Measurement of J/ψ polarization at forward rapidity in pp collisions at √s = 7 TeV with the ALICE detector

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Introduction

- J/ψ polarization: promising observable to discriminate among theoretical models for quarkonia production
- ALICE experiment at the LHC: measures quarkonium and open heavy flavour in the muon channel down to low p_T (0 for quarkonium) at forward rapidity (2.5<y<4)
- Polarization extracted through the analysis of the angular distribution of muons coming from the J/ψ decay
- The progress on the analysis with data collected at √s = 7 TeV is presented.

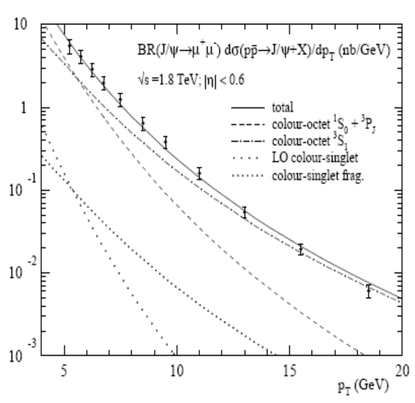
Quarkonium Production

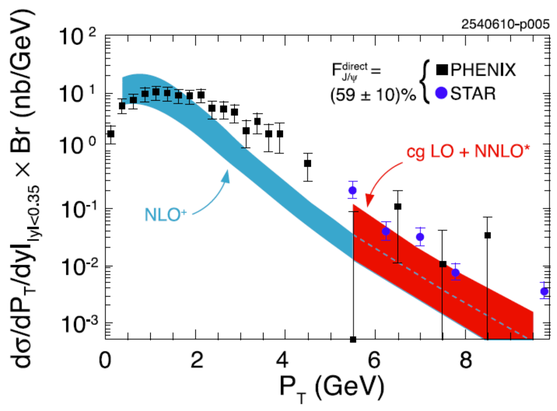
Quarkonium hadroproduction is an issue which is still not theoretically understood.
Several models in the market [1]. Among them:

- **Colour Singlet Model (CSM)**: the heavy quark pair is produced in a colour singlet state;
- **Colour Octet Model (COM)**: the two quarks are created in a colour octet state and then evolve in a colourless bound state with the emission of soft gluons

The two models are different truncations of the effective field theory called Non-Relativistic QCD (NRQCD). [1]

The CSM-LO was ruled out by the CDF Run I p_T differential cross-section [2], while the COM described perfectly the shape [1]. Higher order calculations of CSM [3] are approaching the data (PHENIX and STAR [4,5])





How do we measure Polarization?

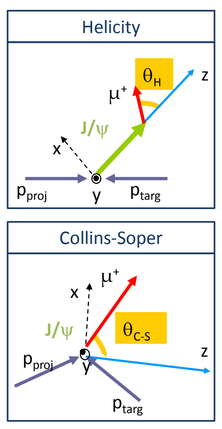
The J/ψ polarization is measured through the study of the angular distribution of the decay products which, taking as a reference the μ^+, is given by:

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

where the λ parameters give the information of how many tranversally/longitudinally polarized J/ψ have been produced

The angular distribution is measured in a given reference frame.
We use two different definitions of the polarization axis:

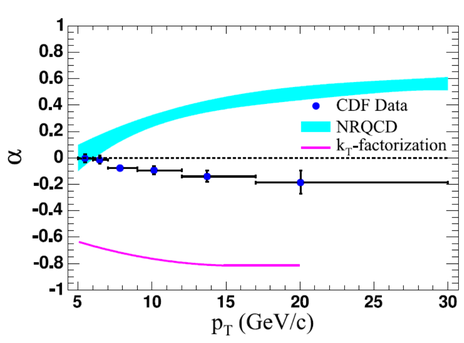
- **Helicity**: direction of the J/ψ in the collision CM frame
- **Collins-Soper**: bisector of the angle of p_{proj} and $-p_{targ}$ in J/ψ C.M.

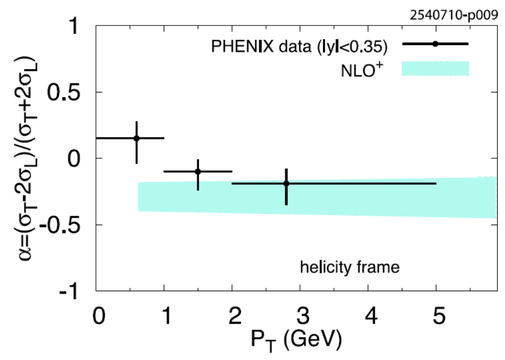


Why is it so important?

