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Filtering Jet Backgrounds in the CDF Central Detector

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Abstract:

Events with jet Et above 70 GeV from about 22 nb-1 of the 1987 CDF run were studied. For central jets, a time-of-flight(HATFLT) veto rejected events with significant out-of-time energy (removing about 16% of the events). We found in the 968 remaining events 33 residual background jets, along with 48 marginal jets (probably good). Smaller jet samples of 30 Gev and 50 Gev were also studied with similar results. The various tools that distinguish good jets from backgrounds is discussed. A summary of central jet backgrounds is given.

Contents:

1 INTRODUCTION:

The CDF 1987 data run recorded about 35 nb-1 of high threshold data; we expect to see jets with Et up to 200 GeV in this sample. This note is concerned with the determination of a good real jet sample in the central scintillation calorimetry, with abs(eta) less than 1.0. Subtantial backgrounds exist, especially at high Et. For example, for events with central jet candidates above 100 GeV Et, 1/2 of the events are cosmic rays(presumably muon bremstrahlung) and main ring splashes which overlap coarsely in time with a minimum bias event. The background to signal ratio gets even worse at higher Et, with 1 signal event above 200 GeV Et while there are dozens of background events in the sample studied.

Thus it is important to define cuts that will efficiently remove the background events, while not cutting into the good event sample significantly. In the central hadron calorimetry, time-of-flight is the least biased and most effective tool available. But backgrounds that occur within the Hatflt time window or give clusters with only em energy are missed, thus further cuts are necessary. These cuts are defined and their effectiveness is demonstrated. How to use the filter program that arose from this study is discussed.

2 DATA SAMPLES USED IN THIS STUDY:

The CDF jet group has processed 50 runs (22 nb-1) and events with 70 Gev jets were written to disk. In addition, 12 runs were processed with a 50 Gev cut. These files were used to determine our signal to background selection criteria. Also, several runs with 30 Gev jets were run to check our results at lower energies.

Certain noise removal procedures were made in the generation of these DSTs, in particular, single PMT background and PEM spikes were removed. This removal seems to work well, as our studies would have uncovered single PMT's, yet none have been seen.

3 TOOLS FOR REJECTING CENTRAL JET BACKGROUNDS:

There are various quantities that are useful to reject backgrounds, these are the ones that were considered in this study:

a) Time-of-flight
b) Jet em/tot fraction
c) Jet Pt/Et fraction from tracking/calorimetry
d) Missing Et
e) Number of clusters/event
f) Number of towers/cluster
g) Ratio of Et's between jet1/jet2

Of these, e,f,g were found to offer no additional information and/or were very inefficient in rejecting backgrounds. The other 4 quantities were found to be very useful in rejecting backgrounds, especially when used in conjunction with each other.

4 TIME-OF-FLIGHT CUT (HATFLT).

We used the cuts defined in Hatflt. These cuts are defined in C$DOC:Hatflt.mem, and one study of this filter module is described in CDF note 521. Our Hatflt study came up with similar conclusions, that Hatflt removes > 90% of the junk events, while removing only one "real" event (which appears to be a satellite bunch collision, i.e. incorrect timing). The 10% of the background missed by Hatflt consists of 5% in-time cosmic rays and 5% apparent cosmic rays that give all electromagnetic energy. Note that the 5% in-time cosmic rays corresponds exactly to the 35ns/700ns time window used by Hatflt. Note also that in this data sample Hatflt removed 100% of the main ring splashes. Figures 1a-c show the cluster time-of-flight means for good events, main ring splashes (>8 out of time hits), and cosmic rays (<8 out of time hits). The TDC gate is from -150 ns to 550 ns, and these figures demonstrate the average cluster times for splashes and cosmic rays come far from beam crossing, while the good events have a clear peak near beam crossing. Figures 2a-c show the cluster time-of-flight sigmas for good events, main ring splashes, and cosmic rays. These figures demonstrate a striking feature of main ring splashes; while the sigmas for good clusters and cosmic rays are small (as expected), the sigmas for main ring splashes are very large. This fact is what enables Hatflt to reject 100% of the main ring splashes in this sample.

5 ADDITIONAL CUTS USED AND CLASSES OF BACKGROUNDS.

5.1 Electromagnetic Fraction Of A Jet (EMF).

Figures 3a-b show the EMF for good events and for main ring splashes (already rejected by Hatflt). These plots demonstrate that the jet EMF is a powerful tool in rejecting backgrounds. We flag the jet EMF as bad if $0.1 > EMF > 0.95$. Note that this cut by itself would throw away some 3-4% of the good events, while not getting rid of all of the events we have found to be junk. This is what led us to require an event to pass only 2 of 3 cuts to be considered good.

5.2 Average Jet Pt/Et Ratio (CHF).

The exact definition of CHF is as follows: for jets above 30 Gev and $-1<eta<1$ a cone of 0.7 radians is made around the jet centroid and the 3-d track scaler Pt's are added within that cone, then the Pt/Et ratio is formed. The average of these quantities for all central jets is the definition of CHF. This average was found to be more efficient than just using the event's leading jet, since there is a correlation between the jet's Pt/Et ratio and EMF. Figures 4a-b show the CHF for good events and for main ring splashes, demonstrating its usefulness. We flag CHF as bad if $CHF < 0.1$.

Since tracking will probably not be available for all jet events, this quantity can be used for high Pt events which are most sensitive to backgrounds. The other 2 cuts can be used at lower Pt with slightly less efficiency, but lower Pt events are less sensitive to a few background events, so this is not a problem.

5.3 Missing Et (MET).

Background events are typically monojets, with large missing Et. However, a straight cut on missing Et in Gev is difficult since missing Et resolution gets worse as the total scaler Et in the event increases. Figures 5a-b demonstrate this. Figure 5a is the missing Et from GOOD events with a 70 Gev jet, while figure 5b is the missing Et from BAD events with a 30 Gev jet. There is significant overlap between the 2 distributions. A better quantity is to define 0.8*SQRT(SumEt) as the missing Et resolution. SumEt is the scaler sum of all clusters with Et>5 Gev. Then MET = Missing Et/(0.8*SQRT(SumEt)) is the number of standard deviations from the expected missing Et. Figures 6a-b demonstrate the improved separation between signal and background. MET is considered bad if MET > 6.

