# Heavy flavor production @ ALICE

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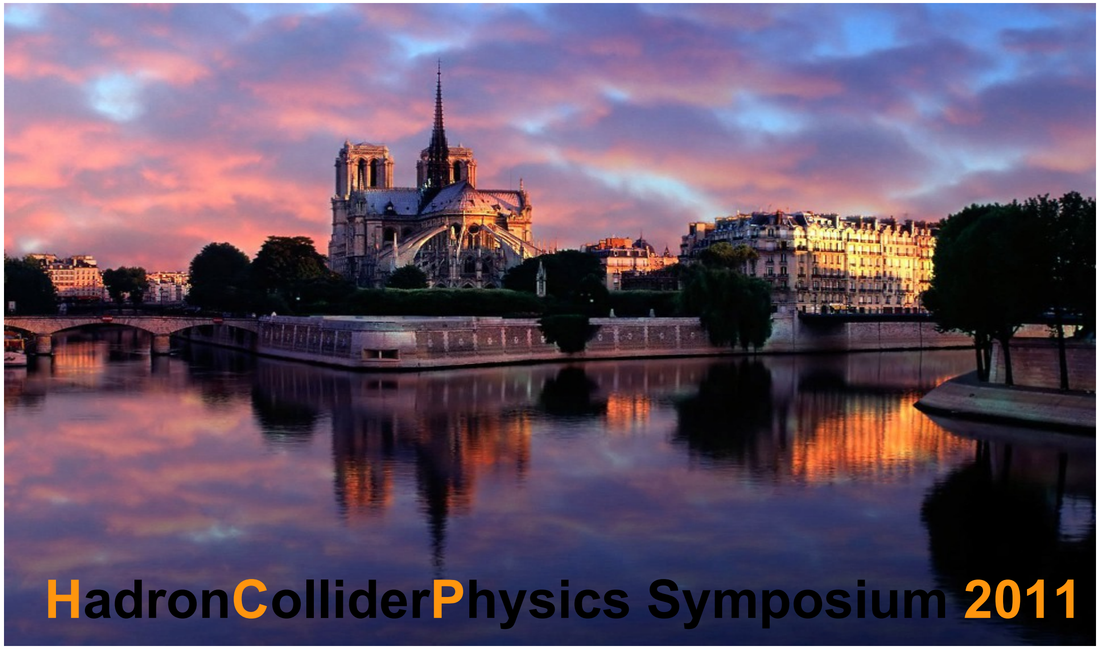
for the ALICE collaboration

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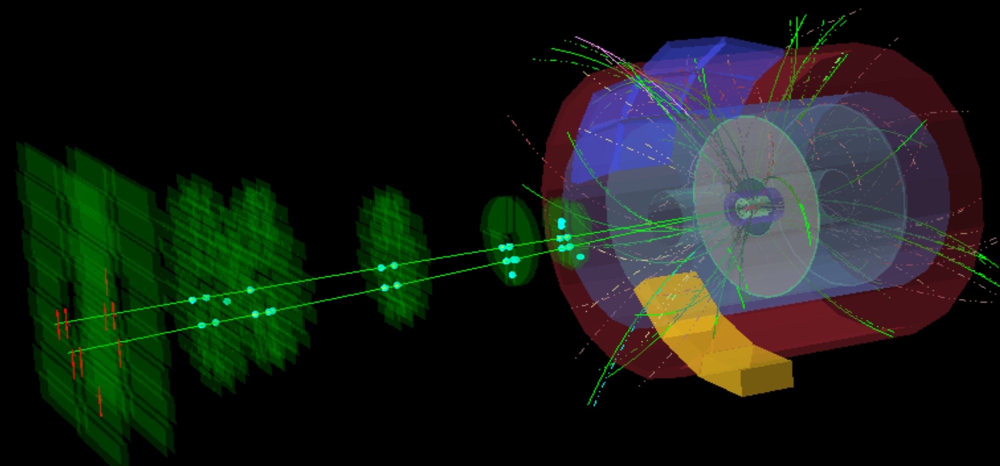
# Outline

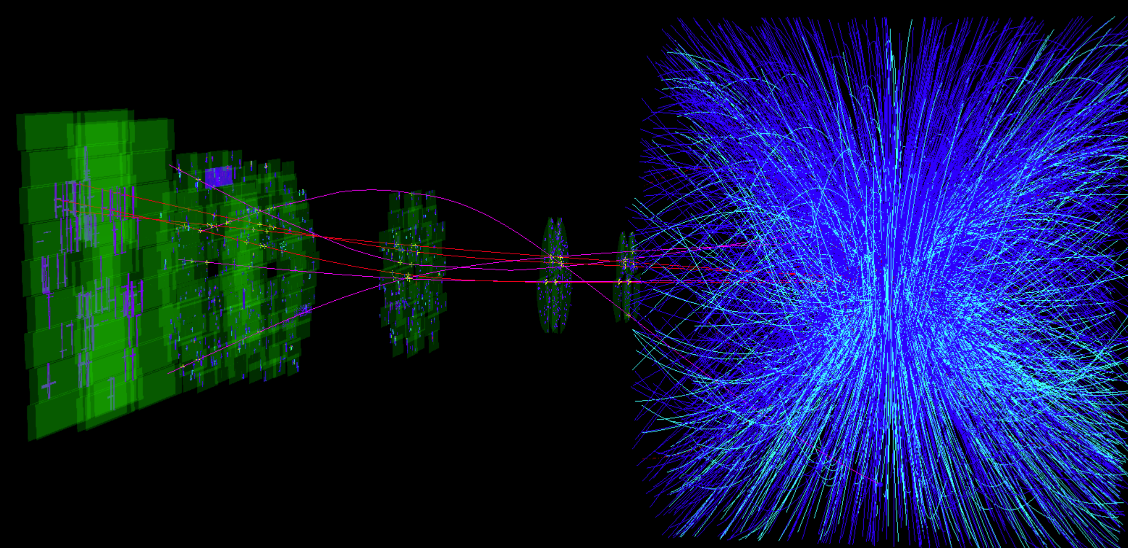
Physics motivations

ALICE detector

Open heavy flavors and quarkonia in p-p and Pb-Pb collisions

Conclusions





# Heavy flavors

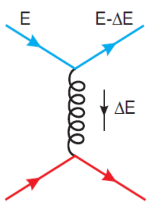
- **heavy flavors in pp collisions:**
  - **test NLO pQCD in a new energy regime**
  - **baseline for p-A and A-A collisions**
- **heavy flavors in A-A collisions, tomography of QCD medium:**
  - **produced in initial hard scattering with short formation time**
  - **sensitivity to the medium properties**

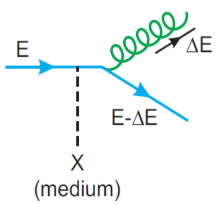
• parton energy loss via diff. mechanisms (collisional $E_{LOSS}$,medium-induced gluon radiation,...)

$\rightarrow \Delta E_{med} \sim \alpha_S\, C_R\, q^{hat}\, L^n$ f(mass) where $q^{hat} \sim$ interaction particle $\leftrightarrow$ medium

• gluon radiation suppressed at $\Theta < m_Q/E_Q$ ("dead cone effect")

$\rightarrow \Delta Eg > \Delta Eq > \Delta Ec > \Delta Eb$ expected




$$R_{AA} = \frac{Y_{AA}}{\langle N_{coll}\rangle_{AA} \times Y_{pp}} = \frac{Y_{AA}}{\langle T_{AA}\rangle_{AA} \times \sigma_{pp}}$$

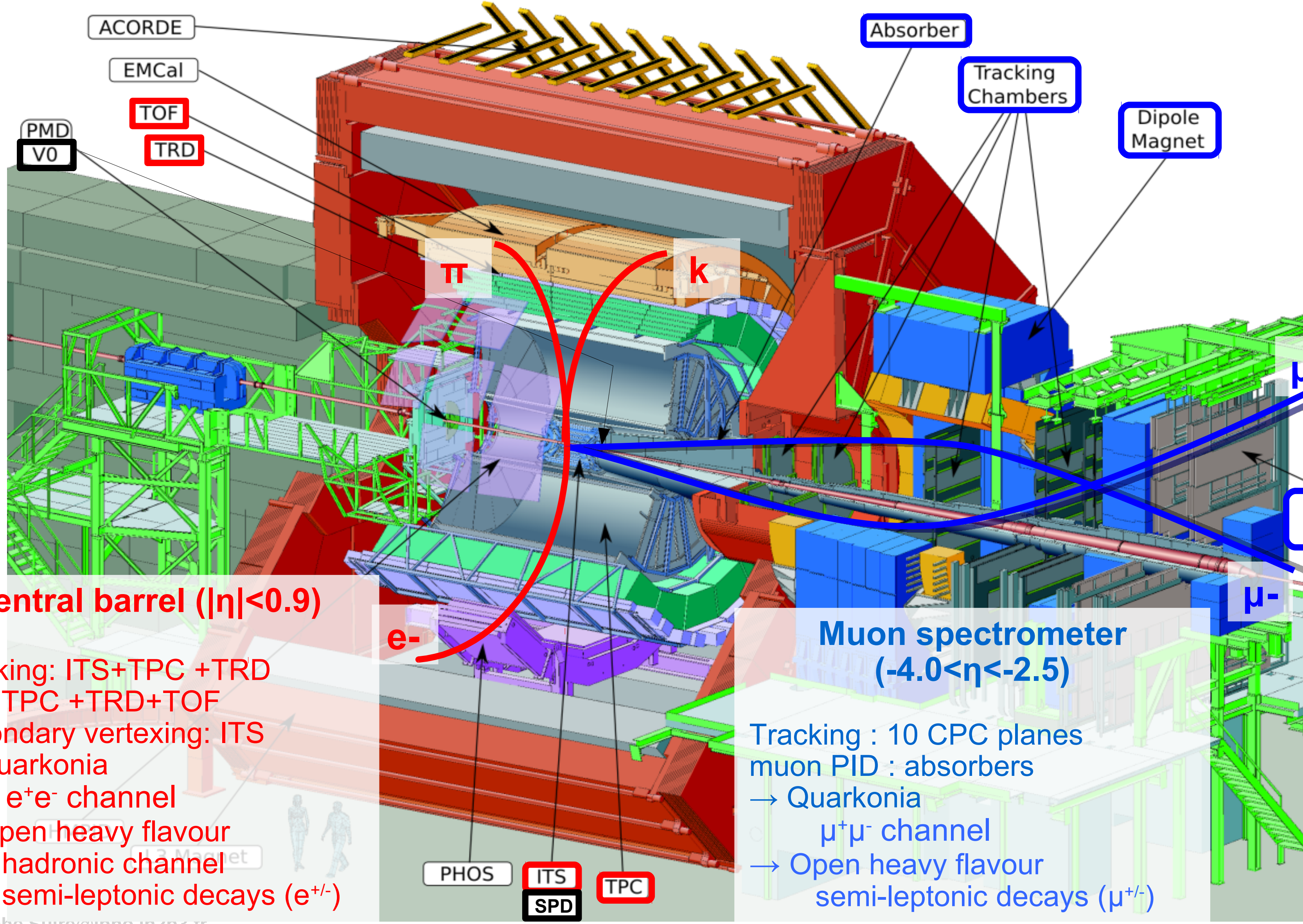
$\rightarrow R^{\pi}_{AA} < R^{D}_{AA} < R^{B}_{AA}$

**see also,**
**monday 14th Heavy Ion, High-$p_T$ session**
**High-$p_T$ results @ ALICE, M. van Leeuwen**

**[Dokshitzer and Kharzeev, PLB 519 (2001) 199.**
**Armesto, Salgado, Wiedemann, PRD 69 (2004) 114003.**
**Djordjevic, Gyulassy, Horowitz, Wicks, NPA 783 (2007) 493...]**

**+ heavy flavors in p-A collisions (not covered in this talk) are also crucial: initial state effects, parton $k_t$ broadening, gluon PDF modification.**

# The ALICE detector




**Central barrel (|η|<0.9)**

Tracking: ITS+TPC +TRD
PID: TPC +TRD+TOF
Secondary vertexing: ITS
→ Quarkonia
$e^+e^-$ channel
→ Open heavy flavour
hadronic channel
semi-leptonic decays ($e^{+/-}$)

**Muon spectrometer (-4.0<η<-2.5)**

Tracking : 10 CPC planes
muon PID : absorbers
→ Quarkonia
$\mu^+\mu^-$ channel
→ Open heavy flavour
semi-leptonic decays ($\mu^{+/-}$)

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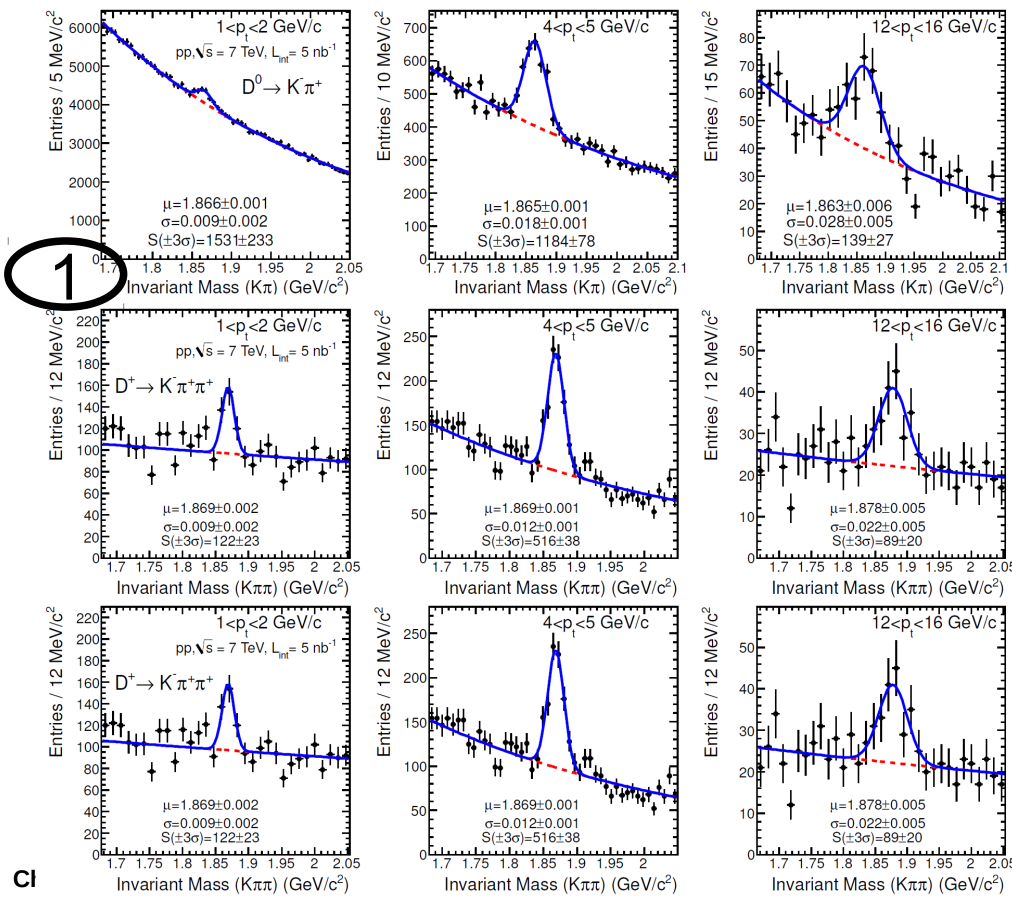
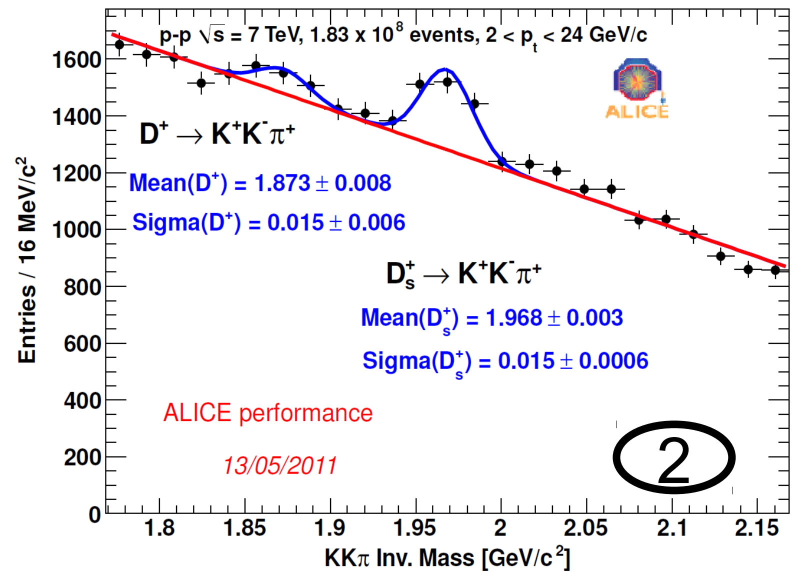
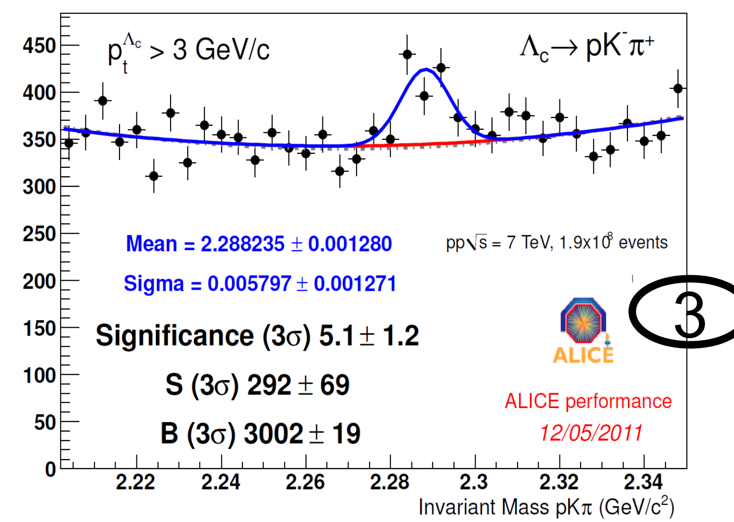
# D meson spectra in p-p collisions at $\sqrt{s_{NN}} = 7 \sqrt{\text{TeV}}$

