Track matching study from TPC to PHOS in ALICE*

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Abstract We present a study for matching charged tracks reconstructed from the ALICE tracking detectors with the clusters measured in the photon spectrometer. Matching efficiency and contaminations due to wrong matches have been deduced for charged pions and muons. For electrons, the effect of the material in front of PHOS is discussed.

Key words ALICE experimental simulation, photon detection, track reconstruction, track matching efficiency

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1 Introduction

ALICE, A Large Ion Collider Experiment[1] under construction at the CERN LHC (Large Hadron Collider) is devoted to the study of Quark Gluon Plasma (QGP) formed in nucleus-nucleus (AA) collisions. Hard probes are well suited for studying the hot and dense matter formed in the early stage of the collisions. In particular, direct photons[2], which only weakly couple to the medium, provide clean information about the state of matter where they have been created. However, because photons originate from several sources during the fireball evolution[3, 4], identifying the photons generated by the QGP in the measured photon spectrum is experimentally challenging.

The ALICE experiment will start operating with the initial proton-proton (pp) run of LHC scheduled in 2008[5]. The nominal LHC energy ($\sqrt{s}=14$ TeV) will be delivered for this run and might be proceeded by a short run at $\sqrt{s}=0.9$ TeV. The ALICE Photon Spectrometer (PHOS)[6] identifies charged particles with the help of the Charged Particle Veto (CPV) detector, however, the matching of tracks reconstructed in the central tracking detectors will provide a complementary method to exclude the charge particles striking on PHOS.

We shall first briefly describe the PHOS and the tracking capabilities of ALICE. We then discuss the track matching algorithm we have developed, and finally present the matching efficiencies.

2 PHOS

The high resolution (energy and position) PHOS of ALICE, consists of 5 modules, placed 4.6 m away from the Interaction Point (IP). They cover the pseudo-rapidity domain from −0.12 to +0.12 and an azimuthal angle domain of 100 degrees. Each module consists of a segmented charged particle detector (multi-wire proportional gas chamber) operated in veto mode (CPV)[7] and a segmented electromagnetic calorimeter (EMC) with 64×56 lead-tungstate crystals (2.2 cm×2.2 cm×18 cm), $PbWO_4$[8].

PHOS will allow to identify photons and neutral mesons through their two-photon decay channel. The primary objective of PHOS is the identification of direct photons obtained by subtracting from the measured photon spectrum the contribution from the decay photons. To achieve this task, PHOS must fulfil the following requirements over a broad dynamical range[9]: high energy and position resolution, good timing properties, and charged particle identification. The performance of PHOS has been established with a prototype module which has been tested with pion and electron secondary beams at the CERN PS and SPS accelerators[10]. The energy resolution ranges

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from 4% at 1 GeV to 1% for 100 GeV, and the position resolution ranges from 3.2 to 3.9 mm at 1 GeV/c, and from 1.2 to 2.6 mm at 10 GeV/c depending on the incident angle. It also shows a fine timing resolution around 1.5 ns. In addition, neutral pions have been identified through a two-photons invariant mass analysis, obtaining an invariant mass resolution of around 10 MeV/c^2.

3 Event reconstruction

The ALICE central charged particle tracking detectors consist of four components: the Time Projection Chamber (TPC), the Inner Tracking System (ITS), the Transition Radiation Detector (TRD) and the Time Of Flight detector (TOF). The TPC[11] is the main tracking device and provides the measurement of the momentum and Particle Identification (PID) by dE/dx measurement. The ITS[12] is primarily a vertex detector, capable of identifying secondary vertices with a resolution of 100 μm. The TRD[13] identifies electrons and pions in the momentum range above 1 GeV/c.

The offline track finding algorithm is based on Kalman-filtering[14] approach. To cope with the expected high occupancies and achieve the best possible results, the standard Kalman filter approach was modified, and the so-called Maximum Information Approach (MIA) was introduced[15]. The tracking efficiency has reached almost 100% even for the highest expected multiplicity ($\mathrm{d}N/\mathrm{d}\eta \approx 4000$).

PHOS reconstruction procedure is proceeded by three steps: clusterization, track segments and particle identification. A cluster is a group of adjacent cells whose digital amplitude greater than the noise threshold. After the cluster finding algorithm the coordinate and energy of the incident particle can be obtained. The last two steps would combine the information from the EMC and CPV detectors, however, additional information from the global tracking has been taken into account for particle identification.