CSM and COM make different predictions on the p_T dependence of λ_θ:

- COM completely fails the prediction of the CDF Run II data [6]
- CSM-NLO makes a better job in reproducing Phenix data at mid-rapidity [3,7]





Conclusions

The polarization study for inclusive J/ψ can be carried out in ALICE in the di-muon channel

The collected statistics at √s = 7 TeV allows the determination of the full angular distribution of muons coming from the J/ψ

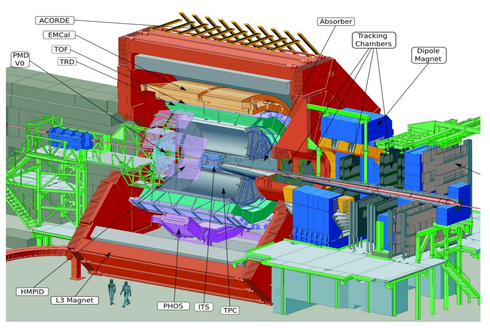
The statistics that we have leads us to a 1D approach: from MC studies we can see that the procedure converges to the values put as an input in simulation

The expected error on the polarization parameters is not larger than 0.15 (λ_θ) for a p_T integrated value ($3 < p_T < 8$ GeV/c) and of the order of 0.2 splitting in 3-4 bins in p_T

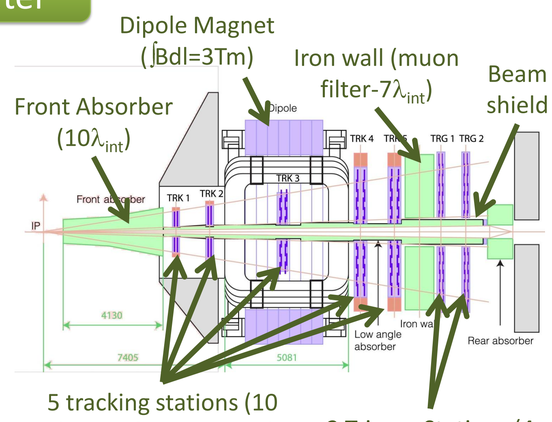
Reference:

[1] N. Brambilla et al., Eur.Phys.J. C71:1534,2011
[2] CDF Collaboration, Phys.Rev.Lett.79, 572 (1997)
[3] J. P. Lansberg, Phys. Lett. B 695 (2011) 149
[4] PHENIX Collaboration, Phys. Rev. Lett. 98 (2007) 232002
[5] STAR Collaboration, Phys. Rev. C 80 (2009) 041902
[6] CDF Collaboration, Phys. Rev. Lett. 99 (2007) 132001
[7] PHENIX Collaboration, Phys. Rev. D 82 (2010) 012001
[8] ALICE Collaboration, 2008 JINST 3 S08002
[9] P. Faccioli et al., Eur. Phys. J. C 69:657-673, 2010

ALICE and the Muon Spectrometer



ALICE [8] is the experiment at the CERN LHC specifically dedicated to the study of the hot and dense matter which is created in ultra-relativistic heavy-ion collisions (QGP).



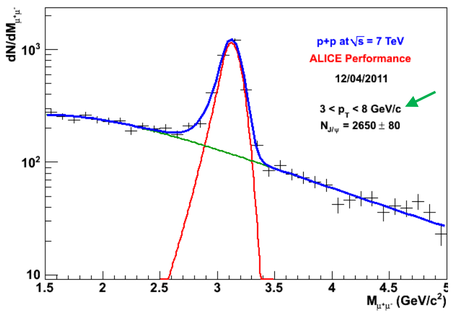
5 tracking stations (10 planes of MWPCs with bi-cathode pad readout)

2 Trigger Stations (4 planes of RPCs)

No vertex detector: only inclusive J/ψ analysis

Analysis Strategy

The data sample used for the analysis corresponds to about 2500 J/ψ collected during the 2010 LHC run in pp at √s = 7 TeV



The statistics do not allow a multi-dimensional analysis

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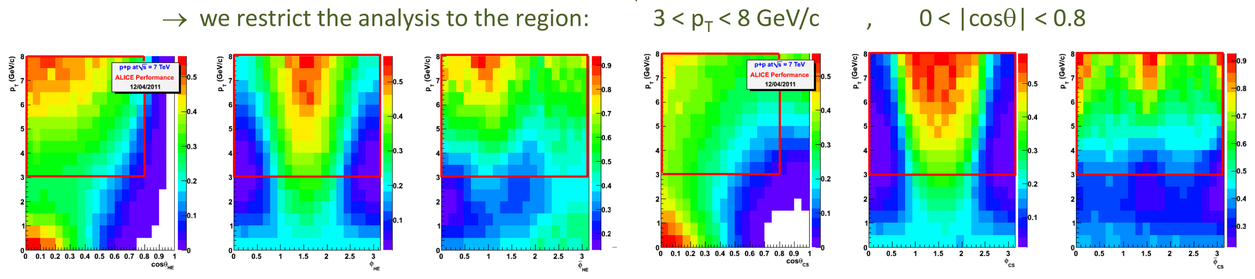
We project the angular distribution in three variables which allow us to extract the three polarization parameters [9]:

$$W(\cos\theta) \propto \frac{1}{3+\lambda_\theta}(1+\lambda_\theta \cos^2\theta)$$

$$W(\varphi) \propto 1 + \frac{2\lambda_\varphi}{3+\lambda_\theta}\cos 2\varphi$$

$$W(\tilde{\varphi}) \propto 1 + \frac{\sqrt{2}\lambda_{\theta\varphi}}{3+\lambda_\theta}\cos\tilde{\varphi} \qquad \tilde{\varphi} = \begin{cases} \varphi - \frac{3}{4}\pi & for\ \cos\theta < 0 \\ \varphi - \frac{1}{4}\pi & for\ \cos\theta > 0 \end{cases}$$

