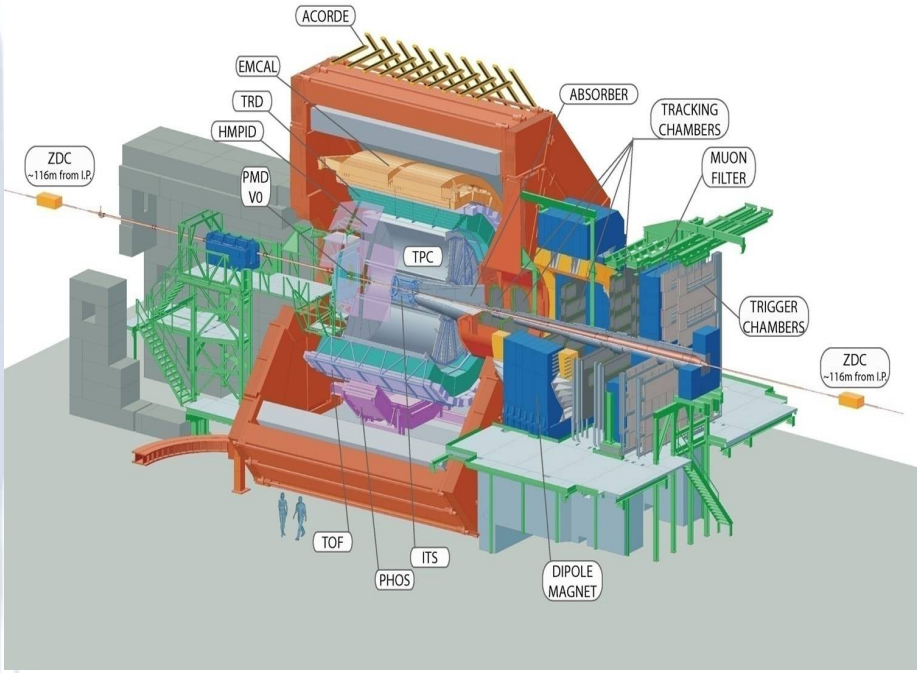
Inclusive J/ψ cross-section in p+p collisions at 7 TeV with the ALICE detector



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GSI

FIAS Frankfurt Institute for Advanced Studies

EMMI

Quarkonium Production – Probing QCD at the LHC, Vienna 18-21 April 2011

Motivation

Motivation

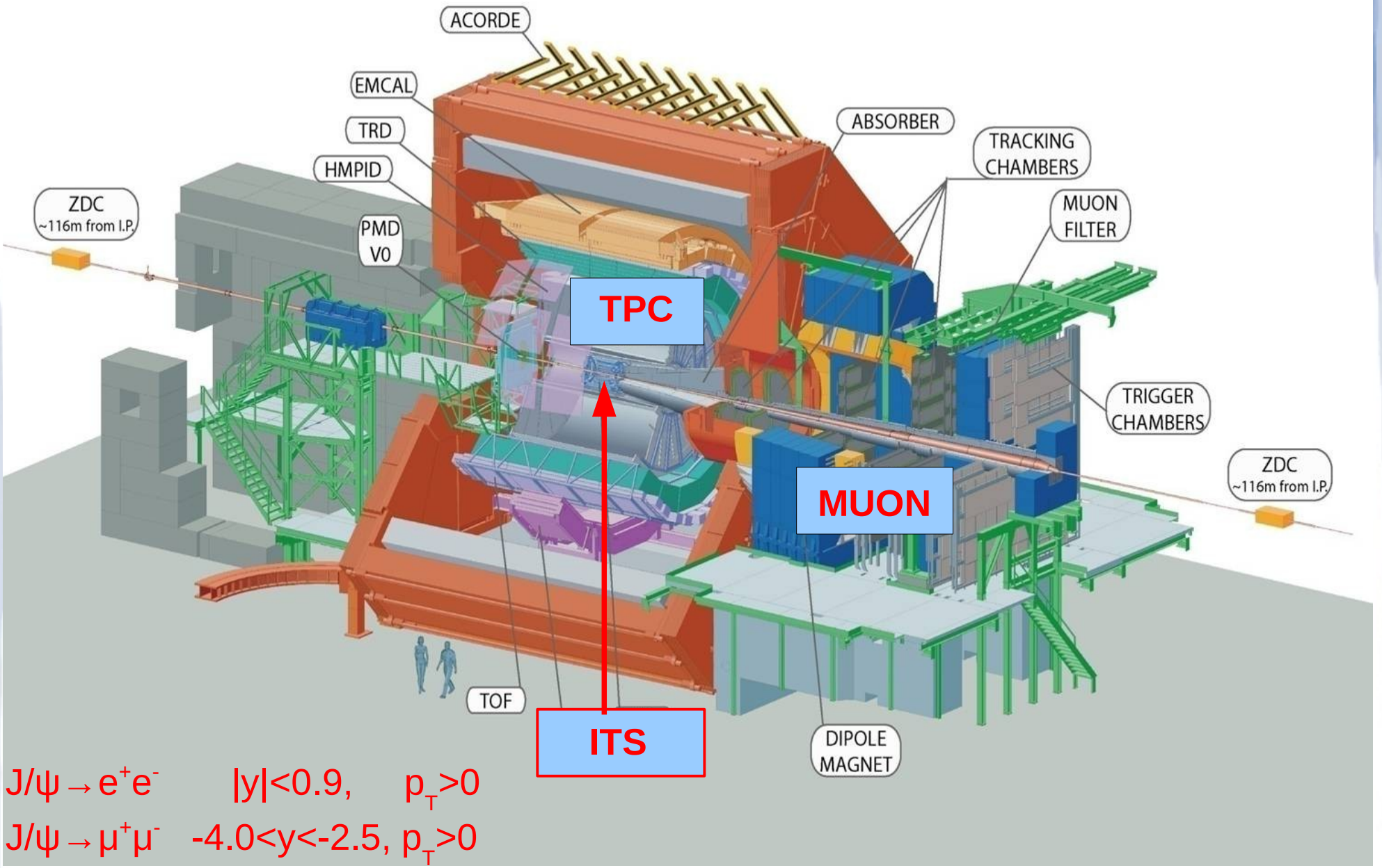
- The J/ψ production mechanisms are not yet well understood and the measurements in p+p collisions at LHC energies will provide constraints for pQCD calculations and hadronization models.
- The J/ψ suppression in heavy ion collisions is one of the proposed signals for the study of the hot and dense deconfined quark-gluon medium created. Thus the understanding of the p+p reference is crucial.
- The main theoretical approaches to explain quarkonium production are:
  - Color Singlet Model (CSM) S.D.Ellis, M.B.Einhorn, C.Quigg, PRL 36 (1976) 1263
  - Color Evaporation Model (CEM) H.Fritzsch, PLB 67 (1977) 217
  - Non-Relativistic QCD G.Bodwin, E.Braaten, G.Lepage, PRD51 (1995) 1125

J/ψ sources

- Inclusive J/ψ production:
  - Prompt direct
  - Prompt indirect: χ_c, $\psi(2S) \rightarrow J/\psi + \gamma$ (~35% of the inclusive cross-section)
  - Non-prompt: Beauty hadron decays (~10% at p_T=1.5 GeV/c at Tevatron and LHC)
- ALICE measured only the inclusive production, using 2010 data, and higher statistics samples are required to separate between different sources (prospects later on).

