

CP Violation Measurement In Two Body B Decay with the LHCb Detector

Mu Hongjie¹,Wang Jianqiao¹

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¹Tsinghua University

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Introduction to CP Violation

- CP is the combined action of charge conjugation (C) and parity (P) transformation.
- CP violation is described in SM by CKM matrix.

$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

- The quantitative predictions of CP violation is difficult.

Experiment

- Using pp collision date collected by LHCb with $\sqrt{s} = 7\text{TeV}$
 - The decay is a weak interaction

$$B_{(s)}^0 \rightarrow K_{(s)}^+ \pi_{(s)}^-$$

- Aimed at detecting the difference between

$$\Gamma(B_{(s)}^0 \rightarrow f_{(s)}) \quad \text{and} \quad \Gamma(\bar{B}_{(s)}^0 \rightarrow \bar{f}_{(s)})$$

- The parameter to represent CP violation is

$$A_{CP}(B_{(s)}^0 \rightarrow f_{(s)}) = \frac{\Gamma(\bar{B}_{(s)}^0 \rightarrow \bar{f}_{(s)}) - \Gamma(B_{(s)}^0 \rightarrow f_{(s)})}{\Gamma(\bar{B}_{(s)}^0 \rightarrow \bar{f}_{(s)}) + \Gamma(B_{(s)}^0 \rightarrow f_{(s)})}$$

- The measurement of the $\Gamma(B_{(s)}^0 \rightarrow f_{(s)})$ can be of great sensitivity



The Method to Get the Value

- From the experiment data we can get $N(B_{(s)}^0 \rightarrow f_{(s)})$.
 - We need to reconstruct the event and remove the backgrounds.
 - Then we can get $A_{raw}(B_{(s)}^0 \rightarrow f_{(s)})$ from $N(B_{(s)}^0 \rightarrow f_{(s)})$
- The other effects should be considered

$$A_{CP}(B_{(s)}^0 \rightarrow f_{(s)}) = A_{raw}(B_{(s)}^0 \rightarrow f_{(s)}) - A_{\Delta}(B_{(s)}^0 \rightarrow f_{(s)})$$

The Results

- The uncertainty includes statistical uncertainty and systematic uncertainty

| Systematic uncertainty | $A_{CP}(B^0 \rightarrow K^+ \pi^-)$ | $A_{CP}(B_s^0 \rightarrow K^- \pi^+)$ |
|--------------------------|-------------------------------------|---------------------------------------|
| PID calibration | 0.0006 | 0.0012 |
| Final-state radiation | 0.0008 | 0.0020 |
| Signal model | 0.0001 | 0.0064 |
| Combinatorial background | 0.0004 | 0.0042 |
| Three-body background | 0.0005 | 0.0027 |
| Cross-feed background | 0.0010 | 0.0033 |
| Detection asymmetry | 0.0025 | 0.0023 |
| Total | 0.0029 | 0.0094 |

