Radiative and Rare B-Decays at BaBar

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for the BaBar Collaboration

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All results are preliminary unless journal ref. is given
limit values are 90% CL unless otherwise specified

Overview

Since this talk is nicely framed between a theoretical introduction and a Belle summary and outlook I will focus on newer results and analysis techniques from BaBar

- FCNC

  $b \to K\nu\nu$

- Purely Leptonic Decays

  $b \to \tau\nu$

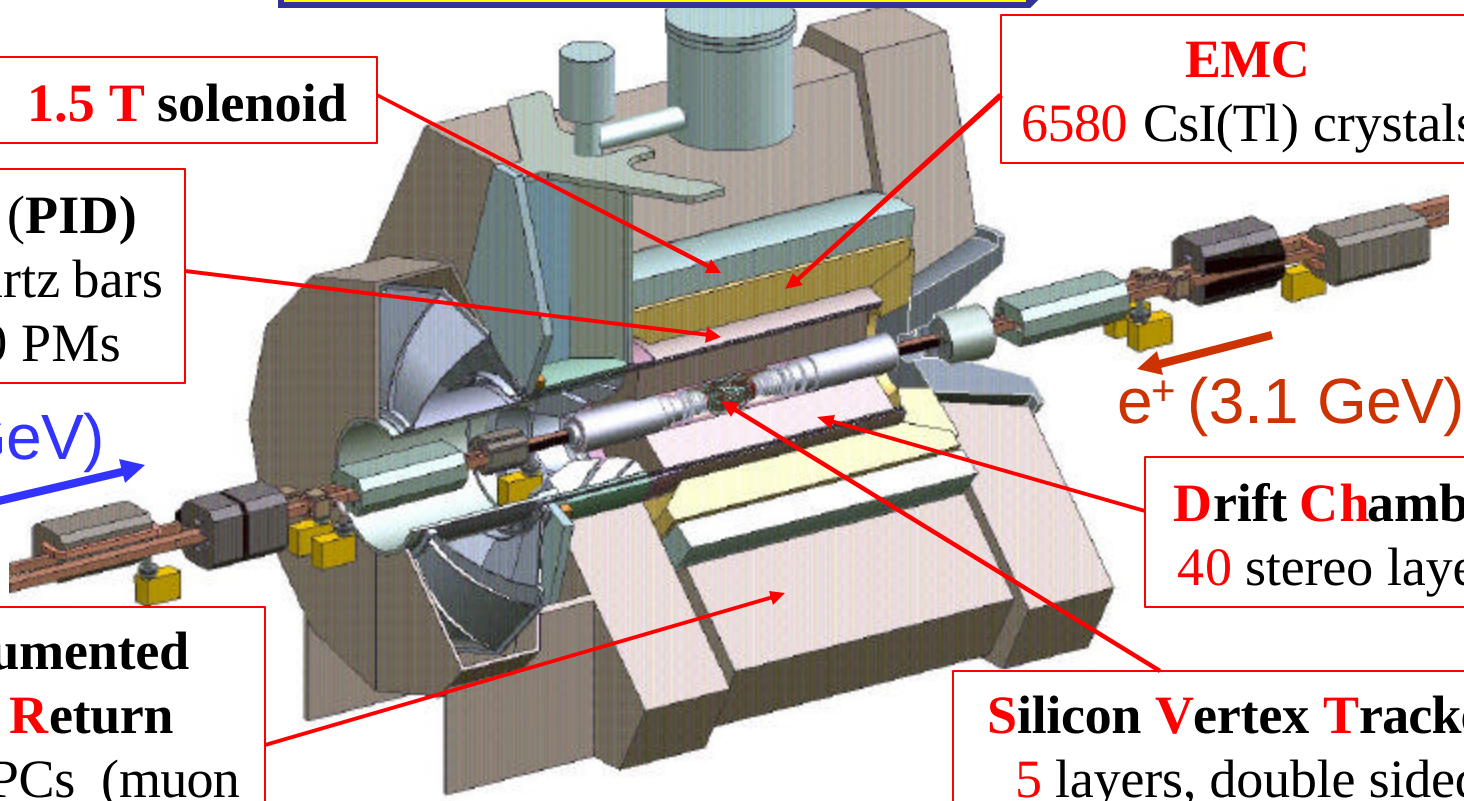
  $b \to \mu\nu$

- $b \to Kll$ and $b \to K^*ll$
- $B \to X_s ll$

- Radiative Decays

  $B^0 \to K_2^{*0}(1430)\,\gamma$ and $B^+ \to K_2^{*+}(1430)\,\gamma$

The BaBar Detector



1.5 T solenoid

EMC
6580 CsI(Tl) crystals

DIRC (PID)
144 quartz bars
11000 PMs

e^- (9 GeV)

e^+ (3.1 GeV)

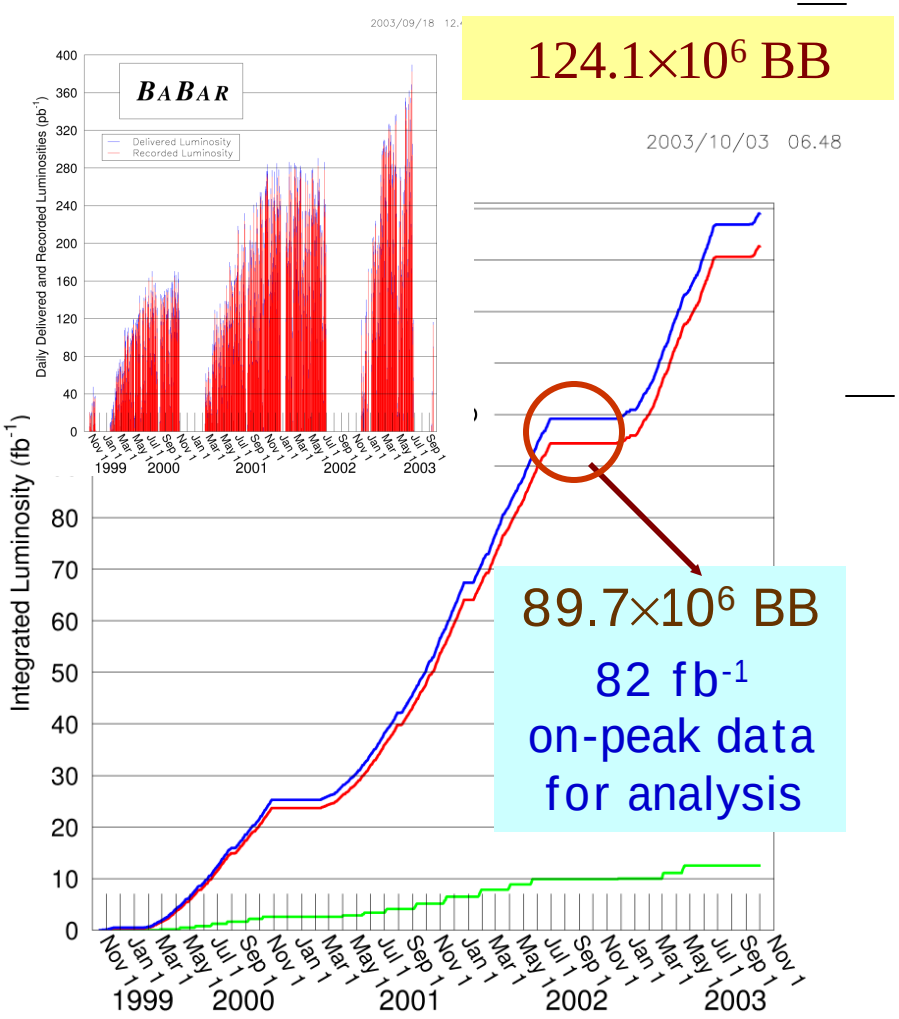
Drift Chamber
40 stereo layers

Instrumented Flux Return
iron / RPCs (muon / neutral hadrons)

Silicon Vertex Tracker
5 layers, double sided strips

SVT+DCH: $\sigma(p_T)/p_T = 0.13\ \% \cdot p_T + 0.45\ \%$, good dE/dx
DIRC: K-π separation 4.2 σ @ 3.0 GeV/c → 2.5 σ @ 4.0 GeV/c
EMC: Very good electron identification and π^0 reconstruction
IFR: Decent muon identification

