# First ATLAS results on charm production

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First results on charm production in $\sqrt{s} = 7\,\mathrm{TeV}$ $pp$ collisions with the ATLAS detector at the LHC are presented. The reconstruction method for $D$ mesons is described and results for $D^*$, $D^\pm$ and $D_s$ are presented using $1.4\,\mathrm{nb}^{-1}$ of integrated luminosity collected from March until May 2010.

## 1. INTRODUCTION

Charm production is one of the first hard processes to be measured at the LHC $pp$ collider. It can occur through Flavour Creation (FC), Flavour Excitation (FE) and Gluon Splitting (GS). The total cross section of $c\bar{c}$ production in $\sqrt{s} = 7\,\mathrm{TeV}$ $pp$ collisions is expected to be 4.4 mb [1]. The reconstruction of $D$ mesons is already feasible in ATLAS with the first LHC data due to the clear signatures of $D$ mesons, the large cross section and the very good ATLAS tracking system.

## 2. THE ATLAS DETECTOR

The ATLAS detector is designed to fully exploit the discovery potential of the LHC [2]. It consists of layers of tracking detectors, calorimeters and muon chambers. For the measurements presented in this paper the trigger system and the Inner Detector tracking system are of particular importance.

The ATLAS Inner Detector has full coverage in $\phi$, covers the $|\eta| < 2.5$ range and is dedicated to precise tracking and vertexing. It consists of the silicon Pixel Detector (Pixel), the Semiconductor Tracker (SCT) and the Transition Radiation Tracker (TRT). These detectors cover a sensitive radial distance from the interaction point of 50.5 mm up to 1066 mm and are immersed in a 2 T axial magnetic field.

The ATLAS detector has a three-level trigger system: Level 1 (L1), Level 2 (L2), and the Event Filter (EF). For the first results on $D$ mesons' reconstruction the L1 Minimum Bias Trigger Scintillators (MBTS) have been used, requiring a hit coincidence in the two sides of the detector. The MBTS efficiency is greater than 99.5% for any track multiplicity.

## 3. EVENT SELECTION

The data used for the charm mesons reconstruction have been collected from March to May 2010 and correspond to $1.4\,\mathrm{nb}^{-1}$ of integrated luminosity. Only segments of runs with stable beam conditions and events with a reconstructed primary vertex have been used.

To tune selection criteria, non-diffractive minimum-bias Monte Carlo (MC) was used. This MC sample has been generated using the PYTHIA MC event generator [3] with a specific set of optimised parameters [4].

## 4. RECONSTRUCTION OF CHARM MESONS

The reconstruction of charm mesons takes into account the following properties [5]:

- The hard nature of charm production, applying selection on the transverse momentum and pseudorapidity of the $D$ mesons.
- The hard nature of charm fragmentation, applying cuts on the fragmentation variable defined as the transverse momentum of the $D$ mesons divided by the total transverse

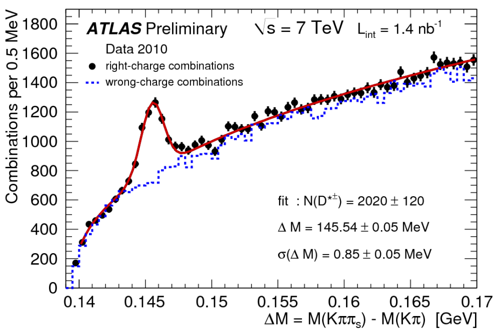


Figure 1. The distribution of the mass difference $\Delta M = M(K\pi\pi_s) - M(K\pi)$. The dashed histogram shows the distribution for wrong-charge combinations. The solid curve represents the fit result.

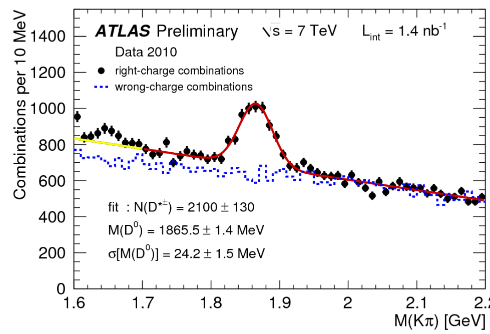


Figure 2. The $M(K\pi)$ distribution for the $D^{*\pm}$ candidates. The dashed histogram shows the distribution for wrong-charge combinations. The solid curve represents the fit result.

energy deposit in the event measured by the calorimeters and the muon system.

- The relatively large lifetime of $D$ mesons, placing requirements on their transverse decay length.
- The "spin" angular behavior of $D$ mesons decays, applying selection criteria on the decay angles.

The goal is to reconstruct the charm mesons in the widest possible kinematical range and make the signal as clean as possible in this kinematical range. The presented kinematical range is $p_T(D) > 3.5\,\mathrm{GeV}$ and $|\eta(D)| < 2.1$. The candidates were reconstructed using tracks measured in the ATLAS Inner Detector tracking system. In order to ensure high reconstruction efficiency and good momentum resolution, the tracks were required to have at least one Pixel hit and four SCT hits and pseudorapidity within the acceptance of the Inner Detector ($|\eta| < 2.5$).

