A STUDY OF GLUON SCATTERING AND GLUON FRAGMENTATION
IN HIGH p_T INTERACTIONS AT THE ISR

Ames-Bologna-CERN-Dortmund-Heidelberg-Warsaw Collaboration

A. Breakstone^{1(*)}, R. Campanini², H.B. Crawley¹, M. Cuffiani²,
G.M. Dallavalle³, M.M. Deninno², K. Doroba⁶, D. Drijard³, F. Fabbri²,
A. Firestone¹, H.G. Fischer³, H. Frehse^{3(**)}, W. Geist^{3(***)}, H. Flöge⁵,
L. Gesswein⁵, G. Giacomelli², R. Gokieli⁶, M. Gorbics¹, M. Gorski³,
P. Hanke⁵, M. Heiden^{3(***)}, W. Herr⁵⁽⁺⁾, D. Isenhower¹, E.E. Kluge⁵,
J.W. Lamsa¹, T. Lohse³, R. Mankel⁴, W.T. Meyer¹, T. Nakada⁵⁽⁺⁺⁾,
M. Panter³⁽⁺⁺⁺⁾, A. Putzer⁵⁽⁺⁾, K. Rauschnabel⁴, B. Rensch⁵, F. Rimondi²,
M. Schmelling⁴, G.P. Siroli^{2(o)}, R. Sosnowski⁶, M. Szczekowski⁶,
O. Ullaland³, D. Wegener⁴ and R. Yeung^{3(oo)}

- 1 Ames Laboratory and Physics Department, Iowa State University, Ames, USA
- 2 Dipartimento di Fisica dell'Università and INFN, Bologna, Italy
- 3 CERN, European Organization for Nuclear Research, Geneva, Switzerland
- 4 Institut für Physik der Universität Dortmund, Germany
- 5 Institut für Hochenergiephysik der Universität Heidelberg, Germany
- 6 University and Institute for Nuclear Studies, Warsaw, Poland

Submitted to Zeitschrift für Physik C

-
- (*) Present address: University of Hawaii, USA
(**) Present address: CDC, Zürich, Switzerland
(***) Present address: LBL, Berkeley, California, USA
(+) Present address: CERN, Geneva, Switzerland
(++) Present address: SIN, Villigen, Switzerland
(+++ Present address: University of Heidelberg, Germany
(o) Present address: University of Maryland, USA
(oo) Present address: University of California, Los Angeles, USA

ABSTRACT

Gluon scattering processes are studied in hadronic high p_T events using data obtained with the Split Field Magnet detector (SFM) at the CERN ISR. The experimental set-up allowed the scanning of a wide range of parton energies and scattering angles. It is shown that for positive pions as trigger particles, the parton composition of the recoil jet is correlated with the polar angle and transverse momentum of the triggering pion. Over the kinematical region studied, the recoil jet originates predominantly from scattered gluons, with an increasing prevalence of the gluon component towards forward triggering angles. The variation of the momentum structure of the recoil jet with the trigger angle indicates that the fragmentation function of gluons is softer than that of quarks.

1. INTRODUCTION

The production of mesons and baryons with large transverse momentum, p_T , in pp interactions is well understood in terms of hard parton scattering [1-4]. The four-jet structure, a characteristic feature of these deep inelastic processes, is experimentally established [3]. It is further known that the high p_T hadron, the "trigger particle", is the leading fragment in one of the transverse jets, often called the "towards jet". It generally contains the quantum numbers of the fragmenting parton. Identified particles can thus be used to tag different kinds of partons (quarks, gluons and diquarks) [4].

The present analysis deals with the properties of the second transverse jet, called the "away jet", which recoils against the trigger particle. In contrast to the towards jet the away parton fragments without necessarily yielding a single particle with large transverse momentum. In the phase space region considered in this paper, the away jet is expected to arise mostly from scattered gluons because the gluonic component of the incoming protons and the strength of the three-gluon coupling are both large [5]. This opens the opportunity to study the fragmentation properties of gluons and to test the predictions of perturbative Quantum Chromo-Dynamics (QCD) for gluonic scattering processes.

