Studies of Heavy Flavour Jet Tagging with ZVTOP in JAS3

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A neural network technique is used to distinguish b-jets from c-jets based on the output of the java-based vertex finding code ZVTOP in JAS3. Three aspects of flavour tagging are considered: the polar angle dependence of the performance of the tag, the use of primary vertex information to improve the tag and the use of neutral energy to enhance the tag performance. Encouraging results are obtained for the potential of the latter two inputs (primary vertex momentum and neutral energy distribution) to improve upon the standard secondary vertex based flavour tagging established at SLD.

1. INTRODUCTION

The LCFI collaboration studies described here are based on 45 GeV jets in selected 2-jet Z^0 bb and Z^0 cc events. Fast Monte Carlo is used to simulate the SiD detector and the events are analysed using JAS3 (Java Analysis Studio). Figure 1 shows a typical bb event with back-to-back jets. The right hand plots shows a zoom in to the scale of the secondary B hadron vertices a few millimeters from the interaction point (IP). In total 30,000 bb events plus 30,000 cc events were used in these studies.

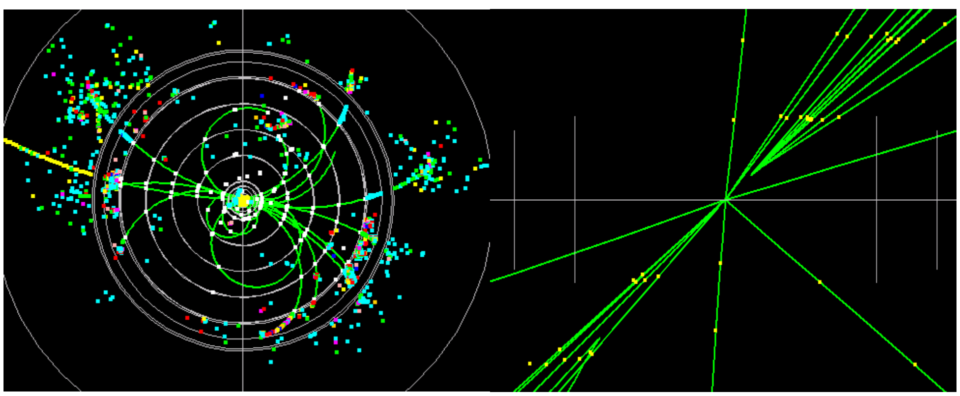

Figure 1: A typical Z^0 bb event viewed with the WIRED event display in JAS3

The vertices are reconstructed in each jet using the version of ZVTOP [1] in JAS3 [2]. Kinematic variables related to the invariant mass of the tracks in the secondary vertex are reconstructed [3]. These and other vertex based inputs are used in a neural network program [4]; the output of which provides the jet flavour tagging.

2. ANGULAR DEPENDENCE

We consider the performance of the CCD based five layer vertex detector shown in figure 2 as described in the TESLA TDR. The impact parameter resolution at the IP is $\sigma = 4.1 \oplus 7.3/(p \sin^{3/2} \theta)$ µm where p is the track momentum in GeV/c and θ is the polar angle. For a track with p = 1 GeV/c and at $\cos\theta \sim 0.9$ this corresponds to around three times poorer resolution in both projections compared with a similar track at cosθ ~ 0.0. We here study the resulting degradation in jet flavour tagging at large |cosθ|. As a second part of this study we examine whether the small angle tagging may be improved by tuning the neural network tag specifically in this region.

