Charm Decays and $\Psi(3770)$ non-$D\bar{D}$ Decays at BESII & BESIII

Gang RONG

Institute of High Energy Physics, CAS

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OUTLINE

Some results on D and $\psi(3770)$ decays from BESII

- Purely leptonic decay and f_D
- Semileptonic decays , CKM matrix elements, and test for Isospin conservation
- Inclusive measurements
- DD cross section
- R measurements in $\psi(3770)$ region
- $\psi(3770)$ and $\psi(3686)$ Resonance Parameters
- Inclusive non-DD branching fractions
- Exclusive non-DD decay $J/\psi\ \pi\ \pi$, . . .

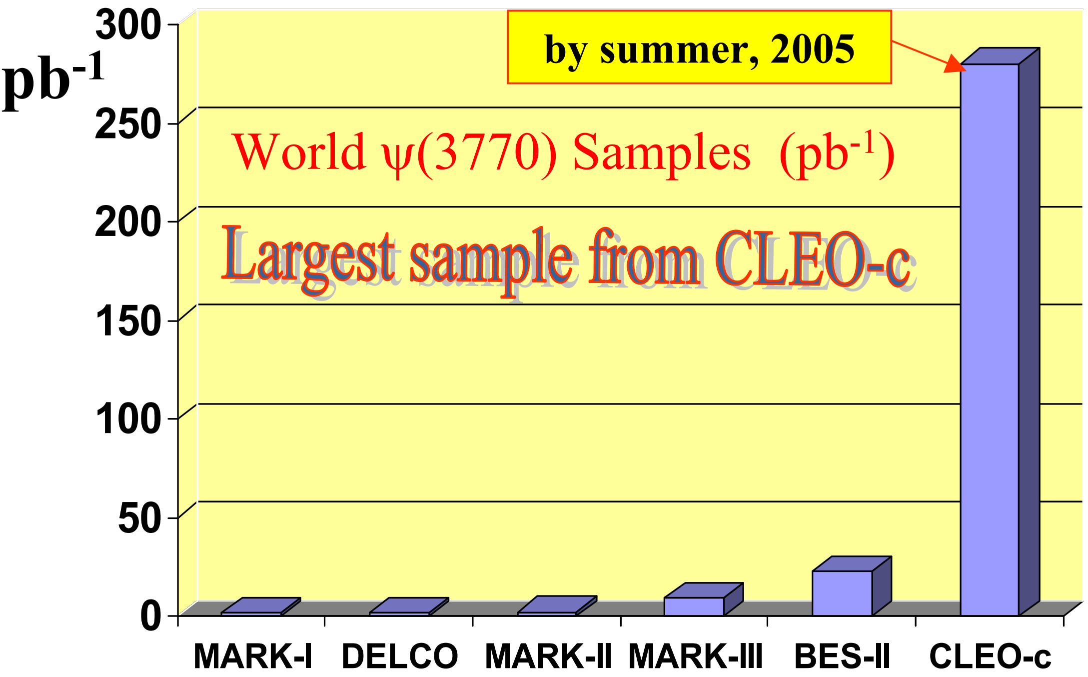
Prospects of Charm Physics at BESIII

Precision Measurements
- Pure leptonic decays
- Semileptonic decays
- Absolute Hadronic Branching fractions
- Cabibbo Suppressed Decays
- Dalitz Plot Analysis

Probe for New Physics: D^0D^0 Mixing,CP Violation,Rare Decays

Related Topics: Lineshape Analysis, …

World ψ(3770) Samples (pb^{-1})



BES-II Data Samples

- about 17.3 pb^{-1} data taken at 3.773 GeV
- ~7 pb^{-1} data taken from 3.768 GeV to 3.778 GeV
- ~8 pb^{-1} data taken from 3.665 to 3.878 GeV

} cross section scan data

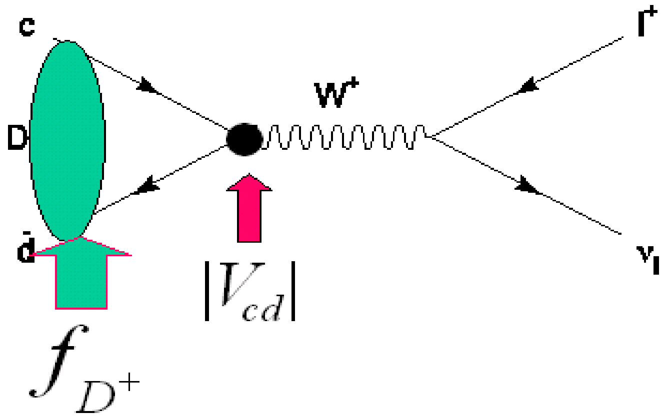
- about 6.5 pb^{-1} data taken at 3.650 GeV
- about 1 pb^{-1} data taken at 3.665 GeV

BESII ψ(3770) data sample of about 33 pb^{-1}

Purely leptonic decay at BESII

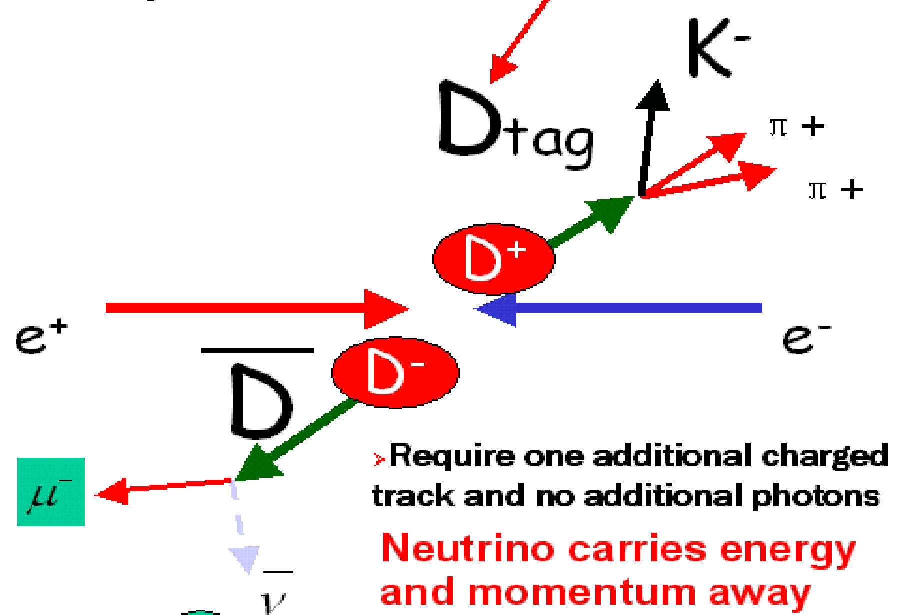
Absolute measurement of f_D

PLB610(2005)183



$N_{D^-_{tag}} = 5321 \pm 128$

- Fully reconstruct one D



- Require one additional charged track and no additional photons

Neutrino carries energy and momentum away

$$Br(D^+ \to l^+\nu) = \frac{G_F^2 |V_{cd}|^2}{8\pi} f_D^2 m_D m_l \tau_D \left(1 - \frac{m_l^2}{m_D^2}\right)^2$$

$$Br(D^+ \to \mu^+\nu) = (0.120^{+0.092+0.010}_{-0.063-0.009})\%,$$

3 events found

$$U_{miss} = E_{miss} - P_{miss}$$

Should be around zero

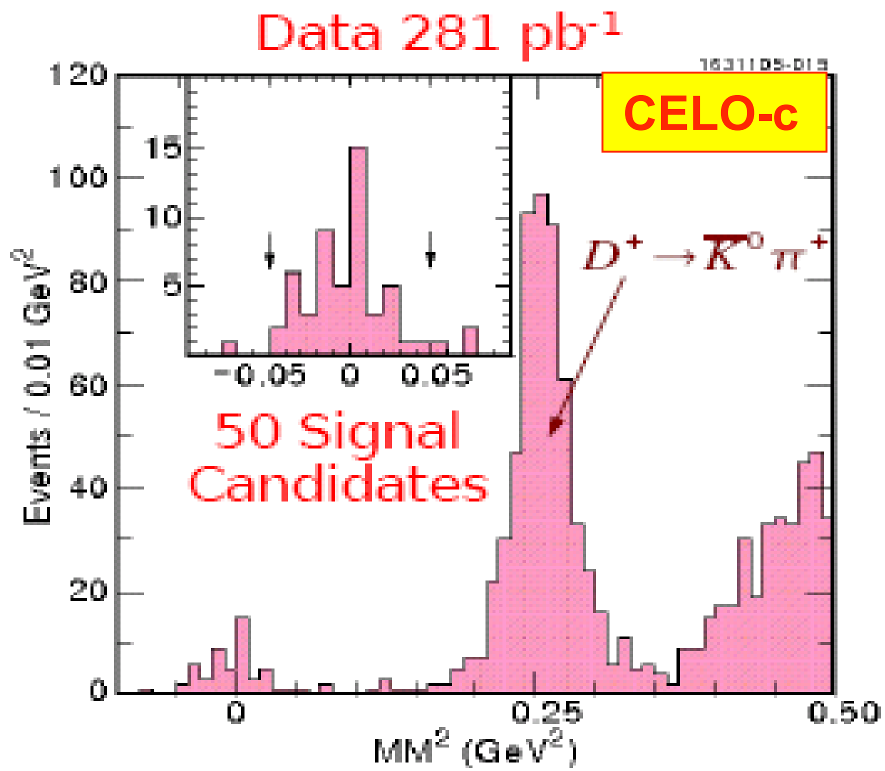
$$f_{D^+} = (365 \ {}^{+121}_{-113} \ {}^{+32}_{-28}) \ \text{MeV}$$

$$\Delta f_{D^+} / f_{D^+} = 33\ \%$$

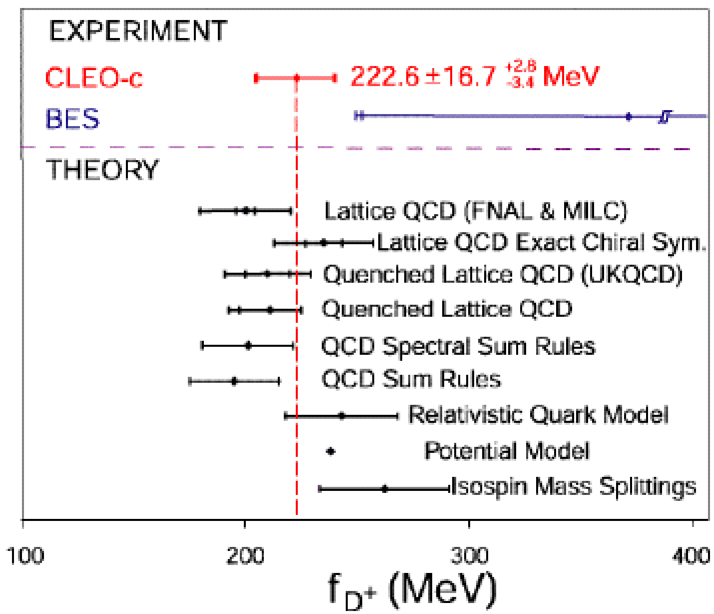
Moriond EW04 (2004-3)
ICHEP'04

BES first observed no ambiguity signal of purely leptonic decay of D+ moson

Purely leptonic decay at BESII



Comparing with Theory



- With 158,354 D^+ tags and an efficiency of 67.7% for signal events to satisfy the selection criteria given a D^+ tag we obtain:

$$Br(D^+ \to \mu^+ \nu) = (4.40 \pm 0.66^{+0.09}_{-0.12}) \times 10^{-4} \quad f_{D^+} = (222.6 \pm 16.7^{+2.8}_{-3.4})\,\text{MeV}$$

PRL 95, 251801 (2005)

- We also obtain $Br(D^+ \to e^+ \nu) < 2.4 \times 10^{-5}$ at 90 C.L.

A. Ryd, Cornell U. -7, 2006 Page: 9

$$\Delta f_{D^+} / f_{D^+} = 8\%$$

CELO-c expects to improve f $_{D+}$ measurement at an accuracy of 5% with 750 pb^{-1} of ψ(3770) data

BES-III will improve f $_{D+}$ measurement at an accuracy of 2% with 4 fb^{-1} of ψ(3770) data

Semileptonic decays at BESII

Why interested in the Semi-leptonic decays of D mesons ?

To measure the standard model parameters V_{cs}, V_{cd}
Probing the hadronic current
Understand the dynamics of semileptonic decays

$$D \rightarrow Pl\,\nu$$

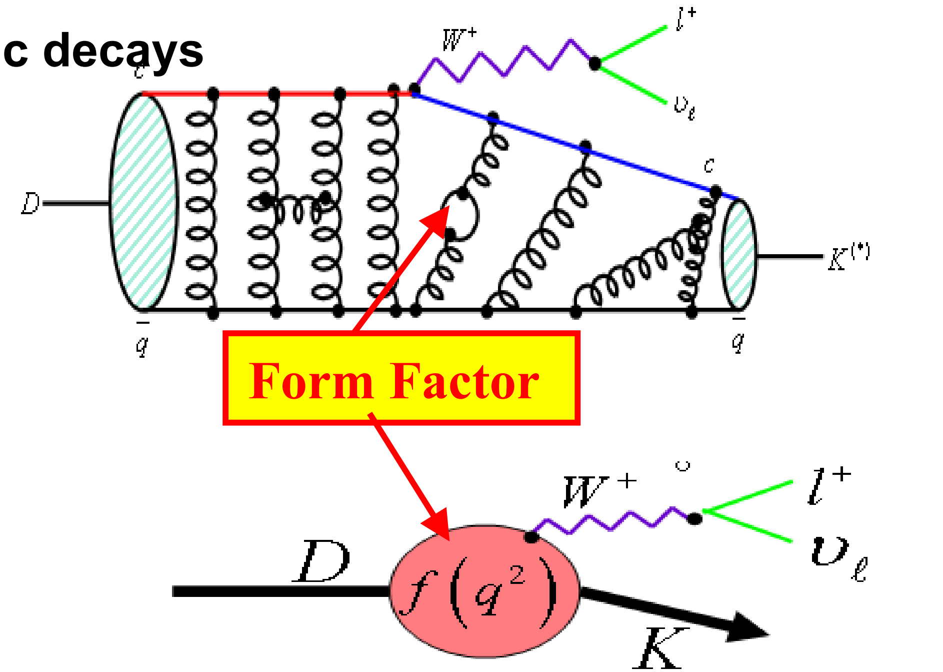
The parameters of Standard Model are:

$\alpha, G_F, \sin^2\theta_w, M_H$, **fermion mass and mixings**

$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{ub} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

Weak eigenstates — CKM — **Mass eigenstates**

The 4 quark mixing parameters (λ, A, ρ, η) reside in CKM matrix



$$\frac{d\Gamma(D \rightarrow Pl\nu)}{dq^2} = \frac{G_F^2}{24\pi^3} p_P^3 |V_{cq}|^2 |f_+(q^2)|^2$$

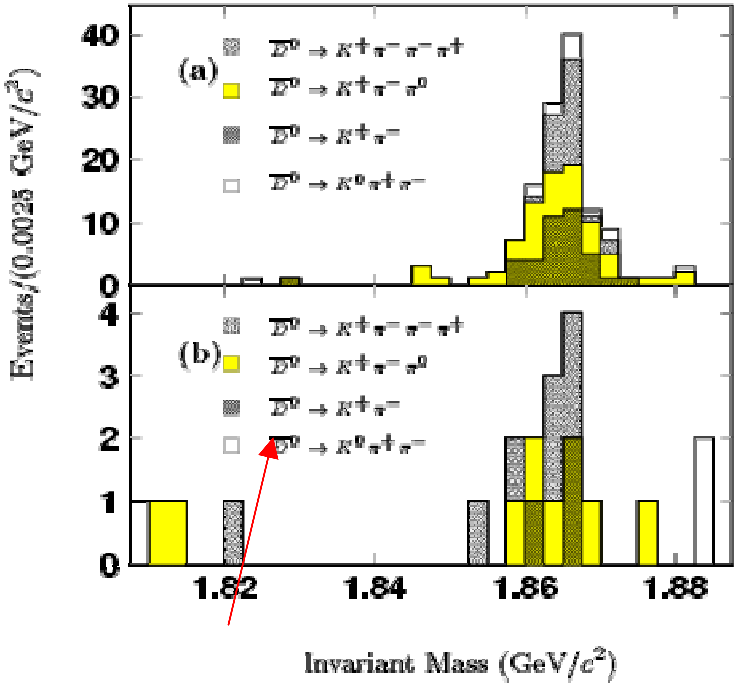
Questions: Does the CKM fully explain quark mixing? CP Violation?

To detect New Physics in flavor change sector, one must know the CKM well

Absolute branching fractions give direct measurements of the CKM matrix elements V_{cd} & V_{cs} and form factors

Semileptonic decays at BESII

$K^- e^+ \nu_e$ (found in REC of $\overline{D}^0$ tags.)



$\pi^- e^+ \nu_e$ (found in REC of $\overline{D}^0$ tags.)

	BESII(%)	CLEO(%)
$Br(D^0 \to K^- e^+ \nu_e)$	3.83±0.40±0.27	3.44±0.10±0.10
$Br(D^0 \to \pi^- e^+ \nu_e)$	0.33±0.13±0.03	0.262±0.025±0.008

PRL95(2005)181802

◆ CKM matrix elments

$\|V_{cs}\|$	$\|V_{cd}\|$	$f_+^{K(\pi)}(0)$ input
$0.998 \pm 0.052 \pm 0.145$	$0.251 \pm 0.049 \pm 0.044$	QCDSR [4]
$1.097 \pm 0.057^{+0.061}_{-0.124}$	$0.255 \pm 0.050^{+0.023}_{-0.036}$	LQCD1 [5]
$1.180 \pm 0.062^{+0.085}_{-0.083}$	$0.286 \pm 0.056^{+0.033}_{-0.033}$	LQCD2 [6]
0.996 ± 0.013	0.224 ± 0.016	PDG

	BES	MARKIII [1]
$\|V_{cd}/V_{cs}\|^2$	$0.043 \pm 0.017 \pm 0.003$	$0.057^{+0.038}_{-0.015} \pm 0.005$

◆ Form factors

	$\|f_+^K(0)\|$	$\|f_+^\pi(0)\|$
QCDSR [4]	0.78 ± 0.11	0.65 ± 0.11
LQCD1 [5]	$0.71 \pm 0.03^{+0.00}_{-0.07}$	$0.64 \pm 0.05^{+0.00}_{-0.07}$
LQCD2 [6]	$0.66 \pm 0.04^{+0.01}_{-0.00}$	$0.57 \pm 0.06^{+0.01}_{-0.00}$
BES	$0.78 \pm 0.04 \pm 0.03$	$0.73 \pm 0.14 \pm 0.06$

$$\left| \frac{f_+^\pi(0)}{f_+^K(0)} \right| = 0.93 \pm 0.19 \pm 0.07$$

PLB597(2004)39

Semileptonic decays at BESII

The 'long-standing puzzle'： whether the Isospin conservation holds in the exclusive semi-leptonic decays of D mesons ?

$$\Gamma(D^0 \to K^- e^+ \nu_e)/\Gamma(D^+ \to \overline{K}^0 e^+ \nu_e) = 1\ ???$$

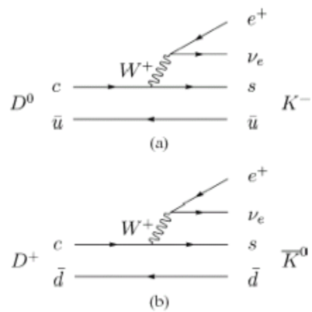
PLB 644（2007）20

Motivation

Isospin conservation implies

$$\Gamma(D^0 \to K^- e^+ \nu_e)/\Gamma(D^+ \to \overline{K}^0 e^+ \nu_e) = 1$$

$$\Gamma(D^0 \to K^- e^+ \nu_e)/\Gamma(D^+ \to \overline{K}^0 e^+ \nu_e) = 1.4 \pm 0.2$$



	BES	MARK III	PDG02
$\frac{\Gamma(D^0 \to K^- e^+ \nu_e)}{\Gamma(D^+ \to \overline{K}^0 e^+ \nu_e)}$	$1.08 \pm 0.22 \pm 0.07$	1.44 ± 0.62	1.4 ± 0.2

Moriond EW04 (2004 年 3 月)
ICHEP'04

Obtained based on the branching fractions quoted from PDG02

BESII results support that Isospin Conservation holds in exclusive semileptonic decays of D mesons

Paper published in
PLB 608 (2005) 24

Measurement of the ratio of the partial widths

	BES	MARK III	PDG02
$\frac{\Gamma(D^0 \to K^- l^+ \nu_e)}{\Gamma(D^+ \to \overline{K}^0 l^+ \nu_e)}$	$1.00 \pm 0.17 \pm 0.06$	1.44 ± 0.62	1.4 ± 0.2

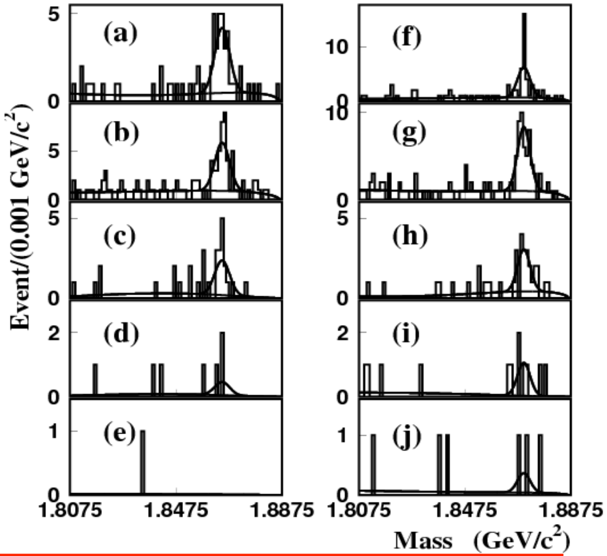
Obtained based on the branching fractions quoted from PDG02

BESII results support that Isospin Conservation holds in exclusive semileptonic decays of D mesons, Solve the longstanding puzzle in D Decays.

