Measurement of Neutral Mesons and Direct Photons in pp collisions with the ALICE EMCal detector at the Large Hadron Collider

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Introduction & Motivation

This poster presents neutral meson and inclusive as well as direct photon measurements carried out by the ALICE experiment at the CERN LHC for pp collisions at $\sqrt{s}$ = 0.9 [1], 2.76 [2], 7 [1] and 8 TeV [3, 4, 5], providing important references/baselines for p-Pb and Pb-Pb collisions.

- **Neutral meson measurements:**
  - No other identified particle spectra are available with comparable p_T reach
    ⇒ important input for fragmentation function fits and comparisons with theory predictions
  - Dominant source of decay photons and, therefore, key input for many measurements (direct photons, di-electrons, HF electrons,...)
    ⇒ precise measurements yield essential knowledge about decay photons
- **Photon measurements:**
  - Distinguish between different categories: **inclusive photons** = **decay + direct photons**
  - Direct photons from different sources: prompt, fragmentation, thermal components
    ⇒ photons are produced at any stage of the collision and escape the medium unaffected

Photon Reconstruction with the EMCal

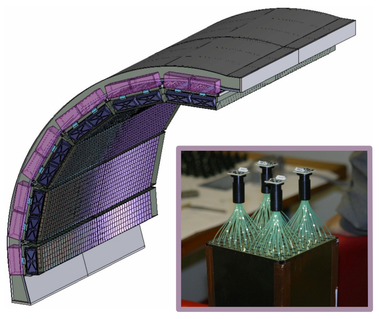
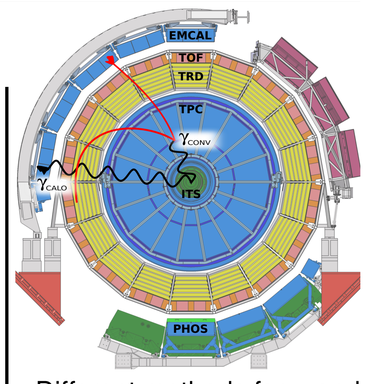


Figure 1: The EMCal with its supporting structure. A module is composed of four separate cells, being read out with wavelength shifting fibres connected to APDs.

- Photon reconstruction by grouping cells with deposited energies into so-called clusters
  - High reconstruction efficiency, design limit of ~20 GeV/c for π^0 reconstruction due to cell segmentation
    ⇒ can be overcome using 'hybrid methods' which combine EMCal and conversion photons
- Triggering capabilities on high energy deposit in the EMCal to enhance p_T reach significantly



- Different methods for γ and neutral meson reconstruction:
  - EMCal, PCM, PHOS
  - PCM-EMCal, (PCM-PHOS)

Neutral Meson Measurements in pp, $\sqrt{s}$ = 0.9, 2.76, 7 and 8 TeV

- Reconstruction via $\pi^0(\eta) \to \gamma\gamma$, with BR of 98.82% (39.31%), using invariant mass technique:

$$M_{\gamma_1\gamma_2} = \sqrt{2E_{\gamma_1}E_{\gamma_2}\left(1-\cos\theta_{\gamma_1\gamma_2}\right)}$$

  - Event-mixing technique to estimate and subtract uncorrelated combinatorial background
  - Correlated background contributions are considered by adding a linear contribution to the fit
  - Fit of signal with Gaussian plus exp. tail ⇒ integration ranges ⇒ raw yields by bin counting

