

$B^\pm \rightarrow DK^\pm, D \rightarrow K_S K^\pm \pi^\mp$ 崩壊の ダリッツ平面解析を用いた CP非保存角 ϕ_3 の測定

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東北大学 鈴木 善明
石川明正、佐貫智行、山本均、
and Belle collaboration
日本物理学会@高知大学

21pSD-4

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- まとめ

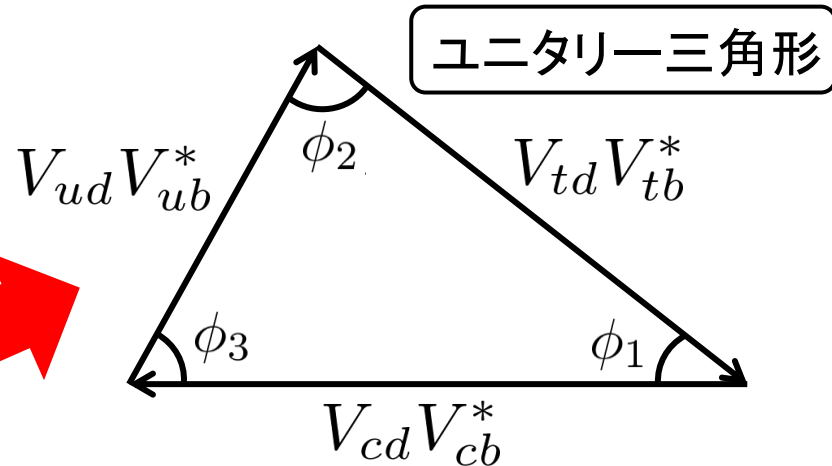
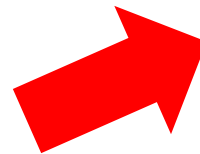
CP非保存角 ϕ_3

CKM行列

$$V_{CKM} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

ユニタリ条件

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



ϕ_1, ϕ_2 は精度よく測定されており、 ϕ_3 の値が新物理の有無(三角形が閉じるか否か)を決める。

$$\phi_1 = 21.38^\circ \begin{matrix} +0.79^\circ \\ -0.77^\circ \end{matrix}$$

$$\phi_2 = 85.4^\circ \begin{matrix} +4.0^\circ \\ -3.9^\circ \end{matrix}$$

$$\phi_3 = 68.0^\circ \begin{matrix} +8.0^\circ \\ -8.5^\circ \end{matrix}$$

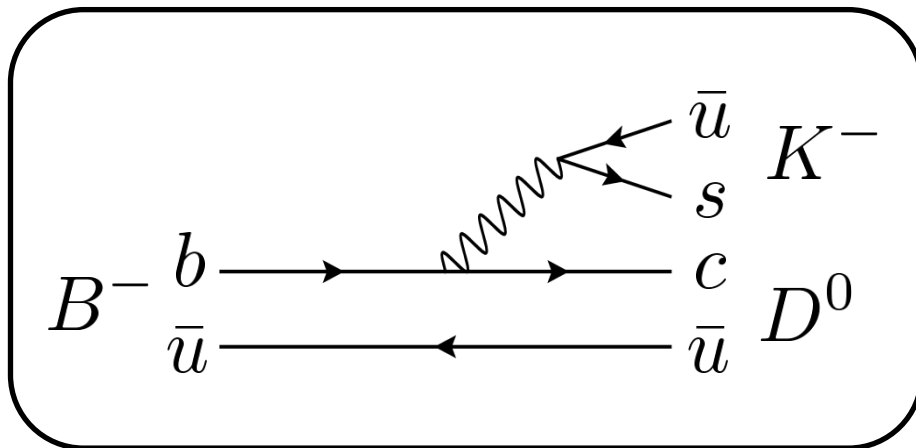
CKMfitter, FPCP2013

ϕ_3 の測定精度の向上が課題

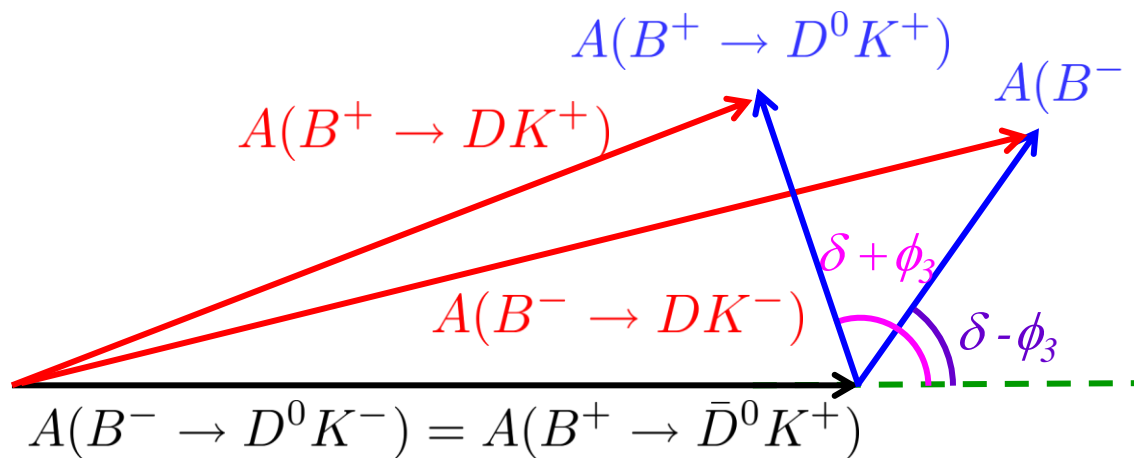
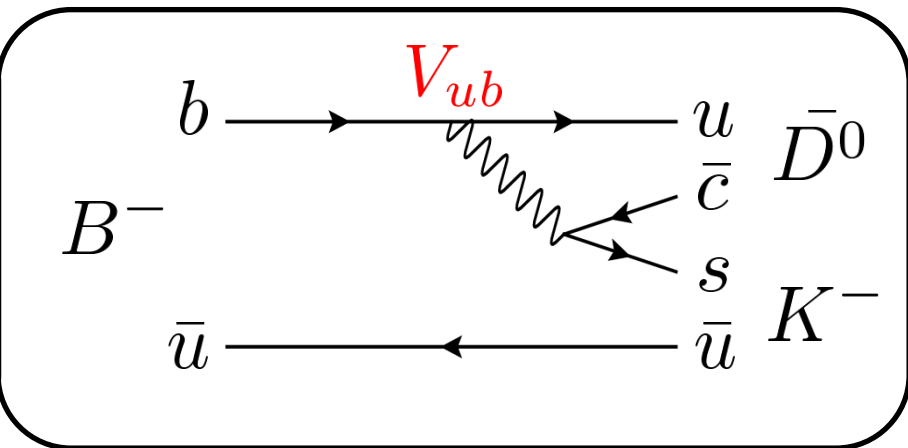
$$\phi_3 \equiv \arg \left(\frac{V_{ud}V_{ub}^*}{-V_{cd}V_{cb}^*} \right) \\ \sim -\arg(V_{ub})$$

B → DK崩壊

$$B^- \rightarrow D^0 K^-$$



$$B^- \rightarrow \bar{D}^0 K^-$$



$D : D^0 \text{ or } \bar{D}^0$

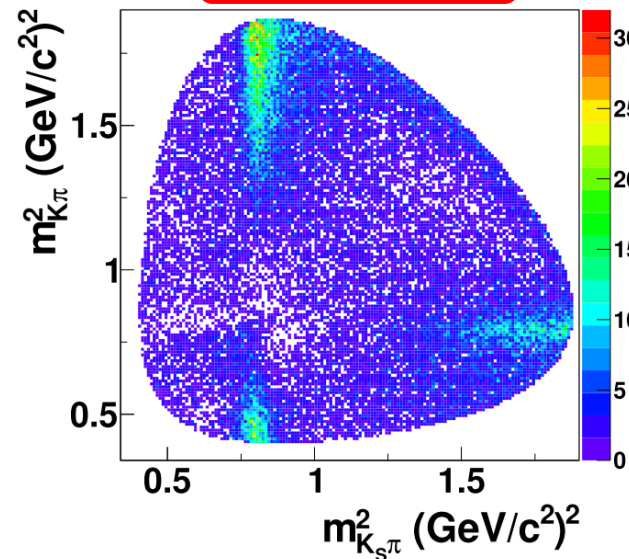
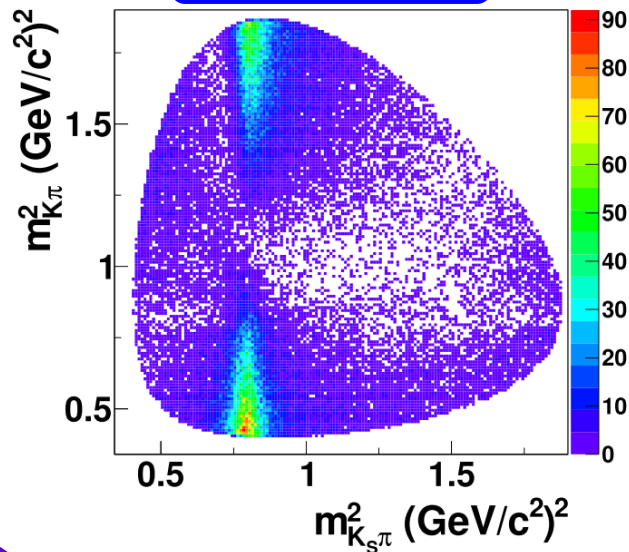
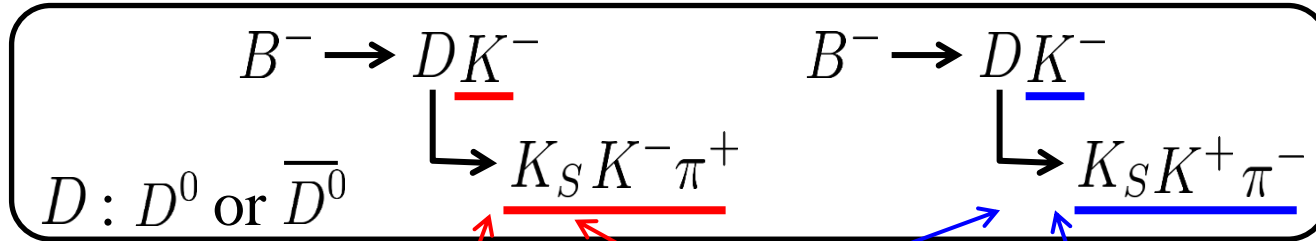
D^0 と \bar{D}^0 は同じ終状態に崩壊しうる。

δ : 強い相互作用に起因する位相差

B^- と B^+ の崩壊分岐比、CP非対称性を測定することで δ, ϕ_3 が求まる。

\bar{D}^0 の崩壊

本研究では、 D の崩壊として $D \rightarrow K_S K \pi$ 崩壊を用いる。



2種類の D^0 の崩壊がそれぞれ寄与する。

$(\overline{D^0})$ の崩壊

崩壊振幅

$$A \left[B^\pm \rightarrow K^\pm (K_S K^\pm \pi^\mp)_D \right] = A_B A_D \left[1 + r_B r_D e^{i(\delta_B + \delta_D \pm \phi_3)} \right]$$

$$A \left[B^\pm \rightarrow K^\pm (K_S K^\mp \pi^\pm)_D \right] = A_B A_D e^{i\delta_D} \left[r_D + r_B e^{i(\delta_B - \delta_D \pm \phi_3)} \right]$$

$$r_B = \frac{|\overline{A_B}|}{|A_B|} = \frac{|A(B^- \rightarrow \overline{D^0} K^-)|}{|A(B^- \rightarrow D^0 K^-)|}, \quad r_D = \frac{|\overline{A_D}|}{|A_D|} = \frac{|A(\overline{D^0} \rightarrow K_S K^- \pi^+)|}{|A(D^0 \rightarrow K_S K^- \pi^+)|}$$

r_B, δ_B, ϕ_3 : 最終的なフィットパラメータ

A_D, r_D, δ_D : ダリッツ平面に依存するパラメータ

- 様々な中間共鳴状態を含むため、ダリッツ平面を用いた解析が必要。
- 様々な中間共鳴状態による様々な強い相互作用の状態が寄与するため、 ϕ_3 に強い制限をかけることが可能。
- 類似の $D \rightarrow K_S \pi \pi$ のダリッツ解析による測定は高精度である。
- $B^\pm \rightarrow DK^\pm, D \rightarrow K_S K^\mp \pi^\pm$ 崩壊を用いた ϕ_3 の測定は未だなされていない。

フィットに用いる $D \rightarrow K_S K \pi$ のダリッツ平面のモデルは D^0 と \bar{D}^0 を区別できる tagged D (from $D^{*+} \rightarrow D^0 \pi^+$, $D^{*-} \rightarrow \bar{D}^0 \pi^-$) を用いて作成する。

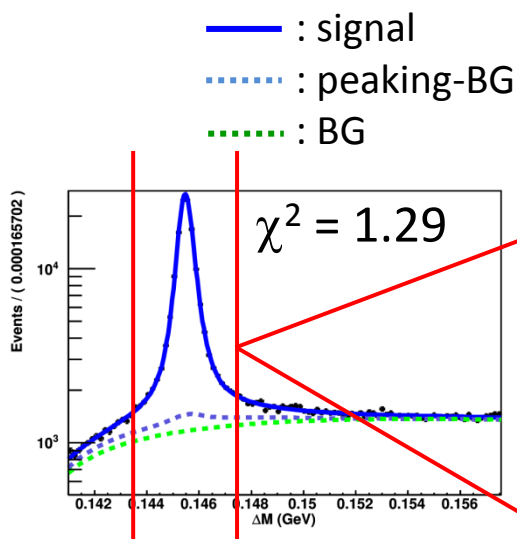
$D^{*\pm} \rightarrow D \pi^\pm$, $D \rightarrow K_S K^{\mp} \pi^\pm$ 崩壊を用いた
ダリッツ平面のモデルの決定

Tagged D の選定

- $Y(4S)$ のデータ 711 fb^{-1} を使用。
- $p^*(D^*) > 2.5 \text{ GeV}/c$
- $|K_S \text{ mass (PDG)} - K_S \text{ mass}| < 12.5 \text{ MeV}/c^2$ ($\sim 4\sigma$)
- Likelihood によって K, π を識別。
- D^0 mass と ΔM は 2σ でカット。

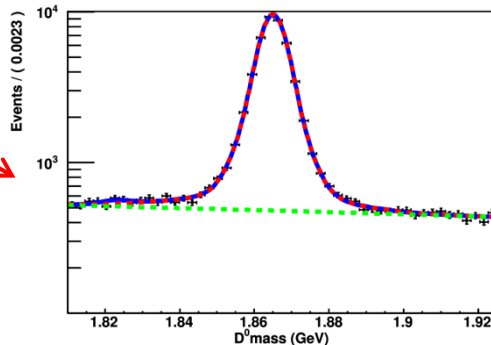
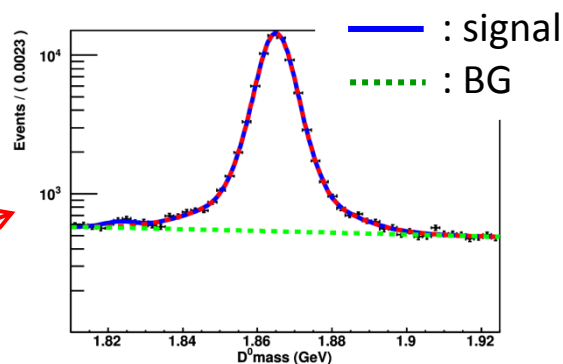
$D^0 \rightarrow K_S K^- \pi^+$
 $D^0 \rightarrow K_S K^+ \pi^-$

$\Delta M (D^* \text{ mass} - D^0 \text{ mass})$



2σ cut & Best candidate selection (using ΔM).

D^0 mass



of events/ 711 fb^{-1} with D^0 mass & ΔM 2σ cut.

$\sim 60,700$ events

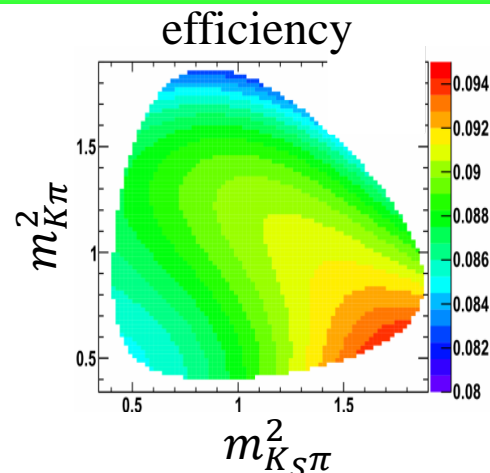
Purity : 93.1%

$\sim 38,900$ events

Purity : 90.6%

フィットの手法

- unbinned likelihood fit を利用。
- ダリッツ平面上の検出効率を考慮。
- BGのフラクション (f_{bkg}) は D^0 mass のフィット結果で固定。
- BG-PDFの形状は D^0 mass のサイドバンドから決定。



$$PDF_{sig}(m_{K_S\pi}^2, m_{K\pi}^2)$$

Breit-Wigner で表される共鳴の重ね合わせ。

$$PDF_{sig}(m_{K_S\pi}^2, m_{K\pi}^2) = N_{norm} \left| \sum_j a_j e^{i\varphi_j} A_j(m_{K_S\pi}^2, m_{K\pi}^2) \right|^2$$

赤字: フィットパラメータ

$A_j(m_{K_S\pi}^2, m_{K\pi}^2)$: B-W amplitude, ダリッツ平面に依存

$$PDF_{bkg}(m_{K_S\pi}^2, m_{K\pi}^2)$$

D^0 mass のサイドバンドから決定。

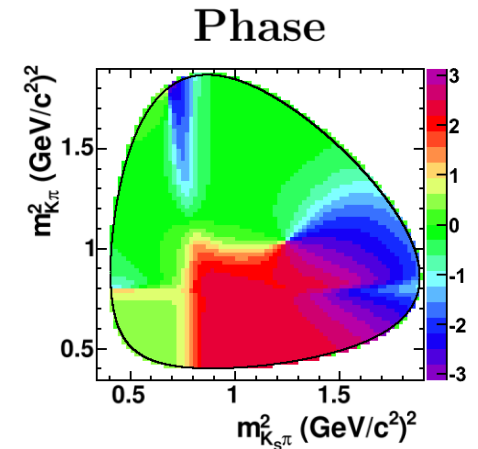
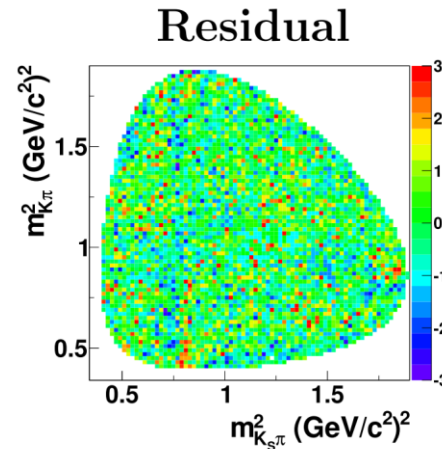
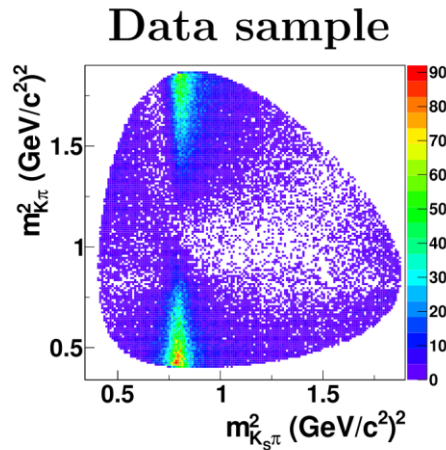
Total PDF

$$PDF(m_{K_S\pi}^2, m_{K\pi}^2) = f_{bkg} PDF_{bkg}(m_{K_S\pi}^2, m_{K\pi}^2) + (1 - f_{bkg}) PDF_{sig}(m_{K_S\pi}^2, m_{K\pi}^2)$$

フィット結果 : $D^0 \rightarrow K_S K^- \pi^+$

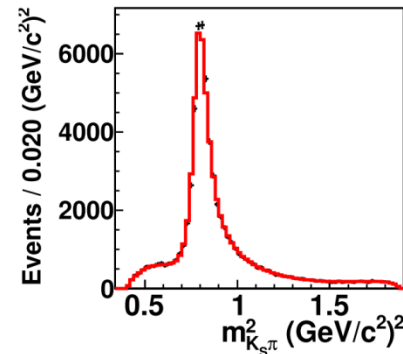
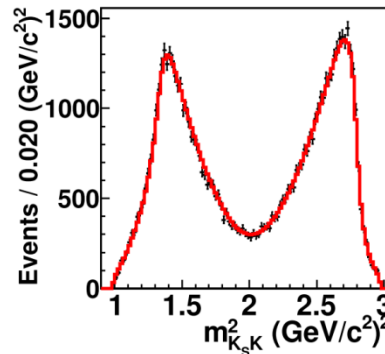
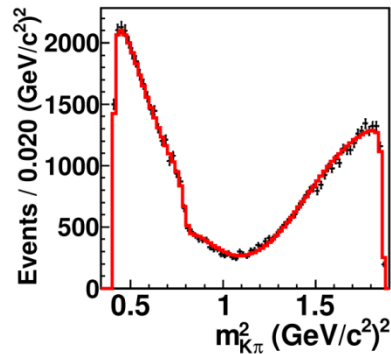
$$D^{*+} \rightarrow D^0 \pi^+, D^0 \rightarrow K_S K^- \pi^+$$

$\bar{K}_0^*(1430)^0 K_S$
$\bar{K}^*(892)^0 K_S$
$\bar{K}_1^*(1410)^0 K_S$
$\bar{K}_1^*(1680)^0 K_S$
$\bar{K}_2^*(1430)^0 K_S$
$K_0^*(1430)^+ K^-$
$K^*(892)^+ K^-$
$K_1^*(1410)^+ K^-$
$K_1^*(1680)^+ K^-$
$K_2^*(1430)^+ K^-$
$a_0(980)^- \pi^+$
$a_0(1450)^- \pi^+$
$a_2(1320)^- \pi^+$
N.R.



