

Dependence on Collision Centrality of Charged Particle Production at $\sqrt{S_{NN}}=2.76$ TeV

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Abstract. The ALICE collaboration provides data for particle collisions. With the help of Glauber model calculation, the collisions are categorized in to different centralities. Then, a tracklet algorithm is used on each of the centrality category. The relationship between charged particle production and collision centrality is derived, and the result is in agreement with similar work done previously.

Keywords: Charged particle production, Glauber model, relationship, collision.

1. Introduction

The particle colliders enable researches about high-energy particle interaction to be conducted. In better understanding the structure of microscopic particles, works has been done investigating collisions between particles in different energy levels. This research is aimed to find out the centrality dependence of charged particle production in Pb-Pb collision. Similar works as been conducted by ALICE collaboration [4] and other research.

The data for this research was derived from the ALICE collaboration at CERN LHC. The Silicon Pixel Detector (SPD) is the primary source of data. It is a two-layer cylindrical detector in direction of the beam axis. The inner and outer layers cover pseudo-rapidity of $|\eta|<2.0$ and $|\eta|<1.4$ respectively. It has at total 9.8×10^6 pixels, computed by 1200 chips. A specific description of the detector is given in Ref.[1]. Two VZERO counters (V0A and V0C) are used to help detect the trigger of collision events. Specific description of the detector can be found in Ref.[2]. An event is triggered when at least two of the following conditions occur: i) two pixel chips hit in the outer layer of the SPD, ii) a signal in VZERO-A, iii) a signal in VZERO-C. Furthermore, two Zero Degree Calorimeters (ZDCs), located at about 116m from the interaction point, are used to help carry out event selection. The trigger occurs at a rate of about 50Hz. About 45Hz is caused by electromagnetic processes. These events are excluded by requiring an energy deposition above 500 GeV in each of the neutron ZDCs. Roughly 1Hz comes from the beam background. This is eliminated using the timing information of the VZERO detectors. As a result, the remaining triggers will be used. [5] Data of 20000 events are used in this paper.



In the following section, the data will be separated into different centrality classes. Then, tracklet method will be applied to each centrality category. After that, corrections and optimization will be done, and uncertainties will be calculated, leading to the result.

Table 1. The centralities values.

Centrality	$\langle N_{\text{part}} \rangle$
0-5%	382.8 \pm 3.1
5-10%	329.7 \pm 4.6
10-20%	260.5 \pm 44.4
20-30%	186.4 \pm 43.9
30-40%	128.9 \pm 43.3
40-50%	85.0 \pm 42.6
50-60%	52.8 \pm 42.0
60-70%	30.0 \pm 41.3
70-80%	15.8 \pm 40.6

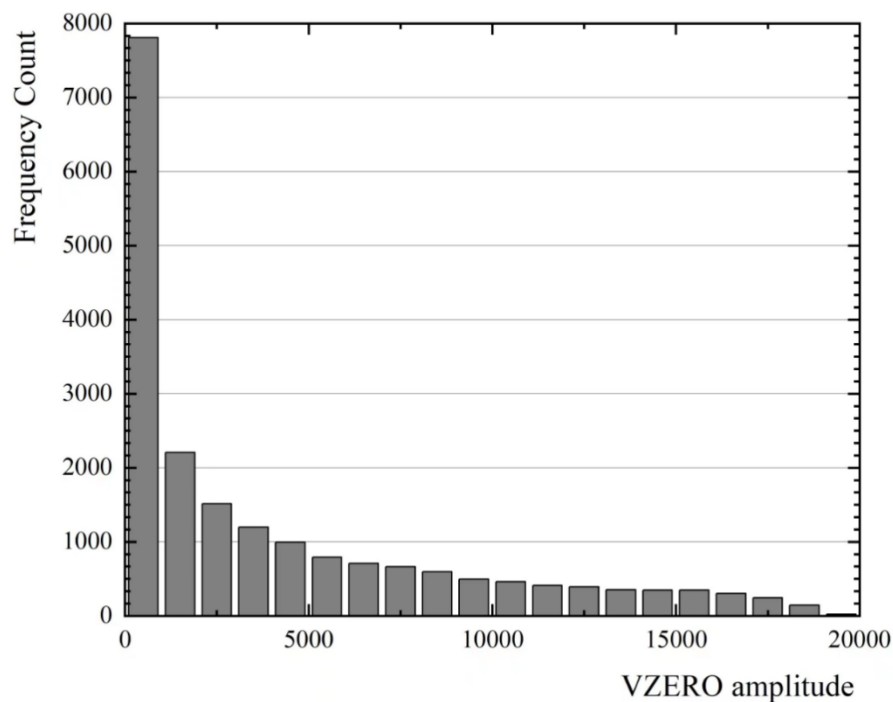


Figure 1. The distribution of VZERO amplitudes.

2. Centrality determination

Centralities are determined using data from VZERO detectors. Figure 1 shows the distribution of VZERO amplitudes of all analyzed events. The centralities are categorized using Glauber model. The values are taken from calculations of same parameters in Ref.[3], as shown in Table 1.

