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H. Schneider
Institut für Kernphysik

Kernforschungszentrum Karlsruhe

KERNFORSCHUNGSZENTRUM KARLSRUHE
Institut für Kernphysik

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H. Schneider

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ABSTRACT

Recent results on the semileptonic branching ratios of c and b quarks are reviewed. Mainly the high energy data from PEP at $\sqrt{s} \sim 29$ GeV and PETRA at $\sqrt{s} \sim 34$ GeV are presented. The influence of the parton fragmentation into hadrons is discussed.

Semileptonische Zerfälle des c und b Quarks

ZUSAMMENFASSUNG

Es wird ein Überblick über neuere Resultate zu semileptonischen Verzweigungsverhältnissen der c und b Quarks gegeben. Dabei werden vorwiegend Daten von Hochenergie-Experimenten an den e^+e^--Speicherringen PEP bei $\sqrt{s} \sim 29$ GeV und PETRA $\sqrt{s} \sim 34$ GeV berücksichtigt. Der Einfluß der Parton-Fragmentation in Hadronen wird diskutiert.

1. INTRODUCTION

The study of inclusive leptons in multihadronic events in high energy e^+e^- annihilation

$$e^+e^- \rightarrow \ell \; \nu \; X \qquad X = \text{multihadrons}$$

yields information on the heavy charm and bottom quarks. The production of hadronic states proceeds via QED, where a heavy quark antiquark pair is generated

$$e^+e^- \rightarrow Q\bar{Q}$$

with a small admixture of $e^+e^- \rightarrow Q\bar{Q}$ + hard gluon bremsstrahlung.

To fragment into hadrons, the quark picks up a light $q\bar{q}$ pair out of the vacuum and forms a heavy meson. The remaining light quark continues this fragmentation chain and builds up a light quark jet (Fig. 1).

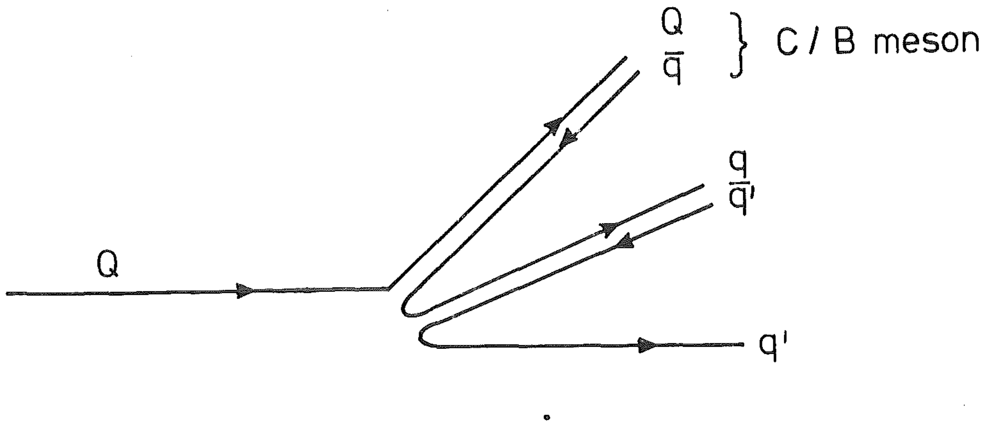

Fig.1

Fig. 1: Fragmentation of a heavy quark into a meson $H(Q\bar{q})$ and light quark jet.

Because quark flavour is conserved in strong and electromagnetic interactions the C or B meson has to decay by weak interaction. In the standard Model (1) (Weinberg-Salam) of electroweak interaction leptons and quarks are grouped into left handed weak isospin doublets and right handed singlets. The Kobayashi Maskawa Model (2) uses the Weinberg Salam SU(2) × U(1) gauge group coupled with three generations of left handed quark doublets, where the charge 1/3 quarks are mixed

$$\begin{pmatrix} u \\ d' \end{pmatrix}_L \begin{pmatrix} c \\ s' \end{pmatrix}_L \begin{pmatrix} t \\ b' \end{pmatrix}_L$$

and in addition six right handed quarks as singlets: The mixing described by the matrix V allows decays with transitions between the generations at a Cabibbo-suppressed rate.

$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = V \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

$$V = \begin{pmatrix} c_1 & s_1c_3 & s_1s_3 \\ -s_1c_2 & c_1c_2c_3+s_2s_3e^{i\delta} & c_1c_2s_3-s_2c_3e^{i\delta} \\ -s_1s_2 & c_1s_2c_3-c_2s_3e^{i\delta} & c_1s_2s_3+c_2c_3e^{i\delta} \end{pmatrix}$$

$c_i = \cos(\theta_i)$, $s_i = \sin(\theta_i)$. θ_i are the generalized Cabibbo angles, δ is the CP violating phase. The angles and the phase are fundamental constants for which no theory exists. They are parameters to be determined by data. If the weak eigenstates were the same as the physical states, there would be no such transitions between the quark generations.

Because of the orthogonality of the mixing matrix no flavour changing neutral currents exist in this model. Therefore only the transitions

$$c \to W^+ s(d) \quad \text{and} \quad b \to W^- c(u)$$

are allowed (suppressed decays are in brackets).

Since the $W^\pm$ couples to leptons as well the standard model predicts, that C/B mesons should also decay to final states with e's, μ's and τ's.

The simplest picture for the leptonic decay of the C/B meson is the spectator model (3) where the c/b quark decays to a s(d) or c(u)-quark emitting a virtual $W^\pm$ whereas the light antiquark partner in the heavy meson does not actively participate. Fig. 2 shows the b quark decay of the picture.

