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Two-Particle Correlation Analysis with ALEPH Data

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Results on two-particle angular correlations for charged particles emitted in e^+e^- collisions at center-of-mass energies ranging from 130 GeV to 209 GeV are presented. The analysis uses 60 thousand collisions collected by the ALEPH detector at LEP. The correlation are studied over a broad range of pseudorapidity and azimuthal angle of the charged particles, as a function of charged particle multiplicity.

PACS numbers:

INTRODUCTION

This paper proposes measurements of two-particle angular correlations of charged hadrons produced in e^+e^- collisions as a function of charged hadron multiplicity with the ALEPH detector. 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) [?], proton-nucleus (pA) [? ? ?], and nucleus-nucleus (AA) [? ?] 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 using 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 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 fragmentation function of energetic jets. Measurements in high-energy AA collisions have shown significant modification of the long-range structure compared with minimum-bias pp collisions, over a very wide range of collision energies [? ? ? ?]. The long-range correlations are commonly interpreted as a consequence of the hydrodynamical flow of the produced strongly interacting medium [?] and usually characterized by the Fourier components of the azimuthal particle distributions. The extraction of the second and third Fourier components, usually referred to as elliptic and triangular flow, is of great interest because it is closely related to initial collision geometry and its fluctuation [?]. Those measurements allow the extraction of the fundamental transport properties of the medium using hydrodynamic models. Recently, measurements in pp [?] and pPb 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. This "ridge-like" correlation has inspired a large variety of theoretical models [? ?]. The physical origin of the phenomenon is not yet fully understood. Moreover, it was found that the elliptic flow signal exists even at the lowest nucleon-nucleon center-of-mass energy of 7.7 GeV in AA collisions at the Relativistic Heavy Ion Collider [?]. 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 and pA data. Studies of high multiplicity e^+e^- collision, where the initial kinematics of the collisions are well-controlled, could bring significant insights about the observed phenomenon. These measurements will also enable a direct comparison between different collision systems for the first time. The studies of ridge signal in e^+e^- collisions will bring significant impact to the field of relativistic heavy ion collisions, either change completely the interpretation of the ridge in pp, pA and AA collisions if a significant signal is observed, or serve as an important reference for the final state effect observed in high multiplicity hadron-hadron scatterings if no long-range correlation signal was detected.

DATA SAMPLE AND EVENT SELECTION

ALEPH Detector

Event Selection

Data Sample and Detector Corrections

ANALYSIS TECHNIQUE

In this analysis, identified protons, pions and kaons with transverse momentum between 0.1 and 4.0 GeV/c are selected for the correlation function analysis. High multiplicity events are sampled using the total number of selected proton, pions and kaons (hadron multiplicity N) in each event. The first step in extracting the correlation function was to divide the sample into bins in the hadron multiplicity. For each hadron multiplicity class, "trigger" particles are defined as charged hadrons in the selected transverse momentum range (0.1 and 4.0 GeV/c). Particle pairs are then formed by associating every trigger particle with the remaining charged hadrons in the same p_{T} interval as the trigger particle. The per-trigger-particle associated yield is defined as:

$$\frac{1}{N_{\mathrm{trig}}}\frac{\mathrm{d}^2\mathrm{N}^{\mathrm{pair}}}{d\Delta\eta \mathrm{d}\Delta\phi} = B(0,0) \times \frac{S(\Delta\eta,\Delta\phi)}{B(\Delta\eta,\Delta\phi)} \quad (1)$$

where N_{trig} is the number of trigger particles in the event, $\Delta\eta$ and $\Delta\phi$ are the differences in η and ϕ of the pair. The signal distribution, $S(\Delta\eta,\Delta\phi)$, is the per-trigger-particle yield of particle pairs in the same event:

$$S(\Delta\eta,\Delta\phi) = \frac{1}{N_{trig}}\frac{\mathrm{d}^2\mathrm{N}^{\mathrm{same}}}{\mathrm{d}\Delta\eta\mathrm{d}\Delta\phi} \quad (2)$$

