

**D MESONS SUPPRESSION IN Pb-Pb
COLLISIONS AT $\sqrt{s_{NN}} = 2.76$ TeV
MEASURED BY ALICE**

ZAIDA CONESA DEL VALLE, CERN
FOR THE ALICE COLLABORATION

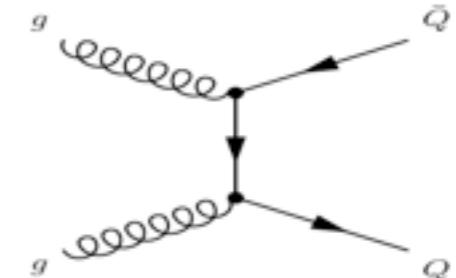
- HARD PROBES 2012 -

WHY MEASURING OPEN CHARM ?

- * Production in nucleon-nucleon collisions $\Rightarrow \Rightarrow$ p-p data
 - ▶ Production time $\tau_p \sim 0.05 - 0.15$ fm/c
 - ▶ Predominant processes: **gluon fusion** and q-qbar annihilation
 - \Rightarrow **Tool to test pQCD calculations**

- * Nuclear environment influence: p-A collisions $\Rightarrow \Rightarrow$ p-Pb data coming in 2012
 - ▶ **Shadowing** (PDF modifications in nuclei)
 - ▶ **Gluon saturation**
 - \Rightarrow **Tool to study nPDFs**

- * Effects in a **QGP**: A-B collisions $\Rightarrow \Rightarrow$ Pb-Pb data in 2010 + 2011
 - ▶ **Thermalisation** in the QGP (low pt)
 - Medium temperature \Rightarrow vs centrality, vs p_t , vs y , flow
 - ▶ **Energy loss** in the QGP (high pt)
 - Medium density and size \Rightarrow vs centrality, vs p_t , vs y
 - Color charge (Casimir factor) : $\Delta E_{u,d,s} < \Delta E_g$ \Rightarrow compare to light hadrons
 - Parton mass (dead cone effect) : $\Delta E_b < \Delta E_c < \dots$ \Rightarrow compare to B production
 - \Rightarrow **Probe of the QCD medium**



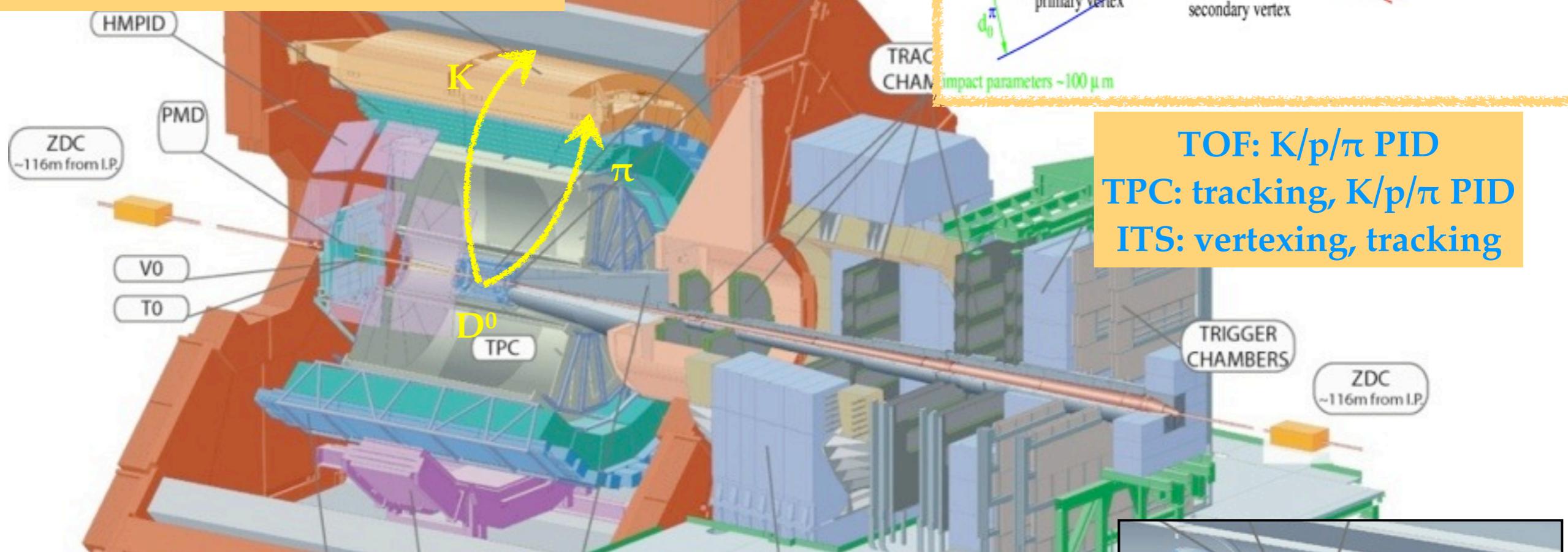
[Dokshitzer and Kharzeev, PLB 519 (2001) 199. Armesto, Salgado, Wiedemann, PRD 69 (2004) 114003. Djordjevic, Gyulassy, Horowitz, Wicks, NPA 783 (2007) 493...]

OUTLINE

- ✓ Introduction: Why measuring open charm ?
- * Open charm measurements in proton-proton interactions at $\sqrt{s} = 7 \text{ TeV}$ and 2.76 TeV
 - ▶ Reference for interpreting the Pb-Pb results [ALICE Coll. JHEP01(2012)128]
[ALICE Coll. arXiv: 1205.4007 (2012)]
- * D mesons in Pb-Pb collisions at $\sqrt{s_{\text{NN}}} = 2.76 \text{ TeV}$
 - ▶ Signal, corrections, systematics
 - ▶ Nuclear modification factor of prompt D mesons : p_t and centrality dependence
 - ▶ Comparison with models and other measurements [ALICE Coll. arXiv:1203.2160 (2012)]
- * Prospects and Conclusions

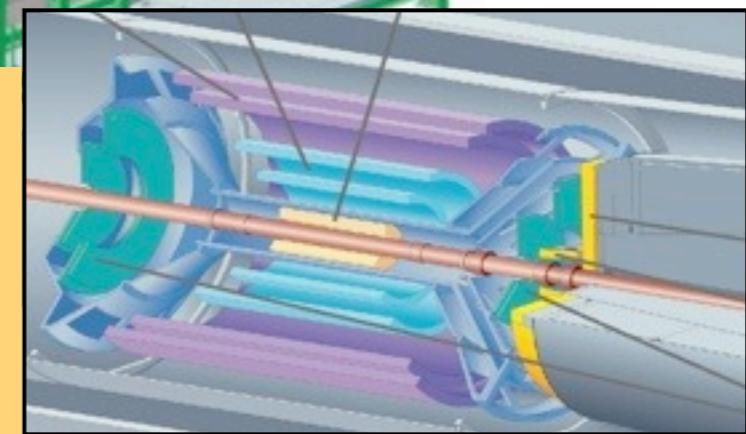
D MESONS AT $|Y|<0.5$

- * $D^0 \rightarrow K \pi (K \pi \pi \pi)$, $c\tau \sim 122.9 \mu\text{m}$
- * $D^+ \rightarrow K \pi \pi$, $c\tau \sim 311.8 \mu\text{m}$
- * $D^{*+} \rightarrow D^0 \pi$
- * $D_s \rightarrow K K \pi$, $c\tau \sim 149.9 \mu\text{m}$
- * $\Lambda_c \rightarrow K p \pi, K^0_s p$ $c\tau \sim 59.9 \mu\text{m}$



TOF: K/p/π PID
 TPC: tracking, K/p/π PID
 ITS: vertexing, tracking

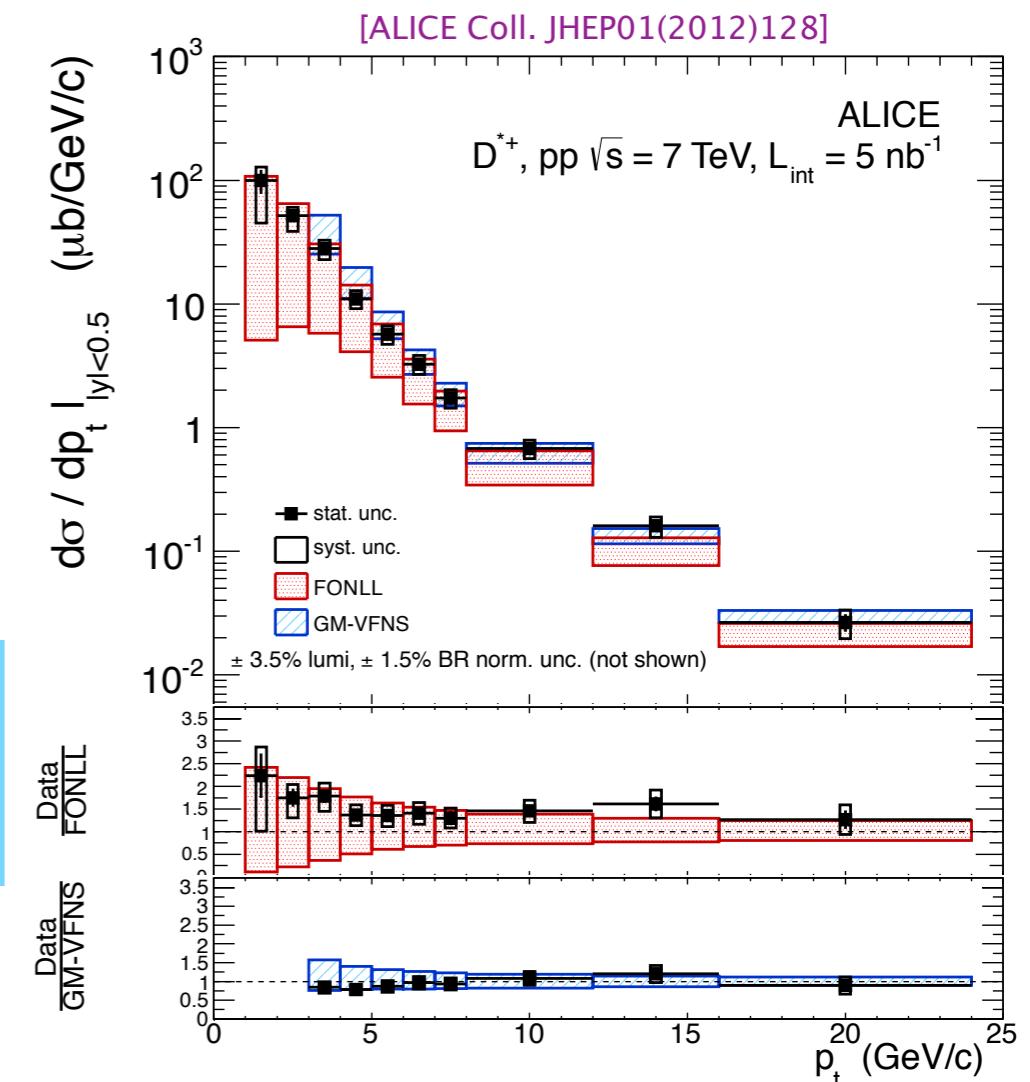
- * Selection strategy, topological cuts: displaced vertices
 - ▶ Impact parameter of the tracks,
 - ▶ Angle between the meson flight line and the particle momentum.
- * Particle identification: TPC + TOF (K identification)



MEASUREMENTS IN PP COLLISIONS

- * 2010 data pp collisions at $\sqrt{s} = 7 \text{ TeV}$, $L_{\text{int}} = 5 \text{ nb}^{-1}$
 - ▶ p_t -differential production cross section of D^0 , D^+ , D^{*+} down to 1 GeV/c and up to 24 GeV/c described by pQCD calculations (FONLL, GM-VFNS)
 - ▶ p_t -differential production cross section of D_s^+
 - ▶ Λ_c studies ongoing in two decay channels...
 - ▶ D to hadron correlations

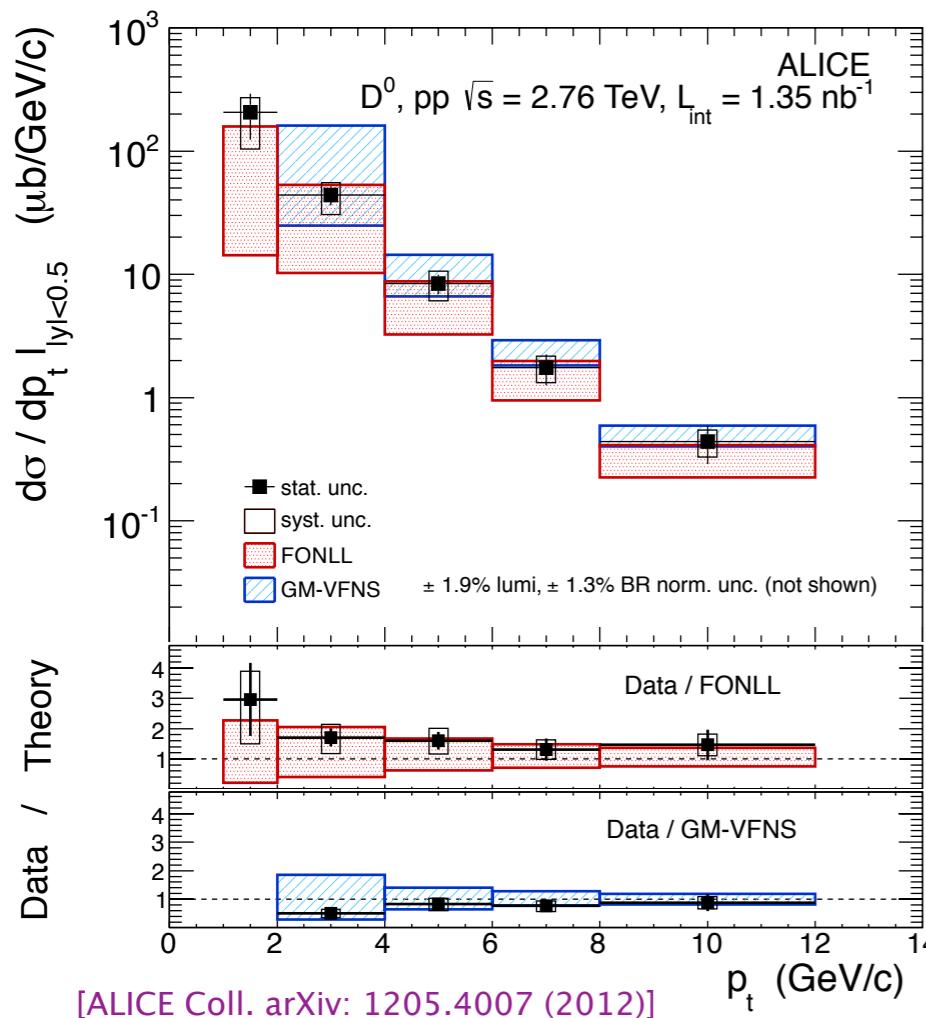
see G. Innocenti's poster
 see P. Pagano's poster
 see S. Bjelogrlic's poster



