$B^0 \to D^* \pi$崩壊事象を用いたCP対称性の破れの測定

板垣　憲之輔 (東北大学)

and Belle collaboration

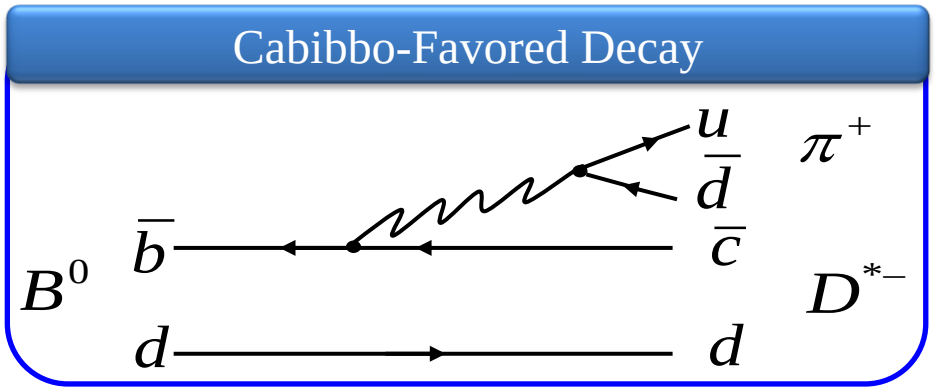
内容

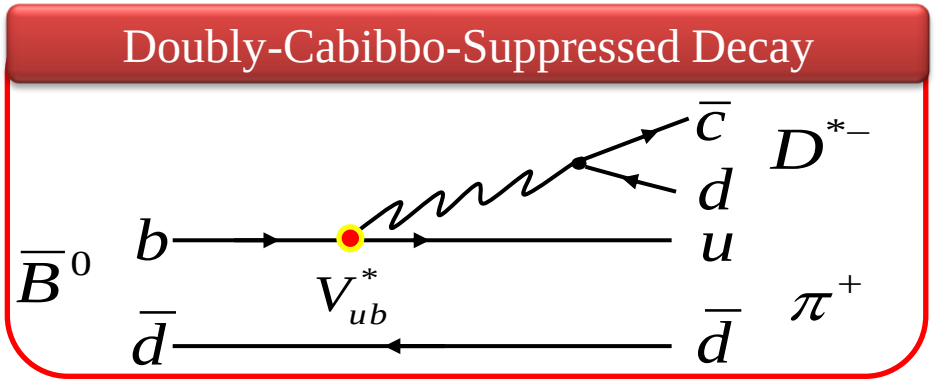
- 導入
- Signal MC の再構成
- Generic MC を使用した Signal fraction の見積もり
- Generic MC のΔt fit
- Signal MC + Generic MC のΔt fit
- まとめ

導入

- 動機：CP非保存角 $\phi_3 \equiv \arg\left(\frac{V_{ud}V_{ub}^*}{-V_{cd}V_{cb}^*}\right) \cong -\arg\left(V_{ub}^*\right)$ の精密測定
- $B^0 \to D^*\pi$ 崩壊
  - 二つの崩壊経路

    $B^0 \to D^{*\mp}\pi^{\pm}, \bar{B}^0 \to D^{*\pm}\pi^{\mp}$
  - DCSD がV_{ub}を含む





崩壊率

$$P\left(B^0 \to D^{*\mp}\pi^{\pm}\right) \propto 1 \pm C\cos\left(\Delta m \Delta t\right) - S^{\mp}\sin\left(\Delta m \Delta t\right)$$

$$P\left(\bar{B}^0 \to D^{*\pm}\pi^{\mp}\right) \propto 1 \pm C\cos\left(\Delta m \Delta t\right) + S^{\pm}\sin\left(\Delta m \Delta t\right)$$

$$S^{\pm} = -\frac{2R}{1+R^2}\sin\left(2\phi_1 + \phi_3 \pm \delta\right)$$

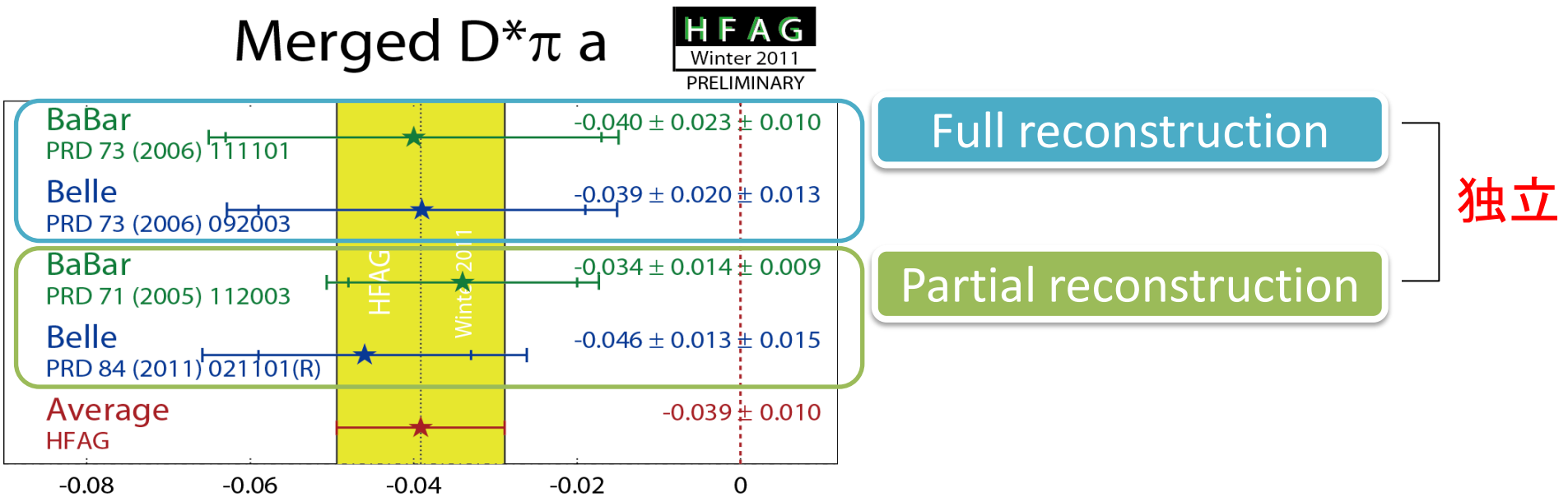
$$R = \frac{\Gamma\left(B^0 \to D^{*+}\pi^-\right)}{\Gamma\left(B^0 \to D^{*-}\pi^+\right)} \sim 0.02,\ \delta = \text{強い相互作用の位相差}$$

⇒ $S^{\pm}$が小さく、精密な測定が必要

導入：今までの結果

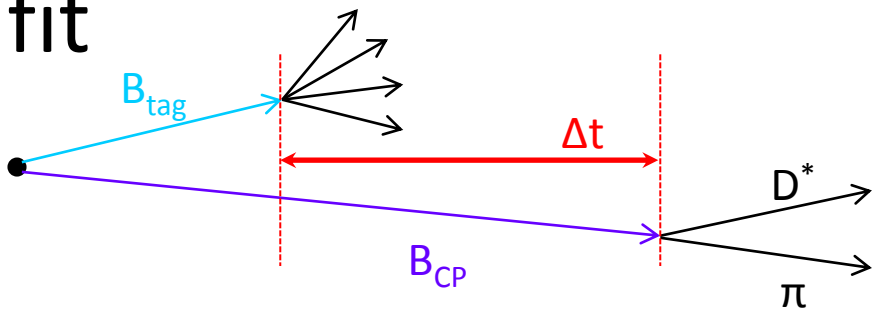
- 再構成方法
  - Partial reconstruction：検出効率が良い
  - Full reconstruction：信号/背景事象 の比が良い

$$B^0 \to D^* \pi$$
$$D^* \to D^0 \pi$$
$$D^* \to D \pi^0$$



- Full reconstruction, $386 \times 10^6 \to 772 \times 10^6$ BB ペア
  - 統計誤差：0.020 → 0.014

Δt fit



- Δt : B_{tag} とB_{CP} の崩壊時間差
  - B_{CP} : $B^0 \to D^* \pi$
  - B_{tag} : flavor 同定に使用

PDF

信号　中性B　荷電B　B以外　Δt の情報を失ったイベントの補正

$$P(\Delta t) = (1-f_{ol})\left[f_{sig}P_{sig} + (1-f_{sig})\left\{f_{B^0\bar{B}^0}P_{B^0\bar{B}^0} + f_{B^+B^-}P_{B^+B^-} + (1-f_{B^0\bar{B}^0}-f_{B^+B^-})P_{con}\right\}\right] + f_{ol}P_{ol}$$

- P_{sig} : 信号事象項

前回はまとめていた
→ より精密な測定のため、個別に求めることとした

Flavor tag 補正,信頼度ごと

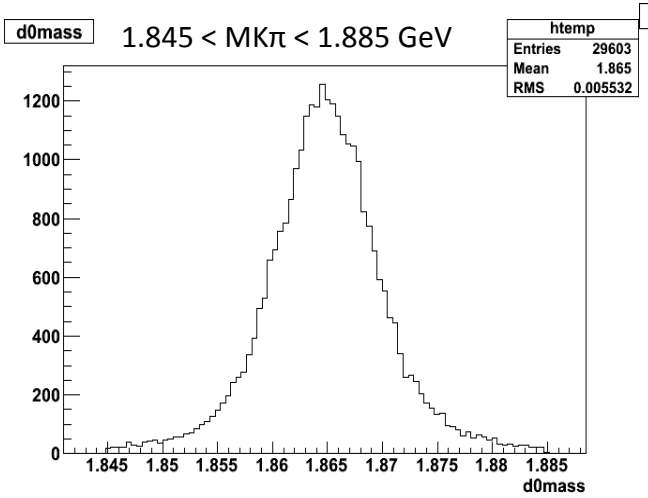
$$P(D^{*\mp}\pi^{\pm}, q_{tag}) = \int \frac{e^{-|\Delta t'|/\tau_{B^0}}}{8\tau_{B^0}} \{1 - q_{tag}\Delta w_i \pm q_{tag}(1-2w_i) \times \left(C\cos(\Delta m \Delta t') - q_{tag} S^{\mp} \sin(\Delta m \Delta t')\right)\} \times R(\Delta t - \Delta t') d\Delta t'$$

検出器のresolution 補正項

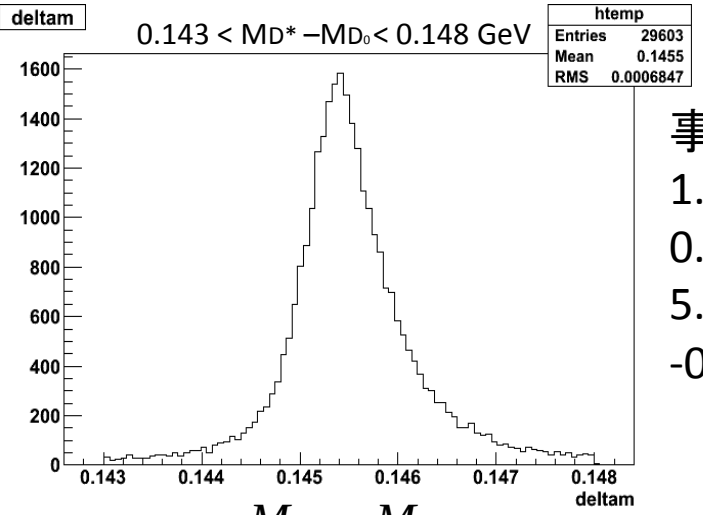
- B の崩壊を模擬したデータサンプル(Generic MC)で、上記を求めた

再構成:$B^0 \to D^* \pi$, $D^* \to D^0 \pi$, $D^0 \to K\pi$

- Signal MC 100,000 events を生成、再構成 (Data : ~ 56,000 events)



