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Masses and branching fractions at CDF

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Abstract

We present a collection of new results on b-meson and Λ_b masses and branching fractions measured at CDF. We have improved our measurement of the Λ_b and B_s mass and we have measured the branching fractions of $B_s \to D_s\pi$, $\Lambda_b \to \Lambda_c\pi$ and $B_u \to \Phi K^{\pm}$.

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	This work (MeV)	Best on PDG (MeV)	
B_u	$5279.32 \pm 0.68 \pm 0.94$	$5279.1 \pm 0.4 \pm 0.4$	[4]
B_d	$5280.30 \pm 0.92 \pm 0.96$	$5279.1 \pm 0.7 \pm 0.3$	[4]
B_s	$5365.50 \pm 1.29 \pm 0.94$	$5369.9 \pm 2.3 \pm 1.3$	[5]
Λ_b	$5620.4 \pm 1.6 \pm 1.2$	$5621 \pm 4 \pm 3$	[6]

Table 1: Masses of b-hadrons measured at CDF with 65 pb^{-1}. The first error is statistic, the second is systematic. For comparison, the best single measurement that appears on the PDG is reported here.

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/ψ 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 Λ_b have been measured using candidates from decays selected by the J/ψ 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% (GeV/c)$^{-1}$ and dE/dx capability, the silicon detector (SVX), with a 30 μm spatial resolution, the Silicon trigger system (SVT) [1], the eXtra Fast Track trigger (XFT) and the muon system [2]

In the following analises 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/Ψ 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/Ψ mass.

The same correction factors have been used to measure the mass of the Ψ' and of the $\Upsilon(1S)$ as a calibration check. Both masses resulted to be within 1σ and 0.5σ 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: $B_u \to J/\Psi K^{\pm}$, $B_d \to J/\Psi K^{0*}$, $B_s \to J/\Psi\Phi$ and $\Lambda_b \to J/\Psi\Lambda$ from the di-muon (J/Ψ) trigger stream. After the standard track quality requirements, the analysis operated cuts on the reconstructed mass of di-muon candidates (3096.9 ± 80 MeV), on the reconstructed decay length and p_t of the b-hadron ($L_{xy} > 100\mu m$ and $p_t > 6.5$ GeV/c), on the p_t of the accompanying meson ($p_t(K) > 2$ 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: ± 10 MeV in the case of the Φ, ± 15 MeV in the case of the Λ, ± 80 MeV in the case of the K^{0*}. In addition, in case of $\Lambda_b \to J/\Psi\Lambda$ we require that the reconstructed baryon originated from the interaction vertex and that the reconstructed Λ points to the J/ψ vertex.

In Fig. 1,2 the mass distribution of the candidate events of B_s and Λ_b is reported, respectively, with a gaussian + background log-likelihood fit superimposed to the data points.

The results are summarized in table 1. For the lighter b-mesons our measurement is in very good agreement with the world average and the precision is comparable with the measurement made by CLEO [4]. For B_s and Λ_b these are the best measurements to date, improving the statistical error by a factor 1.7 and 2.5 with respect to CDF Run-I [5, 6]. The systematic errors come from mass-constrained fit method, from the alignment constants and from the description of the material in the tracking volume.

