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

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NIKHEF and Utrecht University

Strangeness in Quark Matter 2013

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Outline

- Motivations
- D meson reconstruction with the ALICE detector
- D meson nuclear modification factor R_{pPb}:
  - signal extraction for D^0, D^+, D^{*+}, D_s at $\sqrt{s_{NN}} = 5.02$ TeV
  - efficiencies and B feed-down subtraction
  - pp reference at $\sqrt{s_{NN}} = 5.02$ TeV
- Results
- Conclusions

Motivations

- Heavy-quarks are good probes to investigate the hot and dense medium created in HI collisions
  - Produced at the beginning of the collisions
  - Pass through the medium interacting with it

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

$\langle T_{AA} \rangle$ nuclear overlap function

$R_{AA}=1$ no nuclear effects

$R_{AA} \neq 1$ binary scaling broken

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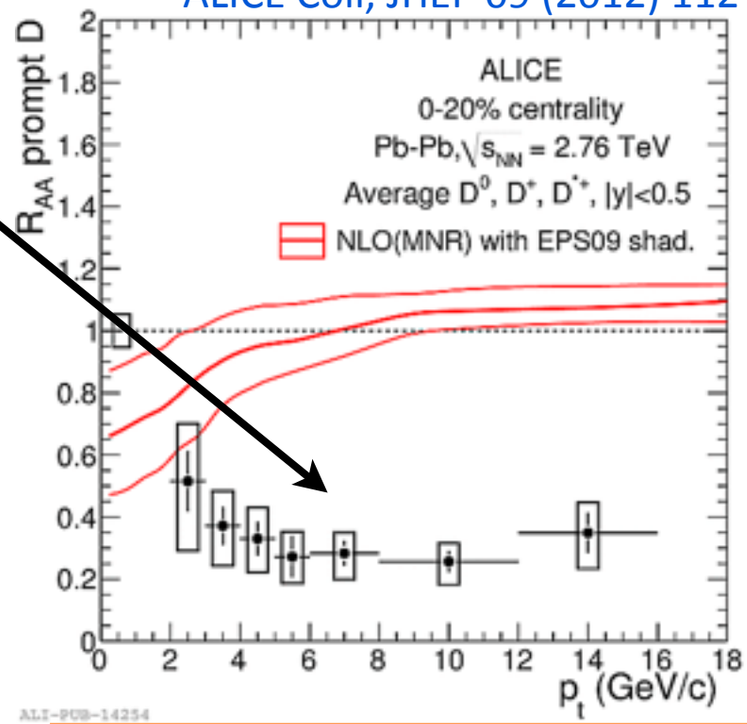
  - Nuclear modification factor (R_{PbPb}) < 1 suppression ~ factor 3-4 for p_T~5GeV/c

ALICE Coll, JHEP 09 (2012) 112



See **E. Bruna** talk for R_{PbPb} measurement

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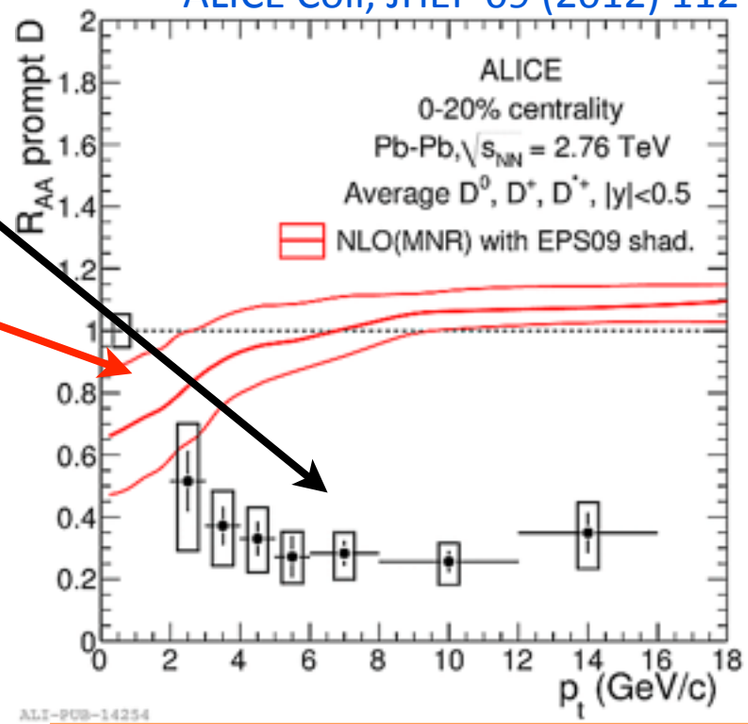
- Evidence of a strong medium effect in Pb-Pb collisions for prompt D mesons
  - Nuclear modification factor (R_{PbPb}) < 1 suppression ~ factor 3-4 for p_T~5GeV/c
  - Binary scaling can be broken for both hot nuclear matter or cold nuclear matter effects
  - Small effect expected from shadowing at p_T< 5 GeV/c

K. J. Eskola, H. Paukkunen and C. A. Salgado, JHEP 0904 (2009) 065

ALICE Coll, JHEP 09 (2012) 112



- Cold nuclear matter effects assessed in ALICE through p-Pb collisions

See **E. Bruna** talk for R_{PbPb} measurement

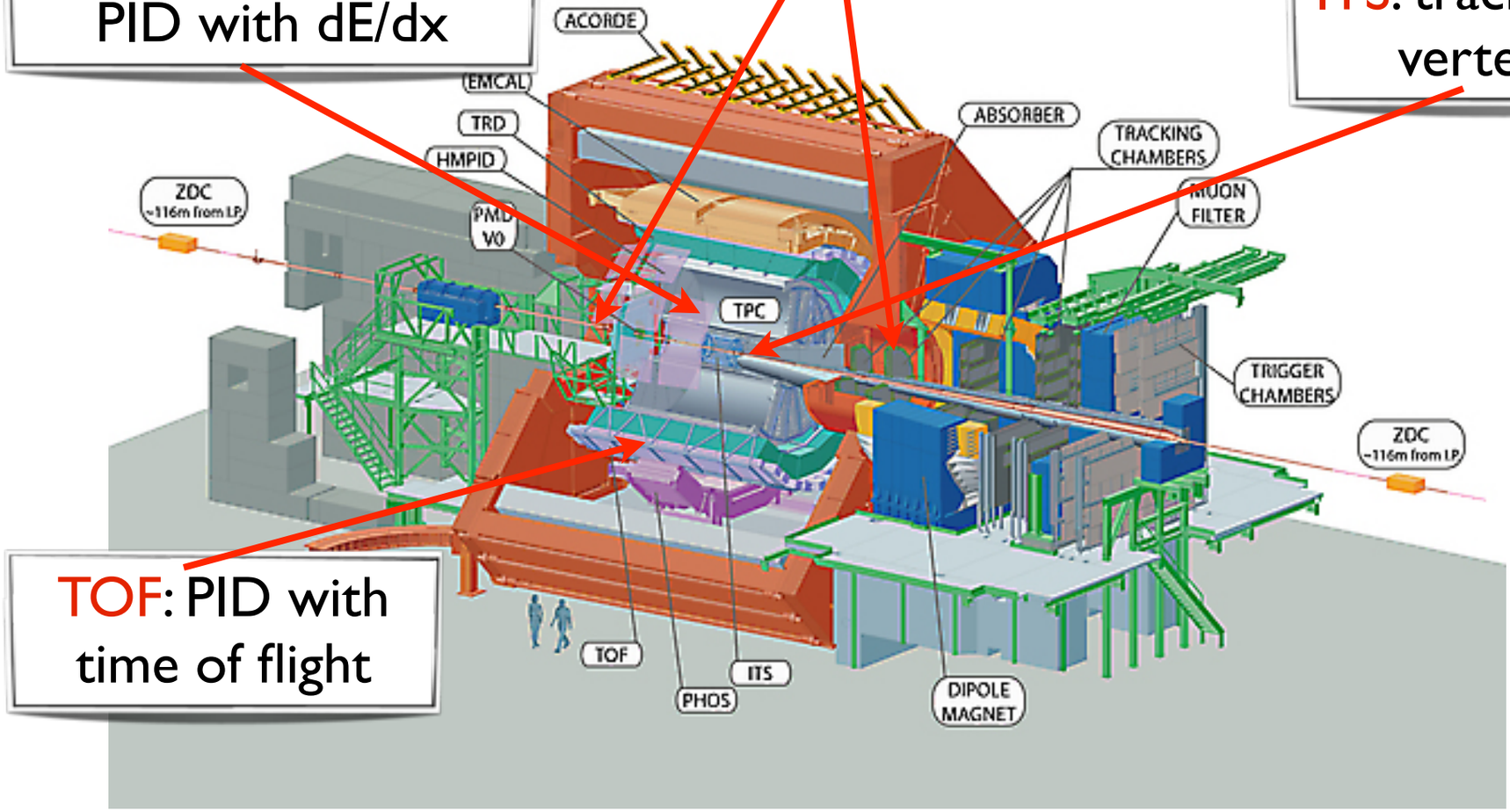
The ALICE detector and data sample

TPC: tracking and PID with dE/dx

VZERO: trigger

ITS: tracking and vertexing

TOF: PID with time of flight



Trigger:
signal in both VZERO detectors

Data sample:
~130M p-Pb MB events collected in January and February 2013

D meson decay channels

$D^0 \to K^-\pi^+$ BR=(3.88±0.05)%, cτ ≈ 120μm

$D^{*+} \to D^0\pi^+$ BR=(67.7±0.5)%

$D^+ \to K^-\pi^+\pi^+$ BR=(9.13±0.19)%, cτ ≈ 310μm

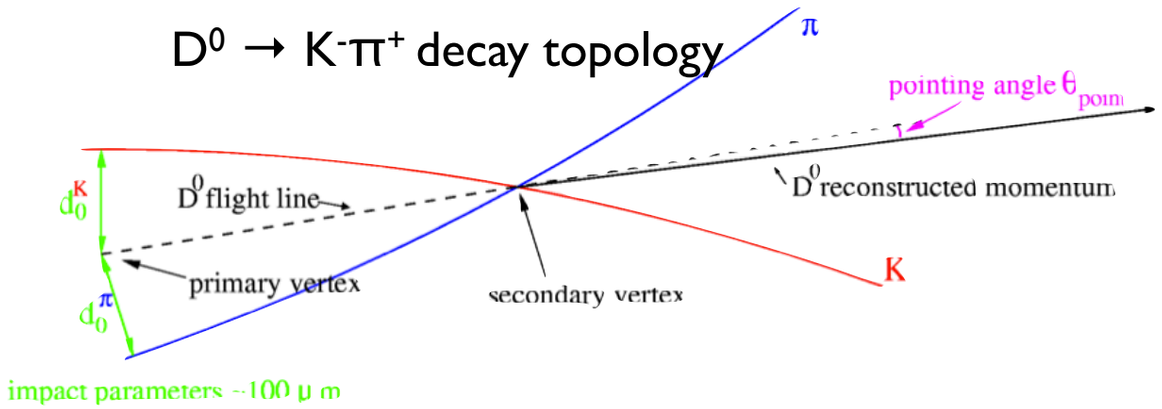
$D_s \to \varphi\,\pi^+ \to K^-K^+\pi^+$ BR=(2.28± 0.12)%, cτ ≈ 150μm

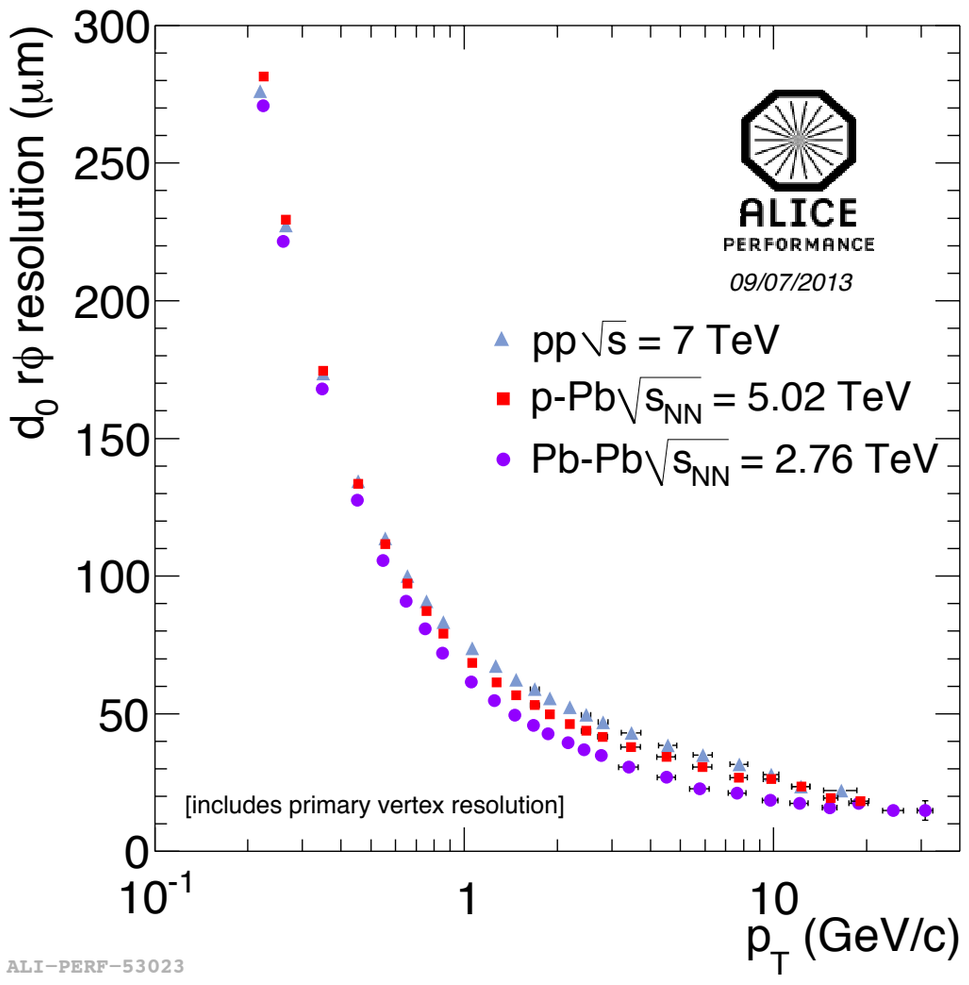
and charge conjugates

D meson reconstruction

Reconstruction strategy:

- Search for secondary vertex displaced by few hundred μm
- Combinatorial background reduced via topological selections