$M_{K\pi}$



$M_{D^*} - M_{D^0}$

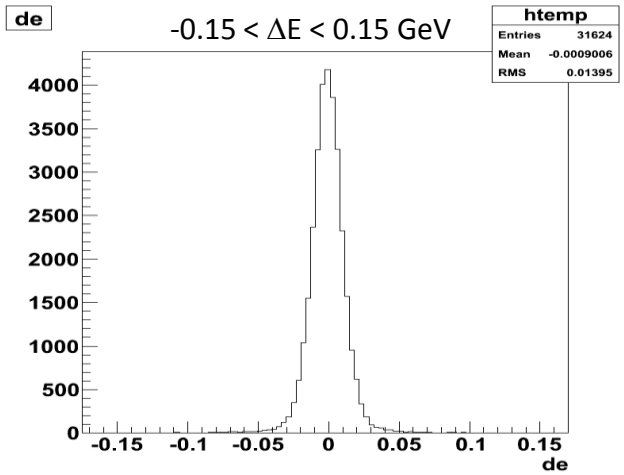
事象選別

1.845 < $M_{K\pi}$ < 1.885 GeV

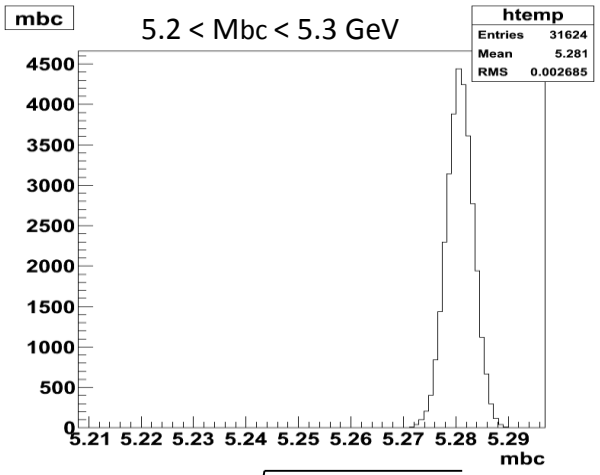
0.143 < $M_{D^*} - M_{D^0}$ < 0.148 GeV

5.27 < Mbc < 5.29 GeV

-0.045 < ΔE < 0.045 GeV



$\Delta E = E_B - E_{Beam}$



$M_{bc} = \sqrt{E_{Beam}^2 - P_B^2}$

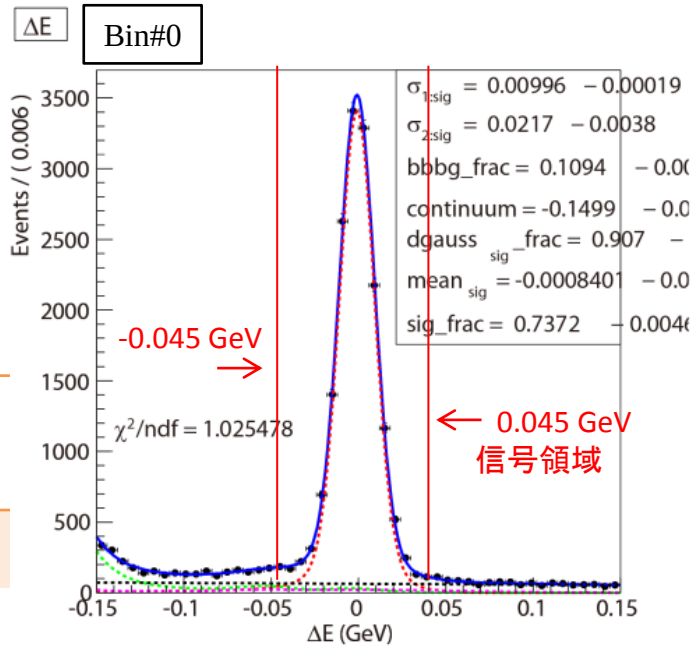
再構成数: 29,603 ~ 30%

Generic MC を使用した Signal fraction 決定

- ΔE を使用して、含まれる信号事象の比を求めた.

Bin#0 → Bin#6 Flavor tag 信頼度高
変数
信号事象:ダブルガウシアン B以外の背景事象:直線 信号事象比
B 背景事象:固定

Flavor tag 信頼度	信号事象	中性B 背景事象	荷電B 背景事象	B以外の 背景事象
Bin#0	89%	2%	4%	5%
Bin#1	89%	2%	4%	5%
Bin#2	90%	3%	4%	3%
Bin#3	90%	2%	3%	5%
Bin#4	89%	3%	4%	5%
Bin#5	91%	3%	3%	3%
Bin#6	95%	3%	2%	0%



信号事象 ~ 89%
B^0 BG ~ 2%, $B^{\pm}$ BG ~ 4%
B 以外 ~ 5%

中性B中間子背景事象のΔt fit

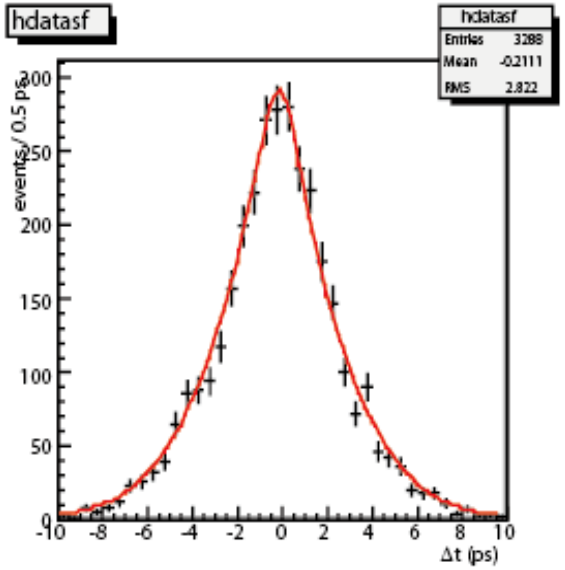
$$P_{B^0BG}(\Delta t, q_{tag}, q_{cp}) = \int \frac{e^{-|\Delta t'|/\tau_{B^0BG}}}{8\tau_{B^0BG}} \{1 - q_{tag} q_{cp} (1 - 2w_{rbin}) \cos(\Delta m \Delta t')\} \times R(\Delta t - \Delta t') d\Delta t'$$

寿命項　　Flavor tag 補正　　B^0B^0bar mixing 項　　Resolution 補正

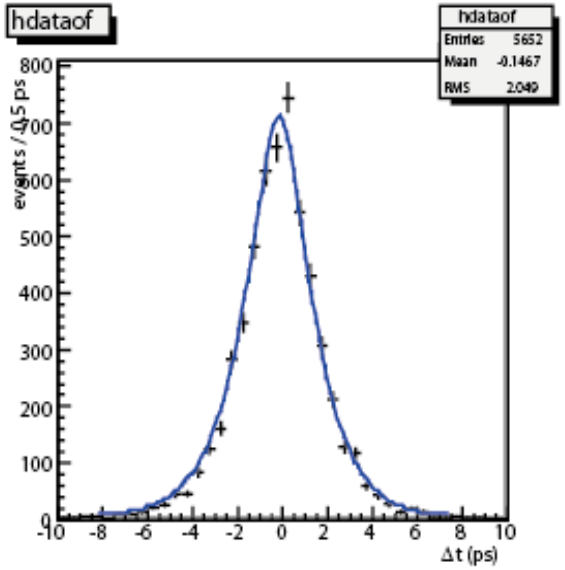
- Fit 結果

Name	Value
τ_{B0BG}	1.525±0.019 (ps)
Δm	0.516±0.013
w_0	0.50 (fixed)
w_1	0.45±0.02
w_2	0.29±0.02
w_3	0.23±0.02
w_4	0.18±0.02
w_5	0.12±0.02
w_6	0.03±0.01

$B_{tag} = \overline{B}^0, f_{CP} = D^{*+}\pi^-$
$B_{tag} = B^0, f_{CP} = D^{*-}\pi^+$



$B_{tag} = \overline{B}^0, f_{CP} = D^{*-}\pi^+$
$B_{tag} = B^0, f_{CP} = D^{*+}\pi^-$



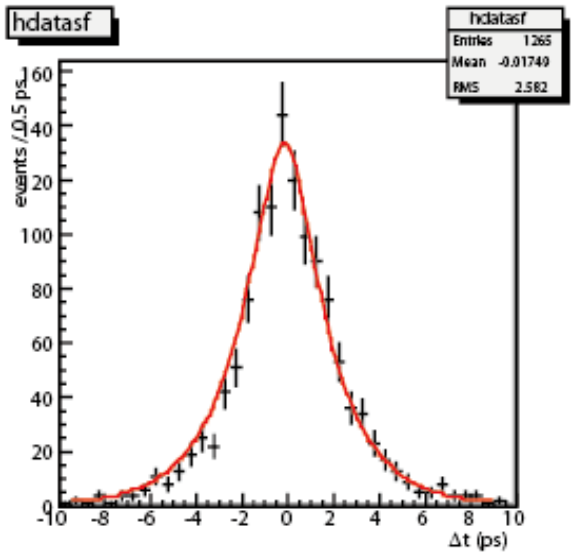
荷電B中間子背景事象のΔt fit

$$P_{chg}(\Delta t, q_{tag}, q_{cp}) = \int \frac{e^{-|\Delta t'|/\tau_{chgB}}}{8\tau_{chgB}} \{1 - q_{tag} q_{cp} (1 - 2w_{rbin})\} \times R(\Delta t - \Delta t') d\Delta t'$$

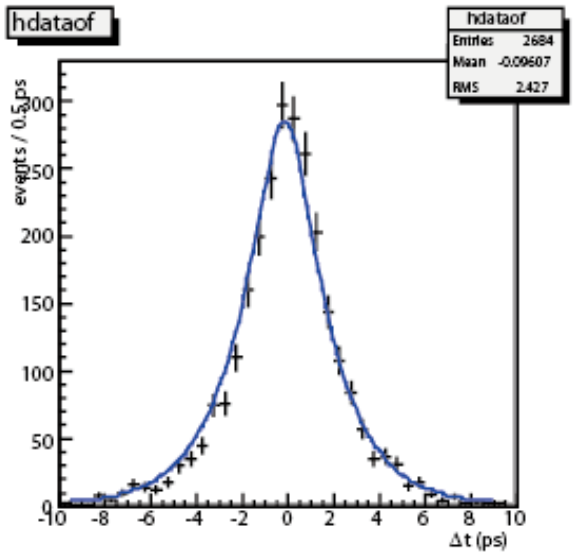
- Fit 結果

Name	Value
τ_{chgB}	1.599±0.029 (ps)
w_0	0.50 (fixed)
w_1	0.44±0.02
w_2	0.32±0.02
w_3	0.26±0.02
w_4	0.16±0.02
w_5	0.13±0.02
w_6	0.04±0.01

$B_{tag} = \overline{B}^0,\ f_{CP} = D^{*+}\pi^-$
$B_{tag} = B^0,\ f_{CP} = D^{*-}\pi^+$



$B_{tag} = \overline{B}^0,\ f_{CP} = D^{*-}\pi^+$
$B_{tag} = B^0,\ f_{CP} = D^{*+}\pi^-$



B以外の背景事象のΔt fit

$$P_{con}(\Delta t) = \int P_{con}(\Delta t') \cdot R_{con}(\Delta t - \Delta t') \cdot d\Delta t'$$

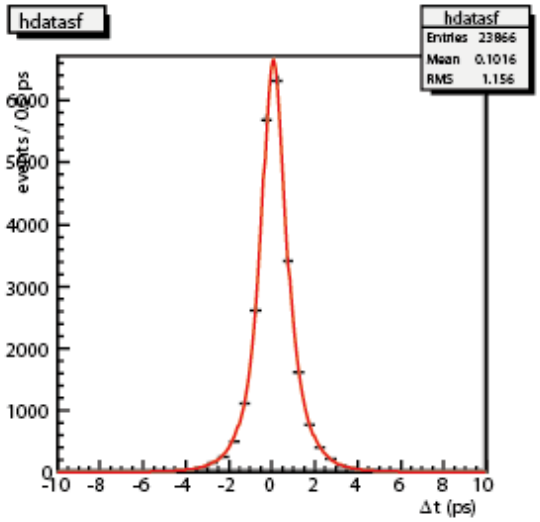
$$P_{con}(\Delta t) = f_{\delta} \cdot \delta(\Delta t - \mu_{\delta}) + (1 - f_{\delta}) \cdot \exp\left(-\frac{|\Delta t - \mu_{\tau}|}{\tau_{con}}\right)$$

$$R_{con}(\Delta t) = (1 - f_{con}^{tail}) \cdot G(\Delta t; s_{con}^{main} \cdot \sigma_{vtx}) + f_{con}^{tail} \cdot G(\Delta t; s_{con}^{tail} \cdot \sigma_{vtx})$$

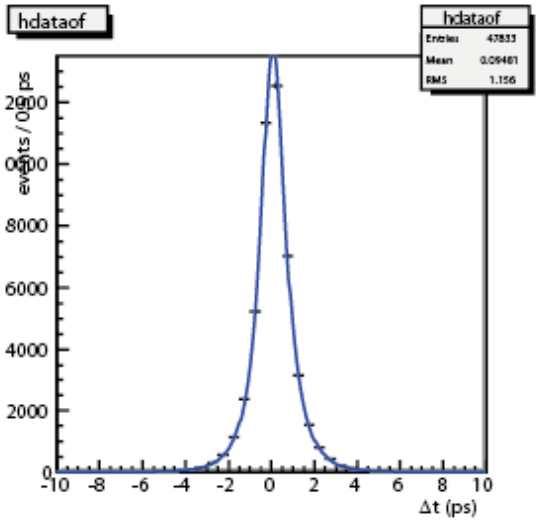
- Fit 結果

	Single-track vertex Either CP or tag B	Multi-track vertex Both CP and tag B
f_d	0.26±0.04	0.39±0.02
m_d	0.046±0.007	
m_τ	0.14±0.01	
τ_{con}	0.58±0.02	
s_{bkg}^{main}	1.07±0.03	1.34±0.02
s_{bkg}^{tail}	5.40±0.42	4.87±0.26
f_{bkg}^{tail}	0.088±0.010	0.047±0.007

