Quarkonium production in ALICE

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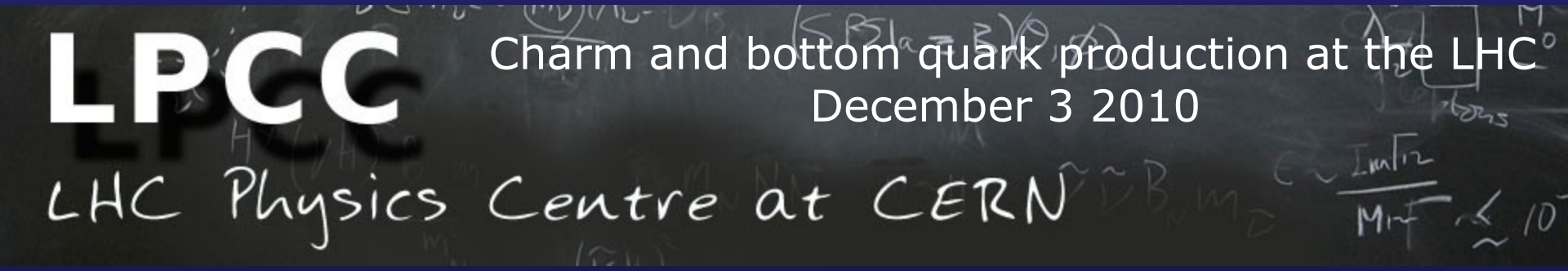
for the ALICE Collaboration

- Introduction
- First results: $J/\psi \rightarrow \mu^+\mu^-$ and $J/\psi \rightarrow e^+e^-$ in p-p collisions at 7 TeV
- Pb-Pb run: first performance plots
- Perspectives and conclusions



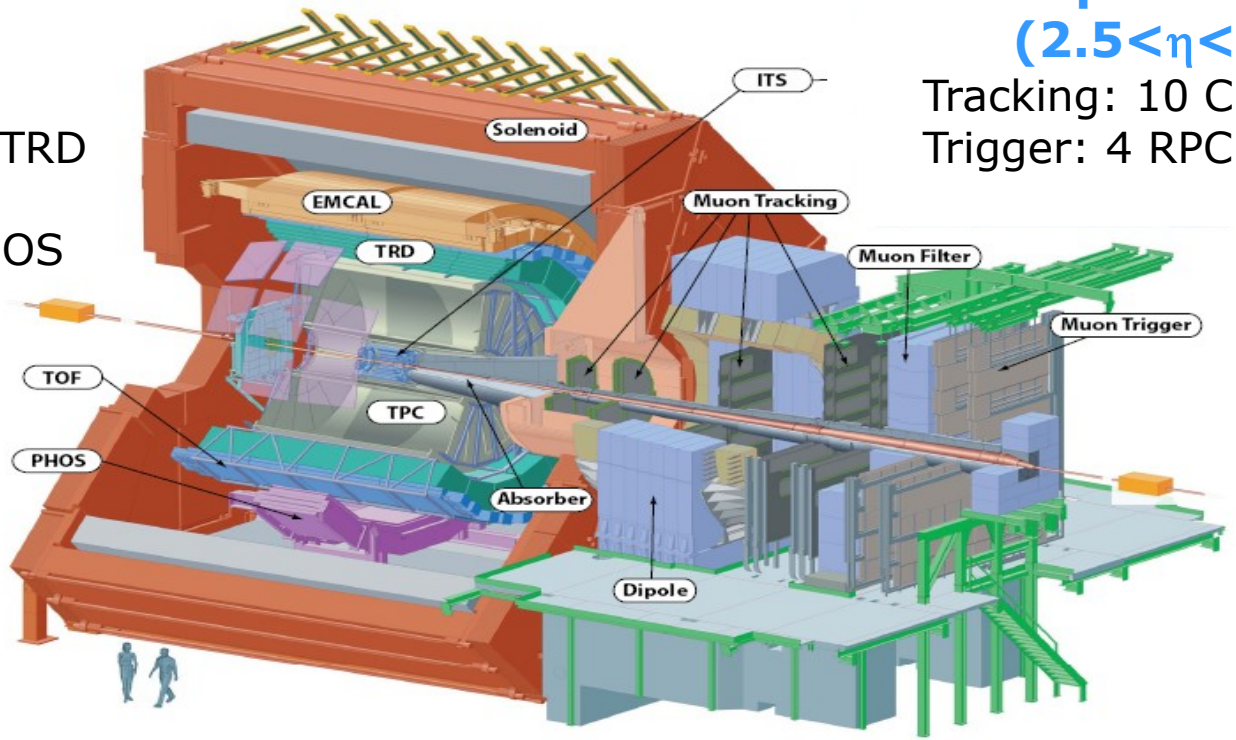
Charm and bottom quark production at the LHC
December 3 2010

The ALICE experiment in a slide

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

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

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



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

Tracking: 10 CPC planes
Trigger: 4 RPC planes

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 ($2.5<y<4$)

- 3 sources of J/ψ

1) Direct production
2) Feed down from heavier cc states

} Prompt J/ψ — radiative decay $\chi_c \rightarrow J/\psi\gamma$ in the central barrel

3) J/ψ from b-hadron decay →
   - can be identified in the central barrel, good impact parameter resolution ($\sigma_{r\phi}$ < 60 μm for p_T>1 GeV/c)
   - forward detection more difficult
     → 3-muon events
     → B cross section from single-μ
     → Semileptonic decays of B pairs

