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# Measurement of the exclusive branching fractions $B^0 \to \eta K^{*0}$ and $B^+ \to \eta K^{*+}$.

The *BABAR* Collaboration

## Abstract

We present the results of searches for $B$ decays to the two charmless two-body final states $B^0 \to \eta K^{*0}$and $B^+ \to \eta K^{*+}$, based on 20.7 $\mathrm{fb}^{-1}$ of data collected in 1999 and 2000 with the *BABAR* detector at PEP-II. We find the branching fractions $\mathcal{B}(B^0 \to \eta K^{*0}) = (19.8^{+6.5}_{-5.6} \pm 1.7) \times 10^{-6}$ and $\mathcal{B}(B^+ \to \eta K^{*+}) = (22.1^{+11.1}_{-9.2} \pm 3.3) \times 10^{-6}$, where the first error quoted is the statistical and the second systematic.

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# 1 Introduction

We report results for searches for $B$ decays to the charmless two-body final states $B^0 \to \eta K^{*0}$ and $B^+ \to \eta K^{*+}$ [1]. These processes are manifestations of penguin or suppressed tree amplitudes proportional to small couplings in hadronic flavor mixing (CKM matrix [2]). As more of these rare decay modes are measured, their phenomenological description will improve, and with it the sensitivity to any contributions through virtual particle loops or interference terms of heretofore undetected physics.

# 2 The *BABAR* detector and dataset

The data were collected with the *BABAR* detector [3] at the PEP-II storage ring [4] located at the Stanford Linear Accelerator Center. The results presented in this paper are based on data taken in the 1999–2000 run. An integrated luminosity of 20.7 $\mathrm{fb}^{-1}$ was recorded at the $\Upsilon(4S)$ resonance corresponding to 22.7 million $B\overline{B}$ pairs ("on-resonance"). In addition 2.6 $\mathrm{fb}^{-1}$ was recorded about 40 MeV below this energy ("off-resonance") to study non-$b\overline{b}$ continuum.

The asymmetric beam configuration in the laboratory frame provides a boost to the $\Upsilon(4S)$ increasing the momentum range of the $B$-meson decay products up to 4.3 GeV/$c$. Charged particles are detected and their momenta are measured by a combination of a silicon vertex tracker (SVT) consisting of five double-sided layers and a 40-layer drift chamber (DCH), both operating in a 1.5 T solenoidal magnetic field. Photons are detected by a CsI electromagnetic calorimeter (EMC), which provides excellent angular and energy resolution with high efficiency for energies above 20 MeV.

Charged particle identification (PID) is provided by the specific ionization loss ($\mathrm{d}E/\mathrm{d}x$) in the tracking devices and by a unique, internally reflecting ring imaging Cherenkov detector (DIRC) covering the central region. A Cherenkov angle $K$–$\pi$ separation of better than $4\sigma$ is achieved for tracks below 3 GeV/$c$ momentum, decreasing to $2.5\sigma$ at the highest momenta in our final states [5].

# 3 Analysis method

We reconstruct a $B$ meson candidate by combining an $\eta$ candidate with a $K^*$ candidate. The daughter resonance decays are $\eta \to \gamma\gamma$, $K^{*0} \to K^+\pi^-$, $K^{*+} \to K^0_S\pi^+$ and $K^0_S \to \pi^+\pi^-$. These modes are kinematically distinct from the dominant $B$ decays to heavier charmed daughters. Backgrounds come primarily from combinatorics among continuum events in which a light quark pair was produced instead of an $\Upsilon(4S)$.

Monte Carlo (MC) simulations [6] of the target decay modes and of continuum background were used to establish the event selection criteria. They were designed to achieve high efficiency and retain sidebands sufficient to characterize the background for subsequent fitting. Photons must satisfy $E_\gamma > 50$ MeV for $\eta$ candidates. We select $\eta$ and $K^*$ candidates with the requirements $490 < m_{\gamma\gamma} < 600$ MeV/$c^2$, and $800 < m_{K\pi} < 990$ MeV/$c^2$. For $K^0_S$ candidates we require $400 < m_{\pi\pi} < 600$ MeV/$c^2$.

The pion (kaon) daughters of the $K^*$ candidates must have DIRC, $\mathrm{d}E/\mathrm{d}x$, and EMC responses consistent with pions (kaons). For the $K^0_S$, the three-dimensional flight distance from the event primary vertex must exceed 2 mm, the two-dimensional angle between the flight and momentum vectors must be less than 40 mrad and the lifetime significance ($\tau/\sigma_\tau$) should be larger than 3.