Experimental setup

ALICE

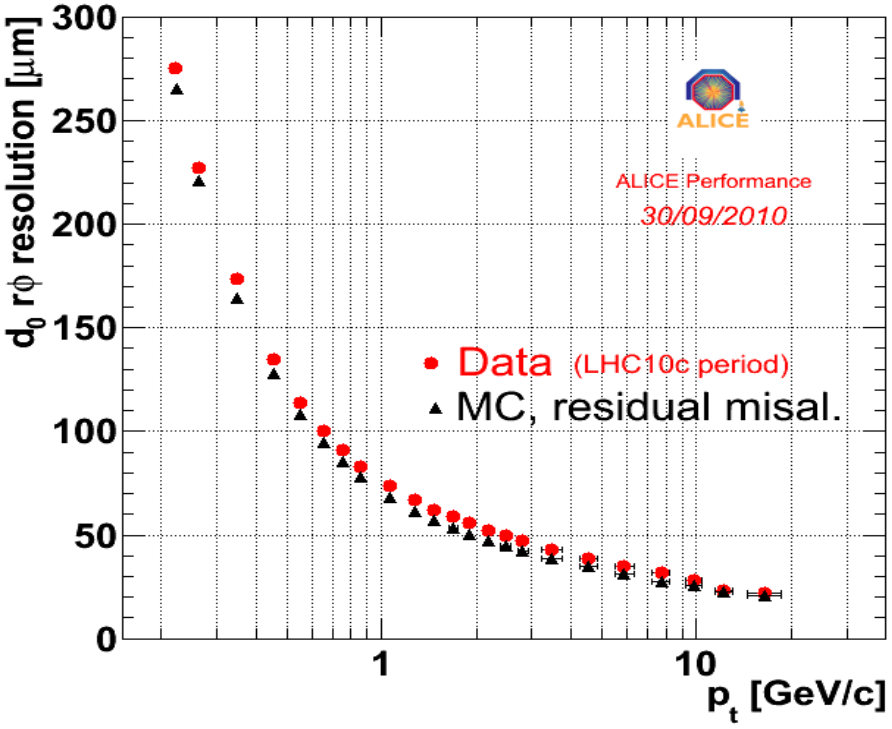


$J/\psi \rightarrow e^+e^-$ $|y|<0.9$, $p_T>0$

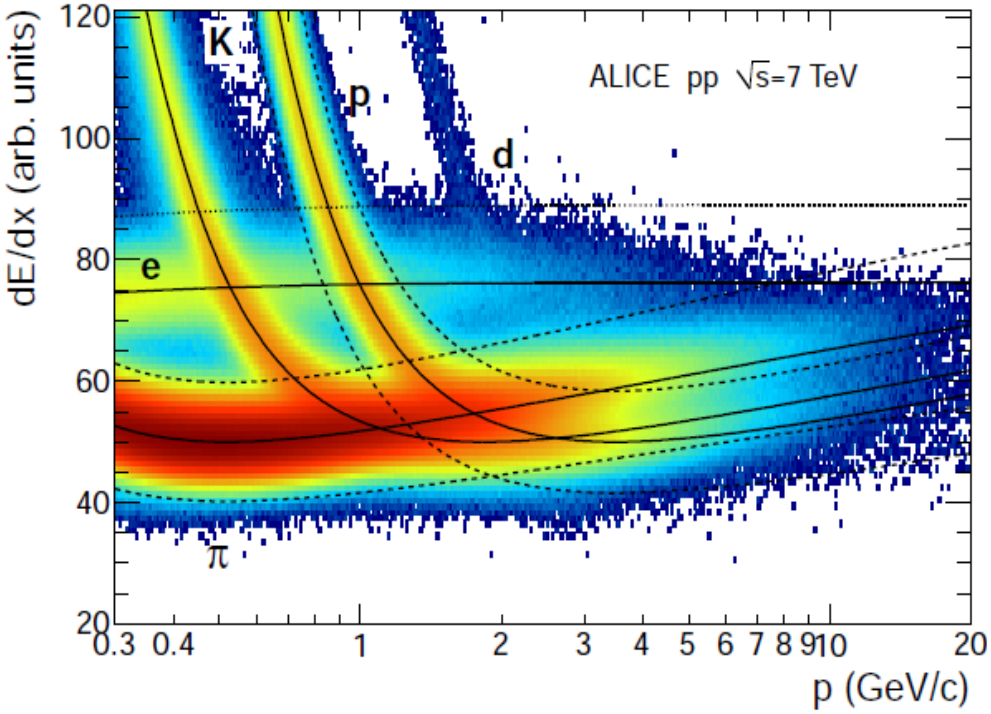
$J/\psi \rightarrow \mu^+\mu^-$ $-4.0<y<-2.5$, $p_T>0$

Inner Tracking System and Time Projection Chamber

Impact parameter resolution

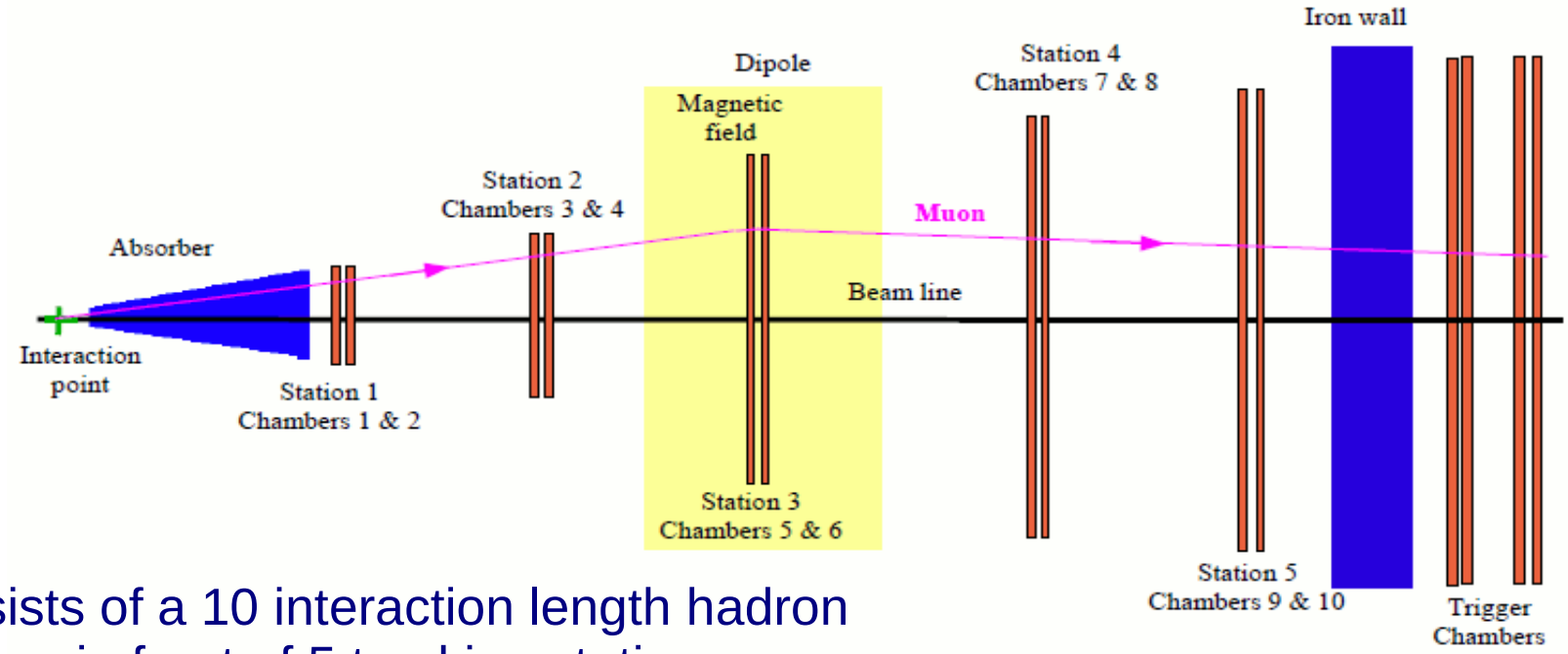


Particle identification

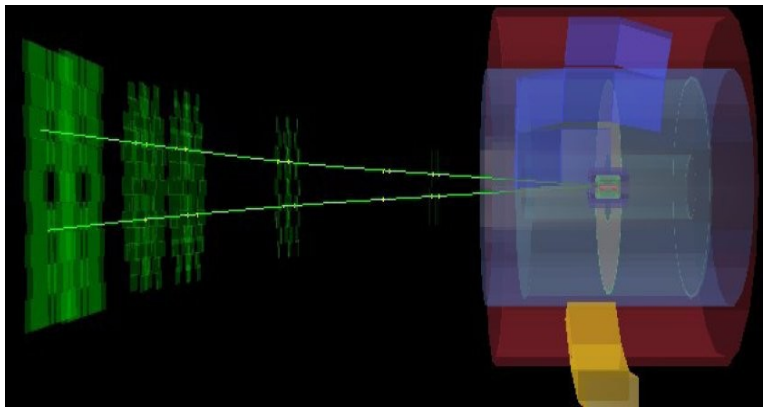


- Full azimuthal coverage in the |η|<0.9 range
- Momentum resolution ~7% at 20 GeV/c when combining ITS and TPC.
- Rejection of electrons from photon conversions in the detector material
- Very good resolution for the measurement of secondary vertices from beauty decays (B->J/ψ+X).
- Particle identification done via specific energy loss (dE/dx) allows the separation of electrons.