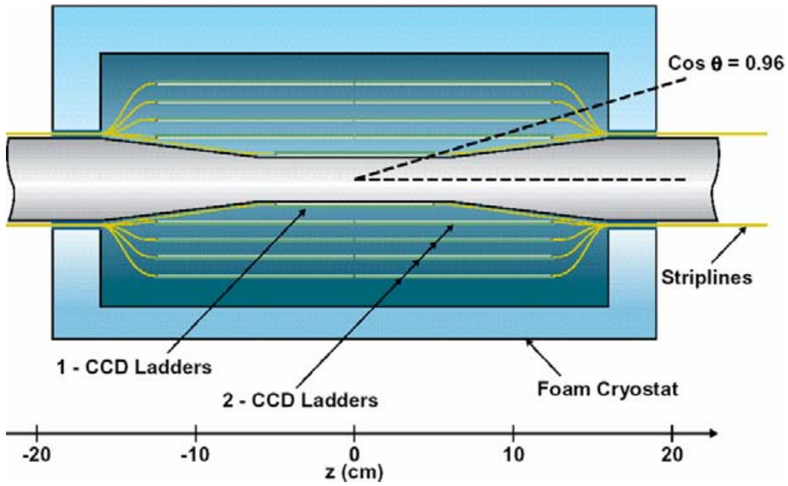

Figure 2: A CCD pixel vertex detector for the ILC

The tagging performance curves are shown in Figure 3. The left-hand plot shows the c-jet mis-tag probability against the b-tag efficiency for the b-tag. The right-hand plot shows the b-jet mis-tag probability against the b-tag efficiency for the c-tag. In both cases the lower curve with diamond points shows the best performance is obtained for a 2-input (vertex mass and momentum) network over the full angular range studied, |cosθ| < 0.9. The other three curves are almost overlapping and show various neural networks applied to the region 0.8 < |cosθ| < 0.9. One corresponds to the same network applied to the small angle region, the second is for a 3-input network with |cosθ| itself as the third input and the third is for the original 2-input network trained only in this 0.8 < |cosθ| < 0.9 region.

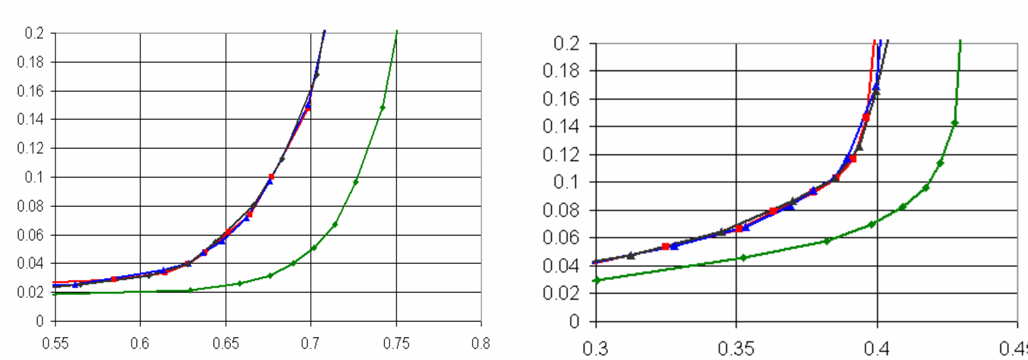

Figure 3: Performance for b-tag (left) and c-tag (right); see text above for details

The results indicate that the flavour tagging performance does indeed significantly degrade at small angles, corresponding to poorer tracking resolution, and that in this study no recovery is found to be possible by tuning the neural network for this region. Full details of this study of the angular dependence and the following one on using the primary vertex are described in [5].

3. PRIMARY VERTEX MOMENTUM

The summed momentum of tracks in the secondary and primary vertex differs for b-jets and c-jets due to differing fragmentation functions. The secondary vertex momentum has been a standard jet flavour tagging variable for some time but this is the first study incorporating information from the primary vertex. The momentum of the primary vertex charged tracks is certainly correlated with that of the secondary; but due to missing neutral energy this correlation is not 100% and extra information may be contained in the primary. Figure 5 shows the secondary (left) and primary (right) momentum for b-jets and c-jets. It can be seen that secondary vertices carry more momentum in b-jets compared with c-jets; while the opposite is true for the primary vertex momentum.

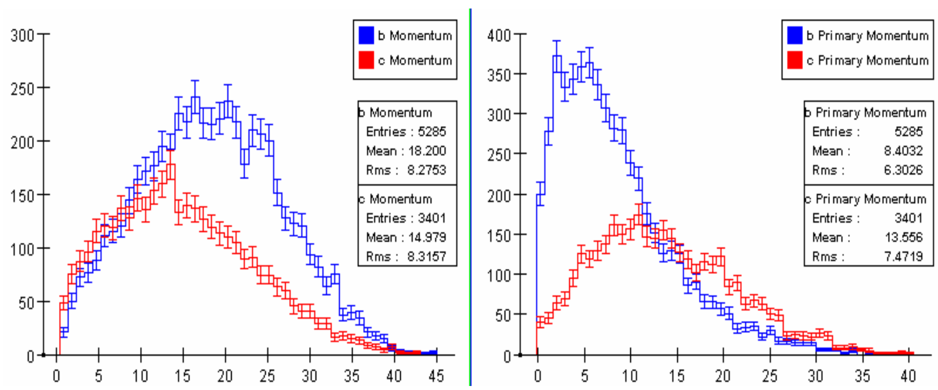

Figure 5: Momentum sum for tracks in secondary vertex (left) and primary vertex (right) in GeV/c.

The tagging performance curves are shown in Figure 6. The left-hand plot shows the c-jet mis-tag probability against the b-tag efficiency for the b-tag. The right-hand plot shows the b-jet mis-tag probability against the b-tag efficiency for the c-tag. In both cases the upper curve with diamond points shows the performance obtained for a 2-input (vertex mass and momentum) network only; while the lower curves with the square points show the improvement obtained in adding the primary vertex momentum information as a third input for a 3-input network. It can be seen that including the primary vertex information improves the b/c-tag separation by around 10%, which is a big gain for a simple input.

