Experimental Status of $B \to$ Q2Body and $B \to$ 3Body Decays

present and future

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- **Introduction/Motivation -** ***3-body Dalitz (3B) vs. quasi-2-body (Q2B)***
- **The experimental situation and systematics**
- **SU(2) and SU(3) multiplets –** ***interest, results and prospects***

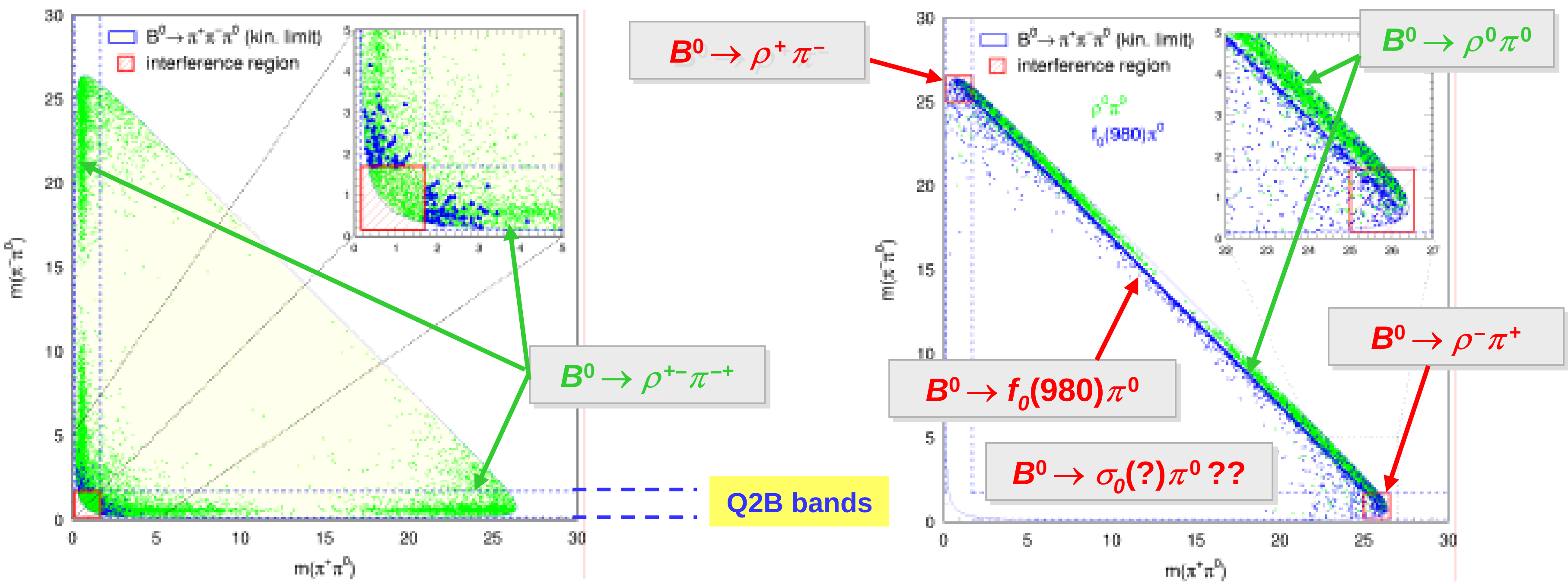
Introduction and Motivation

Talk discusses measurements of:

Q2B modes: modes that correspond to delta functions in the 3-body Dalitz plot, or that have only little overlap (interference) with other modes.

3B modes: non-resonant modes or fractions of sub-resonances obtained from fit to Dalitz plot.

3B analyses experimentally more involved ➡ performed with larger statistics



Introduction and Motivation

Road map to the Unitarity Triangle angles:

A. Time-dependent *CP* measurement of modes with single weak phase in SM ($J/\psi\, K_S$, ϕK_S, ...)

B. Time-dependent *CP* measurement together with SU(2) analysis to determine penguin pollution and weak phase ($\pi\pi$, $\rho\pi$, $\rho\rho$)

C. Time-dependent or time-integrated *CP* measurement using interference between weak and strong phases on Dalitz plot to determine weak and strong phases simultaneously ($\rho\pi$, $D^0 K$, ...)

D. Combined fit of branching fractions, A_{CP}, time-dependent *CP* asymmetries together with SU(3) quark flavor symmetry to determine penguin pollution and weak phase(s)

E. Use theoretical models, *e.g.*, QCD Factorization, to *predict* strong phases and penguin pollution and obtain weak phases from measured observables

Inputs to D, but also to B and C are discussed in this talk.

SU(2) and SU(3) Symmetries

Amplitude relations based on SU(2) and SU(3) symmetry help to reduce the number of unknowns and to make a systems of 2 or 3 particles in the final state solvable in order to determine the occurring weak phase(s).

- **SU(2) symmetry** is a good approximation. Electroweak penguins violate SU(2), but can often be related to known amplitudes. Most famous SU(2) systems are $\pi\pi$, $\rho\pi$ and $\rho\rho$.
- **SU(3) and U-spin symmetry** connects $\Delta S=0$ with $\Delta S=1$ states. It includes a huge number of modes, adding many observables. SU(3) breaking is often parameterized by ratios of decay constants (*e.g.*, f_π/f_ρ), with unclear uncertainties. Famous SU(3) systems are $\pi\pi(K)$, $\rho\pi(K^{(*)})$ and $\rho\rho(K^{(*)})$.

We will in the following only discuss the final states that are known to be used in global fits to determine weak phases.

