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Level 1 Jet Trigger Efficiencies *

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Abstract

Level 1 trigger efficiencies and their dependence on η and P_T have been calculated using single-jet events. Sytematic η effects which have been missed in other studies become apparent and represent a potentially important angular correlation efficiency problem. A method for quickly simulating the trigger efficiencies of specific physics processes has been developed and applied to two-jet QCD events as a check against other, more time-consuming means.

Single-Jet Events

The Lund monte carlo Pythia was used to generate 170 samples of 500 events each. Eta ranged from 0.0 to 4.0 in increments of 0.25 while the values of P_T used were as follows: 2, 5, 10, 20, 30, 50, 75, 100, 125, 150 Gev/c. Phi was randomly generated for each event. These files were then processed by D0Geant using the showerlibrary.

The D-Zero Level 1 trigger simulator calculated efficiencies from the 500 event samples for each value of η and P_T and for many different total E_T

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thresholds and number of trigger towers. A trigger tower is simply a 2×2 block of calorimeter towers, or $\eta \times \phi = 0.2 \times 0.2$ throughout most of the calorimeter. A jet trigger is the requirement that a certain number of trigger towers (either 1, 2, 3 or 4) each contains more total E_T than a given threshold value. So, an event that passes the trigger symbolized by JT(2,10) will have at least 2 trigger towers each with a total E_T (EM and hadronic) deposition greater than 10 GeV. Figures 1-4 show the results for the JT(1,3), JT(1,5), JT(1,9) and JT(1,20) triggers. Note that the level 1 trigger simulator includes calorimeter noise. The effects of the CC-EC transition is visible in each set of plots and can be seen to range up to a 40% reduction in trigger efficiency for certain values of jet P_T and trigger threshold. At high eta, there are 3 non-negligible competing effects : Energy loss down the beam pipe, the decreasing size of the trigger towers with respect to the jet radius, and the abrupt change in size of the calorimeter cells from $\eta \times \phi = 0.1 \times 0.1$ to $\eta \times \phi = 0.2 \times 0.2$ for $|\eta| > 3.2$. The decreasing size of the trigger towers with increasing eta causes the decrease in efficiency for $2.5 < |\eta| < 3.2$ observed in Figures 3 and 4 since the fraction of the jet energy sampled by a trigger tower decreases with increasing eta. Figure 5 shows efficiency vs. η when you require 4 trigger towers greater than 5 Gev. The increasing efficiency with increasing eta in this plot is due to the same effect, only now smaller towers means the jet's energy is spread out over more trigger towers, so more towers are above the threshold.

In Figures 6 and 7 the P_T dependence of the single-jet efficiency is shown for a variety of triggers at $\eta = 0$. From Figure 6 we can make the inference

that the efficiency for single jets in the central calorimeter reaches 95% when the jet $P_T \simeq 5\times$ trigger threshold for single tower triggers. Figure 7 shows the effects of multiple trigger towers on the P_T-dependent efficiency for constant η and trigger threshold.

Two-Jet Events

Transferring the single-jet efficiencies to two-jet events gives us ways of directly comparing triggers in terms of rates and two-jet P_T-dependent efficiencies. This was done by using the partonic Monte Carlo Papageno to generate two-jet events and applying the single-jet efficiencies to each jet of the two-jet event. Step-by-step for a 1-tower trigger:

- Papageno generates a two-jet event.
- For each jet in the two-jet event a value for the trigger efficiency is obtained through interpolation in η and P_T of the tabulated single-jet efficiencies.
- The efficiencies for each jet (say ϵ_1 and ϵ_2) are combined into an overall event efficiency (ϵ) like so:

$$\epsilon = 1 - (1 - \epsilon_1)(1 - \epsilon_2).$$

This may be made more coherent by noting that ϵ is the probability of the trigger being true, so $(1 - \epsilon)$ is the probability of the trigger being false.

Then $(1-\epsilon_1)(1-\epsilon_2)$ is the probability that neither jet caused a trigger so $1-(1-\epsilon_1)(1-\epsilon_2)$ is our event efficiency.

The procedure is modified for 2 trigger towers in the following manner: For each jet you must interpolate not only the 1 trigger tower efficiency (ϵ_1^i, where i is jet 1 or 2) but also the 2 tower efficiency (ϵ_2^i). Then the combination into the total event efficiency is

$$\epsilon = 1-(1-\epsilon_2^1)(1-\epsilon_2^2)(1-\epsilon_1^1\epsilon_1^2).$$

This can be generalized further to 3 tower and 4 tower triggers.

Once we have the ability to calculate the efficiency for two-jet events, we can get rates for any trigger as well as the P_T-dependent efficiency of two-jet events. Rates calculated here for various triggers appear in Table 1 as σ_1. Listed under σ_2 are the cross sections calculated using ISAJET[1]. Note that the ISAJET results are roughly a factor of two smaller than the results generated here, perhaps due to the different fragmentation models used in ISAJET and Pythia as well as differences in two-jet cross section between ISAJET and Papageno. The P_T-dependent two-jet cross section is shown in Figure 8 along with a tabulation into P_T bins for reference. ISAJET jets are known to be smaller than those generated by Pythia which may contribute to a lower efficiency for multiple trigger towers. Of more impotance, perhaps, is the smearing of the z-vertex included in the ISAJET two-jet events but

[1] From Rich Astur. Derived from ISAJET two-jet events treated in the same manner as the single-jet events were treated here. Namely, they were run through D0Geant and the level 1 simulator.

not in the Pythia events. Jets with a large z-vertex will share energy with 2 or more trigger towers, reducing the efficiency. Also shown in Table 1 is the value of P_T at which the efficiency reaches 95%.

