UPPER LIMITS ON BEAUTY MESON PRODUCTION IN π^- COLLISIONS AT 280 GeV/c

NA3 COLLABORATION

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ABSTRACT

From events with two like-sign muons, or with three or four muons, observed in the NA3 spectrometer with 280 GeV/c incoming π^- beam, we deduce upper limits on the production of beauty meson pairs $B\bar{B}$. We use the leptonic branching ratios of B meson measured at CESR storage rings, and assume that no nuclear effects occur in the platinum target. We find $\sigma(B\bar{B}) < 2$ nb/nucleon for centrally produced $B\bar{B}$ pairs, and $\sigma(B\bar{B}) < 10$ nb/nucleon for a diffractive production. These values are one order of magnitude lower than previously published limits. As a consequence, the $\psi\psi$ events observed in our experiment cannot come from $B\bar{B}$ decays.

1) INTRODUCTION

Since the discovery in 1977 of the T meson family [1] many experiments have tried to detect particles carrying the new "beauty" quantum number which is "hidden" in the T states. In spite of considerable efforts, only indirect evidences have been found, mainly in the decay products of the T''' state in the CESR e^+e^- storage ring at Cornell [2] : this state seems to be just above threshold for the production of a pair of so-called B-mesons, carrying the beauty quantum number. Precise bounds on the B mass are obtained ($5.249 \leq M_B \leq 5.264$ GeV) and several inclusive branching ratios into leptons are given, but no exclusive hadronic decay channel has yet been seen.

In hadronic collisions, pairs of beauty mesons or baryons may be produced at high energies; for 200 GeV/c to 400 GeV/c incident particles the predicted cross sections lie in the range from some nanobarns to some hundreds of nanobarns [4].

A search for exclusive decay channels has been attempted in π^- Be collisions at 190 GeV/c [5], looking for the decay channel $B \rightarrow J/\psi + K + \pi$ as suggested by Fritzsch [6]; no signal has been found. At CERN ISR, two experiments using the same experimental facility give contradictory results on a diffractively produced Λ_b baryon [7,8].

Through the semi-leptonic cascade beauty $\rightarrow$ leptons + charm and charm $\rightarrow$ leptons + strangeness, final states with 2 like-sign muons, or 3 muons, or 4 muons may be obtained. Due to the high mass of the b - flavoured states, leptons with unusually high transverse momentum are expected, which may give a good signature of beauty. Several experiments [9-12] have already published upper limits on the production of centrally produced $B\bar{B}$ meson pairs; however these results depend on the assumed production mechanism and also on the values of the B meson branching fractions; we will come back to this point later.

2) APPARATUS AND DATA

In this letter we give results obtained from high statistics collected by the NA3 collaboration with a 280 GeV/c π^- beam hitting a 6 cm

platinum target. The NA3 spectrometer has been described elsewhere [13]; it is particularly well suited for the study of high transverse momentum muon pairs, with a good acceptance around and above the J/ψ mass. However, it may also detect events with 3 or more muons with a good acceptance.

The data discussed here correspond to an integrated beam flux of $5.4 \cdot 10^{12}$ pions, among which about $2 \cdot 10^{12}$ interacted in the target. This corresponds to a luminosity $L = 2.8 \cdot 10^{38} \text{ cm}^{-2}$ (not corrected for acceptance).

It should be noticed that the experiment was by no means designed for beauty production, its main purpose being the study of J/ψ , T and Drell-Yan physics. The trigger requirements were the following [13] :

- either one muon with P_{TV} (vertical component of the transverse momentum) greater than 1 GeV/c, and one other muon signed in the apparatus.
- or two muons with $P_{TV} > 0.7 \text{ GeV/c}$.

The mass resolution was $\sigma = \Delta m/m = 2\%$ at 4 GeV/c^2 and the momentum resolution $\Delta p/p = 2 \cdot 10^{-4} p$ (p in GeV/c).

In the following, we will consider only events in which the two triggering muons are within a time window of ± 3 nanoseconds with respect to the interaction time; the description of this cut has been given in ref.[14] concerning the double J/ψ production observed in the same sample of data. This timing requirement eliminates almost completely two important sources of background due to the large gate width (40 ns) of the counters giving the muon signature :

- Highly energetic muons from the beam halo, which are randomly detected into the spectrometer
- Pile-up of several muons from two interactions within the 40 ns gate width (the beam flux being around $2 \cdot 10^7/\text{s}$).

