ω Meson Production in pp and p–Pb Collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV in ALICE

Hard Probes 2023 - Flash Talk

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Measurement of ω Meson Production in pp and p–Pb Collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV with ALICE

Nicolas Strangmann[1] for the ALICE collaboration

ALICE

Motivation

1. Constraining the parton distribution functions (PDF) and fragmentation functions (FF)
   - Input from e production cross sections and ω/π^0 ratios
   - Comparisons to theoretical model predictions
2. Studying the quark-gluon plasma (QGP) and cold nuclear matter (CNM) effects
   - CNM effects on vector meson production in p–Pb collisions
   - pp and p–Pb collisions as reference to study QGP in Pb–Pb collisions
3. Increasing precision of direct photon measurement
   - ω Third largest decay photon contribution
   - ⇒Vital input for direct photon analyses

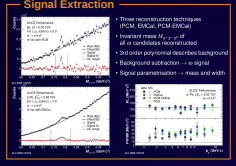
Pion Reconstruction

Charged pions
- Reconstructed from tracks in central barrel detectors
  - Inner tracking system (ITS)
  - Time projection chamber (TPC)
- Particle identification (PID) via dE/dx in the TPC

Neutral pions
- Reconstructed from decay photons: $BR(\pi^0 \to \gamma\gamma) = 99\,\%$
- Select π^0 candidates with reconstructed mass close to M_{π^0}

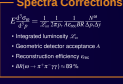
Photons
- Electromagnetic calorimeter (EMCal)
  - Lead-scintillator calorimeter
  - Large acceptance
- Photon conversion method (PCM)
  - Reconstruction of photons converting in inner detector material ($\approx 8\,\%$)
  - $e^{\pm}$ tracks from ITS and TPC
  - Sensitive down to very low p_{T} (≈ 150 MeV/c)

Signal Extraction



- Three reconstruction techniques (PCM, EMCal, PCM-EMCal)
- Invariant mass $M_{\gamma\gamma}$ ($\gamma\gamma$, $e^+e^-\gamma\gamma$) of all π candidates reconstructed
- 3rd order polynomial describes background
- Background subtraction → π signal
- Signal parametrisation → mass and width

Spectra Corrections



$$E\frac{\mathrm{d}^3N}{\mathrm{d}p^3} = \frac{1}{2\pi \cdot \Delta p_{\mathrm{T}} \cdot \Delta y_{\mathrm{cm}}} \frac{N^{\mathrm{raw}}}{BR \cdot \mathcal{L}_{\mathrm{int}} \cdot A \cdot \varepsilon_{\mathrm{rec}}}$$

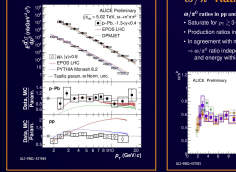
- Integrated luminosity $\mathcal{L}_{\mathrm{int}}$
- Geometric detector acceptance A
- Reconstruction efficiency $\varepsilon_{\mathrm{rec}}$
- $BR(\pi \to \pi^+\pi^-\gamma\gamma) = 89\,\%$

Cross Sections

p–Pb: 2.2 ≤ p_{T} ≤ 20 GeV/c
- Production well described by EPOS LHC
- DPMJet describes shape but underestimates by ≈ 30%

pp: 1.8 ≤ p_{T} ≤ 16 GeV/c
- EPOS LHC overshoots production up to 100 %
- PYTHIA overestimates data up to 40 %

⇒ MC generators struggle to describe ω production

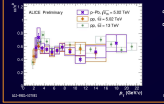


Combination of Methods

- Different ω measurements in agreement
- PCM enables measurement at low p_{T}
- EMCal allows for high p_{T} measurement
- Combination of cross sections using the *best linear unbiased estimator* (BLUE)
  → Based on uncertainties and their correlations

ω/π^0 Ratio

ω/π^0 ratios in pp and p–Pb at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV
- Saturate for $p_{\mathrm{T}} \geq 3$ GeV/c
- Production ratios in pp and p–Pb compatible
- In agreement with measurement in pp at $\sqrt{s} = 13$ TeV
  ⇒ ω/π^0 ratio independent of collision system and energy within uncertainties