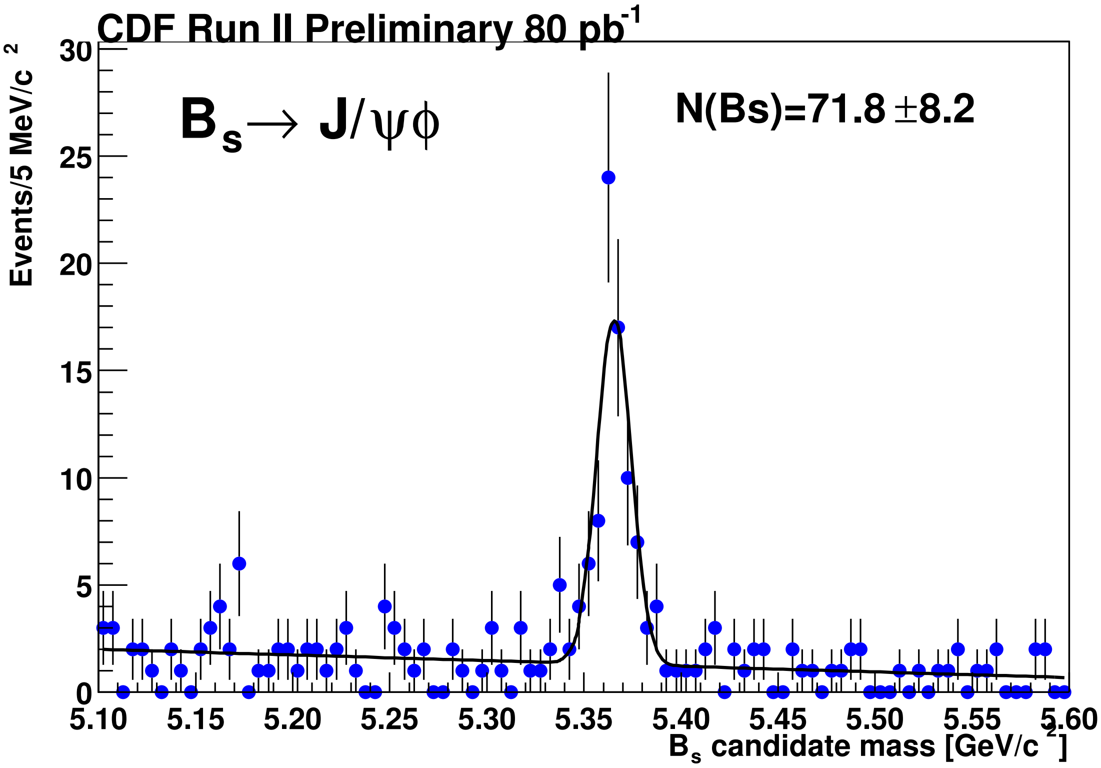

Figure 1: B_s mass spectrum in $B_s \rightarrow J/\Psi\Phi$

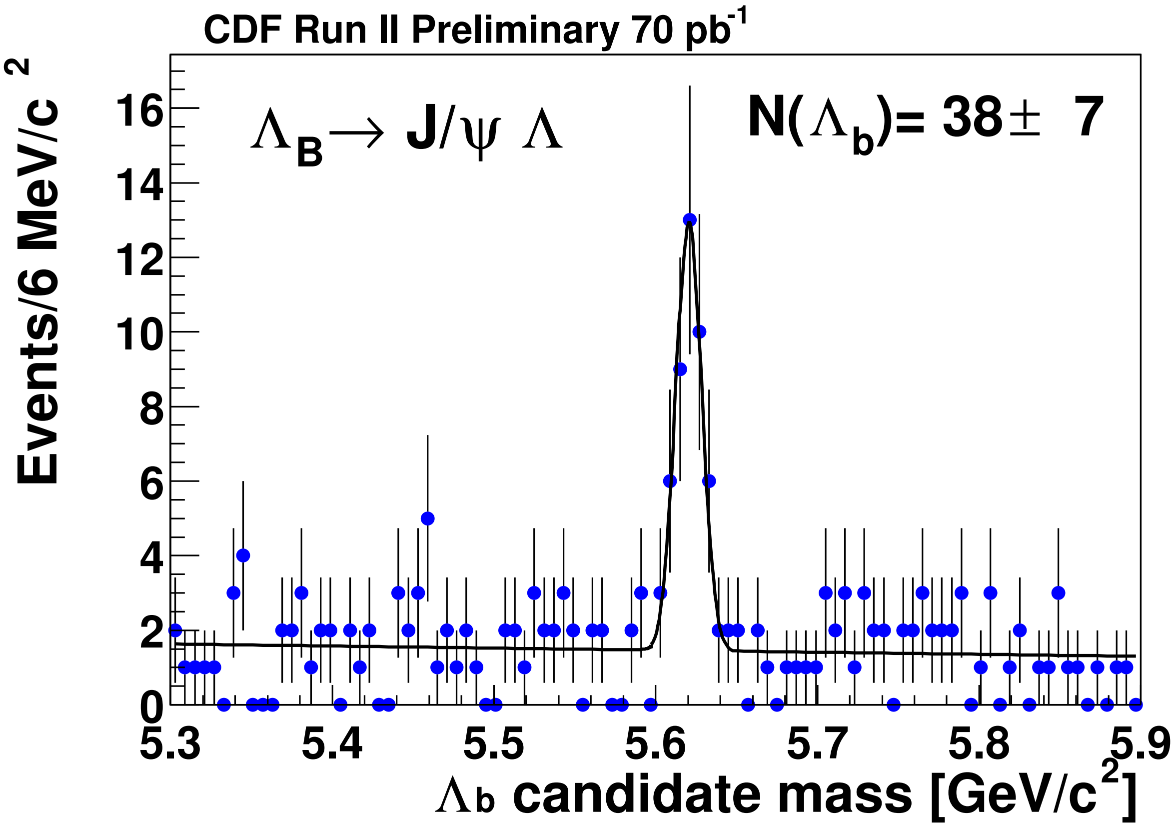

Figure 2: Λ_b mass spectrum in $\Lambda_b \rightarrow J/\Psi\Lambda$

Branching–Fraction measurements [1)]

With the implementation of the Silicon Vertex Trigger (SVT) [1] new decay channels have become available to study at the $p\bar{p}$ collider. The ratio of branching fractions of channels with a similar decay topology in the same trigger stream can be measured with lower systematic error after we correct for the different trigger and reconstruction relative efficiencies. To do so we use a Monte Carlo method combined with a realistic and run-dependent description of the detector configuration and beam position. In general, if we have two processes: 1) $A \xrightarrow{a} CX$ followed by $C \xrightarrow{c}$ *final state 1* and 2) $B \xrightarrow{b} DY$ followed by $D \xrightarrow{d}$ *final state 2* we have

$$\frac{f_A}{f_B}\frac{\mathcal{BR}(a)}{\mathcal{BR}(b)} = \frac{\epsilon_t(2)}{\epsilon_t(1)}\frac{N_A}{N_B}\frac{\mathcal{BR}(c)}{\mathcal{BR}(d)} \tag{1}$$

where f_A and f_B are the production fractions, ϵ_t are trigger efficiencies and N are the number of candidates.

We have measured the branching fraction of the following decays:

- $B_s \to D_s^{\pm}\pi^{\mp}$ with $D_s^{\pm} \to \Phi\pi^{\pm}$ and $\Phi \to K^+K^-$
