Heavy Flavour Production Measurements in pp Collisions at the LHC with ALICE

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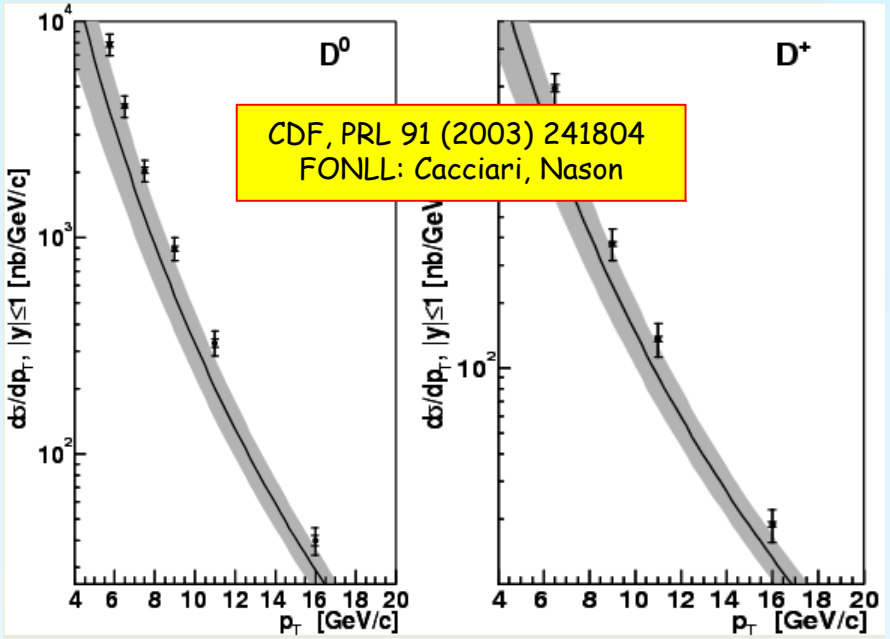
for the **ALICE Collaboration**

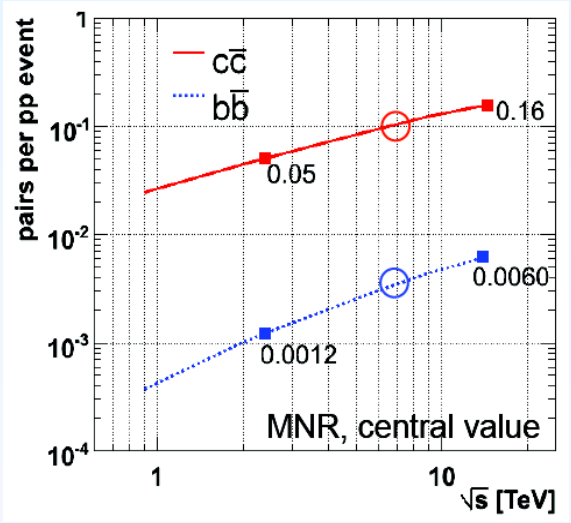
- **Introduction**
- **ALICE apparatus**
- **Open charm and beauty**
  - Hadronic decays
  - Semi-leptonic decays
- **Quarkonia: J/ψ**
- **Conclusion and outlook**

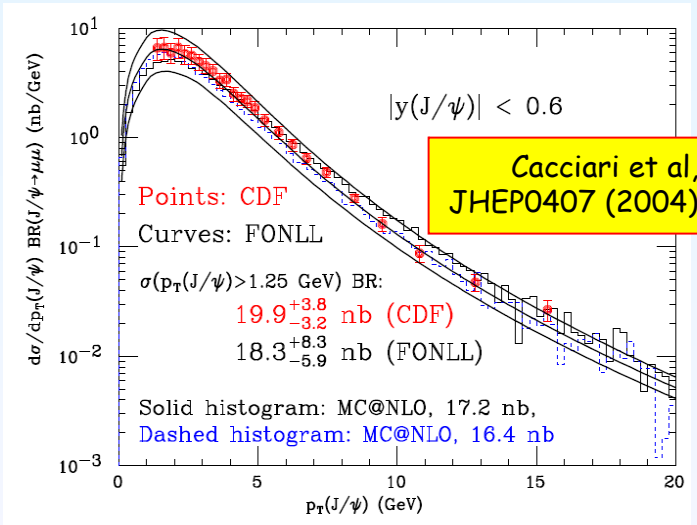
Heavy Flavour Production at LHC in pp Collisions

- **Important test of pQCD in a new energy domain: 3.5-7 × $\sqrt{s}_{TEVATRON}$**
  - c production on the upper edge of prediction, at Tevatron and RHIC
  - J/ψ production cross-section and its polarization not well understood at Tevatron
- **Probe gluon PDF down to $x_{Bjorken} \sim 10^{-4}$**
  - ALICE aims to measure charm < 1 GeV/c
- **LHC: heavy quark factory**
- **Baseline for pA and AA collisions**

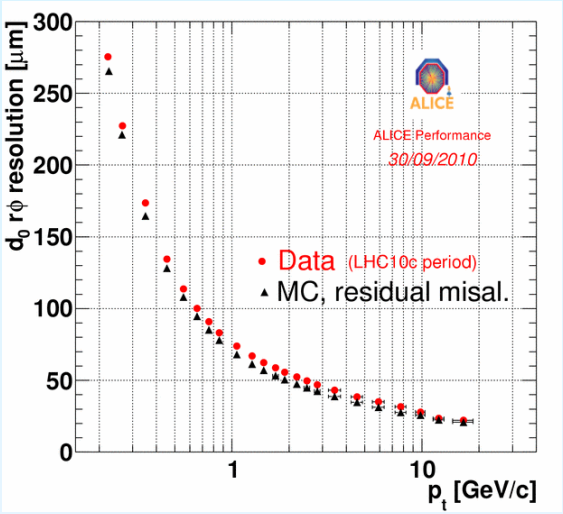


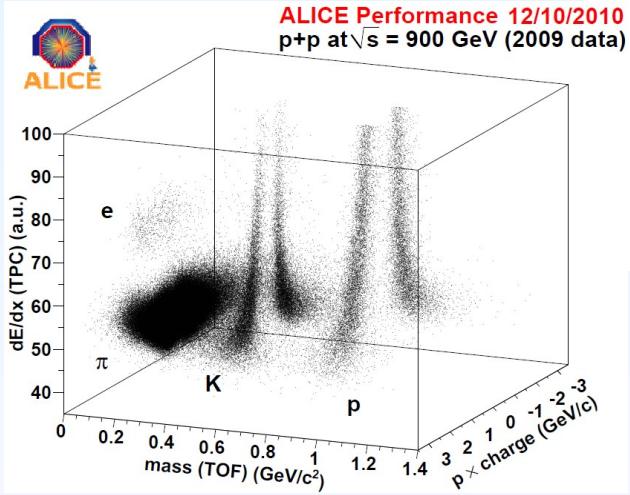
MNR code: Mangano et al, NPB373 (1992) 295