1) D0, D+, D* from 1 to 24 GeV/c with the full 2010 data sample (5 nb$^{-1}$). Recent paper ArXiv:1111.1553
2) Rare Ds cross section measured...
3) Rare Λc starting to show up...
Work in progress...much more to come with 2011 data

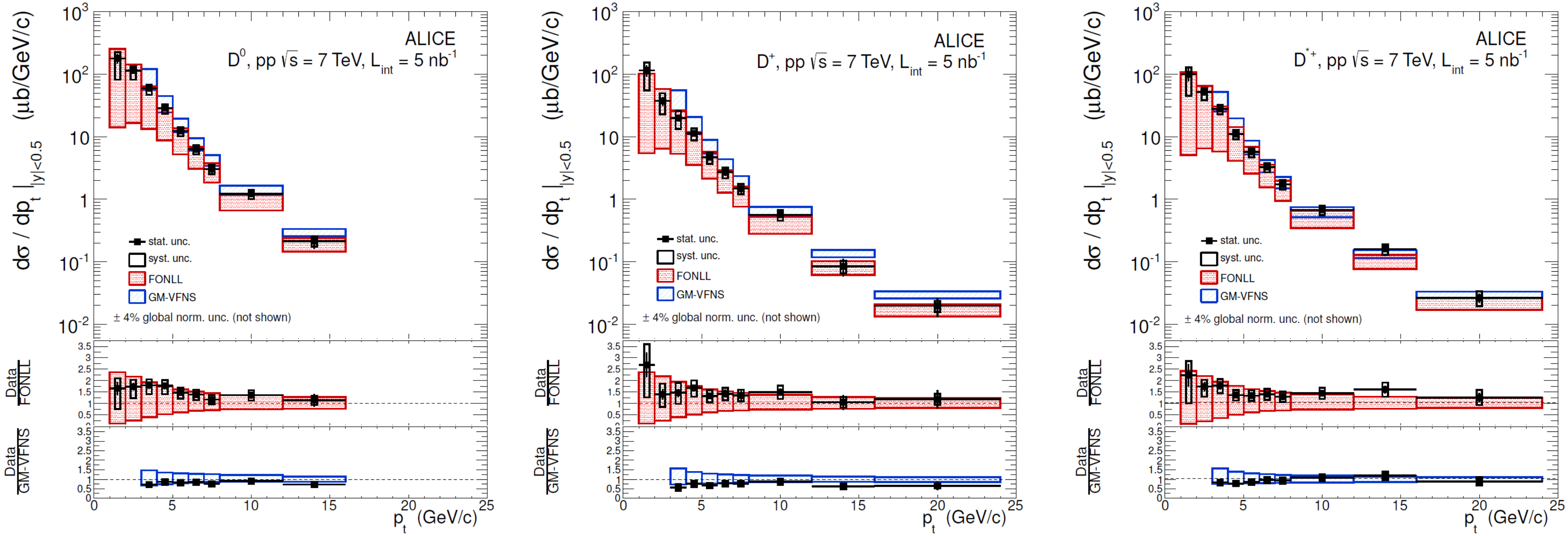



Measurement of charm production at central rapidity in proton–proton collisions at √s = 7 TeV (ALICE Collaboration) ArXiv:1111.1553



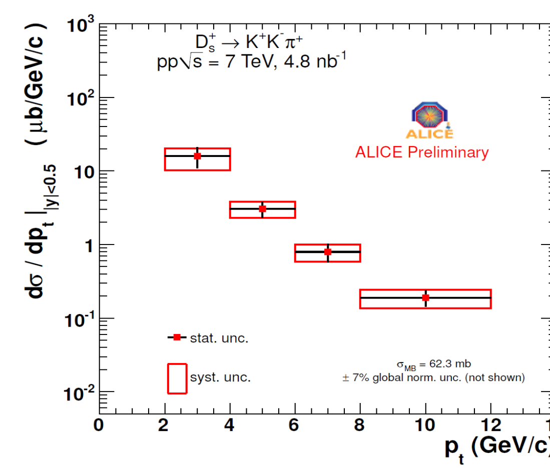



# D meson cross-section in p-p collisions at $\sqrt{s_{NN}}$ = 7 TeV




Measurement of charm production at central rapidity in p-p collisions at $\sqrt{s}$ = 7 TeV (ALICE Collaboration) ArXiv:1111.1553

- 1 < pt < 16(24) GeV/c with 5 $nb^{-1}$ (full 2010 statistics) for D0, D+ & D*, and 4.8 $nb^{-1}$ for D+s
- prompt D meson yield obtained after pQCD (FONLL) driven feed-down subtraction (checked against data using impact parameter distributions)
- data well described by pQCD predictions (FONLL & GM-VFNS) within errors (seem to lie systematically in the upper part of FONLL and lower part of GM-VFNS)




Poster M25 G.M. Innocenti

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

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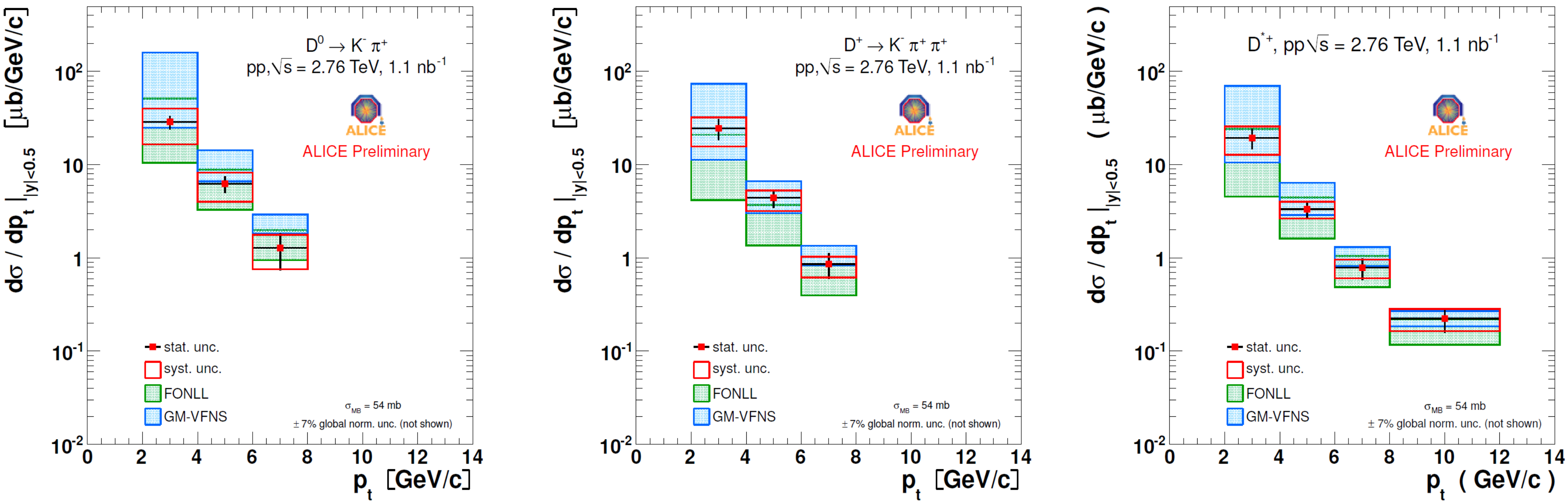
# D meson cross-section in p-p collisions at $\sqrt{s_{NN}} = 2.76$ TeV




- 2 < pt < 8 GeV/c with 1.1 $nb^{-1}$ (3 days of data taking) for D0, D+ & D*
- prompt D meson yield obtained after pQCD (FONLL) driven feed-down subtraction (checked against data using impact parameter distributions)
- data well described by pQCD predictions (FONLL & GM-VFNS) within errors (seem to lie systematically in the upper part of FONLL and lower part of GM-VFNS)

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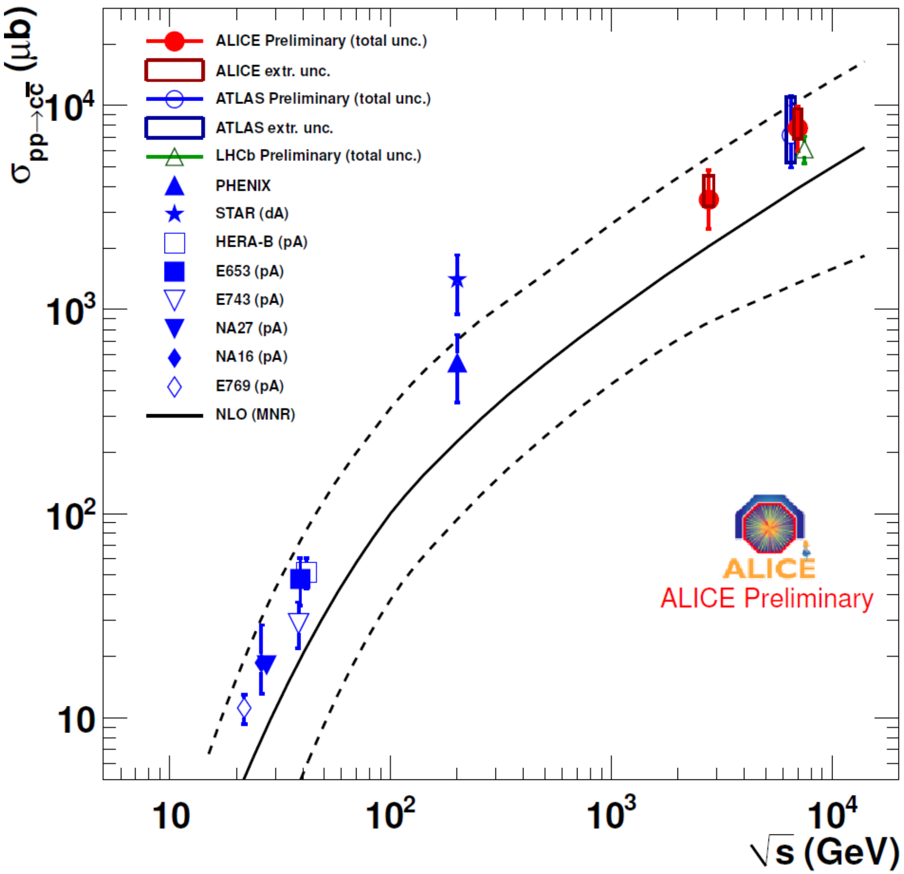
FONLL: M. Cacciari et al., private comm., GM-VFNS: B.A. Kniehl et al., private comm.

# Charm cross-section p-p collisions




**In Alice, extrapolation from the D mesons cross section**

**1) Extrapolation down to $p_T$=0 and full rapidity using FONLL**
**→ ~75% (~10%) of $\sigma_{cc}$ for $p_T$ > 1 GeV/c (|y|<0.5)**
**2) Good agreement with ATLAS and LHCb measurements**
**3) Measurements show a consistent behavior vs √s w.r.t NLO (MNR) calculations.**
**→ data/theory ~ 2**

σ(ALICE, 7TeV) = 7.73 ± 0.54 (stat.) +0.74, -1.38 (syst.) ±0.43 (lum.) +1.90, -0.87(extr.) mb
σ(ATLAS, 7TeV) = 7.13 ± 0.28 (stat.) +0.90, -0.66 (syst.) ±0.78(lum.) +3.82, -1.90(extr.) mb
σ(LHCb, 7TeV) = 6.10 ± 0.93 (total) mb
σ(ALICE, **2.76TeV**) = 3.45 ± 0.41(stat.) +0.72, -0.84 (syst.) ±0.17(lum.) +1.09, -0.24(extr.) mb

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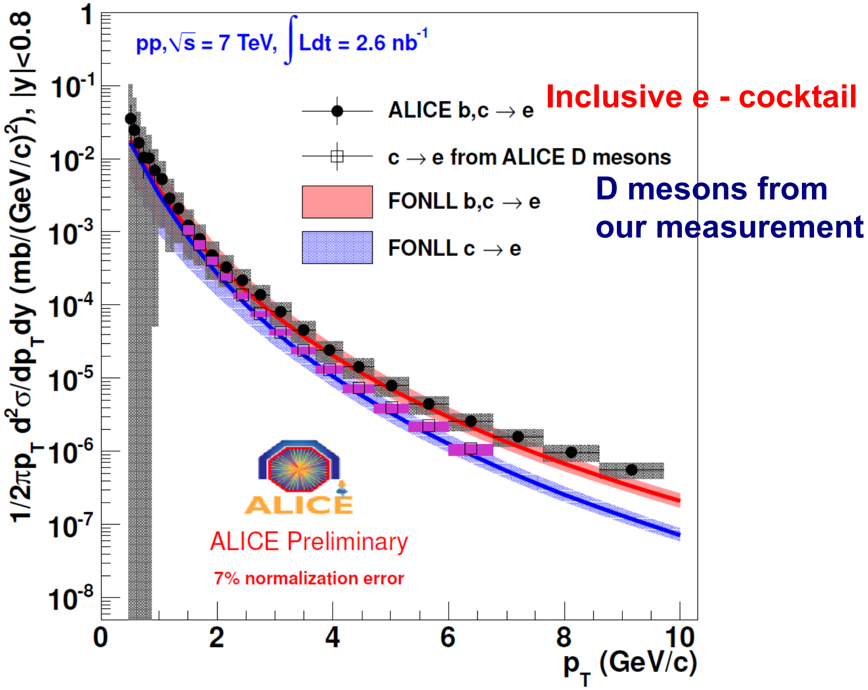
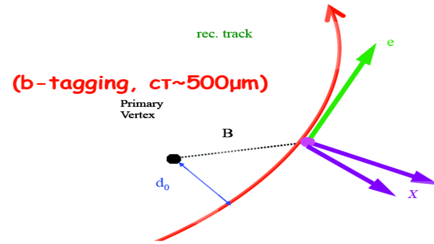
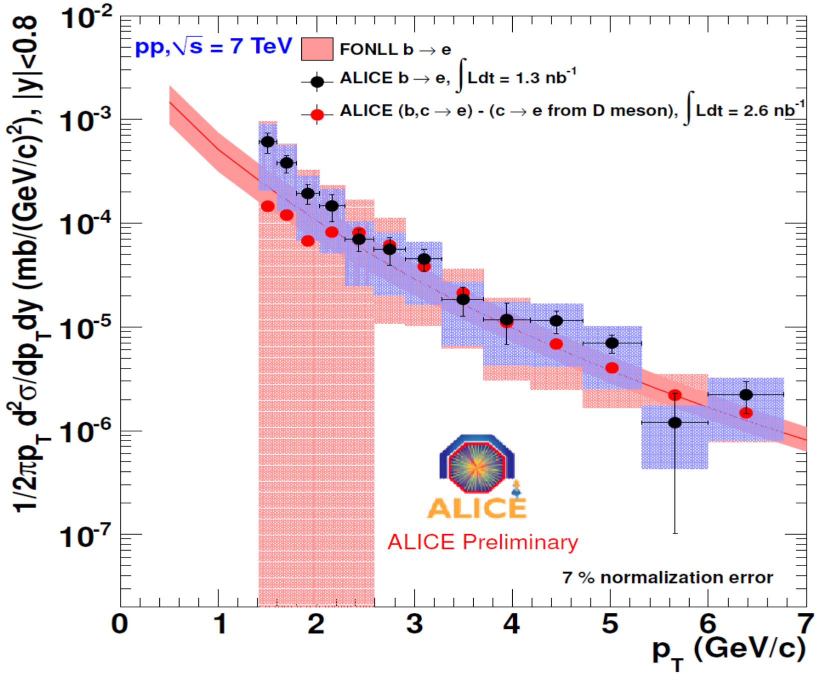
# Heavy flavor electrons in $|\eta|<0.8$ p-p collisions at $\sqrt{s_{NN}} = 7$ TeV