The acceptance for the three variables as a function of p_T show some deep holes (in particular in the cosθ case)
→ we restrict the analysis to the region: $3 < p_T < 8$ GeV/c , $0 < |\cos\theta| < 0.8$



1D analysis in the polarization variables

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Need to make an assumption on the polarization set in the MC sample used for acceptance correction! POSSIBLE BIAS!

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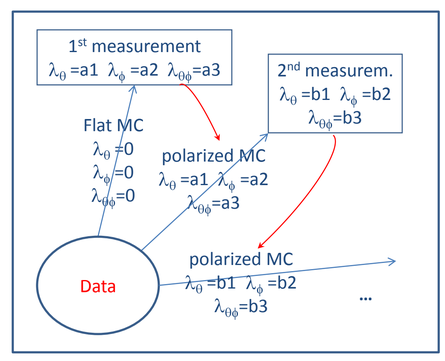
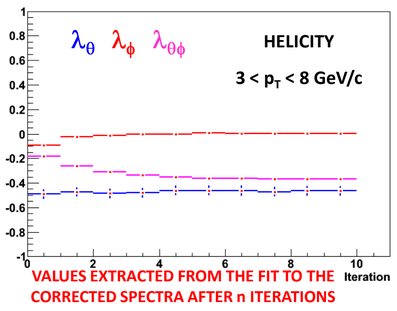
To cope with this problem an iterative procedure is used: in each step we tune the polarization in MC to the values estimated at the previous step

The procedure converges if at the step *n* the values are the same estimated at the step *n-1* (need to demonstrate the convergence!)

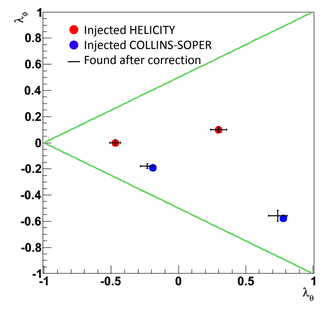


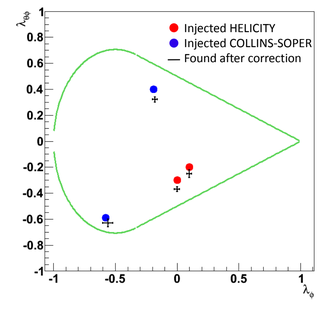
Test of the procedure on MC simulation

Procedure tested on 10^5 J/ψ simulated with realistic kineametical inputs and with a given degree of polarization



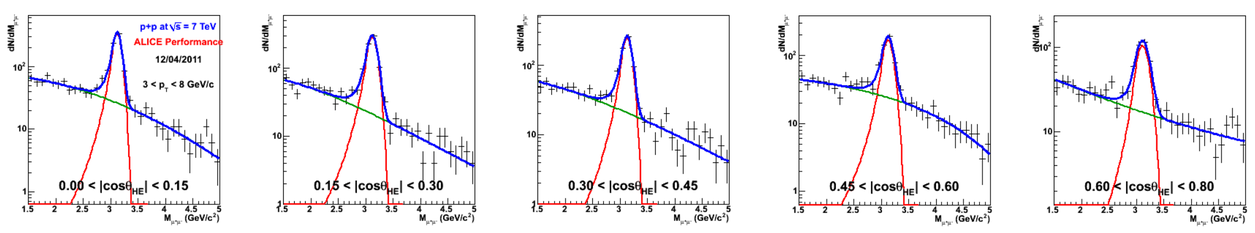
VALUES EXTRACTED FROM THE FIT TO THE CORRECTED SPECTRA AFTER n ITERATIONS





The iterative procedure converges to the input values in less than 5 iterations; nevertheless it's clear that it is important to apply the iterative loop because the values change from the first steps to the last.
Still a systematical underestimation of the $\lambda_{\theta\phi}$ parameter (work in progress).

Performance with current statistics



☹ Unfortunately we don't have 10^5 J/ψ!

☺ But still with the statistics we have we can make 5 bins in cosθ and fit them obtainig a reasonable S/B (~3) .

The statistical error on the three parameters will be lower than 0.15 for an integrated value and of the order of 0.2 for 3 bins in p_T

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