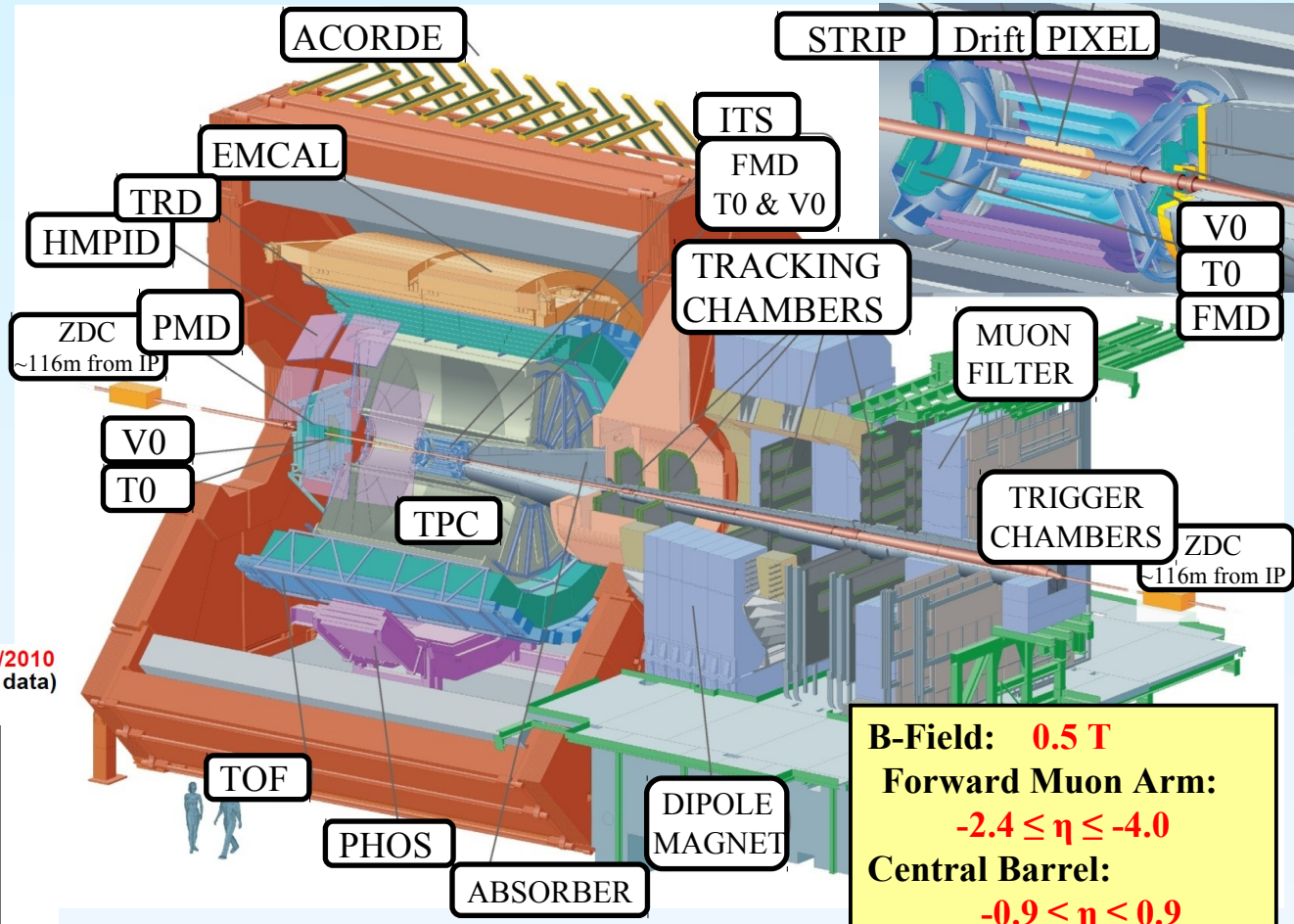




A Large Ion Collider Experiment







B-Field: 0.5 T
Forward Muon Arm:
$-2.4 \leq \eta \leq -4.0$
Central Barrel:
$-0.9 \leq \eta \leq 0.9$

→ Transverse impact parameter resolution
< 75 μm for p_T > 1 GeV/c

→ Particle identification with various systems

D Mesons in pp Collisions

Analysis Strategy

- Main Selection: displaced-vertices topology
- Charged Kaon ID in Time-Projection Chamber and Time of Flight system to reduce bkg at low p_T
- Invariant mass analysis
- Acceptance and Efficiency Correction (PID, selection, reconstruction, ...)
- Feed-down from B meson decays corrected with FONLL (to be compared with data-driven method using full 2010 statistics)

Hadronic decays:

$D^0 \rightarrow K\pi$

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

$D^+ \rightarrow K\pi\pi$

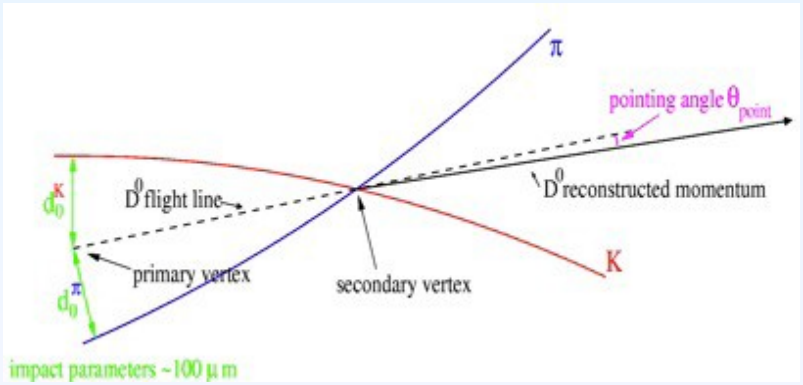
$D_s \rightarrow KK\pi$

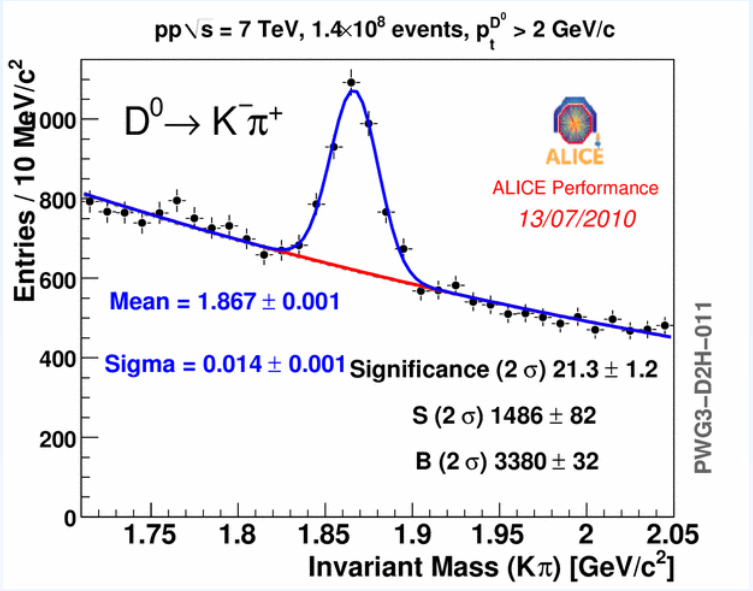
$D^* \rightarrow D^0\pi$

$\Lambda_c \rightarrow \pi Kp$

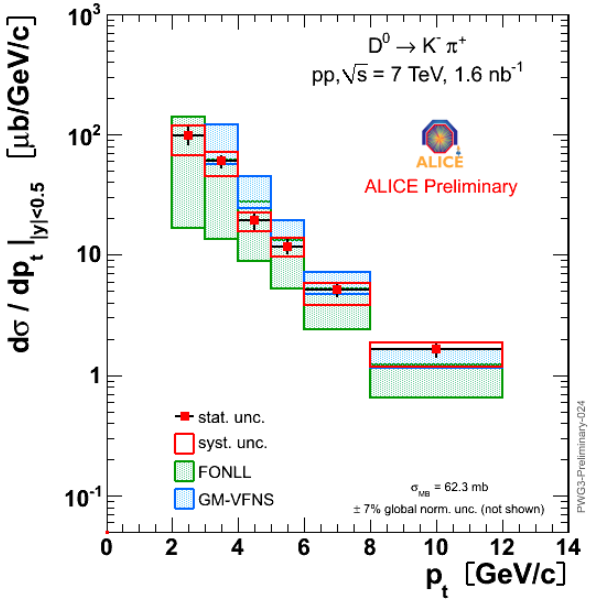
Data Sample

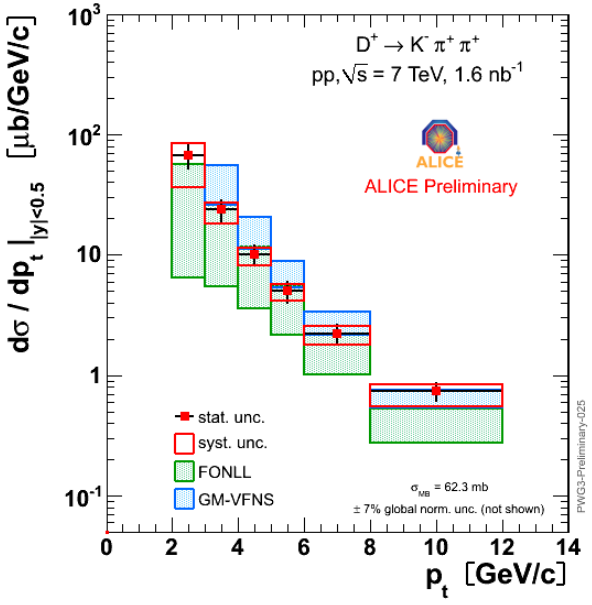
- 10^8 minimum bias events (~20% of 2010 statistics)

