OPEN HEAVY FLAVOUR PRODUCTION IN pp COLLISIONS WITH ALICE AT LHC

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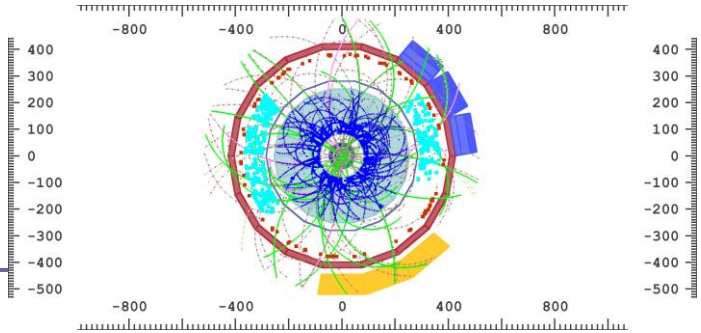
for the ALICE Collaboration

OUTLINE



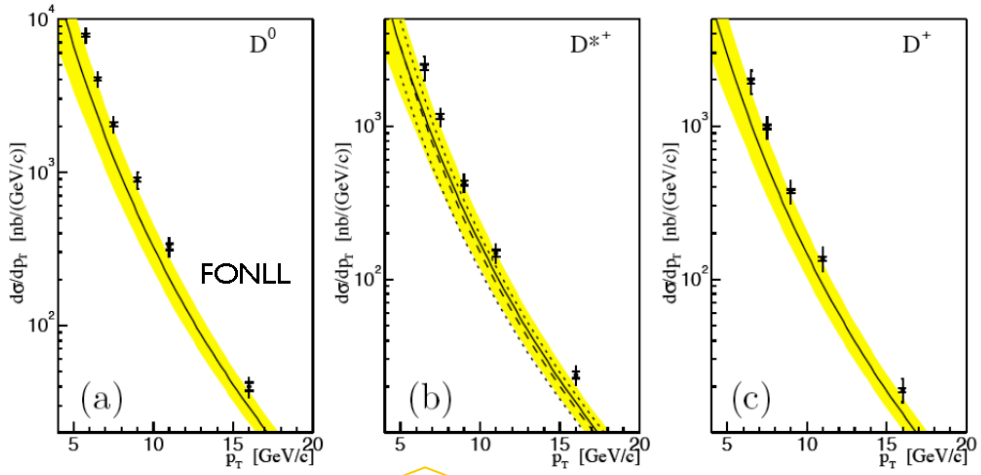
- Motivations for heavy flavour studies at LHC
- The ALICE detector and open heavy flavour measurements
- The charm with ALICE:
  - the measured D mesons cross sections in pp collisions @ 7 TeV and @ 2.76 TeV through their hadronic decays
  - the total charm cross section
- The beauty + charm with ALICE:
  - inclusive measurement of electrons from heavy flavours decay, at central rapidity
  - disentangling the beauty
  - inclusive measurement of muons from heavy flavours decay, at forward rapidity
- Conclusions

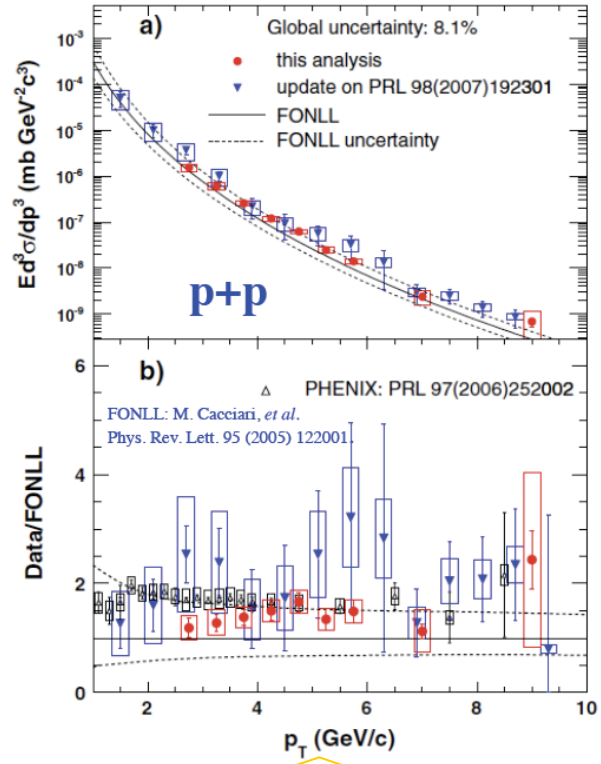
HEAVY FLAVOURS

In this talk!

- ***In p-p collisions:***
  - measure charm and beauty cross section
  - test of pQCD predictions in a new energy domain
  - necessary baseline for Pb-Pb collisions
  - probe an unexplored region of small Bjorken x
- ***In A-A collisions***
  - heavy flavours are a powerful tool to probe the high density medium via heavy quark energy loss, flow
  - provides the natural normalization for charmonium
- ***In p-A collisions***
  - address initial state effects (Cronin enhancement, nuclear PDFs)

SELECTION OF PREVIOUS MEASUREMENTS





Charm production at Tevatron and RHIC not measured at low p_T → bulk of the cross section unmeasured!

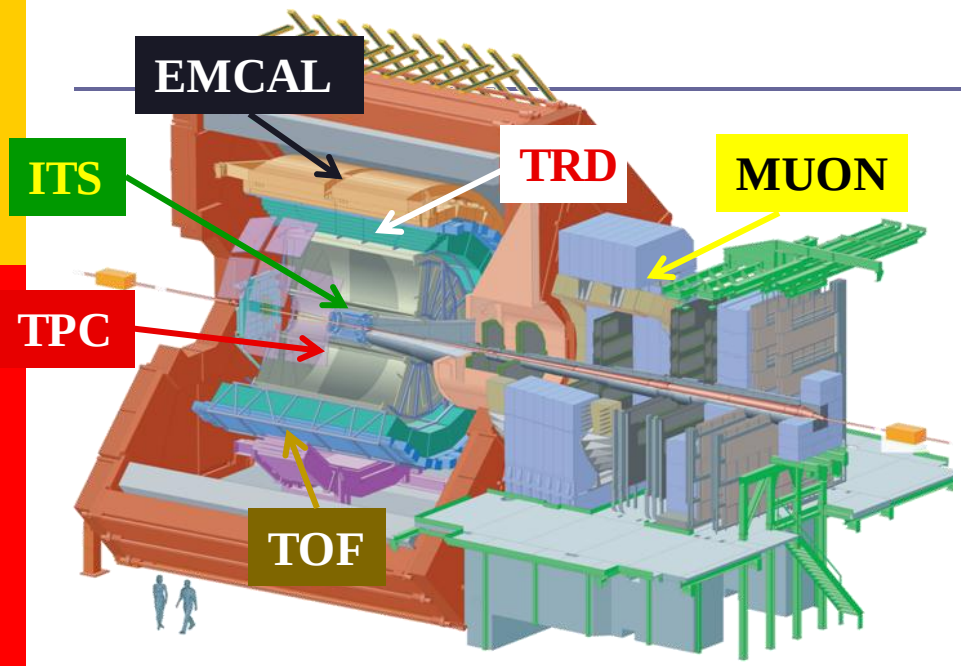
Non photonic electrons measured at RHIC:

FONLL consistent with data

CDF RunII: c->D , PRL 91:241804 (2003)