In the following subsections the reconstruction strategy for each charm meson is presented.

### 4.1. Reconstruction of $D^{*\pm}$ mesons

$D^{*\pm}$ mesons are reconstructed in their $D^{*+} \to D^0(K^-\pi^+)\pi_s^+$ decay channel. Two oppositely charged tracks with $p_T > 1\,\mathrm{GeV}$ are combined to a common vertex. Only pairs for which the fit has been successful with a $\chi^2 < 5$ have been considered. The $D^0$ candidate is required to satisfy cuts on the transverse and longitudinal impact parameters calculated with respect to the primary vertex ($|d_0^{PV}| < 0.2\,\mathrm{mm}$ and $|z_0^{PV}\sin\theta| < 0.5\,\mathrm{mm}$). The transverse decay length of the $D^0$ is required to be positive.

A third track with $p_T > 250\,\mathrm{MeV}$ and charge opposite to that assigned to the kaon track forming $D^0$, corresponding to the soft pion, is selected and impact-parameter cuts with respect to the primary vertex are applied on this track($|d_0^{PV}| < 0.8\,\mathrm{mm}$ and $|z_0^{PV}\sin\theta| < 1.5\,\mathrm{mm}$). The soft pion candidate is combined with the $D^0$ to form the $D^*$ candidate. The fragmentation variable is required to satisfy $p_T(D^*)/E_T > 0.02$.

In Figure 1 the mass difference distribution $\Delta M = M(K\pi\pi_s) - M(K\pi)$ is presented for all $D^*$ candidates which satisfy $|M(K\pi) - M(D^0)^{PDG}| < 35\,\mathrm{MeV}$ and a clear signal can be seen at the expected value. The dashed histogram shows the distribution for wrong-charge combinations and the solid curve represents the fit result. The distribution has been fitted with a Gaussian function for the signal and a threshold function for the non-resonant

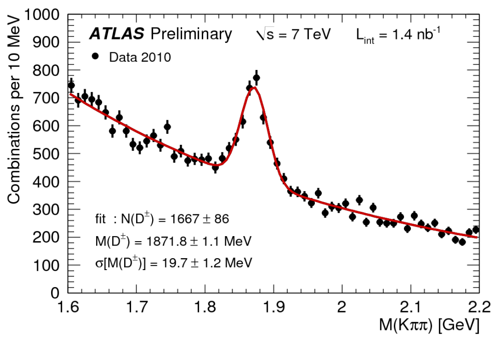


Figure 3. The $M(K\pi\pi)$ distribution for the $D^\pm$ candidates. The solid curve represents the fit result.

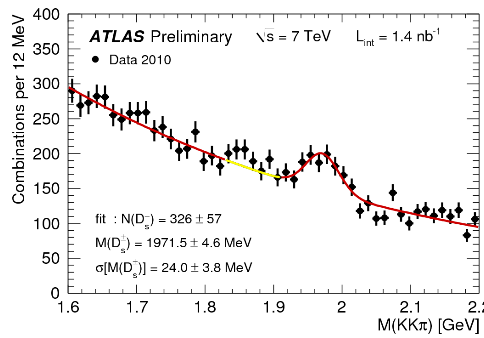


Figure 4. The $M(KK\pi)$ distribution for the $D_s^\pm$ candidates. The solid curve represents the fit result.

background ($c(\Delta M - m_{\pi_s})^a$) and the $D^{*\pm}$ yield is $2020 \pm 120$ while the fitted mass value, $145.54 \pm 0.05$ MeV, is consistent with the PDG world average [6].

In Figure 2 the $M(K\pi)$ distribution is presented for all $D^*$ candidates which satisfy 144 MeV< $\Delta M$ <147 MeV and a clear signal can be seen at the expected value. The dashed histogram shows the distribution for wrong-charge combinations and the solid curve represents the fit result. This distribution has been fitted with a Gaussian function describing the signal and a polynomial function for the background and the $D^{*\pm}$ yield is $2100 \pm 130$ while the fitted mass value, $1865.5 \pm 1.4$ MeV, is consistent with the PDG world average [6].

### 4.2. Reconstruction of $D^\pm$ mesons

$D^\pm$ mesons are reconstructed in their $D^+ \to K^-\pi^+\pi^+$ decay channel. Two same-charge tracks with $p_T > 0.8$ GeV and a third oppositely charged one with $p_T > 1$ GeV are combined to a common vertex. At least one of the two same-charge tracks is additionally required to have $p_T > 1$ GeV. Only three-track combinations for which the fit to the common vertex has been successful with a $\chi^2$ less than 6 have been considered. The $D^\pm$ candidate is required to satisfy cuts on the transverse and longitudinal impact parameters calculated with respect to the primary vertex ($|d_0^{PV}| < 0.15$ mm and $|z_0^{PV} \sin\theta| < 0.3$ mm).

