Non prompt D-meson measurements with ALICE at the LHC

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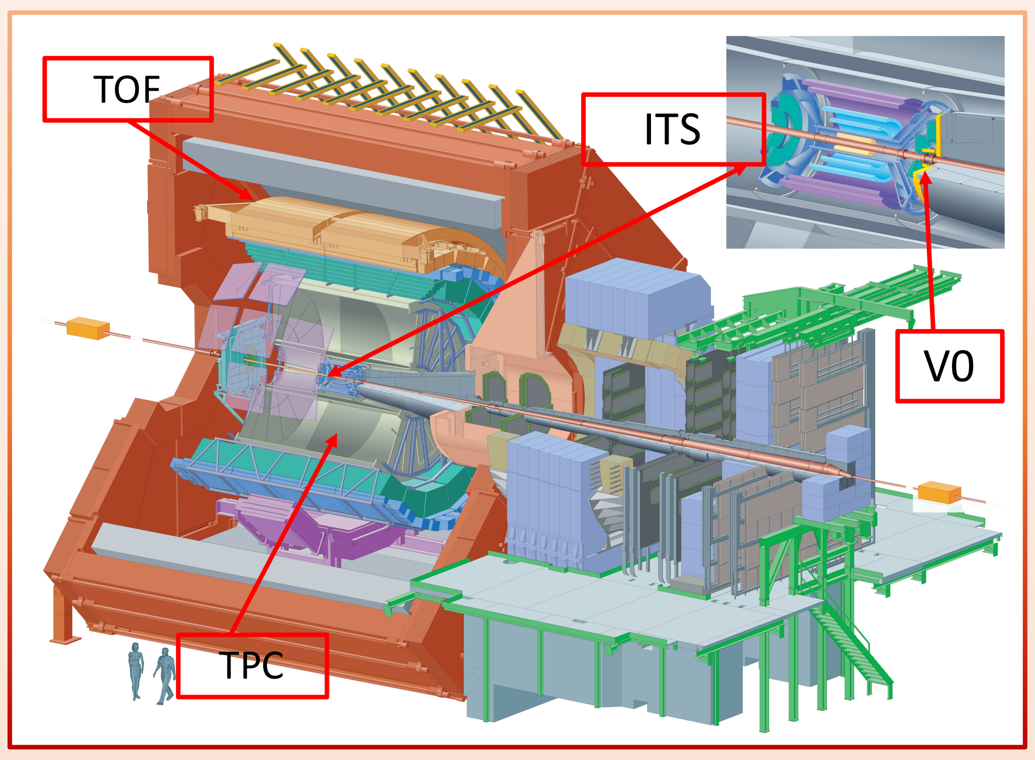


INTRODUCTION

ALICE is the LHC experiment devoted to the study of ultra-relativistic heavy-ion collisions, with the aim of investigating the high-density color-deconfined state of strongly-interacting matter formed in these collisions, known as Quark-Gluon Plasma (QGP).

Due to their large masses, heavy quarks are produced in hard partonic scattering processes on a shorter time scale than the QGP formation time. In Pb-Pb collisions, charm and beauty quarks propagate through the medium interacting with its constituents, thus heavy quarks are sensitive probes of the collective expansion of the medium.

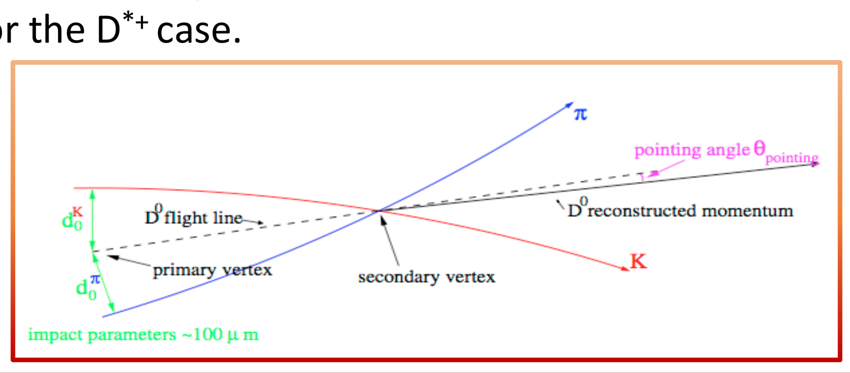
At LHC energies a component of the inclusive D-meson yield originates from the decay of beauty hadrons (non-prompt D mesons), which is essential to be subtracted in order to determine the prompt D-meson production (originating from charm quark fragmentation, either directly or through decays of excited open charm and charmonium states). The evaluation of the non-prompt fraction of D-mesons allows an indirect measurement of beauty production.

