Lepton Flavour Violation and B_s Leptonic Final States at the LHC

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An overview of ATLAS and CMS studies of B_s leptonic decays providing constraints on the lepton flavour violation phenomenon is presented. Except direct lepton flavour violating final states $B_s \rightarrow l_1^+ l_2^-$, constraints can also be set by a measurement of $B_s \rightarrow \mu^+\mu^-$ decay, whose branching ratio in some theoretical models correlates with a branching ratio of $B_s \rightarrow l_1^+ l_2^-$, $\tau \rightarrow \mu\mu\mu$ and some other lepton flavour violating decays. In this paper, the feasibility of measurements of $B_s \rightarrow \mu^+\mu^-$ decay is described, including the present status, the trigger and the offline analysis strategies and the expected reach in the branching ratio measurement. The ATLAS and CMS experiments foresee to provide 3σ evidence of Standard Model $B_s \rightarrow \mu^+\mu^-$ branching ratio by the end of LHC low-luminosity stage (30 fb^{-1}). Also a CMS study of the $\tau \rightarrow \mu\mu\mu$ decay and an initial particle-level based study of the $B_s \rightarrow \tau\mu$ decay are presented. A sensitivity of $\sim 10^{-8}$ for the $\tau \rightarrow \mu\mu\mu$ branching ratio measurement is predicted by CMS.

1. Introduction

The flavour mixing is a common phenomenon in the quark sector as well as mixing by means of neutrino oscillations in the lepton sector. But in the Standard Model (SM) there is no such phenomenon in connection with charged leptons. It is a built-in property based on experimental results, without a corresponding symmetry in the SM. With massive neutrinos, charged lepton flavour violation (LFV) is possible, but the cross-section would be negligible due to the smallness of the neutrino mass and the GIM cancellation mechanism. Thus the branching ratio (BR) would not be detectable by the present experiments. However, beyond the SM there are theoretical models allowing enhanced LFV in the charged leptons sector too.

Due to high LHC luminosity ($10^{33}/10^{34}$ cm^{-2}s^{-1} in low/high luminosity stage), the ATLAS and CMS experiments have excellent capabilities of low-BR decay measurements. One sector, in which LFV decays can be searched for, are the purely leptonic B_s decays. Except for an initial particle-level based test of the feasibility of the measurement of $B_s \rightarrow \tau\mu$ at a general purpose detector for a collider experiment [1] (see section 4), there are no ATLAS/CMS studies concerning direct LFV in leptonic B_s decays yet. However, the phenomenon can also be studied indirectly using correlations between LFV and non-LFV decays. Examples of such correlations can be found e.g. in constrained or general flavour-universal MSSM models [2], relating the BR of a very rare $B_s \rightarrow \mu^+\mu^-$ decay to the LFV decays $B_s \rightarrow l_1^+ l_2^-$ and $\tau \rightarrow \mu\mu\mu$. Both the ATLAS and the CMS experiments performed detailed studies of a possible measurement of flavour-changing neutral currents (FCNC) in $B_s \rightarrow \mu^+\mu^-$ decays [3, 4]. The trigger and the analysis strategy, the background sources, the expected performance and the reach in this channel are described in section 2. CMS also studied $\tau \rightarrow \mu\mu\mu$ LFV decays [5]. The analysis details and resulting performance are presented in section 3.

2. $B_s \rightarrow \mu^+\mu^-$ at ATLAS and CMS

The di-muonic FCNC B-decays $B_s \rightarrow \mu^+\mu^-$ can occur in the SM through higher order diagrams only and are also helicity suppressed, which results in the prediction of a very low BR of $(3.35 \pm 0.32) \cdot 10^{-9}$ [6]. This small BR provides room for New Physics (NP) effects, which may enhance or suppress BR significantly. Present best limits are set by Tevatron: a CDF measurement at 2 fb^{-1} sets the upper limit on the BR to $5.8 \cdot 10^{-8}$ at 95% C.L. [7]. The projected improvement of the Tevatron results [8] does not foresee reaching the SM BR. In constrast the LHC experiments will even be able to measure a suppressed BR w.r.t to the SM prediction, especially after entering the high luminosity stage of LHC.

