BaBar

New BaBar Results on Rare Leptonic B Decays

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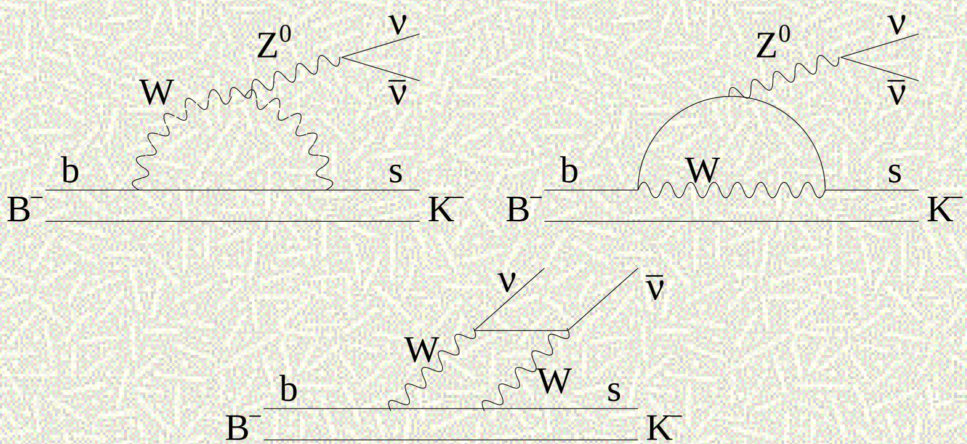
Table of Contents

- Motivation to look for $B^0 \to \ell^+\ell^-$ and $B^- \to K^-\nu\overline{\nu}$
- Analysis Strategy
- Measurement Criteria
- Cut Optimization
- Systematics
- Results

Motivation $B^- \to K^- \nu\bar{\nu}$



Standard Model Feynman diagrams for $B^- \to K^- \nu\bar{\nu}$

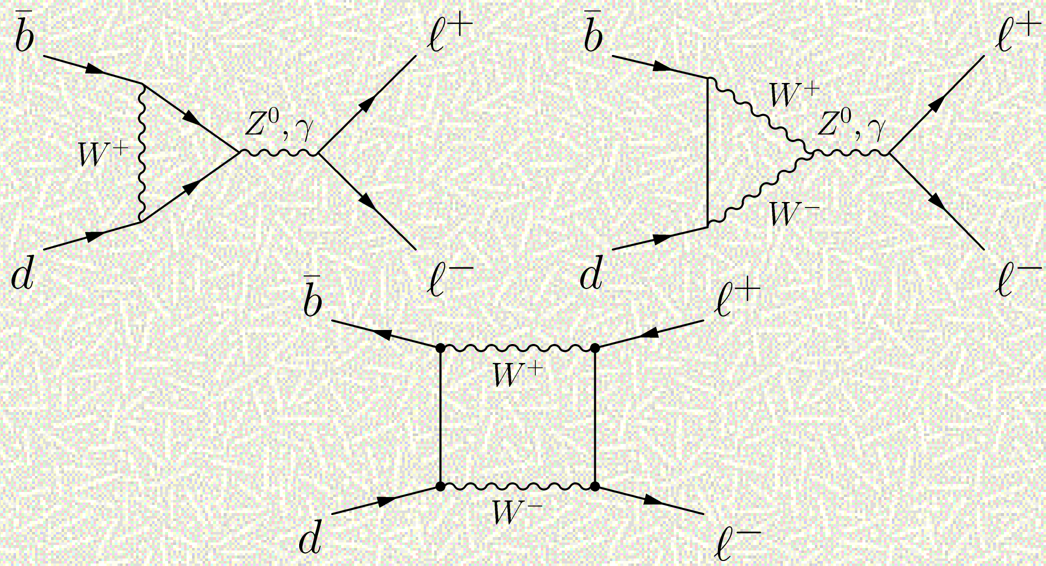
- SM prediction $\mathcal{B}(B^- \to K^- \nu\bar{\nu}) = 3.8^{+1.2}_{-0.6} \times 10^{-6}$
- CLEO best limit $\mathcal{B}(B^- \to K^- \nu\bar{\nu}) < 2.4 \times 10^{-4}$

- The second largest BR for rare B - decays involving leptons is final state
- Only one operator in SM
- Theoretically clean

Enhancements from beyond the SM:

- Fourth generation
- Extra vector-like down quark
- SUSY violating R-parity
- FCNC Z'

Motivation $B^0 \to \ell^+\ell^-$



Standard Model Feynman diagrams for $B^0 \to \ell^+\ell^-$

- $\mathcal{B}(B^0 \to e^+e^-) \sim 10^{-15}$
- $\mathcal{B}(B^0 \to \mu^+\mu^-) \sim 10^{-10}$
- $\mathcal{B}(B^0 \to e^+\mu^-)$
  just allowed due to $\Delta m_{\nu_i} \neq 0$

Enhancements from beyond the SM:

- MHDM with NFC and large $tg\beta$
- Extra vector-like down quark
- MSSM (large $tg\beta$)
- Leptoquark
- SUSY violating R-parity

