Charm production: constraint to transport models and charm diffusion coefficient with ALICE

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FSP ALICE
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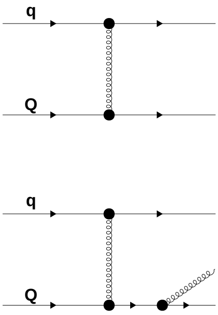
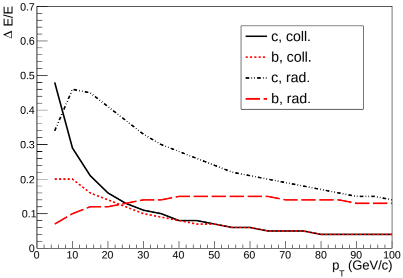
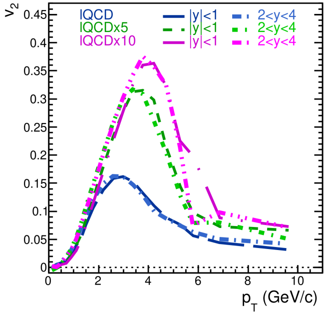
ALICE

Modeling of quark–medium interactions





Andronic et al., EPJ C (2016) 76:107



Andrea Beraudo, HP2020 talk

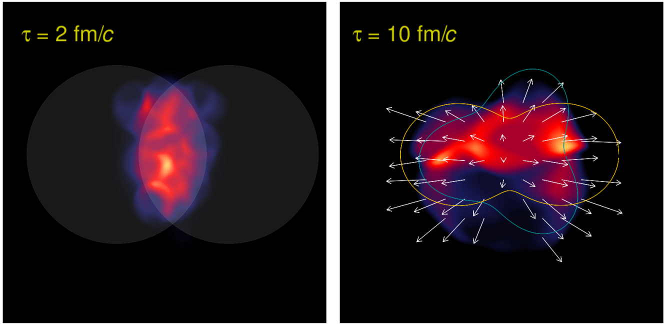
- Interaction with medium often modeled as scatterings
- Can be with quarks and gluons or effective scattering centers
- Can distinguish elastic and radiative processes

- Typically, collisional processes more important at low p_{T}
- Coherence between interactions can modify path length dependence
- Measurements at different p_{T}, masses and path lengths to disentangle

- Propagation of quarks via Boltzmann-, Fokker-Planck, or Langevin-equation
- Can transform parameters to get spatial diffusion coefficient D_{s}; $\langle \vec{r}^2 \rangle = (2d) D_s t$
- Characteristic of the medium

Heavy quarks throughout a heavy-ion collision

CERN Courier May/Jun 2021



Heavy quark mass large compared to:

- Λ_{QCD} – allows perturbative calculations
- T_{QGP} – no thermal production; production in initial hard scatterings
- Energy exchange with medium – easier modeling of interactions

Initial hard scatterings → Pre-equilibrium → QGP evolution → Freeze-out → Hadronic phase

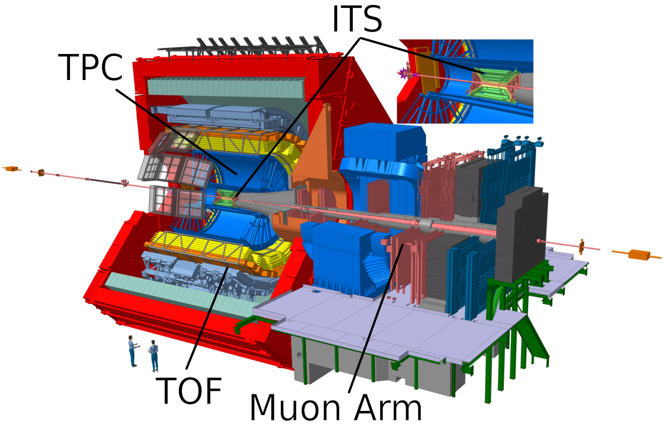
- Important measurements: nuclear modification factors R_{AA} and flow coefficients v_n
- Typically: Suppression at high p_{T} from energy loss; peak at low p_{T} from radial flow
- Affected by transport, but also nPDFs, shadowing and hadronization
- Flow coefficients: compares measurement to itself; low systematic uncertainties