2.1. Trigger Strategies

Both the ATLAS and CMS triggers for $B_s \rightarrow \mu^+\mu^-$ [9] are at the first level (L1) based on a detection of two high-p_T muons and at the high level trigger (HLT) the B_s vertex is fitted and cuts on its quality, eventually position and di-muon invariant mass are applied. Presently, the ATLAS $B_s \rightarrow \mu^+\mu^-$ study requires two $p_T > 6$ GeV muons at L1, while the CMS study lets to pass through muons with $p_T > 3$ GeV. However, based on the first data, the cuts are subject to change with the luminosity in order to keep an acceptable trigger-output rate. At the luminosity of 10^{33} cm^{-2}s^{-1} the ATLAS L1 rate is expected to be 360 Hz and the CMS L1 rate 450 Hz. The detectors have similar pseudorapidity coverage $|\eta| < 2.5$.

At the ATLAS HLT, firstly the muons' detection is confirmed by information from precision chambers and calorimeters. Tracks reconstruction is then performed in a region around the two L1 muon directions

and di-muon candidates are defined. Applying a vertex fit procedure a quality cut $\chi^2 < 10$ and a loose invariant mass cut $M_{\mu^+\mu^-} < 7$ GeV are currently required. However, these cuts could be tightened or new cuts could be introduced (e.g. a cut on B_s transverse decay length L_{xy}) when a too high output rate is experienced with first LHC data. The overall L1 and HLT efficiency of 46% was found on a sample of simulated signal events with muons $p_{\mathrm{T}} > 6$ GeV and $|\eta| < 2.5$. At a very low starting luminosity of $\sim 10^{31}$ cm^{-2}s^{-1} the L1 threshold cut on the muons' p_{T} can be lowered down to 4 GeV and the track reconstruction could be performed in the full volume of the ATLAS inner detector.

The CMS HLT firstly verifies L1 muons, then the primary vertex is searched (only the 3 most-significant vertices are considered) and tracks of $p_{\mathrm{T}} > 4$ GeV are reconstructed in cones around the muon directions. The tracks are always formed from less than six detector hits in order to speed up the reconstruction process, but on the expense of a certain performance degradation (74 MeV B_s mass resolution to be compared to 32 MeV in the offline analysis). After vertex fitting, a decay length cut of $L_{3D} \geq 150$ μm, a vertex quality cut of $\chi^2 \leq 20$ and a B_s invariant mass window of 150 MeV width are applied. The output rate after the HLT is expected to be below 1.7 Hz.

2.2. Offline Analysis

Due to the clear experimental signature, the selection criteria are limited to the following cuts on: the B_s invariant mass window, the secondary vertex displacement and the vertex-fit quality, the B_s momentum pointing to the primary vertex, the isolation of the muon pair and the di-muon opening angle. The detector-driven mass resolution should either be sufficient to distinguish B_s from B_d, or a joint analysis of both decay channels has to be performed. The vertex position and fit-quality cuts reduce combinatorial background originating from the primary vertex. The B_s-pointing-to-the-primary-vertex requirement suppresses events with particles invisible to the detector and originating at the di-muon vertex. Finally, the isolation constraint helps to similarly suppress visible particles originating from the di-muon vertex.

2.2.1. ATLAS

In the ATLAS offline analysis high-p_{T} muon tracks are combined to di-muon pairs and the appropriate vertex is fitted. A preselection of the B_s candidates is performed by requiring 4 GeV $< M_{\mu^+\mu^-} <$ 7.3 GeV for the di-muon pair invariant mass, vertex fit quality $\chi^2 < 10$ and a transverse decay length $L_{xy} < 20$ mm. A final asymmetric invariant mass cut of $M_{B_s} - \sigma_{B_s} < M_{\mu^+\mu^-} < M_{B_s} + 2\sigma_{B_s}$ is used

in order to separate B_s candidates from B_d background. The di-muonic invariant mass resolution at ATLAS is 70 MeV for the barrel region ($\eta_{\mu^+\mu^-} < 1.1$) and 124 MeV for the end-cap. A combined value $\sigma_{B_s} = 90$ MeV is estimated as the invariant mass resolution for the signal events. Secondary vertex separation is defined by requiring a B_s decay length $L_{xy} > 0.5$ mm. In order to assure the B_s pointing to the primary vertex, the B_s momentum and the position vector from the primary to the secondary vertex have to be parallel within an angle of $1°$. The di-muon pair isolation is defined using $I_{\mu^+\mu^-} = p_{\mathrm{T}}(B_s)/(p_{\mathrm{T}}(B_s) + \sum_{tracks} |p_{\mathrm{T}}|) > 0.9$ condition, where the sum runs over all tracks of $p_{\mathrm{T}} > 1$ GeV (excluding signal muons) reconstructed within a cone of $\Delta R = \sqrt{\Delta\phi^2 + \Delta\eta^2} < 1$ around the di-muon momentum.

