Open charm production as a function of charged particle multiplicity in pp collisions at $\sqrt{s}$=7 TeV with ALICE

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Road Map

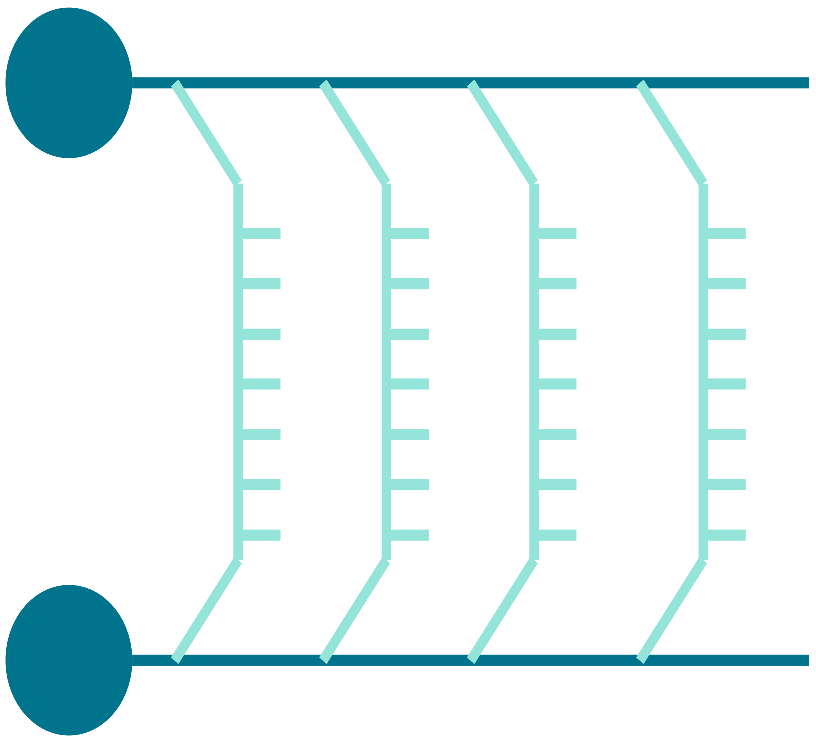
- ➡ Introduction
  - ✓ Physics Motivation
  - ✓ Overview of the ALICE experiment
- ➡ D meson production
  - ✓ D^0, D^+, D^{*+} production cross section
  - ✓ Yield of prompt D mesons as a function of charged particle multiplicity
- ➡ Comparison of prompt D mesons, prompt and non prompt J/ψ production as a function of charged particle multiplicity
- ➡ Summary

Physics Motivation-I

- The LHC is a heavy flavour factory $\begin{cases} \sigma_c(\text{LHC}) \approx 10 \times \sigma_c(RHIC) \\ \sigma_b(\text{LHC}) \approx 100 \times \sigma_b(RHIC) \end{cases}$
- Charm quarks are produced in hard partonic scatterings on a short time scale

$$\tau_{\text{Prod}} \approx 1/m_Q \approx 0.05 - 0.15 \ \text{fm/c}$$

- Test NLO perturbative QCD at LHC energies
- pp cross section provides the reference for studying the medium effect in Pb-Pb
- Test Multi-Parton Interactions (MPI)
  - Several hard interactions possible in one pp collision
  - Number of elementary interactions related to multiplicity
  - In this picture : particle yield should increase with multiplicity

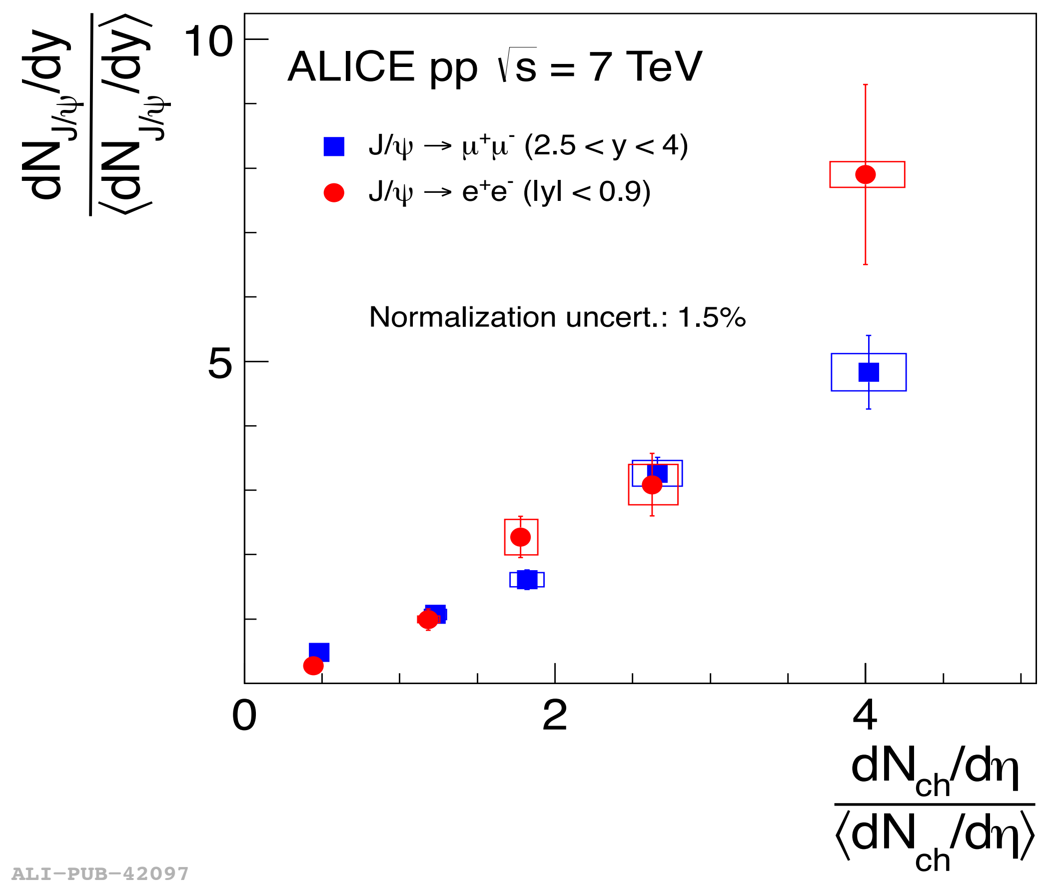


- Investigate the interaction between the hard and soft components in the full pp collision

Physics Motivation-II

- ⟨dNch/dη⟩ in high multiplicity pp collisions at LHC ($\sqrt{s}$ = 7 TeV) comparable to that of CuCu interactions at RHIC ($\sqrt{s_{NN}}$ = 200 GeV) PHOBOS, Phys. Rev. C 83, 024913 (2011)
- Hints of Collective effects in proton-proton collisions K. Werner at al. Phys. Rev. C83:044915, 2011

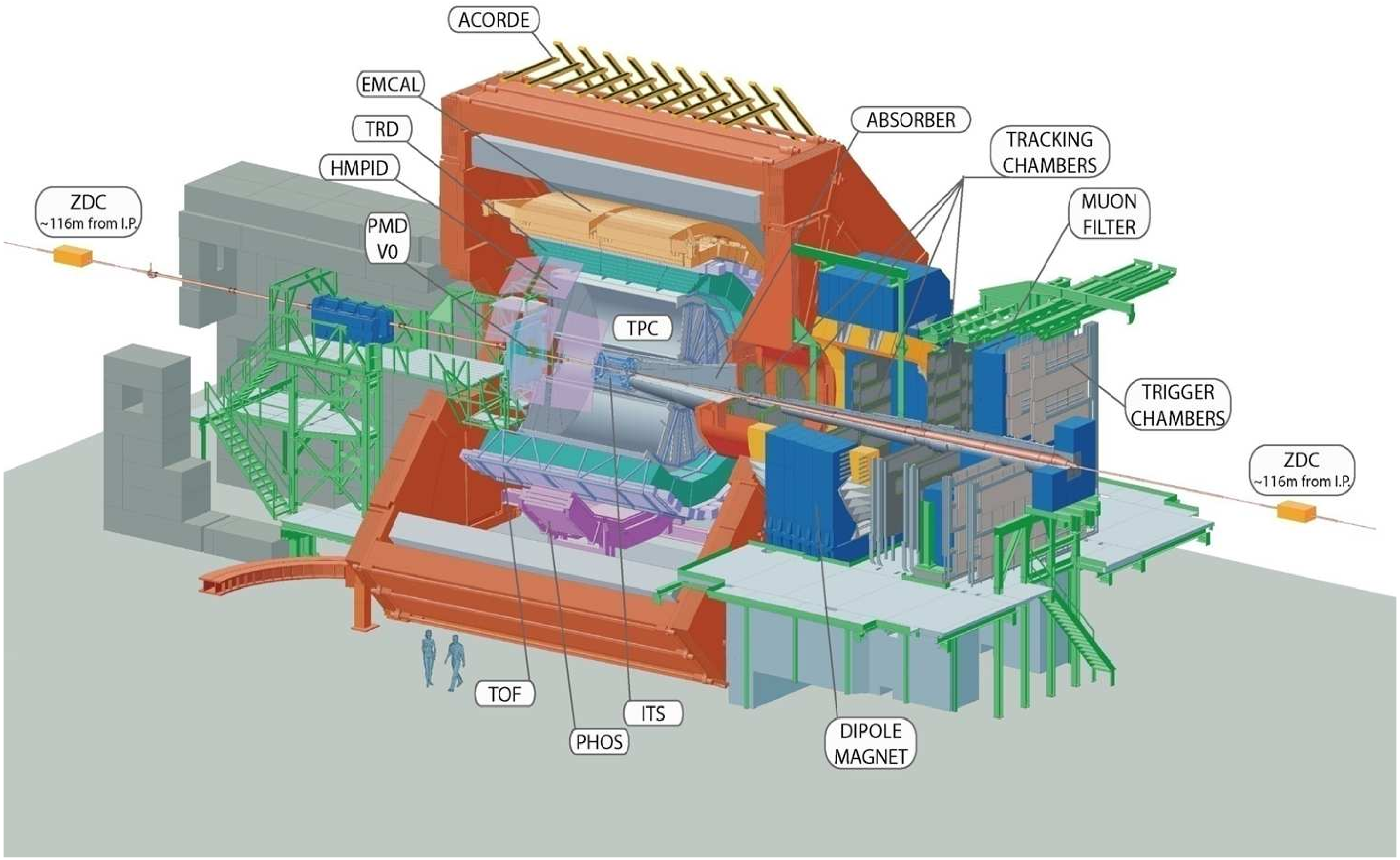
ALICE Coll., Phys. Lett. B 712 (2012) 3, 165-175



- A larger multiplicity in events with charm production with respect to those without charm was observed in 1988 by the NA27 Collaboration
- ALICE observed an increase of the relative inclusive J/ψ yields vs charged particle density in pp collisions at $\sqrt{s}$ = 7 TeV.
  - Same trend in the 2 channels (central and forward rapidity region)

Does this hold for other observables also e.g: D, B mesons?

ALICE detectors



ALICE detectors

Central barrel: $|\eta| < 0.8$

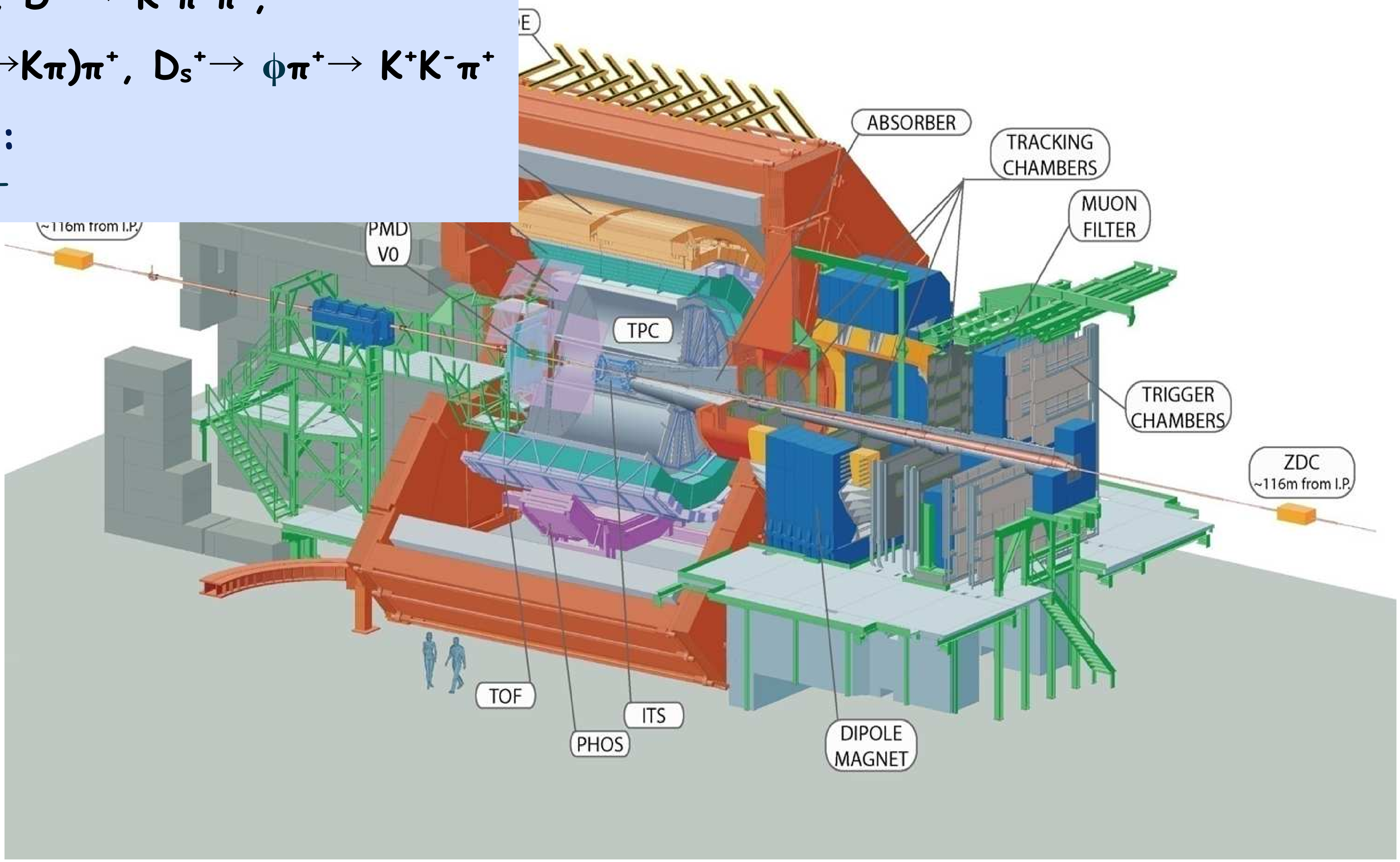
D mesons:

$D^0 \rightarrow K^-\pi^+$, $D^+ \rightarrow K^-\pi^+\pi^+$,

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

Quarkonia:

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



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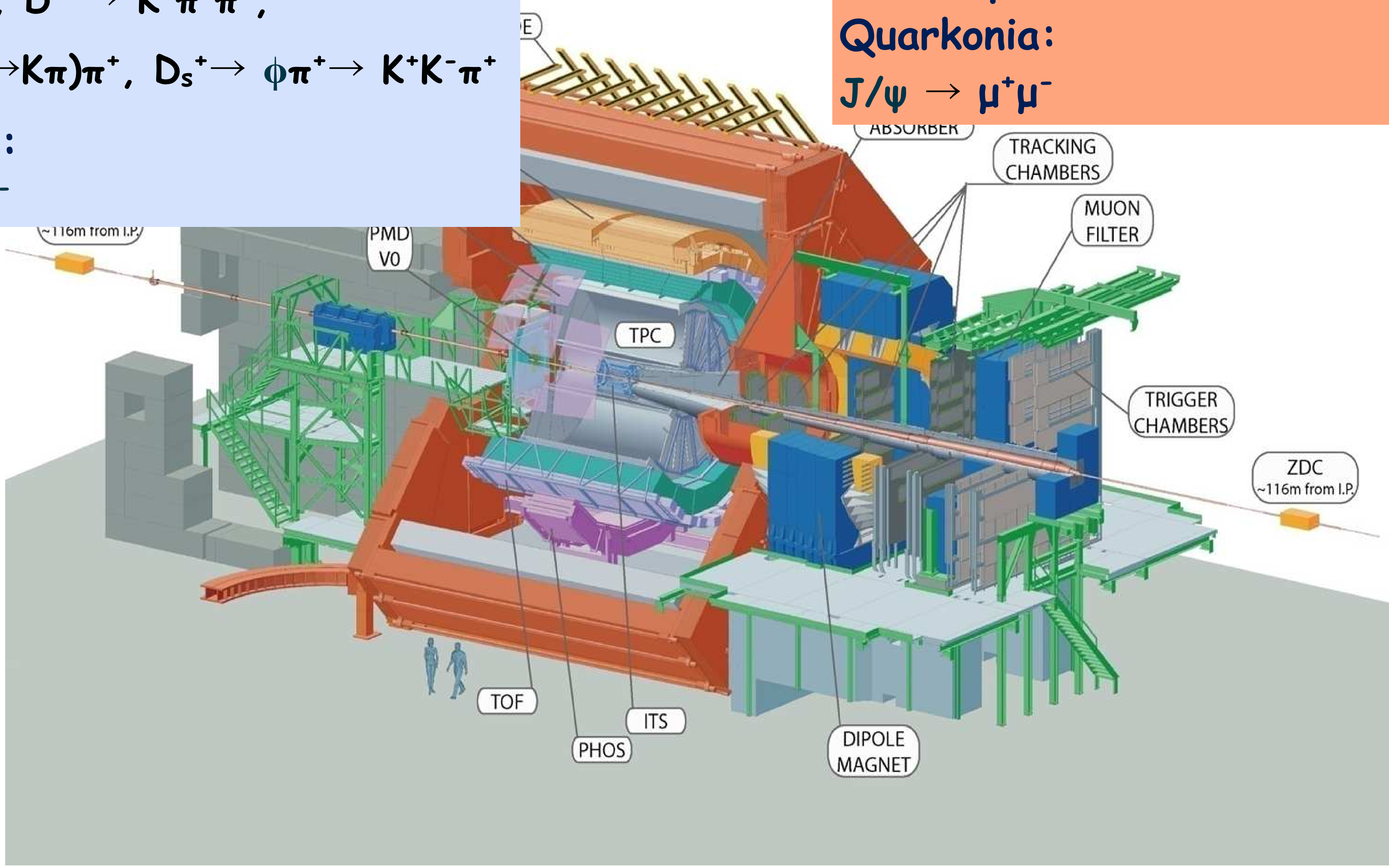
Muon Spectrometer: $-4 < \eta < -2.5$