3) ACCEPTANCE AND MODELS

As the apparatus has a limited geometrical aperture the acceptance for a given final state depends on the detailed production and decay mechanism which is assumed for this state. We have tried in the following only $B\bar{B}$

beauty meson pair generation, since their semi-leptonic decay modes are measured. Much of our results remain valid, at least for what concerns the order of magnitude, if beauty baryons were considered.

a) $B\bar{B}$ pair generation

All previous experiments have assumed a production mechanism in which the $B\bar{B}$ pair comes from a massive "parent" having a substantial transverse momentum, of the order of 1 GeV/c. The acceptance is sensitive to the assumed $B\bar{B}$ pair production mechanism, and not to the details of the B decay.

In order to estimate the possible variations due to the $B\bar{B}$ production mechanism, we have used successively the following models :

- Model 1 : the $B\bar{B}$ pair is the two-body decay product of the T''' meson ($M = 10.56 \text{ GeV}/c^2$) which is generated following the x_F and P_T distribution observed for the T states produced in our experiment [15], this model gives for the T''' $\langle P_T \rangle \sim 1.6 \text{ GeV}/c$.
- Model 2 : The $B\bar{B}$ pair is the decay product of a mass M generated from an exponentially falling mass spectrum above $M = 10.6 \text{ GeV}/c^2$ and a transverse momentum spectrum $d\sigma/dP_T \propto P_T \exp(-1.6P_T)$ giving $\langle P_T \rangle = 1.2 \text{ GeV}/c$. This model is comparable to those of ref.[9] and [10].
- Model 3 : In contrast with the previous models, the B and $\bar{B}$ are produced without correlation with a flat x_F distribution and $\langle P_T \rangle = 300 \text{ MeV}/c$ for each B meson. This is an extreme model, to check how the acceptance varies with respect to the production mechanism, within our experimental set up.

b) B - meson decays

For the semi-leptonic decay $B \rightarrow \mu + \nu + X$ we use the CESR results [2]. The muon spectrum is well fitted with $M_X \sim 2.2 \text{ GeV}/c^2$. This gives a high value to the mean transverse momentum of the muons (about 1.2 GeV/c), which will give a clean signature of $B\bar{B}$ candidates since π and K decays have $\langle P_T \rangle \sim 300 \text{ MeV}/c$ and D mesons give muons with $\langle P_T \rangle \sim 400 \text{ MeV}/c$. The branching ratio is taken as the average value between the most recently published data from CUSB and CLEO experiments [2] :

$$R(B \rightarrow \mu + \nu + X) = 11.8 \pm 1.8\%$$

The decay $B \rightarrow J/\psi + X$ has not yet been seen at CESR; an upper limit has been given for the corresponding branching ratio [2] :

$$R(B \rightarrow J/\psi + X) < 1.4\% \text{ at } 90\% \text{ C.L.}$$

We will assume $R(B \rightarrow J/\psi + X) = 1\%$ in further calculations. We approximate the decay by a two-body process with $M_X \sim 1.2 \text{ GeV}/c^2$, the resulting acceptance being quite insensitive to this value. We use the usual branching ratio $R(J/\psi \rightarrow \mu^\pm \mu^\mp) = 7\%$

For the decay $B \rightarrow \mu^+ + \mu^- + X$, we assume a two-step decay with an intermediate charmed D meson, which then decays semi-leptonically into $\mu + X'$. Concerning the decay of B into charmed mesons, we take from the last Cornell results that the decay fraction of the beauty quark into the charmed quark is compatible with 100%. We will then assume that $R(B \rightarrow D \text{ or } D^* + X) = 100\%$. The semi-leptonic branching ratio of the D is taken from SPEAR experiments [16] to be $R(D \rightarrow \mu + \nu + X) = 8\%$; the muon spectrum is taken from the same data, corrected for the $e - \mu$ mass difference. With these hypothesis we obtain the value

$$R(B \rightarrow \mu^\pm \mu^\mp + X) = 0.95\%$$

4) EVENTS WITH LIKE-SIGN DIMUONS

Semi-leptonic decays of B mesons may give like sign dimuons, following a decay pattern like :

$$\pi^- N \rightarrow B + \bar{B} + X$$

$$\begin{array}{l} \text{then} \quad \begin{array}{l} B \rightarrow \mu + \nu + X' \\ \bar{B} \rightarrow D + Y \\ \quad \quad \quad \downarrow \\ \quad \quad \quad \mu + \nu + Y' \end{array} \end{array}$$

where X, X', Y, Y' may be various hadronic states. The signature of such a process is given by

