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FERMILAB-Conf-94/006-E

CDF

The CDF Top Search in the Multijet Decay Mode

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January 1994

Published Proceedings of the *9th Topical Workshop on Proton-Antiproton Collider Physics*, University of Tsukuba, Tsukuba, Japan, October 18-22, 1993

Operated by Universities Research Association Inc. under Contract No. DE-AC02-76CHO3000 with the United States Department of Energy

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CDF/PUB/TOP/PUBLIC/2327
FERMILAB-CONF-94/006-E

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presented at Tsukuba 1993 $\bar{p}p$ Collider Workshop by

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A status report on the CDF *top* search in the multijet channel is given. After topological cuts and the requirement of a secondary vertex in the silicon microvertex detector, about 120 events remain (21.4 pb^{-1}), in which the signal to background ratio (for a nominal *top* mass of 160 GeV) is estimated to be 1/10. With further improvements it should be possible to improve this ratio to 1/1 while retaining good efficiency for *top*, which will make the multijet channel an important cross check for the leptonic modes.

1. Introduction

In the multijet decay mode, the W's from both members of the $t\bar{t}$ pair decay into quark jets. The final state then consists of at least six jets: the four quark jets from the W's; two more from the b's; and possible additional jets from gluon radiation. This channel accounts for 44% of $t\bar{t}$ decays, however the background from multijet QCD processes is very high. For example, for events with at least 120 GeV of summed transverse energy, the signal to background (S/B) ratio is about $1/10^4$.

The S/B ratio can be improved by applying kinematical cuts and making use of the information from the silicon microvertex detector (SVX). If we can achieve a S/B near 1/1, and still retain of the order of 10 *top* events, the multijet channel will be a useful cross check for a possible *top* discovery in the leptonic channels. This is a challenging task. What follows is an introduction to the CDF multijet *top* analysis and a report on its current status.

2. Comparison to Lepton Plus Jets Channel

To better understand the character of the multijet channel, it is useful to compare it to the lepton plus jets channel. The cuts used in the leptonic channel analysis are:

- The W Cuts:
  - $E_T^{lepton} \geq 20\ GeV$
  - $E_T^{miss} \geq 20\ GeV$
- $E_T^{jets} \geq 15\ GeV$
- SVX tag

where SVX tag means that a secondary vertex was found in the SVX. These simple cuts are relatively Monte Carlo independent and produce a sample of events in which the S/B ratio is expected to be better than 1/1.

Published Proceedings 9th Topical Workshop on Proton-Antiproton Collider Physics, University of Tsukuba, Tsukuba-shi, Japan, October 17-22, 1993

In contrast, for the multijet analysis, restricting ourselves to simple topological cuts and the SVX requirement, i.e.,

- The 'Loose' Cuts:
  - $E_T^{jets} \geq 10\ GeV \quad (|\eta| \leq 2.4)$
  - $N_{jets}^{0.7cone} \geq 6$
  - $\sum E_T \geq 150\ GeV$
- SVX tag

we arrive at a data sample in which the S/B ratio is expected to be of the order of 1/50. In order to make the multijet channel usable, we are obliged to use Monte Carlo as a guide for selecting a region of kinematical phase space where the S/B ratio is higher. This is a qualitative difference between the multijet and the single lepton analyses.

The multijet events are quite clean. The calorimeter LEGO display of a typical event after the loose cuts is shown in figure 1.

3. Additional Kinematical Cuts

Four techniques for improving S/B through kinematics are compared in figure 2, which shows the number of 1993 CDF multijet events remaining versus the expected number of 160 GeV (Isajet) *top* events remaining after applying a given set of cuts. The plot is for data before the SVX tag; data after the SVX tag are similar but statistics are lower. Any fixed set of cuts corresponds to a point in this plot, while varying a parameter in a cut generates a line. For example, the black squares, connected by a solid line, correspond to increasing the minimum E_T^{jets} in the loose cuts (the point for $E_T^{jets} \geq 10\ GeV$ is off the top of the page at about 17000 events).

