Two-particle correlations in pp collisions at the LHC with ALICE

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Abstract

The double ridge structure previously observed in Pb-Pb[1, 2, 3] collisions has also been recently observed in high-multiplicity p-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV [4, 5]. These systems show a long-range structure (large separation in $\Delta\eta$) at the near-side ($\Delta\varphi \simeq 0$) and away-side ($\Delta\varphi \simeq \pi$) of the trigger particle. In order to test whether this near side structure is specific to heavy ion collisions the same analysis was done for pp collisions. Multiplicity classes were selected through looking at the multplicity in the forward region in the VZERO detector.

1 Introduction

The two particle correlation is a powerful tool for analysing particle production in collisions of nuclei at high energy and in proton-proton (pp) collisions. Such studies involve measuring the distributions of relative angles $\Delta\varphi$ and $\Delta\eta$ between pairs of particles: a “trigger” particle in a certain transverse momentum p_{T} interval and an “associated” particle in a $p_{\mathrm{T,assoc}}$ interval, where $\Delta\varphi$ and $\Delta\eta$ are the differences in azimuthal angle φ and pseudorapidity η between the two particles. The particle distributions seen in Pb-Pb collisions involve two obvious features, these are an away side and an near side ridge. These ridges are located at $\Delta\varphi \approx 0$ and $\Delta\varphi \approx \pi$ and are relatively constant along $\Delta\eta$.

For pp collisions the two particle correlation is dominated by the near side jet peak located at $\Delta\varphi \approx 0, \Delta\eta \approx 0$, and at $\Delta\varphi \approx \pi$ and constant along $\Delta\eta$. Although recent measurements for pp [6] and p-Pb [7] collisions with a centre-of-mass energy $\sqrt{s} = 7$ TeV and $\sqrt{s_{NN}} = 5.02$ TeV have observed long range near side ridges for events in higher than average multiplicity. Even more recently for p-Pb collisions the same sear side ridge was observed but also an away side ridge as well [4, 5]. The near side and away side ridge was observed when subtracting the jet counts using low multiplicity events.

This work presents results from two-particle correlation measurements in pp collisions at $\sqrt{s} = 7$ TeV. The analysis is described in detail in section 2 and the results summary is in section 3.

2 Analysis

2.1 Data Analysis

The runs chosen were of pp collisions taken in 2010 from period b AOD 137, c AOD 137 and d AOD 135. The first thing looked at was distribution of the multiplicity in the VZERO detector. The values for this distribution looked at were aquired using this function inputEvent->GetVZEROData()->GetMTotV0A(). This histogram is of the number of counts recieved on the V0A detector, the acceptance of the detector is $2.8 < \eta < 5.1$. The events in histogram are put into bins of the signal they produced (V0AMultiplicity). The first thing done was to look at the VZEROAMultiplicity histograms mean values and compare them for each run, this is shown in figure 1.

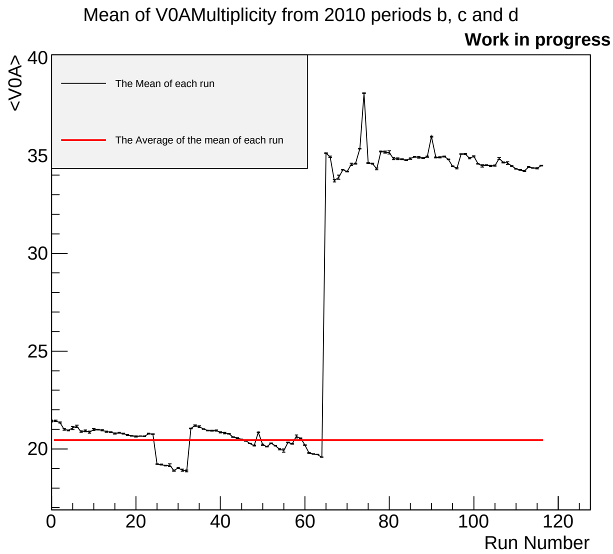

Figure 1: Graph of means extracted from VZEROAMultiplicity histograms and plotted against the runs going in order from b, c to d. The red line is an average of the means for period b and c alone.

