How I was assigned for the talk...

Hi,

I was asked by Ian Shipsey, who is organizing Beyond 10**34 session of BCP4, to find a speaker of 15min talk at evening session. Topic which is supposed be covered is CP asymmetries in a very large range of rare ... (skip) ...

If any of you are interested, please let me know as soon as possible. *Since this is at the evening session (after a few drinks), you dont have to take this too rigorously.*

K.... A..

and I just replied faster than others ...

CP asymmetries in B decays with high-luminosity e^+e^- collision

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Yonsei University / Belle

Overview

- Precision of unitarity angles
  - ★ $\sin 2\phi_1$ and $\sin 2\phi_2$
- CPV in inclusive B decays
  - ★ A_{cp} in like-sign dileptons
  - ★ A_{cp} in $b \to s\gamma$
  - ★ A_{cp} in inclusive $B \to K^{(*)-}X$
- Summary

Stealing freely from others' study ...

CKM angles — $\sin 2\phi_1$

Def.
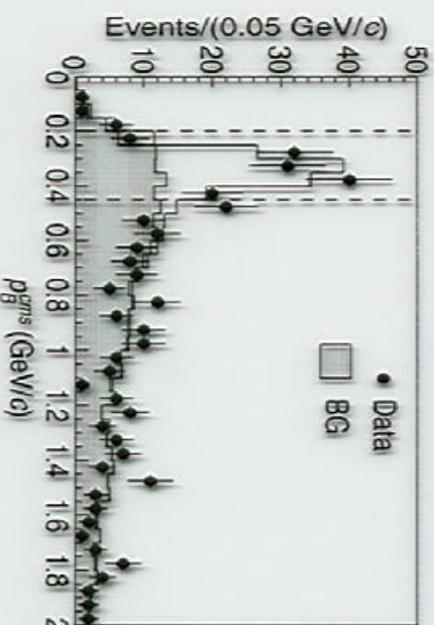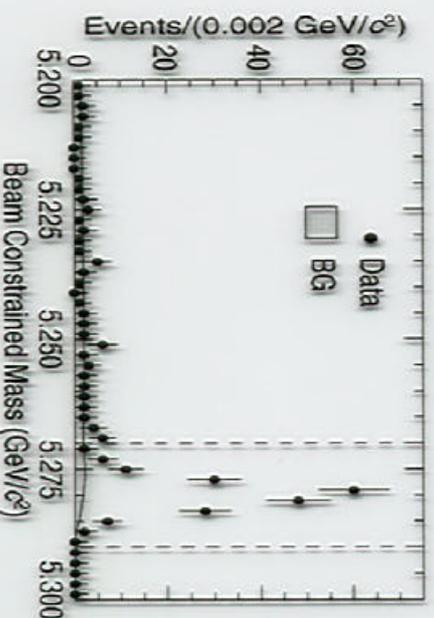
$$\phi_1 \equiv 180^\circ - \arg\left(\frac{-V_{tb}^* V_{td}}{-V_{cb}^* V_{cd}} \right)$$

How to :

$$A(t) \equiv \frac{\Gamma(\overline{B}_d^0 \to f_{CP}) - \Gamma(B_d^0 \to f_{CP})}{\Gamma(\overline{B}_d^0 \to f_{CP}) + \Gamma(B_d^0 \to f_{CP})} = -\xi_f \sin(2\phi_1)\sin(\Delta m_d t)$$

- A result from Belle (Feb. 2001) with $\int \mathcal{L}\, dt = 10.5$ fb^{-1} **(Hazumi)**

Since I have to obtain #'s for many different Luminosity milestones, a very simple (and rough) extrapolation rule is used.

- Stat. Unc. α $\frac{1}{\sqrt{x}}$

- Syst. unc.

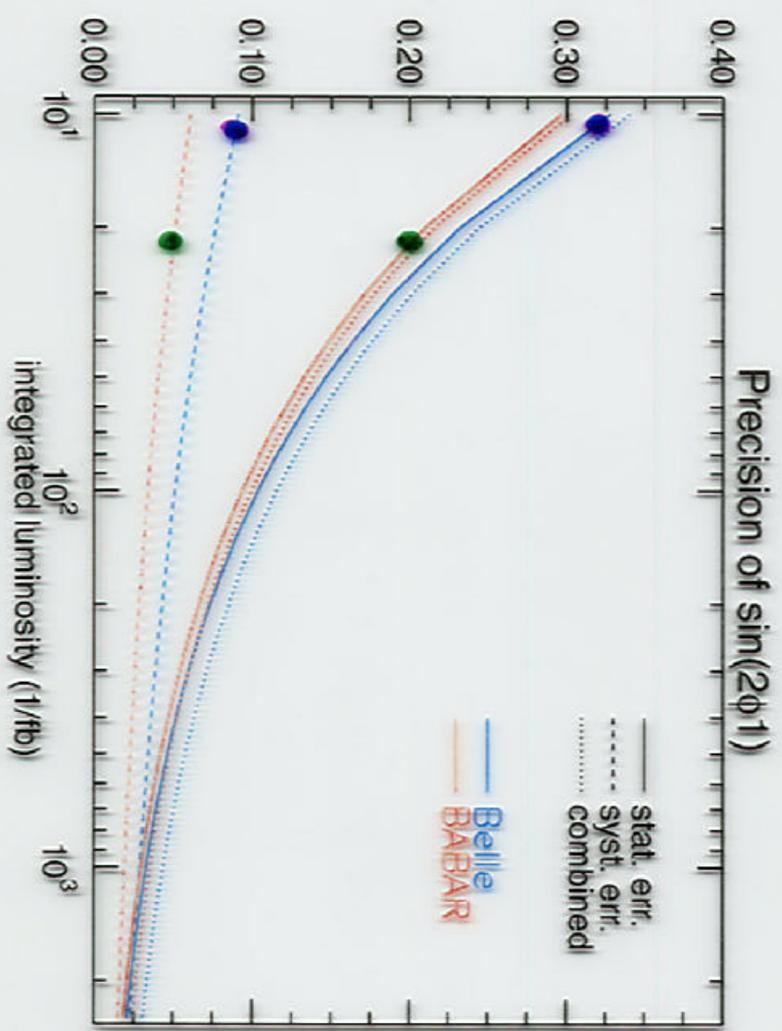 . Some syst. err. remains flat, while others can be reduced with more data.