Two-jet trigger efficiencies versus η appear in Figures 9 - 11 for the many different triggers. A criterion one might use to judge triggers is the P_T range over which the efficiency rises. A step function would make removing trigger bias from the data easiest and minimize the rate when requiring a certain efficiency at a given jet P_T, so the one with the steeper slope is the preferable trigger. Comparing triggers that begin to "turn on" at about the same P_T, Figure 9 shows how the JT(2,5) trigger turns on faster than the JT(1,10) trigger. That is, they start rising at about the same value of P_T, but one has a faster rise that the other. Also, for about the same rate, the JT(2,5) trigger is $\sim$ 20% more efficient in the P_T range from 20 to 35 GeV/c. At higher trigger thresholds, the difference between one and two towers appears to be less distinct.

Table 1

Trigger Rates			
Trigger	σ_1 (μb*)	σ_2 (μb*)	95% Efficiency (GeV/c)
JT(1,3)	3000	1600	20
JT(1,5)	370	220	25
JT(1,9)	53	22	40
JT(1,10)	40	N/A	40
JT(1,15)	7.7	3.3	50
JT(1,20)	2.0	.94	70
JT(2,5)	56	25	30
JT(2,9)	N/A	2.4	N/A
JT(2,10)	4.9	N/A	55
JT(2,15)	1.1	.37	75
JT(2,20)	.38	.11	100
JT(3,5)	13	6.4	55
JT(3,9)	N/A	.42	N/A
JT(3,10)	.71	N/A	115
JT(3,15)	.12	.047	160
JT(4,5)	3.1	1.9	95
JT(4,9)	N/A	.13	N/A
JT(4,10)	.11	N/A	160

* Cross section in μb equals rate in Hz if Luminosity = $10^{30} cm^{-2} s^{-1}$

σ_1: Cross section in μb calculated using the method described in this paper.

σ_2: Cross section in μb calculated using ISAJET (from Astur.)

95% Efficiency: Jet P_T in GeV/c at which the trigger efficiency reaches 95% (from method described here and data shown in Figures 9-11.)

Figure 1 : Single-jet trigger efficiency versus η for the JT(1,3) trigger (at least one trigger tower with E_T greater than 3 GeV) for the values of jet P_T = 2, 5, 10, 20 GeV/c. Error bars are due to statistics only.

Figure 2 : Single-jet trigger efficiency vs. η for the JT(1,5) trigger with the values of jet P_T = 2, 5, 10, 20, 30, 50 GeV/c.

Figure 3 : Single-jet trigger efficiency vs. η for the JT(1,9) trigger with the values of jet P_T = 10, 20, 30, 50, 75 GeV/c.

Figure 4 : Single-jet trigger efficiency vs. η for the JT(1,20) trigger with the values of jet P_T = 20, 30, 50, 75, 100, 125, 150 GeV/c.

Figure 5 : Single-jet trigger efficiency vs. η for the JT(4,5) trigger (4 trigger towers with at least 5 GeV of E_T each) for the values of jet P_T = 30, 50, 75, 100, 125, 150 GeV/c.

Figure 6 : Single-jet efficiencies vs. jet P_T at $\eta = 0$ for the triggers: JT(1,3), JT(1,5), JT(1,9), JT(1,20).

Figure 7 : Single-jet efficiencies vs. jet P_T at $\eta = 0$ for the triggers: JT(1,5), JT(2,5), JT(3,5), JT(4,5).

Figure 8 : Two-jet QCD cross section derived from Papageno.

Figure 9 : Two-jet efficiencies vs. jet P_T for the triggers: JT(1,3), JT(1,5), JT(1,9), JT(1,15), JT(1,20).

Figure 10: Two-jet efficiencies vs. jet P_T for the triggers: JT(1,10), JT(2,5), JT(2,10), JT(2,15), JT(2,20).

Figure 11: Two-jet efficiencies vs. jet P_T for the triggers: JT(3,5), JT(3,10), JT(3,15), JT(4,5), JT(4,10).