5.4 Classes Of Backgrounds.

Using the cuts above, the following classes of events are defined:

Class 0 -- No central jet above 30 Gev.
Class 2 -- Hatflt rejects -- Main Ring (>8 out of time hits)
Class 3 -- Hatflt rejects -- Cosmics (<8 out of time hits)
Class 5 -- In-time hadronic cosmic with
EMF,CHF,MET all bad and EMF<0.1
Class 6 -- Electromagnetic cosmic with
EMF,CHF,MET all bad and EMF>0.95
Class 11 - 2 of 3 cuts fail, probably bad event
Class 21 - 1 of 3 cuts fail, probably good event
Class 31 - 0 of 3 cuts fail, Good event

For most purposes, classes 21 and 31 are kept. But for applications that require a cleaner sample, only class 31 can be kept. For the 1340 events with 70 Gev jets, the breakdown of classes is Class 0--189 evts, 2-96, 3-88, 5-12, 6-12, 11-9, 21-47, 31-887. All of the events in classes 5-21 have been scanned, with the result that all of the class 5-6 events appear bad, about half of the class 11 events are good, and all of the class 21 appear good. Thus if classes 21 and 31 are kept, we believe that all events kept are good, while 4 good events (0.3%) are filtered. These 4 are events where the correlation between EMF and CHF shows up in all-Em jets. Thus if one is studying these jets class 11 could be kept.

5.5 Is This Elaborate Scheme Necessary?

The answer to whether this scheme is necessary depends on what you want to do. In some cases Hatflt may be good enough. In other cases you may want the signal/background ratio maximized. What happens if only one of these cuts are used? If only EMF is used then 22 good events (3%) are filtered and 3 bad events are kept. This is significantly worse than our combination of cuts, but maybe ok for some applications. If only CHF is used then 22 good events (3%) are also filtered while 0 bad events are kept. CHF has the additional problem that track reconstruction needs to be done before track Pt's are measured, and reconstruction may not always be available. If reconstructed tracks are not available then EMF and MET can be used with slightly reduced efficiency. If only MET is used 10 good events are filtered and 1 bad event is kept. These numbers are to be compared with the 4 good events that are filtered and 0 bad events kept when the combination of cuts is used. Missing Et has the additional problem that this cut will not be acceptable to those doing missing Et studies. In their case the CHF and EMF can be used.

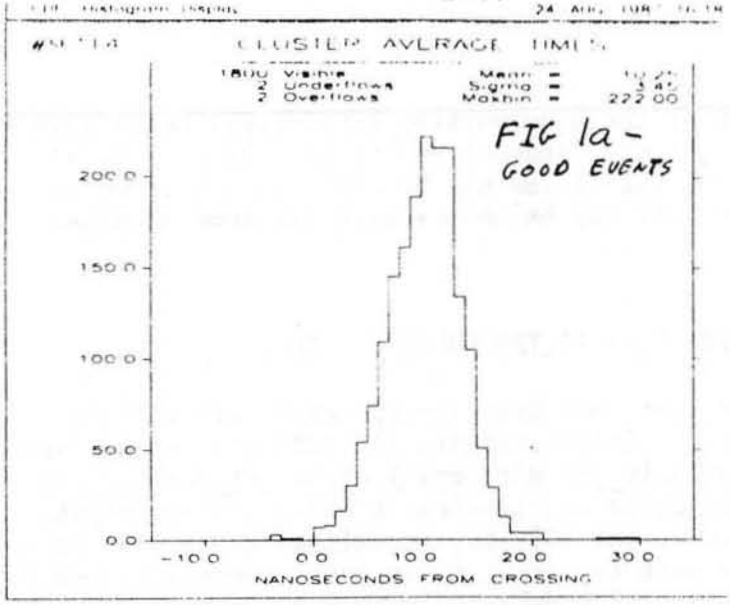
Thus the best signal/background ratio is arrived at by requiring 2 of the 3 quantities EMF,CHF,MET being good if the time-of-flight requirements are meant. But the caveat exists that some of these quantities may be unacceptable or unavailable, or using these cuts may be unnecessary for some studies.

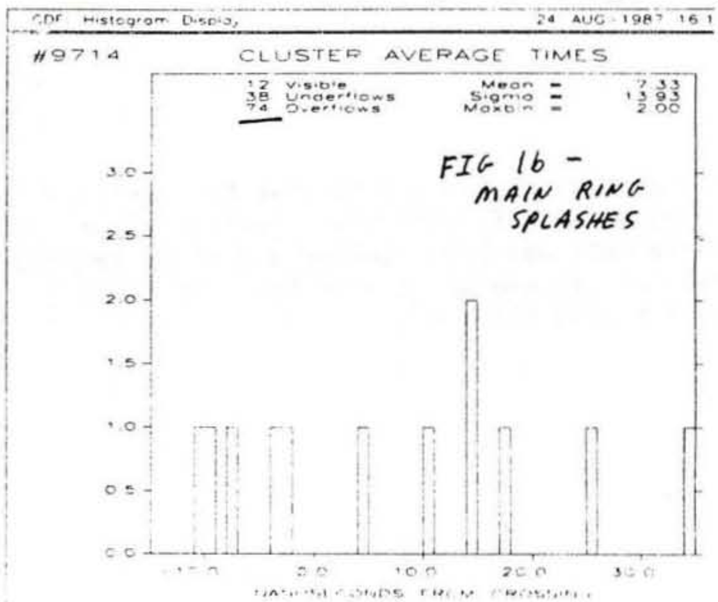
6 THE CENTRAL JET FILTER ROUTINE, CENJET.

