Beauty Production at the CERN $p\bar{p}$ Collider*UA1 Collaboration, CERN, Geneva, Switzerland*

Aachen¹ - Amsterdam (NIKHEF)² - Annecy (LAPP)³ - Birmingham⁴ - Boston⁵ -
CERN⁶ - Helsinki⁷ - Kiel⁸ - Imperial College, London⁹ -
Queen Mary Westfield College, London¹⁰ - Madrid (CIEMAT)¹¹ - MIT¹² -
Padua¹³ - Paris (College de France)¹⁴ - Rome¹⁵ - Rutherford Appleton Lab¹⁶ -
Saclay (CEN)¹⁷ - UCLA¹⁸ - Vienna¹⁹ Collaboration

C. Albajar⁶, M.G. Albrow¹⁶, O.C. Allkofer^{8*}, K. Ankoviak¹⁸, R. Apsimon¹⁶,
B. Aubert³, C. Bacci¹⁵, S. Bartha⁸, G. Bauer⁵, A. Bettini¹³, A. Bezaguet⁶,
P. Biddulph¹⁰, H. Bohn⁸, A. Böhrer¹, R. Bonino⁶, K. Bos², M. Botlo⁶,
D. Brockhausen⁸, C. Buchanan¹⁸, B. Buschbeck¹⁹, G. Busetto¹³, A. Caner¹³,
P. Casoli¹³, H. Castilla-Valdez¹⁸, F. Cavanna³, P. Cennini⁶, S. Centro¹³,
F. Ceradini¹⁵, G. Ciapetti¹⁵, S. Cittolin⁶, E. Clayton⁹, D. Cline¹⁸, J. Colas³,
R. Conte¹³, J.A. Coughlan¹⁶, D. Dau⁸, C. Daum², M. Della Negra⁶, M. Demoulin⁶,
D. Denegri¹⁷, H. Dibon¹⁹, A. DiCiaccio¹⁵, F.J. Diez Hedo⁶, L. Dobrzynski¹⁴,
J. Dorenbosch², J. D. Dowell⁴, D. Drijard⁶, K. Eggert⁶, E. Eisenhandler¹⁰, N. Ellis⁴,
H. Evans¹⁸, H. Faissner¹, M. Felcini⁵, I.F. Fensome⁴, A. Ferrando¹¹, L. Fortson¹⁸,
T. Fuess¹², J. Garvey⁴, A. Geiser¹, A. Givernaud⁶, A. Gonidec⁶, B. Gonzalez^{18*},
J. M. Gregory⁴, J. Gronberg¹⁸, D.J. Holthuisen², W. Jank⁶, G. Jorat⁶, M.I. Josa¹¹,
P.I.P. Kalmus¹⁰, V. Karimäki⁷, I. Kenyon⁴, R. Kinnunen⁷, M. Krammer¹⁹,
D. Kryn¹⁴, F. Lacava¹⁵, S. Lammel¹, M. Landon¹⁰, Y. Lemoigne¹⁷, S. Levegrün⁸,
D. Linglin³, P. Lipa¹⁹, C. Markou⁹, M. Markytan¹⁹, M.A. Marquina⁶, R. Martinelli¹³,
G. Maurin⁶, S. McMahon⁹, J.-P. Mendiburu¹⁴, A. Meneguzzo¹³, J. P. Merlo¹⁷,
T. Meyer⁶, T. Moers¹, M. Mohammadi¹⁸, K. Morgan⁵, A. Morsch⁸, A. Moulin¹,
Th. Muller⁶, R. Munoz⁶, L. Naumann⁶, P. Nedelec¹⁴, M. Nikitas⁴, A. Nisati¹⁵,
A. Norton⁶, V. O'Dell¹⁶, S. Otwinowski⁵, G. Pancheri¹², M. Passaseo¹⁵, F. Pauss⁶,
E. Petrollo¹⁵, G. Piano Mortari¹⁵, E. Pietarinen⁷, M. Pimiä⁷, A. Placci⁶,
L. Pontecorvo¹⁵, J.-P. Porte⁶, R. Priem¹, R. Prosi⁸, E. Radermacher⁶,
M. Rauschkoib⁸, H. Reithler¹, J.-P. Revol^{6,12}, S. Robins¹⁰, D. Robinson¹⁰,
T. Rodrigo⁶, J. Rohlf⁵, C. Rubbia⁶, G. Sajot¹⁴, J.M. Salicio¹¹, D. Samyn⁶,
D. Schinzel⁶, R. Schleichert¹, M. Schröder², C. Seez⁹, T. P. Shah^{6,16},
P. Sphicas⁶, D. Stork¹⁸, C. Stubenrauch⁶, K. Sumorok¹², F. Szoncs¹⁹,
C. H. Tan¹², A. Taurok¹⁹, L. Taylor⁹, S. Tether¹², H. Teykal¹, G. Thompson¹⁰,
E. Torrente-Lujan¹¹, H. Tuchscherer¹, J. Tuominiemi⁷, W. van de Guchte²,
A. van Dijk², M. Vargas¹⁸, S. Veneziano¹⁵, J.P. Vialle³, T.S. Virdee^{6,9},
W. von Schlippe¹⁰, J. Vrana¹⁴, V. Vuillemin⁶, K. Wacker¹, H. Wagner¹, X. Wu¹²,
C.-E. Wulz¹⁹, M. Yvert³, I. Zacharov⁶, L. Zanello¹⁵, Y. Zolnierowski¹³ and P. Zotto⁶.