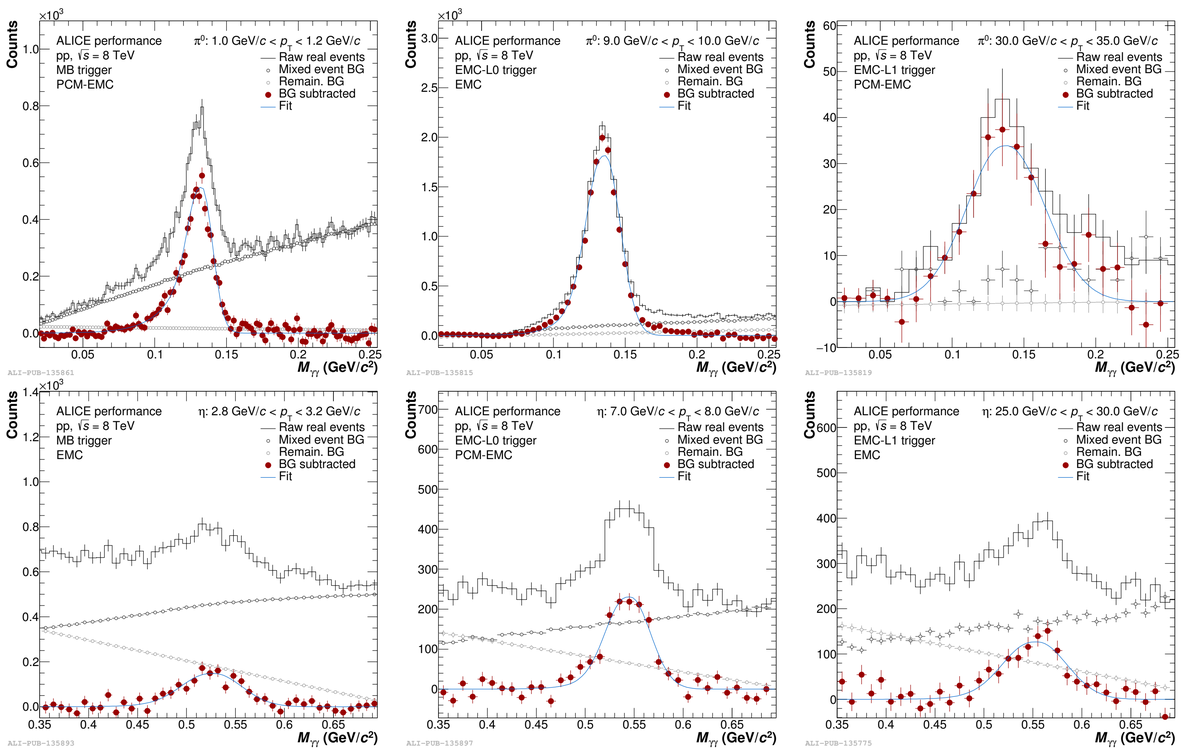


Figure 2: Invariant mass distributions of π^0 (top) and η (bottom) candidates involving EMCal photons for pp, $\sqrt{s}$ = 8 TeV [3, 4], for which raw yields (black), background (gray) and signal (red) distributions as well as fits of signal (blue) are shown.

- Available Monte Carlo simulations based on PYTHIA and PHOJET event generators for pp collisions, after which GEANT3 simulates the full detector response.
  - Corrections for:
    - pileup
    - acceptance
    - efficiency
    - secondaries (from weak decays and material interactions)

- Combination of all reconstruction methods:
  - BLUE (Best Linear Unbiased Estimate), see Ref. [3], and consider cross-correlations of uncertainties
  - Combined measurements include all methods, yielding total uncertainties as low as ~5% (~10%) for π^0 (η) mesons for the most part of transverse momenta