Nuclear Modification Factor

First R_{pPb} of ω mesons at LHC energies
- In agreement with:
  - π^0 R_{pPb} at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV [2]
  - π, R_{pPb} at $\sqrt{s_{\mathrm{NN}}} = 200$ GeV [3]
- Consistent with unity
  ⇒ No nuclear modification visible over measured p_{T} range

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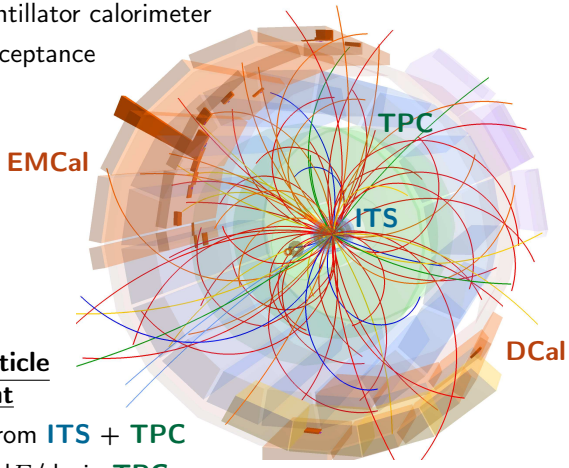
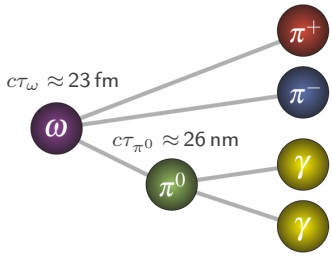
[1] ALICE Collaboration: 2022 The ALICE experiment – A journey through QCD, arXiv:2211.04384
[2] ALICE Collaboration: EPJ C 78 (2018) 624
[3] PHENIX Collaboration: A. Adare et al. Phys. Rev. C 87 (2013) 054907

Detector Setup

Electromagnetic Calorimeter (EMC = EMCal + DCal)

- Lead-scintillator calorimeter
- Large acceptance





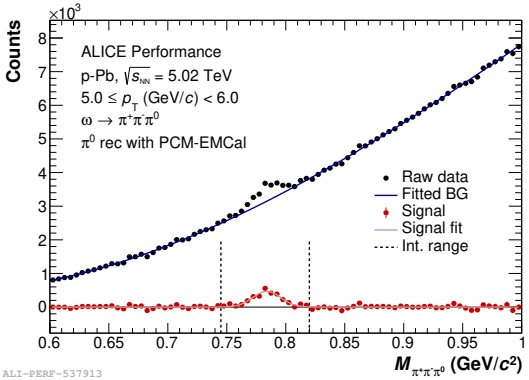
Charged-particle measurement

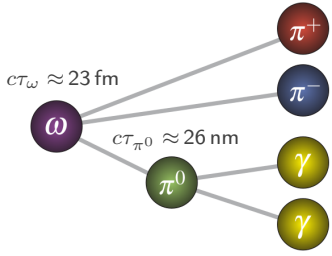
- Tracks from **ITS** + **TPC**
- PID via $\mathrm{d}E/\mathrm{d}x$ in **TPC**

Photon Conversion Method (PCM)

- Utilizing photon conversion probability of $\approx 8\%$
- $e^{\pm}$ tracks from **ITS** + **TPC**
- Sensitive at very low p_{T}

Reconstruction of ω Mesons





- Invariant mass reconstruction in p_T intervals
- Three π^0 reconstruction techniques:
  PCM + PCM-EMCal + EMCal
  ↓ low p_T ↓ high p_T
- Background subtraction, acceptance, efficiency, normalization, branching ratio,...

ω Meson Production at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV

First measurement of ω mesons in p–Pb collisions at LHC energies

→ Constraints for nPDFs and FFs

→ Input for direct photon analyses

p–Pb: $2.2 \leq p_{\mathrm{T}} \leq 20\,\mathrm{GeV}/c$

- Production well described by EPOS LHC
- DPMJET describes shape but underestimates by $\approx 30\,\%$

pp: $1.8 \leq p_{\mathrm{T}} \leq 16\,\mathrm{GeV}/c$

- PYTHIA overestimates data up to 40 %
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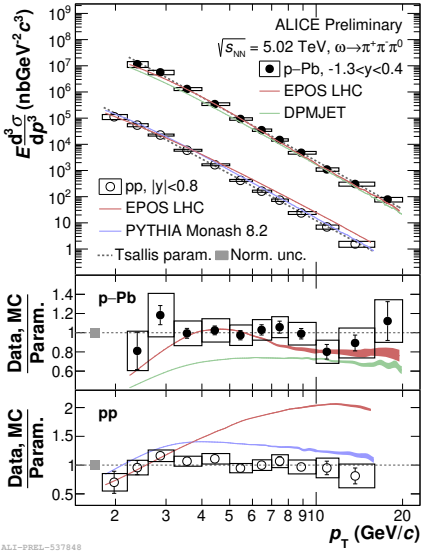
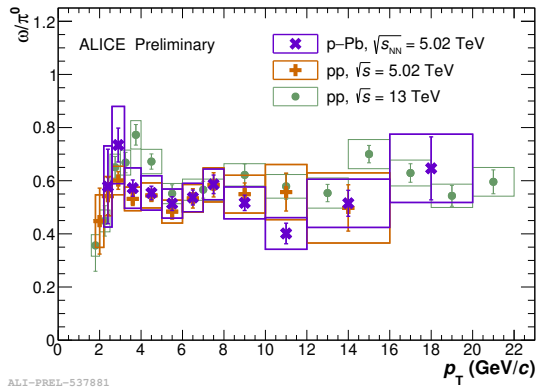


ω/π^0 Ratio

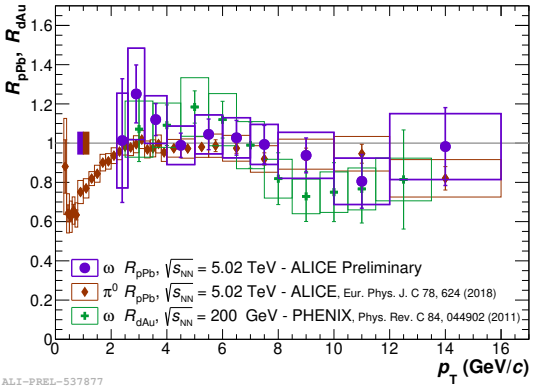
ω/π^0 ratios in pp and p–Pb at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV

- Saturate for $p_{\mathrm{T}} \gtrsim 3\,\mathrm{GeV}/c$
- Production ratios in pp and p–Pb compatible
- In agreement with measurement in pp collisions at $\sqrt{s} = 13$ TeV

$\Rightarrow$ **ω/π^0 ratio independent of collision system and energy within uncertainties**



Nuclear Modification Factor



$$R_{\mathrm{pPb}} = \frac{1}{A_{\mathrm{Pb}}} \frac{\mathrm{d}^2\sigma_{\mathrm{pPb}}/\mathrm{d}p_{\mathrm{T}}\mathrm{d}y}{\mathrm{d}^2\sigma_{\mathrm{pp}}/\mathrm{d}p_{\mathrm{T}}\mathrm{d}y}$$

First R_{pPb} of ω mesons at LHC energies

- Coherent analysis in pp and p–Pb
  $\rightarrow$ Reduces systematic uncertainties
- Consistent with unity
  $\Rightarrow$ No nuclear modification visible over measured p_{T} range
- In agreement with:
  - π^0 R_{pPb} at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV
  - ω R_{dAu} at $\sqrt{s_{\mathrm{NN}}} = 200$ GeV

Bottom Line: ω Mesons in pp and p–Pb at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV

First measurement of ω mesons in p–Pb collisions at LHC energies

→ ω/π^0 ratio independent of collision system and energy

→ First constraints on the nuclear modification factor of the ω