Preliminary ALICE results refer to inclusive J/ψ production

$J/\psi \rightarrow \mu^+\mu^-$: p+p @ $\sqrt{s}$=7 TeV sample

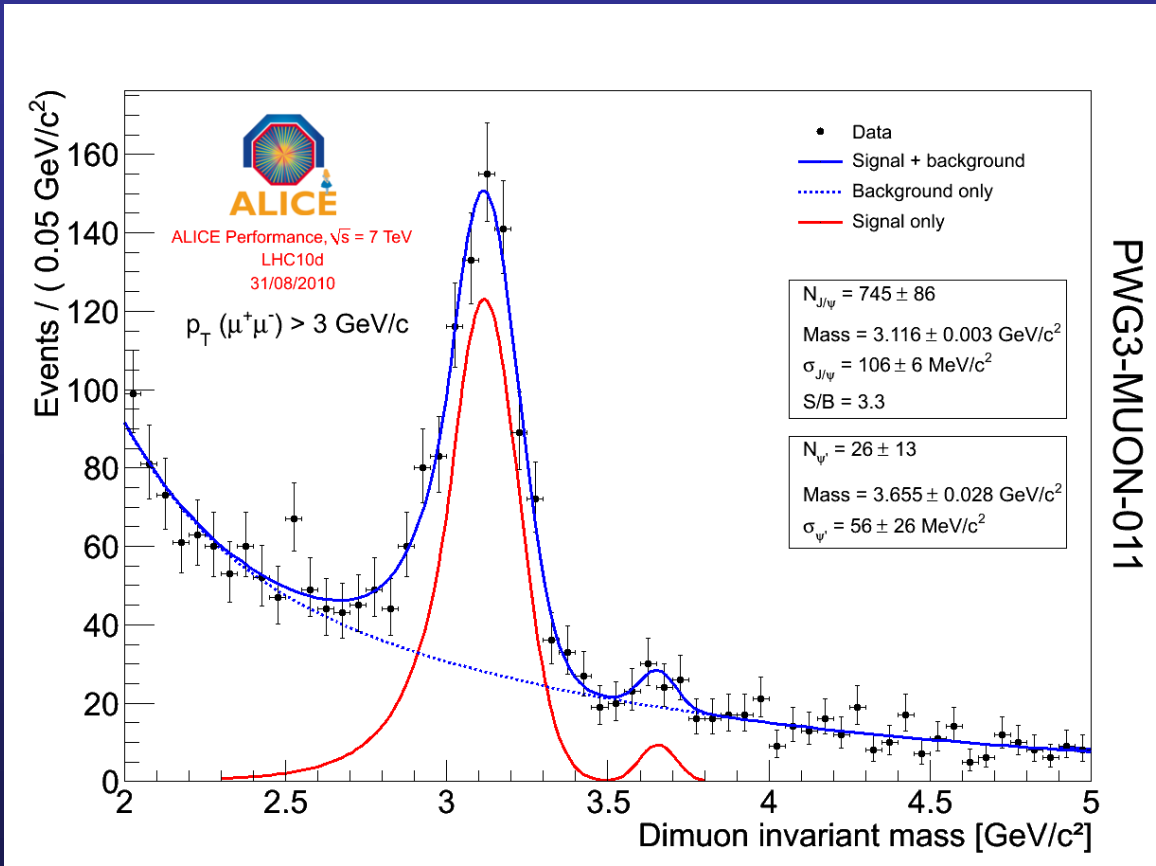
- Data sample:
  - Integrated luminosity = 13.6 nb^{-1}, corresponding to data collected between May and July 2010 (~ 10-15% of the 2010 total statistics)
  - Trigger: muon in the forward spectrometer, in coincidence with minimum bias interaction trigger
- Run Selection:
  - Runs selected according to quality checks on the stability of the muon spectrometer tracking and trigger performances
- Event Selection:
  - at least one vertex reconstructed 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 ($2^0<\theta_{abs}<9^0$)

J/ψ rapidity window: $2.5<y<4$
transverse momentum window $0<p_T<8$ GeV/c (statistics)

$J/\psi \rightarrow \mu^+\mu^-$: signal extraction

- The number of J/ψ is extracted from a fit to the invariant mass spectrum, using

- Crystal Ball shape for the signal (J/ψ and ψ')
- Sum of two exponentials for the background



The available J/ψ statistics, used for the cross section determination is

$N_{J/\psi} = 1909 \pm 78$

S/B (2.9<M<3.3) ~ 2.4

With a suitable p_T cut (smaller background), also the $\psi(2S)$ signal is visible, but with a much lower statistical significance

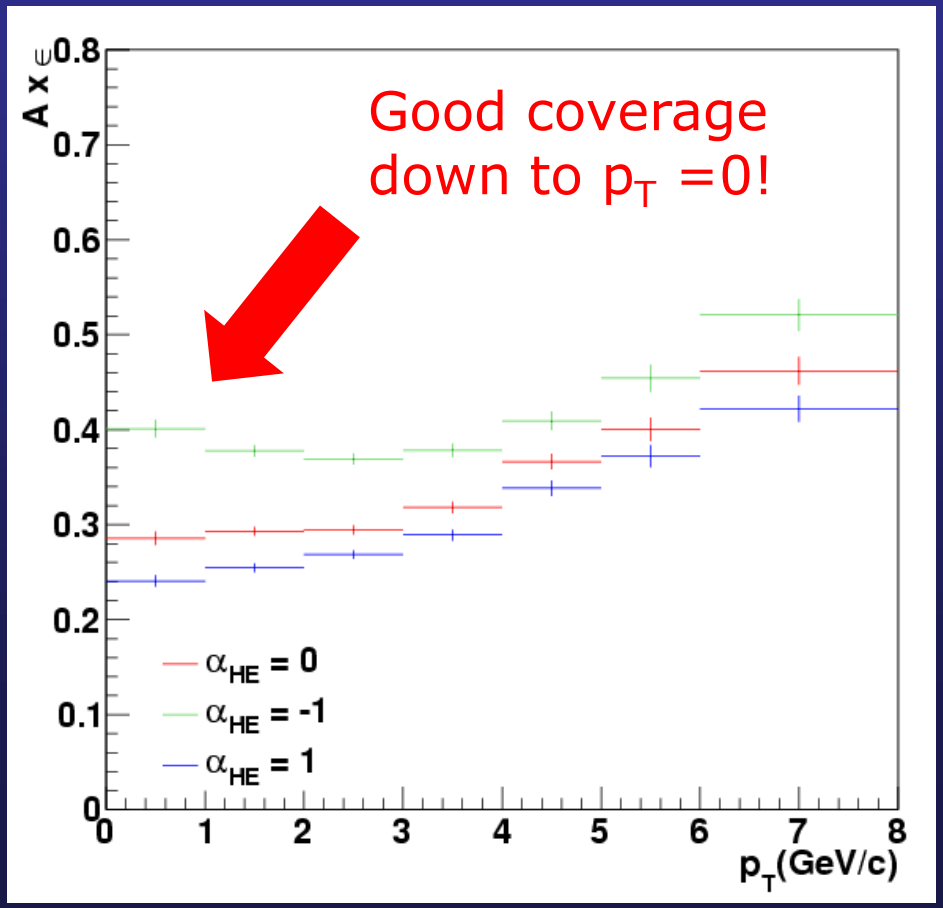
$J/\psi \rightarrow \mu^+\mu^-$: acceptance × efficiency