*RHIC:Phys. Rev. D **83** (2011) 52006*

HEAVY FLAVOURS WITH ALICE



ITS: vertexing + tracking
TPC: tracking + PID (π, K, e)
TOF: PID (π, K, p)
TRD: PID (π, e)
EMCAL: PID (e)
MUON: μ tracking + PID

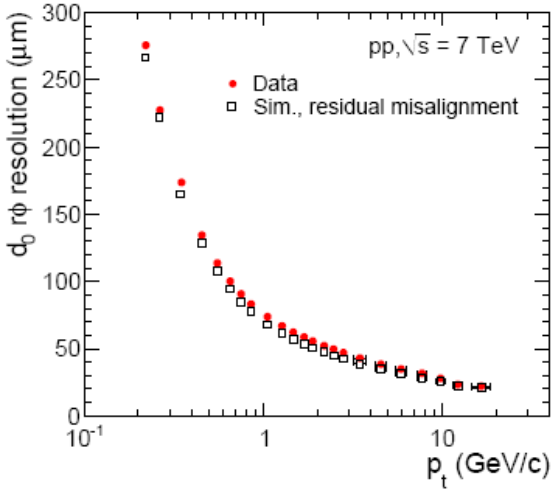
- Open charm from hadronic decays at central rapidity
  - $D^0 \rightarrow K^-\pi^+$ ($c\tau = 123\ \mu$)
  - $D^+ \rightarrow K^-\pi^+\pi^+$ ($c\tau = 311\ \mu$)
  - $D^{*+} \rightarrow D^0\pi^+$
  - $D^0 \rightarrow K^-\pi^+\pi^+\pi^-$
  - $D_s \rightarrow K^-K^+\pi^+$ ($c\tau = 150\ \mu$)
  - $\Lambda_c^+ \rightarrow pK^-\pi^+$ ($c\tau = 60\ \mu$)
- Open charm and open beauty from semileptonic decays
  - $D, B \rightarrow e^\pm + X$ (central rapidity)
  - $D, B \rightarrow \mu^\pm + X$ (forward rapidity)

Minimum bias pp collisions @7TeV and @2.76 TeV

TRACKING & VERTEXING PERFORMANCE

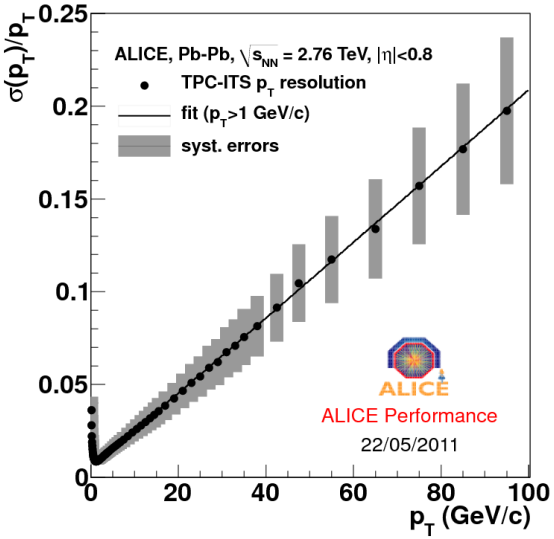
- **Vertexing: Inner Tracking System**
  - 6 layers of silicon detector, with 3 different technologies
  - vertex resolution: <100 μm already at low multiplicities→ allows to distinguish secondary vertices with high precision!

Impact parameter resolution

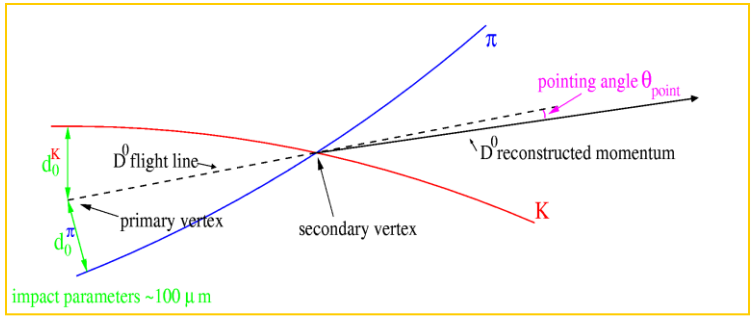


- **Tracking: Time Projection Chamber**
  - the biggest gas detector ever built!
  - p_T resolution 1% for low p_T tracks → allows measurement of heavy flavours down to low p_T!

p_T resolution

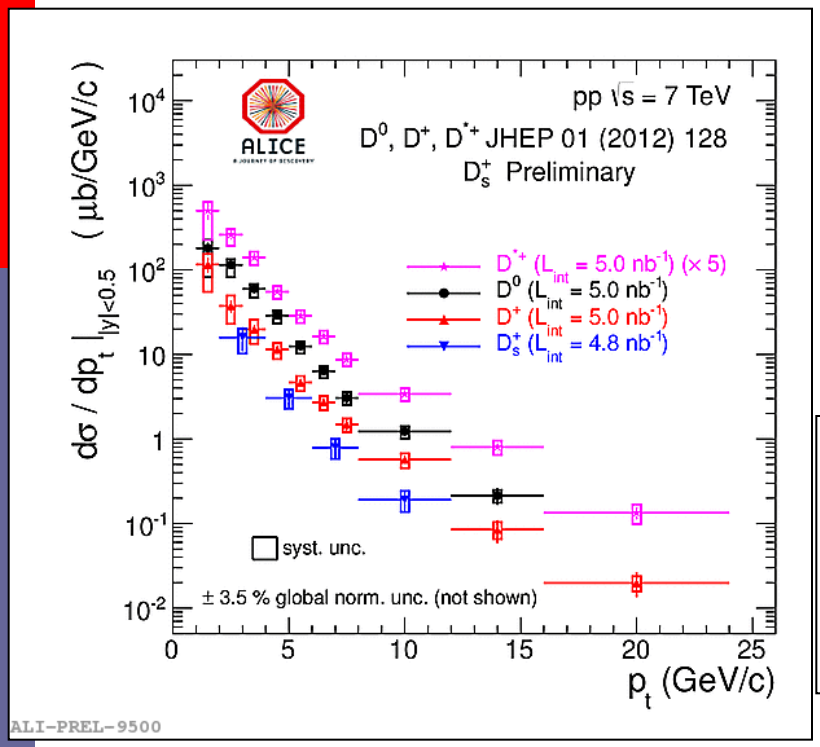


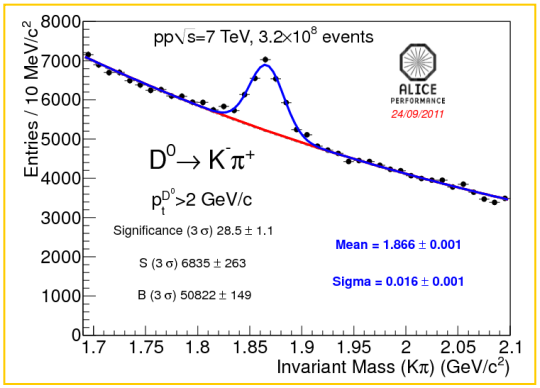
D MESONS CROSS SECTIONS (pp@7TeV)



Example: $D^0 \rightarrow K^- \pi^+$:

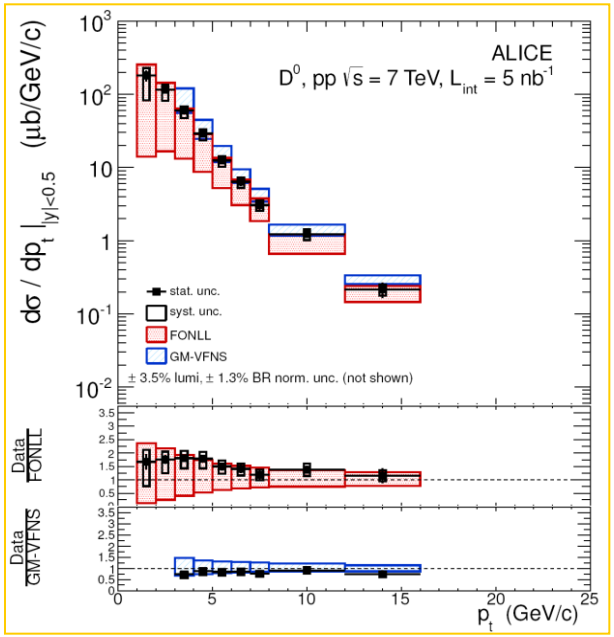
- ✓good pointing of reconstructed D momentum to the primary vertex
- ✓pair of opposite-charge tracks with large impact parameter
- ✓ PID to reduce background





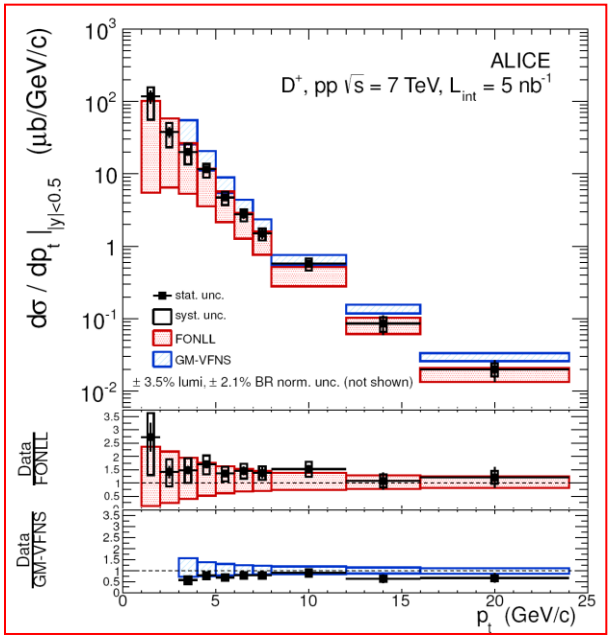
- ✓Obtained with 5 nb^{-1} integrated luminosity
- ✓ $1<p_T<24$ GeV/c → low p_T reach!
- ✓systematic errors ~ 20% – 40 %

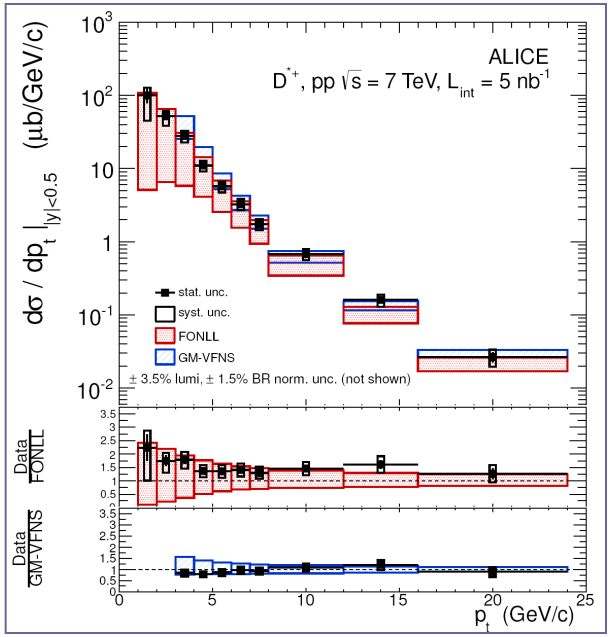
COMPARISON TO pQCD PREDICTIONS



D0

D+





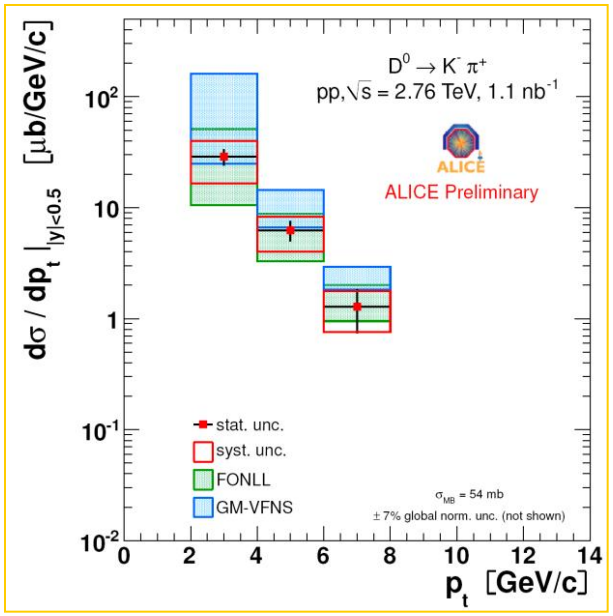
D*

✓pQCD predictions in agreement with data

JHEP01(2012)128 (arXiv:1111.1553)

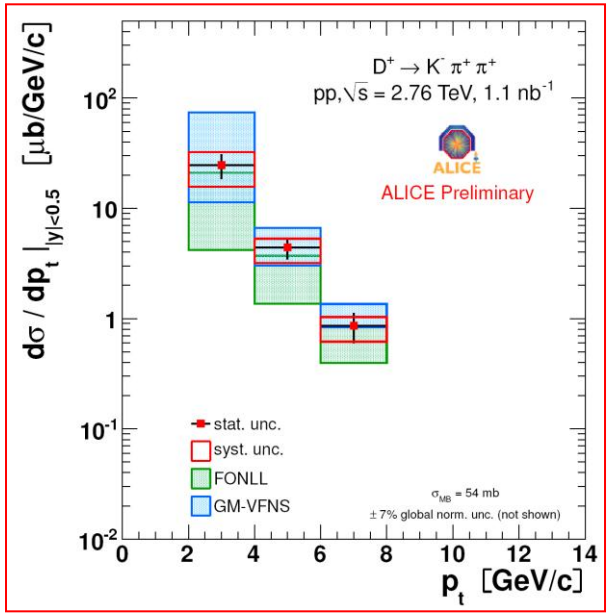
Predictions: FONLL (CERN-PHTH/2011-227) , GM-VFNS (arXiv:1202.0439)

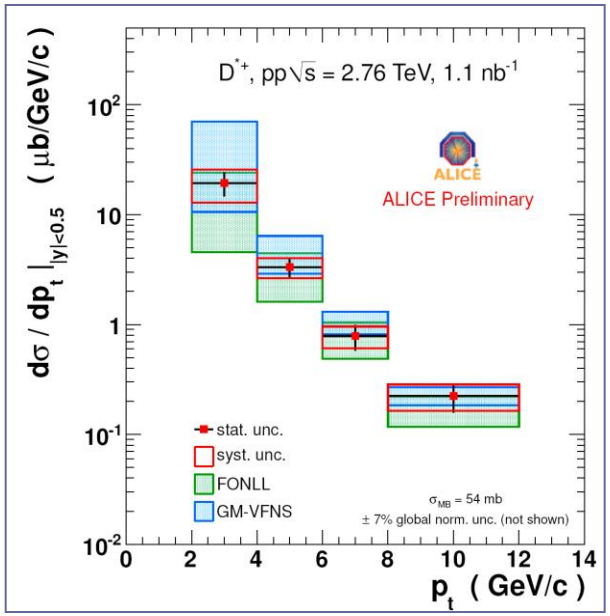
D MESONS CROSS SECTIONS (pp@2.76TeV)



