Journal of Physics: Conference Series

π^0 and η reconstruction from photon conversions in ALICE for first p-p collisions at the LHC

To cite this article: Kenneth Aamodt and the ALICE collaboration 2011 *J. Phys.: Conf. Ser.* **270** 012035

π^0 and η reconstruction from photon conversions in ALICE for first p-p collisions at the LHC.

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Abstract. Measurements of π^0 and η inclusive spectra provide reference data for upcoming heavy ion runs, as well as a check on the applicability of perturbative QCD calculations at LHC energies. The high-resolution central tracking system of ALICE can be used to reconstruct π^0 and η through photon conversions, as an alternative to direct measurement in the ALICE Calorimeters. Knowledge of the ALICE material budget is crucial for the extraction of the absolute yield from the conversion technique. The statistics availible from this technique are comparable to that of the photon spectrometer (PHOS), and the reconstruction method can also be applied for Pb-Pb collisions. Moreover, the implementation of a photon conversion trigger in the High Level Trigger (HLT) framework gives the possibility of identifying π^0 and η candidates online, and increasing the statistics at higher momentum. The status of the π^0 meson reconstruction from photon conversions from p-p collisions at $\sqrt{s} = 900$ GeV and $\sqrt{s} = 7$ TeV is presented in this article.

1. Introduction

Measurements of π^0 and η inclusive p_t spectra in proton-proton collisions are important since they provide the essential reference for jet quenching measurements in heavy ion collisions via inclusive hadron suppression. In addition, they provide a test of the applicability of perturbative QCD (pQCD) calculations at the highest energies ever recorded. Precise knowledge of these spectra is also essential to extract direct photon yields from the large background of decay photons from mainly π^0 and η decays. In heavy-ion collisions direct photons carry thermodynamical information on the quark-gluon plasma (QGP). Results from RHIC [1] have shown that π^0s and ηs are supressed by a factor 5 in heavy-ion collisions compared to the binary scaled proton-proton yield in the nuclear modification factor R_{AA}, while direct photons show no suppression. The suppression is an indication that a dense medium is created in heavy ion collisions, the QGP, in which colored partons (jets) interact while the electromagnetically interacting direct photons escape without modification. The measurements of the π^0 and η inclusive p_t spectra in proton-proton collisions will provide a baseline for heavy-ion collisions, where their suppression can be studied through the nuclear modification factor.

ALICE [2] has two calorimeters, PHOton Spectrometer (PHOS) and ElectroMagnetic CALorimeter (EMCAL), designed to measure photons, neutral mesons, electrons and jets. ALICE also has a high resolution central barrel tracking system capable of reconstructing photons that convert in the detector material. The tracking system consists of Inner Tracking System (ITS) [3], Time Projection Chamber (TPC) [4], Transition Radiation Detector (TRD) and Time Of Flight (TOF). The ITS and TPC are used in the work presented here. Figure 1 depicts the full ALICE detector.

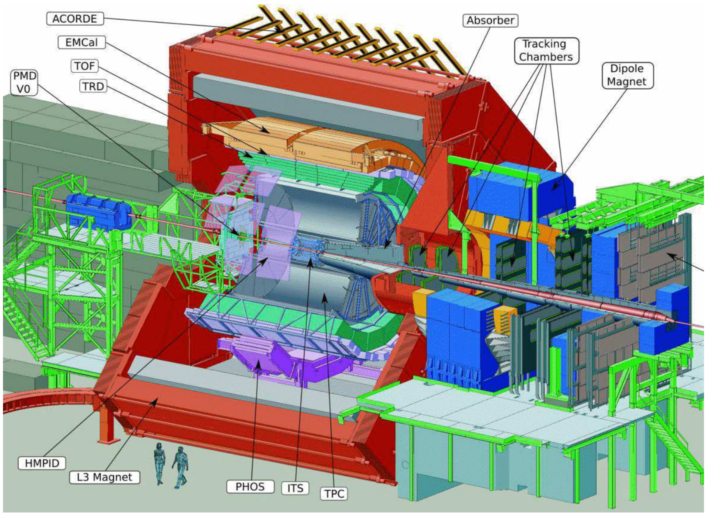

Figure 1. The ALICE detector, the only LHC experiment designed for heavy-ion collisions. The central barrel detectors used in this work are situated around the interaction point and consist of ITS and TPC.