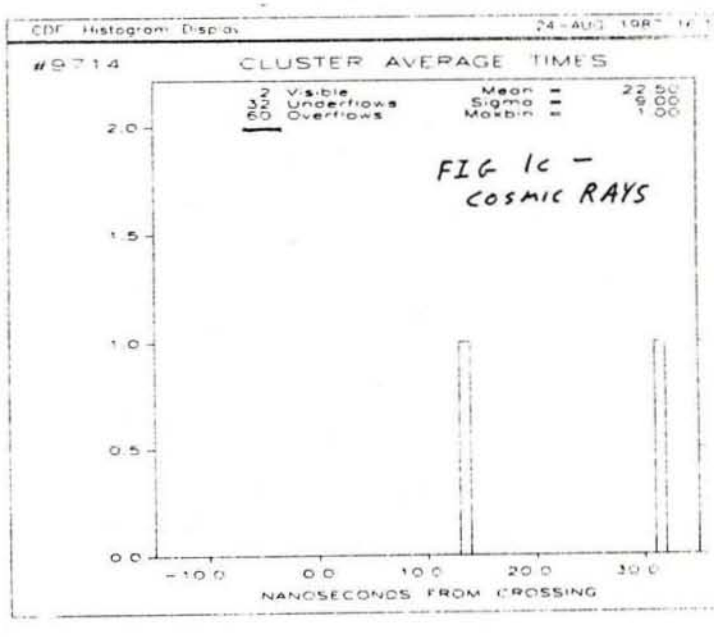
These cuts have been incorporated into a filter routine called Cenjet. Cenjet resides in C$JET and can be linked by putting the build_job dictionary c$jet:jet_decl.uic in the build_job creation and linking in build_job to Cenjet. The cuts are settable in the talk-to, as well as being able to select which classes you want to keep. It is not necessary to use Hatflt if you use Cenjet. The default is to NOT use tracking, this flag must be set in the talk-to. The default cuts are defined above and by default classes 21 and 31 are kept.

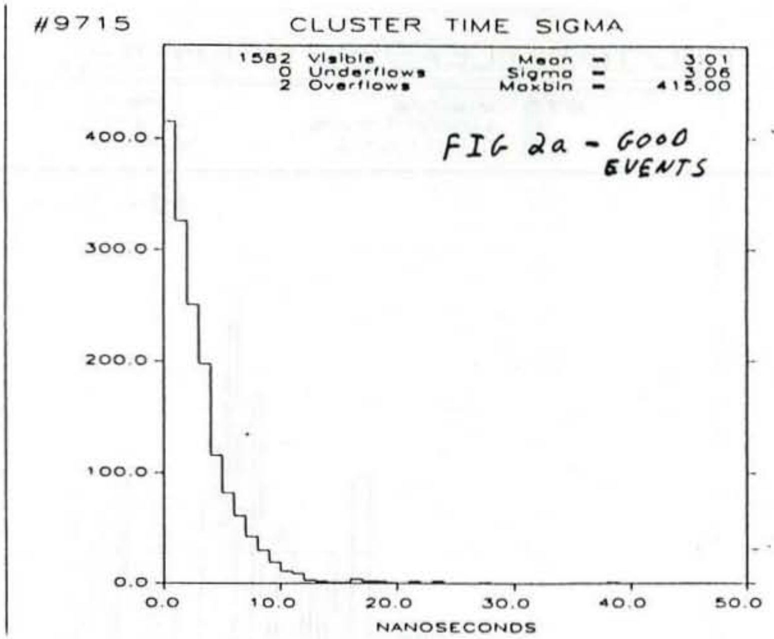
7 SUMMARY.

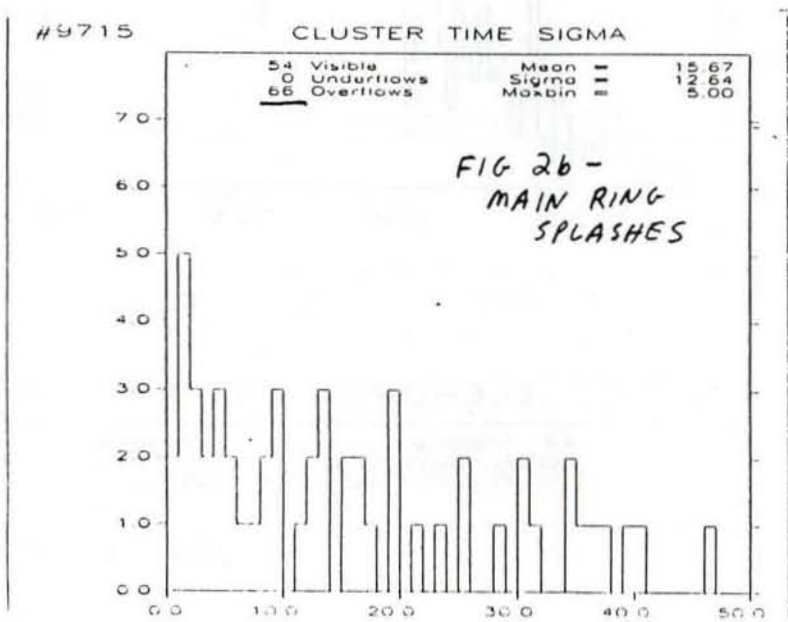
Additional cuts on jet events have been defined that improve (beyond time-of-flight) the rejection of backgrounds. The effect of these cuts has been studied and while keeping a clean sample of central jet events, a very small fraction (0.3%) of good events have been filtered.