D^0

D^+



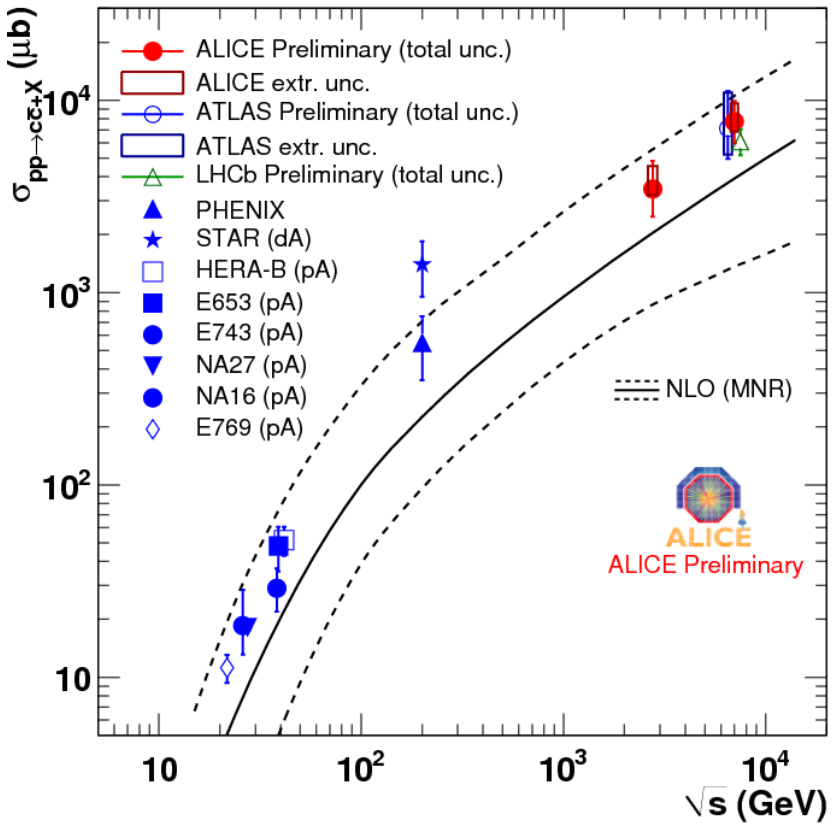


D^*

- ✓ D $^{(0,+,*)}$ cross section pp @ 2.76 TeV, obtained with 1.1 nb^{-1} integrated luminosity
- ✓pQCD predictions are in agreement with measurements at 2.76 TeV

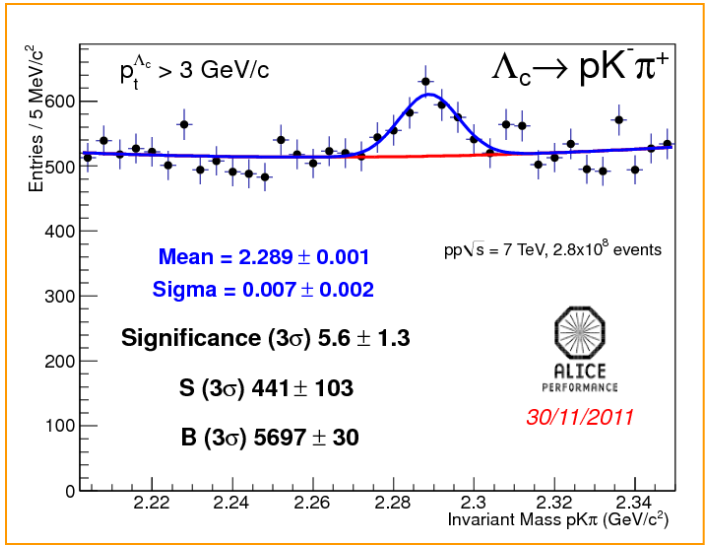
TOTAL CHARM CROSS SECTION

- High c cross section at LHC:
  - More abundant heavy flavour production
  - Better precision (reduced errors)
  - All data lie systematically on the upper side of the pQCD predictions

