

B IDENTIFICATION BY TOPOLOGY WITH THE SLD DETECTOR*

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INTRODUCTION

At both the SLC and LEP large samples of $Z^0 \rightarrow b\bar{b}$ will soon be available. The challenge is to find experimental techniques to *inclusively* tag and identify the various particles b quarks may fragment into. The work described here makes use of the new generation of close-in tracking devices (commonly called vertex detectors) which will achieve unparalleled precision in particle trajectory resolution. Some of these devices (notably in ALEPH at LEP and SLD at the SLC) provide three-dimensional information which is crucial in solving the pattern recognition problem discussed below. In the case where only two-dimensional information is available other than tracking information (e.g., particle identification) may be required. The problem to solve is shown in Fig. 1(a). The tracking system is used to extrapolate tracks into some preselected point (e.g., distance of closest approach to the beam line, a fix radius, etc.). The result is a picture of many crossing tracks and the problem is to find the real vertices among all the possible combinations. The Monte Carlo input which resulted in the "bundle-of-sticks" shown in Fig. 1(a) is shown in Fig. 1(b).

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The algorithm I developed to study B physics with the SLD Detector relies on the three-dimensional precision reconstruction of the tracks. This is the tool which provides for the resolution of ambiguities.

To start, pairs of tracks are subjected to an opening-angle versus total momentum cut. By requiring $\cos\theta_{open} > 0.2$ only tracks in the same jet may be paired.* A total momentum requirement of at least > 0.5 GeV/c eliminates low momentum combinations which have a poor signal-to-noise ratio. I also placed a correlated cut at $\cos\theta_{open}$ vs. P_{TOT} of the form:

$$P_{TOT} < \frac{(0.4 \text{ GeV}/c)}{1 - \cos\theta_{open}} \quad \text{for} \quad \cos\theta_{open} < 0.95 \quad .$$

This cut eliminates pairs of excessively high mass and may cause a slight inefficiency in the detection of some rare B decays (e.g., $B_d \rightarrow \pi^+\pi^-$) but the signal-to-noise ratio in the region eliminated by this cut is extremely poor. A scatter plot of track pairs which come from the same vertex is shown in Fig. 2(a). The cuts are indicated on this figure, as well. Wrong combinations are shown in Fig. 2(b).

The "vertex" of the track pair is assigned to lie on the line of the distance of closest approach (DOCA) between them, weighted by each track's momentum so as to favor the higher momentum track. This weighing is used as most tracks are multiple scattering limited. The " χ^2 " for the association is formed:

$$\chi_{vTX}^2 = \sum_{tracks} \left(\frac{d_i}{\sigma_i} \right)^2 \quad ,$$

where

$$d_i = \left| \bar{x}_i(\text{DOCA}) - \bar{x}_{vTX} \right|$$

and σ_i is the estimated tracking precision, and for the SLD is:

$$\sigma_i \approx 10 \mu\text{m} \oplus \frac{70 \mu\text{m GeV}}{P_{track}/\text{GeV}} \quad .$$

A cut on χ_{vTX}^2 is made: $\chi_{vTX}^2 < 9$. The separation of the vertex from the beam collision point is calculated next. In the case of the SLC, the location each beam

* One advantage of doing this physics at the Z^0 over the Υ_{4s} is that for the most part the jets contain fragments from just one or the other b quarks.

crossing is known to about $30 \mu\text{m}$ and the spot size is $4 \mu\text{m}$. Thus there is negligible uncertainty in the origin of the flight paths. The flight path is "signed" $+(-)$ according to whether the momentum of the vertex points away from (towards) the primary vertex point. As the distance between the primary vertex and the secondary vertex decreases, the number of combinations increases rapidly. A cut is made to require the flight path to be greater than $500 \mu\text{m}$. A good signal-to-noise ratio is thus achieved at the expense of about 30% in efficiency. This is the single largest inefficiency in this vertexing algorithm. The signal and background plots for this cut are shown in Figs. 3(a) and 3(b).