2. EXPERIMENTAL SET-UP

The experiment was performed at the CERN ISR using the Split Field Magnet Detector. The detector consisted of a system of multiwire proportional chambers covering nearly the full solid angle and an array of scintillation counters for time-of-flight measurements. Trigger logic electronics selected events with a high p_T particle ($p_T \geq 1$ GeV/c) produced at three different regions of polar angle ($\theta \approx 10^\circ$, 20° and 45°). The trigger particles were identified using five threshold Cerenkov counters. Two counters at $\theta \approx 20^\circ$, one at $\theta \approx 10^\circ$, and one at $\theta \approx 45^\circ$ were filled with freon 114 at atmospheric pressure (pion threshold $p_{lab} \approx 2.7$ GeV/c). The fifth counter was filled with freon 13 at 7.5 atm (pion threshold $p_{lab} \approx 1.3$ GeV/c) and was mainly used for the separation of kaons from protons at $\theta \approx 45^\circ$. Further details of the set-up, of the trigger scheme and of the trigger acceptance have been described in ref. [6].

The analysis presented here is based on a sample of 182 000 events with an identified π^+ trigger of large transverse momentum ($p_T > 3$ GeV/c at $\theta \approx 45^\circ$ and $p_T > 2$ GeV/c at forward angles). The data were taken in pp collisions at the highest ISR energy of $\sqrt{s} = 62$ GeV.

Sect. 3 deals with general expectations, which are compared to data in sect. 4.

3. GENERAL CONSIDERATIONS

3.1 Phase space coverage

The regions of phase space covered by the samples of π^+ triggers are shown in fig. 1. The transverse momentum, p_T , measured with respect to the event axis (along the c.m.s. direction of flight of the colliding protons) is plotted versus the longitudinal momentum p_L . The data cover polar angles ranging from 50° to less than 10° . The transverse momentum varies from 2 GeV/c up to about 8 GeV/c. When translated into kinematical parameters of the underlying hard parton-parton scattering, the data cover a wide range of parton energies and scattering angles. This aspect will be discussed more quantitatively in sect. 3.3.

3.2 Definition of variables and experimental procedure

Parton-parton scattering is sketched schematically in fig. 2 in the proton-proton rest frame to which all kinematical variables used in the analysis refer. The fractional longitudinal momenta of the incoming partons are described by the variables x_1 and x_2 , where x_1 belongs to the parton moving towards the trigger hemisphere (positive rapidity). One of the outgoing partons produces the trigger hadron with large p_T at a polar angle θ . The second parton fragments without restriction into the away jet.

It is impossible experimentally to separate completely the away jet from the two spectator jets on an event by event basis. One can, however, restrict the analysis to a phase space region which is dominated by away jet fragments. Since the recoiling parton compensates most of the transverse momentum of the trigger jet, it is kinematically restricted to

an azimuthal angle $\theta \approx 180^\circ$ with respect to the trigger particle. Therefore, for this analysis all particles in a narrow wedge of $\approx \pm 25^\circ$ around $\phi = 180^\circ$ are assumed to belong to the away jet.

The polar angle of the away parton, on the other hand, is not fixed by kinematics, leading to a broad away jet rapidity distribution, ranging from $y \approx -2$ to $y \approx +2$.

The longitudinal momentum structure of the away jet is expressed in terms of the variable

$$x_E = - \frac{\vec{p}_T \cdot \vec{p}_T^{tr}}{p_T^{tr^2}} \approx \frac{p_T}{p_T^{tr}} \approx \frac{z}{z_{tr}}$$

with the following notation:

- $\vec{p}_T$: transverse momentum of a particle in the away jet region;
- $\vec{p}_T^{tr}$: transverse momentum of the trigger hadron;
- z : fractional momentum carried by a particle inside the away jet;
- z_{tr} : fractional momentum of the trigger hadron inside the towards jet.

The fractional trigger momentum is known to be of the order of 0.7 - 0.8 in the kinematical range studied in this analysis [7]. Apart from the rescaling by the factor $1/z_{tr}$, x_E is thus equivalent to the fractional momentum z . The x_E distribution can be regarded as an effective fragmentation function of the away jet.

For small values of x_E the contribution from fragments of the spectator jets in the away wedge is not negligible. An attempt was made to subtract this background experimentally on a statistical basis. Events from inelastic pp interactions at an appropriate c.m.s. energy are known to resemble the two spectator jets [8]. The background was therefore calculated using a sample of general inelastic events with a single (low p_T) particle having about the same energy as the towards jet in high p_T events. The density of secondary particles was taken as an estimate of the spectator contributions.

