$B \to K_1(1400)\gamma$

2003 October 23

10^{36} B Factory Workshop

1. Measurements
2. Modelling
3. Outlook

Measurements

- $B \to K^*(892)\gamma$ and $B \to K_2^*(1430)\gamma$ have been measured.
- Belle has measured

$$BR(B^+ \to K^+\pi^+\pi^-\gamma) = (2.5 \pm 0.5^{+0.4}_{-0.2}) \times 10^{-5}$$

  without disentangling K resonances.
- $B \to K_1(1400)\gamma$ has not been measured.

Theorists suggest $BR(B \to K_1\gamma) \sim 0.7 \times 10^{-5}$

e.g. Atwood and Soni, 1994

Polarization

A more interesting reason to study this mode is to measure the photon polarization:

$$\lambda_\gamma \equiv \frac{|\mathcal{M}(\bar{B} \to K_{\rm res}\gamma_L)|^2 - |\mathcal{M}(\bar{B} \to K_{\rm res}\gamma_R)|^2}{|\mathcal{M}(\bar{B} \to K_{\rm res}\gamma_L)|^2 + |\mathcal{M}(\bar{B} \to K_{\rm res}\gamma_R)|^2}$$

It has been shown that for *any* $K_{\rm res}$,

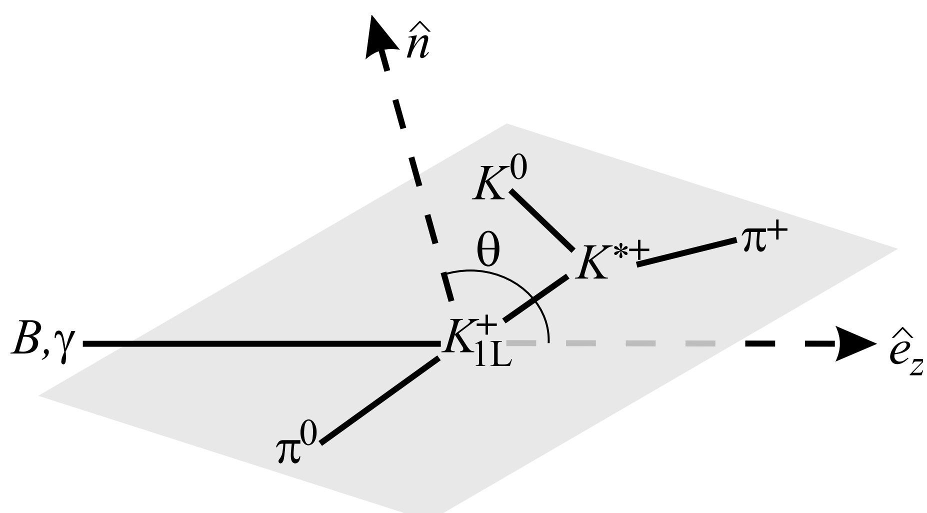
$$\lambda_\gamma = \frac{|C_{7R}|^2 - |C_{7L}|^2}{|C_{7R}|^2 + |C_{7L}|^2}$$

In the SM, $\lambda_\gamma = +1$ for B decays and $\lambda_\gamma = -1$ for $\bar{B}$ decays, in the limit $(m_s^2/m_b^2) \ll 1$.

Measuring polarization

How do you measure λ_γ? By measuring the angular distribution of the recoiling hadronic system, you can measure the helicity of $K_{\rm res}$.

- In two-body $K_{\rm res}$ decays, such as $K_2^*(1430) \to K\pi$, you cannot construct a parity-odd scalar from the final state momenta.
- You can, however, in three-body decays, e.g. $\vec{p}_\gamma \cdot (\vec{p}_K \times \vec{p}_\pi)$.
- Measure angle θ between normal $\hat{n}$ to K_1 decay plane and photon flight axis $\hat{e}_z$ in K_1 rest frame.



Measuring polarization

To extract λ_γ, use channels in which K_1 decays to the same final state via two K^* isospin states, *e.g.*