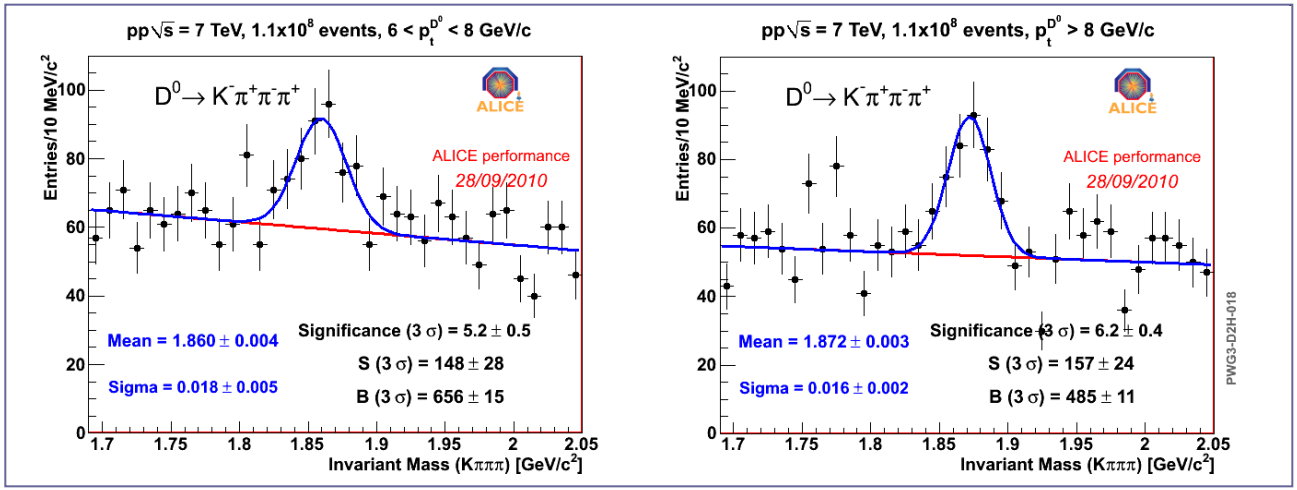


OTHER DECAY CHANNELS UNDER STUDY

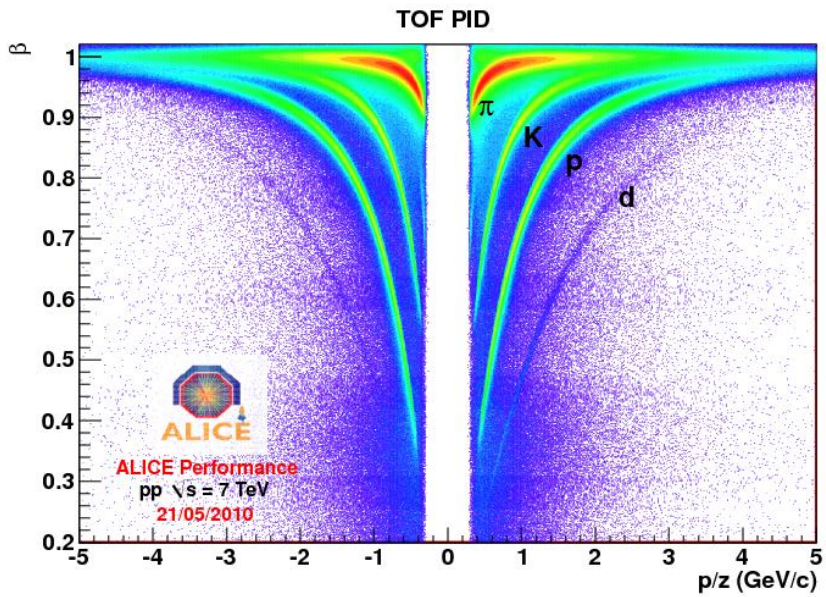
$\Lambda_c \rightarrow pK\pi$

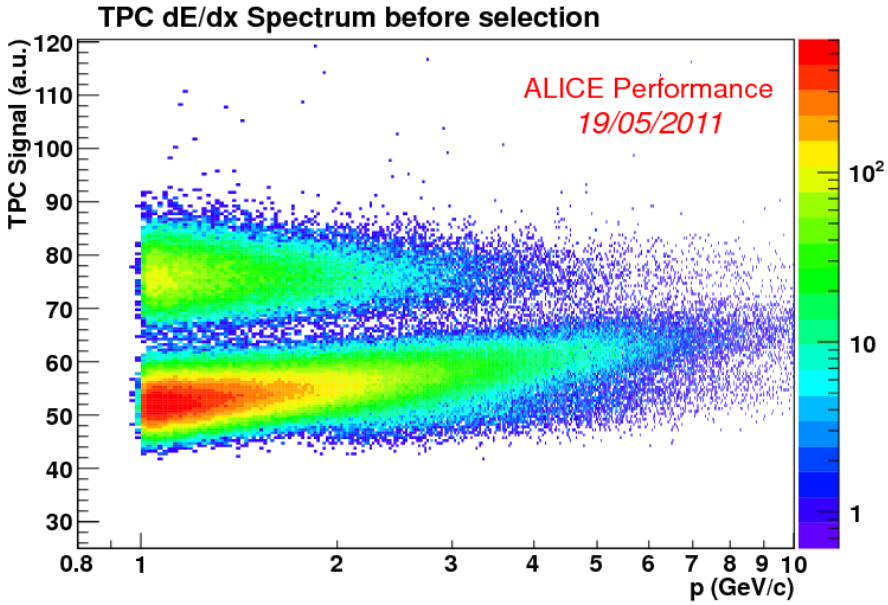


$D^0 \rightarrow K\pi\pi\pi$



ELECTRON ID (I)

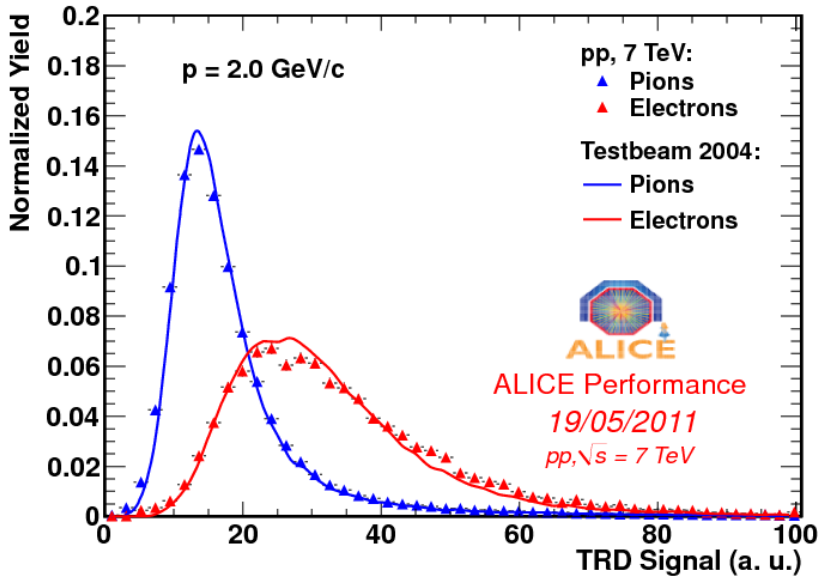




- Time Of Flight:
  - rejects protons up to 3 GeV/c and kaons up to 1.5 GeV/c
- TPC:
  - Electrons well separated from pions up to 6 GeV/c

Hadron contamination negligible up to 6 GeV/c

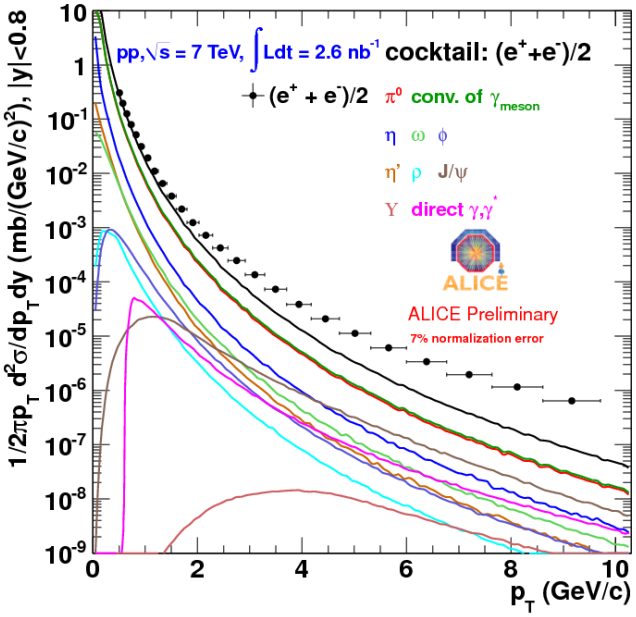
ELECTRON ID(II)

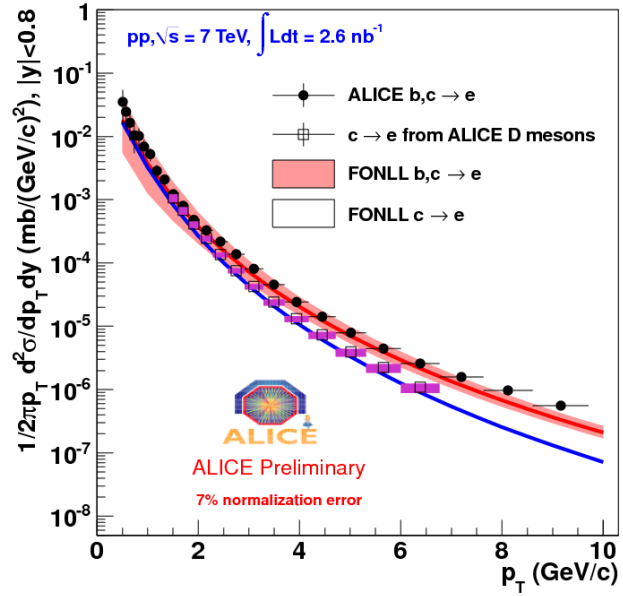


- Transition Radiation Detector:
  - rejects pions up to 10 GeV/c, selecting 80% of electrons

