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PRODUCTION OF MINIJETS IN $p\bar{p}$ COLLISIONS AT $\sqrt{s}$ = 630 GeV

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Abstract

Production of low transverse energy jets has been studied in $p\bar{p}$ collisions at the CERN SPS collider using the barrel hadron calorimeter of the UA1 experiment. A large data sample of 2.3 million events collected with a minimum bias trigger was used. This is ten times larger than the sample used in an earlier study of UA1. Jets with transverse energy in the range 5 GeV to 60 GeV were investigated in a sample of 166 000 events with a jet in the barrel region ($|\eta| < 1.2$). This is three times more than in our earlier study. The transverse energy distribution of the jets is well described with a NLO QCD calculation down to E_t = 5 GeV. The angular distribution of the jets is also consistent with expectations from the elastic scattering of partons with gluon exchange.

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1. Introduction

The properties of high transverse energy jets in proton-antiproton collisions have been succesfully described by QCD over a large range of jet transverse energies, both at the Fermilab and CERN collider energies [1]. In this picture the high E_t jets originate from the hard scattering of two incoming partons, the direction and the energy of the jets providing a measurement of the partons emitted in the hard scattering as described by QCD.

What is still under study is what are the smallest jet transverse energies at which the QCD description is valid. Data on low E_t jets down to 5 GeV transverse energy, published by UA1 at $\sqrt{s}$ = 200, 500, 546, 630 and 900 GeV [2], show that the inclusive E_t distribution of jets can be well described with QCD down to about 10 GeV. In the present study we use data from a dedicated minimum bias trigger run of UA1 in 1987 at $\sqrt{s}$ = 630 GeV. This sample has ten times larger statistics allowing a study of the inclusive E_t distribution in a wider E_t-range ($5 < E_t < 60$ GeV) than in ref. [2] ($5 < E_t < 30$ GeV). Although the angular acceptance in rapidity is narrower ($|\eta| < 1.2$) than in our earlier work ($|\eta| < 2.$) the large statistics allows a detailed comparison of the angular distributions of the low E_t jets with QCD predictions.

In chapter 2 we give a short description of the reconstruction of the jets in the minimum bias events. The inclusive transverse energy distribution of the jets is compared with a dedicated QCD calculation described in chapter 3. In chapter 4 the angular distributions of the jets are studied in the kinematical region where a description by QCD should be valid. In chapter 5 we give the conclusions of our study.

2. Reconstruction of jets

The UA1 electromagnetic lead scintillator calorimeters [3] were removed prior to the 1987 collider run. The remaining hadron calorimeter [3,4], consisting of the iron yoke of the UA1 magnet sandwiched with scintillator plates, was operational.

Data were collected with the minimum bias trigger consisting of the requirement that two charged particles were recorded in opposite rapidity hemispheres in the range $1.5 < |\eta| < 5.5$. This trigger accepts practically all of the inelastic non-diffractive cross section [2]. In total 2.3 million events were recorded. Events were retained in the analysis if they fulfill requirements on timing of the trigger hodoscopes, on the vertex detection in the central tracking detector and on the total energy deposited in the calorimeter. Double interactions in the same SPS bunch crossing were removed by requiring only one interaction vertex reconstructed in the central tracker. With these cuts the background due to beam-gas and halo particle interactions was negligible.

The central part of the hadron calorimeter, the so called C-calorimeter [4], covering the pseudorapidity interval $|\eta| < 1.3$, was used to reconstruct hadronic jets. The C-calorimeter was 12-fold segmented in pseudorapidity η and 24-fold segmented in azimuthal angle ϕ [4]. Because of changes due to the removal of the electromagnetic calorimeters the response of the C-calorimeter was no more completely uniform in ϕ and a correction procedure had to be applied to equalize the response of the calorimeter cells [5]. Jets are reconstructed with the standard UA1 algorithm [2], based on the energy deposited in (η,ϕ) space. Calorimeter cells with deposited $E_t \geq 1.5$ GeV were used to initiate the jets. The initiator cells were ordered in decreasing E_t and reconstruction was started from the highest one. The adjacent cells within the cone $\Delta R = \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2} \leq 1.0$ were summed to obtain the E_t of the jet. The direction of the jet was determined from the vectorial sum of the cell E_t's. Our study here is limited to jets wit $E_t > 5$ GeV as in ref.[2]. About 166 000 events with at least one jet with $E_t > 5$ GeV and $|\eta| < 1.2$ were found.

