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The CKM angle α at LHCb

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Abstract

The potential of LHCb in the extraction of the angle α from the analysis of the $B \rightarrow \rho\pi$ and $B \rightarrow \rho\rho$ decays has been studied. The expected performance is summarized in this document.

1 Introduction

The B^0 -mesons decays involving the $b \rightarrow u$ transition are sensitive to the sum $\beta + \gamma$ of the angles of the related Unitarity Triangle. Despite the non negligible contribution of Penguin transitions, the current B-factories have demonstrated that the $B_d \rightarrow (\rho\pi)^0$, $B^0 \rightarrow \rho^+\rho^-$ and $B^0 \rightarrow \pi^+\pi^-$ are good candidates for the measurement of the angle $\alpha = \pi - \beta - \gamma$, when constraint from the SU(2) (Isospin) related modes are used.

In the hadronic environment of the LHC collisions, the reconstruction of multi-pions final states, including neutrals, is a challenge. The potential of the LHCb experiment in the decays $B \rightarrow \rho\pi$ and $B \rightarrow \rho\rho$ has been studied. This document aims at providing a summary of the expected performance. It is organized as follows: the reconstruction of neutral pions is discussed in section 2. The expected sensitivity on α with the $B \rightarrow \rho\pi$ and $B \rightarrow \rho\rho$ analysis are addressed in the sections 3 and 4, respectively.

2 Neutral pions reconstruction in LHCb

Achieving an efficient reconstruction of the neutral pions is of major importance for the $B_d^0 \rightarrow \pi^+\pi^-\pi^0$ analysis in the hadronic environment of LHCb.

The mean transverse momentum of the neutral pion from the $B_d^0 \rightarrow \pi^+\pi^-\pi^0$ decay is about 3 GeV. Below this value the π^0 s are mostly reconstructed as a resolved pair of well separated photons. As an illustration the invariant mass of the resolved photon pairs is displayed on the left side of the figure 1. The resolution of the neutral pions peak is about 10 MeV/c².

On the other hand, a large fraction of the pairs of γ s coming from the decay of high energy π^0 s cannot be resolved as a pair of clusters within the ECAL granularity.

About 30 % of the reconstructible π^0 s (i.e., π^0 s that decay in the calorimeter acceptance with the transverse momentum of both photons larger than 200 MeV/c²) from the $B_d^0 \rightarrow \pi^+\pi^-\pi^0$ decays lead to a single cluster. Such a configuration, referred as “merged π^0 ”, is reconstructed

based on a dedicated algorithm. This algorithm is based on an iterative procedure using the expected transversal shape of the photon shower to disentangle the contribution of each photon in the cluster. The mass distribution obtained in this way is displayed on the right plot of the figure 1. The resolution of the “merged” π^0 peak is of the order of $15 \text{ MeV}/c^2$.

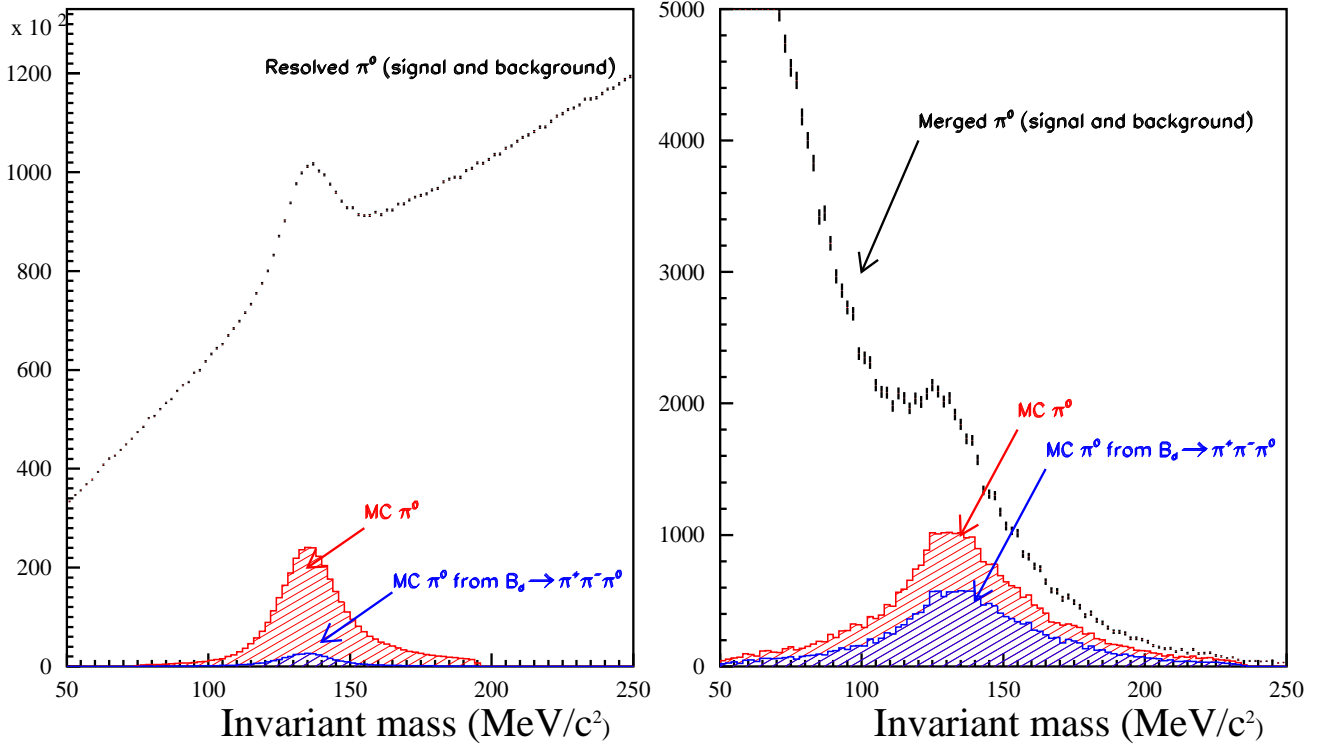


Figure 1: The mass distribution of the photon pairs reconstructed as “resolved” (top left) and “merged” (top right). On both figures, the contribution of the π^0 s and the π^0 s coming from the B decay are indicated. The bottom figure displays the π^0 reconstruction efficiency versus the π^0 transverse momentum. The separate contributions from resolved and merged π^0 reconstruction are indicated by the solid and the dashed histogram, respectively.