All combinations of track pairs satisfying the above criterion are temporarily retained. Hence a vertex with four charged prongs may result in up to six track pairs. The track pairs are now used as "seeds" to form vertices of higher prong count. The procedure used is to first find the next closest track in the same jet [$\cos \theta_{open}$ (vertex-track) > 0]. Closeness is measured in normalized units (σ 's) to avoid momentum dependencies. If a track is within 3.5σ an attempt is made to incorporate it into the vertex. A new vertex location is computed such that

$$\chi^2 = \sum_{tracks} \frac{(\bar{x}_i - \bar{x}_{vTX})^2}{\sigma_i^2}$$

is minimized; \bar{x}_i is the space point on the track at the distance of closest approach to the vertex point \bar{x}_{vTX} , and σ_i is the projected resolution along the distance of closest approach vector. The new vertex is accepted if $\chi^2 < 6.3$ and the new flight path $|\bar{x}_{vTX}|$ is greater than $500 \mu\text{m}$. If it passes these criterion and has not been previously cataloged it is temporarily stored away. This process of adding tracks continues until no more tracks pass the procedure outlined above.

The temporary vertices are grouped by prong count and tested for net charge ($|Q_{net}| \leq 1$), strangeness ($|S_{net}| \leq 1$), and baryon count ($|B_{net}| \leq 1$). The last two criterion rely on the particle identification. Vertices passing these cuts have their apparent mass, four vector, impact parameter with respect to the beam line, the distance to the next close track in the event, and various quantum numbers tabulated and stored away in the output banks.

Cascade topologies are a common occurrence in B decay and may be found by iterating the vertex find process. The starting "track pairs" now contain a track and a "pseudo track" defined by a vertex found in the first pass. The first pass vertices are presumed to be the tertiary (charmed) vertex.

The only new criterion applied is to require that the new (secondary) vertex and the tertiary vertex be separated by at least $150 \mu\text{m}$ and that the secondary vertex is closer to the primary vertex than the tertiary

In both passes of vertex finding no attempt is made to resolve ambiguities; tracks can be (and often are) associated with more than one vertex.

The efficiency for finding cascade topologies from B mesons is 5–10% depending on the cuts used. This is to be compared with the 30% efficiency for the first pass vertex finding on single vertices.

In another contribution to this conference,¹ a detailed breakdown of the cascade topologies as to origin is given. Examination of the entries in Table I (Ref. 1) sorted by the charge of the secondary and tertiary vertices show a favorable distinction between B_u^+ , B_u^- , B^0 and \bar{B} . Separation of B_d and B_s in the B^0 sample requires particle identification.

References

1. ATWOOD, W. B. AND B. MOURS. B physics at the Z^0 pole. SLAC-PUB-5048 (August 1989).

Table I Breakdown of found cascade topology events by secondary and tertiary vertex changes, Q_b and Q_c . For each charge combination, the sample is resolved into particles and antiparticles, as well as the meson flavors B_u , B_d , and B_s (see upper left entries under $Q_b = Q_c = -1$ for key) by referring back to the Monte Carlo input.

		Q _b Vertex					
		-1		0		+1	
Q _c Vertex		B	\bar{B}				
	-1	u	43	2	14	23	1
d		8	6	42	446	2	3
s		2	0	22	159	0	2
0		890	21	73	82	22	899
		93	53	364	394	58	93
		23	22	141	164	27	22
+1		21	0	35	21	1	56
		3	2	492	57	7	3
		3	0	141	31	2	0

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Figure Captions

Fig. 1. A Lund Monte Carlo event of $Z^0 \rightarrow b\bar{b}$: (a) the simulated reconstructed tracks extrapolated into a radius of 1 mm about the beam line; (b) the input Monte Carlo event is shown with the tracks properly associated with their vertices.

