CLHCP 2019

D-meson production in pp and Pb-Pb collisions measured with ALICE at the LHC

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Heavy Flavour: effective probes of the QGP

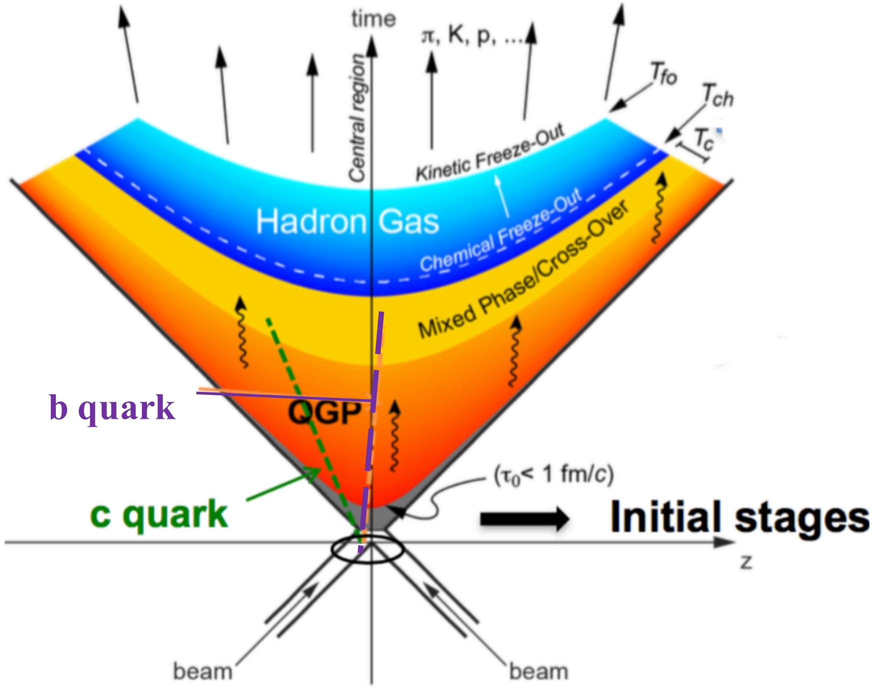
- Produced in **initial hard scattering (high Q^2)** processes
- $\tau_{c/b} \sim 0.01 - 0.1 \text{ fm}/c$ < QGP formation time (~0.1-1 fm/*c*)
  - Experience the whole system evolution **interacting with the medium** formed in Pb-Pb collisions

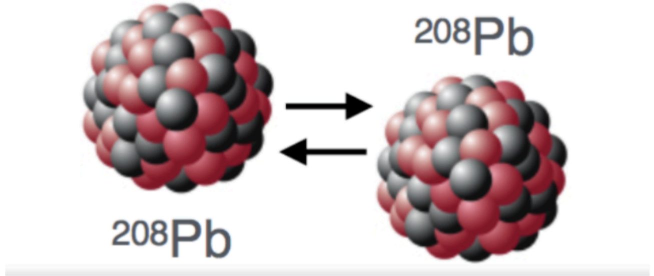
In pp collisions:

- Provide baseline for Pb-Pb collisions
- Test perturbative QCD calculations

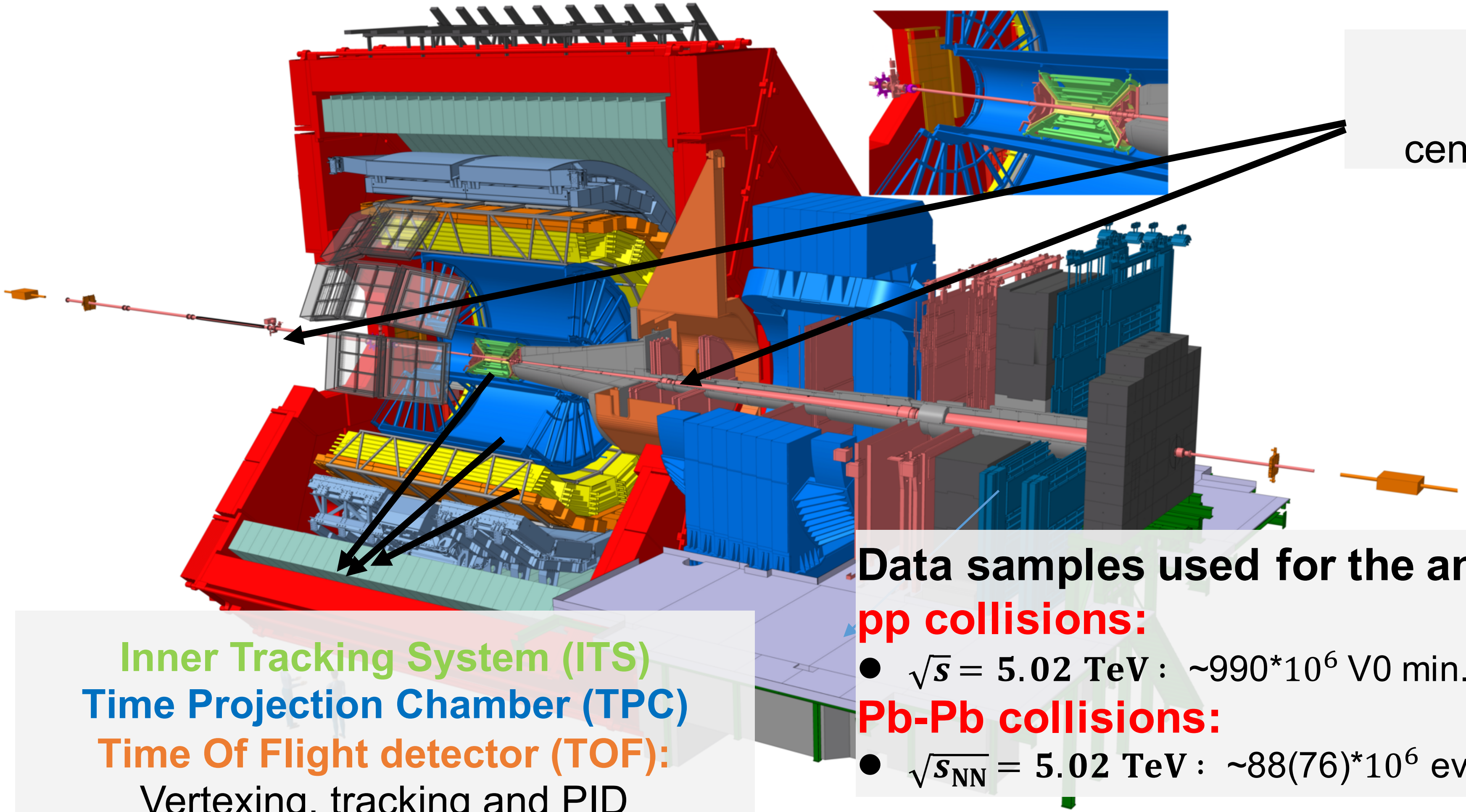
In Pb-Pb collisions:

- Study of charm and beauty energy-loss mechanism in the medium
  - Colour-charge and quark-mass dependence
- Participate in the collective motion and thermalisation of the medium
- Modification of hadronisation mechanism in the medium
  - **Coalescence mechanism**?