2.2.2. CMS

The CMS offline analysis is similar to the ATLAS one. Due to a better B_s invariant mass resolution of 32 MeV, a symmetric mass window of $M_{B_s} - 100$ MeV $< M_{\mu^+\mu^-} < M_{B_s} + 100$ MeV is used. A decay length significance $L_{xy}/\sigma_{xy} \geq 18$ and vertex-fit $\chi^2 \leq 1$ cuts are applied. The B_s momentum and the vector from the primary to the secondary vertex are required to be aligned with each other better than $5.7°$. The muon pair isolation criterion uses a $I_{\mu^+\mu^-} \geq 0.85$ cut, with the $I_{\mu^+\mu^-}$ defined similarly as in ATLAS analysis, only applying lower p_{T} cut of $p_{\mathrm{T}} > 0.9$ MeV on the tracks considered in the cone around the di-muon momentum. Lastly, the opening angle $\Delta R(\mu^+, \mu^-)$ between the two muon tracks is required to satisfy $0.3 < \Delta R(\mu^+, \mu^-) < 1.2$.

2.3. Background Composition

The background comes from random combinatorics of high-p_{T} muons, especially in events with $b\bar{b}$ pairs, where the eventual di-muon vertex position is naturally displaced from the primary vertex by a distance typical for B-hadrons. The two muon candidates can come from semileptonic decays of b and $\bar{b}$ quarks or from a cascade decay of either the b or $\bar{b}$ quark. The extremely low BR of the signal decay channel allows that also rare processes (often not included in standard MC generators) can significantly contribute to the background, as do misidentified hadron-tracks. These background contributions can be evaluated by a MC study of dedicated exclusive background channels. However, the inclusive $b\bar{b} \to \mu^+\mu^- X$ background event generation and the corresponding full detector simulation are limited by the available CPU resources. Thus, events need to be filtered already at the generator level and a factorization of the analysis cuts and a study of correlations between that cuts need to be performed. However, the limited resources still

lead to a very limited precision of the estimated number of background events, waiting for an improvement by the first LHC data. The ATLAS and CMS expectation of the inclusive background at an integrated luminosity of $L_{int} = 10$ fb^{-1} yields 14^{+13}_{-10} and $13.8^{+22.0}_{-13.8}$ events respectively.

The background caused by rare decays or misidentification of muons can be divided into four groups depending on the mechanism mimicking the signal events. Given that the false B_s signals come from B-hadron decays with two oppositely charged high-p_T tracks (real muons or misidentified hadrons) and remaining soft particles in the final state (not seen), the resulting di-muon invariant mass could be close to the B-hadron mass. Therefore the mass resolution is a crucial factor when rejecting these backgrounds. The signal and selected backgrounds invariant mass distributions corresponding to a measurement at ATLAS after one year of low luminosity running is shown at Figure 1.

- The first class of background is formed by rare B-decays that contain three muons coming from the same (or a negligibly close) vertex. A fake B-signal can appear when one of the muons and the remaining neutrino are soft and thus not being considered in the signal decay reconstruction. Representatives of this background class are:
  $B^+ \to \mu^+\mu^-\mu^+\nu_\mu$ (BR $\sim 5 \cdot 10^{-6}$),
  $B_c^+ \to \mu^+\mu^-\mu^+\nu_\mu$ (BR $\sim 5 \cdot 10^{-6}$) and
  $B_c^+ \to J/\psi(\mu^+\mu^-)\mu^+\nu_\mu$ (BR $\sim 1.2 \cdot 10^{-3}$).

  Both the ATLAS study of the first two and the CMS study of all three background decays found them to be negligible.

- Another class of rare-decay contributions to the background is composed of B-hadron decays to two muons and a soft photon or pion:
  $B_{(s)} \to \mu^+\mu^-\gamma$ (BR $\sim 2 \cdot 10^{-8}$),
  $B \to \mu^+\mu^-\pi^0$ (BR $\sim 2 \cdot 10^{-8}$) and
  $B^+ \to \mu^+\mu^-\pi^+$ (BR $\sim 2 \cdot 10^{-8}$).

