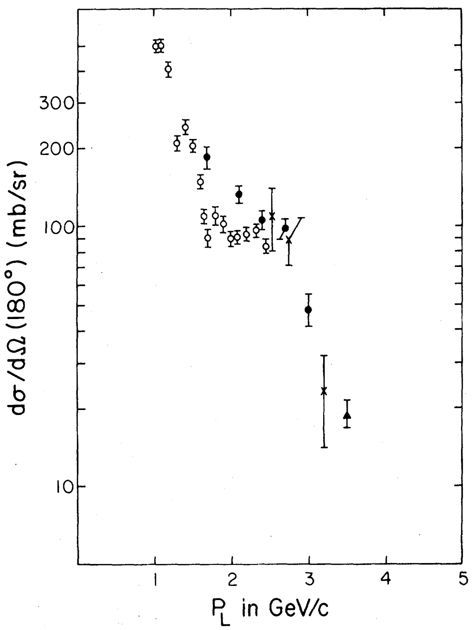

FIG. 5. Extrapolated differential cross sections to $\theta_{c.m.} = 180°$. Closed circles are results of this experiment; open circles, Carroll *et al.*; *X*'s, Whitmore *et al.*; triangle, Banaigs *et al.* (Ref. 3).

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Dependence of Transverse-Momentum Distributions of π^-'s on $P_\perp$ of a Proton in pp Interactions at 28.5 GeV/c*

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We present transverse-momentum distributions of π^-'s produced in the reaction $p_1p_2 \to p_3X$ at 28.5 GeV/c observed by the Multiparticle Argo Spectrometer System. As the transverse momentum of the trigger proton p_3 is raised from 0.4 to 1.6 GeV/c we find that the shape of the π^- momentum distribution *normal* to the (p_1,p_3) plane remains unchanged. The shape of the distribution *in* the plane is also relatively constant but the distribution shifts to balance transverse momentum.

In inelastic high-energy particle collisions there is considerable interest[1] in the details of how the transverse momentum of a high-$P_\perp$ particle is balanced by the other particles. Furthermore, changes in the shape of the momentum distribution of the produced pions normal to the plane defined by the incident and high-$P_\perp$ particle as a function of the high-$P_\perp$ particle's transverse momentum may provide insight into hadronic structure. Specifically, one expects quite different behavior between certain fireball and hard-scattering models.[2] In the former, fireballs decay isotropically and increase their temperature with $P_\perp$. In the latter, events involving large $P_\perp$ exhibit strong correlations in the plane containing the high-$P_\perp$ particle; however, the correlation with particles normal to the scattering plane has no $P_\perp$ dependence beyond that imposed by energy conservation. One might therefore expect that measurement of the shape of the momentum distribution *normal* to the scattering plane is particularly useful in identifying the nature of large-transverse-momentum processes. An increase in the width of this distribution, $D(P_y)$, with $P_\perp$ of a trigger particle would suggest the presence of fireballs, whereas the observation of no variation would point to a hard-scattering process.[3]

We present here a study of transverse-momentun distributions of π^-'s for ~93 000 events of the reaction