- Subtracted cocktail of electron background based on the measured $\pi^0$ spectrum + mt-scaling + pQCD direct photons + LHC J/ψ.
- Good agreement with FONLL b+c over the full pt range
- Consistent with the prompt charm measurement from D mesons




cut on impact parameter $d_0$ to isolate beauty or B→e+X = D,B → e + X - D→e+X




- Measurement of B→ e+X from 1.5 to 6 GeV/c
- Good cross-check with D,B → e + X and D meson measurements
- Well described by FONLL calculations

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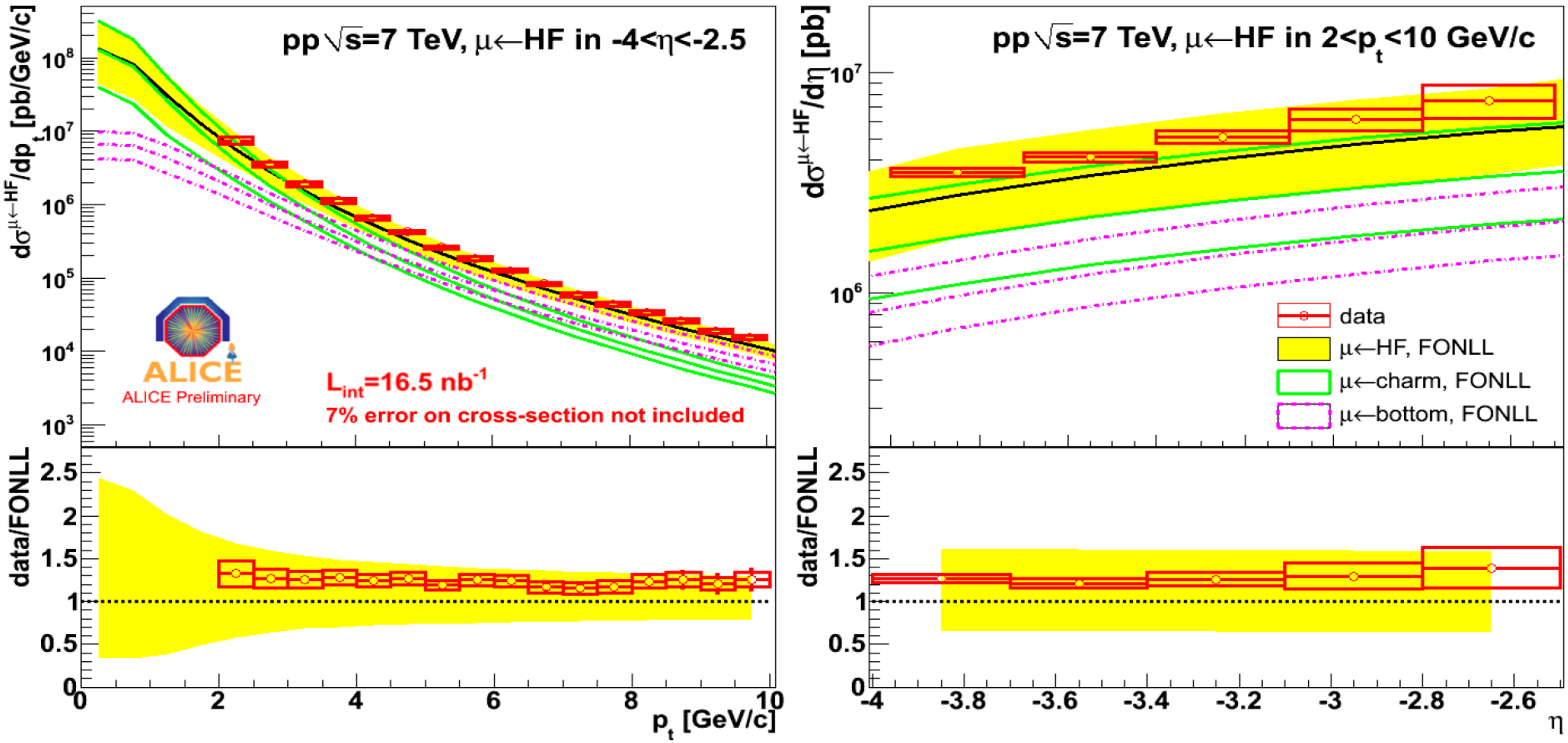
# Heavy flavor muons in -4<η<-2.5 p-p collisions at $\sqrt{s_{NN}}$ = 7 TeV




background (μ←π,K) subtracted using MC normalized to data at low $p_T$

data well described by (upper part) of FONLL up to $p_T$ = 10 GeV/c and vs. η

according to FONLL, μ←b decay dominate for $p_T$ > 6 GeV/c

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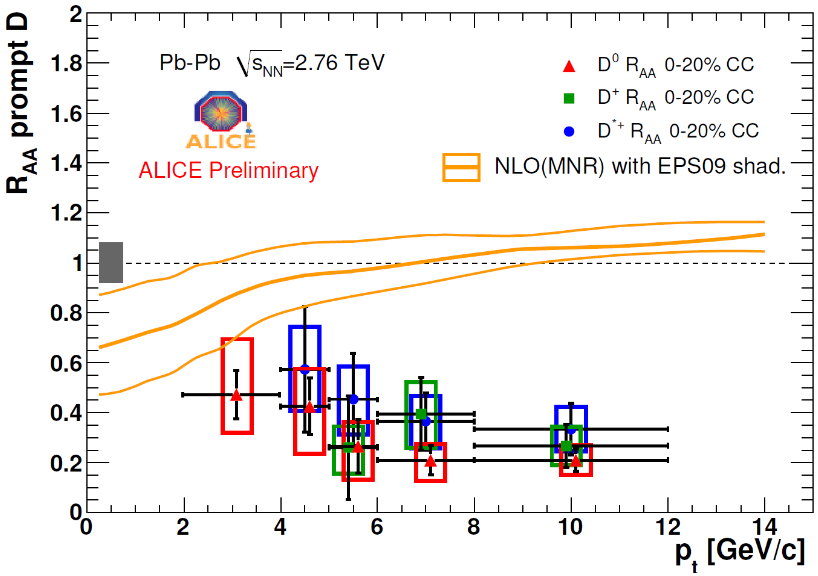
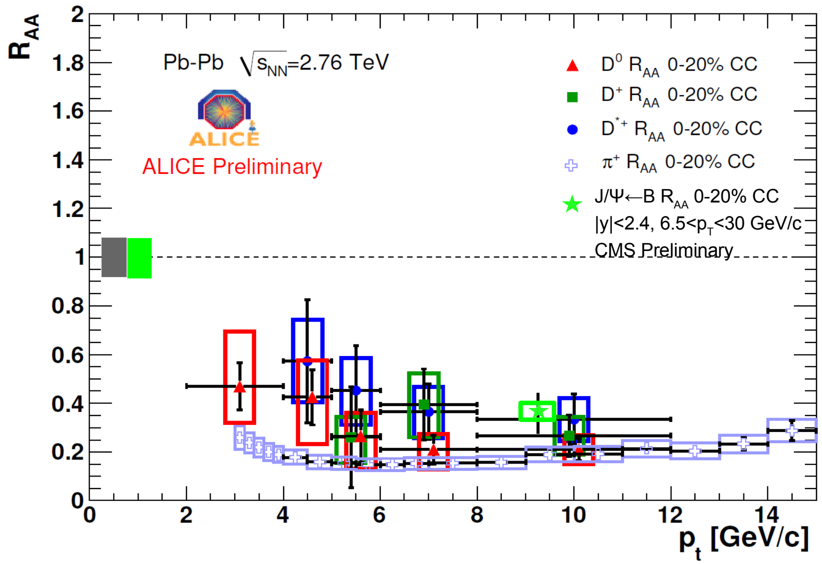
FONLL: M. Cacciari et al.,

# Comparing Pb-Pb to p-p: $R_{AA}$




$$R_{AA}(p_t) = \frac{1}{\langle T_{AA} \rangle} \times \frac{dN_{AA} / dp_t}{d\sigma_{pp} / dp_t}$$

For $p_T$ > 5 GeV/c, significant and genuine hot medium effect.
For $p_T$ < 5 GeV/c, gluon shadowing (EPS09) can play a role
→ will need to be measured at LHC via p-A collisions




Over the full $p_T$ range the π $R_{AA}$ is compatible with charm $R_{AA}$.
→ but systematically lower. More visible at low-pt ?
→ B $R_{AA}$ from CMS comparable to charm $R_{AA}$

Prediction is: $R^{\pi}_{AA} < R^{D}_{AA} < R^{B}_{AA}$

1) Reduce charm $R_{AA}$ error and uncertainty.
2) Measure beauty $R_{AA}$

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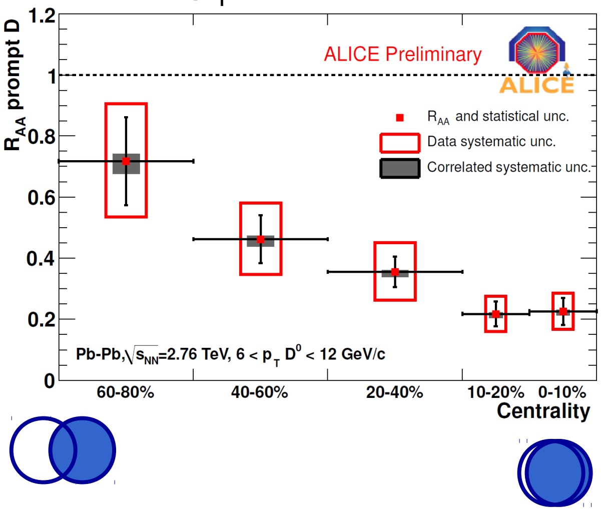
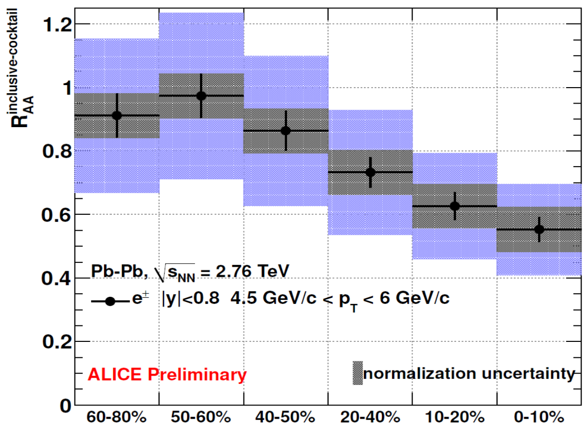
# Centrality dependence of $R_{AA}$

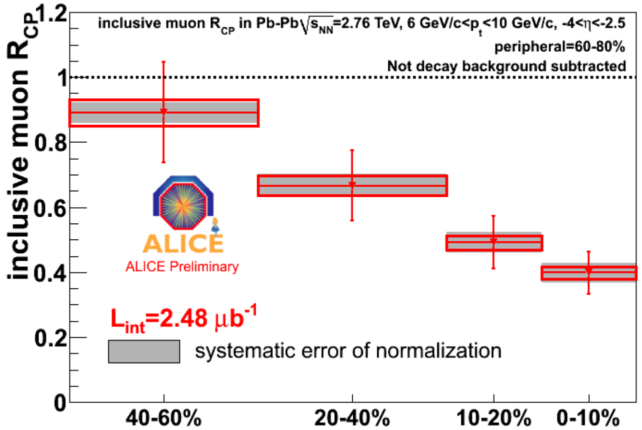
D0, $p_T$ > 6 GeV/c




HFe, $p_T$ > 4.5 GeV/c




HFμ, $p_T$ > 6 GeV/c




Inclusive muon spectra, >90% HF decays for $p_T$ above 6 GeV/c

Consistent centrality dependence of all probes
→ significant energy loss in most central Pb-Pb collisions

Electron (|η| < 0.8) $R_{AA}$ and muon (-4.0 < η <-2.5) $R_{CP}$ show a similar trend
Prompt D mesons $R_{AA}$ seems smaller than lepton (charm+beauty) $R_{AA}$ (large uncertainties for HFE and $R_{CP}$ not $R_{AA}$ for muons)
→ larger Eloss for charm w.r.t to beauty ?

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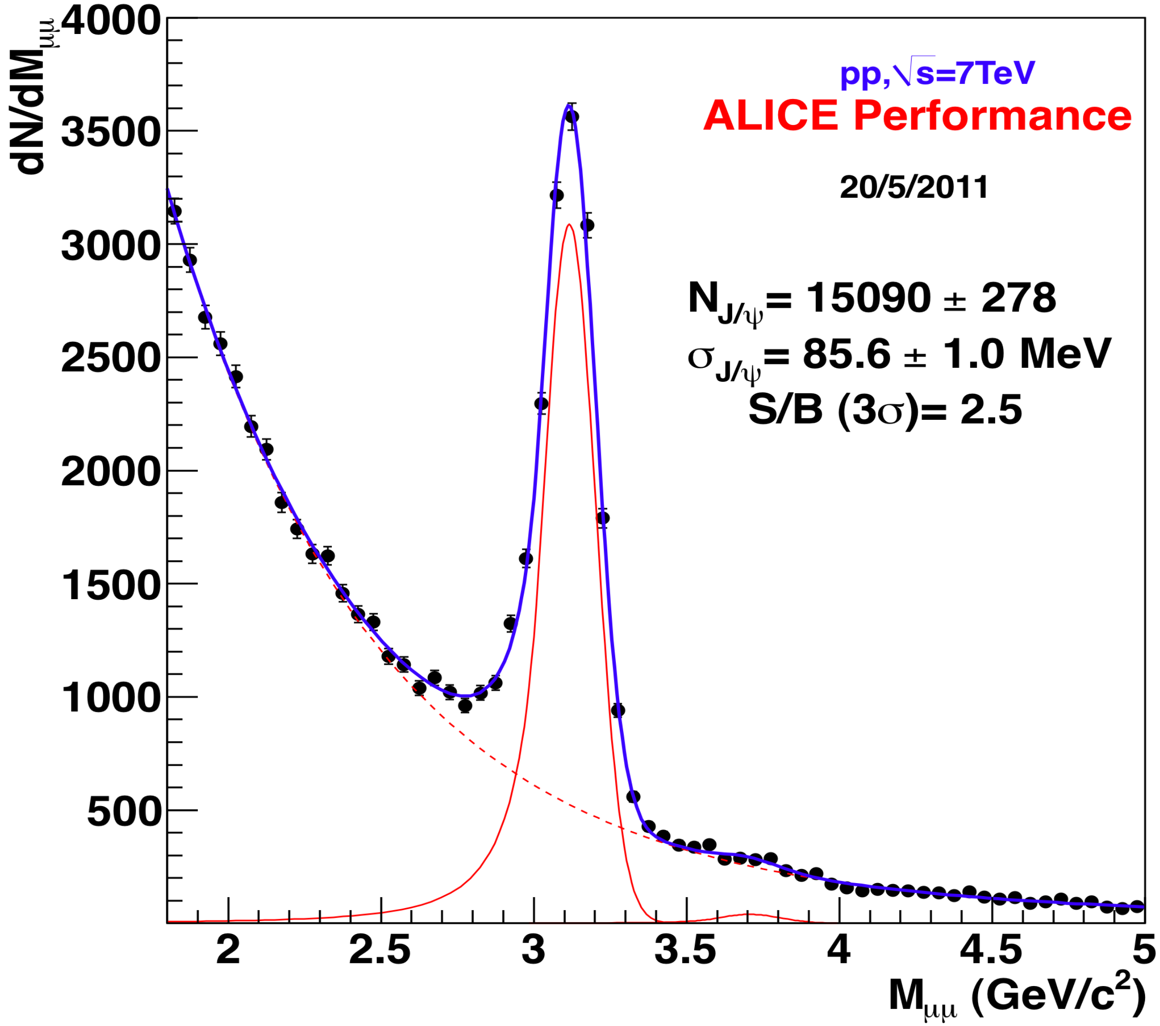
# Quarkonia in ALICE




**In p-p collisions, ALICE has measured charmonia**

→ in $\mu^+\mu^-$, $e^+e^-$ chanels
→ at y [-4;-2.5] and [-0.9;0.9]
→ **down to $p_T$ = 0**
→ differentially in $p_T$, y

→ at $\sqrt{s_{NN}}$ = 2.76 and 7 TeV
→ as a function of $dN_{ch}/d\eta$
→ published results on polarization

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# J/Ψs in ALICE: p-p collisions

