D^+_s production at central rapidity in Pb-Pb collisions at 2.76 TeV with the ALICE detector

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for the ALICE Collaboration
Turin University- INFN Turin

Overview of the talk

- Physics motivation for the D_s^+ analysis in Pb-Pb collisions
- D_s^+ meson reconstruction strategy in ALICE
- pp at $\sqrt{s}$ = 7 TeV:
  - D_s^+ p_T differential cross-section
    ➔ it defines the reference for the Pb-Pb analysis
  - D meson ratios
- D_s^+ meson dN/dp_T and R_{AA} in Pb-Pb at $\sqrt{s_{NN}}$ = 2.76 TeV
- Summary and conclusions

Physics motivation

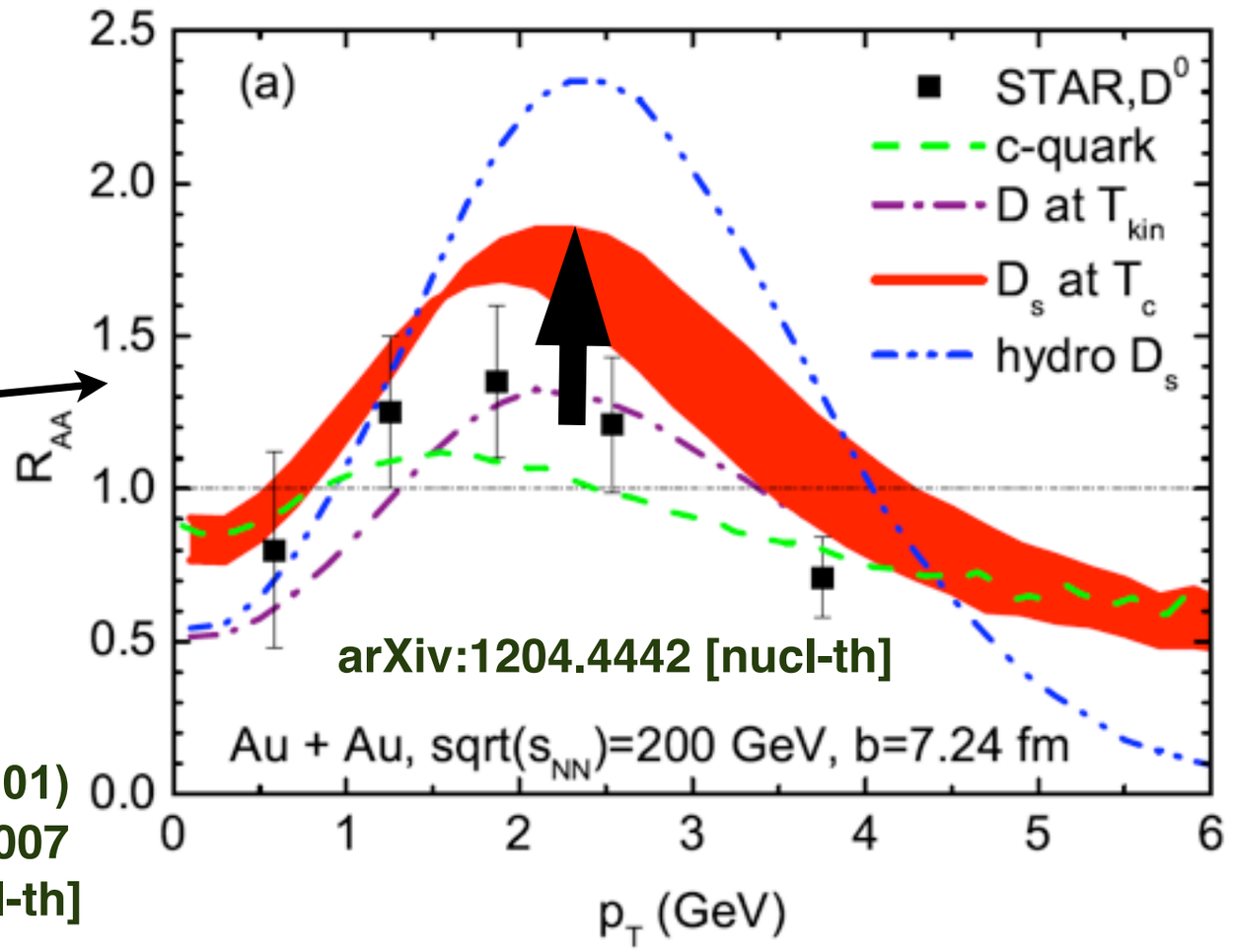
- Heavy quarks produced in the early stages of the collisions (high Q^2)

→ Effective probe of the high-density medium created in heavy-ion collisions

- In-medium ***energy loss*** expected smaller for heavy quarks than for light quarks and gluons due to color charge and dead cone effect [1]

E_{loss}(b) < E_{loss}(c) < E_{loss}(light)

- The relative yield of D^+_s with respect to non-strange D meson expected to be **enhanced** in Pb-Pb collisions in the intermediate p_T if charm quarks hadronize via **recombination** in the medium [2, 3]



[1] Y. L. Dokshitzer, D. E. Kharzeev, Phys. Lett. B519 (2001)
[2] I. Kuznetsova, J. Rafelski, Eur.Phys.J.C51:113-133,2007
[3] M. He, R. J. Fries and R. Rapp, arXiv:1204.4442 [nucl-th]

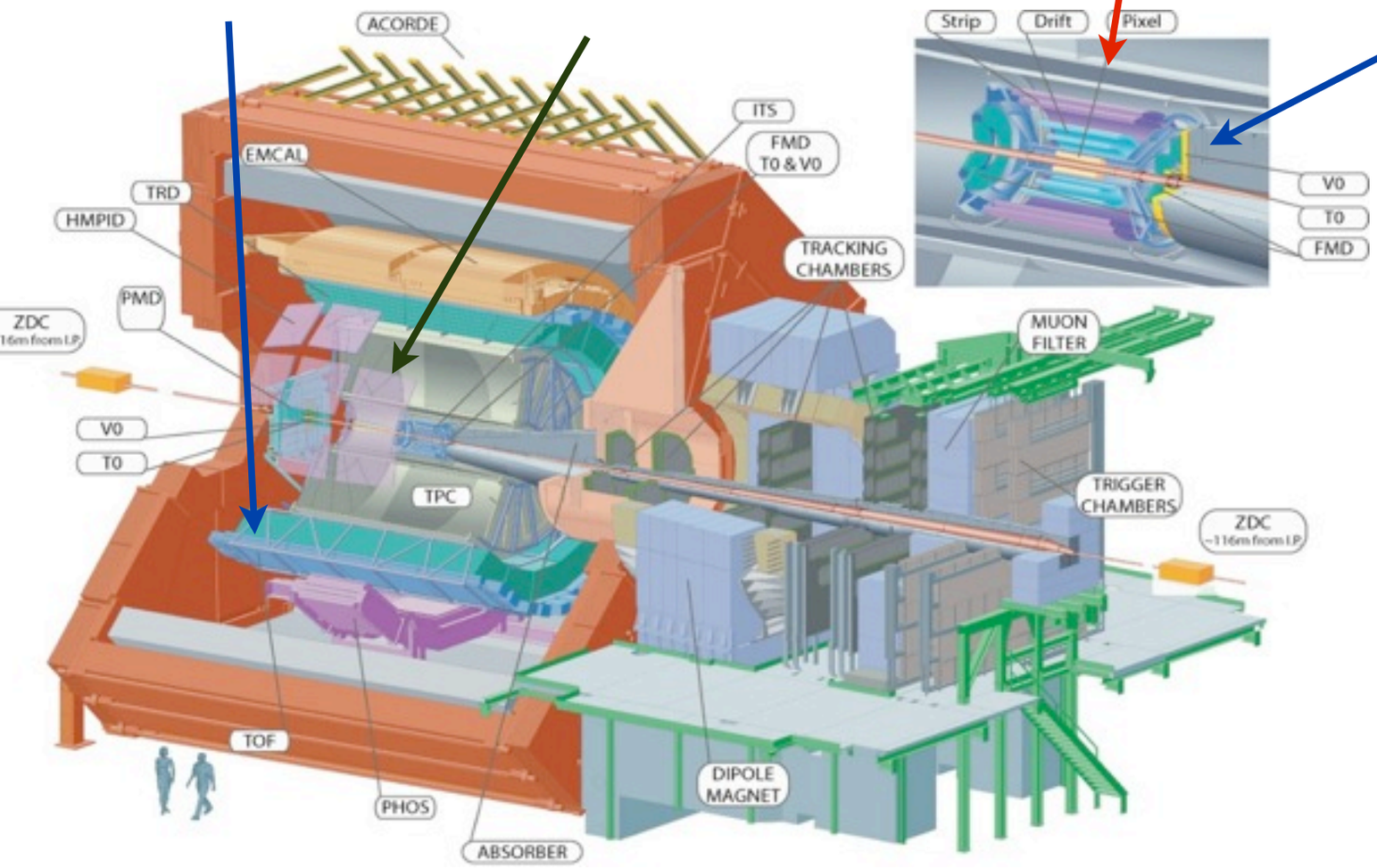
ALICE apparatus and dataset

TOF p/K/π PID

TPC tracking + p/K/π PID

ITS tracking + vertexing

VZERO trigger + centrality



- ***Trigger***
  Trigger based on ITS pixels and VZERO scintillators

- ***Centrality in Pb-Pb***
  Determined via geometrical Glauber model fit of the VZERO amplitude

Central barrel acceptance
$|\eta| < 0.9$

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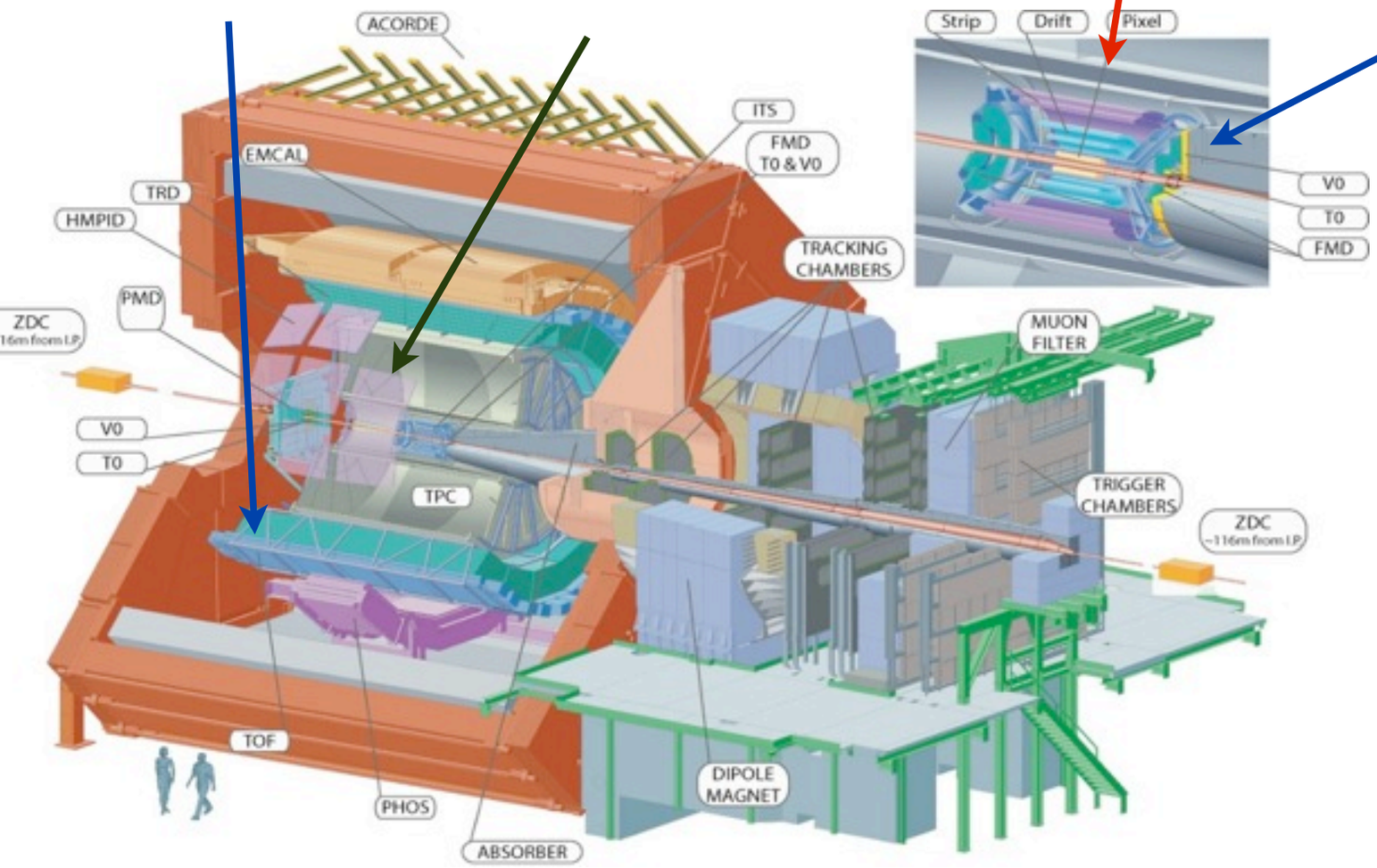

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System	Energy (TeV)	Ev. analyzed	Luminosity
pp	7	3×10^8	4.8 nb^{-1}
Pb-Pb Centrality 0-7.5 %	2.76	1.6×10^7	28 μb^{-1}

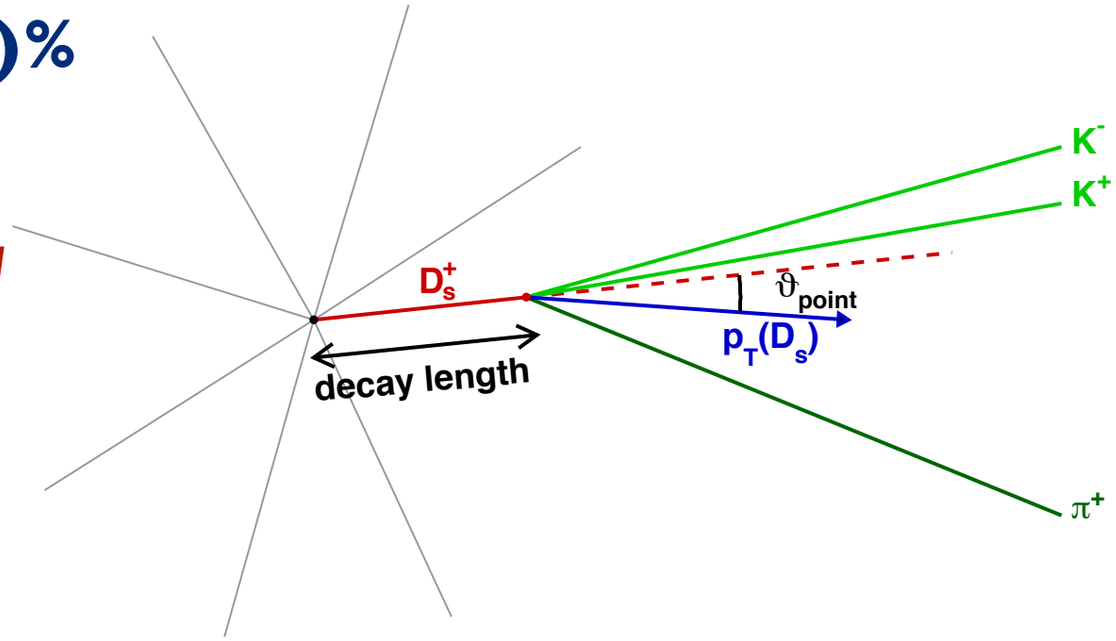
Central barrel acceptance $|\eta| < 0.9$

D^+_s meson reconstruction strategy in the ALICE central barrel

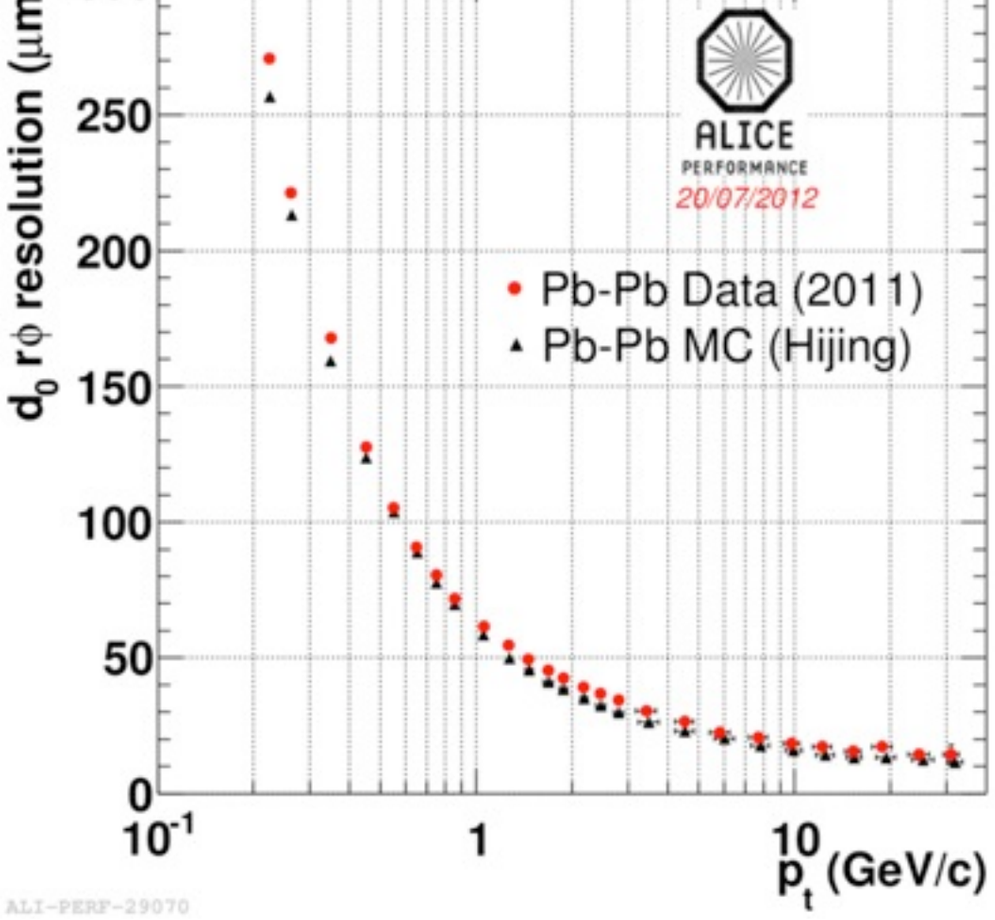
$D_s^+ \rightarrow \Phi\pi^+ \rightarrow K^+K^-\pi^+$ BR= (2.28 ± 0.12)%

