Measurements of inclusive branching fractions of D decays and $\psi(3770)$ non-$D\bar{D}$ decays

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Outline

Measurements of inclusive branching fractions of D decays

1. Inclusive semileptonic decays for $D \to e^+ X$
2. Inclusive semileptonic decays for $D \to \mu + X$
3. Inclusive decays for $D \to KX$

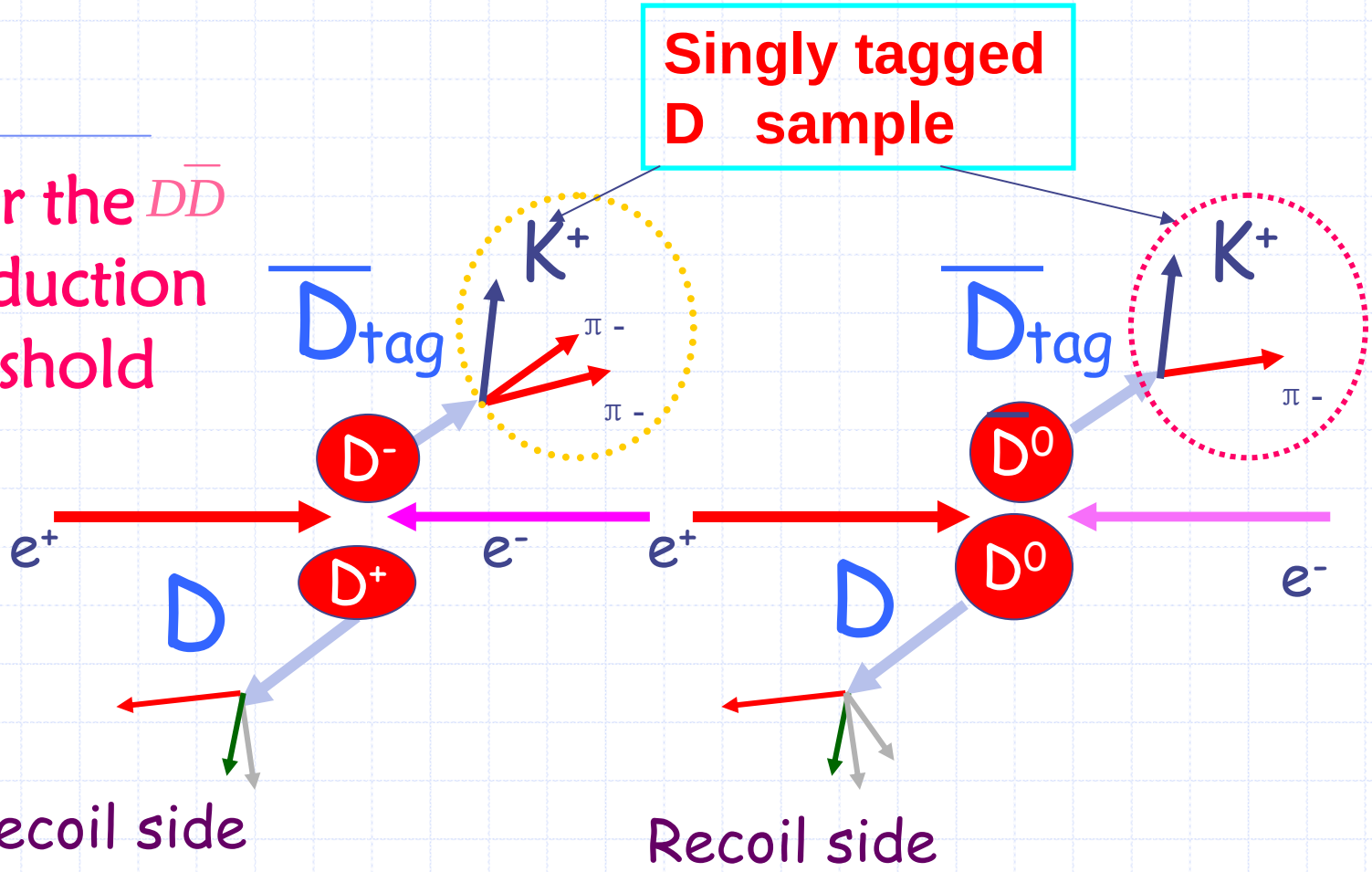
Measurements of branching fractions $\psi(3770)$ non-DDbar decays

1. Branching Fraction of $\psi(3770) \to J/\psi \pi^+ \pi^-$
2. Measurements of branching frantions of $\psi(3770) \to$ non-DDbar decays
3. Search for charmless decays

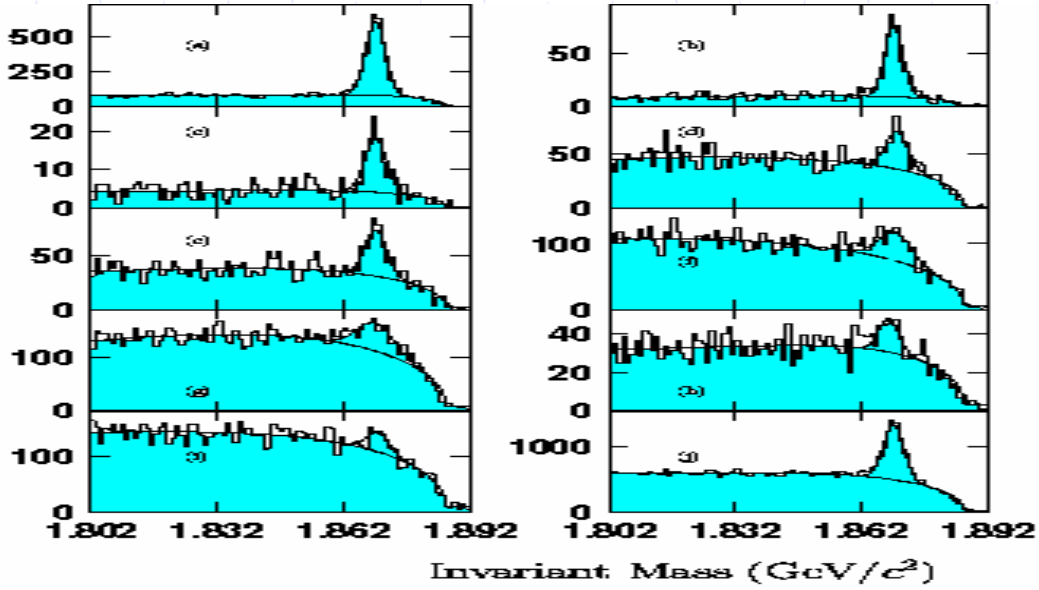
Measurements of inclusive branching fractions of D decays

Double tag methord

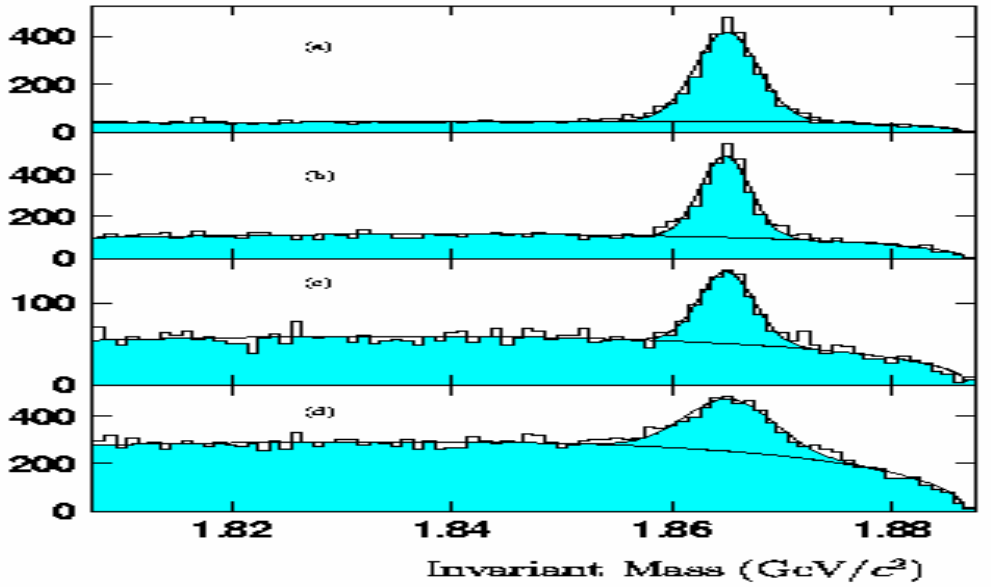
Near the $D\bar{D}$ production threshold



Single tag analysis



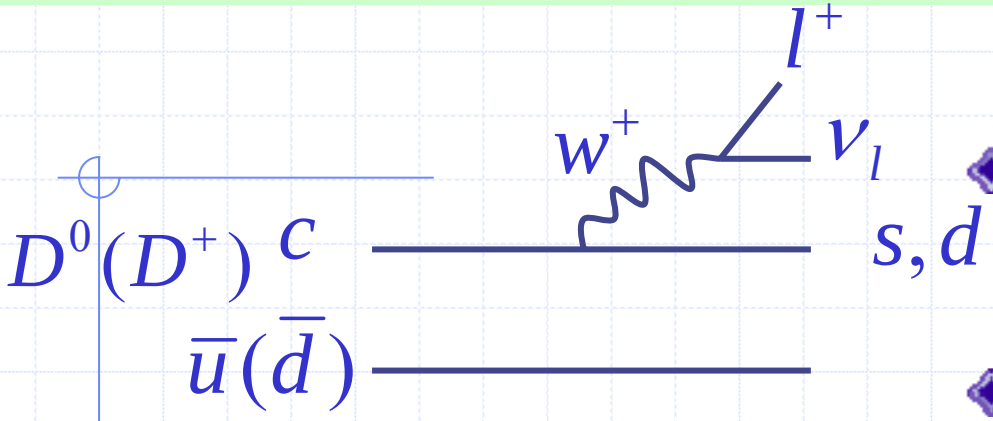
$$N_{\overline{D^0}tag} = 5321 \pm 125 \pm 160$$



$$N_{\overline{D^0}tag} = 7584 \pm 198 \pm 341$$

Charge conjugation

Measurements of inclusive branching fractions of D →l+X



Spectator Model:

$$\Gamma_{SL}(D \to x l^+ \nu_l) = \frac{G_F^2}{192\pi^3} m_c^5 f\left(\frac{m_s^2}{m_c^2}\right)$$

$$Br(c \to s l^+ \nu_l) \approx 16\%$$

$$\tau_+ = \tau_-$$

$$Br(D^+ \to e^+ X) = Br(D^0 \to e^+ X) \approx 16\%$$

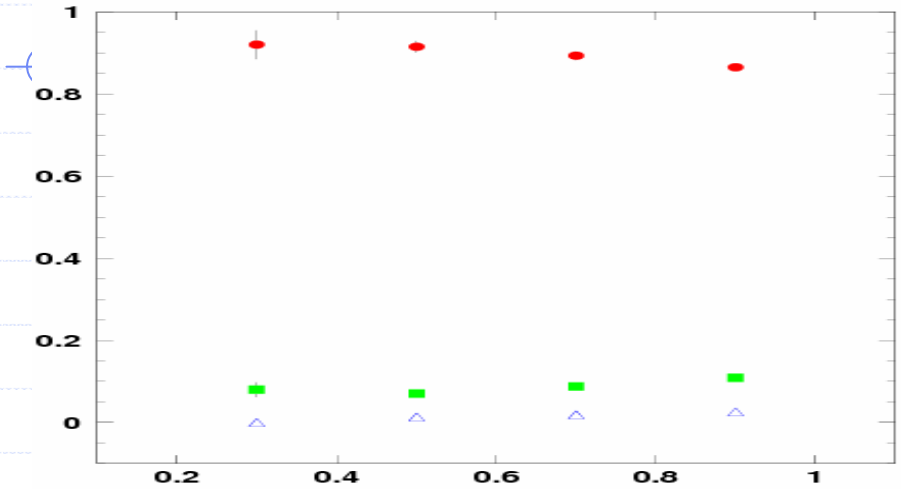
Observed: $\tau_+ / \tau_- > 2.$

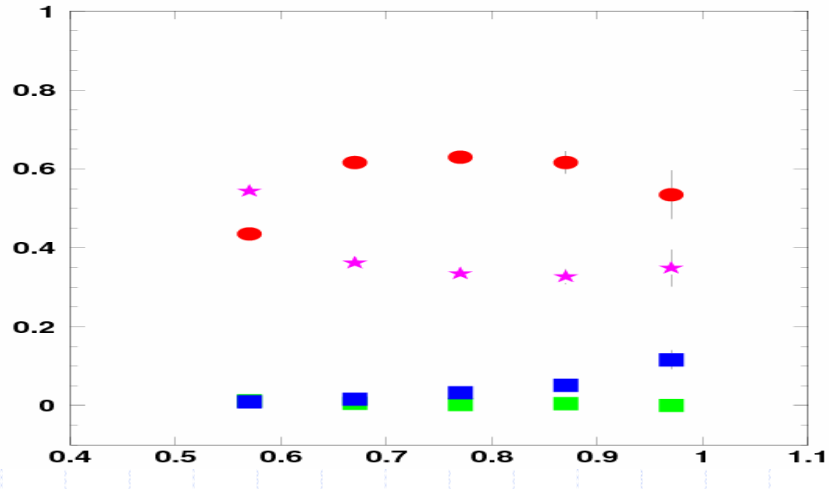
$\Rightarrow$ Final states interference effect for D^+, exchange of W process for D^0...