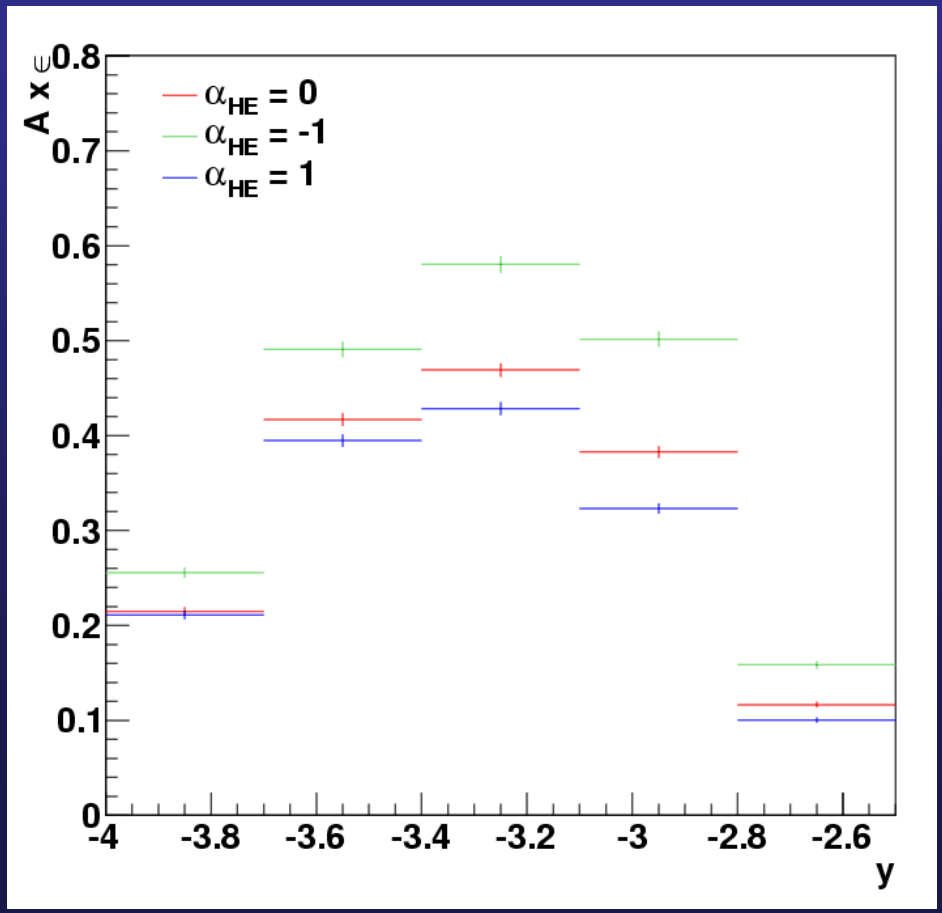
- Based on simulations performed separately for each LHC period, in order to reproduce in a realistic way, the detector status

Input: realistic y and p_T J/ψ distributions

p_T → CDF extrapolation
y → CEM calculation

- Study of differential distributions: 1D acceptance correction





$J/\psi \rightarrow e^+e^-$: p+p @ $\sqrt{s}$=7 TeV sample and signal extraction

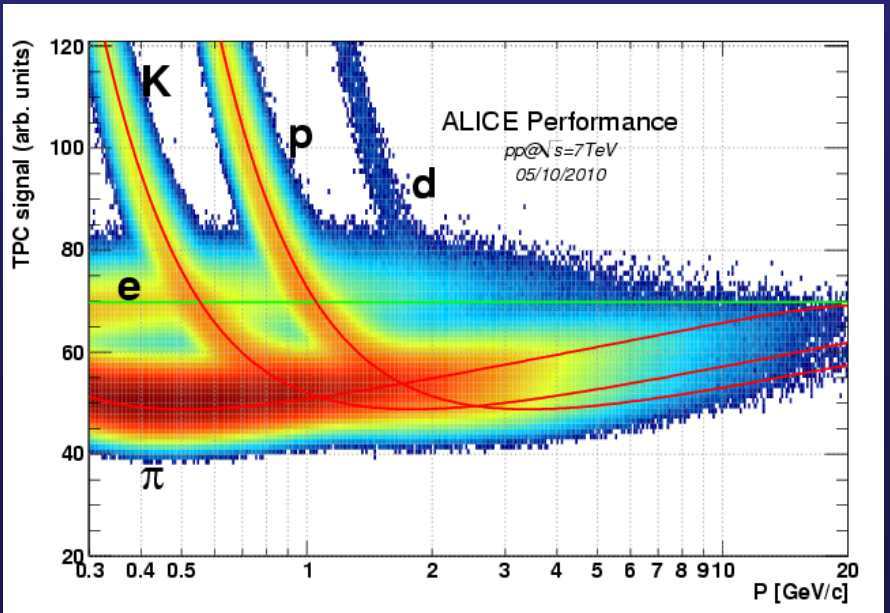
- Analysis is based, for the moment, on a smaller data sample wrt to $J/\psi \rightarrow \mu^+\mu^-$
  → L=4.0 nb^{-1} (~15% of 2010 stat.)

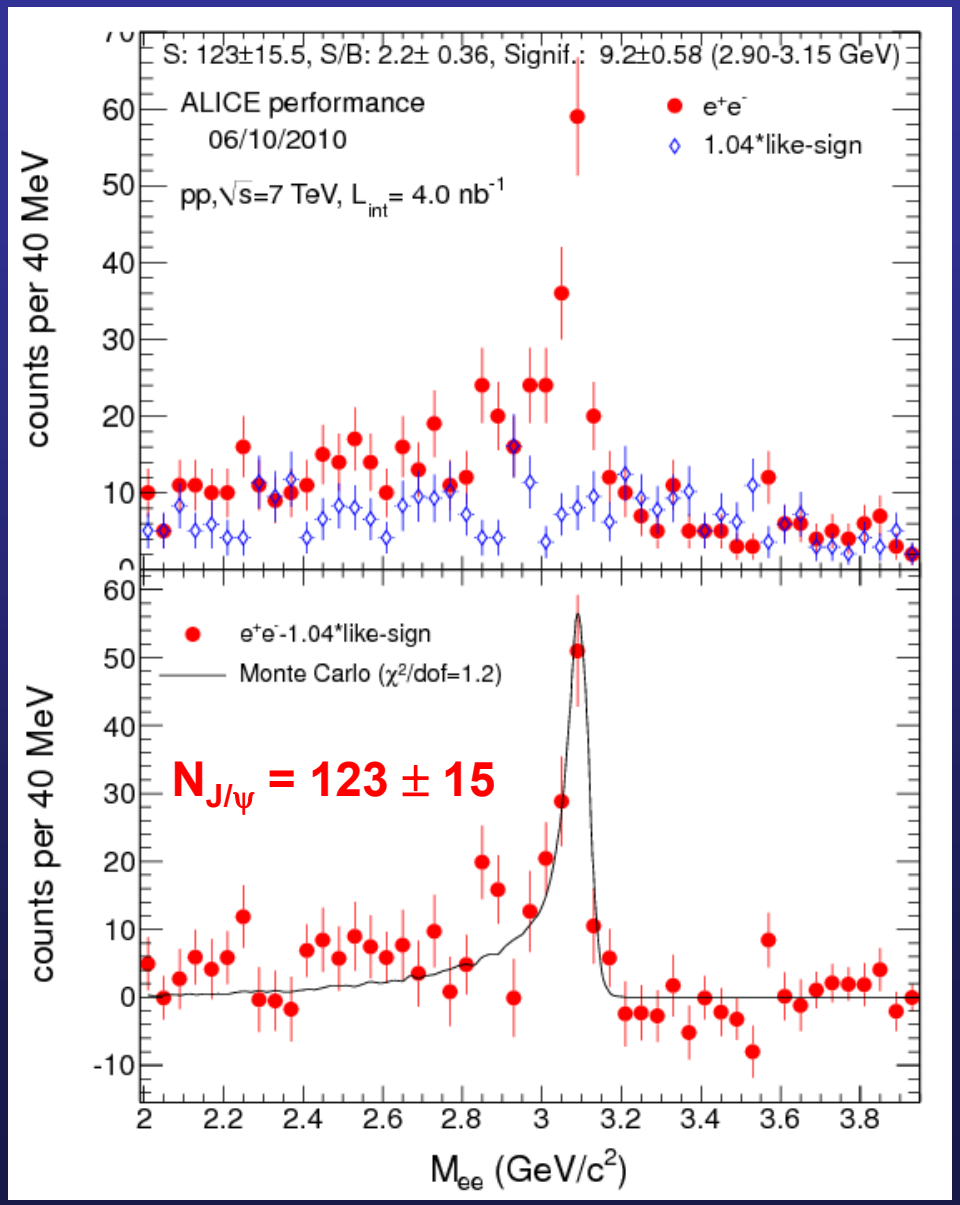
Track selection:

