ATL-PHYS-PROC-2009-135
23 November 2009

Physics with B-mesons in ATLAS

Lidia Smirnova[1], **Alexey Boldyrev**, *on behalf of the ATLAS Collaboration*[*]

[*] *Moscow State University , E-mail: Lidia.Smirnova@cern.ch, Alexey.Boldyrev@cern.ch*

Abstract

B-physics is an important part of studies with the LHC beams at low luminosities. Effective B-meson reconstruction in ATLAS can produce a clean sample of events for detailed physics analysis with first data. The analysis includes measurements of B-meson masses and proper lifetimes to verify the performance of the Inner Detector, and to estimate backgrounds and trigger efficiencies for rare decays.

XXXIX International Symposium on Multiparticle Dynamics
4-9 September 2009
Gomel Region
Belarus

[1] Speaker

1 Introduction

B-physics is one of the important fields that can be studied with the first ATLAS data. Until now the information about B-meson production come from B-factories, high-energy electron-positron and electron-proton colliders and proton-antiproton colliders. The proton-proton collisions at the LHC will be the next step in studies of B-meson production in hadron interactions with large b-quark production cross section and high luminosity. The ATLAS experiment will be able to reconstruct exclusive B-meson decays.
After the introduction, section two describes briefly the ATLAS detector and triggers, relevant for B-physics, with stress on di-muon channels. Reconstruction of inclusive $J/\psi \rightarrow \mu\mu$ decays and separation of J/ψ from direct and indirect (B-hadrons) production mechanisms are discussed. The efficiency of B^{+}-meson reconstruction with $B^{+} \rightarrow J/\psi K^{+}$ decay mode is presented. The main results with B-physics measurements with early data are summarized. All results described in this overview are for the LHC energy 14 TeV.

2 The ATLAS experiment

ATLAS is the largest particle detector at the LHC due to the superconducting air-core toroid, which is the source of the outer magnetic field [1]. The length of detector is 46 m and its diameter is 26 m. Three levels of the muon drift chambers are positioned inside this magnetic field among the toroidal coils. They provide identification for muons in a wide region of transverse momenta (p_{T}) starting from 3 GeVand a precise determination of p_{T} up to about 1 TeV. The Muon Spectrometer and the Inner Detector comprise the ATLAS tracking system. The Inner Detector has a length of 6 m and is 2 m in diameter. It includes three different detector technologies. Closest to the beam pipe there are three levels of pixel detectors with $80 \cdot 10^{6}$ read out electronic channels. Further out there are four layers of silicon microstrip detectors. With the pixels they produce an average of seven precision hits for a charged particle track. The third component of Inner Detector is the Transition Radiation Tracker (TRT) with thin proportional drift tubes 4 mm diameters (straws). Each track crosses at most 36 straws. By selection of high-energy hits from transition radiation, the TRT permits to the identification of electrons among charged particles.
The ATLAS Trigger consists of three levels. The Level 1 trigger operates with trigger muon chambers and calorimetry information, and provides a trigger rate at luminosities $10^{31} - 10^{33} cm^{-2}s^{-1}$ of about 75 kHz. The Level 2 trigger algorithms decrease the event rate to approximately 2 kHz. The resources of the Event Filter as the third trigger step reduce the output event rate 200 Hz, with approximately 5-10% devoted to B-physics. Two different trigger algorithms are available to cover B-decay modes with two muons in final state [2]. The topological di-muon trigger tunes two muons at Level 1 with separate regions of interest (RoI) around each muon direction. These are combined at Level 2 to calculate the invariant mass. A vertex fit can also be applied. The second scheme is applied for early data and one muon at Level 1, and wide the RoI to search for second muon. Invariant mass cuts applied after the search for the second muon candidate in the Inner Detector tracks, confirmed in muon detectors. Both described triggers will be selecting events with J/ψ decaying to muons. To measure trigger efficiency with real data $J/\psi \rightarrow \mu\mu$ decays will be used in the low p_{T} region from a few GeV/c to 20 GeV/c by tag-and-probe method, illustrated in Figure 1, taken from [2]. With starting conditions two muon trigger will be 6 GeV/c for first muon and 4 GeV/c for second muon ($\mu 6$ $\mu 4$).