$c\tau(D_s^+)$ = 150 μm

Invariant mass analysis of fully reconstructed decay topologies originating from displaced decay vertices



Track impact parameter resolution



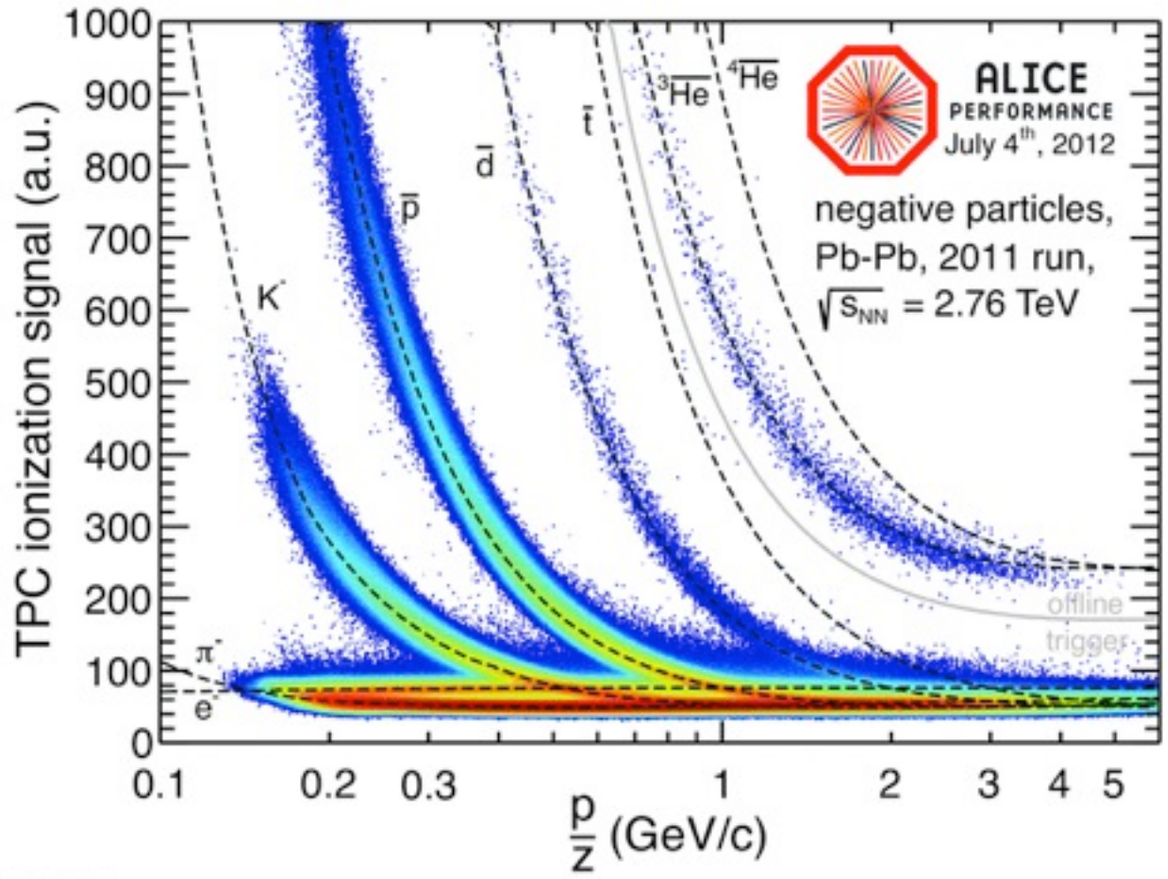
Candidate selection common for pp and Pb-Pb

- Decay length
- Cosine of the pointing angle
- Distance of tracks to secondary vertex
- Invariant mass of the ϕ reconstructed meson

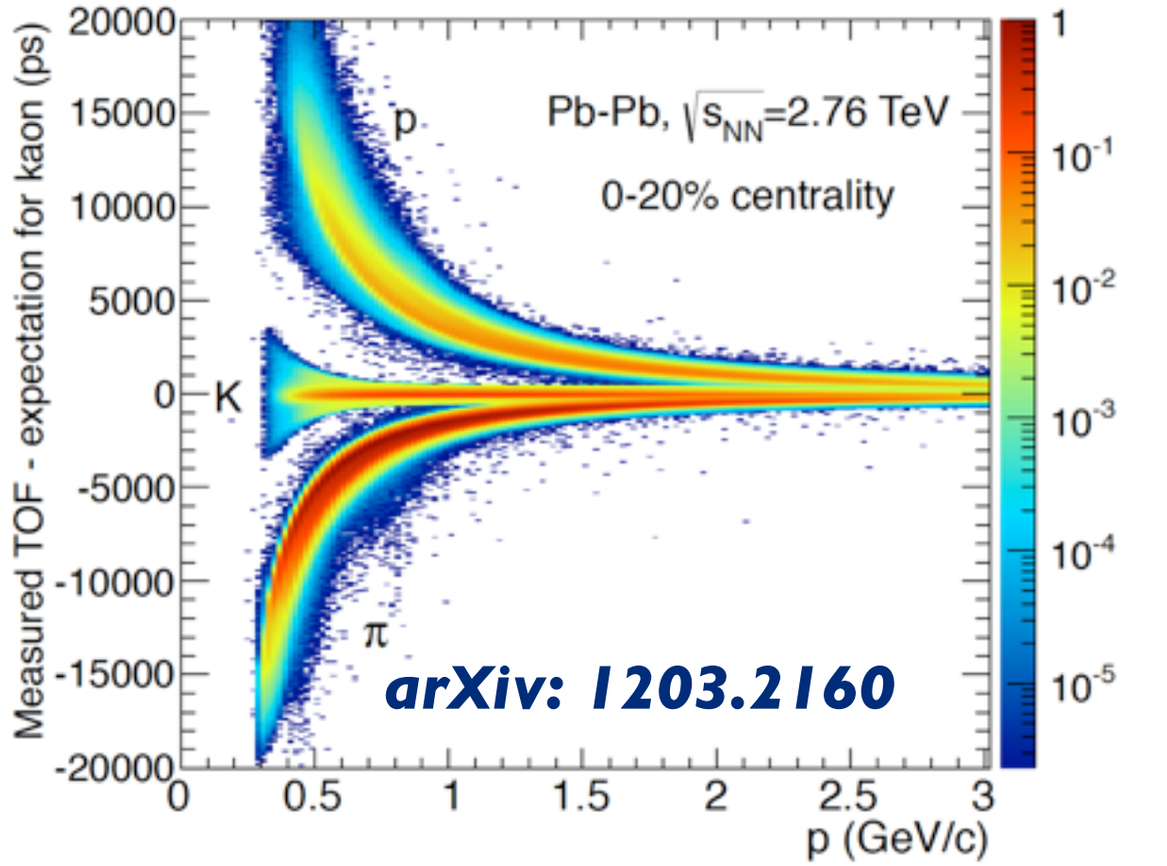
For Pb-Pb analysis only:

- Decay length in the transverse plane (x,y)
- Standardized decay length (x,y)
- Cosine of the pointing angle (x,y)

Particle identification selection (PID)



TPC: identification based on dE/dx:
- N*σ compatibility with Bethe-Bloch curves



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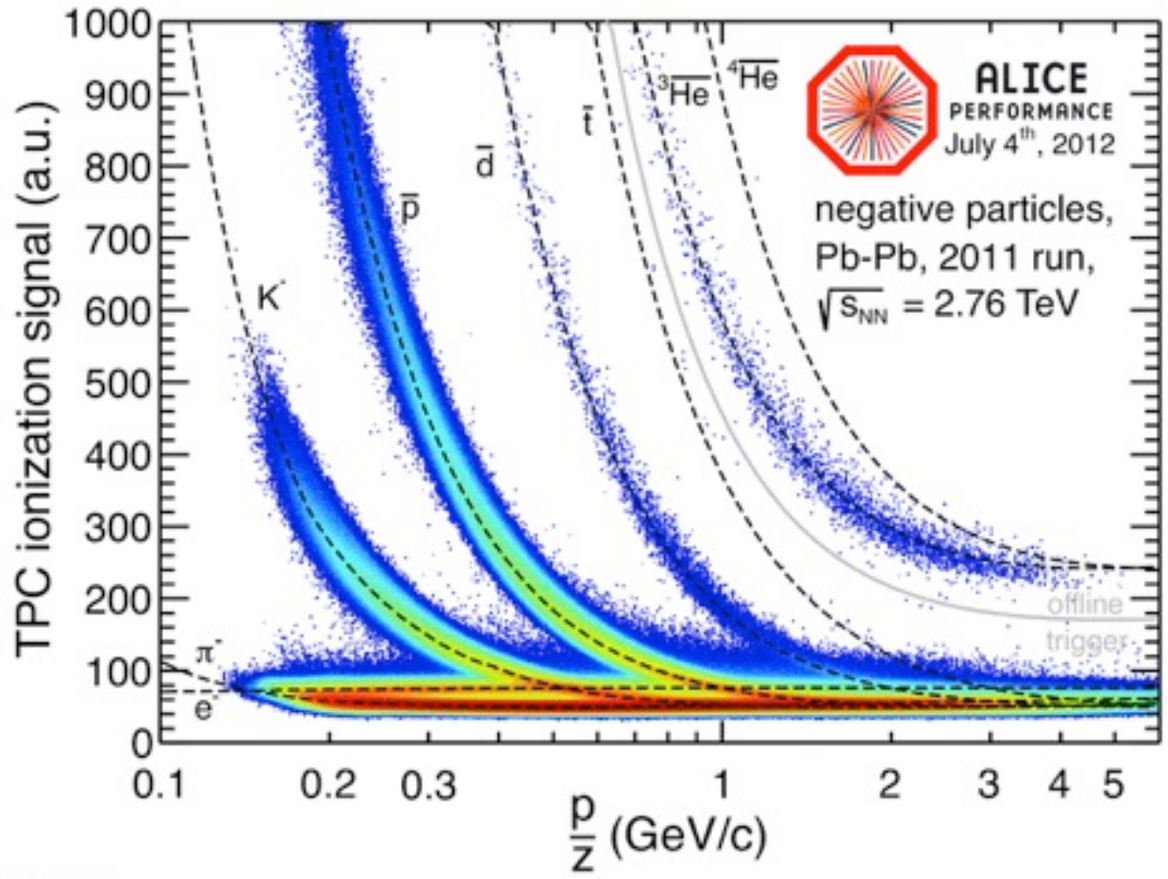

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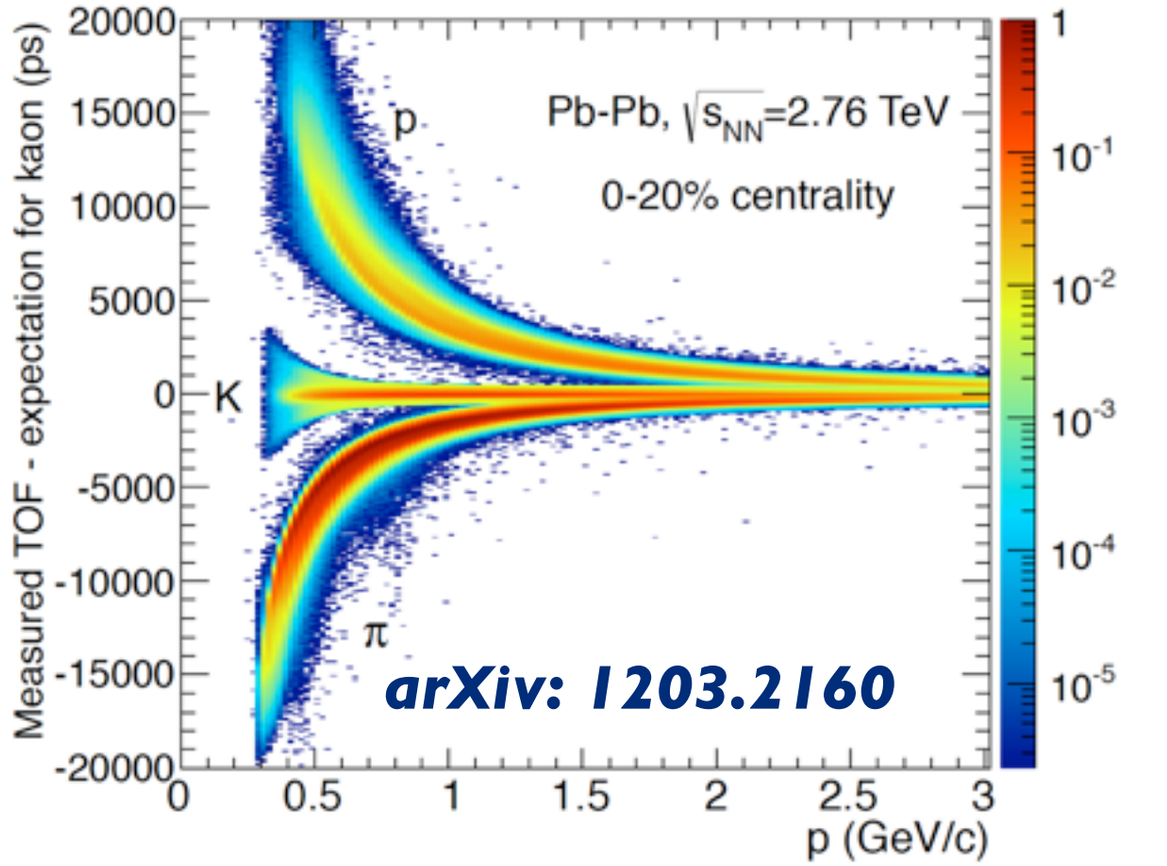

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Track compatible with the kaon or pion hypothesis if both its dE/dx and time-of-flight within 3σ from the expected values, with at least one of them satisfying a 2σ cut

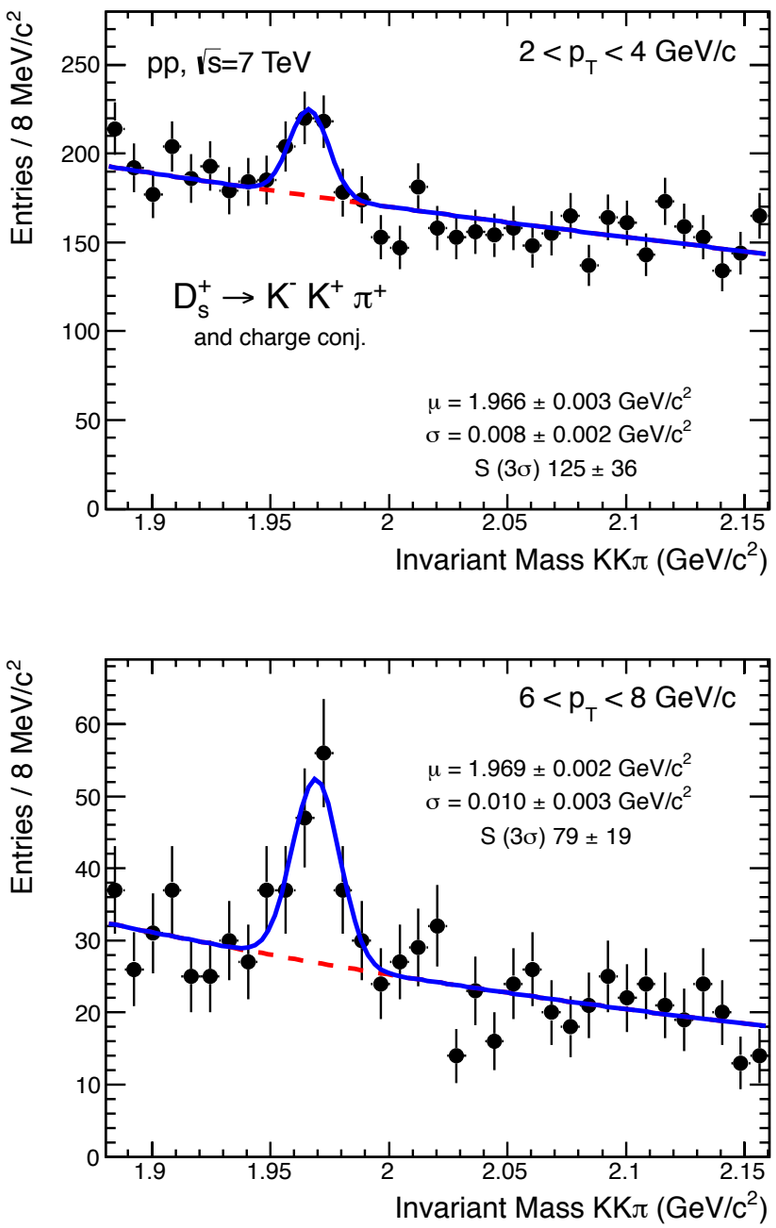
➔ ***Factor > 20 of background reduction in p_T range 4-6 GeV/c in Pb-Pb***

