Measurement of J/ψ production in pp collisions at $\sqrt{s}$=2.76 TeV and 7 TeV with ALICE

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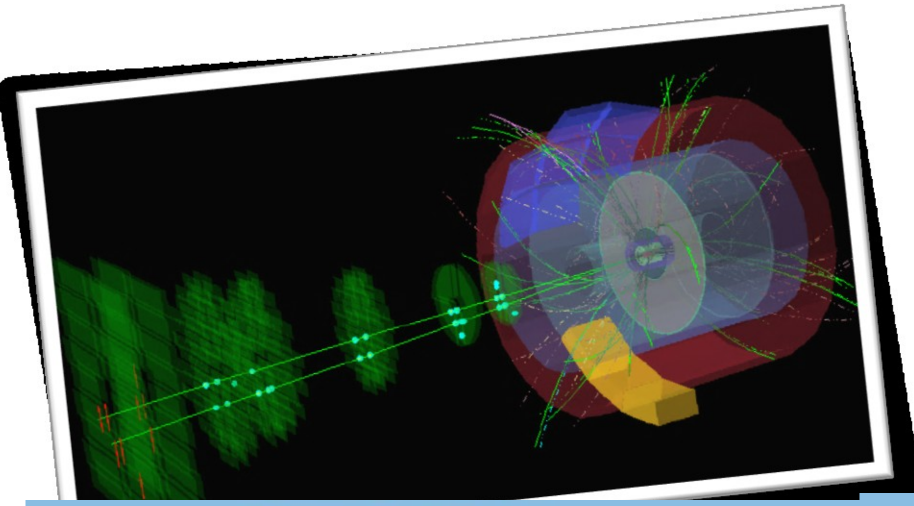
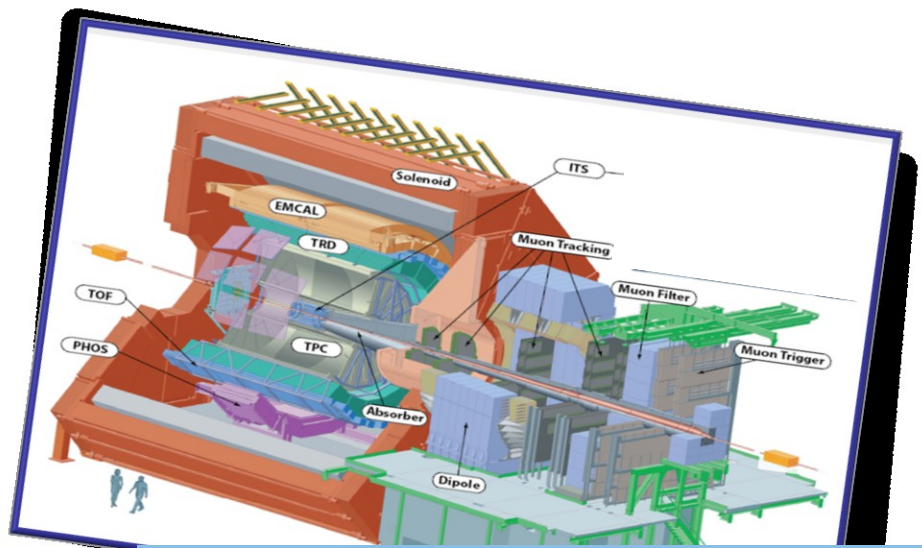


QUARK MATTER 2011
23-28 May 2011 – Annecy, France

Outlook

- J/ψ production cross section in pp collisions at $\sqrt{s}$= 7 TeV
- J/ψ production cross section in pp collisions at $\sqrt{s}$= 2.76 TeV (reference for PbPb data at $\sqrt{s}$= 2.76 TeV)
- Multiplicity dependence of J
  at $\sqrt{s}$= 7 TeV
- Prospects:
  - J/ψ polarization in pp collisions at $\sqrt{s}$= 7 TeV
  - J/ψ from B decays in pp collisions at $\sqrt{s}$= 7 TeV



Quarkonium measurement in ALICE

- Quarkonium in ALICE can be measured in two ways:
  - in the central barrel in the e^+e^- channel ($|y|<0.9$)
  - in the forward spectrometer in the $\mu^+\mu^-$ channel ($2.5<y<4$)

- Acceptance coverage at both central and forward rapidities down to zero p_T (unique at LHC at $y=0$)

- 3 sources of J/ψ
  - Direct production
  - Feed down from heavier charmonium states

  } Prompt J/ψ

  - J/ψ from b-hadron decay

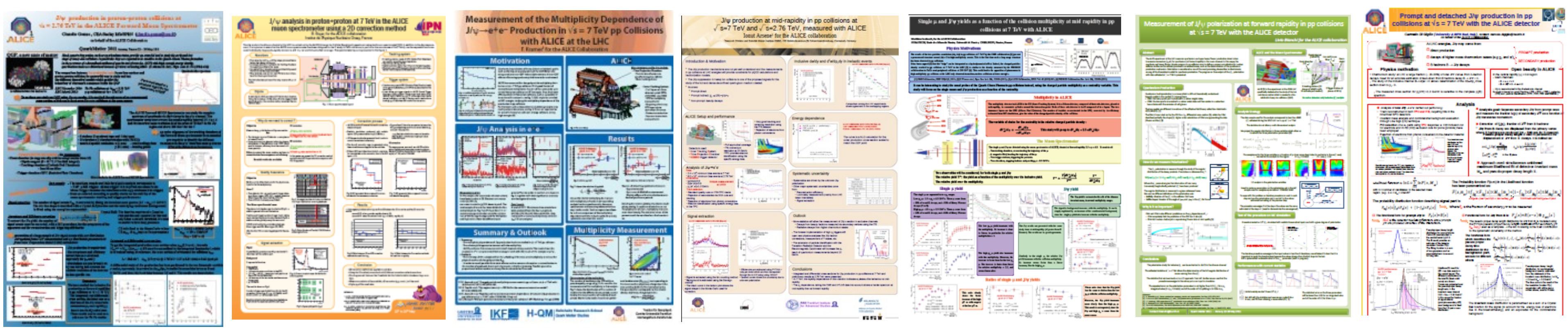
  } J/ψ from B
  - → feasible in the central barrel, thanks to the good impact parameter resolution ($\sigma_{r\phi}$ < 75 μm for p_T>1 GeV/c)
  - → forward detection more difficult
    - → 3-muon events
    - → B cross section from single muon measurement

- ALICE results refer to inclusive J/ψ production

Quarkonium Posters in ALICE

➡ Details on the results presented in this talk will be given in these posters

- J/ψ production at mid-rapidity in pp collisions at $\sqrt{s}$=2.76 and 7 TeV.
  I. Arsene
- J/ψ polarization at forward rapidity in pp collisions at $\sqrt{s}$=7 TeV.
  L. Bianchi
- J/ψ analysis in pp at 7 TeV (forward rapidity) using a 2D correction method
  B. Boyer
- Prompt and detached J/ψ production in pp collisions at $\sqrt{s}$=7 TeV.
  C. Di Giglio
- Forward J/ψ production in pp collisions at $\sqrt{s}$=2.76 TeV.
  C. Geuna
- Multiplicity dependence of $J/\psi \rightarrow e^+e^-$ production in $\sqrt{s}$=7 TeV pp.
  F. Kramer
- Multiplicity dependence of $J/\psi \rightarrow \mu^+\mu^-$ production in $\sqrt{s}$=7 TeV pp.
  M. Lenhardt



J/ψ in pp collisions

Results presented in this talk refers to two data taking periods:

- 2010 → pp collisions @ $\sqrt{s}$ = 7 TeV
- 2011 → pp collisions @ $\sqrt{s}$ = 2.76 TeV

Triggers:

- Minimum bias interaction trigger
- Single muon: forward muon in coincidence with minimum bias trigger

Statistics:
Integrated cross section results are based on the following luminosity

Energy	Integrated luminosity	
	$J/\psi \rightarrow \mu^+\mu^-$	$J/\psi \rightarrow e^+e^-$
7 TeV	15.6 nb^{-1}	3.9 nb^{-1}
2.76 TeV	20.2 nb^{-1}	1.1 nb^{-1}

Same analysis strategy applied to the data collected at $\sqrt{s}$ = 7 TeV and 2.76 TeV (described in details in this second case)