Forward Muon Spectrometer



- Consists of a 10 interaction length hadron absorber in front of 5 tracking stations.
- A muon triggering system is placed further downstream behind an additional 7.2 interaction length wall.
- Allows measurement of heavy quarkonia (J/ψ, ψ', Y family) decaying in the di-muon channel
- Kinematical acceptance: $-4.0<\eta<-2.5$ and $p(\mu)>4.0$ GeV/c
- More details in Livio Bianchi's and Matthieu Lenhardt's talks



Analysis

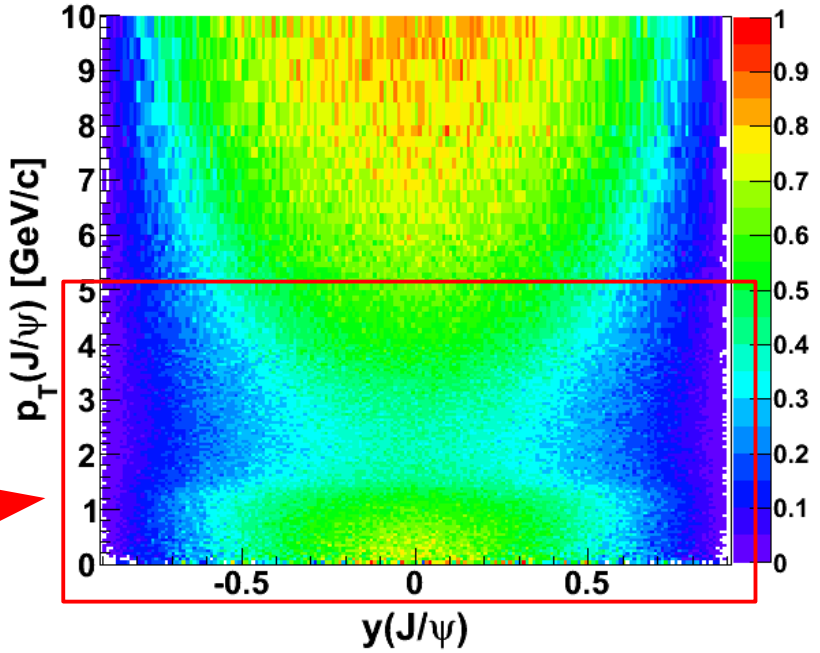
Data

- Events selected using our inelastic trigger (CINT1B):
  - Defined by the coincidence of a hit in the ITS and a hit in one of the VZERO forward trigger detectors
  - Absolute cross-section measured using a Van der Meer scan
    σ_{CINT1B}=62.3±4.4 mb
- $J/\psi \rightarrow e^+e^-$:
  - 2.4×10^8 minimum bias events (CINT1B triggered)
- $J/\psi \rightarrow \mu^+\mu^-$:
  - 1.0×10^7 muon triggered events

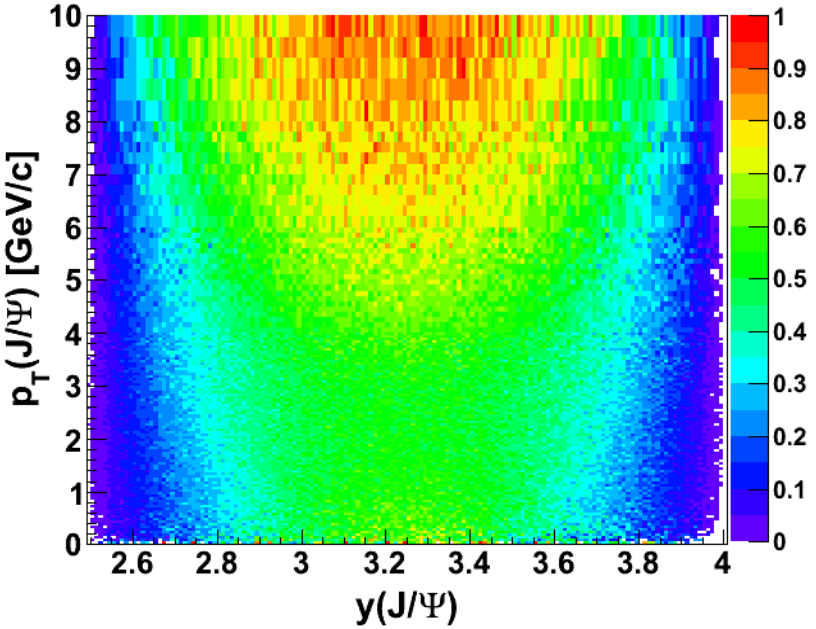
Kinematical cuts

- $J/\psi \rightarrow e^+ + e^-$
  - $|y(J/\psi)| < 0.9$
  - $|\eta(e^+,e^-)| < 0.9$
  - $p_T(e^+,e^-) > 1.0$ GeV/c

Unique measurement at LHC

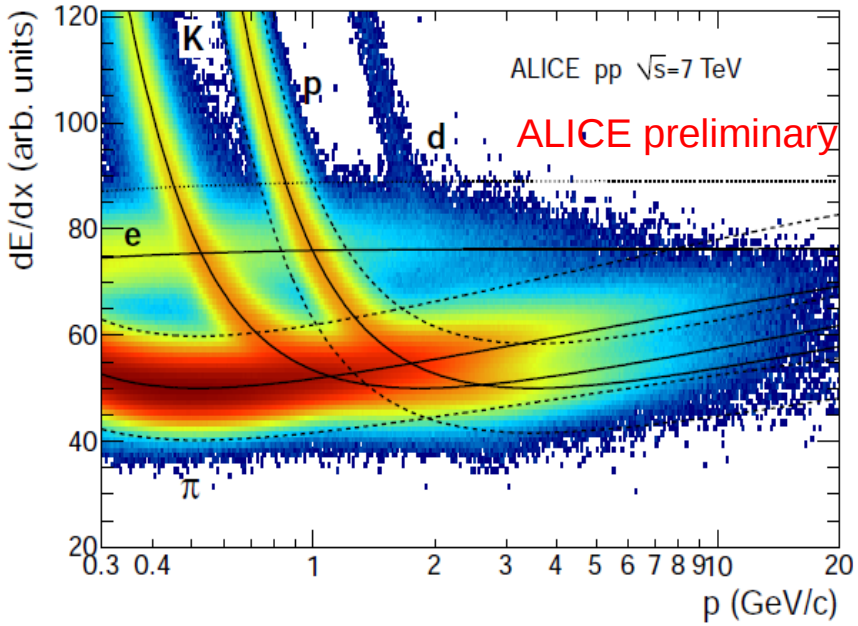


- $J/\psi \rightarrow \mu^+ + \mu^-$
  - $2.5 < y(J/\psi) < 4.0$
  - $p(\mu^+,\mu^-) > 4.0$ GeV/c

