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Evidence for $B_s^{(*)}\overline{B_s}^{(*)}$ Production at the $\Upsilon(5S)$*

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Abstract

Using data collected by the CLEO III detector at CESR, we started a series of investigations on the Υ(5S) resonance decay properties. The data sample used for this analysis consists of 0.42 fb^{-1} of data taken on the Υ(5S) resonance, 6.34 fb^{-1} of data collected on the $\Upsilon(4S)$ and 2.32 fb^{-1} of data taken in the continuum below the Υ(4S). B_s mesons are expected to decay predominantly into D_s meson, while the lighter B mesons decay into D_s only about 10% of the time. We exploit this difference to make a preliminary model dependent estimate of the ratio of $B_s^{(*)}\overline{B_s}^{(*)}$ to the total $b\bar{b}$ quark pair production at the Υ(5S) energy to be $(21 \pm 3 \pm 9)$%.

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I. INTRODUCTION

An enhancement in the total e^+e^- annihilation cross-section into hadrons was discovered at CESR long ago [1], [2] and [3] and its mass measured as 10.865±0.008 GeV. This effect was named the Υ(5S) resonance. Potential models [4], [5] and [6] predict the different relative decay rates of the Υ(5S) into combinations of $B^{(*)}\overline{B}^{(*)}$ and $B_s^{(*)}\overline{B}_s^{(*)}$ where $(*)$ indicates the possible presence or absence of a B^* meson. Some data, $\sim$ 116 pb^{-1}, failed to reveal if B_s mesons were produced. It is important to check the predictions of these and other models; furthermore, e^+e^- "B factories" could exploit a possible B_s yield here as they have done for B mesons on the Υ(4S). In this paper we examine D_s yields because in a simple spectator model the B_s decays into the D_s nearly all the time. Since the $B \to D_sX$ branching ratio has already been measured to be $(10.5\pm2.6\pm2.5)\%$ [9], we expect a large difference between the D_s yields at the Υ(5S) and the Υ(4S) that can lead to an estimate of the size of the $B_s^{(*)}\overline{B_s}^{(*)}$ component at the Υ(5S). When we discuss the Υ(5S) here, we mean the production of any B meson species including B_u, B_d and B_s that occurs at an e^+e^- center-of-mass energy of 10.87 GeV.

II. THE CLEO III DETECTOR

The CLEO III detector is well equipped to measure the momenta and directions of charged particles, identify charged hadrons, detect photons and measure with good precision their directions and energies. Muons above 1.1 GeV can also be identified. The detector is almost cylindrically symmetric with everything but the muon detector inside a superconducting magnet coil run at a current that produces an almost uniform 1.5 T field. The detector consists of a four-layer double sided silicon strip detector at small radius. It is followed by a 47-layer drift chamber that uses a gas mixture of 60% Helium and 40% Propane. These two devices measure charged track vertices and three-momenta with excellent accuracy. The drift chamber also measures energy loss, dE/dx, that is used to identify charged tracks below about 0.7 GeV/c. After the drift chamber there is a Ring Imaging Cherenkov Detector (RICH) [7], that separates pions from kaons from threshold up to about 2.7 GeV/c. The RICH is surrounded by a Thallium doped CsI crystal array consisting of about 8000 tapered crystals 30 cm long and about 5x5 cm^2 at the rear.

III. DATA SAMPLE AND SIGNAL SELECTION

In this analysis we use 0.42 fb^{-1} integrated luminosity representing all the data taken right at the Υ(5S) peak. We also use 6.34 fb^{-1} of integrated luminosity collected on the Υ(4S) and 2.32 fb^{-1} of data taken in the continuum 30 MeV in center-of-mass energy below the Υ(4S) for continuum subtraction.

We looked for D_s candidates through the reconstruction of three charged tracks in hadronic events via the $D_s^+ \to \phi\pi^+$ decay mode. Here and elsewhere in this paper mention of one charge implies the same consideration for the charge-conjugate mode. Since b-quark events are relatively isotropic compared to continuum background events, these latter ones are suppressed by requiring that the Fox-Wolfram shape parameter R_2 [8] is less than 0.25.

The tracks are required to be well measured with momenta between 0.04 and 3 GeV and have at least 50% of the expected number of hits. Each track should also have distance of closest approach to the interaction vertex in the bending plane ≤ 0.005 m and have a z coordinate of the point of closest approach in the bending (xy) plane less or equal to 0.05 m.

We use both charged particle ionization loss in the drift chamber (dE/dx) and RICH information to identify kaons and pions. The RICH is used for momenta larger than 0.62 GeV. Information on the angle of detected Cherenkov photons is translated into a Likelihood of a given photon being due to a particular particle. Contributions from all photons associated with a particular track are then summed to form an overall Likelihood denoted as $\mathcal{L}_i$ for each "i" particle hypothesis. To differentiate between pion and kaon candidates, we use the difference: $-2\log(\mathcal{L}_\pi) + 2\log(\mathcal{L}_K)$.

To utilize the dE/dx information we calculate the differences between the expected ionization losses and the observed losses divided by the error for the pion and kaon cases called σ_π and σ_K.

We use both the RICH and dE/dx information in the following manner: (a) If neither the RICH nor dE/dx information is available, then the track is accepted as both a pion and a kaon candidate. (b) If dE/dx is available and RICH is not, then we insist that pion candidates have $PID_{dE} = \sigma_\pi^2 - \sigma_K^2 < 0$ and kaon candidates have $PID_{dE} > 0$. (c) If RICH information is available and dE/dx is not available, then we require that $PID_{RICH} = -2\log(\mathcal{L}_\pi) + 2\log(\mathcal{L}_K) < 0$ for pions and $PID_{RICH} > 0$ for kaons. (d) If both dE/dx and RICH information are available, we require that $(PID_{dE} + PID_{RICH}) < 0$ for pions and $(PID_{dE} + PID_{RICH}) > 0$ for kaons.

D_s^+ candidates are searched for in the $\phi\pi^+$ decay mode using the $\phi \to K^+K^-$ channel. Pairs of oppositely charged tracks were considered as candidates for the decay products of the ϕ if each track passes the previous selection criteria (except the particle identification cut where just one of the kaons is required to pass), and if the invariant mass of the K^+K^- system was within ± 10 MeV/c^2 of the nominal ϕ mass. A third track passing the track selection requirements (listed above) except the particle identification cuts was combined with the K^+K^- system to form a D_s candidate.

To suppress combinatoric backgrounds, we take advantage of the polarization of the ϕ as it is a vector particle while the other particles are spinless. The expected distribution from real ϕ decays varies as $\cos^2\theta_h$, where θ_h is the angle between the D_s and the K^+ momenta measured in the ϕ rest frame while combinatoric backgrounds tend to be flat. Thus, we require $|\cos\theta_h|$ to be larger than 0.3.

IV. D_s PRODUCTION AT THE Υ(5S) AND Υ(4S)

A. D_s Mass Spectra and Yields

For $\phi\pi^+$ combinations satisfying the previous requirements, we look for D_s candidates having a momentum less than or equal to half of the beam energy. Instead of momentum we choose to work with the variable x which is the D_s momentum divided by the beam energy, to remove at first order differences between continuum data taken just below the Υ(4S), at the Υ(4S) and at the Υ(5S). Since we are interested in calculating the D_s yields versus x, we fit the invariant mass of the $\phi\pi^\pm$ candidates in 10 different x intervals (from 0 to 0.5) for data taken at the Υ(4S) peak, at the continuum below the Υ(4S) and at the Υ(5S) peak as shown in Fig. 1, Fig. 2 and Fig. 3, respectively.

