Measurement of the D⁺ meson production in Pb-Pb and p-Pb collisions with ALICE

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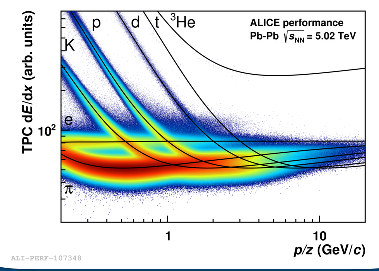
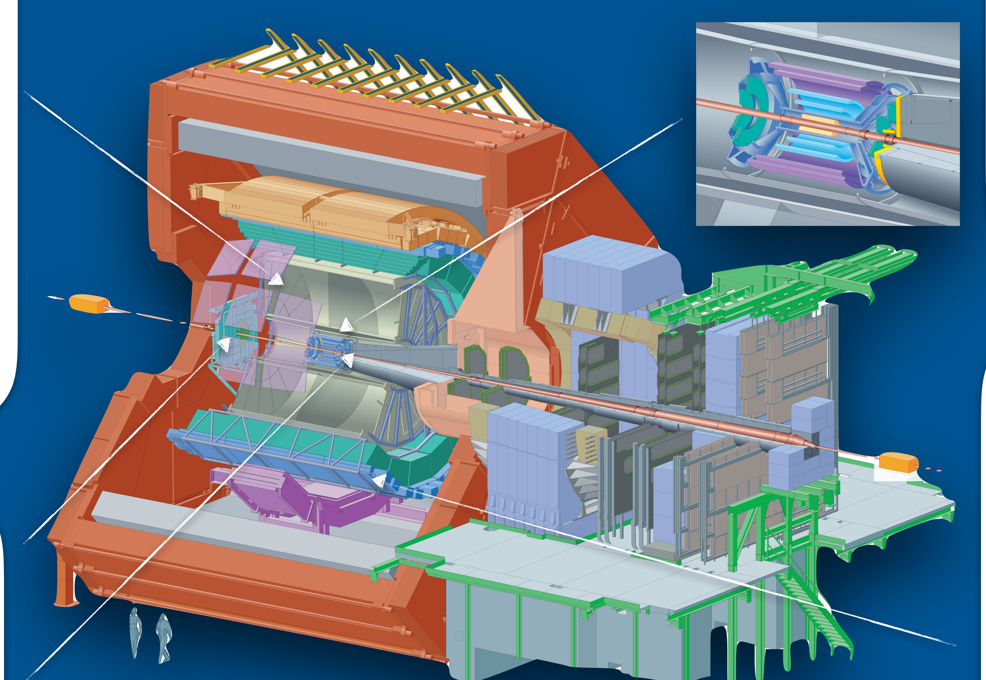
A Large Ion Collider Experiment

Time Projection Chamber

Detector dedicated to tracking and particle identification via d*E*/d*x*





Inner Tracking System

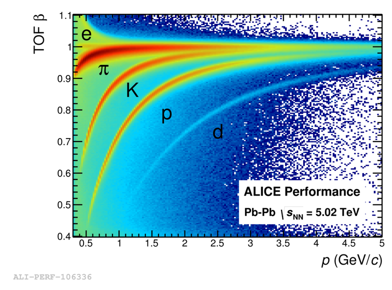
Innermost silicon detector for tracking and reconstruction of primary and secondary vertices

V0

Forward rapidity detectors for MB trigger, centrality determination and estimation of the reaction plane

Time of Flight

Particle identification with time-of-flight measurement



Introduction

Heavy flavours as a probe of the Quark-Gluon Plasma

- **Heavy flavours** (i.e. charm and beauty quarks) are **produced in the initial stages of the collision**
  - Heavy-flavours production time: $t_{prod} \lesssim \hbar/m_{c(b)} \sim 0.1(0.04)\ \mathrm{fm}/c$
  - Quark-Gluon Plasma formation time at LHC [1]: $t_{form} \sim 0.3\ \mathrm{fm}/c$
- **Heavy flavours experience the whole system evolution** interacting with the medium constituents