Projection of Data & PDF

$$\chi^2/\text{ndf} = 1.287$$



dot : data
line : PDF

複数の共鳴の組み合わせを試し、最小の数でフィットできるモデルを選択した。

フィット結果： $D^0 \rightarrow K_S K^- \pi^+$

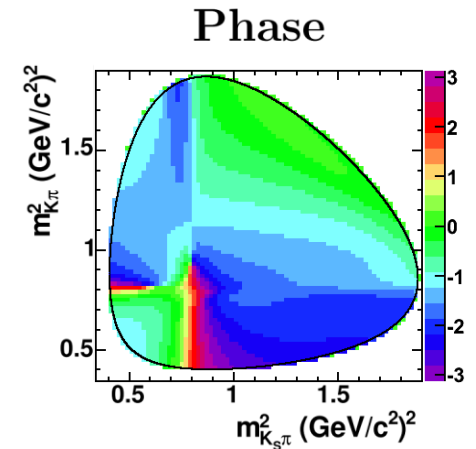
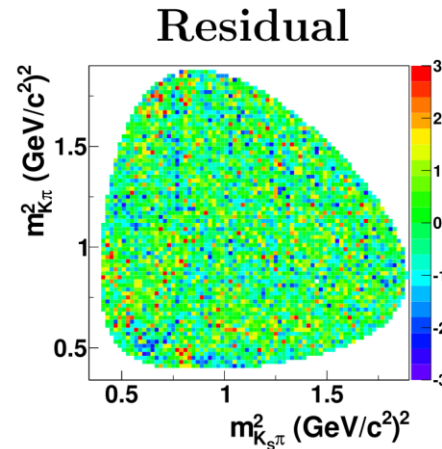
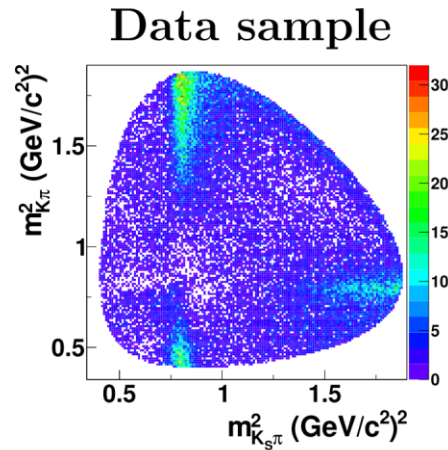
	Amplitude	Phase [rad]
$\bar{K}_0^*(1430)^0 K_S$	2.71 ± 0.21	0.411 ± 0.076
$\bar{K}^*(892)^0 K_S$	0.159 ± 0.008	-1.57 ± 0.032
$\bar{K}_1^*(1410)^0 K_S$	3.37 ± 0.06	2.46 ± 0.05
$K_0^*(1430)^+ K^-$	3.94 ± 0.21	2.93 ± 0.06
$K^*(892)^+ K^-$	1	0
$K_1^*(1680)^+ K^-$	7.81 ± 0.18	2.30 ± 0.04
$K_2^*(1430)^+ K^-$	1.69 ± 0.11	0.503 ± 0.049
$a_0(1450)^- \pi^+$	0.604 ± 0.045	-0.385 ± 0.073
N.R.	3.81 ± 0.32	-0.337 ± 0.117

このモデルを用いて $B \rightarrow DK$ 崩壊をフィットし、 ϕ_3 の値を得る。

フィット結果 : $D^0 \rightarrow K_S K^+ \pi^-$

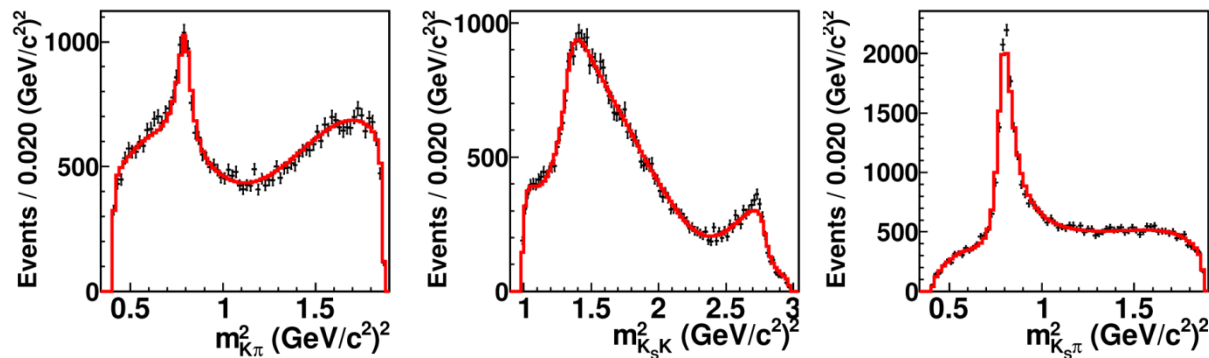
$$D^{*+} \rightarrow D^0 \pi^+, D^0 \rightarrow K_S K^+ \pi^-$$

$\bar{K}_0^*(1430)^0 K_S$
$\bar{K}^*(892)^0 K_S$
$\bar{K}_1^*(1410)^0 K_S$
$\bar{K}_1^*(1680)^0 K_S$
$\bar{K}_2^*(1430)^0 K_S$
$K_0^*(1430)^+ K^-$
$K^*(892)^+ K^-$
$K_1^*(1410)^+ K^-$
$K_1^*(1680)^+ K^-$
$K_2^*(1430)^+ K^-$
$a_0(980)^- \pi^+$
$a_0(1450)^- \pi^+$
$a_2(1320)^- \pi^+$
N.R.



Projection of Data & PDF

$$\chi^2/\text{ndf} = 1.242$$



dot : data
line : PDF

複数の共鳴の組み合わせを試し、最小の数でフィットできるモデルを選択した。

フィット結果 : $D^0 \rightarrow K_S K^+ \pi^-$

	Amplitude	Phase [rad]
$\bar{K}^*(892)^0 K_S$	0.379 ± 0.012	-3.04 ± 0.04
$\bar{K}_1^*(1410)^0 K_S$	2.83 ± 0.20	1.77 ± 0.12
$\bar{K}_2^*(1430)^0 K_S$	2.52 ± 0.33	-3.06 ± 0.07
$K_0^*(1430)^+ K^-$	4.63 ± 0.34	-2.60 ± 0.07
$K^*(892)^+ K^-$	1	0
$K_1^*(1680)^+ K^-$	11.0 ± 0.3	-2.87 ± 0.04
$K_2^*(1430)^+ K^-$	2.48 ± 0.13	1.19 ± 0.07
$a_0(980)^- \pi^+$	2.39 ± 0.26	-1.73 ± 0.16
$a_0(1450)^- \pi^+$	0.627 ± 0.064	-2.40 ± 0.14
N.R.	5.35 ± 0.40	-0.566 ± 0.095

$$g_{KK} = 0.345 \pm 0.021$$

a_0 の PDF の形状を決定するパラメータ

このモデルを用いて $B \rightarrow DK$ 崩壊をフィットし、 ϕ_3 の値を得る。

- $Y(4S)$ のデータ 711 fb^{-1} を使用。
- $| K_S \text{ mass (PDG)} - K_S \text{ mass} | < 12.5 \text{ MeV}/c^2$ ($\sim 4\sigma$)
- $| D^0 \text{ mass (PDG)} - D^0 \text{ mass} | < 15.9 \text{ MeV}/c^2$ ($\sim 3\sigma$)
- Likelihood によって K, π を識別。

BGの種類	詳細
$B \rightarrow D\pi$	$B^\pm \rightarrow \pi^\pm [K_S K^\pm \pi^\mp]_D$ (コントロールサンプル)
$B \rightarrow K^* KK$	$B^+ \rightarrow K^{*+} K^+ K^-$, $B^+ \rightarrow K^0 \bar{K}^{*0} K^+$, $B^+ \rightarrow K^{*-} K^+ K^+$, $B^+ \rightarrow \bar{K}^0 K^{*0} K^+$ + C.C
$B\bar{B}$	$e^+e^- \rightarrow B\bar{B}$ ($B \rightarrow$ not signal)
$q\bar{q}$	$e^+e^- \rightarrow q\bar{q}$ ($q = u, d, s, c$)

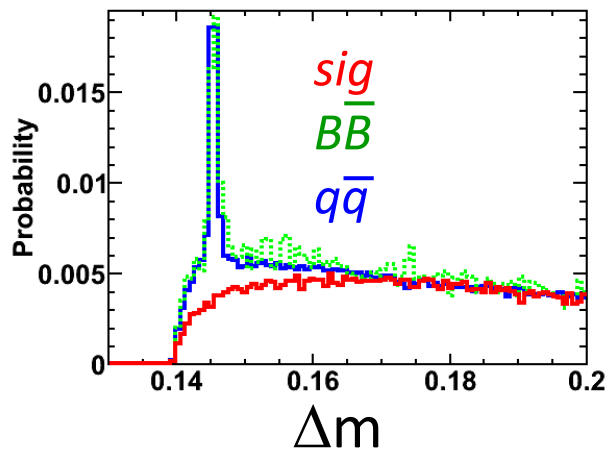
ϕ_3 の測定に向けた $B^\pm \rightarrow DK^\pm, D \rightarrow K_S K^\mp \pi^\pm$ 崩壊の研究

- ◆ $q\bar{q}$ バックグラウンドの抑制。
- ◆ $\Delta E - M_{bc}$ の2次元フィットによる信号の抽出。

$q\bar{q}$ バックグラウンドの抑制

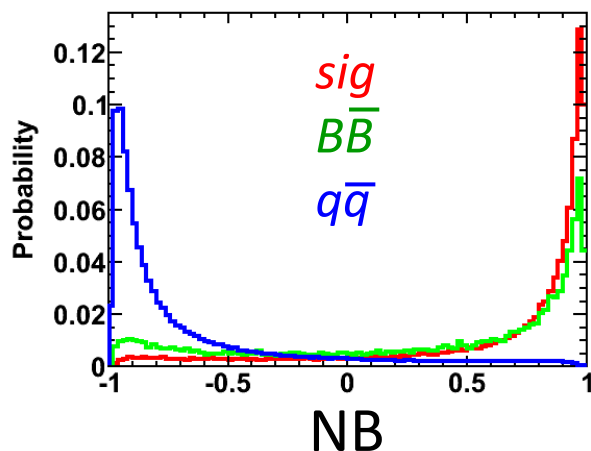
$$e^+e^- \rightarrow q\bar{q} \quad (q = u, d, s, c)$$

Δm



- Δm ($m_{D^*} - m_{D0}$) を使って D^* 由来のバックグラウンドを抑制。
- D^* のシグナル領域を 3σ でカット。

NeuroBayse



- ニューラルネットワークの一種である NeuroBayes を利用して $q\bar{q}$ バックグラウンドを抑制。
- $NB > 0.2$ でカット。

Signal eff. = $\sim 82\%$

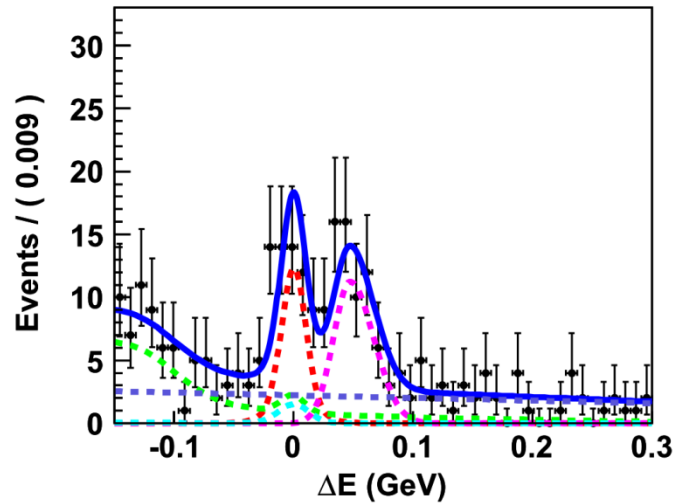
$q\bar{q}$ bkg eff. = $\sim 8.4\%$

それぞれのカットはシグニフィカンスが最大になるように決定した。

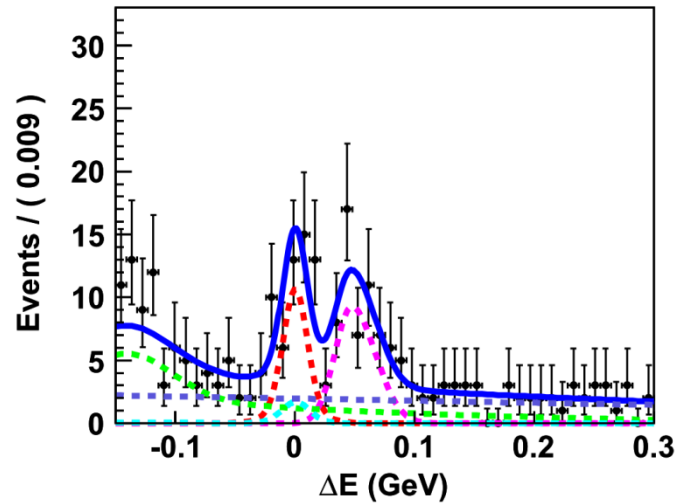
2次元フィット

$$\Delta E \equiv E_B - E_{beam}$$

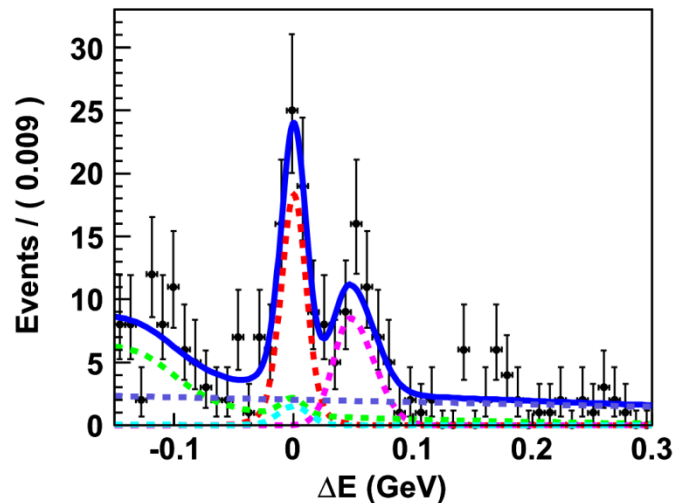
$$B^+ \rightarrow K^+[K_S K^+ \pi^-]_D$$