3.3 Parton-parton scattering process

A QCD-based model calculation was performed in order to study in detail the contributions of the parton-parton scattering subprocesses in different regions of phase space. The model ingredients are described in ref. [9]. The results presented here should be considered as guide-lines rather than quantitative predictions for the event structure. All trends can be understood in terms of simple kinematics together with two assumptions of dynamical origin; that:

- the gluon structure function is considerably softer than that of the up quark;
- QCD favours the three-gluon coupling vertex as compared to the quark-gluon vertex.

As a first result of the calculations, lines of constant mean centre-of-mass energy, $\langle\sqrt{\hat{s}}\rangle$, of the parton-parton system are shown in fig. 1. These curves are determined mostly by kinematics alone. Evidently, for smaller trigger angles, higher energies are needed to reach a given transverse momentum of the trigger particle. The absolute values for $\langle\sqrt{\hat{s}}\rangle$ associated with the lines in fig. 1 do depend, however, on details of the model assumptions and should be taken with some care.

In the experimental analysis of the away jet, the data samples are divided into three sets according to three different values for $\langle\sqrt{\hat{s}}\rangle$ (namely 12, 15 and 18 GeV according to fig. 1). Thus, it is possible to study the fragmentation process at a fixed parton-parton c.m.s. energy for all scattering angles, in complete analogy to e^+e^- experiments.

In fig. 3 the mean fractional momenta $\langle x_1 \rangle$ and $\langle x_2 \rangle$ of the incoming partons are displayed as functions of the trigger angle at fixed $\langle\sqrt{\hat{s}}\rangle \approx 16$ GeV. While at $\theta = 90^\circ$ $\langle x_1 \rangle$ and $\langle x_2 \rangle$ have to be identical for reasons of symmetry, $\langle x_1 \rangle$ rises strongly towards smaller trigger angles, reaching values larger than 0.6 at $\theta = 10^\circ$. Simultaneously, $\langle x_2 \rangle$ becomes smaller and approaches a value of 0.1 at forward angles. The reason for this behaviour is again purely kinematical. Large longitudinal Lorentz boosts are needed to transform a parton scattered at large parton-parton c.m.s. angles into a forward position in the pp c.m.s. frame.

This result suggests how the mixture of subprocesses can be effectively controlled by the trigger conditions exploiting the difference between the structure functions of gluons and valence quarks. At small trigger angles, $\langle x_1 \rangle$ is large and lies in the valence quark region. The second parton, on the other hand, has a small fractional momentum in a region dominated by gluons.

If one triggers on positive pions at small angles, one is therefore expecting a clean situation: Because it is known that a π^+ trigger tends to contain a scattered up quark [4], a high percentage of the interactions should be due to the process "ug $\rightarrow$ ug", i.e. a scattering of an up quark on a gluon where the up quark produces the trigger pion while the gluon hadronizes into the away jet.

This expectation is confirmed by the model predictions shown in fig. 4. The relative contributions of the most important subprocesses are shown as a function of θ on the parton level (a), and in terms of the hadron density (at $x_E > 0.5$) in the away jet region (b). The process "ug $\rightarrow$ ug" starts to dominate already for $\theta \leq 70^\circ$, reaching a 60% contribution at $\theta \approx 10^\circ$. In total, the away jet at forward trigger angles is expected to be of gluonic origin in 70-80% of the cases.

In fig. 5, the relative contributions of the dominant subprocesses are plotted versus $\langle \sqrt{s} \rangle$ at two trigger angles. Here the trends are less obvious. Clearly, the process "uu $\rightarrow$ uu" must become dominant asymptotically because only the up quark structure function has a considerable tail towards high momentum fractions. In the energy region between 12 GeV and 18 GeV, however, the "ug $\rightarrow$ ug" contribution is also increasing, while gluon-gluon scattering is rapidly becoming unimportant. Altogether it is difficult to predict whether the gluon contribution on the away side is rising or falling as a function of $\langle \sqrt{s} \rangle$ without relying heavily on the details of the model assumptions. It is not excluded that the $\langle \sqrt{s} \rangle$ dependence is opposite between $\theta \approx 45^\circ$ and forward angles.

One experimental method to prove the prevalence of gluonic contributions is to show that the electric charge of the away jet is on the average almost zero. Another less direct possibility is offered by the analysis of the asymmetries of the away side particle densities around

$y = 0$. The model predictions for mean values and widths of away side rapidity distributions of different subprocesses are shown in fig. 6 as functions of θ . While the width is almost the same for all processes, the mean values show a wide spread. Again the asymmetries can be understood qualitatively in terms of kinematics by taking into account the fact that gluons are softer than quarks. The only process which stays almost symmetric in the whole angular range is the " $ug \rightarrow ug$ " scattering which is expected to dominate.