Analysis Strategy for $B^- \to K^- \nu \overline{\nu}$

- Tag one B, $B^+ \to \overline{D}^0 \ell^+ \nu (X)$

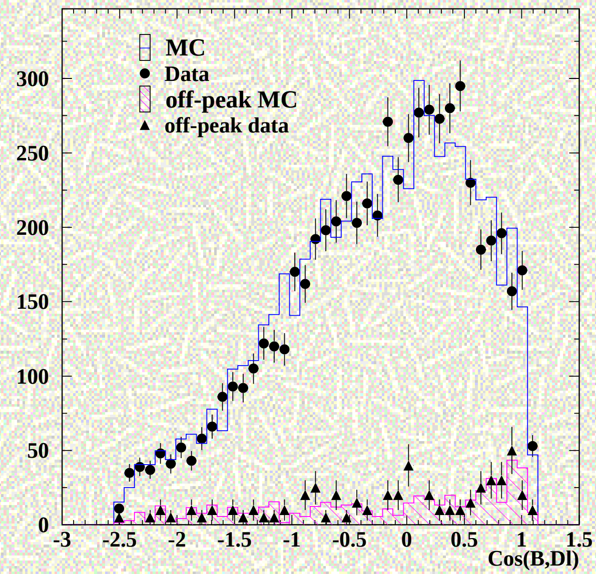
$\overline{D}^0$ modes	D^* modes
$\overline{D}^0 \to K^+ \pi^-$	$\overline{D}^{*0} \to \overline{D}^0 \gamma$
$\overline{D}^0 \to K^+ \pi^- \pi^- \pi^+$	$\overline{D}^{*0} \to \overline{D}^0 \pi^0$
$\overline{D}^0 \to K^+ \pi^- \pi^0$	$D^{*-} \to \overline{D}^0 \pi^-$

- Remove the daughters of the tagged B from the event
- Veto events with more than one charged track
- Attribute the remaining particles with the signature expected from $B^- \to K^- \nu \overline{\nu}$
- No background subtraction applied for UL

This method yield 0.5% of B^+ decays reconstructed as tags
The tagging efficiency was corrected using a double tags sample.

Measurement Criteria for Tagging $B^+ \to \overline{D}^0 \ell^+ \nu(X)$

- Require one lepton with $P^* > 1.3$ GeV
- Loose consistency on $\overline{D}^0$ and $\overline{D}^0 \ell^+$ Vtx
- $P^*_{\overline{D}^0} > 0.5$ GeV
- $M_{\overline{D}^0 \ell^+} > 3$ GeV
- $-2.5 < \cos(\theta_{B,D\ell}) < 1.1$
- $N_{tracks} \leq 3$
- $E_{neutral} < 1$ GeV

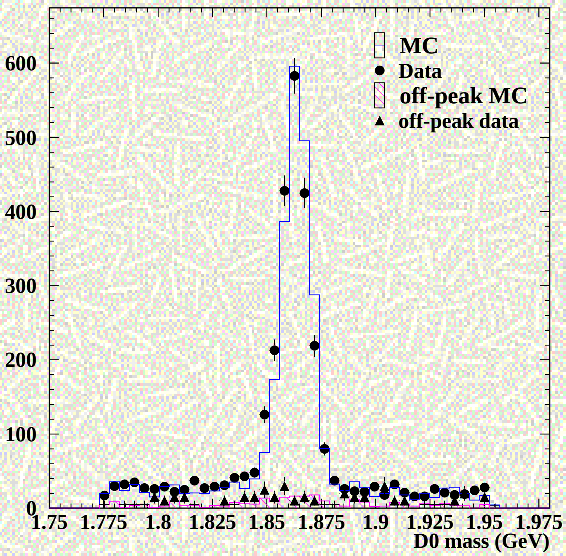


$$\cos\theta_{B\,D\ell} \equiv \frac{2\,E_B E_{D\ell} - m_B^2 - m_{D\ell}^2}{2\,|\vec{p}_B||\vec{p}_{D\ell}|}$$

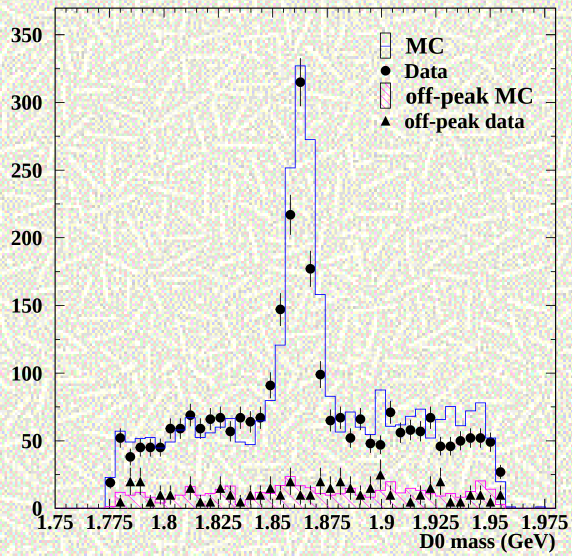
where E_B and $|\vec{p}_B|$ in $\Upsilon(4S)$ frame.

