Measurement of the B^- and $\bar{B}^0$ meson Lifetimes using Semileptonic Decays with Single Lepton Datasets in CDF Run II

(CDF 7458)

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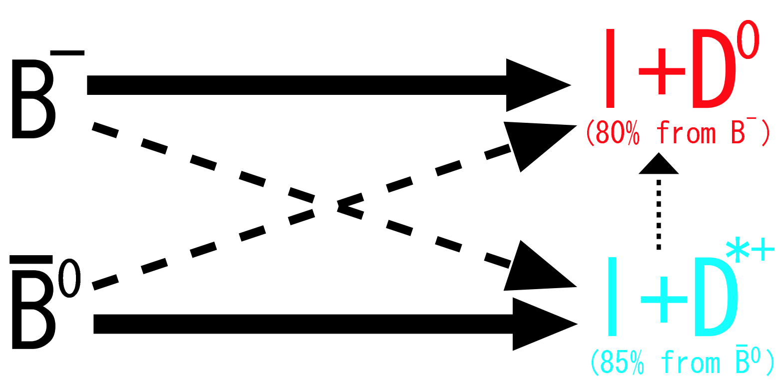
Introduction

Why measuring lifetime is important?

- **Test HQE model (Heavy Quark Expansion, by I.I.Bigi)**
  It involves non-spectator effects. The HQE predicts :
  - $\tau(B^+)/\tau(\bar{B}^0) \sim 1 + 0.05(f_B/200\ \text{MeV})^2$
  - $\tau(B_s)/\tau(\bar{B}^0) \sim 1 \pm 0.01$
- **An unavoidable step to measure** $c\tau(\bar{B}_s^0)$, $\Delta\Gamma(\bar{B}_s^0)$, **and** $B_s^0 \bar{B}_s{}^0$ **oscillation with semileptonics.**

$B^-/\bar{B}^0$ lifetime measurement using semileptonics

- **Use** $B^-/\bar{B}^0 \to \ell^- \bar{\nu} D^0 X (\ell^- = e^-$ **or** $\mu^-)$,
  $D^0 \to K^- \pi^+$
- **Large branching fraction**
- **Charge correlation is useful to identify the** B **signal** $(Q_\ell = Q_K)$
- **Decay chains are somewhat complicated, but can be disentangled by separating** $\ell^- D^{*+}$ **candidates**



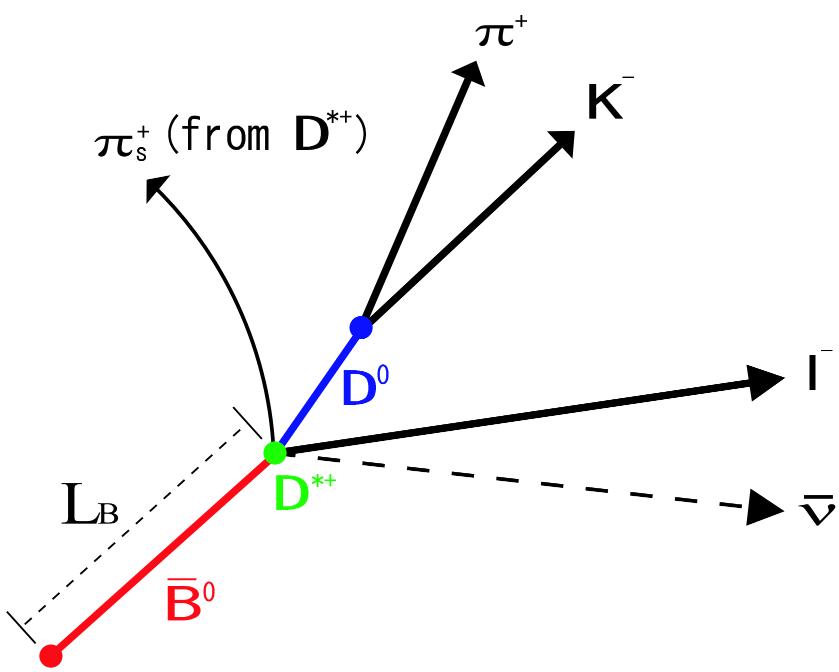
Analysis outline

1. Select a lepton (e or μ) from 8 GeV lepton datasets
2. Reconstruct $D^0 \to K^-\pi^+$ around the lepton
3. Find $D^{*+} \to D^0\pi_s^+$ candidates, and split them from the $\ell^- D^0$ sample
4. Reconstruct $\bar{B} \to \ell^-\bar{\nu}D^0X$ decay vertex in xy plane, and calculate B pseudo decay time
5. Correct missing momentum (K factor)
   - $p_T(B)$ can not be reconstructed due to some missing particles (neutrino, particles from $D^{*,**}$)
   - Correct it using MC
6. Model combinatorial background shape
   - use $D^0(D^{*+})$ mass sideband
7. Determine resolution scale factor
8. Estimate physics backgrounds
   - Prompt charm background
   - Bottom background
9. Estimate sample composition
   - Need to know $B^-/\bar{B}^0$ composition in each $\ell^- D^0$ and $\ell^- D^{*+}$ sample
10. Extract the lifetimes using unbinned likelihood fit
11. Estimate systematic uncertainties

Dataset & Reconstruction

- 8 GeV lepton trigger ..require μ,e with $p_T > 8$ GeV/c
- Minimal trigger bias
- 260 pb^{-1} of the data used for this analysis (electron trigger is dynamically prescaled)

Reconstruction of the B decay vertex in xy plane : (typical case)



pseudo decay time is calculated as

$$ct^* = \frac{L_B}{p_T(\ell^- D^0)} M_B$$

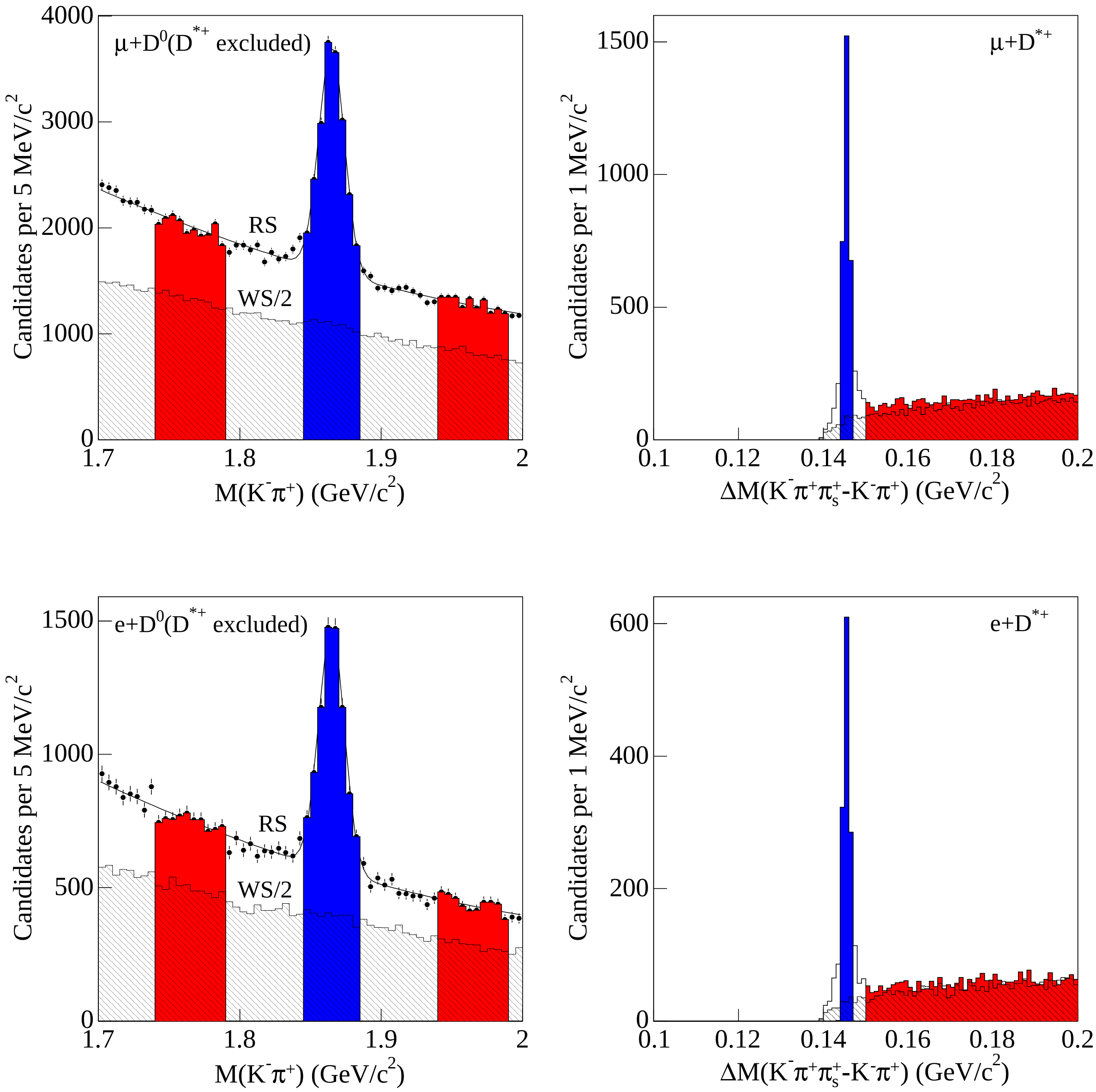
$\boxed{\text{Event selection}}$

- **Muon selection:**
  - $p_T(\mu) > 8$ **GeV/**c
  - χ^2_x(**CMU, CMP**) < 6, χ^2_z(**CMU**) < 5
  - **Iso(**ΣE_T **in** $\Delta R < 0.4$**)/**$p_T(D^0) < 2.5$
- **Electron selection:**
  - $p_T > 8$ **GeV/**c, $E_T > 8$ **GeV/**c^2
  - **Reconstructed in CEM fiducial region.**
  - **LSHR** < 0.2
  - **CES** $|\Delta x| < 1.4$ **cm**
  - **CES** $|\Delta z \sin\theta| < 2$ **cm**
  - **CES** $\chi^2_x, \chi^2_z < 15$
  - $E_{\rm HAD}/E_{\rm EM} < 0.04$ **(if # of associated track = 1)**
  - $E_{\rm HAD}/E_{\rm EM} < 0.1$ **(if # of associated track > 1)**
  - $0.75 < E/p < 1.4$
  - **Conversion Removal :**
    * $|S| < 0.2$ **cm**
    * $|\Delta \cot\theta| < 0.06$

