Measurements of gamma angle using $B_{(s)} \to DKK$ at LHCb

Wenbin Qian
LAPP, Annecy-le-vieux
IN2P3-CNRS et Université de Savoie

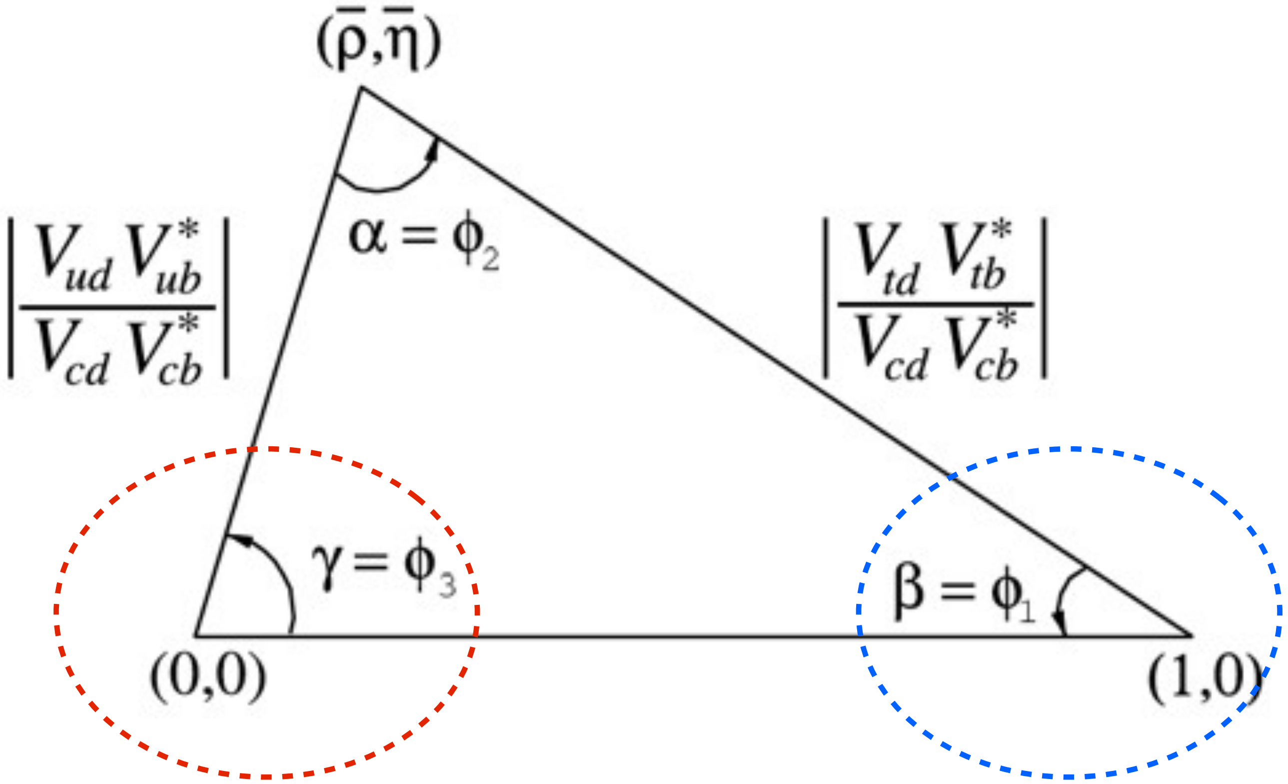
Outline

- ➢ Brief introduction
- ➢ Analysis status
- ➢ Conclusion and Prospects

CKM Angle Connected With $B_{(s)} \to Dhh$

➢ Similar to previous talk, additional channel to access to γ (also see introduction of γ from Alexandra)

$$V_{ud}V_{ub}^* + V_{cd}V_{cb}^* + V_{td}V_{tb}^* = 0$$



Measured using decays access both through $b \to c$ and $b \to u$ transitions

Interference @ tree level: Test standard model

Interference @ loop level: Probe new physics

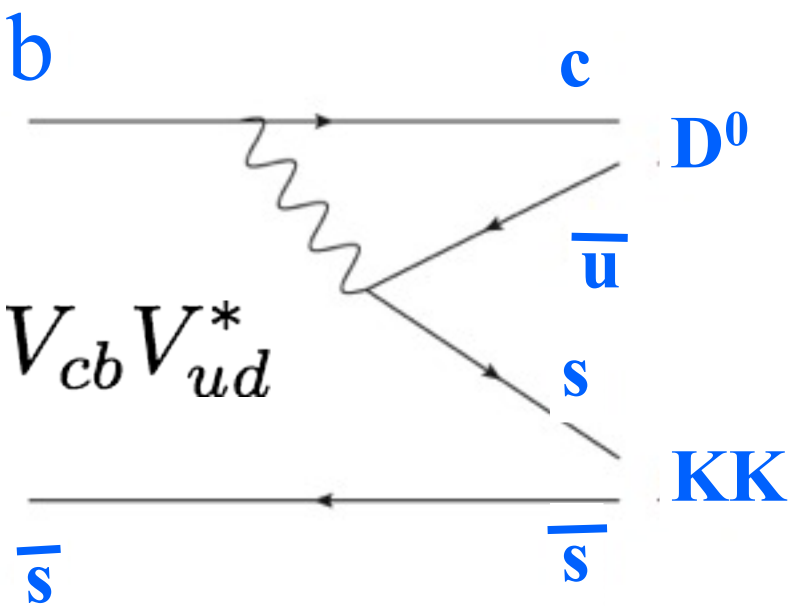
Least well-known CKM constrain: sensitive to lots of channels; need to combine different measurements (@ tree level) to improve its sensitivity

