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Study of influence of particle identification in ALICE detectors and resonance decays on correlation functions

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Abstract The information about dynamics of the collective expansion of the source created in heavy ion collisions can be extracted by using intensity interferometry in different regions of rapidity and transverse momentum (p_t). The study of different factors affecting the p_t-dependence of the radii and the strength of the correlation is necessary and that is why we have studied the influence of the particle identification efficiency and the presence of the pions from resonance decays on (π^+,π^+) correlation function measured by ALICE experiment.

Key words heavy ion collisions • HBT • correlation function • particle identification

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Two-particles identification

There are several detectors of different types in ALICE to identify particles in the momentum range from ~100 MeV/c up to a few GeV/c which cover the full central acceptance region: Internal Tracking System (ITS), Time Projection Chambers (TPC), Time-of-Flight array (TOF) [2]. The upper momentum limit for pion identification via dE/dx measurement with acceptable efficiency and contamination (<20%) from other particles in the TPC and ITS, is about 1.1 GeV/c. The TOF with resolution 120 ps provides a good π separation in the momentum region from 0.5 GeV/c to 2.5 GeV/c. Particle identification can be done by each detector separately, or by different combinations of detectors [4]. We have considered here TPC (dE/dx), ITS (dE/dx), TOF (*ToF*) as “stand alone” detectors.

The events were simulated in the frame of ALICE offline framework [5, 8] by the Hijing [9] generator with the following parameters: 0–3 fm impact parameter range, $|y| < 1$, $45° < \theta < 135°$, $-180° < \phi < 180°$, when y is rapidity, θ and ϕ – polar and azimuthal angles, respectively. The charged particles multiplicity density in Hijing is $dN_{\text{charge}}/dy \sim 7200$ for mid-rapidity events [9]. The simulations were performed at two values of magnetic field B = 0.2 T and 0.4 T. The total ALICE simulation chain was used to find the tracks and reconstruct them in TPC, or in TPC and ITS; totally 200 events were generated. The fast simulation algorithm from [1] (sect. 5.1–5.6) was applied for TPC-TOF simulation; 400 events with B = 0.4 T were generated. The HBT-analyser was used to calculate the correlation functions [8].

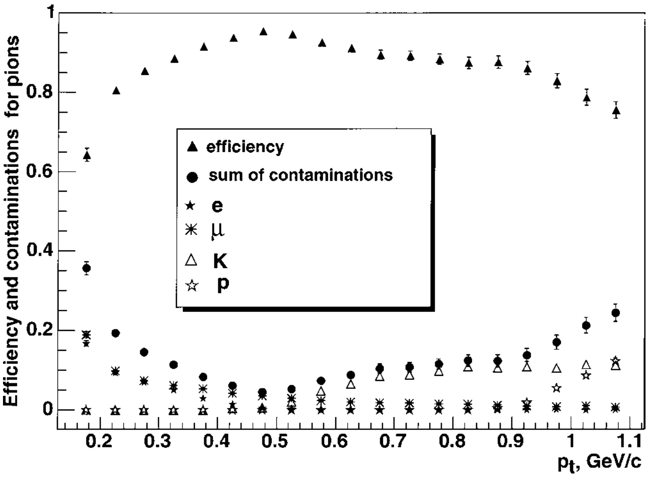

Fig. 1. Efficiency of pion identification and the relative contaminations of pions by electrons, muons, kaons and protons in TPC (B = 0.2 T) as a function of TPC-reconstructed transverse momenta (p_t).

Particle identification in $0.1 < p_t < 1.1$ GeV/c region with TPC and ITS

We used the cut functions in momentum *vs.* dE/dx plot or probability weights [3] for particle identification in TPC and ITS. Figure 1 illustrates the transverse momentum dependence of the efficiency of one pion identification and the relative contaminations. The efficiency is calculated as the ratio of correctly identified pions to all particles identified as pions. The contaminations are determined as the ratios of e, π, K identified as pions to all particles identified as pions. We have found that using the cut on the transverse impact parameter of the track smaller than 2 cm, decreases the electron and muon admixture by a factor of two, the impact parameter of the track is the closest approach to primary vertex.