  $\Rightarrow$ How about $E_{syst.}$ α $1/\ell^{1/4}$?

  "Running" Syst. err.

• Comparison of Belle and BABAR

Expt.	$\int L\, dt$ (fb^{-1})	sin 2φ₁	stat. err.	sys. err.	ε_eff (tag.)
Belle	10.5	0.58	$^{+0.32}_{-0.34}$	$^{+0.09}_{-0.10}$	$0.270^{+0.021}_{-0.022}$
BABAR	22	0.34	±0.20	±0.05	0.267 ± 0.016

Precision of sin(2φ1)

integrated luminosity (1/fb)

stat. err.
syst. err.
combined

Belle
BABAR

~ 100 fb⁻¹
for δ(sin 2φ₁)
~ 10% err.

δ(sin 2φ₁) ~ 0.1
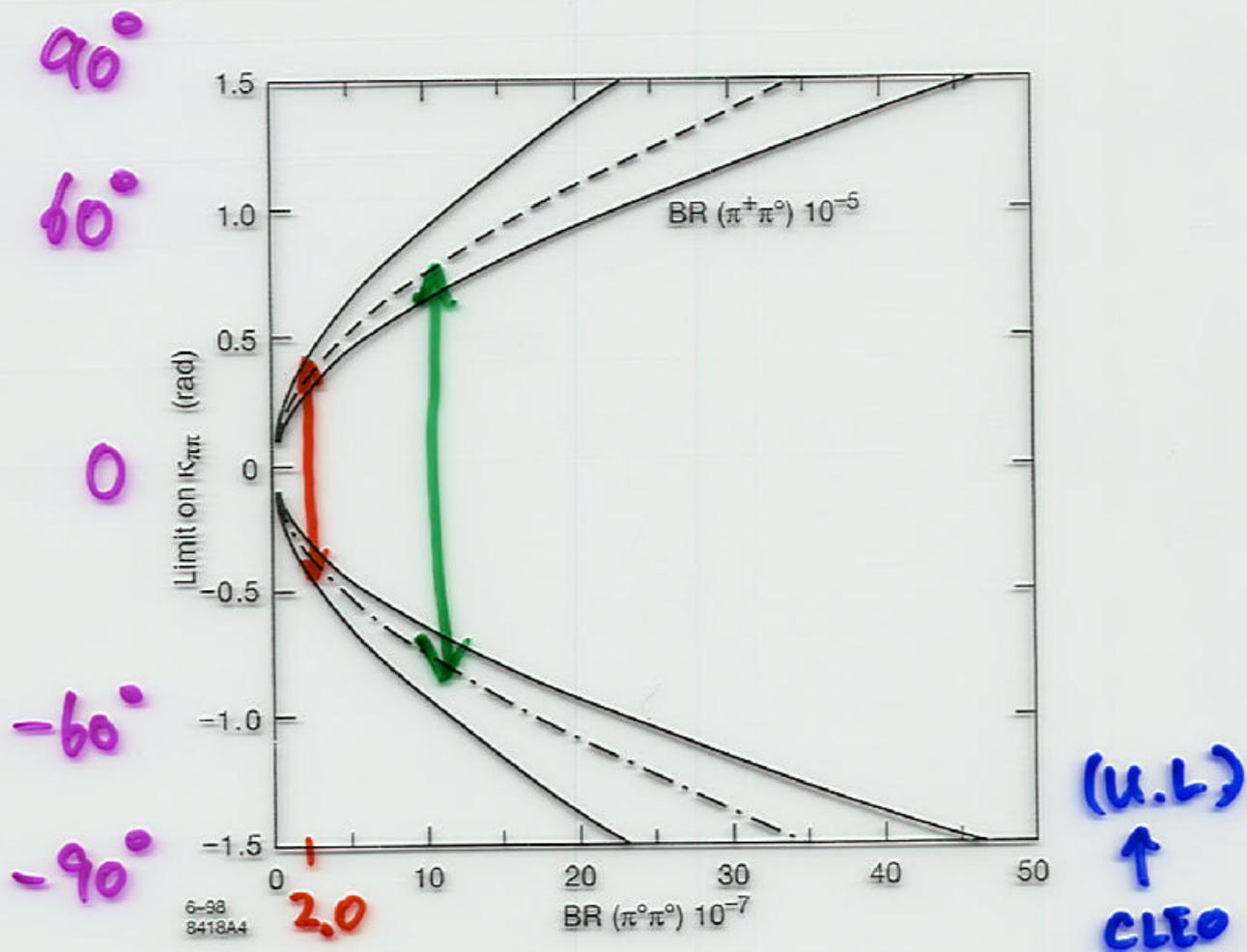
~ 2,500 fb⁻¹
for δ(sin 2φ₁)
~ 0.02

Figure 6-12. Limits for the $\kappa_{\pi\pi}$ confidence level interval $[-\overline{\kappa_{\pi\pi}}, +\overline{\kappa_{\pi\pi}}]$ versus the upper limit on $\mathcal{B}^{00}$ (horizontal scale 10^{-7}). The three curves displayed refer to $\mathcal{B}(B^{\pm} \to \pi^{\pm}\pi^0) = 1 \times 10^{-5}$, 0.75×10^{-5} and 0.5×10^{-5}.

