First Measurement of $\mathcal{B}(e^+e^- \longrightarrow B^0\overline{B}^0)$ at $\Upsilon(4S)$

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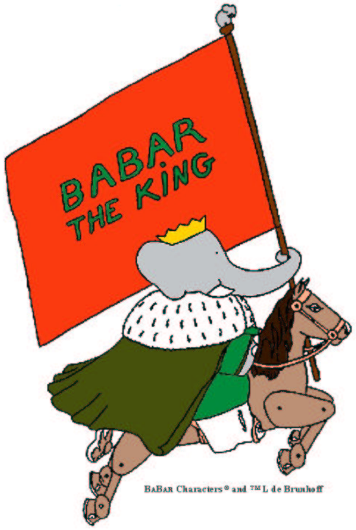
On behalf of

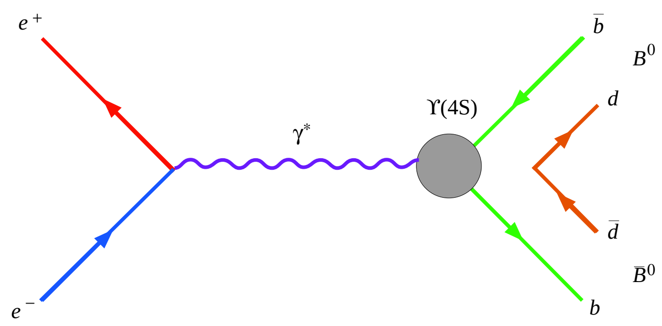
BABAR Collaboration



Motivation

$f_{00} \equiv \mathcal{B}(e^+e^- \to B^0\overline{B}^0)$ at $\Upsilon(4S)$

- First direct measurement of f_{00}
- Most published papers assume $f_{00} = 50\%$



- Our result can be used to eliminate above assumption
- It is important for normalizing all B branching fractions
- Enhance our knowledge of isospin violation effects in $\Upsilon(4S)$ system

Theoretical Predictions

- $R^{+/0} \equiv \frac{f_{+-}}{f_{00}} \sim 1.03 - 1.25$

Authors	$R^{+/0} \equiv \frac{f_{+-}}{f_{00}}$
Atwood et al. (1990)	~ 1.18
Byers et al. (1990)	$1.05 - 1.10$
Lepage (1990)	$1.03 - 1.14$
Kaiser et al. (2003)	$1.04 - 1.25$
Voloshin (2003)	~ 1.19

- Atwood et al., PRD 41, 1736 ('90)
- Byers et al., PRD 42, 3885 ('90)
- Lepage, PRD 42, 3251 ('90)
- Kaiser et al., PRL 90, 142001 ('03)
- Voloshin, MPL. A18, 1783 ('03)

Experimental Results

The previous measurements of $R^{+/0} \equiv \frac{f_{+-}}{f_{00}}$

Mode $B \rightarrow$	$\int \mathcal{L}dt$ (fb^{-1})	$R^{+/0} \equiv \frac{f_{+-}}{f_{00}}$	Method	Source
$J/\psi K^{(*)(+/0)}$	9.2	$1.04 \pm 0.07 \pm 0.04$	F.R.	CLEO '01
$D^{(*)(+/0)}\ell\bar{\nu}$	2.7	$1.058 \pm 0.084 \pm 0.136$	P.R.	CLEO '02
$J/\psi h^{(+/0)}$	20.7	$1.10 \pm 0.06 \pm 0.05$	F.R.	BABAR '02
Dileptons	29.4	$1.01 \pm 0.03 \pm 0.09$	F.R.	BELLE '03
$J/\psi(K^{+}/K^{0}_{s})$	81.9	$1.006 \pm 0.036 \pm 0.031$	F.R.	BABAR '04