Beauty results:
Stefano Politanò
14.6., 14:00

The ALICE detector

Measurements at midrapidity ($|\eta| < 0.8$):

- **I**nner **T**racking **S**ystem: Tracking and reconstruction of primary vertex and track impact parameter
- **T**ime **P**rojection **C**hamber: Tracking and particle identification via $\mathrm{d}E/\mathrm{dx}$
- **T**ime-**O**f-**F**light Detector: Particle Identification



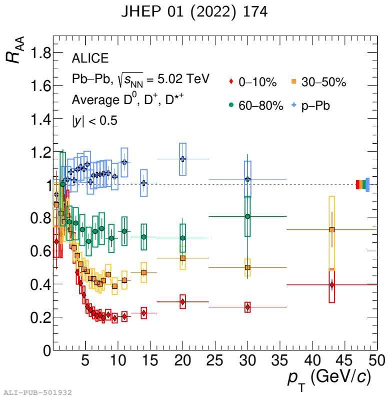
For heavy–flavour decay muon measurements ($2.5 < \eta < 4$):

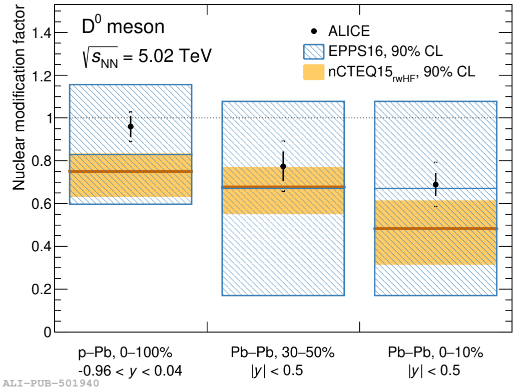
- Muon spectrometer: Triggering and tracking

Hadronic channels
$D^0 \rightarrow K^- \pi^+$
$D^+ \rightarrow K^- \pi^+ \pi^+$
$D^{*+} \rightarrow D^0 \pi^+$
$D_s^+ \rightarrow \phi \pi^+ \rightarrow K^- K^+ \pi^+$
$\Lambda_c^+ \rightarrow pK_s^0 \rightarrow p \pi^+ \pi^-$

Semileptonic channels:
$c, b \rightarrow X + \mu$

Nuclear modification factor of D mesons

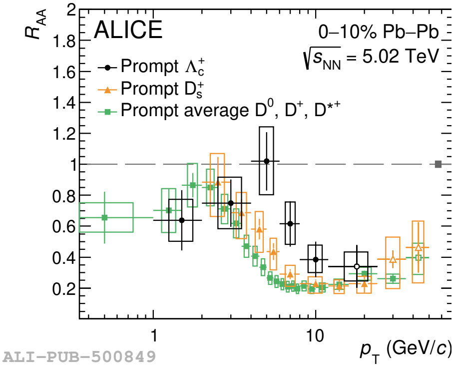


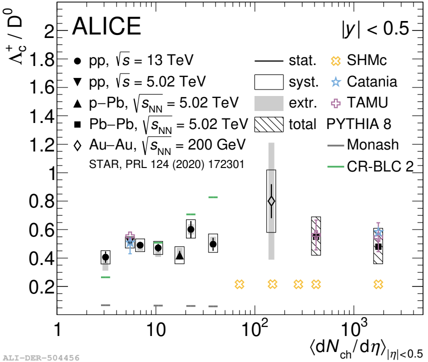


- R_{AA} increases for more central collisions
- D^0 mesons measured down to $p_T = 0$ – can integrate without model uncertainty
- Compared to two sets of nPDFs with shadowing effects included
- R_{AA} can also change due to different charm quark distribution among hadrons