➢ With h = h (h = K or π): can't distinguish $B_{(s)}$, $B_{(s)}$-bar, D^0 and D^0-bar; In addition to normal amplitude interference between $b \to u$ and $b \to c$, there are interference through oscillation; another CKM angle 2β (or Φ_s for similar triangle in B_s system) to describe oscillation effects enters game

Physics With B→Dhh

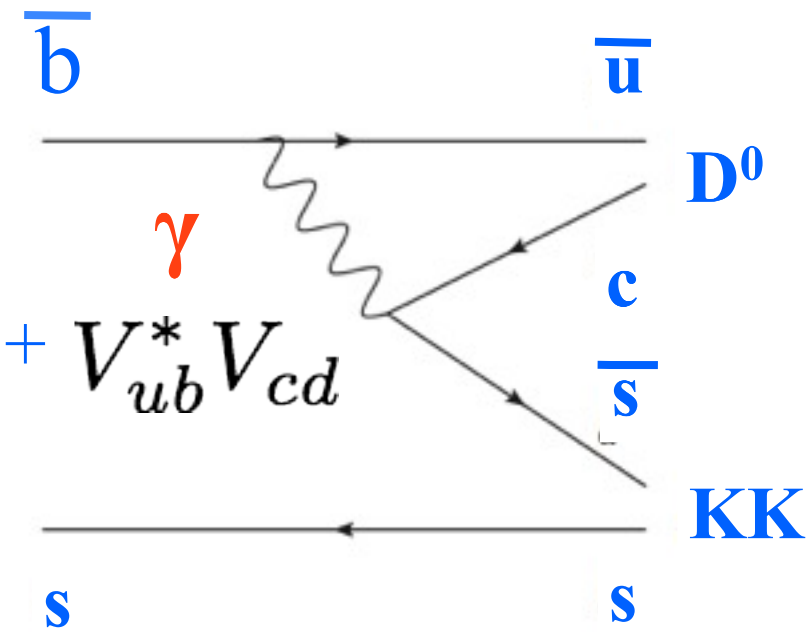
Together with other diagrams (see next slide)

- ➢ Feynman Diagrams



2β γ

B_s oscillation + $V_{ub}^*V_{cd}$



- ➢ D Decays

Table 9: D Decays and their branching fractions

D Decays	Branching fractions	Comments
$D^0 \to K^-\pi^+$	$(3.88 \pm 0.05)\%$	large fraction
$D^0 \to K^+K^-$	$(0.396 \pm 0.008)\%$	CP eigenstates
$D^0 \to \pi^+\pi^-$	$(0.1401 \pm 0.0027)\%$	CP eigenstates
$D^0 \to K^+\pi^-$	$(0.0147 \pm 0.0007)\%$	Suppressed decay

