# Forward B Spectroscopy at The SSC

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## I. Introduction

The SSC is designed primarily as a machine to probe the 1 TeV energy regime. It should also prove to be an excellent machine for probing "low energy" (less then 100 GeV mass scale) physics. By the time the SSC is commissioned B decays will have been studied for over 5 years at LEP and the SLC. Much of the "easy" B physics will have been done. The level of mixing should be known, and experiments will have searched for CP violation. The SSC must be a site for high precision, high statistics studies of small effects such as CP violation and rare B decays.

The SSC can be competitive for two reasons. First is the sheer event rate, at a luminosity of $10^{33}$ there will be $10^5$ B pairs produced per second. Second is the prospect of high quality silicon vertex detector systems which can use the constraint of a 20μm transverse beam spot to tag tracks which do not originate from the primary vertex. At the SSC a significant number of B mesons will travel more than 2 cm. before they decay. These Bs can emerge from the 1-2 cm beam pipe and these decays can be completely measured with excellent constraints on the $B\rightarrow D$ cascade decay.

B quark physics signals were reviewed and some general rate estimates were given in a 1984 Snowmass report[1]. This report concentrated on a detector in the central region. A separate report by Jim Cronin[2] discussed a forward spectrometer covering $3<\eta<5$. I will concentrate on developing rate and cross section estimates for the forward design. The forward spectrometer has the advantage that less detector is needed for full azimuth coverage per unit of rapidity. For that reason the detector could be quite long and cover the full $\Delta\phi$ with lavish instrumentation. The system would be quite similar to a conventional fixed target spectrometer, in particular the detectors would have simple planar geometry.

## II. B Production at the SSC

We have used isajet to try to gain a general understanding of B quark production in jets. The most striking feature of high $p_t$ jets at the SSC is the large fraction of them which contain Bs. Figure 1 shows the fraction of B pair events as a function of jet transverse momentum. Most of these pairs are produced in the fragmentation of *one* of the jets in gluon-gluon scattering. The result of this is that in most cases both of the B mesons are close in phase space and the pair can be contained by a detector of reasonable dimensions.

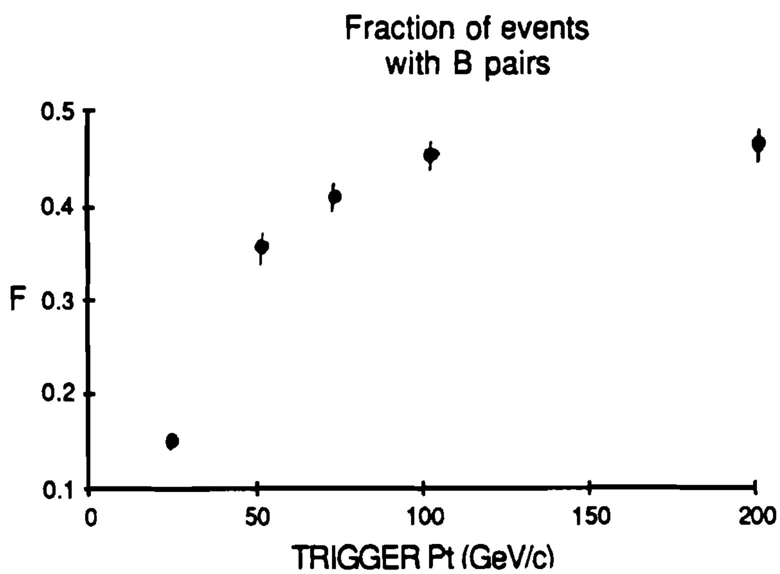


**Figure 1**

Fraction of events with B pairs as a function of trigger transverse energy.