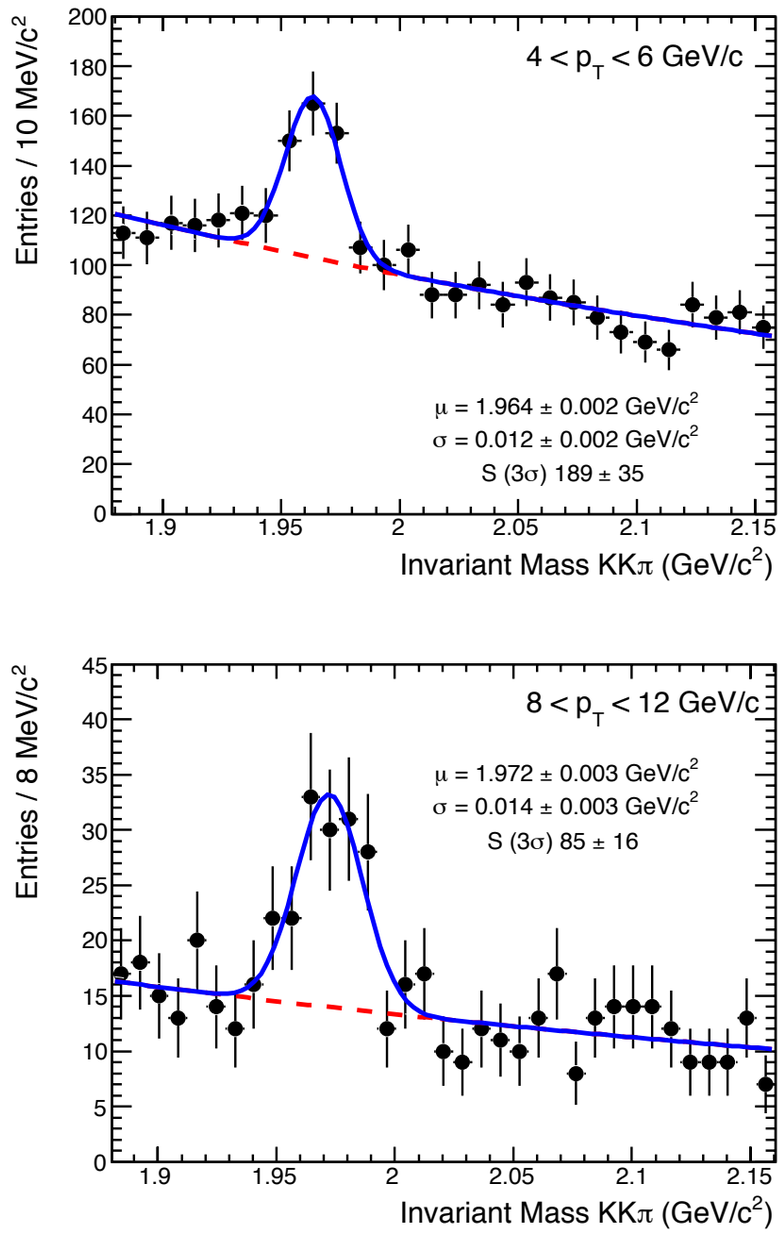
proton-proton analysis at 7 TeV

arXiv: 1208.1948

$D_s^{\pm}$ signal in pp collisions

- Analysis performed on the 2010 pp sample at 7 TeV
- 3 x10^8 minimum bias events corresponding to an integrated luminosity of 4.8 nb^{-1}





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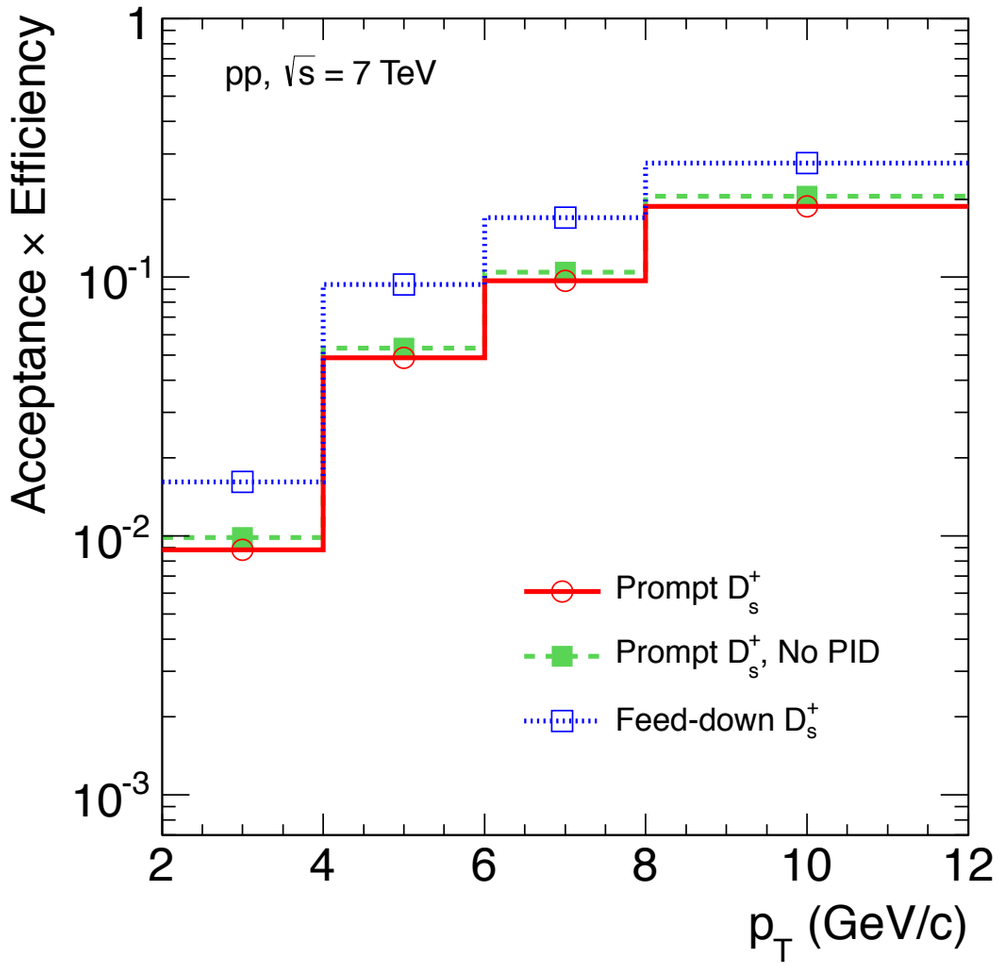
ALI-PUB-40180

Invariant mass distributions of $D_s^{\pm}$ candidates in 4 p_T intervals from 2 to 12 GeV/c fitted with a Gaussian function (signal) + exponential (background)

Efficiency and B feed-down subtraction



ALI-PUB-40184

$$\left.\frac{\mathrm{d}\sigma^{\mathrm{D_s^+}}}{\mathrm{d}p_{\mathrm{T}}}\right|_{|y|<0.5} = \frac{1}{2}\frac{1}{\Delta y\,\Delta p_{\mathrm{T}}}\frac{\left. f_{\mathrm{prompt}}\cdot N^{\mathrm{D_s^\pm\ raw}}\right|_{|y|<y_{\mathrm{fid}}}}{(\mathrm{Acc}\times\varepsilon)_{\mathrm{prompt}}\,\mathrm{BR}\cdot L_{\mathrm{int}}}$$

- Acceptance x efficiency for prompt D_s^+ and D_s^+ from B feed-down

- Higher efficiencies for D_s^+ from B feed-down due to larger displacement from the primary vertex

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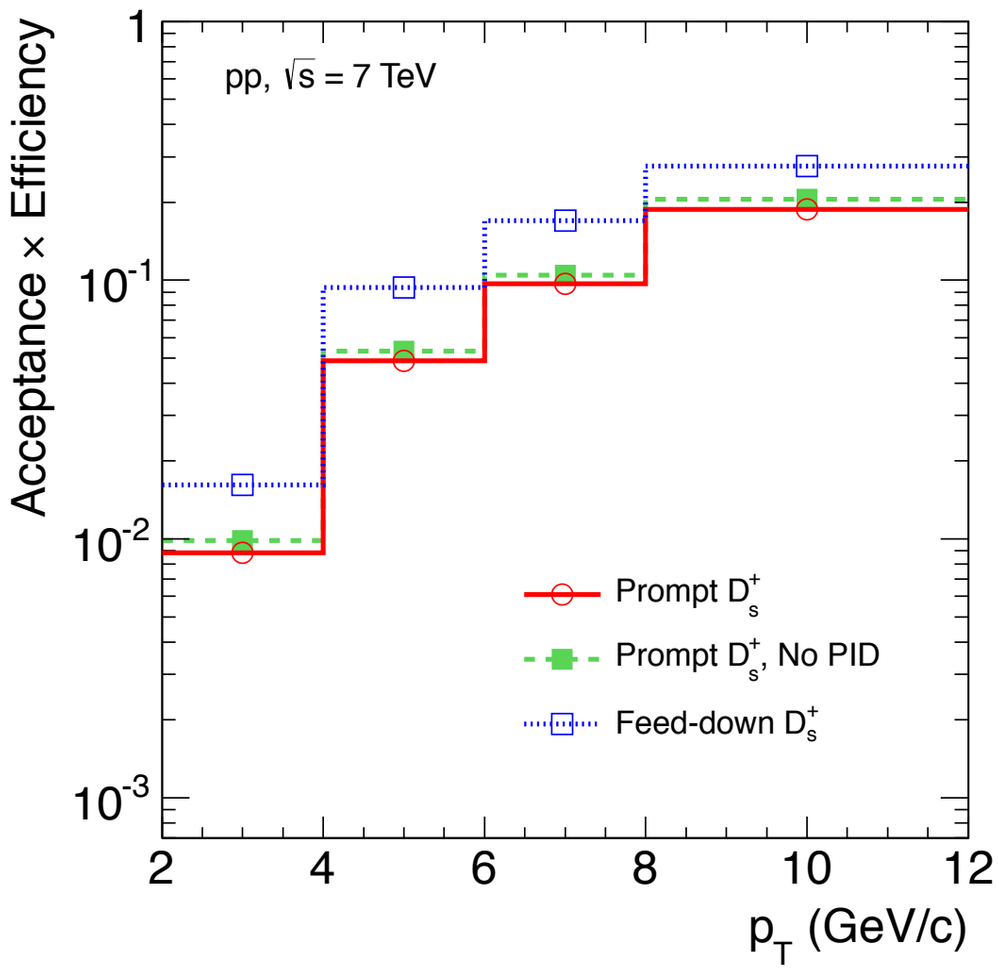

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Feed down subtraction

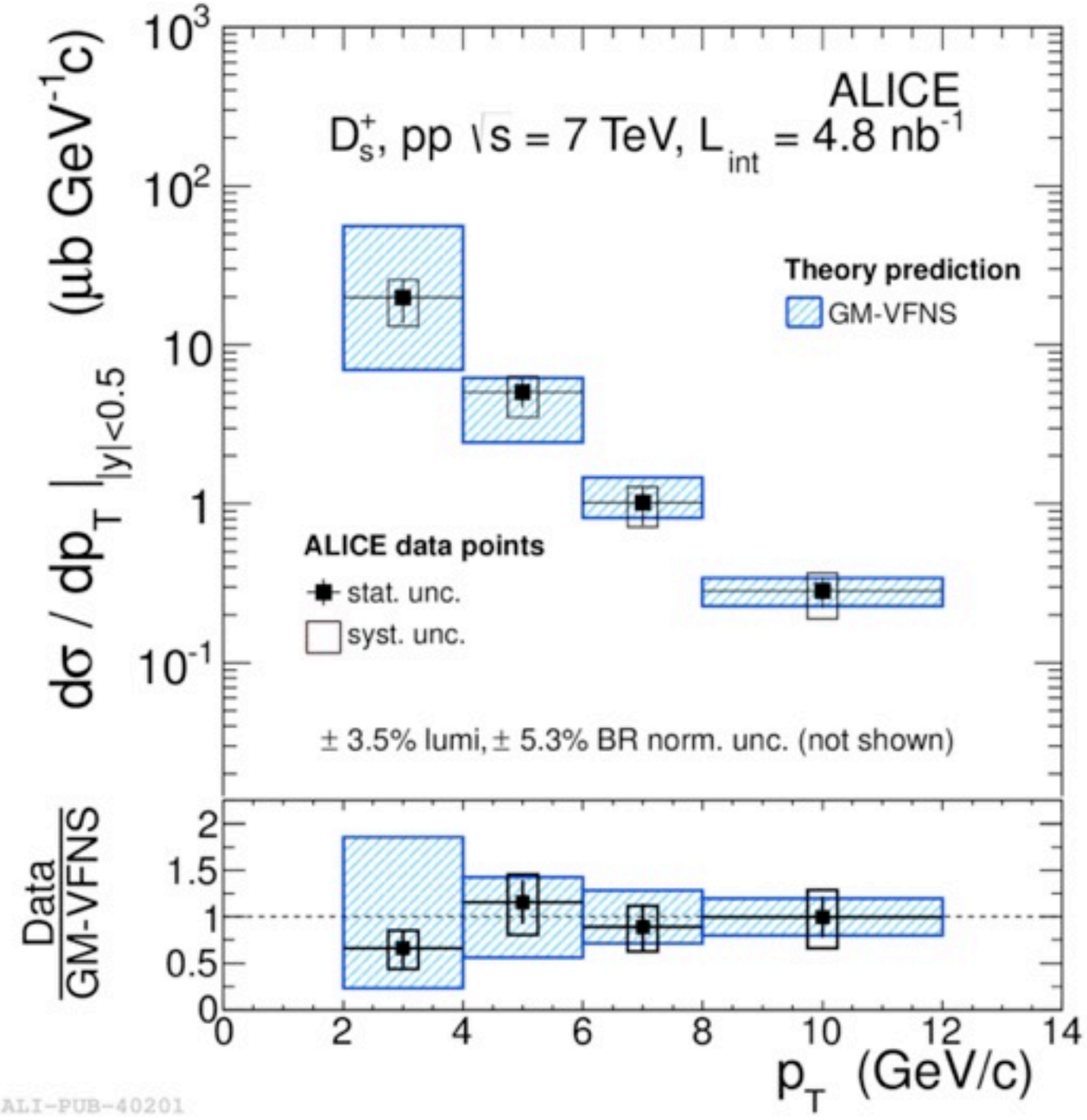
$$f_{prompt} = 1 - \frac{N^{RawD_s^+ fromB}}{N^{RawD_s^+}}$$

- Fraction of prompt D_s^+ mesons f_{prompt} estimated using:
  - beauty production cross section from ***FONLL***[1] calculations
  - **MC efficiency** for feed-down D_s^+

- f_{prompt} ranges from 0.93 to 0.87 depending on the p_T of the D_s^+ meson

[1] M. Cacciari, M. Greco, P. Nason, JHEP 9805 (1998) 007

D^+_s p_T-differential cross section in pp at 7 TeV



- p_T-differential cross section for prompt D_s^+ mesons
- Integrated luminosity of 4.8 nb^{-1}
- Described within uncertainties by GM-VFNS[1] calculations (pQCD)

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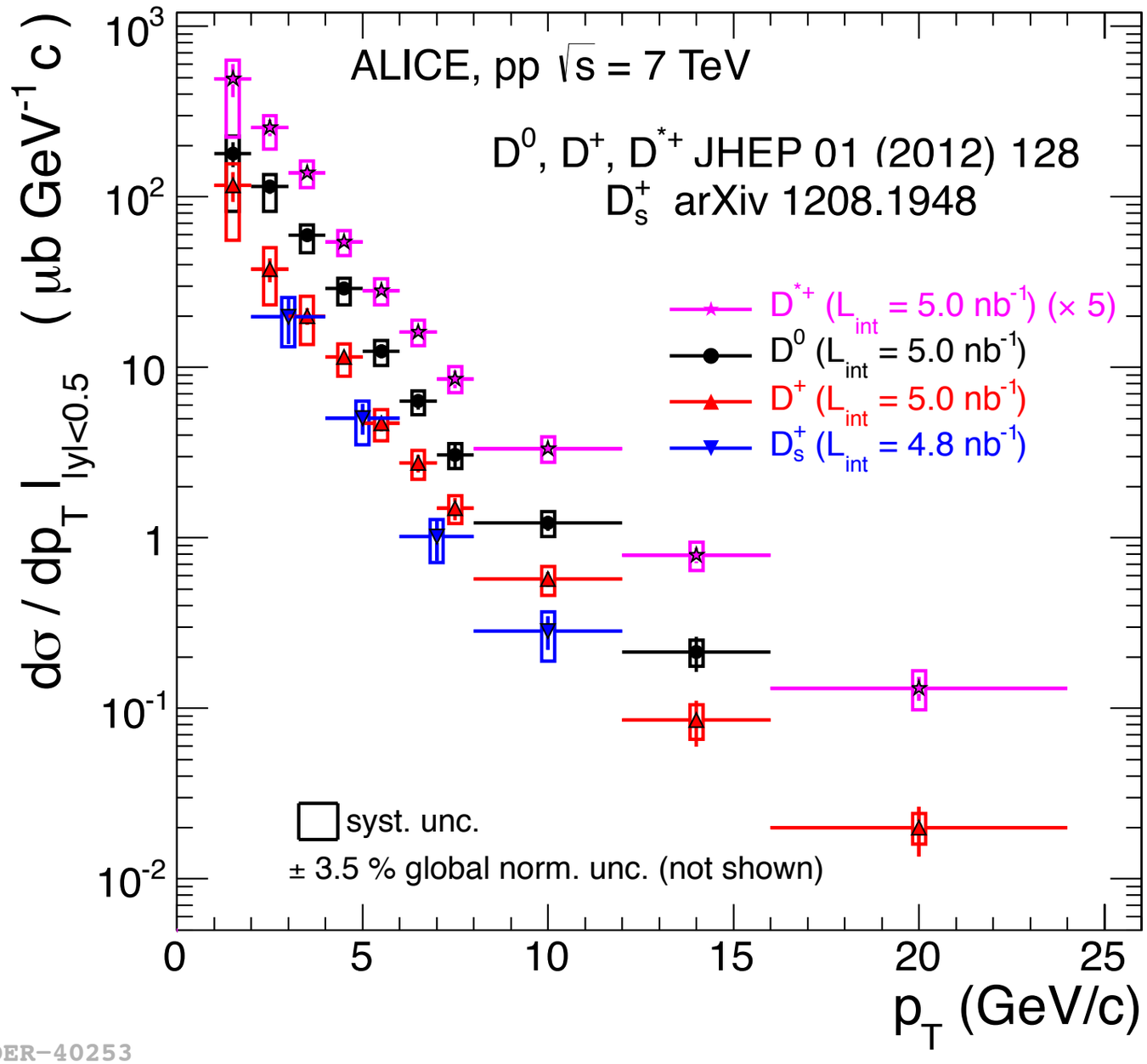