F.R. = Full Reconstruction

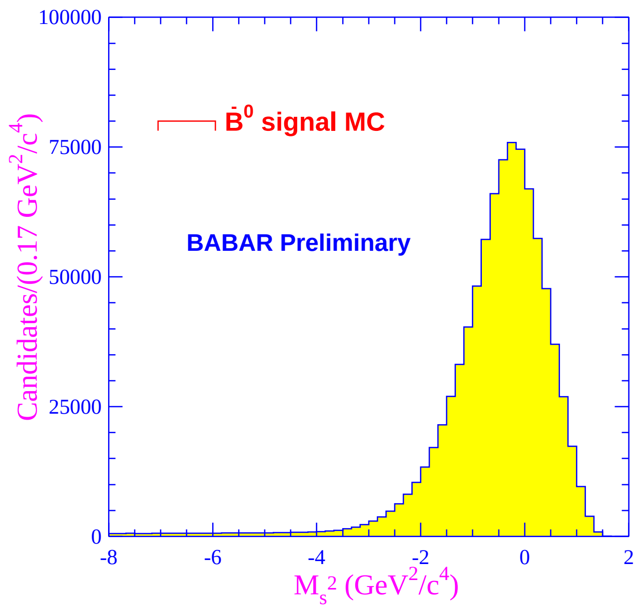
P.R. = Partial Reconstruction

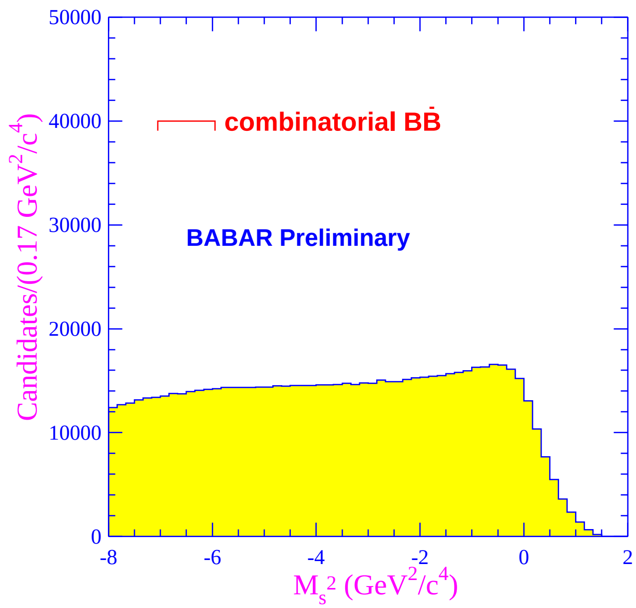
- These $R^{+/0}$ measurements mostly depend on
  - Branching fractions
  - The ratio of B^{+} and $\overline{B}^{0}$ lifetime
  - The assumption of isospin symmetry
- P.R. yields large event samples compared to F.R.
- We are using P.R. with double tag technique which does not rely on above assumptions

Partial Reconstruction

- $\overline{B}^0 \rightarrow D^{*+}\ \ell^-\ \bar{\nu}_\ell\ \ (D^{*+} \rightarrow D^0\ \pi^+)$: D^{*+} is identified by π^+
  - $E_{D^*} \simeq \frac{E_\pi}{E_\pi^{cms}} m_{D^*}$
  - $\vec{p}_{D^*} \simeq \hat{\vec{p}}_\pi \times \sqrt{E_{D^*}^2 - m_{D^*}^2}$
- Observable Missing Mass Squared

$$\mathcal{M}^2 \equiv (E_{\mathrm{beam}} - E_{D^*} - E_\ell)^2 - (\vec{\mathrm{p}}_{\mathrm{D}^*}) + \vec{\mathrm{p}}_\ell^2$$





- Signal region: $\mathcal{M}^2 > -2.0\ \mathrm{GeV}^2/c^4$
- Sideband: $-8 < \mathcal{M}^2 < -4\ \mathrm{GeV}^2/c^4$

Tag Selection

- **Single tags** → at least one neutral B partially reconstructed
  Its total yield is denoted by N_s
  and its missing mass by $\mathcal{M}_s^2$

- **Double tags** → both neutral B partially reconstructed
  Its total yield is denoted by N_d

  There are 2 missing mass variables
  - $\mathcal{M}^2$ of 1^{st} candidate is $\mathcal{M}_1^2$
  - $\mathcal{M}^2$ of 2^{nd} candidate is $\mathcal{M}_2^2$