3. Transverse energy distributions

To obtain the transverse energy distribution of the jets, several corrections have to be applied. The probability to find artificial jets due to fluctuations in E_t as well as the efficiency to reconstruct a genuine jet with fixed E_t were studied with a Monte Carlo simulation [6]. The probability to have an energy fluctuation taken as a jet is negligible above 10 GeV, but is found to increase rapidly with decreasing E_t, reaching 70% at $E_t = 5$ GeV. The efficiency to find a genuine jet is close to 100% above 10 GeV, but decreases with decreasing E_t, being 30% at 5 GeV. The E_t distribution was corrected for these effects. Finally the distribution was corrected for smearing due to the limited jet energy resolution, which is about 30 % at $E_t = 10$ GeV.

The corrected E_t distribution of jets from 5 to 60 GeV is shown in Fig. 1. The systematic error is estimated to be a factor of 2.5 for $E_t = 5$ GeV and a factor of 1.7 for $E_t > 15$ GeV [2]. Also shown is the result of a NLO QCD calculation [7], scaled up by a factor of 1.5. The calculation uses the MRS(D-) next-to-leading order parton structure functions with five active flavors and with $\Lambda_{QCD} = 215$ MeV. The 2-loop formula for α_s was used and the QCD renormalization and factorization scales were chosen as E_t. The same jet cone $\Delta R = \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2} \leq 1.0$ was used in the calculation as in the data analysis. No hadronization is included. The comparison shows a good agreement between the QCD calculation and the data over the whole available range of transverse energies measured.

In Fig. 2 the data are shown together with the corresponding differential cross section obtained from the earlier UA1 data obtained with a dedicated jet trigger [3]. The two distributions are in agreement in the overlap region 20 - 60 GeV.

4. Angular distributions

If the low E_t jets are the result of the electic scattering of incoming partons they should have an angular distribution approximately of the form $(1-\cos^2\theta^*)^{-2}$. To study this we have selected events with at least two reconstructed jets with $E_t > 5$ GeV and $|\eta| < 1.2$ (about 28 600 events). They show a clear back-to-back behaviour in the plane transverse to the beams, where the acceptance of the calorimeter is fairly uniform.

The scattering angle θ^* is calculated with respect to the incoming partons in the rest frame of the two jet system. The direction of the incoming parton is taken to be the average direction of the proton beam [8]. This approximation is good when the total transverse momentum of the two jet system is small compared to the mass of the system. For this analysis we require $p_t(jj) < 3$ GeV, $m(jj) > 10$ GeV, where $p_t(jj)$ and $m(jj)$ are the transverse momentum and the mass of the two jet system, respectively.

The angular acceptance of jets is not uniform in $\cos\theta^*$ because jets are reconstructed in a limited rapidity region $|\eta| < 1.2$, while the longitudinal momenta of the incoming partons vary. The acceptance decreases rapidly with increasing $\cos\theta^*$ due to this rapidity cut , the decrease becoming stronger with the increasing Lorentz boost or increasing dijet rapidity y_{jj}. This is shown in Fig. 3 where the dijet rapidity is plotted together with a result of a Monte Carlo simulation of QCD two jet events. ISAJET [9] was used for the generation. The E_t of the generated jets was scaled in such a way that their E_t distribution agrees with the data.

