Measurement of D^+ meson production in Pb-Pb collisions with the ALICE detector at the LHC

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Introduction

Physics Motivation

Due to their large masses, heavy quarks (charm and beauty) are predominantly produced via hard scattering in the initial phase of the collision. In heavy ion collisions:

➡ They experience the full evolution of the system, losing energy while interacting with the medium.

➡ Theoretical models predict different energy loss for gluons, light quarks and heavy quarks:

$$\Delta E_g > \Delta E_{(u,d,s)} > \Delta E_c > \Delta E_b$$

➡ Nuclear modification factor is an observable sensitive to energy loss. It is defined as:

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

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

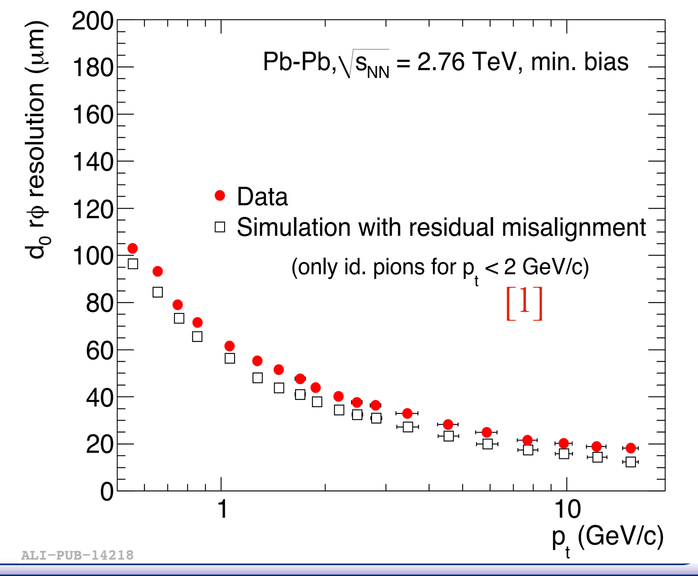
D^+ meson Reconstruction

D^+ mesons are fully reconstructed in the following hadronic decay mode:

$D^+ \rightarrow K^- \pi^+ \pi^+$ (Branching Ratio = (9.13±0.19)%)

The signal extraction for this hadronic decay is based on the invariant mass analysis of fully reconstructed decay topologies displaced from the primary vertex.

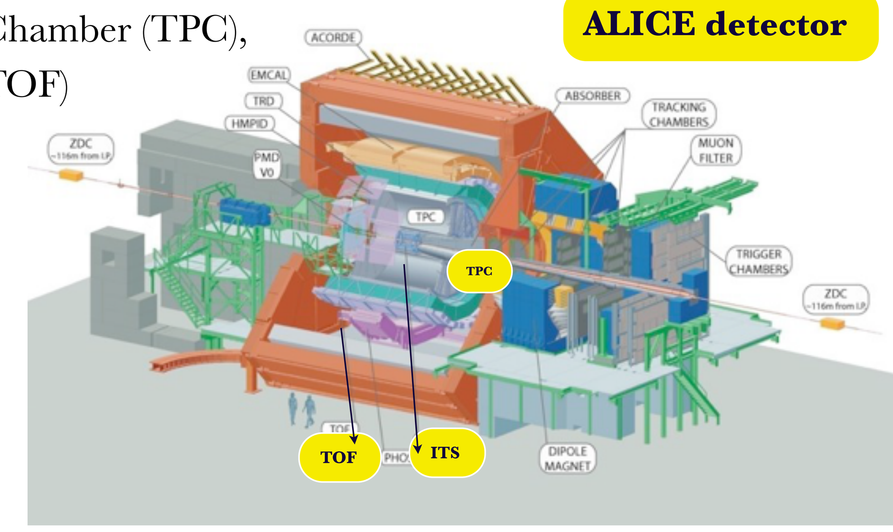
This requires very good impact parameter measurement provided by the Inner Tracking System (ITS)



Experimental Setup

ALICE (A Large Ion Collider Experiment) is specifically optimized for the study of heavy-ion collisions at the LHC.
The main detectors of ALICE, used in this analysis are the:

➡ Inner Tracking System (ITS),
➡ Time Projection Chamber (TPC),
➡ Time Of Flight (TOF)



