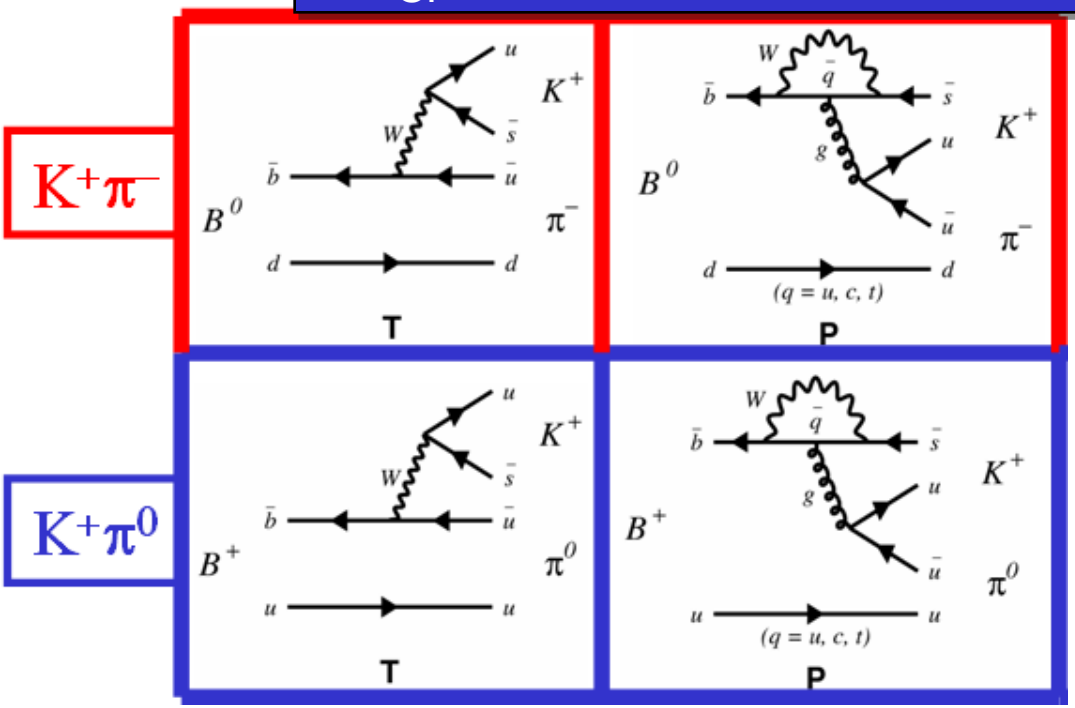
ΔA_{CP} puzzle is established with 5.3σ

$\Delta A_{CP} = A_{CP}(K^+\pi^0) - A_{CP}(K^+\pi^-)$

$= +0.148 \pm 0.028$

ΔA_{CP} puzzle

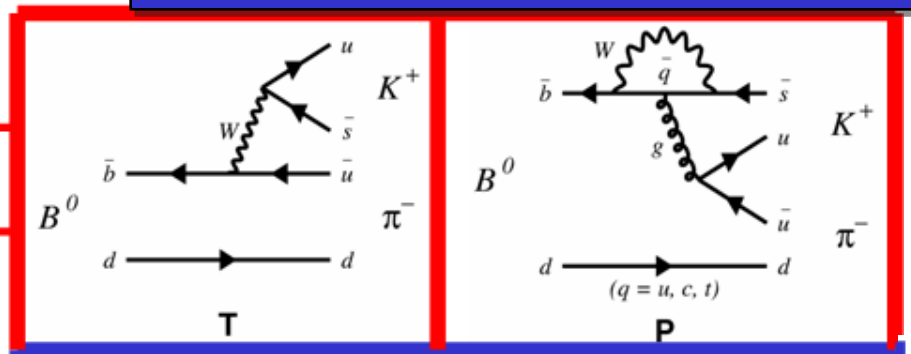
$\Delta A_{CP} \sim 0$ is expected if C and P_{EW} are neglected



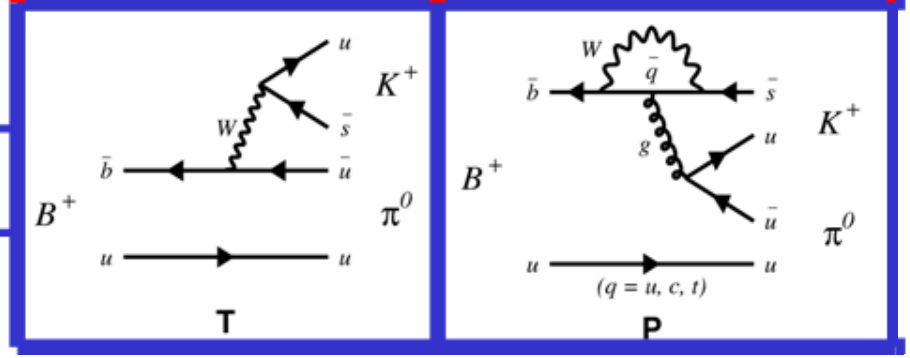
ΔA_{CP} puzzle

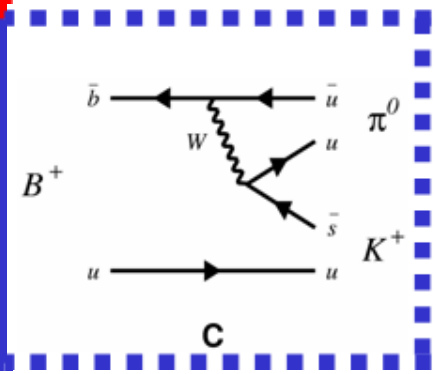
$\Delta A_{CP} \sim 0$ is expected if C and P_{EW} are neglected

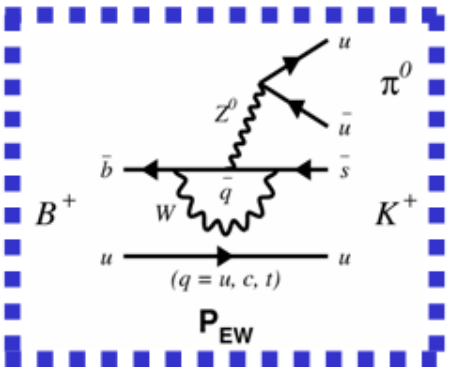
$K^+\pi^-$



$K^+\pi^0$







- C.-W.Chaing, et al., PRD 70, 034020
- Y.-Y.Charng, et al., PRD 71, 014036
- W.-S.Hou, et al., PRL 95, 141601
- S.Baek, et al., PRD 71, 057502
- S.Baek, et al., PLB 653, 249
- H.-n.Li,et al., PRD 72, 114005
- etc…

