Studies of SVT Trigger using SUGRA Four b Quark Signature

DØ Note 3318

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Abstract

This note discusses the effects of a SVT term added to a multijet trigger set. The efficiency of a four b quark SUSY signal and the rejection of backgrounds (trigger rates) for this SVT modified trigger set are determined and compared to the signal efficiency and background rejection for the same multijet trigger set modified by a CFT trigger term.

1 Impact Parameter

The SVT trigger supplies a refined momentum measurement and a estimate of the impact parameter (*bimp*) for tracks defined by the CFT trigger. Currently, the designed maximum number of triggers (trigger = combination of hit fibers) from the CFT is 20. These are the 20 highest p_T triggers. This maximum number is not yet set in stone. Studies [1] have shown the improvements in the momentum resolution and the distinction between signal and background samples for the *bimp* parameter.

For this study a sample of SuperSymmetric (SUSY) events is used. This sample has been generated using ISAJET and the Super Gravity (SUGRA) model. The five SUGRA parameters used are: $m_0 = 200, m_{1/2} = 125, A_0 = 0, \tan\beta = 10$, and sign($\mu$) = -1. For this choice of model parameters, there is a significant branching fraction of gluino ($\tilde{g}$) to b plus $\tilde{b}$ ($\tilde{b} \rightarrow b + X$). There is, therefore, a significant $\tilde{g}\tilde{g} \rightarrow 4b$ signature. A sample of these four b events has been generated and processed with the AUG96 version of UPG_GEANT. These geanted events are then used to make trigger ntuples [2]. The default SVTX_TRIG.RCP file has been used which specifies a 0.1 cm window for SVX hit finding using a CFT trigger defined by the inner and outer hit fiber (two and only two fibers). The minimum number of SVX hits required to form a SVX track is four.

The *bimp* parameter for the signal sample is compared to the dijet plus minimum bias background samples [3] used in trigger studies. The background samples include p_T ranges of 20–40

GeV and 40–80 GeV with zero or three additional minimum bias interactions added. In Fig. 1 the integrated *bimp* distribution is plotted for both the signal and background samples. The distributions are made by matching ($\Delta\eta < 0.5, \Delta\phi < 0.5$) the SVX tracks in a given event to the parton jets (PJET) and selecting the matched track with the largest *bimp*. All good tracks in the event with $p_T > 2.0$ GeV and track fit $\chi^2 < 2.0$ are used. Each entry in the distribution is associated with a PJET that has at least one good matching track. The integrated distribution is normalized to the number of PJETs. Each PJET is tagged with the parent parton identification. In Fig. 1 the top histogram (solid line) is the integrated *bimp* distribution for b jets from the signal sample. The next histogram down (dashed line) is from non-b jets from the signal sample. The last two histograms are non-b jets from the background samples, the top one being from the 40–80 GeV sample. The addition of three minimum bias events to the backgrounds did not produce distinguishing histograms. There are two things to note from Fig. 1: the signal b tracks have significantly larger values of *bimp* compared to the background samples, and while *bimp* for non-b tracks from the signal are noticeably smaller than for b tracks, the signal non-b tracks are quite different from the background. This indicates either that the matching of tracks is not optimal, that the busy environment of the SUSY sample complicates the assessment of *bimp* or both.

In Fig. 2 the normalized integrated impact significance [4] distributions are given for signal and background. The impact significance is *bimp* normalized to the error in *bimp*. This normalization takes out some of the p_T dependence in *bimp*. The top histogram is for b tracks from the signal sample, and the next lower histograms is non-b tracks from the signal sample. The lowest histograms is the 40–80 GeV background sample. We see the same differences as in Fig. 1.

2 SVT vs CFT Information

One of the goals of this study is to see what additional rejection of background one could get from the SVT *bimp* parameter information compared to the CFT trigger (CFT tracks) information. First, several plots in figures 3 through 6 show *bimp* information vs the number of tracks information for signal and background events under various conditions. To conclude this section, a plot of signal efficiency vs background rejection for several sets [1] of trigger conditions will be given. One should note that a CFT track has an associated SVX track, the difference in the two being the p_T. This is to say that a CFT track also satisfies the minimum four SVX hits in the 0.1 window requirement. The final conclusions based on this track or a more general CFT trigger are the same.