Quarkonia:

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



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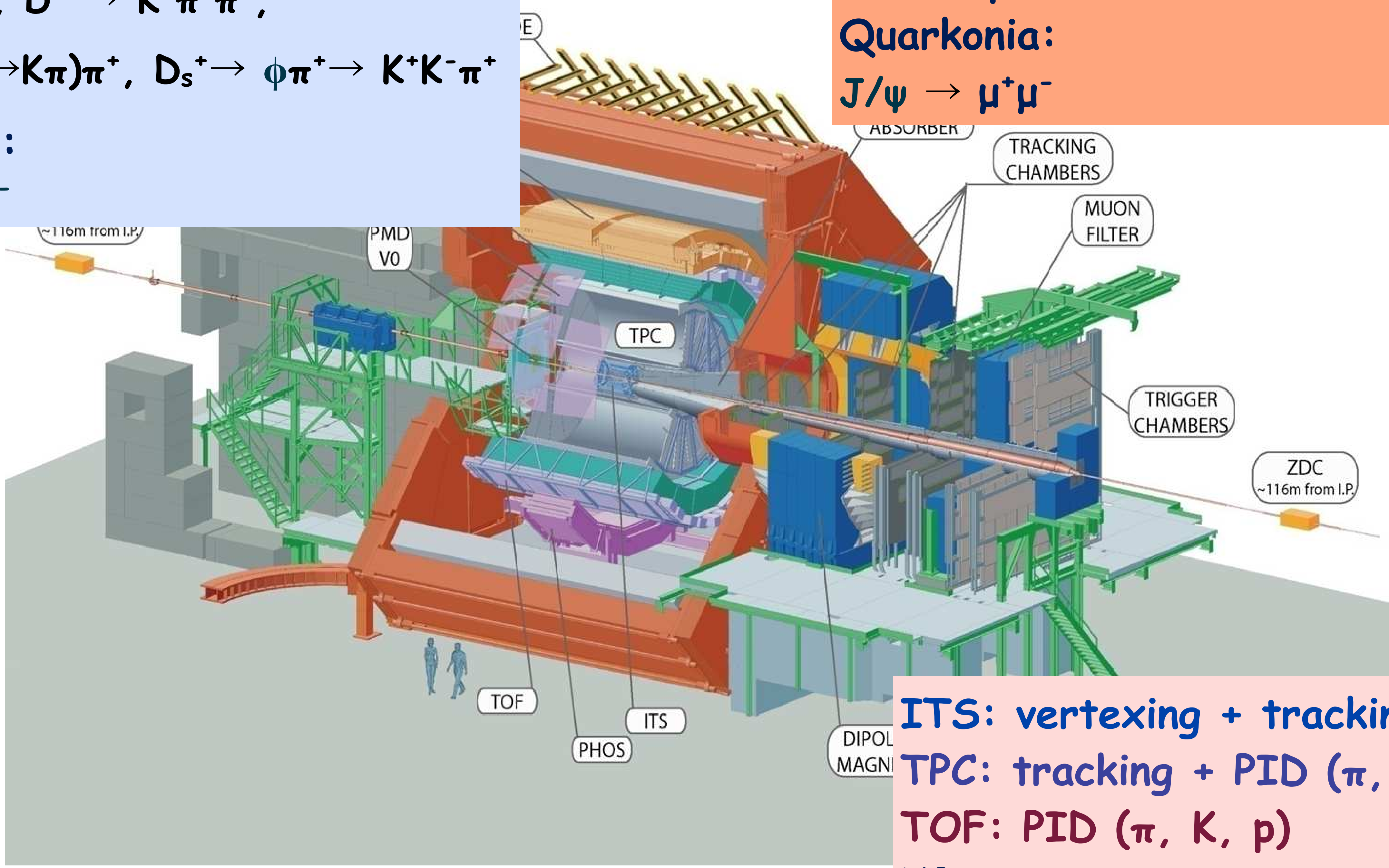


ITS: vertexing + tracking

TPC: tracking + PID (π, K, e)

TOF: PID (π, K, p)

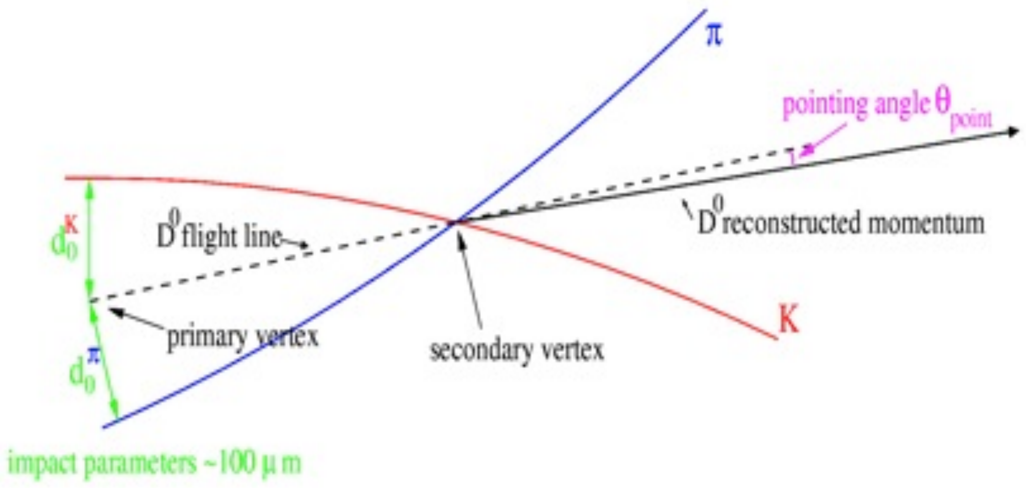
V0: trigger

D meson reconstruction

Main Selection: displaced-vertex topology

e.g: $D^0 \rightarrow K^-\pi^+$

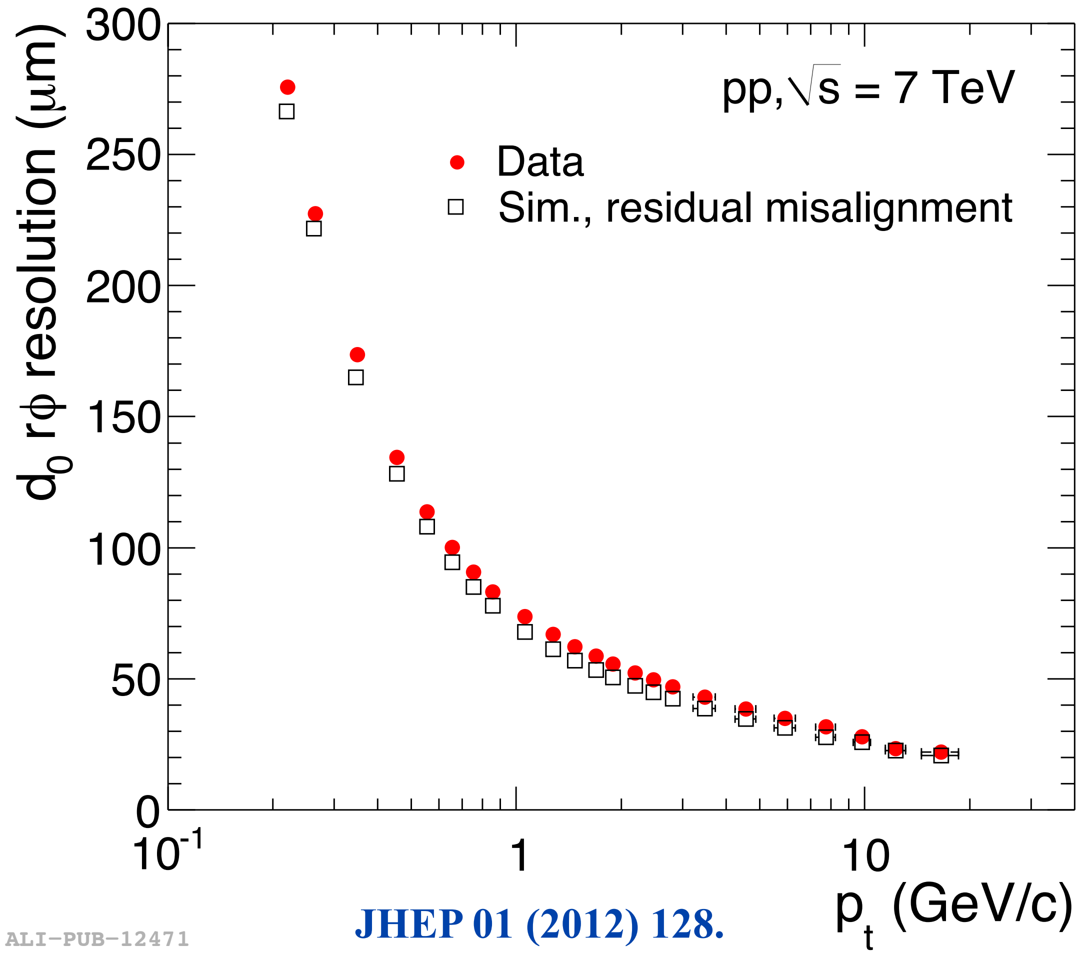
- pair of opposite-charge tracks with large impact parameters
- good pointing of reconstructed D momentum to the primary vertex



Tracking and Vertexing performance is crucial!

- Inner Tracking system (ITS) with 6 Si layers
- Two pixel layers at 3.9 cm (closest barrel layer at LHC) and 7.6 cm.
- Track impact parameter resolution is ~75μm at p_T = 1 GeV/c

  well described in MC



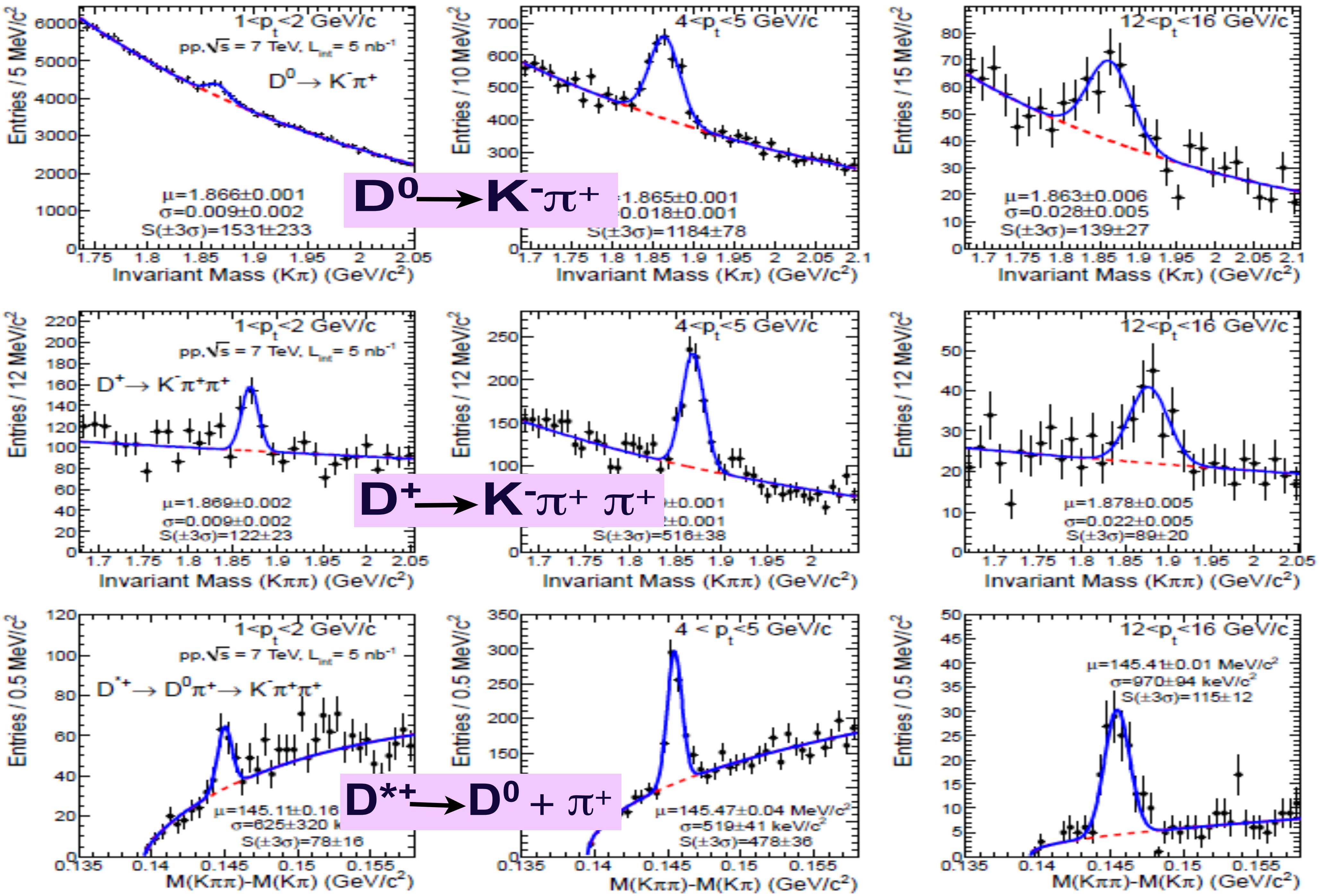
JHEP 01 (2012) 128.

Particle Identification (TOF + TPC) to reduce background, mainly at low p_T

- TPC allows K/π separation up to ~0.6 GeV/c,
- TOF allows K/π separation up to ~2 GeV/c

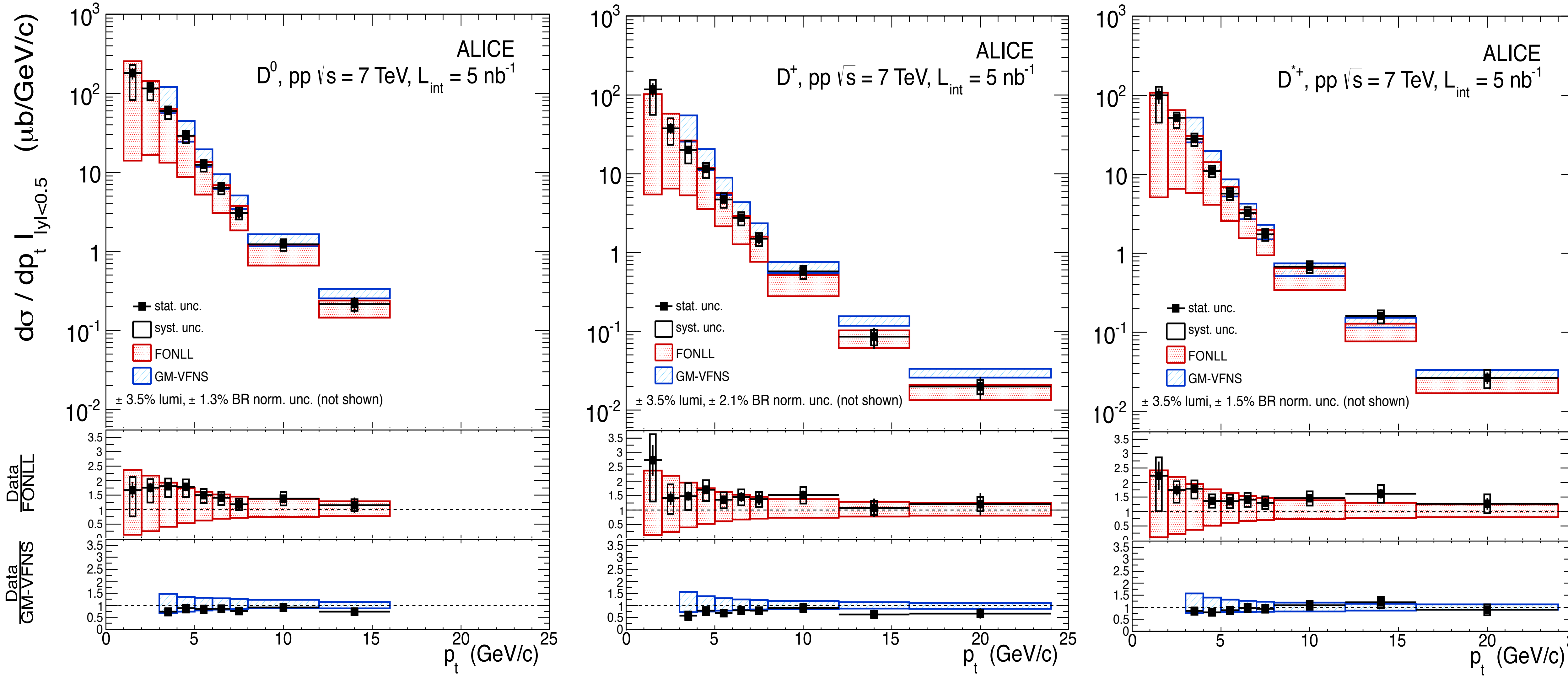
D meson signal vs p_T

Signals in $1<p_T<24$ GeV/c, with 5 nb^{-1}



increasing p_T

D^0, D^+ and D^{*+} cross section in pp collisions @ 7 TeV



JHEP 01 (2012) 128.

