Measurements of branching fraction ratios and CP asymmetries in $B^+ \to D^0_{CP} K^\pm$

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The branching fractions and CP asymmetries of $B^- \to D^0 K^-$ modes allow a theoretically-clean way of measuring the CKM angle γ. In this analysis, we reconstructed modes where the D^0 decays in either $K^-\pi^+$ (flavor eigenstate) or $K^-K^+, \pi^-\pi^+$ (CP-even eigenstates), in a sample of about 1 fb^{-1} of CDF data.

We measure the direct CP asymmetry:

$$A_{CP+} = \frac{BR(B^- \to D^0_{CP+}K^-) - BR(B^+ \to D^0_{CP+}K^+)}{BR(B^- \to D^0_{CP+}K^-) + BR(B^+ \to D^0_{CP+}K^+)} = 0.39 \pm 0.17(stat.) \pm 0.04(syst.).$$

and the double ratio of the branching fractions:

$$R_{CP+} = \frac{R_+}{R} = \frac{\frac{BR(B^- \to D^0_{CP+}K^-) + BR(B^+ \to D^0_{CP+}K^+)}{BR(B^- \to D^0_{CP+}\pi^-) + BR(B^+ \to D^0_{CP+}\pi^+)}}{\frac{BR(B^- \to D^0 K^-) + BR(B^+ \to \overline{D}^0 K^+)}{BR(B^- \to D^0 \pi^-) + BR(B^+ \to \overline{D}^0 \pi^+)}} = 1.30 \pm 0.24(stat.) \pm 0.12(syst.)$$

in agreement with previous measurements from other experiments.

This is the first measurement of these quantities to be performed at a hadron collider.

I. INTRODUCTION

The partial widths of $B^- \to D^0 K^-$ modes allow a thoretically-clean extraction of the CKM [1, 2] angle $\gamma = arg(-V_{ud}V^*_{ub}/V_{cd}V^*_{cb})$ by a variety of methods, depending on the specific D^0 decay channel involved [3–7].

The precision of current experimental data [8] is still far from theoretical uncertainties and is statistics–limited, so the current limited knowledge of γ can be significantly improved by the addition of further data.

All mentioned methods for extracting γ from $B^- \to D^0 K^-$ modes require no tagging or time-dependent measurements, and many of them only involve charged particles in the final state. They are therefore particularly well–suited to analysis in a hadronic collider environment, where the large production can be well exploited.

In this note we describe the reconstruction and analysis of modes where the D^0 decays to either $K^-\pi^+$ (flavor eigenstate) or K^-K^+, $\pi^-\pi^+$ (CP-even eigenstates). These modes allow measuring the following useful parameters for the determination of angle γ ("GLW method" [3, 4]):

$$A_{CP+} = \frac{BR(B^- \to D^0_{CP+}K^-) - BR(B^+ \to D^0_{CP+}K^+)}{BR(B^- \to D^0_{CP+}K^-) + BR(B^+ \to D^0_{CP+}K^+)} \quad (1)$$

$$R_{CP+} = \frac{R_+}{R} \quad (2)$$

where

$$R = \frac{BR(B^- \to D^0 K^-) + BR(B^+ \to \overline{D}^0 K^+)}{BR(B^- \to D^0 \pi^-) + BR(B^+ \to \overline{D}^0 \pi^+)} \quad (3)$$

$$R_+ = \frac{BR(B^- \to D^0_{CP+}K^-) + BR(B^+ \to D^0_{CP+}K^+)}{BR(B^- \to D^0_{CP+}\pi^-) + BR(B^+ \to D^0_{CP+}\pi^+)} \quad (4)$$

These quantities are related to angle γ by the equations:

$$R_{CP+} = 1 + r^2 + 2r\cos\delta\cos\gamma \quad (5)$$

$$A_{CP+} = 2r\sin\delta\sin\gamma/R_{CP+} \quad (6)$$

where r is the magnitude of the ratio of the amplitudes of the processes $B^- \to \overline{D}^0 K^-$ and $B^- \to D^0 K^-$, and δ is the relative strong phase between those two amplitudes.

We reconstruct and separate the relevant modes for this analysis and the larger $B^- \to D^0\pi^-$ modes by a simultaneous Likelihood fit, exploiting their kinematics differences and the particle identification information provided by the specific ionization (dE/dx) in the CDF central drift chamber.

II. DATA SAMPLE AND EVENT SELECTION

The analysis is performed on a sample collected by the upgraded CDF detector [9] between February 2002 and February 2006, corresponding to an integrated luminosity of $\sim 1\ fb^{-1}$. The trigger is based on precision track impact parameters measured by SVT [10], and is designed to select hadronic B meson decays by requiring the presence of at least two charged particles with significant impact parameters with respect to the interaction region.

Candidates for modes $B^- \to D^0\pi^-$ with $D^0 \to K^-\pi^+$ (flavour eigenstate) and the $B^- \to D^0_{CP+}\pi^-$ with $D^0_{CP+} \to \pi^+\pi^-$ and $D^0_{CP+} \to K^+K^-$ (CP-even eigenstate) were reconstructed from a sample collected with the request of at least two tracks with $p_T > 2$ GeV, 120 μm $< |d_0| <$ 1 mm and $\Delta\Phi <= 90°$ ($\Delta\Phi$ is the transverse opening-angle between tracks). Either the two tracks from the D^0, or one track from the D^0 and one from the B may satisfy the trigger requirements. The two subsamples have different kinematical distributions; in the present analysis we explicitly require the trigger tracks to be one from B and a track from D^0; this happens in $\sim 70\%$ of the signal events.

Candidates for each particle decay tree are reconstructed according to a *bottom–up* strategy. This means that, for example, in the case of $B^+ \to \overline{D}^0\pi^+$, $\overline{D}^0 \to K^+\pi^-$, at first we look for a track pair vertex that is compatible with a $\overline{D}^0$ decay, typically, to suppress the combinatorial background, the invariant mass of the track pair is required to lie in a mass range centered in the D^0 mass; we then combine the given D candidate with an additional charged track (new vertex) to reconstruct a new candidate compatible with a $B^+ \to \overline{D}^0\pi^+$ decay. The tracks are fitted to a secondary vertex by applying mass and pointing constraints, at the same time they are forced to comply with the proper vertex topology.

Offline cuts on the tridimensional vertex quality χ^2_{3D} and on the B isolation are very important handles to suppress combinatoric background. The B isolation variable is defined as $I = \frac{p_T(B)}{p_T(B)+\sum p_T}$, where the sum runs over all tracks contained in a cone with radius = 1 in the η - ϕ space around the B meson flight direction.

The threshold placement for all cuts was determined by an optimization procedure aimed at achieving the best resolution on A_{CP+}, which is the most important parameter for extraction of γ. We do this in an ubiased way by using Monte Carlo predictions for the signal distributions, while the properties of the background are extrapolated from real data using the signal sidebands. The optimized cuts are listed in Table I.

After reconstructing D^0 candidates in the three modes of interest, the invariant mass distributions, with a nominal pion mass assignment to the track from B, are reported in Figs. 1, 2 and 3.

Clear B signals are seen in all plots, accompanied by a complex structure produced by partially reconstructed B decays, and a small combinatorial background component.

