Summer Student Project Report

π^0-charged hadron correlations in p-Pb $\sqrt{s_{NN}} = 5.02$ TeV collisions with the ALICE PHOS

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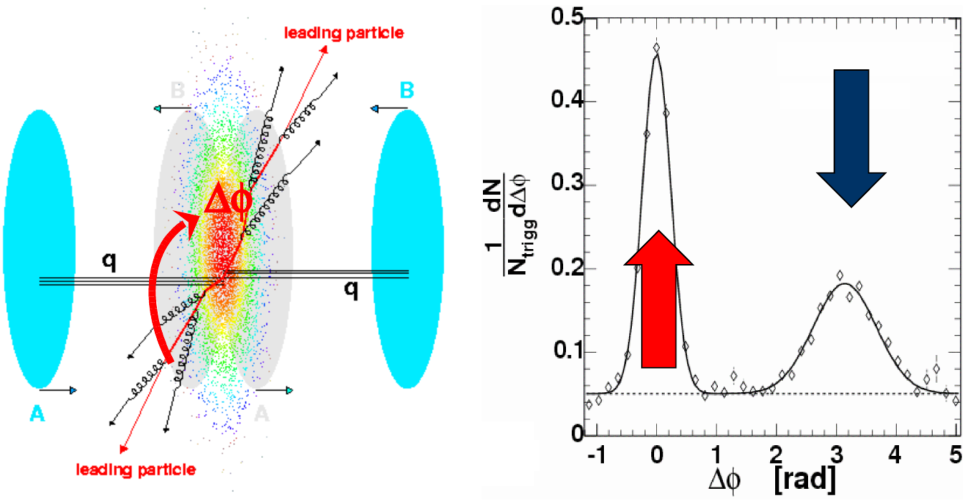
1 Introduction

Measurements of azimuthal correlations between two particles are a powerful tool to study the underlying mechanism of particle production in collisions of hadrons and nuclei at high energy. In this note, the analysis of π - hadron correlations in p-Pb at $\sqrt{s_{NN}} = 5.02$ TeV is presented. The two main measured observables are the azimuthal correlations $\Delta\phi = \phi_{trig} - \phi_{assoc}$ and per-trigger yield of charged hadrons as a function of p_T. The correlation with charged particles emitted in close azimuthal direction to the trigger particle is called near side, and the correlation in opposite azimuthal direction from the trigger particle is called away side. In heavy ion collisions, a parton scattered in the initial stages goes through the medium, in which the parton may lose a fraction of its energy, and ultimately fragment into many hadrons with different transverse momenta (p_T). The high-pT trigger particle from the near side



(a) (b)

Figure 1: Physics model which we used (a) and expected distribution $\Delta\phi$ (b). Red arrow point to Near side pick, blue to Away side pick. [1]

parton may be produced in the surface of the medium and goes through a short length in the medium, and therefore it in difficult to determine whether the parton has itself lost energy event by event, while the away side parton is more likely to traverse a maximal path-length through the medium, and thus more likely to be affected (Fig.1(a) and Fig.1).

The trigger particle was obtained using PHOS detector. The PHOS detector is a high granularity electromagnetic calorimeter capable of measuring the energy and position of electromagnetic particles. Covering $220° < \phi < 280°$ in azimuth and a pseudo rapidity range of $|\eta| < 0.13$, it is divided into three modules each holding 3584 individual cells. A cell consists of a lead tungsten ($PbWO_4$) crystal with a cross section of 22 by 22 mm^2 and a length of 180 mm, which acts as both the absorber and as the scintillator. A PIN photo-diode is used to measure the scintillation light.

2 Data selection and cuts

For all collision types, we accepted events passing physics selection, v_z<10 cm and reconstructed vertex in its 3 components non equal 0. The data sample considered in the analysis are:

- **LHC13(b-f):** pPb collisions at $\sqrt{s_{NN}} = 5.02$ TeV, AliVEvent::kINT7 and AliVEvent::kPHI7 (PHOS trigger). Mixing studies are done with minimum bias AliVEvent::kINT7 events.

