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Measurement of Anisotropic Flow Coefficients V_2 And V_3 Using LHC *Pb+Pb* Collisions Data

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Abstract

Based on the two-particle correlation functions and the data of the detector from the ALICE experiment at the CERN LHC, this paper discusses about measuring and analyzing the anisotropic flow. This team uses python as an approach to plot the graph in order to calculate the value of V2 and V3, resulting in a comparison between this team and the data in the Glauber model. The inspiration this group get comes from the correlation function and the shape of the signal delta phi graph. In addition, this group uses randomness instead of permutation when picking up pairs in order to plot the signal delta phi graph. Eventually, the conclusion this team get is quite similar to the data in the Glauber model but with certain differences. As for the importance of this paper, this group tries their best to explore the mystery inside the nuclei.

Keywords

Anisotropic Flow; Python Calculation; Two-particle Correlation Functions.

1. Introduction

Over the centuries, high-energy formed of matters have been exploring by people gradually. Moreover, this group holds up lots of experiments to break down matters so that they are able to understand the nature and origin of matter at its basic level. For several years, protons and neutrons are regarded as the smallest matter among all. However, in 1960s, the discovery of quarks evolved the main questions in nuclear and particle physics dramatically. The quark model was independently proposed by Murray Gell-Mann and George Zweig [1–3]. It was suggested that the elementary particles were not a multitude of hadrons but combinations of quarks and antiquarks with three flavors: up, down, and strange. In 1968, their hypothesis was proved by the experiment at SLAC [2-4]. Lots of observations was done by physicists by identifying quarks and antiquarks. The unbreakable particles are revealed that they are consist of quarks bonding together through interactions of gluons.

The first and one of only two operating heavy-ion colliders, and the only spin-polarized proton collider is the Relativistic Heavy Ion Collider (RHIC) [1–5]. It was built at Brookhaven National Laboratory in Upton, New York, and used by international team of researchers. As the technique of the equipment improved, the interest in collisions of high-energy nuclei increased largely. Two heavy ion spins rapidly at two respective angle which created a mini-big bang. This experiment gave a clear result about the high-temperate system and hypothesize that there was a critical temperature where the system would have a “free-out” density [3–4]. The experiment from RHIC also caused a large effect attributed to a phenomenon called flow. In collisions between two heavy nuclei at very high energies, the heated overlapping region was perpendicular to the region left behind. Hydrodynamic expansion translated initial configuration space anisotropy into final state momentum distribution.

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The goal in this group experiment is to analyze anisotropic flow using the two-particle correlation functions. The data they based on is from the observation of long range, near side angular correlations in PbPb collisions at LHC. The LHC is the largest and highest-energy particle collider in the world. It is also known as the largest machine in the world. It was built by the European Organization for Nuclear Research between 1998 and 2008 [4–7]. It has collaborated with over 10,000 scientists and hundreds of universities and laboratories, as well as more than 100 countries. Millions of events are collected in the experiment. This group has to figure out the signal and background distribution in order to measure Vn. For calculating the signal distribution, the task is mainly about looping over all pairs of particles 1 and 2 in each event and calculating delta eta and delta phi for each pair and fill 2-D histogram. For the measurement of background distribution, the task is to loop over all pairs of particles 1 and 2 in two different events and calculate delta eta and delta phi and fill 2-D histogram. For the last step, background distribution is assigned to divide the signal distribution. Thus, the function will be arrived. The bigger V_2 and V_3 are, the bigger the elliptic flow and triangular flow are. Through many [8–12], this group finds way out. Comparing the results to predictions from the data in Glauber model, their model is used to calculate "geometric" quantities, which is impact parameter, number of participating nucleons and number of binary nucleon-nucleon collisions. Although results from this group analysis and predictions from the model are quite similar, this group is more specific with the function that contain both V_2 and V_3. The prediction from Glauber model is more general, and this group gets more detailed information to discuss in future.