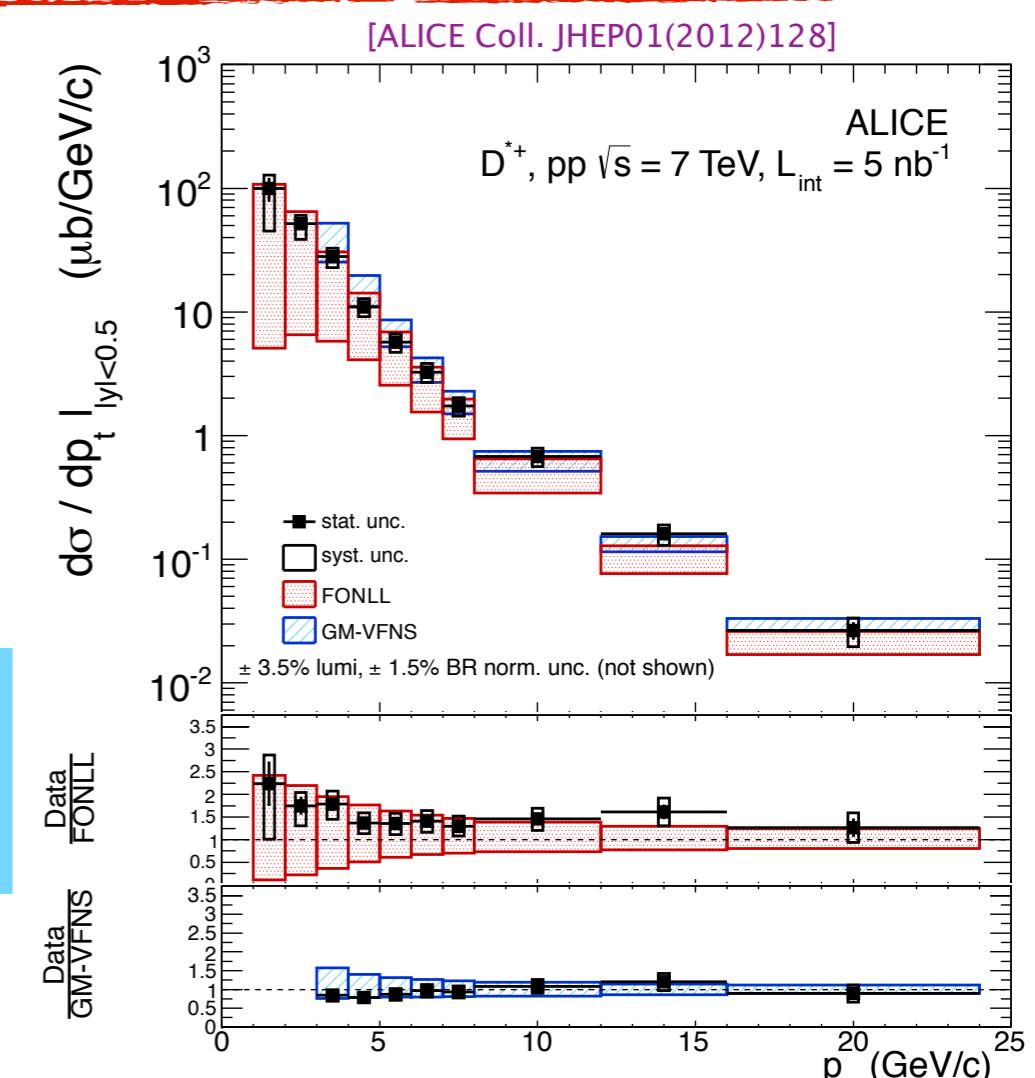
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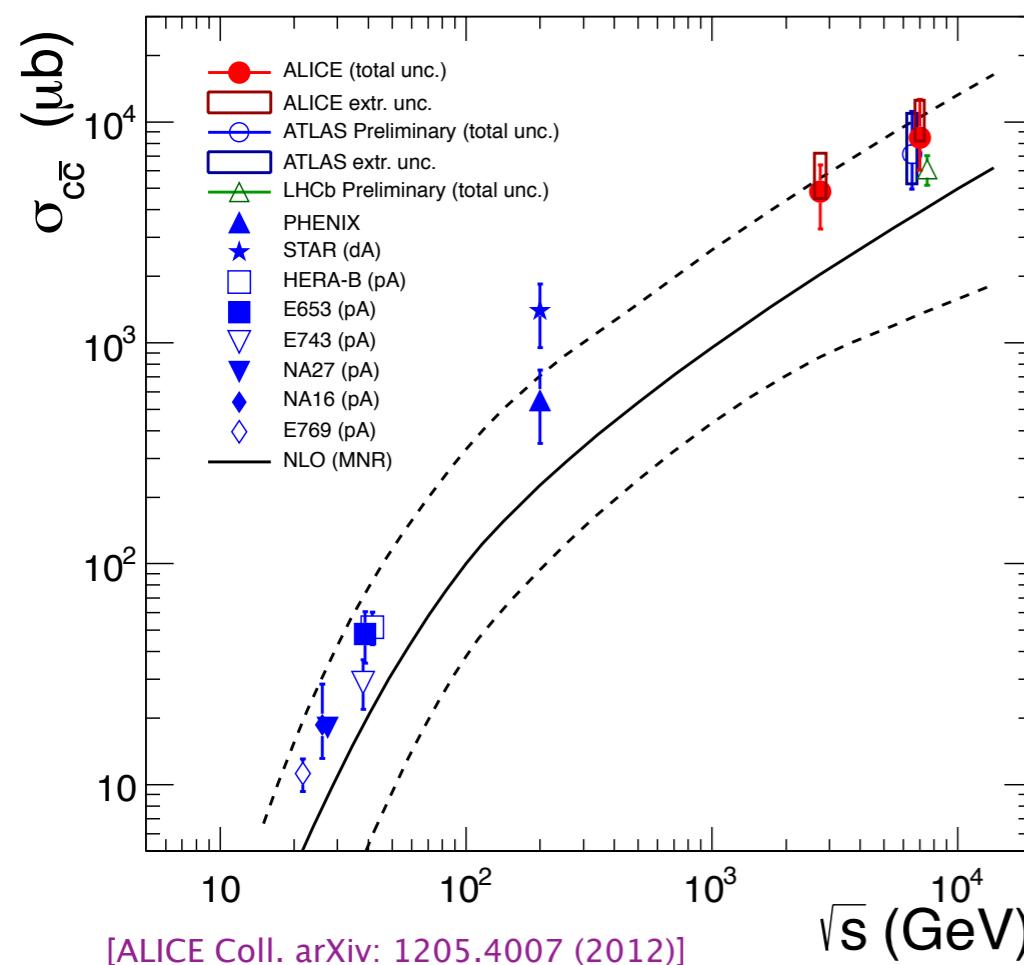
* 2011 data pp collisions at $\sqrt{s} = 2.76 \text{ TeV}$, $L_{\text{int}} = 1.35 \text{ nb}^{-1}$

- ▶ p_t -differential production cross section of D^0 (D^+ , D^{*+}) down to 1 (2) GeV/c and up to 12 GeV/c
- ▶ Total charm nucleon-nucleon cross section

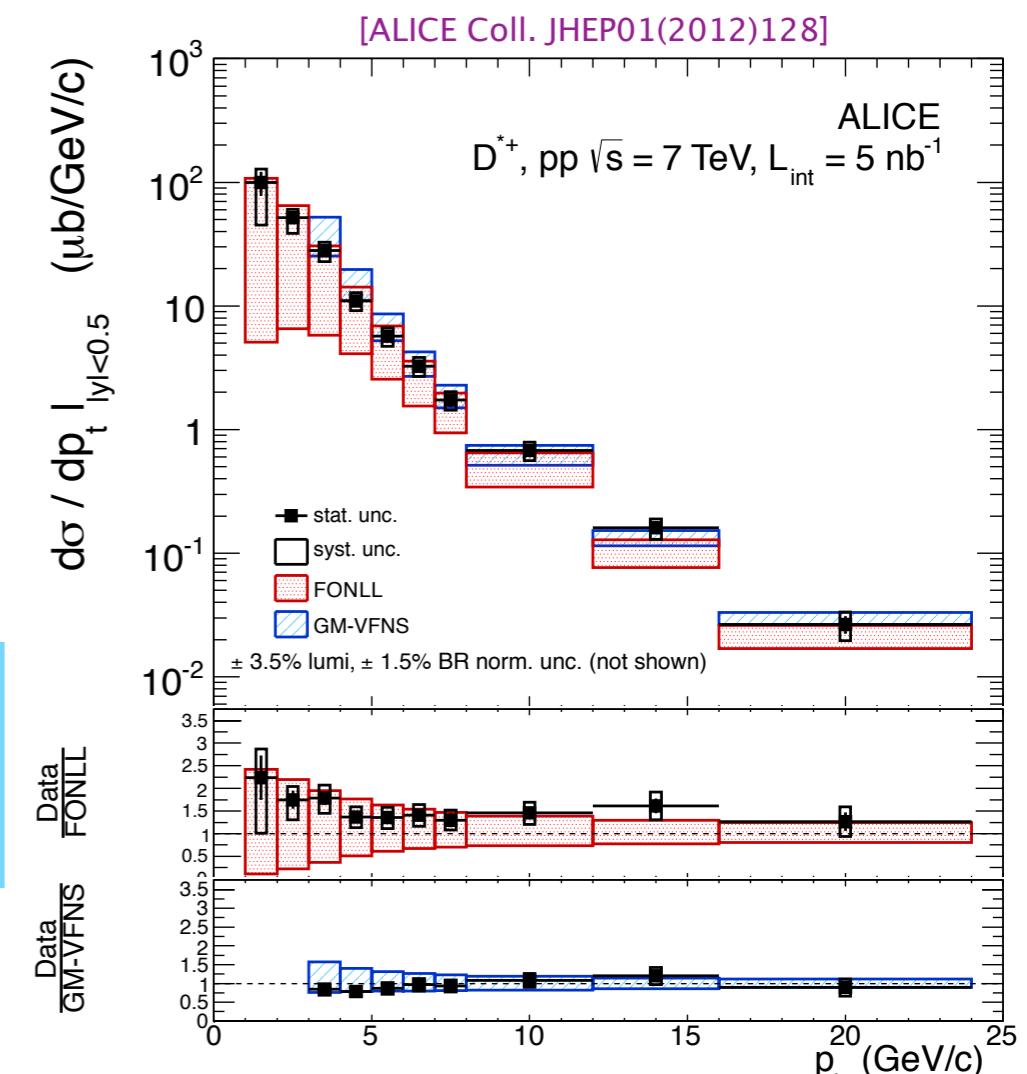
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THE PROTON-PROTON REFERENCE

