EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN-EP/85-116
22 July 1985

INCLUSIVE JET PRODUCTION AT $\sqrt{s}$ = 546 GeV

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(Submitted to Phys. Letters B)

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Abstract

The cross sections for the inclusive production of jets in p$\bar{p}$ collisions at a centre-of-mass energy of 546 GeV are presented for two different regions of rapidity, and compared with previously published data. Rapidity distributions for different threshold values of jet transverse energy are also presented. All measurements agree within errors with current QCD models.

1. Data sample

The data samples used are based on 'inclusive jet' triggers defined by summing transverse energies over calorimeter cells in a sliding geometrical window, whose details have been described before [1]. The analysis is based on three data samples taken at $\sqrt{s}$ = 546 GeV in 1983, with different thresholds on the nominal E_T deposition in these windows,

- $E_T > 15$ GeV (for an integrated luminosity of 6.1 nb^{-1}),
- $E_T > 20$ GeV (40.1 nb^{-1}),
- $E_T > 25$ GeV (64.6 nb^{-1}).

The efficiency of these triggers in terms of transverse jet energies has been determined using jets free of trigger bias in events triggered by other jets, and has been corrected for in the final results. All events had to satisfy the usual quality requirements for acceptable collisions.

The luminosity measurements rely on UA1's luminosity monitor, a hodoscope in the angular range 12 to 56 mrad, which is also part of the collision pretrigger hodoscope. It has been determined from wire scans as being sensitive to a cross section of 35 mb at a beam energy of 273 GeV. The absolute normalization error is estimated to be ± 15%.

During reconstruction of events, corrections are applied for each calorimeter cell which take account of scintillator attenuation and include a response correction factor of 1.13 for hadrons in electromagnetic calorimeters. The corrected energies in the window are typically 10 to 15% higher than the nominal ones, and the effective trigger threshold must be understood accordingly.

2. Jet-finding Algorithm

The algorithm used for defining jets in UA1 calorimeters differs from the one described before [1] only in the treatment of low-energy cells. Jets are defined as clusters in pseudorapidity/azimuth (η/ϕ) space by the following procedure.

An energy vector is associated to each calorimeter cell. For hadronic cells, the vector points from the interaction vertex to the centre of the cell. For electromagnetic cells, the vector points to the energy centroid determined by pulse height measurements (central calorimeter) or by position detectors (forward calorimeter). In the subsequent clustering, cells are treated differently depending on their E_T being above or below an initiator threshold of 1.5 GeV:

– Among the cells with $E_T \geq 1.5$ GeV, the highest E_T cell initiates the first jet. Subsequent cells are considered in order of decreasing E_T. Each cell in turn is added vectorially to the jet closest in (η,ϕ) space, i.e. with the smallest $\Delta R \equiv \sqrt{(\Delta\eta^2 + \Delta\phi^2)}$ (with ϕ in radians), if $\Delta R \leq 1.0$. If there is no jet within $\Delta R \leq 1.0$, the cell initiates a new jet.

– Cells with $E_T < 1.5$ GeV are subsequently added vectorially to the jet nearest in (η,ϕ) if they are closer to the jet than $\Delta R = 1$.

Charged track information was not used for finding jets or for defining their energy. The dependence of jets on the initiator threshold can be shown to be negligible for transverse jet energies of 20 GeV or more.

The use of a clustering algorithm for defining a jet direction and energy entails a number of corrections:

– Partons emitted within $\Delta R = 1$ of each other, from whatever source, will typically be merged into a single jet. This constitutes a part of our jet definition.

– The reconstructed jets will not normally contain any jet debris that has been emitted further from the jet axis than the cut parameter ΔR. From currently accepted fragmentation models [2,3] and published data [1,4] this cut is known to have a measurable effect, in particular on the total jet energy.

– Any spectator remains, i.e. parton debris not connected with the hard interaction, or any fragments from partons not sufficiently separate in ΔR, will be included in the jet by the algorithm if they happen to fall within the acceptance cone of the jet.

– The small non-instrumented zones in UA1's calorimeters cause some losses in jet energy as a function of the jet direction. Only an average value can be calculated for this correction using the detailed knowledge of the detector.