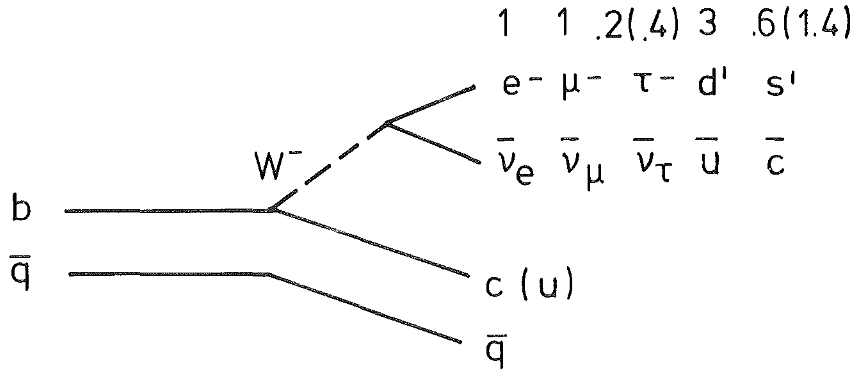

Fig. 2

Fig. 2: b-quark decay in the spectator model (3). The numbers are phase space x colour factors for b → c(u)

The numbers are the relative probabilities for the decay b → c(u) into the different channels, assuming these probabilities only depend on the product of phase space and colour factors. The spectator model predicts a semileptonic branching fraction of the B into electrons or muons of about 15-17%.

Since the spectator model does not work well for the charmed meson (D^+ and D^o have for instance rather different life times (4)), non spectator contributions have to be taken into account. For the semileptonic decay of the B meson the non-spectator effect and QCD corrections are calculated, leading to a predicted branching ratio for either prompt electrons or muons of 11 - 13%. (5).

Several experiments have measured the semileptonic branching ratios of the C/B meson into electrons and/or muons in the last time. The next chapter will deal with the e and μ identification and the backgrounds in the experiments. Chapter 3 then shortly describes for some of the experiments the analysis of the heavy quark fragmentation and the determination of the semileptonic branching ratio of the C and B meson.

2. LEPTON IDENTIFICATION AND BACKGROUNDS

As mentioned above the analysis of inclusive leptons in hadronic events provides a possibility to study weak quark interactions and to measure the fragmentation mechanism of heavy quarks.

The experiments can be divided into two different groups. (i) The production of heavy particles in the continuum as measured at PETRA and PEP at high energies, where a complete spectrum of these heavy mesons can be excited. (ii) At CESR running on the 4S resonance Υ''' of the $b\bar{b}$-system only the B^o and $B^\pm$ meson can be produced.

In the following mainly the higher energy continuum experiments will be discussed. Data of prompt electrons and/or muons are now available from the following detectors (Table 1).

TABLE 1: Available data from high energy experiments

		$\sqrt{s}$ [GeV]	$e^+e^- \to e\nu X$	$e^+e^- \to \mu\nu X$
PETRA	CELLO[6]	14-34	x	x
	MARK J[7]	$33 \leq \sqrt{s} \leq 38.54$		x
	TASSO[8]	~ 34.6	x	x
PEP	DELCO[9]	29	x	
	MAC[10]	29		x
	MARK II[11,12]	29	x	x

2.1 ELECTRONS

To identify electrons in multihadron events all experiments extrapolate the charged tracks into calorimeter type detectors. Above a lower energy threshold of typically 1 - 1.5 GeV measurements of the shape, the magnitude or alignment of the deposited energy in the calorimeter allow to discriminate electrons against other particles.

Backgrounds to the electron signals comes from misidentified hadrons and accidental overlaps of tracks, mainly overlaps of photons with hadrons. Typical background contributions to the electron signal as quoted by the CELLO- and MARK II collaboration are listed in Table 2.

TABLE 2: Background sources for electrons

CELLO	misidentified π's in jet events	0.3%	for $p \geq 1.5$ GeV/c $p_\perp \geq 1.0$ GeV/c
MARK II	misidentified hadrons	0.5%	for $p > 1$ GeV/c
	in the core of a jet up to	3.0%	

Furtheron there are backgrounds to the prompt electron from heavy quark decay arising from a number of trivial electron sources like Dalitz decays of π/K-mesons and photon conversions which are eleminated by a pair finding algorithm (MARK II) and/or Monte Carlo (MC) subtractions. Additional backgrounds arises from

1) Deep inelastic electron-photon scattering

$$e^+e^- \rightarrow e^+e^- + X \ (C = +) \quad X = \text{multihadrons;}$$

one of the outgoing electrons is at large transverse momentum, the quasi-real target photon is emitted by the electron which is scattered at small angles.

2) Inelastic compton scattering

$$e^+e^- \rightarrow e^+e^- + X \ (C = -)$$

this can be considered as a radiative Bhabha process where a real photon is replaced by a massive one which internally converts to the hadronic system X.

Typical magnitudes of the background as quoted by the CELLO-group are listed in Table 3.

TABLE 3: Magnitudes of prompt electrons and background

Source of e at $\sqrt{s}$ = 34 GeV CELLO	Part of e signal W=14 GeV	W=22 GeV	W=34 GeV
light quarks (u,d,s)			
misidentified π's	5.9%	5.5%	7.6%
converted γ; π/K decay	11.8%	2.8%	11.8%
heavy quarks (c,b)			
misidentified π's	4.2%	4.2%	8.0%
converted γ; π/K decay	3.8%	4.4%	10.9%
prompt electrons (all)	73.0%	80.1%	56.8%
b → e only	36.6%	60.0%	34.2%
deep inelastic e-γ scattering	1.3%	2.8%	3.5%
inelastic compton scattering	0.0%	0.2%	1.4%

2.2 MUONS

For the muon identification all experiments make use of the tracking through iron filters of typically 1 m thickness. This implies lower momentum cuts of the order of 1.5 GeV/c for the muon.