Inclusive J/ψ cross sections at 7 TeV

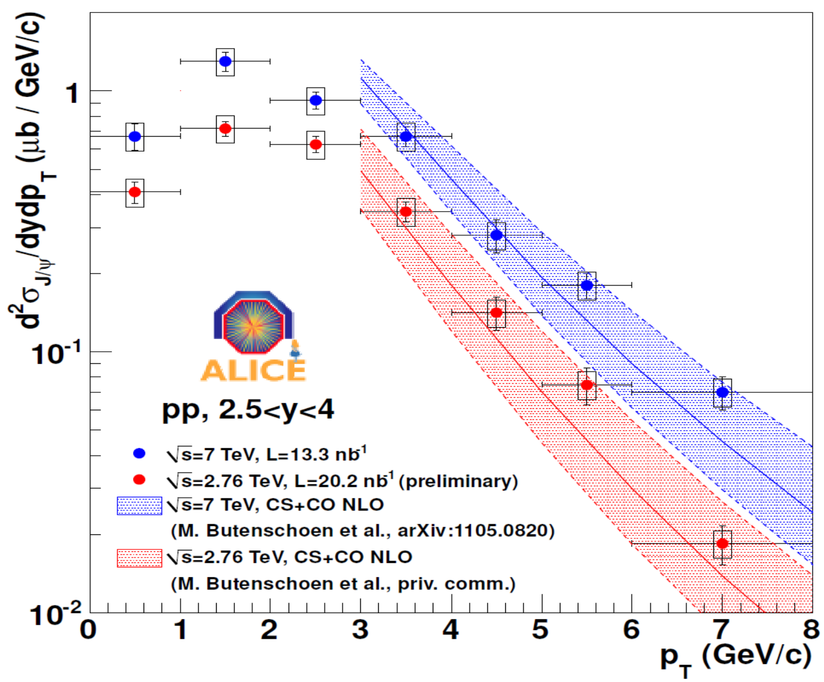
– $\sigma_{J/\psi}$ (|y|<0.9) = 10.7 ± 1.00 (stat) ± 1.70 (syst) + 1.60 ($\lambda_{HE}$=+1) -2.30 ($\lambda_{HE}$=-1) μb

– $\sigma_{J/\psi}$ (2.5<y<4) = 6.31 ± 0.25 (stat) ± 0.76 (syst) + 0.95 ($\lambda_{CS}$=+1) -1.96 ($\lambda_{CS}$=-1) μb

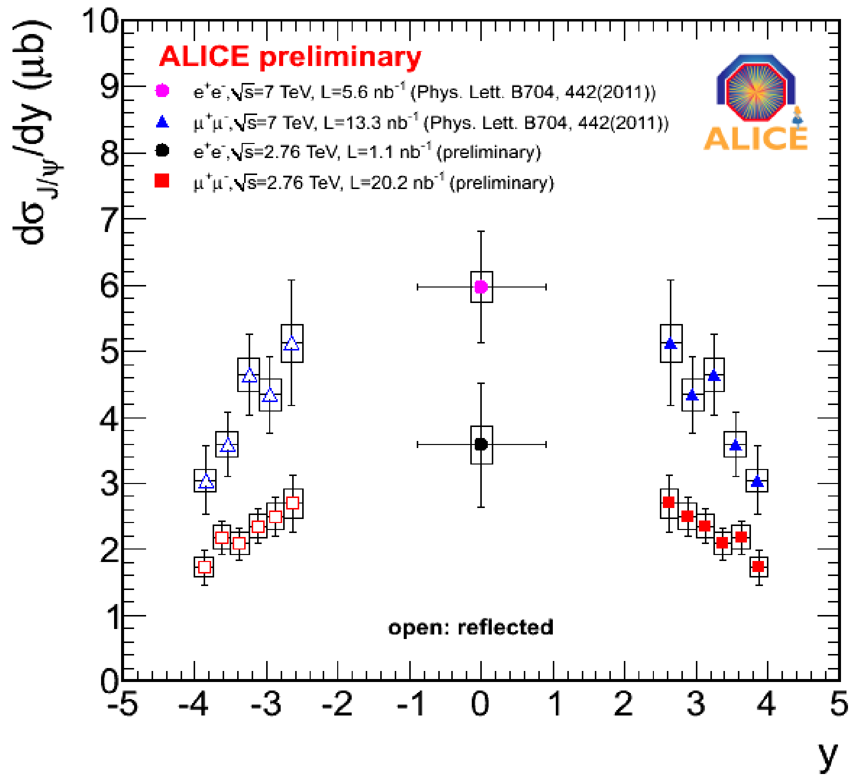
Inclusive J/ψ cross sections at 2.76 TeV

– $\sigma_{J/\psi}$ (|y|<0.9) = 6.44 ± 1.42 (stat) ± 0.88 (syst) ± 0.52 (lumi) + 0.64 ($\lambda_{HE}$=+1) -1.42 ($\lambda_{HE}$=-1) μb

– $\sigma_{J/\psi}$ (2.5<y<4) = 3.46 ± 0.13 (stat) ± 0.32 (syst) ± 0.28 (lumi) + 0.55 ($\lambda_{CS}$=+1) -1.11 ($\lambda_{CS}$=-1) μb




NRQCD calculation describes the $p_T$ dependence measured at both 7 and 2.76 TeV

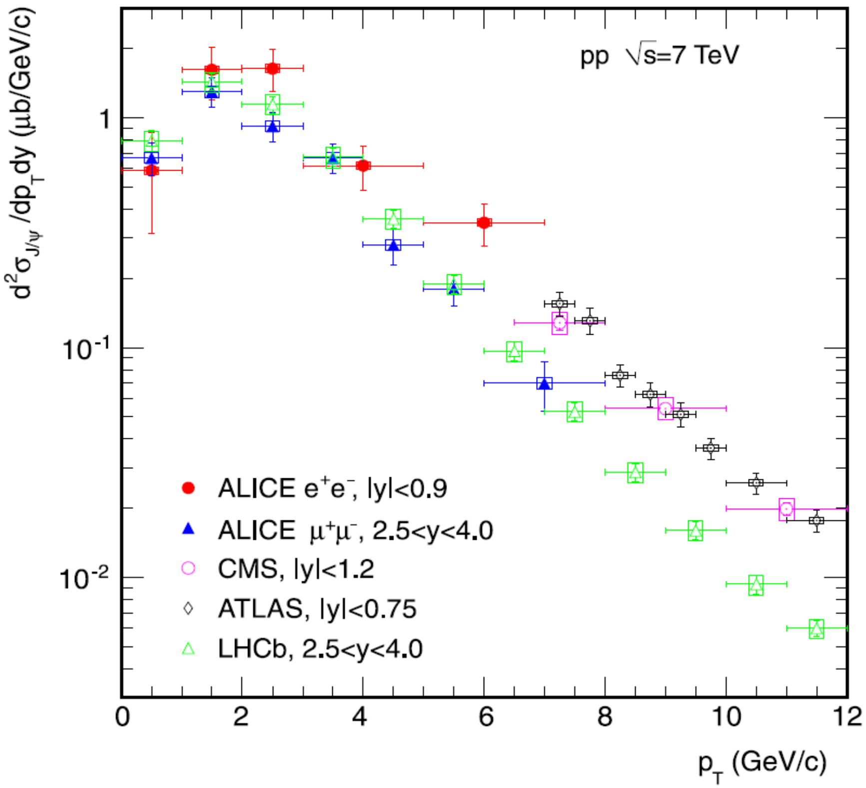


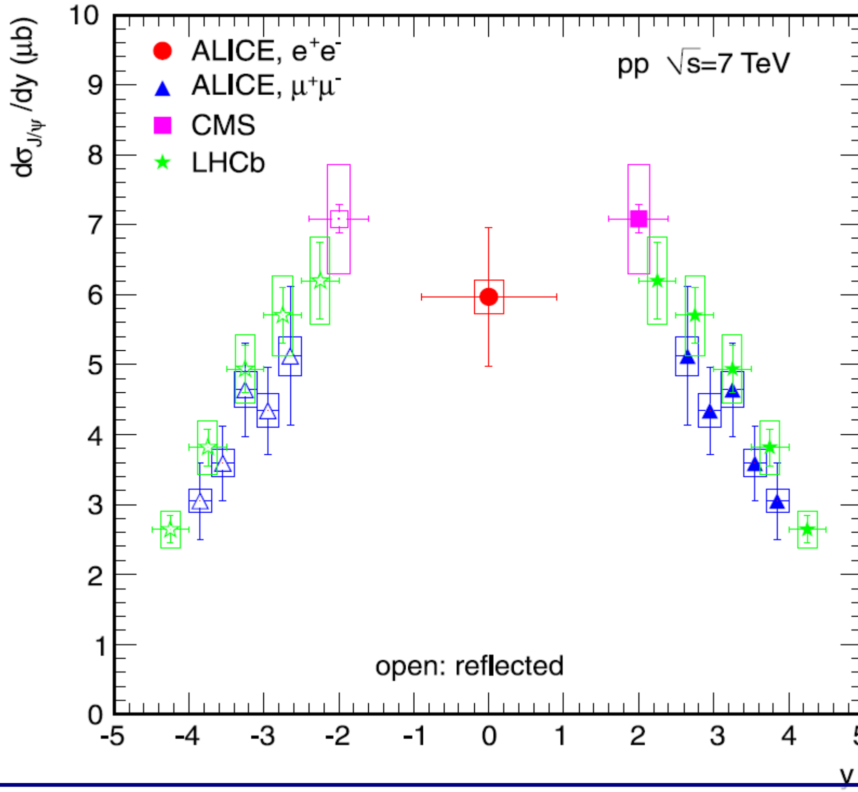

**p-p @ 2.76 TeV reference for Pb-Pb**

Rapidity and transverse momentum dependence of inclusive J/ψ production in pp collisions at sqrt(s) = 7 TeV (ALICE Collaboration) ArXiv:1105.0380

# J/Ψ in ALICE/LHC: p-p collisions at $\sqrt{s_{NN}}$ = 7 TeV

**Rapidity and transverse momentum dependence of inclusive J/ψ production in p-p collisions at $\sqrt{s_{NN}}$ = 7 TeV Physics Letters B 704 (2011), pp. 442-455.**





V. Khachatryan, et al., CMS Collaboration, Eur. Phys. J. C 71 (2011) 1575.
R. Aaij, et al., LHCb Collaboration, Eur. Phys. J. C 71 (2011) 1645.
G. Aad, et al., ATLAS Collaboration, Nucl. Phys. B 850 (2011) 387.


Bars = statistical and systematic errors, excluding luminosity and polarisation
Box = systematic uncertainties on luminosity
→ Good agreement between ALICE and LHCb for 2.5 < y < 4
→ extension of $p_T$ range measured by ATLAS and CMS down to 0 GeV/c

ALICE is unique in its broad rapidity coverage from $p_T$ = 0

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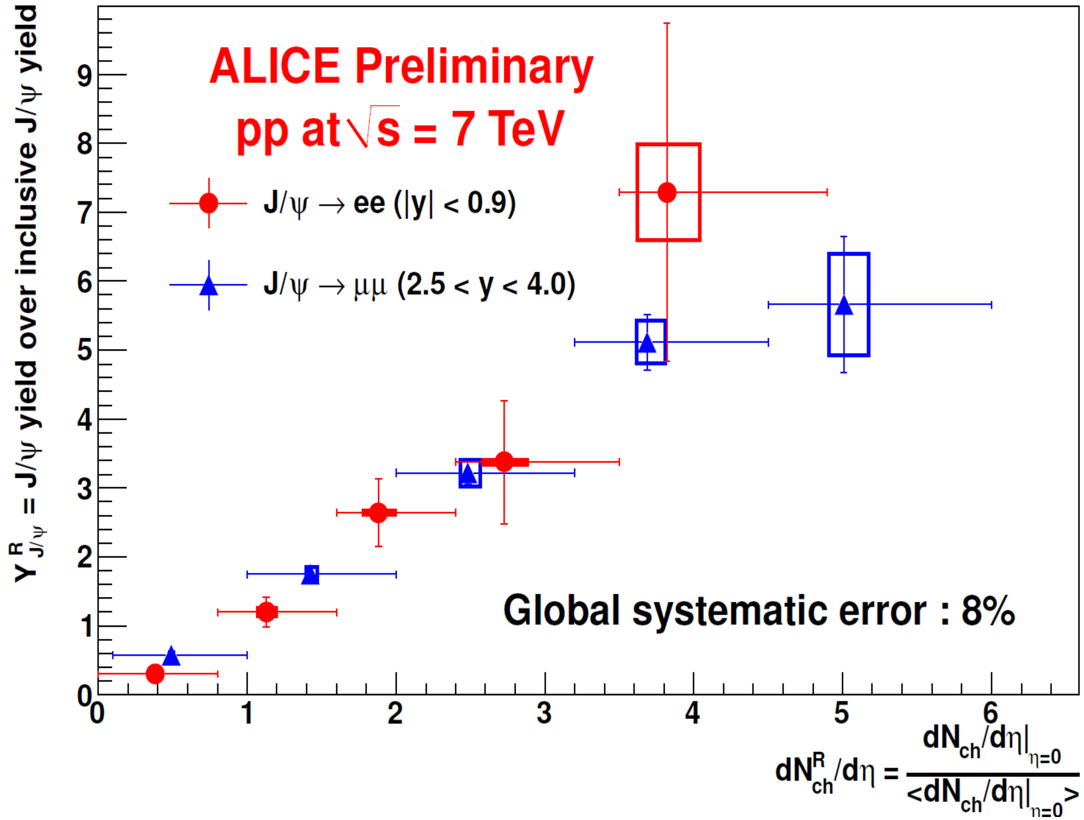
# J/Ψ production vs multiplicity in p-p collisions at $\sqrt{s_{NN}}$ = 7 TeV

Highest charged particle multiplicity ($dN_{ch}/d\eta$ ~30) reached in p-p at 7 TeV is comparable with Cu-Cu collisions (50-55%) @ 200 GeV

[ $dN_{ch}/d\eta|_{\eta=0}$ ~ 6 ]




Relative J/ψ yield increase linearly with the relative multiplicity .
→ should help understand the interplay between hard and soft interactions in the context of multi-partonic interactions (MPI), and/or underlying event
→ model predictions are needed

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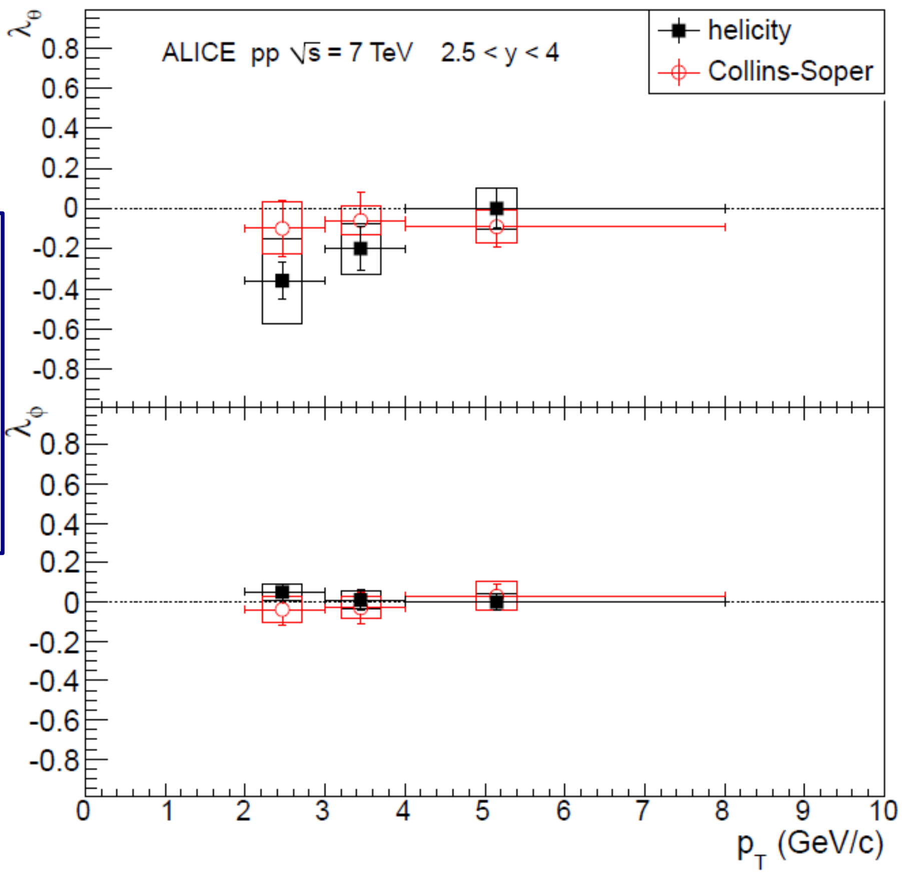
# J/Ψ polarisation in p-p collisions at $\sqrt{s_{NN}}$ = 7 TeV

- 2.5 < y < 4
- inclusive J/Ψ (ψ',$\chi_C$ and J/Ψ ← B)
  estimated J/Ψ ← B ~ 0.05

First measurement of J/Ψ polarization at LHC:
- slight longitudinal polarization (λθ) tending to vanish when increasing $p_T$
- azimuthal component λφ is compatible with 0

