

Two-Particle Correlation Analyses with ALEPH Data

Yen-Jie Lee,¹ Gian Michele Innocenti,¹ Austin Baty,¹ Chris McGinn,¹ Bibek Pandit,¹
Anthony Badea,¹ Paoti Chang,² Tzu-An Sheng,² Bean Huang,² and Marcello Maggi³

¹*Massachusetts Institute of Technology*

²*National Taiwan University*

³*INFN Bari*

(Dated: August 16, 2017)

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. In AA collisions, a significant long-range angular correlation between particles was observed. The common interpretation of the results based on the hydrodynamics calculations was that a thermalized system was created in the AA collisions. Recently, similar correlation signals were observed in high particle multiplicity pp and pA collisions. 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 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. 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. These measurements will enable a direct comparison between e^+e^- , pp, pA and AA collisions for the first time.

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) [1], proton-nucleus (pA) [2–4], and nucleus-nucleus (AA) [5, 6] 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 counter-clockwise 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 signifi-

cant modification of the long-range structure compared with minimum-bias pp collisions, over a very wide range of collision energies [7–10]. The long-range correlations are commonly interpreted as a consequence of the hydrodynamical flow of the produced strongly interacting medium [11] 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 [12]. Those measurements allow the extraction of the fundamental transport properties of the medium using hydrodynamic models. Recently, measurements in pp [1] and pPb collisions [2–4] 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 [13, 14]. 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 [15]. Due to the complexity of the hadron-hadron collisions, possible initial state correlations of the partons, such as those arise from color-glass condensate [16, 17], 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.

DATASAMPLE

Add here a description of the data sample.

ANALYSIS

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:

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

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:

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

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

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

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.

SYSTEMATIC UNCERTAINTIES

Add here discussion of the systematic results

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.

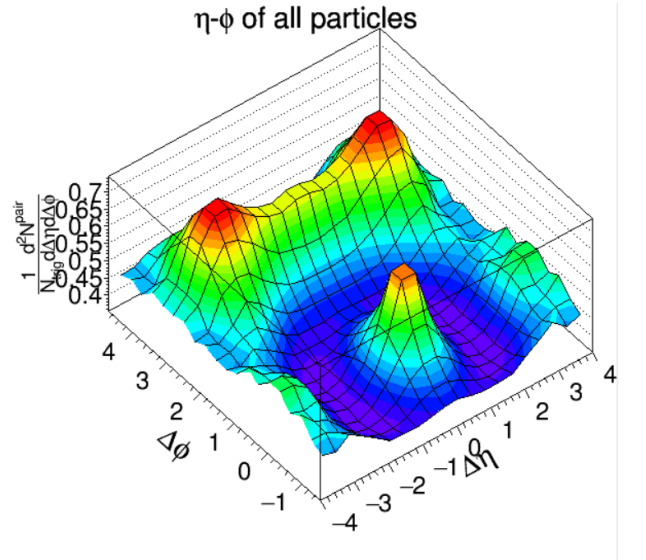


FIG. 1: Two-particle correlation functions versus $\Delta\eta$ and $\Delta\phi$ in e^+e^- collisions for events with particle multiplicity > 20 .

SUMMARY

The ALEPH data has been used to perform measurements of two-particle angular correlation functions for

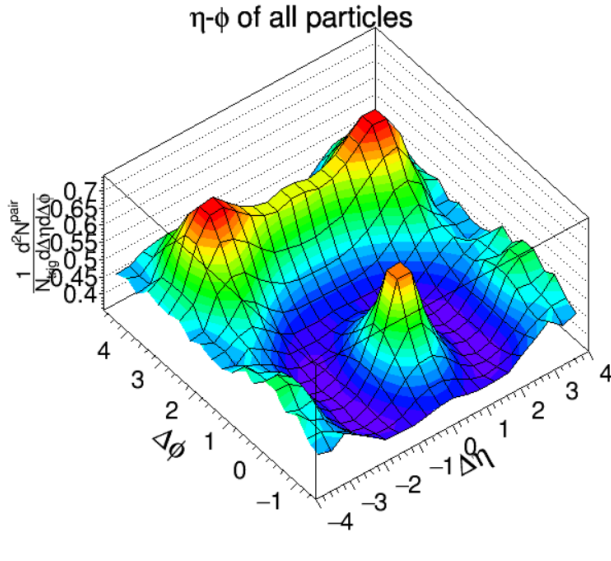


FIG. 2: Two-particle correlation functions versus $\Delta\eta$ and $\Delta\phi$ in e^+e^- collisions for events with particle multiplicity > 50 .

the first time. A hint of long-range ($|\Delta\eta| > 2$) ridge-like structure at the near-side ($\Delta\phi \sim 0$) was shown 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.

We wish to acknowledge

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