Quarkonium and open heavy flavours in pp collisions with ALICE

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ALICE

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Content

Physics motivations.

The ALICE experiment.

Data sets and trigger
- Central Barrel.
- Muon Spectrometer.

Quarkonium
- Inclusive cross-sections.
- Polarization.
- Multiplicity.
- Prompt/non-prompt.

Open heavy flavours
- D mesons.
- e, μ ← HF.
- e ← B.

Conclusions.

Alice in wonderland

Physics motivations

- The LHC is a heavy-flavour factory

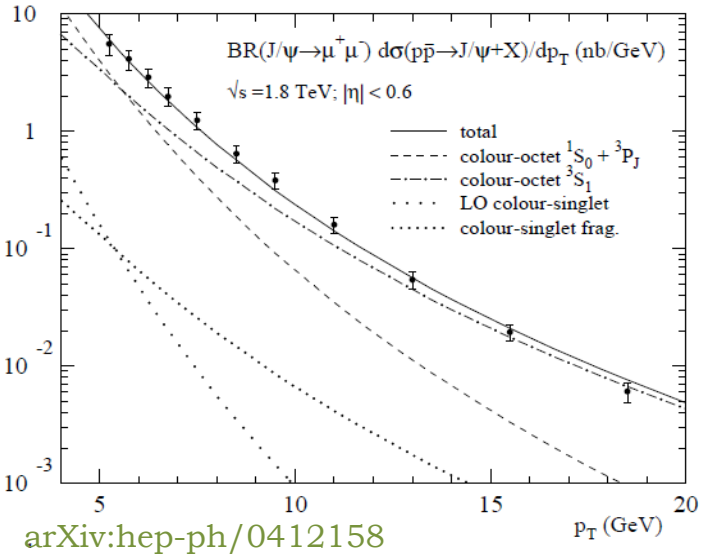
$$\begin{cases} \sigma_c(\mathrm{LHC}) \approx 10 \times \sigma_c(RHIC) \\ \sigma_b(\mathrm{LHC}) \approx 100 \times \sigma_b(RHIC) \end{cases}$$

- Produced in the initial hard partonic collisions:

$$\tau_{\mathrm{Prod}} \approx 1/m_{\mathrm{Q}} \approx 0.05 - 0.15 \ \mathrm{fm/c}$$

→ Test NLO pQCD in a new energy regime (large theoretical uncertainties!)

- Quarkonium production models (CSM, CEM and NRQCD) cannot describe all the observables.



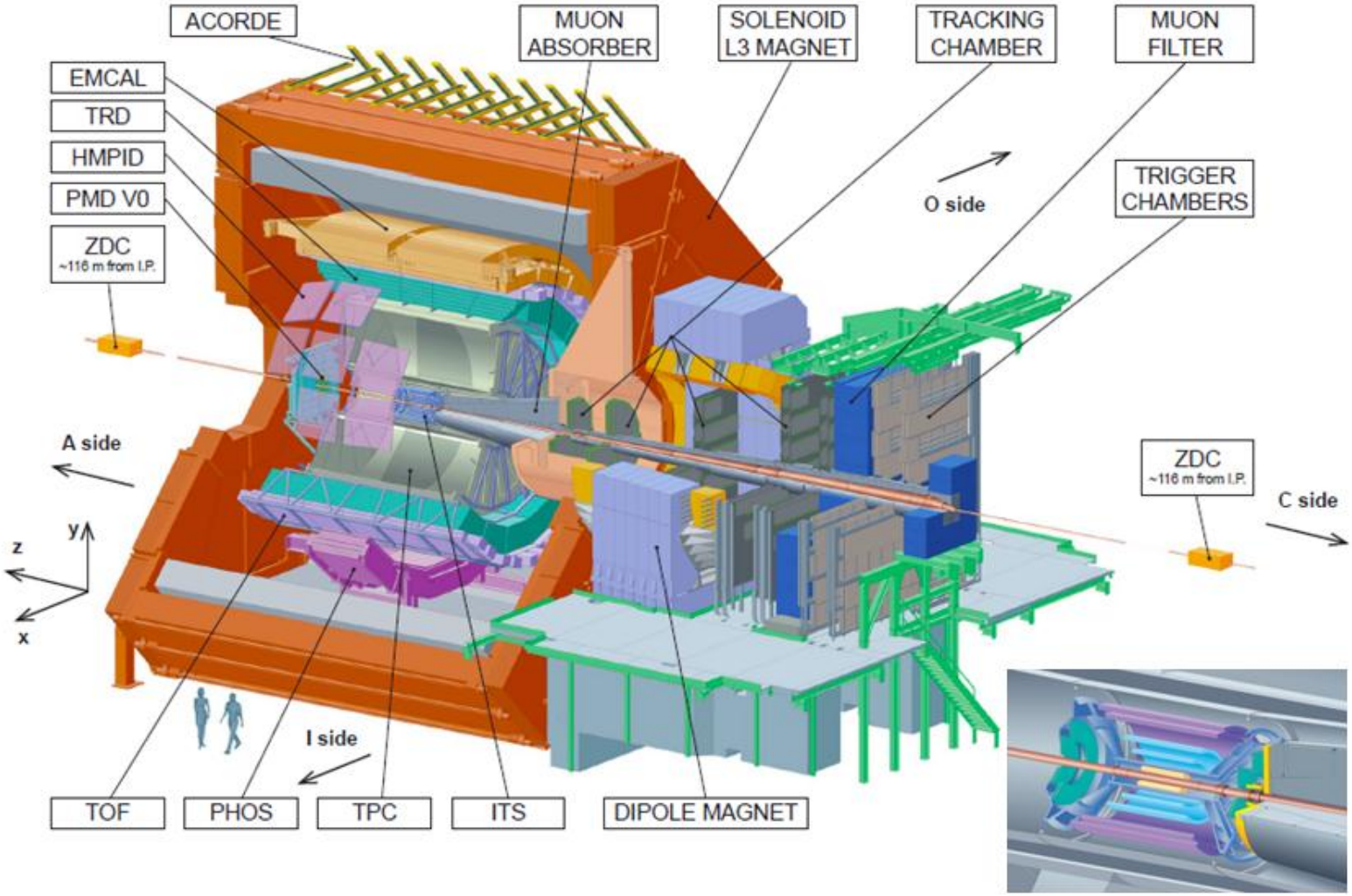
arXiv:hep-ph/0412158

→ J/ψ polarization measurement is a stringent test for theoretical calculations.

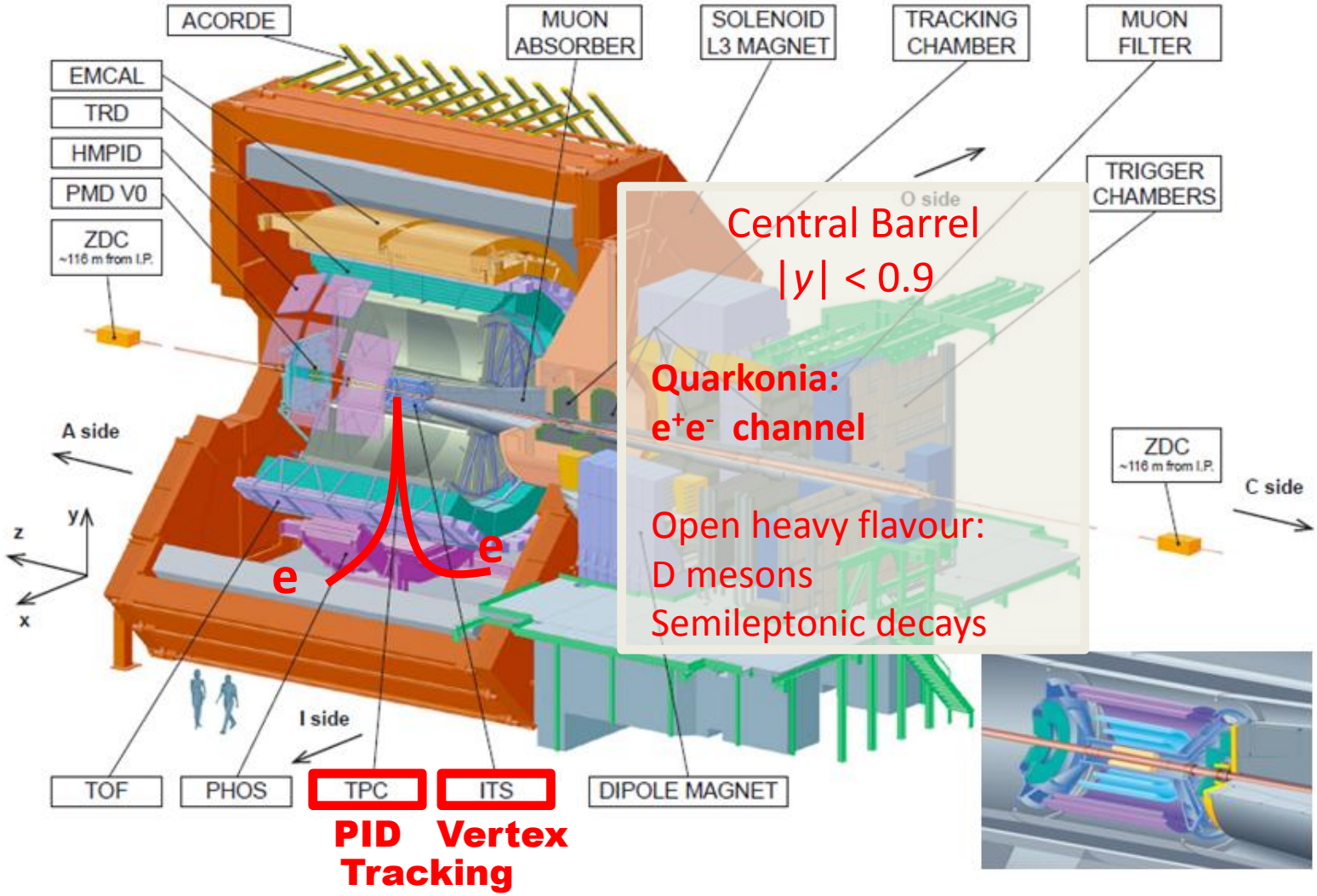
- Baseline for AA studies $R_{\mathrm{AA}}(p_{\mathrm{T}}, \eta) = \dfrac{1}{\langle N_{\mathrm{Coll}} \rangle} \dfrac{d^2N_{\mathrm{AA}}/dp_{\mathrm{T}}d\eta}{d^2N_{\mathrm{pp}}/dp_{\mathrm{T}}d\eta}$