A $B$ meson candidate is characterized by two kinematic observables. In the CMS system, due to the two-body nature of the $B$ meson production at the $\Upsilon(4S)$, the $B$ meson candidate's energy $E_B^*$ must be equal to $\sqrt{s}/2$, where $\sqrt{s}$ is the center of mass energy. This is taken into account by requiring that $|\Delta E| = |E_B^* - \sqrt{s}/2|$ be less than 0.2 GeV, and the beam energy constrained mass $m_{\rm EC} = \sqrt{\hat{E}_B^{*2} - \hat{p}_B^{*2}}$, where $\hat{E}_B^*$ and $\hat{p}_B^*$ are values obtained from a kinematic fit with the constraint $E_B^* = \sqrt{s}/2$.

To discriminate against tau-pair and two-photon background we require the event to contain at least three (four) charged tracks for neutral (charged) $B$ meson candidates. To reject continuum background we make use of the angle $\theta_T$ between the thrust axis of the $B$ candidate and the rest of the tracks and neutral clusters in the event, calculated in the center-of-mass frame. The distribution of $\cos\theta_T$ is sharply peaked near ±1 for combinations drawn from jetlike $q\bar{q}$ pairs, and nearly uniform for the isotropic $B$ meson decays. We require $|\cos\theta_T| \leq 0.9$.

Event yields are obtained by an unbinned extended maximum likelihood (ML) fit analysis, while requirement based analyses are used to validate the results. The input observables are $\Delta E$, $m_{\rm EC}$, the invariant masses $m_{\gamma\gamma}$ and $m_{K\pi}$ of the two resonant daughter candidates and a Fisher discriminant $\mathcal{F}$. The $K_S^0$ spectrum is not fitted because candidates in the background are dominantly real $K_S^0$. The Fisher discriminant [7] combines two production angles and a nine bin representation of the energy flow about the $B$ decay axis. For the $\eta$ mode the helicity angle $\theta_\eta^{\rm hel}$ is the angle in the $\eta$ rest frame between the direction of one of the photons and the $\eta$ flight direction. We require $\cos\theta_\eta^{\rm hel} \leq 0.92$ to discriminate against $K^*\gamma$ background. A second $B$ candidate satisfying the preliminary requirements occurs in about 11% of the events. In this case the "best" combination is selected according to a $\chi^2$ computed from $m_\eta$ and $m_{K^*}$.

The requirement based analyses use the same variables as the ML fit with tighter selection criteria for the signal. A large sideband in the $m_{\rm ES}$, $\Delta E$ plane gives an estimate of the continuum background which, with appropriate scaling, is subtracted from the raw signal yield.

We use MC to estimate backgrounds from other $B$ decays, including modes with and without charmed daughters. We find these contributions to be negligible.

The likelihood function for $N$ observed events is

$$\mathcal{L} = \frac{e^{-(\sum n_j)}}{N!} \prod_{i=1}^{N} \mathcal{L}_i \, ,$$

where the contribution of event $i$ is

$$\mathcal{L}_i = \sum_{j=1}^{m} n_j \mathcal{P}_j(\vec{x}_i).$$

Here $n_j$ is the population size for species $j$ (e.g., signal, background) and $\mathcal{P}_j(\vec{x}_i)$ the corresponding probability distribution function (PDF), evaluated with the observables $\vec{x}_i$ of the $i$th event.

For the fits $\mathcal{L}_i$ becomes (with the event index $i$ suppressed on both sides of the equation)

$$\mathcal{L} = n_S \mathcal{P}_S + n_C \mathcal{P}_C \, ,$$

where $n_S$ is the number of signal events and $n_C$ is the number of continuum background events. These quantities are the free parameters of the ML fit. The probabilities for the components are $\mathcal{P}_S$ for signal and $\mathcal{P}_C$ for background. Since we measure the correlations among the observables in the data to be small, we take each $\mathcal{P}_j$ to be a product of the PDFs for the separate observables.

We determine the PDFs for the likelihood fit from simulation for the signal component, and off-resonance and on-resonance sideband data for the continuum background. Peaking distributions (signal masses, $\Delta E$, $\mathcal{F}$) are parameterized as “crystal ball shape” [8], double Gaussian or bifurcated Gaussian functions. Slowly varying distributions (combinatoric background under mass or energy peaks) have polynomial shapes. The combinatoric background in $m_{\mathrm{EC}}$ is described by a phase space motivated empirical function [9], the Argus shape. Control samples of $B$ decays to charmed final states of similar topology are used to verify the simulated resolutions in $\Delta E$ and $m_{\mathrm{EC}}$.

## 4 Results

We compute the branching fractions from the fitted signal event yields, reconstruction efficiency, daughter branching fractions, and the number of produced $B$ mesons, assuming equal production rates of charged and neutral pairs. In Figure 1 the Likelihood function for the two modes is plotted.

