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EFFICIENCY FOR b JET TAGGING IN $t\bar{t}$ EVENTS

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Efficiency for b Jet Tagging in $t\bar{t}$ Events

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1 Introduction

In this note we investigate the potential use of the SDC tracking system for tagging b quark jets produced in $t\bar{t}$ events. If the top quark mass is greater than 120 GeV/c^2 or so, it may not have been discovered by the time the SSC is operating. For top masses below 250 GeV/c^2, $t\bar{t}$ pairs are expected to be produced copiously at the SSC, and could be a serious background to other physics signals. In any event, the capability to recognize b jets through secondary vertices with reasonable efficiency would provide a powerful handle for distinguishing $t\bar{t}$ events from other processes.

2 Impact Parameter Resolution

In this study, the tracking system that was used consisted of a silicon tracker of 10 layers between 18 and 45 centimeters with an outer straw tube chamber and radial drift chamber[1]. Two cases were considered: with and without a pixel vertex detector. The vertex detector is assumed to have three layers at 6, 8 and 10 centimeters radius, with a resolution in $r\phi$ of 5 microns, and covers out to 2.5 in pseudo-rapidity. The transverse impact parameter resolution for the two cases has been calculated by Jim Hylen. In Figure 1, the impact parameter resolution is shown as a function of p_t at $\eta = 0$. The three sets of points are for the silicon tracking detector alone (upper set), the silicon and straw detectors (middle set), and the silicon, straw and pixel vertex detector (lower set). The two curves show the parametrizations that were used in this study:

$$\sigma_b(p_t) = \begin{cases} \frac{-19.2}{p_t^2} + \frac{178.9}{p_t} + 14. \text{ microns} & \text{without vertex detector} \\ \frac{-20.6}{p_t^2} + \frac{73.1}{p_t} + 4. \text{ microns} & \text{with vertex detector} \end{cases}$$

Since the track curvature and impact parameter measurements are highly correlated, the outer detector improves the impact parameter measurement substantially by reducing the curvature uncertainty. The impact parameter resolution varies on the order of 20% with

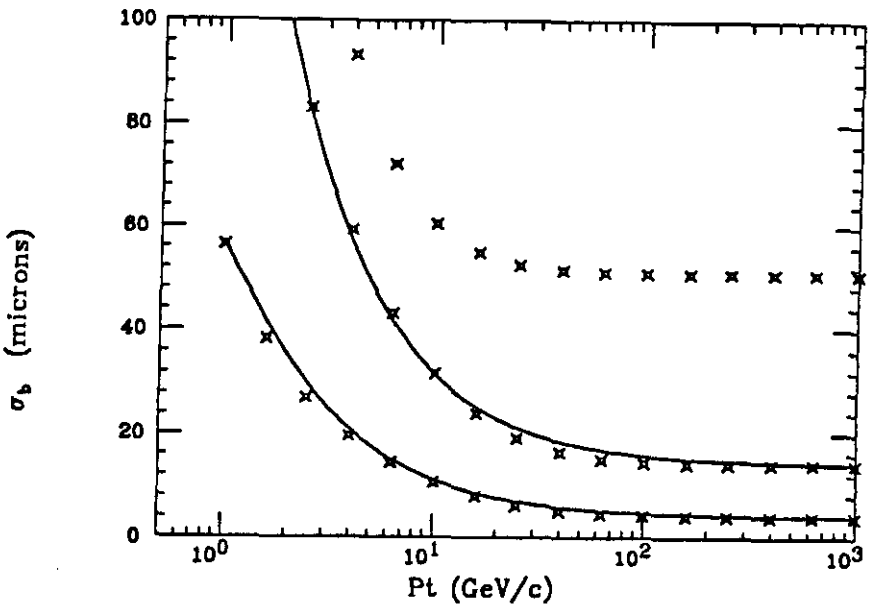

Figure 1: Impact parameter resolution for the tracking system with and without a pixel vertex detector[3].

pseudo-rapidity, due to increasing amounts of material traversed and larger momenta for a given p_t. This variation of σ_b with η is ignored in this study. In the case with an inner vertex detector, the high p_t resolution of 4 microns might be less than systematic errors on the beam position and detector alignment.