2. Reconstruction

This work presents results from the two channels $\pi^0 \to \gamma\gamma \to e^+e^-e^+e^-$ and $\eta \to \gamma\gamma \to e^+e^-e^+e^-$. Both π^0 and η have the two photon decay channel as their most abundant one, with branching ratios of 0.99 and 0.39, respectively. Both decay photons are required to convert to e^+ e^- pairs in the detector material, support structures or gas. The acceptance of ALICE for reconstructing conversions is $|\eta| < 0.9$ and radius $r < 180$ cm, corresponding to full tracking in η for conversion daugthers. For $r > 180$ cm the e^+ and e^- tracks are too short to reconstruct the γ with high presicion.

Reconstruction of the photons is done with a general $V0$ reconstruction package which reconstructs Λ, $\overline{\Lambda}$, and K^0_S, as well as conversion photons. Several cuts need to be applied to select the photons from the total $V0$ sample. A series of quality cuts are applied to the tracks and $V0$ properties in order to obtain a clean sample of conversion photons. The most efficient cuts are listed in Table 1.

Table 1. Most significant cuts used to extract photons from $V0$ sample. The numbers in square brackets corresponds to the cut value used for the 900 GeV and 7 TeV data, respectively.

$\chi^2 < [30, 50]$ χ^2 of $V0$ reconstruction package fit function
$dE/dx(e) - [3, 10]\sigma_{(dE/dx)} < dE/dx < dE/dx(e) + [5, 10]\sigma_{(dE/dx)}$ dE/dx of tracks used in the $V0$ combination is required to be higher than $[3, 10]\sigma$ below the dE/dx electron line, and lower than $[5, 10]\sigma$ above the dE/dx electron line
$dE/dx > dE/dx(\pi)$, $p > 1\mathrm{GeV}/c$ dE/dx of tracks must be higher than the dE/dx pion line for $p > 1$ GeV/c

3. Results

Using the reconstructed conversion point locations, it is possible to make a map of where the material of ALICE is located. Comparison between real data and simulated data shows very good agreement on the material budget. Studies using simulated data have been performed to determine the conversion probability, which is 8% within the acceptance. The simulated data also allow for checking the reconstruction efficiency. It is defined as the number of reconstructed photons divided by number of converted photons. For the cuts used in this analysis the photon reconstruction efficiency is found to be 69% for p_t larger than 1.1 GeV/c. This gives a maximum π^0 and η reconstruction efficiency of 0.0030.

In Figure 2 the two-photon invariant mass distribution is shown for 900 GeV minimum bias p-p collisions, using a sample of 3.5×10^6 events. The black points are the data, and a clear π^0 peak can be seen. In blue the combinatorial background, determined by a mixed event technique in which photons from different events are combined in the same z-vertex and charged track multiplicity classes, is scaled to the total distribution in the region [0.6 GeV/c^2, 0.8 GeV/c^2]. The background describes the data very well. Figure 3 shows the same distribution for 7 TeV minimum bias p-p collisions, where both a clear π^0 and η peak can be seen.

Less strict cuts were used to extend the measurement to higher p_t, also resulting in more background. Investigation is ongoing to understand why the background is not describing the data between the π^0 and η peaks, currently believed to be an effect of the less strict cuts.

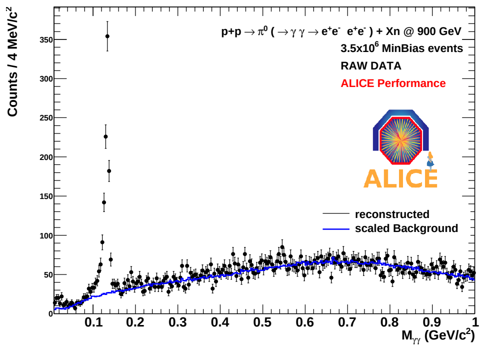

Figure 2. Invariant mass distribution for 3.5×10^6 minimum bias p-p events at 900 GeV.

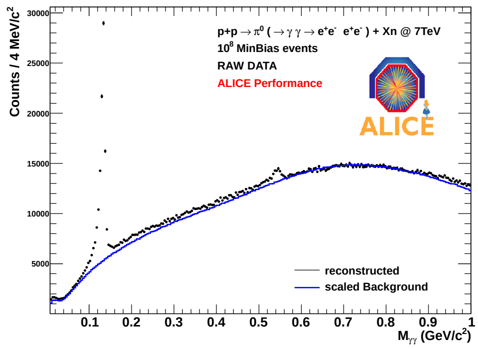

Figure 3. Invariant mass distribution for 10^8 minimum bias p-p events at 7 TeV.