Observables

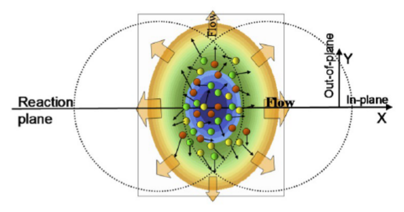
- **Nuclear modification factor R_{AA}** : ratio of the measured yield in AA collisions to the one in pp interactions scaled by average number of binary nucleon-nucleon collisions (N_{coll})

$$R_{AA}(p_T) = \frac{1}{N_{coll}} \frac{dN_{AA}/dp_T}{dN_{pp}/dp_T}$$

Provides information about the **in-medium energy loss** mechanism, the **dependence on the mass of the quark** (comparing c and b quarks) and the **colour-charge dependence** (comparing heavy flavours with light hadrons)

- **Elliptic flow v_2** : second harmonic coefficient of the Fourier decomposition of the azimuthal distribution of final-state particles referred to the reaction plane (Ψ_{RP})

$$v_2 = \langle \cos 2(\varphi - \Psi_{RP}) \rangle$$



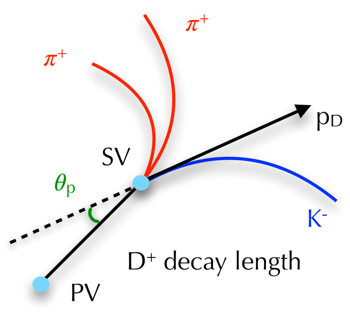
Provides information about the **participation of heavy flavours in the collective expansion** and their **thermalisation** in the Quark-Gluon Plasma

D⁺ in Pb-Pb collisions

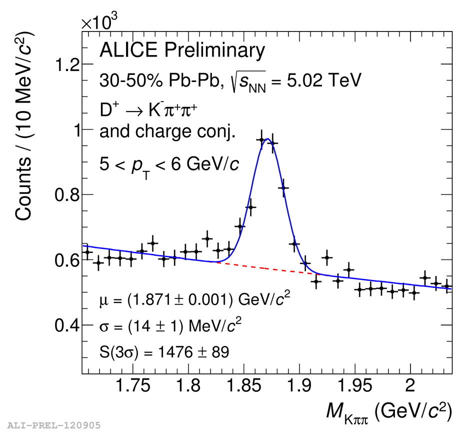
Reconstruction of prompt D⁺ mesons in ALICE

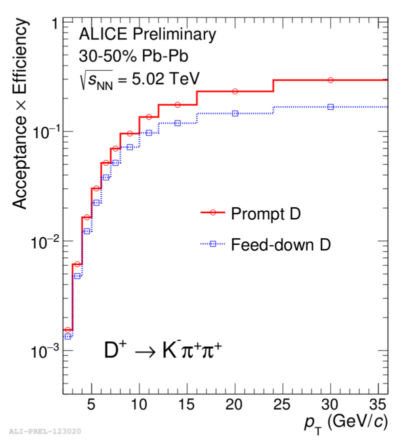
- **D⁺ mesons** and their charge conjugates are **reconstructed in the hadronic decay channel**

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



- D⁺ candidates built **combining triplets of tracks** with proper charge combination
- Decay **topology fully reconstructed**
- **Particle identification** (PID) applied to the daughter tracks
- **Selection criteria applied** on reconstructed **geometrical quantities** (e.g. the decay length) to improve signal over background ratio
- Signal extracted by **fitting** the **invariant-mass distribution** of the candidates