CKM angles — $\sin 2\phi_2$

- large penguin pollution

- Gronau & London's isospin triangle to clean up penguin pollution (*unlike* $\sin 2\phi_1$)

$$B \to \pi^+\pi^-$$
$$\pi^+\pi^0$$
$$\pi^0\pi^0$$

$$\bar{B} \to \pi^-\pi^+$$
$$\pi^-\pi^0$$
$$\pi^0\pi^0$$

$$BF < 5.7 \times 10^{-6}$$

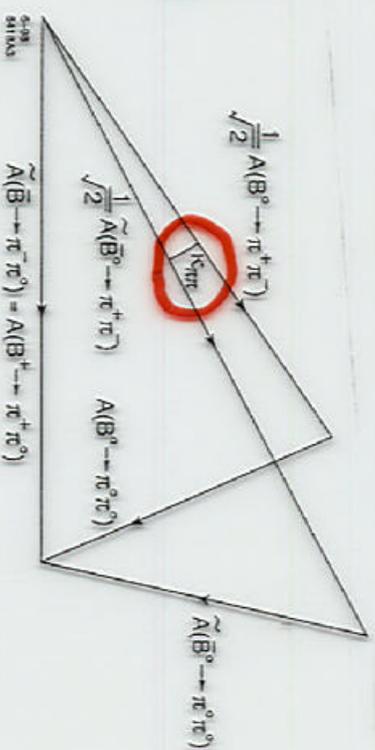* $B \to \pi^0\pi^0$ might be a problem...

* interesting bounds on $\delta(\sin 2\phi_2)$ by Grossmann & Quinn

$$\delta(\sin 2\phi_2) \leq \sqrt{\frac{B(B \to \pi^0\pi^0)}{B(B^\pm \to \pi^\pm\pi^0)}}$$

(A. Lyon)   but ...

- using $B \to \rho\pi$ (Snyder & Quinn)

- Somehow, I have to provide $\delta(\sin 2\phi_2)$ as a function of $\int \mathcal{L}\, dt$. *again!*

- Without doing full simulation, nor detailed mastery of underlying theories, I devised a (very rough) ball-park estimation scheme, as following:

(*Part 1*)

$$\delta(\sin 2\phi_{\text{eff}}) \approx \sqrt{\frac{1 + N_{\text{bkg}}/N_{\text{obs}}}{N_{\text{obs}}}} \frac{1}{d(1 - 2w)},$$

where ϕ_{eff} is the CPV phase distorted by penguin pollution.

Some arbitrary choice of input numbers

* $d = 1$ (dilution factor)
* $1 - 2w = 0.27$ (from Belle's $\sin 2\phi_1$ paper)
* N_{bkg} and N_{obs} are taken from newest Belle results (See Iijima's talk.)

on $B \to \pi^+\pi^-$

ππ / Kπ / KK Summary

- Results w/ 11.1M BB̄

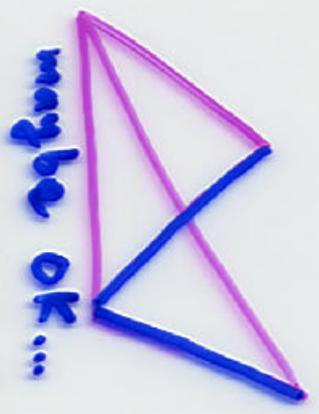| Mode	Ns	Σ	Eff (%)	Br(10^{-5})	U.L. (10^{-5})
$B^0 \to \pi^+\pi^-$	$17.7^{+7.1}_{-6.4}$	3.1	28	$0.59^{+0.24}_{-0.21} \pm 0.05$	-
$B^+ \to \pi^+\pi^0$	$9.4^{+4.8}_{-4.0}$	2.9	12	$0.71^{+0.36}_{-0.30}{}^{+0.09}_{-0.12}$	1.26
$B^0 \to K^+\pi^-$	$60.3^{+10.6}_{-9.9}$	7.8	29	$1.87^{+0.33}_{-0.30} \pm 0.16$	-
$B^+ \to K^+\pi^0$	$35.8^{+7.7}_{-7.0}$	7.5	19	$1.70^{+0.37}_{-0.33}{}^{+0.20}_{-0.22}$	-
$B^+ \to K^0\pi^+$	$10.3^{+4.3}_{-3.6}$	3.5	13	$1.31^{+0.55}_{-0.46} \pm 0.26$	-
$B^0 \to K^0\pi^0$	$8.8^{+3.7}_{-3.1}$	4.2	11	$1.46^{+0.61}_{-0.51} \pm 0.27$	-
$B^0 \to K^+K^-$	$0.2^{+3.8}_{-0.2}$	-	24		0.27
$B^+ \to K^+K^0$	$0.0^{+0.9}_{-0.0}$	-	13		0.25

- To consider uncertainties from isospin analysis (for $B \to \pi\pi$)
  $\Rightarrow$ a naiive order-of-magnitude guesstimate:

$$\delta\phi_{\text{penguin}} \approx \sqrt{\left(\frac{\sigma_{+-}}{B_{+-}}\right)^2 + \left(\frac{\sigma_{+0}}{B_{+0}}\right)^2 + \left(\frac{\sigma_{00}}{B_{00}}\right)^2},$$

where σ_{ij} is the error in $B(B \to \pi^i \pi^j)$.

maybe OK... *8-)* *maybe not...*

??