The background is mainly due to π/K decays and punch through. The MARK II group quotes for the probability of π/K-decays ~ .005 calculated by MC and .002 - .005 for the measured sum of punch through and overlap. With respect to the μ-signal the quoted numbers from the experiments CELLO, MAC and MARK J are listed in Table 4.

TABLE 4: Background sources for muons

Exp.	decay %	punch through %
CELLO	9	22
MAC	23 ±1	9 ±7
MARK J	19	13

The subtraction of the backgrounds from the inclusive electron and muon signal then leads to the prompt lepton signal.

3. **SEMILEPTONIC BRANCHING RATIOS**

3.1 SEPARATION OF THE LEPTON CONTRIBUTIONS FROM C- AND B-DECAYS

In the previous chapter the experimental lepton identification and the preparation of the prompt lepton signal was described. Kinematical considerations suggest that the hadron which contains the heavy quark carries a relatively high fraction of the jet momentum. Those leptons resulting from the semileptonic decay of the heavier b quark are expected to have a harder transverse momentum distribution with respect to the jet axis than the leptons from the c-decay. This allows to enrich (or even separate) the contributions of b and c quarks to the prompt lepton signal (Fig. 3).

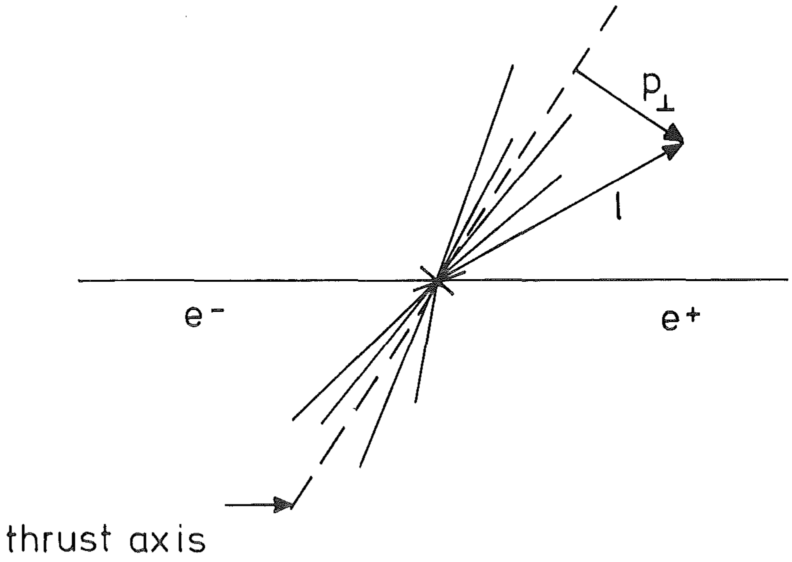

Fig.3

Fig. 3: $p_\perp$ definition for an inclusive lepton event

Typical numbers are quoted by the MARK J group

for $p_\perp > 1.2$ GeV/c	64% of the muons originate from B decay
for $p_\perp < 1.2$ GeV/c	85% muons from C decay

As mentioned before the measured spectra of the leptons suffer quite hard cuts. The momentum cut for the electron or muon is critical, because to correct the measured momentum and transverse momentum distributions the heavy quark fragmentation and the properties of the weak decay have to be known. But so far only few data are available on the fragmentation of heavy quarks, in particular for the b quark. Kinematical considerations lead to a different shape (13) for heavy quark fragmenting into a hadron containing Q (see Fig. 1) than for light quarks. The fragmentation function is harder, than that of the light quark which is characterized by $z^{-1}(1-z)^2$ behaviour.

The different experiments try to determine the heavy quark fragmentation together with the branching ratios or at least to absorb the different possibilities of fragmentation functions into the systematic error. The next section shortly describes these analyses for each experiment.

3.2 CELLO data

The CELLO group measured the inclusive electrons and muons in hadronic events at $\sqrt{s}$ = 14, 22 and 34 GeV. Their kinematical cuts on the leptons are: the momentum and transverse momentum with respect to the thrust-axis has to be larger than 1.6 GeV/c and 1.0 GeV/c respectively ($p_\perp > 0.5$ GeV for $\sqrt{s}$ = 14 GeV).

The CELLO group performs an extensive study of the influence of different MC generators, the uncertainties of fragmentation parameters and different fragmentation functions to semileptonic branching ratios.

In the Hoyer MC (14) the semileptonic decay of heavy mesons is performed according to phase space and changed to the (V-A)-decay matrix element. A mass dependend QCD matrix element is introduced and a variation of α_s by as much as 20% is performed. In summary the CELLO collaboration gets for these three variations systematic errors of 5% to the branching fractions of c- and b-decays.

Secondly the fragmentation parameters in the Hoyer MC as the transverse momentum spread, the quark ratios u:d:s and the vector to pseudovector ratio are varied within experimentally reasonable limits. Furtheron, following the original suggestion of Feynman and Field (FF) (15) a random $p_\perp$-distribution is attributed to the primary quark, so that the primordial first rank meson follows the same $p_\perp$ distribution as the higher rank mesons of the cascade. The systematic errors due to these changes of fragmentation parameters do not exceed 5%.

The differences of the yields between the Hoyer MC and Lund MC (16) are not significant for the b decay, but from the c decay the yield is 18% lower in the Lund MC. Therefore the CELLO group estimates an overall systematic error of 18% for the c decay and of 5% for the b decay.