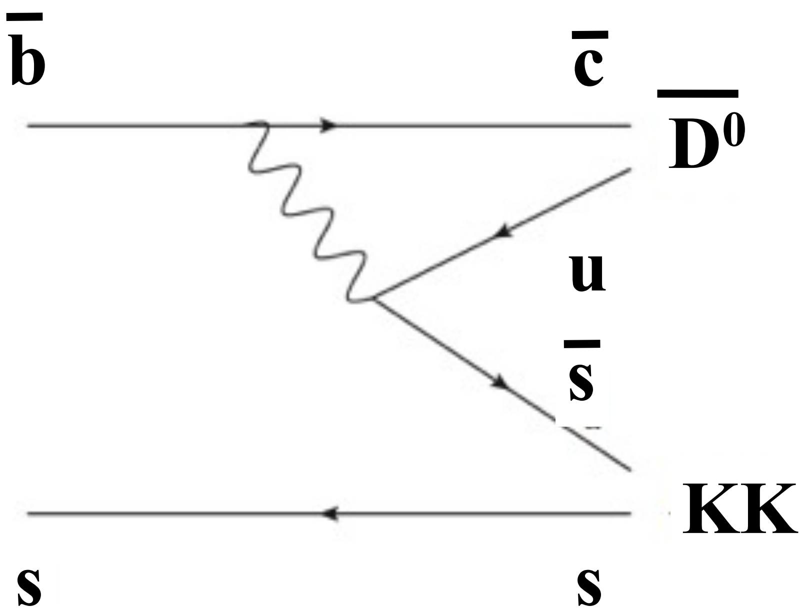
Semi-flavor tagged decay

Both access by D^0 and $\overline{D}^0$

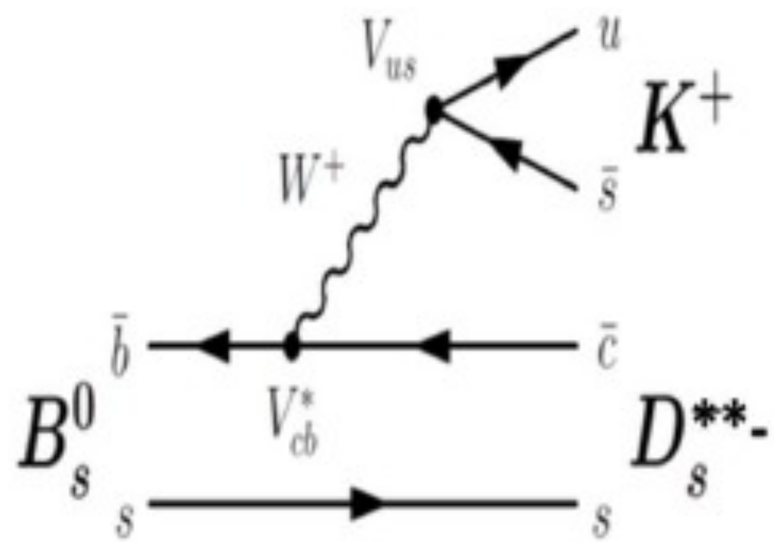
- ➢ $D^0 \to K^-\pi^+$: Time dependent analysis; access γ-$2\beta(\phi_s)$; only interference via oscillation
- ➢ $D^0 \to$CP eigenstates: time dependent analysis; access γ, $2\beta(\phi_s)$; interference both via oscillation and $B\to D^0hh$, $B\to\overline{D}^0hh$

Dalitz Analysis With B→Dhh

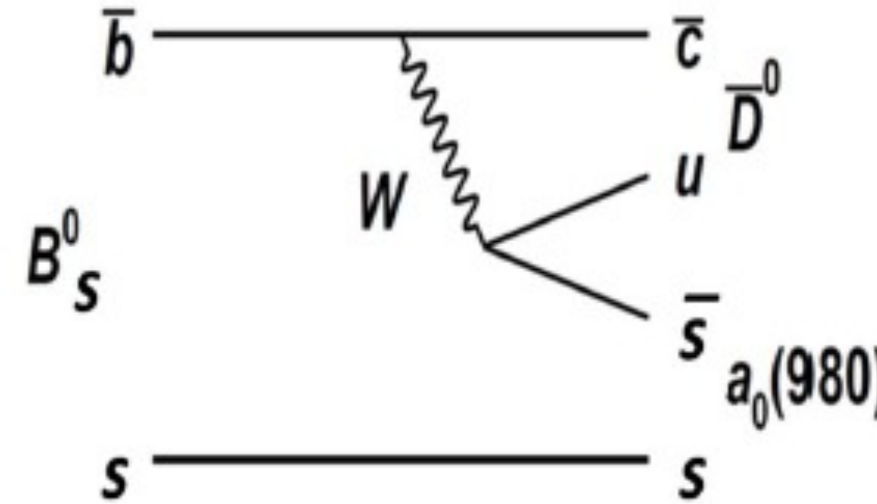
➢ **Further more, Dalitz analysis could be performed to enhance its sensitivity on γ (most sensitive channel for γ measurement is the $B^- \to DK^-$ GGSZ mode with D→Kshh)**



non-resonance



D_s^* resonance



KK resonance

➢ **With even statistics, a time-dependent Dalitz could be performed**

➢ **Further details see S. Nandi and D. London, Phys. Rev. D 85, 114015 (2012), S. Ricciardi, LHCb-PUB-2010-005, M. Gronau et al., Phys. Rev. D 69, 113003 (2004): There are motivations for measuring γ where one can compare time dependent analysis of $B_s \to D_s\Phi$ to $B^- \to DK^-$ GLW mode, $B_s \to D_sKK$ to $B^- \to DK^-$ GGSZ mode ($D^0 \to K_s\pi\pi$)**

Analysis Status(1)

- ➢ The analysis on $B_{(s)} \to DKK$ still at its early stage due to its low branching fraction; Only $D^0 \to K^-\pi^+$ considered at the moment

- ➢ First observation of $B^0 \to D^0KK$ and first evidence of $B_s \to D^0KK$ with $D^0 \to K^-\pi^+$ made by LHCb using 2/3 of 2011 data (0.62 fb^{-1}) (Phys. Rev. Lett. 109, 131801 (2012))

- ➢ Current analysis ongoing to update the previous branching fraction measurements and to make the first discovery of $B_s \to DKK$ with 5 times more data (1 fb^{-1} 2011 data and 2 fb^{-1} 2012 data)

Analysis Status(2)

➢ **Re-optimization of selections and background study with 2011+ 2012 data finalized; update on branching fraction ongoing**

➢ **Current efforts also on performing Dalitz Analysis on $B \to D\pi\pi$ and $B \to DKK$: to understand the resonance structure and their properties; to further extend to a time-dependent Dalitz analysis if possible (for $B \to D\pi\pi$)**

➢ **As current analysis are still in progress, we describe previous analysis here, indicating improvements with prospects at the end**

Selections

➢ **The selections are all optimized using $B^0 \to D^0 \pi\pi$**

➢ **MVA techniques used: NeuroBayes in previous analysis, Fisher in current onging analysis after similar preselections (Linear MVA gives similar performance as nonlinear ones)**

➢ **Both signal and background (combinatorial) events for MVA inputs come from sweighted data sample of $B^0 \to D^0 \pi\pi$**

