Evidence for $B \to K^* l^+ l^-$ and Measurement of $B \to K l^+ l^-$

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Outline:

• Physics motivation
• Analysis strategy
• Results and conclusions
Flavor changing neutral currents $b \rightarrow s l^+ l^-$

- These decays are highly suppressed: in the SM they are forbidden at tree level and proceed via loop diagrams

- $E.g.$, supersymmetric particles can contribute to the rate
Theory predictions for $B \rightarrow K^{(*)} l^+ l^-$
$B$ reconstruction

$$m_{ES} = \sqrt{E_{\text{beam}}^* - \left( \sum_i p_i^* \right)^2} \quad \Delta E = \sum_i \sqrt{p_i^*^2 + m_i^2} - E_{\text{beam}}^*$$

$a^*$ denotes quantities in the center-of-mass

Signal Monte Carlo

Radiative tail
Analysis overview

This analysis is based on the Run 1 + Run 2 datasample of $(88.5 \pm 0.9) \times 10^6 B \bar{B}$ pairs.

We fully reconstruct $B$ candidates in the modes

\[ B^+ \rightarrow K^+ l^+ l^- \quad B^0 \rightarrow K^{*0} l^+ l^- , \quad K^{*0} \rightarrow K^+ \pi^- \]
\[ B^0 \rightarrow K_S^0 l^+ l^- \quad B^+ \rightarrow K^{*+} l^+ l^- , \quad K^{*+} \rightarrow K_S^0 \pi^+ \]

where $l$ is either an $e$ or a $\mu$ and $K_S^0 \rightarrow \pi^+ \pi^-$

Leptons candidates are selected with tight particle identification
- $\sim 0.2\%$ pion fake rate for electrons and $\sim 2\%$ pion fake rate for muons.
- For electrons we recover bremsstrahlung photons.
- Charged kaons are identified by the DIRC.
- The signal yields are extracted using an unbinned maximum likelihood fit in $m_{ES}$ and $\Delta E$.
- In the $K^*$ modes we in addition use the $K \pi$ mass in the fit.
Backgrounds

- Combinatorial background from $B\bar{B}$ and $q\bar{q}$ events are suppressed using a likelihood and a Fisher discriminant respectively.
- Peaking backgrounds arise from several possible sources
  - Hadronic $B$ decays where hadrons are misidentified as leptons
  - In the muon mode we veto $B \to D\pi$ decays.
- Charmonium presents a large possible background and we veto these events in the $m_{ll}$ vs. $\Delta E$ plane

\[ B \to J/\psi (\to l^+ l^-) K \]
Hadronic peaking backgrounds

- Processed data without applying any lepton ID
- Weight histograms with fake rates and fit for background yields
- Backgrounds negligible in the electron channels

\[ B \rightarrow K \pi \pi , KK \pi , KKK , D \pi \ldots \]

- 0.007 events
- 0.27 events
- 0.001 events
- 0.05 events
Peaking backgrounds

- We have considered the following sources of peaking backgrounds
Charmonium control samples

We reverse the charmonium veto and use the $J/\psi$ events as a control sample for efficiency and checks of kinematic distributions.

We find good agreement in our check using the charmonium control samples.
$\Delta E$ vs. $m_{ES}$ in the $B \rightarrow Kl^+ l^-$ modes

Preliminary
Combined $B \rightarrow Kl^{+} l^{-}$ fits

$-0.11 < \Delta E < 0.05 \text{GeV}$  \hspace{2cm} $5.2724 < m_{ES} < 5.2856 \text{GeV}$

Preliminary

\[
Br ( B \rightarrow Kl^{+} l^{-}) = (0.68^{+0.17}_{-0.15} \pm 0.04) \times 10^{-6} \quad (7 \sigma)
\]
Dilepton mass distributions

Preliminary
Charmonium vetoes

Preliminary
$\Delta E$ vs. $m_{ES}$ in the $B \to K^* l^+ l^-$ modes

Preliminary
Combined $B \rightarrow K^* l^+ l^-$ fits

Preliminary

\[ 0.817 < m_{k\pi} < 0.967 \text{ GeV} \]
\[ -0.11 < \Delta E < 0.05 \text{ GeV} \]

\[ 5.2724 < m_{ES} < 5.2856 \text{ GeV} \]
\[ 0.817 < m_{k\pi} < 0.967 \text{ GeV} \]

\[ 5.2724 < m_{ES} < 5.2856 \text{ GeV} \]
\[ -0.11 < \Delta E < 0.05 \text{ GeV} \]

\[ Br\left( B \rightarrow K^* l^+ l^- \right) = \left( 1.40^{+0.57}_{-0.49} \pm 0.21 \right) \times 10^{-6} \]  \hspace{1cm} (3.0 \sigma)
Combined $B \to K^* l^+ l^-$ fits

For the combined fits in the $K^*$ modes we use the constraint

$$\frac{Br(B \to K^* e^+ e^-)}{Br(B \to K^* \mu^+ \mu^-)} = 1.33$$


We quote the combined $B \to K^* l^+ l^-$ result for the electron channel.
Systematic uncertainties and significance

- Multiplicative systematic uncertainties do not affect the significance of the signal. We have considered:
  - Tracking and PID efficiencies
  - Model dependence, Monte Carlo statistics
- Additive systematic uncertainties arise from the fit and do affect the significance. Parameters for the background shape are determined in the fit to the data and do not contribute to a systematic uncertainty. Systematic effects that we have considered:
  - Signal shape parameters, mean and width
  - Radiative tail in electron modes
  - Background shape parametrization
  - Peaking backgrounds
- The significance was evaluated by combining the variations that lead to a decrease in the signal significance.
Results
Conclusions

- Analyzed the BABAR Run 1 and Run 2 data sample of $(88.5 \pm 0.9) \times 10^6 B\bar{B}$ pairs.
- We have added the $K\pi$ mass to the likelihood fit for the $B \rightarrow K^* l^+ l^-$ modes and obtained the preliminary results:
- Clear signal ($\sim 7 \sigma$) for $B \rightarrow K l^+ l^-$
  \[ Br( B \rightarrow K l^+ l^-) = (0.68^{+0.17}_{-0.15} \pm 0.04) \times 10^{-6} \]
- Evidence ($3.0 \sigma$) for $B \rightarrow K^* l^+ l^-$
  \[ Br( B \rightarrow K^* l^+ l^-) = (1.40^{+0.57}_{-0.49} \pm 0.21) \times 10^{-6} \]
Backup slides
Contributions from new physics to $B \to K^{(*)} \mu \mu$

$B \to K \mu \mu$

$J/\psi K$  $\psi' K$

$B \to K^{*} \mu \mu$

$J/\psi K^{*}$  $\psi' K^{*}$

SUSY models

SM

$q^{2}$  $\text{GeV}^{2}$  $q^{2}$  $\text{GeV}^{2}$
Multiplicative systematic uncertainties

- Particle ID systematics checked in our particle ID blind control samples