BOTTOM EXCITATION CONTRIBUTION TO DILEPTON PRODUCTION IN $\nu, \bar{\nu}$ REACTIONS

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Abstract :

Bottom production in ν and $\bar{\nu}$ deep inelastic reactions is discussed within the framework of the standard model for quarks and leptons. Using the Kobayashi-Maskawa model it is found that dilepton events available at present can have a bottom contribution which can be as high as 10% (upper bound).

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The impressive experimental verification of the GIM proposal (1) for describing charm within the standard model of weak and electromagnetic interactions (2), has settled the basis for a sequential model for quarks and leptons. Although there is no deeper understanding of this lepton-quark symmetry (3), the standard model is the most successful one in accounting for a large variety of phenomena. Besides the well known absence of $\Delta S = 1$ neutral currents, charm spectroscopy, etc., we note that dilepton production in $\nu, \bar{\nu}$ interactions through charm excitation can also be included. The fewer discrepancies with the standard model as the y-anomaly or parity violations in atomic physics seem presently to be excluded. The inclusion of the τ lepton and the upsilon within this approach is very appealing. Besides respecting the quark-lepton symmetry, it provides a cancellation of the triangle anomalies. We should also mention that the Kobayashi-Maskawa model (4) provides an elegant description of CP violation. The V-A nature of the $\begin{pmatrix} \nu_\tau \\ \tau \end{pmatrix}_L$ doublet has an increasing experimental evidence (5). On the other hand there is no evidance for a right coupling of the $\begin{pmatrix} t \\ b \end{pmatrix}$ doublet even if it cannot be completely ruled out.

The purpose of this note is to discuss bottom production in $\nu, \bar{\nu}$ reactions within the framework just described. As we have stated, the most reliable model for flavordynamics is a sequential one with left couplings in the usual way. We shall use then the Kobayashi-Maskawa model in describing bottom production, instead of the right type of coupling previously used (6).

We have performed first a detailed analysis of dilepton experiments using the usual deep inelastic charm excitation model (7) in order to compare with the contributions coming from bottom. We have used in this analysis the following inputs :

i) For the quark distribution functions those coming out from the CDHS experimental data (8).

ii) Recent experiments on D-meson production in e^+e^- collisions, indicate that the charm fragmentation function falls as $Z \to 1$ (9). The preferred functional forms are then exp (- 3Z) and $(1 - Z)^2$. They provide similar results in our calculations.

iii) The charm semileptonic branching ratio in known to be very close to 10% (10). We have adopted this value and a V-A four fermion interaction to describe the semileptonic decay of the charmed hadron (11) in order to go beyond the approximations of ref. (7).

The bulk of $\mu^+\mu^-$ and μe data can be accounted for with the above assumptions. We shall present a detailed analysis of those topics elsewhere (12). Nevertheless it is worth to notice that the only paramenter employed directly from dilepton production is the strange sea distribution. We will come back to this point latter.

Let us go now to the production ratio of the bottom. The possible transitions are expressed in the current

$$J_\mu = (\bar{u}, \bar{c}, \bar{t})\ \gamma_\mu\ (1 - \gamma_5)\ M \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

where M is the Cabbibo generalized unitary 3 x 3 matrix. It has three mixing angles and a CP violating phase and was first introduced by Kobayashi and Maskawa (4). We then conclude that under the assumption of negligible c- and t-sea contributions, bottom production is realized through

$$\nu + \bar{u} \rightarrow \mu + \bar{b} \qquad \text{and} \qquad \bar{\nu} + u \rightarrow \mu + b$$

where the coupling is given by $|\sin\theta_c \sin\theta_3|^2$. The variation range of the mixing angles is still very large. The most recent estimations (13) give an upper bound for θ_3 such that $|\sin\theta_3| \leq 0.5$. Using this limiting value, we have obtained the upper bound for the ratio $R(\bar{\nu} + N \rightarrow \mu + b\ /\ \bar{\nu} + N \rightarrow \mu + c)$ shown in Fig. 1. (the analogous neutrino ratio is negligible).