➢ **Inputs of MVA includes 15 variables from kinematic and geometrical properties; Reexamined in current analysis, some removed for latter Dalitz analysis or combined to improve MVA performance (10 variables used now with better MVA performance)**

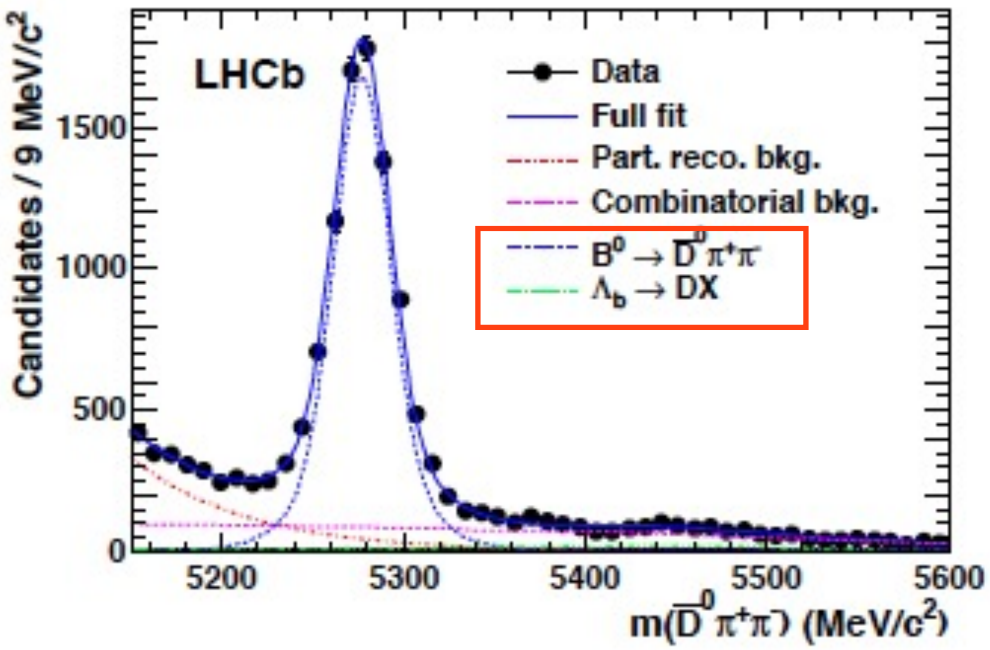
➢ **Particle identification optimized after MVA and calibrated using $D^* \to D^0 \pi$**

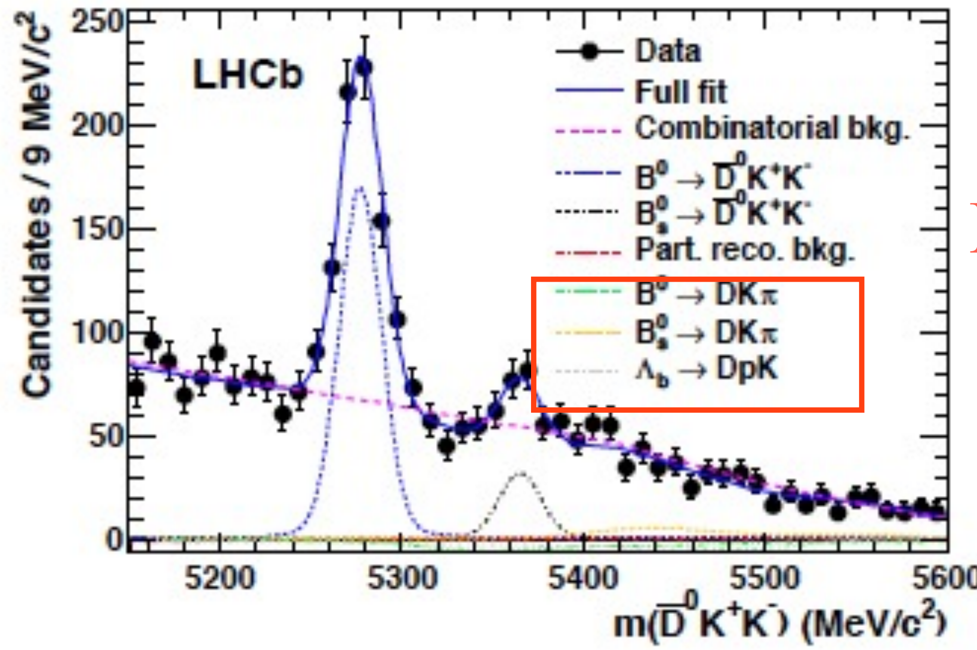
Mass(Dalitz) Distribution

Phys. Rev. Lett. 109, 131801 (2012)