- We used BABAR data
  - 82 fb^{-1} $\Upsilon(4S)$-resonance
    (mean energy of 10.580 GeV)
  - 10 fb^{-1} off-resonance

f_{00} Determination

The relation of N_s and N_d to $\mathcal{B}$

$$N_s = 2\ N_{B\overline{B}}\ f_{00}\ \epsilon_s\ \mathcal{B}(\overline{B}^0 \to D^{*+}\ell^-\bar{\nu}_\ell)$$

$$N_d = N_{B\overline{B}}\ f_{00}\ \epsilon_d\ [\mathcal{B}(\overline{B}^0 \to D^{*+}\ell^-\bar{\nu}_\ell)]^2$$

where

- $N_{B\overline{B}}$ is the total number of $B\overline{B}$
- $\epsilon_s(\epsilon_d)$= reconstruction efficiencies of the single(the double) tags
- Define $C \equiv \epsilon_d/\epsilon_s^2 = 0.9946 \pm 0.0078$ (measured from MC) and solve f_{00}

$$\boxed{f_{00} = \frac{CN_s^2}{4N_dN_{B\overline{B}}}}$$

Backgrounds

□ Single & Double Tag Backgrounds

- **Continuum:** $e^+e^- \rightarrow \gamma^* \rightarrow q\overline{q}$
  (subtracted using off-resonance data)

- **Combinatoric:** random combinations of ℓ and π
  (shape obtained from MC simulated events)

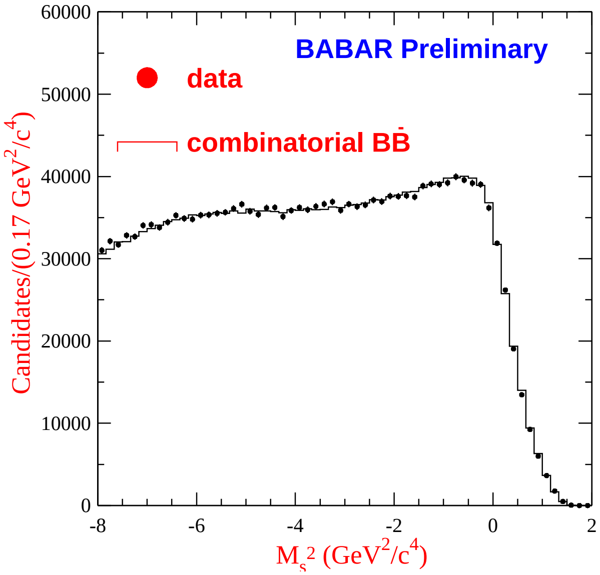
- **Peaking:** $B \rightarrow D^*(n\pi)\ell\bar{\nu}_\ell$, $D^*(n\pi)$ may or may not coming from D^{**}
  (shape obtained from MC simulated events)

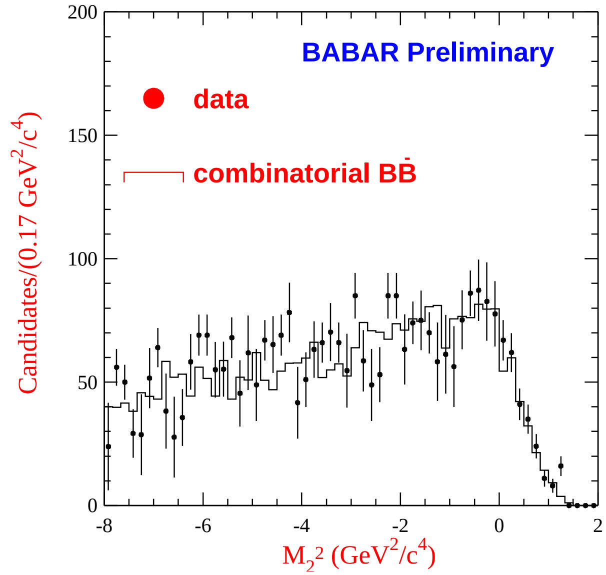
□ Additional backgrounds for double tags