M. Marchisone's talk (this afternoon)

The ALICE experiment



The ALICE experiment



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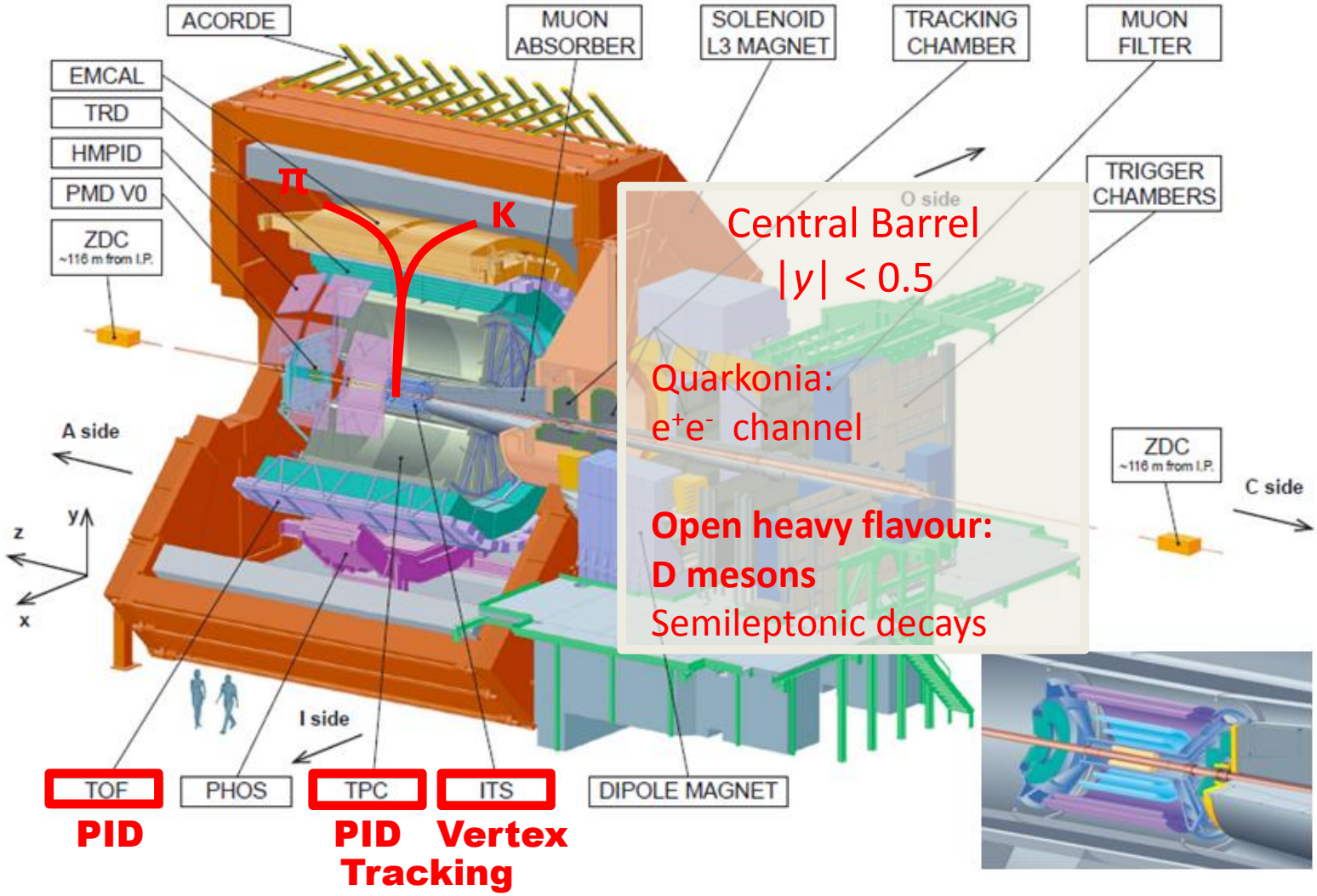
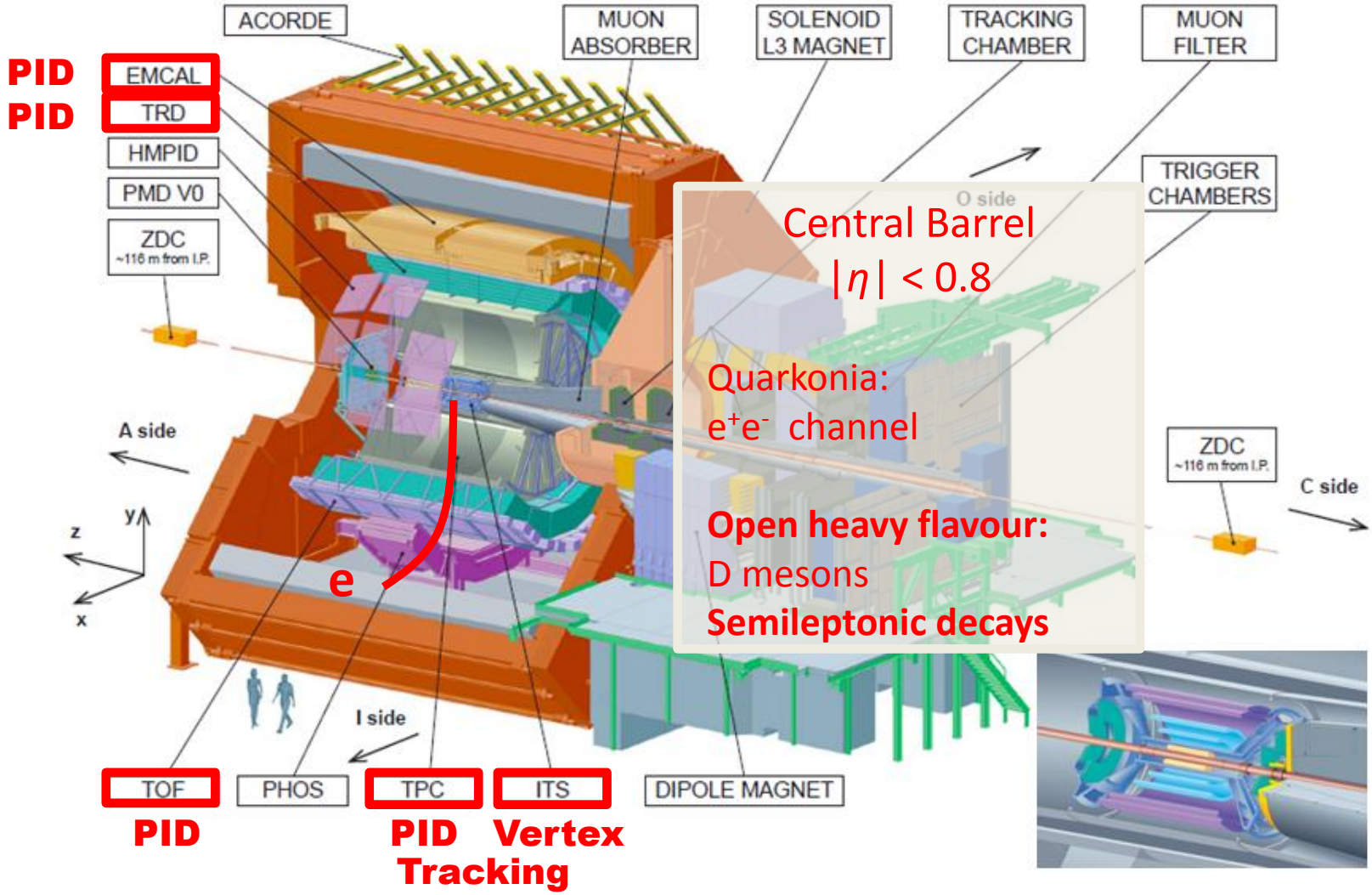


The ALICE experiment



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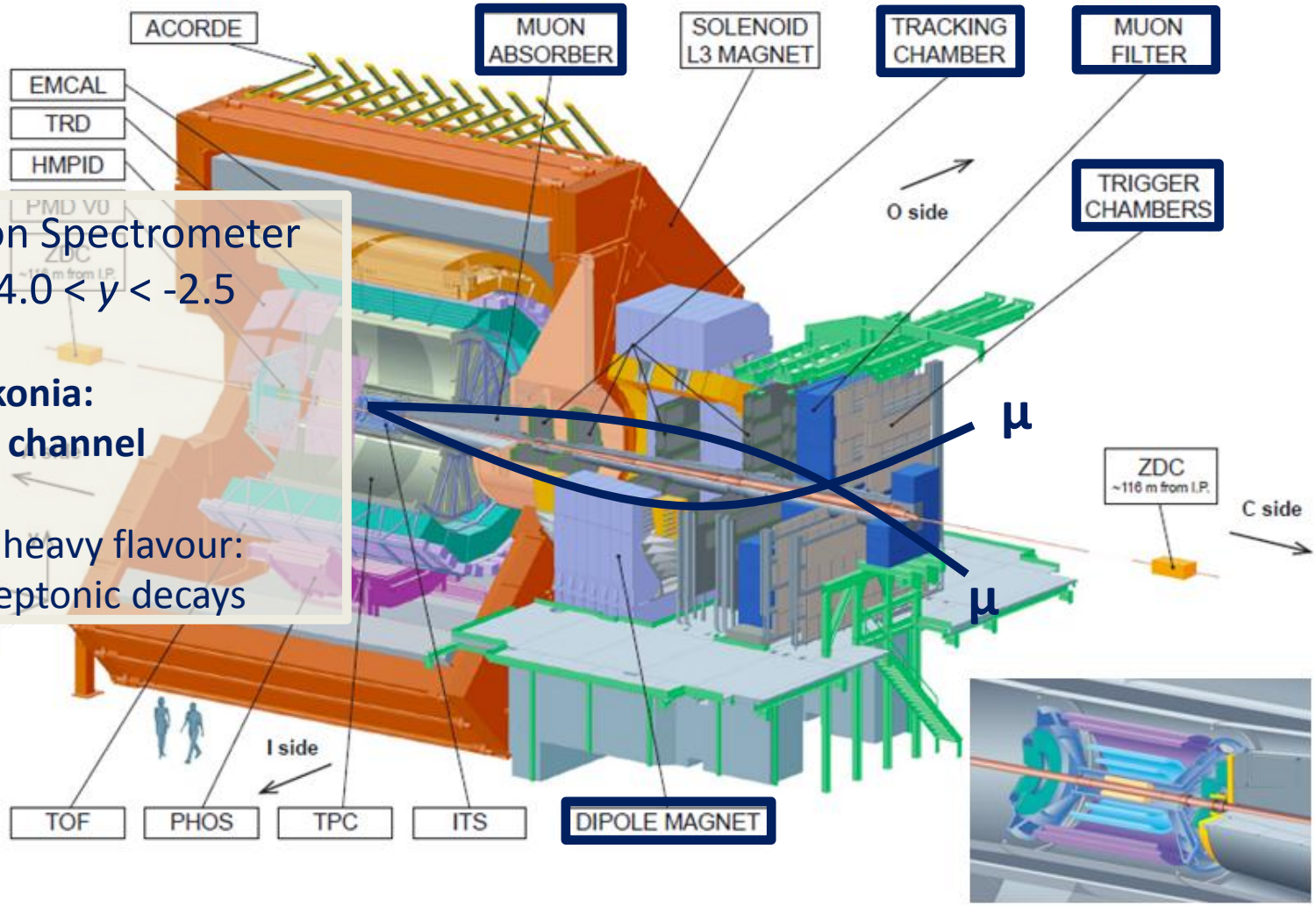
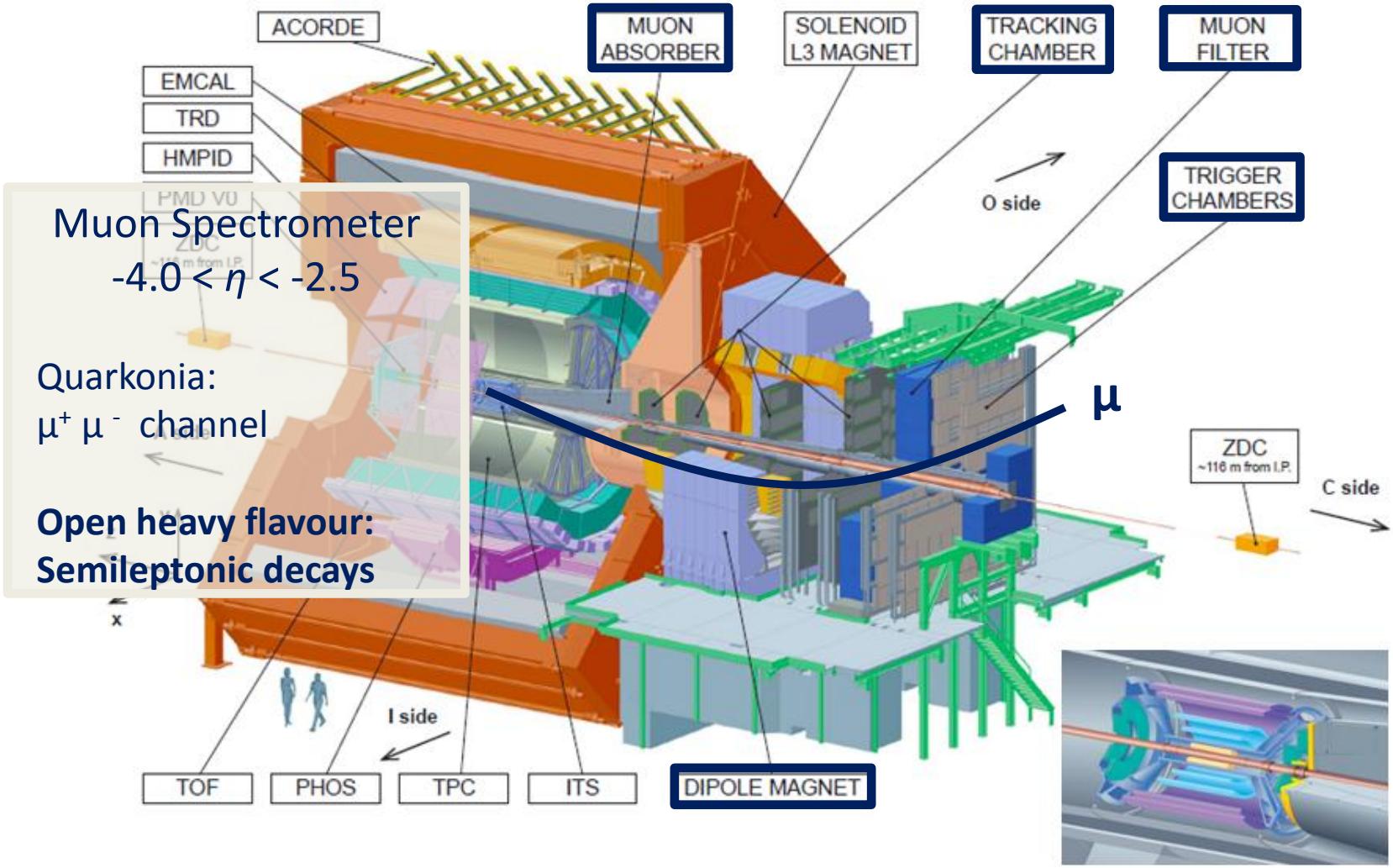