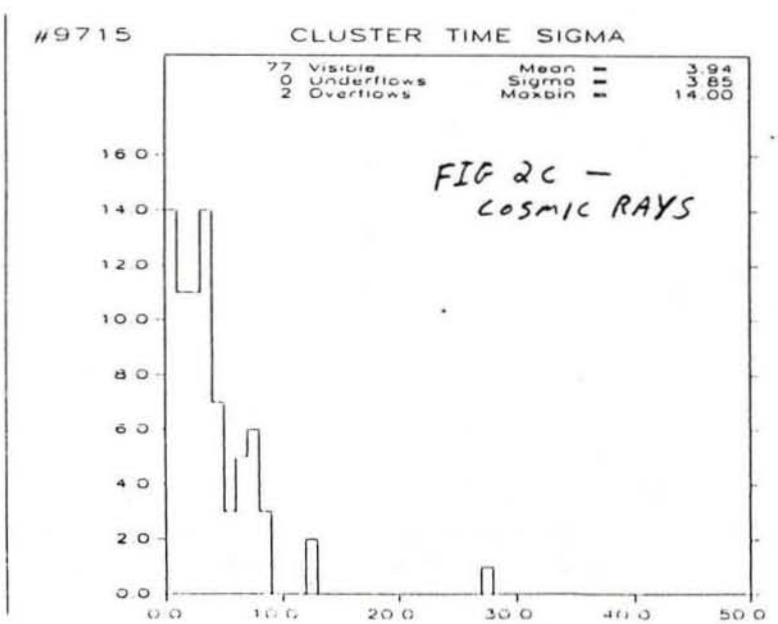

CLUSTER AVERAGE TIMES
1800 Visible
2 Underflows
2 Overflows
Sigma =
222.00
FIG 1a -
GOOD EVENTS
200.0
150.0
100.0
50.0
0.0
-10.0
0.0
10.0
20.0
30.0
NANOSECONDS FROM CROSSING


CDF Histogram Display
24 AUG 1987
#9714
CLUSTER AVERAGE TIMES
12 Visible
38 Underflows
74 Overflows
Mean = 7.33
Sigma = 13.93
Maxbin = 2.00
FIG 1b -
MAIN RING
SPLASHES
3.0
2.5
2.0
1.5
1.0
0.5
0.0
10.0
20.0
30.0

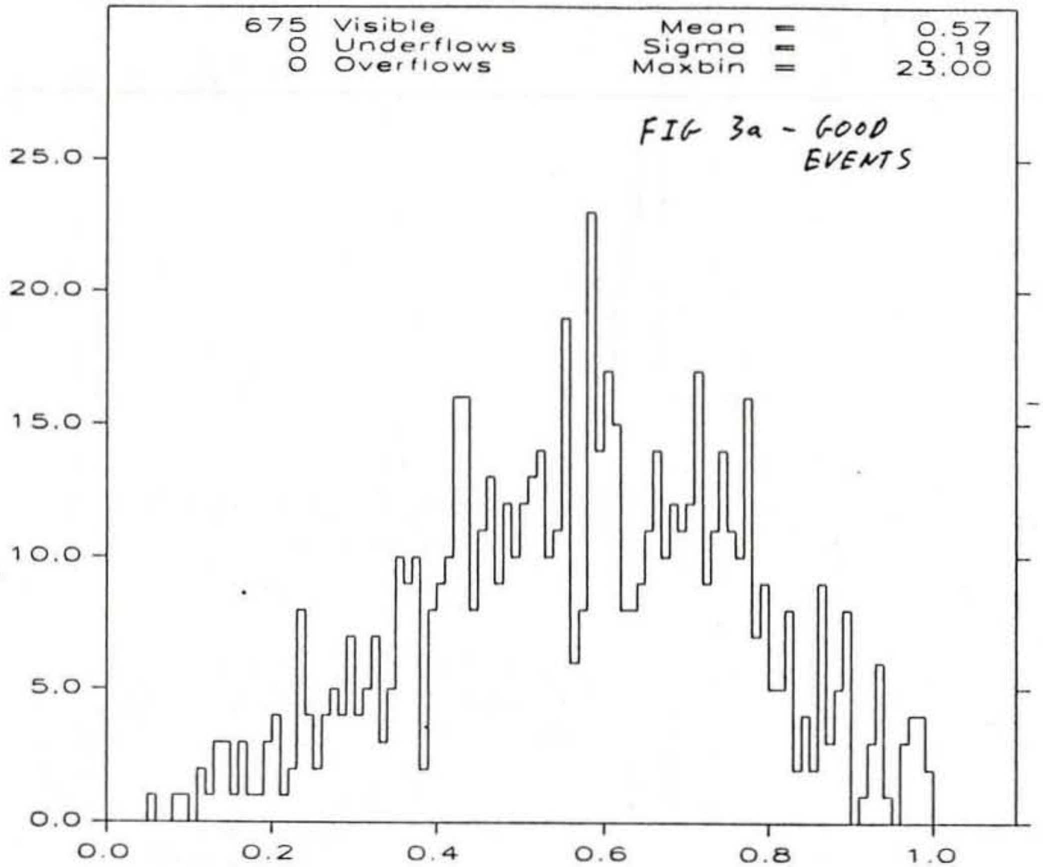

CDF Histogram Display
#9714
CLUSTER AVERAGE TIMES
2 Visible
32 Underflows
60 Overflows
Mean = 22.50
Sigma = 9.00
Maxbin = 1.00
FIG 1c -
COSMIC RAYS
2.0
1.5
1.0
0.5
0.0
-10.0
0.0
10.0
20.0
30.0
NANOSECONDS FROM CROSSING


#9715
CLUSTER TIME SIGMA
1582 Visible
0 Underflows
2 Overflows
Mean = 3.01
Sigma = 3.06
Maxbin = 415.00
FIG 2a - GOOD EVENTS
400.0
300.0
200.0
100.0
0.0
0.0
10.0
20.0
30.0
40.0
50.0
NANOSECONDS