III. LIKELIHOOD FIT

Our goal is to measure the relative yields of $B^- \to D^0_{(CP+)}K^-$ to $B^- \to D^0_{(CP+)}\pi^-$ and their charge asymmetries. To this purpose, we performed an unbinned maximum likelihood fit which combines invariant mass, momenta, and Particle IDentification (PID) information for all three modes of interest simultaneously.

Fig. 4 shows the contribution to physics background from other B modes, obtained from a generic B Montecarlo sample. A single component dominates the background in the mass region of the DK signal: the mode $B^+ \to \overline{D}^{0*}\pi^+$ where a soft γ or π^0 from D^{0*} decay was lost. We limited our fit to the range of mass between 5.17 and 5.60 GeV/c^2 in order to ensure that contributions other than $B^+ \to \overline{D}^0\pi^+$ and $B^+ \to \overline{D}^{0*}\pi^+$ were negligible. The presence of a pion in these backgrounds, allows exploiting the dE/dx information on the B track as a handle in separating them from the DK signal.

We perform a simultaneous fit for the three channels, the flavor mode ($B^- \to D^0K^- \to [K^-\pi^+]K^-$) and the two DCP modes ($B^- \to D^0_{CP+}K^- \to [K^-K^+]K^-$ and $B^- \to D^0_{CP+}K^- \to [\pi^-\pi^+]K^-$). The structure of the Likelihood, described below, is the same for all three channels; an additional discrete observable flags the D^0 mode for each event, which is unambiguously determined at reconstruction time.
The fraction of the physics background ($B^- \to D^{0*}\pi^-$) with respect to the total signal ($B^- \to D^0\pi^-$ + $B^- \to D^0K^-$ + $B^- \to D^{0*}\pi^-$) is common to the three modes and the fraction of $B^- \to D^0_{CP}\pi^-$ is common to the two DCP modes. The simultaneous fit allows us to take advantage of the channel with more statistics to constrain the common parameters in a consistent way.

The observables used in the fit are:

- $M_{D^0\pi}$: the invariant mass assigning the pion mass at the track from B.
- The momentum imbalance α defined as:
  - if $p_{tr} < p_{D^0}$ $\quad \alpha = 1 - p_{tr}/p_{D^0} > 0$
  - if $p_{tr} \geq p_{D^0}$ $\quad \alpha = -(1 - p_{D^0}/p_{tr}) \leq 0$.

  As shown in Fig. 5, where the mass vs α is reported for $B^+ \to \overline{D}^0\pi^+$ and $B^+ \to \overline{D}^0K^+$, these two variables provide some separation between the two channels.
- $p_{tot} = p_t + p_{D^0}$.
- The “kaonness” κ which contain the dE/dx information for the track from B. The “kaonness” κ is defined as

$$\kappa = \frac{\frac{dE}{dx}_{meas} - \frac{dE}{dx}_{exp}(\pi)}{\frac{dE}{dx}_{exp}(K) - \frac{dE}{dx}_{exp}(\pi)} \tag{7}$$

  where the $\frac{dE}{dx}_{meas}$ is the measured energy lost by the particle in the drift chamber and the $\frac{dE}{dx}_{exp}(\pi(K))$ is the expected value for the energy lost in the drift chamber in a given particle hypothesis ($\pi(K)$) given the particle momentum. The average of κ observable respectively in pion and kaon hypothesis is $<\kappa>_\pi = 0$ and $<\kappa>_K = 1$. The particle identification is used only for the track from B to distinguish between BDK and BDπ mode. The distribution of kaonness k is crosschecked with the two tracks from the D0 which are unambiguosly identified from kinematics.

Using $M_{D^0\pi}$, α and p_{tot} the B mass in the kaon hypothesis can be expressed as:

- if $\alpha > 0$

$$M^2(\alpha,p_{tot}) = M_{Bu}^2 + m_\pi^2 - m_K^2 + 2\cdot\sqrt{m_{D^0}^2 + (p_{tot}/(2-\alpha))^2}\cdot \\ \cdot\left(\sqrt{(m_\pi^2 + (p_{tot}(1-\alpha)/(2-\alpha))^2} - \sqrt{m_K^2 + (p_{tot}(1-\alpha)/(2-\alpha))^2}\right) \tag{8}$$

- if $\alpha \leq 0$

$$M^2(\alpha,p_{tot}) = M_{Bu}^2 + m_\pi^2 - m_K^2 + 2\cdot\sqrt{m_{D^0}^2 + (p_{tot}(1+\alpha)/(2+\alpha))^2}\cdot \\ \cdot\left(\sqrt{(m_\pi^2 + (p_{tot}/(2+\alpha))^2} - \sqrt{m_K^2 + (p_{tot}/(2+\alpha))^2}\right). \tag{9}$$

The expression of the likelihood is then:

$$L = \prod_k^{Nevents}((1-b)\cdot(f_\pi\cdot F_\pi(\alpha,p_{tot},M_{D^0\pi},\kappa) + f_D\cdot BG_D(\alpha,p_{tot},M_{D^0\pi},\kappa) + \\ + (1-f_\pi-f_D)\cdot F_K(\alpha,p_{tot},M_{D^0\pi},\kappa)) + b\cdot BG_{comb}(\alpha,p_{tot},M_{D^0\pi},\kappa)). \tag{10}$$

Where b is the combinatorial background fraction measured with respect to all the events, f_π the fraction of $B^+ \to \overline{D}^0\pi^+$ with respect to the total signal and f_D the fraction of $B^+ \to \overline{D}^{0*}\pi^+$ with respect to the total signal (as a consequence, the fraction of $B^+ \to \overline{D}^0K^+$ is $f_K = 1 - f_\pi - f_D$).
We wrote six Likelihoods terms of this kind, one for each channel and each charge.
The fraction of the physics background is common to the three decays, so we will have only two parameters, f_D+ (positive charge) and f_D- (negative charge), instead of six. The fraction of $B^+ \to D^0_{CP}\pi^+$ and of $B^- \to D^0_{CP}\pi^-$ are common to both DCP modes ($D^0_{CP} \to K^+K^-$ and $D^0_{CP} \to \pi^+\pi^-$).

$F_\pi(\alpha,Ptot,M_{D^0\pi},\kappa)$ and $F_K(\alpha,Ptot,M_{D^0\pi},\kappa)$ are the pdf respectively of $B^+ \to \overline{D}^0\pi^+$ and $B^+ \to \overline{D}^0K^+$. The expression of these pdf is given by:

$$F_i(\alpha,p_{tot},M_{D^0\pi},\kappa) = G(M_{D^0\pi} - M_i(\alpha,p_{tot}))P(\alpha,p_{tot})P(\kappa) \tag{11}$$

where $G(M_{D^0\pi} - M_i(\alpha,p_{tot}))$ is the mass resolution function of each i-mode when the correct mass is assigned to the track from B. We have defined the “correct mass” as $M_{corr} = M_{D^0\pi} - \delta(\alpha,p_{tot})$ where $\delta(\alpha,p_{tot}) = M(\alpha,p_{tot}) - M_{Bu}$ is the mass shift due to the incorrect mass assignment ($\delta(\alpha,p_{tot}) = 0$ for $B^+ \to \overline{D}^0\pi^+$). G resolution function was parameterized using a modified full CDF II simulation including the most recent theoretical QED-calculations for non gaussian tails due to the emission of one or more photons in the final state (FSR) [11] (Figs. 6, 7).

