# $D^+$-meson nuclear modification factor in Pb-Pb collisions with ALICE

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## Heavy quarks: physics motivation

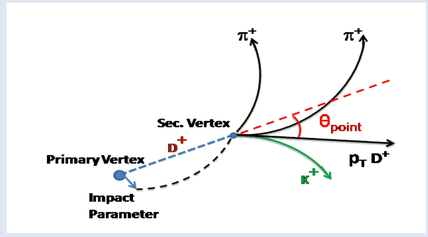
- Heavy quarks are produced in **hard scattering processes in the inital stages of the collisions** → they are an excellent probe to study the medium created in heavy-ion collisions.
- They interact with the medium and lose energy via: **gluon radiation and elastic scatterings in the medium.**
- Colour-charge and mass-dependent energy loss → $\Delta E_g > \Delta E_{u,d} > \Delta E_c > \Delta E_b$ [1]
- To quantify D-meson production we evaluate the nuclear modification factor:

$$R_{AA} = \frac{dN_{AA}/dp_T}{\langle T_{AA}\rangle d\sigma_{pp}/dp_T},$$

where $\langle T_{AA}\rangle$ is the average nuclear overlap function from the Glauber model.

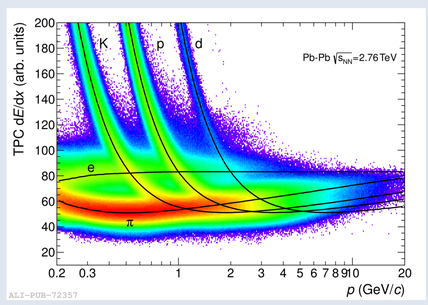
## $D^+ \to K^-\pi^+\pi^+$ reconstruction

$D^+$ fully reconstructed via their **hadronic decay channel** $D^+ \to K^-\pi^+\pi^+$ (B.R. $\sim 9.13\%$) and charge conjugates.
$D^+$ displaced by few hundred $\mu$m from the primary vertex.



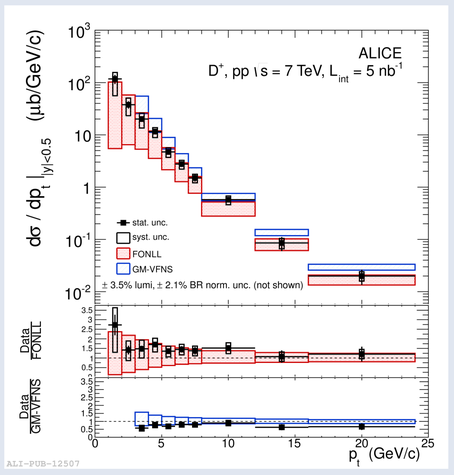

Require excellent capabilities in:

- Vertex reconstruction to separate primary and secondary vertices.
- Tracking for impact parameter and $p_T$ resolution.
- Particle identification to reduce the huge combinatorial background.




**PID approach:** $3\sigma$ compatibility cut between the expected and measured signals of $dE/dx$ in TPC and TOF time-of-flight for the different particle species.
**Analysis strategy:** selections based on topological selections, i.e. distance between primary and secondary vertices.