PEP- II Lumi Performance and Recorded BaBar Lumi



Best Peformance

PEPII peak Luminosity:
6.582×10^{33} cm^{-2} sec^{-1}

Integrated Luminosity
Shift: 135.2 pb^{-1} in 24 hours: 391.2 pb^{-1}

	On(off)-peak
Run 1+2	82 (10)fb^{-1}
Run 3	31 (4) fb^{-1}
Run 4	6 (0)fb^{-1}

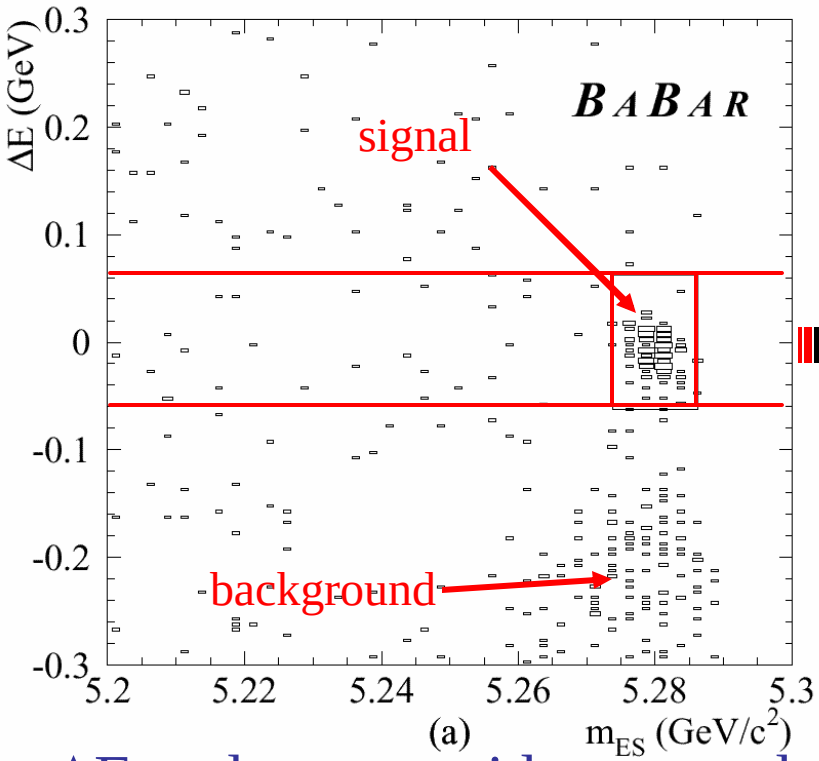
Standard Variables in U(4S) Frame

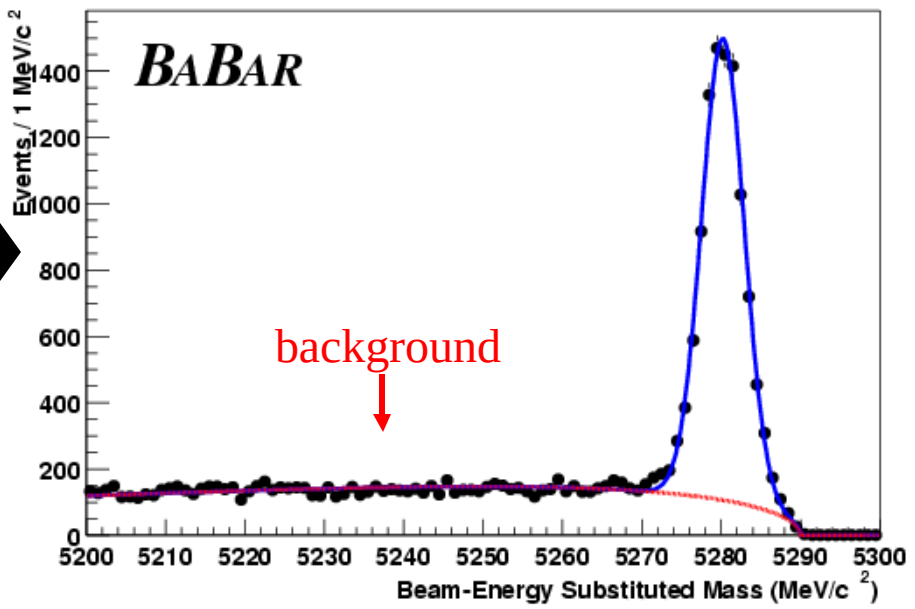
$e^+e^- \rightarrow Y(4S) \rightarrow BB$ ➡ B produced almost at rest in Y(4S) frame

For B decay with no missing particles use beam energy to constrain mass and energy of the reconstructed B

$\Delta E = E_B^* - E_{beam}^*$ ➡ 0 for signal

$m_{ES} = \sqrt{\left(E_{beam}^2 - P_B^2\right)}$ ➡ m_B for signal

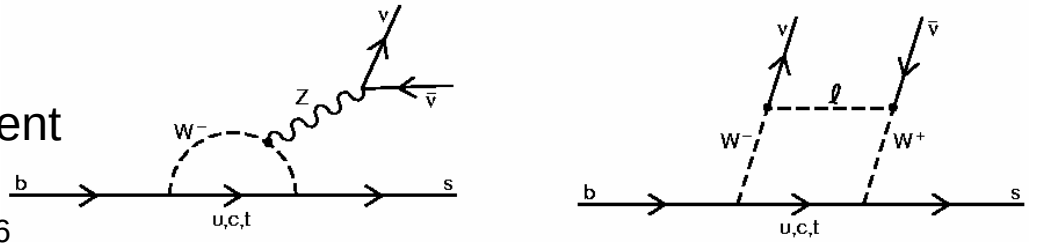




ΔE and m_{ES} provide uncorrelated measurement of energy and mass

$B^+ \to K^+ \nu\bar{\nu}$ Search

A rare flavour changing neutral current (FCNC) $b \to s\nu\nu$ decay
SM prediction: Br ($B \to K\nu\nu$) $\cong 4\times10^{-6}$
Summed over all neutrino species



- The best upper limits (@90% CL):
  - CLEO: Br ($B \to K\nu\nu$) $< 2.4\times10^{-4}$ PRL 86 2950 (2001)
  - *BABAR*: Br ($B \to K\nu\nu$) $< 9.4\times10^{-5}$ hep-ex/0207069

  Semi-Leptonic B-tags: $B \to Dl\nu X$ ($X = \gamma$, π^0 or nothing) 50.7 fb^{-1}

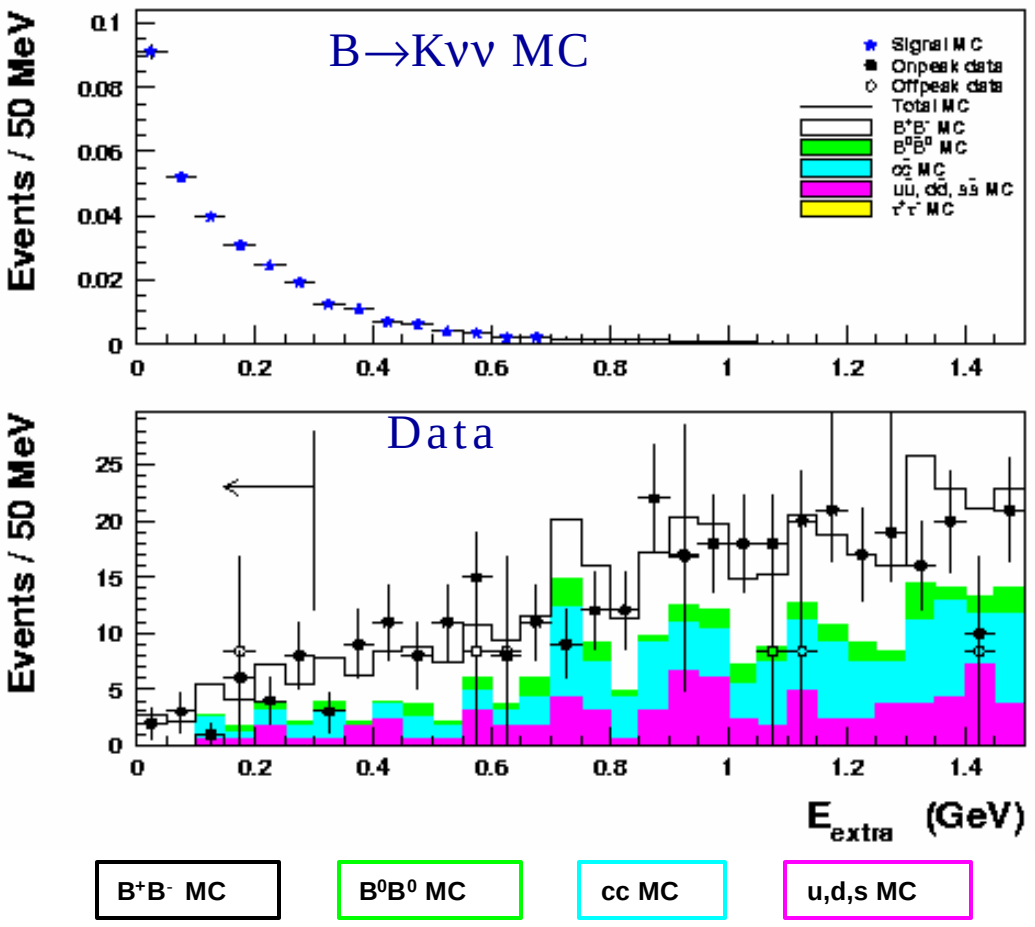
- New search (80 fb^{-1}) with hadronic B-tags
  - $B^\pm \to D^0(*)\ (\pi^\pm)\ \ (K^\pm)\ \ (K^0_S)\ (\pi^0)$