Hadron contamination < 2% up to 10 GeV/c

ELECTRON SPECTRUM & COCKTAIL



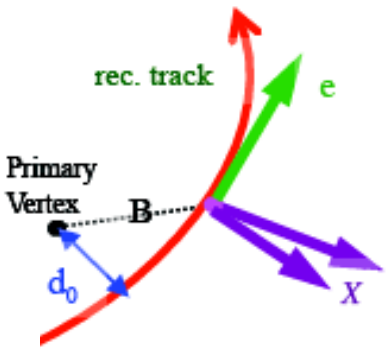


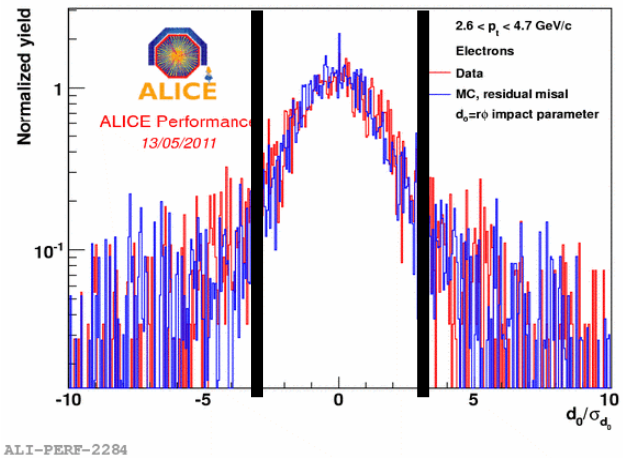
- Ingredients for the cocktail:
  - Dalitz decay of π^0 (from data)
  - heavy mesons (η,η',ρ,Φ,ω,J/ψ)
  - photon conversions (in the beam pipe and in the innermost layer of the ITS)

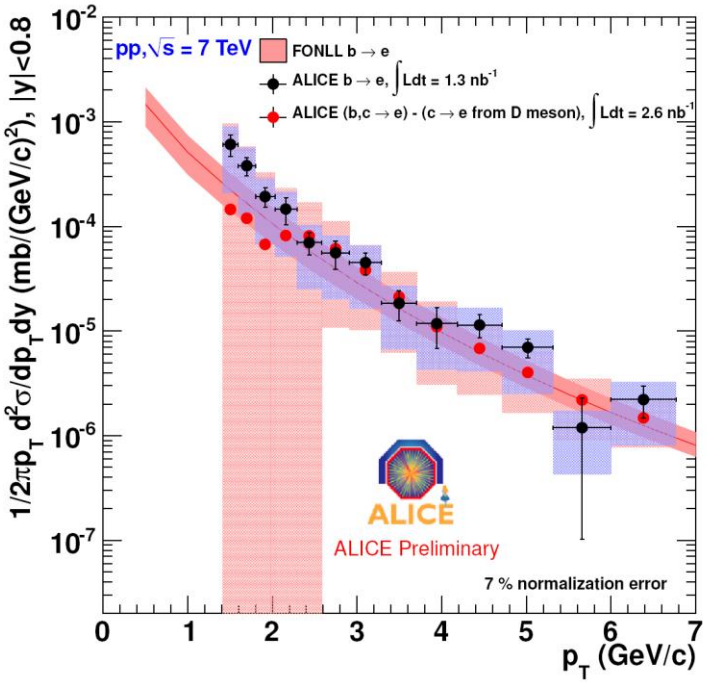
- Inclusive electrons – cocktail (D,B → e + X)
- Measured D mesons → e + X
- FONLL in good agreement with the measurement

ELECTRONS FROM BEAUTY HADRON DECAYS

- Selection of electrons with high impact parameter

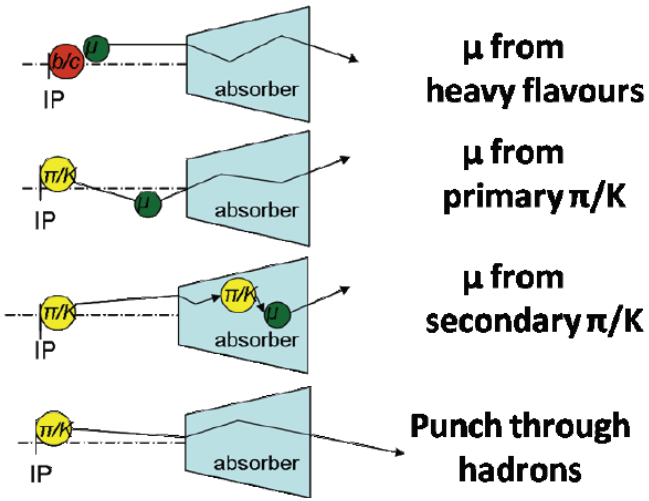


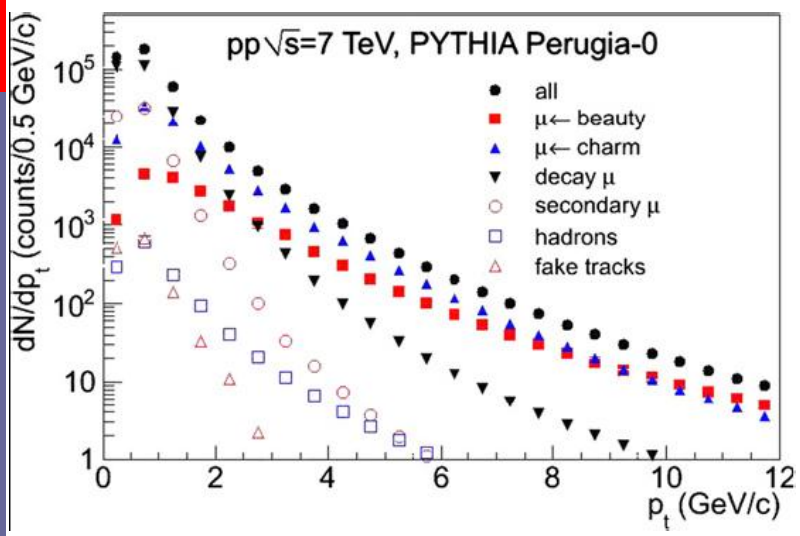




- B→e+X measured from 1.5 to 6 GeV/c
- Cross check with D,B → e+ X and measured D mesons
- FONLL predictions in agreement with data

HEAVY FLAVOR SINGLE MUONS





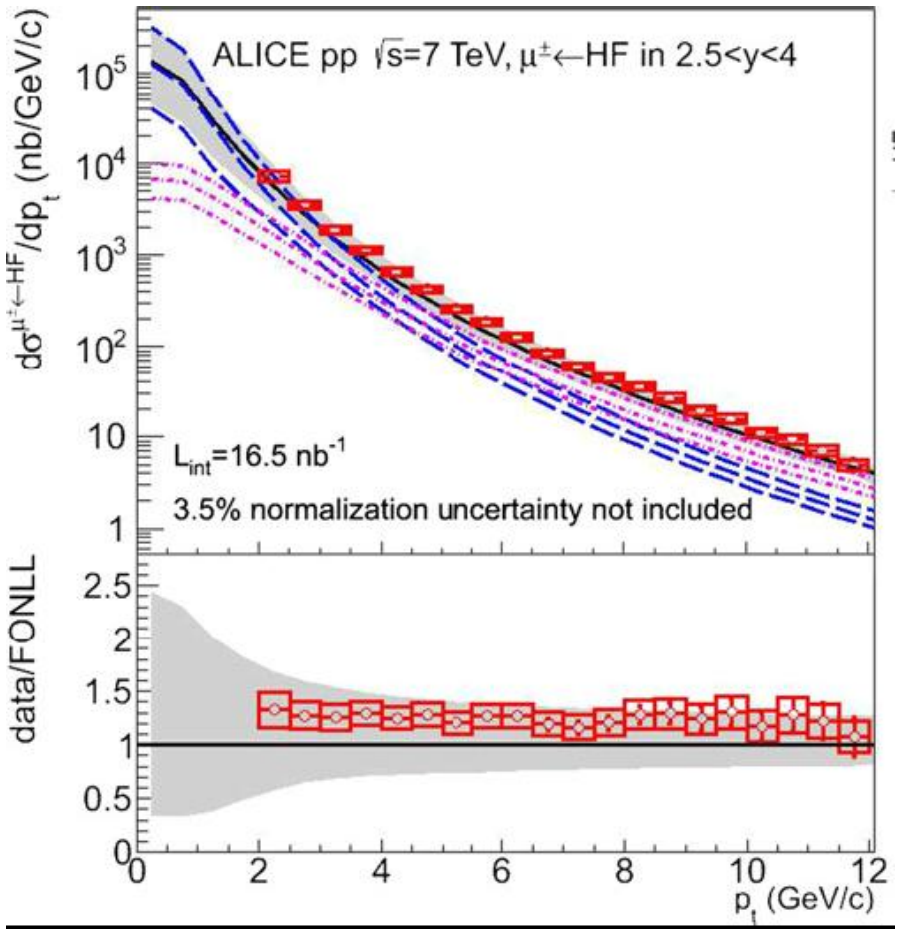
- Analysis strategy:
  - Remove hadrons and low p_t secondary muons that do not reach the trigger station
  - Remove muons from primary pions and kaons by subtracting MC dN/dp_t normalized to data at low p_t