$BG_D(\alpha,Ptot,M_{D^0\pi},\kappa)$ and $BG_{comb}(\alpha,Ptot,M_{D^0\pi},\kappa)$ are the pdf respectively of the physics background ($B^+ \to \overline{D}^{0*}\pi^+$) and of the combinatorial background. The expression of these pdf is given by:

$$BG_i(\alpha,p_{tot},M_{D^0}\pi,\kappa) = BG(M_{D^0\pi})P(\alpha,p_{tot})P(\kappa). \tag{12}$$

We choose an exponential function to model the mass distribution of combinatorial background. The normalization and the shape of the exponential (one for each mode) were left free in the maximum likelihood fit.

The $P(\alpha,p_{tot})$ is the 2-dimensional distribution of the kinematical variables α and p_{tot}, and it is parameterized for each mode by a product of polynomial and exponential functions fitted to MC samples for $B^- \to D^0K^-$, $B^- \to D^0\pi^-$ and $B^- \to D^{0*}\pi^-$ and to mass sideband of data for the combinatorial background.

P(κ) is the distribution of the particle identification variable κ obtained using a sample of kaons and pions from $D^0 \to K^-\pi^+$ decays.

The PID pdf for the combinatorial background was obtained in the assumption that it is dominated by pions and kaons:

$$a\cdot pdf_\pi(\kappa) + (1-a)\cdot pdf_K(\kappa) \tag{13}$$

where a is the fraction of pions in the combinatorial background and is left free to float in the central fit.

There are additional sources of background for the DCP modes: the three-body B^- decays. The $B^- \to K^-K^+K^-$ forms a mass peak in the same region as the $B^- \to D_{CP+}K^- \to [K^-K^+]K^-$; the $B^- \to K^-\pi^+\pi^-$ forms a mass

peak in the same region as $B^- \to D_{CP+}K^- \to [\pi^-\pi^+]K^-$ and finally the $B^- \to \pi^-\pi^+\pi^-$ forms a mass peak in the same region as the $B^- \to D_{CP+}\pi^- \to [\pi^-\pi^+]\pi^-$. To suppress these backgrounds we choose a tight cut on the D^0 decay length with respect to the B meson: $L_{xyB}(D) > 0.01$ cm.
From the MC simulation of the three-body decays we observed that after this cut the $B^- \to K^-\pi^+\pi^-$ and the $B^- \to \pi^-\pi^+\pi^-$ backgrounds become negligible. In the case of the $B^- \to K^-K^+K^-$, after the tightened $L_{xyB}(D)$ cut, the ratio between the number of $B^- \to K^-K^+K^-$ events and the number of the $B^- \to D_{CP+}K^- \to [K^-K^+]K^-$ events is about 8%. We included the $B^- \to K^-K^+K^-$ mode in the maximum likelihood fit. In the fit the number of $B^- \to K^-K^+K^-$ events is Gaussian constrained.

IV. FIT RESULT

The raw results of the maximum Likelihood fit are reported in tables II and III.

In order to visualize the agreement between the fit and the data we report the plots of fit projections. The most relevant projections are those for the observables $M_{D^0\pi}$, α, p_{tot} and κ (Figs 8-12).

A further check, giving confidence in the correctness of the fit, can be done using the PID variable "kaonness" κ defined in equation 7. Fig. 13 shows the mass fit projection for $\kappa > 0.5$ for the three decay modes. The average κ, respectively in pion and kaon hypothesis is $<\kappa>_\pi = 0$ and $<\kappa>_K = 1$, so cutting at 0.5 we select a kaon enriched sample and the ratio between the two yields $N(B^- \to D^0K^-)/N(B^- \to D^0\pi^-)$ increases. These projections show nicely the good agreement between the fit results and the data.

The raw fit results are first corrected for small biases, measured by testing the fit on Toy MC (2600 pseudo-experiment, the toy input values are the results obtained from the fit on data): $Bias_{RCP+} = -0.027 \pm 0.005$, $Bias_{ACP+} = 0.015 \pm 0.003$ and $Bias_R = -0.0021 \pm 0.0001$. We obtain then:

$$R\Big|_{raw} = 0.0705 \pm 0.0043 \tag{14}$$

$$R_{CP+}\Big|_{raw} = 1.30 \pm 0.24 \tag{15}$$

$$A_{CP+}\Big|_{raw} = 0.38 \pm 0.17 \tag{16}$$

These results must be further corrected for detector effects and analysis efficiencies. Several factors cancel out in the double ratio of branching fractions. The analysis efficiencies were determined from the detailed detector simulation. The lower specific ionization of kaons with respect to pions in the drift chamber is responsible for a $\sim 3\%$ lower efficiency to reconstruct a kaon by the XFT. This effect was measured in a sample of $D^+ \to K^-\pi^+\pi^+$ decays triggered on two tracks, using the unbiased third track.

The only correction needed by the direct CP-asymmetry A_{CP+} is due to different probability for K^+ and K^- to interact with the tracker material. This effect is reproduced rather well by GEANT [12]. The asymmetry $\frac{\epsilon(K^+)}{\epsilon(K^-)} = 1.0178 \pm 0.0023(stat.) \pm 0.0045(syst.)$ is estimated with a careful study on a large Monte Carlo sample. The corrected result are:

$$R = 0.0745 \pm 0.0043(stat.) \tag{17}$$

$$R_{CP+} = 1.30 \pm 0.24(stat.) \tag{18}$$

$$A_{CP+} = 0.39 \pm 0.17(stat.). \tag{19}$$

V. SYSTEMATICS UNCERTAINTIES

- *Input mass.* The B_u mass is an input parameter to the fit through the analytic expression of M(α,p_{tot}). We generate distinct ensembles of pseudo-experiments in which we vary the B_u input mass within $\pm 1\sigma$ statistical uncertainty of the published CDF II mass measurements [13] to evaluate the systematics due to the uncertainty on the input mass.

- *Mass scale.* The central fit is performed by assuming a known global mass scale in which we assign to the B_u mass the value measured by CDF in Run II. Since the mass is one of the variables used in separating all the different contributions we decide to include a mass scale parameter that is left free to be determined by the fit. From the fit we obtained a mass scale of 0.4 ± 0.2 MeV/c^2.