D^0, D^+, D^{*+} measured in p_T range 1-24 GeV/c, with 5 nb^{-1}

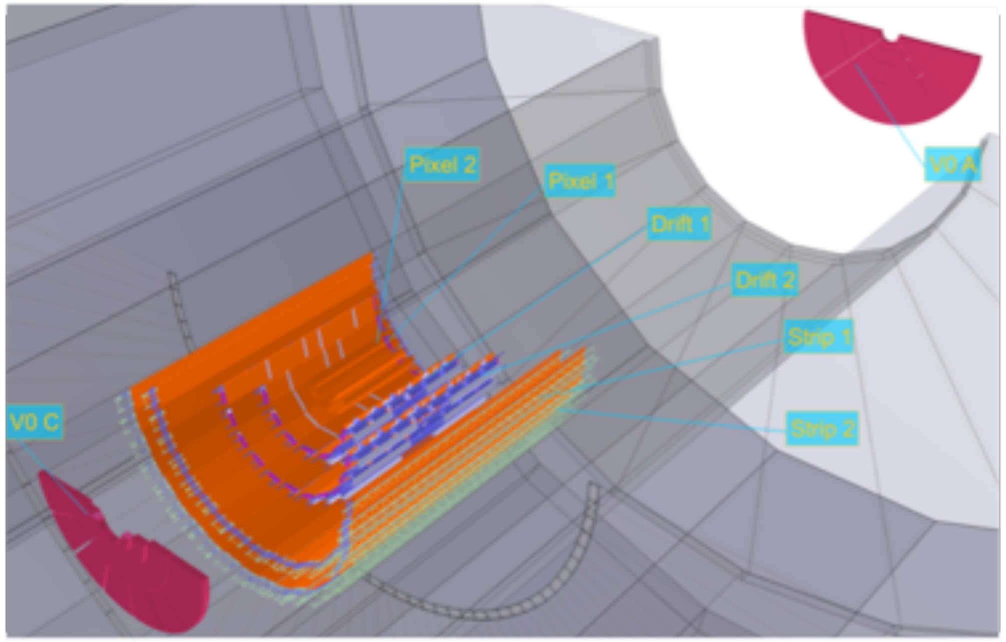
Data well described by pQCD predictions

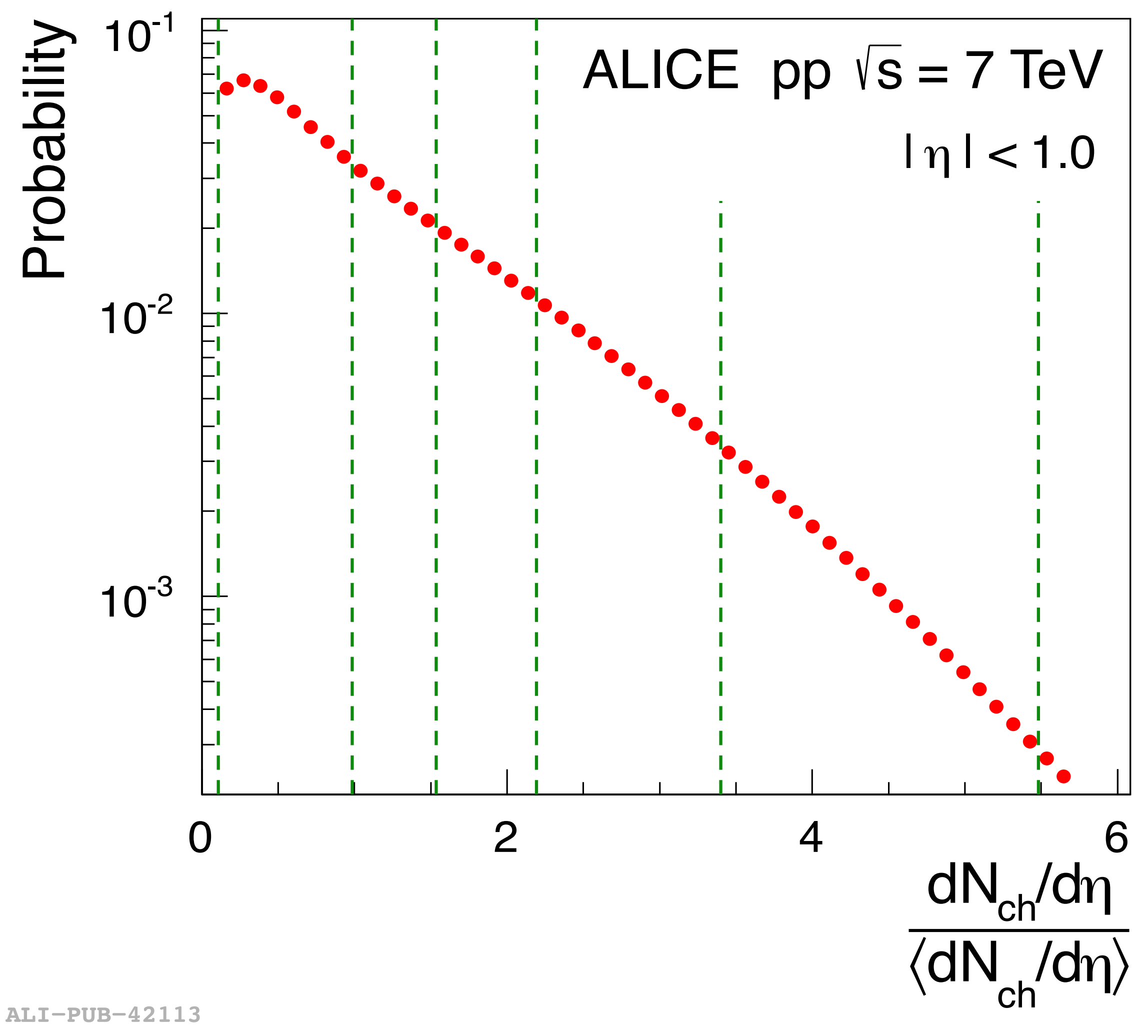
- On upper side of FONLL
- On lower side of GM-VFNS
- k_t factorization approach

M. Cacciari, S. Frixione, N. Houdeau, M.L. Mangano, P. Nason, and G. Ridolfi, CERN-PH- TH/2011-227 (2011), arXiv:1205.6344 (2012).
B. A. Kniehl et al., DESY 12-013, MZ-TH/12-07, LPSC 12019, arXiv: 1202.0439 (2012).
Maciula, Szczurek, arXiv:1301.3033

Multiplicity Estimation

- Multiplicity estimator: number of track segments (or tracklets) in the Silicon Pixel detector
- 2010 data, with MB trigger: SPD or V0A or V0C.





- Analysis performed on a data sample of Lint = 5 nb^{-1}
- Ntracklets ∝ dNch/dη

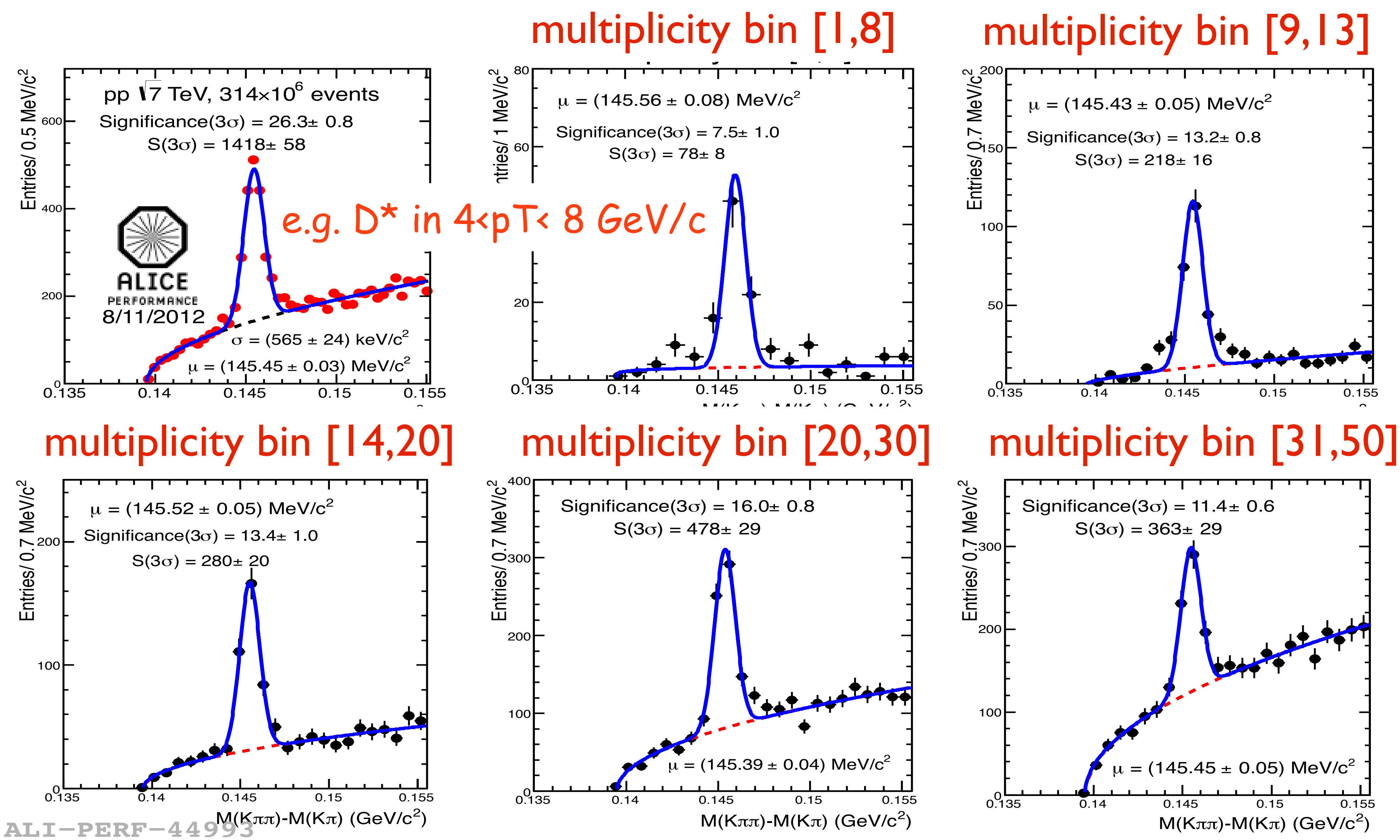
$\langle dN_{ch}/d\eta \rangle = 6.01 \pm 0.01(stat.)\ ^{+0.20}_{-0.12}(syst.)$ for $|\eta|<1.0$

ALICE Coll., Eur. Phys. J. C 68 (2010) 345.
ALICE Coll., Phys. Lett. B 712 (2012) 3, 165-175

D meson signal in various multiplicity bins

D^0, D^+, D^{*+} signal studied

- in 5 multiplicity bins, with Number of tracklets (1,9,14,20,31,50) and
- 3-5 p_T bins (1,2,4,8,12,20) GeV/c



Raw yield correction

- The raw yields in a given multiplicity bin (Y^{mult}) are corrected for detector acceptance × reconstruction and selection efficiency (ε^{mult}) and divided by the respective values on the multiplicity integrated sample ($Y^{mult\ int}$ & $\varepsilon^{mult\ int}$).
- Normalized to the number of events in each multiplicity bin ($Nevent^{mult}$) and corrected to that of inelastic collisions ($Nevent^{inelastic}$)

$$\frac{\frac{\mathrm{d}^2 N}{\mathrm{d}p_{\mathrm{T}}\mathrm{d}y}}{\left\langle \frac{\mathrm{d}^2 N}{\mathrm{d}p_{\mathrm{T}}\mathrm{d}y} \right\rangle} = \frac{Y^{\mathrm{mult}} / (\epsilon^{\mathrm{mult}} \times N_{\mathrm{event}}^{\mathrm{mult}})}{Y^{\mathrm{mult\ int}} / (\epsilon^{\mathrm{mult\ int}} \times N_{\mathrm{event}}^{\mathrm{inelastic}})}; \qquad N_{\mathrm{event}}^{\mathrm{inelastic}} = N_{\mathrm{event}}^{\mathrm{multint}} / 0.85.$$

- fractions of prompt D mesons (f_{prompt}) in the multiplicity bins are assumed to be equal to those in the multiplicity integrated sample, so cancel in the ratio
- f_{prompt} evaluated with FONLL and taken into account in the systematic uncertainties

Systematic Uncertainties

Relative charged particle multiplicity:

- Uncertainties on $(\langle dN_{ch}/d\eta \rangle) / dN_{ch}/d\eta$ due to deviation from linear dependence of $dN_{ch}/d\eta$ on $N_{tracklet}$: 5.4 % Phys. Lett. B 712 (2012) 3, 165-175
- $\langle dN_{ch}/d\eta \rangle$ measurement: $^{+3.3\%}_{-2\%}$ Eur. Phys. J. C 68 (2010) 345.

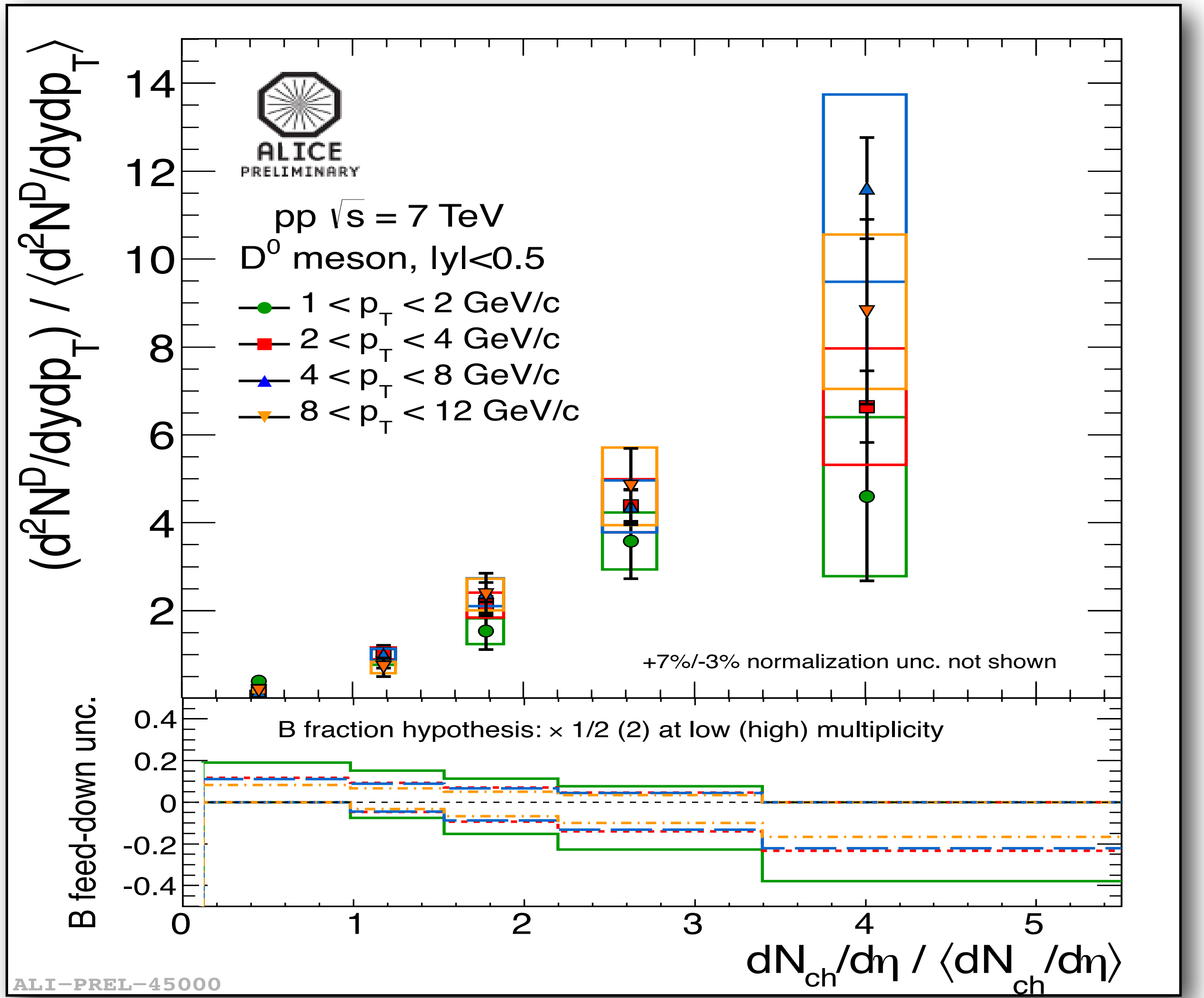
Relative prompt-D meson yields:

- Yield extraction: vary the signal and background fit function, 5-10%
- Topological selections: redo the analysis varying the analysis cuts, 5-10%
- Monte Carlo: description of the signal, N_{ch} and the detector conditions, 10%
- Feed-down Subtraction: using FONLL predictions for B meson p_T-differential cross-section. Account for possible different multiplicity dependence of B and D production by allowing the fraction for prompt D mesons obtained via FONLL to vary by a factor 2 up(down) at high(low) multiplicity, 5%

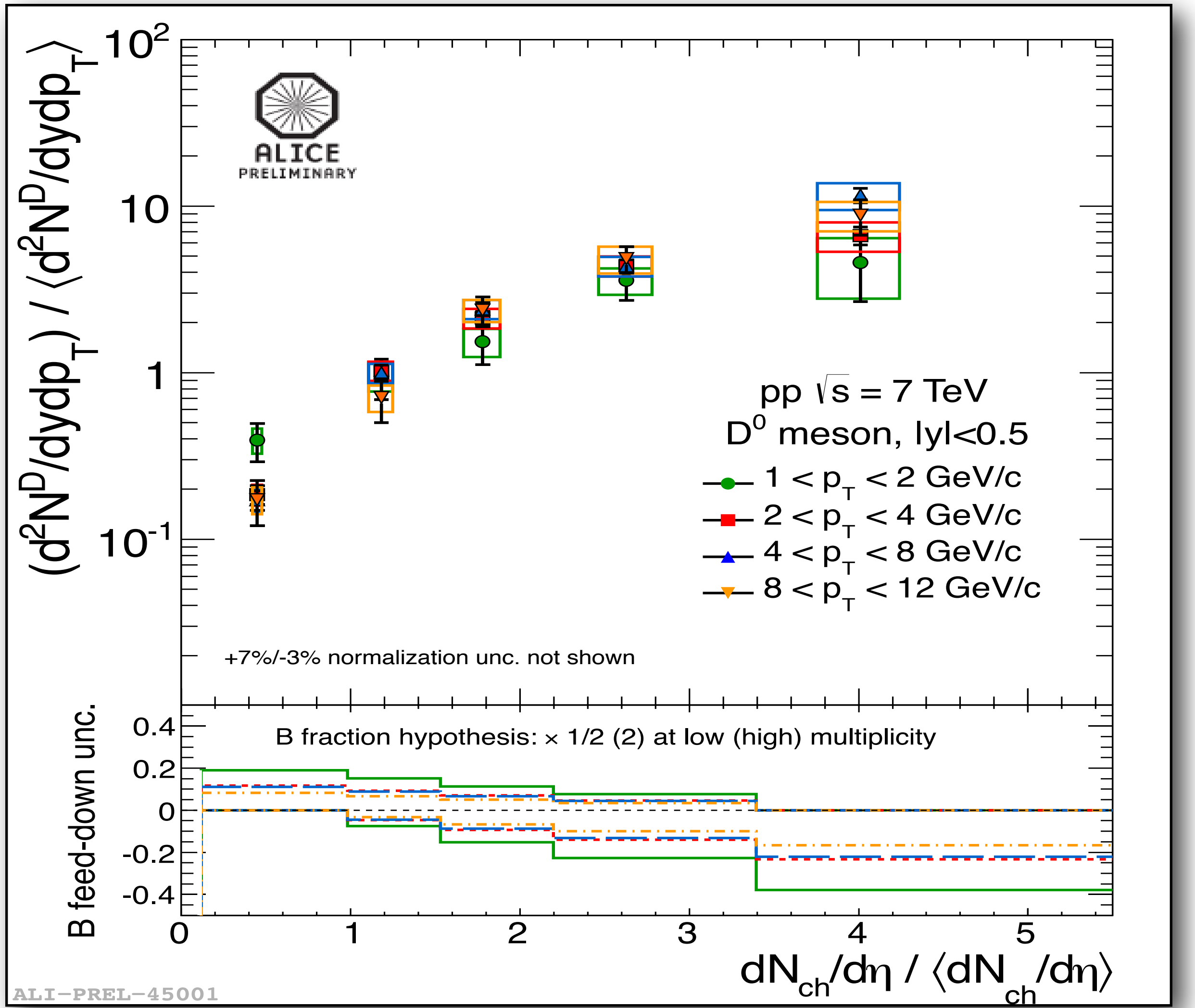
Normalization: trigger efficiency correction factor $0.85^{+7\%}_{-3\%}$

ALICE Coll., arXiv:1208.4968 (2012)

Relative D^0 meson yields vs dNch/dη



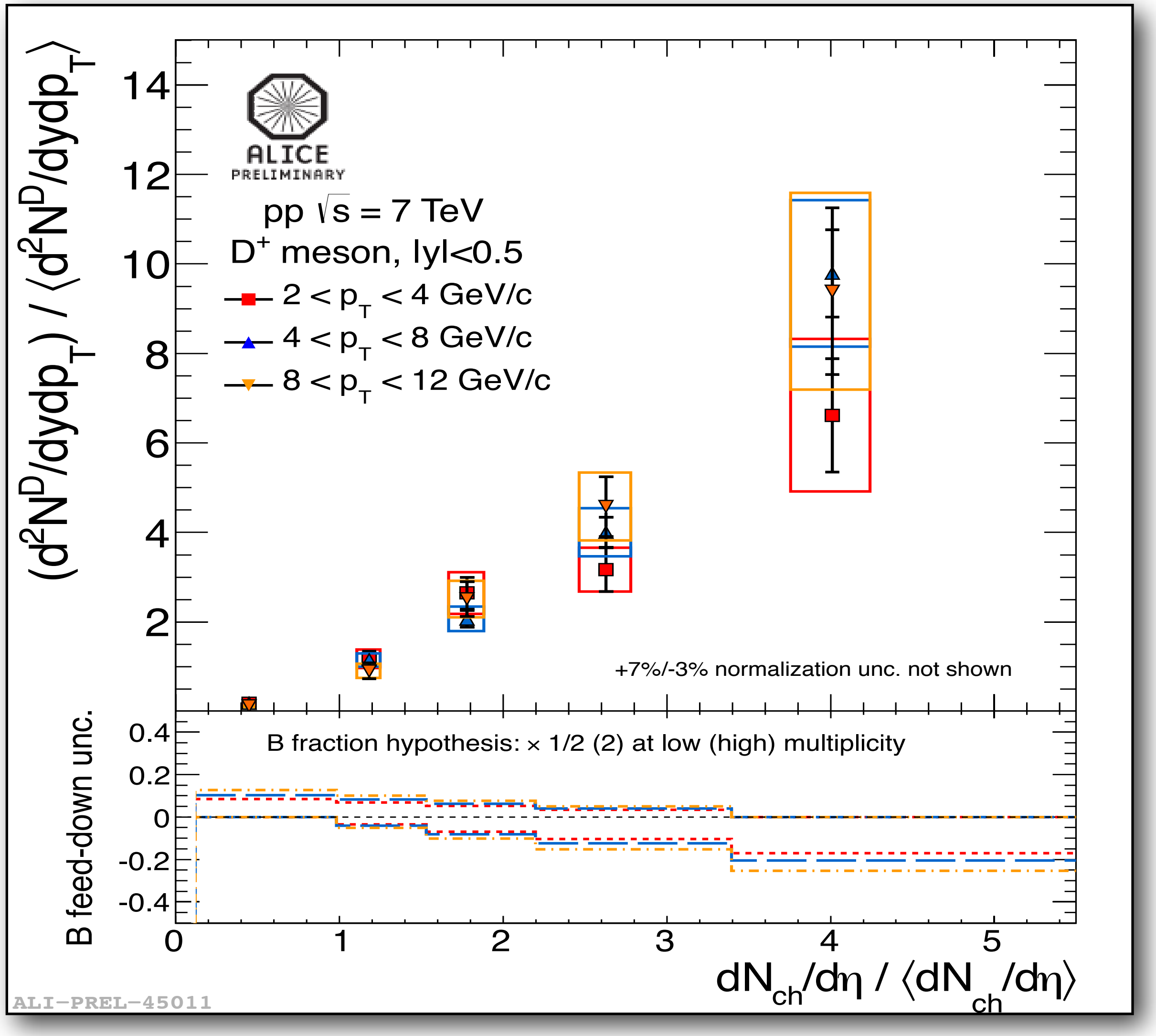
Linear Scale



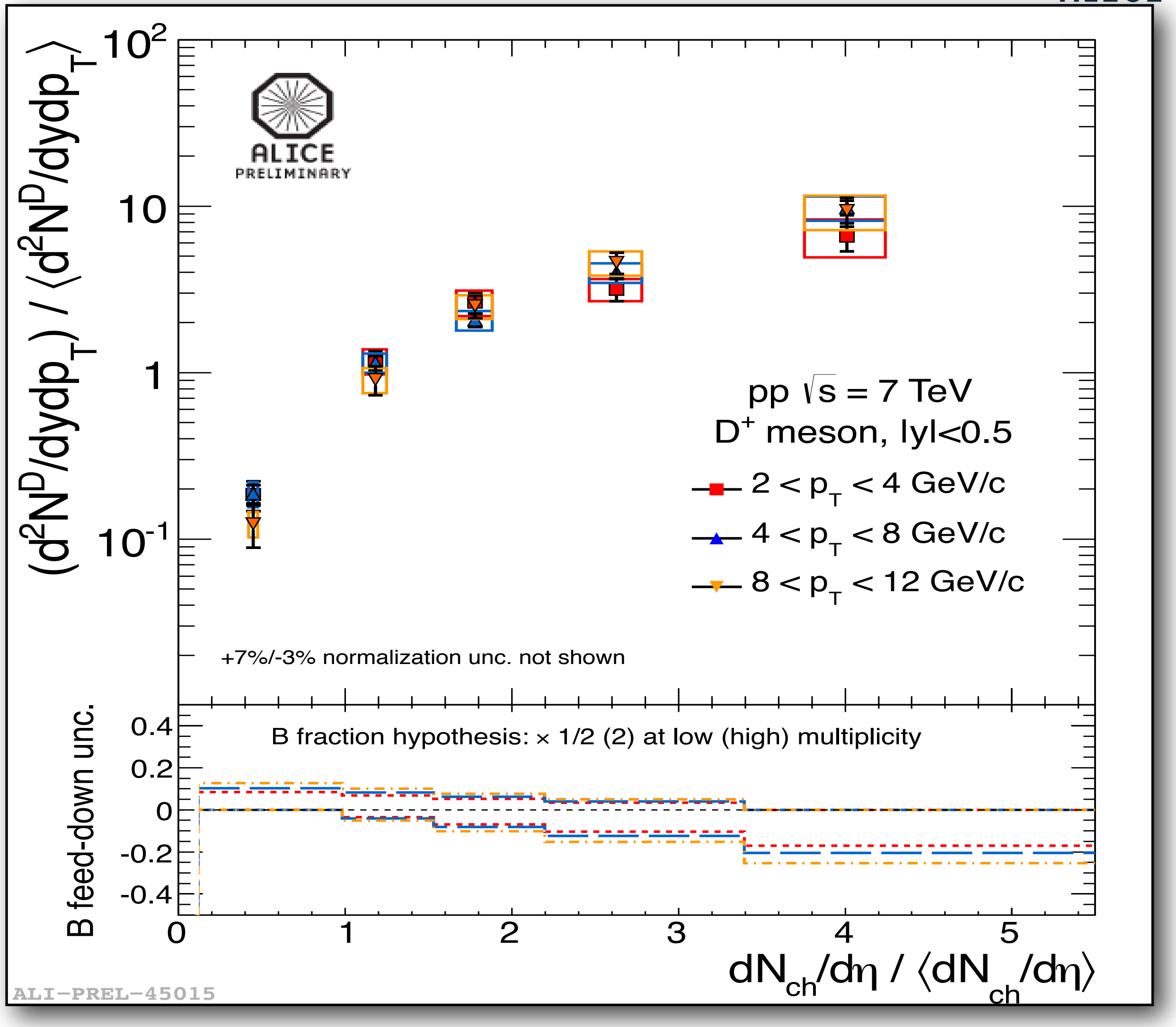
Logarithmic Scale

- D^0 meson yields increase with charged particle multiplicity
- Similar trend in all p_T bins. Within the current uncertainties, no p_T dependence is observed