3 Method

The method used here to recognize secondary vertices utilizes the transverse impact parameter only. To tag a b jet, we use a very simple algorithm, which is to count the number of tracks in the jet direction (within 15° in ϕ) which are above a p_t threshold (1 GeV/c) and which are not consistant at the 2-3 sigma level with the primary vertex. Presumably something can be gained by using the z coordinate information; however, the tracking system resolution in the polar direction is substantially worse, and there will be additional vertices along the beam from multiple interactions.

A typical $t\bar{t}$ event from Isajet is shown in Figure 2, with $m_{top} = 150$ GeV/c^2. Charged tracks with $p_t > 1$ GeV/c and $|\eta| < 2.5$ are shown. In Figure 2A, the measured impact parameter is plotted vs the track azimuth, with the impact parameter smeared with the resolution for the system without the vertex detector. The B meson and baryon lifetimes are all assumed to be 1.2 picoseconds, and the other lifetimes are taken from the CDF decay

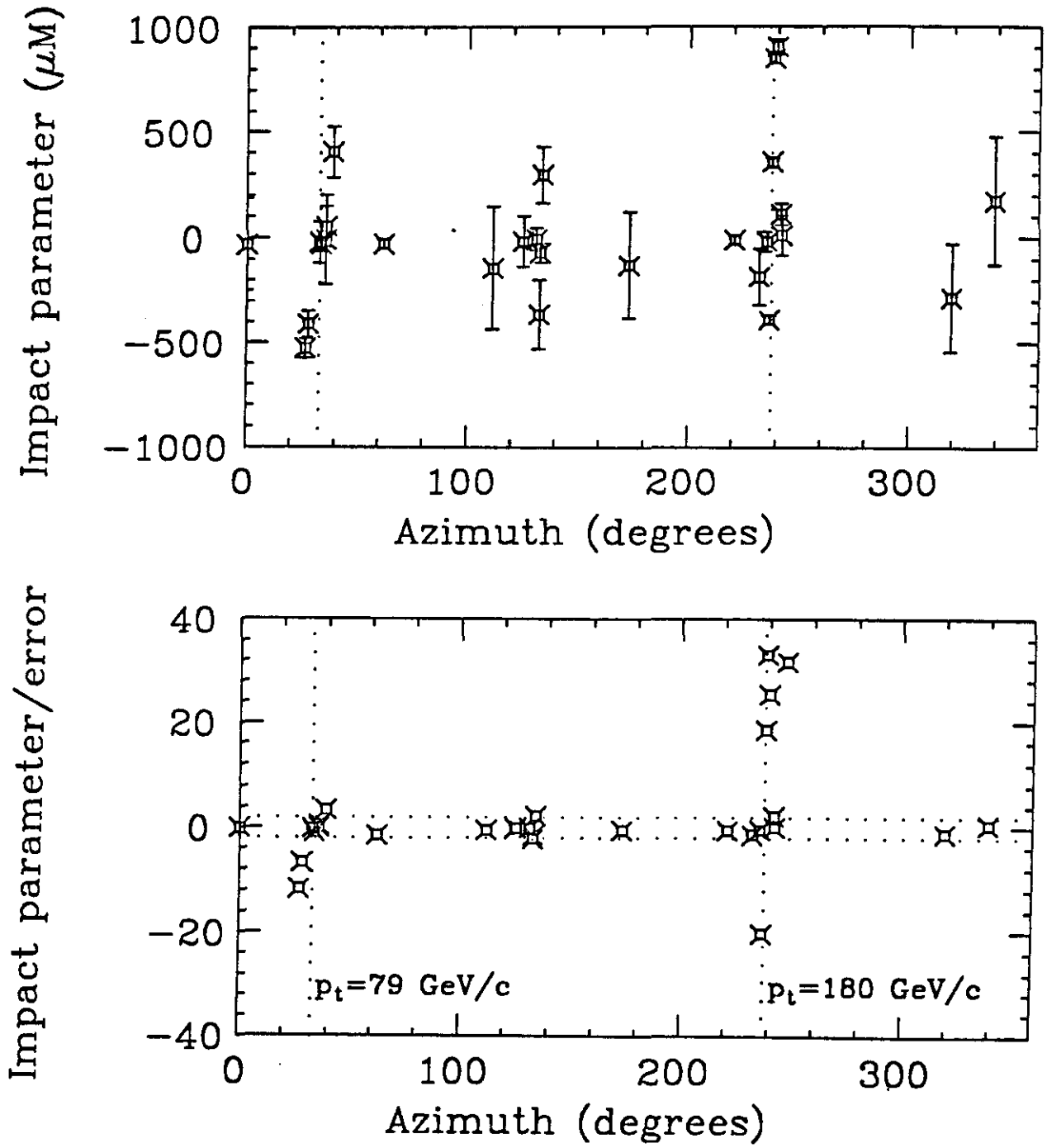

Figure 2: Charged tracks ($|\eta| < 2.5$, $p_t > 1$ GeV/c) in an Isajet $t\bar{t}$ event with $m_{top} = 150$ GeV/c^2. A.) Simulated impact parameter and error vs. azimuth ϕ.. The two b jets are indicated by dotted lines. B.) Number of sigma of impact parameter vs. azimuth ϕ. The horizontal dotted lines show 3 sigma cut.

tables. The two b jets are indicated with dotted lines. The sign of the impact parameter used is whether the impact parameter passes the beam position to the right or to the left (not the same as the convention used by CDF, for example). With perfect resolution, the tracks emanating from a displaced vertex would fall on a sinusoid crossing the horizontal axis at the same ϕ as the jet, but since the tracks tend to be boosted the jet direction it approximates a straight line. In Figure 2B, the number of sigma from zero is plotted vs the track azimuth. The horizontal lines show a cut at 2 sigma.

4 Monte Carlo Results