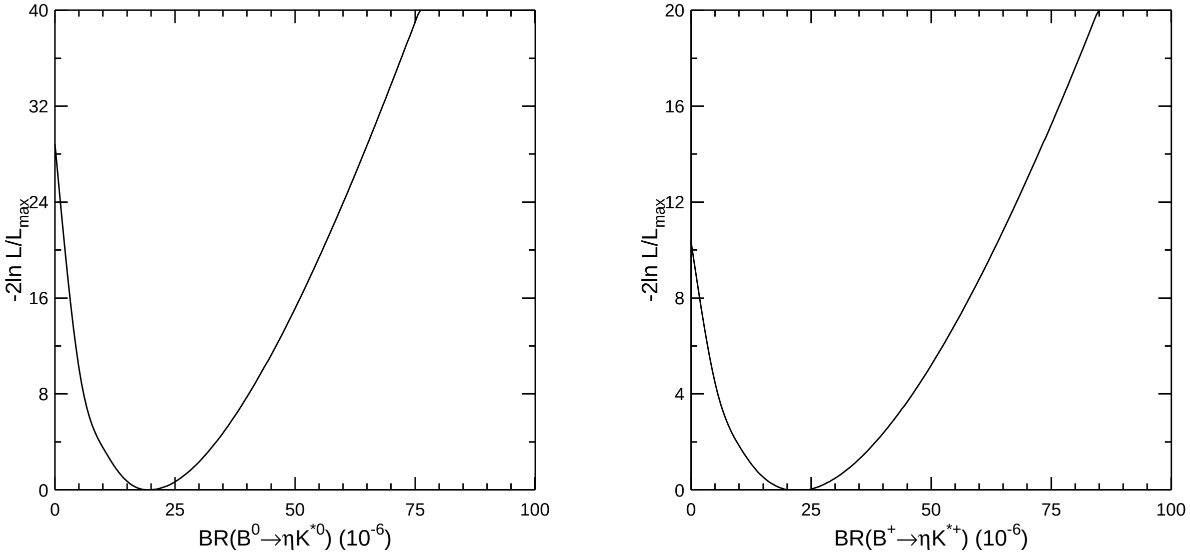

Figure 1: likelihood functions for $B^0 \to \eta K^{*0}$ (left) and $B^+ \to \eta K^{*+}$ (right) branching fractions.

Table 1 shows for both decay chains the branching fraction we measure, together with the quantities entering into its computation. The statistical error on the number of events is taken as the shift from the central value that changes the quantity $\chi^2 \equiv -2\ln\mathcal{L}$ by one unit. We also give the statistical significance $S$, computed as the square root of the difference between the value of $\chi^2$ for zero signal and the value at its minimum.

In Fig. 2 we show projections of $m_{\mathrm{EC}}$ for both modes. The projections are made by applying a requirement on the individual event likelihood (computed without $m_{\mathrm{EC}}$) to select the more signal-like events. The overlaid curves represent the ML fit PDF scaled to take into account the effect of the additional requirement.

For each measurement the supporting requirement-based analysis yielded compatible results with comparable, if somewhat larger, statistical errors.

Table 1: signal event yield with statistical uncertainty, detection efficiency ($\epsilon$, %), daughter branching fractions (%), significance $S$, and branching fraction result for each decay chain.

| Mode | Signal yield | $\epsilon$ | $\prod \mathcal{B}_i$ | $S$ | $\mathcal{B}(\times 10^{-6})$ (CL 90 % ) |
|---|---|---|---|---|---|
| $\eta K^{*0}$ | $21 \pm 6$ | 19.0 | 26.1 | 5.4 | $19.8^{+6.5}_{-5.6} \pm 1.7$ |
| $\eta K^{*+}$ | $14 \pm 7$ | 17.6 | 17.9 | 3.2 | $22.1^{+11.1}_{-9.2} \pm 3.3$ (33.9) |