Experimental Approaches

Although some of the older results are still based on cut & count analyses, all 3B and Q2B groups are now operating maximum likelihood (ML) fits. Fit inputs are:

- **Continuum (dominantly) background-fighting MVA (Neural Network or Fisher), using mostly L_0 , L_2 , cos(*B-dir*,*z*) and cos(T_B-*dir*,z)**
- **Kinematic variables: ΔE and m_{ES}**
- **Time-dependent analyses use Δt and *B* flavor tagging**

Dalitz plot (DP) analyses keep main parts of phase space:

- **Full dynamical analysis**
- **Accountable model-dependence of results**
- **DP is correlated with event shape ➡ MVA cannot be used in ML fit without 3D treatment**
- **Mis-reconstructed signal events require 4D resolution matrix of DP**

Q2B analyses keep only signal bands of DP:

- **Simplified analysis ➡ faster results**
- **Interference regions (DP overlaps) have to be removed**
- **Unaccountable model-dependence of results**

Systematics Projections

Systematic errors mainly affect rates (*BR*s). Direct *CP* asymmetries are less sensitive to systematics, and TD *CP* asymmetries even less. Systematic errors sources are (in hierarchical order):

- ***B*-related background** modes, mainly of equal number and more particles in the final state as signal, since the *BR*s of these are lesser known.
  - Assume systematics scale like (Luminosity)$^{-1/2}$.
- **π^0 and K_S** reconstruction and **tracking efficiencies**.
  - Assume that $\sigma(\varepsilon\text{-}\pi^0)$ improves from today 5% to future 3%.
  - Systematics magnify with number of π^0's in final state.
- **Model dependence** in 3B modes: can be reduced with more sophisticated fits, but will stay important in modes involving *K** and ρ^0.
  - Assume: at 200 fb^{-1}: 8% for all *K** and ρ^0, and 5% for ρ^+;
    at 500 fb^{-1}: 5% for all *K** and ρ^0, and 3% for ρ^+
- **Signal reference distributions** in ML fit: with increasing statistics, more and more shape parameters can be obtained from the ML fit as is already done for continuum background.
  - Assume systematics scale like (Luminosity)$^{-1/2}$.

SU(2) Multiplets: the $\pi\pi$ and $\rho\rho$ systems

Triangular amplitude relation for $B \to \pi\pi$ (and equivalently for $B \to \rho\rho$) :

(7 observables vs. 7 unknowns)

$$A^{+0} = \frac{1}{\sqrt{2}} A^{+-} + A^{00}$$

see talk by **G. Cavoto**

Gronau-London
PRL 65, 3381 (1990)

Pentagonal amplitude relation for $B \to \rho\pi$:

(13 observables vs. 12 unknowns)

$$\sqrt{2}\left[A^{+0} + A^{0+}\right] = A^{+-} + A^{-+} + 2A^{00}$$

see talk by **J. Wu**

Lipkin-Nir-Quinn-Snyder
PRD 44, 1454 (1991)

Mode	Observables: measured by BABAR	Observables: not yet measured by BABAR
$B^0 \to \pi^+\pi^-$	*BR, S, C*	-
$B^0 \to \pi^0\pi^0$	***BR***	*C*
$B^+ \to \pi^+\pi^0$	*BR, A_{CP}*	-
$B^0 \to \rho^{+-}\pi^{-+}$	*BR, S, C, ΔS, ΔC, A_{CP}*	-
$B^0 \to \rho^0\pi^0$	***BR_{limit}***	*S, C*
$B^+ \to \rho^+\pi^0$	*BR, A_{CP}*	-
$B^+ \to \rho^0\pi^+$	*BR, A_{CP}*	

not yet discovered

SU(2) Multiplets: the $K\pi\pi$ system

Amplitude relations between the even angular momentum states of the $[\pi\pi]$ system in $B \to K[\pi\pi]_{I=0,2}$ decays allow to determine γ :

$(\pi\pi)_{I=0,1,2}$ states are distinguished in the Dalitz plot due to the distributions of their helicity angles; $(\pi^0\pi^0)$ is always I=0 (even).

Lipkin-Nir-Quinn-Snyder
PRD 44, 1454 (1991)
Deshpande-Sinha-Sinha
PRL 90, 061802 (2003)

$$\boxed{A^{K=0[\pi=+,\pi=0]} = A^{0[+-]} + A^{0[00]}}$$

$$A^{+[-0]} = A^{+[+-]} + A^{+[00]}$$

$$A^{0[+0]} = -A^{+[-0]}$$

(*charge conjugation implied*)

System yields 7 observables (incl. TD measurement of S, C in $B^0 \to K^0[\pi^+\pi^-]$), and 12 unknowns. Using the two isospin relations and the hypothesis that $B^+ \to K^0(\pi^+\pi^0)$ has only one common strong phase ➡ 7 unknowns ➡ γ can be determined.