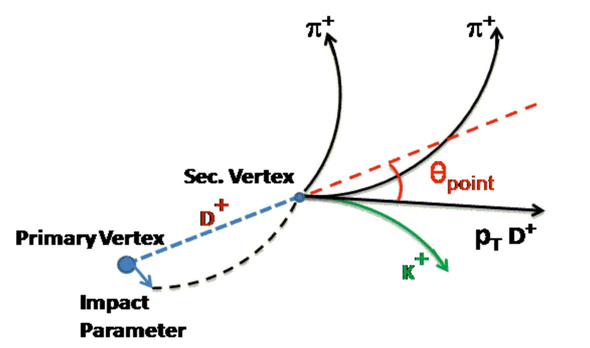
Track reconstruction: with ITS and TPC in $\eta < |0.9|$

Particle identification with TPC and TOF via the measurement of the specific energy loss dE/dx and of the time of flight

➡ separate pions and kaons up to 2 GeV/c

Analysis Strategy

Selection Strategy ($D^+ \rightarrow K^- \pi^+ \pi^+$)

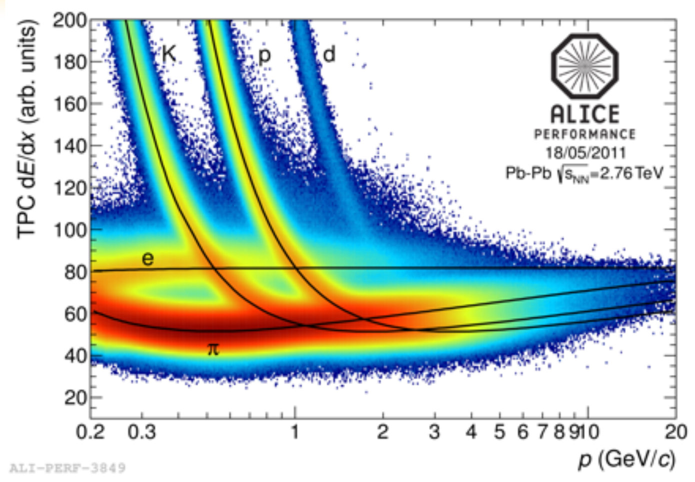


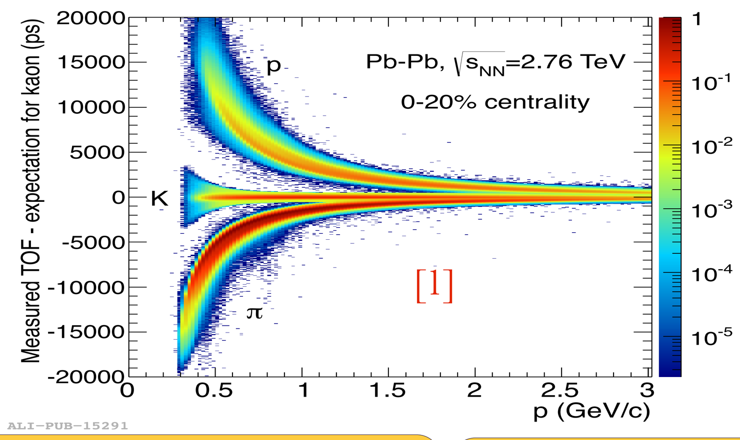
Main Selection: displaced-vertex topology

➡ good pointing of reconstructed D momentum to the primary vertex
➡ distance between primary and secondary vertex.

Particle Identification (PID) with the TPC and TOF information helps to reduce the background at low p_T

➡ 3 σ cut on the difference between the measured signals in TPC and TOF and those expected for the given particle species.