The ALICE detector



V0, ZDC:
Event plane, trigger and
centrality/multiplicity determination

Inner Tracking System (ITS)
Time Projection Chamber (TPC)
Time Of Flight detector (TOF):
Vertexing, tracking and PID
$|\eta| < 0.9$

Data samples used for the analyses discussed:

pp collisions:

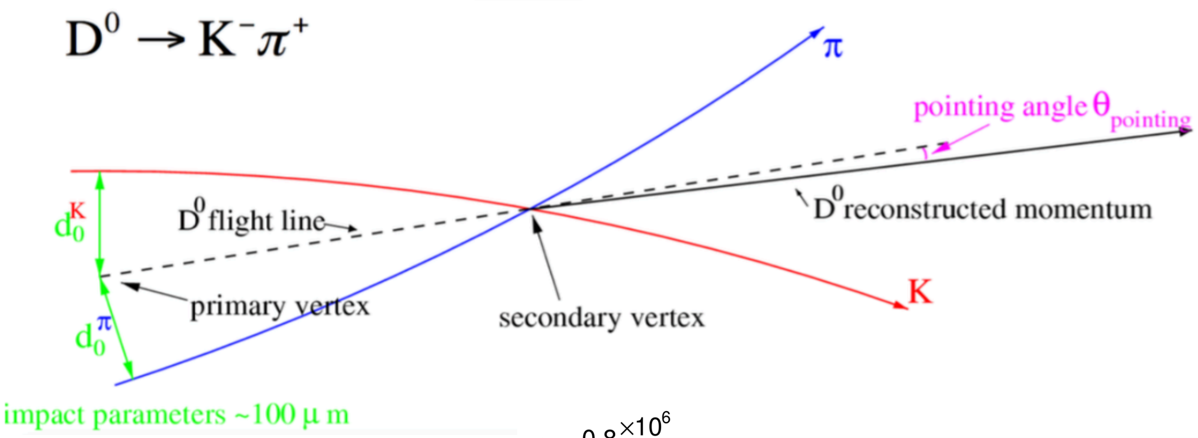
- $\sqrt{s} = \mathbf{5.02\ TeV}$: ~990*$10^6$ V0 min.bias events $L_{\rm int} = 19.3\ {\rm nb}^{-1}$

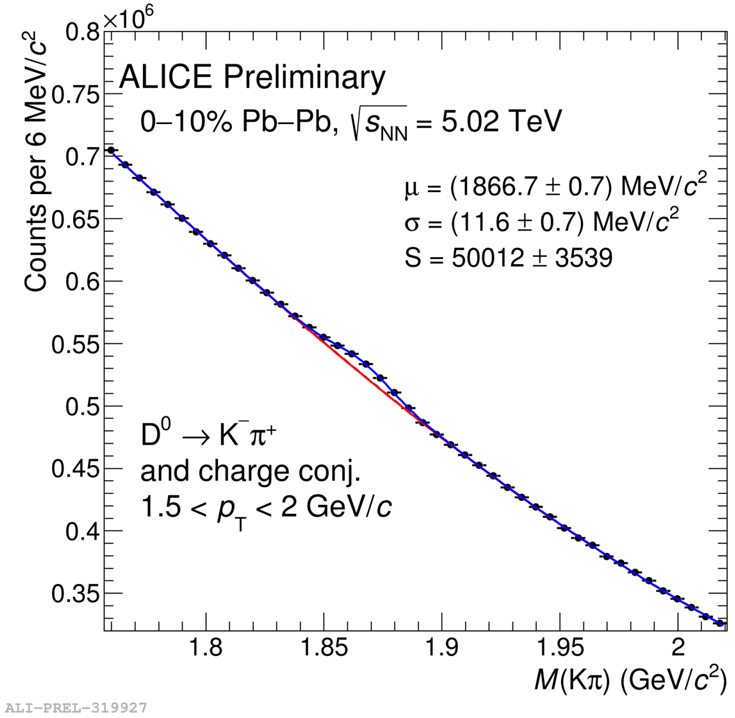
Pb-Pb collisions:

- $\sqrt{s_{\rm NN}} = \mathbf{5.02\ TeV}$: ~88(76)*$10^6$ events in 0-10(30-50)% centrality classes

Prompt D-meson reconstruction

$D^0 \to K^-\pi^+$	BR ~ 3.93%	$c\tau \sim 123\ \mu m$
$D^+ \to K^-\pi^+\pi^+$	BR ~ 9.46%	$c\tau \sim 312\ \mu m$
$D^{*+} \to D^0(K^-\pi^+)\pi^+$	BR ~ 2.66%	-
$D_s^+ \to \phi(K^-K^+)\pi^+$	BR ~ 2.27%	$c\tau \sim 150\ \mu m$

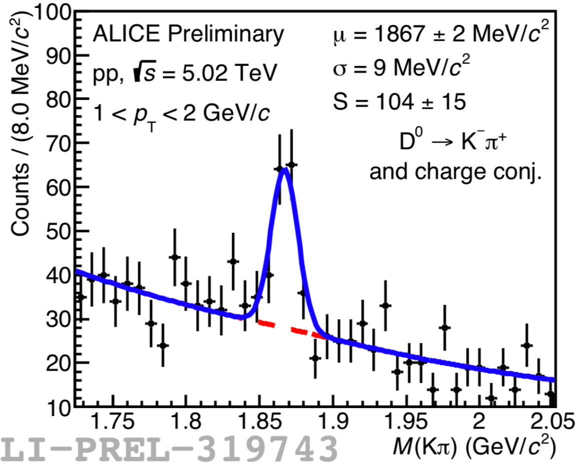




- Decay topology selections and PID used to reduce the combinatorial background
- Signal is extracted via an invariant-mass analysis
- Feed-down from beauty-hadron decays are subtracted exploiting FONLL calculations. In Pb-Pb collisions, with further assumptions on feed-down nuclear modification factor

