Neutral pion-hadron correlations in pp and Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV with ALICE

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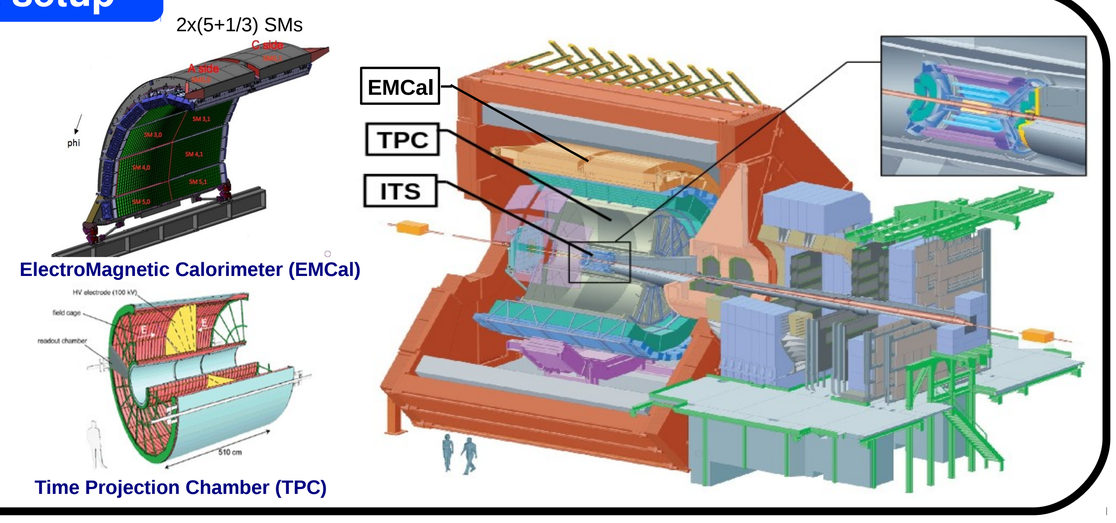
Motivation

Di-hadron azimuthal correlation measurements provide a powerful tool to understand the properties of the hot, dense matter produced in relativistic heavy-ion collisions. In this poster, we present the azimuthal correlation between a π^0 trigger and charged hadrons in $\Delta\varphi = \varphi^{trig}_{\pi^0} - \varphi^{assoc}_{h^{ch}}$. The goal is to study the near-side ($|\Delta\varphi| < \pi/3$) and away-side ($|\Delta\varphi - \pi| < \pi/2$ and $|\Delta\varphi - \pi| < \pi/5$) nuclear suppression factors $I_{AA}(p_T^{\pi^0}, p_T^{h^{ch}})$ and $I_{CP}(p_T^{\pi^0}, p_T^{h^{ch}})$ in Pb-Pb collisions.

ALICE experiment setup

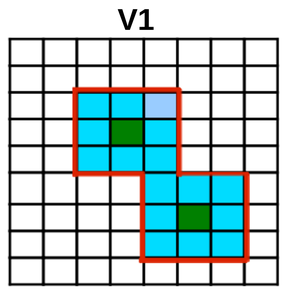
ALICE is a multipurpose, large-acceptance detector at the LHC, designed for comprehensive measurements in the high-multiplicity environment of high energy Pb-Pb collisions.

- The EMCal is a lead-scintillator sampling calorimeter covering large acceptance ($|\eta| < 0.7$ and $\Delta\varphi = 100°$) with good energy resolution. It provides efficient triggering on
  - high energy jets;
  - high-p_T neutral pions and photons.
- The TPC is a cylindrical gas detector covering full azimuth and $|\eta| < 0.9$ with a tracking efficiency dependence of track p_T (~85% at $1 < p_T < 10$ GeV/c). It provides
  - charged particle momentum measurement ($0.015 < p_T < 100$ GeV/c);
  - particle identification (dE/dx resolution ~5.5% at low multiplicity and ~6.8% at Pb-Pb central);
  - two-track separation (resolution in relative momentum below 5 MeV/c).



EMCal clusterization algorithms

The energy deposited by photons and charged hadrons in the calorimeter is reconstructed by grouping nearby cells into a cluster. Two clusterizer algorithms are used in this analysis.



V1: Add neighboring cells to a seed cell with energy larger than E_{seed} if $E_{cell} > E_{min}$. If different particles hit EMCal closely, a single cluster might be created.

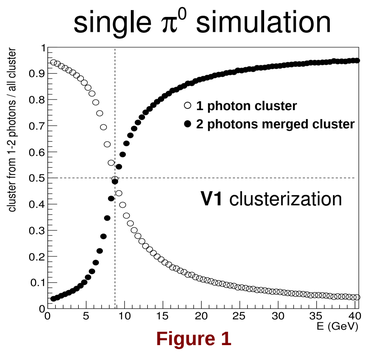
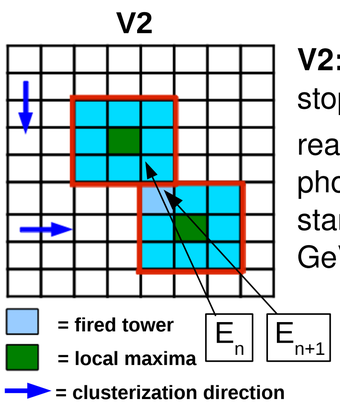


Figure 1



V2: similar to **V1**, but stops when $E_{n+1} \geq E_n$ is reached. The decay photons "EM showers" start to merge at 20 GeV.