- **Enhancement of C ?**
  - → C>T is needed
  - → breakdown of theoretical understanding
- **Enhancement of P_{EW} ?**
  - → Would indicate new physics.
- **Due to poor understanding of strong interactions?**

ΔA_{CP} puzzle

- **Isospin sum rule among B→Kπ CP asymmetries**

  (M.Gronau, PLB 672(2005), 82-88)

$$\mathcal{A}_{CP}(K^+\pi^-) + \mathcal{A}_{CP}(K^0\pi^+)\frac{\mathcal{B}(K^0\pi^+)}{\mathcal{B}(K^+\pi^-)}\frac{\tau_0}{\tau_+} = \mathcal{A}_{CP}(K^+\pi^0)\frac{2\mathcal{B}(K^+\pi^0)}{\mathcal{B}(K^+\pi^-)}\frac{\tau_0}{\tau_+} + \mathcal{A}_{CP}(K^0\pi^0)\frac{2\mathcal{B}(K^0\pi^0)}{\mathcal{B}(K^+\pi^-)}$$

- **A violation of the sum rule would be unambiguous evidence of new physics.**

- **Isospin sum rule predicts:**

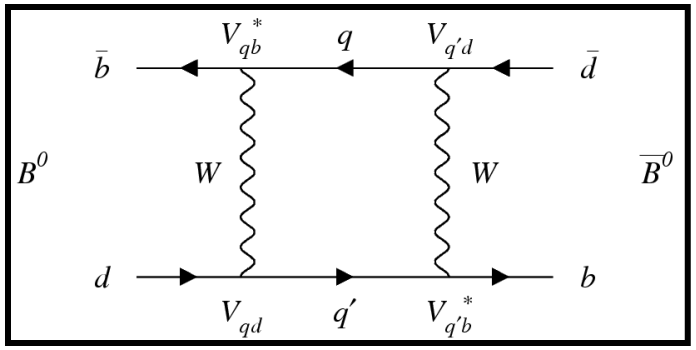
  using world average values(A_{CP},Br,τ_+,τ_0) except for $A_{CP}(K^0\pi^0)$

  $A_{CP}(K^0\pi^0) = -0.153 \pm 0.045$

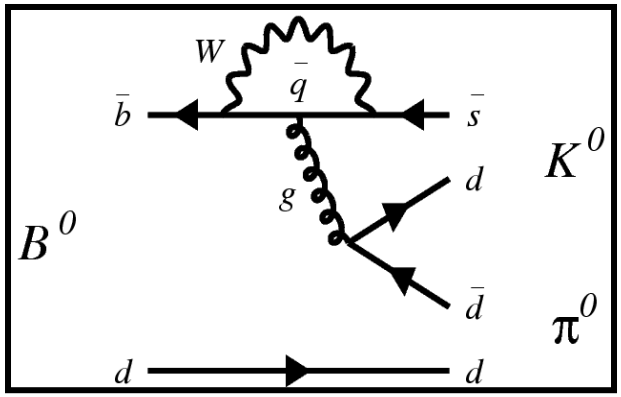
- **However, assuming that P dominates in $B^0 \to K^0\pi^0$: $A_{CP}(K^0\pi^0)=0$ is expected…**

CPV in $K^0\pi^0$

- Mixing-induced CPV and Direct CPV.



+



$$A_f(t) = \frac{\Gamma(\bar{B}^0(t) \to f) - \Gamma(B^0(t) \to f)}{\Gamma(\bar{B}^0(t) \to f) + \Gamma(B^0(t) \to f)} = -\eta_f \sin 2\phi_1 \sin(\Delta m \Delta t) + A_{CP} \cos(\Delta m \Delta t)$$

- In SM, $\sin 2\phi_1^{eff} = \sin 2\phi_1$ from $b \to c\bar{c}s$
- Non-SM particles in P loop may modify the relation
  - $\Delta S = \sin 2\phi_1^{eff} - \sin 2\phi_1 \neq 0$
  - For details, see T.Aushev's talk
- P dominant mode → null A_{CP} is expected.

CPV in $K^0\pi^0$

	$\sin 2\phi_1$	A_{CP}
Belle	$0.67 \pm 0.31 \pm 0.06$	$-0.14 \pm 0.13 \pm 0.06$
Babar	$0.55 \pm 0.20 \pm 0.03$	$+0.13 \pm 0.13 \pm 0.03$
Avg.	0.57 ± 0.17	$+0.01 \pm 0.10$

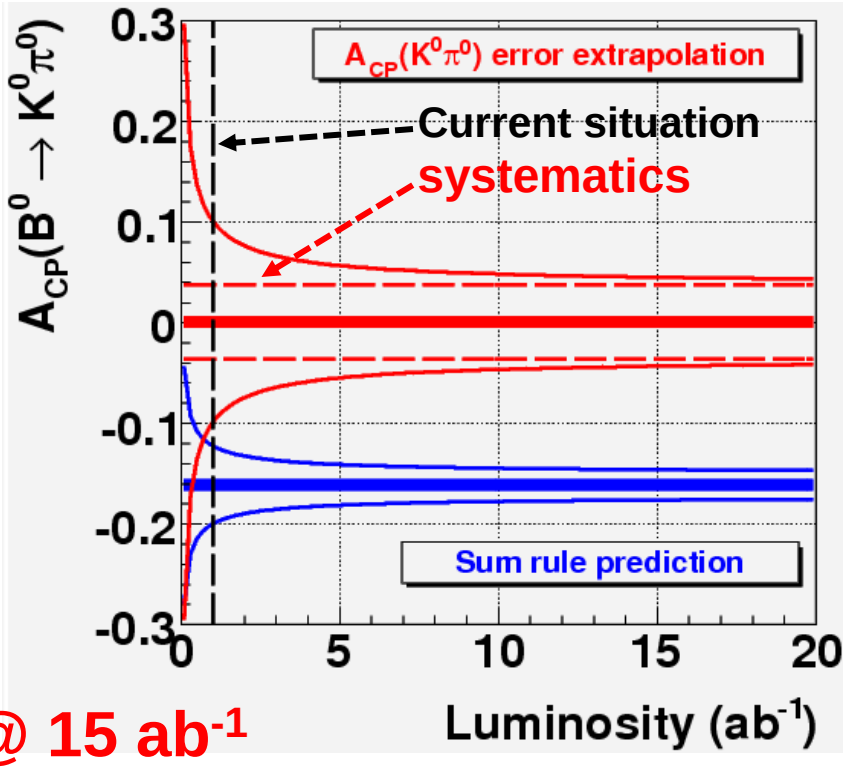
- $\sin 2\phi_1(K^0\pi^0)$ agrees with $\sin 2\phi_1(b \to c\bar{c}s) = 0.67 \pm 0.02$.