(submitted to Phys. Lett. B)

(* deceased)

Abstract

We report measurements of b-quark and B-hadron production in $p\bar{p}$ collisions at $\sqrt{s} = 630$ GeV. We use muon data samples to extract beauty production cross-sections over a wide range of transverse momentum in the central rapidity range $|y| < 1.5$. We compare our results to an $O(\alpha_s^3)$ QCD prediction and find good agreement over the measured b-quark transverse momentum range 6 GeV/c to 54 GeV/c. Using the shape of the p_T and y distributions predicted by QCD to extrapolate our data, we infer a total cross-section for b-quark production at $\sqrt{s} = 630$ GeV of $\sigma(p\bar{p} \rightarrow b\bar{b} + X) = 19.3 \pm 7(\text{exp.}) \pm 9(\text{th.}) \mu\text{b}$.

1. Introduction

We present an analysis of 4.7 pb^{-1} of muon data recorded by the UA1 collaboration at the CERN $p\bar{p}$ collider during 1988 and 1989. We study b-quark and B-hadron production using four independent decay channels: (i) $p\bar{p} \rightarrow b \rightarrow \mu X$; (ii) $p\bar{p} \rightarrow b \rightarrow J/\psi$ followed by $J/\psi \rightarrow \mu^+\mu^-$; (iii) $p\bar{p} \rightarrow b \rightarrow c\mu X$ followed by $c \rightarrow \mu X$; (iv) $p\bar{p} \rightarrow b\bar{b}$ followed by $b \rightarrow \mu X$ and $\bar{b} \rightarrow \mu X$. We measure cross-sections for each of these processes from which we infer b-quark and B-hadron cross-sections using the method described in ref. [1].

This work improves on our earlier analysis of b-quark production in the following respects. We have extended our analysis of b-quark production to higher transverse momentum and include for the first time cross-sections for B-hadrons. By using muon-jet data and requiring non-isolated muons we have reduced the sensitivity to non-heavy-flavour processes, especially $W \rightarrow \mu\nu$ at high muon transverse-momentum.

2. Muon measurements

The UA1 detector and triggering systems have been described elsewhere [2]. In this section we present measurements of cross-sections for prompt muons originated from the processes discussed above. In section 3 we discuss how these prompt muon cross-sections are used to infer cross-sections for b-quark and B-hadron production at large transverse momentum.

