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CP Violation and Rare B decays at ATLAS

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The primary goal of ATLAS experiment at LHC is to search for the Higgs boson and supersymmetry. However, other physics sectors like CP violation and rare B-decays, can be explored. The full proper-time and angular analyses allow several parameters of physics interest to be investigated using the $B_s^0 \rightarrow J/\psi\phi$ decays. In the B_s sector measurements, special emphasis is made on the ΔM_s. ATLAS will be able to reach ΔM_s-regions that are today covered by the fit combining all existing data. By investigating rare decays of beauty mesons and baryons, ATLAS will be capable of performing sensitive tests of physics phenomena beyond the Standard Model. The effort concentrate especially on those rare B decays that can be identified already at the first and second trigger level.

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1. The ATLAS B-Physics potential and the trigger strategy

The LHC (Large Hadron Collider) will be fully operational by 2007 colliding protons against protons at 14 TeV in the center of mass energy. The primary goal of ATLAS experiment at LHC is to search for the Higgs boson and supersymmetry (SUSY). However, other physics sectors like CP violation and rare decays can be explored.

The study of B-physics gives an opportunity: **1)** to check the Standard Model (SM) predictions in a high perturbative order; **2)** to search "new physics": SUSY, LR, Extra Dimensions, Technicolor, Two Higgs-doublet models and others; **3)** to find the values of $|V_{ts}|$ and $|V_{td}|$ CKM matrix elements; **4)** to provide new information on long-distance QCD effects in matrix elements of the tensor currents.

In comparison with B-factories LHC can: **1)** study the rare B_s^0-decays ($B_s^0 \to \phi\gamma$, $B_s^0 \to \phi\mu^+\mu^-$, etc.) and Λ_b-decays ($\Lambda_b \to \Lambda J/\psi$, $\Lambda_b \to \Lambda\mu^+\mu^-$, etc.); **2)** rare decays of $B_{d,s}^0$-mesons with extremely small branching ratios ($\leq 10^{-9}$) such as $B_{d,s}^0 \to \gamma\mu^+\mu^-$ and $B_{d,s}^0 \to \mu^+\mu^-$; **3)** differential distributions for rare semi-leptonic $B_{d,s}^0$-meson decays with high accuracy. We should point out that these distributions are very sensitive to SM extensions. As compared with Tevatron, LHC can produce 50 times more $b\bar{b}$-pairs. So LHC will be more efficient in all rare B-decay studies.

For the on-line decreasing of ATLAS data flow from 90 MHz to 100 Hz, a complex hardware and software system of trigger is used. At initial LHC luminosity $(0.5-2.0)\times 10^{33}$ cm^{-2}s^{-1} rare decays $B_{d,s}^0 \to \mu^+\mu^-$, $B_d^0 \to K^*\mu^+\mu^-$, $B_s^0 \to \phi\mu^+\mu^-$ and $\Lambda_b \to \Lambda\mu^+\mu^-$ will be covered by the Level 1 (LVL1) di-muon trigger. The same strategy can also be used at the nominal LHC luminosity 10^{34} cm^{-2}s^{-1}. For the decays $B_d^0 \to K^*\gamma$ and $B_s^0 \to \phi\gamma$ ATLAS will use a LVL1 trigger in which both the muon signal and the electromagnetic cluster are identified. For the decays $B_s^0 \to \mu^+\mu^-\gamma$ and $B_d^0 \to \pi^0\mu^+\mu^-$ both LVL1 trigger strategies will be used.

2. CP violation: ϕ_s and ΔM_s measurements

The full proper-time and angular analyses allow several parameters of physics interest to be investigated using the $B_s^0 \to J/\psi\phi$ decays. If the SM expectations are correct, the weak phase (ϕ_s) will not be measured with useful significance, but the measurements are sensitive to the larger values predicted in some non-SM. The sensitivity will improve the analyses are combined with B_s^0 mixing observables in a simultaneous fit [1].

In the El Dorado of LHC B_s measurements, special emphasis is made on the ΔM_s. In ATLAS, these measurements can achieve at initial luminosity, with an integral of 30 fb^{-1}, 5 σ measurement at the value of 21 ps^{-1} and 95% CL limit at the value of 29 ps^{-1}. At the nominal luminosity and for an integral of 10 fb^{-1}, ATLAS will be able to reach ΔM_s region that is today covered by the fit combining all existing data, see Fig. 1. As also shown on the figure, the SM cannot easily accommodate with $\Delta M_s > 25$ ps^{-1}.

3. Rare decays

$B_{d,s}^0 \to \mu^+\mu^-$ decays have very small branching ratios in the SM while they might give clear signature (due to dimuon trigger) and good sensitivity to SUSY and other possible SM extensions.

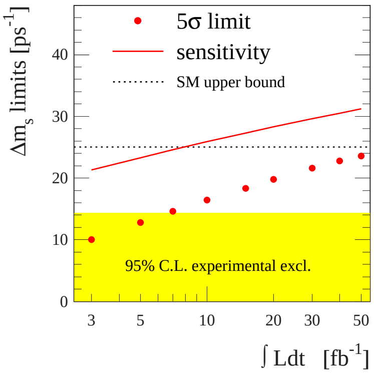

Figure 1: ΔM_s reach at high luminosity compared to the SM predictions [2]

After three years of the LHC operation at initial luminosity, $B_s^0 \to \mu^+\mu^-$ decay could be detected with 2.8 σ significance. Adding one year with nominal luminosity an upper limit for $B_d^0 \to \mu^+\mu^-$ decay is set to 3×10^{-10} with 95% CL, and a detection of $B_s^0 \to \mu^+\mu^-$ with 4.3σ significance [3].

