[14]The observed $\Delta(\nu W_2)$ in Fig. 3 is derived by averaging the measure of scaling violations, $(q^2/3)^{(0.25-x)}$, over the dimuon data.

[15]For example, the predicted dimuon rate is also somewhat sensitive to the coefficient of x' in the exponential in (2). Using a value of 8 (also suggested by BN) instead of 10 increases the dimuon rate by about 25% and lowers the predicted scale violation by this same amount. Note also the dependence on the D branching ratio.

Azimuthal Correlations of High-Transverse-Momentum π^0 Pairs

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We have studied correlations between two π^0's produced at the CERN intersecting storage rings, utilizing detectors with large azimuthal acceptance. We find that the previously observed enhancement of two π^0's produced at azimuthal difference near 180° can be made to vanish when certain kinematic effects are removed. However, we observe aligned configurations above 8 GeV of transverse energy unexplained by such kinematic effects.

Most studies[1] of correlations between two particles of high transverse momentum have been limited to nearly coplanar configurations (azimuthal-angle difference $\Delta\varphi \sim 0°$, $\Delta\varphi \sim 180°$). In this experiment, we have measured the distributions of neutral pion pairs over nearly the full angular range of the azimuthal difference. These measurements enable us to remove certain kinematic effects in the analysis of particles emitted in opposite directions at the CERN intersecting storage rings (ISR). We find that the excess in "back-to-back" π^0 pair production previously observed can be made to vaish when these kinematic effects are removed, reappearing only when one of the π^0's exceeds 4 GeV/c in transverse momentum.

The data for this study were derived primarily from the ISR runs with c.m. energy $\sqrt{s} = 52$ GeV. The integrated luminosity was $\sim 3 \times 10^{36}$ cm^{-2}. Our apparatus (cf. Kourkoumelis[2] and Cobb[2] for a more detailed description) consists of four lead-liquid-argon calorimeters placed adjacently around the intersection region, each covering the polar-angle region $90° \pm 45°$ and each having

45° acceptance in azimuth. The calorimeters' three views, realized by 20-mm-wide traversing strips at different angles, allow the reconstruction of individual showers, and three radial electronic subdivisions allow the verification of normal shower development. The calorimeter trigger and subsequent analysis require two photons of energy greater than 1.2 GeV to strike different calorimeters, providing coverage in the c.m. system of $23° < \Delta\varphi < 180°$.[3]

For the purpose of this analysis, neutral pions are identified by the presence of at least one reconstructed photon shower of energy greater than 1.2 GeV/c, accompanied by additional nearby energy, not associated by our reconstruction program with the solved photon shower. Detailed investigation showed that these events are primarily pions with the two showers not cleanly resolved.[4]

Each of the π^0 pairs thus defined may be characterized by their momenta P_{T_1}, P_{T_2} and azimuthal-angle difference $\Delta\varphi$. We have subdivided the data by two methods for display purposes, with each subdivision related to simple models of the collision mechanism. Below we give the results first for a selection based on "P_T" and then for one based on "E_T" as defined below.

The distribution in $\Delta\varphi$ for events where each π^0 has transverse momentum greater than the stated limit P_T is shown in Fig. 1.[5] As P_T is increased, a strong, narrowing peak develops at $\Delta\varphi = 180°$, similar to that observed in previous experiments.

The enhancement favoring π^0 pairs in a back-to-back configuration may result from underlying consituent–hard-scattering structure, but there exist a number of possible "kinematical" explanations for the emergence of such a correlation. First, conservation of transverse momentum may produce an excess of events in this configuration. In addition, since increasing transverse energy is associated with decreasing cross sections, it is expected that π^0 pairs produced with an azimuthal opening angle $\Delta\varphi \sim 90°$ and therefore *requiring* additional balancing transverse momentum are less copiously produced than those with $\Delta\varphi = 180°$. With these points in mind, we consider the second method of grouping the data.

We define the total transverse energy E_T as follows: First we construct for each π^0 pair a missing, or "ghost," transverse momentum $\vec{P}_{TG} = -(\vec{P}_{T_1} + \vec{P}_{T_2})$, which must be nonzero for $\Delta\varphi < 180°$. We then define the total transverse energy (assuming negligible masses) $E_T = |P_{T_1}| + |P_{T_2}| + |P_{TG}|$ and examine the azimuthal spectrum, this time for events in the E_T *intervals* shown in Fig. 2. The selection on E_T depends on a scalar quantity without the obvious biases of the previous selection. Any peak now observed cannot be due to those biases.