2.1. Muon-jet events

The muon-jet data sample consists of 6103 events containing at least one high transverse-momentum muon ($p_T^\mu > 10 \text{ GeV}/c$) and at least one high transverse-energy jet ($E_T > 10 \text{ GeV}$) separated from the muon by more than $\Delta R = [\Delta\eta^2 + \Delta\phi^2]^{1/2} = 1.0$ in pseudorapidity-azimuth space. The muon is required to lie in the central rapidity range $|\eta| < 1.5$. At low p_T^μ , the dominant source of background is the decay of pions and kaons in flight, which represents 38% of the muons.

In our previous analysis [1], we used inclusive muon data with no jet requirement for which the dominant source of muons at high p_T^μ was from $W \rightarrow \mu\nu$ and $Z \rightarrow \mu^+\mu^-$ decays. The subtraction of these contributions required a detailed understanding both of the W and Z cross-sections and of the resolution of the muon momentum measurement which had to be unfolded. By demanding a jet with $E_T > 10 \text{ GeV}$, the contribution from these processes is very much reduced, while the acceptance for muons from heavy-flavour decays is in the range 0.65–0.81 depending on p_T^μ . A better description of the resolution of the muon momentum measurement was achieved by including some systematic uncertainties affecting the muon reconstruction, which were neglected in our

previous analysis, hence the corrections to the muon cross-sections at large p_T^μ due to resolution effects are more reliable

To further reduce the contribution from non-heavy-flavour events we require that the muons are non-isolated ($I > 2$), as expected in semileptonic charm and beauty decays. We use the same isolation variable as in refs. [2, 3]: $I = [(\Sigma E_T(\mu)/3))^2 + (\Sigma p_T(\mu)/2)^2]^{1/2} < 2$ GeV, where $\Sigma E_T(\mu)$ and $\Sigma p_T(\mu)$ are the transverse-energy and transverse-momentum sums in a cone of $\Delta R = 0.7$ defined around the direction of the muon. Finally we suppress contributions from $W \rightarrow \mu\nu$ decays by applying a muon-neutrino transverse-mass cut, $m_T < 25$ GeV/c². The transverse mass is defined as $m_T = [2p_T^\mu p_T^\nu (1 - \cos\Delta\phi_{\mu\nu})]^{1/2}$, where p_T^μ is the transverse momentum of the muon, p_T^ν is the missing transverse energy and $\Delta\phi_{\mu\nu}$ is the azimuthal angle difference between the muon and the missing transverse energy. These cuts reject only 4% of the events where the muons come from semileptonic heavy-flavour decays.

We measure the fraction of $b\bar{b}$ events in the data on a statistical basis using the transverse momentum of the muon with respect to the axis of the jet containing the muon, p_T^{rel} . As in ref. [3] the jet axis is measured with charged tracks only in a cone radius of $\Delta R = 0.6$, using the muon track as initiator. The jet is required to have at least one track with $p_T > 1$ GeV/c in addition to the muon. The result of fitting the data with a sum of contributions for $b\bar{b}$ and $c\bar{c}$ events, plus the background is shown in fig. 1. The shapes for $b\bar{b}$ and $c\bar{c}$ are predicted by the ISAJET Monte Carlo program [4]. The background comes mainly from decays of pions and kaons in flight. However, it also includes small contributions from the Drell-Yan mechanism, and from $J/\psi \rightarrow \mu^+\mu^-$, $\Upsilon \rightarrow \mu^+\mu^-$, $W \rightarrow \mu\nu$ and $Z \rightarrow \mu^+\mu^-$ decays. The background is constrained to the calculated number of background events (see ref. [2] for a description of how the background is calculated). The $b\bar{b}$ and $c\bar{c}$ fractions are determined by fitting to the data with a weighted sum of the predictions for the two processes. It is worth noting that the ISAJET Monte Carlo model [4] describes well many features of the muon-jet events, as shown in ref. [2,3].