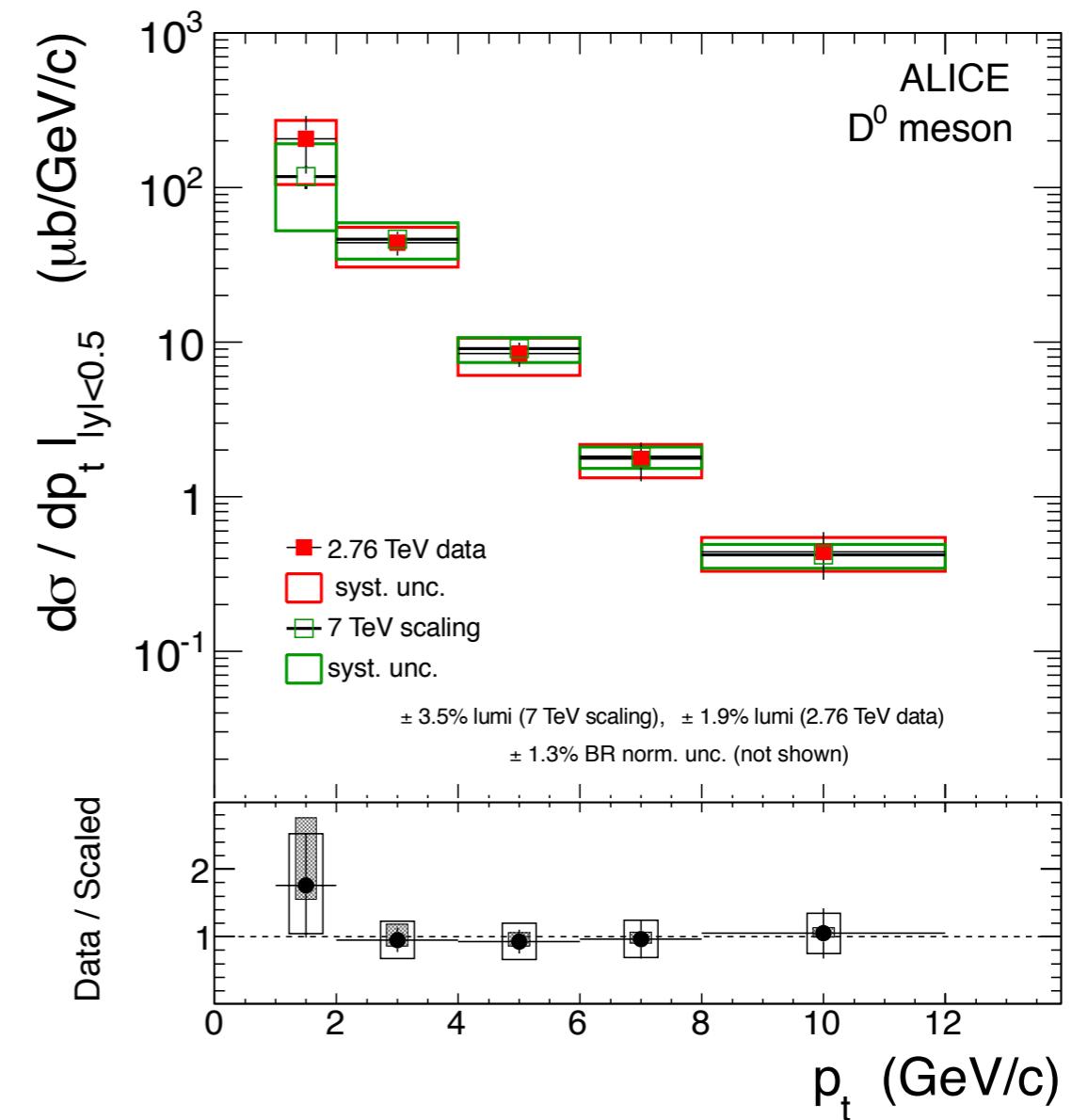
[ALICE Coll. JHEP01(2012)128]
 [R. Averbeck et al, arXiv:1107.3243 [hep-ph] (2011)]
 [ALICE Coll. arXiv: 1205.4007 (2012)]

- * Scaling 7 TeV measurements to 2.76 TeV with pQCD.

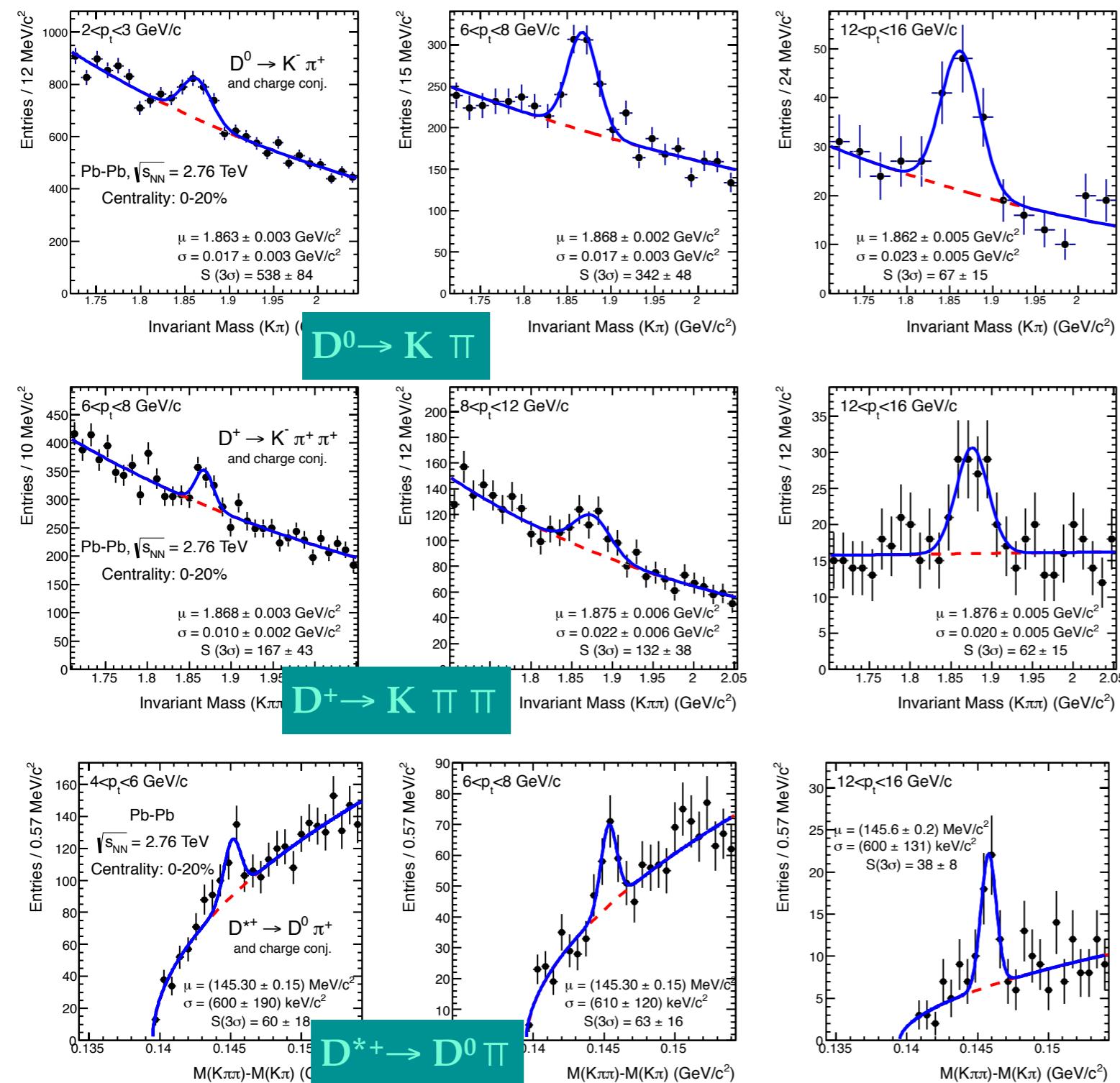
- ▶ The scaling factor was the ratio of the **FONLL predictions** at 7 TeV and 2.76 TeV.
- ▶ The scaling uncertainties were determined varying the calculation parameters (μ_F, μ_R, m_c). They range within $^{+25}_{-10}\%$ for the 2-4 GeV/c p_t bin, to $^{+8}_{-5}\%$ for 8-12 GeV/c.

- * The 7 TeV data scaling agrees with the measurement at 2.76 TeV within 5-10% in most p_t bins.

- ⇒ Validated the scaling procedure !
- ⇒ Good reference to interpret Pb-Pb data.



SIGNAL WITH 2010 Pb-Pb DATA



D⁰, D⁺ and D^{*+} signals in p_t bins for 0-20% CC

[ALICE Coll. arXiv:1203.2160 (2012)]

* 2010 run with Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV using MB trigger

- MB trigger : the innermost layers of the ITS and the VO scintillators
- Centrality : fit of the VO scintillators amplitude with a Glauber-MC model

$$L_{\text{int}} = 2.12 \pm 0.07 \mu\text{b}^{-1}$$

* D⁰, D⁺ and D^{*+} signals observed

- 3M events in 0-20% CC
D⁰ signal down to p_t 2 GeV/c
D⁰, D⁺ & D^{*+} up to p_t 16 GeV/c
- 6M events in 40-80% CC
D⁰ signal down to p_t 2 GeV/c
D⁰ & D^{*+} up to p_t 16 GeV/c

see D.Caffarri's poster

CORRECTIONS

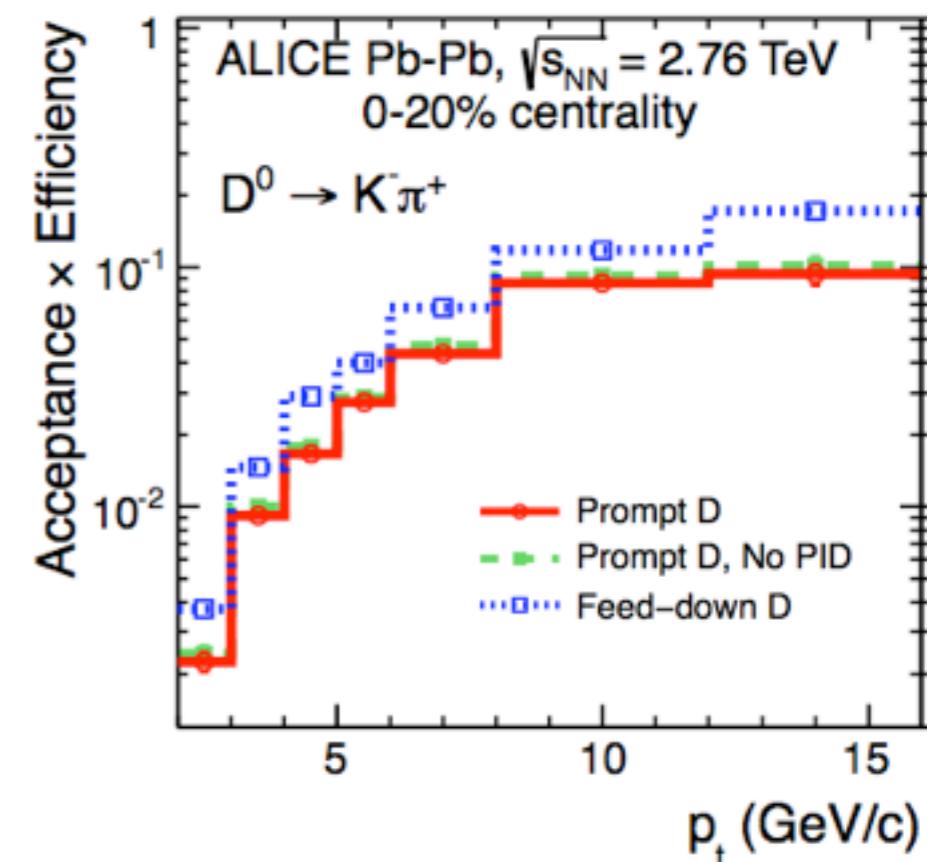
$$\frac{dN^{D^+}}{dp_t} \Big|_{|y|<0.5} = \frac{1}{\Delta y \Delta p_t} \frac{f_{\text{prompt}}(p_t) \cdot \frac{1}{2} N^{D^\pm \text{ raw}}(p_t) \Big|_{|y|<y_{\text{fid}}}}{(\text{Acc} \times \epsilon)_{\text{prompt}}(p_t) \cdot \text{BR} \cdot N_{\text{evt}}}$$

* Acceptance x Efficiency

- ▶ HIJING v1.36 + PYTHIA v6.4.21 (charm enriched) detector and LHC conditions description run-by-run
- ▶ Small centrality dependence of 5-10%
- ▶ PID selection criteria keeps ~95% of the signal

* Fraction of prompt D

- ▶ Evaluated using pQCD B FONLL calculations, and the EvtGen B→D decay kinematics
- ▶ Amounts within 5% and 15%, depending on the p_t range

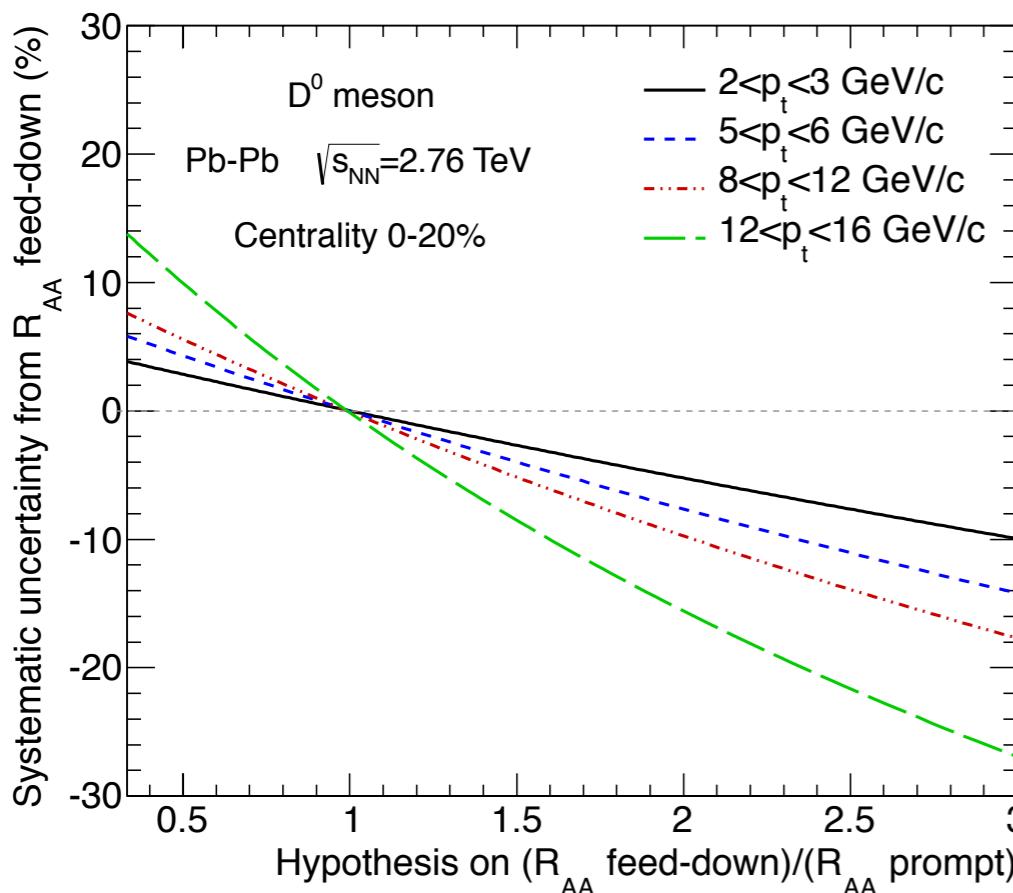


[FONLL: M. Cacciari, et al, JHEP 9805 (1998) 007, JHEP 0103 (2001) 006, CERN-PH- TH/2011-227 (2011).]
[EvtGen:D. J. Lange, Nucl. Instrum. Methods A462 (2001) 152.]