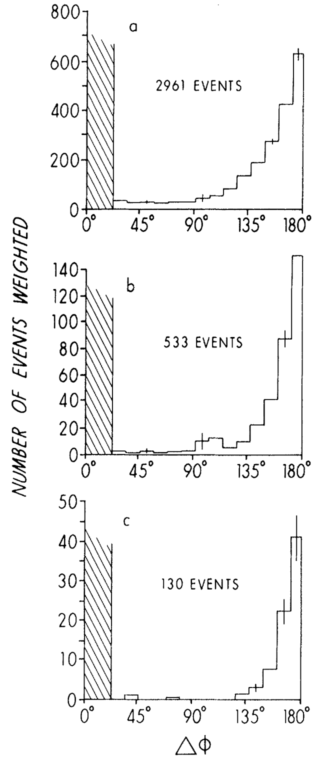

FIG. 1. Fully corrected distributions of azimuthal-angle differences $\Delta\varphi$ between two π^0's emitted with polar angles $45° < \theta < 135°$ and $\Delta\varphi > 23°$ with each of transverse momentum greater than (a) 2.0 GeV/c, (b) 2.5 GeV/c, and (c) 3.0 GeV/c.

A striking feature of the spectrum, for $E_T < 8$ GeV is the disappearance of the peak in back-to-back configurations observed in Fig. 1.[6] Instead we note a larger cross section for configuration where the π^0's are in the same hemisphere. This type of correlation can result from the production of resonances or clusters. The change in distribution implies that kinematic factors are important in determining the angular correlation. Therefore firm conclusions can be reached only by comparison of the data with models in which kinematic effects are taken into account.

First, without reference to a specific model, we have examined the dependence of the angular correlations on E_T. As the selected E_T interval rises beyond 8 GeV, we note the reappearance of preference towards the back-to-back configura-

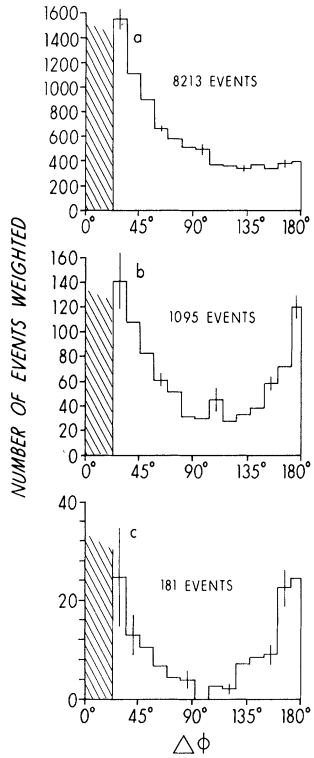

FIG. 2. Azimuthal differences of two π^0's with angular acceptances as in Fig. 1, but with total transverse energy (see text) in the interval (a) 6 GeV < E_T < 8 GeV; (b) 8 < E_T < 10 GeV; (c) 10 GeV < E_T < 12 GeV. The minimum π^0 transverse momentum required for inclusion is P_T = 1.2 GeV/c.

tion, together with the highly populated configuration at small $\Delta\varphi$. Next, to assess the significance of the observed structures, we have compared the data to the simple independent-emission model of Michael and Vanryckegham,[7] which derives "jetlike" configurations from the necessity to conserve energy and momentum. In the "E_T" selection, this model predicts an essentially uniform distribution for the spectra of Fig. 2.

Finally, to explore the observed structure in more detail, we have constructed the diplot of Fig. 3 which illustrates all of the transverse variables simultaneously. The plot is symmetrized, with coordinates $u_i = (2P_{Ti}/E_T)$, $i = 1, 2$, and is analogous to a Dalitz plot.[8] We note that, for the interval 10 GeV < E_T < 12 GeV, the kinematic boundaries of the plot are preferentially populated, indicating alignment of the transverse momenta of the π^0's and "ghost." Hard-scattering models, with the two scattering constituents each fragmenting into π^0 + "other" with relative transverse momenta of the fragments, qualitatively predict

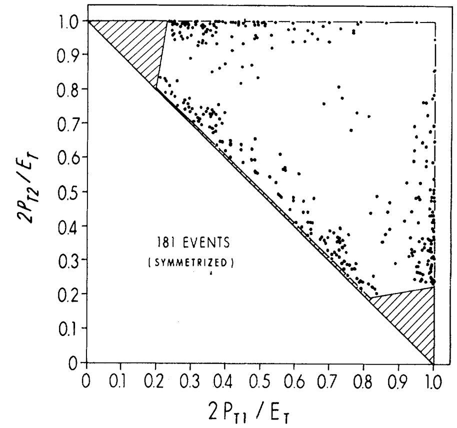

FIG. 3. Normalized symmetrized diplot with horizontal and vertical coordinates $u_i = 2P_{Ti}/E_T$ for each π^0 (uncorrected) of Fig. 2(c). The excluded striped regions inside the triangular boundary have P_T < 1.2 GeV/c. Also excluded (by the requirement $\Delta\varphi > 23°$) is a small region close to the diagonal boundary.

such alignment. The distribution of events along the kinematic boundary, including the depletion of events in the $P_{TG} = 0$ corner of the plot, can be varied by assigning a nonzero mass to the ghost.