$$B^+ \to K_1^+ \gamma \qquad\qquad B^+ \to K_1^+ \gamma$$

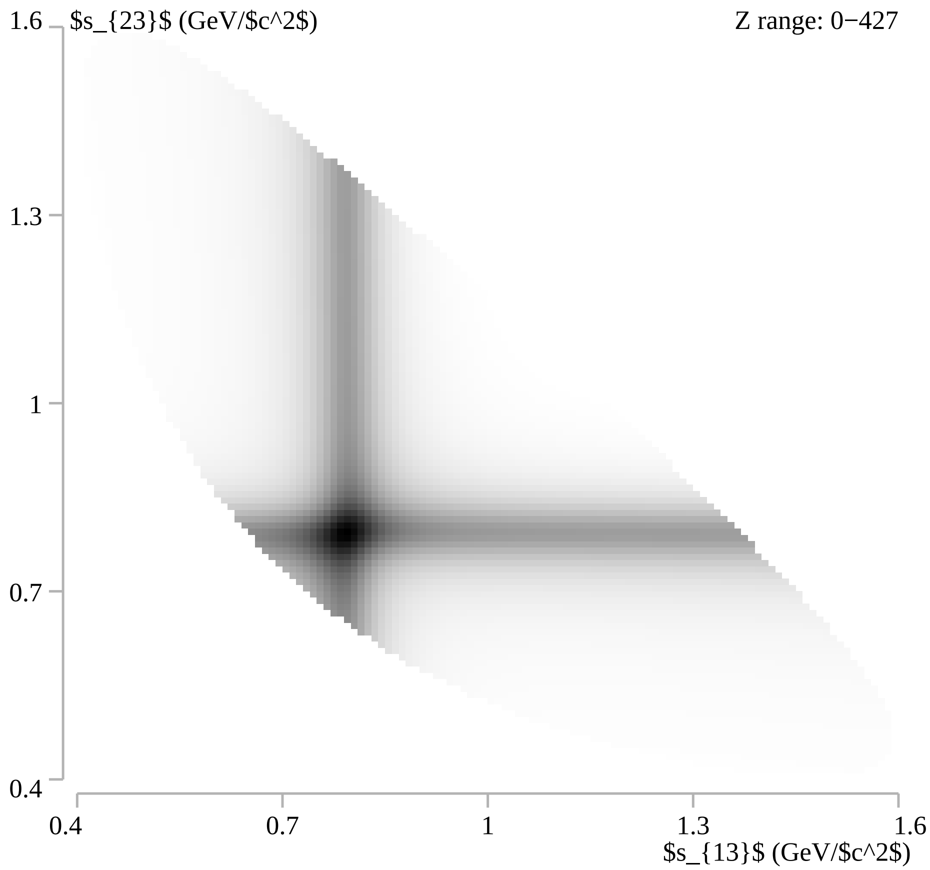
$$K_1^+ \to K^{*+} \pi^0 \qquad\qquad K_1^+ \to K^{*0} \pi^+$$

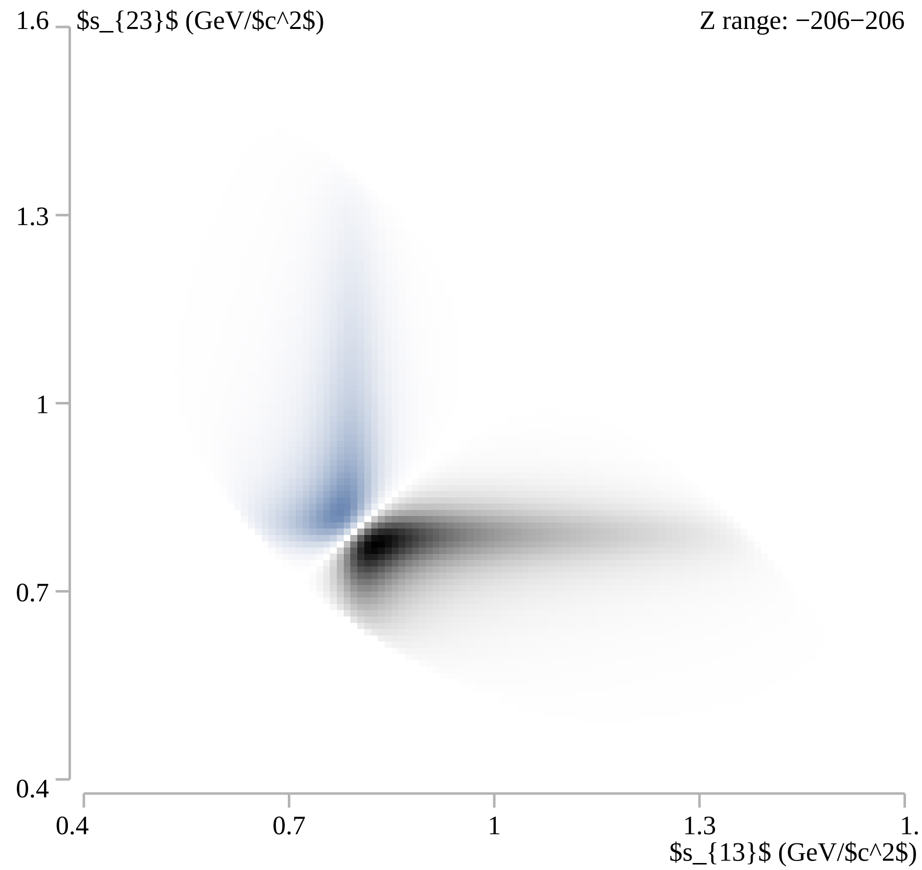
$$K^{*+} \to K^0 \pi^+ \qquad\qquad K^{*0} \to K^0 \pi^0$$

