Measurement of CP Violation in $B^{\pm} \to \pi^{\pm}\pi^{+}\pi^{-}$ Decay Channal at Large Hadron Collider

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Abstract: A set of selected pp collision data samples which were collected by LHCb[1] in 2011 are studied. Contained $B^{\pm} \to \pi^{\pm}\pi^{+}\pi^{-}$ decays in magnet "up" and "down" polarity are constructed. Global CP asymmetry in this channal is measured to be $A_{CP} = 0.126 \pm 0.023 \pm 0.026$, in which the first and second uncertainties are statistical and systematical respectively. Larger local asymmetry in different phasespace is also observed.

1 Introduction

The Standard Model[2] (SM) of particle physics, which developed in early 1970s, has been successfully explaining almost all experiment results and made precise predictions including Higgs boson before it was discovered. Although the SM has been considered as the best theory describing fundamental particles and their interaction, phenomena such as large scale of matter antimatter asymmetry in the universe are not fully explained. Matter antimatter asymmetry is described by Charge Parity (CP) invarinace violation in the SM, but the effect is too small to explain the reason why objects in the universe is made almost entirely of matter, while only small amount of antimatter managed to survive. Therefore, additional sources of CP violation from new physics above SM may contributes to the exceeding magnitude of asymmetry. Charmless B meson to 3 hadrons decay is observed to have the largest CP violation, also contains rich interference pattern gives us a chance to investigate the asymmetry originate from different resonant states in the phase space.[3] Measuring CP violation provides evidence of physics beyond Standard Model.

2 Candidates Selection

The LHCb[1] detector is designed for studying particles containing b and c quark. Analysed data was preselected by hardware and software trigger from approximatly 10^{14} pp collision events with centre-of-mass energy of 7 TeV. Most important pre-selection cuts are listed in the labscript[4].
Information from the particle identification system[5] are used to seperate $B^{\pm} \to \pi^{\pm}\pi^{+}\pi^{-}$ events, apart from rejecting muon, the probability of each particle to be a pion is required to be larger than 0.794, in order to make sure 50 per cent of final decay products are all pion. CP Asymmetry introduced by charmed decay of B mesons are removed by rejecting D^0 resonance by excluding $\pm 50MeV$ region of D^0 meson invariance mass in two body invariant mass $M_{\pi^+\pi^-}$ phase space.

3 Global Asymmetry

Raw asymmetry of $B^{\pm} \to \pi^{\pm}\pi^{+}\pi^{-}$ modes is defined as $A_{raw} = \epsilon^{-} - \epsilon^{+}$, where $\epsilon^{\pm} = \frac{N_{B^{\pm}}}{N_{B^{+}}+N_{B^{-}}}$ is called efficiency. $N_{B^{\pm}}$ is estemated by fitting B meson invariant mass spectra then integrating signal model contribution. Cruijff function with zero right radiative tail was chosen to be signal model, the mean, width and left tail were left free. We described the combinatorial background by an exponential function, all of its parameters were left to be fitted. Backgrounds caused by four-body-decay were parametrized by gaussian, whose peak positions were fixed to 5134 MeV for B^{+} and 5040 MeV for B^{-} by optimizing deduced χ^2 of fitting, We also tried to introduce a small peak centred in 5215 MeV to describe $B^{\pm} \to K^{\pm}\pi^{+}\pi^{-}$ in which one Kaon was misidentified, however, contribution of it is negligible with rather strict selection criteria we implemented. The invariant mass contribution and fitting results are shown in figure 1. Integral of signal model gives

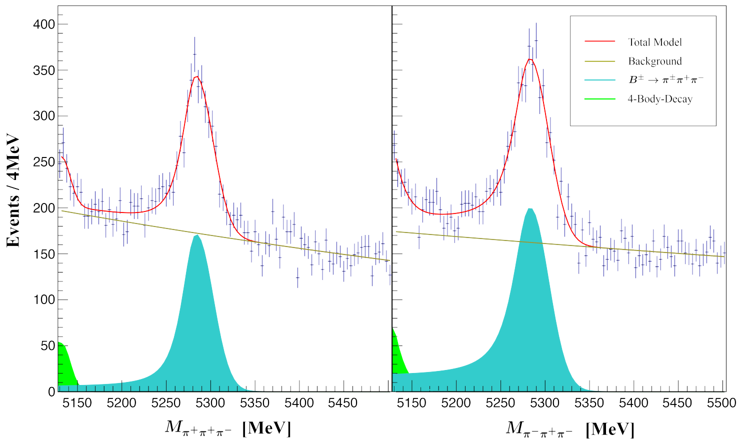

Figure 1: Invariant mass spectra and fitting results. Left panel is B^{+} and Right panel is B^{-}

$N_{B^{+}} = 2251 \pm 81$ and $N_{B^{-}} = 2789 \pm 82$. Raw CP asymmetry yields $A_{raw} = 0.107 \pm 0.023(statistical)$. Since detector efficiencies for B^{+} and B^{-} are not equal in different polarities, a detector polarity correction is made based on $\epsilon^{\pm}_{up}$ and $\epsilon^{\pm}_{down}$ in two subsets of data, defined as $A_{cor} = \epsilon^{-}_{cor} - \epsilon^{+}_{cor}$, where $\epsilon^{\pm}_{cor} = (\epsilon^{\pm}_{up} + \epsilon^{\pm}_{down})/2$. A_{CP} is constructed by excluding B-meson production asymmetry $A_P = 0.004 \pm 0.004$[3] from A_{cor}, which yields $A_{CP} = A_{cor} - A_P = 0.126 \pm 0.023$, Uncertainty above is statistical only, estimated by integrating fitting-error within 3-sigma width around signal mean. 4 aspect of sources of systematic uncertainties were studied. uncertainty introduced by polarity correction is significantly larger than other sources, estimated by $\pm(A_{raw} - A_{cor})$.Method used in calculating error of chosen signal model is comparing A_{raw} given by "similar-good-fitting" Cruijff function and double gaussian signal model,defined as $\pm(A_{raw}^{Cruijff} - A_{raw}^{Gaussian})$. This two function give deduced $\chi^2_+ = 1.109$, $\chi^2_- = 1.065$ and $\chi^2_+ = 1.162$, $\chi^2_- = 1.118$ respectively. Lorentz function was not included since it gives relatively higher deduced χ^2. By shifting the position of 4-body gaussian funtion, we estimated uncertainty of partially reconstructed 4-body-decay. However, its magnitude is around 10^{-5}, which is negligible. B meson production uncertainty was considered as systematic error. total systematical uncertainty is calculated by sum in quadrature of each contribution, main systemetical uncertainties are listed in Table 1.

Table 1: Main systematical Uncertainties

Source	Uncertainty
Polarity Correction	0.023
Signal Function	0.011
4-body Backgrounds	0.000
A_P	0.004
Total	0.026

In summary, inclusive CP asymmetry is measured to be $A_{CP} = 0.126 \pm 0.023(statistical) \pm 0.026(systematical)$ total uncertainty is calculated by $\pm\sqrt{0.023^2 + 0.026^2} = \pm 0.0347$, significance yeilds 3.63σ.

4 Local Asymmetry

In order to identify the distribution of CP violation, we studied

5 Conclusions

References

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