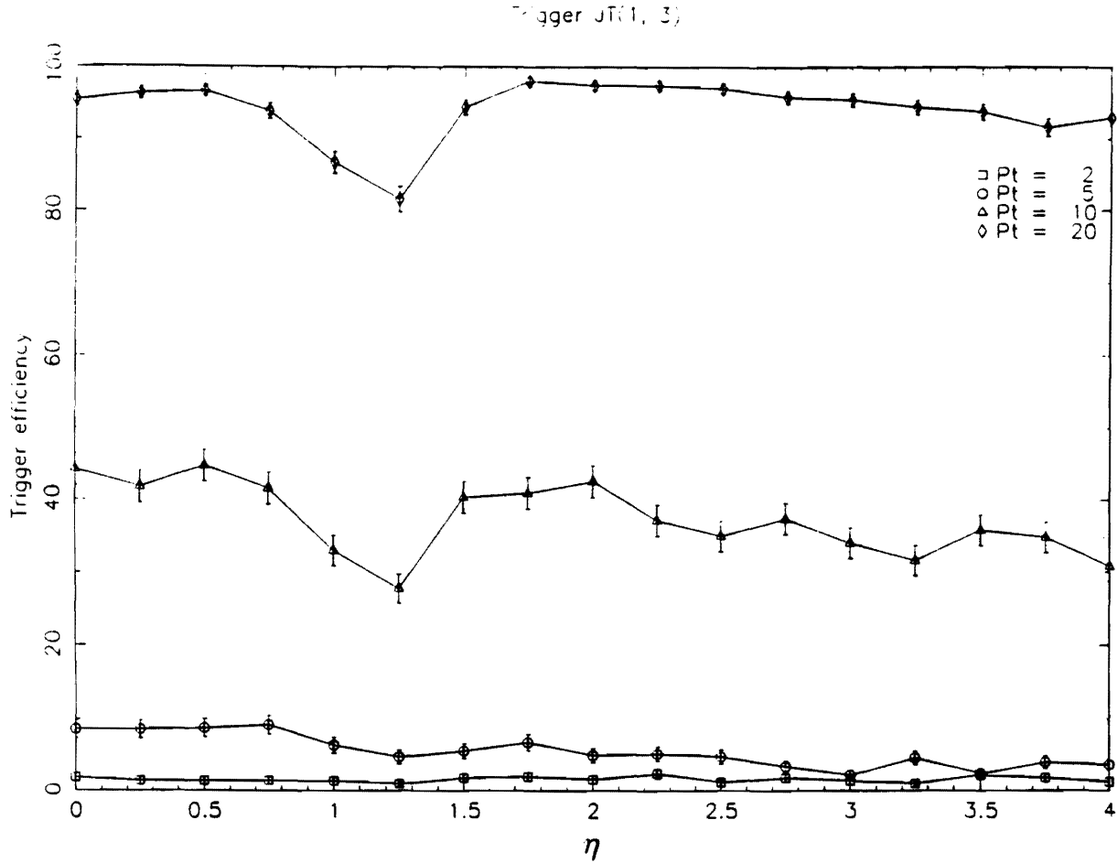

Trigger JT(1, 3)
Trigger efficiency
η
Pt = 2
Pt = 5
Pt = 10
Pt = 20

Fig 1

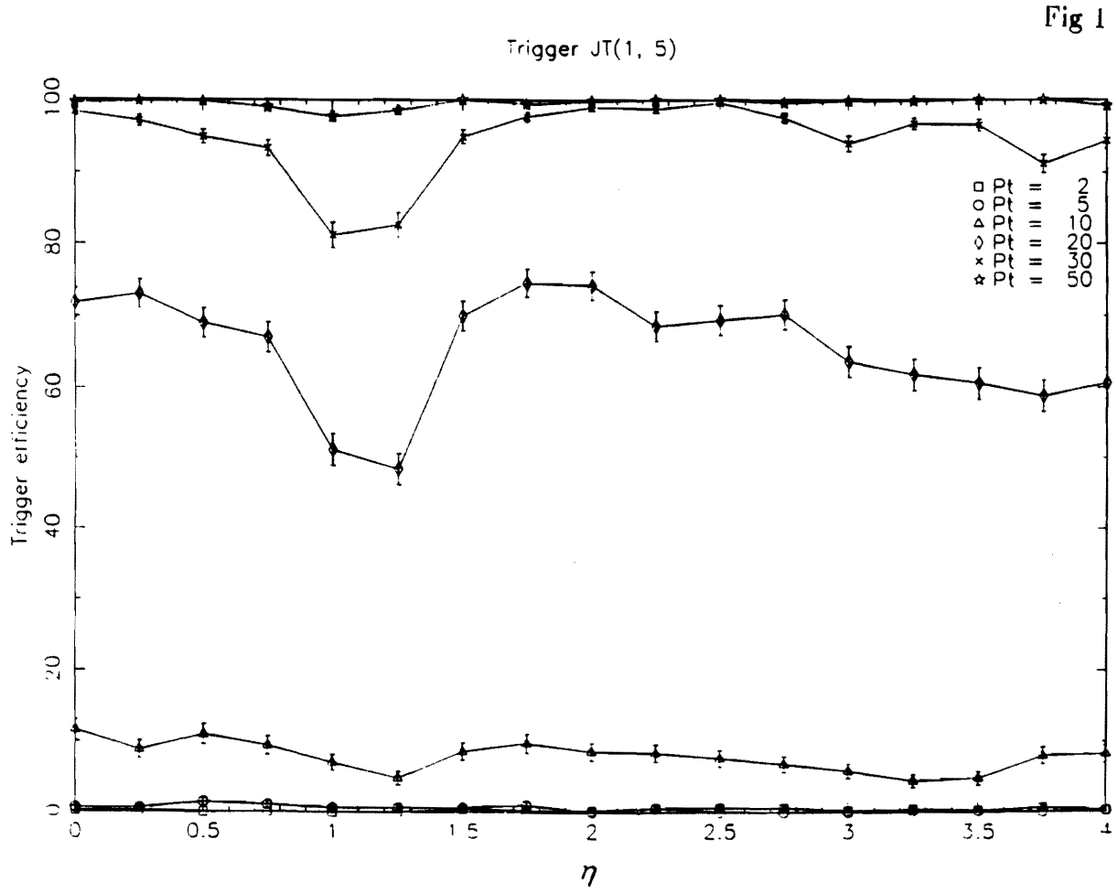

Trigger JT(1, 5)
Trigger efficiency
η
Pt = 2
Pt = 5
Pt = 10
Pt = 20
Pt = 30
Pt = 50