Non-prompt D^0 reconstruction

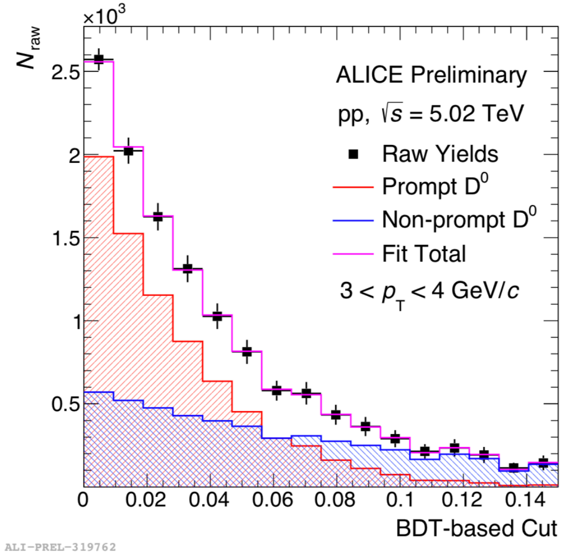
- Use ML based method (BDT) to combine and optimize topological cuts on SV to achieve high fraction non-prompt D^0
  - ➢ Two step BDT-based cut applied, first step aims to increase non-prompt D^0 fraction, second step used to suppress the combinatorial background

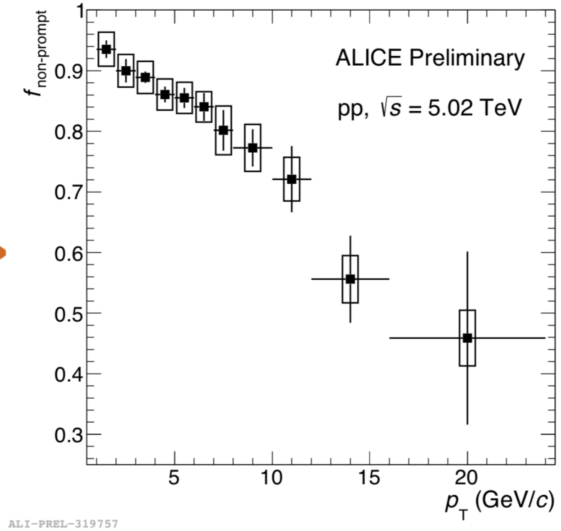


- New data-driven approach applied to extract non-prompt D^0 fraction

$$N_{\mathrm{raw}}(x) \approx N_{\mathrm{c}} \cdot \varepsilon_{\mathrm{c}}(x) + N_{\mathrm{b}} \cdot \varepsilon_{\mathrm{b}}(x)$$

$\varepsilon_{c,b}$ = efficiency for c,b→D⁰



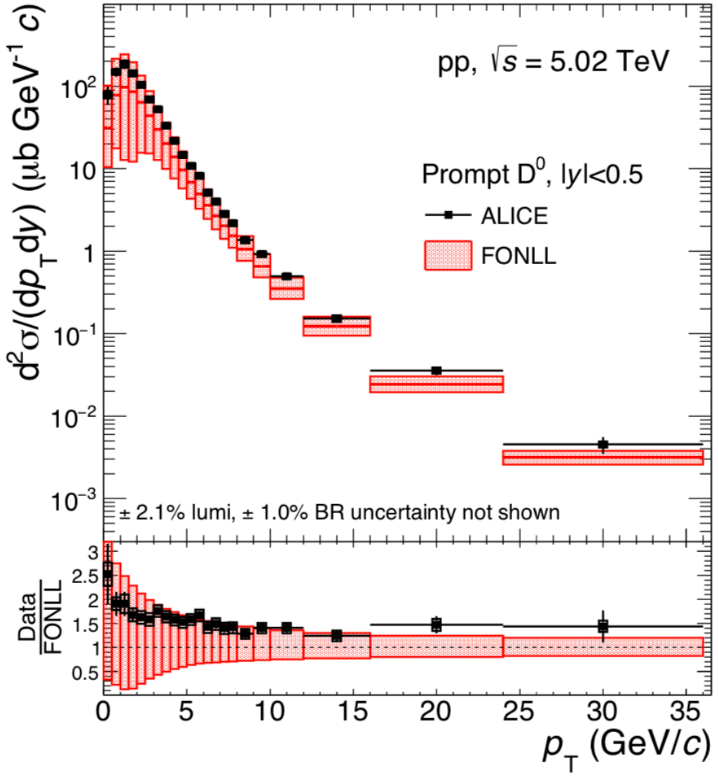


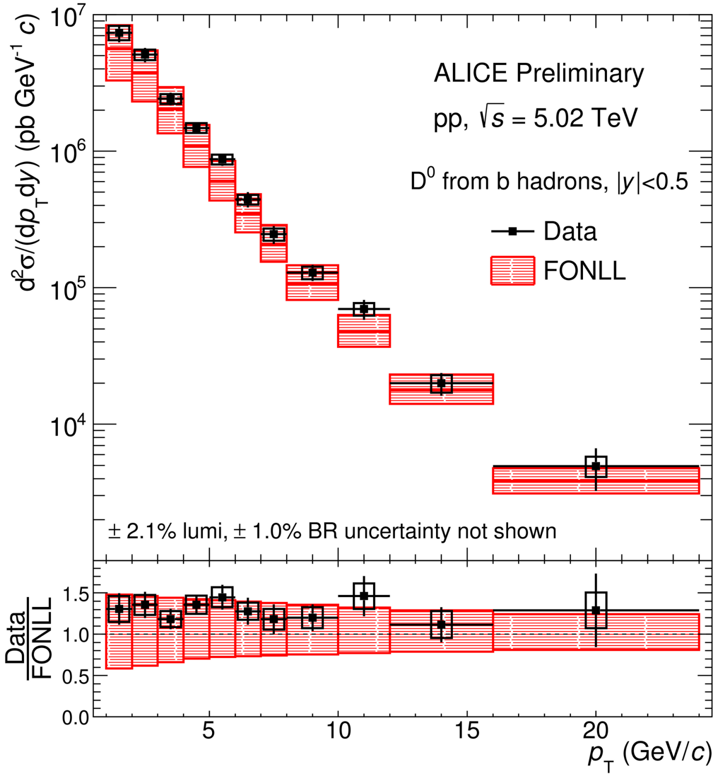
$$f_{\mathrm{np}}(x) = \frac{N_{\mathrm{b}}\varepsilon_{\mathrm{b}}(x)}{N_{\mathrm{c}}\varepsilon_{\mathrm{c}}(x) + N_{\mathrm{b}}\varepsilon_{\mathrm{b}}(}$$

[1] J. High Energ. Phys. (2012) 2012: 137

D^0 meson p_T-differential cross section in pp collisions at $\sqrt{s} = 5.02$ TeV