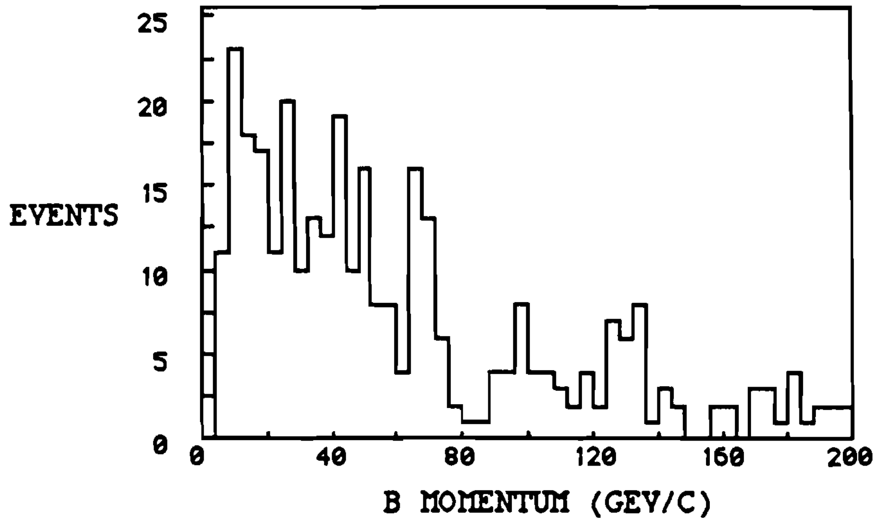


**FIGURE 2**

B meson momentum in 50 GeV jets.

Figure 2 shows the distribution of B meson momenta.At jet transverse momenta greater than 50 GeV about 40% of all jets contain a B pair.

Single and multiple jet inclusive cross sections have been compiled by Frank Paige in a contribution to this conference. The inclusive cross section for jets over 50 GeV, which will contain 35% B pairs, is about 10μb. For a luminosity of $10^{32}$ the $4\pi$ 50 GeV $p_t$ jet trigger rate is 1000/sec. From isajet studies we expect 14% of the B-pairs to appear in the jet rapidity interval 3-5. So we expect a first level trigger rate of 140/sec. An even better signal/background ratio can be achieved with a second level impact parameter trigger (see Steve Bracher's contribution to this workshop). The efficiency can be quite high for the high multiplicities in B decay and the background should then be quite small. One should be able to make such a trigger decision in less than 50 μs. The second level rate is approximately 50 events per second.

At this point we have to think more carefully about what we will do with the data. Writing all the data to optical disk ($10^9$ Bytes) at a conservative 100K bytes/event will use 1 disk every three minutes. The alternative is to further search for specific topologies on line.

## III $B \to \Psi K_S$

The $B \to \Psi K_S$ topology seems to be the best candidate in which to search for decay channel CP violation. A dilepton $\Psi$ trigger would be used at the first trigger level. The second level would require that both leptons have a non zero impact parameter. The cross section for $B \to \Psi K_S$, $\Psi \to ee$, $\mu\mu$ into the forward spectrometer is about .05 nanobarn, or 1 event every 6 hours or so. This is more optimistic than the result of reference 1, but does not include $K_S \to \pi^+\pi^-$ branching ratios, or efficiencies and branching ratios for leptons from the decay of the second B, which when included, will lower the reconstructed rate by an order of magnitude.

The rates are:

$\sigma$ (level 2 TRIGGER) = 100 $\mu$b --B pair cross section
x.14 --$\Delta$Y acceptance
x.001-- BR($B \to \Psi K$)
x.14 --BR($\Psi \to l^+ l^-$)
x.4 --impact parameter cut = .8 nb
(this does not require all secondaries seen)

$\sigma$(Reconstructed $B \to \Psi K_S$, $B \to l$ X) = .8nb
x.24--Br($B \to lx$)
x .5--lepton impact parameter $\leq 9.6 \times 10^{-11}$ barns

The requirements for geometrical reconstruction and secondary momenta cuts, as noted in ref. 1, should reduce this by yet another order of magnitude.

## III. Rare B Decays

For studies of rare B decay the sample must be background free. A rare decay trigger could simply consist of 2 or more tracks with large impact parameters forming a consistent secondary vertex.