2.1 Track selection

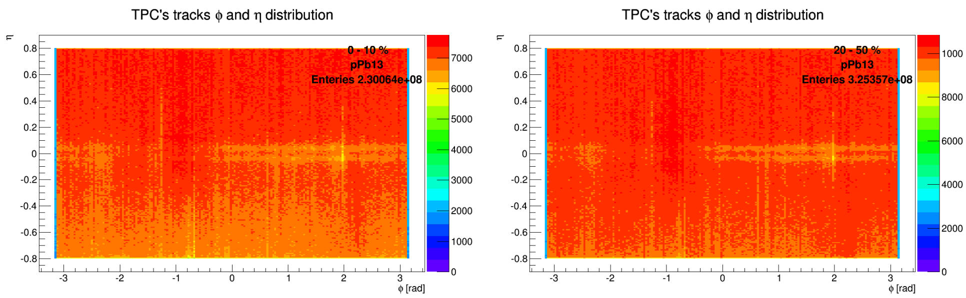
In the analysis, the hibrid track cuts are used, which are defined in the AODs, when the following line is true:

- aodTrack->IsHybridGlobalConstrainedGlobal()

In all the AOD samples under study, this track definition is available. More details about hybrid tracks can be found in [2].

Also, all tracks should have 0.5<pT<20 GeV/c and $|\eta|$>0.8 .

Fig.2 shows the track distribution as ϕ vs η in pPb for all events.



(a) (b)

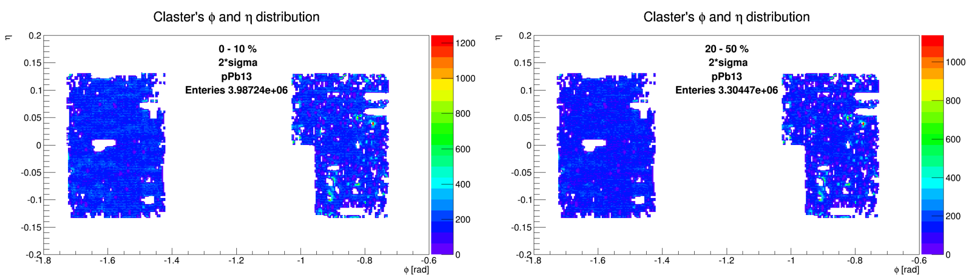
Figure 2: TPC track quality for Central (0-10%) and SemiCentral (20-50%) events in pPb (a-b) correspondingly.

2.2 Cluster selection

The following cluster cuts are used:

- Number of cells in cluster larger then 3
- E>0.3 GeV (PIDcalls **all**)
- Shower shape cut M02>0.2 (PID calls **disp**)
- Charged particles veto using extrapolation method with TPC (PID calls **cpv**)

Fig.3 shows the cluster distribution as ϕ vs η in pPb.



(a) (b)

Figure 3: PHOS cluster quality for Central (0-10%) and SemiCentral (20-50%) events in pPb (a-b) correspondingly.

