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ω and η' production in proton-proton collisions at the LHC measured with ALICE

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**VIRTUAL
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ALICE



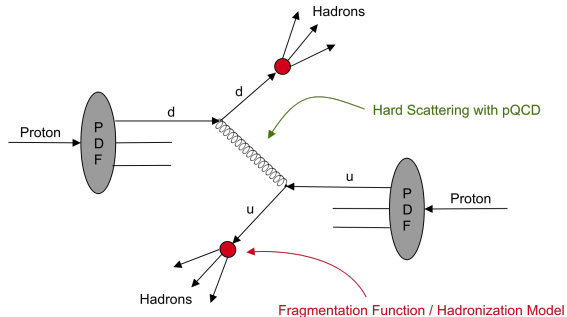
Motivation I: Theoretical motivations

- measurements of hadron production allow to **test theory calculations** and constrain underlying ...

... parton distribution functions (PDF)

... fragmentation functions (FF)

- heavy neutral mesons (e.g. ω and η') are an **interesting complementary probe** to existing π^0 and η measurements (different mass, spin ...)



- spark interest for new developments** of fragmentation functions:
"No such considerable interest has been shown towards vector meson production due to the scarcity of the data available so far." (arXiv:1705.00214)

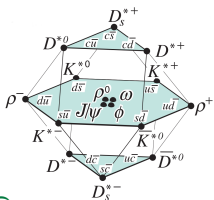
Experimental Motivations I: Ones signal is others background

- neutral mesons contribute as **background in other measurements**
 - decay photons in direct photon measurements (e.g. $\omega \rightarrow \pi^0 \gamma$)
 - background in di-lepton measurements (e.g. $\omega \rightarrow e^+ e^-$)
- ⇒ better knowledge of background
- ⇒ smaller uncertainties on signal

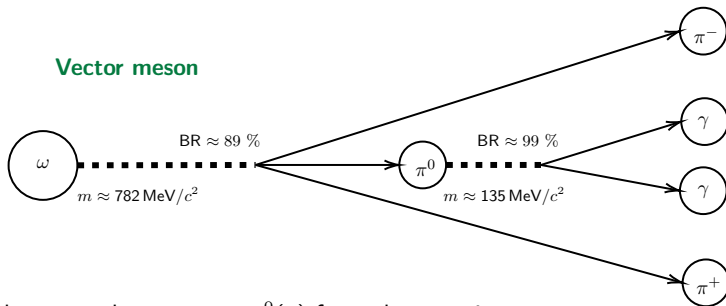
Experimental Motivations II: Probe for the quark-gluon plasma (QGP)

- pp data baseline for study of production suppression in p-Pb or Pb-Pb due to QGP
 $\rightarrow \omega, \eta'$ vs. π^0, π^\pm : dependence on mass, spin, flavor?
- modification of meson properties (mass, width) due to partial restoration of chiral symmetry in QGP

Analysis recipe

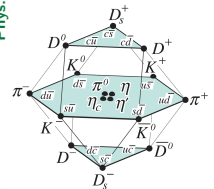


Vector meson

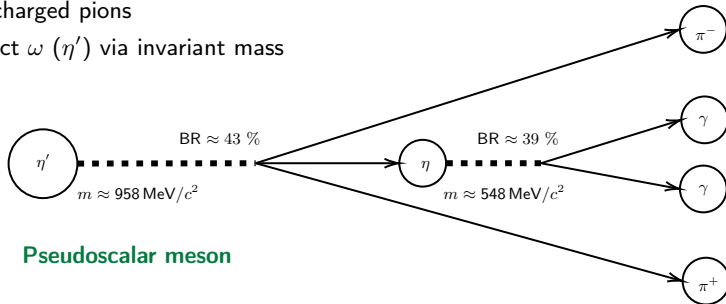


Strategy:

- 1 Measure photons and reconstruct $\pi^0(\eta)$ from photon pairs
- 2 Measure charged pions
- 3 Reconstruct ω (η') via invariant mass

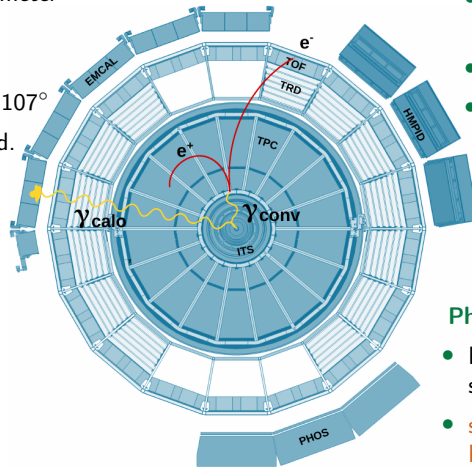


Pseudoscalar meson



ElectroMagnetic Calorimeter (EMCal)

- Pb-scintillator sampling calorimeter
- **larger acceptance** than PHOS but **lower resolution**
- acceptance: $|\eta| < 0.7$, $\Delta\varphi = 107^\circ$
- size per tower ≈ 2 Molière rad.



Photon Conversion Method (PCM)

- measurement of photons via their conversion to e^+e^- pairs
- good resolution and low- p_T reach
- limited by conversion probability of $\approx 8\%$

Photon Spectrometer (PHOS)

- based on lead-tungstate scintillation crystals
- **smaller acceptance** than EMCAL but **higher resolution**
- acceptance: $|\eta| < 0.13$, $\Delta\varphi = 70^\circ$
- crystal size ≈ 1 Molière radius

Dijet Calorimeter (DCal)

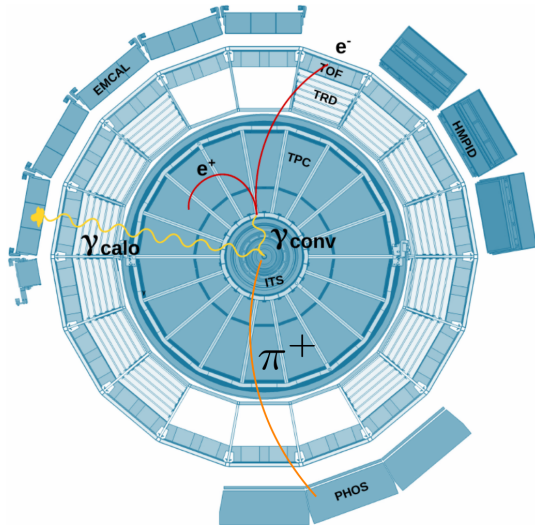
- installed since 2015
- extension of EMCAL at opposite side in azimuth

General track selection

- reconstruction of track in Inner Tracking System (ITS) and Time Projection Chamber (TPC)
- cuts on the number of hit points in TPC & χ^2 of track fitting ensure good track quality

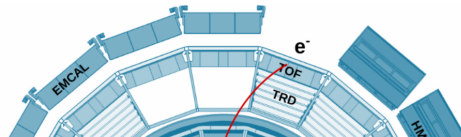
Charged pion identification

- selection of primary particle through cut on DCA to collision vertex
- identification of pions via energy loss dE/dx in TPC



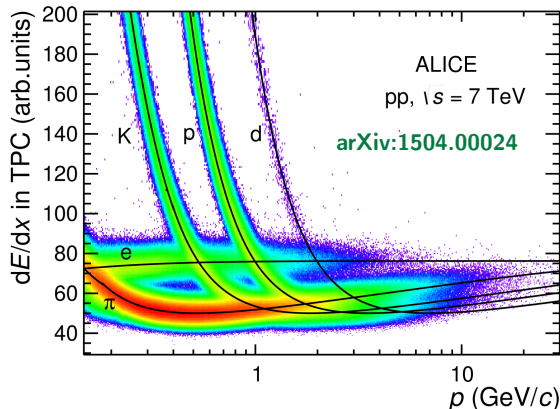
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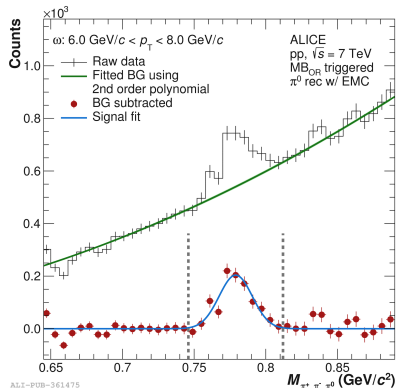
Meson reconstruction

π^0 or η reconstruction

- reconstruction via $\pi^0/\eta \rightarrow \gamma\gamma$
- Idea:** combine all different photon reconstruction methods to profit from advantages of each method:
 - PCM-PCM
 - PCM-EMCal
 - PCM-PHOS
 - EMCal-EMCal
 - PHOS-PHOS
- calculate inv. mass of all possible $\gamma\gamma$ pairs in given event
- select pairs in vicinity of $\pi^0(\eta)$ mass as $\pi^0(\eta)$ candidate

ω or η' reconstruction

- calculate invariant mass of all $\pi^+\pi^-\pi^0$ ($\pi^+\pi^-\eta$) combinations
- signal+background description using Gaussian + second order polynomial
- signal extraction by bin counting within 2σ of Gaussian



ALICE-PUB-361475

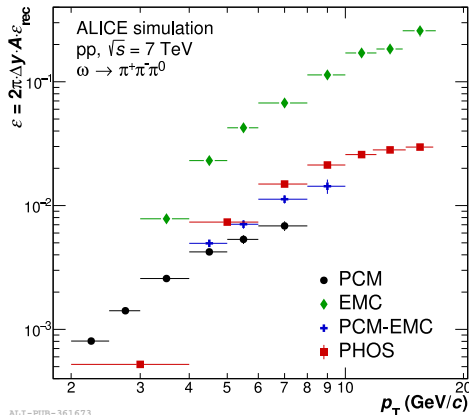
From raw yields to cross sections

$$E \frac{d^3\sigma}{dp^3} = \frac{1}{2\pi} \frac{1}{p_T} \cdot \frac{\sigma_{\text{MB,OR}}}{N_{\text{evt.,MB}}} \cdot \frac{1}{A \cdot \epsilon_{\text{rec.}}} \cdot \frac{1}{\text{BR}} \cdot \frac{N_{\text{raw}}^\omega}{\Delta y \Delta p_T}$$

Correction factors for ω mesons in pp at $\sqrt{s} = 7$ TeV

Spectra corrections:

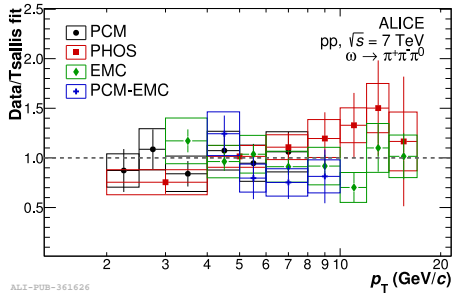
- correction factors accounting for geometrical **acceptance** A and reconstruction **efficiency** $\epsilon_{\text{rec.}}$.
- obtained using MC events with full GEANT3 detector simulation
- correction factor $\epsilon = 2\pi\Delta y \cdot A \cdot \epsilon_{\text{rec.}}$ showcases strength of each reconstruction method



ALI-PUB-361673

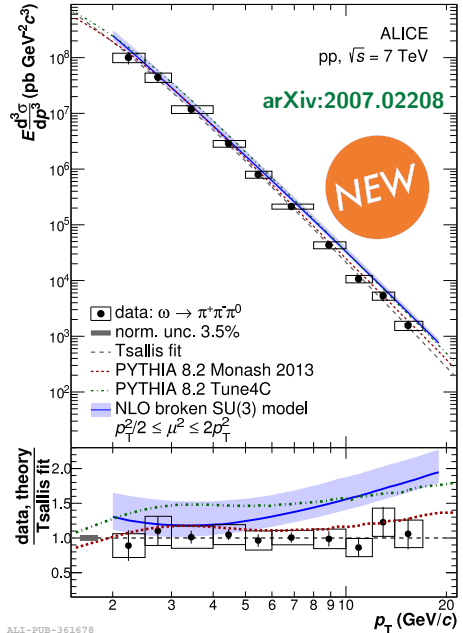
Results: ω production in pp collisions at $\sqrt{s} = 7$ TeV

Combination of Individual Measurements



ALI-PUB-361626

- **Dataset:** MB pp collisions at $\sqrt{s} = 7$ TeV recorded by ALICE in 2010 (≈ 400 mio evt., $\mathcal{L}_{\text{Int}} \approx 7 \text{ nb}^{-1}$)
- ω cross section measured for the **first time at mid-rapidity at LHC energies** over momentum range of $2 < p_T < 17 \text{ GeV}/c$
- sys. uncertainties dominated by signal extraction

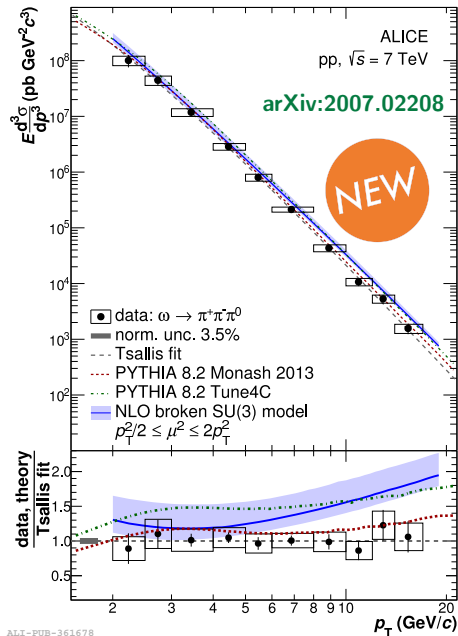


ALI-PUB-361678

Results: ω production in pp collisions at $\sqrt{s} = 7$ TeV

Comparison to theory

- PYTHIA 8.2 Tune4C overestimates data by $\approx 50\%$
- PYTHIA 8.2 Monash 2013 tune describes data within uncertainties over full p_T range
 - tune includes more recent experimental results and vector meson production parameters lowered
- NLO calculation in agreement with data at low p_T ; overestimation by $\approx 50\%$ at high p_T
 - model with broken SU(3) symmetry describing fragmentation of entire vector meson nonet
 - model tuned using pp (RHIC) and e^+e^- (LEP) data (arXiv:1705.00214)



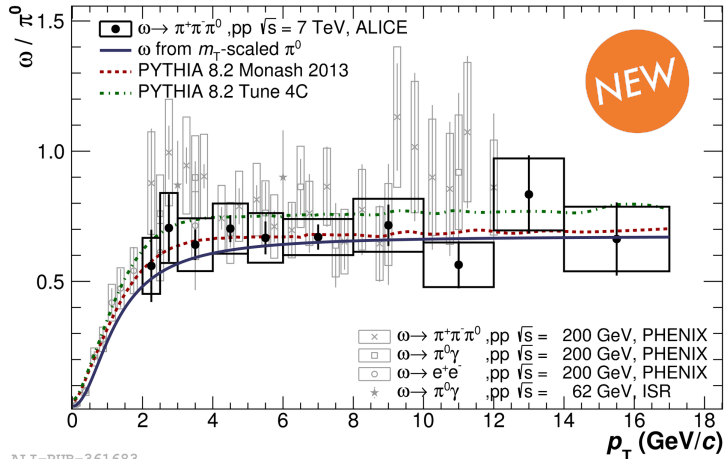
ALI-PUB-361678

Results: ω production in pp collisions at $\sqrt{s} = 7$ TeV

- ratio of ω production to π^0 production ([arXiv:1205.5724](https://arxiv.org/abs/1205.5724)) constant above 2.5 GeV/c:

$$C^{\omega/\pi^0} = 0.69 \pm 0.03 \text{ (stat)} \pm 0.04 \text{ (sys)}$$

- ratio in agreement with PYTHIA 8.2 predictions & measurements at lower collision energies
- compatible with m_T scaling (phenomenological scaling rule previously observed at RHIC & ISR)



ALI-PUB-361683

ω and η' production in pp collisions at $\sqrt{s} = 13$ TeV

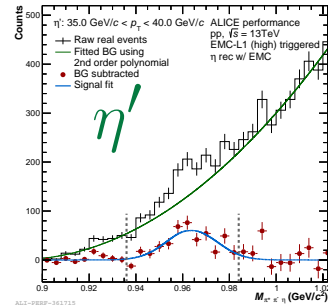
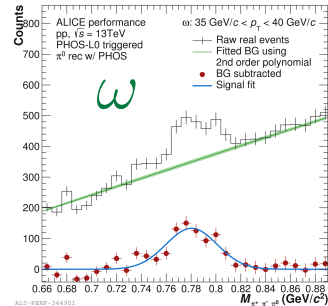
Dataset

- pp collisions at $\sqrt{s} = 13$ TeV recorded with ALICE from 2016-2018
- significantly more MB statistics (1650 mio. vs. 400 mio in 2010)
- triggers available offer high statistics at high p_T (e.g. EMCal trigger > 8 GeV with $\mathcal{L}_{\text{Int}} \approx 9.6 \text{ pb}^{-1}$)
- ALICE detector upgrades increase available statistics further

Measurements

- measurement of ω production expected to cover an unprecedented momentum range of 1.6 to 45 GeV/c with overall smaller unc.
- inclusive production cross section of η' mesons will be measured for the first time at LHC energies, covering a momentum range of 3 to 45 GeV/c !

Stay tuned!



What have we measured?

- ω production in pp at $\sqrt{s} = 7$ TeV has been measured for the first time at mid-rapidity at LHC energies
- measurement in agreement with PYTHIA 8.2 Monash 2013 and NLO (at low p_T)

What are we working on?

- the measurement of ω & η' mesons in pp at $\sqrt{s} = 13$ TeV will provide insights into their production over an unprecedented mom. range