By selecting events with a small laboratory velocity of the two jet system we obtain the widest acceptance in θ^*. We choose the cut $|\tanh(y_{jj})| < 0.28$ where the distribution is still fairly uniform (Fig.3). In Fig. 4 we show the $\cos\theta^*$ distribution for events satisfying this cut , for two different dijet mass thresholds. We compare this with the the angular distribution of the jets in the generated QCD events. The curves in Fig. 4 show the $\cos\theta^*$ distribution of the Monte Carlo jets after UA1 detector simulation. The distributions agree reasonably well with the data showing that we understand the kinematical acceptance of the apparatus and that the experimental angular distributions are well described by QCD.

5. Conclusion

We have analyzed the E_t and $\cos\theta^*$ distributions of the jets in jet events selected from the data taken with a minimum bias trigger in the UA1 experiment in 1987. The measured inclusive E_t distribution of the jets is well described by QCD from 5 GeV to 60 GeV. Similarly the $\cos\theta^*$ distributions of jets in the events with two or more jets agree in shape with the predictions of QCD elastic scattering of partons with gluon exchange. The results confirm and complete the observations obtained by UA1 in an earlier analysis [2] and extends the range of measurements from $E_t = 40$ GeV to $E_t = 60$ GeV.

Acknowledgements

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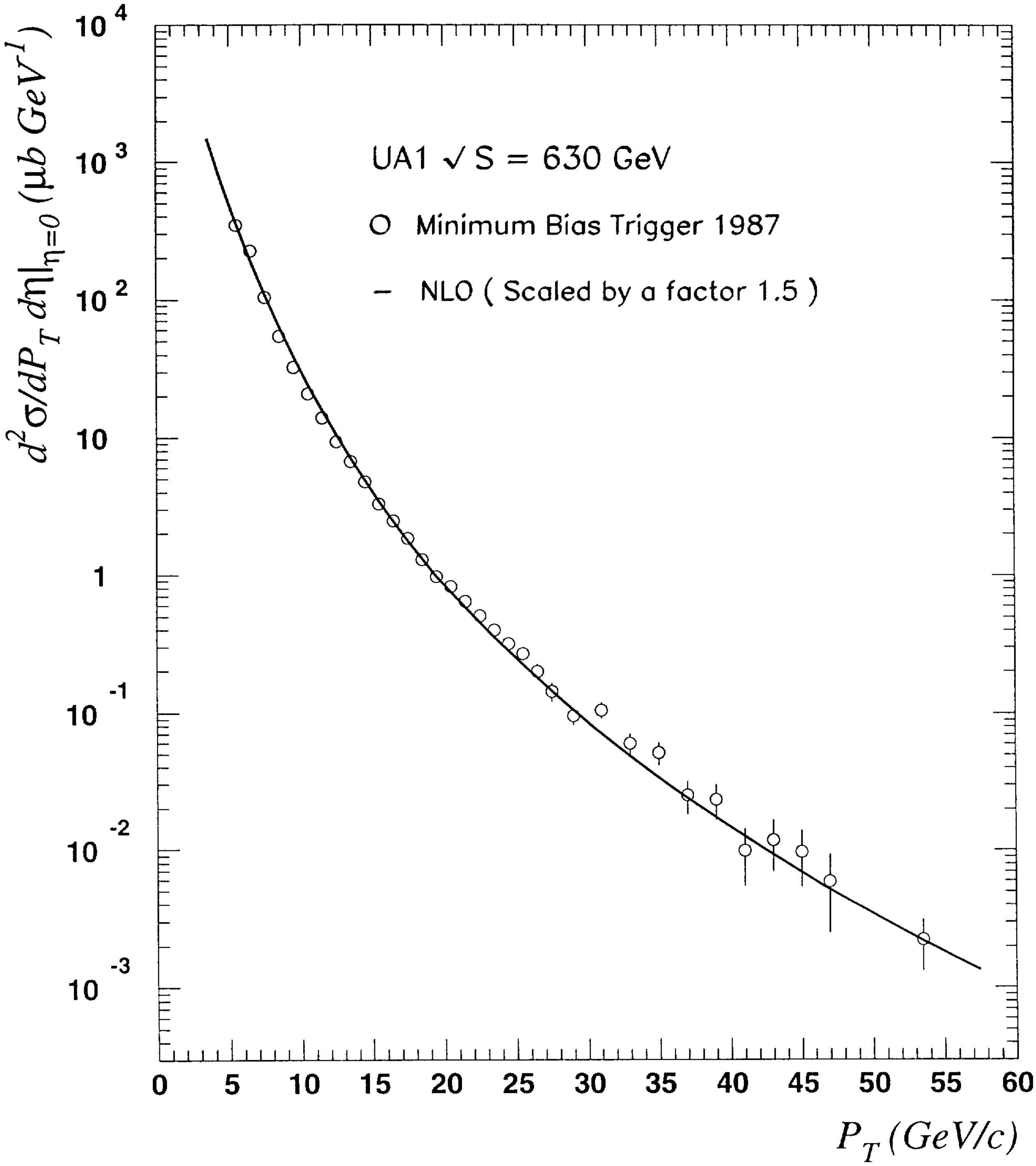
Figure captions

