π^0 and η meson production in proton-proton collisions at $\sqrt{s} = 8$ TeV

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Introduction & Motivation

This poster introduces the performance of invariant differential cross section measurements of π^0 and η meson production at mid-rapidity in pp collisions at $\sqrt{s} = 8$ TeV which are carried out by ALICE. Furthermore, the particle production ratio η/π^0 will be obtained. The reported measurements will provide:

- a sensitive probe of strong interaction by comparisons with theory predictions
- tests for the empirical m_{T}-scaling law and for the universality of η/π^0 ratio
- a key input for inclusive direct photon measurement via π^0-tagging
- a reference for p-Pb run at $\sqrt{s}$ = 8.16 TeV (taken in Nov-Dec 2016)

Data Set, Detectors & Reconstruction Methods

ALICE has recorded pp collisions at $\sqrt{s} = 8$ TeV in 2012. Besides collecting minimum bias data, three calorimeter photon triggers were running (EMCal-L0/L1 + PHOS-L0) with approx. energy thresholds of (2/8.4 GeV + 4 GeV).

reconstruction methods	π^0	η	η/π^0
PCM	0.3 - 12.0	0.4 - 8.0	0.4 - 8.0
EMCal	1.2 - 20.0	2.0 - 35.0	2.0 - 20.0
PCM-EMCal	0.8 - 35.0	1.2 - 25.0	1.2 - 25.0
PHOS	1.0 - 35.0	N/A	N/A
	available p_{T} reach (GeV/c)		

Table 1: Photon reconstruction is performed by means of two fundamentally different methods: (i) using photon conversion method (PCM) and (ii) using EM-calorimeters (EMCal+PHOS). Various cuts on track/photon quality and cluster/meson selection are applied.

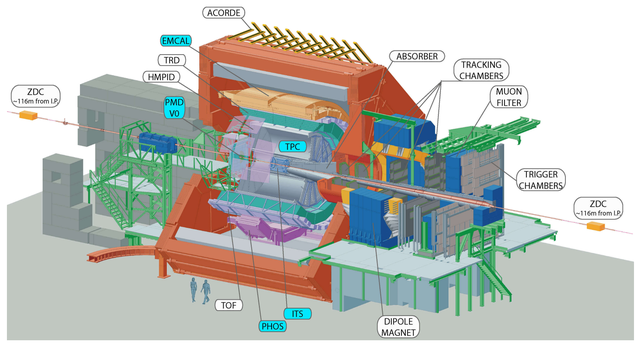

Figure 1: ALICE and its sub-detectors – most relevant detectors for the presented analyses are highlighted in light blue.

The following luminosities were recorded for each trigger:
- minimum bias trigger, V0AND
  ($\mathscr{L}_{\mathrm{MB}} \approx 2\ \mathrm{nb}^{-1}$)
- calorimeter triggers, EMCal-L0/L1 + PHOS-L0
  ($\mathscr{L}^{\mathrm{EMC}}_{\mathrm{L0/L1}} \approx 41/615\ \mathrm{nb}^{-1}$ and $\mathscr{L}^{\mathrm{PHOS}}_{\mathrm{L0}} \approx 136\ \mathrm{nb}^{-1}$)

Invariant Mass Analysis

Neutral mesons are reconstructed via their two-gamma decay channels $\pi^0(\eta) \rightarrow \gamma\gamma$ with branching ratios of 98.823±0.034 % (39.31±0.20 %). The invariant mass of two photon candidates ($\gamma 1$, $\gamma 2$) is determined by $M_{\gamma 1 \gamma 2} = \sqrt{2E_{\gamma 1}E_{\gamma 2}(1 - \cos\theta_{\gamma 1 \gamma 2})}$, which is used to determine the raw yields:

- event-mixing technique to subtract uncorrelated combinatorial background
- correlated background contributions are considered by adding a first order polynomial to the fit
- fit of signal distributions with a Gaussian plus exponential tail or a Crystal Ball (PHOS only) from which the integration ranges are obtained to determine the raw yields

