Masses and branching fractions at CDF

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Abstract. We present a collection of new results on b-meson and \( A_b \) masses and branching fractions measured at CDF. We have improved our measurement of the \( A_b \) and \( B_s \) mass and we have measured the branching fractions of \( B_s \to D_s \pi, A_b \to \Lambda_c \pi \) and \( B_u \to \phi K^\pm \).

Introduction

The Collider Detector Facility (CDF) at the Fermi National Accelerator Laboratory is presently taking data from \( p\bar{p} \) collisions at 1.960 TeV c.m.s. with increased luminosity and better detector performances. In particular, a trigger based on tracks with impact parameter allows us to study fully hadronic decay modes of b-hadrons.

In this paper we present a review of new results on mass and branching ratio measurements at CDF.

We have used two main trigger paths: two opposite charge muons \( p_t > 1.5 \) GeV/c associated with tracks, that we refer to as \( J/\psi \) trigger; two tracks with impact parameter \( d_0 > 120 \mu m \) and \( p_t > 2.0 \) GeV/c, the “two-track trigger”. The masses of \( B^+, B^0, B_s \) and \( A_b \) have been measured using candidates from decays selected by the \( J/\psi \) trigger. The branching fractions that we present here have been measured using candidates from the two-track trigger data.

The main components that have been used in this work are the central tracking chamber (COT) that has a momentum resolution of 0.1% \((\text{GeV/c})^{-1}\) and \( dE/dx \) capability, the silicon detector (SVX), with a 30 \( \mu m \) spatial resolution, the Silicon trigger system (SVT) [1], the eXtra Fast Track trigger (XFT) and the muon system [2].

In the following analyses we have used an integrated luminosity of up to 120 \( pb^{-1} \).

Mass measurements

The mass scale has been calibrated using a sample of 470000 \( J/\psi \to \mu\mu \) candidates. Two corrections have been applied: we corrected for the amount of any material missing from the geometry description, in order to eliminate \( p_t \) dependence of the \( J/\psi \) mass. This is mainly due to the description of SVX cables. A correction for magnetic field was applied, in order to obtain an agreement with the PDG [3] value of the \( J/\psi \) mass.

The same correction factors have been used to measure the mass of the \( \Phi' \) and of the \( T(1S) \) as a calibration check. Both masses resulted to be within 1\( \sigma \) and 0.5\( \sigma \) of the statistical error from the PDG value, respectively, with a maximum discrepancy of 0.0085 %.

We have measured the mass of b-hadrons selecting the following exclusive decays: \( B_u \to J/\psi K^\pm, B_d \to J/\psi K^{\ast0}, B_s \to J/\psi \Phi \) and \( A_b \to J/\psi \Lambda \) from the di-muon \( (J/\psi) \) trigger stream. After the standard track quality requirements, the analysis operated cuts on the reconstructed mass of di-muon candidates \( (3096.9 \pm 80) \text{ MeV}, \) on the reconstructed decay length and \( p_t \) of the b-hadron \( (L_{xy} > 100 \mu \text{m} \) and \( p_t > 6.5 \text{ GeV/c}) \), on the \( p_t \) of the accompanying meson \( (p_t(K) > 2 \text{ GeV/c}) \). Additional cuts, that were specific to each channel, were the width of the window around the PDG mass value of the accompanying meson: \( \pm 10 \text{ MeV} \) in the case of the \( \Phi, \pm 15 \text{ MeV} \) in the case of the \( \Lambda, \pm 80 \text{ MeV} \) in the case of the \( K^\ast \). In addition, in case of \( A_b \to J/\psi \Lambda \) we require that the reconstructed baryon originated from the interaction vertex and that the reconstructed \( \Lambda \) points to the \( J/\psi \) vertex.

In Fig. 1,2 the mass distribution of the candidate events of \( B_s \) and \( A_b \) is reported, respectively, with a gaussian...
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\[
\frac{f_A \, BR(a)}{f_B \, BR(b)} = \frac{\epsilon_1(2) \, N_A \, BR(c)}{\epsilon_1(1) \, N_B \, BR(d)}
\]

where \(f_A\) and \(f_B\) are the production fractions, \(\epsilon_1\) are trigger efficiencies and \(N\) are the number of candidates.