Neubert-Rosner
PLB 441, 403 (1998)

➡ **Interesting but challenging analysis that requires large statistics. Not evaluated here.**

SU(2.5) Multiplets: the *KKK* system

The extraction of sin(2β) from large sample of $B^0 \to K^0 K^+ K^-$ events (BR ~ 30×10^{-6}) has two caveats:

- *CP*-parity unknown
- possible $b \to u$ tree contributions

Grossman-Ligeti-Nir-Quinn
PRD 68, 015004 (2003)
Gronau-Rosner
PLB, 564, 90 (2003)

Belle,hep-ex/0208030

D. Dujmic, BAD 737

One can use SU(2) and SU(3), and the modes

- $K^+K^-K^+$, $K^+K^-K^0$, $K^+K_SK_S$, $K_SK_SK_S$
- $K^+K^-\pi^+$, $K^+\pi^-\pi^+$, $\pi^+\pi^-\pi^+$

Legend

BLUE	:	measured
GREEN	:	for 2004 (?)
RED	:	uncovered

to obtain constraints on the *KKK* system

- using SU(3), on can estimate $b \to u$ contribution: $\frac{A^{KKK}_{b\to u}}{A^{KKK}_{\rm total}} \approx \frac{BR(B^+ \to K^+K^-\pi^+)}{BR(B^+ \to K^+K^-K^+)} \times \left(\frac{f_K}{f_\pi}\right)^2 |V_{us}|^2$
- use SU(2) to build sum rules, e.g.: $BR(B^0 \to K^+K^-K^0) = BR(B^+ \to K^+K^-K^+) \times \left(\frac{\tau_{B^0}}{\tau_{B^+}}\right)$
- other SU(2) relations can be used to determine the *CP*-even component in $K^+K^-K^0$

SU(3) Multiplets: $B \to PV$

- Extrapolation of present results (and missing modes) into 200+500 fb^{-1}
- Numbers at end of this talk
- Qualitative discussion in the following
- Extrapolations used by **D. Suprun** for SU(3) fits of γ

see talk by **D. Suprun**

Usually, phenomenological analyses involve **ground states in narrow width approximation** only, parameterized by the corresponding meson decay constants. In principle, this approach also allows to include **higher radial excitations** (such as $\rho(1450)$, $K_1(1270)$, $K^*(1410)$, etc), but this is not done yet since the experimental situation is often unclear. **Therefore, we only report on ground states here.**

SU(3) Multiplets: $B \to PV$ (3B)

« Expected » refers to QCD FA: **Beneke-Neubert**, hep-ph/0308039

Summary of modes

Mode	Observables: measured by BABAR	Observables: not yet measured by BABAR
$B^0 \to \rho^{+-}\pi^{-+}$	$BR, S, C, \Delta S, \Delta C, A_{CP}$	-
$B^0 \to \rho^0\pi^0$	BR_{limit}	S, C
$B^+ \to \rho^+\pi^0$	BR, A_{CP}	-
$B^+ \to \rho^0\pi^+$	BR, A_{CP}	
$B^0 \to K^{*+}\pi^-$	-	BR, A_{CP}
$B^0 \to K^{*0}\pi^0$	-	BR, A_{CP} (S, C)
$B^+ \to K^{*+}\pi^0$	-	BR, A_{CP}
$B^+ \to K^{*0}\pi^+$	BR	A_{CP}

Time-dep. *CP* analysis
small penguins expected

Color-suppressed tree
measures penguins

Possible contributions from scalars (f_0, $\sigma(500)$)

Time-dep *CP* analysis possible, but *BR* could be much smaller than $B^0 \to K^0\pi^0$
measures $\sin(2\beta_{\mathrm{eff}})$, sensitive to New Physics

Linked via SU(2) analysis ➡ α

Measures penguin in $B^0 \to \rho^+\pi^-$

Penguin-dominated
small A_{CP} expected

Pure penguin: measures penguin in $B^0 \to \rho^-\pi^+$

SU(3) Multiplets: $B \to PV$ (3B)

Experimental situation

Outlook ➡ 500 fb^{-1}

- Q2B TD-*CP* analysis redone for LP 2003
- New update/publication in 2004
- Perhaps merged with full DP analysis, less model dependence
- *CP* not syst. limited

Update 2004 as part of full DP analysis

First obs. by BABAR

- Inclusive $K^+\pi^0\pi^0$ DP analysis (➡ 2004)
- Exclusive modes?

- Exclusive $K^{*0}K^+$ analysis ongoing
- Will include $K^{*0}\pi^+$ (?)

Mode	Observables: measured by BABAR	Observables: not yet measured by BABAR
$B^0 \to \rho^{+-}\pi^{-+}$	BR, S, C, ΔS, ΔC, A_{CP}	-
$B^0 \to \rho^0\pi^0$	BR_{limit}	S, C
$B^+ \to \rho^+\pi^0$	BR, A_{CP}	-
$B^+ \to \rho^0\pi^+$	BR, A_{CP}	
$B^0 \to K^{*+}\pi^-$	-	BR, A_{CP}
$B^0 \to K^{*0}\pi^0$	-	BR, A_{CP} (S, C)
$B^+ \to K^{*+}\pi^0$	-	BR, A_{CP}
$B^+ \to K^{*0}\pi^+$	BR	A_{CP}

- All modes measured for LP'03 (publ.)
- Neutral modes updated for 2004 with full DP analysis
- *BR*s systematically limited (but for $\rho^0\pi^0$)

- No BABAR results so far !!
- $K^+\pi^-\pi^0$ ($K^{*+}\pi^-$, $K^{*0}\pi^0$, ρ^-K^+) DP analysis just started (➡ 2004)
- uses $\rho\pi$ framework

SU(3) Multiplets: $B \to PV$ (3B)

Decays involving ρ, K, K^*:

Summary of modes

Mode	Observables: measured by BABAR	Observables: not yet measured by BABAR
$B^0 \to \rho^- K^+$	BR, A_{CP}	-
$B^0 \to \rho^0 K^0$	-	BR_{limit}, S, C
$B^+ \to \rho^+ K^0$	-	BR, A_{CP}
$B^+ \to \rho^0 K^+$	BR_{limit}	A_{CP}
$B^0 \to K^{*+} K^-$	-	BR_{limit}, S, C
$B^0 \to K^{*-} K^+$	-	BR_{limit}, S, C
$B^0 \to K^{*0} \bar{K}^0$	-	BR_{limit}, S, C
$B^0 \to \bar{K}^{*0} K^0$	-	BR_{limit}, S, C
$B^+ \to K^{*+} \bar{K}^0$	-	BR_{limit}, A_{CP}
$B^+ \to \bar{K}^{*0} K^+$	-	BR_{limit}, A_{CP}

Measures penguin in $B^0 \to \rho^- \pi^+$

Time-D *CP* analysis possible
measures $\sin(2\beta_{\text{eff}})$, sensitive to New Physics

Pure Penguin: measures penguin in $B^0 \to \rho^+ \pi^-$

Penguin or weak-annihilation-dominated
BRs expected to be small

SU(3) Multiplets: $B \to PV$ (3B)

Decays involving ρ, K, K^*:

Mode	Observables: measured by BABAR	Observables: not yet measured by BABAR
$B^0 \to \rho^- K^+$	BR, A_{CP}	-
$B^0 \to \rho^0 K^0$	-	BR_{limit}, S, C
$B^+ \to \rho^+ K^0$	-	BR, A_{CP}
$B^+ \to \rho^0 K^+$	BR_{limit}	A_{CP}
$B^0 \to K^{*+} K^-$	-	BR_{limit}, S, C
$B^0 \to K^{*-} K^+$	-	BR_{limit}, S, C
$B^0 \to K^{*0} K^{0\sim}$	-	BR_{limit}, S, C
$B^0 \to K^{*0\sim} K^0$	-	BR_{limit}, S, C
$B^+ \to K^{*+} K^0$	-	BR_{limit}, A_{CP}
$B^+ \to K^{*0} K^+$	-	BR_{limit}, A_{CP}

- Important mode!!
- Search for 2004 (?)
- Time-D *CP* analysis should be realized

In work (➡ 2004)

- Part of $K^+ \pi^- \pi^+$ DP
- Results for 2004 (?)

$K^+ K^- \pi^0$ ($K^{*+-} K^{-+}$) DP analysis under study (2004 ?)

Part of $K^0 (\pi/K)^+ \pi^-$ DP unlikely for 2004

C&C analyses In work (➡ 2004 ?)

Experimental situation

Outlook ➡ 500 fb^{-1}

- Q2B measured simultaneously with $B^0 \to \rho^{+-}\pi^{-+}$
- now covered by $K^+ \pi^- \pi^0$ DP (➡ 2004)

- Very few BABAR results so far in this sector !!!
- Exp. confirmation for suppression of these modes is important!

SU(3) Multiplets: $B \to PP, PV, VV$ (Q2B)

Decays involving η, η'

Summary of modes

Mode	Observables: measured by BABAR	Observables: not yet measured by BABAR
$B^0 \to \eta^{(\prime)}\eta$	-	BR_{limit}, C
$B^0 \to \eta^{(\prime)}\pi^0$	-	BR_{limit}, C
$B^0 \to \eta^{(\prime)}\rho^0$	-	BR_{limit}, S, C
$B^+ \to \eta^{(\prime)}\pi^+$	BR, A_{CP}	-
$B^+ \to \eta^{(\prime)}\rho^+$	BR	A_{CP}
$B^0 \to \eta^{(\prime)}K^0$	$BR_{(limit)}$, S, C	
$B^0 \to \eta^{(\prime)}K^{*0}$	$BR_{(limit)}$, A_{CP}	-
$B^+ \to \eta^{(\prime)}K^+$	BR, A_{CP}	-
$B^+ \to \eta^{(\prime)}K^{*+}$	$BR_{(limit)}$, A_{CP}	-

Tree-dominated, but penguins possible
could give large A_{CP}

Time-D *CP* analysis
measures sin$(2\beta_{\rm eff})$, sensitive to New Physics

Penguin-dominated
small A_{CP} expected, except ηK^+ and η'K^{*+}

ηK^+ "normal",
η'K^+ huge ("anomaly"),
no "anomaly" for η'K^{*+}

marked by "(limit)": either one of the $\eta^{(\prime)}$ modes is unseen

SU(3) Multiplets: $B \to PP, PV, VV$ (Q2B)

Decays involving η, η'

Mode	Observables: measured by BABAR	Observables: not yet measured by BABAR
$B^0 \to \eta^{(\prime)}\eta$	-	BR_{limit}, C
$B^0 \to \eta^{(\prime)}\pi^0$	-	BR_{limit}, C
$B^0 \to \eta^{(\prime)}\rho^0$	-	BR_{limit}, S, C
$B^+ \to \eta^{(\prime)}\pi^+$	BR, A_{CP}	-
$B^+ \to \eta^{(\prime)}\rho^+$	BR	A_{CP}
$B^0 \to \eta^{(\prime)}K^0$	$BR_{(limit)}$, S, C	
$B^0 \to \eta^{(\prime)}K^{*0}$	$BR_{(limit)}$, A_{CP}	-
$B^+ \to \eta^{(\prime)}K^+$	BR, A_{CP}	-
$B^+ \to \eta^{(\prime)}K^{*+}$	$BR_{(limit)}$, A_{CP}	-

marked by "(limit)": either one of the $\eta^{(\prime)}$ modes is unseen

Neutral modes expected out of reach for 500 fb^{-1}

Challenging charm-less analyses with multiple tracks and π^0's

***BR*s for $\eta' K^+$, $\eta' K^0$ syst. limit. at 500 fb^{-1}**

Experimental situation

Outlook ➡ 500 fb^{-1}

- **Challenging modes with 4 photons in final state**
- **Ongoing (➡ 2004)**

Ongoing (➡ 2004)

Time-D *CP* analysis $\eta' K^0$ not syst. limit.