Fig. 1. The inclusive production cross section of jets with $|\eta| < 1.2$ as a function of E_t from the minimum bias data of 1987. The jet cone is $\Delta R \leq 1.0$. The curve is a NLO calculation of S.G.Salesch [7], scaled up by a factor of 1.5.

Fig. 2. The inclusive production cross section of jets with $|\eta| < 1.2$ as a function of E_t for three sets of UA1 data [2].

Fig. 3. The distribution of the absolute value of the hyperbolic tangent of the rapidity of the two-jet system (y_{jj}) for events with the transverse momentum of the two-jet system < 3 GeV/c and with $m_{jj} > 10$ GeV/c^2 (m_{jj} is the mass of the two jet system). The curve is the result of the ISAJET [9] Monte Carlo simulation.

Fig. 4. The distribution of the scattering angle of jets in the two-jet rest frame with $|\tanh(y_{jj})| < 0.28$ and a) with $m_{jj} > 10$ GeV/c^2 , b) with $m_{jj} > 15$ GeV/c^2.
The curves are from the ISAJET [9] simulation.



UA1 √S = 630 GeV
O Minimum Bias Trigger 1987
– NLO (Scaled by a factor 1.5)
$d^2\sigma/dP_T d\eta|_{\eta=0}$ ($\mu b\ GeV^{-1}$)
10^4
10^3
10^2
10
1
10^{-1}
10^{-2}
10^{-3}
0
5
10
15
20
25
30
35
40
45
50
55
60
P_T (GeV/c)

Fig. 1.

