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First Results in Exclusive Radiative Penguin Decays at *BABAR*

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Abstract

We present a preliminary measurement of the branching fraction of the exclusive penguin decay $B^0 \to K^{*0}\gamma$ using $(8.6 \pm 0.3) \times 10^6$ $B\overline{B}$ decays

$$\mathcal{B}(B^0 \to K^{*0}\gamma) = (5.42 \pm 0.82(stat.) \pm 0.47(sys.)) \times 10^{-5}.$$

In addition we search for the related penguin decays with a lepton pair in the final state,$B^+ \to K^+l^+l^-$, $B^0 \to K^{*0}\ l^+l^-$. We find no evidence for these decays in $3.7 \pm\ 0.1 \times\ 10^6$ $B\overline{B}$ decays and set preliminary 90 % C.L upper limits of

$$\begin{aligned}
\mathcal{B}(B^+ \to K^+e^+e^-) &< 12.5 \times 10^{-6}, \\
\mathcal{B}(B^+ \to K^+\mu^+\mu^-) &< 8.3 \times 10^{-6}, \\
\mathcal{B}(B^0 \to K^{*0}e^+e^-) &< 24.1 \times 10^{-6}, \\
\mathcal{B}(B^0 \to K^{*0}\mu^+\mu^-) &< 24.5 \times 10^{-6}.
\end{aligned}$$

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1 Introduction

In the Standard Model the exclusive decay $B^0 \to K^{*0}\gamma$ proceeds by the $b \to s\gamma$ loop "penguin" diagram. Precise measurements of decay modes involving these transitions and modes with the related $b \to d\gamma$ transition such as $B^0 \to \rho\gamma$ will allow measurements of the top quark couplings V_{ts} and V_{td}. The strength of these transitions may also be enhanced by the presence of non-Standard Model contributions [1]. In the first year of running the *BABAR* experiment has accumulated a dataset comparable to the world's largest to date, and this will increase by an order of magnitude over the next few years. A comprehensive program to study these decays is now underway. The first step in this program is the preliminary measurement of the branching fraction of the exclusive decay mode $B^0 \to K^{*0}\gamma$ using the leading decay mode, $K^{*0} \to K^+\pi^-$. Here K^{*0} refers to the $K^{*0}(896)$ resonance, and charge conjugate channels are assumed throughout. We also present a search for the rarer and as yet unobserved exclusive penguin decays $B \to K\ell^+\ell^-$ and $B \to K^*\ell^+\ell^-$, where ℓ is either an electron or muon.

The data were collected with the *BABAR* detector at the PEP-II asymmetric e^+e^- storage ring. The results presented in this paper are based upon an integrated luminosity of 7.5 fb^{-1} of data corresponding to $(8.6 \pm 0.3) \times 10^6$ $B\overline{B}$ meson pairs recorded at the $\Upsilon(4S)$ energy ("on-resonance") and $1.1\,\mathrm{fb}^{-1}$ below the $\Upsilon(4S)$ energy ("off-resonance"). We compute quantities in both the laboratory frame and the rest frame of the $\Upsilon(4S)$. Quantities computed in the rest frame are denoted by an asterisk; eg. E_b^* is the energy of the e^+ and e^- beams which are symmetric in the $\Upsilon(4S)$ rest frame.

2 Measurement of $\mathcal{B}(B^0 \to K^{*0}\gamma)$

We begin the selection by requiring a good photon candidate in the calorimeter with an energy $2.20\,\mathrm{GeV} < \mathrm{E}_\gamma^* < 2.85\,\mathrm{GeV}$. We veto photons from π^0's. We next reconstruct the K^{*0} from K^+ and π^- candidates. We consider all pairs of tracks in the event. A track is identified as a kaon by the ring imaging Cherenkov detector (DIRC) and we require $806\,\mathrm{MeV} < \mathrm{M}_{\mathrm{K}^+\pi^-} < 986\,\mathrm{MeV}$. The B^0 candidates are reconstructed from the K^{*0} and γ candidates. There are backgrounds from continuum $q\overline{q}$ production with the high energy photon originating from initial state radiation or from a π^0 or η. We exploit event topology differences between signal and background to reduce the continuum contribution [5]. In the rest frame of the $\Upsilon(4S)$ the $B\overline{B}$ pairs are produced approximately at rest and therefore decay isotropically while the $q\overline{q}$ pair recoil against each other in a jet-like topology.

Since the B^0 mesons are produced via $e^+e^- \to \Upsilon(4S) \to B\overline{B}$ the energy of the B^0 is given precisely by the beam energy, E_b^* . We reconstruct the B^0 candidate substituting E_b^* for the measured energy of the candidate daughters. We define the difference of the beam energy and energy of the B^0 daughters, $\Delta E^* = E_b^* - E_{K^*}^* - E_\gamma^*$ and require $-200\,\mathrm{MeV} < \Delta\mathrm{E}^* < 100\,\mathrm{MeV}$. The B^0 mass is given by, $M_{ES} = \sqrt{E_{beam}^{*2} + |p_B^{*2}|}$, where $|p_B^*|$ is the momentum of the B^0 candidate calculated using the measured momenta of the charged daughters and the energy of the photon. Figure 1 shows the M_{ES} of the candidates. The background is determined empiracally by fitting the ARGUS function [4] to off-resonance data. We find a signal of 48.4 ± 7.3 events with the error coming from the statistical error of the fit.