Going now to the next step, the fragmentation of the b quark, we have found that as far as total cross sections are concerned, the fragmentation function plays a minimum role. The functional forms $\exp(-3Z)$, constant and $\delta(Z - 1/m_B)$ give pratically the same result (12).

The really unknown in the determination of cross sections are the mixing angles. They fix the couplings and play a dominant role in the decays of the bottom. Concerning this we recall that the earlier estimations (14) indicated the dominance of the $b \rightarrow c$ transition. This effect seems to be confirmed by more recent and accurate calculations (15).

We have evaluated upper bounds for the ratio $\sigma(2\text{ leptons})/\ \sigma(1\ \mu)$ taking into account the upper limits of ref. (13) and (14) for the $b \rightarrow c$ coupling ($\simeq 1$)

and branching ratio (≃ 30%). The results of our calculation for charm and the upper limit for charm plus bottom are shown in Fig. 2. The slight difference in the experimental cuts of the CDHS and FHOPRW results (8) was taken into account.

Our main conclusion is that dilepton events available at present can have a bottom contribution which can be as high as 10% (upper bound). Of course, those events should be recognised through their different distributions. Besides the invariant mass, the clearest signature of the bottom induced events will be the average energy of the secondary lepton which should be considerably greater than the corresponding to charm. A complete description of the bottom distributions espected are presented elsewhere (12). We mention that the x-distribution of those events are flatter than those corresponding to the charmed induced ones. A correct strange sea determination at higher energies, where bottom production should increase, must account for this effect. We also notice that QCD-type corrections as those included in parametrizations à la Buras and Gaemers (16) do not play any significant role in our calculations (12).

We finally emphasize that there are both theoretical and experimental reasons to look for a left coupled bottom quark in antineutrino induced reactions. Although this is a small effect, its experimental search could be extremelly useful in the determination of the Kobayashi-Maskawa parameters.

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REFERENCES

(1) S.L. Glashow, J. Iliopoulos and L. Maiani, Phys. Rev. D2 (1970) 1285.

(2) A. Salam in : Proc. 8th Nobel Symposium, ed. N. Svartholm (Stockholm 1968) ;
S. Weinberg, Phys. Rev. Lett. 19 (1967) 1264.

(3) M.B. Gay Ducati, J. Leite Lopes and J.A. Martins Simões, Lett. Nuovo Cimento 24 (1979) 432.

(4) M. Kobayashi and K. Maskawa, Prog. Theor. Phys. 49 (1973) 652.

(5) W. Bacino et al., Phys. Rev. Lett. 42 (1979) 799.

(6) R.M. Barnett and F. Martin, Phys. Rev. D16 (1977) 2765.

(7) L.M. Sehgal and P.M. Zerwas, Nucl. Phys. B108 (1976) 483.

(8) H.G. de Groot et al. Zeits. für Phys. 1 (1979) 143 ;
M. Holder et al., Phys. Lett. 69B (1977) 377.

(9) P.A. Rapidis et al., SLAC-PUB-2184 (1978).

(10) S. Wojcicki in : Proc. of Summer Institute on Particle Physics, ed. M.C. Zipf (SLAC, Stanford 1978).

(11) V. Barger and R.J.N. Phillips, Phys. Rev. Lett. D14 (1976) 80.

(12) C.A. Garcia Canal, M.B. Gay Ducati and J.A. Martins Simões, in preparation

(13) V. Barger, W.F. Long and S. Pakvasa, Phys. Rev. Lett. 42 (1979) 1585 ;
R.E. Shrock, S.B. Treiman and L.L. Wang, Phys. Rev. Lett. 42 (1979) 1589.

(14) M.K. Gaillard, Fermilab - CONF - 78/64THY (1978).

(15) G. Anastaze, thèse 3ème cycle CRN/HE 79-9 (Strasbourg 1979).

(16) A.J. Buras and K.J.F. Gaemers, Nucl. Phys. B132 (1978) 249.