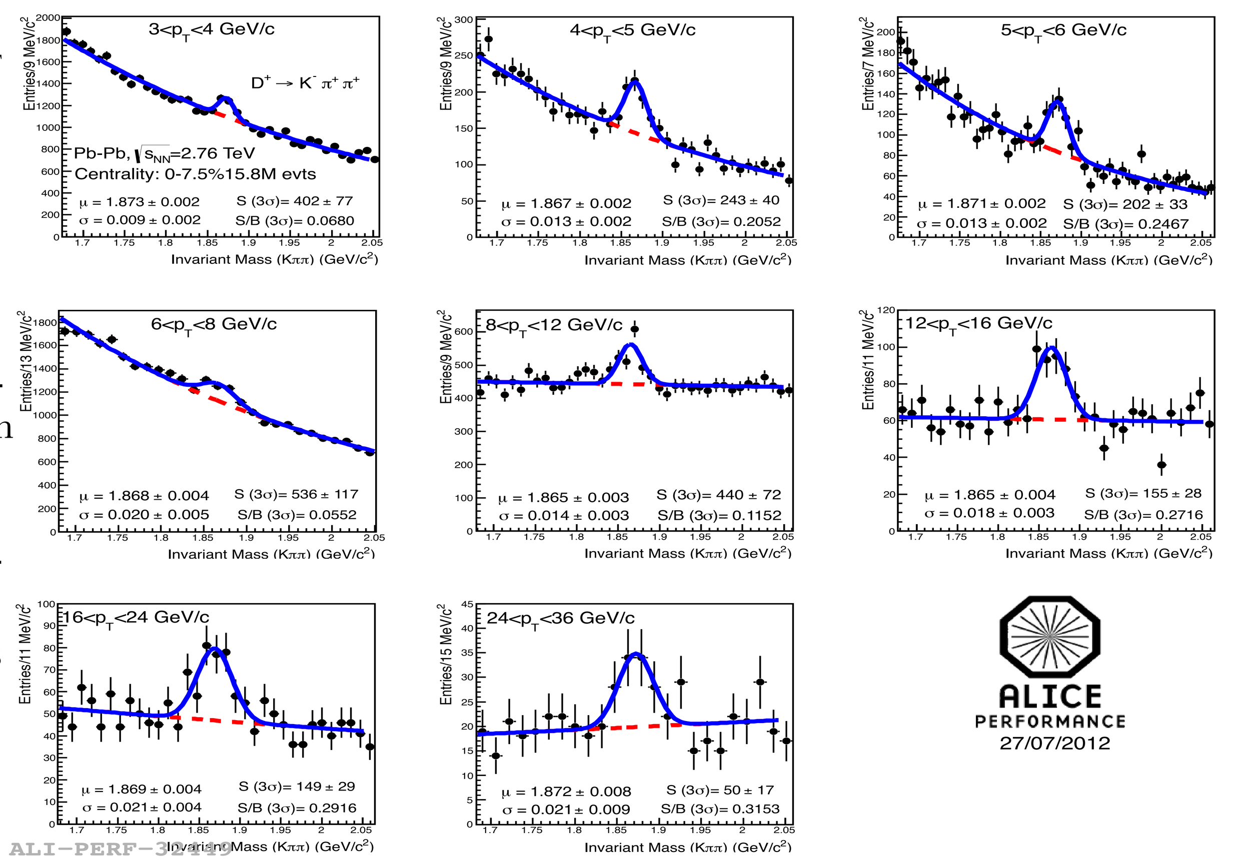


Raw Yield Extraction

➡ Raw yield extracted in different p_T intervals by fitting the invariant mass distributions of $D^+ \rightarrow K^- \pi^+ \pi^+$ candidates (and charge conjugates) which pass the topological and PID selections

➡ The fit function comprises a Gaussian term describing the signal and an exponential term for the background

➡ Fig. shows the invariant mass spectra in 8 p_T intervals in the range $3 < p_T < 36$ GeV/c for Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV, centrality class 0-7.5%



Correction

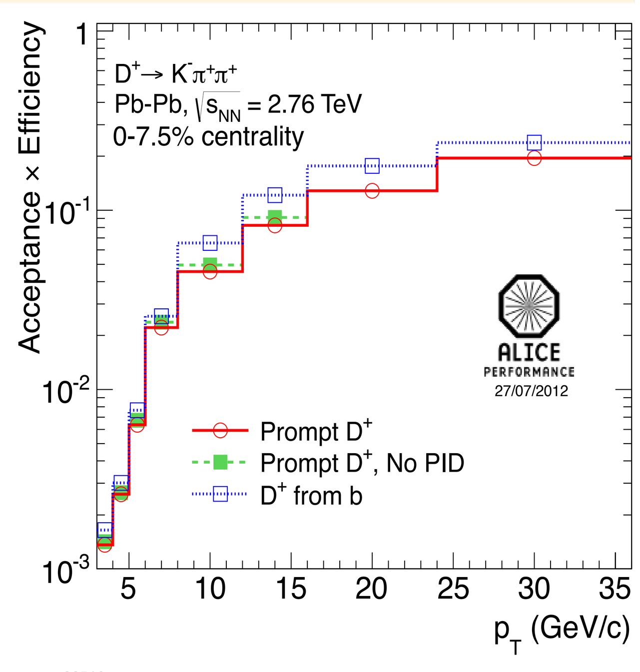
D^+ meson raw yields extracted from the fits to the invariant mass spectra corrected for:

acceptance x efficiency: correction factor from MC simulation

B feed down Subtraction:

➡Contribution of D^+ mesons from B decays evaluated using a MC estimate based on FONLL predictions

➡ Hypothesis on the R_{AA} of feed down D^+ mesons (sensitive to b-quark in-medium energy loss): R_{AA} (feed-down) = 2 R_{AA} (prompt). Systematic uncertainties estimated by varying the hypothesis in the range $1 < R_{AA}$ (feed down)/R_{AA}(prompt) < 3.