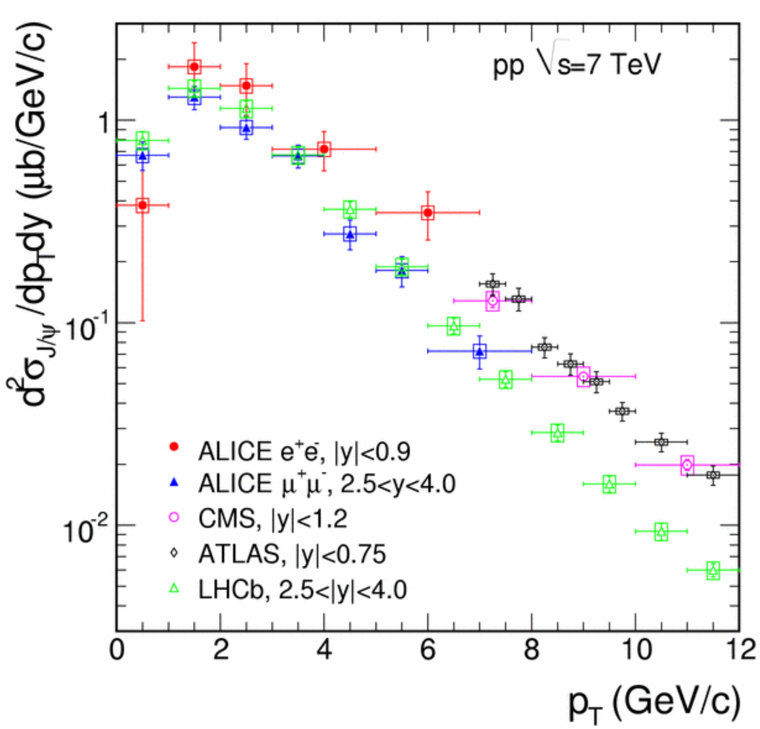
J/ψ in pp collisions @ √s=7 TeV

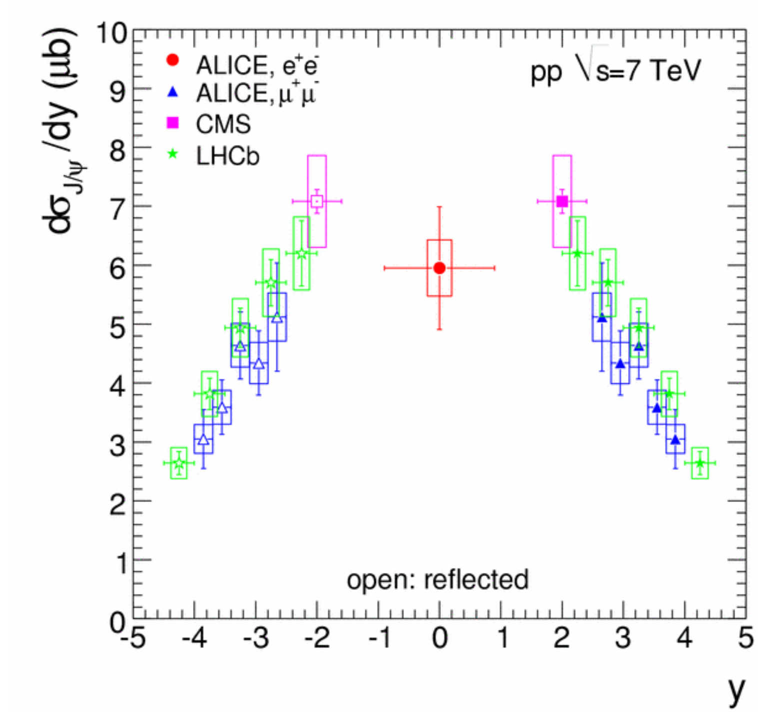
- The integrated J/ψ production cross sections are (arXiv:1105.0380):

$\sigma_{J/\psi}$ (2.5<y<4)= 6.31±0.25(stat)±0.80(syst)+0.95(λ_{CS}=1)-1.96(λ_{CS}=-1) μb

$\sigma_{J/\psi}$ (|y|<0.9)= 10.7±1.2(stat)±1.7(syst)+1.6(λ_{HE}=1)-2.3(λ_{HE}=-1) μb

- The y and p_T dependence of the J/ψ production in ALICE are compared to the results of the other LHC experiments





Higher pt will be reached with full 2010 statistics

(ATLAS Coll, arXiv:1104.3038, CMS Coll, arXiv:1011.4193, LHCb Coll, arXiv:1103.0423)

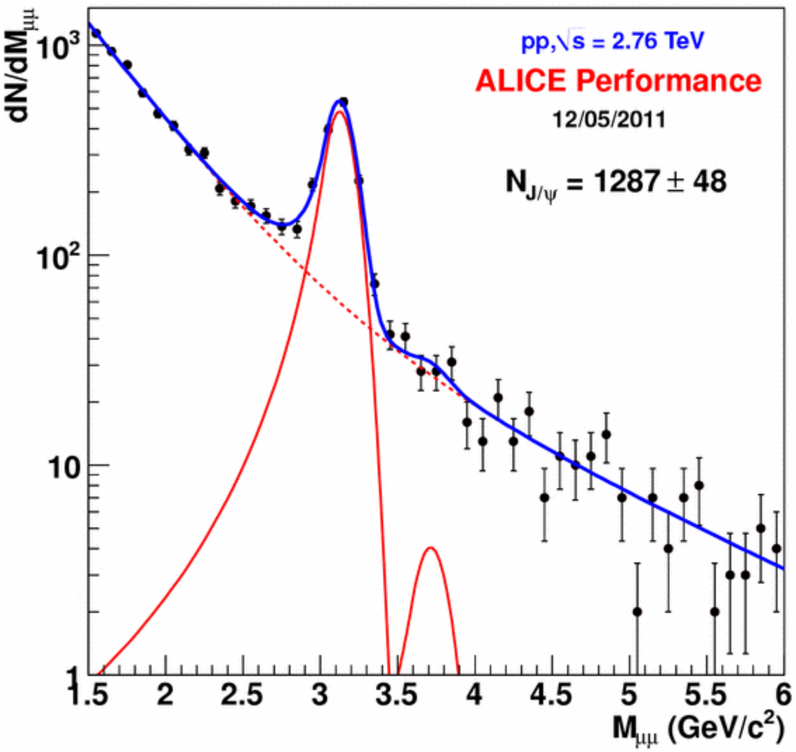
$J/\psi \rightarrow \mu^+\mu^-$ in pp @ $\sqrt{s}$=2.76 TeV

Data sample:

- 3 days of data taking in March 2011, corresponding to L= 20.2 nb^{-1}

Event Selection:

- at least one interaction vertex in the silicon pixel detector
- at least one muon reconstructed in the tracking and trigger chambers satisfying the trigger algorithm
- cut on the track position at the end of the front absorber
- $2.5 < y_{J/\psi} < 4$, $p_{T\ J/\psi} > 0$ GeV/c



Signal extraction

The J/ψ yield is extracted from a fit to the invariant mass spectrum assuming

- Crystal Ball shape for the signal (J/ψ and ψ', with the ψ' parameters bound to the J/ψ)
- double exponential for the background