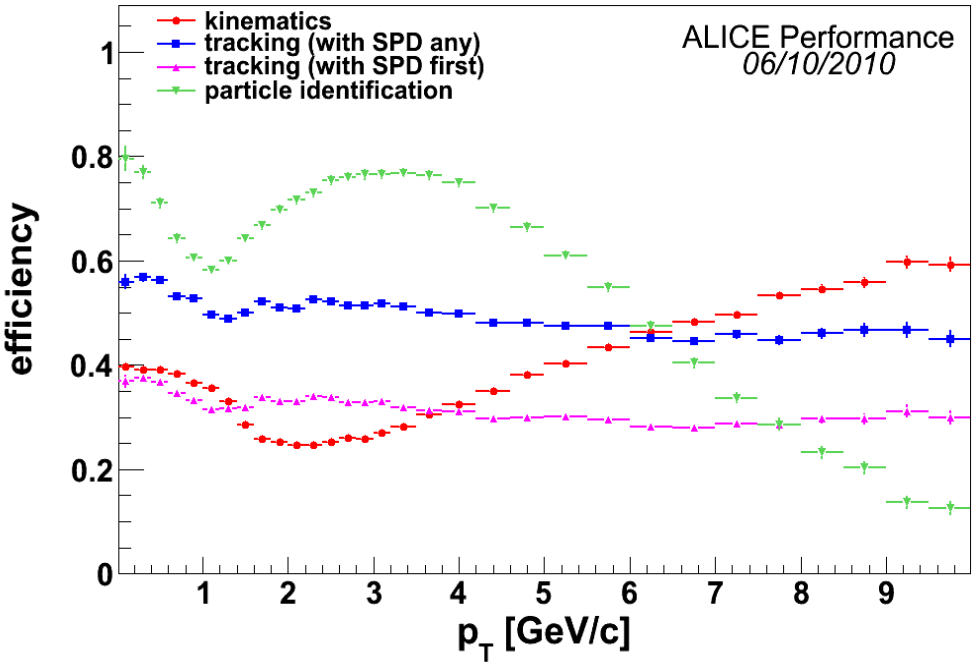


Track selection and particle identification

Particle identification



Partial efficiencies

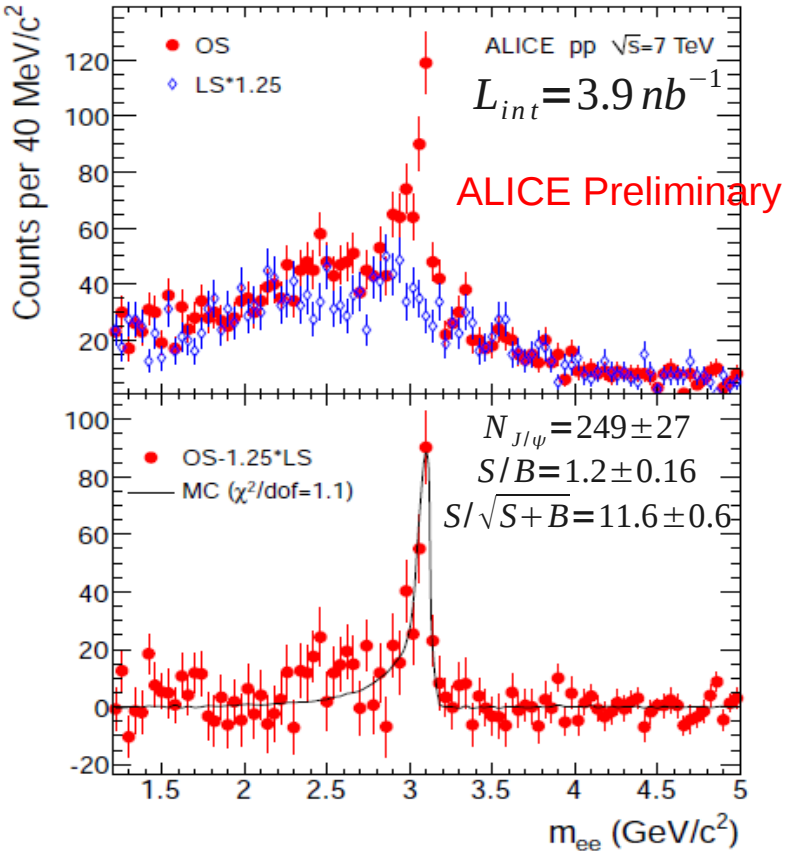


- **J/ψ → e⁺e⁻ :**
  - Standard quality cuts on the ITS+TPC tracks
  - Rejection of secondaries via tracking or DCA cuts
  - Rejection of electrons from photon conversions in the detector material
  - Electron selection done using the Bethe-Bloch curves for the specific energy loss in the TPC

- **J/ψ → μ⁺μ⁻:**
  - Hadron rejection is done via the 2 absorbers
  - Matching between the tracking and trigger stations is required for the muon tracks

Signal extraction

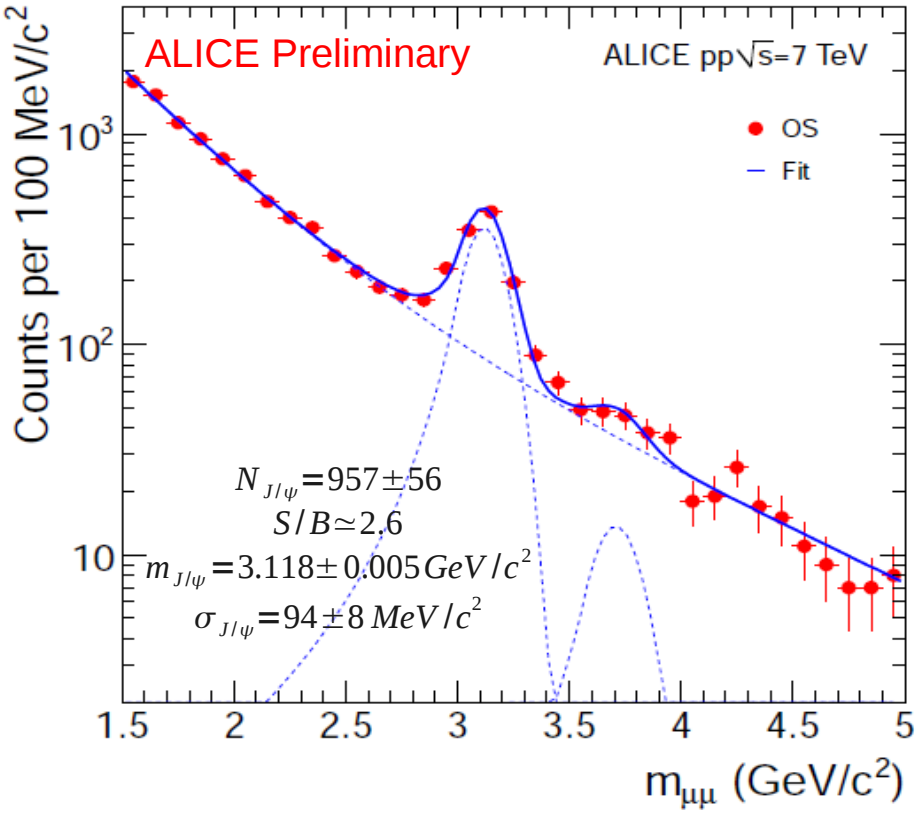
J/ψ → $e^+ + e^-$



- 2.4 x 10^8 p+p min.bias collisions
- Bin counting with like sign background subtraction method employed