- *dE/dx induced systematics.* We generate distinct ensembles of pseudo-experiments in which the dE/dx parameters of the likelihood function are randomly varied in a 1σ-radius multidimensional sphere, in the space of the parameters of dE/dx calibrations.
- *Combinatorial background systematics.*
  - *Mass model.* Our central fit assumes a mass-shape of the combinatorial background events distribuited as an exponential function. To evaluate the systematics we generate distinct ensembles of pseudo-experiments in which we vary the mass-shape of the combinatorial background using polynomials of second and third degree.
  - *Kinematical parameterization.* To evaluate the systematics associated with the kinematical parameterization of the combinatorial background we generate distinct ensembles of pseudo-experiments in which we vary the bidimensional function $P(\alpha, p_{tot})$ using a different parameterization.
- *Kinematical parameterization of the signal and of the physics background.* To evaluate the systematics associated with the kinematical parameterization of the signal ($D^0\pi$ and D^0K) and of the physics background ($D^{0*}\pi$) we generate distinct ensembles of pseudo-experiments in which we vary the function $P(\alpha, p_{tot})$ using a different parameterization.
- *$D^{*0}\pi$ mass model.* To evaluate this systematics we leave free in the main fit some parameters of the $D^{*0}\pi$ mass parameterization. We parameterize the $D^{*0}\pi$ mass with three gaussians plus an exponential between 5.06 and 5.6. The idea is to see how the results (R, R_{CP+} and A_{CP+}) change letting free in the main fit the parameters of the exponential or of the gaussian that falls in the fit window [5.17,5.6].
  To check that we are treating correctly the $D^{0*}\pi$ decay, we compare what the fit predicted in the mass region below 5.17 with the data and we obtained a good agreement between the two.
- *Monte Carlo statistics.* The Monte Carlo statistics is the uncertainty deriving from the limited statistics of the Monte Carlo samples used to estimate the relative efficiencies. The statistic uncertainty on the relative efficiency is 0.004.
- *Uncertainty on the XFT-bias correction* The lower specific ionization of kaons with respect to pions in the drift chamber is responsible for a $\sim 3\%$ lower efficiency to reconstruct a kaon by the XFT. This effect was measured in a sample of $D^+ \to K^-\pi^+\pi^+$ decays triggered on two tracks, using the unbiased third track. We quoted an associated systematics due to the uncertainty of the parameterization of this effect.

A summary of all systematics is reported in Tab. IV. The total systematic uncertainty on each measurement is determined as the sum in quadrature of all systematic uncertainties.

VI. RESULTS

We measure the ratios of the branching fractions

$$R = \frac{BR(B^- \to D^0K^-) + BR(B^+ \to \overline{D}^0K^+)}{BR(B^- \to D^0\pi^-) + BR(B^+ \to \overline{D}^0\pi^+)} = 0.0745 \pm 0.0043(stat.) \pm 0.0045(syst.)$$

$$R_{CP+} = \frac{BR(B^- \to D^0_{CP+}K^-) + BR(B^+ \to D^0_{CP+}K^+)}{[BR(B^- \to D^0K^-) + BR(B^+ \to \overline{D}^0K^+)]/2} = 1.30 \pm 0.24(stat.) \pm 0.12(syst.)$$

and the direct CP asymmetry

$$A_{CP+} = \frac{BR(B^- \to D^0_{CP+}K^-) - BR(B^+ \to D^0_{CP+}K^+)}{BR(B^- \to D^0_{CP+}K^-) + BR(B^+ \to D^0_{CP+}K^+)} = 0.39 \pm 0.17(stat.) \pm 0.04(syst.).$$

These quantities are measured for the first time in hadron collisions. The results are in agreement with existing measurements performed at $\Upsilon(4S)$ resonance (Figs. 14 and 15), and have comparable resolution. The significance of A_{CP+} being different from zero increases from 3σ to 4σ when adding the current measurement into the world average. These measurements can be combined with other $B^- \to D^0K^-$ decay parameters to improve the determination of CKM angle γ.

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Parameter	Value
$\chi 3D$	< 13
$Isol$	> 0.65
$\frac{L_{xy}(B)}{\sigma_{L_{xy}(B)}}$	> 12
$L_{xy}(D)$	> 0.04 cm
$\lvert d_0(B)\rvert$	< 0.007
p_t (track from B)	> 2 GeV/c
$\Delta R_{\pi,D^0} = \sqrt{\Delta\phi^2 + \Delta\eta^2}$	< 2

TABLE I: Optimized cuts

Mode	Raw fraction	Raw yield
$B^+ \to \overline{D}^0\pi^+$	0.902 ± 0.006	3769 ± 68
$B^- \to D^0\pi^-$	0.902 ± 0.006	3763 ± 68
$B^+ \to \overline{D}^0 K^+$	0.060 ± 0.005	250 ± 26
$B^- \to D^0 K^-$	0.064 ± 0.005	266 ± 27
$B^+ \to D^0_{CP+}\pi^+ \to [K^+K^-]\pi^+$ (f_π^{dcp+})	0.910 ± 0.018	381 ± 25
$B^- \to D^0_{CP+}\pi^- \to [K^+K^-]\pi^-$ (f_π^{dcp-})	0.854 ± 0.018	399 ± 26
$B^+ \to D^0_{CP+}K^+ \to [K^+K^-]K^+$ (f_K^{dcp+})	0.052 ± 0.018	22 ± 8
$B^- \to D^0_{CP+}K^- \to [K^+K^-]K^-$ (f_K^{dcp-})	0.105 ± 0.018	49 ± 11
$B^+ \to D^0_{CP+}\pi^+ \to [\pi^+\pi^-]\pi^+$ (f_π^{dcp+})	0.910 ± 0.018	101 ± 13
$B^- \to D^0_{CP+}\pi^- \to [\pi^+\pi^-]\pi^-$ (f_π^{dcp-})	0.854 ± 0.018	117 ± 14
$B^+ \to D^0_{CP+}K^+ \to [\pi^+\pi^-]K^+$ (f_K^{dcp+})	0.052 ± 0.018	6 ± 6
$B^- \to D^0_{CP+}K^- \to [\pi^+\pi^-]K^-$ (f_K^{dcp-})	0.105 ± 0.018	14 ± 6

TABLE II: Raw results from the maximum likelihood fit.

Quantity	Measurement (raw)
R	0.0684 ± 0.0043
A_{CP} flavor	0.03 ± 0.06
R_{CP+}	1.30 ± 0.24
A_{CP+}	0.39 ± 0.17

TABLE III: Raw results from the maximum likelihood fit.

Source	R	R_{CP+}	A_{CP+}
dE/dx	0.0028	0.056	0.030
$D^{0*}\pi$ mass model	0.0028	0.025	0.006
Input mass to the fit (Bu mass)	0.0002	0.004	0.002
Combinatorial background mass model	0.0002	0.020	0.001
(α, p_{tot}) combinatorial background	0.0002	0.100	0.020
(α, p_{tot}) $D^0\pi$	0.0001	0.002	0.001
(α, p_{tot}) D^0K	0.0006	0.002	0.004
(α, p_{tot}) $D^{0*}\pi$	0.0007	0.004	0.002
Bias error	0.0001	0.005	0.003
MC statistics/XFT eff	0.002	-	-
Total(sum in quadrature)	0.0045	0.12	0.04

TABLE IV: Systematics summary.

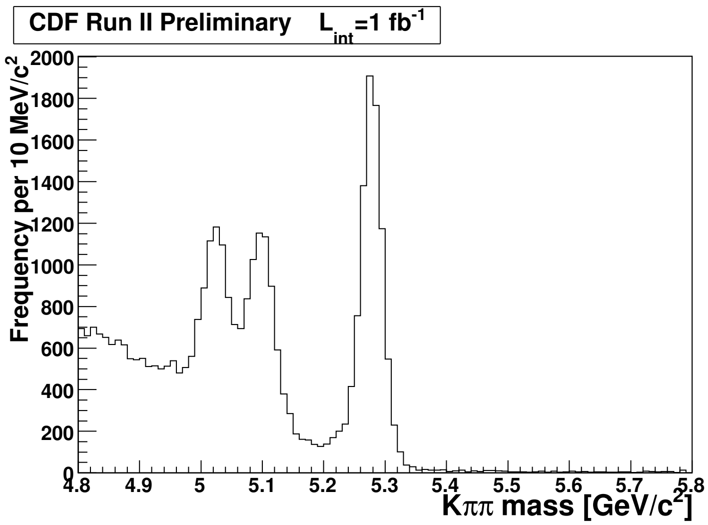

FIG. 1: Invariant mass distribution of $B^- \to D^0\pi^-$ with $D^0 \to K^-\pi^+$ (flavour eigenstate) with the optimized cuts.