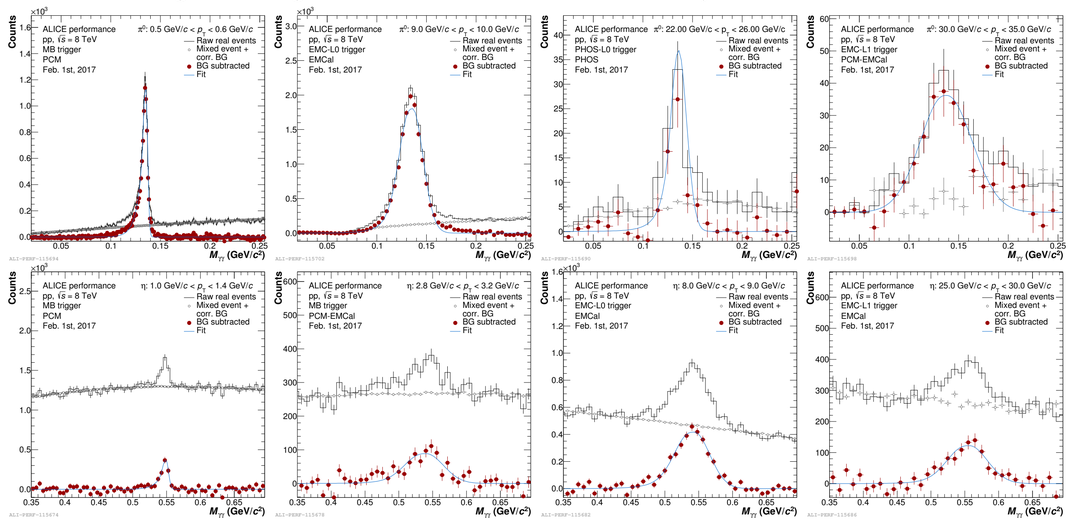

Figure 2: Invariant mass distributions of π^0 (top) and η (bottom) candidates showing raw yields (black), background (gray) and signal (red) distributions as well as fits of signal (blue). The selection of reconstruction methods represents their given performance as a function of transverse momenta and a selection of triggers used in the analyses.

Cluster – V0-Track Matching for Hybrid Method PCM-EMCal

The so-called hybrid PCM-EMCal analysis provides a crucial cross-check and furthermore overcomes cluster merging limitation of EMCal π^0 measurement at high momenta. A special feature of this reconstruction method is the need of matching the conversion photon legs with calorimeter clusters:

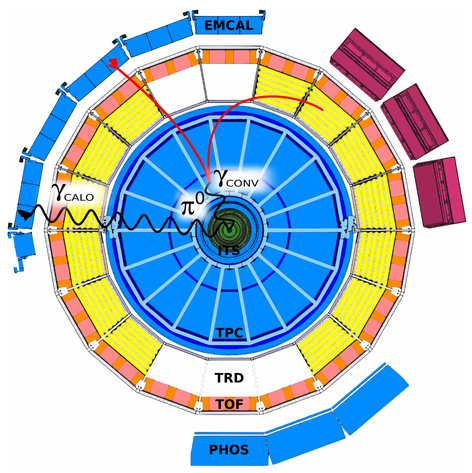

Figure 3: Visualization of a π^0 decay into two photons. One leg of the conversion photon γ_{conv} reaches EMCal and, hence, creates a cluster. Combining γ_{calo} and γ_{conv} gives the invariant mass of the true candidate. However, γ_{conv} is also combined during analysis with the cluster created by the conversion daughter in red. These pairings are removed with high efficiency (>99 %) by propagating and matching the conversion daughters with EMCal clusters.

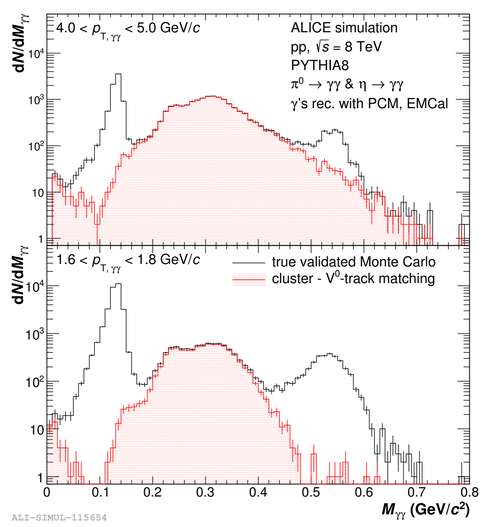

Figure 4: In black, some invariant mass distributions for true validated neutral pions decaying into two photons are shown. After propagating and matching the conversion daughters, the red distribution could be subtracted, yielding clear meson peaks and pronouncing the importance of this procedure.