[ALICE Coll. arXiv:1203.2160 (2012)]

SYSTEMATICS

[ALICE Coll. arXiv:1203.2160 (2012)]



- * Yield extraction 5% to 20%
- * Tracking efficiency 5% per track
 - ▶ Finding, prolongation and selection criteria
- * Topological selection efficiency 10% to 15%
- * PID selection $^{+15}_{-5}\%$ at low p_t 5% for $p_t > 6 \text{ GeV}/c$
- * MC p_t shape < 5%
- * FONLL feed-down correction
 - ▶ Calculation uncertainties
 - ▶ Consider the ratio of prompt/feed-down predictions instead of the B cross section
- * Hypothesis : $0.3 < R_{AA} \text{ feed-down} / R_{AA} \text{ prompt} < 3$

$$\begin{aligned}
 f_{\text{prompt}} &= 1 - (N^D \text{ feed-down raw} / N^D \text{ raw}) = \\
 &= 1 - \langle T_{AA} \rangle \cdot \left(\frac{d^2 \sigma}{dy dp_t} \right)_{\text{feed-down}}^{\text{FONLL}} \cdot R_{AA}^{\text{feed-down}} \cdot \frac{(Acc \times \epsilon)_{\text{feed-down}} \cdot \Delta y \Delta p_t \cdot BR \cdot N_{\text{evt}}}{N^D \text{ raw} / 2}
 \end{aligned}$$

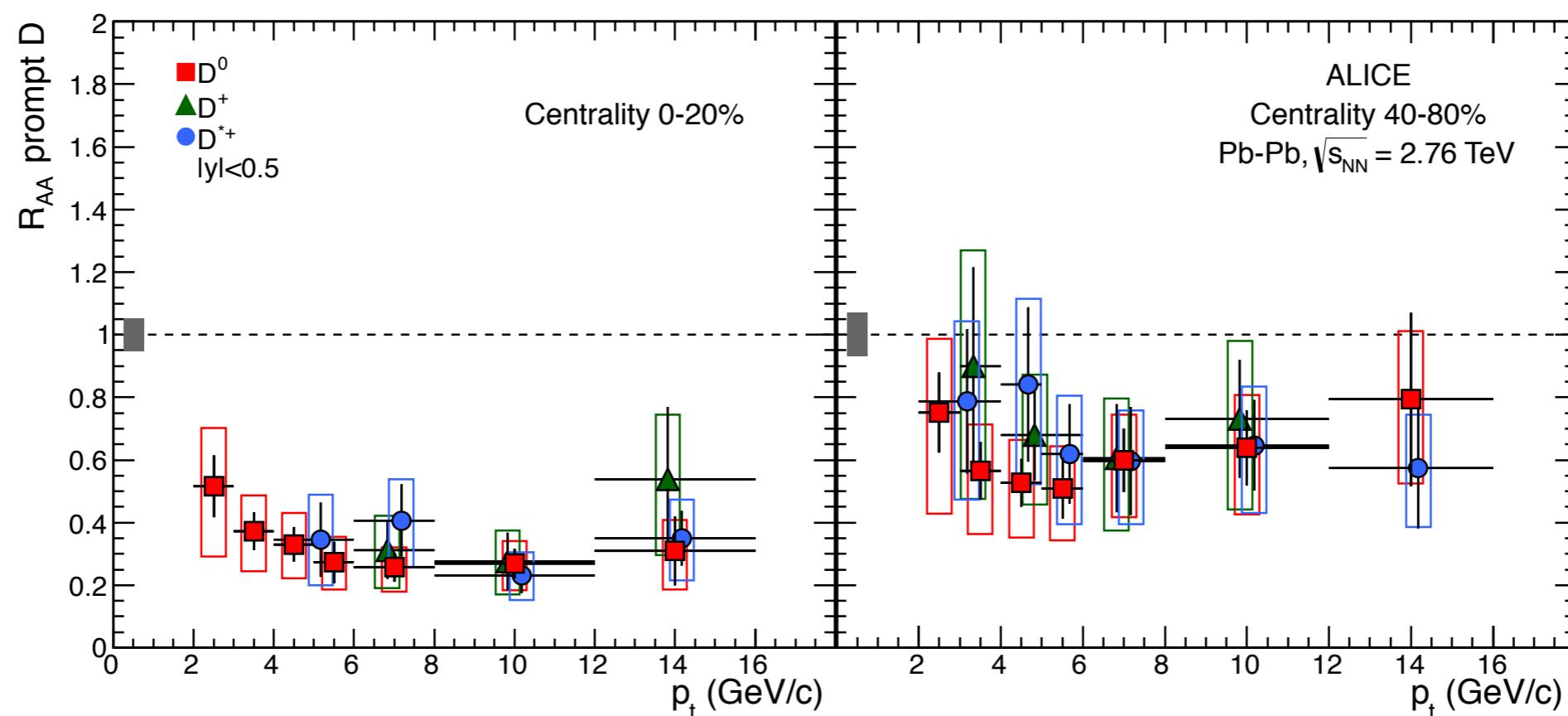
D MESON R_{AA} VS P_T

- * Nuclear modification factor
 - ▶ $d\sigma_{pp}/dp_t$ from scaling of 7 TeV data measurements
 - ▶ dN_{AA}/dp_t from 2010 PbPb data
 - ▶ $\langle T_{AA} \rangle$ evaluated via Glauber-MC
- * D⁰, D⁺, D^{*+} R_{AA} are compatible within statistical uncertainties
- * D meson R_{AA} (0-20%) is suppressed by a factor of 3-4 for $p_t > 5$ GeV/c
- * D meson R_{AA} (40-80%) is suppressed by a factor of 1-3 for $p_t > 5$ GeV/c

$$R_{AA} = \frac{1}{\langle T_{AA} \rangle} \frac{dN_{AA}/dp_t}{d\sigma_{pp}/dp_t}$$

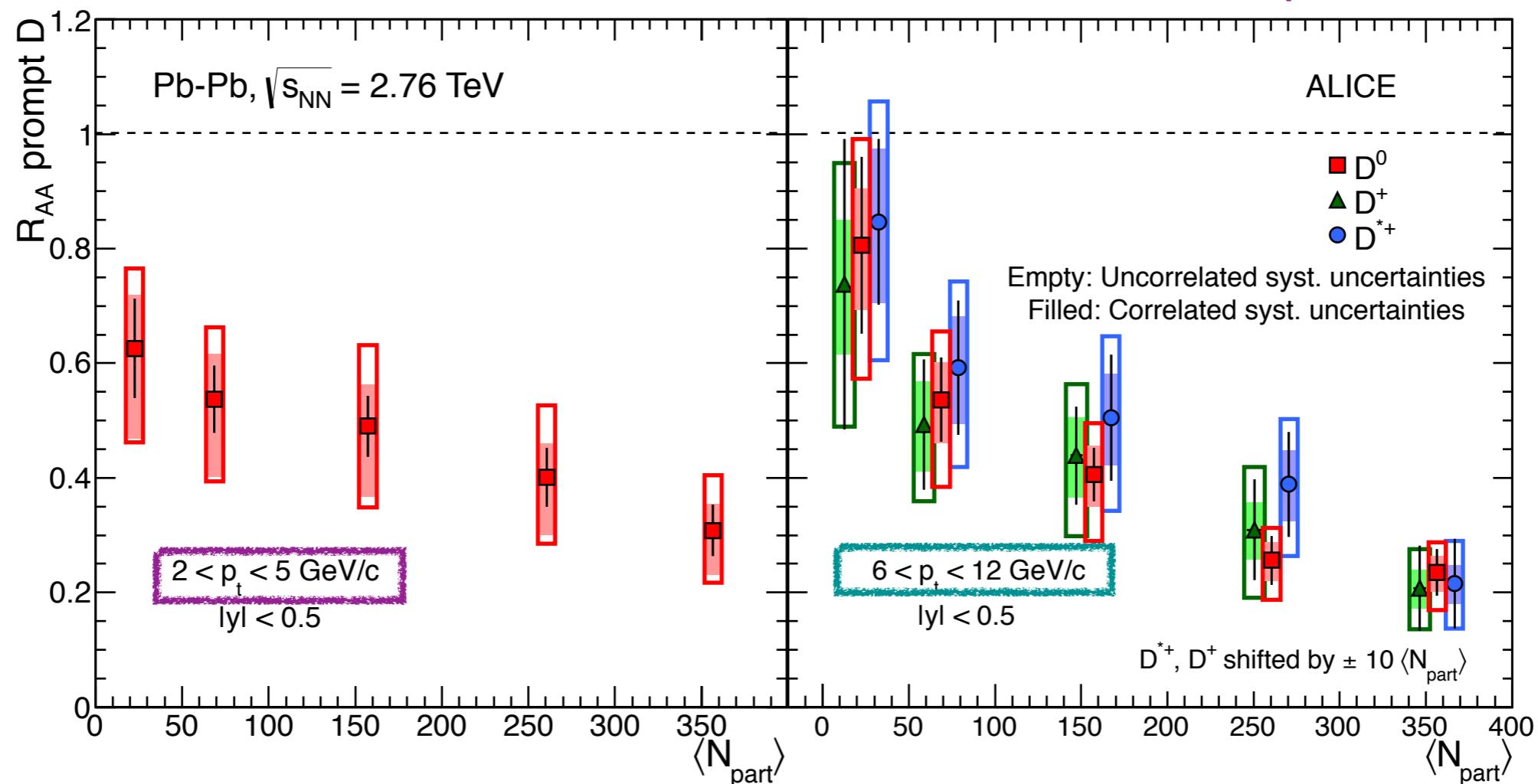
[ALICE Coll. arXiv: 1205.4007 (2012)]

[ALICE Coll. arXiv:1203.2160 (2012)]



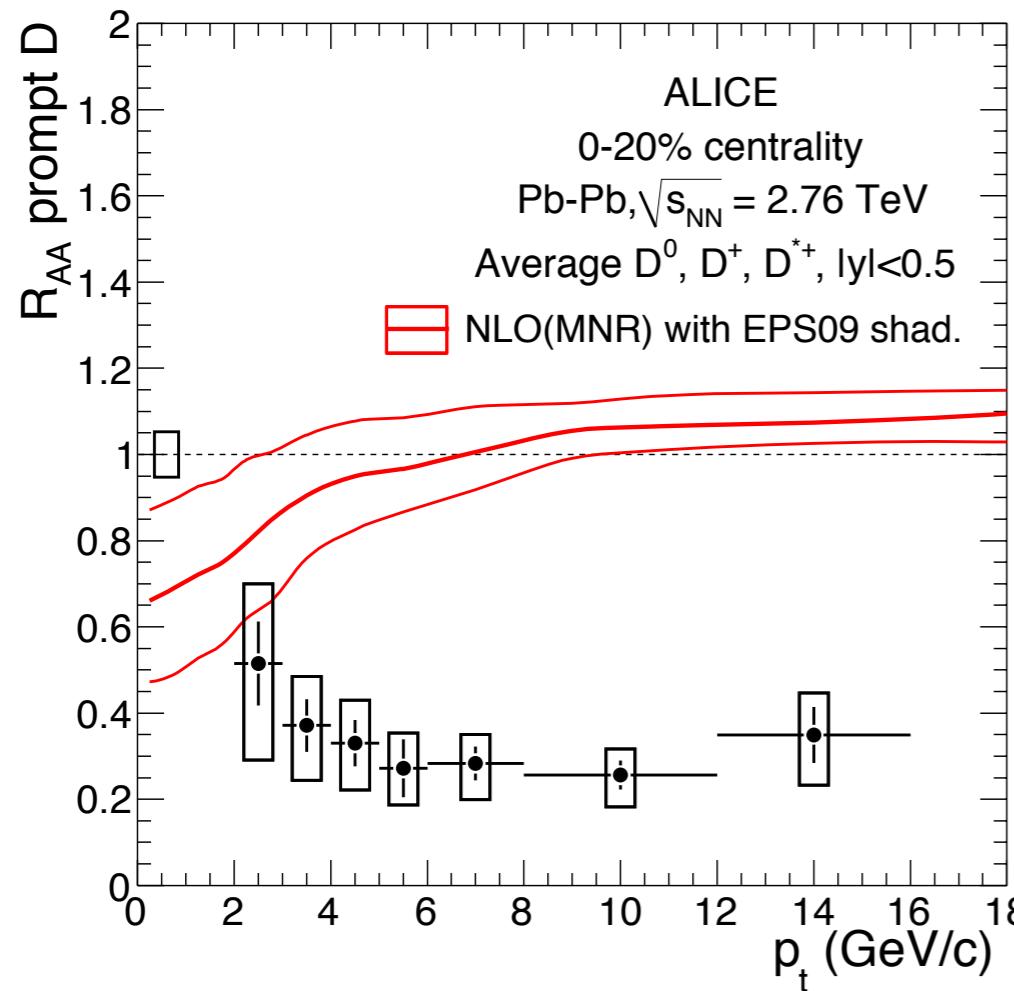
R_{AA} VS CENTRALITY

[ALICE Coll. arXiv:1203.2160 (2012)]