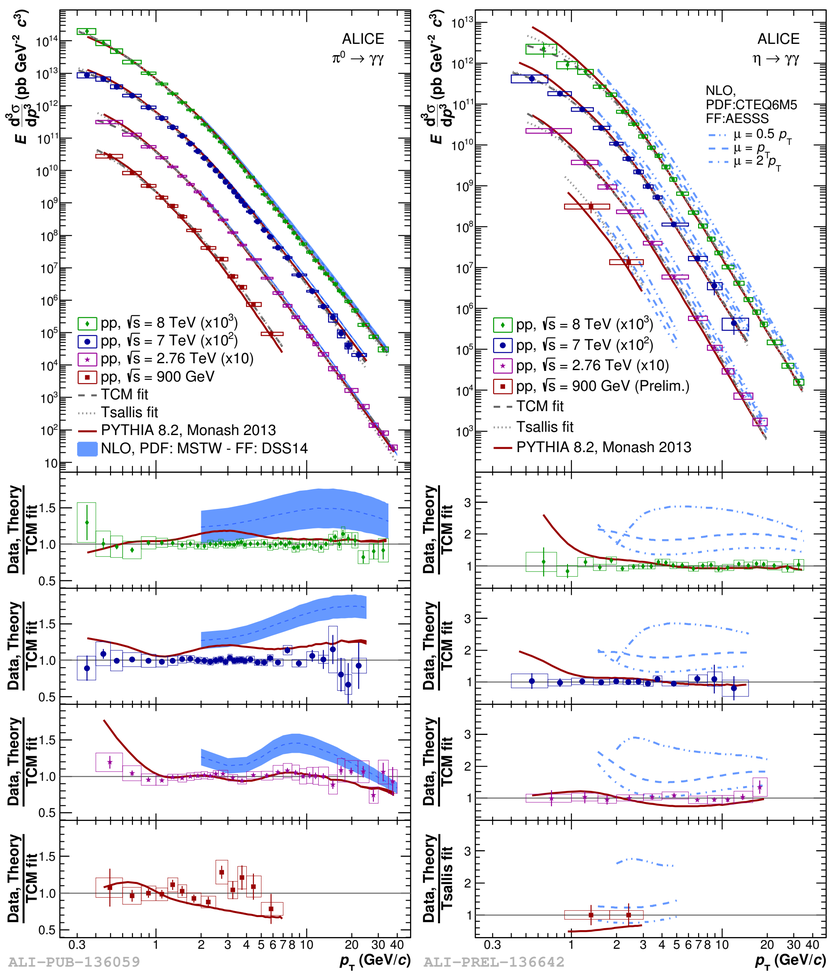


Figure 3: Invariant cross sections for neutral meson production in pp, $\sqrt{s}$ = 0.9 [1], 2.76 [2], 7 [1] and 8 TeV [3, 4], compared with NLO pQCD calculations using FF:DSS14 (FF:AESSS) for π^0 (η) and different tunes of PYTHIA 8.2. The spectra are fitted using the two-component model (TCM) as well as Tsallis parameterizations.

Direct Photon Measurements in pp, $\sqrt{s}$ = 2.76 and 8 TeV

- Description of decay photons by particle decay simulation (so-called cocktail)
- Direct photons via subtraction method:

$$\gamma_{dir} = \gamma_{inc} - \gamma_{dec} = \left(1 - \frac{\gamma_{dec}}{\gamma_{inc}}\right)\cdot\gamma_{inc} = \left(1 - \frac{1}{R_\gamma}\right)\cdot\gamma_{inc}$$

- Direct photon excess ratio:

$$R_\gamma = \left(\frac{\gamma_{inc}}{\pi^0}\right)_{meas} \Big/ \left(\frac{\gamma_{dec}}{\pi^0}\right)_{sim} \approx \frac{\gamma_{inc}}{\gamma_{dec}}$$

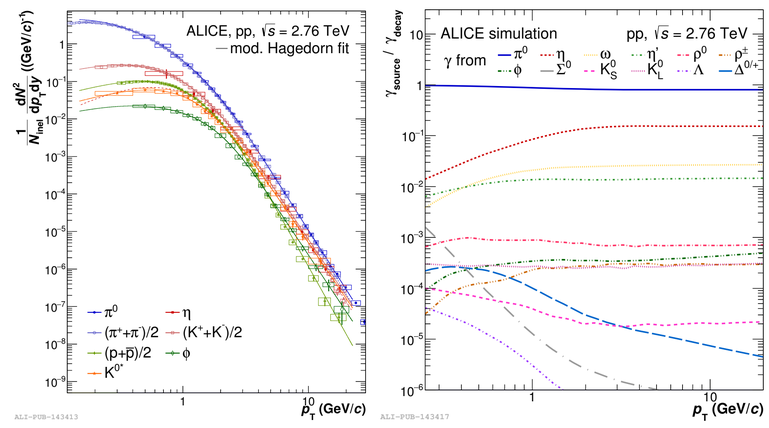


Figure 4: (left) Measured particle spectra and their parameterizations which are input for the particle decay simulation containing all sources of decay photons, as used in Ref. [5]. The remaining spectra are obtained with m_T-scaling. (right) The fraction of decay photons from each individual particle compared to the total amount of decay photons, plotted versus p_T. The dominant sources are the π^0 (~ 82%) and η (~ 16%) meson, which are published in Refs. [2].