- $A_{CP}(K^0\pi^0)$ is consistent with zero…
  - Sum rule $A_{CP}(K^0\pi^0) = -0.153 \pm 0.045$
  - Deviation from sum rule is ~1.5σ
  - Error of $A_{CP}(K^0\pi^0)$ is still large…

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

Expectation using

- **current world average central values**
- **by fixing current systematics**



@ 15 ab^{-1}

Source	$\Delta\mathcal{A}_{K^0\pi^0}$
Wrong tag fraction	0.005
Physics parameters	0.001
Resolution function	0.007
Background Δt shape	0.006
Background fraction	0.022
Possible fit bias	0.020
Vertex reconstruction	0.022
Tag side interference	0.054
Total	0.064

- **$\delta A_{CP}(K^0\pi^0)$ ~ 5%**
- **Sum rule – $A_{CP}(K^0\pi^0)$ > 3σ**
- **But, will be systematics dominant…**

- **Situation is same as Babar**
- **Need to reduce TSI**

ΔA_{CP} puzzle

Vol 452|20 March 2008 nature

NEWS & VIEWS

PARTICLE PHYSICS

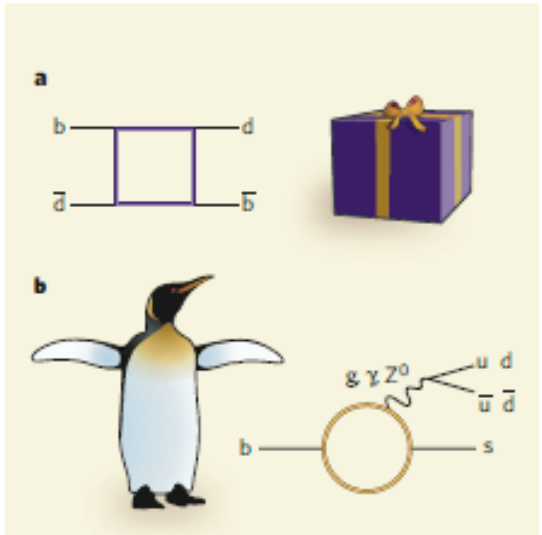
Song of the electroweak penguin

Michael E. Peskin

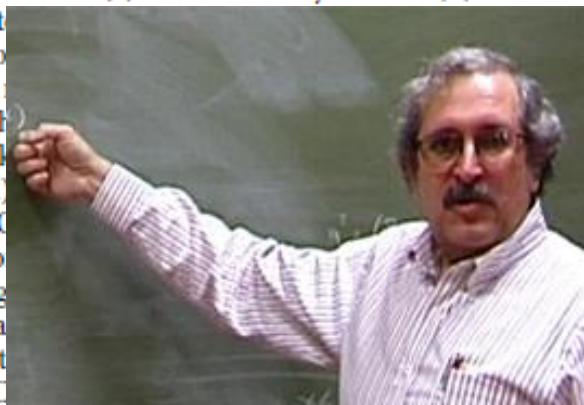
An unexpected imbalance in how particles containing the heaviest quarks decay might reveal exotic influences — and perhaps help to explain why matter, rather than antimatter, dominates the Universe.

Elsewhere in this issue, the Belle collaboration, based at the electron–positron particle collider of the high-energy accelerator laboratory KEK in Japan, announces their measurement of an anomalous asymmetry in the decay rates of exotic particles known as B mesons (Lin *et al.*, page 332)[1]. Combined with recent measurements of the same decays from the BaBar collaboration[2,3], a similar experiment at the Stanford Linear Accelerator Center (SLAC) in California, the new finding provides a tantalizing glimpse of a possible new source for a very fundamental asymmetry: the dominance of matter over antimatter in our Universe.

The two great principles of modern physics, quantum mechanics and Einstein's relativity,



time only three types of quark were known: up (u), down (d) and strange (s). But in the following decades, three more were discovered: charm (c), and the heavy bottom (b) and t
led to
on B
which
quark
(KM)
Pier
perfo
energ
(the a
const
SLAC



ΔA_{CP} p

Vol 452|20 March 2008

PARTICLE PHYSICS

Song

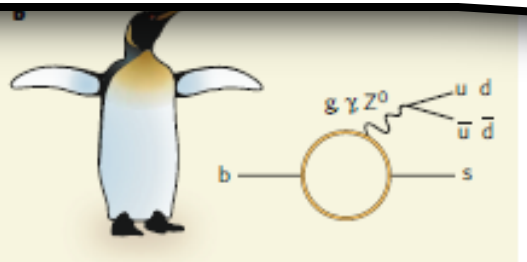
Michael E. Peskin

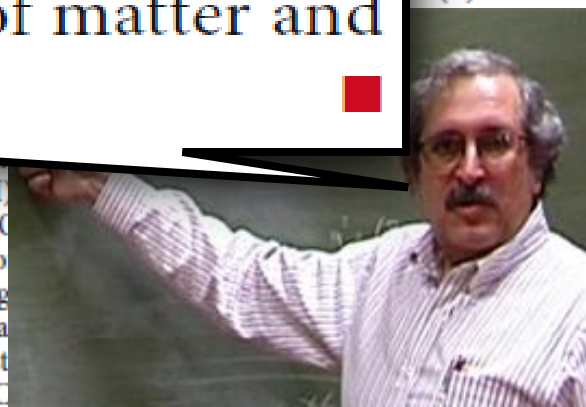
An unexpected i
influences — an

Elsewhere in this issue
based at the electron–p
of the high-energy acc
in Japan, announces
an anomalous asymm
of exotic particles kn
et al., page 332)[1]. Com
urements of the same
collaboration[2,3], a similar experiment at the
Stanford Linear Accelerator Center (SLAC)
in California, the new finding provides a tantalizing glimpse of a possible new source for a very fundamental asymmetry: the dominance of matter over antimatter in our Universe.