Figure 2 shows purity (P) and contamination for pion pairs as a function of the momentum difference (Q_{inv}). The contamination is calculated as the ratio of the pairs containing at least one non-pion to all pairs identified as (π,π). The purity is the ratio of the pairs containing only correctly identified pions to all pairs identified as (π,π).

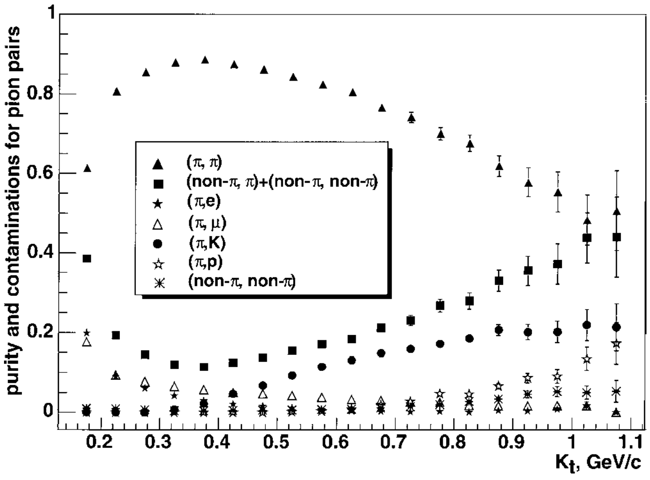

Fig. 3. Purity and contamination for pion pairs (see text) as a function of K_t. The impact parameter cut of TPC-track was used.

The particles passed through the track impact parameter cut. From Fig. 2 one can see almost constant dependence of the particle pair contaminations on the Q_{inv} variable. At the absence of momentum correlations between particles, this behaviour demonstrates the absence of specific effects of the PID procedure in TPC which could influence the shape of Q_{inv}-correlation function. The purity and contamination dependences on the pair transverse momenta K_t are shown in Fig. 3.

The Q_{inv} dependence of the simplest correlation function CF = $1 + \lambda{*}\exp(-Q_{inv}^2R^2)$ with spherical source radius R = 8 fm and $\lambda = 1$, is presented in Fig. 4 for the following particle samples:

- "ideal" – with no PID inefficiency, the upper curve;
- simulated TPC PID efficiency with impact parameter cut, middle curve;
- simulated TPC PID efficiency without impact parameter cut, lower curve.

We found that in the second case (the middle curve) λ value is only by ~10% lower than the one obtained for CF with 100% PID efficiency (the upper curve). This result is a consequence of the fact that the region of the better purity, 0.3–0.4 GeV/c (Fig. 3), corresponds to the region of the

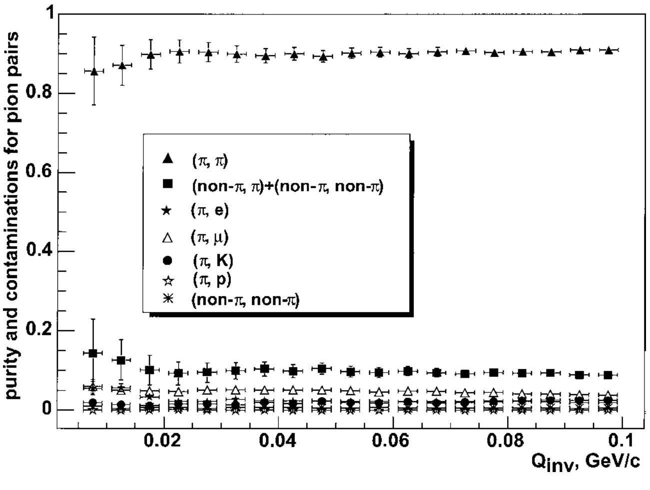

Fig. 2. Purity and contamination for pion pairs (see text) as a function of Q_{inv}. The impact parameter cut of TPC-track was used.