Fig. 2. Scatter plots of P_{TOT} vs. $\cos \theta_{open}$ for all track pairs: (a) only correctly associated pairs are shown; (b) only incorrectly associated pairs are plotted.

Fig. 3. Plots of the signed flight path from the primary vertex to the pair vertex: (a) only correctly taken pairs are shown; (b) only wrong combinations are shown.

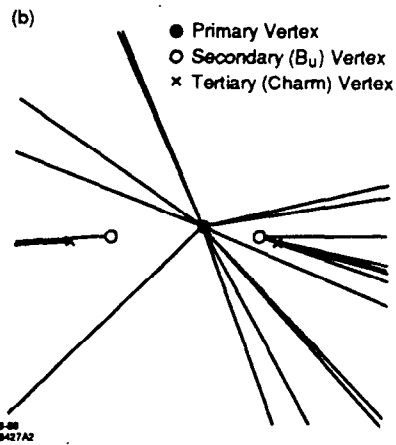
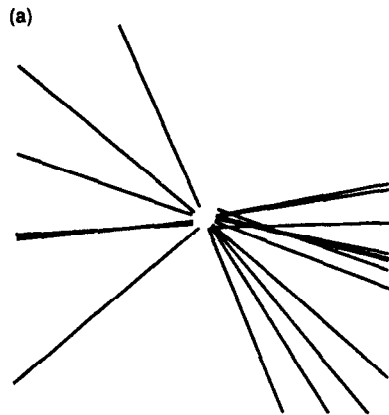


Fig 1

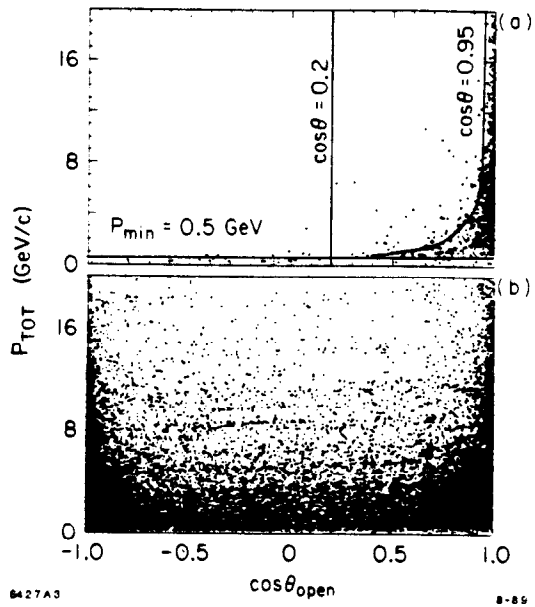


Fig. 2

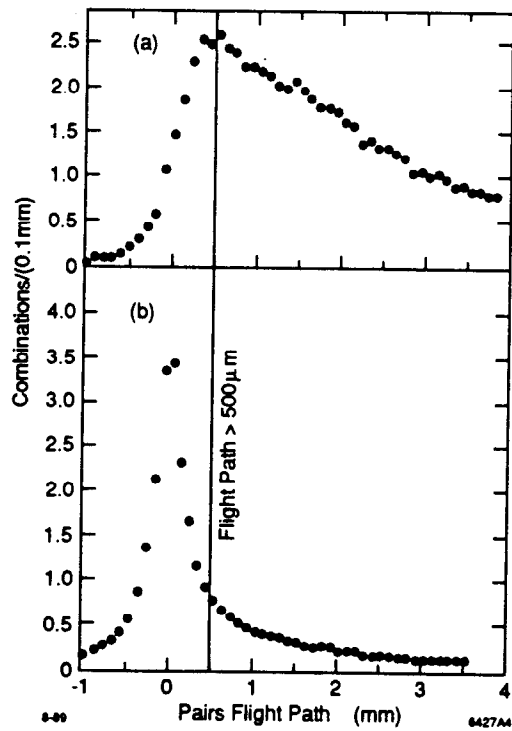


Fig. 3