- Provides some tests of the contributions from different diagrams
- Provide information for understanding the origin of life time difference of D+ and D0 mesons.
- As a check on the sum of the measured branching fractions for exclusive decay modes
- Provide helpful information for the studies of the B meson decays.

Measurements of inclusive branching fractions of D →l+X

The rate of (mis)identifying the particle i as j





Pion samples, kaon samples, electron samples, muon samples are selected form J/ψ→ωπ+π-, J/ψ→ϕK+K-, radiative bhabha andcosmic rays, respectively.

$$\begin{pmatrix} N^{e}_{obs} \\ N^{\pi}_{obs} \\ N^{K}_{obs} \end{pmatrix} = \begin{pmatrix} \kappa_e & f_{\pi\to e} & f_{K\to e} \\ f_{e\to\pi} & \kappa_\pi & f_{K\to e} \\ f_{e\to K} & f_{\pi\to K} & \kappa_K \end{pmatrix} \begin{pmatrix} N^{e}_{real} \\ N^{\pi}_{real} \\ N^{K}_{real} \end{pmatrix}$$

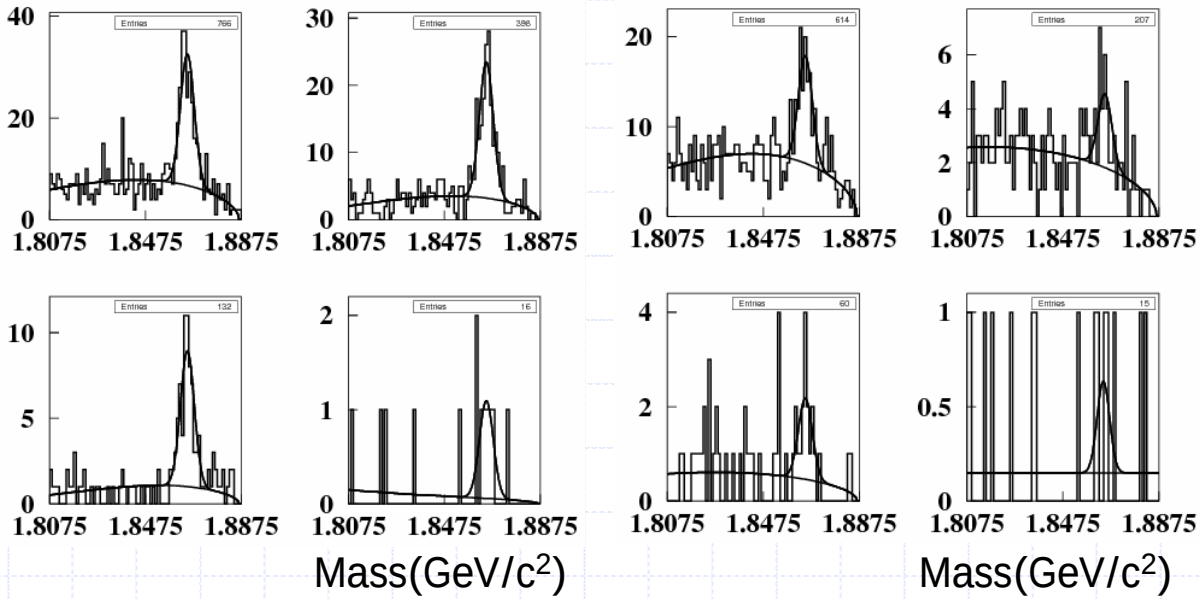
$$\begin{pmatrix} N^{\mu}_{obs} \\ N^{e}_{obs} \\ N^{k}_{obs} \\ N^{\pi}_{obs} \end{pmatrix} = \begin{pmatrix} \varepsilon_{\mu-\mu} & \varepsilon_{e-\mu} & \varepsilon_{k-\mu} & \varepsilon_{\pi-\mu} \\ \varepsilon_{\mu-e} & \varepsilon_{e-e} & \varepsilon_{k-e} & \varepsilon_{\pi-e} \\ \varepsilon_{\mu-k} & \varepsilon_{e-k} & \varepsilon_{k-k} & \varepsilon_{\pi-k} \\ \varepsilon_{\mu-\pi} & \varepsilon_{e-\pi} & \varepsilon_{k-\pi} & \varepsilon_{\pi-\pi} \end{pmatrix} \times \begin{pmatrix} N^{\mu}_{real} \\ N^{e}_{real} \\ N^{k}_{real} \\ N^{\pi}_{real} \end{pmatrix}$$

Using the unfolding matrix to subtract the bachground due to the misidentification.

Measurements of inclusive branching fractions of D $\rightarrow e^{+}X$

Signal of $D \rightarrow e^{+}X$:

Data of $33pb^{-1}$



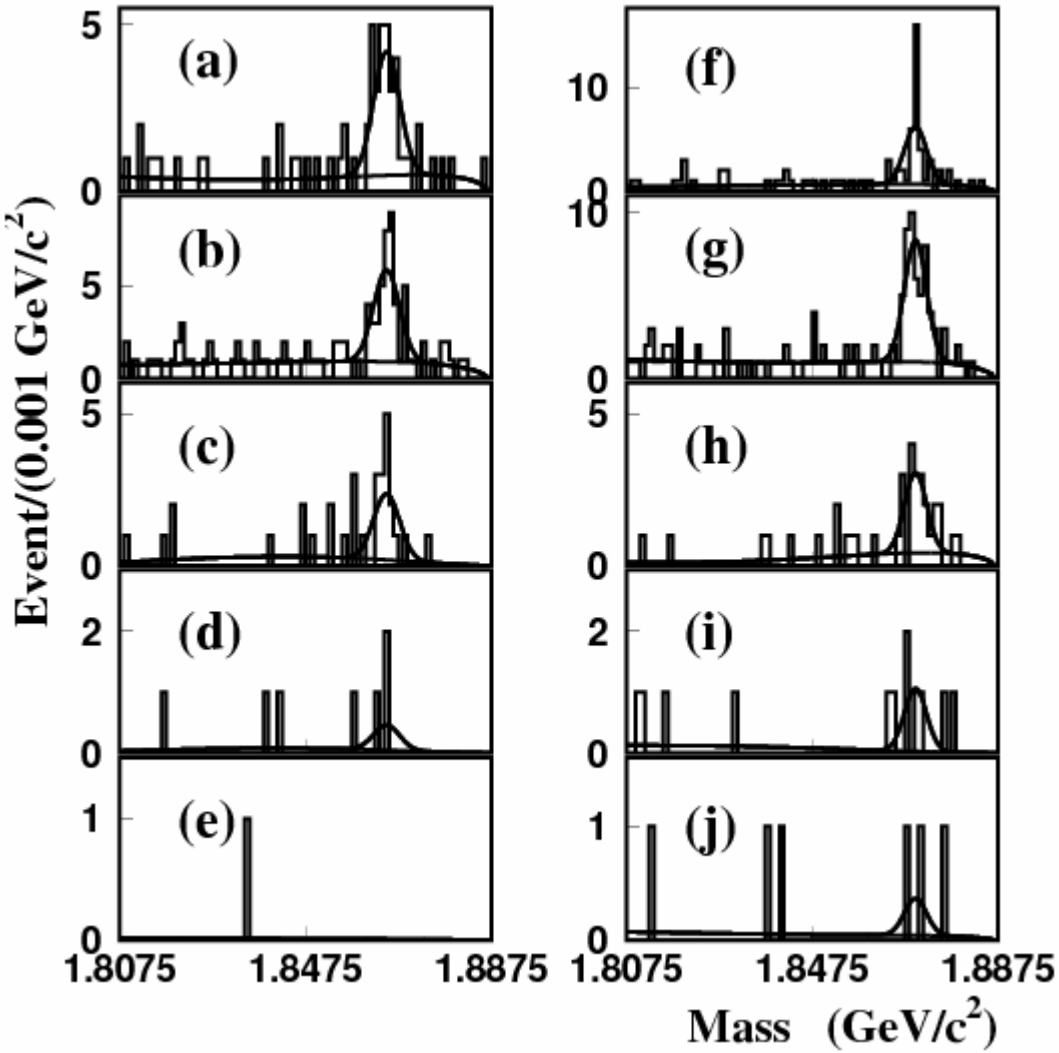
Right-sign **Wrong-sign**

Electrons with the charge opposite to the charm of the single tagged D-bar mesons are defined as right-sign electron, on the contrary, they are defined wrong-sign ones, which are accounting for the decays of charge symmetric backgrounds such as $\pi 0 \rightarrow \gamma e+e-$ and γconvertions, etc.

Measurements of inclusive branching fractions of $D \to \mu^+ X$

Signal of $D^0 \to \mu^+ X$ and $D^+ \to \mu^+ X$:

Data of $33 pb^{-1}$



The contaminations from the decay $K^+ \to \mu^+ \upsilon$ and $\pi^+ \to \mu^+ \upsilon$ are estimated by the Monte carlo simulations.