D-meson reconstruction

D^0, D^+, D^{*+} and D_s mesons, and their charge conjugates, were reconstructed via their hadronic decays channels in pp, p-Pb and Pb-Pb collisions [1][2].

The analysis strategy was based on the selection of decay topologies displaced from the primary vertex and, at low p_T, on the estimation and subtraction of combinatorial background, without D^0 decay-vertex reconstruction [1]. Further reduction of the combinatorial background was obtained by applying particle identification (PID) to the decay tracks.

The D-meson raw yields are extracted by fit to D-meson invariant mass distributions. The fit functions are the sum of an exponential and a Gaussian term for D^0 and D^+, and a threshold function multiplied by an exponential for the D^{*+} case.

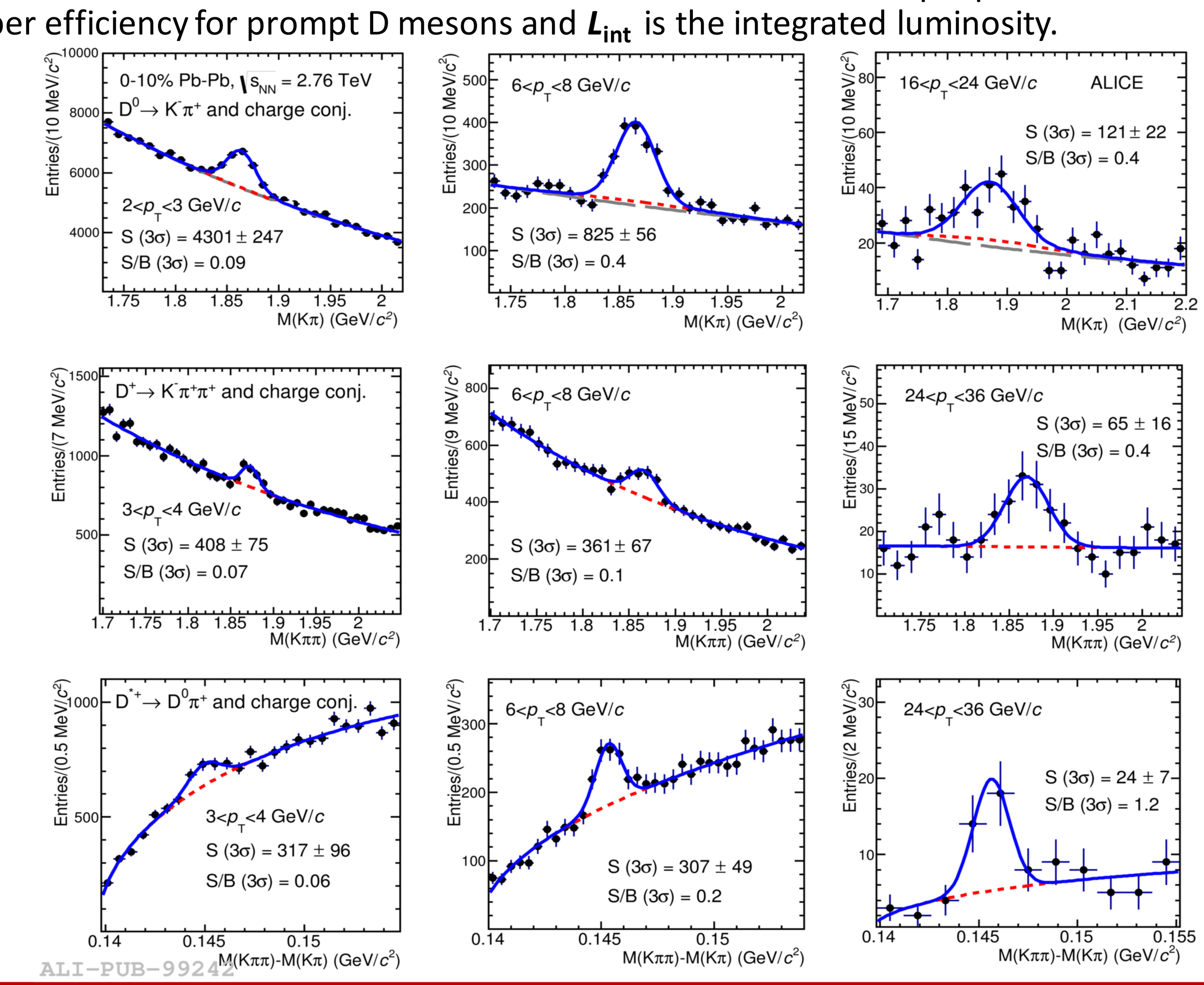


- $D^0 \rightarrow K^- \pi^+$ (BR = 3.88 ± 0.05%)
- $D^+ \rightarrow K^- \pi^+ \pi^+$ (BR = 9.13 ± 0.19%)
- $D^{*+} \rightarrow D^0 \pi^+$ (BR = 67.7 ± 0.5%) $\rightarrow K^- \pi^+ \pi^+$
- $D_s^+ \rightarrow \phi \pi^+ \rightarrow K^- K^+ \pi^+$ (BR = 2.24 ± 0.10%)

The raw yield $N_{\mathrm{raw}}^{\mathrm{D+\bar{D}}}(p_T)$ (sum of particles and antiparticles) includes the contributions of both prompt and feed-down D mesons.
The D-meson **raw yields** extracted in each p_T interval [2] were corrected to obtain the prompt D-meson cross section:

$$\left.\frac{\mathrm{d}^2\sigma}{\mathrm{d}p_T\mathrm{d}y}\right|_{|y|<0.5} = \frac{1}{2}\cdot\frac{f_{\mathrm{prompt}}\cdot N_{\mathrm{raw}}^{\mathrm{D+\bar{D}}}(p_T)}{\Delta p_T \Delta y}\cdot\frac{1}{(\mathrm{Acc}\times\varepsilon)_{\mathrm{prompt}}(p_T)}\cdot\frac{1}{\mathrm{BR}\cdot L_{\mathrm{int}}}$$

Where f_{prompt} is the fraction of prompt D mesons in the raw yield, $(\mathrm{Acc}\times\varepsilon)_{\mathrm{prompt}}$ is the product of acceptance per efficiency for prompt D mesons and L_{int} is the integrated luminosity.



How can we extract the prompt D-meson fraction (f_{prompt})?

1 FONLL-based method

The FONLL-based [4] method estimates f_{prompt}, the fraction of prompt D mesons in the raw yield, as:

$$f_{\mathrm{prompt}} = 1 - \frac{N_{\mathrm{raw}}^{\mathrm{D+\bar{D}}\,\mathrm{feed-down}}}{N_{\mathrm{raw}}^{\mathrm{D+\bar{D}}}} =$$

$$= 1 - R_{\mathrm{AA}}^{\mathrm{feed-down}} \cdot \langle T_{\mathrm{AA}} \rangle \left(\frac{\mathrm{d}\sigma}{\mathrm{d}p_T}\right)^{\mathrm{FONLL}}_{\mathrm{feed-down},|y|<0.5} \frac{\Delta p_T \cdot \Delta y\,(\mathrm{Acc}\times\varepsilon)_{\mathrm{feed-down}}\cdot \mathrm{BR}\cdot L_{\mathrm{int}}}{N_{\mathrm{raw}}^{\mathrm{D+\bar{D}}}}$$

The procedure starts from B-meson production cross section in pp collisions estimated with FONLL[5] pQCD calculations considering the B → D+X decay kinematics from the EvtGen[6] package. Then the cross section in p-Pb and Pb-Pb collisons is extracted considering the possible nuclear modification factor R_{AA} of the spectra compared to pp collisions and the nuclear overlap function T_{AA} to scale FONLL.