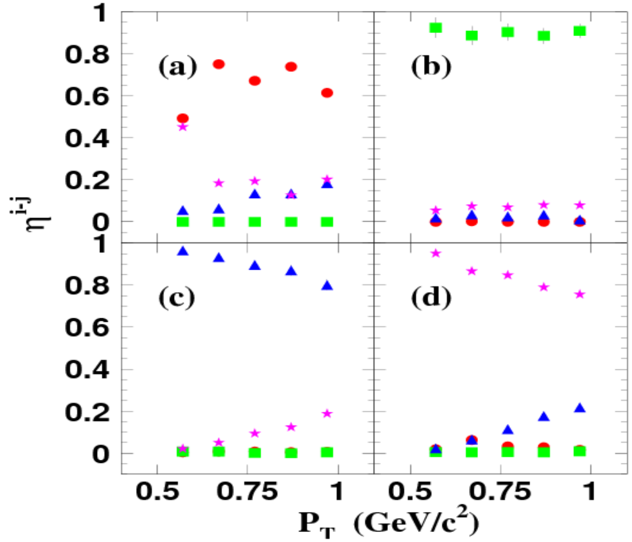
CLEO-c confirmed the BES-II result

$$\frac{\Gamma(D^0 \to K^- e^+ \nu_e)}{\Gamma(D^+ \to \overline{K}^0 e^+ \nu_e)} = 1.00 \pm 0.05 \pm 0.04$$

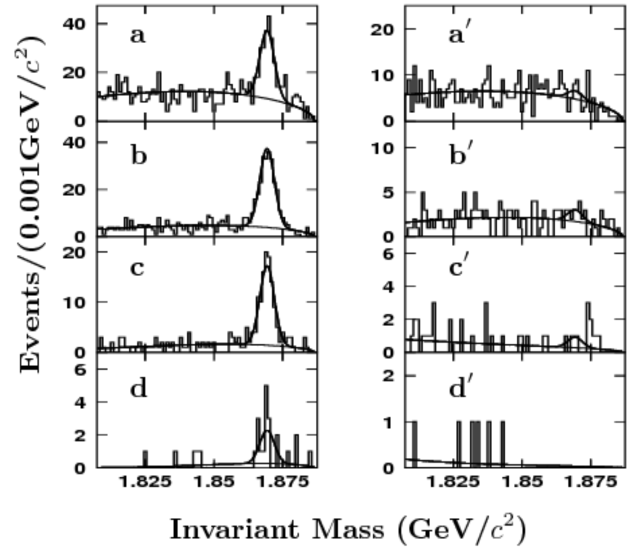
Charm Physics - $D\to\mu^+X$ and $D\to e^+X$



Preliminary



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



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

First measurement

B[%]	$D^0\to l^+X$	$D^+\to l^+X$
μ^+X	6.8±1.5±0.6	17.6±0.7±1.3
e^+X	6.3±0.7±0.4	15.2±0.9±0.8

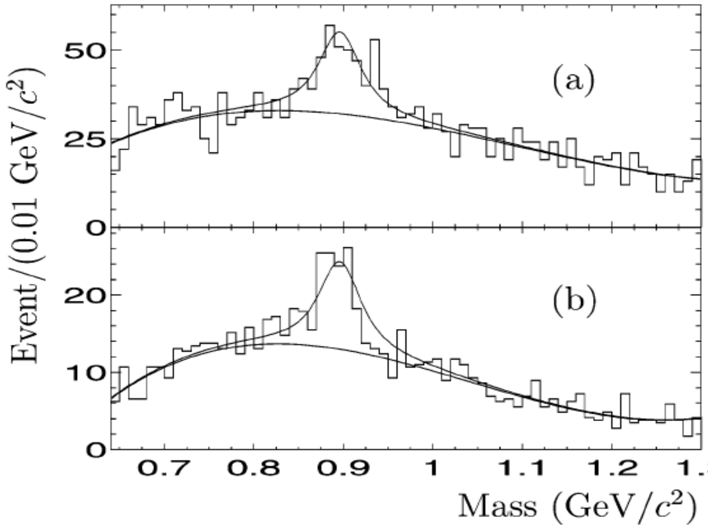
$$\frac{BF(D^+\to e^+X)}{BF(D^0\to e^+X)} = 2.41\pm0.30\pm0.18$$

$$\frac{\tau_{D^+}}{\tau_{D^0}} = 2.54\pm0.02\ \text{(PDG2006)}$$

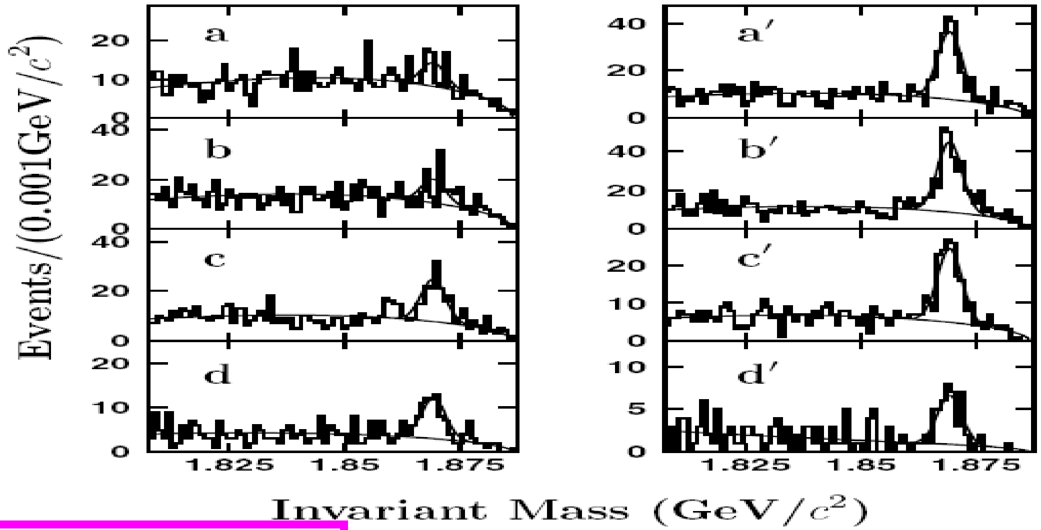
$$\frac{BF(D^+\to \mu^+X)}{BF(D^0\to \mu^+X)} = 2.59\pm0.70\pm0.15$$

$$\frac{\Gamma(D^+\to e^+X)}{\Gamma(D^0\to e^+X)} = 0.95\pm0.12\pm0.07$$

Charm Physics - D→KX



PLB 625 (2005) 196



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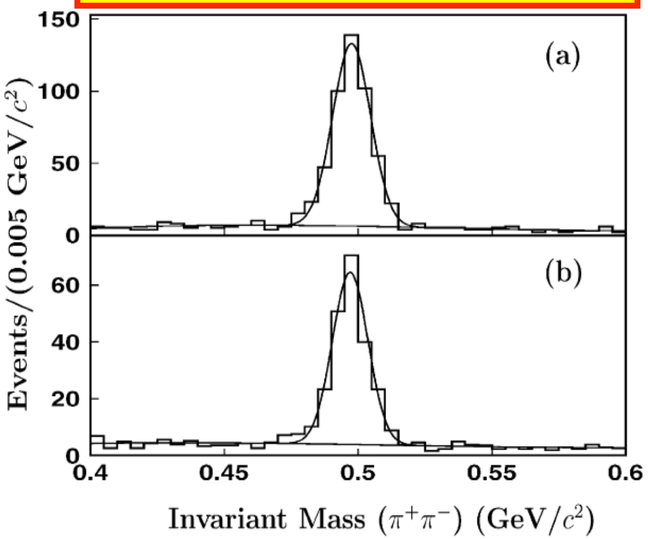


PLB 643 (2006) 246

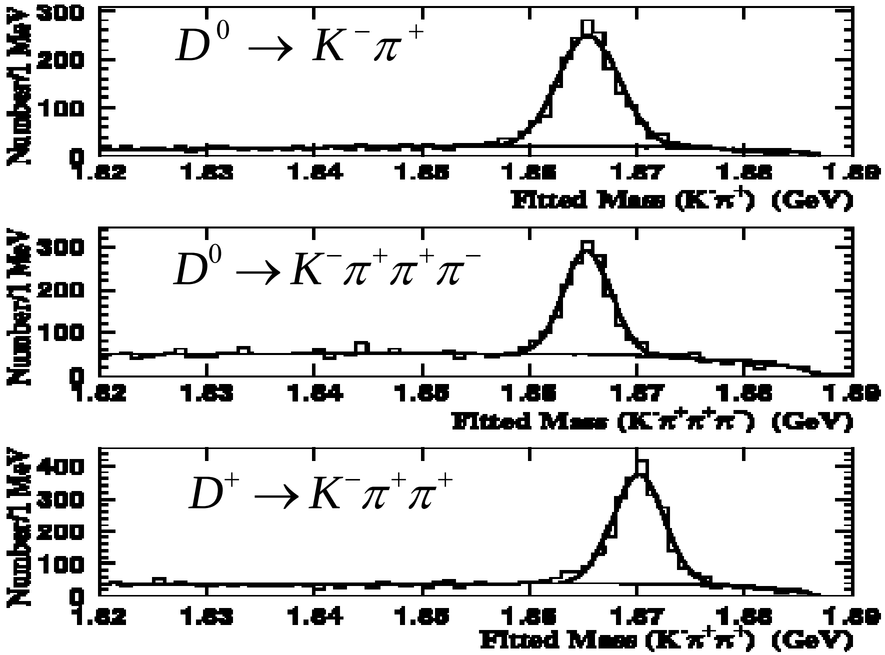
Improved & First measurements

B[%]	D^0→KX	D^+→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

Charm Physics-$D\bar{D}$ cross section

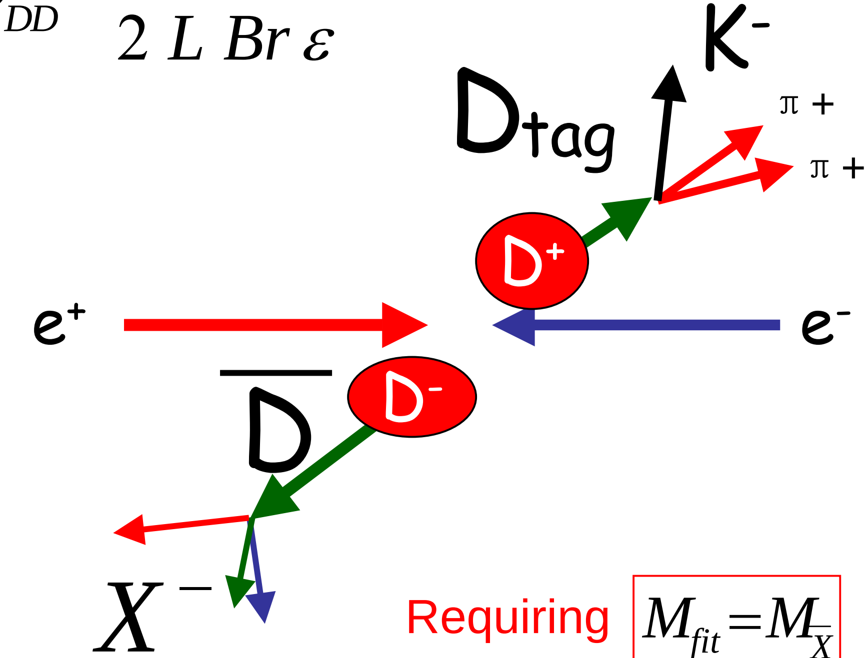
- $L = 17.3\ \mathrm{pb}^{-1}$ of data @ 3.773 GeV

Single tag method



Using Kinematic fit method to improve momentum resolution and select the singly tagged D meson

$$\sigma^{obs}_{D\bar{D}} = \frac{N_{D_{tag}}}{2\ L\ Br\ \varepsilon}$$



Requiring $M_{fit} = M_{\bar{X}}$

Observed cross sections for DD-bar production at 3.773 GeV

$\sigma^{obs}_{D^0\bar{D}^0}$	=	3.58	± 0.09	± 0.31	nb
$\sigma^{obs}_{D^+D^-}$	=	2.56	± 0.08	± 0.26	nb
$\sigma^{obs}_{D\bar{D}}$	=	6.14	± 0.12	± 0.50	nb

PLB 603(2004)130

Charm Physics-$D\bar{D}$ cross section

Double tag method

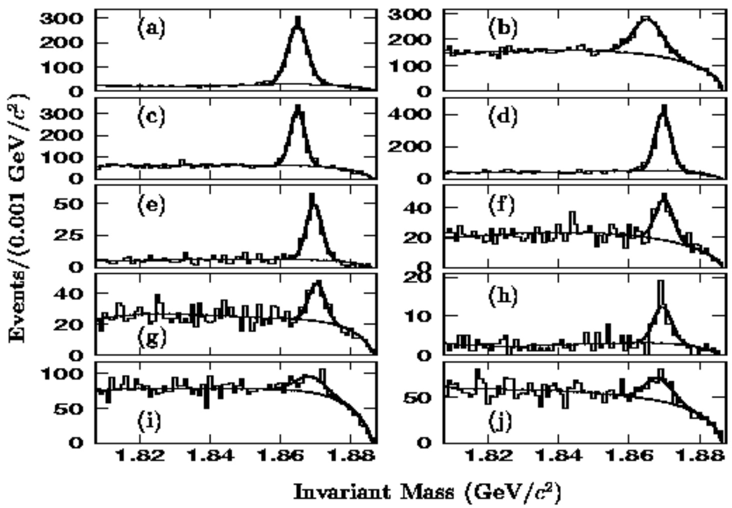


FIG. 1: The distribution of the invariant masses of the $nK m\pi$ ($n = 1, 2$; $m = 1, 2, 3$) combinations for the single tag modes: (a) $D^0 \to K^-\pi^+$, (b) $D^0 \to K^-\pi^+\pi^0$, (c) $D^0 \to K^-\pi^+\pi^+\pi^-$, (d) $D^+ \to K^-\pi^+\pi^+$, (e) $D^+ \to K^0_S\pi^+$, (f) $D^+ \to K^0_S\pi^+\pi^+\pi^-$, (g) $D^+ \to K^-K^+\pi^+$, (h) $D^+ \to K^0_S K^+$, (i) $D^+ \to K^-\pi^+\pi^+\pi^0$, (j) $D^+ \to K^0_S\pi^+\pi^0$.

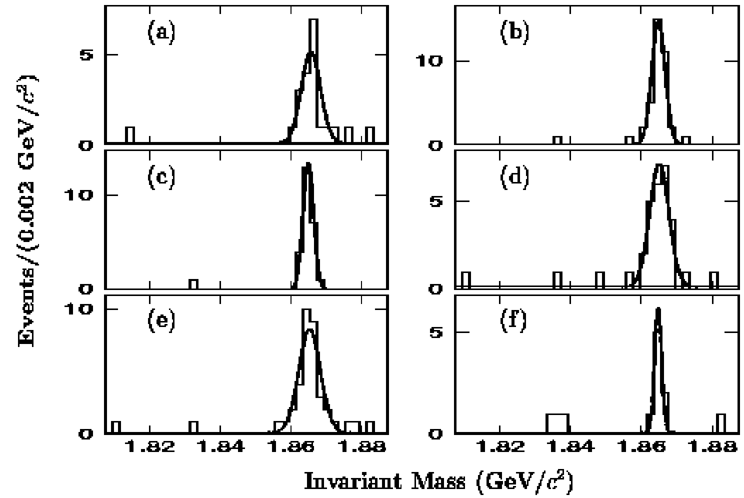


FIG. 2: Distribution of the invariant masses for $K m\pi$ (m=1, or 2, or 3) combinations of six double tag $D^0\bar{D}^0$ modes: (a) $D^0 \to K^-\pi^+$ vs $\bar{D}^0 \to K^+\pi^-$, (b) $D^0 \to K^-\pi^+$ vs $\bar{D}^0 \to K^+\pi^-\pi^0$, (c) $D^0 \to K^-\pi^+$ vs $\bar{D}^0 \to K^+\pi^-\pi^-\pi^+$, (d) $D^0 \to K^-\pi^+\pi^0$ vs $\bar{D}^0 \to K^+\pi^-\pi^0$, (e) $D^0 \to K^-\pi^+\pi^0$ vs $\bar{D}^0 \to K^+\pi^-\pi^-\pi^+$, (f) $D^0 \to k^-\pi^+\pi^+\pi^-$ vs $\bar{D}^0 \to K^+\pi^-\pi^-\pi^+$.

$$\chi^2 = \sum_i \left(\frac{N_s(i) - N_s^{net}(i)}{\sigma^{net}_{N_s(i)}}\right)^2 + \sum_{ij} \left(\frac{N_d(i,j) - N_d^{net}(i,j)}{\sigma^{net}_{N_d(i,j)}}\right)^2$$

$$\sigma^{obs}_{D^0\overline{D^0}} = 3.47 \pm 0.32 \pm 0.21 \text{ nb}$$

$$\sigma^{obs}_{D^+D^-} = 2.46 \pm 0.33 \pm 0.20 \text{ nb}$$

$$\sigma^{obs}_{D\bar{D}} = 5.93 \pm 0.46 \pm 0.35 \text{ nb}$$

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An absolute measurement

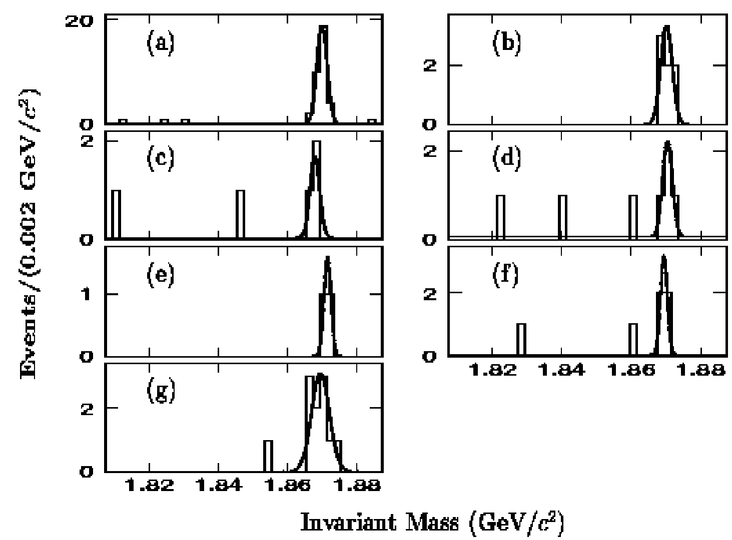
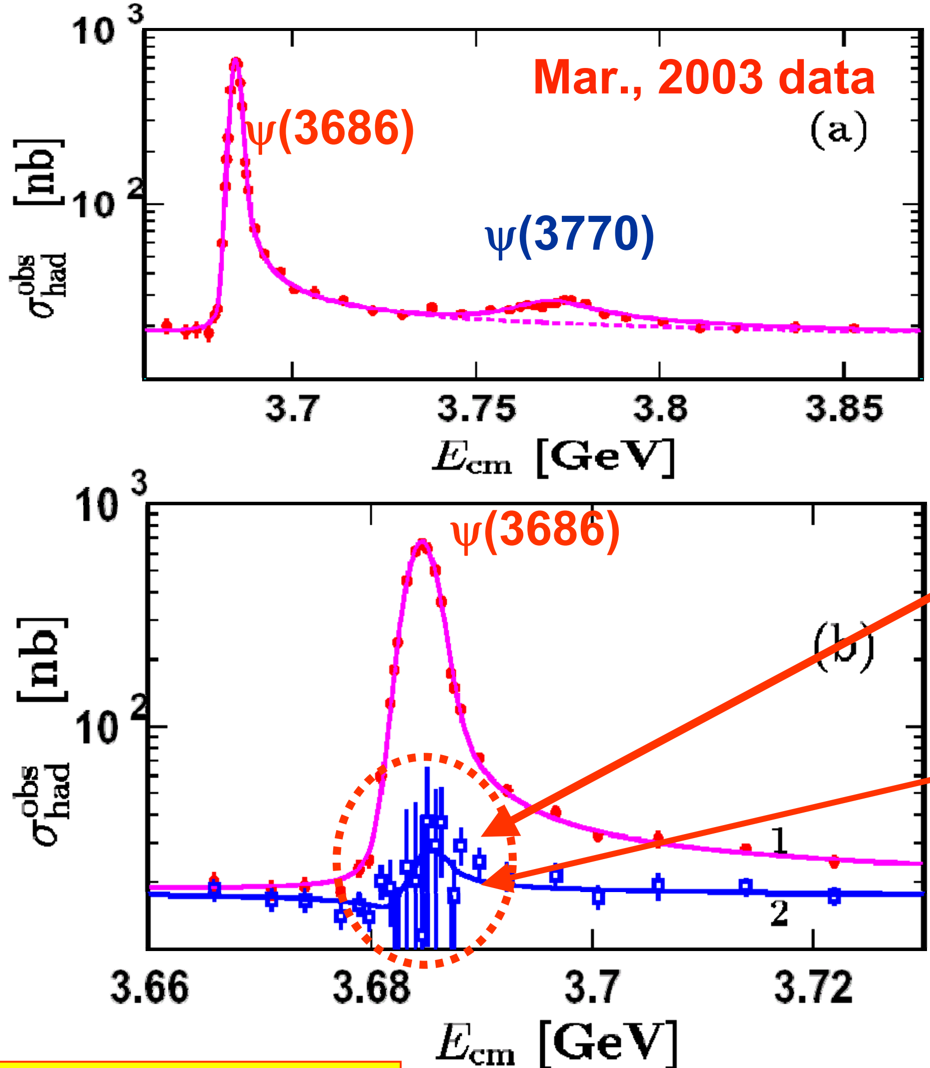


FIG. 3: Distribution of the invariant masses for $K^-\pi^+\pi^+$ combinations of seven double tag D^+D^- modes: (a) $D^+ \to K^-\pi^+\pi^+$ vs $D^- \to K^+\pi^-\pi^-$, (b) $D^+ \to K^-\pi^+\pi^+$ vs $D^- \to K^0_S\pi^-$, (c) $D^+ \to K^-\pi^+\pi^+$ vs $D^- \to K^0_S\pi^-\pi^-\pi^+$, (d) $D^+ \to K^-\pi^+\pi^+$ vs $D^- \to K^-K^+\pi^-$, (e) $D^+ \to K^-\pi^+\pi^+$ vs $D^- \to K^0_S K^-$, (f) $D^+ \to K^-\pi^+\pi^+$ vs $D^- \to K^+\pi^-\pi^-\pi^0$, (g) $D^+ \to K^-\pi^+\pi^+$ vs $D^- \to \bar{K}^0\pi^-\pi^0$, where the shadow part is background study from Monte Carlo simulation.