Monte Carlo Simulations & Performance

Monte Carlo productions used for analysis:
- minimum bias PYTHIA 8 and Phojet
- PYTHIA 8 with hard QCD processes to be able to correct triggered data up to high meson momenta above 30 GeV/c.

Combination of different measurements:
- BLUE (Best Linear Unbiased Estimate) + considering cross-correlations of errors

Final results will be corrected for
- detector acceptance
- reconstruction efficiency
- secondary contributions from weak decays and material interactions
- track multiplicities
- pile-up contributions (PCM)
- bin-shifting

The performance and projected p_{T} reach of neutral meson analyses are demonstrated by the following figures which already contain combined results of all available triggers for each method:

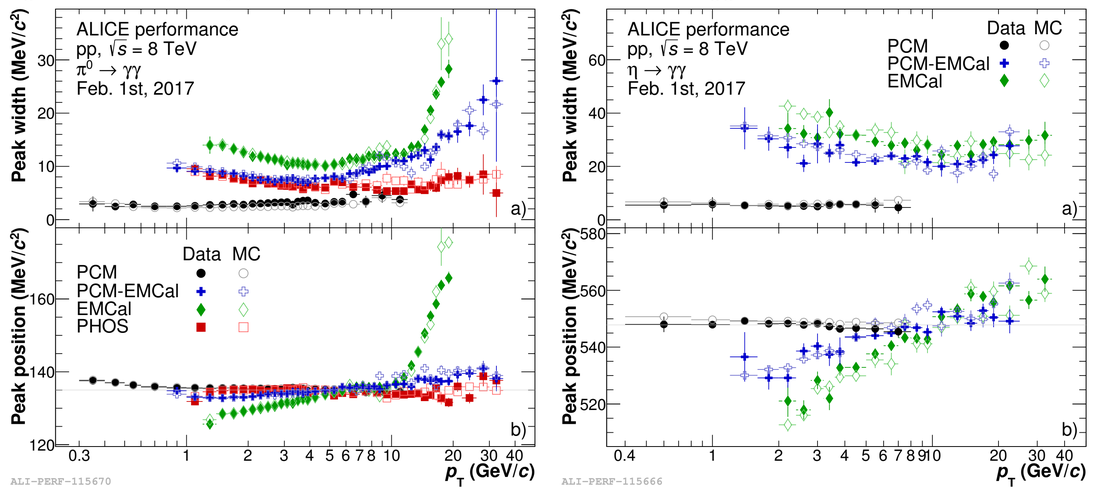

Figure 5: Meson masses and widths extracted from fits of invariant mass distributions in data and Monte Carlo simulations are shown for π^0 (left) and η mesons (right). Results of each method already show combinations of all available triggers. An agreement within errors is found confirming a proper detector description and response in Monte Carlo.