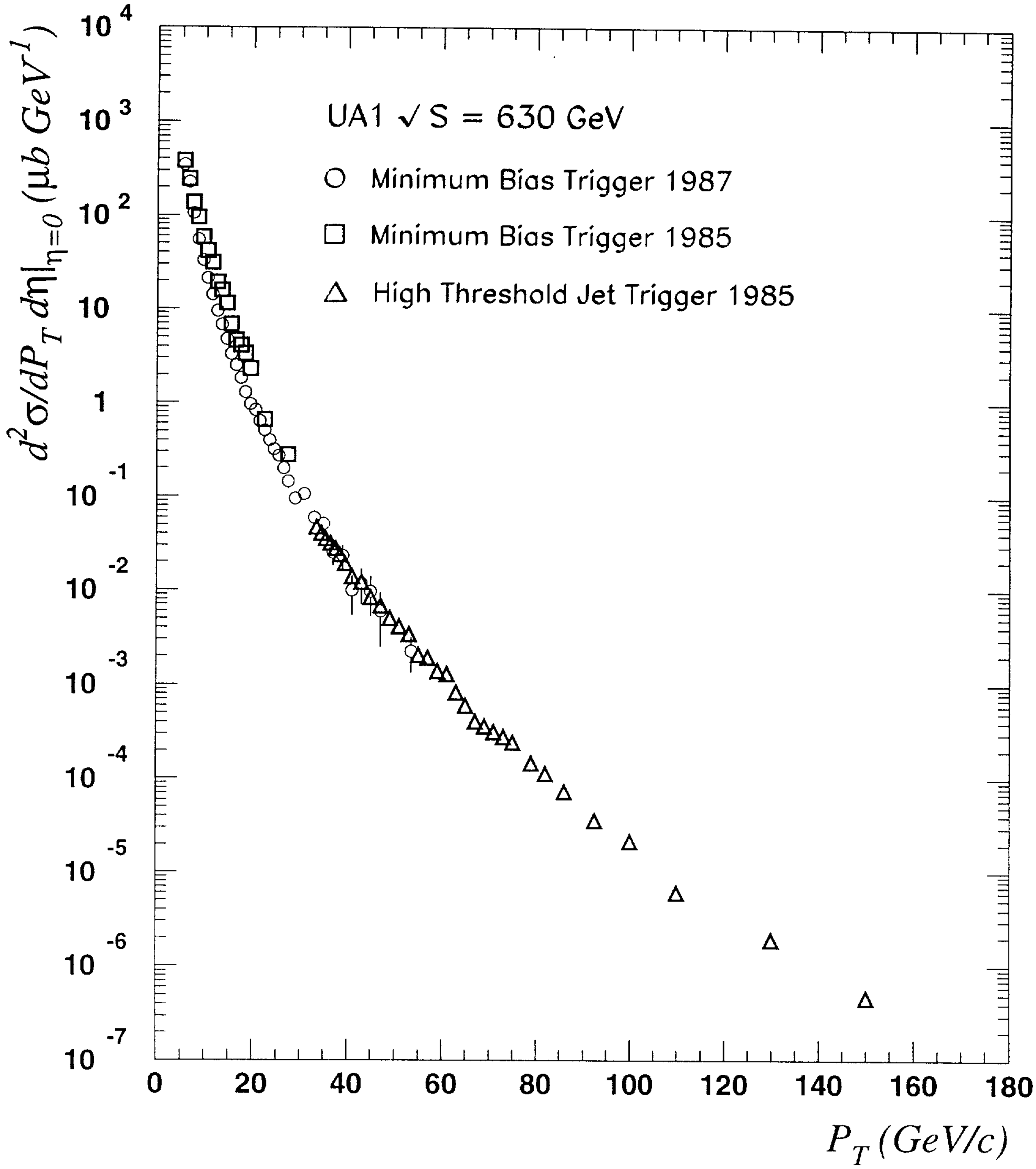