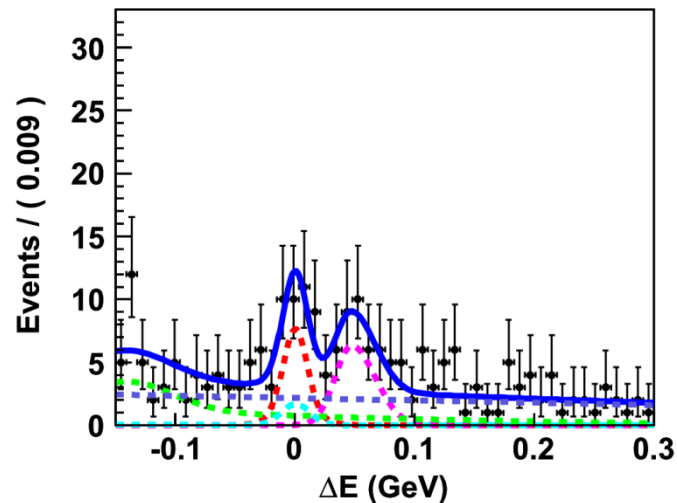
$$B^+ \rightarrow K^+[K_S K^- \pi^+]_D$$



$$B^- \rightarrow K^-[K_S K^- \pi^+]_D$$



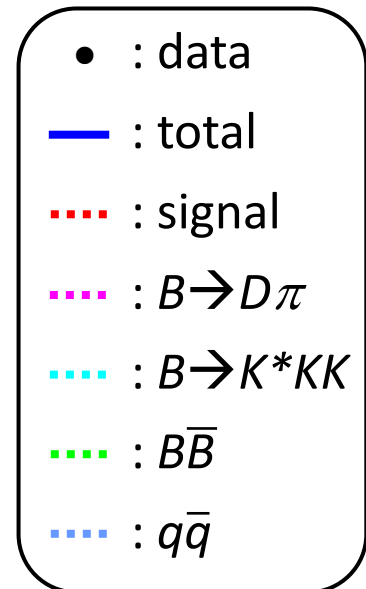
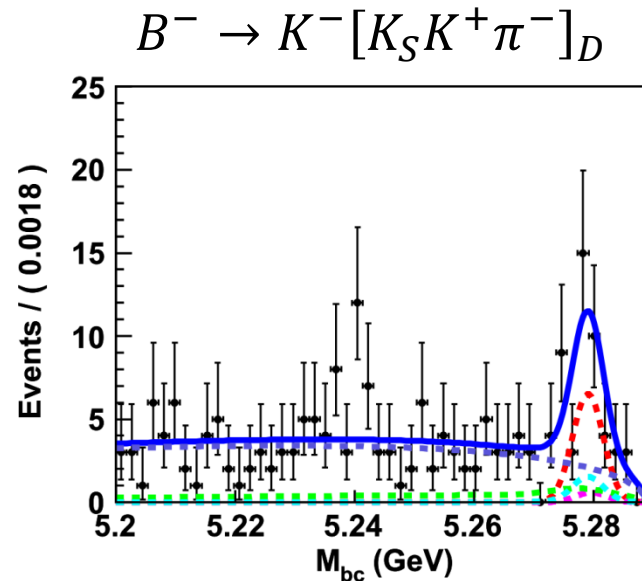
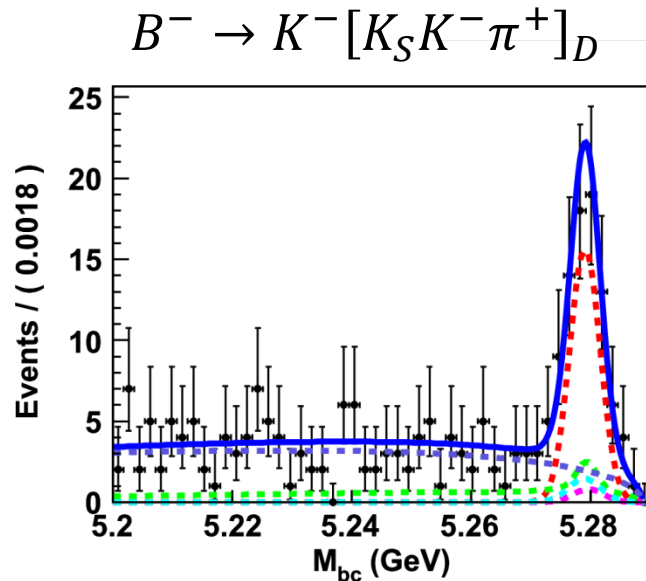
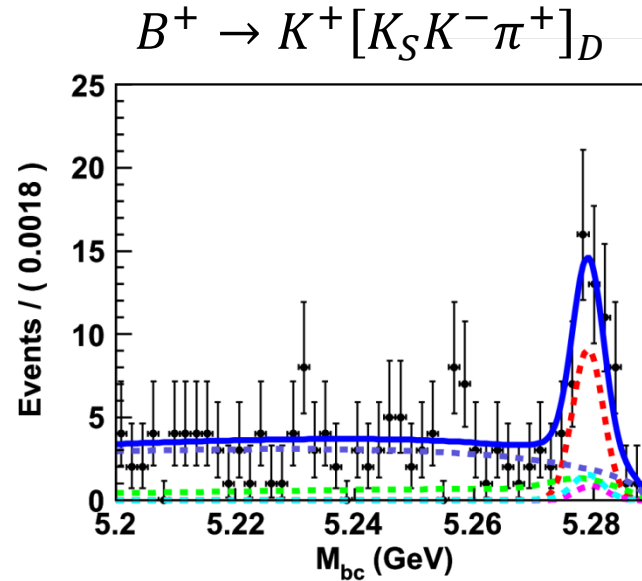
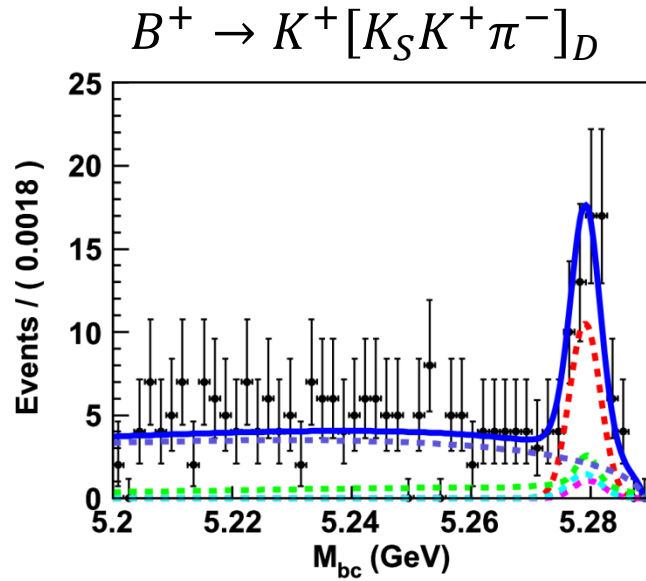
$$B^- \rightarrow K^-[K_S K^+ \pi^-]_D$$



- : data
- : total
- ⋯ : signal
- ⋯ : $B \rightarrow D\pi$
- ⋯ : $B \rightarrow K^* KK$
- ⋯ : $B\bar{B}$
- ⋯ : $q\bar{q}$

2次元フィット

$$M_{bc} \equiv \sqrt{E_{beam}^2 - |\vec{p}_B|^2}$$



2D-fit result for Data

	$B^+, D \rightarrow K_s K^+ \pi^-$	$B^-, D \rightarrow K_s K^- \pi^+$	$B^+, D \rightarrow K_s K^- \pi^+$	$B^-, D \rightarrow K_s K^+ \pi^-$
Total (fit/count)	1451.9/1452	1356.2/1356	1334.0/1334	1322.8/1323
Signal	38.4 ± 8.4	56.9 ± 9.3	33.1 ± 7.5	23.7 ± 6.7
$B \rightarrow D \pi$	53.7 ± 8.9	40.6 ± 7.8	44.2 ± 8.2	30.1 ± 7.0
$B \rightarrow K^* K K$	9.11 (fix)	9.11 (fix)	9.62 (fix)	9.62 (fix)
$B\bar{B}$	226.7 ± 40.2	220.6 ± 38.2	247.7 ± 41.6	155.9 ± 39.6
$q\bar{q}$	1124.0 ± 49.6	1029.1 ± 47.2	999.4 ± 49.4	1103.4 ± 50.1

$\Delta E - M_{bc}$ の2次元フィットにより、シグナルを抽出することが出来た。

まとめとプラン

$B \rightarrow DK, D \rightarrow K_S K \pi$ 崩壊を用いた ϕ_3 の測定を目指した解析を行っている。

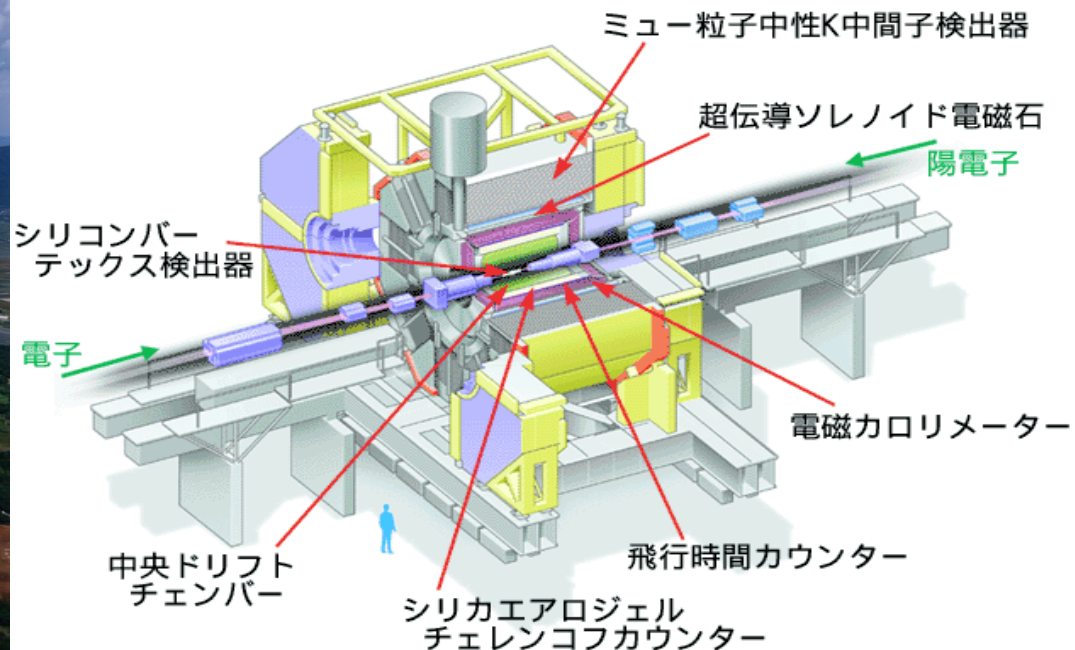
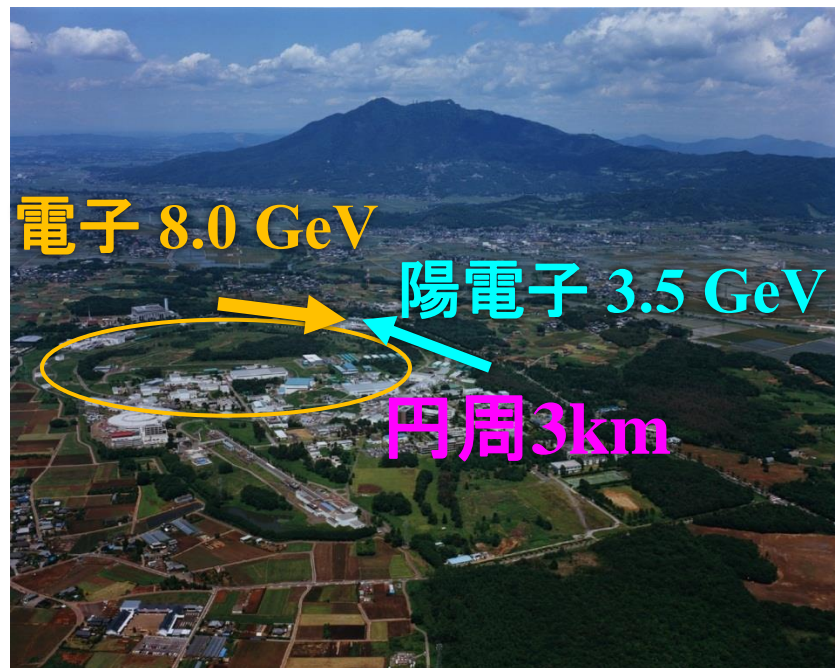
- $B \rightarrow DK, D \rightarrow K_S K \pi$ 崩壊を用いた ϕ_3 の測定はどの実験でもまだされていない。
- フレーバーが分かる $D^{*+} \rightarrow D^0 \pi^+$ 由来の D を用いて $D^0 \rightarrow K_S K^\pm \pi^\mp$ のダリッツ平面をフィットし、モデルを決定した。
- $\Delta E - M_{bc}$ の2次元フィットにより、 $B \rightarrow DK, D \rightarrow K_S K \pi$ のシグナルを抽出した。

プラン

- $B \rightarrow DK, D \rightarrow K_S K \pi$ のダリッツ平面のフィットを Toy-MC を使って確認する。
- コントロールサンプル ($B \rightarrow D \pi, D \rightarrow K_S K \pi$) を使ってフィットの手法を確認する。
- $B \rightarrow DK, D \rightarrow K_S K \pi$ のダリッツ平面をフィットし、 ϕ_3 の情報を得る。

BACKUP

Belle実験



- 積分ルミノシティ : 10^{14} fb^{-1} (Y(4S) : 711 fb^{-1})
- SuperKEKB, BelleIIへのアップグレードのため2010年6月に運転終了。

For D^* study

Angular dependence

Spin 0

$$A_0 = F_D F_r \frac{1}{M_r^2 - M_{AB}^2 - iM_r \Gamma_{AB}}$$

Spin 1

$$A_1 = F_D F_r \frac{M_{BC}^2 - M_{AC}^2 + \frac{(M_D^2 - M_C^2)(M_A^2 - M_B^2)}{M_{AB}^2}}{M_r^2 - M_{AB}^2 - iM_r \Gamma_{AB}}$$

Spin 2

$$A_2 = \frac{F_D F_r}{M_r^2 - M_{AB}^2 - iM_r \Gamma_{AB}} \left[\left(M_{BC}^2 - M_{AC}^2 + \frac{(M_D^2 - M_C^2)(M_A^2 - M_B^2)}{M_{AB}^2} \right)^2 - \frac{1}{3} \left(M_{AB}^2 - 2M_D^2 - 2M_C^2 + \frac{(M_D^2 - M_C^2)^2}{M_{AB}^2} \right) \left(M_{AB}^2 - 2M_A^2 - 2M_B^2 + \frac{(M_A^2 - M_B^2)^2}{M_{AB}^2} \right) \right]$$

$a_0(980)^\pm$

$$A_{a_0(980)} = F_D F_r \frac{g_{K\bar{K}}}{M_r^2 - M_{AB}^2 - i(\rho_{\eta\pi} g_{\eta\pi}^2 + \rho_{K\bar{K}} g_{K\bar{K}}^2)}$$

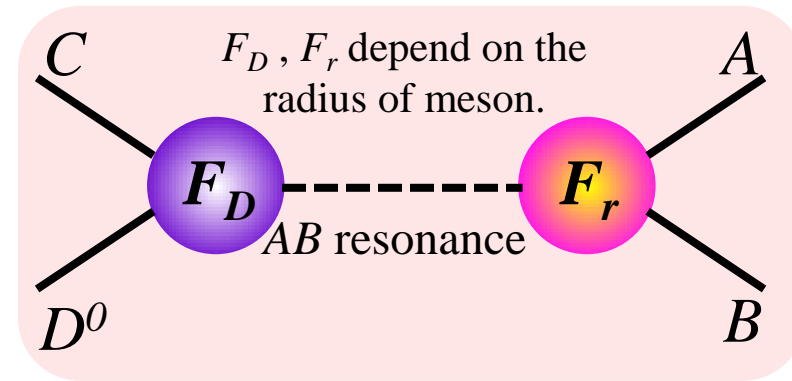
S. Kopp et al. (CLEO Collaboration),
Phys. Rev. D 63, 092001 (2001)

Red letter : free parameter

$$PDF = f_{sig} N_{norm} \left| \sum_j a_j e^{i\varphi_j} A_j \right|^2 + (1 - f_{sig}) PDF_{bkg}$$

Definition of fraction

$$f_i = \frac{\int |a_i e^{i\varphi_i} A_i|^2 dm_x^2 dm_y^2}{\int |\sum_j a_j e^{i\varphi_j} A_j|^2 dm_x^2 dm_y^2}$$



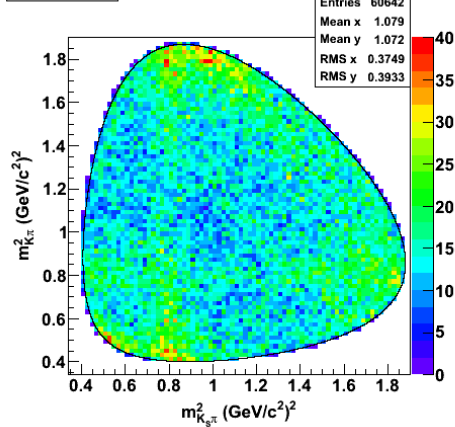
Background PDF

Tagged-D data

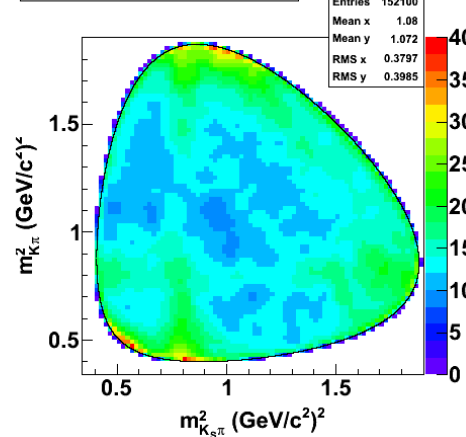
Favored mode, $D^0 \rightarrow K_S K^- \pi^+$

$\chi^2/\text{ndf} = 0.98$

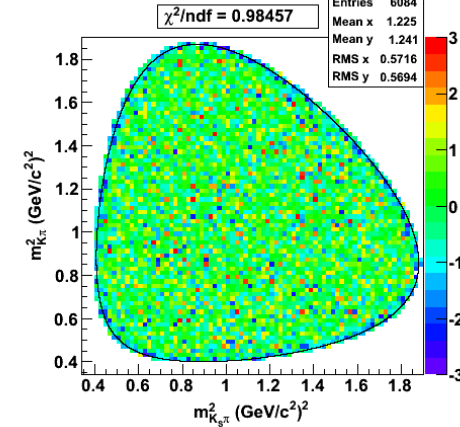
Bkg of d0



Smoothed Bkg-PDF of d0



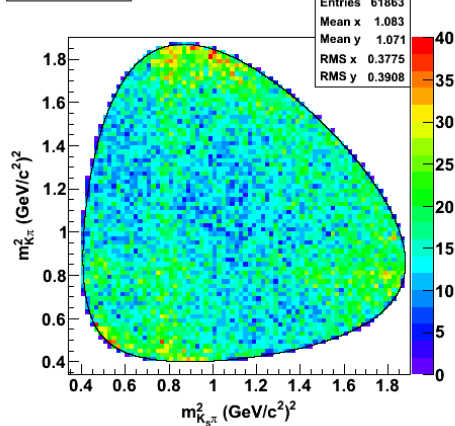
Residual Distribution



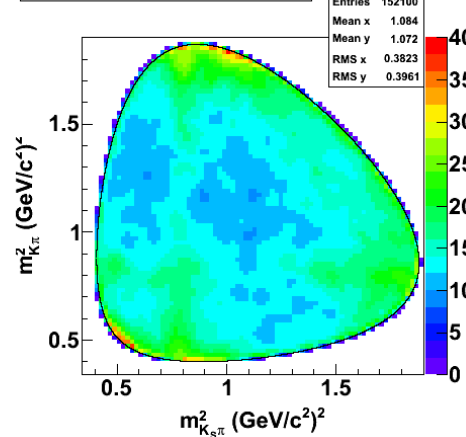
Favored mode, $\overline{D^0} \rightarrow K_S K^+ \pi^-$

