Measurement of $\mathcal{B}(\Upsilon(4S) \rightarrow B^0\bar{B}^0)$

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On behalf of

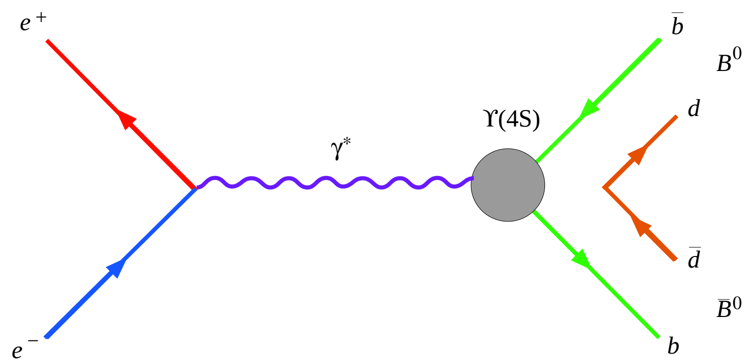
BABAR Collaboration

- **Motivation**
- **Experimental Results**
- **Analysis Technique**
- **Summary**

Motivation

$f_{00} \equiv \mathcal{B}(\Upsilon(4S) \to B^0 \bar{B}^0)$

- ☐ First direct measurement of f_{00}
- ☐ Important for normalizing all B branching fractions
- ☐ Most published papers assume $\mathcal{B}(\Upsilon(4S) \to B^0 \bar{B}^0) = 50\%$



- ☐ Enhance our knowledge of isospin violation effects in $\Upsilon(4S)$ decays

Theoretical Predictions

☐ $\frac{f_{+-}}{f_{00}} \equiv \frac{\Gamma(\Upsilon(4S) \to B^+ B^-)}{\Gamma(\Upsilon(4S) \to B^0 \bar{B}^0)} \sim 1.03 - 1.25$

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
- ☐ Byers *et al.*, PRD 42, 3885
- ☐ Lepage, PRD 42, 3251
- ☐ Kaiser *et al.*, PRL 90, 142001
- ☐ Voloshin, Mod.Phys.Lett. A18, 1783

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
$\psi K^{(*)(+/0)}$	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
$\psi h^{(+/0)}$	20.7	$1.10 \pm 0.06 \pm 0.05$	F.R.	BABAR '02
$\psi(K^+/K_s^0)$	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 are depend on:
  - the ratio of B^+ and $\bar{B}^0$ lifetime
  - the assumption of isospin symmetry

- Previous results has shown that Partial Reconstruction (P.R.) is a powerful tools in-terms of the statistical error

Partial Reconstruction

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

$$\mathcal{M}_\nu^2 \equiv (E_{\text{beam}} - \widetilde{E}_{D^*} - E_\ell)^2 - (\widetilde{\vec{\mathbf{p}}}_{D^*} + \vec{\mathbf{p}}_\ell)^2$$

- $1.5\ \mathrm{GeV}/c < p_\ell < 2.5\ \mathrm{GeV}/c$
- $60\ \mathrm{MeV}/c < p_\pi < 200\ \mathrm{MeV}/c$
- In this analysis, we are using:
  - $\Upsilon(4S)$-resonance data of 82 fb^{-1}
  - Off-resonance data of 10 fb^{-1}

Tag Selection

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

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

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

- For both single and double tags:
  - Signal region: $\mathcal{M}_\nu^2 > -2.0$ GeV$^2/c^4$
  - Sideband: $-8 < \mathcal{M}_\nu^2 < -4$ GeV$^2/c^4$

f_{00} Determination

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

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

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

where:

- $N_{B\bar{B}}$ is the total number of $B\bar{B}$
- $\epsilon_s(\epsilon_d)$= reconstruction efficiencies of the single(the double) tags
- Define $C = \epsilon_d/\epsilon_s^2$ and solve f_{00}:

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

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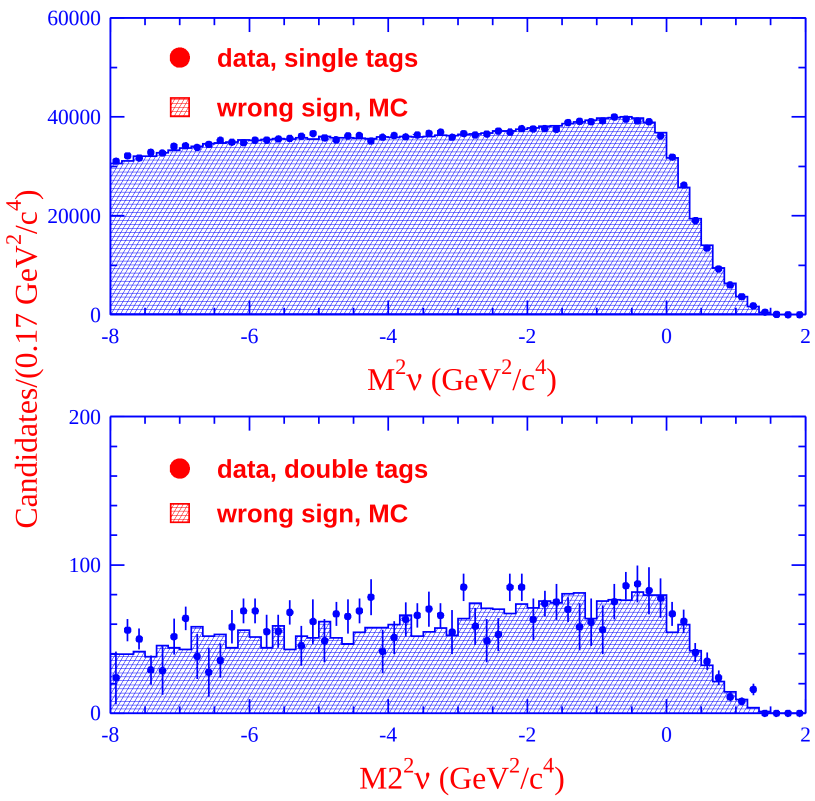
Backgrounds

- Single & Double Tag Backgrounds:
  - **Continuum:** $e^+e^- \to \gamma^* \to q\bar{q}$
  - **Combinatoric:** random combinations of leptons and soft pions
  - **Peaking:** $B \to D^*(n\pi)\ell\bar{\nu}_\ell$ decays, $D^*(n\pi)$ may or may not from D^{**}
- Additional backgrounds for double tags
  - $\mathcal{M}1^2_\nu$ **Combinatoric:** 1^{st} candidate is combinatoric & 2^{nd} candidate is signal
  - $\mathcal{M}1^2_\nu$ **Peaking:** 1^{st} candidate is a peaking & 2^{nd} candidate is signal

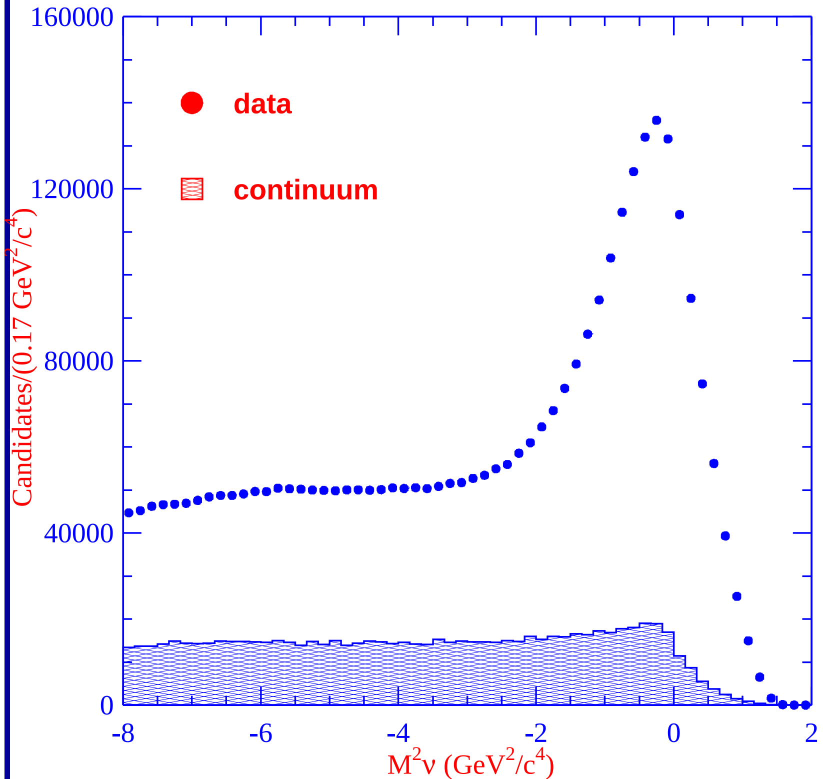
Combinatoric bkg is validated by the wrong sign combination: $(\ell^\pm - \pi^\pm)$