The transverse decay length of the $D^\pm$ is required to be greater than 1.3 mm and the fragmentation variable is required to satisfy $p_T(D)/E_T > 0.02$. To suppress combinatorial background a cut of $\cos\theta^*(K) > -0.8$ was imposed, where $\theta^*(K)$ is the angle between the kaon in the $K\pi\pi$ rest frame and the $K\pi\pi$ line of flight in the laboratory frame.

To suppress contributions from $D^*$ and $D_s^+ \to \phi(K^+K^-)\pi^+$ decays, events with $\Delta M = M(K\pi\pi) - M(K\pi) < 150$ MeV and $|M(K\text{“K”}) - M(\phi)^{PDG}| < 8$ MeV were vetoed.

In Figure 3 the $M(K\pi\pi)$ distribution is presented and a clear signal can be seen at the expected $M(D^+)$ value. This distribution has been fitted with a Gaussian function describing the signal and an exponential function describing the background and the $D^\pm$ yield is $1667 \pm 86$ while the fitted mass value, $1871.8 \pm 1.1$ MeV, is consistent with the PDG world average [6].

### 4.3. Reconstruction of $D_s^\pm$ mesons

$D_s^\pm$ mesons are reconstructed in their $D_s^+ \to \phi(K^+K^-)\pi^+$ decay channel. Two oppositely charged tracks with $p_T > 0.7$ GeV are combined to a common vertex to form the $\phi$ candidates and then a third track with $p_T > 0.8\,\mathrm{GeV}$ is combined to form a second common vertex. Only candidates for which the fit has been successful with a $\chi^2 < 6$ have been considered while the combined vertex track is also required to satisfy cuts on the transverse and longitudinal impact parameters calculated with respect to the primary vertex ($|d_0^{PV}| < 0.15\,\mathrm{mm}$ and $|z_0^{PV} \sin\theta| < 0.3\,\mathrm{mm}$).

The transverse decay length of the $D_s^\pm$ is required to be greater than 0.4 mm and the fragmentation variable is required to satisfy $p_T(D)/E_T > 0.04$. To suppress further combinatorial background, cuts on the decay angles have been imposed: $\cos\theta^*(\pi) < 0.4$ and $|\cos\theta'(K)|^3 > 0.2$, where $\theta^*(\pi)$ is the angle between the pion in the $KK\pi$ rest frame and the $KK\pi$ line of flight in the laboratory frame and $\theta'(K)$ is the angle between one of the kaons and the pion in the $KK$ rest frame.

In Figure 4 the $D_s^\pm$ invariant mass distribution is presented for the candidates which satisfy $|M(KK) - M(\phi)^{PDG}| < 6\,\mathrm{MeV}$ and a clear signal can be seen at the expected value. This distribution has been fitted with a Gaussian function describing the signal and an exponential function describing the background and the $D_s^\pm$ yield is $326 \pm 57$ while the fitted mass value, $1971.5 \pm 4.6\,\mathrm{MeV}$, is consistent with the PDG world average [6].

In Figure 5 the $M(KK)$ distribution is presented for $D_s^\pm$ candidates which satisfy $1.93\,\mathrm{GeV} < M(KK\pi) < 2.01\,\mathrm{GeV}$ and a clear signal can be seen at the expected $M(\phi)$ value. This distribution has been fitted with a non-relativistic Breit-Wigner function convoluted with a Gaussian for the signal and a threshold function describing the non-resonant background ($c(M(KK) - 2m_K)^a$) and the fitted mass value, $1020.3 \pm 0.3\,\mathrm{MeV}$, is consistent with the PDG world average [6].

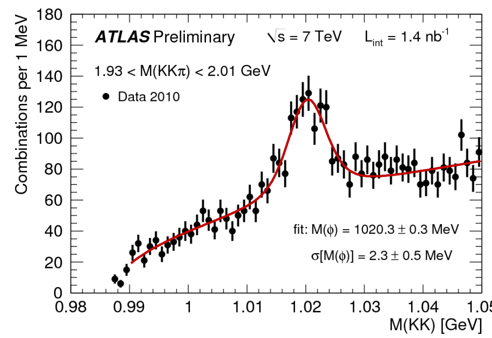


Figure 5. The $M(KK)$ distribution for the $D_s^\pm$ candidates. The solid curve represents the fit result.

## 5. SUMMARY

Clear $D^{*\pm}, D^\pm$ and $D_s^\pm$ signals have been reconstructed with the ATLAS detector in $pp$ collisions at $\sqrt{s} = 7\,\mathrm{TeV}$ using $1.4\,\mathrm{nb}^{-1}$ of integrated luminosity. The reconstruction of charm mesons has confirmed the high performance of the ATLAS detector for precision tracking measurements and has validated the vertexing algorithms in ATLAS.

## REFERENCES


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