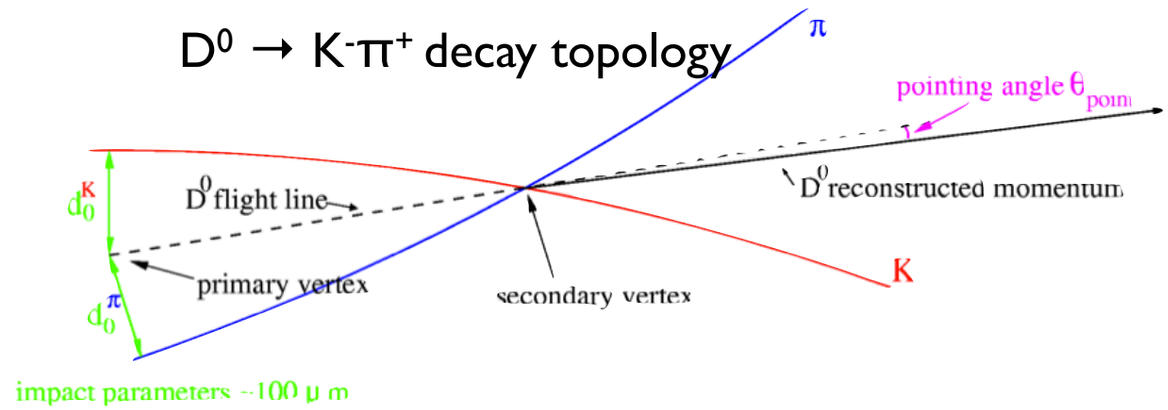


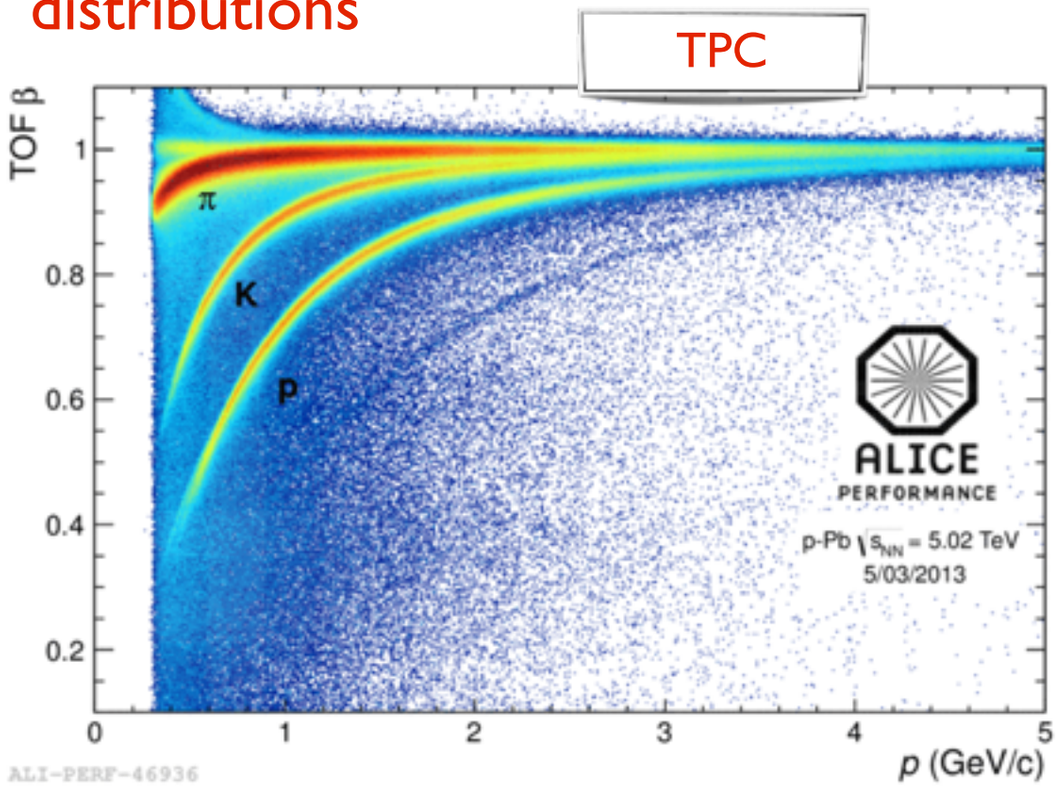


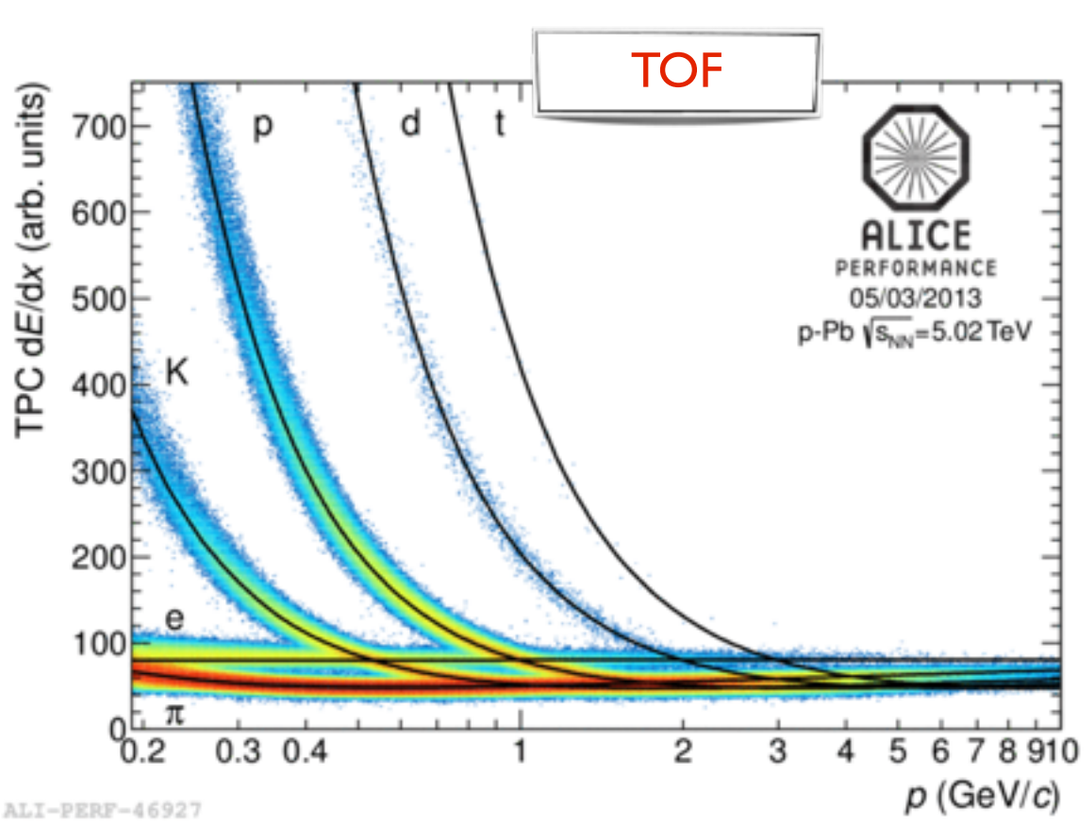
D meson reconstruction

Reconstruction strategy:

- Search for secondary vertex displaced by few hundred μm
- Combinatorial background reduced via topological selections
- Particle Identification with TPC and TOF to further reduce the background
- Signal extracted from fit to invariant mass distributions



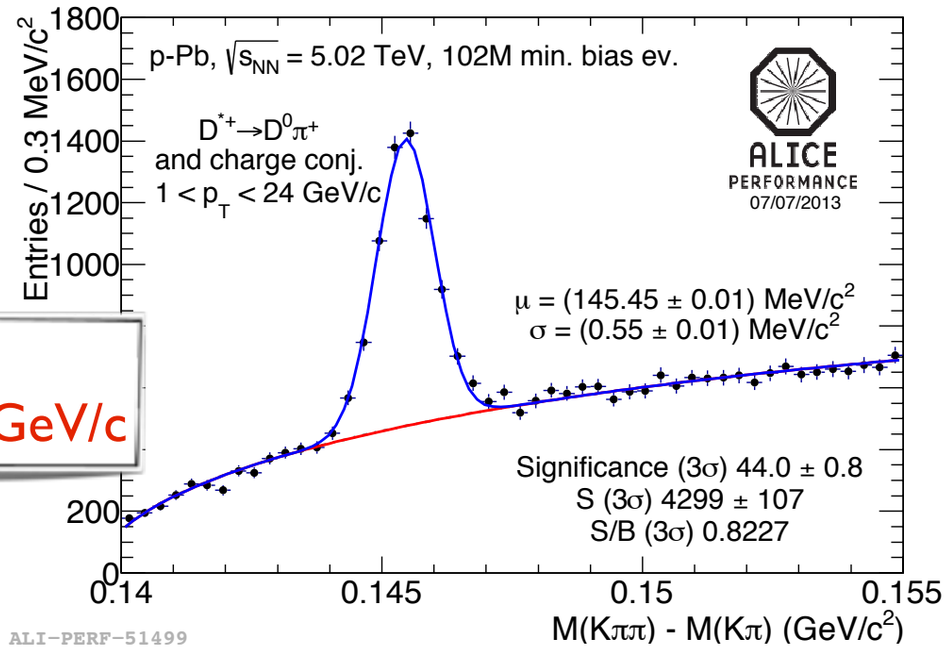




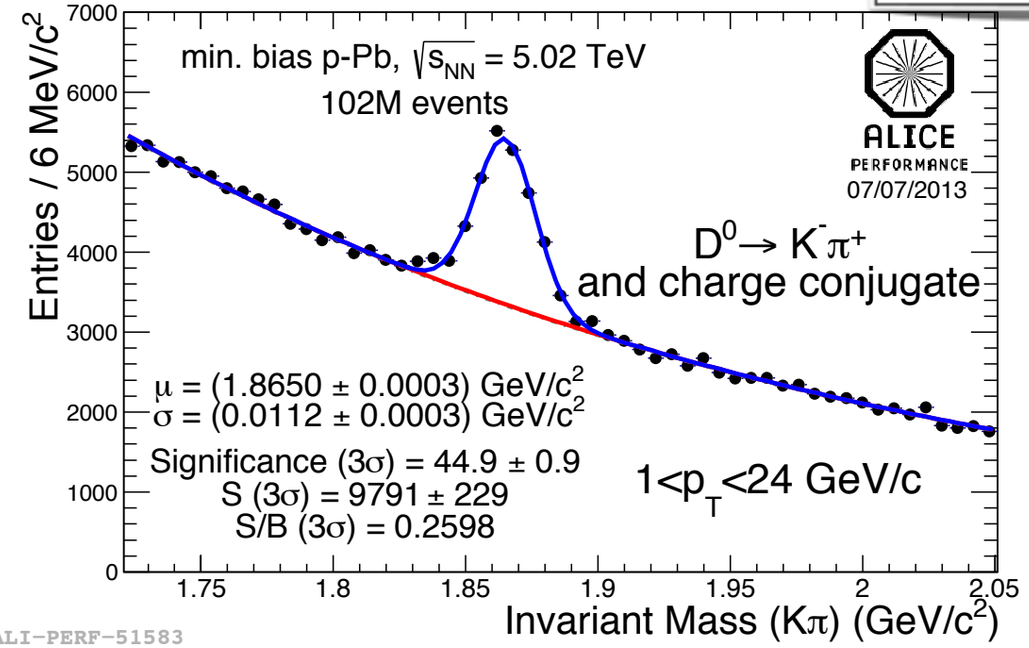
D meson signal in p-Pb data

Signal extracted in broad p_T range with large significance

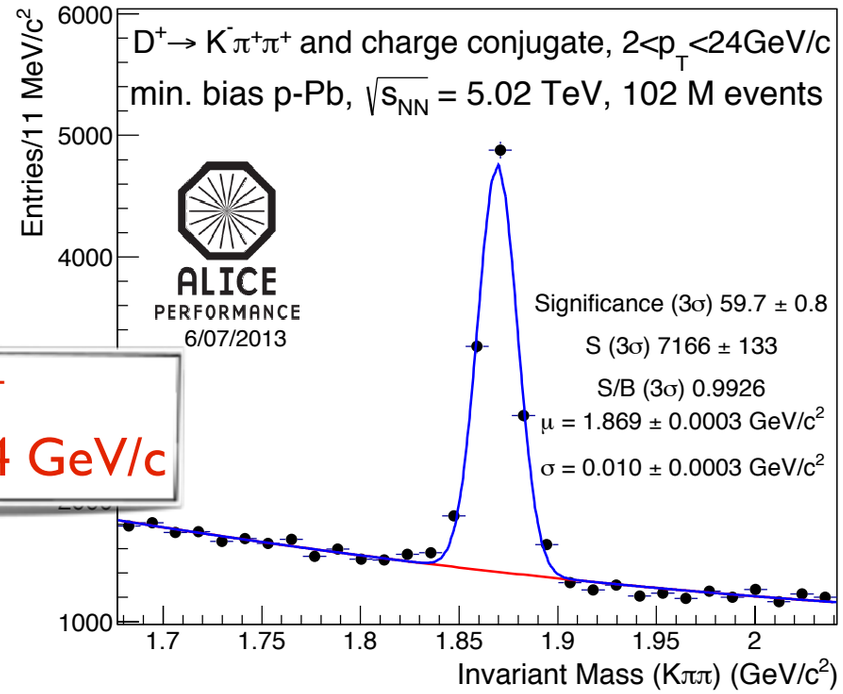
D^0
$1 < p_T < 24$ GeV/c



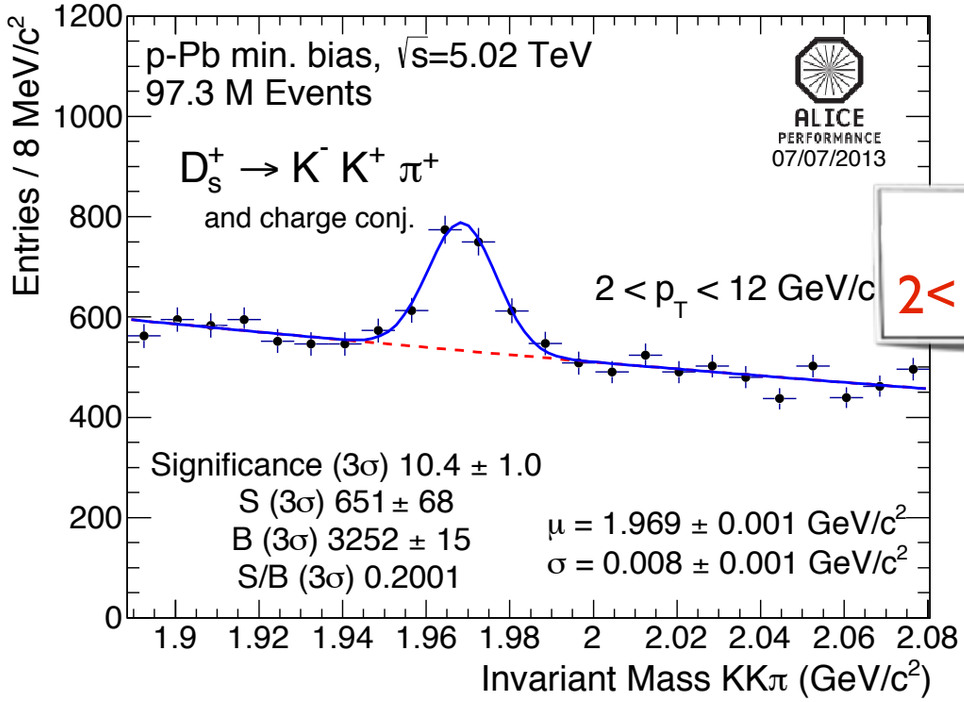
D^{*+}
$1 < p_T < 24$ GeV/c



D^+
$2 < p_T < 24$ GeV/c

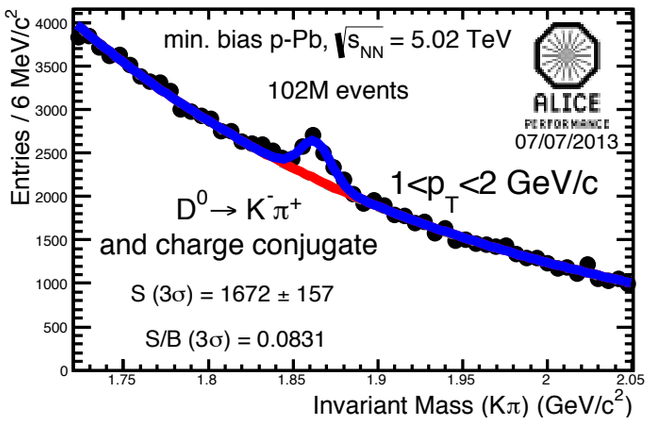


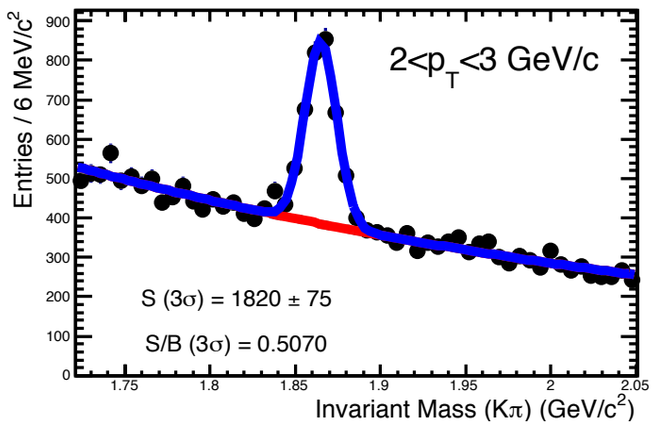
D_s
$2 < p_T < 12$ GeV/c

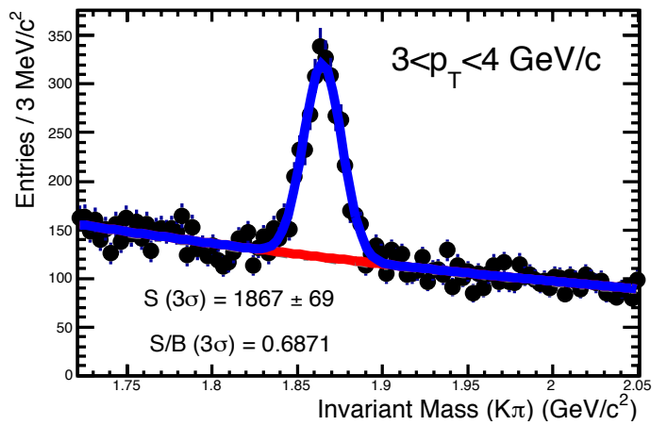


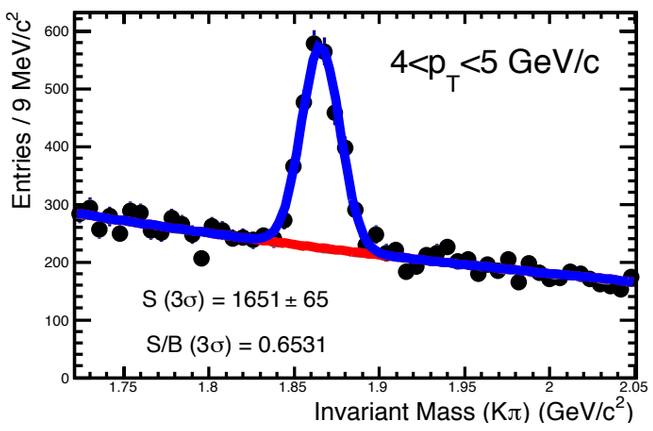
Example of signal in p_T bins

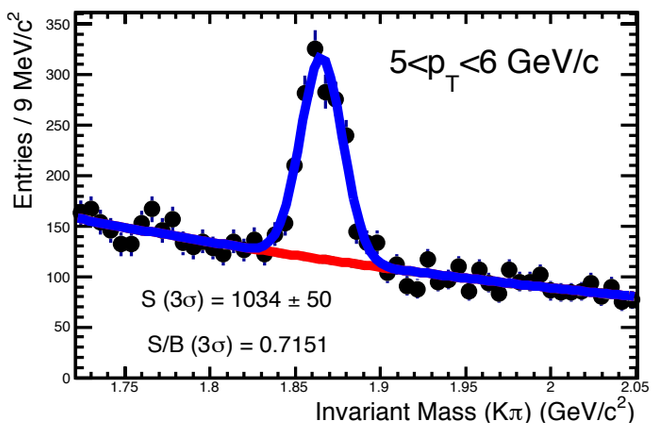
D^0 signal in 9 p_T bins from 1 to 24 GeV/c