The mixed-event background distribution, used to account for random combinatorial background, is defined as

$$B(\Delta\eta,\Delta\phi) = \frac{1}{N_{trig}}\frac{\mathrm{d}^2\mathrm{N}^{\mathrm{mix}}}{\mathrm{d}\Delta\eta\mathrm{d}\Delta\phi} \quad (3)$$

and is constructing by pairing the trigger particles from two random events in the same hadron multiplicity interval. The symbol N^{mix} denotes the number of pairs taken from the mixed event, while $B(0,0)$ represents the mixed-event associated yield for both particles of the pair going in the same direction and thus having full pair acceptance. Therefore, the ratio $B(0,0)/B(\Delta\eta,\Delta\phi)$ represents the pair-acceptance correction factor used to derive the corrected per-trigger-particle associated yield distribution. The signal and background distributions are first calculated for each event and then averaged over all the events within the track multiplicity class.

RESULTS

In Fig. 1, the two-particle correlation functions from low (N>20) multiplicity events is presented. In low-multiplicity events, 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 elongated structure at $\Delta\phi \sim \pi$ for pairs of particles from back-to-back jets. The same-side jet peak and back-to-back correlation structures are also observed in high multiplicity events. In addition, a hint of "ridge"-like structure is visible at $\Delta\phi \sim 0$ in the right panel of Fig. 2.

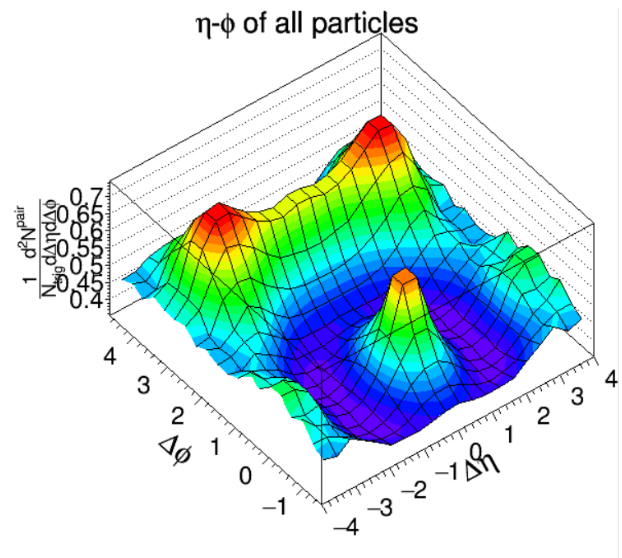

FIG. 1: Two-particle correlation functions versus $\Delta\eta$ and $\Delta\phi$ in e^+e^- collisions for events with particle multiplicity > 20.

SYSTEMATIC UNCERTAINTIES

Add here discussion of the systematic results

MONTE CARLO COMPARISON

Add here discussion of the monte carlo comparisons

LEP2

SUMMARY

The ALEPH data has been used to perform measurements of two-particle angular correlation functions for the first time. A hint of long-range ($|\Delta\eta| > 2$) ridge-like structure at the near-side ($\Delta\phi \sim 0$) was shown

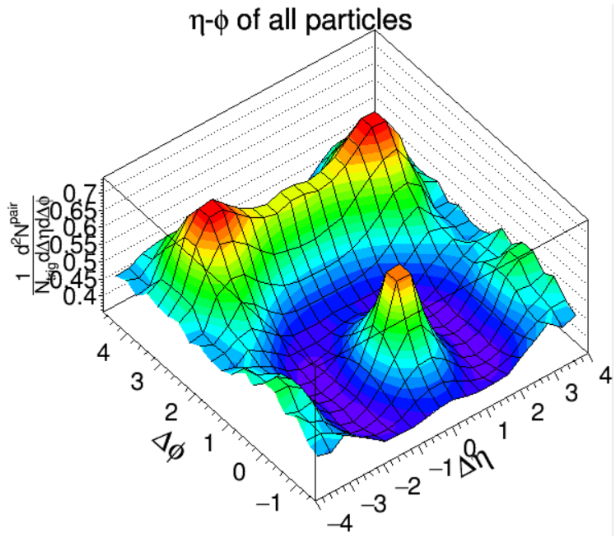

FIG. 2: Two-particle correlation functions versus $\Delta\eta$ and $\Delta\phi$ in e^+e^- collisions for events with particle multiplicity > 50.

in the Belle data. However, the limited statistics precludes drawing firm conclusions and we propose to perform those measurements with the unique high statistics hadronic data recorded by the Belle detector.