$B_{tag} = \bar{B}^0,\ f_{CP} = D^{*+}\pi^-$
$B_{tag} = B^0,\ f_{CP} = D^{*-}\pi^+$



$B_{tag} = \bar{B}^0,\ f_{CP} = D^{*-}\pi^+$
$B_{tag} = B^0,\ f_{CP} = D^{*+}\pi^-$



信号事象＋背景事象での Δt fit

- PDF

$$P(\Delta t) = (1 - f_{ol})\left[f_{sig} P_{sig} + (1 - f_{sig})\left\{ f_{B^0\bar{B}^0} P_{B^0\bar{B}^0} + f_{B^+B^-} P_{B^+B^-} + (1 - f_{B^0\bar{B}^0} - f_{B^+B^-}) P_{con} \right\}\right] + f_{ol} P_{ol}$$

  - 信号事象/背景事象比： f_{sig}, $f_{B^0\bar{B}^0}$, $f_{B^+B^-}$
  - $P_{B^0B^0}$: 中性B中間子背景事象項
  - $P_{B^+B^-}$: 荷電B中間子背景事象項
  - P_{con} : B中間子以外の背景事象項
  - $f_{ol}P_{ol}$: Δt の情報を失った成分 ← 40 ps の幅を持つガウシアン
  - P_{sig} : 信号事象項

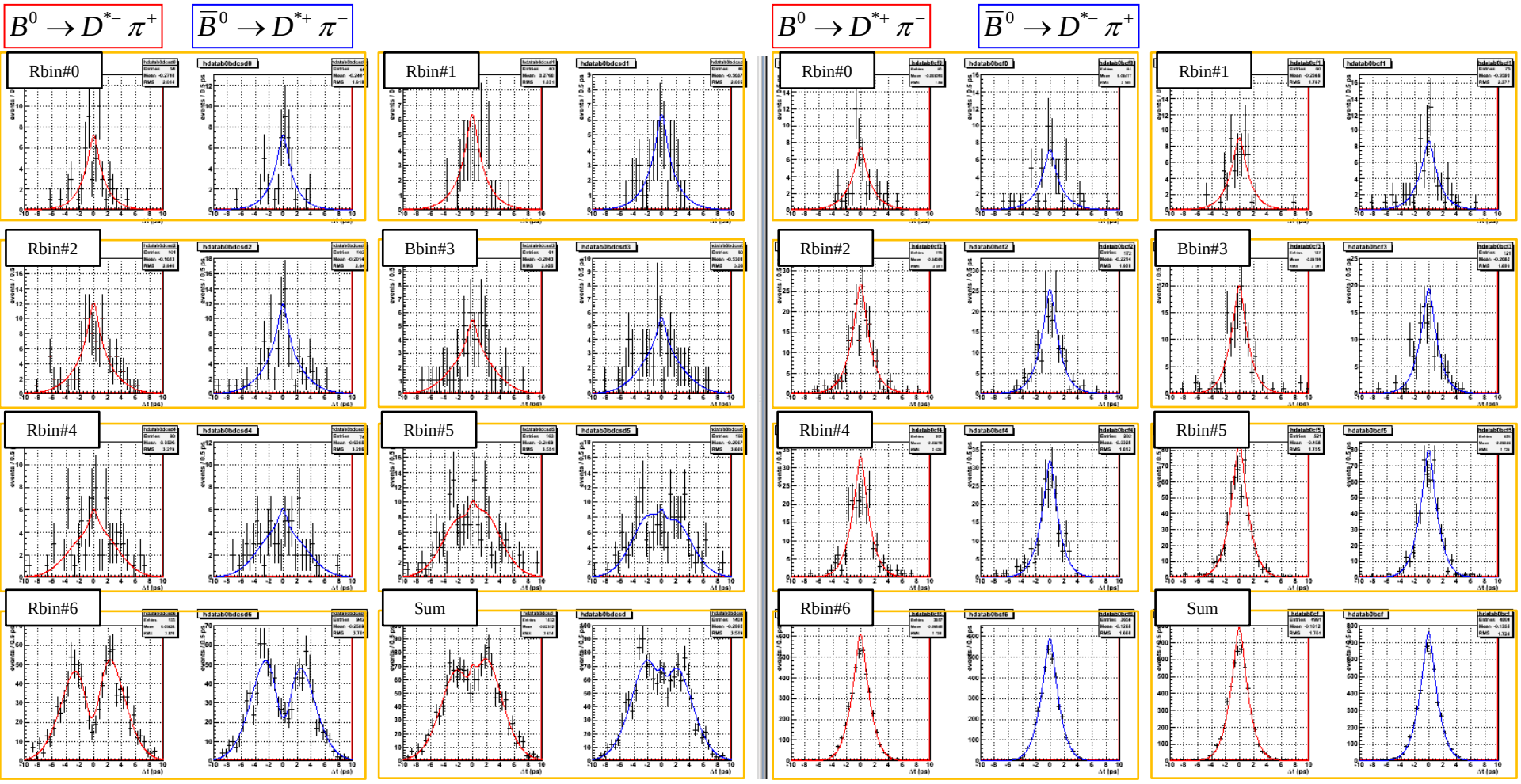
$$P(D^{*\mp}\pi^{\pm}, q_{tag}) = \int \frac{e^{-|\Delta t'|/\tau_{B^0}}}{8\tau_{B^0}} \{1 - q_{tag}\Delta w_i \pm q_{tag}(1 - 2w_i) \times \left(C\cos(\Delta m \Delta t') - q_{tag} S^{\mp} \sin(\Delta m \Delta t')\right)\} \times R(\Delta t - \Delta t') d\Delta t'$$

Flavor tag 補正,信頼度ごと

検出器のresolution の補正項

→ signal MC + generic MC について $S^{\pm}$ を fit

$2\phi_1+\phi_3 = 1.8,\ \delta = 0,\ R = 0.02$



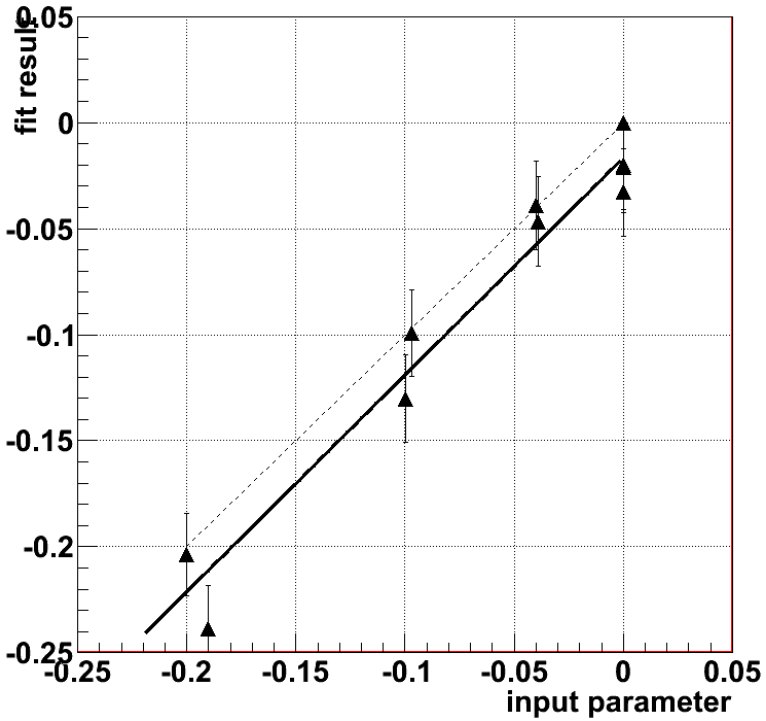
$S^{\pm}$ (input)	S^{+} (diff)	S^{-} (diff)
-0.039	-0.047 ± 0.0055 (0.36 σ)	-0.032 ± 0.0055 (0.35 σ)

信号事象＋背景事象での Δt fit

- 9 通りのMC を作り、$S^{\pm}$ のリニアリティを確認した
  - Fit function : y = P1x + P0

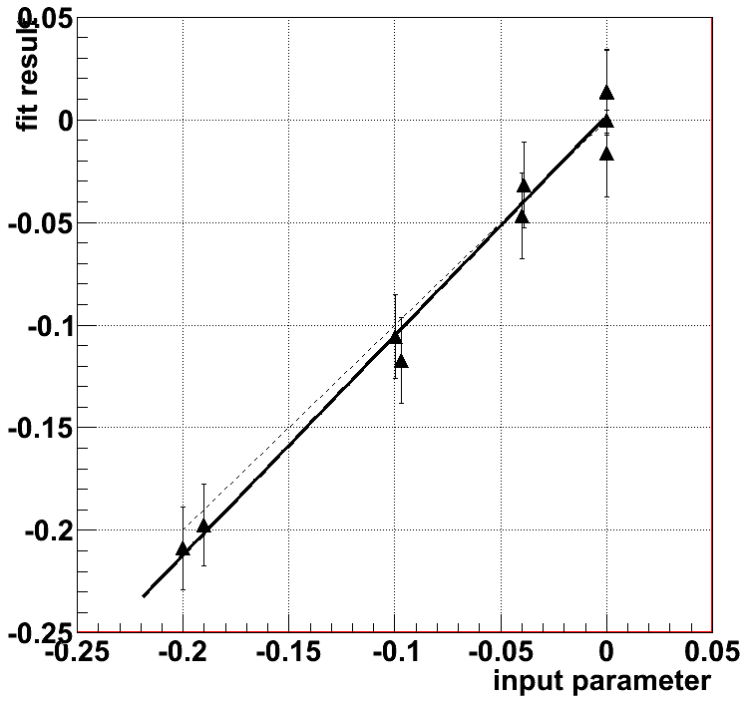
S+

P0=-0.017±0.0098
P1=1.02±0.091



S-

P0=0.0020±0.0097
P1=1.07±0.091



まとめ

- 目的:ϕ_3 の測定
- Belle 全データ：統計誤差 0.020(前回) → ~0.014
- $D^* \to D^0\pi$, $D^0 \to K\pi$
  - Signal fraction を見積もった
  - Continuum BG, B^0 BG, $B^\pm$ BG のΔt PDF を求めた ← new
  - 9 通りのMC を作り、fit した$S^\pm$ のリニアリティを確認した

計画

- 使用する下位崩壊について、背景事象を求める
- Tag-side interference の取り扱い
- 系統誤差の見積もり
- Data fit

系統誤差
Signal Δt resolution
continuum Background Δt shape
Neutral B Background Δt shape
Charged B Background Δt shape
Signal Background fraction
Wrong tag fraction
Vertexing
Physics parameters(τ, Δm)
Fit bias

Buck up

信号事象のΔt fit

- τ , Δm を fit

$$P_{sig}(\Delta t, q_{tag}, q_{cp}) = \frac{1}{8\tau} e^{-|\Delta t|/\tau} \left\{1 - q_{tag}\Delta w_{rbin}^{official} - q_{tag}q_{cp}(1 - 2w_{rbin}^{official})\cos(\Delta m \Delta t)\right\}$$

$B_{tag} = \bar{B}^0, f_{CP} = D^{*-}\pi^+$ と $B_{tag} = B^0, f_{CP} = D^{*+}\pi^-$

$B_{tag} = \bar{B}^0, f_{CP} = D^{*+}\pi^-$ と $B_{tag} = B^0, f_{CP} = D^{*-}\pi^+$

を $\delta = 0$ として 統合 → sin 項を無視

w, Δw : flavor tagの間違いを補正

$$w = \frac{w_{B^0} + w_{\bar{B}^0}}{2}, \Delta w = w_{B^0} - w_{\bar{B}^0}$$

Official wrong tag fraction を使用

R bin #	official wrong tag fraction	
Bin#0	w = 0.5	Δw=0.
Bin#1	w = 0.412222	Δw=0.00408778
Bin#2	w = 0.307838	Δw=0.010326
Bin#3	w = 0.212765	Δw=-0.00479522
Bin#4	w = 0.149933	Δw=0.00151989
Bin#5	w = 0.0913264	Δw=0.0143633
Bin#6	w = 0.0218754	Δw=0.00189979

背景事象のΔt fit

- 背景事象のPDFを得るため、各々を fit
- Fit 範囲 : -0.15 GeV < ΔE < 0.15 GeV, 5.2 GeV < M_{bc} < 5.3 GeV

中性B中間子背景事象 PDF

$$P_{B^0BG}(\Delta t, q_{tag}, q_{cp}) = \frac{1}{8\tau_{B^0BG}} e^{-|\Delta t|/\tau_{B^0BG}} \left\{1 - q_{tag} q_{cp} (1 - 2w_{rbin}) \cos(\Delta m \Delta t)\right\}$$

荷電B中間子背景事象 PDF

$$P_{chg}(\Delta t, q_{tag}, q_{cp}) = \frac{1}{8\tau_{chgB}} e^{-|\Delta t|/\tau_{chgB}} \left\{1 - q_{tag} q_{cp} (1 - 2w_{rbin})\right\}$$