Event selection (cont'd)

- For $D^0 \to K^-\pi^+$ and $D^{*+} \to D^0\pi_s^+$ reconstruction:
  - \# of COT axial(stereo) hits $\geq$ 20(16) (for ℓ,K,π)
  - \# of SVXII rϕ hits $\geq$ 3 (for ℓ,K,π,π_s)
  - $|\Delta z_0(\ell - K, \pi)| < 1.25$ cm
  - $p_T(K) > 1.5$ GeV/c, $p_T(\pi) > 0.5$ GeV/c
  - $\Delta R(\ell - K) < 0.6$, $\Delta R(\ell - \pi) < 0.7$
  - $M(\ell^- D^0) <$ 5.3 GeV/c^2
  - $L_{xy}(D^0 - P.V.) >$ 0
  - $|ct(D^0)| < 0.1$ cm
  - $-0.15 < ct^*(B) < 0.3$ cm
  - $\sigma_{ct*}(B)$, $\sigma_{ct}(D^0) < 0.02$ cm

$\ell^- D^0(D^{*+})$ signal



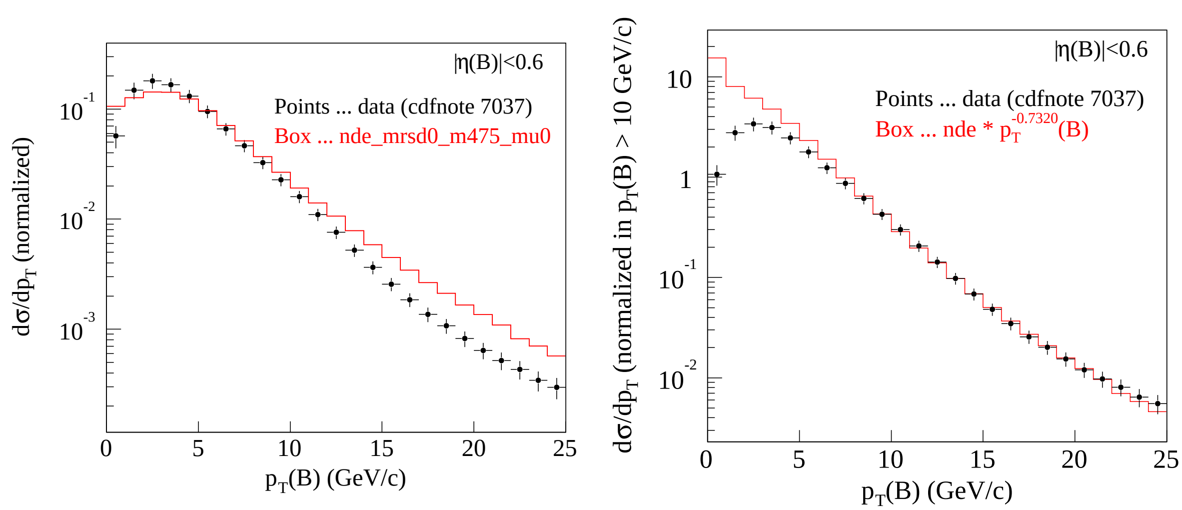
	N_{D^0} (D^{*+})	Signal fraction
$\mu^- D^0$	9338	0.425 ± 0.004
$\mu^- D^{*+}$	2673	0.907 ± 0.007
$e^- D^0$	4022	0.471 ± 0.007
$e^- D^{*+}$	1107	0.908 ± 0.010

$\boxed{B \text{ monte carlo samples}}$

Monte carlo samples are indispensable for this analysis. B signal monte carlo samples are generated with Bgenerator + QQ .
We have two type of MC samples:

- parametric MC sample ... keep only generator-level information. Much statistics, used to calculate muon K factors
- full simulation sample ... apply full simulation, used for electron K factor calculation, and sample compositin estimation both muon and electron datasets.

Tuning on the $p_T(B)$:
$p_T(B)$ spectrum used in the Bgenerator have somewhat different shape from the real spectrum measured by J/ψ data (cdf7037). We correct the difference by weighting the MC events with a factor of $p_T(B)^{-0.7320}$.



Missing momentum correction (K factor)

"Real" decay time of a B meson :

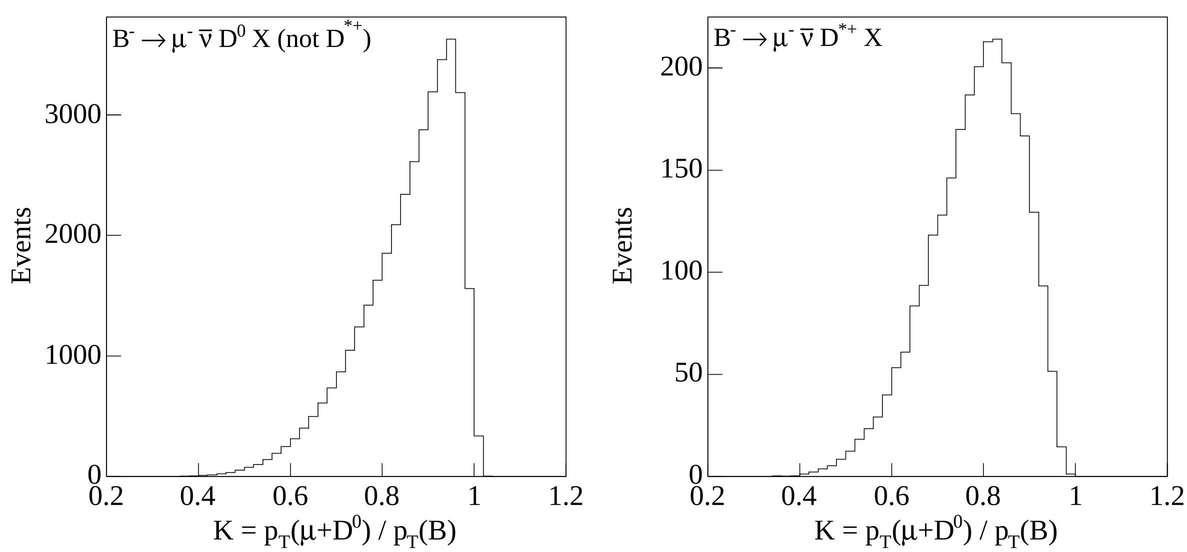
$$ct = \frac{L_B}{p_T(B)} M_B$$

But since the B is not fully reconstructed, what we can measure is $P_T(\ell^- D^0)$ and "pseudo" decay time ct^*.

$$ct^* = \frac{L_B}{p_T(\ell^- D^0)} M_B = ct \cdot K \quad \text{where } K \equiv \frac{p_T(\ell^- D^0)}{p_T(B)}$$

From the distributions of both ct^*(data) and K factor, we can extract the lifetime of "true" decay time.

The K factor distributions are obtained from the B monte carlo samples.
Totally 8 K distributions are prepared for the lifetime fit.
($\bar{B} \to \ell^- \bar{\nu} D X$, $\bar{B} = B^- / \bar{B}^0$, $\ell = \mu/e$, $D = D^0 / D^{*+}$)



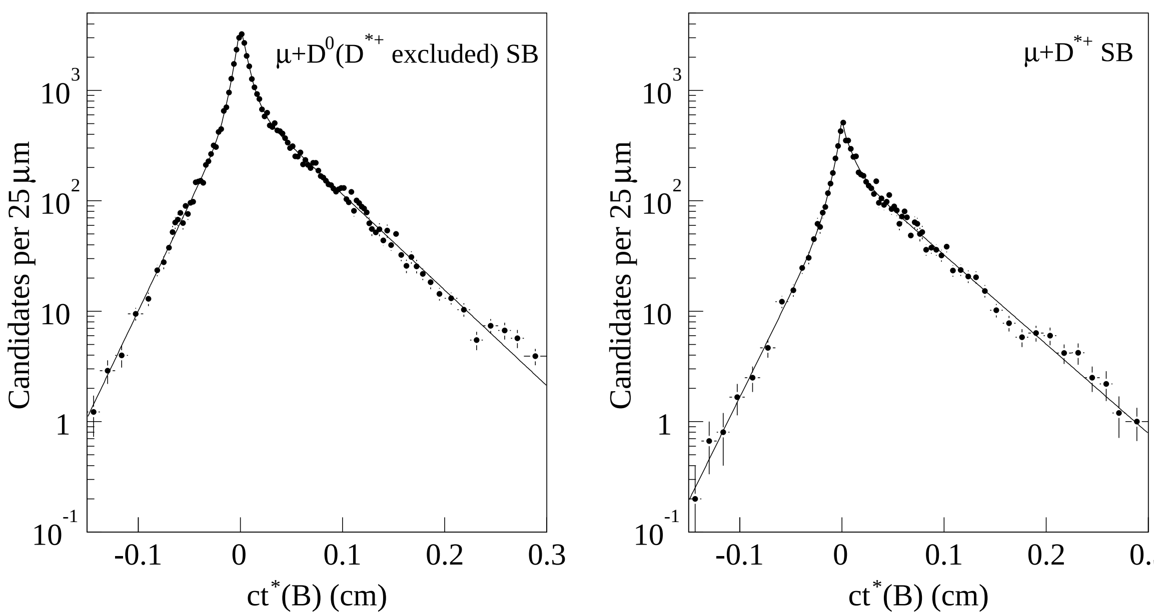
Combinatorial background modeling

The shape of the combinatorial background is taken from the $M(D^0)$ (or ΔM) sideband events.
The sideband events are modeled with following background function:

$$
\begin{aligned}
\mathcal{F}_{BG}(ct^*) \;=\; & (1 - f_{1+} - f_{2+} - f_{1-} - f_{2-})\; G(ct^*;\sigma) \\
& + \{f_{1+}\mathrm{Exp}(-x;\lambda_{1+}) + f_{2+}\mathrm{Exp}(-x;\lambda_{2+})\}\,\theta(x) \otimes G(\sigma) \\
& + \{f_{1-}\mathrm{Exp}(+x;\lambda_{1-}) + f_{2-}\mathrm{Exp}(+x;\lambda_{2-})\}\,\theta(-x) \otimes G(\sigma)
\end{aligned}
$$

where $G(ct^*;\sigma)$ is a normalized Gaussian,
$\theta(x)$ is step function (0 for $x > 0$, 1 for $x < 0$).

