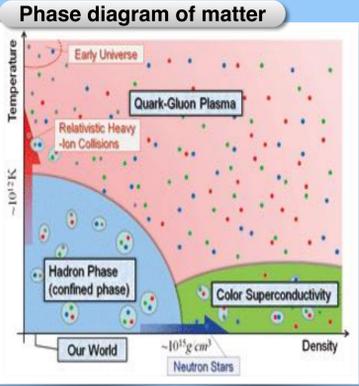# Inclusive J/Ψ production in pp collisions at √s = 5 TeV at forward rapidity with ALICE at the LHC

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## Physics motivations and theory

Phase diagram of matter

- In our everyday world, quarks and gluons are **confined** into hadrons (proton, neutron...)
- Other states can be reached at high temperature. The one we are interested in is a **deconfined** state of matter, the **Quark and Gluon Plasma (QGP)**

QGP can be formed in Pb-Pb collisions

Pb-Pb collision dynamic

Pb + Pb — NN-coll. — QGP — Hadron Gas — "Freeze-Out"
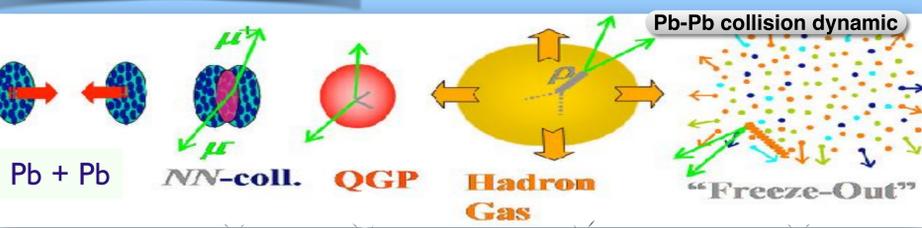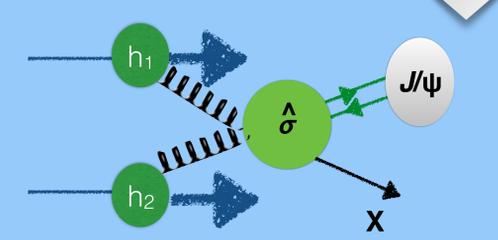
How do we study it ?

Color screening mechanism
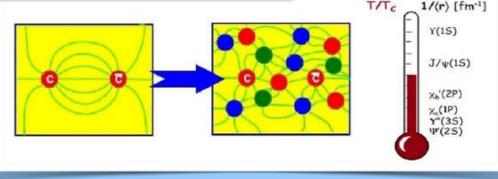
- **Charmonium states** are produced in the earliest stages of the collision
- Charmonium states can be **suppressed and (re)generated in the QGP** depending on **the medium properties**
- Observable: the **J/ψ nuclear modification factor R_{AA}**

Centrality

$$R^i_{AA}(\Delta p_T, \Delta y) = \frac{N^i_{J/\psi}(\Delta p_T, \Delta y)}{BR_{J/\psi \to \mu^+\mu^-} N^i_{MB} A\epsilon^i(\Delta p_T, \Delta y) \langle T^i_{AA} \rangle \sigma^{pp}_{J/\psi}(\Delta p_T, \Delta y)}$$
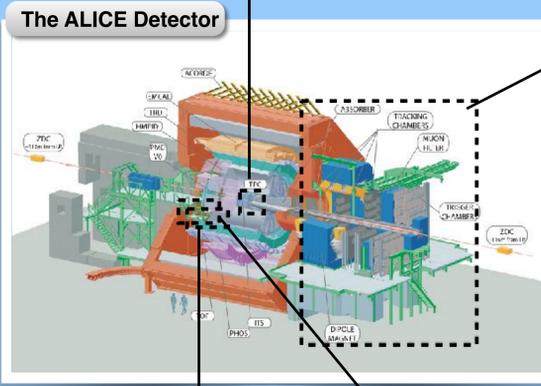
The QCD « vacuum »