B中間子以外からの背景事象 PDF

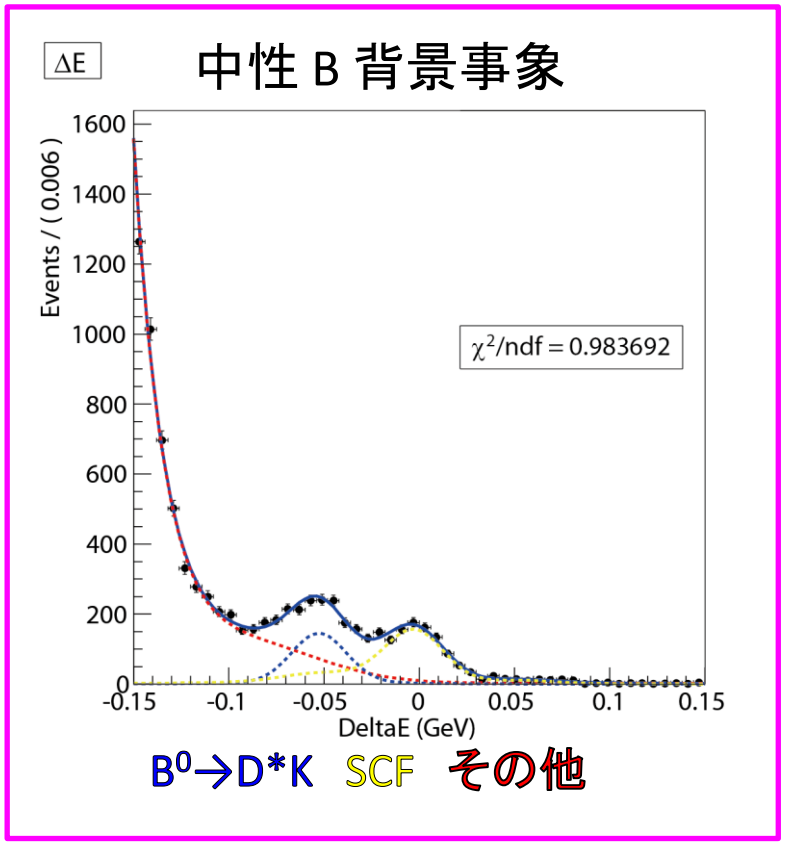
$$P_{con}(\Delta t) = \int P_{con}(\Delta t') \cdot R_{bkg}(\Delta t - \Delta t') \cdot d\Delta t'$$

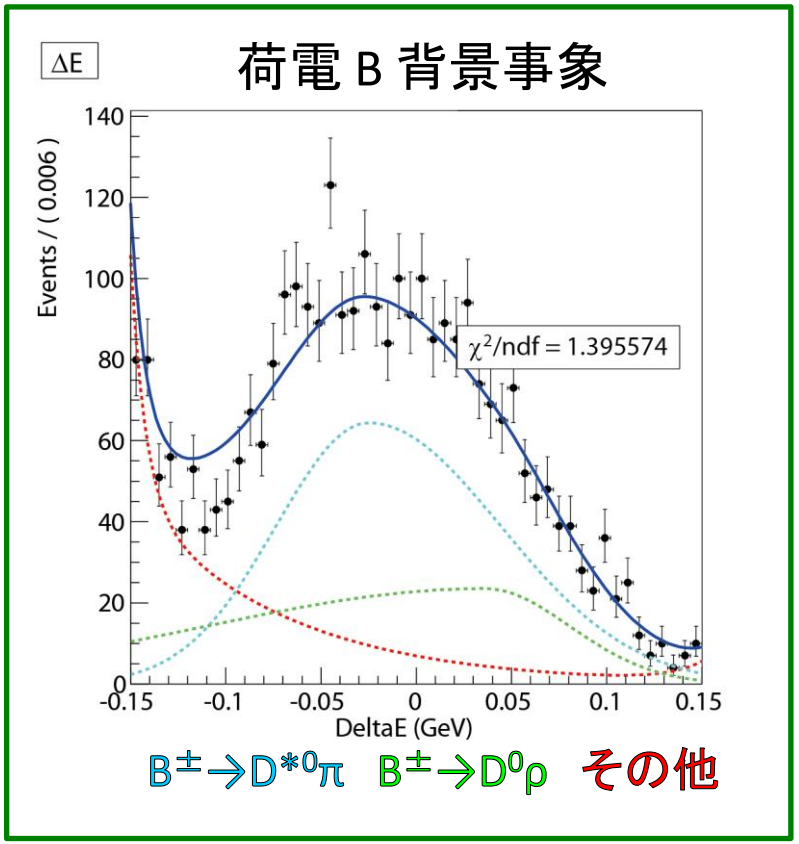
$$P_{con}(\Delta t) = f_\delta \cdot \delta(\Delta t - \mu_\delta) + (1 - f_\delta) \cdot \exp\left(-\frac{|\Delta t - \mu_\tau|}{\tau_{con}}\right)$$

$$R_{con}(\Delta t) = (1 - f_{con}^{tail}) \cdot G(\Delta t; s_{con}^{main} \cdot \sigma_{vtx}) + f_{con}^{tail} \cdot G(\Delta t; s_{con}^{tail} \cdot \sigma_{vtx})$$

ΔE PDF

- Signal fraction を計算するため、**ΔE PDF を見積もった**
  実験データの 5倍の統計量を使用
  範囲 : $5.27\ \mathrm{GeV} < M_{bc} < 5.29\ \mathrm{GeV}$ $-0.15\ \mathrm{GeV} < \Delta E < 0.15\ \mathrm{GeV}$
- 得られた 中性/荷電 B 背景事象のΔE PDF





Signal fraction

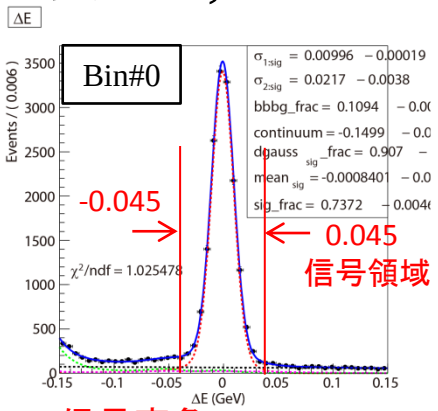
- ΔE を使用して、含まれる信号事象の比を求めた.
  - flavor tag の信頼度ごと, Generic MC

Bin#0 → Bin#6
信頼度高

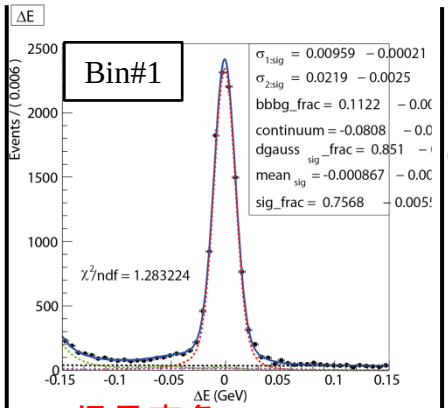
変数

信号事象:ダブルガウシアン
B以外の背景事象:直線
信号事象比

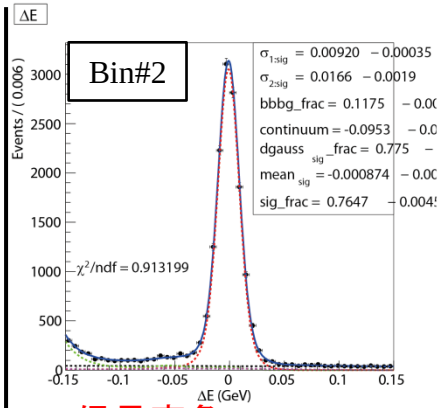
B 背景事象:固定



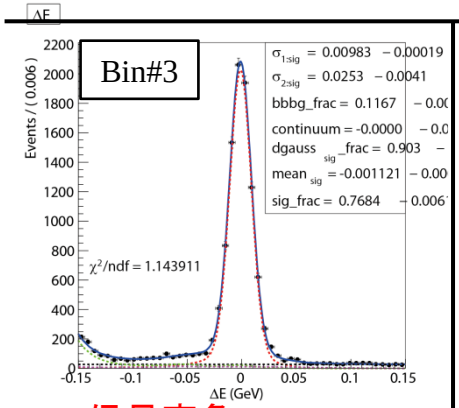
信号事象 ~ 89%
B^0 BG ~ 2%, $B^{\pm}$ BG ~ 4%
B 以外 ~ 5%



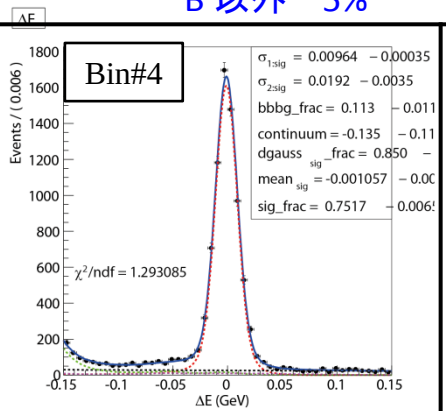
信号事象 ~ 89%
B^0 BG ~ 2%, $B^{\pm}$ BG ~ 4%
B 以外 ~ 5%



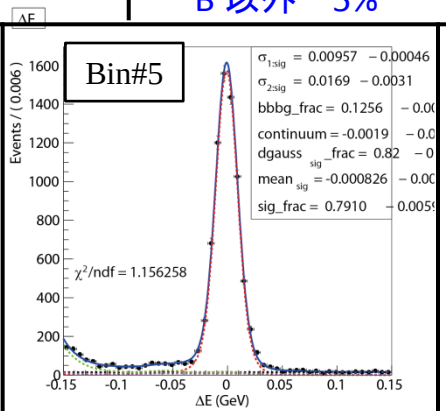
信号事象 ~ 90%
B^0 BG ~ 3%, $B^{\pm}$ BG ~ 4%
B 以外 ~ 3%



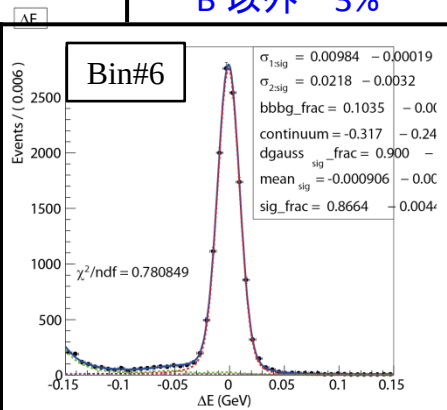
信号事象 ~ 90%
B^0 BG ~ 2%, $B^{\pm}$ BG ~ 3%
B 以外 ~ 5%



信号事象 ~ 89%
B^0 BG ~ 2%, $B^{\pm}$ BG ~ 4%
B 以外 ~ 5%



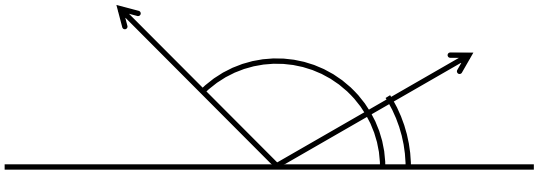
信号事象 ~ 91%
B^0 BG ~ 3%, $B^{\pm}$ BG ~ 3%
B 以外 ~ 3%



信号事象 ~ 95%
B^0 BG ~ 3%, $B^{\pm}$ BG ~ 2%
B 以外 ~ 0%

Partial recon Signal event selection

- 正確なvertex の決定のための Fast pion への要求
- Impact parameter
  - radial : $dr < 0.1\,cm$
  - longitudinal : $|dz| < 2.0\,cm$
  - SVDにヒットをもつ
  - Polar angle in the laboratory frame : $30° < \theta_{lab} < 135°$



- The vertex positions are obtained by fits of the candidate tracks with the IP.
- Lepton, kaon hypothesis と一致しない
  - Based on information from the CDC, TOF and ACC.
- Fast pion cms momentum : $1.83\,{}^{GeV}\!/_{c} < p_{\pi_f} < 2.43\,{}^{GeV}\!/_{c}$

Partial recon Signal event selection

- Slow pion cms momentum : $0.05\ {}^{GeV}\!/_{c} < p_{\pi_s} < 0.30\ {}^{GeV}\!/_{c}$
- Particle identification のとき、slow pion には何の条件も課さない
- Vertexing に使用しない
- IP から生じることのみ要求する

- fast pion とslow pion は逆の電荷をもつ

D*π 数

- **771.581 x 10^6 x 2.76 x 10^-3 = 2.13 x 10^6**
  - **Kπ : x 67.7 x 10^-2 x 3.89 x 10^-2 = 56000**

- 使用する下位崩壊

  $D^{*} \rightarrow D^{0}\pi$ (67.7%)

  $D^{0} \rightarrow K\pi$ (3.89%), $K\pi\pi^{0}$ (13.9%), $K\pi\pi\pi$ (8.09%), $K_{s}\pi\pi$ (2.94%)