All modes will be updated for 2004

SU(3) Multiplets: $B \to P(V)V$ (Q2B)

Decays involving ω:

Summary of modes

Mode	Observables: measured by BABAR	Observables: not yet measured by BABAR
$B^0 \to \omega\pi^0$	BR_{limit}	*S, C*
$B^0 \to \omega\eta^{(\prime)}$	-	*BR, C*
$B^0 \to \omega\rho^0$	-	*BR, S, C*
$B^0 \to \omega K^0$	*BR*	*S, C*
$B^0 \to \omega K^{*0}$	-	*BR*, A_{CP} (*C*)
$B^+ \to \omega\pi^+$	*BR*, A_{CP}	-
$B^+ \to \omega\rho^+$	*BR*, A_{CP}	-
$B^+ \to \omega K^+$	*BR*, A_{CP}	-
$B^+ \to \omega K^{*+}$	-	*BR*, A_{CP}

Time-dependent *CP* analyses possible

Tiny *BR*s expected

Expected to be smaller than $B^0 \to \rho^0 K^0$ due to larger EW Pen. in latter

SU(3) Multiplets: $B \rightarrow P(V)V$ (Q2B)

Decays involving ω:

Q=S=0 modes expected out of reach for 500 fb^{-1}

Time-dependent *CP* analyses expected

Challenging charm-less analyses with multiple tracks and π^0's

Mode	Observables: measured by BABAR	Observables: not yet measured by BABAR
$B^0 \rightarrow \omega\pi^0$	BR_{limit}	S, C
B	-	BR, C
$B^0 \rightarrow \omega\rho^0$	-	BR, S, C
$B^0 \rightarrow \omega K^0$	BR	S, C
$B^0 \rightarrow \omega K^{*0}$	-	$BR, A_{CP}\,(C)$
$B^+ \rightarrow \omega\pi^+$	BR, A_{CP}	-
$B^+ \rightarrow \omega\rho^+$	BR, A_{CP}	-
$B^+ \rightarrow \omega K^+$	BR, A_{CP}	-
$B^+ \rightarrow \omega K^{*+}$	-	BR, A_{CP}

Experimental situation

Outlook ➨ 500 fb^{-1}

Ongoing (➨ 2004)

$\omega\eta$ ongoing,
$\omega\eta'$ uncovered

Ongoing (➨ 2004 ?)

Ongoing (➨ 2004 ?)

Ongoing (➨ 2004 ?)

Ongoing (➨ 2004 ?)

SU(3) Multiplets: $B \to P(V)V$ (Q2B)

Decays involving ϕ:

Summary of modes

Mode	Observables: measured by *BABAR*	Observables: not yet measured by *BABAR*
$B^0 \to \phi\pi^0$		BR_{limit}, S, C
$B^0 \to \phi\eta^{(\prime)}$	$BR_{(limit)}$	C
$B^0 \to \phi\rho^0$	-	BR, S, C
$B^0 \to \phi\omega$	-	BR, S, C
$B^0 \to \phi K^0$	BR, S, C	-
$B^0 \to \phi K^{*0}$	BR, A_{CP}	(S, C)
$B^+ \to \phi\pi^+$	BR_{limit}	A_{CP}
$B^+ \to \phi\rho^+$	-	BR_{limit}, A_{CP}
$B^+ \to \phi K^+$	BR, A_{CP}	-
$B^+ \to \phi K^{*+}$	BR, A_{CP}	-

Time-dependent *CP* analyses possible (B^0 modes)

Expected to be undetectable within SM ($B^0 \to \phi\pi^0$)

Measure $\sin(2\beta)$ *sensitive to New Physics* ($B^0 \to \phi K^0$, $B^0 \to \phi K^{*0}$)

Expected to be undetectable within SM ($B^+ \to \phi\pi^+$)

marked by "(limit)": either one of the $\eta^{(\prime)}$ modes is unseen

SU(3) Multiplets: $B \to P(V)V$ (Q2B)

Decays involving ϕ:

Experimental situation

Outlook ➡ 500 fb^{-1}

Mode	Observables: measured by BABAR	Observables: not yet measured by BABAR
$B^0 \to \phi\pi^0$		BR_{limit}, S, C
$B^0 \to \phi\eta^{(\prime)}$	$BR_{\mathrm{(limit)}}$	C
$B^0 \to \phi\rho^0$	-	BR, S, C
$B^0 \to \phi\omega$	-	BR, S, C
$B^0 \to \phi K^0$	BR, S, C	-
$B^0 \to \phi K^{*0}$	BR, A_{CP}	(S, C)
$B^+ \to \phi\pi^+$	BR_{limit}	A_{CP}
$B^+ \to \phi\rho^+$	-	BR_{limit}, A_{CP}
$B^+ \to \phi K^+$	BR, A_{CP}	-
$B^+ \to \phi K^{*+}$	BR, A_{CP}	-

Expected to be undetectable with 500 fb^{-1} ($B^0 \to \phi\pi^0$, $\phi\eta^{(\prime)}$, $\phi\rho^0$, $\phi\omega$)

sin(2β) not systematically limited ($B^0 \to \phi K^0$)

Expected to be undetectable with 500 fb^{-1} ($B^+ \to \phi\pi^+$, $\phi\rho^+$)