Semi-exclusive $\overline{D}^0$ Mass Reconstruction

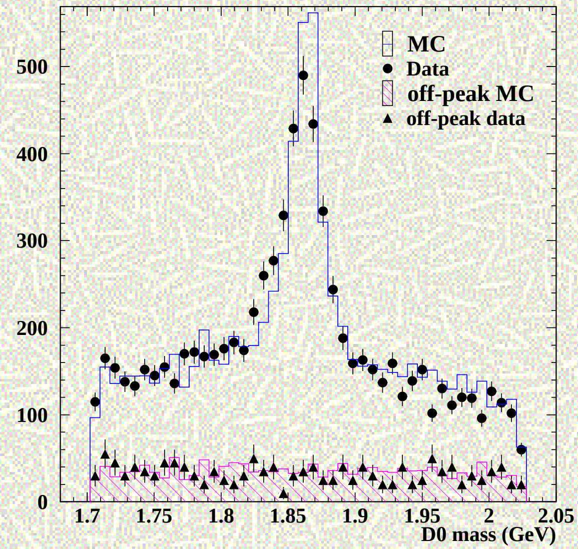
$\overline{D}^0 \rightarrow K^+\pi^-$



$\overline{D}^0 \rightarrow K^+\pi^-\pi^-\pi^+$



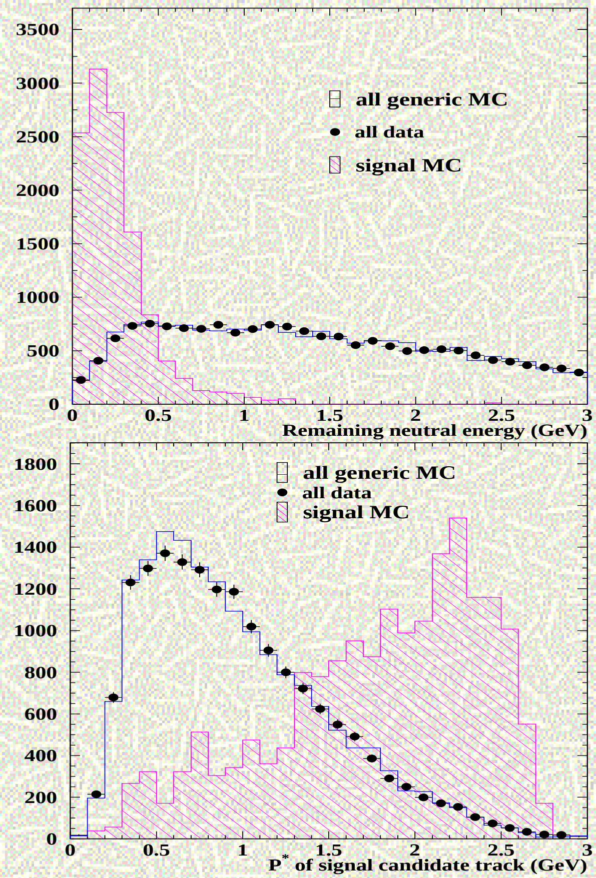
$\overline{D}^0 \rightarrow K^+\pi^-\pi^0$



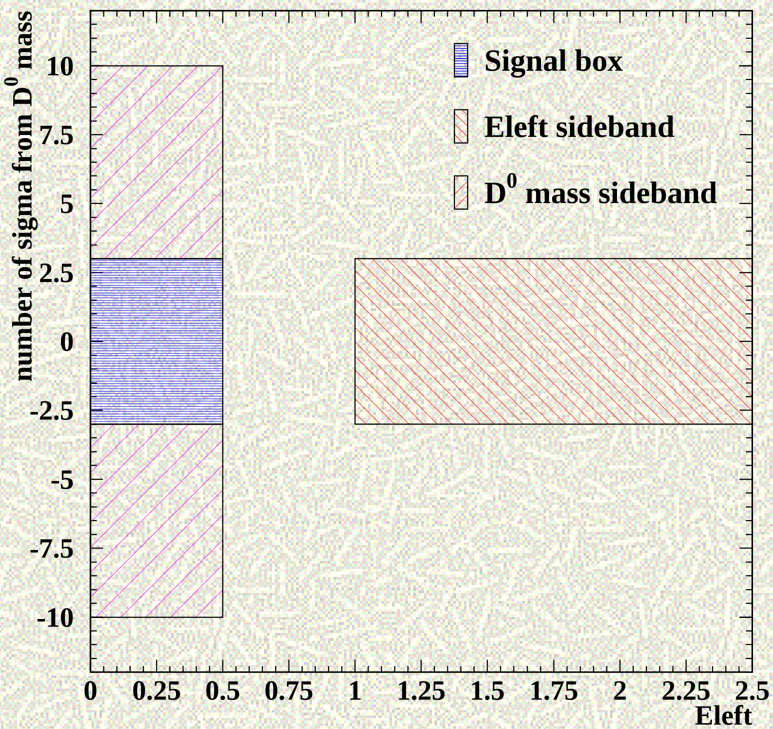
Measurement Criteria for the Signal

$B^- \to K^- \nu\bar{\nu}$

- One Kaon with charge opposite to the tagged lepton
- $P^*_{K^+} > 1.5\text{GeV}$
- $-0.9 < \cos\theta_{K\ell} < 0.8$
- $N_{IFR} = 0$ clusters consistent with coming from a neutral hadron
- $E_{neutral} < 0.5\text{GeV}$

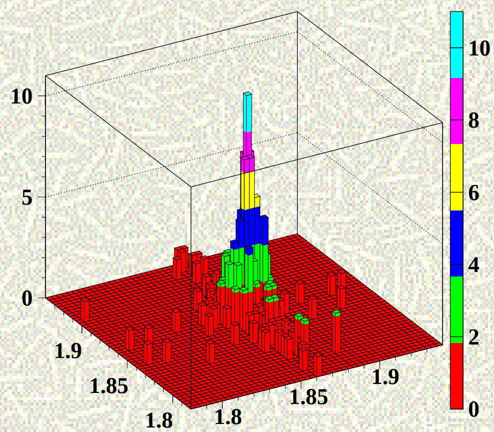


Signal and Sideband Definition



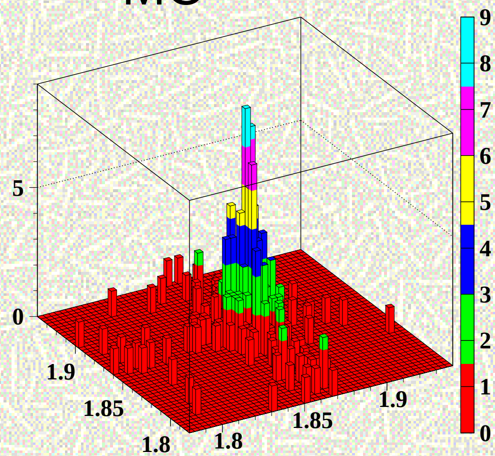
- Signal box
  - $E_{\text{left}} < 0.5\,\text{GeV}$
  - $(m_D - m_D^{\text{fit}}) < 3\sigma_D^{\text{fit}}$
- E_{left} and D^0 mass Sideband
  - $1. < E_{\text{left}} < 2.5\,\text{GeV}$
  - $(m_D - m_D^{\text{fit}}) > 3\sigma_D^{\text{fit}}$