The two great principles of modern physics, quantum mechanics and Einstein's relativity,

The new results[1–3] are not conclusive, but they are tantalizing. They might be due to properties of standard b-quark weak interactions that we cannot quite yet estimate precisely, but it is equally possible that this is the first hint of an entirely new mechanism for particle–antiparticle asymmetry. In the next few years, these ideas will be tested, both through the analysis of the huge Belle and BaBar data set, and from the hunt for exotic particles at the LHC. We do not yet know whether it is penguins or even more unusual creatures that produce our Universe made of matter and not antimatter. ■





Summary

- $B \rightarrow K\pi$ is a powerful tool to search for NP.

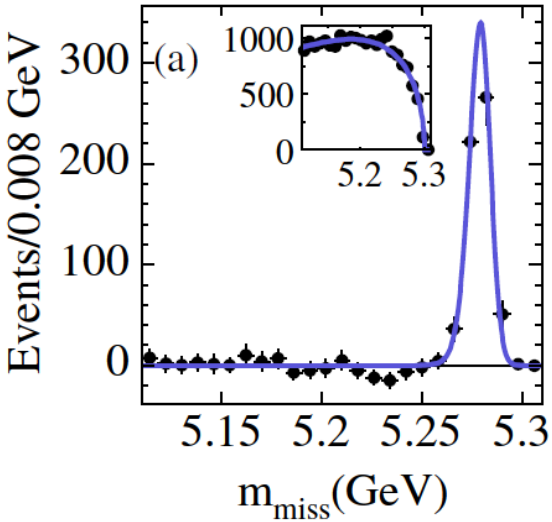
- Puzzle in Rc-Rn disappeared…
  - Need to reduce systematic error seriously.
- ΔA_{CP} puzzle is established w/ 5.3σ
  - sum rule predicts $A_{CP}(K^0\pi^0) = -0.153 \pm 0.045$
  - $\delta A_{CP}(K^0\pi^0) \sim 5\%$ @ $15ab^{-1}$

- To check "isospin sum rule" precisely, more data by upgraded B factories is needed.

Backup

CPV in $K^0\pi^0$ (signal yield)

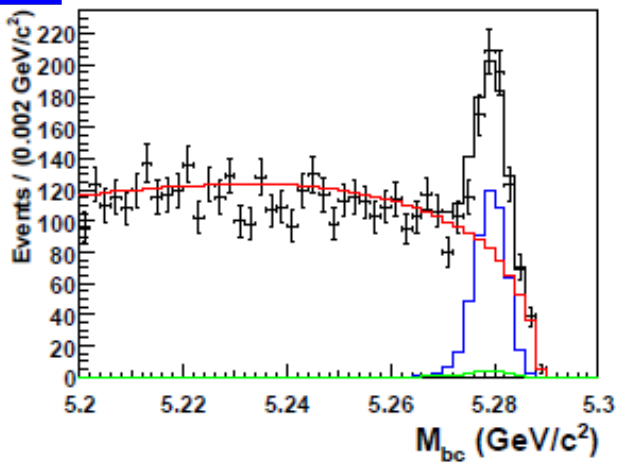
(465 $MB\bar{B}$)



$N(K_S\pi^0)=556\pm32$

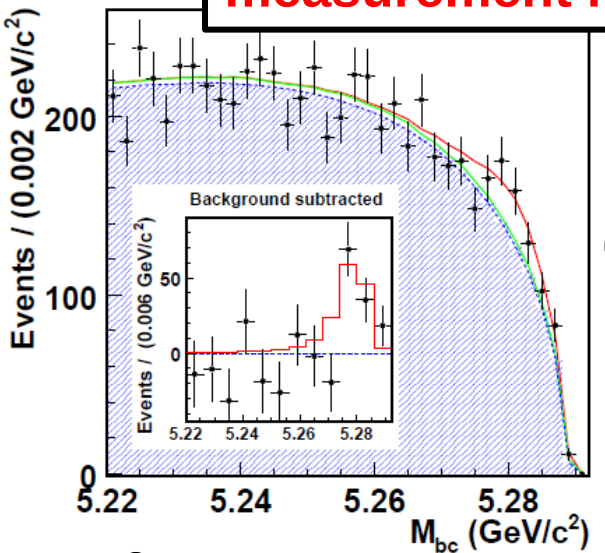
BELLE

(657 $MB\bar{B}$)