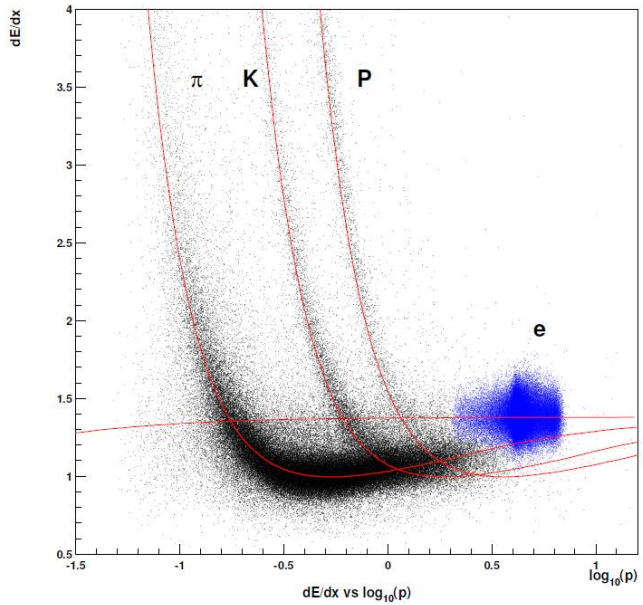
  $D^{*} \rightarrow D\pi^{0}$ (30.7%)

  $D \rightarrow K\pi\pi$ (9.4%)

再構成

- $D^* \rightarrow D^0\pi$, $D^0 \rightarrow K\pi$ 信号選択

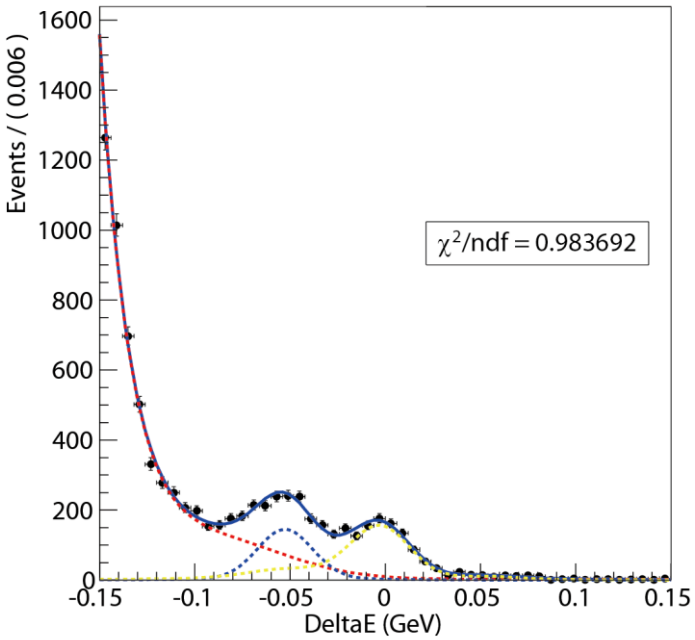
Slow π 以外の π SVD hit in r-ϕ ≧1, z ≧2 Pid(K/ π) ≦ 0.7	D^0 1.82 GeV < $\lvert M_{K\pi}\rvert$ < 1.92 GeV
K SVD hit : π と同じ Pid(K/ π) ≧ 0.3	D^* 0.143 GeV < $M_{D^*} - M_{D^0}$ < 0.148 GeV
Slow π 要求なし	B 5.2 GeV < M_{bc} < 5.3 GeV -0.15 GeV < ΔE < 0.15 GeV 最良候補選択（M_{bc}, $M_{D^*} - M_{D^0}$）



Neutral B BG ΔE PDF

ΔE

B^0 background



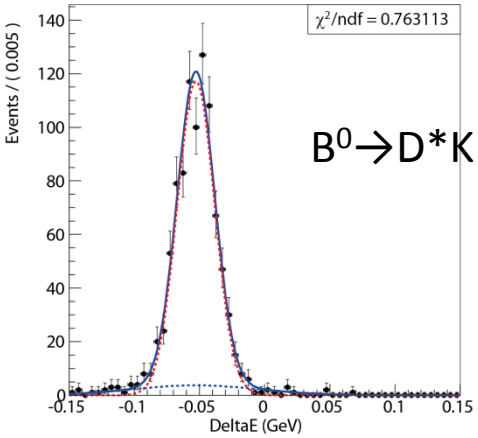
$B^0 \rightarrow D^*K$

SCF

Others

ΔE

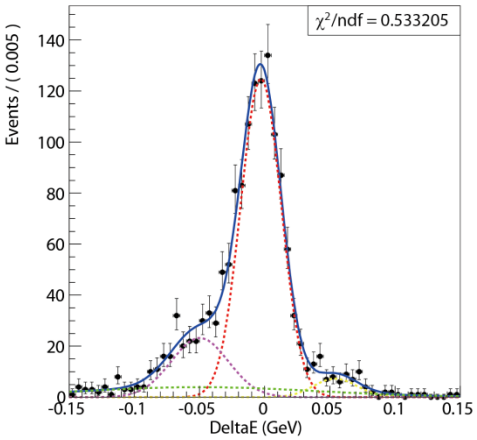
$B^0 \rightarrow D^*K$



Double gaussian

ΔE

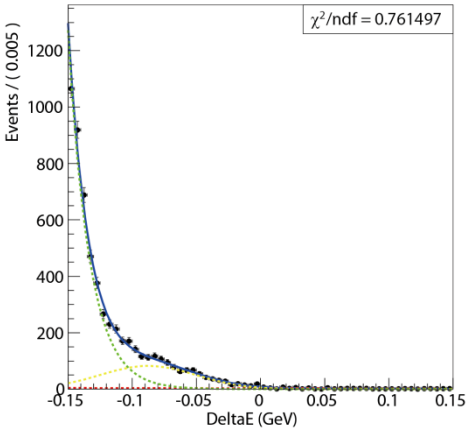
SCF



Gaussian x4

ΔE

Others



Exponential

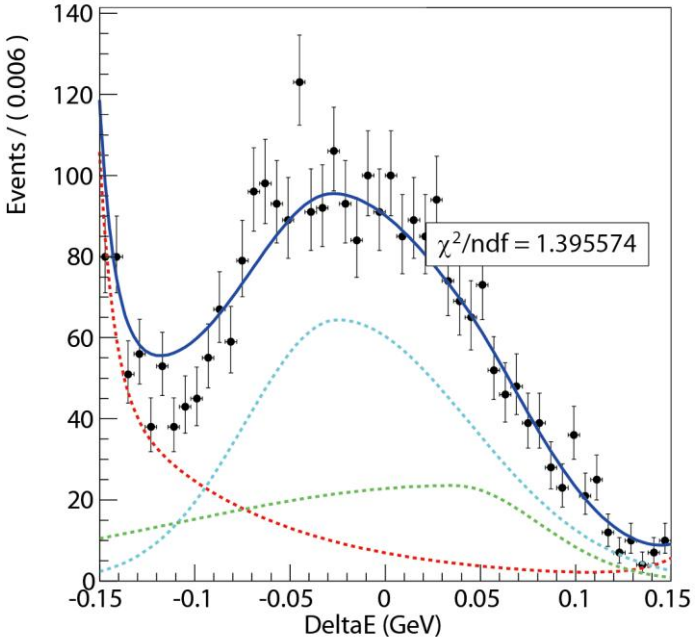
Line

gaussian

Charged B BG ΔE PDF

ΔE

$B^{\pm}$ background



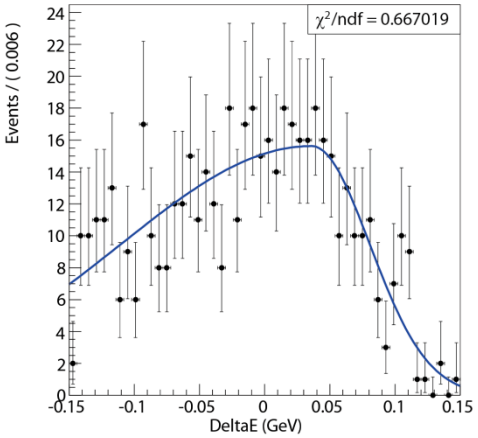
$B^{\pm} \to D^{0*}\pi$

$B^{\pm} \to D^{0}\rho$

Others

ΔE

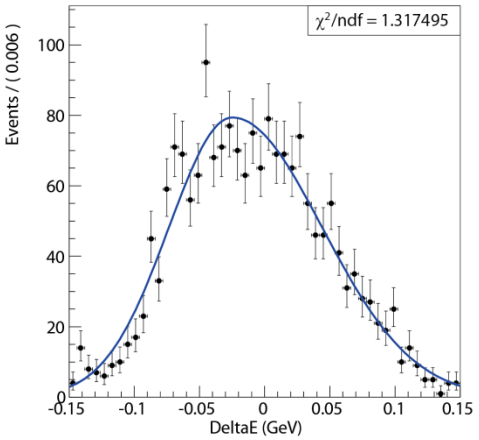
$B^{\pm} \to D^{0}\rho$



Bifurcated gaussian

ΔE

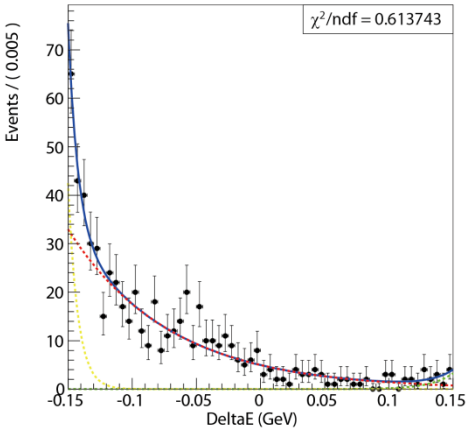
$B^{\pm} \to D^{*0}\pi$



Bifurcated gaussian

ΔE

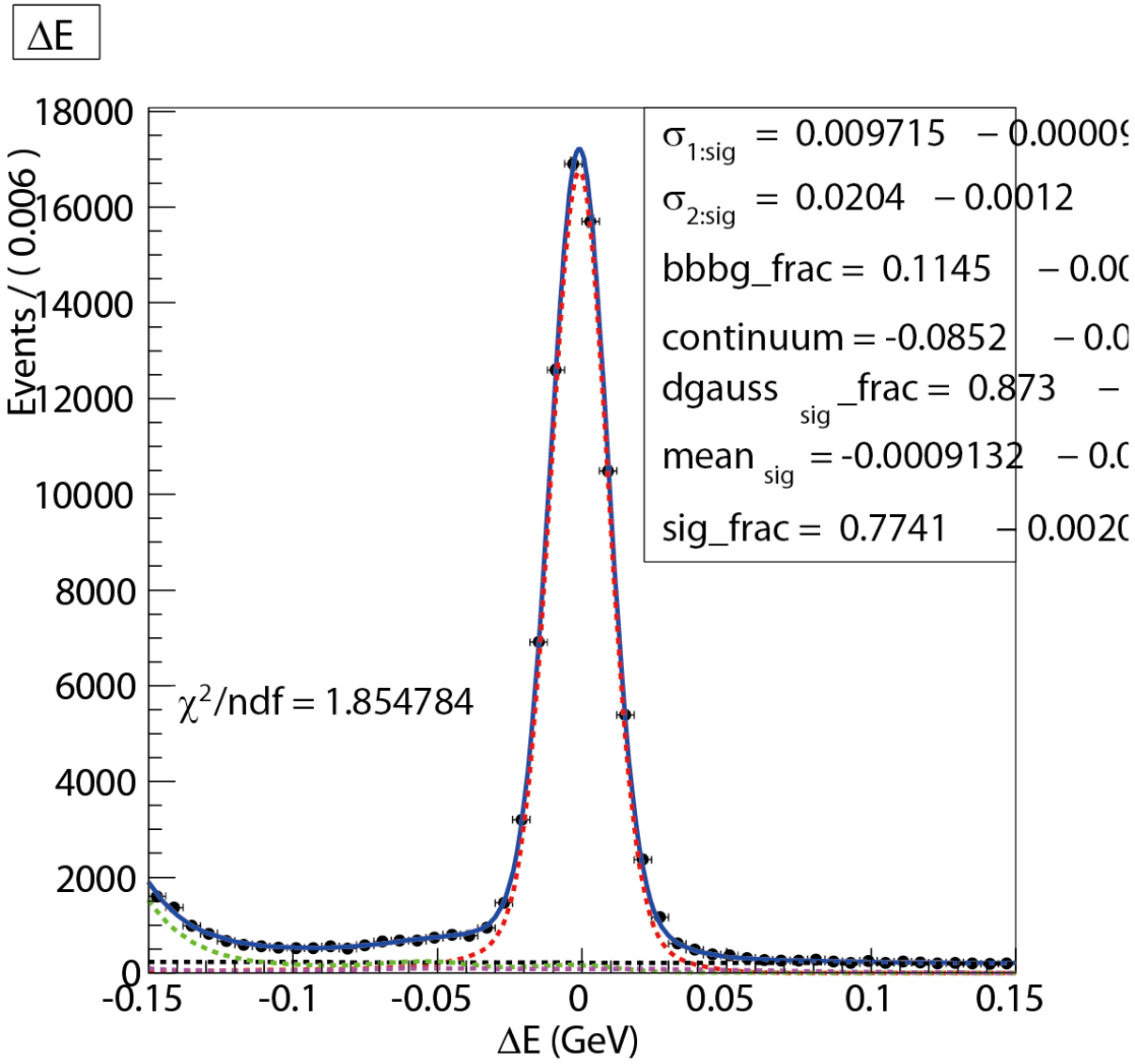
Others



Exponential x3

B reconstruction

- Generic MC were reconstructed.
  - Case B
  - 5 streams



r bin

- r bin : bin definition of the flavor tagging category

R bin #		**wrong tag fraction for SVD2 MC**	
Bin#0	0 <= |r| <= 0.1	w = 0.5	Δw = 0.
Bin#1	0.1 < |r| <= 0.25	w = 0.412222	Δw = 0.0569661
Bin#2	0.25 < |r| <= 0.5	w = 0.307838	Δw = 0.0126192
Bin#3	0.5 < |r| <= 0.625	w = 0.212765	Δw = 0.0147724
Bin#4	0.625 < |r| <= 0.75	w = 0.149933	Δw = 0.000550289
Bin#5	0.75 < |r| <= 0.875	w = 0.0913264	Δw = 0.00887704
Bin#6	0.875 < |r| <= 1.0	w = 0.0218754	Δw = 0.00465683