Some x intervals did not have enough statistics to allow floating the fitting function

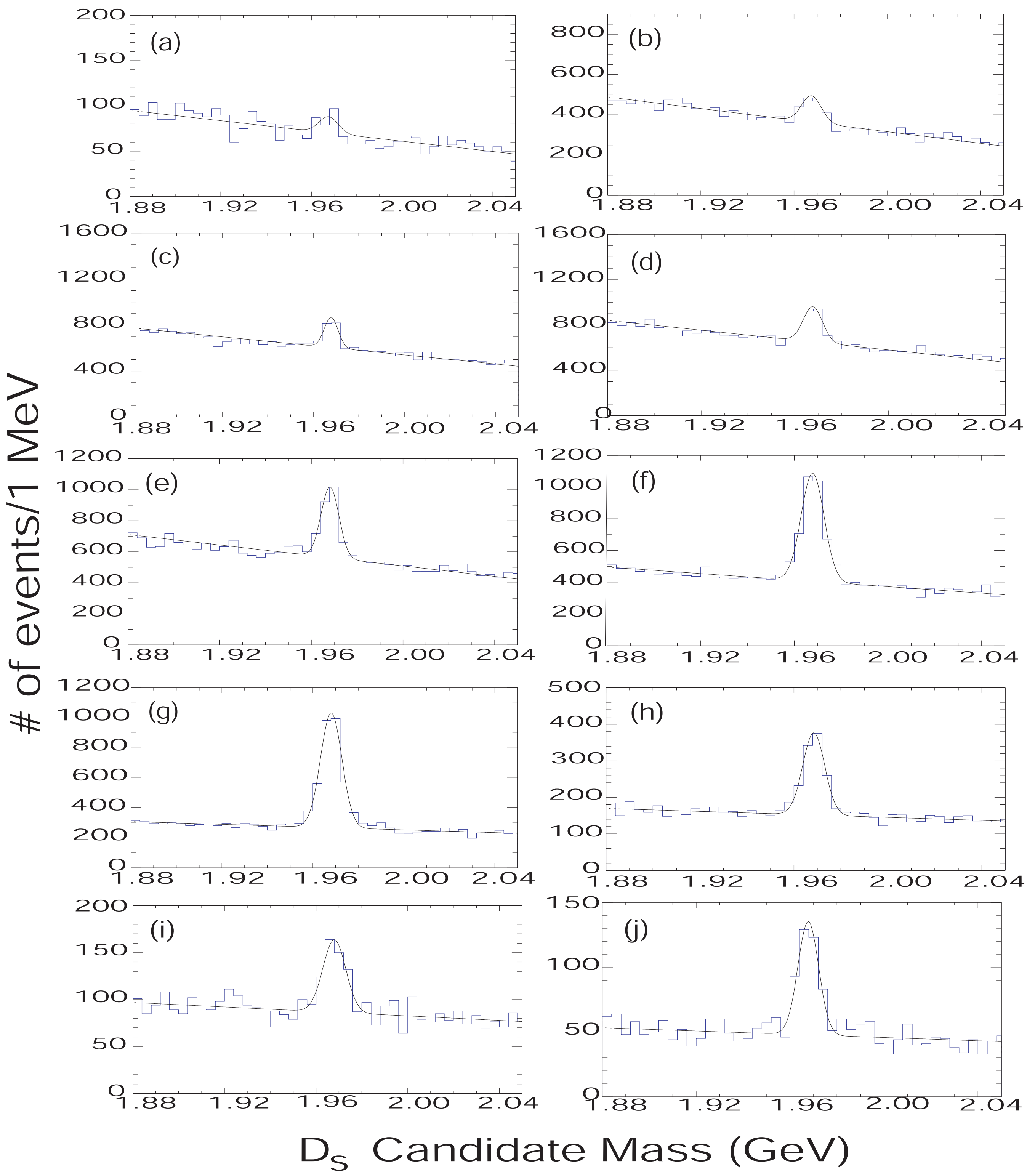

FIG. 1: The $\phi\pi^+$ mass combinations, fitted to a Gaussian signal shape centered at the D_s mass plus a polynomial background for $\Upsilon(4S)$ on-resonance data in the x intervals: (a) $0 < x < 0.05$, (b) $0.05 < x < 0.10$, (c) $0.10 < x < 0.15$, (d) $0.15 < x < 0.20$, (e) $0.20 < x < 0.25$, (f) $0.25 < x < 0.30$, (g) $0.30 < x < 0.35$, (h) $0.35 < x < 0.40$, (i) $0.40 < x < 0.45$, (j) $0.45 < x < 0.50$ (Preliminary).