The largest effect comes from the changes of the fragmentation functions, the influence of the following functions are studied (Fig. 4) with the Hoyer MC as well as with the Lund MC.

flat (Hoyer)[14]	$f_c(z) = f_b(z) = 1$	$z = \frac{2E_H}{\sqrt{s}}$	
Lund[16]	$f_q(z) = (1+a_q)(1-z)^{a_q}$	$a_c = 0.216$	$a_b = 0.086$
Peterson et al.[17]	$f_q(z) = 1/z(1 - \frac{1}{z} - \frac{\varepsilon_q}{1-z})^2$	$\varepsilon_c = 0.11$	$\varepsilon_b = 0.013$
Suzuki[18]	$f_q(z) = \exp(-\frac{1}{2} m_\pi(m_q+M)(z + \frac{\alpha_q}{z})$	$M = 1$ GeV	$\alpha_q = (\frac{m_H}{m_q+M})^2$
		$f(z) = 0$,	$z < \alpha_q$

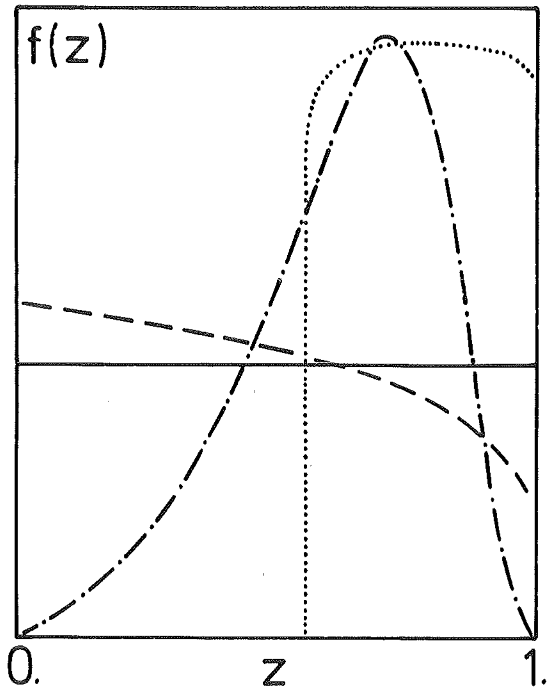

Fig. 4: Different fragmentation functions of heavy quarks

___ Hoyer et al.

--- Lund

-.- Peterson et al.

... Suzuki

TABLE 5
Influence of different fragmentation functions f(z) in the Lund MC event generator on the number of leptons (muons or electrons) with $p > 1.6$ GeV/c for 10000 multihadronic events at $W = 34$ GeV using $BR(c \to l\nu X) = 9\%$ and $BR(b \to l\nu X) = 12\%$.

f(z)	no $p_\perp$ - cut		$p_\perp > 1$ GeV/c	
	$c \to l\nu X$	$b \to l\nu X$	$c \to l\nu X$	$b \to l\nu X$
Flat	160.0±4.0	92.2±3.0	19.5±1.4	62.9±2.5
Lund	154.4±3.9	94.6±3.1	20.2±1.4	64.8±2.5
Peterson et al.	208.5±4.6	101.9±3.2	27.2±1.6	67.9±2.6
Suzuki	225.3±4.7	109.9±3.3	33.7±1.8	73.0±2.7

Table 5 shows the number of prompt leptons expected from the c and b decays normalized to 10000 generated multihadronic events for each function. Because of the lack of statistics the CELLO collaboration absorbed all variations into the systematic errors. In summary applying the Peterson et al. (17) fragmentation function and the (V-A)-decay matrix element the CELLO collaboration estimates an overall relative systematic error due to all MC dependent effects of 25% for the branching fractions of c decays and 10% for b decays.

Table 6 shows the derived branching ratios for the energies $\sqrt{s}$ = 14, 22, 34 GeV using in the MC simulation the fragmentation functions from Peterson et al. and (V-A)-decay. The averaged branching ratios are

$$BR(b \to e\nu x) = 14.1 \pm 5.8 \pm 3.0 \quad \%$$
$$BR(b \to \mu\nu x) = 8.8 \pm 3.4 \pm 3.5 \quad \%$$
$$BR(c \to \mu\nu x) = 12.3 \pm 2.9 \pm 3.9 \quad \%$$

Table 6

Branching ratios for the semileptonic decay of the heavy quarks at three c.m. energies W. The first error is the statistical one, the second error the systematic one.

W (GeV)	Branching ratios $b \to e\nu X$	 $b \to \mu\nu X$	 $c \to \mu\nu X$
14	4.0±11.0±4.3%	26.0±8.2±3.9%	20.5±7.2±4.9%
22	21.3±10.5±2.1%	3.8±6.2±3.7%	15.0±4.9±3.4%
34	15.5±9.0±2.8%	6.3±4.8±3.5%	8.1±4.3±3.9%
Average	14.1±5.8±3.0%	8.8±3.4±3.5%	12.3±2.9±3.9%

3.3 MARK II data

The MARK II group studies the momenta spectra of prompt e's and μ's at $\sqrt{s}$ = 29 GeV in the following four regions of $p_\perp$ ($p_\perp$ relative to the thrust axis)

a) $p_\perp < 0.5$ GeV/c
b) $0.5 < p_\perp < 1.0$ GEV/c $\qquad p > 1$ GeV/c
c) $1.0 < p_\perp < 1.5$ GeV/c
d) $p_\perp > 1.5$ GeV/c

The contributions from b and c → e(μ) to the experimental spectra binned in 24 (20) p and $p_\perp$ channels are represented with MC simulations including gluon radiation as incorporated by Ali et al. (19) and a FF hadronization model.