4 Track matching algorithm

The data reconstruction algorithms are implemented in the AliRoot framework[16], based on the ROOT system[17], for simulation, reconstruction and analysis. The matching between reconstructed charged tracks and PHOS hits is performed using the data from the Event Summary Data (ESD) where all reconstructed data are stored. The matching algorithm applies the following steps:

1) Retrieve all PHOS clusters with the following information: its position (x_c, y_c, z_c) in the ALICE reference system, its energy (E), the inclination angle (α) in the ALICE reference system of the PHOS modules where clusters has been found, and the Monte-Carlo particles at the origin of the clusters.

2) Retrieve all the reconstructed charged tracks whose point in the direction of PHOS.

3) Loop, for each cluster, over the tracks whose endpoint is in the module containing the cluster. Taking into account PHOS misalignment, and to ensure that the track is propagated to the PHOS plane, the track is first rotated by an angle α. Then, the track candidates are propagated analytically to the x plane, where $x = x_c \cdot \cos\alpha + y_c \cdot \sin\alpha$. Finally, we calculate from the distance between the cluster position and the charged track projection in x, (dx), and z, (dz), directions, the distance in the xz as, $D_{xz}=\sqrt{\mathrm{d}x^2+\mathrm{d}z^2}$.

4) Sort the matching candidates according to the D_{xz} value. Tracks with D_{xz} smaller than a given value, $D_{\min}$, are declared matched and marked as used. One cluster is assigned to no more than one track.

5) Save the matched clusters and tracks for further analysis.

The following categories to determine the track matching efficiency and contamination are defined:

1) True match ($N_{\rm t}$): The cluster and the track originate from the same Monte Carlo particle.

2) Found match ($N_{\rm fo}$): All the matched clusters and tracks.

3) Good match ($N_{\rm g}$): The found matches for which the cluster and the track originate from the same Monte Carlo particle.

4) Fake match ($N_{\rm fa}$): The found matches for which the cluster and the track originate from different Monte Carlo particles.

Track matching efficiency (ϵ) and contamination (c) are defined as:

$$\epsilon = \frac{N_{\rm g}}{N_{\rm t}}, \quad (1)$$

$$c = \frac{N_{\rm fa}}{N_{\rm fo}}. \quad (2)$$

5 Results

Electrons and photons can be discriminated only by identifying the electric charge of the particle. In pp and AA collisions they are only rarely produced and the hadron composition of the final state of the collision is dominated by charged pion mesons. We have therefore studied the performance of the track matching algorithm for single particle events of electrons (e^-) and pions (π^+). The algorithm was also tested with single muon (μ^-) events. The AliGenBox generator of AliRoot v4-06-00 has been used and the generated particles were forced to point in the direction of one PHOS module inside the fiducial acceptance excluding the edge crystals ($262° \leqslant \phi \leqslant 278°$, $-0.11 < \eta < +0.11$). To evaluate the combined track matching efficiency, ALICE barrel detectors ITS+TPC and ITS+TPC+TRD cases were simulated in the magnetic filed 0.5 T.

To apply the above track matching algorithm, one needs to establish first the value of $D_{\min}$. The azimuthal and polar distribution of the distance between the impact of the propagated track on the PHOS surface and the PHOS cluster position (Fig. 1) are well described by a gaussian distribution. The dependence of the gaussian mean value as a function of the transverse momentum ($p_{\rm t}$) of the impinging particle (Fig. 2) indicates that for the less blended high $p_{\rm t}$ particles the track prolongation and cluster position become closer and their relative distance is better defined.

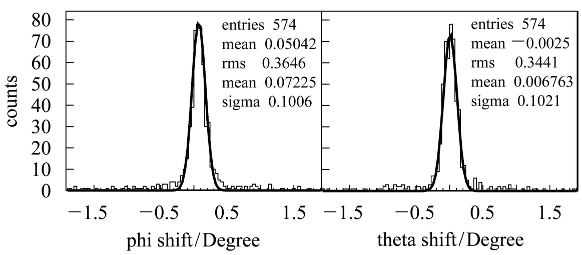

Fig. 1. Azimuthal and polar distribution of the distance between the impact of the propagated track on the PHOS surface and the PHOS cluster position.

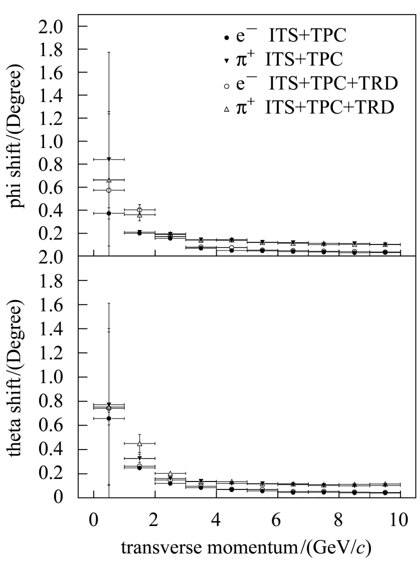

Fig. 2. Mean distance between the track prolongation and the cluster position as a function of the transverse momentum of different particles ($e^{\pm}$, $\pi^{\pm}$) and for various configurations of tracking detectors in front of PHOS.