In figures 3 through 6, the average of the top five *bimp* values for selected tracks in a given event vs the number of selected SVX tracks is plotted. For events with less than five good tracks, the average is determined for the 1–4 tracks. The upper left-handed plot is the four b signal sample. The upper right-handed plot is the 20-40 GeV dijet sample with no additional interactions. The lower left-handed plot is the 40-80 GeV dijet sample with no additional interactions. The lower

[1] set = collection of trigger terms, ie. jet counts, tracks counts, ect.

right-handed plot is the 40-80 GeV dijet sample with three additional interactions. The signal sample has a total of 150 events, and the three background samples have respectively 999, 999, and 932 events. Each event entry in the plots has at least one track satisfying the p_T and χ^2 requirements. In all cases the tracks are require to have $p_T > 1.0$ GeV. In figures 3 and 4, all tracks are counted provided they satisfy the selection requirements. In Fig. 3 in addition to the p_T requirement, the tracks are required to have $\chi^2 < 2000$, while in Fig. 4 $\chi^2 < 2$. In figures 5 and 6, only the top 20 p_T CFT triggers are considered; the corresponding SVX fitted tracks (if any) are required to satisfy the selection requirements. In addition to the 1 GeV p_T requirement, we have $\chi^2 < 2000$ for Fig. 5 and $\chi^2 < 2$ for Fig. 6.

There are several general features evident in figures 3 through 6. First, the average *bimp* is greatly effected by the maximum χ^2 cut; for a tight cut on χ^2 the average *bimp* is reduced. This effect reduces the distinction between the signal and background. Being restricted to the first 20 highest p_T CFT triggers also reduces the average *bimp* and reduces the distinction between signal and background. This reduction in the average *bimp* is primarily due to the fact the lower momentum SVX tracks (and by inference lower CFT triggers) have higher impact parameters on average. Comparing the lower plots in figures 5 and 6, multiple interactions increase significantly the number of tracks found, but they also significantly decrease the number of tracks with low χ^2.

In most cases, cutting on the number of tracks appears to give better discrimination of signal to background compared to cutting on the average *bimp*; it is difficult to tell for the case shown in Fig. 6. The efficiency and background trigger rates [5] have been determined for several sets of trigger conditions. The basic trigger set is the JetMax trigger set which requires four L1 jets with $E_T > 5$ GeV and one L2 jet with $E_T > 45$ GeV. The rate for this trigger set is 13.1 Hz. Other trigger sets are constructed by adding CFT track information or SVT track information which includes *bimp*. A plot of signal efficiency versus background rejection is shown in Fig. 7. The rejection is the ratio of the trigger rate for the trigger set in question to the JetMax trigger set. The trigger conditions represented by the letters in Fig. 7 are described in Table 1.

The JetMax trigger set is represented by the asterisk labeled 'a', and The JetMult trigger set is represented by the asterisk labeled 'b'. The JetMult trigger set requires four L1 jets with $E_T > 5$ GeV and four L2 jet with $E_T > 15$ GeV. The solid circles represent trigger sets utilizing unrestricted tracking information, while the open circles represent trigger sets utilizing only the top 20 p_T CFT triggers. The top solid line connects those triggers sets that use only CFT trigger information (modulo the SVX hit requirements). The bottom dotted line connects those trigger sets that also incorporate the SVT trigger information. Some general observations are: 1) Being restricted to the highest 20 p_T CFT triggers adversely effects the efficiency at a given rejection. This is more serious for rejections > 10. 2) The use of *bimp* information does not seem to outperform just using only the CFT information, the discrepancy again more serious at rejections > 10. 3) It is possible to get very large rejections while maintaining good efficiencies for the four b signature using CFT triggers.

Table 1: The tracking trigger terms for the trigger sets that have been tested. The "alltrk" specification indicates that all tracks are available as found from the CFT trigger information and satisfying the four hit minimum in the SVX. The "20trk" specification indicates that only the top 20 p_T CFT triggers are used. These 20 CFT triggers are then required to satisfy the four hit minimum in the SVX. The numbers in parentheses are the track condition requirements. 'IMPS' is the impact significance, and 'AVGIMPS' is the average of the four highest IMPSs excluding the highest IMPS in the event.