→ What is left are muons from charm and beauty decays

- Apply efficiency corrections

The muon spectrometer covers the region 2.5 < y < 4

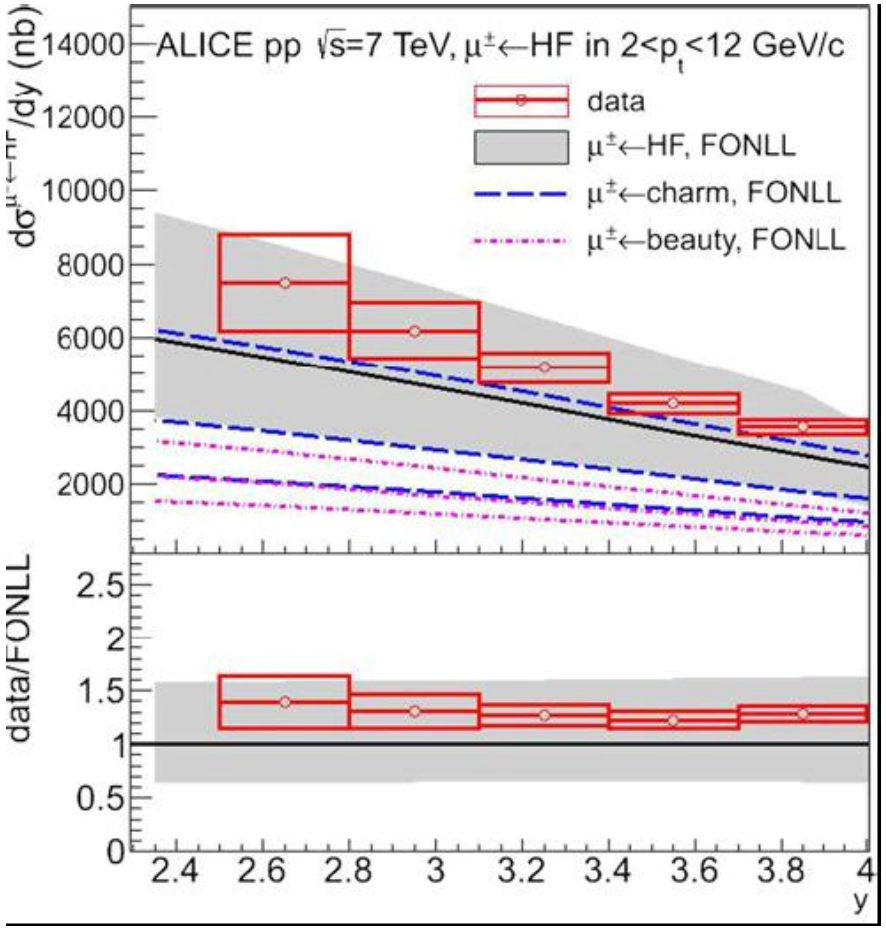
HEAVY FLAVOR SINGLE MUONS $d\sigma/dp_t$



- ✓ p_t differential cross section for muons from B and D decays measured in pt range 2 -12 GeV/c
- ✓ Obtained with 16.5 nb-1 integrated luminosity → reach 15-20 GeV/c with full 2011 statistics
- ✓ FONLL predictions in agreement with data

Phys.Lett.B708:265-275,2012. [arXiv:1201.3791]

COMPARISON WITH FONLL



- ✓ y differential cross section for muons from B and D decays, with $2 < p_T < 12$ GeV/c, measured in y range 2.5 - 4
- ✓ FONLL predictions in agreement with data

Phys.Lett.B708:265-275,2012. [arXiv:1201.3791]

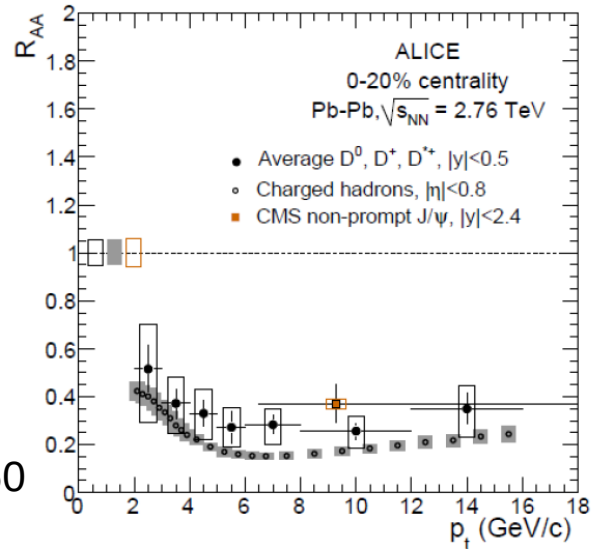
CONCLUSIONS

- Heavy flavours are a unique probe
  - to test pQCD calculations in pp collisions and provide reference to A-A collisions
  - to understand the properties of the medium in A-A collisions
- ALICE has a very rich heavy flavour programme:
  - heavy flavour cross section is measured both in the hadronic and semi leptonic channels, in different rapidity regions, down to low p_T
- Results from p-p data:
  - cross sections of charmed mesons D measured.
  - heavy flavour electron cross section measured and at high p_T we measure the beauty component
  - heavy flavour muon cross section in the forward rapidity region is also measured
  - pQCD calculations are in agreement with data

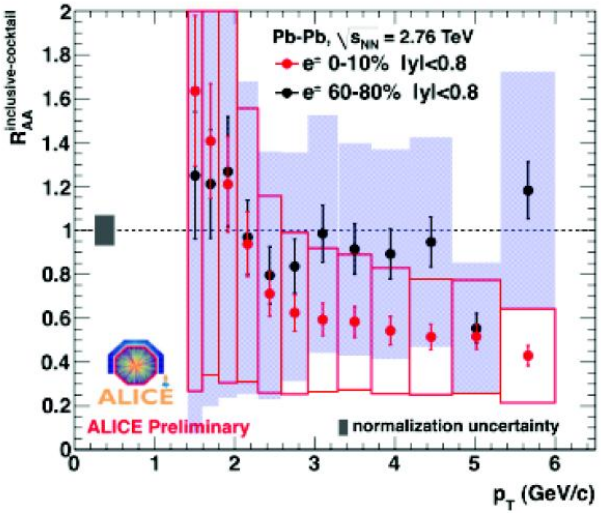
OUTLOOK

Partons are expected to lose energy crossing a deconfined medium.

