Heavy-Flavor measurements in proton-proton collisions with ALICE at the LHC

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Heavy-flavor – A probe for pQCD

- Heavy quarks: charm, beauty
  $m_c \sim 1.5 \text{ GeV}/c^2$
  $m_b \sim 5 \text{ GeV}/c^2$

- Produced in hard partonic collisions

- Short formation time

- High q^2 allows perturbative calculations

- Heavy-flavor production at the LHC
  - Large production cross section
  - $\sqrt{s} = 7$ TeV provides higher energy domain for pQCD tests: $3.5 \times \sqrt{s}_{Tevatron}$
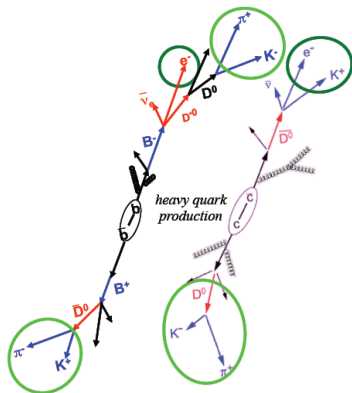
In this talk

- Heavy-flavor measurements in ALICE

- D-meson cross sections

- Measurements of semileptonic decays
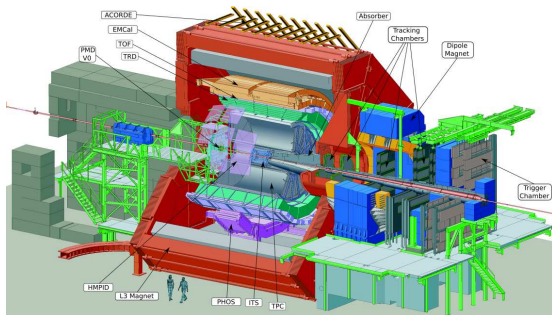
Heavy-Flavor measurements in ALICE

Ground states of heavy-flavor hadrons decay via weak interaction
→ decay lenght D mesons: $c\tau$ 100-300 μm, B mesons: $c\tau \sim 500$ μm

- Hadronic decays: D → hadrons
  $| \eta | < 0.8$, $p_{\mathrm{T}} > 1$ GeV/c

- Semileptonic decays:
  b/c → e + X : $| \eta | < 0.8$, $p_{\mathrm{T}} > 0.5$ GeV/c

  b/c → μ + X : $-4 < \eta < -2.5$, $p_{\mathrm{T}} > 2$ GeV/c

- Involved detectors
  - ITS: tracking, vertexing
  - TPC: tracking, PID
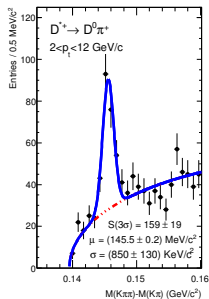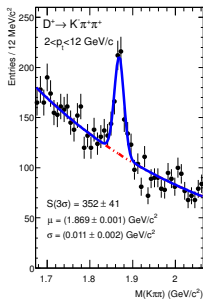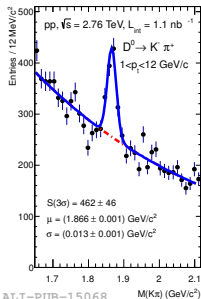 - TOF: PID
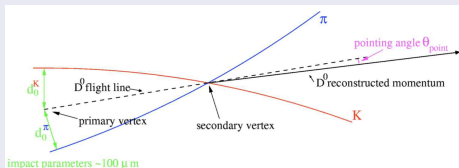 - TRD: PID
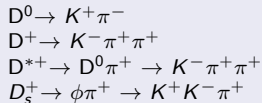 - EMCAL: PID
  - MUON: tracking, PID

D-meson cross sections

D-meson measurement

Search for secondary vertices

Displacement by a few hundred μm from interaction vertex

$D^0 \rightarrow K^+\pi^-$
$D^+ \rightarrow K^-\pi^+\pi^+$
$D^{*+} \rightarrow D^0\pi^+ \rightarrow K^-\pi^+\pi^+$
$D_s^+ \rightarrow \phi\pi^+ \rightarrow K^+K^-\pi^+$
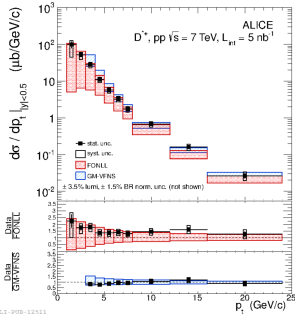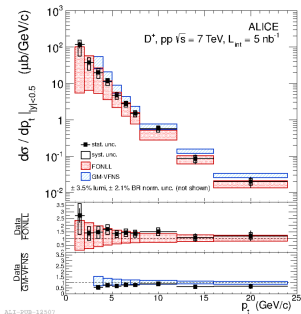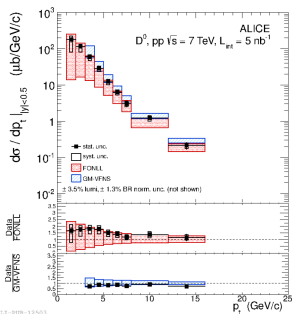

