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Long-range angular correlations of charged particles in high multiplicity e^+e^- collisions at 91 GeV using archived data from the ALEPH detector at LEP

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The first measurements of two-particle angular correlations for charged particles emitted in e^+e^- collisions at a center-of-mass energy of 91 GeV are presented. The archived data are collected with the ALEPH detector at LEP. The correlation functions are measured over a broad range of pseudorapidity and azimuthal angle of the charged particles. Those results are compared to predictions from the PYTHIA event generator. In contrast to the results from high charged particle multiplicity nucleon-nucleon, nucleon-nucleus and nucleus-nucleus collisions, where long-range correlations with a large pseudorapidity gap are observed, no significant enhancement of long-range correlations is observed with respect to PYTHIA predictions, which do not include additional final state interactions of the outgoing partons.

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Two-particle correlations in high-energy collisions provide valuable information for characterizing Quantum Chromodynamics and have been studied previously for a broad range of collision energies in proton-proton (pp) [1, 2], proton-nucleus (pA) [3, 4, 5], deutron-nucleus (dA) [6], and nucleus-nucleus (AA) [7, 8] collisions. Such measurements can elucidate the underlying mechanism of particle production and reveal possible collective effects resulting from the high particle densities accessible in these collisions. Studies of two-particle angular correlations are typically performed the using the two-dimensional $\Delta\eta - \Delta\phi$ correlation functions, where $\Delta\phi$ is the difference in the azimuthal angle ϕ between the two particles and $\Delta\eta$ is the difference in pseudorapidity $\eta = -\ln(\tan(\theta/2))$. The polar angle θ is defined relative to the reference axis, which is in the counterclockwise hadron beam direction. Of particular interest in studies of collective effects is the long-range (large $|\Delta\eta|$) structure of the two-particle correlation functions. In this region, the function is less susceptible to other known sources of correlations such as resonance decays and the fragmentation of energetic partons. Measurements in high-energy AA collisions have shown significant modifications of the long-range structure with respect to minimum-bias pp collisions, over a very wide range of collision energies [9, 10, 11]. The long-range correlations are interpreted as a consequence of the hydrodynamical flow of the produced strongly interacting medium and are closely related to initial collision geometry and its fluctuations. Those measurements allow for the extraction of the fundamental transport properties of the medium using hydrodynamic models. Recently, measurements in pp, pPb collisions and dAu collisions have revealed the emergence of long-range, near-side ($\Delta\phi \sim 0$) correlations in the selection of collisions with very high number of final state particles. The physical origin of the phenomenon is not yet fully understood. Due to the complexity of the hadron-hadron collisions, possible initial state correlations of the partons, such as those arise from color-glass condensate, could complicate the interpretation of the pp, pA and dA data. Studies of high charged particle multiplicity e^+e^- collisions, where the initial kinematics of the collisions are well-defined, could bring significant insights. In these proceedings, the first measurements of the two-particle correlation function charged particles emitted in e^+e^- collisions at a center-of-mass energy of 91 GeV is presented. Archived data collected with the ALEPH detector at LEP is used and converted to an MIT Open Data format. Details of the selection of hadronic events are described in [12]. Events are accepted with at least five good tracks and with a total charged energy in excess of 15 GeV. The sphericity axis and its polar angle (Θ_{sph}) reconstructed with both tracker and calorimeters is required to be $|\cos\Theta_{\mathrm{sph}}| < 0.9$ to ensure that the event is well contained within the detector.