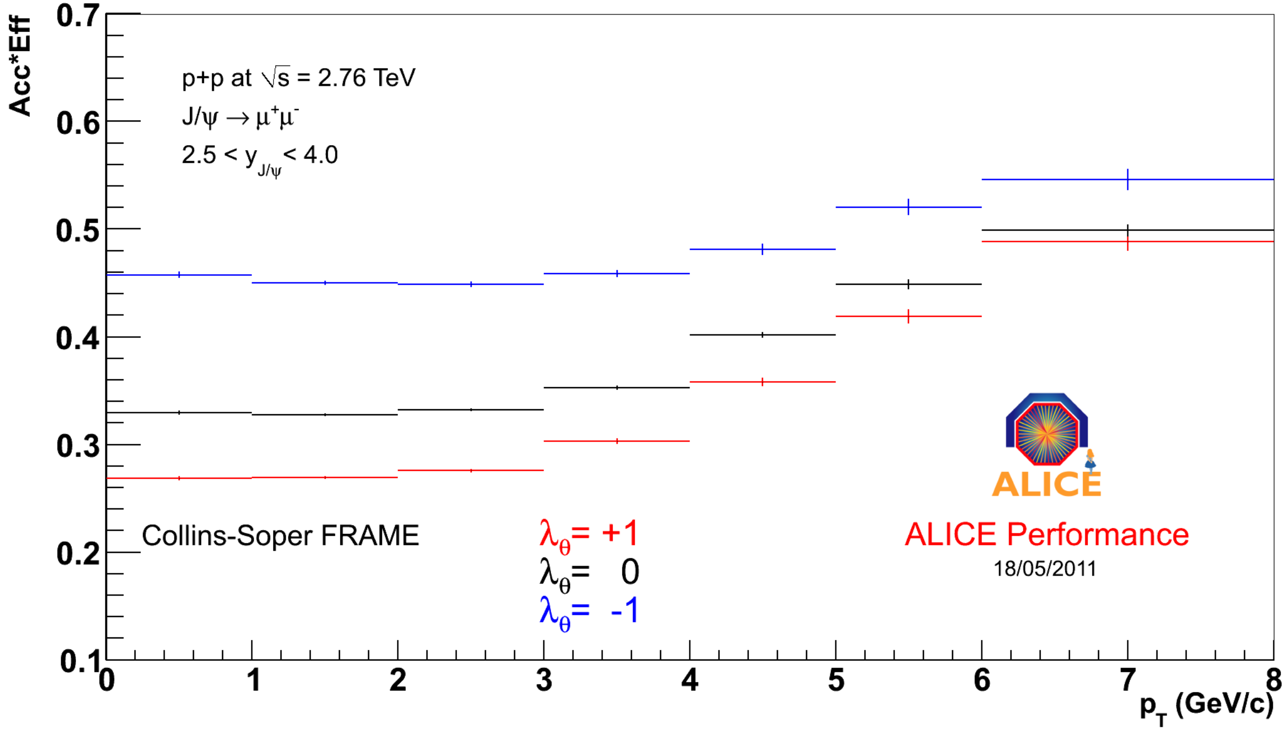
$N_{J/\psi}$ = 1287 ± 48

S/B (3σ) ~ 3.5

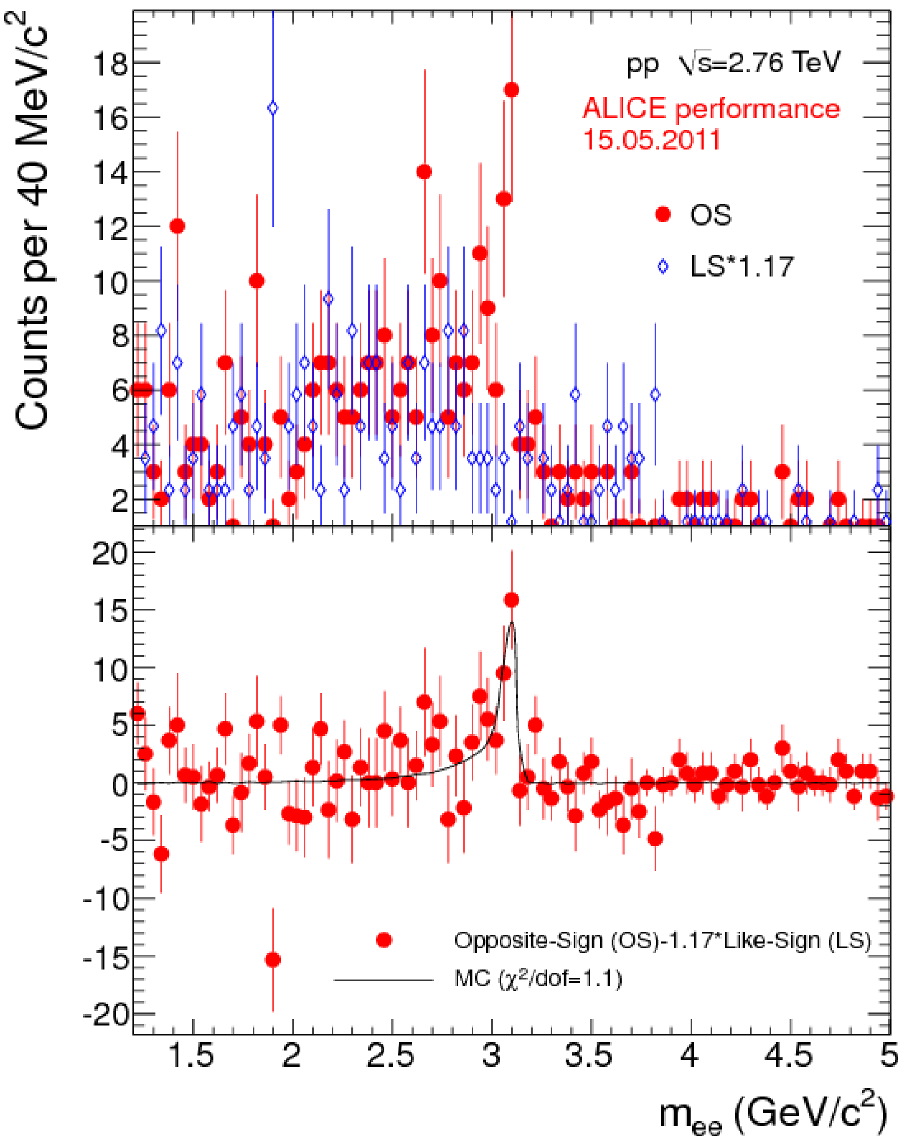
(was 1.8 @ 7TeV)

$J/\psi \rightarrow \mu^+\mu^-$: acceptance x efficiency

- Based on simulations reproducing the detector status
  - Realistic J/ψ y and p_T distributions
    - $p_T \rightarrow$ CDF extrapolation
    - $y \rightarrow$ CEM calculation
  - 1D correction (as for the $\sqrt{s}$=7 TeV analysis) has been adopted for the study of the J/ψ p_T and y differential distributions



$J/\psi \rightarrow e^+e^-$ in pp @ 2.76 TeV



Analysis is based on L= 1.1 ± 0.1 nb^{-1}

$|y_{J/\psi}|<0.9$, $p_{T\,J/\psi}>0$ GeV/c

Track selection:

$|\eta^{e+,e-}|<0.9$ and $|y_{J/\psi}|<0.9$

$p_T^{\,e+,e-} > 1$ GeV/c

- Tracks with hits in the TPC and ITS (at least one in the pixel detector)
- Electron PID based on TPC dE/dx

Signal extraction:

Yield extracted from bin counting (above like-sign background) in M_{e+e-}=2.92-3.16 GeV/c^2

$N_{J/\psi} = 41 \pm 9$

J/ψ@2.76TeV:integrated cross section

$$\sigma_{J/\psi} = \frac{N_{J/\psi}}{(A\times\varepsilon)\ BR(J/\psi\to l^+l^-)\ L_{int}}$$

L_{int} has been derived from a van der Meer scan

J/ψ → μ⁺μ⁻

$N_{J/\psi}$ = 1287±48(stat)±77(syst)

$A\times\varepsilon$ = 0.352±0.001(stat)±0.009(syst)

$BR\ J/\psi\to\mu^+\mu^-$ = 0.0593±0.0006(syst)

L_{int} = 20.2±1.6(syst) nb^{-1}

J/ψ → e⁺e⁻

$N_{J/\psi}$ = 41±9(stat)±3(syst)

$A\times\varepsilon$ = 0.094±0.001(stat)±0.009(syst)

$BR\ J/\psi\to\mu^+\mu^-$ = 0.0594±0.0006(syst)

L_{int} = 1.1±0.1(syst) nb^{-1}

$$\sigma_{J/\psi}(2.5<y<4)=3.46\pm0.13(stat)\pm0.32(syst)\pm0.28(lumi)^{+0.55}_{-1.11}(pol)\ \mu b$$

$$\sigma_{J/\psi}(|y|<0.9)=6.44\pm1.42(stat)\pm0.88(syst)\pm0.52(lumi)^{+0.64}_{-1.42}(pol)\ \mu b$$

(see next slide for details on systematic uncertainties)

- $\sigma_{J/\psi}$ is obtained at the same energy as the PbPb data

→ it is used as the pp reference in the R_{AA} evaluation →Talk P. Pillot

J/ψ @2.76 TeV: systematic uncertaintie

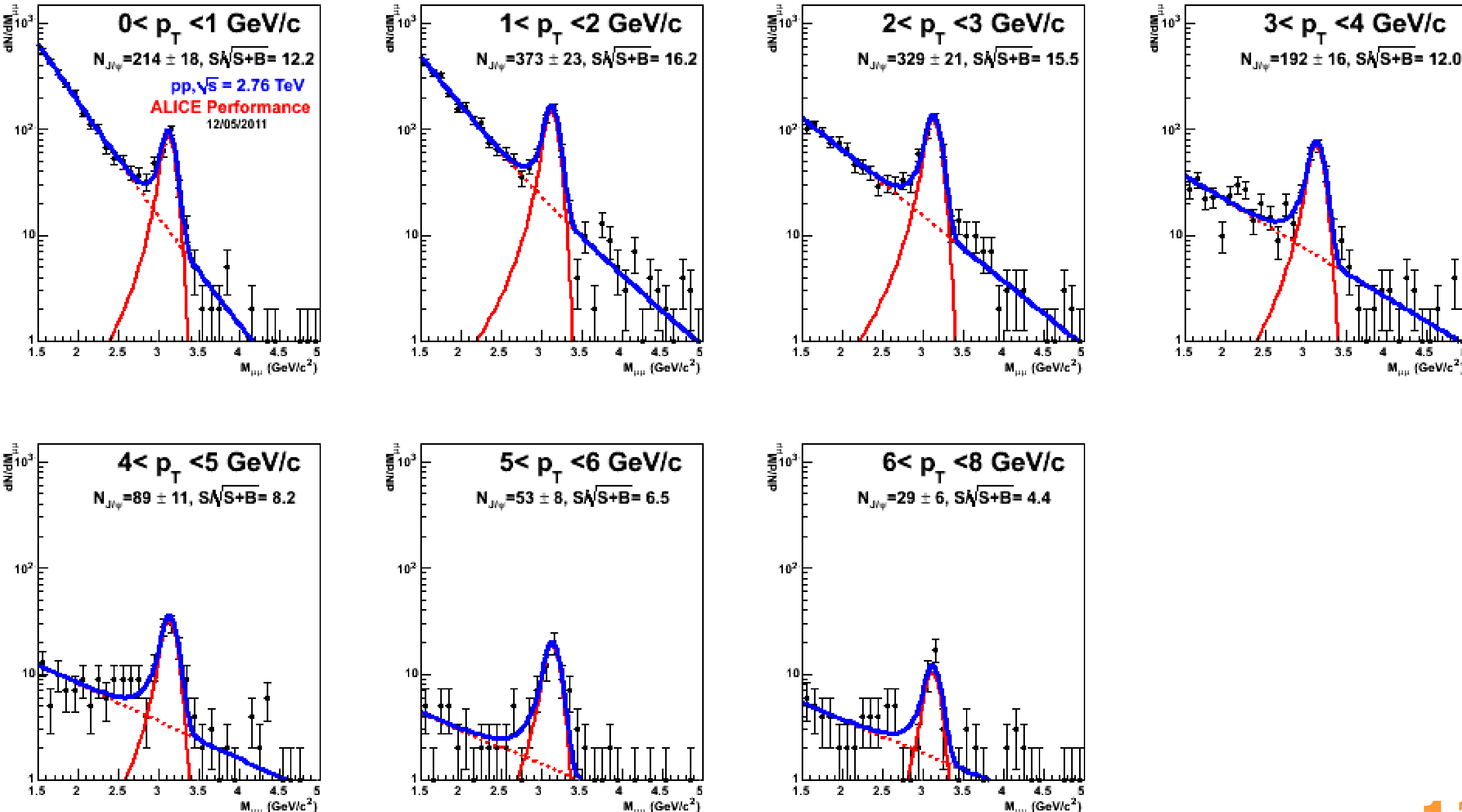
Source of systematic uncertainty	$J/\psi \to \mu^+\mu^-$	$J/\psi \to e^+e^-$
signal extraction	6 %	8.5 %
Acceptance inputs	2.5%	1 %
Trigger efficiency	4%	-
Reconstruction efficiency	4%	11 %
Trigger enhancement	3%	-
Luminosity	8%	8 %
Total systematic uncertainty	**12.1 %**	**16.1%**