The overall reconstruction efficiency for the neutral pions coming from the $B \rightarrow 3\pi$ decay in the LHCb acceptance is 53%. The configuration of ‘merged’ π^0 amounts for 40% of the total efficiency. The reconstruction efficiency is displayed as a function of the transverse momentum of the π^0 on the figure 2. The respective contribution of the “resolved” and “merged” configuration is indicated.

3 α from $B_d \rightarrow (\rho\pi)^0$ modes

3.1 The method

Assuming that the $B_d(\bar{B}_d) \rightarrow \pi^+\pi^-\pi^0$ transition mainly proceeds through the $\rho \rightarrow \pi\pi$ vector resonance, 6 interfering modes ($B_d \rightarrow \rho^+\pi^-$, $B_d \rightarrow \rho^-\pi^+$, $B_d \rightarrow \rho^0\pi^0$ and charge conjugates) contributes in the Dalitz plot of the 3-body decay. Moreover, both Tree and Penguin transition contribute to each mode. Using Isospin constraints, it has been shown [1] that the proper-time

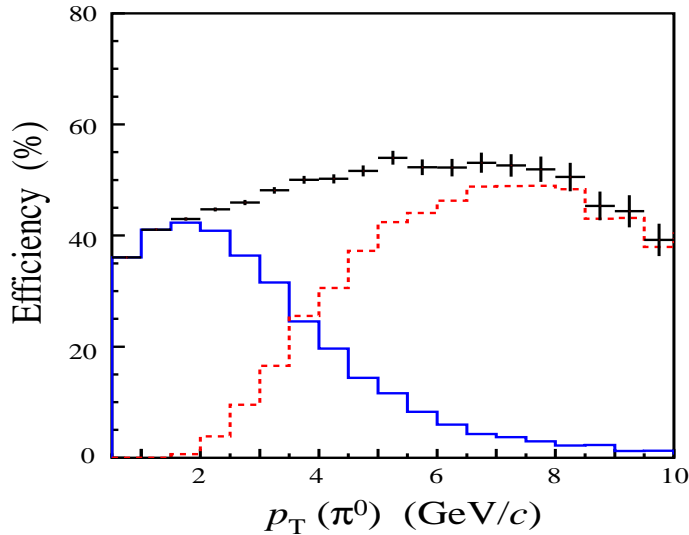


Figure 2: The π^0 reconstruction efficiency versus the π^0 transverse momentum. The separate contributions from resolved and merged π^0 are indicated by the solid and the dashed histogram, respectively.

evolution of the tagged Dalitz distributions, provides enough information to determine simultaneously the angle α and the relative amplitudes and strong phases between all transition processes. Figure 3 displays the time evolution of the tagged Dalitz distribution for the $B_d \rightarrow (\rho\pi)^0$ decay.

The evolution of the $B_d(\bar{B}_d) \rightarrow \pi^+\pi^-\pi^0$ Dalitz-time distribution is driven by the amplitudes :

$$\begin{aligned}\mathcal{M}(\vec{X}) &= e^{-\frac{\Gamma\tau}{2}} \left\{ \cos\left(\frac{\Delta m}{2}\tau\right)\mathcal{A}(s^+, s^-) + i\frac{q}{p}\sin\left(\frac{\Delta m}{2}\tau\right)\bar{\mathcal{A}}(s^+, s^-) \right\} \\ \bar{\mathcal{M}}(\vec{X}) &= e^{-\frac{\Gamma\tau}{2}} \left\{ \cos\left(\frac{\Delta m}{2}\tau\right)\bar{\mathcal{A}}(s^+, s^-) + i\frac{p}{q}\sin\left(\frac{\Delta m}{2}\tau\right)\mathcal{A}(s^+, s^-) \right\}\end{aligned}\quad (1)$$

where $\vec{X} \{s^+ = m_{\pi^+\pi^0}^2, s^- = m_{\pi^-\pi^0}^2, \tau\}$ is the position in the Dalitz-time space. The overall amplitude $\mathcal{A}(s^+, s^-) = f^+A^{+-} + f^-A^{-+} + f^0A^{00}$ is the sum of the individual amplitude, $A^{ij} = e^{-i\alpha}T^{ij} + P^{ij}$, of the $B_d \rightarrow \pi^+\pi^-\pi^0$ transitions driven by the ρ with charge i . The ρ -line shape is described by the form factor $f^i(s^i, \theta^i)$ accounting for the angular distribution of the vector meson ρ^i as well as the higher-mass $\pi^+\pi^-$ resonances¹.

Using Isospin symmetry, 9 independent theoretical parameters, $\vec{\alpha}$ (including the angle α) can be defined to describe the 3-body transition. This set of parameters, together with the relative fractions, \vec{r} , of the various contaminating background sources can be extracted by means of the minimization of the unbinned Likelihood function built on the $B_d \rightarrow \pi^+\pi^-\pi^0$ data sample :

$$\mathcal{L}(\vec{\alpha}, \vec{r}) = \prod_i^{N_{evt}} [(1 - |\vec{r}|) \cdot \mathcal{L}_i^{sig}(\vec{X}_i, b_i, \vec{\alpha}) + \vec{r} \cdot \mathcal{L}_i^{bkg}(\vec{X}_i, b_i)] \otimes G(\vec{\sigma}_X)$$

where \mathcal{L}_i^{sig} (\mathcal{L}_i^{bkg}) is the measured Likelihood value for the signal (background types) hypothesis attached to the i^{th} $B_d \rightarrow (\rho\pi)^0$ candidate with the tagged flavour $b_i=(+1,0,-1)$, located at the position \vec{X}_i in the Dalitz-time space measured with the experimental resolution $\vec{\sigma}_X$. The later