2.2 Multiplicity Class

As can be seen in figure 1 the means over the runs vary especially for period d. The variations can come from a difference in data taking conditions such as environment or detector configuration. The average of the means of period b and c has been plotted in order to correct for this variation scale factors were worked out for each run from this average. These scaling factors are applied to the VZEROAMultiplicity signal. To check whether or not the variation in the runs mean were due to the shape of the histograms or whether it needs a simple scaling factor a ratio of two scaled histograms was performed in figure 2.

As can be seen from figure 2 the ratio of the histograms comes out flat up to V0AMultiplicity of 100. This clearly shows that the shapes of the histograms are not different and are not causing the fluctuations so it is just a simple scaling factor needed. The scaling factors were applied to the runs and the means were plotted again.

Figure 3 shows that the means have now been scaled to around the average calculated in figure 1 and is now flat. The VZEROMultiplicity histograms

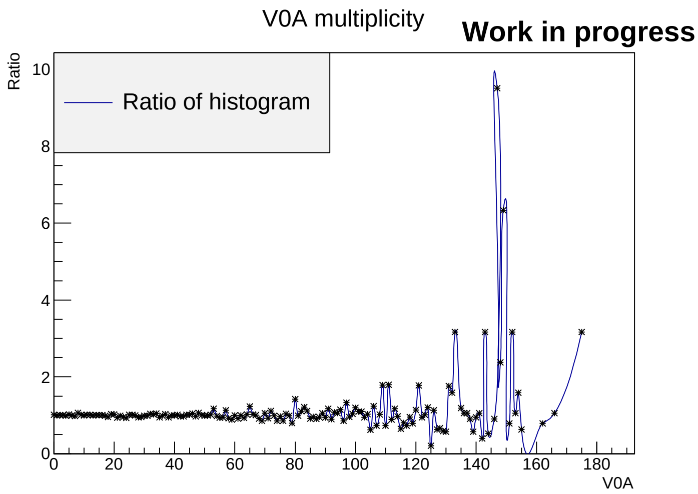

Figure 2: Graph of two VZEROMultiplicity histograms scaled divided. Run numbers 116403 and 119163.

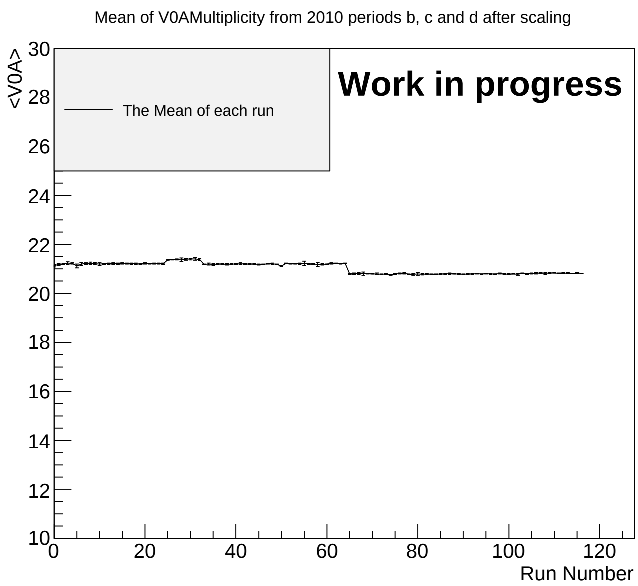

Figure 3: Graph of means extracted from VZEROAMultiplicity histograms after being scaled and plotted against the runs going in order from b, c to d.

were then merged and multiplicity classes were defined as the fraction of events within the VZERO signal.