Fit results (only μ results are shown here):



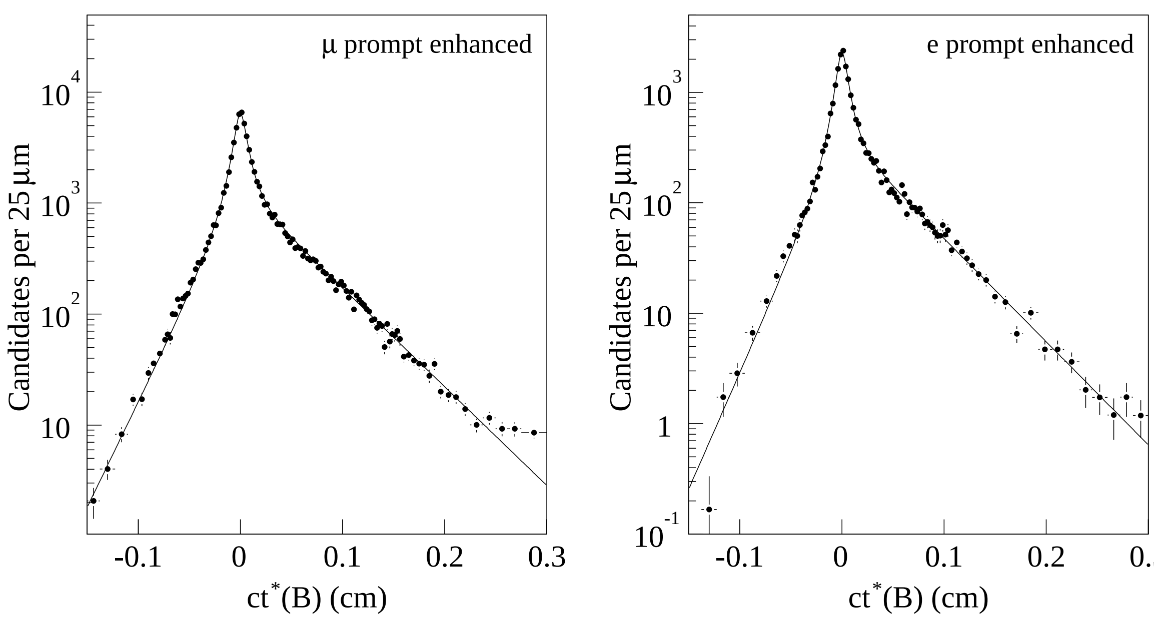
The background shapes under the signal peak are defined by these fits.

Resolution scale factor

The value of σ_{ct^*} provided by CTVMFT is NOT known to be a right resolution. To correct it, we introduce a resolution scale factor s, and scale the σ_{ct^*} to $s\sigma_{ct^*}$.

To determine the scale factor, we use a "prompt enhanced sample" selected by loosening the lepton ID cuts. From this sample, we pick sideband events and fit the ct^* distribution with the following likelihood function

$$\begin{aligned}\mathcal{F}_{\text{prompt}} &= G(ct^*, s\sigma_{ct*}) \\ &\quad + f_+ \text{Exp}(-ct^*; \lambda_+)\theta(x) \otimes G(s\sigma_{ct^*}) \\ &\quad + f_- \text{Exp}(+ct^*; \lambda_-)\theta(-x) \otimes G(s\sigma_{ct^*})\end{aligned}$$



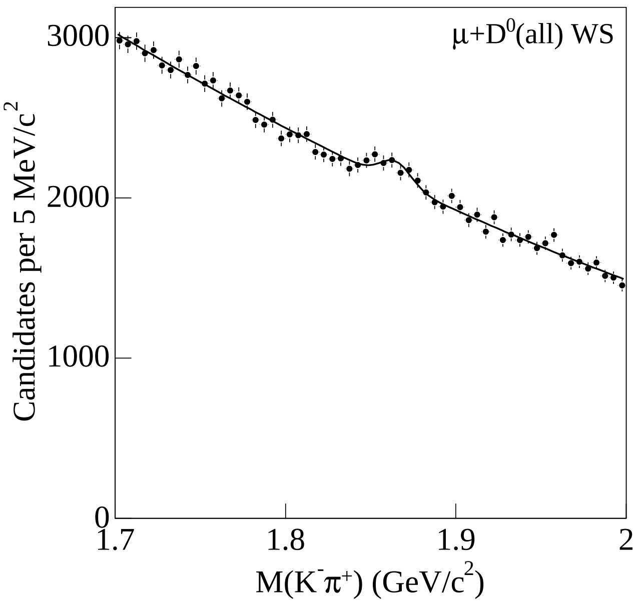
The scale factors are found to be

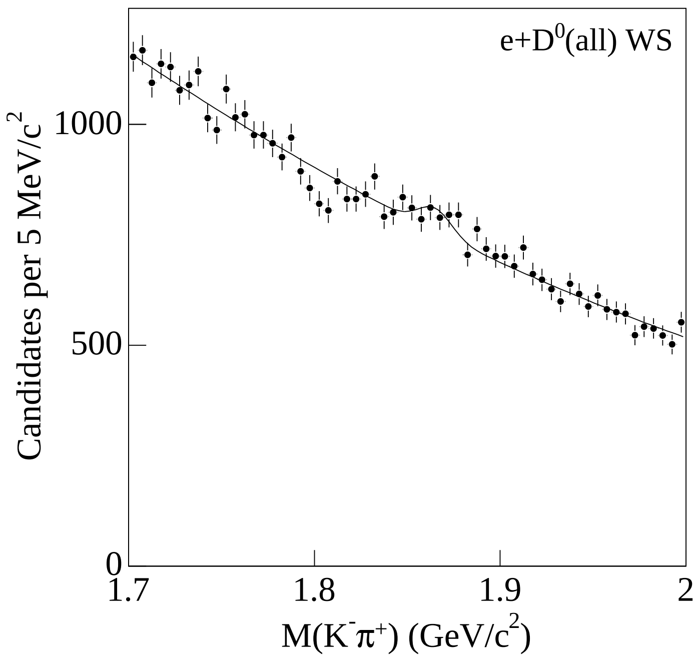
$$s = \begin{cases} 1.52 \pm 0.01 & \text{for muon} \\ 1.45 \pm 0.02 & \text{for electron} \end{cases}$$

Physics background

Physics background $\equiv$ events which are observed as $\ell^- D^0$, but not the semileptonic $B^-/\bar{B}^0$ decays.

Clue of the physics background:
There are small peaks observed in the Wrong-Sign combination events ($\ell^+ D^0$).





$$N_{D^0}(WS) = \begin{cases} 677.7 \pm 141.7 & (5.6 \pm 1.2\% \text{ of RS}) \text{ for muon} \\ 262.7 \pm 85.3 & (5.0 \pm 1.6\% \text{ of RS}) \text{ for electron} \end{cases}$$

These events should come from:
(assuming the leptons could be fakes)

1. Prompt D^0 + track from P.V.
2. bottom background ($\bar{b}b \to \ell^+ D^0$, etc..)

And same kind of physics backgrounds may exist also in the RS peak.

Charm background

Following prompt charm events give the RS track+D^0 combinations.

1. $c \to D^0$ + prompt track
2. $c\bar{c}$, $c \to D^0$, $\bar{c} \to$ track $+ X$

We need to measure the fraction of the prompt charm backgrounds from the RS data sample.

Since it is difficult to distinguish them using any kinematic quantities, we utilize a decay length information to estimate the prompt charm fraction.

We define following variable:

$$ct_2 = \frac{L_{xy}(D^0 - P.V.)}{p_T(K^-\pi^+)} M(K^-\pi^+)$$

- If the D^0 is generated at P.V. (namely prompt charm), the mean lifetime of ct_2 should be same with $c\tau(D^0) = 123\ \mu$m.
- If the event is secondary charm from B decays, the lifetime will be much longer. (Convolution of two exponentials)

Charm background (cont'd)

Idea : fit the ct_2 distribution with following templates, and measure the charm fraction f_c in each sample.

