Measurement of ω mesons via their three pion decay with ALICE in pp collisions at $\sqrt{s} = 7$ TeV

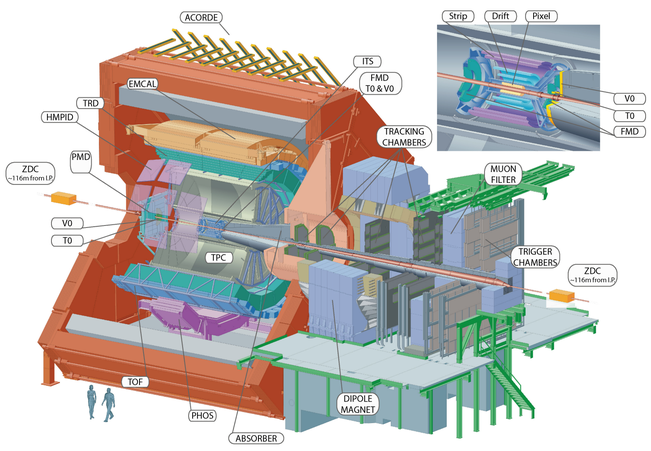
Florian Jonas for the ALICE collaboration
Westfälische Wilhelms-Universität Münster, Germany
Oak Ridge National Laboratory, TN, United States

137th LHCC Meeting 2019

Abstract

In this contribution, the differential invariant cross section of ω meson production at mid-rapidity in proton-proton collisions at $\sqrt{s} = 7\,\mathrm{TeV}$ is presented. The meson is reconstructed using its $\pi^+\pi^-\pi^0$ decay channel, requiring the identification and measurement of charged pions using ALICE's tracking capabilities as well as the reconstruction of neutral pions via their decay to two photons. All methods available in ALICE to measure photons at mid-rapidity are used: Its two calorimeters, the EMCal and the PHOS, as well as the so-called Photon Conversion Method (PCM), which allows to measure photons via pair conversions. In addition, two hybrid approaches are used for the neutral pion reconstruction which combine calorimeter photon measurements with the PCM.

Introduction



ALICE [1] is designed as a heavy-ion experiment and its research mainly focuses on the properties of the quark-gluon plasma (QGP) – a phase of strongly interacting matter in which quarks and gluons exist as deconfined particles. Due to the high energy densities reached in Pb-Pb collisions at the LHC, the creation of the QGP is expected and supported by measurements up to this point.

Studying the particles created in a collision (in this case the ω meson) offers important insights into the different stages of the collision and the obtained meson production cross sections have a variety of applications:

- **Theoretical Motivations:**
  - By comparing the measured cross sections to theory predictions, the underlying models and assumptions can be tested and constrained (e.g. the used Fragmentation Function or Parton Distribution Function).
- **Experimental Motivations:**
  - The obtained cross sections are needed as input for other analyses such as direct photon [2] and di-electron measurements to determine the background of decay photons and leptons, respectively.
  - The cross sections are probes for the QGP: The suppression of hadron production in Pb-Pb collisions at high transverse momentum (p_T) with respect to pp collisions is expected due to the presence of the QGP. Furthermore, a decrease of the ω mass and increase in its width is expected due to partial restoration of chiral symmetry in the QGP [3].

Event Selection

- The data used in this analysis consists of about 440 million minimum bias pp events at $\sqrt{s} = 7\,\mathrm{TeV}$ (integrated luminosity $\mathcal{L}_\mathrm{int} \approx 7\,\mathrm{nb}^{-1}$), recorded at the LHC in 2010. The minimum bias trigger requires a hit in either of the two V0 detectors or a hit in the Silicon Pixel Detector (SPD), the innermost layer of the Inner Tracking System (ITS).
- The same amount of events is generated using the Monte Carlo event generator PYTHIA6 and the generated particles are further propagated through the ALICE detectors using GEANT3.

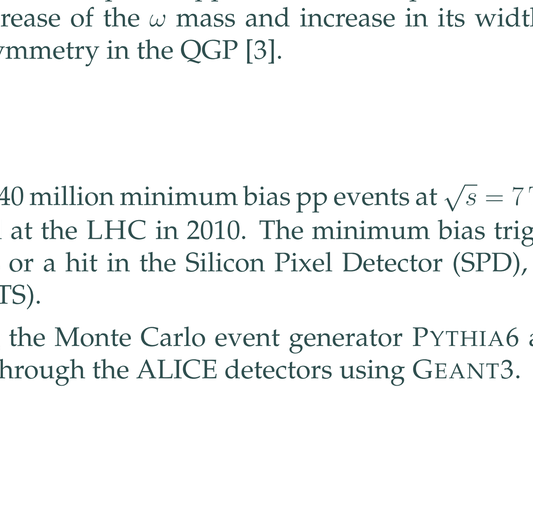
Photon Reconstruction

Three different techniques are available in ALICE to measure photons at mid-rapidity:

Photon Conversion Method (PCM)
- Coverage: $|\eta| < 0.9,\ 0° < \varphi < 360°$
- Photons can undergo pair creation in detector material and the created e^+e^- pairs are visible as two charged tracks with opposite curvature.
- Reconstruction of secondary-vertex $\Rightarrow$ conversion point of original photon
- Allows photon measurements down to very low momentum ($p_\mathrm{T} \sim 0.2\,\mathrm{GeV}/c$).

Photon Spectrometer (PHOS):
- Coverage: $|\eta| < 0.13,\ 260° < \varphi < 320°$ [4]
- Consists of 10 752 lead-tungstate crystals.
- Smaller coverage than EMCal but higher granularity.
- Optimised for low momenta photons (down to $p_\mathrm{T} \sim 0.3\,\mathrm{GeV}/c$).

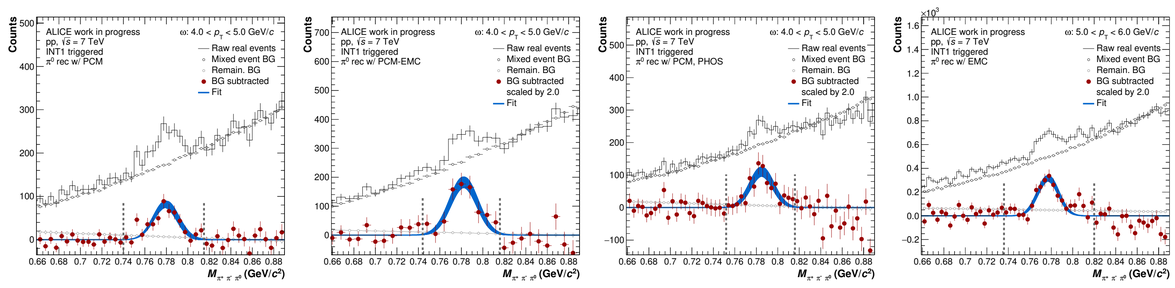
Electromagnetic Calorimeter (EMCal):
- Coverage: $|\eta| < 0.7,\ \Delta\varphi = 40°$ [5]
- Layered Pb-scintillator sampling calorimeter
- Designed for high-p_T measurements



Charged Pion Measurement

- Reconstruction of tracks in the Time Projection Chamber (TPC) and the ITS
- Identification of charged pion tracks via $\mathrm{d}E/\mathrm{d}x$ measurement in the TPC

Invariant Mass Analysis



- The ω is reconstructed via its decay to $\pi^+\pi^-\pi^0$ by calculating the invariant mass of all three-pion combinations in a given event [6].
- Neutral pions are reconstructed via their decay to two photons [7]. Five different methods are used for the π^0 reconstruction that differ in how each of its decay photons is measured:
  PCM, PCM-EMCal, PCM-PHOS, EMCal and PHOS
- The underlying background is described using event mixing, π^0 sideband mixing or like-sign mixing.
- Any residual background is described using a linear fit and the signal is then fitted using a Gaussian.

$\omega(782)$ [8]
$m = 782.65(12)\,\mathrm{MeV}/c^2$
$\Gamma_\mathrm{Tot} = 8.49(8)\,\mathrm{MeV}/c^2$
Decays:
$\Gamma_{\pi^+\pi^-\pi^0}/\Gamma_\mathrm{Tot} = 89.20(7)\,\%$
...

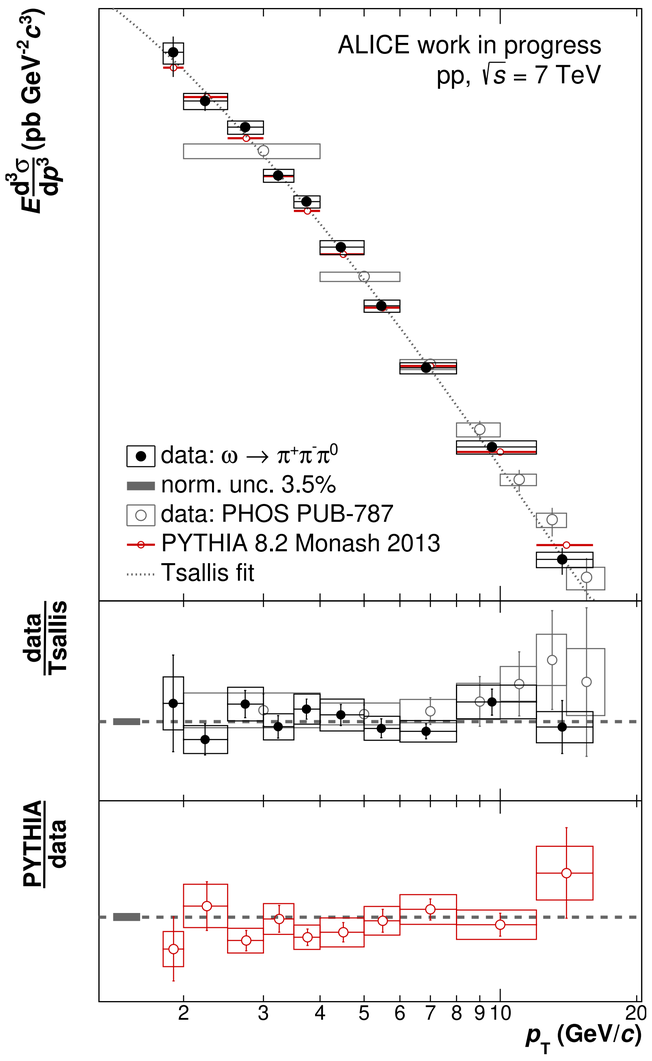
π^0 [8]
$m = 134.9970(5)\,\mathrm{MeV}/c^2$
$c_\tau = 25.5\,\mathrm{nm}$
Decays:
$\Gamma_{\gamma\gamma}/\Gamma_\mathrm{Tot} = 98.823(34)\,\%$
...

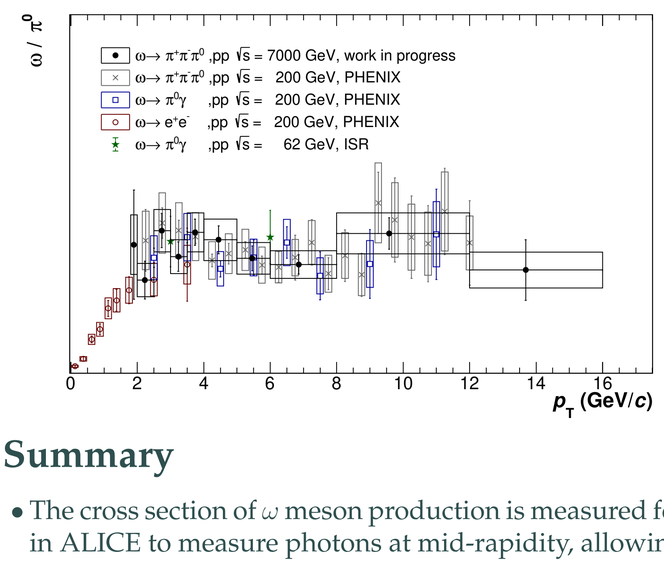
Results

- The five individual measurements are combined using the Best Linear Unbiased Estimate (BLUE) method [9] which weights the measurements according to their stat. and sys. uncertainties.
- The cross section of ω meson production in pp collisions at $\sqrt{s} = 7\,\mathrm{TeV}$ is successfully measured for $1.8 < p_\mathrm{T} < 16\,\mathrm{GeV}/c$.
- Parameterization of the cross section possible using Tsallis function.

Comparison to other measurement:
- Data in agreement with stand-alone PHOS measurement [10].
- Improved momentum resolution at low p_T.

Comparison to theory:
- PYTHIA8.2 with Monash 2013 tune in agreement with data over whole momentum range.





Particle ratios:
- ω/π^0 ratio in agreement with measurements at lower collision energies
  $\Rightarrow$ supporting observation that ratio is independent of collision energy at high p_T
- Constant cross section ratio at high p_T can be used for m_T-scaling [11] of other mesons.

Summary

- The cross section of ω meson production is measured for the first time using all available methods in ALICE to measure photons at mid-rapidity, allowing to access a wide momentum range.
- Results consistent with stand-alone PHOS measurement & PYTHIA theory predictions.
- ω/π^0 ratio in agreement with measurements at lower collision energies.

References

[1] K. Aamodt et al. The ALICE experiment at the CERN LHC. *JINST*, 3:S08002, 2008.
[2] Jaroslav Adam et al. Direct photon production in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV. *Phys. Lett.*, B754:235–248, 2016.
[3] Yuji Tsuchimoto. In-Medium Modifications of Low-Mass Vector Mesons in PHENIX at RHIC. *Nucl. Phys.*, A830:487C–490C, 2009.
[4] V Man'ko et al. ALICE Photon Spectrometer (PHOS): Technical Design Report. Technical Report CERN-LHCC-99-004, 1999.
[5] P Cortese et al. ALICE Electromagnetic Calorimeter Technical Design Report. Technical Report CERN-LHCC-2008-014. ALICE-TDR-14, Aug 2008.
[6] F. Jonas. Measurement of ω and η mesons via their three pion decay with ALICE in pp collisions at $\sqrt{s} = 7$ TeV, Sep 2018. CERN-THESIS-2018-313.
[7] 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.*, B717:162–172, 2012.
[8] M. Tanabashi et al. Review of particle physics. *Phys. Rev. D*, 98:030001, Aug 2018.
[9] A. Valassi et al. Information and treatment of unknown correlations in the combination of measurements using the BLUE method. *Eur. Phys. J.*, C74:2717, 2014.
[10] S. Acharya et al. Production of $\omega(782)$ in pp collisions at $\sqrt{s} = 7$ TeV. May 2018. ALICE-PUBLIC-2018-004.
[11] L. Altenkämper et al. Applicability of transverse mass scaling in hadronic collisions at energies available at the CERN Large Hadron Collider. *Phys. Rev.*, C96(6):064907, 2017.