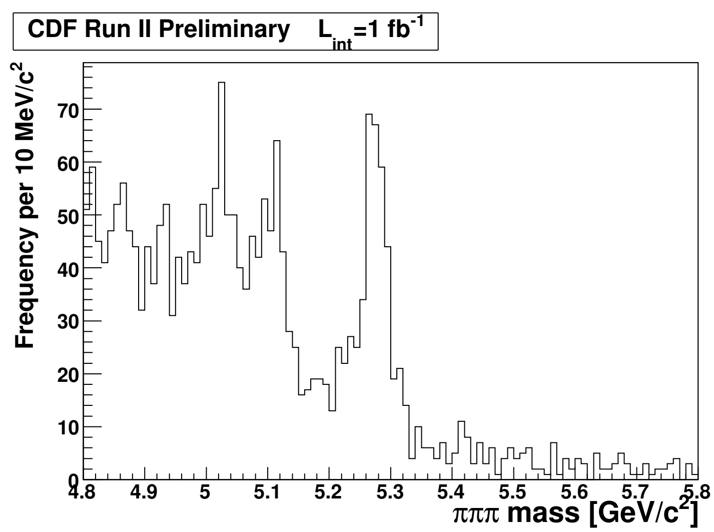

FIG. 2: Invariant mass distribution of $B^- \to D^0_{CP+}\pi^-$ with $D^0_{CP+} \to \pi^+\pi^-$ (CP-even eigenstate) with the optimized cuts.

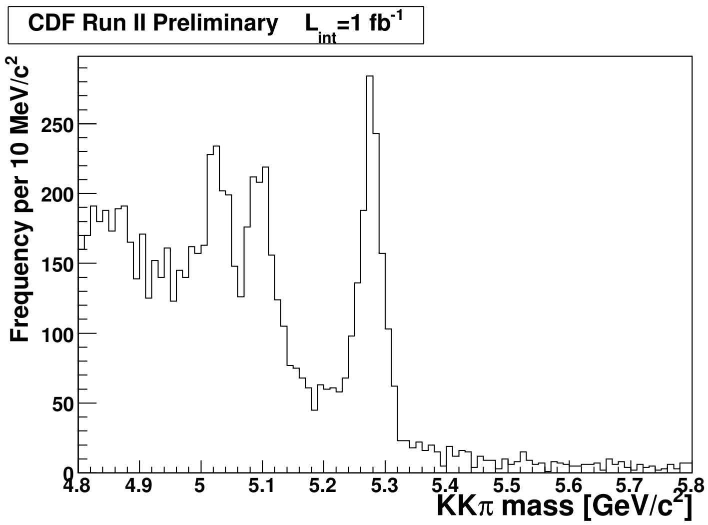

FIG. 3: Invariant mass distribution of $B^- \to D^0_{CP+}\pi^-$ with $D^0_{CP+} \to K^+K^-$ (CP-even eigenstate) with the optimized cuts.

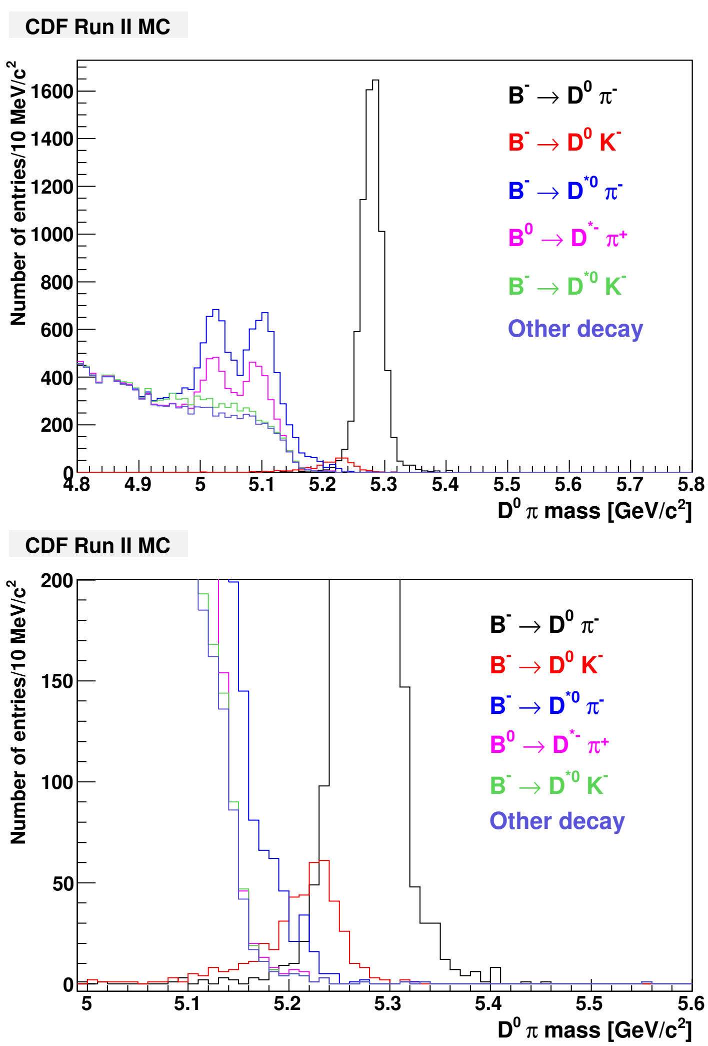

FIG. 4: Generic MC of B^+. On the bottom a Zoom of the mass distributions to see the $B \to D^0K$ decay.

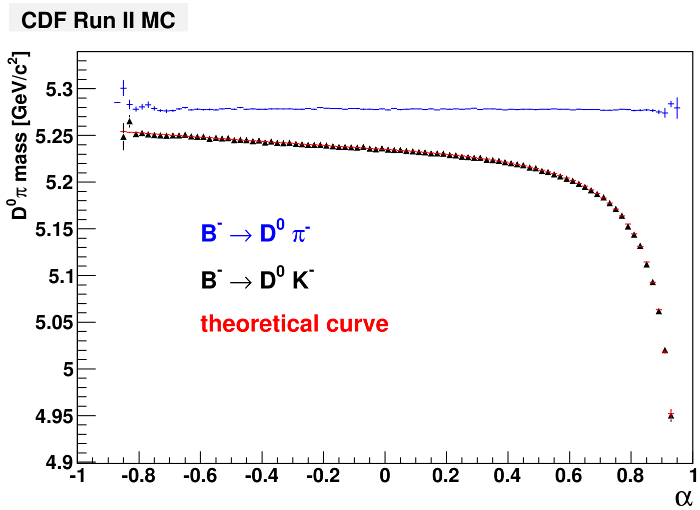

FIG. 5: Mass vs α using MC. Blue: $M_{D^0\pi}$. Black: M_{D^0K}. Red: theoretical curve obtained using the analytical formula

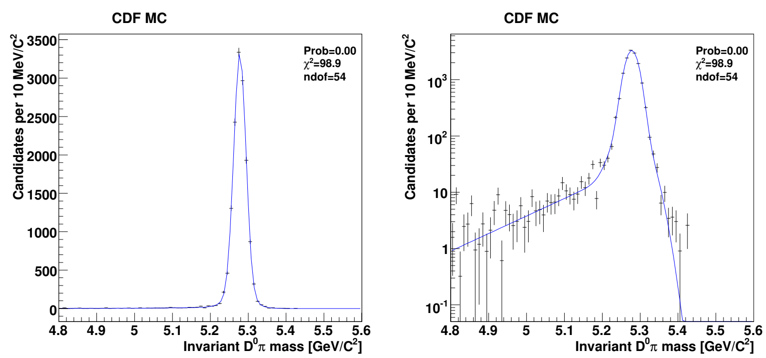

FIG. 6: Invariant mass distribution (correct mass assignment) of the simulated $B^+ \rightarrow \overline{D}^0\pi^+$ events (on the left linear scale, on the right logarithmic scale). We overlaided the mass template.

