

# Heavy Flavour Production in ATLAS

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ATLAS has studied heavy flavour production in a variety of decay channels and inclusive signatures including charmed mesons, jets originating from b-quarks and inclusive muons and electrons. Differential production cross sections for beauty and charm are extracted from these signatures and compared with a variety of theoretical predictions.

## 1 Introduction

The goals of the heavy-flavour physics program at ATLAS are to test theoretical models for heavy-flavour production within the Standard Model (SM) and to search for new physics through rare decays or new sources of CP violation. The proceedings present a selection of analyses that completed during 2011 based on 2010 data and include cross-section and lifetime measurements. The quarkonium cross-sections are presenting in a separate article.

Details of the ATLAS detector may be found in [1]. The sub-detectors used in these analyses are the Inner Detector Tracker (ID) and Muon Spectrometer (MS). In many cases the data collection relied on specific B-physics triggers selection implemented in the Higher Level Trigger (HLT).

## 2 D meson cross-section measurements

Using an integrated luminosity of  $1.1 \text{ nb}^{-1}$ ,  $D^{*\pm}$ ,  $D^\pm$  and  $D_S^\pm$  charmed meson with  $p_T > 3.5 \text{ GeV}$  and  $|y| < 2.1$  are reconstructed using tracks measured in the ATLAS ID [2]. Using the example of the  $D^{*\pm}$ , which is identified in the decay channel  $D^{*\pm} \rightarrow D^0 \pi_s^\pm \rightarrow (K^- \pi^+) \pi_s^\pm$ , where the  $\pi_s^\pm$  is the slow pion in the  $D^{*\pm}$  decay frame, pairs of oppositely-charged tracks with  $p_T > 1.0 \text{ GeV}$  are combined to form  $D^0$  candidates, with kaon and pion masses assumed for the appropriate track to calculate the invariant mass. Any additional track, with  $p_T > 0.25 \text{ GeV}$  and a charge opposite to that of the kaon track, is assigned the pion mass and combined with the  $D^0$  candidate to form a  $D^{*\pm}$  candidate. A clear signal in Fig. 1 in the distribution of the mass difference  $\Delta M = M(K\pi\pi_s) - M(K\pi)$  at the nominal value of  $M(D^{*\pm}) - M(D^0)$ . From a fit to the  $\Delta M$  distribution, a  $D^{*\pm}$  yield of  $2310 \pm 130$  is obtained and its mass was fitted as  $145.41 \pm 0.03 \text{ MeV}$  in agreement with the PDG world average. The results for the  $D^\pm$  (yield  $1546 \pm 81$ ) and  $D_S^\pm$  (yield  $304 \pm 51$ ) mesons are also found to be consistent with PDG world averages. Using Monte Carlo to correct for the detector response, the  $D^{*\pm}$  and  $D^\pm$  production cross-sections (in the kinematic acceptance for the D-mesons of  $p_T > 3.5 \text{ GeV}$  and  $|y| < 2.1$ ) are found and shown in Fig. 1 for the  $D^{*\pm}$  meson. The cross section appears to be generally larger than theories predict, especially at low  $p_T$ .

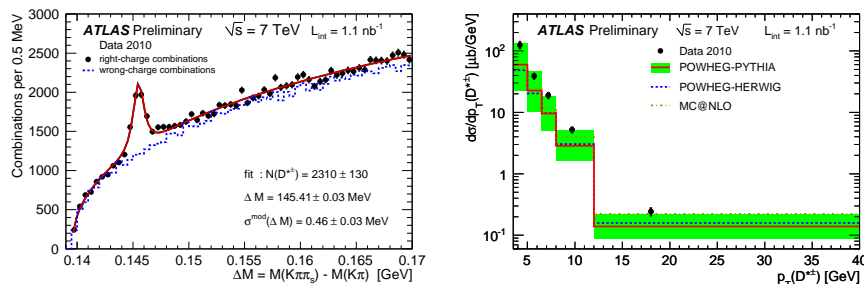


Figure 1: (Left) The distribution of the mass difference,  $\Delta M = M(K\pi\pi_s) - M(K\pi)$ , for  $D^{*\pm}$  candidates. The dashed lines show the distribution for wrong-charge combinations and the solid curves represent the fit results. (Right) Differential cross-section for  $D^{*\pm}$  mesons as a function of  $p_T$  for data compared to the NLO QCD calculations of POWHEG-PYTHIA, POWHEG-HERWIG and MC@NLO for  $D$  mesons produced within  $|y| < 2.1$ . The bands show the estimated theoretical uncertainty of the POWHEG-PYTHIA calculation.