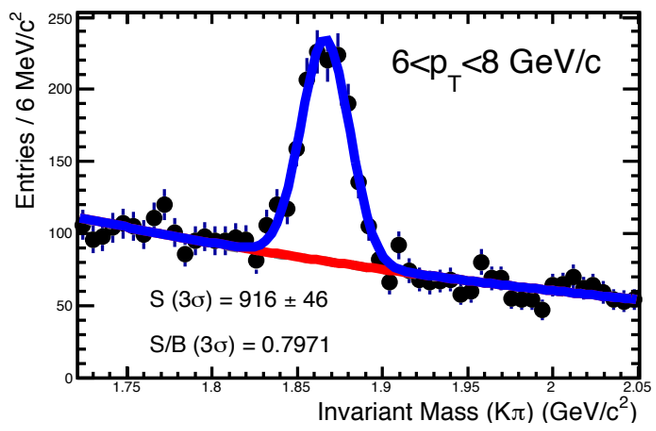


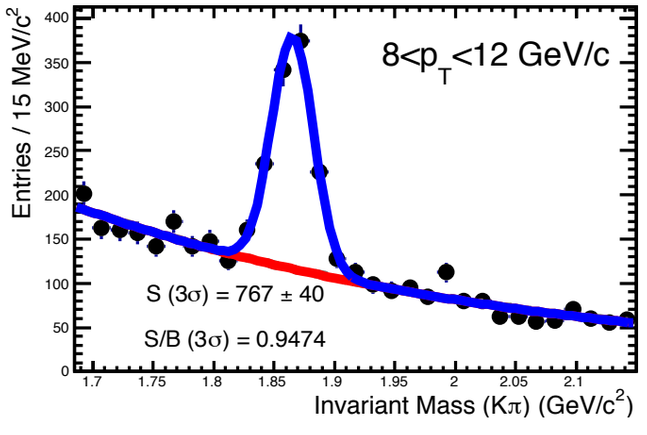


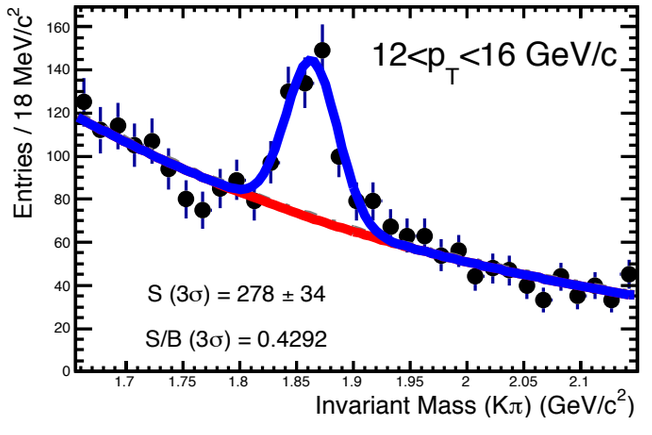


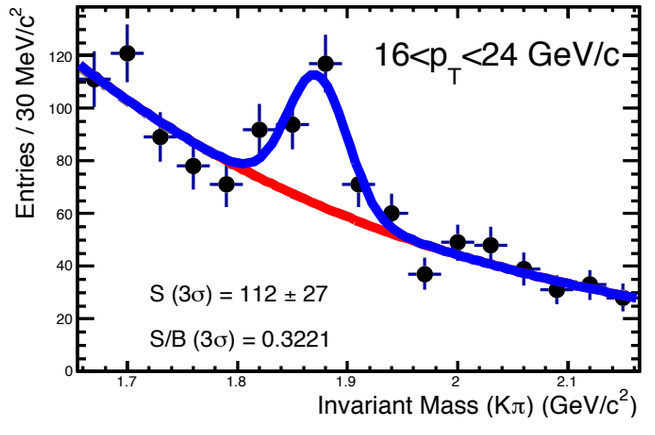










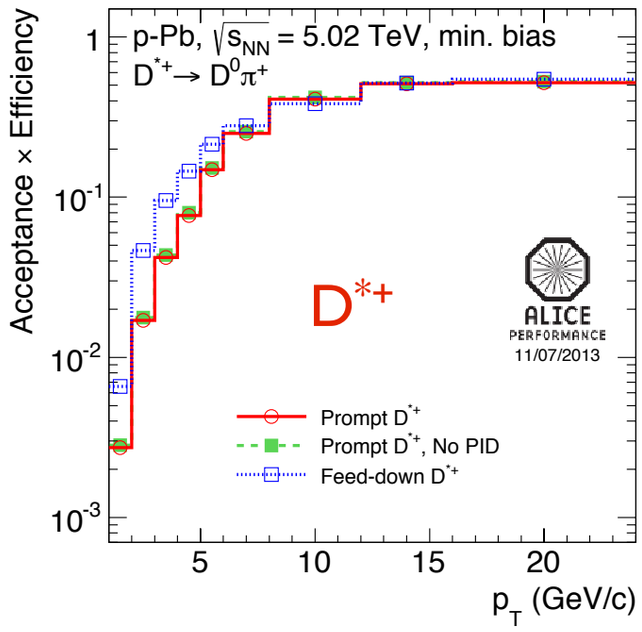


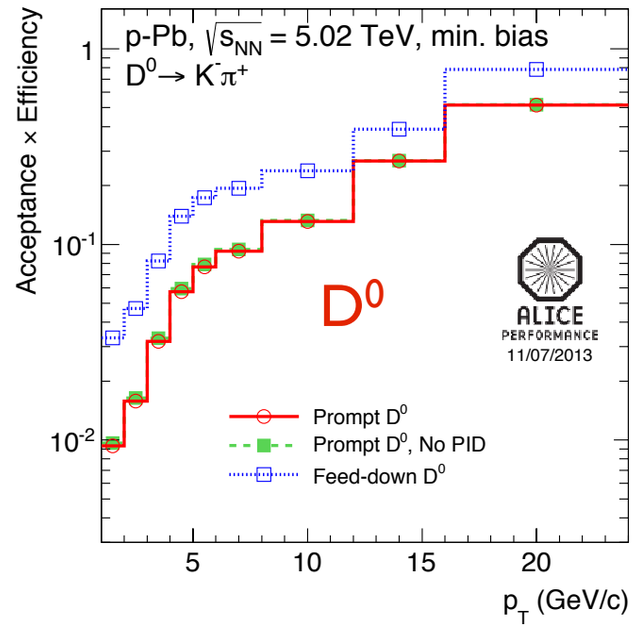
D meson efficiencies

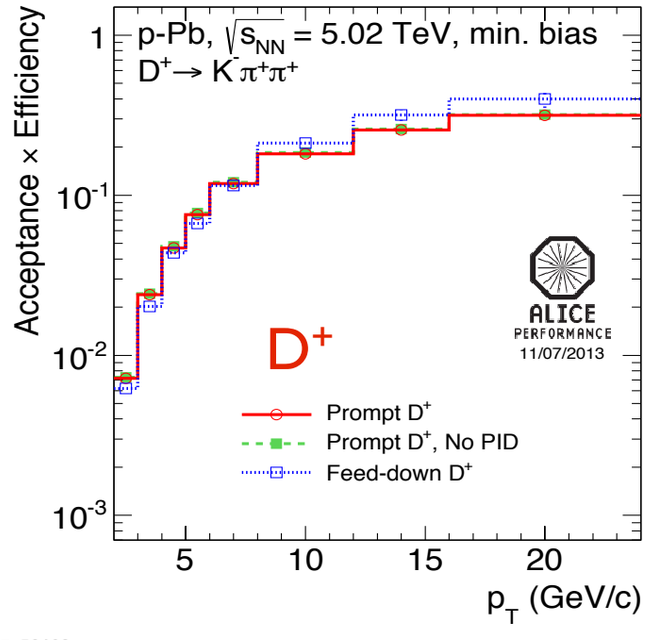
From MC simulations: HIJING + PYTHIA 6 (D meson enriched)

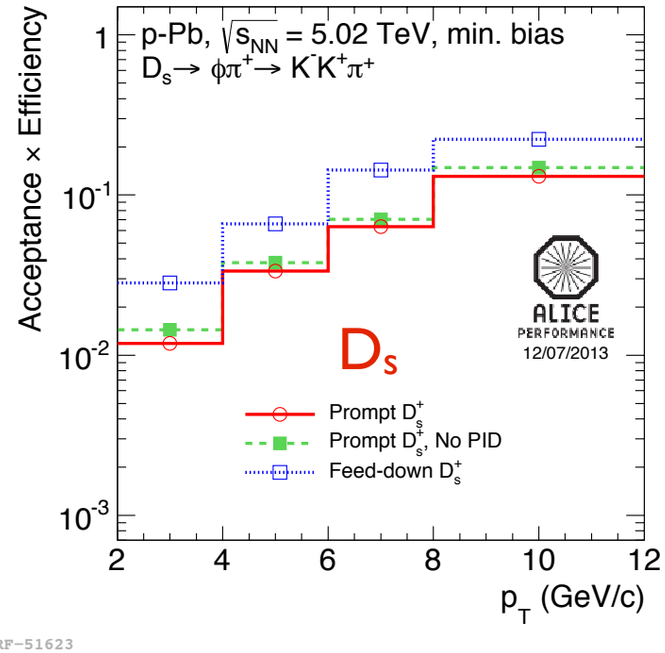
- Acceptance, beam and detector conditions reproduced in the MC as in the data taking
- Dependence from raw multiplicity of produced particles taken into account via re-weighting

- Prompt D meson efficiencies vary from ~1% up to 40%
- Efficiencies for D from B feed-down are larger (due to applied topological cuts)









B feed-down subtraction

- The fraction of the secondary D from B hadron decays has to be subtracted from the raw yield to compute the prompt D meson R_{pPb}
- Method relies on FONLL B.I. Abelev et al. [ALICE Coll], JHEP 09 (2012) 112
- Fraction of prompt D mesons **f_{prompt}** estimated using:

$$f_{prompt} = 1 - (N_{D\ from\ B}^{uncorrected} / N_{D\ all}^{uncorrected})$$

$$N_{D\ from\ B}^{uncorrected} = \Delta p_T \times \epsilon_{D\ from\ B} \times A \times R_{pA}^{D\ from\ B} \times \left(\frac{d\sigma}{dp_T}\right)^{D\ from\ B}$$

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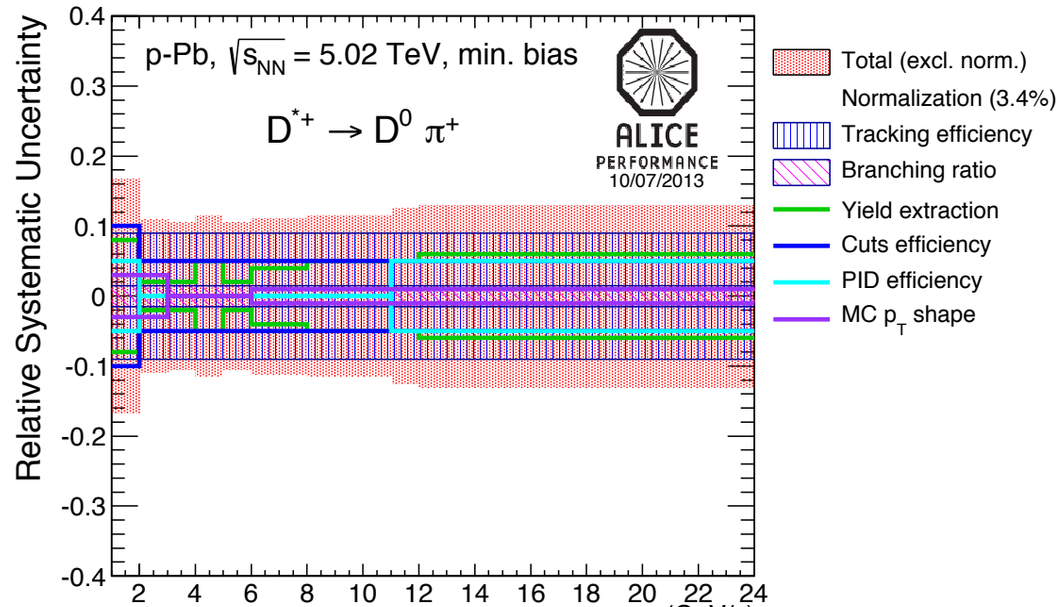
MC efficiency for feed-down D

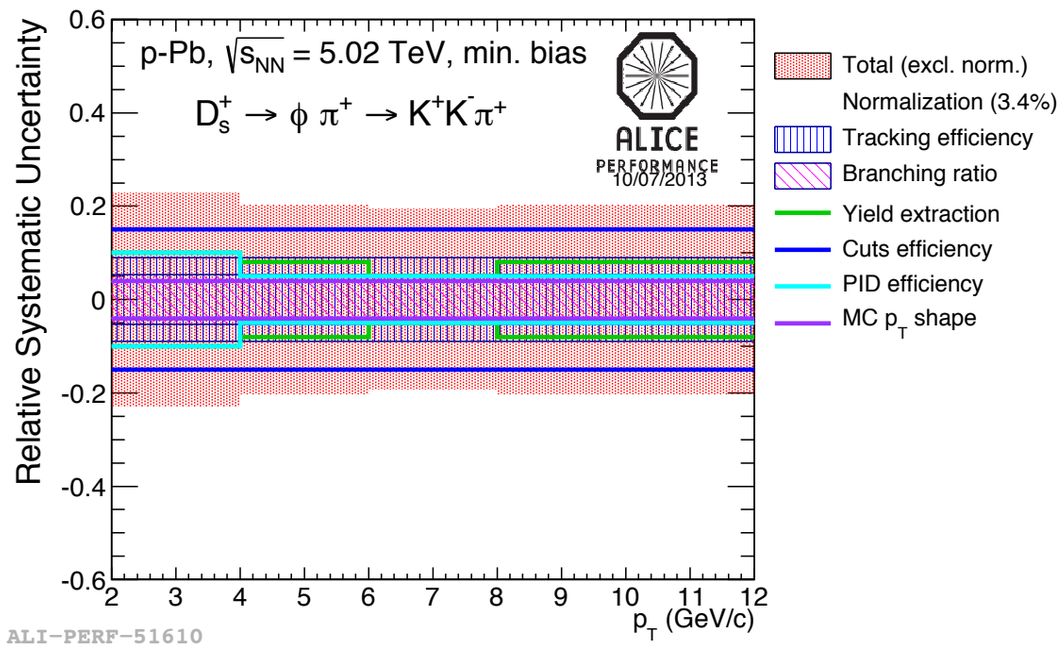
From FONLL B cross section + EvGen decay kinematics

- Hypothesis on the R_{pA} of D from B
  - Central value assuming R_{pA} (D from B)/R_{pA} (D prompt) =1 (consistent with shadowing predictions from EPS09) K. J. Eskola, H. Paukkunen and C. A. Salgado, JHEP 0904 (2009) 065
  - Systematic uncertainty from the variation of the hypothesis $0.9 < R_{pA}(\text{D from B}) / R_{pA}(\text{D prompt}) < 1.3$

Summary of the systematic uncertainties

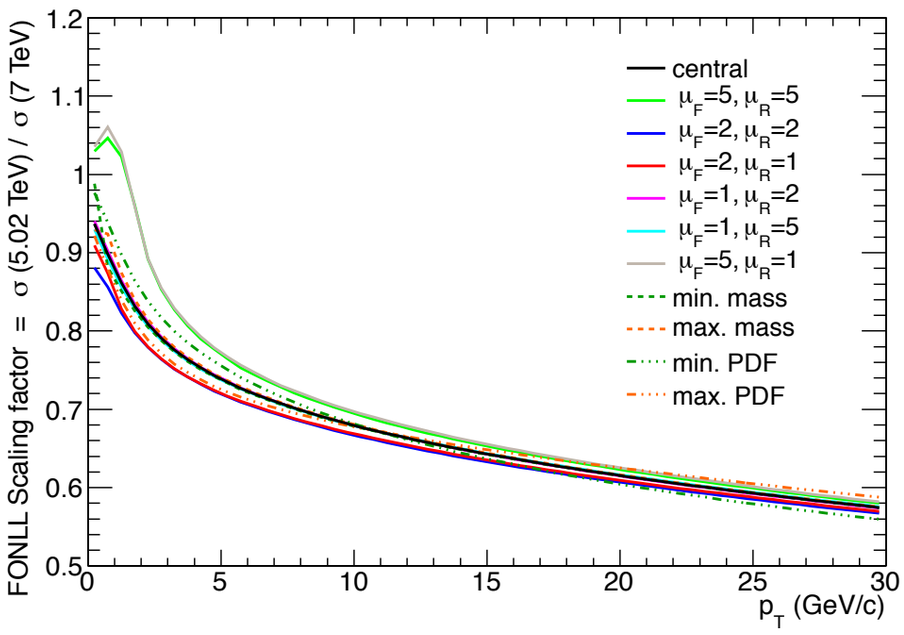
- Systematic uncertainties taken into account
  - Tracking efficiency
    - Different track quality cuts
  - Yield extraction
    - Vary fit range, background fit function, bin counting method, w/wo fixed sigma and mean
  - Topological selections
    - Tighter and looser sets of cuts
  - PID: analysis w/wo PID
  - Generated p_T distribution of the D mesons
    - PYTHIA Perugia-0 vs FONLL shape





pp reference

- pp reference defined by scaling the measurement from pp collisions at 7 TeV (no pp data at 5.02 TeV available)



- Ratio between FONLL predictions for D meson production at 5.02 TeV and 7 TeV used for scaling

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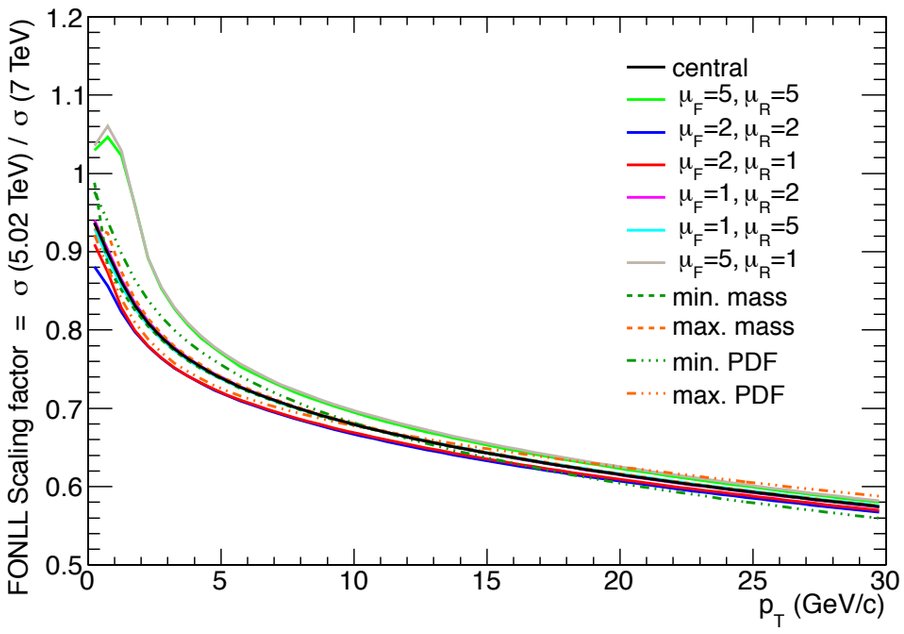