$B^0 \rightarrow D^0\pi\pi$

$B^0_{(s)} \rightarrow D^0KK$

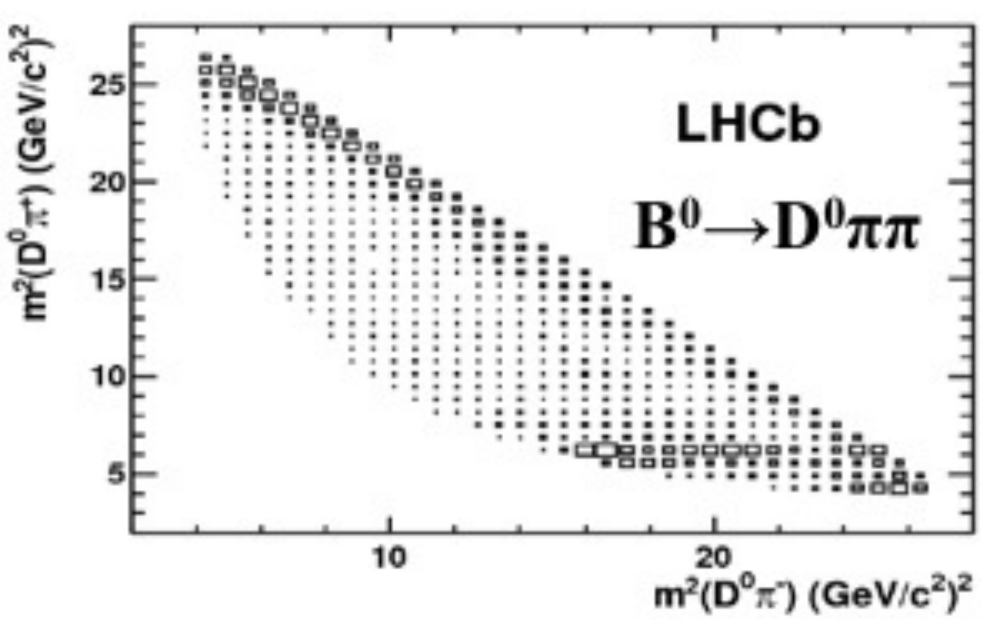


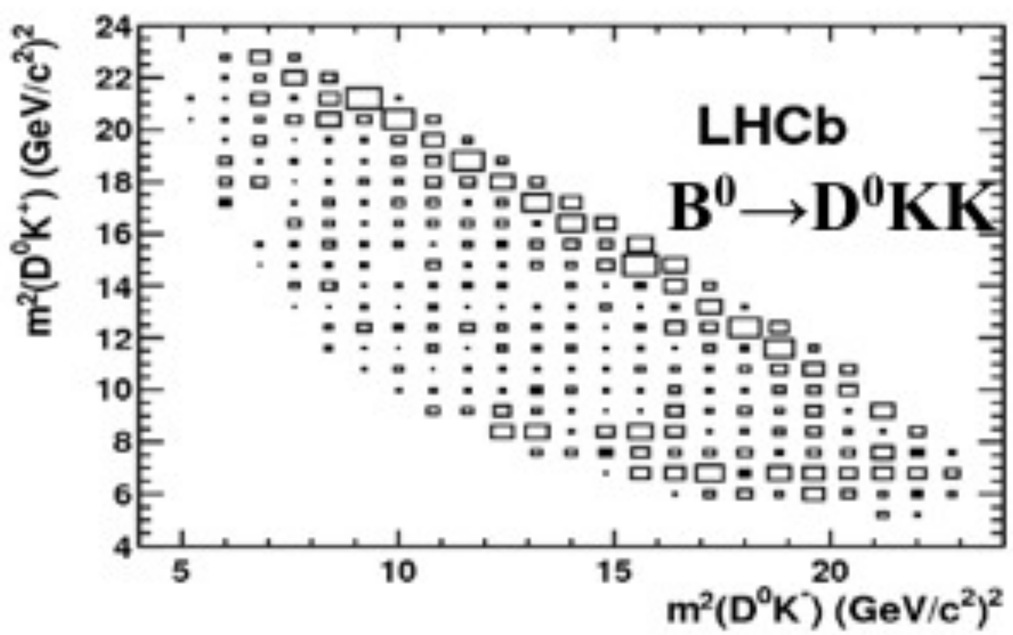


Mis-ID background (see latter)

8060 (773 charmless)

B^0: 558 (126 charmless) B_s: 124 (0 charmless)





➢ Charmless background ($B \rightarrow KKK\pi$, $K\pi\pi\pi$ etc.) not vetoed; Calculated using D^0 mass sidebands and subtracted for branching fraction measurements

Charmless Background

➢ To avoid charmless contamination for Dalitz analysis, we use dedicated selection criteria to remove charmless background in ongoing analysis; we also use D^0 sidebands to monitor the selection