$\chi^2/\text{ndf} = 1.01$

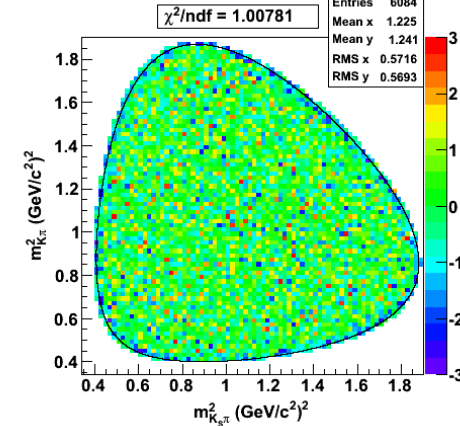
Bkg of d0b



Smoothed Bkg-PDF of d0b



Residual Distribution

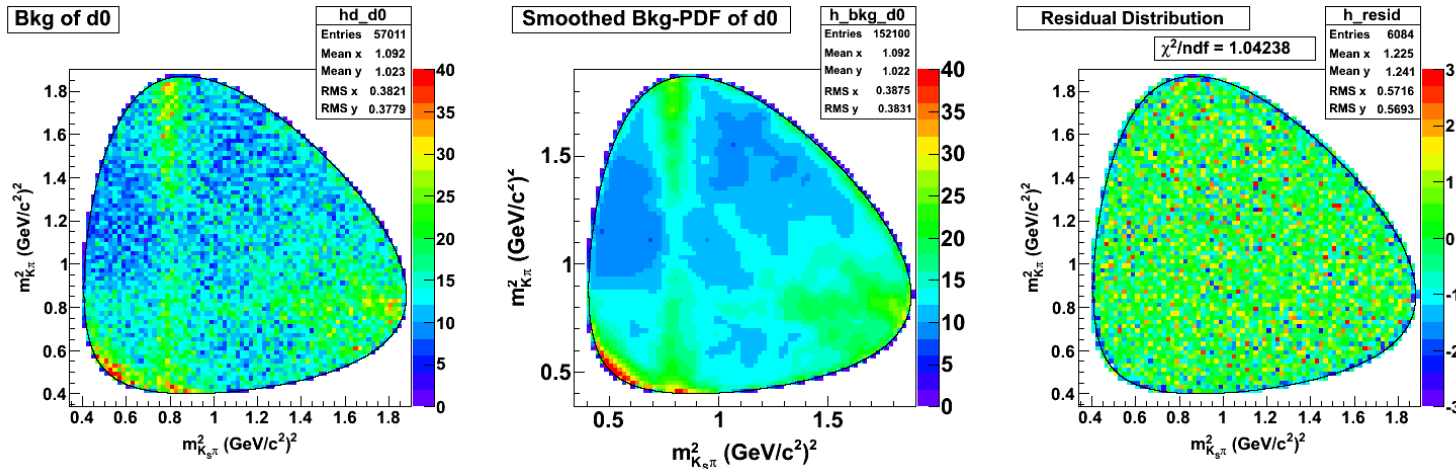


Background PDF

Tagged-D data

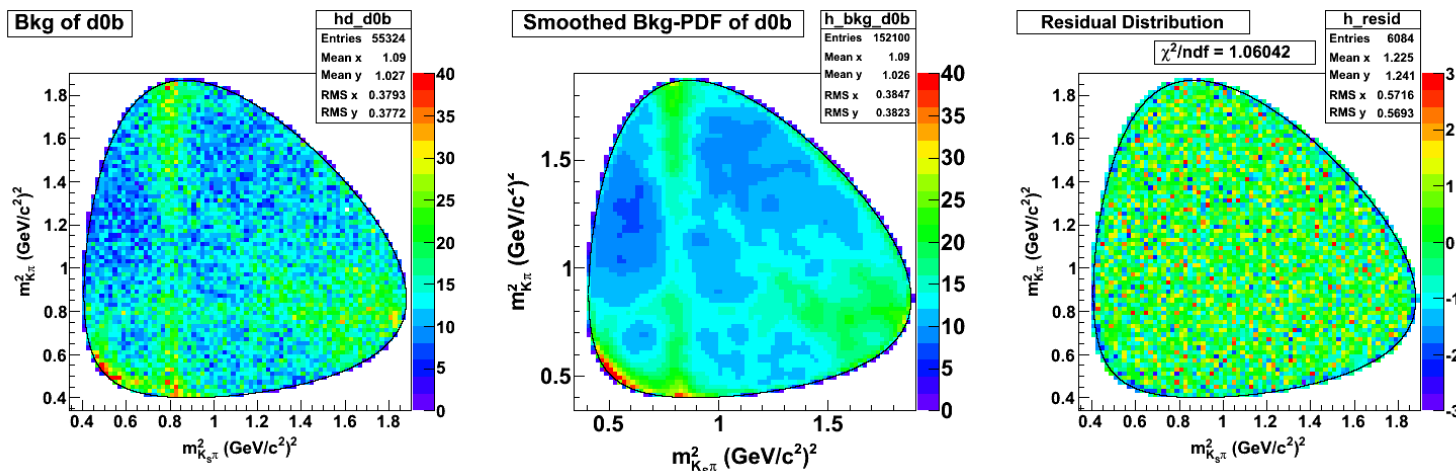
Suppressed mode, $D^0 \rightarrow K_S K^+ \pi^-$

$\chi^2/\text{ndf} = 1.04$



Suppressed mode, $\overline{D^0} \rightarrow K_S K^- \pi^+$

$\chi^2/\text{ndf} = 1.06$

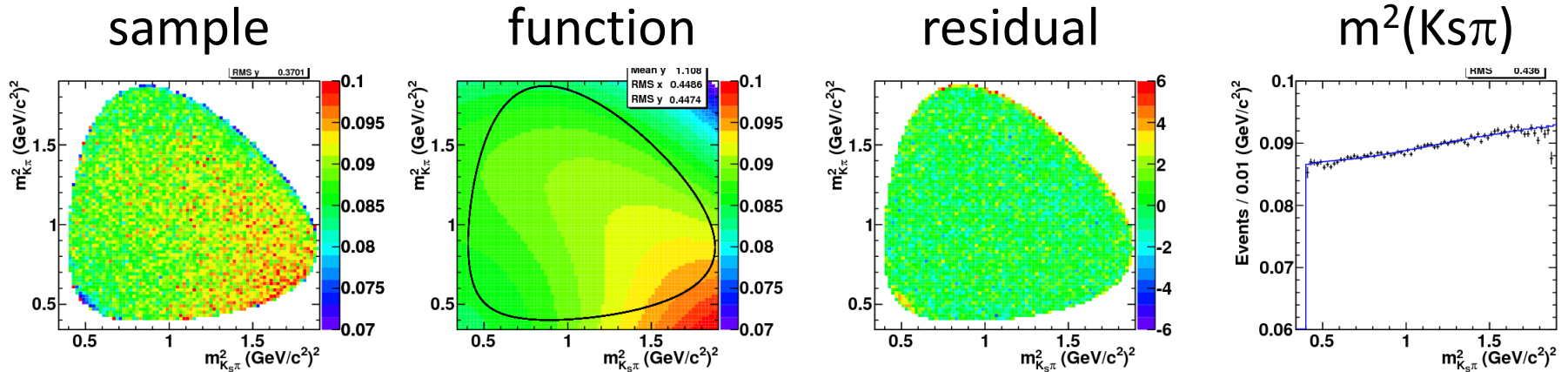


Smoothed distributions describe the background correctly.

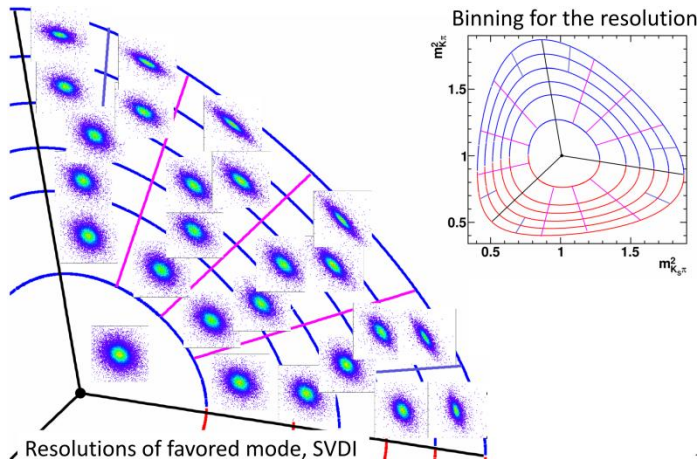
Efficiency & resolution

In the Dalitz fit, the efficiency of the Dalitz plane is considered, and the resolution is convolved.

Efficiency: favored mode, SVD2



Resolution



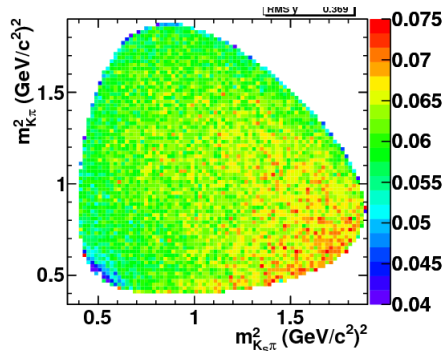
If you want the detail, please refer to backup or my previous talk.

Efficiency

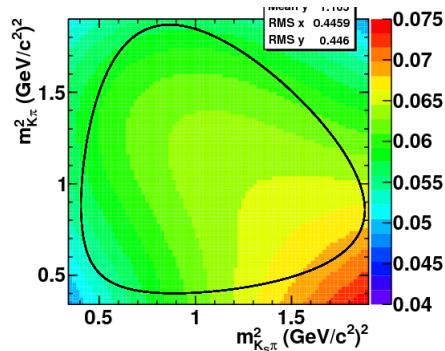
Favored mode, SVD1

Fit function : cubic polynomial.

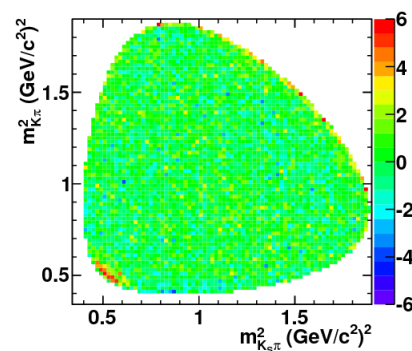
sample



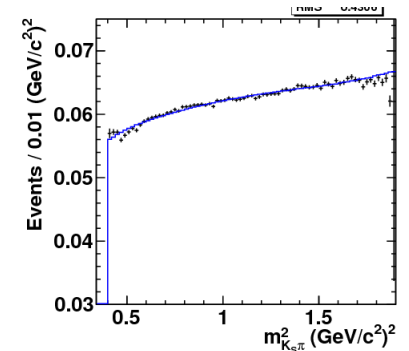
function



residual

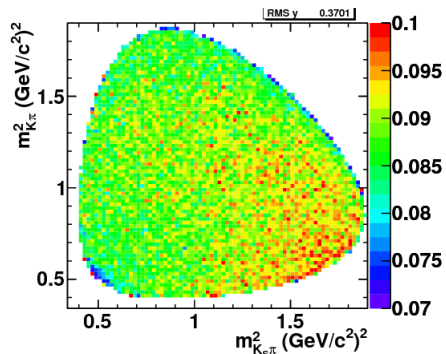


$m^2(K_S\pi)$

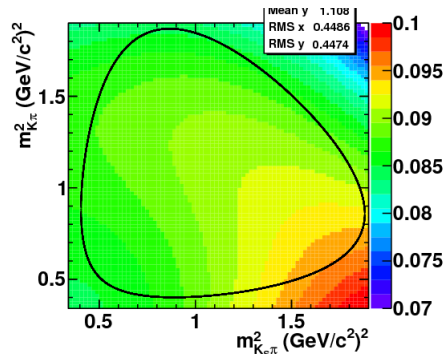


Favored mode, SVD2

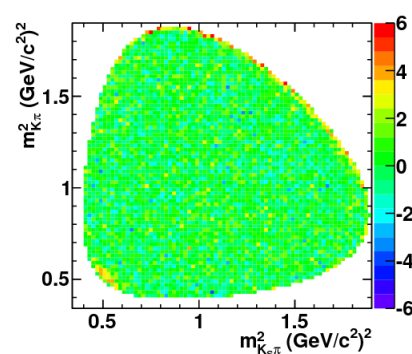
sample



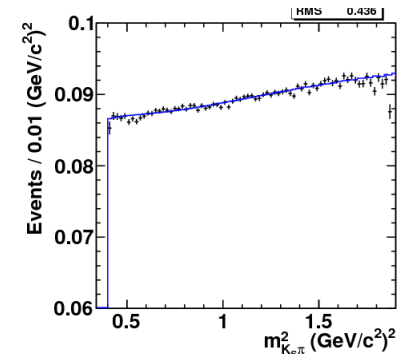
function



residual

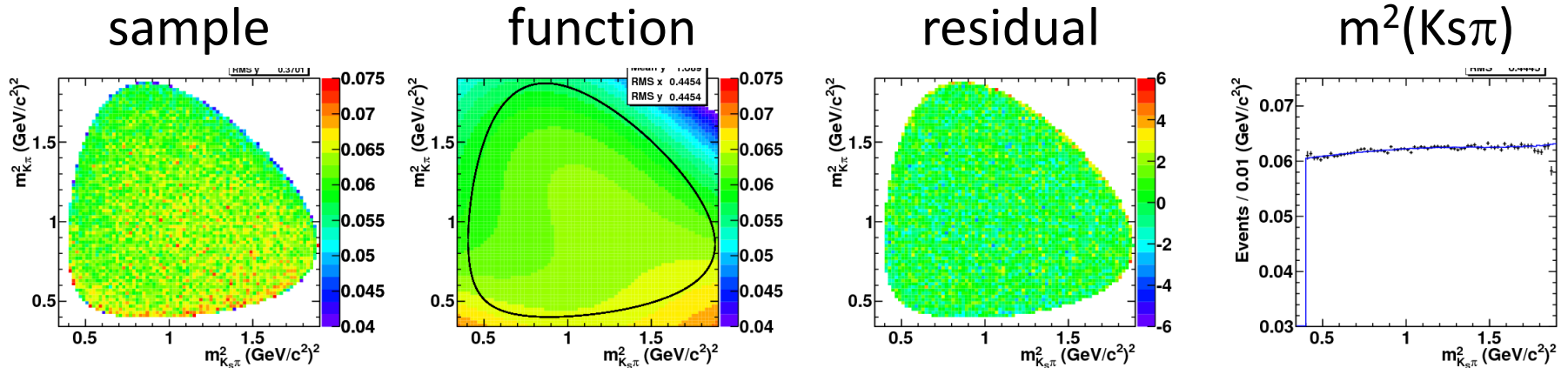


$m^2(K_S\pi)$

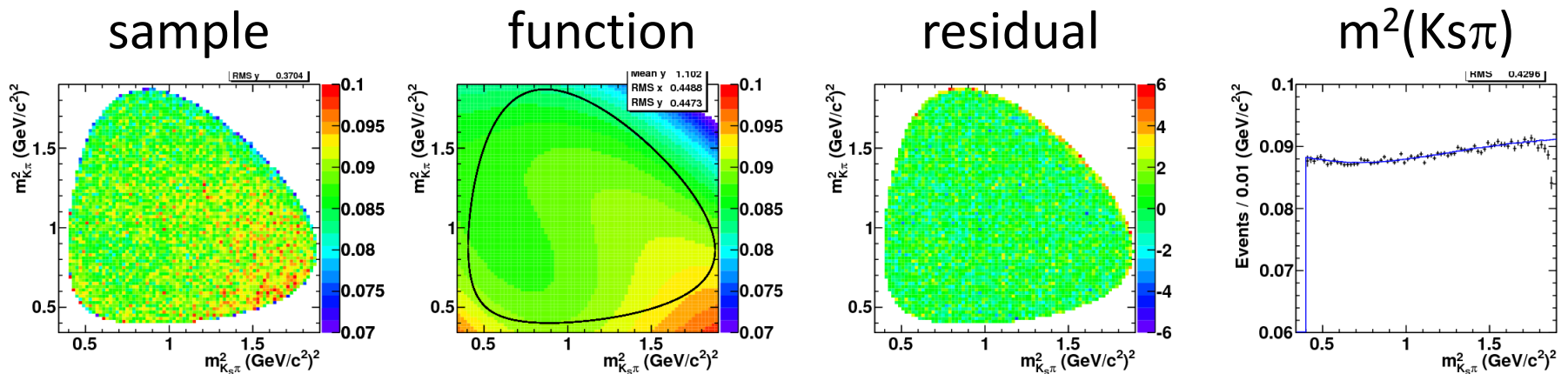


Efficiency

Suppressed mode, SVD1

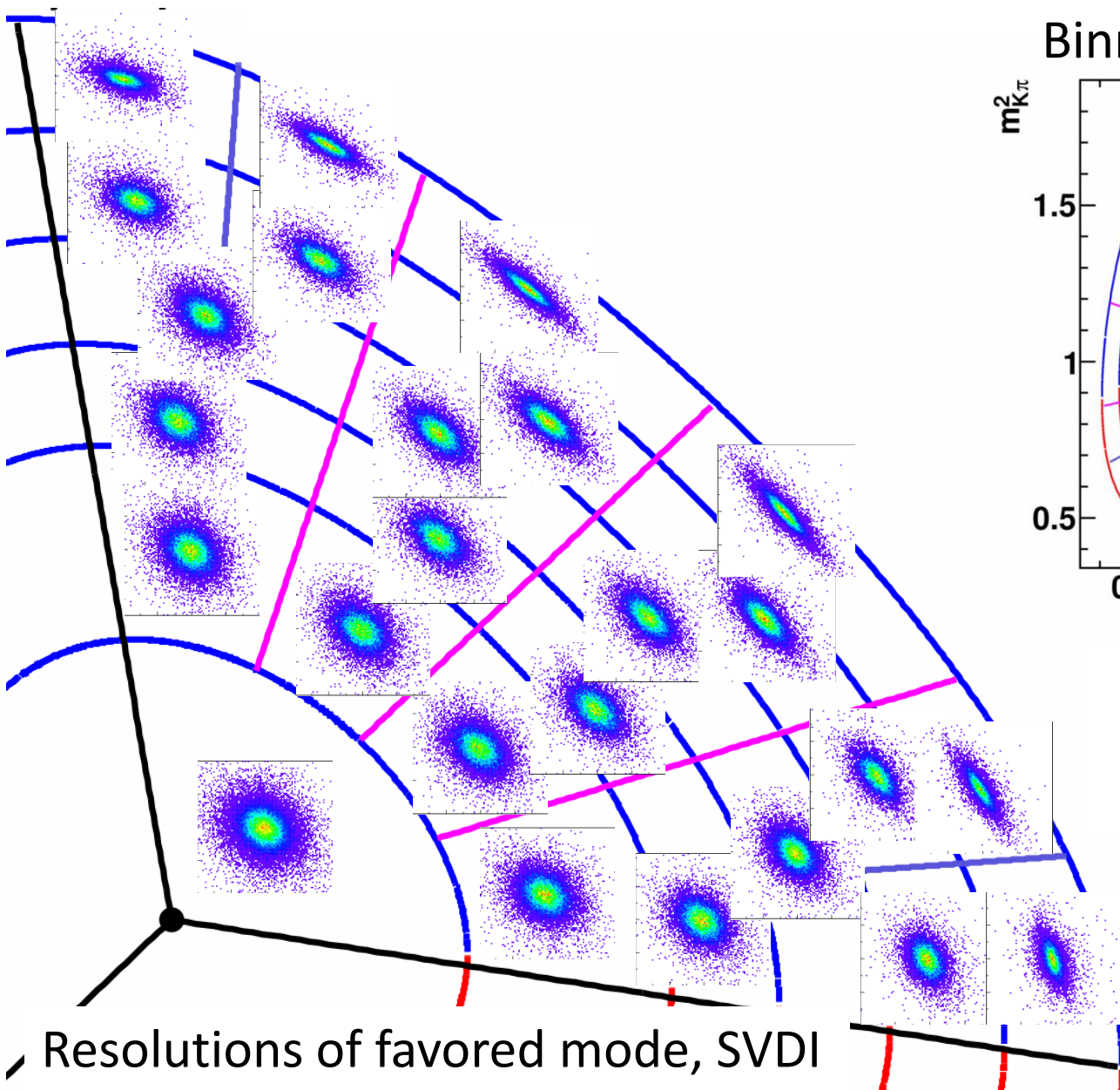


Suppressed mode, SVD2

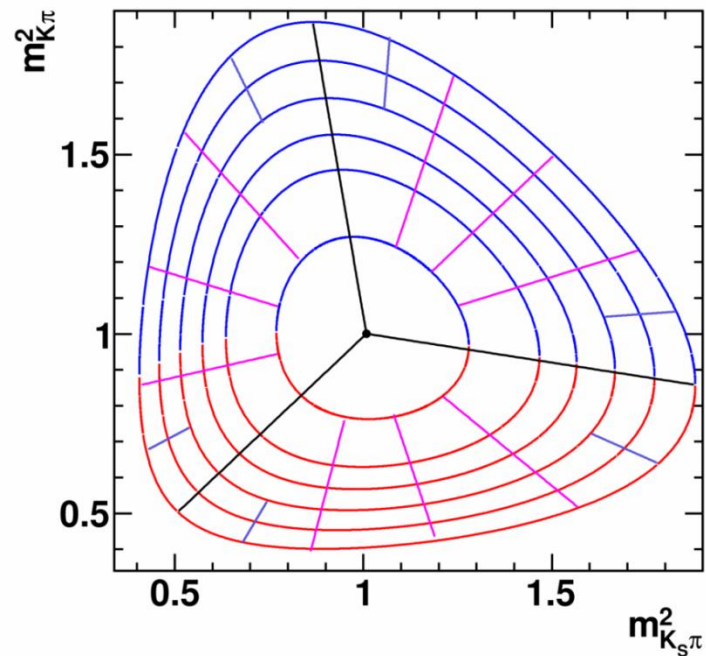


Efficiencies are determined correctly.