¹In the following, we use the Kühn-SantaMaria [2] parametrisation for the ρ -line shape, including the ρ_{770} with its two radial excitations, ρ_{1450} and ρ_{1700} . In addition the ρ^0/ω mixing is taken into account. More details about the used parametrisation can be found in [3]

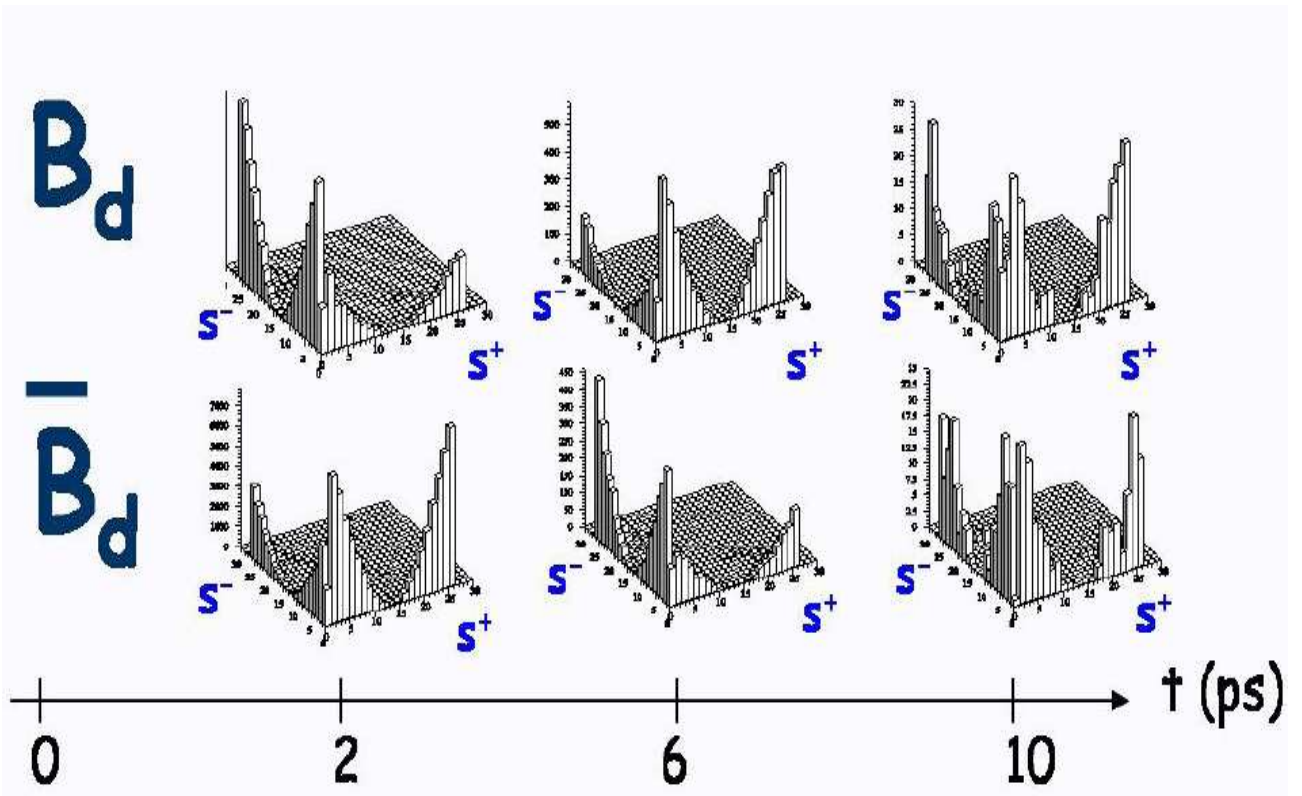


Figure 3: Time evolution of the Dalitz distribution for the $B(\bar{B}) \rightarrow (\rho\pi)^0$ decay.

resolution is included in the Likelihood definition via the convolution of the probability density function with the resolution function $G(\vec{\sigma}_X) = G(s^+, s^-) \times G(\tau)$. The resolution function $G(s^+, s^-)$ is the 2-dimensional Gaussian distributions of the correlated variables s^+ and s^- . The proper-time resolution is accounted in the Gaussian distribution $G(\tau)$.

The individual Likelihood for the signal hypothesis:

$$\mathcal{L}_i^{sig}(\vec{X}_i, b_i, \vec{\alpha}) = \epsilon^{sig}(\vec{X}_i) \sum_{f=+,-} \Omega_f^{b_i} |\mathcal{M}_f(\vec{X}_i, \vec{\alpha})|^2$$

accounts for the experimental distortions, i.e the selection acceptance, $\epsilon^{sig}(\vec{X}_i)$, and the tagging dilution, $\Omega_f^{b_i}$ defined as :

$$\Omega = \begin{pmatrix} 1 - \omega & 1/2 & \omega \\ \omega & 1/2 & 1 - \omega \end{pmatrix}$$

where ω is the wrong-tag fraction. Although not sensitive to α , the untagged sample is an useful ingredient to constrain the amplitudes, thereby improving the convergence of the fit.

The method requires an accurate knowledge of the both the phenomenological ingredients (ρ line-shapes) and the experimental ingredients (acceptance and tagging performances) entering in the Likelihood.

The experimental ingredients in the context of LHCb are discussed in the next subsection.

3.2 Selection of the $B \rightarrow \pi^+ \pi^- \pi^0$

The hard spectrum of the neutral pion, together with the vertex constraints of the charged pions pair means that the decay can be well isolated from the combinatorial background, even in the high

multiplicity environment of the LHC. A performant background rejection is obtained by means of a PDF-like multivariate selection[4][5] combining several variables based on the identification of neutral and charged pions, the kinematics of the decay or the displaced vertex of the B decay. The discriminating power of the multivariate variable is shown in figure 4.