Label	Tracking Trigger Terms
a	JetHigh trigger
b	JetMult trigger
c	20 CFT tracks($p_T > 2$), alltrk
d	10 CFT tracks($p_T > 2$), alltrk
e	25 CFT tracks($p_T > 2$), alltrk
f	20 CFT tracks($p_T > 3$), alltrk
g	10 CFT tracks($p_T > 2$), 20trk
h	12 CFT tracks($p_T > 2$), 20trk
i	15 CFT tracks($p_T > 2$), 20trk
j	10 CFT tracks($p_T > 3$), 20trk
k	15 CFT tracks($p_T > 3$), 20trk
l	10 SVX tracks($p_T > 2$, IMPS > 5, $\chi^2 < 2000$), alltrk
m	10 SVX tracks($p_T > 2$, IMPS > 5, $\chi^2 < 2000$), 20trk
n	5 SVX tracks($p_T > 2$, IMPS > 5, $\chi^2 < 2000$), alltrk
o	5 SVX tracks($p_T > 2$, IMPS > 5, $\chi^2 < 2000$), 20trk
p	2 SVX tracks($p_T > 2$, IMPS > 5, $\chi^2 < 2$), alltrk
q	2 SVX tracks($p_T > 2$, IMPS > 5, $\chi^2 < 2$), 20trk
r	10 CFT tracks($p_T > 3$) AVGIMPS > 5 (SVX: $p_T > 2$, $\chi^2 < 2000$), alltrk
s	10 CFT tracks($p_T > 3$) AVGIMPS > 5 (SVX: $p_T > 2$, $\chi^2 < 2000$), 20trk
t	10 CFT tracks($p_T > 3$) AVGIMPS > 1 (SVX: $p_T > 2$, $\chi^2 < 2000$), alltrk
u	10 CFT tracks($p_T > 3$) AVGIMPS > 1 (SVX: $p_T > 2$, $\chi^2 < 2000$), 20trk
v	10 CFT tracks($p_T > 3$) AVGIMPS > 1 (SVX: $p_T > 2$, $\chi^2 < 2$), alltrk
w	10 CFT tracks($p_T > 3$) AVGIMPS > 1 (SVX: $p_T > 2$, $\chi^2 < 2$), 20trk
x	AVGIMPS > 2 (SVX: $p_T > 2$, $\chi^2 < 2$), alltrk
y	AVGIMPS > 2 (SVX: $p_T > 2$, $\chi^2 < 2$), 20trk
z	AVGIMPS > 1 (SVX: $p_T > 2$, $\chi^2 < 2$), 20trk

3 Conclusions

It seems that the SVT does not gain us anything for the four b SUSY signature; we can do significantly better with requiring CFT triggers. This may be due to the fact that the four b signature is rich with track producing charged particles compared to other processes such as Higgs associated production. Therefore, there is no uncorrelated rejection left for the impact parameter to contribute. It may also be possible that the high density of charged particles confuses the SVT tracking causing greater inefficiencies for the signal compared to the much less busy backgrounds. A study has been done where the SVT hit finding window is altered along with the minimum number of hits requirement for the four b signature MC sample. It has been found that for a window of 0.02 cm and a minimum number of SVX hits of two, there is an improvement of 20-30% in the number of good tracks found, depending on the χ^2 requirement. It is possible that this improvement in the SVX track efficiency could make the SVT more useful compared to just the CFT trigger information. Background studies need to be done to verify this.

Regardless of the outcome of any additional studies, it has been shown that increasing the number of CFT triggers (eg. more than 20) that is passes to the L2 preprocessors benefits significantly the efficiency at a given rejection, especially if rejections of > 10 are needed. This may only benefit signatures, like the SUSY four b signature, with large numbers of tracks. The average number of tracks (CFT trigger with at least four hits in the SVX within the window of 0.1) is about 150.

References

[1] Many studies have been done by the SVT working group. See http://d0sgi0.fnal.gov/ wahl/vtxt.html.

[2] The ntuple code is described on http://d0sgi0.fnal.gov/~wahl/trgcode/trigstud.html.

[3] The background ntuples are made from dijet MC data overlayed with 0-7 additional minimum bias collisions. These ntuples are located at tmp$root346:[gerber.level2.ntup]DJ*.ntup.

[4] The impact significance is discusses in "Benefits of a Silicon Vertex Trigger for $t\bar{t}$ Events", by Frédéric Stichelbaut, DØ Note 3312.

[5] I used a modified versions of Jerry Blazey's trigger kumac files.

Figure 1: The integrated impact parameter distribution for a SUSY four b jet signature and backgrounds.