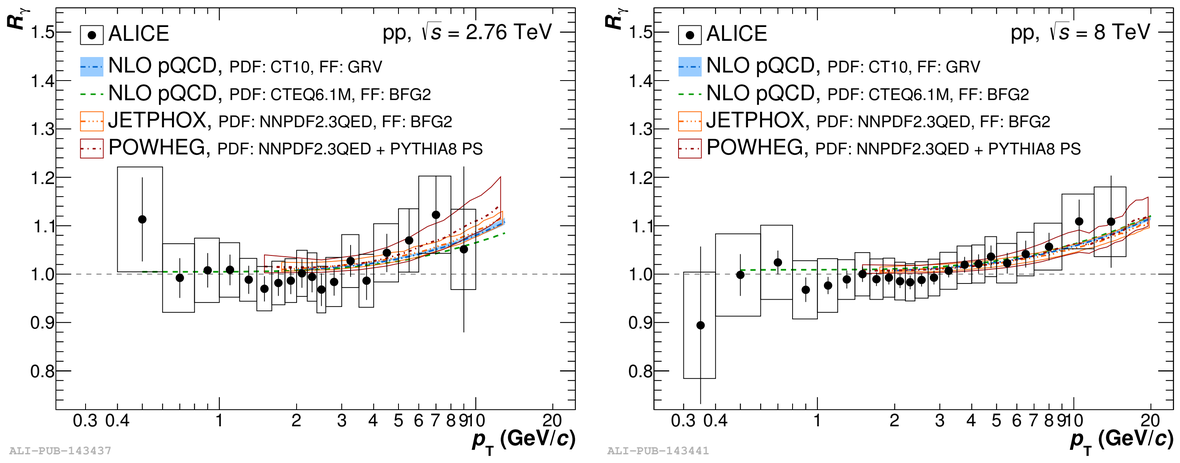


Figure 5: Final results for R_γ obtained after combining all available reconstruction methods (PCM, PCM-EMCal and EMCal ⇒ BLUE method with proper correlations of uncertainties as input) for pp, $\sqrt{s}$ = 2.76 and 8 TeV [5].

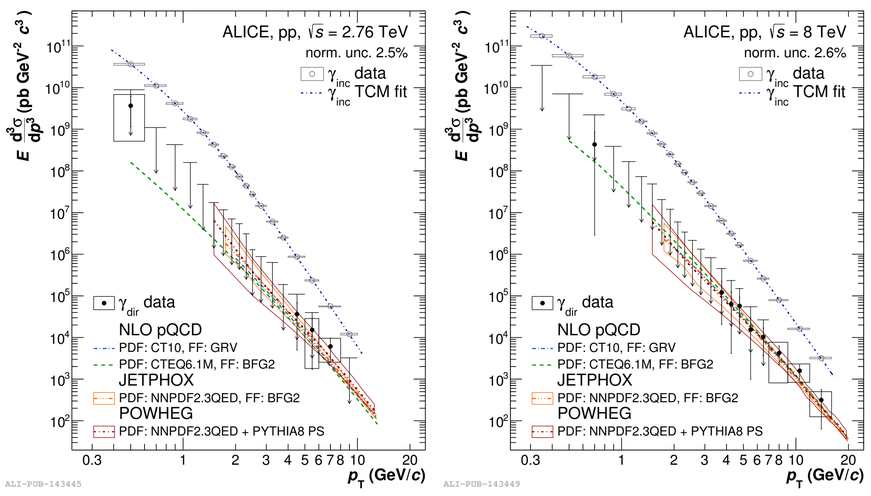


Figure 6: The measured cross sections of inclusive and direct photon production for pp, $\sqrt{s}$ = 2.76 and 8 TeV [5], obtained via the subtraction method. If the measured R_γ is compatible with unity within its statistical (systematic) uncertainties, upper limits are given at 90% C.L. for direct photons, otherwise data points are provided.

- $R_\gamma > 1$
  ⇒ direct photon signal!
- NLO theory predictions plotted as:
  $R_{NLO} = 1 + \frac{\gamma_{dir}^{NLO}}{\gamma_{dec}}$
- Within uncertainties no access at low p_T
  ⇒ reinforces PbPb interpretation [6]

- Inclusive photon reconstruction: corrected for purity, secondaries, efficiency, momentum resolution, conv. prob. (PCM)

References

[1] **ALICE** Collaboration, B. Abelev *et al.*, "Neutral pion and η meson production in proton-proton collisions at $\sqrt{s}$ = 0.9 TeV and $\sqrt{s}$ = 7 TeV," *Phys. Lett.* **B717** (2012) 162–172, arXiv:1205.5724.

[2] **ALICE** Collaboration, S. Acharya *et al.*, "Production of π^0 and η mesons up to high transverse momentum in pp collisions at 2.76 TeV," *Eur. Phys. J.* **C77** (2017) 339, arXiv:1702.00917.

[3] **ALICE** Collaboration, S. Acharya *et al.*, "π^0 and η meson production in proton-proton collisions at $\sqrt{s}$ = 8 TeV," *Eur. Phys. J.* **C78** (2018) 263, arXiv:1708.08745.

[4] **ALICE** Collaboration, S. Acharya *et al.*, "Supplemental figures: π^0 and η meson production in proton-proton collisions at $\sqrt{s}$ = 8 TeV," ALICE-PUBLIC-2017-009. http://cds.cern.ch/record/2282851.

[5] **ALICE** Collaboration, S. Acharya *et al.*, "Direct photon production at low transverse momentum in proton-proton collisions at $\sqrt{s}$ = 2.76 and 8 TeV," arXiv:1803.09857.

[6] **ALICE** Collaboration, J. Adam *et al.*, "Direct photon production in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV," *Phys. Lett.* **B754** (2016) 235–248, arXiv:1509.07324.

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