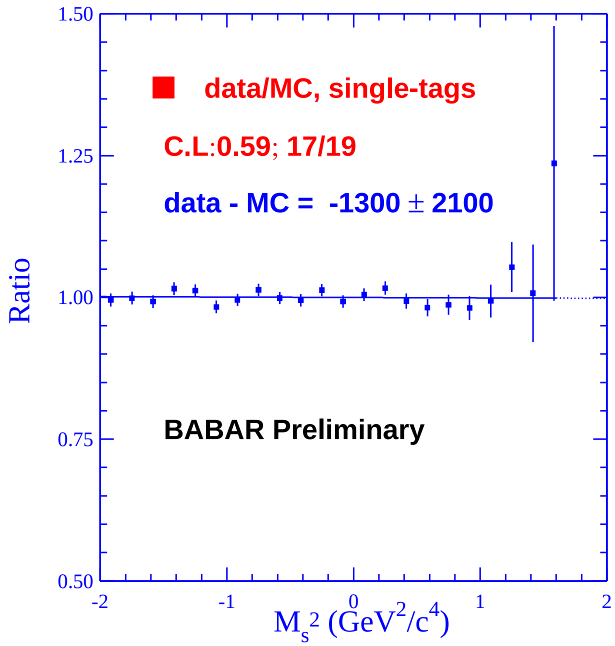
- $\mathcal{M}_1^2$ Combinatoric ($\sim 3\%$)
  (subtracted using $\mathcal{M}_1^2$ sideband data)
  1^{st} candidate is combinatoric &
  2^{nd} candidate is signal

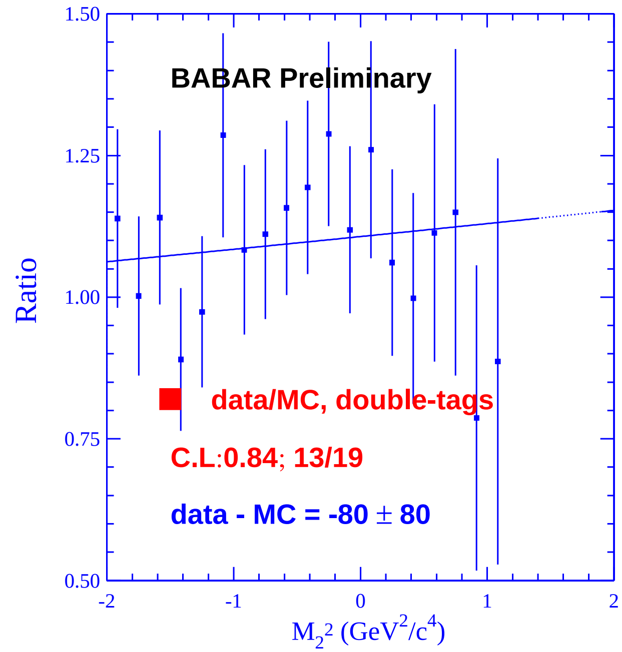
- $\mathcal{M}_1^2$ Peaking ($\sim 1\%$)
  (subtracted using MC simulated events)
  1^{st} candidate is a peaking &
  2^{nd} candidate is signal