We have measured the branching fraction of the following decays:

- \(B_s \rightarrow D^{\mp} \pi^\pm\) with \(D^{\mp} \rightarrow \Phi \pi^\pm\) and \(\Phi \rightarrow K^+ K^-\)
- \(A_b \rightarrow \Lambda_b^0 \pi^-\) with \(\Lambda_b^0 \rightarrow p K^- \pi^+\) and c.c.
- \(B_d \rightarrow \pi^+ \pi^- / B_d \rightarrow K^+ \pi^-\)
- \(A_b \rightarrow \Phi K^\pm\) with \(\Phi \rightarrow K^+ K^-\)

For the first two channels we used the decay \(B_d \rightarrow D^{\pm} \pi^\mp\) with \(D^{\pm} \rightarrow (K \pi \pi)^\pm\) as the reference mode. The third channel is described elsewhere in these proceedings [7]. The yield of \(B_u \rightarrow \Phi K^\pm\) candidates was compared with the one of \(B_u \rightarrow J/\psi K^\pm\) with \(J/\psi \rightarrow \mu^+ \mu^-\) as measured in the same trigger stream. The analysis cuts vary for each decay mode, as they have been optimized by using Monte Carlo signal and background from data side-bands.

For the \(B_s \rightarrow D^{\pm} \pi^\mp\) two tracks of the candidate are required to be trigger tracks, the \(\Phi\) candidate must have a mass within 1019 ± 8 MeV/c² and the \(D_s\) candidate tracks are mass-constrained to the \(D_s\) PDG value. Cuts are also applied to the impact parameter of the reconstructed \(B_s\) and to its flight distance. The mass spectrum is shown in fig. 3, with a fit with a templated function. The broader peak on the left is mainly due to partially reconstructed decays of \(B_s\) with 5 tracks in the final state. The resulting number of candidates is \(N(B_s) = 84 ± 11\), while with identical cuts the number of reference sample candidates is \(N(B_d) = 1135 ± 43\). From Monte Carlo the ratio of efficiencies, including analysis cuts, is 1.08 ± 0.02. The resulting ratio of branching fractions is:

\[
\frac{f_s \, BR(B_s \rightarrow D_s \pi)}{f_d \, BR(B_d \rightarrow D^{\pm} \pi^\mp)} = 0.35 ± 0.05 \pm 0.04 ± 0.09
\]

Where the first error is statistical, the second systematic, the third is systematic due to our knowledge of the \(D\)'s branching ratios. Using the PDG values we have:

\[
BR(B_s \rightarrow D_s \pi) = (4.2 ± 0.6 ± 0.5 ± 1.3 ± 0.5) \times 10^{-3},
\]

where the fourth error is systematic due to our limited knowledge of \(f_s / f_d\).

For \(A_b \rightarrow \Lambda_c^0 \pi\) similar cuts have been used. The main issue here is the presence of a component due to misidentified tracks from \(b\)-hadron decays, in particular from the reference channel. This was parametrized and taken into account in the fitting procedure by using a template based on Monte Carlo. The resulting log-likelihood fit is shown in fig. 4. We detected 96 ± 13 candidates in 65 pb⁻¹. The reference process with identical cuts yielded 321 ± 22 candidates, with a Monte Carlo global relative efficiency \(\epsilon_R = 1.20 ± 0.02\).

\[
\frac{f_A \, BR(A_b \rightarrow \Lambda_c \pi)}{f_d \, BR(B_d \rightarrow D^{\pm} \pi^\mp)} = 0.66 ± 0.11 ± 0.09 ± 0.18
\]
Using the PDG 2002 values for the known decay and production fractions we obtain:

\[ \mathcal{B}(B_u \to \phi K^\pm) = (6.8 \pm 2.1 \pm 0.7) \times 10^{-3} \]

The decay \( B_u \to \phi K^\pm \) is interesting for search of direct CP asymmetry. Also, the \( \mathcal{B} \) measured by BaBar and Belle were different by a factor of 2. Our analysis cuts are based on mass window cutst, track impact parameter, decay length and isolation cuts. The mass distribution is shown in fig. 5; the log-likelihood fit to the data gives \( 22.8 \pm 6.7 \) candidates in 120 pb\(^{-1}\). In the same data-set the corresponding reference sample \( B_u \to J/\psi K^\pm \) yields 406 \( \pm 26 \) candidates. The relative Monte Carlo efficiency is \( \epsilon_R = 0.818 \pm 0.012 \). The fraction of muons in the reference sample was measured to be \( 0.839 \pm 0.066 \).

\[ \frac{\mathcal{B}(B_d \to J/\psi K^\pm)}{\mathcal{B}(B_d \to \phi K^\pm)} = (6.8 \pm 2.1 \pm 0.7) \times 10^{-3} \]

Which gives

\[ \mathcal{B}(B_d \to \phi K^\pm) = (6.9 \pm 2.1 \pm 0.8) \times 10^{-6} \]

in good agreement with the recent measurements by BaBar [8], Belle [9] and CLEO [10].

**Conclusions**

In RunII CDF has improved the precision on mass measurement for \( B_s \) and \( B_u \), and has measured for the first time two branching ratios with all hadronic final states, demonstrating the feasibility of these measurements at the \( p\bar{p} \) collider. With more statistics we'll improve the precision and accuracy of our mass measurements and a large quantity of decay channels will become available. Improving the statistics on the available channels will lead us to study mixing and CP violation.

**References**

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