4. EXPERIMENTAL RESULTS

4.1 Away side rapidity distributions

The normalized away side rapidity distributions for π^+ triggered events with $\langle \sqrt{s} \rangle = 15$ GeV (fig. 1) are presented in fig. 7 for three different trigger angles, including only fast charged particles in the away jet ($0.5 < x_E < 1.0$). The positions of the trigger particle are indicated by arrows. All distributions are corrected for acceptance losses. The contributions from spectator jets, which are smaller than 20% at all trigger angles, are subtracted using the method described in sect. 3.2.

Three conclusions can be drawn:

- (a) The total particle density decreases towards forward trigger angles by almost a factor of 2. This may indicate that for small θ one observes partons with softer fragmentation functions than for $\theta \simeq 45^\circ$. The problems associated with this interpretation will be quantitatively discussed in sect. 4.4.
- (b) The width of the rapidity distribution increases towards forward trigger angles as expected by the model calculations (fig. 6). The broadening is a combined effect of the widening of the distributions for the different subprocesses and the increasing spread of their mean values.
- (c) None of the y distributions shows any extreme asymmetry. This will be discussed quantitatively in the following section.

4.2 Asymmetries of away side rapidity distributions

The mean values, $\langle y \rangle$, of the away side rapidity distributions (restricted to $-2 < y < +2$ and $0.5 < x_E < 1.0$) for π^+ triggered events are shown in fig. 8 as functions of θ for three different values of $\langle \sqrt{s} \rangle$. A slight "back-to-back" structure (i.e. $\langle y \rangle < 0$) is observed. It is slowly becoming stronger with increasing $\langle \sqrt{s} \rangle$. No obvious θ dependence of $\langle y \rangle$ is observed.

The model calculations are also indicated in fig. 8. Clearly the data are compatible with a strong prevalence of the " $ug \rightarrow ug$ " process. All other contributions, except " $gg \rightarrow gg$ ", show asymmetries which disagree with the data by at least 0.5 units in $\langle y \rangle$. Of course, a mixture of two extremes is in principle also not excluded by fig. 6 alone. Such a situation would, however, strongly contradict the measured charge structure which will be discussed in the next section.

4.3 The charge structure of the away jet

The charge structure of the away jet can be described by the ratio, R , of positive and negative particle densities. This quantity is shown as functions of y , x_E and $\langle \sqrt{s} \rangle$ for $\langle \theta \rangle = 47^\circ$ and $\langle \theta \rangle = 18^\circ$ in figs. 9(a), 9(b) and 9(c) respectively (integrated or averaged over all other variables as indicated in the figures).

Generally, R is considerably larger at $\langle \theta \rangle = 47^\circ$ than for smaller θ . This shows that the gluon component is indeed strongly increasing with decreasing θ , as expected by the model predictions.

The charge ratio is smallest for the rapidity region $0 < y < 1$ (fig. 9(a)). It is compatible with 1 for small θ and only slightly bigger at 47° . In this phase space region, gluon scattering dominates for all angles θ . Towards negative rapidities, R is only slowly increasing at $\langle \theta \rangle = 18^\circ$ while it is steeply rising for $\langle \theta \rangle = 47^\circ$. This shows the different importance of the away side up quark component in the case of "back-to-back" event topologies at different trigger angles. Also in the very asymmetric case $1 < y < 2$, the up quark component again seems to become more important in all θ regions.

Fig. 9(b) shows the $\langle\sqrt{s}\rangle$ dependence of R . While at $\langle\theta\rangle = 47^\circ$ R is rising with $\langle\sqrt{s}\rangle$, no clear trend is observed for smaller trigger angles. The largest difference between the gluon contributions at $\langle\theta\rangle = 47^\circ$ and $\langle\theta\rangle = 18^\circ$ occurs at $\langle\sqrt{s}\rangle = 18$ GeV.

Finally, fig. 9(c) shows that R is rising with the fragmentation variable x_E . The trend is much stronger at $\langle\theta\rangle = 47^\circ$ than at forward angles. The rise of R measures the amount of up-quark jets in the away side. It has essentially two possible origins: First, up-quark jets were measured to be mostly positively charged in the leading region [10], i.e. at high x_E , and second, if gluons have softer fragmentation functions than quarks, then the relative importance of the up-quark component should increase towards large x_E . The latter possibility will be discussed in the next section.