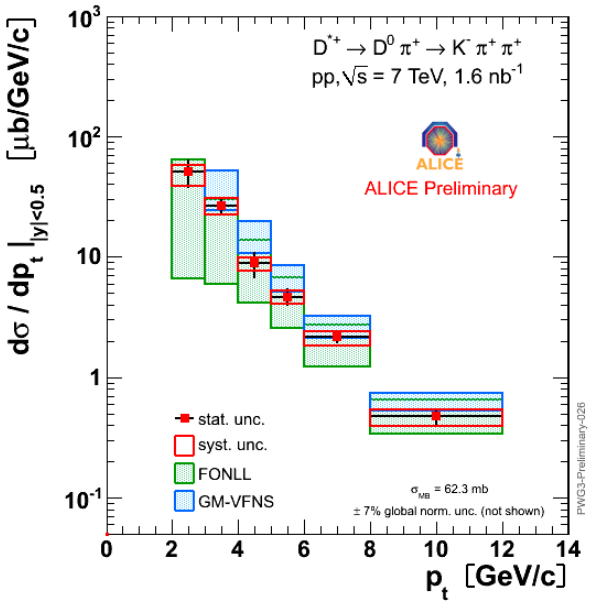




D Mesons Cross Section
pp @ 7TeV, |y| < 0.5





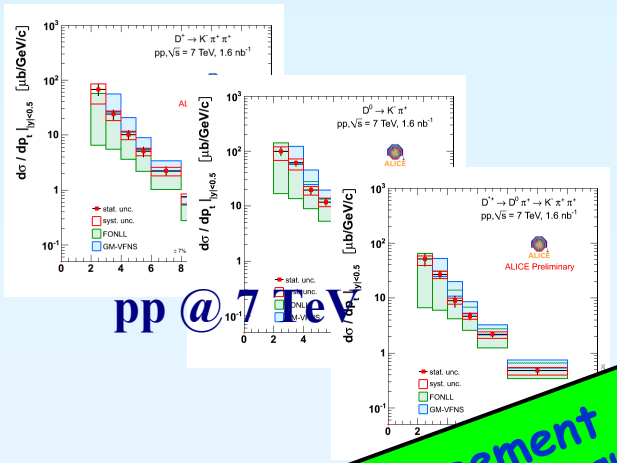


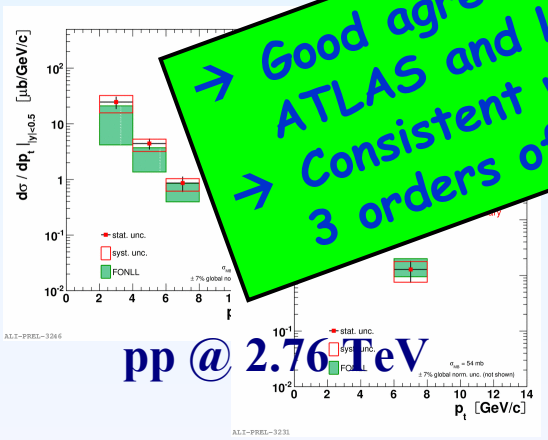
FONLL: Cacciari et al., private comm.
GM-VFNS: Kniehl et al., private comm.

→ pQCD predictions (FONLL and GM-VFNS) compatible with data, but data on the high side of FONLL

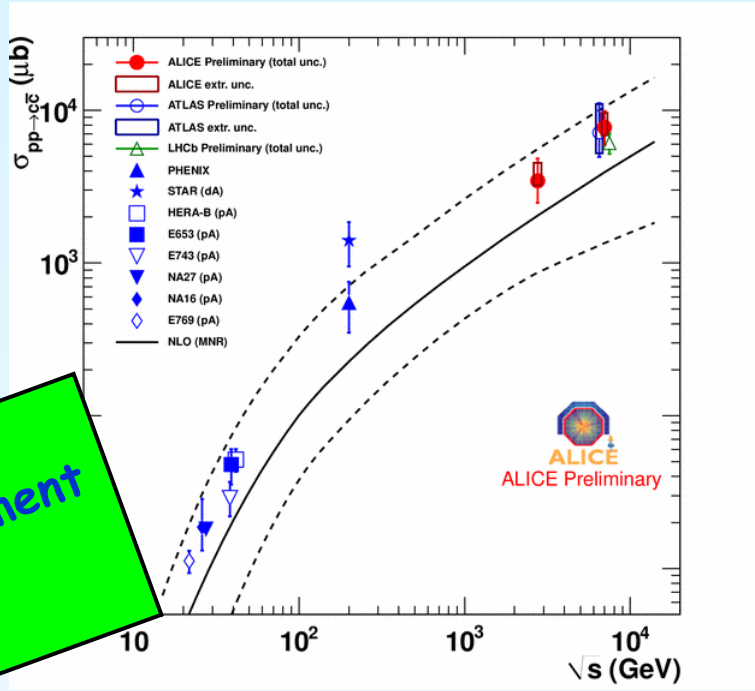
Total Charm Cross Section in pp

- **Strategy: Extrapolation from p_T = 2 GeV/c to 0 and full y using FONLL**





→ Good agreement with ATLAS and LHCb measurement
→ Consistent with NLO over 3 orders of magnitude



$$\sigma(ALICE, 2.76\text{TeV}) = 3.45 \pm 0.41(stat.)^{+0.72}_{-0.84}(syst.) \pm 0.17(lum.)^{+1.09}_{-0.24}(extr.)\,mb$$

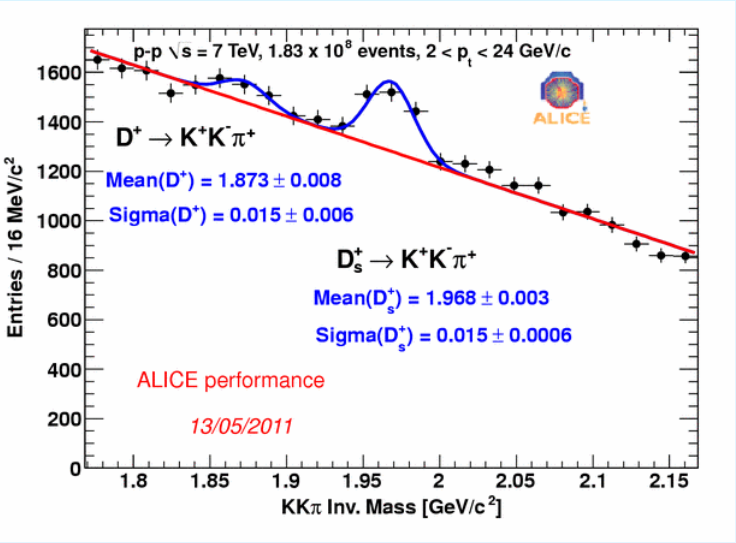
$$\sigma(ALICE, 7\text{TeV}) = 7.73 \pm 0.54(stat.)^{+0.74}_{-1.38}(syst.) \pm 0.43(lum.)^{+1.9}_{-0.87}(extr.)\,mb$$

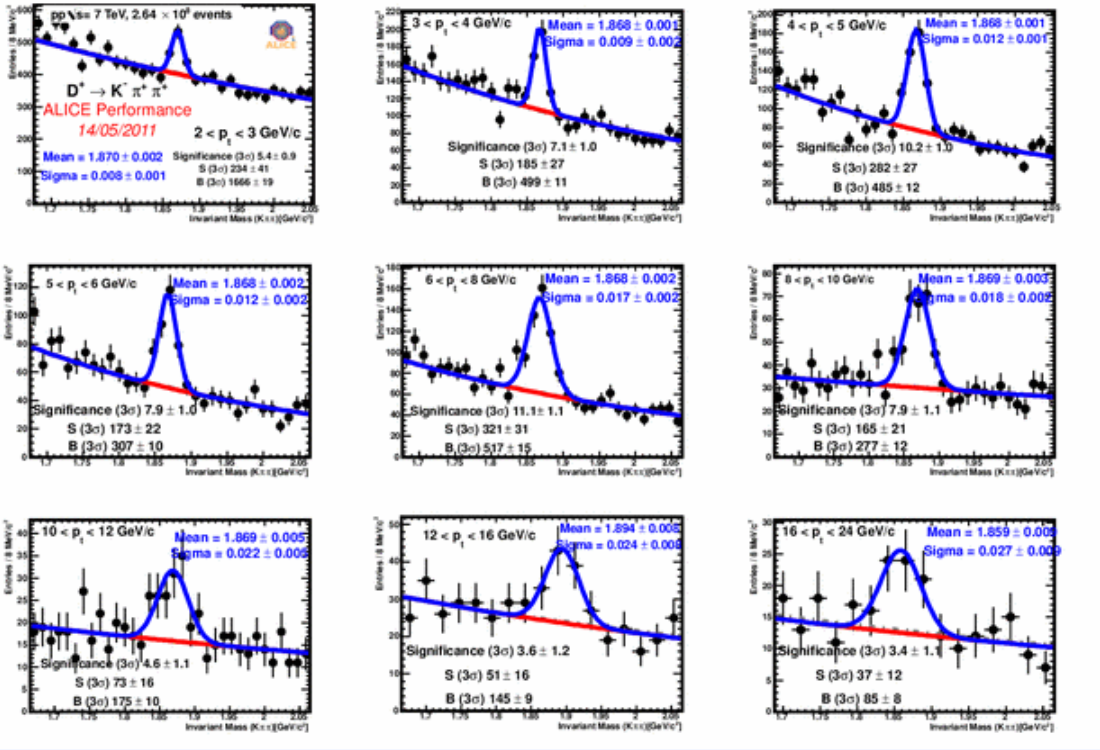
$$\sigma(ATLAS, 7\text{TeV}) = 7.13 \pm 0.28(stat.)^{+0.9}_{-0.66}(syst.) \pm 0.78(lum.)^{+3.82}_{-1.9}(extr.)\,mb$$