Need a baseline : pp collisions

- Measurement of the J/ψ yield in pp collisions :
  - ➡ to **provide a reference** for Pb-Pb studies
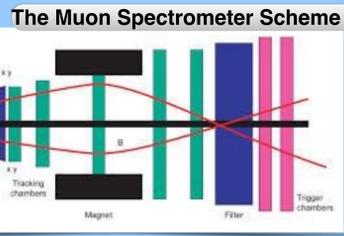 - ➡ to **understand production mechanisms**

h_1, h_2 — $\hat{\sigma}$ — J/ψ, X

The ALICE apparatus

The ITS detector
- is a Silicon tracker detector
- mesures **the vertex** of the collisions in this analysis

The ALICE Detector

The Muon Spectrometer Scheme

The V0 hodoscopes :
- provides **minimum bias trigger**

The T0 detector :
- is a two arrays of Čerenkov counters
- is used as a **Luminometer**

The Muon Spectrometer :
- provides **(di)muon triggers**
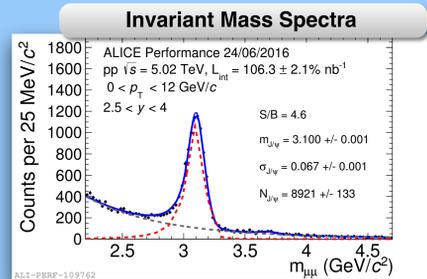- **filters and reconstructs muons**

Analysis

The pp cross section

$$\frac{d^2\sigma^{pp}_{J/\psi}}{dp_T dy} = \frac{N_{J/\psi}(\Delta p_T, \Delta y)}{BR_{J/\psi \to \mu^+\mu^-} A\epsilon(\Delta p_T, \Delta y) L^{pp}_{int} \Delta p_T \Delta y}$$

The Integrated Luminosity

- Converts opposite-sign muon events into equivalent number of minimum bias events

- $L_{int}^{pp} = 106$ nb^{-1}

The Number of J/ψ
- It is extracted from a fit to the dimuon inv. mass spectrum combining :
  - ➡ a signal function (CB2 or NA60)
  - ➡ a background function (VWG or POL2/POL3)
- The final value is the average of many tests (fit functions)
- The syst. uncert. is the RMS of all the tests varying signal and background shapes and fit range

Invariant Mass Spectra

ALICE Performance 24/06/2016
pp √s = 5.02 TeV, L_{int} = 106.3 ± 2.1% nb^{-1}
0 < p_T < 12 GeV/c
2.5 < y < 4
S/B = 4.6
$m_{J/\psi}$ = 3.100 +/- 0.001
$\sigma_{J/\psi}$ = 0.067 +/- 0.001
$N_{J/\psi}$ = 8921 +/- 133

The Acceptance x Efficiency
- It is the response function of the detector
- It is evaluated from simulations accounting for the time-dependent status of the detector during data taking
- Several sources of systematic uncertainties are taken into account:
  - ➡ Tracking efficiency
  - ➡ Trigger efficiency
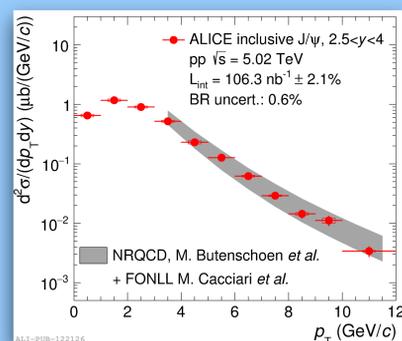 - ➡ Tracking-trigger matching
  - ➡ Generated J/ψ kinematic input shapes