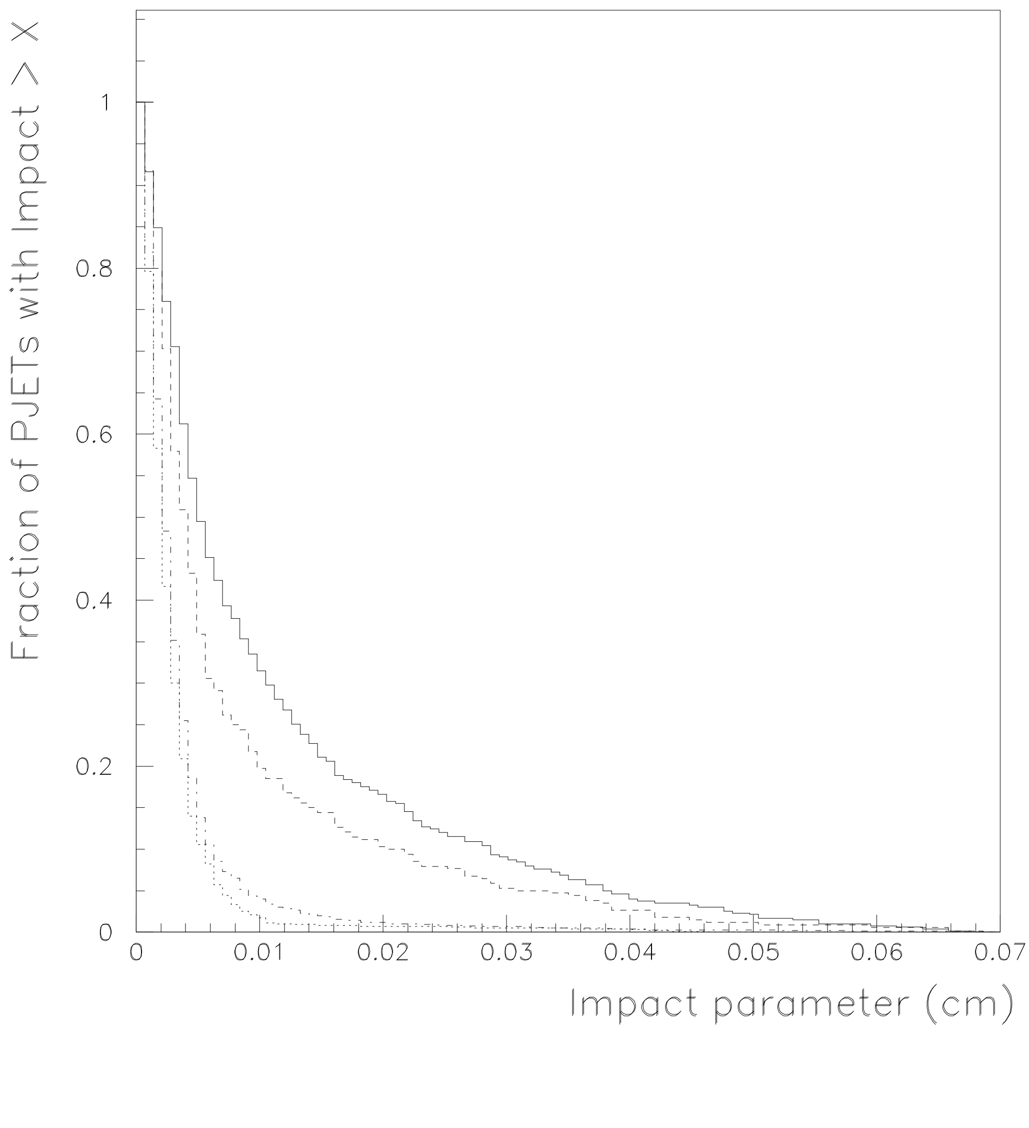

Figure 2: The integrated impact parameter significance distribution for a SUSY four b jet signature and backgrounds.