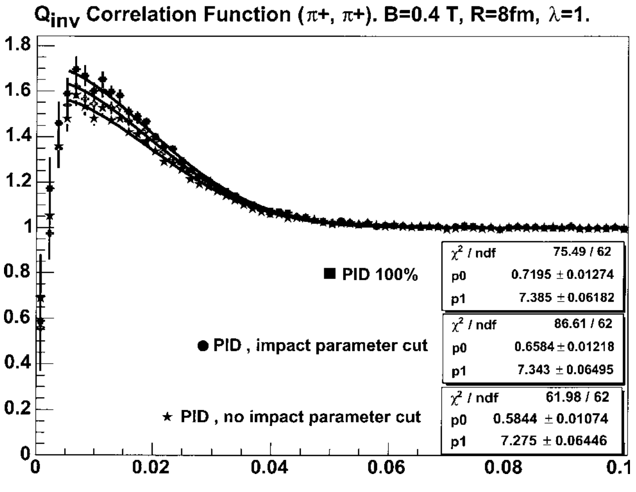

Fig. 4. The correlation function with the "ideal, 100%" PID and with the realistic PID in TPC as "stand alone" detector (0.4 T).

largest pion population in p_t-distribution. In different parts of the considered K_t interval, the λ will follow the purity K_t dependence (Fig. 3): $\lambda(K_t) = P(K_t)^*\lambda_0$, where λ_0 is the strength of correlations at the 100% efficiency case.

This means that in the realistic situation the PID procedure in the TPC decreases the strength of correlations, i.e. λ parameter as compared with the "ideal" case, but the radius remains unchanged due to the constant Q_{inv} dependence of PID procedure in TPC.

The same procedure has been done for the (ITS and TPC) reconstructed tracks. The contaminations of pion spectra by e and μ are negligible if the tracks taken for the reconstruction crossed all six ITS layers, due to the small rate of K, π decays and γ-conversion in the region before the ITS.

We found the efficiency of one pion identification in ITS to be 96% at $p_t < 0.5$, and 90% at $p_t = 1.1$ GeV/c. The kaon and proton admixture increases from ~3% to ~15% at $p_t = 0.5$ GeV/c and $p_t = 1.1$ GeV/c, respectively. No dependence of the PID procedure efficiency on Q_{inv} was observed.

Particle identification in the $0.5 < p_t < 2.5$ GeV/c region with TOF

The TOF geometry, TOF granularity, efficiency of TPC-TOF matching procedure influence the purity of the pion sample [1]. The TPC-track matched with the corresponding fired TOF pad has a true time-of-flight value; the set of such tracks is denoted as N_t. If the pad corresponding to the matched track is fired by another track (may be by noise), the track has a wrong time-of-flight value; the set of such tracks is denoted as N_w. There are mismatched TPC-tracks: TOF pad corresponding to the track is not fired (N_0) and the tracks for which the fired pad was matched to more than one track (N_2). The PID in TOF was realised by the specific contour cuts on the TPC reconstructed momentum *vs.* the TOF reconstructed mass plot [1]. The purity P depends on the choice of these cuts. We have considered the softest cut for pion identification, i.e. all particles which are not inside the contours for protons and kaons are identified as pions. Momentum dependence of contaminations and the efficiency of one pion identification are shown in Fig. 5 for $N_t + N_w$ tracks. From Fig. 5 one can see that the sum of contaminations is almost constant and is equal to about 10% in the full momentum region, 0.5–2.5 GeV/c; the efficiency is about 90%, respectively. Populations of different Q_{inv} regions by different types of the tracks matched from the TPC to the TOF are shown in Fig. 6. Population is calculated as the ratio of tracks of the considered type to all $N_t + N_w + N_2 + N_0$ tracks. One can see the maximum at small Q_{inv} for N_2 tracks corresponding to the narrow minimum for N_t and for $N_t + N_w$ track populations. It means that if we do not use the N_2 set of tracks we remove a part of the tracks with the close velocities and, as a consequence, get the narrower CF. The strength of this effect depends on the TOF occupancy [1]. In our consideration this effect is rather small because of the small number of N_2 tracks (Fig. 6). If we use N_2 tracks the contamination will be larger compared with $N_t + N_w$ case, but the difference for pions is small, ~3%. The more qualitative estimation of the TPC-TOF PID efficiency influence on CF can be obtained with the full ALICE simulation chain including TOF.