- The results are

$$A_{raw}(B^0 \rightarrow K^+ \pi^-) = -0.091 \pm 0.006$$

$$A_{raw}(B_s^0 \rightarrow K^- \pi^+) = 0.28 \pm 0.04$$

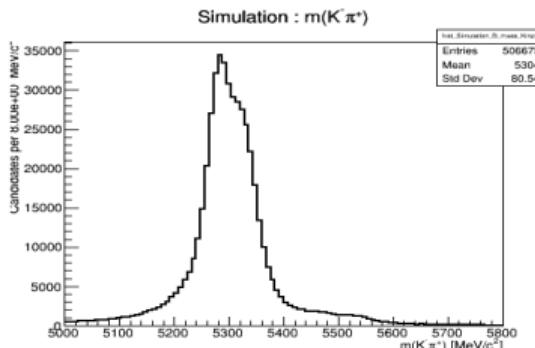
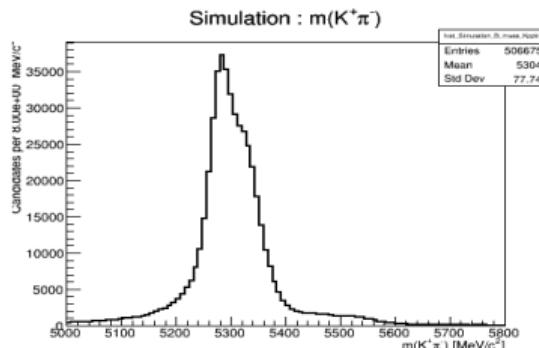
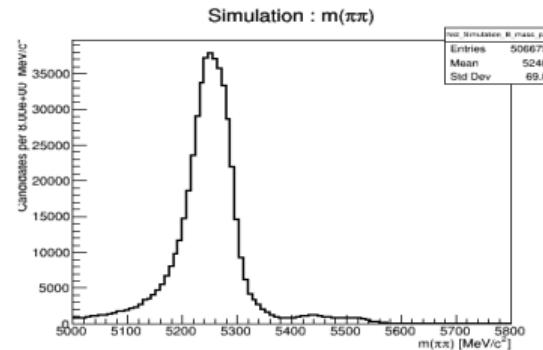
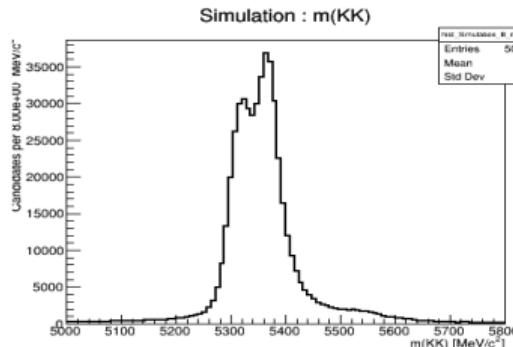
$$A_{CP}(B^0 \rightarrow K^+ \pi^-) = -0.080 \pm 0.007(\text{stat}) \pm 0.003(\text{syst})$$

$$A_{CP}(B_s^0 \rightarrow K^- \pi^+) = 0.27 \pm 0.04(\text{stat}) \pm 0.01(\text{syst})$$

- We will use the simulated data and the real data to analysis in two steps.
- The decay channels are $B_{(s)}^0 \rightarrow h^+h^-$, $h = K$ or π .
- The simulation is to add different cut on data and display different variable and to calculate the CP asymmetry.
- Two important variables in the simulation
 - m The invariant mass of the decay.
 - D_{lk} The possibility of a particle to be a K .

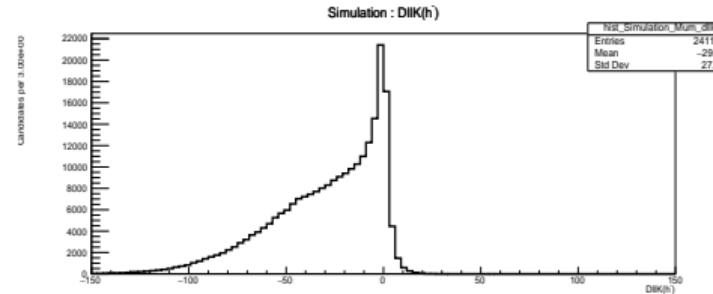
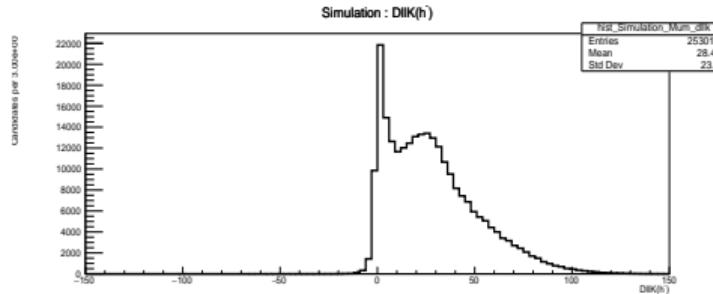
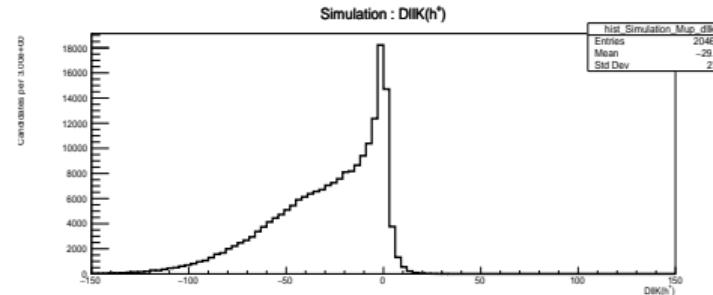
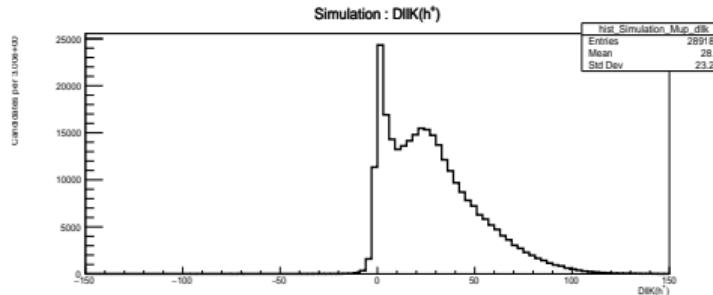
Using Simulated Data

- The invariant mass of B of different decay mode.