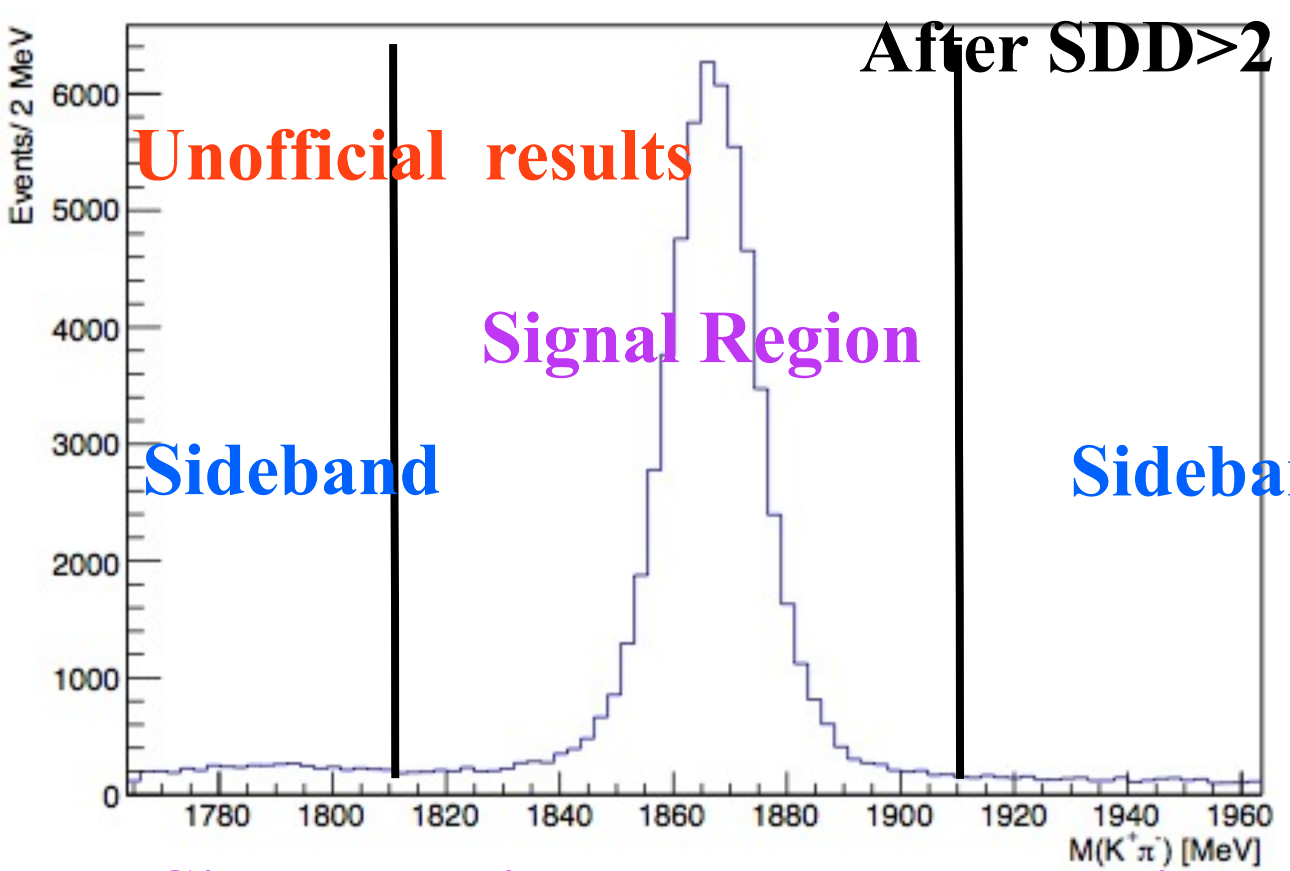
$$SDD = \frac{Z_{D^0} - Z_{B^0}}{\sqrt{\sigma^2_{z_{D^0}} + \sigma^2_{z_{B^0}}}}$$

z position of B(D) vertex

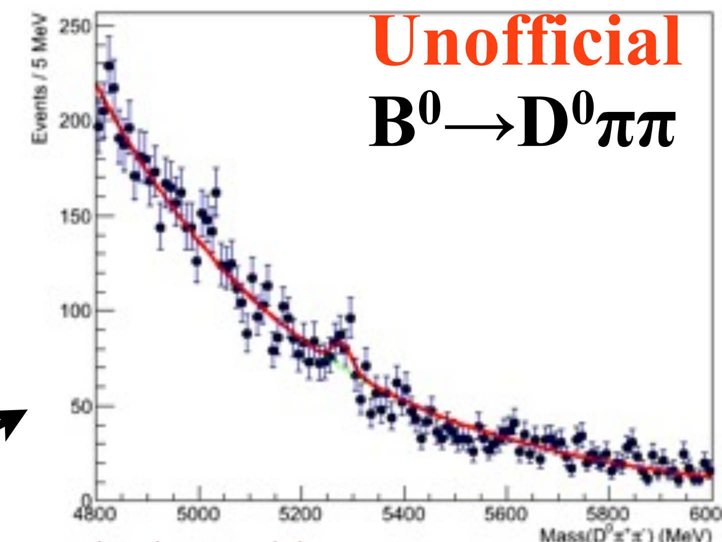
z error of B(D) vertex

➢ The selection (SDD>2) is applied

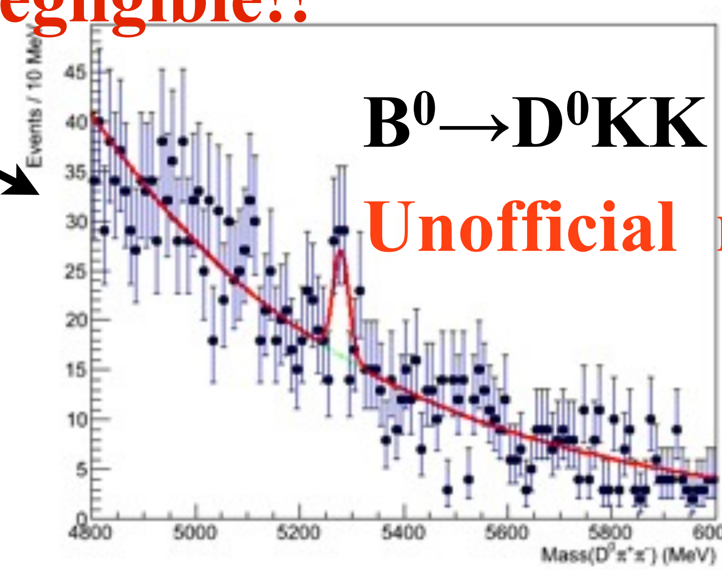
D mass distribution



Signal Region chosen that peaking backgrounds from D/D_s do not contribute



Negligible!!