- topological analysis for secondary vertices
- invariant mass analysis
- PID reduces combinatorial background

Left to right: Invariant-mass spectrum of $D^0 + \overline{D^0}$ and $D^+ + D^-$ candidates, and invariant-mass difference, $\Delta m = m_{K\pi\pi} - m_{K\pi}$, for $D^{*+} + D^{*-}$ candidates in pp collisions at $\sqrt{s}$=2.76 TeV.

JHEP 07 (2012) 191

ALI-PUB-15068

D-meson cross sections in pp collisions at $\sqrt{s} = 7$ TeV

B. Abelev et al., JHEP 1201 (2012) 128

- D^0: $|y| < 0.5$ $1 < p_T < 16$ GeV/c (9 bins)
- D^+, D^{*+}: $|y| < 0.5$ $1 < p_T < 24$ GeV/c (10 bins)
- Contribution from b feeddown estimated using a FONLL prediction
- Data well described by pQCD calculations

     $\Rightarrow$ Fixed-Order-Next-to-Leading-Log (FONLL) Cacciari et al., JHEP 1210 (2012) 137
     $\Rightarrow$ General-Mass Variable-Flavor-Number Scheme (GM-VFNS) Kniehl et al., Eur.Phys.J. C72 (2012)
     $\Rightarrow$ k_t factorization approach Maciula, Szczurek, arXiv:1301.3033
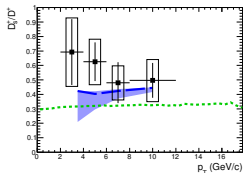
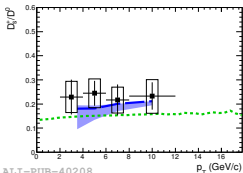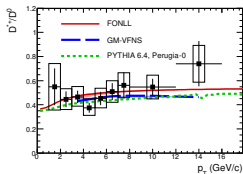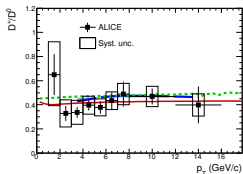# Measurement of charm-strange meson D_s^+
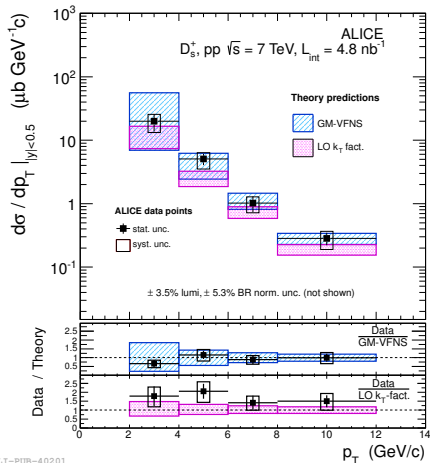
- p_T differential inclusive cross section for prompt D_s^+ meson production
- pp collisions at $\sqrt{s} = 7$ TeV
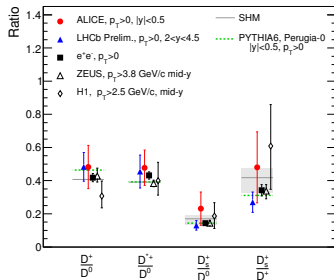- Good Agreement with theoretical predictions from GM-VFNS and from k_t-factorization at LO

B. Abelev et al., PLB 718 (2012), pp. 279-294

Ratios of D-meson yields

Comparison to models and other experiments
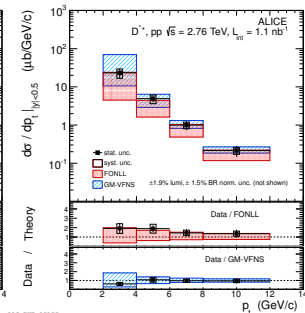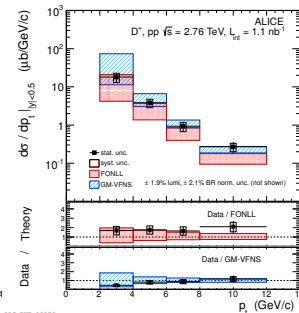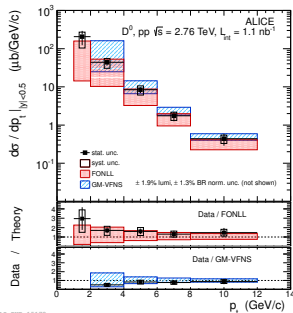