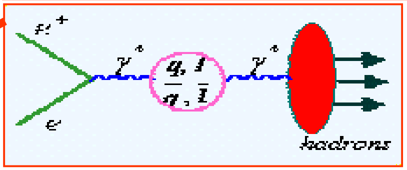
ψ" and ψ' resonance parameters

Line-Shape and Resonance Parameters of ψ(3770) and ψ(3686)



To measure the resonance parameters of ψ(3770) or ψ(3686), one had better to simultaneously fit ψ(3686) and ψ(3770) resonances, since there are strong correlations between the fitted parameters of the two resonances.

If one do not consider the effects of vacuum polarization corrections on the observed cross sections in the data reduction, the total width of ψ(3686) would decrease by about 40 keV!



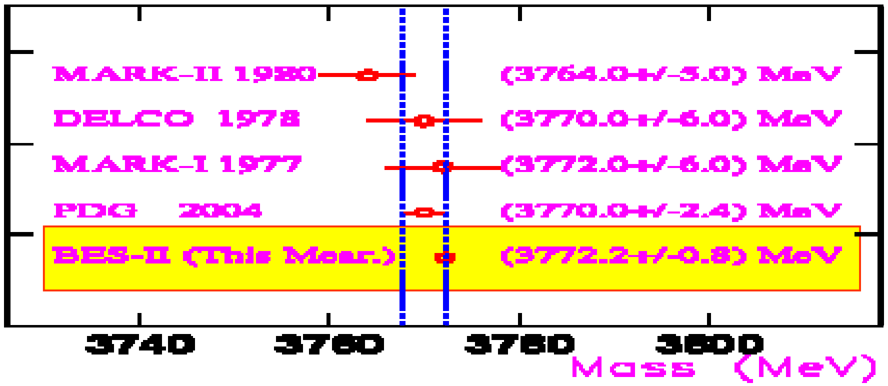
Mainly due to vacuum polarization corrections

After subtraction of ψ(3686) , ψ(3770) and J/ ψ from the observed cross sections, one obtains the expected cross sections of the continuum hadron production.

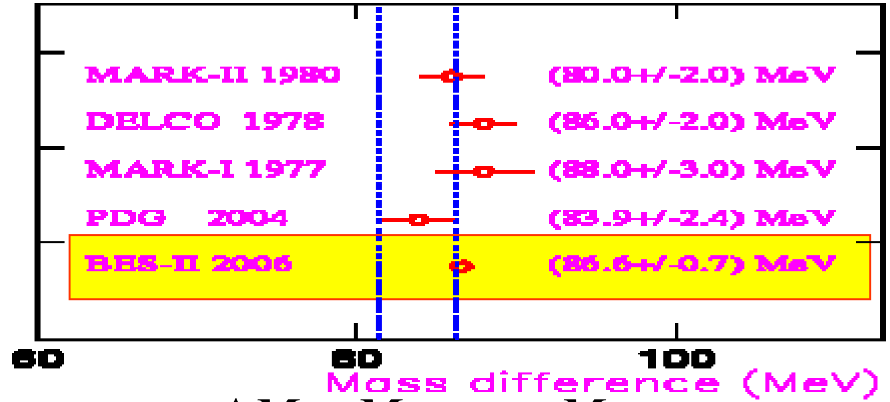
PRL 97 (2006) 121801

ψ" and ψ' resonance parameters

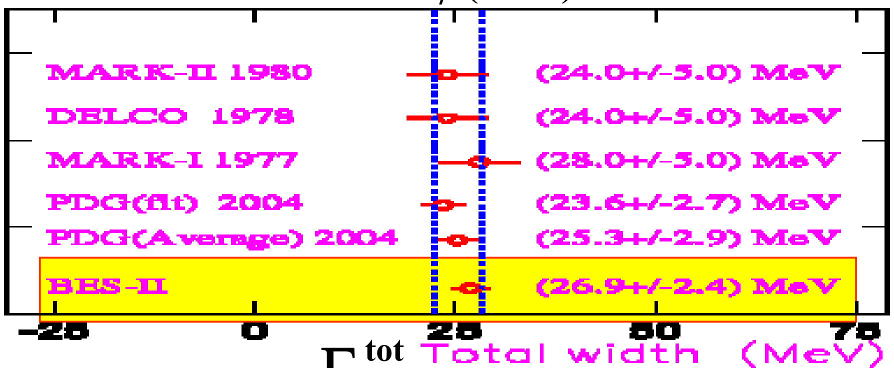
Comparison of ψ(3770) Resonance Parameters



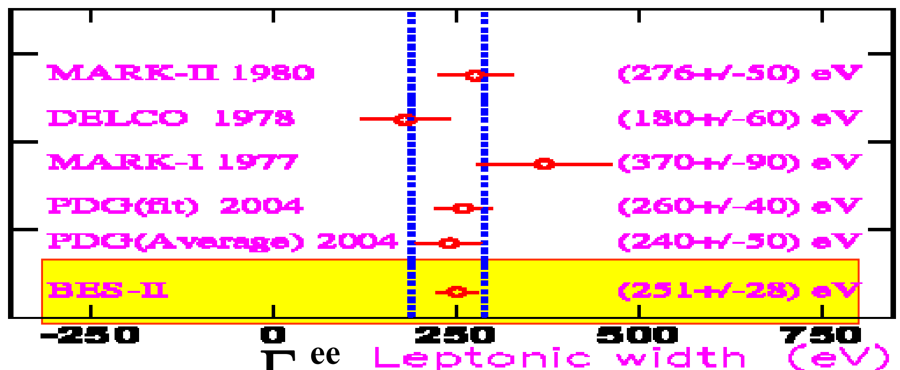
$M_{\psi(3770)}$



$\Delta M = M_{\psi(3770)} - M_{\psi(2S)}$



$\Gamma^{tot}_{\psi(3770)}$



$\Gamma^{ee}_{\psi(3770)}$

$$\sigma^{prd}_{\psi(3770)}\big|_{\sqrt{s}=3772.3\ \mathrm{MeV}} = 9.63 \pm 0.66 \pm 0.35\ \ \mathrm{nb}$$

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

PRL 97 (2006) 121801

$$\sigma^{obs}_{\psi(3770)}\big|_{\sqrt{s}=3772.3\ \mathrm{MeV}} = 6.94 \pm 0.48 \pm 0.28\ \ \mathrm{nb}$$

which is consistent within error with

$$\sigma^{obs}_{\psi(3770)}\big|_{\sqrt{s}=3772.3\ \mathrm{MeV}} = 8.12 \pm 1.56\ \ \mathrm{nb}$$

obtained based on PDG04 parameters

ψ" and ψ' resonance parameters

Comparison of ψ(3686) Resonance Parameters

Obtained based on cross section scan

experiment	$M_{\psi'}$ (MeV)	$\Gamma_{\psi'}^{tot}$ (keV)	$\Gamma_{\psi'}^{ee}$ (keV)
E760	$3686.0 \pm 0.1 \pm 0.3$	$306 \pm 36 \pm 16$	
BES-II	N/A	264 ± 27	2.44 ± 0.21
PDG04	3686.09 ± 0.03	281 ± 17	2.12 ± 0.12
BES-II [Mar. 2003 data]	$3685.5 \pm 0.0 \pm 0.3$	$331 \pm 58 \pm 2$	$2.33 \pm 0.04 \pm 0.11$

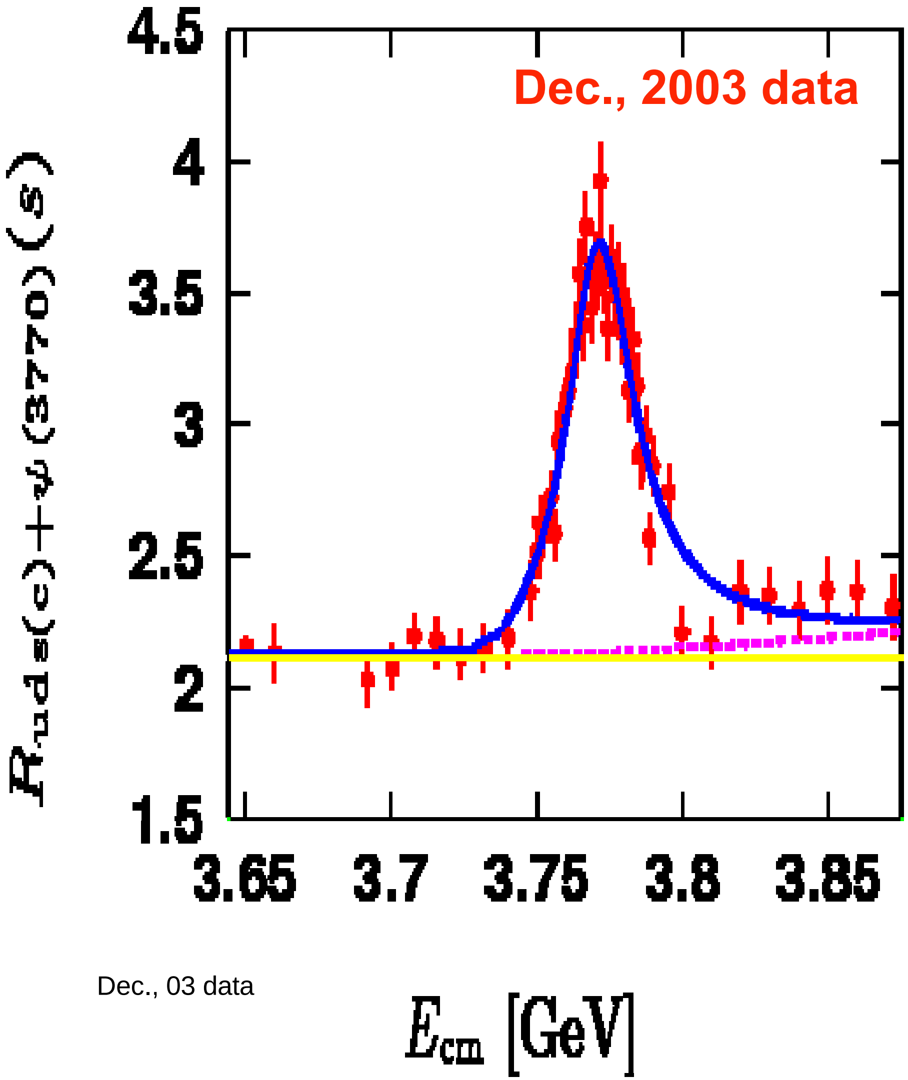
PRL 97 (2006) 121801

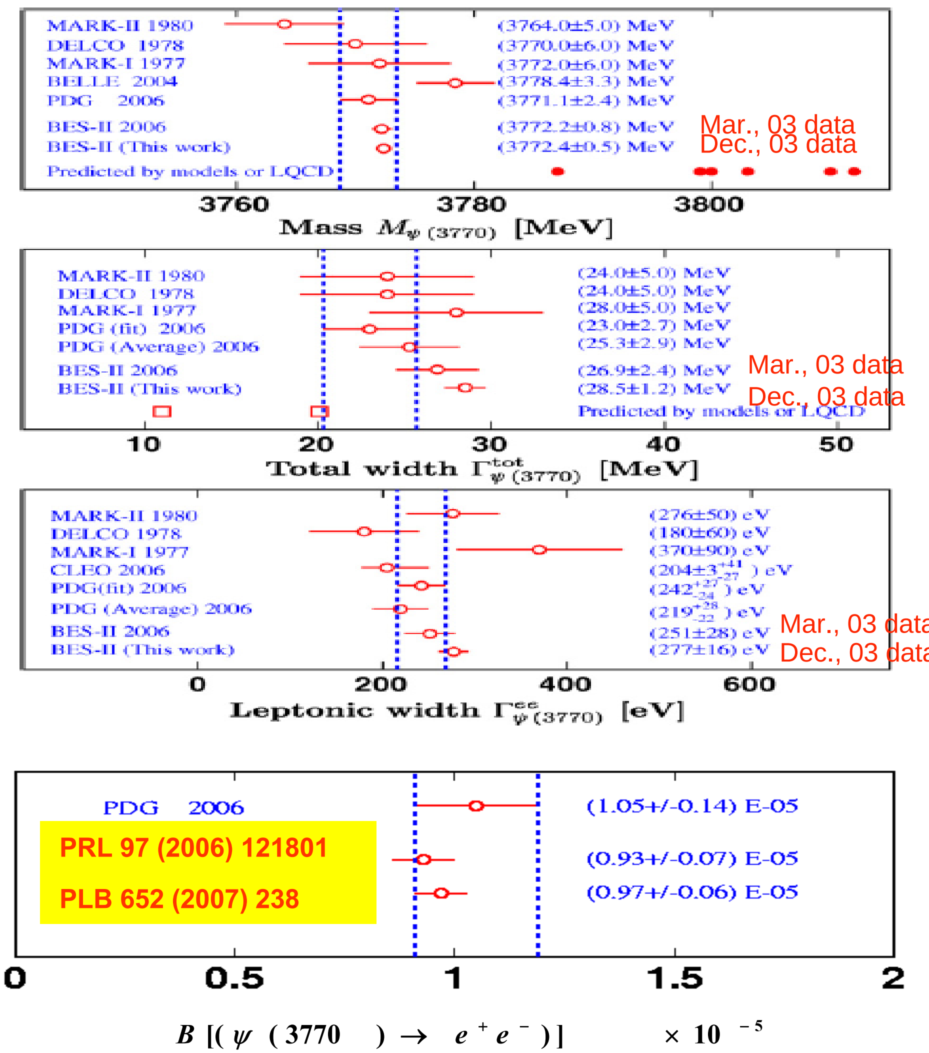
Taking into consideration the effect of vacuum polarization correction on the measured parameters for the first time in the energy scan experiment.

ψ(3770) resonance parameters

Precision Measurements of the Mass, Total and Leptonic Widths of ψ(3770)

PLB652(2007)238





Dec., 03 data

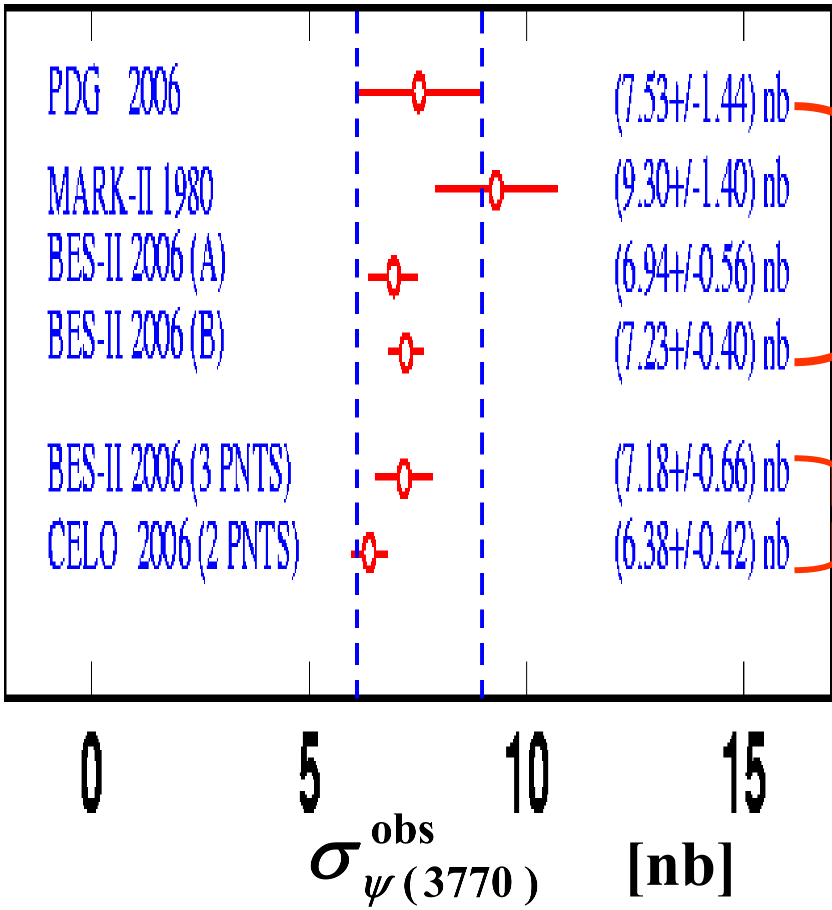
$$B[\psi(3686)\to e^+e^-] = (0.704 \pm 0.122 \pm 0.033)\%$$

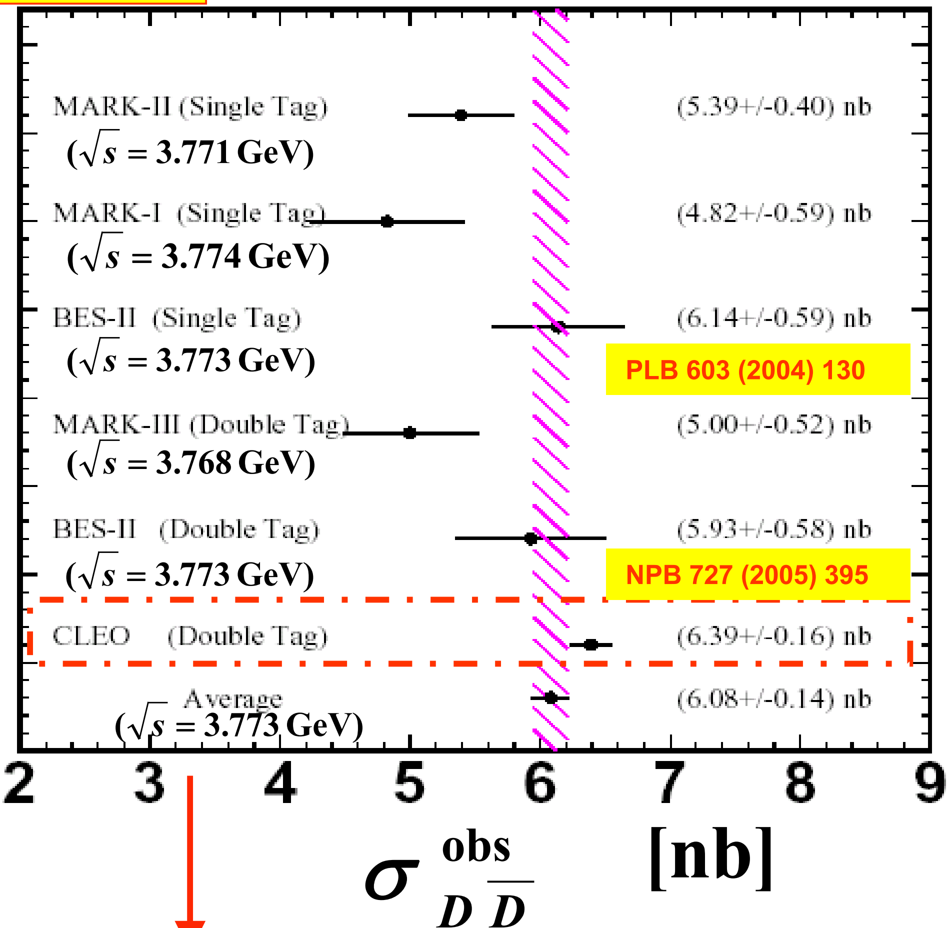
ψ” and $D\bar{D}$ Cross section

Comparison of ψ(3770) cross section

Obtained based on resonance parameters

Comparison of DD cross section





Measured cross section based on the data taken at 3.773 GeV and at 3.66 (or 3.67) GeV

