PROCEEDINGS OF SCIENCE

Heavy Flavours in Atlas

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ATLAS prepared a program for measurements of production cross sections both of b-hadrons and Onia in central proton-proton collisions. Dedicated triggers based on muon, di-muon or electron signatures are designed to accommodate large statistics with early data. After a few pb^{-1} of $7TeV$ collision data have been taken at the LHC, ATLAS has been able to start probing the new energy regime with decays of the ψ and Y families of mesons into pairs of muons, the open charm and open beauty sector. In this paper, first measurements at 7 TeV of ATLAS will be presented. In particular will be shown the J/ψ cross section measurement and non-prompt to prompt ratio, the Y observation, the first signals of D-mesons and observation of $B^{\pm} \to J/\psi K^{\pm}$. Crucial to all of these measurements are the performance of the muon triggers and the offline muon reconstruction and identification, as well as the inner detector performance and tracking.

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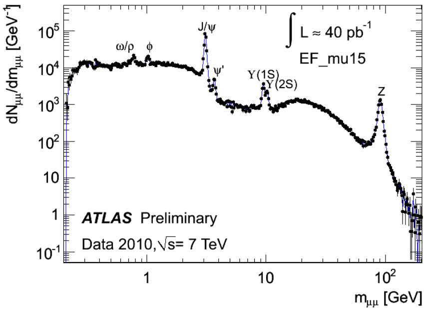


Figure 1: Di-muon invariant mass spectrum for data, from fully combined opposite sign muons. The data corresponds to an integrated luminosity of about 40 pb^{-1}.

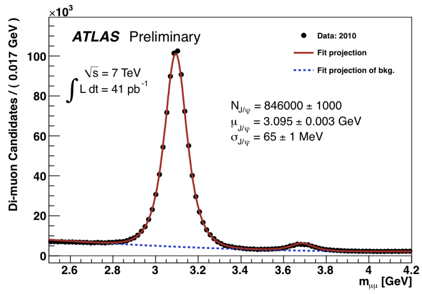


Figure 2: Invariant mass of opposite sign di-muon pairs (points) in the range 2-4 GeV. The solid line shows a fit to the signal and background, the dashed line shows the background fit.

1. Introduction

ATLAS [1] is a multipurpose detector operating at the LHC at CERN. Its excellent tracking and muon system up to high pseudorapidity makes it well suited for heavy flavour studies. During 2010 the LHC proton-proton collisions were recorded at a centre of mass energy $\sqrt{s} = 7\ TeV$ and it has recorded 41 pb^{-1} of data with a data-taking efficiency of about 95%.

Heavy quarkonium is a multiscale system which can probe both perturbative and non perturbative regimes of QCD. ATLAS have prepared analyses to probe the region of large transverse momenta with high statistics accessible only at the LHC to improve on understanding of the production mechanism and the quarkonia polarization state. Furthermore, the relevance of Quarkonia studies for ATLAS are not only restricted to the understanding of the basics QCD processes but it can also be used as a standard candle for a alignment and calibration of the trigger, tracking and muon systems. A precise measurement of onia production allows to correctly subtract background for rare/interesting processes with onia indirect production detector/trigger. These two items need prompt to non-prompt separation capability, where non-prompt are J/ψ from decays of B hadrons.

2. J/ψ and Y observation

Measuring the quarkonia decays $J/\psi \to \mu^+\mu^-$ and $Y \to \mu^+\mu^-$ in ATLAS is an important step for understanding the detector and trigger performance as well as for first B-physics measurements. In figure 2 is shown the di-muon invariant mass spectrum in the $0-100\ GeV$ range with an integrated luminosity of about 40 pb^{-1}. The selected di-muon are combined opposite sign muons with $p_T(\mu_1) > 15\ GeV/c$ and $p_T(\mu_2) > 2.5\ GeV/c$ and the High Level Trigger (EF) with p_T threshold of 15 GeV/c has been required. The J/ψ, $\psi\prime$ and the Y peaks are clearly visible, at lower masses there are the ϕ and the ω/ρ and at higher masses there is the Z peak. Figure 2 shows the invariant mass distribution for all oppositely charged muons in the mass ranges $2-4\ GeV$ using 41 pb^{-1} of data. The J/ψ peaks is clearly visible as well as the smaller $\psi\prime$ peak. The plots in figure 3 show the invariant mass distribution for all oppositely charged muons in the mass ranges $5-12\ GeV$ using 41 pb^{-1} of data respectively to when both muons detected in the barrel, both muons are detected