SHM - Statistical Hadronization Model

B. Abelev et al., PLB 718 (2012), pp. 279-294

- Model calculations show good agreement with data
- Good agreement between ALICE and LHCb
- Charm-strange mesons suppressed in the fragmentation of charm quark – suppression looks similar at different energies and in other systems
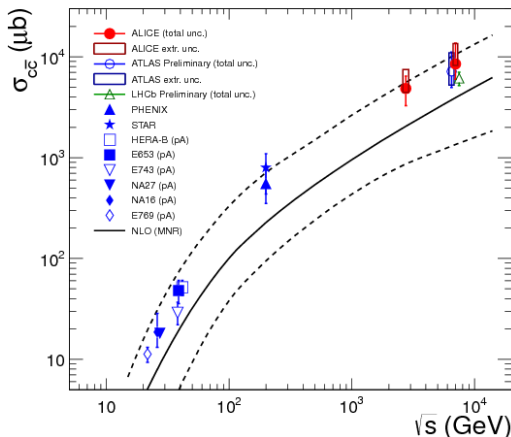
D-meson cross sections in pp collisions at $\sqrt{s} = 2.76$ TeV

B. Abelev et al., JHEP 1207 (2012) 191

- p_T range: $2 < p_T < 12 \text{ GeV}/c$
- Limited statistics
- Described within uncertainties by FONLL and GM-VFNS

# Total charm production cross section & evolution with $\sqrt{s}$

B. Abelev et al., JHEP 1207 (2012) 191

- Total nucleon-nucleon charm production cross section (pp)
- In case of proton-nucleus (pA) or deuteron-nucleus (dA) collisions, measured cross sections scaled down by the number of binary nucleon-nucleon collisions (Glauber model calculation)
- Compared to NLO MNR calculation represented by solid - uncertainties dashed - lines. (Nucl. Phys. B 373 1992 295)

$\Rightarrow$ Agreement with predictions within uncertainties of the calculation, data fall in the upper part of the theoretical uncertainty band at all energies
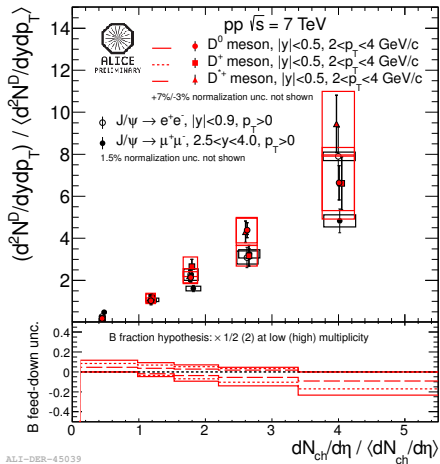
D-meson production vs. Multiplicity

Evaluate contribution of multi-parton interactions on hard scale
by studying evolution with charged particle multiplicity
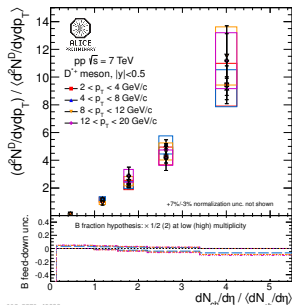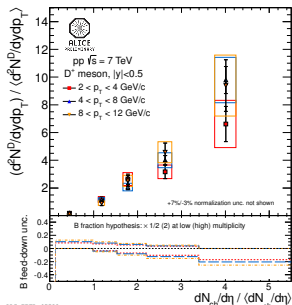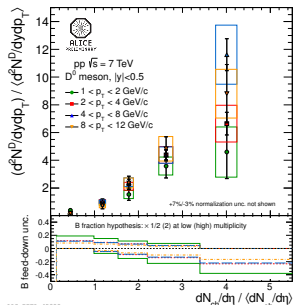
- Increase of the yield with charged particle multiplicity
- D^0, D^+, D^{*+} measured → good consistency
- No evident p_T dependence within uncertainties