  CMS tested the first and ATLAS all three possible background decays resulting in negligible contributions.

- Although the misidentification of hadron tracks as muons is a rare effect (typical probability of the order of 0.1%) it can cause a dangerous background for the very rare decays. A study of B-hadron decays to a muon, hadron and a soft neutrino was performed, accounting for the hadron track misidentification in the following decays:
  $B \to \pi^-\mu^+\nu_\mu$ (BR $\sim 1.4 \cdot 10^{-4}$) and
  $B_s \to K^-\mu^+\nu_\mu$ (BR $\sim 1.4 \cdot 10^{-4}$).

  As in the previous cases the studies showed an insignificant rate of the fake signal decays.

- An isolated $B_s \to \mu^+\mu^-$ fake candidate can also be formed when a double misidentification of the hadrons as muons occurs in two body B-hadron decays:
  $B_s \to K^+K^-$ (BR $\sim 2.4 \cdot 10^{-5}$),
  $B_s \to \pi^+\pi^-$ (BR $\sim 0.4 \cdot 10^{-6}$),
  $B_s \to \pi^+K^-$ (BR $\sim 5.0 \cdot 10^{-6}$),
  $B \to \pi^+\pi^-$ (BR $\sim 5.1 \cdot 10^{-6}$),
  $B \to K^+\pi^-$ (BR $\sim 2.0 \cdot 10^{-5}$),
  $\Lambda_b \to \rho^+\pi^-$ (BR $\sim 1 \cdot 10^{-6}$), and
  $\Lambda_b \to \rho^+K^-$ (BR $\sim 2 \cdot 10^{-6}$).

The ATLAS study found a negligible contribution to the background from the first three decays in the list. Similarly in the CMS study less than 0.3 fake signal decays for each of the decays listed above were expected for $L_{int} = 10$ fb^{-1}.
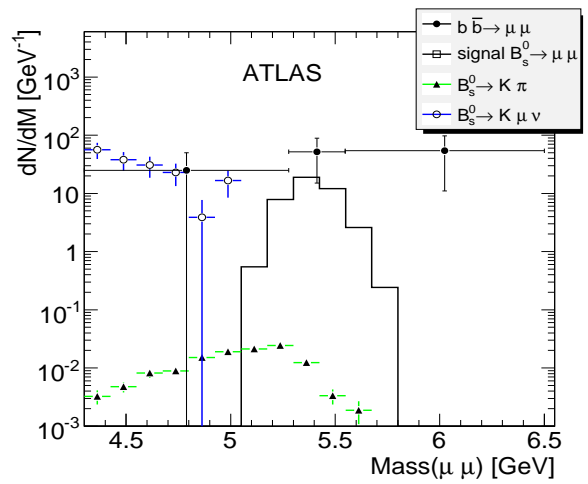

Figure 1: Di-muonic invariant mass spectrum of the signal B-hadrons, inclusive $b\bar{b}$ contribution and selected misidentification-based background channels [3]. Statistics corresponds to $L_{int} = 10$ fb^{-1}.

2.4. Expected Reach

The performed studies predict a 3σ evidence of the SM BR already by the end of the initial LHC low-luminosity stage ($L_{int} = 30$ fb^{-1}). The observation at 5σ level will be possible after the first year of LHC running at high luminosity, provided the background will be at the level expected from extrapolations. The BR upper limits can be calculated using the Bayesian approach [10]. For example, picking up the CMS expectation of the number of signal events (supposing SM BR): $6.1 \pm 0.6_{stat} \pm 1.5_{sys}$, and accounting also for the background events expected as mentioned in section 2.3, the upper 90% C.L. limit would be set to $1.4 \cdot 10^{-8}$.

In Table I the number of signal events is summarized at the following stages: after approximately

Table I Expected $B_s \to \mu^+\mu^-$ signal yield at given integrated luminosity. The ATLAS results for 100 fb^{-1} are given for older studies [11]*.

Experiment	2 fb^{-1}	10 fb^{-1}	30 fb^{-1}	100 fb^{-1}	130 fb^{-1}
ATLAS	1.1	5.7	17.1	92*	109*
CMS	1.2	6.1	18.3		

Table II Sources of τ leptons at the LHC.