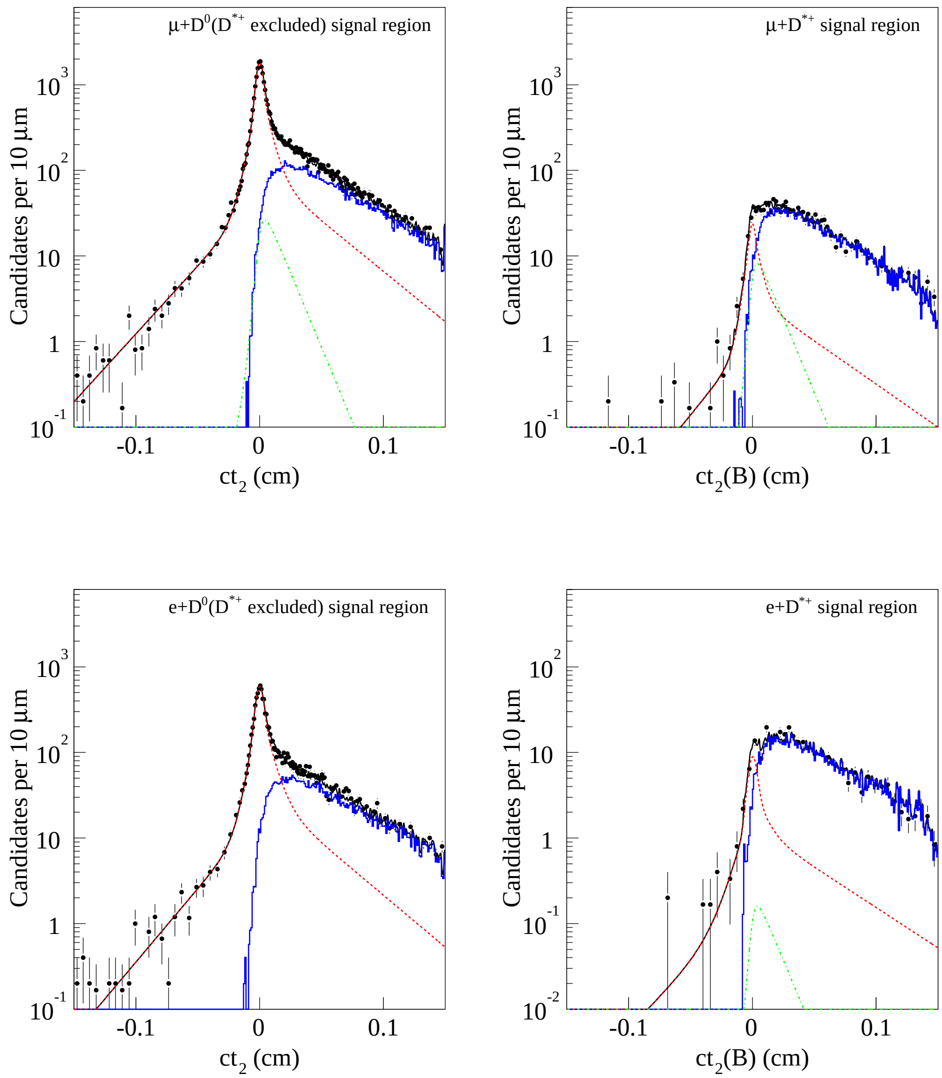
- Charm component (F_c) ... exponential with $c\tau =$ 123 μm, smeared by resolution
- B component (F_B) ... shape obtained from B full simulation sample, smeared with proper resolution
- combinatorial BG (F_{BG}) ... shape taken from the side-band events

Likelihood function :

$$F = f_{\mathrm{sig}}(f_c F_c + (1 - f_c)F_B) + (1 - f_{\mathrm{sig}})F_{\mathrm{BG}}$$

The $L_{xy} > 0$ cut is disabled at the f_c fit.

Fit for prompt charm fraction



$$f_c = \frac{N_c}{N_{D^0}} = \begin{cases} 5.7 \pm 1.2\% & \text{for } \mu + D^0(D^{*+} \text{ excluded) sample} \\ 5.8 \pm 1.3\% & \text{for } \mu + D^{*+} \text{ sample} \\ 0.0\ ^{+2.0}_{-0.0}\% & \text{for } e + D^0(D^{*+} \text{ excluded) sample} \\ 0.3\ ^{+1.9}_{-0.3}\% & \text{for } e + D^{*+} \text{ sample} \end{cases}$$

The small f_c in electron dataset is not fully understood, presumably some electron ID cuts might have suppressed the prompt charms.

ct^* shape of the charm background

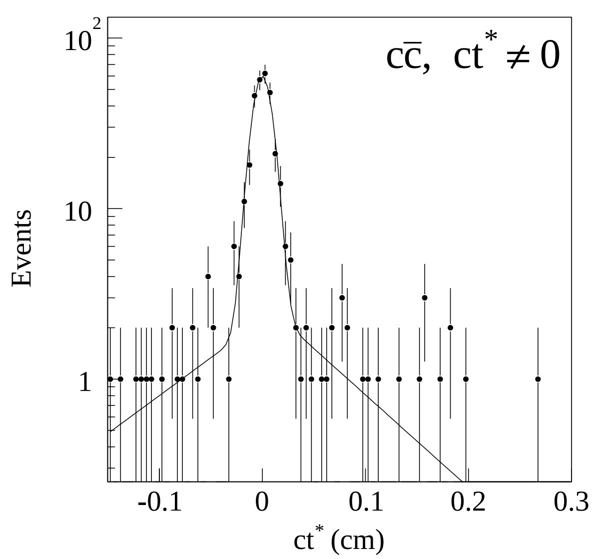
We can categorize prompt charm backgrounds into following two types:

1. $ct^* = 0$ events .. both D^0 and track are from the P.V.
2. $ct^* \neq 0$ events ... $c\bar{c}$ event, track is from a pseudo-scalar $\bar{D}$ hadron

For the $ct^* = 0$ events, the ct^* shape is given by Gaussian,

$$\mathcal{F}_c^{\text{zero}} = G(ct^*; s\sigma_{ct^*})$$

For the $ct^* \neq 0$, we use pythia $c\bar{c}$ MC to calculate the ct^* shape $\mathcal{F}_c^{\text{non-zero}}$.



In the final lifetime fit we use the $\mathcal{F}_c^{\text{zero}}$ as the charm background shape $\mathcal{F}_c$. The $\mathcal{F}_c^{\text{non-zero}}$ is used for evaluation of the systematic uncertainties.

Bottom background

We use $b\bar{b}$ monte carlo by Pythia + QQ to estimate the effect of the bottom background. Since branching fractions of various B decay processes are measured by many experiments and are implemented to QQ, we can calculate bottom background fraction against the B semileptonic signals reliably from the $b\bar{b}$ monte carlo.

Breakdown of the $b\bar{b} \to \ell^- D^0$ MC processes (by Pythia + QQ, no detector simulation):

process	$\ell^- D^0$(D^{*+} excluded)	$\ell^- D^{*+}$
Semileptonic $\ell^- D^0$	**5226**	**2702**
non-semileptonic $\ell^- D^0$	**217**	**108**
$\bar{B}_s^0 \to \ell^- \bar{\nu} D_s^{**+}, D_s^{**+} \to D^0 X$	84	50
$\bar{B} \to \tau^- \bar{\nu} D^0, \tau^- \to \ell^- \bar{\nu}$	52	27
$\bar{B} \to D^0 D_s^- X, D_s^- \to \ell^- X'$	46	8
$\bar{B} \to D^0 D_s^- X, D_s^- \to \tau^- X'$, $\tau^- \to \ell^- X''$	18	5
$\bar{B} \to D\bar{D}X \to \ell^- D^0 X'$	7	6
$b\bar{b}, b \to D^0 X, \bar{b} \to \ell^+ X'$, ($b$ or $\bar{b}$ oscillates and give RS)	6	8
$b\bar{b}, b \to D^0 X, \bar{b} \to \bar{c} \to \ell^- X'$	2	1
others	2	3
hadron+D^0	**3371**	**2138**
single $b \to h^- D^0$	3308	2117
$b\bar{b} \to h^- D^0$	63	21

From the table, we obtain the bottom BG fraction

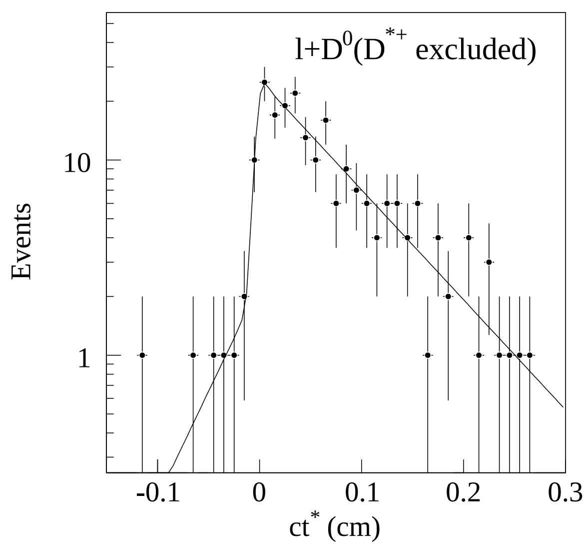
$$f_b = \frac{N_b}{N_{D^0}} = \begin{cases} 3.8 \pm 0.3\% & \text{for } \mu + D^0(D^{*+} \text{ excluded}) \\ 3.6 \pm 0.4\% & \text{for } \mu + D^{*+} \\ 4.0 \pm 0.3\% & \text{for } e + D^0(D^{*+} \text{ excluded}) \\ 3.8 \pm 0.4\% & \text{for } e + D^{*+} \end{cases}$$

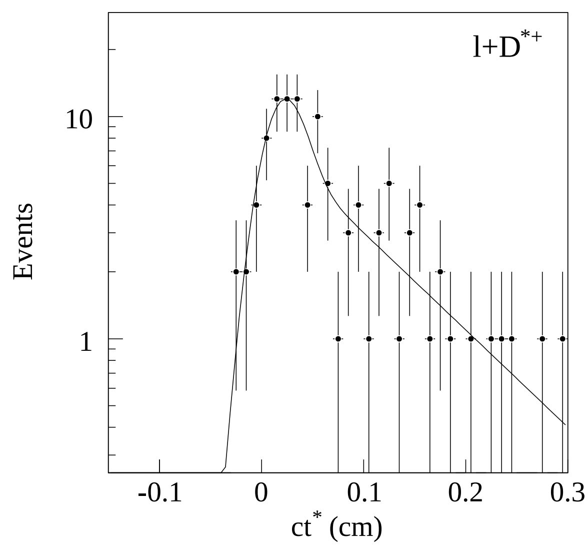
Bottom background (cont'd)

From the non-semileptonic $\ell^- D^0$ events in the $b\bar{b}$ monte carlo sample, we get shapes of the bottom backgrounds.