- Again, I use Belle's newest results for $B(B \to \pi^+\pi^0)$ and $B(B \to \pi^+\pi^-)$.
- Assume $B(B \to \pi^0\pi^0) = 10^{-6}$ and 2×10^{-7} with $S/N \sim 1/2$ for the 10^{-6} case.
- Assume $\varepsilon_{\text{signal}} \sim 15\%$
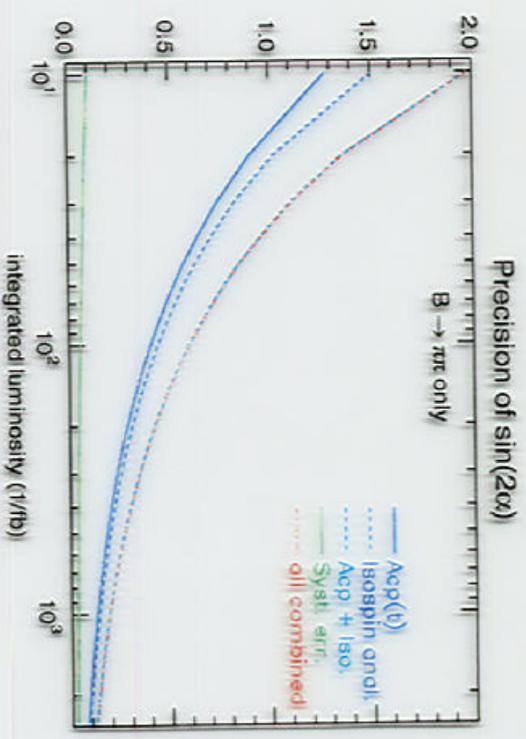 $\sim 29\%$ for CLIO (A. Lyon)   ($\leftarrow$ BaBar report)

① $B(B \to \pi^0 \pi^0) \simeq 10^{-6}$

Precision of $\sin(2\alpha)$

- at $\int \mathcal{L} \, dt = 500 \text{ fb}^{-1}$, $\delta(\sin 2\phi_2) \sim 0.3$
- at $\int \mathcal{L} \, dt = 2500 \text{ fb}^{-1}$, $\delta(\sin 2\phi_2) \sim 0.1$
- In other words, we may need $10^{37} \text{cm}^{-2}\text{s}^{-1}$ fo
  A nice agreement (coincidence?) with Sandla's pr
- If results from other modes/methods ($B \to \rho\pi$
  etc.) are combined, we may gain a few factors

Can we

CPV in inclusive B decays

- Why inclusive?

  $\Rightarrow$ *EHT taught me the fun of inclusive analysis.., 8-)*

  $\Rightarrow$ unique for $\Upsilon(4S)$ experiments, *i.e.* B-factory!

- In general, SM prediction is small, but some models predict large A_{CP}.

  $\Rightarrow$ nice window for new physics search!

I will talk about:

- A_{cp} in like-sign dileptons **(K. Ecklund)**
- A_{cp} in $b \to s\gamma$ **(A. Lyon)**
- A_{cp} in inclusive $B \to K^{(*)-} X$

• and theorists love inclusive ...

CPV in like-sign dileptons
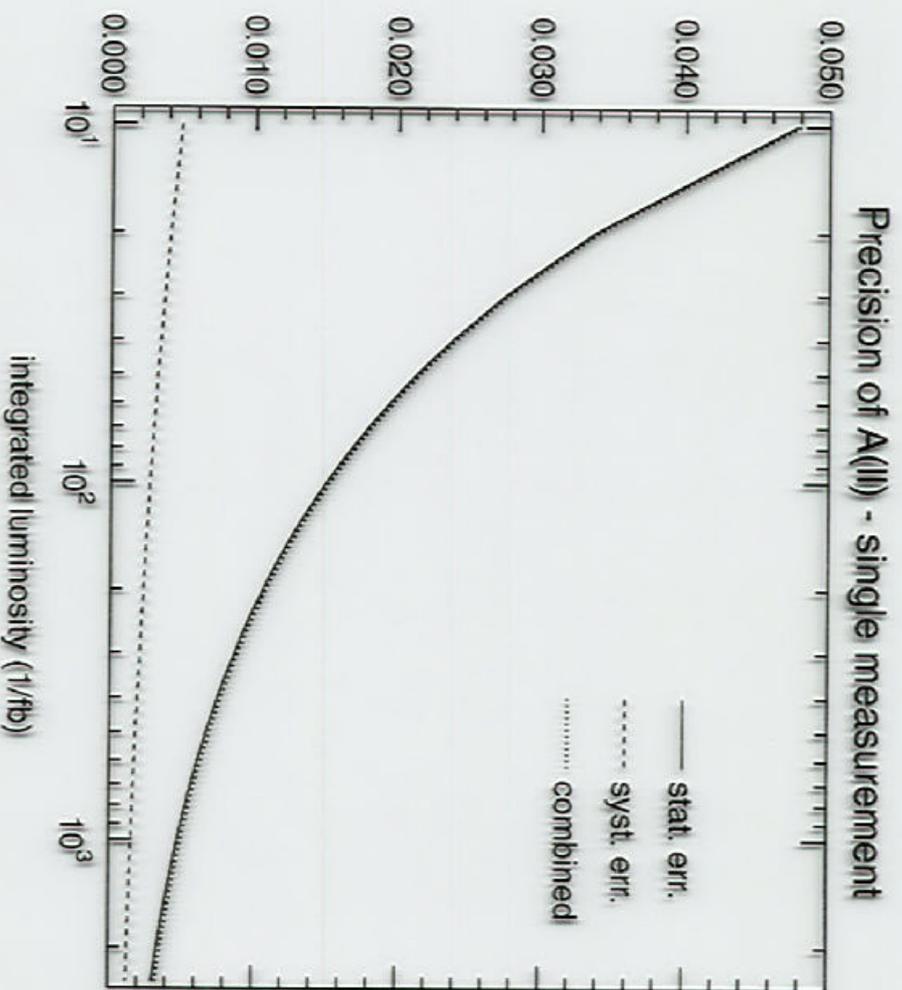
- Charge asymmetry

$$A_{\ell\ell} \equiv \frac{N(\ell^+\ell^+) - N(\ell^-\ell^-)}{N(\ell^+\ell^+) + N(\ell^-\ell^-)}$$