The invariant mass distributions have also been divided into several p_t bins to extract the raw yield of the π^0. A clear π^0 peak was seen in p_t bins ranging from p_t of 0.4 GeV/c to 3.4 GeV/c for the 900 GeV data, and 0.4 GeV/c to 10 GeV/c for the 7 TeV data. For the 900 GeV/c data the signal-to-background (S/B) ranges between 2 and 6 for the four p_t bins, with significance between 35 and 60. The 7 TeV data were divided into 13 p_t bins where the S/B ranged between 1.5 for the lowest and highest p_t bins up to 4.5 for the midrange bins. The significance was between 10 and 350, where for most of the p_t bins it was above 100.

To fit the peaks in the different p_t bins Equation 1 is used. It is a Gaussian function modulated with an exponential to account for the bremsstrahlung tail.

$$y = G + \exp\left(\frac{M_{\gamma\gamma} - m_{\pi^0}}{\lambda}\right)(1-G)\theta(m_{\pi^0} - M_{\gamma\gamma}), \qquad G = \exp\left(-\frac{1}{2}\left(\frac{M_{\gamma\gamma} - m_{\pi^0}}{\sigma}\right)^2\right) \quad (1)$$

The peak position is systematically around 0.5 MeV/c^2 below the PDG value of 135 MeV/c^2 due to calibration. The resolution of the peaks is very good, ranging from 3-5 MeV.

In Figure 4 the raw yield of π^0 is shown for both the 900 GeV data in blue points, and for the 7 TeV data in red points. The error bars are statistical. The p_t range achieved for the 900 GeV data is from 0.4 GeV/c to 3.4 GeV/c. For the 7 TeV data it ranges from 0.4 GeV/c to 10 GeV/c.

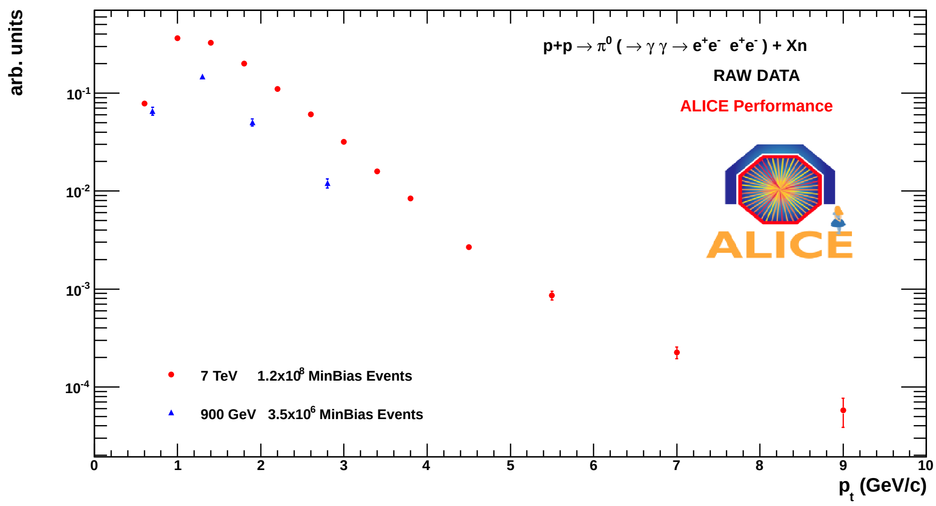

Figure 4. Raw yield of π^0 in arbitrary units versus p_t for 900 GeV data in blue, and 7 TeV data in red. Different sets of cuts have been used for the 900 GeV and the 7 TeV data.

4. Summary and outlook

It has been shown that measuring photons using reconstructed e^+e^- pairs from conversions can be carried out with high precision. Reconstructed conversion points provide information on the material budget of ALICE. Very good knowledge of the material budget is achieved so far, and further discussions with individual subdetector groups are ongoing to improve this agreement further. π^0 and η mesons can be reconstructed via converions with a mass resolution of 3-5 MeV, and very high significance. These measurements extend the measurement to low p_t, 0.4 GeV/c, below the reach of the calorimeter approach. A raw yield for the π^0 meson has been shown as a function of p_t for 900 GeV and 7 TeV data.

In the near future statistics at high p_t will be enriched using a conversion trigger that has been developed and is undergoing testing in the High Level Trigger (HLT), the online reconstruction framework of ALICE. In addition, the implementation of a conversion trigger in the TRD at hardware level is planned. PID can be improved further by using information from TOF and TRD, and using cuts in q_t from Armenteros-Podolanski plots. Fully corrected π^0 and η inclusive spectra will soon be available. Reconstruction using photon conversion from Dalitz decay is ongoing, and a study in which calorimeter and photon conversion measurements are combined has been started.

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