- i) one muon with a high transverse momentum coming from the semileptonic decay of the B, typically $\langle P_T \rangle > 1.5$ GeV/c in central models (1) and (2).
- ii) the second muon with a transverse momentum substantially higher than muons from π or K decays, since it comes from the semi-leptonic decay of a D meson (typically $\langle P_T \rangle \sim 600$ MeV/c in central models).

The trigger conditions and geometry requirements (both muons in the acceptance of the "timing hodoscope") eliminate almost 90% of "central" simulated events (Models 1 and 2) and about 96% of simulated events from Model 3.

Let us now turn to the data : we start from 6082 like-sign dimuons assigned to the platinum target and satisfying the timing signature described in paragraph 2. In order to eliminate as much as possible events which cannot be $B\bar{B}$ decay candidates, we operate the following cuts :

- i) All events with one muon having a longitudinal momentum greater than 160 GeV/c are removed. This eliminates remaining muons from beam halo; 3% of data only are eliminated by this cut, and almost no remaining simulated $B\bar{B}$ events.
- ii) A cut on the transverse momentum of both muons is performed, in order to eliminate low P_T muons from π and K decays. We ask one muon with $P_T > 1.5$ GeV/c and the other with $P_T > 0.6$ GeV/c. This cut eliminates 75% of data and only 15% to 29% of simulated events surviving all previous cuts, depending on the assumed $B\bar{B}$ production mechanism.
- iii) Finally we eliminate events with $M_{\mu\mu} < 2$ GeV/c² and $x_F < 0.$, since our acceptance drops rapidly below these values, and since for $x_F < 0$ the reinteractions in the target become relatively important [17]. These cuts eliminate 26% of surviving data, and 8% to 15% of generated events surviving the previous cuts.

After these cuts, we are left with 1081 events; their mass spectrum is given on Fig.1 and can be compared to the predicted shape of mass distribution from $B\bar{B}$ decay. We are confident that beam halo contributions are negligible in this sample of events, since $\mu^+\mu^+$ and $\mu^-\mu^-$ spectra are fairly compatible.

From Fig.1, a further cut can be applied in order to enrich the sample of $B\bar{B}$ candidates. The calculated dimuon spectrum from central models, seen in our acceptance from $B\bar{B}$ decays surviving the previous cuts, peaks at mass values above $3.0 \text{ GeV}/c^2$; in contrast the data distribution falls down steeply above $2 \text{ GeV}/c^2$. We have chosen rather arbitrarily to cut events with $M_{\mu\mu} < 2.75 \text{ GeV}/c^2$: 75% of data are eliminated and 75% of simulated events from Model 1 are kept. A cut at a higher mass value could have been chosen, but it would have selected only tails of the expected distribution from Model 3, thus increasing the model dependence of the result.

Only 286 events remain with $M_{\mu\mu} > 2.75 \text{ GeV}/c^2$. In these events, possible hadronic contaminations remain, one of which may be estimated from the experiment : trimuon events with a J/ψ and a third muon, where one of the muons of the J/ψ escapes the muon hodoscope, giving a $\mu^+\mu^+$ or $\mu^-\mu^-$ pair. This background has been estimated from like-sign dimuons with a third track not signed as muon, giving a J/ψ mass with one of the identified muons : it corresponds to 57 ± 22 events which may be subtracted from the above events. Thus we are left with 229 ± 26 candidates, which give the upper limits on $B\bar{B}$ cross sections given in Table 1, using the relation :

$$\sigma(\mu^{\pm}\mu^{\pm}) = 2\sigma(B\bar{B}) R(B \rightarrow \mu + \nu + X) R(B \rightarrow D + X') R(D \rightarrow \mu + \nu + Y)$$

with the numerical values for the branching ratios given in paragraph 3. The cross sections per nucleon are given assuming no nuclear effect in the platinum target.

It should be noticed that the difference between Model 1 and Model 2 is only 20%, which is compatible with experimental errors. Model 3 gives a limit 5 times higher than other models, as could be expected since our acceptance is much better for high x_F .