Eur.Phys.J. C79 (2019) no.5, 388



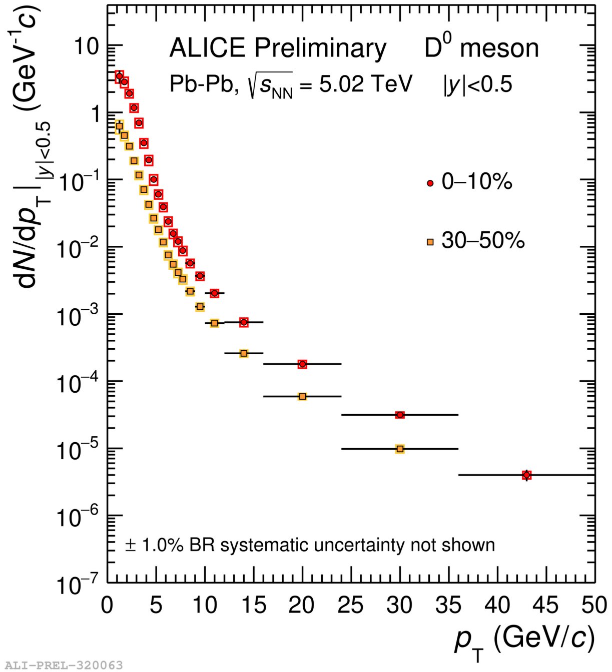


ALI-PREL-319648

$$\frac{d^2\sigma^{D}}{dp_{T}dy} = \frac{1}{c_{\Delta y}(p_{T})\Delta p_{T}} \cdot \frac{1}{BR} \cdot \frac{\frac{1}{2}\, f_{prompt}(p_{T}) \cdot N^{D+\bar{D},raw}(p_{T})\Big|_{|y|<y_{fid}(p_{T})}}{(Acc \times \varepsilon)_{prompt}(p_{T})}\, \frac{1}{L_{int}}$$

- Fully-corrected cross section down to p_T = 0 (1) GeV/*c* for prompt (non-prompt) D^0
- FONLL[1] prediction can simultaneously reproduce the prompt and non-prompt D^0 data within uncertainties, but data lie on the upper edge of the FONLL uncertainty across all p_T

D-meson corrected p_{T}-spectra in Pb-Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV



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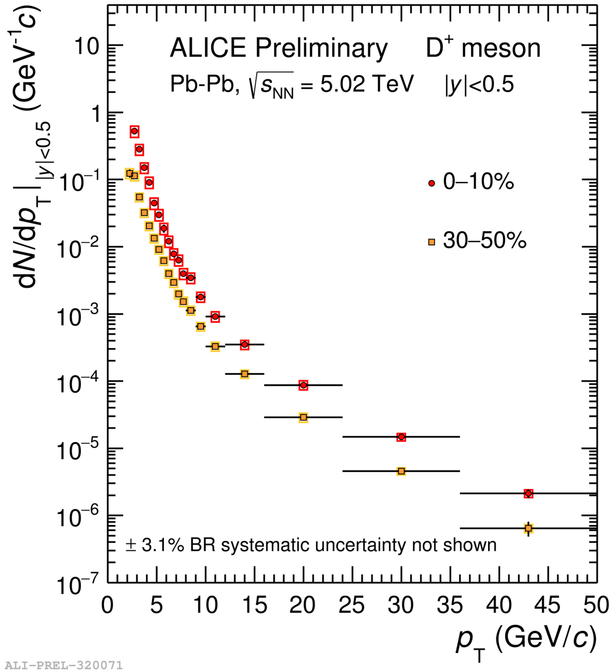

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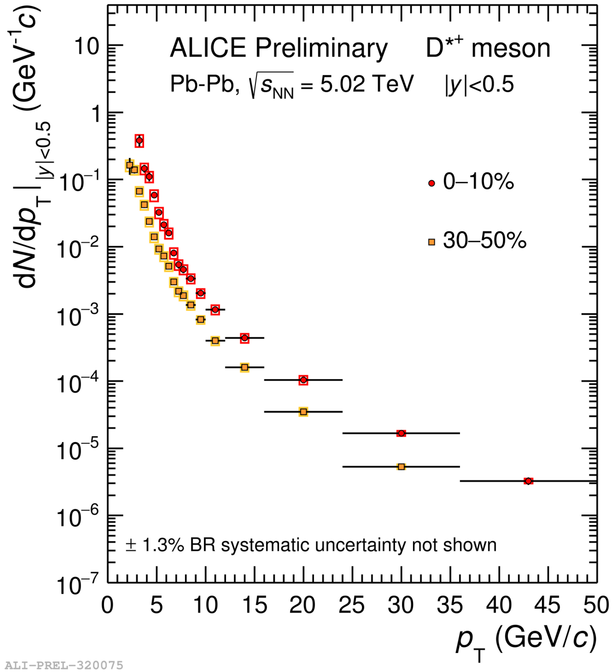

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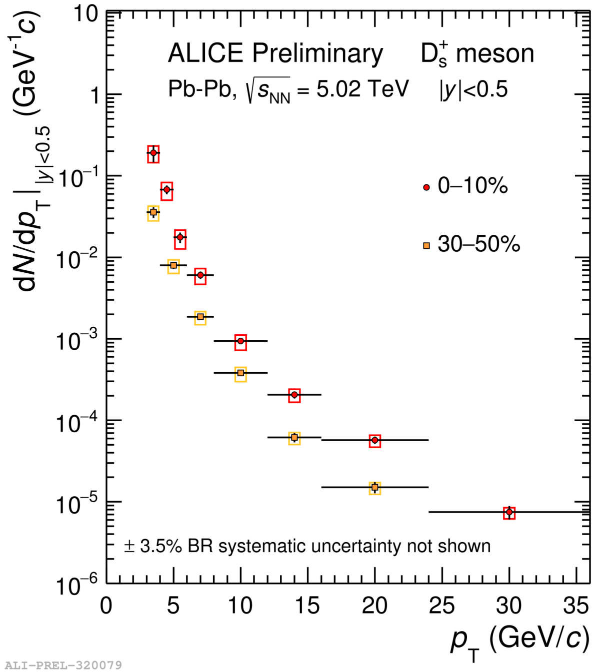
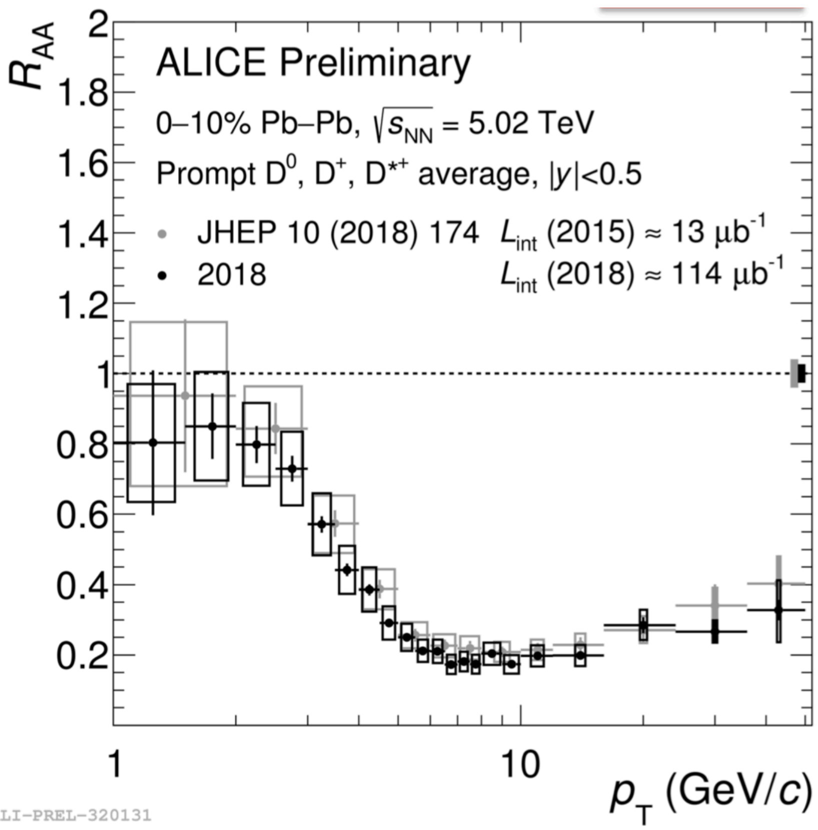