$BF(D^0 \to \mu^+ X) = (6.8 \pm 0.5 \pm 0.8)\%$

$BF(D^+ \to \mu^+ X) = (17.6 \pm 2.7 \pm 1.8)\%$

Preliminary

Summary of inclusive branching fractions of D $\to l^+X$

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$$\frac{BF(D^+ \to e^+X)}{BF(D^0 \to e^+X)} = 2.41 \pm 0.30 \pm 0.18$$

$$\frac{\Gamma(D^+ \to e^+X)}{\Gamma(D^0 \to e^+X)} = 0.95 \pm 0.12 \pm 0.07$$

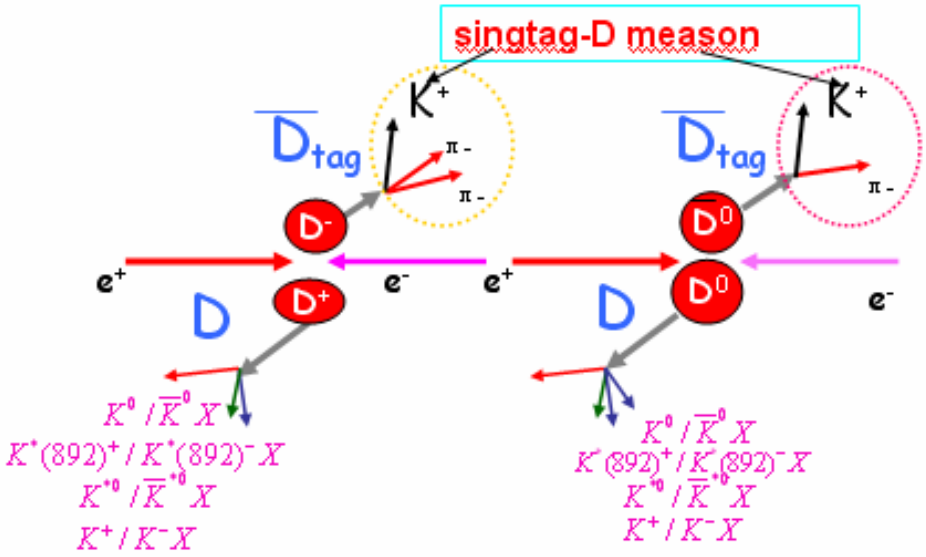
BF(%)	BESII	CLEO-c	MARKIII
$D^0 \to e^+X$	6.3±0.7±0.4	6.46±0.17±0.13	7.5±1.1±0.4
$D^+ \to e^+X$	15.2±0.9±0.8	16.13±0.20±0.33	17.0±1.9±0.7
$D^0 \to \mu^+X$	6.8±1.5±0.8	-	-
$D^+ \to \mu^+X$	17.6±2.7±1.8	-	-

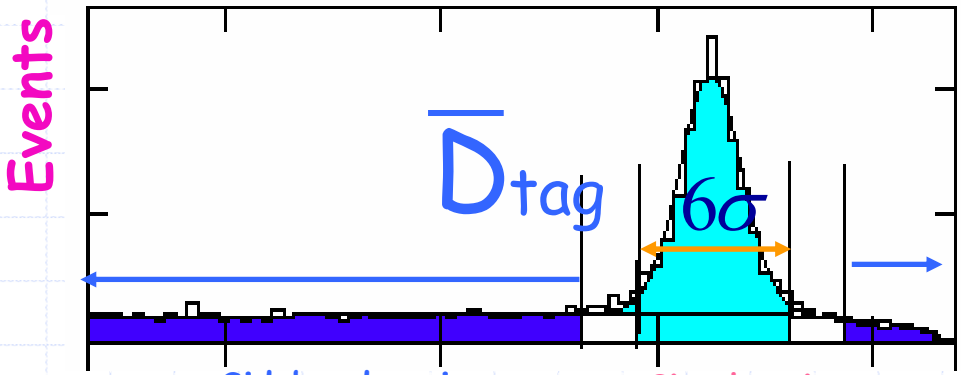
$$\frac{\tau_{D^+}}{\tau_{D^0}} = 2.54 \pm 0.02(\text{PDG2006})$$

First measurement

$$\frac{BF(D^+ \to \mu^+X)}{BF(D^0 \to \mu^+X)} = 2.59 \pm 0.70 \pm 0.25$$

Measurements of inclusive branching fractions of D →KX





($M_D \pm 4\sigma_{M_D}$)

$$N_{net} = N_{signal} - a * N_{sideband}$$

Normalization factor

$$a = \frac{Area_{background}^{signal}}{Area_{sideband}}$$

Helpful for understanding the weak decay mechanism.

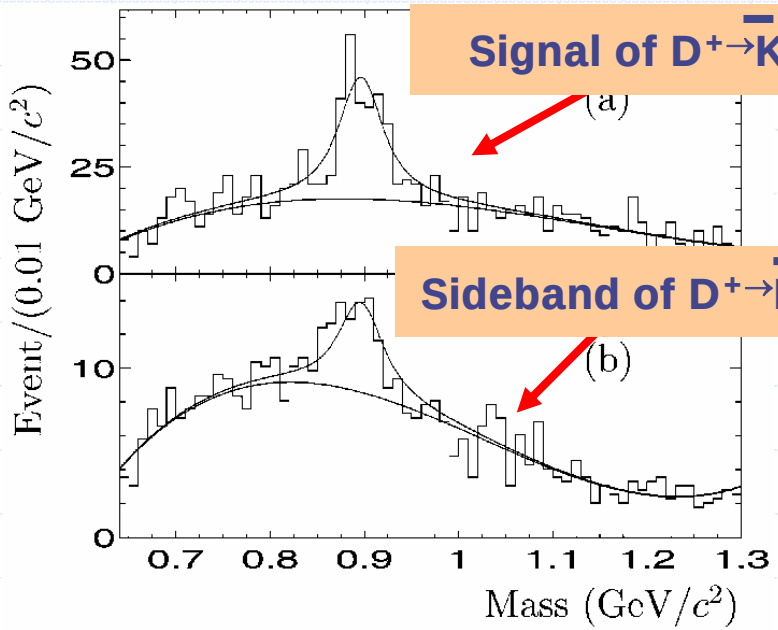
Comparing the measured inclusive branching fraction with the sum of those for the exclusive decays provides some information about the decay modes which have not been observed yet .

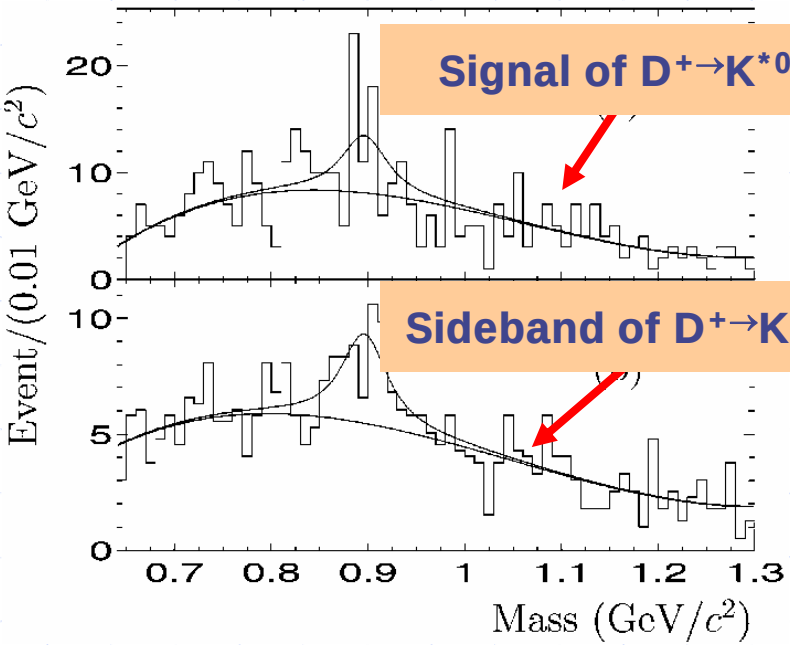
Measurements of the branching fractions for the inclusive $D \to K^{*+(-)}/K^{*0}/\overline{K}^{*0}X$ help to study the relative strength of the Cabibbo-favored and Cabibbo-suppressed decays .

The knowledge of the inclusive *D* meson decay properties will also help one to understand *B* decays.

Branching fractions of D $\to K^{*0}/\bar{K}^{*0}X$

Data of 33pb^{-1}





Decay mode	N	N_b	n
$D^0 \to \bar{K}^{*0}X$	188.5 ± 37.3	92.6 ± 23.5	95.9 ± 44.1
$D^0 \to K^{*0}X$	30.8 ± 13.2	0.0 ± 0.1	30.8 ± 13.2
$D^+ \to \bar{K}^{*0}X$	232.5 ± 30.9	43.4 ± 18.4	189.1 ± 36.0
$D^+ \to K^{*0}X$	43.7 ± 17.6	31.4 ± 15.2	12.3 ± 23.3

Decay mode	BF(%)
$D^0 \to \bar{K}^{*0}X$	$8.7 \pm 4.0 \pm 1.2$
$D^0 \to K^{*0}X$	$2.8 \pm 1.2 \pm 0.4$
$D^+ \to \bar{K}^{*0}X$	$23.2 \pm 4.5 \pm 3.0$
$D^+ \to K^{*0}X$	$1.5^{+2.9}_{-1.0} \pm 0.2$ (<6.6@90%)

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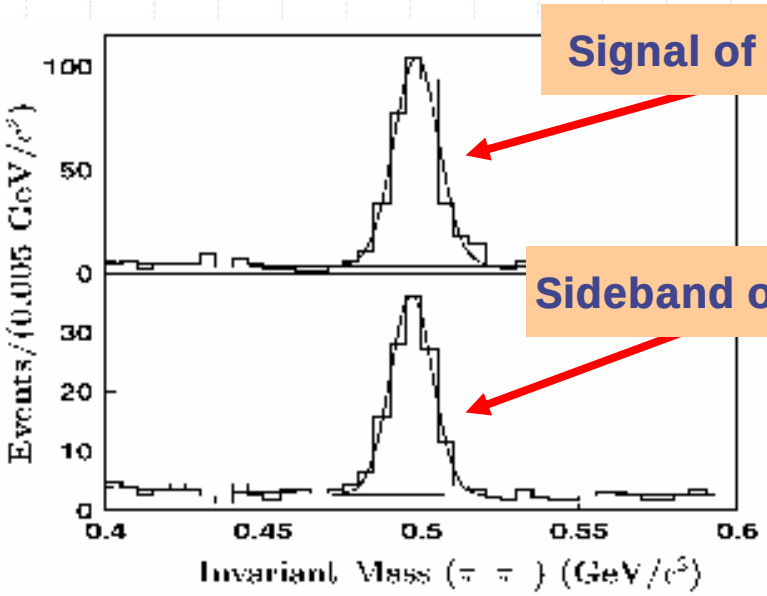
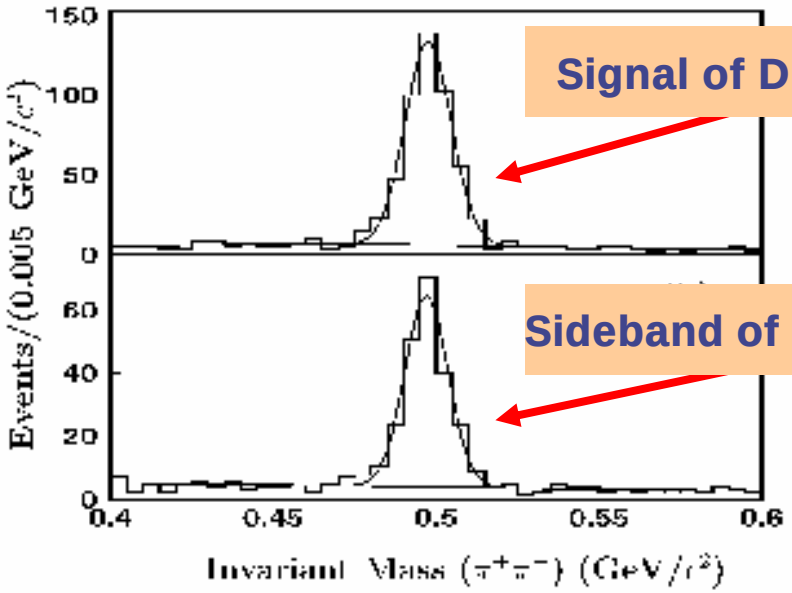
Branching fractions of $D \to K^0/\bar{K}^0X$

Data of 33pb^{-1}



Decay mode	BF(%)
$D^0 \to K^0/\bar{K}^0X$	47.6±4.8±3.0
$D^+ \to K^0/\bar{K}^0X$	60.5±5.5±3.3



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Branching fractions of D →K*+/K*-X