Systematics and Efficiency Correction



MC

$M(D^0)$ vs $M(K\pi)$, simulation



DATA

$M(D^0)$ vs $M(K\pi)$, on-peak data

- Tag $B^+ \rightarrow \overline{D^0}(K\pi)\ell^+\nu X$ and the other to $B^- \rightarrow D^0\,\ell^-\overline{\nu}$
- Use double-tags to extract a correction to the efficiency calculated from the signal MC.
- Double tag yield:
  - In data 148 ± 15
  - In MC 175 ± 16
- Rate in data is 0.85 the rate in simulation
- ϵ_{signal} is corrected by 0.92 ± 0.06 where the error is taken as the systematic

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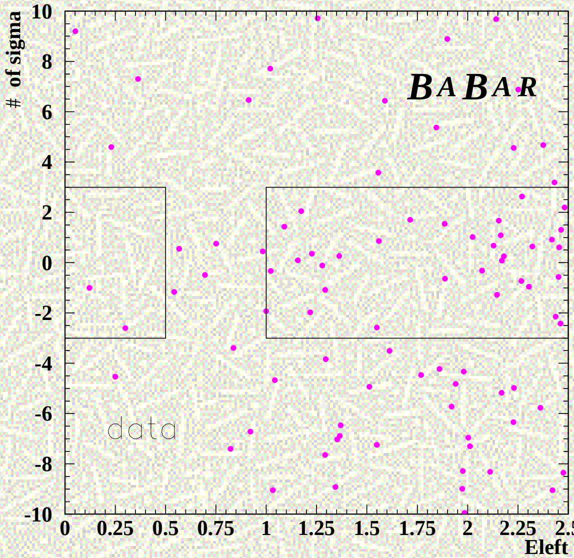
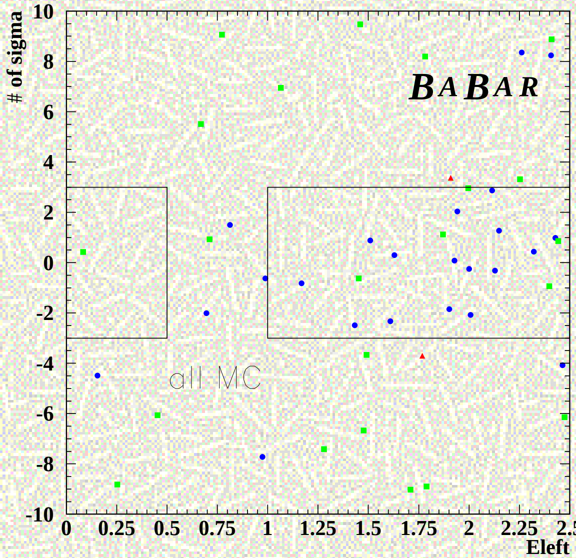
Systematic Errors

Quantity	$\delta\varepsilon/\varepsilon[\%]$
B -counting	1.1
tagging efficiency	6.0
Kaon momentum	1.8
Kaon selection	2.0
E_{left}	4.3
N_{IFR}	3.6
Total	8.7

The resulting overall signal efficiency is 0.1%

Unblinded Results





$B\overline{B}$/$C\overline{C}$/UDS MC should be scaled with 1.09/2.21/3.56 to on-peak lumi

The UL for 50 fb^{-1} with 90% CL for $B^- \to K^- \nu\overline{\nu}$ is:

$$BR(B^- \to K^- \nu\overline{\nu}) < 9.4 \times 10^{-5}$$

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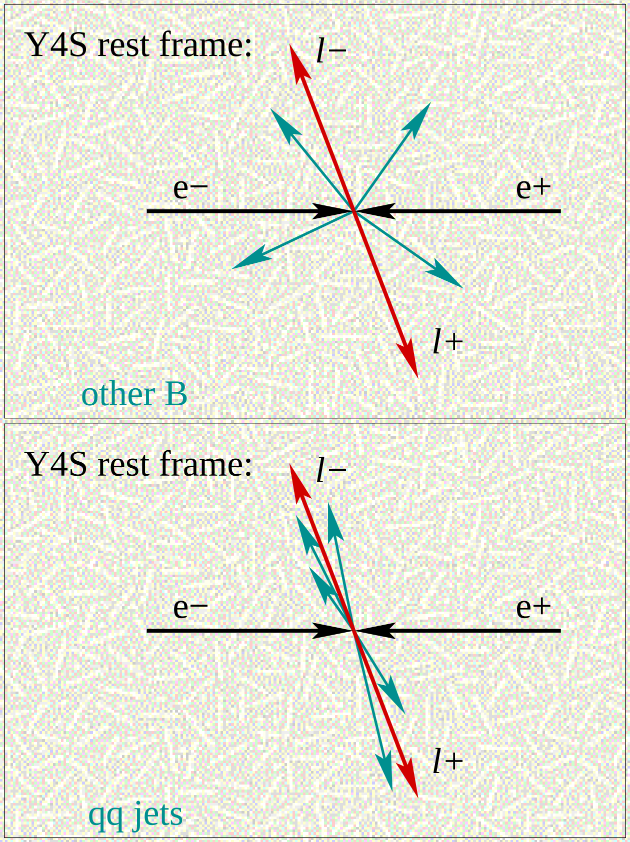
Analysis Strategy $B^0 \to \ell^+\ell^-$