ALI-PREL-320079

$$\left.\frac{\mathrm{d}N^{\mathrm{D}}}{\mathrm{d}p_{\mathrm{T}}}\right|_{|y|<0.5} = \frac{f_{\mathrm{prompt}}(p_{\mathrm{T}}) \cdot \frac{1}{2} N_{\mathrm{raw}}^{\mathrm{D}+\overline{\mathrm{D}}}(p_{\mathrm{T}})\Big|_{|y|<y_{\mathrm{fid}}(p_{\mathrm{T}})}}{\Delta p_{\mathrm{T}} \cdot \alpha_y(p_{\mathrm{T}}) \cdot (\mathrm{Acc} \times \varepsilon)_{\mathrm{prompt}}(p_{\mathrm{T}}) \cdot \mathrm{BR} \cdot N_{\mathrm{events}}}$$

Non-strange D-meson R_{AA}



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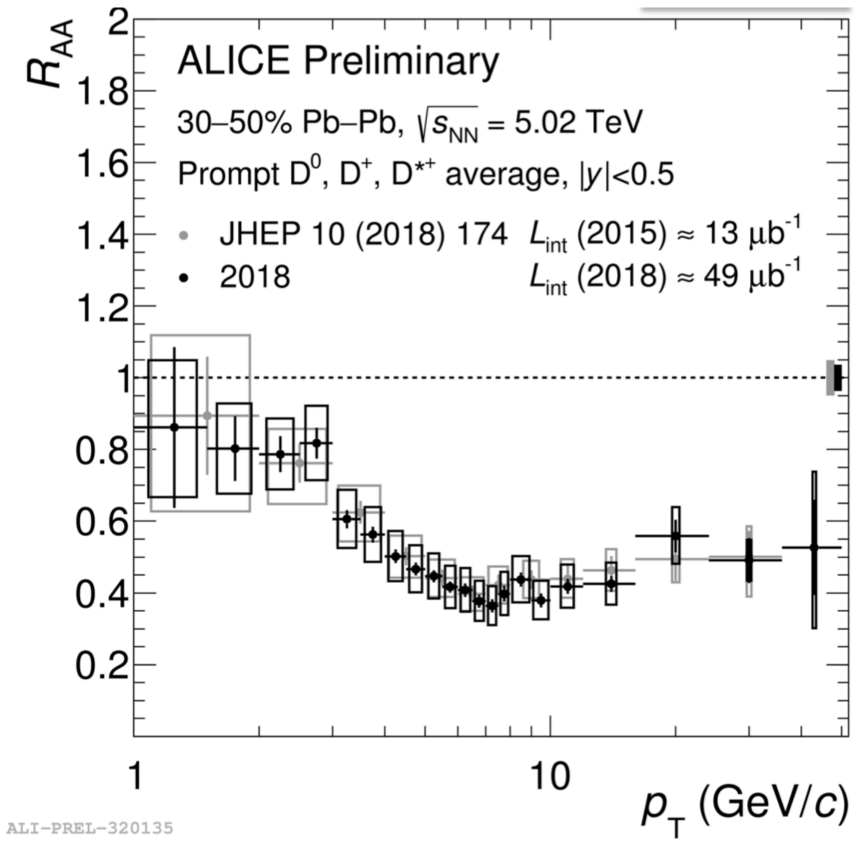
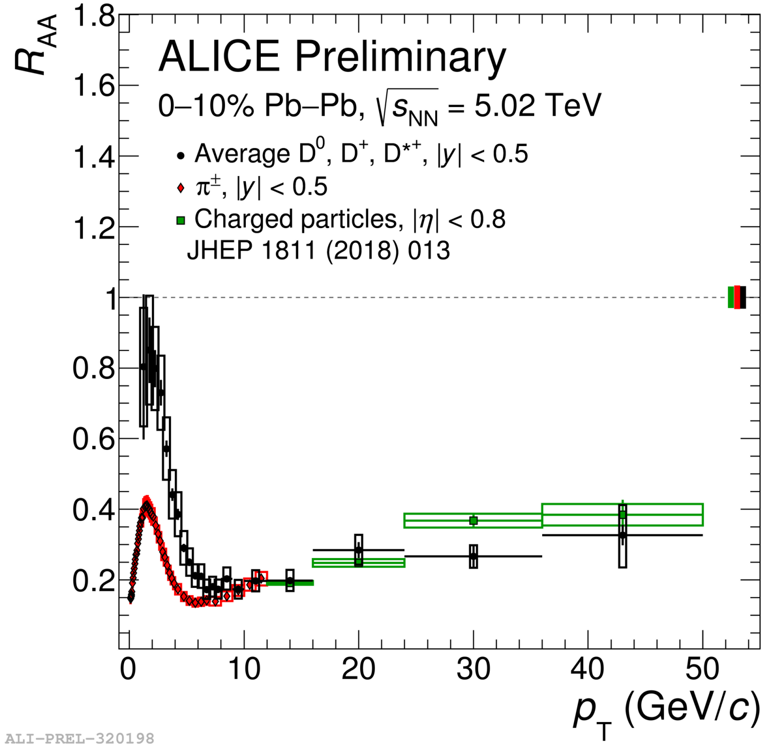