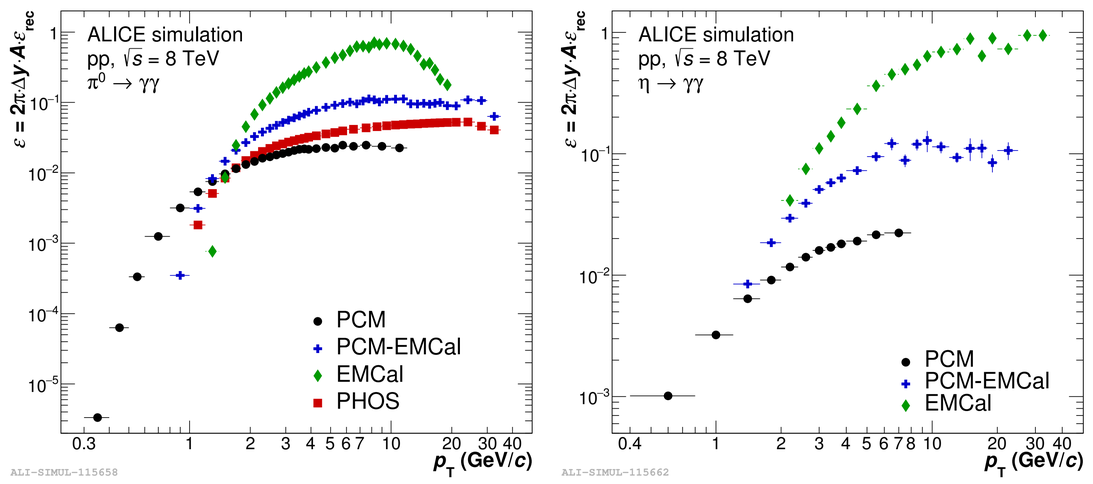

Figure 6: Normalized efficiencies 'ϵ' for π^0 (left) and η mesons (right), including acceptance corrections and reconstruction efficiencies. The quoted values are normalized to polar angle as well as rapidity in order to enable a direct comparison of reconstruction methods.

Final Results & Publication

Neutral meson measurements are being carried out using the presented reconstruction methods which will be properly combined to obtain final results. A publication will be submitted soon, highlighting:

- a combined measurement of π^0 and η meson production for $0.3 < p_{\mathrm{T}} < 35.0$ GeV/c and $0.4 < p_{\mathrm{T}} < 35.0$ GeV/c accordingly
- a combined measurement of η/π^0 ratio for $0.4 < p_{\mathrm{T}} < 25.0$ GeV/c
- comparisons of results with NLO pQCD calculations using FF:DSS14 (FF:AESSS for η) and different tunes of PYTHIA 8.2
- a powerful test of $\mathrm{m_T}$ scaling and universality of η/π^0

Direct Photon Analysis: Neutral Pion Tagging

An inclusive direct photon analysis using neutral pion tagging via hybrid method PCM-EMCal:

+ material budget related errors cancel
+ additional, independent measurement of R_γ
− but EMCal related uncertainties enter

An inclusive photon measurement by PCM gives:

$$N_\gamma^{\mathrm{incl}} \overset{(1)}{=} \epsilon_{\mathrm{pur}}\, P_{\mathrm{conv}}\, \epsilon_{\gamma,\mathrm{eff}}\, A_\gamma\, \gamma^{\mathrm{incl}},$$

whereas number of tagged π^0 decays reads as:

$$N_\gamma^{\pi^0_{\mathrm{Tag}}} \overset{(2)}{=} \langle \epsilon_\gamma f \rangle\, P_{\mathrm{conv}}\, \epsilon_{\gamma,\mathrm{eff}}\, A_\gamma\, \gamma^{\pi^0},$$

where $\langle \epsilon_\gamma f \rangle$ is the conditional probability if photon (1) is converted and reconstructed to find second photon within acceptance of EMCal which is furthermore successfully reconstructed.

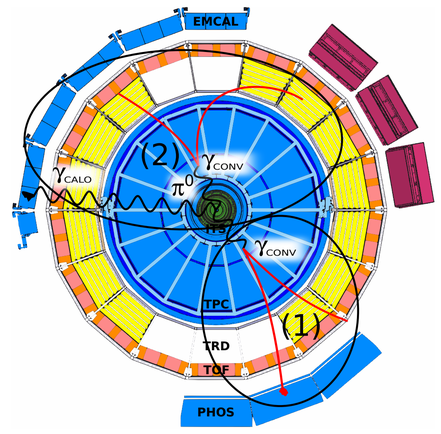

Figure 7: (1) A PCM photon candidate with two conversion legs - (2) A tagged neutral pion candidate by detecting one conversion photon and the associated EMCal photon.

$\Rightarrow R_\gamma$ may be obtained by:

$$R_\gamma = \frac{\gamma^{\mathrm{incl}}}{\gamma^{\mathrm{hadron}}} = \frac{\gamma^{\mathrm{incl}}/\gamma^{\pi^0}}{\gamma^{\mathrm{hadron}}/\gamma^{\pi^0}} = \frac{\langle \epsilon_\gamma f \rangle \left(\frac{N_\gamma^{\mathrm{incl}}}{N_\gamma^{\pi^0,\mathrm{Tag}}} \right)_{\mathrm{Data}}}{\epsilon_{\mathrm{pur}} \left(\frac{N_\gamma^{\mathrm{hadron}}}{N_\gamma^{\pi^0}} \right)_{\mathrm{Sim}}}$$

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