Decay channel	$N_\tau(L_{\rm int} = 10 \text{ fb}^{-1})$
$W \to \tau\nu_\tau$	$1.7 \cdot 10^8$
$Z \to \tau\tau$	$3.2 \cdot 10^7$
$B^0 \to \tau X$	$4.0 \cdot 10^{11}$
$B^\pm \to \tau X$	$3.8 \cdot 10^{11}$
$B_s \to \tau X$	$7.9 \cdot 10^{10}$
$D_s \to \tau X$	$1.5 \cdot 10^{12}$

the first 2 months (2 fb^{-1}) and the first year of LHC running (10 fb^{-1}), at the end of low luminosity stage (30 fb^{-1}), yield of a year of LHC high luminosity (100 fb^{-1}) and after four years of running (130 fb^{-1}, end of the first year of high luminosity). However, there is a theoretical uncertainty of factor of two in the b-production cross-section at LHC energies and consequently all the mentioned number of events scale accordingly.

3. $\tau \to \mu\mu\mu$ at CMS

The neutrino-less τ decay BR is correlated to the BR of very rare B_s decays, as mentioned in section 1. Out of the number of LFV τ-decays, the channel $\tau \to \mu\mu\mu$ is likely to be the only detectable at ATLAS and CMS, although studies of the other channels are also under consideration. CMS has performed a detailed study of this particular τ decay channel [5], the ATLAS study is ongoing. Beyond the SM there is number of theoretical possibilities allowing LFV. A BR$(\tau \to \mu\mu\mu)$ estimate within the expected CMS sensitivity of 10^{-8} is found e.g. in mSUGRA theories with right handed neutrinos and universal input parameters at the GUT scale. The present 90% C.L. upper limit on the BR$(\tau \to \mu\mu\mu)$ is $3.2 \cdot 10^{-8}$ [12].

The total inclusive τ production cross-section was found to be $\sigma(pp \to \tau + X) \sim 120$ μb [5], resulting in 10^{12} τ leptons within the CMS tracker acceptance for $L_{\rm int} = 10$ fb^{-1}. There are several possible sources of τ leptons at the LHC: the D-mesons, B-mesons and decays of W and Z bosons. The expected number of τ leptons from each of the sources is presented in Table II. Although the W and Z bosons as sources of the τ leptons have a much lower production cross-section than the D- and B-mesons, they become the most important sources for the selected signal due to the higher $p_{\rm T}$ of the final state muons.

3.1. Trigger Strategy

The trigger selection of the $\tau \to \mu\mu\mu$ decays is based on the detection of high-$p_{\rm T}$ muons. At the first level (L1) a single $p_{\rm T} > 14$ GeV muon will be required or a di-muon with $p_{\rm T} > 3$ GeV for each muon. The cuts are raised at HLT when $p_{\rm T} > 19$ GeV for single muons and $p_{\rm T} > 7$ GeV for di-muons is applied.

However, the trigger condition will have to be more stringent at the high luminosity stage due to a growing pile-up contribution.

3.2. Offline Analysis

The offline analysis selections vary with the sources of the τ leptons, but some parts are common to all of them. Similarly to the very rare decays of the B_s the experimental signature is very simple. The basic identification requires only three good muon candidates from the tracker with $p_{\rm T} > 4$ GeV in the barrel or with $p_{\rm T} > 2.5$ GeV in the endcap. An isolation criterion is applied for the case of τ leptons coming from the W- or Z boson decays. The corresponding condition is to have no charged tracks of $p_{\rm T} > 0.7$ GeV inside a cone of $\Delta R = 0.4$ around the muonic tracks. Also the reconstructed τ candidates need to have an invariant mass within a window of $M_\tau - 25$ MeV $< M_{\mu\mu\mu} < M_\tau + 25$ MeV. The predicted τ-mass resolution is 24 MeV.