We find the fraction of $b\bar{b}$ events in the data to be $0.33 \pm 0.03 \pm 0.03$ where the first error is statistical and the second one reflects the uncertainty on the normalization of the background. The ratio of numbers of events $N(b\bar{b})/[N(b\bar{b})+N(c\bar{c})] = 0.54 \pm 0.10$ is assumed to be constant over the range of p_T^μ considered below. We have checked that the values for this ratio obtained for p_T^μ between 10 GeV/c and 15 GeV/c, and for p_T^μ between 15 GeV/c and 20 GeV/c are consistent with this assumption.

We measure the cross-section for muons from beauty decays, $\sigma(p\bar{p} \rightarrow b \rightarrow \mu X)$, in six bins in p_T^μ from 10–40 GeV/c as shown in table 1. The non-heavy-flavour contribution (predicted by the Monte Carlo and the background calculation) is subtracted, then the ratio $N(b\bar{b})/[N(b\bar{b})+N(c\bar{c})]$ is used to calculate the cross-section

from beauty decays. A correction is made for the inefficiency of the jet, isolation and transverse-mass cuts for $b\bar{b}$ events. The systematic errors include an 8% uncertainty on the integrated luminosity and 12% from the jet energy scale uncertainty. We also include systematic errors for the detector acceptance (8%) and for uncertainties in correcting for the resolution of the muon transverse-momentum measurement which are important at high p_T^μ (2% for $p_T^\mu = 10\text{--}15\text{ GeV}/c$, rising to 50% for $p_T^\mu = 35\text{--}40\text{ GeV}/c$).

2.2. The J/ψ sample

The UA1 J/ψ results have been presented in a recent paper [5]. In summary, the cross-section times branching ratio for J/ψ production is found to be $BR(J/\psi \rightarrow \mu^+\mu^-)\sigma(p\bar{p} \rightarrow J/\psi) = 6.18 \pm 0.24 \pm 0.81\text{ nb}$ for $p_T > 5\text{ GeV}/c$ and $|\eta| < 2.0$. The fraction of J/ψ 's from B-hadron decays is measured using the isolation of the observed J/ψ 's. We find that $(31 \pm 2 \pm 12)\%$ of the observed events come from $p\bar{p} \rightarrow b \rightarrow J/\psi X$, with the remainder coming from direct charmonium production. Thus we obtain a cross-section for J/ψ production via B-hadron decays $BR(J/\psi \rightarrow \mu^+\mu^-)\sigma(p\bar{p} \rightarrow J/\psi) = 1.92 \pm 0.15 \pm 0.79\text{ nb}$ for $p_T^{J/\psi} > 5\text{ GeV}/c$ and $|\eta| < 2.0$. We estimate that $(25 \pm 10)\%$ of this cross-section comes from the chain $b \rightarrow \psi' \rightarrow J/\psi$.

2.3. The high-mass dimuon sample

The high-mass dimuon sample contains 2444 events having two reconstructed muons, each with $p_T^\mu > 3\text{ GeV}/c$. The invariant mass of the dimuon system is required to lie in the range $6\text{ GeV}/c^2 < m_{\mu\mu} < 35\text{ GeV}/c^2$. The lower limit ensures that the muons do not come from the same parent b-quark and the upper limit excludes $Z \rightarrow \mu^+\mu^-$ decays.

The isolation of the dimuons is defined using the variable

$$S = (\Sigma E_T(\mu_1)/2)^2 + (\Sigma p_T(\mu_1))^2 + (\Sigma E_T(\mu_2)/2)^2 + (\Sigma p_T(\mu_2))^2$$

where $\Sigma E_T(\mu)$ and $\Sigma p_T(\mu)$ are defined in section 2.1 above. We define isolated events to be those which have $S < 8\text{ GeV}^2$; the majority of such events are from the Drell-Yan mechanism and from $\Upsilon \rightarrow \mu^+\mu^-$ decays.