Symmetric and antisymmetric terms

Gronau, Grossman *et al.* (2002) give the Dalitz distribution to be

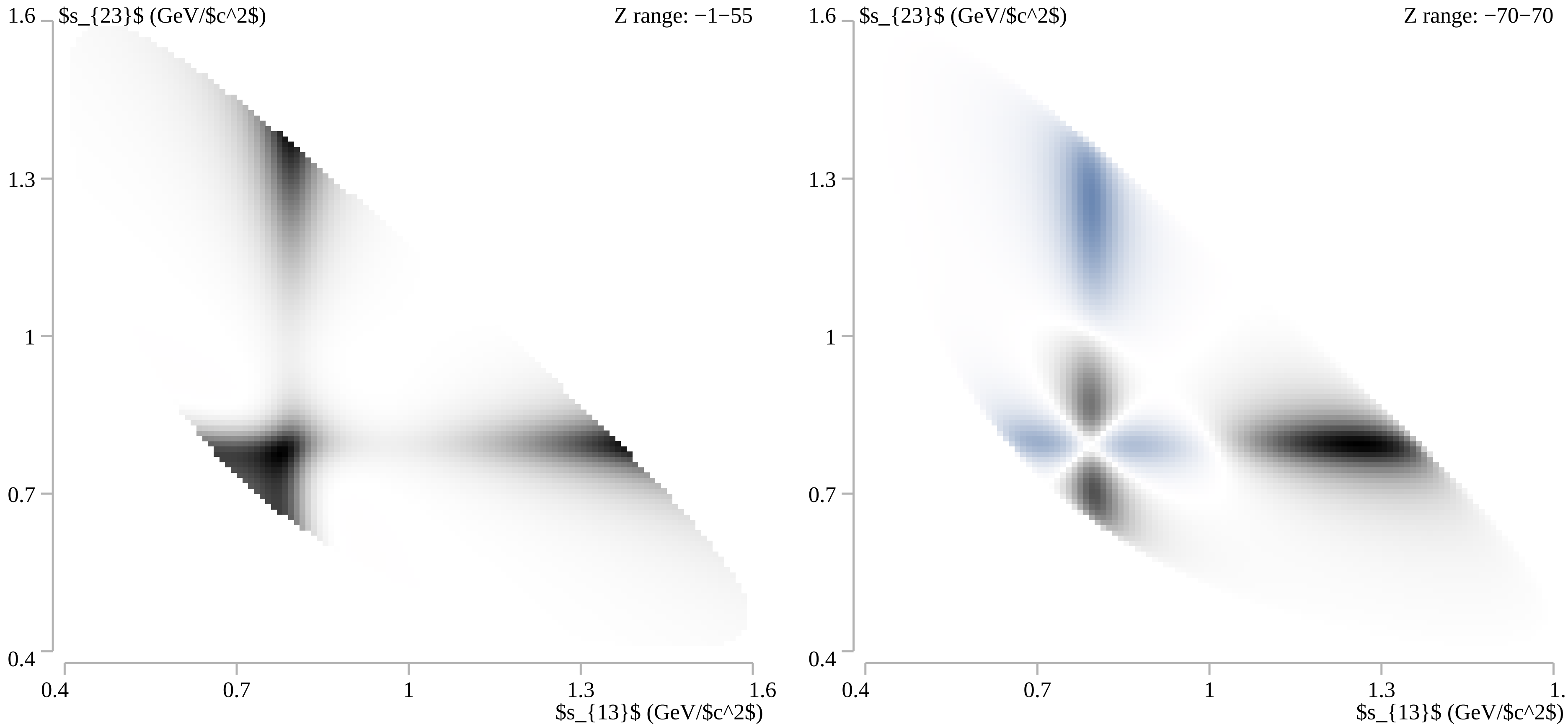
$$\frac{d\Gamma}{ds_{13}ds_{23}d\cos\theta} \propto |\vec{J}|^2(1+\cos^2\theta) + 2\lambda_\gamma \operatorname{Im}\left(\hat{n}\cdot(\vec{J}\times\vec{J}^*)\right)\cos\theta$$