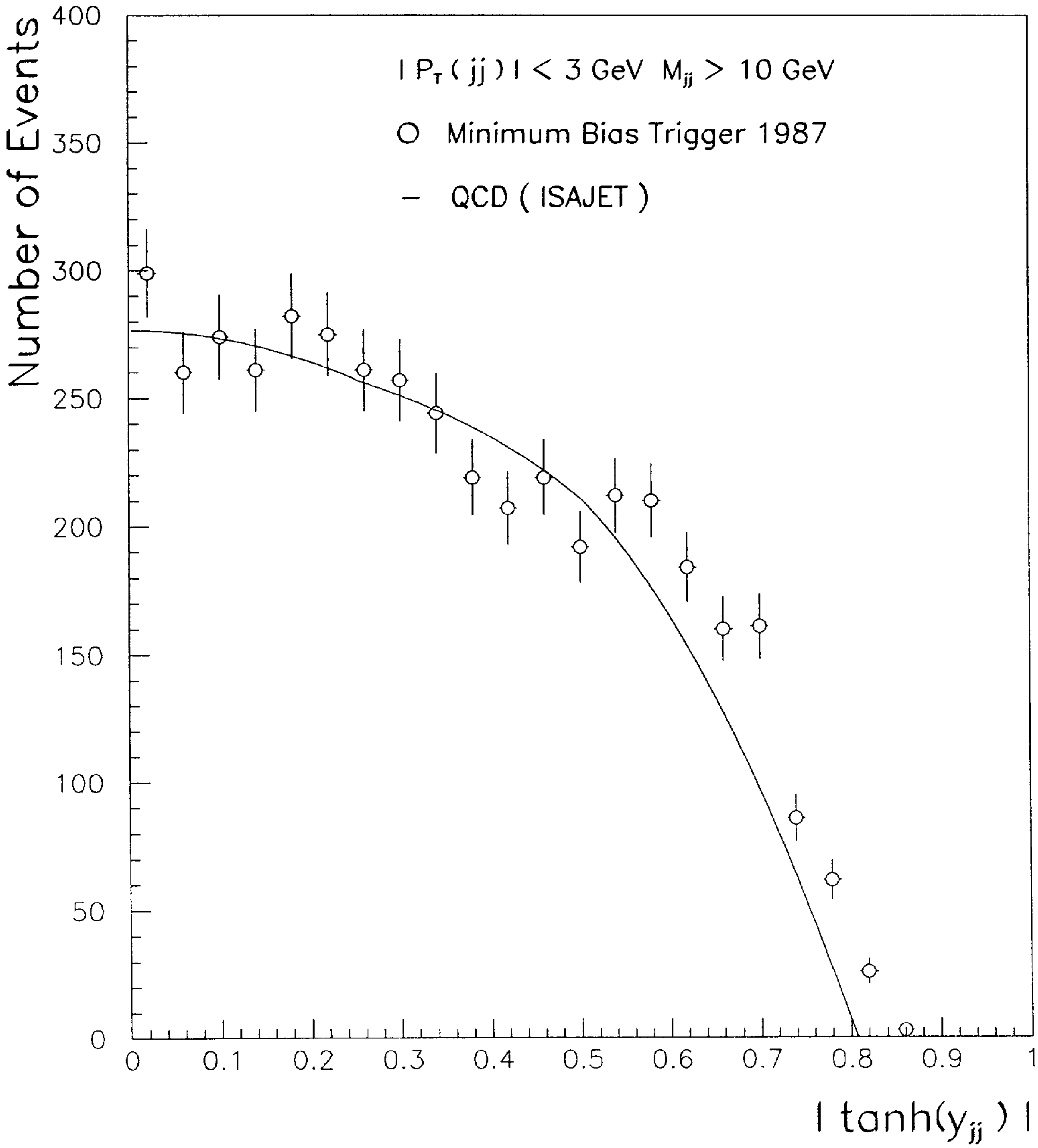