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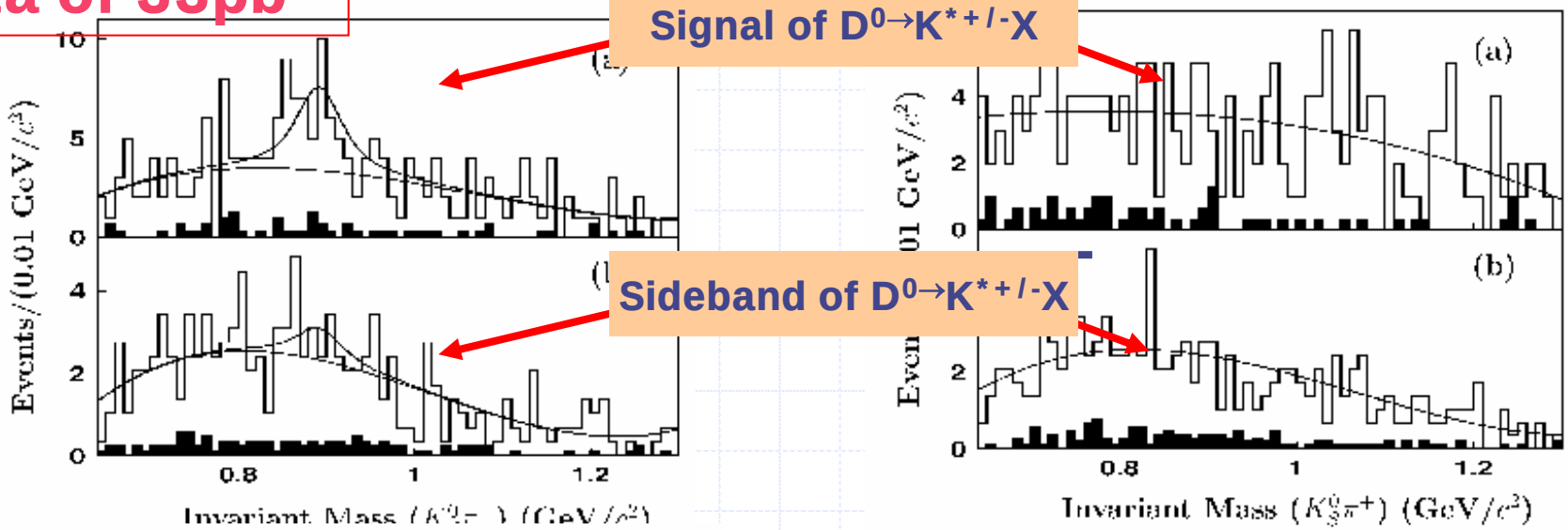
Data of 33pb^{-1}

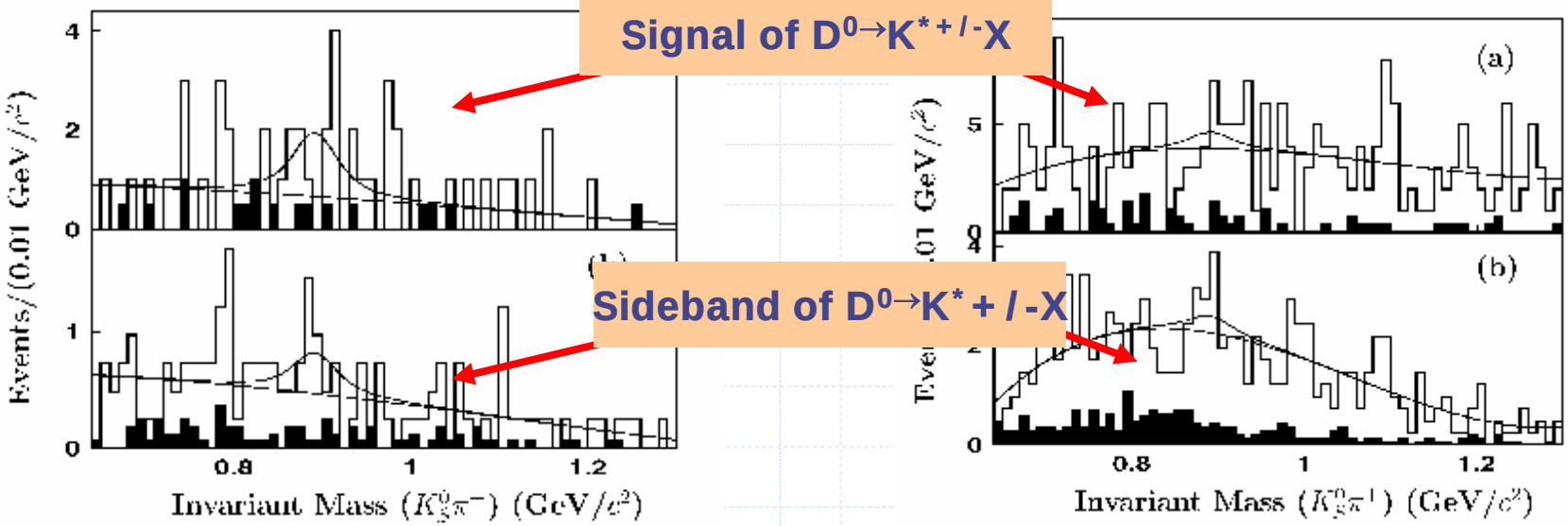
Signal of D^0→K*+/-X

Sideband of D^0→K*+/-X



Signal of D^0→K*+/-X

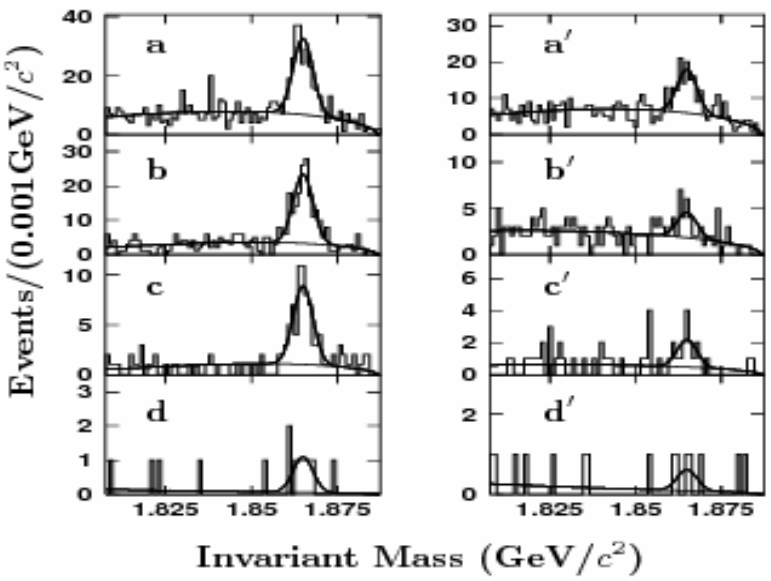
Sideband of D^0→K*+/-X



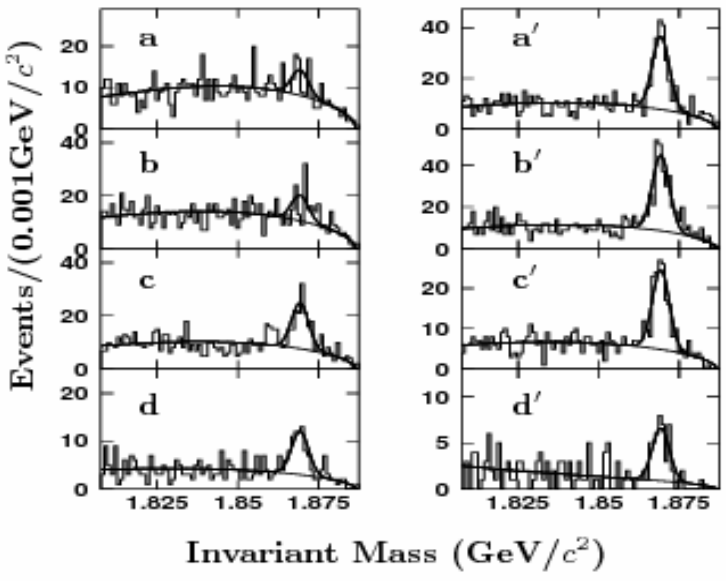
Shadows shows the normalized backgrounds estimated by Ks^0 sideband

Branching fractions of D →K⁺/K⁻X

Data of 33pb^{-1}



D⁰→K⁻/⁺X



D⁺→K⁻/⁺X

$$\begin{pmatrix} N^{e}_{obs} \\ N^{\pi}_{obs} \\ N^{K}_{obs} \end{pmatrix} = \begin{pmatrix} \kappa_e & f_{\pi\to e} & f_{K\to e} \\ f_{e\to\pi} & \kappa_\pi & f_{K\to e} \\ f_{e\to K} & f_{\pi\to K} & \kappa_K \end{pmatrix} \begin{pmatrix} N^{e}_{real} \\ N^{\pi}_{real} \\ N^{K}_{real} \end{pmatrix}$$

Decay mode	BF(%)
D⁰→K⁻X	57.8±1.6±3.2
D⁰→K⁺X	3.5±0.7±0.3
D⁺→K⁻X	24.7±1.3±1.2
D⁺→K⁺X	6.3±0.7±0.4

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Summary of inclusive branching fractions of D →KX

With improved presicion compare to PDG06

B[%]	$D^0 \to KX$	$D^+ \to KX$
K^+X	3.5 ±0.7 ±0.3	6.1 ±0.9 ±0.4
K^-X	57.8 ±1.6 ±3.2	24.7 ±1.3 ±1.2
$K^0/K^{0bar}X$	47.6 ±4.8 ±3.0	60.5 ±5.5 ±3.3
$K^{*0}X$	2.8 ±1.2 ±0.4	$1.5^{+2.9}_{-1.0}$±0.2(<6.6@90%)
$K^{*0bar}X$	8.7 ±4.0 ±1.2	23.2 ±4.5 ±3.0
$K^{*+}X$	<3.6(@90%)	<20.3 (@90%)
$K^{*-}X$	15.3 ±8.3 ±1.9	5.7 ±5.2 ±0.7

First measurements

Measurements of branching fractions of $\psi(3770) \to \text{non-}D\bar{D}$

Measurements of branching fractions of $\psi(3770)\to$non-$D\bar{D}$

- It is believed to be a mixture of 1^3D_1 and 2^3S_1 states of ccbar system. It is thought to decay almost entirely to pure DD-bar.
- However, there is a ***Long-standing puzzle*** of $\psi(3770)$ production and decays:

According to PDG04 parameters:

$$\sigma^{prd}_{\psi(3770)} = \frac{12\pi}{M^2_{\psi(3770)}} \times BF(\psi(3770)\to e^+e^-) = 11.6 \pm 1.8\ \text{nb}$$

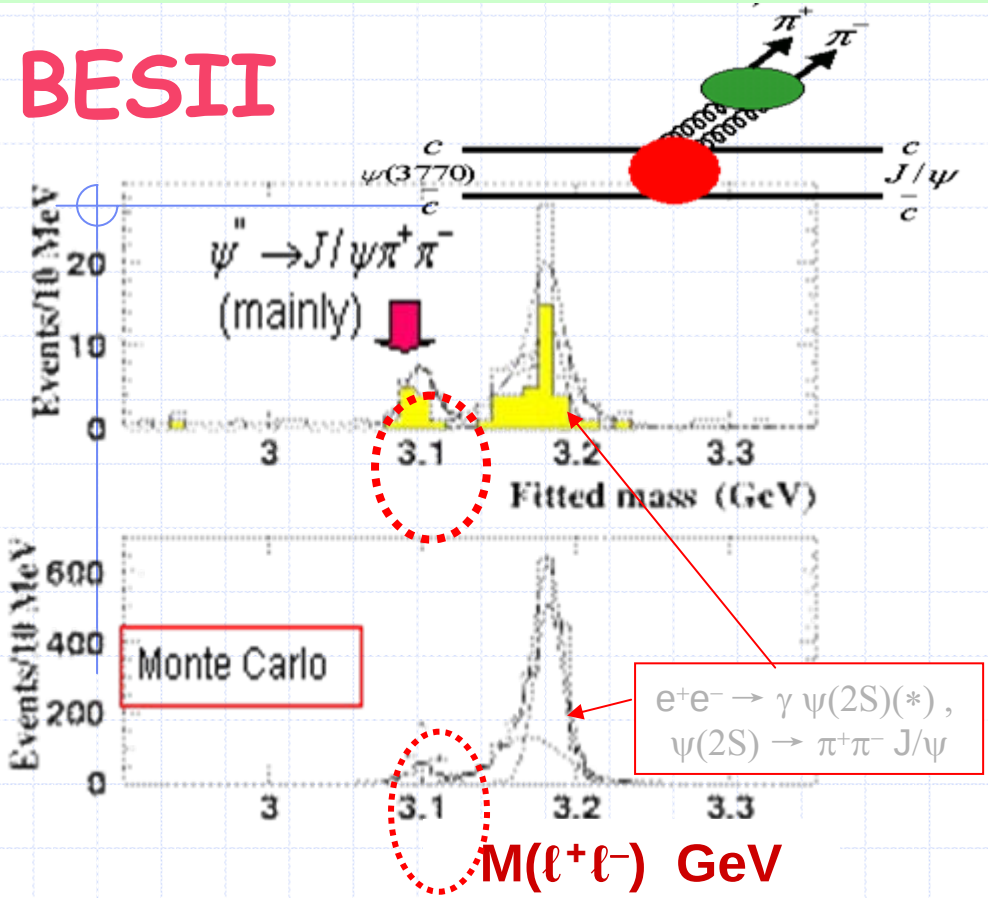
$$\sigma^{prd}(e^+e^- \to D\bar{D}) = 7.1 \pm 0.7\ \text{nb}$$

$$\sigma^{obs}(e^+e^- \to D\bar{D}) = 5.0 \pm 0.5\ \ \text{nb}\ (\text{MARK-III})$$