In the Monte-Carlo study, $t\bar{t}$ events were generated with Isajet for m_{top} = 120, 150 and 180 GeV/c^2. The t and $\bar{t}$ were forced to decay semileptonically. Events were required to have two two electrons within $|\eta| < 2.5$ with $p_t > 20$ GeV/c, and one or both of the b jets with observed jet $p_t > 30$ GeV/c and $|\eta| < 2.0$. The jet energies were smeared using Ian's jet_smear routine and assumed to be found with perfect efficiency for the purposes of this study. The dilepton rate corresponds to roughly 4% of the $t\bar{t}$ cross section, assuming perfect efficiency for electrons and muons. The efficiency for the dilepton events to pass the above requirements varies from 35% to 50% for m_{top} between 120 and 180 GeV/c^2. The rate for these events would be on the order of 0.1 Hz at design luminosity, depending on the top mass.

The two other ingredients besides the B lifetime which affect the tagging efficiency are the b jet p_t spectrum and the B hadron fragmentation function. These are shown in Figures 3 and 4, for the Isajet data. The track finding efficiency for these low p_t jets (typically 50 GeV/c) is expected to be close to 100% for the silicon tracker alone[2].

The b tagging efficiency is shown in Figure 5A as a function of the observed p_t of the b jet, comparing the cases with and without the inner vertex detector. Here three or more tracks with $b > 2$ sigma are required to define a tag. The efficiency at low jet p_t is low, because of the poor impact parameter resolution for low p_t tracks and because of the 1 GeV/c p_t cut. At higher jet momenta, the efficiency increases to approximately 50% for the case of no vertex detector, and 70% for the vertex detector. The effect on the tagging efficiency of varying the number of sigma cut is shown in Figure 5B. Raising this cut from two to three sigma lowers the efficiency at high p_t to 40%, for no vertex detector. On the other hand, requiring only two tracks for a tag rather than three increases the efficiency substantially.

The overall efficiency for tagging one or both of the b jets in $t\bar{t}$ events is shown in Figure 6, the two detector configurations. In either case it should be possible to recognize secondary vertices in a large fraction of these events. One should keep in mind that with