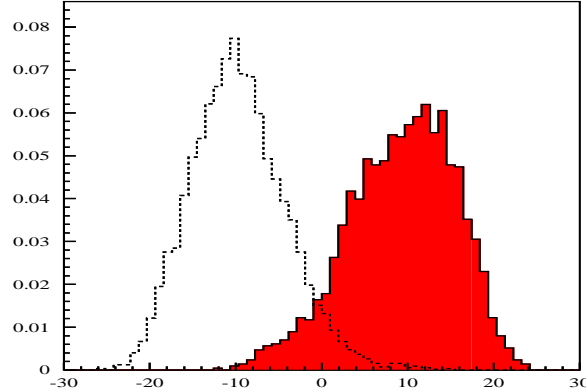


Figure 4: *Multivariate variable used for the $B \rightarrow \pi^+\pi^-\pi^0$ selection. The filled and dashed histograms display the distribution for the signal events and the generic $B\bar{B}$ events, respectively.*

The expected performance of the selection has been estimated using the full reconstruction and pattern recognition of 1M of Monte-Carlo simulated pp collisions producing the $B \rightarrow \pi^+\pi^-\pi^0$ decay in the LHCb acceptance. This accumulated statistics almost represents 10 days of data taking with the nominal LHCb luminosity of $2 \cdot 10^{32} \text{ cm}^{-2}\text{s}^{-1}$. About 1300 simulated events pass the trigger and selection criteria among which 50% are reconstructed with a 'merged' π^0 .

The corresponding expected annual yield (10^7 s) is 14k reconstructed $B \rightarrow \pi^+\pi^-\pi^0$ decays with an overall efficiency $\epsilon_{acc} \times \epsilon_{sel/acc} \times \epsilon_{trig/sel} = 7 \cdot 10^{-4}$. The included trigger efficiency with respect to the selected sample, $\epsilon_{trig/sel}$, is about 50%, meaning that half of the events that would be reconstructed and selected are actually rejected by the trigger criteria.

The mass and proper time resolution of the selected $B \rightarrow \pi^+\pi^-\pi^0$ candidates, respectively $\sigma_M=60$ MeV/ c^2 and $\sigma_\tau=50$ fs, are dominated by the $Ecal$ energy resolution.

The proper-time-dependent and the Dalitz-position-dependent acceptances of the selection are illustrated by figure 5. As can be seen, the low proper-time region and the lower Dalitz corner regions are depopulated, due to the large impact parameter required for the π^\pm and the large transverse energy required for the π^0 , respectively.

The LHCb tagging performance [6] has been estimated for the $B_d \rightarrow \pi^+\pi^-\pi^0$ decay using the Monte-Carlo history of the decay. A tagging efficiency $\epsilon = 40\%$ and a wrong tag fraction $\omega = 31\%$ are obtained, leading to an effective tagging power $\epsilon_{\text{eff}} = \epsilon(1 - 2\omega)^2 = 5.8\%$. On the real data analysis, the auto-tagged decay $B \rightarrow K^+\pi^-\pi^0$ could be used as a control sample for an accurate determination of the tagging performance over the Dalitz figure.

The background contamination has been estimated with the simulation of 33M of inclusive pp collision producing the B flavour in the final state. This corresponds to about 13 mn of LHCb data taking. Three $B \rightarrow \pi^+\pi^-\pi^0$ signal events are selected in this sample. Five other events,

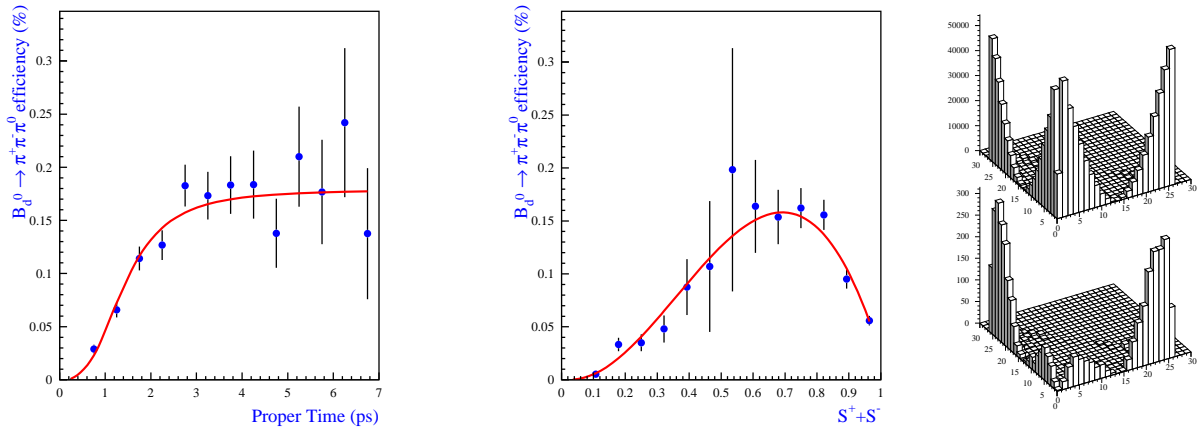


Figure 5: Selection efficiency as a function of the proper time (left) and as a function of the sum of the Dalitz coordinates (center). The 2-dimensional histograms on the right display the Dalitz distribution before (top) and after (bottom) the selection is applied.

passing the selection but rejected by the trigger criteria, lie in the left side-bands of the mass spectrum ($\pm 500 \text{ MeV}/c^2$). These $\pi^+\pi^-\pi^0$ candidates are mostly the combinatorial fragment from the $B \rightarrow D_{(s)}\pi$ or $B \rightarrow D_{(s)}\rho$ charmed decays.

decay	simulated LHCb period	Branching Ratio [7]	B/S
generic $B\bar{B}$	13 mn	1	0.20 (<0.8)
$B^0 \rightarrow \text{charmless}$	1.5 hours	0.58%	0.40 (<1.0)
$B^+ \rightarrow \text{charmless}$	1.5 hours	0.61%	0.17 (<0.6)
$B^0 \rightarrow \rho^+\rho^-$	4 days	$23.1 \cdot 10^{-6}$	0.08
$B^0 \rightarrow \rho^+\rho^0$	5 days	$18.2 \cdot 10^{-6}$	0.02
$B^0 \rightarrow K^*\gamma$	1.3 days	$40.1 \cdot 10^{-6}$	0.06
$B^0 \rightarrow K^+\pi^-\pi^0$	6 days	$35.6 \cdot 10^{-6}$	0.11

Table 1: Expected background contamination. An upper limit at 90% of confidence level is given when less than 5 MC events are available for the estimation of the B/S ratio. Note that the various background sources can overlap.