- Rong Gang, Zhang Dahua & Chen Jiangchuan did a quantity analyze in considering ISR correction and find that 38% of $\psi(3770)$ does not decay to $D\bar{D}$. (hep-ex/0506051)

Branching fractions of $\psi(3770)\to J/\psi\pi^+\pi^-$

BESII



11.8±4.8±1.3 signals observed
(0 from the continuum region)

$BF(\psi(3770)\to J/\psi\pi^+\pi^-) = (0.34\pm0.14\pm0.09)\,\%$

$\Gamma(\psi(3770)\to J/\psi\pi^+\pi^-) = (80\pm33\pm23)\,\%$

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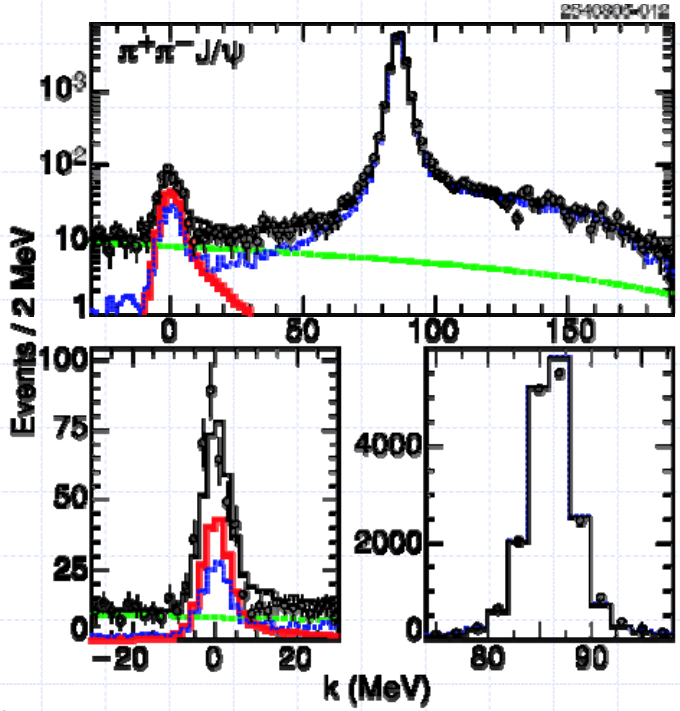
CLEO-c



CLEO-c confirmed BES' result!

$BF(\psi(3770)\to J/\psi\pi^+\pi^-) = (0.189\pm0.22^{+0.007}_{-0.004})\,\%$

PRL 96, 082004 (2006)

Measurements of branching fractions of $\psi(3770) \to \text{non-}D\bar{D}$

A better way to uncover the puzzle is the cross section scan experiments,

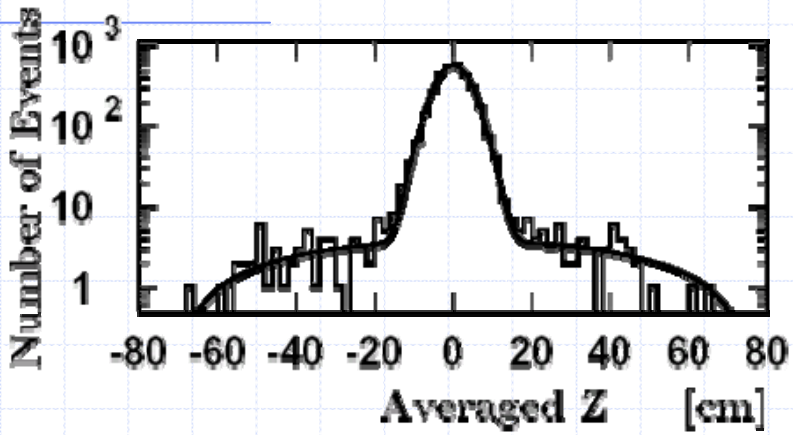
The data were collected at 49 energy points from 3.650 to 3.872 GeV, which begin from off-resonance, covering both the $\psi(2s)$ and $\psi(3770)$ and stop at DD* production threshold. (data taken in March, 2003)

The data were collected at 67 energy points from 3.660 to 3.872 GeV, which begin from off-resonance, mainly cover $\psi(3770)$ and stop at DD* production threshold .(data taken in Dec. 2003)

The data taken in April 2003 around $\psi(3770)$ peak.

Measurements of branching fractions of $\psi(3770)\to$non-$D\bar{D}$

Observed hadronic cross sections:



Fitting the distribution of the event vertex gives the numbe of hadronic events nhad.

$$\sigma_{had}^{obs}(E_{cm}) = \frac{n_{had}}{L(E_{cm})\ \varepsilon_{had}(E_{cm})\ \varepsilon_{trg}}$$

$$n_{had} = N^{obs} - n^{b}$$

$$\sigma_{had}^{expect}(s) = \int_0^1 dx\ F(x,s)\ \sigma^{B}(s(1-x))$$

$F(x,s)$ *is sampling function*

(Kuraev and Fadin)

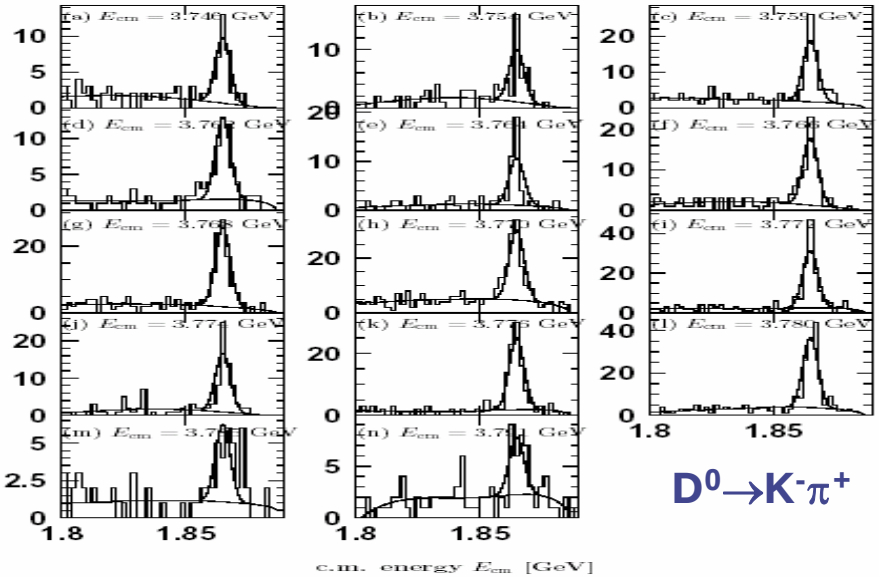
$$\sigma^{B}(s) = \frac{12\pi\Gamma_{ee}\Gamma_{f}(s)}{(s-M^2)^2 + M^2\Gamma_{tot}^2(s)}$$

For $\psi(3770)$, we use energy-dependent total width $\Gamma_{tot}(s)$

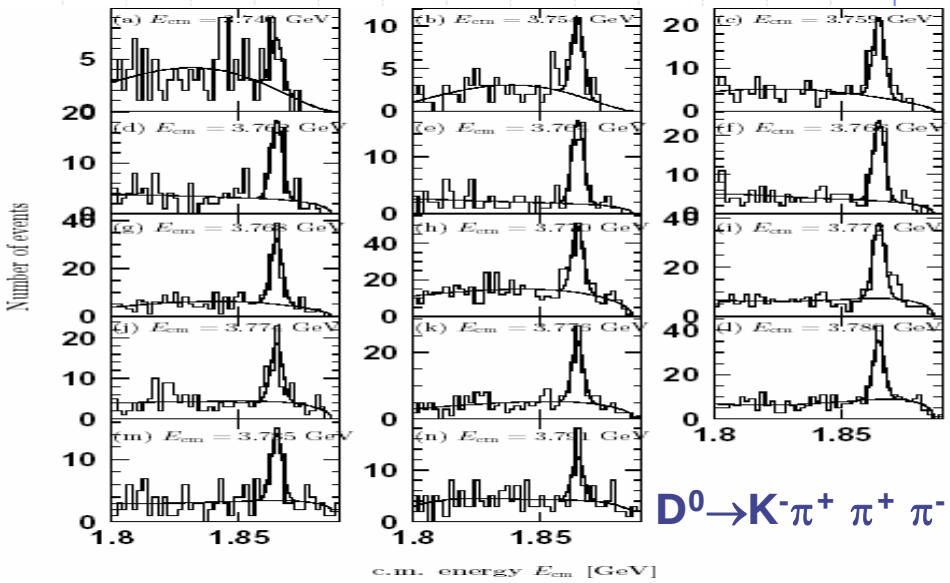
The back grounds come from $e^+e^-\to\tau^+\tau^-$, γe^+e^-,$\gamma\mu^+\mu^-$ and two-photon exchange processes.

DDbar production

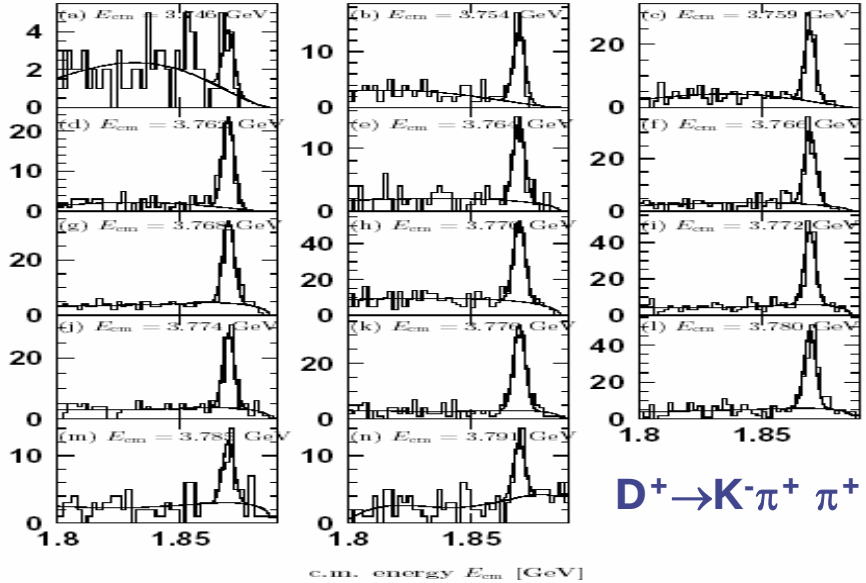
Energy dependent cross sections



$D^0 \to K^-\pi^+$



$D^0 \to K^-\pi^+ \pi^+ \pi^-$



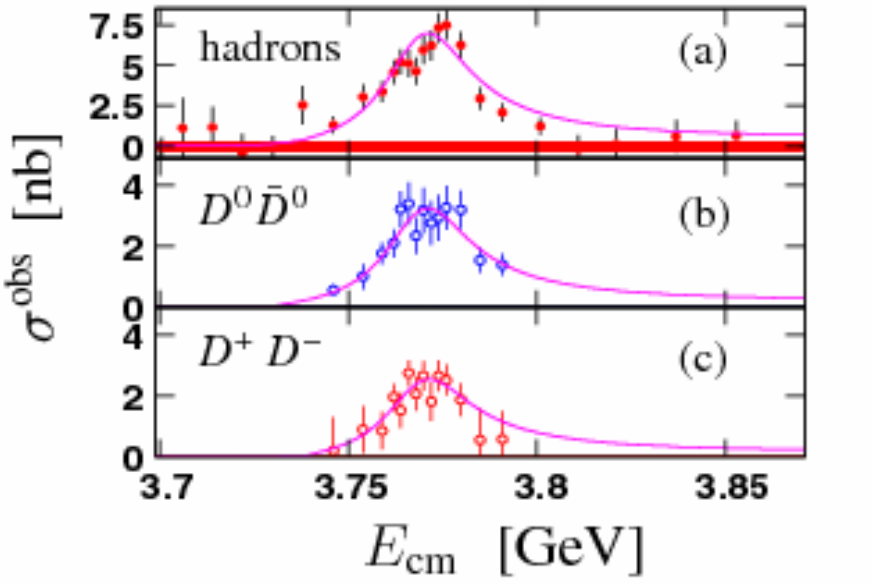
$D^+ \to K^-\pi^+ \pi^+$

Distributions of invariant masses of mKnπ combinations at different c.m. energies

$$\sigma^{obs}_{D^0\bar{D}^0(\text{or } D^+D^-)} = \frac{N_{D^0_{tag}}(\text{or } N_{D^+_{tag}})}{2 \times L \times B \times \epsilon},$$

