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$J/\psi \to \mu\mu$ from 7 TeV pp collisions in ATLAS: physics with the first data

Andrew Nelson*
(For the ATLAS Collaboration)
Iowa State University
E-mail: andrew.james.nelson@cern.ch

ATLAS has a rich charmonium and beauty physics programme. After a few pb^{-1} of 7 TeV collision data have been taken at the LHC, ATLAS will be able to start probing the new energy regime with decays of the ψ and Upsilon meson families into pairs of muons. The very first physics measurement, already possible with less than 1 pb^{-1} of data, is the fraction of J/ψ mesons produced in b-hadron decays. We present preliminary results for this measurement, and discuss the measurement of the differential cross section and J/ψ polarization.

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*Speaker.

1. Introduction

Charmonium production in hadronic collisions is still not well understood, and measurements at the LHC can help shed light on some unanswered questions in this field. We present here two measurements by ATLAS using the J/ψ resonance in its decay to $\mu\mu$ from LHC proton-proton collisions at 7 TeV: the production cross section of J/ψ as a function of J/ψ transverse momentum (p_T) and rapidity (y) and the ratio, $\mathscr{R}$, of J/ψ produced by non-prompt mechanisms (like the decay of long lived particles, e.g. b-hadrons) to those produced by prompt mechanisms (e.g. QCD processes) as a function of J/ψ p_T.

2. Detector

The ATLAS detector is described elsewhere [1]. We will only swiftly describe the most pertinant components for the analysis here. Muon reconstruction relies primarily on the Inner Detector (ID) and the Muon Spectrometer (MS). The ID covers the full range of ϕ values and $|\eta| < 2.5$. It is made up of three subdetectors, in order of increasing distance from the interaction point they are the Pixel Detector, the SemiConductor Tracker (SCT), and the Transition Radiation Tracker. The MS is only used in this analysis to identify which ID tracks came from muons, and to trigger on events with muons. We reconstruct two types of muon tracks: the combined muons, which take information from the ID and MS into one refitted muon track, and the tagged muons, which take an ID track and match it to hits in the MS.

The measurements presented [2] here use the Minimum Bias Trigger Scintillators (MBTS) and the muon trigger chambers. A dedicated MBTS trigger at the Event Filter level was unprescaled for the early data period used in the measurement. This trigger will be referred to as the "EF trigger". The $\mathscr{R}$ measurement also uses the L1 muon trigger from the MS which has the lowest p_T threshold.

3. Event Selection

For the differential cross section measurement only the EF trigger is used. Since the $\mathscr{R}$ measurement does not rely on the trigger efficiency, events passing either the EF trigger or the L1 muon trigger are used. This results in an integrated luminosity of 9.5 nb^{-1} for the differential cross section measurement, and 17.5 nb^{-1} for the $\mathscr{R}$ measurement. To remove cosmic rays, each event is required to have at least one reconstructed primary vertex with three good tracks (i.e. a track with at least one hit in the Pixel tracker and six hits in the SCT). Only oppositely charged muon pairs are considered. Each muon in the pair is required to be associated with a good ID track, and to pass acceptance cuts. At least one of the muons must be a combined muon, to remove background from fake muons at low p_T. The muon pairs are fitted to a common vertex, and if the fit is successful, the event is selected. Figure 1 shows the invariant mass distribution of the dimuons used in the cross section analysis, and the J/ψ p_T and y in the signal mass region.

4. Double-Differential Cross Section Measurement

The double-differential cross section is calculated in bins of the J/ψ's p_T and y. To determine the number of produced decays, a weight is applied to each candidate, defined as $w^{-1} \equiv \mathscr{A}(p_T, y) \times$

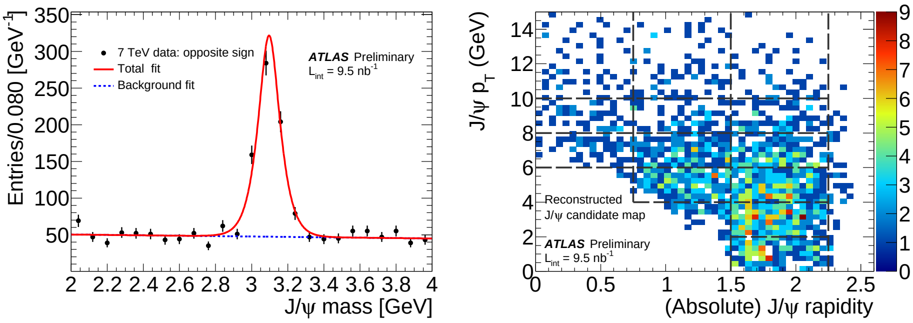


Figure 1: Invariant mass distribution of reconstructed $J/\psi \to \mu\mu$ used in the cross section analysis, and the distribution of reconstructed J/ψ in the signal mass region ($m_{J/\psi} \pm 3\sigma$) in p_T and y.