Polarization	λ=-1 λ=+1	λ=-1 λ=+1
Collins-Soper	+32 -16 %	+19 -13 %
Helicity	+24 -12 %	+21 -15 %

➡ Total systematic uncertainties similar to the ones at 7 TeV

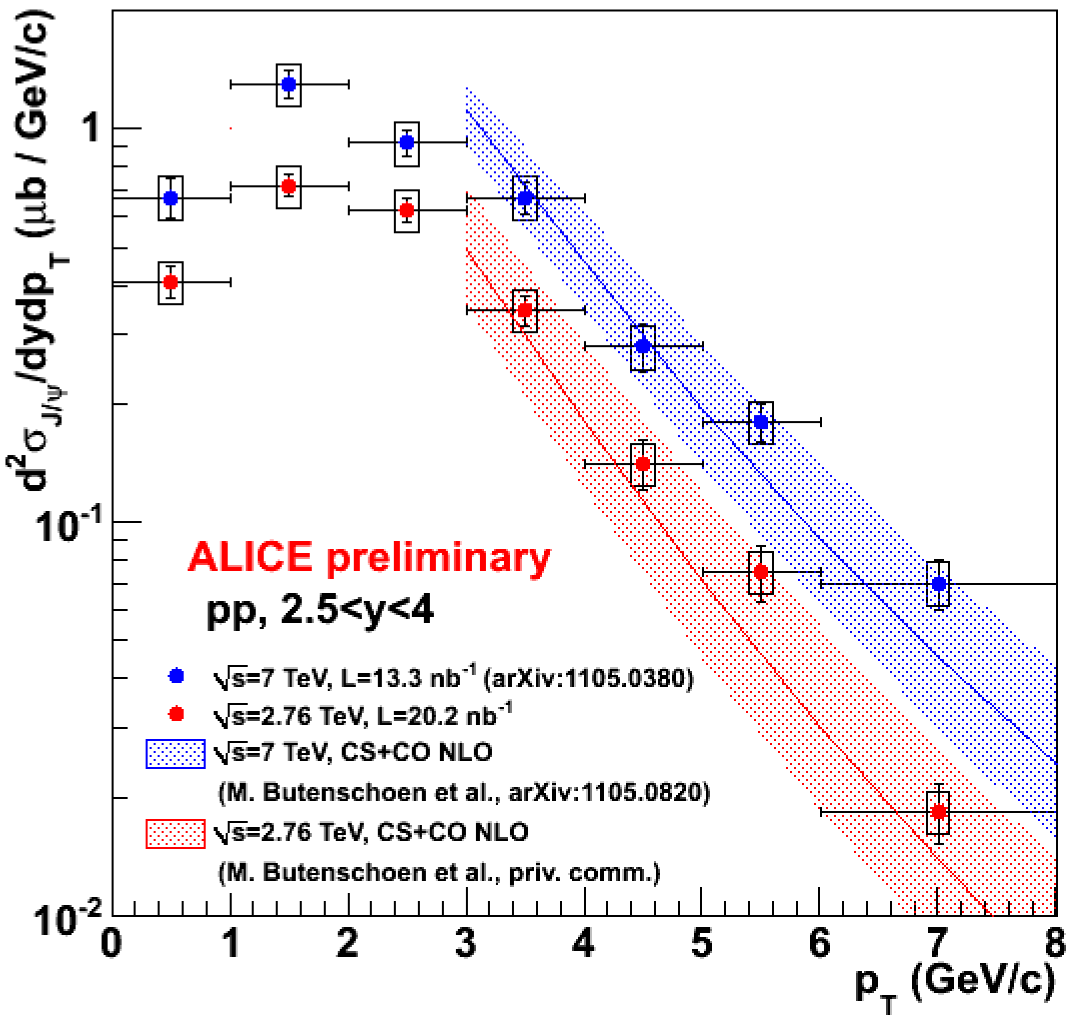
$J/\psi \rightarrow \mu^+\mu^-$: differential distributions

- Signal has been extracted in 7 p_T bins (or 6 y bins) in the kinematic range $2.5<y<4$, $0<p_T<8$ GeV/c