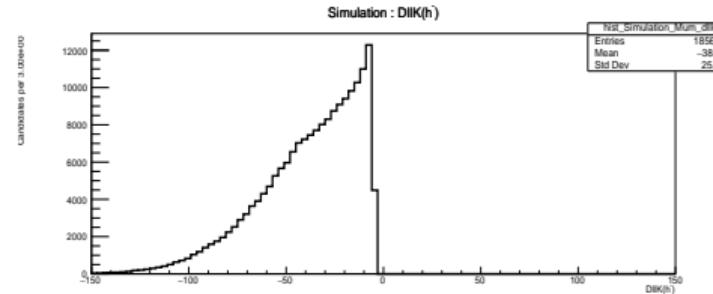
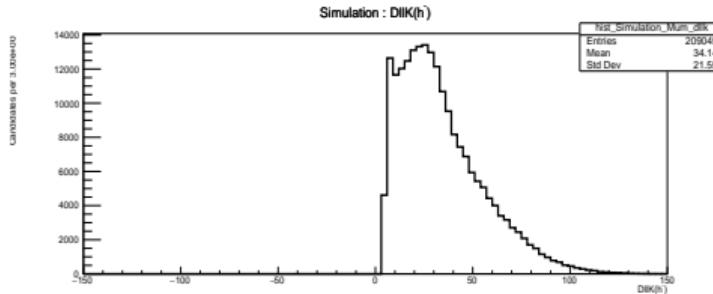
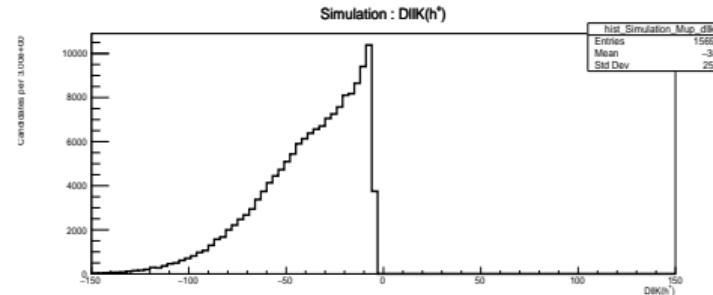
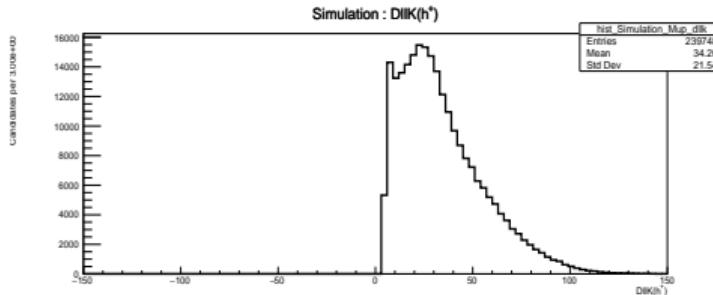
The Plot of DLLk

- The DLLk variable for true kaons and pions.