Measure: $$R_{AA}(p_T) = \frac{1}{\langle N_{coll} \rangle} \frac{dN_{AA}/dp_T}{dN_{pp}/dp_T}$$, expected: $$R_{AA}^{\pi} < R_{AA}^{D} < R_{AA}^{B}$$



arXiv:1203.2160



- Similar suppression for D mesons and pions
  - ✓Hint of $R_{AA}^{D} > R_{AA}^{\pi}$ at low p_T
  - ✓CMS measurement of displaced J/Ψ (from B feeddown) indicate $R_{AA}^{B} > R_{AA}^{D}$

- Suppression for heavy flavour electrons in central Pb-Pb collisions: factor 1.5 – 4 above 3.5 GeV/c

BACKUP

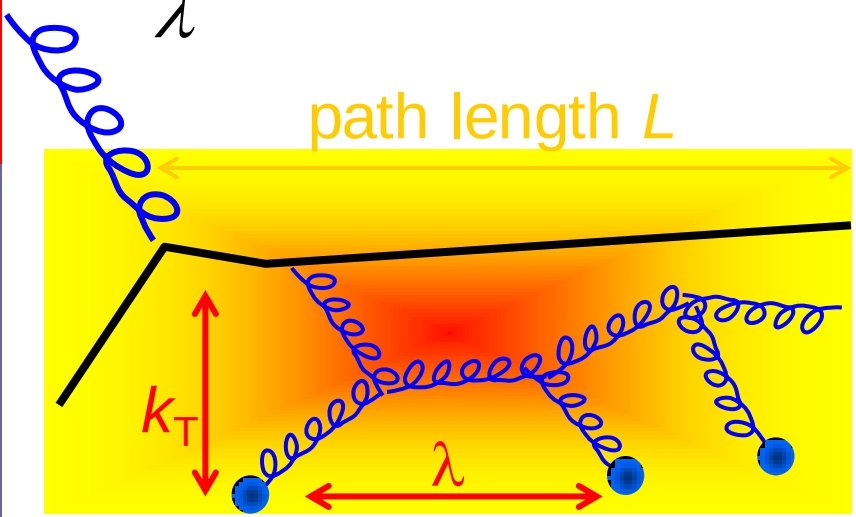
HEAVY QUARK ENERGY LOSS

$$\langle \Delta E \rangle \propto \alpha_s \, C_R \, \hat{q} \, L^2$$

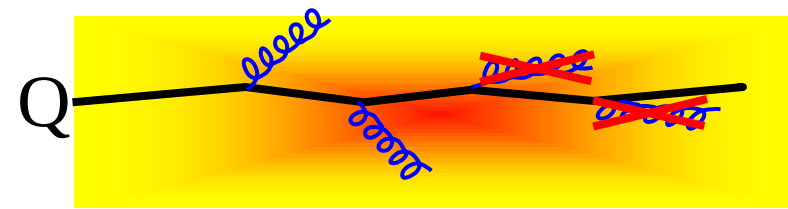
Energy loss

color coupling factor: 4/3 for q, 3 for g

$$\frac{\langle k_T^2 \rangle}{\lambda}$$ medium transport coefficient



"Dead cone" effect for heavy quarks:

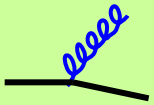


✓ in vacuum, gluon radiation suppressed at $q < m_Q/E_Q$

✓ in medium, dead cone implies lower energy loss

✓ similar mass effect expected for collisional energy loss

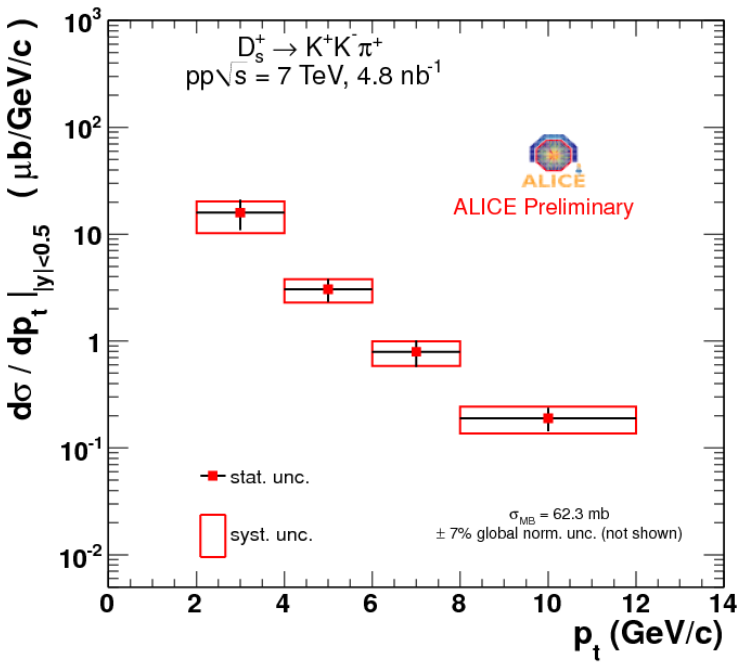
Gluonsstrahlung probability

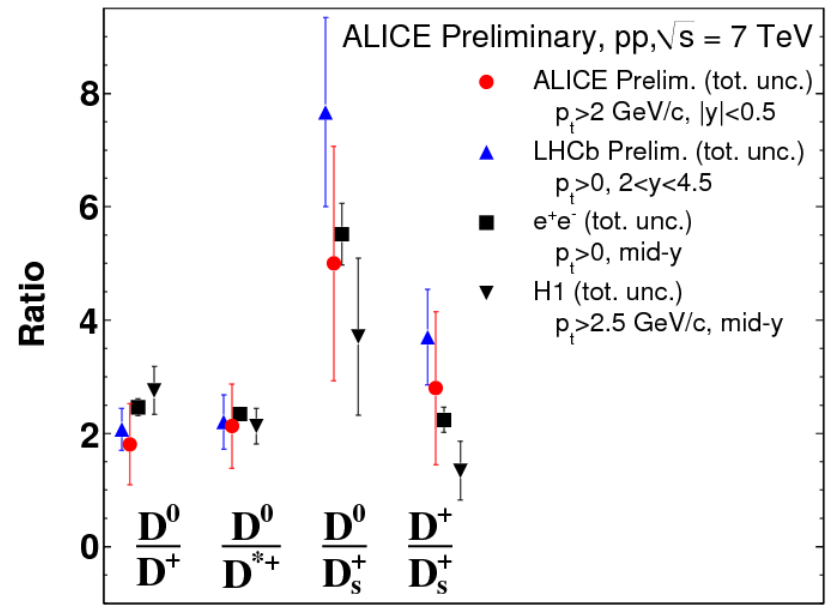


$$\propto \frac{1}{[\theta^2 + (m_Q / E_Q)^2]^2}$$

Baier, Dokshitzer, Mueller, Peigne', Schiff, NPB 483 (1997) 291. Salgado, Wiedemann, PRD 68(2003) 014008.
Dokshitzer and Kharzeev, PLB 519 (2001) 199. Armesto, Salgado, Wiedemann, PRD 69 (2004) 114003.

CROSS SECTIONS (II)





- ✓Obtained with 5 nb^{-1} integrated luminosity
- ✓ 2<p_T<12 GeV/c
- ✓systematic errors ~ 20% – 40 %
- ✓ratios in agreement with the world systematics