We fit these distributions with following function:

$$\begin{aligned}\mathcal{F}_b &= (1 - f_+ - f_-)G(ct^* - \alpha; \sigma) \\ &+ f_+\mathrm{Exp}(-ct^*; \lambda_+)\theta(x) \otimes G(\sigma) \\ &+ f_-\mathrm{Exp}(+ct^*; \lambda_-)\theta(-x) \otimes G(\sigma)\end{aligned}$$

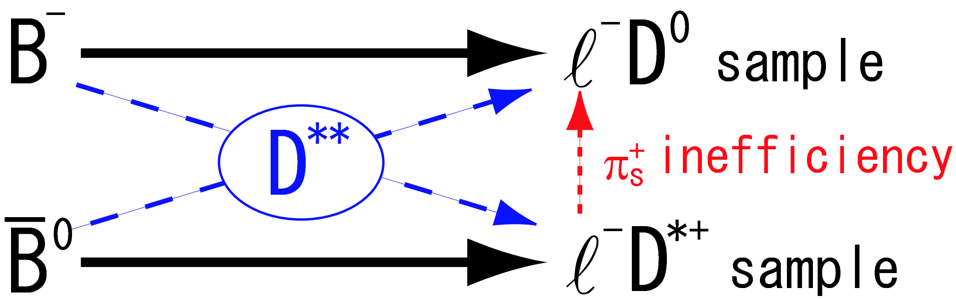




The $\mathcal{F}_b$ is used as the bottom background shape in the final lifetime fit.

Sample composition

For the lifetime fit, we need to know $B^-/\bar{B}^0$ composition each in $\ell^- D^0$(D^{*+} excluded) and $\ell^- D^{*+}$ sample.



There are two causes of the cross talks.

1. **Semileptonic B decays through D^{**} states**
   Following decays through D^{**} cause cross talks of $B^-/\bar{B}^0$ components.

$$B^- \to \ell^- \bar{\nu} D^{**0}, D^{**0} \to D^{*+}\pi^+$$
$$\bar{B}^0 \to \ell^- \bar{\nu} D^{**+}, D^{**+} \to D^0\pi^-$$
$$\bar{B}^0 \to \ell^- \bar{\nu} D^{**+}, D^{**+} \to D^{*0}\pi^-, D^{*0} \to D^0 X^0$$

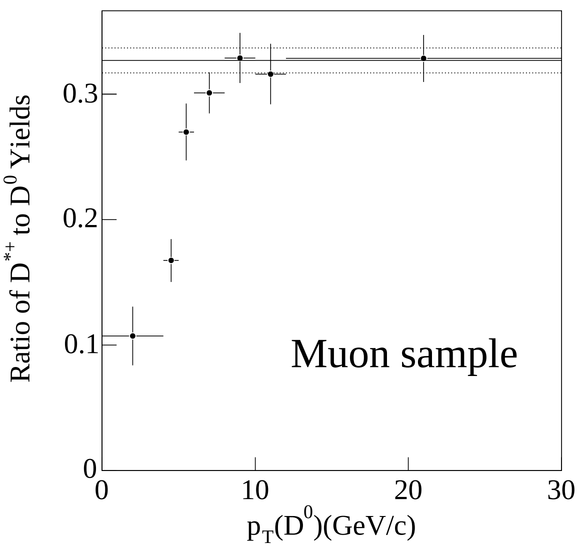
   We utilize the full simulation sample to estimate these cross talks.

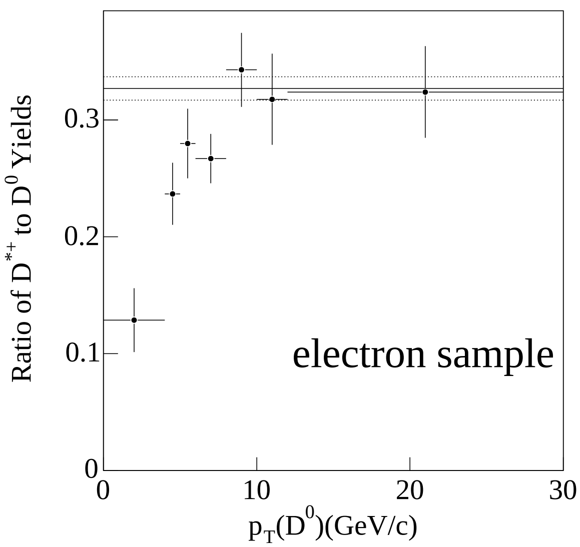
2. **Inefficiency of π_s^+ reconstruction**
   The slow pions from $D^{*+} \to D^0\pi_s^+$ decays have low p_T, where the COT tracking efficiency is not perfect. It causes a cross talk from D^{*+} to D^0 sample.

Considering these effects, we estimate B^- fraction g_- in each sample.

Sample composition (cont'd)

We measure the slow pion efficiency from the ratio of D^{*+}/D^0 yields against $p_T(D^0)$.





We divide the samples into plateau ($p_T(D^0) > 8$ GeV/c) and low $p_T(D^0)$ regions.
Assuming that in the plateau region π_s^+ tracking efficiency is 99.6% (from cdfnote 6314), $\epsilon(\pi_s^+)$ values in each sample are calculated as follows.

Dataset	$p_T(D^0)$ region	D^{*+}/D^0 ratio	$\epsilon(\pi_s^+)$
Muon	$<$ 8 GeV/c	0.221 $\pm$ 0.010	0.673 $\pm$ 0.037
	$>$ 8 GeV/c	0.326 $\pm$ 0.012	0.993 $^{+0.007}_{-0.049}$
Electron	$<$ 8 GeV/c	0.232 $\pm$ 0.013	0.707 $\pm$ 0.046
	$>$ 8 GeV/c	0.330 $\pm$ 0.021	1.000 $^{+0.000}_{-0.067}$

Sample composition (cont'd)

To estimate dilution by D^{**}, we make use of the B monte carlo sample with full detector simulation.

Sample composition in the monte carlo sample:
(involving $\epsilon(\pi_s^+)$ measured in the data)

	$p_T(D^0)$	$\ell^- D^0$		$\ell^- D^{*+}$	
Dataset	range	N_{B^-}	$N_{\bar{B}^0}$	N_{B^-}	$N_{\bar{B}^0}$
Muon	$<$ 8 GeV/c	2959.4	1032.2	145.1	1051.5
	$>$ 8 GeV/c	2050.1	402.5	148.4	1011.4
Electron	$<$ 8 GeV/c	2176.8	701.1	100.4	823.8
	$>$ 8 GeV/c	1044.4	156.4	61.6	515.0

From this table, we calculate the B^- fraction as,

$$g_- = \frac{N_{B^-}}{N_{\bar{B}^0}\frac{\tau_{\bar{B}^0}}{\tau_{B^-}} + N_{B^-}}$$

Summary of g_- with $\tau(B^-)/\tau(\bar{B}^0) = 1$:

Dataset	$p_T(D^0)$ range	$\ell^- D^0$	$\ell^- D^{*+}$
Muon	$<$ 8 GeV/c	0.741	0.121
	$>$ 8 GeV/c	0.836	0.128
Electron	$<$ 8 GeV/c	0.756	0.109
	$>$ 8 GeV/c	0.870	0.107

Likelihood function for lifetime fit

Likelihood function for the semileptonic B signal:

$$\mathcal{F}_B(ct^*, \sigma_{ct^*}) = \exp\left(-\frac{ct}{c\tau}K\right) \otimes D(K) \otimes G(ct^*; s\sigma_{ct^*})$$

ct^*, σ_{ct^*}	...	B pseudo decay time and its resolution, given event-by-event
$c\tau$	...	B meson lifetime
$D(K)$	...	K factor distribution
s	...	resolution scale factor

Event likelihood:

$$\begin{aligned} l_i(ct^*(i), \sigma_{ct^*}(i)) &= f_{\rm sig}\{(1 - f_c - f_b)\mathcal{F}_{\rm sl} + f_c\mathcal{F}_c + f_b\mathcal{F}_b\} \\ &\quad +(1 - f_{\rm sig})\mathcal{F}_{\rm BG} \\ \mathcal{F}_{\rm sl} &= g_-\mathcal{F}_{B^-} + (1 - g_-)\mathcal{F}_{\bar{B}^0} \end{aligned}$$

i	...	event ID in each sample
$f_{\rm sig}$	...	fraction of $D^0(D^{*+})$ events in signal region
$\mathcal{F}_{\rm BG}(ct^*)$	...	combinatorial BG shape (gaus + 4 tails)
f_c, $\mathcal{F}_c(ct^*)$	...	fraction and shape of charm background
f_b, $\mathcal{F}_b(ct^*)$	...	fraction and shape of bottom background
g_-	...	fraction of B^- in each sample

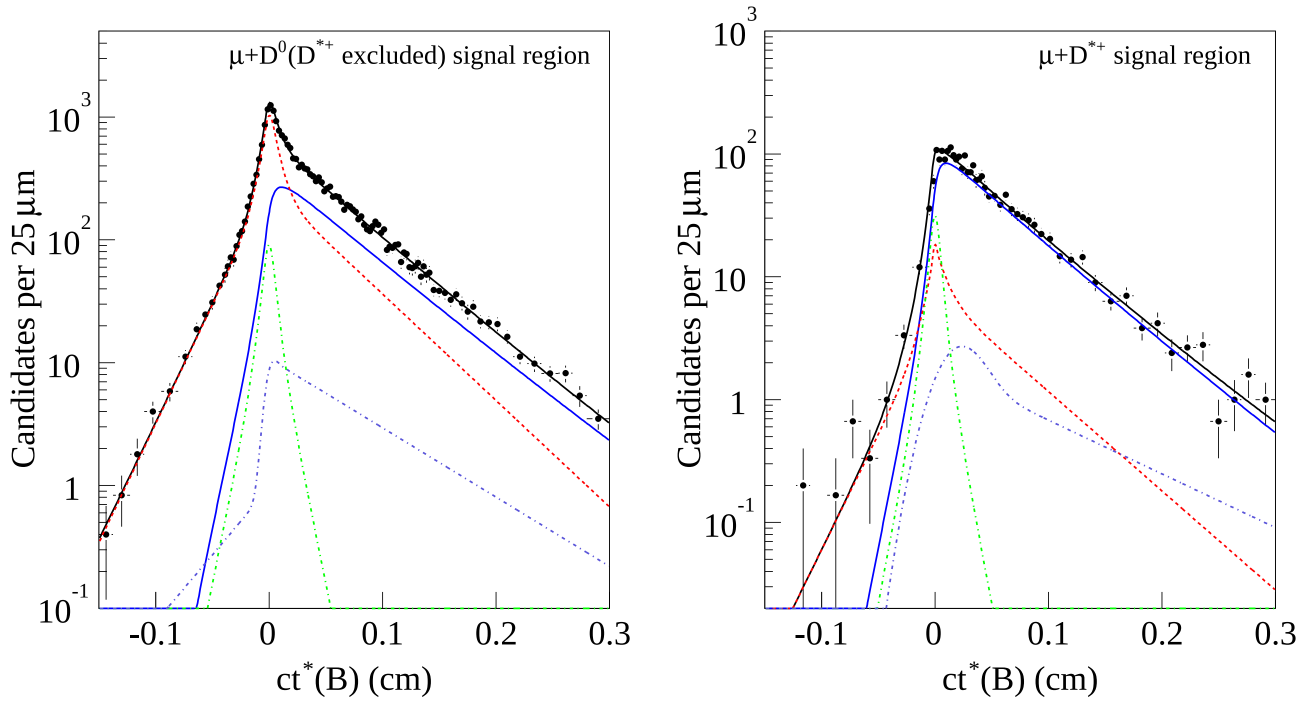
Combined likelihood for each sample:

$$L_X = \prod_i l_i \ (\mathrm{X} = \mu^- D^0, \mu^- D^{*+}, e^- D^0, e^- D^{*+})$$

Fit results for the muon dataset

First we fit the muon and electron datasets separately. Only the $c\tau(B^-)$, $c\tau(\bar{B}^0)$ are floated at the fit.

