Exclusive $B \to K^{**}\gamma$ decays

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Outline

- Model predictions for absolute rates
- $B \to K\pi\pi\gamma$ correlations as a probe of photon helicity
- Conclusions

$b \to s\gamma$ in the Standard Model

In the Standard Model, $b \to s\gamma$ decays are mediated by the electromagnetic penguin operator

$$\mathcal{H}_{\text{eff}} = \frac{G_F}{\sqrt{2}} V_{ts} V_{tb}^* C_7 \mathcal{O}_7 \qquad \left(\mathcal{O}_7 = \frac{e m_b}{16\pi^2} \bar{s} \sigma_{\mu\nu} \frac{1}{2}(1+\gamma_5) b F^{\mu\nu} \right)$$

- Couples mostly to left-handed photons because of the $(V - A)$ $W^{\pm}$ couplings to quarks in the Standard Model (right-handed for $\bar{b} \to \bar{s}\gamma$)
- The most general case can include both left- and right-handed couplings

$$\mathcal{H}_{\text{eff}} = \frac{G_F}{\sqrt{2}} V_{ts} V_{tb}^* \left(C_{7L} \mathcal{O}_{7L} + C_{7R} \mathcal{O}_{7R} \right)$$

- While the rate is only sensitive to $|C_{7R}|^2 + |C_{7L}|^2$, the photon polarization can probe the individual Wilson coefficients

$$P_\gamma = \frac{|C_{7R}|^2 - |C_{7L}|^2}{|C_{7R}|^2 + |C_{7L}|^2}$$

Exclusive $B \to X_s \gamma$ decays

The exclusive modes are dominated by the lowest lying vector K^*

Babar - PRL 88, 101805 (2002)

$$
\begin{aligned}
\mathcal{B}(B^+ \to K^{*+}\gamma) &= (3.83 \pm 0.62 \text{ (stat)} \pm 0.22 \text{ (sys)}) \times 10^{-5} \\
\mathcal{B}(B^0 \to K^{*0}\gamma) &= (4.23 \pm 0.40 \text{ (stat)} \pm 0.22 \text{ (sys)}) \times 10^{-5}
\end{aligned}
$$

Higher excitations are also seen

$$
Br(B \to K_2^*(1430)\gamma) = \begin{cases} (1.50^{+0.58+0.11}_{-0.53-0.13}) \times 10^{-5} & \text{(BELLE)} \\ (1.66^{+0.59}_{-0.53} \pm 0.13) \times 10^{-5} & \text{(CLEO)} \end{cases}
$$

The absolute values of the rates depend on the value of a hadronic form factor - can be computed in models

Model computations

	J^P	(M, Γ)	[1]	[2]	[3]
$K_1(1270)$	1^+	(1273, 90)	4.5 ± 10.1	4.3 ± 1.6	1.5 ± 0.5
			$1.8 - 4.0$	1.20 ± 0.44	0.45 ± 0.15
$K_1(1400)$	1^+	(1402, 174)	6.0 ± 13.0	2.1 ± 0.9	2.6 ± 0.6
			$2.4 - 5.2$	0.58 ± 0.26	0.78 ± 0.18
$K_1^*(1410)$	1^-	(1414, 232)	7.2 ± 10.6	4.1 ± 0.6	-
			-	-	-
$K_2^*(1430)$	2^+	(1430, 100)	17.3 ± 37.1	6.2 ± 2.9	5.7 ± 1.2
			$6.9 - 14.8$	1.73 ± 0.80	1.7 ± 0.6

For each model, we show $(r_i, Br \times 10^5)$ with

$$r_i = \frac{\mathcal{B}(B \to K^{**}\gamma)}{\mathcal{B}(B \to X_s\gamma)}$$

[1] A. Ali, T. Ohl, T. Mannel, Phys. Lett. B 298, 195 (1993)
[2] M. Olsson, S. Veseli - Phys. Lett. B367, 309, (1996)
[3] D. Ebert, R. Faustov and V. Galkin, Phys. Rev. D 64, 054001 (2001)

Photon polarization from $B \to (K^{**} \to K\pi\pi)\gamma$

- In the decay $B \to K^*\gamma$, the photon helicity is transferred to the hadron K^*. Is it possible to measure it through the strong decays $K^* \to |f\rangle$?

This requires an asymmetry between the decay distributions of a left/right-polarized K^* $\quad |A(K_R^* \to f)| \neq |A(K_L^* \to f)|$

- In two body decays $K^* \to K\pi$ parity invariance of the strong interactions rules out a right/left asymmetry

This is possible in 3-body decays of K^{**} resonances

Weinstein, Islam

Gronau, Grossman, DP, Ryd

The most general distribution involves the interference of multiple decay channels and partial waves $\rightarrow$ strong phases required for a nonvanishing $T-$odd asymmetry

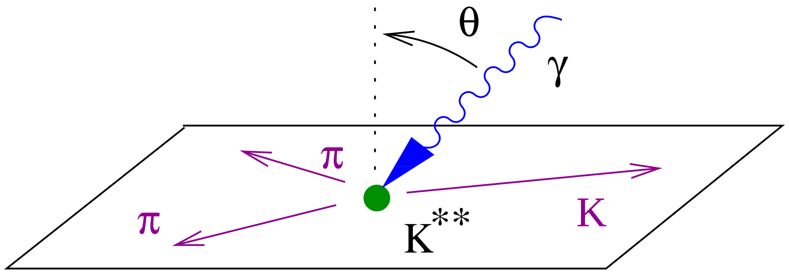
The signal is observable in both charged and neutral B decays

$$B^+ \to \left\{ \begin{array}{c} K_1(1400) \\ K_1(1410) \\ K_2^*(1430) \end{array} \right\} \gamma \to \left\{ \begin{array}{c} K^{*+}\pi^0 \\ K^{*0}\pi^+ \\ \rho^+ K^0 \end{array} \right\} \gamma \to K^0\pi^+\pi^0\gamma \, .$$

and

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

Many of the partial widths and strong phases have been directly measured in a $K\pi\pi$ production experiment (ACCMOR (1981))



$$
\begin{aligned}
\Gamma \simeq \quad & |c_1|^2 \left(1+\cos^2\theta + P_\gamma R_1 \cos\theta\right) && (1^+) \\
+ \quad & |c_2|^2 \left(\cos^2\theta + \cos^2 2\theta + P_\gamma R_2 \cos\theta\cos 2\theta\right) && (2^+) \\
+ \quad & |c_3|^2 \sin^2\theta && (1^-) \\
+ \quad & c_{12}(3\cos^2\theta - 1) + c'_{12} P_\gamma \cos^3\theta && (1^+ - 2^+)
\end{aligned}
$$

Gronau, DP

$$\boxed{R_1 = 0.22 \pm 0.03\,, \quad R_2 = 0.01 - 0.05}$$

Conclusions

- Measurements of the branching ratios $\mathcal{B}(B \to K^{**}\gamma)$ can test quark model computations
- Angular distributions in $B \to (K_{\rm res} \to K\pi\pi)\gamma$ offer a unique probe of the photon helicity in $b \to s\gamma$
  - Search for New Physics in $b \to s\gamma$ which would not be observable in the rate
  - The method has advantages over existing probes of photon polarization: larger rates, no tagging, both $B^{\pm}$, B^0 decays can be used
- Can be done with existing data samples at $N_B = 10^8$