Muon Spectrometer
$-4.0 < y < -2.5$

Quarkonia:
$\mu^+ \mu^-$ channel

Open heavy flavour:
Semileptonic decays

The ALICE experiment



Muon Spectrometer

$-4.0 < \eta < -2.5$

Quarkonia:

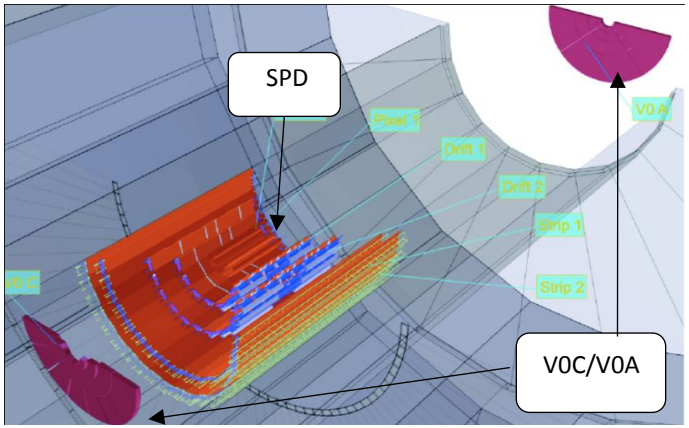
$\mu^+ \mu^-$ channel

Open heavy flavour: Semileptonic decays

Data sets and trigger (Central Barrel)

$\sqrt{s}$	**e ← HF**	**e ← B**	**$D^0/D^+/D^{*+}$**	**D_s^+**	**$J/\psi \rightarrow ee$ $\sigma/N_{ch}/B$**
7 Tev	2.6 nb^{-1} MB	2.2 nb^{-1} MB	5 nb^{-1} MB	5 nb^{-1} MB	5.6/5.6/5.6 nb^{-1} MB
2.76 TeV	Not today	Not today	1.1 nb^{-1} MB	---	1.1/---/--- nb^{-1} MB

$D^0 \rightarrow K\,\pi$ $D^+ \rightarrow K\,\pi\,\pi$ $D^{*+} \rightarrow D^0\,\pi$ $D_s^+ \rightarrow \varphi\,\pi$

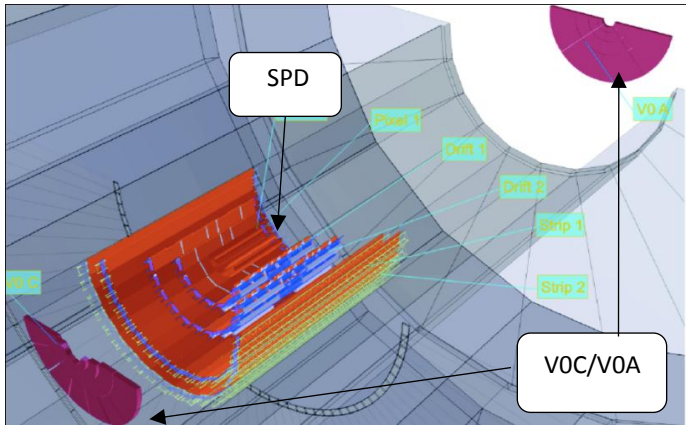


Minimum Bias (MB) trigger: a combination of
- SPD (one or two hits).
- VZERO (one or both sides).

VZERO detector is made out of two hodoscopes of plastic scintillators (V0A and V0C) at both sides of the SPD.

Data sets and trigger (Muon Spectrometer)

$\sqrt{s}$	$\mu \leftarrow$ HF	$J/\psi \rightarrow \mu\mu$ σ/N_{ch}/Pol
7 Tev	16.5 nb^{-1} Muon	15.6/7.7/100 nb^{-1} Muon
2.76 TeV	19 nb^{-1} Muon	19.9/---/--- nb^{-1} Muon



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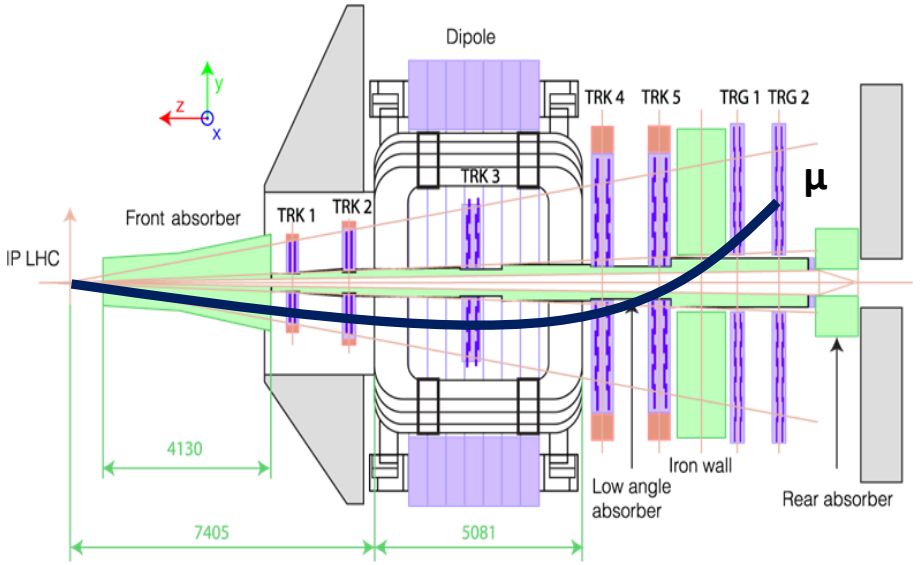
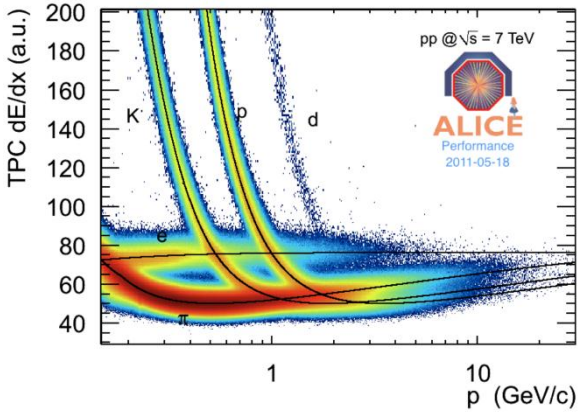


QUARKONIUM

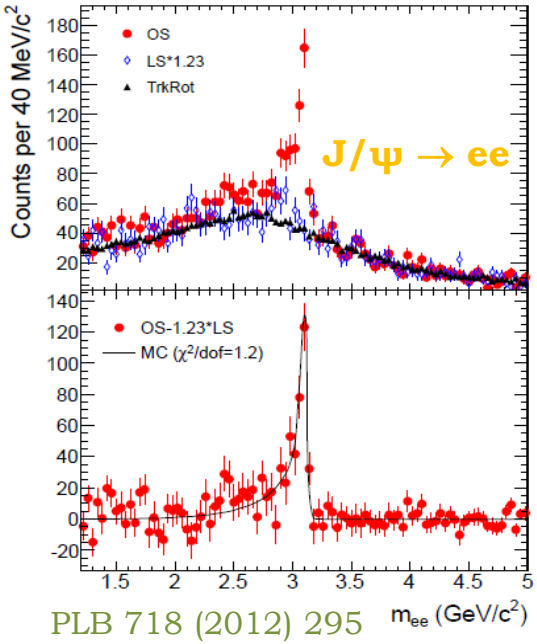
ALICE performance



ALICE is unique at the LHC

→ J/ψ measurements, both at mid and forward rapidity, are performed down to p_T = 0 GeV/c.

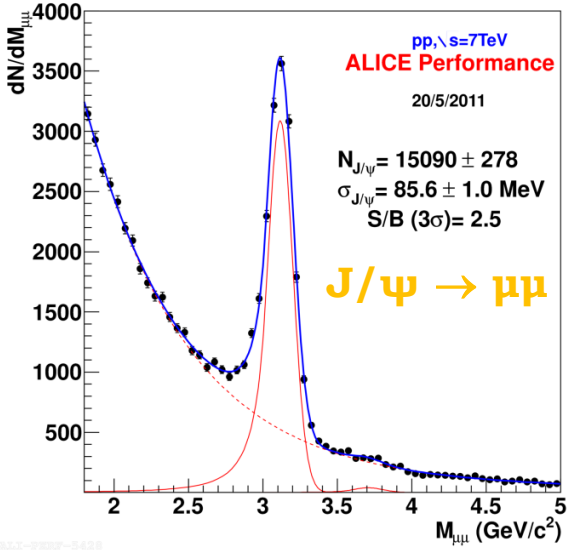
Electron identification via the specific energy loss (dE/dx) in the TPC.