My estimation only , Input with PDG06 Br

Measurements of R_{had}, $R_{uds(c)}$ and $R_{uds(c)+\psi(3770)}$

PRL 97(2006) 262001

PLB 641 (2006) 145

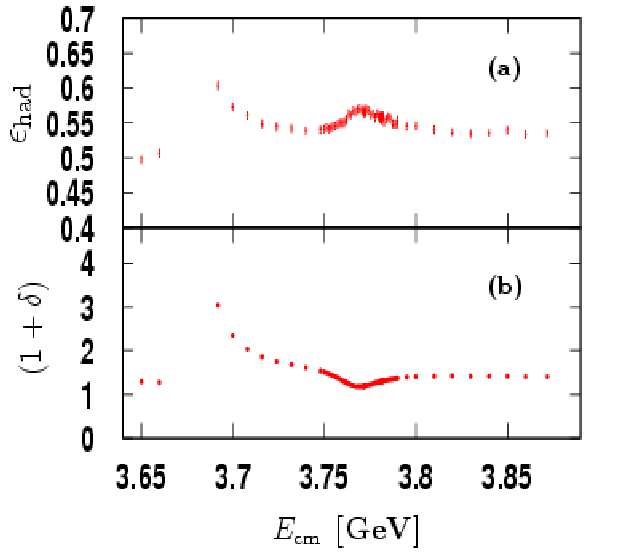
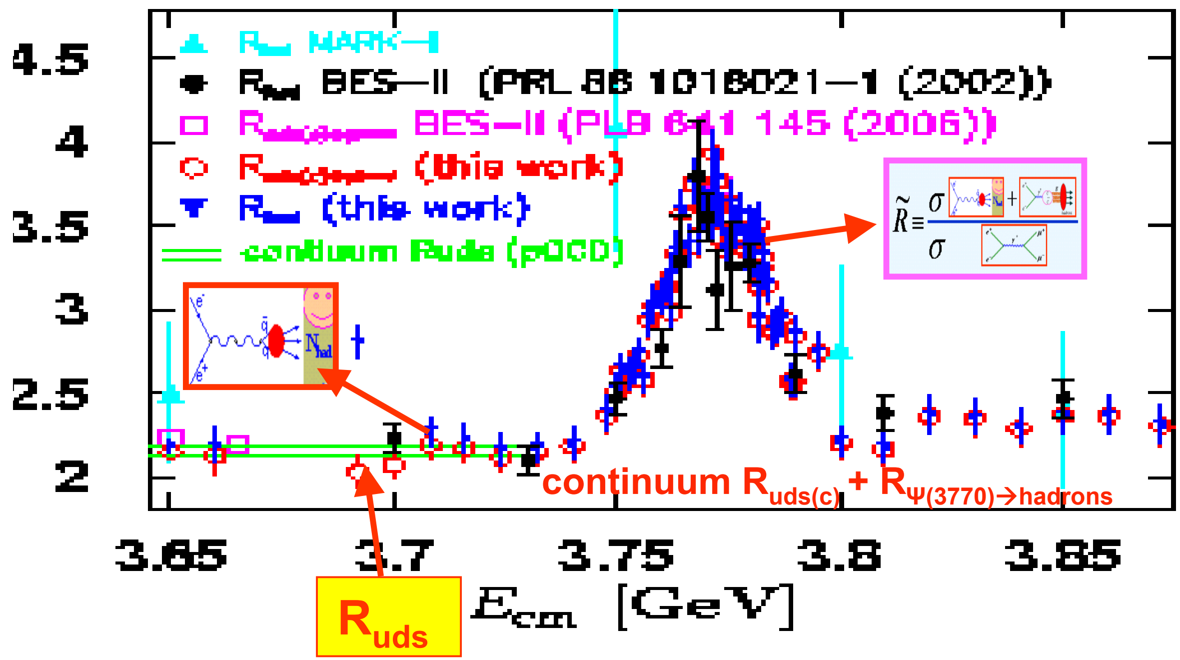
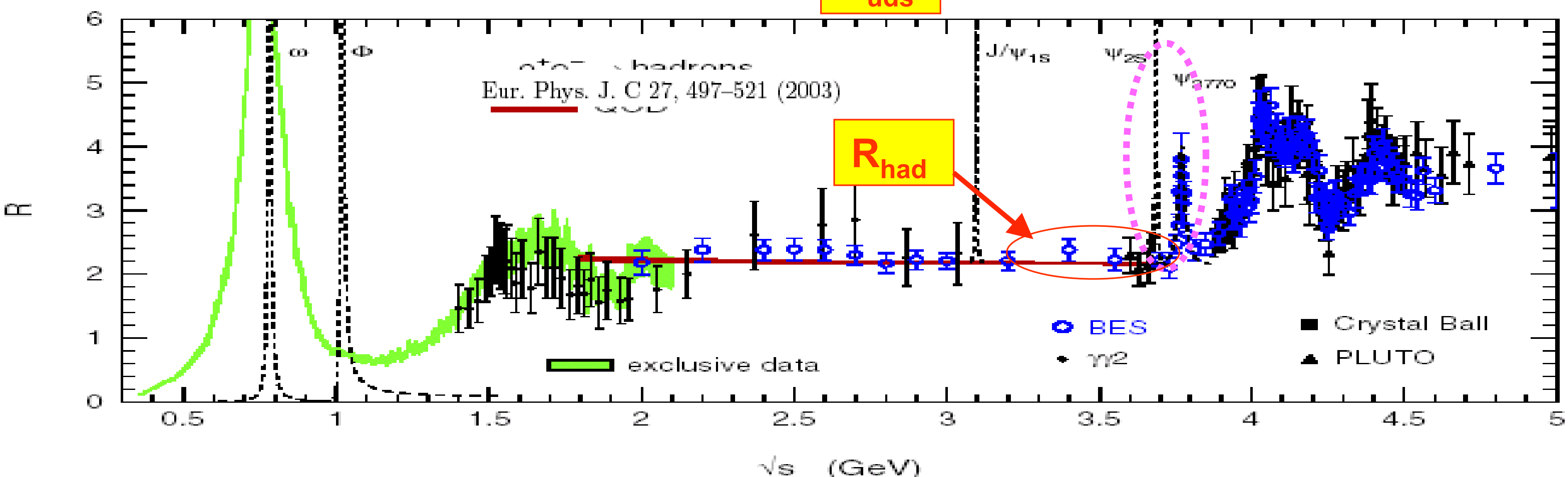


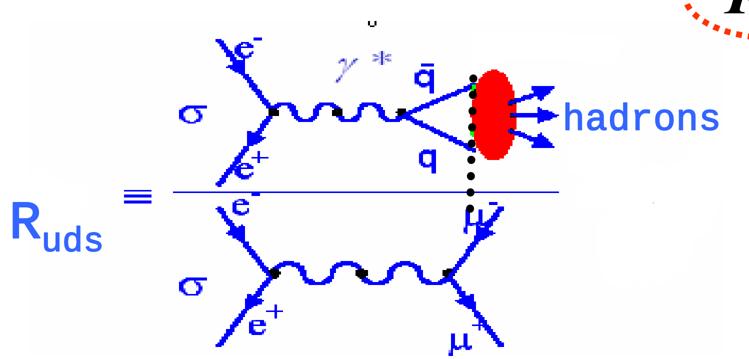
FIG. 2: (a) The efficiency versus the nominal c.m. energy; (b) The ISR factor versus the nominal c.m. energy (see text).





Measurements of R_{had}, $R_{uds(c)}$ and $R_{uds(c)+\psi(3770)}$

$$R_{uds(c)+\psi(3770)}(s) = \begin{cases} R_{uds(c)}(s) + R_{\psi(3770)}(s) & \text{above cc-bar threshold} \\ R_{uds} & \text{below cc-bar threshold} \end{cases}$$



$R_{uds} = 2.134 \pm 0.025 \pm 0.085$

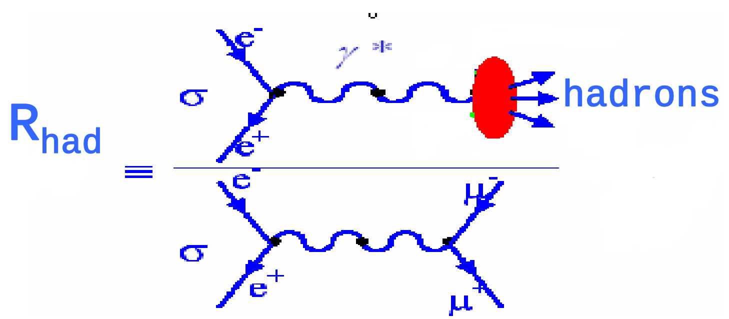
Below DD-bar threshold

$R^{pQCD}_{uds} = 2.15 \pm 0.03$

Measured R_{uds} for the first time in this energy region. calculate → $\alpha_s(s)$

$R_{had}(s)=R_{uds(c)}(s)+\Sigma R_{res,i}(s)$,

$R_{res,i}(s)$ is R values due to all 1^{--} resonances decay to hadrons except $\Psi(3770)$.

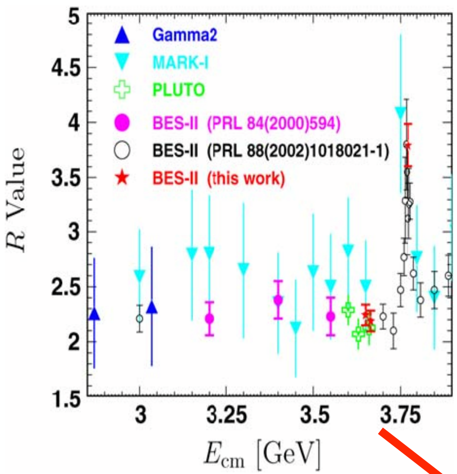


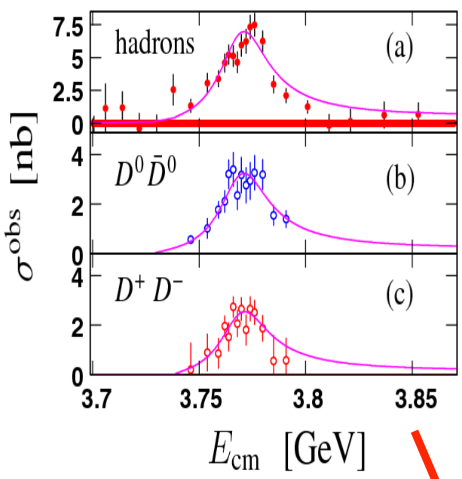
calculate →

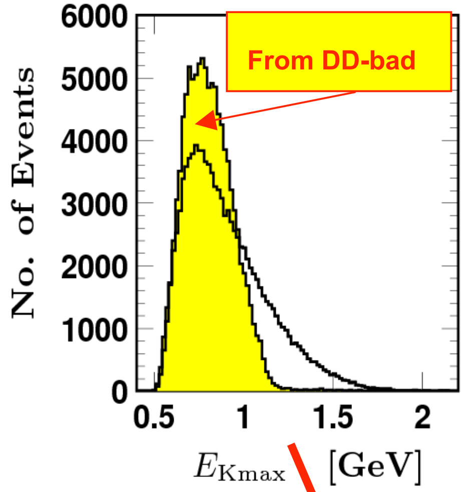
$\alpha_{QED}(M_Z)$

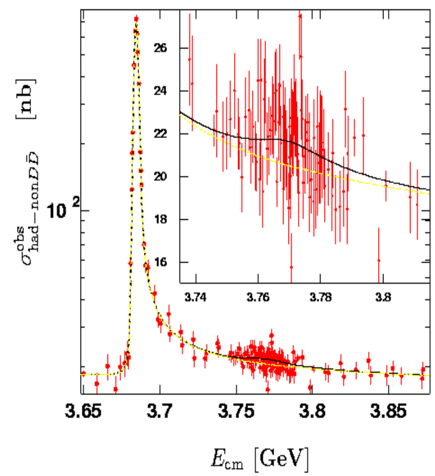
$a_\mu = (g_\mu - 2)/2$

Measurements of B[$\Psi(3770)\rightarrow$non$D\bar{D}$]



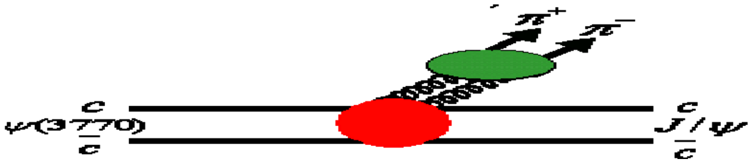




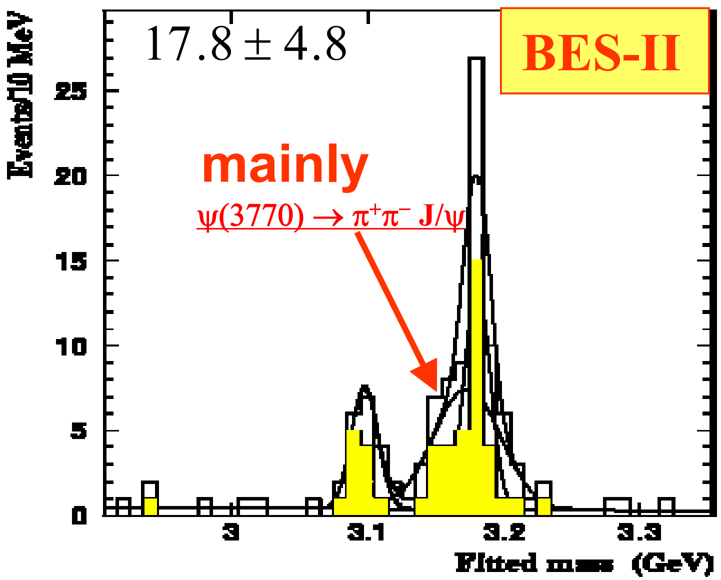


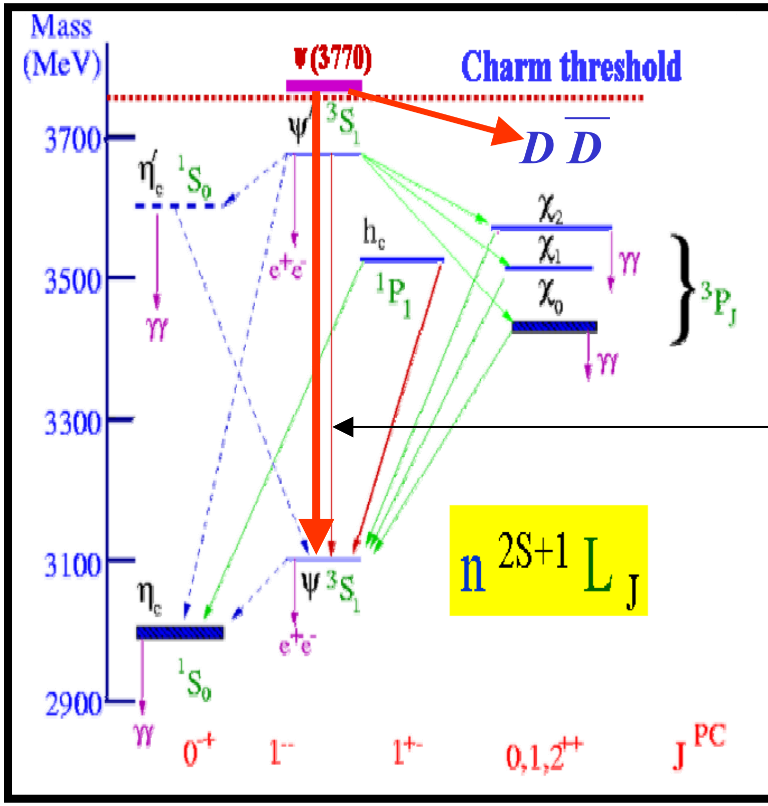
	PLB641, 145	PRL97,121801	Accepted by PRD	Accepted by PLB
B($\psi''\rightarrow D^0D^0$)[%]	49.9±1.3±3.8	46.7±4.7 ± 2.3	--	--
B($\psi''\rightarrow D^+D^-$)[%]	35.7±1.1±3.4	36.9 ±3.7 ±2.8	--	--
B($\psi''\rightarrow DD$)[%]	85.5±1.7±5.8	83.6 ±7.3 ±4.2	86.6±5.0±3.6	84.9±5.6±1.8
B($\psi''\rightarrow$non-DD)[%]	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	--

$\Psi(3770) \to J/\psi\ \pi^+\pi^-$



It is an interesting question whether hadronic transitions inside the ψ(3770) exist.





Yes

BES-II observed the first non-DD events of ψ(3770) decays. CLEO-c conformed the BES observation of the non-DD decay.

$$BF(\psi(3770) \to J/\psi\pi^+\pi^-) = (0.34 \pm 0.14 \pm 0.09)\%$$ BES-II — PLB 605 (2005)63

$$BF(\psi(3770) \to J/\psi\pi^+\pi^-) = (0.189 \pm 0.022\,^{+0.007}_{-0.004})\%$$ CLEO-c — PRL96,082004(2006)

The two measurements are consistent within the errors.

Other Charmless Decays

Upper limits are set at 90% CL

PLB650(2007)111, PLB656(2007)30, EPJC52(2007)805

Mode	$\sigma^{3.773}$[pb]	$\sigma^{3.650}$[pb]	$B^{up}[\times10^{-3}]$
$\phi\pi^0$	<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

Mode	$\sigma^{3.773}$[pb]	$\sigma^{3.650}$[pb]	$B^{up}[\times10^{-3}]$
$K^+K^-2(\pi^+\pi^-)$	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
$\omega\pi^+\pi^-$	<37.1	<50.8	<5.5
ωK^+K^-	<44.4	<53.2	<6.6
ωpp^{bar}	<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
$\Lambda\Lambda^{bar}\pi^0$	<7.9	<21.4	<1.2

No obvious cross section discrepancy at the two energy points is observed. However, to extract the non-DD-bar BFs of $\psi(3770)$ decays, one needs to consider the interference between the two amplitudes of the continuum and the resonances, and to consider the difference of ISR & vacuum polarization corrections at two energy points.

Charm Physics at BESIII

Precision Measurements at BES-III

Charm Production at BES-III

Average Lum: $\mathcal{L} = 0.5 \times$ Peak Lum.;
One year data taking time: $T = 10^7$s

Assuming 6 month running for Physics/year & average efficiency of collecting data is 70%.

$$N_{event} / year = \sigma_{exp} \times L \times T \times \varepsilon_{data\,taking}$$

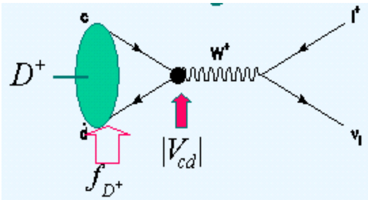
Resonance	Mass(GeV) CMS	Peak Lum. ($10^{33}cm^{-2}s^{-1}$)	Physics Cross Section (nb)	Nevents/yr
J/ψ	3.097	0.6	3400	6×10^9
τ	3.670	1.0	2.4	7.3×10^6
$\psi(2S)$	3.686	1.0	640	2.0×10^9
D^0D^0bar	3.770	1.0	3.6	11×10^6
D^+D^-	3.770	1.0	2.6	7.9×10^6
DsDs	4.030	0.6	0.32	0.6×10^6
DsDs	4.140	0.6	0.67	1.2×10^6

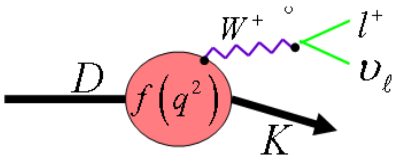
Why are we interested in Charm ?

Charm plays an important role in understanding the SM (standard model) dynamics in two respects:

Precision measurements

Precision measurements of decay constants f_D, f_{Ds}, form-factors of semileptonic decays of Charm mesons provide the calibration of Lattice QCD calculation. In turn, the very precise calculation of the ratios of these decay constants f_D/f_B, f_{Ds}/f_{Bs} and form-factors from LQCD support measurements for B physics.





The parameters of Standard Model are:
$\alpha, G_F, \sin^2\theta_w, M_H$, **fermion mass and mixings**

The 4 quark mixing parameters (λ, A, ρ, η) reside in CKM matrix

$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

Weak eigenstates **CKM** **Mass eigenstates**

$$\begin{pmatrix} 1-\frac{1}{2}\lambda^2 & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\frac{1}{2}\lambda^2 & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix} + \Theta(\lambda^4)$$

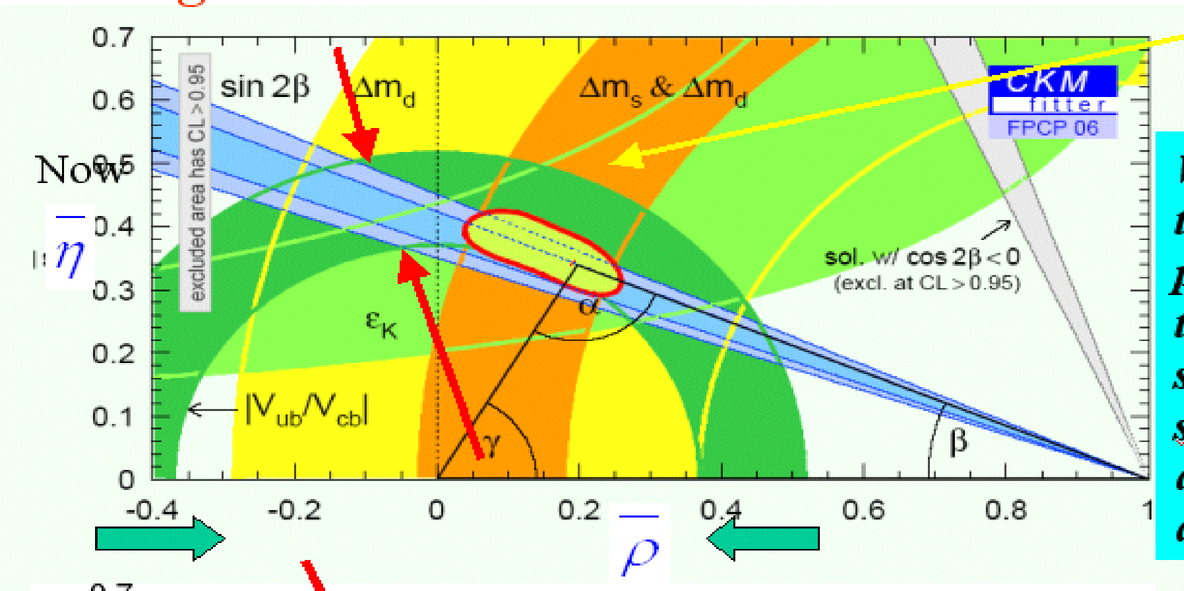
CKM

To understand the quark mixing and CP violation in SM, and detect New Physics in flavor change sector, one must determine the CKM elements as precisely as possible !