- SM prediction:

$$Re(\epsilon_B) \sim 10^{-3}$$

$$A_{\ell\ell} = 4 \times Re(\epsilon_B)/(1 + \epsilon_B{}^2) \sim 4 \times 10^{-3}$$

- super-weak model (SW) prediction may allow up to an order of magnitude larger $A_{\ell\ell} \sim 10^{-2}$

- newest result from CLEO (Jan. 2001) with $\int \mathcal{L}\, dt = 9.1$ fb^{-1}

$$A_{\ell\ell} = (0.013 \pm 0.050 \pm 0.005)(1.00 \pm 0.10)$$

Precision of A(ll) - single measurement

integrated luminosity (1/fb)

- stat. err.
- syst. err.
- combined

- $\sim 200\ \mathrm{fb}^{-1}$ is needed to check SW, and all of 2,500 fb^{-1} for SM signal search.

CPV in $b \rightarrow s\gamma$ inclusive

- inclusive decays: very clean calculation

- exclusive channels may show similar A_{cp}, but theoretical calculation is not as clean

- SM prediction: very small
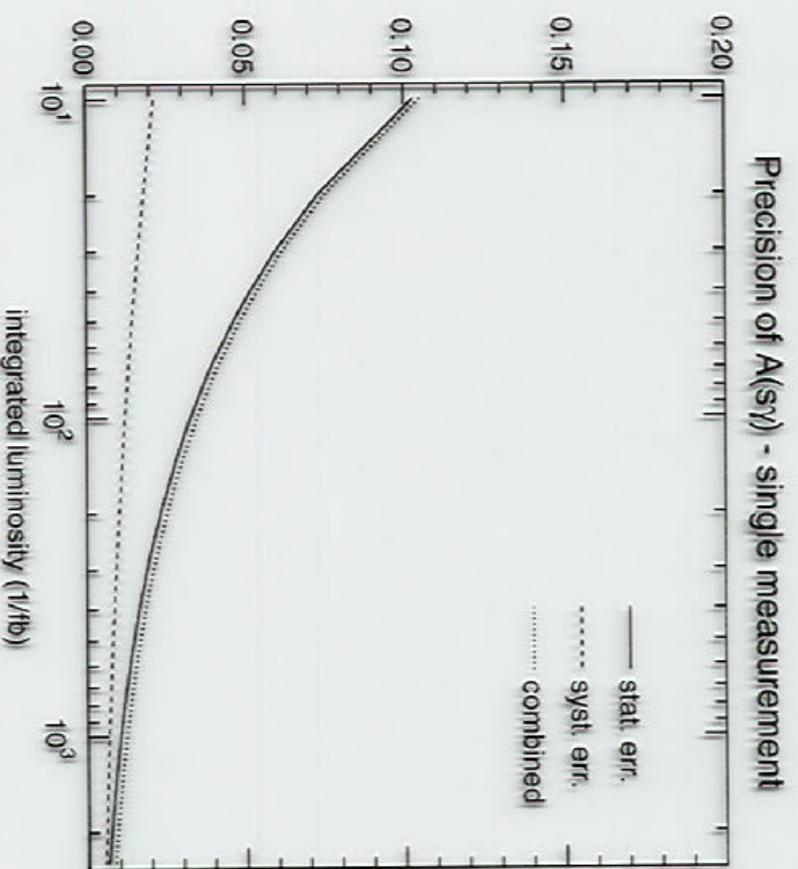
$$A^{s\gamma}_{CP} < 0.01$$

- if chromomagnetic dipole transitions (caused by some new flavor physics at a high scale) is enhanced,

$$A^{s\gamma}_{CP} \sim 0.1$$

Kagan & Neubert; Aoki, Cho & Oshimo

- newest result from CLEO (Jan. 2001) with $\int \mathcal{L}\, dt = 9.1$ fb^{-1}

$$A^{s\gamma}_{CP} = (-0.079 \pm 0.108 \pm 0.022)(1.00 \pm 0.030)$$

Precision of A(sγ) - single measurement

— stat. err.
······ syst. err.
········ combined

integrated luminosity (1/fb)

- already rules out some extreme non-SM

- at $\int \mathcal{L}\, dt = 100$ fb^{-1}, $\delta(A^{s\gamma}_{CP}) \sim 0.03$

- at $\int \mathcal{L}\, dt = 500$ fb^{-1}, $\delta(A^{s\gamma}_{CP}) < 0.02$

- at $\int \mathcal{L}\, dt = 2500$ fb^{-1}, $\delta(A^{s\gamma}_{CP}) < 0.01$

Table 1: Integrated decay rates and asymmetries for $B \rightarrow K^{(*)}X$ Decay

Process	BR (1.65×10^{-4})	Integrated A_{CP}
$B^- \rightarrow K^- X$	1.02, 0.79, 1.20	$-0.10, -0.11, -0.050$
with $E_K \geq 2.1\text{GeV}$	0.81, 0.74, 0.77	$-0.12, -0.12, -0.07$
$\overline{B}^0 \rightarrow K^- X$	0.6, 0.7, 0.8	$-0.12, -0.12, -0.13$
$B^- \rightarrow K^{*-} X$	1.37, 1.24, 2.30	$-0.11, -0.14, -0.11$
with $E_{K*} \geq 2.1\text{GeV}$	1.05, 1.16, 1.67	$-0.14, -0.15, -0.14$
$\overline{B}^0 \rightarrow K^{*-} X$	1.05, 1.16, 1.39	$-0.15, -0.15, -0.16$