$$N_{J/\psi}=N_{OS}-R\times N_{LS}$$

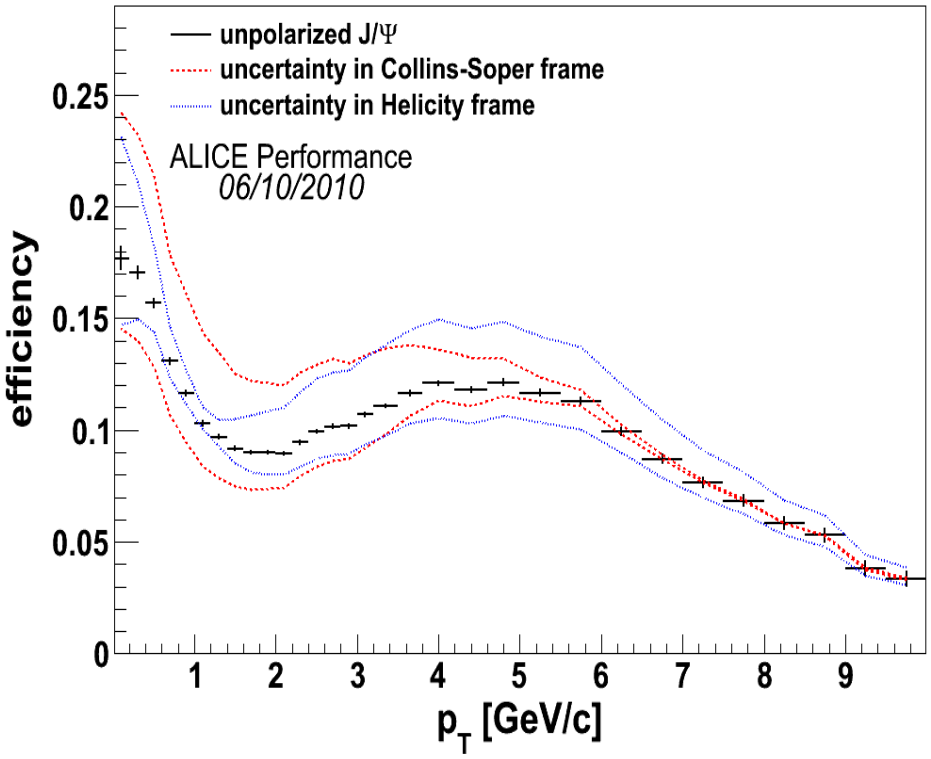
J/ψ → $\mu^+ + \mu^-$



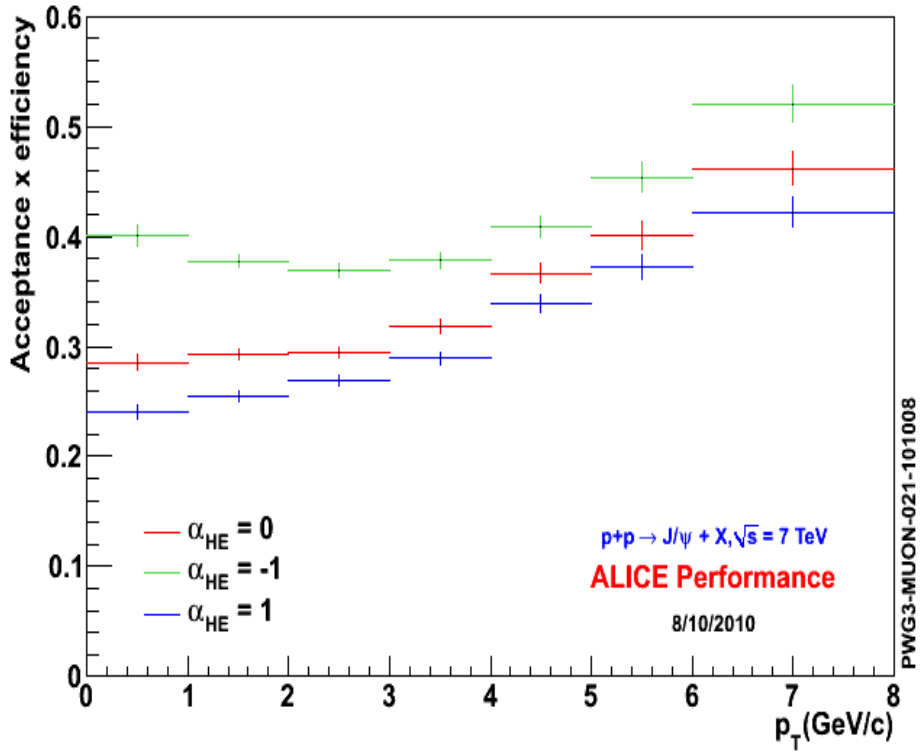
- 10^7 μ triggered events (just a sub-period of the entire dataset)
- Signal extracted using fits with the Crystall-Ball functions

Efficiency and polarization systematics

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



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



- Unpolarized J/ψ assumption was used for the calculation of total efficiencies
- The impact of unknown polarization was calculated by assuming extreme polarization cases

Systematic uncertainty

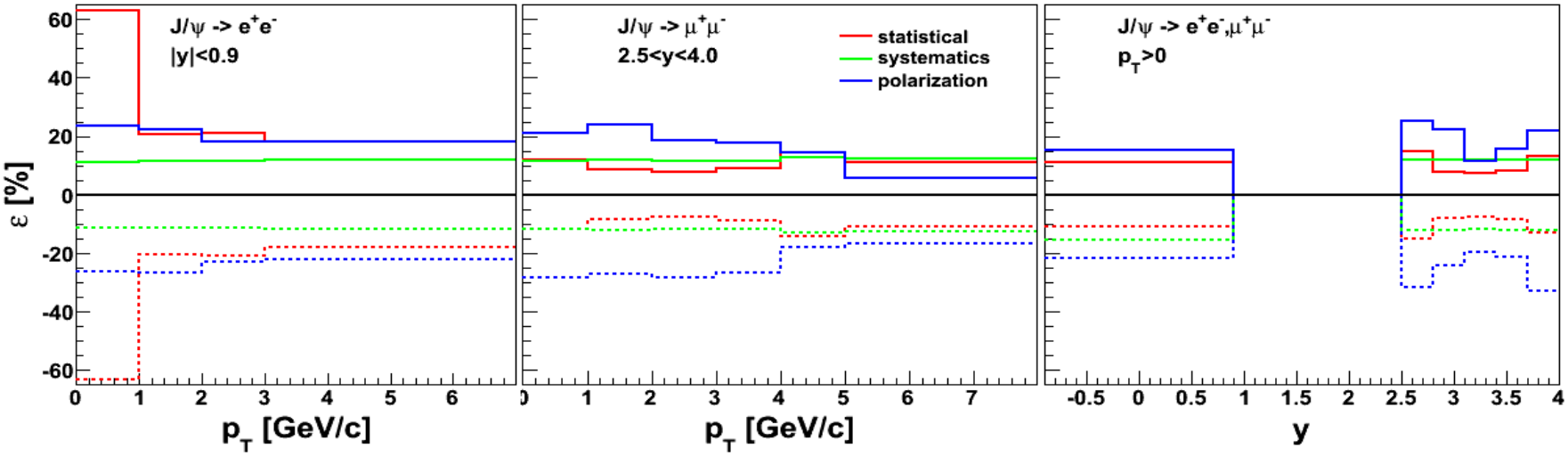
ALICE Preliminary

Channel	e^+e^-		$\mu^+\mu^-$	
Signal extraction	8.5		7.5	
Acceptance input	1		2	
Trigger efficiency	0		4	
Reconstruction efficiency	11		3	
R factor	0		3	
Luminosity	7			
B.R.	1			
Polarization	$\lambda = -1$	$\lambda = 1$	$\lambda = -1$	$\lambda = 1$
CS	+19	−13	+31	−15
HE	+21	−15	+22	−10

Total (w/o polarization): ±15.6 ±12.0

Total: +26.2 -21.7 +33.2 -19.2

- Systematic error in both channels driven by the unknown polarization
- Other major systematic errors come from signal extraction and reconstruction efficiency (especially for the di-electron channel)