The MARK II collaboration has parametrized the fragmentation for the heavy b quark into hadrons by the function of Peterson et al. where the parameter ε_b is fitted. For ε_c of the c quark fragmentation function the value $\varepsilon_c = 0.25$ is assumed (20) and checked by fitting. This ε_c corresponds a mean z $\langle z_c \rangle$ = 0.54.

For the b quark a much harder fragmentation function is required by the data. The MARK II group obtained from the prompt e and μ-decay respectively

$$\varepsilon_b^e = 0.015 \pm {}^{0.022+0.023}_{0.011-0.011}$$

$$\varepsilon_b^\mu = 0.042 \pm {}^{0.218+0.120}_{0.041-0.035}$$

corresponding to a mean $\langle z_q \rangle$

$$\langle z_b^e \rangle = 0.79 \pm 0.06 \pm 0.06 \qquad \langle z_b^\mu \rangle = 0.73 \pm 0.15 \pm 0.10$$

and for the branching ratios

$BR^{e}(c) = 6.6 \pm 1.4 \pm 2.8\%$ $BR^{e}(b) = 13.5 \pm 2.6 \pm 2.0\%$

$BR^{\mu}(c) = 8.3 \pm 1.3 \pm 1.8\%$ $BR^{\mu}(b) = 12.6 \pm 6.2 \pm 3.0\%$

Fig. 5 shows the experimental electron spectra of the 4 $p_\perp$ regions together with the results of the fits. The contributions of the semileptonic decays of the primary b and c, and the secondary c are marked. The χ^2/dof is 13.4/18 (9.98/17 for the μ). All three fractions together reproduces well the data.

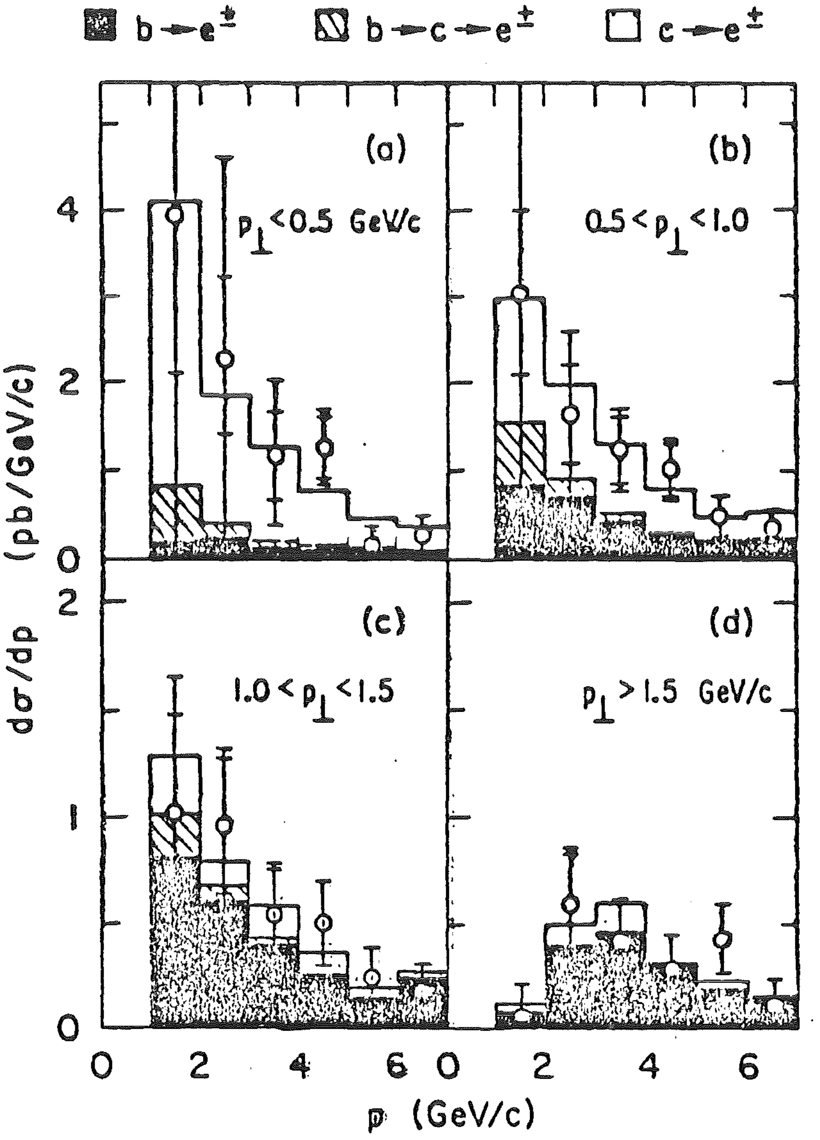

Figure 5

Prompt electron momentum spectra in four regions of $p_\perp$ (GeV/c). Two sets of error bars are shown. for each data point. The smaller ones are statistical, the larger ones are statistical and systematic errors added in quadratures. The histograms show the results of the fit.

The MARK II experiment has also studied a fragmentation parametrization different from the function of Peterson et al., for example $z^{\alpha}(1-z)$ and has obtained qualitatively similar results.

3.4 MAC data

The MAC group has published measurements of C and B semimuonic decay branching ratio at $\sqrt{s} = 29$ GeV

$$e^+e^- \rightarrow \mu\nu X$$

The momentum cut of the μ is at 2 GeV/c. To estimate the remaining background and to study heavy flavor decay the Ali MC and FF hadronization is used.