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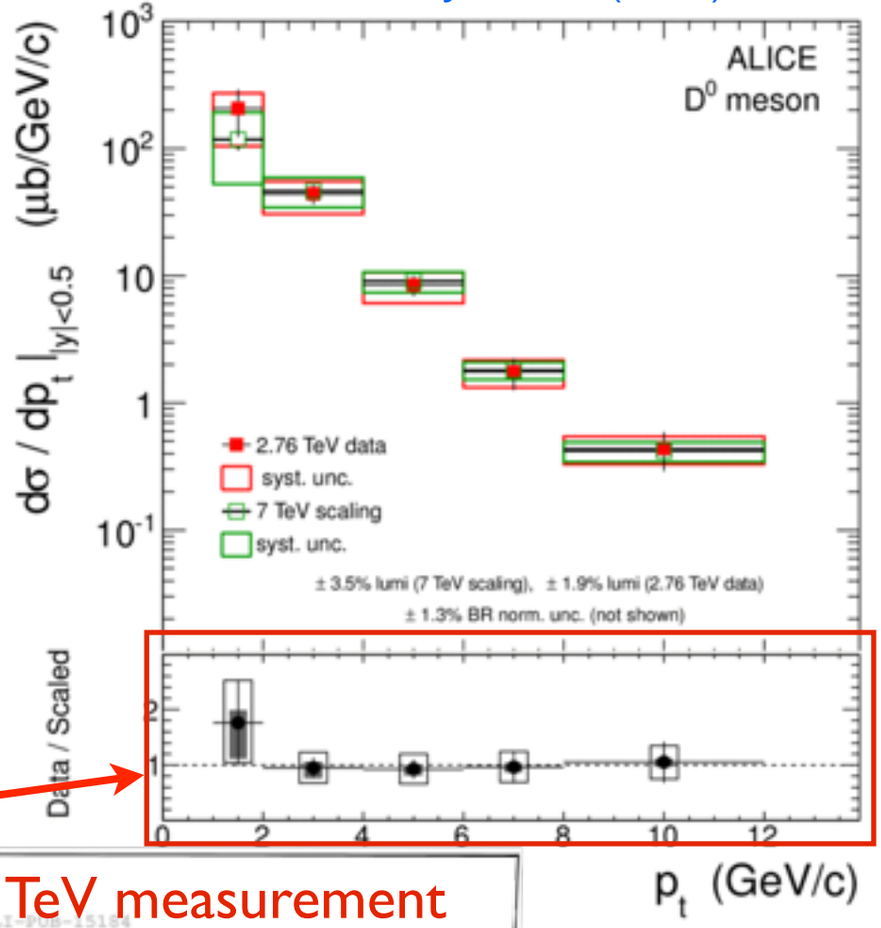
ALICE Coll., JHEP 07 (2012) 191



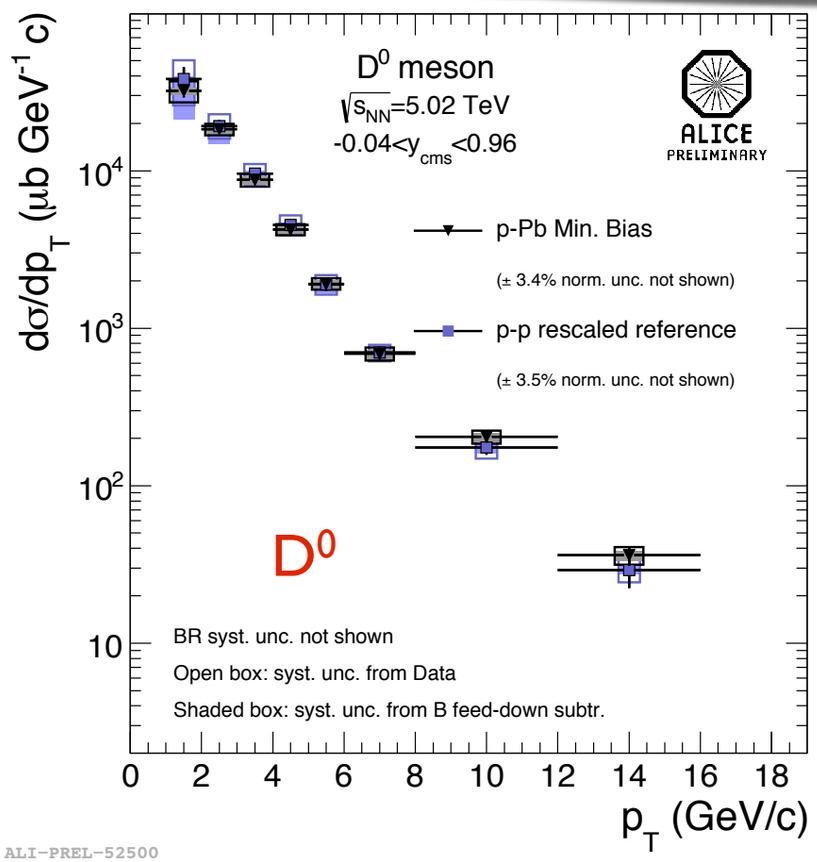
- Method validated comparing:
  - ALICE 7 TeV measurement and CDF 1.96 TeV

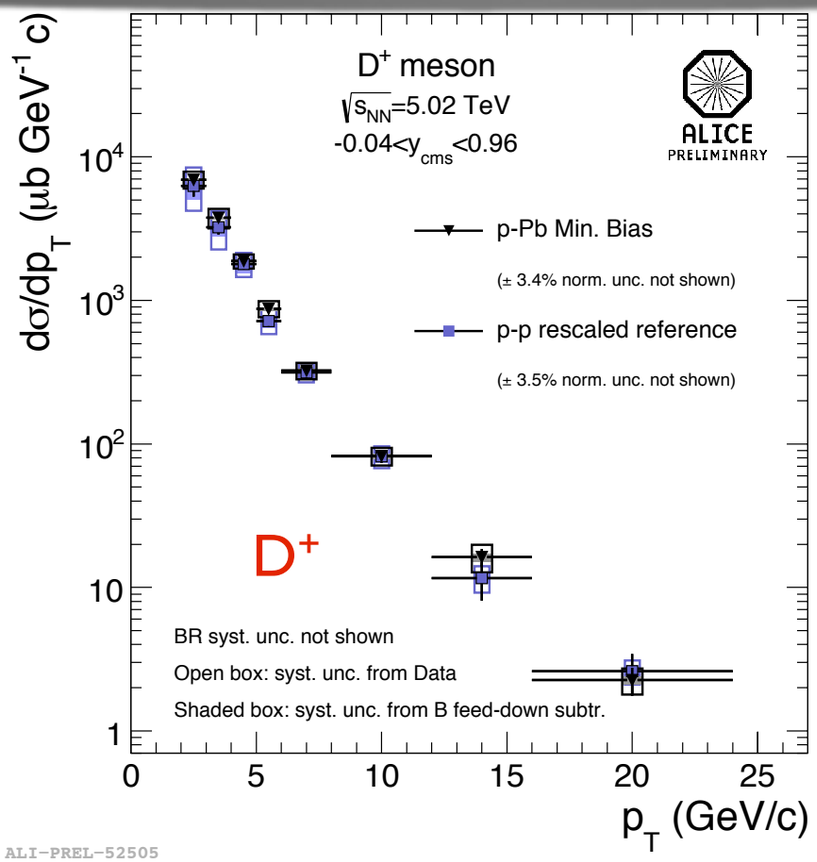
R. Averbeck, N. Bastid, Z. Conesa del Valle, A. Dainese, X. Zhang, arXiv:1107.3243 (2011)

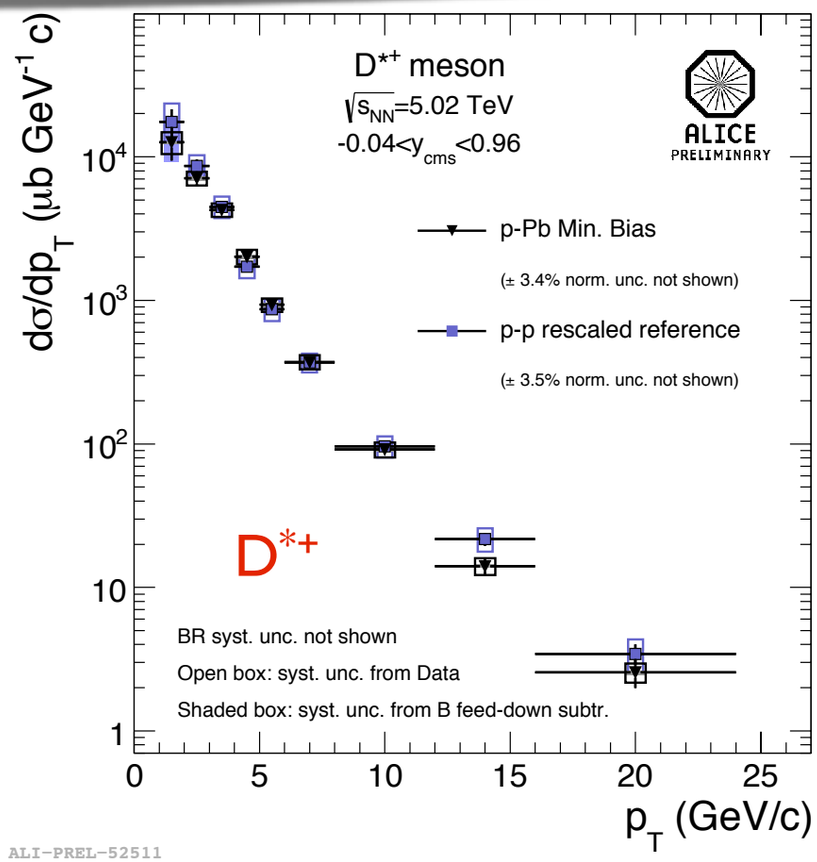
  - D meson cross section at 2.76 TeV and scaled 7 TeV measurement

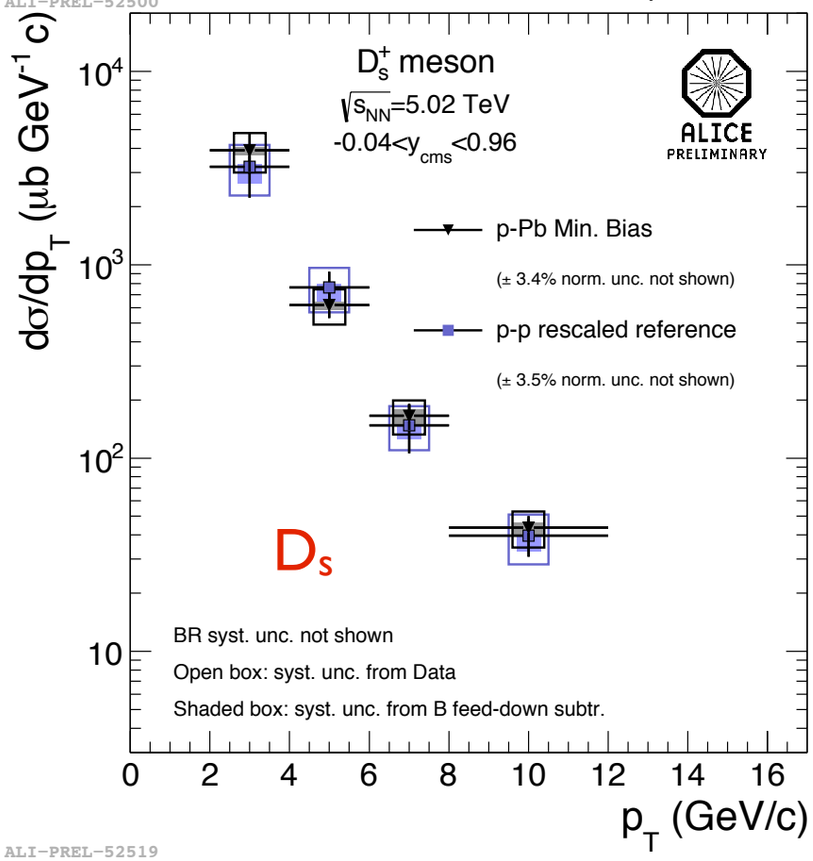
Good agreement between data at 2.76 TeV and scaled 7 TeV measurement

dσ/dp$_T$ in p-Pb









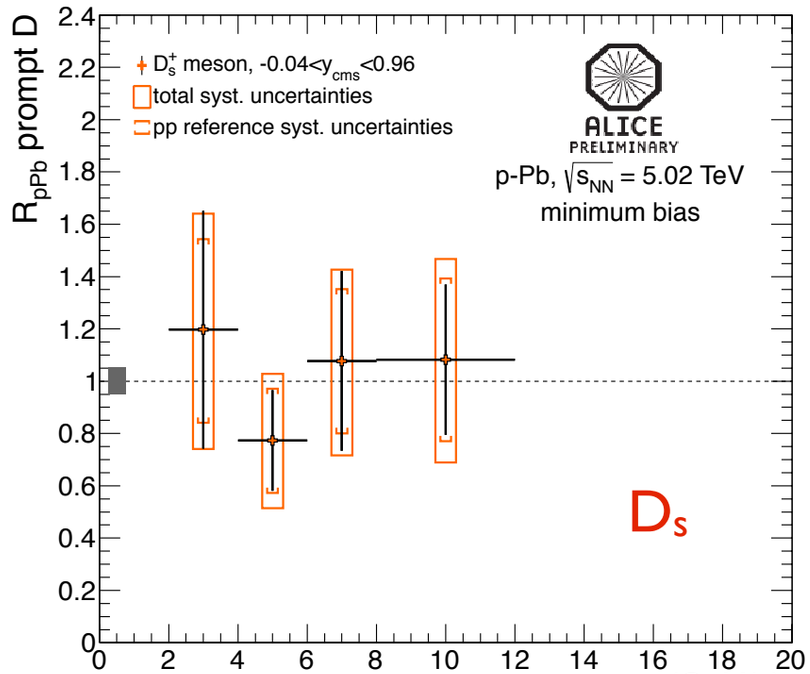
pp data at 7 TeV scaled to 5.02 TeV and multiplied by the Pb mass number

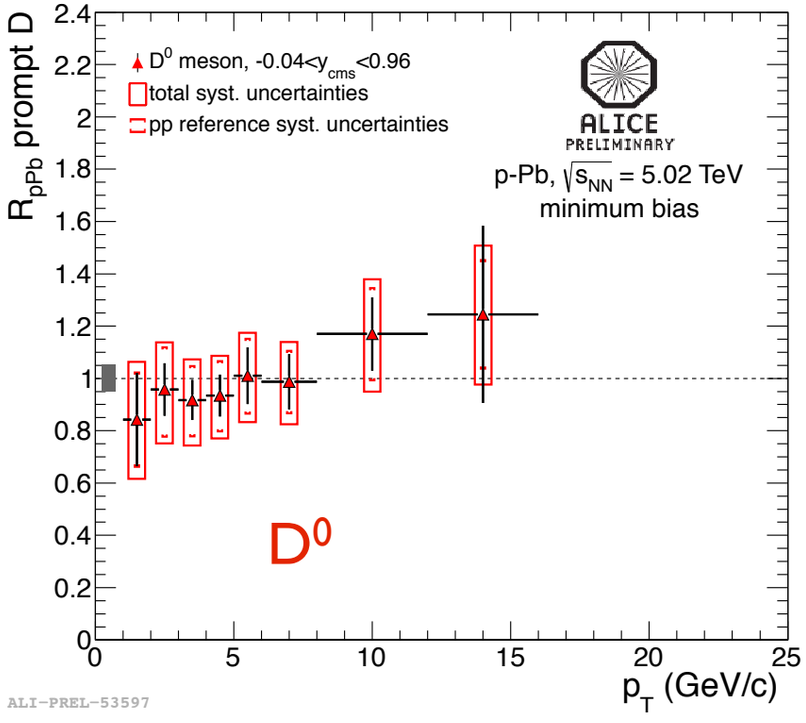
pp scaled and p-Pb cross sections compatible within uncertainties

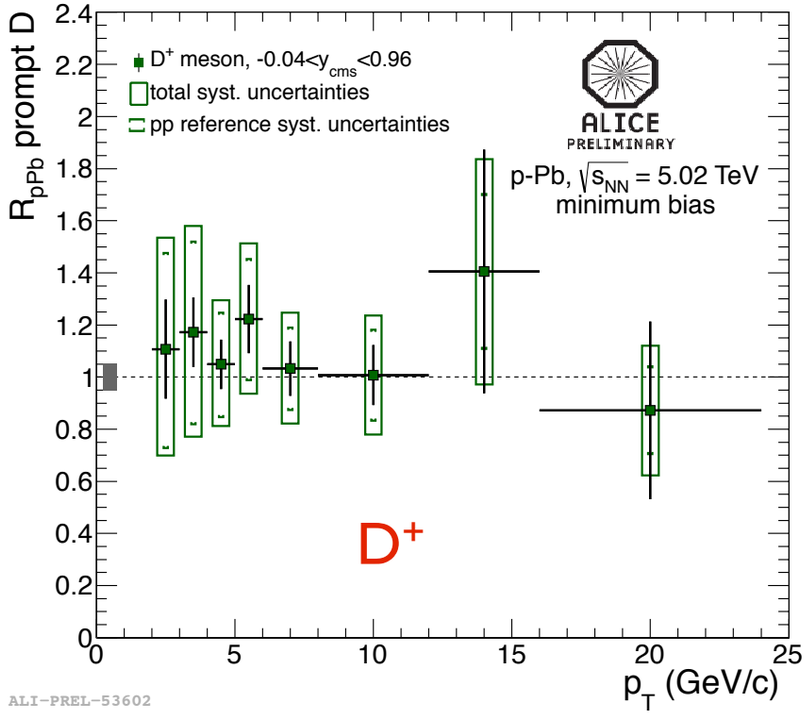
D meson nuclear modification factor in p-Pb