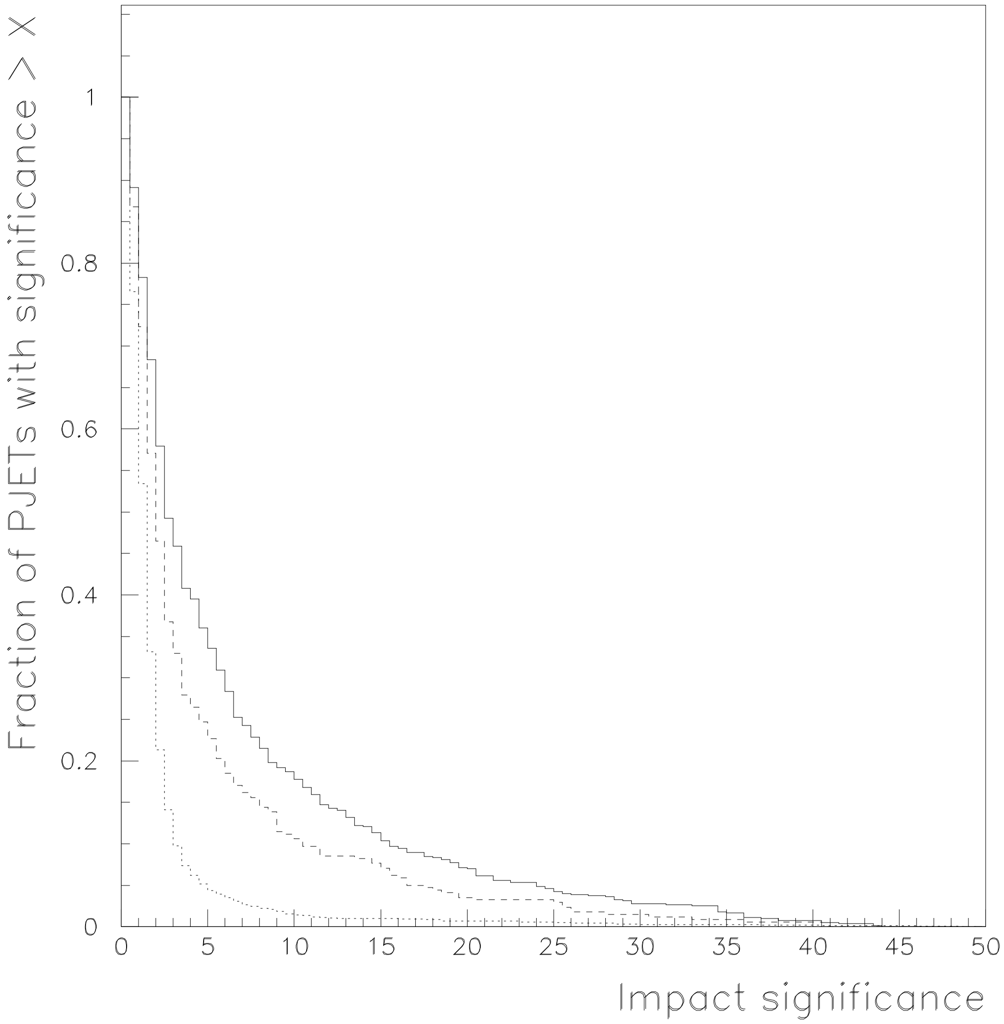

Figure 3: The average of the top five *bimp* values for selected tracks in a given event vs the number of selected tracks. All tracks with a minimum p_T of 1 GeV and maximum χ^2 of 2000 are used. The upper left-handed plot is the four b signal sample. The upper right-handed plot is the 20-40 GeV dijet sample with no additional interactions. The lower left-handed plot is the 40-80 GeV dijet sample with no additional interactions. The lower right-handed plot is the 40-80 GeV dijet sample with three additional interactions. The signal sample has a total of 150 events, and the three background samples have respectively 999, 999, and 932 events. Each event entry in the plots has at least one track satisfying the p_T and χ^2 requirements.