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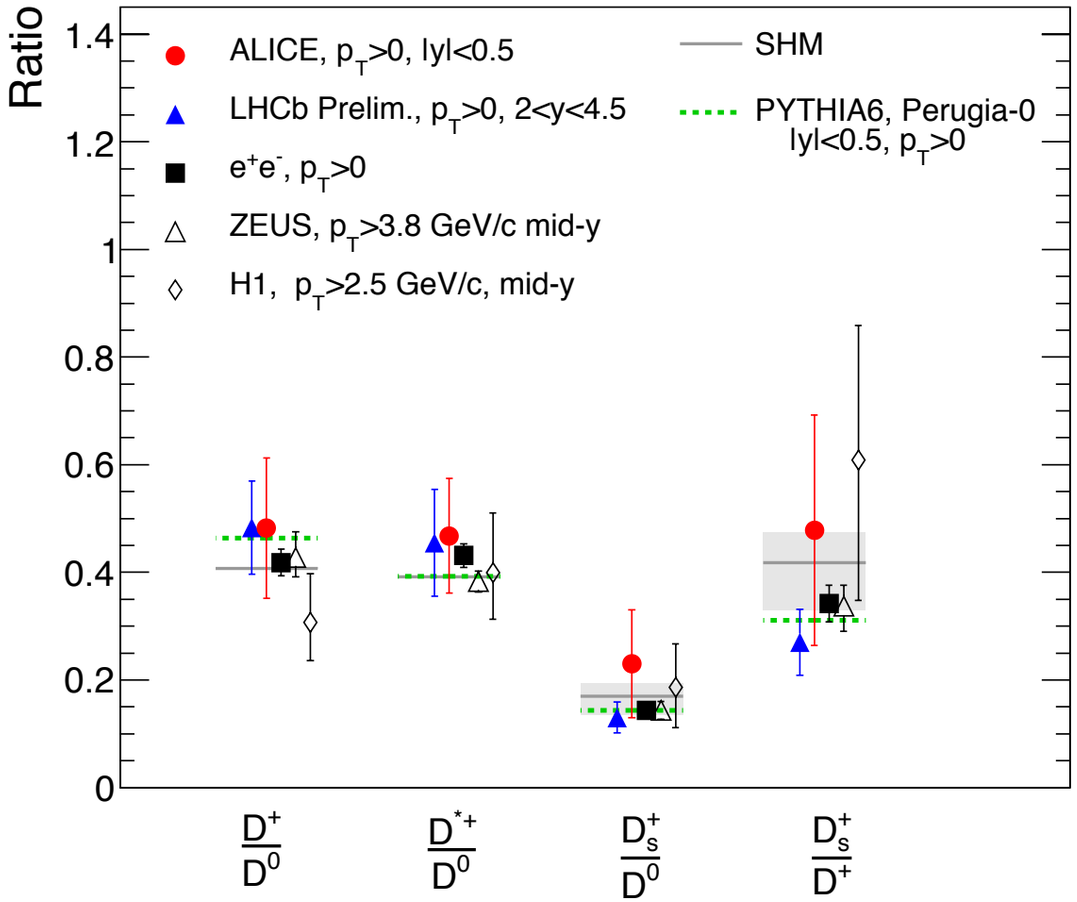
- D^0, D^+ and D^{*+} p_T-differential cross section also measured at the same energy

[1] B. A. Kniehl, G. Kramer, I. Schienbein and H. Spiesberger, arXiv:1202.0439 [hep-ph]

D meson ratios

Measured cross sections extrapolated to full p_T range with FONLL



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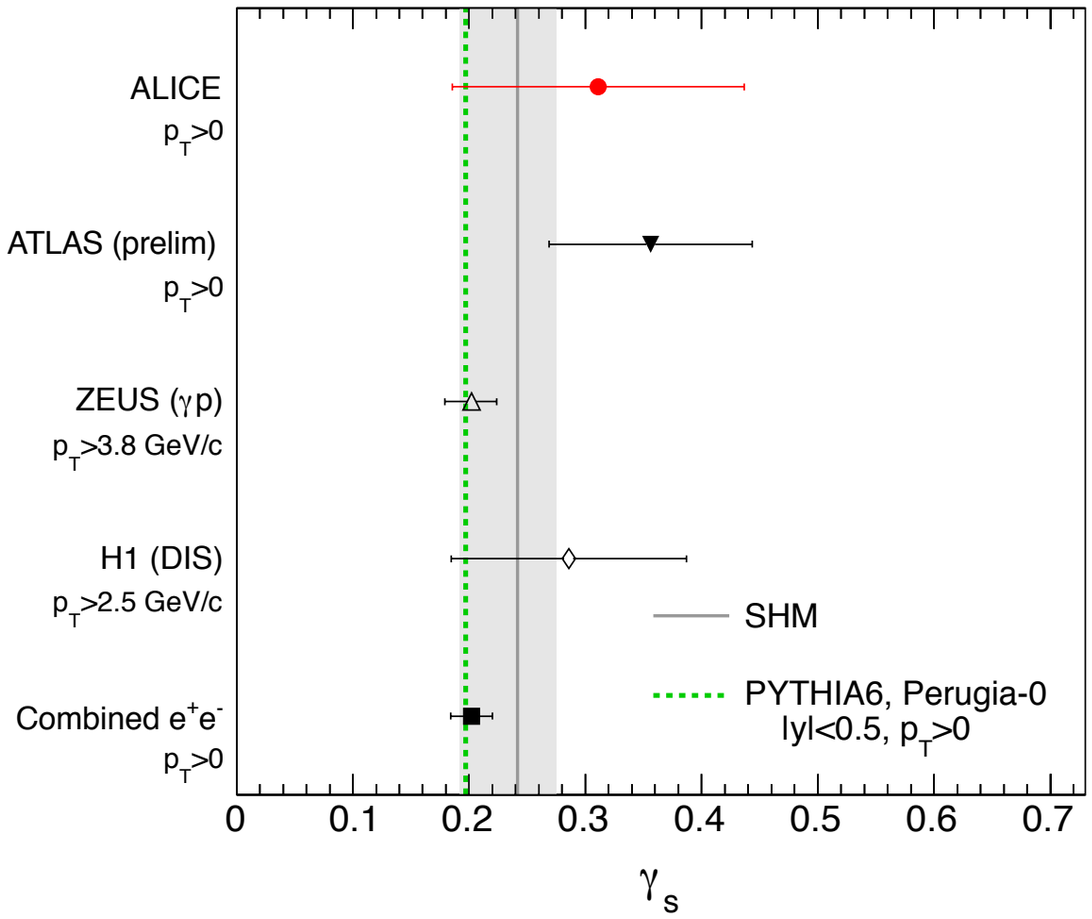

ALI-PUB-40219

- Ratios of D meson cross sections compatible within uncertainties with results at different energies and collision systems

- strangeness suppression factor γ_s

$$\gamma_s = \frac{2\,d\sigma(D_s^+)/dy}{d\sigma(D^0)/dy + d\sigma(D^+)/dy}$$

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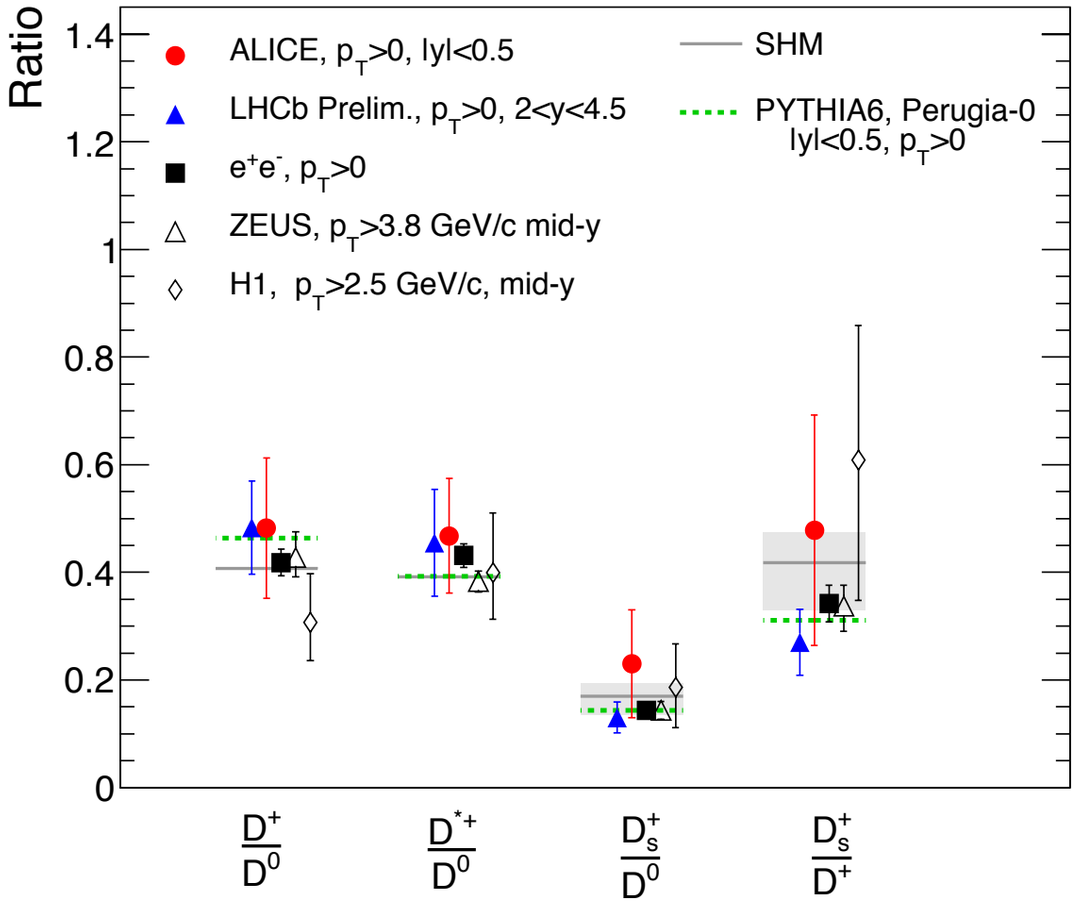

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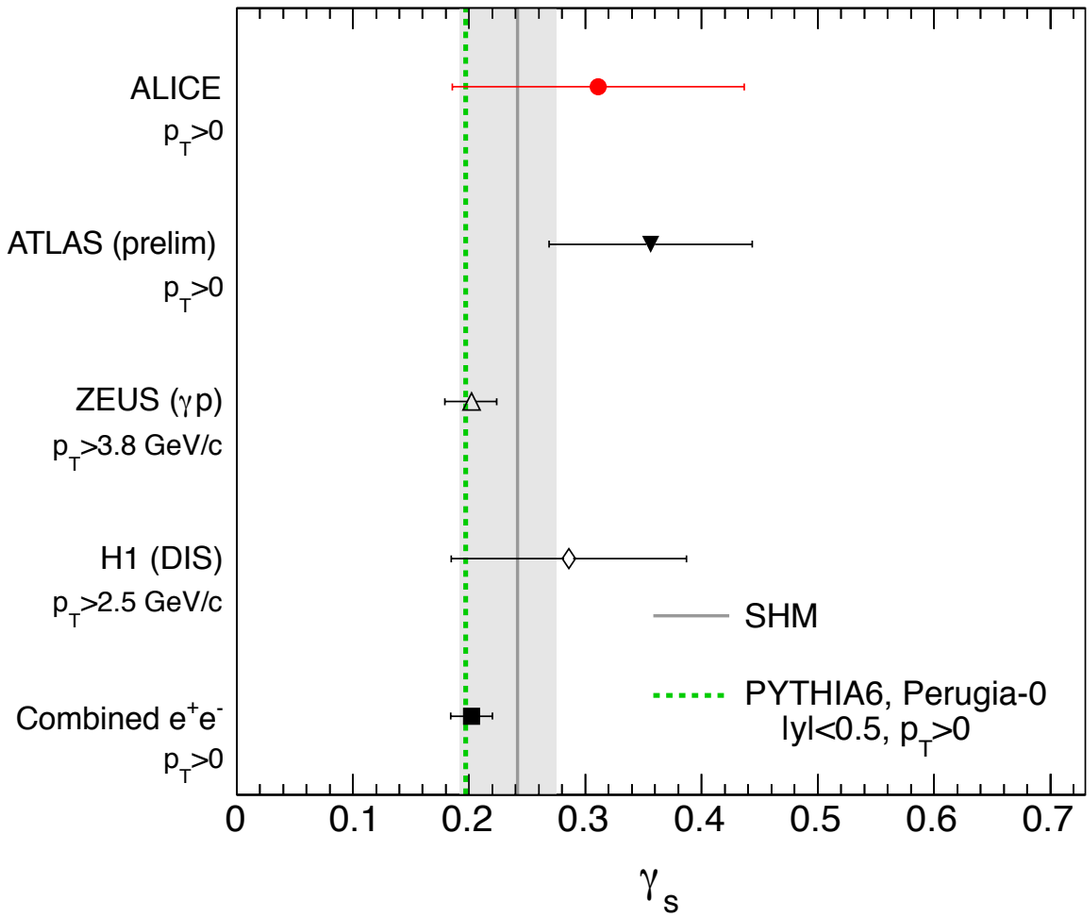

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Experimental results compared to predictions from PYTHIA [1] and Statistical Hadronization Model (SHM) [2]

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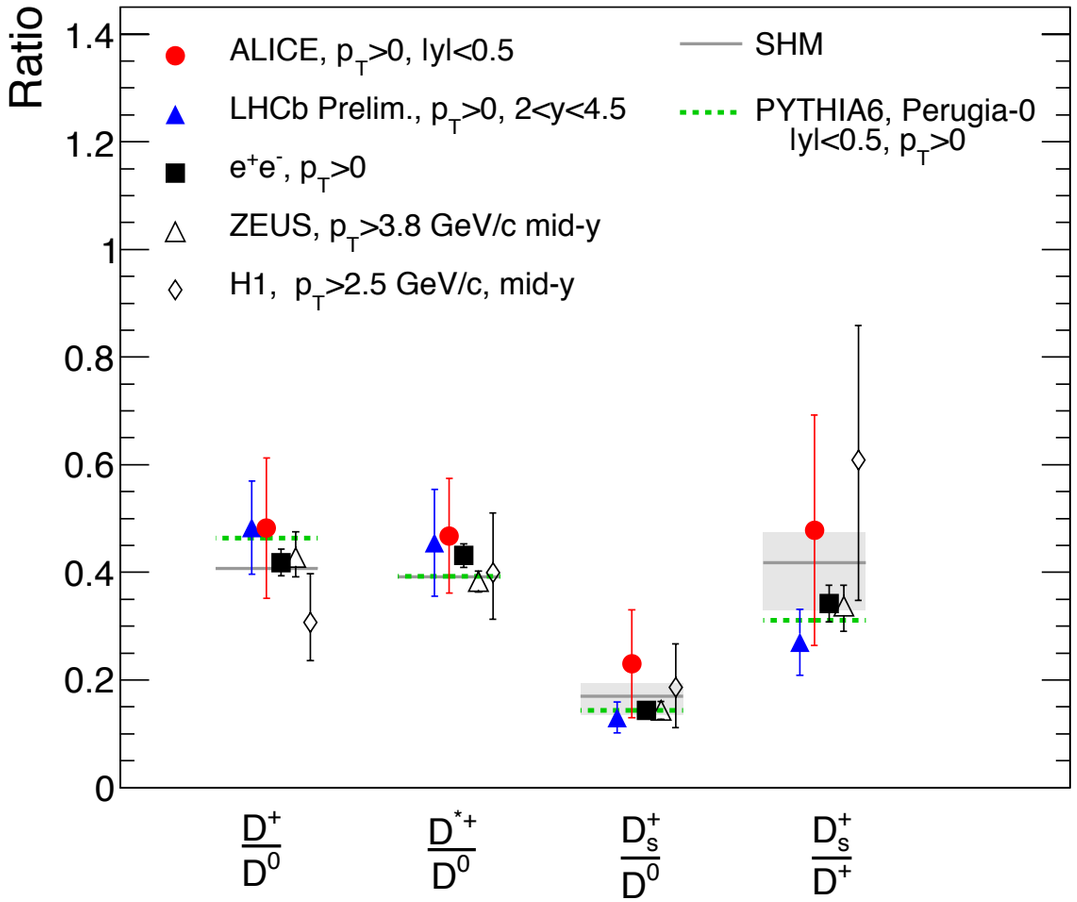

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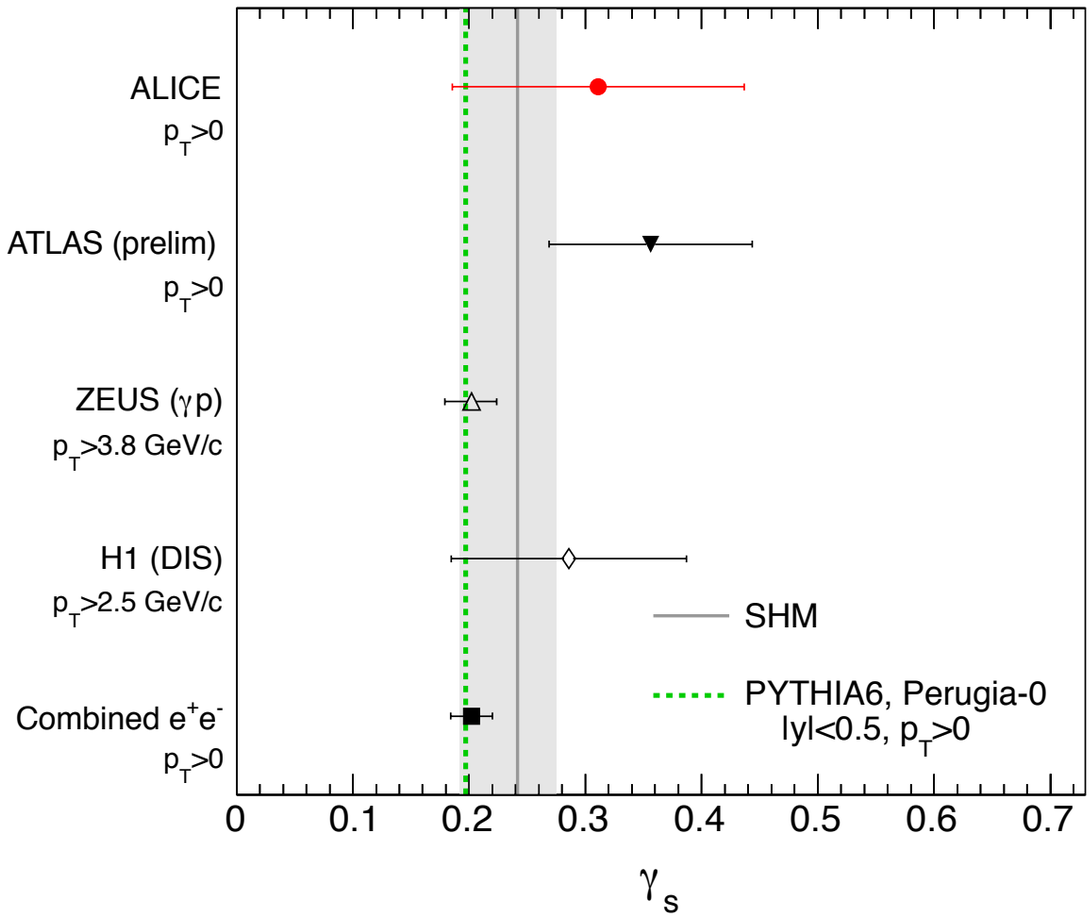