4.4 The longitudinal structure of the away jet

As discussed in sect. 3.2 the inclusive fragmentation function of the away jet can be described in terms of the variable x_E . The corrected x_E distributions of charged particles are displayed in fig. 10 for two different trigger angles ($\langle\theta\rangle = 47^\circ$ and $\langle\theta\rangle = 18^\circ$) and three different parton-parton c.m.s. energies. Contributions from spectator fragments have been subtracted.

At small values of x_E ($x_E \leq 0.3$) the distributions are significantly different for the two trigger angles. This can be at least partly explained by the effect that the away ϕ wedge (defined in sect. 3.2) does not contain all the soft fragments of the away jet. At fixed $\langle\sqrt{s}\rangle$ and fixed (small) x_E these losses become more severe at forward trigger angles, as suggested by the model calculations.

For $x_E > 0.3$ the effective fragmentation functions agree at the two trigger angles for $\langle\sqrt{s}\rangle = 12$ GeV, apart from a slight shift in absolute normalization. The slopes, however, become increasingly different at larger values of $\langle\sqrt{s}\rangle$. Taking into account the increasing prevalence of gluon jets towards smaller trigger angles and larger $\langle\sqrt{s}\rangle$, this result could indicate that gluons have softer fragmentation functions than quarks.

However, there are two effects which complicate this interpretation. First, intrinsic transverse momenta of partons inside the proton lead to transverse Lorentz boosts which affect the x_E distributions. As confirmed by the model calculations, the effects are only important for small values of x_E , and are not sufficient to explain the angular variation of the slopes at large x_E .

Second, x_E represents the fragmentation variable z only up to a rescaling by $1/z_{tr}$. The observed θ dependence of the x_E distributions could thus reflect a θ dependence of the fractional trigger momentum z_{tr} . Model calculations show that $\langle z_{tr} \rangle$ is indeed slightly increasing towards small θ . While the absolute value of $\langle z_{tr} \rangle$ is model dependent, this rise turns out to be smaller than 10% independent of model assumptions. In fig. 11 the x_E distributions are redrawn as functions of the variable

$$z' = x_E \times \langle z_{tr} \rangle ,$$

which approximates well the fragmentation variable z apart from effects of the event-to-event variation of z_{tr} . The relative theoretical error on the z' scales for the two trigger angles are indicated in fig. 11 by horizontal error bars, whenever they are larger than the width of the data points. For better visibility, exponential fits to the data in the intervall $0.3 < z' < 1.0$ are also shown.

It is observed that the two z' distributions almost agree at $\langle \sqrt{s} \rangle = 12$ GeV (for $z' \geq 0.3$). Towards larger energies, the trend of increasing differences in the slopes is still present. In conclusion, it is unlikely that the observed effect is of kinematical origin.

A similar indication of soft gluon fragmentation has been recently observed at the $\bar{p}p$ collider by the UA1 collaboration [11]. However, the data are restricted to fragments of relatively small fractional momenta $z \lesssim 0.5$.

5 CONCLUSIONS

The analysis of asymmetries and charge structures of away jets produced in high p_T events with π^+ triggers at three different regions of polar angles showed that in the kinematical range under consideration the "ug $\rightarrow$ ug" parton-parton scattering process is dominant. The contribution of gluons to the away side increases towards forward trigger angles and higher parton-parton c.m.s. energies. All trends are qualitatively expected in the framework of QCD.

The longitudinal structure of the away jet was found to soften with decreasing trigger angle indicating a softer inclusive fragmentation function for gluons than for quarks.

Acknowledgements

This experiment was greatly helped by contributions from the SFM Detector Group. We are indebted to the ISR Experimental Support Group. The Dortmund and Heidelberg Groups were supported by a grant from the Bundesministerium für Forschung und Technologie of the Federal Republic of Germany. The Ames Group was supported by the U.S. Department of Energy under contract W-7405-ENG-82. Two of us (W.G. and M.H.) were partially supported by the U.S. Department of Energy under contract DE-AC03-76SF00098.

