STUDIES OF B-QUARK FRAGMENTATION

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I will review new studies of b-quark fragmentation performed at the Z peak by ALEPH and SLD. An improved sensitivity to distinguish between fragmentation model and more accurate measurements of the mean b-hadron scaled energy have been obtained.

1 Introduction

In e^+e^- collisions the b-quark fragmentation function is given by the normalized scaled energy distribution of b-hadrons

$$D(x) \equiv \frac{1}{\sigma}\frac{d\sigma}{dx} \qquad (1)$$

where x is the ratio of the observed b-hadron energy to the beam energy. Usually, since the b-quark mass is much larger than the QCD scale Λ, the b-quark energy prior to hadronization is calculated using perturbative QCD. Hence the b-hadron energy is related to the quark energy via model-dependent assumptions. Therefore measurement of $D(x)$ serve to constrain both perturbative QCD and model predictions. Furthermore, the uncertainty in the fragmentation function $D(x)$ must be taken into account in studies of the production and decay of heavy quarks: more accurate measurements of this function will allow increased precision test of heavy flavour physics.

At this conference new measurements have been presented by ALEPH[1] and by SLD[2].

2 ALEPH measurement

ALEPH searches for B^+ and B^0 mesons[a] in five semi-exclusive decay channels $B \rightarrow D^{(*)}\ell\nu X$. In three of them the B decays to $D^{*+}\ell\nu X$, followed by $D^{*+} \rightarrow D^0\pi^+$, and the D^0 is reconstructed in the decay channels

[a]Charge conjugation implied throughout

Table 1. ALEPH: results of model-dependent analysis. Errors include systematic uncertainty

Model	$\langle x_B^L \rangle$	χ^2/ndf
Peterson[3]	0.733 ± 0.006	116/94
Kartevelishvili[4]	0.746 ± 0.008	97/94
Collins[5]	0.712 ± 0.007	164/94

$D^0 \rightarrow K^-\pi^+$, $D^0 \rightarrow K^-\pi^+\pi^+\pi^-$ and $D^0 \rightarrow K^-\pi^+\pi^0$. The remaining two channels are $B \rightarrow D^0\ell\nu X$, followed by $D^0 \rightarrow K^-\pi^+$, and $B \rightarrow D^+\ell\nu X$, followed by $D^+ \rightarrow K^-\pi^+\pi^+$. Using the full data sample collected at the Z peak, about 4 million hadronic Z decays, a total of 2748 candidates have been found, with a signal purity between 63% and 90%, depending on the decay channel. The B energy is estimated from $D^{(*)}$ and lepton momentum, plus the hemisphere missing energy, due to the neutrino. The energy resolution is described by the sum of two Gaussians, with widths of 0.04 and 0.10, and 50-60% of the candidates in the core.

The mean scaled energy $\langle x_B \rangle$ is extracted from the raw x_B distribution in both a model dependent and a model-independent way. In the first case, three different fragmentation models have been used to hadronize the b-quark after the parton shower, simulated by JETSET 7.4[6]. Reconstruction efficiency and energy resolution, as well as missing pions from B^{**} and D^{**} decays, are taken into account by Monte Carlo simulation. Then, for each model, the reconstructed x_B spectrum
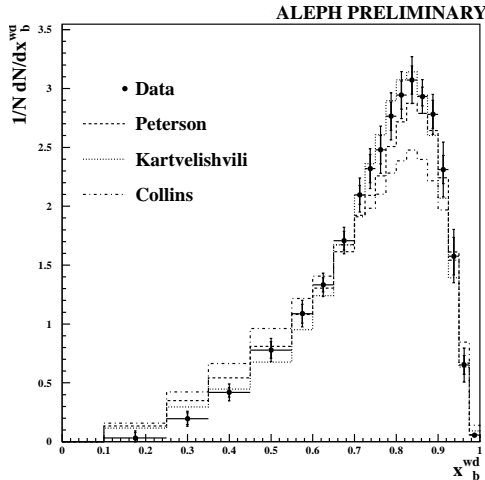
Figure 1. Scaled energy distribution of weakly-decaying B mesons as measured by ALEPH.

in Monte Carlo is compared to data and a minimization of the difference is performed by varying the model parameter. Table 1 shows the results for $\langle x_B^L \rangle$, the mean scaled energy of the leading B, the meson resulting from hadronization, prior to any decay. The fragmentation model of Kartvelishvili et al.[4] gives the better agreement with data. In the model-independent analysis, the Monte Carlo is used to calculate the efficiency, $\epsilon(x_B)$, and the resolution matrix $G(x_B, x_B^{reco})$, defined as the probability for the B meson to have a scaled energy x_B, given the measured x_B^{reco}. Hence the fragmentation function $D(x_B)$ is obtained by unfolding the measured distribution $D^{data}(x_B^{reco})$:

$$D(x_B) = \epsilon^{-1}(x_B) \cdot G(x_B, x_B^{reco}) \cdot D^{data}(x_B^{reco}) . \quad (2)$$

Since G depends on the Monte Carlo fragmentation function, the procedure must be iterated, using in the Monte Carlo the above D function obtained from data, until convergence is reached. The results of this analysis are $\langle x_B^L \rangle = 0.7499 \pm 0.0065(stat) \pm 0.0069(syst)$, for the leading B meson, and $\langle x_B^{wd} \rangle = 0.7304 \pm 0.0062(stat) \pm 0.0058(syst)$, for the weakly decaying one. Figure 1 shows the resulting fragmentation function

for the weakly-decaying B meson, compared to the distributions obtained from the model-dependent analysis.