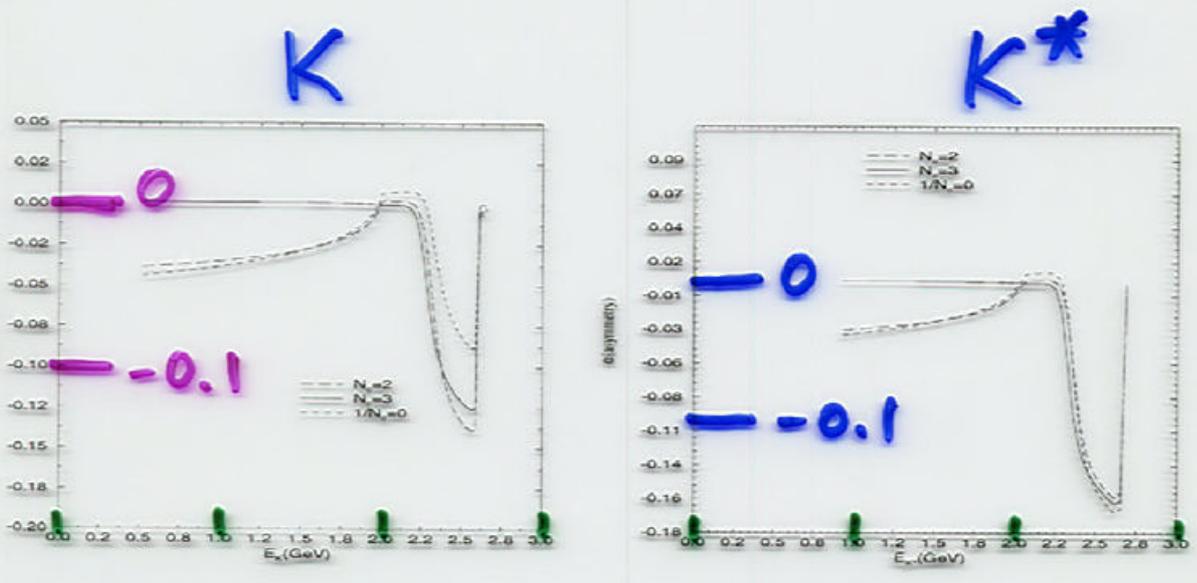*(handwritten annotations: BR ~ 10^{-4}, Integrated A_{CP} ~ 0.1)*

Figure 3: Predicted Asymmetries for $B^- \rightarrow K^- X$ and $B^- \rightarrow K^{*-} X$ as a function of the kaon energy. The three sets of curves indicate the sensitivity of the asymmetry to the value of N_c. The values $N_c = 2, 3, \infty$ are considered.

CPV in inclu. $B \to K^{(*)-}X$

– original study was performed by Browder, Datta, He, and Pakvasa (PRD 57, 6829)
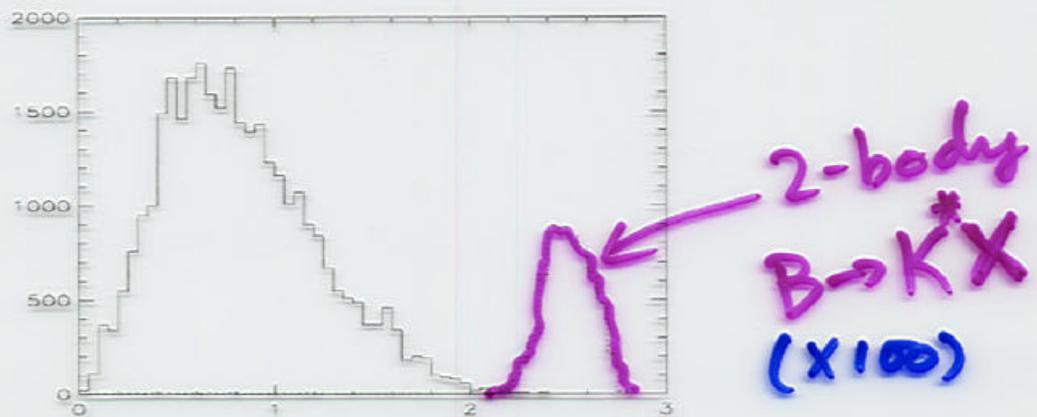
and recently also by He, Jin, and Ma (hep-ph/0011317)

(handwritten annotation: 2-body $B \to K^*X$ (x100))

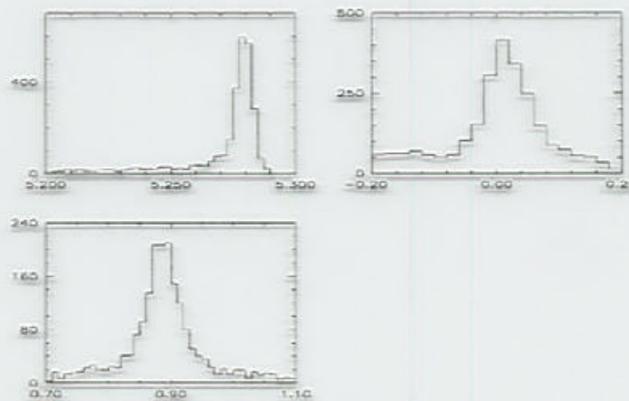Figure 1: Generated Inclusive $B \to K^{*-}$ momentum spectrum.

Figure 2: MC signal plots of inclusive $B \to K^{*-}X$ with the B reconstruction method.