REFERENCES

- [1] R.P. Feynman et al., Phys. Rev. D18 (1978) 3320;
R.D. Field, Phys. Rev. D27 (1983) 546.
- [2] M. Della Negra et al., Nucl. Phys. B127 (1977) 1.
- [3] A. Breakstone et al., Zeitschr. für Phys. C23 (1984) 9.
- [4] A. Breakstone et al., Zeitschr. für Phys. C25 (1984) 21;
A. Breakstone et al., Zeitschr. für Phys. C27 (1985) 205;
A. Breakstone et al., Zeitschr. für Phys. C28 (1985) 335.
- [5] M. Glück and E. Reya, Phys. Lett. 98B (1981) 444.
- [6] D. Drijard et al., Nucl. Phys. B208 (1982) 1.
- [7] H.G. Fischer, Proc. Int. Conf. on High Energy Physics, Lisbon
(1981) 297;
J.L. Alonso et al., Zeitschr. für Phys. C6 (1980) 21;
A.L.S. Angelis et al., Nucl. Phys. B209 (1982) 284.
- [8] A. Breakstone et al., Zeitschr. für Phys. C23 (1984) 9;
W. Herr, Ph.D. Thesis, Heidelberg (1985) unpublished.
- [9] D. Drijard et al., Phys. Lett. 121B (1983) 433;
T. Lohse, Diploma Thesis, Dortmund (1982) unpublished.
- [10] P. Allen et al., Nucl. Phys. B214 (1983) 369.
- [11] G. Arnison et al., Nucl. Phys. B276 (1986) 253.

FIGURE CAPTIONS

- Fig. 1 Phase space in the $p_L - p_T$ plane covered by the data with a positive pion at large p_T . Also shown are the lines of constant c.m.s. energy in the parton-parton system as calculated by a QCD model.
- Fig. 2 Schematic representation of the parton-parton scattering process.
- Fig. 3 Mean fractional momenta $\langle x_1 \rangle$ and $\langle x_2 \rangle$ as functions of trigger angle at $\langle \sqrt{\hat{s}} \rangle = 16$ GeV as predicted by model calculations.
- Fig. 4 Contributions of different subprocesses in the QCD model as functions of θ at fixed $\langle \sqrt{\hat{s}} \rangle$ on the parton level (a), and in terms of the hadron density (at $x_E > 0.5$) in the away jet (b).
- Fig. 5 Contributions of different subprocesses to the away jet (at $x_E > 0.5$) as function of $\langle \sqrt{\hat{s}} \rangle$ for two different values of θ , as predicted by the model calculations.
- Fig. 6 Predictions for mean values and widths of away side rapidity distributions ($x_E > 0.5$) for different subprocesses as functions of θ .
- Fig. 7 Rapidity distributions for leading fragments ($0.5 < x_E < 1.0$) in the away jet for π^+ triggered events at $\langle \sqrt{\hat{s}} \rangle = 15$ GeV and three different trigger angles. The arrows indicate the rapidities of the trigger particle.
- Fig. 8 Mean values of the away side rapidity distributions for particles with $0.5 < x_E < 1.0$ and $-2 < y < +2$ in events with π^+ triggers as functions of θ . The data are shown for three different values of $\langle \sqrt{\hat{s}} \rangle$. Typical model predictions for $\langle \sqrt{\hat{s}} \rangle = 16$ GeV are also indicated (fig. 6).

FIGURE CAPTIONS (Cont'd)

Fig. 9 Away side charge ratio, R , for π^+ triggered events:

- (a) as a function of y for all particles with $0.3 < x_E < 1.0$
 averaged over three different regions of $\langle \sqrt{s} \rangle$;
- (b) as a function of $\langle \sqrt{s} \rangle$ for all particles with $-2 < y < +2$
 and $0.3 < x_E < 1.0$;
- (c) as a function of x_E for all particles with $-2 < y < +2$
 averaged over three different regions of $\langle \sqrt{s} \rangle$.

Data at $\langle \theta \rangle = 47^\circ$ and $\langle \theta \rangle = 18^\circ$ are shown separately.

Fig. 10 Normalized x_E distributions for events with a π^+ trigger. All particles with $-2 < y < +2$ in the away wedge are included. The distributions are shown for two different trigger angles and three values of $\langle \sqrt{s} \rangle$.

Fig. 11 The same as fig. 10 but plotted versus the fragmentation variable $z' = x_E \times \langle z_{tr} \rangle$. The mean fractional trigger momentum $\langle z_{tr} \rangle$ was estimated by model calculations (see text). Exponential fits to the data in the interval $0.3 < z' < 1.0$ are also shown.

Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5

Fig. 6

Fig. 7

Fig. 8

Fig. 9

Fig. 10

Fig. 11