$|\eta^{e+,e-}|<0.88$ and $|y^{J/\psi}|<0.88$

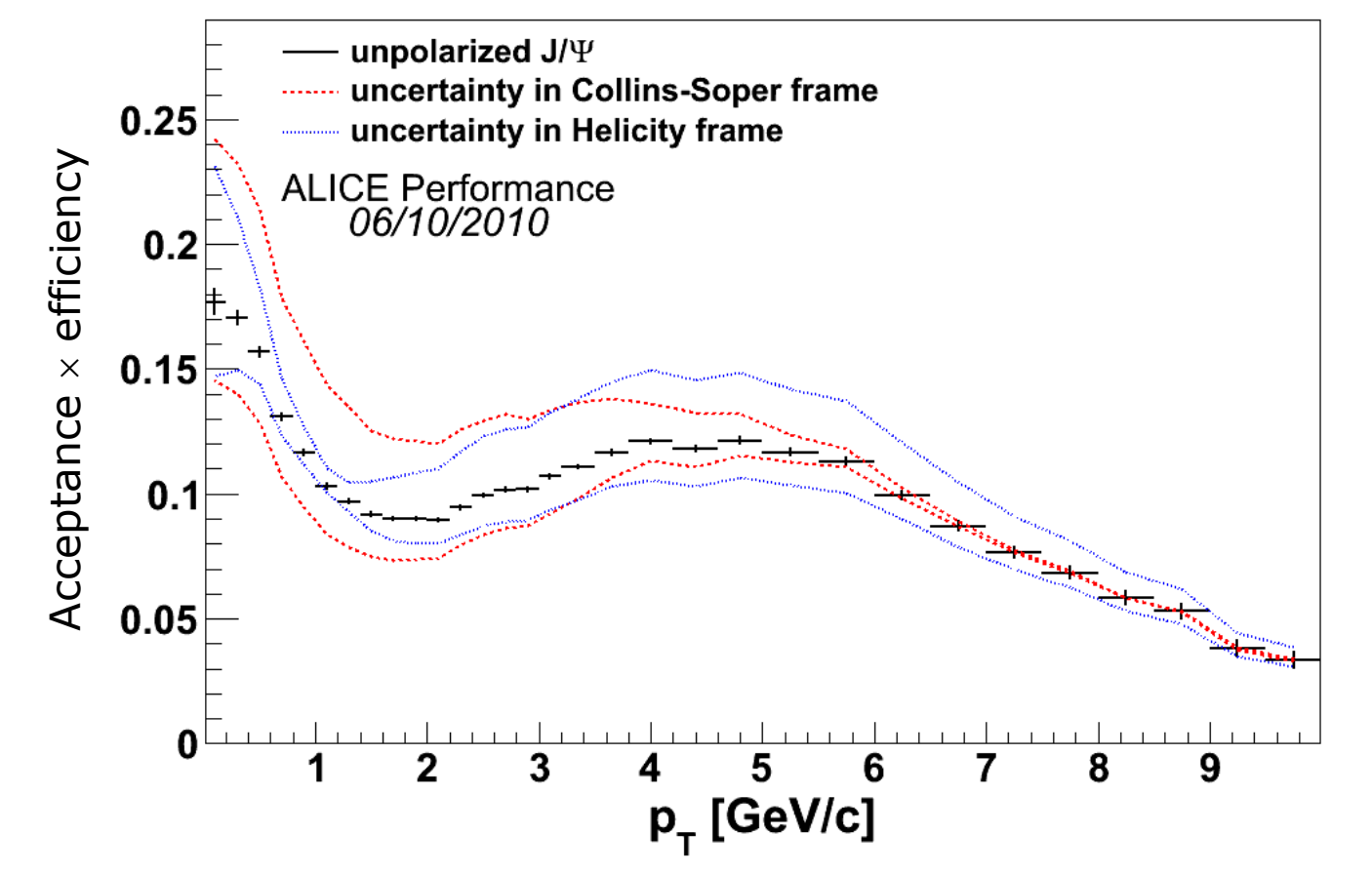
$p_T^{e+,e-} > 1$ GeV/c

TPC-based PID





$J/\psi \rightarrow e^+e^-$: acceptance × efficiency



- Also in the electron channel, very good coverage down to $p_T = 0$

Integrated cross section(s)

- Cross section calculated as $\sigma_{J/\psi}(2.5<y<4)=\frac{N_{J/\psi}}{Acc_{J/\psi}\times\varepsilon}\times\frac{1}{L}$

- The ALICE results, integrated over y and p_T, are:

$$\sigma_{J/\psi}(-0.88<y<0.88)=12.95\pm2.15\,(stat)\pm2.32\,(syst)^{+1.26}_{-2.55}\,(syst.pol.)\;\mu b$$

$$\sigma_{J/\psi}(2.5<y<4)=7.25\pm0.29\,(stat)\pm0.98\,(syst)^{+0.87}_{-1.50}\,(syst.pol.)\;\mu b$$

(polarization-related errors calculated in the helicity frame)

➡ Very good agreement with the corresponding LHCb result obtained at forward rapidity (ICHEP2010)

$$\sigma_{J/\psi}(2.5<y<4)=7.65\pm0.19(stat)\pm1.10(syst)^{+0.87}_{-1.27}(syst.pol.)\;\mu b$$

Systematic errors

Muons

Source of systematic error	
Uncertainty on signal extraction	7.5 %
p_T and y shapes in the MC	2%
Trigger efficiency	4%
Tracking efficiency	2%
Normalization	10 %
Total systematic error	**13.5 %**