For $\Lambda_b \to \Lambda\mu^+\mu^-$ decay, as described in [4], the forward-backward asymmetry A_{FB} is very sensitive to SUSY both for small and large values of $\hat{s}$ where $\hat{s} = (p_{\mu^+} + p_{\mu^-})^2/M^2_{\Lambda_b} \equiv q^2/M^2_{\Lambda_b}$. ATLAS simulation shows that the muon triggers are not expected to change the shape of A_{FB} distribution. For 30 fb^{-1} about 1500 signal events are expected. The $\hat{s}$ parameter is divided in three region intervals: the first interval is from $(2m_\mu/M_{\Lambda_b})^2$ to the so-called "zero-point" [5]; the second interval is from the "zero-point" to lower boundaries of J/ψ and ψ' resonances and the last interval is from the resonances area to $(M_{\Lambda_b} - M_\Lambda)^2/M^2_{\Lambda_b}$ limit. The results are shown in Figure 2(Left). The three dots with error bars correspond to simulated data. Upper points set corresponds to the theoretical SM predictions and the lower set corresponds to one of possible non-standard model prediction for $C^{SM}_{7\gamma}/C^{eff}_{7\gamma} < 0$, $C^\alpha_{i\gamma}$ being the Wilson coefficients. As seen, ATLAS will be able to separate SM from some of its extensions with high confidence level.

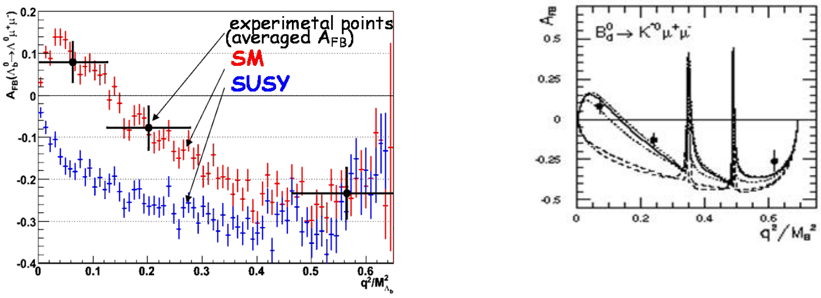

Figure 2: **(Left)** Forward-backward asymmetry for $\Lambda_b \to \Lambda\mu^+\mu^-$ decay [6]. **(Right)**Forward-backward asymmetry for $B_d^0 \to K^*\mu^+\mu^-$ decay [7].

The branching ratios for the semi-leptonic decays $B_d^0 \to K^*\mu^+\mu^-$ and $B_s^0 \to \phi\mu^+\mu^-$ are rather sensitive to the SM extensions, but the differential distributions, especially for A_{FB} are very sensitive to SUSY extension.

Full ATLAS detector simulation and reconstruction of rare semi-muonic B_d^0 decay was performed with initial luminosity [3]. During modeling, the theoretical-based matrix element was used [8]. We expect 2000 signal events and 290 Background (BG) events after 3 years of LHC operation at initial luminosity for $B_d^0 \to K^* \mu^+ \mu^-$ and 410 signal events with 140 BG for $B_s^0 \to \phi \mu^+ \mu^-$.

In Fig. 2(Right) the asymmetry A_{FB} is presented for $B_d^0 \to K^* \mu^+ \mu^-$ decay. Solid line corresponds to SM predictions according to [8]. Dashed and dotted lines are boundaries for MSSM predictions [9]. Three bold dots with error bars correspond to the simulated values of A_{FB}. Each dot lies in one of the three kinematic intervals, as for the Λ_b case. It is shown that the statistics is enough, after 3 years of LHC operation, for SM confirmation and setting strong limits on SM extensions.

In spite of CLEO, BaBar and Belle results it will be interesting to measure radiative penguin decay $B_d^0 \to K^* \gamma$ in ATLAS. It will be also interesting to measure $B_s^0 \to \phi \gamma$. Both these decays can give us information about CKM matrix element $|V_{ts}|$ and the value of photon penguin contribution. This contribution is important for the extraction of the physics beyond SM from the rare semi-leptonic *B*-meson decays. A simulation of these decays was performed [10]. After 3 years of LHC operation at initial luminosity, a significance of the $B_d^0 \to K^* \gamma$ signal will be beyond 5 σ. For $B_s^0 \to \phi \gamma$, the significance will be beyond 7 σ.

Detailed studies of radiative leptonic decays, $B_{d,s}^0 \to \mu^+ \mu^- \gamma$, are planned to be performed as well as the main backgrounds for rare radiative leptonic decays.

4. Conclusion

ATLAS strategy for B-physics is to concentrate efforts on: **1)** measurements that can show New Physics effects or constrain New Physics models; **2)**measurements where CP violation effects are predicted to be small in the SM; **3)** measurements where ATLAS can make a significant contribution. ATLAS proved to be capable of extracting signals of all main rare B-decays of interest at LHC. Earlier ATLAS studies (1998-1999) proved that dimuon channels program can be followed up to nominal LHC luminosity.

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