2. Data and experiment

This group uses the data of the detector from the ALICE detector. The ALICE detector contains several parts. The first part is the tracking detector. It contains the Inner Tracking System, the transition radiation detector, silicon vertex detector and the time projection chamber. These will help to track the particles decay and low momentum particles. To be able to identify the particles, ALICE detector contains several other detectors such as the HMPID detector which is $10m^2$ proximity focusing ring and the transition radiation detector which will identify electrons above 1 Gev. The forward muon arm is also designed to measure the production of heavy quarks and identify muon in the gas detector (resistive plate chamber). The last part of the ALICE detector is the trigger detector. The trigger detector consists of several small and specialized parts of detectors responsible for measuring the global event characteristic including (T0, V0, ZDC, SPD, TOF, TRD, PHOS, EMCal, Muons, ACORDE). They all have fast trigger capabilities.

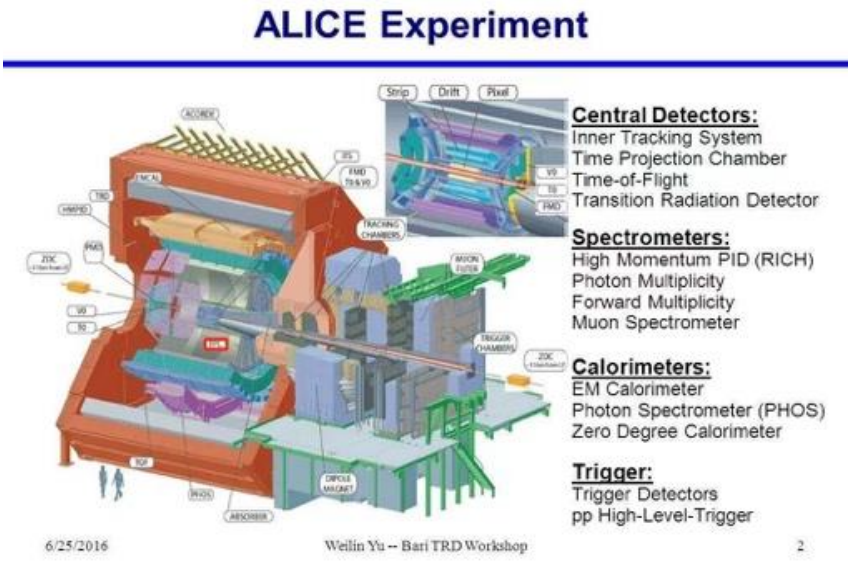

Fig. 1 This figure shows composers of ALICE detector.

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Using the data from the RHIC experiment to demonstrate the correlation functions and measure V_2 and V_3 using the correlation functions. The correlation function contains two parts: the signal distribution and the background distribution. They all look like triangular shape since 2 flat distributions are coenveloped. When this group divides the single distribution by the background distribution, they can get the correlation function [13].

The correlation function shows how much particles are correlated when delta eta (Δη) and delta phiΔφ changed, which means the difference between the azimuthal angle of two particles and a means the pseudo rapidity between particles. For instance, when the correlation function is flat, it tells that the particles are uncorrelated, i.e., a particle's trail is independent of other particles trial, and they don't like to be close to each other. When the correlation function reveals a peak (maximum), it means that the particles is like to be at the particular distance. After that, this group can analyze the anisotropic flow using the correlation function and calculate V_2 and V_3. The bigger the V_2 and V_3 means the bigger the elliptic flow and triangular flow. The flow signal is in the modulation of the correlation function in and characterized by the coefficients V_2 and V_3 of a fit like $f = N \times (1+2\times V2^2\times\cos(2\times\Delta\varphi) +2\times V\ 3^2\times\cos(3\times\Delta\varphi)$. The signal distribution can be calculated by looping over all pairs of particles 1 and particles 2 in each event and then measure Δφ and Δη by using the formula $\Delta\eta = \eta1 - \eta2$ and $\Delta\varphi = \varphi1 - \varphi2$. After that, this group is able to illustrate the 2-D histogram for signal distribution. As for background distribution, this group loops all pairs of particles1 and 2 in 2 different events and calculate Δη and Δφ. Finally, this group is able to divide two histograms to obtain the correlation function to calculate V_2 and V_3.