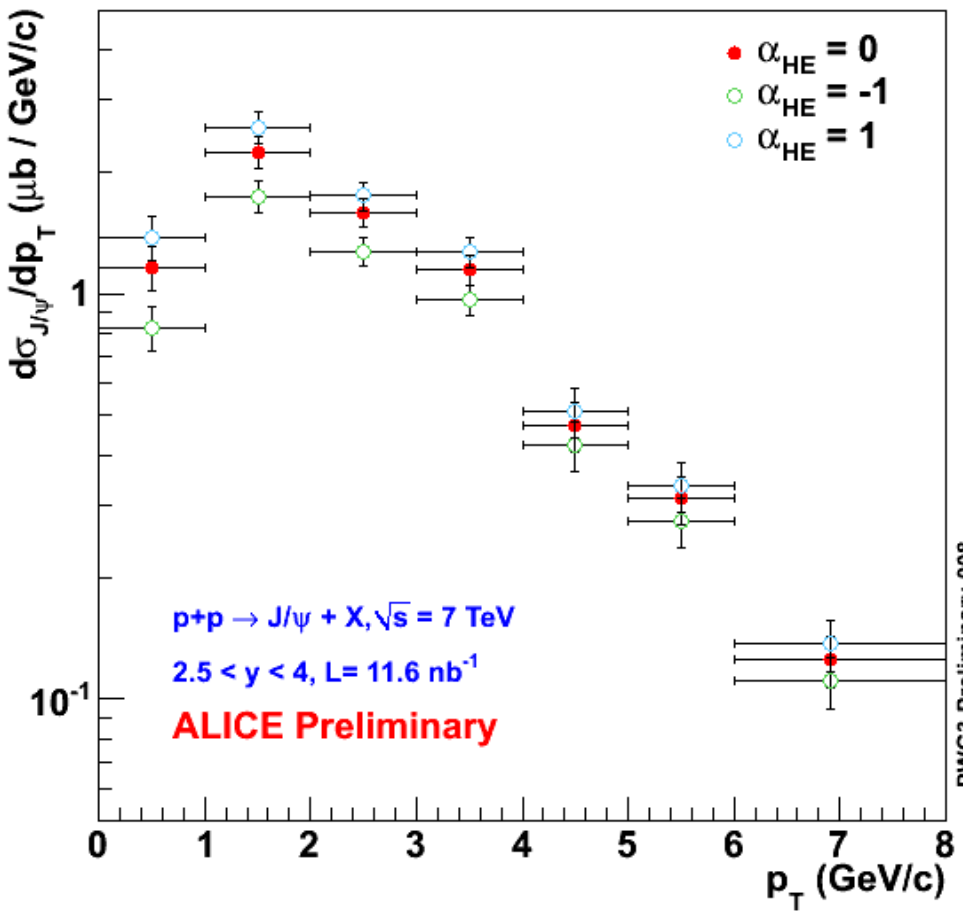
polarization	λ=-1	λ=1
Helicity	-21%	+12%
Collins-Soper	-31%	+15%

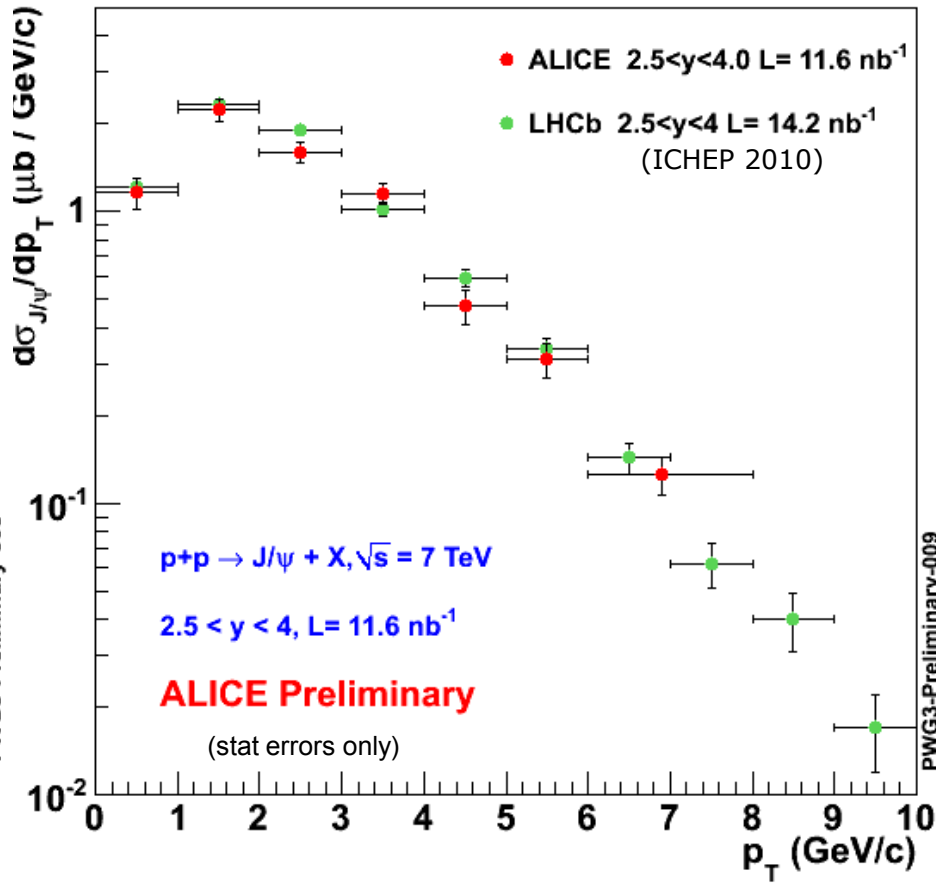
Electrons

Source of systematic error	
Kinematics	<1%
Track quality,#clusters TPC	10%
PID cuts	10%
Signal extraction range	4%
Normalization	10 %
Total systematic error	**18 %**

polarization	λ=-1	λ=1
Helicity	-20%	+10%
Collins-Soper	-25%	+12%

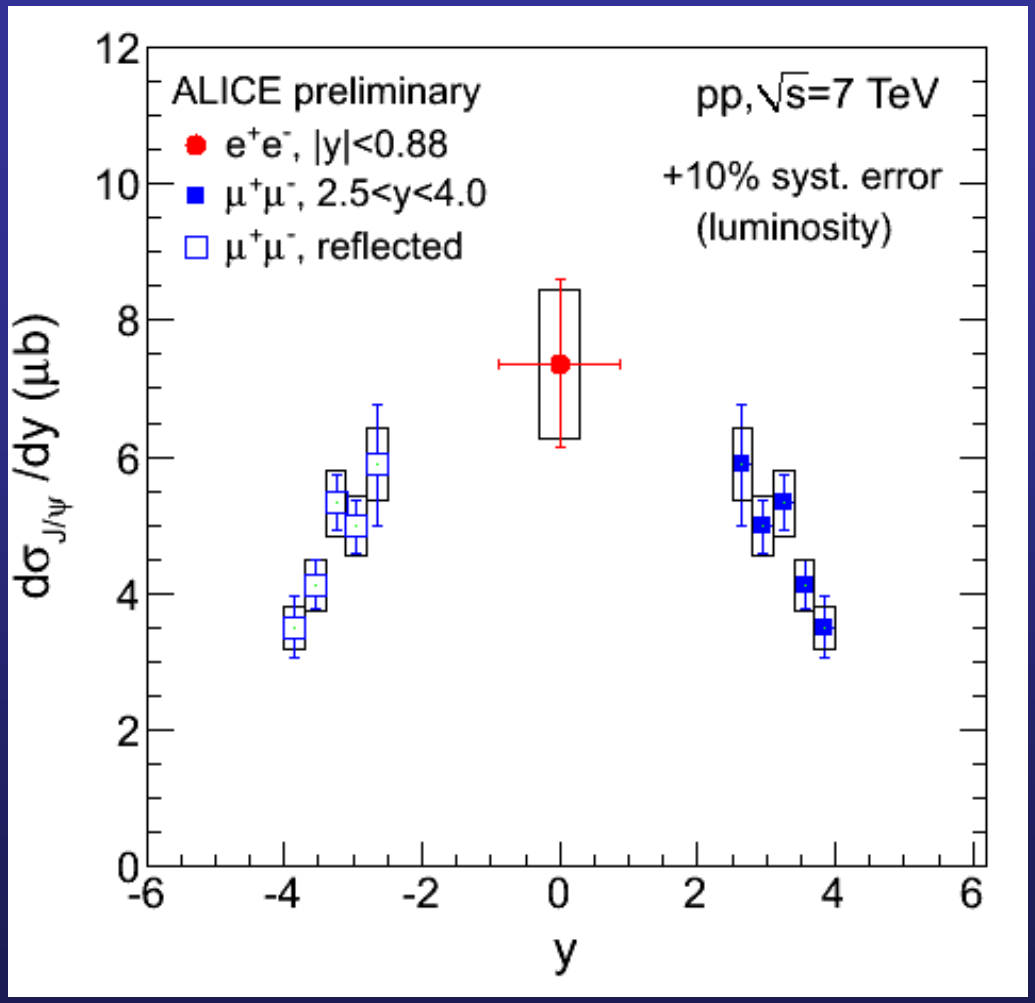
Differential cross section: $d\sigma_{J/\psi}/dp_T$ (2.5<y<4)