Validations



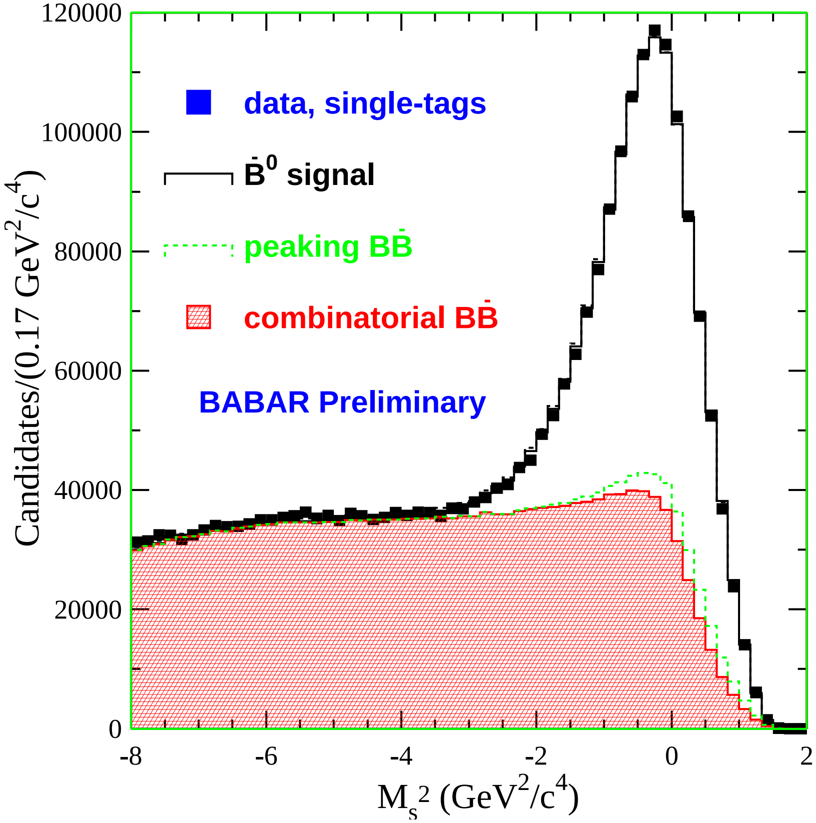




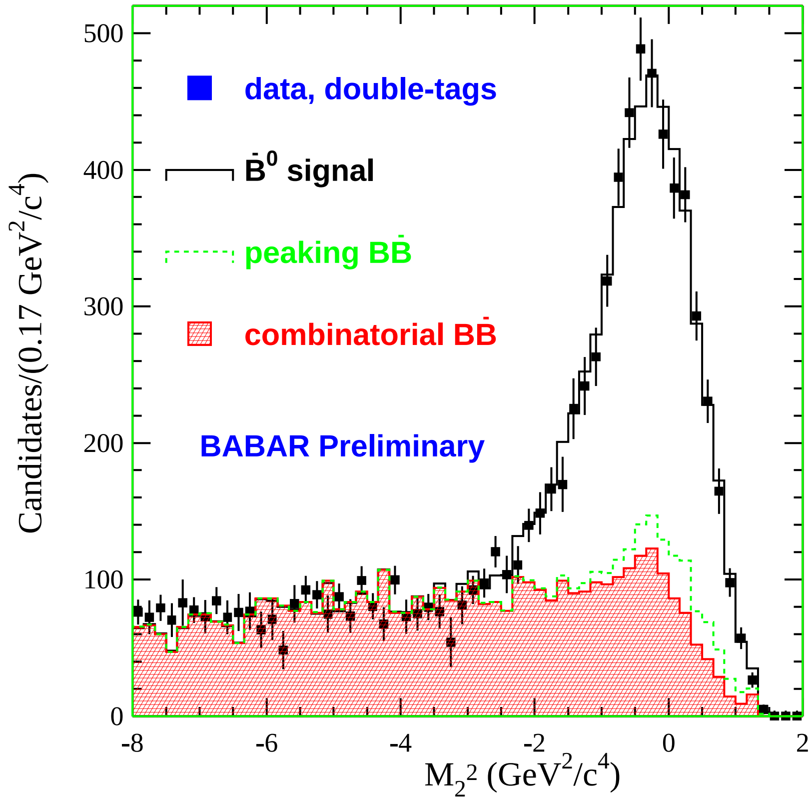


Data Fits

Single Tags



Double Tags



- **Single tags χ^2 binned fit**
  after subtracting continuum

- **Double tags χ^2 binned fit**
  after subtracting continuum, $\mathcal{M}_1^2$ combinatoric, and $\mathcal{M}_1^2$ peaking

Systematic Errors

Summary of the absolute systematic error for f_{00}

Source	$\delta(f_{00})$
B-meson counting	0.0055
Peaking background	0.004
Efficiency correlation	0.004
$\Upsilon(4S) \to$ non-$B\overline{B}$	0.0025
Combinatorial background shape	0.0025
Monte Carlo statistics	0.002
$\mathcal{M}_1^2$-combinatorial	0.0005
$\mathcal{M}_1^2$-peaking	0.0005
Total	0.009

- The largest systematic error comes from B-meson counting, including the uncertainties on hadronic selection criteria and tracking efficiency
- Systematic error due to lepton and pion momentum spectrums are negligible
- This result depends very weakly on the simulated reconstruction efficiency

Summary

- This is first direct measurement of $f_{00} \equiv \mathcal{B}(e^+e^- \rightarrow B^0\overline{B}^0)$ at $\Upsilon(4S)$
- We obtain a preliminary result of (hep-ex/0408022)

$$f_{00} = 0.486 \pm 0.010(stat.) \pm 0.009(sys.)$$

  - This result has been presented to the 32$^{\text{nd}}$ International Conference on High-Energy Physics, ICHEP 2004, Beijing, China

- This f_{00} measurement is independent of
  - The ratio of B^+ and $\overline{B}^0$ lifetime
  - $\overline{B}^0$ and D^{*+} branching fractions
  - Assumption of isospin symmetry

- Precision measurement of f_{00} is important for
  - Re-normalizing all B meson branching fractions
  - Understanding the isospin violation effect in the $\Upsilon(4S)$ system