This background contamination from the generic $B\bar{B}$ events has been extrapolated under the B_d mass window ($\pm 200 \text{ MeV}/c^2$) and has been estimated to be consistent with a ratio $B/S = 20\%$ (< 80% with a 90% Confidence Level).

In addition to this generic $B\bar{B}$ background, the possible contamination from the specific, low branching ratio, charmless B decays have been studied using dedicated simulation, as reported in the table 1. The expected accumulated mass spectrum for the selected signal and the various background sources is shown in figure 6.

In the following, the overall $B/S = 1$ ratio is assumed.

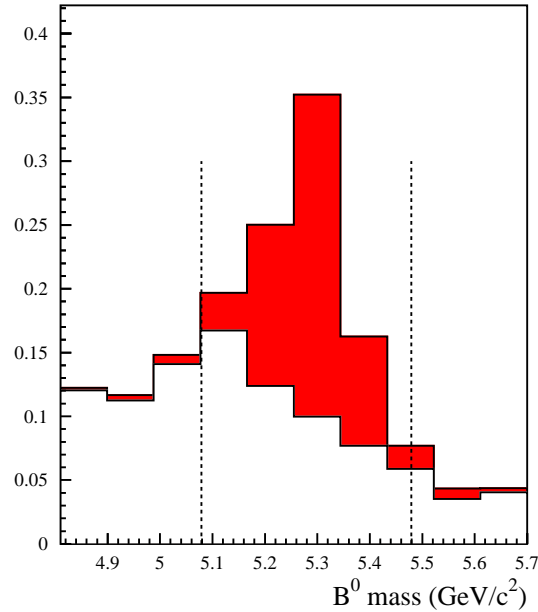


Figure 6: *Accumulated mass spectrum for the selected signal events (dashed) and the various background sources quoted in table 1 (white). The dotted lines indicate the $(\pm 200\text{MeV}/c^2)$ selection mass window.*

3.3 Prospective on α extraction with the $B \rightarrow \pi^+ \pi^- \pi^0$ analysis

The expected sensitivity on the angle α has been estimated using a toy Monte Carlo method, taking the resolutions, tagging performance and acceptances from the full simulation. Repeated toy experiments are performed, each of which has 10000 signal events, almost corresponding to an accumulated luminosity of 2 fb^{-1} (i.e. one nominal year of LHCb data taking). The background is modelled as a combination of non-resonant (i.e. 3-body produced in the phase-space), resonant and $B \rightarrow K^+ \pi^- \pi^0$ contributions, with an overall $B/S = 1$ ratio. The 3D relative fractions, \vec{r} , corresponding to the 3 assumed contributions to the background contamination are free parameters of the unbinned log-likelihood fit together with the 9D theoretical parameters $\vec{\alpha}$. The 'strong

α	T^{-+}	Φ^{-+}	T^{00}	Φ^{00}	P^{+-}	δ^{+-}	P^{-+}	δ^{-+}
96.5°	0.47	0.00	0.14	0.00	-0.20	-0.50	0.15	2.0

Table 2: *Relative values of the Penguin and Tree amplitudes and phases used for the simulation of the toys experiment. The overall amplitude normalisation and the phase reference is given by $T^{+-} = 1.0$ and $\Phi^{+-} = 0.0$, respectively.*

penguin' scenario [8], detailed in the table 2, has been considered for the relative values of the Penguin and Tree amplitudes and phases contributing to the final state.

The left side of the figure 7 shows the projection onto α of the variation in χ^2 for fits to many toy experiments. A clear minimum is obtained near the input value of $\alpha = 96.5^\circ$ for most of the experiments.

The statistical error on the α measurement is below the 10° level for about 90% of the toy experiments. The mean value is 8.5° . With an accumulated luminosity of 2 fb^{-1} , about 85% of the