- * Centrality represented by $\langle N_{\text{part}} \rangle$
- * Analysis performed in wide p_t and thin centrality intervals
- * At $6 < p_t < 12 \text{ GeV}/c$, R_{AA} suppression increases with centrality
- * At lower p_t , the centrality dependence is less pronounced

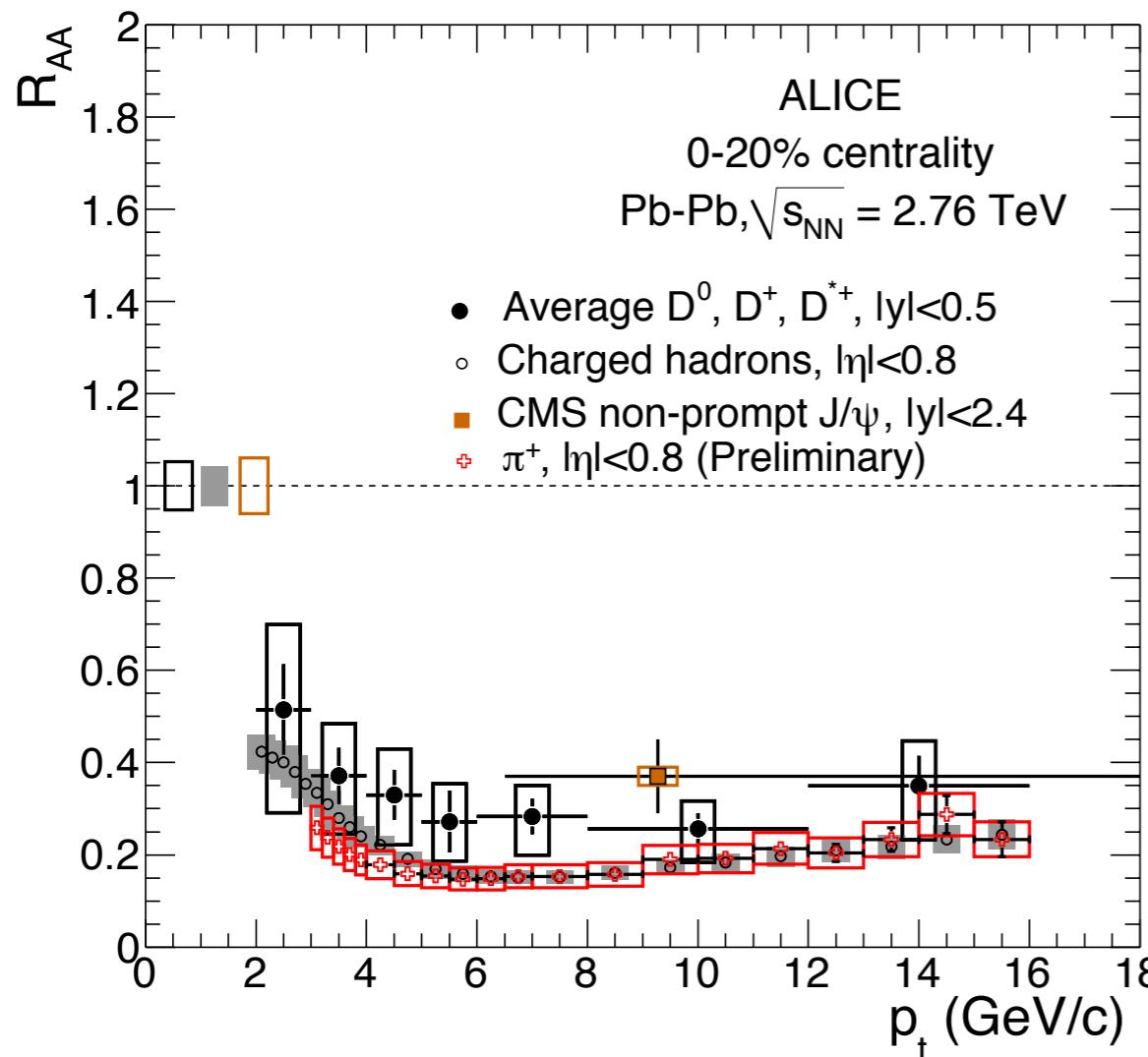
R_{AA} VS P_T DISCUSSION I



[ALICE Coll. arXiv:1203.2160 (2012)]

- * Average D meson R_{AA} using the statistical uncertainties as weights
- * Shadowing alone can not explain the D meson suppression in the 0-20% CC for p_T > 4 GeV/c
⇒ likely a final state effect

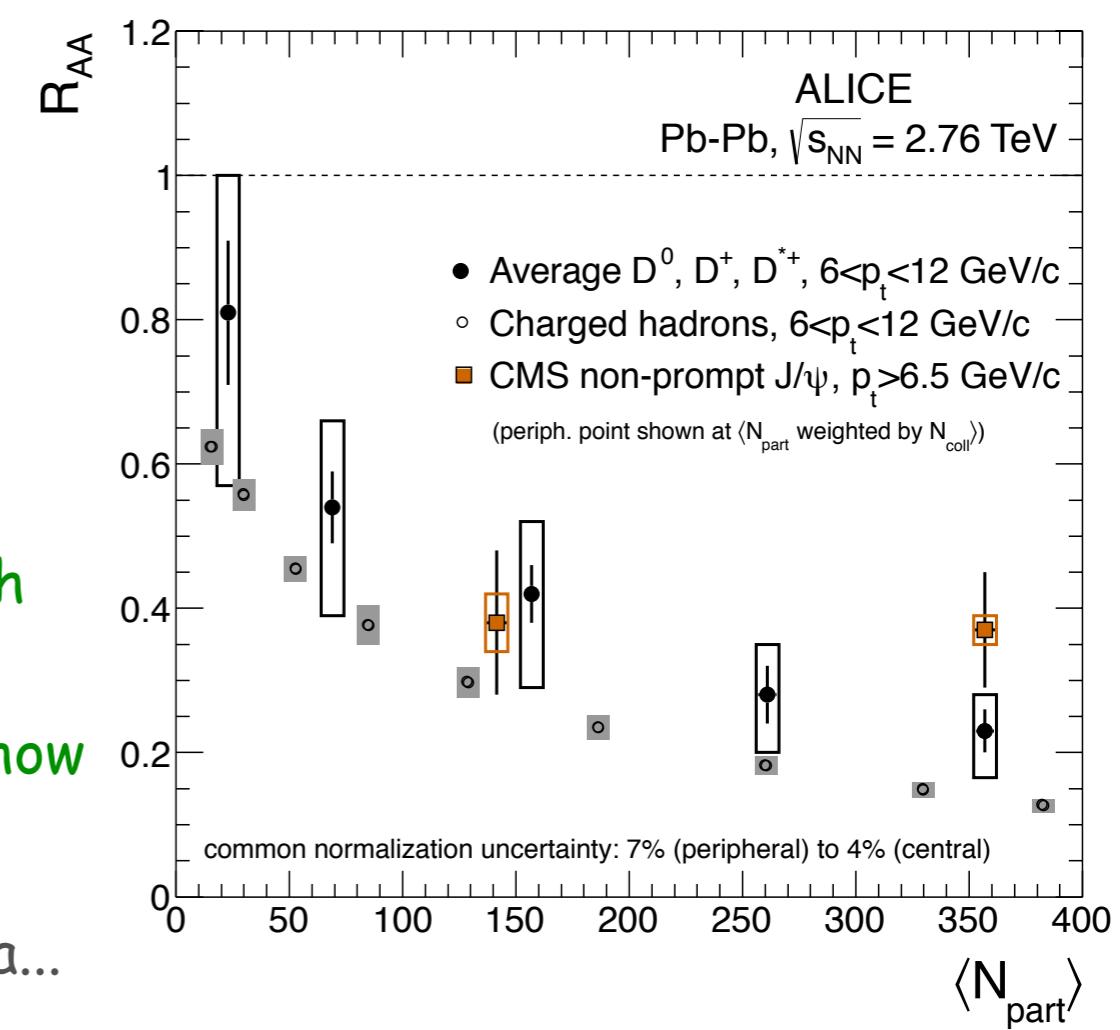
R_{AA} VS P_T DISCUSSION I



- * Similar R_{AA} than charged hadrons and π[±], though the central values are systematically larger...
- * Non-prompt J/ψ ($B \rightarrow J/\psi$) measured by CMS show less suppression than N_{ch}
- ⌚ Need more precise measurements and p-Pb data...

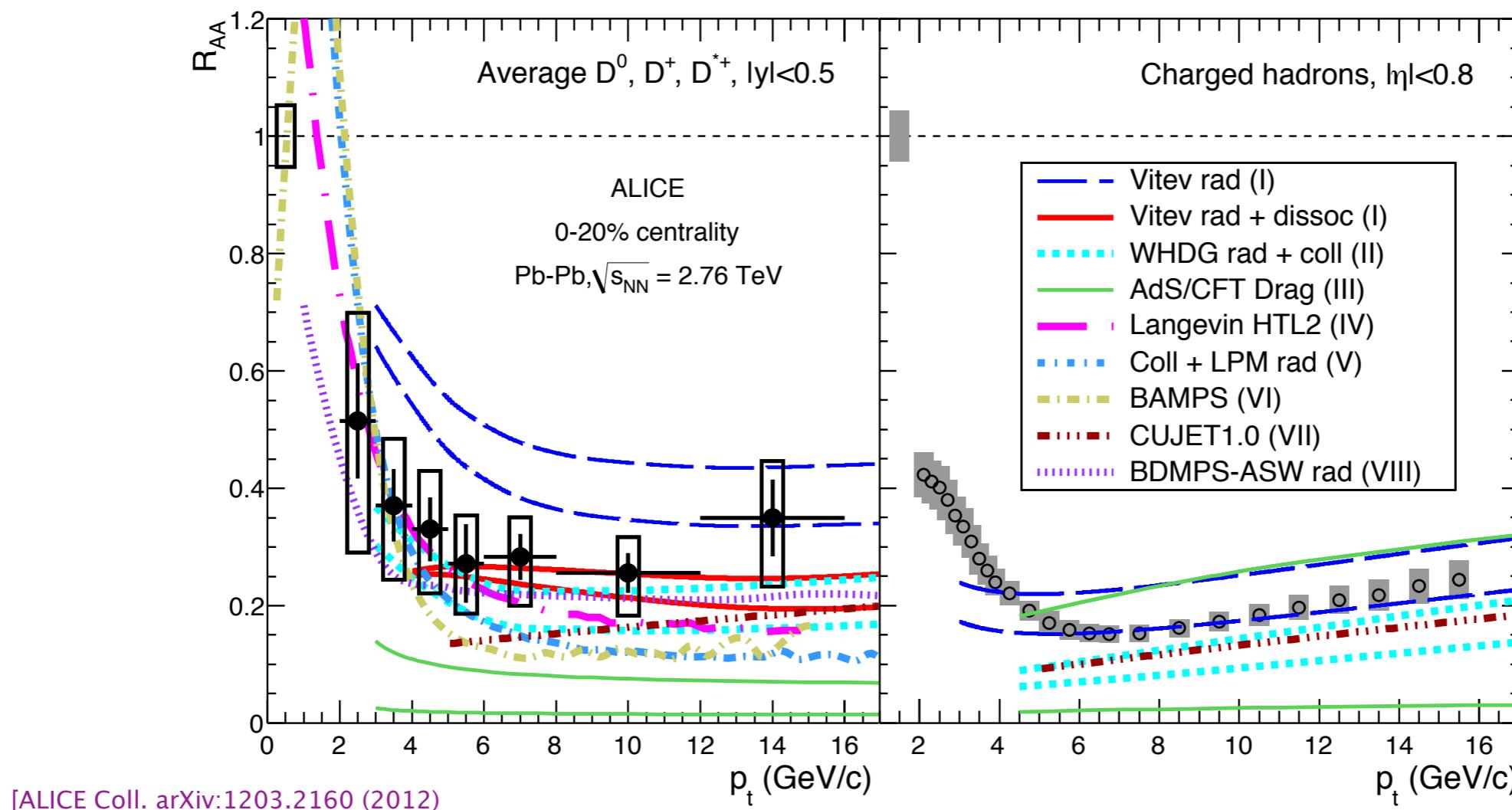
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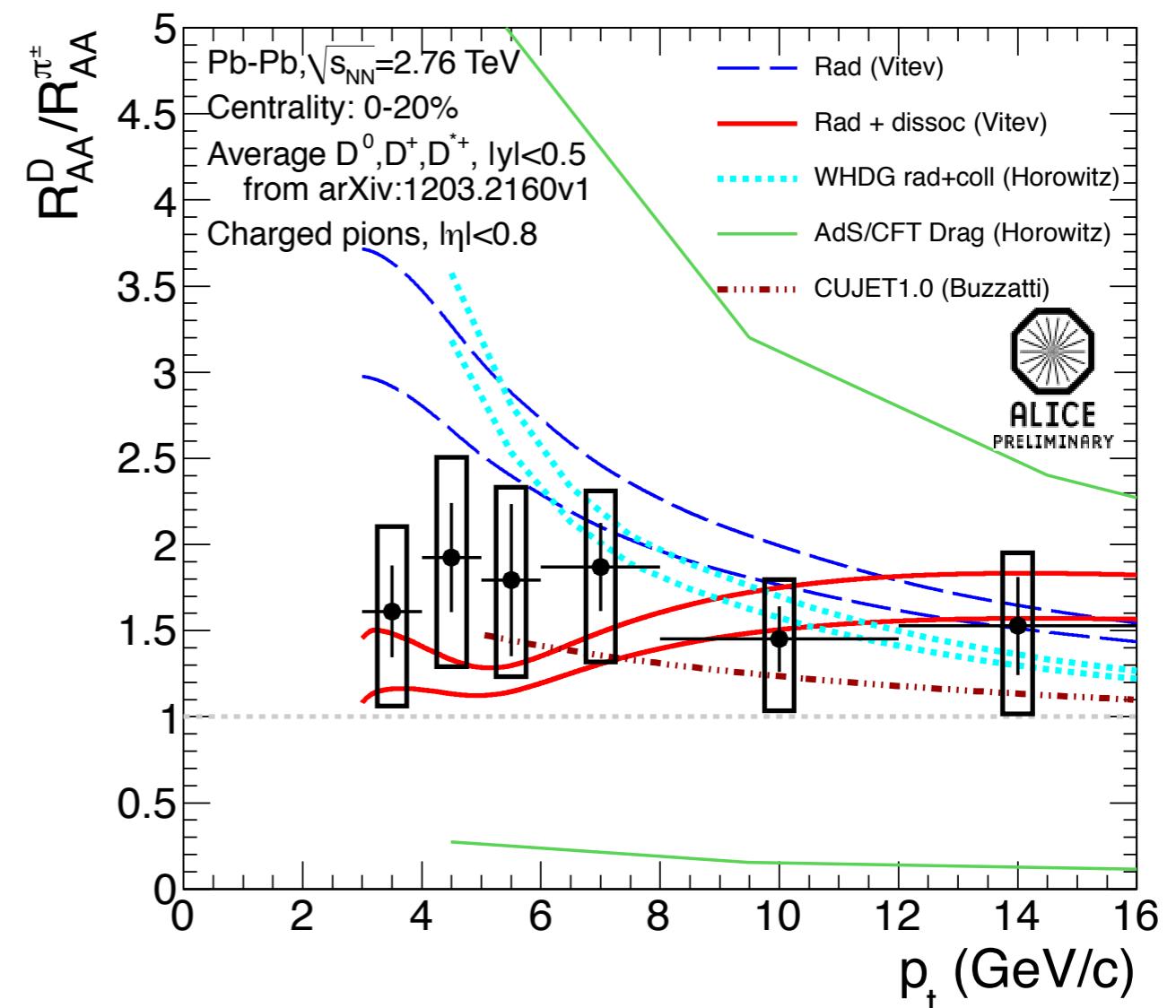
R_{AA} VS P_T DISCUSSION II