$N(K_S\pi^0)=634\pm36$

$K_L\pi^0$ first-time measurement for A_{CP}



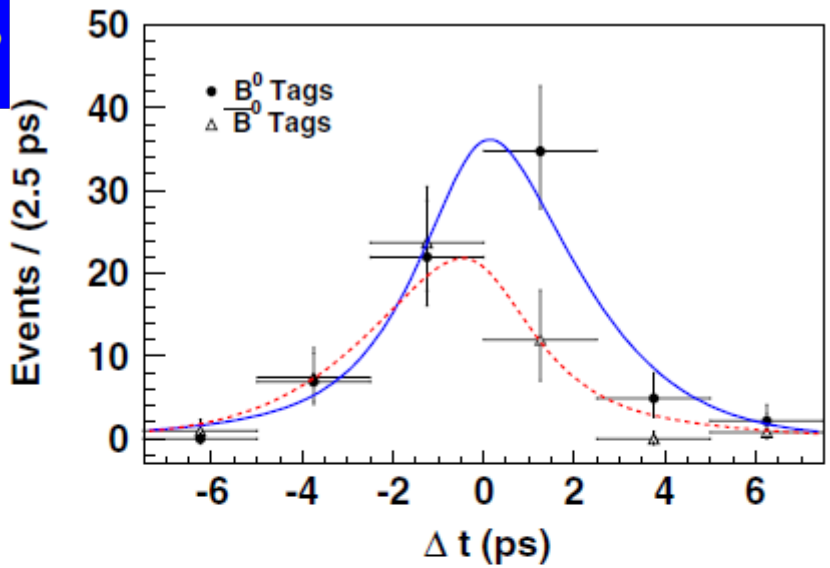
BELLE

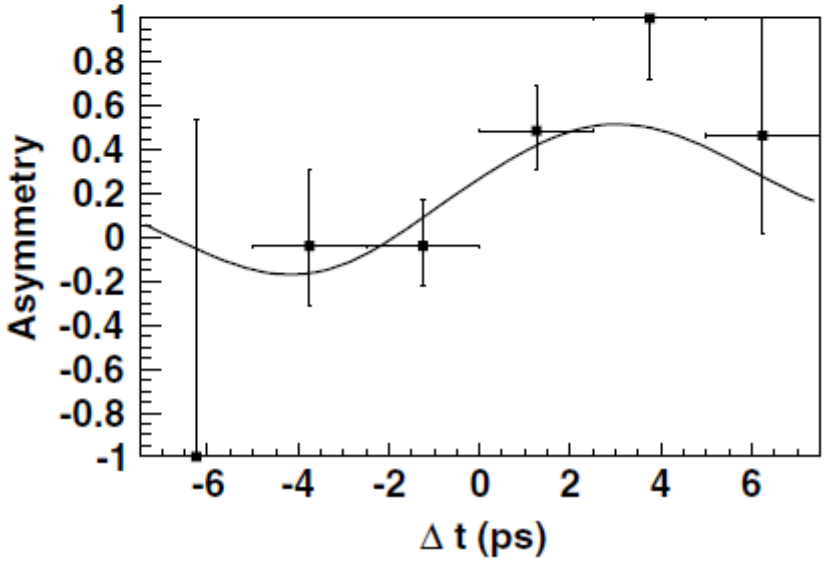
(657 $MB\bar{B}$)

$N(K_L\pi^0)=285\pm52\pm57$ (3.7σ)

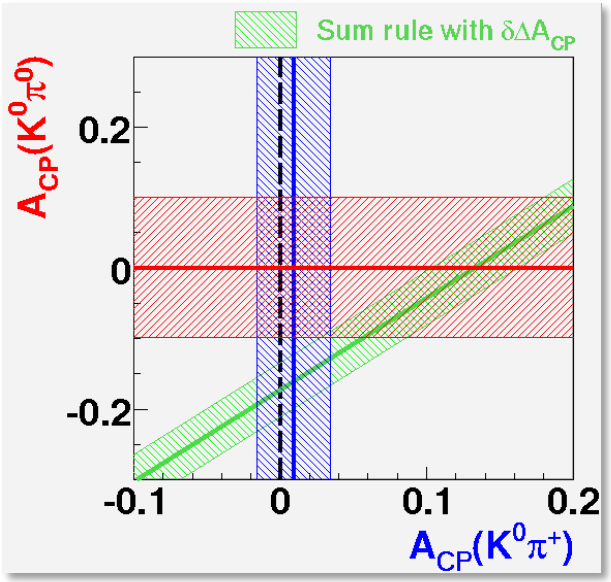
CPV in $K^0\pi^0$ (tCPV)

BELLE



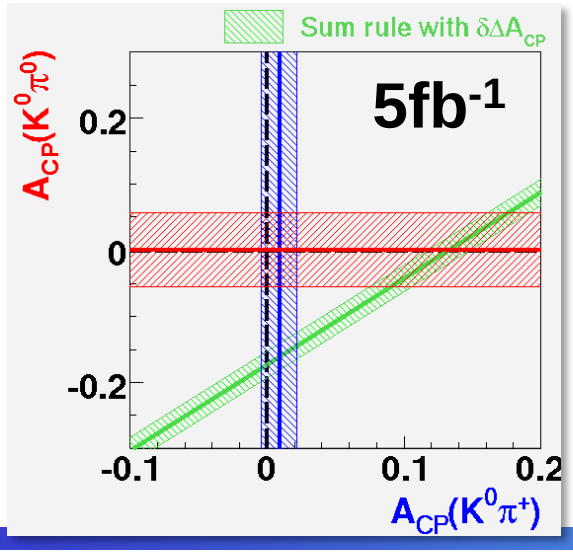


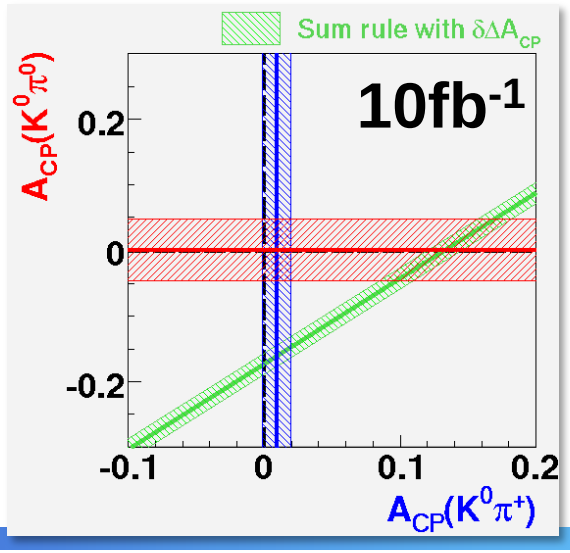
$A_{CP}(B \to K\pi)$

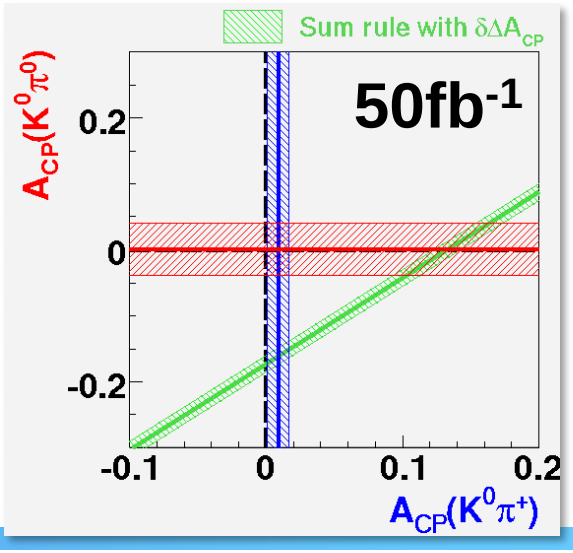


Current situation(~1ab^{-1}) using world average central values: $A_{CP}(B \to K\pi)$, $Br(B \to K\pi)$, τ_0, τ_+