Fit for muon sample ... maximize $L_\mu = L_{\mu^- D^0} \cdot L_{\mu^- D^{*+}}$



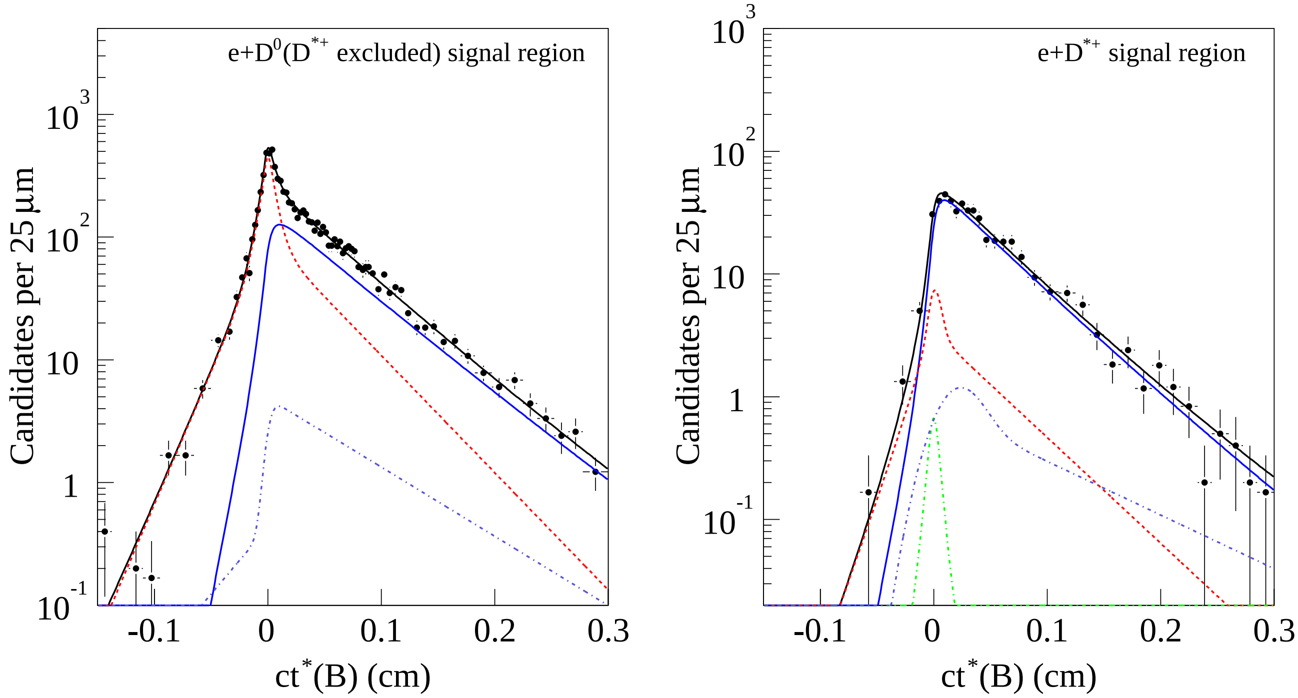
Points	...	**data**
Black	...	$\mathcal{F} = \mathcal{F}_B + \mathcal{F}_{BG} + \mathcal{F}_c + \mathcal{F}_b$
Blue	...	$\mathcal{F}_B$
Red	...	$\mathcal{F}_{BG}$
Dashed green	...	$\mathcal{F}_c$
Dashed blue	...	$\mathcal{F}_b$

Fit results for the muon:

$$c\tau(B^-) = 489.8 \pm 10.8\ \mu\mathrm{m}$$
$$c\tau(\bar{B}^0) = 453.6 \pm 13.6\ \mu\mathrm{m}$$
$$\tau(B^-)/\tau(\bar{B}^0) = 1.080 \pm 0.048$$

Fit results for the electron dataset

Fit for electron sample ... maximize $L_e = L_{e^- D^0} \cdot L_{e^- D^{*+}}$



Points ... **data**

Black ... $\mathcal{F} = \mathcal{F}_B + \mathcal{F}_{BG} + \mathcal{F}_c + \mathcal{F}_b$

Blue ... $\mathcal{F}_B$

Red ... $\mathcal{F}_{BG}$

Dashed green ... $\mathcal{F}_c$

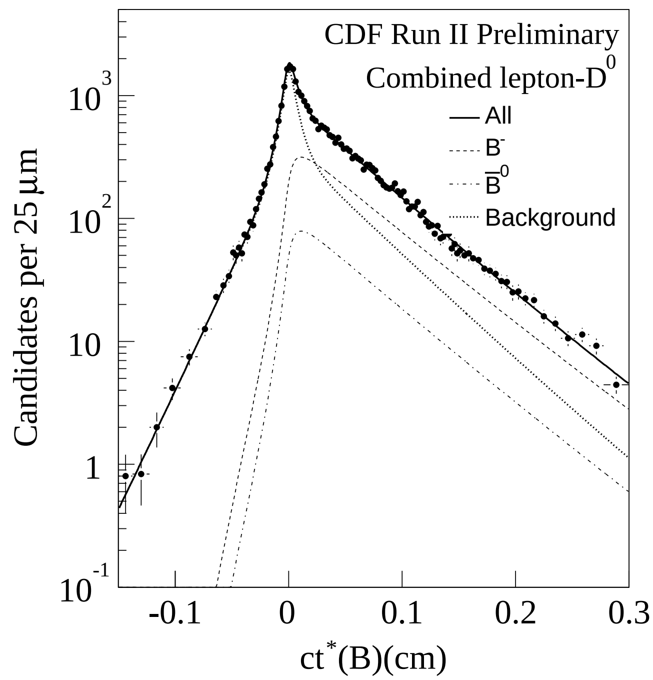
Dashed blue ... $\mathcal{F}_b$

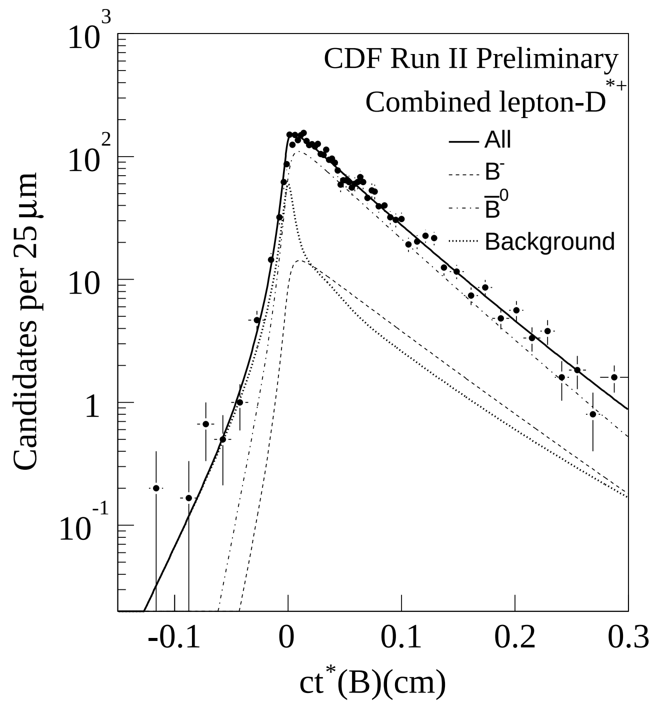
Fit results for the electron:

$$c\tau(B^-) = 504.7 \pm 13.9 \ \mu\text{m}$$
$$c\tau(\bar{B}^0) = 418.1 \pm 18.2 \ \mu\text{m}$$
$$\tau(B^-)/\tau(\bar{B}^0) = 1.207 \pm 0.072$$

Combined fit result

Maximize $L_{\textbf{combined}} = L_e \cdot L_\mu$





μ, e combined fit results:

$$
\begin{aligned}
c\tau(B^-) &= 495.6 \pm 8.6\ \mu\text{m} \\
c\tau(\bar{B}^0) &= 441.5 \pm 10.9\ \mu\text{m} \\
\tau(B^-)/\tau(\bar{B}^0) &= 1.123 \pm 0.040
\end{aligned}
$$

Systematic uncertainties

Source	Contribution to		
	$c\tau(B^-)(\mu\text{m})$	$c\tau(\bar{B}^0)(\mu\text{m})$	$\tau(B^-)/\tau(\bar{B}^0)$
Charm background			
Charm BG fraction (f_c)	$^{+3.7}_{-1.9}$	$^{+5.7}_{-3.7}$	$^{+0.006}_{-0.007}$
Charm BG shape ($\mathcal{F}_c$)	± 2.6	± 5.2	± 0.007
Bottom background			
Bottom BG fraction (f_b)	$^{+0.3}_{-0.9}$	$^{+0.7}_{-1.5}$	$^{+0.001}_{-0.002}$
Bottom BG shape ($\mathcal{F}_b$)	± 2.6	± 1.4	± 0.002
Sample composition			
D^{**} fraction (f^{**})	$^{+2.5}_{-0.6}$	$^{+6.5}_{-10.1}$	$^{+0.032}_{-0.018}$
D^{**} composition (P_V)	$^{+0.7}_{-1.4}$	$^{+11.0}_{-8.6}$	$^{+0.023}_{-0.031}$
π_s^+ reconstruction	$^{+0.1}_{-0.6}$	$^{+0.8}_{-0.0}$	$^{+0.000}_{-0.004}$
K factor			
$p_T(B)$ spectrum	± 6.1	± 5.3	-
B decay model	± 1.0	± 1.3	-
Electron cuts	± 2.0	± 1.4	-
Signal fraction (f_{sig})	± 2.4	± 0.9	$\pm$ 0.003
Resolution scale factor	± 9.5	± 5.3	± 0.008
Decay length cut	$^{+0.0}_{-1.8}$	$^{+0.0}_{-2.2}$	$^{+0.001}_{-0.000}$
Combinatorial BG shape	± 0.7	± 0.1	± 0.002
Detector alignment	± 2.0	± 2.0	-
Total	$^{+13.3}_{-12.8}$	$^{+17.0}_{-17.0}$	$^{+0.041}_{-0.039}$

Total systematic uncertainties are order of 3-4%.