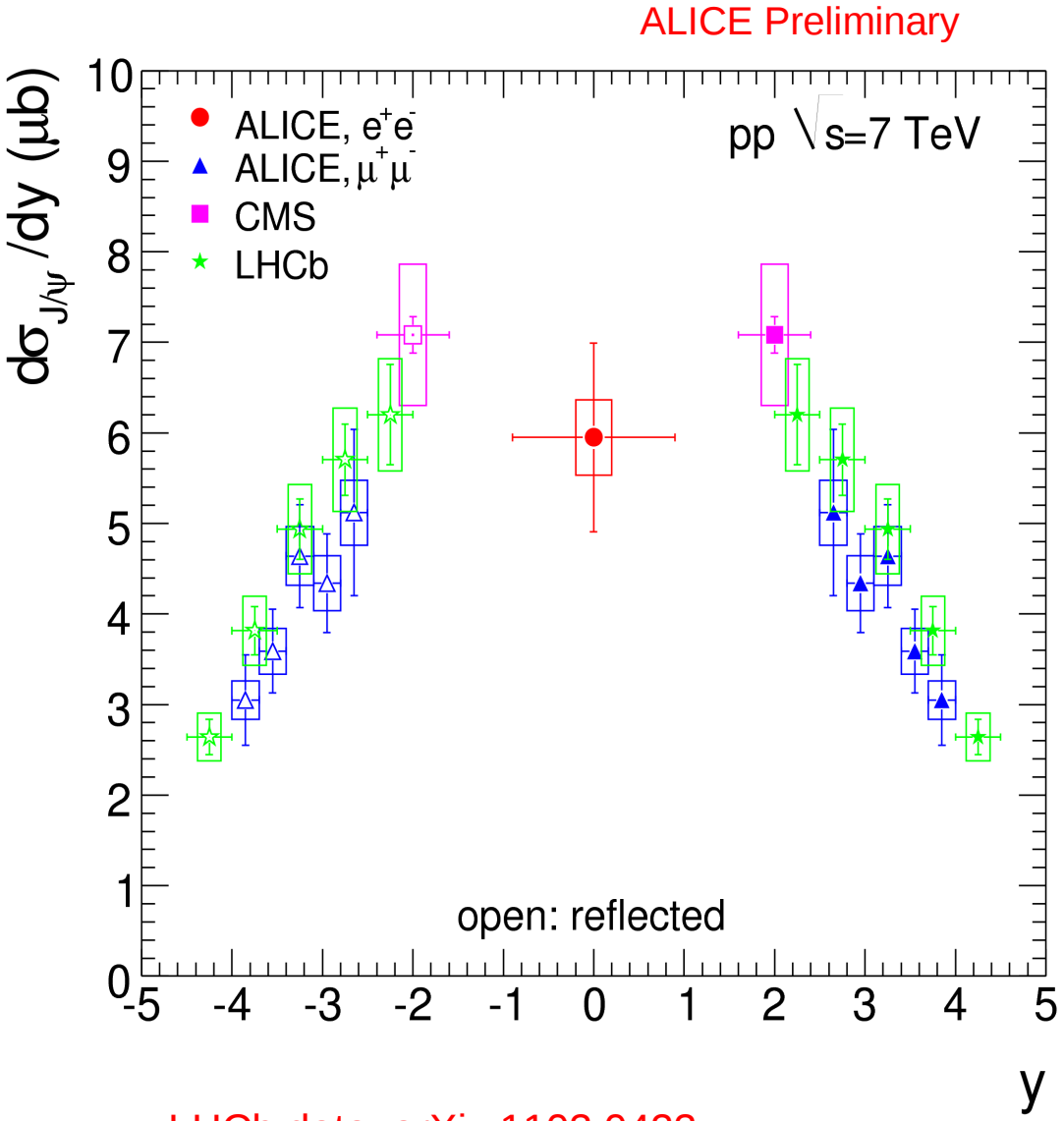
Results

Inclusive dσ/dy

$$\sigma_{J/\psi} = \frac{N^{cor}_{J/\psi}}{BR(J/\psi \to \ell^+\ell^-)} \times \frac{\sigma_{MB}}{N_{MB}}$$

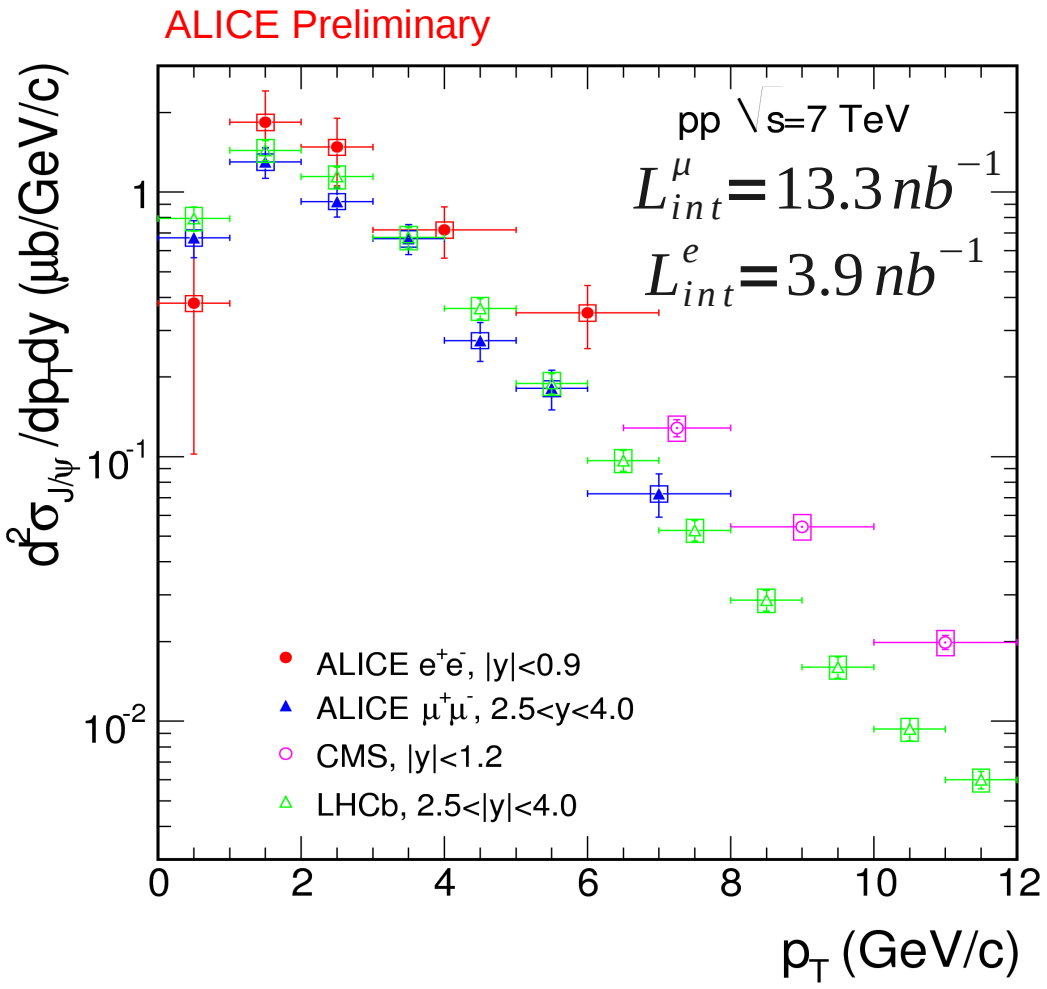
- Error bars are statistical and uncorrelated systematic errors added in quadrature.
Boxes are correlated error bars from luminosity (only part of them are correlated).

- Comparison to CMS and LHCb shows agreement within error bars



LHCb data: arXiv:1103.0423
CMS data: arXiv:1011.4193

Inclusive $d^2\sigma/dp_T dy$

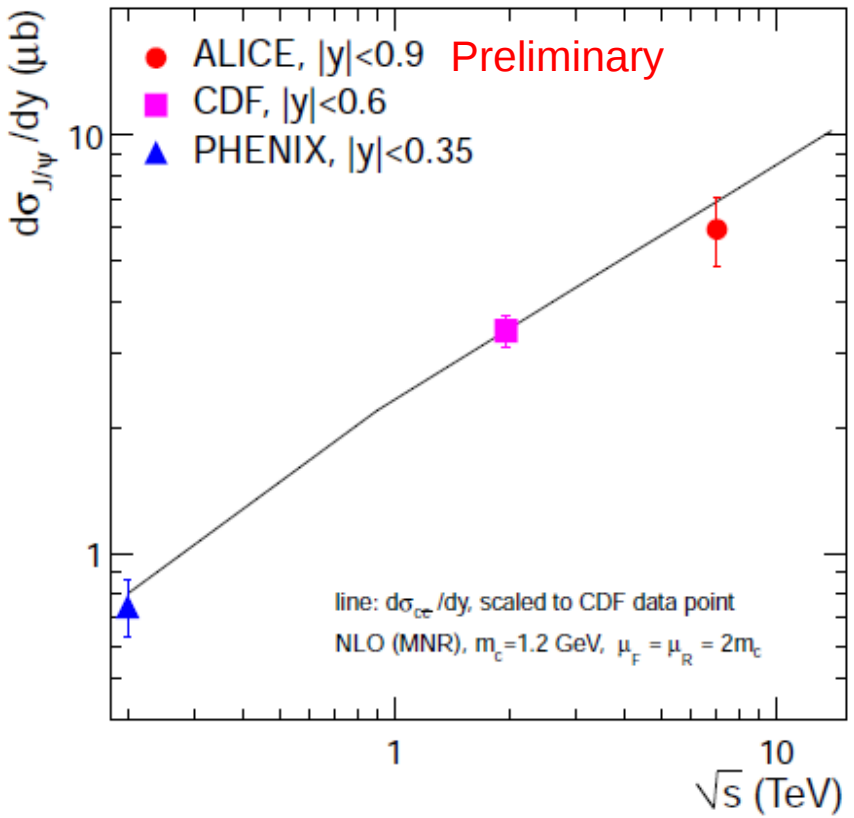


- The pt spectrum at mid-rapidity seems to be slightly harder than the one at forward rapidity
- Good agreement between ALICE and LHCb observed in the 2.5<y<4.0 range
- At mid-rapidity, ALICE and CMS cover complementary pt ranges