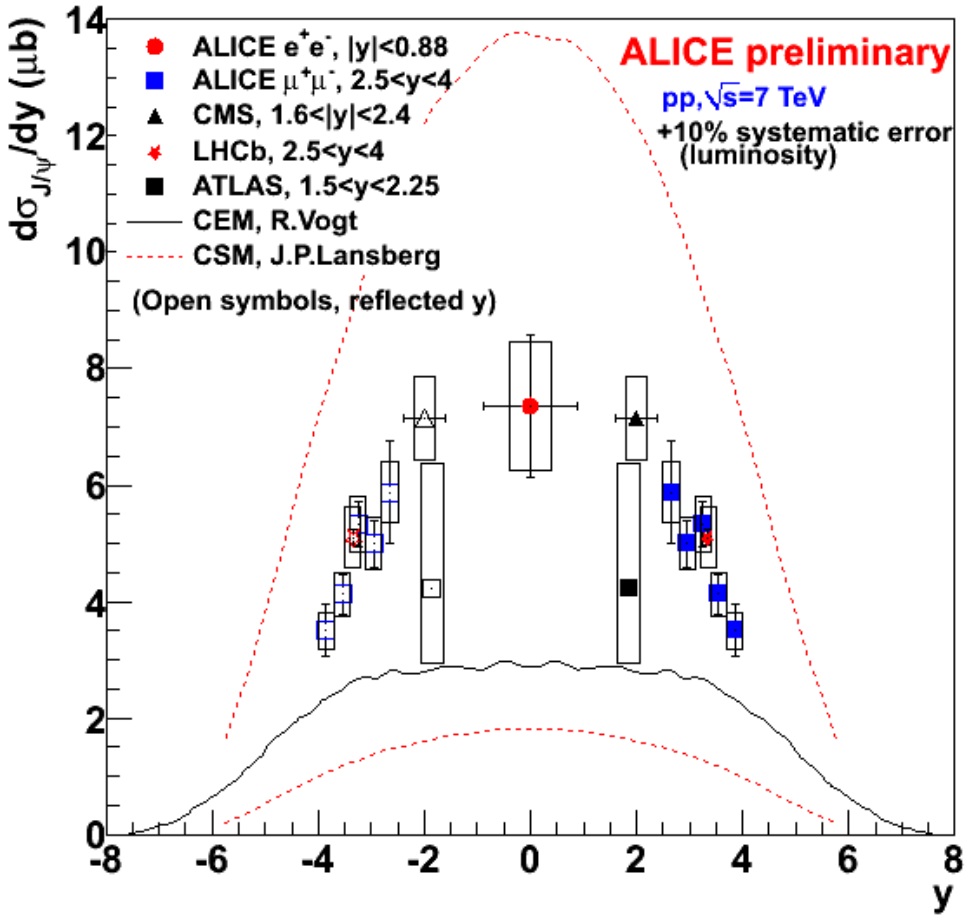
- Very good agreement with the LHCb result in the same rapidity range
- Other sources of point to point systematic errors (signal extraction, acceptance input) vary between 3 and 10% (not yet fully evaluated)

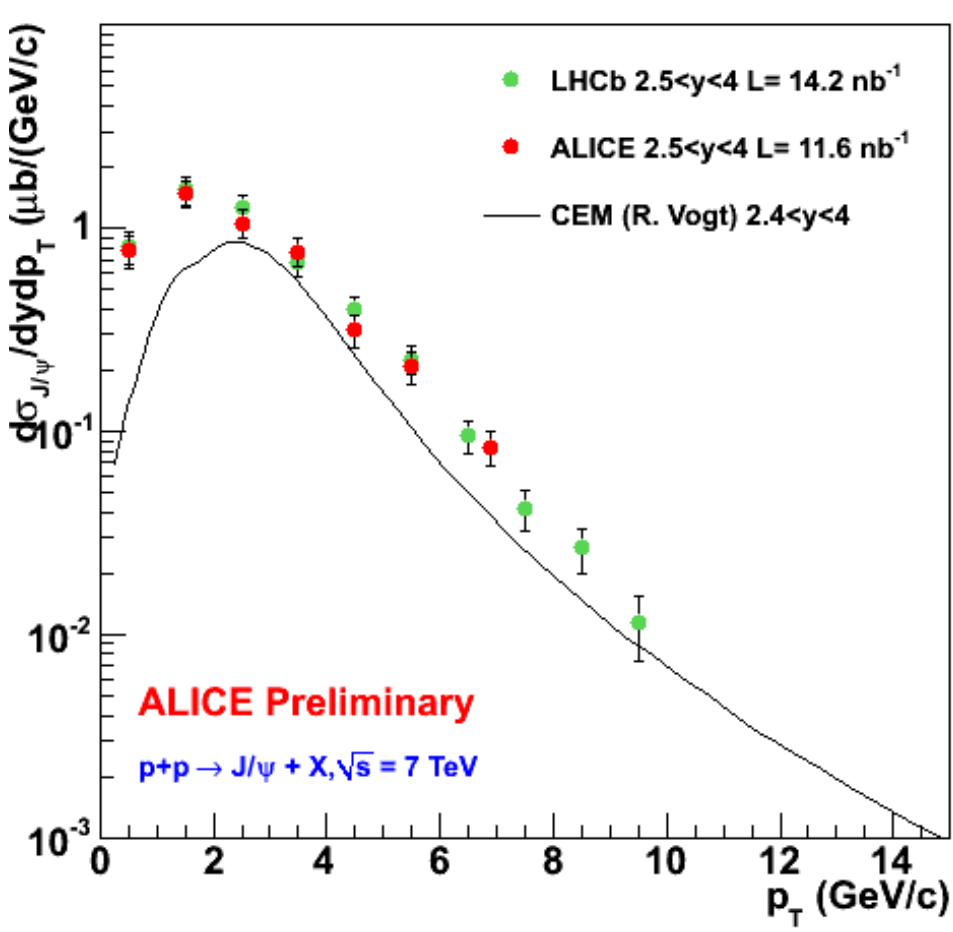
Differential cross section: $d\sigma_{J/\psi}/dy$ ($p_T>0$)