Update for 2004 ($B^0 \to \phi\pi^0$)

$\phi\eta$ update for 2004 ($B^0 \to \phi\eta^{(\prime)}$)

Not covered ($B^0 \to \phi\rho^0$, $\phi\omega$)

Update for 2004 ($B^0 \to \phi K^0$, ϕK^{*0}, $B^+ \to \phi\pi^+$)

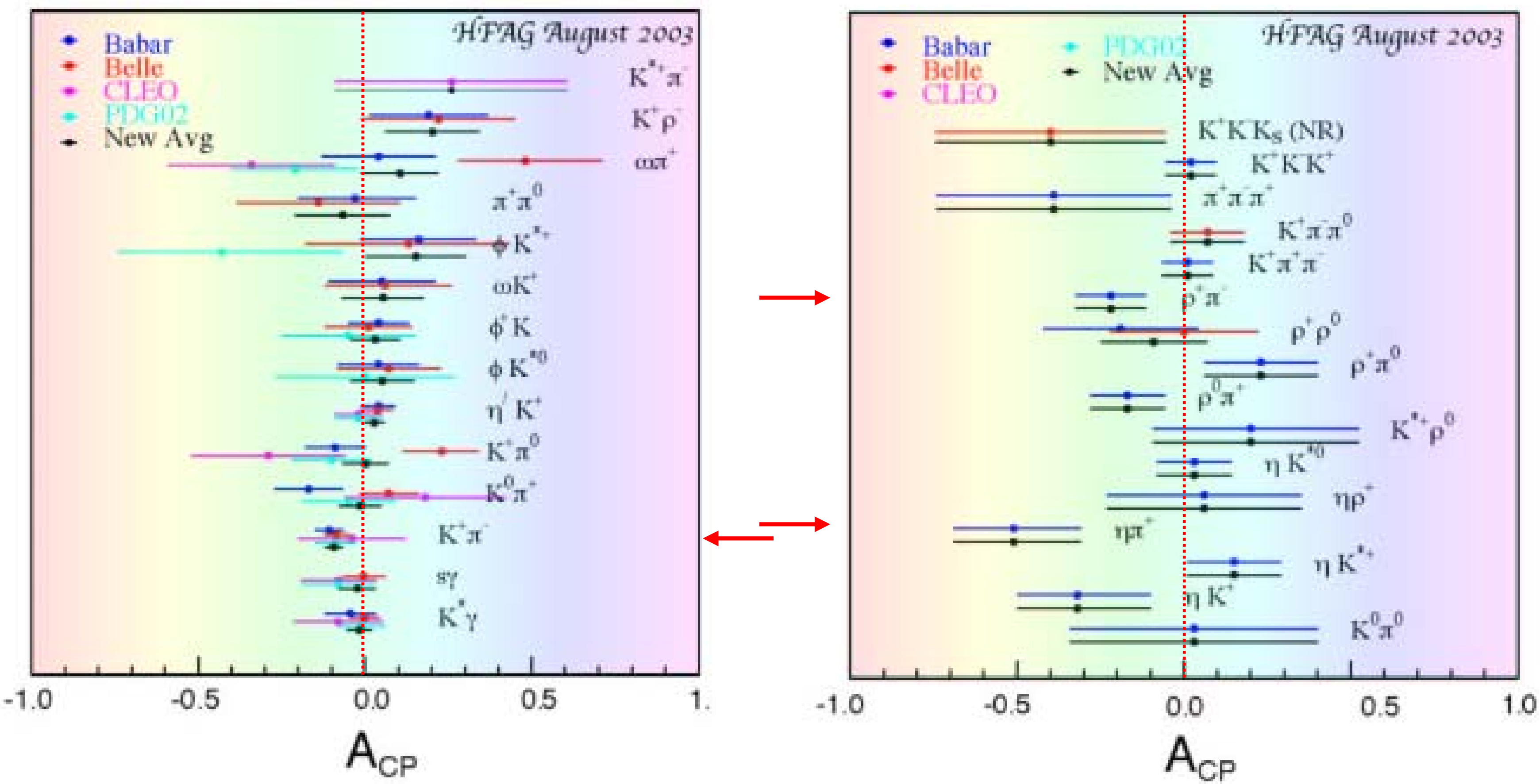
Not covered ($B^+ \to \phi\rho^+$)

Update for 2004 ($B^+ \to \phi K^+$, ϕK^{*+})

marked by "(limit)": either one of the $\eta^{(\prime)}$ modes is unseen

Direct *CP* Asymmetries

- **Expect A_{CP} to be statistically limited at 500 fb^{-1} ➡ errors scale like (Luminosity)$^{-1/2}$**
- **No observation of direct CPV so far in the data**
- **Most promising candidate: $A_{CP}(K^{+}\pi^{-}) = -0.095 \pm 0.028$ [HFAG'03] ➡ 3.4σ**



Conclusions

- **3B: many Q2B sub-modes still missing!**

  How many results can we expect for 2004 ?