3 SLD measurement

SLD measurement is based on 350,000 Z hadronic decays collected in 97 and 98. The analysis method is the same used for an already published SLD result[7], based on a smaller data sample. A topological secondary vertex finder exploits the small and stable SLC beam spot and the CCD-based vertex detector to inclusively reconstruct b-decay vertices with high efficiency and purity. Precise vertexing allows to reconstruct accurately the b-hadron flight direction and hence the transverse momentum of tracks associated to the vertex with respect to this direction. Their invariant mass, corrected for the transverse momentum of missing particle, is used to separate b-hadrons from $udsc$ background, yielding a 98% pure b-sample with 44% efficiency.

The b-hadron energy is also measured from the invariant mass and the transverse momentum of the tracks associated to the vertex. Constraining the vertex mass to the B^0 mass, an upper limit on the mass of the missing particles is found for each reconstructed b-decay vertex, and is used to solve for the longitudinal momentum of the missing particles, and hence for the energy of the b-hadron. In order to further improve the b-sample purity and the reconstructed b-hadron energy, only vertices with low invariant mass are kept. The selection yields 4164 candidates, with an overall efficiency of 4.2% and 9.6% energy resolution in the core, which accommodate about 80% of the candidates. Moreover, both the efficiency and the energy resolution are remarkably flat in the region $x_b > 0.2$

Several fragmentation functions have been fitted to the candidates scaled energy distribution, as shown in Figure 2. A good
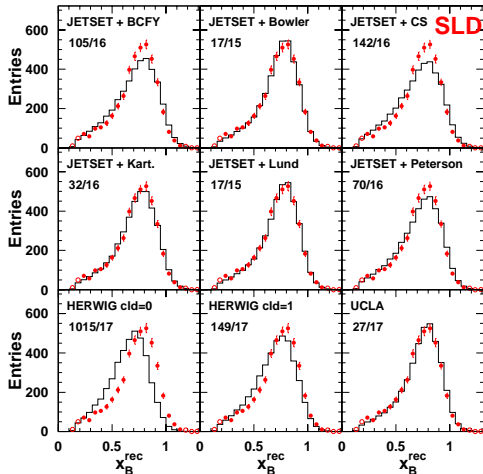
Figure 2. SLD test of fragmentation models.

Figure 3. Scaled energy of the weakly-decaying b-hadron as measured by ALEPH and SLD.

description of the data is obtained using JETSET together with the phenomenological models of the Lund group[8], Bowler[9] and Kartvelishvili et al.[4], or using the UCLA[10] fragmentation model. Several functional forms of the true energy distribution $D(x_b)$ have been tried too, and four of them have been found consistent with data. Hence the true distribution has been obtained from equation 2, using the above eight best fitted distributions to calculate the unfolding matrix G from Monte Carlo. The resulting mean scaled energy for the weakly-decaying b-hadron is $\langle x_b^{wd} \rangle = 0.710 \pm 0.003(stat) \pm 0.005(syst) \pm 0.004(model)$.

4 Summary and conclusions

In Figure 3, the fragmentation functions measured by ALEPH and SLD are compared. A slight disagreement is observed between the two. However it must be pointed out that ALEPH selects B mesons only, while the SLD sample also includes B_s and barions, which may be responsible of the observed difference.
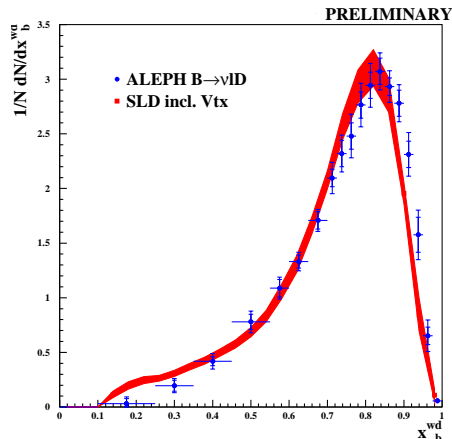
References

1. R Barate et al., ALEPH Collab., ALEPH 2000-68, CONF 2000-46, 2000.
2. K. Abe et al., SLD Collab., SLAC-PUB-8504, 2000.
3. C. Peterson et al., Phys. Rev. D **27**, 105 (1983).
4. V. G. Kartvelishvili et al., Phys. Lett. B **78**, 615 (1978).
5. P. D. B. Collins and T. P. Spiller, J. Phys. G **11**, 1289 (1985).
6. S. Sjöstrand, Comp. Phys. Comm. **82**, 74 (1994).
7. K. Abe et al., Phys. Rev. Lett **84**, 4300 (2000).
8. B. Andersson et al., Phys. Rep. **97**, 32 (1983).
9. M. G. Bowler, Z. Phys. C **11**, 169 (1981).
10. S. Chun and C. Buchanan, Phys. Rep. **292**, 239 (1998).