Mar. 2003 data set

Measurements of branching fractions of $\psi(3770)\to$non-$D\bar{D}$



Mar. 2003 data set

$\psi(3770)\to$	B (%)	$\psi(3770)\to$	B (%)
$D^0\bar{D}^0$	$46.7\pm4.7\pm2.3$	$D\bar{D}$	$83.6\pm7.3\pm4.2$
D^+D^-	$36.9\pm3.7\pm2.8$	non-$D\bar{D}$	$16.4\pm7.3\pm4.2$

$$R_{uds} = 2.262 \pm 0.054 \pm 0.109$$

$$(3.660 \sim 3.872)$$

$$M_{\Psi(3770)} = 3772.2 \pm 0.7 \pm 0.3 MeV$$

$$\Gamma^{tot}_{\Psi(3770)} = 26.9 \pm 2.4 \pm 0.3 MeV$$

$$\Gamma^{ee}_{\Psi(3770)} = 251 \pm 26 \pm 11 eV$$

$$M_{\Psi(2S)} = 3685.5 \pm 0.0 \pm 0.3 MeV$$

$$\Gamma^{tot}_{\Psi(2S)} = 331 \pm 58 \pm 2 keV$$

$$\Gamma^{ee}_{\Psi(2S)} = 2.330 \pm 0.036 \pm 0.110 keV$$

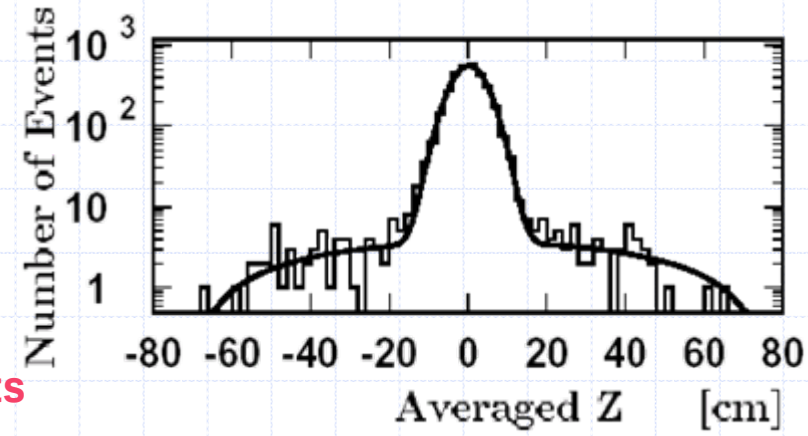
BF($\psi(3770)\to$non-DD)=(16.4±7.3±4.2)%

Phys. Rev. Lett. 97 (2006) 121801

Measurements of R values at the 3.773,3.650,3.6648GeV

R is one of the most fundamental quantities in particle physics, which counts directly the charges, the flavors and the colors of quarks involved .

$$R = \frac{\sigma^{B}_{had}}{\sigma^{B}_{\mu^+\mu^-}} = 3\sum_{i}^{N_f} Q_i^2$$



$$\sigma^{obs}_{had} = \frac{N_{had}}{L \cdot \varepsilon_{had}}$$

Number of hadronic events

luminosity

Efficiency

Fitting the distribution of the event vertex gives the numbe of hadronic events nhad.

$$\sigma^{Born}_{had} = \frac{\sigma^{exp}_{had}}{(1+\delta)}$$

(1+δ): radiative correction factor

E_{cm} (GeV)	L (nb^{-1})	N^{zfit}_{had}	$n_{l^+l^-}$	$n_{e^+e^-l^+l^-}$ & $n_{e^+e^-h}$
3.650	5537.7 ± 102.3	54 576 ± 239	2038	219
3.6648	998.2 ± 19.2	9615 ± 100	382	40
3.773	17 300.0 ± 319.6	274 021 ± 538	8603	701

Measurements of branching fractions of $\psi(3770)\to$non-$D\bar{D}$

Summary of the radiative factors, the lowest order cross sections, and the R values:

Energy (GeV)	$(1+\delta(s))$	$\sigma_h^0(s)$ (nb)	R
3.6500	1.291	$14.578\pm0.067\pm0.141\pm0.588$	$2.236\pm0.010\pm0.022\pm0.089$
3.6648	1.263	$14.128\pm0.158\pm0.139\pm0.580$	$2.185\pm0.024\pm0.022\pm0.087$
3.7730	1.210	$22.855\pm0.046\pm0.220\pm1.144$	$3.746\pm0.008\pm0.036\pm0.187$

$R_{uds}=2.218\pm0.019\pm0.089$

$\sigma^B(3770)=(9.323\pm0.253\pm0.801)$nb

$$BF\left(\psi(3770)\to D\bar{D}\right)=\frac{\sigma^{\rm obs}_{D\bar{D}}}{(1+\delta)_{D\bar{D}}\sigma^{\rm B}_{\psi(3770)}},$$

$BF(\psi(3770)\to D^+D^-)=(49.9\pm1.3\pm3.8)\%$

$BF(\psi(3770)\to D^0\bar{D}^0)=(35.7\pm1.1\pm3.4)\%$

$BF(\psi(3770)\to$non-$D\bar{D})=(14.5\pm1.7\pm5.8)\%$

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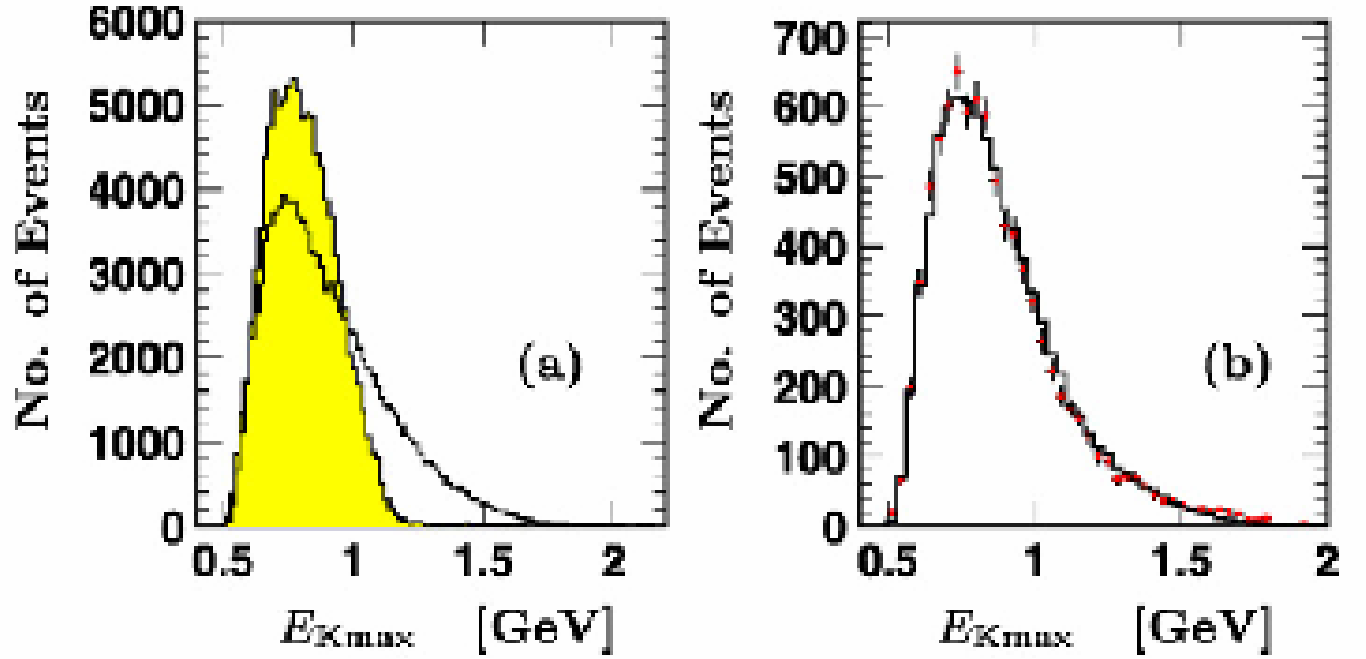
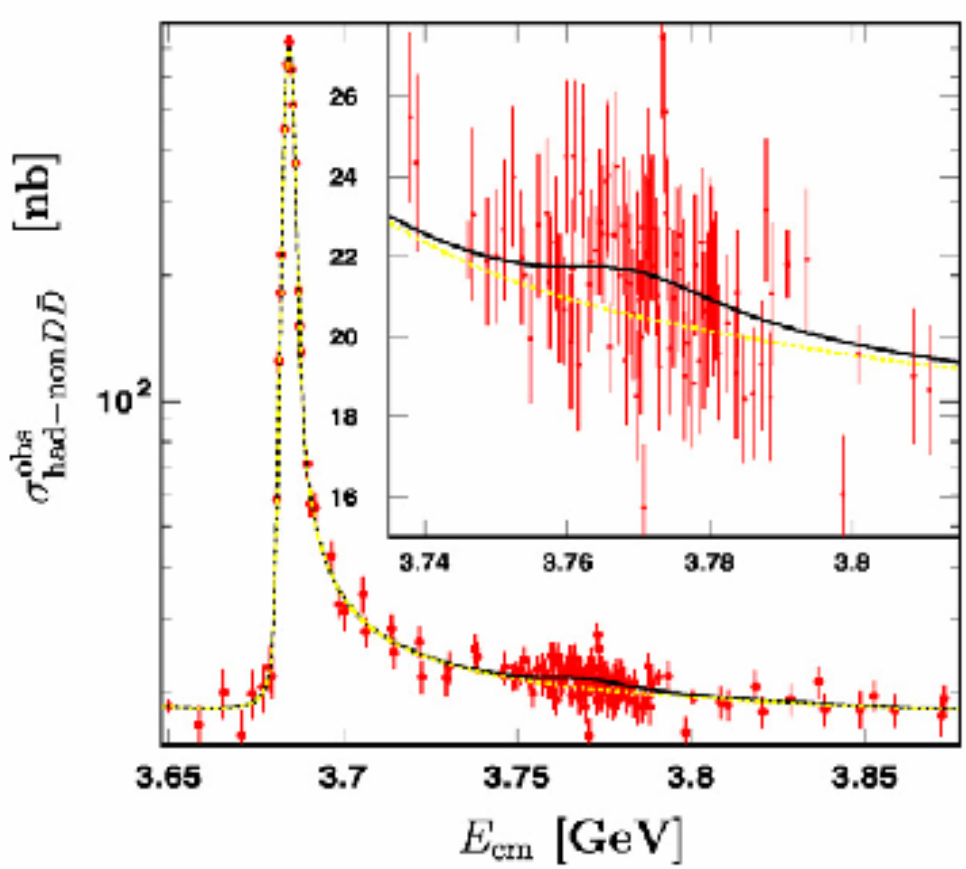
Measurements of branching fractions of $\psi(3770)\to$non-$D\bar{D}$

By tagging the largest energy of assumed kaon , we directly measured the Branching fractions of $\psi(3770)\to$non-DD.