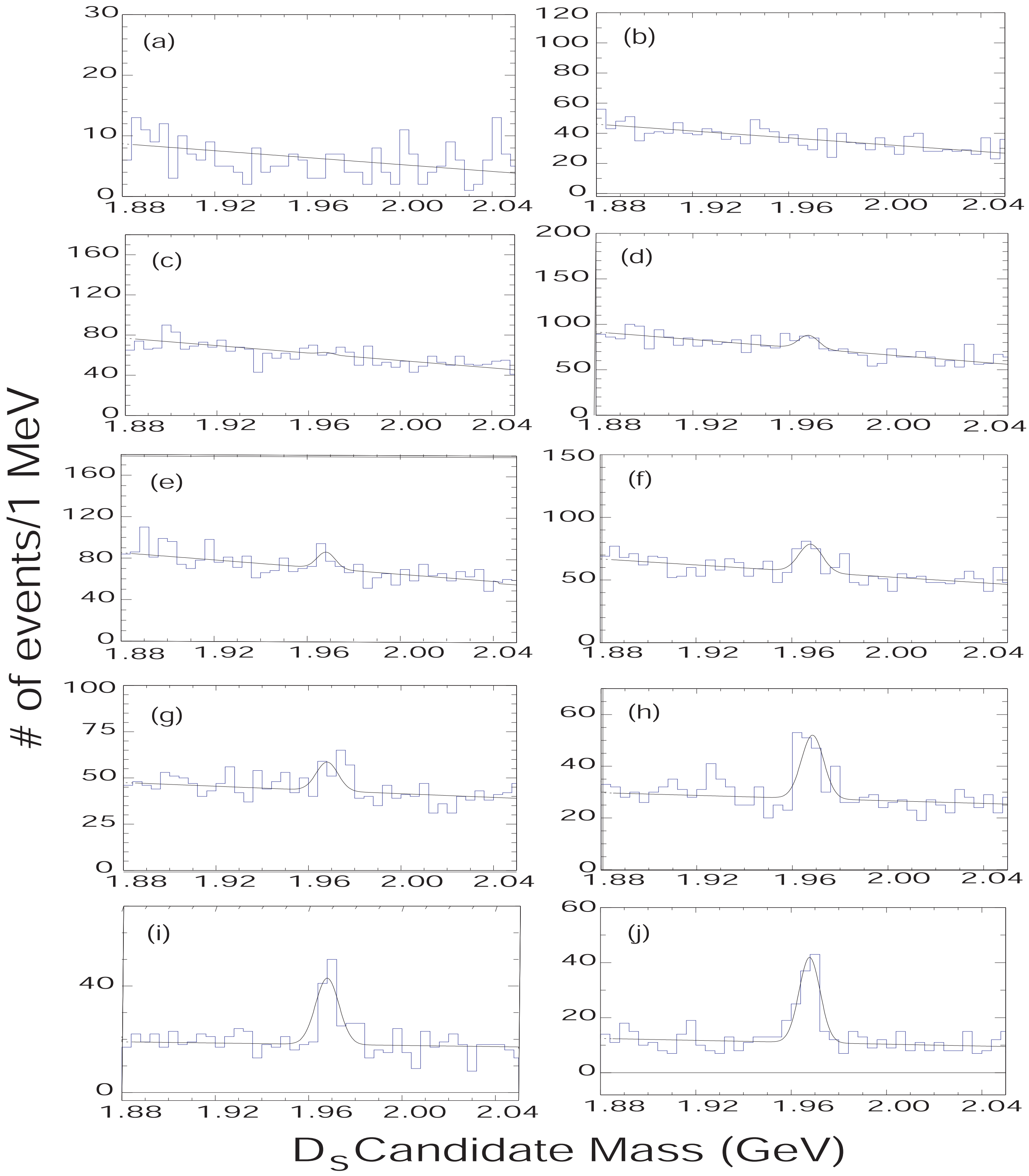

FIG. 2: The $\phi\pi^+$ mass combinations, fitted to a Gaussian signal shape centered at the D_s mass plus a polynomial background for the continuum below the $\Upsilon(4S)$ data in the x intervals: (a) $0 < x < 0.05$, (b) $0.05 < x < 0.10$, (c) $0.10 < x < 0.15$, (d) $0.15 < x < 0.20$, (e) $0.20 < x < 0.25$, (f) $0.25 < x < 0.30$, (g) $0.30 < x < 0.35$, (h) $0.35 < x < 0.40$, (i) $0.40 < x < 0.45$, (j) $0.45 < x < 0.50$ (Preliminary).

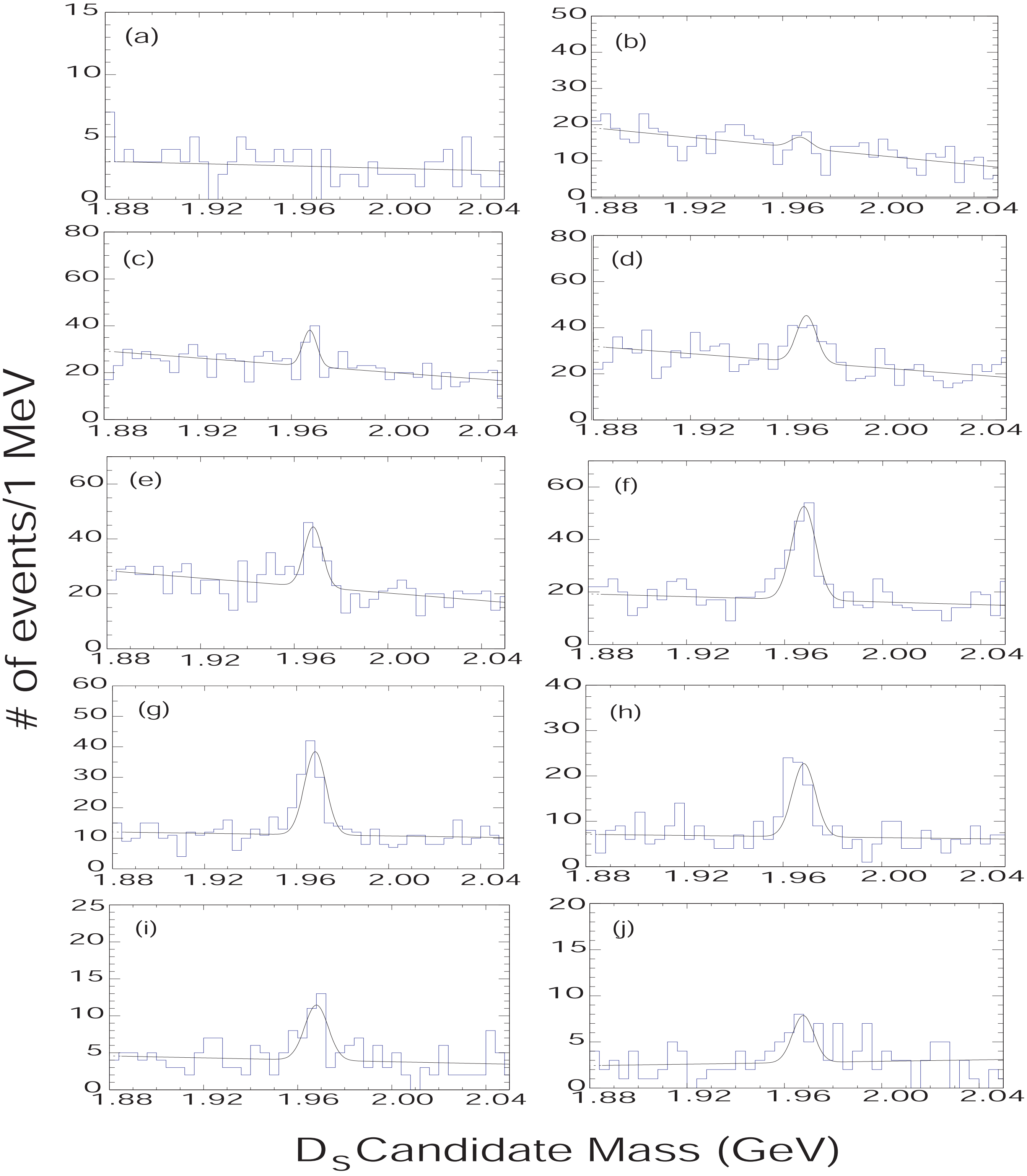

FIG. 3: The $\phi\pi^+$ mass combinations, fitted to a Gaussian signal shape centered at the D_s mass plus a polynomial background for $\Upsilon(5S)$ data in the x intervals: (a) $0 < x < 0.05$, (b) $0.05 < x < 0.10$, (c) $0.10 < x < 0.15$, (d) $0.15 < x < 0.20$, (e) $0.20 < x < 0.25$, (f) $0.25 < x < 0.30$, (g) $0.30 < x < 0.35$, (h) $0.35 < x < 0.40$, (i) $0.40 < x < 0.45$, (j) $0.45 < x < 0.50$ (Preliminary).

parameters in each of our three data samples. Thus we fixed the width of the Gaussian signal shapes by fitting the large $\Upsilon(4S)$ data sample in each x interval allowing the width to float. Then we fixed the widths to these values when fitting at the other energies. The raw D_s yields extracted from the fitting are shown in Fig. 4 (a), (b) and (c) and listed in the second and third column of Table 1 and Table 2.