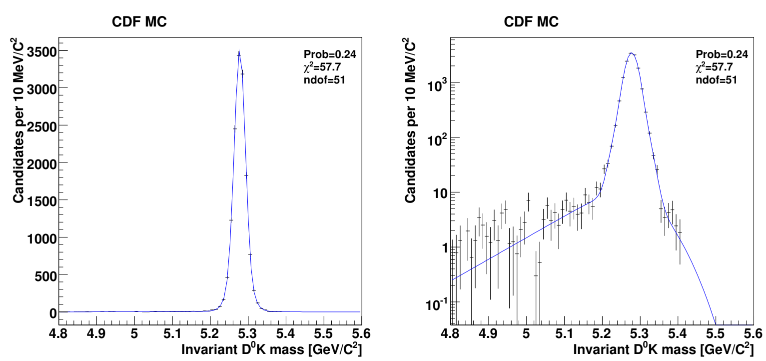

FIG. 7: Invariant mass distribution (correct mass assignment) of the simulated $B^+ \rightarrow \overline{D}^0K^+$ events (on the left linear scale, on the right logarithmic scale). We overlaided the mass template.

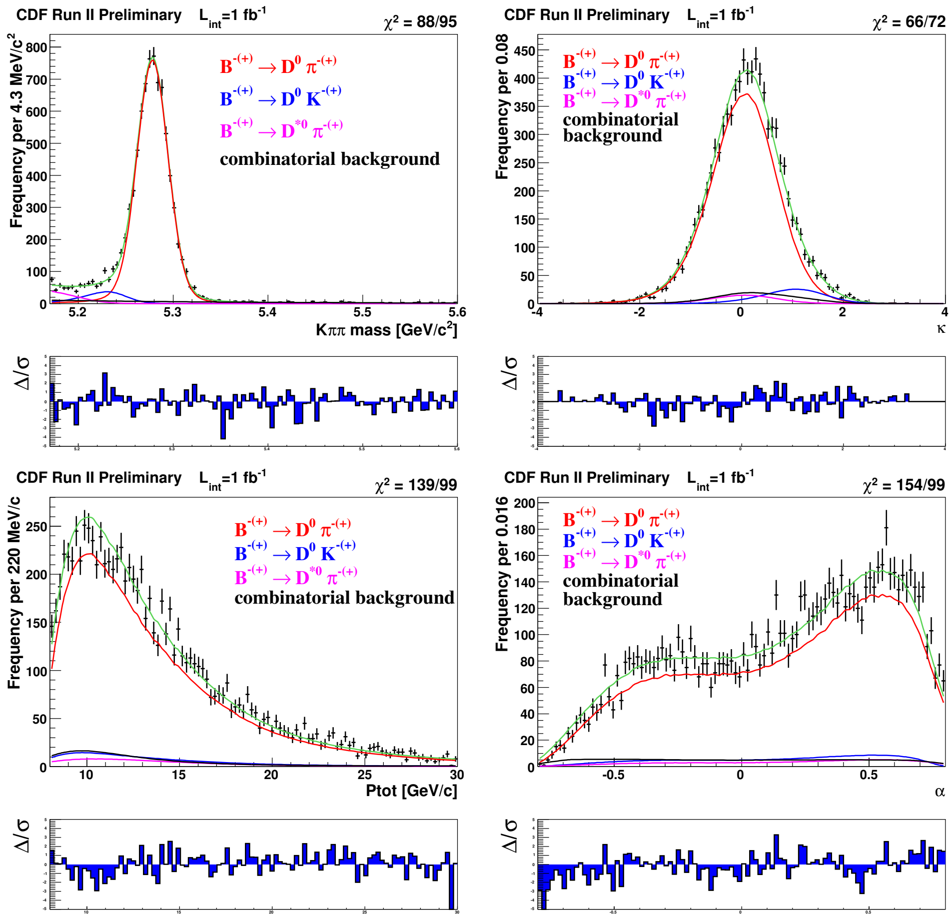

FIG. 8: Fit projection in all mass range onto the $m_{D^0\pi}$, κ, p_{tot}, α variables for the flavor modes.

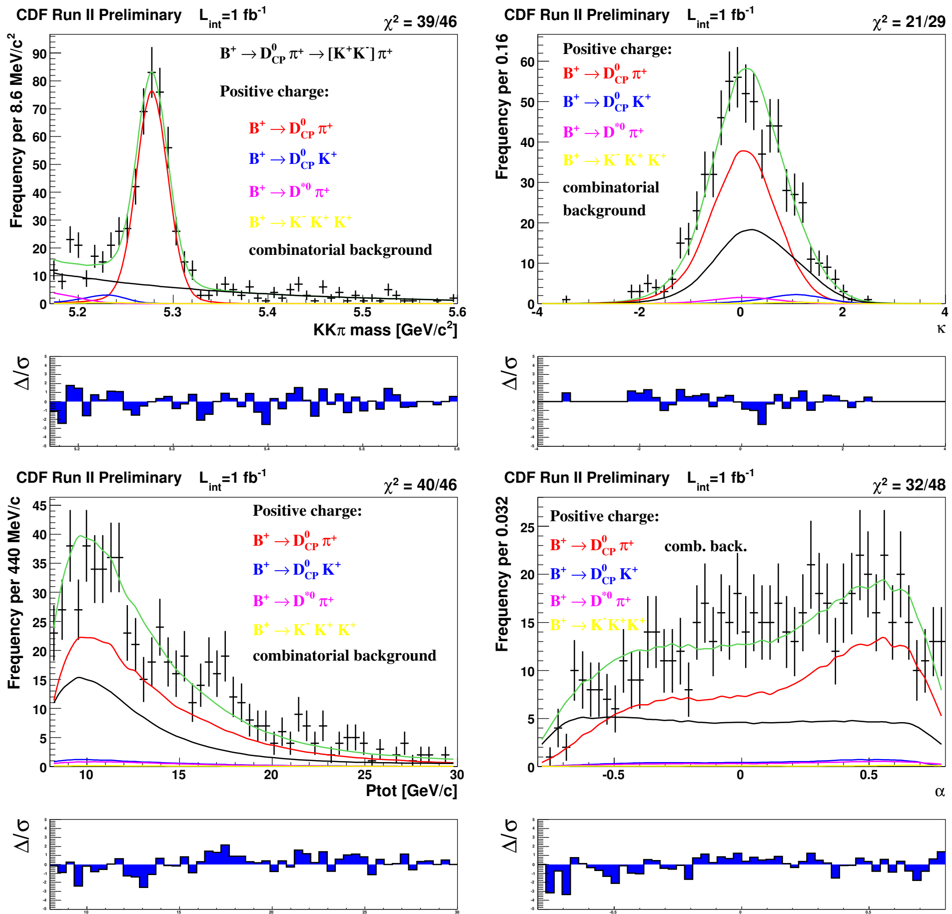

FIG. 9: Fit projection in all mass range onto the $m_{D^0\pi}$, κ, p_{tot}, α variables for $B^+ \to D^0_{CP+}K^+ \to [K^+K^-]K^+$.