$|\vec{J}|^2$ (S-wave only) $\operatorname{Im}\left(\hat{n}\cdot(\vec{J}\times\vec{J}^*)\right)$

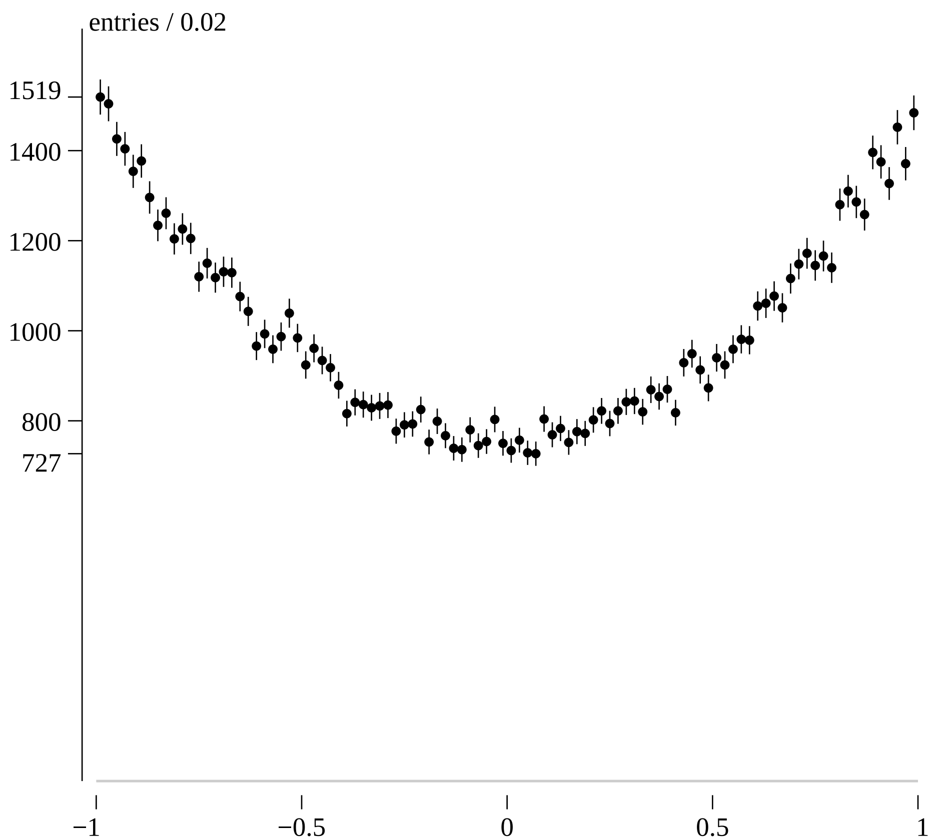
D-wave contribution

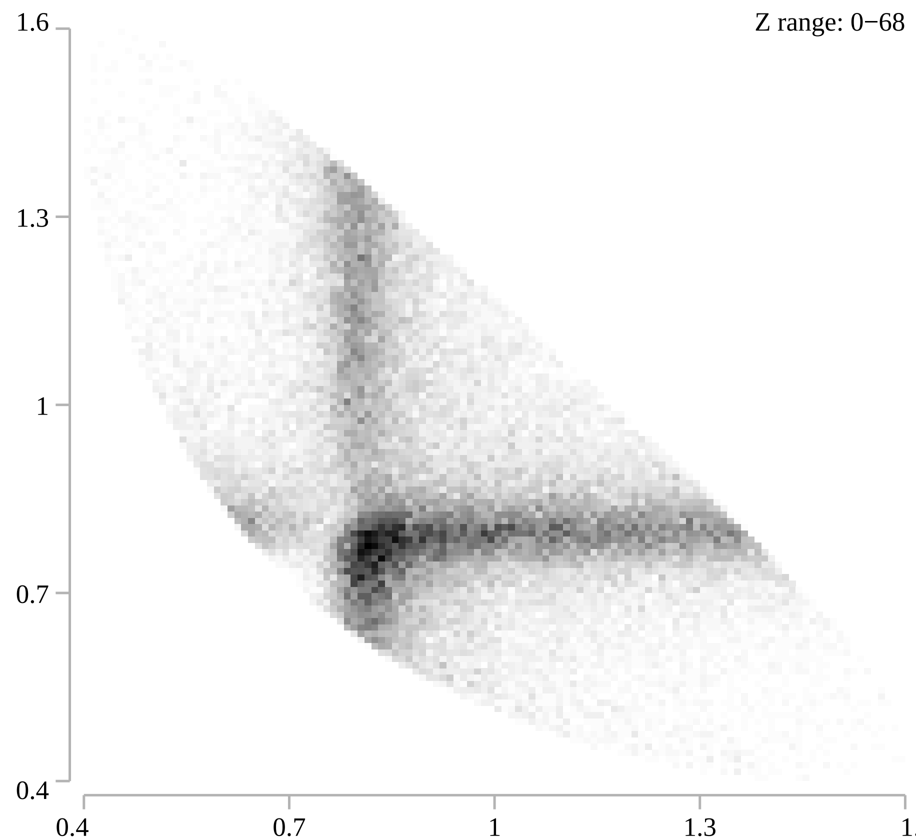


$|\vec{J}|^2$ D-wave contributions $\mathrm{Im}\left(\hat{n}\cdot(\vec{J}\times\vec{J}^*)\right)$

EvtGen model

We have developed a Monte Carlo decay model for this process.





$\cos\theta$ distribution

Dalitz plot, $\cos\theta > 0$

Complications

We plan to fit the distribution of $(s_{13}, s_{23}, \cos\theta)$ to extract λ_γ.

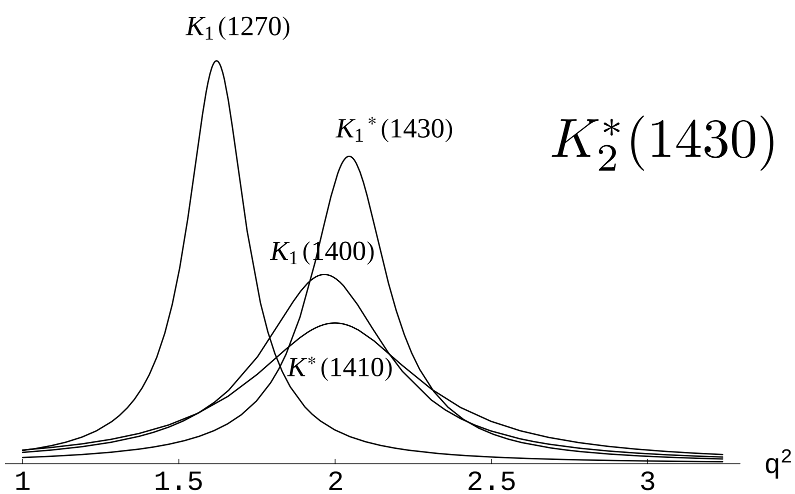
The fit will need to account for

- S- and D-wave contributions in the $K_1 \to K^*\pi$ decay.
- contribution from $K_1 \to K\rho$
- contributions from other K resonances

Higher K resonances

K resonances with $J \geq 1$, which can participate in $B \to K_{\rm res}\gamma$:

resonance	J^P	mass	width	principal decays	
$K_1(1270)$	1^+	1.273	0.090	$K\rho$	42%
				$K_0^*(1430)\pi$	28%
				$K^*(892)\pi$	16%
$K_1(1400)$	1^+	1.402	0.174	$K^*(892)\pi$	94%