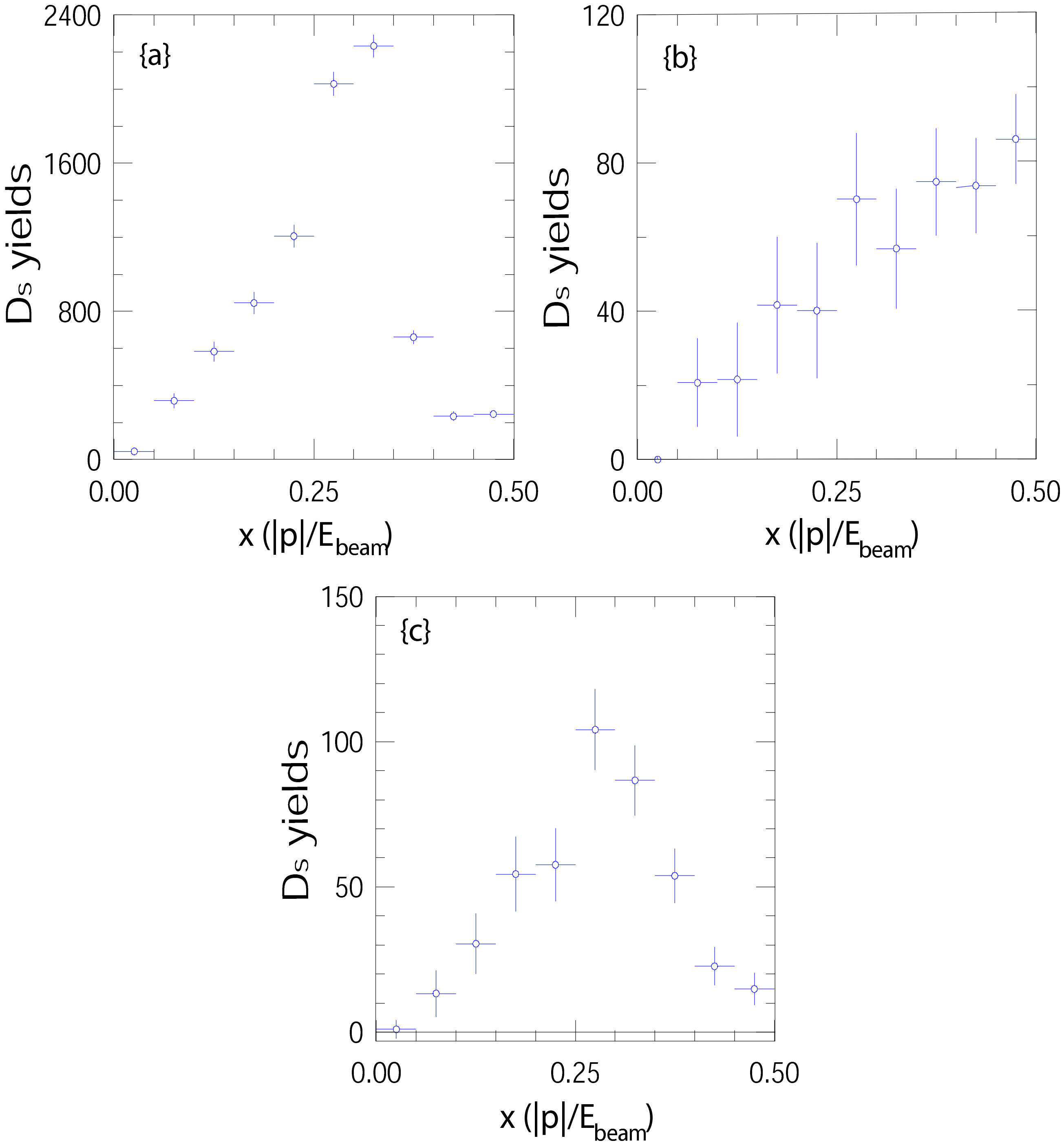

FIG. 4: D_s yields from: (a) the $\Upsilon(4S)$ data (b) the continuum below the $\Upsilon(4S)$ data (c) the $\Upsilon(5S)$ data (Preliminary).

B. Continuum Subtraction

The number of signal events is determined by subtracting the scaled continuum data below the $\Upsilon(4S)$ from the $\Upsilon(4S)$ and from the $\Upsilon(5S)$ data. We note, that the data below the $\Upsilon(4S)$ represent four-flavor continuum events containing u, d, s and c quarks. To determine the scale factor, S_i we used two different methods, the first one accounts for both the ratio of luminosities and the s dependence of the continuum cross section. Here

$$S_i = \frac{L^{(i)}}{L_{cont}} \cdot \left(\frac{E_{cont}}{E^{(i)}}\right)^2 \tag{1}$$

where $L^{(i)}$, L_{cont}, $E^{(i)}$ and E_{cont} are the collected luminosities and the center of mass energies at the resonance (i) and at the continuum below the $\Upsilon(4S)$. We find

$$S_{4S} = 2.713 \pm 0.001 \pm 0.029 \tag{2}$$

and the scale factor between the continuum below the $\Upsilon(4S)$ and the $\Upsilon(5S)$:

$$S_{5S} = (17.14 \pm 0.01 \pm 0.38) \cdot 10^{-2} \tag{3}$$

The systematic errors use the absolute errors on the luminosity determination at each energy. They are clearly conservative as part of this error will cancel since we are concerned only with the error in the luminosity ratio. To estimate the systematic error in an independent manner, we do a second measurement of these scale factors using the data and take the difference between the two values as an estimate the systematic error. In this method we measure the number of charged tracks between $0.5 < x < 0.8$ for each of the three data sets. The ratio of tracks $\Upsilon(4S)$/Continuum gives $S_{4S} = 2.738 \pm 0.008(stat)$ and for $\Upsilon(5S)$/Continuum $S_{5S} = (16.86 \pm 0.04(stat)) \cdot 10^{-2}$, both with a negligible statistical error. These numbers differ by 1.0% and 1.7% from the previous method and we take these differences as the systematic errors. Thus we use

$$S_{4S} = 2.713 \pm 0.001 \pm 0.026 \tag{4}$$

$$S_{5S} = (17.14 \pm 0.01 \pm 0.28) \cdot 10^{-2} \tag{5}$$

The four-flavor continuum subtracted D_s yields at the $\Upsilon(4S)$ and $\Upsilon(5S)$ are listed in the fourth column of Tables 1 and 2, respectively.

C. D_s reconstruction efficiency

In order to convert the fitted event numbers into branching ratios, we have simulated both $\Upsilon(4S)$ and $\Upsilon(5S)$ $B^{(*)}$ and $B_s^{(*)}$ decays that have D_s mesons in the final state. We reconstructed the simulated D_s as we did for the data and we fitted the invariant mass to a Gaussian signal and a polynomial background shape. The x dependent D_s detection efficiencies at the $\Upsilon(4S)$ and $\Upsilon(5S)$ are shown in Fig. 5. The efficiencies of two datasets are consistent with each other and since there is no reason to believe that they differ, in what follows we assume they are equal. The x dependent D_s yields extracted from the fit of the $\Upsilon(4S)$ and $\Upsilon(5S)$ simulated events are shown in Fig. 6 (a) and (b). We show in Fig. 7(a) and (b) the x distribution of the inclusive D_s yields from the $\Upsilon(4S)$ and the $\Upsilon(5S)$ decays respectively, continuum subtracted, efficiency corrected, and normalized to the number of $\Upsilon(4S)$ and $\Upsilon(5S)$ resonance events.