In Fig. 1, the two-particle correlation functions from high (N>35) multiplicity events are presented using the beam axis as the reference axis for the calculation of η and ϕ of the charged particles. The dominant features of the correlation function are the jet peak near $(\Delta\eta, \Delta\phi) = (0,0)$ for pairs of particles originating from the same jet and the away-side structure at $\Delta\phi \sim \pi$ for pairs of particles from back-to-back jets. Correlated yields are obtained from an zero-yield-at-minimum (ZYAM) method as a function of $|\Delta\phi|$ averaged over $1.6 < |\Delta\eta| < 3.0$, which are shown in the right panel of Fig. 1. Different from the results from pp and pA collisions, no "ridge"-like structure is found at $\Delta\phi \sim 0$. To investigate the collective behavior transverse to the direction of the color string of the outgoing quark and anti-quark pairs from Z decay, the event thrust axis is used to replace the role of the electron beam axis. The charged particle pseudorapidity and polar angles are recalculated with respect to the thrust axis. The obtained correlation functions are shown in Fig. 2. In the away-side at $\Delta\phi \sim \pi$, the elongated structure is more similar to the ones obtained in pp and pA collisions. The correlated yields as a function of $\Delta\phi$ are consistent with archived simulated PYTHIA events, where no additional final state interactions of the partons are implemented. To suppress the contribution of jet correlations and increase the sensitivity to soft gluon emissions perpendicular to the thrust axis, a pseudorapidity selection of the charged particle $|\eta| < 1.6$ is applied.

The resulting correlation function and the correlated yields with this selection are shown in Fig. 3. The sharp near-side peaks from jet correlations have been truncated to better illustrate the structure outside that region. The observed correlated yields are also consistent with results from simulated PYTHIA events. Correlated yield obtained from ZYAM procedure as a function of $|\Delta\phi|$ are shown. The error bars correspond to statistical uncertainties, while the shaded areas denote the systematic uncertainties.

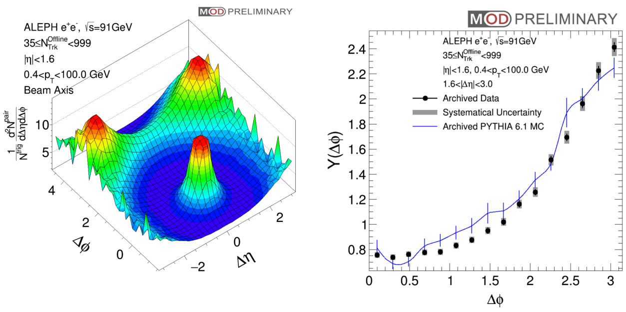

Figure 1: (Left panel) Two-particle correlation functions in e^+e^- collisions at 91 GeV for events with particle multiplicity $N > 35$.

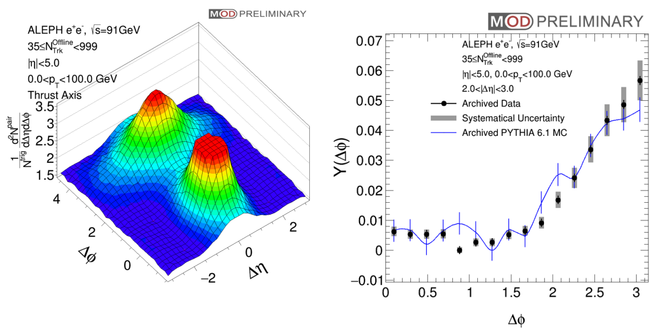

Figure 2: Two-particle correlation functions with thrust axis in e^+e^- collisions at 91 GeV for events with particle multiplicity $N > 35$.

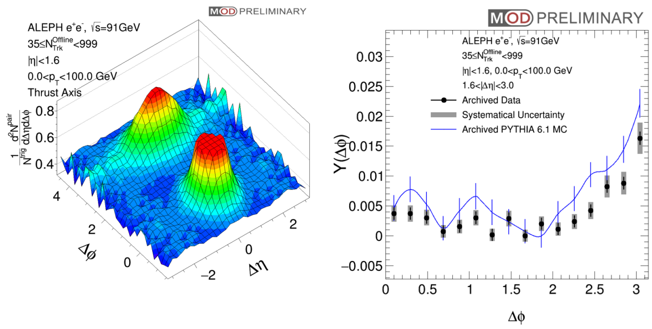

Figure 3: Two-particle correlation functions with thrust axis in e^+e^- collisions at 91 GeV for events with particle multiplicity $N > 35$.

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