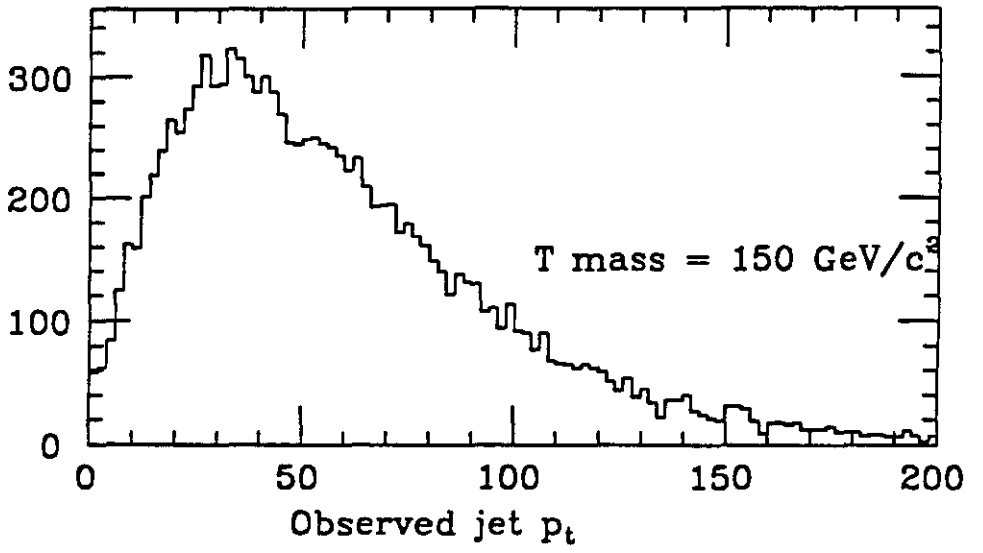

Figure 3: Observed b jet p_t spectrum for Isajet $t\bar{t}$ events with $m_{top} = 150$ GeV/c^2.

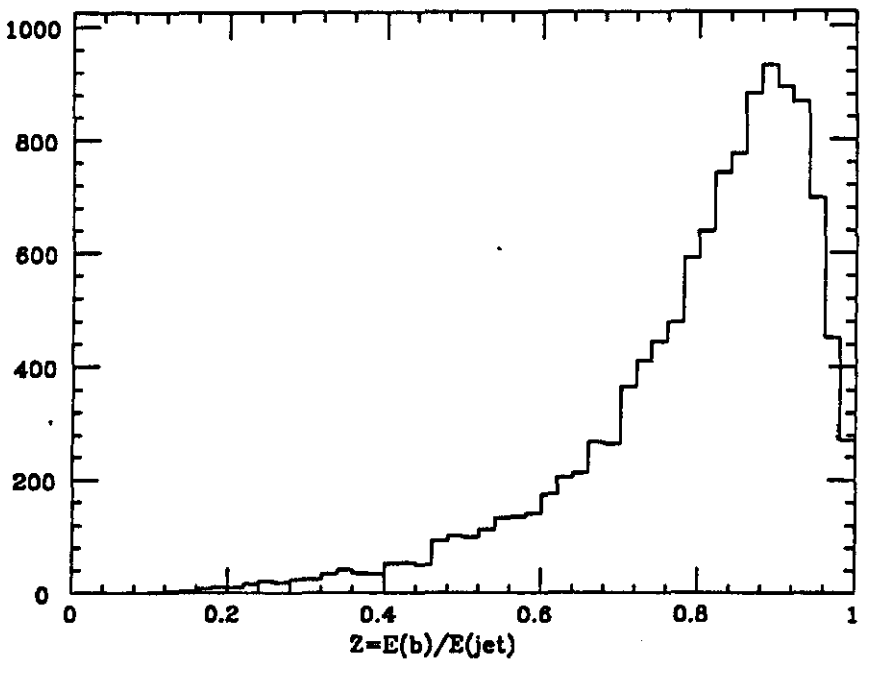

Figure 4: B meson fragmentation function in Isajet.