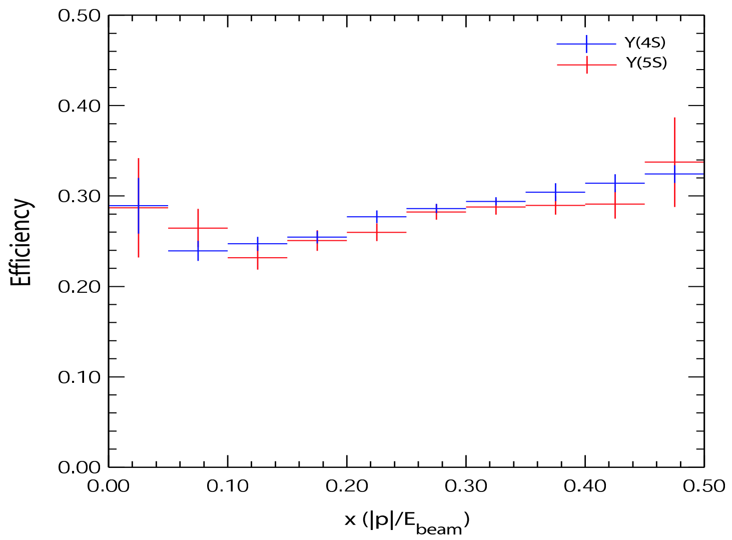

FIG. 5: D_s reconstruction efficiency from the Υ(4S) and the Υ(5S) data(scaled).

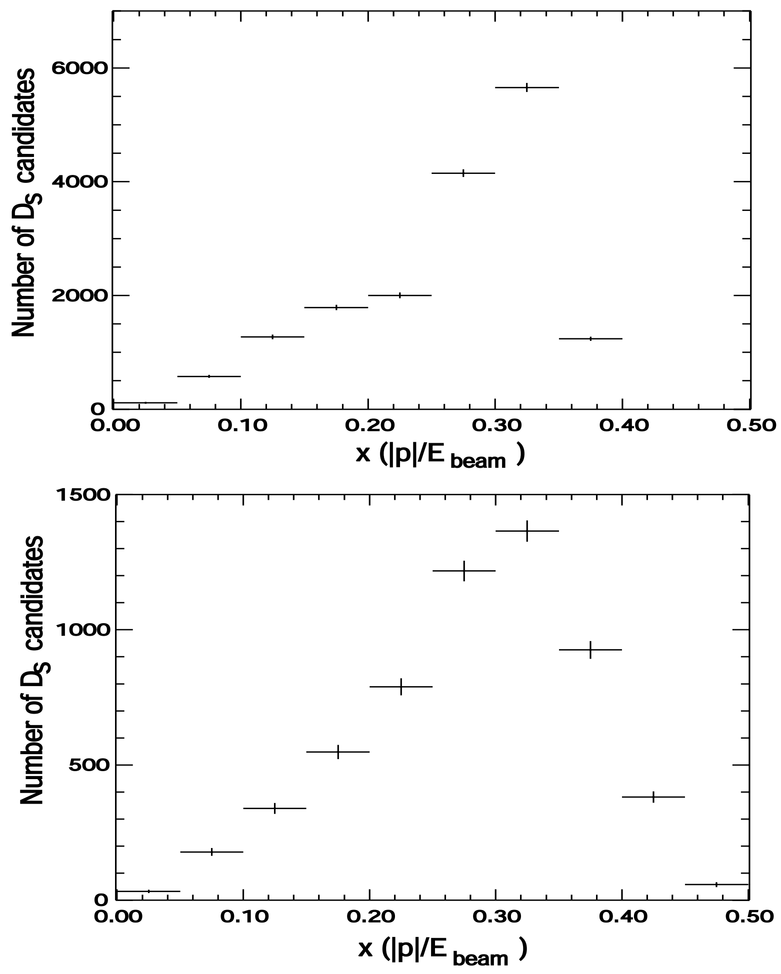

FIG. 6: D_s yields from: (a) the Υ(4S) MC (b) the Υ(5S) MC.

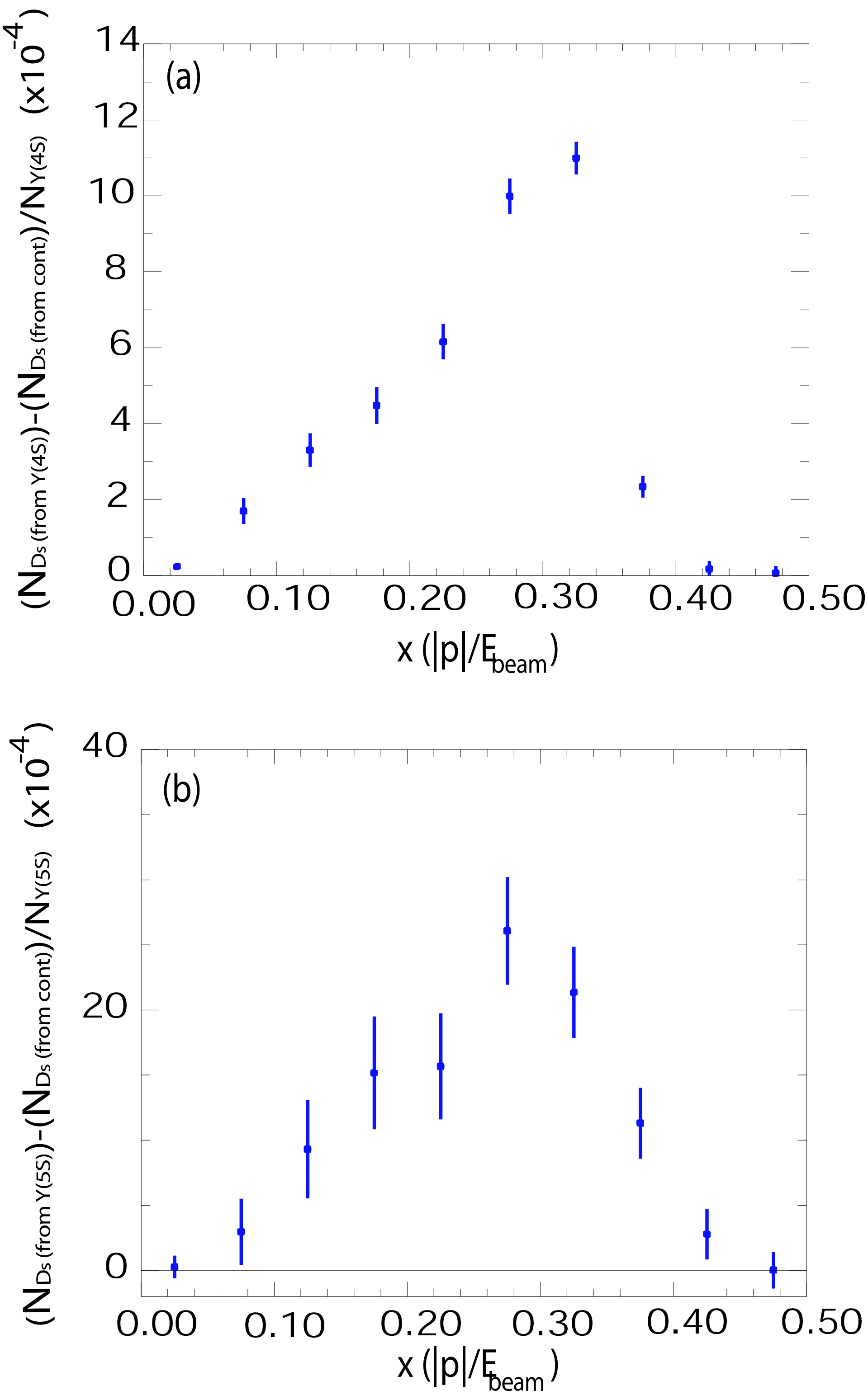

FIG. 7: D_s yields vs x from: (a) the $\Upsilon(4S)$ decays, (b) the $\Upsilon(5S)$ decays. Both plots are continuum subtracted, efficiency corrected, and normalized to the number of resonance events (Preliminary).