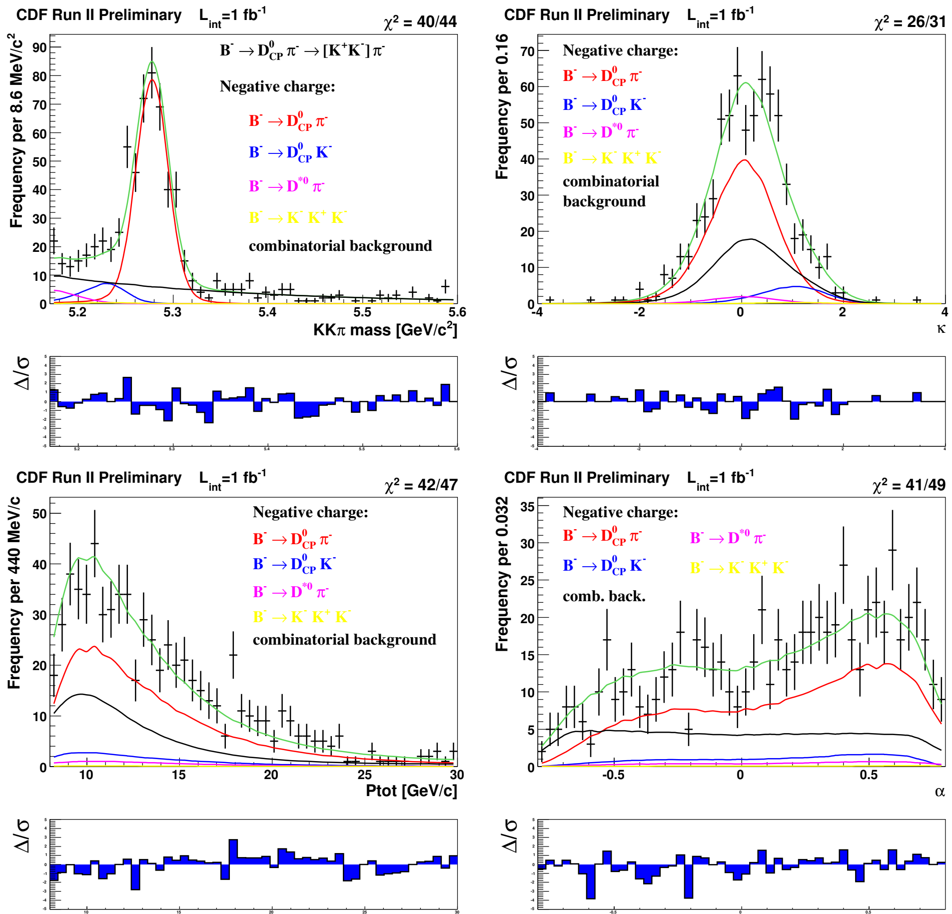

FIG. 10: Fit projection in all mass range onto the $m_{D^0\pi}$, κ, p_{tot}, α variables for $B^- \to D^0_{CP+}K^- \to [K^+K^-]K^-$.

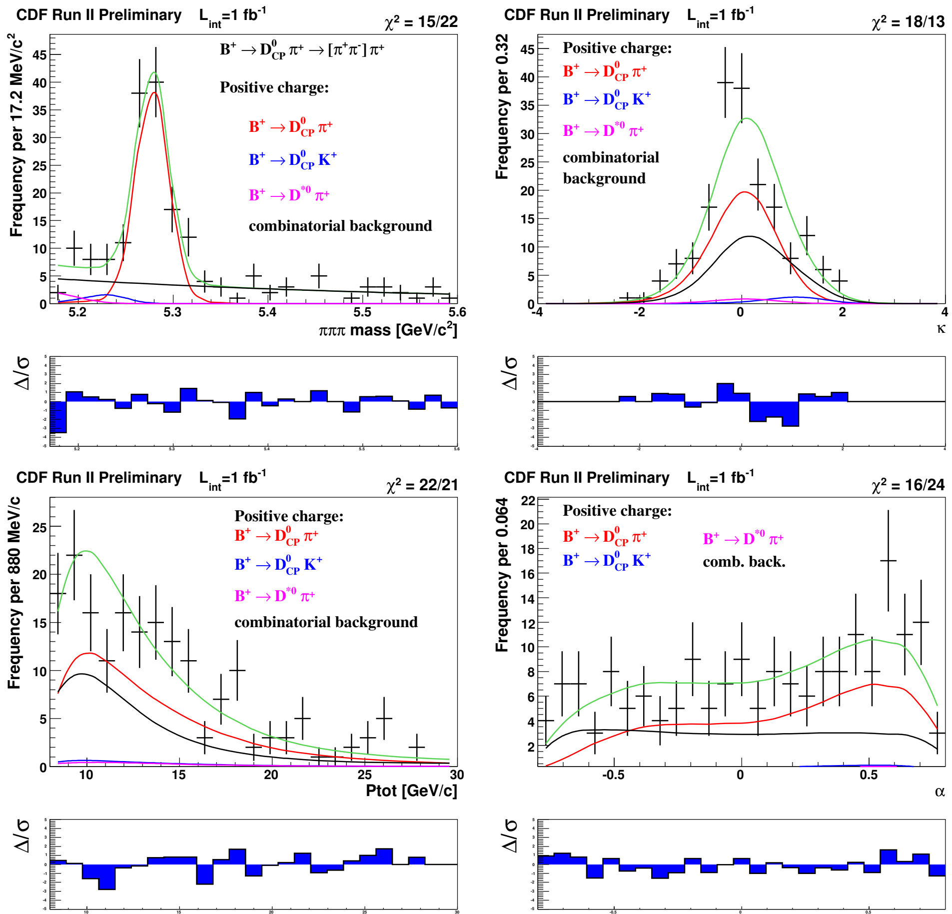

FIG. 11: Fit projection in all mass range onto the $m_{D^0\pi}$, κ, p_{tot}, α variables for $B^+ \to D^0_{CP+}K^+ \to [\pi^+\pi^-]K^+$.