The main sources of muons being able to pass through the trigger and the identification cuts are muons from $b\bar{b}$ and $c\bar{c}$ decays. There are two topologically different ways to obtain three muons in the final state of those decays. In the first case (BR $\sim 10^{-3}$), one muon comes from a semileptonic decay of a heavy quark and the other two muons from a sequential decay of the opposite side B- or D-meson. These events are rejected by constraining the maximum opening angle of each pair of muons. In the second case (BR $\sim 10^{-5}$) all the three muons come from the decay chain of the same b or c quark. The dominant source of background is due to the following decay channels:

- $c\bar{c} \to DxD_s \to \mu\nu_\mu\phi(\mu\mu) + X$

- $b\bar{b} \to BxB_s \to \mu\nu_\mu D_s(K, \pi, \rho + \phi(\mu\mu)) + X$

In order to exclude these events, every muon pair is required to have an invariant mass of more than 25 MeV away from the ϕ nominal mass. The background from $b\bar{b}$ is naturally suppressed by the triple muon effective mass that is shifted to higher values of 4 to 5 GeV. For the $b\bar{b}$ events one muon is originating at the B-meson decay point and the other two

at the ϕ decay point. The distance between these two points is significant and thus the quality of the three muons vertex fit or the maximum distance between each muon pair vertices could be significantly different from the signal events, thus providing another discriminating variable.

3.2.1. W bosons as source

The $W \rightarrow \tau\nu_\tau$ boson decay is characterized by a large missing transverse energy E_{Tmiss}. An application of the condition $E_{\mathrm{Tmiss}} > 20$ GeV rejects the background. It also separates the signal from $Z \rightarrow \tau\tau$, which is selected using different criteria (see next section).

3.2.2. Z bosons as source

With the τ lepton from the Z boson source, the presence of the second high-p_{T} τ is the determining attribute. The second τ lepton is allowed to decay to any mode and thus will be detected as a one or three collimated charged tracks (τ-jet), well isolated from the other tracks in the event: these tracks are required to fit in a cone of $\Delta R = 0.03$ and no other $p_{\mathrm{T}} > 1.5$ GeV tracks should be found within a complementary external cone of $\Delta R = 0.4$. Another characteristics is the three muons' momentum $p_T^{3\mu}$ that is, on average, higher for signal than for the background. An optimization of the cut leads to the condition $p_T^{3\mu} > 23$ GeV. Finally, the missing energy in these events should be consistent with the energy of a ν_τ from the τ-jet. Reconstructing the invariant mass M_Z from the three muons, the τ-jet and E_{Tmiss}, a distribution that peaks at the Z boson mass is obtained (when applied to signal events). A cut $M_Z > 70$ GeV removes about 70% of background while keeping the signal event loss acceptably low.

3.2.3. B-mesons as source

Due to the low muon p_{T}, the detection of τ leptons coming from a B-meson decay would only be possible at the low luminosity stage, when muonic trigger cuts can be lower while keeping an acceptable trigger output rate. In order to select these events, a b-tagging algorithm is used. Any event containing a jet with three muons and having three or more tracks with an impact parameter significance greater than 2 is accepted. The same cut is also applied on the second b-jet in the event. In this analysis the muonic tracks' isolation condition has to be omitted. The combination of the b-tag for the two jets gives a 20% efficiency for signal events and about 7% efficiency for the $c\bar{c}$ background.

3.2.4. D-mesons as source

Although the τ-production cross-section from D-mesons is the largest one from all the possible sources, the very low muon p_{T} leads to a suppression of the number of detectable τ decays well below the contribution of the other sources. However, some possible improvements are under study [13], e.g. the low-p_{T} muon identification efficiency could be improved.

3.3. Expected Reach

The predicted upper limits at 90% C.L. for the BR($\tau \rightarrow \mu\mu\mu$) from Z and W bosons as sources are summarized in Table III. The expected reach in the W-source channel after the initial low-luminosity stage of LHC ($L_{\mathrm{int}} = 30$ fb^{-1}) corresponds to the present limit set by the Belle experiment [14].

Table III Expected reach in BR($\tau \rightarrow \mu\mu\mu$) measurement at CMS (90% C.L. limits).

τ lepton source	$L_{\mathrm{int}} = 10$ fb^{-1}	$L_{\mathrm{int}} = 30$ fb^{-1}
W boson decay	$7.0 \cdot 10^{-8}$	$3.8 \cdot 10^{-8}$
Z boson decay	-	$3.4 \cdot 10^{-7}$
B hadron decay	-	$2.1 \cdot 10^{-7}$

A significant improvement for the contribution from B-mesons is envisaged once a better performing b-tagging algorithm is implemented. An improved sensitivity could be reached by combining results from all the sources. The measurements will also continue during the high luminosity phase of the LHC, but the studies need to consider pile-up effects.