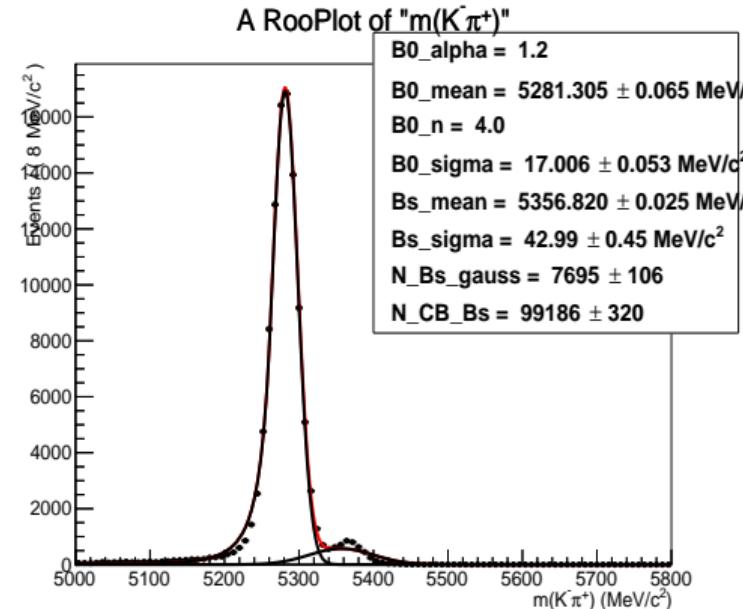
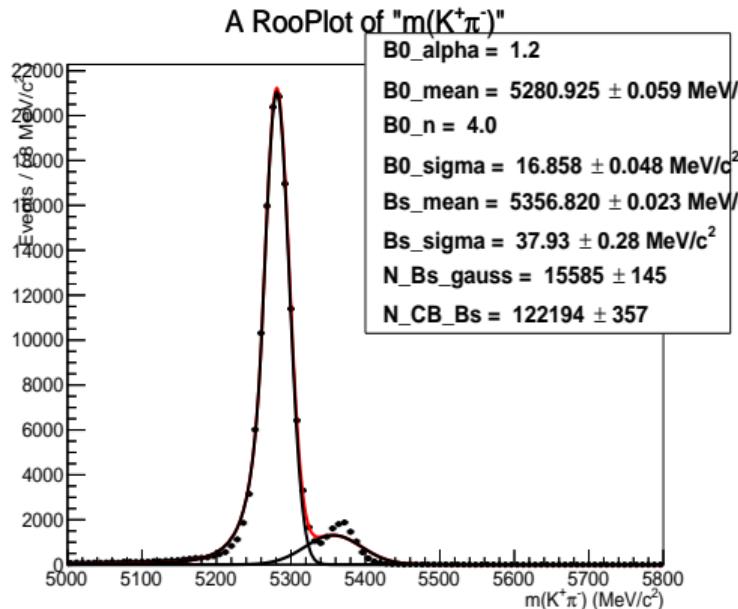
The Plot of DLLk

- The DLLk variable for true kaons and pions with cut.



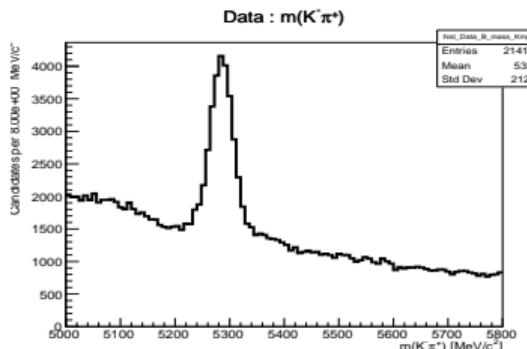
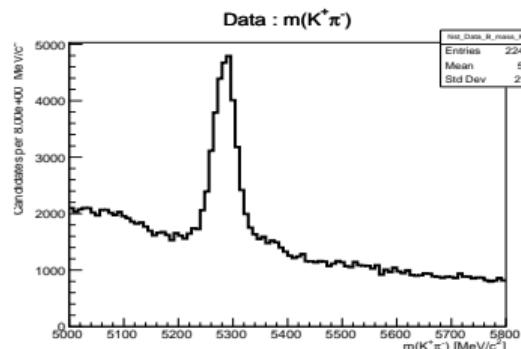
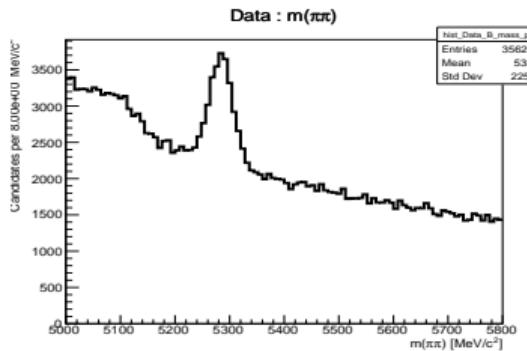
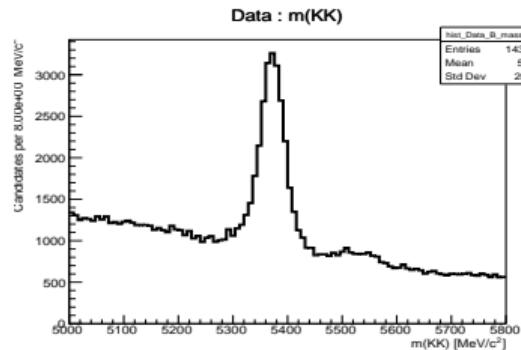
Select the $B \rightarrow K\pi$ decay mode