A second approach is to examine data and Monte Carlo distributions 'by hand' to produce a set of 'ad hoc' cuts. This resulted in the

- 'Tight' Cuts:
  - $\sum_i E_T^i \geq 70\ GeV + 20\ GeV * N_{jets}^{0.7cone}$ (sum over cone 0.7 jets)
  - $\sum_i |\eta_{jet}^i| / N_{jet}^{0.7cone} \leq 1$
  - $N_{jet}^{0.4cone} \geq 6$

The situation after the tight cuts is represented by the black circle labelled 'tight alone'.

The performance of the tight cuts can be further improved by cutting on the output of a *neural network classifier*. Our classifier was trained on 1988/89 CDF data (assumed to be pure background) and Isajet *top* data. The neural network output is proportional to the probability that an event is *top*. The dashed line connecting the remaining black circles was generated by increasing the cut on this output.

Cuts based upon reconstructed physical quantities can also be effective, e.g., top events should be more spherical and less planar than QCD multijet events. Making the cuts,

- sphericity > 0.3

- aplanarity > 0.05

gives the point labelled by the asterisk in figure 2. Top decays should also be consistent with the decay of a heavy object in the sense that most of the $\hat{s}$ in the event should show up as transverse energy:

- 'X-Tight' Cut:
  - $\sqrt{\hat{s}}/\sum E_T < 1.4$

Applying this cut gives the open diamond labelled 'x-tight' alone. The x-tight cut can be further improved by cutting also on the neural network output, generating the dotted line connecting the rest of the open diamonds.

The x-tight, sphericity/aplanarity, and neural network cuts seem to be correlated. The final set of kinematic cuts has not yet been chosen.

4. SVX Tagged Data

After the kinematic cuts, a secondary vertex requirement is made, using the JETVTX algorithm [1]. The secondary vertex is required to have at least two good SVX tracks and to have a pseudo-$c\tau$ of at least 3σ significance. The ability of CDF to identify heavy flavour decays using the SVX has already been demonstrated [2]. A standard CDF procedure was used [1] to estimate the expected number of background tags.

Figure 3 shows the number of 1993 data events and (Isajet) *top* events as a function of *top* mass after tight cuts and tight plus SVX tag. The tight plus SVX tag rate, about 120 events, agrees well with the predicted background rate, also shown. For a nominal *top* mass of 160 GeV, some 10 *top* events are expected, indicating a S/B ratio at this point of about 1/10.

6. Improvements

A S/B ratio of 1/10 is still not good enough to be useful in the *top* search; however a number of improvements are possible:

- **Tuning kinematical cuts.** The value 1/10 is at the level of the tight cuts. Using the x-tight, neural net, sphericity/aplanarity, or some combination of them can easily give another factor of 2 improvement with about 80% efficiency, and perhaps even more.
- **Use of 'Stream-1' data.** Results presented thus far are based on the so–called 'Express Line' data. Also on tape is the 'Stream-1' data which will allow us to improve efficiency about a factor of two by allowing jets clustered with a cone of 0.4.
- **Soft lepton tag.** It is also possible to identify decays of b-mesons by searching for a soft lepton associated with a jet. This type of tag is used in to complement the SVX tagging in the lepton plus jets analysis and can also be incorporated into the multijet analysis.
- **Quark/gluon discrimination.** The six jets from a $t\bar{t}$ decay are all quark jets. Some success has been shown in CDF in distinguishing quark jets from gluon jets [3]; it may be possible to incorporate this information into the multijet analysis.

- **Constrained fits.** It is possible to assign a χ^2 to each event based upon the presence of two W's in the event and the equality of the t and $\bar{t}$ system masses. This technique was found to be less useful than originally hoped, but may add something to the analysis.
- **Optimization of SVX tagging.** The multijet channel has more activity and higher backgrounds. It may be desirable to optimize the SVX tagging algorithm to improve S/B for the multijet channel.
- **Double SVX tags.** The S/B can certainly be brought to 1/1 by requiring a second SVX tag in the event; however the remaining number of events is very small. This technique may prove more useful in the upcoming run.

5. Conclusion

The multijet channel is an important one which can be a valuable cross check for the other channels provided a S/B ratio near 1/1 can be achieved, while still retaining a handful of events. At the present time we have reached about 1/10, but it should be possible with the stated improvements to achieve the desired 1/1. The multijet channel looks particularly promising for the higher statistics of the upcoming run.