3 Inclusive J/ψ events

The exclusive B-decay channels will be selected by inclusive J/ψ triggers and subsequently fully reconstructed using offline tools. Understanding of inclusive Jpsi events is a first milestone in measuring exclusive decays of B-hadrons to J/ψ. The inclusive J/ψ events are composed of J/ψ directly produced

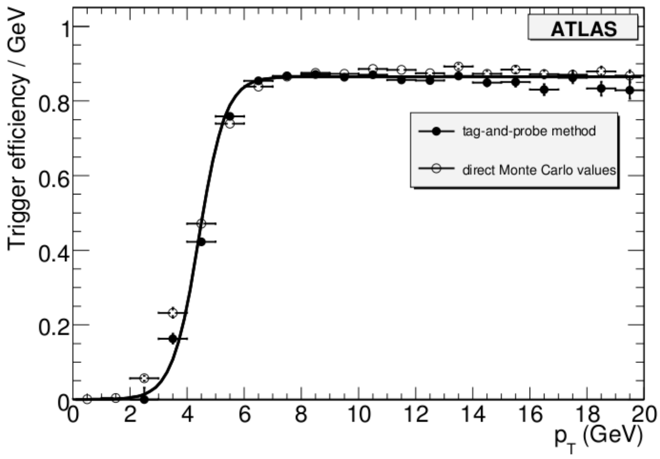

Figure 1: The overall efficiency of the Level 1 single muon trigger with respect to the offline selection obtained by the tag-and-probe method (filled circles) and the efficiency estimated from a single muon MC sample (open circles). The curve is a fit to efficiency obtained by tag-and-probe method.

in proton-proton collisions and from indirect once, mostly coming from B-decays. Positive displacement of J/ψ-vertex from primary interaction means non-zero life time and indicate the indirect J/ψ production. The simulated pseudo-proper time measurements for $J/\psi \to \mu\mu$ decays is shown in Figure 2. The distribution for prompt J/ψ around zero has the dark shading and the sum of prompt and indirect J/ψ candidates is shown by lighter shading. For the J/ψ events selected with p_{T} thresholds 6 GeV and 4 GeV for the harder and the softer muon respectively, the pseudo-proper time cut of > 0.15 ps gives bb$\to J/\psi$X selection efficiency of 80% with 20% prompt J/ψ contamination.

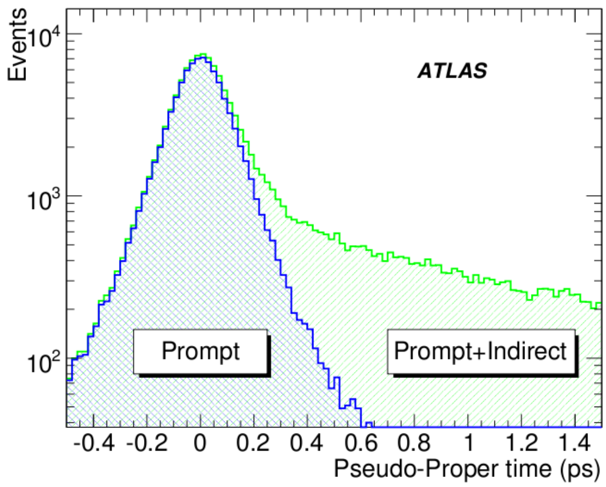

Figure 2: Pseudo-proper time distribution for reconstructed prompt J/ψ and the sum of prompt and indirect J/ψ candidates

4 Early measurements of B^+-meson

The exclusive channel $B^+ \to J/\psi K^+$ can be measured at early stage of LHC running with integral luminosity $\sim$ 10 pb^{-1}[2], due to the clear event topology and relatively large branching ratio $(1.007 \pm 0.035) \cdot 10^{-3}$. It can serve as a reference channel for searches of the very rare decay $B_s \to \mu\mu$, as a control channel for CP violation measurements due to the low direct CP violation of the channel [3]. Measurements of such well-known masses and lifetimes [4] will be used for Inner Detector calibration and alignment studies, and for searches of association particle production. The reconstructed B^+ meson mass is shown in Figure 3 with fit results. The expected mass resolution for B^+-mesons is 42.2 $\pm$ 1.3 MeV. One can sees that the background in the signal mass region is very low and the event sample with produced B^+-meson is clean enough for the further event analysis.

With early data B^+ production cross sections, both absolute and differential, depending on transverse momenta, can be measured. Given that a statistical precision of O (1%) will be reached with an integrated luminosity of 0.1 fb^{-1}, the contribution of the systematics will dominate the uncertainties of the first measurements. This is the case even for the differential cross-section measurement. Although the statistics in each p_{T} bin is limited, the total uncertainty is dominated by the systematic uncertainties in the branching ratio of the $B^+ \to J/\psi K^+$ and in the luminosity, which are of the same order. For the exclusive cross-section measurement in the $B^+ \to J/\psi K^+$ channel, the relative uncertainties of the differential and total cross-sections are given in Table 1. The first row of the table contains the quadratic sum of the statistical uncertainty corresponding to an integrated luminosity of 0.01 fb^{-1}and the uncertainty in the efficiency. The latter is based on the statistics of the Monte Carlo dataset used. The second row is calculated by adding in quadrature the above uncertainty to the systematic uncertainty of the luminosity and the branching ratio for every p_{T} bin.