- ALICE can measure the distribution of the inclusive J/ψ production in a wide rapidity range
- p_T coverage extends to zero at both central and forward rapidities

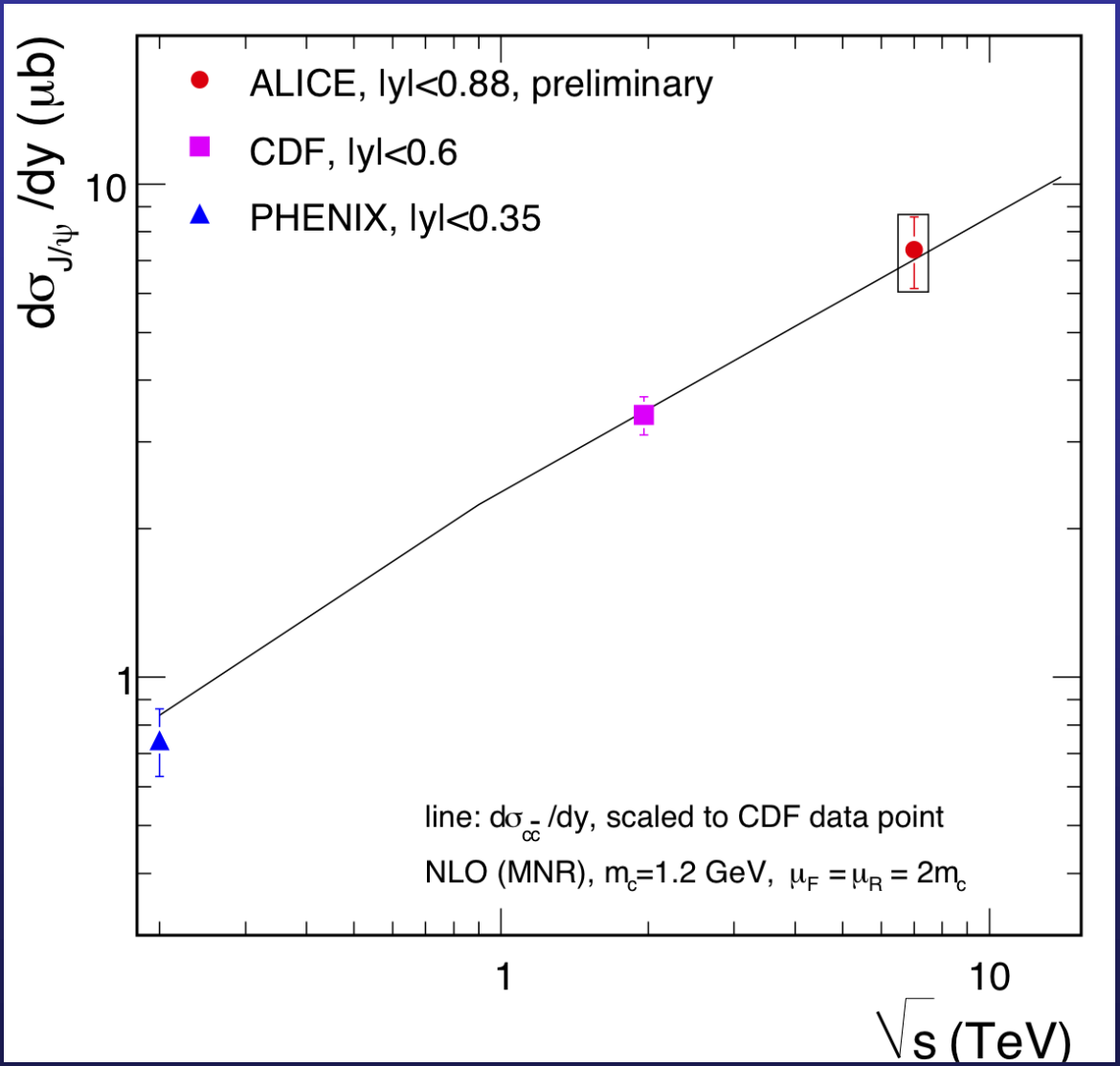
Preliminary comparison(s)





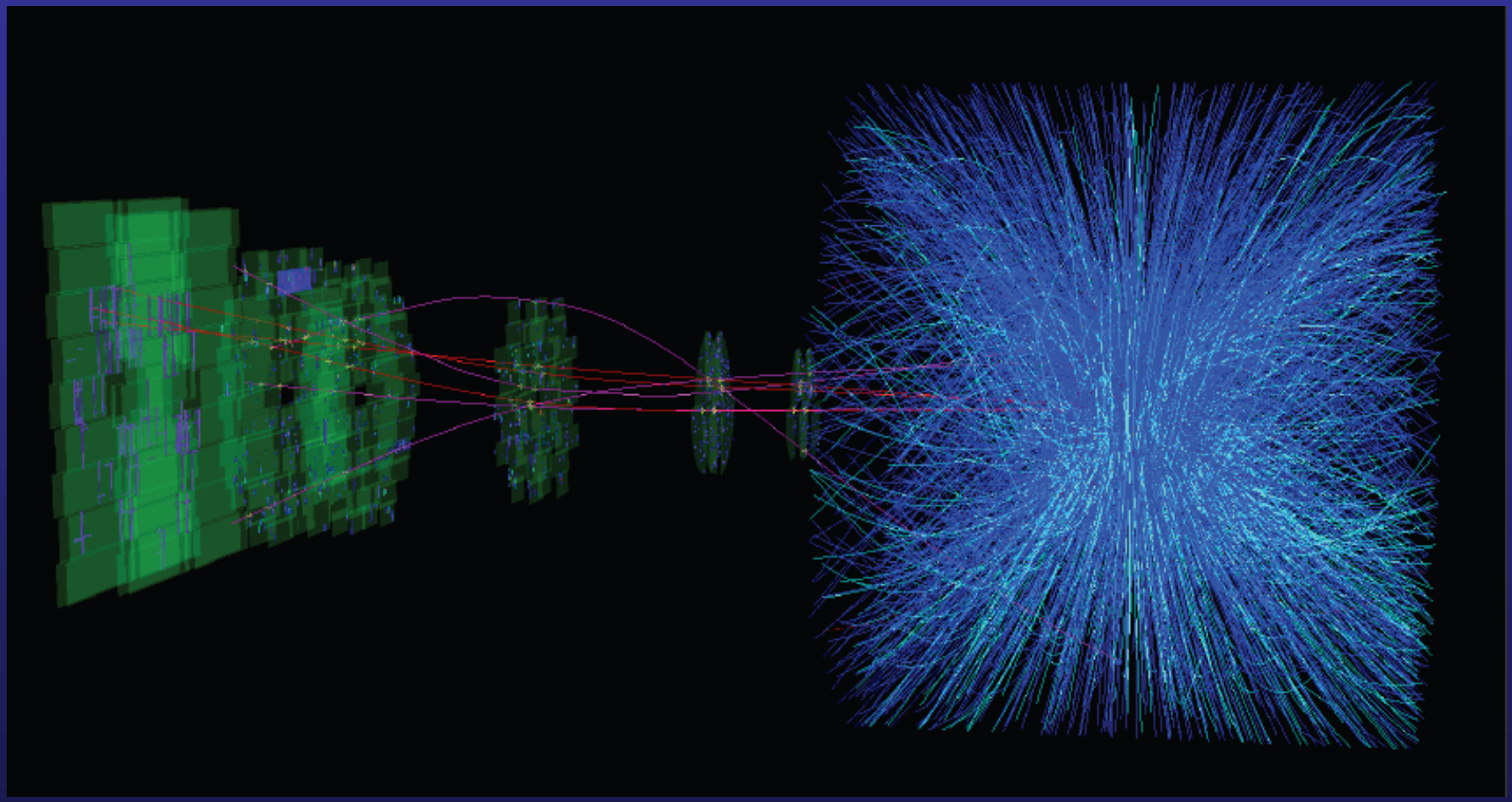
- Model calculations:
  - R.Vogt, Phys. Rev. C 81 (2010) 044903
  - J.P. Lansberg, arXiv:1006.2750
- CMS: p_T-integrated cross section 1.6<y<2.4 from (arXiv:1011.4193)
- ATLAS: $d\sigma/dy$ 1.5<y<2.25, ATLAS-CONF-2010-062
- LHCb: $d\sigma/dy$ 2.5<y<4 from LHCb-CONF-2010-010