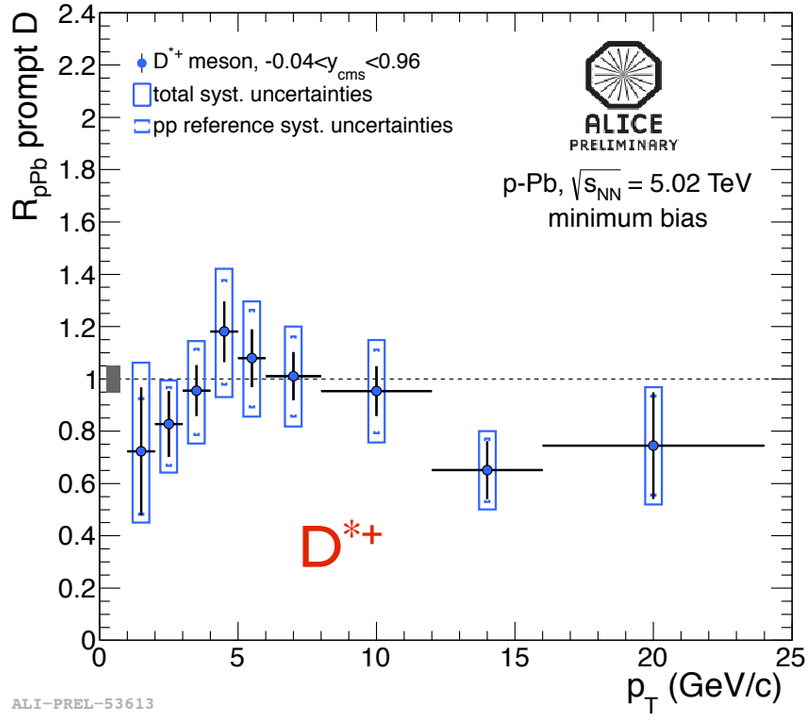
$$R_{pPb} = \frac{(d\sigma/dp_T)_{pPb}}{A \times (d\sigma/dp_T)_{pp}}$$

All measured R_{pPb} are compatible with unity within statistical and systematic uncertainties





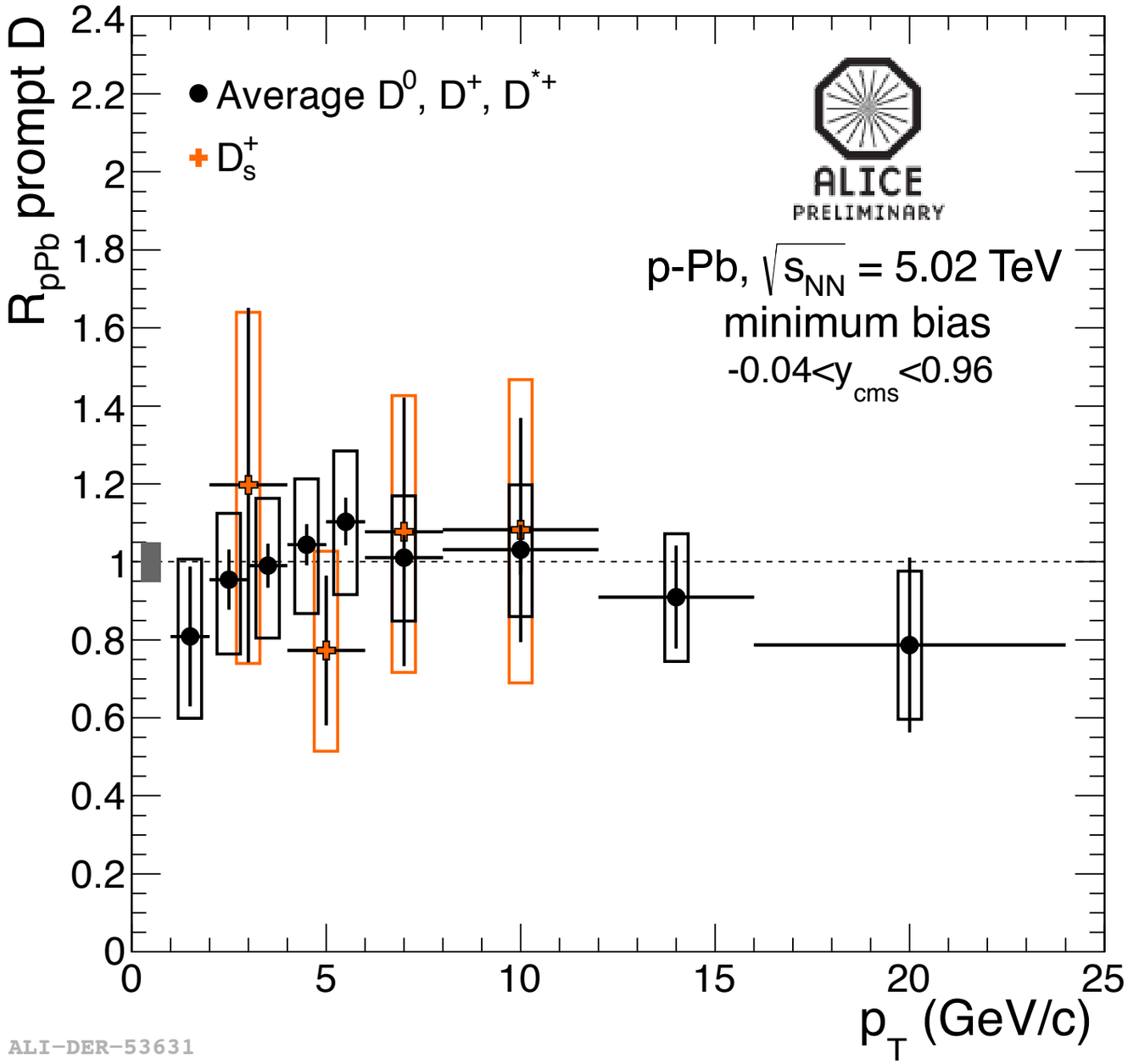




Average R_{pPb}

$$R_{pPb} = \frac{(d\sigma/dp_T)_{pPb}}{A \times (d\sigma/dp_T)_{pp}}$$

- Average R_{pPb} of D^0, D^+, D^{*+} compared with D_s R_{pPb}
- Compatible within uncertainties



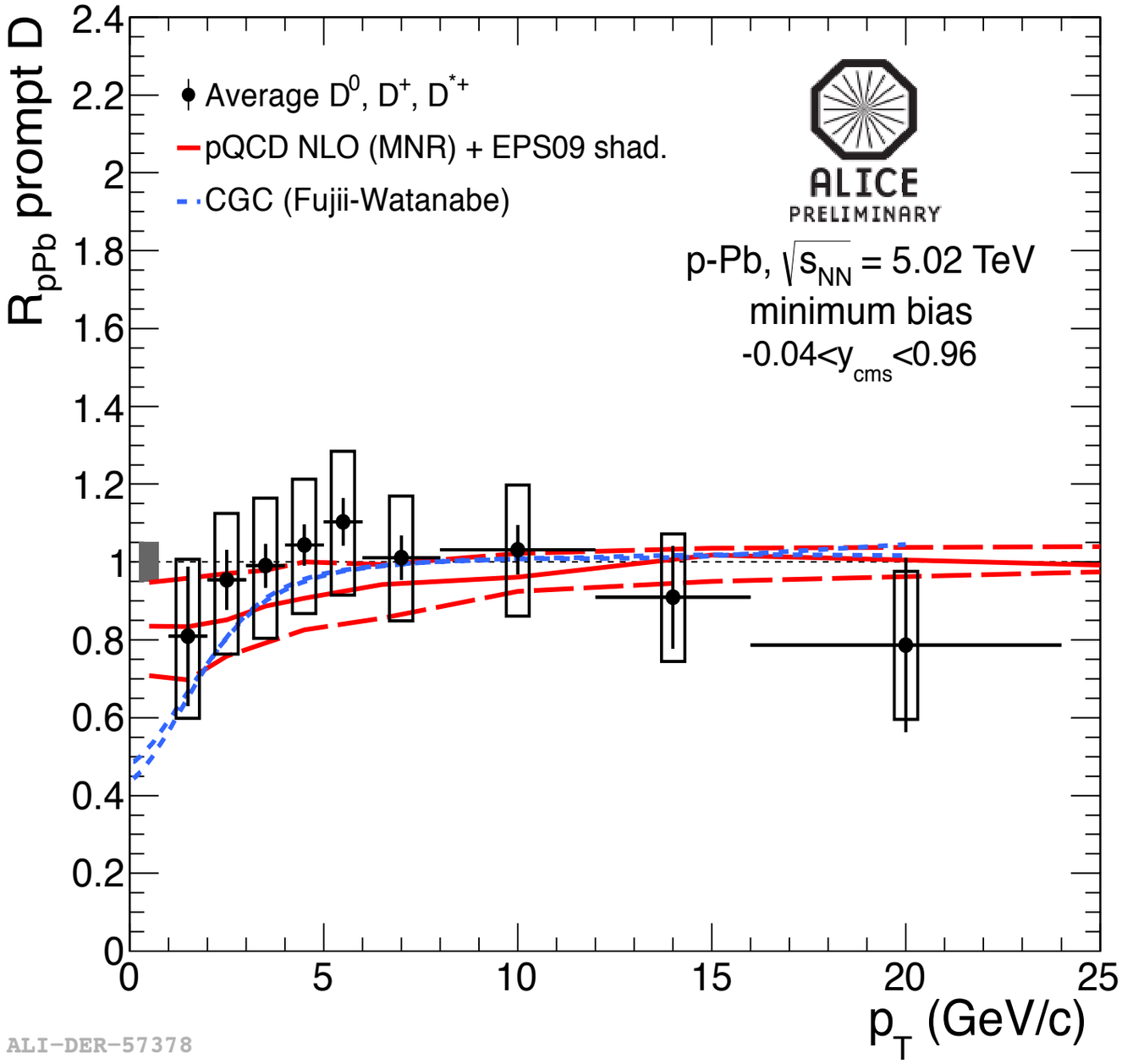
Comparison with model

$$R_{pPb} = \frac{(d\sigma/dp_T)_{pPb}}{A \times (d\sigma/dp_T)_{pp}}$$

- Average R_{pPb} compared with predictions from MNR + EPS09 shadowing parametrization and CGC

M. Mangano, P. Nason and G. Ridolfi, Nucl. Phys. B373 (1992) 295
K. J. Eskola, H. Paukkunen and C.A. Salgado, JHEP 0904 (2009) 065
Fujii - Watanabe, private communication

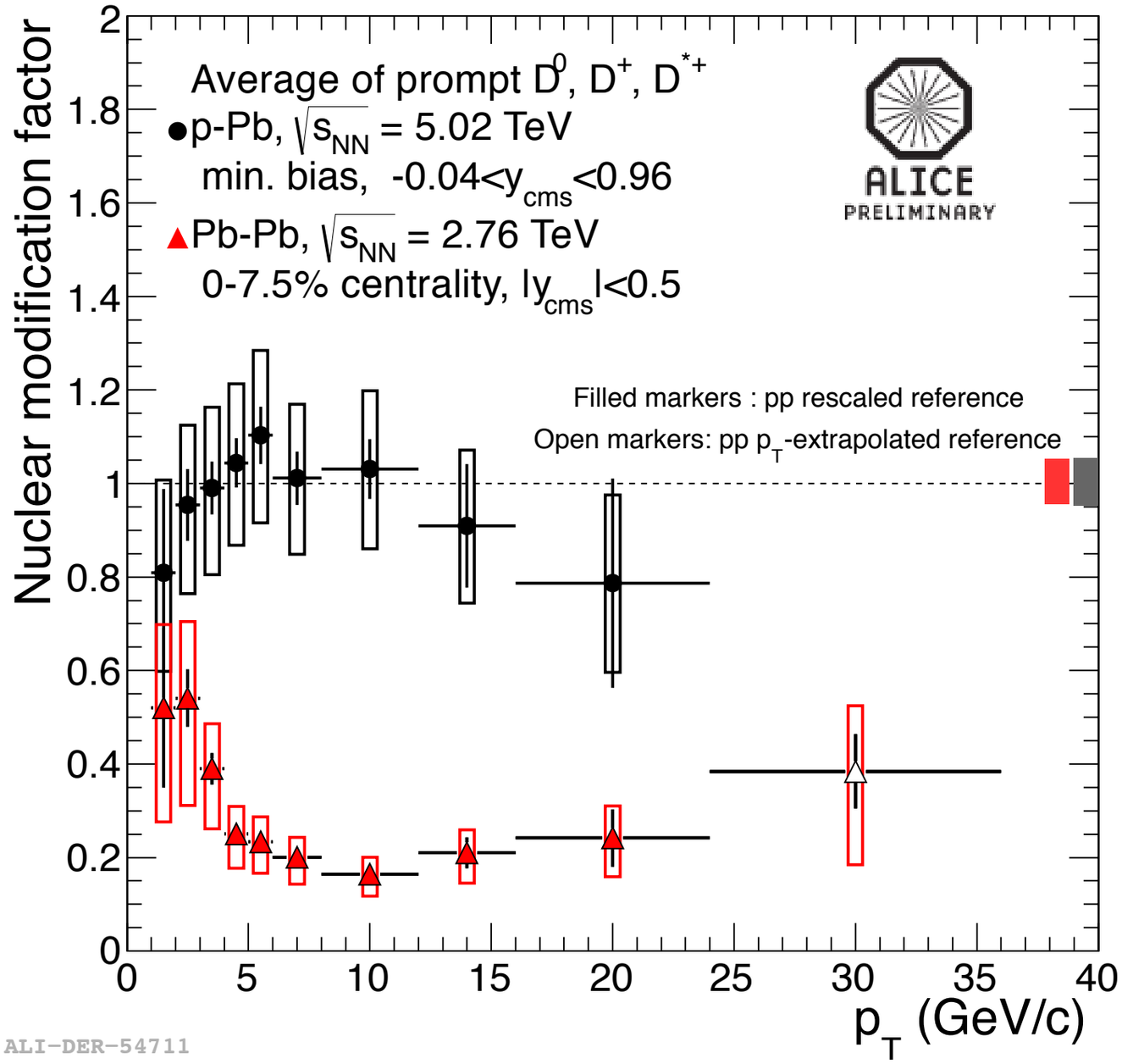
- Consistent within statistical and systematic uncertainties



Comparison with R_{PbPb}

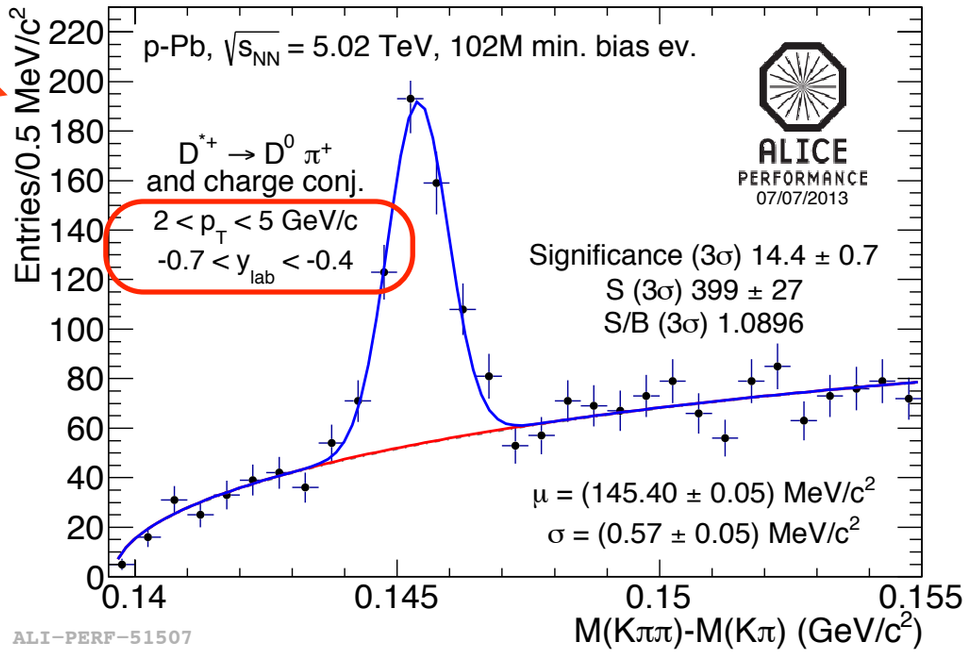
$$R_{pPb} = \frac{(d\sigma/dp_T)_{pPb}}{A \times (d\sigma/dp_T)_{pp}}$$

- D meson **R_{PbPb}** compared with **R_{pPb}**
- Observed suppression in Pb-Pb collisions is a final state effect