$J/\psi \rightarrow \mu^+\mu^-$: $d^2\sigma/dydp_T$

- Comparison between results obtained at $\sqrt{s}$= 2.76 and 7 TeV

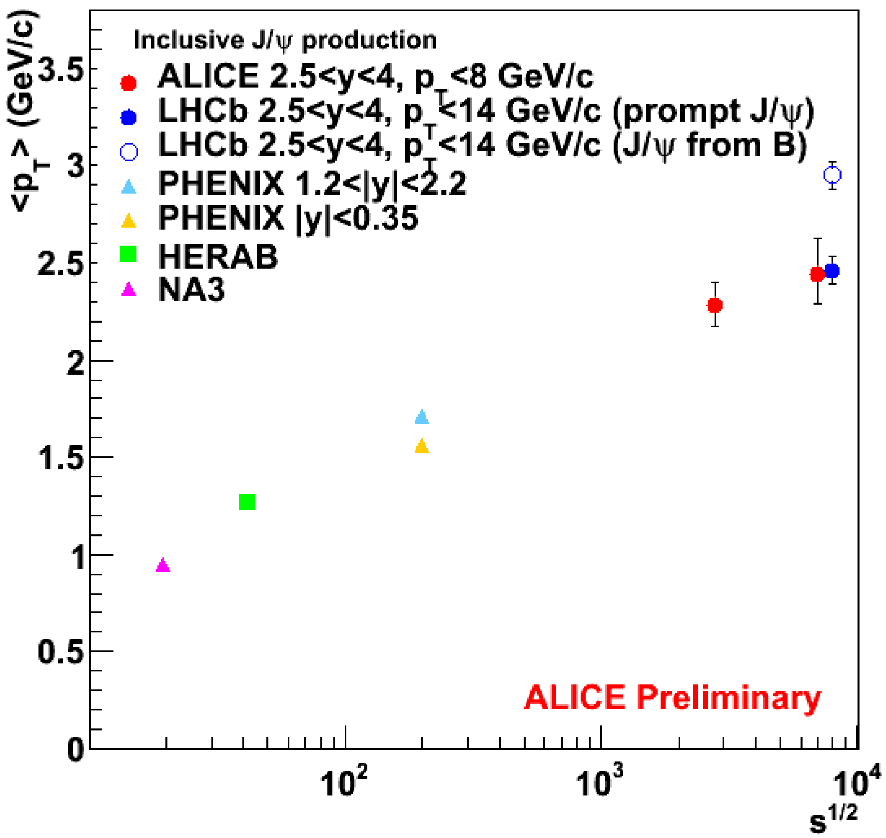


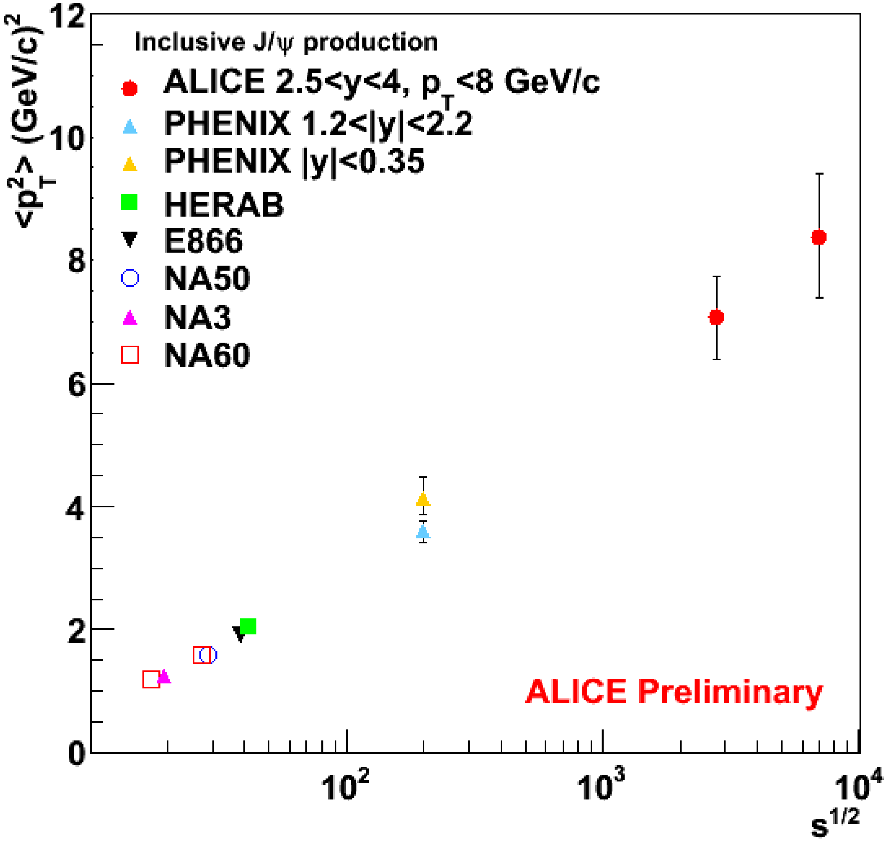
- Good agreement between $d^2\sigma/dydp_T$ with NLO NRQCD calculations

$J/\psi \rightarrow \mu^+\mu^-$: $<p_T>$ and $<p_T^2>$

- The ALICE results on J/ψ $<p_T>$ and $<p_T^2>$, extracted from fits to the p_T differential distributions, can be compared to results from other experiments

$$\frac{d\sigma}{dp_T} \propto \frac{p_T}{\left(1+\left(\frac{p_T}{p_0}\right)^2\right)^x}$$

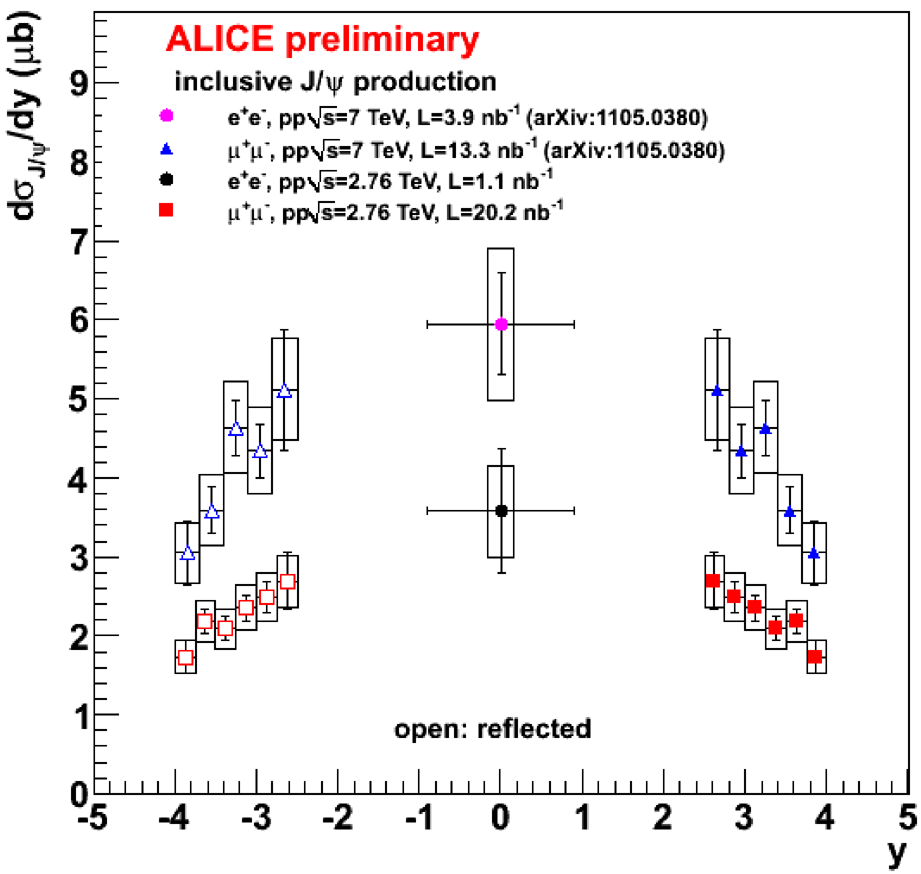


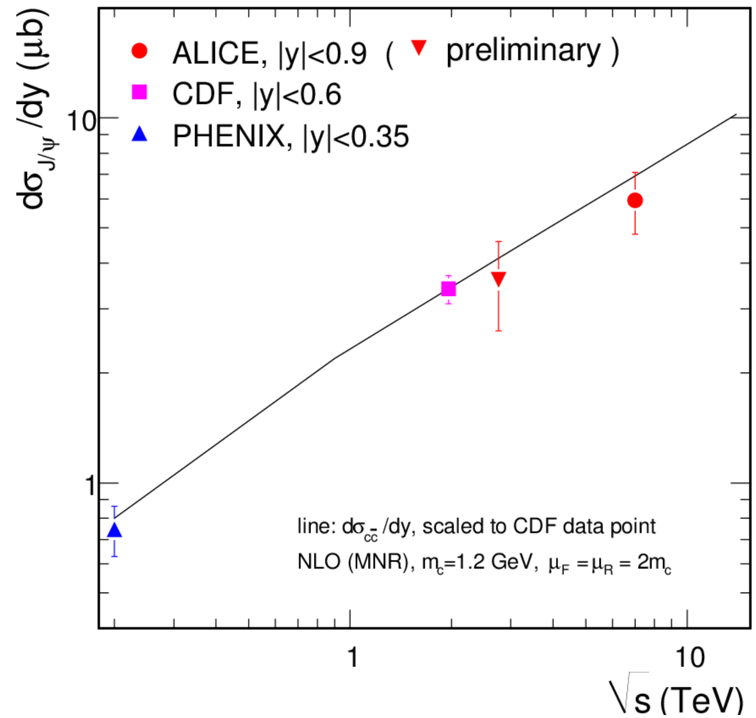


- Approximately logarithmic increase with $\sqrt{s}$ continues up to LHC energy

J/ψ: dσ/dy

- J/ψ production cross section measured in the two rapidity ranges covered by the ALICE experiment





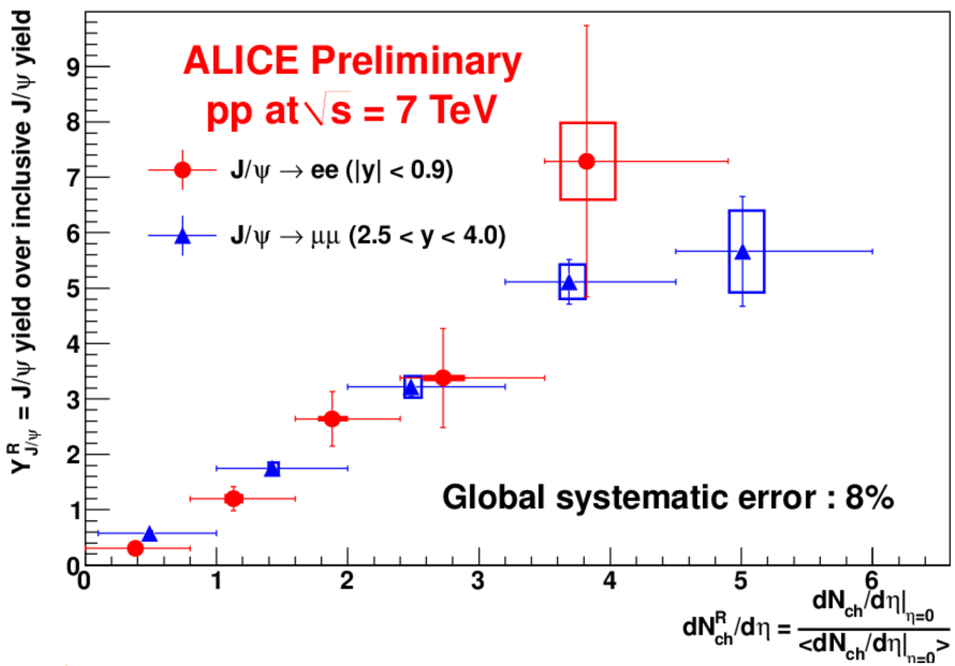
- The cross section obtained at mid-rapidity is compared to PHENIX and CDF results