Relative D^+ meson yields vs dNch/dη



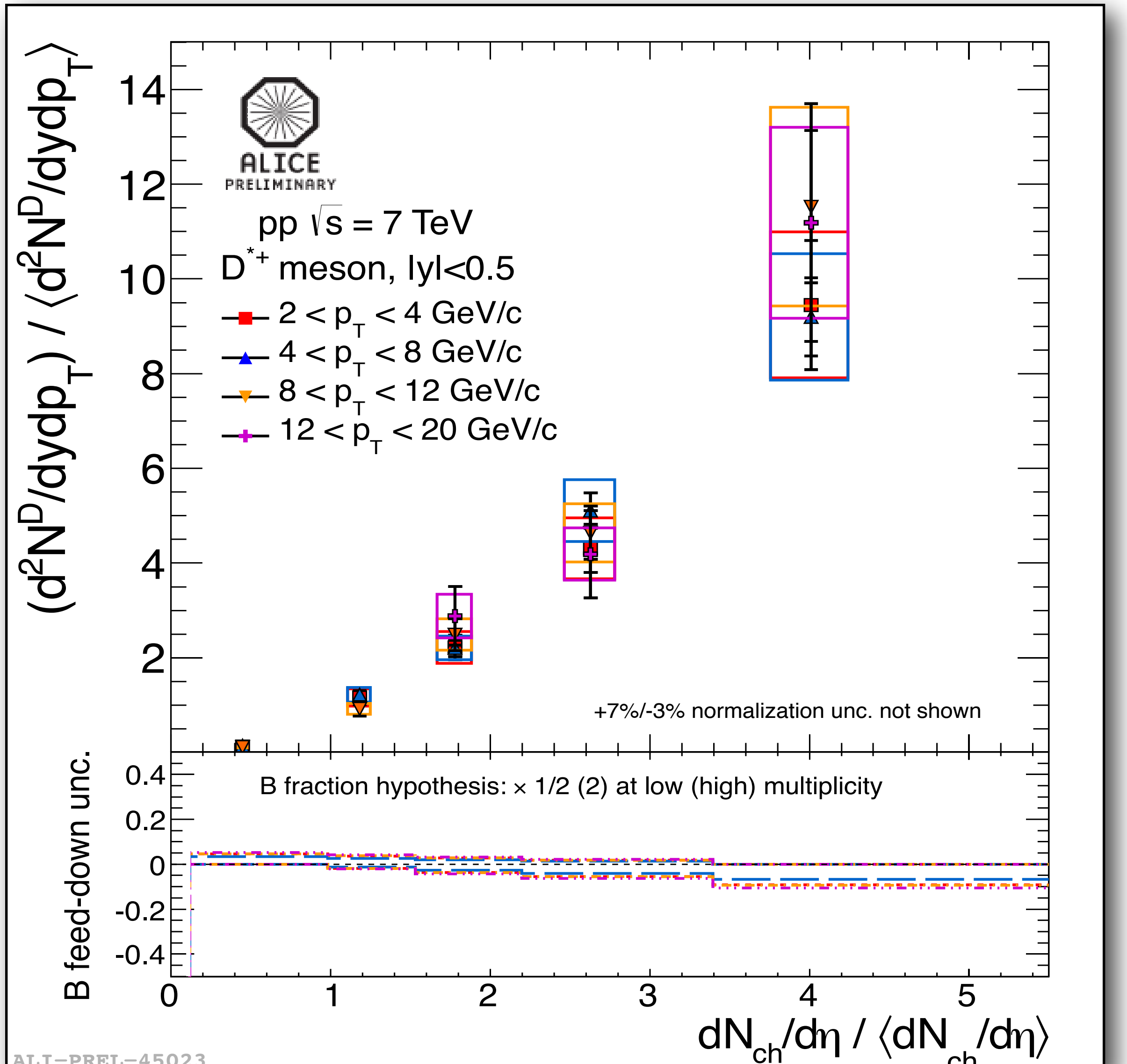
Linear Scale



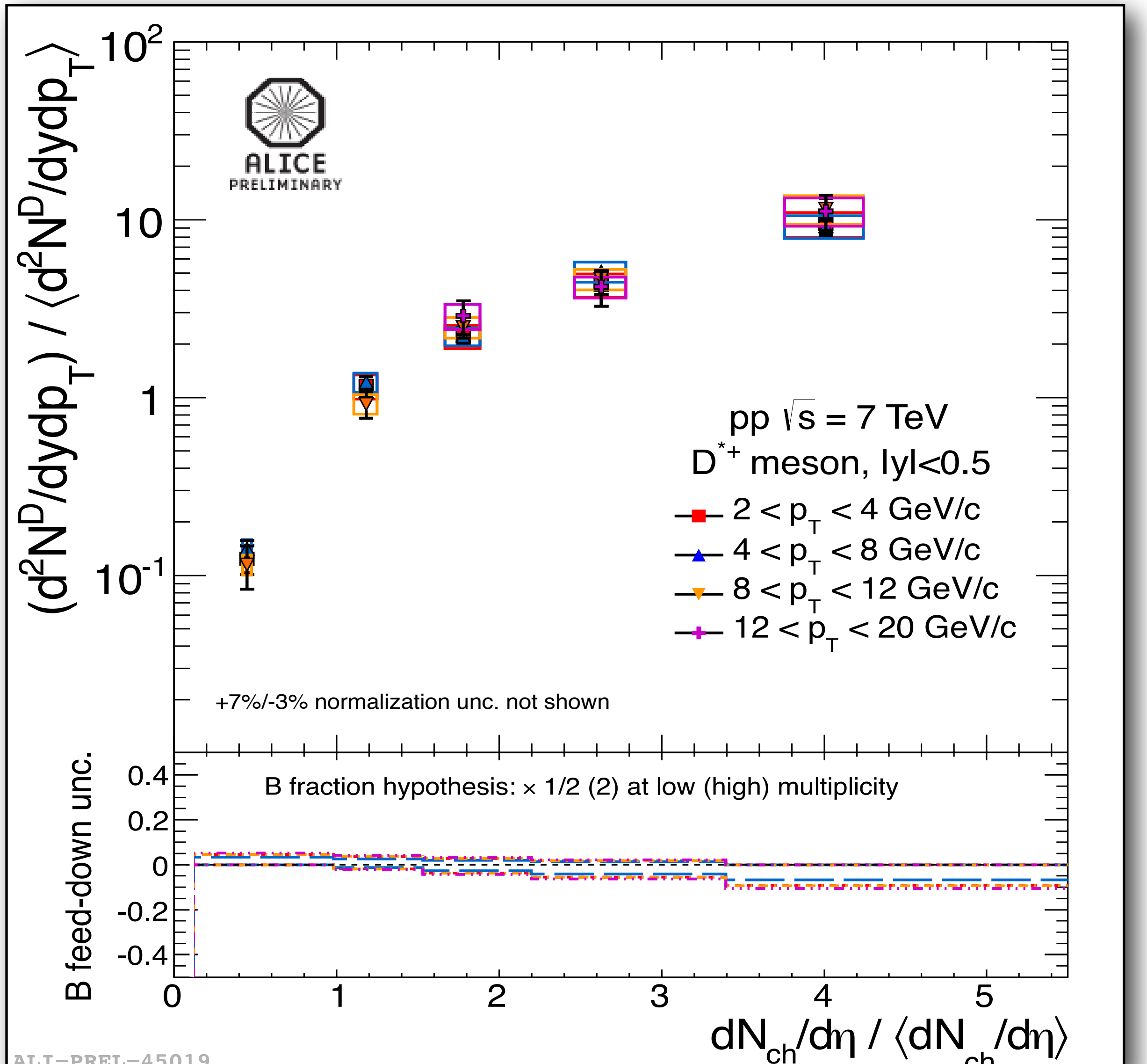
Logarithmic Scale

- D^+ meson yields increase with charged particle multiplicity
- Similar trend in all p_T bins. Within the current uncertainties, no p_T dependence is observed

Relative D^{*+} meson yields vs dNch/dη



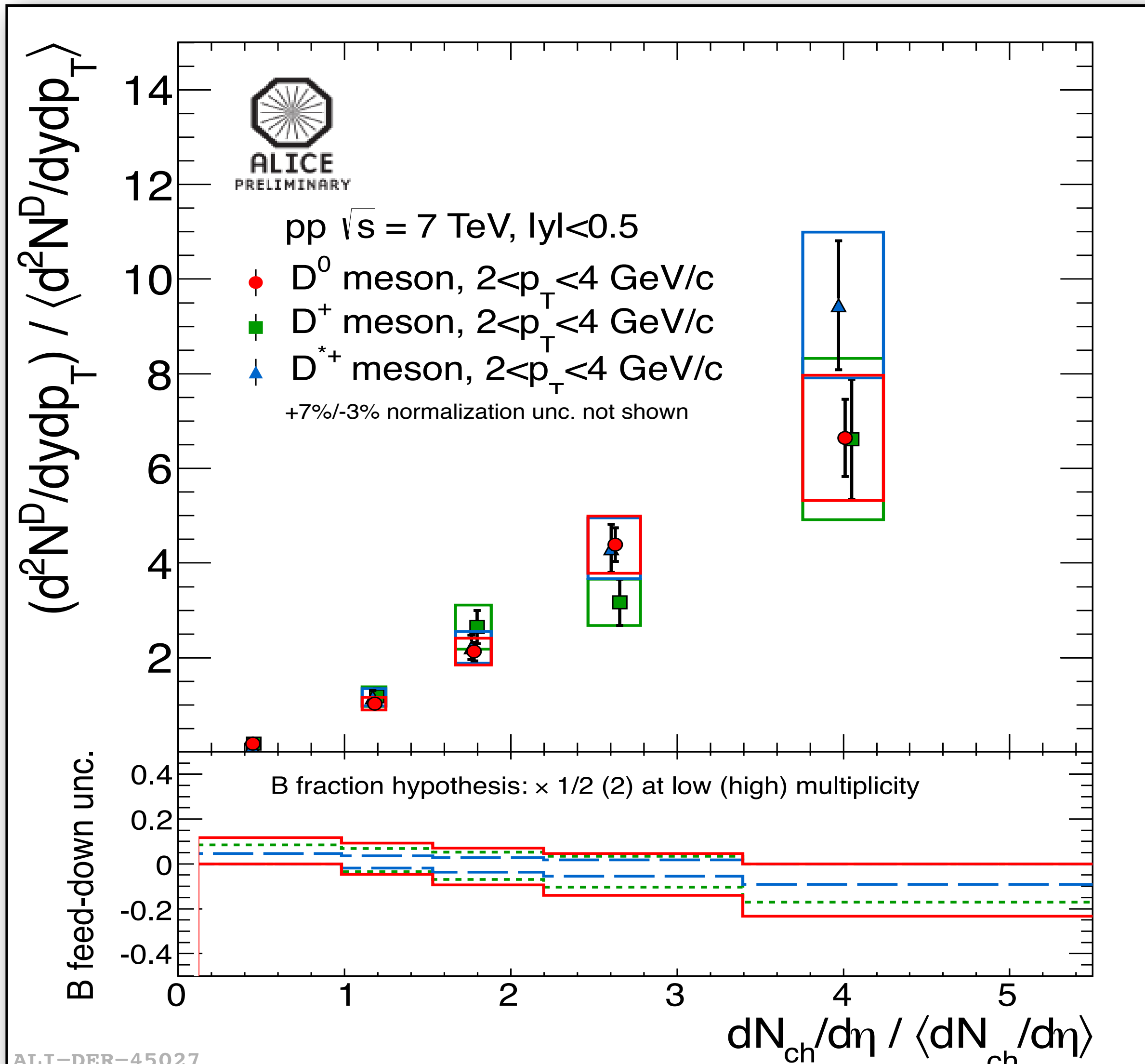
Linear Scale

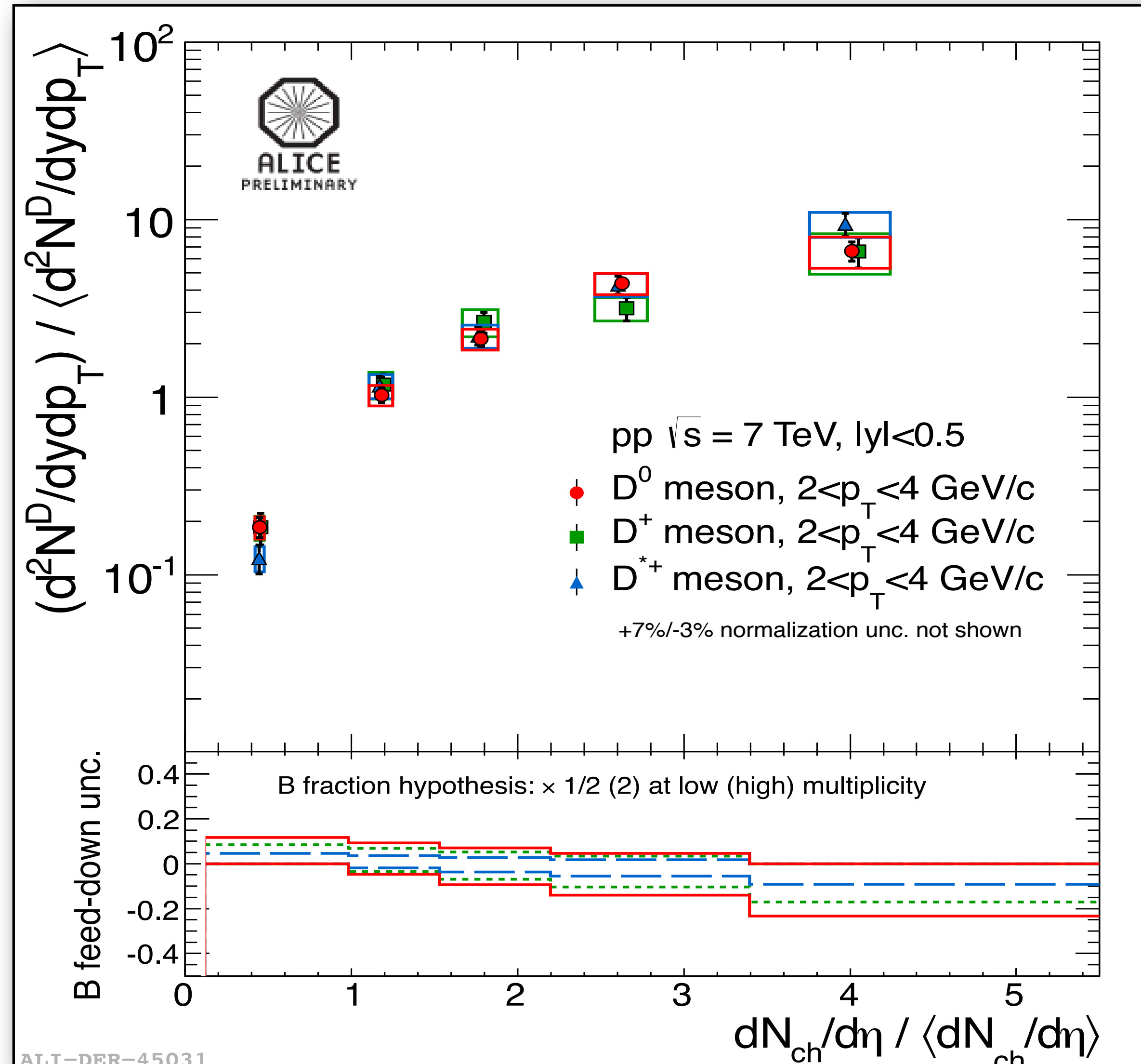


Logarithmic Scale

- D^{*+} meson yields increase with charged particle multiplicity
- Similar trend in all p_T bins. Within the current uncertainties, no p_T dependence is observed

Comparison of relative D meson yields vs dNch/dη



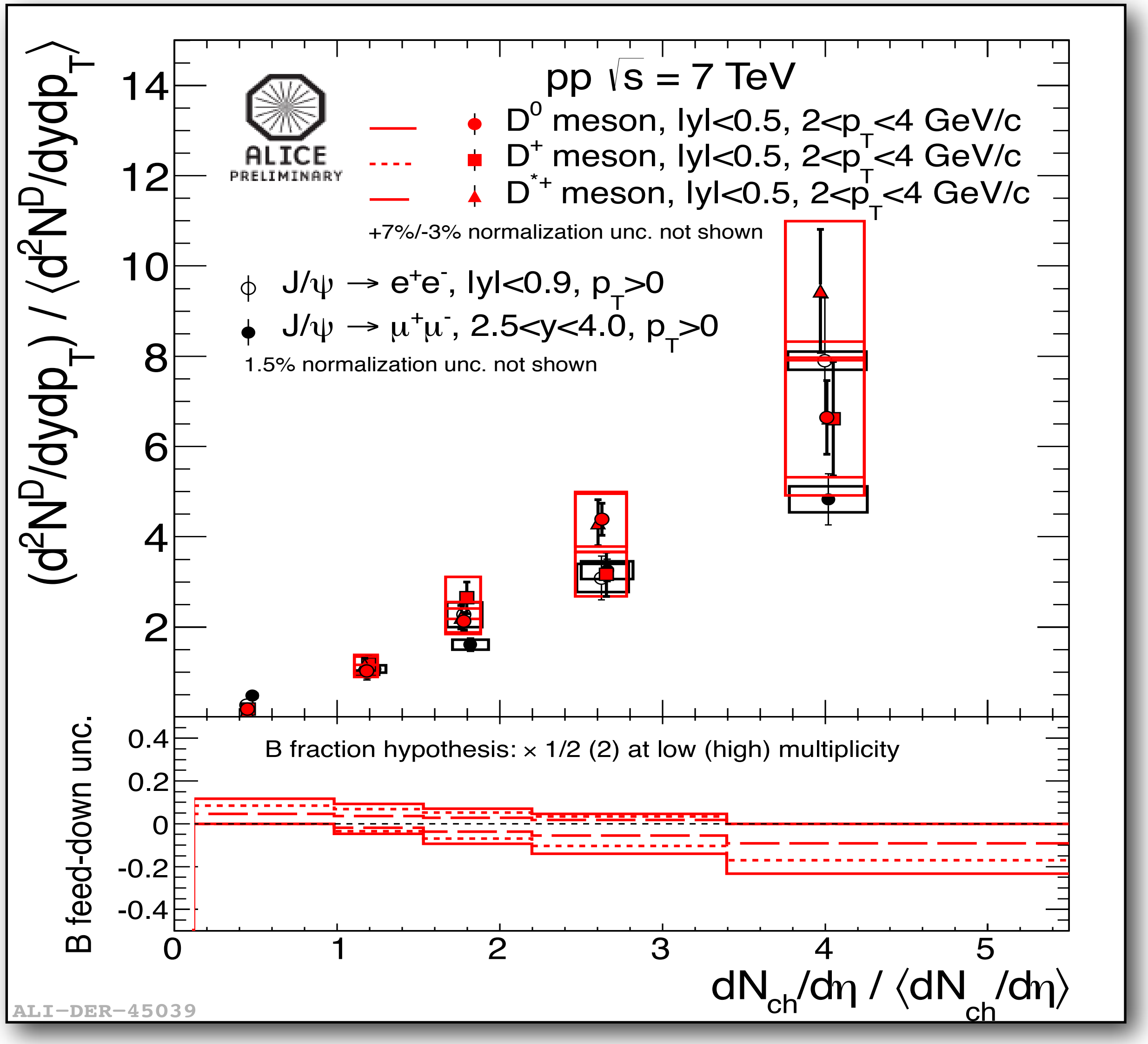


Linear Scale

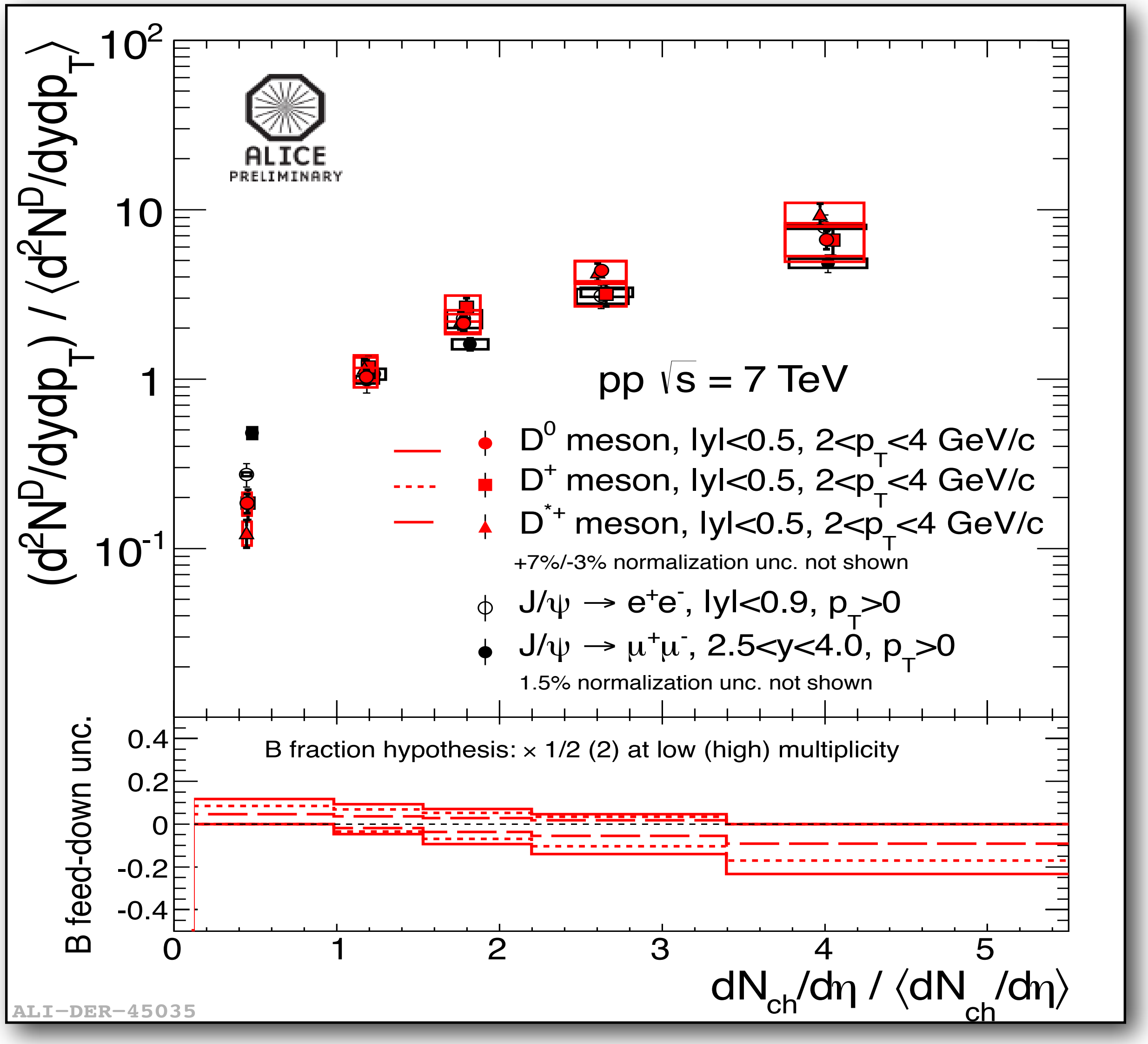
Logarithmic Scale

- The results of D^0, D^+ and D^{*+} are consistent within the statistical and systematic uncertainties
- Also consistent for all measured p_T bins

Relative inclusive J/ψ and D meson yields vs dNch/dη



Linear Scale



Logarithmic Scale

Prompt D meson and inclusive J/ψ (p_T>0) yields show a similar increase with charged particle multiplicity.