				$K\rho$	3%
$K^*(1410)$	1^-	1.414	0.232	$K^*(892)\pi$	$> 40\%$
				$K\pi$	7%
$K_2^*(1430)$	2^+	1.430	0.104	$K\pi$	50%
				$K^*(892)\pi$	25%
				$K^*(892)\pi\pi$	13%



Estimates

Assume:

- 1 $\text{at}^{-1} \sim 10^9\, B\bar{B}$ pairs
- $\text{Br}(B \to K_1\gamma) = 0.7 \times 10^{-5}$
- only consider $K_S \to \pi^+\pi^-$

Expectations

Fraction of total $B \to K_1\gamma$, and expected production:

Mode	Fraction	Produced	
$B^0 \to K_S\pi^0\pi^0\gamma$	1.8%	250	
$B^\pm \to K_S\pi^\pm\pi^0\gamma$	7.1%	1000	$\star$
$B^0 \to K_S\pi^\pm\pi^\mp\gamma$	7.1%	1000	
$B^\pm \to K^\pm\pi^0\pi^0\gamma$	5.2%	700	
$B^0 \to K^\pm\pi^\mp\pi^0\gamma$	20.9%	2900	$\star$
$B^\pm \to K^\pm\pi^\mp\pi^\pm\gamma$	20.9%	2900	

$\star$ can be used for polarization measurement

Outlook

- Br($B \to K_1(1400)\gamma$) can be measured in current B factories.
- Feasibility of polarization measurement in current B factories is questionable.
- Polarization should be measureable with a $\mathcal{L} = 10^{36}$ experiment.