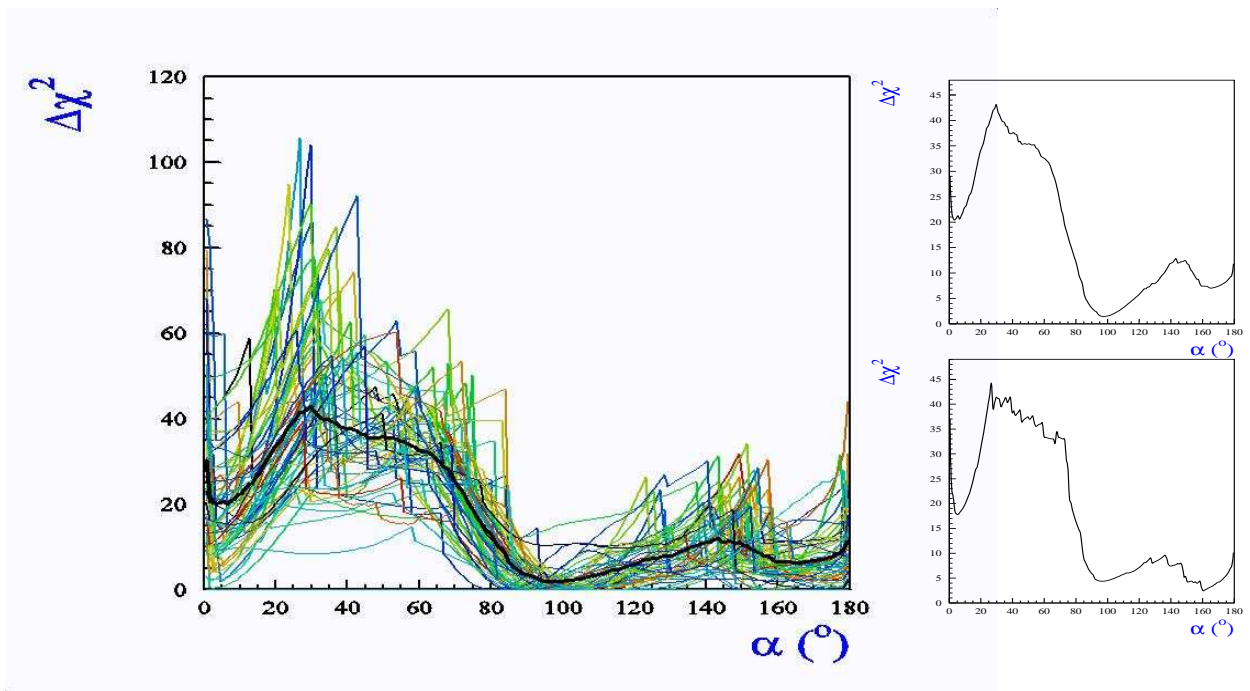


Figure 7: Variation in χ^2 as a function of α for fits to many toys experiments (left figure). The averaged $\Delta\chi^2$ is indicated by the thick black curve. The top (bottom) figure on the right side, displays the averaged variation in χ^2 for fits to the toy experiments converging to the correct (pseudo-mirror) solution for α .

toy experiments converge to the correct input value for α . The remaining 15% of the experiments mostly converge to the most prominent pseudo-mirror solution located near $\frac{3}{2}\pi - \alpha \sim 175^\circ$. In this case the correct solution still correspond to a deep minimum of the χ^2 curve, as shown on the bottom right curve on figure 7. The fraction of the toy experiments converging to the pseudo mirror solution is strongly reduced when more luminosity is accumulated. With $10fb^{-1}$ this fraction is expected to be less than 1%. The figure 8 displays the Confidence Level projected onto α for a typical LHCb experiment with an accumulated luminosity of $2fb^{-1}$. The corresponding 1σ interval is $\alpha = (97_{-4}^{+9})^\circ$. The current Babar measurement (including the systematical errors) is also shown for comparison.

4 α from $B_{d(u)} \rightarrow (\rho\rho)^{0\pm}$ SU(2)-related modes

4.1 The method

The B_d decay into the vector meson pair $\rho^+\rho^-$ decays has been measured to be an almost pure CP-eigenstates. In the absence of Penguin transition the time-dependent asymmetry would thus be directly proportional to $\sin(2\alpha)$, providing a measurement of α up to a two-fold trigonometric ambiguity. Due to non negligible Penguin contribution, the time-dependent asymmetry writes :

$$A_{\rho\rho}^{+-}(\tau) = C_{\rho\rho}^{+-} \cos(\Delta m\tau) - S_{\rho\rho}^{+-} \sin(\Delta m\tau) \quad (2)$$

where $S_{\rho\rho}^{+-} = \sqrt{1 - (C_{\rho\rho}^{+-})^2} \sin(2\alpha_{\text{eff}})$ with $\alpha_{\text{eff}} = \alpha + \Delta\alpha$.

It has been shown [9] that measuring the branching ratio of the SU(2)-related modes, $B_u \rightarrow \rho^+\rho^0$ and $B_d \rightarrow \rho^0\rho^0$, allows to put a constraint on the $\Delta\alpha$ deviation. This gives access to an α measurement up to a eight-fold ambiguities. Moreover, the time-dependent asymmetry of the

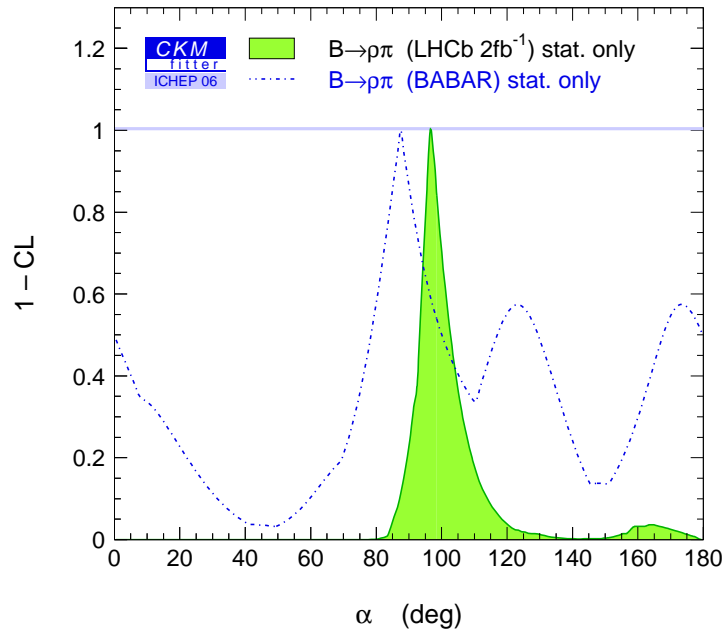


Figure 8: Confidence level as a function of α for a typical LHCb toy experiment (solide curve). The dotted curve corresponds to the current Babar measurement (including the systematical errors).

$B_d \rightarrow \rho^0 \rho^0$ decay could provide the additional information that allows to reduce the degeneracy of the mirror solutions.

Similar analysis can be done with $\pi\pi$ decays. The $\rho\rho$ system has however several advantages. Firstly, the branching ratio of the $\rho^+\rho^-$ (BR^{+-}) and $\rho^+\rho^0$ (BR^{+0}) modes are 5 times larger than the equivalent in the $\pi\pi$ system while the BR^{00}/BR^{+-} ratio is smaller. Eventually, the time-dependent asymmetry for the $\rho^0\rho^0$ mode is experimentally accessible while being out of reach of the experiments for the purely neutral final state $\pi^0\pi^0$.