Fig 2

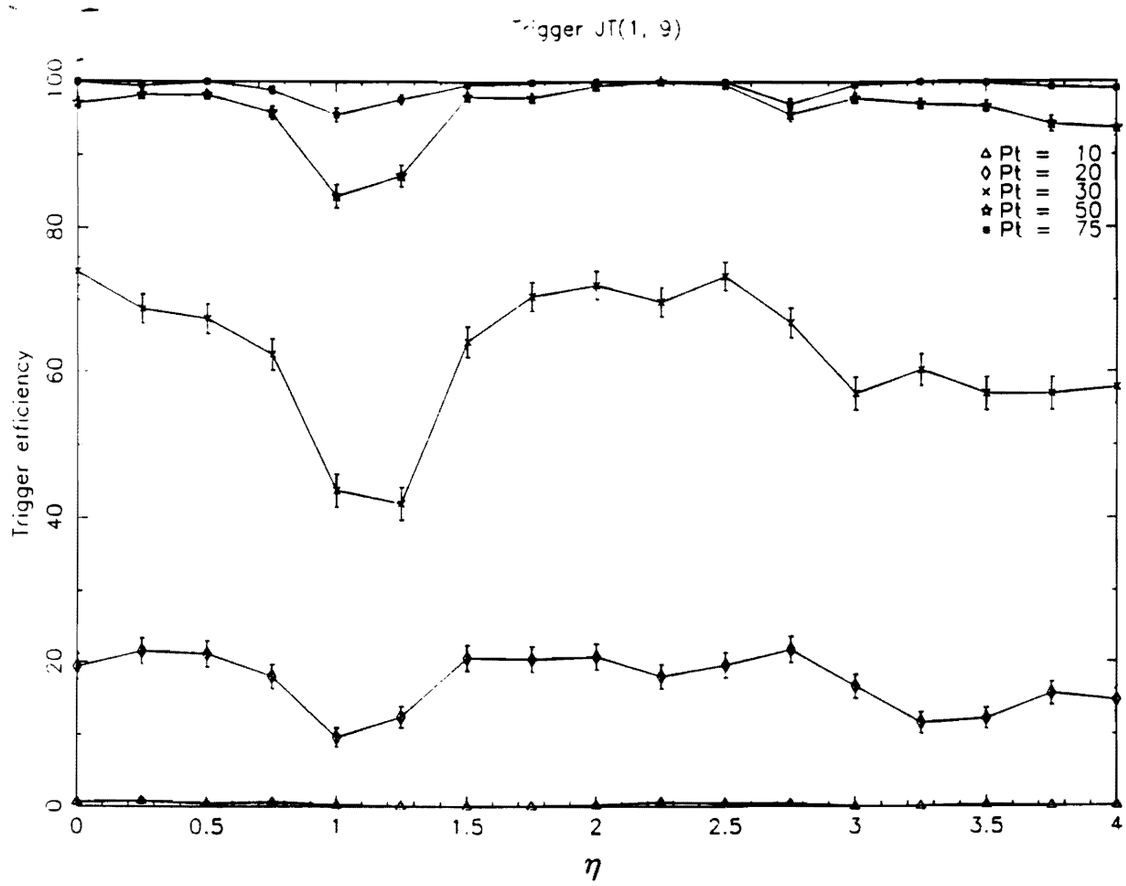

Trigger JT(1, 9)
Trigger efficiency
η
Pt = 10
Pt = 20
Pt = 30
Pt = 50
Pt = 75

Fig 3

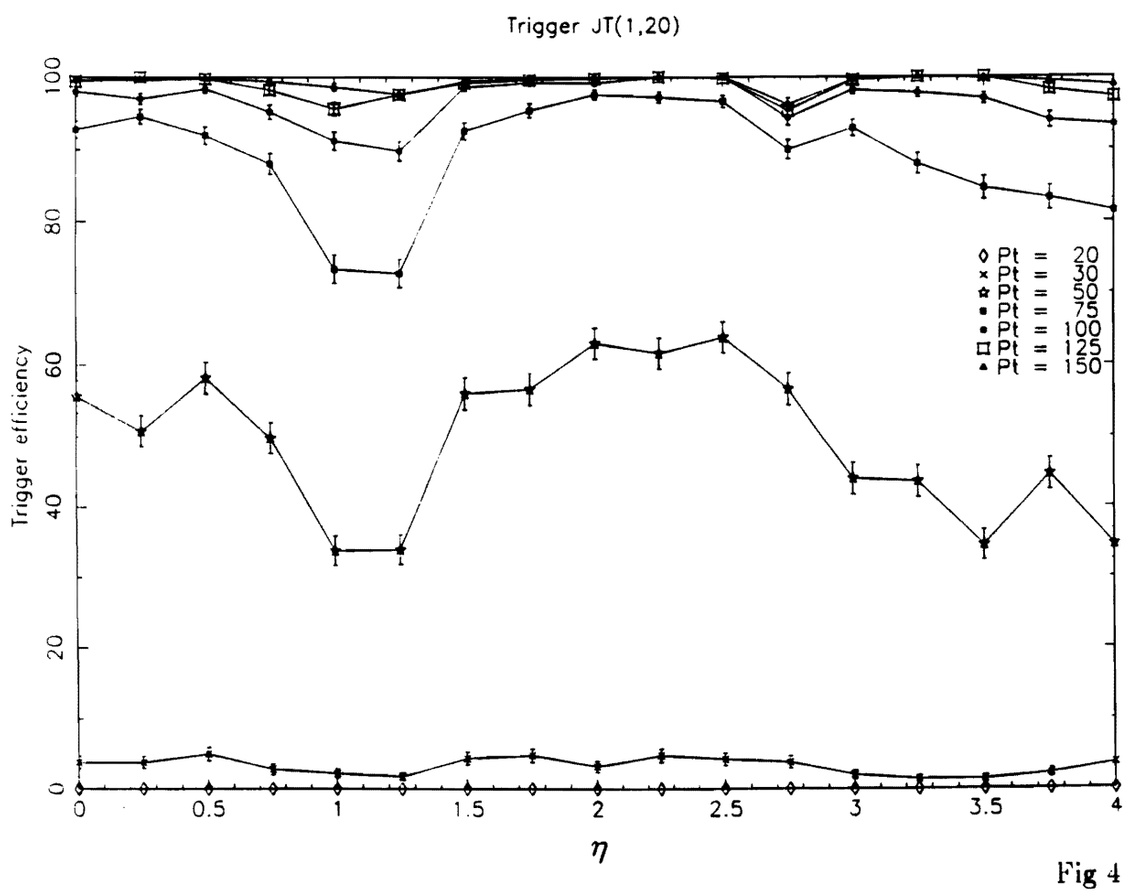

Trigger JT(1,20)
Trigger efficiency
η
Pt = 20
Pt = 30