    ($D^* \to D^0\pi$ and $D^0 \to K\pi$, $K\pi\pi^0$, $K3\pi$, $K_S\pi\pi$)
  - B constraining kinematic variables: Δ_E and m_{ES}

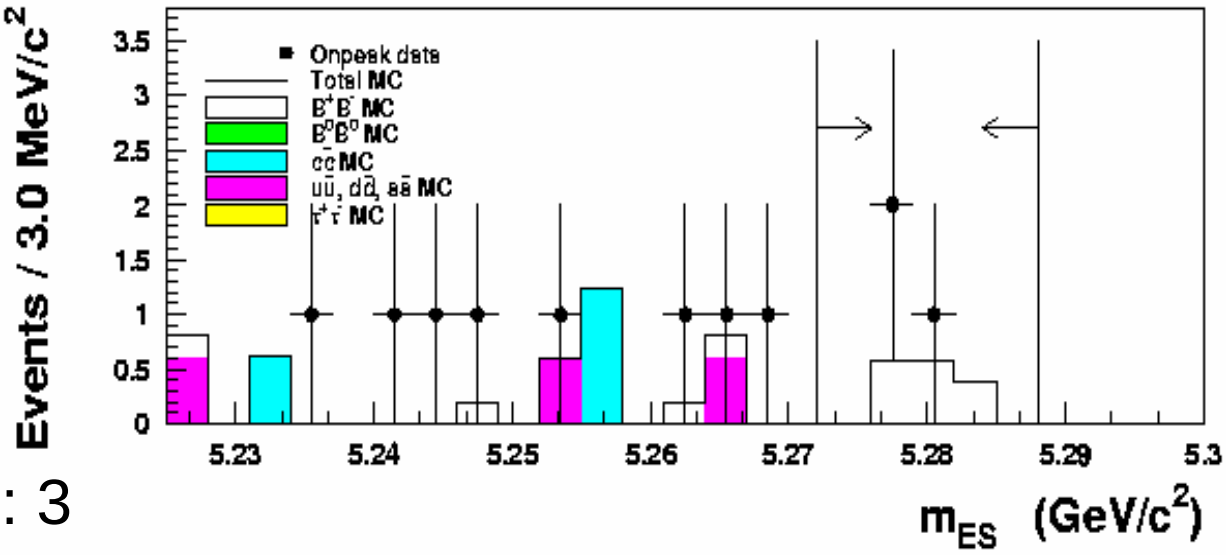
$B^+ \rightarrow K^+ \nu\nu$ Search II

- Identify *tag B* in signal ΔE and m_{ES} area
- All remaining tracks and neutrals belong to the recoiling signal-side B

  - One well identified Kaon
  - no π^0
  - Missing momentum not in the beam pipe
  - "extra" Energy < 300 MeV



$B^+ \to K^+ \nu\bar{\nu}$ Upper Limit



- Selected events: 3
- Expected background events: 2.7±0.8

$$Br(B \to K\nu\bar{\nu}) < 1.05 \times 10^{-4} \quad @\ 90\%\ CL$$

hep-ex/0304020

• Combining this result with the previous, ($Br(B \to K\nu\nu) < 9.4 \times 10^{-5}$) statistically independent *BABAR* result, yields a new limit:

$$Br(B \to K\nu\bar{\nu}) < 7.0 \times 10^{-5} \quad @\ 90\%\ CL$$

Going to PRL

$B \to \tau\nu$ Search

2 analyses of the 1999-2002 data sample: ~81 fb^{-1}

Reconstruct one B meson as

Semi–Leptonic B-tag	Hadronic B-tag
$B \to Dl\nu\ X$	$B \to DX_{had}$

The remaining neutrals and tracks are signal candidates

- $\tau \to (e, \mu)\ \nu_{(e,\mu)}\ \nu_\tau$

- $\tau \to (e, \mu)\ \nu_{(e,\mu)}\ \nu_\tau$
- $\tau \to (\pi, \pi\pi^0, \pi\pi\pi)\ \nu_\tau$

very clean but low efficiency (~ 0.25 – 0.30 %)

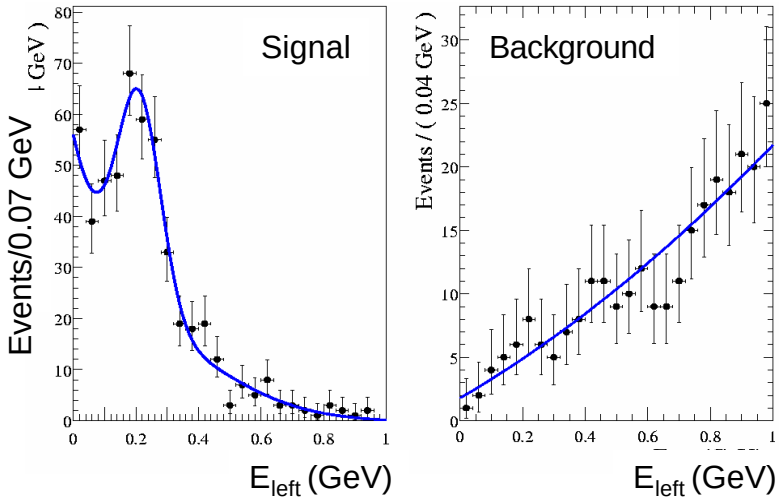
The two samples of *tag B* mesons are statistically independent

τ Signal Selection

Semi–Leptonic B-Tag

- $\tau^+\tau^-$ event veto
- Only one charged track having low impact parameter
- Track is not identified as a kaon
- Track is an identified lepton
- Residual neutral energy is

used to model PDFs to extract signal and background contributions



- Signal efficiency: 22.5%

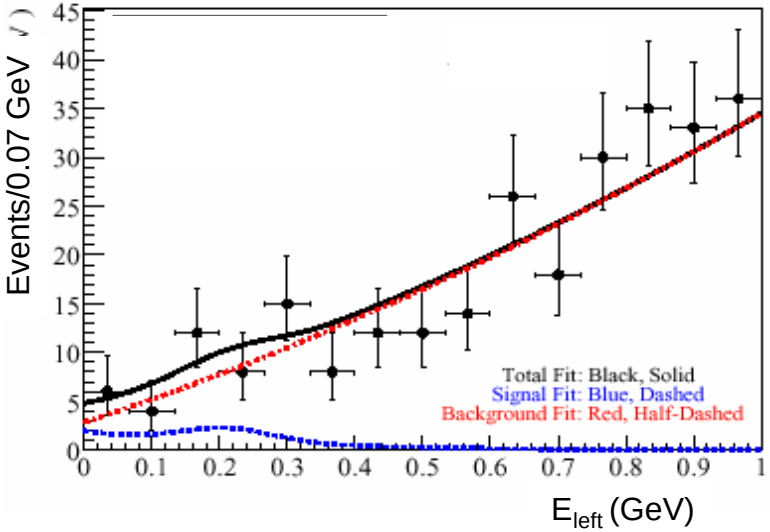
Hadronic B-Tag

- Three preselections
  - 1 track, 0 π^0
  - 1 track, 1 π^0
  - 3 tracks, 0 π^0
- Track is not identified as a kaon
- Track is identified as lepton or pion
- Additional cuts on
  - Missing momentum
  - Residual neutral energy
  - Track momentum
  - Invariant masses
- Background mainly from V_{cb} events
- Signal efficiency: 11.3%

$B \to \tau\nu$ Results

Semi–Leptonic B-Tag

Expected Bkg from MC	**40.9 ± 3.8**
Expected Bkg in onpeak data (sideband extrapolation)	**39.9 ± 2.8**
Observed events onpeak data	**47.7 ± 7.0**



$Br(B^- \to \tau^- \nu) < 4.9 \times 10^{-4}$

hep-ex/0303034

Hadronic B-Tag

Selection	Total Bkg	Data candidates
$\tau \to e \nu_e \nu_\tau$	6.7 ±2.0 ±0.6	10
$\tau \to \mu \nu_\mu \nu_\tau$	5.0 ±1.7 ±0.4	8
$\tau \to \pi \nu_\tau$	11.2 ±2.5 ±0.5	6
$\tau \to \pi\pi^0 \nu_\tau$	10.4 ±2.6 ±1.2	7
$\tau \to \pi\pi\pi \nu_\tau$	4.3 ±1.4 ±0.3	4
All	37.6 ±4.7 ±1.5	35