6. References

1. *Top Search in the Single Lepton + Jets Channel at CDF*, CDF Collaboration, presented by M. Contreras, this workshop.
2. *B Lifetimes at CDF*, CDF Collaboration, presented by J. Skarha, this workshop.
3. *Jet Structure and Quark/Gluon Separation in CDF*, CDF Collaboration, presented by M. Ninomiya, this workshop.

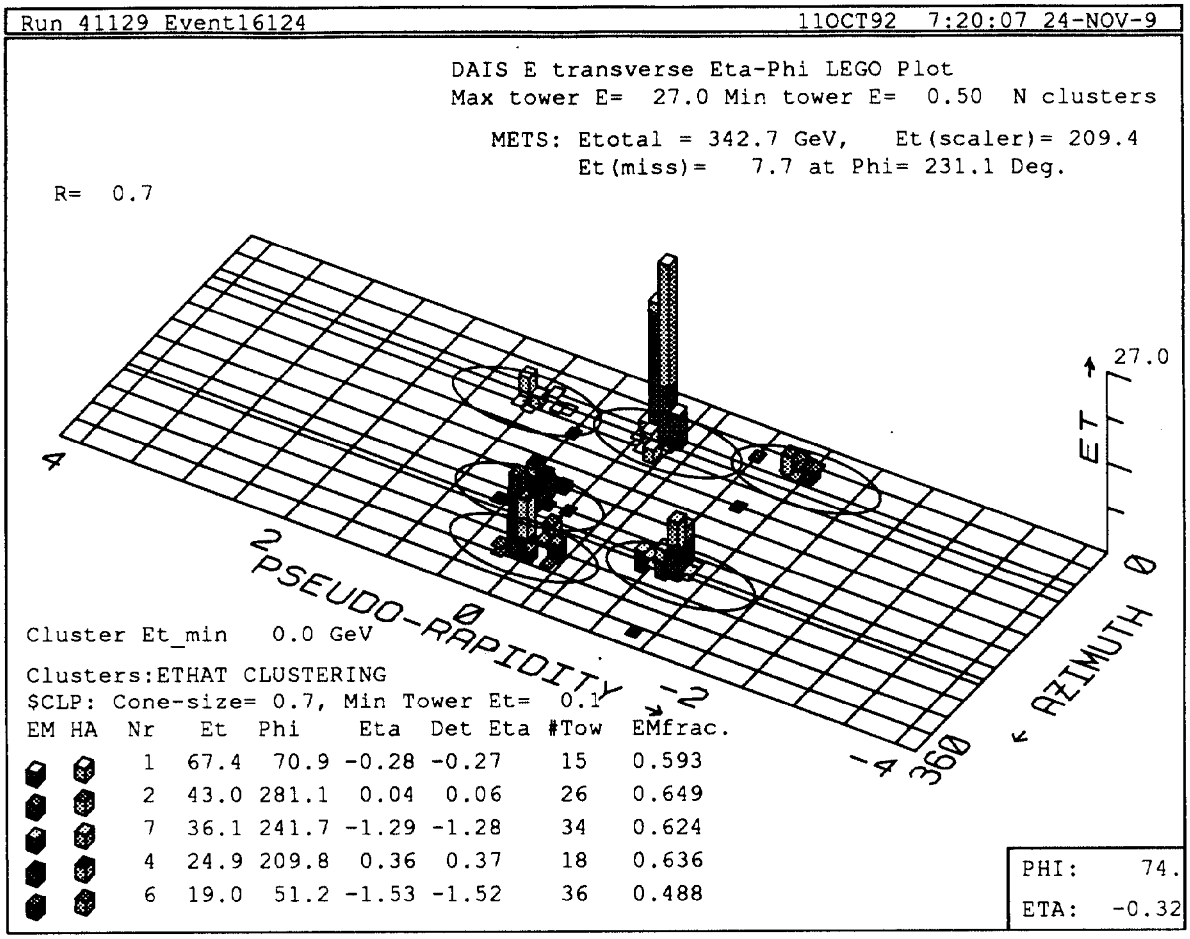

Figure 1: **Figure 1.** Calorimeter LEGO plot of a typical CDF multijet event after the loose cuts, showing six clean jets.