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Non prompt J/ψ measurement as a function of multiplicity

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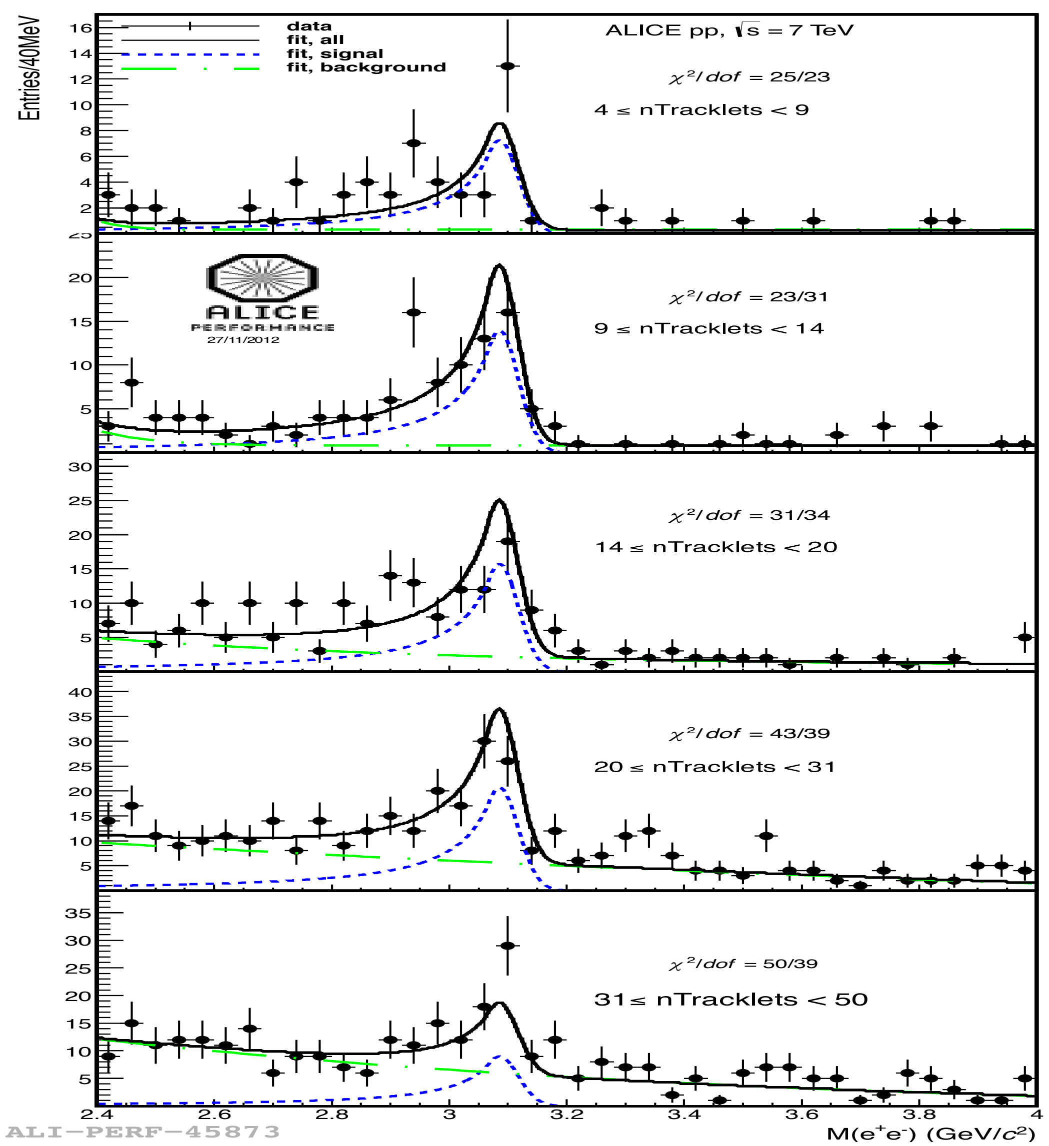
Fraction of non-prompt J/ψ (from B hadron decays) estimated via a simultaneous fit to invariant mass and pseudo-proper decay length distributions

Invariant mass distribution of opposite sign electron pairs



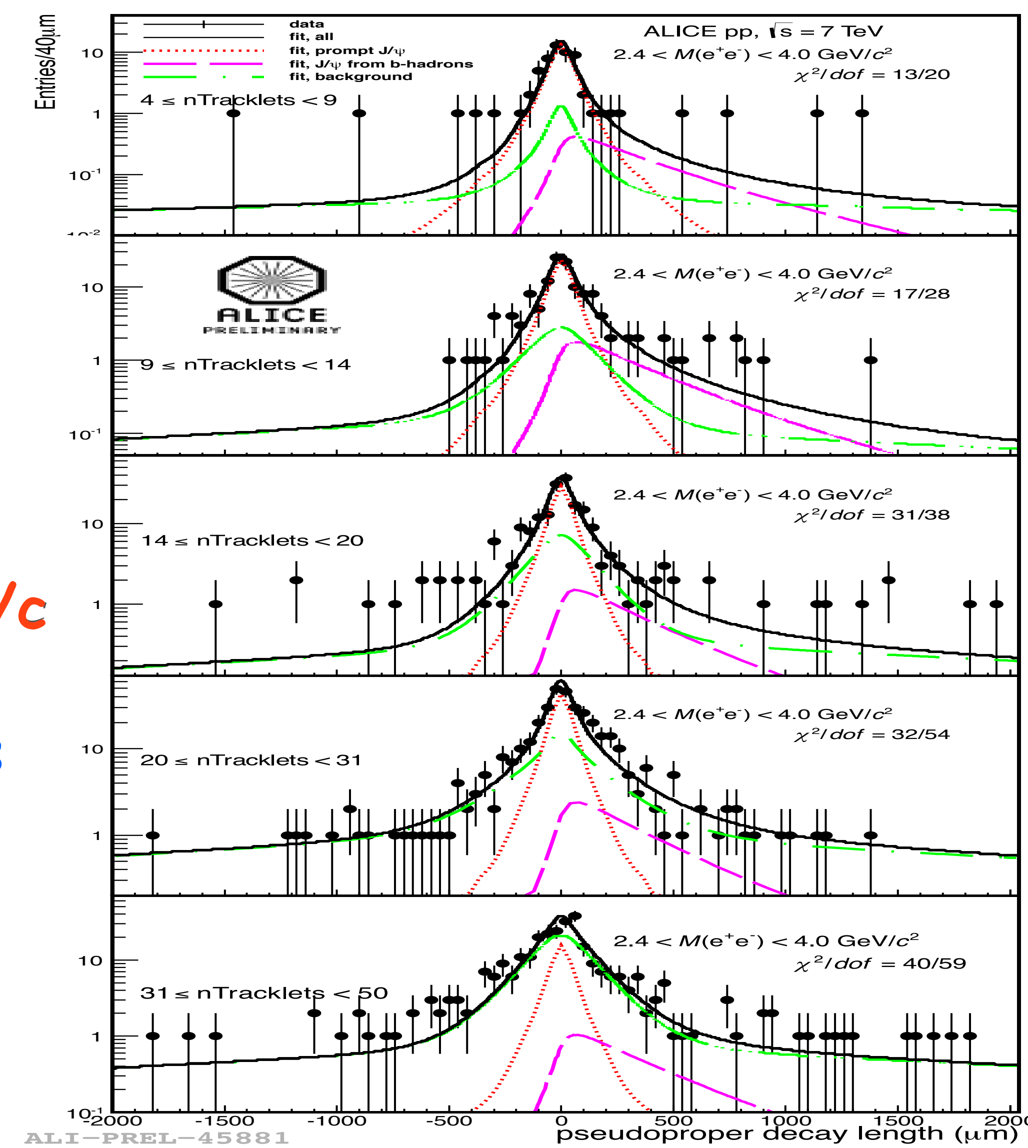
|y|<0.9

pT>1.3 GeV/c

Fiorella Fionda's talk

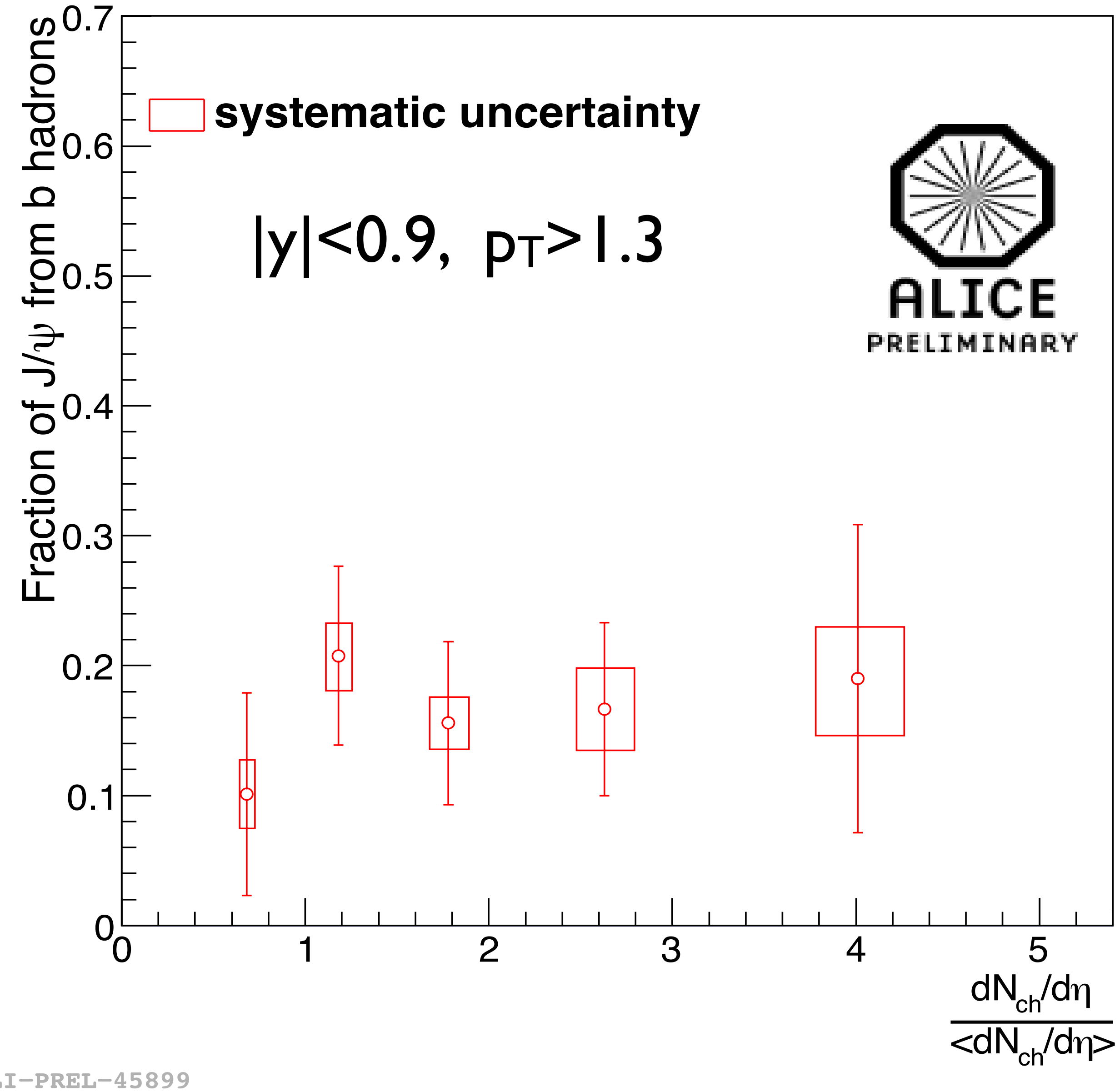
pseudoproper decay length

x = $L_{xy} \cdot c \cdot m(J/\psi) / p_T (J/\psi)$; $L_{xy} = L.\ p_{T.} (J/\psi)$



Relative non prompt J/ψ fraction vs dNch/dη

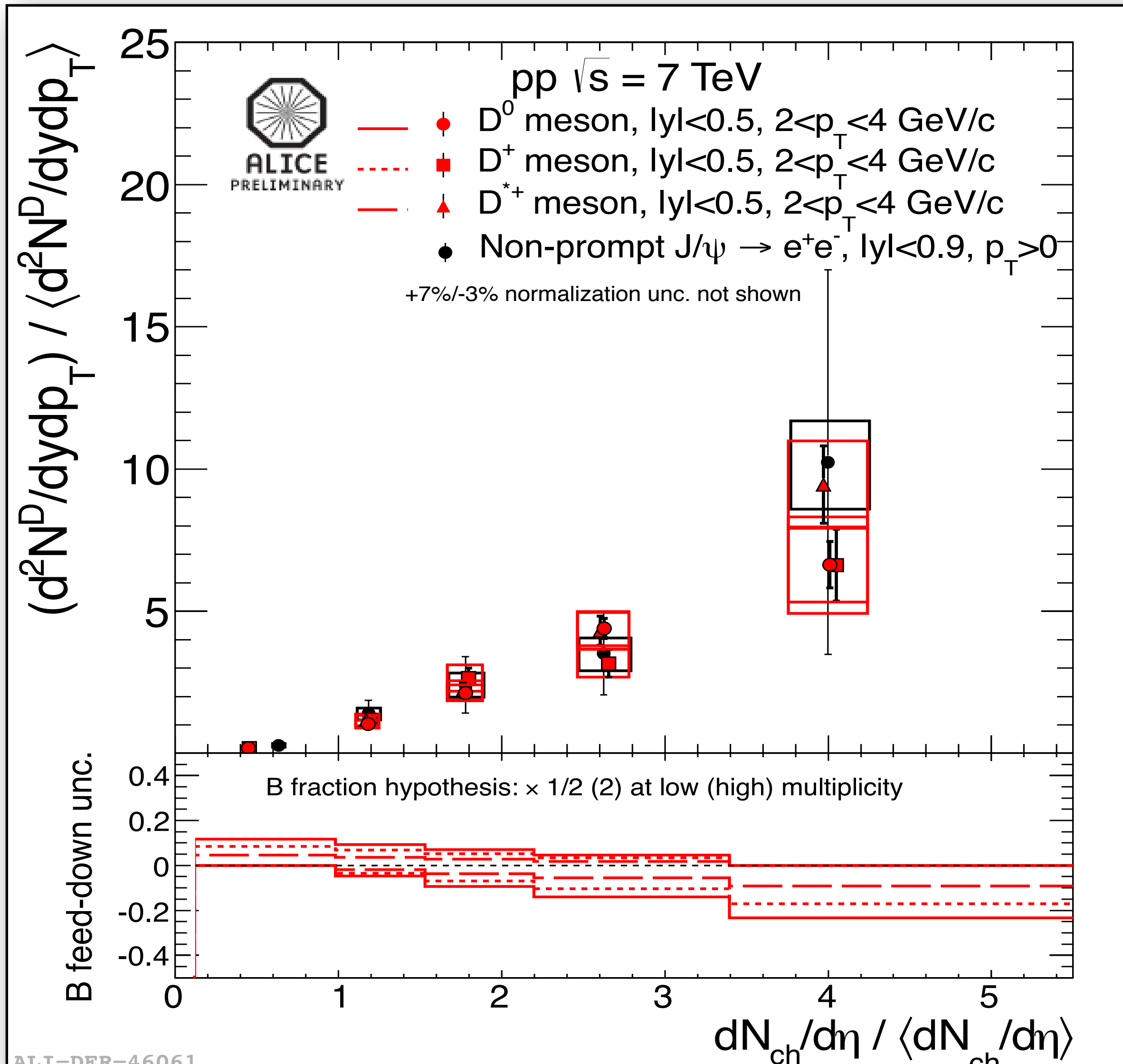
$$f_B = \frac{N_{J/\Psi \leftarrow h_B}}{N_{prompt J/\Psi} + N_{J/\Psi \leftarrow h_B}}$$