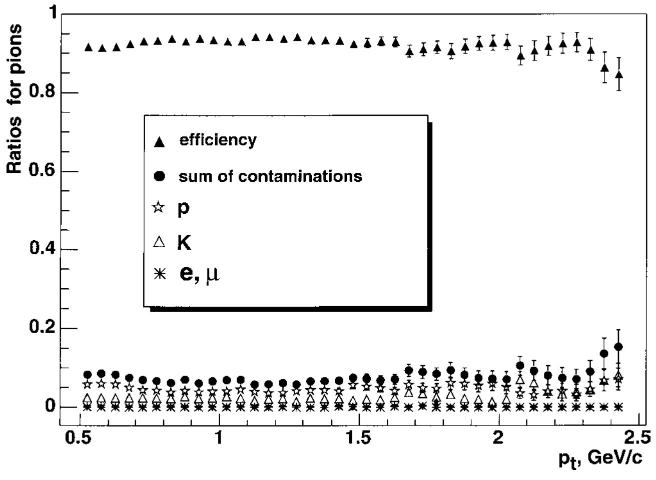

Fig. 5. Efficiency of pion identification in TOF and relative contaminations of pions by electrons, muons, kaons and protons as a function of p_t.

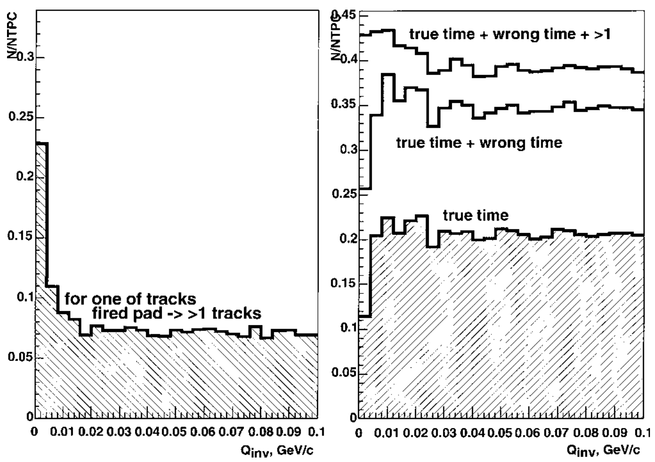

Fig. 6. Populations of Q_{inv} regions by the different sets (see text) of TPC-tracks matched from TPC to the TOF (or mismatched ones).

Calculations of resonance decays influence on CF in rescattering model

The resonance decays are known to influence the K_t-dependence of the measured radii and the strength of the correlations especially for pions [7, 10]. The Hijing generator has been used to estimate the p_t-dependence of the relative numbers of different resonances which give significant contributions to pion p_t-spectra measured in the TPC (Fig. 7). There are long-lived states as η^0, η' with widths 1.19 keV and 0.2 MeV, respectively, and the particles as K^+, K_s^0, K_l^0, Λ producing the CF components which are too narrow to measure. The admixture of the pions from the decays of such states decreases the intercept Λ of the CF, leaving the radius unchanged. We have found that the cut on the impact parameter of the TPC-track decreases the number of pions from K^+, K_s^0, K_l^0, Λ by a factor of two (Fig. 7).