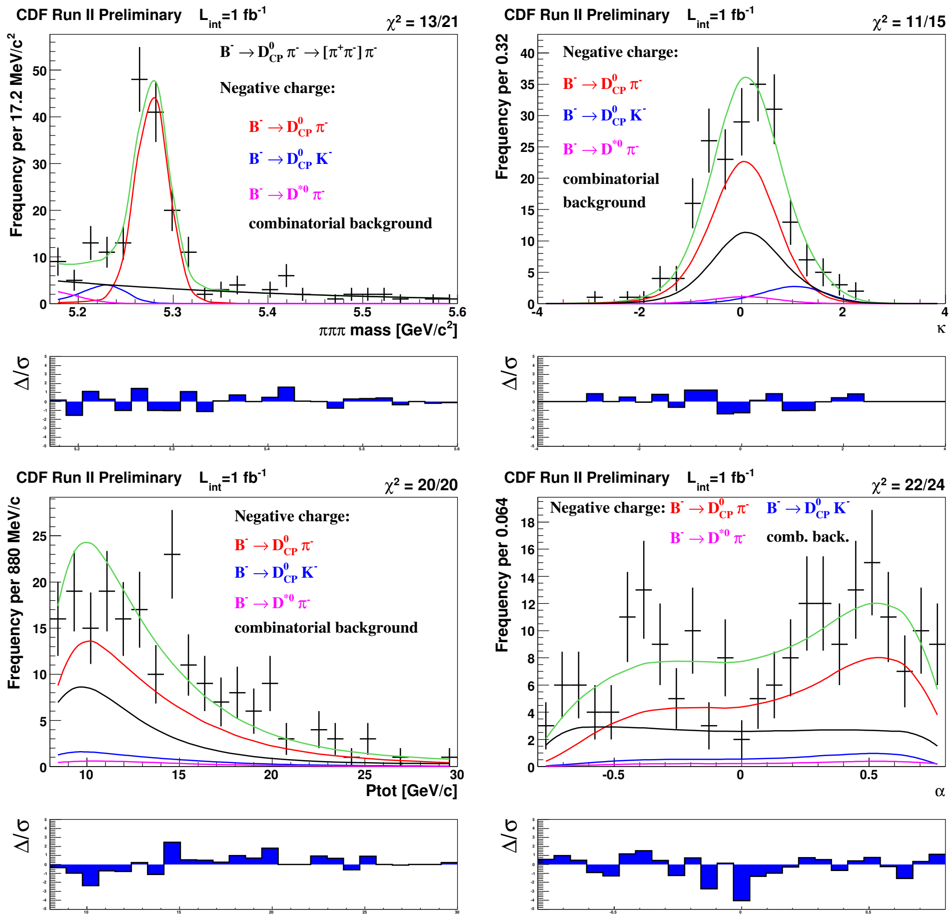

FIG. 12: Fit projection in all mass range onto the $m_{D^0\pi}$, κ, p_{tot}, α variables for $B^- \to D^0_{CP+}K^- \to [\pi^+\pi^-]K^-$.

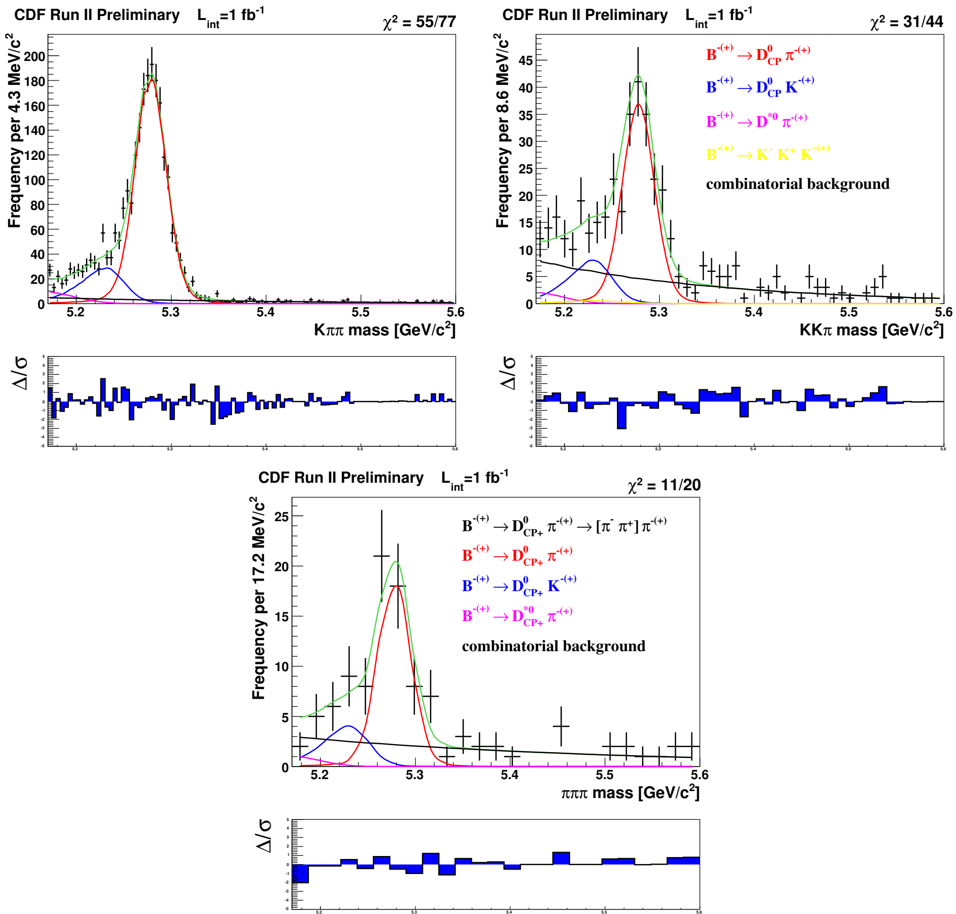

FIG. 13: Fit projection in all mass range onto the $m_{D^0\pi}$ for the three decay modes requiring $\kappa > 0.5$. Top left: flavor mode. Top right: DCP mode, $D^0_{CP+} \to K^- K^+$. Bottom: DCP mode, $D^0_{CP+} \to \pi^- \pi^+$.

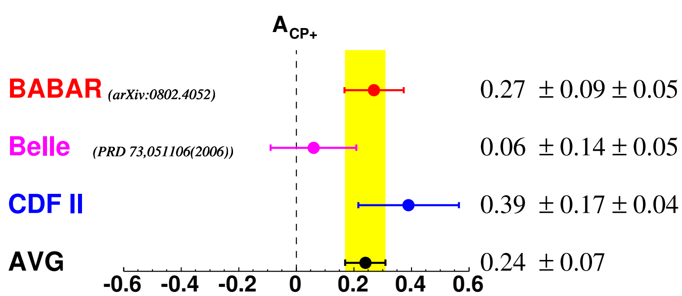

FIG. 14: A_{CP+} measurement. Comparison with other experiments.

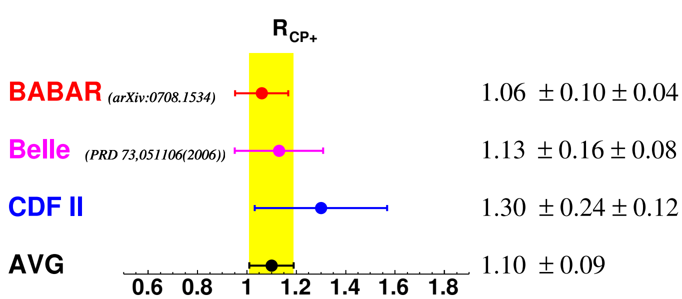

FIG. 15: R_{CP+} measurement. Comparison with other experiments.