Why are we interested in Charm ?

The constraints in (ρ, η) plane arising from some measurements …

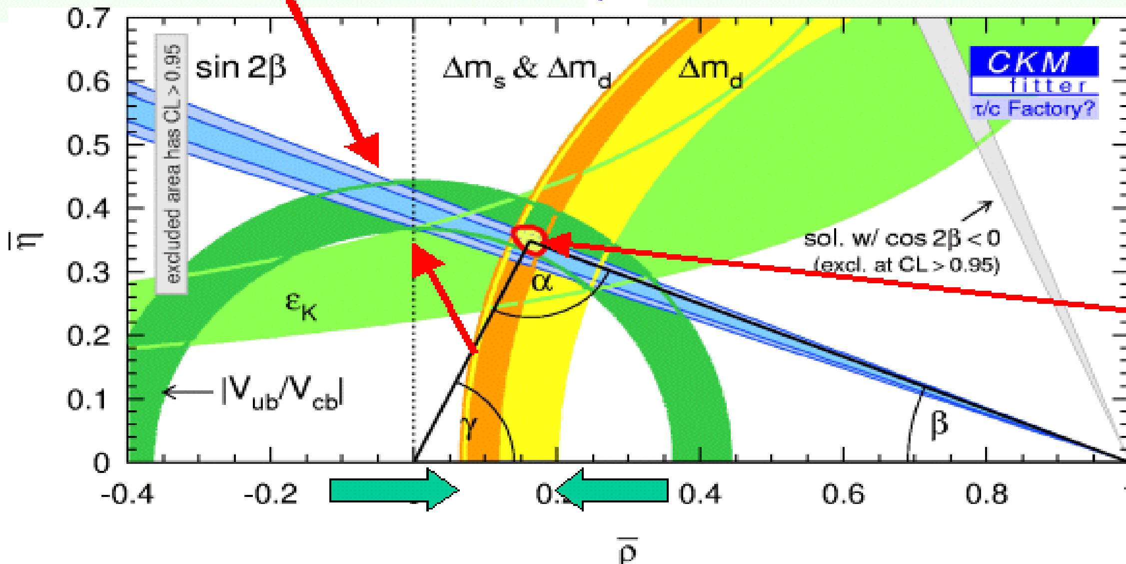
The width of band is mainly dominated by theoretical (LQCD) errors on f_B, f_{Bs} and B semileptonic form factors .



With Charm data one can calibrate the QCD calculations. If the QCD pass the test with the charm data, the theory errors of a few % on B system decay constants & semileptonic form factor are achieved, and the CKM elements achieved to

Table 8. LQCD impact (in per cent) on the precision of CKM matrix elements.

	V_{cd}	V_{cs}	V_{cb}	V_{ub}	V_{td}	V_{ts}
2004	7	11	4	15	36	39
LQCD	1.7	1.6	3	5	5	5



Then the uncertainties will be reduced to

500 fb-1 @ BABAR/Belle

Why are we interested in Charm ?

Probes for New Physics

Measurements of some transition rates of Charm provide probes for New Physics.

In the SM, the $D^0\bar{D}^0$ mixing, CP violation and rare decays of charm are all small. However, some New Physics effects beyond the SM can enhance the mixing, the CP violation and the rare decays. So search for the mixing, the CP violation and the rare decays provide the unique opportunities to search for New Physics beyond the SM indirectly.

Monte Carlo samples

Generated 0.8 fb^{-1} @ 3.773 GeV with BOSS6.0.2

Generated 1.0 fb^{-1} @ 3.773 GeV with BOSS6.1.0

BES-III software

$$e^+e^- \to \psi(3770)$$

Generated Monte Carlo events

0.58 → $D^0\overline{D}^0$ → Charge conjugation

- $K^-\pi^+$
- $K^-\pi^+\pi^0$
- $K^-\pi^+\pi^+\pi^-$
- $K^0\pi^+\pi^-$
- $K^0\pi^+\pi^-\pi^0$
- $K^-l^+\nu_l$
- $\pi^-l^+\nu_l$
- $K^0\pi^-l^+\nu_l$
- $\vdots$

0.42 → D^+D^- → Charge conjugation

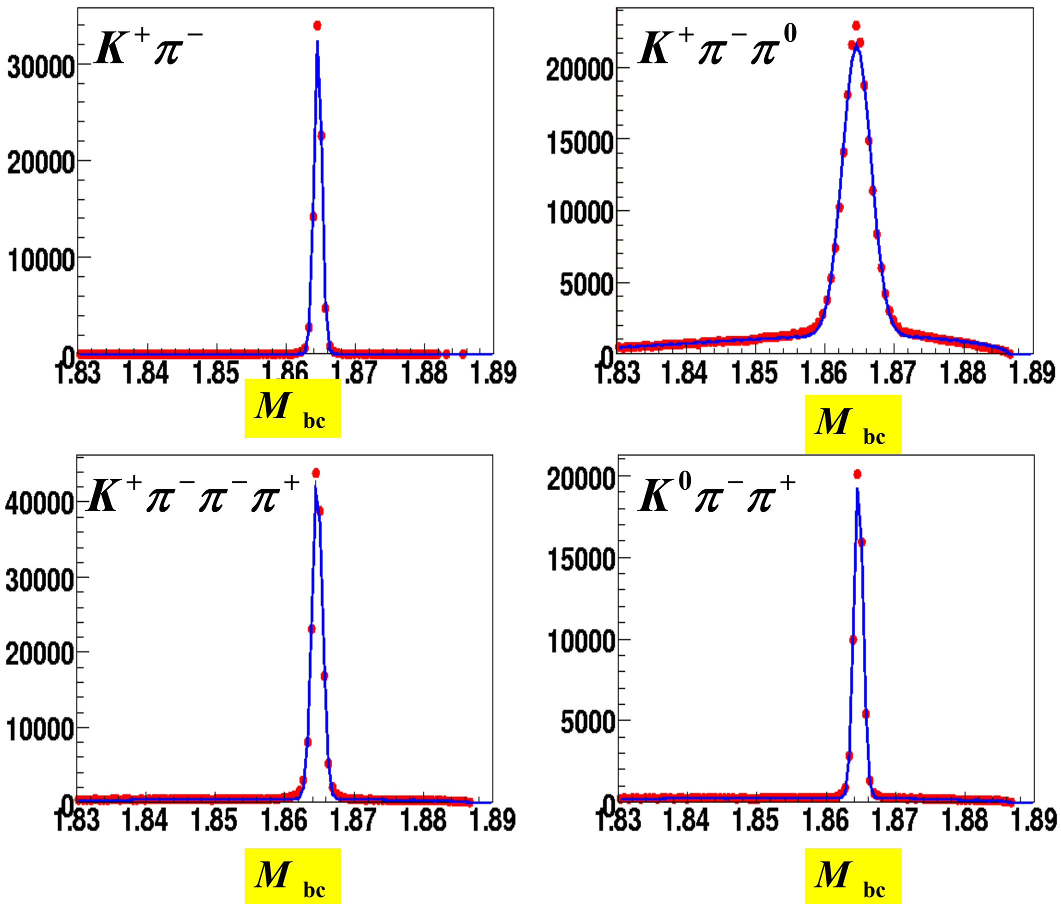
- $K^-\pi^+\pi^+$
- $K^-\pi^+\pi^+\pi^0$
- $K^0\pi^+$
- $K^0\pi^+\pi^0$
- $K^0\pi^+\pi^+\pi^-$
- $\mu^+\nu_\mu$
- $K^0l^+\nu_l$
- $K^-\pi^+l^+\nu_l$
- $K^{*0}l^+\nu_l$
- $\vdots$

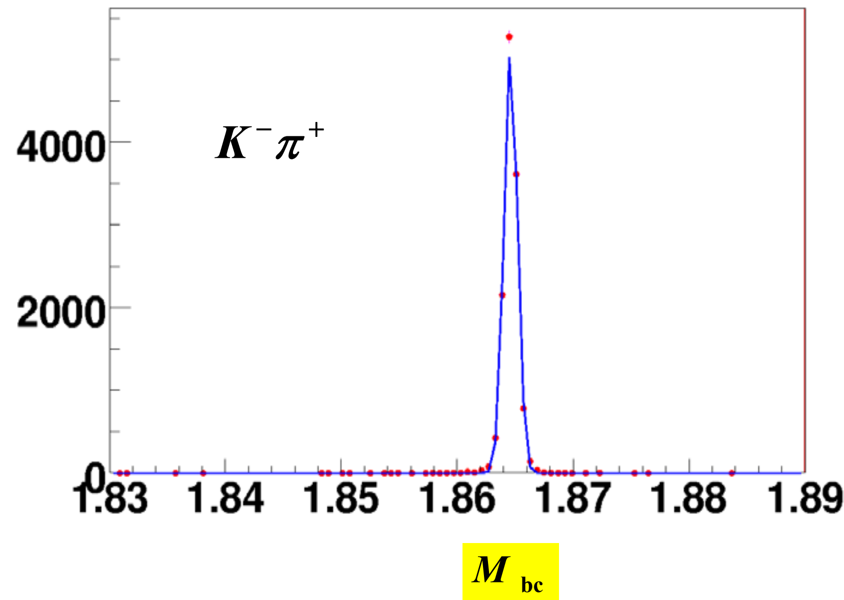
Full simulation

Absolute Branching Fractions at BESIII

$B(D^o \to K^-\pi^+)$

Double tag analysis, Independent of Luminosity and cross section in the double tag measurements





$$N_{\overline{D}^0_{tag}} = 433000 \pm 750$$

$$N(D^0 \to K^-\pi^+) = 12350 \pm 125$$

$$\varepsilon = 74.4\%$$

$$B(D^0 \to K^-\pi^+) = (3.83 \pm 0.04)\%$$

$$B(D^0 \to K^-\pi^+) = 3.80\% \text{ (MC INPUT)}$$

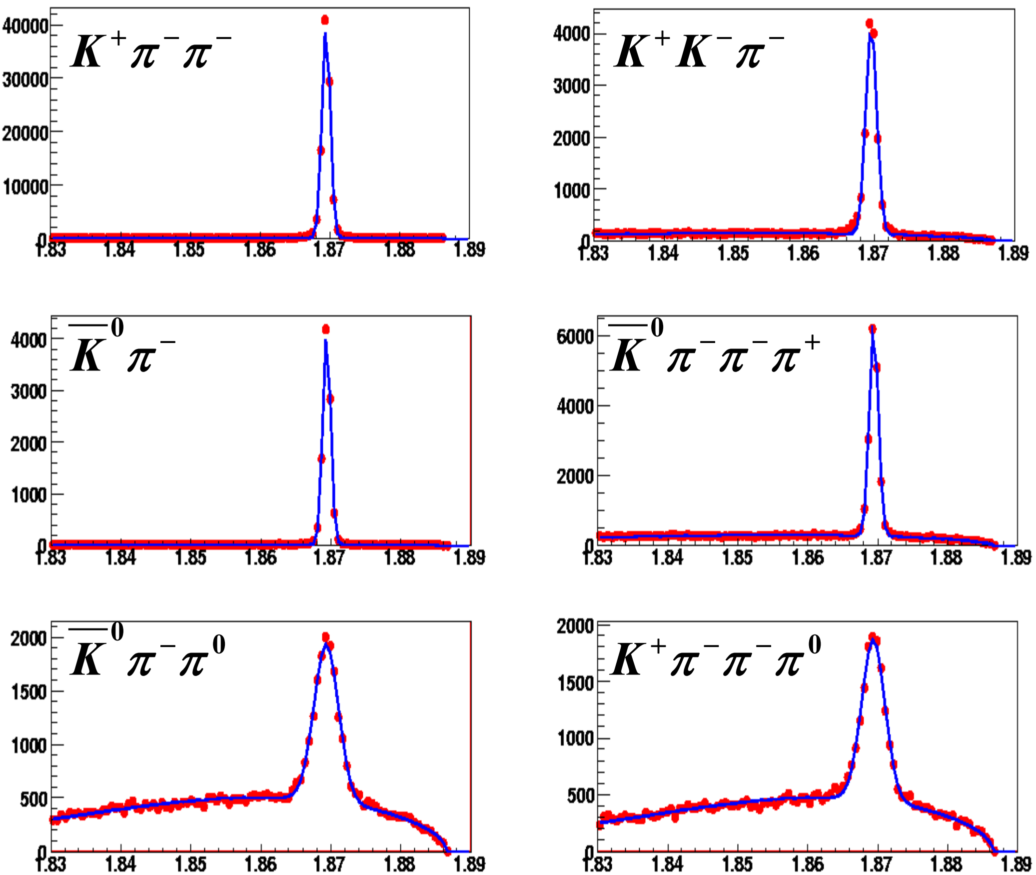
BES III MC $(L = 800 \text{ pb}^{-1})$

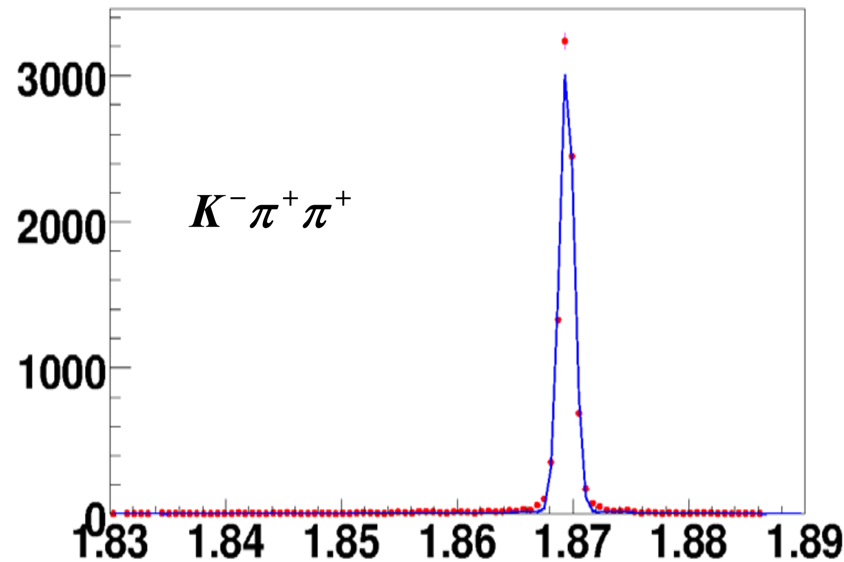
$$\delta B / B = 0.5\% / 4 \text{ fb}^{-1}$$

Absolute Branching Fractions at BESIII

$B(D^+ \to K^-\pi^+\pi^+)$

Independent of Luminosity and cross section in the double tag measurements





$$N_{D^-_{tag}} = 158800 \pm 440$$

$$N(D^+ \to K^-\pi^+\pi^+) = 8130 \pm 100$$

$$\varepsilon = 54.0\%$$

$$B(D^+ \to K^-\pi^+\pi^+) = (9.48 \pm 0.12)\%$$

$$B(D^+ \to K^-\pi^+\pi^+) = (9.2 \pm 0.6)\% \text{ (MC INPUT)}$$

BES III MC $(L = 800 \text{ pb}^{-1})$

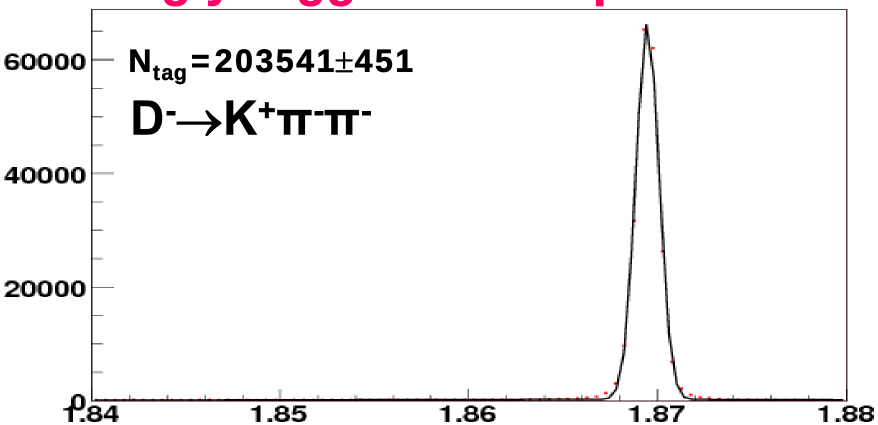
$\delta B / B = 0.5\% / 4 \text{ fb}^{-1}$

Pure leptonic decays at BESIII

BES III Full MC simulation

Monte Carlo Sample for 1 fb^{-1}

Singly tagged D^- samples



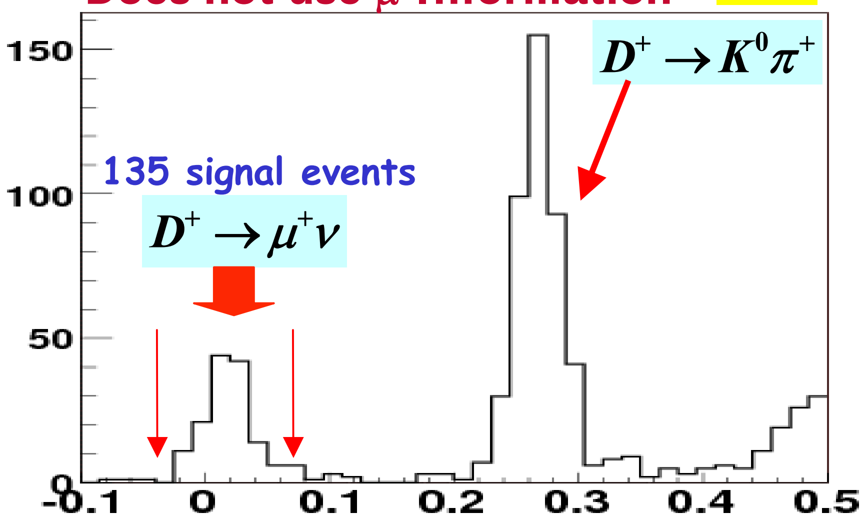
M_{bc}

Beam Constraint Mass

$$M_{bc} = \sqrt{E_{beam}^2 - p_{mKn\pi}^2}$$

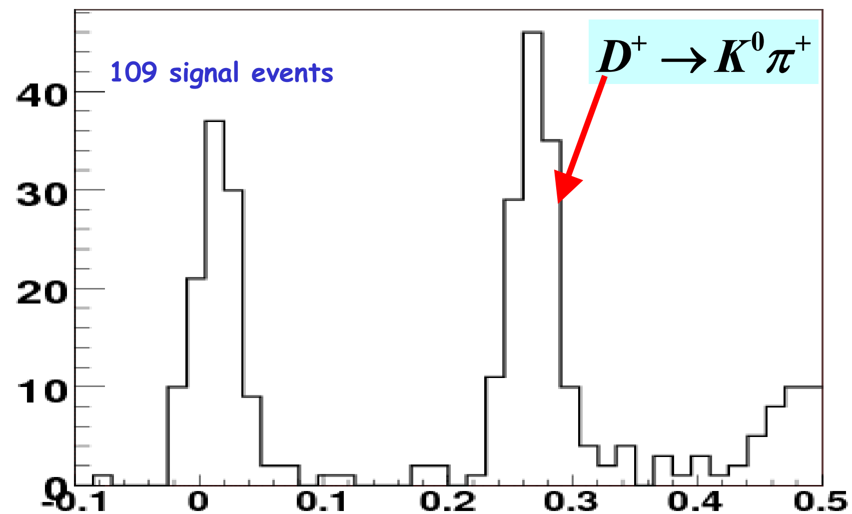
$$B(D^+ \to \mu^+\nu_\mu) = \frac{N(D^+ \to \mu^+\nu_\mu)}{N_{tag} \times \varepsilon_{D^+ \to \mu^+\nu_\mu}}$$