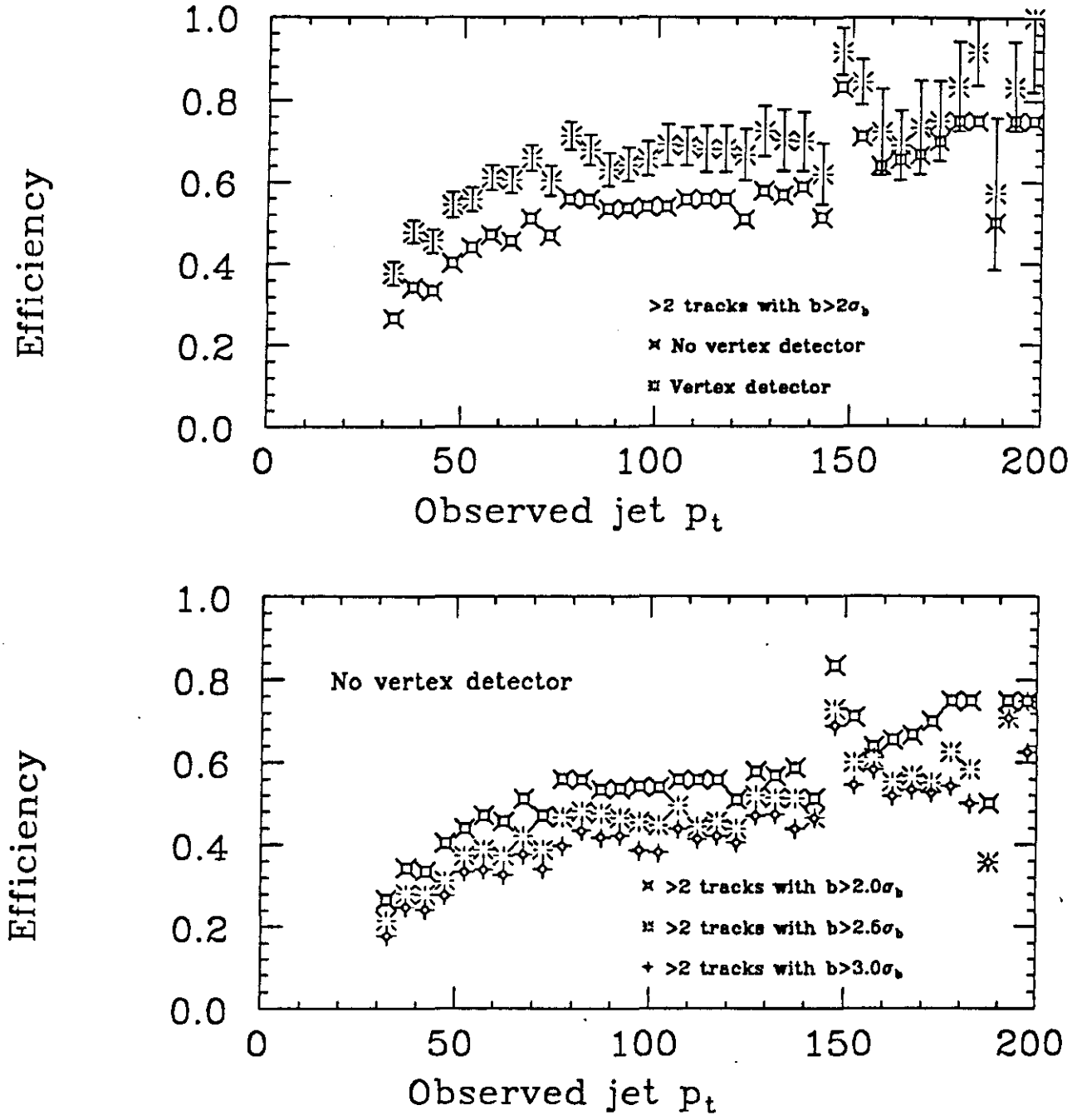

Figure 5: Tagging efficiency for b jets vs. b jet p_t. A.) Efficiency requiring 3 or more tracks with more than 2 sigma impact parameter, for the tracking system with and without a pixel vertex detector. B.) Efficiency for three values of the # sigma cut, for the system without a pixel vertex detector.