PLB 718 (2012) 295

Muons are identified by requiring that they fire the muon trigger system.

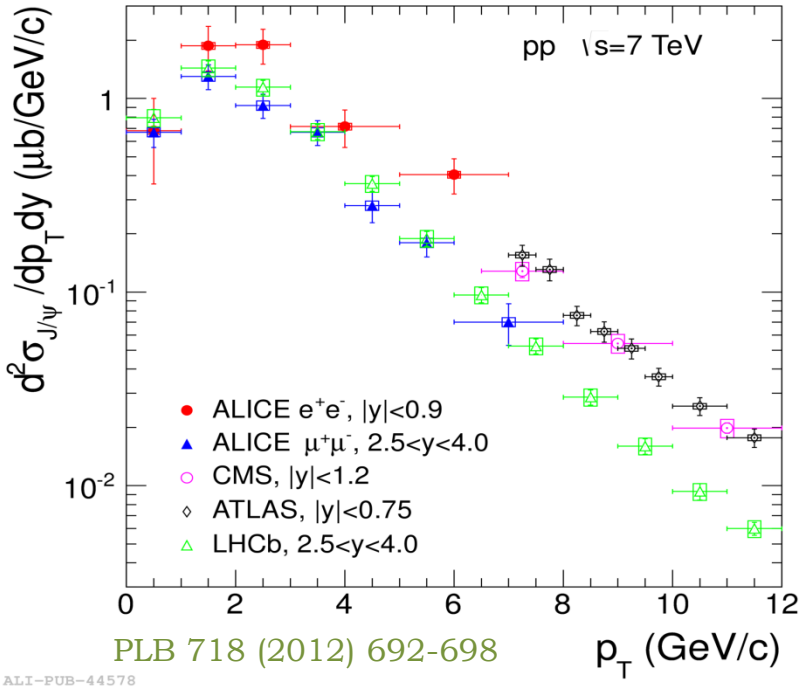
Very good performance in J/ψ detection in a large rapidity range!



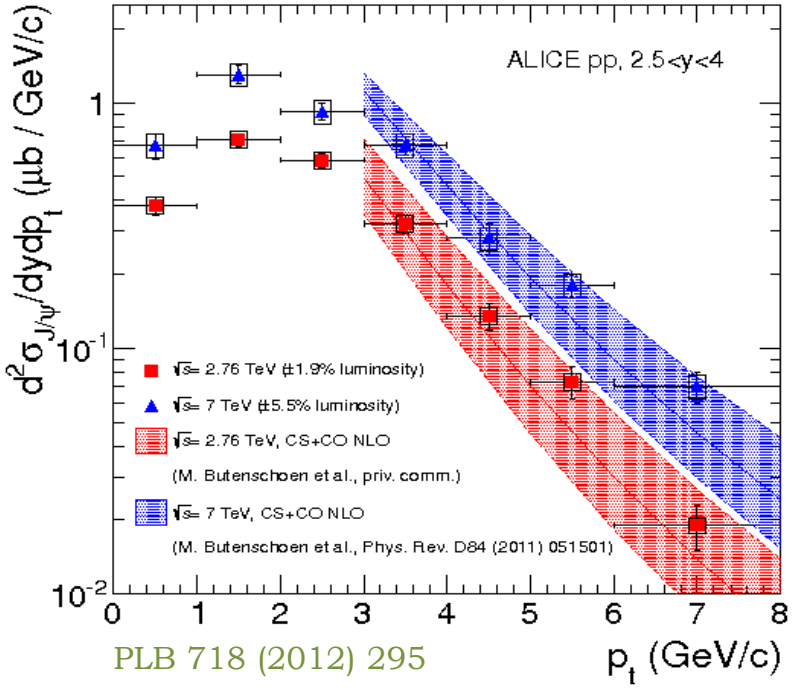
Inclusive cross-sections

Comparison, at 7 TeV, with other LHC experiments: good agreement, both at mid (ALICE complementary to ATLAS and CMS) and forward y (with LHCb).

$2.5 < y < 4.0$: NRQCD calculations describe the measured $d^2\sigma/dy dp_T$ at 7 and 2.76 TeV.



PLB 718 (2012) 692-698



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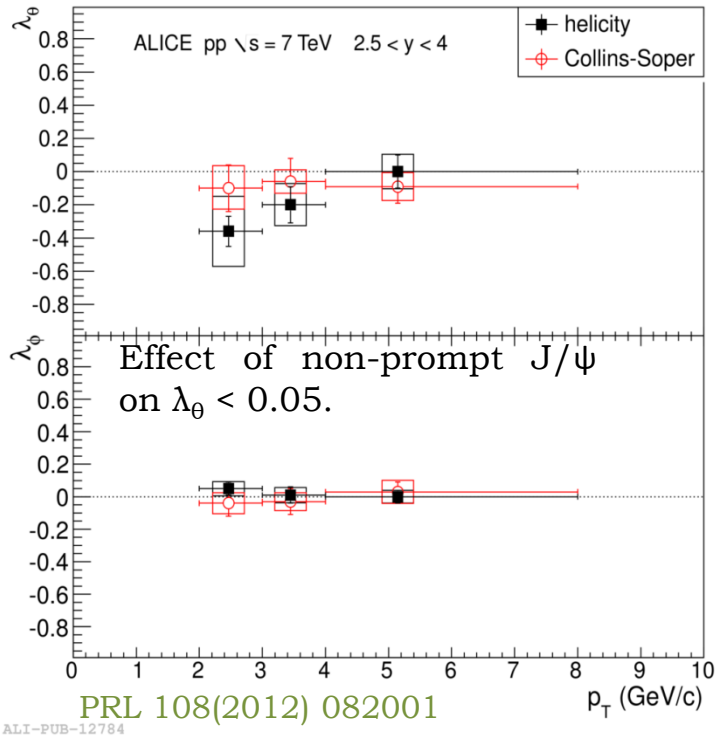
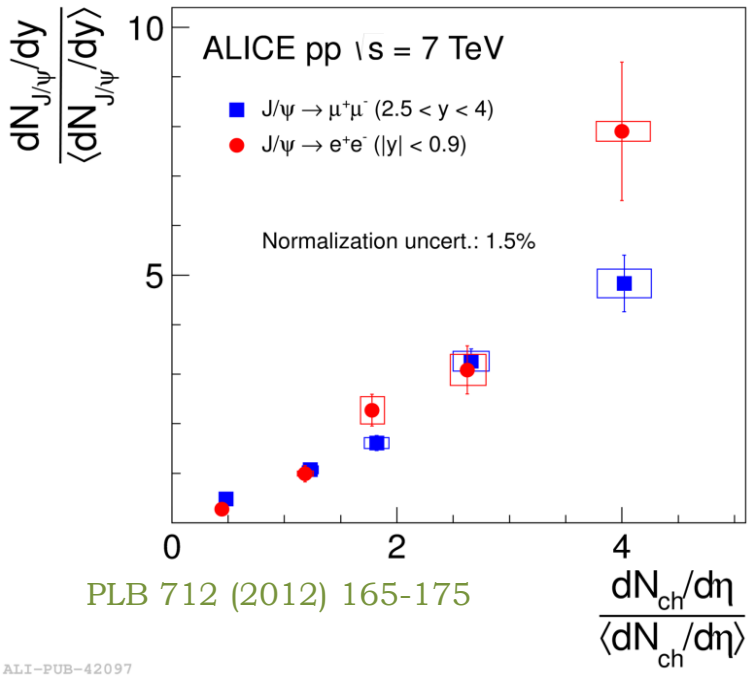
Polarization & yield vs multiplicity



PRL 108(2012) 082001

No significant polarization observed for p_T < 8 GeV/c.

Hint of longitudinal polarization at low-p_T in the helicity frame.



PLB 712 (2012) 165-175

Relative J/ψ production yield vs relative charged particle multiplicity density: observed an approximately linear increase in both rapidity regions.

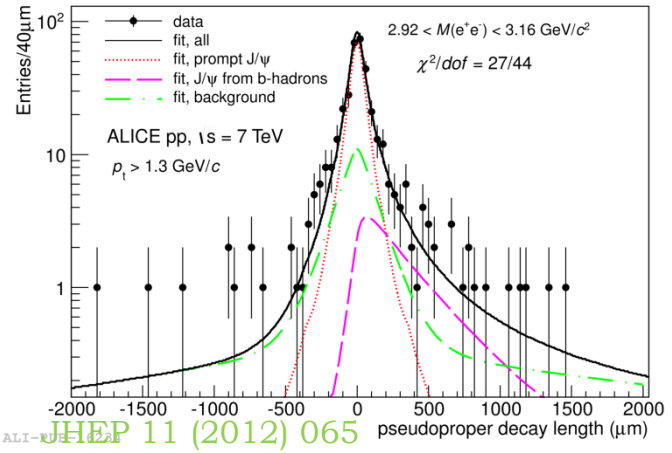
J/ψ production accompanied by a strong hadronic activity.

Prompt/non-prompt J/ψ

prompt J/ψ + non-prompt J/ψ = inclusive J/ψ

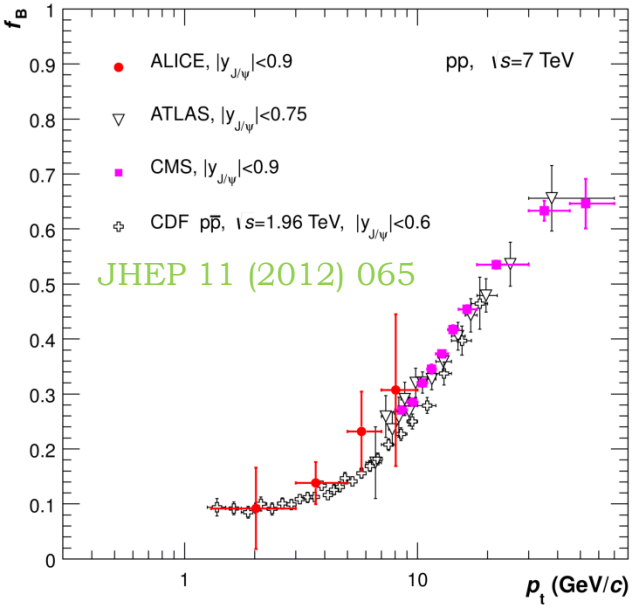
Can be separated at mid rapidity by measuring the J/ψ pseudoproper decay length.

Precise determination of the primary and secondary vertex is needed!



Contribution of non-prompt J/ψ measured by ALICE ranges from 10% (at low- p_T) up to 30% (p_T ≈ 10 GeV/c).

ALICE complements ATLAS and CMS measurments by extending the p_T reach down to ≈ 1 GeV/c.