√s-dependence of inclusive J/ψ



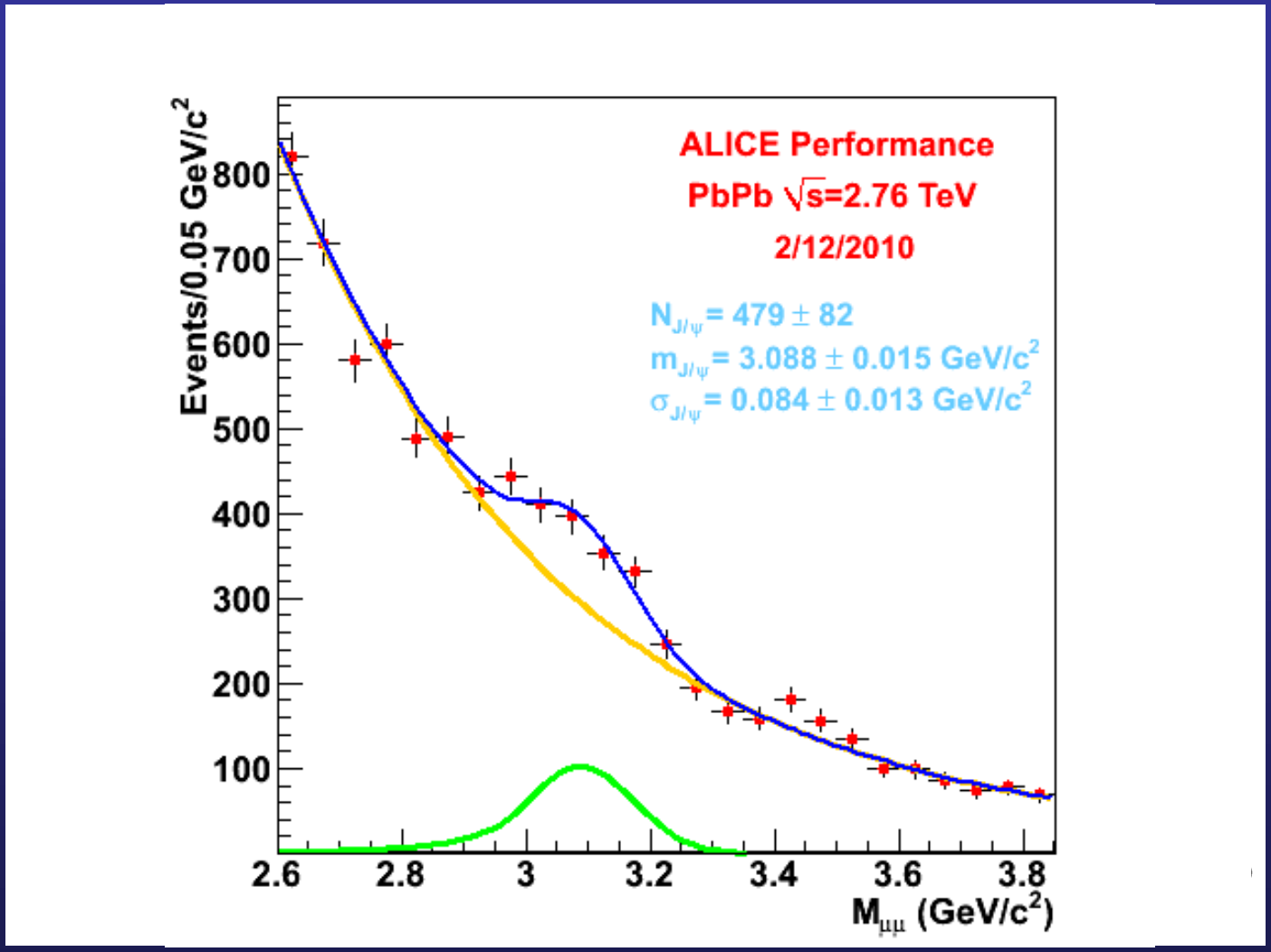
- NLO calculation for $c\bar{c}$ by Mangano et al., normalized to the CDF point
- Same √s-dependence for the inclusive J/ψ cross section

November 2010: moving from p-p to Pb-Pb



- Higher occupancy with respect to Pb-Pb
- Re-tuning of reconstruction parameters

First J/ψ signal from Pb-Pb collisions



- The J/ψ is not completely suppressed!
- Expected final statistics for Pb run → O(10^3)
- Extract R_{AA} in (some) centrality bins

Conclusions, perspectives

ALICE has measured inclusive J/ψ production

- Over a wide rapidity range (-0.88<y<0.88, 2.5<y<4)
- With good coverage down to p_T=0

Next steps, in the dimuon channel, with higher statistics:

- Extend the analysis to other charmonium (ψ(2S)) and bottomonium states
- Integrated and differential J/ψ polarization study

Pb-Pb run close to be completed

- J/ψ signal observed
- Next step: nuclear modification factor vs centrality