Sources of Systematic Uncertainties

➡ Yield extraction: different fit range, function for background (polynomial), signal extraction techniques (bin counting after background subtraction vs fit function integral)

➡ Topological Selections : repeat the analysis with different selection criteria

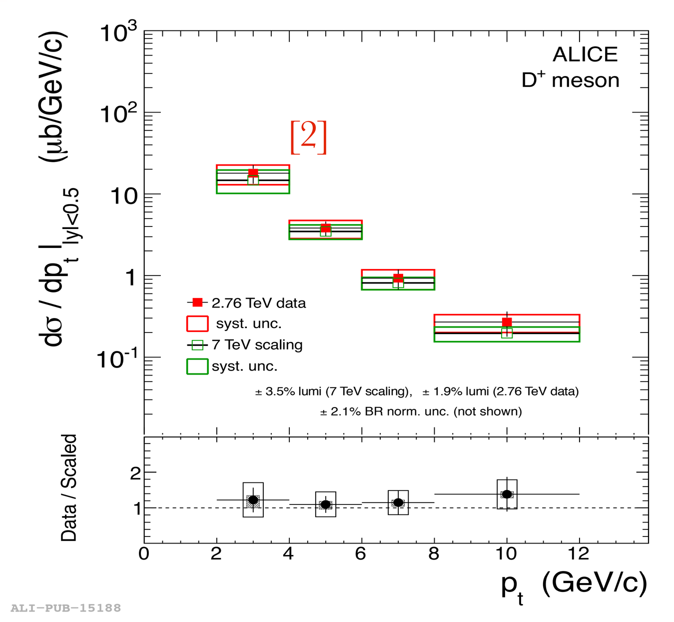
➡ PID efficiency: evaluate the PID selection effect, repeating the analysis without PID

➡ Tracking efficiency: different track selection criteria

➡ MC p_T shape : evaluate the efficiencies with different generated D meson p_T distributions

➡ Normalization uncertainty on pp reference and T_{AA}

pp reference



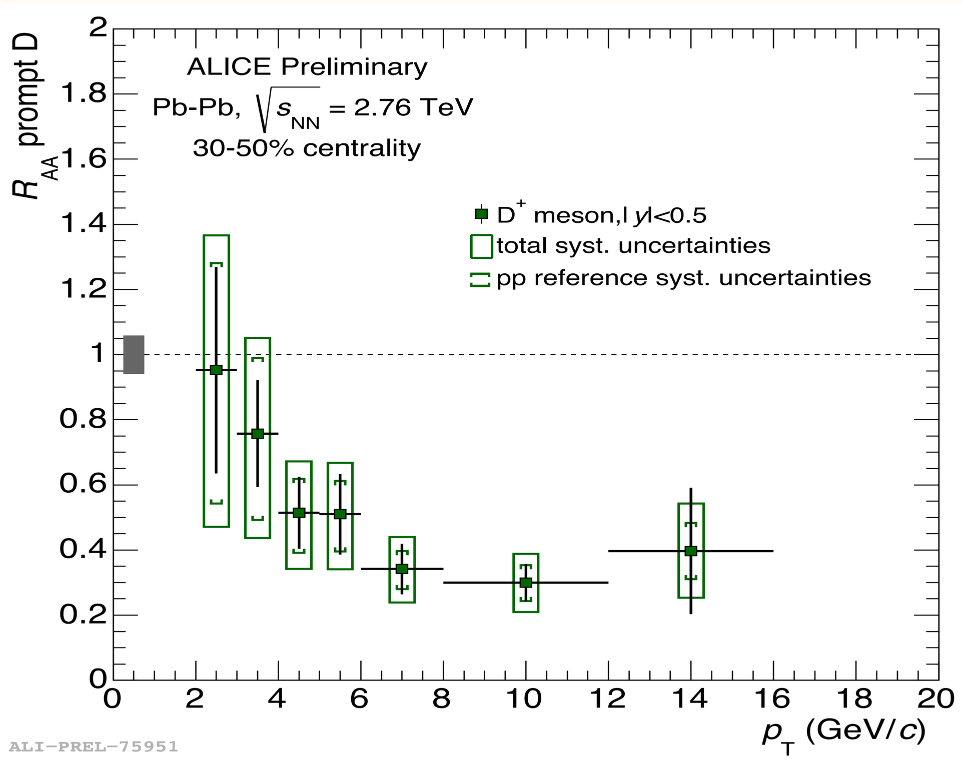
➡ Reference at $\sqrt{s}$= 2.76 TeV obtained via energy scaling of $\sqrt{s}$=7 TeV data using the ratio of FONLL predictions at the two energies