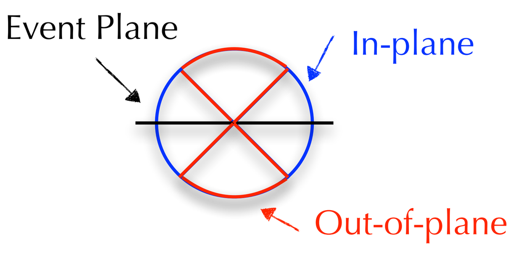


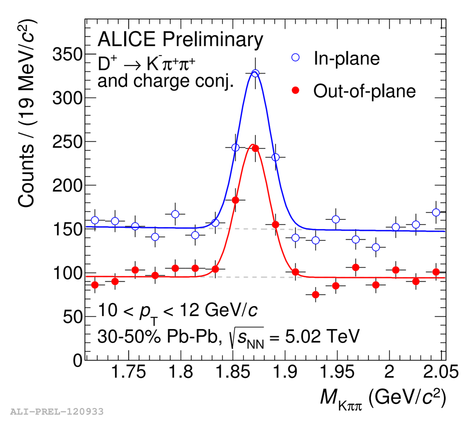
- **Efficiency** correction computed with **MC simulations** based on **HIJING** events enriched with **PYTHIA** $c\bar{c}$ and $b\bar{b}$ pairs
- **Subtraction** of D⁺ mesons coming **from B-hadron decays** based on **theoretical calculations** of their production cross section (FONLL [2])
- **Reaction plane** for the elliptic flow measurement **estimated** with the reconstructed **event plane**

$$\Psi_2 = \frac{1}{2} tan^{-1}\left(\frac{Q_{2,y}}{Q_{2,x}}\right) \text{ where } Q_2 \text{ is the flow vector } Q_2 = \begin{pmatrix} \sum_{i=0}^{N_{tracks}} w_i \cos 2\varphi_i \\ \sum_{i=0}^{N_{tracks}} w_i \sin 2\varphi_i \end{pmatrix}$$

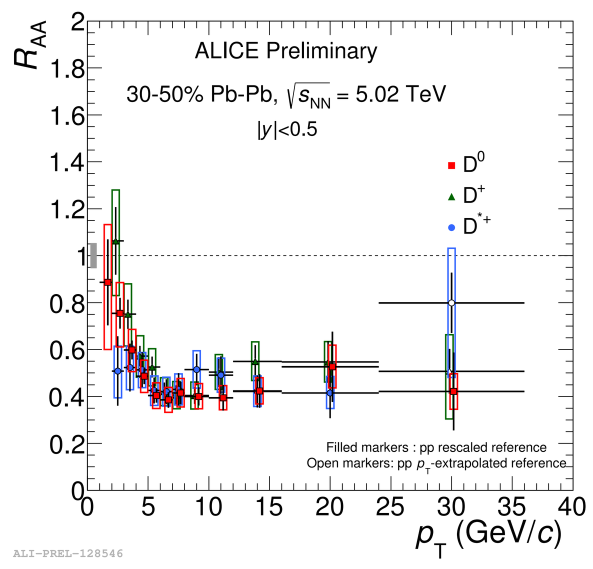
- D⁺ v_2 evaluated with the **anisotropy** between the **in-plane** and the **out-of-plane** regions, corrected for the **event plane resolution R_2**