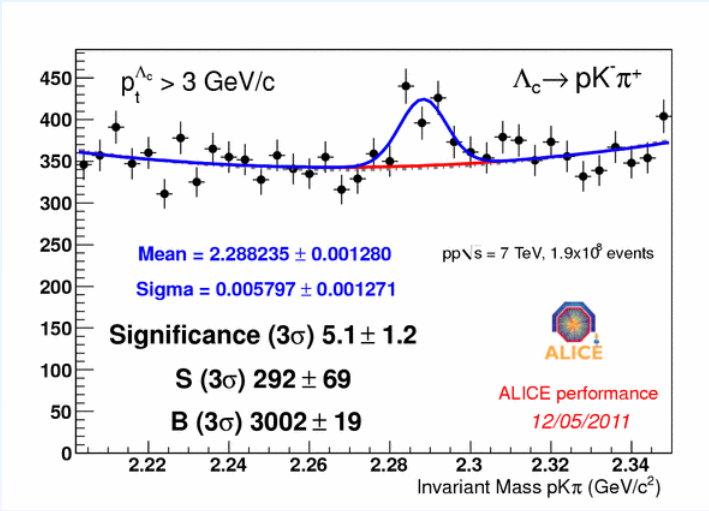
$$\sigma(LHCb, 7\text{TeV}) = 6.10 \pm 0.93(total)\,mb$$

Charm in pp 7 TeV: Outlook

→ Extend p_T range with full 2010 statistics:
1—20 GeV/c (e.g. D* shown)
→ The shy charming: D_s and Λ_c







Reconstruction of Electrons from Semi-electronic c/b Decays

Analysis Strategy

- Electron Identification with Time Of Flight system, Time-Projection Chamber and Transition Radiation Detector
- Remaining hadron contamination determined via fits of dE/dx in momentum slices
- Requirement of a hit in the innermost layer of the Inner Tracking System (r = 3.9 cm) to reduce bkg from photon conversion
- Acceptance and Efficiency Correction (PID, selection, reconstruction, ...)
- Subtraction of the background via data-tuned MC cocktail

Data Sample

- $1.8 \cdot 10^8$ minimum bias events

Semi-electronic decays:

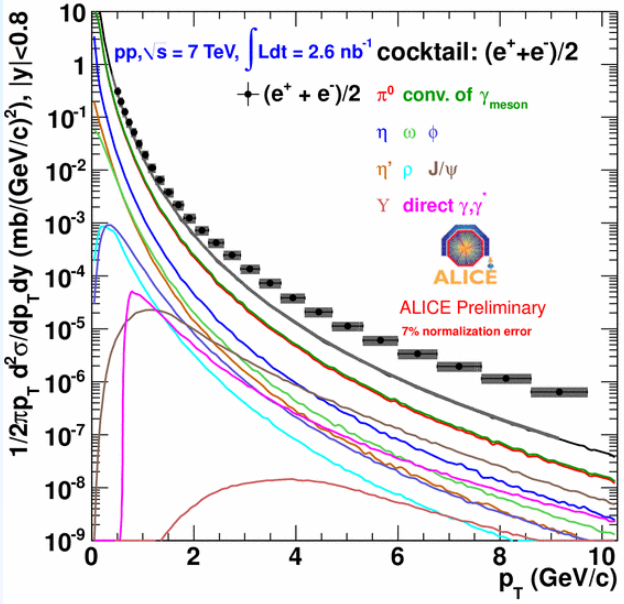
$D^0 \rightarrow e + anything$

$D^{\pm} \rightarrow e + anything$

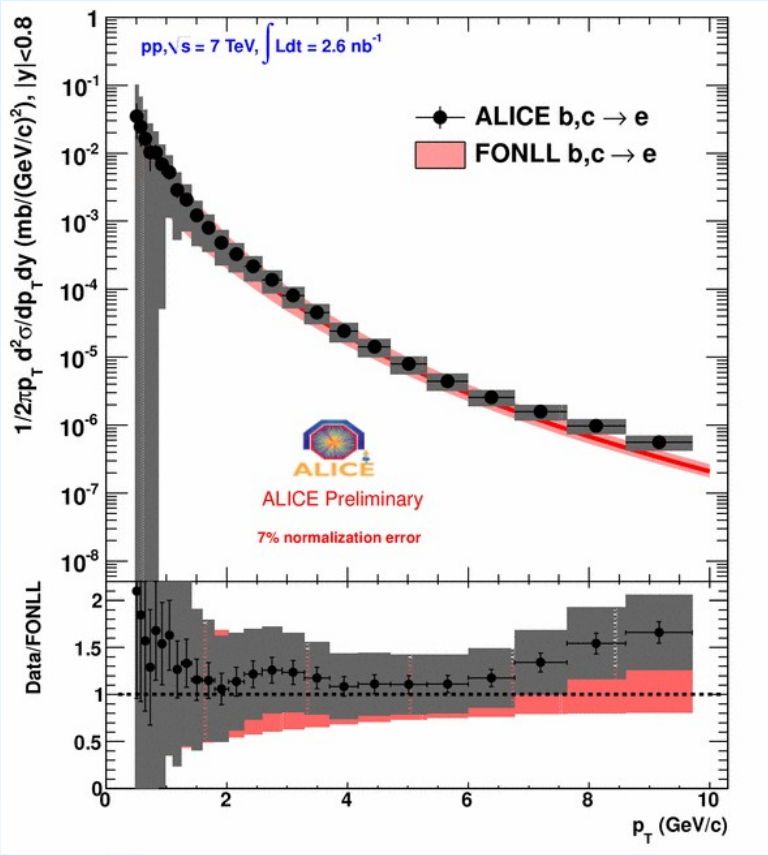
$B^{\pm} \rightarrow e + anything$

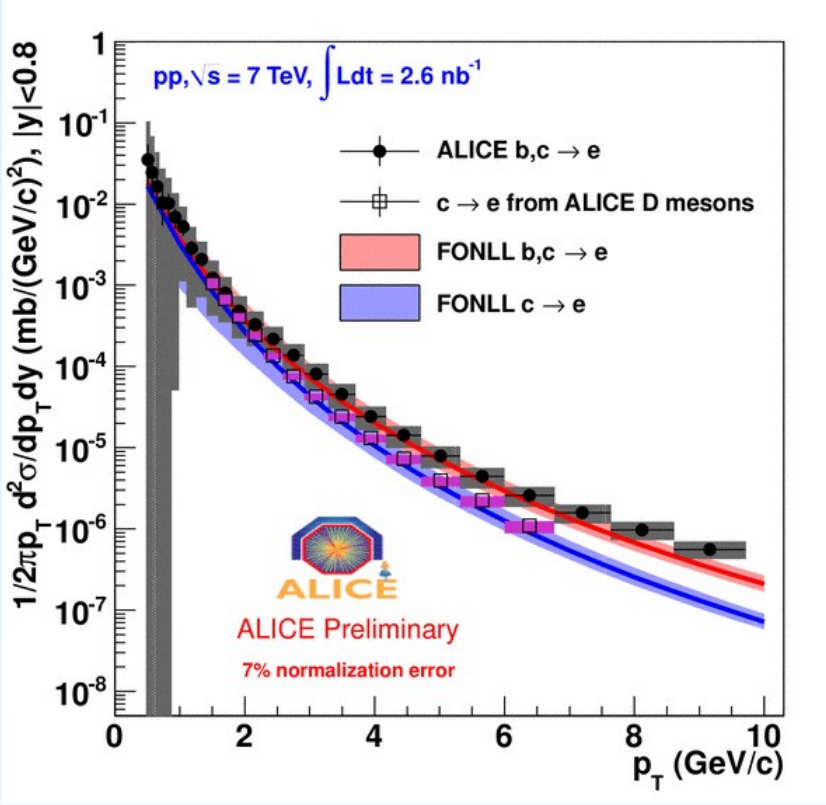
$\Lambda_c \rightarrow e + anything$

$B \rightarrow D \rightarrow e + anything$



Electrons from Semi-electronic c/b Decays





→ FONLL b + c in agreement with data
→ Consistent with prompt charm measurement from D mesons in the low p_T-region, where charm dominates