Average corrections for these effects have been determined by extensive Monte Carlo calculations. Perturbative QCD 2-jet events were generated in varying E_T bins by the event generator ISAJET [2]. The final state particles (fragmentation of scattered partons and spectator particles) were followed through the detector using in particular a suitable approximation for energy deposition in the calorimeters [5]. The jet algorithm was then applied, and reconstructed jets were compared with the generated partons in transverse energy (defined as vector sum of energy depositions in the calorimeters) and direction, if the ΔR between emitted parton and reconstructed jet was less than one. The efficiency of associating jets unambiguously is very nearly 100% for jets of $E_T > 15$ GeV. Average values and r.m.s. errors for corrections in transverse energy E_T, rapidity η, and azimuthal angle ϕ were evaluated as a function of E_T, η and ϕ.

This global correction procedure calls for two remarks:

– Emitted prompt partons may radiate other partons. If this radiation is hard and at large angle, it may result in separate jets by any definition (see for example ref.[6]), and thus contribute to the inclusive cross section. Our association and averaging procedures when determining corrections in E_T would ignore such radiated jets. It should be noted, however, that the integrated feedthrough of separately reconstructable radiated jets is, according to ISAJET (final state bremsstrahlung only), no larger than 0.3% at $E_T = 20$GeV, and decreases for higher transverse energies.

– Fragmentation effects, spectator background, algorithm biases, and detector losses are all summed in the correction we apply. We have attempted to isolate the effects in various studies, and estimate the correction uncertainty related to model assumptions to result in an overall systematic cross section error of a factor of 1.5 (+50%, −33%), dominating all other estimated errors.

3. Event Selection

Triggers were further selected as follows:

– In order to avoid zones of low acceptance, a cut in the corrected jet transverse energies of 24, 40, and 44 GeV was applied to the three trigger samples.

– A veto against beam halo (in overlap with collisions) was applied by eliminating any event having a jet with more than 90% of its energy in the hadronic part of the calorimeter stack. From test beam measurements we can estimate this to cause negligible losses.

– A double interaction veto eliminated events with a total observed energy in excess of 700GeV (less than 2%).

– A fiducial cut in azimuthal angle ϕ was used to exclude zones of maximum trigger inefficiency and of maximum uncertainty in reconstructed jet energy due to constructional properties of the UA1 calorimeters: jets with their axis (as defined by the vector sum of contained cells) closer than 30^0 to the vertical direction were not retained. For the same reason, an energy containment constraint was used: events with a missing transverse energy vector (see ref. [7] for definition) of more than 25 GeV were also rejected.

– A visual scan covering all events with transverse jet energy larger than 70 GeV (50 GeV for rapidity larger than 1.5), and a sample of events at lower E_T, gave us confidence that the above cuts retain no or only a negligible fraction of instrumental background events.

4. Results

In order to compare the measured cross sections with theoretical predictions, the effect of energy resolution has still to be corrected for in the data. A Gaussian error in the horizontal scale of a steeply falling distribution results in an average shift of cross sections towards higher values. For a correction procedure model assumptions are needed in order to get free of statistical fluctuations. The correction results in additional uncertainties for the low cross section tail. We have used the QCD calculations of ref. [8] as the basis for smearing corrections. For the two rapidity bins considered ($|\eta| < 0.7$ and $0.7 \leq |\eta| < 1.4$), we find correction factors (of the order of 0.5) independent of E_T to within 10%, using an average resolution function found from Monte Carlo calculations. The residual uncertainty of this correction is of the order of ± 10%.

In fig. 1 we compare the measured inclusive cross sections, after smearing corrections, with different QCD predictions for parton transverse momenta. All QCD predictions fit within the errors quoted for our data and for the reliability of the predictions, the best agreement in slope being observed when comparing to ref. [3]. The measured inclusive cross section is also presented numerically in table 1.

In fig. 2 the data for central rapidity are compared with previously published data from UA2 [9,10], at the same collision energy. Again the agreement is well within the limits of quoted errors.

Fig. 3 gives the differential cross section integrated over jet transverse energy, with an E_T threshold varying from 20 to 50 GeV. The energy smearing was taken into account by raising the transverse energy limit by an amount following from the slope and the smearing correction applied to the cross section curve. This shift in E_T(cut) varies from 3.0 GeV (at $E_T = 20$ GeV) to 4.4 GeV (at $E_T = 50$ GeV). The predictions from ref. [3] again describe the data in a satisfactory way.