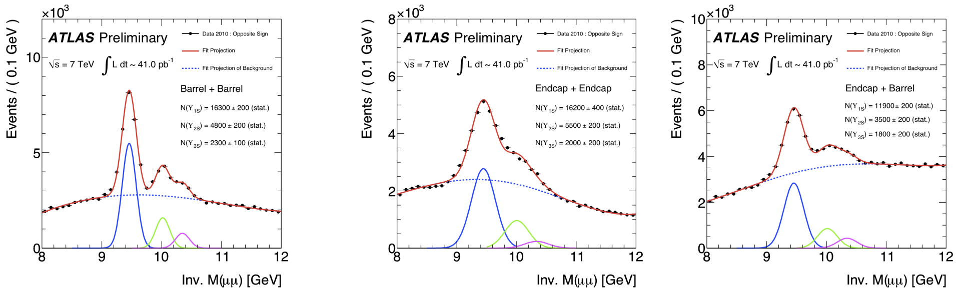
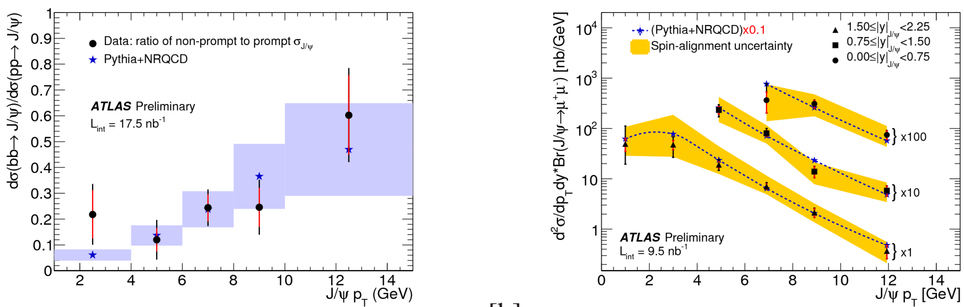


Figure 3: Invariant mass of opposite sign di-muon pairs (points) in the range 5-12 GeV. The tree plots are referred respectively to when both muons detected in the barrel, both muons are detected in the endcaps, one muon is detected in the barrel and one in the endcap.

in the endcaps, one muon is detected in the barrel and one in the endcap. The Y family peaks are clearly visible.

Two measurements based on the J/ψ are presented here [2]. The J/ψ can be produced in non-prompt events via the decay of a long lived particle such as a B-hadron or in prompt decays from short lived sources such as QCD-related subprocesses. The ratio of the number of non-prompt J/ψ to the number of prompt J/ψ is measured in 5 bins of transverse momentum (p_T). In each p_T bin an unbinned maximum likelihood fit to the pseudo-proper time distribution[1] is used to extract the ratio from the data. The plot a) of the figure 4 shows the measured ratio as a



[a] [b]

Figure 4: a) Ratio of non-prompt to prompt J/? production cross-sections as a function of the J/? transverse momentum. Overlaid is a band representing the prediction from PYTHIA Monte Carlo using various spin-alignment scenarios; b) Corrected inclusive J/? cross-sections as a function of J/? transverse momentum and rapidity.

function of J/ψ p_T showing good agreement with the prediction from the PYTHIA Monte Carlo. The differential cross-section for $J/\psi \to \mu^+\mu^-$ is measured in bins of transverse momentum and rapidity. The events are weighted to account for detector acceptance, reconstruction efficiency and trigger efficiency. An unbinned maximum likelihood fit is used to extract the mass and number of signal candidates in each bin. The plot b) of the figure 4 shows the results of the cross-section measurement compared to predictions from PYTHIA. The distributions for the 3 different rapidity bins have been multiplied by a scale factor (as indicated on the plot) in order to visually separate the

[1] Pseudoproper time $\tau = L_{xy} m(J/\psi)/p_T(J/\psi)$ where L_{xy} is the xy displacement of the candidate from the primary vertex, $m(J/\psi)$ is the mass of the J/ψ candidate and $p_T(J/\psi)$ is the transverse momentum of the J/ψ candidate.

three sets of data. Statistical errors are shown in red while the systematic errors coming from the polarization are parametrized in the yellow bands. The shape of the distributions are in agreement with respect to p_T and rapidity (y) although the overall normalization in the Monte Carlo is a factor 10 higher. This factor 10 of disagreement is due to a known problem in the ATLAS tuning and p.d.f. of MonteCarlo. Moreover recent theoretical prediction are in the range of $100-200$ *nb* with an error that is 3 times the absolute value of the prediction. Adding this connection to the $NNLO^*$(enhanced) on the CSM the agreement is good. At low p_T the curves are also consistent with the framework of CEM predictions.