- $\Lambda_b \to \Lambda_c^+\pi^-$ with $\Lambda_c^+ \to pK^-\pi^+$ and c.c.
- $B_d \to \pi^+\pi^-$ / $B_d \to K^+\pi^-$
- $B_u \to \Phi K^{\pm}$ with $\Phi \to K^+K^-$

For the first two channels we used the decay $B_d \to D^{\pm}\pi^{\mp}$ with $D^{\pm} \to (K\pi\pi)$ as the reference mode. The third channel is described elsewhere in these proceedings [7]. The yield of $B_u \to \Phi K^{\pm}$ candidates was compared with the one of $B_u \to J/\psi K^{\pm}$ with $J/\psi \to \mu^+\mu^-$ 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 $B_s \to D_s^{\pm}\pi^{\mp}$ two tracks of the candidate are required to be trigger tracks, the Φ candidate must have a mass within 1019 ± 8 MeV/c^2 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 $N(B_s) = 84 \pm 11$, while with identical cuts the number of reference sample candidates is $N(B_d) = 1135 \pm 43$. From Monte Carlo the ratio of efficiencies, including analysis cuts, is 1.08 ± 0.02 The resulting ratio of branching fractions is:

$$\frac{f_s}{f_d}\frac{\mathcal{BR}(B_s \to D_s\pi)}{\mathcal{BR}(B_d \to D^{\pm}\pi^{\mp})} = 0.35 \pm 0.05 \pm 0.04 \pm 0.09$$

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:

$$\mathcal{BR}(B_s \to D_s\pi) = (4.2 \pm 0.6 \pm 0.5 \pm 1.3 \pm 0.5) \times 10^{-3},$$

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

For $\Lambda_b \to \Lambda_c\pi$ 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 $\epsilon_R = 1.20 \pm 0.02$.