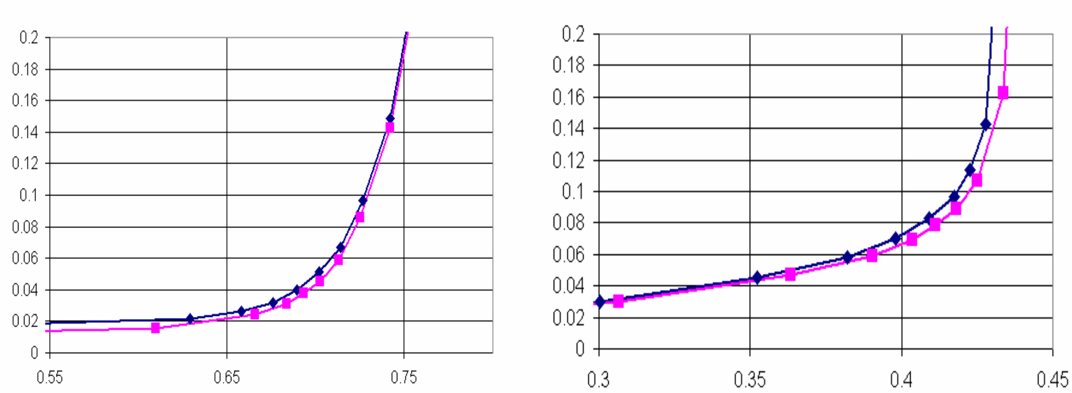

Figure 6: Performance for b-tag (left) and c-tag (right); see text above for details

4. USE OF NEUTRAL ENERGY

All previous flavour tagging studies have concentrated on the charged track information, and in particular on the reconstructed charged mass of the decaying heavy hadron. The distribution of the 'Pt corrected mass' [3] is shown in Figure 7. If it was possible to fully reconstruct all of the decay products we would see well separated peaks at around 1.9 GeV for c-jets and around 5.3 GeV for b-jets in this plot. Instead (due to missing energy that it has not been possible to correct for) both distributions spread over into lower mass regions leading to a loss of purity for the charm tag and a loss of efficiency for the b-tag due to b-events reconstructed with mass below around 2 GeV.

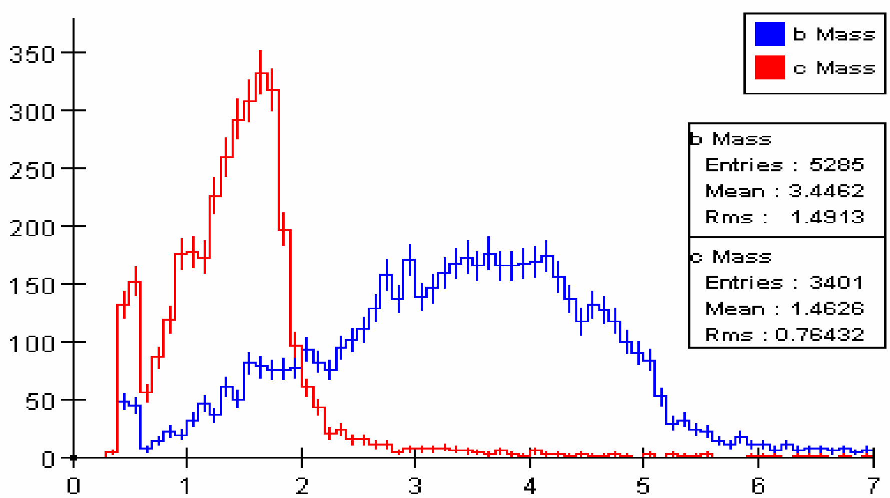

Figure 7: 'Pt corrected mass' for secondary vertices in b-jets and c-jets.

Since most of the missing energy is in the form of π^0 particles that may be observable in a high resolution electromagnetic calorimeter it may be considered whether this non-vertex information might be kinematically associated with decay vertex and improve the flavour separation, (this study is described in detail in [6]).

Using neutral Monte Carlo truth information (in addition to the reconstructed vertex) the highest energy π^0 in the jet is identified. The 'Pt corrected mass' is then recalculated with the kinematic 4-vector information of this π^0 included. The performance of the original 2-input (charged 'Pt corrected mass' and momentum) neural network was then compared with a 4-input network. The two new inputs being the π^0 energy (this variable discriminates between whether the π^0 came from the primary or secondary vertex; with higher energy particles generally coming from the latter) and the 'Pt corrected mass' with the π^0 included (this variable discriminates between b-jets and c-jets, with the latter more likely to have a mass less than 2 GeV). The main effect of including the neutral energy in this study was to lower the b-jet background to the c-tag by a relative 10-25%, (with a corresponding gain in the b-tag efficiency of ~1%.)

References

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