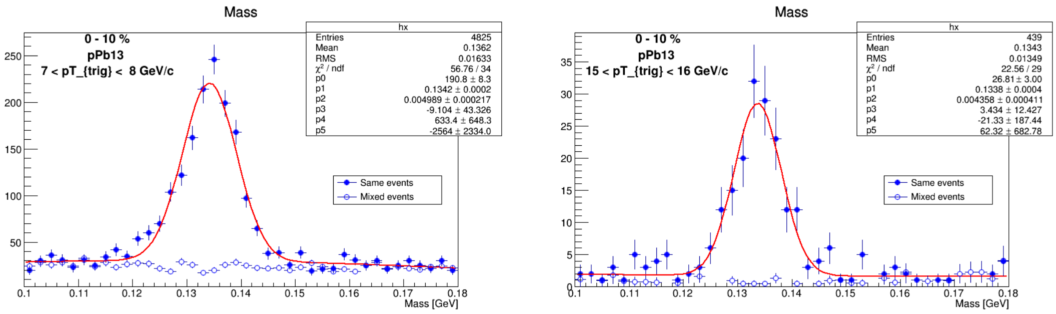
3 π^0 reconstruction

Neutral pions decay into photon pairs with a probability of 98.823% [3]. Due to the short lifetime of π^0 of c_τ=25.5 nm, they approximately decay right at the vertex of collision. Therefore, the momentum of decay photons can be determined by measuring their energy and position in the PHOS as well as measuring the position of the vertex of collision. Since the source of any particular photon in unknown, all combinations of photons in mass window $M_{\pi^0} \pm 2 \cdot \sigma$ in event are considered as π^0 candidates (referred to as "real events"). The invariant mass (m_{inv}) of a photon pair is calculated as:

$$m_{inv}(\gamma\gamma) = \sqrt{2 \cdot E(\gamma_1) \cdot E(\gamma_2) \cdot (1 - cos(\alpha))} \tag{1}$$

Fig.4 shows invariant mass distributions. They was fitted by Eq.2. Using this results mass window for selection trigger particles was made and number of trigger particles in different p_T bins was calculated.

$$f(x) = p_0 * e^{-(x-p_1)^2/p_2^2} + p_3 + p_4 * x + p_5 * x^2 \tag{2}$$



(a) (b)

Figure 4: Invariant mass distribution for p-Pb at 0-10% centrality for 7.0 $< p_T <$ 8.0 GeV/c (a) and 15.0 $< p_T <$ 16.0 GeV/c

4 Per-trigger correlated yields

The associated per-trigger yield as a function of the azimuthal angle difference $\Delta\phi = \phi_{trig} - \phi_{assoc}$ and pseudo-rapidity difference $\Delta\eta = \eta_{trig} - \eta_{assoc}$ is defined as:

$$\frac{dN(\Delta\phi)}{d\Delta\phi} = \frac{1}{N_{trig}} \frac{dN_{assoc}}{d\Delta\phi} \tag{3}$$

This distribution is obtained for different p_T bins for trigger particles and associated particles, depending on available statistics. For the analysis whith pPb and collisions data with π^0 triggers, we selected the triggered p_T^{trig} range [7.0-16.0] GeV/c for azimuthal correlations measurements. The associated particles, charged hadrons, are grouped in the following p_T^{assoc} bins: [0.5-1.0], [1.0-1.5],[1.5-2.0],[2.0-3.0],[3.0-5.0],[5.0-7.0] GeV/c.

4.1 Method

The analysis is done by filling two kinds of histograms:

- $N_{trig}(p_T^{assoc})$: number of trigger particles as a function of their p_T^{assoc}.
- $N_{assoc}(p_T^{trig}, p_T^{assoc}, \Delta\phi, \Delta\eta)$: number of associated particles to a number of trigger particles N_{trig}.

The per-trigger yield is measured for different ranges of trigger p_T^{trig} and associated transverse momentum p_T^{assoc} and in bins of centrality.

Similar histograms are filled for the mixed event, where we compare the trigger particle with charged hadrons in different events but with similar global properties:

- z vertex bin 2 centimeter bin, 10 bins from -10 to 10 cm
- 2% wide bin with 5 bins to 0-10% centrality, 5% wide bin with 6 bins to 20-50% centrality.
- Reaction plane ("V0" method), 6 bins between 0 and π radians.