- Select the decay mode to be $B \rightarrow K^+\pi^-$ and $B \rightarrow K^- + \pi^+$



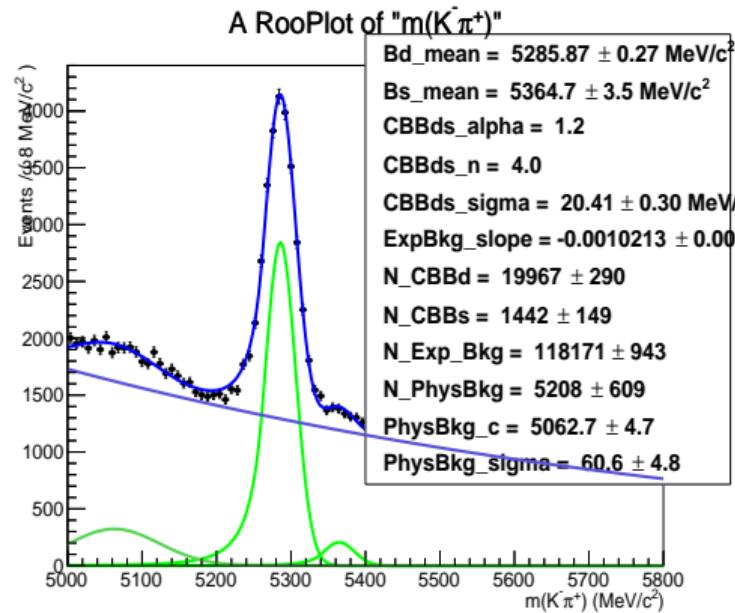
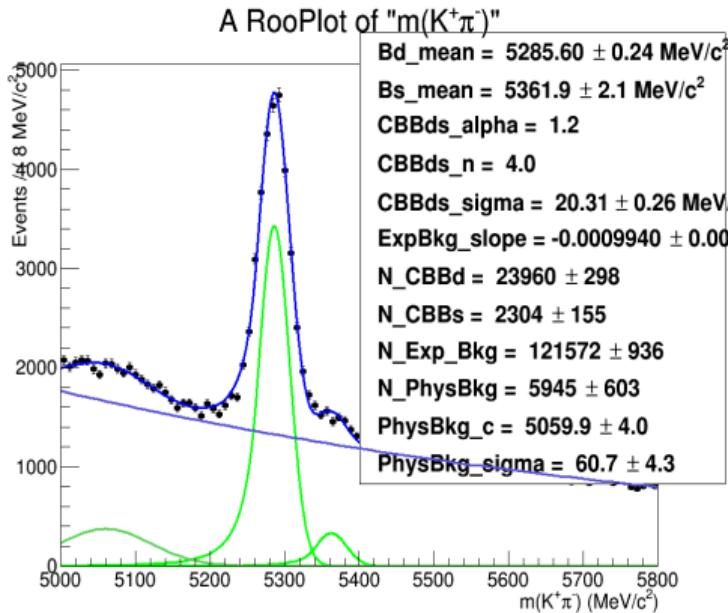
Using Real Data

- The invariant mass of B of different decay mode.



Calculate the A_{raw}

- The invariant mass of B of the $K\pi$ decay mode.



Calculate the A_{raw}

- The values we want from the fit is

$$N(B^0 \rightarrow K^+ \pi^-) = 23960 \pm 298$$

$$N(B^0 \rightarrow K^- \pi^+) = 19967 \pm 290$$

$$N(B_s^0 \rightarrow K^+ \pi^-) = 2304 \pm 115$$

$$N(B_s^0 \rightarrow K^- \pi^+) = 1442 \pm 119$$



Conclusion

- Use the formular to calculate the result

$$A_{raw}(B^0 \rightarrow K^+ \pi^-) = -0.091 \pm 0.009$$

$$A_{raw}(B_s^0 \rightarrow K^- \pi^+) = 0.23 \pm 0.05$$

- Compare to the result of the paper

$$A_{raw}(B^0 \rightarrow K^+ \pi^-) = -0.091 \pm 0.006$$

$$A_{raw}(B_s^0 \rightarrow K^- \pi^+) = 0.28 \pm 0.04$$

- The values are very close.
- The uncertainty is larger.



Thanks