3. $B^{\pm} \rightarrow J/\psi K^{\pm}$ production

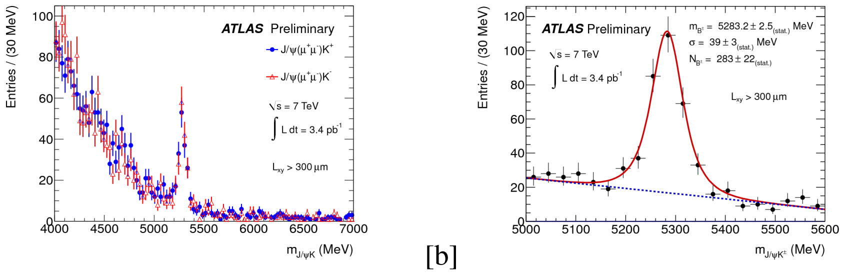
Charged B meson arising from $b\bar{b}$ pair can be reconstructed in the $B^{\pm} \rightarrow J/\psi K^{\pm}$ decay, when the J/ψ dacays in a di-muon final state. This channel is a reference for a variety of high-precision B-physics measurements, such as the branching ratio of the rare B-decay $B_s \rightarrow \mu^+\mu^-$. It will be used as a calibration tool for flavour tagging, needed for CP violation studies. The mass and lifetime measurements will test the performance of the inner detector (e.g. alignment, magnetic field and material). The selection ask for 2 opposite sign muons in the J/ψ mass range ($2915-3275\ MeV$). Di-muon candidates have been refitted to a common vertex asking for a third track and assigning it a kaon mass. These triplets have been selected if the χ^2/dof of the 3−track vertex is < 6 and $p_T > 10\ GeV$. The plot a) of the figure 5 shows the invariant mass distribution for all such candidates, with those containing a negative third track (B^- candidates) plotted separately from the B^+ candidates. An unbinned Maximum Likelihood function has been applied to extract the $B^{\pm}$ mass and the number of candidates from the 3 pb^{-1} of data. The signal has been assumed as gaussian while the background has been modeled using a linear function. The plot b) of the figure 5 shows the invariant mass distribution for $B^{\pm}$ candidates passing all the above selections in the reduced mass range $5000-5600\ MeV$. The result of the unbinned maximum likelihood fit is projected onto the distribution. The $B^{\pm}$ mass returned by the fit is $5283.2 \pm 2.5\ MeV$, which is consistent with the world average value of $5279.17 \pm 0.29\ MeV$. The number of $B^{\pm}$ signal decays is 283 ± 22 and the mass resolution of the $B^{\pm}$ signal is $39 \pm 3\ MeV$. The number of background candidates in the mass range $m_{B^{\pm}} \pm 3\sigma$, is 131 ± 13. All given errors are statistical. For further details see [3].

4. D-production studies

Due to the large cross-section of $c\bar{c}$ and $b\bar{b}$ values and clean D^* meson signatures, reconstruction of charm mesons is already feasible with first LHC data. Clean $D^{*\pm}$, $D^{\pm}$ and D_s^+ signals have been reconstructed with the ATLAS detector with $1.4nb^{-1}$ of integrated luminosity. The fitted mass values were found to be in agreement with their PDG world averages while the observed invariant mass resolution agrees with MC expectations. This study confirms the high performance of the ATLAS detector for precision tracking measurements [4].

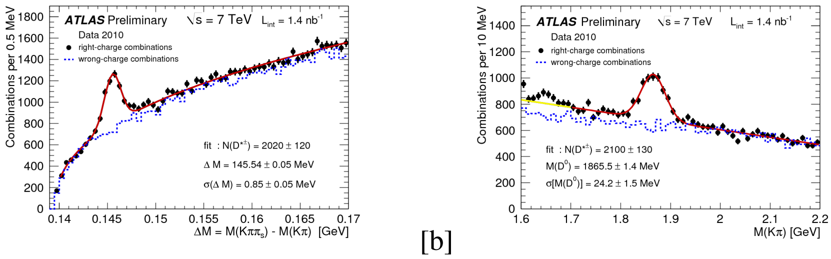
Reconstruction of $D^{*\pm}$

$D^{*\pm}$ mesons were identified using the decay channel $D^{*+} \rightarrow D^0\pi^+ \rightarrow (K^-\pi^+)\pi^+$. In each event,



[a] [b]

Figure 5: a) Invariant mass distributions of reconstructed $J/\psi K^+$ (solid circles) and $J/\psi K^-$candidates (triangles) in mass range $4000-7000\ MeV$; b) Invariant mass distribution of reconstructed $B^{\pm} \to J/\psi K^{\pm}$ candidates. The points with error bars are data. The solid line is the projection of the result of the unbinned maximum likelihood fit to all $J/\psi K^{\pm}$ candidates in the mass range $5000-5600\ MeV$. The dashed line is the projection for the background component of the same fit.