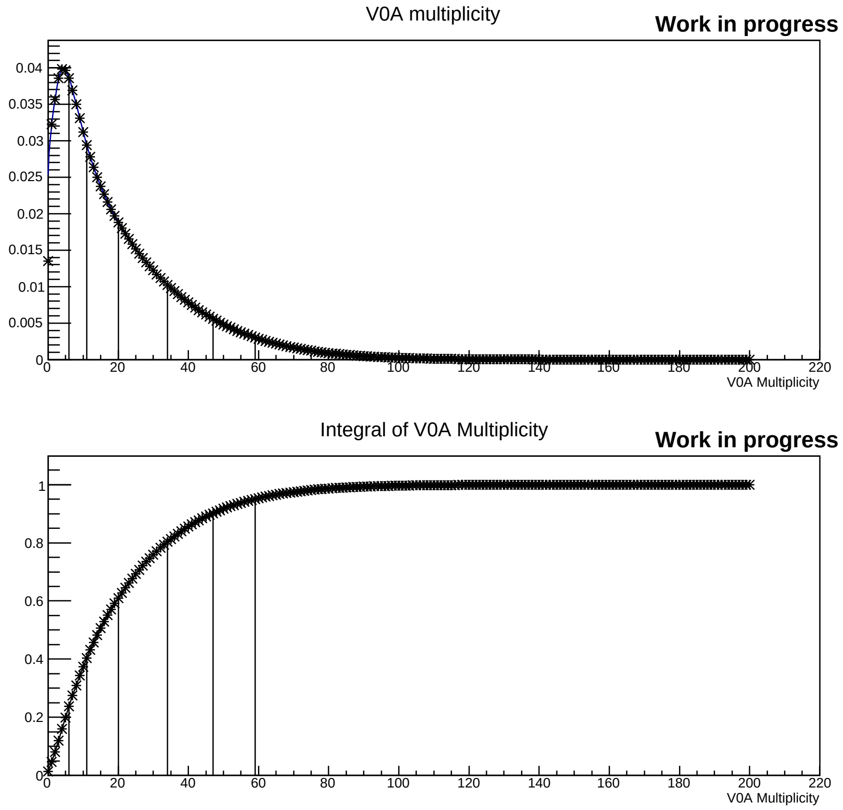

Figure 4: The upper graph is the merged histograms with the lines defining the event classes. Lower graph is of the integration of the merged VZERO-Multiplicity histograms, the lines showing the V0A values that correspond to where the multiplcity class cuts have been made.

Event Class	V0M range (a.u.)
60-100%	< 11
40-60%	$11 - 20$
20-40%	$20 - 34$
0-20%	> 34

From figure 4 the event classes defined were 60-100%, 40-60%, 20-40% and 0-20%.

2.3 Analysis Procedure

For each event class the two particle correlation between pairs of trigger and associated charged particles is measured as a function of the azimuthal angle difference $\Delta\varphi$ and pseudorapidity difference $\Delta\eta$. The correlation is expressed with the associated yield per trigger particle for different intervals of trigger and associated transverse momentum, $p_{\mathrm{T,trig}}$ and $p_{\mathrm{T,assoc}}$, respectively, and $p_{\mathrm{T,assoc}} < p_{\mathrm{T,trig}}$. The associated yield per trigger particle is defined as

$$\frac{1}{N_{trig}}\frac{d^2N_{assoc}}{d\Delta\eta d\Delta\varphi} = \frac{S(\Delta\eta,\Delta\varphi)}{B(\Delta\eta,\Delta\varphi)} \tag{1}$$

an example is shown in figure 5.

From figure 5 the $\Delta\varphi$ projection the data points are fitted with the function $a_0 + 2a_2\cos(2\Delta\varphi) + 2a_3\cos(3\Delta\varphi)$. From this function the variable v_n is defined as $v_n = \sqrt{\frac{a_n}{b}}$ where b is the baseline of the $\Delta\varphi$ projection for the multiplicity class $(0-20\%)$. The parameter looked at is v_2 to quantify the near side and away side ridge. In order to reduce the affect of the near side jet peak on the v_2 values data points with a region around $\Delta\eta = 0$ were removed. The default size of this region were points within $|\Delta\eta| < 0.8$. The v_2 values were also compared to p-Pb collisions with the same analysis done.

In the bottom left of figure 5 for pp collisions it can be seen there is still a large near side jet peak left after the multiplicity class subtraction $(0-20\%) - (60-100\%)$. This differs greatly compared to p-Pb collisions which can be seen in figure 6 bottom left. It can be seen there is a very little near side jet peak left and that there is a clear near side ridge.

In figure 5 bottom right it can be seen that the away side ridge data points have a much smaller error than the near side. This difference in errors causes the function fit to have bias on the away side. In order to reduce this bias $\Delta\eta$ cuts were also applied to the away side ridge increasing the size of the error bars this can be seen in figure 8 top left. This time v_2 was calculated with data $|\Delta\eta| < 0.4$ removed and also no data points removed.