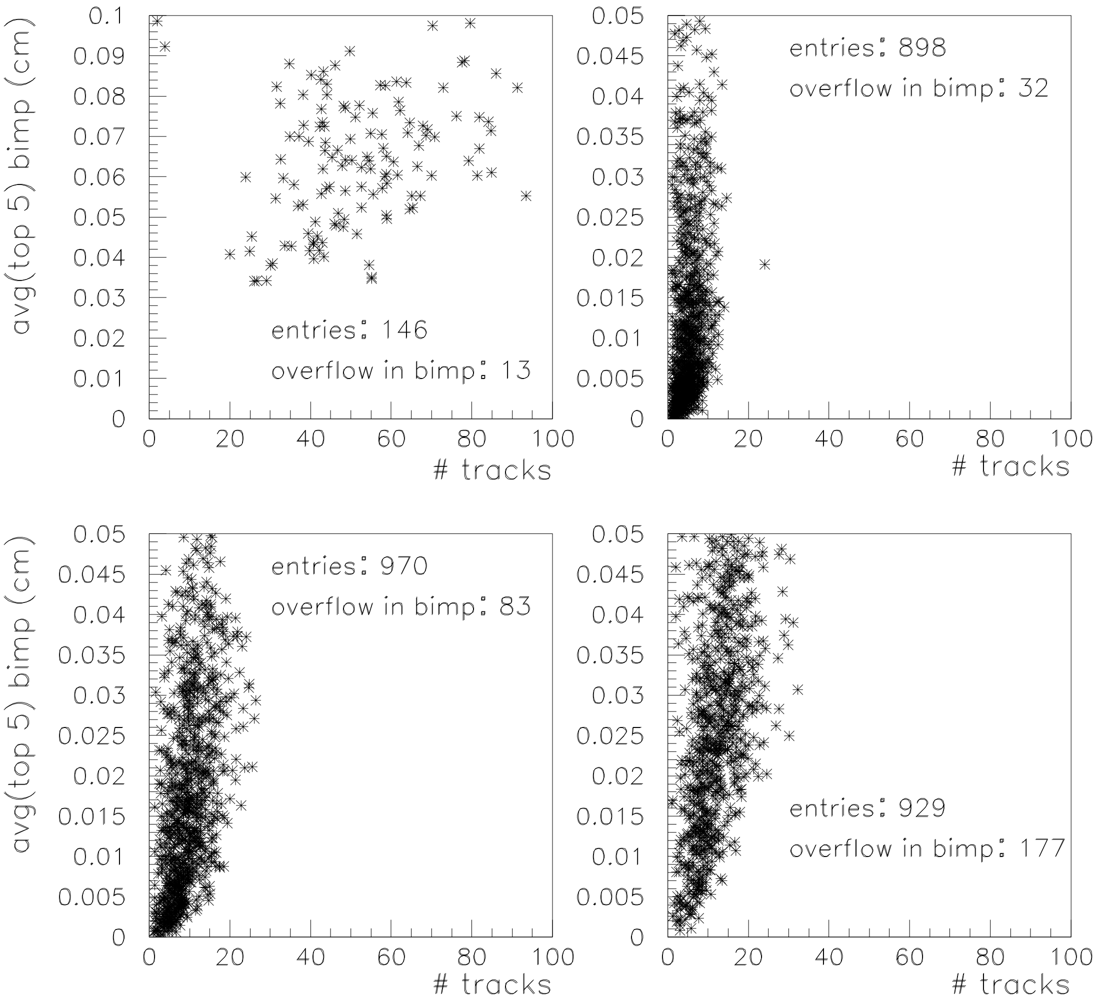

Figure 4: The average of the top five *bimp* values for selected tracks in a given event vs the number of selected tracks. All tracks with a minimum p_T of 1 GeV and maximum χ^2 of 2 are used. The upper left-handed plot is the four b signal sample. The upper right-handed plot is the 20-40 GeV dijet sample with no additional interactions. The lower left-handed plot is the 40-80 GeV dijet sample with no additional interactions. The lower right-handed plot is the 40-80 GeV dijet sample with three additional interactions. The signal sample has a total of 150 events, and the three background samples have respectively 999, 999, and 932 events. Each event entry in the plots has at least one track satisfying the p_T and χ^2 requirements.