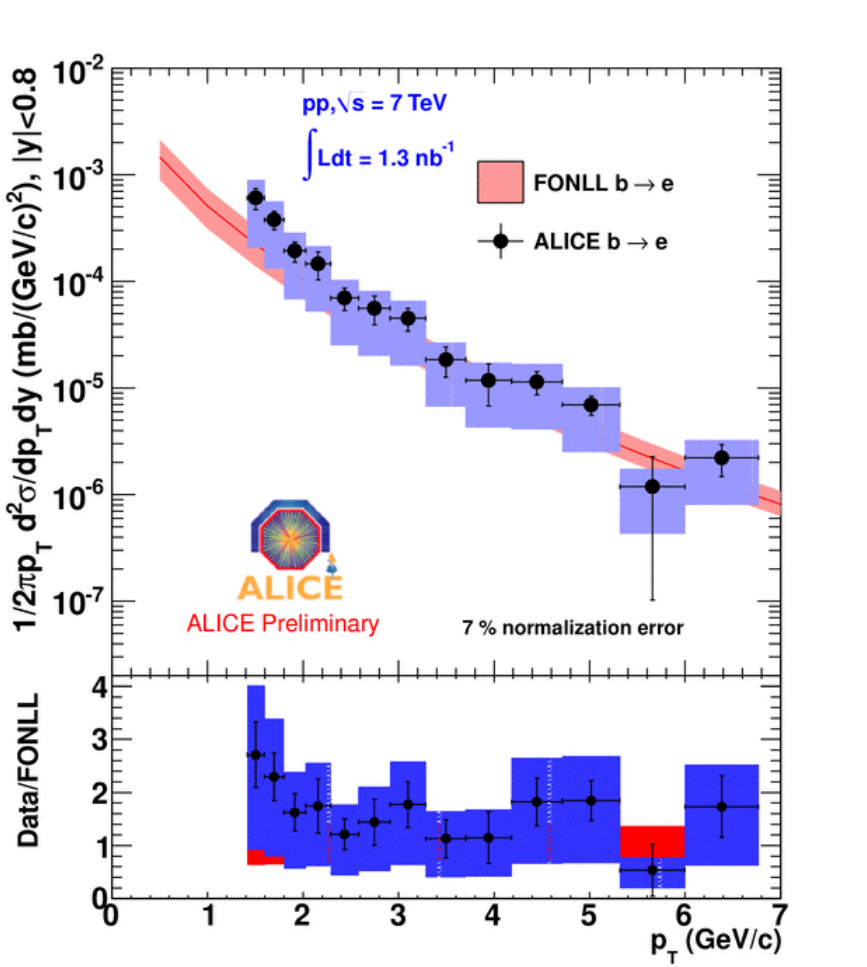
Beauty Decay Electrons

- **Analysis Strategy: selection of electrons displaced from the primary vertex**

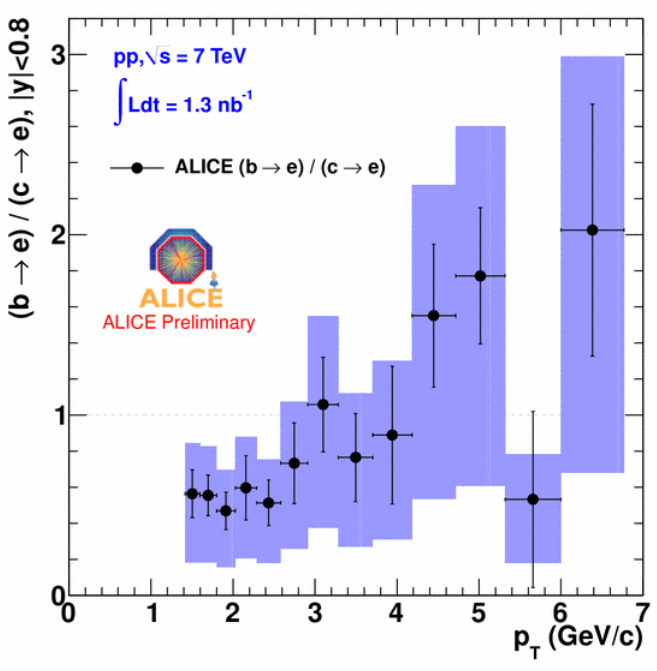
Semi-electronic decays:

$B^{\pm} \rightarrow e +$ anything

$B \rightarrow D \rightarrow e +$ anything



→ FONLL in agreement with data
→ b/c ratio increases with p_T



Open Heavy Flavour from Forward Muons

Analysis Strategy

- Muon identification with muon arm
- Removal of hadrons and low p_T secondary muons via requirement of a muon trigger signal, p_T cut-off and DCA cut
- Subtract muons from pion and kaon decays by subtracting MC $dNdp_T$ normalized to data at low p_T
- Acceptance and Efficiency Correction

Semi-muonic decays:

$D^0 \rightarrow \mu$ + anything

$D^{\pm} \rightarrow \mu$ + anything

$B^{\pm} \rightarrow \mu$ + anything

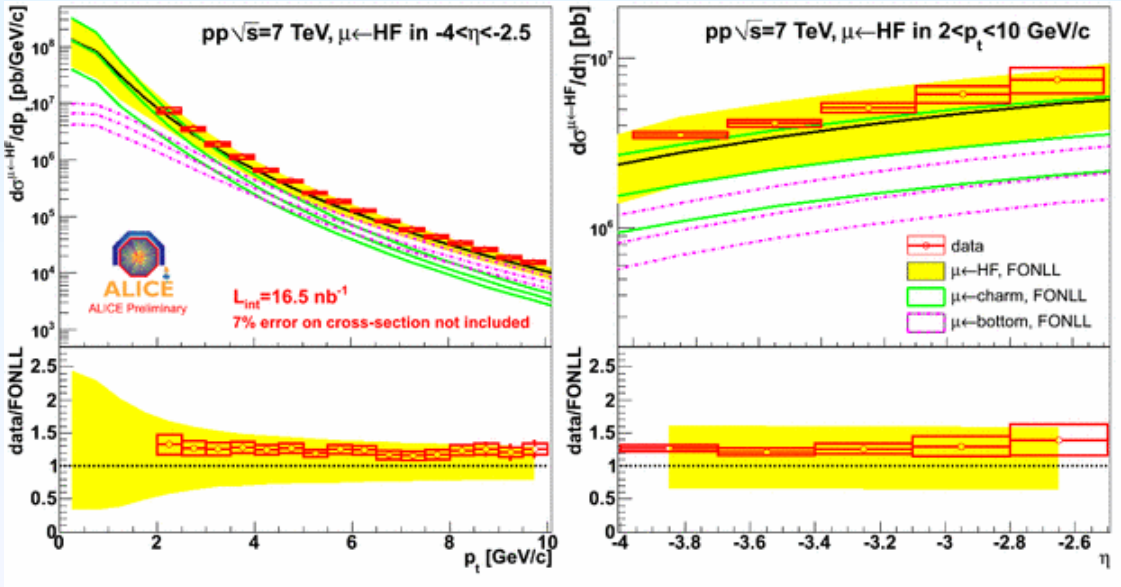
$B \rightarrow D \rightarrow \mu$ + anything

Data Sample

- 16.5/nb (muon trigger events)