$$p_1 + p_2 \to p_3 + \mathrm{MM} \quad (1)$$

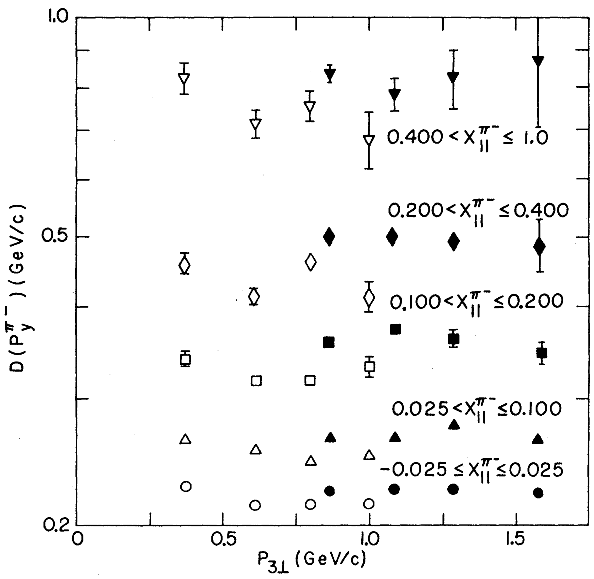

FIG. 1. Width of the negative-pion momentum distribution normal to the proton scattering plane, $D(P_y^{\pi^-})$, as a function of the transverse momentum of the scattered proton, $P_{3\perp}$, for various $X_{\parallel}^{\pi^-}$ intervals. The range of X for the forward trigger proton is $0.1 < X_{\parallel}^{p_3} \lesssim 1$. The open symbols are for data below the rise in multiplicity (see Ref. 7) and the solid symbols are for data above the rise. Within errors the average value of the π^- momentum component normal to the scattering plane does not depend on $P_{3\perp}$ with the exception of a systematic level shift of ~5% between data above and below the rise in multiplicity. The errors are statistical only.

as a function of the transverse momentum of p_3, $p_{3\perp}$. The data were taken at the Brookhaven National Laboratory alternating-gradient synchrotron with the Multiparticle Argo Spectrometer System. The high-momentum spectrometer momentum-analyzed and identified p_3 and the vertex spectrometer[4] (VS) momentum-analyzed the remaining charged particles. The apparatus has been described elsewhere.[5] The VS tracks were reconstructed by the computer code PITRACK[6] and fitted to a common vertex.

For purposes of this discussion we choose the z axis along the direction of the incident proton, p_1, the scattering plane to be the x-z plane, and y normal to the scattering plane. With this choice of coordinates the y component of the momentum of the particles comprising MM must average to zero. Although approximately 16% of the charged particles escape the VS and we do not measure the neutrals, we find that $\langle P_y^{\pi^-}\rangle$ averaged over many events is zero within errors for all subsets of the data analyzed. The width or dispersion of the P_y distribution, $D(P_y^{\pi^-}) \equiv \langle (P_y^{\pi^-} - \langle P_y^{\pi^-}\rangle)^2\rangle$, is presented in Fig. 1 for five bins in the Feynman variable $X_{\parallel}^{\pi^-} = 2P_z^{\text{c.m.}}/\sqrt{s}$ as a function of $P_{3\perp}$. Only bins with $X_{\parallel}^{\pi^-} > -0.025$ were chosen since the VS has certain biases in the backward hemisphere. For any given $X_{\parallel}^{\pi^-}$ bin we note independence of $D(P_y^{\pi^-})$ on $P_{3\perp}$ from 0.4 to 1.6 GeV/c[7] (Fig. 1) and on missing mass MM over a range

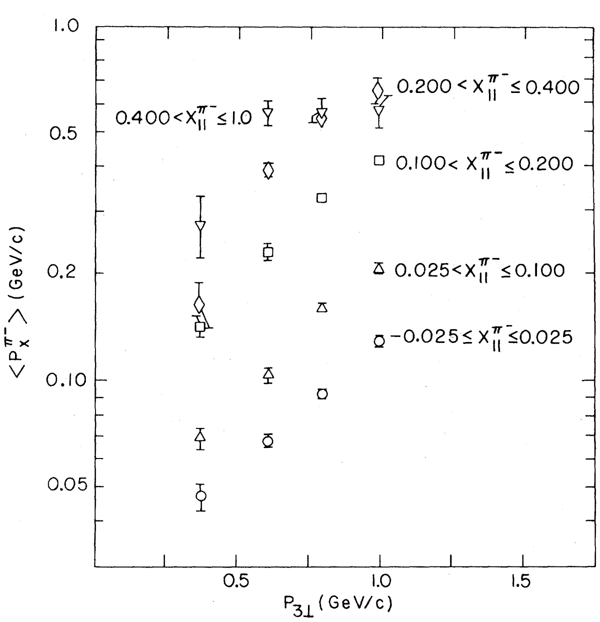

FIG. 2. Average x component of momentum of the negative pions as a function of trigger transverse momentum. All points are for data below the rise.

