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“Characterization of the Topology of Proton-Proton Collisions”

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Abstract
In the LHC’s high-energy proton-proton collision experiments, a great amount of particles are produced after the interaction processes. To better understand the production mechanisms of such particles, it is convenient to study and characterize their topology. To do so, we shall study two-particle correlation functions. These functions are calculated with data generated by the PYTHIA event simulator, and in several different intervals of correlated particle’s transverse momentum. In this way, we may observe a particle jet structure, observed in the experiments and previewed by perturbative QCD, and how such structure is affected by different hadronization models.

Key words:
Elementary Particles, Proton-Proton Collisions, Large Hadron Collider

Introduction

QCD – Quantum Chromodynamics is a quantum field theory, which describes the strong interaction between quarks and gluons. Perturbative QCD (pQCD), one of the theory’s methods, is valid only for high energies, and thus it is expected to describe some of the results observed in LHC’s experiments.
A consequence of this theory is that high momentum quarks are first emitted and undergo fragmentation and hadronization processes afterwards. Therefore, as hadrons are produced, they travel in approximately the same direction as the original quark, in what is called a “jet” structure. Identifying jets in proton-proton collisions processes indicates us the validity of the perturbative theory in describing interactions.
Our objective is to study jet structures using the two-particle correlation method, which gives us functions that describe the topology of the produced particles. Furthermore, after characterizing the topology, we study how different hadronization models available at simulation, such as MPI and Colour Reconnection, affect our results.

Results and Discussion

Our data is generated by PYTHIA 8.2, a Monte Carlo event simulator; it is then analyzed via the 2-particle correlation method, using the ROOT 6.10/04 analysis software. We select particles with $p_T > 4.0$ GeV/c as “trigger” particles, comparing with them “associated” particles with smaller transverse momentum values, p_{Tassoc}. We compare the pseudorapidity η and the angle between the transverse momentum of such particles, φ, thus populating an histogram in (Δη,Δφ) space.
Such a comparison is made for particles generated in the same event, to generate $C_{same}(\Delta\eta,\Delta\varphi)$. We apply a restriction of $|\eta| < 2$ to the data, and this acceptance limitation applies a mathematical bias to the function, which must be corrected. To do this, we must calculate a new correlation function from particles generated in different events, $C_{mix}(\Delta\eta,\Delta\varphi)$; by dividing both functions, we obtain $C_{correct}(\Delta\eta,\Delta\varphi)$, which we shall use for our studies (Image 1). Once we have our correlation functions ready, we project each of them in both axes. Since the peak is approximately gaussian, a gaussian function plus a constant background fits the data. With this fitting function, it is possible to obtain some of the peak’s properties, such as its height, width, and the background’s value.

By doing this, we compare these properties, calculated for each interval of p_{Tassoc}, and observe fewer correlated particles in the jets as their momentum grows.
We then repeat our analysis, now enabling PYTHIA’s Multi-Parton Interaction, Colour Reconnection and Colour Ropes, aiming to observe how these models change the topology and the jets, in particular.

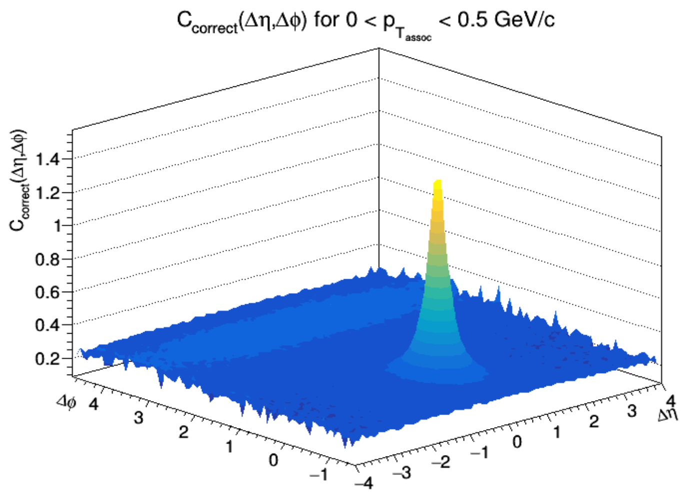

Image 1. $C_{correct}(\Delta\eta,\Delta\varphi)$ for $0 < p_{Tassoc} < 0.5$GeV. The peak observed at (0,0) is the jet structure.

Conclusions

Correlation functions in the (Δη,Δφ) space are a good tool to study the topology of particles produced in high-energy proton collisions. Using two-particle correlation techniques, it was possible to identify the jet structure, as expected according to pQCD, and to analyse how the jets change as the associated particles’ transverse momentum change. Different hadronization models also affect our results.

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