- Reconstruct the signal B with two high momentum leptons
- Apply cuts to suppress the background
- Estimate the background in signal box
  - Fit the data in the sidebands
  - Normalization from data
- No background subtraction applied for Upper Limit



Measurement Criteria

- Event Preselection
  - $N_{trk} \geq 3$ in drift chamber
  - $R_2 \leq 0.98$
  - Two tracks with $p^* > 1.8$ GeV
- Track selection
  - Tight Doca
  - $22^\circ < \theta_{lab} < 120^\circ$
- Event selection
  - $E_{tot} < 11$ GeV
  - $P_{miss} < 3$ GeV
  - $N_{mult} (\equiv N_{trk} + N_\gamma/2) \geq 6$, $E_\gamma > 80$ MeV

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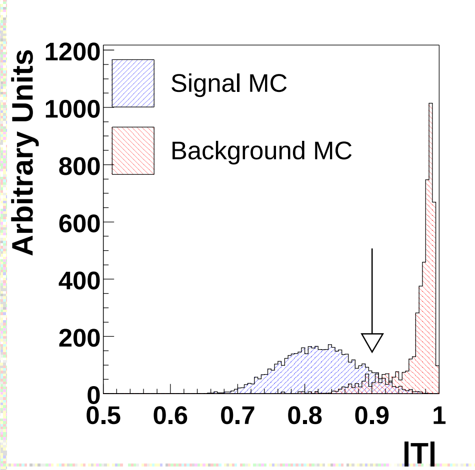
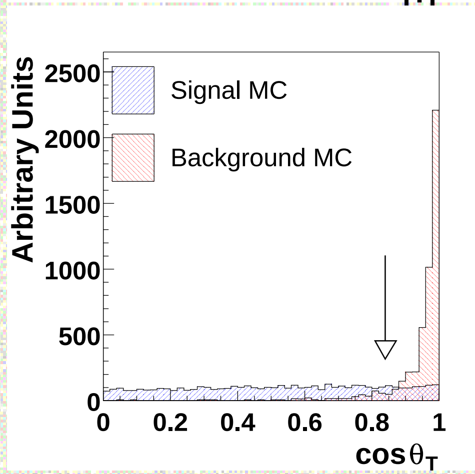
- Vertexing
  - Well reconstructed vertex
  - $\mathcal{P}(\chi^2) > 0.1\%$
- Shape Variables
  - $|T| < 0.9$
  - $|\cos(\theta_T)| < 0.84$
- B-reconstruction

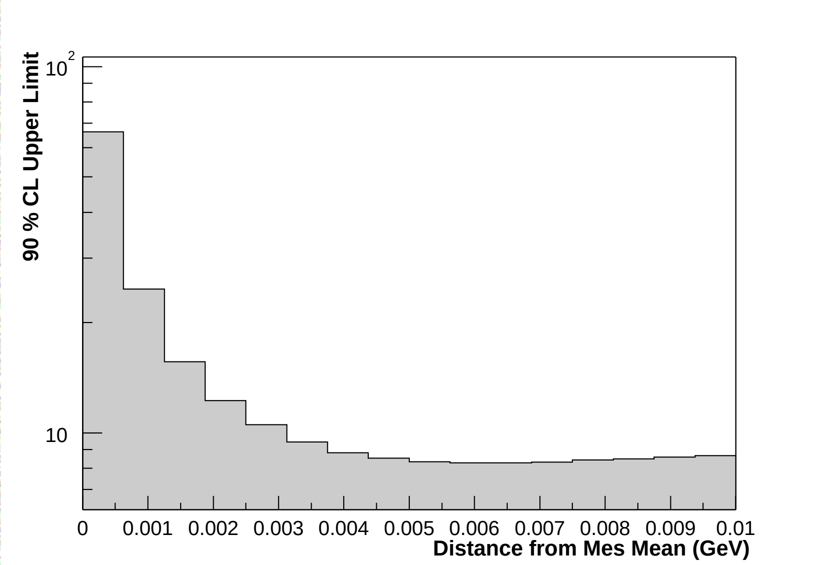
  Cuts on standard variables

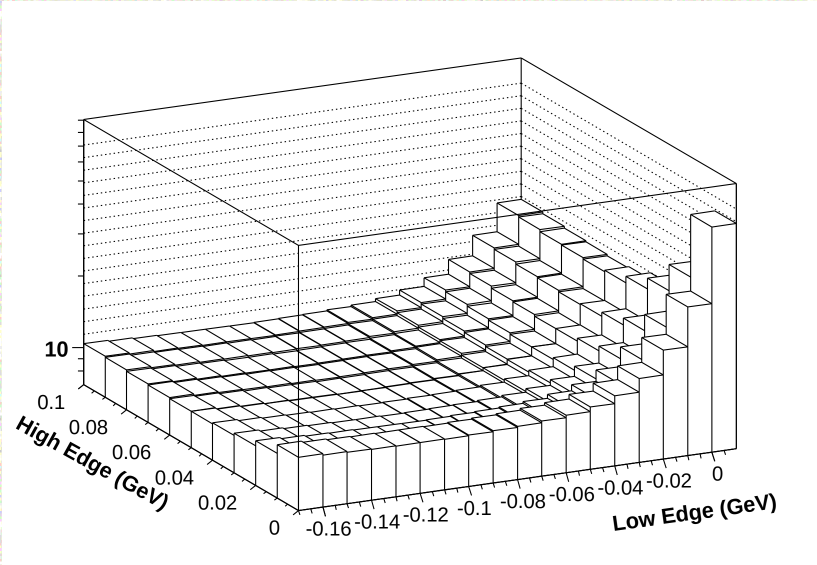
  m_{ES} and ΔE are optimized for best UL.