信号事象のΔt fit

- Fit 結果

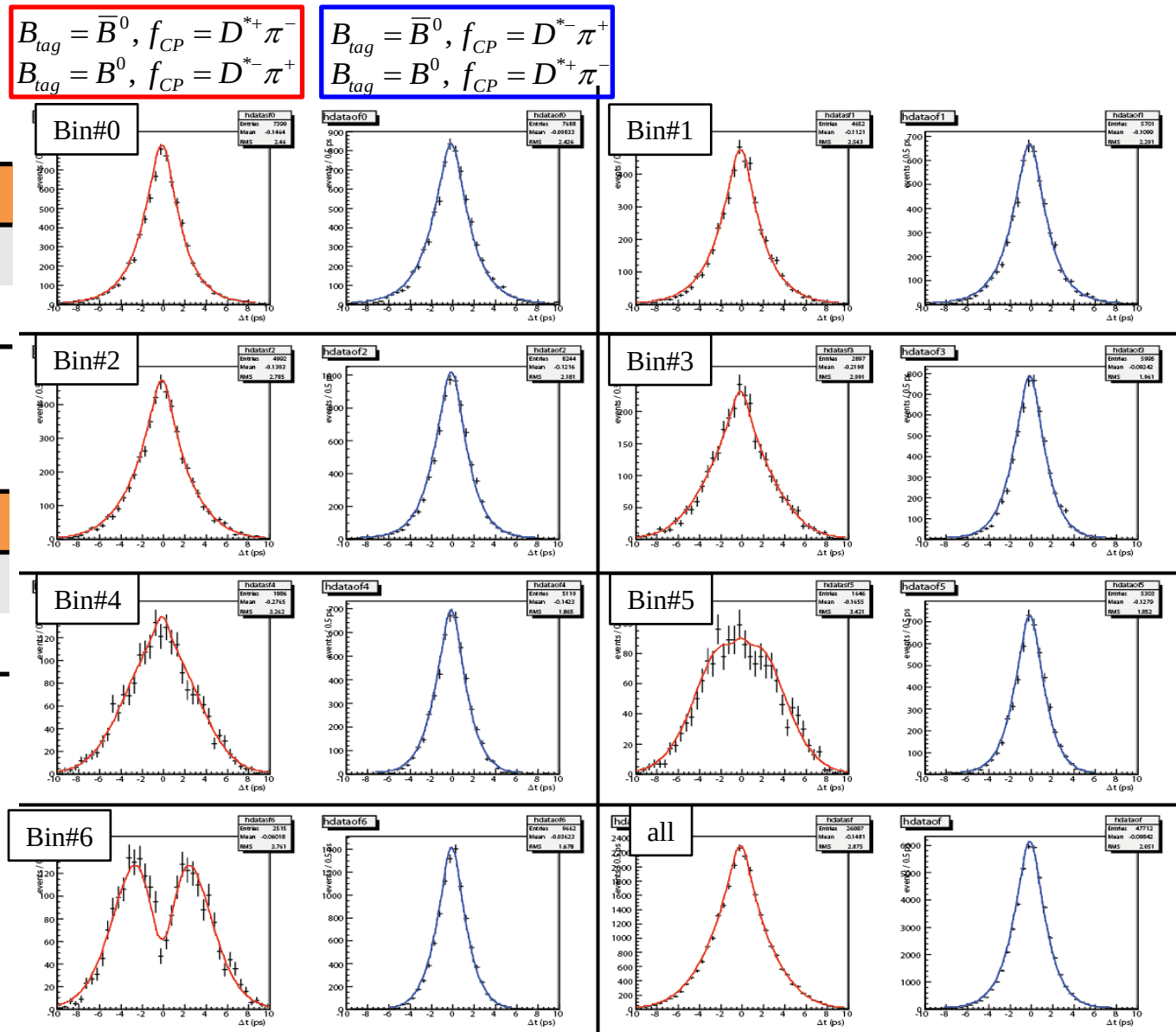
MC 入力値

Name	Value
τ_{B0}	1.534
Δm	0.507

Fit 結果

Name	Value
τ_{B0}	1.533 ± 0.006 (ps)
Δm	0.505 ± 0.004

- Fit 結果は入力値と consistent



Signal + $B^0\overline{B^0}$ Background

- To check the correctness of BG PDF, Signal + $B^0\overline{B^0}$ BG was fitted.

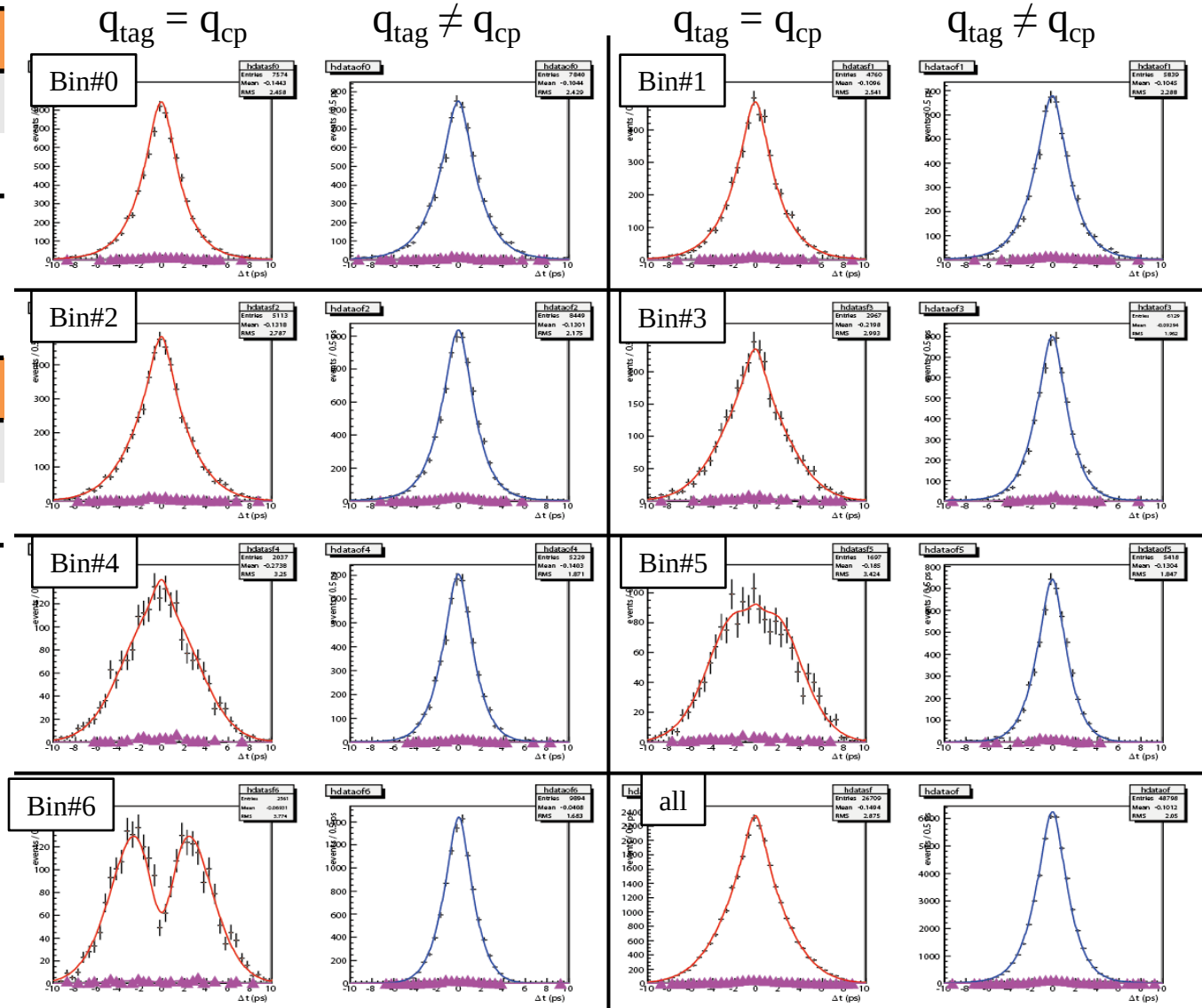
Name	Value	Signal Only
τ_{B0}	1.533±0.006 (ps)	
Δm	0.505±0.004	

⇩ + $B^0\overline{B^0}$ BG

Name	Value
τ_{B0}	1.535±0.006 (ps)
Δm	0.505±0.004

- Fit results for signal and signal + $B^0\overline{B^0}$ BG are consistent.

→ $B^0\overline{B^0}$ BG PDF were obtained.



Signal + B^+B^- Background

- To check the correctness of BG PDF, Signal + B^+B^- BG was fitted.

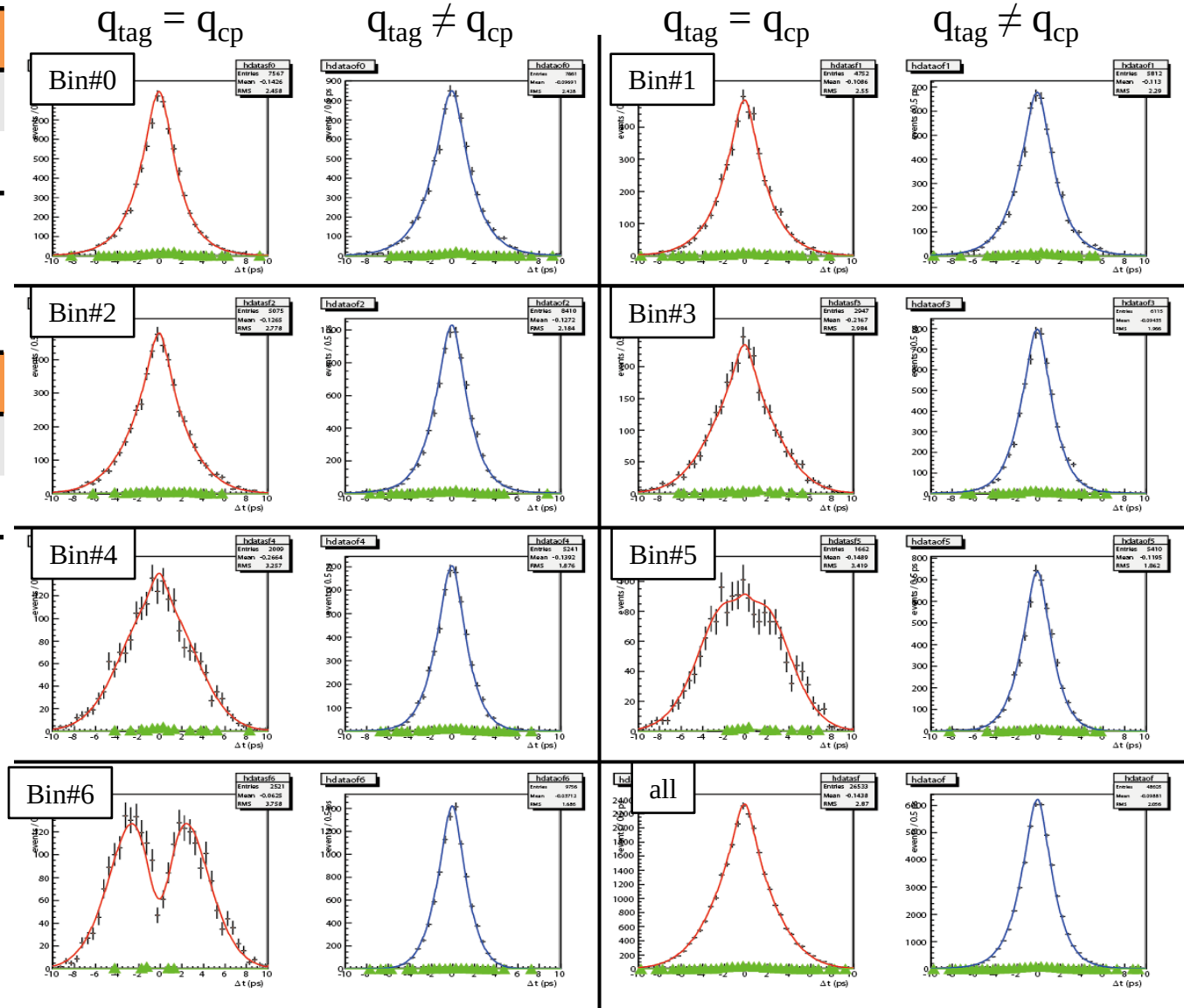
Name	Value	Signal Only
τ_{B0}	1.533 ± 0.006 (ps)	
Δm	0.505 ± 0.004	

⇩ + B^+B^- BG

Name	Value
τ_{B0}	1.535 ± 0.006 (ps)
Δm	0.506 ± 0.004

- Fit results for signal and signal + B^+B^- BG are consistent.