- * Models predicting reasonably well both charged particles and D meson R_{AA} :
 - ▶ I. Radiative energy loss + D meson in-medium dissociation (tuned to jet LHC data)
 - ▶ II. Radiative + collisional energy loss (tuned to RHIC data)
 - ▶ VII. Radiative + collisional energy loss (tuned to RHIC data)
- * AdS/CFT drag coefficients (III) underestimate the charm R_{AA} and have limited predictive power for the light flavour R_{AA}.



D MESON TO PION R_{AA} RATIO

- * Double ratio of the D meson and π R_{AA} shows little dependence on p_t at intermediate to large p_t.
- * Models predicting reasonably well both charged particles and D meson R_{AA} describe properly R_{AA}(D)/R_{AA}(π).
- * AdS/CFT drag coefficients have limited predictive power for the light flavour R_{AA}.

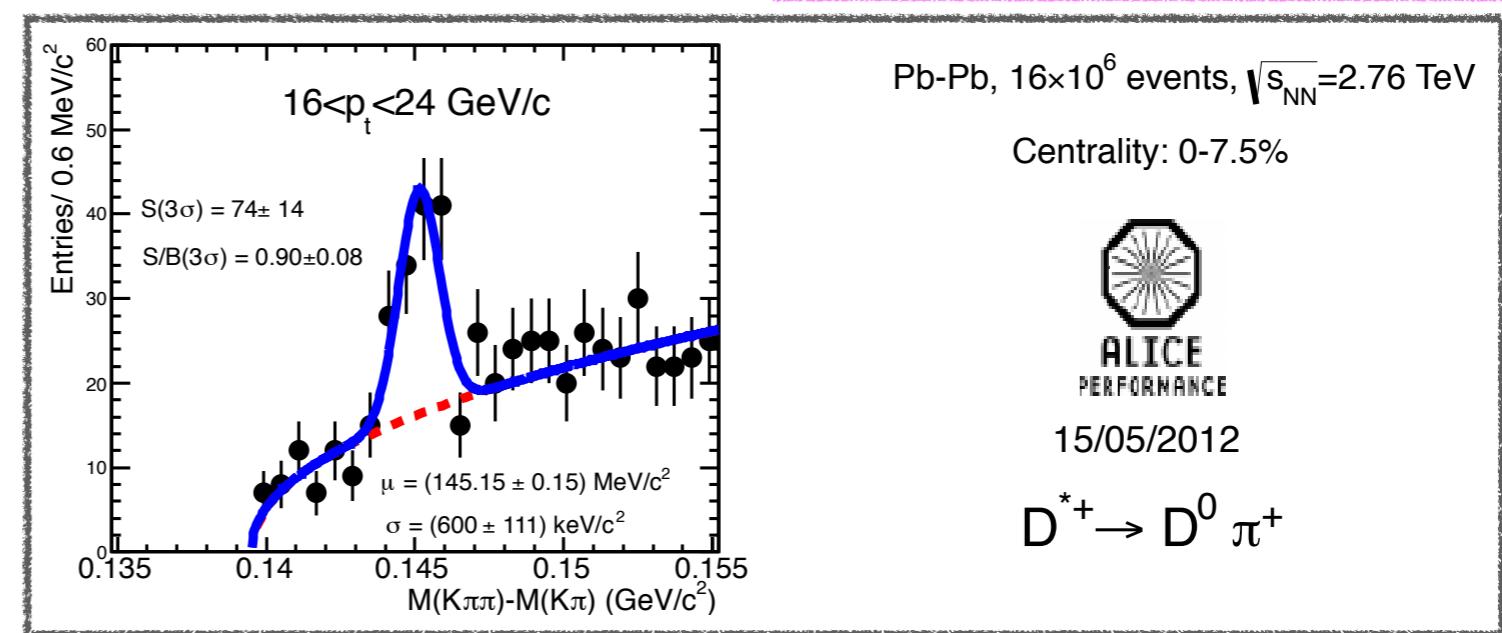
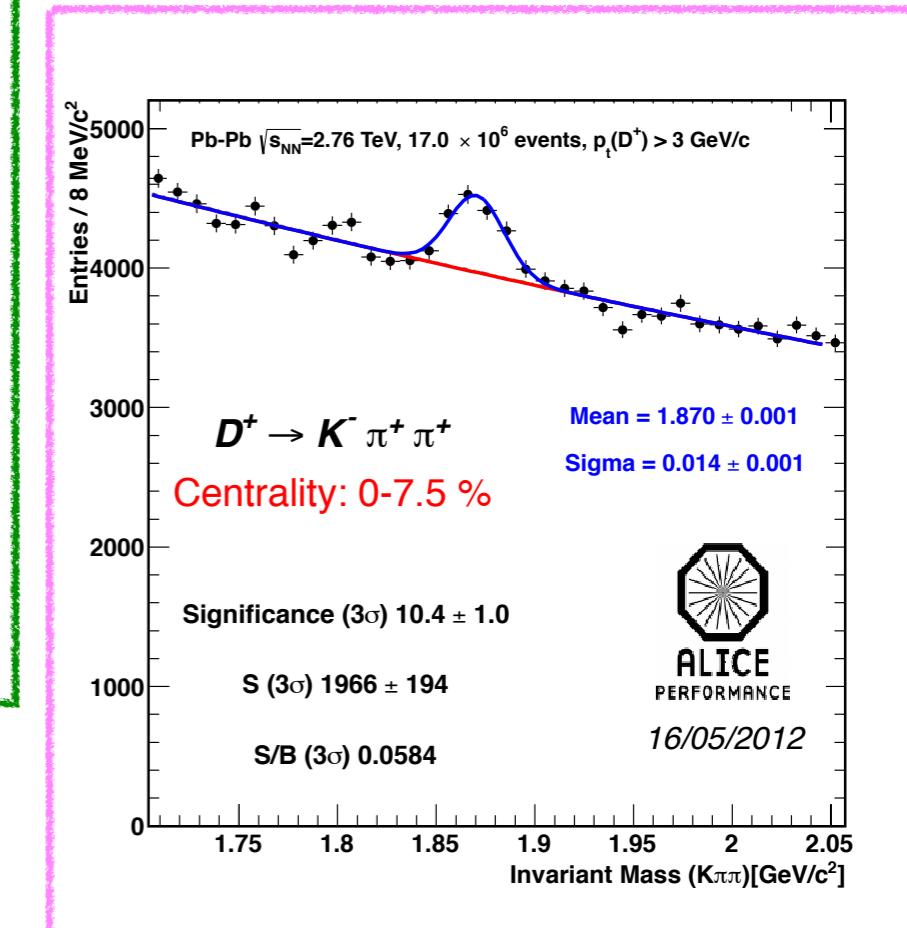
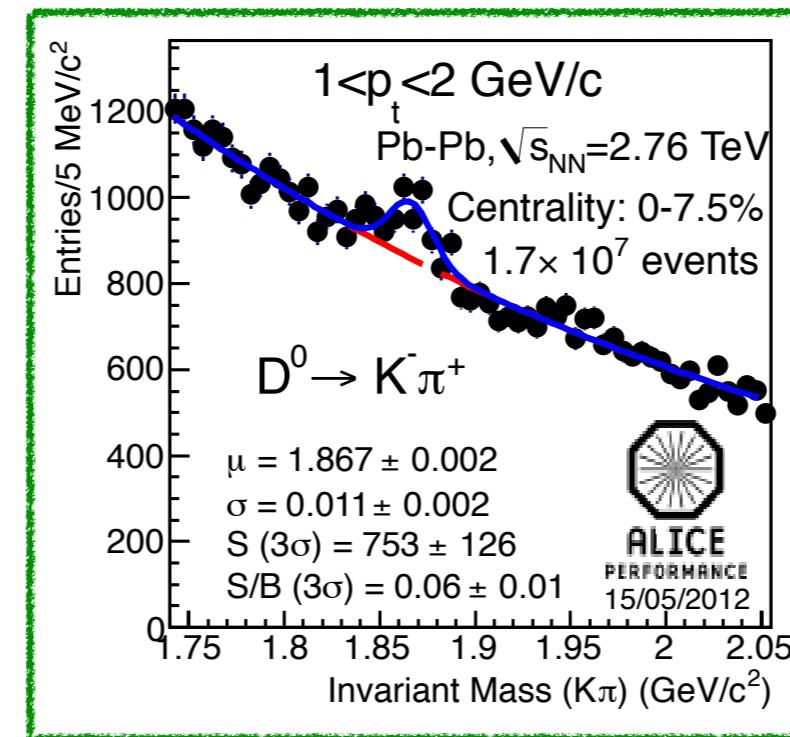


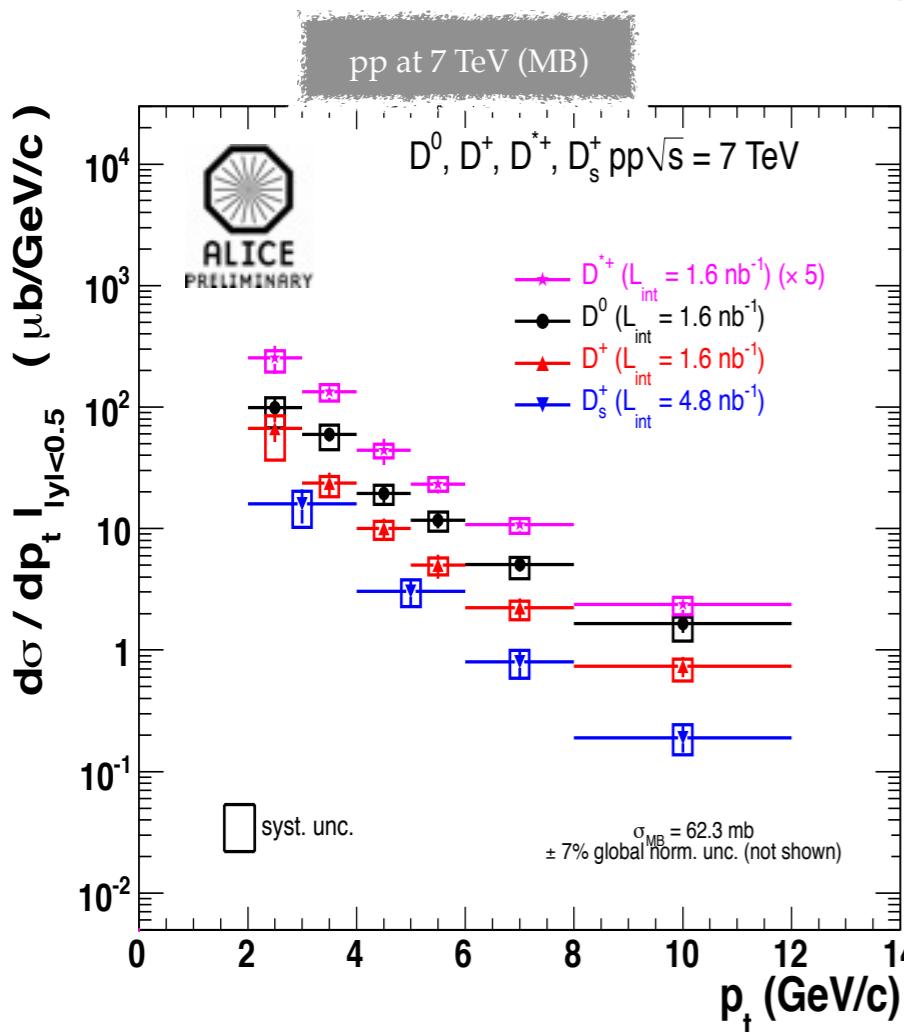
COMING WITH 2011 Pb-Pb DATA...