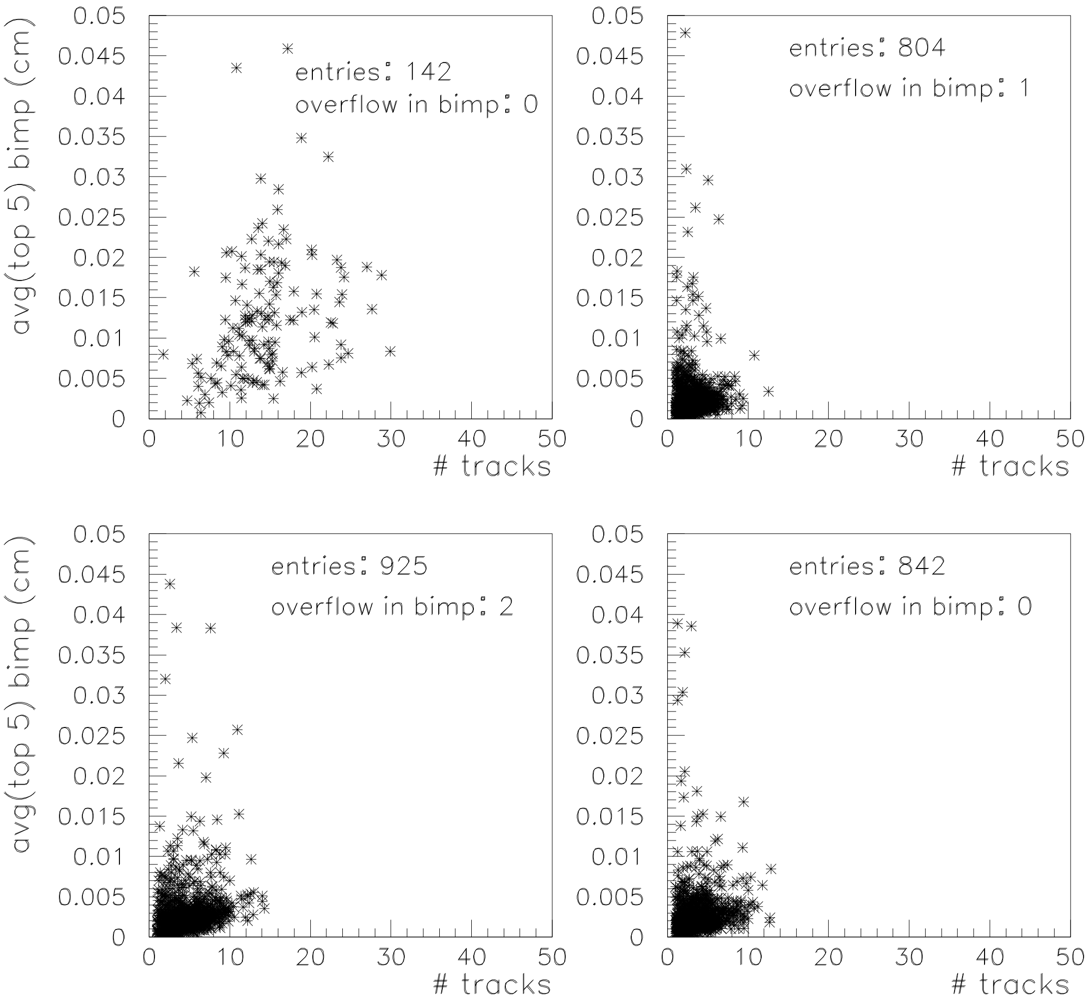

Figure 5: The average of the top five *bimp* values for selected tracks in a given event vs the number of selected tracks. Only the 20 highest p_T CFT triggers are considered. The corresponding SVX fitted track is then required to have a minimum p_T of 1 GeV and maximum χ^2 of 2000. The upper left-handed plot is the four b signal sample. The upper right-handed plot is the 20-40 GeV dijet sample with no additional interactions. The lower left-handed plot is the 40-80 GeV dijet sample with no additional interactions. The lower right-handed plot is the 40-80 GeV dijet sample with three additional interactions. The signal sample has a total of 150 events, and the three background samples have respectively 999, 999, and 932 events. Each event entry in the plots has at least one track satisfying the p_T and χ^2 requirements.