Phys. Lett. B 659 (2007) 74

Measurements of branching fractions of $\psi(3770)\to$non-$D\bar{D}$



The data used in this analysis is taken in mar. 2003, in Apr. 2003 and during Dec. 2003 to Jan. 2003.

Fitting these 153 energy points, we get the direct $\psi(3770)\to$non-$D\bar{D}$ branching fractions:

BF($\psi(3770)\to$non-$D\bar{D}$) = $(15.1 \pm 5.6 \pm 1.8)$ %

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Measurements of branching fractions of $\psi(3770)\to$non-$D\bar{D}$

E_{cm} [GeV]	L [nb^{-1}]	$N^{zcnt}_{han-non\text{-}D\bar{D}}$	$n_{l^+l^-}$	$n_{e^+e^-l^+l^-\&e^+e^-h}$	$n_{D\bar{D}}$	$\epsilon_{had-non\text{-}D\bar{D}}$[%]	$\sigma^{obs}_{had-non\text{-}D\bar{D}}$ [nb]
3.650	5537.7	7622 ± 88	238	27	0	7.11 ± 0.06	18.69 ± 0.22 ± 0.18
3.6648	998.2	1418 ± 39	45	6	0	7.19 ± 0.06	19.05 ± 0.54 ± 0.18
3.773	17 300	30 787 ± 177	943	77	865 ± 72	7.75 ± 0.07	21.56 ± 0.13 ± 0.21

σ_1 = 14.48±0.22±0.55 @ 3.650GeV

σ_2 = 15.08±0.45±0.57 @ 3.6648GeV

Including J/ψ due to ISR, ψ'due to ISR ,ψ(3770) production, And light hadron Production

R_{uds1} = 2.200±0.034±0.084 @ 3.650GeV

R_{uds2} = 2.272±0.070±0.088 @ 3.6648GeV

Ruds = 2.214±0.031±0.088 ±0.033

After considering the ISR and VP correction, and summing the other two components, $\sigma^{obs}_{lt\ had+\psi(3686)+J/\psi} = (20.61 \pm 0.24 \pm 0.67 \pm 0.25)$ nb.

BF($\psi(3770)\to$non-$D\bar{D}$) = (13.4±5.0±3.6)%

Phys. Rev. D 76 (2007) 122002

Search for Charmless decays of $\psi(3770)$

Mode	$\sigma^{3.773}$[pb]	$\sigma^{3.650}$[pb]	$B^{up}[\times 10^{-3}]$
$\phi\pi^0$	<3.5	<8.9	<0.5
$\phi\eta$	<12.6	<18.0	1.9
$2(\pi^+\pi^-)$	173.7±8.4±18.4	177.7±13.3±18.8	4.8
$K^+K^-\pi^+\pi^-$	131.7±10.1±14.1	161.7±17.9±17.1	4.8
$\phi\pi^+\pi^-$	<11.1	<22.9	1.6
$2(K^+K)$	19.9±3.6±2.1	24.1±6.5±2.6	1.7
ϕK^+K	15.8±5.1±1.8	17.4±9.2±2.0	2.4
$pp^{bar}\pi^+\pi^-$	33.2±3.4±3.8	42.1±6.1±4.8	1.6
$pp^{bar}K^+K$	7.1±2.0±0.8	6.1±3.1±0.7	1.1
ϕpp^{bar}	<5.8	<9.1	0.9
$3(\pi^+\pi^-)$	236.7±14.7±33.4	234.9±23.8±33.1	9.1
$2(\pi^+\pi^-)\eta$	153.7±40.1±18.4	86.6±40.3±10.4	24.3
$2(\pi^+\pi^-)\pi^0$	80.9±13.9±10.0	124.3±21.7±14.9	6.2
$K^+K^-\pi^+\pi^-\pi^0$	171.6±26.0±20.9	222.8±37.7±27.2	11.1
$2(K^+K)\pi^0$	18.1±7.7±2.1	<23.0	4.6
$pp^{bar}\pi^0$	10.1±2.2±1.0	9.2±3.4±1.0	1.2
$pp^{bar}\pi^+\pi^-\pi^0$	53.1±9.2±6.8	29.0±11.1±3.7	7.3
$3(\pi^+\pi^-)\pi^0$	105.8±34.4±16.9	126.6±47.1±19.2	13.7

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Search for Charmless decays of $\psi(3770)$

Mode	$\sigma^{3.773}$[pb]	$\sigma^{3.650}$[pb]	$B^{up}[\times 10^{-3}]$
$K^+K^-2(\pi^+\pi^-)$	168.0±18.2±23.7	164.9±30.3±23.2	<10.3
$2(K^+K^-)\pi^+\pi^-$	11.9±5.8±1.7	<49.1	<3.2
$pp^{bar}2(\pi^+\pi^-)$	23.5±5.0±3.5	22.8±8.4±3.4	<2.6
$4(\pi^+\pi^-)$	131.8±19.5±23.6	76.2±24.4±13.9	<16.7
$K^+K^-2(\pi^+\pi^-)\pi^0$	231.5±63.6±37.5	<375.2	<52.0
$4(\pi^+\pi^-)\pi^0$	<206.9	<119.4	<30.6
$\rho^0\pi^+\pi^-$	111.9±13.1±13.1	113.6±21.3±13.1	<6.9
$\rho^0K^+K^-$	34.2±11.5±4.4	57.6±17.9±6.3	<5.0
ρ^0pp^{bar}	13.1±3.2±1.8	17.7±6.2±2.8	<1.7
$K^{*0}K^-\pi^+$	94.7±15.5±10.4	85.5±26.3±14.4	<9.7
$\Lambda\Lambda^{bar}$	<2.5	<6.1	<0.4
$\Lambda\Lambda^{bar}\pi^+\pi^-$	<26.7	<42.9	<4.4

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Search for Charmless decays of $\psi(3770)$

Mode	$\sigma^{3.773}$[pb]	$\sigma^{3.650}$[pb]	$B^{up}[\times 10^{-3}]$
$\omega\pi^+\pi^-$	<37.1	<50.8	5.5
ωK^+K^-	<44.4	<53.2	6.6
$\omega p\bar{p}$	<20.3	<30.9	3.0
$\phi\pi^+\pi^-\pi^0$	<25.5	<66.7	3.8
$K^{*0}K^-\pi^+\pi^0$	116.3±32.7±20.0	128.1±59.5±17.9	16.3
$K^{*+}K^-\pi^+\pi^-$	173.9±73.3±26.1	189.0±116.3±28.2	32.4
$K^+K^-\rho^0\pi^0$	<5.6	47.6±33.4±10.7	0.8
$K^+K^-\rho^+\pi^-$	94.2±31.6±11.7	141.9±53.3±19.7	14.6
$\Lambda\bar{\Lambda}\pi^0$	<7.9	<21.4	1.2

EPJC 52 (2007) 805

Up limit are set at 90 % CL

We searched for $\psi(3770)\rightarrow$light hadrons over 40 channels, no significan t signals were found. This does not mean that $\psi(3770)$ does not decay into light hadrons. To extract the branching fractions for $\psi(3770)\rightarrow$light hadrons from the observed cross sections, one need to make finer cross section scan covering both $\psi(3686)$ and $\psi(3770)$ with larger data samples (BES-III can do this well).

SUMMARY

- BES measured the branching fractions of the inclusive semileptonic decays of D mesons. Among them, the branching fraction of $D^+ \to \mu^+ X$ is a first measurement. The ratio between the $D^+ \to l^+ X$ and $D^0 \to l^+ X$ is consistent with the ratio of the lifetimes of D^+ and D^0.
- BES measured the branching frachions of the inclusive K decays of D^+ and D^0. The branching fractions of $D^0 \to K^{*+/-} X$, $D^+ \to K^{*+/-} X$, $D^0 \to K^{*0}/\bar{K}^{*0} X$ and $D^+ \to K^{*0}/\bar{K}^{*0} X$ are first measurements. Compare to the PDG06, the measurements of branching fractions of $D^0 \to K^{-/+} X$ and $D^+ \to K^{-/+} X$ are with improved precision.

SUMMARY

- BES found the first $\psi(3770) \rightarrow J/\psi\pi^+\pi^-$ non-$D\bar{D}$ decay mode, and first measured the branching frachtions of $\psi(3770)$ non-DDbar decays $\psi(3770) \rightarrow J/\psi\pi^+\pi^-$ to be

  $BF(\psi(3770) \rightarrow J/\psi\pi+\pi-) = (0.34 \pm 0.14 \pm 0.09)\%$.

- Using defferent methords, BES measured the branching fraction of $\psi(3770) \rightarrow$ non-$D\bar{D}$ decays.

$BF(\psi(3770) \rightarrow \text{non-}D\bar{D}) = (16.3 \pm 7.3 \pm 4.2)\%$	PRL 97 (2006) 121801
$BF(\psi(3770) \rightarrow \text{non-}D\bar{D}) = (14.5 \pm 1.7 \pm 5.8)\%$	PLB 641 (2006) 145
$BF(\psi(3770) \rightarrow \text{non-}D\bar{D}) = (15.1 \pm 5.6 \pm 1.8)\%$	PLB 659 (2007) 74
$BF(\psi(3770) \rightarrow \text{non-}D\bar{D}) = (13.4 \pm 5.0 \pm 3.6)\%$	PRD 76 (2007) 122002

- BES searched for $\psi(3770) \rightarrow$ light hadrons over 40 channels.

THANK YOU!

Back up slides

Fit to the observed cross sections

Fitting the observed inclusive hadron and DD-bar cross sections to the theoretical cross sections, we obtain the branching fractions

$$\sigma^{B}_{\psi(3770)} = \frac{12\pi\Gamma^{0}_{ee}\Gamma_{tot}(s)}{(s-M^{2})+M^{2}\Gamma^{2}_{tot}(s)} \qquad \sigma^{B}_{D\bar{D}} = \frac{12\pi\Gamma^{0}_{ee}\Gamma_{D\bar{D}}(s)}{(s-M^{2})+M^{2}\Gamma^{2}_{tot}(s)}$$

The total energy dependent width has three components:

$$\Gamma_{tot}(s)=\Gamma_{D^0\bar{D}^0}(s)+\Gamma_{D^+D^-}(s)+\Gamma_{non-D\bar{D}}(s)$$

momentum of D at peak

$$\Gamma_{D^0\bar{D}^0}(s) = \Gamma_0\theta(E_{cm}-2M_{D^0})\frac{1+(rp^{0}_{D^0})^2}{1+(rp_{D^0})^2}\frac{(p_{D^0})^3}{(p^{0}_{D^0})^3}B(\psi(3770)\to D^0\bar{D}^0)$$

ψ(3770) total width

threshold function

momentum of D

$$\Gamma_{D^+D^-}(s) = \Gamma_0\theta(E_{cm}-2M_{D^+})\frac{1+(rp^{0}_{D^+})^2}{1+(rp_{D^+})^2}\frac{(p_{D^+})^3}{(p^{0}_{D^+})^3}B(\psi(3770)\to D^+D^-)$$

Blatt-Weisskopf penetration factor

$$\Gamma_{non-D\bar{D}}(s) = \Gamma_0(1-B(\psi(3770)\to D^0\bar{D}^0-B(\psi(3770)\to D^+D^-)$$

$$\chi^2=\sum\left(\frac{\sigma^{obs}_{had}(i)-\sigma^{exp}_{had}(i)}{\Delta_{had}(i)}\right)^2+\sum\left(\frac{\sigma^{obs}_{D^0\bar{D}^0}(j)-\sigma^{exp}_{D^0\bar{D}^0}(j)}{\Delta_{D^0\bar{D}^0}(j)}\right)^2+\sum\left(\frac{\sigma^{obs}_{D^+D^-}(j)-\sigma^{exp}_{D^+D^-}(j)}{\Delta_{D^+D^-}(j)}\right)^2$$