The event mixing may be usefull to correct for detector acceptance or performance (missing or misbehaving TPC sectors) and analysis cuts effects. To subtract the underlying event contributions to the correlations, one can apply following formula:

$$\frac{dN(\Delta\phi)}{d\Delta\phi} = \frac{1}{N_{trig}}\left(\frac{dN^{raw}}{d\Delta\phi} - \beta\frac{dN^{mixed}}{d\Delta\phi}\right) \tag{4}$$

Calculating the factor *beta* in $\Delta\phi$ region from 1 to 1.5, where it is expected the background is dominant, as written in Eq. 5, is similar to do ZYAM.

$$\beta = \int_1^{1.5} \frac{dN^{raw}}{d\Delta\varphi} / \int_1^{1.5} \frac{dN^{mixed}}{d\Delta\varphi} \tag{5}$$

Fig. 5 shows azimuthal angle correlation distributions of the same event, mixed event (left) and the corrected acceptance and subtracted the background from underlying events correlation distribution by Eq. 4 in π^0 trigger at 7.0<p_T^{trig}<16.0 GeV/c and associated at 2.0<p_T^{assoc}<3.0 GeV/c in pPb at 5.02 TeV.

Subsequently the yield on the near (away) side is summed over a region of 0 (π) $\pm$ some width. In our analysis, two regions are taken into account to extract the yield.

- Near side $|\Delta\phi| < 0.7$ *radians*
- Away side $|\Delta\phi - \pi| < 0.7$ *radians*

4.2 Correction

In this note we didn't made any types of correction, but in future to get correct results, we must do following steps and calculate there systematic uncertainties:

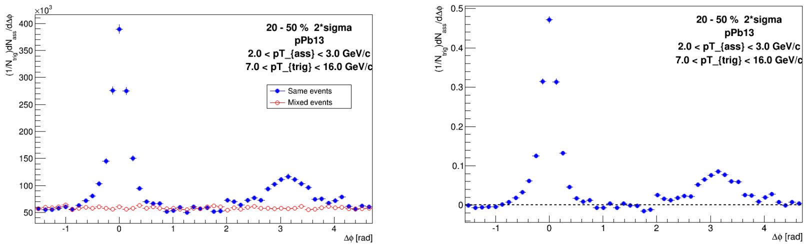
- π^0 contamination correction
- π^0 efficiency correction
- π^0 and TPC track p_T resolution correction
- TPC track efficiency and contamination correction

5 Results

In this section, results for the azimuthal correlations and per-trigger yields are shown with out correction and statistical error presented only.

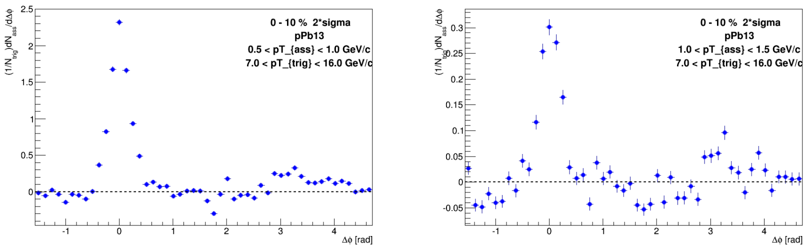
Fig. 6 and Fig. 7 show the azimuthal correlations for π^0 trigger p_T bins at 7.0<p_t^{trig}<16.0 GeV/c with four associated hadrons p_T bins (0.5<p_T^{assoc}<1.0 GeV/c, 1.0<p_T^{assoc}<1.5 GeV/c, 1.5<p_T^{assoc}<2.0 GeV/c, 2.0<p_T^{assoc}<2.5 GeV/c) in p-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV at central (0-10%) and semicentral (20-50%), respectively.