Summary

We have measured the B^- and $\bar{B}^0$ meson lifetimes using semileptonic decays with 8 GeV single lepton datasets.

The lifetimes are found to be

$$\begin{aligned} c\tau(B^-) &= 495.6 \pm 8.6\,^{+13.3}_{-12.8}\ \mu\text{m} \\ c\tau(\bar{B}^0) &= 441.5 \pm 10.9 \pm 17.0\ \mu\text{m} \end{aligned}$$

or

$$\begin{aligned} \tau(B^-) &= 1.653 \pm 0.029\,^{+0.044}_{-0.043}\ \text{ps} \\ \tau(\bar{B}^0) &= 1.473 \pm 0.036 \pm 0.057\ \text{ps} \end{aligned}$$

And we find the lifetime ratio to be

$$\tau(B^-)/\tau(\bar{B}^0) = 1.123 \pm 0.040\,^{+0.041}_{-0.039}$$

where the first and second uncertainties are statistical and systematic respectively.

These results are consistent with following current world average values.

World average values (by HFAG in 2004 summer)

$$\begin{aligned} c\tau(B^-) &= 495.6 \pm 4.2\ \mu\text{m} \\ c\tau(\bar{B}^0) &= 459.9 \pm 3.9\ \mu\text{m} \\ \tau(B^-)/\tau(\bar{B}^0) &= 1.081 \pm 0.015 \end{aligned}$$

Brief history of lifetime fit results

- Production 4.8.4, $\sim$ 90 pb^{-1} 8 GeV muon data
  no separation of D^0 and D^{*+}
  $c\tau(B) = 440 \pm 10\mu$m (short lifetime era)

- Production 5.3.1, 260 pb^{-1}
  New beamline, new refitting procedure, tighten some cuts
  $c\tau(B) = 455 \ \pm 6\mu$m (no D^0/D^{*+} separation)
  $c\tau(B^-) = 469 \pm 10$ μm
  $c\tau(\bar{B}^0) = 438 \pm 13$ μm

- Tuning on Monte Carlo (correct $p_T(B)$ spectrum)
  $c\tau(B^-) = 475 \pm 11$ μm
  $c\tau(\bar{B}^0) = 443 \pm 13\mu$m

- Subtract prompt charm background
  $c\tau(B^-) = 489 \pm 11$ μm
  $c\tau(\bar{B}^0) = 467 \pm 14$ μm

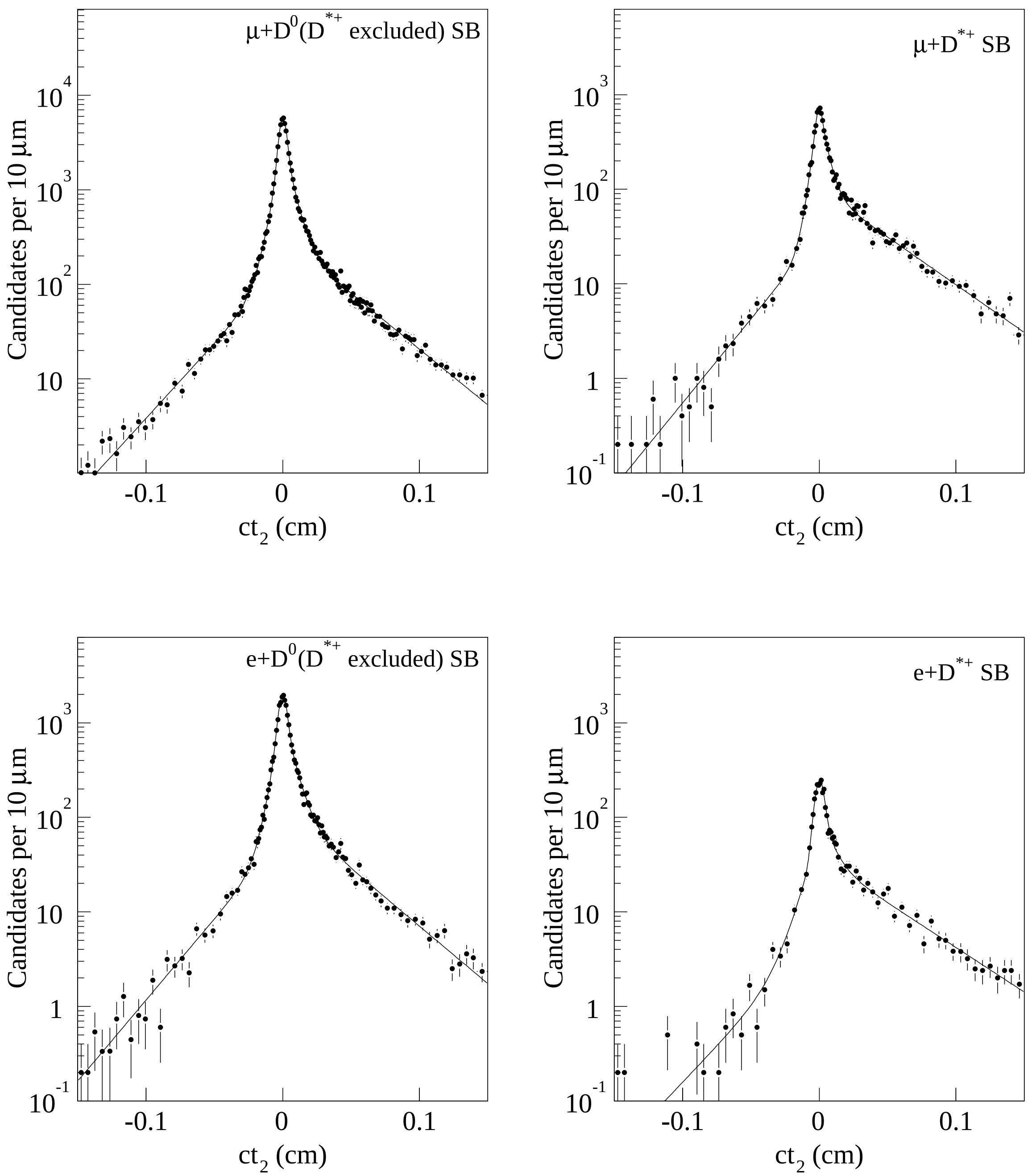
- Subtract bottom background (current result for muon)
  $c\tau(B^-) = 490 \pm 11$ μm
  $c\tau(\bar{B}^0) = 454 \pm 14$ μm

- Combine electron data
  $c\tau(B^-) = 496 \pm 9$ μm
  $c\tau(\bar{B}^0) = 442 \pm 11$ μm

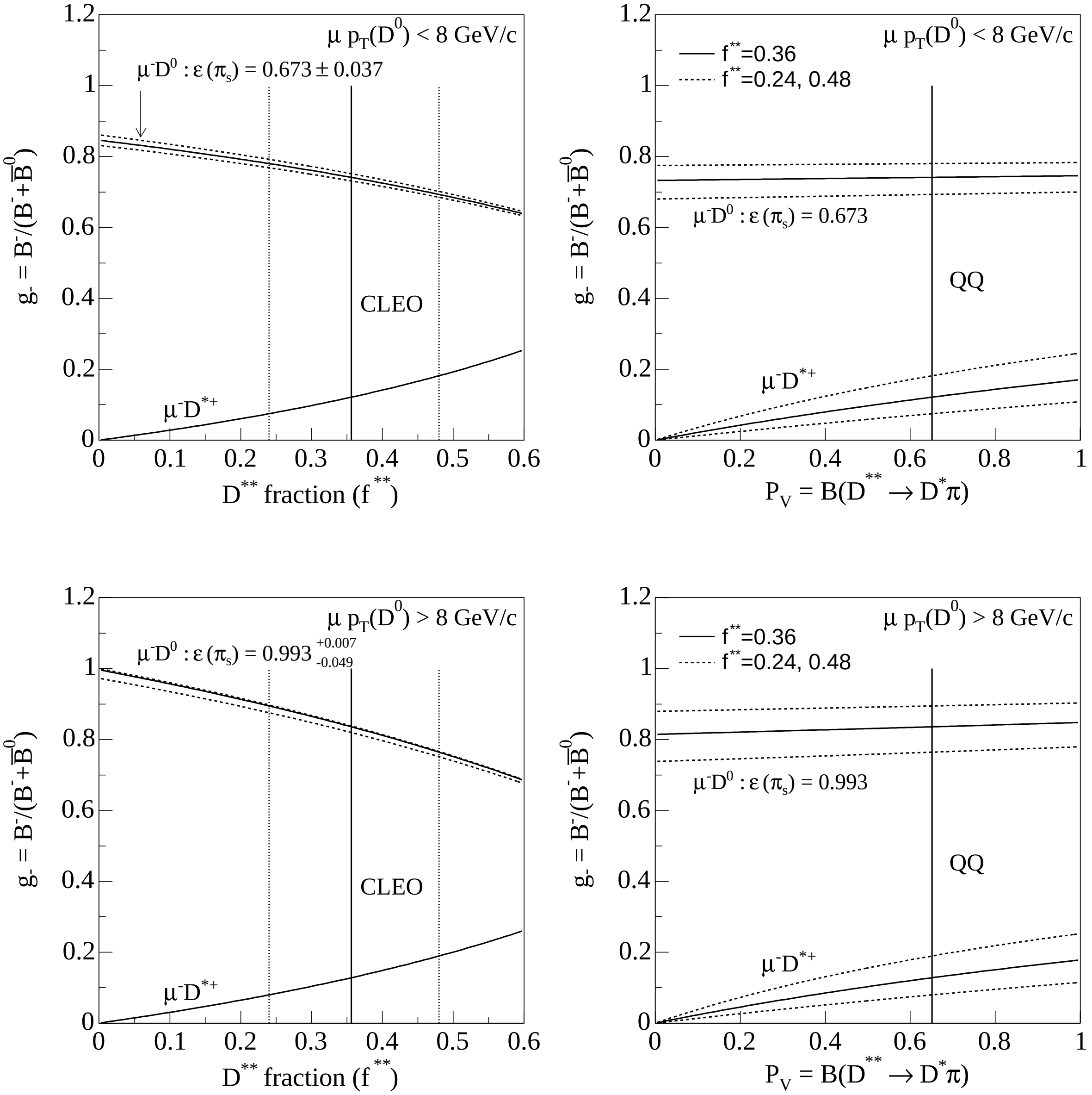
As a brief conclusion, prompt charm background gives a major contribution to the short lifetime.