Investigating charm hadrochemistry

Λ_c^+: arXiv:2112.08156; D_s^+: Phys. Lett. B 827 (2022) 136986



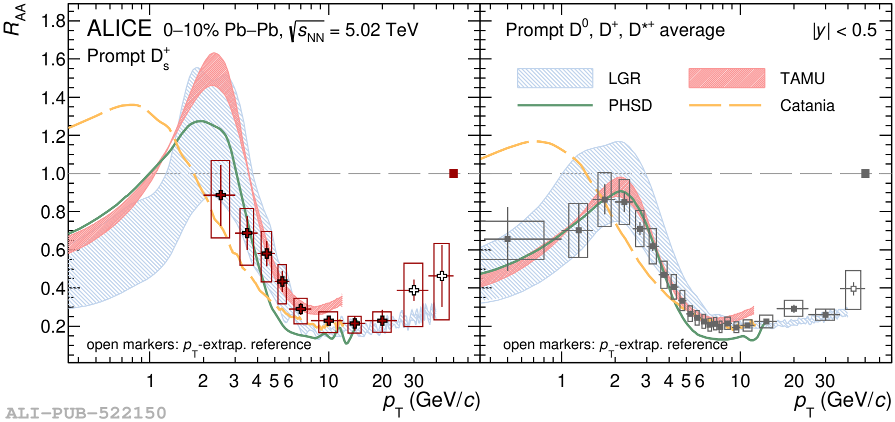


- Indication of mass ordering of R_{AA} peak, possibly due to participation in flow or hadronization mechanisms
- Some extrapolation needed for total yield of Λ_c^+
- Baryon fraction larger than Monash tunes; but no strong dependence on system
- Thermalized Λ_c^+ yield a factor 2 below data

Jinjoo Seo, 14.6., 12:10

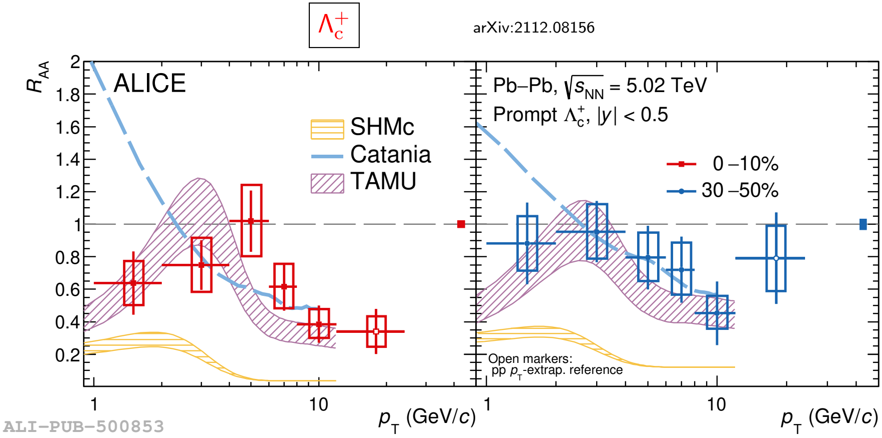
D_s^+ measurement compared with models

D_s^+ Phys. Lett. B 827 (2022) 136986



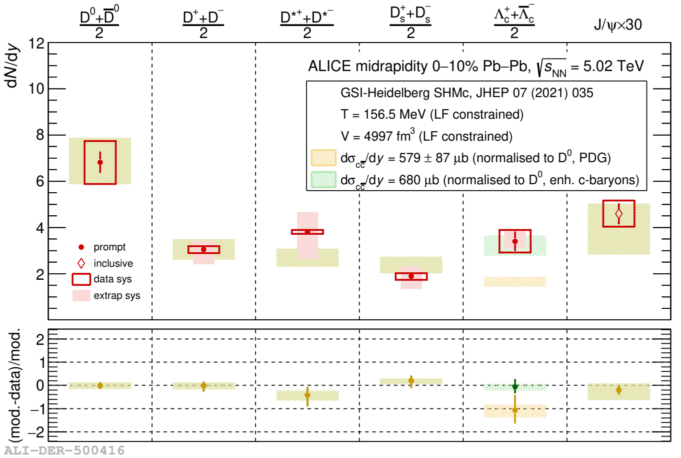
- Fair description of the D_s^+ R_{AA} by models including enhanced strange quark content of the QGP and coalescence effects

Λ_c^+ measurement compared with models



- Reasonable description of the Λ_c^+ by TAMU
- Catania off at low p_T, assumes QGP also in pp
- SHMc (thermal+pp-like) yield underpredicts yield
- Models include coalescence effects