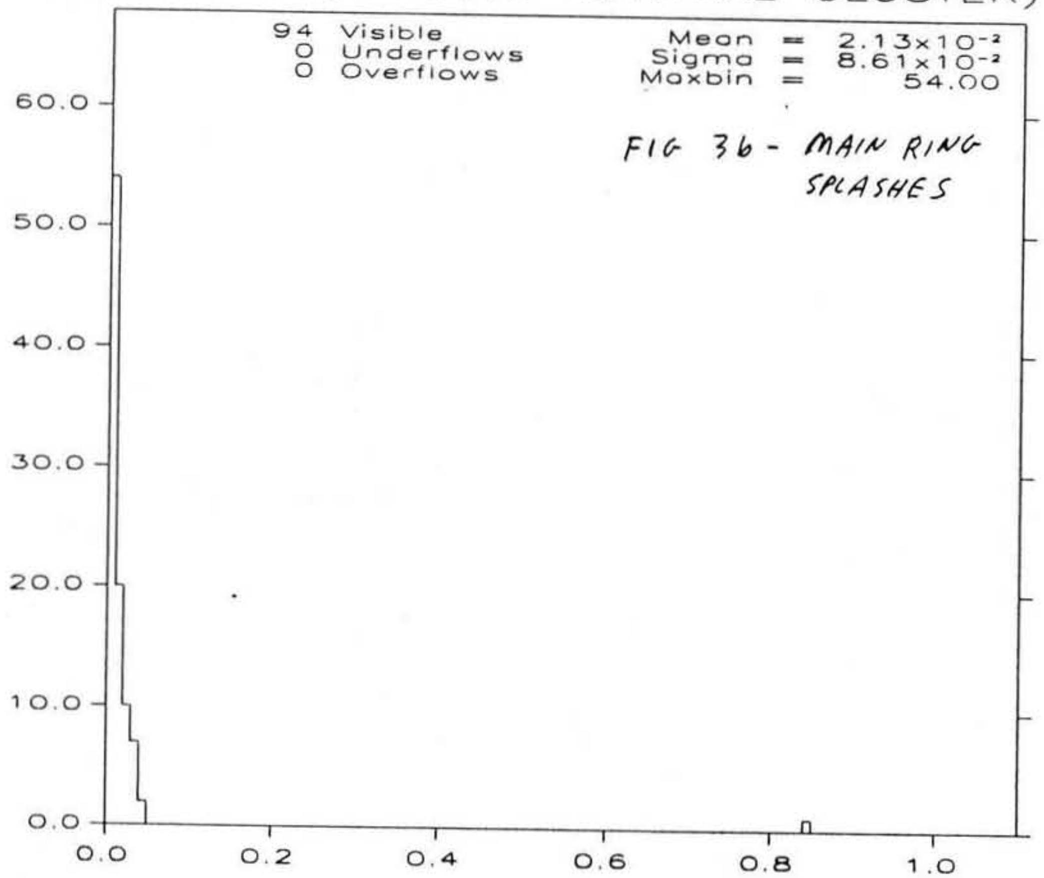

#9715
CLUSTER TIME SIGMA
54 Visible
0 Underflows
66 Overflows
Mean = 15.67
Sigma = 12.64
Maxbin = 5.00
FIG 2b - MAIN RING SPLASHES
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0.0
10.0
20.0
30.0
40.0
50.0


#9715
CLUSTER TIME SIGMA
77 Visible
0 Underflows
2 Overflows
Mean = 3.94
Sigma = 3.85
Maxbin = 14.00
FIG 2c - COSMIC RAYS
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0.0
10.0
20.0
30.0
40.0
50.0

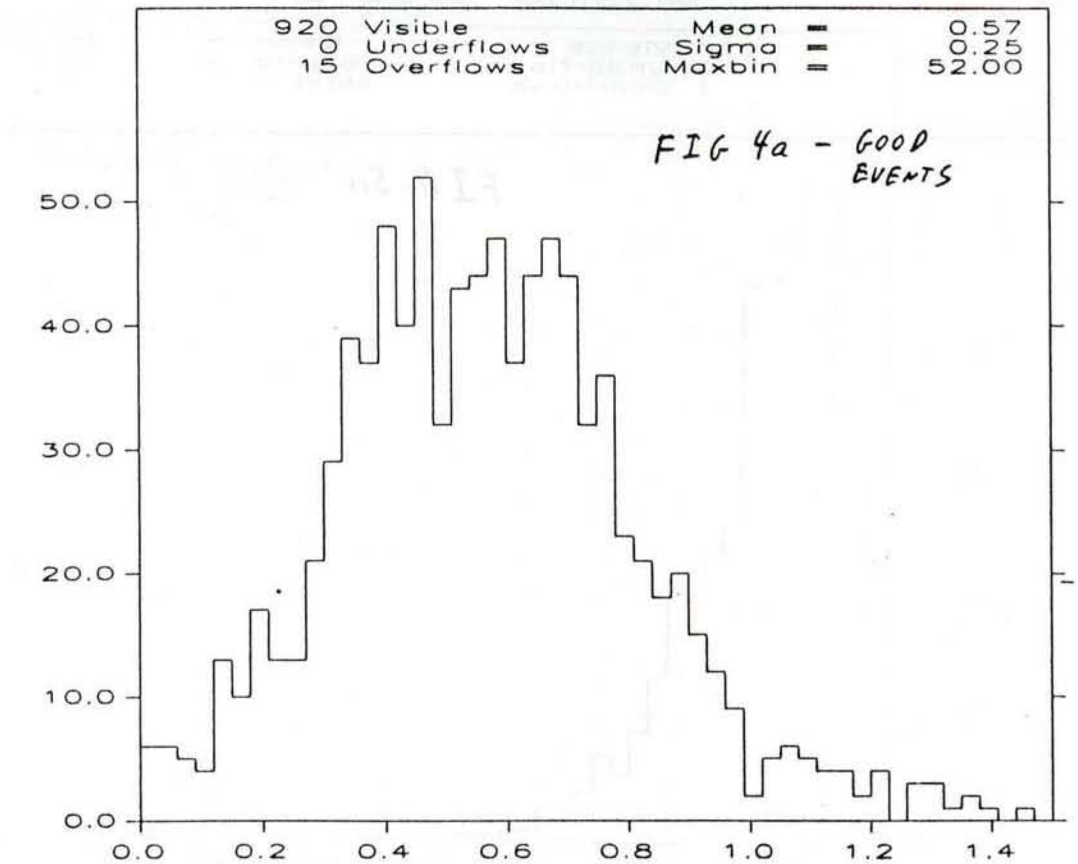
#9712 EM/TOT (LEADING CENTRAL CLUSTER)