5. Conclusions

The data presented in this paper confirm previously published data and corroborate agreement with QCD calculations using different published algorithms. For the first time, rapidity distributions for jets are shown with different thresholds for E_T; they are in good agreement with those obtained by the QCD model that fits best our inclusive cross sections.

Acknowledgements

We gratefully acknowledge the help of the management and the technical staff of CERN, and of all outside institutes collaborating in UA1. The following funding agencies in our home countries have contributed to this programme:

Fonds zur Förderung der Wissenschaftlichen Forschung, Austria.
Valtion Luonnontieteellinen Toimikunta, Finland.
Institut National de Physique Nucleaire et de Physique de Particules,
and Institut de Recherche Fondamentale (CEA), France.
Bundesministerium für Forschung und Technologie, Germany.
Istituto Nazionale di Fisica Nucleare, Italy.
Science and Engineering Research Council, United Kingdom.
Department of Energy, United States of America.

Thanks are also due to the following people who have worked with the collaboration in the preparation of and data collection for the runs described here:
F.Bernasconi, F.Cataneo, L.Dumps, D.Gregel, J.-J.Malosse, H.Muirhead, G.Stefanini, R.Wilson, Y.G.Xie and E.Zurfluh.

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Table 1

Inclusive cross sections for two bins of rapidity

(E_T, ΔE_T are bin center and width, $\Delta\sigma$ are statistical errors)

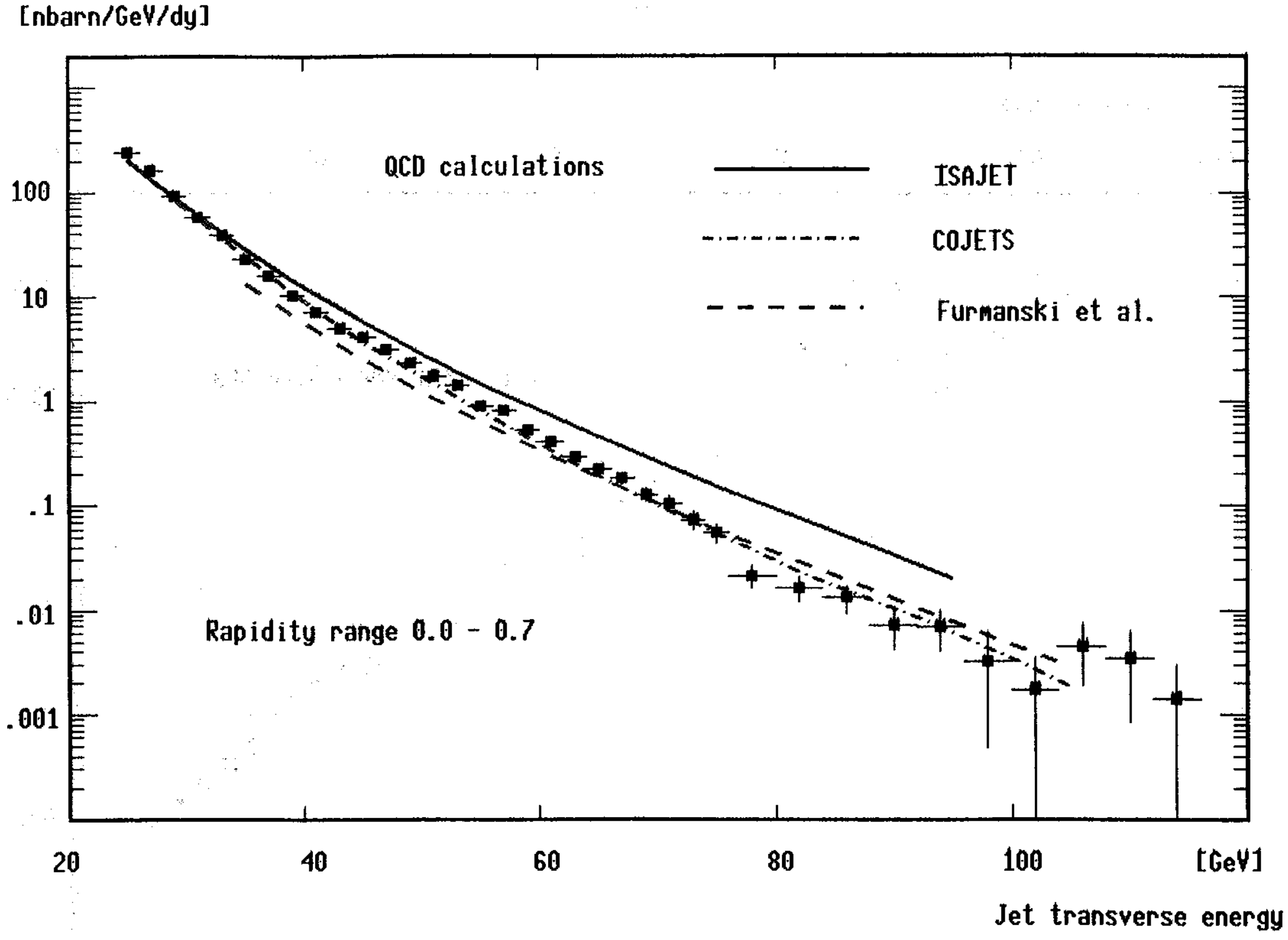
E_T [GeV]	ΔE_T	$d\sigma/dE_Td\eta$ (for $\lvert\eta\rvert < 1.4$) [nb/GeV]	$\Delta\sigma$	$d\sigma/dE_Td\eta$ (for $1.7 < \lvert\eta\rvert < 2.4$) [nb/GeV]	$\Delta\sigma$
25	2	243.90	3.12	–	–
27	2	164.06	2.56	–	–
29	2	92.84	1.92	68.41	1.55
31	2	57.73	1.52	42.85	1.22
33	2	38.44	1.24	25.07	0.94
35	2	23.14	0.96	17.34	0.78
37	2	15.73	0.79	10.45	0.60
39	2	10.26	0.64	6.80	0.49
41	2	7.096	0.197	4.790	0.152
43	2	4.972	0.165	3.455	0.129
45	2	4.082	0.097	2.579	0.072
47	2	3.175	0.085	1.956	0.063
49	2	2.352	0.073	1.474	0.054
51	2	1.722	0.063	0.965	0.044
53	2	1.415	0.057	0.720	0.038
55	2	0.8990	0.0454	0.5386	0.0329
57	2	0.8140	0.0432	0.3625	0.0270
59	2	0.5274	0.0348	0.2237	0.0212
61	2	0.4073	0.0306	0.2465	0.0223
63	2	0.2874	0.0257	0.2016	0.0201
65	2	0.2204	0.0225	0.1110	0.0154
67	2	0.1810	0.0204	0.0904	0.0135
69	2	0.1285	0.0172	0.0567	0.0107
71	2	0.1053	0.0155	0.0557	0.0106
73	2	0.0721	0.0129	0.0371	0.0089
75	2	0.0547	0.0112	0.0352	0.0084
78	4	0.0211	0.0049	0.0122	0.0035
82	4	0.0163	0.0043	0.0030	0.0023
86	4	0.0131	0.0039	0.0040	0.0025
92	8	0.0070	0.0020	0.0004	0.0004
100	8	0.0024	0.0016	0.0006	0.0006
112	16	0.0023	0.0020	0.0	–