Recent paper ArXiv:1111.1630

| | $p_t$ (GeV/$c$) | $\lambda_\theta$ | $\lambda_\phi$ |
|---|---|---|---|
| HE | 2-3 | $-0.36\pm0.09\pm0.21$ | $0.05\pm0.04\pm0.04$ |
| | 3-4 | $-0.20\pm0.11\pm0.13$ | $0.01\pm0.05\pm0.05$ |
| | 4-8 | $0.00\pm0.10\pm0.10$ | $0.00\pm0.04\pm0.04$ |
| CS | 2-3 | $-0.10\pm0.14\pm0.13$ | $-0.04\pm0.08\pm0.07$ |
| | 3-4 | $-0.06\pm0.14\pm0.07$ | $-0.03\pm0.08\pm0.05$ |
| | 4-8 | $-0.09\pm0.10\pm0.08$ | $0.03\pm0.06\pm0.07$ |




Next, increase $p_T$ range to compare to models and to upcoming measurements at LHC

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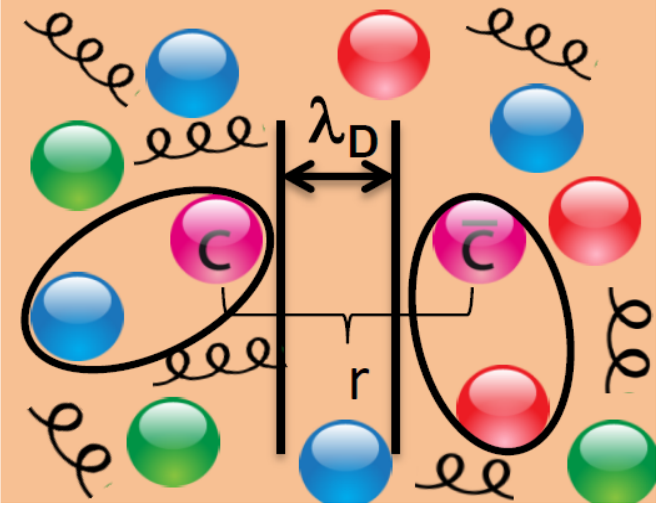
# Quarkonia in Pb-Pb: the J/Ψ case

**The long standing unambiguous signature of deconfined quark matter:**

**Sketch of J/ψ suppression by color screening of a c-cbar pair in a dense partonic system →**

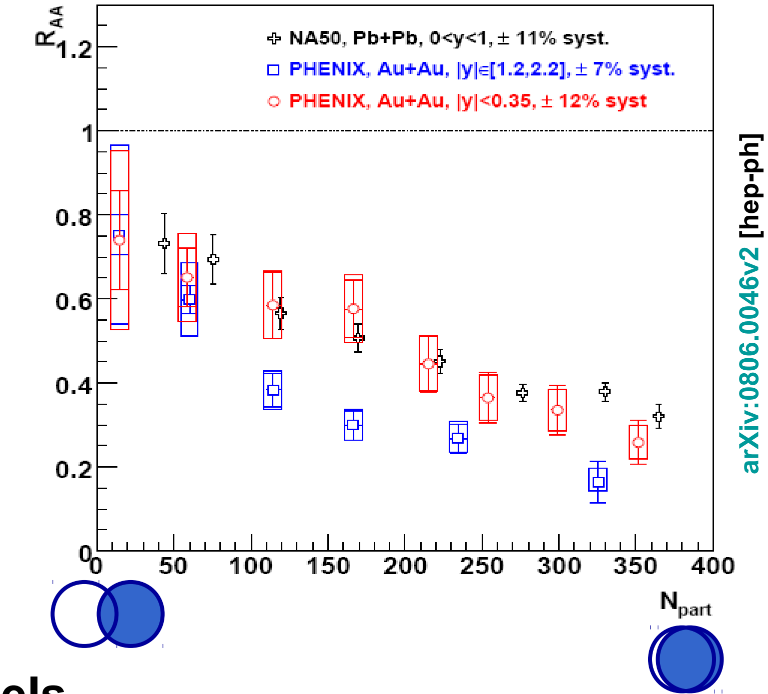



T. Matsui and H. Satz, J/ψ Suppression by Quark-Gluon Plasma Formation, Phys. Lett. B178, 416 (1986).

# Quarkonia in Pb-Pb: the J/Ψ case

**The long standing unambiguous signature of deconfined quark matter has somehow become ambiguous:**

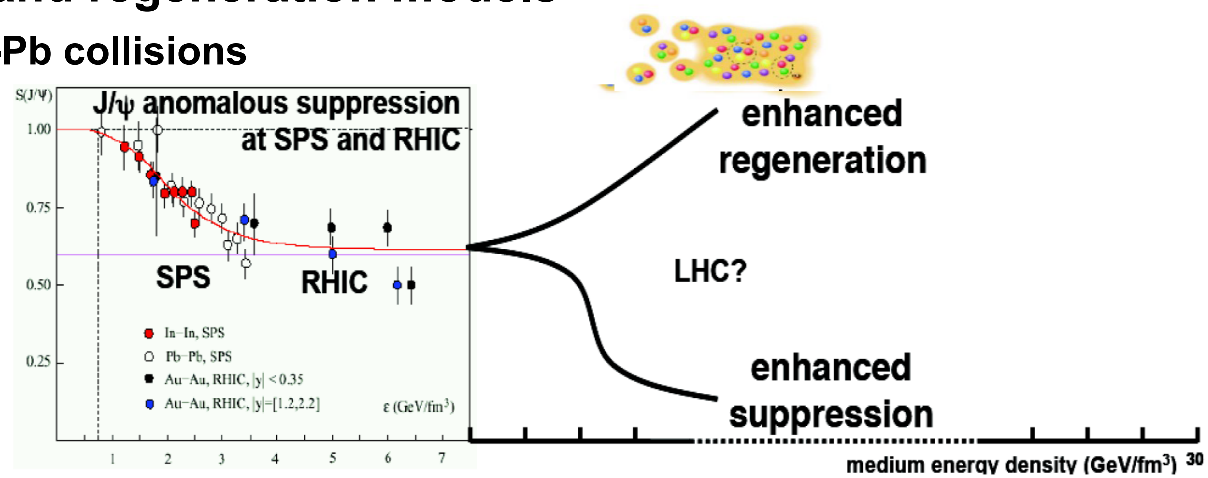
- **suppression pattern "anomalously" comparable at SPS and RHIC.**
- **sequential suppression: ψ', $\chi_c$ only**
- **other effects**
  - → **nuclear absorption**
  - → **gluon PDF modification (anti-) shadowing**




## Statistical hadronization and regeneration models

**large charm production in Pb-Pb collisions**

| In most central A-A collisions | SPS 20 GeV | RHIC 200 Gev | LHC 2.76 TeV |
|---|---|---|---|
| $N_{ccbar}$/event | 0.2 | 10 | 56 |

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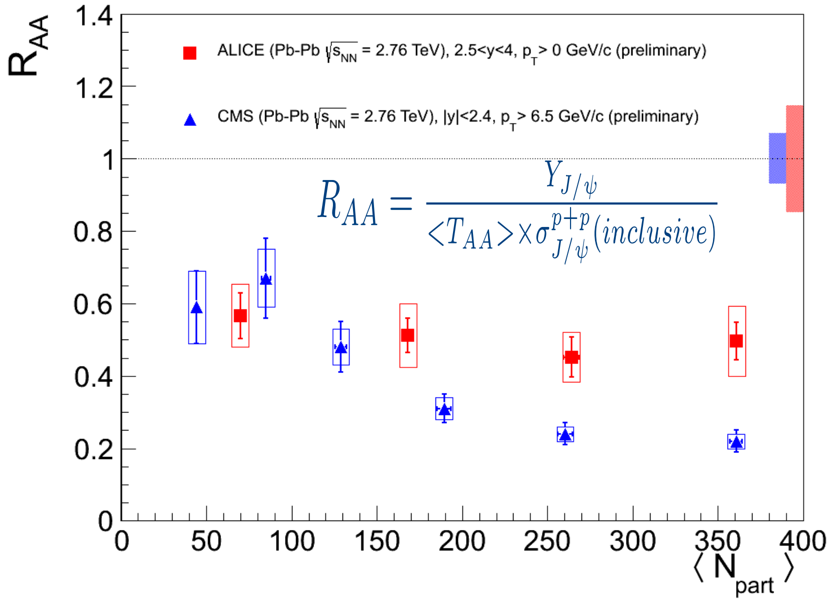
# Pb-Pb collisions: J/ψ $R_{AA}$

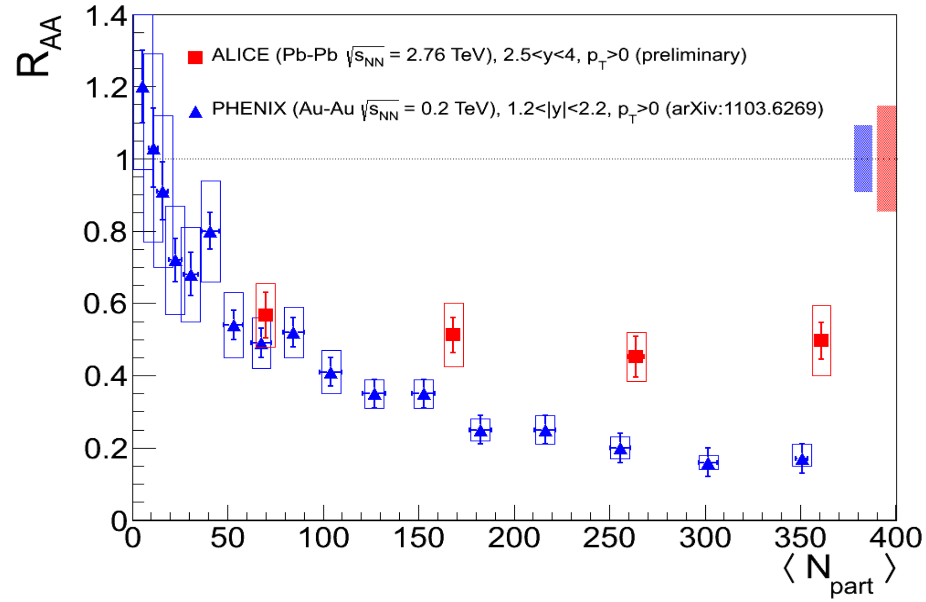
ALICE inclusive J/ψ $R_{AA}^{0-80\%}$ = 0.49 ± 0.03 (stat.) ± 0.11 (sys.)

Weak centrality dependence

Prompt J/ψ $R_{AA}^{0-80\%}$ could be 11% smaller due to beauty contribution




ALICE observes less J/Ψ suppression in most central collisions than CMS → but $p_T$ (y) ranges are separated: no overlap at all !




At forward rapidity (blue and red), clear difference for $N_{part}$ > 160 .

Different production mechanism or new/other effects ?

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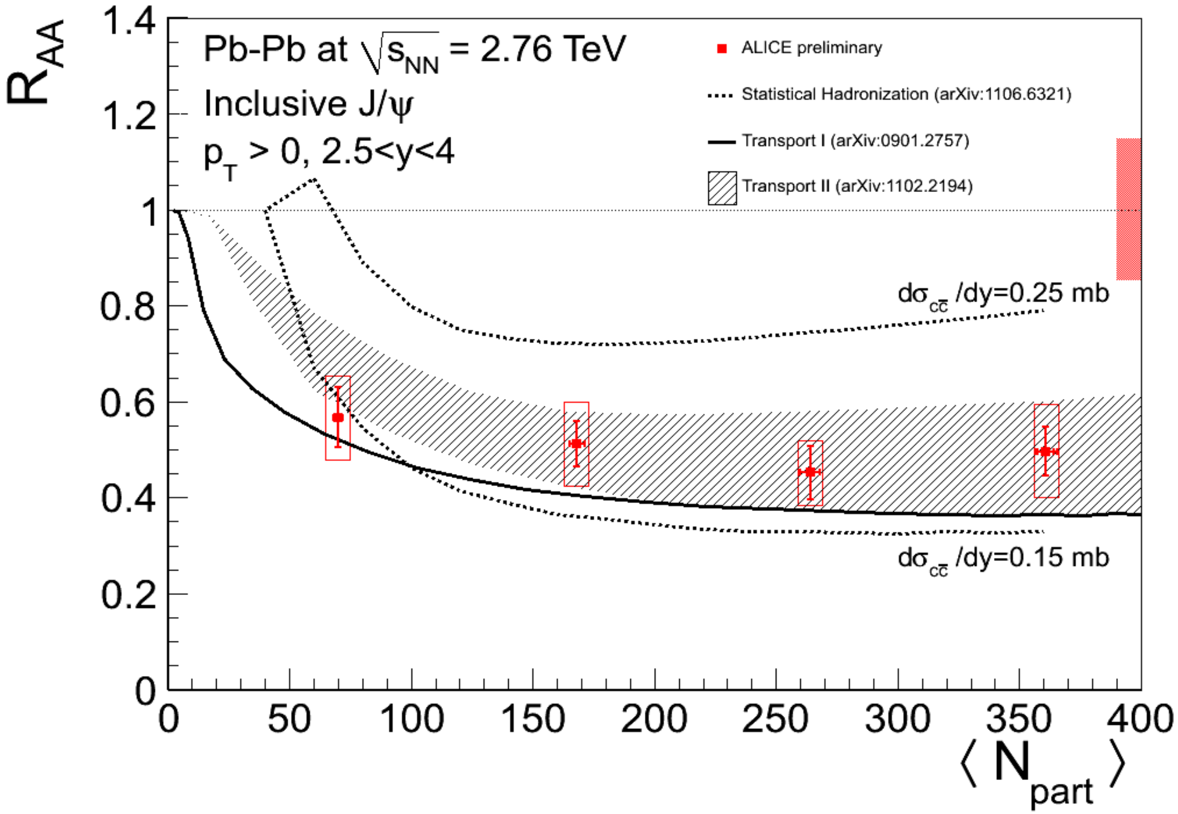
# Pb-Pb collisions: J/ψ $R_{AA}$




**Bars: statistical uncertainty**

**Open box: centrality dependent sys. uncertainty**

**Red box: common sys. uncertainty**

Statistical hadronisation (transport) model have a full (partial ~ 50%) J/Ψ production from c-cbar of the deconfined medium (PQG).

Realistic charm cross-section, shadowing, b-feeddown implemented but corresponding measurements are not available....
→ charm cross-section to be measured precisely
→ gluon shadowing from pA collisions

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# Conclusions

- **ALICE has measured the prompt D, HF electron/muon cross sections in p-p collisions**
  - **both at $\sqrt{s}$ = 7 and 2.76 TeV**
  - **down to low-$p_T$ (~ 1-2 GeV/c)**
  - **very well described by FONLL and GM-VFNS models**
- **Heavy flavor nuclear modification factor, $R_{AA}$ in Pb-Pb collisions at 2.76TeV has been measured.**
  - **Prompt D mesons (inclusive HF e/μ) $R_{AA}$ is suppressed by about a factor of 4 (3) in the 0-20% most central Pb-Pb collisions.**

- **J/ψ production measured in p-p collisions at $\sqrt{s}$ = 7 TeV and 2.76 TeV:**
  - **down to $p_T$ = 0 at mid and forward rapidity [→ solid reference for Pb-Pb collisions]**
  - **J/Ψ production scales with event multiplicity.**
  - **small longitudinal J/Ψ polarization observed at LHC**
- **J/ψ $R_{AA}$ in Pb-Pb collisions exhibits a novel behavior with respect to PHENIX (lower energy) and CMS (high-pt J/ψ)**

- **Prospects for the ongoing 2011 Pb-Pb data taking**
  - **High precision measurement: $R_{AA}$ $p_T$ dependence and elliptic flow**

    **→ for open charm and J/ψ !**

see also,
tuesday 15th Soft QCD/MinBias/Diffraction
Results from ALICE, P. Antonioli
Tomorrow
Heavy ion (II) soft
ALICE+ATLAS+CMS, P. Kuijer

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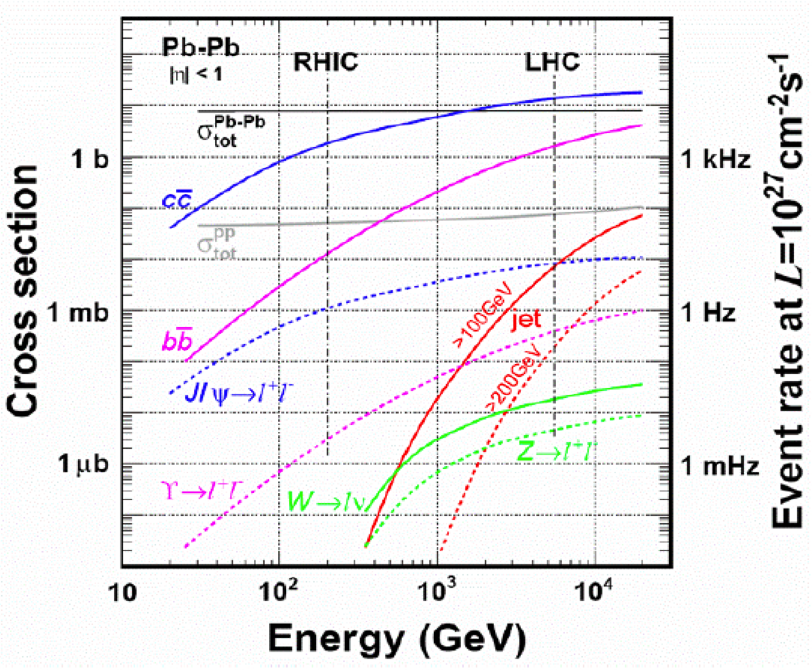
# Additional slides