GLOBAL OBSERVABLES

LEP 1

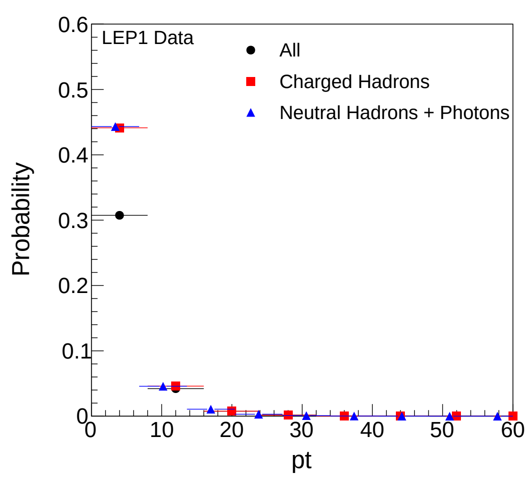

FIG. 3: Momentum of all particles, charged hadrons, and neutral hadrons+photons in LEP 1.

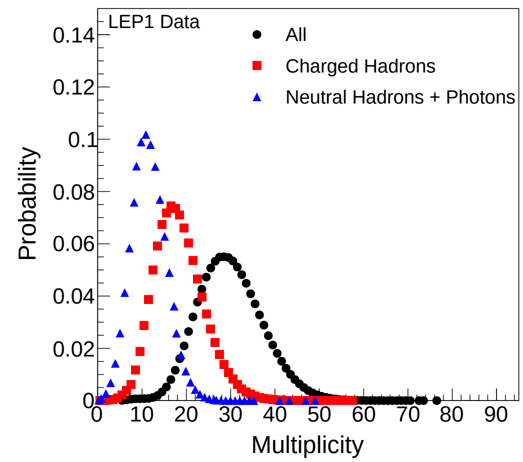

FIG. 4: Multiplicity of all particles, charged hadrons, and neutral hadrons+photons in LEP 1.

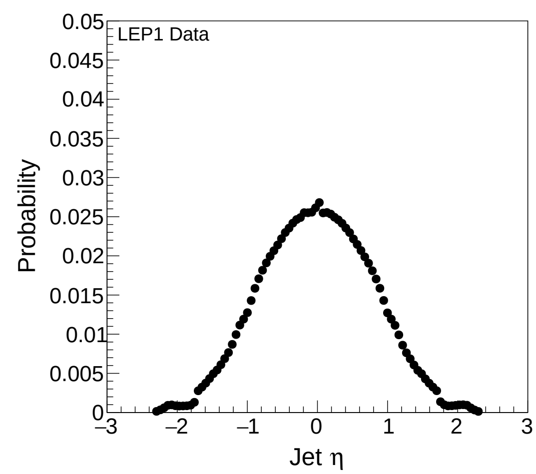

FIG. 5: Jet eta distribution in LEP 1.

LEP1 Monte-Carlo

LEP 2

LEP2 Monte-Carlo

We wish to acknowledge ....

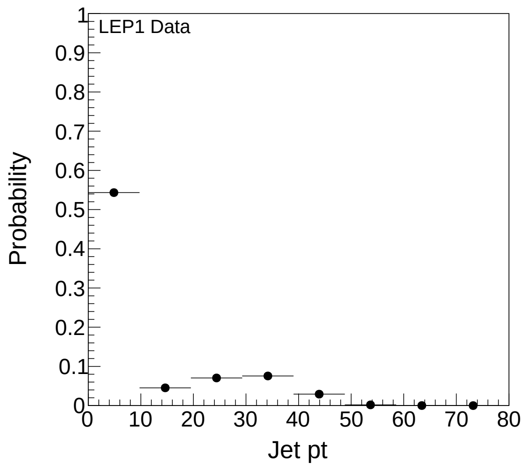

FIG. 6: Jet pt distribution in LEP 1.