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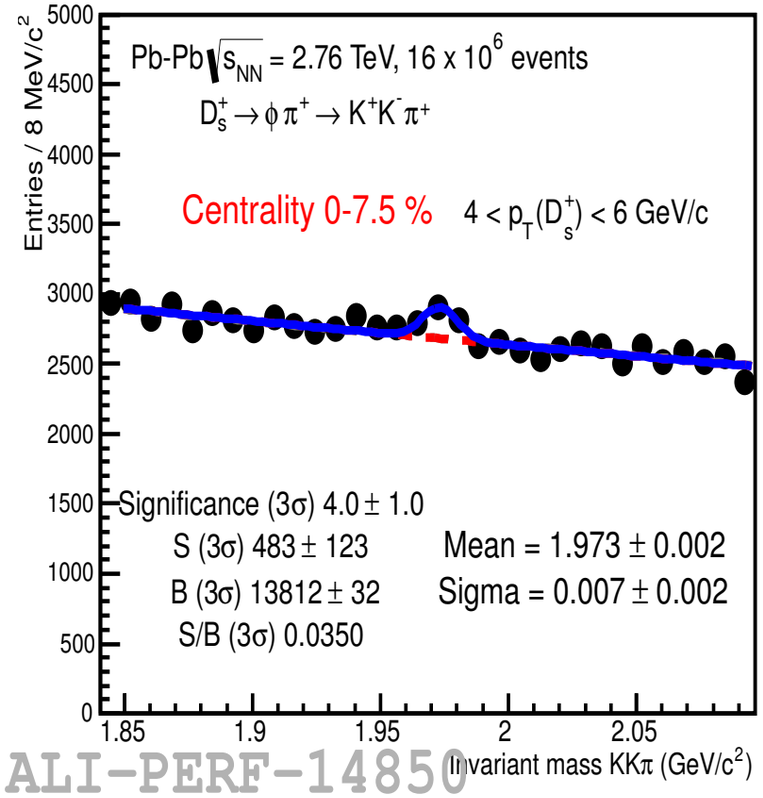
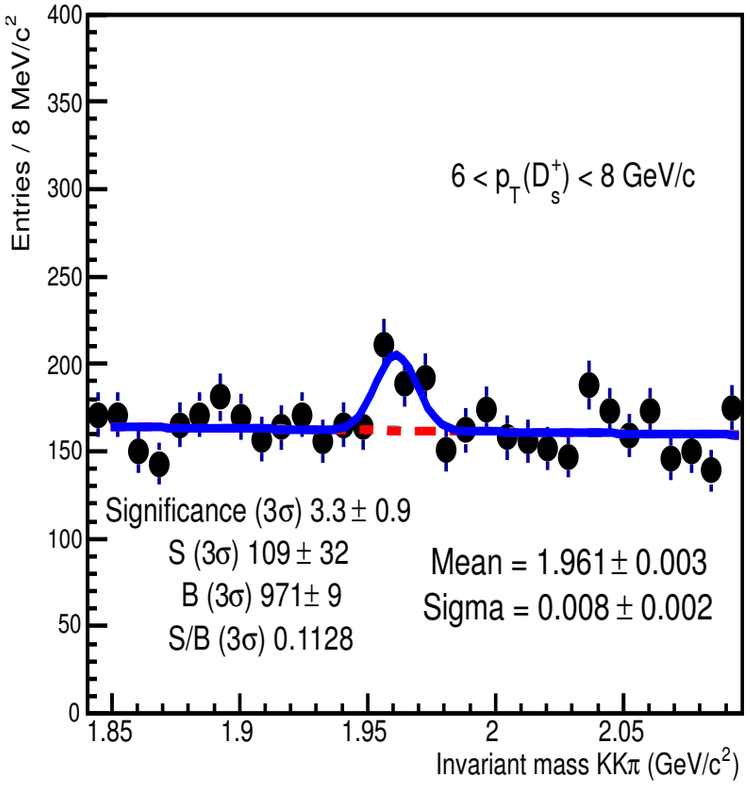
[1] T. Sjostrand, S. Mrenna, P. Skands, JHEP 05 (2006) 026
[2] A. Andronic, F. Beutler, P. Braun-Munzinger, K. Redlich and J. Stachel, Phys. Lett. B 678 (2009) 305

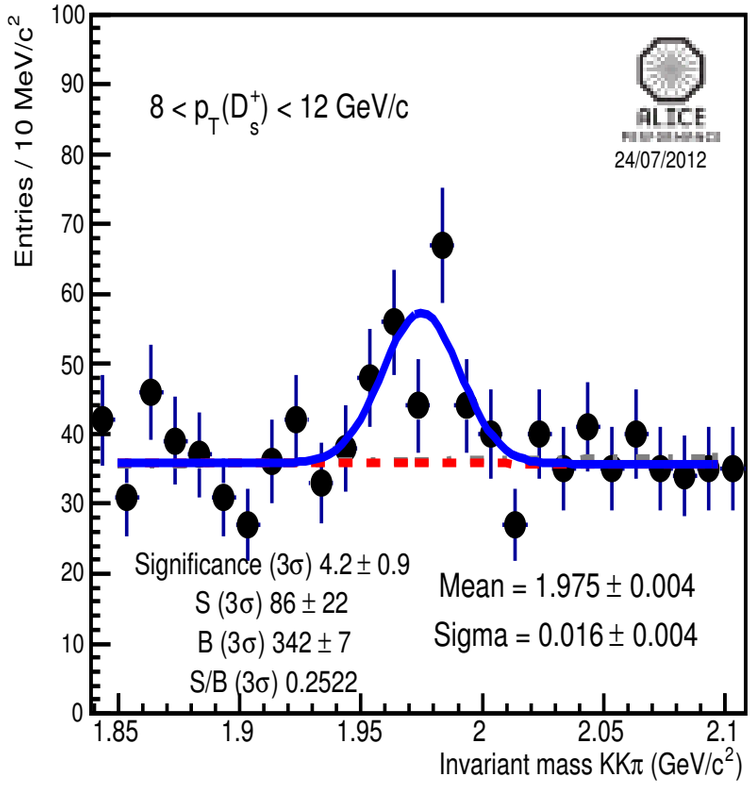
Pb-Pb analysis at 2.76 TeV

$D_s^{\pm}$ signal in central Pb-Pb collisions

- Analysis performed on the 2011 Pb-Pb sample at 2.76 TeV
- 1.6 x10^7 events in the 0-7.5 % centrality range corresponding to an integrated luminosity of 28 μb^{-1}







Invariant mass distributions of $D_s^{\pm}$ candidates in 3 p_T intervals from 4 to 12 GeV/c fitted with a Gaussian function (signal) + exponential (background)

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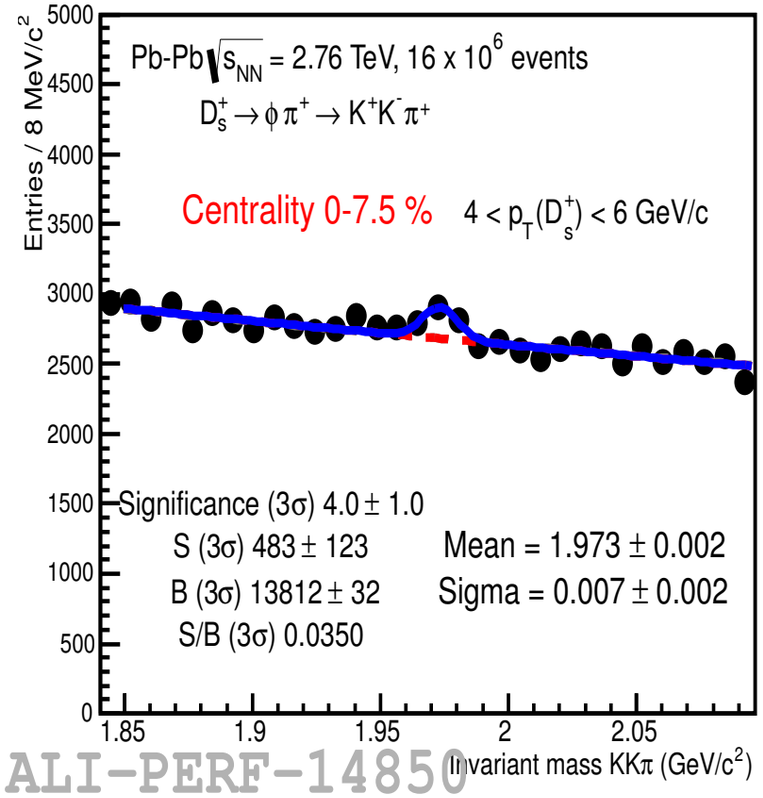

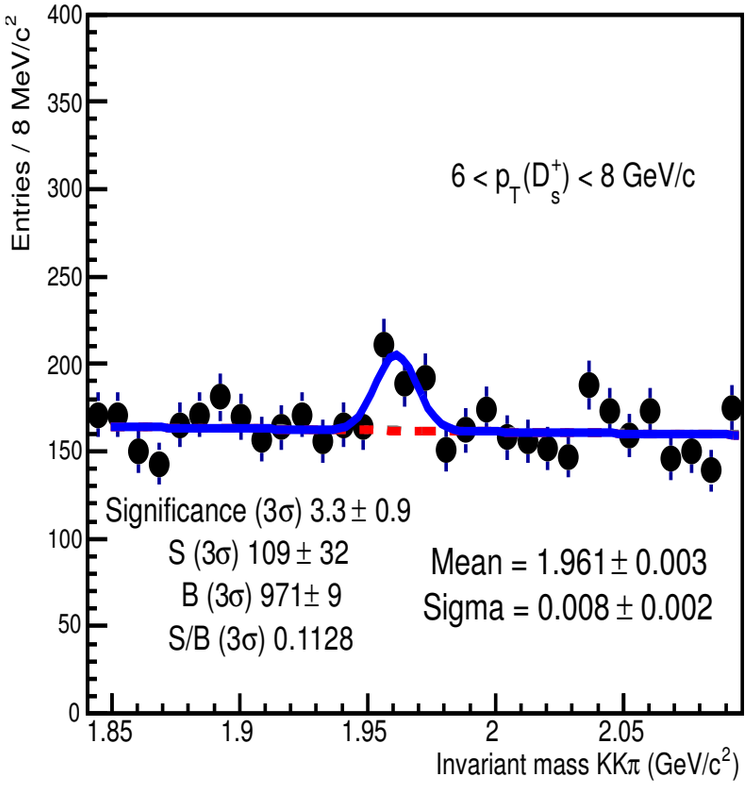

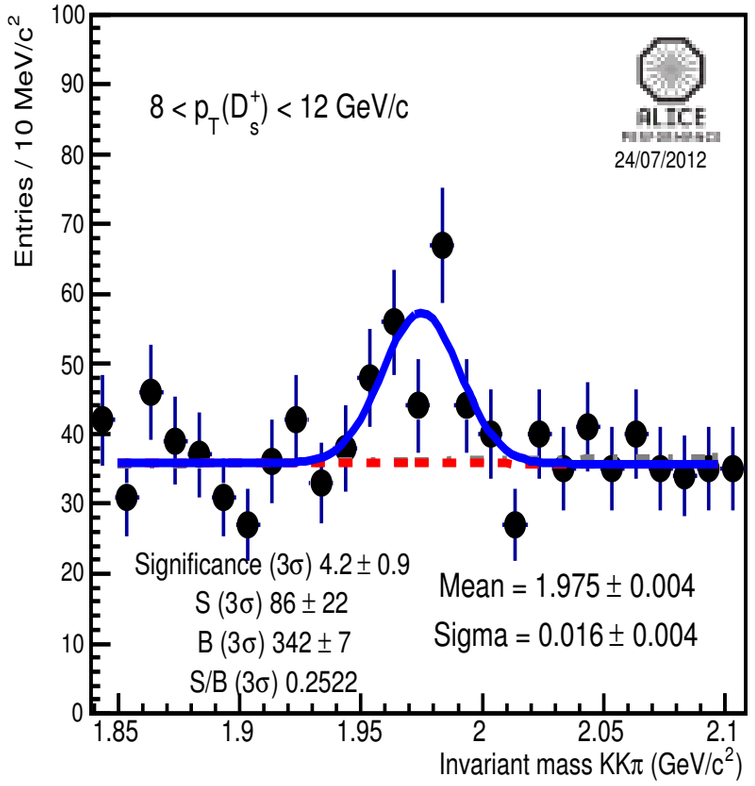

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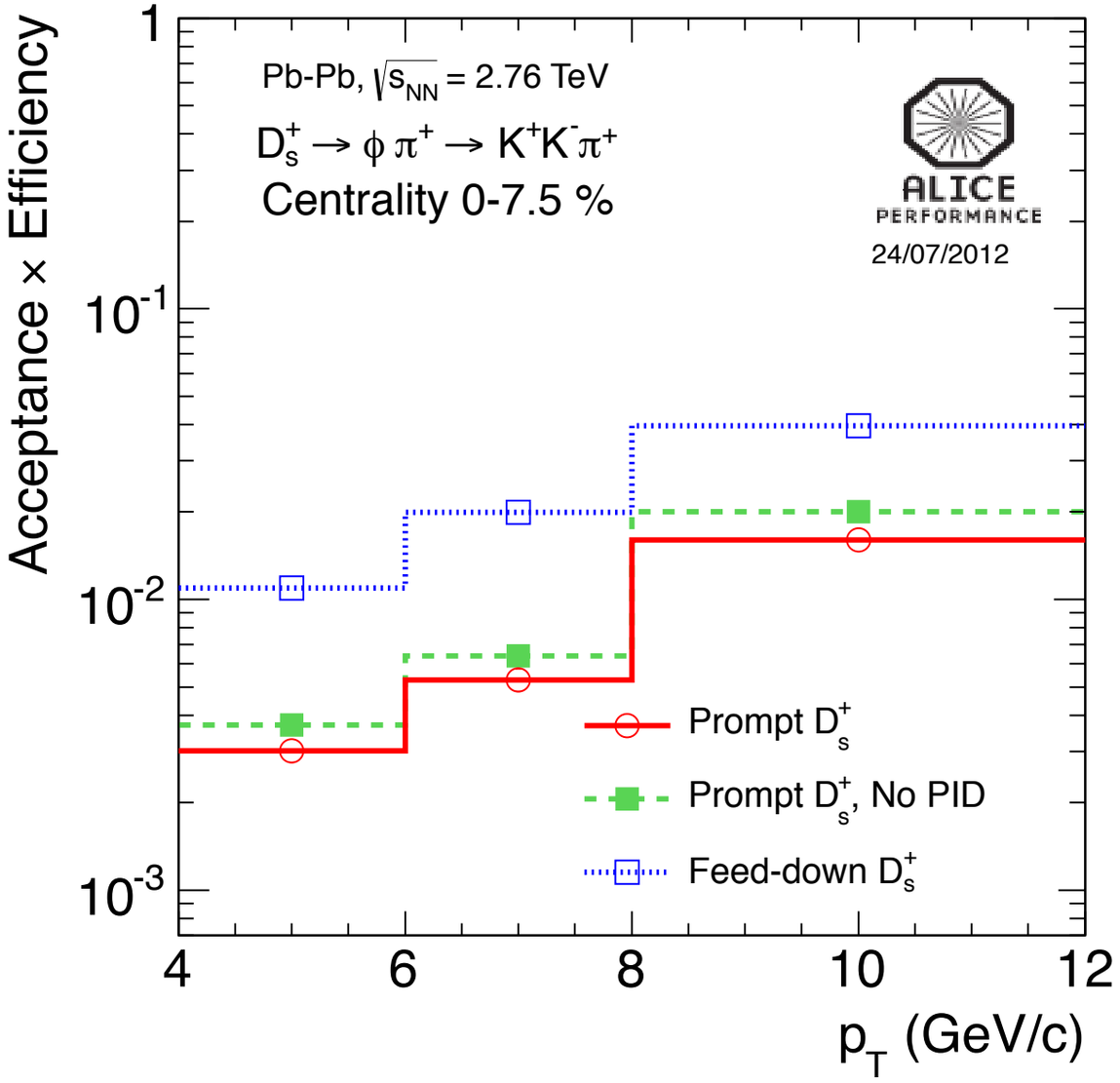
Same PID approach adopted for the pp analysis

Efficiency and B feed-down subtraction



- Acceptance x efficiency for prompt D_s^+ and D_s^+ from B feed-down

- Efficiency lower by a factor 5-10 with respect to pp due to the tighter selection applied