### 3 Lifetime measurements

Precise measurements of B-hadron lifetimes allow tests of theoretical predictions from the Heavy Quark Expansion framework, which can predict lifetime ratios for different B-hadron species with per cent level accuracy. An average lifetime measurement of the inclusive decay  $B \rightarrow J/\psi X \rightarrow \mu\mu X$  is made on the full 2010 dataset (totalling  $35 \text{ pb}^{-1}$ ) [3]. Since the inclusive decay has orders of magnitude higher statistics than an individual exclusive decay this measurements allows a details investigation of the decay length resolution and the impact of residual misalignment of the tracking system. The inclusive lifetime measurement is of the average lifetime of the admixture of B-hadrons produced at the LHC and decaying to final states including a  $J/\psi$ .  $J/\psi$  mesons produced from the decays of B-hadrons are non-prompt, having a displayed decay vertex due to the B-hadron lifetime. The average B-lifetime is extracted from the data by performing an unbinned maximum likelihood fit simultaneously to the  $J/\psi$  invariant mass and the pseudo-proper decay time. To extract the real lifetime of the B-hadrons, a correction for the smearing introduced by the use of the pseudo-proper lifetime is used. This correction, called the “F-factor” is obtained using Monte Carlo with the  $J/\psi$  spectrum re-weighted to match BaBar data. The invariant mass and pseudo-proper decay time projections of the fit are shown in Fig. 3. The average B-lifetime is measured to be:

$$\langle \tau_B \rangle = 1.1489 \pm 0.016(\text{stat.}) \pm 0.043(\text{syst.}) \text{ ps} \quad (1)$$

with the main systematic uncertainty due to the radial alignment of the inner detector. This source of uncertainty can be improved in future analyses. These results agree with recent measurements from CDF and the PDG lifetimes calculated from average lifetime.

### 4 $B \rightarrow J/\psi X$ exclusive decays

The masses of the  $B_d^0$  and  $\Lambda_b$  mesons are reconstructed through the exclusive decays  $B_d^0 \rightarrow J/\psi K_s$  and  $\Lambda_b \rightarrow J/\psi \mu^+ \mu^- \Lambda(p^+ \pi^-)$ . These decays will be expanded upon in future analyses

investigating heavy quark effective theory, QCD and the  $B_d^0 \rightarrow J/\psi K_s$  can be used to investigate CP violation. The mass spectrum for each decay can be seen in Fig. 2.

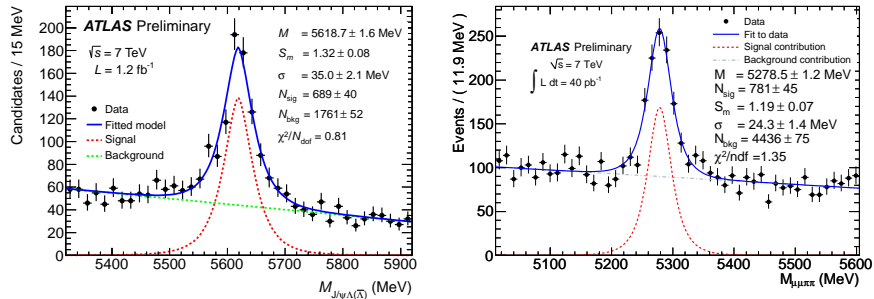


Figure 2: (Left) the reconstructed mass of the  $\Lambda_b^0 \rightarrow J/\psi \mu^+ \mu^- \Lambda(p^+ \pi^-)$  decay without a proper decay time cut (Right) The reconstructed mass of the  $B_d^0 \rightarrow J/\psi K_s$  without a proper decay time cut