- **Modes involving η, η', ω, ϕ in good shape. Many updates expected for 2004**
- **Main systematic difficulties for high luminosities:**

  ***BR*s: π^0 reconstruction efficiency, model dependencies**

- **A_{CP} should be statistically limited at 500 fb^{-1}**
- **Missing/other resonances:**

- **No results so far for modes involving the $a_1(1260)$ ➡ can be used for *CP* studies!**
- **$a_0(980)(\rightarrow\eta\pi)\pi$: conf. report with signal evidence for 20 fb^{-1} ➡ follow up BAD almost done !**
- **other scalar resonances, like, $\sigma(\sim 400)$, $f_0(980, 1300)$ measured in the corresponding DP's**
- **no effort so far for $\pi\pi(1300)$ and other "exotics"**

PV Modes: Results and Projections

3-Body

			BABAR							AT 200fb-1			AT 500fb-1			
Modes	BAD	lumi	BR	stat	sys	sys scale	sys fix	other		stat	sys	tot	stat	sys	tot	
B+ -> K*0bar K+ * **			0,5	theory	similar to k*0pi					0,1711	0,0574	0,18	0,1082	0,0442	0,12	
B+ -> K*+ K0bar * **			0,6	theory	similar to K*0pi, add sys for pi0/ks					0,1874	0,072	0,2	0,1185	0,0699	0,14	
B+ -> rho0 pi+	573	82	9,3	1	0,8	0,63606	0,48521	0		0,6403	0,9772	1,17	0,405	0,7197	0,83	dominated
B+ -> rho+ pi0	575	82	11	1,9	1,9	1,53229	0,02741	1,1	2 pi0s	0,7043	1,3634	1,53	0,7694	0,8296	1,13	sys domin
B+ -> K*0 pi+	362	56	15,5	1,8	4	0,62559	0,80868	3,985038	model+inte	0,9525	1,7793	2,02	0,6024	1,3693	1,5	dominated
B+ -> K*+ pi0 * **			15	theory	similar to rho+pi0, except only 1/2 measurable					1,1632	1,8592	2,19	1,2707	1,1313	1,7	
B+ -> rho0 K+	362	56	3,9	1,2	3,5	0,53451	0,20347	3,417601	model+inte	0,635	0,4677	0,79	0,4016	0,3338	0,52	
B+ -> rho+ K0 * **			12,6	theory	similar to rho+pi0					0,7538	1,5617	1,73	0,8235	0,9503	1,26	dominated
B0 -> K*0bar K0 * **			0,5	theory	similar to K*0pi					0,1711	0,0574	0,18	0,1082	0,0442	0,12	
B0 -> K*0 K0bar * **			0,6	theory	similar to K*0pi					0,1874	0,0689	0,2	0,1185	0,053	0,13	
B0 -> rho- pi+	350	82	22,6	1,8	2,2	1,80433	0,55451	1,13	pi0	1,1526	1,8828	2,21	0,7289	1,2269	1,43	sys domin
B0 -> rho0 pi0	494	82	1,4	0,6	0,3	0,29387	0,06031	0,07	pi0	0,3842	0,2324	0,45	0,243	0,1532	0,29	
B0 -> K*+ pi-			15	exp+theo	similar to K*0pi but add pi0/ks sys					0,937	1,8002	2,03	0,5926	1,7479	1,85	sys domin
B0 -> K*0 pi0 * **			0,8	exp+theo	similar to rho0pi0					0,2904	0,1328	0,32	0,1837	0,0876	0,2	
B0 -> rho- K+	350	82	7,3	1,3	1,3	1,23479	0,17911	0,365	pi0	0,8324	0,925	1,24	0,5265	0,5928	0,79	sys domin
B0 -> rho0 K0 * **			7,2	theory	similar to rho0pi0					0,8713	1,195	1,48	0,551	0,7881	0,96	

*** indicates BR taken from hep-ph/0307395, gamma=63 deg, stat error a guess

stat error goes as 1/sqrt(lumi)

Systematics

fix sys: pid, trk, Ks eff and Nbb, BR(phi->kk)

others:	at 200fb-1	at 500fb-1
pi0 sys from 5% to 3.5% to 2%	3,50%	2%
k*0 model uncertainties	10%	7%
rho0	8%	5%
rho+ k*+	5%	3%

all other sys scale with 1/sqrt(lumi)

no accounting for B+/B0 prod ratio and FS radiation

For channels with no measurement, use theoretical results from Suprun's paper hep-ph/0307395

and assume error same as similar channel (same no. pi0s, similar BF, same resonance)