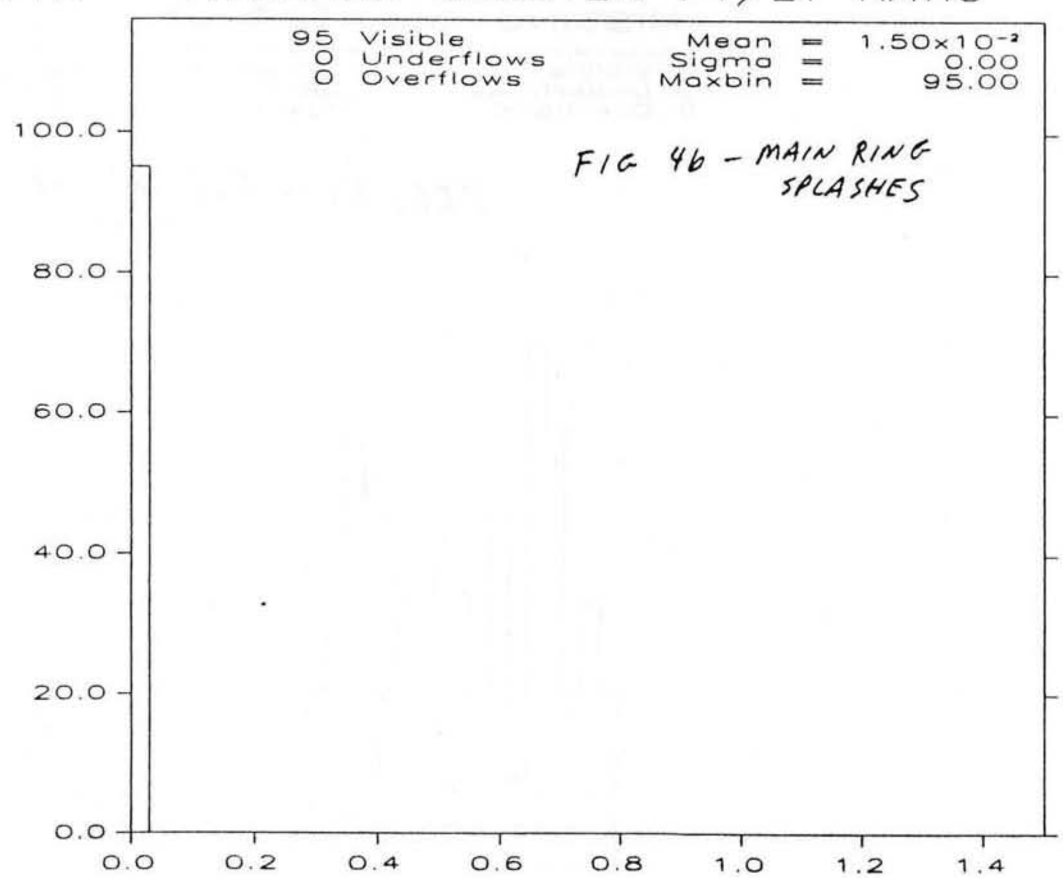
#9712 EM/TOT (LEADING CENTRAL CLUSTER)