4.2 Prospect for extracting α from $B_d \rightarrow \rho^0 \rho^0$

The $B_d \rightarrow \pi^+\pi^-\pi^0$ multivariate selection has been extended to the 4-body decays for the $B_d \rightarrow \rho^+(\pi^-\pi^0)\rho^-(\pi^-\pi^0)$, $B_u \rightarrow \rho^+(\pi^-\pi^0)\rho^0(\pi^+\pi^-)$, and $B_d \rightarrow \rho^0(\pi^-\pi^-\pi^0)\rho^0(\pi^+\pi^-)$ modes. The performance, summarized in the table 3, are essentially driven by the number of neutral pions in the final states.

mode	Branching Ratio ($\times 10^6$) [7]	selection efficiency	Annual Yield ($2fb^{-1}$)	B/S	σ_M (MeV/c ²)	σ_τ (fs)
$B_d \rightarrow \rho^+\rho^-$	23.1 ± 3.3	0.01%	2000	< 5	80	85
$B_u \rightarrow \rho^+\rho^0$	18.2 ± 3.0	0.045%	7000	~ 1	52	47
$B_d \rightarrow \rho^0\rho^0$	1.2 ± 0.5	0.16%	1200	< 5	16	32

Table 3: Performance of the LHCb selection for the $B_d \rightarrow \rho\rho$ $SU(2)$ -related modes.

The expected $B_d \rightarrow \rho^+\rho^-$ annual yield is 2000 events. Due to this relatively small amount combined with the low tagging performance due to the hadronic production of the neutral B ,

several years of LHCb data taking will be needed to get a competitive measurement of the $C_{\rho\rho}^{+-}$ and $S_{\rho\rho}^{+-}$ observables with respect to the current B factories achievement.

The main contribution of LHCb to the $\rho\rho$ analysis could be the improvement of the measurement of the $\rho^0\rho^0$ mode, as discussed in the next sub-section.

4.3 Prospective on α extraction

In order to evaluate the contribution of LHCb in the extraction of α , some assumptions have to be made on the $B_d \rightarrow \rho^0\rho^0$ parameters.

Firstly, the Branching ratio ($BR = 1.2 \cdot 10^{-6}$) is assumed to be the central value of the current B factories measurement [7]. The relative B-factories resolution on this measurement is 40%, and corresponds to an event yield which is more than a factor 10 lower than the expected LHCb statistics with $2 fb^{-1}$. In the following, it is then conservatively assumed that LHCb will reach a 20% relative uncertainty on the $B_d \rightarrow \rho^0\rho^0$ Branching Ratio measurement.

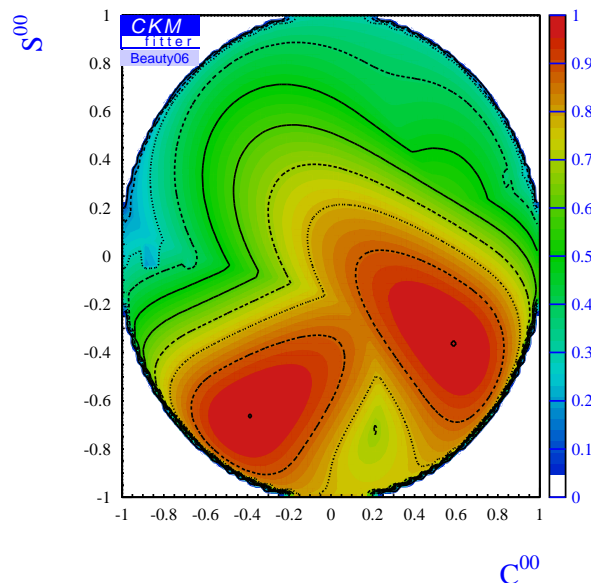


Figure 9: Confidence Level projection onto the $(C_{\rho\rho}^{00}, S_{\rho\rho}^{00})$ plane.

The value of the time-independent and time-dependent parameters of the asymmetry, $C_{\rho\rho}^{00}$ and $S_{\rho\rho}^{00}$, are assumed to match their preferred value extracted from the global fit of the current data [10]. As shown on figure 9 the current data result in a weak constraint in the $(C_{\rho\rho}^{00}, S_{\rho\rho}^{00})$ plane. The preferred values consist in 2 sets : $(C_{\rho\rho}^{00}, S_{\rho\rho}^{00}) = (0.51, -0.30)$ and $(-0.33, -0.62)$, leading to degenerate value of the Confidence Level. The first set of values, producing the most conservative impact on alpha, will be used in the following. Eventually, LHCb is assumed to reach a resolution of $\sigma_{C/S} = 0.4$ on both the parameters with an integrated luminosity of $2 fb^{-1}$. This value is supported by the rescaling of the expected LHCb performance for the asymmetry measurement of the $B \rightarrow \pi^+\pi^-$ decay [11].

The resulting performance on the α extraction is illustrated by figure 10. As can be seen on the left curve, the improvement of the branching ratio measurement would not provide a significant impact on α with respect to the current constraints. Measuring in addition the time-independent asymmetry $C_{\rho\rho}^{00}$ will allow to distinguish the mirroring of the eight-fold solutions. However the global constraint is almost unchanged (in particular the 1σ interval is unaffected).

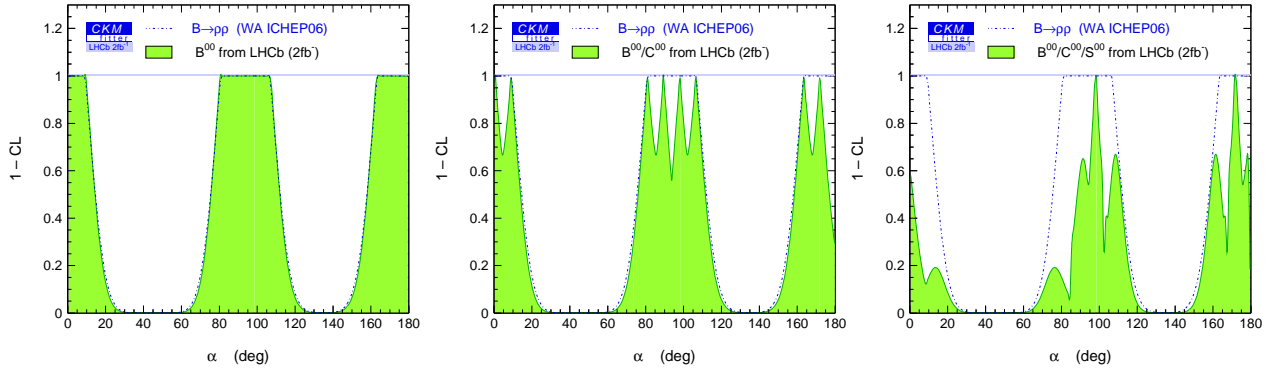


Figure 10: Confidence level as a function of α for various LHCb measurement related to the $B \rightarrow \rho\rho$ modes (see text).