In the **V1** clusterizer, the decay photons "EM showers" start to merge at 6 GeV. The fraction of merged photons increases with π^0 energy. It is larger than 50% above 10 GeV.

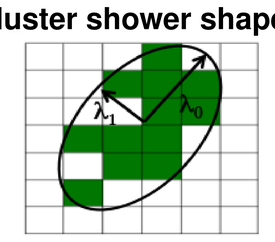
Values for E_{seed} and E_{min} in this analysis:

- In pp: E_{seed} = 100 MeV, E_{min} = 50 MeV (**V1**, **V2**)
- In Pb-Pb: E_{seed} = 300 MeV, E_{min} = 150 MeV (**V1**)

Neutral pion reconstruction

Based on the performance of the two clusterizer algorithms, two methods are used to reconstruct the π^0 in both pp and Pb-Pb.

Cluster shower shape parameters



$$\lambda^2_{0(1)} = 0.5(\delta_{\varphi\varphi} + \delta_{\eta\eta}) \pm \sqrt{0.25(\delta_{\varphi\varphi} - \delta_{\eta\eta})^2 + \delta^2_{\eta\varphi}}$$

$$\delta_{XY} = \sum_i \frac{w_i X_i Y_i}{w_{tot}} - \sum_i \frac{w_i X_i}{w_{tot}} \sum_i \frac{w_i Y_i}{w_{tot}}, (X, Y = \varphi, \eta)$$

$$w = Max\left(0, w_0 + \log\left(\frac{E_{cell}}{E_{cluster}}\right)\right), \quad w_0 = 4.5$$

where i is a cell of the cluster, $0 \leq \eta_i < 48, 0 \leq \varphi_i < 24$.

- **Method 1: smaller shower shape cluster with V2 clusterizer**
  - Select **V2** clusters identified as photon candidates via shower shape cut ($0.1 < \lambda_0 < 0.27$) and charged particle veto.
  - Build invariant mass of cluster pairs over all clusters, shown in the right figure upper. A Gauss+3rd order polynomial is fitted to the distribution between $8.0 < p_T < 15.0$ GeV/c (Figure 2).
- **Method 2: larger shower shape cluster + cluster splitting with V1 clusterizer**
  - A **V1** cluster with $\lambda_0 > 0.5$ is split into two new clusters.
  - Every new cluster is centered around seed cells with local maximal energy and formed with maximum of 3x3 cells.
  - If cells are common to both clusters, their energy is divided with the energy of the seed cell as weights.
  - With the two new split clusters, the invariant mass is calculated (Figure 3).

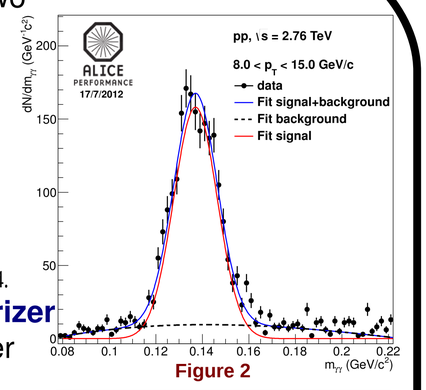


Figure 2

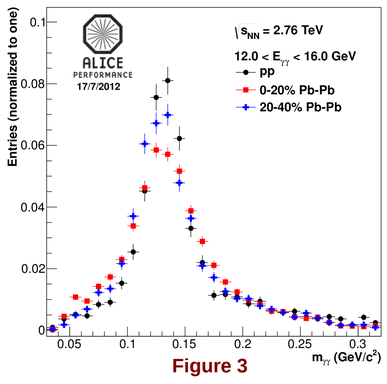


Figure 3

Neutral pion-hadron correlation methods and results

Two strategies are used to extract π^0-hadron correlations based on the two π^0 reconstruction methods using EMCal triggered events in pp and Pb-Pb.