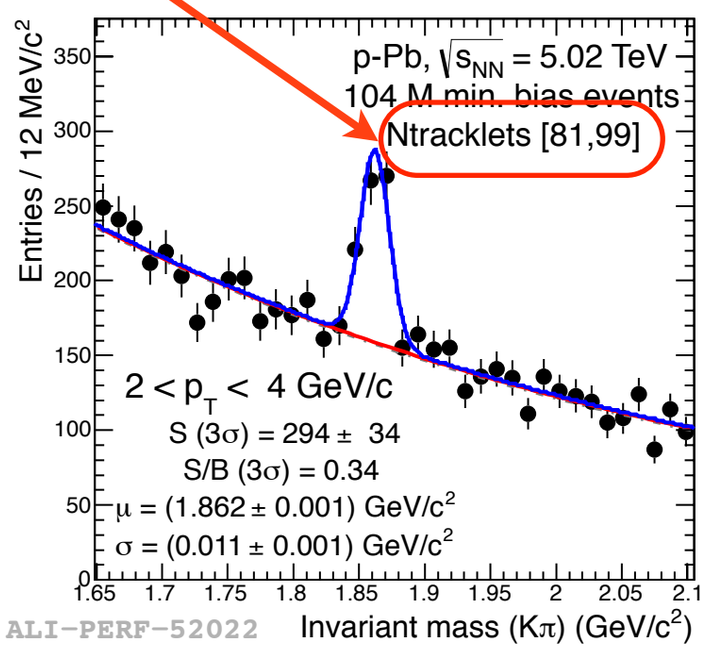


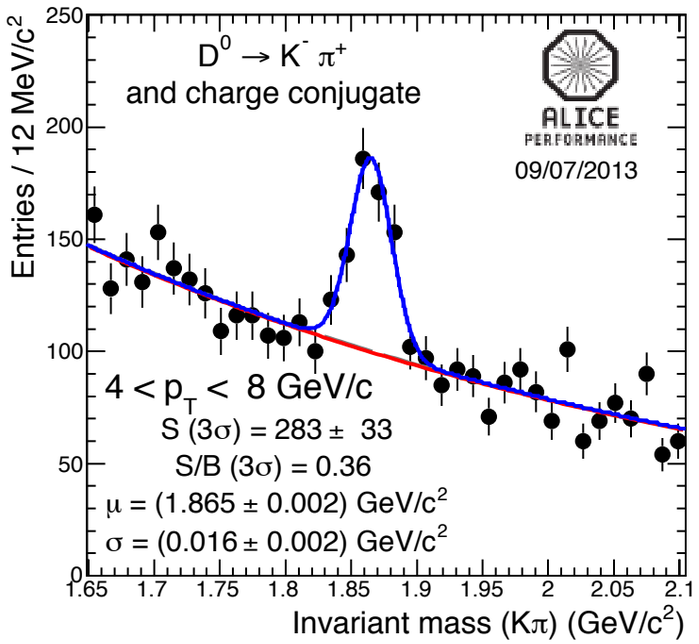
An outlook

- Signal in bins of rapidity
  - cross section as a function of y in a range $-0.8 < y_{lab} < 0.8$



- Signal in bins of charged particle multiplicity (estimated with the number of tracklets in the two innermost layers of the ITS)
  - Cross section as a function of the charged particle multiplicity





See **R. Bala** talk for the pp vs multiplicity measurement

Conclusions

- D meson cross section in p-Pb collisions and R_{pPb} measured in a wide p_T range:
  - [1,16] GeV/c for D^0, [1,24] GeV/c for D^{*+}, [2,24] GeV/c for D^+, [2,12] for D_s
- R_{pPb} is compatible with unity within statistical and systematic uncertainties
- Predictions from pQCD+EPS09 and CGC model describe the measured R_{pPb} within uncertainties

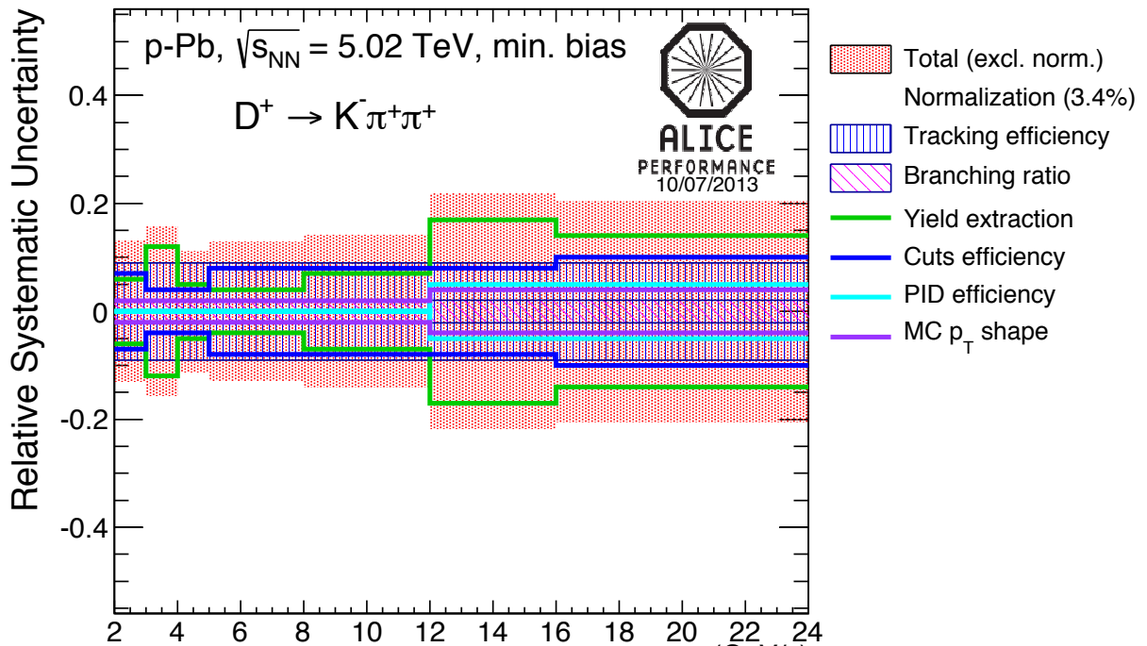
K. J. Eskola, H. Paukkunen and C. A. Salgado, JHEP 0904 (2009) 065
Fujii - Watanabe, private communication

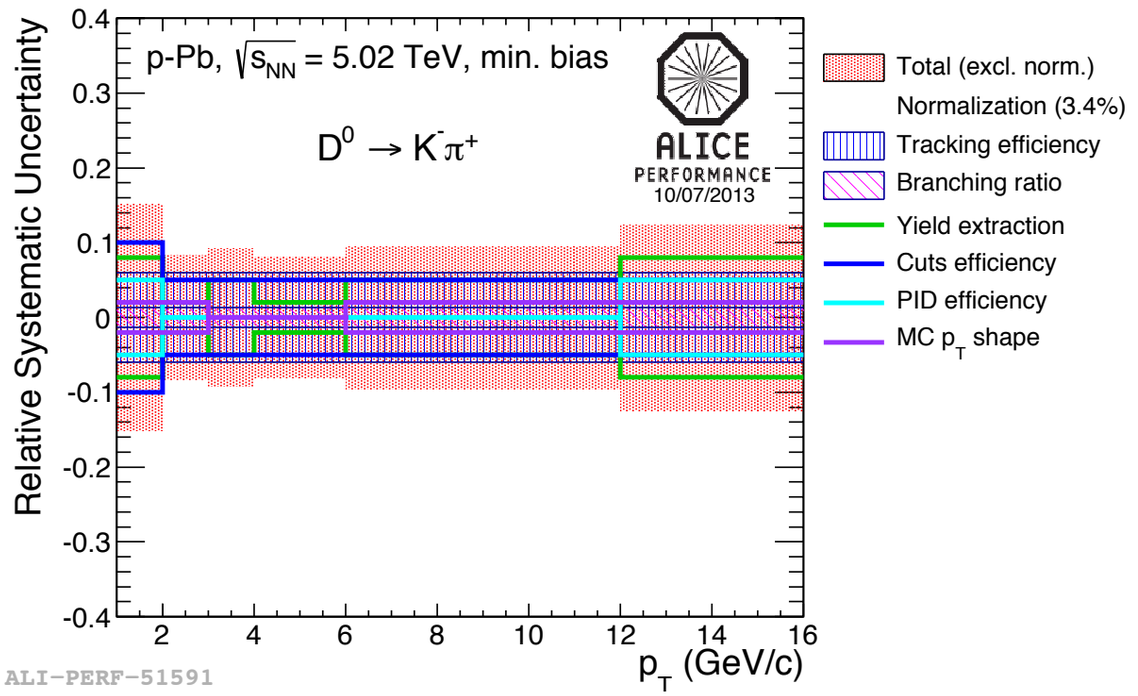
- D meson R_{pPb} measurement allows to confirm that the D meson suppression observed at high-p_T in Pb-Pb collisions is an effect due to hot nuclear matter
- Outlook: possibility to extract the signal in rapidity and N_{ch} bins

Back up slides

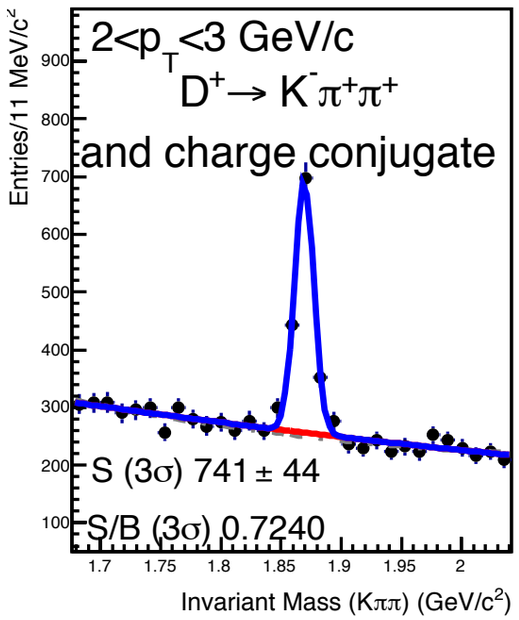
Summary of the systematic uncertainties

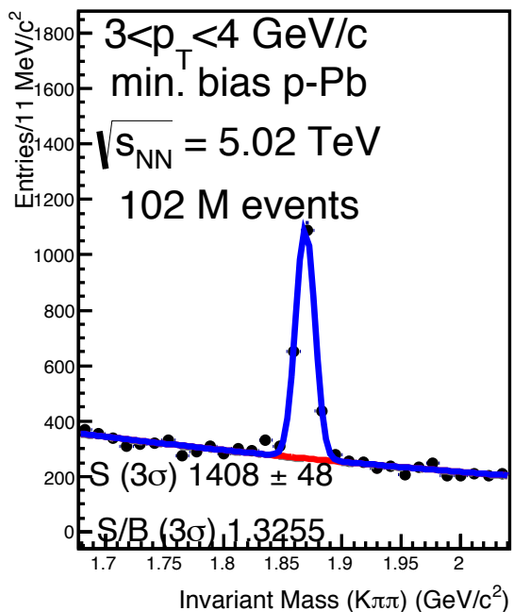
- Tracking efficiency
  - 3% for each track
- Yield extraction
  - from 2 to 20% (depending on the D meson and p_T)
- Cuts
  - from 2 to 20% (depending on the D meson and p_T)
- PID
  - ~5% at pT<2 GeV/c and pT>12 GeV/c
  - larger for D_s
- MC p_T shape
  - 2% at p_T<3 GeV/c and p_T>6 GeV/c
  - for Ds 4%