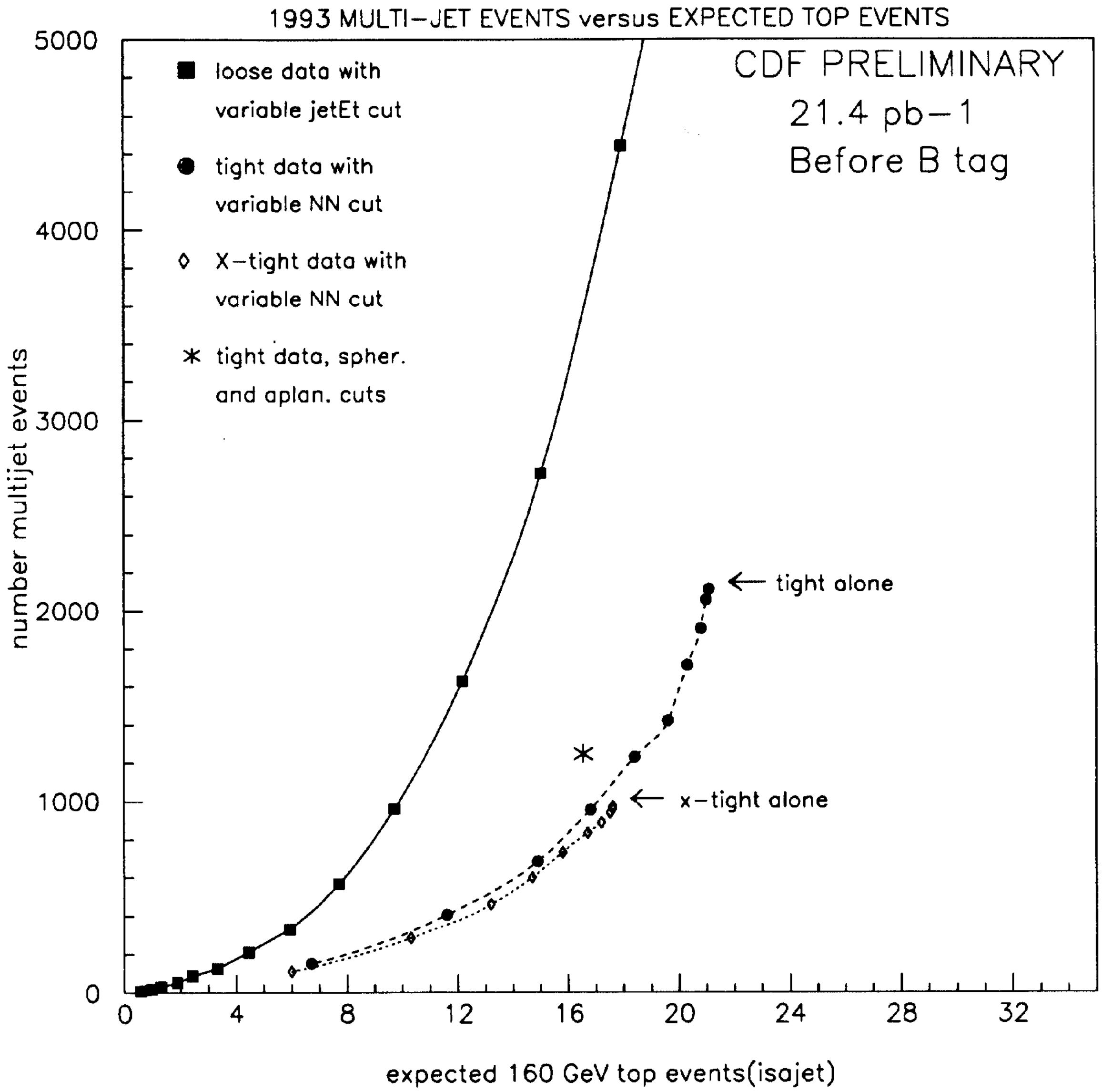

Figure 2: **Figure 2.** Number of 1993 CDF events versus expected number of 160 GeV (Isajet) *top* events for various types of cuts. The black line is generated by starting from the loose cuts and increasing the minimum jet E_T ($E_T^{jets} \geq 10\ GeV$ point is off the page at 17000 events). The dashed and dotted lines are generated by starting with the 'tight' or 'x-tight' cuts (described in text) respectively, and then cutting on the output of a neural network classifier. The asterisk corresponds to the sphericity and aplanarity cuts described in the text.