ALI-PREL-320135

$$R_{AA}(p_T) = \frac{1}{\langle T_{AA} \rangle} \cdot \frac{dN_{AA}/dp_T}{d\sigma_{pp}/dp_T}$$

- Improved measurement (in terms of precision) of D-meson R_{AA} using 2018 data w.r.t 2015 data
  - Better constraint to model calculation especially at low p_T

D-meson and charged-particle R_{AA} comparison



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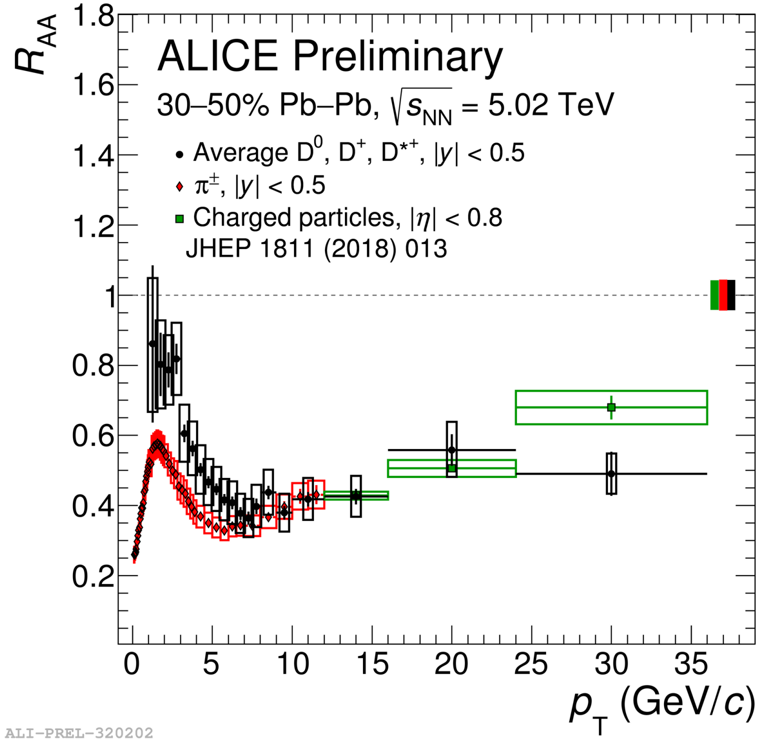

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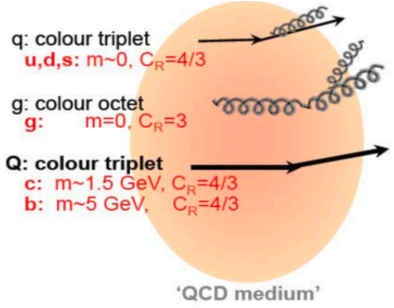


$\Delta E_{\mathrm{g}} > \Delta E_{\mathrm{u,d,s}} \sim \Delta E_{\mathrm{c}} > \Delta E_{\mathrm{b}}$

$R_{\mathrm{AA}}(\pi) < R_{\mathrm{AA}}(\mathrm{D}) < R_{\mathrm{AA}}(\mathrm{B})$?

$\pi^{\pm}$ ALICE preliminary

Charged-particle: JHEP 1811 (2018) 013

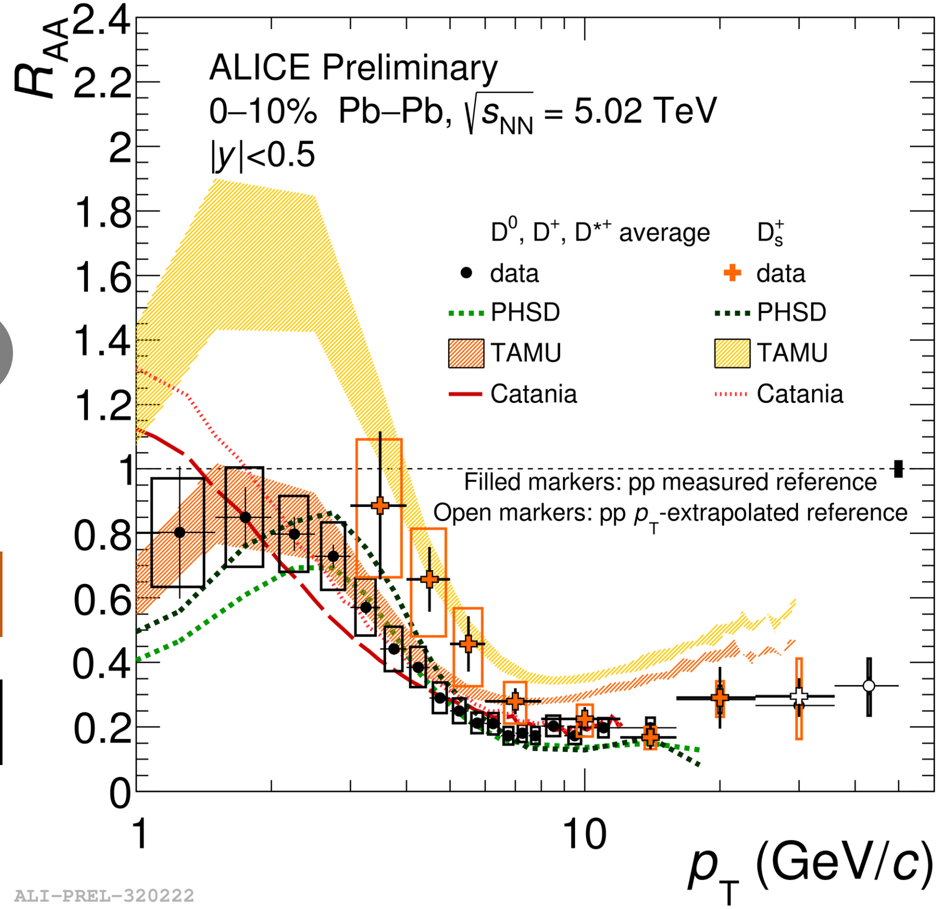
- Similar D-meson, $\pi^{\pm}$ and charged-particle R_{AA} result for $p_{\mathrm{T}} > 10$ GeV/*c* in 0-10% and 30-50%
- D-meson R_{AA} larger than that of charged pions at low p_{T} for 0-10% and 30-50% centrality classes
  - Not straightforward interpretation: N_{part} vs N_{coll} scaling at low p_{T}, different fragmentation and initial spectra shapes, possible mass and Casimir factor effects, different impact of coalescence and radial flow