LHCb data: arXiv:1103.0423
CMS data: arXiv:1011.4193

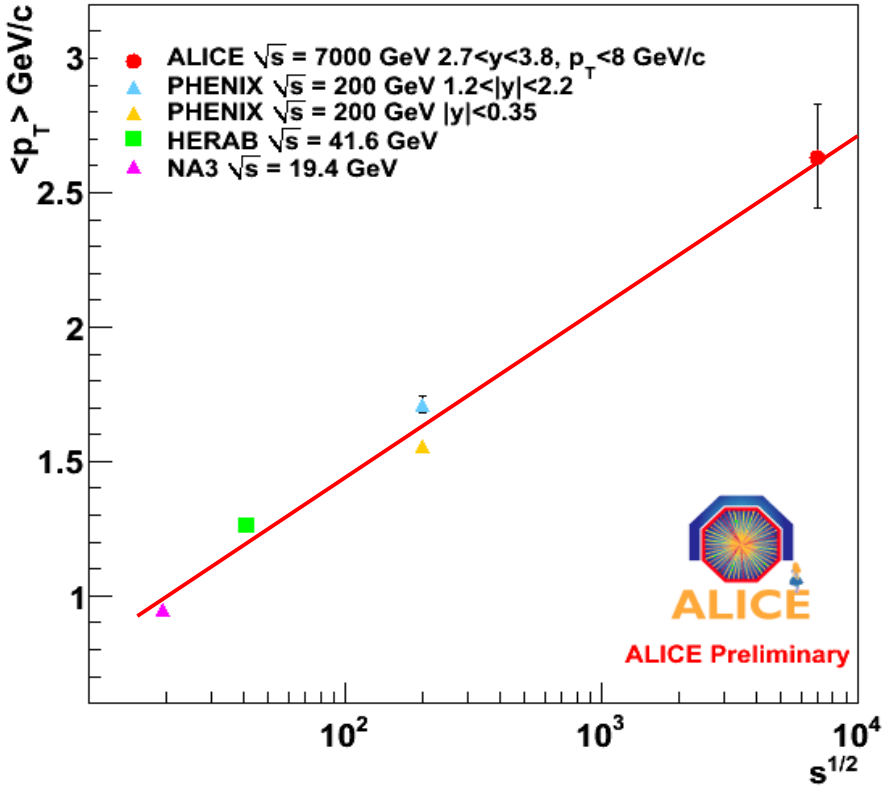
Error bars are statistical and uncorrelated systematic errors added in quadrature.
Boxes are correlated errors from luminosity.

Energy dependence



CDF Collaboration PRD71 (2005) 032001
PHENIX Collaboration, PRL 98 (2007) 232002

The line is a NLO calculation for the ccbar cross-section scaled to the CDF point.



The J/ψ $\langle p_T \rangle$ seems to grow roughly with $\ln(s^{1/2})$

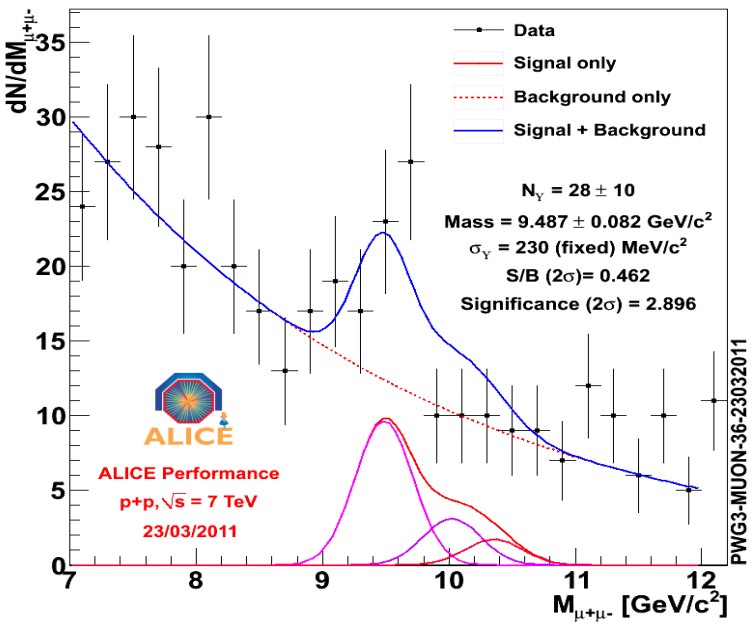
Perspectives

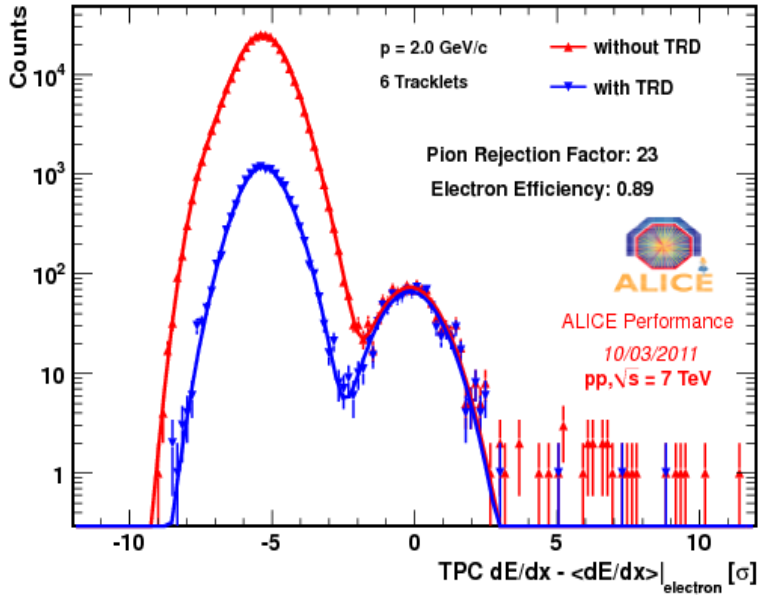
Perspectives

- The measurements of J/ψ in Pb+Pb collisions will constrain models and provide a very good tool to study the deconfined quark-gluon medium.
- The analysis of other observables important for the characterization of J/ψ production mechanisms are ongoing:
  - Polarization: see Livio Bianchi's talk on tuesday
  - J/ψ production as a function of multiplicity: see Matthieu Lenhardt's talk on thursday
- More statistics will allow the measurement of J/ψ x-sections in exclusive channels like:
  - Decays from beauty hadrons measured via the secondary vertices using the ITS
  - Radiative decays from higher charmonium states (χ_c, ψ(2S))

Perspectives

- Running with higher luminosity in 2011, will increase dramatically the forward rapidity statistics and give access to Y states
- At mid-rapidity, the forseen implementation of high pt triggers at mid-rapidity will open new physics analyses like J/ψ-hadron correlations, measurement of Y production, etc.
- The extension of particle identification with the Transition Radiation Detector and the Electromagnetic Calorimeter will increase the pt reach of quarkonium measurements at y=0 beyond 10 GeV/c.