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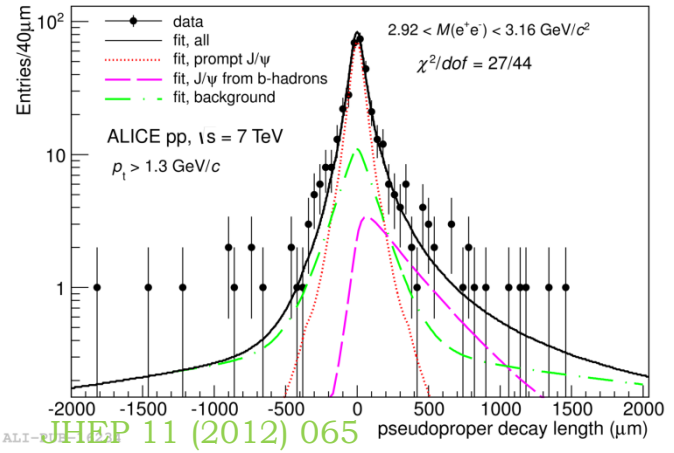

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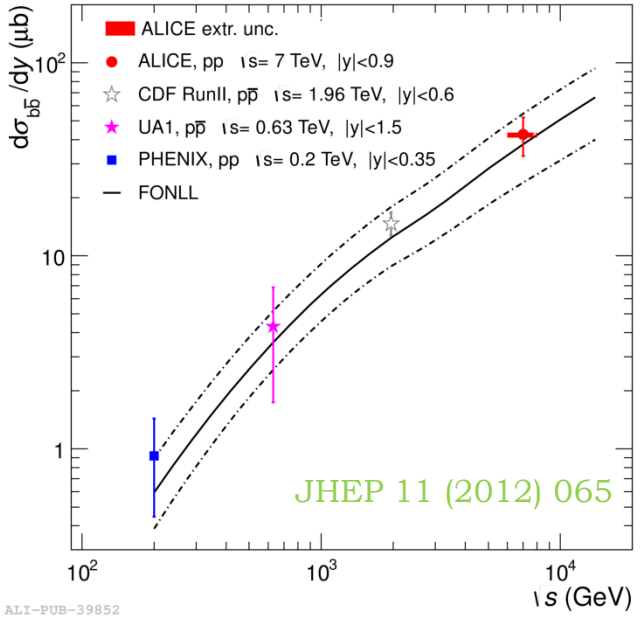
B production cross-section at mid rapidity from ALICE and lower energy experiments is well described by FONLL calculations.

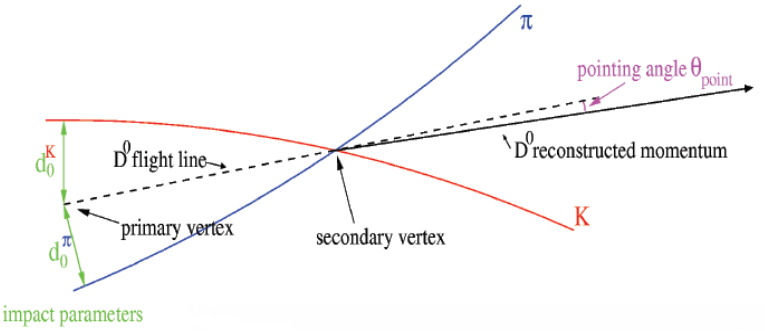


OPEN HEAVY FLAVOURS

ALICE performance

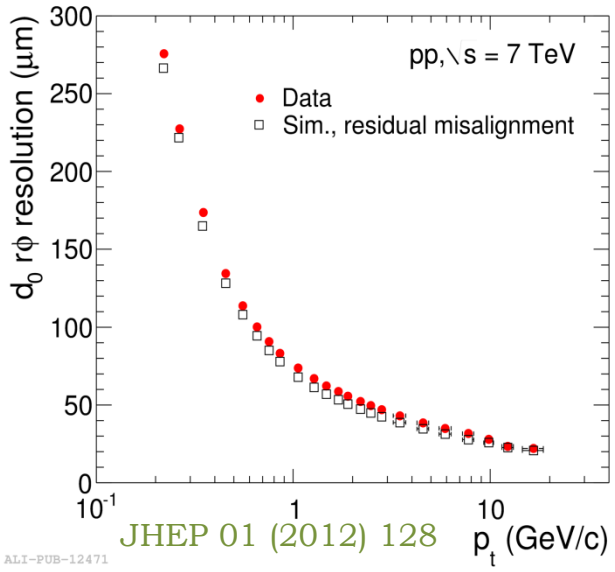
Open heavy flavours in Central Barrel

- Displaced vertex topology.
- Particle Identification.



Precise tracking and vertexing precision needed!

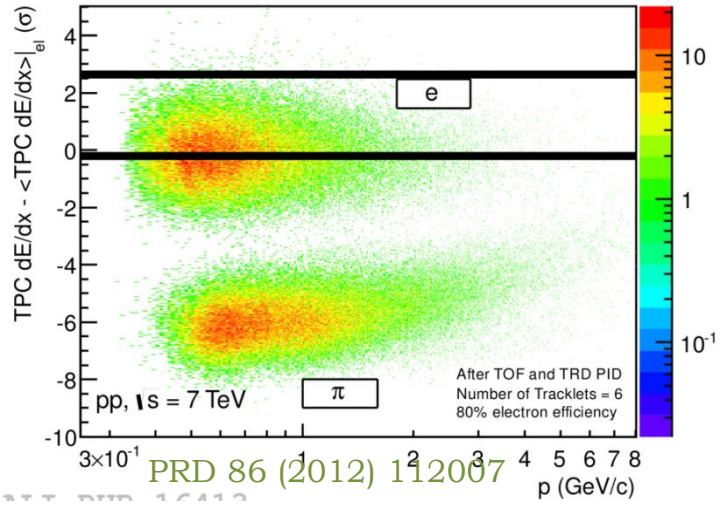
- Primary vertex
- Secondary vertex
- Impact parameter



ALICE: excellent impact parameter resolution.

PID

- ✓ π/K: TPC and TOF.
- ✓ e: TOF, TPC, TRD and EMCAL.

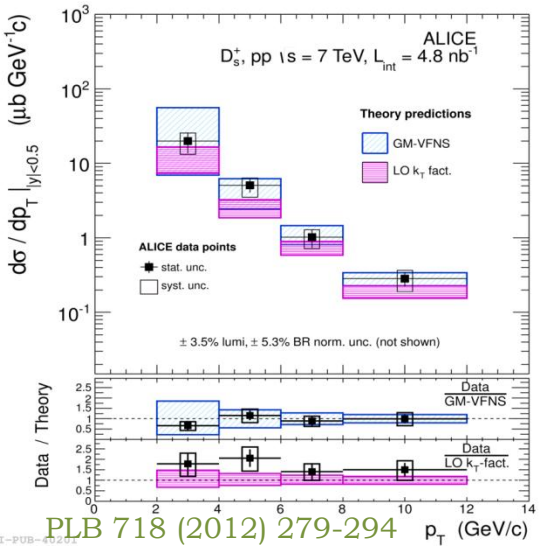


D mesons @ 7 TeV

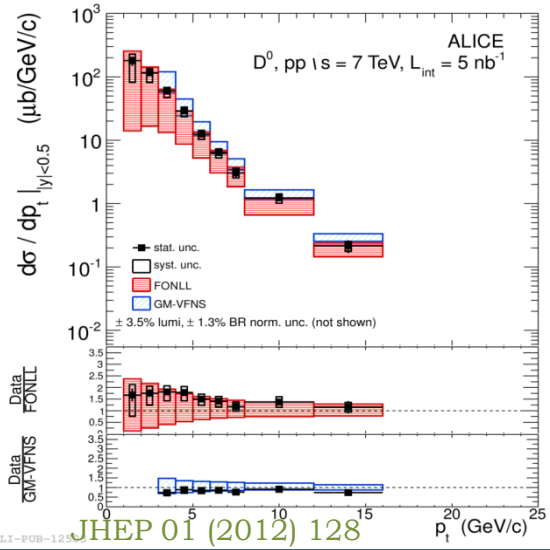
B → D feed down subtracted with FONLL

Prompt D mesons p_T differential cross-sections are described within uncertainties by pQCD calculations (FONLL & GM-VFNS).

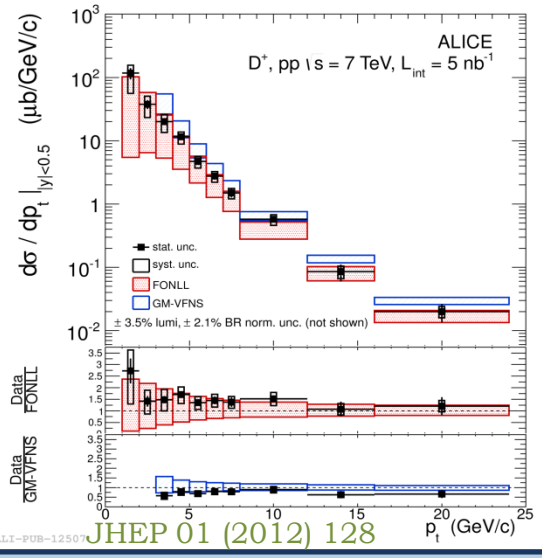
D^0, D^+ and D^{*+} results also available at 2.76 TeV.



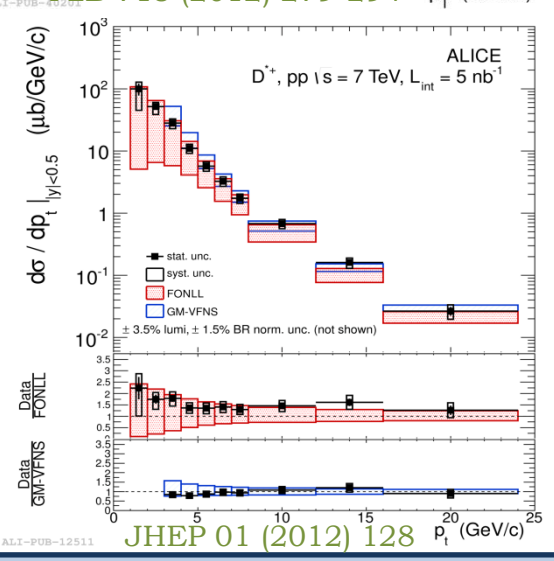
PLB 718 (2012) 279-294



JHEP 01 (2012) 128



JHEP 01 (2012) 128



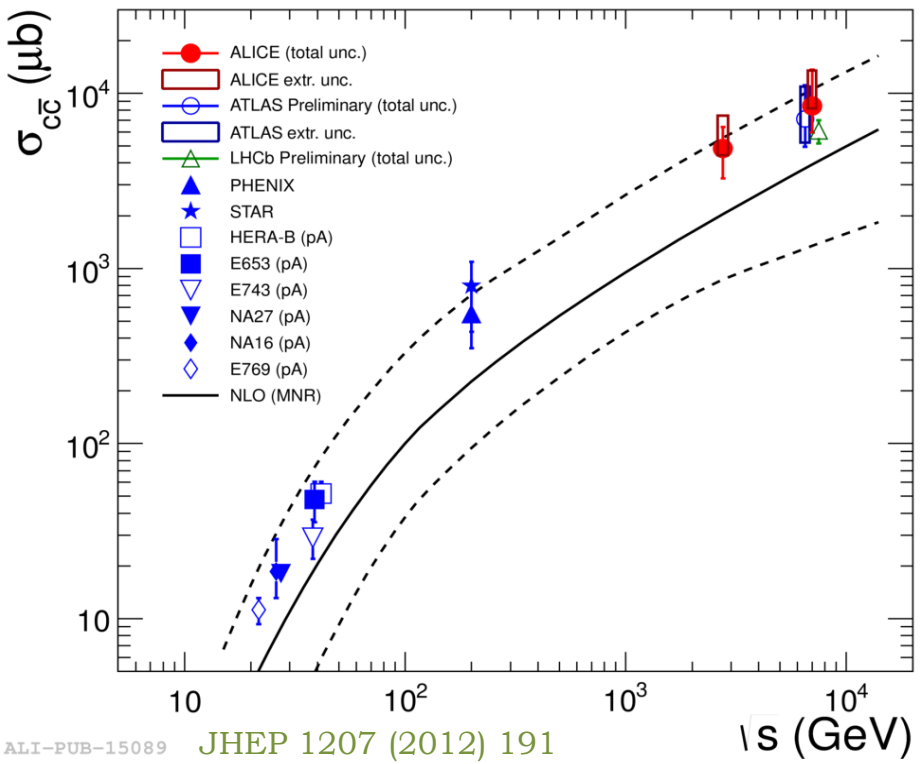
JHEP 01 (2012) 128

Total charm cross-section

Measured cross-sections extrapolated to full phase space using FONLL scaling factors.