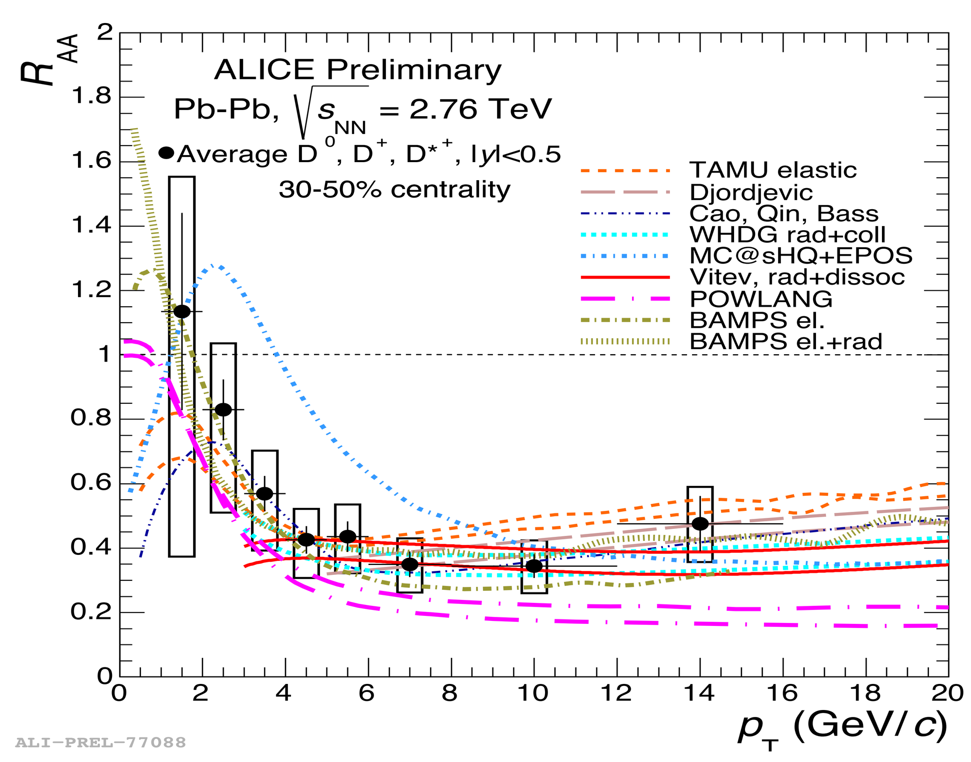
➡ Good agreement with 2.76 TeV data → limited statistics (58 M events) →$2 < p_T < 12$ GeV/c

➡ Lack of pp reference for $p_T > 24$ GeV/c: 7 TeV measurement extrapolated to higher p_T based on FONLL p_T shape