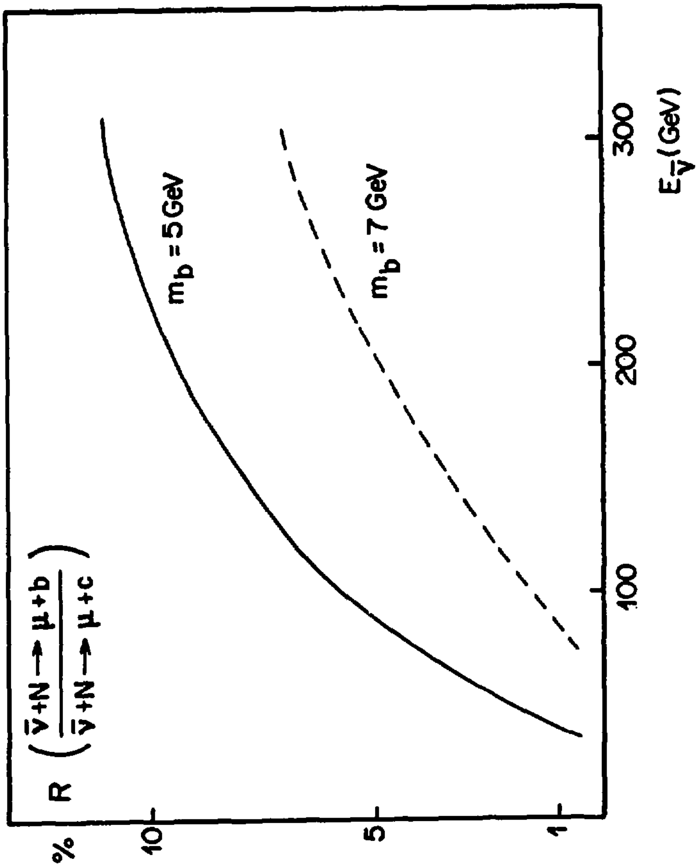

Fig. 1. : Bottom excitation in $\bar{\nu}$ reactions as a function of incident energy

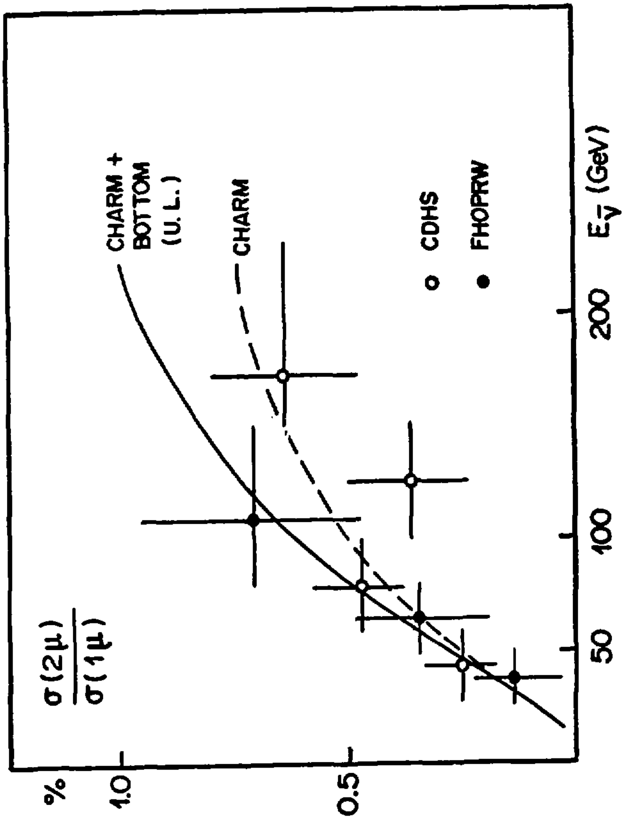

Fig. 2. : $\sigma(2\mu)/\sigma(1\mu)$ in $\bar{\nu}$ induced reactions as a function of incident energy.

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