Signal Box Upper Limit Optimization





m_{ES} range:

$5.273 — 5.285 \quad [\mathrm{GeV}/c^2]$

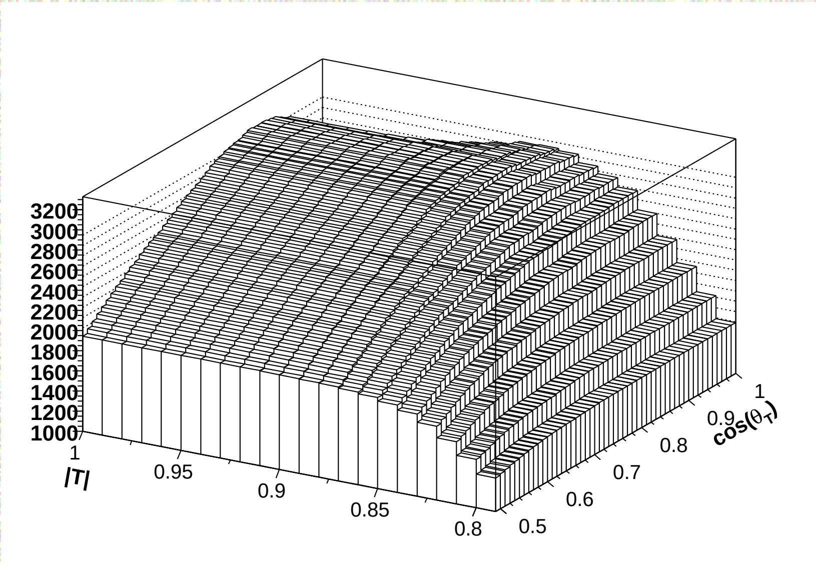
ΔE range:

$-0.105 — 0.050 \quad [\mathrm{GeV}]$

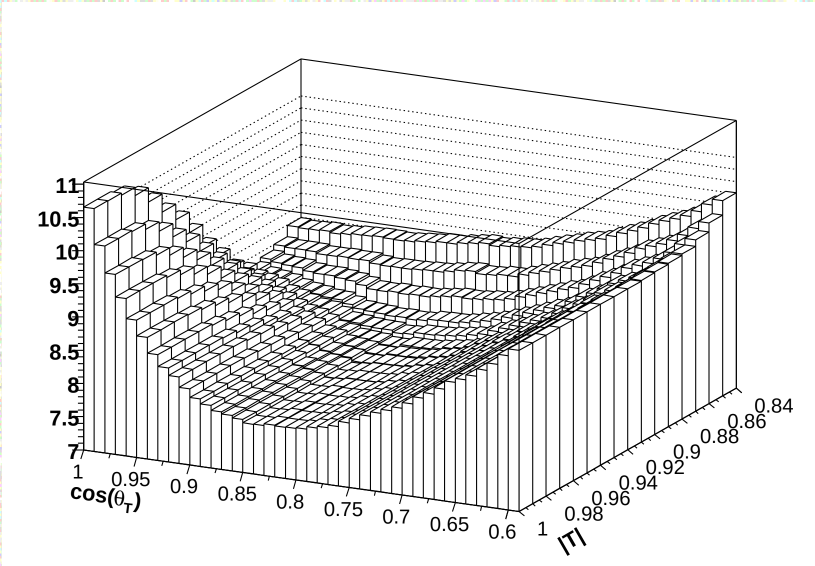
The scale in these plots is proportional to the 90% CL Upper Limit on the BR

Shape Variables Optimization

The simultaneous upper limit optimization of $|T|$ and $\cos(\theta_T)$ yielded somewhat harder cuts than $S^2/(S+B)$.



$S^2/(S+B)$



UL optimization

$|T| < 0.9$, $\cos(\theta_T) < 0.84$

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The resulting signal efficiency after applying all cuts amounts to:

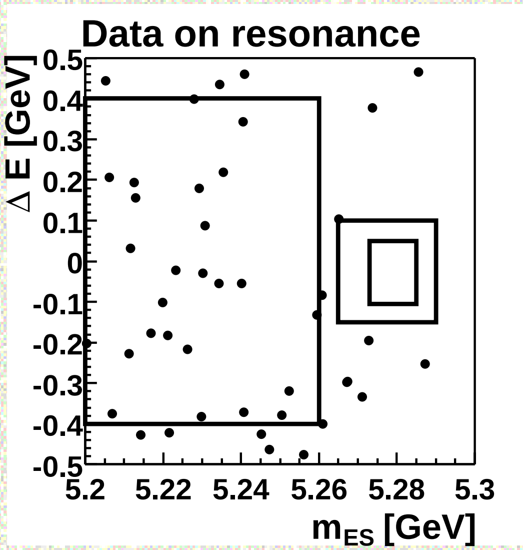
- $\varepsilon = 19.3 \pm 0.4_{stat}\%$ for $B^0 \to e^+e^-$
- $\varepsilon = 18.8 \pm 0.3_{stat}\%$ for $B^0 \to \mu^+\mu^-$
- $\varepsilon = 18.3 \pm 0.3_{stat}\%$ for $B^0 \to e^\pm\mu^\mp$

These numbers include the different size of the signal box in the three channels.