3. The tracklet algorithm

To estimate the $dN_{ch}/d\eta$ ($|\eta| < 1$) for each centrality, the Tracklet Algorithm is used in this section. A pair of $[\Delta\phi, \Delta\eta]$ is labeled as "tracklet". The $\Delta\phi$ means the differences in the azimuthal angles between a point in the inner layer and another in the outer layer, and the $\Delta\eta$ can be obtained in the same way.

As in Figure 2, the 2D histogram of $\Delta\phi, \Delta\eta$ shows a pick in the center area, representing the N_{ch} mentioned before.

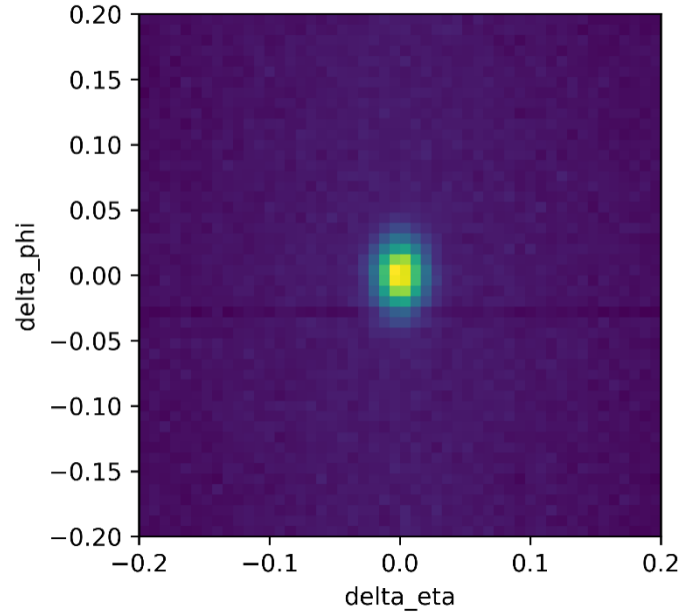


Figure 2. The 2D histogram of $\Delta\phi$ (only the central part).

In order to obtain the $N_{ch}/d\eta$ distribution from the background signal, the Algorithm first divides the distribution into two parts along $\Delta\phi$ axis:

- Center Band(CB): contains the signal of N_{ch} , ranging from $\Delta\phi \in [-\Delta\phi_{cut}, \Delta\phi_{cut}]$
- Side Band(SB): denotes the background signal, ranging from $\Delta\phi \in [-2\Delta\phi_{cut}, -\Delta\phi_{cut}] \cup [\Delta\phi_{cut}, 2\Delta\phi_{cut}]$

where the $\Delta\phi_{cut}$ is a parameter whose value should be estimated in the following steps. In the following steps, $fN_{cb}(\Delta\eta, \Delta\phi)$ is used to denote the 2D distribution of center band, while $fN_{sb}(\Delta\eta, \Delta\phi)$ is for that of side band.

1. Integral $fN_{cb}(\Delta\eta, \Delta\phi)$ over $\Delta\phi \in [-\Delta\phi_{cut}, \Delta\phi_{cut}]$ and $fN_{sb}(\Delta\eta, \Delta\phi)$ over $\Delta\phi \in [-2\Delta\phi_{cut}, -\Delta\phi_{cut}] \cup [\Delta\phi_{cut}, 2\Delta\phi_{cut}]$ to get 1D distribution $fN_{sb}(\Delta\eta)$ and $fN_{cb}(\Delta\eta)$

2. Integral $N_{sb}(\Delta\eta)$ and $fN_{cb}(\Delta\eta)$ over $|\Delta\eta| > |\Delta\eta_{cut}|$ and obtain N'_{sb} and N'_{cb}

3. Scale(normalize) the CB distribution $fN_{cb}(\Delta\eta)$ with a factor $\frac{N'_{sb}}{N'_{cb}}$

4. Calculate the $fN_{ch}(\Delta\eta) = fN_{cb}(\Delta\eta) - fN_{cb}(\Delta\eta) \frac{N'_{sb}}{N'_{cb}}$

5. Integral $fN_{ch}(\Delta\eta)$ over $|\Delta\eta| < 2$ and get $dN_{ch}/d\eta$

In this article, the $\Delta\eta_{cut}$ is selected as 0.25.

