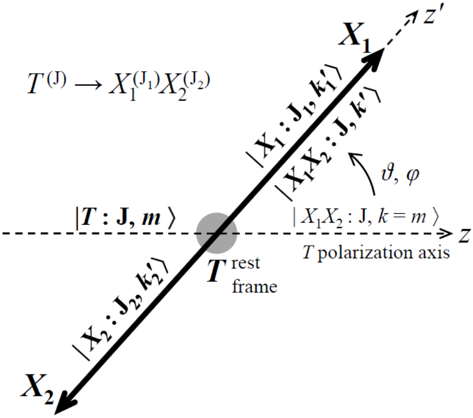
Measurement of J/ψ polarization in CMS

Francisco Albergaria, Henrique Borges

September 5, 2019

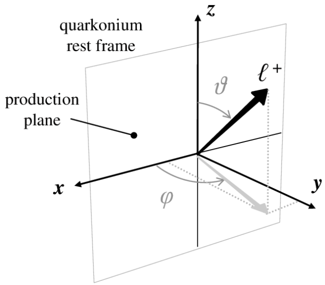
Introduction

A **J/ψ meson** consists of a **charm quark** and a **charm antiquark** and it can decay into a **muon** and an **antimuon**. In this project we studied the **polarization of the J/ψ**.



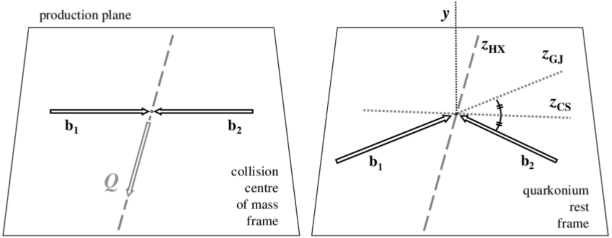
Introduction

The measurement of the distribution requires **the choice of a coordinate system**, with respect to which the momentum of one of the two decay products is expressed in spherical coordinates. In inclusive quarkonium measurements, **the axes of the coordinate system** are fixed with respect to the physical reference provided by the **directions of the two colliding beams as seen from the quarkonium rest frame**. Because of limited time, in this project we **only considered the** $cos(\theta)$ **distribution**.



Introduction

In the analysis of the quarkonium decay distributions we can consider three different conventions for the orientation of the polar axis: the **Collins-Soper** axis (CS), the **Gotfried-Jackson** axis (GJ) and the **Helicity** axis (Hx). In our project, we considered only the **Helicity** axis.



Project Main Goals

Our goal was to obtain a preliminary **measurement of prompt-J/ψ polarization as a function of** p_T, using CMS data not used before for this measurement and a Monte Carlo simulation generated assuming **unpolarized production** (uniform J/ψ decay distribution).

Cuts applied

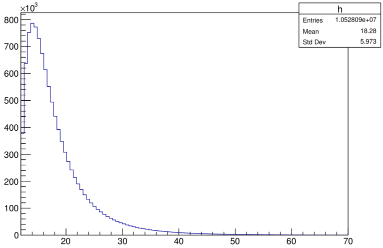
We used **CMS** data of **2012**.
We applied the following cuts to clean the **sample**, define the **phase space,** and reduce **combinatorial background** and contamination from **nonprompt J/ψ**:

- Single muon $p_T > 6$ GeV/c;
- Single muon absolute pseudorapidity < 2.0;
- Dimuon rapidity < 1.5;
- J/ψ mass in $[3, 3.2] GeV/c^2$;
- Dimuon lifetime significance $|ct/ct_{err}| < 2$.

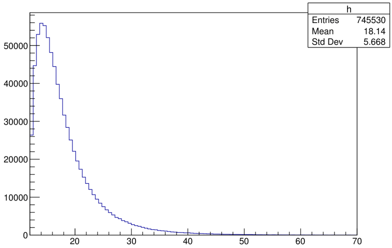
After the cuts, we had 10528090 experimental events and 745530 events from the Monte Carlo simulation.

Binning

We **divided** the sample in **9 bins of dimuon** p_T, determined so that the resulting uncertainty is comparable in all bins, obtaining (in GeV/c): [12, 14], [14, 15.5], [15.5, 17.5], [17.5, 19], [19, 21], [21, 22.5], [22.5, 25], [25, 29], [29, 70].