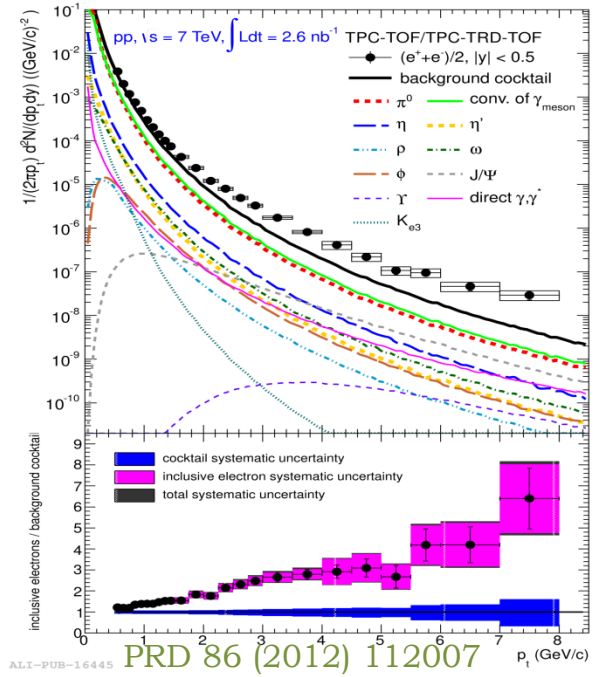
Results in good agreement with other LHC experiments.

All data points lie on the upper band of the NLO MNR predictions.

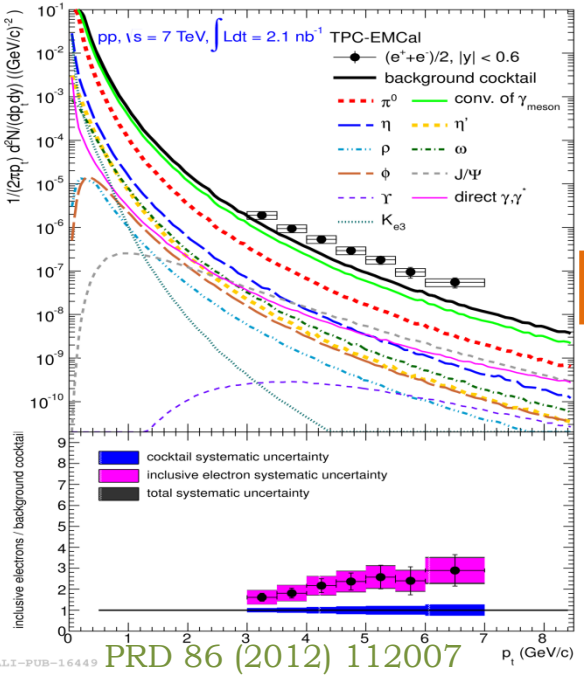


JHEP 1207 (2012) 191

e ← HF @ 7 TeV



PRD 86 (2012) 112007



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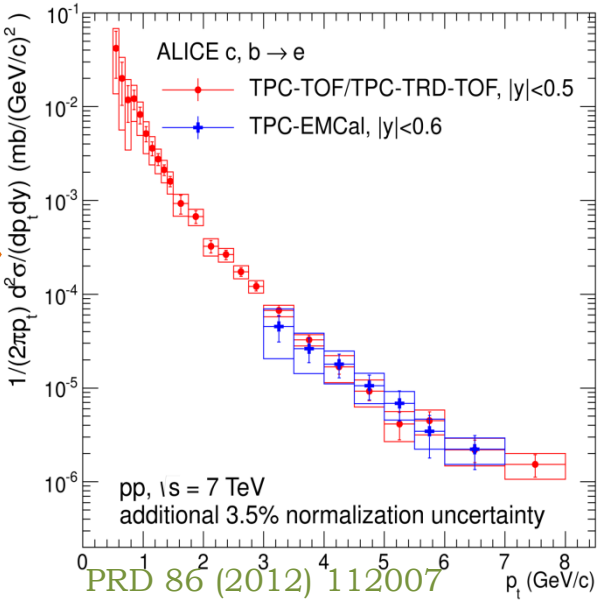
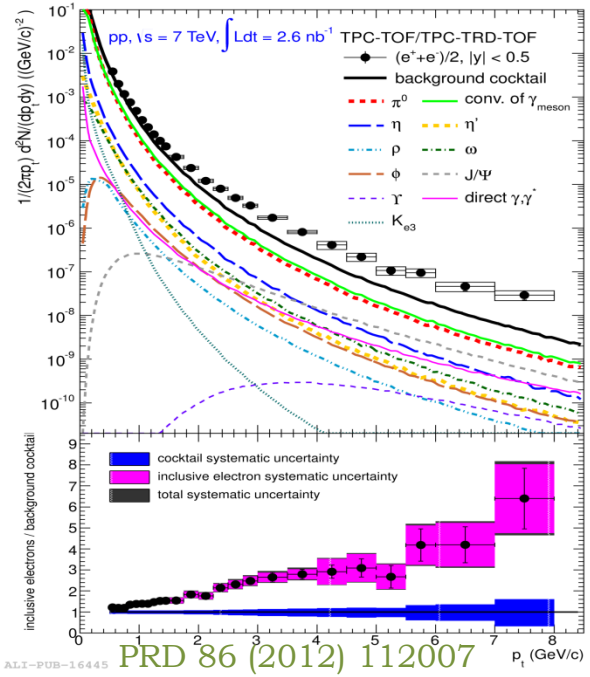


PRD 86 (2012) 112007

Inclusive *e* spectrum with two different PID techniques.
Cocktail of background sources: π^0 (the most important contribution), quarkonium and light vector mesons decays, etc.
Inclusive – cocktail = e ← HF.

e ← HF @ 7 TeV



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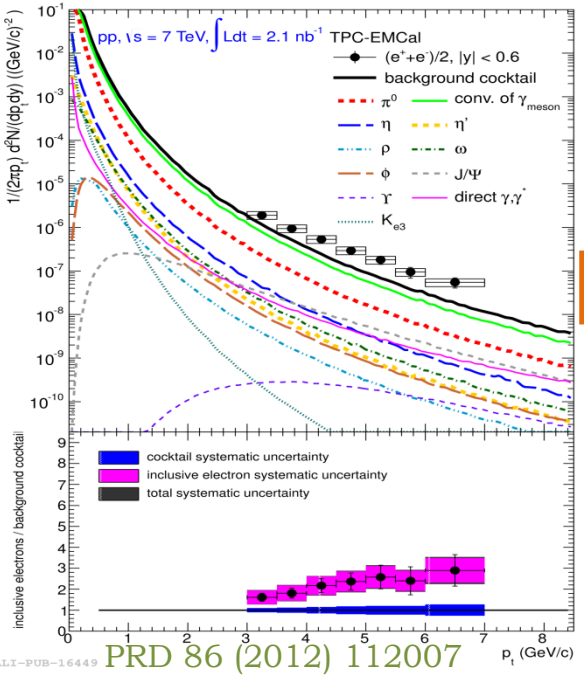

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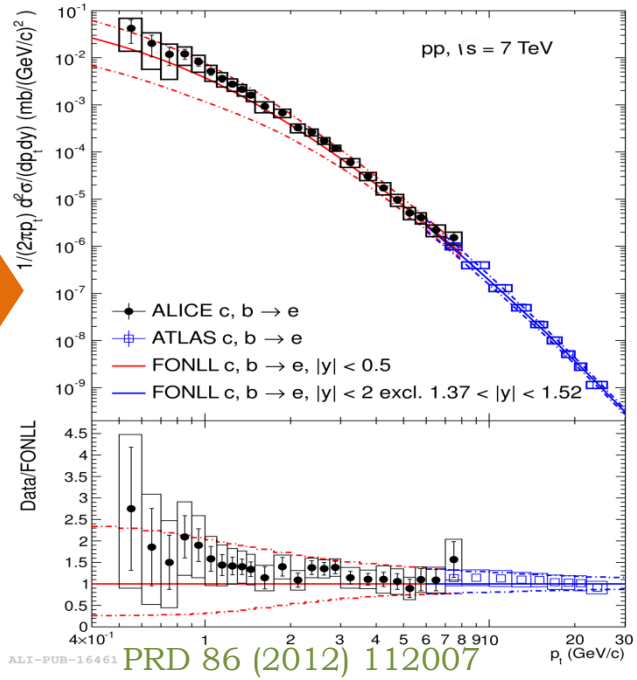


PRD 86 (2012) 112007

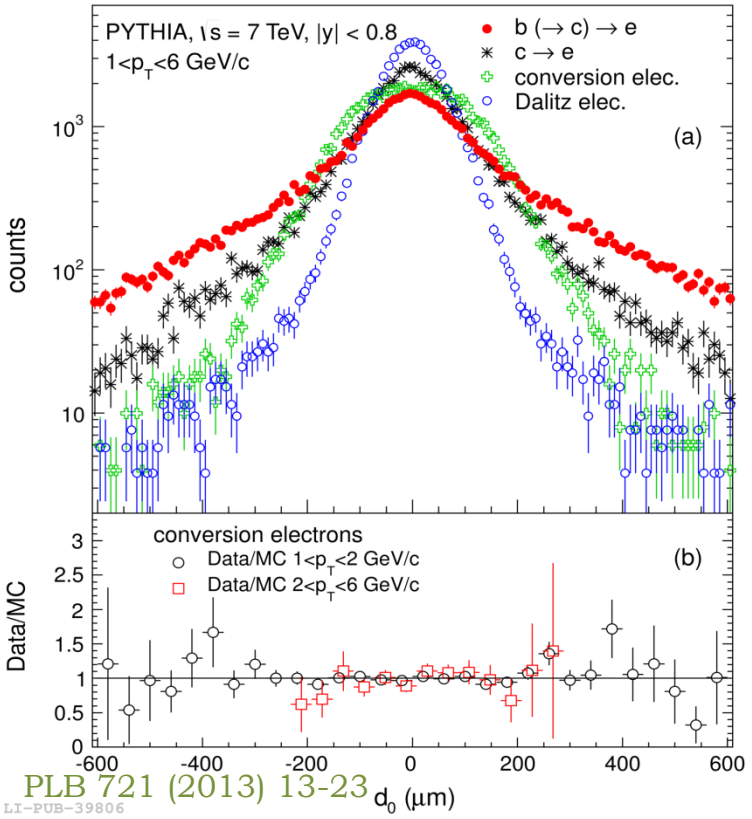
Inclusive e spectrum with two different PID techniques.
Cocktail of background sources: π^0 (the most important contribution), quarkonium and light vector mesons decays, etc.
Inclusive – cocktail = e ← HF.

Combined results: ALICE complements ATLAS results in the low-p_T regime.
FONLL provides a good description of the results over a broad p_T range.

e ← B @ 7 TeV

Exploit large displacement of B decay electrons ➔ apply impact parameter cut!