Conclusions

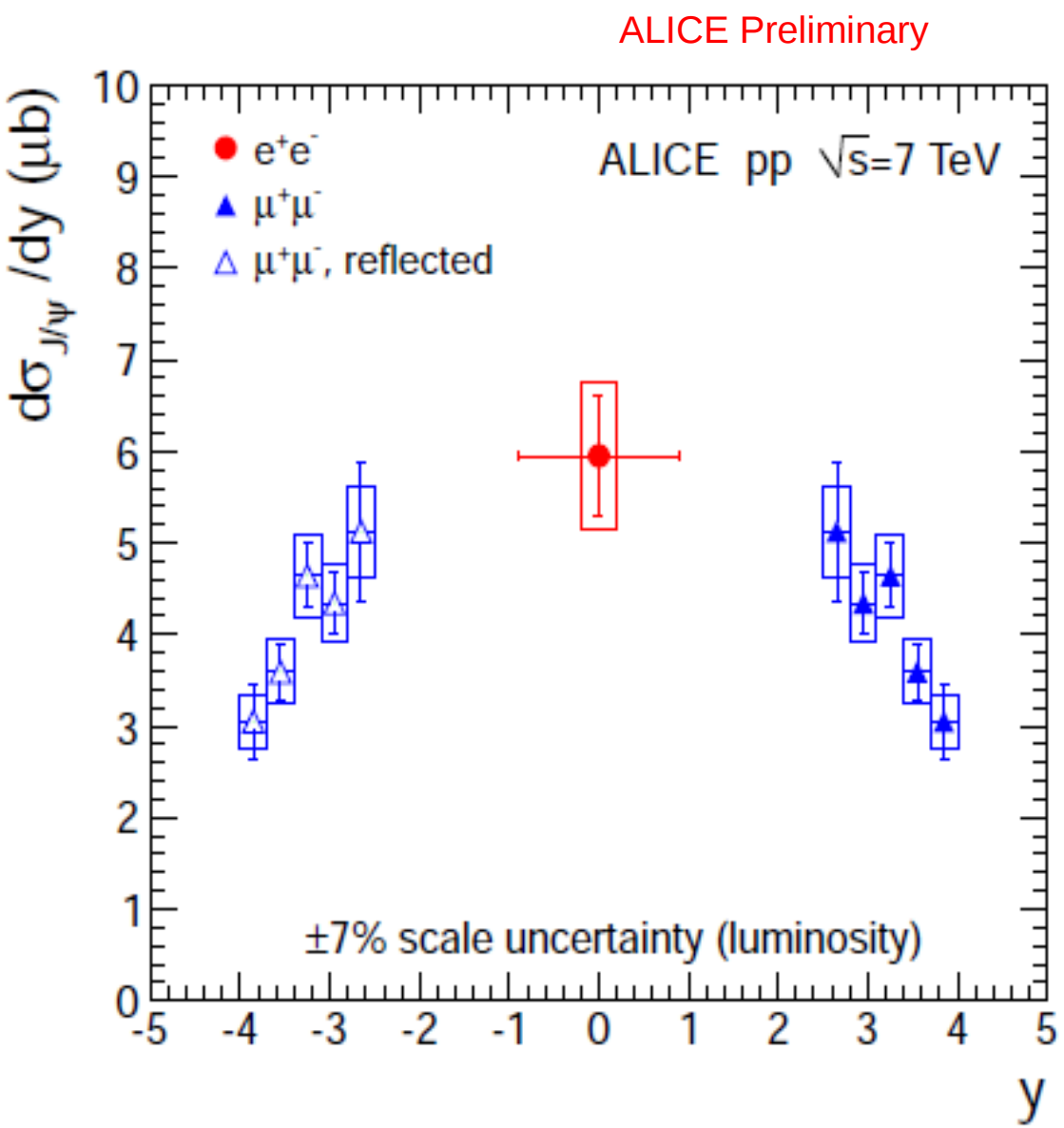
- The inclusive cross-section of J/ψ production in p+p collisions at 7 TeV recorded with ALICE was presented.
- The rapidity dependence of the x-section indicates a plateau like behaviour at mid-rapidity and a steep decrease with increasing rapidity.
- The results from CMS and LHCb are consistent within error bars with the ALICE results.
- The pt dependence (taking the CMS data into account) indicate a slightly harder spectrum at mid-rapidity than at forward rapidity.
- Increased statistics will allow for more precision in the present measurements but will also make possible new ones (e.g. exclusive J/ψ production channels, higher charmonium states, Y family)

Backups

Inclusive dσ/dy

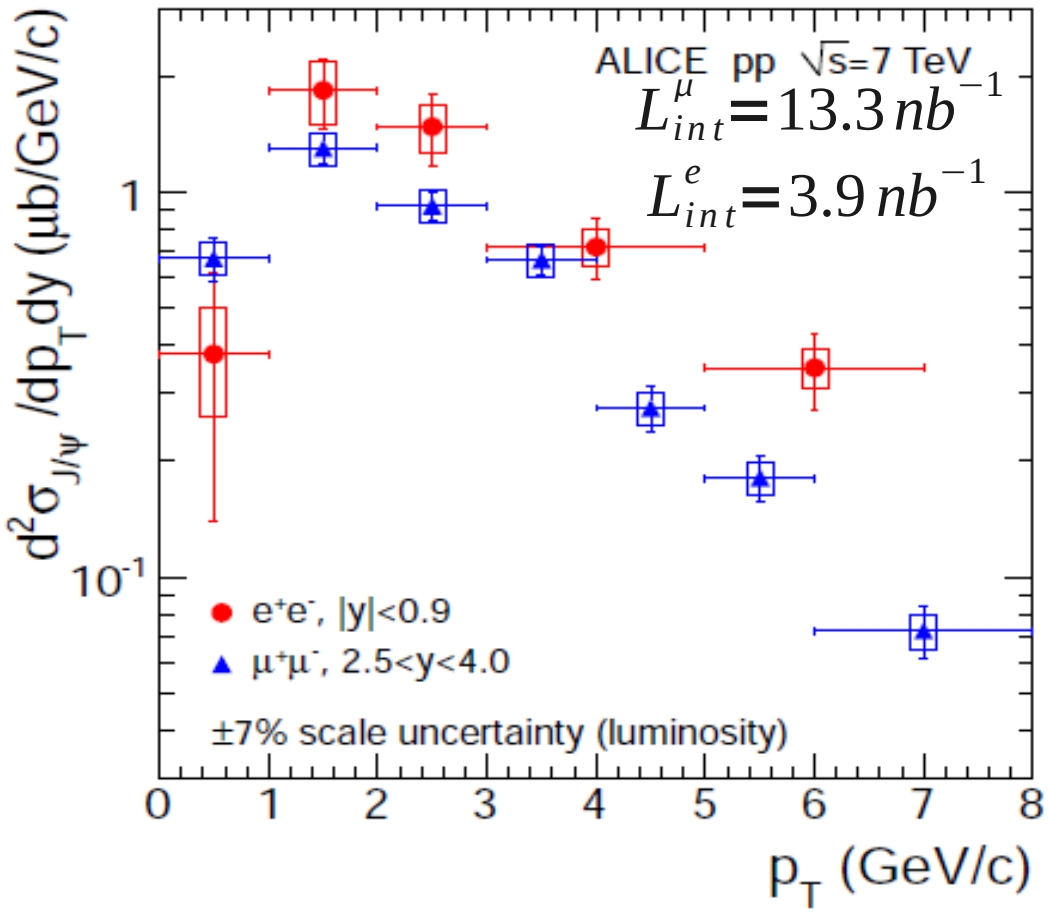
$$\sigma_{J/\psi} = \frac{N^{cor}_{J/\psi}}{BR(J/\psi \to \ell^+\ell^-)} \times \frac{\sigma_{MB}}{N_{MB}}$$

- Error bars are statistical. Boxes are systematic error bars (part of them are correlated due to luminosity).



Inclusive $d^2\sigma/dp_T dy$

ALICE Preliminary



- The pt spectrum at mid-rapidity seems to be slightly harder than the one at forward rapidity

Error bars are statistical.
Boxes are systematic errors (part of them are correlated due to luminosity).