$Br(B^- \to \tau^- \nu) < 7.7 \times 10^{-4}$

hep-ex/0304030

Combined limit

$Br(B^- \to \tau^- \nu) < 4.1 \times 10^{-4}$ @ 90% CL

SM prediction: $< 9.2 \times 10^{-5}$

hep-ex/0305034

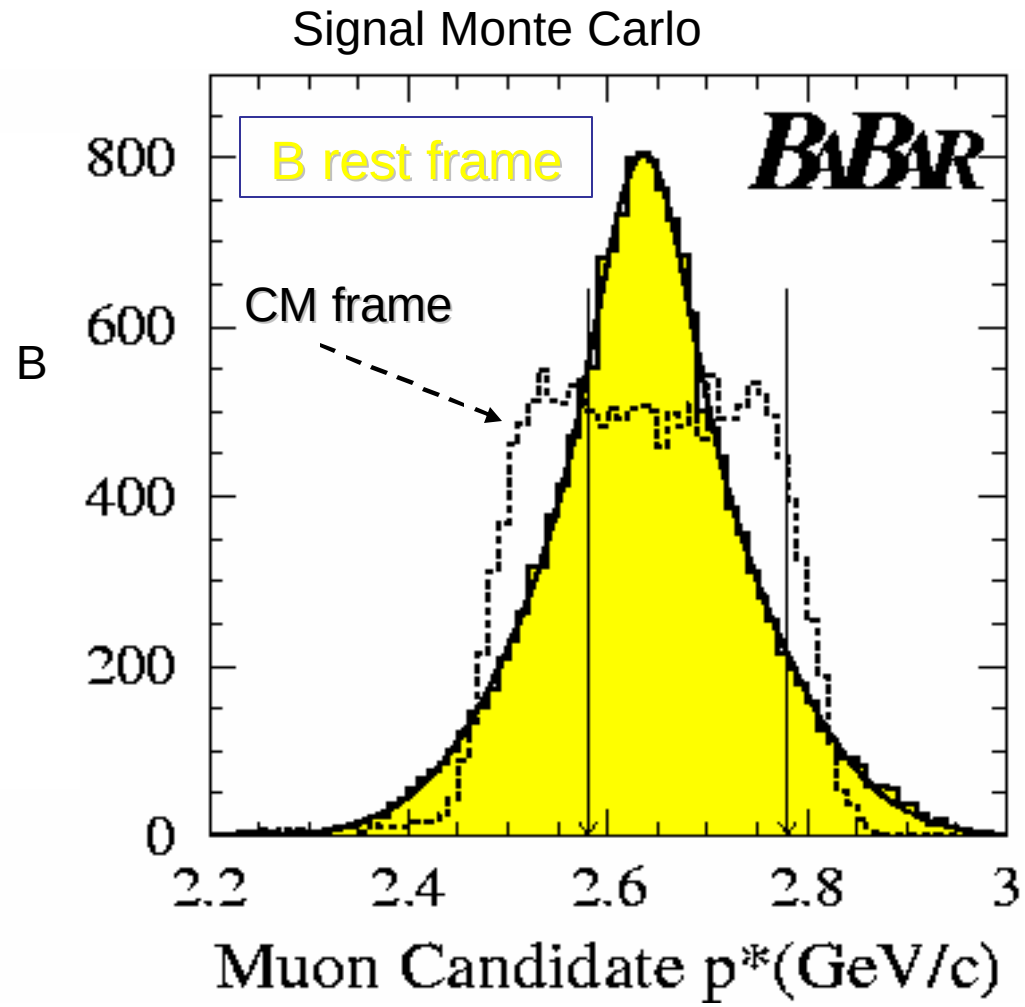
B→mn Search

Data sample 1999–2002: ~81fb^{-1}

Two Body decay → p(μ) ~ $m_B/2$

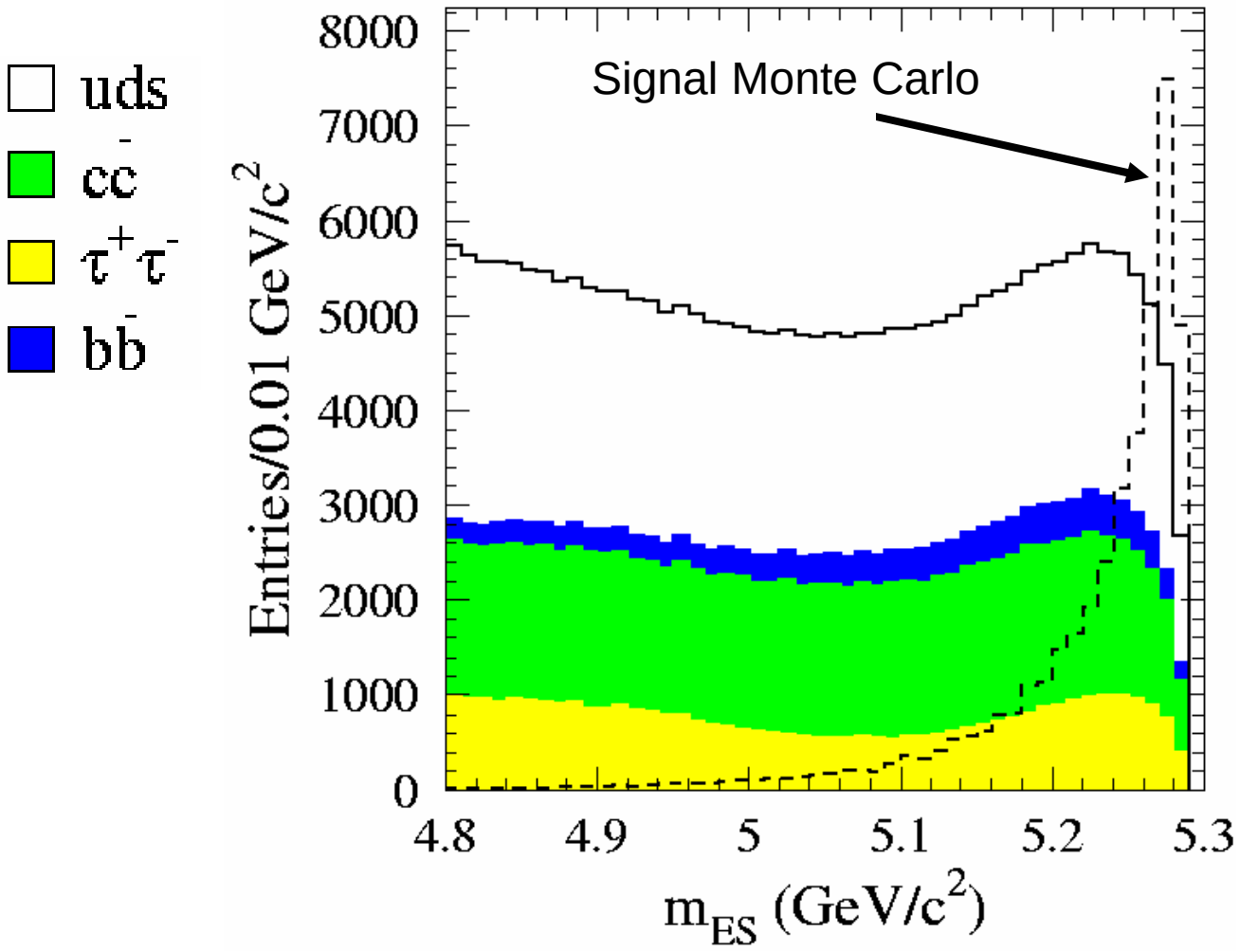
- One well identified muon
- All the rest is from the companion B
  - do particle identification
  - No additional leptons allowed

- After the companion B was found, p(μ) is re-reconstructed in the signal B rest frame



B→mn Search

All other tracks and neutrals make the *Companion*-B

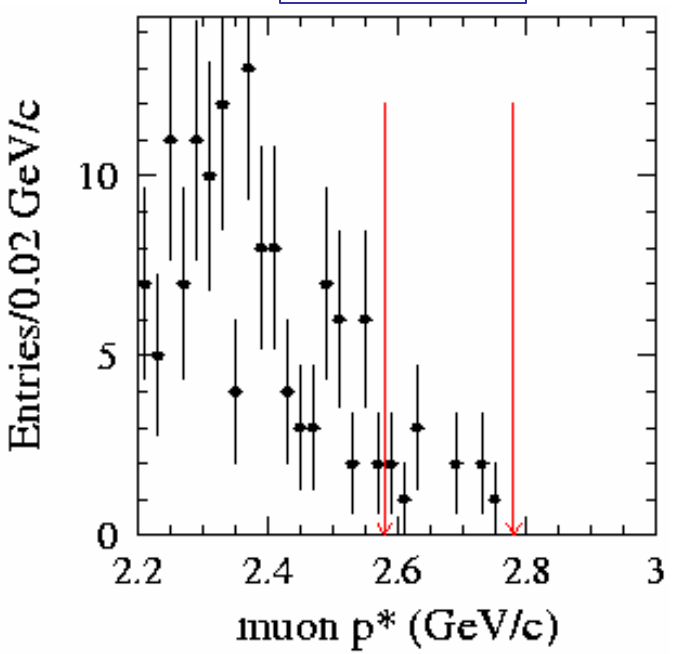


Upper Limit for $B \to \mu\nu$

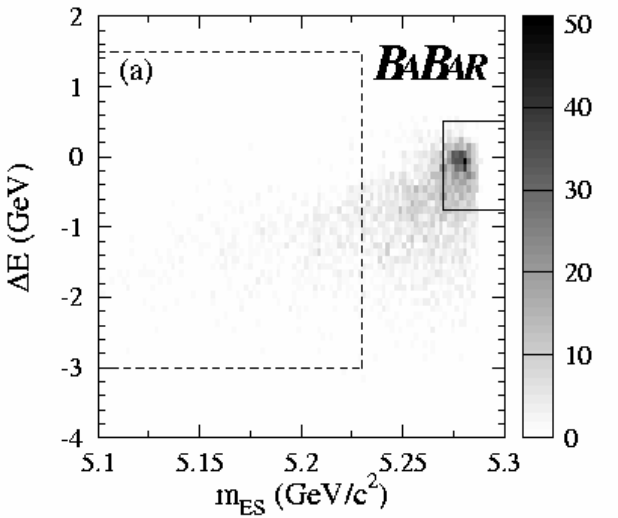
- Signal Selection efficiency: 2.09%
- Selected events: 11
- Expected background: $5.0^{+1.8}_{-1.4}$