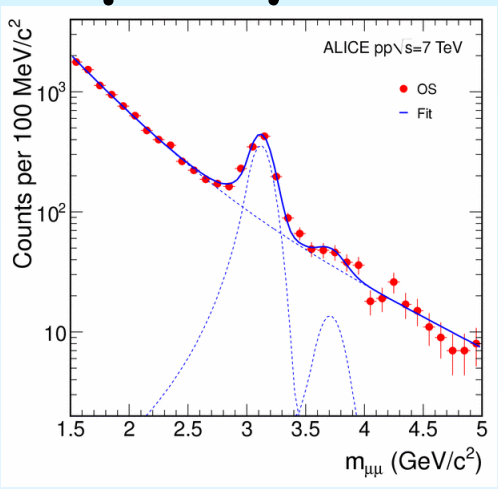
→ p_T and η distributions well described by FONLL

→ FONLL indicates beauty dominance above 6 GeV/c



J/ψ Production Cross Section at Mid- and Forward Rapidity

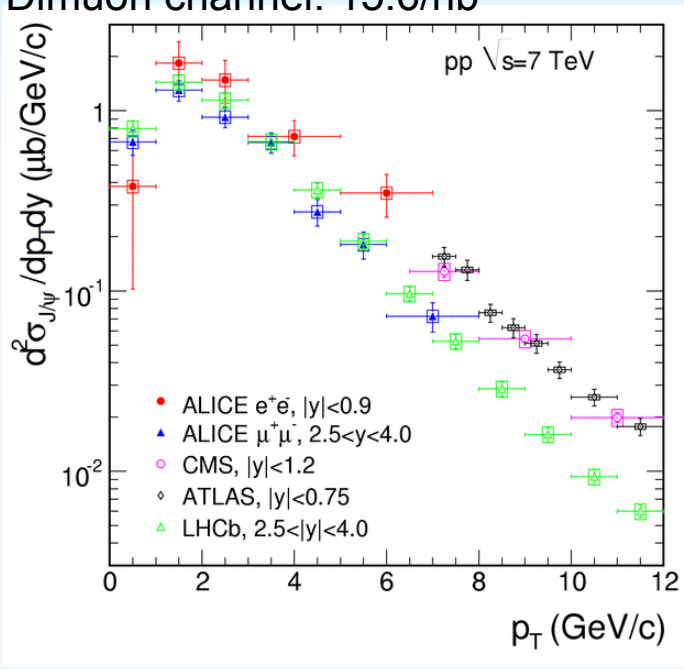
- **Analysis Strategy**
  - Particle identification with muon arm or Time-Projection Chamber
  - Invariant mass analysis: inclusive J/ψ
  - Acceptance and Efficiency Correction
- **Data Sample**
  - Dielectron channel: 3.9/nb
  - Dimuon channel: 15.6/nb

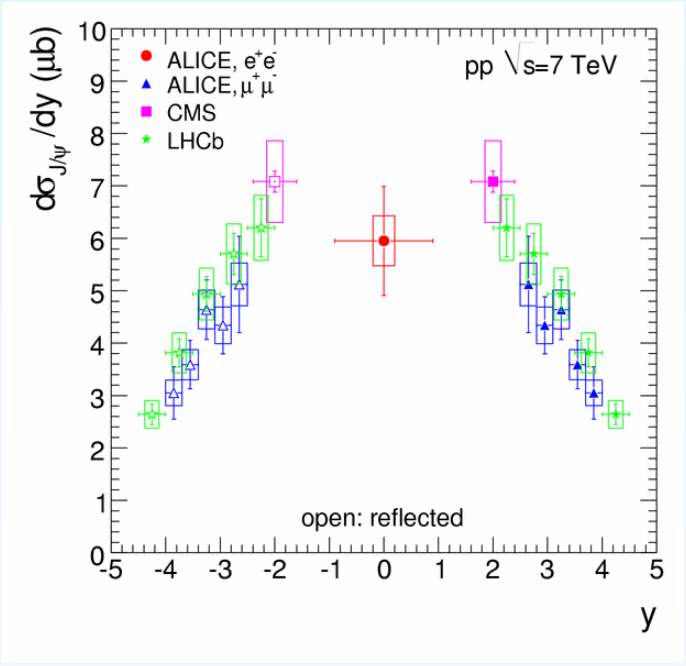


Decays:

$J/\psi \rightarrow \mu^+ + \mu^-$

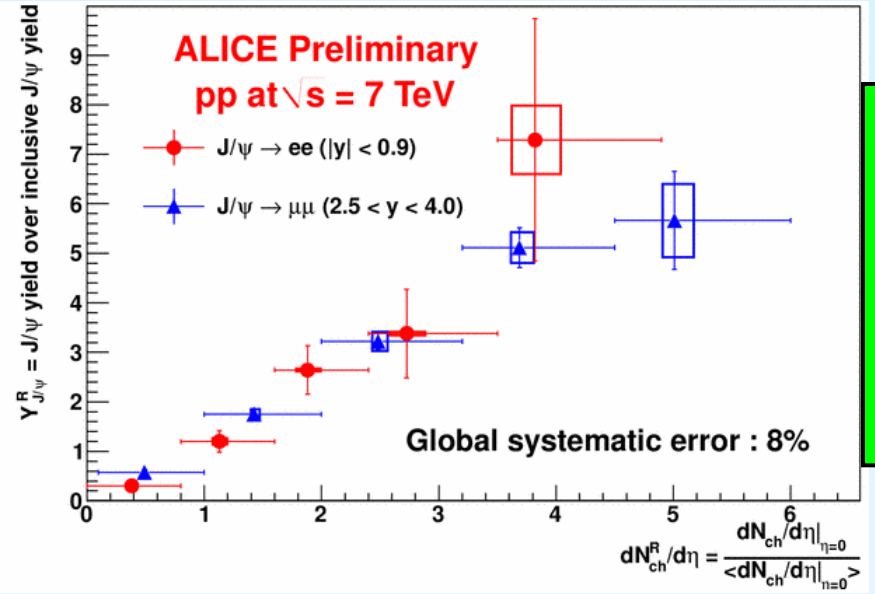
$J/\psi \rightarrow e^+ + e^-$





K. Aamodt et al, arXiv:1105.0380v1 [hep-ex]

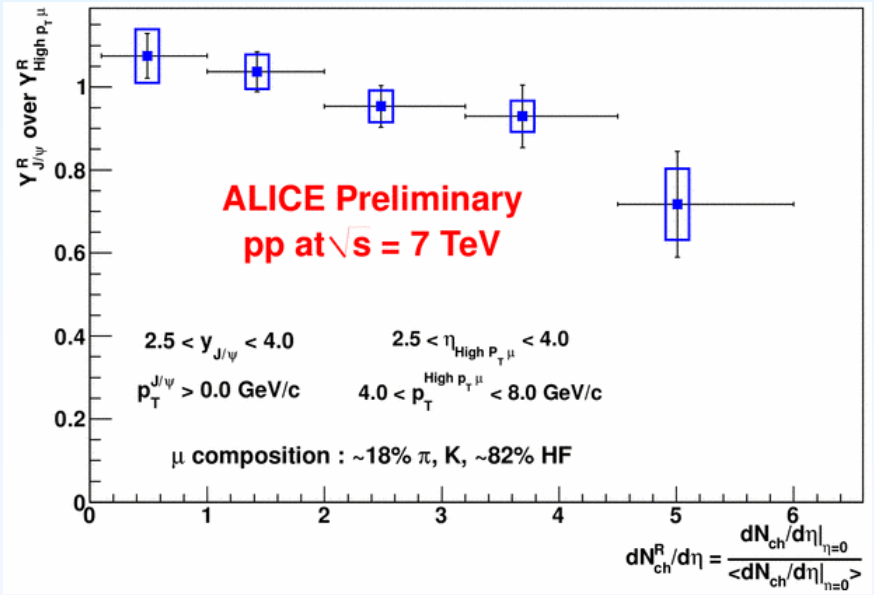
J/Ψ Multiplicity Studies



→ Almost linear dependence of relative J/Ψ yield vs relative multiplicity

→ Decreasing relative J/Ψ yield over high p_T muon yield vs the relative multiplicity