Does not use μ Information



$U_{miss} = E_{miss} - P_{miss}$

Use μ Information

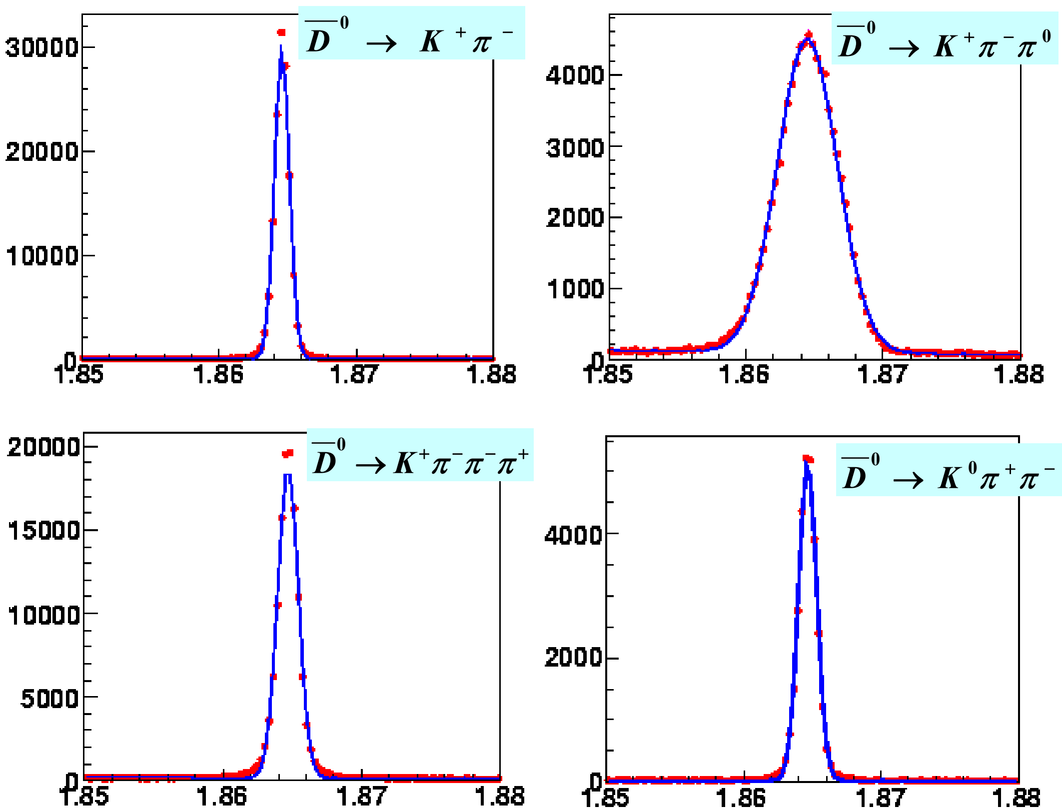


$U_{miss} = E_{miss} - P_{miss}$

Semileptonic decays at BESIII

BES III Full MC **simulation**

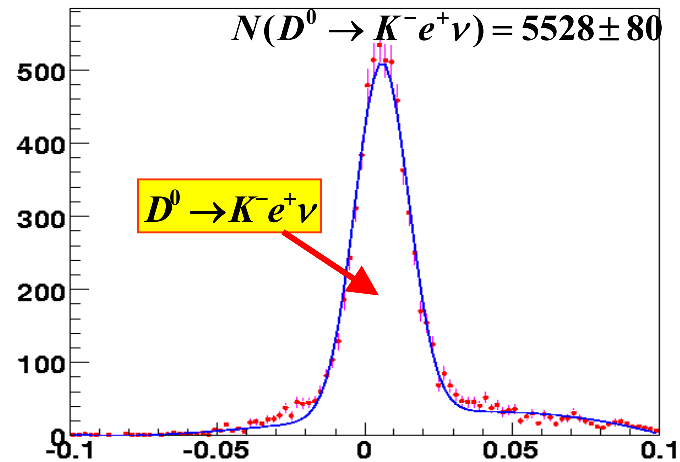
Monte Carlo Sample for 0.8 fb^{-1}



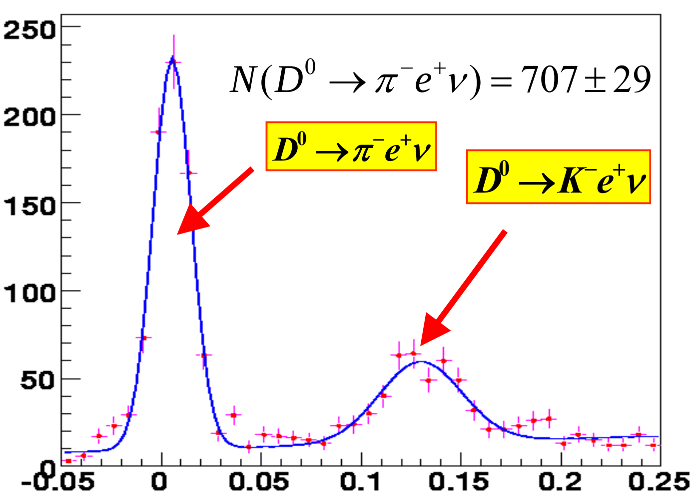
M_{BC}

$N_{tag} = 359884 \pm 600$

Singly tagged D^{0bar} samples



$U_{miss} = E_{miss} - P_{mis}$



$U_{miss} = E_{miss} - P_{mis}$

Precise Measurements at BESIII

Statistical error only

Relative error (%) on the measurements

281 pb^{-1}

Mode	$\delta B/B$ (4 fb^{-1})	$\delta B/B$ (20 fb^{-1})	$\delta B/B$ (PDG 04)	CLEO-c
$D^0 \to K^-\pi^+$	0.5	0.2	2.3	
$D^+ \to K^-\pi^+\pi^+$	0.5	0.2	6.5	
$D^0 \to K^-e^+\nu$	0.7	0.3	5.0	
$D^0 \to \pi^-e^+\nu$	1.8	0.8	16.6	
$D^0 \to K^-\mu^+\nu$	0.9	0.4		
$D^0 \to \pi^-\mu^+\nu$	2.1	1.0		
$D^+ \to \mu^+\nu$	4.0	2.0	~100	15.0
f_{D^+}	2.0	0.9		7.5

314 pb^{-1}

Mode	$\delta B/B$ (4.03GeV)	$\delta B/B$ (4.17GeV)	$\delta B/B$ (PDG 06)	CLEO-c
$D_s^+ \to \phi\pi^+$	4.0		14	
$D_s^+ \to \phi e^+\nu$	5		17	
$D_s^+ \to \mu^+\nu$	5.7		18	
$D_s^+ \to \tau^+\nu$				
$f_{D_s^+}$	~2.8	1.3	9	4.7

One year data taking → 4fb^{-1}

Precise Measurements at BESIII

Decay rates relates to CKM Matrix elements and form fator

$$\frac{d\Gamma(D\to Pl\nu)}{dq^2}=\frac{G_F^2}{24\pi^3}p_P^3|V_{cq}|^2|f_+(q^2)|^2$$

$$f_+(q^2)=\frac{f_+(0)}{1-q^2/m_{\text{pole}}^2}$$

$$\Gamma(D\to Ke\nu_e)=\frac{B(D\to Ke\nu_e)}{\tau_D}=1.53|V_{cs}|^2|f_+^K(0)|^2\times10^{11}s^{-1}$$

$$\Gamma(D\to \pi e\nu_e)=\frac{B(D\to \pi e\nu_e)}{\tau_D}=3.01|V_{cd}|^2|f_+^\pi(0)|^2\times10^{11}s^{-1}$$

To extract V_{cs} & V_{cd} need form factor from theory at one fixed q^2 point.

$$\frac{\Delta|V_{cq}|}{|V_{cq}|}=\sqrt{\left(\frac{\Delta B}{2B}\right)^2+\left(\frac{\Delta\tau_D}{2\tau_D}\right)^2+\left(\frac{\Delta f}{f}\right)^2}$$

1. Well measured life times of D mesons from PDG06

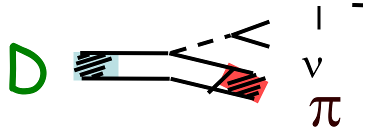
$$\frac{\Delta\tau_{D^0}}{\tau_{D^0}}=0.4\%$$

2. With 4 fb^{-1} $\Psi(3770)$ data at BESIII

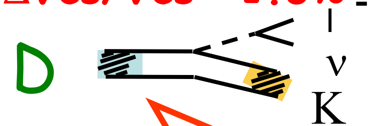
$$\left(\frac{\Delta B}{B}\right)_{\text{stat.}}\sim 0.7\%,\ 1.8\%$$

3. Form factor from theory (Lattice QCD). Assuming $\Delta f/f$ ~1.5%.

$\Delta Vcd/Vcd$ ~1.8%



$\Delta Vcs/Vcs$ ~1.6%



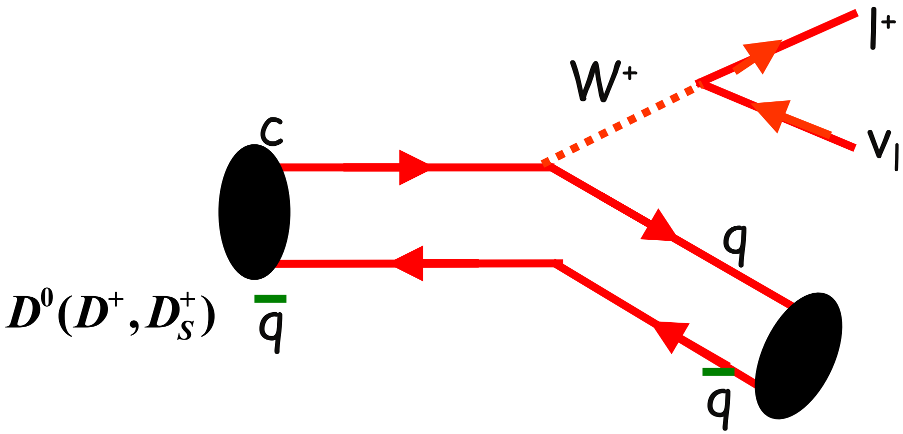
BESIII: $L=4\ fb^{-1}$
$\psi(3770)$ MC simulation

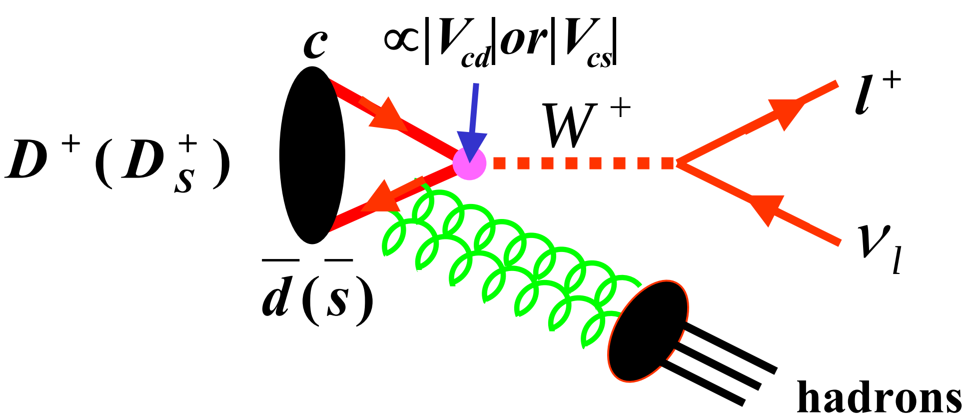
Quark models, HQET, Lattice & other methods have all been invoked to calculate form factor absolute normalizations. These calculations have been done mostly at $q^2=0$ or $q^2=q^2_{max}$. (i.e w=1, just like F in V_{cb} in $B\to D^* l\nu$)

Great contribution to CKM Unitarity

Precise Measurements at BESIII

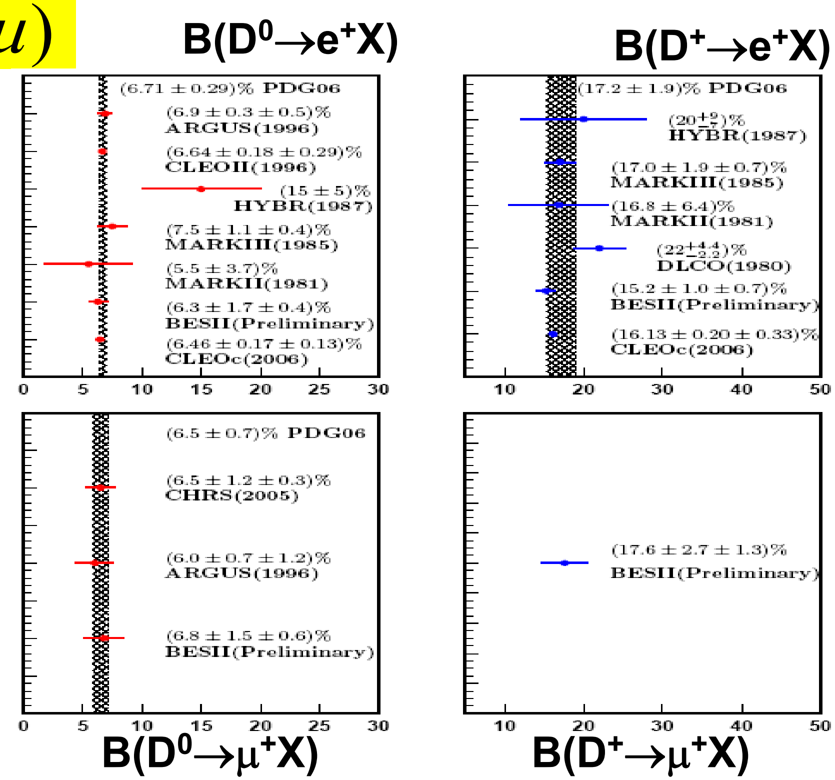
Measurements of $B(D \to \ell^+ X)(\ell = e, \mu)$





with the BES-III detector, we may have the opportunity to study these decays, to check:

$$\Gamma_{SL}(D^0 \to X\ell^+ \nu_\ell) \overset{?}{=} \Gamma_{SL}(D^+ \to X\ell^+ \nu_\ell) \overset{?}{=} \Gamma_{SL}(D_S^+ \to X\ell^+ \nu_\ell)$$



CLEOc's results are not used in PDG06 average

ΔB/B[%]	Current Exp.	BESIII [4 fb^{-1}]
$D^0 \to e^+X$	2.6%	~0.3%
$D^+ \to e^+X$	1.3%	~0.3%
$D^0 \to \mu^+X$	22%	~1.0%
$D^+ \to \mu^+X$	15%	~1.0%

Precise Measurements at BESIII

A short summary on the Absolute Measurement

After CLEO-c, the accuracy on the absolute measurements still needs to be improved.

Why is it so important ?

1) Form factors in D semi-leptonic decays & decay constants f_{D+} and f_{Ds+} can be used to calibrate Lattice QCD calculations. $[f_{D^+} = 235 \pm 8 \pm 14 \text{ MeV} \quad \text{LQCD}]$

$$[\Delta f_{D^+} / f_{D^+} = 7\% \quad \text{LQCD}]$$

2) Precise measurements of inclusive semileptonic branching fractions ←→ lifetimes of D mesons → to understand decay mechanism.

3) Engineering measurements

a) Determine production rate of charm in B decays.

b) Realism of MC generator & BCK subtraction when looking for New Physics in general.

CELO-c expects to improve f_{D+} measurement at 5% with 750 pb^{-1} of $\psi(3770)$ data

BES-III can improve f_{D+} measurement at ~2% accuracy level with 4 fb^{-1} of $\psi(3770)$ data; and improve f_{Ds} measurement at 1.3% accuracy level with 4 fb^{-1} of $\psi(4170)$ data

$D^0\overline{D}^0$ Mixing at BESIII

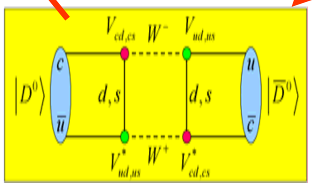
The kinds of the box diagrams lead to the estimate: $R_{mix} \sim 10^{-7}$

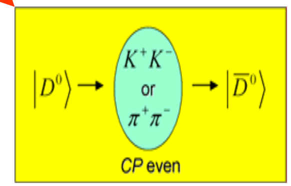
SM might allow for $R_{mix} \sim 10^{-3}$ [I. Bigi]

BES-III Sensitivity for R_{mix}: ~7.5×10^{-4} with 4 fb^{-1}

$$\text{mixing}: D^0 \Rightarrow \overline{D}^0$$

Change of identity due to





$$R_{mix} \equiv \frac{x_D^2 + y_D^2}{2}$$

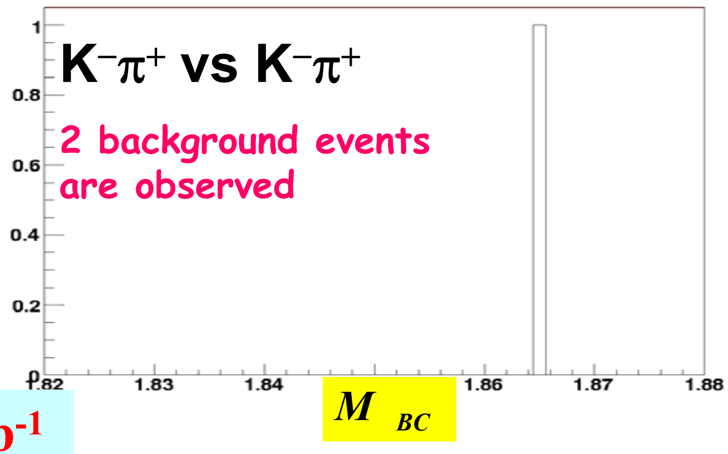
$$x_D = \frac{\Delta M_D}{\Gamma}$$

$$y_D = \frac{\Delta\Gamma}{2\Gamma}$$

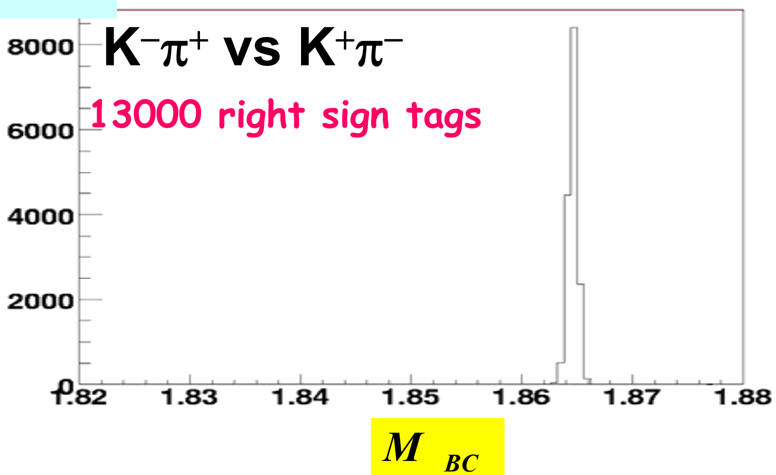
y_D is expected to be small (D. Hitlin, R. Morrison)

Standard model predicts very small D^0-D^0bar mixing: x_D & $y_D \leq 10^{-2}$

$$R_{mix} \equiv \frac{x_D^2 + y_D^2}{2} \approx \frac{N(K^\pm\pi^\mp, K^\pm\pi^\mp)}{N(K^\pm\pi^\mp, K^\mp\pi^\pm)}$$

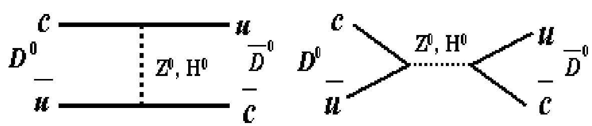


20 fb^{-1}



BESIII Monte Carlo Simulation

New physics not contained in SM such as



and . . .

can enhance the mixing.

$D^0\bar{D}^0$ Mixing at BESIII

Monte Carlo simulation

BES-III Sensitivity with 20 fb^{-1}

Mode	Right sign events	R_{mixing}
$\psi(3770)\to(K^-\pi^+)(K^+\pi^-)$	13000	1.5×10^{-4}
$\psi(3770)\to(K^-e^+\nu_e)(K^+e^-\nu_e)$	~32000	
$\psi(3770)\to(K^-e^+\nu_e)(K^+\mu^-\nu_\mu)$	~29000	
$\psi(3770)\to(K^-\mu^-\nu_\mu)(K^+\mu^-\nu_\mu)$	~ 6500	

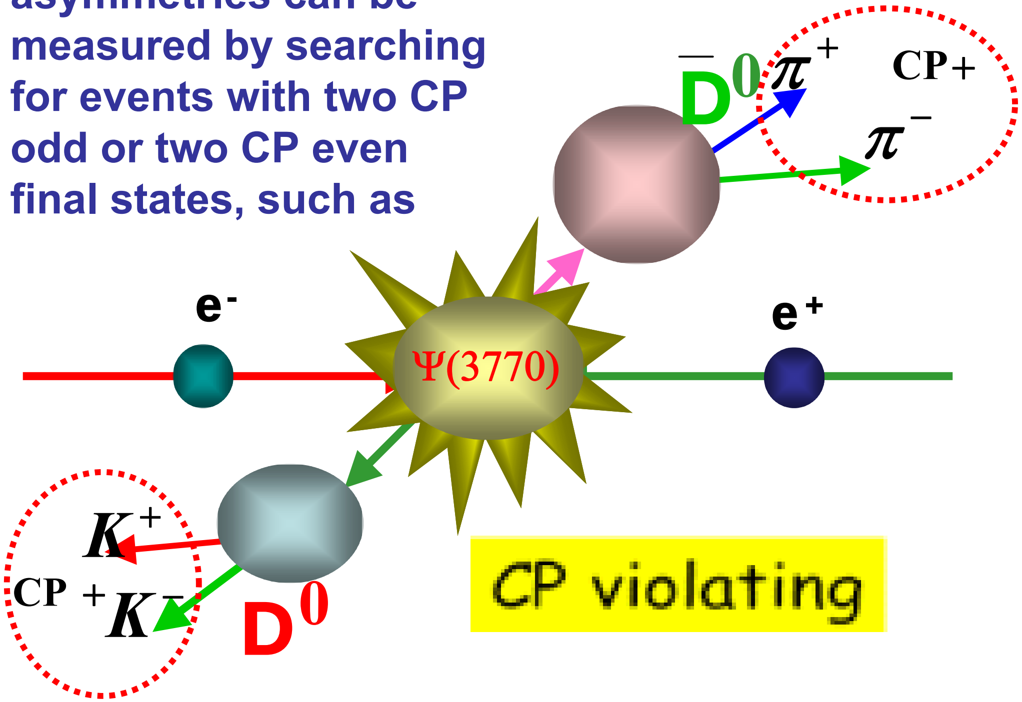
For the other modes, the numbers of right sign events are estimated with DD-bar cross section, branching fractions and detection efficiencies

Detail Monte Carlo study of $D^0\bar{D}^0$ mixing with tagging the semileptonic decay modes are still in progress !