PHSD: Phys. Rev. C93 no. 3, (2016) 034906
TAMU: Phys.Lett. B735 (2014) 445–450
Catania: Eur.Phys.J.C (2018) 78:348

strange and non-strange D-meson R_{AA}

D_s

D



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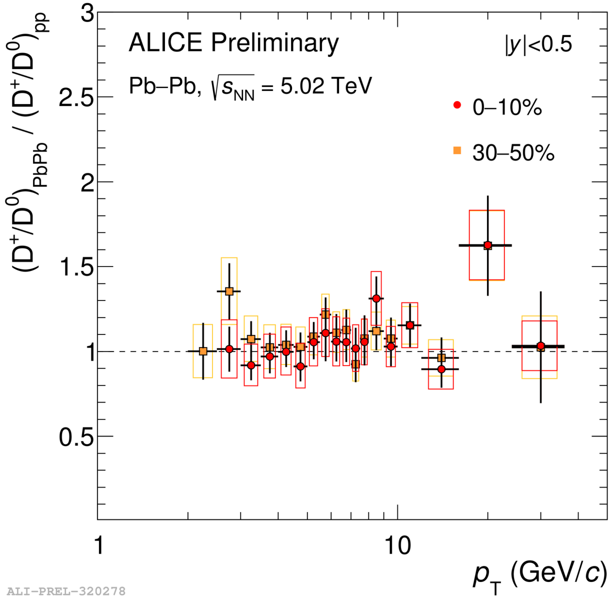

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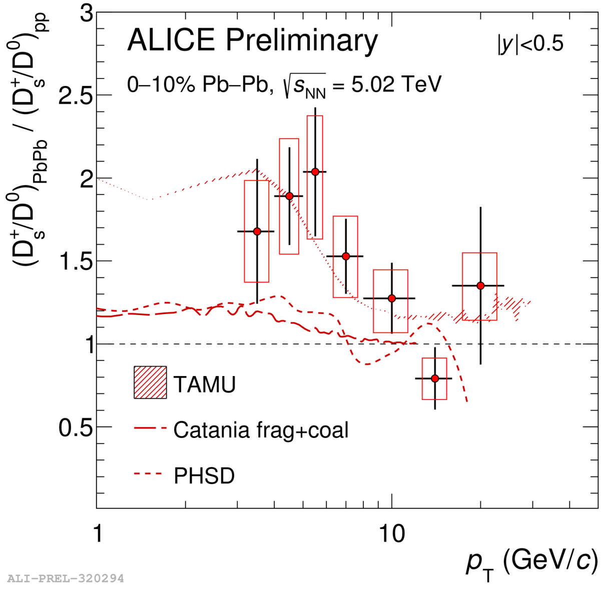
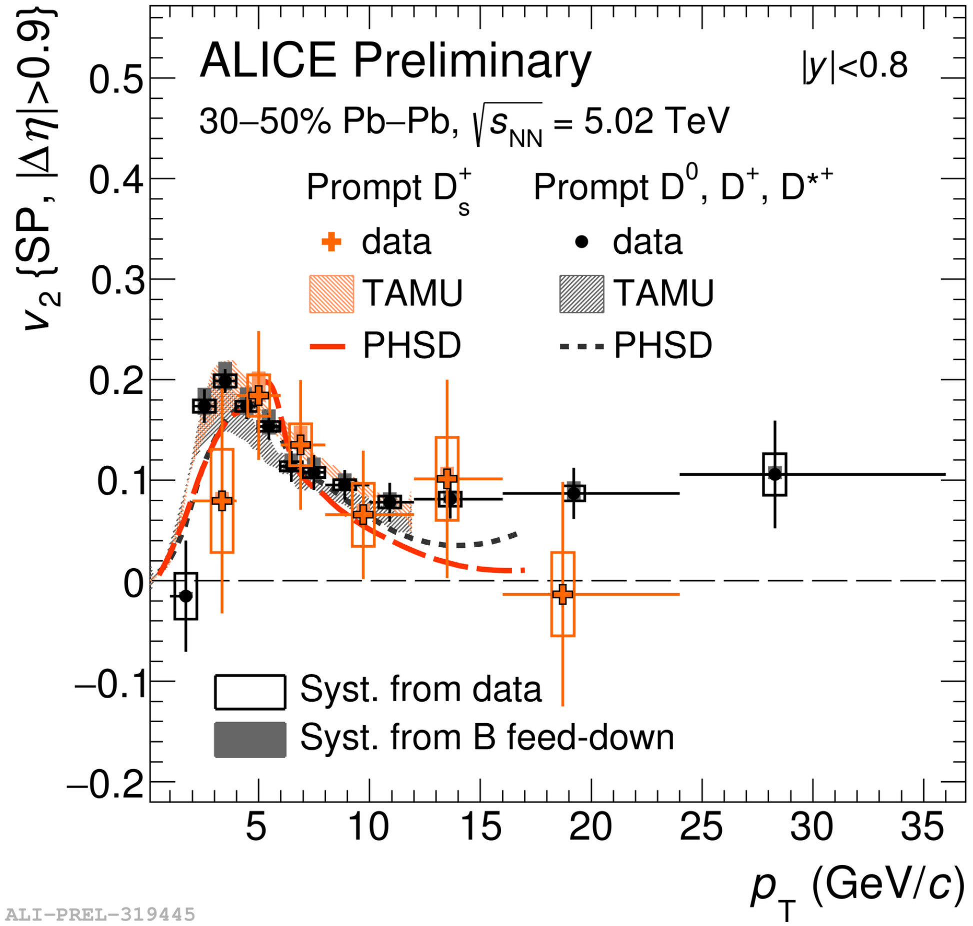


ALI-PREL-320294

- Hint of **enhanced** D_s production in comparison to non-strange D mesons in Pb-Pb collisions. Expected from models
  - ➢ **Effect of coalescence + strangeness enhancement?**

D-meson v_2



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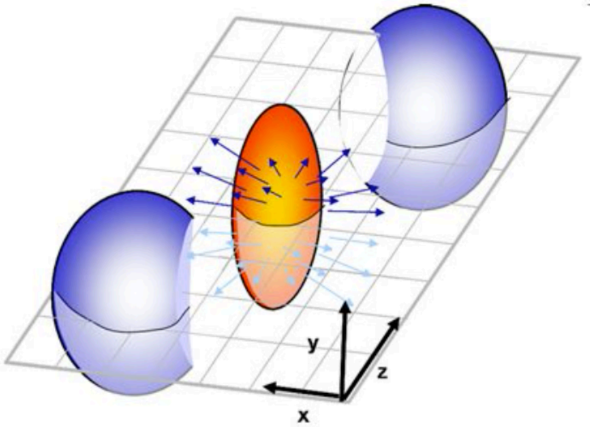
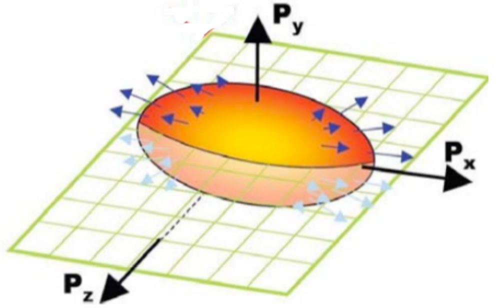