The lifetimes of the  $B_d^0$  and  $B_s^0$  mesons are determined from their exclusive decay modes  $B_d^0 \rightarrow J/\psi K^{*0}$  and  $B_s^0 \rightarrow J/\psi \phi$ , using the  $J/\psi$  decay to a di-muon state, the  $K^{*0} \rightarrow K^+ \pi^-$  and the  $\phi \rightarrow K^+ K^-$ . The currently published analyses is based on an integrated luminosity of  $40 \text{ pb}^{-1}$  [4]. The study of the  $B_s \rightarrow J/\psi \phi$  decay is of special interest because it allows the measurement of the  $B_s^0$  mixing phase which can generate CP violation in this channel. The standard model prediction for this phase is small meaning an excess would be a clear indication of new physics. The light ( $B_L$ ) and heavy ( $B_H$ ) mass eigenstates have two distinct decay widths  $\Gamma_L$  and  $\Gamma_H$  which have been determined at the Tevatron using a technique of time dependant angular analyses that simultaneously extracts the CP-even and CP-odd amplitudes. The  $B_d^0$  decay provides a testing ground thanks to its similar topology and larger statistics.

The candidates are reconstructed by selecting all pairs of oppositely charged tracks not identified as muons for the  $K^{*0}$  or  $\phi$  and tracks identified as muons by the muon spectrometer are used for the  $J/\psi$ . The four final state tracks that pass certain selection cut have their decay vertex calculated and the proper decay time extracted. The mass and decay time are used in an unbinned maximum likelihood fit using event by event errors. The  $B_d^0$  lifetime is found to be

$$\tau_{B_d} = 1.51 \pm 0.04(\text{stat.}) \pm 0.04(\text{syst.}) \text{ ps} \quad (2)$$

$$\tau_{B_s} = 1.41 \pm 0.08(\text{stat.}) \pm 0.05(\text{syst.}) \text{ ps} \quad (3)$$

## References

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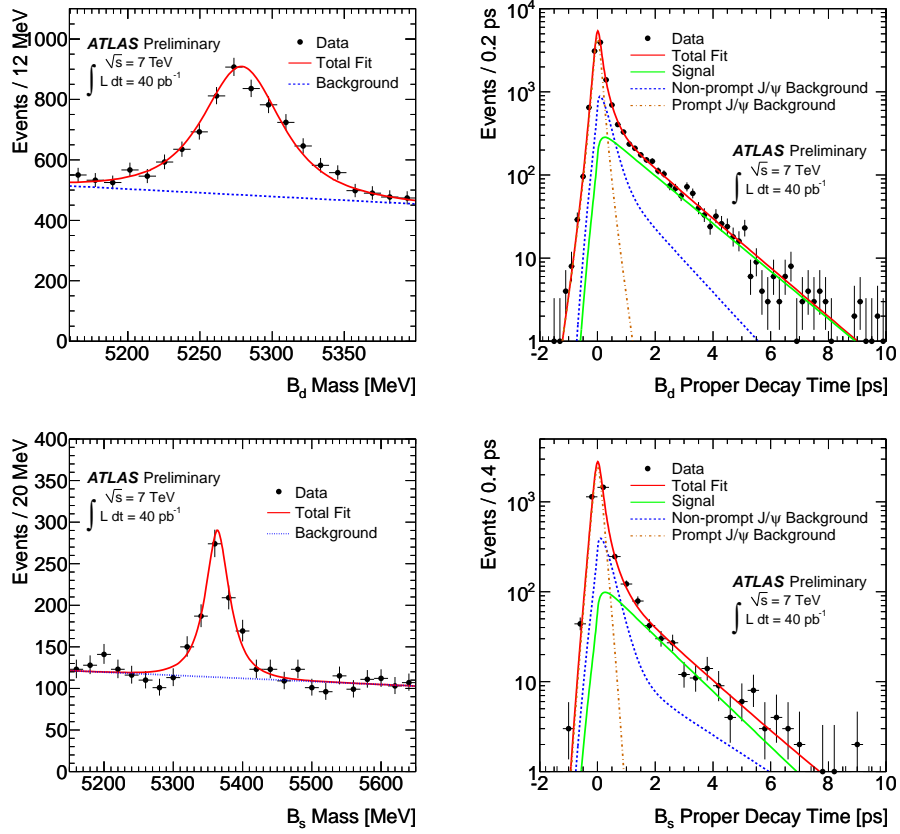


Figure 3: (Top) The simultaneous mass lifetime fit of the  $B_d^0 \rightarrow J/\psi K^{*0}$  decay, using per candidate errors. (Bottom) The simultaneous mass lifetime fit of the  $B_s^0 \rightarrow J/\psi \phi$  decay, using per candidate errors