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Rare and charmless decays of b-hadrons at Tevatron

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Summary. — I report the most recent results from the CDF and DØ Collaborations on the search for rare-decay modes of the b-hadrons. The results involve the current best limit on $B^0_{(s)} \to \mu^+\mu^-$ and $B^0_{(s)} \to e^+\mu^-$ decay modes, further results in charmless decays are expected soon.

PACS `13.20.-v` – Leptonic, semileptonic, and radiative decays of mesons.
PACS `13.30.-a` – Decays of baryons.
PACS `14.40.Nd` – Bottom mesons.

1. – Introduction

The search for the rare and charmless b-hadron decays is an important precision test for the Standard Model (SM). Moreover the small branching ratio (BR) of these decay modes makes them very sensitive to new physics (NP) contribution. The CDF II [1] and DØ detectors [2] can look for these modes thanks to the large heavy-flavor production cross-section at the Tevatron $p\bar{p}$ accelerator, with a collision energy of $\sqrt{s} = 1.96\,\text{TeV}$.

2. – Search for the $B^0_{(s)} \to \mu^+\mu^-$ decays

The $B^0_{(s)} \to \mu^+\mu^-$ decays are mediated by Flavor-Changing Neutral Current (FCNC) diagrams, forbidden at tree level in the SM. The predicted BR are $\mathcal{B}(B^0_s \to \mu^+\mu^-) = (3.44 \pm 0.54) \times 10^{-9}$, while a further reduction by a factor $|V_{td}/V_{ts}|^2$ is expected for B^0 decay mode, with a prediction of $\mathcal{B}(B^0 \to \mu^+\mu^-) = (1.00 \pm 0.14) \times 10^{-10}$ [3]. Many different NP scenarios predict an increase of the BR up to two orders of magnitude [4].

Both CDF II and DØ detectors are searching for those modes. The main trigger strategies is common: the $B^0_{(s)} \to \mu^+\mu^-$ candidates at trigger level are selected by looking for two isolated muons candidates in the muon detectors. The signal and the background candidates are discriminated using multivariate algorithms in order to maximize their separation. The input variables are: p_T, decay length, isolation for the di-muon candidate, lower muon candidate momentum, pointing angle of the B candidate, and the flight direction. The training sample is taken from the detailed Monte Carlo (MC) simulation for the signal, the background is extracted from the side-bands of the B candidate invariant mass. The signals are normalized to the $B^+ \to J/\psi K^+$ mode. Only CDF can resolve the B_s^0 and the B_d^0 mass peaks, making a direct measurement of the later decay mode.

The most recent results are from CDF using a sample corresponding to the first $2\,\text{fb}^{-1}$. No excesses were found and upper limits were set of: $\mathcal{B}(B_s^0 \to \mu^+\mu^-) < 4.7 \times 10^{-8}$ and $\mathcal{B}(B^0 \to \mu^+\mu^-) < 1.5 \times 10^{-8}$ at 90% CL [5]. The DØ Collaboration is expected to provide an update very soon using $5\,\text{fb}^{-1}$: the expected upper limit is $\mathcal{B}(B_s^0 \to \mu^+\mu^-) < 4.3 \times 10^{-8}$ at the 90% CL [6].

3. – b-hadron charmless decays

The CDF experiment, using the ability to reconstruct tracks early at the trigger stage, collects a very rich sample of two-body hadronic decays. This sample permits to reach a very high precision on the measurements of the BRs and and direct CP asymmetry for the B^0, $B_{(s)}^0$, and the Λ_b^0 charmless decays [7, 8], competitive with the B-factories and with the unique possibility to combine B_d and B_s modes.

The analysis disentangles 8 decay modes using a maximum-likelihood fitting technique that uses 5 observables: the invariant mass for the two-body decay candidate, the scalar momenta of the daughter tracks, and the particle identification information for each track.