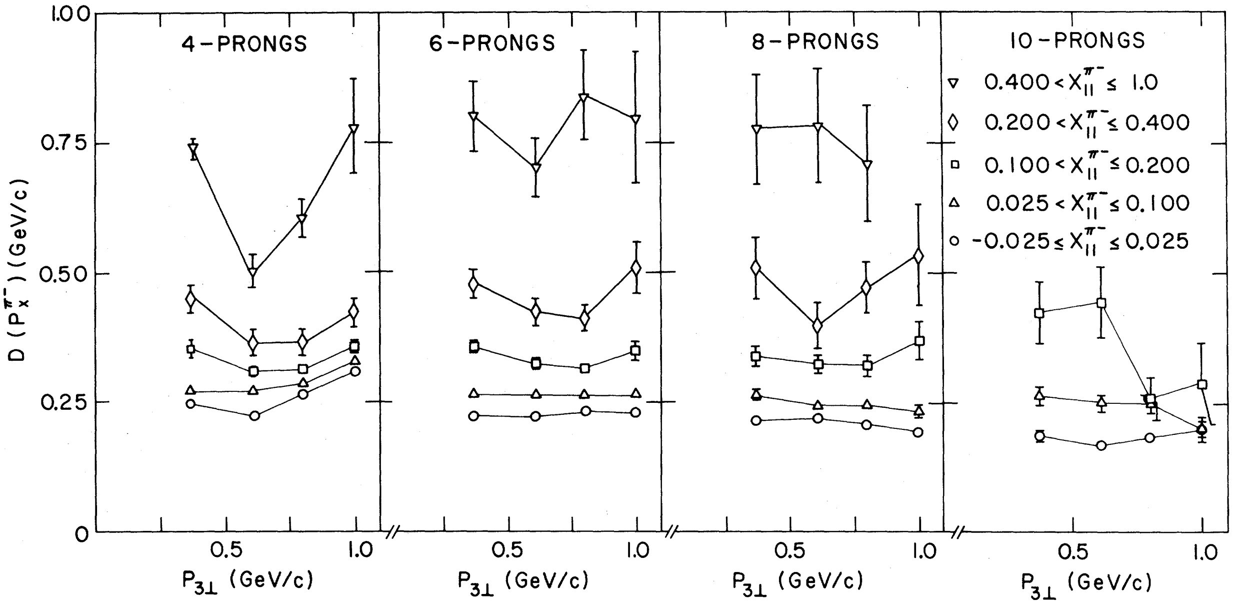

FIG. 3. Widths of the x component of the negative-pion momentum as a function of trigger transverse momentum for 4-, 6-, 8-, and 10-prong events, respectively.

of 1.3 to 6.5 GeV (not shown). We have also investigated the higher moments of the P_y distributions and find them to be flat within errors. We conclude that the shape of the P_y distribution of produced negative pions and hence the pion temperature normal to the production plane is independent of the trigger proton.

