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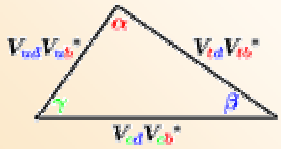
Charmless Vector-Vector B Meson Decays

Why we Study $B \to \rho\rho$ Decays

Chamless B meson decays provide an opportunity to measure the weak-interaction phases arising from the elements of the CKM quark-mixing matrix.

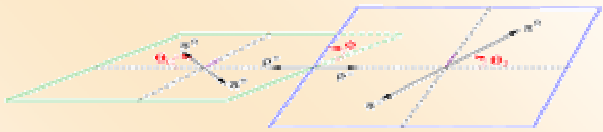


Decays $B \to \rho\rho$ are expected to proceed through tree-level $b \to u$ transitions and *CKM*-suppressed $b \to d$ penguins. Time-dependent *CP*-violating asymmetries in $B \to \rho\rho$ ($\pi\pi$, $\rho\pi$) decays are related to CKM angle $\alpha \equiv \arg\left[-V_{td}V_{tb}^*/V_{ud}V_{ub}^*\right]$.

The presence of penguins and both *CP*-even (*S*- and *D*-wave) and *CP*-odd (*P*-wave) components in the decay amplitude complicates the measurement of α. Isospin relations among the three $B \to \rho\rho$ modes may reduce the uncertainties in the measurement of α due to penguin contributions. The experimental limit on $B \to \rho^0\rho^0$ and the measurement of $B \to \rho^+\rho^0$ indicate that the penguin pollution can be constrained in $B \to \rho\rho$ modes better than in analogous $B \to \pi\pi$ modes. Polarization measurements in $B \to \rho\rho$ presented here provide evidence that the *CP*-even longitudinal component dominates, and this also simplifies *CP*-violation studies.

$B \to$ Vector-Vector Angular Formalism

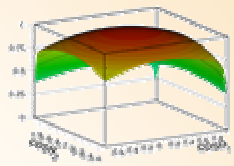
The angular distribution of $B \to VV$ final state is in general a combination of S-, P- and D-wave contributions. We define helicity angles θ_1, θ_2 of ρ decays and angle φ between the decay planes of the two vector-particle decays.



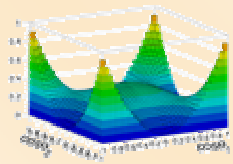
We integrate over angle φ between the two decay planes (there are no acceptance effects in azimuthal direction). The differential decay width is then defined as:

$$\frac{1}{\Gamma}\frac{d^2\Gamma}{d\cos\theta_1 d\cos\theta_2} = \frac{9}{4}\left\{\frac{1}{4}(1-f_L)\sin^2\theta_1\sin^2\theta_2 + f_L\cos^2\theta_1\cos^2\theta_2\right\}$$

The longitudinal fraction $f_L = \Gamma_L/\Gamma$ is the fraction of the longitudinal over the total decay width.



Angular acceptance distribution $G(\theta_1, \theta_2)$ for $B^0 \to \rho^+\rho^-$ signal



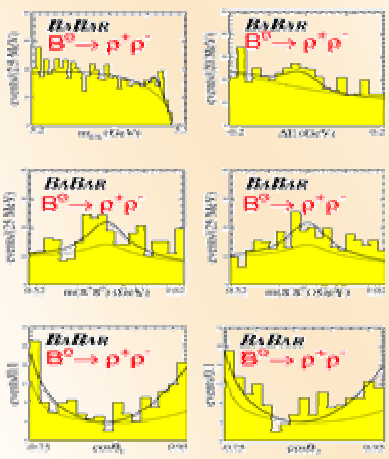
Distribution in 2D of the cosine angles in $B \to VV$ decays for an arbitrary polarization f_L

New results: $B^0 \to \rho^+\rho^-$ (preliminary)

Reconstruction efficiency $\varepsilon = 3.9^{+0.9}_{-0.6}\%$.
Signal event yield $n_{sig} = 93^{+23}_{-21} \pm 9$.

Statistical significance of the $B^0 \to \rho^+\rho^-$ measurement is 5.9σ, and this is the first observation of this *B* decay mode with a significance greater than 3σ. The decay amplitude is predominantly longitudinal.

The projections of the fit input variables are shown below. The projections are made after a requirement on the signal-to-background probability ratio. The histograms show data with about 40–60% of signal retained, the lines show the PDF projections from the full sample.