Monte Carlo study of measuring the $D^0\bar{D}^0$ mixing with charm data collected at 4.14 (or 4.17) GeV will begin soon.

CP Violation at BESIII

CP violating asymmetries can be measured by searching for events with two CP odd or two CP even final states, such as



CP+(-) eigenstate Tags

CP+ $\pi^+\pi^-$, K^+K^-, $\pi^0\pi^0$, $\rho^0\pi^0$ …

CP− $K_S\pi^0$, $K_S\rho^0$, $K_S\phi$, $K_S\omega$ ...

for the decay of $\psi(3770) \to f_1 f_2$

$$CP(f_1 f_2) = CP(f_1) \cdot CP(f_2) \cdot (-1)^L = -$$

$$CP[\psi(3770)] = +$$

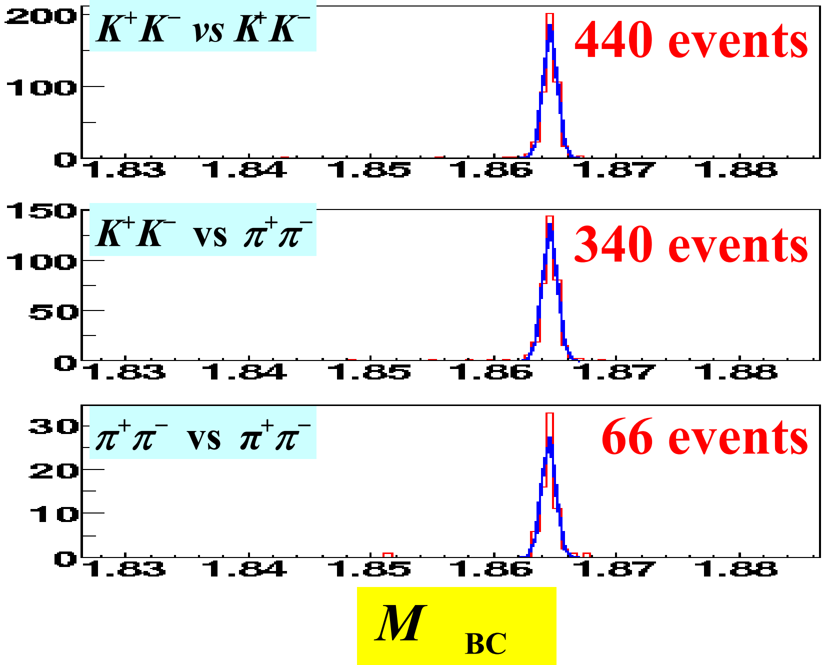
($D^0 \overline{D}^0$ are in a p wave)

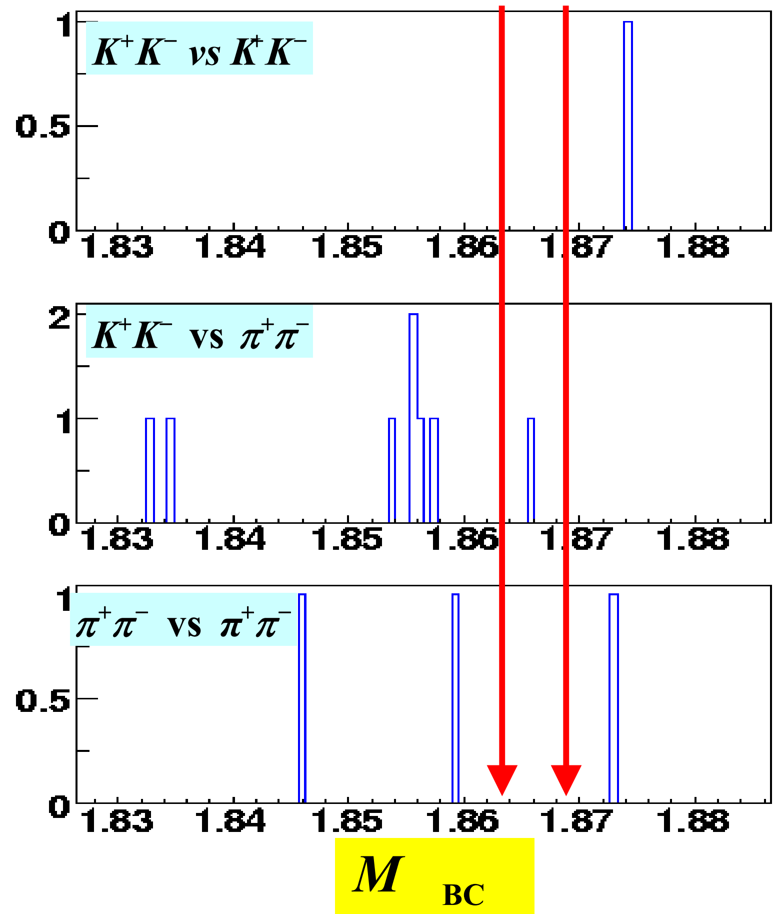
from 4 fb^{-1} Ψ(3770) data, we can select about 1x10^5 CP+ tags and about 1x10^5 CP- tags. With the large CP tagged samples we can probe the direct CP violation,

If we observed two CP odd or two CP even final states simultaneously ➔ we need to analyze many channels to elucidate the sources of CP violation !

MC simulation for CP violation at BESIII

$20\ fb^{-1}$





Remove the events of K^+K^- vs K^+K^-, K^+K^- vs $\pi^+\pi^-$ and $\pi^+\pi^-$ vs $\pi^+\pi^-$ away from the MC sample to study the ability of background rejection with the BES-III detector by looking for these modes from the MC samples

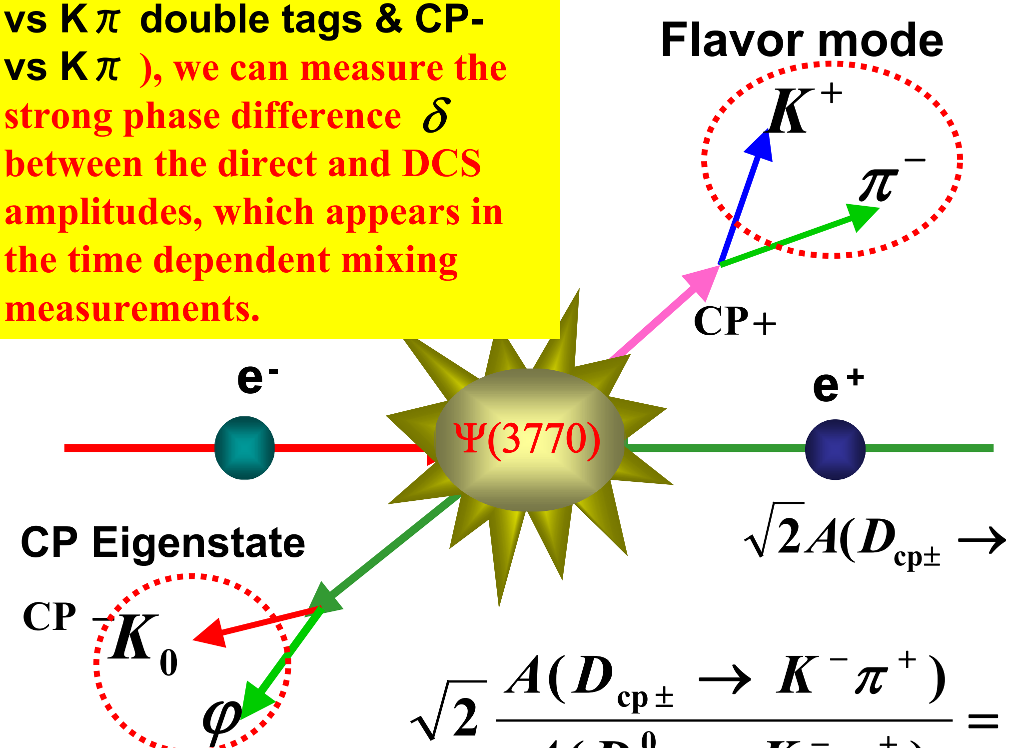
$A_{CP} < 2.5\times10^{-2}$ @ 90% C.L. for 4 fb^{-1}

$A_{CP} <$ ~10^{-3} @ 90% C.L. for 20 fb^{-1}

Experiment sensitivity

The strong phase δ at BESIII

Using the CP tag samples (CP+ vs Kπ double tags & CP- vs Kπ), we can measure the strong phase difference δ between the direct and DCS amplitudes, which appears in the time dependent mixing measurements.



We can measure δ at ψ(3770)

$$|D_{cp\pm}> = \frac{1}{\sqrt{2}}[|D^0> \pm |\overline{D}^0>]$$

$$\sqrt{2}A(D_{cp\pm} \to K^-\pi^+) = A(D^0 \to K^-\pi^+) \pm A(\overline{D}^0 \to K^-\pi^+)$$

CF decay DCS decay

$$\sqrt{2}\frac{A(D_{cp\pm} \to K^-\pi^+)}{A(D^0 \to K^-\pi^+)} = 1 \pm \frac{A(\overline{D}^0 \to K^-\pi^+)}{A(D^0 \to K^-\pi^+)} = 1 \pm \sqrt{R_D}e^{i\delta}$$

$$\cos\delta = \frac{Br(D_{cp+} \to K^-\pi^+) - Br(D_{cp-} \to K^-\pi^+)}{2\sqrt{R_D}Br(D^0 \to K^-\pi^+)}$$

$$[R_D = (3.7 \pm 0.09) \times 10^{-3}]$$

$$\Delta(\cos\delta) \approx \frac{1}{\sqrt{N}}\frac{1}{2\sqrt{R_D}}$$

We have to neglect CP violation in mixing

4 fb^{-1}

N~1800 CP+ vs Kπ
N~1800 CP- vs Kπ
} tags

$\Delta(\cos\delta) \approx \pm 0.19$ **4 fb^{-1}**

$\Delta(\cos\delta) \approx \pm 0.08$ **20 fb^{-1}**

Rare decays of D mesons at BESIII

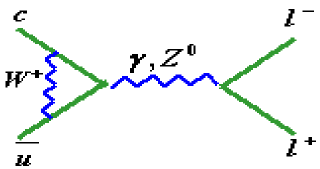
Observation of D^+ FCNC and lepton number violating decays could indicate new physics.

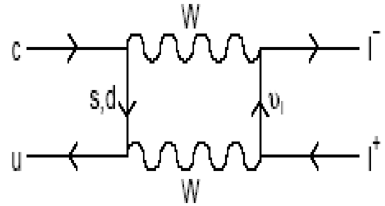
In the SM (Standard Model), the short distance charm FCNC (flavor changing neutral currents) are much highly suppressed by the GIM mechanism than down type quarks due to the large mass difference between up type quarks.

The dilepton decay proceeds by penguim annihilation or box diagram.

SM

$$B(D^0 \to e^+e^-) \sim 10^{-23}$$
$$B(D^0 \to \mu^+\mu^-) \sim 3\times10^{-13}$$





New Physics (Beyond the Standard Model) may enhance these decay processes.
For example, R-parity violating SUSY:gives

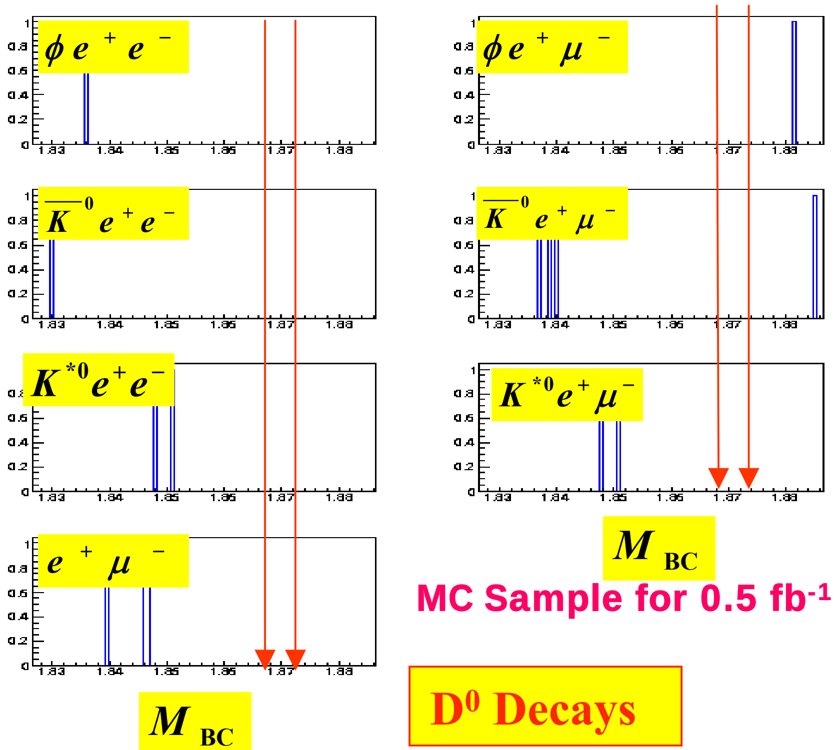
$$\mathrm{B}\left(D^0 \to e^+e^-\right) \text{ up to } 10^{-10}$$
$$\mathrm{B}\left(D^0 \to \mu^+\mu^-\right) \text{ up to } 10^{-6}$$
$$\mathrm{B}\left(D^0 \to e^\pm\mu^\mp\right) \text{ up to } 10^{-6}$$

Best limits are from BABAR
(Burdman et al., Phys. Rev. D66, 014009).

The decay $D^0 \to e^\pm\mu^\mp$ is strictly forbidden in the SM.

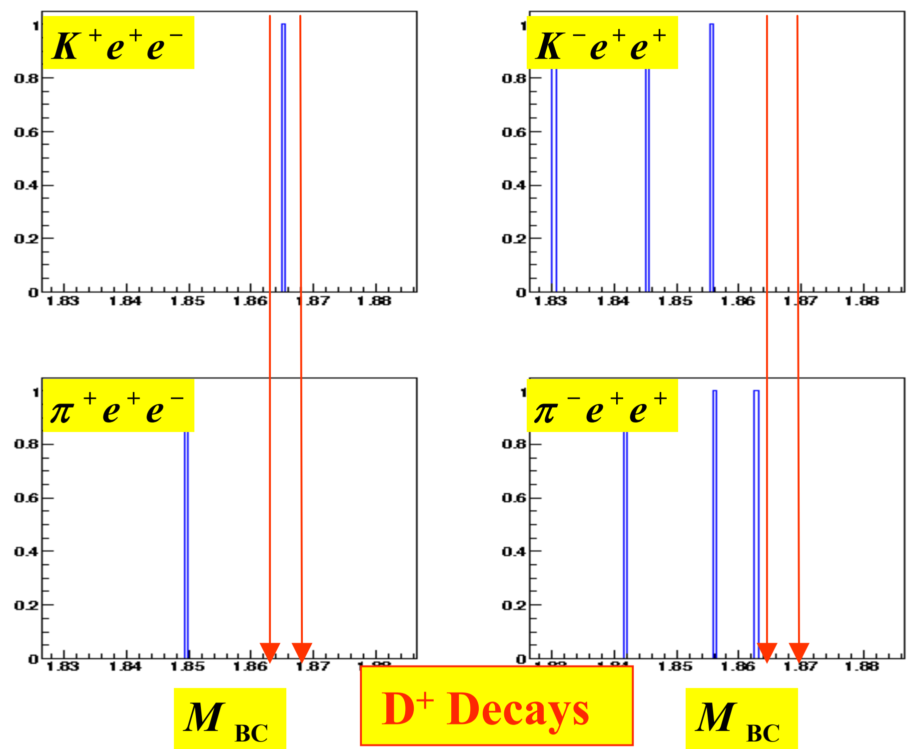
Search for these kinds of rare decays can probe New Physics

MC simulation for rare decays at BESIII

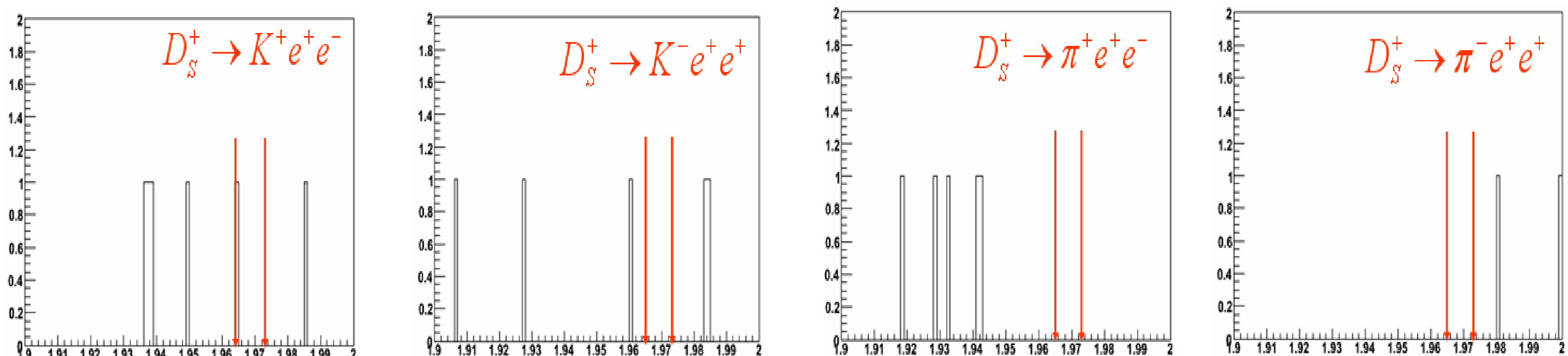


MC Sample for 0.5 fb^{-1}

D^0 Decays



D^+ Decays



D^+_S Decays

MC Sample for 4 fb^{-1}

Full MC simulation for rare decays of $D_{(s)}$ mesons

MC simulation for rare decays at BESIII

D_S^+ Decay	BES-III(10^{-6})
$D_S^+ \to K^+ e^\pm \mu^\mp$	12.2
$D_S^+ \to K^- e^+ \mu^+$	7.14
$D_S^+ \to \pi^+ e^\pm \mu^\mp$	7.14
$D_S^+ \to \pi^- e^+ \mu^+$	7.14
$D_S^+ \to K^+ \mu^+ \mu^-$	7.71
$D_S^+ \to K^- \mu^+ \mu^+$	4.53
$D_S^+ \to \pi^+ \mu^+ \mu^-$	13.2
$D_S^+ \to \pi^- \mu^+ \mu^+$	7.71
$D_S^+ \to K^+ e^+ e^-$	6.58
$D_S^+ \to K^- e^+ e^+$	3.89
$D_S^+ \to \pi^+ e^+ e^-$	3.89
$D_S^+ \to \pi^- e^+ e^+$	3.89

D^+ Decay

D^+ Decay Mode	U.L.$\times 10^{-6}$(0.5 fb^{-1})
$D^+ \to \pi^+ e^+ e^-$	3.40
$D^+ \to \pi^+ \mu^+ \mu^-$	3.40 *
$D^+ \to \pi^+ e^\mp \mu^\pm$	3.40 *
$D^+ \to \pi^- e^+ e^+$	3.53
$D^+ \to \pi^- \mu^+ \mu^+$	3.53 *
$D^+ \to \pi^- e^+ \mu^+$	3.53 *
$D^+ \to K^+ e^+ e^-$	6.62
$D^+ \to K^+ \mu^+ \mu^-$	6.62 *
$D^+ \to K^+ e^\mp \mu^\pm$	6.62 *
$D^+ \to K^- e^+ e^+$	3.73
$D^+ \to K^- \mu^+ \mu^+$	3.73 *
$D^+ \to K^- e^+ \mu^+$	3.73 *
$D^0 \to K^{*+} e^+ e^-$	24.87 *
$D^0 \to K^{*+} \mu^+ \mu^-$	24.87 *
$D^0 \to K^{*+} e^\mp \mu^\pm$	24.87 *
$D^0 \to K^{*-} e^+ e^+$	24.87 *
$D^0 \to K^{*-} \mu^+ \mu^+$	24.87 *
$D^0 \to K^{*-} e^+ \mu^+$	24.87 *