2 Data-driven method

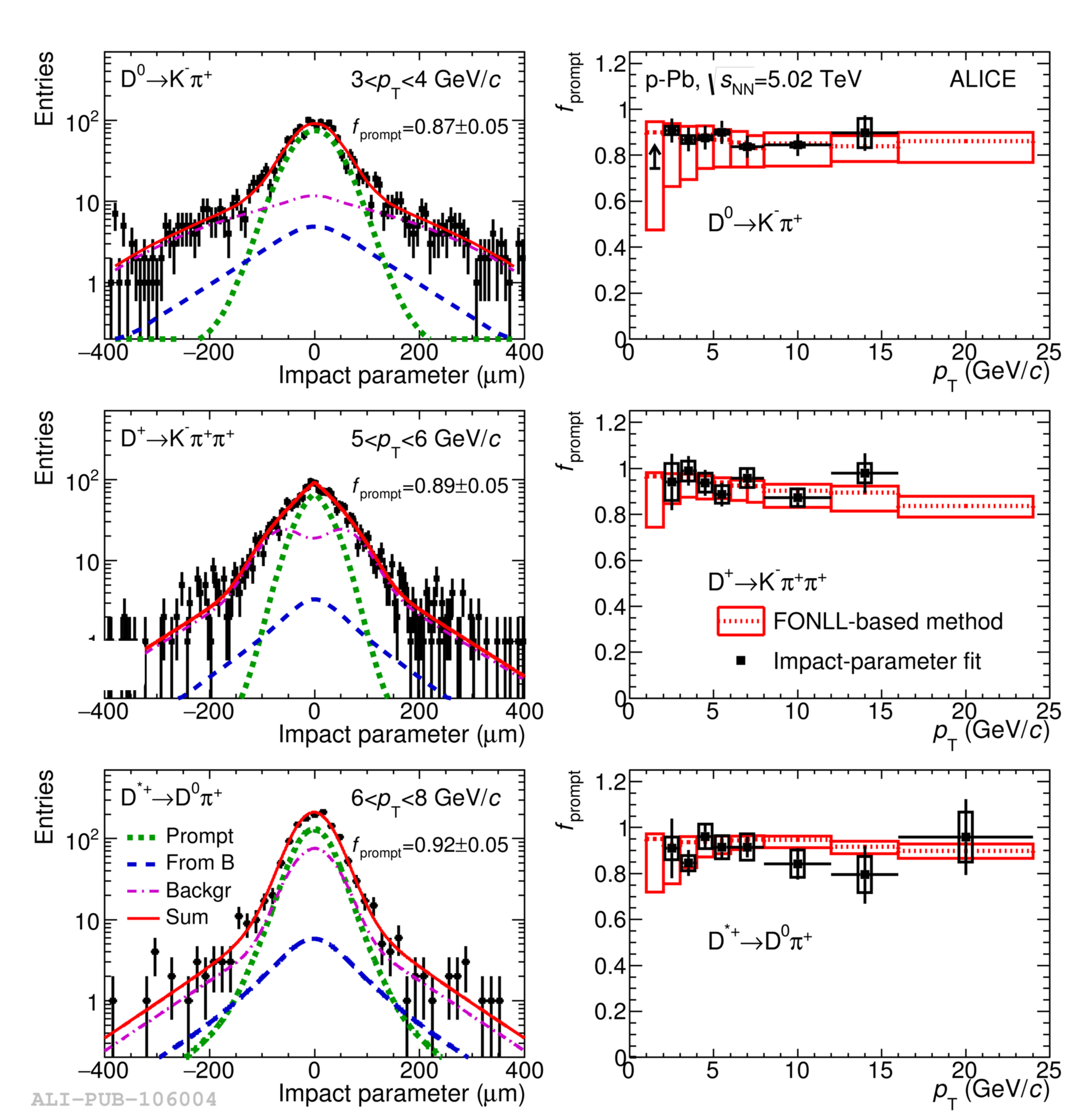
The **data-driven method** [1] has been employed to extract the prompt fraction f_{prompt} in the raw yield of D^0, D^+ and D^{*+} mesons in p-Pb collisions. It exploits the different shapes of the distributions of the transverse-plane impact parameter to the primary vertex (d_0) of prompt and feed-down D mesons.

The prompt fraction was estimated via an **unbinned likelihood fit** of the d_0 distribution. The following fit function is used:

$$F(d_0) = S\cdot\left[\left(1-f_{\mathrm{prompt}}\right)F^{\mathrm{feed-down}}(d_0) + f_{\mathrm{prompt}}\,F^{\mathrm{prompt}}(d_0)\right] + B\cdot F^{\mathrm{backgr}}(d_0).$$

$F^{\mathrm{prompt}}(d_0)$, $F^{\mathrm{feed-down}}(d_0)$ and $F^{\mathrm{backgr}}(d_0)$ are the templates describing the impact parameter distributions of prompt D mesons, feed-down D mesons, and background, respectively.