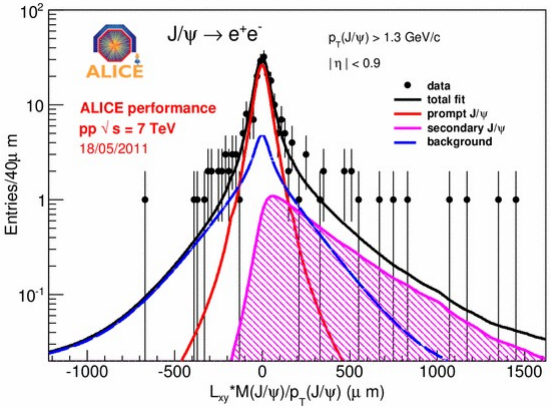
- **Study of relative J/psi yield**
- **High p_T muons**
  - ~ 82% heavy flavour
  - ~ 12% π, K decays



Conclusion and Outlook

- **Measurements of heavy flavour production cross sections in pp collisions**
  - Open Charm at forward and mid-rapidity
    - FONLL calculations agree within uncertainties, but data on high side of calculation
    - First measurement of b → $e^{\pm}$ + anything using displaced vertex topology
  - J/ψ at mid- and forward rapidity
    - Broad acceptance in rapidity; sensitivity down to zero p_T at all rapidities

- **In progress**
  - Higher Statistics → wider momentum ranges
  - J/ψ
    - Polarization
    - Separate prompt and secondary J/ψ
  - Measure Ψ' production at forward rapidity



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A Large Ion Collider Experiment

Strength of ALICE

Large acceptance at low p_T:

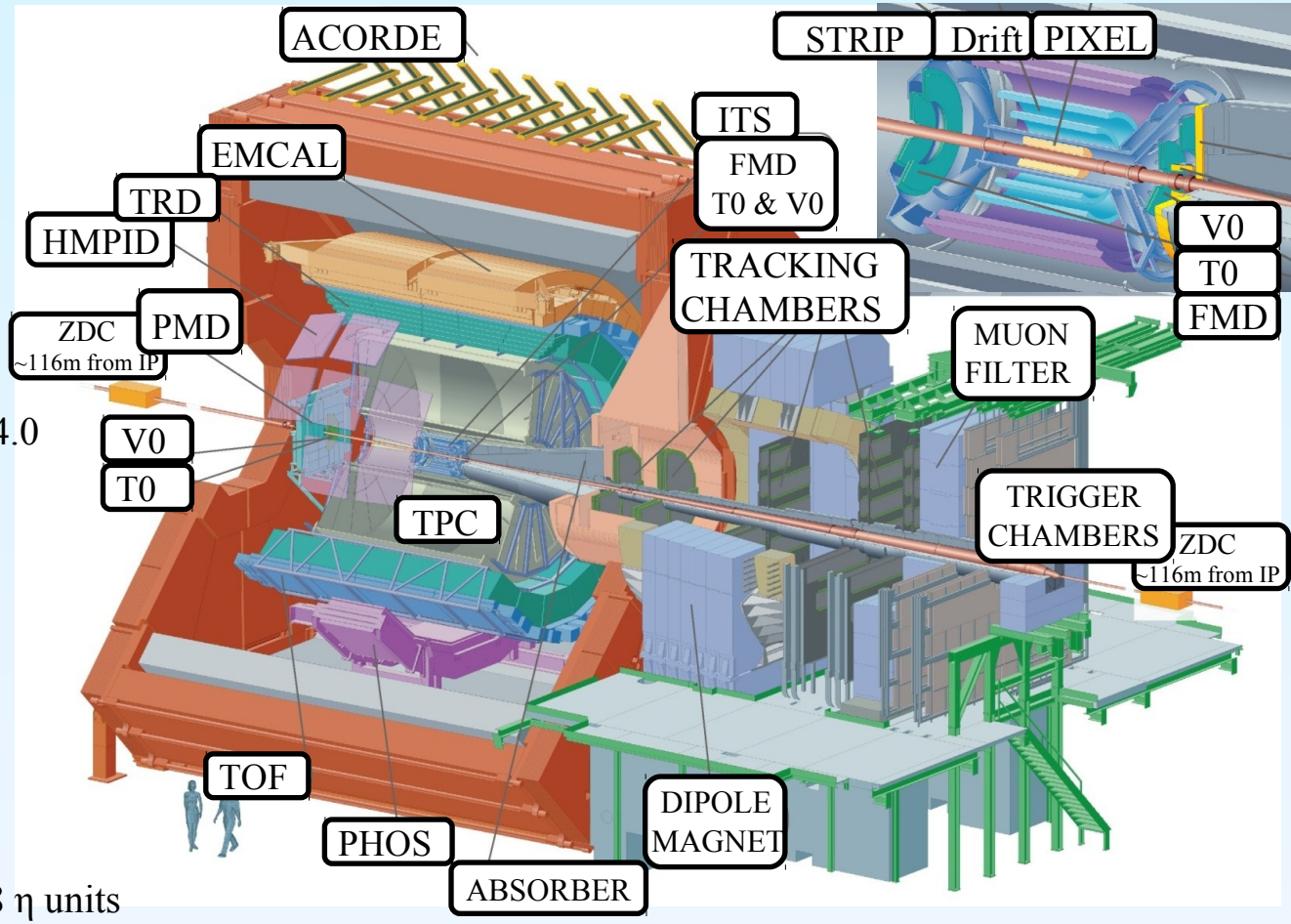
- For J/ψ from $p_T = 0$ GeV/c
- For open heavy flavour from $p_T = 1$ GeV/c

Large acceptance in rapidity:

- Central barrel: $-0.9 \leq \eta \leq 0.9$
- Forward muon arm: $-2.4 \leq \eta \leq -4.0$

Measure various final states:

Hadronic, electronic and muonic



Trigger

Minimum bias:

- SPD or V0A or V0C
- At least one charged particle in 8 η units
- ~ 95% of σ_{inel}

Single-muon trigger:

- Forward muon in coincidence with Min Bias

Both activated in coincidence with the BPTX beam pickups

Configuration in 2010:

Complete, besides TRD 39%, PHOS 60%, EMCAL 36 %

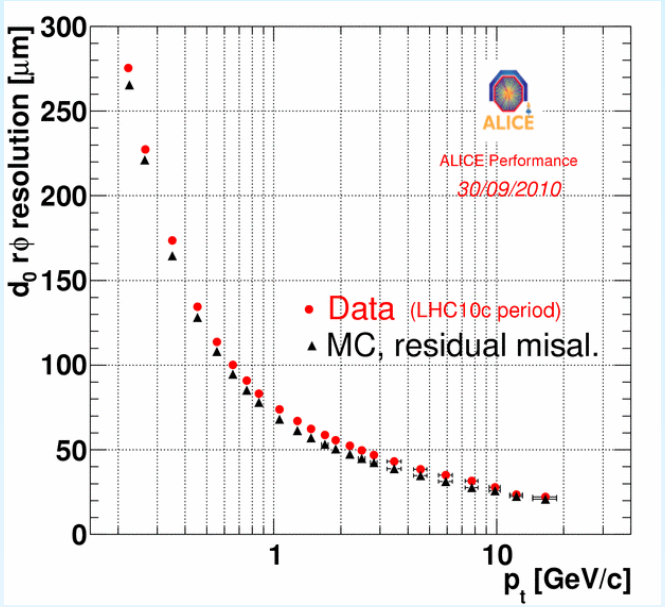
Tracking and Particle Identification Performance

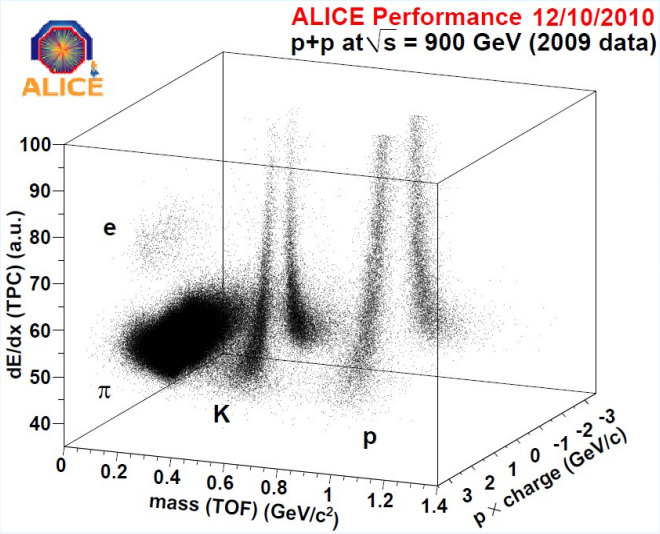
- **Transverse Impact Parameter Resolution**
  - Inner Tracking System (ITS) with 6 Si Layers
    - Two pixel layers at r ≈ 3.9 and 7.6 cm
  - < 75 μm for p_T > 1 GeV/c