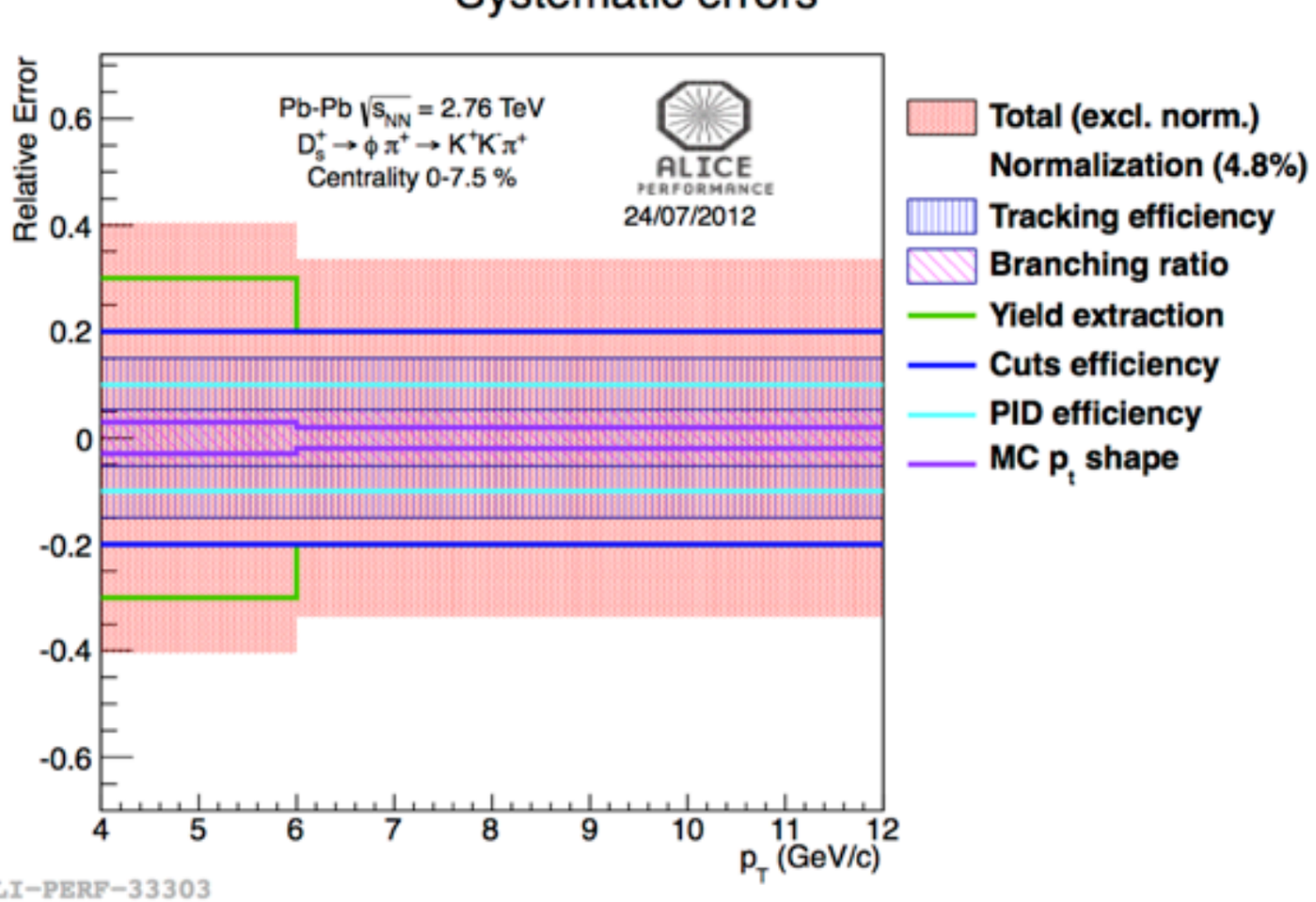
Feed down subtraction

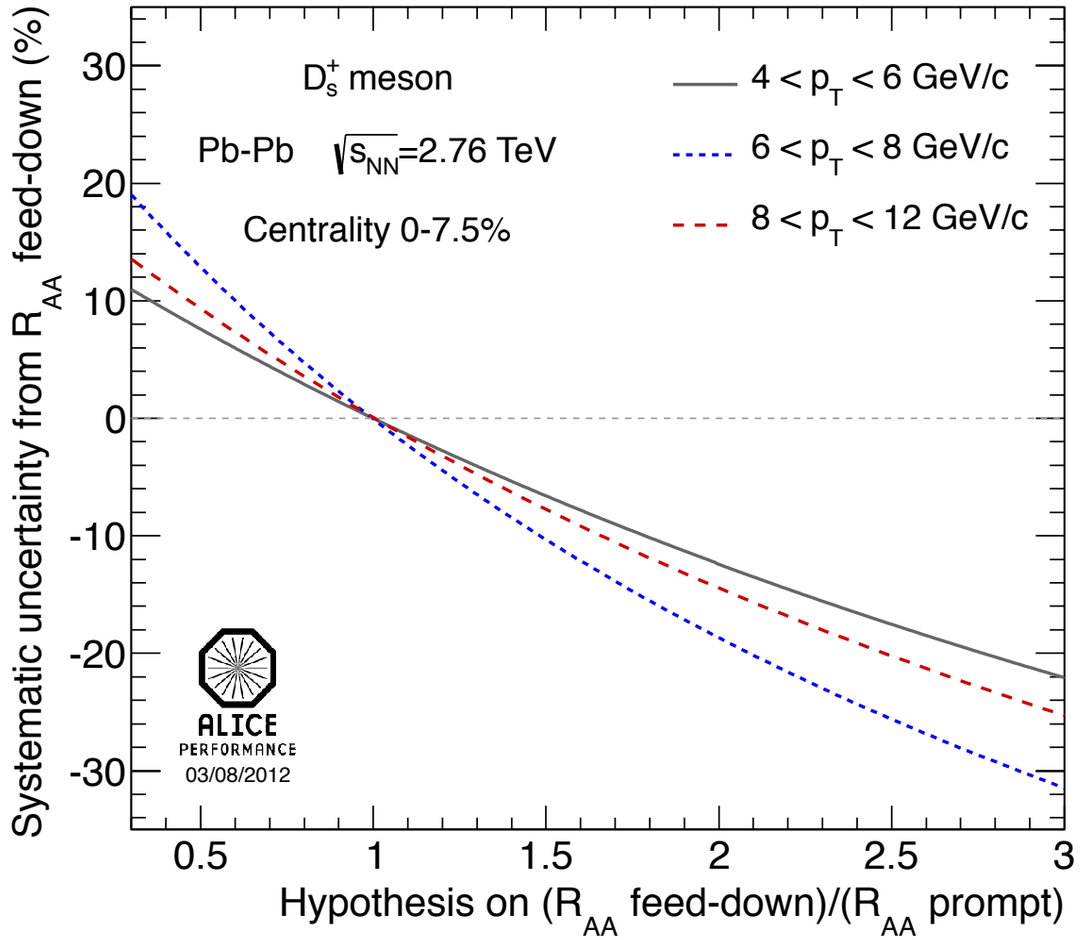
Similar approach as for the pp analysis
- FONLL prediction
- MC efficiencies

+ *Hypothesis on the R_{AA} of D_s^+ from B*:
  - central value assuming
    R_{AA} (D_s^+ from B)=R_{AA} (prompt D_s^+)

  - Systematic uncertainties from the variation of the hypothesis
    1/3 < R_{AA} (D from B)/R_{AA} (prompt D)<3

Systematic uncertainties for D^+_s in Pb-Pb

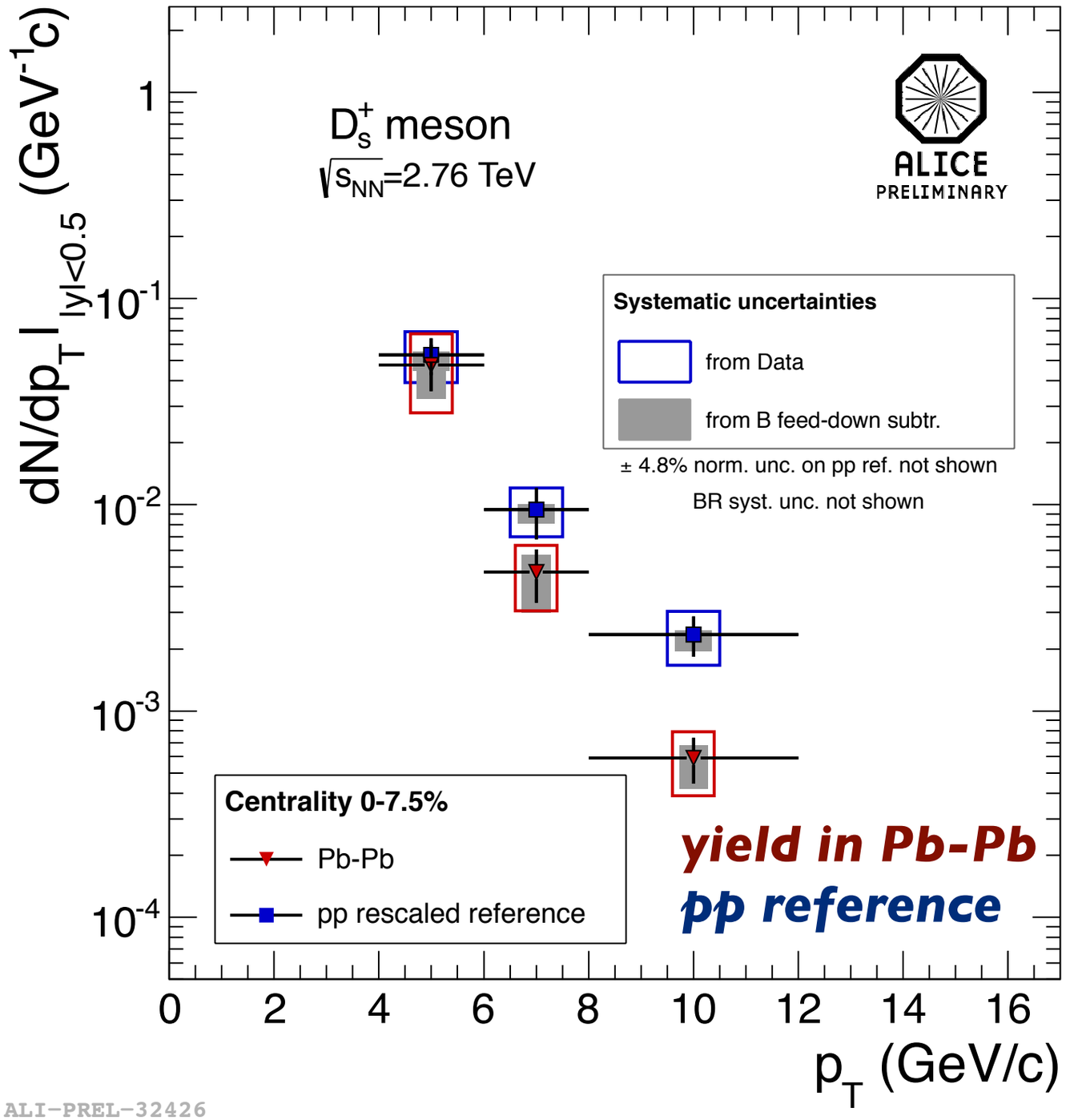




- Summary plot of systematic uncertainty contributions (feed-down from B excluded)

- Systematic uncertainties from B-feed down on R_{AA} as a function of the different hyphotesis on the R_{AA} feed-down in the range considered ($1/3 < R_{AA}$ (D from B)/R_{AA} (prompt D)<3)

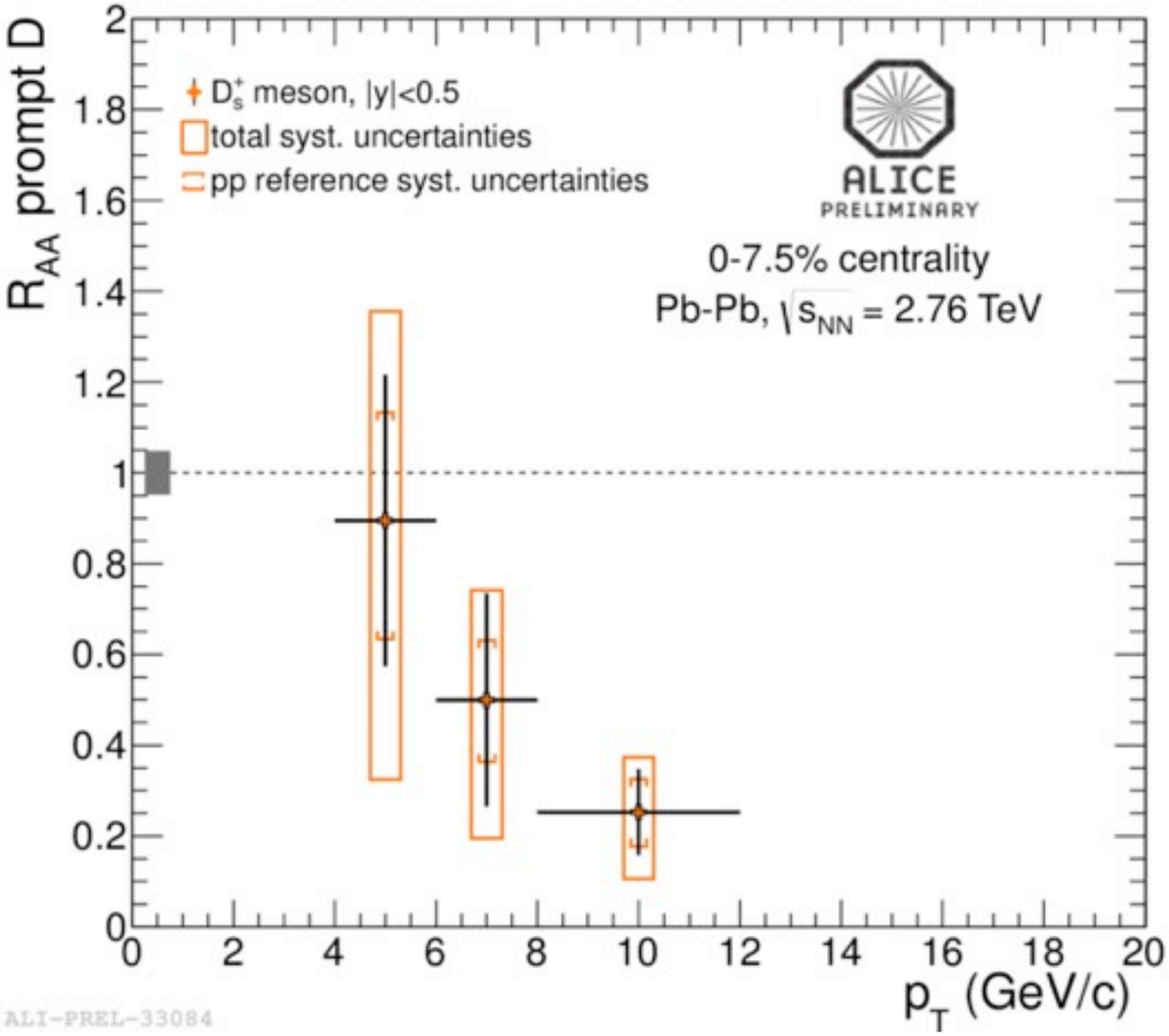
dN/dpT in Pb-Pb and pp



- dN/dpT in Pb-Pb collisions at 2.76 TeV compared to the pp reference
- pp reference obtained from the measured cross section at 7 TeV by:
  - scaling to 2.76 TeV using FONLL
  - multiplying by the nuclear overlap function $\langle T_{AA} \rangle$

First measurement of D^+_s R_{AA} in heavy-ion collisions

Pb-Pb collisions at 2.76 TeV in the centrality range 0-7.5 %



$$R_{\mathrm{AA}}(p_{\mathrm{T}}) = \frac{1}{< T_{\mathrm{AA}} >} \frac{\mathrm{d}N_{\mathrm{AA}}/\mathrm{d}p_{\mathrm{T}}}{\mathrm{d}\sigma_{\mathrm{pp}}/\mathrm{d}p_{\mathrm{T}}}$$

- Large statistical and systematic uncertainties with the present data sample

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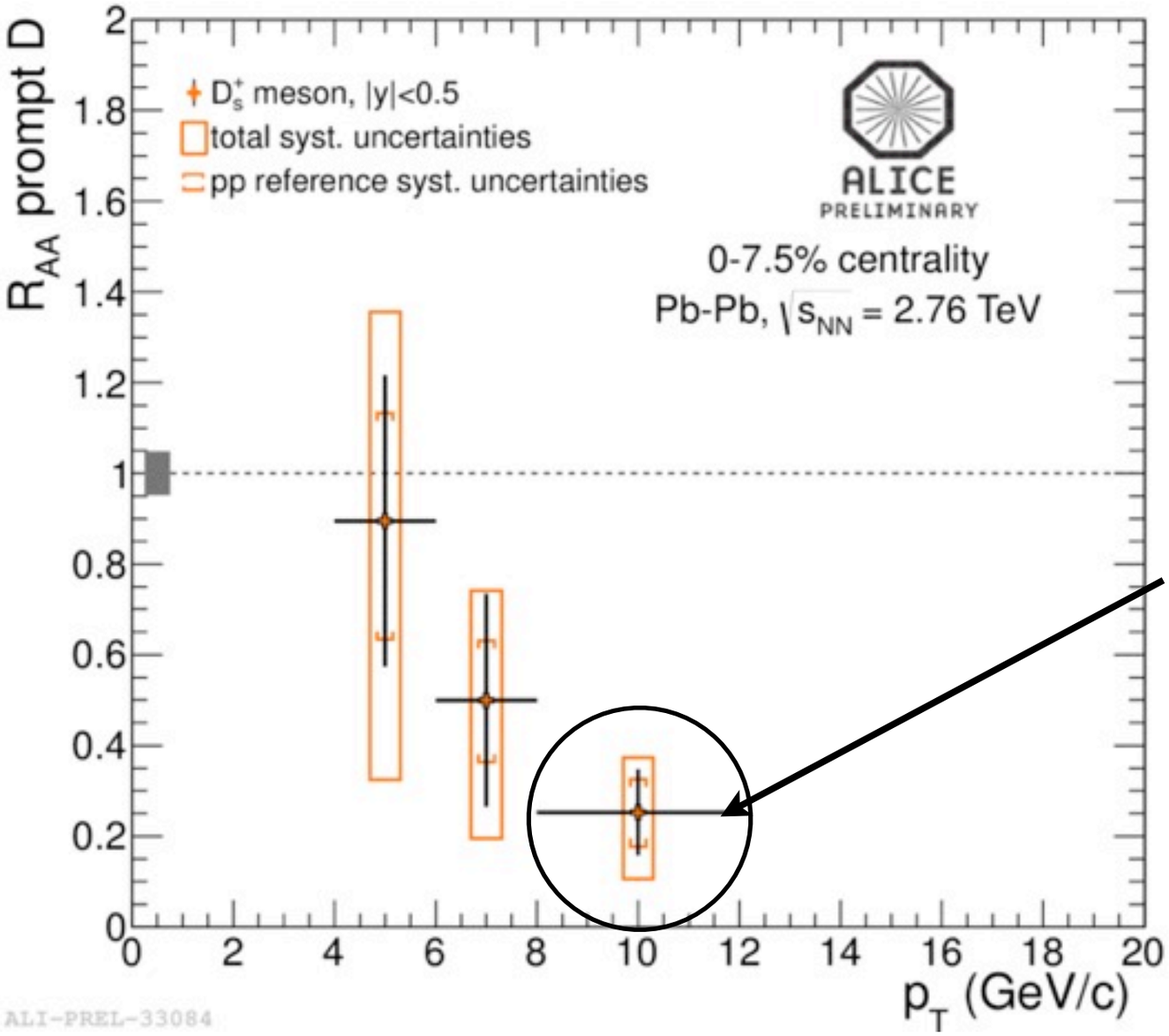