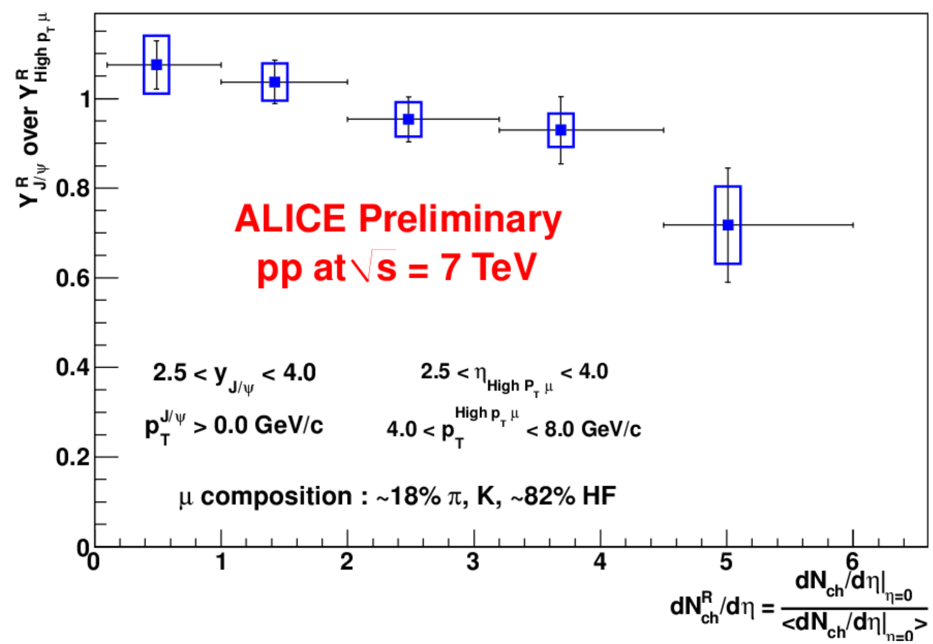
  The curve is the MNR NLO calculation for the $c\bar{c}$ production cross section, scaled to match the CDF point

J/ψ production versus $dN_{ch}/d\eta$ @7 TeV

The highest charged particle multiplicity ($dN_{ch}/d\eta_{max}$ ~30) reached in pp @ 7 TeV is comparable with CuCu collisions (50-55%) @ 200 GeV

→ heavy-ion related effects also in pp at LHC?





The J/ψ yield, to a good approximation, linearly increases with charged particle multiplicity

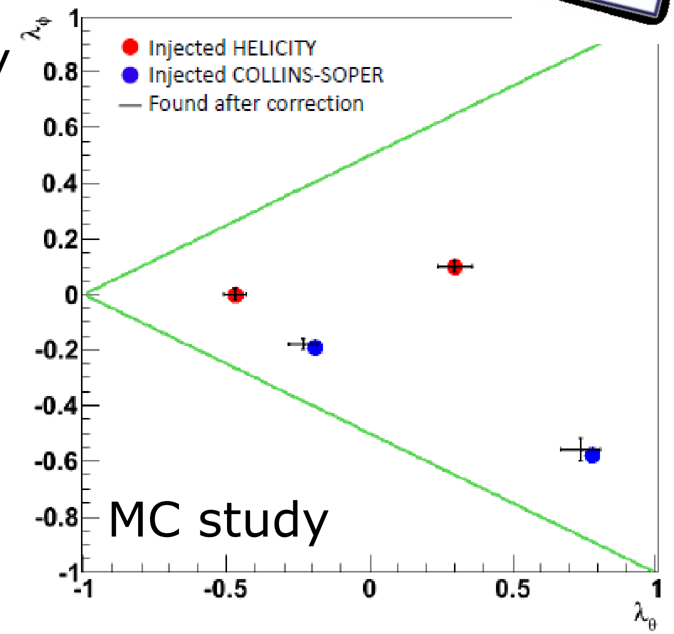
J/ψ yield increases more slowly wrt muons from heavy flavour decays.
→ Theoretical interpretations needed!

Prospects: J/ψ polarization

- Crucial observable for comparison with theory
  Puzzling results from Tevatron

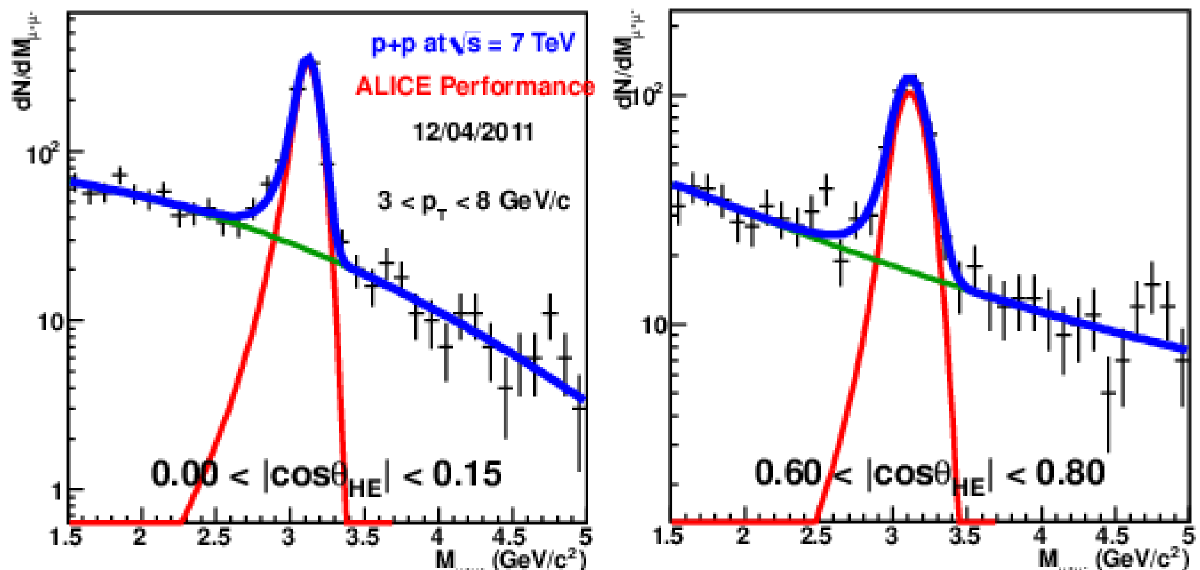
- The total collected statistics at $\sqrt{s}$ = 7 TeV allows the determination of the full angular distribution of the J/ψ decay leptons.

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



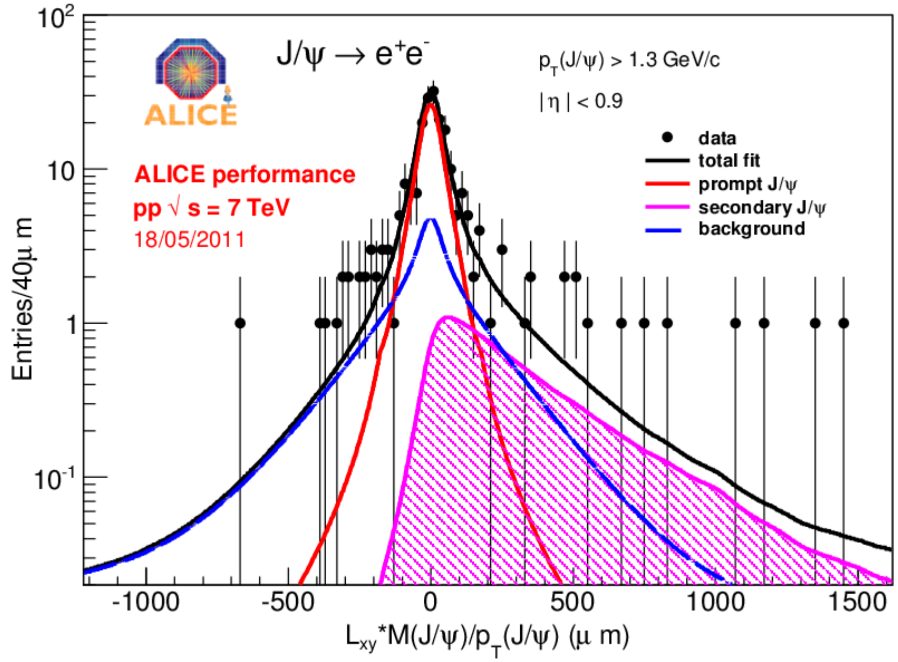
- 1D efficiency correction with an iterative procedure works well at the MC level.