Table 2. Relationship between $dN/d\eta$ and Npart values for each centrality category.

dN/ d η	Error	Npart	Error	(dN/d η)/Npart	Error	(dN/d η)/(Npart/2)	Error2
2600.417692	522.36	382.80	3.1	6.79	1.37	13.59	2.73136489
2163.21692	444.99	329.70	4.6	6.56	1.35	13.12	2.70555078
1586.10385	366.89	260.50	4.4	6.09	1.41	12.18	2.824310363
1046.27154	243.60	186.40	3.9	5.61	1.31	11.23	2.624307443
670.878923	161.09	128.90	3.3	5.20	1.26	10.41	2.513581821
409.022308	103.96	85.00	2.6	4.81	1.23	9.62	2.46376656
232.789077	66.37	52.80	2	4.41	1.27	8.82	2.536166996
120.618769	37.87	30.00	1.3	4.02	1.27	8.04	2.548282529
57.1938077	22.17	15.80	0.6	3.62	1.41	7.24	2.819494324

Table 3. Values of standard deviation in each centrality class.

standard deviation									
384.376	335.021	293.317	193.804	132.525	90.4423	57.8904	33.4311	20.1694	
405.854	356.753	308.247	201.345	136.73	92.9436	58.9309	34.3089	20.3196	
431.406	366.089	320.254	207.194	140.239	94.8289	60.6341	34.8168	20.3167	
448.6	389.569	330.127	215.157	144.841	95.2529	61.9246	35.5257	20.8104	
469.466	406.56	336.991	223.61	149.047	97.1899	62.7185	36.4541	21.224	
486.238	427.864	350.279	231.913	153.668	99.3976	64.9134	36.8264	21.3691	
501.872	447.315	363.841	242.416	158.399	101.012	66.5805	37.235	21.754	
537.013	460.539	374.791	249.636	163.316	103.51	67.4143	37.869	22.1139	
570.053	470.362	386.902	257.929	168.519	107.303	68.5396	39.1182	22.4137	
592.174	490	398.238	267.234	174.395	110.207	70.0769	39.661	22.8484	
618.429	511.216	415.128	277.534	182.694	115.133	72.1079	40.9366	23.5629	
652.612	545.61	433.976	291.598	190.331	118.903	74.4337	42.2652	25.138	
692.573	577.942	457.474	307.48	199.431	125.356	76.6664	43.7995	26.1421	

After having the first group of our result, we find that the data show that the number of particles for each centrality show an increase trend as the band width get larger, which is not what we are looking for. This is mainly because the shape of both η and ϕ background have a triangular shape which dropped as we go away from 0. This leads to a low sideband region background estimate when we do the measurement in δ and with the sideband and signal region selected in ϕ . To eliminate the effect, we tried to normalize the signal-deta distribution ($|\phi| < 0.05$) and the sideband-deta distribution ($|\phi| > 0.05$) away from the signal. Firstly, obtain the integral of signal-deta distribution for $|\eta| > 0.25(N_S)$, then we

calculate the integral for the sideband-deta distribution in the same range (N_{SB}). Finally we multiply all the entries in the sideband deta distribution by the scale N_S/N_{SB} , then subtracts the central band with the sideband. The main source of the systematic error is the error propagation from N_S and N_{SB} . Those uncertainties are shown in Table 2, and standard deviation values are given in Table 3.

4. Conclusion

So, our procedure shows that the mean of $dN/d\eta$ will decrease gradually as the centrality goes up and the same for the variance. When the centrality is 0–5%, the mean of $dN/d\eta = 2600.418 \pm 522.359$, in 20–30% $dN/d\eta = 1046.272 \pm 243.604$. The relationship between $(dN_{ch}/d\eta)/\langle N_{part}/2 \rangle$ and N_{part} is shown in Figure 3.

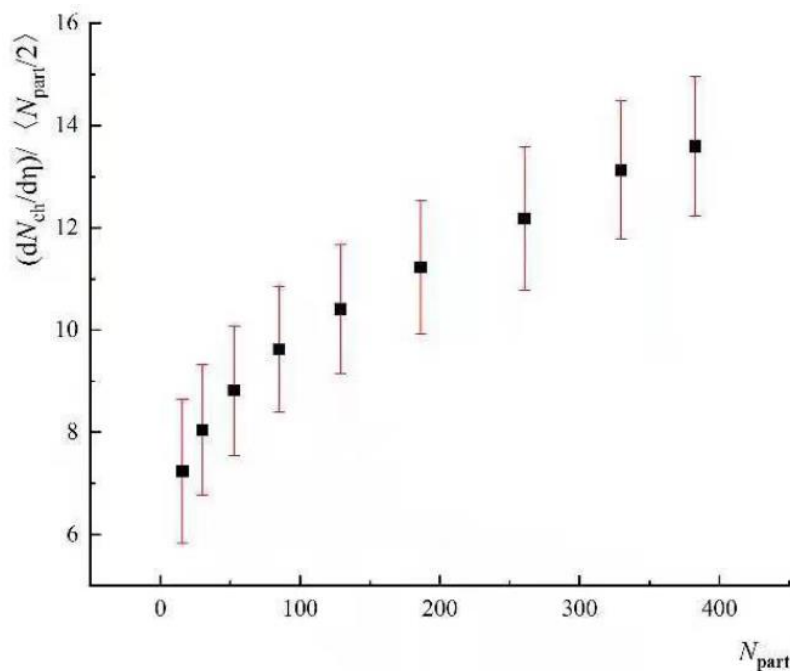


Figure 3. Centrality dependence of charged particle production.

References

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