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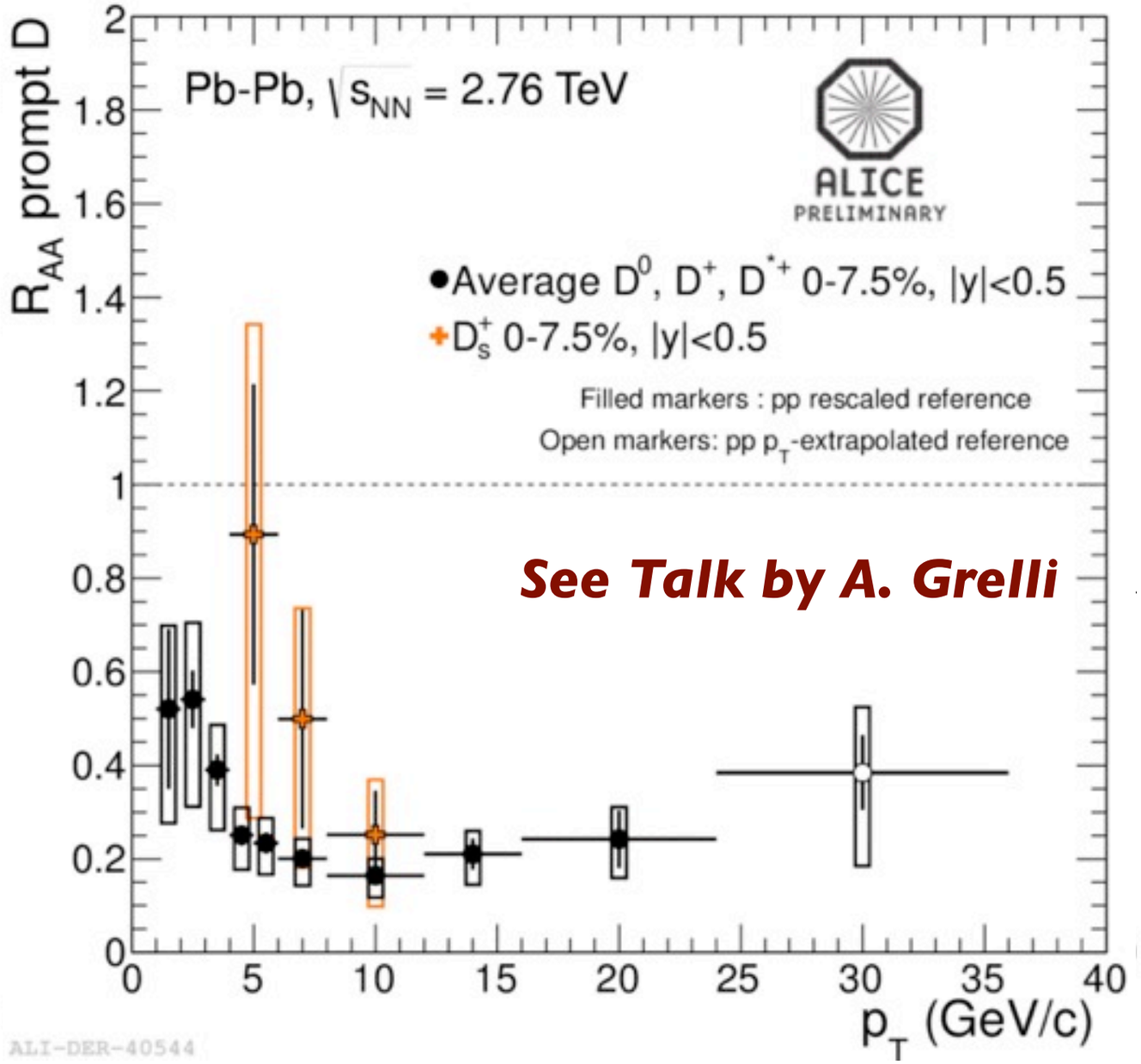

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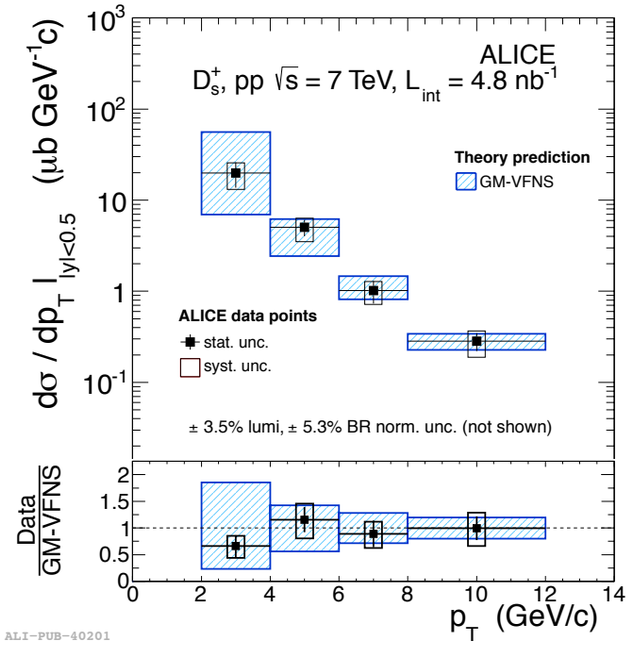
- R_{AA} seems to increase at low p_T
  - Current data do not allow a conclusive comparison to other D mesons within uncertainties

Summary and Conclusions

- D_s^+ meson reconstructed in pp and Pb-Pb
- pp results interesting for studying strange to non-strange D meson yield in new energy regime.



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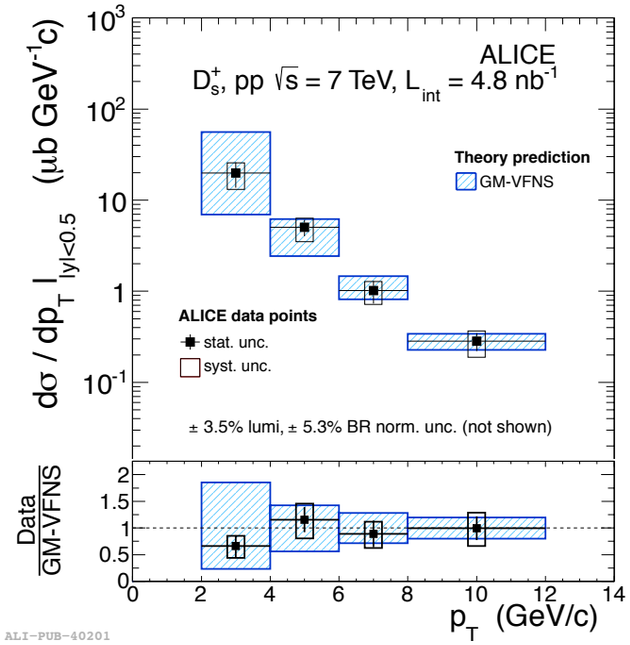
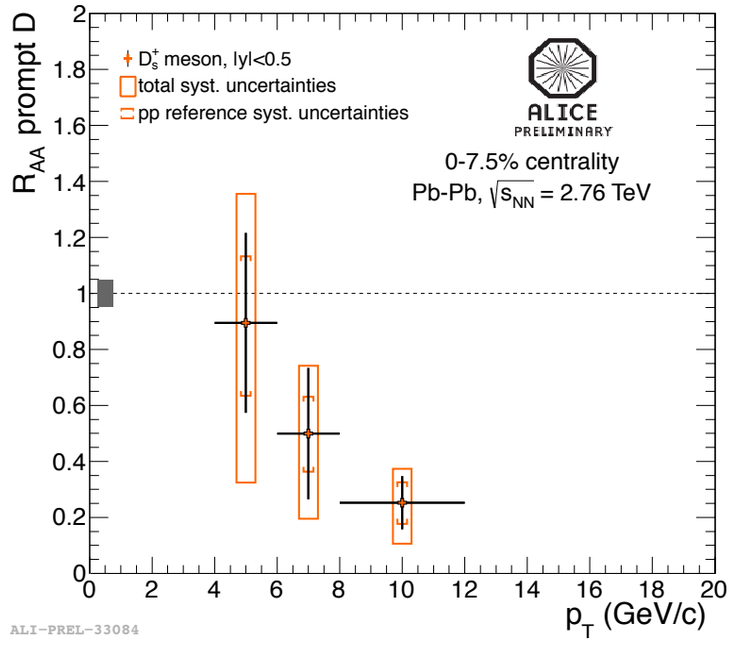
- pp results interesting for studying strange to non-strange D meson yield in new energy regime.
- **First measurement of D_s^+ yield in HI** :
  - D_s^+ dN/dp_T and D_s^+ R_{AA} measured in 3 intervals of p_T from 4 to 12 GeV/c
  - Strong suppression observed for p_T 8-12 GeV/c





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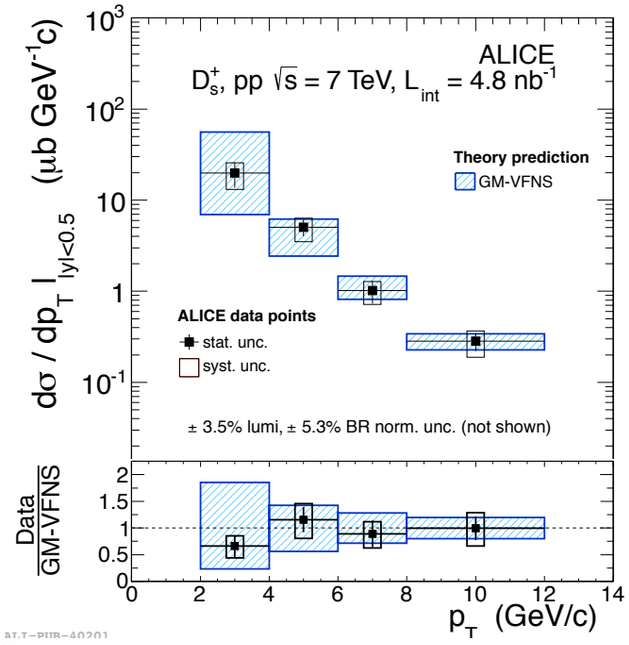

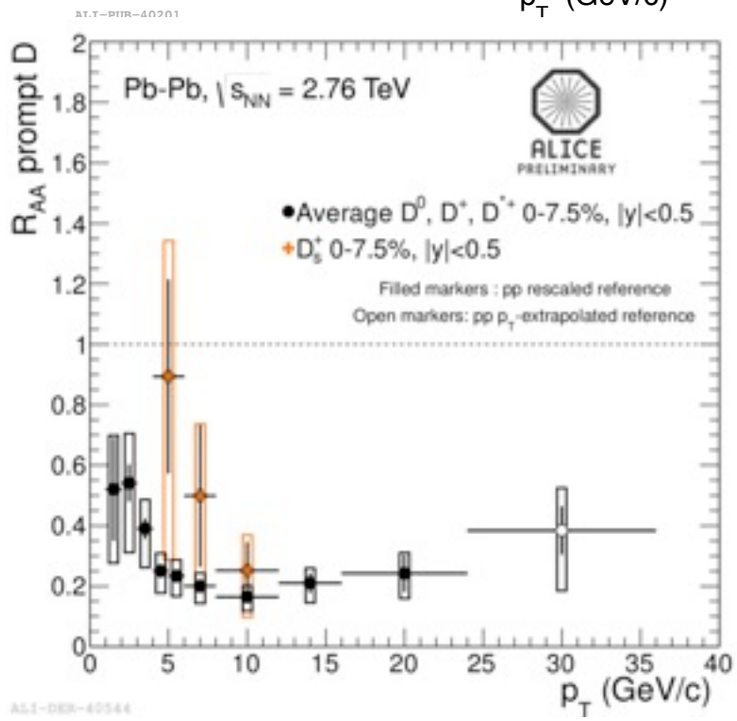

Intriguing results to be improved with future LHC pp and Pb-Pb runs

See also ALICE Upgrade talk by R. Lemmon

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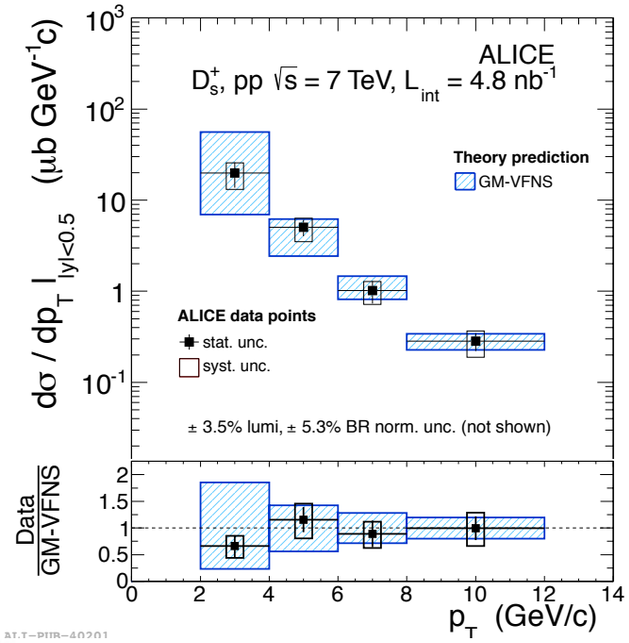

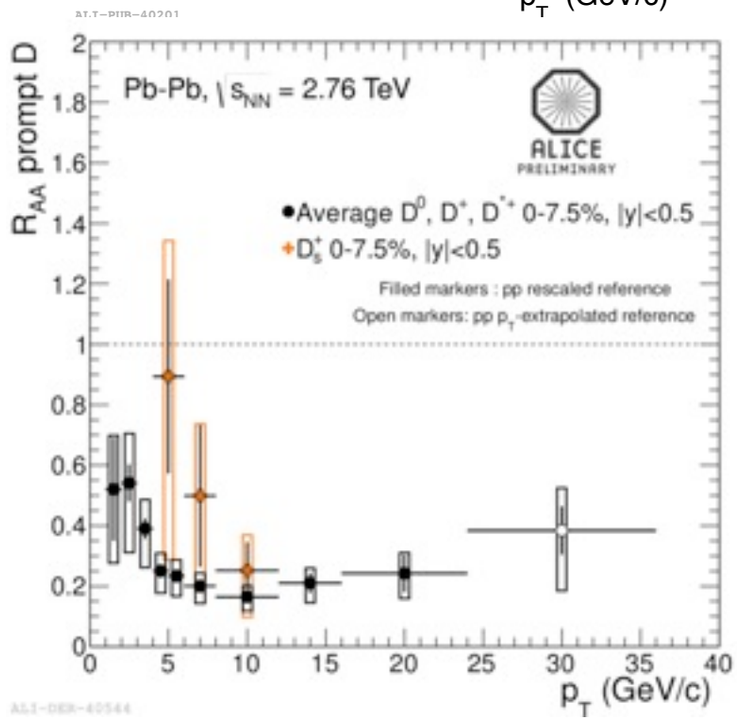

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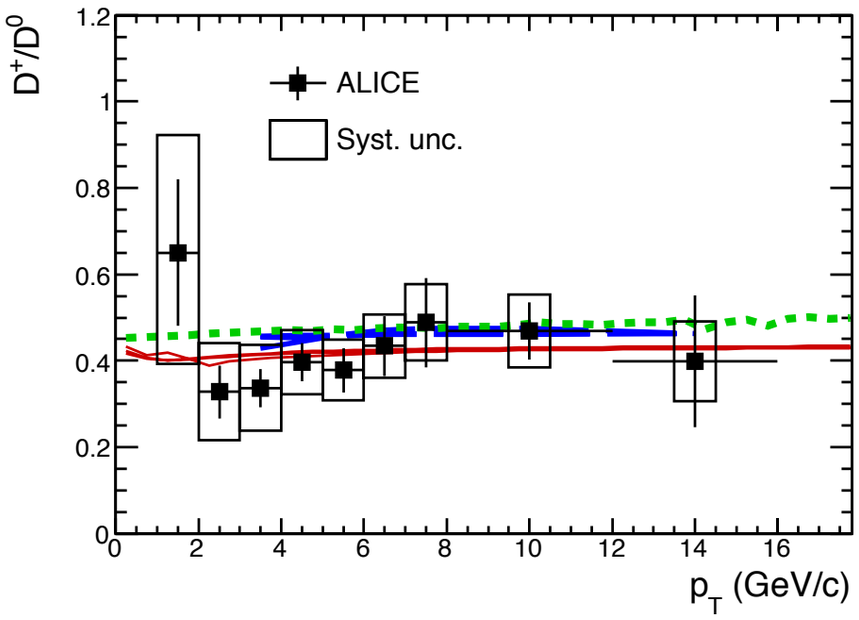
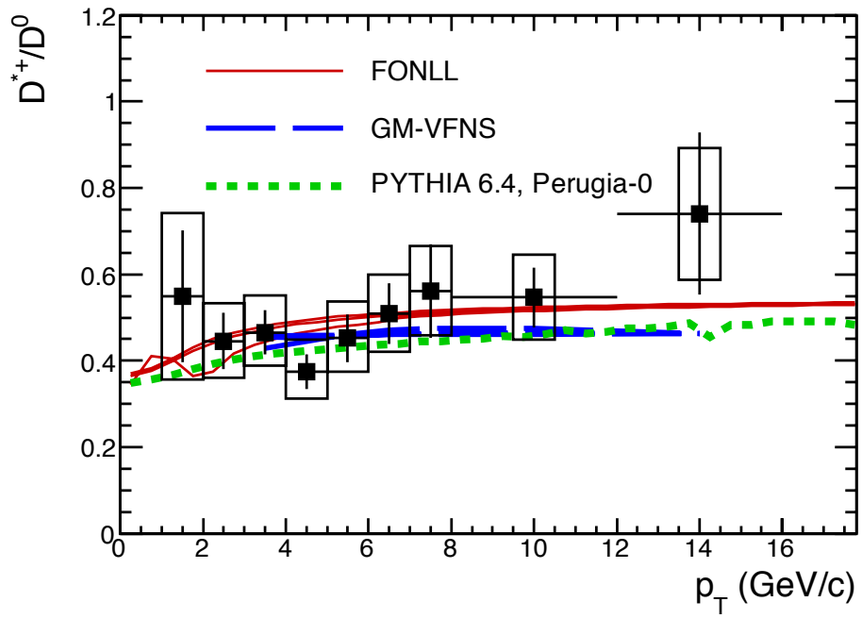
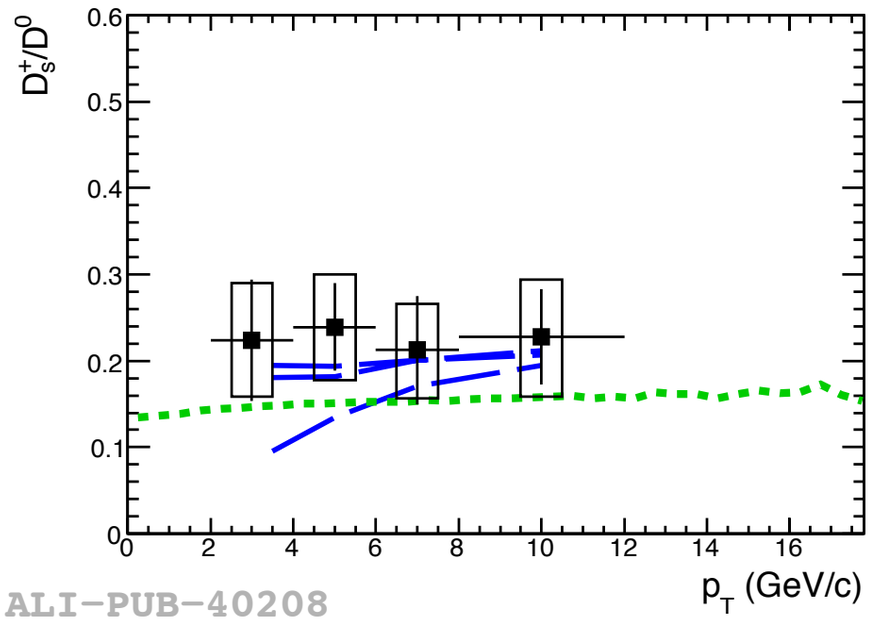
Thank you for your attention!