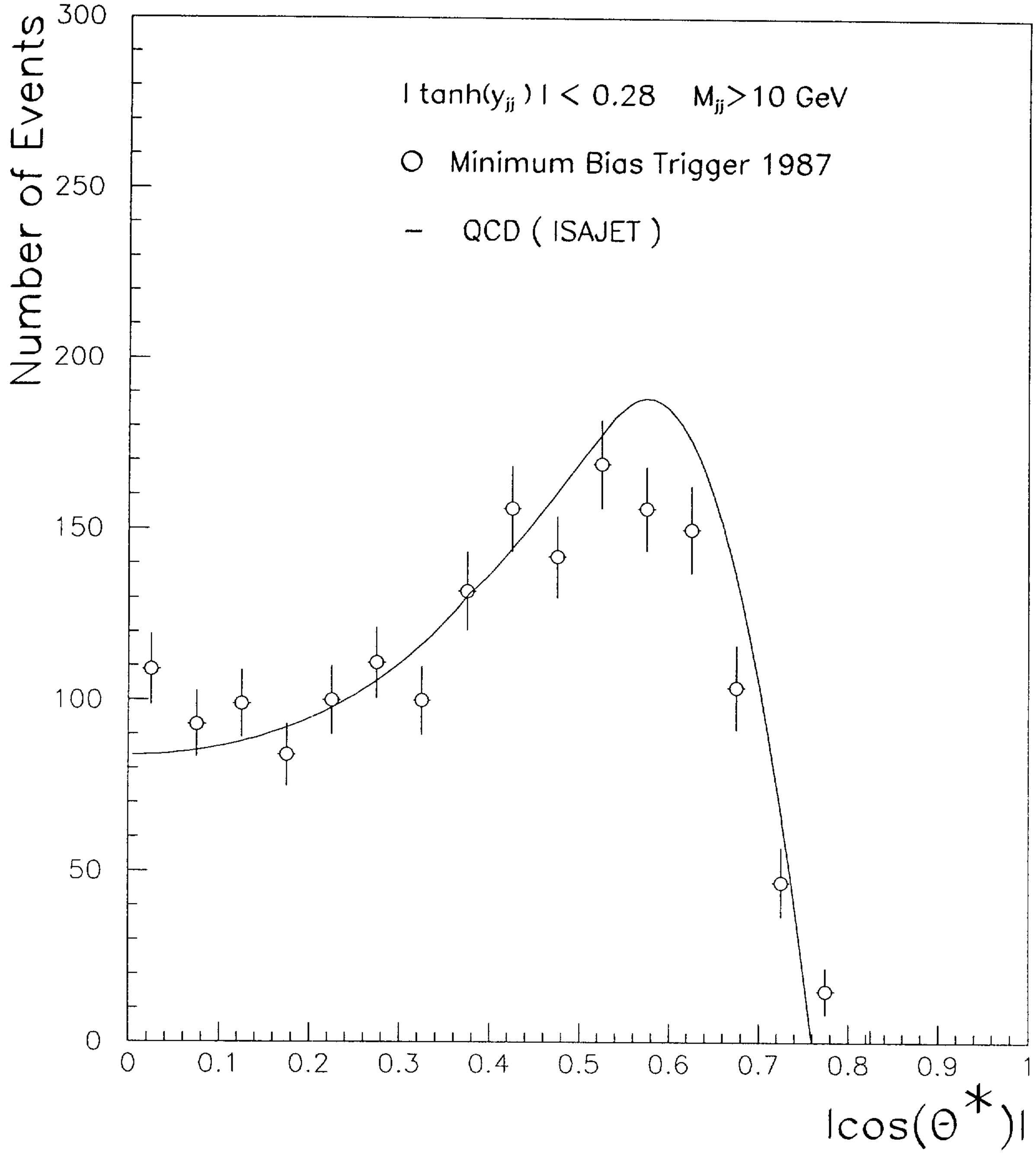