→ B^+B^- BG PDF were obtained.



Signal + continuum Background

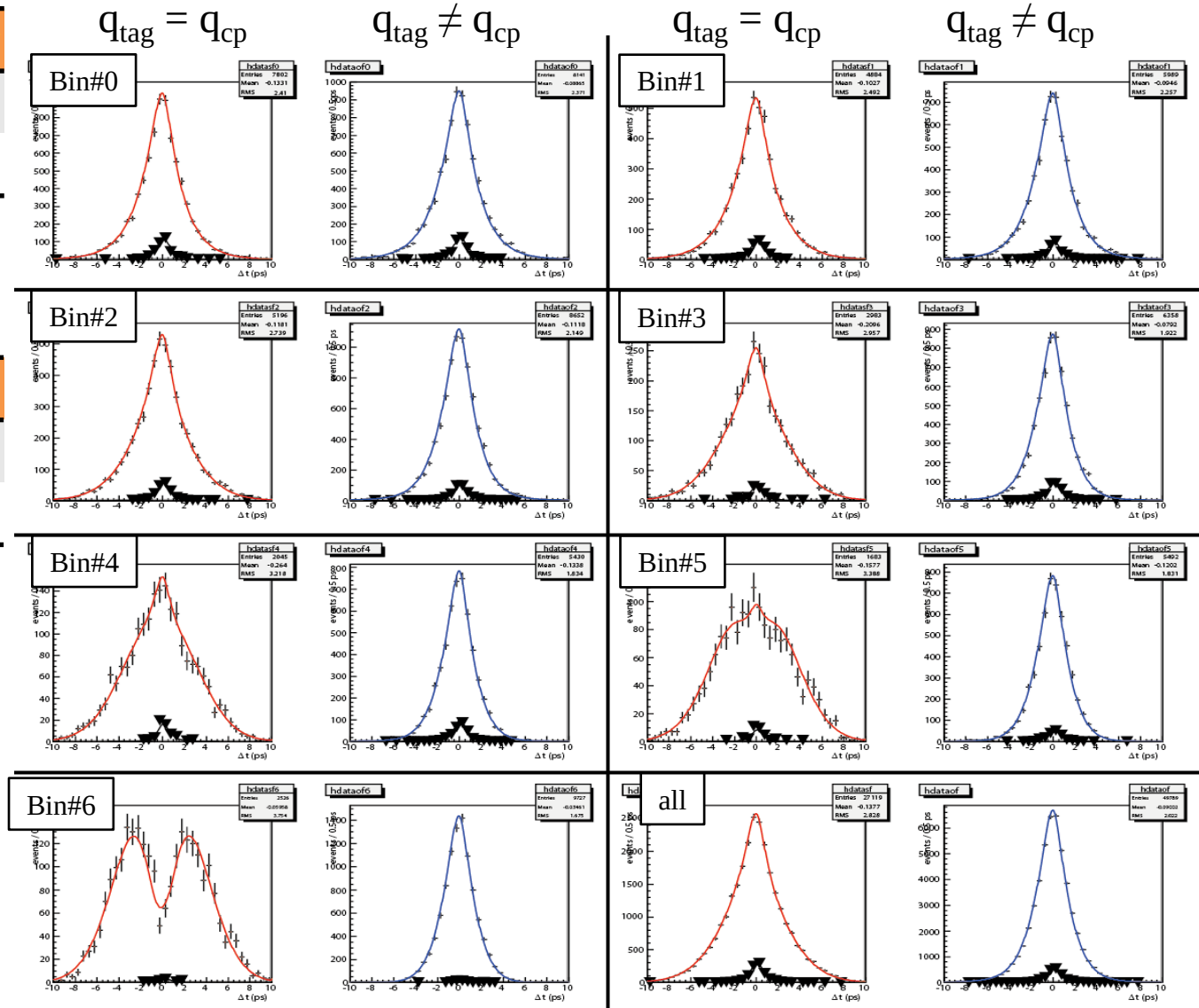
- To check the correctness of BG PDF, Signal + continuum BG was fitted.

Name	Value	Signal Only
τ_{B0}	1.533 ± 0.006 (ps)	
Δm	0.505 ± 0.004	

⇩ + continuum BG

Name	Value
τ_{B0}	1.534 ± 0.006 (ps)
Δm	0.505 ± 0.004

- Fit results for signal and signal + continuum BG are consistent.
→ continuum BG PDF were obtained.



信号事象＋背景事象

- signal fraction に従って背景事象を加え、信号事象の τ , Δm をfit

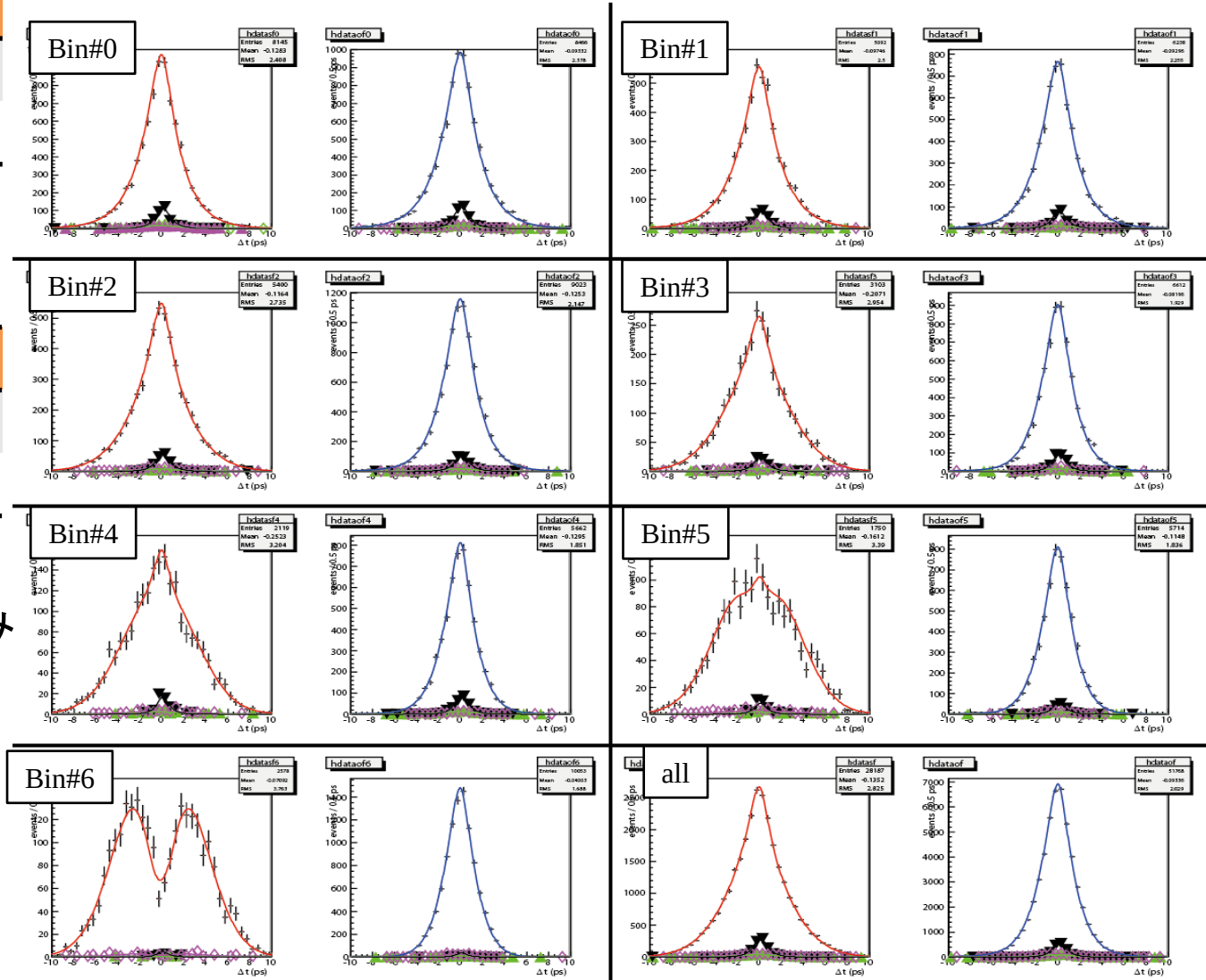
Name	Value 信号事象のみ
τ_{B0}	1.533±0.006 (ps)
Δm	0.505±0.004

⇩ + 背景事象

Name	Value
τ_{B0}	1.534±0.006 (ps)
Δm	0.506±0.004

Fit 結果は信号事象のみと consistent.

背景事象 PDF が得られた



中性B中間子背景事象のΔt fit

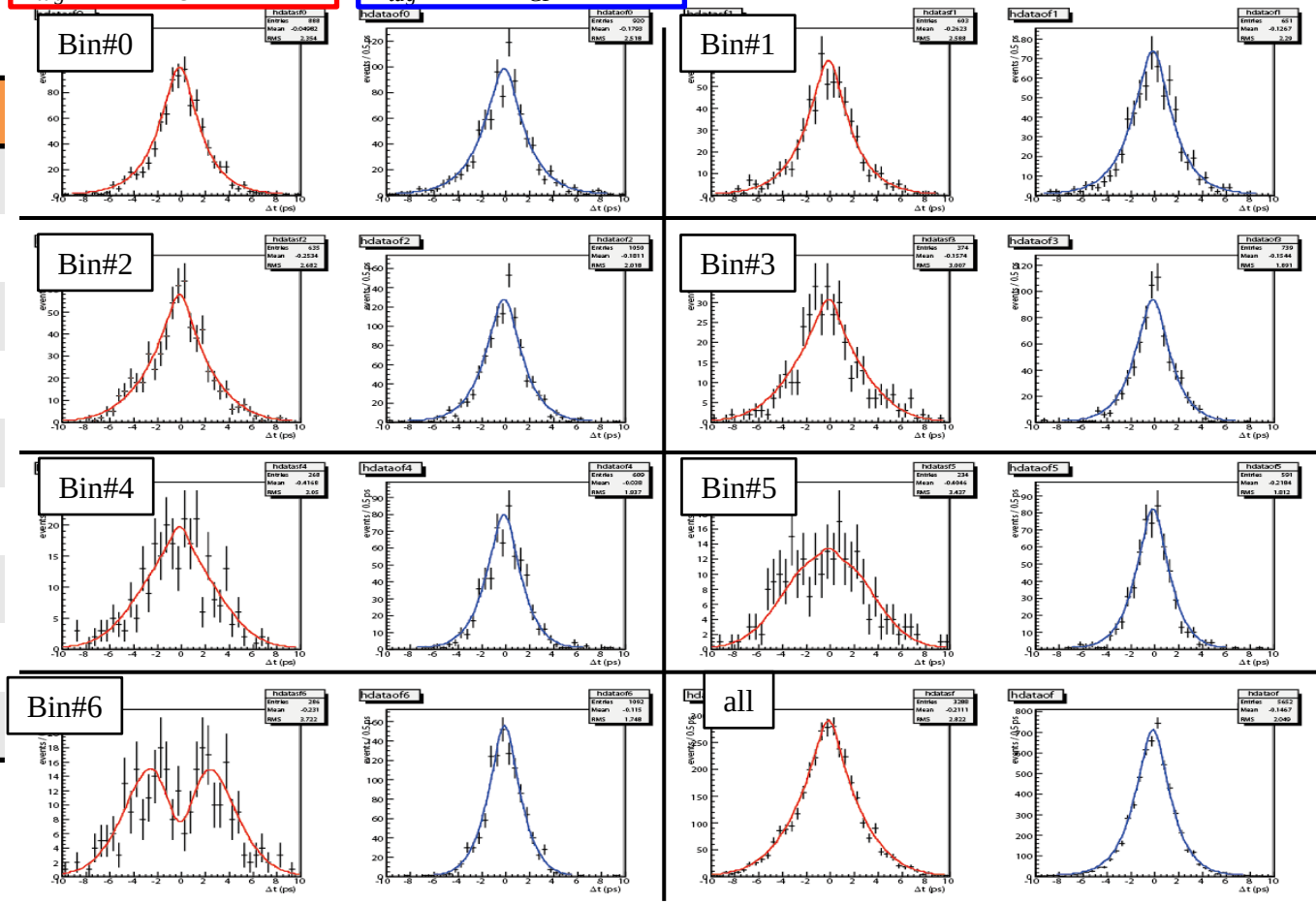
$$P_{B^0BG}(\Delta t, q_{tag}, q_{cp}) = \underbrace{\frac{1}{8\tau_{B^0BG}} e^{-|\Delta t|/\tau_{B^0BG}}}_{\text{寿命項}} \{1 - \underbrace{q_{tag} q_{cp} (1-2w_{rbin})}_{\text{Flavor tag 補正}} \underbrace{\cos(\Delta m \Delta t)}_{\text{B}^0\text{B}^0\text{bar mixing 項}}\}$$