	$B^0 \to e^+e^-$		$B^0 \to \mu^+\mu^-$		$B^0 \to e^\pm\mu^\mp$	
Box Name	m_{ES}	ΔE	m_{ES}	ΔE	m_{ES}	ΔE
Signal Box	5.273–5.285	-0.105–0.050	5.274–5.285	-0.050–0.050	5.274–5.284	-0.070–0.050
Grand Sideband	5.200–5.260	-0.400–0.400	5.200–5.260	-0.400–0.400	5.200–5.260	-0.400–0.400

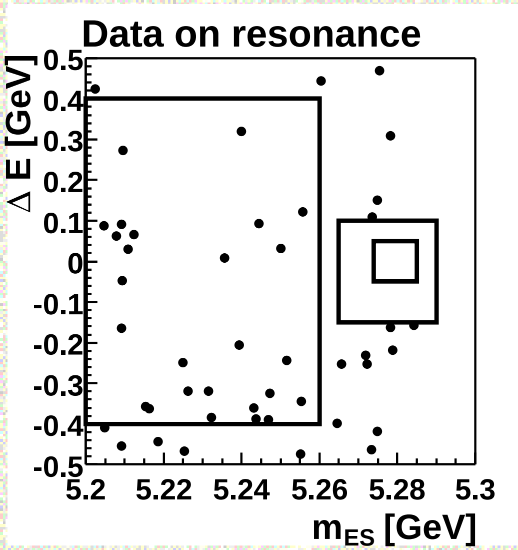
Blind Analysis: $B^0 \to \ell^+\ell^-$

$B^0 \to e^+e^-$



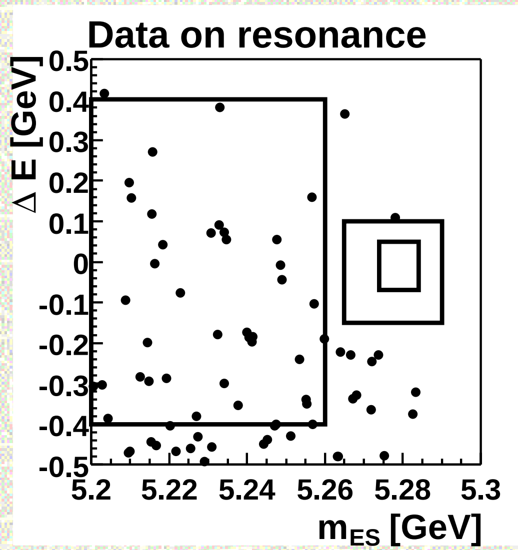
25 events observed in the GSB in data

$B^0 \to \mu^+\mu^-$



26 events observed in the GSB in data

$B^0 \to e^\pm\mu^\mp$



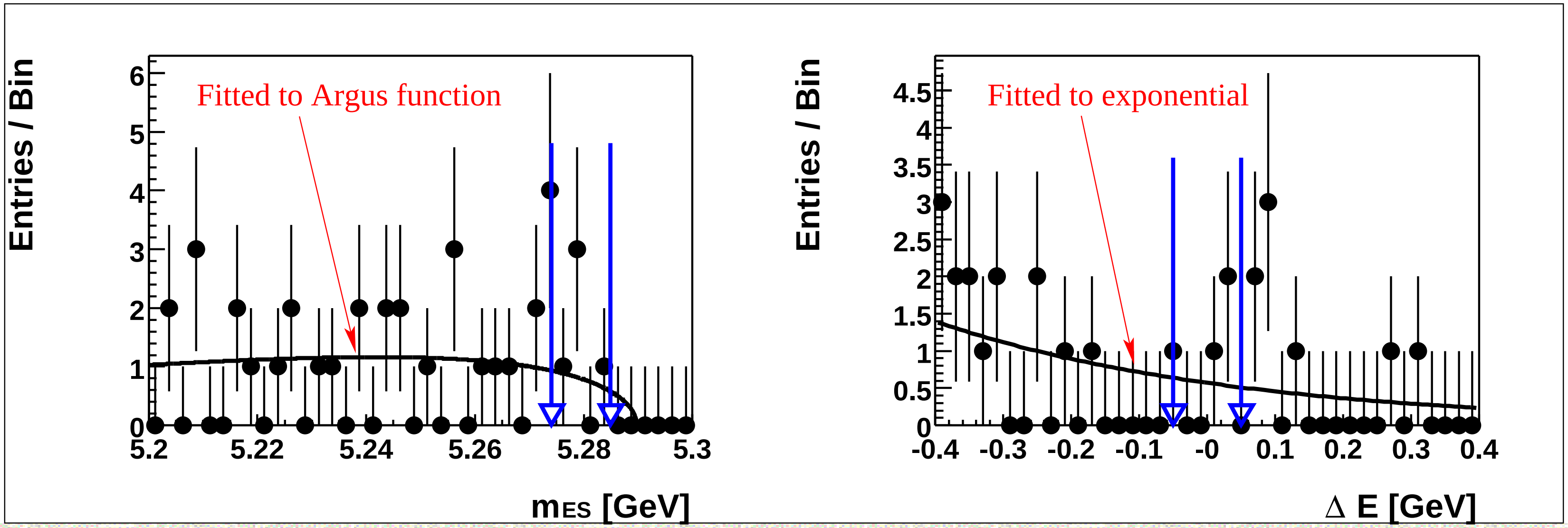
37 events observed in the GSB in data

Background Sources

The main sources of background for the three $B^0 \to \ell^+\ell^-$ channels

- A common background composed of real leptons for all channels comes from $c\overline{c}$
- In additions fake muon are introduced by misidentified pions in the $B^0 \to \mu^+\mu^-$ and $B^0 \to e^\pm\mu^\mp$ channels
- $\gamma\gamma$ processes contribute to $B^0 \to e^+e^-$ and $B^0 \to e^\pm\mu^\mp$

Background Estimation



The Unbinned Maximum Likelihood fit results are:

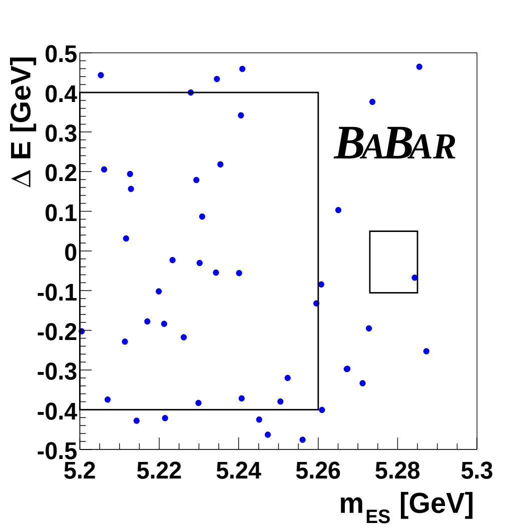
Background estimate		
$B^0 \to e^+e^-$	$B^0 \to \mu^+\mu^-$	$B^0 \to e^{\pm}\mu^{\mp}$
0.60 ± 0.24	0.49 ± 0.19	0.51 ± 0.17

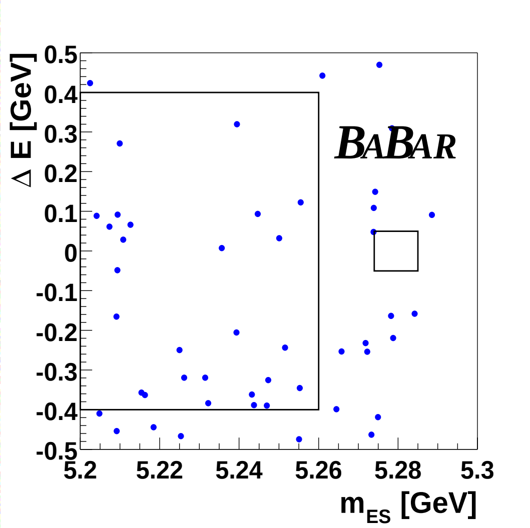
Systematics

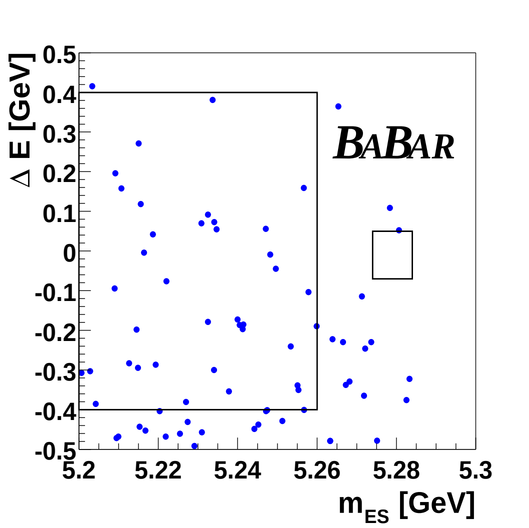
The systematic uncertainty is estimated by using a control sample $B^0 \to J/\psi\, K^0_S$, with $J/\psi \to \ell^+\ell^-$.

	$B^0 \to \mu^+\mu^-$		$B^0 \to e^+e^-$	
Quantity	$\delta x/x[\%]$	$\delta\varepsilon/\varepsilon[\%]$	$\delta x/x[\%]$	$\delta\varepsilon/\varepsilon[\%]$
Track smearing and efficiency, per track	0.7	1.4	0.7	1.4
Electron identification, per electron		1.4	1.8	3.6
Hadron misidentification, per track	50	-	50	-
ΔE	$2.4 \oplus 0.9$	2.56	$3.4 \oplus 2.8$	4.4
m_{ES}	1.7	1.7	0.1	0.1
$\cos\theta_T$	0.5	0.5	0.7	0.7
$\|T\|$	2.5	2.5	2.5	2.5
N_{mult}	1.4	1.4	6.0	6.0
E_{tot}	0.009	0.009	1.5	1.5
$\|p_{miss}\|$	0.13	0.13	0.1	0.1
primary Vertex	0.14	0.14	0.1	0.1
B-candidate Vertex	0.05	0.05	1.6	1.6
Sub-Total	2.92	2.92	6.9	6.9
Total	-	4.68	-	8.2

Results







Channel	N_{exp}	N_{obs}	N_{BG}	ε[%]	UL (90% CL)
$B^0 \to e^+e^-$	1×10^{-8}	1	0.60 ± 0.24	$19.3 \pm 0.40_{stat} \pm 1.60_{syst}$	3.3×10^{-7}
$B^0 \to \mu^+\mu^-$	4×10^{-3}	0	0.49 ± 0.19	$18.8 \pm 0.28_{stat} \pm 2.00_{syst}$	2.1×10^{-7}
$B^0 \to e^\pm\mu^\mp$	—	0	0.51 ± 0.17	$18.3 \pm 0.38_{stat} \pm 1.50_{syst}$	2.1×10^{-7}

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BaBar Results for the Rare B Decays

The Upper Limits values for the BR of $B^0 \to \ell^+\ell^-$ and $B^- \to K^-\nu\overline{\nu}$ at 90% CL are:

Mode	CLEO	Belle	Babar
$\mathcal{B}(B^- \to K^-\nu\overline{\nu})$	2.4×10^{-4}	-	9.4×10^{-5}
$\mathcal{B}(B^0 \to e^+e^-)$	8.3×10^{-7}	6.3×10^{-7}	3.3×10^{-7}
$\mathcal{B}(B^0 \to \mu^+\mu^-)$	6.1×10^{-7}	2.8×10^{-7}	2.0×10^{-7}
$\mathcal{B}(B^0 \to e^\pm\mu^\mp)$	15.0×10^{-7}	9.4×10^{-7}	2.1×10^{-7}
Luminosity	9.1 fb^{-1}	21.3 fb^{-1}	54.4 fb^{-1}