UA1 √S = 630 GeV
Minimum Bias Trigger 1987
Minimum Bias Trigger 1985
High Threshold Jet Trigger 1985
$d^2\sigma/dP_T\,d\eta|_{\eta=0}$ ($\mu b\ GeV^{-1}$)
P_T (GeV/c)
10^4
10^3
10^2
10
1
10^-1
10^-2
10^-3
10^-4
10^-5
10^-6
10^-7
0
20
40
60
80
100
120
140
160
180

Fig. 2.



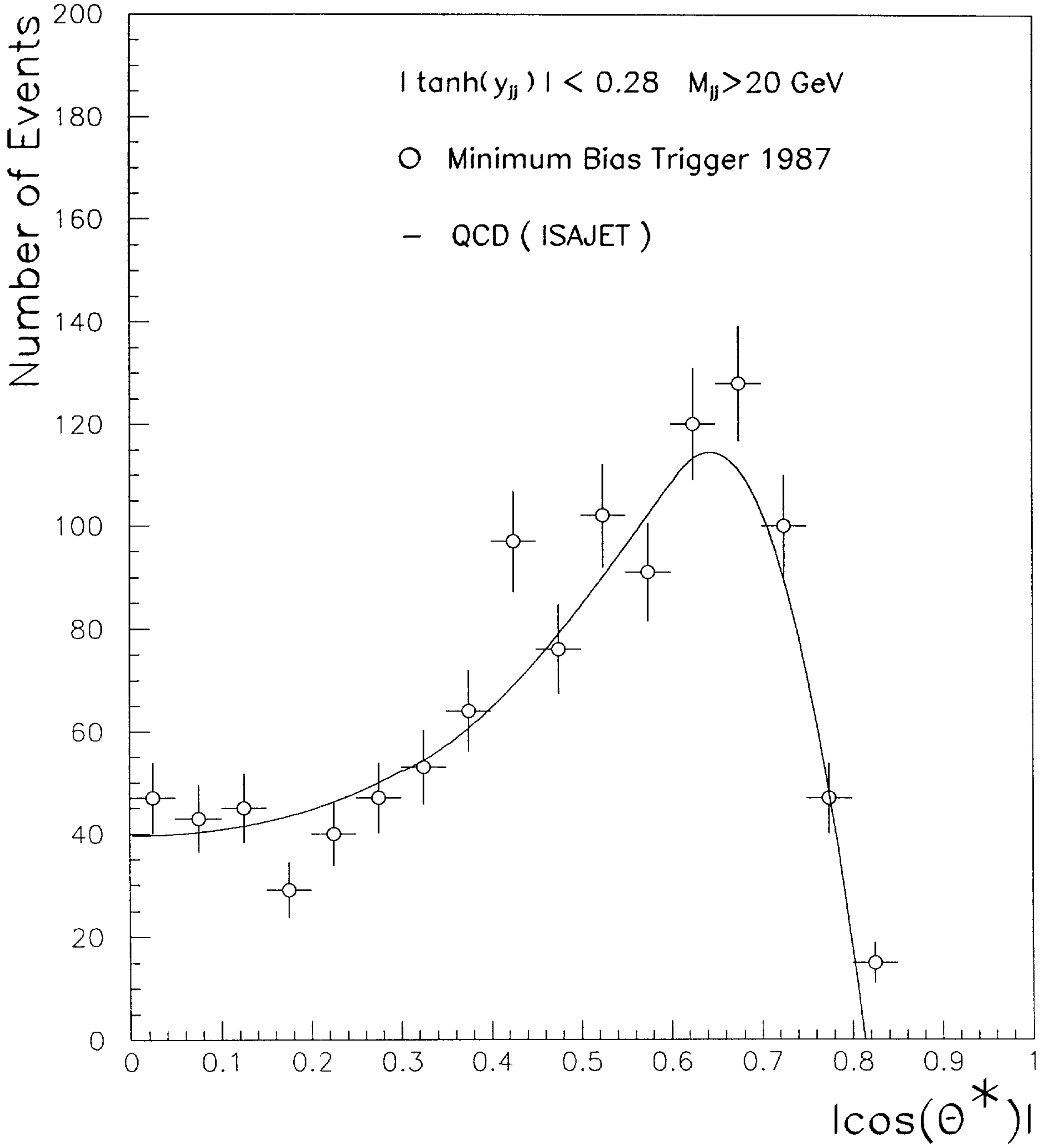
Number of Events
400
350
300
250
200
150
100
50
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
| P_T (jj) | < 3 GeV M_{jj} > 10 GeV
O Minimum Bias Trigger 1987
— QCD (ISAJET)
| tanh(y_{jj}) |

Fig. 3.



Number of Events
300
250
200
150
100
50
0
| tanh(y_{jj}) | < 0.28 M_{jj}>10 GeV
O Minimum Bias Trigger 1987
— QCD (ISAJET)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
|cos(Θ*)|

Fig. 4a.



| tanh(y_{jj}) | < 0.28 M_{jj}>20 GeV
O Minimum Bias Trigger 1987
– QCD (ISAJET)
Number of Events
|cos(Θ*)|
0
20
40
60
80
100
120
140
160
180
200
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

Fig. 4b.