#9719 AVERAGE CLUSTER PT/ET RATIO

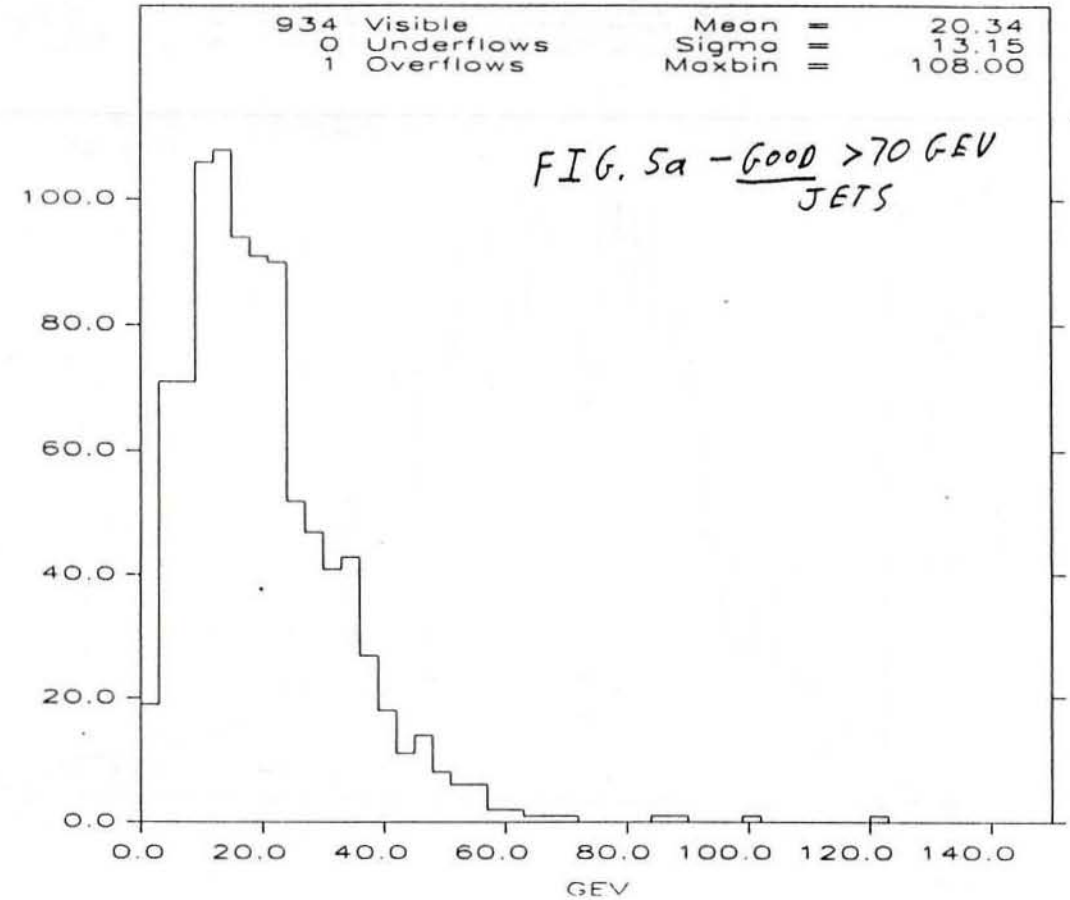


#9719 AVERAGE CLUSTER PT/ET RATIO



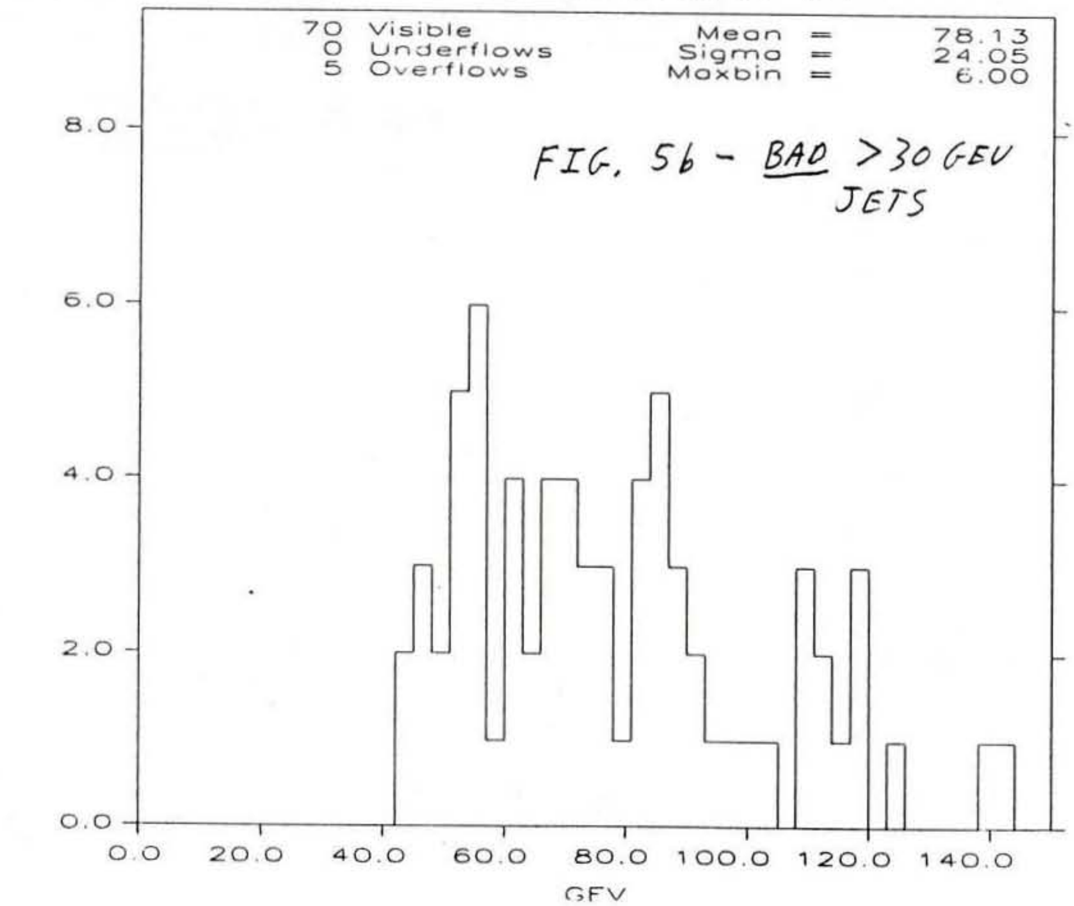
#9722

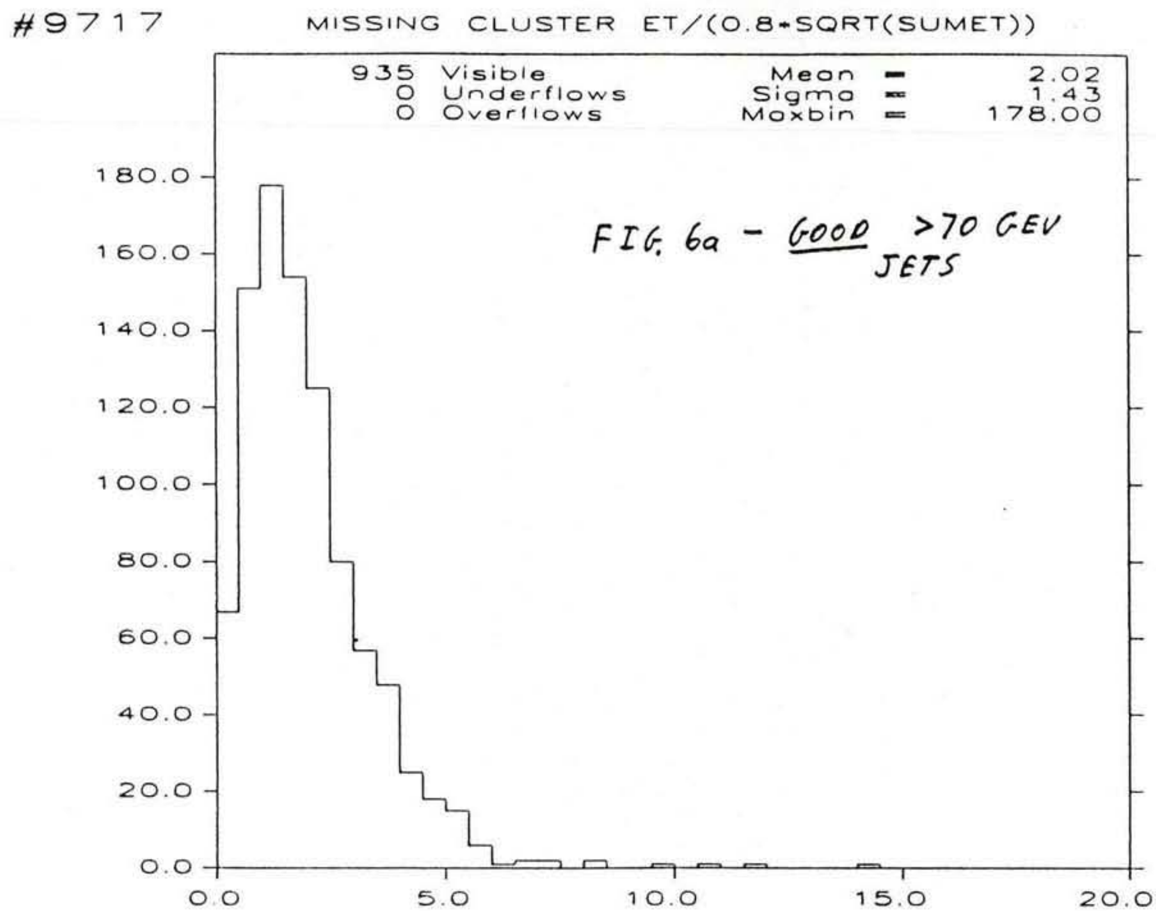
MISSING CLUSTER ET



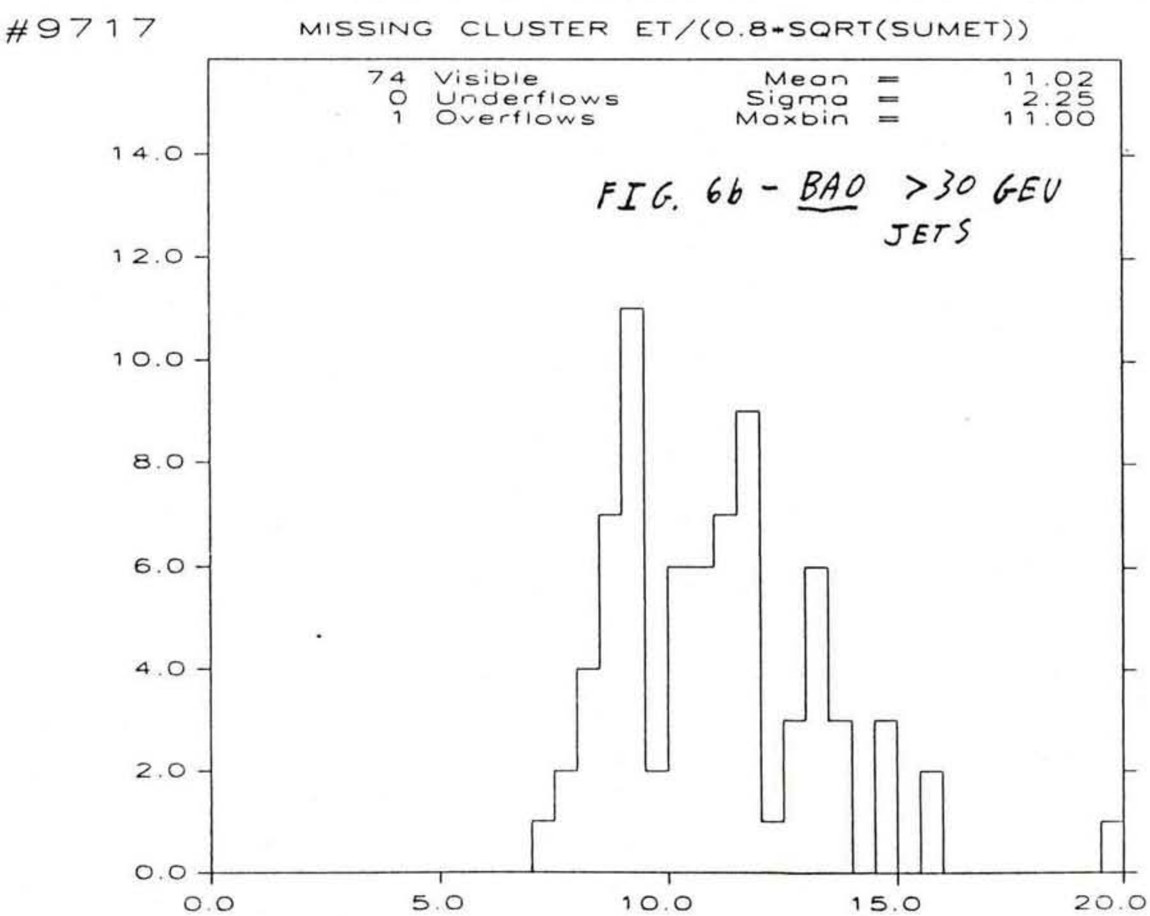
#9722

MISSING CLUSTER ET





#9717
MISSING CLUSTER ET/(0.8*SQRT(SUMET))
935 Visible
0 Underflows
0 Overflows
Mean = 2.02
Sigma = 1.43
Maxbin = 178.00
180.0
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
0.0
5.0
10.0
15.0
20.0
FIG. 6a - GOOD >70 GEV JETS



#9717
MISSING CLUSTER ET/(0.8*SQRT(SUMET))
74 Visible
0 Underflows
1 Overflows
Mean = 11.02
Sigma = 2.25
Maxbin = 11.00
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0.0
5.0
10.0
15.0
20.0
FIG. 6b - BAD >30 GEV JETS