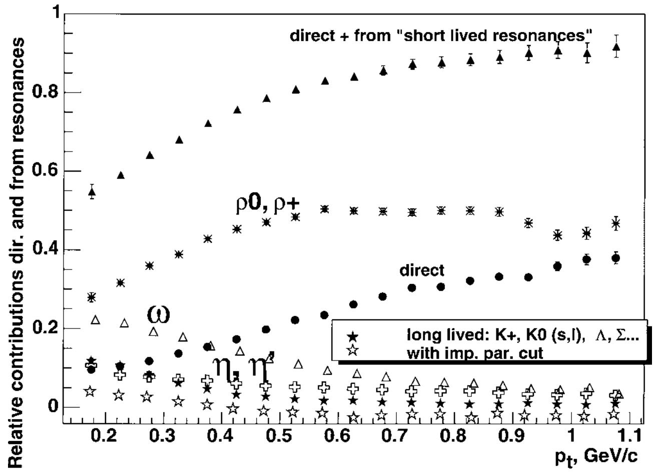

Fig. 7. Relative numbers of pions from different resonances in Hijing as a function of p_t.

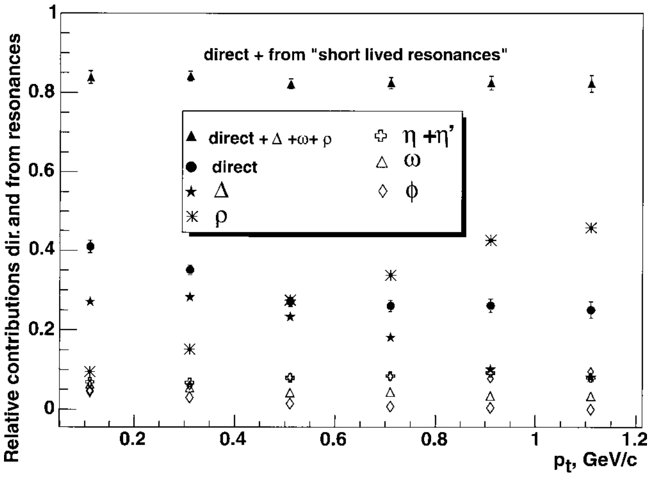

Fig. 8. Relative numbers of pions from different resonances in RM as a function of p_t.

There are more serious problems with the resonances having short (ρ) and intermediate (ω) lifetimes. These resonance decays can modify the shape of the CF [7, 10]. We note that the Hijing generator cannot be used for these investigations due to the absence of the space-time information on the particle source.

To study the interplay between the resolution effects and the change of the radius because of the resonances production and rescattering, the Rescattering Model (RM) [6] was implemented in the offline framework. This RM reproduces well the RHIC results for a slow increase of the lambda parameter with m_t [6]. This increase can take place due to: 1) reduction of the number of pions from the resonance (η, ω) decays at higher m_t (p_t) (see Fig. 7) and 2) the position-momentum correlations that affect the shape of the pion source to make it more (or less) Gaussian as a function of p_t [6]. It should be, however, noted that the p_t-dependence of the relative numbers of the pions from different resonance decays obtained in the RM (Fig. 8) has shown different behaviour as compared with the Hijing p_t-dependence (Fig. 7). Namely, the relative numbers of pions from η, ω resonances do not change with p_t in the RM. This difference is conditioned by strong rescatterings in the RM mixing up between the resonance and non-resonance production washing away the memory of the origin [6]. It means that mainly the p_t-dependence of the deviations from Gaussian gives the effect of the slow increase of λ as a function of p_t in [6]. We have found that the pion CF calculated for all pions and the CF omitting pions from η or from η and ω, show very small differences because of small numbers of pions from these resonances in freeze-out according to the RM (Fig. 8). A detailed study of three-dimensional CF in different K_t ranges is necessary to understand the relative roles of the source dynamics and the detector influence effects.

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