Then, subtract remaining background electrons with a cocktail.



PLB 721 (2013) 13-23

LI-PUB-39806

e ← B @ 7 TeV

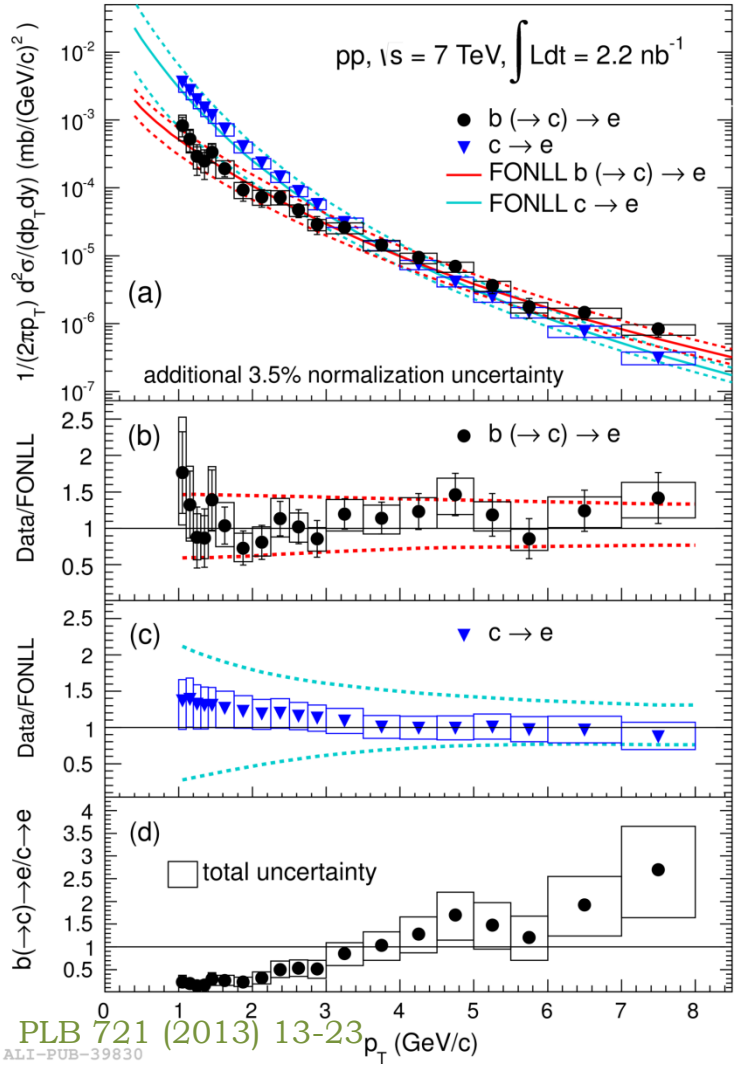
Exploit large displacement of B decay electrons ➔ apply impact parameter cut!

Then, subtract remaining background electrons with a cocktail.

Differential cross-sections well described by FONLL.

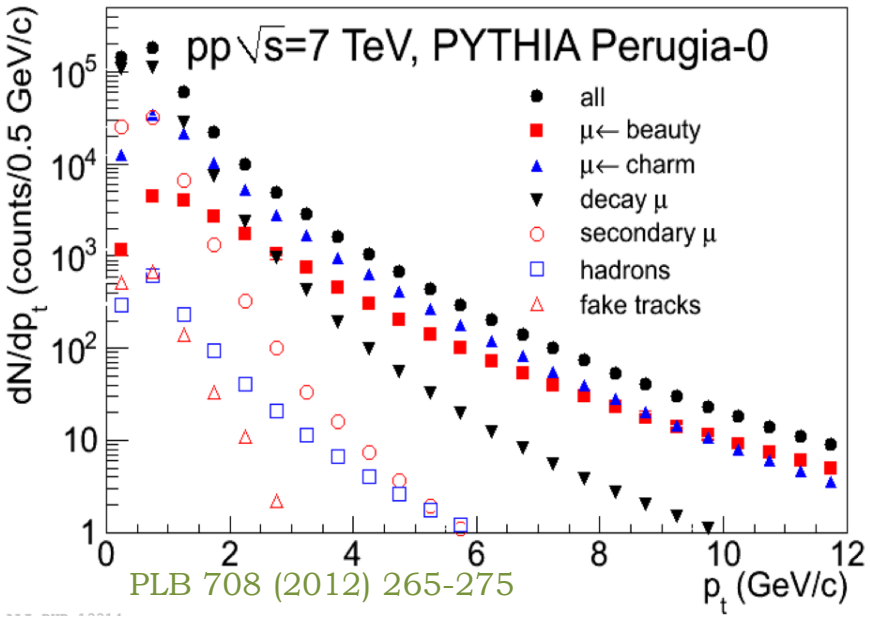
Low-p_T: e from HF predominantly from charm hadrons.

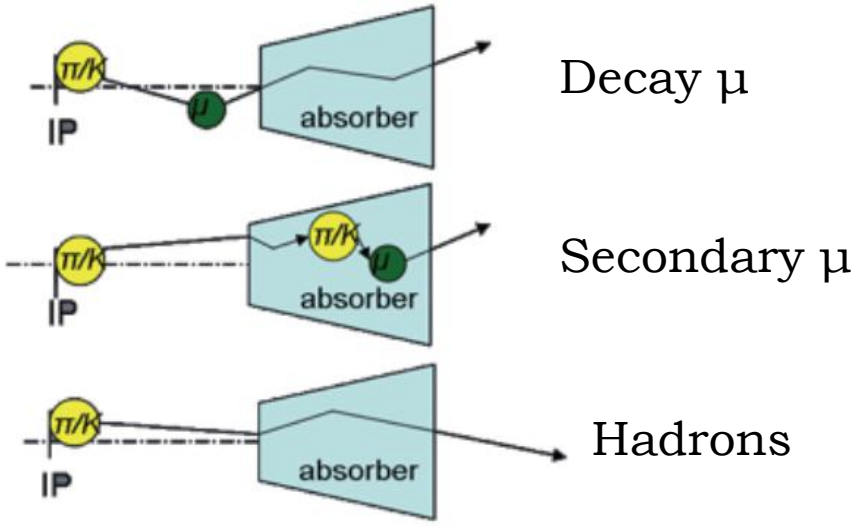
High-p_T: beauty hadrons become dominant.



PLB 721 (2013) 13-23

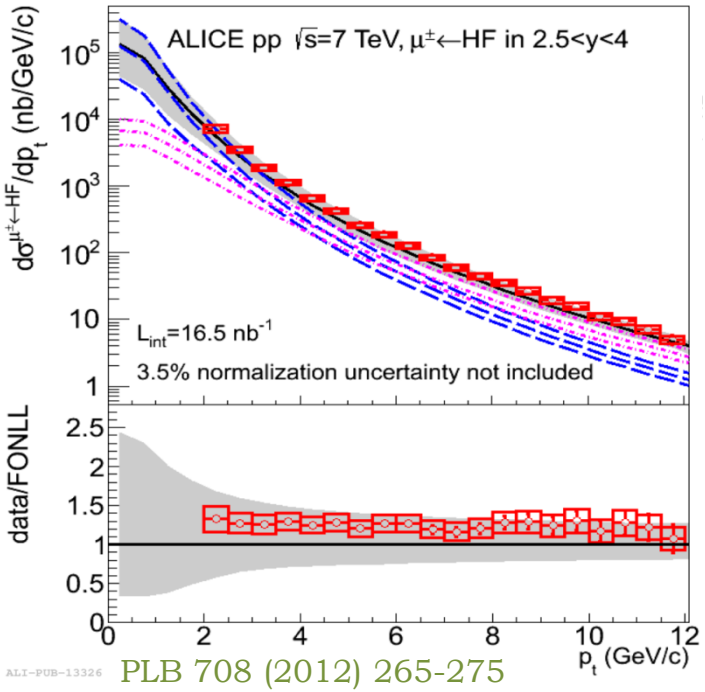
μ ← HF @ 7 and 2.76 TeV



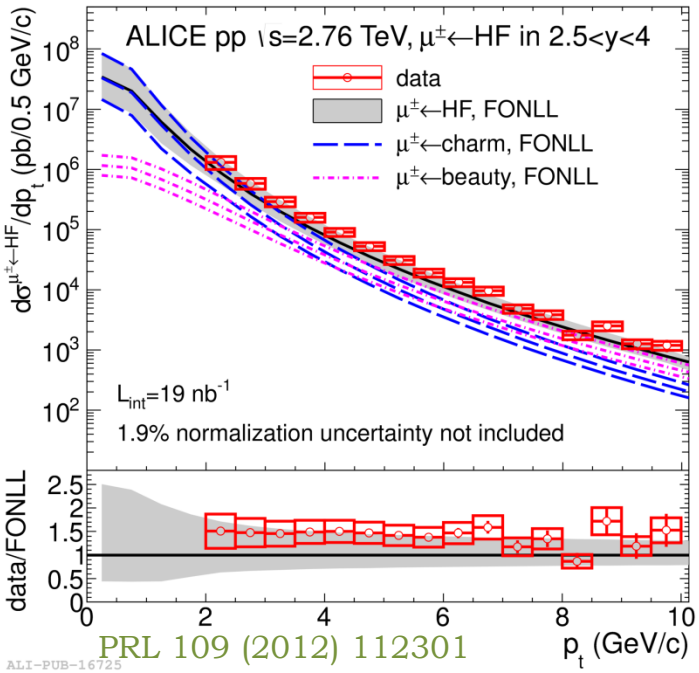


Different sources of background ➔ Analysis restricted to p_T > 2 GeV/c. In this range, μ from π and K decays amount to 25% of the total yield. This is then subtracted based on realistic MC simulations and what is left are μ from HF.

μ ← HF @ 7 and 2.76 TeV



PLB 708 (2012) 265-275



PRL 109 (2012) 112301

Different sources of background ➔ Analysis restricted to p_T > 2 GeV/c. In this range, μ from π and K decays amount to 25% of the total yield. This is then subtracted based on realistic MC simulations and what is left are μ from HF.

Differential cross-sections well described by FONLL.
Beauty contribution is dominant at high-p_T.

Conclusions

- ALICE performs detailed studies on quarkonium and open heavy flavours, both at mid and forward rapidity.
- Inclusive J/ψ production @ 2.76 and 7 TeV is in good agreement with other LHC experiments in the common kinematic regions.
- At forward rapidity and $2 < p_T < 8$ GeV/c J/ψ is unpolarized.
- D mesons (2.76 and 7 TeV) and e, μ ← HF (7 TeV) differential cross sections well described by pQCD.
- At mid rapidity ALICE complements ATLAS and CMS results by extending the measurements to the low-p_T region.