We use p_T^{rel} to measure the fraction of $b\bar{b}$ events in the high-mass, non-isolated dimuon data, as in our analysis of data from the 1984 and 1985 runs [6]. The p_T^{rel} distributions are plotted in fig. 2a and fig. 2b for the like-sign (325 events) and unlike-sign (525 events) events respectively. The main background to the charm and beauty events is from the decay-in-flight of pions and kaons which accounts for 28% (44%) of the unlike-sign (like-sign) data. For the like-sign events, the fitted $c\bar{c}$ fraction is

consistent with zero as expected. For the unlike-sign events (fig. 2b) we find the fractions of $b\bar{b}$ and $c\bar{c}$ events to be $(55 \pm 4 \pm 1)\%$ and $(17 \pm 4 \pm 4)\%$, respectively.

Using the measured $b\bar{b}$ fraction, we obtain $\sigma(p\bar{p} \rightarrow b\bar{b} \rightarrow \mu\mu X) = 2.12 \pm 0.15 \pm 0.36$ nb for both muons with $p_T^\mu > 3$ GeV/c in the central rapidity region $|\eta| < 1.5$, and dimuon mass in the range $6 \text{ GeV}/c^2 < m_{\mu\mu} < 35 \text{ GeV}/c^2$. Small contributions from the Drell-Yan mechanism and from $\Upsilon \rightarrow \mu^+\mu^-$ and $Z \rightarrow \mu^+\mu^-$ decays have been subtracted. The systematic errors include the uncertainties on the integrated luminosity (8%), the normalization of the background (1%), the trigger efficiency and detector acceptance (10%), and the efficiency of the non-isolation requirement (10%). The very small error from the normalization of the background results from the distinctive p_T^{rel} distribution for b-quark decays.

2.4. The low-mass dimuon sample

The low mass dimuon sample contains 1529 events of which 1278 are unlike-sign and 251 are like-sign. Both muons are required to have $p_T^\mu > 3$ GeV/c and the invariant mass of the dimuon system is required to have $2m_\mu < m_{\mu\mu} < 6 \text{ GeV}/c^2$. Because of the p_T^μ and mass cuts, both muons tend to be in the same azimuthal half-cylinder. This means that the cones defined around the muon direction for the purpose of the isolation measurement may overlap. If the distance between the two muons in pseudorapidity–azimuth space is less than $\Delta R = 1.4$, we define an event as isolated if $I(\mu_1) < 2.5$ GeV and $I(\mu_2) < 2.5$ GeV for the individual muons, and $I(\mu\mu) < 2.5$ GeV for a cone around the dimuon momentum vector. Here, we define $I(\mu) = [(\Sigma E_T(\mu)/2)^2 + (\Sigma p_T(\mu))^2]^{1/2}$ where $\Sigma E_T(\mu)$ and $\Sigma p_T(\mu)$ are as defined in section 2.1 above.

In fig. 3 we show the invariant mass distribution for the non-isolated, unlike-sign, low-mass dimuon events; the sample contains 731 events. We make a simultaneous fit to the invariant mass distributions for isolated and non-isolated, like-sign and unlike-sign events as described in ref. [7]. Figure 3 shows the results of the fit, where the solid line includes contributions from J/ψ , ψ' , ρ , ω , ϕ , η and η' , and a small contribution from the Drell-Yan mechanism, in addition to heavy-flavour semileptonic decays and the background from decays-in-flight. The individual contributions from b-chain decays ($b \rightarrow c\mu X$ followed by $c \rightarrow \mu X$), other heavy-flavour processes ($Q\bar{Q} = b\bar{b}$ or $c\bar{c}$) where the muons originate from different heavy quarks, and the background are also shown. We estimate 204 ± 38 events from charm and beauty decays in the non-isolated, unlike-sign sample. Of these, 100 ± 27 events are attributed by the fit to b-chain decays.

We find $\sigma(p\bar{p} \rightarrow b \rightarrow \mu\mu X) = 0.27 \pm 0.07 \pm 0.04$ nb from b-chain decays for both muons with $p_T > 3$ GeV/c in the central rapidity region $|\eta| < 1.5$. The systematic error includes the uncertainty on the integrated luminosity (8%) and the acceptance (11%).