The efficiency for the selection of $B^0 \to K^{*0}\gamma$ candidates is $(15.6 \pm 0.3)\%$. The branching fraction is measured to be $\mathcal{B}(B^0 \to K^{*0}\gamma) = (5.42 \pm 0.82(stat.) \pm 0.47(sys.)) \times 10^{-5}$ consistent both with previous measurements [2] and with the standard model expectations [3]. The total systematic error of 8.6% is a quadratic sum of several uncorrelated components given in Table 1 [5].

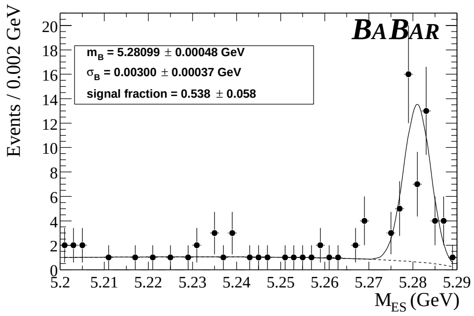

Figure 1: The M_{ES} projection for $B^0 \to K^{*0}\gamma$ $K^{*0} \to K^+\pi^-$ candidates from $(8.6 \pm 0.3) \times 10^6$ $B\overline{B}$ decays.

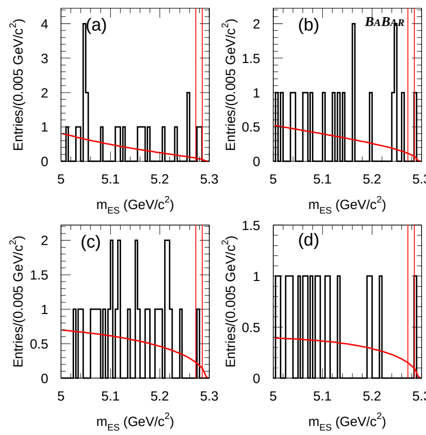

Figure 2: m_{ES} for data after all other event selection criteria are applied: (a) $B^+ \to K^+e^+e^-$, (b) $B^+ \to K^+\mu^+\mu^-$, (c) $B^0 \to K^{*0}e^+e^-$, and (d) $B^0 \to K^{*0}\mu^+\mu^-$. The shape of the fit (the ARGUS function) is obtained from the large statistics sample of fast parameterized Monte Carlo events. The lines indicate the signal region.

Table 1: The fractional systematic uncertainties in the measurement of $\mathcal{B}(B^0 \to K^{*0}\gamma)$.

Uncertainty	$\Delta B/B$ %
Tracking efficiency	5.0
Luminosity	3.6
Kaon-id efficiency	3.0
Track resolution	3.0
Energy Resolution	2.5
Background shape	2.3
Monte Carlo Statistics	1.9
Calorimeter energy scale	1.0
Calorimeter efficiency	1.0
$\pi^0\eta$ veto	1.0
Merged π^0 modeling	1.0
Total	8.6

3 Search for $B^+ \to K^+l^+l^-$, $B^0 \to K^{*0}\ l^+l^-$

We search in both the electron and muon channels using a subset of the data corresponding to $3.7 \pm\ 0.1 \times\ 10^6$ $B\overline{B}$ decays. The main goal of our study is to test the performance of a "blind" analysis in which the event selection is optimized without use of the signal or sideband regions in the data. The dominant backgrounds come from random leptons and kaons in $B\overline{B}$ and continuum processes, and from $B \to J/\psi K^{(*)}$ or $B \to \psi(2S)K^{(*)}$ with J/ψ or $\psi(2S) \to \ell^+\ell^-$. The B candidates are reconstructed from K^{*0}, electron and muon candidates. The K^{*0} is reconstructed in the $K^+\pi^-$ final state as above. Electron candidates are identified using the ratio of the deposited calorimeter energy to the associated charged track momentum. Muons are identified by their depth of penetration into the muon detector. Continuum backgrounds are suppressed using event shape variables [6]. The backgrounds from $B \to J/\psi K^{(*)}$ and $B \to \psi(2S)K^{(*)}$ are eliminated by cutting in the ΔE^* vs. $M_{\ell^+\ell^-}$ plane [6]. Figure 2 shows the $m_{\rm ES}$ distributions for the four modes. No evidence of a signal is observed and table 2 gives the derived limits on these processes. The derivation of the limits takes into account the systematic uncertainties given in table 3 [6].

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Table 2: Signal efficiencies, the number of observed events, the number of estimated background events, and upper limits on the branching fractions.

Mode	Eff. (%)	Obs. evts	Bkg. est.	$\mathcal{B}/10^{-6}$ (90% C.L.)
$K^+e^+e^-$	13.1	2	0.20	< 12.5
$K^+\mu^+\mu^-$	8.6	0	0.25	< 8.3
$K^{*0}e^+e^-$	7.7	1	0.50	< 24.1
$K^{*0}\mu^+\mu^-$	4.5	0	0.33	< 24.5

Table 3: Summary of the systematic uncertainties given as a percentage error on the branching fraction

	$(\Delta\mathcal{B}/\mathcal{B})$ (%)			
	Kee	$K\mu\mu$	K^*ee	$K^*\mu\mu$
Track eff.	7.5	7.5	10.0	10.0
Lepton-id	4.0	5.0	4.0	5.0
Kaon-id	3.0	3.0	3.0	3.0
ΔE eff.	2.0	2.5	3.3	1.5
m_{ES} eff.	3.0	3.0	3.0	3.0
Vertex eff.	3.0	3.0	4.0	4.0
Fisher eff.	3.0	3.0	3.0	3.0
Luminosity	3.6	3.6	3.6	3.6
MC stat.	3.4	4.0	4.3	6.1
Total	11.7	12.3	14.2	14.8

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