ISR corrections

$$\sigma_{had}^{expect}(s) = \int_0^{x_{max}} dx \; F(x,s) \; \sigma^B(s(1-x)) \, |1-\Pi(s(1-x))|^{-2}$$

$\sigma^B(s)$ is Born order cross sections

$F(x,s)$ *is sampling function*

Effective c.m. energy

$$x = 1 - \frac{s'}{s}$$

Moninal c.m. energy

Kuraev & Fadin

$$F(x,s) = \beta x^{\beta-1} \delta^{V+S} + \delta^{H}$$

$$\beta = \frac{2\alpha}{\pi}\left(\ln\frac{s}{m_e^2} - 1\right)$$

the electron equivalent radiator thickness

$$\delta^{V+S} = 1 + \frac{3}{4}\beta + \frac{\alpha}{\pi}\left(\frac{\pi^2}{3} - \frac{1}{2}\right) + \beta^2\left(\frac{9}{32} - \frac{\pi^2}{12}\right)$$

$$\delta^{H} = \delta_1^{H} + \delta_2^{H}$$

$$\delta_1^{H} = -\beta\left(1 - \frac{x}{2}\right)$$

$$\delta_2^{H} = \frac{1}{8}\beta^2\left[4(2-x)\ln\frac{1}{x} - \frac{1+3(1-x)^2}{x}\ln(1-x) - 6 - x\right]$$

Vacuum polarization correction

$$\frac{1}{1-\Pi(s)} = 1+\Pi(s)+\Pi^2(s)+\ldots$$

$$\Pi = \Pi_h + \Pi_l$$

$$\Pi_h = \frac{s}{4\pi^2\alpha}\left[\mathrm{PV}\int \frac{\sigma^B(s')}{s-s'}ds' + i\pi\sigma^B(s)\right]$$

$$\Pi_l = 1 + \frac{1}{2}\delta^{l^+l^-}_{vac}$$

$$\delta^{l^+l^-}_{\mathrm{vac}}(s) = \frac{2\alpha}{\pi} f(x), \qquad \left(x = \frac{4m_l^2}{s}\right)$$

$$f(x) = -\frac{5}{9} - \frac{x}{3} + \frac{\sqrt{1-x}(2+x)}{6}\log\left[\frac{1+\sqrt{1-x}}{1-\sqrt{1-x}}\right], \quad (x \le 1)$$

$$f(x) = \frac{5}{9} - \frac{x}{3} + \frac{\sqrt{1-x}(2+x)}{3}\tan^{-1}\frac{1}{\sqrt{x-1}}, \quad (x > 1)$$

Vacuum polarization change the photon propagator

$$\frac{-ig_{\mu\nu}}{q^2} \Rightarrow \frac{-ig_{\mu\nu}}{q^2\left(1-\Pi(q^2)\right)}$$

results in

$$\sigma^B \Rightarrow \frac{\sigma^B}{|1-\Pi(s)|^2}$$

$$(1+\delta) = \frac{\sigma^{\mathrm{expect}}_{\mathrm{had}}}{\sigma^B}$$

Ψ(3770) and $D\bar{D}$ Production

Independent hadron and DD-bar data sample

$$\sigma_{had}^{obs}(i) = \frac{N_{had}^{net}}{L\,\varepsilon_{had}}$$

$$N_{had}^{net} = N_{had}^{obs} - N_{D\bar{D}}^{obs}$$

$$\sigma_{had}^{exp}(i) = \frac{n_{had}^{net}}{L\,\varepsilon_{had}}$$

$$n_{had}^{net} = n_{had}^{exp} - n_{D\bar{D}}^{exp}$$

Branching fraction for the singly tagged D channel

$$n_{had}^{exp} = \sigma_{had}^{exp} L\,\varepsilon_{had}$$

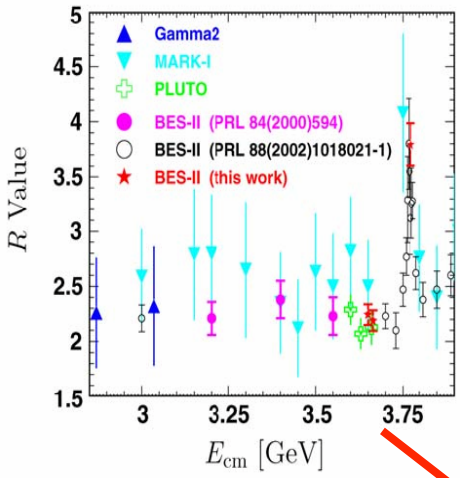
$$n_{D\bar{D}}^{exp} = \sigma_{\psi(3770)}^{prd}(1+\delta_{ISR})L\left[B_0(B_1\varepsilon_1 + B_2\varepsilon_2) + B_+ B_3\varepsilon_3\right]$$

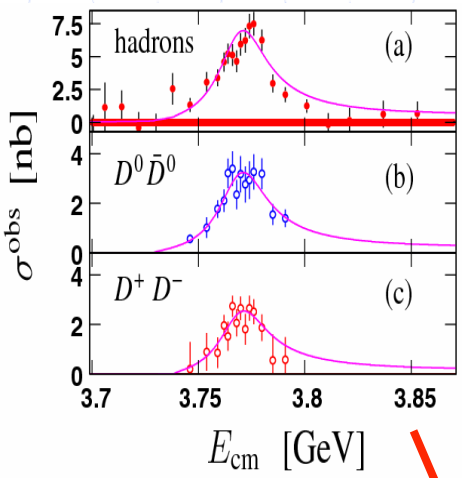
$$B_0 = B(\psi(3770) \to D^0\bar{D}^0)$$

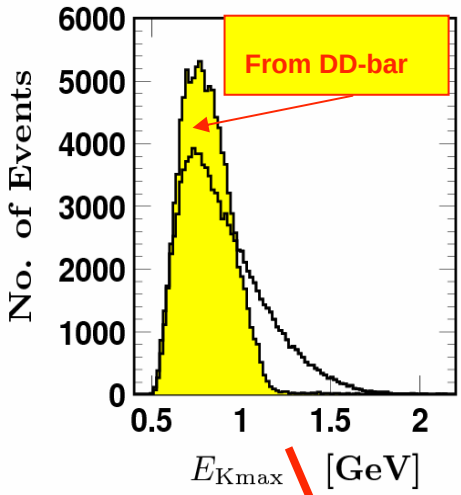
$$B_+ = B(\psi(3770) \to D^+D^-)$$

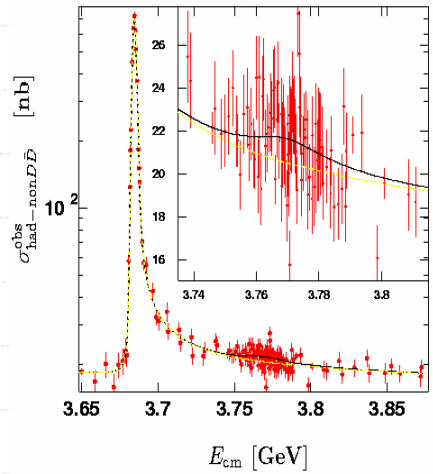
These relations remove those hadronic events which also appear in the DD-bar samples, so that the inclusive hadronic and DD-bar samples are independent.

Measurements of $B[\Psi(3770)\to nonD\bar{D}]$



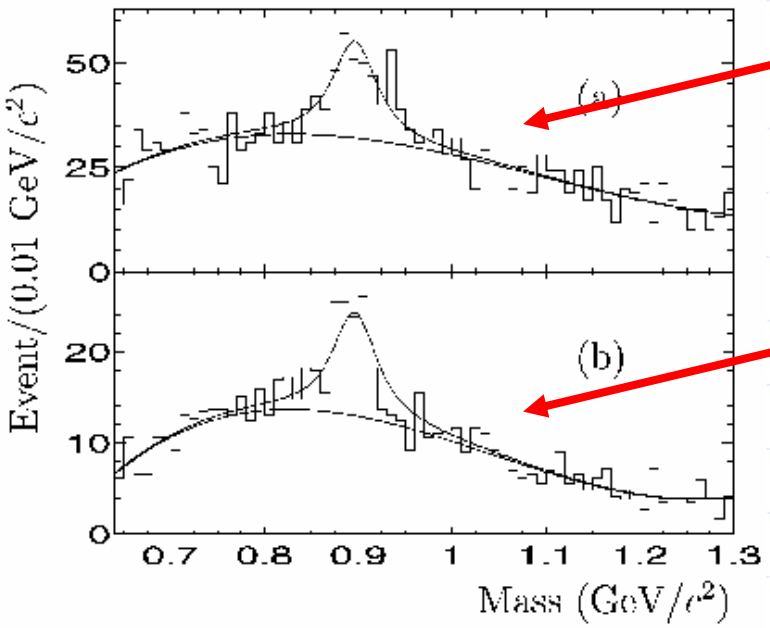






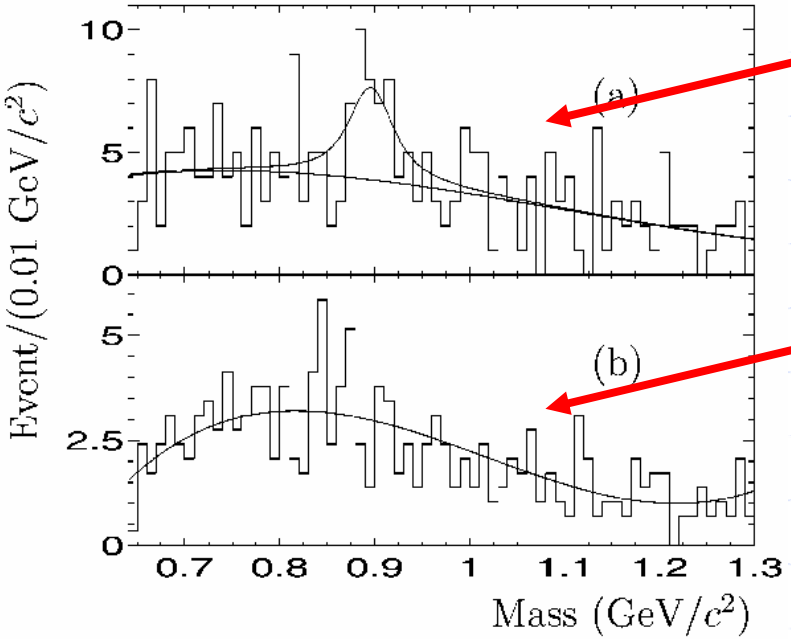
	PLB641, 145	PRL97,121801	PRD76,122002	PLB 659,74
$B(\psi''\to D^0D^0)[\%]$	49.9±1.3±3.8	46.7±4.7 ± 2.3	--	--
$B(\psi''\to D^+D^-)[\%]$	35.7±1.1±3.4	36.9 ±3.7 ±2.8	--	--
$B(\psi''\to D\bar{D})[\%]$	85.5±1.7±5.8	83.6 ±7.3 ±4.2	86.6±5.0±3.6	84.9±5.6±1.8
$B(\psi''\to$ non-$D\bar{D})[\%]$	14.5±1.7±5.8	16.4 ±7.3 ±4.2	13.4±5.0±3.6	15.1±5.6±1.8
Ruds	2.218±0.019±0.089	2.262±0.054±0.109	2.214±0.031±0.094	2.199±0.047±0.11 9
$\sigma^{obs}_{\psi(3770)}$ [nb]	7.18±0.20±0.63	6.94±0.48±0.28	7.07±0.36±0.45	--
σ_{nonDD} [nb]	--	--	0.95±0.35±0.29	1.08±0.40±0.15
σ_{DD} [nb]	--	--	6.12±0.37±0.23	--

branching fractions of $D \to K^{*0}/\bar{K}^{*0}X$



Signal of $D^0 \to \bar{K}^{*0}X$

Sideband of $D^0 \to \bar{K}^{*0}X$



Signal of $D^0 \to K^{*0}X$

Sideband of $D^0 \to K^{*0}X$