- Bg fluctuation prob. to the signal: 4%

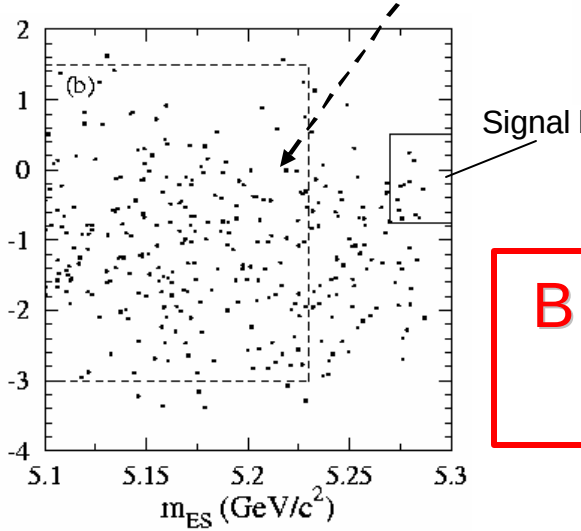
Data



$B \to \mu\nu$ MC



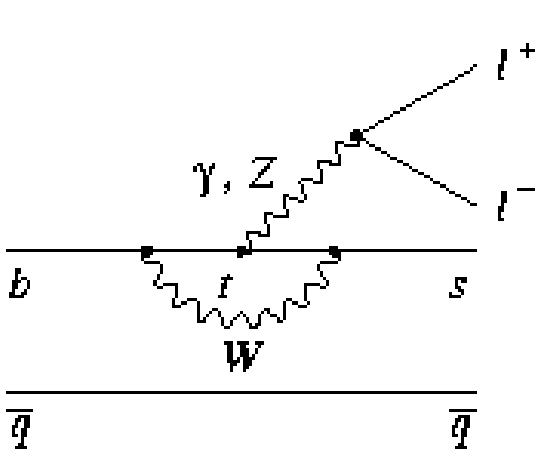
Data



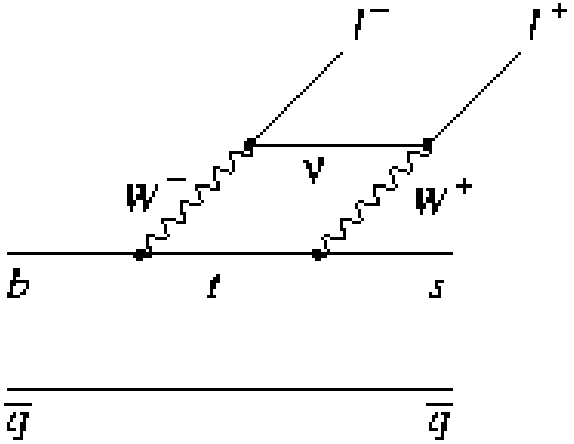
$$B(B \to \mu\nu) < 6.6 \times 10^{-6} \text{ @ 90\% CL}$$

BABAR-CONF-03-007

b→ $K^{(*)}$ l l



penguin diagram b→ s ll



box diagram b→ s ll

Updated result on 113 fb^{-1} accepted by PRL

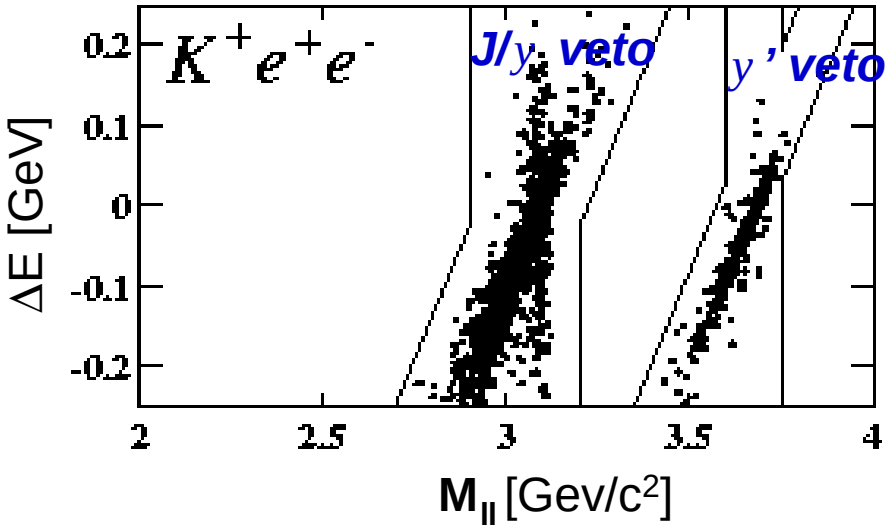
Reconstruct K^+, $K_s \rightarrow \pi^+\pi^-$, $K^{*0} \rightarrow K^+\pi^-$, $K^{*+} \rightarrow K_s\pi^+$

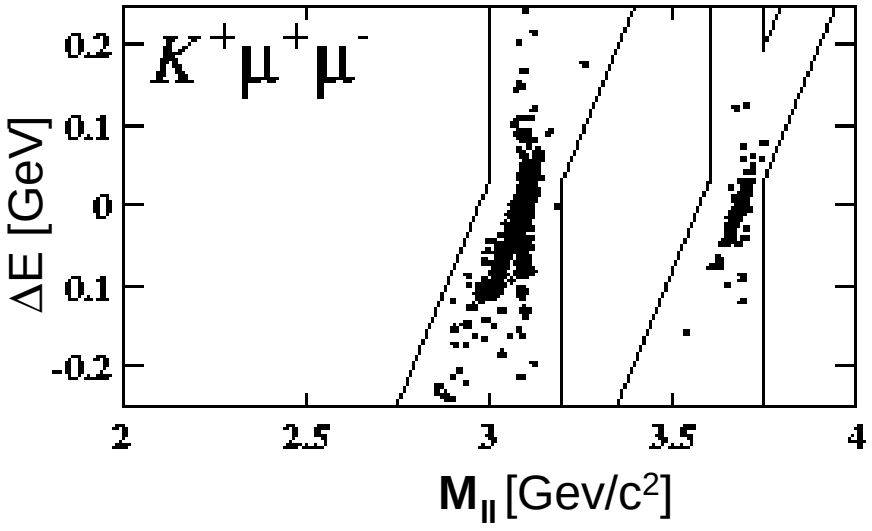
Lepton identification for
e^+e^- with p(e) > 0.5 GeV/c,
$\mu^+\mu^-$ with p(μ) > 1.0 GeV/c

b→ $K^{(*)}$ l l Peaking Background

Events with the same final state:

B → J/ψ K(*), ψ' K(*)





Signal is scattered in this above area

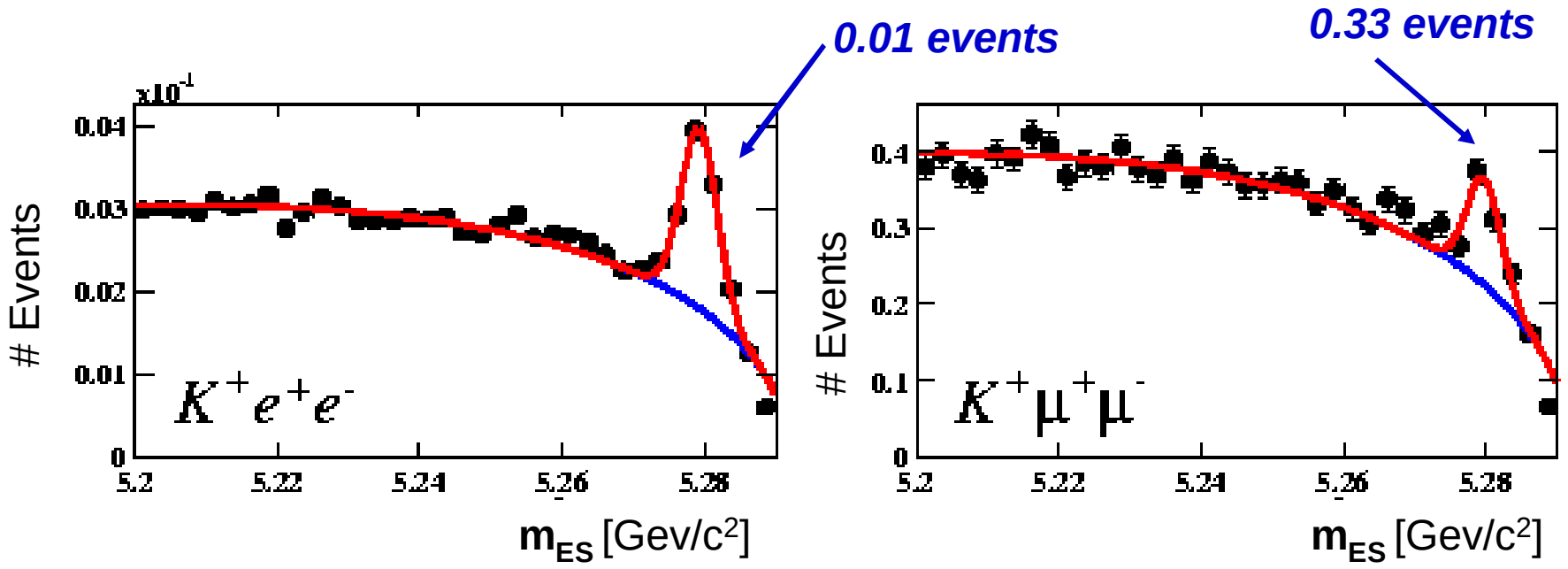
500 fb^{-1} B → J/ψ K(*), ψ' K(*) Monte Carlo
little to no contribution
outside these veto bands