D. D_s production rates at the Υ(4S) and the Υ(5S)

The total number of hadronic events above four-flavor continuum at the energies corresponding to the Υ(4S) and Υ(5S) energies are

$$N^{Res}_{\Upsilon(4S)} = N^{on}_{\Upsilon(4S)} - S_{4S} * N^{off}_{\Upsilon(4S)} = 6,420,910 \pm 5,738 \pm 240,542 \tag{6}$$

$$N^{Res}_{\Upsilon(5S)} = N^{on}_{\Upsilon(5S)} - S_{5S} * N^{off}_{\Upsilon(5S)} = 131,396 \pm 810 \pm 26,546 \tag{7}$$

Using these numbers together with $N^i_{\Upsilon(4S)}$ ($N^i_{\Upsilon(5S)}$) and ϵ^i which are the D_s yield and D_s reconstruction efficiency in the i-th x interval, we measure the partial Υ(4S) and Υ(5S) to D_sX branching ratios in the ith x interval as follows

$$\mathcal{B}^i(\Upsilon(4S) \to D_sX) = \frac{1}{N^{Res}_{\Upsilon(4S)} * \mathcal{B}(D_s \to \phi\pi) * \mathcal{B}(\phi \to K^+K^-)} * \left(\frac{N^i_{\Upsilon(4S)}}{\epsilon^i}\right) \tag{8}$$

$$\mathcal{B}^i(\Upsilon(5S) \to D_sX) = \frac{1}{N^{Res}_{\Upsilon(5S)} * \mathcal{B}(D_s \to \phi\pi) * \mathcal{B}(\phi \to K^+K^-)} * \left(\frac{N^i_{\Upsilon(5S)}}{\epsilon^i}\right) . \tag{9}$$

The results are listed in Tables 2 and 3 respectively.

$x^i(\frac{\lvert p\rvert}{Ebeam})$	ON Υ(4S)	Continuum	$N^i_{\Upsilon(4S)}$	$\epsilon^i(\%)$	$B^i(\%)$
0.00-0.05	44.4 ± 15.7	0.0 ± 0.0	44 ± 16	28.9	0.1 ± 0.1
0.05-0.10	317.6 ± 39.6	20.7 ± 12.0	261 ± 51	23.9	1.0 ± 0.2
0.10-0.15	583.6 ± 53.9	21.6 ± 15.3	525 ± 68	24.7	1.9 ± 0.5
0.15-0.20	845.5 ± 59.0	41.7 ± 18.5	732 ± 77	25.4	2.5 ± 0.6
0.20-0.25	1206.4 ± 60.6	40.2 ± 18.3	1097 ± 78	27.7	3.5 ± 0.9
0.25-0.30	2028.6 ± 63.8	70.3 ± 18.0	1838 ± 80	28.6	5.6 ± 1.4
0.30-0.35	2233.7 ± 60.7	57.0 ± 16.2	2079 ± 75	29.4	6.2 ± 1.6
0.35-0.40	660.8 ± 37.9	75.0 ± 14.5	457 ± 55	30.4	1.3 ± 0.3
0.40-0.45	233.5 ± 25.9	73.4 ± 12.9	34 ± 43	31.4	0.1 ± 0.1
0.45-0.50	245.8 ± 22.2	86.0 ± 12.1	13 ± 40	32.4	0.0 ± 0.0

TABLE I: D_s yields from the Υ(4S) data, continuum below the Υ(4S) and the Υ(4S) continuum subtracted data ($N^i_{\Upsilon(4S)}$). Also listed are the D_s reconstruction efficiencies (ϵ^i), and the partial $\Upsilon(4S) \to D_sX$ branching fractions vs x (Preliminary).

To compute the total production rate, we sum the partial production rates to obtain

$$\mathcal{B}(\Upsilon(4S) \to D_sX) = \frac{1}{N^{Res}_{\Upsilon(4S)} * \mathcal{B}(D_s \to \phi\pi) * \mathcal{B}(\phi \to K^+K^-)} \sum_i \left(\frac{N^i_{\Upsilon(4S)}}{\epsilon^i}\right) \tag{10}$$

$$\mathcal{B}(B \to D_sX) = \frac{1}{2} * \mathcal{B}(\Upsilon(4S) \to D_sX) \tag{11}$$

$$\mathcal{B}(\Upsilon(5S) \to D_sX) = \frac{1}{N^{Res}_{\Upsilon(5S)} * \mathcal{B}(D_s \to \phi\pi) * \mathcal{B}(\phi \to K^+K^-)} \sum_i \left(\frac{N^i_{\Upsilon(5S)}}{\epsilon^i}\right) . \tag{12}$$

$x^i(\frac{\lvert p \rvert}{Ebeam})$	ON Υ(5S)	Continuum	$N^i_{\Upsilon(5S)}$	$\epsilon^i(\%)$	$B^i(\%)$
0.00-0.05	1.0 ± 3.2	0.0 ± 0.0	1 ± 3	28.9	0.1 ± 0.1
0.05-0.10	13.3 ± 8.1	20.7 ± 12.0	9.7 ± 8.3	23.9	1.8 ± 1.6
0.10-0.15	30.4 ± 10.4	21.6 ± 15.3	26.7 ± 10.7	24.7	4.7 ± 2.2
0.15-0.20	54.4 ± 13.0	41.7 ± 18.5	47.2 ± 13.3	25.4	8.0 ± 3.0
0.20-0.25	57.6 ± 12.7	40.2 ± 18.3	50.7 ± 13.0	27.7	7.9 ± 2.8
0.25-0.30	104.1 ± 14.0	70.3 ± 18.0	92.0 ± 14.3	28.6	13.9 ± 4.1
0.30-0.35	86.7 ± 12.1	57.0 ± 16.2	76.9 ± 12.4	29.4	11.3 ± 3.4
0.35-0.40	53.9 ± 9.4	75.0 ± 14.5	41.0 ± 9.7	30.4	5.8 ± 2.0
0.40-0.45	22.6 ± 6.7	73.4 ± 12.9	10.1 ± 7.0	31.4	1.4 ± 1.0
0.45-0.50	14.9 ± 5.6	86.0 ± 12.1	0.1 ± 6.0	32.4	0.0 ± 0.8

TABLE II: D_s yields from the Υ(5S) data, continuum below the Υ(4S) and Υ(5S) continuum subtracted data($N^i_{\Upsilon(5S)}$). Also listed are the D_s reconstruction efficiencies(ϵ^i), and the partial $\Upsilon(5S) \to D_s X$ branching fractions vs x (Preliminary).