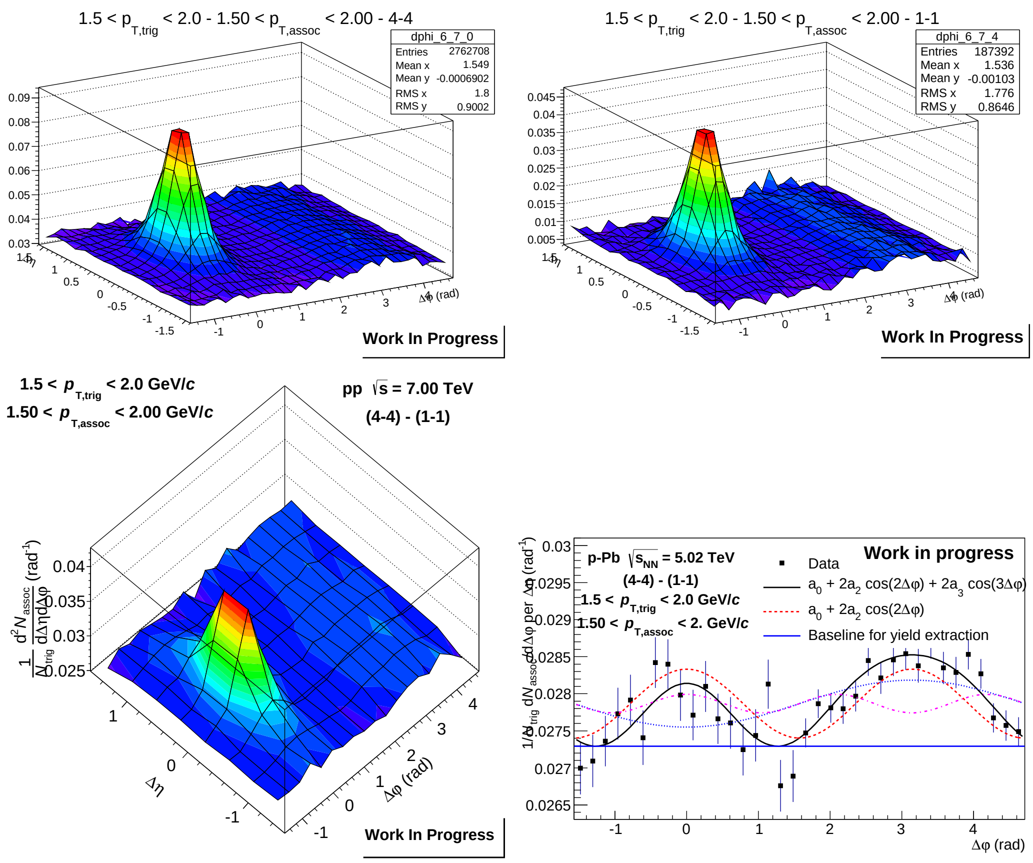

Figure 5: All figures above are of pp collisions p_{T} range 1.5-2.0 GeV. The top left, top right and bottom left figures are all of the associated yield per trigger against $\Delta\eta$ and $\Delta\varphi$. The top left is the event class 0-20%, top right is the event class 60-100% and the bottom left is of the subtraction (0-20%)-(60-100%). The bottom right figure is of $\Delta\varphi$ projection of the bottom left figure with data points $|\Delta\eta| < 0.8$ removed for the near side ridge as to eliminate v_2 dependance on the near side jet peak.