Distribution of the resolution

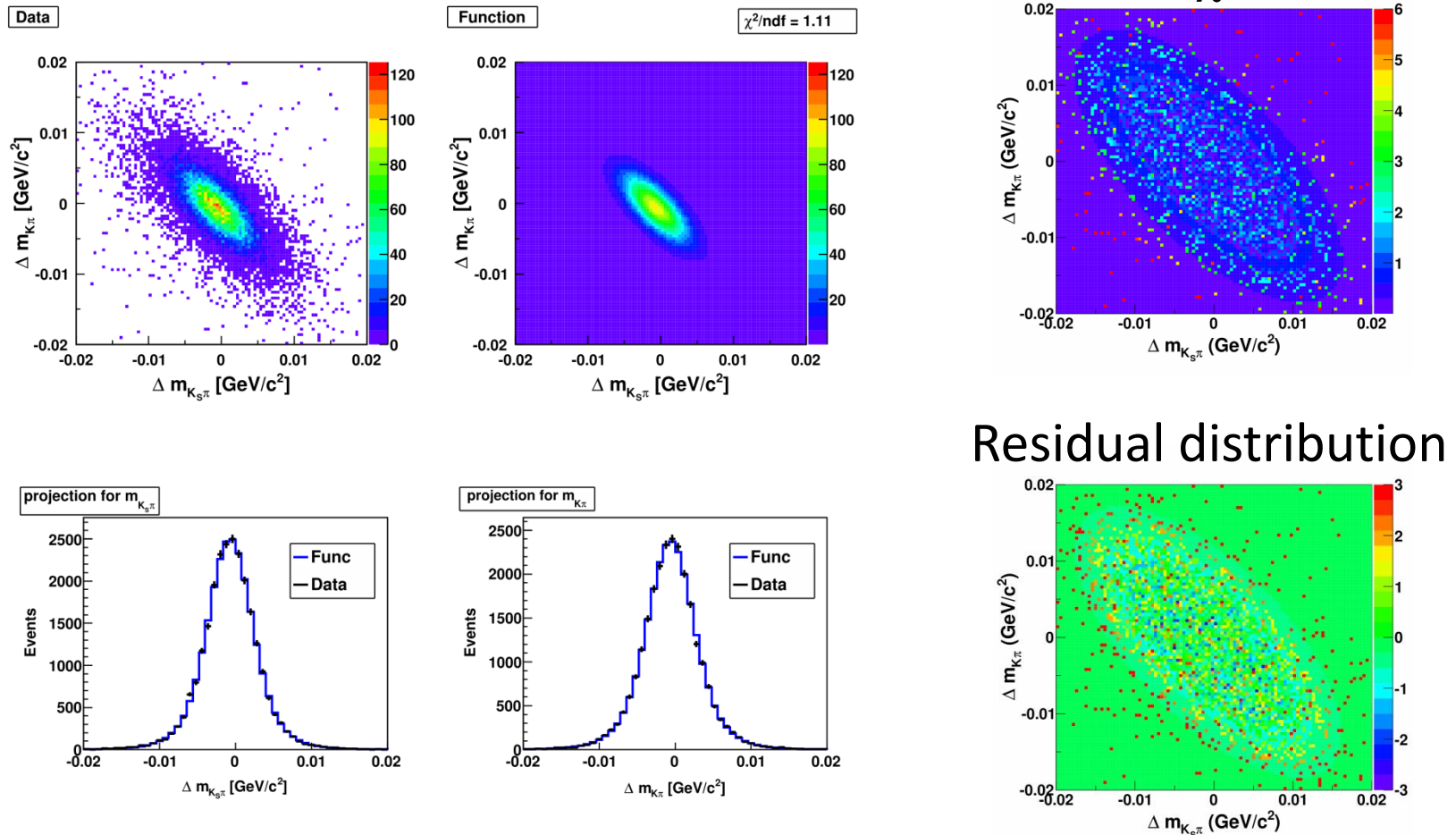


Binning for the resolution



Fitting of resolution

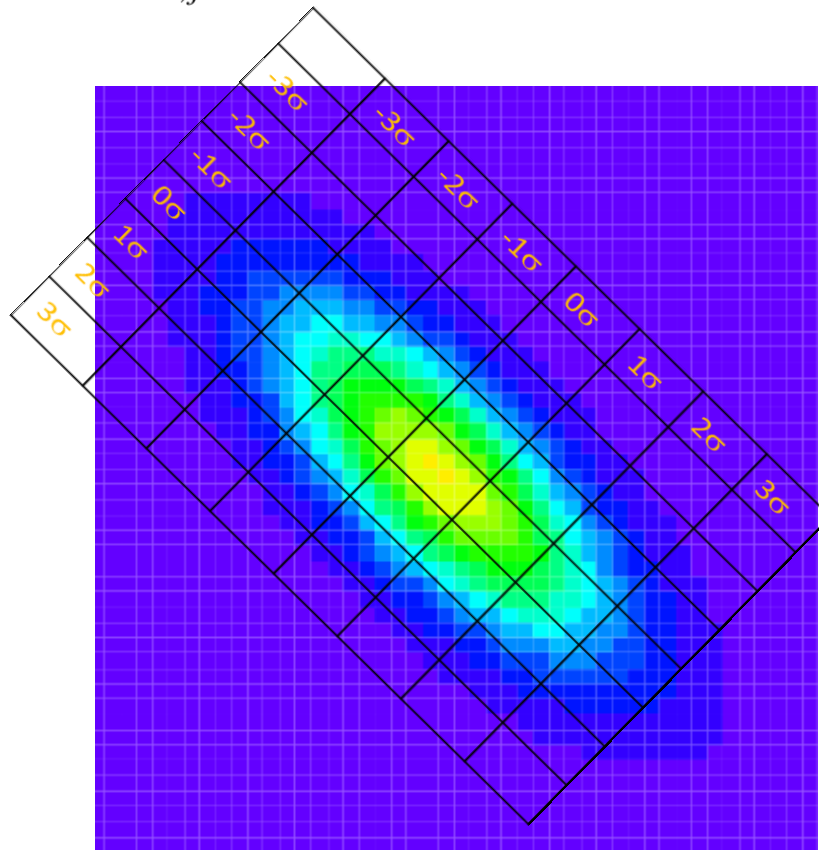
The resolution distributions were fitted by quadropole 2D-Gaussian.



Resolution convolution

1σ is defined as width include 68.26% of the resolution function.
The resolution function is described as binned function which has width of 1σ , and convolved up to the point include 99.74%.

$$pdf_{smeared}(x, y) = \sum_{l=-3, j=-3}^{3,3} pdf(x + l\sigma_x, y + j\sigma_y) \cdot W_{lj} / \sum_{l=-3, j=-3}^{3,3} W_{lj}$$



For B study

Mode definition

Bfav $B^\pm \rightarrow DK^\pm, D \rightarrow K_S K^\pm \pi^\mp$

Bsup $B^\pm \rightarrow DK^\pm, D \rightarrow K_S K^\mp \pi^\pm$

Dfav $D^{*\pm} \rightarrow D\pi^\pm, D \rightarrow K_S K^\mp \pi^\pm$

Dsup $D^{*\pm} \rightarrow D\pi^\pm, D \rightarrow K_S K^\pm \pi^\mp$

PDFs

$$\text{Bfav} \quad A \left[B^\pm \rightarrow K^\pm (K_S K^\pm \pi^\mp)_D \right] = |A_B A_D| \left[1 + r_B r_D e^{i(\delta_B + \delta_D \pm \phi_3)} \right]$$

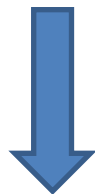
$$\text{Bsup} \quad A \left[B^\pm \rightarrow K^\pm (K_S K^\mp \pi^\pm)_D \right] = |A_B A_D| e^{i\delta_D} \left[r_D + r_B e^{i(\delta_B - \delta_D \pm \phi_3)} \right]$$

$$r_B = \left| \frac{\overline{A_B}}{A_B} \right| = \left| \frac{A(B^- \rightarrow \overline{D^0} K^-)}{A(B^- \rightarrow D^0 K^-)} \right|, \quad r_D = \left| \frac{\overline{A_D}}{A_D} \right| = \left| \frac{A(\overline{D^0} \rightarrow K_S K^- \pi^+)}{A(D^0 \rightarrow K_S K^- \pi^+)} \right|$$

$$PDF_{Bfav\pm} = N_{norm} |A_D|^2 \left[1 + r_B^2 r_D^2 + 2r_B r_D \cos(\delta_B + \delta_D \pm \phi_3) \right]$$

$$PDF_{Bsup\pm} = N_{norm} |A_D|^2 \left[r_B^2 + r_D^2 + 2r_B r_D \cos(\delta_B - \delta_D \pm \phi_3) \right]$$

$|A_B|^2$ はダリッツ平面に依存しないので N_{norm} に吸収される。



$$x_\pm \equiv r_B \cos(\delta_B \pm \phi_3)$$

$$y_\pm \equiv r_B \sin(\delta_B \pm \phi_3)$$

$$PDF_{Bfav\pm} = N_{norm} |A_D|^2 \left[1 + (x_\pm^2 + y_\pm^2) r_D^2 + 2x_\pm r_D \cos \delta_D - 2y_\pm r_D \sin \delta_D \right]$$

$$PDF_{Bsup\pm} = N_{norm} |A_D|^2 \left[r_D^2 + x_\pm^2 + y_\pm^2 + 2x_\pm r_D \cos \delta_D + 2y_\pm r_D \sin \delta_D \right]$$

Background components

B → Dπ

The background from $B^\pm \rightarrow D\pi^\pm$ decays.

B → K*KK

The background from $B^\pm \rightarrow K^*KK$ decays.

Suppressed mode

	PDG	Decay.dec
$B^+ \rightarrow K^{*+}K^+K^-$	3.6×10^{-5} (include $K^*\phi$)	3.13×10^{-5}
$B^+ \rightarrow K^{*+}\phi$	1.0×10^{-5}	1.0×10^{-5}
$B^+ \rightarrow K^0\overline{K}^{*0}K^+$	—————	1.5×10^{-5}
$B^+ \rightarrow K^{*-}K^+K^+$	—————	1.5×10^{-5}
$B^+ \rightarrow \overline{K}^0K^{*0}K^+$	—————	1.5×10^{-5}

Favored mode

- These BGs peak like signal in the ΔE - m_{bc} plane.
- The fractions of Decay.dec are used in this analysis.

BB

Other background from BB.

qq

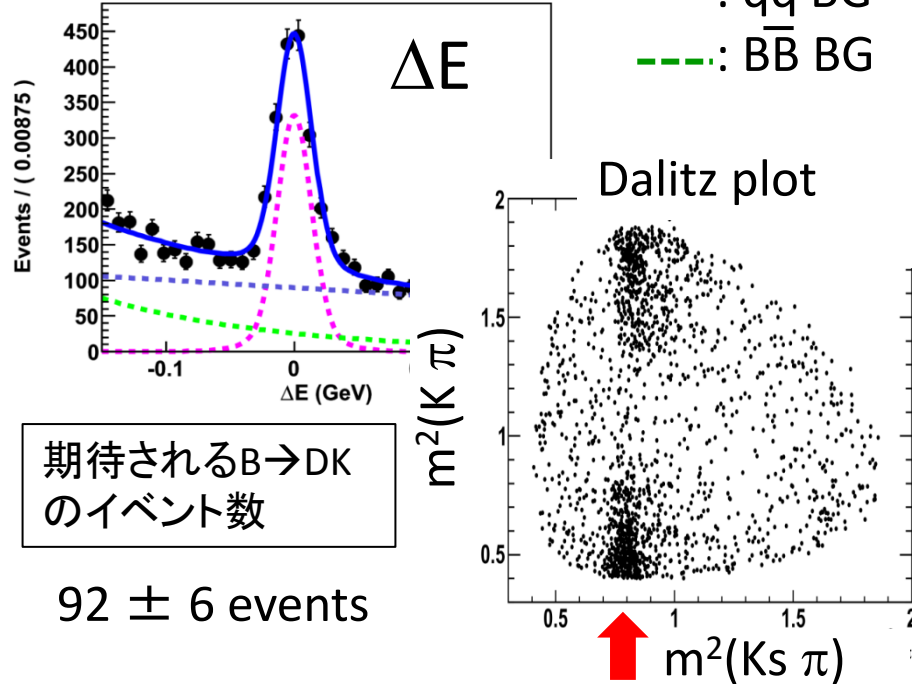
The background from qq.

Control sample : $B \rightarrow D\pi, D \rightarrow KsK\pi$

$B^- \rightarrow D\pi^-, D \rightarrow KsK^-\pi^+$

—: total pdf
 - - -: signal
 - - -: $q\bar{q}$ BG
 - - -: $B\bar{B}$ BG

Signal : $1359 \pm 44(\text{stat})$

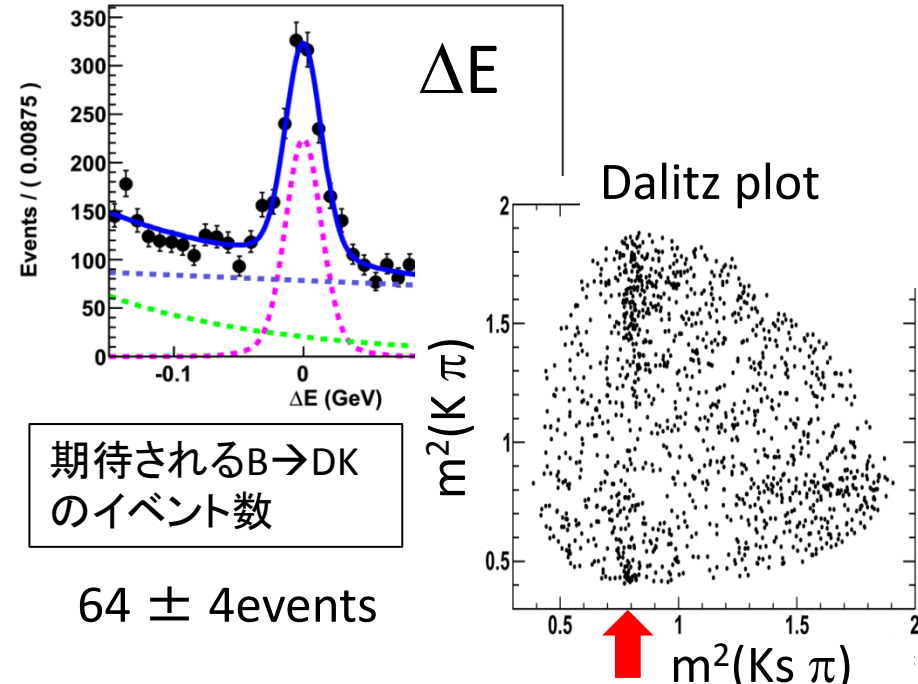


期待される $B \rightarrow DK$
 のイベント数

92 ± 6 events

$B^- \rightarrow D\pi^-, D \rightarrow KsK^+\pi^-$

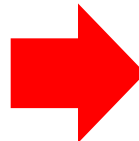
Signal : $946 \pm 38(\text{stat})$



期待される $B \rightarrow DK$
 のイベント数

64 ± 4 events

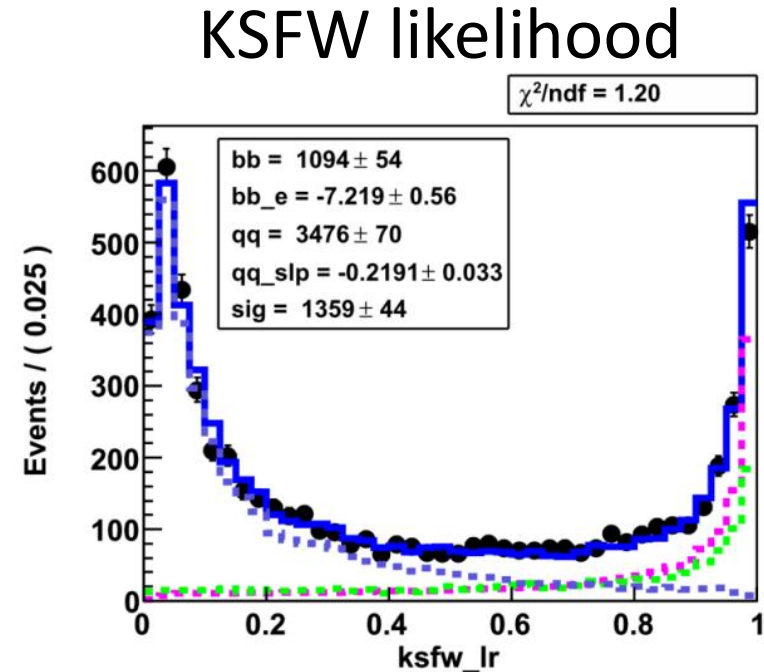
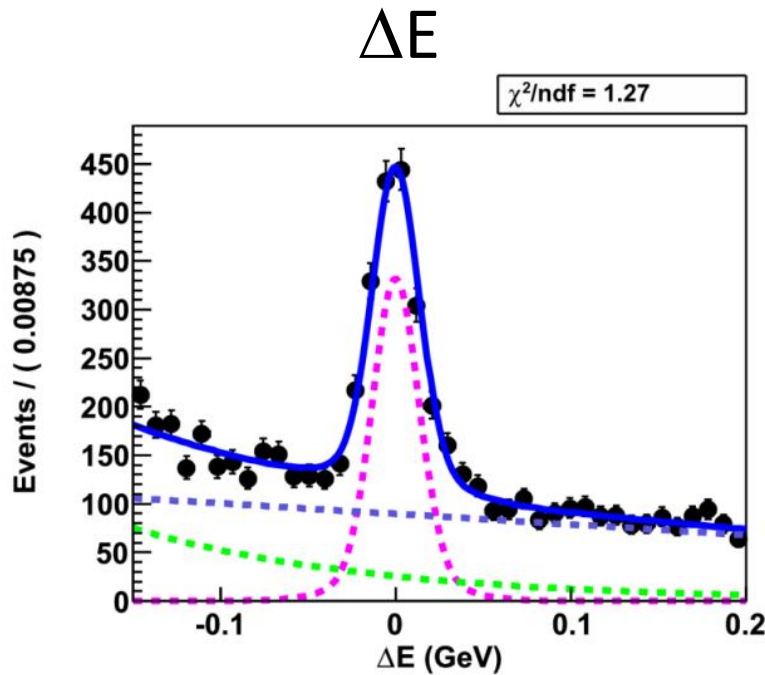
Dalitz plot 上の複雑な構造が見て取れる