$$v_2 = \frac{1}{R_2} \frac{1}{4\pi} \frac{N_{in} - N_{out}}{N_{in} + N_{out}}$$

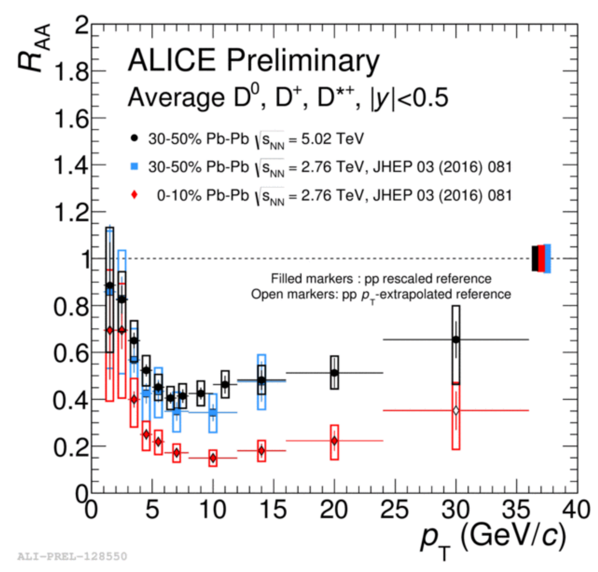




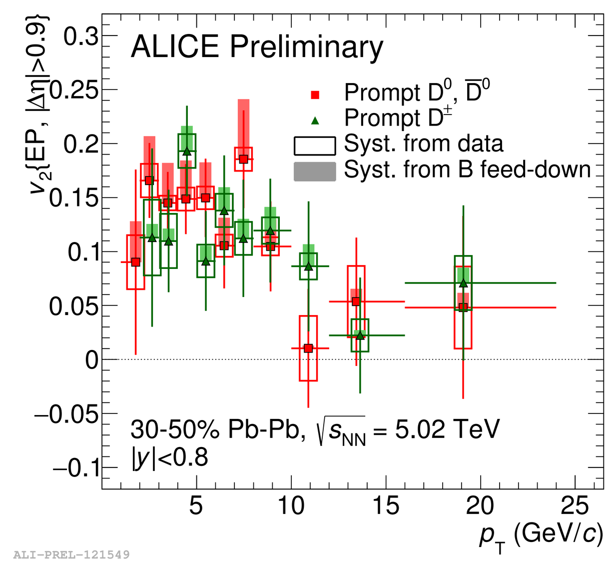
Nuclear modification factor R_{AA}

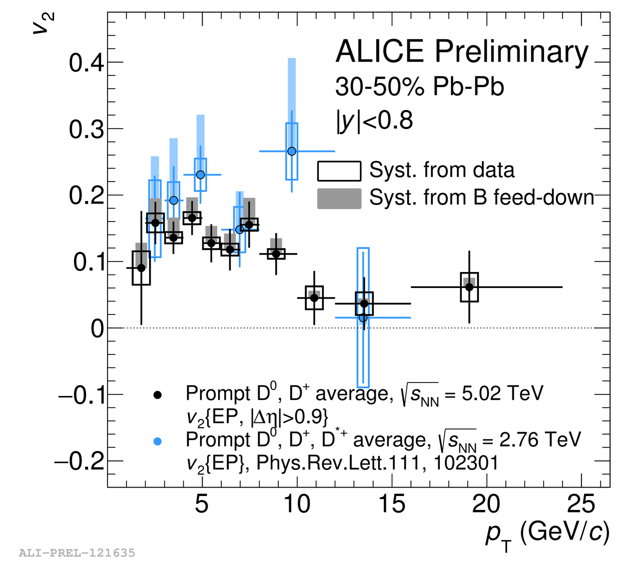


- **Measured nuclear modification factor** for **D⁺, D⁰** and **D*⁺** in **semi-peripheral** collisions at **$\sqrt{s_{NN}}$ = 5.02 TeV compatible** within uncertainties
- **Suppression** observed in **semi-peripheral** collisions **smaller** than the one in **central** collisions
- D-meson **nuclear modification factor** in semi-peripheral collisions at **$\sqrt{s_{NN}}$ = 5.02 TeV compatible** with the one measured at **$\sqrt{s_{NN}}$ = 2.76 TeV**



Elliptic flow v_2

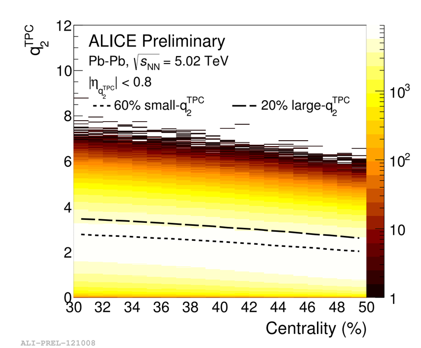




- **Measured v_2** for **D⁺** and **D⁰** in **semi-peripheral** collisions at **$\sqrt{s_{NN}}$ = 5.02 TeV compatible** within uncertainties
- D-meson **elliptic flow larger than zero** for $2 < p_T < 10$ GeV/c, indicating that the **azimuthal anisotropy** of the system is **transferred to the charm quarks**
- **Result compatible** with the measurement at **$\sqrt{s_{NN}}$ = 2.76 TeV**