3. Determination of b-quark and B-hadron cross-sections

To relate our measured muon cross-sections to quark and hadron cross-sections, we use the ISAJET Monte Carlo model [4] as described in ref. [1]. Briefly, each muon sample is sensitive to a range of b-quark (B-hadron) transverse momentum above some minimum value. We define $p_T^{min}(b)$ for each sample, such that 90% of the b-quarks which contribute to the muon sample have $p_T^b > p_T^{min}(b)$. Then we estimate the cross-section ratios $\sigma(p\bar{p} \rightarrow b+X; p_T^b > p_T^{min}(b))/\sigma(\text{muon})$ for each muon sample. These ratios depend mainly on the b-quark fragmentation function, branching ratios and decay kinematics, all of which have been studied in experiments at e^+e^- colliders; they also depend on the assumed shape of the b-quark transverse-momentum distribution. For B-hadron measurements, p_T^{min} and the cross-section ratio are similarly defined.

The uncertainties in the above method result from the following:

- (i) The choice of fragmentation function parameterization. We use the form due to Peterson et al. [8] with $\epsilon_b = 0.02$. The uncertainty on the fragmentation function has little effect on the hadron cross-section determination. However, for the quark cross-section, we include a 6% error from this source (12% for the high-mass dimuon measurement where the two muons come from the fragmentation of different b quarks). The fragmentation model which we use gives good agreement with recent results from LEP [9].
- (ii) The uncertainty on the branching fractions. We use recent measurements [10], $BR(b \rightarrow \mu) = 10.2\%$ and include a 10% error on this value. (The shape predicted by ISAJET for the lepton spectrum in the decay $B \rightarrow \mu$ has been checked against measurements from $\Upsilon(4S)$ decays [9].) For the measurement with J/ψ 's, we take $BR(b \rightarrow J/\psi) = (1.12 \pm 0.18)\%$ and $BR(J/\psi \rightarrow \mu^+\mu^-) = (6.9 \pm 0.9)\%$. For the low-mass dimuon measurement, we include a 20% uncertainty on the average branching ratio for $c \rightarrow \mu$; this is needed because of the large difference in semileptonic branching ratios between neutral and charged D-mesons, combined with the unknown mixture of charmed hadrons produced in the B-hadron decays.
- (iii) The assumed shape of $d\sigma/dp_T^b$. We use the shape given by the ISAJET flavour-creation process which agrees well with the $O(\alpha_s^3)$ QCD prediction of Nason et al. [11]. As in [1], we include a 20% uncertainty on the b-quark and B-hadron cross-sections from this source.

For each sample we quote cross-sections for b-quark ($Q = -1/3$ only) and B-hadron (one charge only) production in the rapidity range $|y| < 1.5$. The results are given in table 2 and are shown in figs. 4 and 5 for the b-quark and B-hadron measurements respectively. We remark that to extract an inclusive cross-section from the high-mass dimuon measurement (open circle), we have to rely on the ISAJET prediction for the correlation between the b and the $\bar{b}$ -quark, since the two muons originate from two different b's. All the other measurements, where the muons come from the same b-quark, are directly related to the inclusive b-quark cross-section.

4. Comparison with QCD

In fig. 4 we show a comparison of our data with the $O(\alpha_s^3)$ QCD prediction of Nason et al. [11]. The uncertainties in the prediction are due to the value of the b-quark mass m_b , the value of the QCD parameter Λ , the choice of the factorisation scale μ and the choice of the structure functions. There is good agreement over the whole measured range of p_T^{min} .