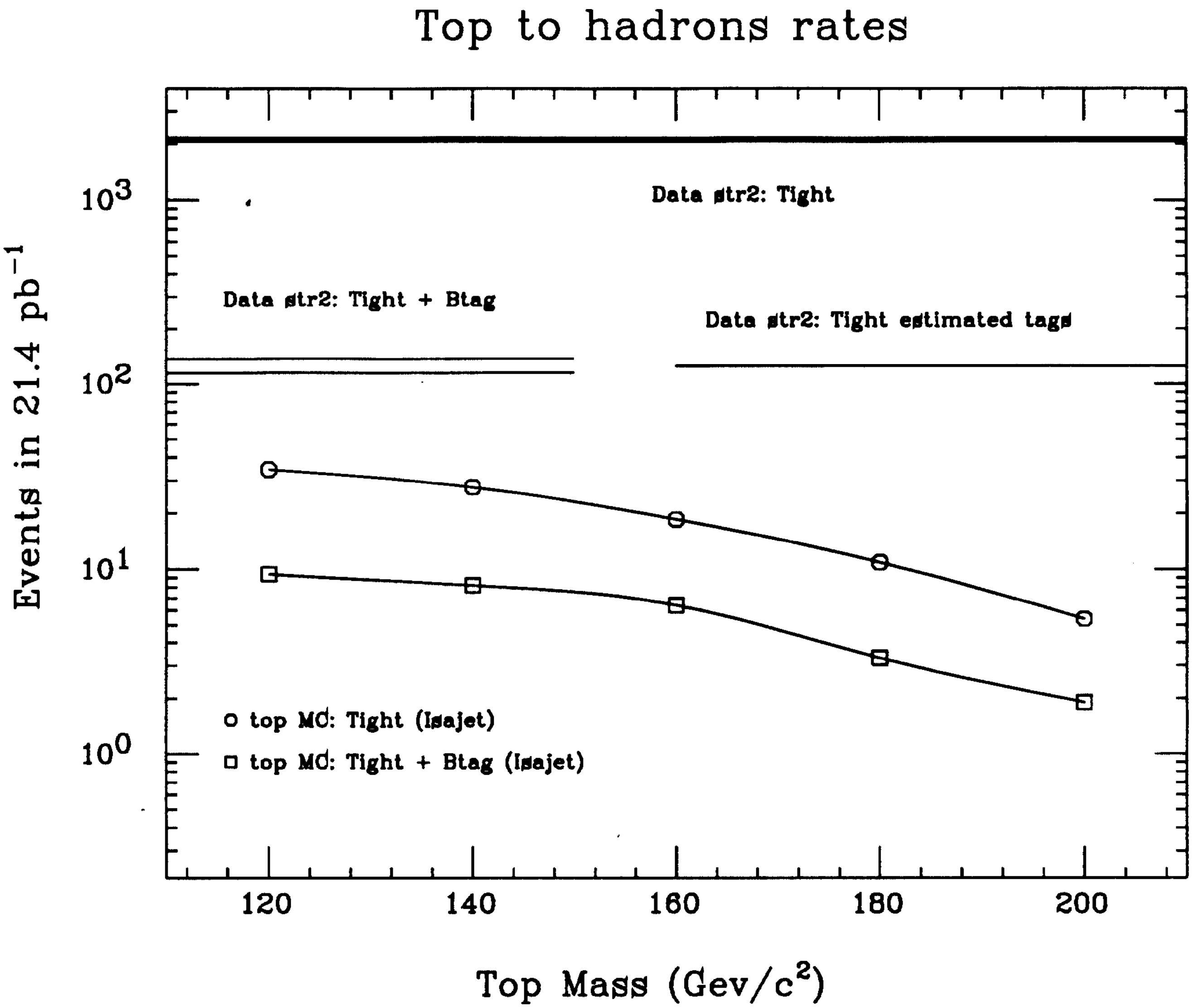

Figure 3: Figure 3. Number of 1993 multijet events and number of expected *top* events as a function of mass, in 21.4 pb^{-1}, after tight cuts, and after tight cuts plus SVX tag. The number of expected SVX tagged events due to background is also shown.