High P_T Jets in UA2

The UA2 Collaboration
Bern - Cambridge - CERN - Dortmund - Heidelberg - Melbourne
Milano - Orsay (LAL) - Pavia - Perugia - Pisa - Saclay (CEN)

Presented by
Andrea Dell'Acqua
CERN - PPE Division
Geneva - Switzerland

Abstract

In this paper we present results on jet physics obtained with the UA2 detector at the CERN $\bar{p}p$ Collider, using data taken in the 1988 and 1989 runs at 630 GeV and corresponding to an integrated luminosity of 7.4 pb^{-1}. Events containing two high-p_T jets have been studied and the angular distribution of the two-jet systems has been used in order to look for scale-violating effects and for possible deviations from QCD predictions, suggesting the presence of a contact interaction between the quark constituents. A study of three-jet events has also been performed. Comparison with leading order QCD has shown that three-jet production can be understood in terms of initial- and final-state radiation of gluons, whilst a phase-space-like production mechanism can be definitely ruled out. In both cases, QCD has been found to describe well the data.

1 Introduction

Jet physics has become an important field of investigation at hadron colliders since the earlier observations of two–jet production dominance in high transverse energy events at the CERN $\bar{p}p$ Collider. The dynamics of the jet production processes, the inclusive cross–section and the parton fragmentation properties have been extensively studied and found to be in good agreement with perturbative QCD predictions.

In this paper, we present results on two-jet physics (Section 3) and on the study of events containing three high-p_T jets (Section 4); the data samples used in these analyses were collected at the CERN $\bar{p}p$ collider in 1988 and 1989 and correspond to an integrated luminosity of about 7.4 pb^-1.

2 Jet Identification in UA2

The UA2 detector has been substantially upgraded between 1985 and 1987 to increase the calorimeter coverage and the electron identification capabilities; a complete description of the experiment can be found in Ref. [1]. Jets are defined through their energy deposition pattern in the calorimeter, by joining into clusters all the cells with a transverse energy content above 400 MeV and sharing a common edge. Due to the high trigger rate, no track information is recorded in the jet events and the longitudinal position of the event vertex is calculated by time–of–flight measurement using counter arrays on both sides of the interaction region.

3 Study of Two-Jet Angular Distribution

The data for these studies were selected requiring two clusters with a transverse energy in excess of 40 GeV in the pseudorapidity range $| \eta_{1,2} | \leq 1.8$ and with an angular separation in the transverse plane of at least 160°: to suppress three-jet events, the transverse energy of a possible third cluster must not exceed 10 GeV. Some additional cuts on the cluster radius and on the energy fraction deposited in the hadronic calorimeter were used to eliminate luminosity-dependent background and beam-halo effects.

After a boost to the CMS of the two-jet system, the angle Θ^* between the two-jet axis and the beam direction (according to Ref. [2]) was calculated (Fig. 1); in order to study the two-jet angular distribution and to look for possible deviations from the QCD-expected behaviour, the variable $\chi = (1+\cos\Theta^*)/(1-\cos\Theta^*)$, which eliminates the steep "Rutherford-like" dependence on $1/\sin^4(\Theta^*/2)$, was used.

The selected data are compared with a leading-order calculation [7] where the momentum transfer scale is chosen as $Q^2 = (E_{T,1}^2 + E_{T,2}^2)$ and the structure functions of Ref. [3] are used. A full simulation of the UA2 calorimeters is included and the generated events are then selected using the same criteria as the data.

The study of the χ distribution for two-jet events gives the possibility to show the presence of scaling violations and to put constraints on the choice of the Q^2 scale. For each choice of Q^2, the χ distributions for the data and the Monte Carlo have been compared using a χ^2 minimization. Definitions of Q^2 in which the scaling violations do not depend on Θ^* can be ruled out whilst Θ^*-dependent scale definitions give in general good agreement; the minimal χ^2 value is obtained for $Q^2_{opt} = (E^2_{T,1} + E^2_{T,2})/64$. Scaling violations can be switched on ($Q^2 = Q^2_{opt}$) or off (Q^2 =constant) independently in the structure functions and in the strong coupling constant α_S. Whenever Q^2 =constant, no acceptable fit is obtained; on the other hand, a good agreement between data and Monte Carlo predictions is obtained for $Q^2 = Q^2_{opt}$.

The presence of a hypothetical four–quark contact interaction with a coupling proportional to Λ_C^{-2} would lead to an enhancement of the production of jet pairs in the central region and to a distortion of the χ distribution. Fig. 2 shows the effect of the contact interaction (with the assumption Λ_C =400 GeV) on the χ distribution; the distribution for Λ_C =400 GeV is in clear disagreement with the data while the QCD Monte Carlo ($\Lambda_C = \infty$) reproduces the observed distribution. Various sources of systematic uncertanties have to be taken into account, like the variation of the Q^2 scale, the choice of different structure functions and the uncertainty on the energy scale of the calorimeter. Assuming the most pessimistic combination of all of these parameters, a limit of $\Lambda_C > 415$ GeV at 95% C.L. is obtained.

4 Study of Three-Jet Events

Three-jet events in UA2 were selected requiring three energy clusters in the calorimeter, the leading one with a tranverse energy of at least 60 GeV in the region $|\eta_1| \leq 2$, the second and the third with a transverse energy of at least 10 GeV and less than 10 GeV for any additional cluster. Technical cuts on the cluster radii and on the energy of the underlying event were applied to get rid of luminosity-dependent background.