Fig. 8 shows the per-trigger yield of charged hadrons on near side, away side in pPb at $\sqrt{s_{NN}} = 5.02$ TeV for different centrality. Results at different PID was fitted by $y = k \cdot x + b$ and presented on Tab. 1

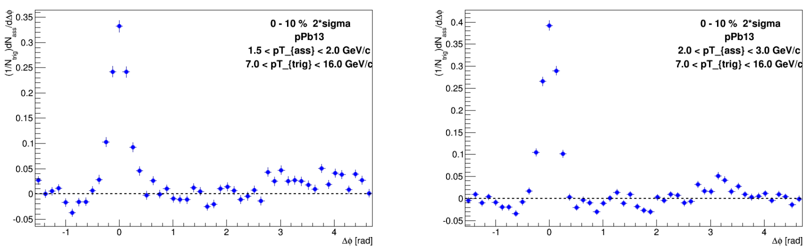


(a) (b)

Figure 5: Azimuthal correlations extraction process for trigger p_T at $7.0<p_t^{trig}<16.0$ GeV/c and associated hadrons p_T at $2.0<p_T^{assoc}<3.0$ GeV/c in p-Pb at $\sqrt{s_{NN}}$ = 5.02 TeV at central (20-50%) events. Raw distributions (left) and result (right).

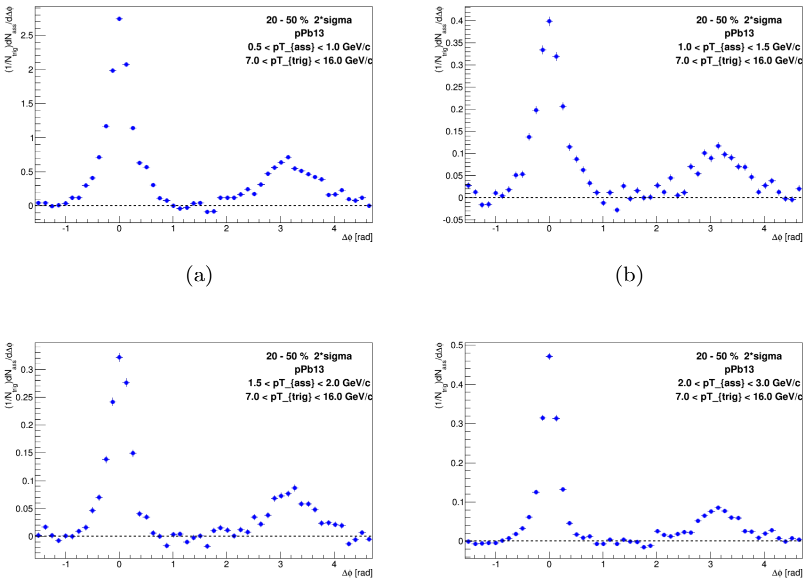


(a) (b)



(c) (d)

Figure 6: Azimuthal correlations for trigger p_T at $7.0<p_t^{trig}<16.0$ GeV/c and associated hadrons p_T at $0.5<p_T^{assoc}<1.0$ GeV/c,$1.0<p_T^{assoc}<1.5$ GeV/c,$1.5<p_T^{assoc}<2.0$ GeV/c,$2.0<p_T^{assoc}<2.5$ GeV/c in p-Pb at $\sqrt{s_{NN}}$ = 5.02 TeV at central (0-10%) events.

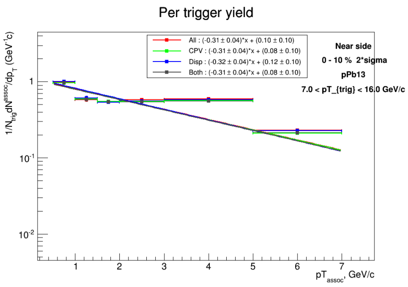


(a) (b) (c) (d)

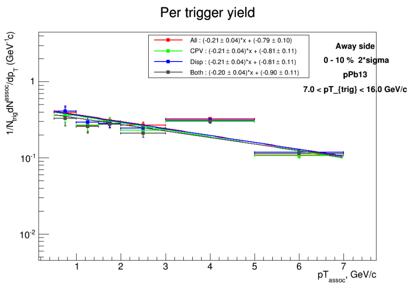
Figure 7: Azimuthal correlations for trigger p_T at 7.0<p_t^{trig}<16.0 GeV/c and associated hadrons p_T at 0.5<p_T^{assoc}<1.0 GeV/c,1.0<p_T^{assoc}<1.5 GeV/c,1.5<p_T^{assoc}<2.0 GeV/c,2.0<p_T^{assoc}<2.5 GeV/c in p-Pb at $\sqrt{s_{NN}}$ = 5.02 TeV at semicentral (20-50%) events.