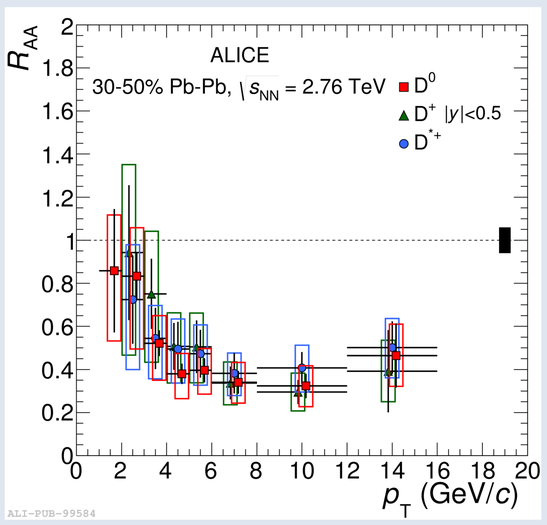
## pp reference



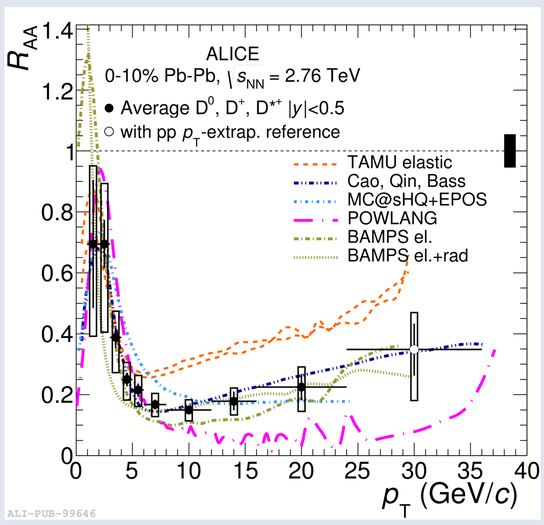

ALICE, JHEP 01 (2012) 128

- pp reference at $\sqrt{s} = 2.76$ TeV obtained by scaling the measured cross section at $\sqrt{s} = 7$ TeV because of the higher statistics available.
- Measured $p_T$-differential cross section reproduced within uncertaintes by pQCD predictions.
- No reference for $24 < p_T < 36$ GeV/$c$, extrapolation to high $p_T$ based on FONLL $p_T$ shape, systematic uncertainty → $^{+37}_{-56}\%$
- Systematic uncertainty on the pp normalization → 3.5%.

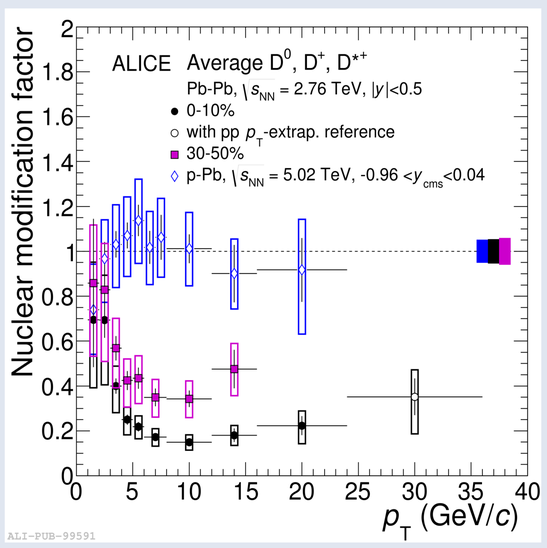
## Results




ALICE, arXiv:1509.06888




References to the models in the "References" box

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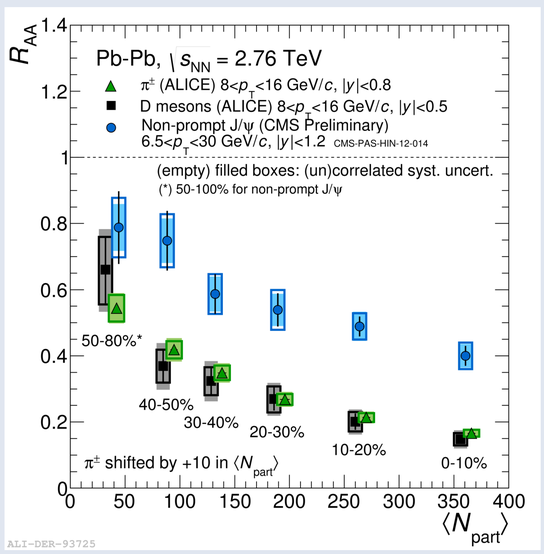
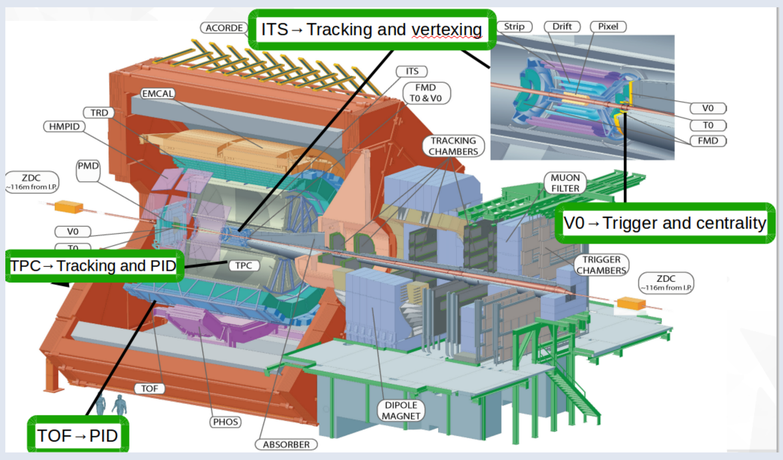