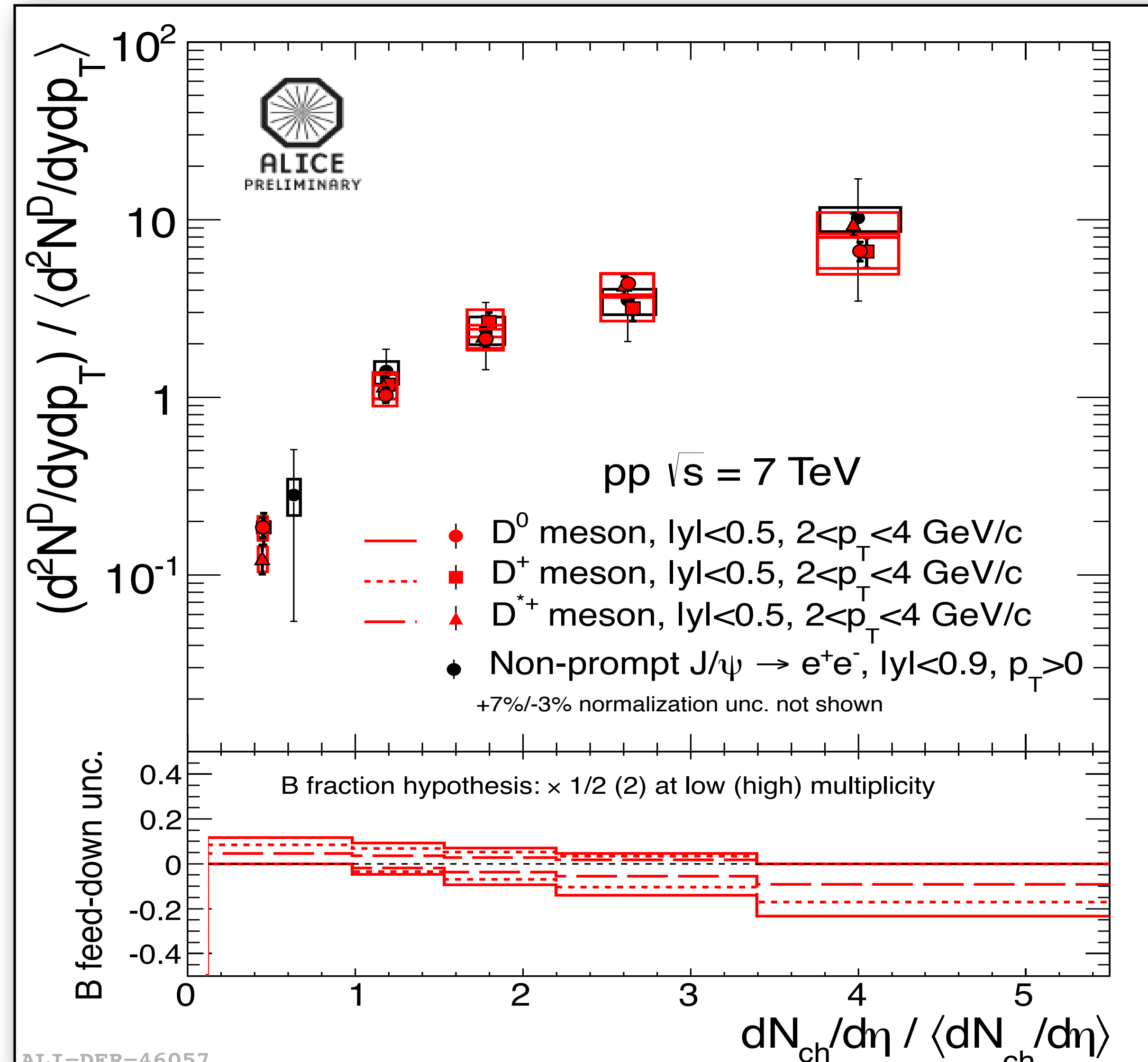
Approximately flat non-prompt J/ψ fraction as a function of charged particle multiplicity

Relative non-prompt J/ψ and D meson yields vs. $dN_{ch}/d\eta$

ALICE



Linear Scale



Logarithmic Scale

Global trend vs. multiplicity similar for open charm and beauty: universality?

Summary

ALICE

✓ D meson production cross section measured down to 1 GeV/c, well described by perturbative QCD calculations.

✓ Prompt-D meson yields increase with charged particle multiplicity

✓ The results of D^0, D^+ and D^{*+} mesons are consistent.

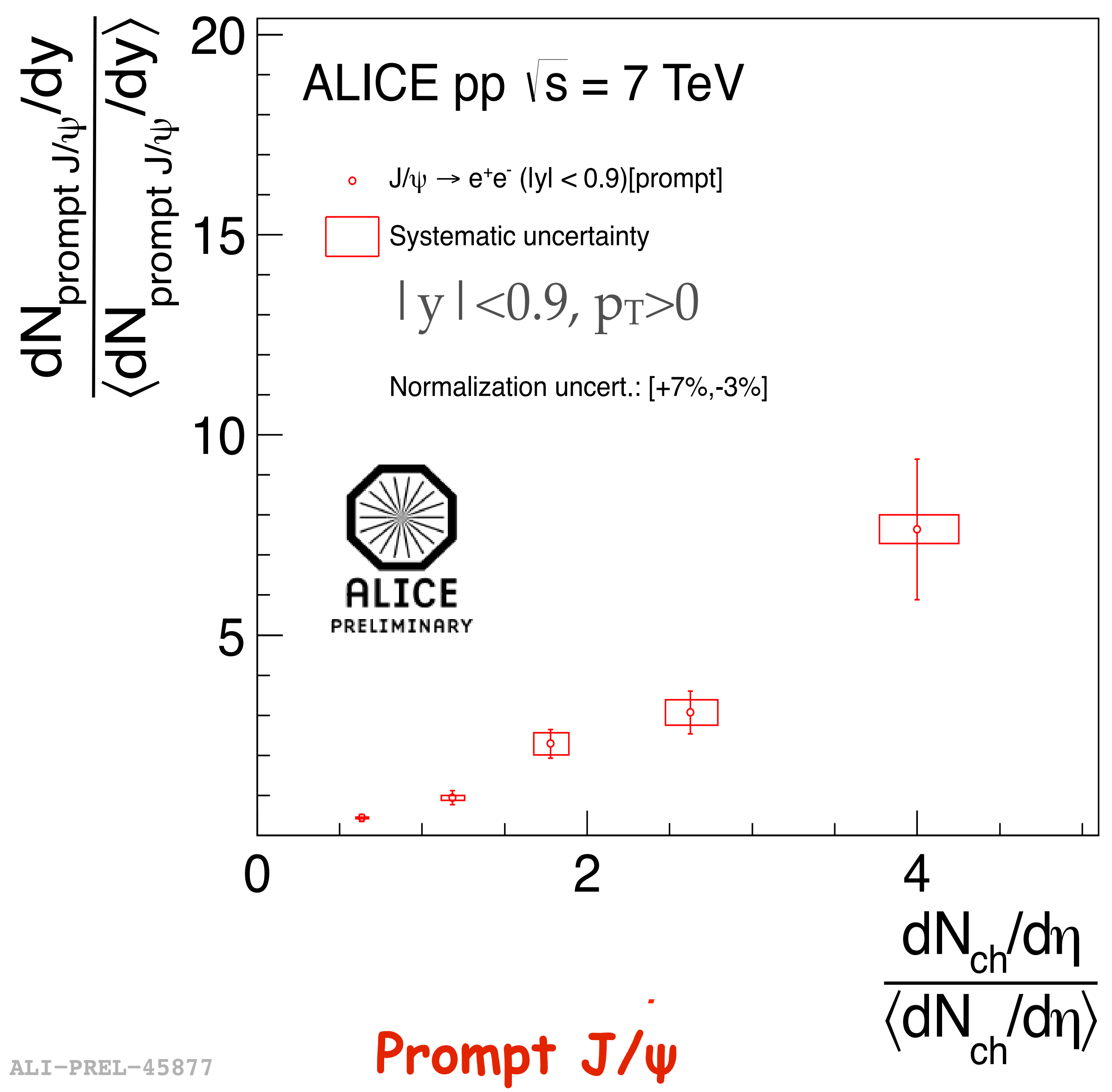
✓ Similar trend observed in all p_T bins. Within the current uncertainties, no p_T dependence observed on the D meson multiplicity evolution.

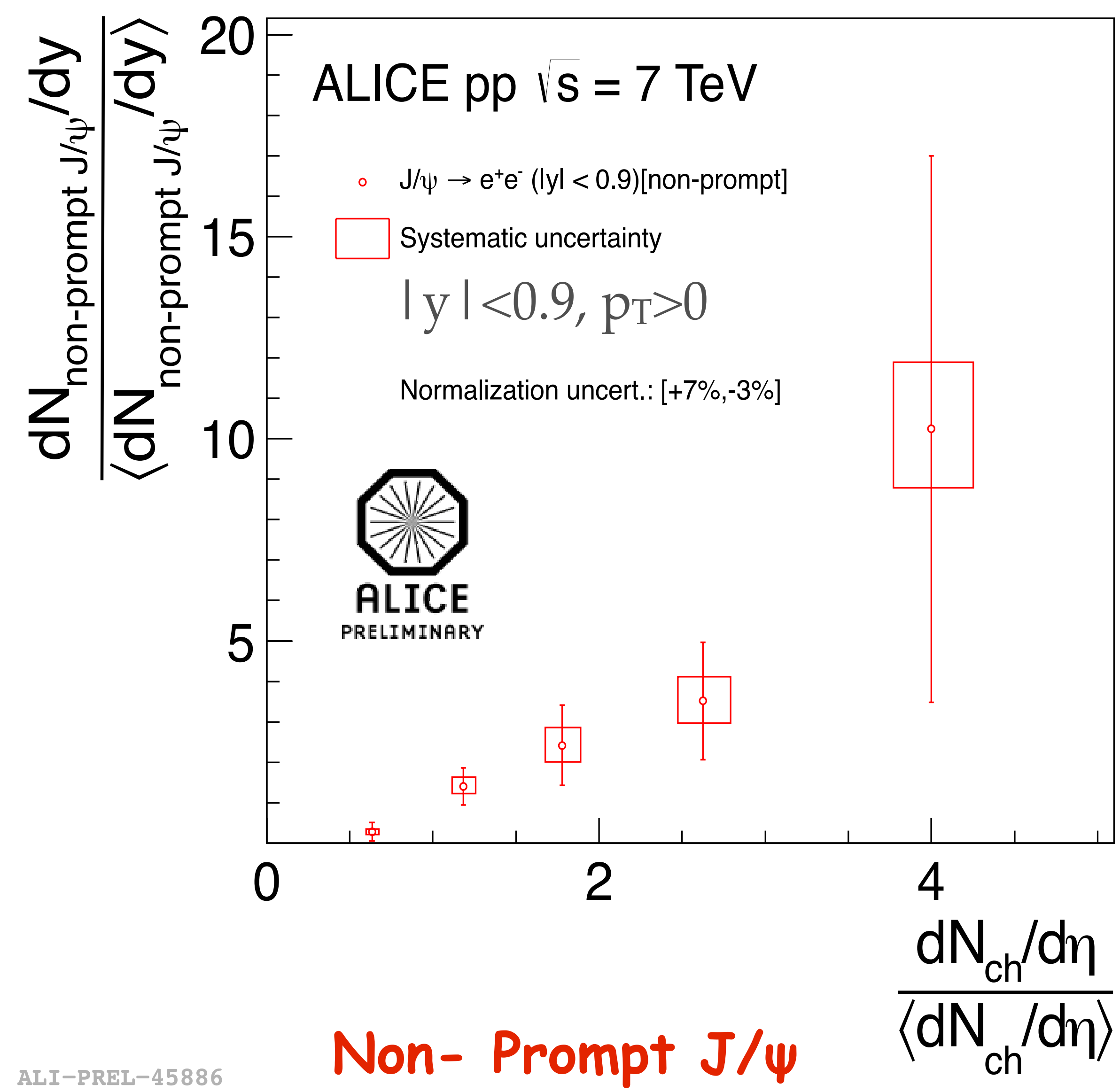
✓ Prompt-D meson, prompt and non-prompt J/ψ yields show a similar increase with charged particle multiplicity.

✓ Results may indicate that either D meson production in pp collisions is connected with a strong hadronic activity, or multi-parton interactions also affect the hard momentum scales relevant for charm quark production.

Backup

Relative prompt and non-prompt J/ψ yields vs. $dN_{ch}/d\eta$





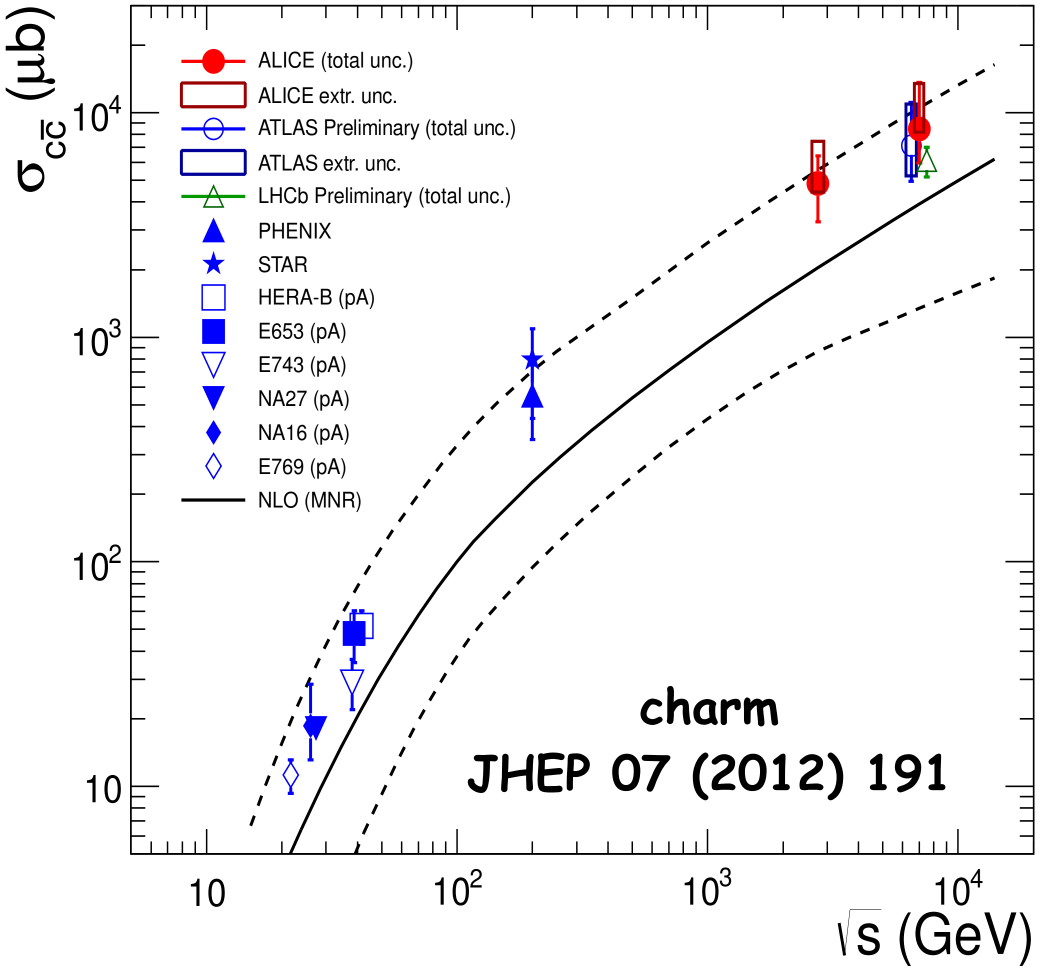
Approximately linear increase with charged particle multiplicity of both prompt and non-prompt J/ψ

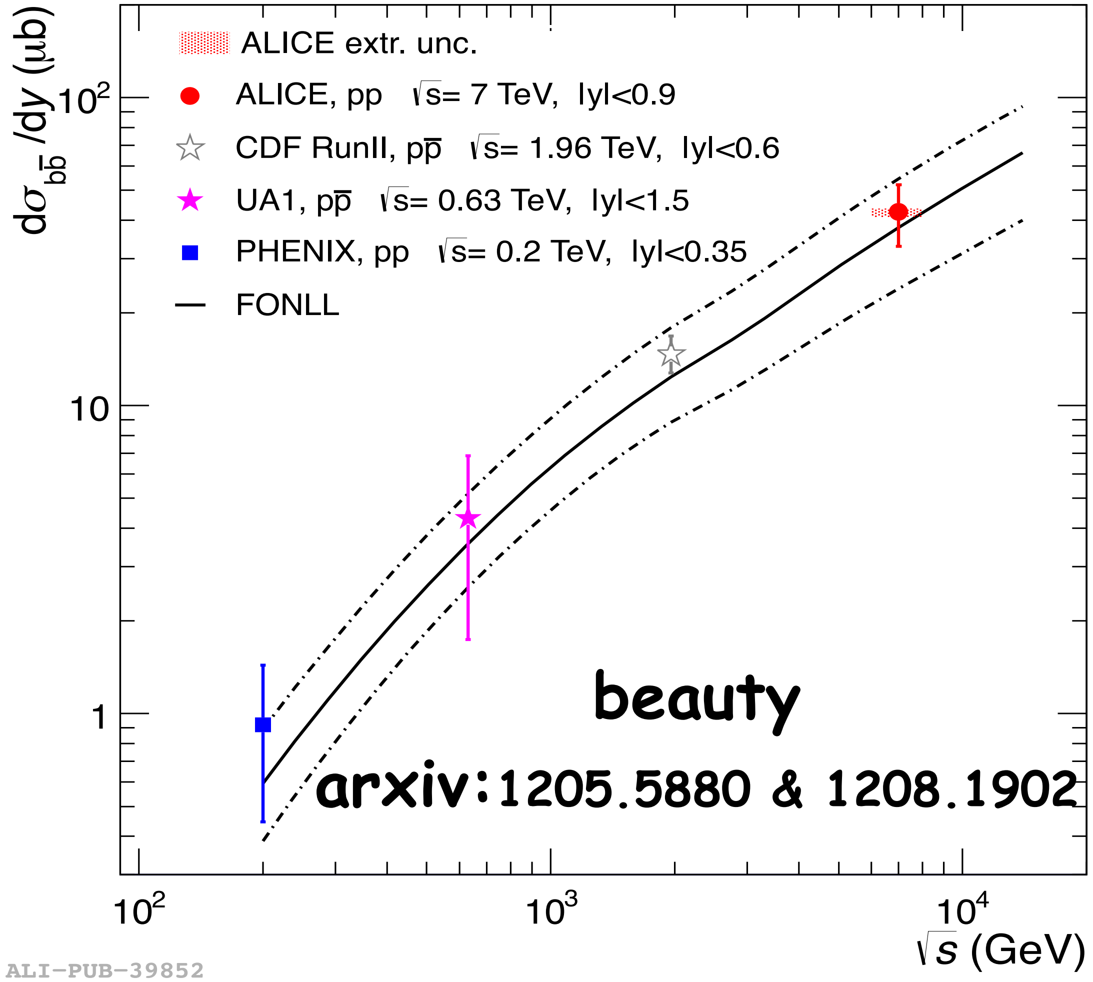
WHAT CAN BE LEARN AT LHC?