- Cross section at LHC
- Data sample
- Alice Muon Spectrometer
- Charm an beauty decays
- J/ψ from B decays in p-p
- FONLL uncertainties
- D meson elliptic flow
- J/ψ $R_{CP}$ at LHC

# Cross-section @ LHC

NLO predictions for charm/bottom
(+ binary scaling & shadowing (average EKS98 & EPS08) in PbPb)

| | pp 14 TeV | pp 7 TeV | Pb-Pb (5%) 5.5 TeV | Pb-Pb (5%) 2.76 TeV |
|---|---|---|---|---|
| $\sigma^{NN}_{qqbar}$ (mb) | 11.2/0.5 | 6.9/0.23 | 3.4/0.14 | 2.1/0.075 |
| $N_{qqbar}$(/event) | 0.16/0.007 | 0.1/0.003 | 90/3.7 | 56/2 |

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# Datasets and triggers

| System | pp | pp | pp | pp | PbPb |
|---|---|---|---|---|---|
| √sNN [TeV] | 7 | 7 | 2.76 | 2.76 | 2.76 |
| trigger | MB | μ-trigger | MB | μ-trigger | MB |
| $N_{events}$ | up to 298 M | 130 M | 65 M | ~9 M | 17 M |
| L×A1×A2 ($nb^{-1}$) | up to 4.8 | 16 | 1.1 | 20 | 118 |

## p-p

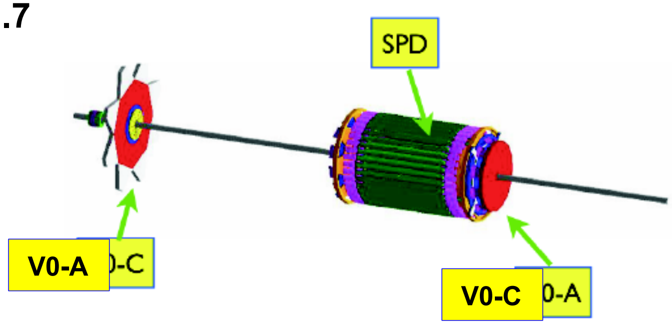
– Minimum bias (MB) trigger
  - V0-A or V0-C or SPD

– Single-muon trigger
  - forward muon in coincidence with MB trigger

$2.8 < \eta_{V0\text{-}A} < 5.1$

$-3.7 < \eta_{V0\text{-}C} < -1.7$

$|\eta_{SPD}| < 2$



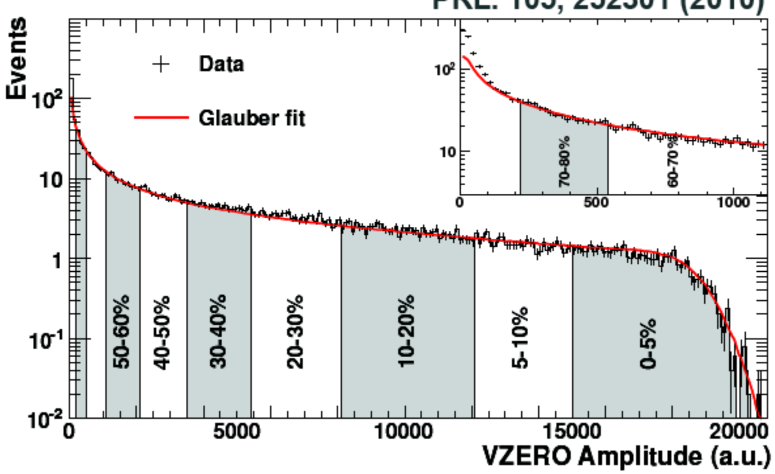

V0: Array of scintillators
SPD: Silicon Pixel Detector

## Pb-Pb

– Minimum bias trigger (MB)
  - V0-A and V0-C and SPD

– Centrality from Glauber model fit to V0 signal

PRL. 105, 252301 (2010)

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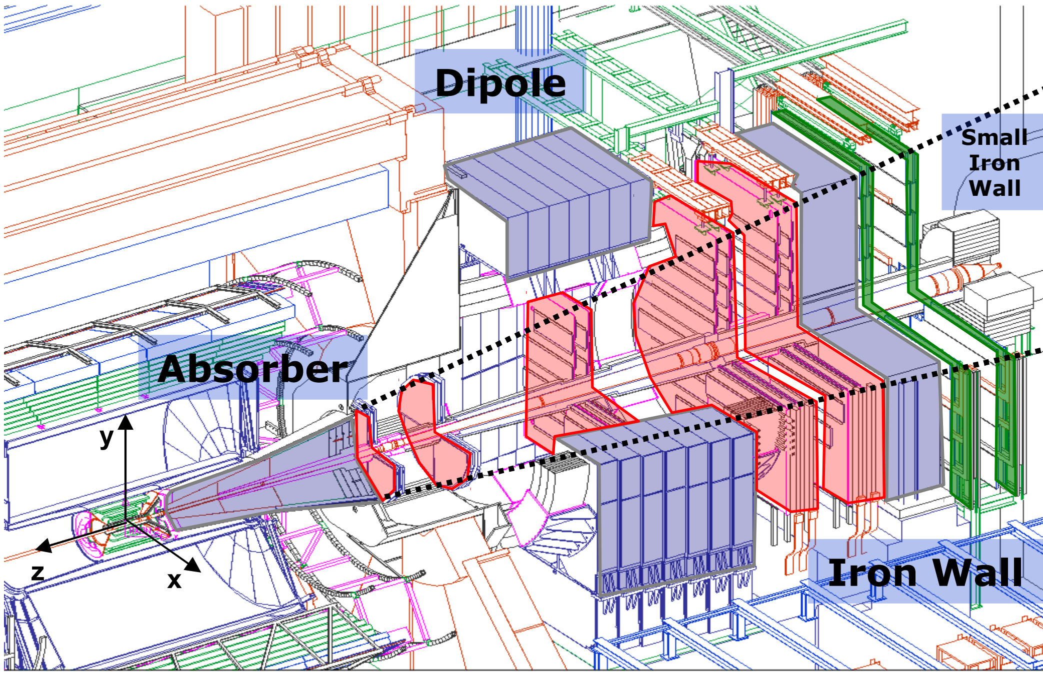
# The ALICE muon spectrometer

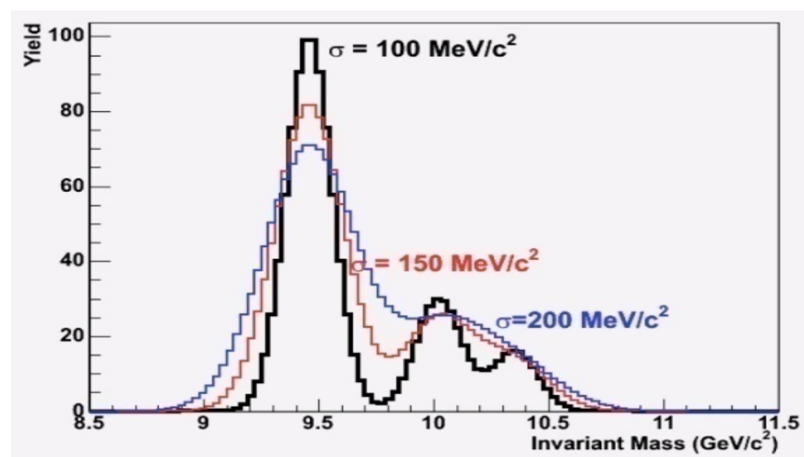



**Muon spectrometer is dedicated to the (di-)muons measurement (2.5<η<4)**

**2 stations of Trigger Chambers**

**5 stations of Tracking Chambers**
**1 & 2 : quadrant type**
**3, 4 & 5 : slats type**

**Mass resolution for ϒ < 100 MeV**
**→ spatial resol. < 100 μm along y**

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# Charm hadronic decays

p-p collisions at $\sqrt{s_{NN}}$ = 7 TeV Recent paper ArXiv:1111.1553

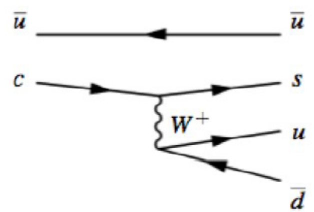
D0: dσ/dy = 511±41(stat.)+ 69−173(syst.)±20(lumi.)+119−37(extr.) μb,

D+: dσ/dy = 245±29(stat.)+52−90(syst.)±10(lumi.)+56−18(extr.) μb,

D*+: dσ/dy = 244±27(stat.)+36−80(syst.)±10(lumi.)+57−16(extr.) μb.

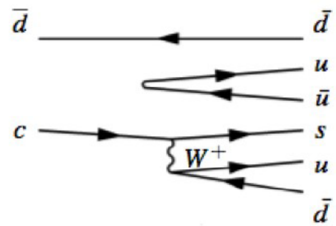
$D^0 \rightarrow K^- + \pi^+$

BR = 0.0389 ± 0.0005



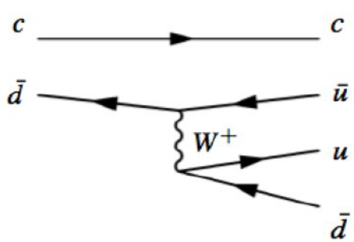

$D^+ \rightarrow K^- + \pi^+ + \pi^+$

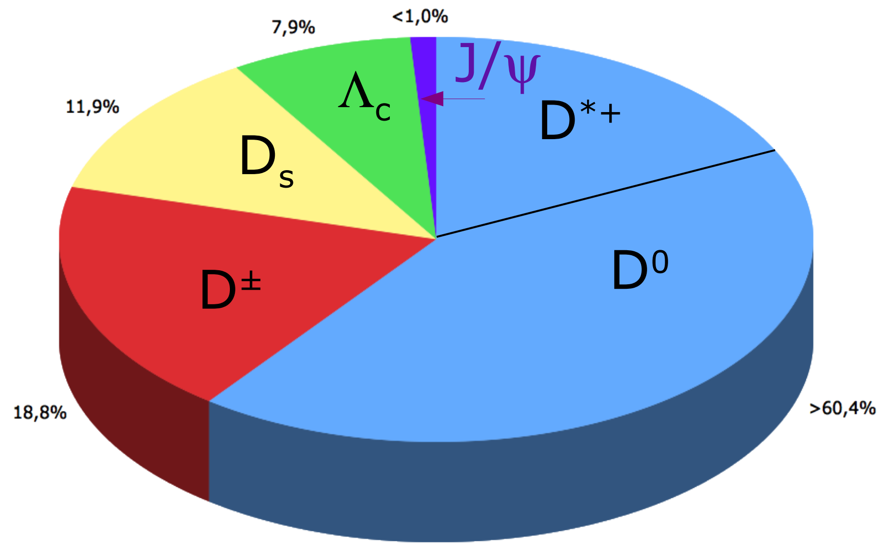
BR = 0.094 ± 0.004




$D^{*+} \rightarrow D^0 + \pi^+$

BR = 0.677 ± 0.005




**Pythia p-p 14 TeV, |y| < 1**
**ALICE PPR vol II, table 6.56**

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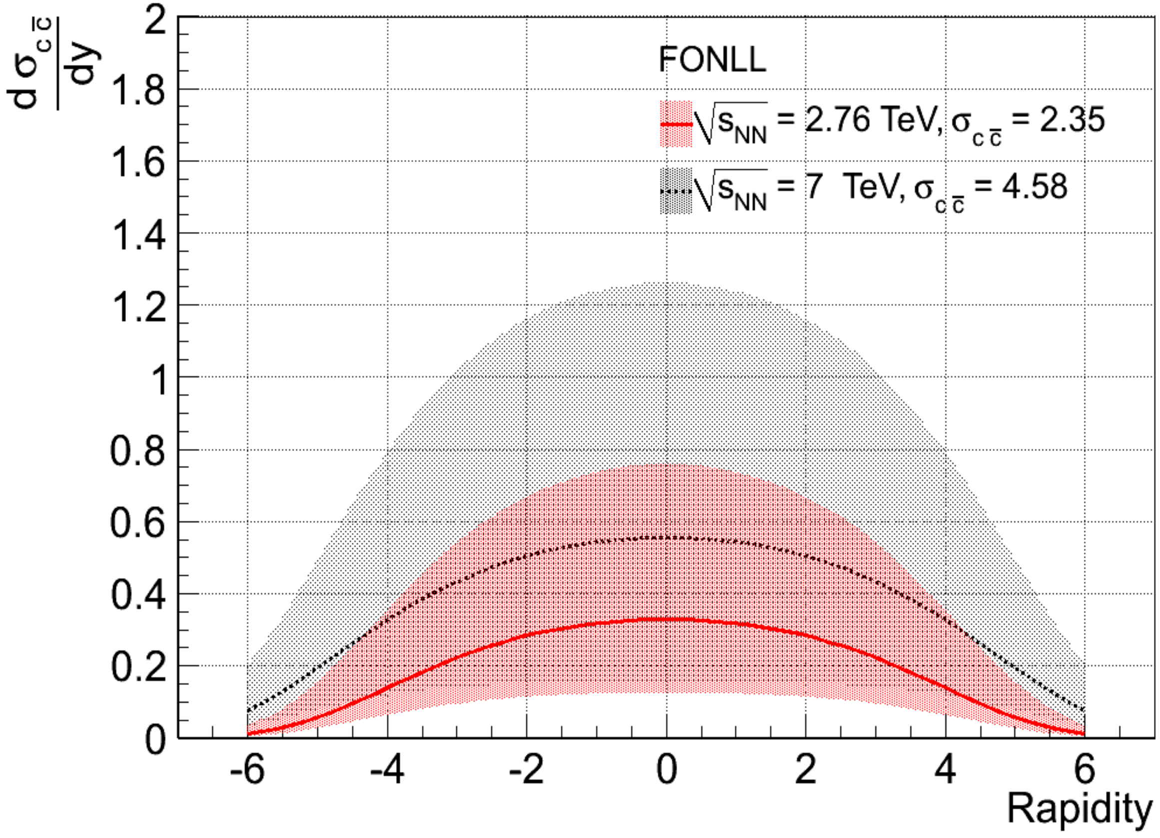
# FONLL uncertainties

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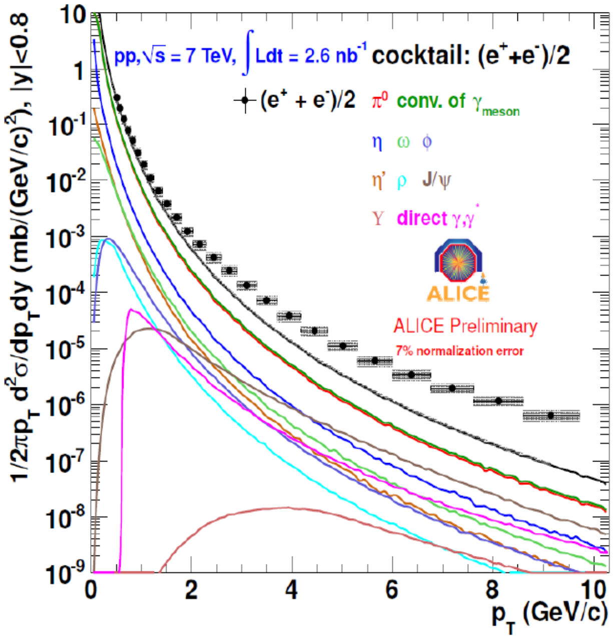
# inclusive electron spectrum and b-tagging