Near side 0-10% **All:** (-0.31±0.04)*x + (0.10±0.10) **CPV:** (-0.31±0.04)*x + (0.08±0.10) **DISP:** (-0.32±0.04)*x + (0.12±0.10) **BOTH:** (-0.32±0.04)*x + (0.08±0.10)	Near side 20-50% **All:** (-0.21±0.04)*x + (0.79±0.10) **CPV:** (-0.21±0.04)*x + (0.81±0.11) **DISP:** (-0.21±0.04)*x + (0.81±0.11) **BOTH:** (-0.20±0.04)*x + (0.9±0.11)
Away side 0-10% **All:** (-0.39±0.04)*x + (0.63±0.09) **CPV:** (-0.40±0.04)*x + (0.64±0.10) **DISP:** (-0.39±0.04)*x + (0.61±0.09) **BOTH:** (-0.40±0.04)*x + (0.61±0.09)	Away side 20-50% **All:** (-0.45±0.05)*x + (0.64±0.10) **CPV:** (-0.47±0.05)*x + (0.63±0.11) **DISP:** (-0.46±0.05)*x + (0.62±0.11) **BOTH:** (-0.46±0.05)*x + (0.61±0.11)

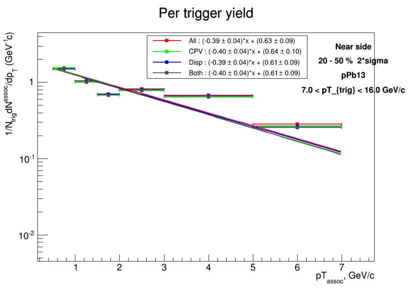
Table 1: Per-trigger yield fit of different PID results of charged hadrons on near side $|\Delta\phi| < 0.7$, away side $|\Delta\phi - \pi| < 0.7$ in trigger p_T at 7.0<p_T^{trig}<16.0 GeV/c in p-Pb at $\sqrt{s_{NN}}$ = 5.02 TeV at central (0-10%) and semicentral (20-50%) events. Only statistical errors presented.



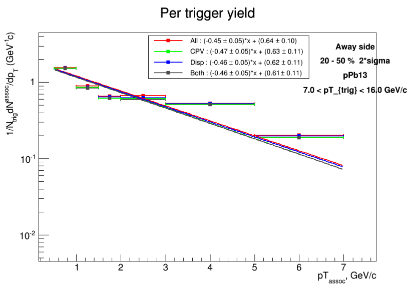
(a)



(b)



(c)



(d)

Figure 8: Per-trigger yield of charged hadrons on near side $|\Delta\phi| < 0.7$ (left), away side $|\Delta\phi - \pi| < 0.7$ (right) in trigger p_T at $7.0 < p_T^{trig} < 16.0$ GeV/c in p-Pb at $\sqrt{s_{NN}} = 5.02$ TeV at central (0-10%) and semicentral (20-50%) events. Only statistical errors presented.

References

[1] S.S. Adler et al., Phus.Pev.D74,072202 (2006)

[2] Hibrid track cuts twiki: http://twiki.cern.ch/twiki/bin/viewauth/ALICE/HybridTracks.

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[5] Andrew M. Adare, PhD Thesis, "Transverse momentum evolution of neutral pion triggered dihadron correlations in Au+Au collisions at $\sqrt{s_N N} = 200$ GeV", B.S. Wheaton College