In contrast to the previous discussed experiments the MAC collaboration assumes no special shape of the fragmentation of the C or B. The fragmentation function is approximated by histograms of 6 z bins with adjustable heights, equally distributed in the range $0 < z_c < 1$ for the c quark and in the range $0.4 < z_b < 1$ for the b quark. The MAC groups does a simultaneous fit of their p and $p_\perp$ distributions to extract $\langle z_c \rangle$, $\langle z_b \rangle$, BR(c), BR(b). As a result a broad range of c fragmentation functions is permitted with a one-standard-deviation envelope

$$0.17 < \langle z_c \rangle < .67$$

For the mean $\langle z_b \rangle$ of the b fragmentation function it is found

$$\langle z_b \rangle = 0.8 \pm 0.1$$

The semimuonic branching ratios of the c and b quark result to

$$BR(c) = 7.6 \,{}^{+\,9.7}_{-\,2.7}\% \qquad BR(b) = 15.5 \,{}^{+\,5.4}_{-\,2.9}\%$$

A comparison to the fragmentation function of Peterson et al. to the discussed methods yields an $\varepsilon_q = 0.008 \, {}^{+\,0.037}_{-\,0.008}$ with a somewhat worse χ^2 value than for a more sharply peaked function.

In Fig. 6 the $p_\perp$ spectrum of the observed muons is shown together with the MC predictions for muons from b and c quarks and the overall (decay + punch through) background predictions

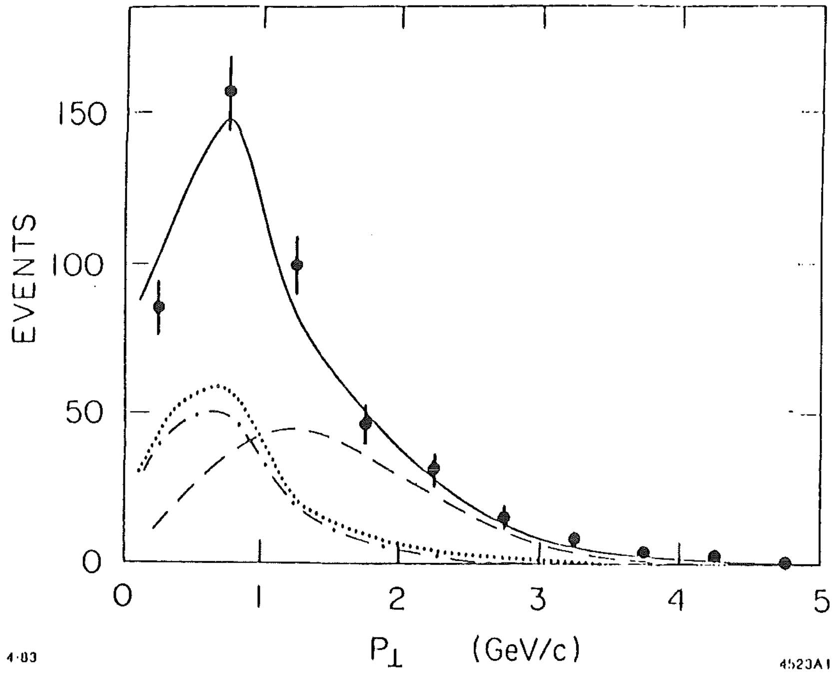

Fig. 6 $p_\perp$ spectrum of muons wih $b\bar{b}$ (dashed curve), $c\bar{c}$ (dot-dashed), background from decay and punch through (dotted), and total (solid curve) predictions.

3.5 MARK J data

The MARK J group has analysed prompt μ decay of C and B at high energies

$$e^+e^- \rightarrow \mu\nu X \qquad 33 \leq \sqrt{s} \leq 38.54 \text{ GeV}$$

The MARK J collaboration studies the thrust distribution of the events, the $x = 2p_\mu/\sqrt{s}$ and the $p_\perp$ distributions of the inclusive muons. Fig. 7a shows the differential cross section versus $p_\perp^2$ for inclusive muons and for pions for comparison. In the muon distribution a shoulder in the range $2 \lesssim p_\perp^2 \lesssim 5$