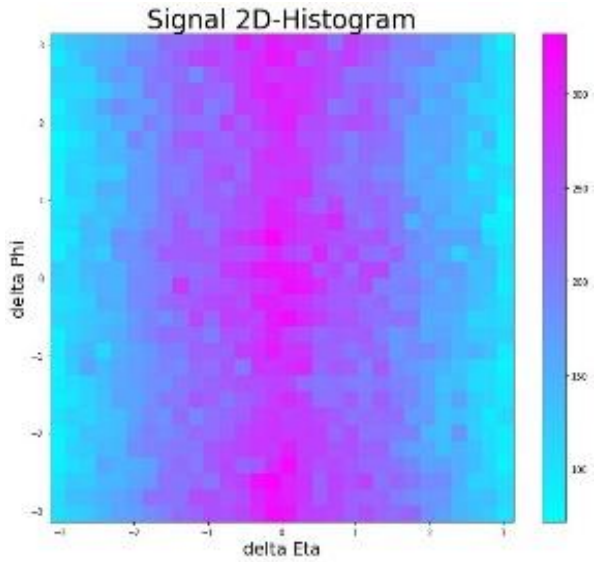

Fig. 2 This figure shows the signal 2-D histogram

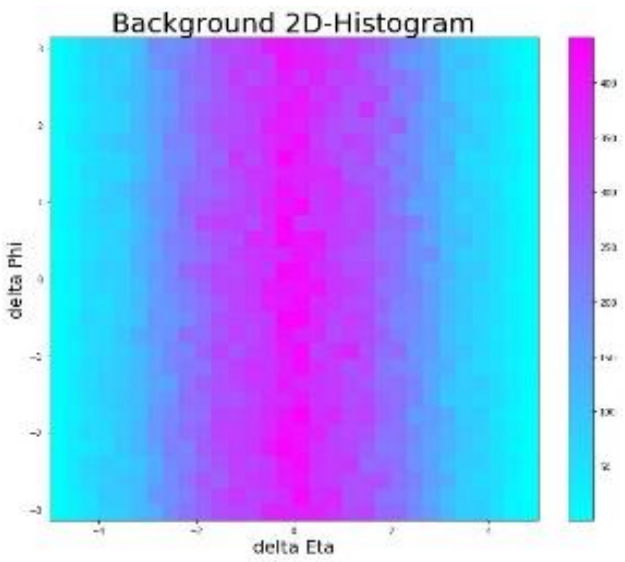

Fig. 3 This figure displays the background 2-D histogram

Furthermore, this group uses Python as a tool to calculate V_2 and V_3. In the consideration of python coding language, four lists are first built to store the values of pt, eta, phi, charge. This can accomplish the goal of importing data and eta [0] [1] which can be used to represent the first eta value in event 0. In addition, during the process to pick up pairs of particles, this group comes up with two approaches to accomplish their purpose: the first method is to use permutation, and the second way is to pick up pairs of particles randomly. Then, after a few trials, this group decides to pick pairs of particles randomly instead of using permutation because this can minimize the error brought by the fact that phi values in the file are organized. After this group subtract the phi and eta values from the pairs of particles chosen from the same event, they are able to access of two lists: signal delta eta and signal delta phi. Also, this group randomly pick up pairs of particles in different events, which enables them to acquire background delta eta and background delta phi by using the same method except collecting

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pairs of particles from different events. In this case, the following part is to produce signal and background 2-D histogram using these 4 lists.

In order to calculate V_2 and V_3, this group uses the same way of importing and choose pairs of particles. Next, this group obtains the list which contained the values of delta phi and construct a 1-D histogram of it. Finally, by best fitting the shape of the histogram, this group gains the unknown values in the function $f = N \times (1+2\times V2^2\times\cos(2\times\Delta\varphi) +2\times V\ 3^2\times\cos(3\times\Delta\varphi)$.