Expectations using
- **Current world avg. central values**
- **Fixing current systematics**



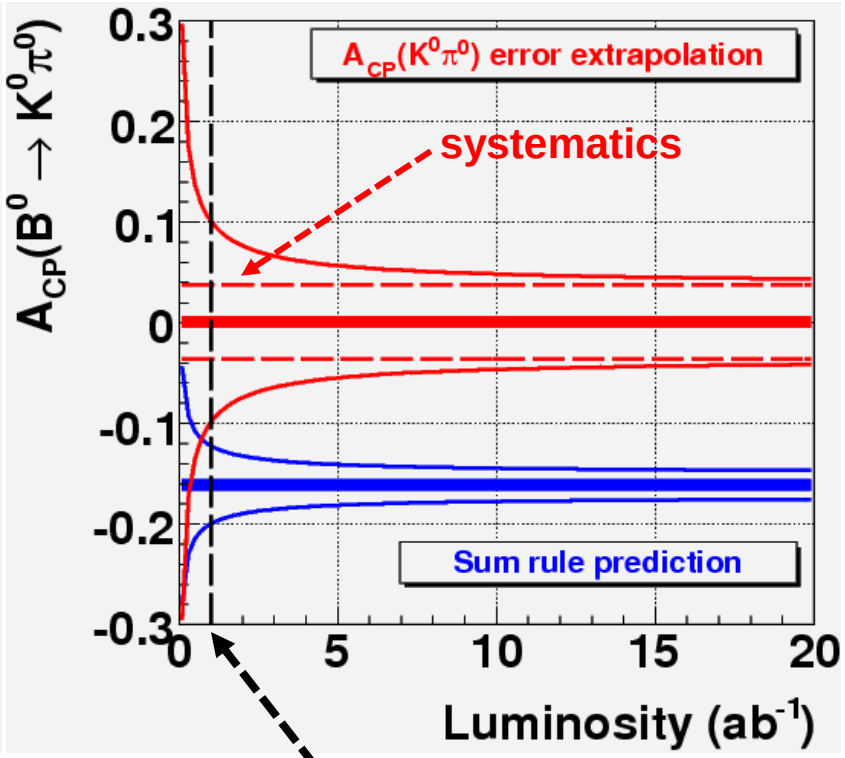




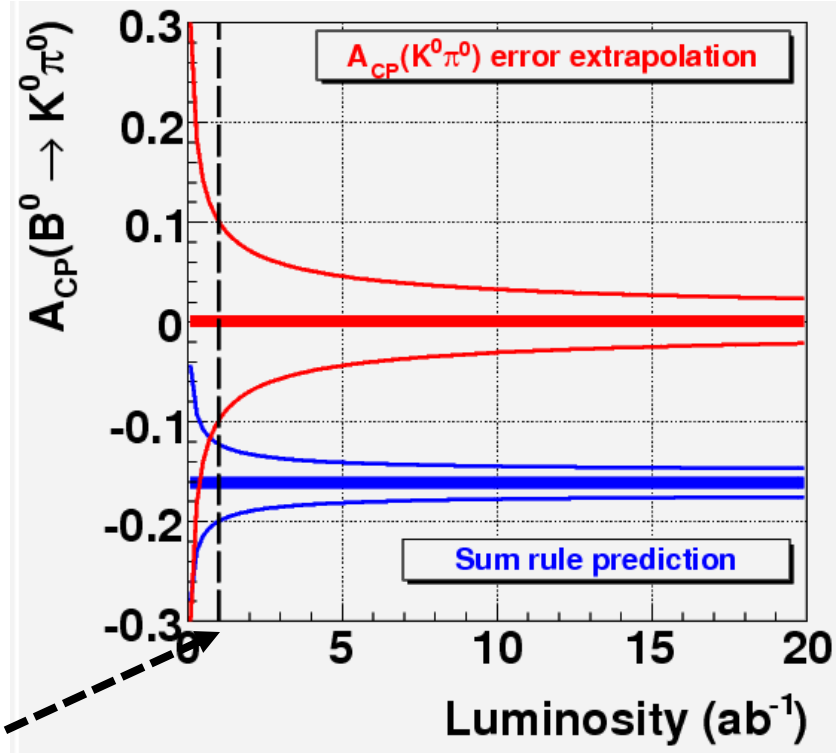
$A_{CP}(B \to K\pi)$

Expectation using current world average central values

(case 1)
Fix current systematics



(case 2)
systematics depends on statistics



Current situation($1ab^{-1}$)

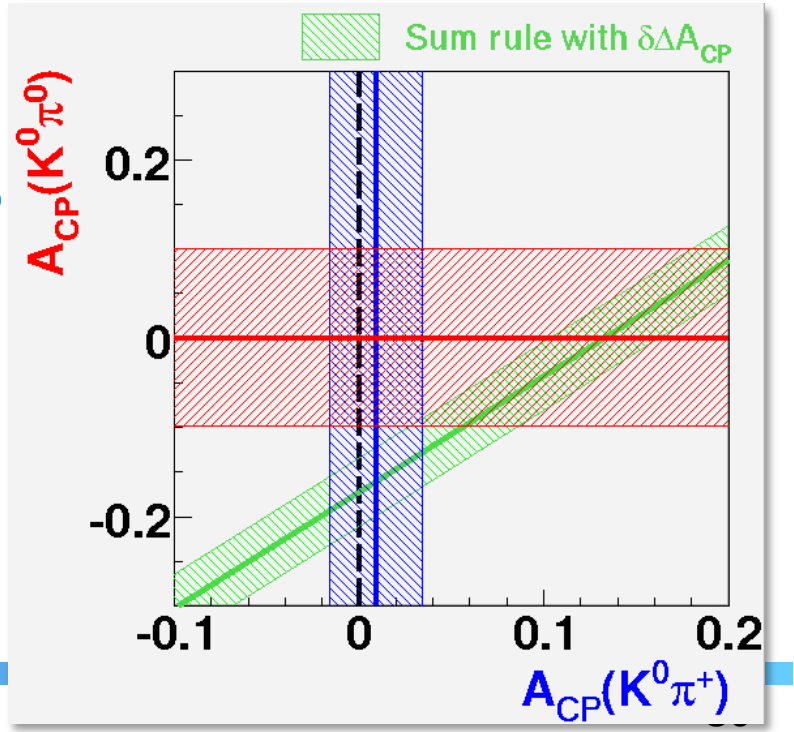
CPV in $K^0\pi^0$

	$\sin 2\phi_1$	A_{CP}
Belle	$0.67 \pm 0.31 \pm 0.06$	$-0.14 \pm 0.13 \pm 0.06$
Babar	$0.55 \pm 0.20 \pm 0.03$	$+0.13 \pm 0.13 \pm 0.03$
Avg.	0.57 ± 0.17	$+0.01 \pm 0.10$

$\sin 2\phi_1(K^0\pi^0)$ agrees with $\sin 2\phi_1(b \to c\bar{c}s) = 0.67 \pm 0.02$.