Comparison to thermal model



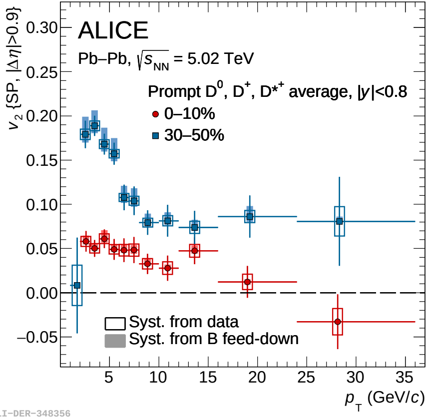
- Expected charmed hadron yields assuming statistical hadronization
- Good agreement with measurements, apart from Λ_c^+
- Would be explained by additional charmed baryon resonances

Flow coefficients of non strange D mesons

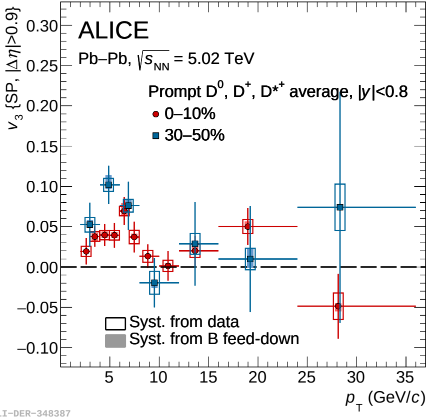
v_2

PLB 813 (2021) 136054

v_3



ALI-DER-348356



ALI-DER-348387

- Substantial elliptic flow coefficient for non-strange D mesons
- Initial state density fluctuations impart v_3 in D mesons

Elliptic flow of strange charmed hadrons

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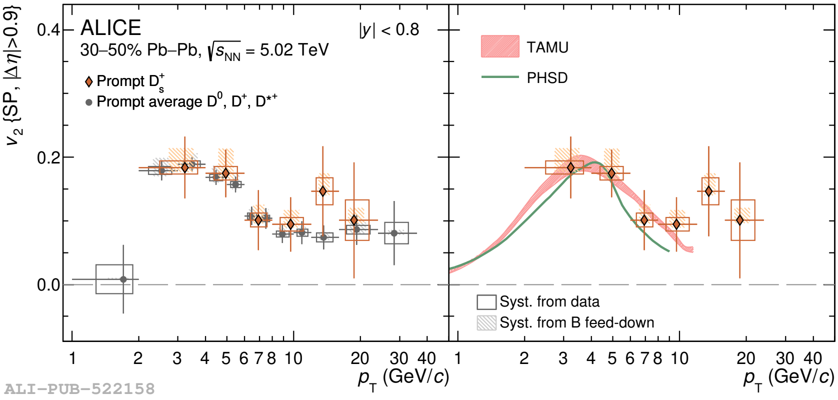
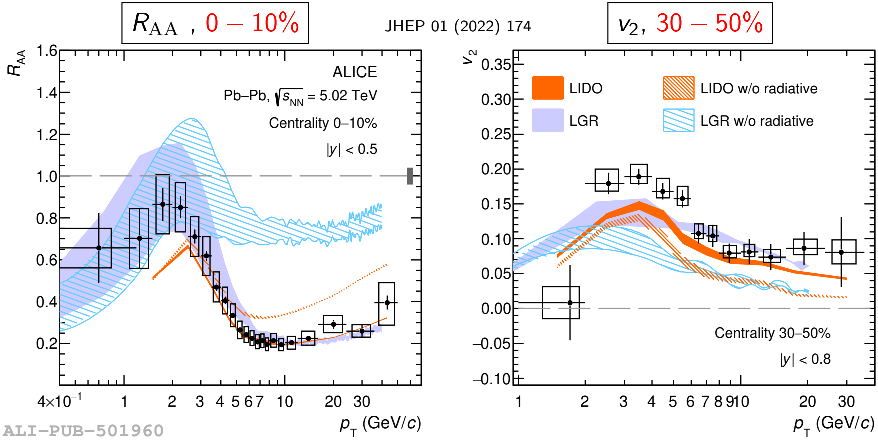