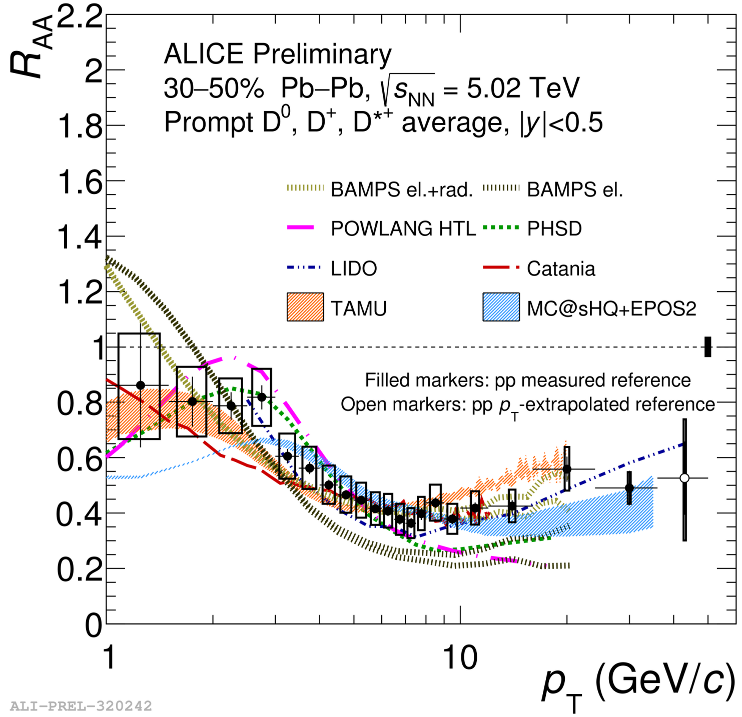


$$E\frac{d^3N}{d^3p} = \frac{1}{2\pi}\frac{d^2N}{p_T dp_T dy}\left\{1 + \sum_{n=1}^{\infty} v_n \cos[n(\varphi - \Psi_{RP})]\right\} \qquad v_2 = \langle \cos[2(\varphi - \Psi_2)] \rangle$$

- **Positive** D-meson v_2 in p_T > 2 GeV/c
  - ➢ Charm quark sensitive to medium collective motion
- Measurement of D_s^+ v_2
  - ➢ Compatible with that of non-strange D mesons within uncertainties
- Hadronisation via quark recombination included in both TAMU and PHSD models. Both show a good agreement with data at low- and intermediate-p_T

Comparison with models

POWLANG: Eur. Phys. J. C75 no. 3, (2015) 121
MC@sHQ: Phys.Rev. C89 no. 1, (2014) 014905
LBT: Phys. Lett. B777 (2018) 255–259
BAMPS: J. Phys. G42 no. 11, (2015) 115106
PHSD: Phys. Rev. C93 no. 3, (2016) 034906



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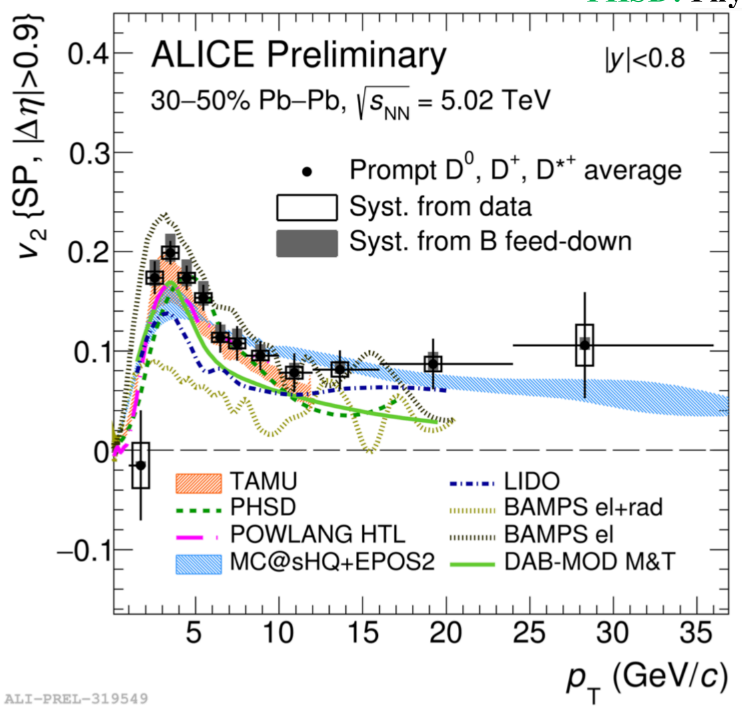

ALI-PREL-319549

- Models in which charm quarks pick up collective flow via **recombination or subsequent elastic collisions in expanding medium** better describe both v_2 and R_{AA} at low p_T (**MC@sHQ**, **PHSD**, **POWLANG**)
- Improved precision of the measurement can provide **important constraints** on models and help to extract information about the medium properties. For models describing reasonably the data
  - v_2 -> $\boxed{1.5 < 2\pi T D_s(T) < 7}$ at T_c -> $\boxed{\tau_{\mathrm{charm}} = 3\text{-}14\ \mathrm{fm}/c}$

Diffusion coefficient

Charm thermalisation time

Summary

- **D mesons results in pp collisions at $\sqrt{s} = 5.02$ TeV :**
  - Non-prompt D^0 measured for the first time in ALICE -> both prompt and non-prompt D^0 lie on the upper edge of the uncertainty of FONLL
- **D mesons results in Pb-Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV :**
  - $\mathrm{D}^0, \mathrm{D}^+, \mathrm{D}^{*+}, \mathrm{D}_s^+$: **increasing suppression** from mid-central to central collisions
  - Ratio of D_s^+ w.r.t non-strange D-meson results: **hint of enhancement in Pb-Pb w.r.t pp → coalescence and strangeness enhancement?**
  - $\mathrm{D}^0, \mathrm{D}^+, \mathrm{D}^{*+}, \mathrm{D}_s^+$ v_2 : **strong coupling of charm quark with the medium**
- **Non-prompt D^0 results in Pb-Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV will be released during QM 2019!**