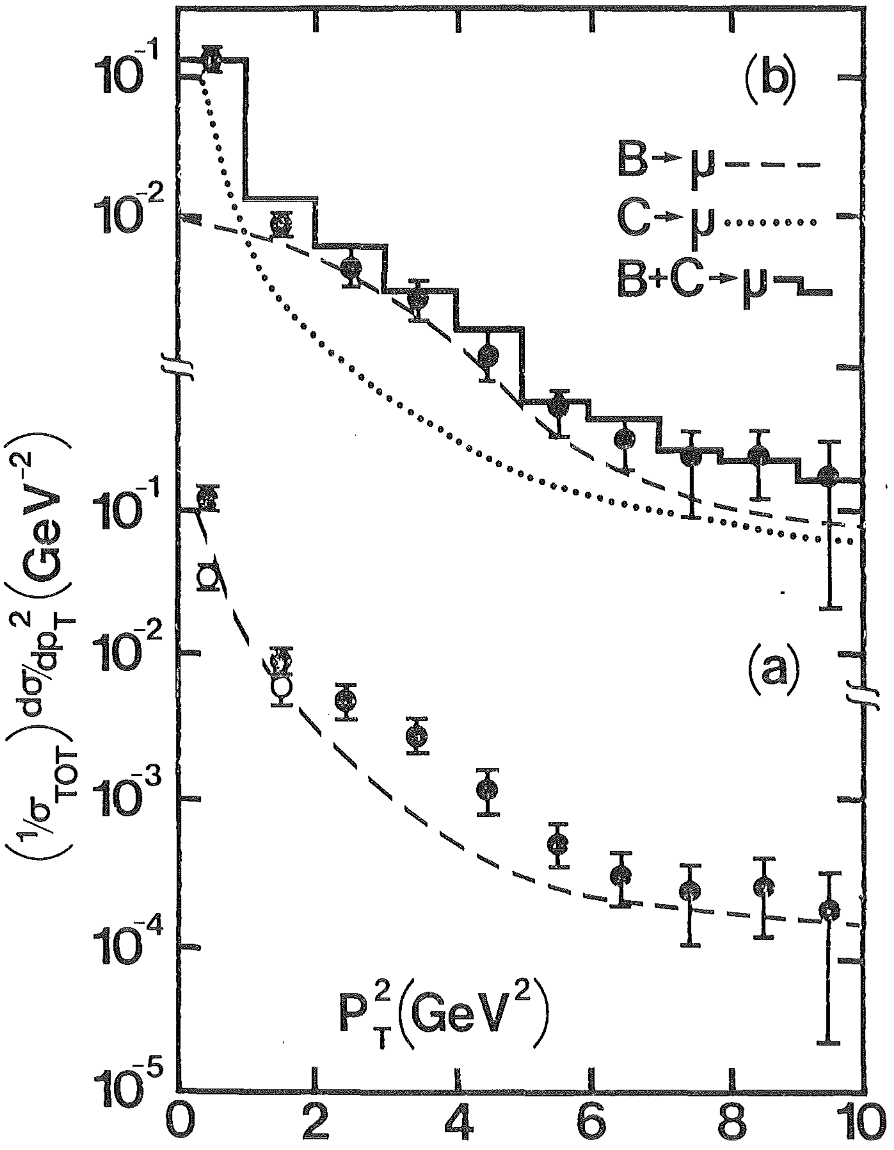

Fig. 7: a) $p_\perp^2$ distributions of muons normalized to the total hadronic cross section σ_T.
o cross section with p 2 GeV
● cross section extrapolated to all p
They differ only on the first two points with $p_\perp^2$ 2 $(\mathrm{GeV})^2$
--- inclusive π spectrum scaled by 10^{-2}
b) Comparison of the inclusive muon data with Monte Carlo including individual $B \to \mu$, $C \to \mu$ contributions.

GeV^2 is visible which is indicative of the decay of a particle of mass around 5 GeV. The shoulder is well explained by B decays as shown in Fig. 7b, where the μ-data and the MC predictions for the $c \rightarrow \mu + x$ and $B \rightarrow \mu + x$ decay is plotted.

For the determination of the heavy quark fragmentation two strategies of analyses are used: 1) the function of Peterson et al. is taken with $\varepsilon_q = h_q^2$

$$\varepsilon_q(z) = \frac{1}{z}\left(1 - \frac{1}{z} - \frac{h_Q^2}{1-z}\right)^{-2}$$

and 2) without any assumption of the shape of the fragmentation function the z region is divided into 10 equal bins and fitted bin by bin.

For the first method, the MARK J group considers the C enriched ($p_\perp < 1.2$ GeV) and b enriched ($p_\perp > 1.2$ GeV) sample. To obtain Br(B), BR(C), and h_q, the p, $p_\perp$ of the μ- and the thrust distribution is divided in 8 x 8 x 8 bins and fitted with maximum likelihood method. The MARK J collaboration gets:

$$BR(c) = 11.5 \pm 1.0 \pm 1.7\% \qquad BR(b) = 10.5 \pm 1.5 \pm 1.3\ \%$$

$$|h_c| = 0.8 \pm 0.1 \pm 0.2 \qquad |h_b| = 0.15 \pm 0.03 \pm 0.05$$

$|h_c|$, $|h_b|$ corresponds a mean $\langle z \rangle$ of

$$\langle z_c \rangle = 0.46 \pm 0.02 \pm 0.05 \qquad \langle z_b \rangle = 0.75 \pm 0.03 \pm 0.06$$

For the second method, the MARK J experiment obtains for the mean $\langle z \rangle$

$$\langle z_c \rangle = 0.46 \pm 0.05 \qquad \langle z_b \rangle = 0.74 \pm 0.1$$

Fig. 8 shows the x distribution of the data of the B enriched an C enriched sample together with the MC fits. The histogram which is the sum of the B and C decays nicely follows the data.