- Experimental methods for continuum suppression

  * quasi-inclusive ("pseudo-reconstruction")

   1. $B^- \to K^{(*)-} \pi^0$
    2. $\bar{B}^0 \to K^{(*)-} \pi^+$
    3. $B^- \to K^{(*)-} \pi^- \pi^+$
    4. $\bar{B}^0 \to K^{(*)-} \pi^+ \pi^0$
    5. $\bar{B}^0 \to K^{(*)-} \pi^+ \pi^- \pi^+$
    6. $B^- \to K^{(*)-} \pi^+ \pi^- \pi^0$
    7. $B^- \to K^{(*)-} \pi^+ \pi^- \pi^+ \pi^-$
    8. $\bar{B}^0 \to K^{(*)-} \pi^+ \pi^- \pi^+ \pi^0$

    $\varepsilon \sim 5\%$ for $\eta' X$

    "Methods similar to these have been successfully used by the CLEO II experiment to isolate a signal in the inclusive single photon energy spectrum and measure the branching fraction for inclusive $b \to s\gamma$ transitions ... It is clear from these studies that the B reconstruction method provides adequate continuum background suppression." **PRD 57, 6829**

  * An alternative: K-lepton correlations – self-tagging

    (Belle preliminary)

K-e Other B
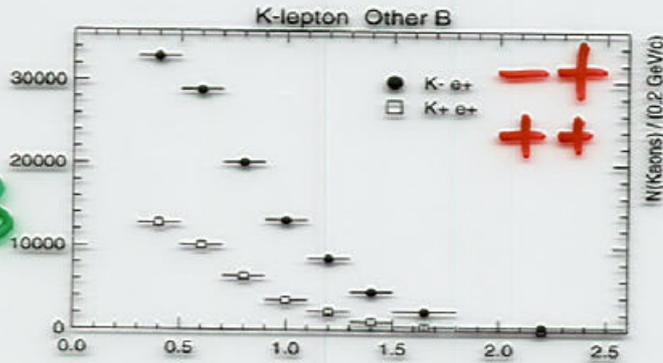
Same B
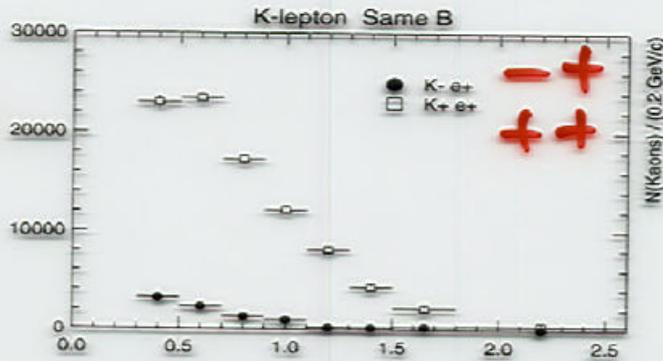
Basic principles

K-ℓ [1987 CLEO
1994 ARGUS
1998 CLEO
D-ℓ

Measurement of flavor-specific inclusive kaons in B decays.

- A main tool is the $\cos\theta_{K-\ell}$ and charge correlation between the Kaon and lepton.

- A high-momentum lepton tags the flavor of its parent B very effectively.

- The direction of a final state particle of a B shows a strong back-to-back correlation with the directions of the final state particles from the same B. And in the other B case, there is almost no angular correlation.

- Using the charge-angle correlation information, we can derive the flavor-specific inclusive charged kaon rates

$$\frac{N(K^+\ell^-\,;\text{opposite B})}{N(\text{leptons})} \Rightarrow \mathcal{B}(B \to K^+ X)$$

$$\frac{N(K^-\ell^-\,;\text{opposite B})}{N(\text{leptons})} \Rightarrow \mathcal{B}(B \to K^- X)$$

$$\frac{N(K^-\ell^+\,;\text{same B})}{N(\text{leptons})} \Rightarrow \mathcal{B}(B \to K^-\ell^+ X)$$

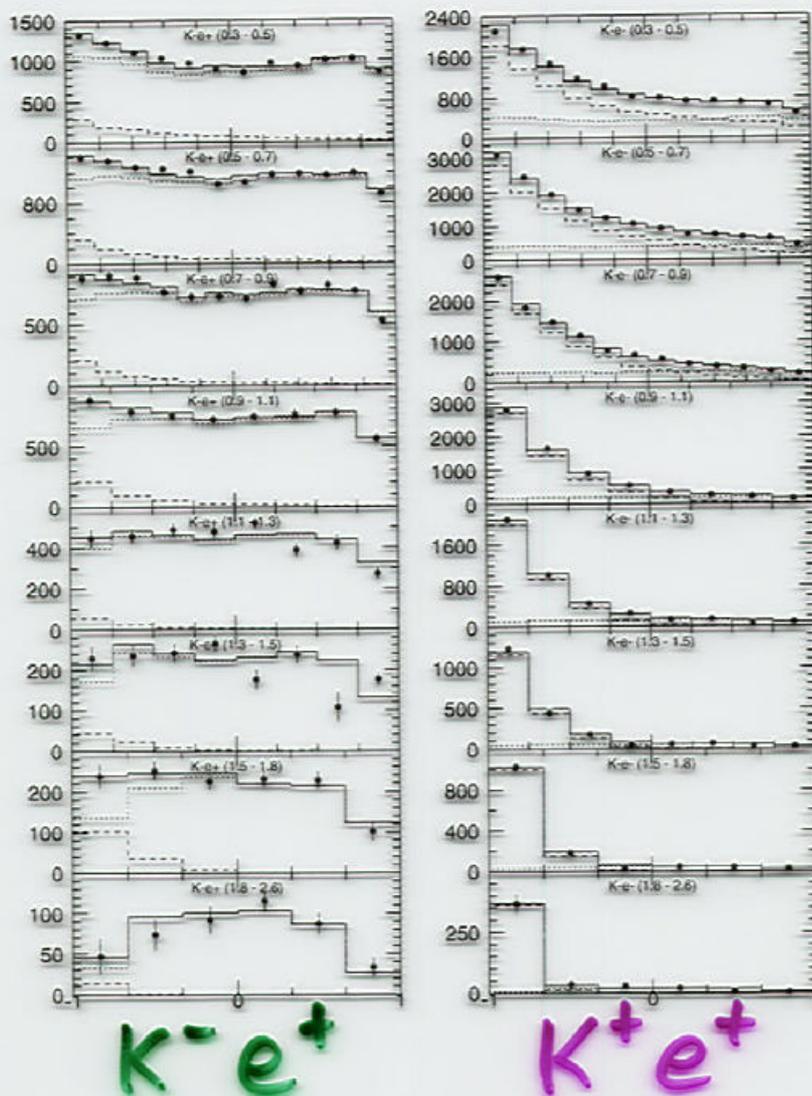$$\frac{N(K^+\ell^+\,;\text{same B})}{N(\text{leptons})} \Rightarrow \mathcal{B}(B \to K^+\ell^+ X)$$