$A_{CP}(K^0\pi^0)$ is consistent with zero

- Sum rule $A_{CP}(K^0\pi^0) = -0.153 \pm 0.045$
- Deviation from sum rule is ~1.5σ
- Error of $A_{CP}(K^0\pi^0)$ is still large…



CPV in $K^0\pi^0$

TABLE I. Systematic uncertainties in $\sin 2\phi_1^{\rm eff}$ and $\mathcal{A}_{K^0\pi^0}$.

Source	$\Delta \sin 2\phi_1^{\rm eff}$	$\Delta \mathcal{A}_{K^0\pi^0}$
Wrong tag fraction	0.007	0.005
Physics parameters	0.007	0.001
Resolution function	0.063	0.007
Background Δt shape	0.015	0.006
Background fraction	0.029	0.022
Possible fit bias	0.010	0.020
Vertex reconstruction	0.013	0.022
Tag side interference	0.014	0.054
Total	0.077	0.064

Systematics of A_{CP}

	$K^{\pm}\pi^{\mp}$	$K^{\pm}\pi^{0}$
Signal PDF	$^{+0.0003}_{-0.0002}$	± 0.0004
Charmless B fraction	± 0.0001	$^{+0.0006}_{-0.0004}$
$\pi^{+}\pi^{-}$ amount	$^{+0.0003}_{-0.0001}$	–
Fake rate of $\pi^{+}\pi^{-}$ to $K^{+}\pi^{-}$	± 0.0013	–
Detector bias	± 0.0081	± 0.0056
Total	± 0.0082	± 0.0056

- detector bias of $K^{+}\pi^{0}$,$\pi^{+}\pi^{0}$ from qq bkg in (ΔE, m_{bc})
- detector bias of $K^{+}\pi^{-}$ from $D^{*+} \rightarrow D^{0}(\rightarrow K\pi)\pi^{+}$

Br(B→Kπ)

(10^{-6})	$K^+\pi^-$	$K^+\pi^0$	$K^0\pi^+$	$K^0\pi^0$
Belle	$19.9\pm0.4\pm0.8$ (449M) PRL99,121601(2007)	$12.4\pm0.5\pm0.6$ (449M) PRL99,121601(2007)	$22.8^{+0.8}_{-0.7}\pm1.3$ (449M) PRL98,181804(2007)	$8.7\pm0.5\pm0.6$ (657M) PRD81,011101
Babar	$19.5\pm0.6\pm0.6$ (227M) PRD75,012008(2007)	$13.6\pm0.6\pm0.7$ (383M) PRD76,091102(2007)	$23.9\pm1.1\pm1.0$ (348M) PRL97,171805(2006)	$10.1\pm0.6\pm0.4$ (467M) arXiv/0807.4226
CLEO	$18.0^{+2.3}_{-2.1}{}^{+1.2}_{-0.9}$ (15M) PRD68,052002(2002)	$12.9^{+2.4}_{-2.2}{}^{+1.2}_{-1.1}$ (15M) PRD68,052002(2002)	$18.8^{+3.7}_{-3.3}{}^{+2.1}_{-1.8}$ (15M) PRD68,052002(2002)	$12.8^{+4.0}_{-3.3}{}^{+1.7}_{-1.4}$ (15M) PRD68,052002(2002)
Avg.	19.4 ± 0.6	12.9 ± 0.6	23.1 ± 1.0	9.5 ± 0.5

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

	$K^+\pi^-$	$K^+\pi^0$	$K^0\pi^+$	$K^0\pi^0$
Belle	-0.094±0.018±0.008 (535M) Nature452,332(2008)	+0.07±0.03±0.01 (535M) Nature452,332(2008)	0.03±0.03±0.01 (449M) PRL98,181804(2007)	+0.14±0.13±0.06 (657M) PRD81,011101(2010)
Babar	$-0.107\pm0.016^{+0.006}_{-0.004}$ (467M) arXiv/0807.4226	+0.030±0.039±0.010 (383M) PRD76,091102(2007)	-0.029±0.039±0.010 (348M) PRL97,171805(2006)	-0.13±0.13±0.03 (467M) PRD79,052003(2009)
CDF	-0.086±0.023±0.009 (1fb) NPB170,39-45(2007)	---	---	---
CLEO	-0.04±0.16±0.02 (10M) PRL85,525(2000)	-0.29±0.23±0.02 (10M) PRL85,525(2000)	0.18±0.24±0.02 (10M) PRL85,525(2000)	---
Avg.	$-0.098^{+0.012}_{-0.011}$	0.050±0.025	0.009±0.025	0.01±0.10

Introduction (Direct CP violation)

- **Decay amplitudes:**

$$A(B \to f) = \sum_i A_i e^{i(\delta_i + \phi_i)}$$
$$\overline{A}(\overline{B} \to \overline{f}) = \sum_i A_i e^{i(\delta_i - \phi_i)}$$

- **CP violating asymmetry (A_{CP}) is defined as:**

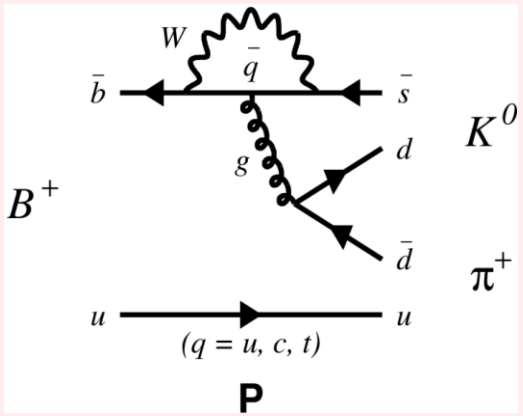
$$\mathcal{A}_{CP}(B \to f) = \frac{|\overline{A}|^2 - |A|^2}{|\overline{A}|^2 + |A|^2} \propto \sum_{i,j} A_i A_j \sin(\delta_i - \delta_j) \sin(\phi_i - \phi_j)$$