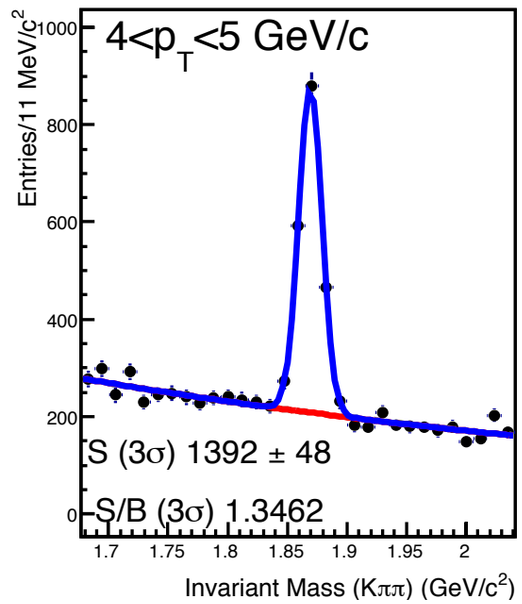


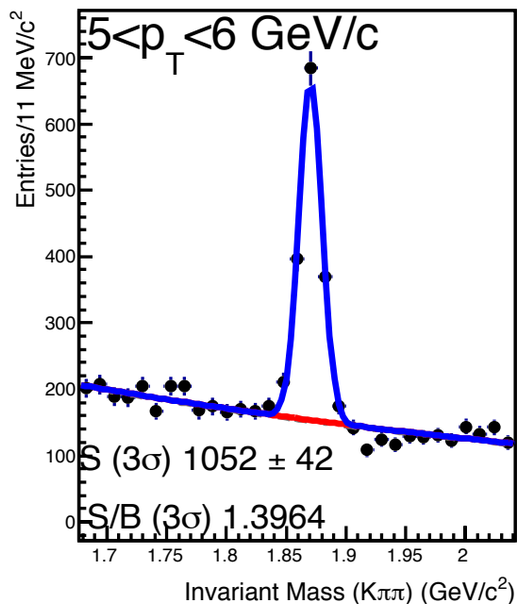


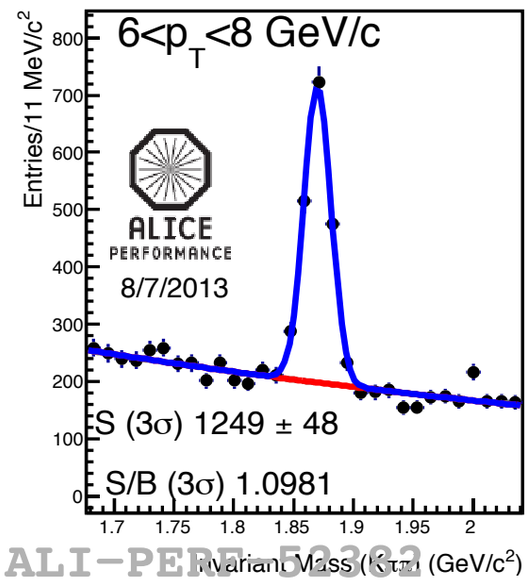
D^+ signal in p_T bins

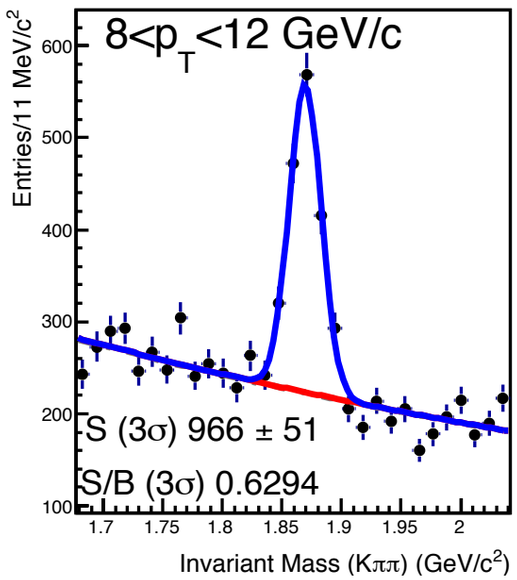


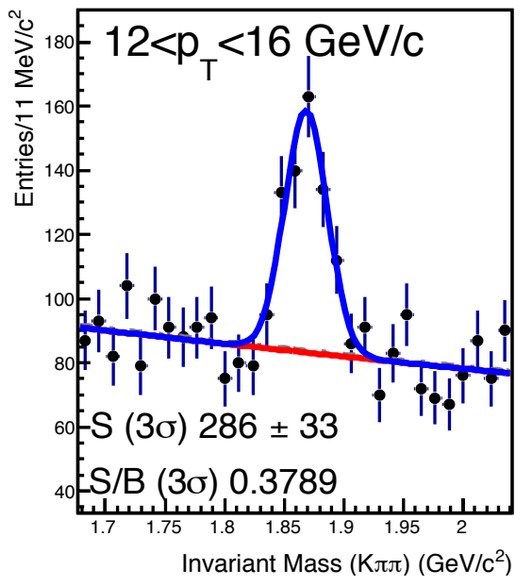


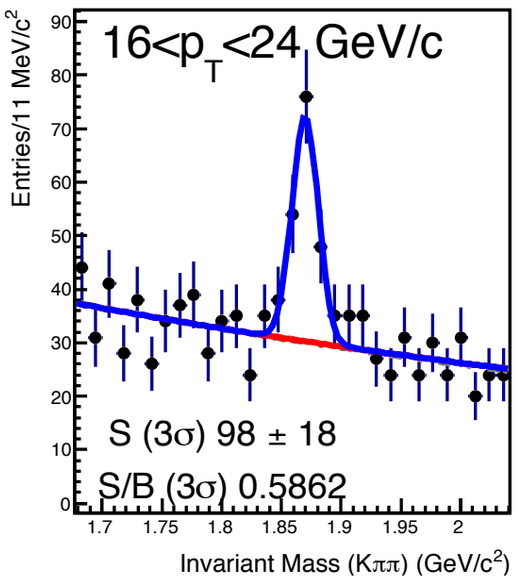




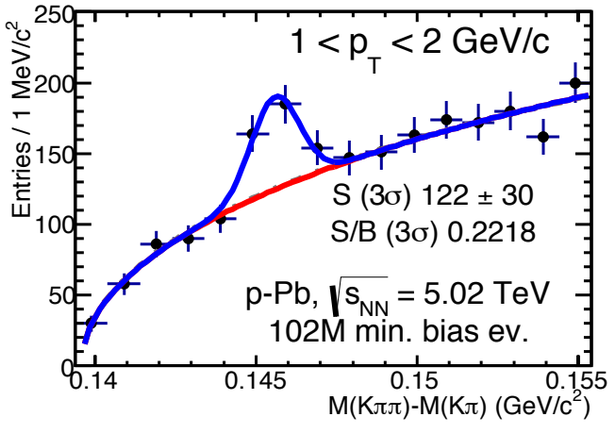


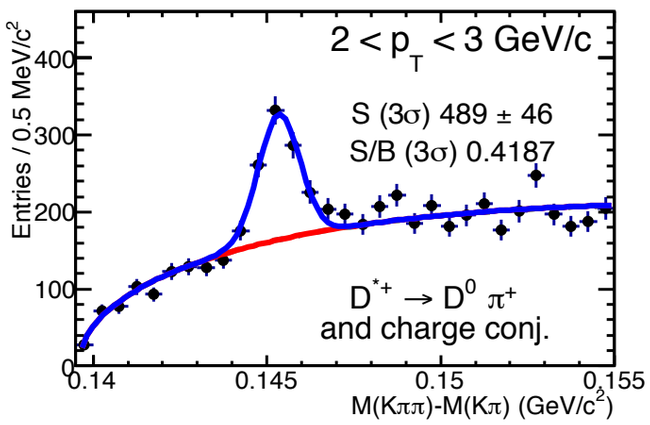


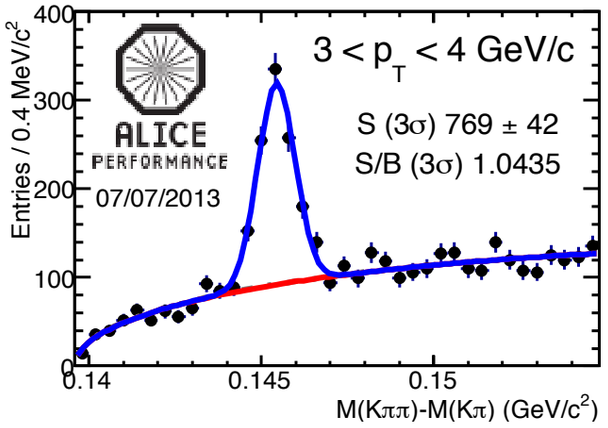


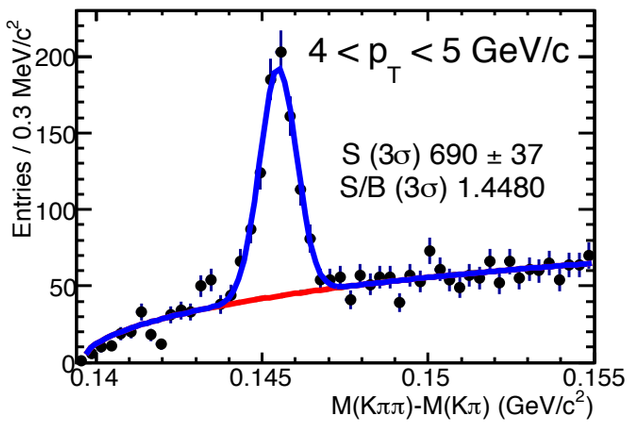


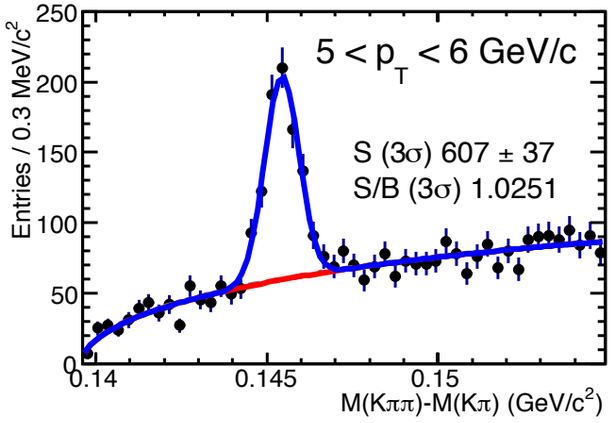
D^{*+} signal in p_T bins

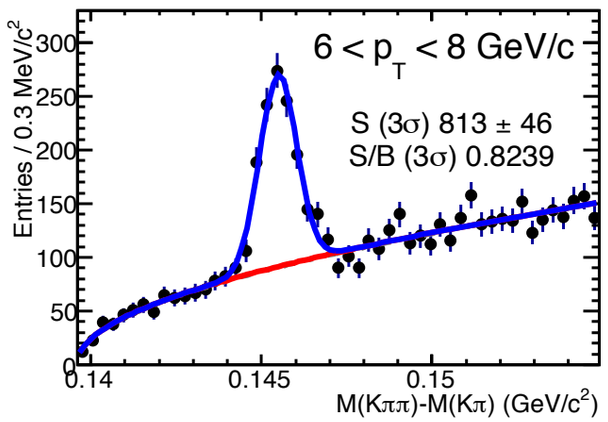


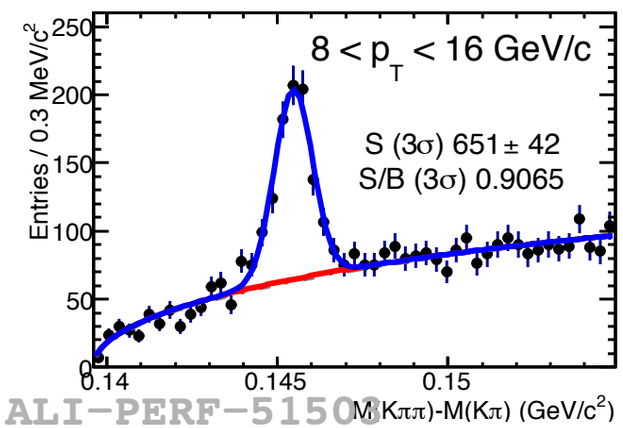


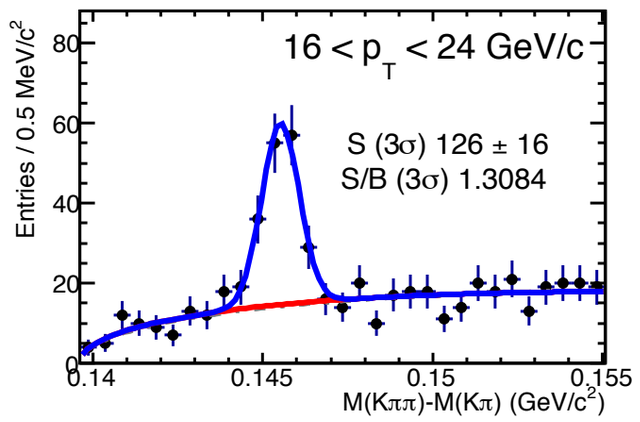


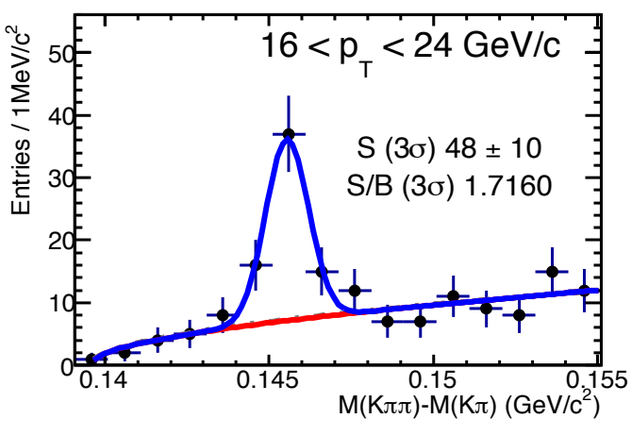






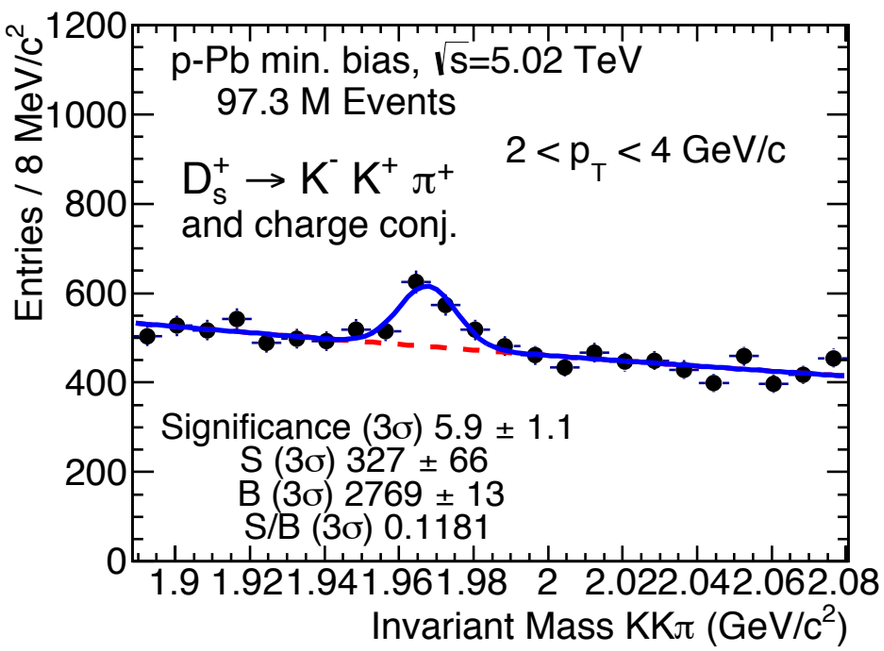


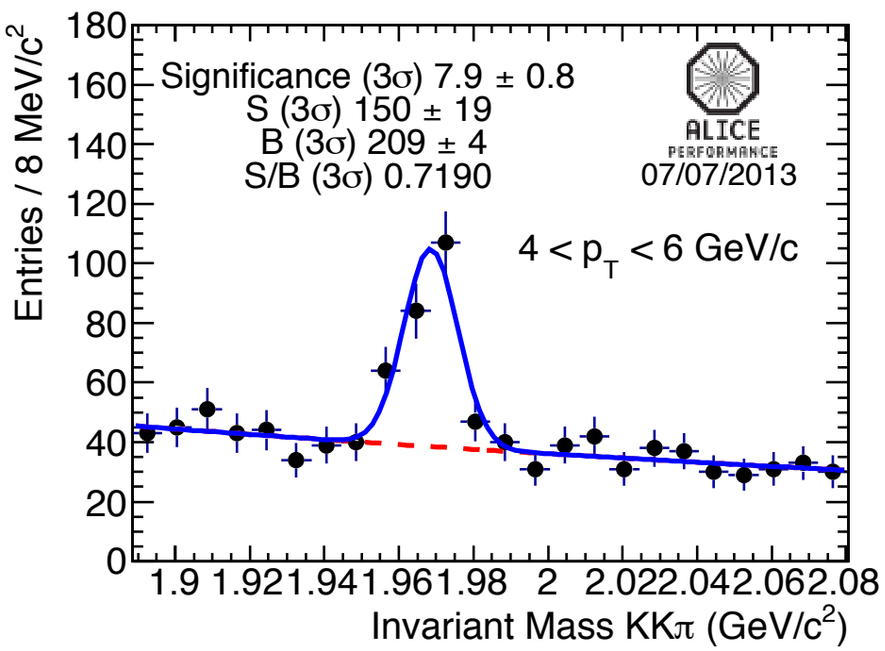


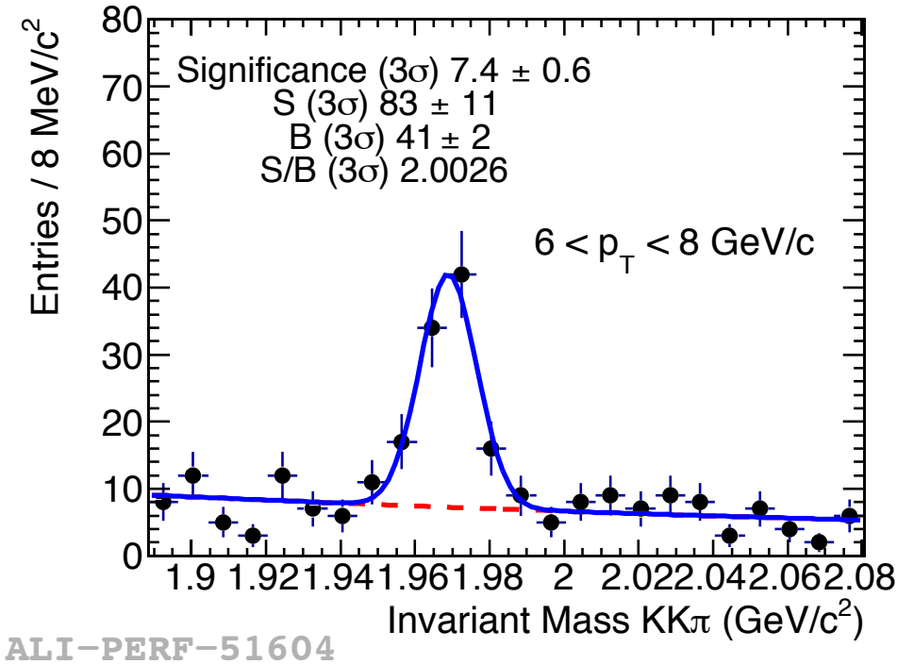


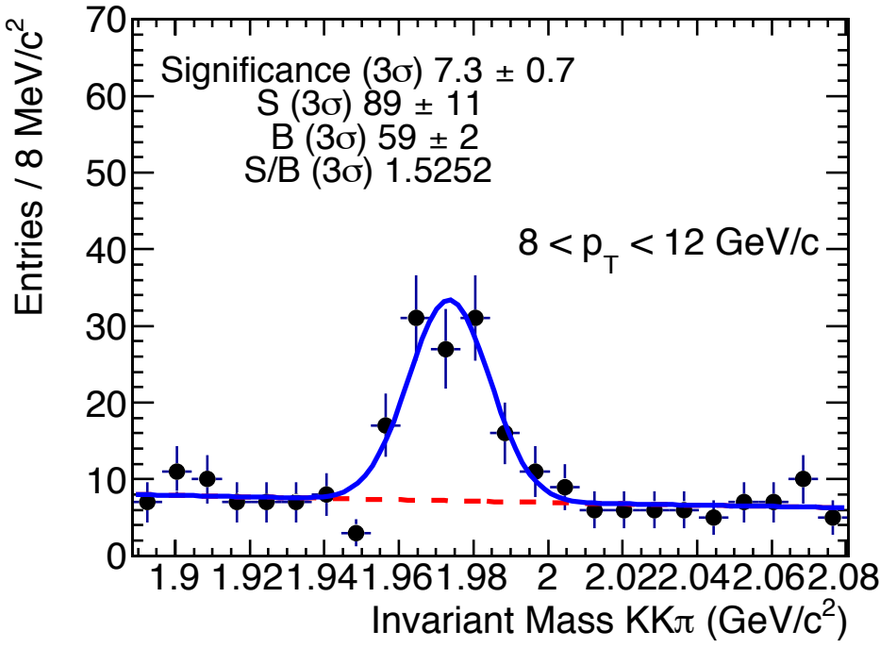
D_s signal in p_T bins

D_s
Signal in 4 p_T bins from 2 to 12 GeV/c