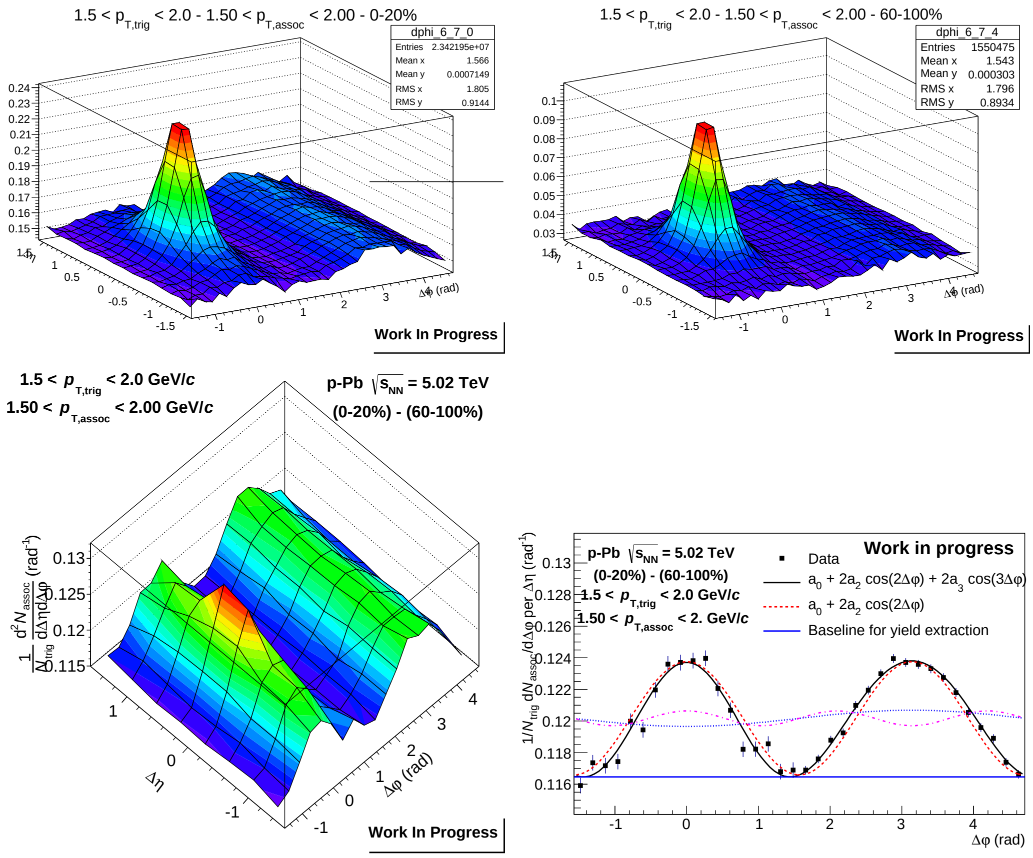

Figure 6: All figures above are p-Pb collisions of p_{T} range 1.5-2.0 GeV. The top left, top right and bottom left figures are all of the associated yield per trigger against $\Delta\eta$ and $\Delta\varphi$. The top left is the event class 0-20%, top right is the event class 60-100% and the bottom left is of the subtraction (0-20%)-(60-100%). The bottom right figure is of $\Delta\varphi$ projection of the bottom left figure with data points $|\Delta\eta| < 0.8$ removed for the near side ridge as to eliminate v_2 dependance on the remaining near side jet peak.

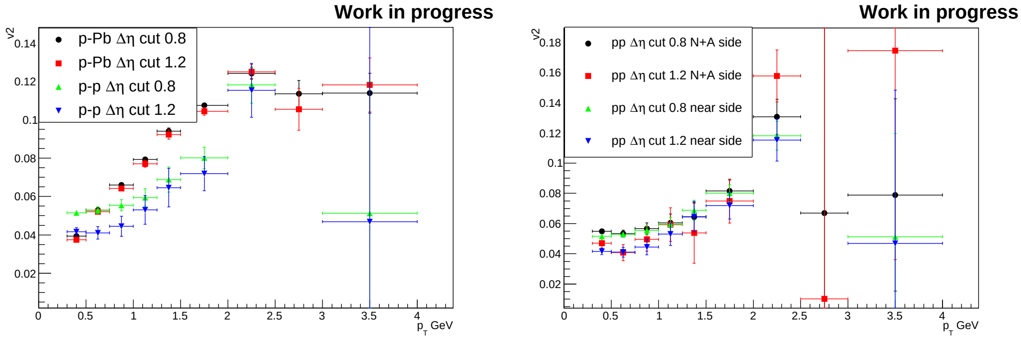

Figure 7: Left is a graph of v_2 values for pp and p-Pb collisions with cuts $|\Delta\eta| < 0.8$ and $|\Delta\eta| < 1.2$. Right is a graph of v_2 values for pp collisions with $\Delta\eta$ cuts $|\Delta\eta| < 0.8$ and $|\Delta\eta| < 1.2$ but this time with the cuts applied to the away side as well.