Same-B / Other-B decomposition

$p_K^{c.m.}$

K^-e^+ K^+e^+

- Inclusive kaon branching fraction
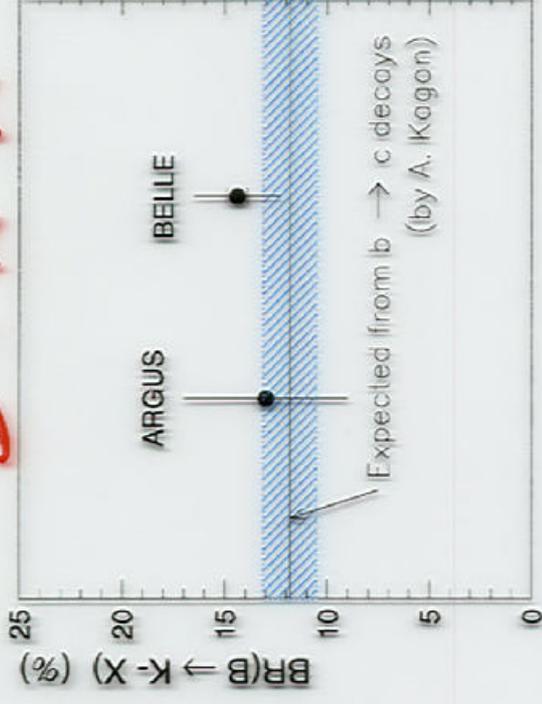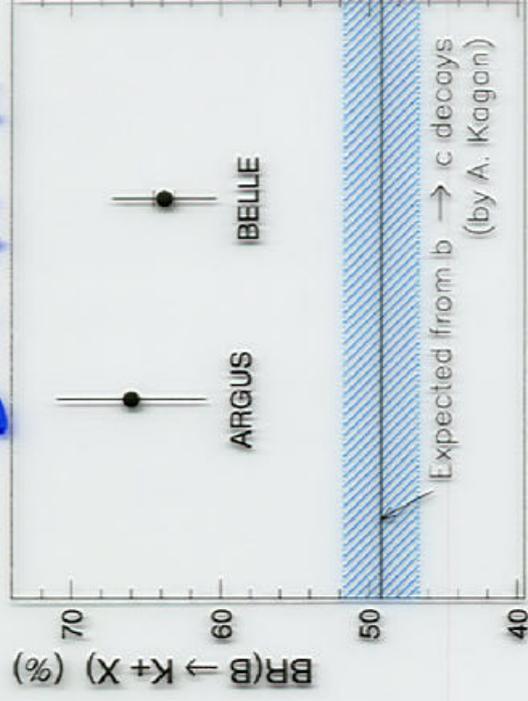
$$\mathcal{B}(B \to K^{\pm}X) = 0.782 \pm 0.007 \pm 0.035$$

- Flavor-specific inclusive kaon branching fraction

$$\mathcal{B}(B \to K^+X) = 0.638 \pm 0.007 \pm 0.035$$
$$\mathcal{B}(B \to K^-X) = 0.144 \pm 0.005 \pm 0.020$$

Belle preliminary!!!

$B \to K^- X$

$B \to K^+ X$

- Note that Kagan's calculation assumes PDG values for inclusive $D_{(s)} \to K^\pm X$. Are they reliable?

- We have not analyzed the "Same-B" components.

- "Same-B" is mostly $B \to X_c \ell \nu$, hence we may obtain inclusive $D \to K^\pm X$.

- We will determine any new physics contents only after we study the Same-B components.

BCP4, Feb. 20, 2001

Y. Kwon (Yonsei Univ.)

OK, ... but what's that to do with CPV?

- Remember TEB's (&Co.) suggestion for pseudo-recon.
  is for continuum suppression

- Then, consider:
  high-p ℓ⁻ } mostly back-to-back
  high-p K⁺
  some B (and very few ...)
  from f: Rpt some

For continuum:

$$b \to c \to s \, K^-, \quad \bar{c} \to \ell^+$$

- Moreover, high-p ℓ, high-p lepton has a substantial
  continuum suppression by itself (A. Lyon)
  (back-to-back again ...)

Y. Kwon (Yonsei Univ.)

- Using $K-\ell$ correlation,
  we deal with right kind of K's only

- Since high-p lepton gives
  automatic flavor-tagging,
  We may even try $C\!\!\!/P$ search in
  $B \to K_s X$.

- At least, am interesting cross-check
  for TEB's suggestion.
  ($\&$ co.)

- Using a simple and rough prescription,
  $S(\sin 2\phi_1)$, $S(\sin 2\phi_2)$ vs. $\int \mathcal{L}dt$

- Also went through CPV search in inclusive B decays

mode / $\int \mathcal{L}dt$	100 (fb^{-1})	500	2,500
$S(\sin 2\phi_1)$	~0.1	~0.05	~0.02
$S(\sin 2\phi_2)$	~0.6	~0.3	~0.1