Comparison with J/ψ results

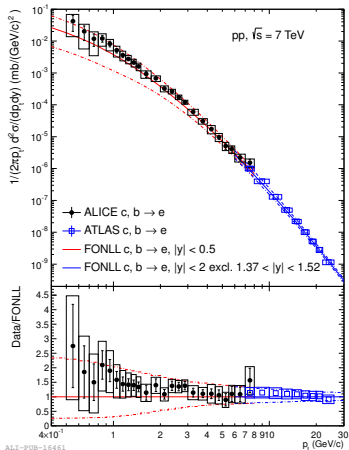- D^0, D^+ and D^{*+} meson: $|y| < 0.5$, $2 < p_T < 4$ GeV/c
- $J/\psi \to e^+e-$: $|y| < 0.9$, $p_T > 0$ GeV/c
- $J/\psi \to \mu^+\mu-$: $2.5 < y < 4$, $p_T > 0$ GeV/c

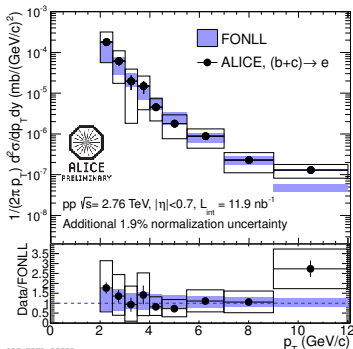Open and hidden charm show similar behavior

Semileptonic decay products

Heavy-flavor decay electron cross sections in pp collisions

Electrons from heavy flavours =
$\qquad$ inclusive electrons - cocktail (based on measured π^0 + m$_T$ scaling)
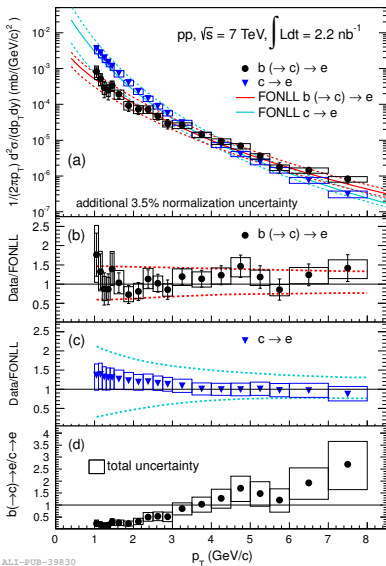

B. Abelev et al., Phys. Rev. D 86, 112007 (2012)

- Results at 7 TeV complementary to ATLAS results at high p_T
  G. Aad et al., PLB 707 (2012) 438
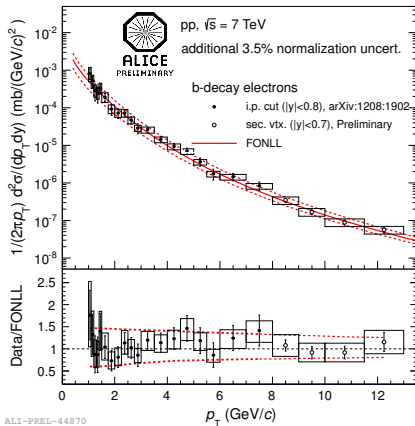- Data at both energies well described by FONLL calculations
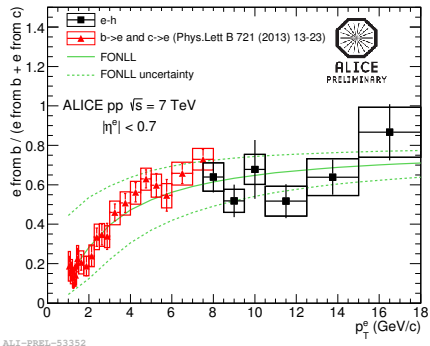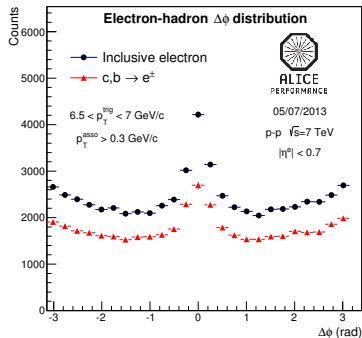
Beauty production at mid-rapidity

- Large displacement of B-decay electrons allows to cut on impact parameter
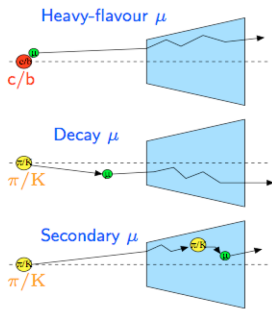- Beauty and charm differential cross section described well by FONLL pQCD predictions down to low p_T