ALICE

Higher c and b cross sections:

- More abundant heavy flavour production
- Better precision (reduced errors)



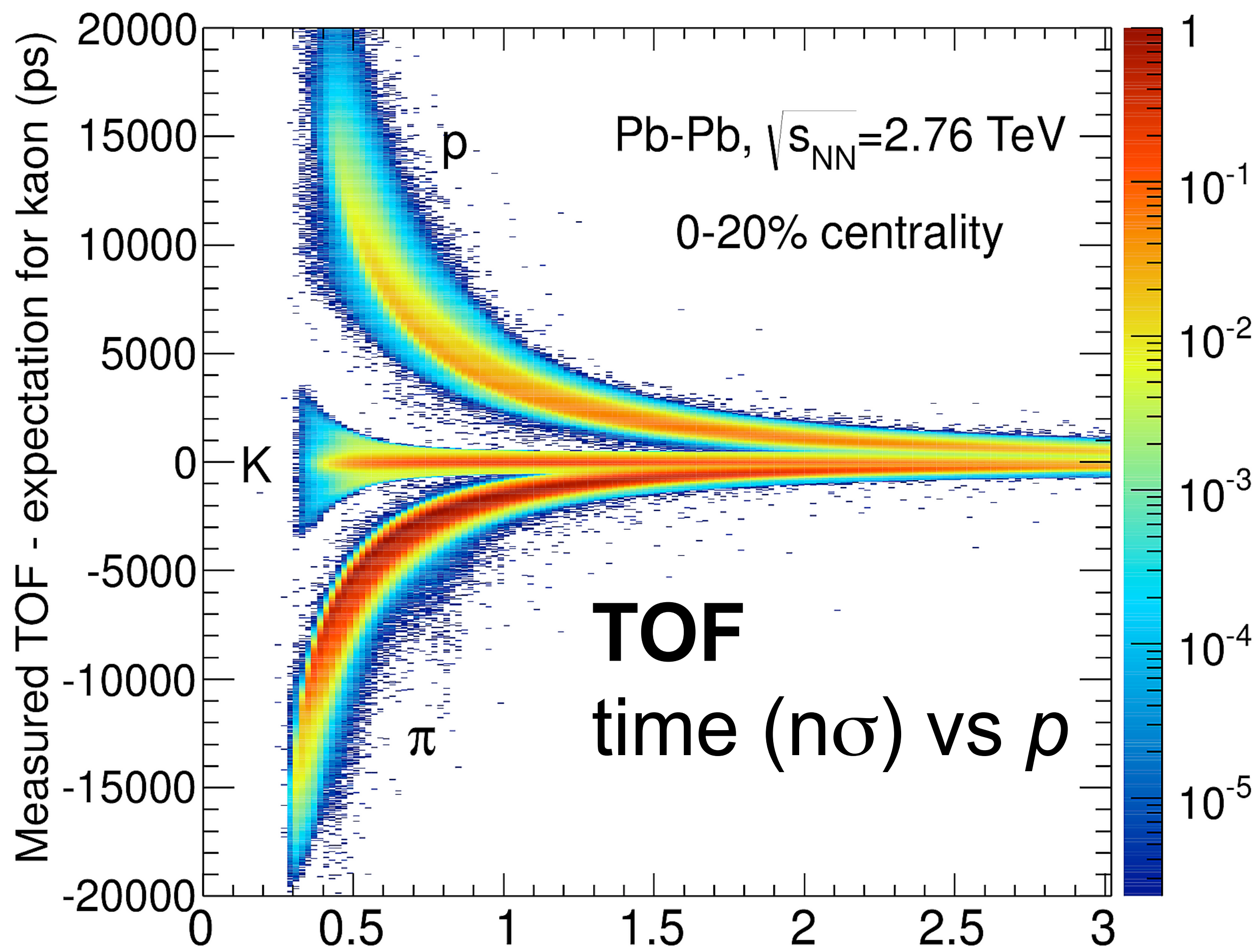


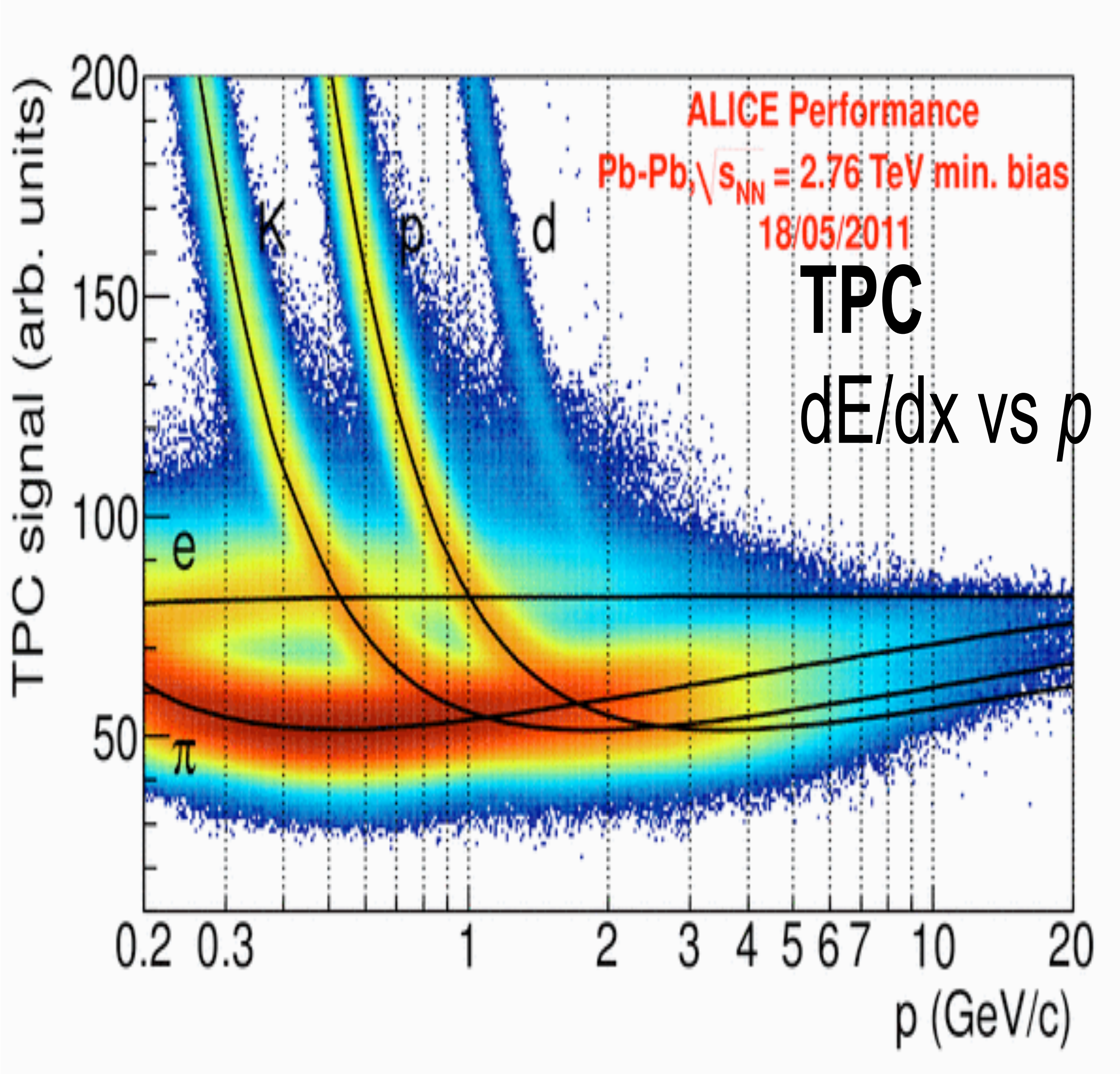
$$\sigma_{LHC}^{c\bar{c}} \approx 10.\sigma_{RHIC}^{c\bar{c}}$$

$$\sigma_{LHC}^{b\bar{b}} \approx 100.\sigma_{RHIC}^{b\bar{b}}$$

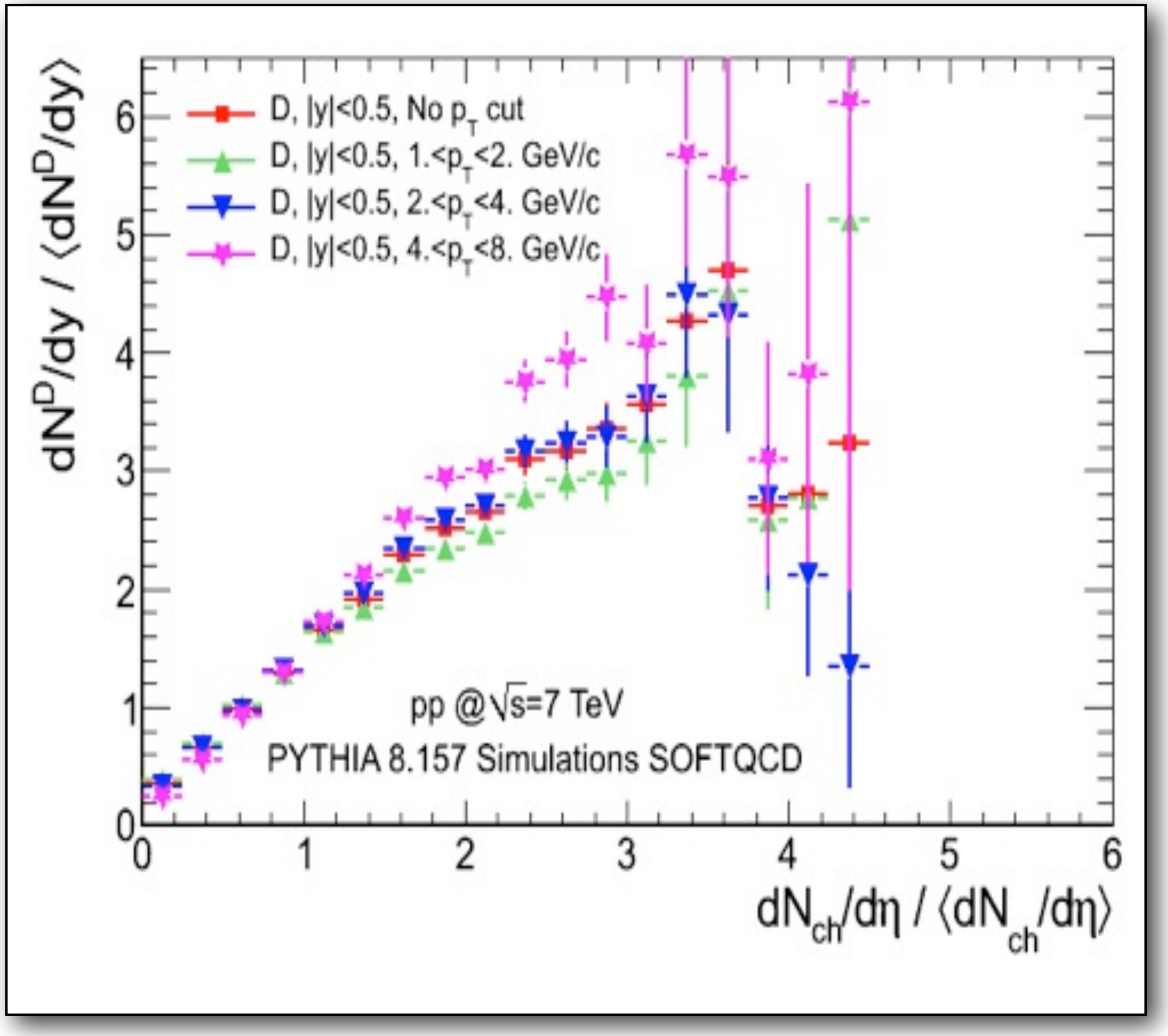
TOOLS: PARTICLE IDENTIFICATION

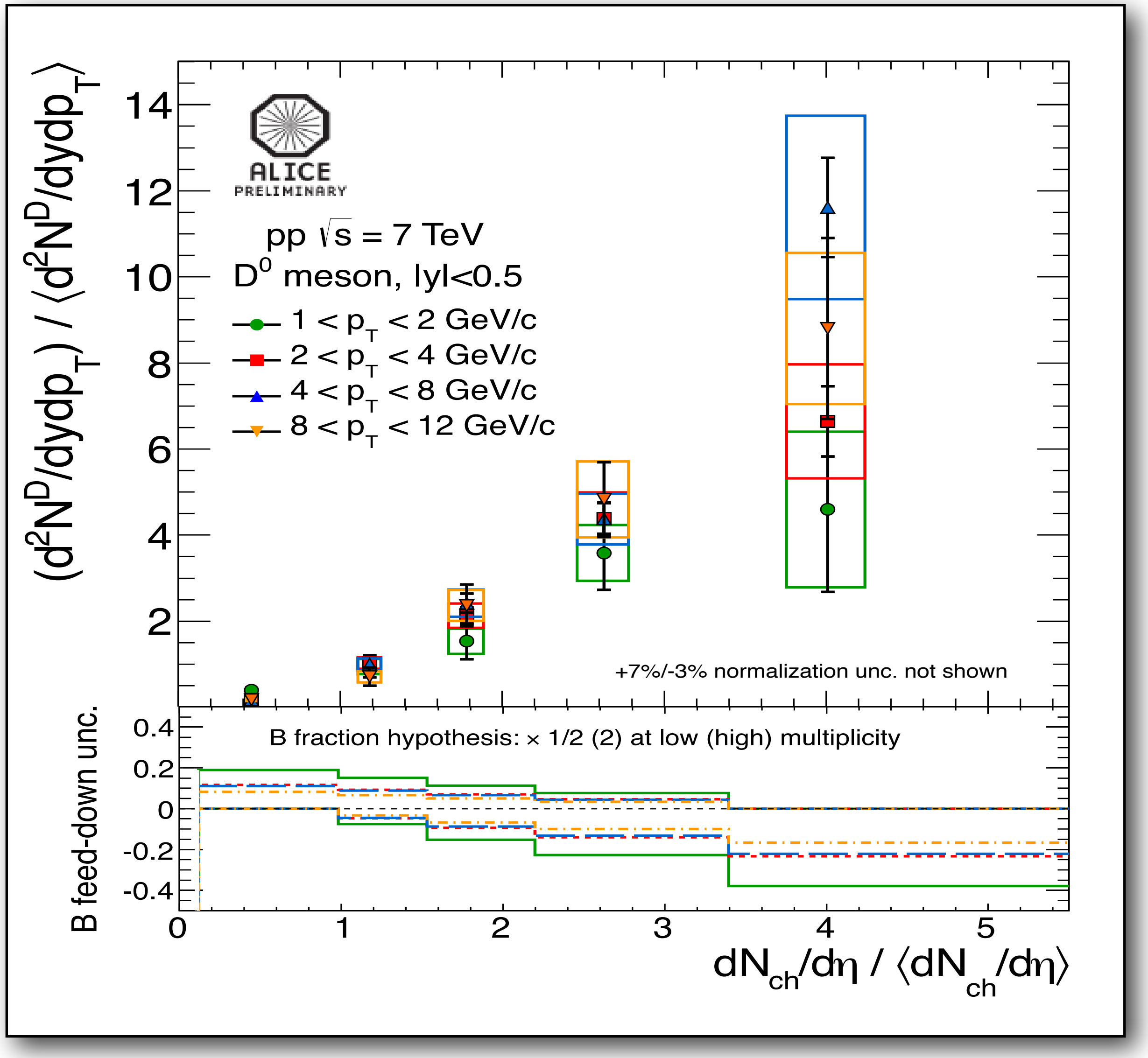
Proton, kaon and pion separation using dE/dx in TPC and TOF information





Comparison with PYTHIA 8: an example





- PYTHIA8 minbias tune as reference
- Soft QCD: minbias tune.