The prompt fraction of D^0, D^+ and D^{*+} mesons estimated with the impact parameter fits is found to be compatible with the FONLL-based estimation within uncertainties.



3 Method based on pseudo-proper decay length

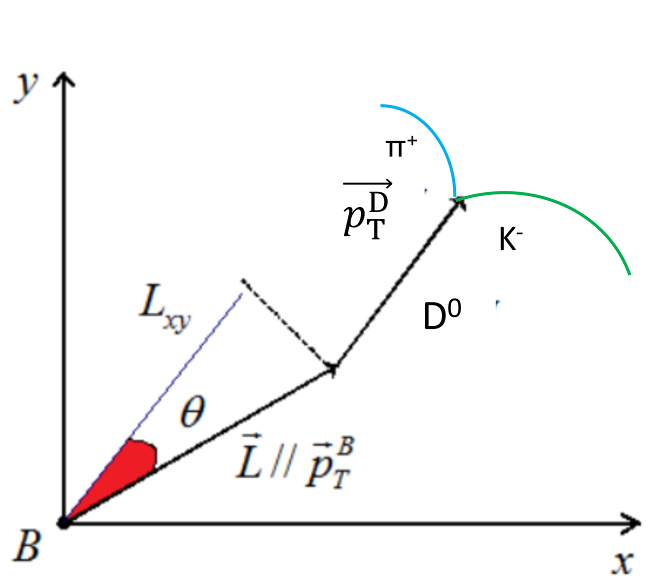
NEW!!

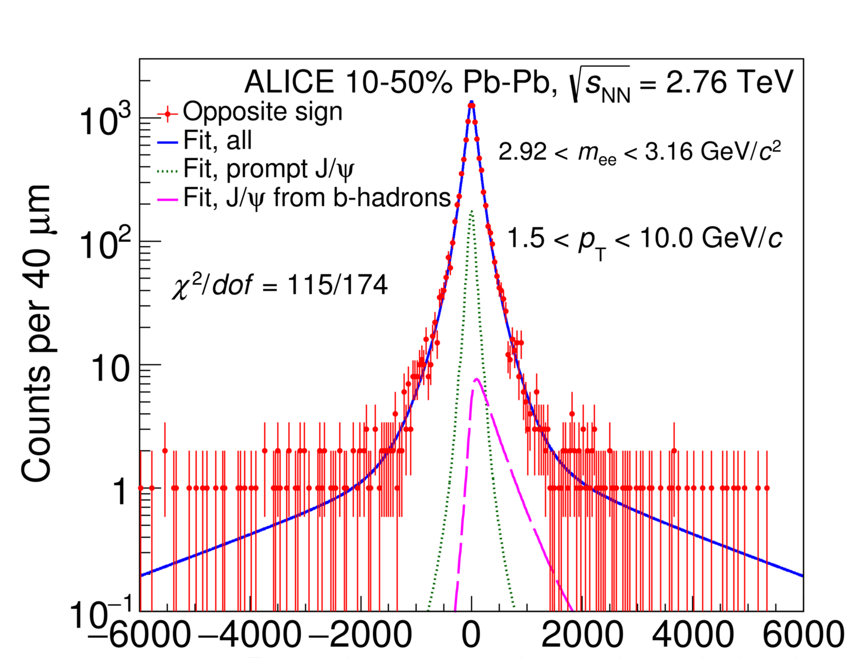
A new method is under study for the separation of the prompt D-meson fraction from the non-prompt one in Pb-Pb collisions. This new approach is based on the definition of a decay-length dependent variable: the pseudo-proper decay length x.
The starting point is to introduce the **scalar variable L_{xy}**, defined as the signed projection of the D^0 flight distance onto its transverse momentum vector : $L_{xy} = \vec{L}\cdot\frac{\vec{p}_T^{\,D}}{|\vec{p}_T^{\,D}|}$.

Therefore, the **pseudo-proper decay length** is defined as: $x = \frac{L_{xy} M^D}{|\vec{p}_T^{\,D}|}$.

This approach would achieve the separation of the two components exploiting the different shapes of the pseudo proper decay distributions of prompt and feed-down D mesons.

The pseudo-proper decay method has been successfully employed for the measurement of prompt and non-prompt J/ψ in pp [4] and Pb-Pb [3] collisions.





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