- **A non-zero A_{CP} requires the following 3 conditions:**
  - more than 2 amplitudes
  - non-zero strong phase difference : $\delta_i - \delta_j = \Delta\delta \neq 0$
  - non-zero weak phase difference : $Á_i - Á_j = \Delta Á \neq 0$

- **DCPV measurement plays important roles:**
  - Test KM model
  - Help to understand B decay mechanism
  - Search for new physics beyond SM
  - In ratios of BFs, systematic uncertainties cancel

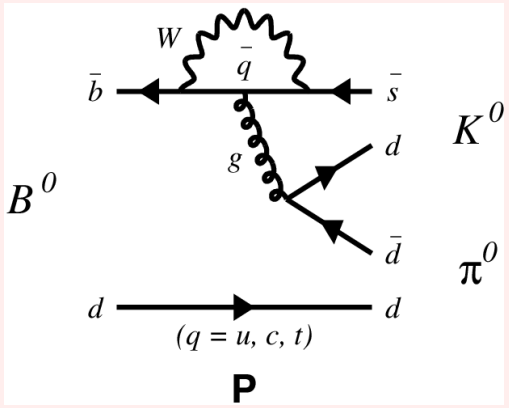
Introduction ($B \to K\pi$)

$B^+ \to K^0\pi^+$ (P)



- A_{CP}~0 in SM

$B^0 \to K^0\pi^0$ (P)



- A_{CP}~0 in SM
- S~sin2$\phi_1(\beta)$ in SM (ΔS~O(0.1))
- help to test ΔS puzzle:

  sin2ϕ_1 from b→sq$\bar{q}$ differs from J/ψK^0

$B^0 \to K^0K^+$ (P)

- b→d Penguin
- Br ~0.05 x Br($B^+ \to K^0\pi^+$)
- Sizable A_{CP} in SM

  (J.-M. Gerard, W.-S. Hou, PLB253,478)

$B^+ \to \pi^+\pi^0$ (T)

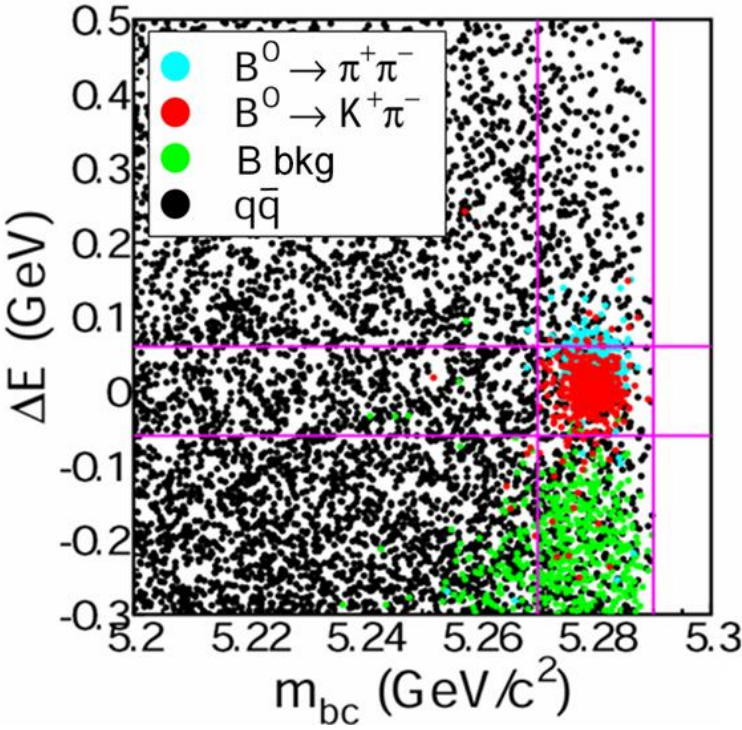
- A_{CP}~0 in SM
- No P due to Isospin symmetry

Analysis Overview

Kinematic reconstruction

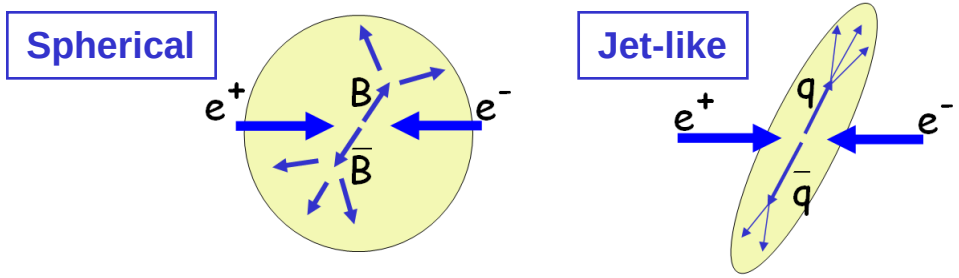
- $K^0 \rightarrow K_S \rightarrow \pi^+\pi^-$
- $\pi^0 \rightarrow \gamma\,\gamma$
- B reconstruction

$$\begin{cases} \Delta E & \equiv & E_B^* - E_{\rm beam}^* \\ m_{bc} & \equiv & \sqrt{E_{\rm beam}^{*2} - p_B^{*2}} \end{cases}$$



Main background

- $e^+e^- \rightarrow q\bar{q}(q=u,d,s,c)$ ➔ event topology



- π / K separation ➔ PID

Signal extraction

- Unbinned ML fit to ΔE, m_{bc} for B & $\bar{B}$

$$\begin{cases} \mathcal{L} & = & \dfrac{exp(-\sum_j n_j)}{n!} \prod_{i=1}^{n_{cand}} (\sum_j n_j \mathcal{P}_j^i) \\ \mathcal{P}_j^i & = & \dfrac{1}{2}(1 - q^i \cdot \mathcal{A}_{CP_j})\, \mathcal{P}_j'(m_{bc}{}^i, \Delta E^i) \end{cases}$$