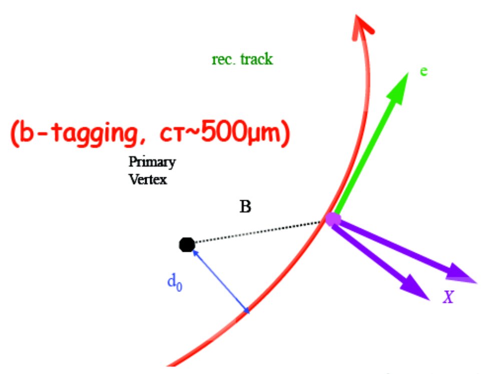

## Inclusive electron spectrum

electron ID with TOF-TRD-TPC

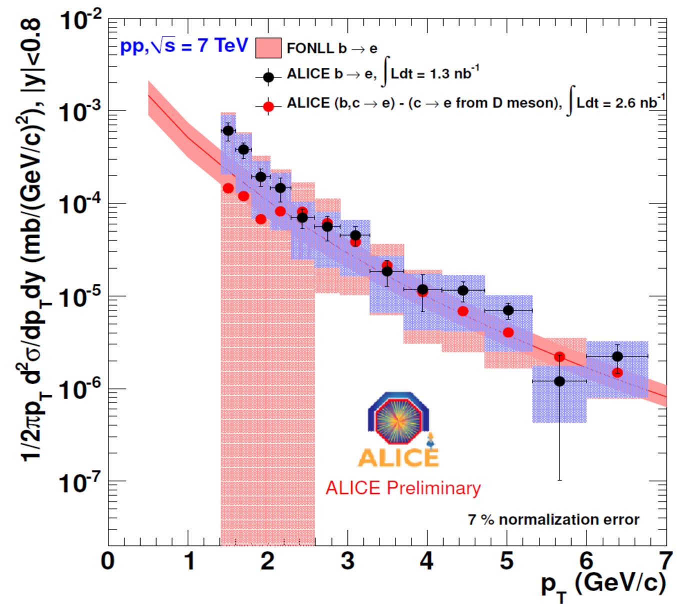
## Cocktail of known background e

- $\gamma$ conversion in the detector material
- $\pi^0$, $\eta$, $\eta'$ Dalitz-decays
- $\rho$, $\omega$ , $\phi$ decays
- $J/\psi$, $\Upsilon$ decays
- Direct $\gamma$, $\gamma^*$ (based on NLO, W. Vogelsang)

- **measured $\pi^0$ as input**
- **heavier mesons: $m_T$ scaling**
- **$J/\psi$, $\Upsilon$: ALICE and CMS measurements**
- **ratio Conversions/Dalitz: from the known material budget**




- Strategy : select electrons from displaced vertexes
→ B-tagged electron spectrum agrees with FONLL
→ HF electrons - Charm electrons (from D mesons) = B-tagged electrons
→ Measured the fraction of beauty/charm vs pt

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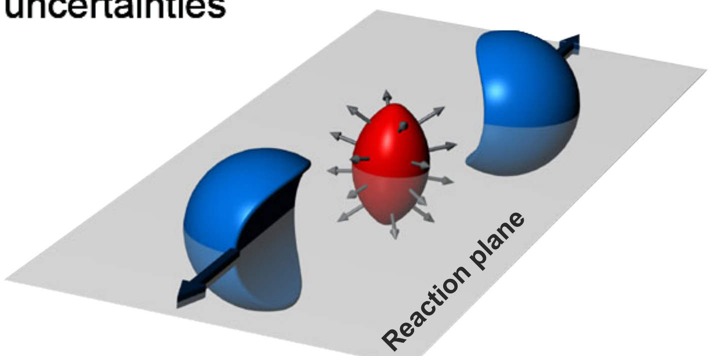
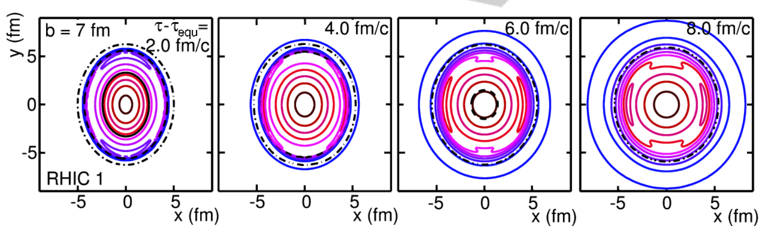
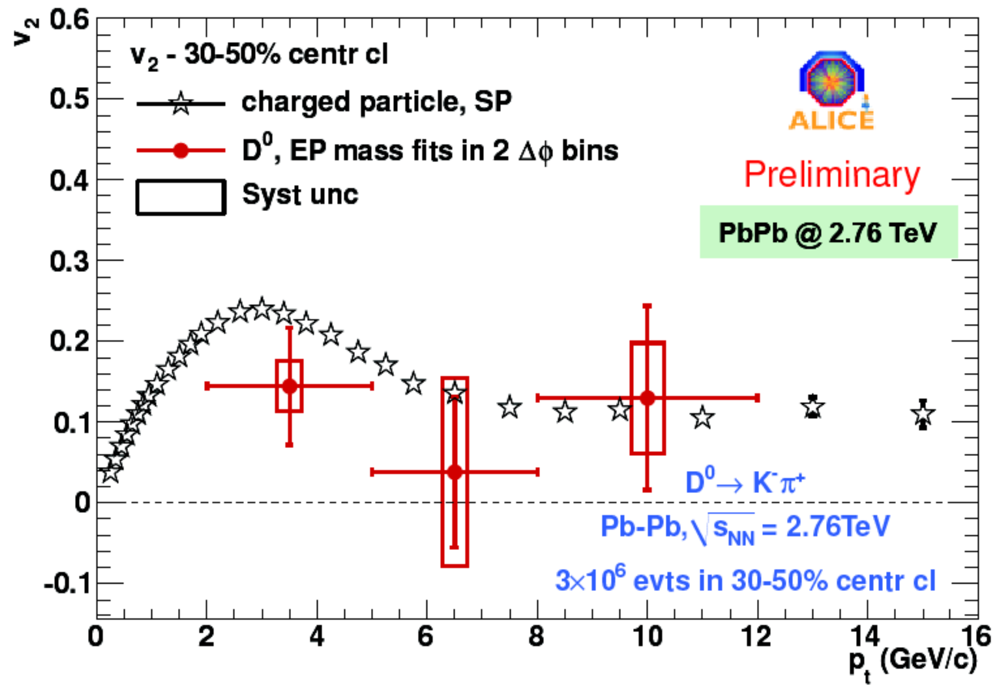
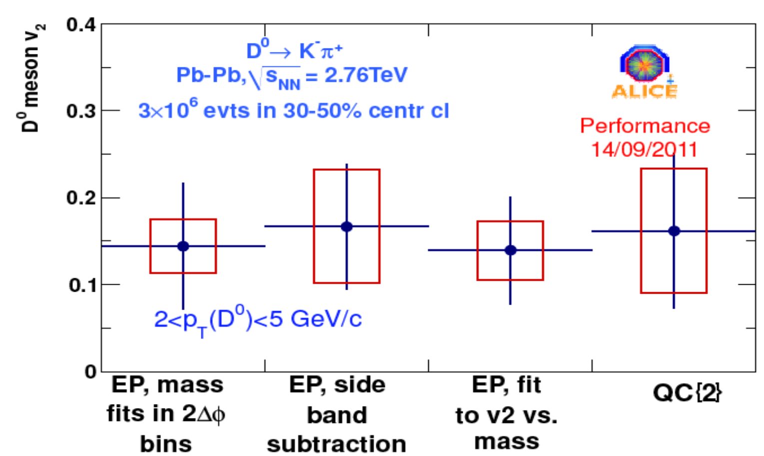
# D meson elliptic flow

- First measurement of $D^0 \rightarrow K\pi$ elliptic flow using EP $\Delta\varphi$ methods
- Results cross-checked with other EP methods and Q{2} method
- Looking forward for 2011 data (November) to reduce stat and syst uncertainties




Density, pressure gradients convert spatial anisotropy into momentum space

$$\frac{dN}{d\phi} = N\left(1 + 2v_2\cos 2(\phi - \psi)\right)$$

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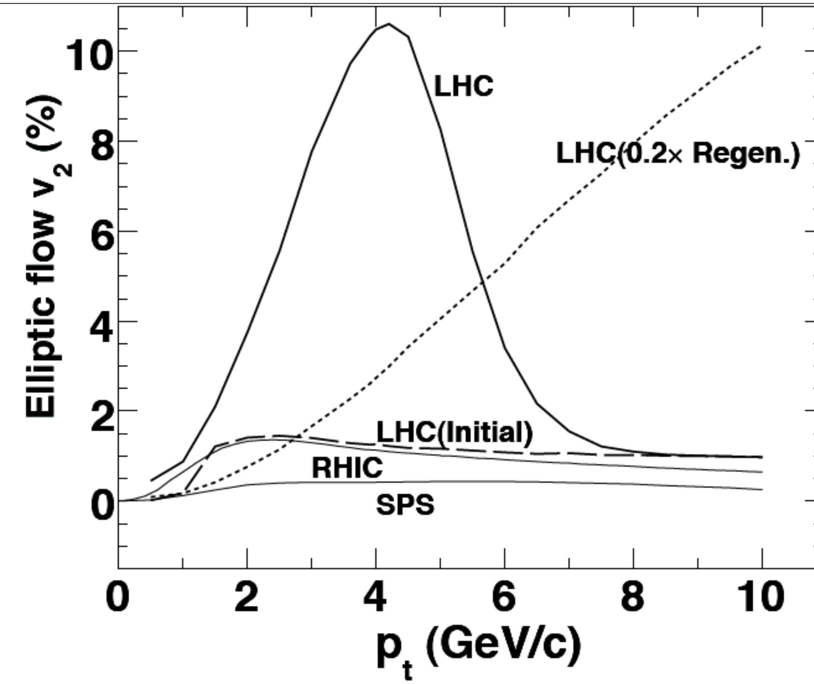
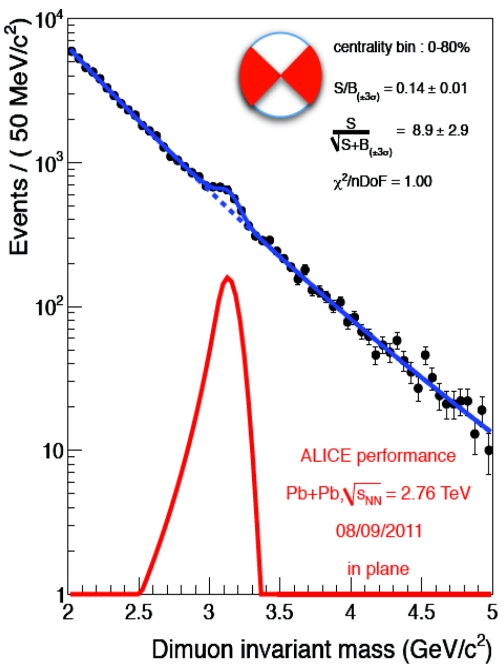
# J/ψ elliptic flow

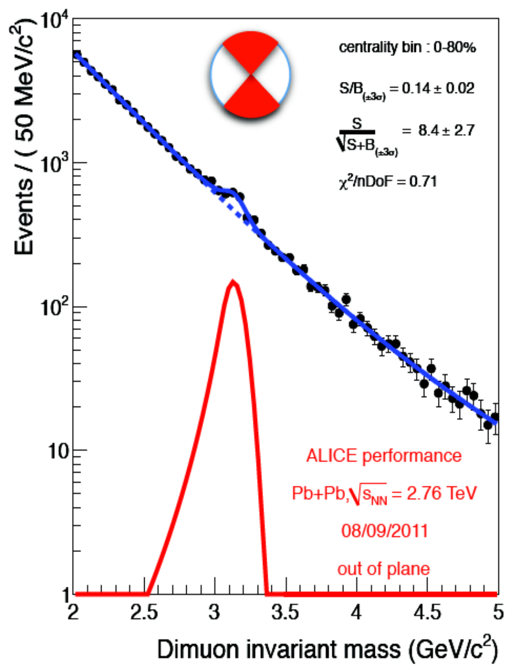
Lower energy measurements do not exhibit any significant v2 (or compatible with 0).

Regeneration or recombination of charm quarks for J/Ψ production will dominate the J/Ψ flow at LHC comparing to that at lower energies.
→ low and mid $p_T$ ranges are crucial

Y. Liu, N. Xu, P. Zhuang, Nucl.Phys.A834 (2010) 317c



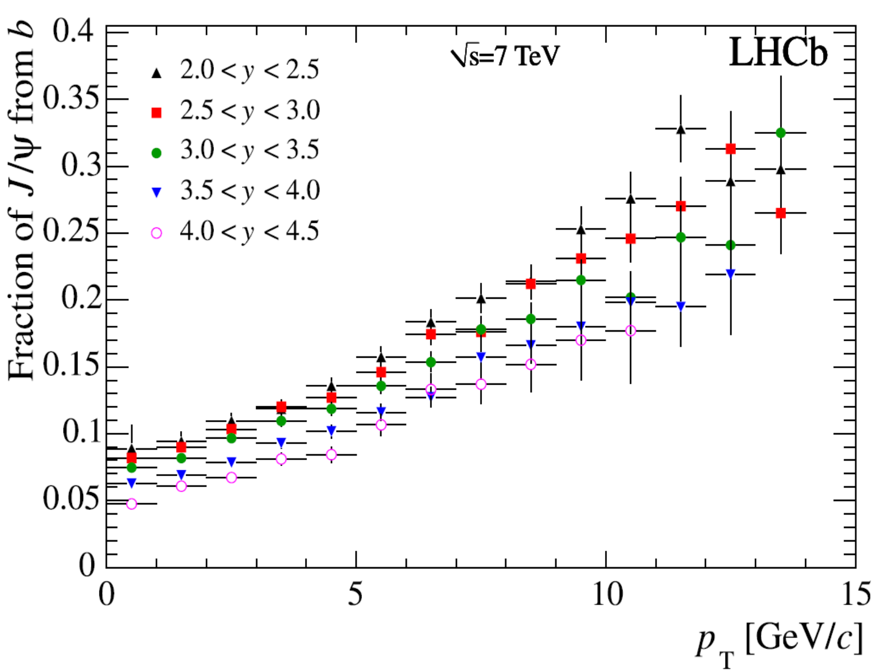

Status of the analysis in ALICE : READY
1) event plane with TPC tracks
2) only 2 ΔΦ bins (in and out of plane)
→ to low statistic with 2011 data
→ higher statistic is needed and will be there in a few months !

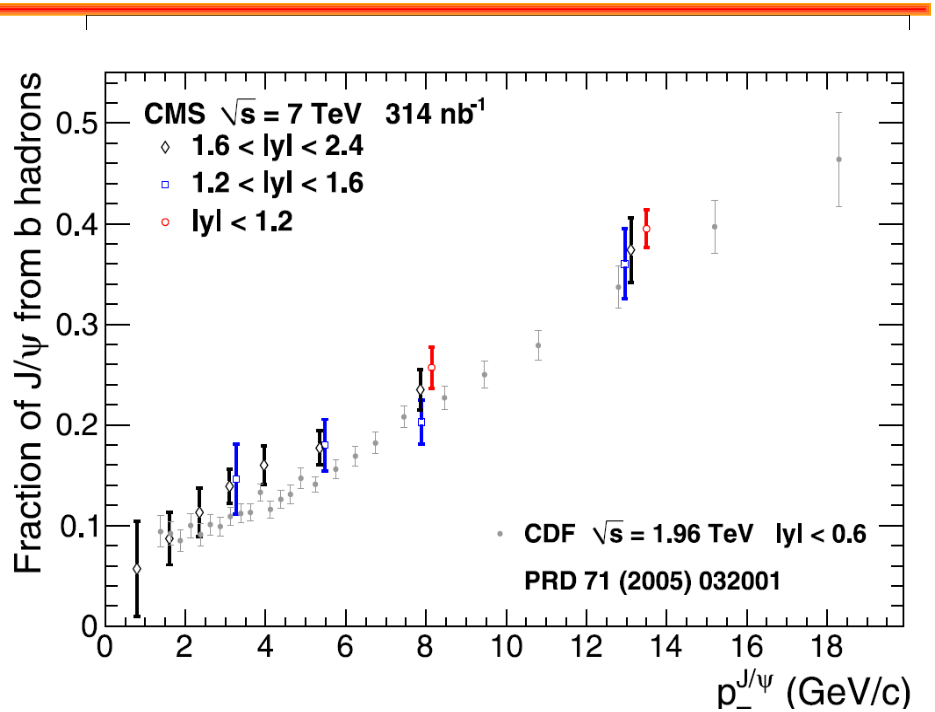
# non-prompts J/Ψs at LHC: p-p collisions

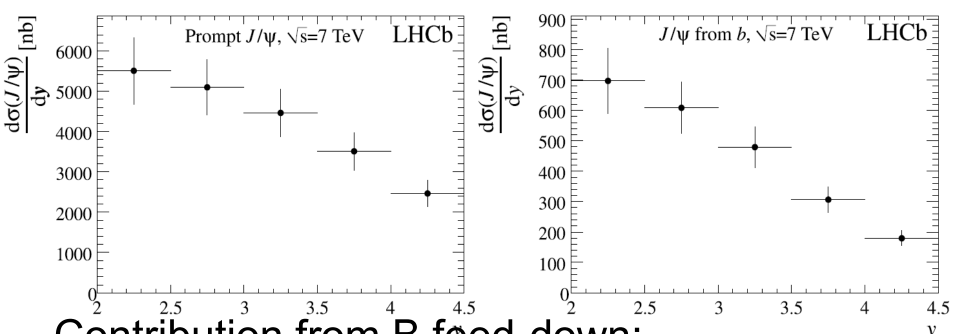
LHC experiments have excellent measurement capabilities

In p-p, LHCb is overlapping ALICE acceptance both in $p_T$ (down to 0) and y. At y=0, CMS covers the $p_T$ > 6.5 GeV/c region.