ALICE, arXiv:1506.06604

## The ALICE experiment




**Data sample:**

2011 Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV

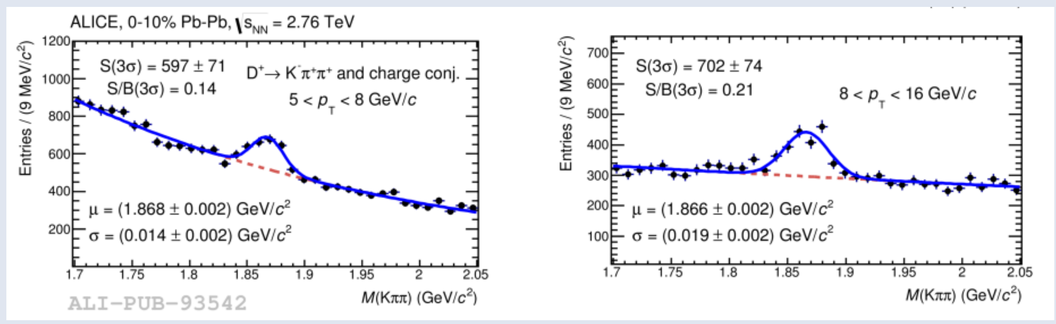
$16 \cdot 10^6$ events in 0-10%
$18 \cdot 10^6$ events in 10-50%

Track reconstruction in $|\eta| < 0.9$

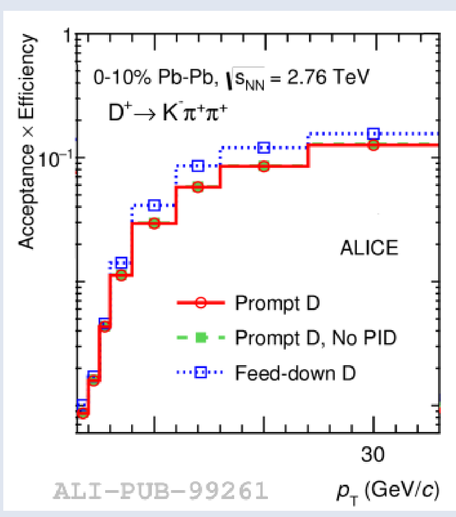
**Centrality classes** defined on the basis of the geometrical Glauber model applied to the measured VZERO amplitude.

## Raw yield extraction

Raw yield extracted fitting the invariant mass distributions of the candidates with a Gaussian for the signal and an exponential term for the background.




## Corrections




- **Efficiency:**
  Correction factor obtained from Monte Carlo simulations to take into account geometrical acceptance of the detector, the tracking efficiency and the selection cuts.
- **B feed-down subtraction:**
  Contribution of $D^+$ mesons from B-hadron decays evaluated from FONLL prediction [2].

Hypothesis on non-prompt $R_{AA}$: $2^*R_{AA}$ prompt.
Systematic uncertainty evaluated varying the hypothesis in the range:
$1 < R_{AA}(\text{non-prompt})/R_{AA}(\text{prompt}) < 3 \to 7 - 16\%$.

## $D^+$-yield systematic uncertainties

- **Yield extraction:** variation of fit range, background function (polynomial) and signal extraction technique (bin counting after background subtraction or fit integral), $8 - 12\%$.
- **Topological selection:** analysis repeated with different selections, $10 - 15\%$.
- **Tracking efficiency:** different track selection criteria, 15%.
- **PID efficiency:** analysis repeated without PID, 5%.
- **MC $p_T$ shape:** vary the simulated $D^+$ $p_T$ distribution to evaluate the efficiency, $1 - 10\%$.

## Summary

- $R_{AA}$ is compatible for all three D-meson species over the full $p_T$ range.
- D-meson production suppressed by a **factor of about 6 (3) in $p_T = 10$ GeV/$c$ in central (semi-peripheral) Pb-Pb collisions**.
- Several theoretical models can reproduce D-meson $R_{AA}$ reasonably well.
- No indication of cold nuclear matter effects in p-Pb collisions, **suppression at high $p_T$ in central Pb-Pb collisions due to the interaction with the medium**.
- D-meson **suppression increases from peripheral to central collisions**.
- Similar suppression observed for D mesons and charged pions.
- Indication of a **difference in the suppression of D mesons and non-prompt J/$\psi$ from B decays** (measured by CMS [3]).

## References

[1] Dokshitzer and Kharzeev, PLB 519 (2001) 199
[2] M Cacciari *et al.*, JHEP 10 (2012) 137
[3] S. Chatrchyan *et al.* [CMS Collaboration], JHEP 05 (2012) 063

- TAMU elastic: PLB 735 (2014) 445-450
- Cao, Qin, Bass: PRC 88 (2013) 044907
- POWLANG: EPJ C71 (2011) 1666
- BAMPS: PLB 717 (2012) 430