Dalitz plot のフィットによって各共鳴の情報を得ることができる

Control sample : $B^- \rightarrow D \pi^-$, $D \rightarrow K_s K^- \pi^+$

Projection for each axis

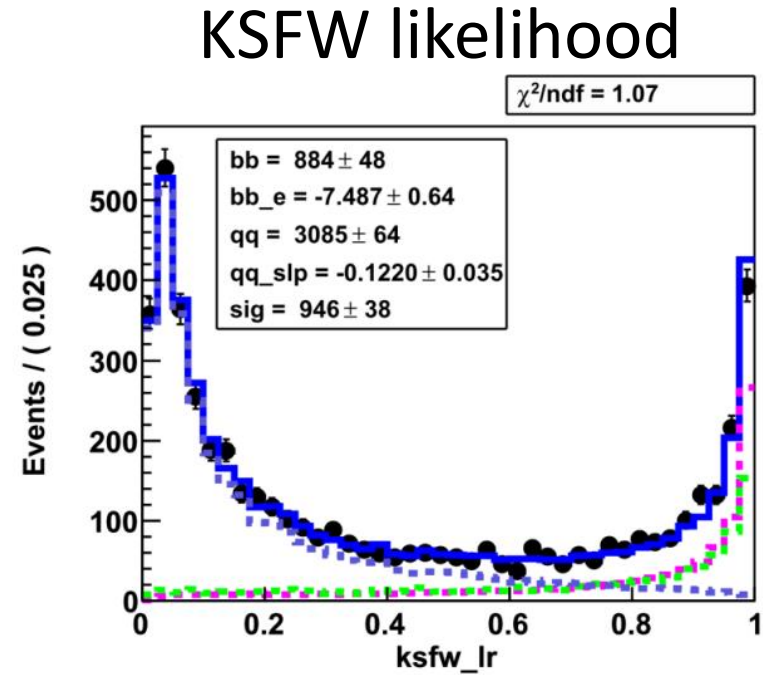
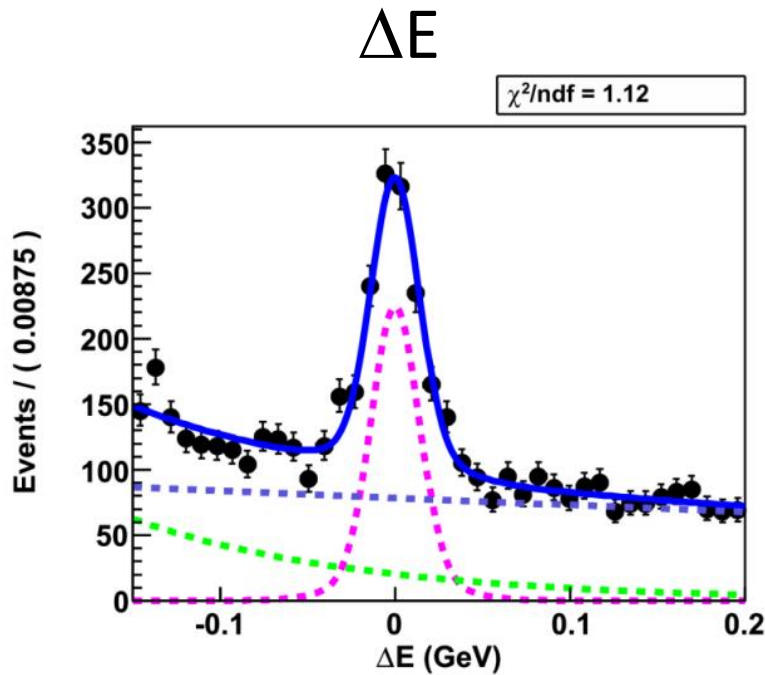


Blue solid : total pdf, Magenta dashed : signal
Blue dashed : $q\bar{q}$ BG, Green dashed : $B\bar{B}$ BG

Signal events : $1359 \pm 44(\text{stat})$

Control sample : $B^- \rightarrow D \pi^-$, $D \rightarrow K_s K^- \pi^+$

Projection for each axis



Blue solid : total pdf, Magenta dashed : signal
Blue dashed : $q\bar{q}$ BG, Green dashed : $B\bar{B}$ BG

Signal events : $946 \pm 38(\text{stat})$

期待される $B \rightarrow DK$ イベントの数

$B^- \rightarrow D\pi^-, D \rightarrow K_s K^- \pi^+ : 1,359 \pm 44(\text{stat}) \text{ events}$

$B^- \rightarrow D\pi^-, D \rightarrow K_s K^+ \pi^- : 946 \pm 38(\text{stat}) \text{ events}$

$B \rightarrow DK, D \rightarrow K\pi$ の解析によると、

(Y. Horii, K. Trabelsi, H. Yamamoto et al., PRD 78, 071901(R) (2008))

$$\frac{\text{Br}(B^- \rightarrow DK^-)}{\text{Br}(B^- \rightarrow D\pi^-)} = [6.77 \pm 0.23(\text{stat}) \pm 0.30(\text{syst})] \times 10^{-2}$$

期待される $B \rightarrow DK, D \rightarrow K_s K\pi$ イベントの数は、

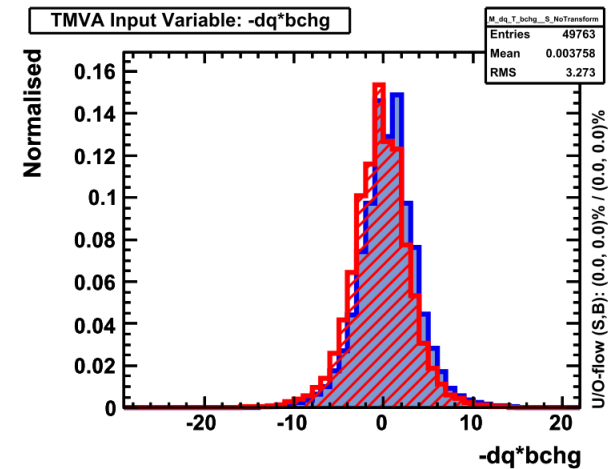
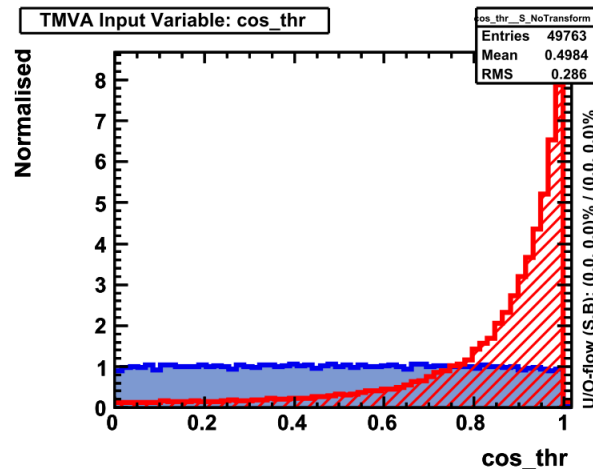
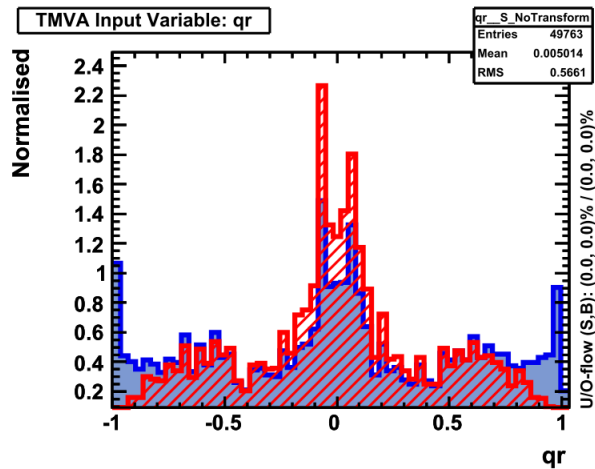
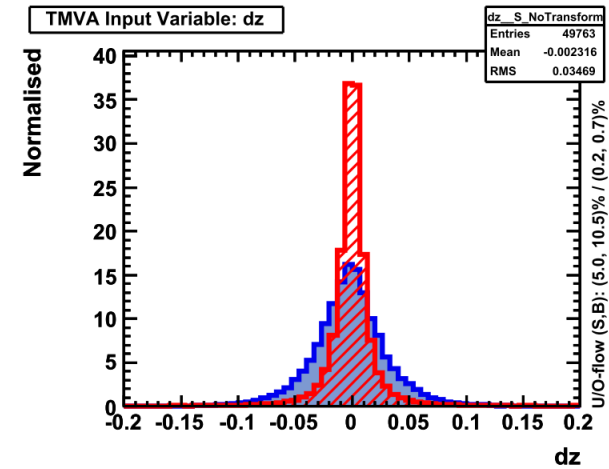
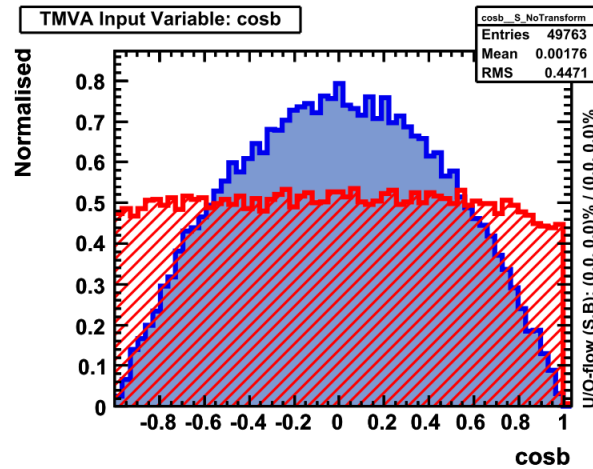
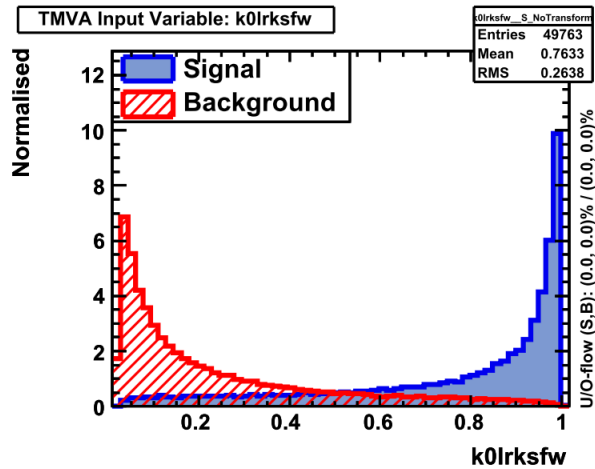
$B^- \rightarrow DK^-, D \rightarrow K_s K^- \pi^+ : 92 \pm 6 \text{ events}$

$B^- \rightarrow DK^-, D \rightarrow K_s K^+ \pi^- : 64 \pm 4 \text{ events}$

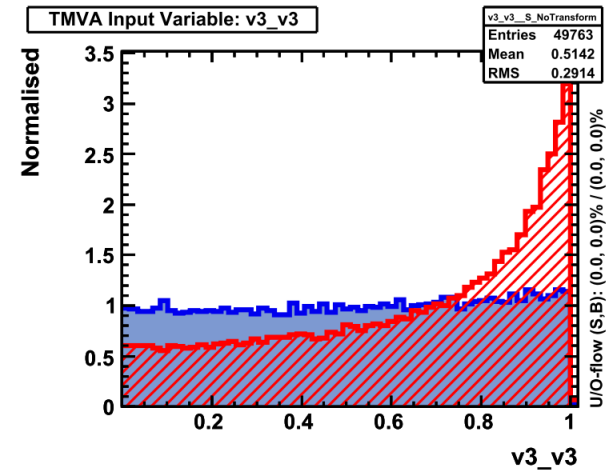
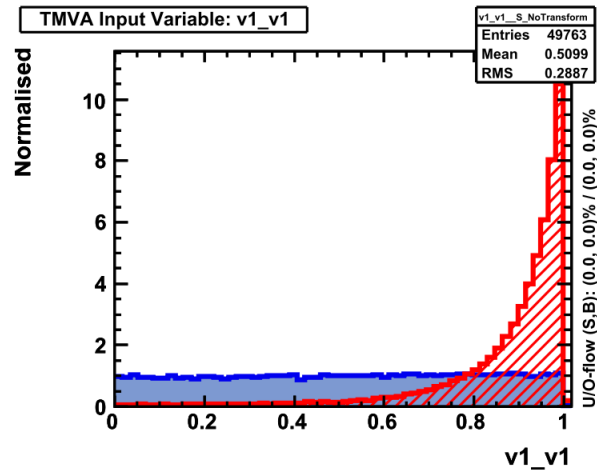
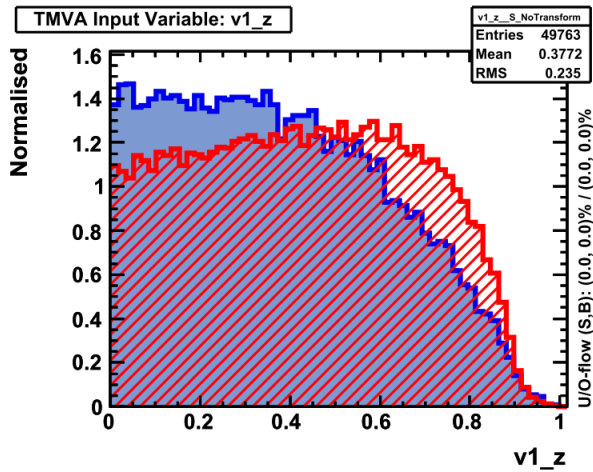
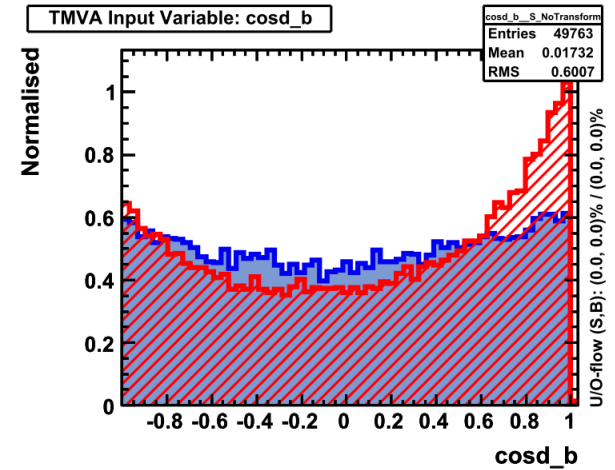
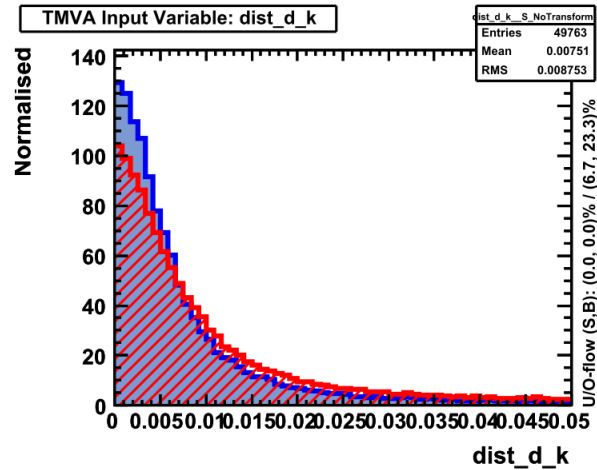
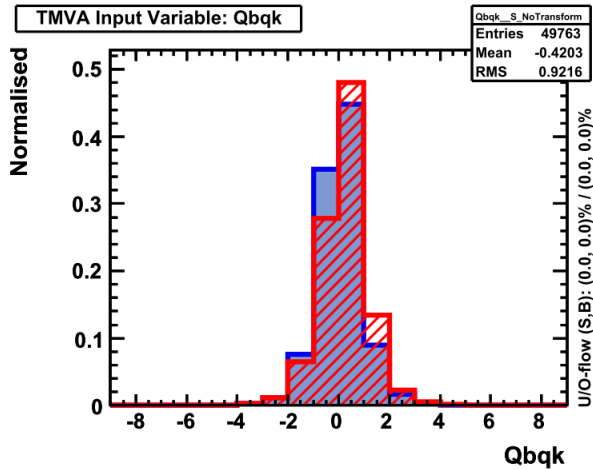
NB variables

14 variables are used as NB input variables.

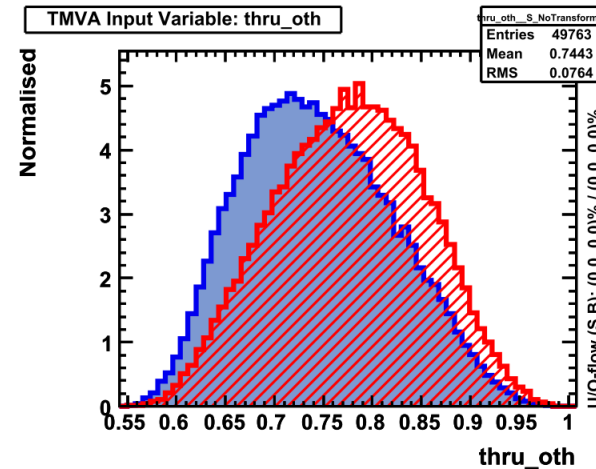
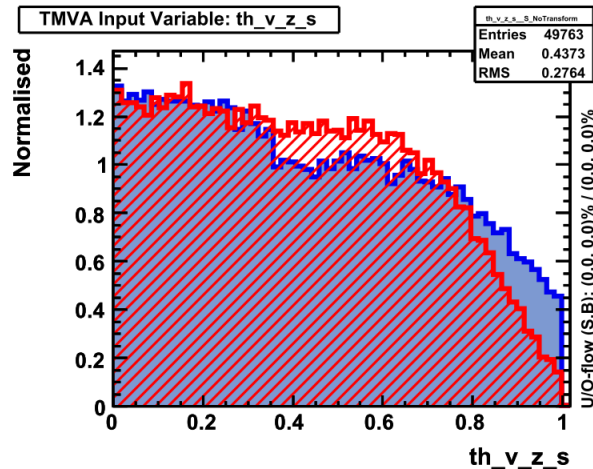
(Each distribution of variables is shown in the backup.)



NB variables



NB variables

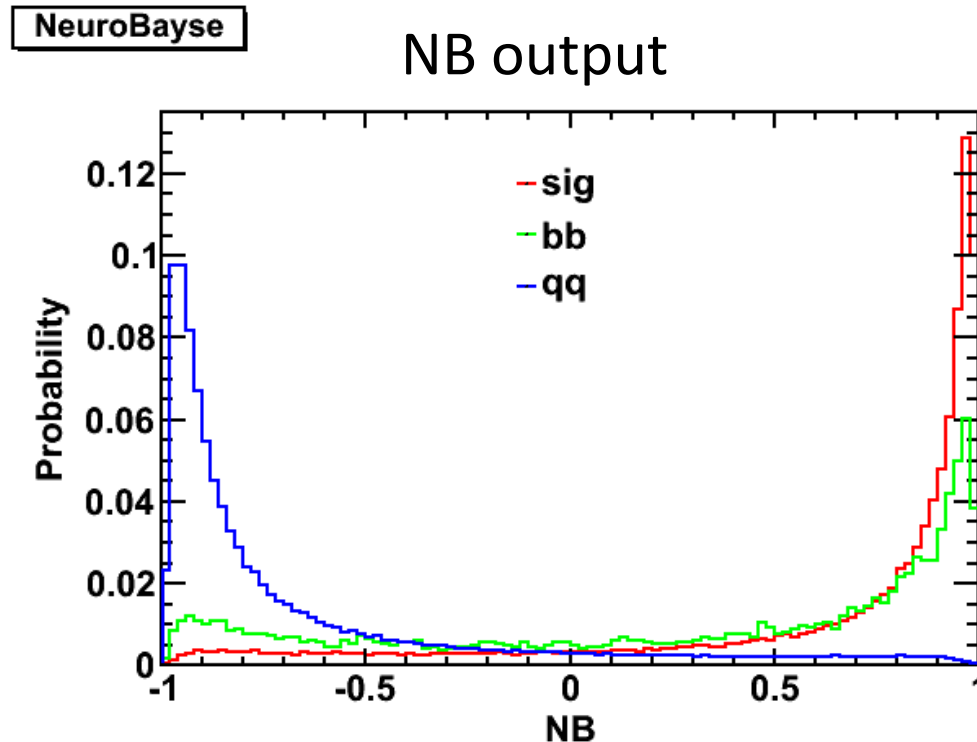


These variables have difference between signal and qq background.