3. Results and discussion

The values of V_2 and V_3 are 0.008248080201074308 and 0.002011151468920877. The values of V_2 and V_3 were calculated in the correlation function after plotting signal delta phi graph and finding best fit shape of the graph. Compared the result with the graph in the Glauber model, this group's result is quite similar with that. However, this group gets inspiration in the correlation function and the shape of the signal delta phi graph. What is more, when this group plots the signal delta phi graph, they decide to pick pairs of particles randomly instead of using permutation, since this can reduce the error brought by the fact that phi values in the file are organized. As a result, the prediction this group supposes is more detailed rather than general, and the accuracy of values is high.

Nevertheless, there are several drawbacks of their approach. First, this group has not averaged the values, which means they could still eliminate many errors in the future development. Second, they are able to enlarge the data used in their calculations, since their approach is to randomly calculate angle of the delta phi rather than using the permutation. Third, the number of strips of the 1-D histogram created by python are limited. In this regard, the accuracy of the final values for V_2 and V_3 are also limited. In addition, this group supposes that the value of V_2 is in the interval of [0.006, 0.009] and the value of V_3 is in the interval [0.001,0.005].

After several group discussions, group members got solutions. First, in order to improve the 1-D histogram, this group should repeatedly run the file in python thousands of times in order to average the values to eliminate almost all the error. Admittedly, randomly picking up the pairs to calculate the delta phi means that there are still some pairs this group has not used when they calculate the value of V_2 and V_3. The more data being used, the more representative the final result is. As a result, the second goal of this group is to deal with more data they used in the calculation of signal and background graph. Third, they should increase the number of strips as many as possible to increase the accuracy. All in all, their result is quite successful and matched their hypothesis. Furthermore, this group's discussion is efficient, helpful, and meaningful.

4. Conclusion

Although team members in this group come from different parts of the country, which means they can only communicate online, they sacrificed their leisure time and burned mid-night oil, spending tons of time and energy. Modifying the python code, revising the paper, asking questions to professor and teacher assistant about specific academic knowledge. Thanks to professor's high-standard requirement, along with logic and rigorous process, the prediction in the hypothesis is fortunately in the proper range. This group focuses on calculating the value of V_2 and V_3 in the correlation function after plotting signal delta phi graph and finding best fit shape of the graph. As for the unique part of the project, python is used by this group to plot the graph, and randomness is placed of the permutation, improving the accuracy of the result. However, this group still has to make up several shorts in their result. First, to improve the 1-D histogram, they should repeatedly run the file in python thousands of time in order to average the values to eliminate almost all the error. Admittedly, randomly picking up the pairs to calculate the delta phi means that there are still some pairs this group has not used when they calculate the value of V_2 and V_3. Plus, the data should be as representative as possible. Thus, the second goal of this group is to enlarge the data they used in the calculation of signal and background graph. Third, they should increase the number of strips as many as possible to increase the accuracy. The result arrived in this paper is quite similar to the values in the Glauber model. In addition, the result is not only accurate but also specific, allowing us to do deeply analysis in the future.

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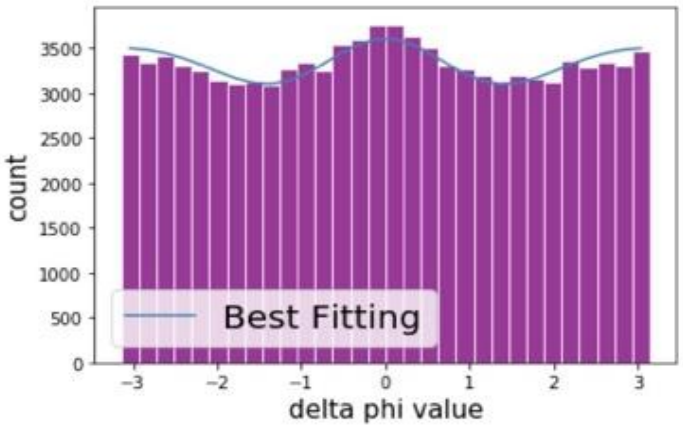

Fig. 4 This graph shows the best fit line

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