Eur. Phys. J. C71 (2011) 1645 LHCB collaboration




Contribution from B feed-down:

- ~ 10% from p-p measurement [LHCb arXiv:1103.0423]
- Rough estimation assuming simple $N_{coll}$ scaling only: ~ 11% reduction of centrality int. $R_{AA}$

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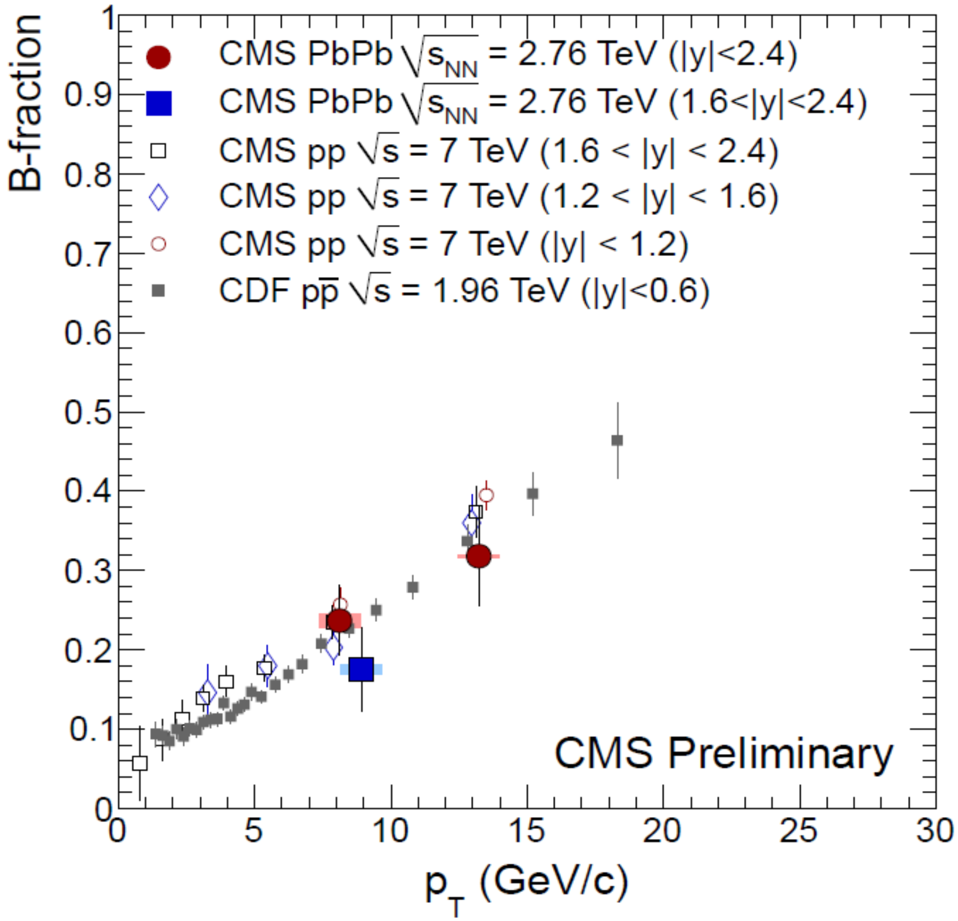
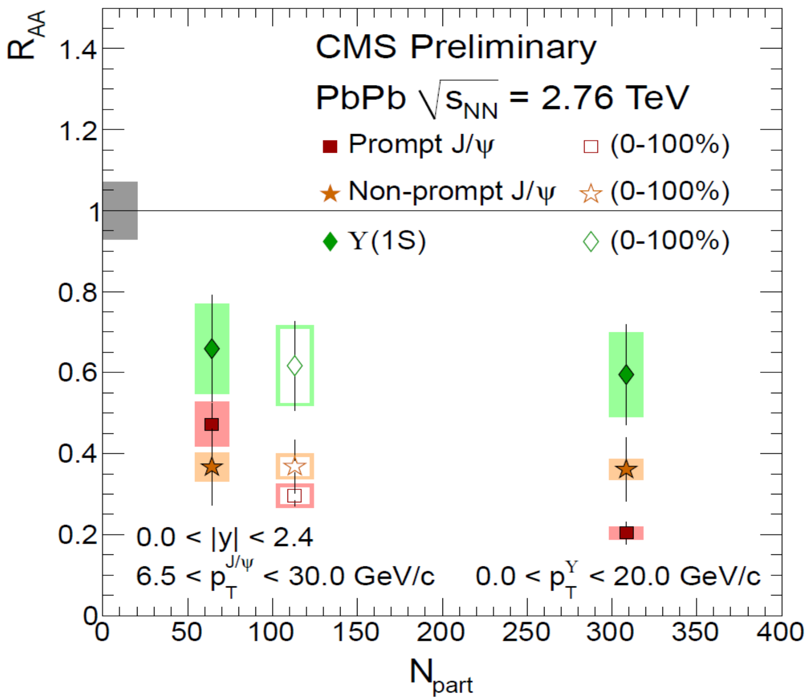
# J/Ψ ← B




1) within uncertainties J/ψ from B in Pb-Pb do not exhibit any deviation from J/ψ from B in p+p.
2) energy dependence seems quite small
→ We have estimated the non-prompt J/ψ from LHCb p+p 7 TeV to be 11%




CMS has measured a low $R_{AA}$ for non-prompts J/Ψ in |y| < 2.4 but at high $p_T$ (>6.5 GeV/c).
→ one can not extrapolate to low $p_T$...

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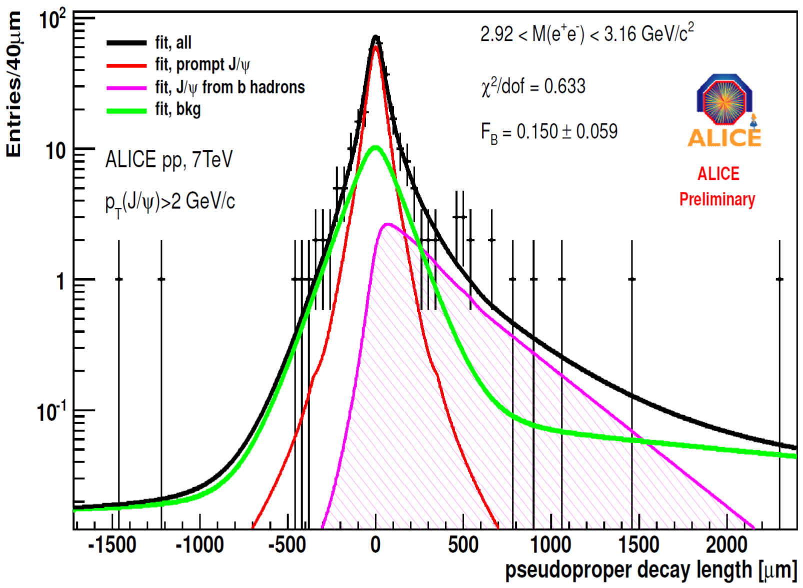
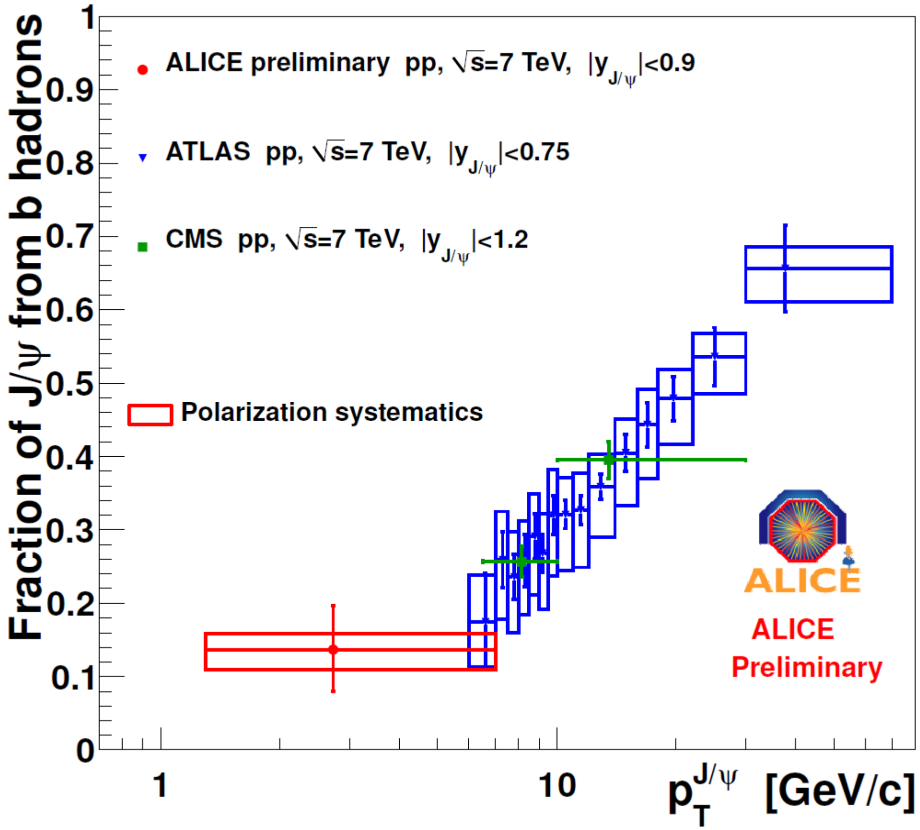
# non-prompts J/Ψs in ALICE : p-p collisions

Impact parameter resolution: $\sigma_{r\varphi}$ < 75 µm for $p_T$>1 GeV/c, at mid-rapidity
→ Contributions from B decays estimated from the pseudo-proper decay length




J/ψ from B decays at mid rapidity and low $p_T$: unique at LHC!
$\sigma_{J/\psi}$ (prompt, |y|<0.9, $p_T$>2GeV/c) = 3.2 ± 0.38 (stat) ± 0.43 (syst) + 0.82 - 0.58 (pol) ± 4% (lum) µb
→ improvements to come: higher stat. and dedicated trigger.

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# J/Ψ $R_{CP}$ at LHC

$R_{CP}$ at LHC, independent of the p-p reference. One assumes here that 40-80% centrality bin is equal to binary collision scaled p-p reference...

→ ALICE, 2.5<y<4.0

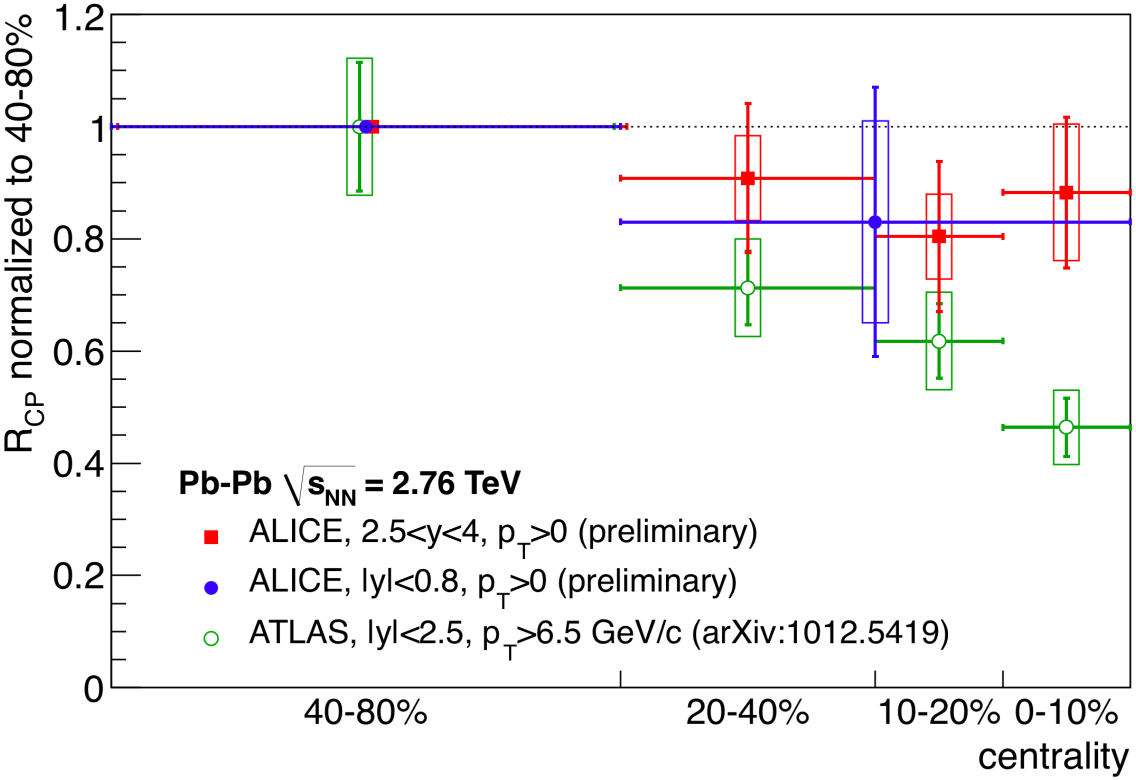
$p_T$≥0 GeV/c

→ ALICE, |y|<0.8

$p_T$≥0 GeV/c

→ ATLAS, |y|<2.4

80% J/ψ with $p_T$≥6.5 GeV/c;
Error in 40-80% centrality bin not propagated.




$$R_{CP} = \frac{Y_{J/\psi} \times <T_{AA}^{40-80\%}>}{<T_{AA}> \times Y_{J/\psi}^{40-80\%}}$$

Many systematics cancel and pp reference not needed.
→ but peripheral bin is not completely equivalent to pp

Same collision energy but VERY different phase space
→ J/ψ from beauty contamination is large at high $p_T$
→ Less suppression at low $p_T$
→ Challenging measurement at y=0 and $p_T$≥0 GeV/c
→ better to work with $R_{AA}$

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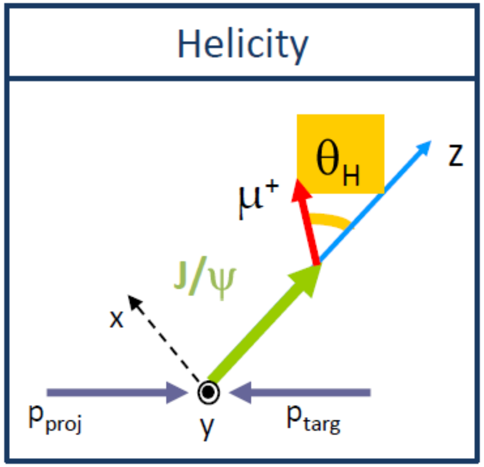
# Polarisation

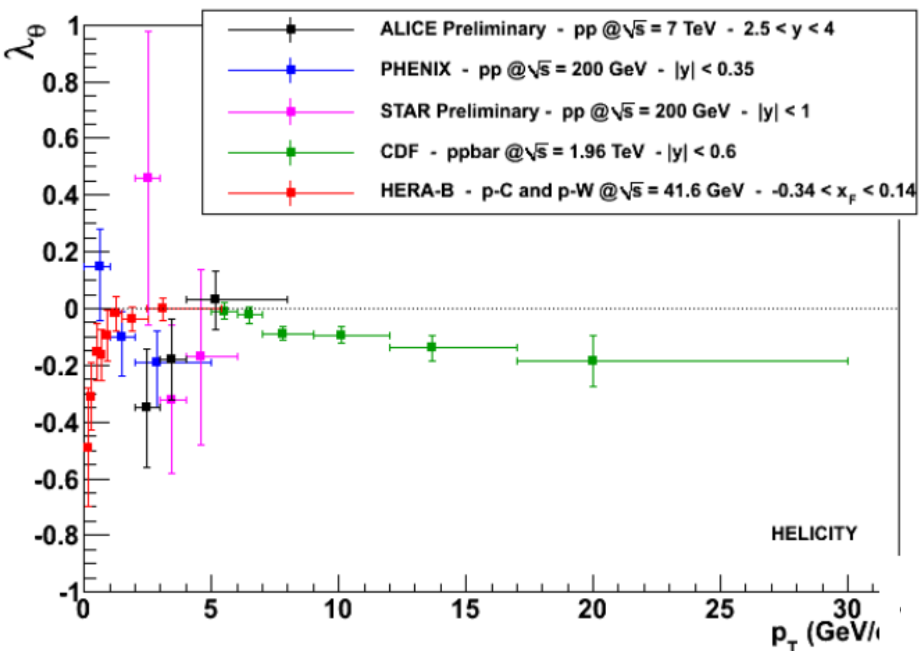
The polarization of the J/ψ can be measured through the angular analysis of its daughter particles. Taking as a reference the $\mu^+$, its angular distribution can be expressed as:

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

The reference frame can be chosen in different ways and is defined on a event-by-event basis




Direction of the quarkonium in the C.M. frame of the collision.




Disclaimer: taking into account the very different kinematical domains and the wide range of the center-of-mass energies we don't expect a $p_T$ scaling

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