4. $B_s \rightarrow \tau\mu$ Particle Level Study

A particle level based feasibility study of the LFV $B_s \rightarrow \tau\mu$ decay has been reported in [1]. A new reconstruction method for decays with a missing particle is used, based on topological information gained from secondary vertices [15]. Given a 3-prong τ decay and assuming knowledge of the τ production vertex, the τ flight direction is determined as well as the transverse momenta of the 3-prong system w.r.t. the τ flight direction. Then the unknown longitudinal coordinate of the neutrino momentum can be calculated with a two-fold ambiguity by constraining the reconstructed τ mass.

Given a $B_s \rightarrow \mu\tau$(3 prong) decay, the τ production vertex is not known, but is required to be located on the muon track. Since the B_s hadron is expected to originate from the primary vertex, the B_s decay vertex position is fixed by a B_s momentum pointing-to-primary-vertex constraint.

In this feasibility study, the MC track parameters and the vertex positions were smeared according to realistic resolutions of a general purpose detector for a hadron collider experiment, as described

in Table IV. The reconstructed B_s mass distribution has a non-gaussian shape with a FWHM of 0.59 GeV as shown in Figure 2. A non-resonant background consisting of unconstrained $b\bar{b}$ semimuonic decays with a muon and a τ lepton in the final state is also presented in the Figure 2 (no normalization to cross-sections). Contributions from exclusive decays as $B \to \mu\nu_\mu D(3\ \text{prong})$ are still to be studied.

Table IV MC track and vertex smearing parameters.

Variable		Resolution
Momentum	ϕ	0.58 mrad
	η	$5.8 \cdot 10^{-4}$
	$1/p_{\text{T}}$	$0.013\ (\text{GeV/c})^{-1}$
Primary vertex	xy-plane	20 μm
	z-direction	40 μm
Secondary vertex	parallel	70 μm
	perpendicular	10 μm

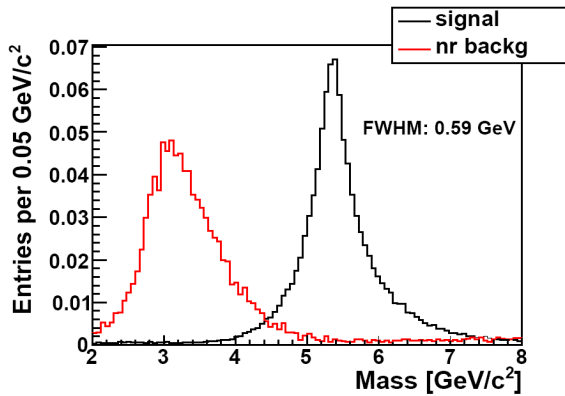

Figure 2: Reconstructed mass distribution for $B_s \to \tau\mu$ and non-resonant background [1]. Both histograms are normalized to unity.

5. Summary

A set of ATLAS and CMS analyses relating lepton flavour violation phenomena to purely leptonic B_s decays were summarized. Presently, there is only a particle based feasibility study of a direct LFV measurement on $B_s \to l_1^+ l_2^-$ decays, but the phenomena can also be constrained by measuring the BR of the very rare decay $B_s \to \mu^+\mu^-$. In some models [2] the BR of $B_s \to \mu^+\mu^-$ is correlated with the BRs of the LFV decays $B_s \to l_1^+ l_2^-$ and $\tau \to \mu\mu\mu$.

The $B_s \to \mu^+\mu^-$ studies of the decay show that the BR measurement will improve limits from Tevatron measurement already after the first year of LHC running at low-luminosity. The 3σ measurement of Standard Model BR is expected by the end of the low luminosity stage and 5σ observation should be made shortly after the first year of running at high luminosity. A detailed analysis of possibly strong background contributions from other rare decays and particle-misidentification effects was performed, predicting negligible contribution. Thus the decays $b\bar{b} \to \mu^+\mu^- X$ remain the main source of background.

The 90% C.L. upper limits on the BR($\tau \to \mu\mu\mu$) measured at CMS will reach present Belle bounds by the end of LHC's low luminosity stage. The analysis of the τ lepton sources predict that the τ leptons from W and Z boson decays will dominate the measurements, because the lower cross-section w.r.t. to B- and D-meson induced τ decays, is compensated by a higher trigger acceptance.

An initial study of the topological reconstruction of decays with missing particles applied to the $B_s \to \tau\mu$ channel demonstrated the feasibility of such measurements at ATLAS and CMS, but a proper trigger study, full detector simulation and a background analysis still needs to be performed.

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