Normalizing the QCD prediction shown in fig. 4 to the first three data points, excluding the high-mass dimuon point, and extrapolating to $p_T^{min} = 0$, we obtain a prediction for the b-quark production cross-section in the central rapidity range $|y| < 1.5$ of $\sigma(p\bar{p} \rightarrow b+X) = 12.8 \pm 4.7(\text{exp.}) \pm 6(\text{th.}) \mu\text{b}$. Using the rapidity dependence predicted by QCD, we obtain a total cross-section for b production at $\sqrt{s} = 630 \text{ GeV}$ integrated over all rapidities of $\sigma(p\bar{p} \rightarrow b\bar{b}+X) = 19.3 \pm 7(\text{exp.}) \pm 9(\text{th.}) \mu\text{b}$. The first experimental error results from the normalisation of the theoretical QCD shape to the data; the second theoretical error is an estimation of the error in the extrapolation coming from the uncertainty on the QCD predicted shape. We note that in our previous publication [1] the first three data points are in agreement with the new measurements and that the smaller extrapolated cross-section quoted in [1] is only due the difference in the QCD shape used for the extrapolation. In [1] we used a preliminary calculation by Nason done with a factorisation scale $\mu = m_b = 5 \text{ GeV}/c^2$; in this analysis the QCD shape is obtained with a different factorisation scale [4]: $\mu = [(p_T^{min})^2 + m_b^2]^{1/2}$, $m_b = 4.75 \text{ GeV}/c^2$. The quoted theoretical error reflects the effect of the different shapes. In making the above extrapolation, we assume that b production is entirely explained by perturbative QCD processes up to $O(\alpha_s^3)$; in particular we neglect forward production of b-quark by non-perturbative processes such as diffraction.

5. Conclusions

We have measured production cross-sections for muons originating from b-quark decays using four independent muon samples. From these results we have inferred b-quark and B-hadron production cross-sections over a wide range of transverse

momentum in the central rapidity interval $|y| < 1.5$. We find good agreement with an $O(\alpha_s^3)$ QCD prediction over the whole measured transverse-momentum range. Normalizing the QCD prediction to our measurements, we extrapolate to obtain a total production cross-section $\sigma(p\bar{p} \rightarrow b\bar{b}+X) = 19.3 \pm 7(\text{exp.}) \pm 9(\text{th.}) \mu\text{b}$.

Acknowledgements

We are grateful to the management and staff of CERN and of all participating Institutions for the vigorous support of this experiment. The following funding agencies have contributed to this programme:

Fonds zur Förderung der Wissenschaftlichen Forschung, Austria;
Valtion luonnontieteellinen toimikunta, Suomen Akatemia, Finland;
Institut National de Physique Nucléaire et de Physique des Particules, and
Institut de Recherche Fondamentale (CEA), France;
Bundesministerium für Forschung und Technologie, Fed. Rep. Germany;
Istituto Nazionale di Fisica Nucleare, Italy;
Science and Engineering Research Council, United Kingdom;
Stichting Voor Fundamenteel Onderzoek der Materie, The Netherlands;
Centro de Investigaciones Energetica, Medioambientales y Tecnológicas (CIEMAT), Spain;
Department of Energy, United States of America.

Thanks are due to the following people who have worked with the Collaboration in the preparation for and data collection on the runs described here: L. Baumard, F. Bernasconi, D. Brozzi, V. Cecconi, L. Dumps, G. Fetchenhauer, G. Gallay, S. Lazic, J.C. Michelon, S. Pavlon and L. Pollet. We would also like to thank P. Nason, R.K. Ellis and B. Lampe for useful discussions.

References

- [1] C. Albajar et al., (UA1 Collab.), Phys. Lett. **B213** (1988) 405.
- [2] C. Albajar et al., (UA1 Collab.), Z. Phys. **C38** (1990) 1.
- [3] C. Albajar et al., (UA1 Collab.), Z. Phys. **C37** (1988) 489.
- [4] F. Paige and S.D. Protopopescu, Brookhaven report BNL-38034 (1986).
- [5] C. Albajar et al., (UA1 Collab.), CERN-PPE/90-154.
- [6] C. Albajar et al., (UA1 Collab.), Phys. Lett. **B186** (1987) 237.
- [7] C. Albajar et al., (UA1 Collab.), Phys. Lett. **B209** (1987) 397.
- [8] C. Peterson et al., Phys. Rev. **D27** (1983) 105.
- [9] H. Evans, (UA1 Collab.); presented at XXth Int. Symp. on Multiparticle Dynamics, Dortmund, 10–14 September 1990.
D. Decamp et al. (ALEPH Collab.), preprint CERN-EP / 90-54.
M. Danilov (ARGUS Collab.), preprint DESY 89-147.
M. Artuso et al. (CLEO Collab.), Phys. Rev. Lett. **62** (1989) 2233.
- [10] H. Albrecht et al. (ARGUS Collab.), preprint DESY 90-088.
R. Fulton et al. (CLEO Collab.), Phys. Rev. Lett. **64** (1990) 16 and references therein.
- [11] P. Nason, S. Dawson, R. K. Ellis, Nucl. Phys. **B303** (1988) 607, Nucl. Phys. **B327** (1989) 49, and Nucl. Phys. **B335** (1990) 260.