Mis-ID Background

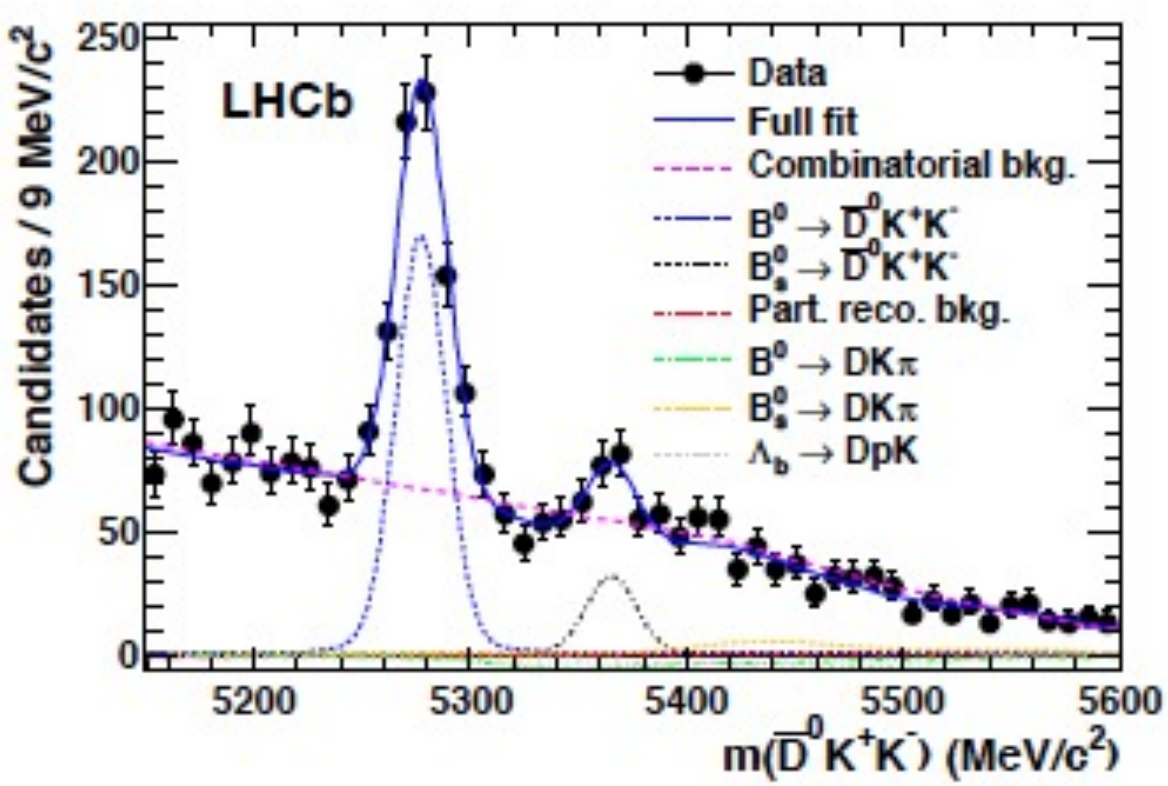
Phys. Rev. Lett. 109, 131801 (2012)

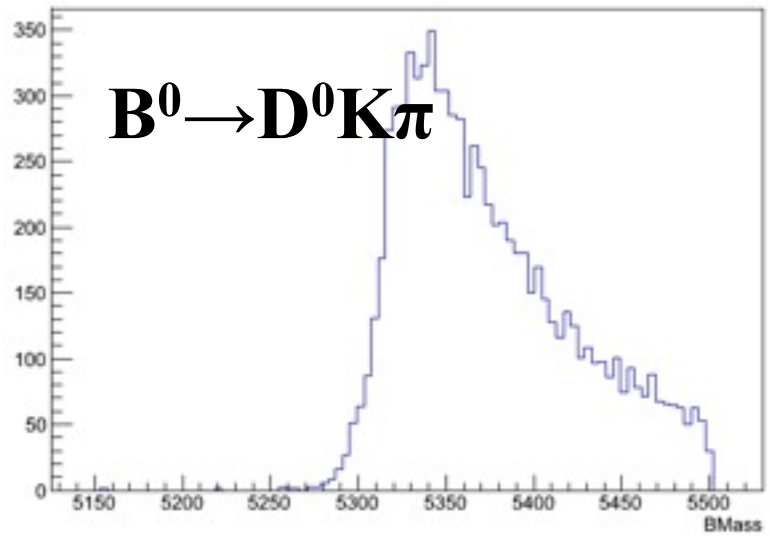
➢ The mis-ID background from D^0 daughters is removed by restricting D mass window

➢ The mis-ID background from B^0 daughters still remains and may cause peaking structures around B^0 mass

➢ We obtain the shape of these background directly from Monte Carlo simulations; The number of these backgrounds (in full fit range) are obtained by fitting them together with other contributions