Pt = 50
Pt = 75
Pt = 100
Pt = 125
Pt = 150

Fig 4

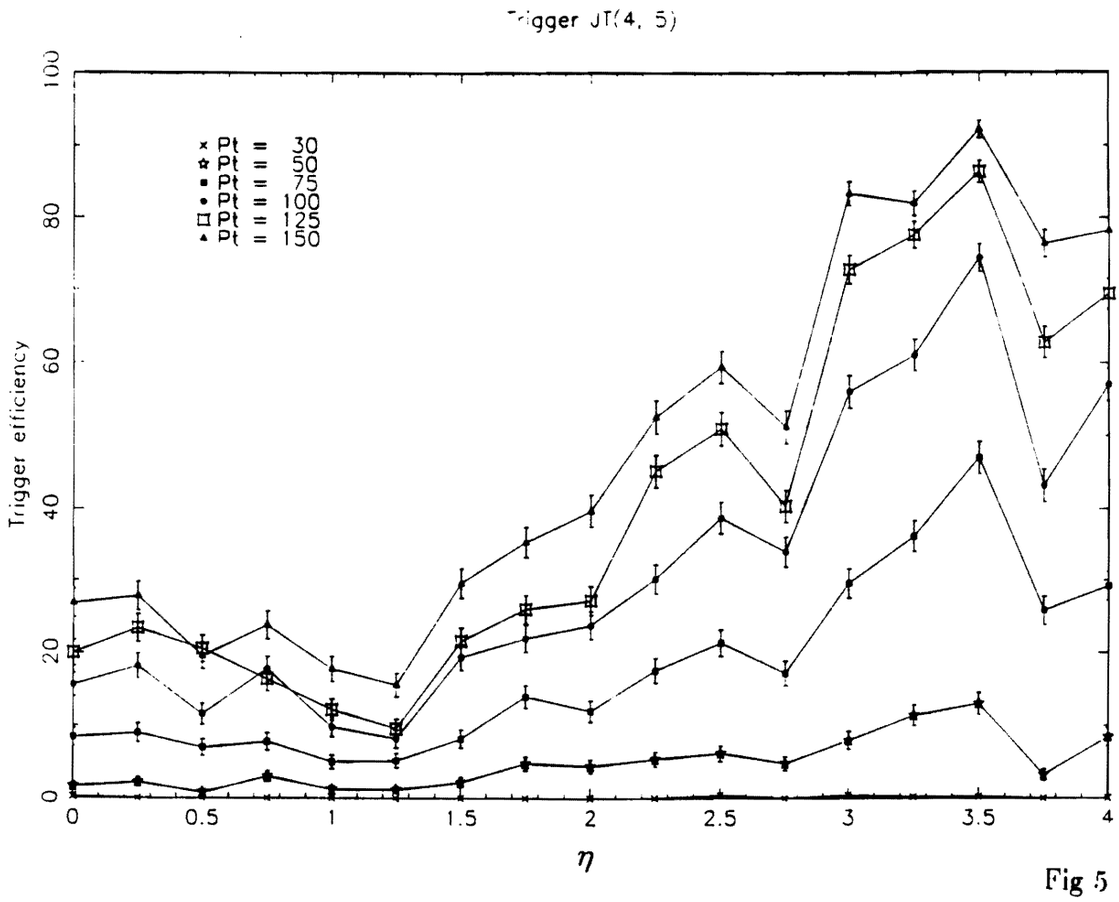

Trigger JT(4, 5)
× Pt = 30
☆ Pt = 50
▪ Pt = 75
• Pt = 100
□ Pt = 125
▲ Pt = 150
Trigger efficiency
0
20
40
60
80
100
0
0.5
1
1.5
2
2.5
3
3.5
4
η