- In the muon channel, the expected error on the polarization parameters is smaller than 0.15 (λ_θ) for an analysis in the range $3<p_T<8$ GeV/c



Prospects: J/ψ from B decay

- Possible at central rapidity, thanks to the good impact parameter resolution ($\sigma_{r\phi}$ < 75 μm for p_T>1 GeV/c)
- B decay contribution will be estimated from a fit to the pseudo proper decay time L_{xy} x M(J/ψ)/p_T(J/ψ) distribution, for p_T>1.3 GeV/c



- First estimation of secondary fraction is ongoing
- High statistics sample to be collected this year (also with electron trigger) should allow for a precise measurement

Conclusions

- **The ALICE experiment has presented results on J/ψ production both in the dimuon and dielectron decay channels at $\sqrt{s}$ = 2.76 and at 7 TeV**

- $d^2\sigma/dydp_T$ and $d\sigma/dy$ for inclusive J/ψ production have been measured
  - Results are in good agreement with NLO NRQCD calculations
  - $\sqrt{s}$ = 2.76 TeV results are used as a reference for the PbPb R_{AA} evaluation

- The inclusive J/ψ yield shows a linear increase as a function of $dN_{ch}/d\eta$

- Ongoing effort on the J/ψ polarization measurement and on the identification of J/ψ from B decay

backup

The ALICE experiment

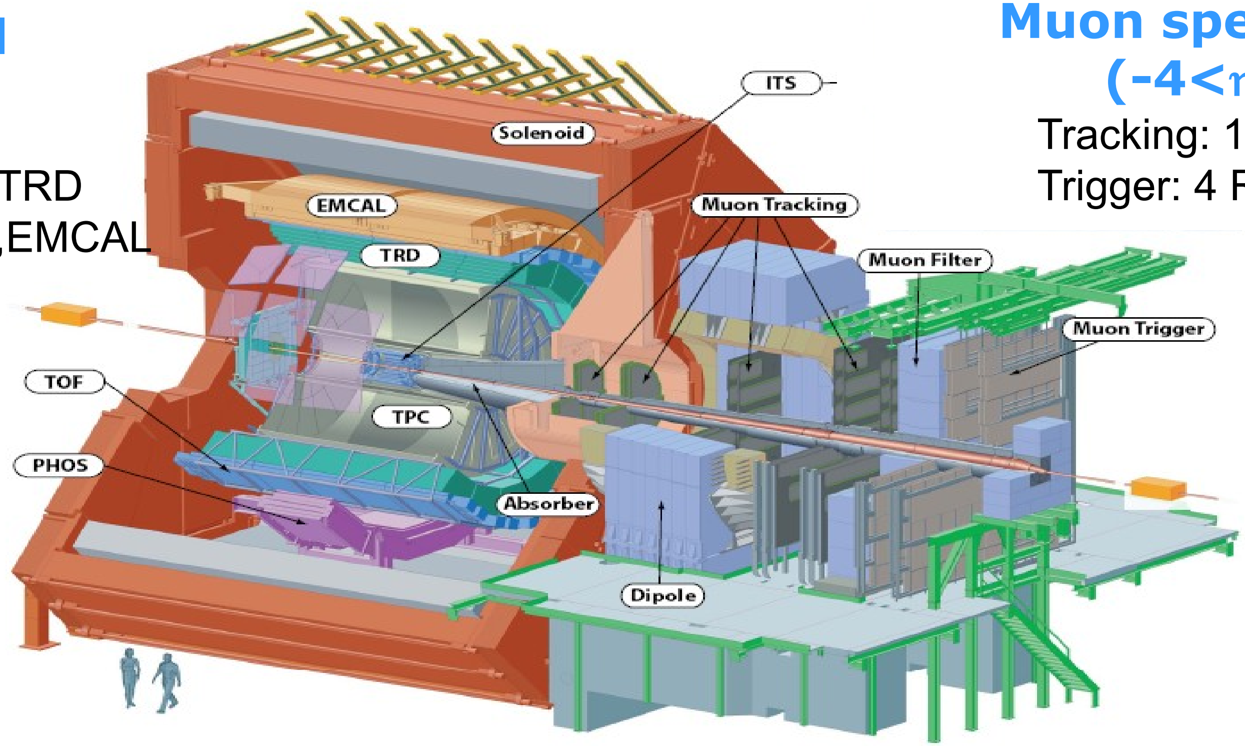
- **ALICE** is the dedicated heavy-ion experiment at the LHC
  - **PbPb collisions**: main focus of the experiment
    - QGP studies
  - **pp collisions**: important aspect of the physics program
    - reference for heavy-ion collision studies
    - pp physics

Central barrel
($|\eta|<0.9$)

Tracking: ITS,TPC,TRD
PID:TPC,TRD,TOF,EMCAL

Muon spectrometer
($-4<\eta<-2.5$)

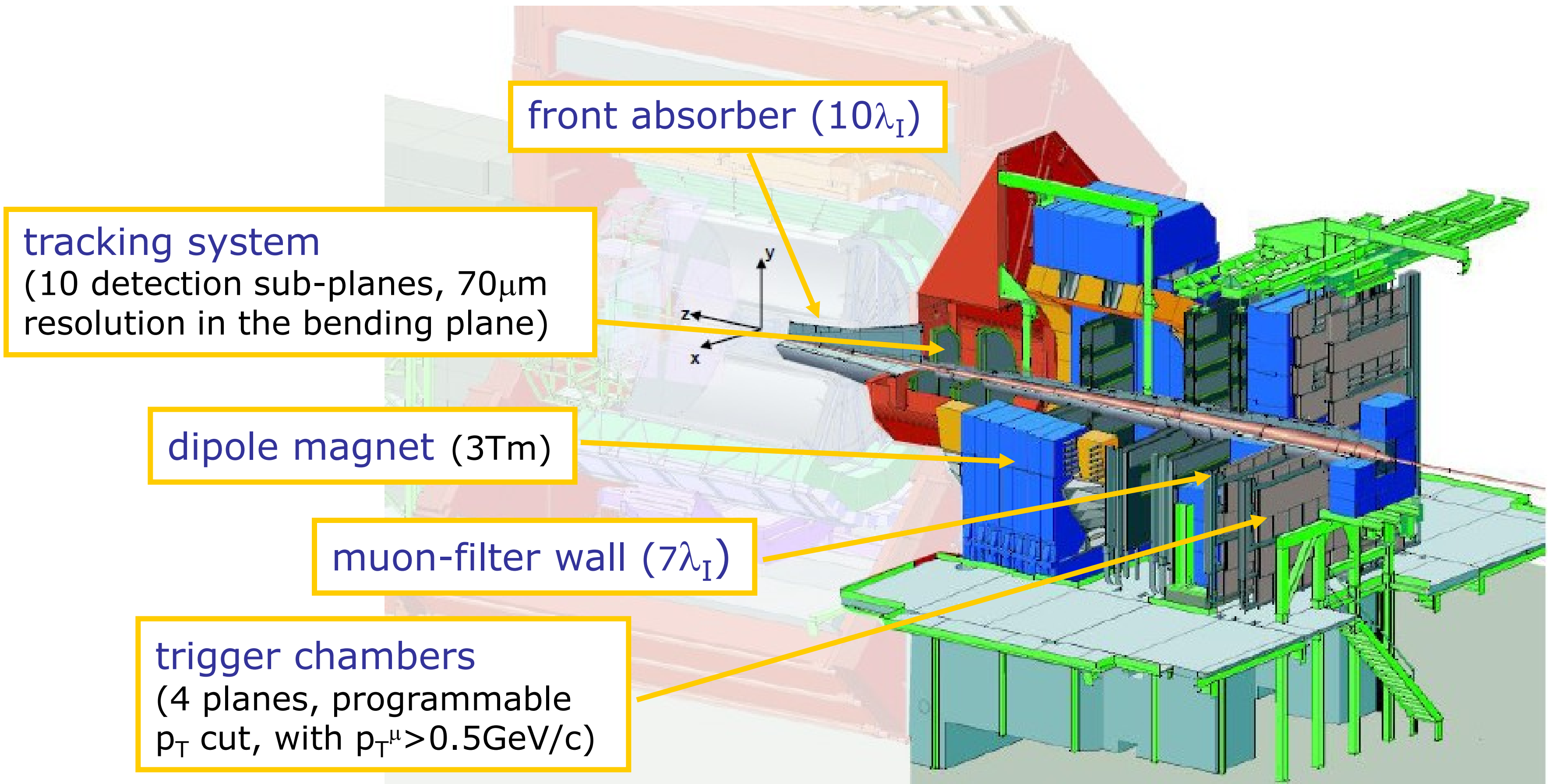
Tracking: 10 TPC planes
Trigger: 4 RPC planes