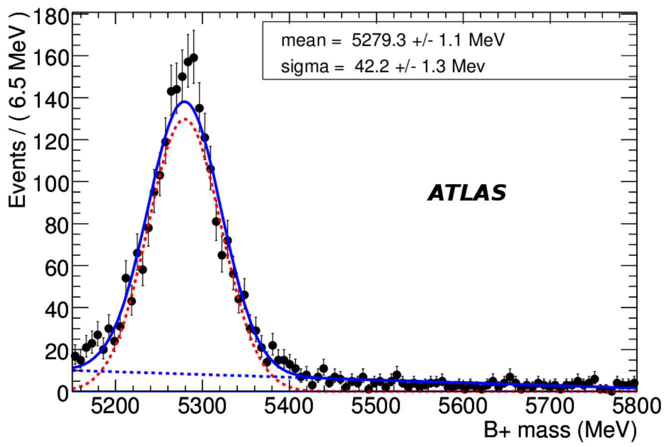

Figure 3: B^+ mass fit with the both signal (red) and background (blue) contributions shown separately

For the high statistics p_{T} bins as well as for the total cross-section, the total relative uncertainty is dominated by systematic errors, originating mainly from the uncertainty in the luminosity, which is assumed to be 10 % for the initial phase, and the 10 % uncertainty in the branching ratio of $B^+ \to J/\psi K^+$. The effect of the assumed background shape on the measurements is estimated to be less than 1 %. Finally, the precision of the lifetime measurement, for the same integrated luminosity is 2.5 %, where no systematic effects are taken into account.

p_{T} range [GeV]	$p_{\mathrm{T}} \in [10,18]$	$p_{\mathrm{T}} \in [18,26]$	$p_{\mathrm{T}} \in [26,34]$	$p_{\mathrm{T}} \in [34,42]$	$p_{\mathrm{T}} \in [10,inf)$
$stat. + \mathscr{A}[\%]$	7.7	6.9	10.5	13.9	4.3
$total[\%]$	16.1	15.8	17.6	19.8	14.8

Table 1: Statistical and total uncertainties for the $B^+ \to J/\psi K^+$ differential and total cross-section measurements for an integrated luminosity of 0.01 fb^{-1}. Total uncertainties include luminosity and BR systematic uncertainties.

5 Early measurements with B_d^0 and B_s^0 mesons

With the early data, the decays $B_d^0 \to J/\psi K_0^*$ and $B_s \to J/\psi\phi$ can be used to measure B hadron masses and lifetimes with sufficient precision to permit sensitive tests of the detector performance. In particular, the B_d^0 lifetime can be determined with a relative statistical error of 10%, with an integrated luminosity of 10 pb^{-1}, and the same precision will be achieved for the B_s^0 lifetime with 150 pb^{-1}[2]. The proposed method of a simultaneous fit of background and signal events allows a sensitive determination of the masses and decay times of B mesons. With early data, the optimal overall precision will be obtained with no cuts on the secondary vertex displacement. This is appropriate for the early data when the performance of the detector and reconstruction algorithms may not be well understood. This strategy is consistent with that of the early B-physics triggers, where no displacement cuts on the J/ψ will be applied at the trigger level. In the early data taking phase, the self-tagging decay $B_d^0 \to J/\psi K_0^*$ will be used to calibrate the jet charge tag for jets containing a B_d^0. This will be of use for physics studies involving B_d^0 decays, but also this good understanding for the tagging performance for $B_d^0 \to J/\psi K_0^*$ will allow the fragmentation modelling for $B_s \to J/\psi\phi$ decays to be improved.

6 Conclusions

With early data the reconstruction of exclusive B-meson decays with two muons in the final state, especially with J/ψ, will be done. The measurements of B hadron masses and lifetimes will help to improve the detector performance. The analysis B^+-decay and $B_d^0 \to J/\psi K_0^*$ decay will serve as a reference channel to the $B_s \to \mu\mu$ analysis. The B_d^0-decays early physics studies will improve $B_s \to J/\psi\phi$ decays analysis, where the CP violation parameters can be measured. The ATLAS B-physics first data is very important for following new physics studies beyond SM.

References

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

[2] ATLAS Collaboration, G. Aad et al., *Expected Performance of the ATLAS Experiment, Detector, Trigger and Physics*, CERN-OPEN-2008-020, 2008

[3] V.M. Abazov et al., D0 Collaboration, Phys. Rev. Lett. **100** (2008) 211802

[4] W.-M. Yao. et al., J. of Phys. **G33** (2006) 1