Fig 5

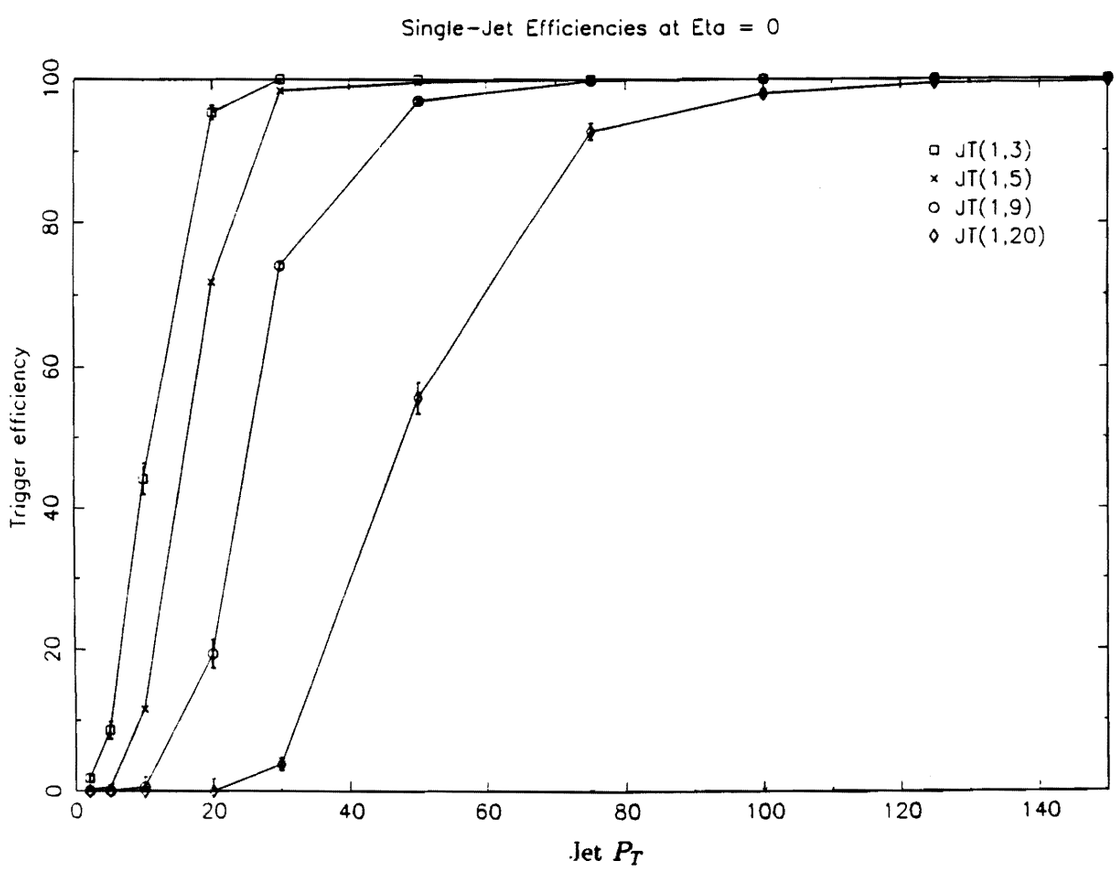

Single-Jet Efficiencies at Eta = 0
□ JT(1,3)
× JT(1,5)
○ JT(1,9)
◇ JT(1,20)
Trigger efficiency
0
20
40
60
80
100
0
20
40
60
80
100
120
140
Jet P_T