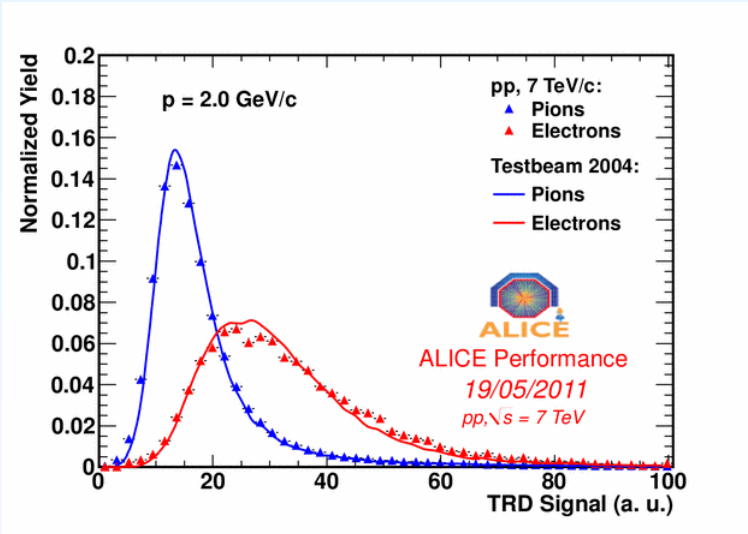
→ Allows to select displaced-vertex

- **Particle Identification with various systems**
  - TOF, TPC, TRD, EMCAL, Muon Spectrometer

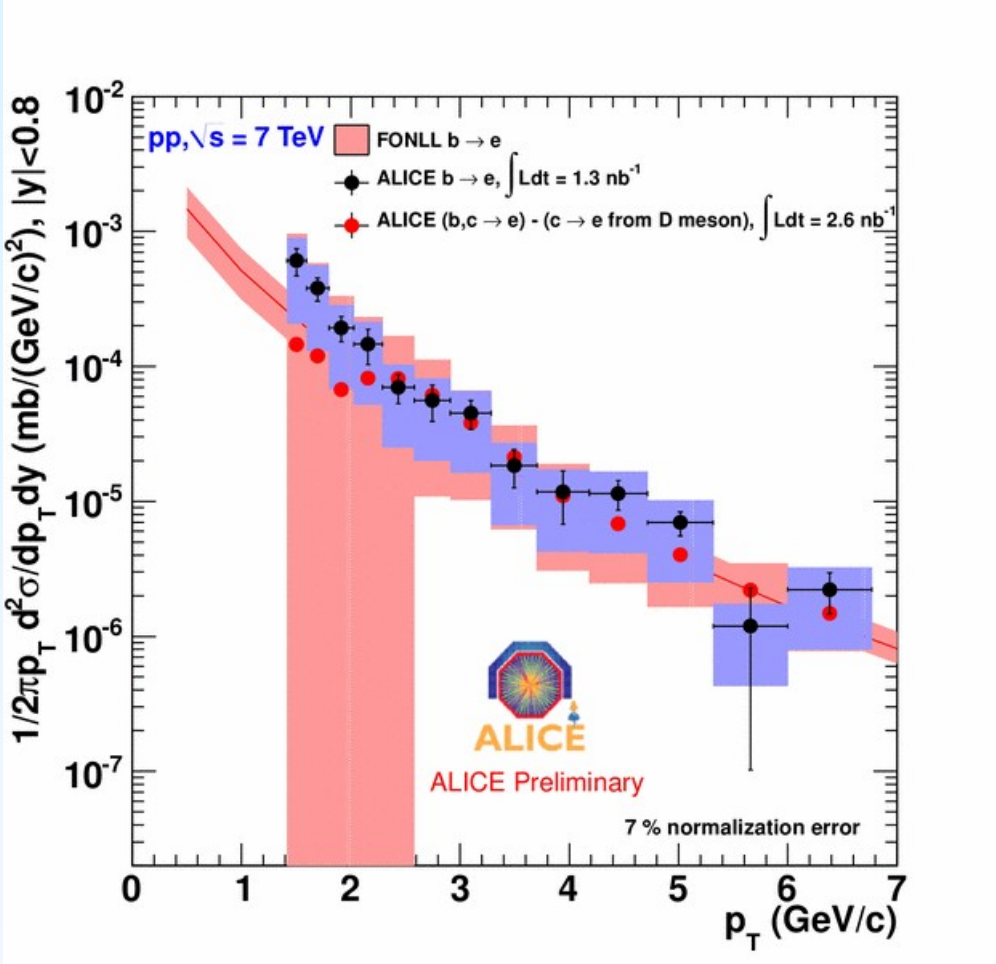
→ e. g. hadronic D decays: rejection of Kaons (reduce low p_T bkg)



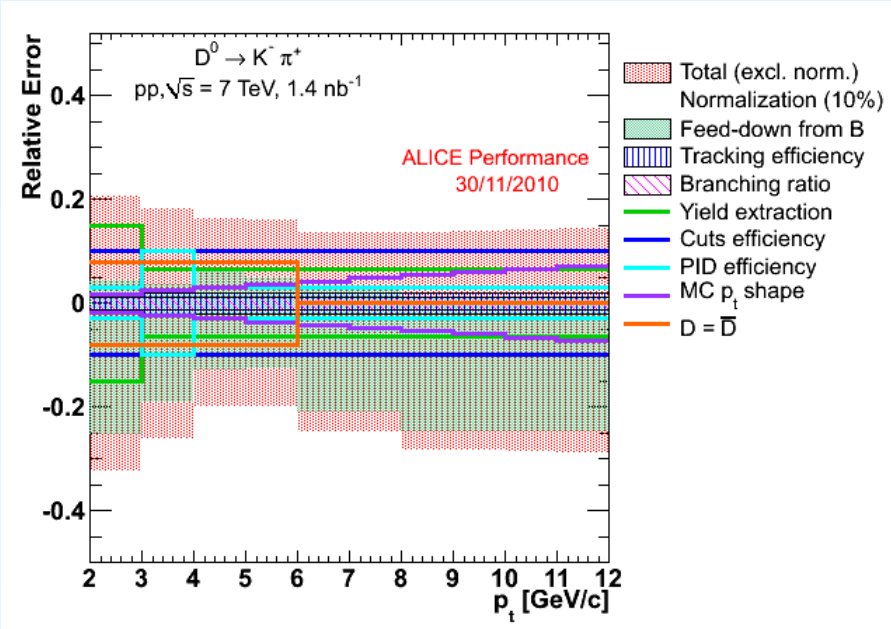


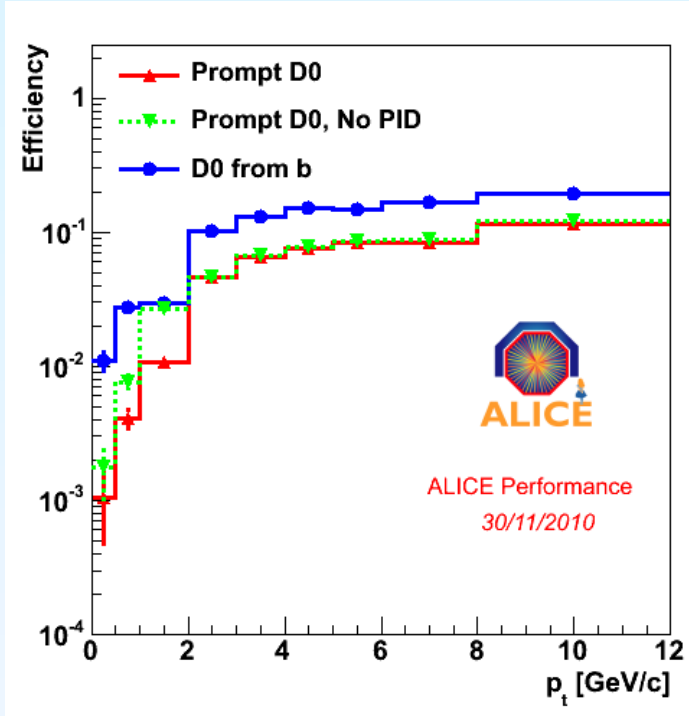


Cross Check Beauty Decay Electron Analysis



D^0: Systematic Uncertainties and Efficiency Correction





HFE: Systematic Uncertainties