In summary, we have studied the preference of two π^0's for "back-to-back" configurations by a novel method. After removing an obvious kinematic bias, we still observe, at high transverse energies, an enhancement of configurations with alignment of the π^0's and missing momentum. The association of high energies and back-to-back configurations is suggestive of underlying constituent–hard-scattering structure, and is not expected in simple models with no such structure built in, such as the independent-emission model. We can not exclude the possibility that more sophisticated models, or high-mass resonant states with unexpectedly high cross sections,[9] can explain our data.

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[1]For π^0 correlations, see K. Eggert *et al.*, Nucl. Phys. B98, 49 (1975); F. W. Büsser *et al.*, Phys. Lett. 51B, 311 (1974). For charged-particle correlations, see M. Della Negra *et al.*, CERN Report No. CERN/EP/PHYS77-10 (to be published); see also recent reviews by G. C. Fox and H. J. Frisch, Brookhaven National Laboratory Report No. BNL-50598, edited by H. Gordon and R. F. Peierls, Proceedings of the American Physical Society Meeting, Division of Particles and Fields, Upton, New York, 1976 (unpublished); by H. Bøggild, in Proceedings of the Seventh International Symposium on Multiparticle Dynamics, Kayserberg, June 1977 (unpublished); by M. Della Negra, in Proceedings of the European Conference on Particle Physics at Budapest, July 1977 (unpublished).

[2]C. Kourkoumelis, CERN Report No. CERN 77-06 (unpublished); J. H. Cobb *et al.*, Phys. Lett. 68B, 101 (1977).

[3]Although we have taken data by separate trigger with acceptance at smaller angles, their analysis is not yet complete.

[4]A more certain, but biased π^0 definition requires two reconstructed photons with π^0 effective mass. However, this definition yields poor efficiency at high P_T. When two reconstructed showers coexist in the same octant, the π^0 energy was taken as that of the highest-energy shower. The inclusion of the lower-energy shower or additional nearby energy in the π^0 definition has no significant effect on our results.

[5]The spectrum has been weighted for geometrical and energy efficiency as determined by calibration runs at the CERN proton synchrotron so that the two π^0's, when given random angles would have a flat distribution, independent of transverse momentum above $P_T = 1.2$ GeV/c. Trigger corrections due to the ISR intersection angle have been made. The weight of an event varies from 0.3 to 3, with an average weight of 1.

[6]We have also examined the product $\Pi = P_{T_1} \cdot P_{T_2} \cdot P_{TG}$. We find distributions similar to those of the E_T selection.

[7]C. Michael and L. Vanryckegham, University of Liverpool Report No. LTH 31, May 1977 (to be published), and private communication. We compared our spectrum in $\Delta\varphi$ with that predicted by the independent-emission model for events with $9 < E_T < 12$ GeV and $P_{T_1} > 1$ GeV; $P_{T_2} > 3$ GeV. The 412 events in our sample have a distribution essentially the same as that of Fig. 2(b). The model predicts a nearly uniform distribution with variations of < 20% over our azimuthal coverage.

[8]The diplot of Fig. 3 is not corrected for efficiency which varies by less than 30% in the populated regions.

[9]Recent measurements of $\Upsilon(9.5) \to e^+e^-$ in the same apparatus [J. H. Cobb *et al.*, Phys. Lett. 72B, 273 (1977)], combined with an assumed 3% branching ratio to electrons, would indicate that there are several hundred decays of $\Upsilon(9.5)$ to hadrons in the data sample from which the present events are drawn.

Atomic Electron Correlation in Nuclear Electron Capture

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The effect of electron-electron Coulomb correlation on orbital-electron capture by the nucleus has been treated by the multiconfigurational Hartree-Fock approach. The theoretical ^{7}Be L/K capture ratio is found to be 0.086, and the ^{37}Ar M/L ratio, 0.102. Both ratios are smaller than the independent-particle predictions. Measurements exist for the Ar M/L ratio, and agreement between theory and experiment is excellent.

Benoist-Gueutal's insight[1] that atomic electrons must be included in a complete description of orbital-electron capture by the nucleus[2] led to the introduction of atomic exchange and imperfect-overlap factors in the theoretical capture probability.[3-6] All existing work on electron capture has been carried out in the independent-particle approximation; effects due to electron-electron Coulomb correlation have been neglected. Here we report on a first effort to take correlation into account, by using the multiconfigurational Hartree-Fock (MCHF) approach.[7] We calculate the ^{7}Be L/K and ^{37}Ar M/L capture ratios.

The nuclear-electron-capture rate is[2]

$$\lambda_i = \lambda_i^0 B_i, \quad i = K, L, M, \dots, \tag{1}$$

where λ_i^0 is the rate obtained when atomic matrix elements are neglected,[8] and B_i is the exchange-