Fig 6

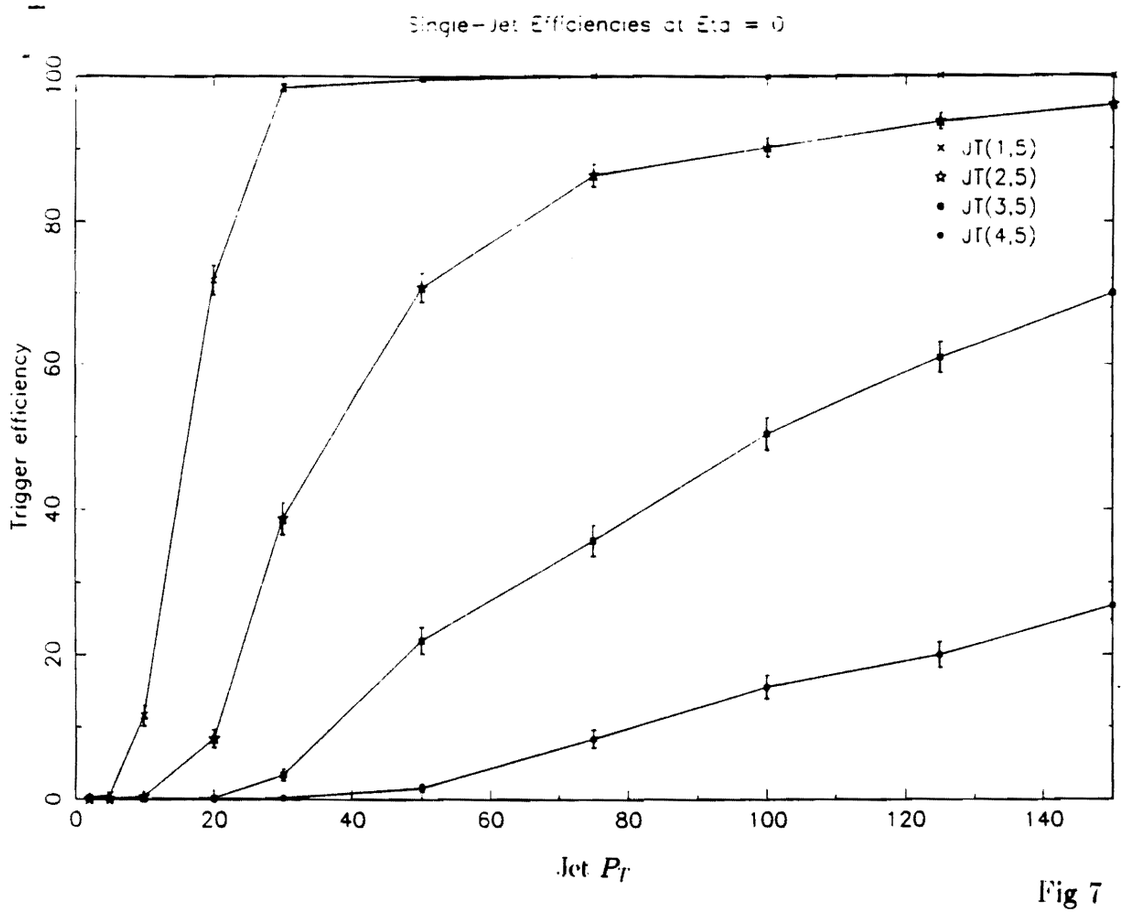
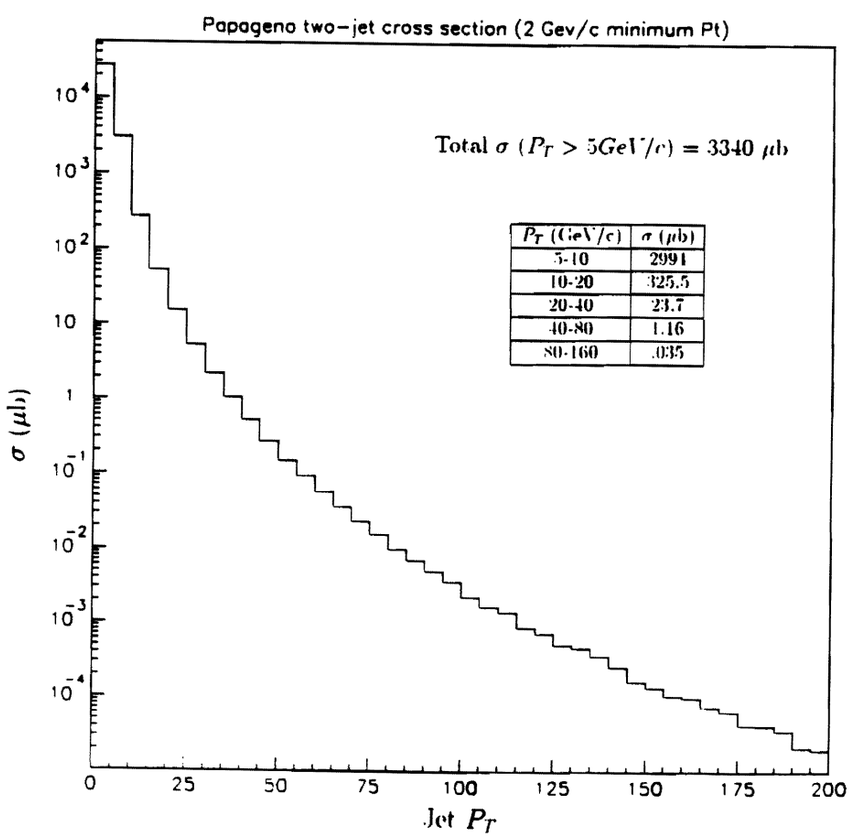


Fig 7



P_T (GeV/c)	σ (μb)
5-10	2991
10-20	325.5
20-40	23.7
40-80	1.16
80-160	.035

Fig 8

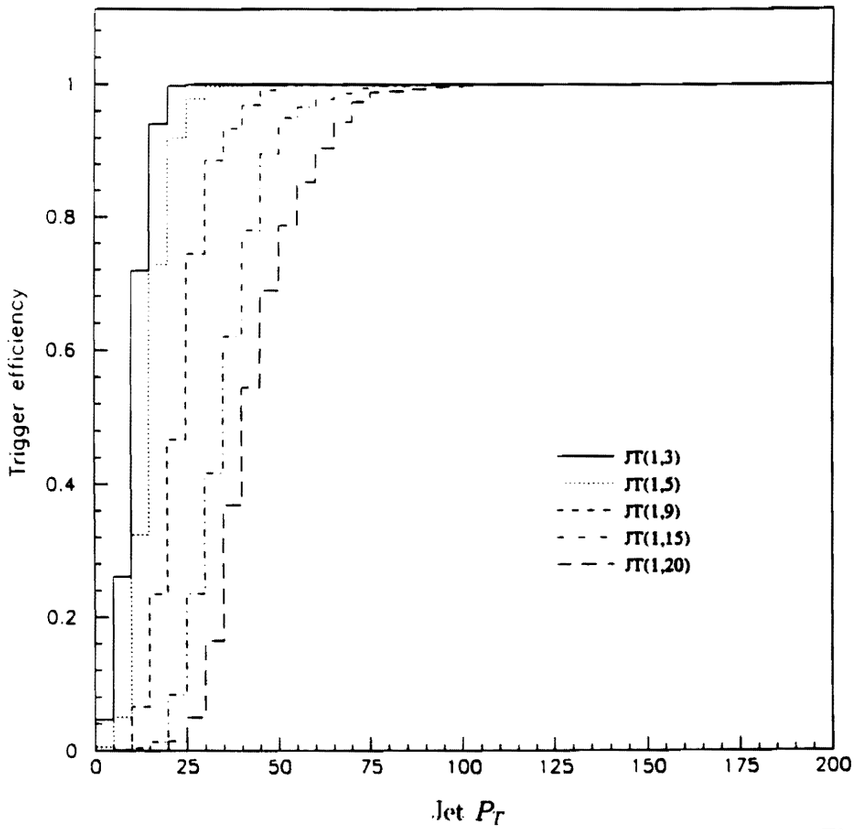

Trigger efficiency
Jet P_T
JT(1,3)
JT(1,5)
JT(1,9)
JT(1,15)
JT(1,20)