Backup Slides

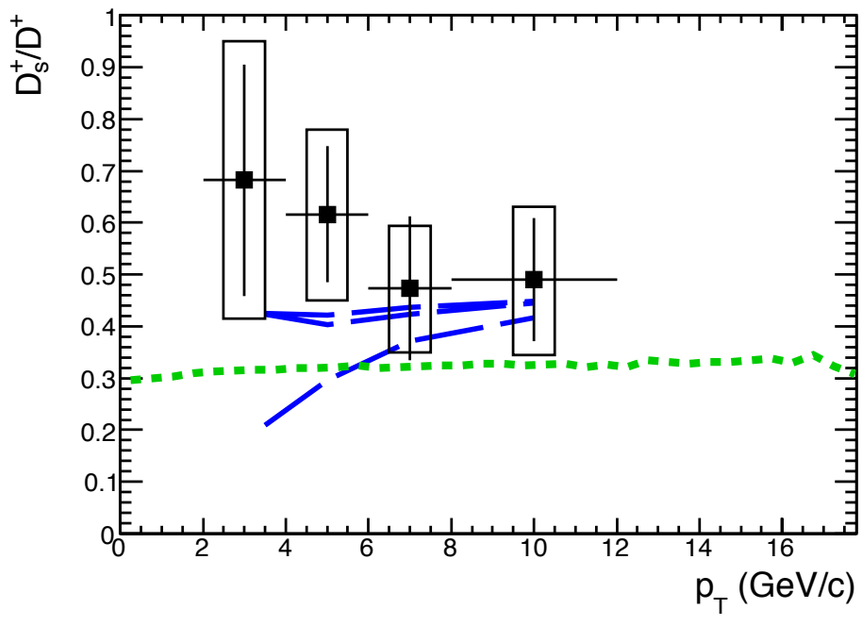
D meson ratios in pp at 7 TeV







ALI-PUB-40208



arXiv: 1208.1948

B feed down subtraction in Pb-Pb analyses

The same approach has been used for the four D mesons studied in ALICE D^+_s ,D^0,D^+ and D^{*+}

Fraction of prompt D_s^+ mesons f_{prompt} estimated as:

$$f_{\mathrm{prompt}} = 1 - \langle T_{\mathrm{AA}} \rangle \cdot \left(\frac{\mathrm{d}^2\sigma}{\mathrm{d}y\,\mathrm{d}p_{\mathrm{t}}} \right)^{\mathrm{FONLL}}_{\mathrm{feed-down}} \cdot R_{\mathrm{AA}}^{\mathrm{feed-down}} \cdot \frac{(\mathrm{Acc} \times \varepsilon)_{\mathrm{feed-down}} \cdot \Delta y \Delta p_{\mathrm{t}} \cdot \mathrm{BR} \cdot N_{\mathrm{evt}}}{N^{\mathrm{D}^{\pm}\ \mathrm{raw}}/2}$$

average nuclear overlap function in the centrality class considered

beauty production cross section from ***FONLL***[1] calculations

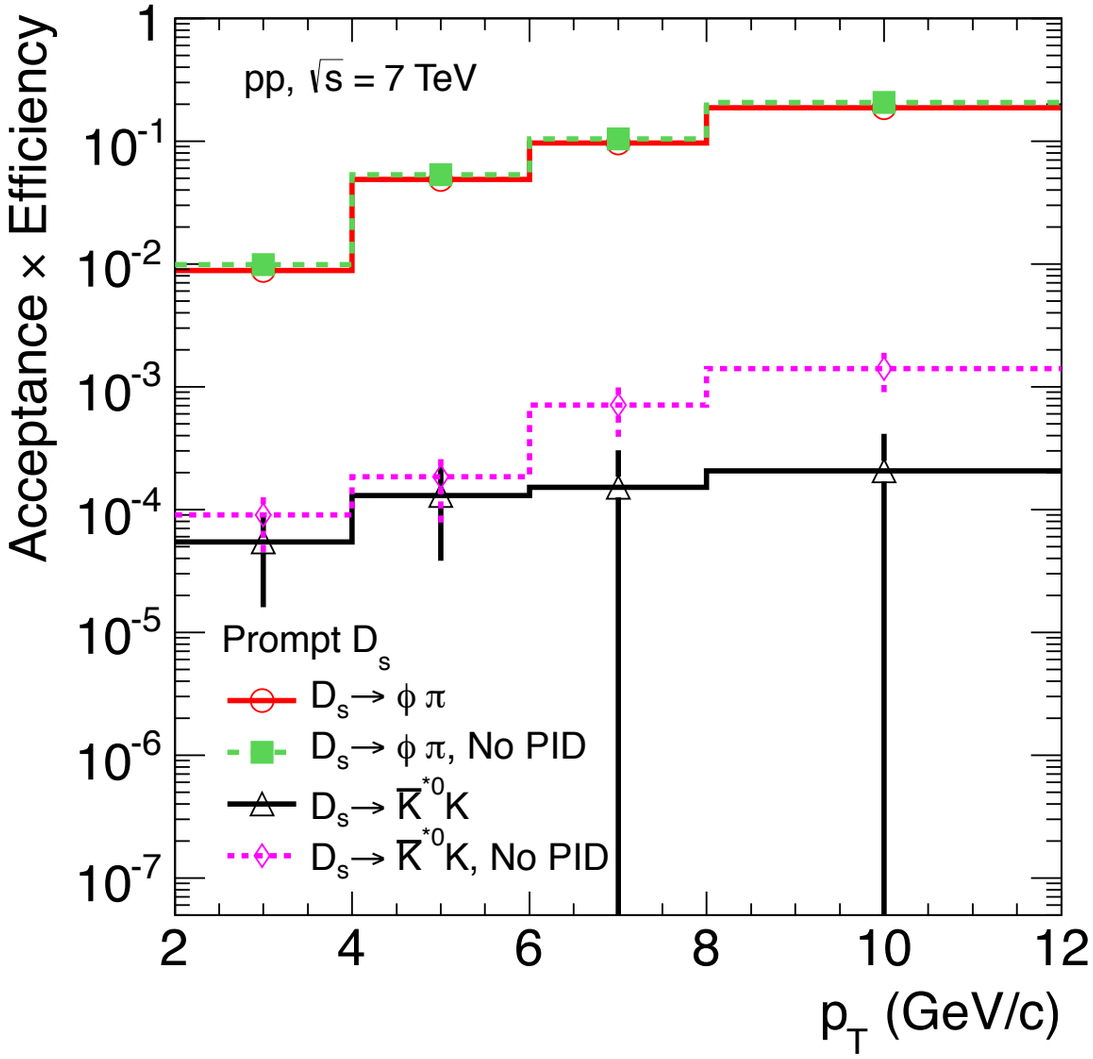
Hypothesis on the R_{AA} of D_s^+ from B:
central value assuming
R_{AA} (D_s^+ from B)=R_{AA} (prompt D_s^+)

Alternative approach used to estimated the systematic uncertainty from B feed-down

$$f_{\mathrm{prompt}} = \left(1 + \frac{(\mathrm{Acc} \times \varepsilon)_{\mathrm{feed-down}}}{(\mathrm{Acc} \times \varepsilon)_{\mathrm{prompt}}} \cdot \frac{\left(\frac{\mathrm{d}^2\sigma}{\mathrm{d}y\,\mathrm{d}p_{\mathrm{t}}} \right)^{\mathrm{FONLL}}_{\mathrm{feed-down}}}{\left(\frac{\mathrm{d}^2\sigma}{\mathrm{d}y\,\mathrm{d}p_{\mathrm{t}}} \right)^{\mathrm{FONLL}}_{\mathrm{prompt}}} \cdot \frac{R_{\mathrm{AA}}^{\mathrm{feed-down}}}{R_{\mathrm{AA}}^{\mathrm{prompt}}} \right)^{-1}$$

[1] M. Cacciari, M. Greco, P. Nason, JHEP 9805 (1998) 007

Resonant decay channels



ALI-PUB-40188

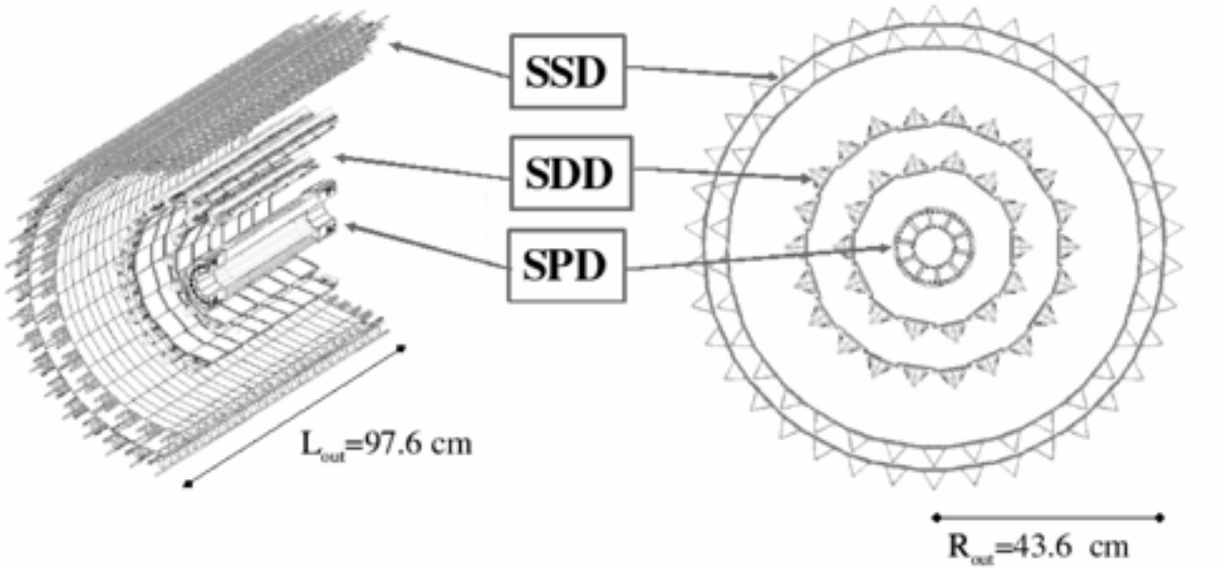
The D_s^+ decays to the same **KKπ** final state via various resonant channels. The two with larger BRs are:

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

The possible contribution of the K^{*0} channel has been studied by evaluating the acceptance x efficiency factor for the two channels after topological and PID selections

The K^{*0} channel is strongly suppressed by the requirement on the φ mass and by the PID selection

Inner Tracking System

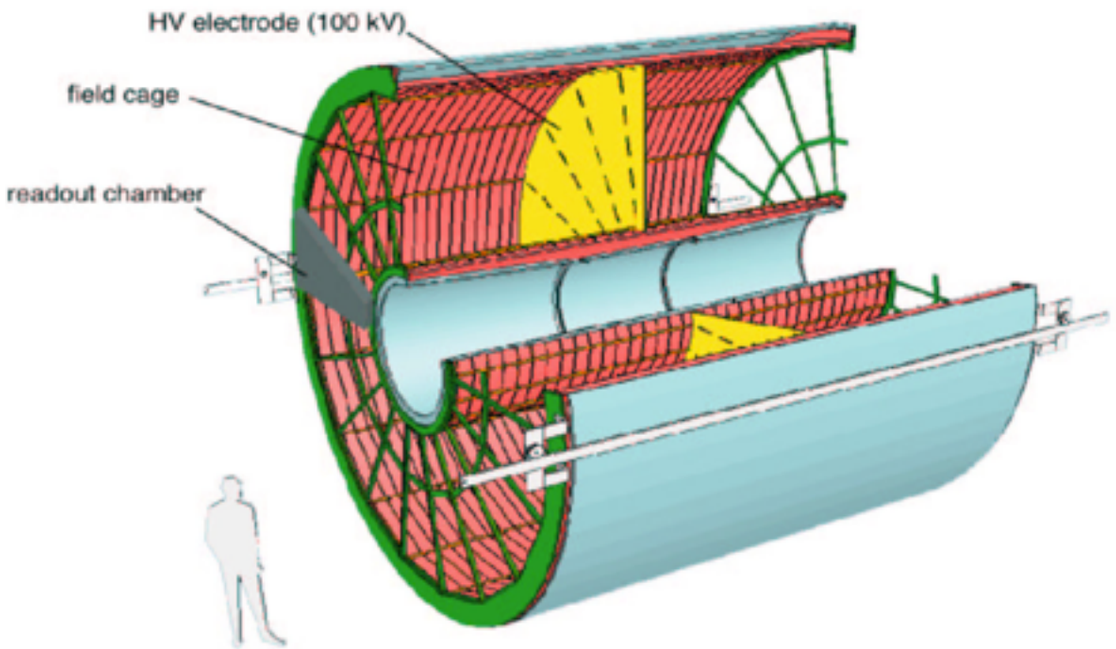


- 6 cilindrical layers of silicon detectors with radii from 3.9 to 43.0 cm
- two innermost layer are equipped with Silicon Pixel Detectors with radii 3.9 and 7.6 cm
- ITS has coverage $|\eta| < 0.9$ (1.98 for SPD)

Main goals:

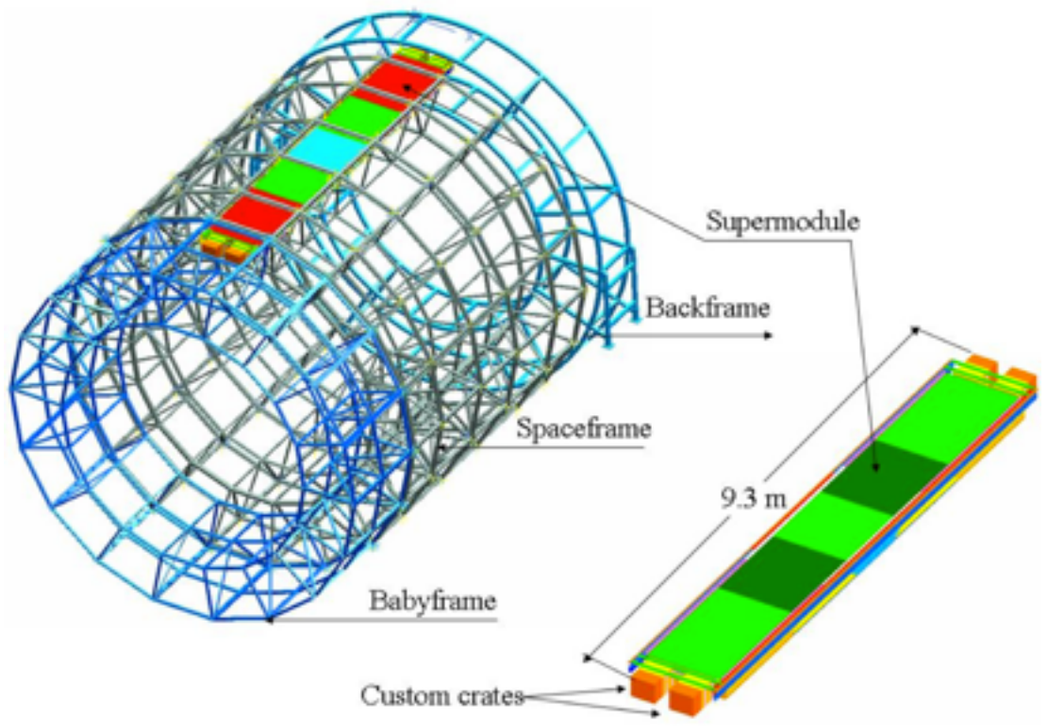
- primary and secondary vertex reconstruction with high resolution required for the detection of open charm and beauty
- measurement with resolution better than 100 μm of the impact parameter of the tracks
- reconstruction and identification of the low momentum tracks with p_T < 200 MeV/c

Time Projection Chamber and Time of Flight Detector



TPC

- 510 cm long cylindrical chamber filled with 90 m^3 of drift volume filled with a gas mixture
- TPC has coverage $|\eta| < 0.9$ for tracks with full radial length
- *main tracking detector of the ALICE central barrel (from 0.2 to 100 GeV/c)*
- *particle identification via specific energy deposit*



TOF

- large array area of MRPC that covers the full azimuthal angle and $|\eta| < 0.9$ in pseudorapidity at radii from 370-399 cm

- *particle identification in the intermediate momentum range via time of flight measurement*

  $p_T < 2.5$ GeV/c for pions and kaons
  $p_T < 4$ GeV/c for protons.