Backup slides

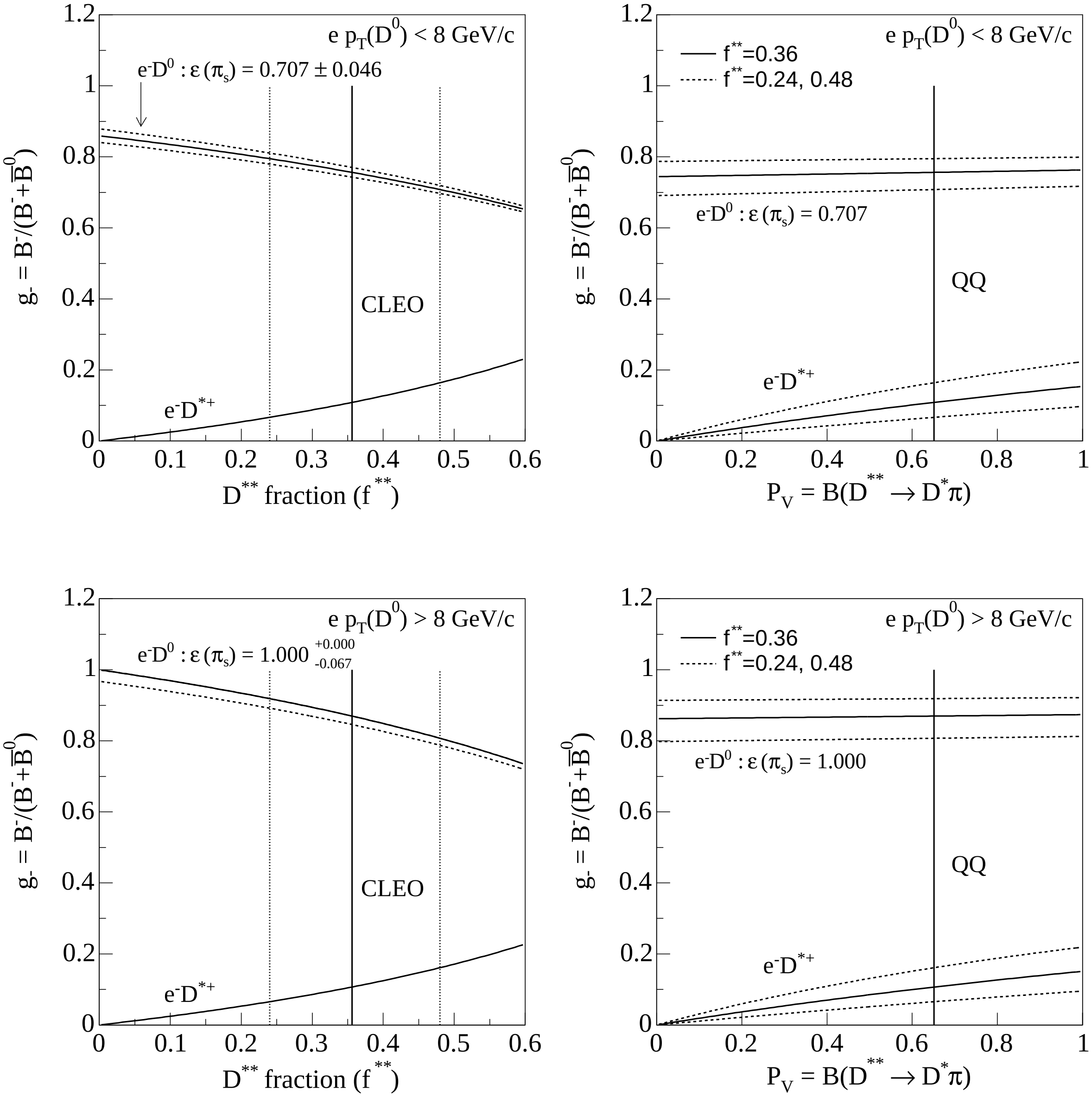
Background shapes for ct_2



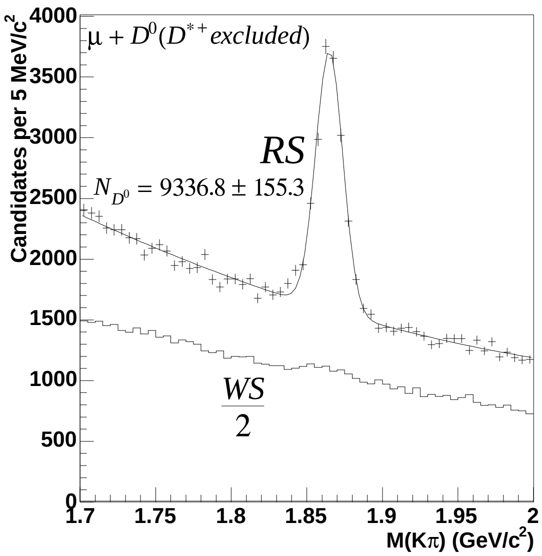
g_- changes as function of f^{**} and P_V, for muon

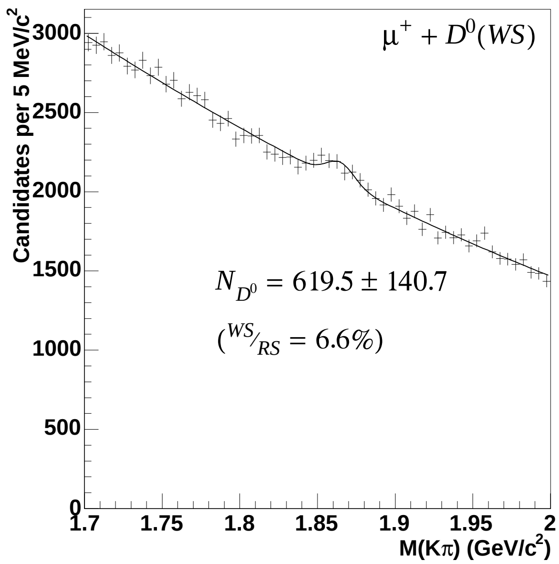


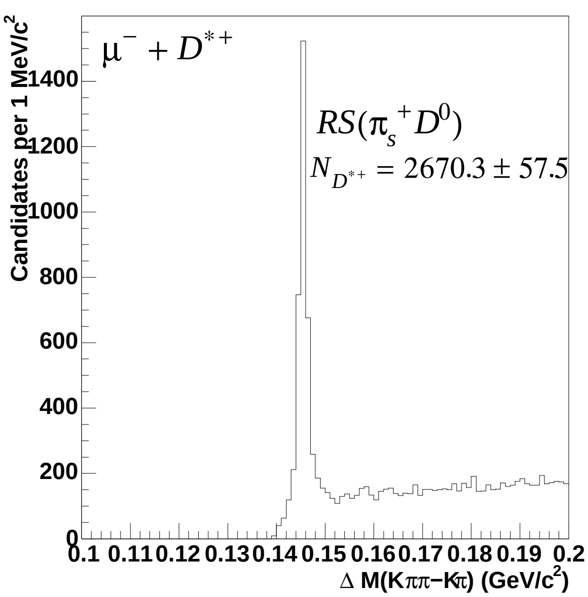
g_- changes as function of f^{**} and P_V, for electron

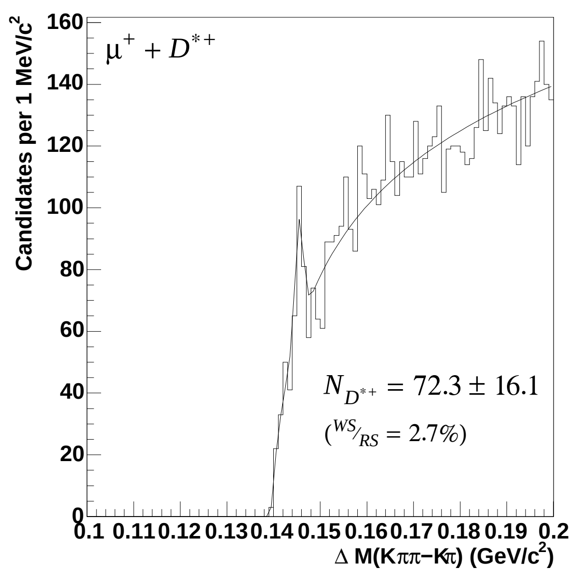


WS peak in wrong-sign μD^0 and μD^{*+}









ct^* shape of WS events

ct^* distributions for WS events, signal-SB plots: