Quark Matter 2019, Wuhan

Light neutral meson production in the era of precision physics at the LHC

Mike Sas
ALICE Collaboration

Utrecht University & NIKHEF

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Universiteit Utrecht

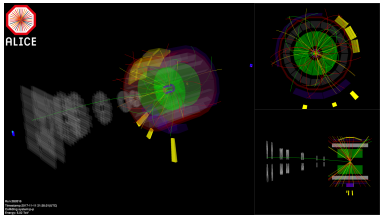
ALICE
A JOURNEY OF DISCOVERY

Nikhef

Big questions in heavy-ion physics

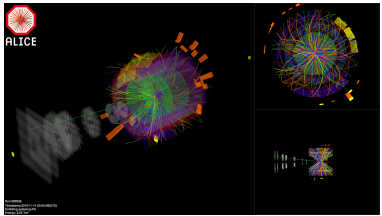
- What are the different particle production mechanisms across different system sizes?
- Can we find the onset of the QGP? $\rightarrow$ Is there a QGP droplet formed in small systems?

pp



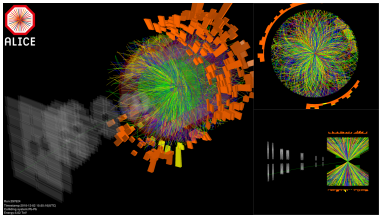
$N_{\text{particles}} \sim 10^1$

p–Pb



$N_{\text{particles}} \sim 10^2$

Pb–Pb

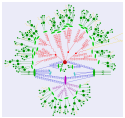
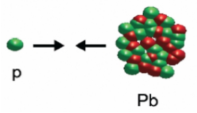
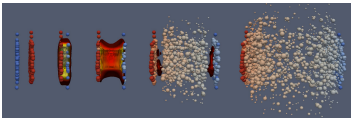


$N_{\text{particles}} \sim 10^4$

Why measure neutral mesons?

$\pi^0 \to \gamma\gamma, \quad \eta \to \gamma\gamma, \quad \omega \to \pi^0\gamma, \quad \ldots$

- Straightforward identification (M_{inv}) $\to$ study the particle production mechanisms
- Main background for γ_{direct} $\to$ precise neutral meson measurements lead to precise γ_{direct} measurements

pp	**p–Pb**	**Pb–Pb**
		
• Jet production • Underlying event studies	• Cold nuclear matter effects • Multiplicity dependence	• QGP effects • Centrality dependence

ALICE: Photon and event multiplicity measurements

Photon Conversion Method (PCM)

- ITS and TPC
- $|\eta| < 0.9$ and $0^{\circ} < \varphi < 360^{\circ}$
- $E_{\gamma} > 100$ MeV, $E_{\pi^0} > 300$ MeV
- conversion probability $\sim 8\%$

PHOS calorimeter

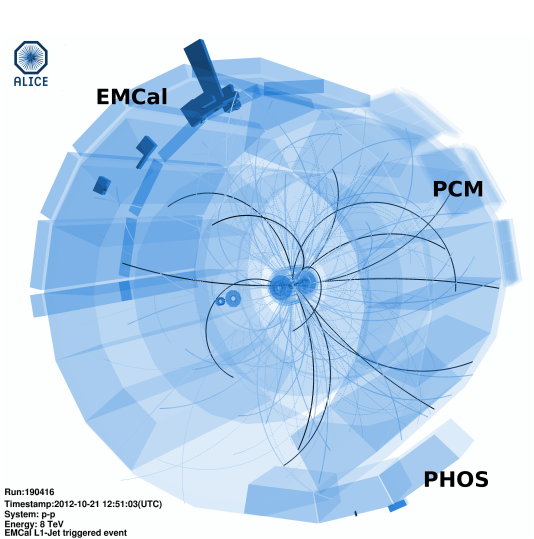
- $PbWO_4$ crystals (cell size 2.2 cm x 2.2 cm, at 4.6 m)
- $|\eta| < 0.12$ and $250^{\circ} < \varphi < 320^{\circ}$
- $E_{\gamma} > 200$ MeV, $E_{\pi^0} > 400$ MeV

EMCal calorimeter

- Pb-scintillator towers (cell size 6 cm x 6 cm, at 4.28 m)
- EMCal: $|\eta| < 0.7$, $80^{\circ} < \varphi < 187^{\circ}$
- DCal: $0.22 < |\eta| < 0.7$, $260^{\circ} < \varphi < 320^{\circ}$
- DCal: $|\eta| < 0.7$, $320^{\circ} < \varphi < 327^{\circ}$
- $E_{\gamma} > 700$ MeV, $E_{\pi^0} > 1.4$ GeV

Centrality estimator V0M

- V0A: $2.8 < \eta < 5.1$, V0C: $-3.7 < \eta < -1.7$
- Measures forward multiplicity in central barrel

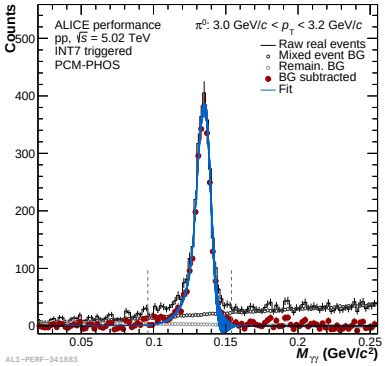


Neutral meson reconstruction in ALICE

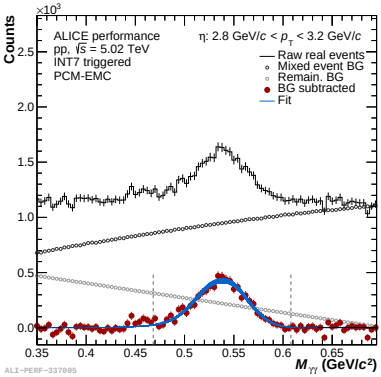
Analysis strategy:

1. Reconstruct the photons
2. Obtain the meson raw yield: integrate M_{inv} distributions
3. Correct raw yield for efficiency, acceptance, feed-down from secondaries
4. Combine the different reconstruction methods
5. More differential studies

π^0



η



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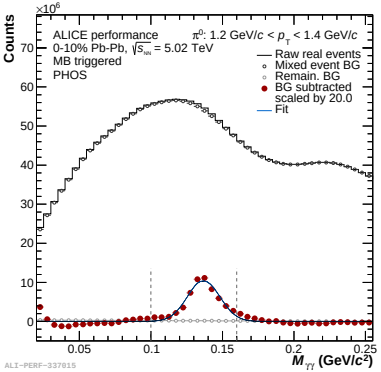

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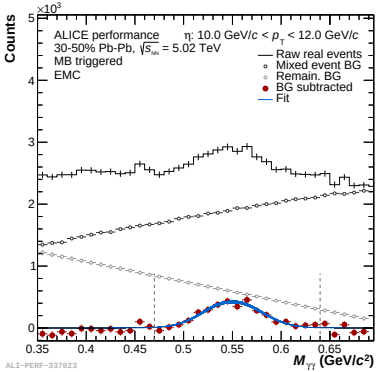

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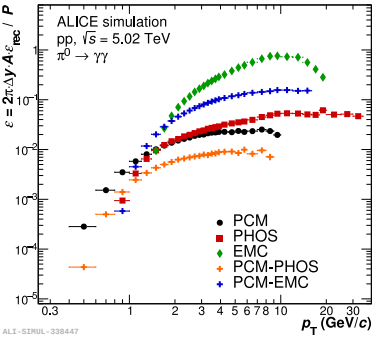
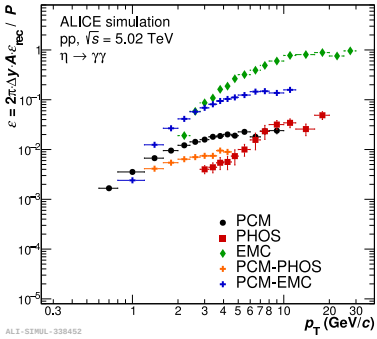


η



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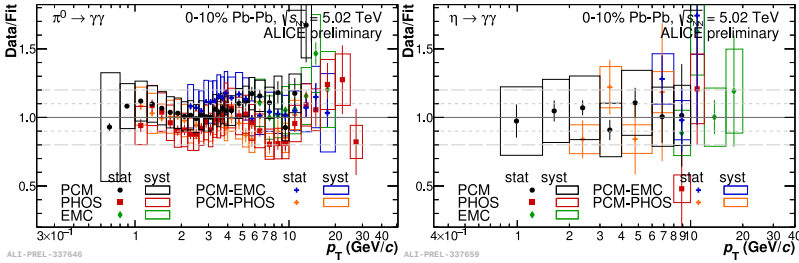

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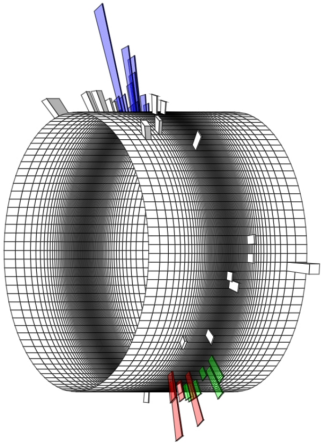
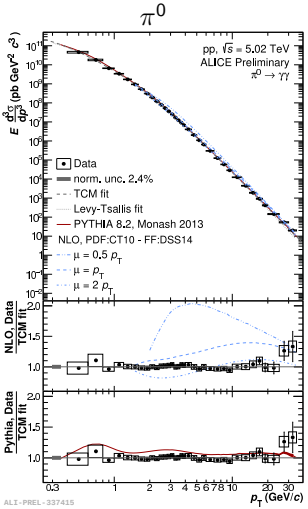
- vs. event multiplicity
- vs. event shape: $0 < S_{\mathrm{T}} < 1$
  - Pencil-like: $S_{\mathrm{T}} \approx 0$
  - Spherical: $S_{\mathrm{T}} \approx 1$
- In-jet production
  - Reconstruct neutral mesons inside charged jets
  - Algorithm: anti-k_{t}, $R = 0.4$, $E > 10$ GeV

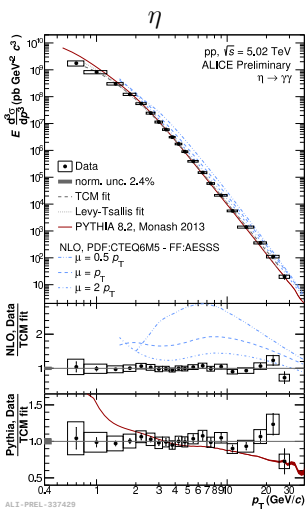


Neutral mesons in pp collisions

Main reasons for study:

- Fragmentation
- Contribution underlying event
- Main background for γ_{direct}





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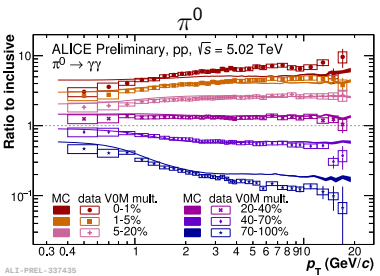
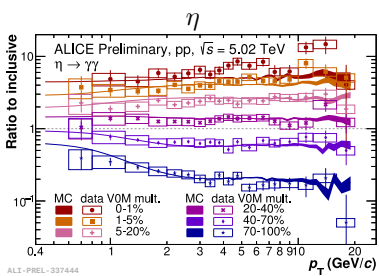
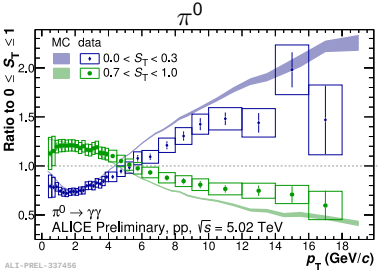
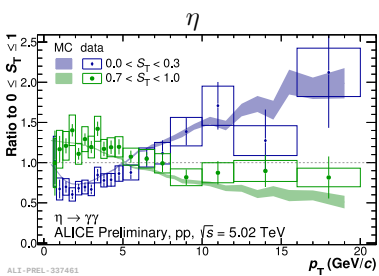
Comparisons to predictions:

- PYTHIA overpredicts π^0, except for high multiplicity
- PYTHIA overpredicts π^0 pencil-like events, underpredicts spherical events
- η/π^0 significantly modified for the in-jet production









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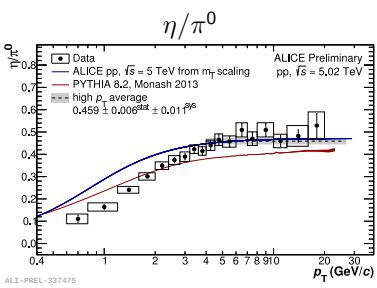
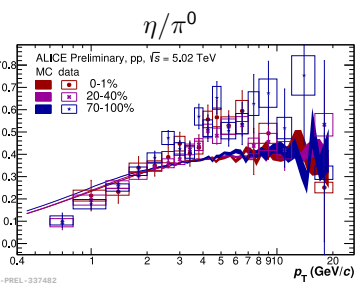
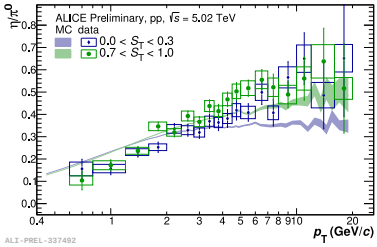
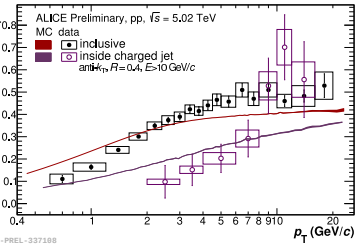


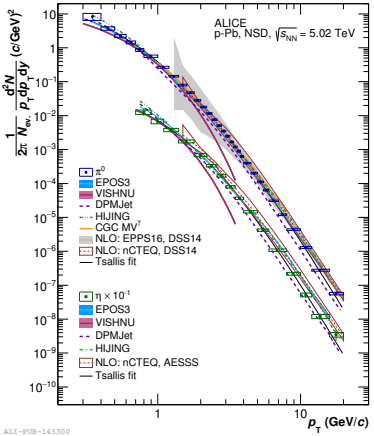




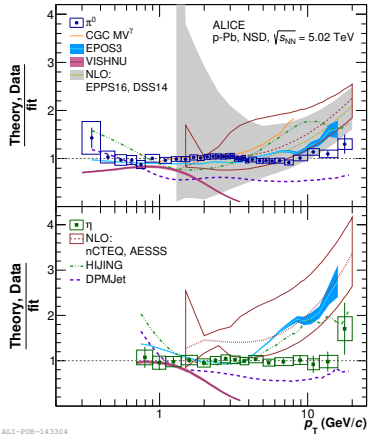


Neutral mesons in p–Pb collisions

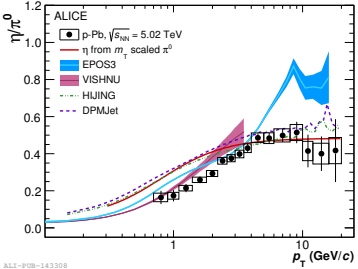
π^0 & η



Ratio to theory



η/π^0



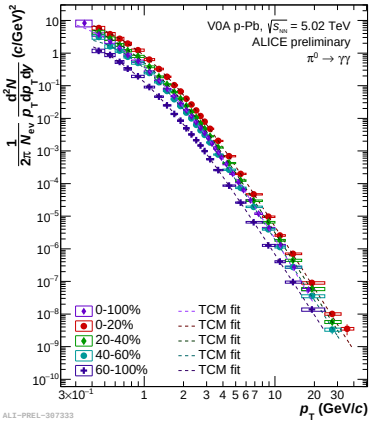
Minimum Bias production

- Model comparisons show only consistency for limited p_T ranges
- Full Run 1 + Run 2 data will improve the results precision

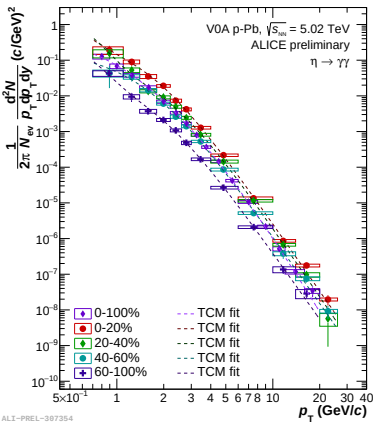
arXiv:1801.07051, Eur. Phys. J. C (2018) 78: 624

Neutral mesons in p–Pb collisions

π^0



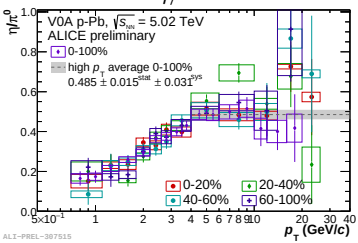
η



Multiplicity dependent production

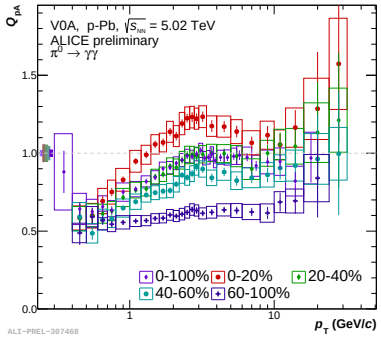
- No significant centrality dependence in the η/π^0 ratio
- Q_{pA} shows significant change of slope at low p_T

η/π^0

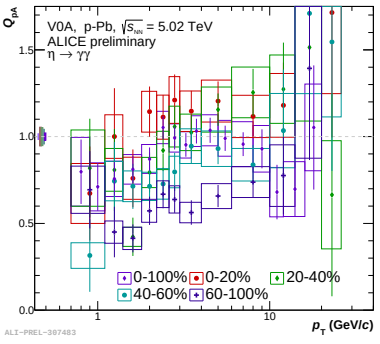


Neutral mesons in p–Pb collisions

π^0



η



Nuclear modification factor:

$$Q_{\mathrm{pA}} = \frac{dN^{\mathrm{pA}}/dp_{\mathrm{T}}}{< T_{\mathrm{pA}} > d\sigma^{\mathrm{pp}}/dp_{\mathrm{T}}}$$

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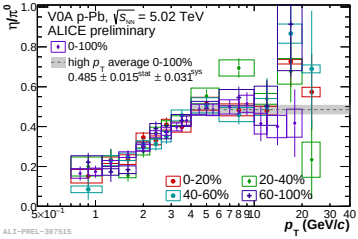
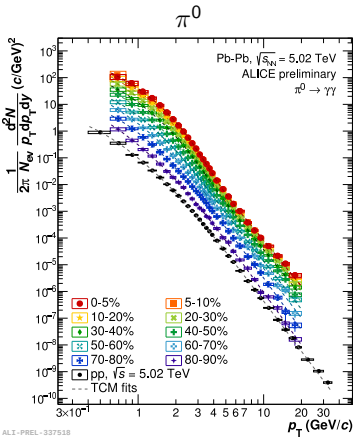
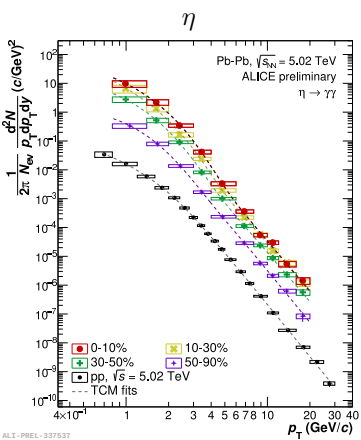


Neutral mesons in Pb–Pb collisions



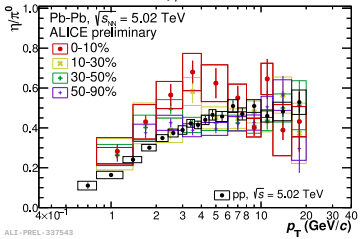


Multiplicity dependent production

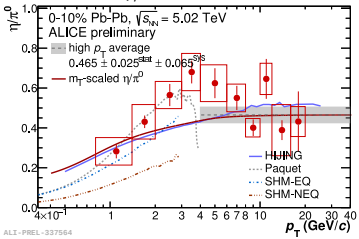
- Precise spectra over large momentum range
- Main background for direct photon analysis
- η/π^0 shows significant modification for non-peripheral collisions
- R_{AA} shows strong suppression for central collisions

Neutral mesons in Pb–Pb collisions

η/π^0



η/π^0 0-10%



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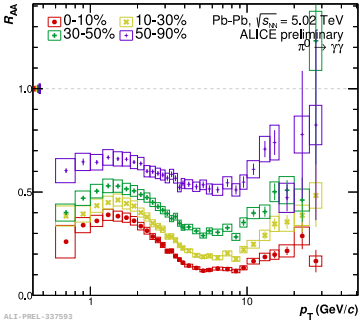
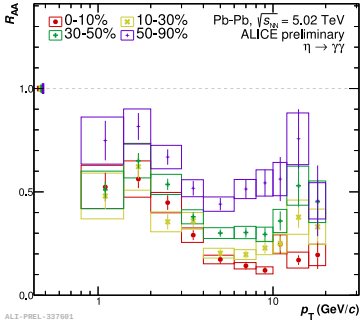
π^0 R_{AA}



η R_{AA}



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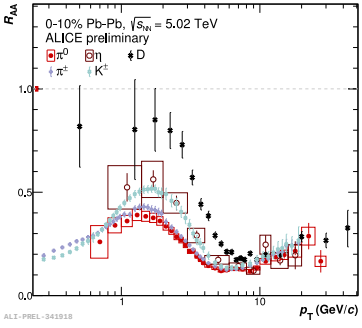
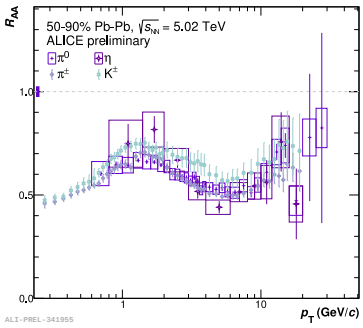
Neutral mesons in Pb–Pb collisions

R_{AA} 0-10%



R_{AA} 50-90%



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Summary and outlook

Neutral mesons spectra measurements provide us with:

- Benchmark for all photon analyses in ALICE
- Information on particle production mechanisms using detailed comparisons to model calculations
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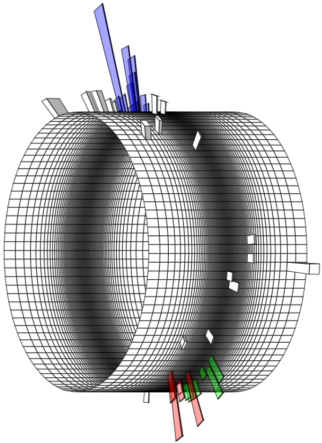
2. Direct photons $\rightarrow$ **under which conditions do we measure an excess of low p_{T} direct photons?**



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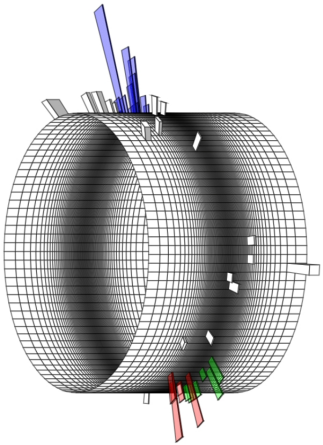

Thanks for your attention.

Backup

The ALICE detector

- ITS
- TPC
- EMCal
- PHOS