Therefore, we measure the following preliminary quantities. The product of the D_s production rate at the Υ(4S) and the $\mathcal{B}(D_s \to \phi\pi)$ is

$$\mathcal{B}(\Upsilon(4S) \to D_s X) \cdot \mathcal{B}(D_s \to \phi\pi) = \frac{\sum_i \left(\frac{N^i_{\Upsilon(4S)}}{\epsilon^i}\right)}{N^{Res}_{\Upsilon(4S)} * \mathcal{B}(\phi \to KK)} = (8.0 \pm 0.3 \pm 0.4) \cdot 10^{-3} \quad (13)$$

and the product of the D_s production rate at the Υ(5S) and the $\mathcal{B}(D_s \to \phi\pi)$ is

$$\mathcal{B}(\Upsilon(5S) \to D_s X) \cdot \mathcal{B}(D_s \to \phi\pi) = \frac{\sum_i \left(\frac{N^i_{\Upsilon(5S)}}{\epsilon^i}\right)}{N^{Res}_{\Upsilon(5S)} * \mathcal{B}(\phi \to KK)} = (20 \pm 2 \pm 4) \cdot 10^{-3} \quad , \quad (14)$$

thus demonstrating a much larger production of D_s at the Υ(5S) energy than at the Υ(4S).

Using $\mathcal{B}(D_s \to \phi\pi^+) = (3.6 \pm 0.9)\%$ [9], we find

$$\mathcal{B}(\Upsilon(4S) \to D_s X) = (22.3 \pm 0.7 \pm 5.7)\% \quad (15)$$

hence:

$$\mathcal{B}(B \to D_s X) = (11.1 \pm 0.4 \pm 2.9)\% \quad , \quad (16)$$

which is in a good agreement with the PDG [9] value of

$$\mathcal{B}(B \to D_s X) = (10.5 \pm 2.6 \pm 2.5)\% \quad . \quad (17)$$

In addition, we find

$$\mathcal{B}(\Upsilon(5S) \to D_s X) = (55.0 \pm 5.2 \pm 17.8)\% \; . \quad (18)$$

V. B_s PRODUCTION AT THE Υ(5S)

We want to see if D_s production at the $\Upsilon(5S)$ is in excess of what is expected from $B\overline{B}$ alone. In Fig. 8 we show the D_s x spectrum from the $\Upsilon(5S)$ with the $\Upsilon(4S)$ spectrum subtracted. The data were normalized such that the number of continuum subtracted resonance decay events were the same in both cases. The spectrum shows a significant excess of D_s at the $\Upsilon(5S)$, which is a significant evidence for B_s production at the $\Upsilon(5S)$.

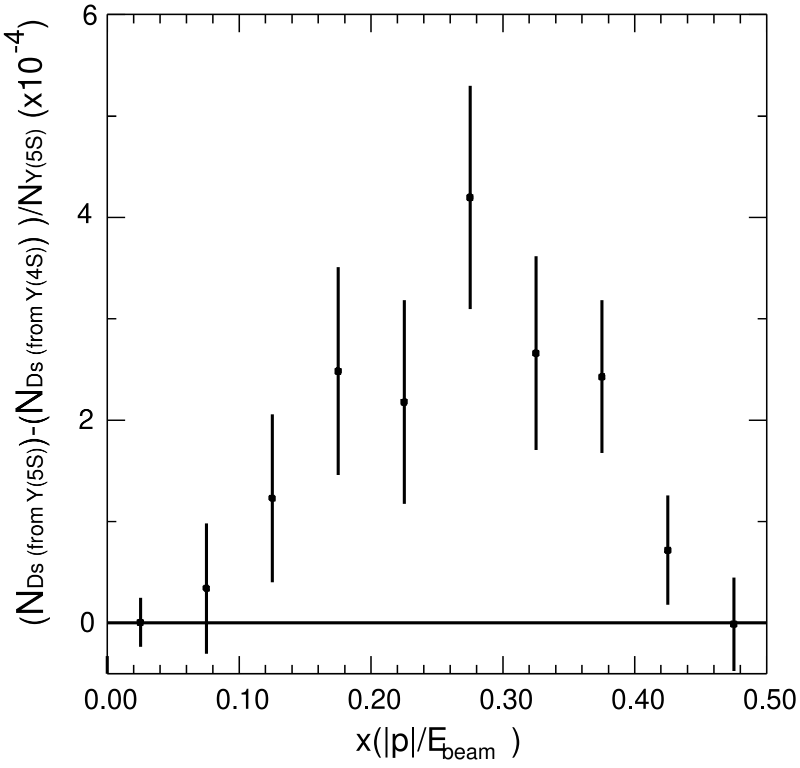

FIG. 8: The enhancement of D_s yields at the $\Upsilon(5S)$ vs x (no efficiency correction, Preliminary).

From these results, we can estimate the size of $B_s^{(*)}\overline{B}_s^{(*)}$ component at the $\Upsilon(5S)$ in a model dependent manner. We know that the preliminary $B \to D_s X$ branching ratio we

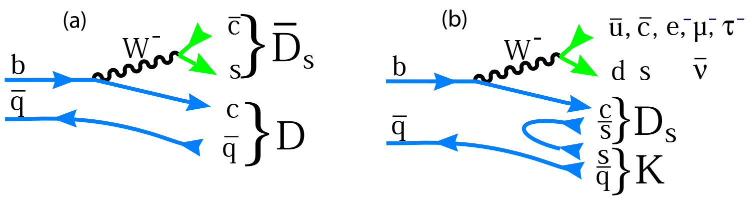

FIG. 9: Dominant decay diagrams for a B meson into D_s mesons (q can be here either a u or a d quark).

measure

$$\mathcal{B}(B \to D_s X) = (11.1 \pm 0.4 \pm 2.9)\% \tag{19}$$

comes either from the the $W^- \to \overline{c}s$ or from the $b \to c$ piece if it manages to create an $s\overline{s}$ pair through fragmentation as shown in Fig. 9(a) and Fig. 9(b) respectively.

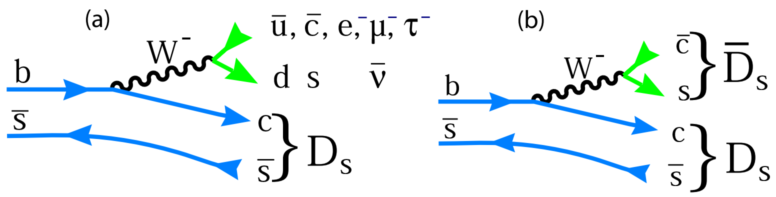

FIG. 10: Dominant decay diagrams for a B_s meson into D_s mesons.

Similarly, the production of D_s mesons from B_s decay arises from two dominant processes as well. Fig. 10 shows a large, possible greater than 100% D_s rate; here the primary $b \to c$ transition has the charm quark pairing with the spectator anti-strange quark. D_s can also be produced from the upper vertex in Fig. 10(a) when the $W^- \to \bar{c}s$ and these two quarks form a color singlet pair. The chances of this occurring should be similar to the chance of getting an upper-vertex D_s in B decay (Fig.9), that is, a D_s along with a D. We can use data to give us a guide to these processes. The $B \to DD_s$ modes have branching fractions that sum to about 5%. The observations of such B decays together with the consideration of some additional decays due to both measured and unmeasured $B \to D^{**}D_s$ and $B \to DD_{sJ}^{(*)}$ decays, lead to an estimate of an extra $(7 \pm 3)\%$ of D_s mesons in B_s decays into $D_s^{+(*)}D_s^{-(*)}$ final state. However, It is possible that some D_s are lost from these processes since any $c\bar{s}$ pairs in Fig.10(a) and Fig.10(b) could fragment into a kaon with a D particle instead of a D_s by producing a $u\bar{u}$ or $d\bar{d}$. We don't actually know the size of the fragmentation though it's clear that producing a light quark-antiquark pair ($d\bar{d}$ or $u\bar{u}$) is easier than $s\bar{s}$. Therefore, reducing the yield from the $b \to c$ transition due to fragmentations is estimated to be a $(-15 \pm 10)\%$ effect. Thus we get a model dependent estimate of $(100 + 7 - 15)\% = 92\%$,