Eventually, the measurement of the time-dependent asymmetry results in a significant improvement of the constraint, thanks to the reduction of the mirror solution degeneracy. The resulting resolution on α is $(97_{-13}^{+15})^\circ$. The resolution improvement will however be strongly dependent on the central value of the measured $(C_{\rho\rho}^{00}, S_{\rho\rho}^{00})$.

5 Conclusions

Two complementary approaches have been studied for the extraction of the angle α with LHCb.

- The time dependent analysis of the $B_d \rightarrow (\rho\pi)^0$ Dalitz decay.
The method allows, in principle, a clean extraction of the angle α free of ambiguities in the $[0, \pi]$ range. When integrating $2fb^{-1}$, LHCb could provide a measurement of α with a statistical error below the 10° level.
Pseudo-mirror solutions exist to which the fit can converge due to fluctuations in the finite size data sample. The probability of such a configuration decreases from 15% to less than 1% when the accumulated luminosity increases from $2fb^{-1}$ to $10fb^{-1}$.
Studies of potential systematic uncertainties indicate that an accurate control of both the experimental distortions (acceptance and tagging performance) and the phenomenological inputs (rho line-shape parametrisation) is required.
- The SU(2) analysis of the $B_d \rightarrow \rho\rho$ modes.
This method provides a measurement of α up to an eight-fold ambiguity. Several years of LHCb data taking will be needed to get a competitive measurement of the time-dependent asymmetry in the $B_d \rightarrow \rho^+\rho^-$ decay with respect to the current B factories achievement. The main contribution of LHCb to the $\rho\rho$ analysis could be the improvement of the measurement of the $\rho^0\rho^0$ mode. In particular, the measurement of the time-dependent parameter of the decay asymmetry, will allow to reduce the degeneracy between the mirror solutions. An improvement of the α measurement down to the 15° level could be achieved with an integrated luminosity of $2fb^{-1}$.

Figure 11 displays a tentative sketch of the constraint on α when $2fb^{-1}$ of LHCb data will be accumulated at the end of the decade. The combined constraint including the LHCb contributions to the $\rho\pi$ and $\rho\rho$ (and marginally $\pi\pi$) analysis is shown. The corresponding 1σ interval in α is

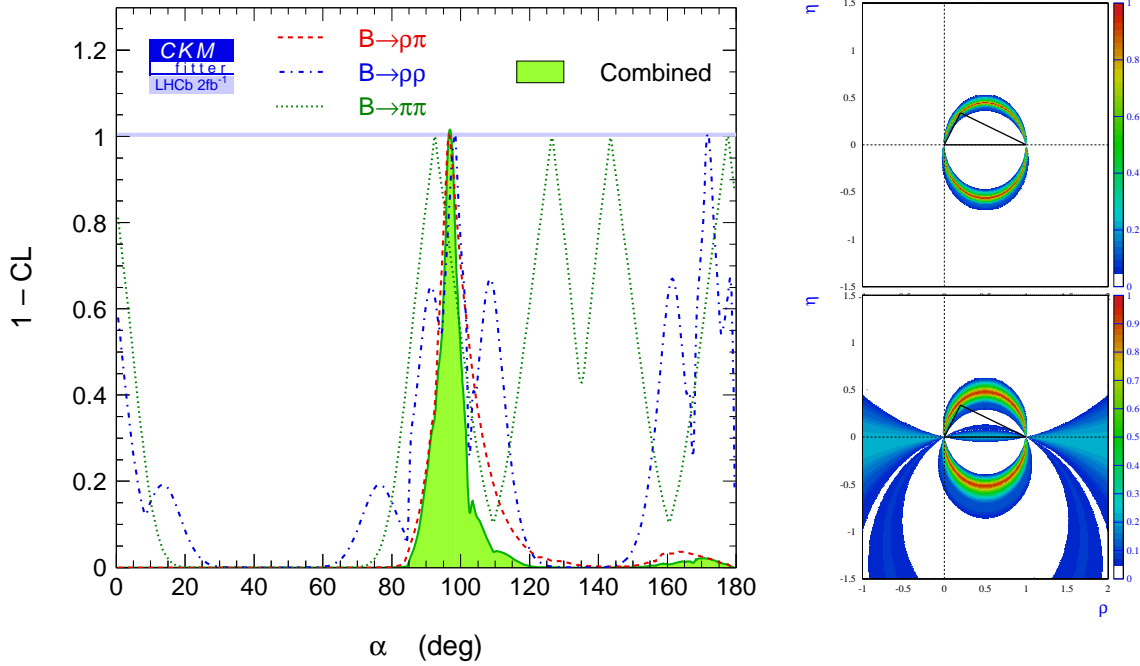


Figure 11: Sensitivity on α when the contributions from 2fb^{-1} of LHCb data are included. The dashed curve indicates the constraint from the $\rho\pi$ dalitz analysis using the LHCb data only. The dash-dotted curve is the constraint from the world averaged $\rho\rho$ data including the expected LHCb contribution to the $\rho^0\rho^0$ mode. The dotted curve is the constraint from the world averaged $\pi\pi$ data including the (marginal) LHCb contribution to the measurement of the $\pi^+\pi^-$ asymmetry. The shaded curve is the combined constraint.

$(97^{+6}_{-4})^\circ$.

During the LHCb era, the precision of the α extraction could thus reach the few degrees level. The theoretical limitations of the analysis (SU(2)-breaking effects, electroweak Penguin contribution, ...) could then be an issue [12].

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