Figures

- Fig 1. The p_T^{rel} distribution for the muon-jet data sample. The fitted contributions from the various processes are indicated.
- Fig 2 The p_T^{rel} distribution for the high-mass dimuon data and results of a fit to determine the contributions from charm and beauty production:
(a) For the non-isolated, like-sign, dimuon data sample. Each event contributes only once with the highest transverse-momentum muon, likely to come from b semileptonic decay.
(b) For the non-isolated, unlike-sign, dimuon data sample. In each event, both muons can enter the plot.
- Fig 3 The invariant mass distribution in the range $2m_\mu < m_{\mu\mu} < 6 \text{ GeV}/c^2$ for non-isolated, unlike-sign dimuon events with $p_T^\mu > 3 \text{ GeV}/c$ for both muons. The fitted contributions from the various processes are indicated (see text).
- Fig 4 The inclusive b-quark ($Q=-1/3$) cross-section for $|\eta| < 1.5$ versus the b-quark transverse-momentum threshold. The curve is the $O(\alpha_s^3)$ QCD prediction of Nason et al. [11]. The experimental points come from independent measurements discussed in this paper: $J/\psi \rightarrow \mu^+\mu^-$ (solid circle), high-mass dimuons (open circle), low-mass dimuons (triangle), muon-jets (squares).
- Fig 5 The inclusive B-hadron cross-section for $|\eta| < 1.5$ versus the B-hadron transverse-momentum threshold. The different symbols used for the experimental points have the same meaning as in Fig. 4.

	Muon Transverse Momentum [GeV/c]					
	10–15	15–20	20–25	25–30	30–35	35–40
$\sigma(p\bar{p} \rightarrow b \rightarrow \mu)$ [nb]	1283±269	180±40	24.3±6.5	3.2±1.4	1.1±0.6	0.14±0.09

Table 1: Cross-sections for muons from beauty decays in six p_T^μ intervals.

	b-quark ($Q=-1/3$) production		B-hadron production	
	$p_T^{min}(b)$ [GeV/c]	cross-section [nb]	$p_T^{min}(B)$ [GeV/c]	cross-section [nb]
J/ ψ	6.0	2360±1215	6.0	1650±840
high-mass dimuons	6.0	2660±1330	5.5	2390±1150
low-mass dimuons	10	390±170	9.0	340±145
muon-jet $p_T^\mu = 10-15$ GeV/c	15	120±38	14	80±24
muon-jet $p_T^\mu = 15-20$ GeV/c	23	24±8	20	19±6
muon-jet $p_T^\mu = 20-25$ GeV/c	30	4.1±1.4	26	3.5±1.2
muon-jet $p_T^\mu = 25-30$ GeV/c	39	0.55±0.3	33	0.5±0.2
muon-jet $p_T^\mu = 30-35$ GeV/c	46	0.32±0.2	41	0.21±0.12
muon-jet $p_T^\mu = 35-40$ GeV/c	54	0.04±0.03	48	0.025±0.015

Table2: The inclusive b-quark ($Q=-1/3$) and B-hadron cross-sections for $|\eta| < 1.5$ and $p_T > p_T^{min}$ in $p\bar{p}$ collisions at $\sqrt{s} = 630$ GeV.

FIG. 1

FIG. 2a

FIG. 2b

FIG. 3

FIG. 4

FIG. 5