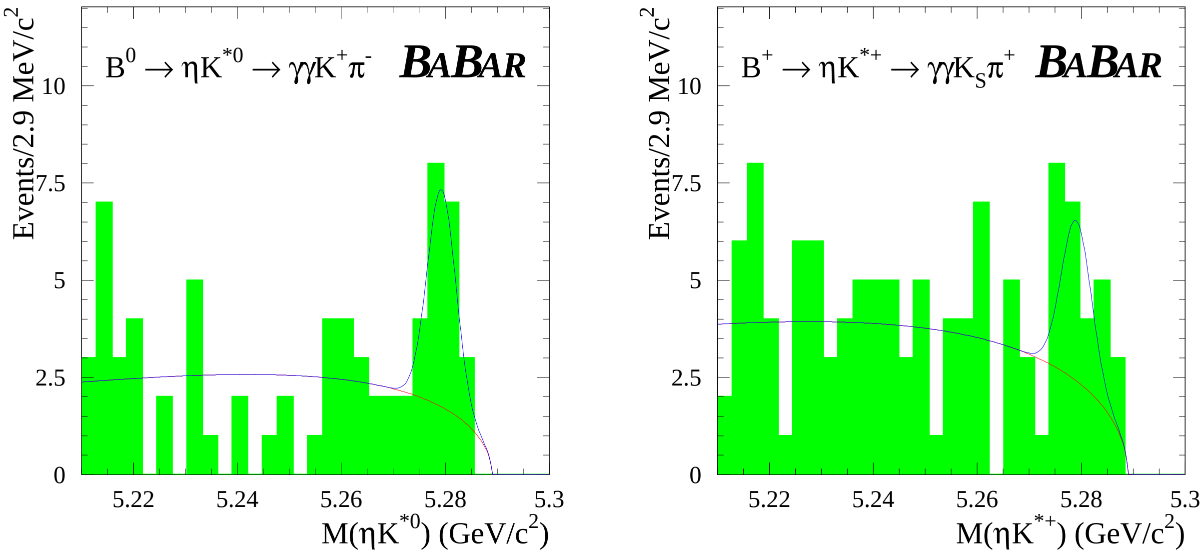

Figure 2: $B$ candidate invariant mass for $B^0 \to \eta K^{*0}$(left) and $B^+ \to \eta K^{*+}$(right). Histograms represent data, and smooth curves represent the fit function.

# 5 Systematic studies

We have evaluated systematic errors, which are dominated by the PDF uncertainties (6–12%, depending on the decay mode). To determine these we varied parameters of the PDFs within their uncertainties and estimated the impact on the fit yield. This is the only additive systematic error; all others are multiplicative.

Auxiliary studies lead to systematic errors of 1%, 2.5%, and 5% respectively for the imperfect simulation of track, photon, and $K_S^0$ efficiencies. These errors are summed linearly for the $B$ daughters. The $B$ production systematic error has been estimated in a separate study to be 1.6%. Published world averages [10] provide the $B$ daughter branching fraction uncertainties.

Systematic errors associated with the event selection are minimal given the generally loose requirements. We account explicitly for $|\cos\theta_T|$ (1%), for which we observe a nearly uniform distribution in the signal simulation. We also include errors of 4% due to the PID requirements.

# 6 Summary

We have found significant event yields in the decay $B \to \eta K^*$, as reported in Table 1. The final results are generally in agreement with those previously reported [11]. We confirm the rather larger than predicted [12] rate for $B \to \eta K^*$ obtained by the CLEO Collaboration [11]. The enhancement in $B \to \eta K^*$ could be due to constructively interfering internal penguin diagrams [13].

# 7 Acknowledgments

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# References

[1] Charge conjugate states are implied throughout this paper.

[2] N. Cabibbo, Phys. Rev. Lett. **10**, 531 (1963); M. Kobayashi and T. Maskawa, Prog. Th. Phys. **49**, 652 (1973).

[3] The *BABAR* Collaboration, B. Aubert *et al.*, SLAC-PUB-8569, hep-ex/0105044 (to appear in Nucl. Instr. and Methods **)**.

[4] PEP-II Conceptual Design Report, SLAC-R-418 (1993).

[5] The *BABAR* Collaboration, B. Aubert *et al.*, SLAC-PUB-8838, hep-ex/0105061, see Fig. 1(b) (Submitted to Phys. Rev. Lett. ).

[6] The *BABAR* detector Monte Carlo simulation is based on GEANT:
R. Brun *et al.*, CERN DD/EE/84-1.

[7] CLEO Collaboration, D.M. Asner *et al.*, Phys. Rev. D **53**, 1039 (1996).

[8] T. Skwarnicki [Crystal Ball Collaboration], "A Study Of The Radiative Cascade Transitions Between The Upsilon-Prime And Upsilon Resonances," DESY F31-86-02 (thesis, unpublished) (1986).

[9] ARGUS Collaboration, H. Albrecht *et al.*, Phys. Lett. B **241** (1990) 278;
Phys. Lett. B **254** (1991) 288.

[10] Particle Data Group, D.E. Groom *et al.*, Eur. Phys. Jour. C **15**, 1 (2000).

[11] CLEO Collaboration S.J. Richichi *et al.*, Phys. Rev. Lett. **85**, 520 (2000);
CLEO CONF 99-12 (1999).

[12] A. Ali, G. Kramer, and C.D. Lü, Phys. Rev. D **58**, 094009 (1998);
Y. H. Chen *et al.*, Phys. Rev. D **60**, 094014 (1999).

[13] H. J. Lipkin, Phys. Lett. B B **254**, 247 (1991).