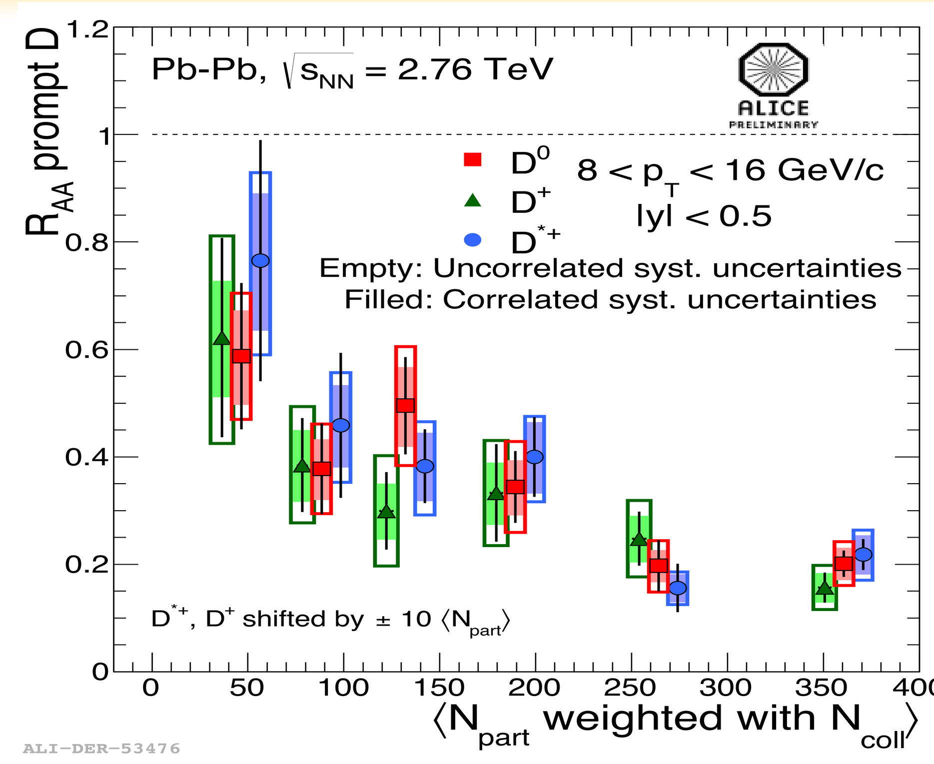
Results

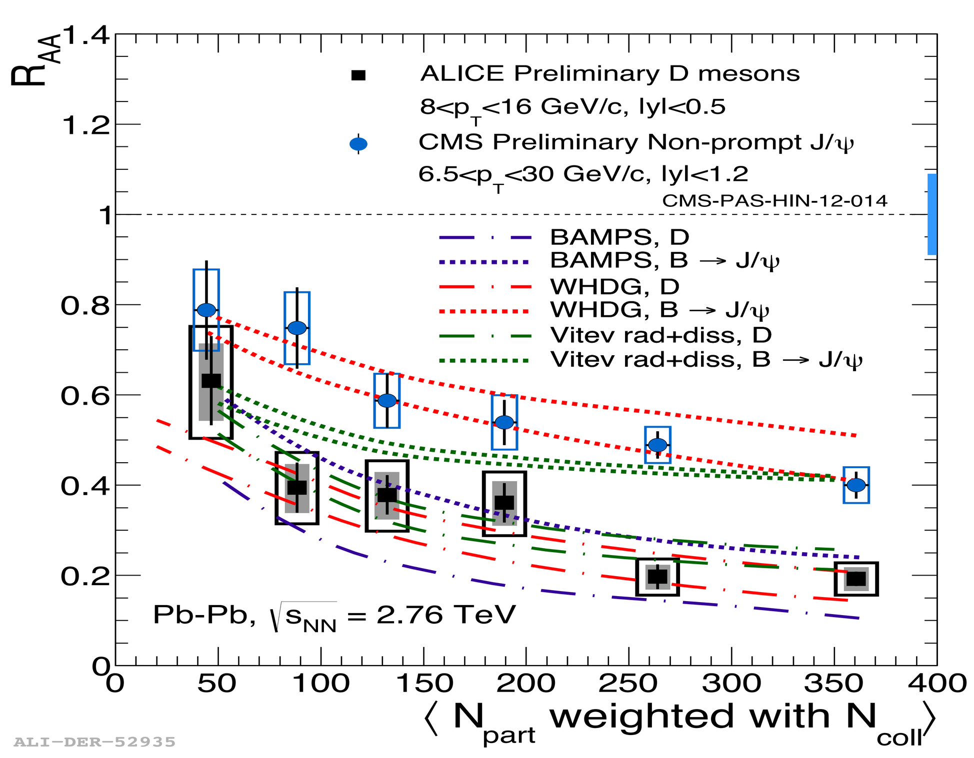
D meson R_{AA} as a function of p_T





D meson R_{AA} as a function of Centrality





Summary

➡ D meson R_{AA} shows a suppression of factor 4-5 at p_T>5 GeV/c in central collisions.

➡ Consistent measurement among the different D meson species.

➡ D meson R_{AA} reproduced within uncertainties by models including in-medium energy loss.

➡ Suppression increases from peripheral to central collisions.

➡ Difference between R_{AA} of D-mesons (ALICE) and non prompt J/ψ from B decays (CMS) in central collisions→described by theoretical models including mass dependent energy loss.

References

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