Given the resolution of current or probable vertex detectors we will need long decay lengths, possible 3 lifetimes or more, to clearly group the tracks coming from any particular vertex. This reduces our efficiency to 5% at best, and more probably 1%. So our sample of $10^8$ B decays yields $10^6$ clean events. This is two orders of magnitude lower than reference 1 and may be overly **pessimistic.** In this case a central detector may be a better device since the vertex detectors are closer with better impact parameter resolution. Many high momentum B mesons will escape a 2 cm beam pipe and decay in the SSD system. These may well be "golden" events for rare decays.

## IV. Dilepton Studies

CP violation can be studied by measuring the assymetry parameter:

$$A = \frac{N(\ell^+\ell^+) - N(\ell^-\ell^-)}{N(\ell^+\ell^+) + N(\ell^-\ell^-)}$$

A possible trigger would be two leptons with impact paramter $>3\sigma$. This should be quite fast since only two tracks and the vertex z point need to be reconstructed. We should collect about 10 events per second. In this case, since we want to avoid using leptons from D decay in the calculation of A , identifying which lepton came from which secondary vertex is crucial. There is an additional ambiguity in assigning the second and third vertices to B or C decays without some kinematic fitting. A histogram of the minimum distance between vertices is shown in figure 3.

Only those vertices separated by $>3\sigma$ are used, assuming $\sigma = 200\mu$. The efficiency for all vertices in the event to be separated by more than $600\mu$ is .44. The final sample is:

$$10^8 \times .44 \times Br(B \rightarrow leptons)^2 = 5 \times 10^6 \text{ B pairs.}$$

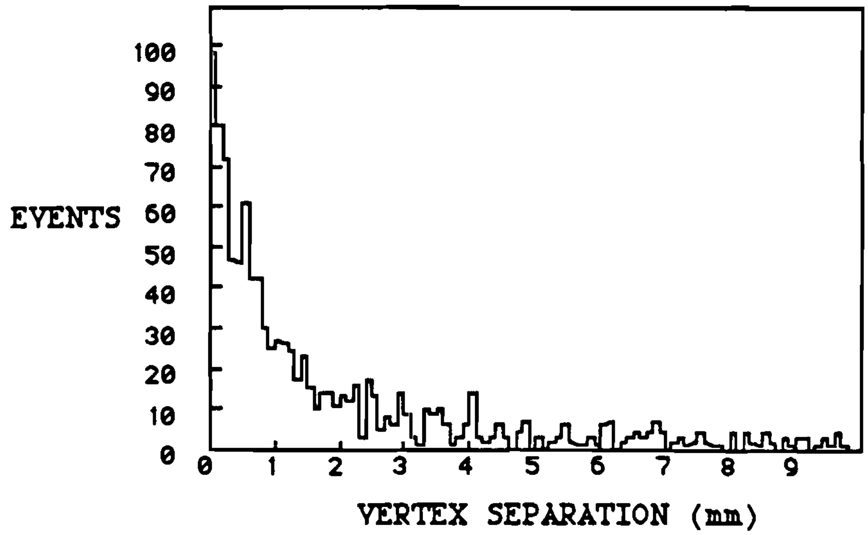


**FIGURE 3**

Distance from a B or C decay vertex to the nearest secondary vertex.

## V Conclusions

In conclusion a forward detector which can detect $10^8$ - $10^9$ B pairs in a $10^7$ sec run appears feasible. Approximately $10^4$ $B \rightarrow \Psi K_S$ are expected and $10^6$ dilepton pairs from BB decay. The branching ratio sensitivity for rare decays is expected to be at the $10^{-6}$ level.


1. J. Cronin et. al., *Report of The Working Group on CP Violation and Rare Decays*, in Design and Utilization of the SSC, p161.
2. J. Cronin, *Detection of B Meson at Small Angles at The SSC*, op.cit., p170.