Q2B

B+ -> eta pi+	584	82	4,2	1	0,3	0,18802	0,10271	0,21	pi0	0,6403	0,216	0,68	0,405	0,153	0,43	
B+ -> eta' pi+	642	82	2,7	1,2	0,3	0,25404	0,08508	0,135	pi0	0,7684	0,2065	0,8	0,486	0,144	0,51	
B0 -> eta pi0 **	744	82	0,7	0,8	0,1	0,06976	0,01529	0,07	2 pi0s	0,5122	0,068	0,52	0,324	0,0426	0,33	
B0 -> eta' pi0 **	744	82	0,8	1	0,1	0,07121	0,01747	0,068	1.7 pi0s	0,6403	0,0682	0,64	0,405	0,0434	0,41	
B+ -> eta K+	584	82	2,8	0,8	0,2	0,12535	0,06847	0,14	pi0	0,5122	0,144	0,53	0,324	0,102	0,34	
B+ -> eta' K+	490	82	76,9	3,5	4,4	1,00502	3,33253	2,692	0.7pi0	2,2411	3,8913	4,49	1,4174	3,529	3,8	syst limite
B0 -> eta K0	584	82	2,9	1	0,2	0,02693	0,13509	0,145	pi0	0,6403	0,1699	0,66	0,405	0,1474	0,43	
B0 -> eta' K0	490	82	60,6	5,6	4,6	1,47939	3,80431	2,121	0.7pi0	3,5857	4,1975	5,52	2,2678	3,9454	4,55	syst limite
B+ -> rho+ eta	686	82	10,5	3	1,3	0,73138	0,22932	1,05	2 pi0s	1,9209	0,9012	2,12	1,2149	0,5628	1,34	
B+ -> rho+ eta'	686	82	14	4,9	1,9	1,35304	0,60265	1,19	1.7pi0	3,1375	1,3454	3,41	1,9843	0,9438	2,2	
B+ -> w pi+	600	82	5,4	1	0,5	0,38489	0,17016	0,27	pi0	0,6403	0,3541	0,73	0,405	0,2548	0,48	
B+ -> phi pi+ ***	406	82	0	0,2	0,1	0,0998	0,0063	0		0,1281	0,0642	0,14	0,081	0,0409	0,09	
B+ -> K*+ eta	686	82	25,7	3,7	2,2	0,6445	0,84224	1,928	1.5 pi0	2,3692	1,6432	2,88	1,4984	1,1713	1,9	
B+ -> K*+ eta'	686	82	6,1	3,6	1,2	1,10134	0,30512	0,366	1.2pi0	2,3051	0,81	2,44	1,4579	0,5599	1,56	
B+ -> w K+	600	82	5	1	0,4	0,26958	0,15756	0,25	pi0	0,6403	0,292	0,7	0,405	0,2162	0,46	
B+ -> phi K+	406	82	10	0,9	0,5	0,33272	0,37323	0		0,5763	0,4298	0,72	0,3645	0,3968	0,54	syst limite
B0 -> rho0 eta ***	521	82	0,1	1	0,4	0,3958	0,029	0,05	pi0	0,6403	0,2551	0,69	0,405	0,1629	0,44	
B0 -> rho0 eta' ***	521	82	0,1	2	0,8	0,79114	0,09594	0,07	0.7pi0	1,2806	0,5156	1,38	0,8099	0,3344	0,88	
B0 -> w pi0 ***	145	21	0,1	1,1	0,3	0,27807	0,02402	0,11	2 pi0s	0,3564	0,0935	0,37	0,2254	0,062	0,23	
B0 -> w eta ***		82	0,4	0,5	0,1	0,0911	0,01006	0,04	2 pi0s	0,3202	0,0655	0,33	0,2025	0,0415	0,21	
B0 -> w eta' ***		82	0,3	0,7	0,1	0,09595	0,01201	0,026	1.7 pi0	0,4482	0,0651	0,45	0,2835	0,0419	0,29	
B0 -> phi pi0 ***		82	0	0,5	0,1	0,09621	0,01092	0,025	pi0	0,3202	0,0626	0,33	0,2025	0,0405	0,21	
B0 -> phi eta ***		82	0	0,5	0,1	0,09573	0,0145	0,025	pi0	0,3202	0,063	0,33	0,2025	0,0414	0,21	
B0 -> phi eta' ***	462	82	0	0,7	0,1	0,09095	0,03358	0,025	0.7pi0	0,4482	0,0672	0,45	0,2835	0,0498	0,29	
B0 -> K*0 eta	686	82	19	2,2	1,3	0,58267	0,66933	0,95	pi0	1,4087	1,0146	1,74	0,8909	0,805	1,2	
B0 -> K*0 eta'	686	82	3,2	1,8	0,9	0,87401	0,18318	0,112	0.7pi0	1,1526	0,5994	1,3	0,7289	0,4011	0,83	
B0 -> w K0	600	82	5,3	1,3	0,5	0,35958	0,22467	0,265	pi0	0,8324	0,3713	0,91	0,5265	0,288	0,6	
B0 -> phi K0	406	82	7,6	1,3	0,5	0,26396	0,42465	0		0,8324	0,457	0,95	0,5265	0,4379	0,68	

** indicates BR taken from hep-ph/0306021, stat error a guess

*** indicates BR taken from hep-ph/0307395, gamma=63 deg, stat error a guess

Stat error goes as 1/sqrt(lumi)

Systematics: fix sys: pid, trk, Ks eff and Nbb, intermediate BFs

others:	at 200ft	at 500fb-1
pi0 sys from 5% to 3.5% to 2%	3,50%	2%

all other sys scale with 1/sqrt(lumi)

no model errors. no accounting for B+/B0 prod ratio and FSR

For channels with no measurement, use theoretical results from Suprun's paper hep-ph/0307395

SU(3) Multiplets: $B \to PP$

Decays involving π, K:

see talk by **M. Pierini**

Mode	Observables: *measured by BABAR*	Observables: *not yet measured by BABAR*
$B^0 \to \pi^+\pi^-$	BR, S, C	-
$B^+ \to \pi^+\pi^0$	BR, A_{CP}	-
$B^0 \to \pi^0\pi^0$	BR	C
$B^0 \to K^+\pi^-$	BR, A_{CP}	-
$B^0 \to K^0\pi^0$	BR, S, C	-
$B^+ \to K^+\pi^0$	BR, A_{CP}	-
$B^+ \to K^0\pi^+$	BR, A_{CP}	-
$B^0 \to K^+K^-$	$BR_{\rm limit}$	-
$B^0 \to K^0\bar{K}^0$	$BR_{\rm limit}$	-
$B^+ \to K^+K^0$	$BR_{\rm limit}$	-

Linked via SU(2) analysis ➡ α

Penguin-dominated
"measures" penguin pollution in $B^0 \to \pi^+\pi^-$

Penguin or weak-annihilation-dominated
BRs expected to be small

Measures penguin in $B^0 \to \pi^+\pi^-$

QCD Factorization predicts small A_{CP}'s

Measures penguin in $B^0 \to \pi^+\pi^-$