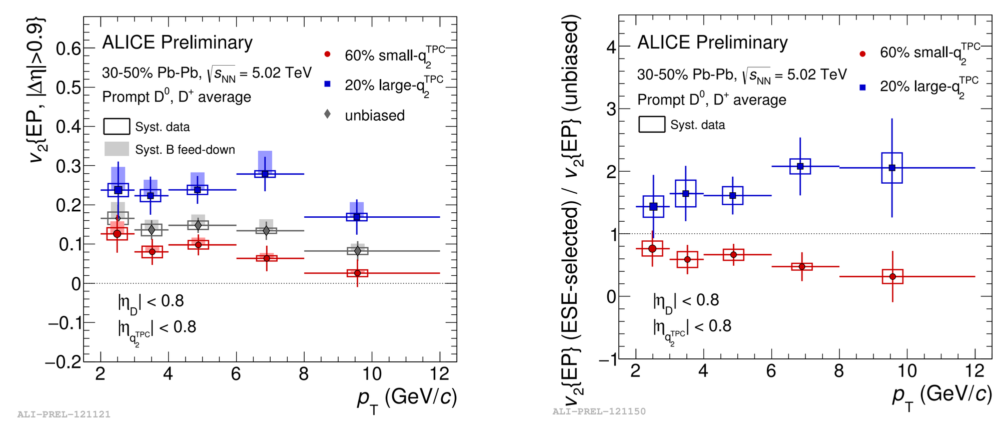
Event-shape engineering for elliptic flow

- **D-meson v_2 measured** for classes of **events with different average elliptic flow** in the same centrality interval
- Events selected considering the **reduced flow vector q_2**



$$q_2 = |Q_2|/\sqrt{M}$$

- **Q_2** is the second harmonic **flow vector**
- ***M*** is the multiplicity

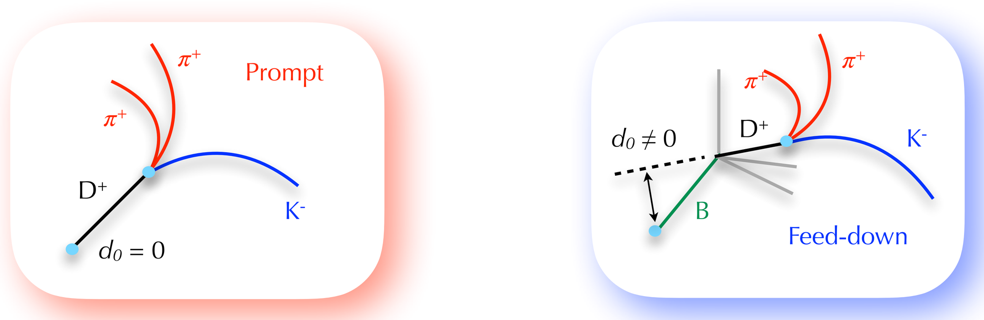


- The measurement suggests that the **D-meson v_2** is **larger** for events with large average elliptic flow (**large-q_2**) and **smaller** for events with small average elliptic flow (**small-q_2**)
- **Non-flow contributions** and **auto-correlation** between measured **q_2** and **D-meson** candidates are **included**, however their **contribution** is **expected to be small**