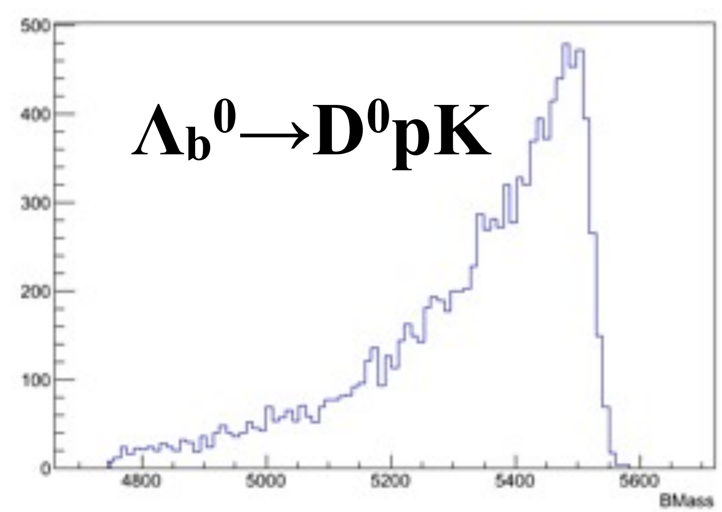
$B^0_{(s)} \rightarrow D^0KK$

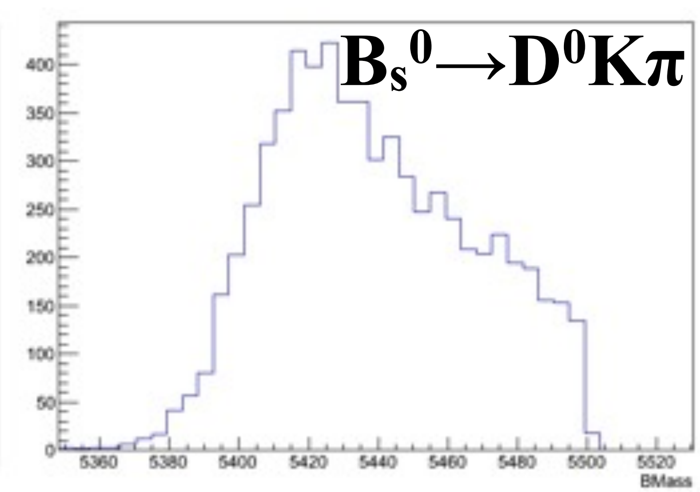




LHCb Simulation

Negligible contributions





Branching Fraction Measurements

Phys. Rev. Lett. 109, 131801 (2012)

- Branching fraction of $B^0 \to DKK$ measured w. r. t. $B^0 \to D\pi\pi$

$$\frac{\mathcal{B}\left(B^0 \to \bar{D}^0 K^+ K^-\right)}{\mathcal{B}\left(B^0 \to \bar{D}^0 \pi^+ \pi^-\right)} = \frac{N^{\mathrm{corr}}(DKK)\left(1 - \frac{N^{\mathrm{peak}}(DKK)}{N(DKK)}\right)}{N^{\mathrm{corr}}(D\pi\pi)\left(1 - \frac{N^{\mathrm{peak}}(D\pi\pi)}{N(D\pi\pi)}\right)}$$

Charmless background

Efficiency corrected Yields

- Per-event efficiency over Dalitz plot obtained from Monte Carlo

- Branching fraction of $B_s \to DKK$ measured w. r. t. $B^0 \to DKK$

$$\frac{\mathcal{B}\left(B_s^0 \to \bar{D}^0 K^+ K^-\right)}{\mathcal{B}\left(B^0 \to \bar{D}^0 K^+ K^-\right)} = \left(\frac{f_s}{f_d}\right)^{-1} \frac{N(B_s^0 \to DKK)}{N(B^0 \to DKK) - N^{\mathrm{peak}}(B^0 \to DKK)}$$

- Measured Branching fractions:

$$\frac{\mathcal{B}\left(B^0 \to \overline{D}^0 K^+ K^-\right)}{\mathcal{B}\left(B^0 \to \overline{D}^0 \pi^+ \pi^-\right)} = 0.056 \pm 0.011 \pm 0.007\,,$$

5.8σ observation

stat. sys.

$$\frac{\mathcal{B}\left(B_s^0 \to \overline{D}^0 K^+ K^-\right)}{\mathcal{B}\left(B^0 \to \overline{D}^0 K^+ K^-\right)} = 0.90 \pm 0.27 \pm 0.20\,.$$

3.8σ evidence

Conclusion and Prospects

➢ $B_{(s)} \to DKK(\pi\pi)$: (another) sensitive channels for CKM angle γ (β, Φ_s) measurements

➢ LHCb made first observation of $B^0 \to D^0KK$ and first evidence of $B_s \to D^0KK$ with $D^0 \to K^-\pi^+$

➢ Current analysis ongoing to improve the measured branching fraction and to make the first discovery of $B_s \to DKK$ with full dataset

➢ We can expect around 30000 $B^0 \to D^0\pi\pi$, 2500 $B^0 \to D^0KK$ and 600 $B^0_s \to D^0KK$ signal events with 3 fb^{-1}

➢ Dalitz analysis is ongoing for $B^0 \to D^0KK(\pi\pi)$