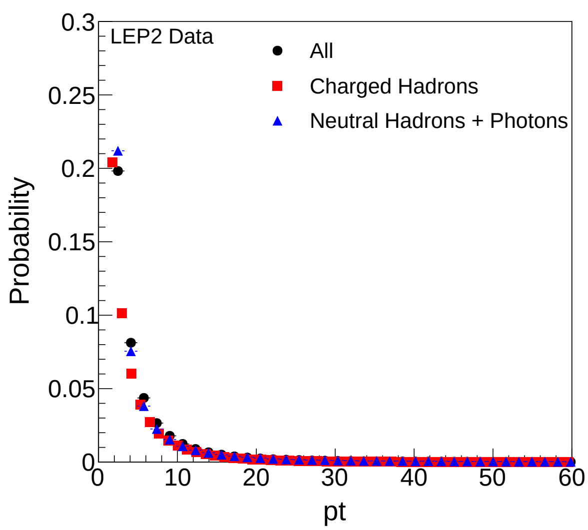

FIG. 7: Momentum of all particles, charged hadrons, and neutral hadrons+photons in LEP 2.

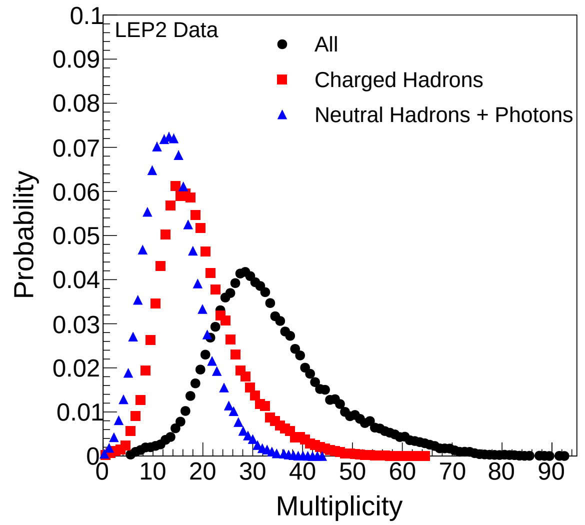

FIG. 8: Multiplicity of all particles, charged hadrons, and neutral hadrons+photons in LEP 2.

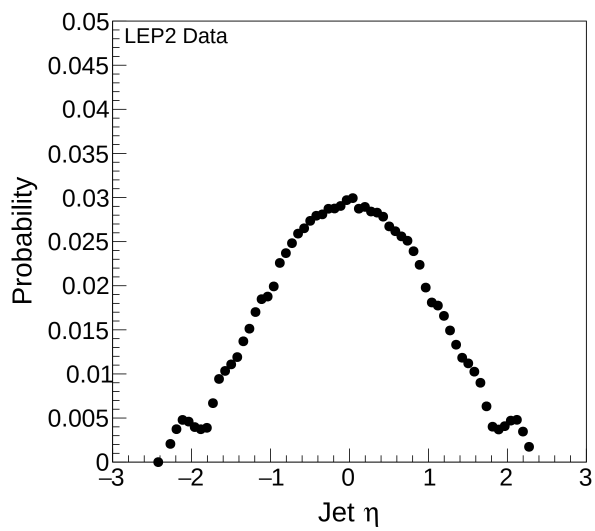

FIG. 9: Jet eta distribution in LEP 2.

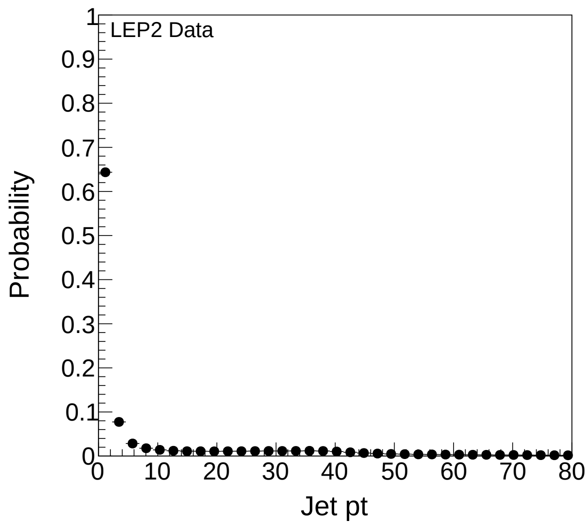

FIG. 10: Jet pt distribution in LEP 2.