- * 2011 run with Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV using centrality triggers
 - ▶ 0-7.5% CC : 17M events ~ 5 × 2010 data
 - ▶ 20-40% CC : 8M events ~ 2.5 × 2010 data

- * D^0 signal visible down to $p_t \sim 1$ GeV/c,
- * D^0, D^+, D^{*+} signal up to $p_t \sim 24$ GeV/c

- 💡 Working on the extension to lower and higher p_t !

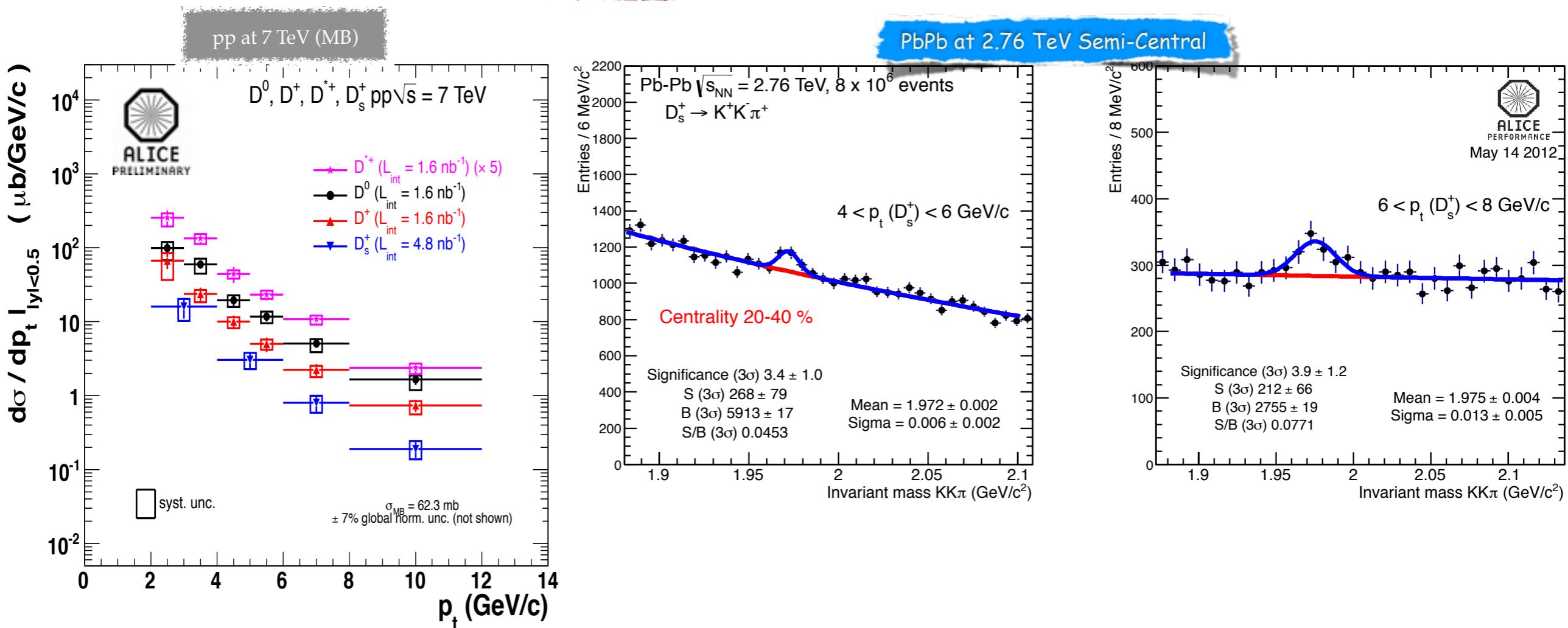




- * D_s cross section measured in pp collisions at $\sqrt{s} = 7$ TeV
 - * D_s signal visible in Pb-Pb collisions in both 0-7.5% and 20-40% centrality classes and in at least two p_t bins !!
 - Studying D meson zoology in Pb-Pb data... stay tuned !

see G. Innocenti's poster

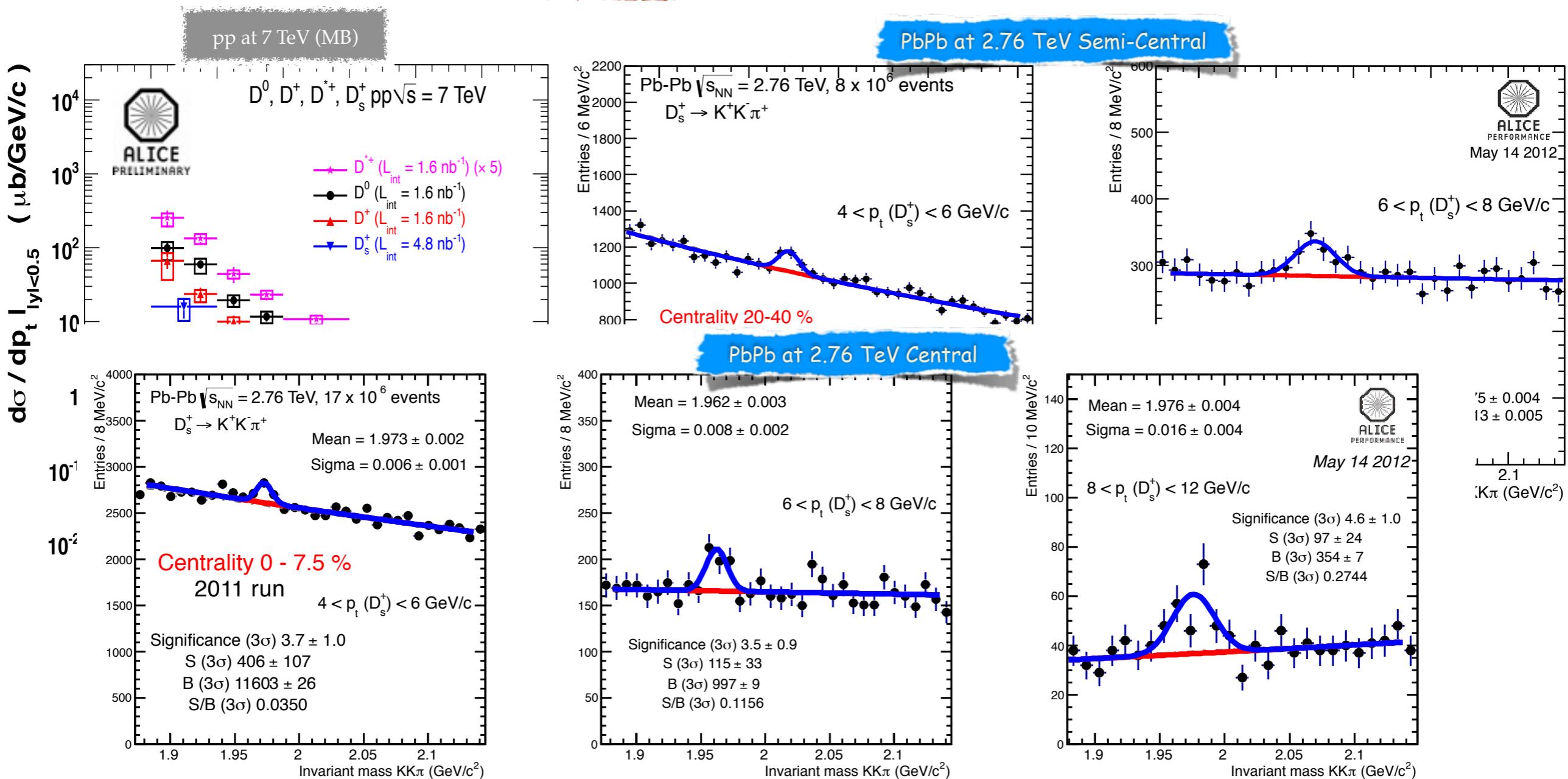
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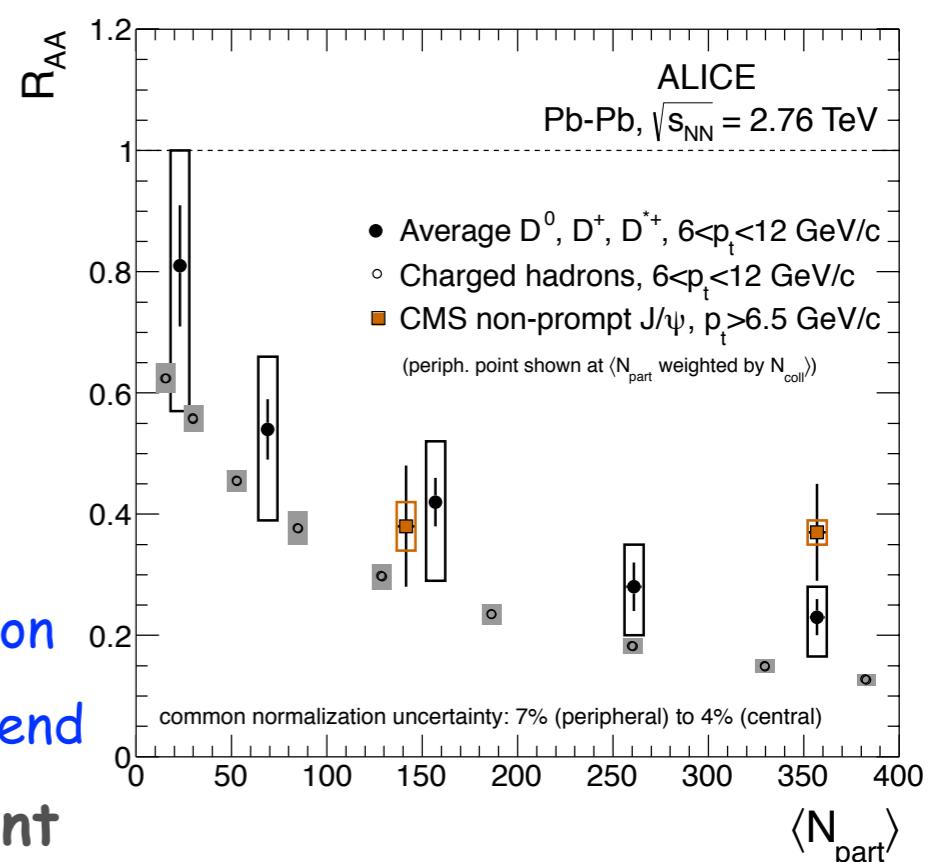