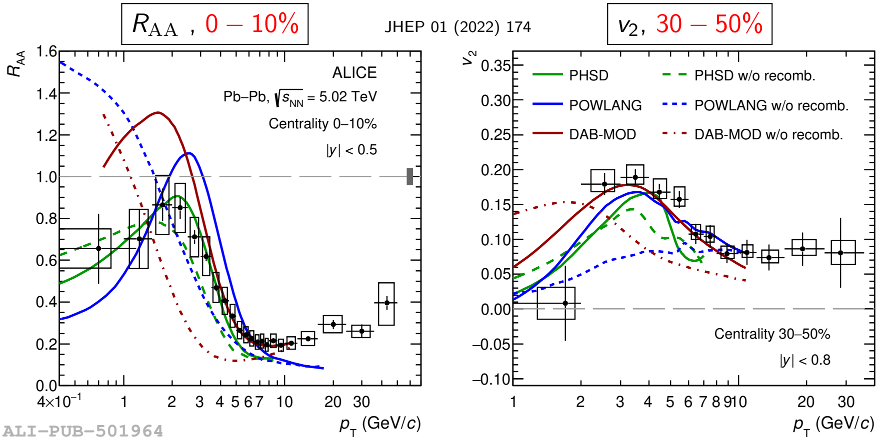
- Significant elliptic flow of strange charmed hadrons; 6.4σ for $2 \leq p_T \leq 8$ GeV/c
- Can give additional constraints for hadronization mechanism
- No difference to v_2 of non-strange D mesons observed
- Good model description from models including coalescence effects

Contribution of radiative energy loss



- Comparison of models with radiative interactions turned off
- Particularly important for description at high p_T
- Models without radiative processes typically in limited p_T-range

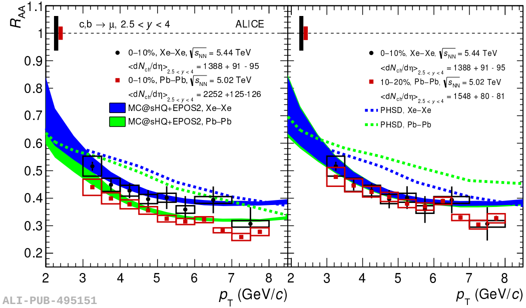
Contribution of recombination

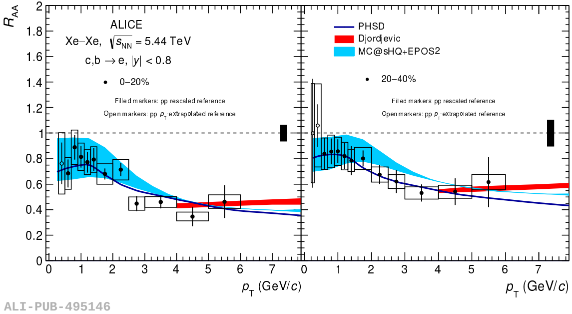


- Recombination of quarks in the medium to form hadrons
- With only fragmentation, model description of data deteriorates

Path length dependence from Xe–Xe measurements

$\mu^{\pm}$ PLB 819 (2021) 136637 $e^{\pm}$





- Xe–Xe: different relation of system size, anisotropy and particle production compared to Pb–Pb
- Information about interaction scaling with path length from interference of radiative interactions
- Different scaling of models; but no simple conclusion on path length dependence
- PHSD does not include radiative interactions