In the following, we will consider only Model 1 which is the most pessimistic of the "central" models, and allows comparisons with previously published results.

5) EVENTS WITH THREE MUONS

We select events with either the three muons satisfying the timing signature within ± 3 nanoseconds, or with the two triggering muons well-timed and the other outside the acceptance of the timing device (in order to increase slightly the acceptance).

a) $J/\psi + \mu$ events

Such events may be the signature of $B\bar{B}$ production through the decays :

the signature being given by the high transverse momentum of the muon coming from the semi-leptonic decay of the B or $\bar{B}$. We start from a sample of 1116 $J/\psi + \mu$ events assigned to the platinum target. We select events with the transverse momentum of the third muon greater than 1.7 GeV/c. This value has been chosen from the estimation of the background coming from $J/\psi + \pi$ or K decays, which is negligible above 1.5 GeV/c, and from the shape of the expected P_T distribution for simulated events (Fig.2a). Table 2 gives the number of events, acceptance and cross section limits from the relation

$$\sigma[(\mu^+ \mu^- \text{ from } J/\psi) + \mu^\pm] = 2 \sigma(B\bar{B}) R(B \rightarrow J/\psi + X) R(B \rightarrow \mu + \nu + X') R(J/\psi \rightarrow \mu^+ \mu^-)$$

and taking $R(B \rightarrow J/\psi + X) = 1\%$

b) $\mu^+ \mu^- \mu^\pm$ events without J/ψ

These events may come from the semi-leptonic muon decay of one B meson, the other B meson decaying through the cascade $B \rightarrow \mu + D + X$, $D \rightarrow \mu + \nu + X'$. Events having one $\mu^+ \mu^-$ combination in the J/ψ mass region are eliminated (that is to say, with our mass resolution, $2.7 < M_{\mu^+ \mu^-} < 3.5$ GeV/c²)(Fig. 2b).

If we classify the three muons with respect to their transverse momentum :

$$P_{T_1} > P_{T_2} > P_{T_3}$$

we perform the following cuts to select $B\bar{B}$ candidates :

- P_{T_1} and $P_{T_2} > 1.5$ GeV/c, with a topology + - for muons 1 and 2, in order to select the semi-leptonic decay of the B mesons.
- $P_{T_3} > 0.4$ GeV/c in order to eliminate most of π and K decays, but not too many D meson decays.

The results are given in Table 2, the cross section being calculated from the relation

$$\sigma(\mu^+ \mu^- \mu^\pm) = 2\sigma(B\bar{B}) R(B \rightarrow \mu + \nu + X) R(B \rightarrow \mu^\pm \mu^\mp X')$$

c) Remarks

- The upper limits obtained in Table 2 are certainly too high, since all events are attributed to $B\bar{B}$ production, whereas some hadronic processes may give trimuon final states (in particular $J/\psi D\bar{D}$ production).
- The $J/\psi + \mu$ events are certainly not a good way to give reliable limits on $B\bar{B}$ production, since only an upper limit is known for $R(B \rightarrow J/\psi + X)$.

6) EVENTS WITH FOUR MUONS

Events like $\mu^+ \mu^- \mu^+ \mu^-$ may come from the decay chain of both B and $\bar{B}$ mesons through D. Of course all $\psi \mu^+ \mu^-$ or $\psi \psi$ events have to be excluded. Starting from a sample of 173 quadrimuons with a good topology, we select events with a μ^+ and a μ^- having both $P_T > 1$ GeV/c, (if we ask $P_T > 1.5$ GeV/c as required for $\mu^+ \mu^- \mu^\pm$ we find zero candidates), the two others having $P_T > 0.4$ GeV/c. At least two muons must have a good timing; the others are allowed to be outside the acceptance of the timing device. Only 3 events remain, giving the limits of Table 3 from the relation

$$\sigma(\mu^+ \mu^- \mu^+ \mu^-) = \sigma(B\bar{B}) [R(B \rightarrow \mu^\pm \mu^\mp X)]^2$$

7) COMPARISON WITH OTHER RESULTS

Previously published upper limits on $B\bar{B}$ production in hadronic collisions were obtained using different theoretical prejudices on the decay branching ratios of the B meson, in particular all of them used $R(B \rightarrow J/\psi + X) = 3\%$. In Table 3 we compare the upper limits on cross section times branching ratio in the various channels; for $\sigma(B\bar{B})$ we use values given in paragraph 2 for the branching ratios of the B meson.