b→ $K^{(*)}$ l l Peaking Background II

Background from lepton miss-identification

B → h^+h^- $K^{(*)}$

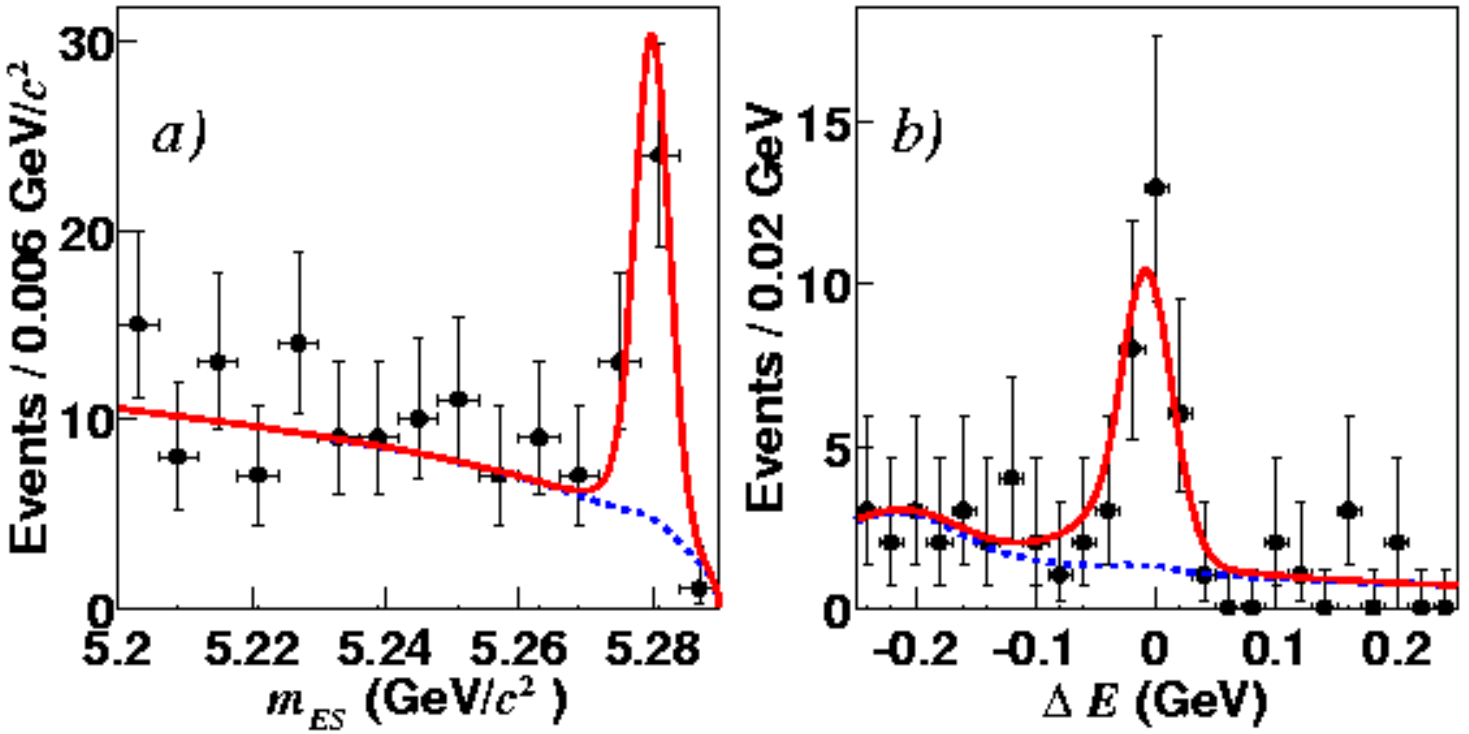
h^+h^- $K^{(*)}$ events in data convolved with rates for h to fake e, m



Included as part of the fit to data

b→ *K l l* Results

2-D unbinned maximum LH fit to m_{ES} and ΔE on all 4 decays $K^+ee/\mu\mu$ and $K_s^0 ee/\mu\mu$



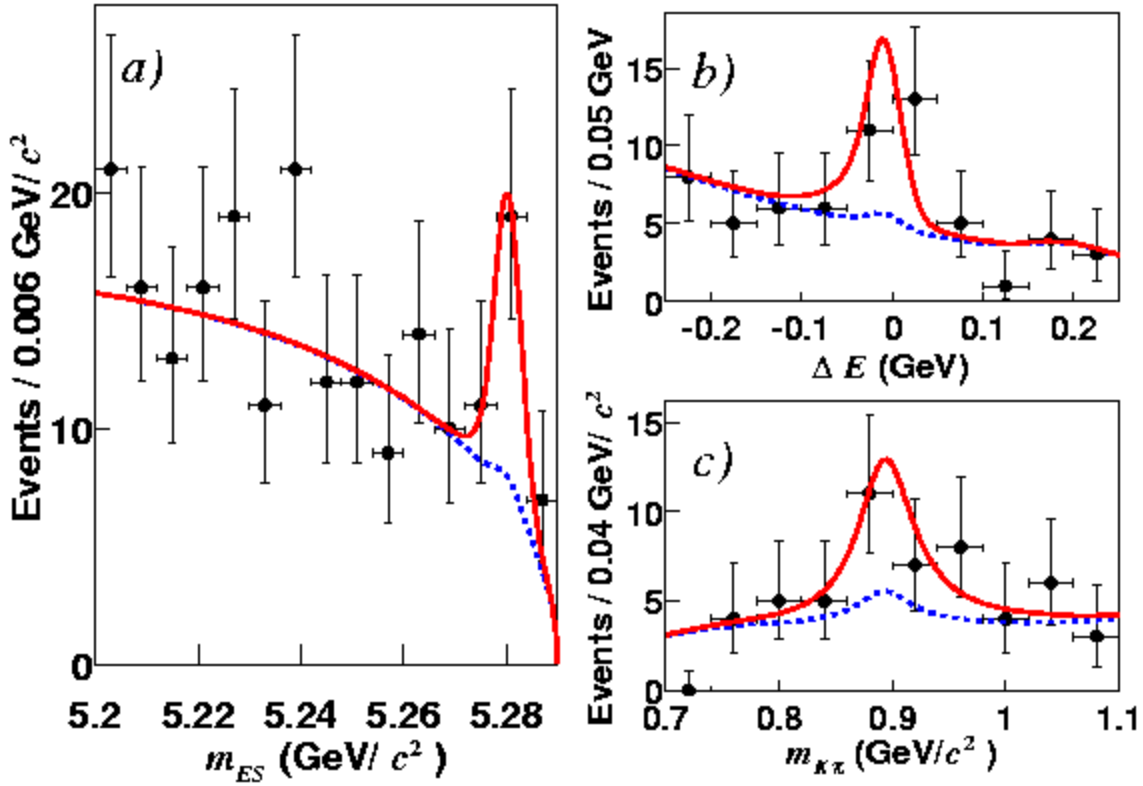
8.4σ excess over background

$$Br(b \to K\, ll) = (6.5\ ^{+1.4}_{-1.3} \pm 0.4)\ 10^{-7}$$

accepted by PRL

b→ *K* l l* Results

3-D unbinned maximum LH fit to m_{ES}, DE and m_{Kp}



3.3 s excess over background

Constrain: K*ee = 1.33 X K*μμ

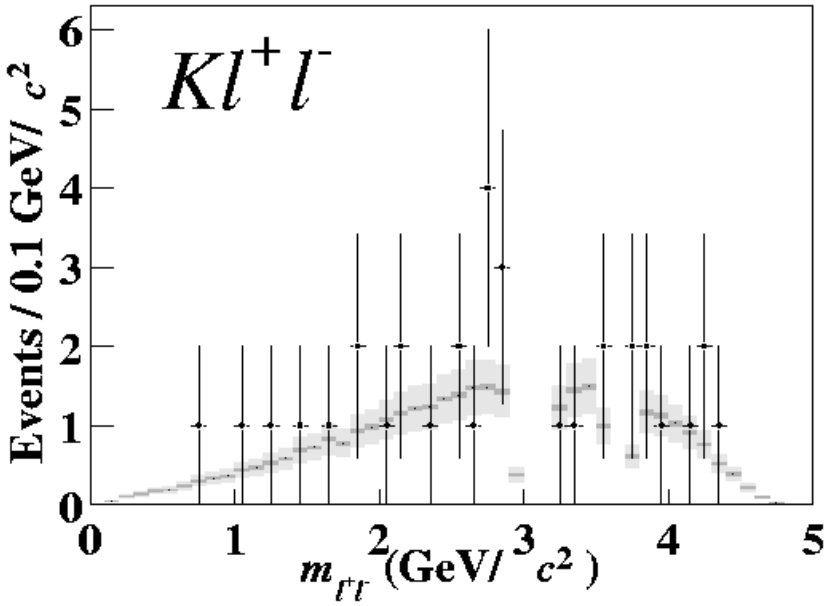
$\Gamma_{tot}(B^0) = 1.08 \times \Gamma_{tot}(B^+)$