Strategy 1: side-band subtraction

Based on **method 1** utilizing **V2** cluster, trigger π^0 candidates are selected within two ranges in the invariant mass distribution (Figure 4):

- signal+background ($0.12 < m_{\gamma\gamma} < 0.15$ GeV/c^2)
- side-band (background) ($0.17 < m_{\gamma\gamma} < 0.20$ GeV/c^2)

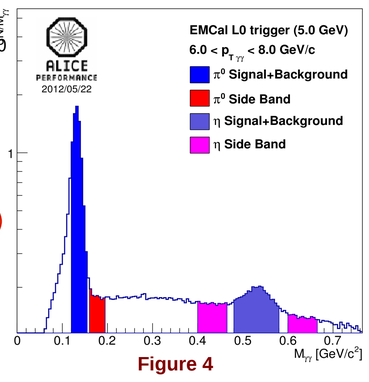


Figure 4

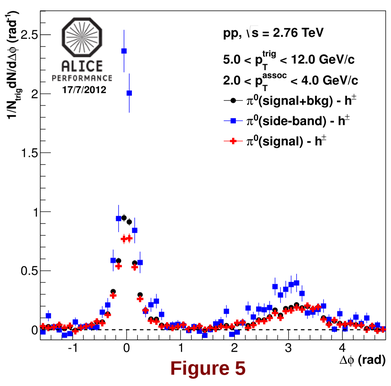


Figure 5

π^0 trigger correlation extraction

The signal to background ratio f_{bkg} is obtained from fitting the invariant mass distribution. Then

$$Y_S = Y_{S+B}\left(1 + \frac{1}{f_{bkg}}\right) - Y_B / f_{bkg}$$

Y_{S+B}: trigger yield in signal+background range
Y_B: trigger yield in side band range
Y_S: signal π^0 trigger yield

Figure 5 shows the azimuthal correlation between π^0 trigger and charged hadrons in signal+background (black) and side-band (blue) ranges. The signal, shown as red points, is extracted by subtracting side-band from signal+background.

Strategy 2: merged-cluster splitting

Based on the invariant mass distribution using **method 2**, π^0 candidates are selected around the mass peak at $0.10 < m_{\gamma\gamma} < 0.18$ GeV/c^2.

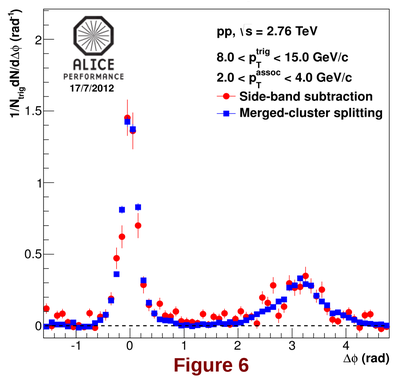


Figure 6

Figure 6 shows the comparison of the neutral pion-hadron correlation using the two strategies discussed. Results are seen to be consistent. Since the merged-cluster splitting strategy significantly enhances the hight pt trigger yield statistics, it is preferred in both pp and Pb-Pb analyses.

Mixed event technique

- **In pp and Pb-Pb**
  - 10 bins in $|z_{vertex}| < 10$ cm;
  - Only Minimum-bias trigger events in the mixed event pool.
- **In pp**
  - 10 bins in the multiplicity.
- **In Pb-Pb**
  - 3 bins in a centrality bin;
  - 3 bins in the event plane.

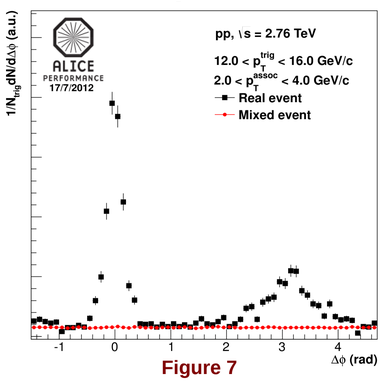


Figure 7

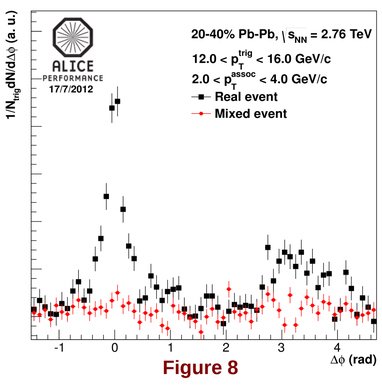


Figure 8

Figure 7 and Figure 8 show the real and mixed event in pp and 20-40% in Pb-Pb, respectively.

Summary and references

In this poster, we present neutral pion-charged hadron azimuthal correlations with neutral pion trigger reconstructed by two methods based on two different clusterizer algorithms. In pp, we show that both lead to consistent results. The merged-cluster splitting strategy is used to extract neutral pion-hadron azimuthal correlation in real and mixed event in pp and Pb-Pb. For the measurement of nuclear suppression factors $I_{AA}(p_T^{\pi^0}, p_T^{h^{ch}})$ and $I_{CP}(p_T^{\pi^0}, p_T^{h^{ch}})$, the background in Pb-Pb as well as the tracking efficiency needs to be obtained.

References:

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Acknowledgment:

The author thanks Gustavo Conesa Balbastre (LSPC) for many helps.
This work is supported by CCNU-QLPL Innovation Fund (QLPL2012P01), the NSFC 11020101060 (Key Grant) and 10975061, the CCNU2011 (Key Grant) and the Program of Introducing Talents of Discipline to Universities of China (B08033).