[a] [b]

Figure 6: The distribution of the mass difference$= M(K\pi\pi_s) - M(K\pi)$ (plot a) and the $M(K\pi)$ distribution (plot b) for the $D^{*\pm}$ candidates (points).

pairs of oppositely-charged tracks, each with $p_T > 1.0 GeV$ were assigned to $K\pi$ system and refitted to a common vertex. Any additional track, with $p_T > 0.25 GeV$ and a charge opposite to that of the kaon track, was assigned the pion mass and combined with the D^0 candidate to form a D^{*+} candidate. The plot a) in figure 6 shows the mass difference between the D^* candidate and the $K\pi$ system provided that $1.83 < M(K\pi) < 1.90\ GeV$. A clear signal is seen at the nominal value of $M(D^{*+}) - M(D^0)$. The plot b) in figure 6 shows the $M(K\pi)$ distribution for the $D^{*\pm}$ candidates which satisfy $144 < \Delta M < 147 MeV$. A clear signal is seen at the nominal value of $M(D^0)$. The ΔM distribution was fitted with a Gaussian function describing the signal and a threshold function describing the non-resonant background. The fitted $D^{*\pm}$ yield was $N(D^{*\pm}) = 2100 \pm 130$ and the fitted mass value, $1865.5 \pm 1.4 MeV$, was consistent with the PDG world average. The width of the signal was $24.2 \pm 1.5 MeV$ in agreement with MC expectation.

Reconstruction of $D^{\pm}$ mesons

$D^{\pm}$ mesons were reconstructed from the decay $D^+ \to K^- \pi^+ \pi^+$. In each event, two same-charge tracks were combined with with a track of the opposite charge to form a $D^{\pm}$ candidate. The pion mass was assigned to the two tracks with the same charge and the kaon mass was assigned to the third track, after which the candidate invariant mass, $M(K\pi\pi)$, was calculated. Background contamination from D^* is removed requiring $M(K\pi\pi) - M(K) > 0.15\ GeV$ Figure 7 shows the $M(K\pi\pi)$ distribution for the $D^{\pm}$ candidates after selection cuts. A clear signal is seen at the nominal value of D^+ mass. The mass distribution was fitted to the sum of a Gaussian function describing

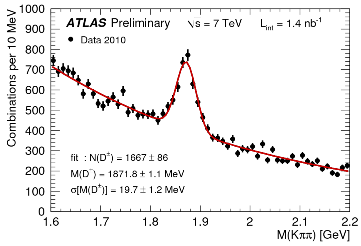
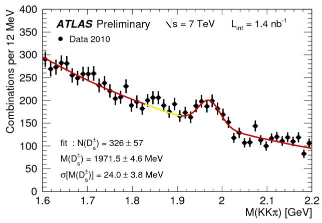
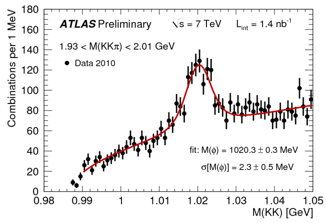


Figure 7: The $M(K\pi\pi)$ distribution for the $D^{\pm}$ candidates (points).



[a]



[b]

Figure 8: The $M(KK\pi)$ distribution (plot a) and $M(KK)$ distribution (plot b) for the $D_s^{\pm}$ candidates (points).

the signal and an exponential function describing the background. The fitted $D^{\pm}$ mass was consistent with the PDG world average and the width of the signal was in agreement with MC expectation.

Reconstruction of $D_s^{\pm}$ mesons

$D_s^{\pm}$ mesons were reconstructed from the decay $D_s^{\pm} \to \phi\pi^{+}$ with $\phi \to K^{+}K^{-}$. In each event, tracks with opposite charges were assigned the kaon mass and combined in pairs to form ϕ candidates. The ϕ candidate was kept if its invariant mass, $M(KK)$, was within $\pm 6\,MeV$ of the ϕ mass. Any additional track was assigned the pion mass and combined with the ϕ candidate to form a $D_s^{\pm}$ candidate with invariant mass $M(KK\pi)$. The plot a in figure 8 shows the $M(KK\pi)$ distribution for the $D_s^{\pm}$ candidates. A clear signal is seen at the nominal value of $M(D_s^{+})$. The plot b in figure 8 shows the $M(KK)$ distribution for the $D_s^{\pm}$ candidates that satisfy $1.93 < M(KK\pi) < 2.01 GeV$. A clear signal is seen at the nominal value of $M(\phi)$. The $M(KK\pi)$ distribution was fitted to the sum a Gaussian function describing the signal and an exponential function describing the background. The fitted $D_s^{\pm}$ mass value was consistent with the PDG world average and the width of the signal was in agreement with the MC expectation.

References

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

[2] ATLAS Collaboration, *ATLAS-CONF-2010-062* [http://cdsweb.cern.ch/record/1281333].

[3] ATLAS Collaboration, *ATLAS-CONF-2010-098* [http://cdsweb.cern.ch/record/1307530].

[4] ATLAS Collaboration, *ATLAS-CONF-2010-034*[http://cdsweb.cern.ch/record/1277669].