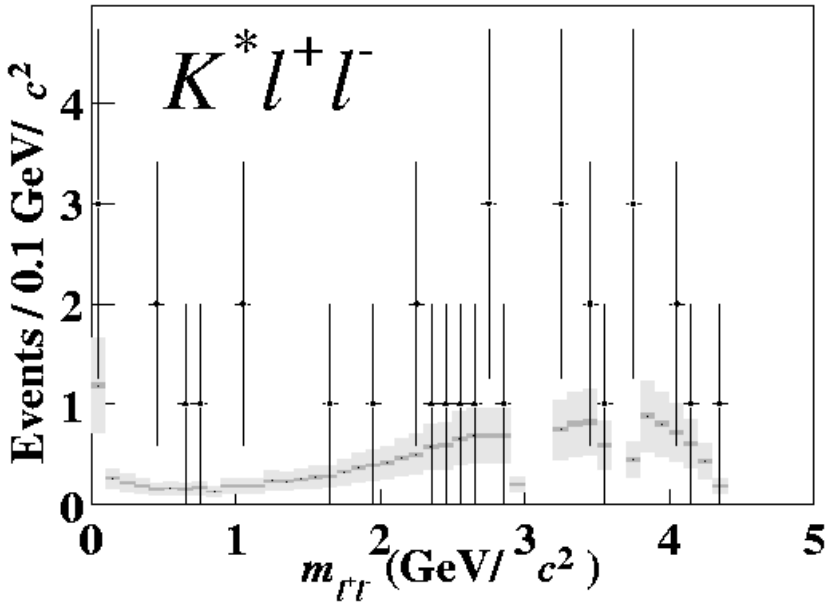
Br(b→K* ll) = $(8.8\ ^{+3.3}_{-2.9} +/- 1.0)\ 10^{-7}$

accepted by PRL

b→ $K^{(*)}$ l l Results

Comparison of m_{ll} in data with simulation, normalized to the measured Br





Fits well

Semi-Inclusive B→ Xs *l l*

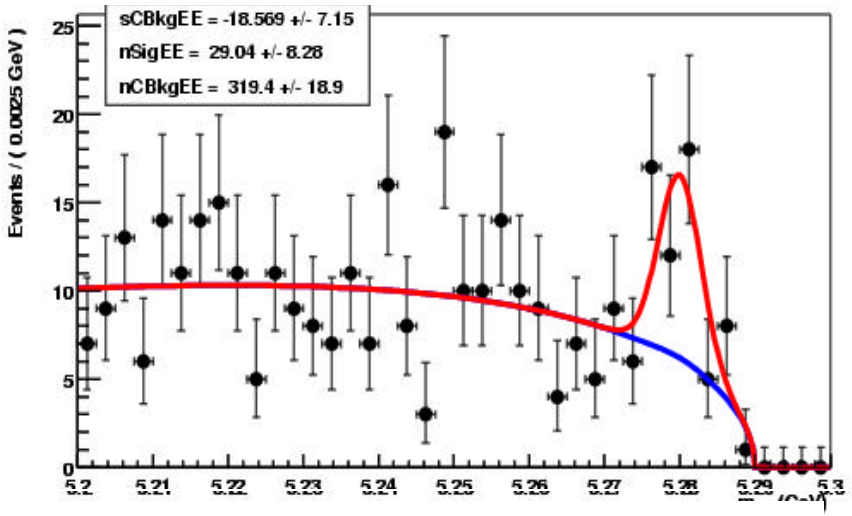
Sum of exclusive modes approach:

reconstruct X_s with 1 $K^{\pm}$ or $K^0_s \rightarrow \pi^+\pi^-$, # $(\pi^{\pm} + \pi^0) \leq 2$, # $\pi^0 \leq 1$

10 modes, ~50% of BR($B \rightarrow X_s\, l^+l^-$) (75% if assumed K_S=K_L)

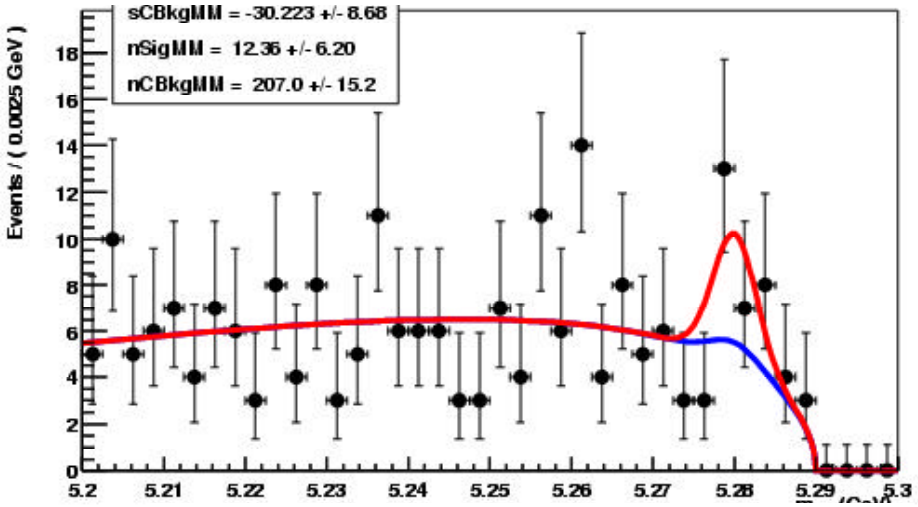
Similar analysis as b→ $K^{(*)}$ ll but with higher combinatoric background

B→ Xs e^+e^-



m_{ES} [Gev/c^2]

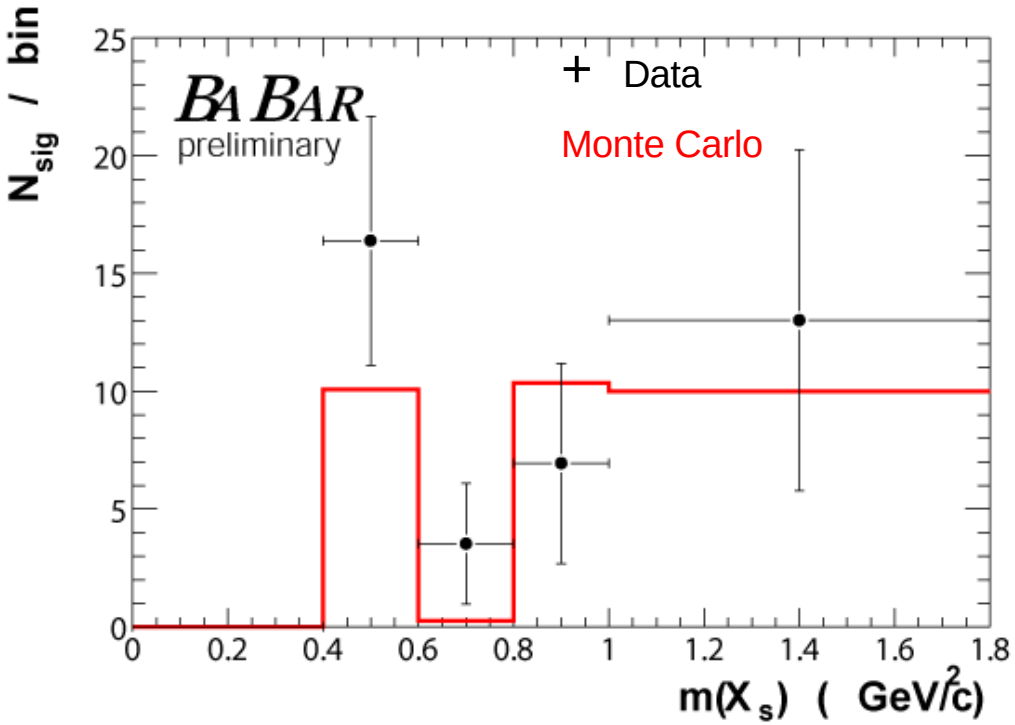
B→ Xs m^+m^-



m_{ES} [Gev/c^2]