$$\mathcal{B}(B_s \to D_s X) = (92 \pm 11)\% \tag{20}$$

We can estimate now the fraction of the Υ(5S) that decays into $B_s^{(*)}\overline{B}_s^{(*)}$, which we denote as f_s. The D_s yields at the $\Upsilon(5S)$ comes from two sources, B and B_s mesons. The equation linking them is

$$\begin{aligned}\mathcal{B}(\Upsilon(5S) \to D_s X)\mathcal{B}(D_s \to \phi\pi^+)/2 = f_s \cdot \mathcal{B}(B_s \to D_s X)\mathcal{B}(D_s \to \phi\pi^+) \\ + \frac{(1-f_s)}{2} \cdot \mathcal{B}(\Upsilon(4S) \to D_s X)\mathcal{B}(D_s \to \phi\pi^+)\end{aligned} \tag{21}$$

Where the product branching fractions $\mathcal{B}(\Upsilon(5S) \to D_s X).\mathcal{B}(D_s \to \phi\pi^+)$ and $\mathcal{B}(\Upsilon(4S) \to D_s X).\mathcal{B}(D_s \to \phi\pi^+)$ are given by equations 14 and 13 respectively. Therefore, we obtain the preliminary estimate of the $B_s^{(*)}\overline{B_s}^{(*)}$ ratio to the total $b\bar{b}$ quark pair production at the Υ(5S) energy

$$f_s \;=\; \mathcal{B}(\Upsilon(5S) \to B_s^{(*)}\overline{B}_s^{(*)}) = (21 \pm 3 \pm 9)\% \tag{22}$$

Our result agrees with the theoretical expectations [4] and [5].

VI. SOURCES AND ESTIMATION OF SYSTEMATIC ERRORS

The systematic errors in this analysis have a large component due to the 25% error on the absolute $D_s \to \phi\pi$ branching fraction.

There is also a component from the D_s detection efficiency of 4.1%, which includes a 2% error on the tracking efficiency and a 2% error on the particle identification, both per track. We also have 5% error on the yields due to the fitting method.

The 1% relative error on S_{4S} and 1.7% on S_{5S} scale factors also contribute large components to the error on the number of hadronic events above continuum at the Υ(4S) and Υ(5S) energies. Work will continue to improve the errors.

The total systematic error is obtained by summing all entries in quadrature.

VII. CONCLUSIONS

We present here the first preliminary evidence of a substantial production of B_s mesons at the Υ(5S) resonance. Using a model dependent estimate of $\mathcal{B}(B_s \to D_s X)$, we determine the $\Upsilon(5S) \to B_s^{(*)}\overline{B}_s^{(*)}$ branching fraction.

There have been several published phenomenological predictions of the different relative decay rates of the Υ(5S) into combinations of $B^{(*)}\overline{B}^{(*)}$ and $B_s^{(*)}\overline{B}_s^{(*)}$. The hadronic cross section in the Upsilon region is fairly well described by the Unitarized quark model (UQM) [4] and [5] which is a coupled channel model. In the Upsilon region, the model predicts the b-quark state meson cross section to be dominated by $B^{(*)}\overline{B}^{(*)}$ and $B_s^{(*)}\overline{B}_s^{(*)}$ production, with the latter one accounting for about one third of the total Υ(5S) cross section. However other models exist that predict a smaller amount of B_s at the Υ(5S).

Using 131,396 Υ(5S) decays and 6.42 million Υ(4S) decays collected by the CLEO III detector, we have started a series of investigations to open the mysteries of the Υ(5S) properties by performing the inclusive D_s meson study, from which we present the preliminary measurements:

- We presented the D_s meson x dependent mass and yield spectra at the continuum below the Υ(4S) resonance, at the Υ(4S) peak and at the Υ(5S) peak.

- From the Υ(4S) data, we measured the production rate of D_s mesons at the Υ(4S) to be:
$$\mathcal{B}(\Upsilon(4S) \to D_s X) \cdot \mathcal{B}(D_s \to \phi\pi) = (8.0 \pm 0.3 \pm 0.4) \times 10^{-3} \tag{23}$$
and using $\mathcal{B}(D_s \to \phi\pi^+) = (3.6 \pm 0.9)\%$ [9] we find
$$\mathcal{B}(\Upsilon(4S) \to D_s X) = (22.3 \pm 0.7 \pm 5.7)\% \tag{24}$$
and hence the Branching ratio:
$$\mathcal{B}(B \to D_s X) = (11.1 \pm 0.4 \pm 2.9)\% \tag{25}$$

- From the Υ(5S) data, we measured the production rate of D_s mesons at the Υ(5S), which has never been measured before to be:
$$\mathcal{B}(\Upsilon(5S) \to D_s X) \cdot \mathcal{B}(D_s \to \phi\pi) = (2.0 \pm 0.2 \pm 0.4) \times 10^{-2} \tag{26}$$
Using again $\mathcal{B}(D_s \to \phi\pi^+) = (3.6 \pm 0.9)\%$ [9], we find
$$\mathcal{B}(\Upsilon(5S) \to D_s X) = (55.0 \pm 5.2 \pm 17.8)\% \tag{27}$$

- We compared the D_s production rates at the Υ(5S) with the Υ(4S) and we found

$$\frac{\mathcal{B}(\Upsilon(5S) \to D_s X)}{\mathcal{B}(\Upsilon(4S) \to D_s X)} = 2.5 \pm 0.3 \pm 0.6 \tag{28}$$

  Using $\mathcal{B}(B_s \to D_s X) = (92 \pm 11)\%$, we demonstrate a substantial, model dependent estimate of ratio of $B_s^{(*)}\overline{B_s}^{(*)}$ to the total $b\bar{b}$ quark pair production at the Υ(5S) energy

$$\mathcal{B}(\Upsilon(5S) \to B_s^{(*)}\overline{B}_s^{(*)}) = (21 \pm 3 \pm 9)\% \tag{29}$$

Our result, at the current level of precision, is consistent with the previously published phenomenological prediction cited above.

[1] D. Besson *et al.* (CLEO Collaboration), Phys. Rev. Lett **54**, 381 (1985).
[2] J. Lee-Franzini *et al.* (CUSB Collaboration), Phys. Rev. Lett **65**, 2947 (1990).
[3] D. M. Lovelock *et al.* (CUSB Collaboration), Phys. Rev. Lett **54**, 377 (1985).
[4] S. Ono, A. I. Sanda and N. A. Törnqvist, Phys. Rev. Lett **55**, 2938 (1985).
[5] N. A. Törnqvist, Phys. Rev. Lett **53**, 878 (1984).
[6] S. Ono and N. A. Törnqvist, Phys. Rev. D **34**, 186 (1986).
[7] M. Artuso *et al.*, Nucl. Instrum. and Meth. **A502**, 91 (2003).
[8] G. Fox and S. Wolfram, Phys. Rev. Lett. **41**, 1581 (1978).
[9] "Review of Particle Physics", K. Hagiwara *et al.*. Phys. Rev. D 66, 010001 (2002) and 2003