- Fit 結果

Name	Value
τ_{B0BG}	1.525±0.019 (ps)
Δm	0.516±0.013
w_0	0.50 (fixed)
w_1	0.45±0.02
w_2	0.29±0.02
w_3	0.23±0.02
w_4	0.18±0.02
w_5	0.12±0.02
w_6	0.03±0.01

$B_{tag} = \bar{B}^0, f_{CP} = D^{*+}\pi^-$
$B_{tag} = B^0, f_{CP} = D^{*-}\pi^+$

$B_{tag} = \bar{B}^0, f_{CP} = D^{*-}\pi^+$
$B_{tag} = B^0, f_{CP} = D^{*+}\pi^-$

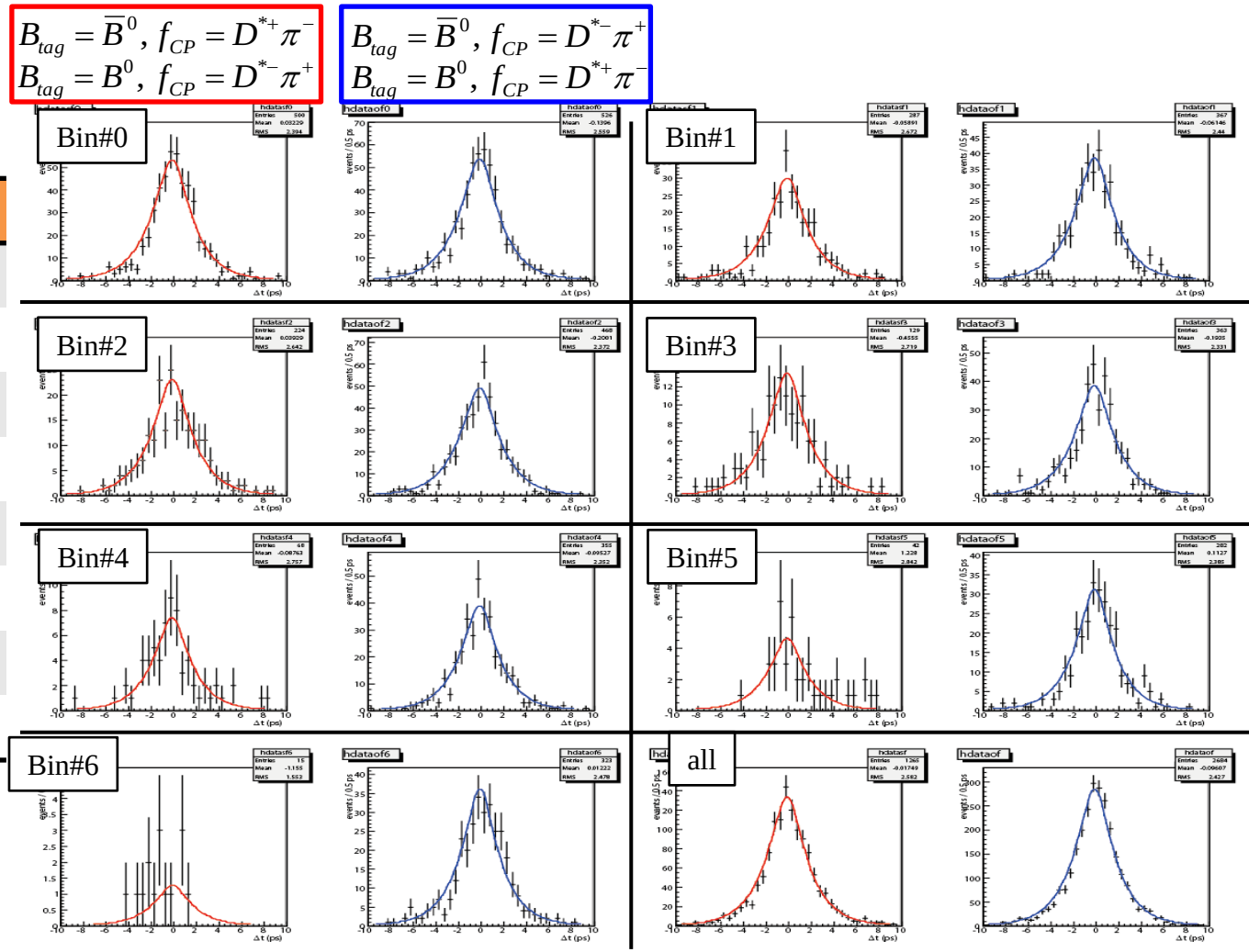


荷電B中間子背景事象のΔt fit

$$P_{chg}(\Delta t, q_{tag}, q_{cp}) = \frac{1}{8\tau_{chgB}} e^{-|\Delta t|/\tau_{chgB}} \{1 - q_{tag} q_{cp} (1 - 2w_{rbin})\}$$

- Fit 結果

Name	Value
τ_{chgB}	1.599±0.029 (ps)
w_0	0.50 (fixed)
w_1	0.44±0.02
w_2	0.32±0.02
w_3	0.26±0.02
w_4	0.16±0.02
w_5	0.13±0.02
w_6	0.04±0.01



B以外の背景事象のΔt fit

$$P_{con}(\Delta t) = \int P_{con}(\Delta t') \cdot R_{bkg}(\Delta t - \Delta t') \cdot d\Delta t'$$

$$P_{con}(\Delta t) = f_\delta \cdot \delta(\Delta t - \mu_\delta) + (1 - f_\delta) \cdot \exp\left(-\frac{|\Delta t - \mu_\tau|}{\tau_{con}}\right)$$

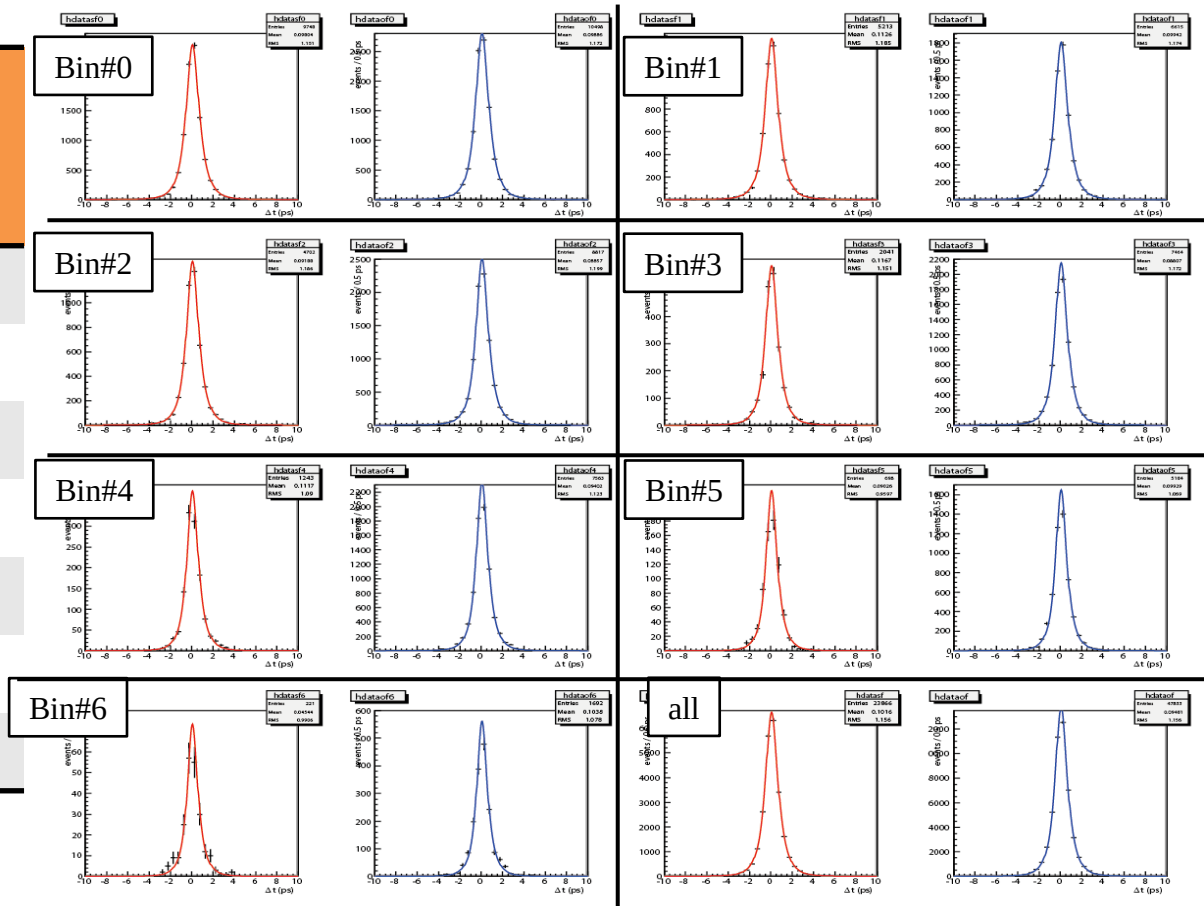
$$R_{con}(\Delta t) = (1 - f_{con}^{tail}) \cdot G(\Delta t; s_{con}^{main} \cdot \sigma_{vtx}) + f_{con}^{tail} \cdot G(\Delta t; s_{con}^{tail} \cdot \sigma_{vtx})$$

- Fit 結果

	Single-track vertex Either CP or tag B	Multi-track vertex Both CP and tag B
f_d	0.26±0.04	0.39±0.02
m_d	0.046±0.007	
m_τ	0.14±0.01	
τ_{con}	0.58±0.02	
s_{bkg}^{main}	1.07±0.03	1.34±0.02
s_{bkg}^{tail}	5.40±0.42	4.87±0.26
f_{bkg}^{tail}	0.088±0.010	0.047±0.007

$B_{tag} = \bar{B}^0,\ f_{CP} = D^{*+}\pi^-$
$B_{tag} = B^0,\ f_{CP} = D^{*-}\pi^+$

$B_{tag} = \bar{B}^0,\ f_{CP} = D^{*-}\pi^+$
$B_{tag} = B^0,\ f_{CP} = D^{*+}\pi^-$



信号事象＋背景事象での Δt fit

$$P\left(B^0 \to D^{*\mp}\pi^{\pm}\right) = \frac{e^{-|\Delta t|/\tau_{B^0}}}{8\tau_{B^0}}\left[1 \pm C\cos\left(\Delta m\Delta t\right) - S^{\mp}\sin\left(\Delta m\Delta t\right)\right]$$

$$P\left(\overline{B}^0 \to D^{*\pm}\pi^{\mp}\right) = \frac{e^{-|\Delta t|/\tau_{B^0}}}{8\tau_{B^0}}\left[1 \pm C\cos\left(\Delta m\Delta t\right) + S^{\pm}\sin\left(\Delta m\Delta t\right)\right]$$

- fit results

$\phi_1+\phi_3/2$	ratio	$S^{\pm}$ (input)	S^{+} (diff)	S^{-} (diff)
0.89685	0.02	-0.039	-0.047 ± 0.021 (0.36 σ)	-0.032 ± 0.021 (0.35 σ)
	0.05	-0.097	-0.099 ± 0.021 (0.11 σ)	-0.12 ± 0.021 (0.98 σ)
	0.1	-0.19	-0.24 ± 0.020 (2.4 σ)	-0.20 ± 0.020 (0.38 σ)
π/2	0.02	0.0	-0.021 ± 0.021 (0.98 σ)	0.013 ± 0.021 (0.65 σ)
	0.05	0.0	-0.033 ± 0.021 (1.60 σ)	0.014 ± 0.020 (0.69 σ)
	0.1	0.0	-0.020 ± 0.021 (0.96 σ)	-0.016 ± 0.021 (0.78 σ)
π/4	0.02	-0.040	-0.039± 0.021 (0.049 σ)	-0.047 ± 0.021 (0.32 σ)
	0.05	-0.10	-0.13± 0.021 (1.49 σ)	-0.11 ± 0.020 (0.28 σ)
	0.1	-0.20	-0.20± 0.019 (0.20 σ)	-0.21 ± 0.020 (0.43 σ)