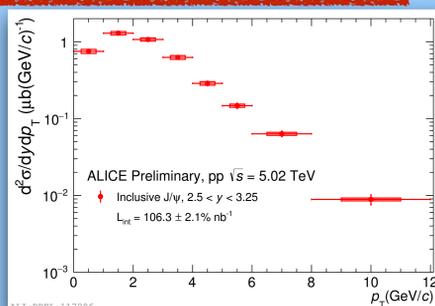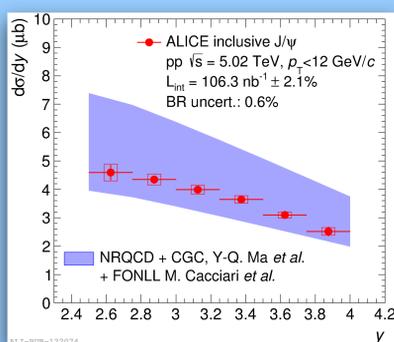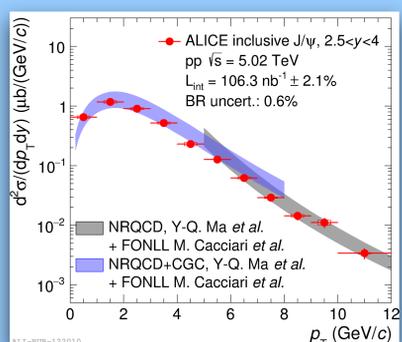| source	integrated	vs p_T	vs y
signal	3%	1.5-9.3%	2.6-4.1%
MC input	2%	3%	3%
track. eff.	1%	1%	1%
trigg. eff.	1.8%	1.5-1.9%	1.5-2.3%
Matching	1%	1%	1%
L_{int}^{pp}	2.1%*	2.1%*	2.1%*
B.R	0.5%*	0.5%*	0.5%*

*=global uncertainty

Results

- The **pp cross section** has been measured **versus p_T and y**
- Two models:
  - ➡ NRQCD + FONLL at higher p_T
  - ➡ NRQCD + CGC at lower p_T
- **Good agreement between data and theoretical predictions**

The high amount of statistics collected allows to extract the cross section versus p_T in **two rapidity ranges**, used as **a reference** for the multi-differential study of the R_{AA}

ALICE inclusive J/ψ, 2.5<y<4
pp √s = 5.02 TeV
L_{int} = 106.3 nb^{-1} ± 2.1%
BR uncert.: 0.6%
NRQCD, M. Butenschoen et al. + FONLL M. Cacciari et al.

ALICE Collaboration, **arXiv:1702.00557**

ALICE inclusive J/ψ, 2.5<y<4
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NRQCD, Y.-Q. Ma et al. + FONLL M. Cacciari et al.
NRQCD+CGC, Y.-Q. Ma et al. + FONLL M. Cacciari et al.

ALICE inclusive J/ψ
pp √s = 5.02 TeV, p_T <12 GeV/c
L_{int} = 106.3 nb^{-1} ± 2.1%
BR uncert.: 0.6%
NRQCD + CGC, Y.-Q. Ma et al. + FONLL M. Cacciari et al.

ALICE Preliminary, pp √s = 5.02 TeV
Inclusive J/ψ, 2.5 < y < 3.25
L_{int} = 106.3 ± 2.1% nb^{-1}

ALICE Preliminary, pp √s = 5.02 TeV
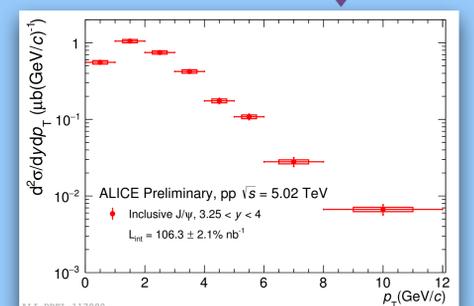Inclusive J/ψ, 3.25 < y < 4
L_{int} = 106.3 ± 2.1% nb^{-1}

ALICE Collaboration, **arXiv:1606.08197**
Y.-Q. Ma, K. Wang, and K.-T. Chao, **Phys. Rev. Lett. 106** (2011) 042002, arXiv:1009.3655 [hep-ph]
Y.-Q. Ma and R. Venugopalan, **Phys. Rev. Lett. 113 no. 19**, (2014) 192301, arXiv:1408.4075 [hep-ph].
M. Cacciari, S. Frixione, N. Houdeau, M. L. Mangano, P. Nason, and G. Ridolfi, **JHEP 10** (2012) 137, arXiv:1205.6344 [hep-ph].
M. Butenschoen and B. A. Kniehl, **Phys. Rev. Lett. 104** (2010) 072001, arXiv:0909.2798 [hep-ph].