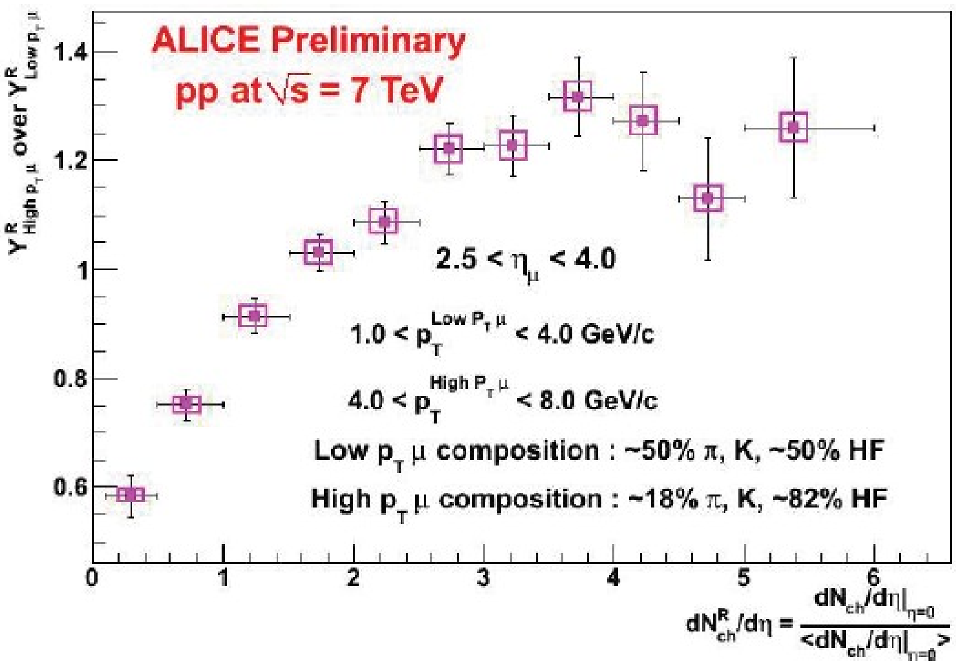
The muon spectrometer

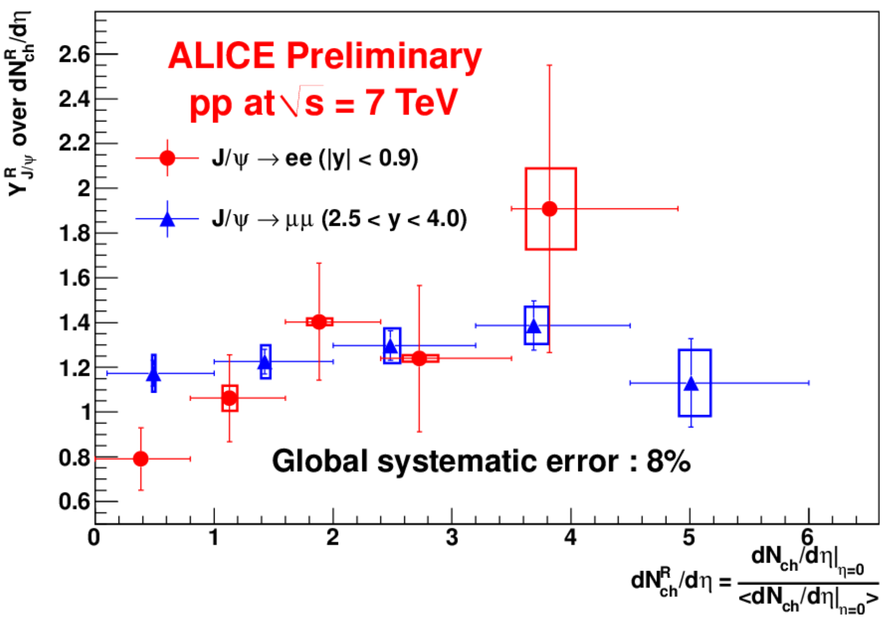
➡ It is designed in order to have:

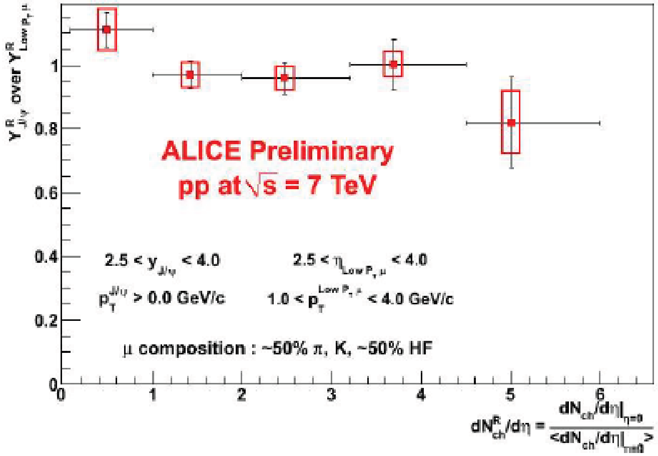
- large geometrical acceptance → to increase dimuon statistics
- acceptance down to p_T~0 → where direct J/ψ production dominates
- good mass resolution → to separate the Υ family
- tracking/trigger high granularity read-out → to cope with the high multiplicity

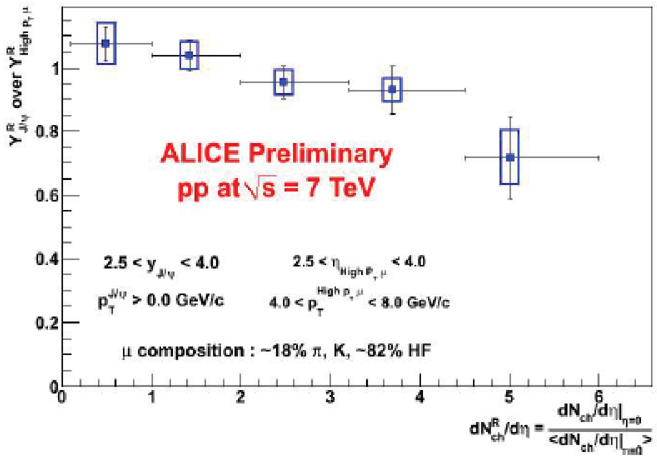


J/ψ vs. multiplicty









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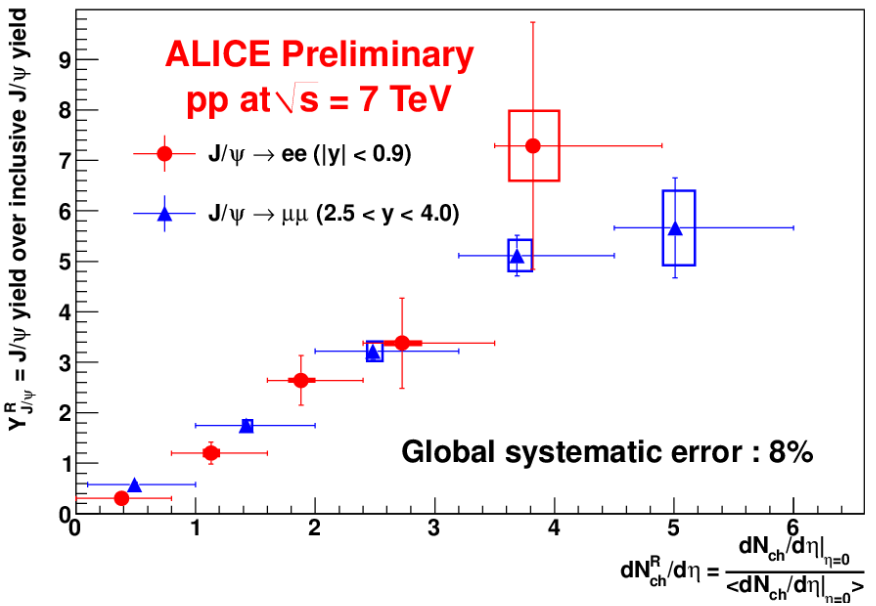
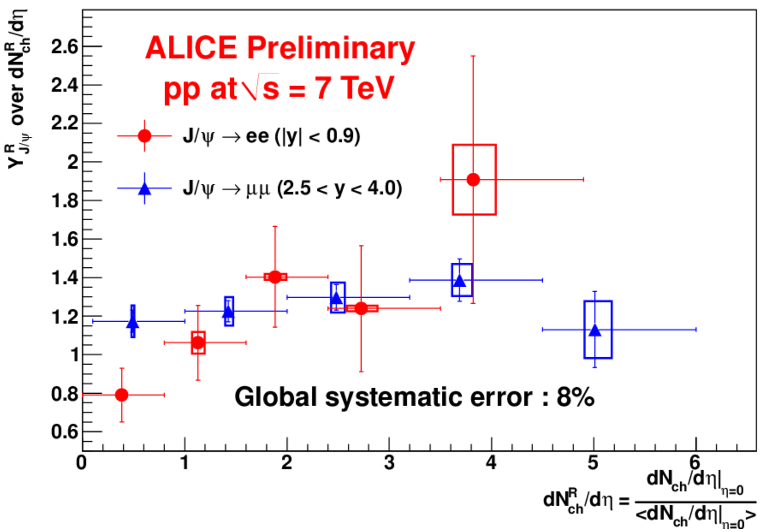
  → QGP related effects also in pp at LHC?





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