The QCD Monte Carlo is based on the model of Ref. [4] in which $\Lambda_{QCD} = 200$ MeV has been set and the Duke-Owens structure function set [5] has been used. The fragmentation of the outgoing partons is perfomed using the Field-Feynman algorithm [6], modified to include additional radiation of soft gluons in order to describe correctly the observed cluster radius. A full simulation of the UA2 calorimeters is performed to simulate the detector response and the underlying event is described by superposition of real minimum bias events to the generated ones. To emphasize the features of the underlying dynamics of three-jet systems, a set of pure phase-space–like MC events has been produced following the same procedure.

By transforming the three-jet system to their CMS, the jet 3-momenta $\mathbf{p}_1^*$,$\mathbf{p}_2^*$ and $\mathbf{p}_3^*$ define a plane (event plane). In the CMS, the kinematics of the leading jet can be described by the polar angle Θ^*, defined by the beam direction and $\mathbf{p}_1^*$ as from Ref. [2] (Fig. 3). A variable which describes the internal configuration of the three-jet system is Ψ^*, defined as the angle between the $\mathbf{p}_1^*$–beam plane and the event plane. Initial state radiation, which tends to produce a third jet close to the beam axis, is characterized by peaks at $\Psi^* = 0$ and $\Psi^* = \pi$ (Fig. 4). A useful variable to study the bremsstrahlung nature of the third jet is the Ellis-Karliner angle ζ, defined by the relation $\cos\zeta = (p_2^* - p_3^*)/p_1^*$. For final state radiation, the $\cos\zeta$ distribution is expected to peak at $\cos\zeta = 1$; the experimental data (Fig. 5) show a rather flat distribution because of initial state radiation which results in small values of $\cos\zeta$. The same feature is visible in the distribution of $\omega_{2,3}$, the angle between the second and the third jet in the event plane (Fig. 6); the peak at $\cos\omega_{2,3} = 1$, due to final state radiation, is broadened by the limited two–jet angular resolution of the calorimeter and the presence of initial state radiation creates an enhancement in the region $\cos\omega_{2,3} \approx 0$.

References

[1] UA2 Collaboration, C. N. Booth, Proc. 6th Topical Workshop on $\bar{p}p$ Collider Physics (Aachen, 1986), eds. K. Eggert et al. (World Scientific, Singapore, 1987) p. 381;

[2] J.C. Collins, D.E. Soper, Phys. Rev. **D16** (1977) 2919;

[3] E. Eichten *et al.*, Rev. Mod. Phys. **56** (1984) 579; Rev. Mod. Phys. **58** (1986) 1065(E);

[4] H. Kuijf *et al.*, Nucl. Phys. **B 333** (1990) 120; Phys. Lett. **B 232** (1990) 266;

[5] D. W. Duke and J. F. Owens, Phys. Rev. **D 30** (1984) 49;

[6] R. D. Field and R. P. Feynman, Nucl. Phys. **B 136** (1978) 1;

[7] H.U Bengtsson, T. Sjostrand, PYTHIA, Comput. Phys. Comm. **46** (1987) 43;

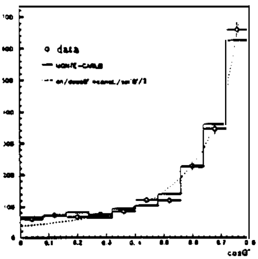

Fig. 1 - Angular distribution for 2-jet events.

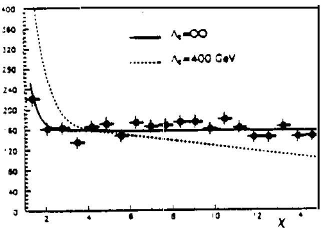

Fig. 2 - χ-distributions for different Λ_C values.

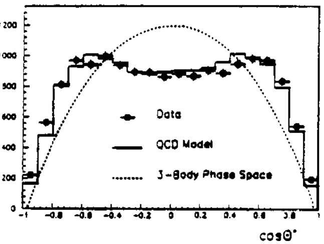

Fig. 3 - $\cos\Theta^*$ distribution for three-jet events.

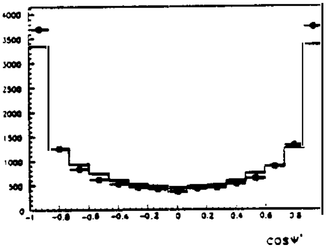

Fig. 4 - $\cos\Psi^*$ distribution for three-jet events.

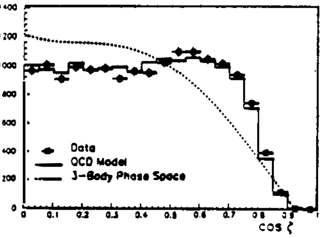

Fig. 5 - $\cos\zeta$ distribution for three-jet events.

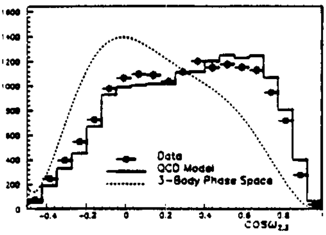

Fig. 6 - $\cos\omega_{2,3}$ distribution for three-jet events.