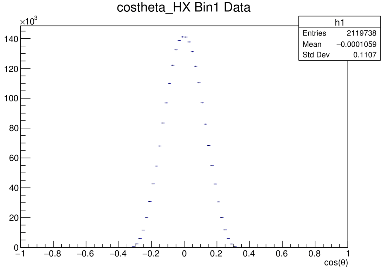
Distribution of p_T for the experimental data



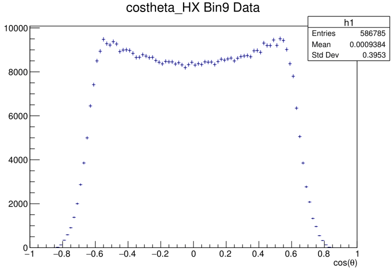
Distribution of p_T for the Monte Carlo simulation data

Results

We obtained the $cos(\theta)$ **distribution in the helicity frame for each p_T bin** for both experimental and Monte Carlo data. Here we have **two** $cos(\theta)$ **distributions** for different bins and we can see that the **range in** $cos(\theta)$ **changes with the change of** p_T:



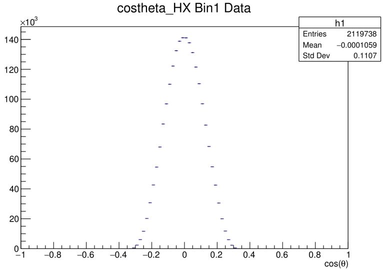
Experimental data $cos(\theta)$ distribution for bin 1



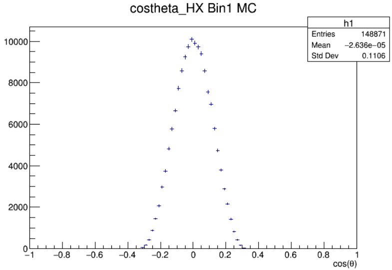
Experimental data $cos(\theta)$ distribution for bin 9

Results

Here we have **two** *cos*(θ) **distributions**, one for experimental data and another for Monte Carlo data and we can see that they are **similar**:



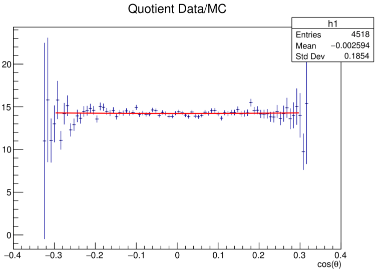
Experimental data *cos*(θ) distribution for bin 1



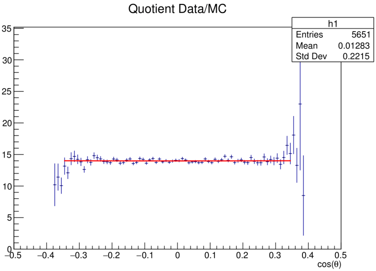
Monte Carlo data *cos*(θ) distribution for bin 1

Results

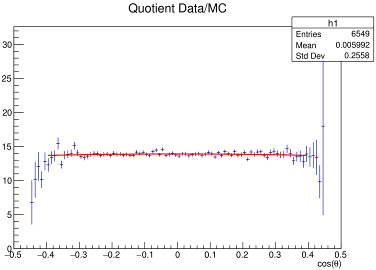
We **divided the experimental data and the Monte Carlo simulation distributions** to correct for the effects of acceptance and efficiency, recovering in this way the physical distribution. After that we **fitted the quotient** with the function $A\,(1+\lambda\, cos(\theta)^2)$, obtaining the following distributions:



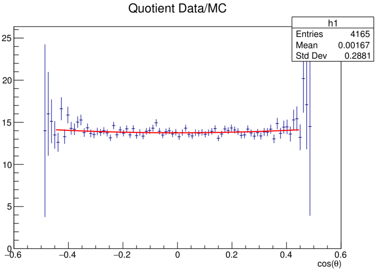
Bin 1: $\chi^2 = 82.9837,\ NDF = 72$



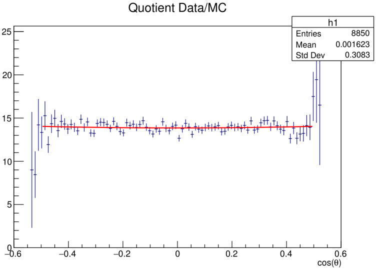
Bin 2: $\chi^2 = 67.9176,\ NDF = 68$



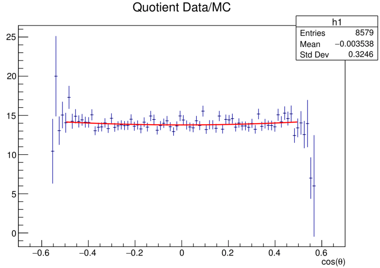
Bin 3: $\chi^2 = 70.1499$, $NDF = 78$



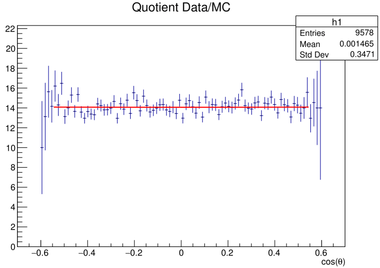
Bin 4: $\chi^2 = 70.7223$, $NDF = 73$



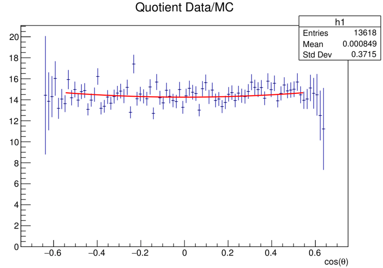
Bin 5: $\chi^2 = 89.957$, $NDF = 82$



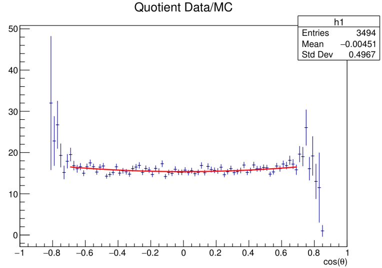
Bin 6: $\chi^2 = 65.6946$, $NDF = 70$



Bin 7: $\chi^2 = 83.3194$, $NDF = 76$



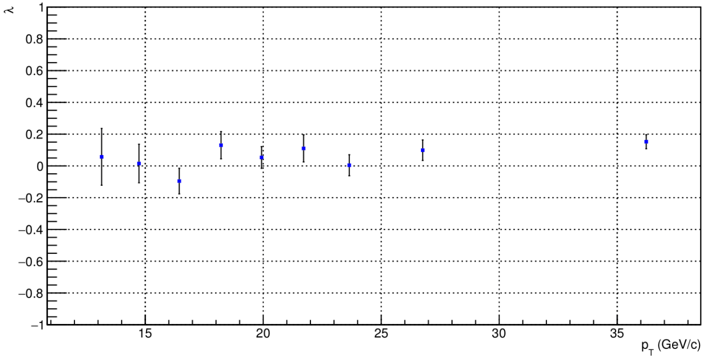
Bin 8: $\chi^2 = 100.439$, $NDF = 72$



Bin 9: $\chi^2 = 81.7336$, $NDF = 68$

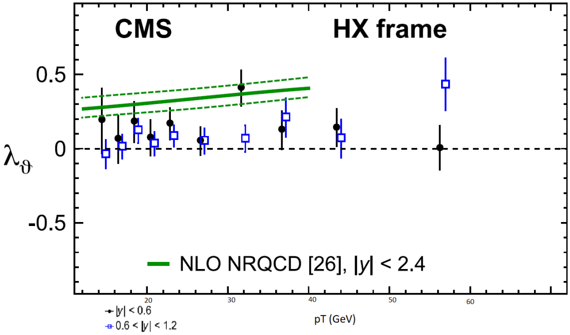
Results

Here is the **plot of λ as a function of p_T**:



Conclusions

- We found that the **J/ψ is produced almost unpolarized** (λ compatible with zero).
- This is in **agreement with the published CMS result** using earlier data:



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Possible next steps

- **Extend measurement to higher p_T** using also more recent data;
- **Determine systematic uncertainties**, for example, changing the selection cuts and the intervals in $cos(\theta)$ used in the fits.

References

P. Faccioli, C. Lourenço, J. Seixas, and H. Wohri, *Eur. Phys. J.* C69(2010) 657, arXiv:1006.2738 , doi: 10.1088/0034-4885/77/6/065901 (2014).

CMS Collaboration , *Physics Letters* B727 (2013) 381