$$\frac{f_\Lambda}{f_d}\frac{\mathcal{BR}(\Lambda_b \to \Lambda_c\pi)}{\mathcal{BR}(B_d \to D^{\pm}\pi^{\mp})} = 0.66 \pm 0.11 \pm 0.09 \pm 0.18$$

Using the PDG 2002 values for the known decay and production fractions we obtain:

$$\mathcal{BR}(\Lambda_b \to \Lambda_c\pi) = (6.5 \pm 1.1 \pm 0.9 \pm 2.3) \times 10^{-3}$$

The decay $B_u \to \Phi K^{\pm}$ is interesting for search of direct CP asymmetry. Also, the $\mathcal{BR}$ measured by BaBar and Belle were different by a factor of 2. Our analysis cuts are based on mass window cuts, 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 ± 6.7 candidates in 120 pb^{-1}. In the same data-set the corresponding reference sample $B_u \to J/\psi K^{\pm}$

[1)] These results were updated after the conference.

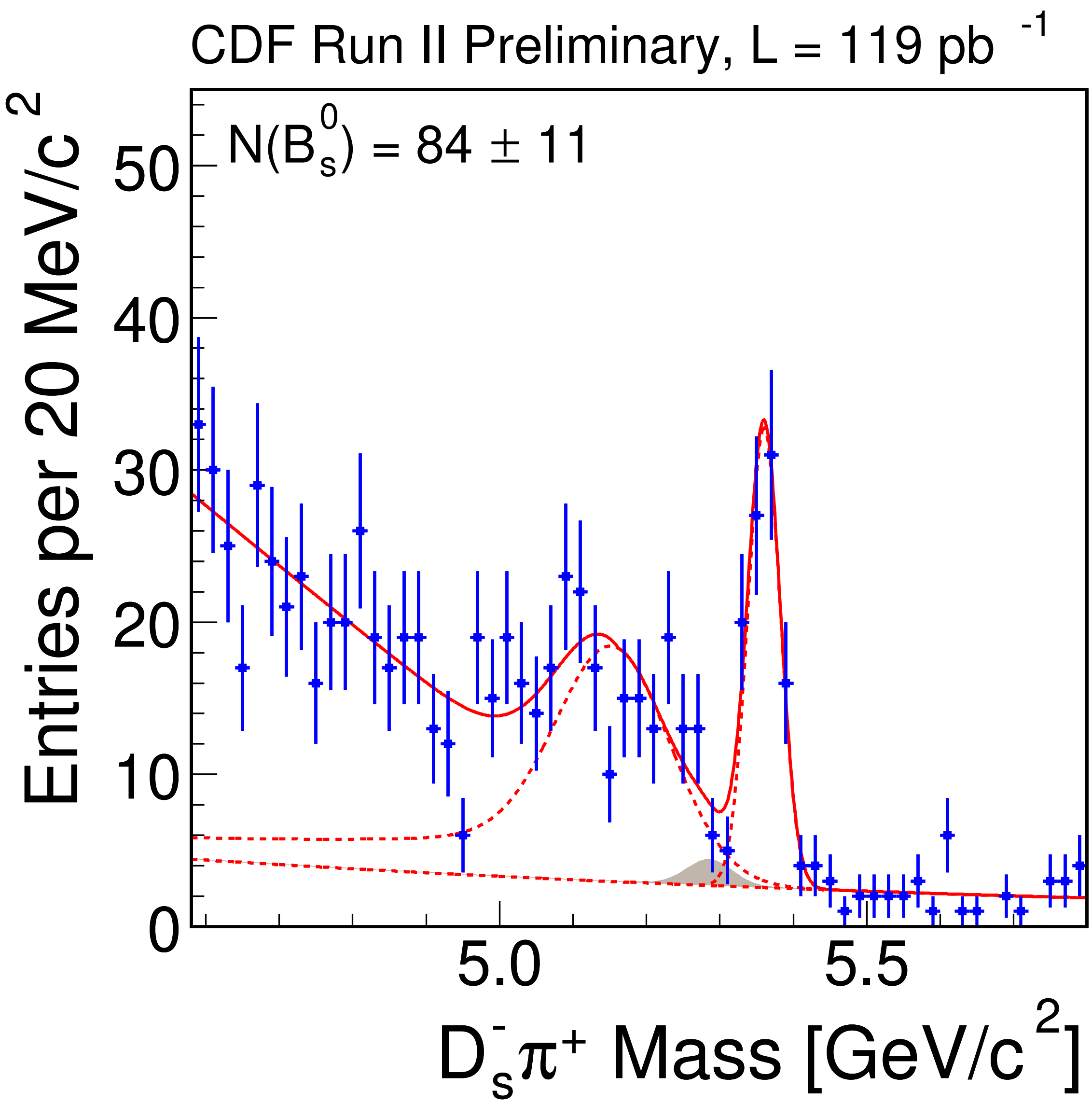

Figure 3: Mass spectrum of candidate $B_s \to D_s\pi$ with $D_s \to \Phi\pi$

yields 406 ± 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 ± 0.066.

$$\frac{\mathcal{BR}(B_d \to \Phi K^{\pm})}{\mathcal{BR}(B_d \to J/\psi K^{\pm})} = (6.8 \pm 2.1 \pm 0.7) \times 10^{-3}$$

Which gives

$$\mathcal{BR}(B_d \to \Phi K^{\pm}) = (6.9 \pm 2.1 \pm 0.8) \times 10^{-6}$$

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 Λ_b, 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.

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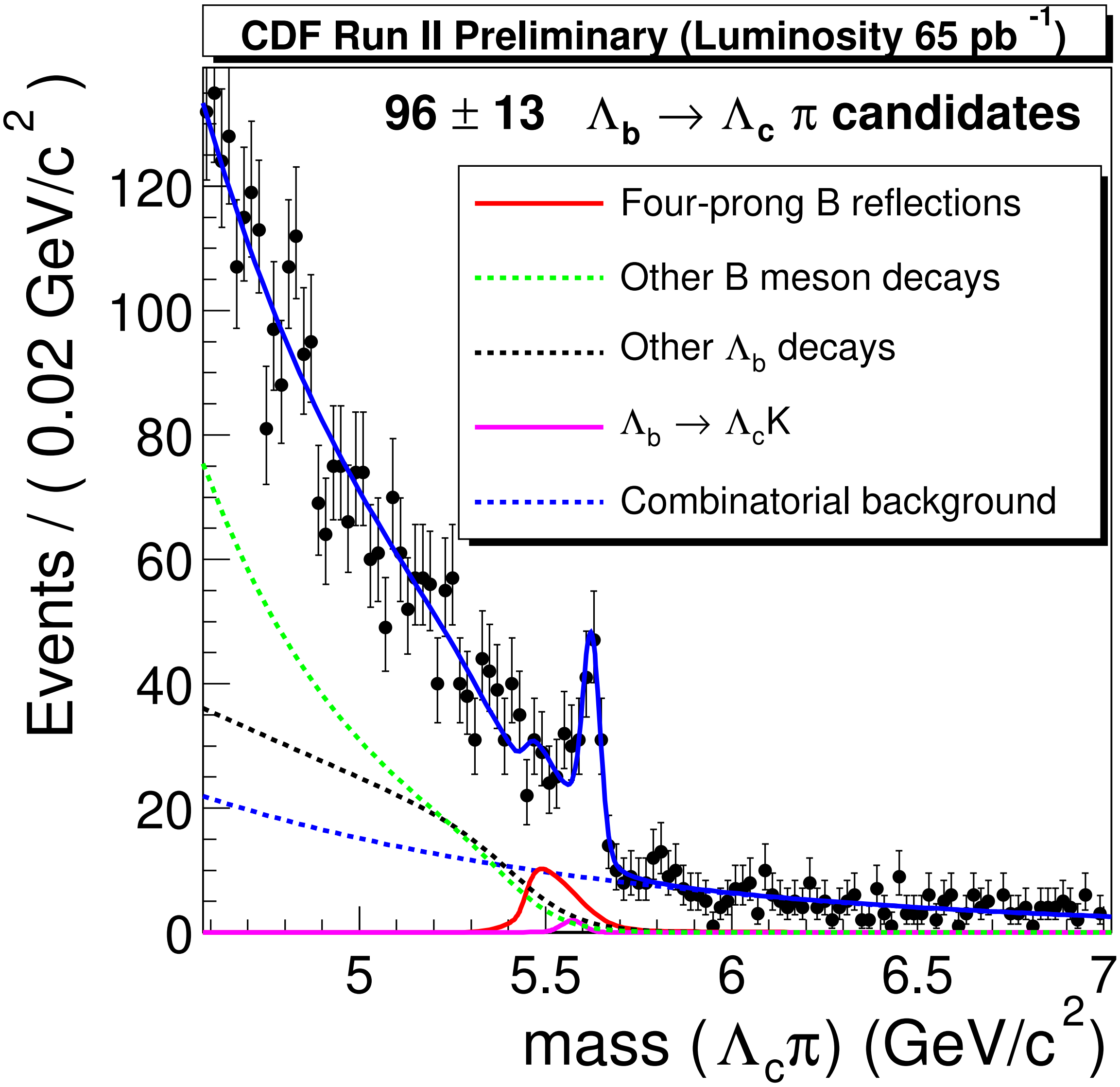