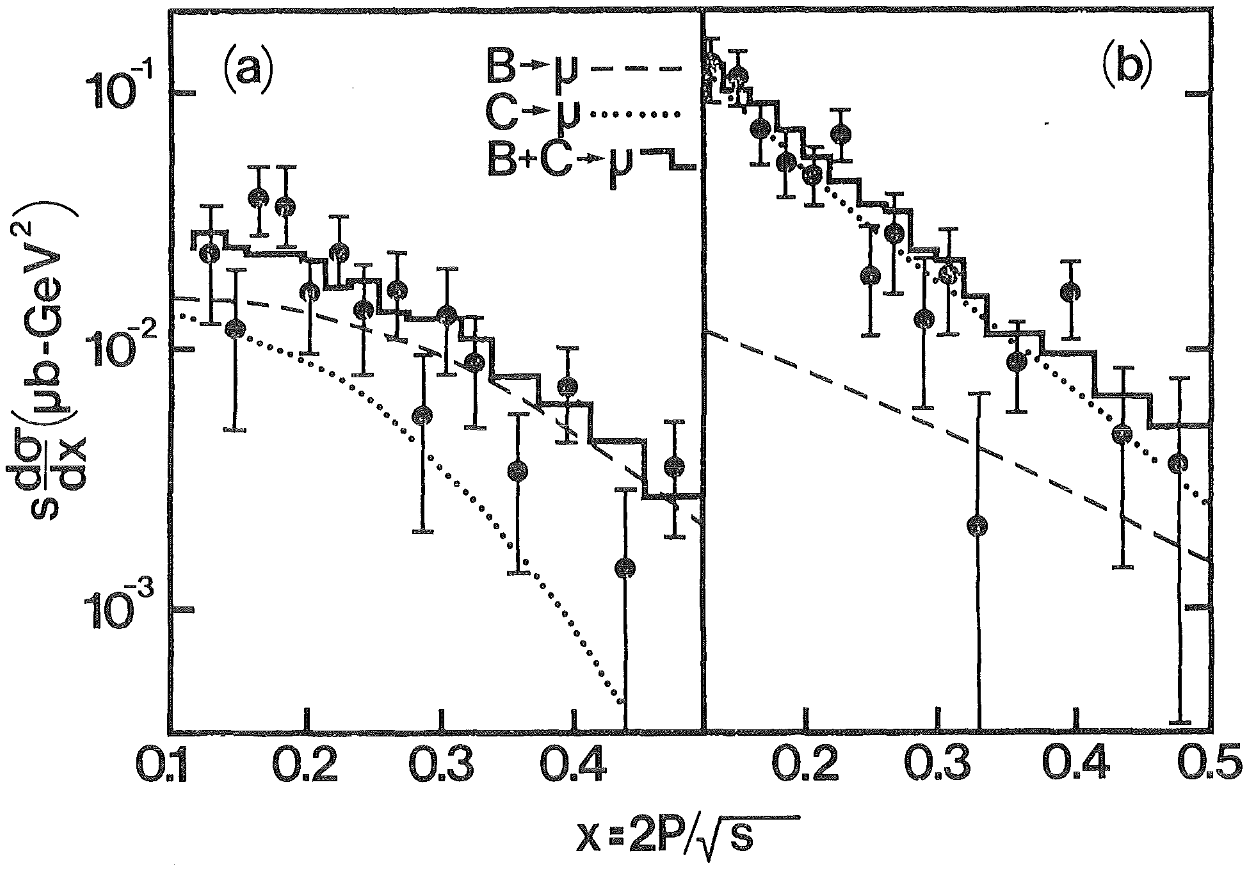

Fig. 8 a) The x distribution for the B-enriched sample
b) The C enriched sample.
The MC curves are also shown.

4. SUMMARY

The results can be summarized in two tables for the fragmentation function of heavy quarks and their semileptonic branching fraction. Added are results from TASSO and DELCO and also the non continuum CESR values from CLEO and CUSB measured on the T(4S) resonance.

Table 7 shows, that the fragmentation of the B meson is considerably harder than the fragmentation of the charmed meson as one would naively expect from the high mass of this quark. But without any assumptions on the shape of the heavy quark fragmentation function the error of the mean z is still quite high.

TABLE 7: Heavy quark fragmentation

	$f(z) \approx \frac{1}{z}(1 - \frac{1}{z} - \frac{\varepsilon_q}{1-z})^{-2}$ Peterson et al.		no assumption for	the shape of f(z)
	$\langle z_c \rangle$	$\langle z_b \rangle$	$\langle z_c \rangle$	$\langle z_b \rangle$
MARK J	$0.46 \pm 0.02 \pm 0.05$	$0.75 \pm 0.03 \pm 0.06$	0.46 ± 0.05	0.74 ± 0.1
TASSO[21]	$0.55^{+0.11}_{-0.09}$	0.75 ± 0.08		
MAC			$0.17 < \langle z_c \rangle < 0.67$	0.8 ± 0.1
MARK II(e)		$0.79 \pm 0.06 \pm 0.06$		
MARK II(μ)		$0.73 \pm 0.15 \pm 0.10$		

Experimental results on the branching ratios are summarized in Table 8.

Table 8: Semileptonic branching ratios

	W (GeV/c)	BR($b \to e \nu X$) %	BR($b \to \mu \nu X$) %	BR($c \to e \nu X$) %	BR($c \to \mu \nu X$) %
CELLO	14-34	$14.1 \pm 5.8 \pm 3.0$	$8.8 \pm 3.4 \pm 3.5$		$12.3 \pm 2.9 \pm 3.9$
MARK J	$33 \leq \sqrt{s} \leq 38.5$		$10.5 \pm 1.5 \pm 1.3$		$11.5 \pm 1.0 \pm 1.7$
TASSO	~34.6	$13.6 \pm 4.9 \pm 4.0$	$15.0 \pm 3.5 \pm 3.5$		
MAC	29		$15.5^{+5.4}_{-2.9}$		$7.6^{+9.7}_{-2.7}$
MARK II	29	$13.5 \pm 2.6 \pm 2.0$	$12.6 \pm 5.2 \pm 3.0$	$6.6 \pm 1.4 \pm 2.8$	$8.3 \pm 1.3 \pm 1.8$
DELCO	29	$12.8 \pm 4.0 \pm 4.0$			
CLEO[22]	$\Upsilon(4S)$	$12.0 \pm 1.7 \pm 1.3$	$10.2 \pm 1.4 \pm 1.5$		
CUSB[23]	$\Upsilon(4S)$	$13.6 \pm 2.5 \pm 3.0$			

The fraction agree with predictions of the standard model and moreover no experiment reports an excess of dilepton events as would be expected by flavour changing neutral currents.

If one would attempt to calculate an average value for the branching fractions one would get $\overline{BR}(b \rightarrow e/\mu\ \nu X) = (12.0 \pm 1.3)\%$ for the PEP and PETRA experiments and $\overline{BR}(b \rightarrow e/\mu\ \nu X) = (11.4 \pm 1.3)\%$ for the CESR experiments. The statistical and systematical errors (if present) are added in quadrature. These numbers confirm that the naive spectator model (yielding 15-17%) is too crude, whereas including non spectator effects the theoretical value of 11-13% is in good agreement with the measurements.

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