NeuroBayes is trained using these variables.

NeuroBayes output

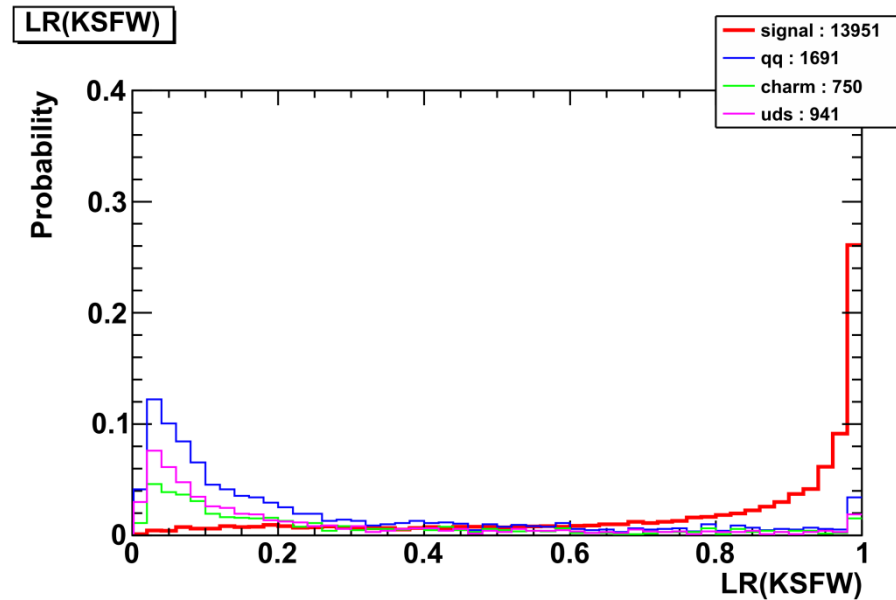
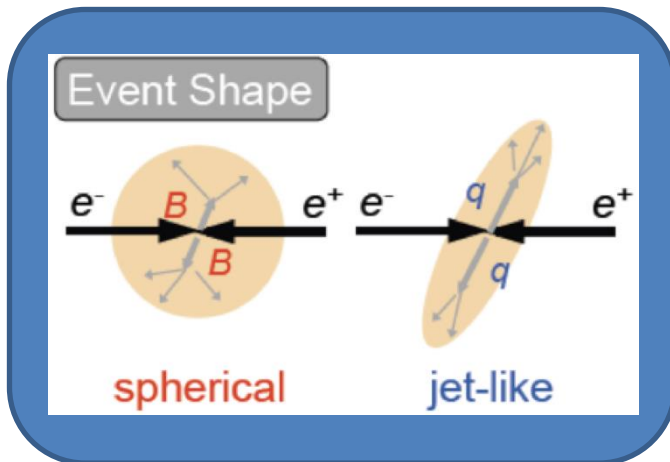
NB was trained using $\sim 100,000$ signal events and qq background events.



Signal events are separated from qq background.

Likelihood Ratio (KSFW)

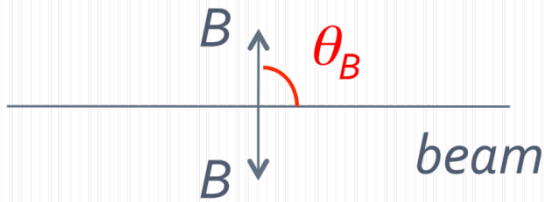
- Likelihood Ratio of KSFW.
- I used rooKSFW package.



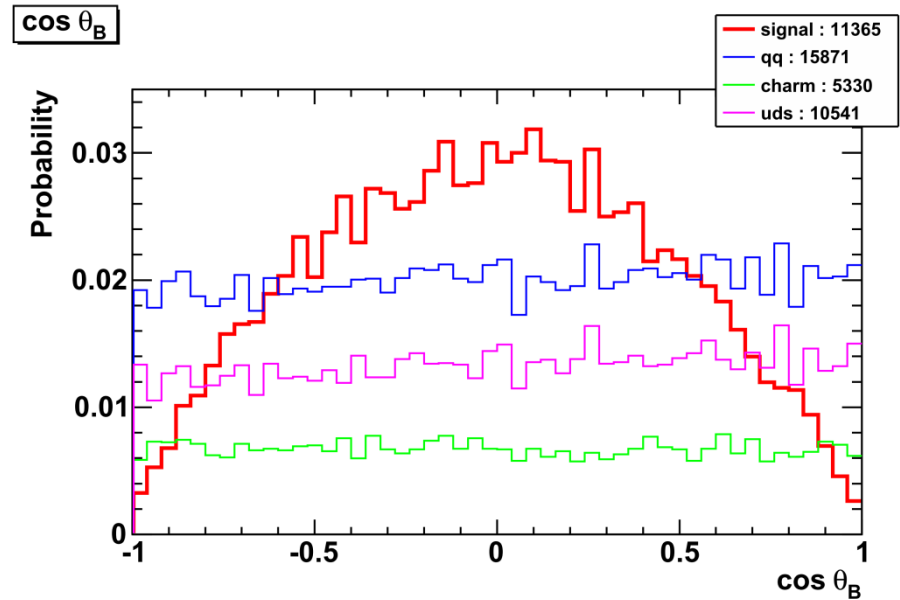
Red : signal

Blue : qq (charm + uds)

$\cos\theta_B$



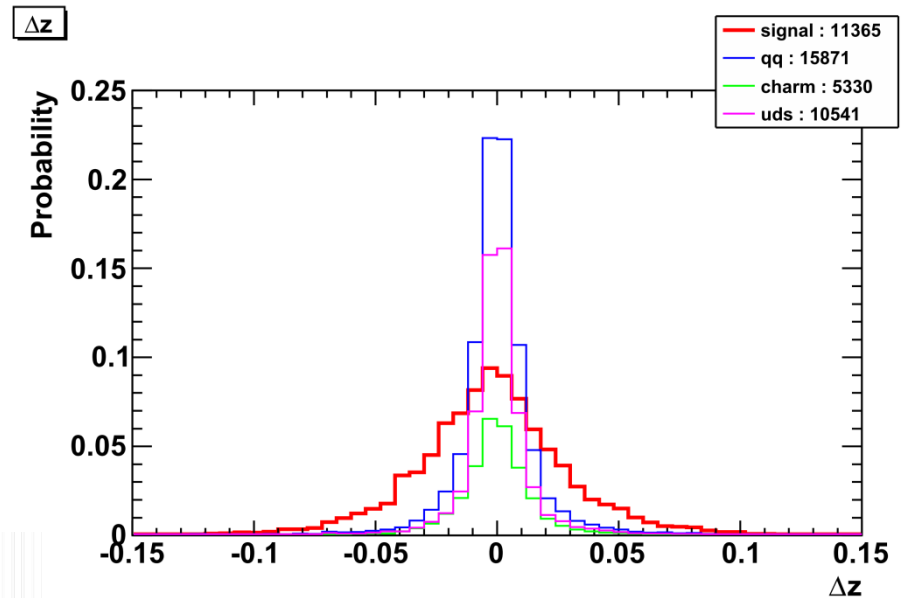
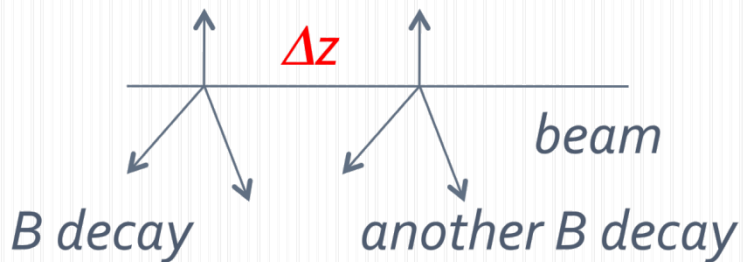
- Angle of B-flight and beam axes in CM frame.
- Signal : $\sin^2\theta_B$.
- BG : flat.



Red : signal
Blue : qq (charm + uds)

Δz

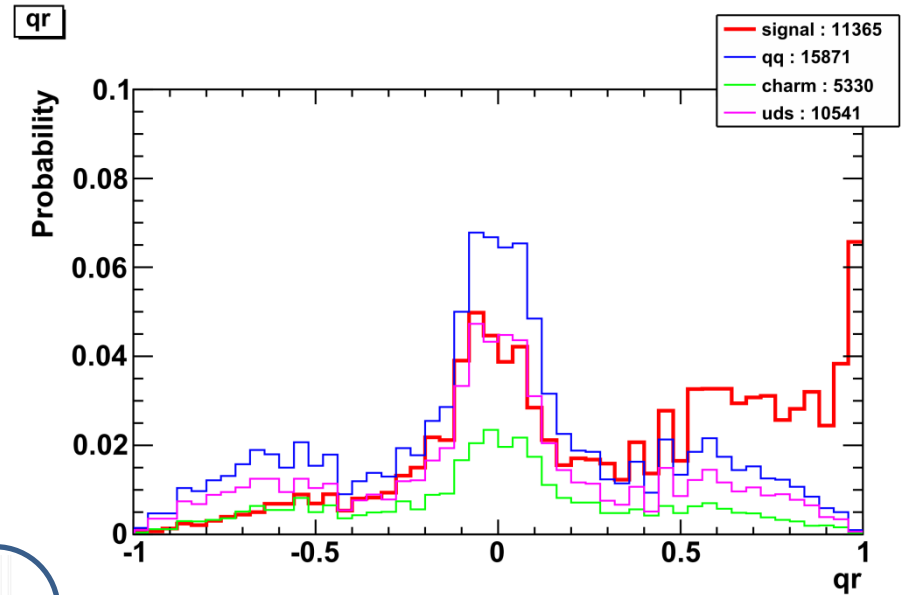
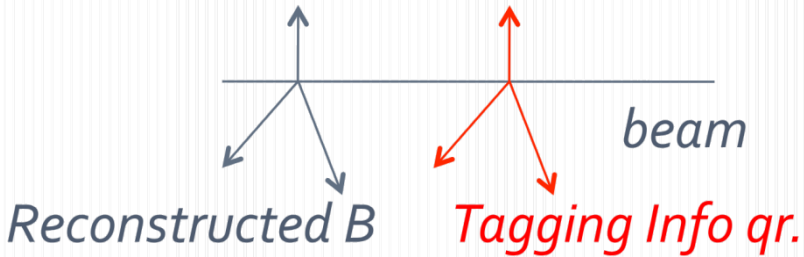
- Distance of reconstructed and tag-side B vertices in z axis.
- **Signal** : can be larger.
- **BG** : smaller.



Red : signal
Blue : qq (charm + uds)

qr

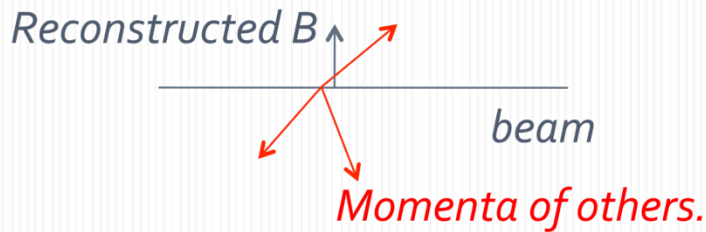
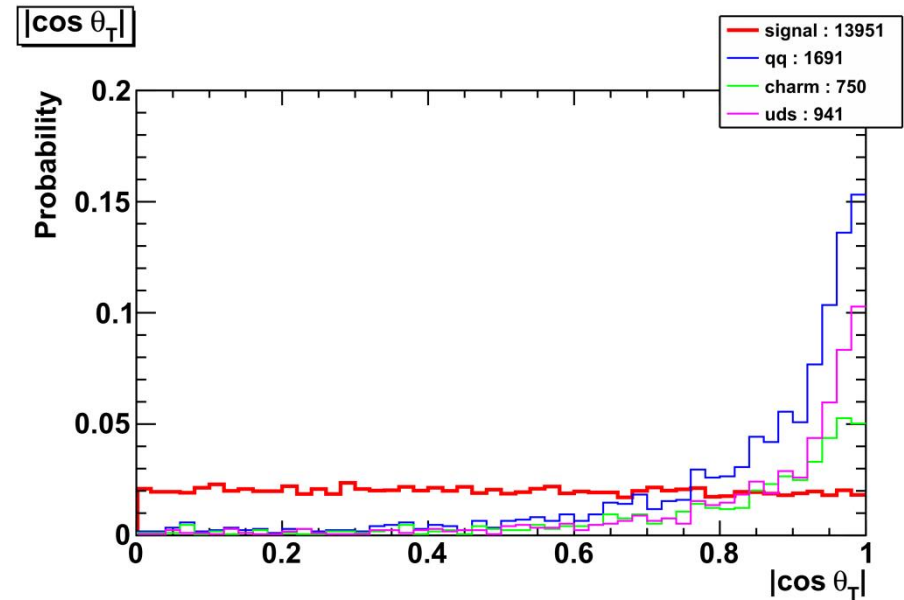
- Information for the tag side.
 - q : b-flavor.
 - r : quality of the tagging.
- Signal : events near 1 or -1.
- BG : small amount of events near 1 or -1.



Red : signal
Blue : qq (charm + uds)

$|\cos\theta_{\text{tht}}|$

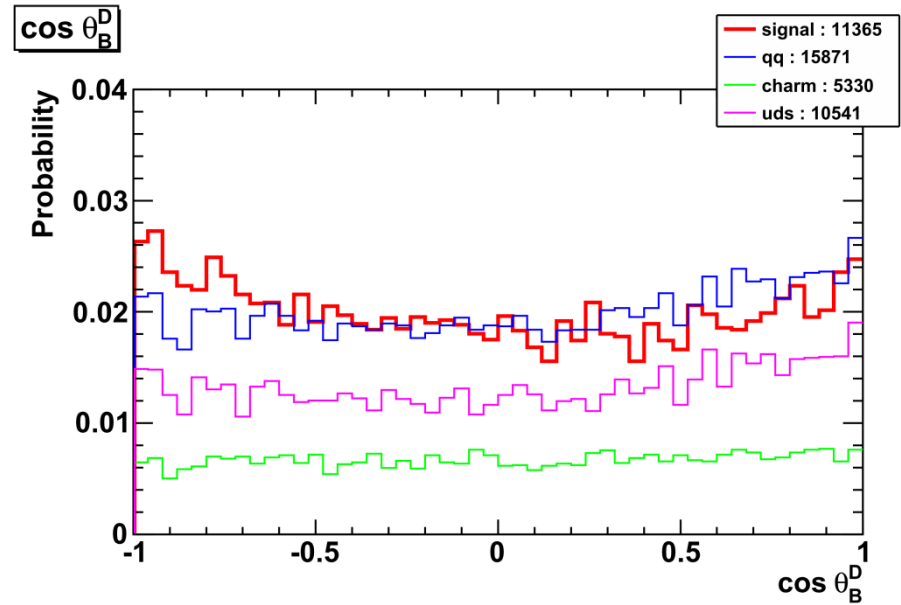
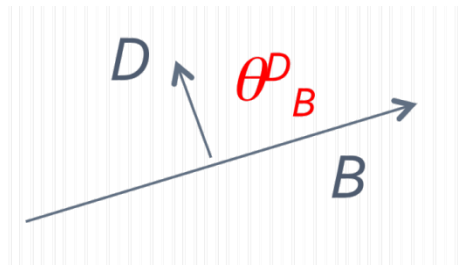
- Absolute value of $\cos\theta_{\text{T}}$, where θ_{T} is the angle in CM frame between thrust axes of the candidate and the detected remainder of the event.
- **Signal : flat.**
- **BG : strongly peaked at 1.**



Red : signal
Blue : qq (charm + uds)

$$\cos\theta_B^D$$

- Cosine of θ_B^D , where θ_B^D is the decay angle in $B \rightarrow DK$.

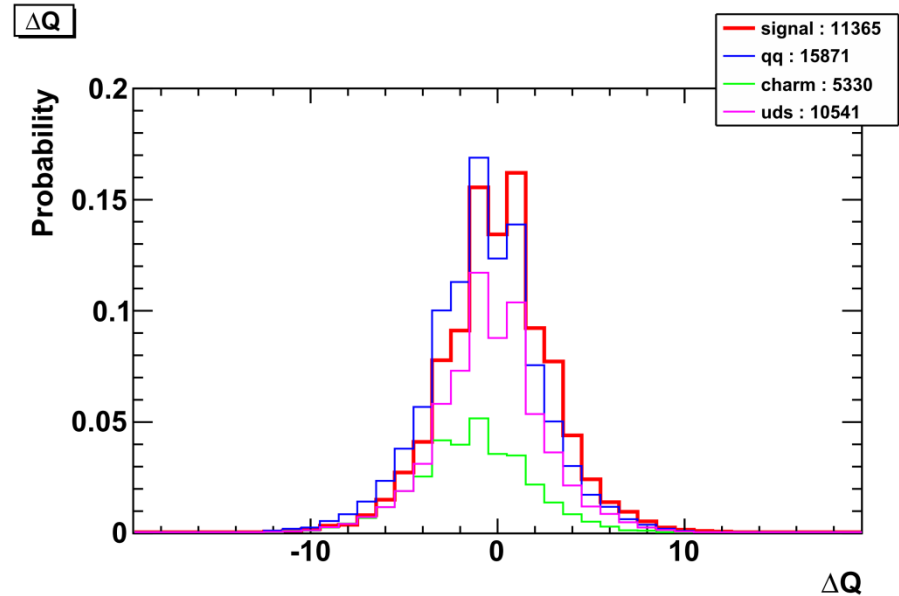


Red : signal

Blue : qq (charm + uds)

ΔQ

- The charge difference between the sum of the charges of tracks in the D hemisphere and the sum of the charges of tracks in the opposite hemisphere excluding the tracks used in the reconstruction of B

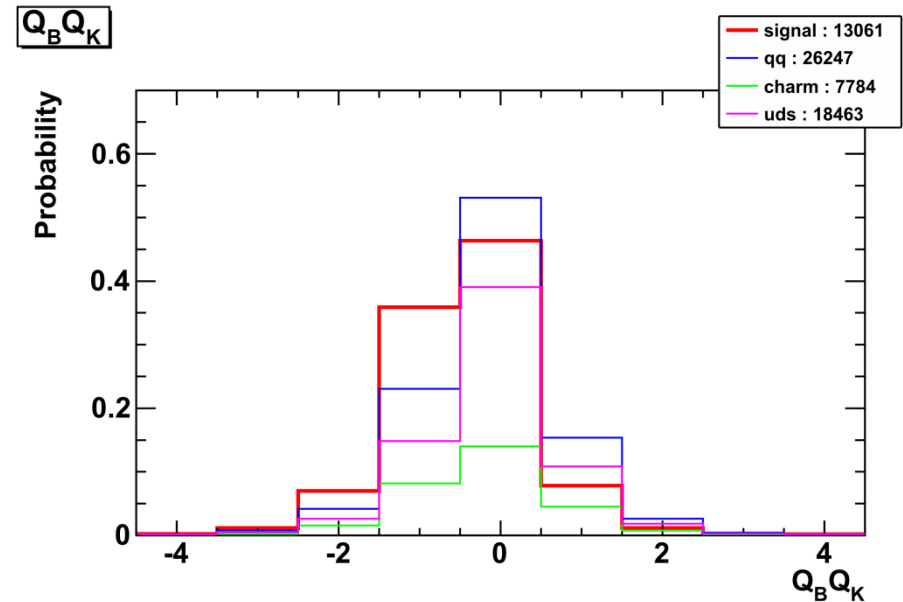


Red : signal

Blue : qq (charm + uds)

$$Q_B Q_K$$

- The product of the charge of B candidate and the sum of the charges of all kaons not in the reconstructed B.