Fig 9

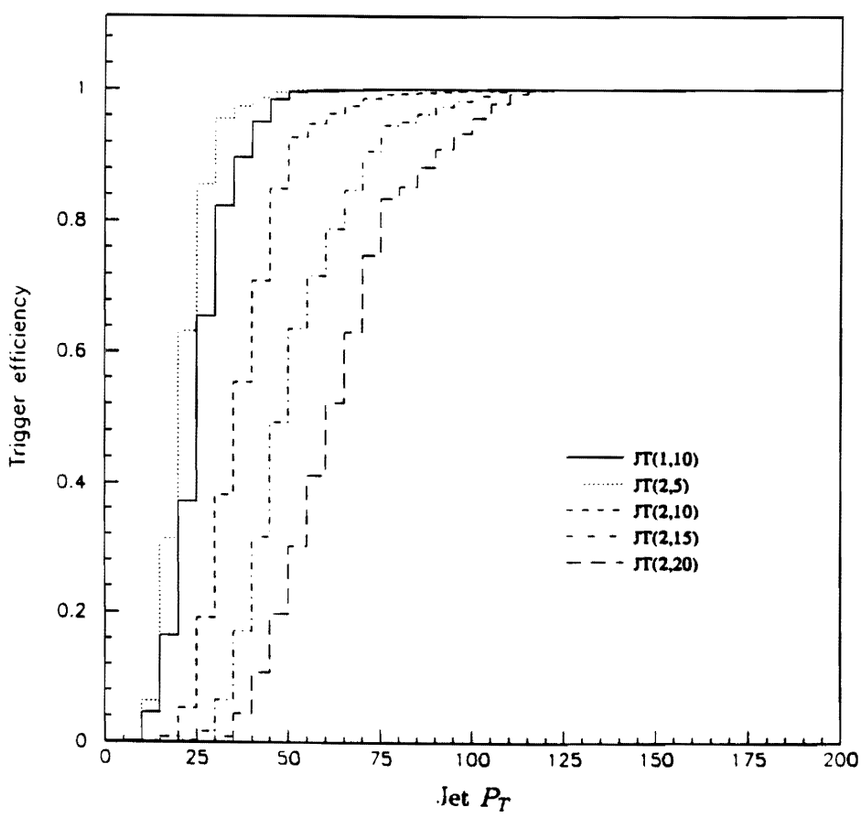

Trigger efficiency
Jet P_T
JT(1,10)
JT(2,5)
JT(2,10)
JT(2,15)
JT(2,20)

Fig 10

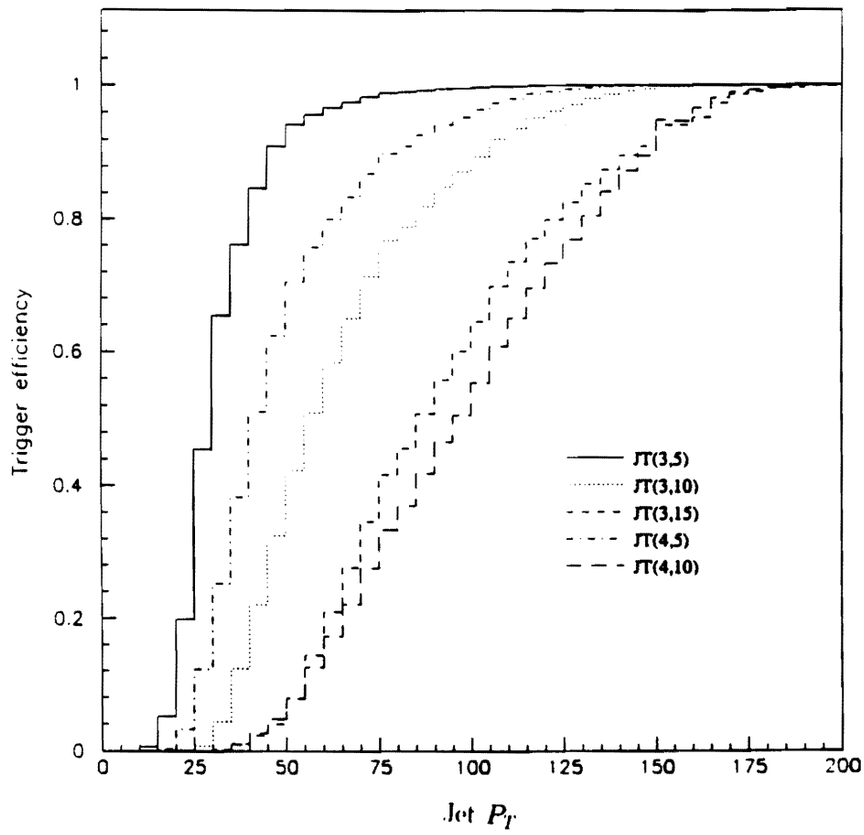

Trigger efficiency
0
0.2
0.4
0.6
0.8
1
0
25
50
75
100
125
150
175
200
Jet P_T
JT(3,5)
JT(3,10)
JT(3,15)
JT(4,5)
JT(4,10)

Fig 11