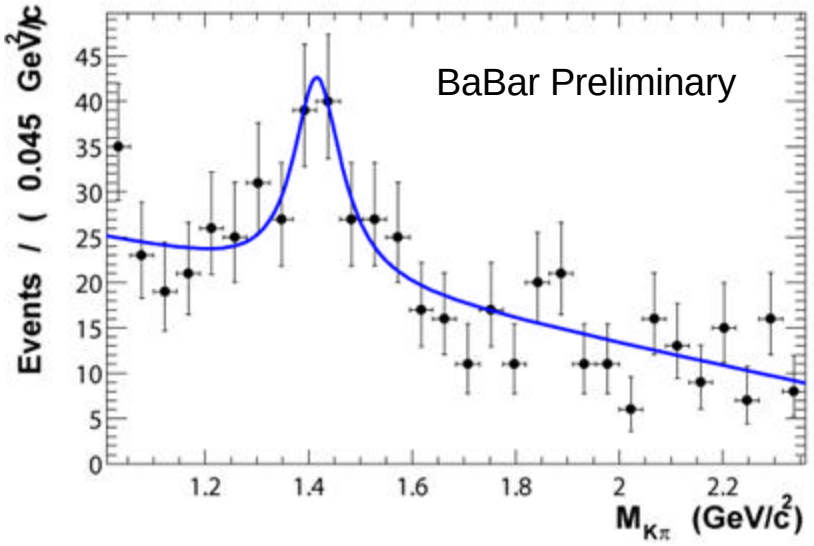
Semi-Inclusive B→ Xs l l Results

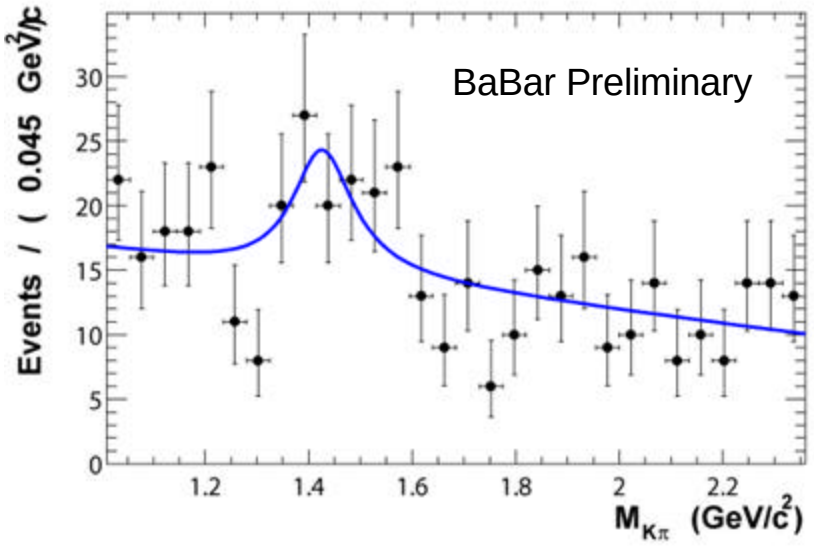
Mode	N_{sig} (± stat)	Signifi-cance (stat)	Effici-ency
$B \to X_s e^+e^-$	29.0 ± 8.3	4.0	2.5%
$B \to X_s \mu^+\mu^-$	12.4 ± 6.2	2.2	1.2%
Sum	41.4 ± 10.3	4.6	



$$Br(B \to X_s e^+e^-) = (6.6 \pm 1.9 \pm {}^{1.9}_{1.6}) \times 10^{-6}$$
$$Br(B \to X_s \mu^+\mu^-) = (5.7 \pm 2.8 \pm {}^{1.7}_{1.4}) \times 10^{-6}$$
$$Br(B \to X_s l^+l^-) = (6.3 \pm 1.6 \pm {}^{1.8}_{1.5}) \times 10^{-6}$$

$B^0 \to K_2^{*0}(1430)\,\gamma$ and $B^+ \to K_2^{*+}(1430)\,\gamma$





Br ($B^0 \to K_2^{*0}(1430)\,\gamma$) **Br ($B^+ \to K_2^{*+}(1430)\,\gamma$)**

BaBar $(12.2 \pm 2.5 \pm 1.1)\times 10^{-6}$ $(14.4 \pm 4.0 \pm 1.3)\times 10^{-6}$

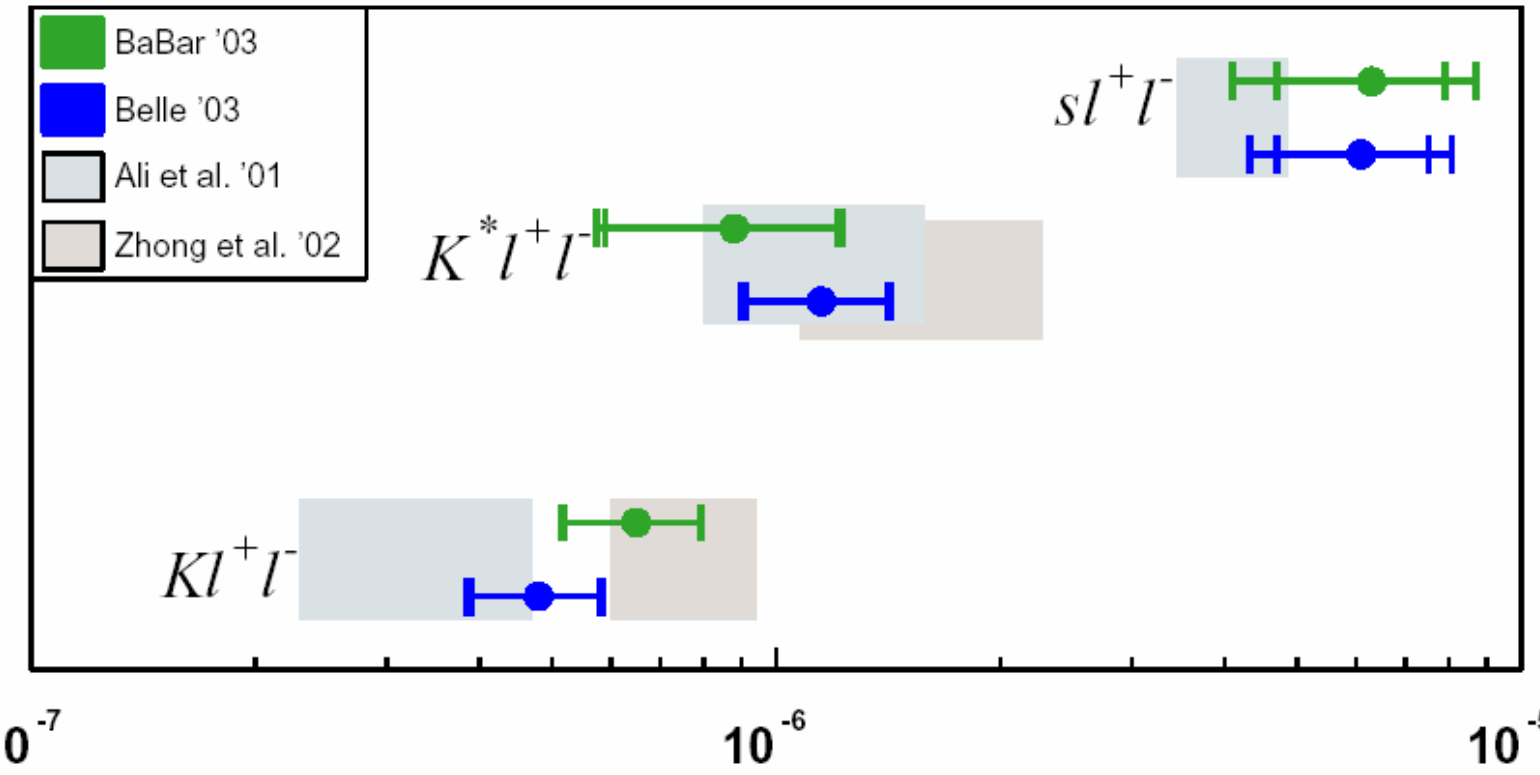
Belle $(13 \pm 5 \pm 1)\times 10^{-6}$

Cleo $(16.6 \pm 5.9 \pm 1.3)\times 10^{-6}$

Summary (1)

- FCNC
  $b \to K\nu\nu$ — *3 bg events expected 3 seen*
- Purely Leptonic Decays
  $b \to \tau\nu$ — *difficult*
  $b \to \mu\nu$ — *looks quite interesting*
- Radiative Decays
  $B^0 \to K_2^{*0}(1430)\,\gamma$ and $B^+ \to K_2^{*+}(1430)\,\gamma$ — *BaBar is in the game*

B→ s l l Summary



Br(b→s ll) in good agreement within experiments and prediction

Next step: measure angular and kinematic distributions

…and have fun with the next talk covering all the other interesting rare results measured by Belle