Figure Captions

Fig. 1 :
Inclusive differential jet cross sections $d^2\sigma/(d\eta dE_T)$, after correcting for resolution smearing, and comparison with QCD calculations. Errors given are statistical only. The QCD curves have been computed using ISAJET [2], COJETS [3] and an algorithm corresponding to ref. [8] (courtesy H. Kowalski). Their normalization is independent of our data. Data and calculations for a) the rapidity bin 0 to 0.7, b) the rapidity bin 0.7 to 1.4.

Fig. 2 :
Comparison of this experiment (data for $|\eta| < 0.7$) with UA2 published data [9] for the same c.m. energy of 546 GeV. For clarity, data have been grouped in E_T and divided by a crude parametrization curve of the form $d^2\sigma/dE_T d\eta = 66.84 \exp(-0.2526E_T + 0.000862E_T{}^2)$, with σ in μb and E_T in GeV. The UA1 data are presented with statistical errors only; the systematic errors have been discussed above and can be summarily expressed as a factor 1.5 uncertainty. UA2 data have been scaled according to ref. [10] and contain E_T-dependent systematic errors.

Fig. 3 :
$d\sigma/d\eta$ integrating over jet transverse energy, with E_T threshold values varying from 20 to 50 GeV. The data points have been obtained from bias-free jets (i.e. not necessary for triggering), normalized in the central region ($|\eta| < 1$) to trigger jets and corrected for trigger efficiency. The regions in $|\eta|$ from 1.2 to 1.8 and > 2.8 have been left out in order to avoid jets that deposit large fractions of energy in apparatus zones having very different characteristics. The energy smearing correction was applied as explained in the text. The curves have been obtained from COJETS, and their normalisation is independent of the data.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100
10
1
.1
.01
.001
20
40
60
80
100
[GeV]
Jet transverse energy
QCD calculations
ISAJET
COJETS
Furmanski et al.
Rapidity range 0.0 - 0.7

Fig. 1a

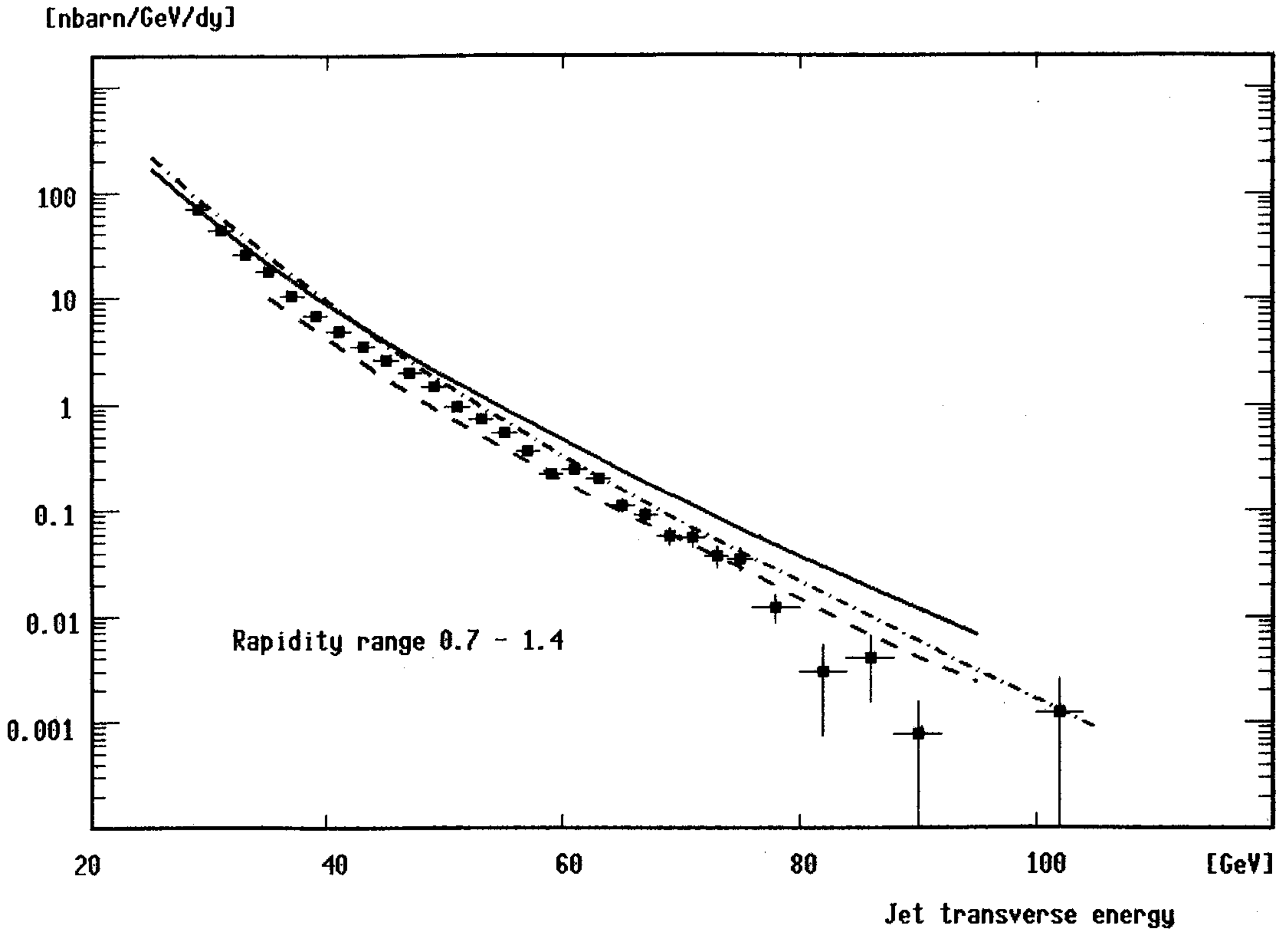

[nbarn/GeV/dy]
100
10
1
0.1
0.01
0.001
Rapidity range 0.7 - 1.4
20
40
60
80
100
[GeV]
Jet transverse energy