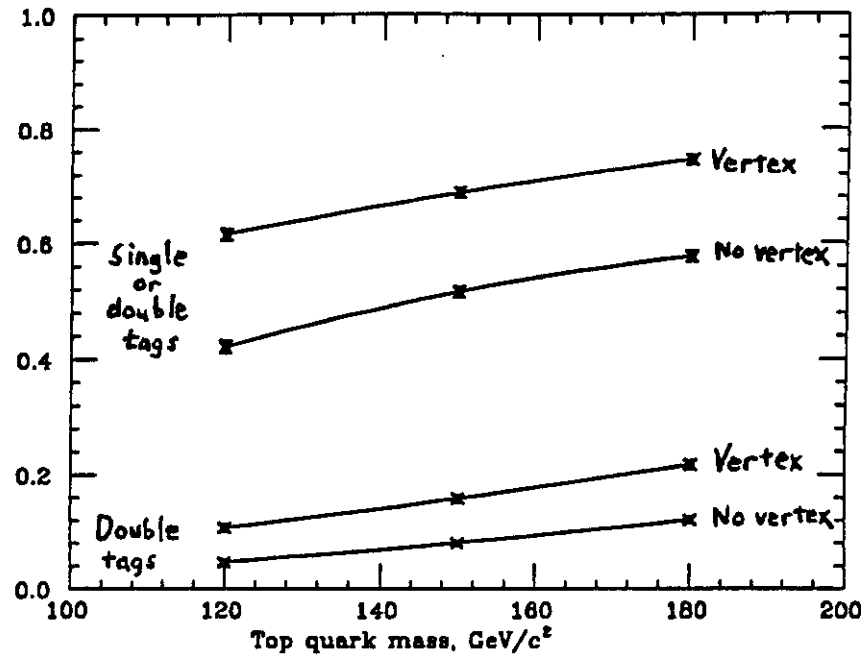

Figure 6: Overall efficiency for single and double tags vs. m_{top} for the tracking system with and without a pixel vertex detector.

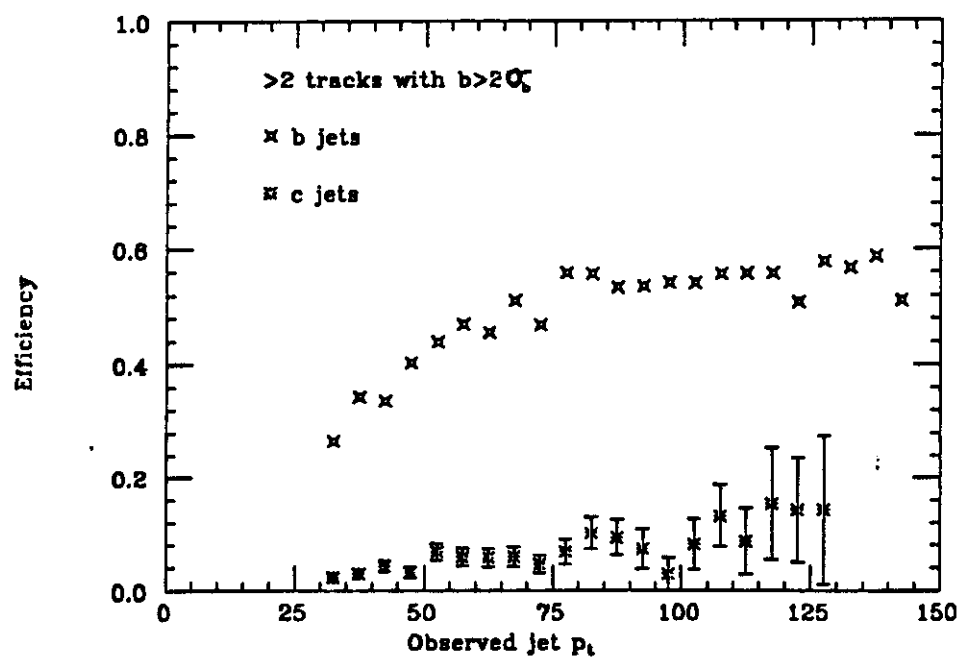

Figure 7: Tagging efficiency for c jets compared to b jets vs. jet p_t, for the tracking system without an inner vertex detector.

the vertex detector, the situation would be significantly more clear on an event by event basis, allowing one to associate a lepton with a particular vertex, and perhaps recognizing both b and c vertices on some events. Also, the higher efficiency for double tags is desirable, since a comparison of the rates for zero, one and two tagged jets should be useful.

One potential background to b jets from top would be charmed mesons produced in conjunction with Ws[4], if only one lepton were required for event selection. The efficiency for the simple algorithm for tagging c jets was investigated, and is shown in Figure 7, for the system with no vertex detector. The algorithm gives a factor of rejection of c jets compared with b jets, mainly due to the lower multiplicity of the charm decay. Adding a minimum cut on the decay invariant mass would increase this rejection factor, with a moderate loss of signal.

There are several complications which have been ignored in this work, and should be studied further. These include:

- the efficiency for track finding and linking through the entire tracking system. The tagging efficiency would be proportional to the tracking efficiency cubed, so if it is far from unity the above conclusions should be modified.
- potential non-Gaussian impact parameter resolution from hit or segment mis-association.
- determination of the primary vertex, and effects of multiple interactions.
- effects of systematic errors in alignment on impact parameter resolution.

References

[1] Expression of Interest, Solenoid Detector Collaboration, May, 1990.

[2] Silicon Tracking Detector design report, in preparation.

[3] J. Hylen, private communication.

[4] I. Hinchliffe, private communication.