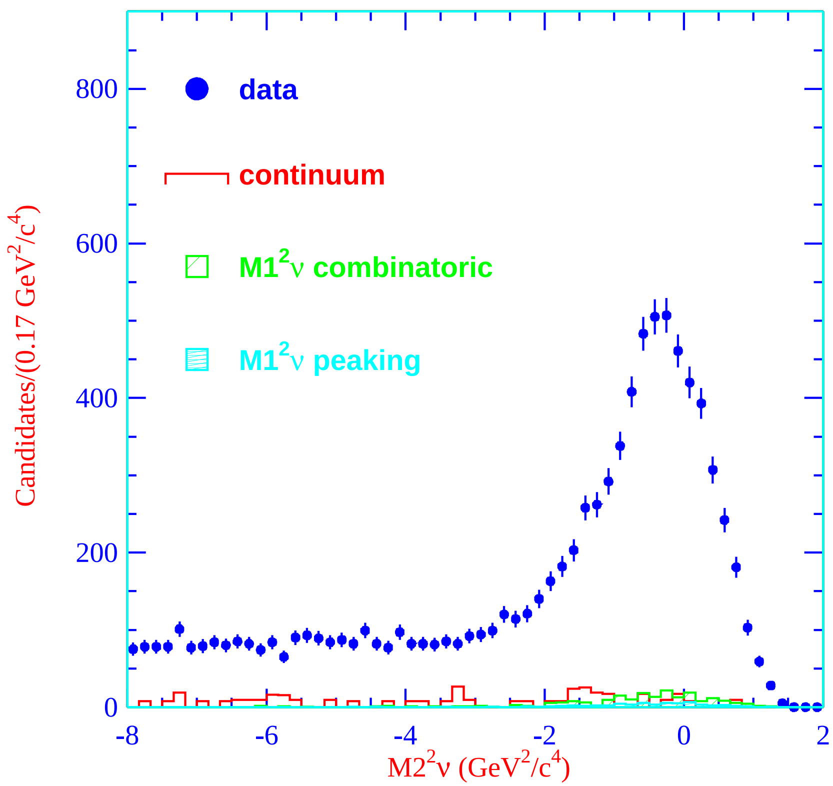
- No signal is expected for both tags

Signal Distribution

Single Tags



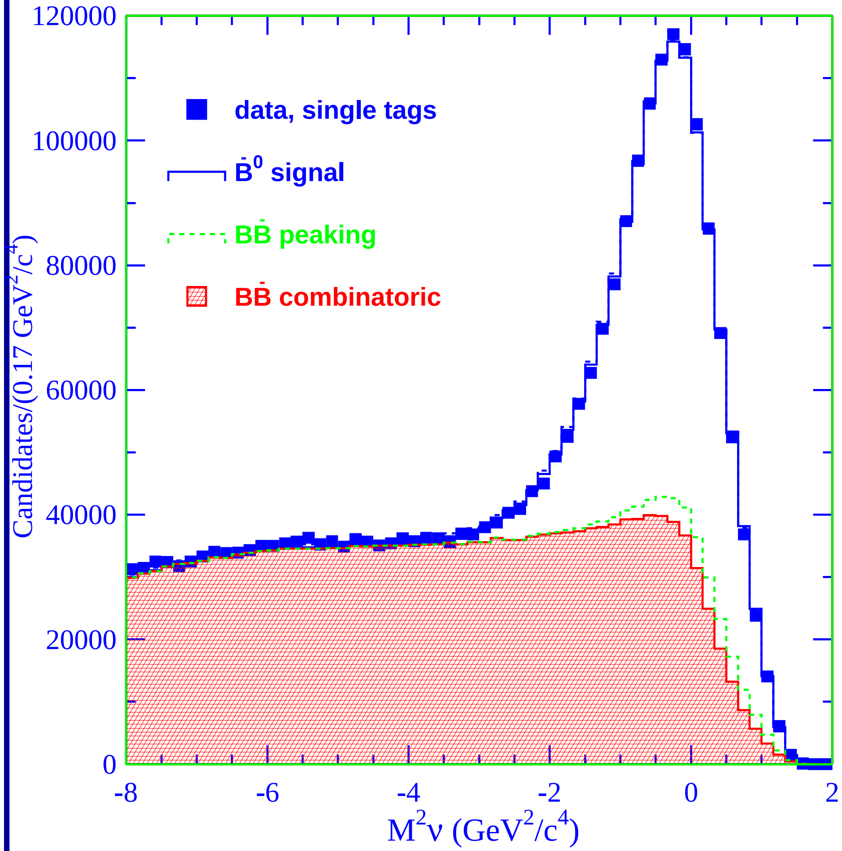
Double Tags



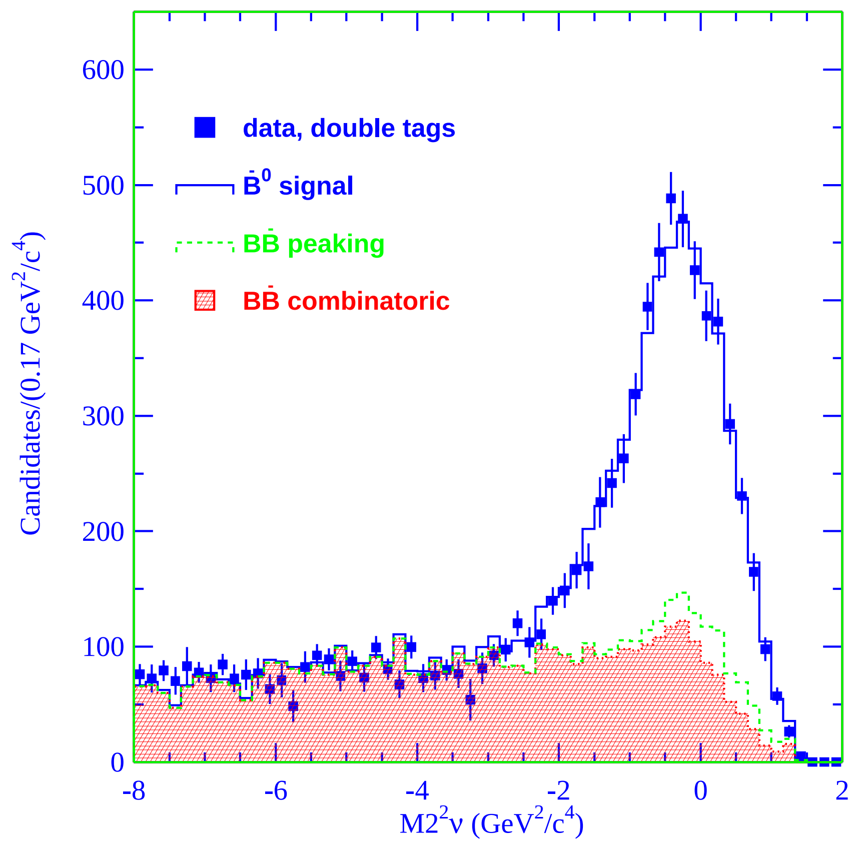
- ☐ **Data with scaled continuum background**
- ☐ **Data with continuum, $\mathcal{M}1_\nu^2$ combinatoric and $\mathcal{M}1_\nu^2$ peaking backgrounds**

Signal Distribution

Single Tags



Double Tags



- □ **Single tags χ^2 binned fit**

  after subtracting continuum

- □ **Double tags χ^2 binned fit**

  after subtracting continuum,

  $\mathcal{M}1_\nu^2$ combinatoric, and $\mathcal{M}1_\nu^2$ peaking

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Summary

- This is first direct measurement of $f_{00} \equiv \mathcal{B}(\Upsilon(4S) \to B^0\bar{B}^0)$

- This f_{00} measurement is independent of:
  - $\bar{B}^0$ lifetime
  - D^{*+} branching fraction
  - assumption of isospin symmetry

- Preliminary errors (under internal review):
  - $\sim 1\%$ statistical error
  - $\sim 2\%$ relative systematic error

- Precision measurement of f_{00} is an important value:
  - for normalizing all B branching fractions
  - for understanding the isospin violation effect in $\Upsilon(4S)$ decays

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