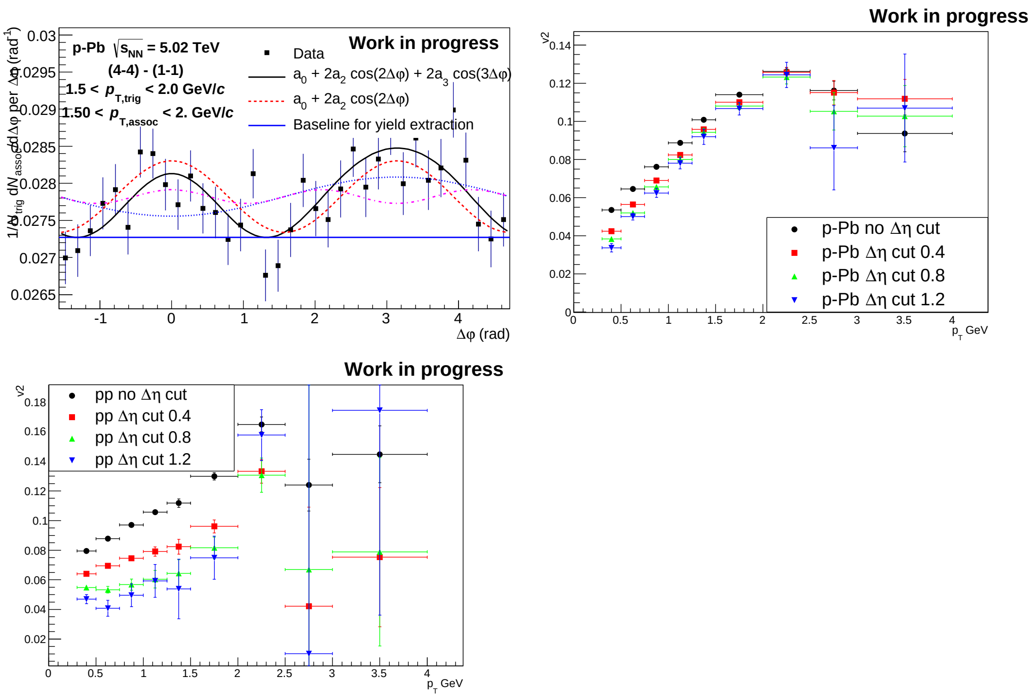

Figure 8: Top left figure is $\Delta\varphi$ projection of the bottom left figure in figure 5 with data points $|\Delta\eta| < 0.8$ removed on the near side and away side ridge. The top right figure and bottom left figure are graphs of v_2 values for different p_T bins. The top right graph is v_2 values for p-Pb collisions and bottom left is for pp collisions both with different $\Delta\eta$ cuts.

3 Results

The particle correlation analysis on pp collisions of centre-of-mass energy $\sqrt{s} = 7$ TeV are looked at for various p_{T} bins within $0.2 < p_{\mathrm{T,assoc}} < p_{\mathrm{T,trig}} <$ 4GeV/c. From the v_2 values extracted from the $\Delta\varphi$ projections a clear difference can be seen between p-Pb and pp. In figure 7 on the left the v_2 values do not have much $\Delta\eta$ dependance for p-Pb, and only a slight $\Delta\eta$ cut dependance for pp below $p_{\mathrm{T}} < 1GeV/c$. After the $\Delta\eta$ cuts applied to the away side ridge as well as the near side the v_2 values have more $\Delta\eta$ cut dependance as is seen in figure 7 graph on the right. The $\Delta\eta$ cut dependancy is more clear in figure 8 the away side is again cut and lower $\Delta\eta$ cuts are made. As pp collisions v_2 values have a much bigger $\Delta\eta$ cut dependance than p-Pb collisions its evidence that there is no significant near side ridge present in pp collision events for the event class $(0-20\%)$ and jet contribution dominates.

References

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