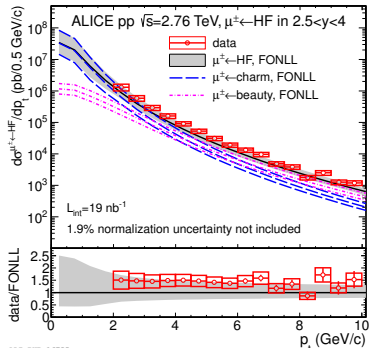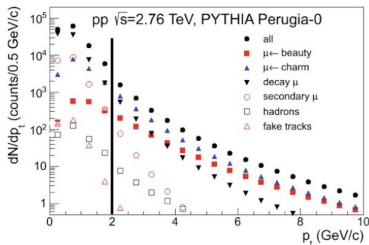B. Abelev et al., PLB 721 (2013) 13

Complementary method based on e-hadron azimuthal correlations

Muons from heavy-flavor decays at $\sqrt{s} = 2.76$ TeV
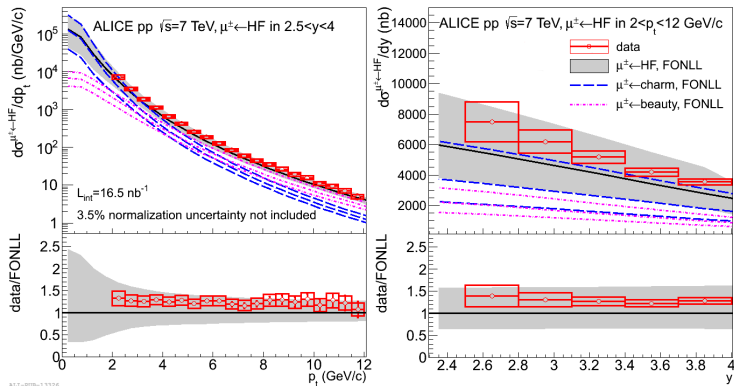

- Measurement done in forward Muon detector $2.5 < y < 4$, $p_T > 2$ GeV/c
- Contains background from different sources
- p_T shape of background estimated using a MC simulation normalised to data at low p_T

Phys. Rev. Lett. 109, 112301 (2012)

Muons from heavy-flavor decays at $\sqrt{s}$= 7 TeV

Physics Letters B 708 (2012)

- Available rapidity range allows measurement as function of y
- p_T- and y-differential cross sections described by FONLL pQCD calculations within uncertainties

Conclusions

- With ALICE, the production cross section in proton-proton collisions has been measured at 2.76 and 7 TeV of charmed mesons and leptons from heavy-flavor decays at mid and forward rapidity

- D meson differential cross section measured down to $1 \ \mathrm{GeV}/c$ and D meson ratios agree with results at different energies and in different collision systems

- Differential and total cross sections reproduced by pQCD calculations

- Increasing D-meson yields with charged particle multiplicity observed and could be due to multipartonic interaction at hard momentum scales

- ALICE complements other LHC experiments accessing the low p_T region both for charm and beauty
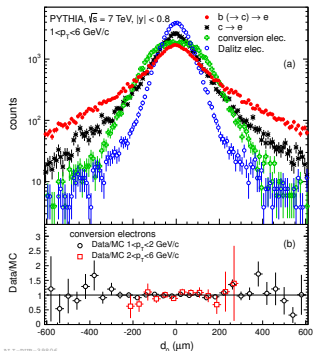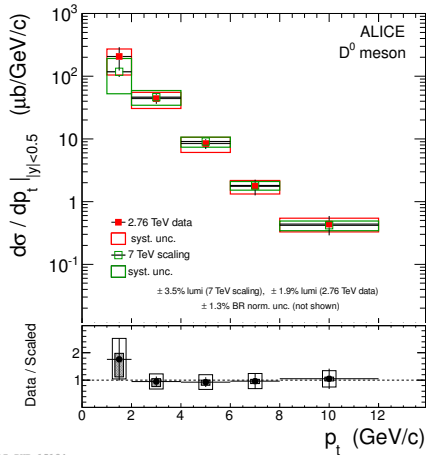
Thank you!

Backup
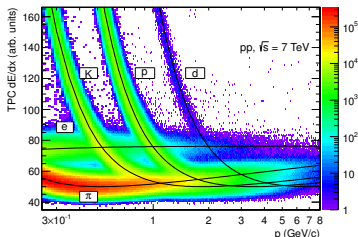
Electron identification
- TPC+TRD+TOF
- TPC+EMCAL

Transverse impact parameter distributions of electrons from different sources

Comparison of measurements at $\sqrt{s}=$ 2.76 TeV and $\sqrt{s}=$ 7 TeV

- D^0 meson p_T-differential cross section
- Data at 7 TeV scaled using FONLL