The most sensitive limit is obtained from like-sign dimuons from the present data. All the limits from the four independent channels described above are compatible and much lower than previously published limits. We can conclude that at 280 GeV/c, for a centrally produced $B\bar{B}$ pair :

$$\sigma(B\bar{B}) < 2.2 \text{ nb from like-sign dimuons} \quad (1a)$$

$$\sigma(B\bar{B}) < 2.5 \text{ nb from events with 3 muons without a } J/\psi \quad (1b)$$

$$\sigma(B\bar{B}) < 8 \text{ nb from events with four muons} \quad (1c)$$

However these limits are model-dependent, since for a diffractively produced $B\bar{B}$ pair they become about 5 times higher.

These results, as well as previously published limits, have been obtained using a heavy target and assuming no nuclear effect in the $B\bar{B}$ production; this means that if the cross section is parametrized as :

$$\sigma = \sigma_0 A^\alpha$$

(A being the atomic number of the target), we suppose $\alpha = 1$. This assumption seems reasonable since for the J/ψ at the same energies $\alpha \approx 0.93$ [18] and for the T [1] $\alpha \approx 1$.

8) CONSEQUENCES OF THESE RESULTS

a) Do $\psi\psi$ events come from $B\bar{B}$ production?

From the upper limits on $\sigma(B\bar{B})$ given in this letter, we can deduce the amount of $\psi\psi$ events detected in our apparatus, which may come from $B\bar{B}$ decays :

$$\sigma(B\bar{B} \rightarrow \psi\psi) = \sigma(B\bar{B}) [R(B \rightarrow J/\psi + X)]^2$$

with

$$R(B \rightarrow J/\psi + X) < 1.4\% \text{ from ref. [2] we find :}$$

$$\begin{aligned} \sigma(B\bar{B} \rightarrow \psi\psi) &< 0.4 \text{ picobarns from (1a) or (1b)} \\ &< 1 \text{ picobarn from (1c)} \end{aligned}$$

Even if the pessimistic results from Model 3 were used, it would be impossible to account for the measured cross section found in ref. [14] at 280 GeV/c :

$$\sigma(\psi\psi) = 30 \pm 10 \text{ picobarns}$$

An independant proof of this result, without any assumption on $\sigma(B\bar{B})$, may be given as follows. Consider events with four muons, without any $\psi\psi$ candidates, corresponding to the same requirements as the 7 $\psi\psi$ events seen in our data (no cut on P_T , but all muons with a good timing signature). If all the $\psi\psi$ events come from $B\bar{B}$ decays, then we expect

$$N(4\mu) = N(\psi\psi) \frac{R(B\bar{B} \rightarrow 4\mu) \text{ Acceptance}(4\mu)}{R(B\bar{B} \rightarrow \psi\psi) \text{ Acceptance}(\psi\psi)} \quad (2)$$

With $R(B \rightarrow J/\psi + X) < 1.4\%$ we expect $N(4\mu) > 156$ events, whereas only 8 events are observed.

Thus we conclude that the $\psi\psi$ events seen in our data cannot come from $B\bar{B}$ production, which enforces arguments for other types of production ($q\bar{q}$ or gluon-gluon mechanisms [19]).

b) Contamination of Drell-Yan by $B\bar{B}$ decays

It has been sometimes argued that the Drell-Yan continuum of lepton pairs could be substantially contaminated by $B\bar{B}$ semi-leptonic decays. We have computed the acceptance for $B\bar{B} \rightarrow \mu^+\mu^-$ with $M(\mu^+\mu^-) > 4.1 \text{ GeV}/c^2$ (which is the cut taken in our Drell-Yan analysis to exclude the ψ' meson). We find that the contamination of Drell-Yan by $B\bar{B}$ is (within our acceptance) :

- < 1.1% for centrally produced $B\bar{B}$ pairs
- < 1.5% for diffractively produced $B\bar{B}$.

The contamination is therefore negligible.