The most recent results were obtained using $1\,\text{fb}^{-1}$ of data. Using these results it is possible to combine $B_s^0 \to KK$, $B_s^0 \to K\pi$, and other related B-meson measurement to test some models. Using the U-spin symmetry and other assumptions it is possible to extract the γ angle [9]. A value in agreement with the average value can be found only constraining the weak phases to values not in agreement with other determinations. A different test links the decay rate of the $B^0 \to K\pi$ with the $B_s^0 \to K\pi$ decay, this is a weakly model-dependent test proposed in [10, 11]. In SM hypothesis for the $K\pi$ final states is expected $\Delta = (\Gamma(\bar{B}^0) - \Gamma(B^0))/(\Gamma(\bar{B}_s^0) - \Gamma(B_s^0)) = -11$, the analysis gives $\Delta = -0.83 \pm 0.42$ in agreement with the SM expectation within the experimental errors.

The analysis is still on-going, and fig. 1 shows a preliminary plot with the data collected using the current calibrated sample, corresponding to $2.7\,\text{fb}^{-1}$. Using this sample CDF is expected to improve the precision on the rare BR and to reach a resolution on the CP asymmetries close to 5σ on the $B_s^0 \to K\pi$ and $\Lambda_b^0 \to ph^-$ modes.

4. – $B_{(s)}^0 \to e^+e^-$ and $B_{(s)}^0 \to e^+\mu^-$ decay modes

The CDF experiment performs an analysis to search for $B_{(s)}^0 \to e^+\mu^-$ and $B_{(s)}^0 \to e^+e^-$ decay modes. The $B_{(s)}^0 \to e^+e^-$ decay modes are FCNC mediated, with respect to the $B_{(s)}^0 \to \mu^+\mu^-$ modes described in sect. **2** they are further suppressed by a factor $(m_e/m_\mu)^2$, making the observation of those modes more challenging but also with more room for non-minimal NP insertion. The $B_{(s)}^0 \to e^+\mu^-$ decay modes are forbidden in the SM: they are allowed in minimal extensions of the SM, including massive neutrinos via the lepton flavor oscillation matrix. Other Beyond-SM theory as Pati-Salam model [12], Super-Symmetry model, or Extra-Dimension models [13] have a large impact on these modes, increasing the predicted BRs.

The sample is collected using the displaced-track trigger sample, described in sect. **3** and uses the $B^0 \to K\pi$ decay mode as normalization. The final selection, optimized

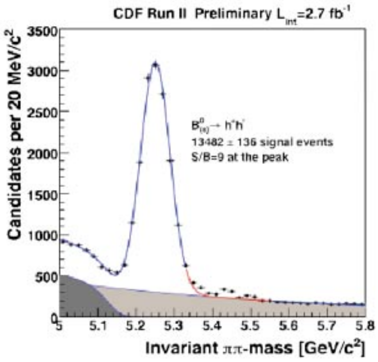

Fig. 1. – The plot shows the invariant-mass distribution for the charmless decay sample using $2.7\,\text{fb}^{-1}$ by CDF.

for the search, selects two tracks with $p_{T,1/2} > 2\,\text{GeV}/c$, impact parameter $d_0(1/2) \in (140\,\mu\text{ m}, 1\,\text{mm})$, $p_{T,1} + p_{T,2} > 5.5\,\text{GeV}/c^2$, and with an opening angle $20° < \Delta\phi < 135°$. The B-candidate is requested to have a transverse decay length $L_{xy} > 375\,\mu\text{m}$. The candidates produced outside the collision point are rejected requiring a pointing angle $\Delta\varphi < 0.11$, the combinatoric background due to light mesons is rejected requiring an isolation $p_T(B)/\sum p_{T,i} > 0.675$.

Using $2\,\text{fb}^{-1}$ of integrated luminosity the observed number of events are compatible with the background expectations. The resulting Bayesian upper limits at 90% of credibility level are $\mathcal{B}(B_s^0 \to e^+\mu^-) < 2.0 \times 10^{-7}$, $\mathcal{B}(B^0 \to e^+\mu^-) < 6.4 \times 10^{-8}$, $\mathcal{B}(B_s^0 \to e^+e^-) < 2.8 \times 10^{-7}$, $\mathcal{B}(B^0 \to e^+e^-) < 8.3 \times 10^{-8}$, with a Pati-Salam leptoquark lower bound $M_{LQ}(B^0 \to e^+\mu^-) > 59.3\,\text{TeV}/c^2$ [14].

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