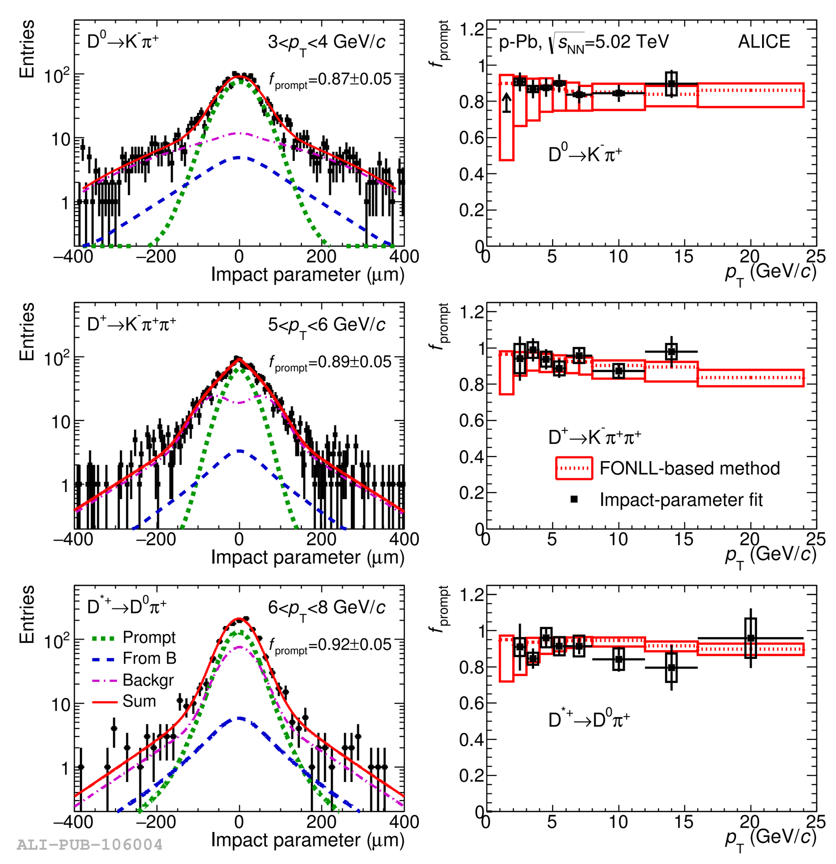
D⁺ in p-Pb collisions

Fraction of prompt D⁺ with a data-driven approach

- Measured raw yield includes **prompt** D⁺ (which derives **directly from** the hadronisation of a **charm quark** or from the **decay of excited open charm** and **charmonium states**) and **feed-down** D⁺ (coming **from B-hadron** decays)



- **Fraction of prompt D mesons** usually **estimated** using **theoretical predictions** of production cross sections for prompt and feed-down D mesons
- An alternative **data-driven approach** exploits the **different shape** of the distributions of the **transverse-plane impact parameter** to the primary vertex (**d_0**) [3]
- **Fraction of prompt D⁺ measured** via an **unbinned log-likelihood fit** of the **d_0 distributions** of D⁺ candidates in the invariant-mass region of the signal



- The **fitting function** includes **three** different **contributions**

$$F(d_0) = S \cdot \{ f_{prompt} \cdot F^{prompt}(d_0) + (1 - f_{prompt}) \cdot F^{feed-down}(d_0) \} + B \cdot F^{bkg}(d_0)$$

where:

- **f_{prompt}** is the **fraction of prompt D⁺** in the raw yield
- ***S*** and ***B*** are the **signal** and the **background** in the selected invariant-mass region
- **F^{prompt}** is the **detector resolution term** (Gaussian function plus a symmetric exponential term)
- **$F^{feed-down}$** is the **convolution** of the distribution which describes the **intrinsic impact parameter distribution of D from B** and the **resolution term**
- **F^{bkg}** is the function describing the **combinatorial background**, modelled by fitting the **impact-parameter distribution** obtained **from the side-bands** of the selected invariant-mass region
- The **fraction of prompt D mesons** with **data-driven** method is **compatible** with **theory-driven** method and can **improve** the result for the **D⁰**

Outlook

- The **measurement** of the **D⁺ nuclear modification factor** and the **elliptic flow** in **Pb-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV** will also be performed in **different centrality classes**
- The **data-driven** approach for the determination of the **fraction of prompt D⁺** will be **applied** to the **measurement in Pb-Pb collisions** to confirm the result obtained from theoretical calculations

References

[1] Liu, Fu-Ming and Liu, Sheng-Xu Phys. Rev. C 89, 034906 (2014)
[2] Cacciari, Matteo et al. JHEP 1210 (2012) 137
[3] ALICE Collaboration (Adam, Jaroslav et al.) Phys. Rev. C 94, 054908 (2016)