Knowing the distance between the TPC outer radius and the PHOS surface (210 cm), we have adopted a value of 4 cm for $D_{\min}$ corresponding to five standard deviations of these mean values.

In Fig. 3, the track matching efficiency for muons is found close to $\epsilon = 1$ with a low contamination $c \leqslant 0.03$ demonstrating the performance of the track matching algorithm. For other particles, which are more sensitive to the material they traverse, the efficiency is lower and the contamination higher depending on the amount of material in front of PHOS. The contamination is the largest for electrons, mainly caused by bremsstrahlung. To reject these clusters we have to resort to additional vertex information.

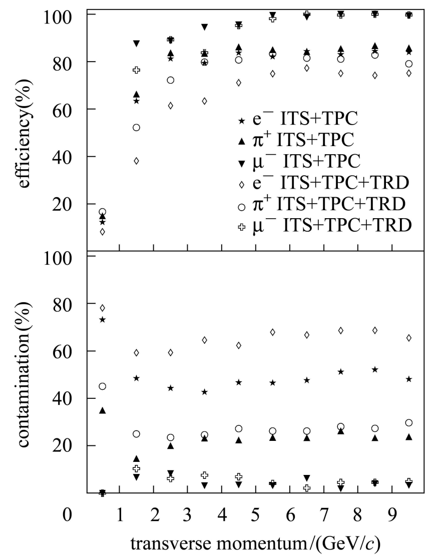

Fig. 3. Track matching efficiency (above) and contamination (down) from TPC to PHOS with different combined barrel detectors, at mul.=10 towards PHOS third module.

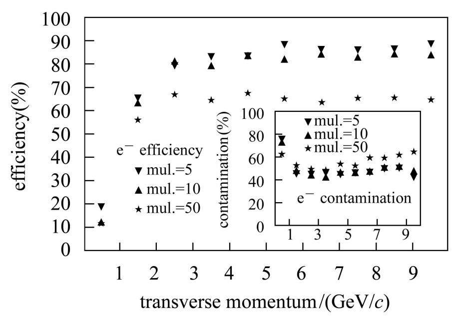

Fig. 4. e^- track matching efficiency and contamination with different particle multiplicity, in one PHOS module covered by ITS and TPC only.

To study the dependence of the track matching efficiency and contamination with the particle density, we have simulated the environment by generating more than one particle per event pointing in the direction of one PHOS module: 5, 10 and 50 which correspond to $dN/d\eta$ of 400, 800 and 4000 separately. For both electrons (Fig. 4) and pions (Fig. 5) the track matching efficiency is very sensitive to the track density but stays at a reasonable high level even for the highest density. The contamination however becomes high even if only the TPC and ITS materials are in front of PHOS.

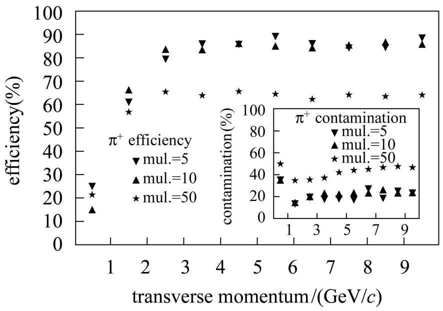

Fig. 5. π^+ track matching efficiency and contamination with different particle multiplicity, in one PHOS module covered by ITS and TPC only.

6 Conclusion

Based on the good performance of PHOS , and on the high momentum resolution and track reconstruction efficiency of the ALICE tracking detectors, the matching of charged tracks with PHOS hits has been studied. The matching efficiency depends on the charged track density, from 80% for low density $\mathrm{d}N/\mathrm{d}\eta$=400, down to 70% for high densities $\mathrm{d}N/\mathrm{d}\eta$=4000. No significant dependence is observed with the particle transverse momentum. However, for electrons, the large contamination is caused by the material in front of PHOS due to photon conversion, which will cause more systematical errors for neutral meson extraction and direct photon access. To improve the charged particle identification and get relative high purity photon spectrum with PHOS, this track matching algorithm has to be applied together with additional PID analysis to discriminate hadrons from electrons, such as the shower shape analysis[18], or searching for secondary vertices to identify photon conversions. In addition, the study also suggests that less materials needed for TRD and TOF detectors in front of PHOS or their installation need to be further discussed for the realization of PHOS physical goals.

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