Summary of Results

B decay mode	$\mathcal{B}(\times 10^{-6})$	f_L
$\rho^+\rho^-$ *	27^{+7+2}_{-6-7}	$0.99^{+0.01}_{-0.07} \pm 0.03$
$\rho^+\rho^0$	$23^{+6}_{-5} \pm 6$	$0.97^{+0.03}_{-0.07} \pm 0.04$
$\rho^0\rho^0$	< 2.1 (90% CL)	–

* preliminary result

Analysis Methods

We fully reconstruct all B $\to \rho\rho$ final states, where the masses of $\rho^+(\pi^+\pi^0)$, $\rho^0(\pi^+\pi^-)$ and $\pi^0(\gamma\gamma)$ candidates are required to lie within experimentally defined tolerances of the nominal values. We identify *B* candidates using the beam energy-substituted mass $m_{ES} = \left[(s/2 + \vec{p}_i \cdot \vec{p}_B)^2/E_i^2 - \vec{p}_B^{\,2}\right]^{1/2}$ and energy difference $\Delta E = (E_i E_B - \vec{p}_i \cdot \vec{p}_B - s/2)/\sqrt{s}$. To reject the dominant continuum background, we require $|\cos\theta_T| < 0.8$, where θ_T is the "thrust angle". We also construct an 11-variable Fisher discriminant ($\mathcal{F}$) to describe the topology of the event.

We use an unbinned, extended maximum-likelihood fit to extract the signal yield and angular polarization. The extended likelihood for a sample of events is:

$$\mathcal{L} = \exp\left(-\sum_j n_j\right)\prod_i \exp\left(\frac{1}{N_i!}\ln\left(\sum_j n_j \mathcal{P}_j(\vec{x}_i;\vec{\alpha})\right)\right)$$

The seven fit input variables x_j are m_{ES}, ΔE, $\mathcal{F}$, invariant masses of ρ candidates, and corresponding helicity angles θ_1 and θ_2.

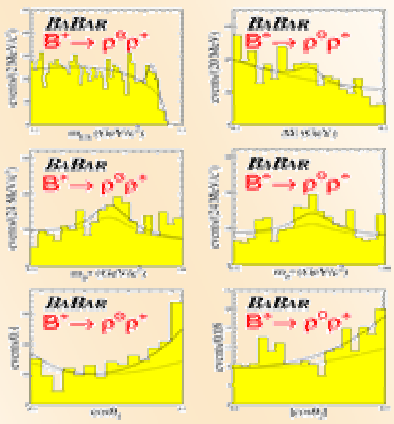
The PDF parameters α are extracted from MC simulation and on-resonance m_{ES}–ΔE sidebands.

About 5% of the events in the final sample are expected from other *B* decays. This background is explicitly accounted for in the fit.

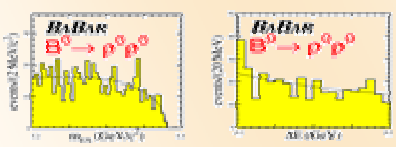
The event yields n_j and polarization f_L are obtained by minimizing the quantity $\chi^2 = -2\ln\mathcal{L}$. We quote statistical errors corresponding to a unit increase in χ^2.

Previous results: $B^+ \to \rho^+\rho^0$, $B^0 \to \rho^0\rho^0$ [1]

$B^+ \to \rho^+\rho^0$: Reconstruction efficiency $\varepsilon = 4.7 \pm 0.9\%$.
Signal event yield $n_{sig} = 93^{+24}_{-22} \pm 10$.



$B^0 \to \rho^0\rho^0$: Reconstruction efficiency $\varepsilon = 17.6 \pm 1.5\%$.
Signal event yield $n_{sig} = 9.7^{+11.9}_{-9.4} \pm 2.0$.



The 90% confidence upper limit on the ratio of the longitudinal amplitudes in decays is

$$\frac{\mathcal{B}(B^0 \to \rho^0\rho^0) \times f_L(B^0 \to \rho^0\rho^0)}{\mathcal{B}(B^+ \to \rho^0\rho^+) \times f_L(B^+ \to \rho^0\rho^+)} < 0.10.$$

[1] BaBar Collaboration, B. Aubert *et al*, BABAR-PUB-03/018, hep-ex/0307026, submitted to Phys. Rev. Lett.