Fig. 1b

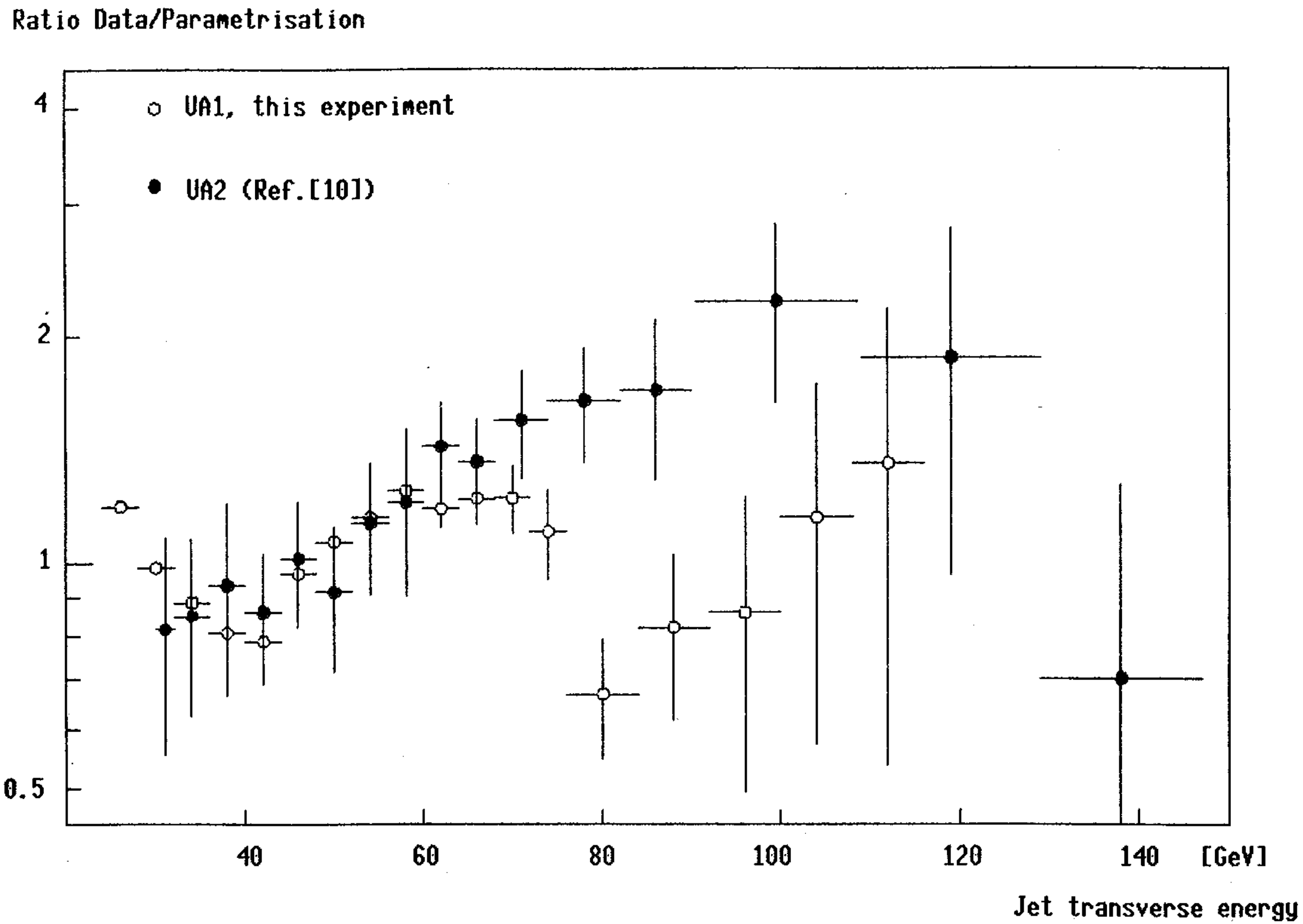
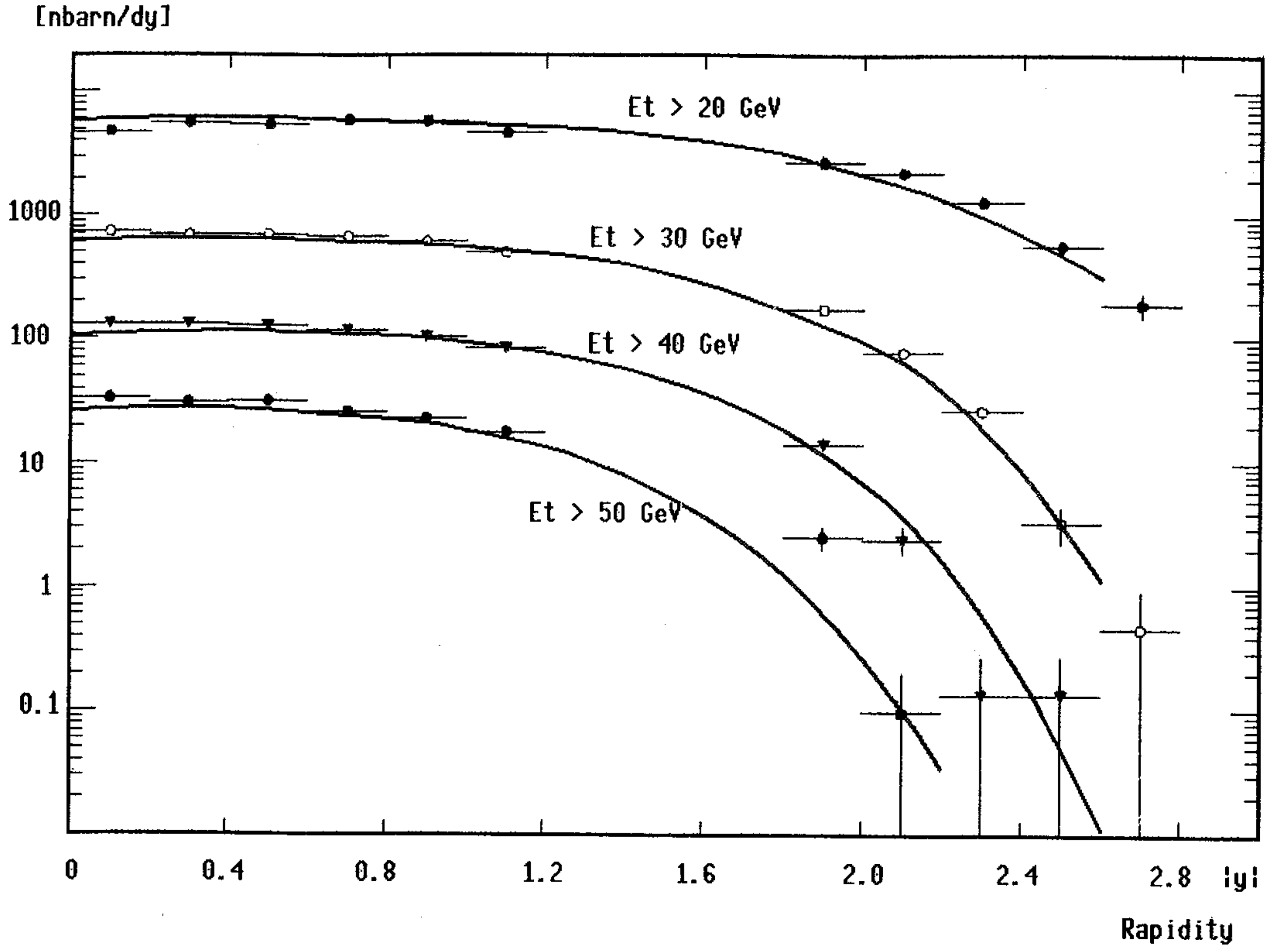

Ratio Data/Parametrisation
4
2
1
0.5
○ UA1, this experiment
● UA2 (Ref.[10])
40
60
80
100
120
140
[GeV]
Jet transverse energy

Fig.2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1000
100
10
1
0.1
Et > 20 GeV
Et > 30 GeV
Et > 40 GeV
Et > 50 GeV
0
0.4
0.8
1.2
1.6
2.0
2.4
2.8
|y|
Rapidity

Fig.3