Evaluating model description of D meson measurements

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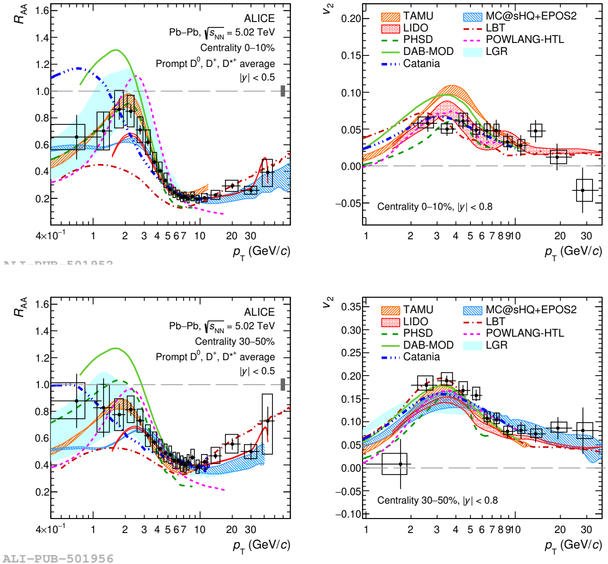
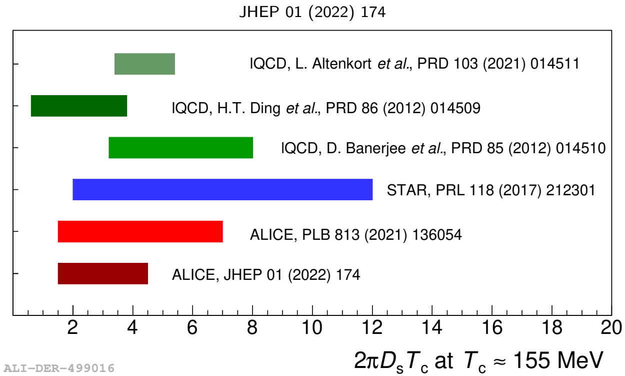


- D meson measurements: small uncertainties, large p_{T} range results for R_{AA}, v_2 and v_3
- Different p_{T} reach: Compare for $p_{\mathrm{T}} < 8$ GeV/c
- Choose models with $\chi^2/\mathrm{ndf} < 5$ for R_{AA} and $\chi^2/\mathrm{ndf} < 2$ for the v_2
- TAMU, MC@sHQ, LIDO, LGR, and Catania provide reasonable description
- Includes experimental and model uncertainties

Conclusion

- Models with reasonable description have $1.5 < 2\pi D_s T_c < 4.5$ – corresponds to relaxation time $\tau_c \approx 3 - 8\ \mathrm{fm}/c$
- Models need radiative and collisional interactions to describe data over large p_T range
- Recombination effects important in the charm sector
- Measurements with high accuracy over large p_T range and for different hadron species give strong constraints to models



Appendix

Yield extraction via invariant mass

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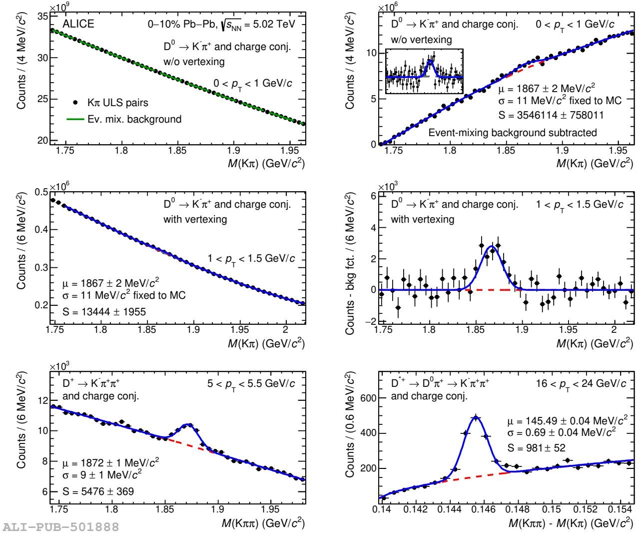

D Meson species R_{AA} comparison

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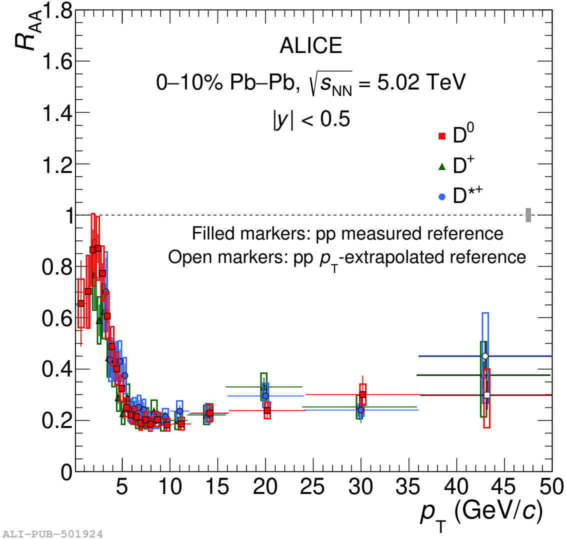

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