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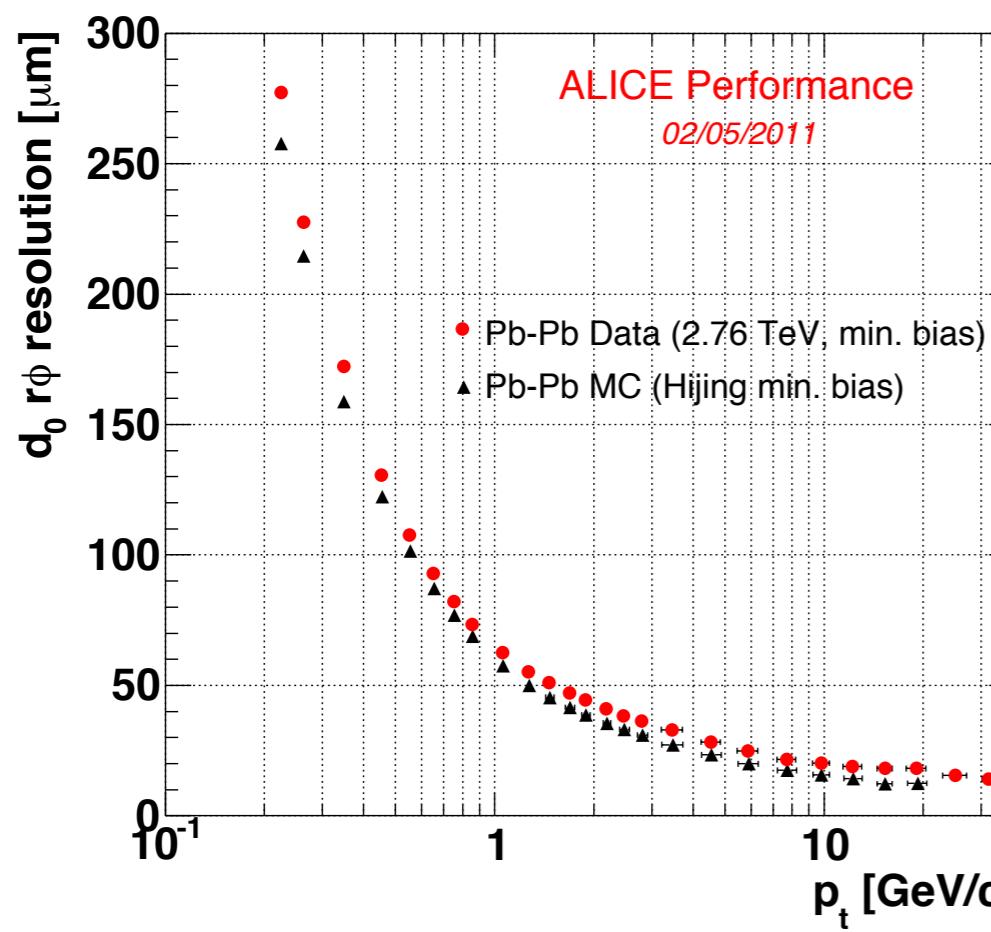
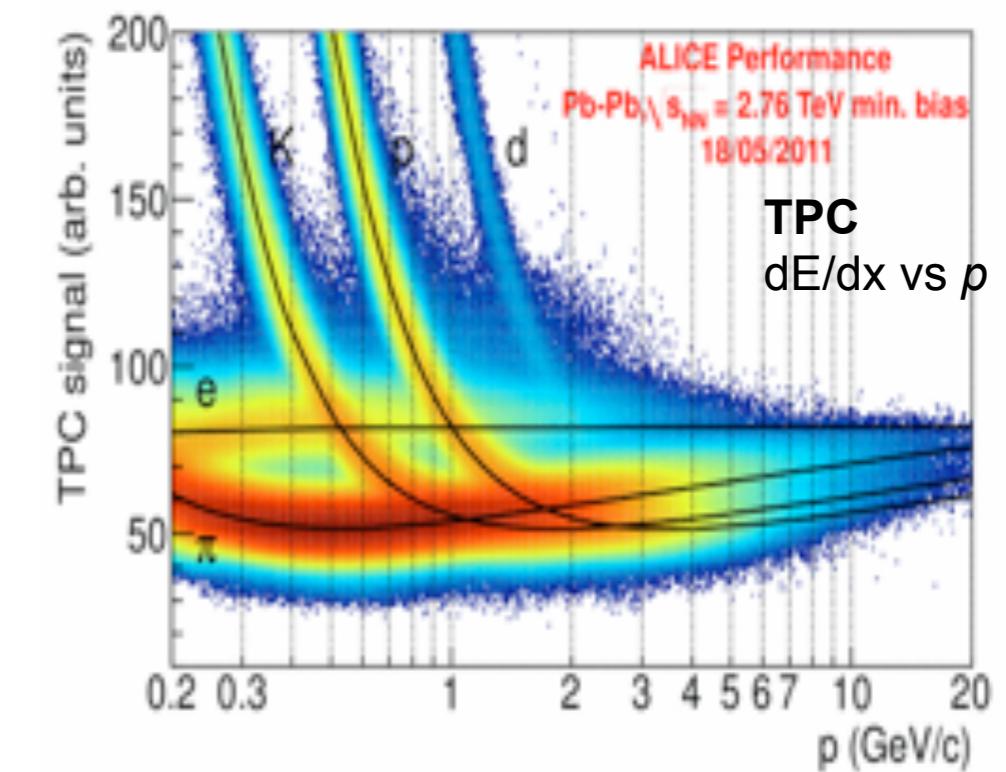
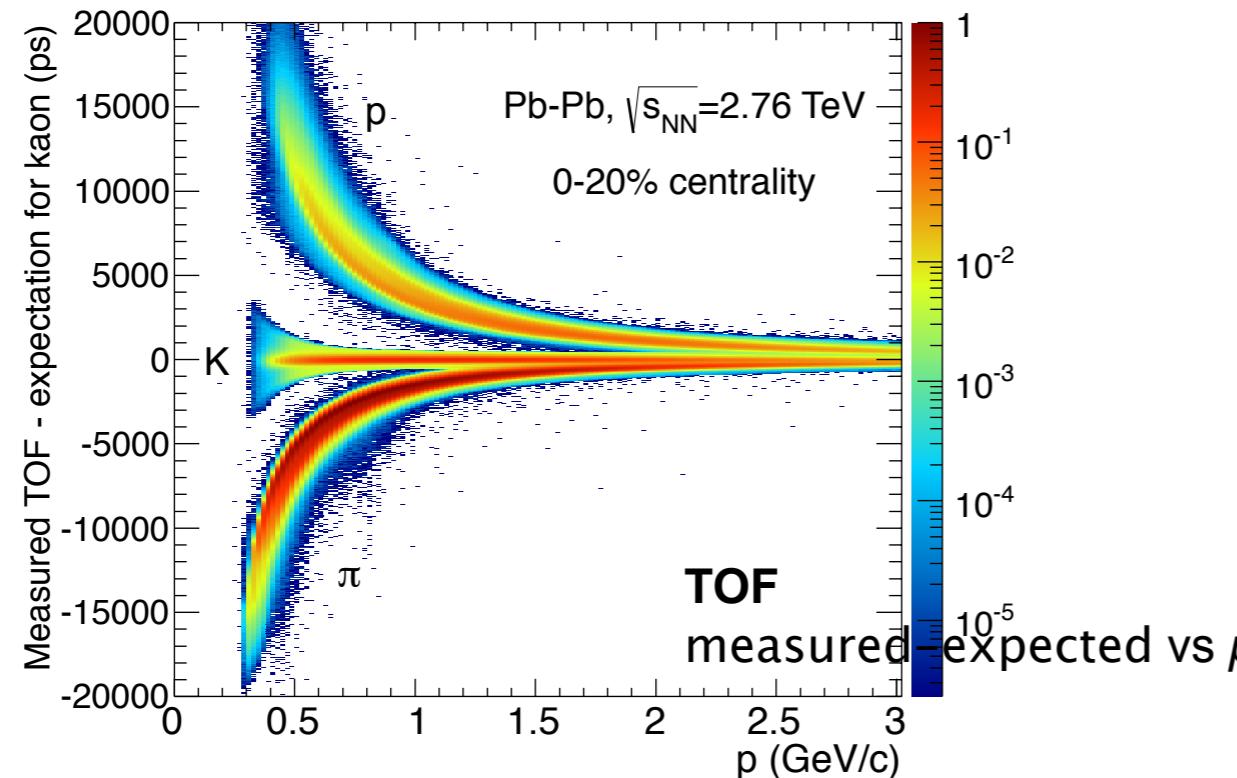
SUMMARY

- * D^0, D^+, D^{*+} nuclear modification factor in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV
 - ▶ $D^0, D^+, D^{*+} R_{AA}$ are compatible within statistical uncertainties
 - ▶ For $p_t > 6$ GeV/c D meson R_{AA} diminishes increasing centrality
 - ▶ R_{AA} (0-20%, $p_t > 6$ GeV/c) is suppressed by a factor of 3-4,
 R_{AA} (40-80%, $p_t > 6$ GeV/c) is suppressed by a factor of 1-3.
- * Comparison with data
 - ▶ D meson R_{AA} shows the same trend as N_{ch} and π^\pm ,
 the central values are systematically larger
 - ▶ $R_{AA}(B \rightarrow J/\psi, CMS) > R_{AA}(N_{ch})$ for $p_t > 6$ GeV/c
 - 📌 Need more precise measurements and p-Pb data...
- * Comparison with models
 - ▶ Shadowing alone can not explain the high $p_t R_{AA}$ suppression
 - ▶ Diverse models describe reasonably well the measured trend
 - 📌 Working on 2011 Pb-Pb to extend and improve current measurements and to have a first glance at D_s in HIC !



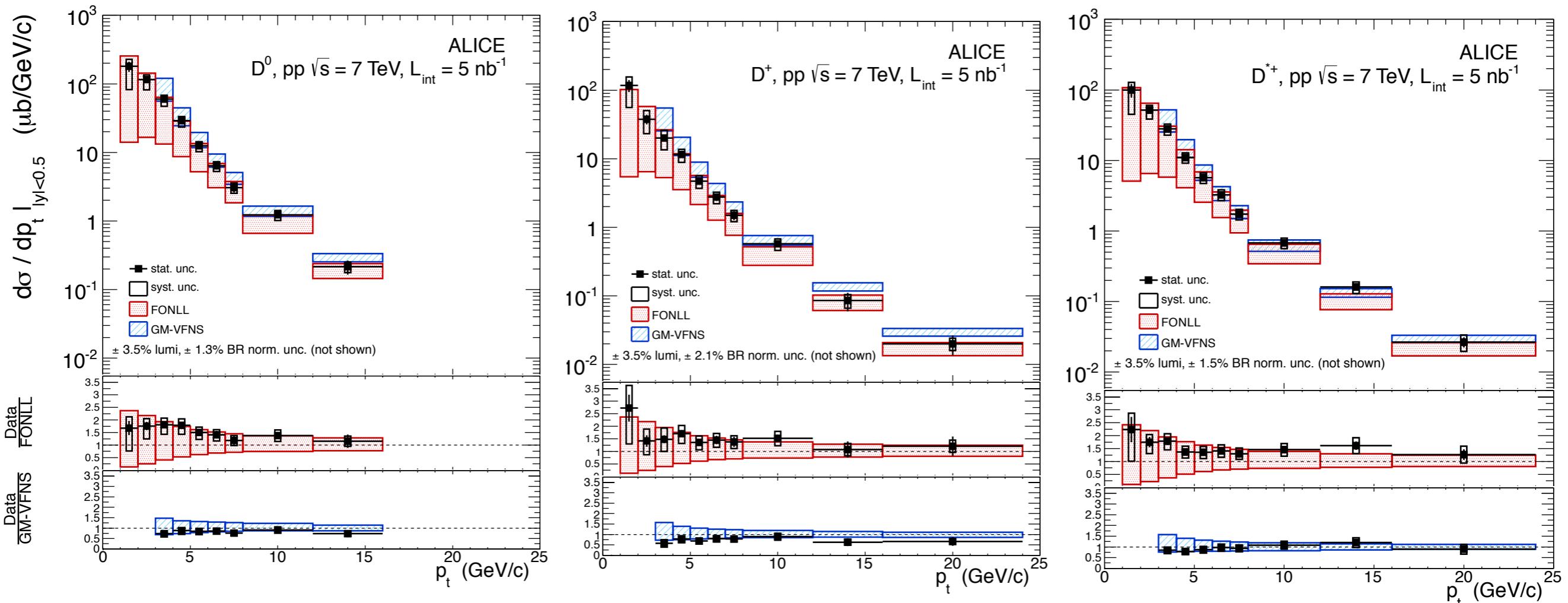
BACKUP

PARTICLE IDENTIFICATION

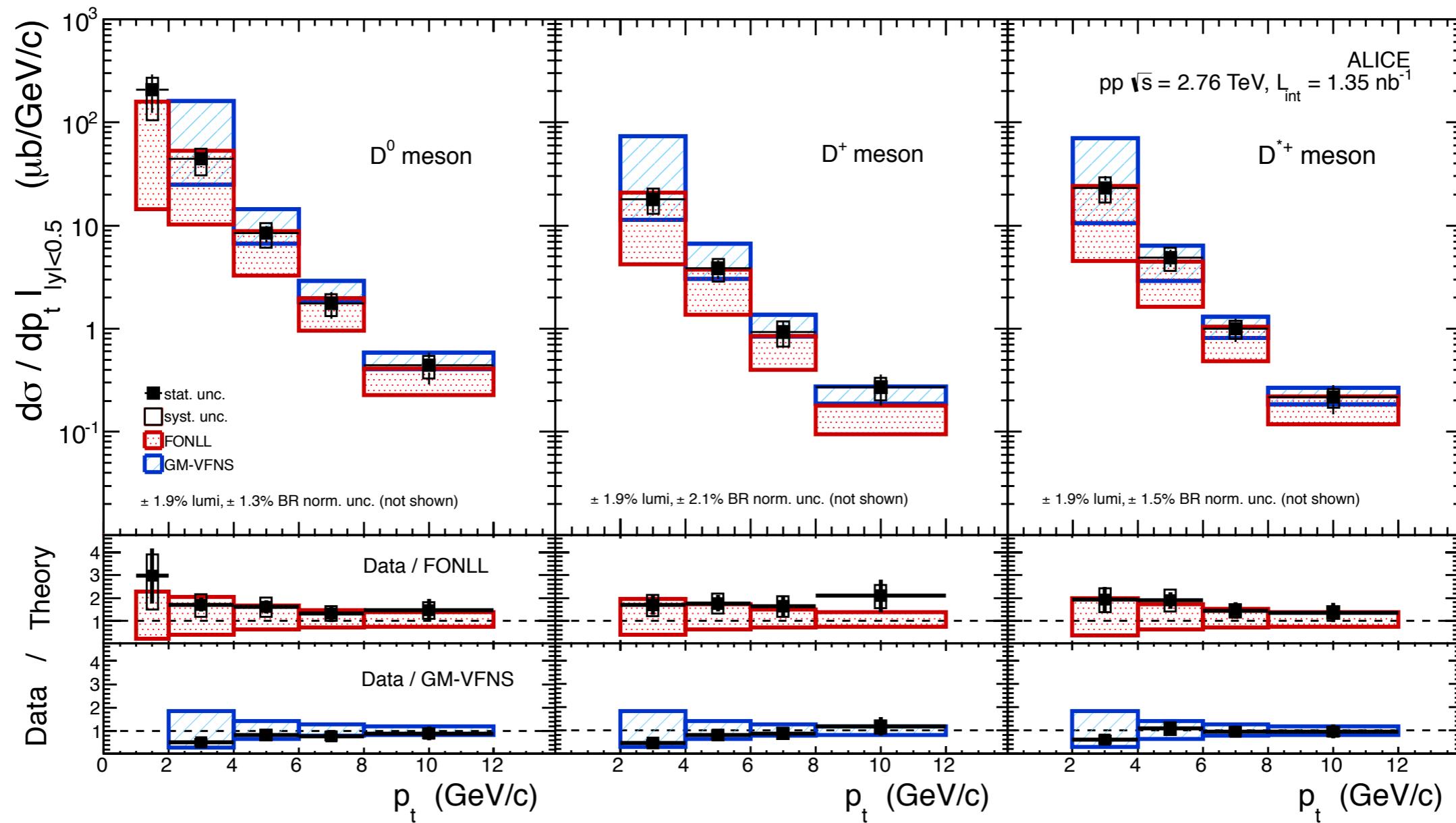


- * **Particle identification:** K identification thanks to the TPC+TOF helps to reject background at low p_t
 - ▶ TPC allows K/π separation up to $\sim 0.6 \text{ GeV}/c$,
 - ▶ TOF allows K/π separation up to $\sim 2 \text{ GeV}/c$.

CROSS SECTION, PP AT 7TeV



CROSS SECTION, PP AT 2.76 TEV



THE PROTON-PROTON REFERENCE