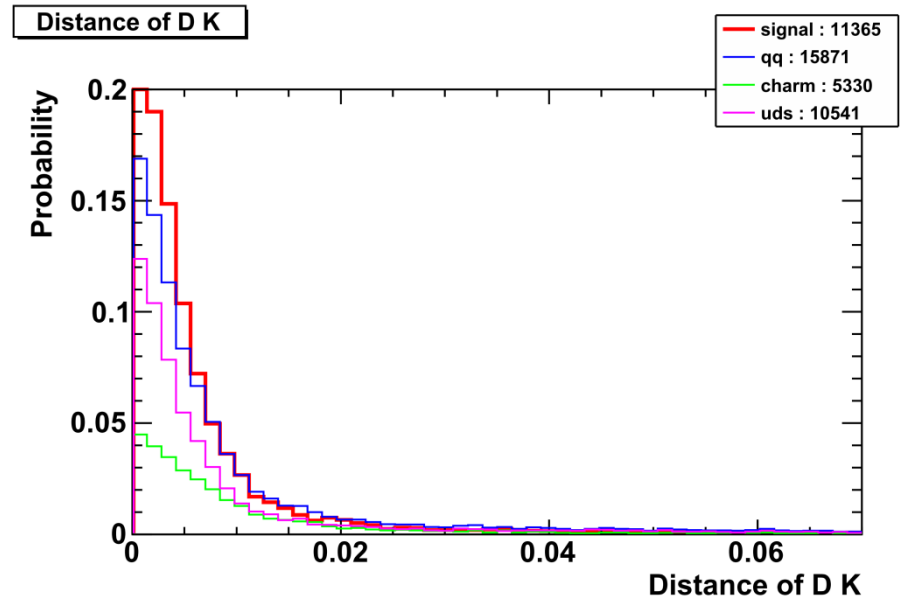
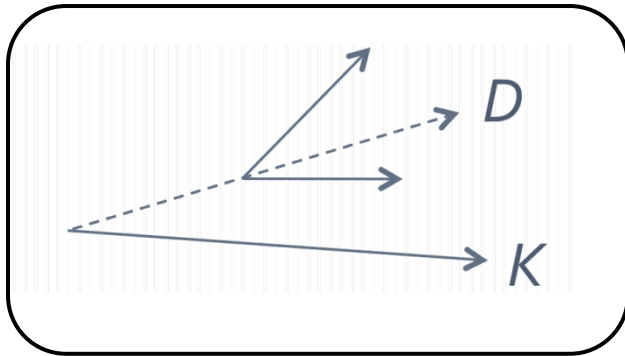


Red : signal

Blue : qq (charm + uds)

Distance of tracks of K/D

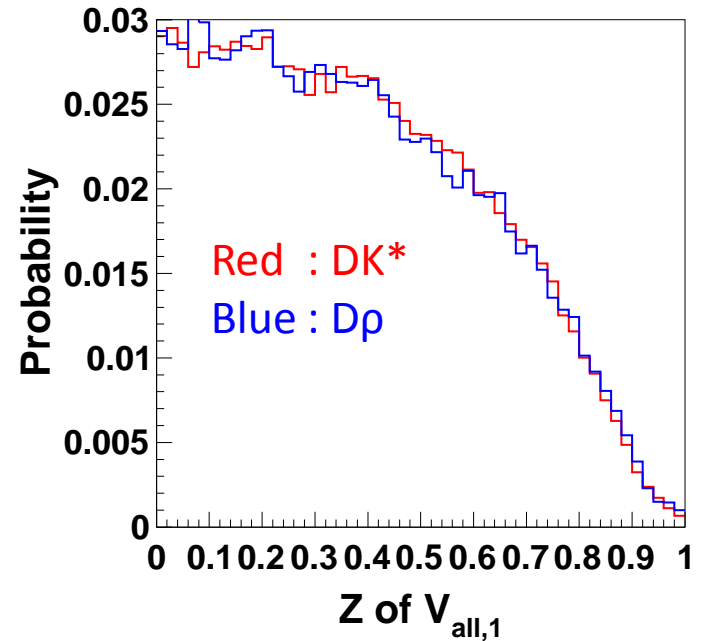
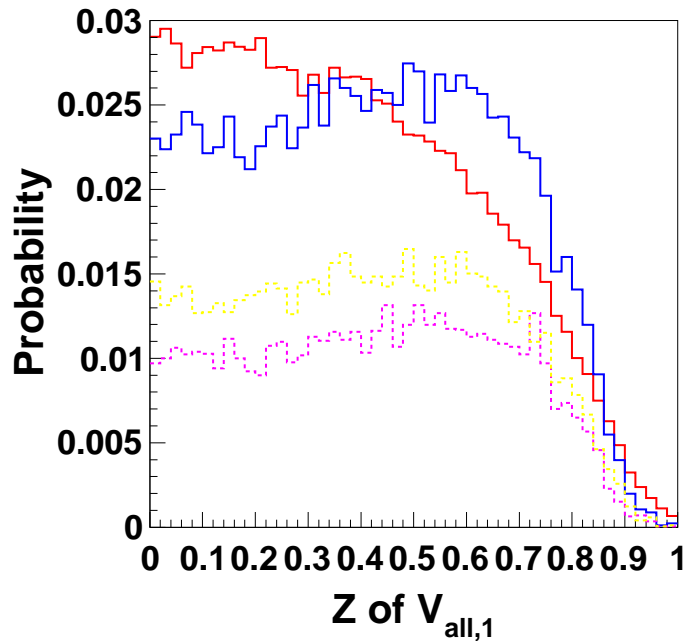
- The distance of closest approach between the prompt K track and the trajectory of the D.
- **Signal** : consistent with 0.
- **BG** : can be larger in charm events.



Red : signal

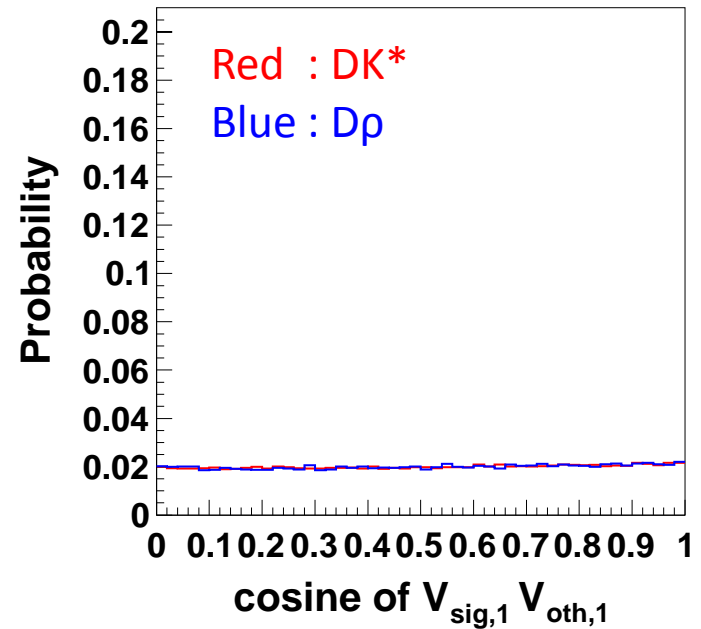
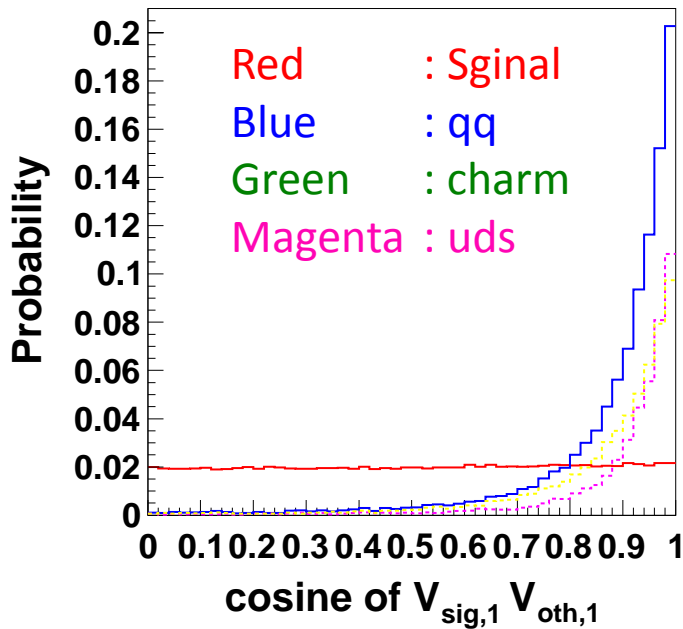
Blue : qq (charm + uds)

v1_z



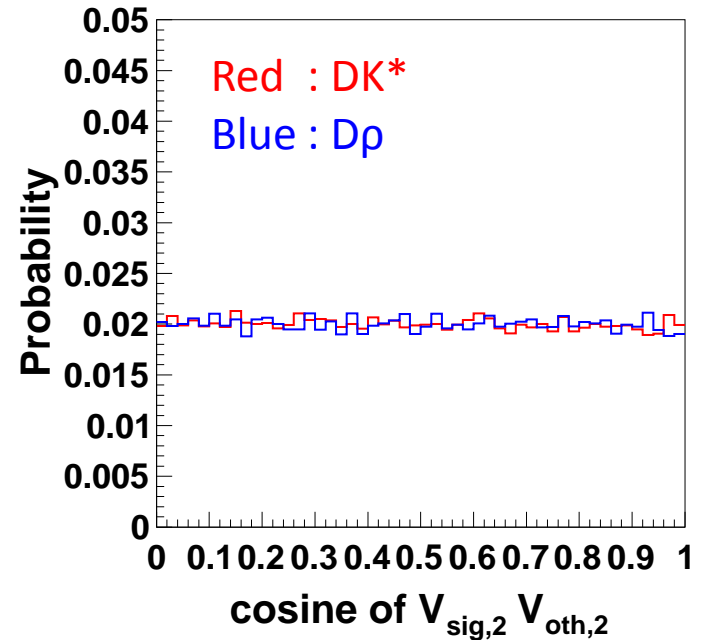
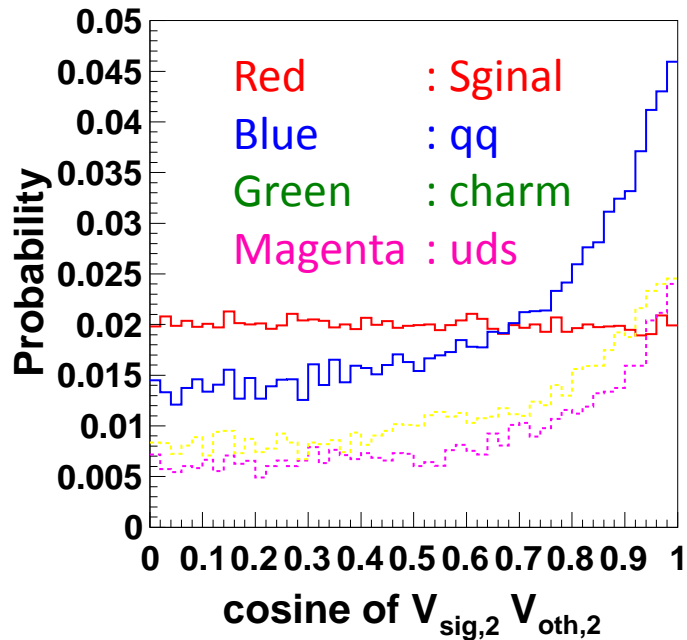
- $v1_z$
 - Z component of sphericity vector 1 from all tracks. qq distribution tend to be ~ 1 , because qq jet tend to be toward beam axis.

v1_v1



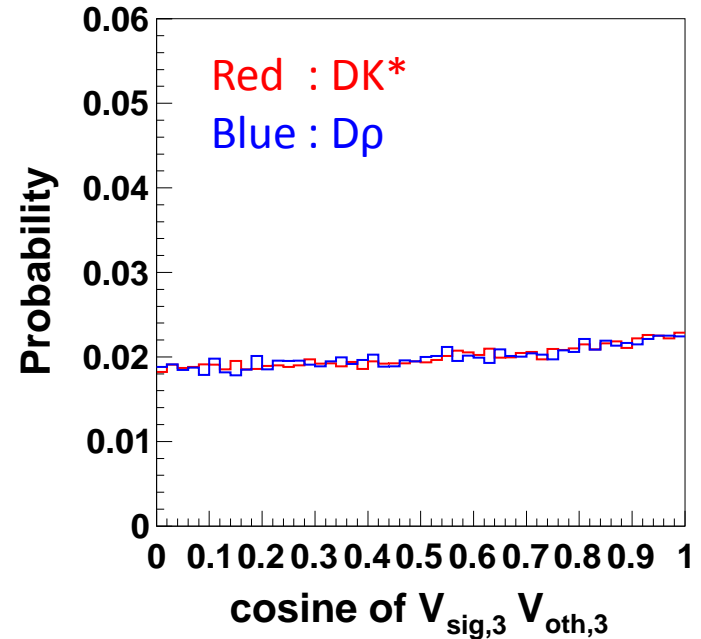
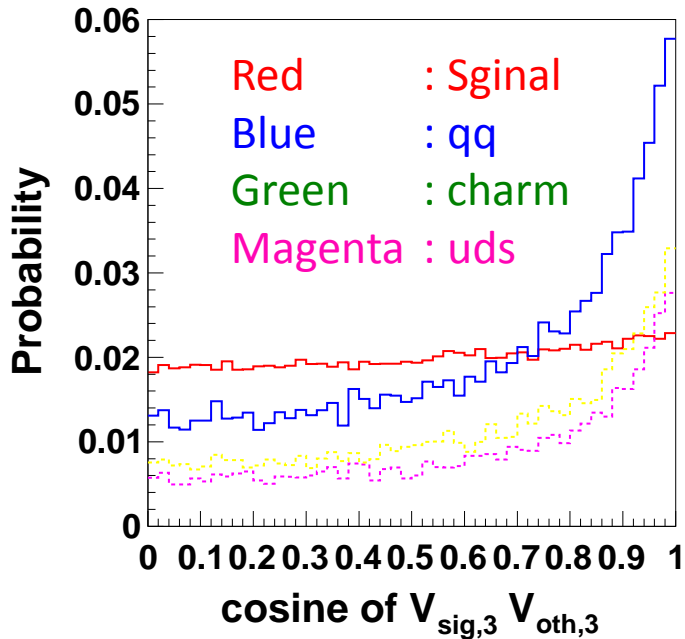
- v1_v1
 - Cosine between sphericity vectors 1 from signal and tag-side tracks.
qq distribution should be ~ 1 , because qq jets must be back to back.

v2_v2



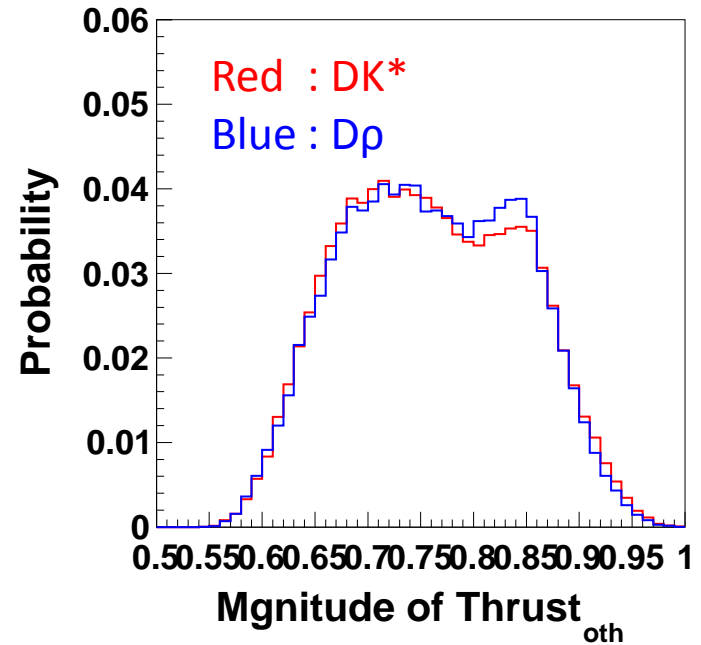
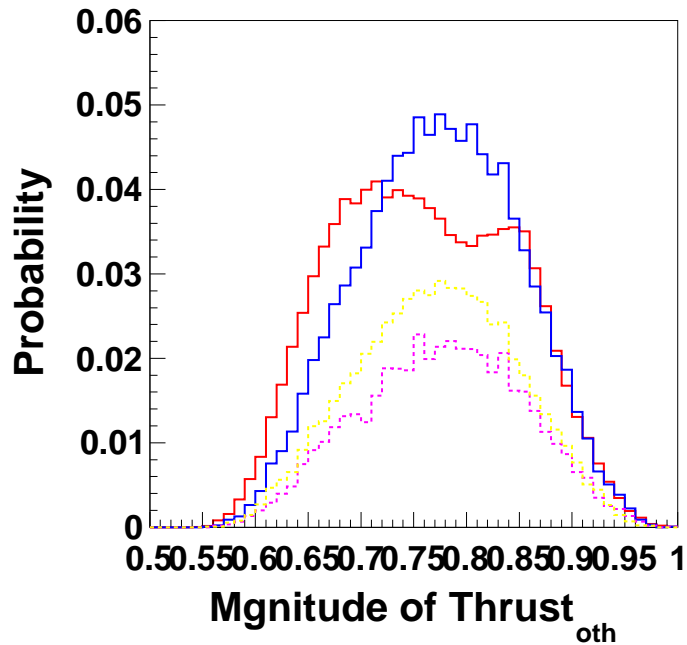
- v2_v2
 - Cosine between sphericity vectors 2 from signal and tag-side tracks.
qq distribution should be ~ 1 , because qq jets must be back to back.

v3_v3



- v3_v3
 - Cosine between sphericity vectors 3 from signal and tag-side tracks.
qq distribution should be ~ 1 , because qq jets must be back to back.

thru_oth



- $thru_{oth}$
 - Magnitude of thrust vector from tag-side tracks.

2D fit for the ΔE - m_{bc} plane

Each background fraction is determined by the 2 dimensional fitting of ΔE - m_{bc} .

PDFs	
	ΔE PDF * m_{bc} PDF
Signal	rotated double 2D-gaussian
$B \rightarrow D\pi$	rotated 2D-gaussian
$B \rightarrow K^*KK$	2D-gaussian + exponential*argus (yield is fixed)
BB	1 st chebyshev*argus + (exponential + gaussian)*gaussian for D* bkg + 2D-gaussian for peaking bkg
qq	1 st chebyshev*argus