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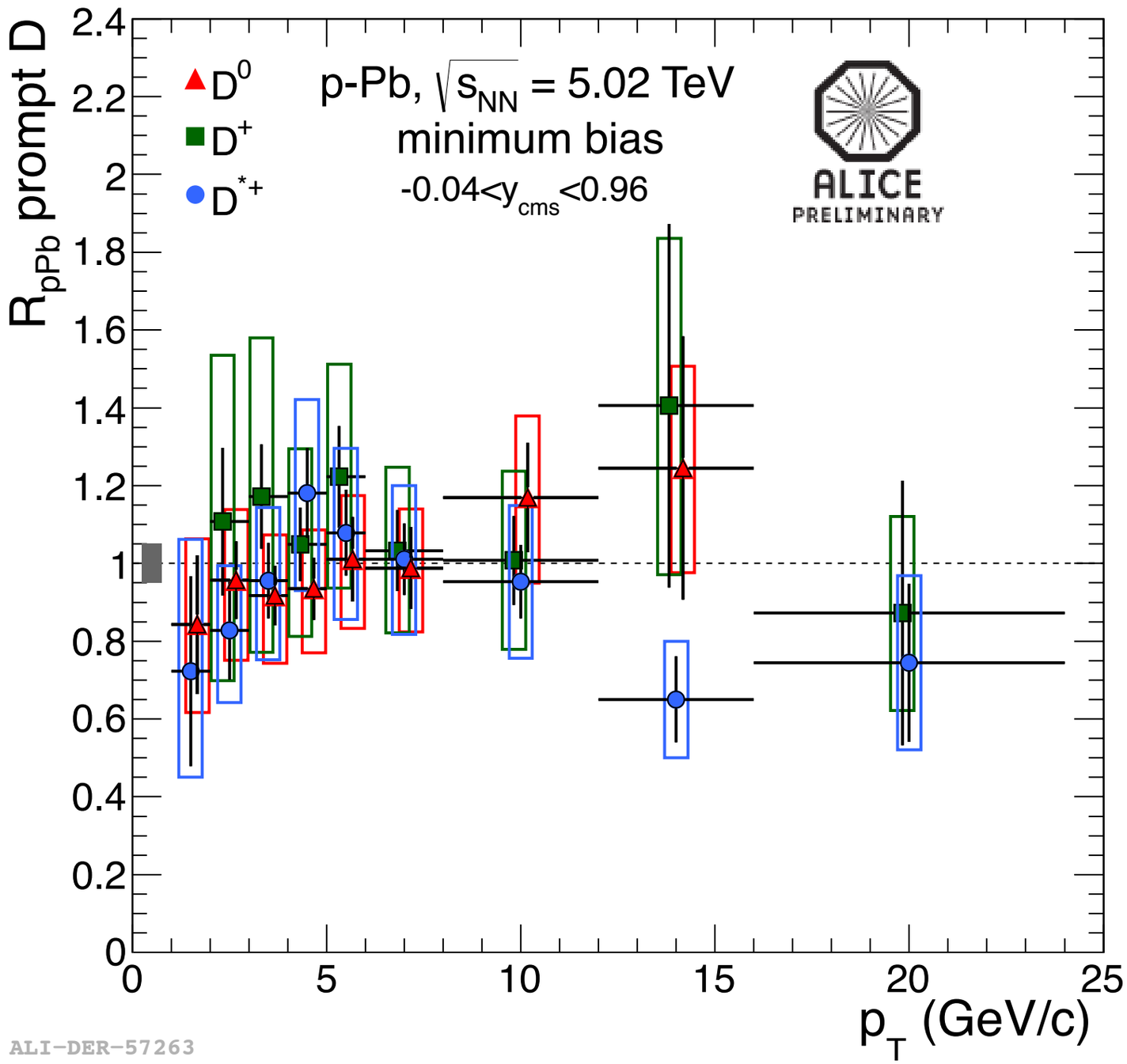
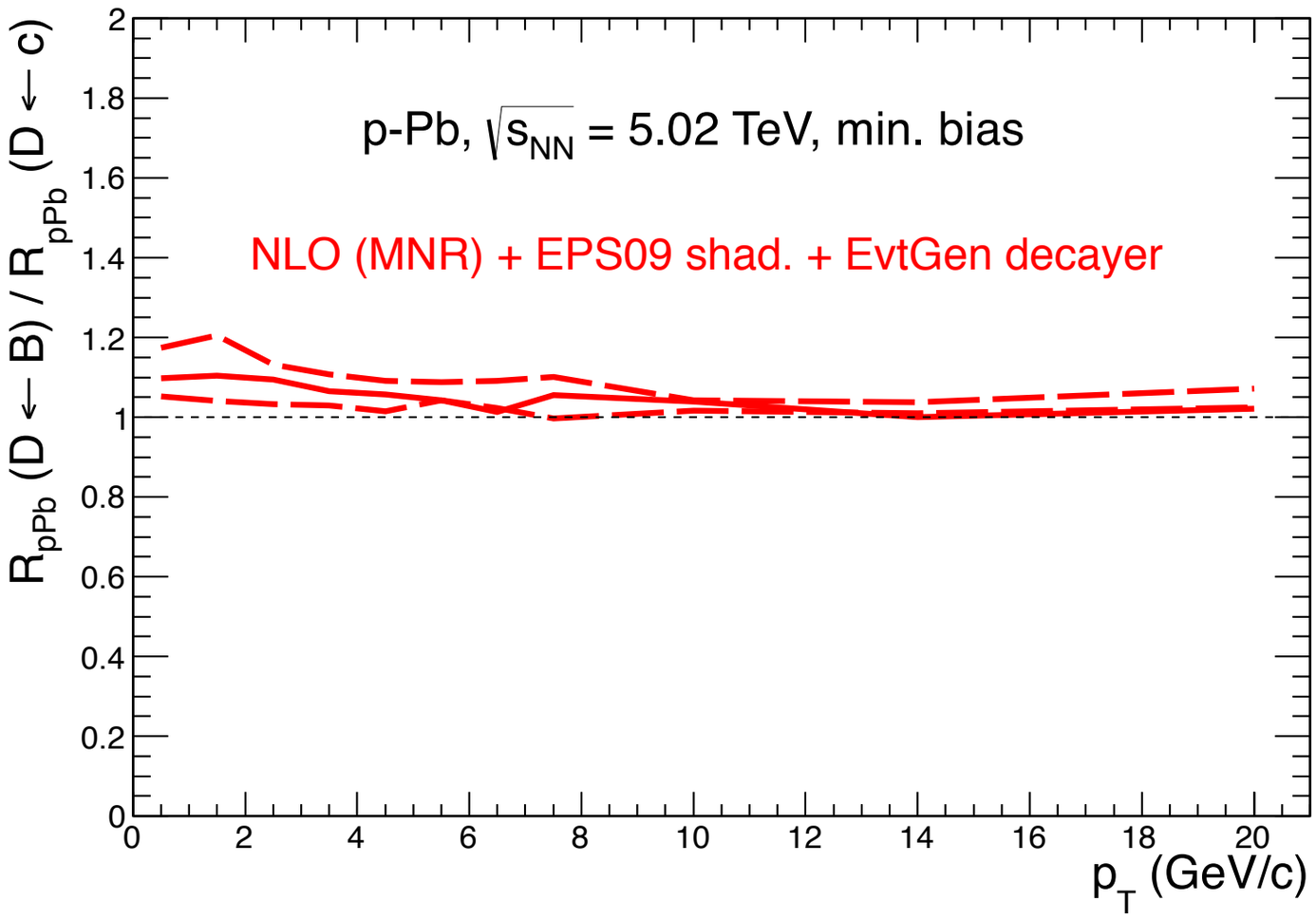
R_{pA} D^0, D^+, D^{*+}


R_{pPb} prompt D
D^0
D^+
D^{*+}
p-Pb, $\sqrt{s_{NN}}$ = 5.02 TeV
minimum bias
-0.04<y_{cms}<0.96
ALICE
PRELIMINARY
p_T (GeV/c)
ALI-DER-57263

R_{pA} shadowing predictions for B and D mesons

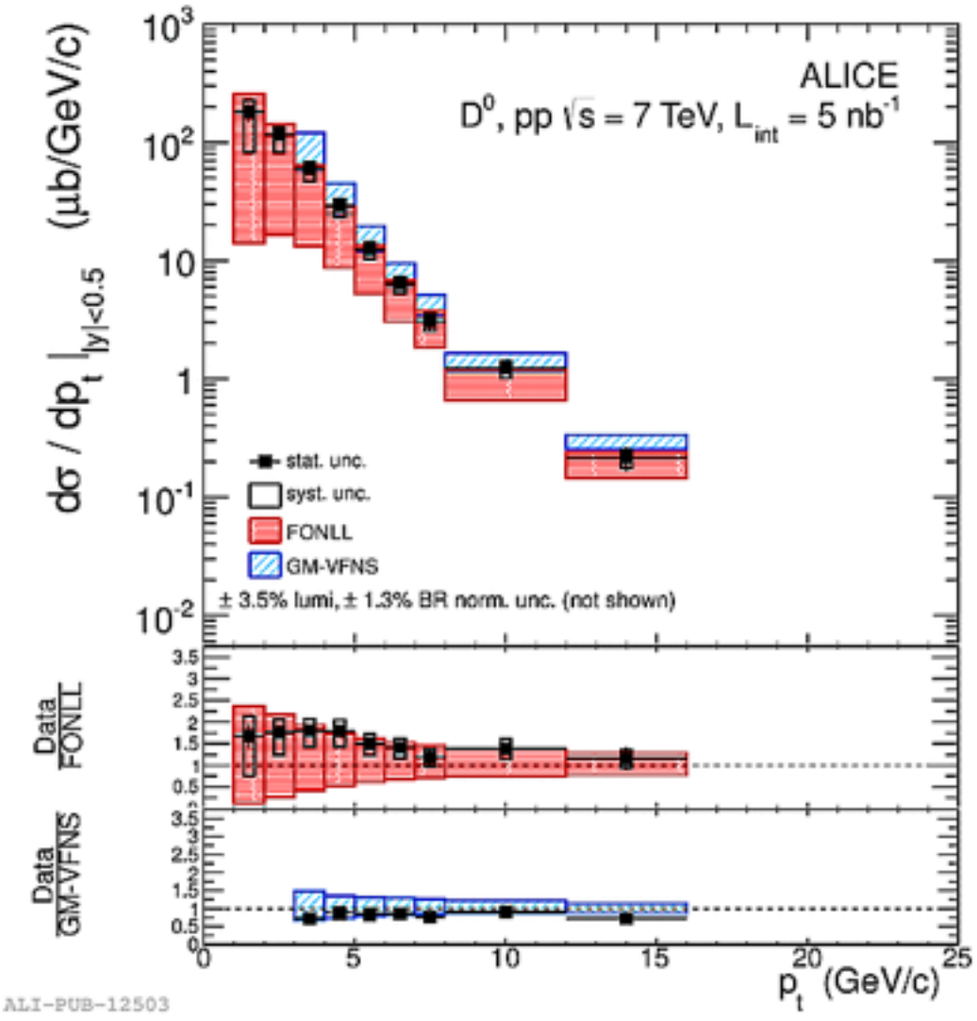


K. J. Eskola, H. Paukkunen and C.A. Salgado, JHEP 0904 (2009) 065

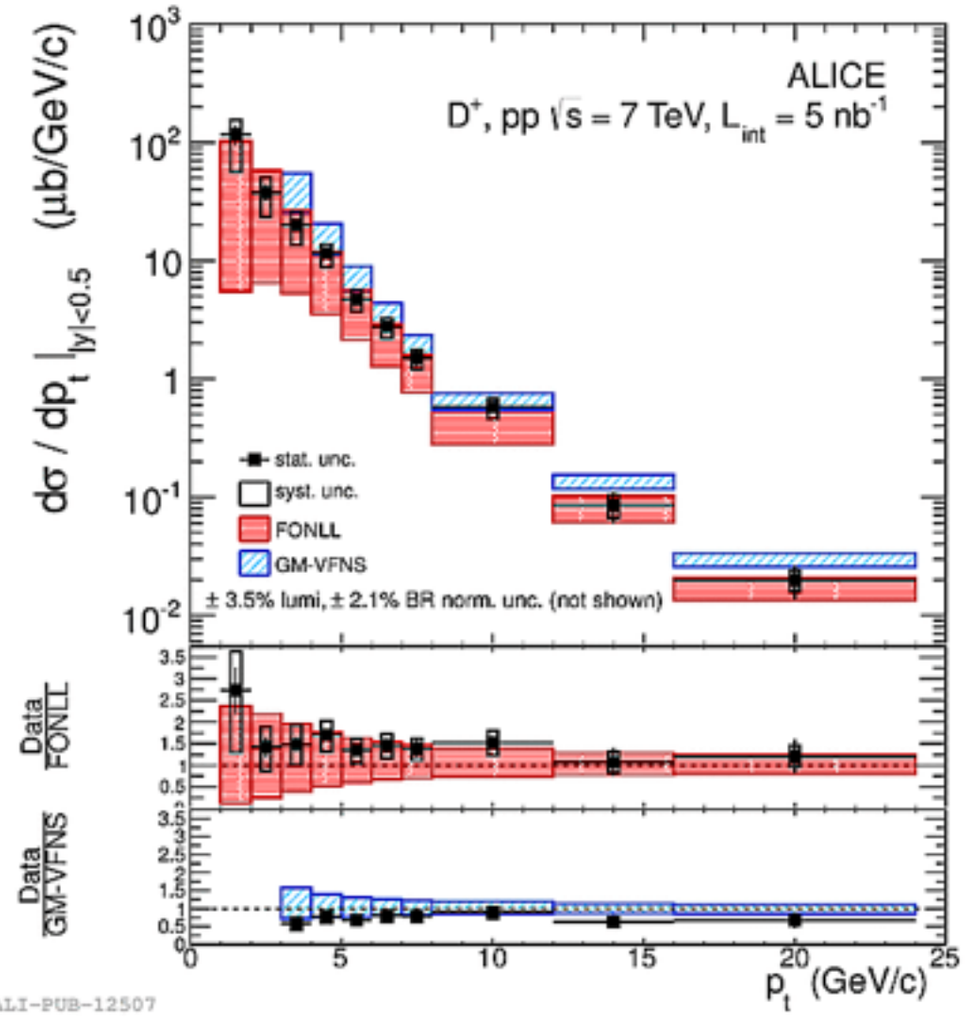
M. Mangano, P. Nason and G. Ridolfi, Nucl. Phys. B373 (1992) 295
K. J. Eskola, H. Paukkunen and C.A. Salgado, JHEP 0904 (2009) 065

pp cross sections at 7 TeV

ALICE Coll., JHEP 01 (2012) 128

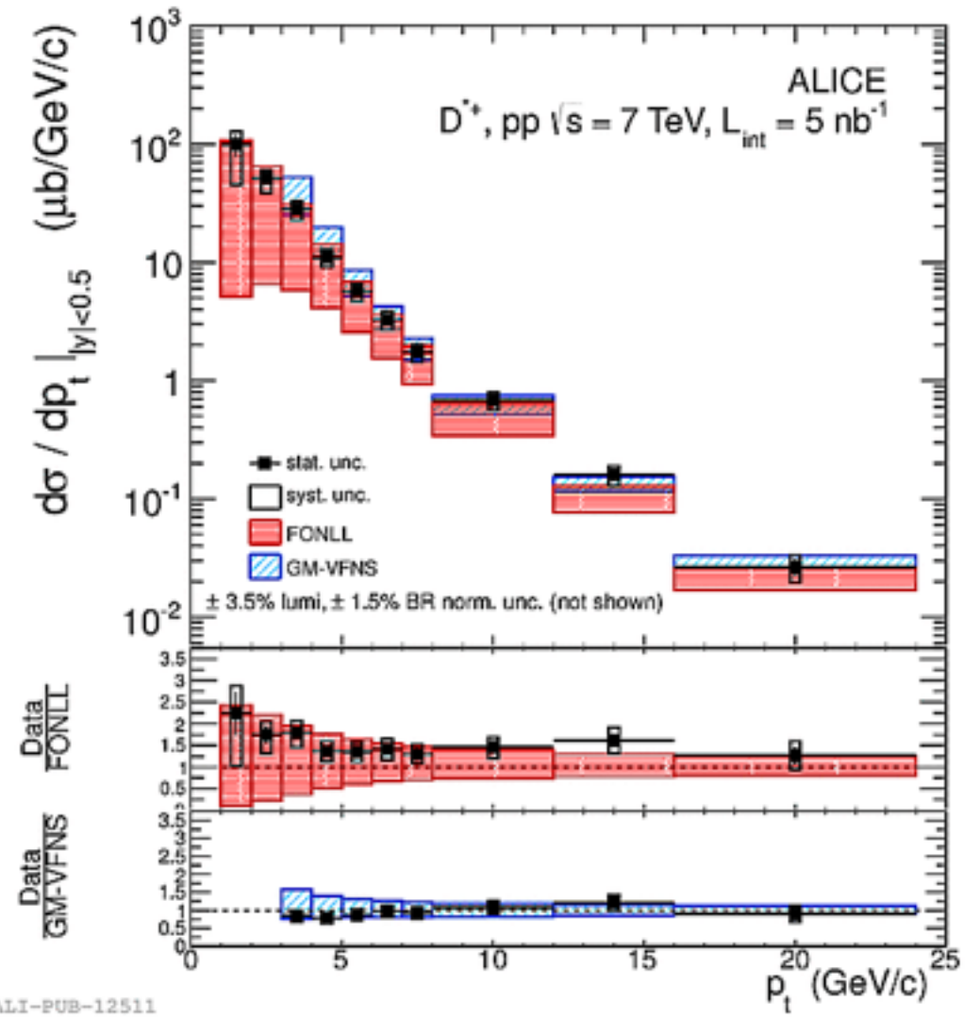


ALICE Coll., JHEP 01 (2012) 128



pp cross sections at 7 TeV

ALICE Coll., JHEP 01 (2012) 128



ALI-PUB-12511

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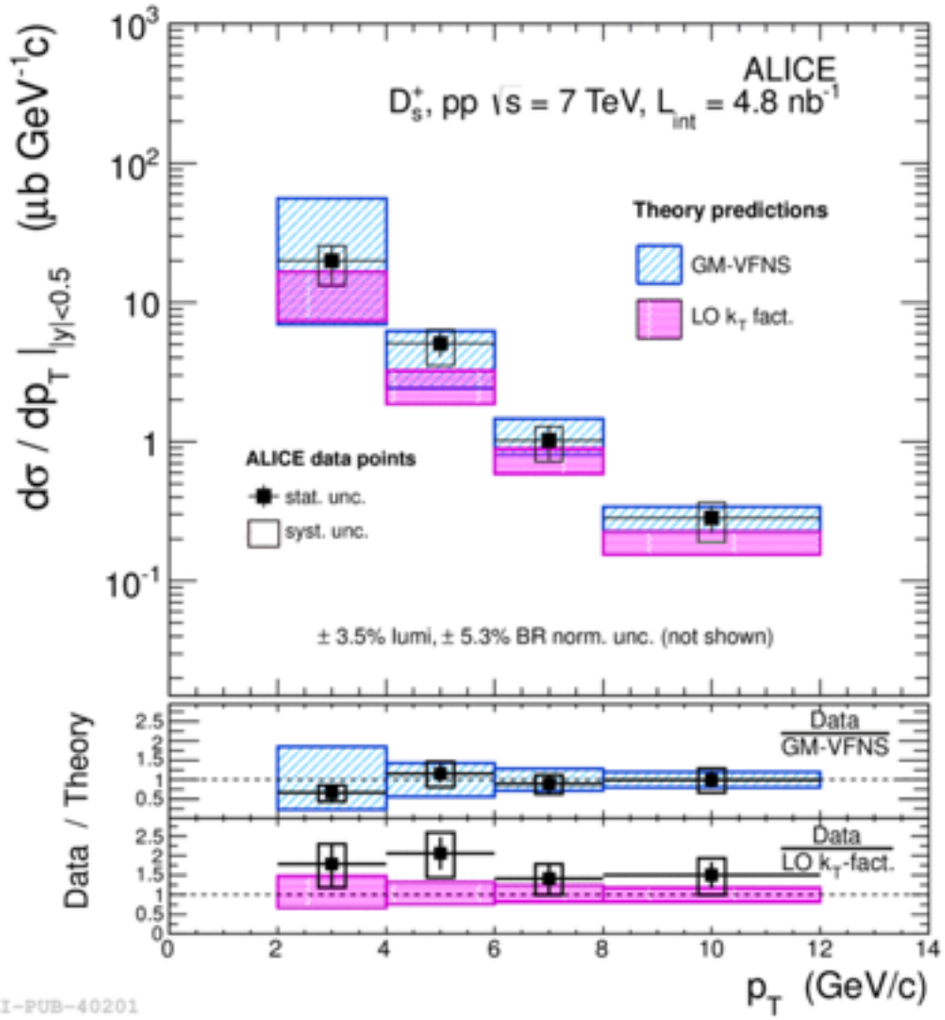

ALI-PUB-40201