Figure 4: Mass spectrum of $\Lambda_b \to \Lambda_c \pi$ with $\Lambda_c \to pK\pi$.

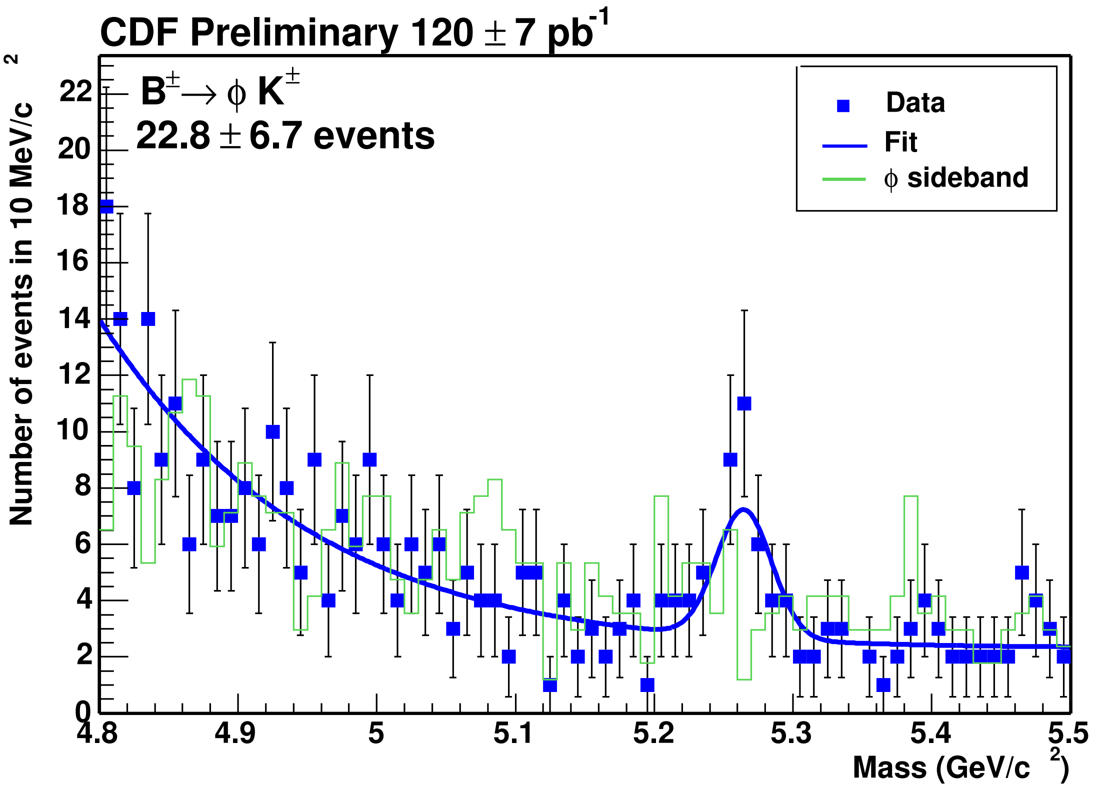

Figure 5: Mass spectrum of $B_u \to \Phi K^{\pm}$ candidates.

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