In Fig. 2 we present $\langle P_x^{\pi^-}\rangle$ for the same five $X_{\parallel}^{\pi^-}$ bins as a function of $P_{3\perp}$ for data below the rise in multiplicity.[8] We observe momentum balancing taking place at all $X_{\parallel}^{\pi^-}$ values measured. However it appears that balancing is achieved differently at small $X_{\parallel}^{\pi^-}$ than at large $X_{\parallel}^{\pi^-}$ since the small-$X_{\parallel}^{\pi^-}$ curves are linear while the large-$X_{\parallel}^{\pi^-}$ ones seem to saturate. We suggest that this behavior can be described in terms of two classes of pions, produced in quite different abundances: pions at large $X_{\parallel}^{\pi^-}$ (peripheral pions) and pions near $X_{\parallel}^{\pi^-}=0$ (central pions). At low $P_{3\perp}$ both classes help to balance transverse momentum (both large- and small-$X_{\parallel}^{\pi^-}$ curves rise) while at large $P_{3\perp}$ only the large fraction of central pions balance further increases of transverse momentum. Furthermore we observe that the widths of the $P_x^{\pi^-}$ distributions at a given $X_{\parallel}^{\pi^-}$ are approximately independent of $P_{3\perp}$ (Fig. 3) with the exception of the four-prong events.[9] In other words, for increasing $P_{3\perp}$ the central pion cloud tends to move as a whole to balance transverse momentum rather than to increase its width on the side opposite the trigger particle.

As one might expect, $\langle P_x^{\pi^-}\rangle$ is found to be larg-

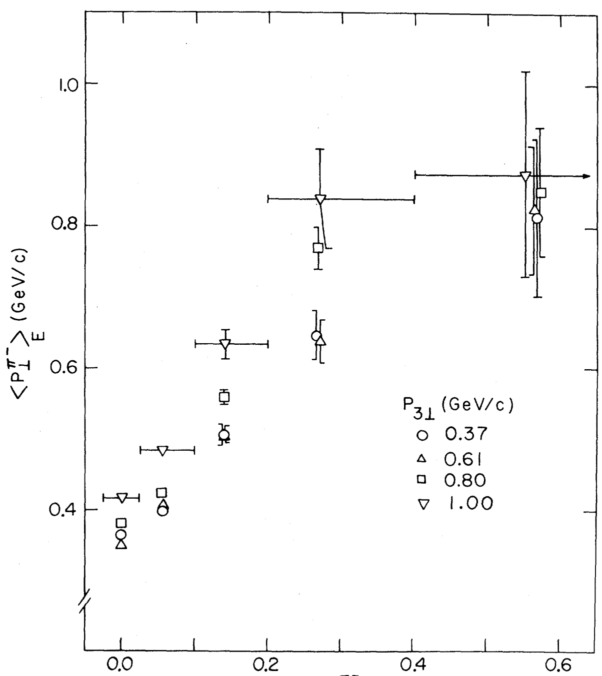

FIG. 4. The seagull effect as a function of the trigger-proton transverse momentum. The average negative-pion transverse-momentum distribution has been weighted by $1/E$ to eliminate relativistic phase-space effects. Horizontal error bars indicate bin boundaries.

er for lower multiplicities (not shown).

In Fig. 4 we present $\langle P_\perp^{\pi^-}\rangle_E = \langle E^{-1}[(P_x^{\pi^-})^2 + (P_y^{\pi^-})^2]^{1/2}\rangle$ versus $X_\parallel^{\pi^-}$ where we have weighted our integrals with the inverse of the energy E of the π^-'s to remove relativistic phase-space effects. Qualitatively, we observe the same correlation seen previously[10] and known as the seagull effect but explore it here over a substantial range of transverse momentum for p_3. A dependence on $P_{3\perp}$ is seen and can be understood in light of the $P_x^{\pi^-}$ and $P_y^{\pi^-}$ distributions presented. All changes in shape arise from the dependence of $\langle P_x^{\pi^-}\rangle$ on $P_{3\perp}$.

In summary we have shown that in inelastic pp interactions at 28.5 GeV/c, the transverse-momentum distribution normal to the scattering plane of inclusive π^-'s is independent of the transverse momentum of a forward trigger proton over a wide range of its phase space, an observation which is in conflict with certain fireball models but in agreement with the family of hard-scattering models. Furthermore, on the average, more than one pion, maybe most, tend to participate in balancing the transverse momentum of the trigger proton.

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