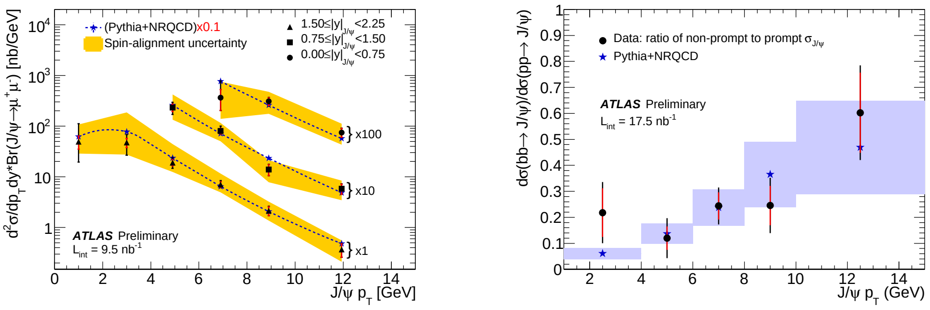
$\mathscr{E}_\mu(\vec{p}_1) \times \mathscr{E}_\mu(\vec{p}_2) \times \mathscr{E}_{\rm trig}(\vec{p}_1, \vec{p}_2)$. The acceptance, $\mathscr{A}$, is the probability that a J/ψ with y and p_T is within the fiducial volume of the ATLAS detector, calculated by generator level cuts on the momenta and pseudorapidities of the two muons. The reconstruction efficiency, $\mathscr{E}_\mu$, varies as a function of the $\vec{p}_1$, $\vec{p}_2$ of the two ID tracks, and is calculated from Monte Carlo simulation and validated by Tag and Probe studies on data. Trigger efficiency maps, $\mathscr{E}_{\rm trig}$, are calculated from Monte Carlo simulation.

A weighted unbinned maximum-likelihood fit is used to extract the J/ψ mass and the weighted yield. The double-differential cross section compared to the Monte Carlo PYTHIA prediction is shown in Figure 2(a). The shape of the distributions agree in both p_T and y, but the overall normalization is off by about a factor of 10. However, the overall normalization is consistent with various other theoretical models. The most significant systematic contribution to this measurement is the spin-alignment uncertainty of the J/ψ, which affects the acceptance. Other systematic contributions are the statistical fluctuations of the acceptance, reconstruction, and trigger efficiency maps. The effect of the map binning was evaluated by performing the measurement with the interpolated values of the weights, and the effect on the measurement of excluding pairs of tagged muons was also included. Finally, the uncertainty in the integrated luminosity, which is not shown in the plot, is $\pm 11\%$.

5. $\mathscr{R}$ Measurement

Promptly and non-promptly produced J/ψ are distinguished using the transverse decay length from the refitted J/ψ vertex and the primary vertex of the event: $L_{xy} \equiv \frac{\vec{L} \cdot \vec{p}_T(J/\psi)}{|\vec{p}_T(J/\psi)|}$. The probability for a b-hadron to decay follows an exponential distribution. However, this is an inclusive measurement, and the b-hadron is not fully reconstructed. The pseudoproper decay time, τ, approximately follows an exponential probability distribution: $\tau \equiv \frac{L_{xy} m(J/\psi)}{p_T(J/\psi)}$, and is used instead.

$\mathscr{R}$ is derived from a simultaneous maximum-likelihood fit to both the reconstructed dimuon mass and τ. The mass PDF provides information on the ratio of signal to background, and the τ PDF has a signal component which distinguishes between non-prompt and prompt J/ψ and a component which parameterizes the background. The signal τ PDF's prompt component is represented by a delta function, and non-prompt component by a one-sided exponential, and both



(a) Corrected inclusive J/ψ cross section as a function of J/ψ p_T and y.

(b) Ratio of non-prompt to prompt J/ψ cross sections as a function of the J/ψ p_T.

Figure 2: Cross section and $\mathscr{R}$ measurement results.

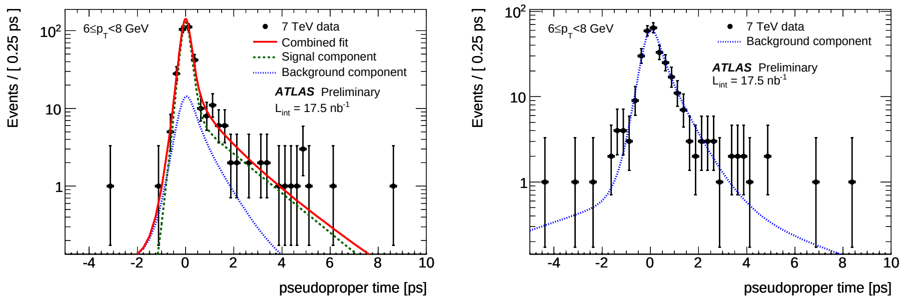


Figure 3: Example of the pseudoproper time distribution of J/ψ candidates in the signal and background region in the p_T bin from 6-8 GeV. The fit distributions are represented by lines, and are projected in the mass window from 2.9-3.3 GeV, and 2-2.9 and 3.3-4 GeV, respectively.

are convoluted with the resolution function. The background τ PDF has components describing prompt and long-lived fractions. Examples of the τ fit in signal and background mass windows are shown in Figure 3. Figure 2(b) shows the differential $\mathscr{R}$ measurement, as a function of J/ψ p_T. There is good agreement with the PYTHIA prediction in each bin, suggesting that the discrepancy in the overall normalization from the differential cross section measurement affects promptly and non-promptly produced J/ψ equally. Systematics were determined by repeating the fit under various assumptions: different background models, different detector resolution models, higher order polynomials for the mass fit background, varying the fit method.

References

[1] The ATLAS Collaboration, *The ATLAS Experiment at the CERN Large Hadron Collider*, *JINST* **3** S08003 (2008).

[2] The ATLAS Collaboration, *The measurement of the differential cross section for the $J/\psi \to \mu\mu$ resonance and the fraction of J/ψ from B-decays with pp collisions at $\sqrt{s} = 7 TeV$ in ATLAS*, ATLAS-CONF-2010-062 (2010).