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Je vous remercie de votre attention

BACKUP

Polarization

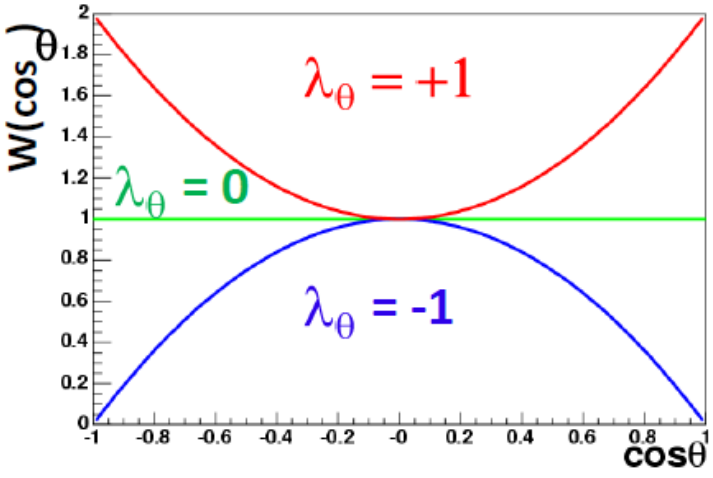
Inclusive J/ψ polarization measured using the angular distribution of daughter muons in the quarkonium rest frame

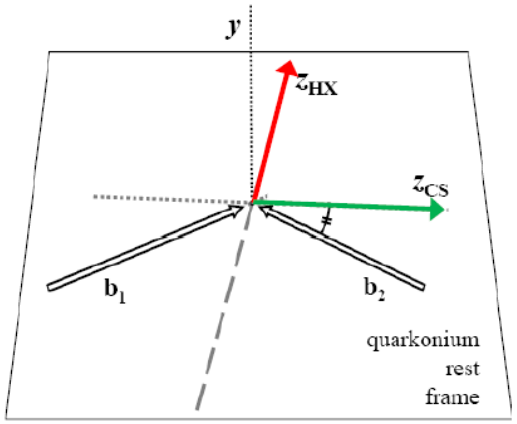
$$W(\cos\theta,\phi) \propto \frac{1}{3+\lambda_\theta}(1+\lambda_\theta \cos^2\theta + \lambda_\phi \sin^2\theta \cos 2\phi + \lambda_{\theta\phi} \sin 2\theta \cos\phi)$$

λ_θ = +1 → transverse polarization

λ_θ = 0 → no polarization

λ_θ = -1 → longitudinal polarization



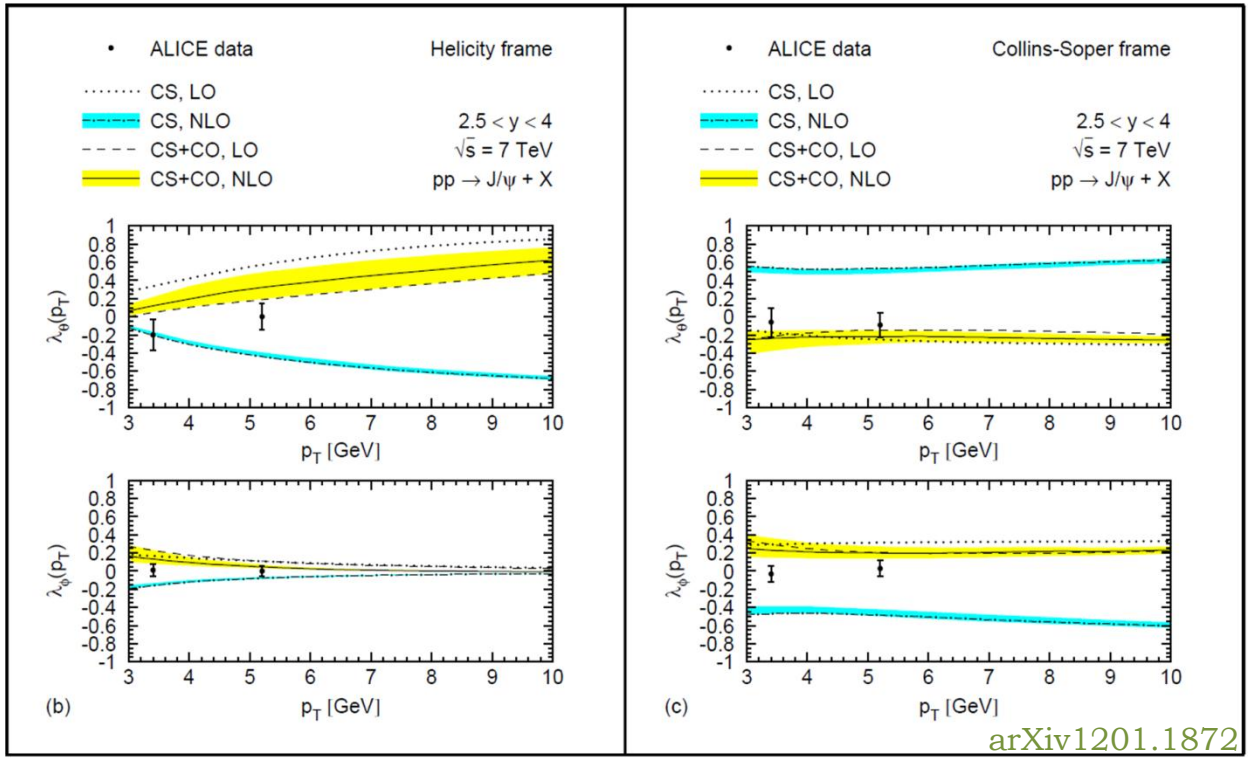


Two different definitions of *z*-axis considered

- Helicity: direction of the decaying particle in the CM frame of the collision.
- Collins-Soper: bisector of the angle between one beam and the opposite of the direction of the other one, in the rest frame of the decaying particle.

Polarization

ALICE results compared to LO and NLO predictions from **NRQCD** and **CSM**.



arXiv1201.1872

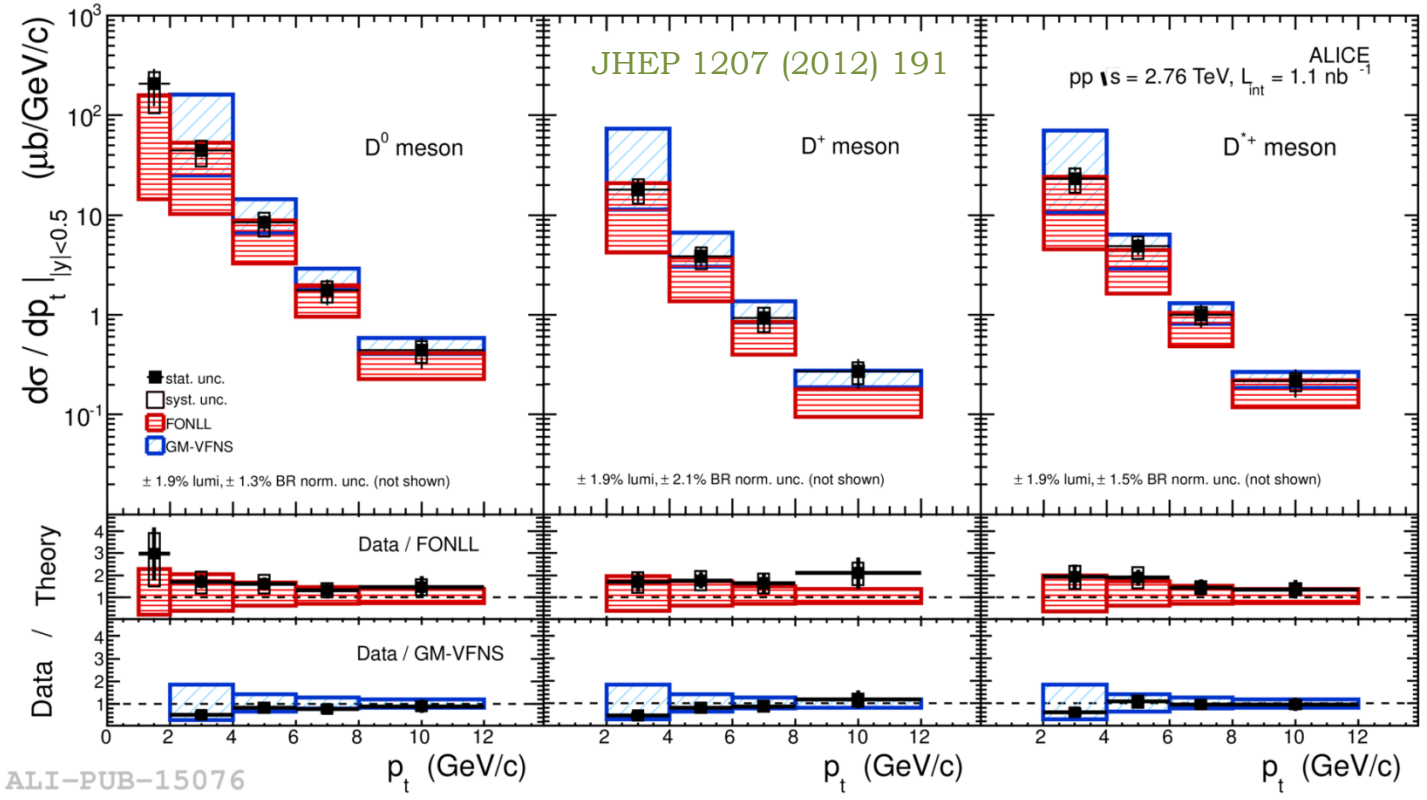
None of the models can perfectly describe the experimental results.

However, NRQCD is slightly favored.

D mesons @ 2.76 TeV

B → D feed down subtracted with FONLL

Prompt D mesons p_T differential cross-sections are described within uncertainties by pQCD calculations (FONLL & GM-VFNS).

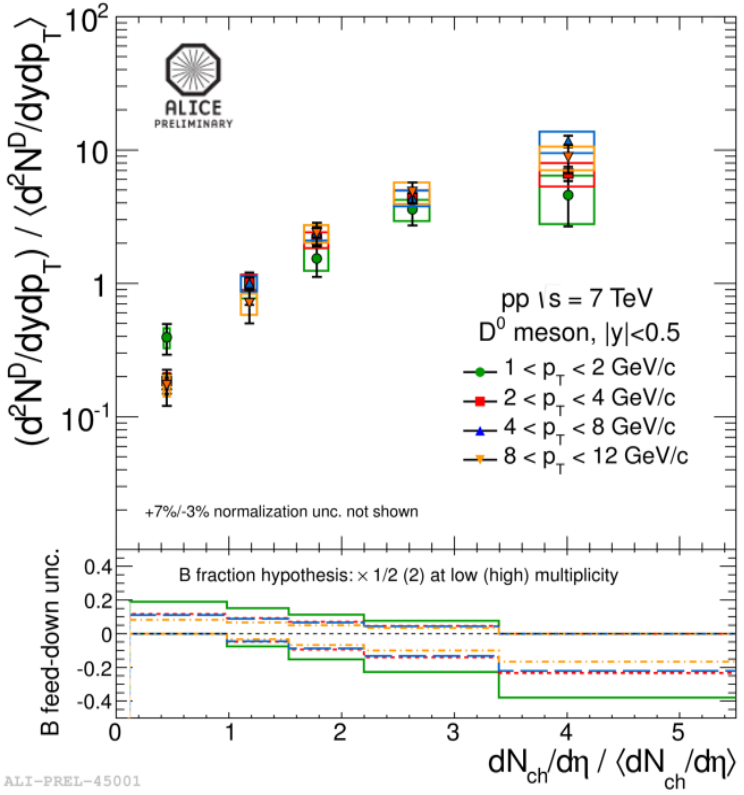


D mesons vs multiplicty

Contribution of Multi Parton Interactions at the LHC?

Correlation between D mesons yield and the total charged particle multiplicity

- Linear increase of the yield with the charged particle density.
- Good consistency of the 3 D mesons species.
- No evident p_T dependence within uncertainties.



D & J/ψ vs multiplicity

- Linear increase of the yield with charged particle density
- Very good consistency of the D mesons species.
- D and J/ψ mesons measurements agree within uncertainties.