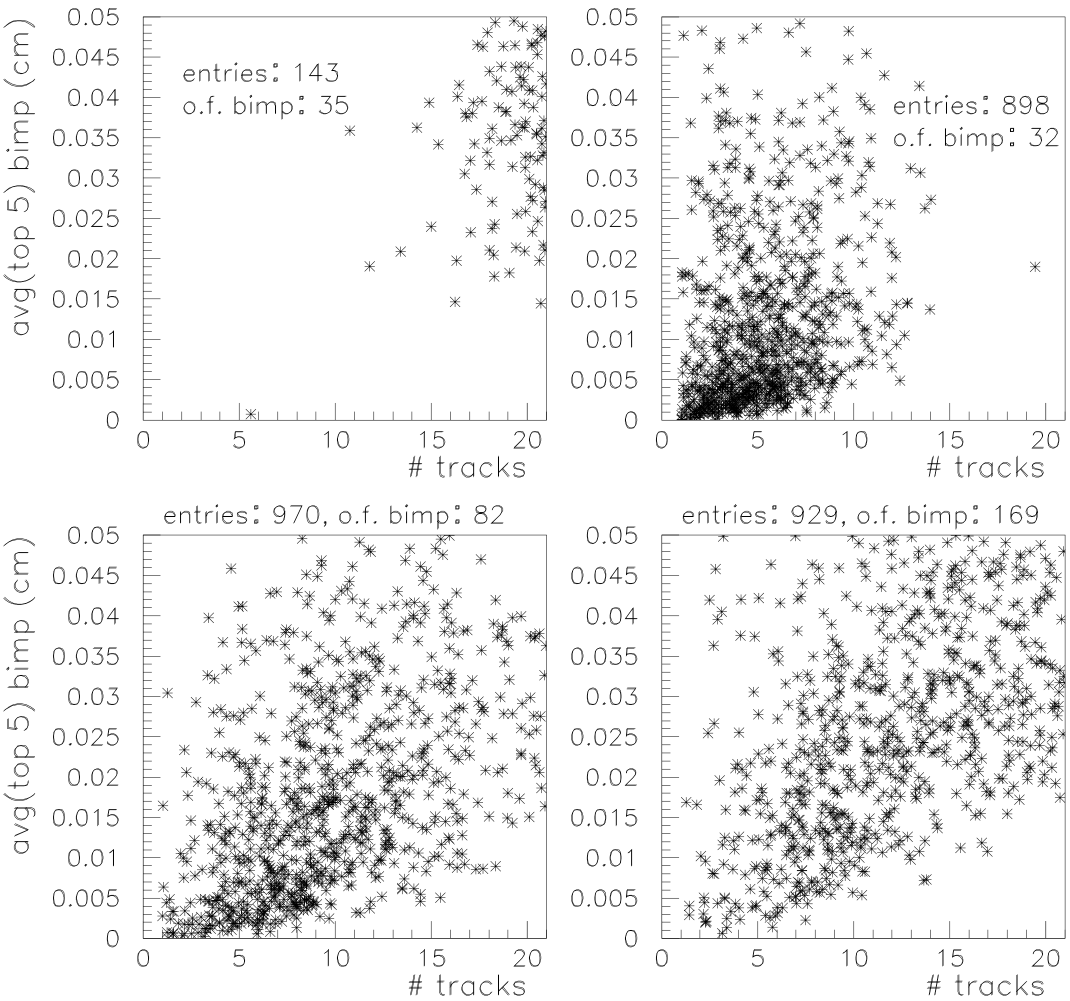

Figure 6: The average of the top five *bimp* values for selected tracks in a given event vs the number of selected tracks. Only the 20 highest p_T CFT tracks are considered. The corresponding SVX fitted track is then required to have a minimum p_T of 1 GeV and maximum χ^2 of 2. The upper left-handed plot is the four b signal sample. The upper right-handed plot is the 20-40 GeV dijet sample with no additional interactions. The lower left-handed plot is the 40-80 GeV dijet sample with no additional interactions. The lower right-handed plot is the 40-80 GeV dijet sample with three additional interactions. The signal sample has a total of 150 events, and the three background samples have respectively 999, 999, and 932 events. Each event entry in the plots has at least one track satisfying the p_T and χ^2 requirements.

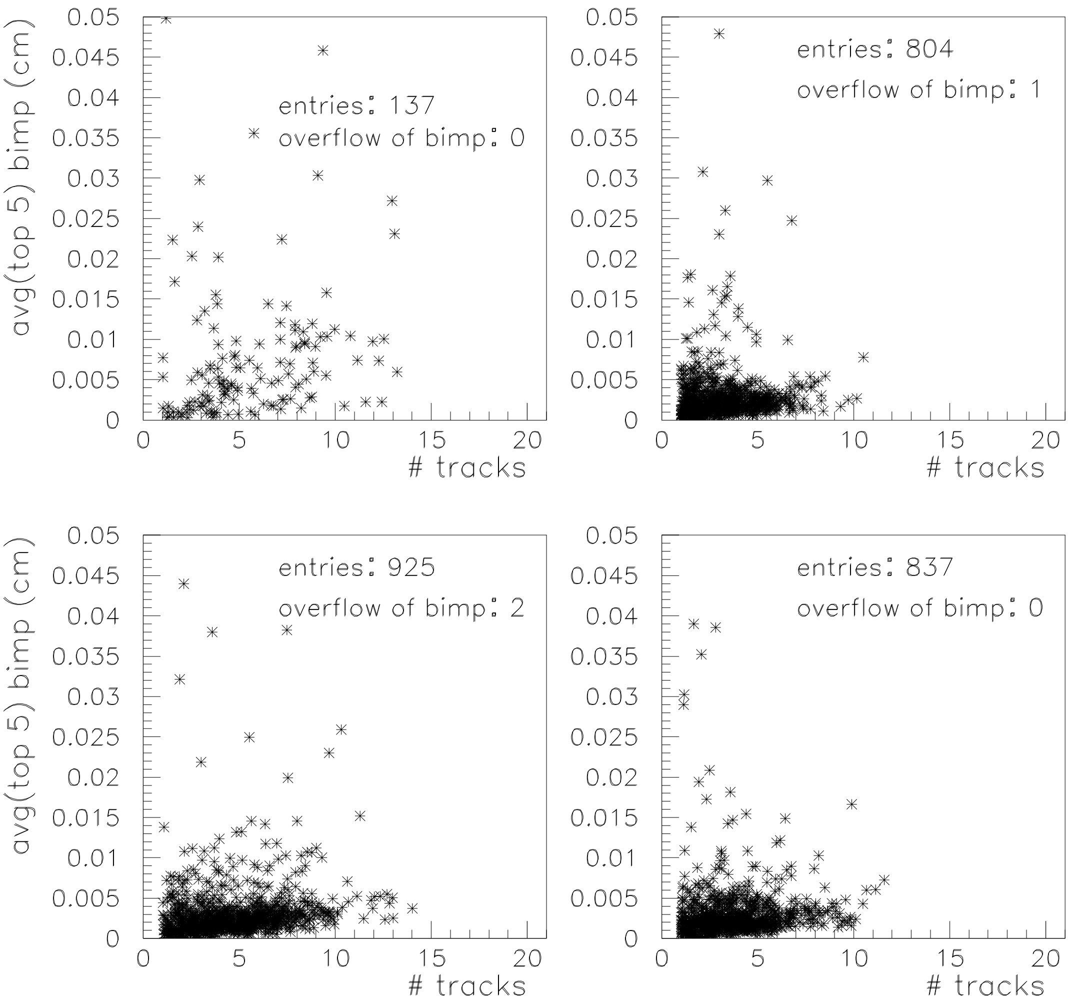

Figure 7: The efficiency versus the rejection for various choices of trigger sets. The asterisk represent the JetMax and JetMult trigger sets. The Solid circles represent trigger sets utilizing unrestricted tracking information, while the open circles represent trigger sets utilizing only the top 20 p_T CFT triggers. The top solid line connects those trigger sets that use only CFT trigger information. The bottom dotted line connects those trigger sets that also incorporate the SVT trigger information.