9) CONCLUSIONS

As a by-product of an experiment designed to study high mass $\mu^+\mu^-$ pairs, we have given upper limits on the production of beauty meson pairs by π^- mesons at 280 GeV/c. We find $\sigma(B\bar{B}) < 2$ nanobarns/nucleon if the $B\bar{B}$ pair is produced centrally, $\sigma(B\bar{B}) < 10$ nanobarns/nucleon if it is produced diffractively. These limits are about one order of magnitude lower than previously published limits. The observation of B mesons in hadronic collisions appears thus to be an experimental challenge, which will perhaps be resolved by forthcoming experiments at higher energies.

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FIGURE CAPTIONS :

- Fig. 1 Mass and P_T distributions for the 1081 like-sign dimuons with $M_{\mu\mu} > 2 \text{ GeV}/c^2$, satisfying the cuts described in the text. The curves are predictions of Model 1 (see text) for simulated events satisfying the same cuts.
- a) Invariant mass = $\mu^+\mu^+$ (full histogram), $\mu^-\mu^-$ (dashed)
 - b) Distribution of the highest individual transverse momentum in the pair.
- Fig. 2 Events with three muons :
- a) Transverse momentum distribution of the third muon in $J/\psi + \mu$ events. Full line = 1116 events with good timing. Dashed line = background events (without good timing), normalized to the same number of events. Curve = prediction of Model 1 for simulated events satisfying all trigger and geometry requirements.
 - b) Invariant mass distribution of $\mu^+\mu^-$ pairs in all $\mu^+\mu^-\mu^\pm$ events with good timing, showing the J/ψ signal.

TABLE 1 : Acceptance and upper limits on $\sigma(B\bar{B})$ for like-sign dimuons. The limits are given for the models of $B\bar{B}$ production described in the text; the branching fraction $R(B\bar{B} \rightarrow \mu^{\pm}\mu^{\pm})$ is $1.9 \cdot 10^{-2}$.

	Acceptance	90% C.L. limit on $\sigma(\mu^{\pm}\mu^{\pm})$ (picobarns/nucleon)	90% C.L. upper limit on $\sigma(B\bar{B})$ (nanobarns/nucleon)
Model 1	2.8%	41	2.2
Model 2	3.4%	34	1.8
Model 3	0.58%	196	10.4

TABLE 2 : Acceptance and upper limits from final states with three or four muons corresponding to the cuts described in the text.

Final state	Number of events	Acceptance	90% C.L. upper limit on $\sigma(B\bar{B}) \times \text{B.F.}$ (picobarns)	90% C.L. upper limit on $\sigma(B\bar{B})$ (nanobarns)	Branching fraction (B.F.)
$J/\psi \mu^{\pm}$	20 ± 5	7.5%	1.6	9.5	$1.65 \cdot 10^{-4}$
$\mu^{+} \mu^{-} \mu^{\pm}$	22 ± 5	3.1%	0.5	2.5	$2.2 \cdot 10^{-3}$
$\mu^{+} \mu^{-} \mu^{+} \mu^{-}$	3	4%	0.75	8.0	$9 \cdot 10^{-5}$

TABLE 3 : Comparison between present experiment and previously published results :

For the comparison on $\sigma(B\bar{B})$, the previously published limits have been corrected for the now measured values of branching ratios from CESR results [2], taking $R(B \rightarrow J/\psi + X) = 1\%$. All experiments assume no nuclear effect, and use rather central models for the $B\bar{B}$ generation.

Channel	90% C.L. limit on $\sigma \times$ (B.F.) (pb/nucleon)	90% C.L. limit on $\sigma(B\bar{B})$ (nb/nucleon)	Experiment and reference
$J/\psi \mu^\pm$	5.6	34	Ref.[9] Beam dump π^- -tungsten 225 GeV/c
$\mu^+ \mu^+$ only	320	33	} Ref.[10] Target calorimeter p-Iron 400 GeV/c
$\mu^+ \mu^- \mu^\pm$	145	65	
visual detection	-	90	Ref.[12] Emulsions π^- 350 GeV/c
$J/\psi + K^*$	-	24	Ref.[5] Open spectrometer π^- Beryllium 190 GeV/c
$\mu^\pm \mu^\pm$	40	2.2	} This experiment. Beam dump π^- Platinum 280 GeV/c Values for $\sigma(B\bar{B})$ from central model
$J/\psi \mu^\pm$	1.6	9.5	
$\mu^+ \mu^- \mu^\pm$	0.5	2.5

FIG. 1a

FIG. 1b