D^0 Decay

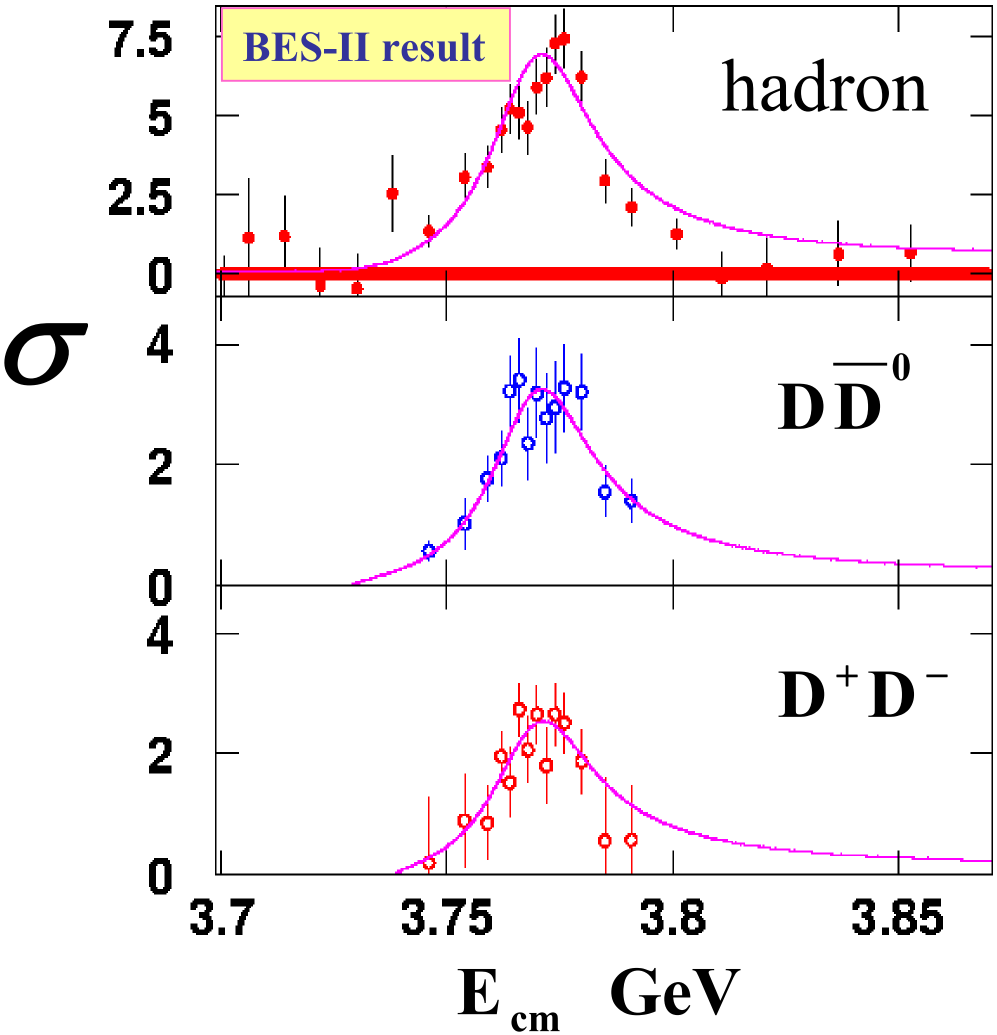
D^0 Decay Mode	U.L.$\times 10^{-6}$(0.5 fb^{-1})
$D^0 \to e^+ e^-$	1.58
$D^0 \to \mu^+ \mu^-$	1.58 *
$D^0 \to e^\mp \mu^\pm$	1.58
$D^0 \to \phi e^+ e^-$	7.88
$D^0 \to \phi \mu^+ \mu^-$	7.88 *
$D^0 \to \phi e^\mp \mu^\pm$	7.88
$D^0 \to \bar{K}^0 e^+ e^-$	5.57
$D^0 \to \bar{K}^0 \mu^+ \mu^-$	5.57 *
$D^0 \to \bar{K}^0 e^\mp \mu^\pm$	5.57
$D^0 \to K^{*0} e^+ e^-$	5.52
$D^0 \to K^{*0} \mu^+ \mu^-$	5.52 *
$D^0 \to K^{*0} e^\mp \mu^\pm$	5.52
$D^0 \to \rho^0 e^+ e^-$	3.45 *
$D^0 \to \rho^0 \mu^+ \mu^-$	3.45 *
$D^0 \to \rho^0 e^\mp \mu^\pm$	3.45 *

With 4 fb^{-1} of Ψ(4030) data, the sensitivity can go down to about $10^{-5} \sim 10^{-6}$.

Sensitivity can go down to 10^{-7} with 4 fb^{-1} of ψ(3770) data,.

Ratio of charged/neutral $D\bar{D}$ production

Why are we interested in ?

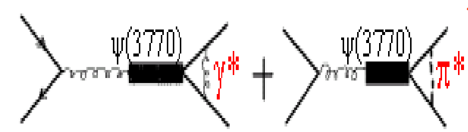


Fraction of D^+ and D^0 yields

$$f = \left[\frac{p_{+-}}{p_{00}}\right]^3 = 0.69 \quad \textbf{pure phase space}$$

$$f = F\left[\frac{p_{+-}}{p_{00}}\right]^3$$

F accounts for



$$f = \frac{\sigma(e^+e^- \to D^+D^-)}{\sigma(e^+e^- \to D^0\bar{D}^0)} = 0.787 \pm 0.074 \pm 0.05$$

$E_{cm} = 3.773\,\text{GeV}$

BES

$$f = \frac{\sigma(e^+e^- \to D^+D^-)}{\sigma(e^+e^- \to D^0\bar{D}^0)} = 0.715 \pm 0.026 \pm \Delta_{sys}$$

CLEO-c

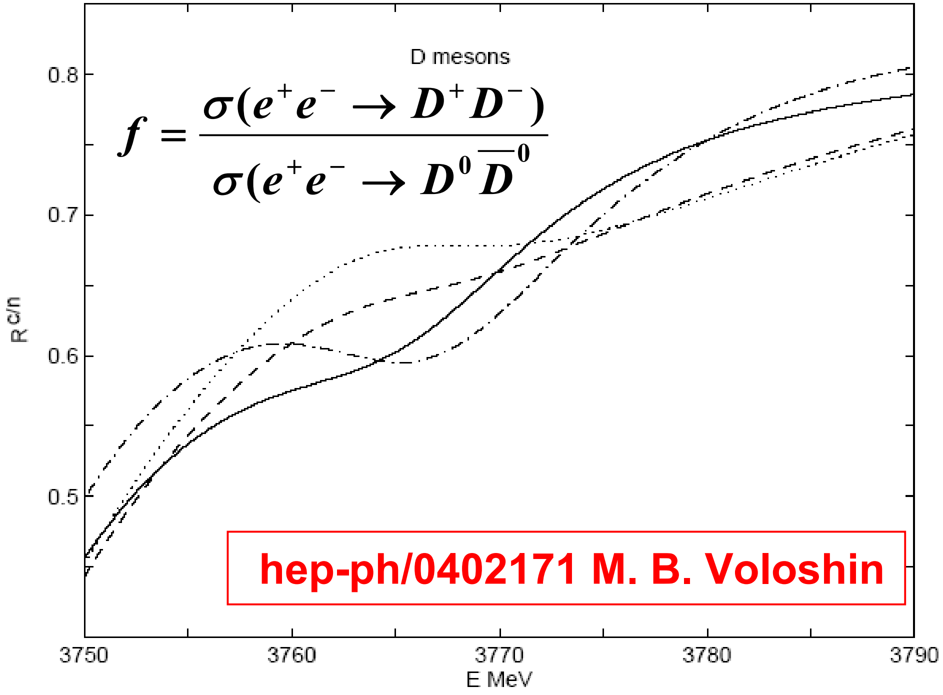
$$f = \frac{\sigma(e^+e^- \to D^+D^-)}{\sigma(e^+e^- \to D^0\bar{D}^0)} = 0.776 \pm 0.024^{+0.014}_{-0.006}$$

The ratio would vary with changing the c.m. energy.

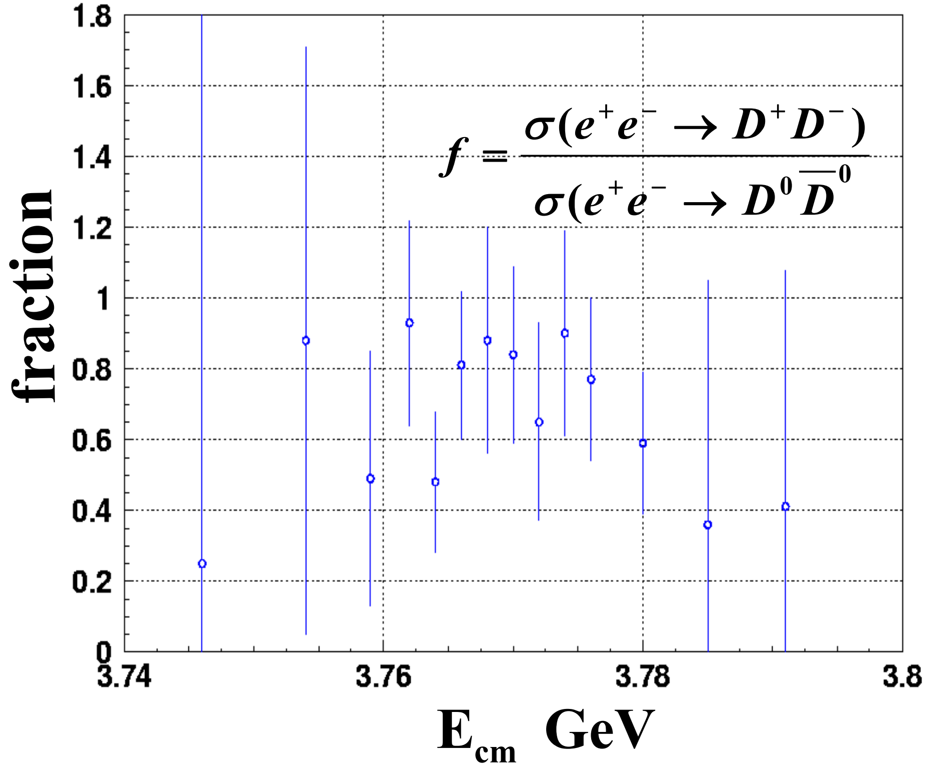
Ratio of charged/neutral $D\bar{D}$ production

Fraction of charged and neutral yields

Theoretical prediction



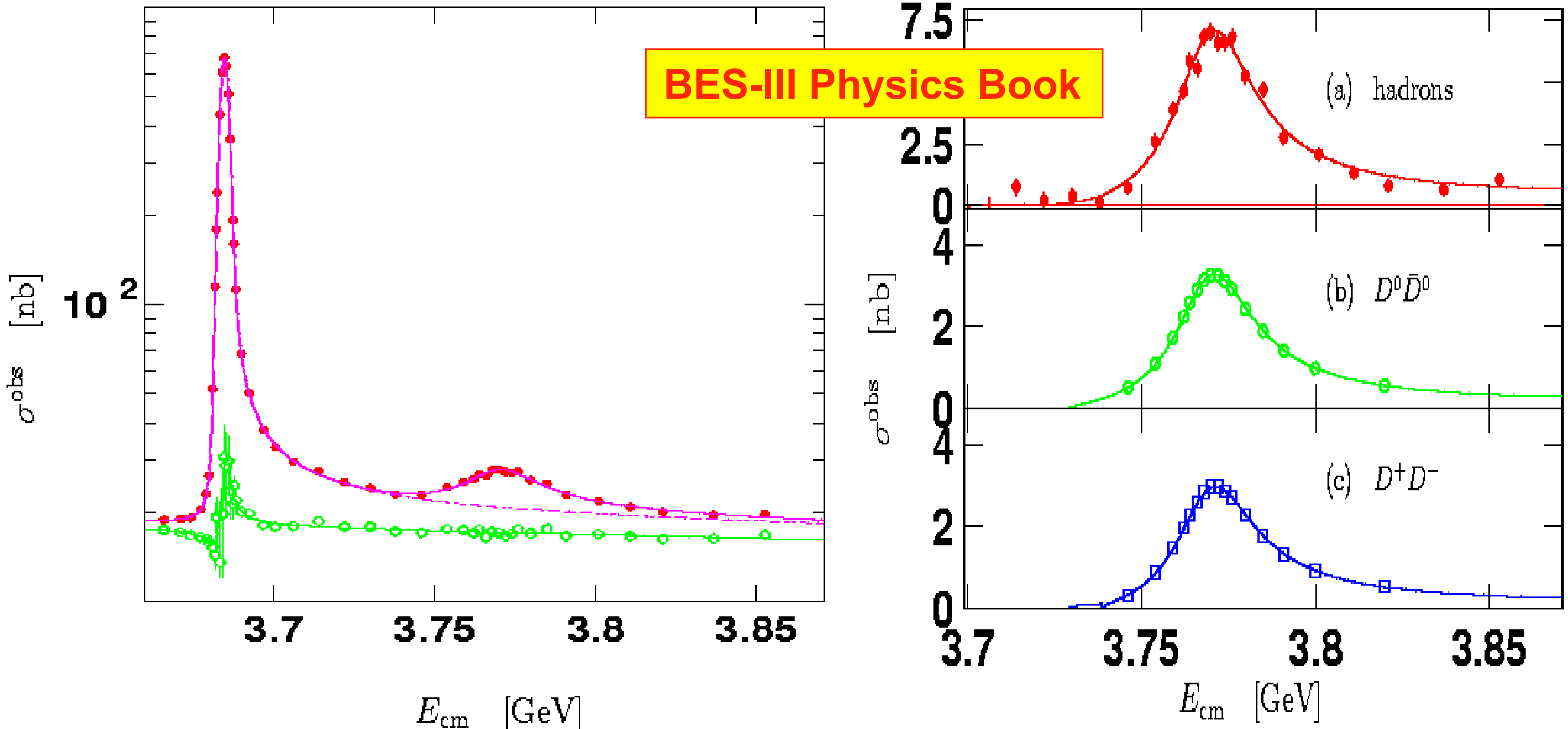
My calculations based on the two observed cross sections only! It is not official !!



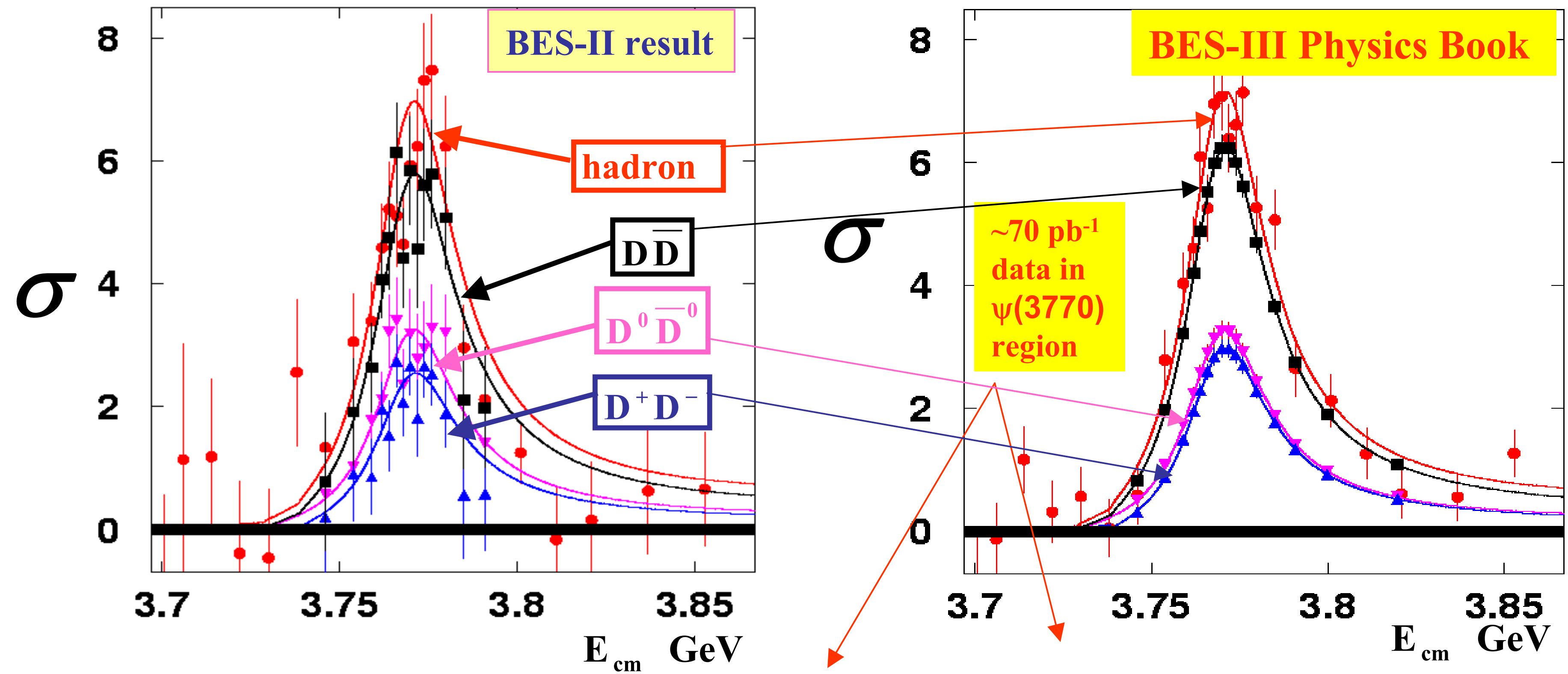
We can measure the fraction f vs E_{CM}. A finer cross section scan over the ψ(3770) resonance with the BES-III at the BEPC-II will give results on these measurements

Measurements of ψ(3770) Parameters

The inclusive hadron & DD-bar production line shapes along with the continuum hadron production shape with vacuum polarization corrections



BF[ψ(3770) → non-$D\bar{D}$]



	Measured value	Input value
$\Gamma^{tot}_{\psi(3770)}$	26.8 ± 0.5 MeV	26.9 MeV
$\Gamma^{ee}_{\psi(3770)}$	256±9 eV	251 eV

$B[\psi(3770) \to D\bar{D}]$	
(88.2 ± 2.4 ± ~ 2.0) %	Measured value
89 %	Input value

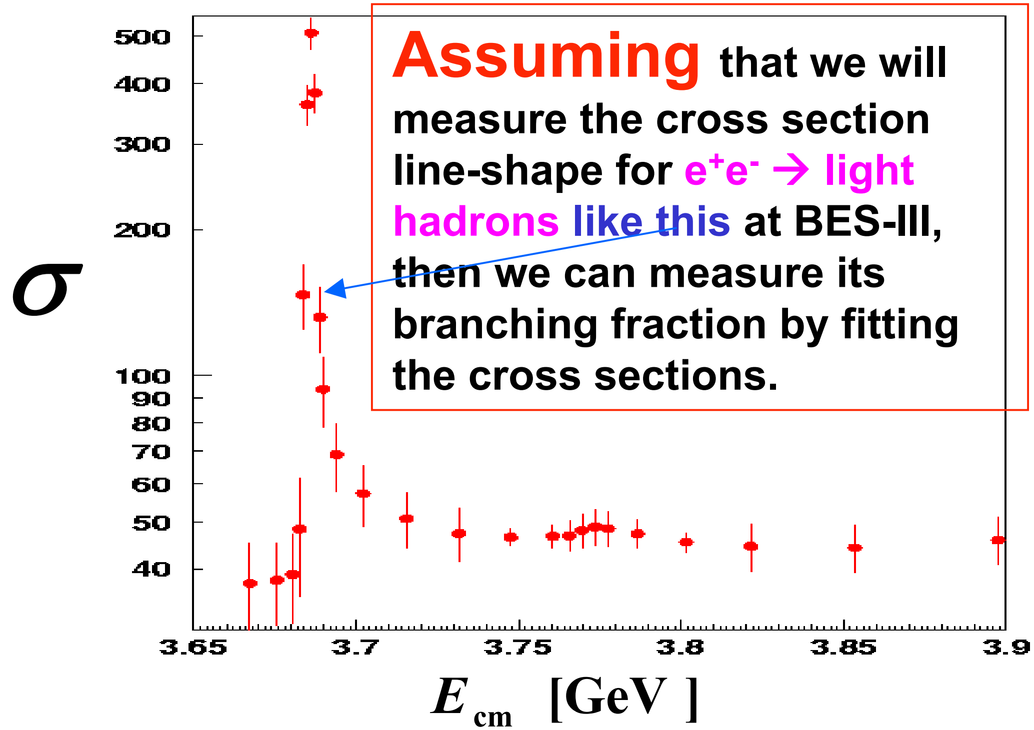
With ~70 pb^{-1} of data collected from 3.65 to 3.875 GeV with the BES-III Detector at BEPC-II, we can measured the non-DDbar branching fraction of ψ(3770) decays at an absolute precision level of ~3% (from cross section scans).

Lineshape analysis for light hadrons

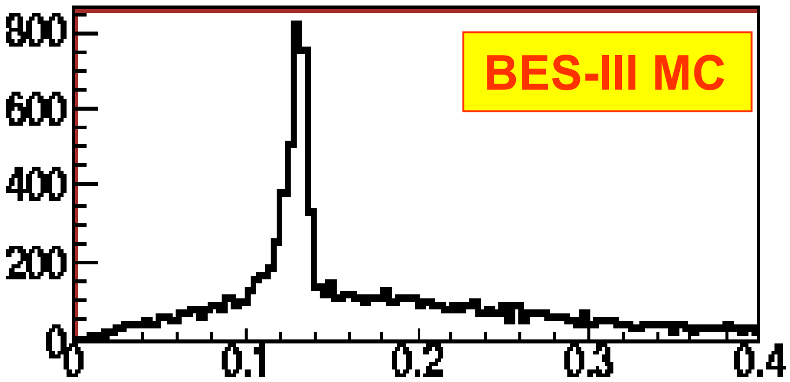
Measurements of branching fractions for $\psi(3770)\rightarrow$ light hadrons with the BES-II at BEPC

$$e^+e^- \rightarrow p\bar{p}\pi^+\pi^-\pi^0$$

ILLUSTRATION ONLY !!!



Assuming that we will measure the cross section line-shape for $e^+e^- \rightarrow$ light hadrons like this at BES-III, then we can measure its branching fraction by fitting the cross sections.



The way to measure the branching fractions for $\psi(3770)\rightarrow$ light hadrons is to analyze the energy dependent cross sections, since there are interferences between the amplitudes of the exclusive final states from resonance and from the continuum. But needing large cross section scan data samples!

We believe that this would be the best method to carefully study the charmless decays of $\psi(3770)$ with the BES-III at the BEPC-II, since it can separate the contributions from both the QED and the resonance decays, and it can extract out the phase differences between the amplitudes.

Search for New 1^{--} states

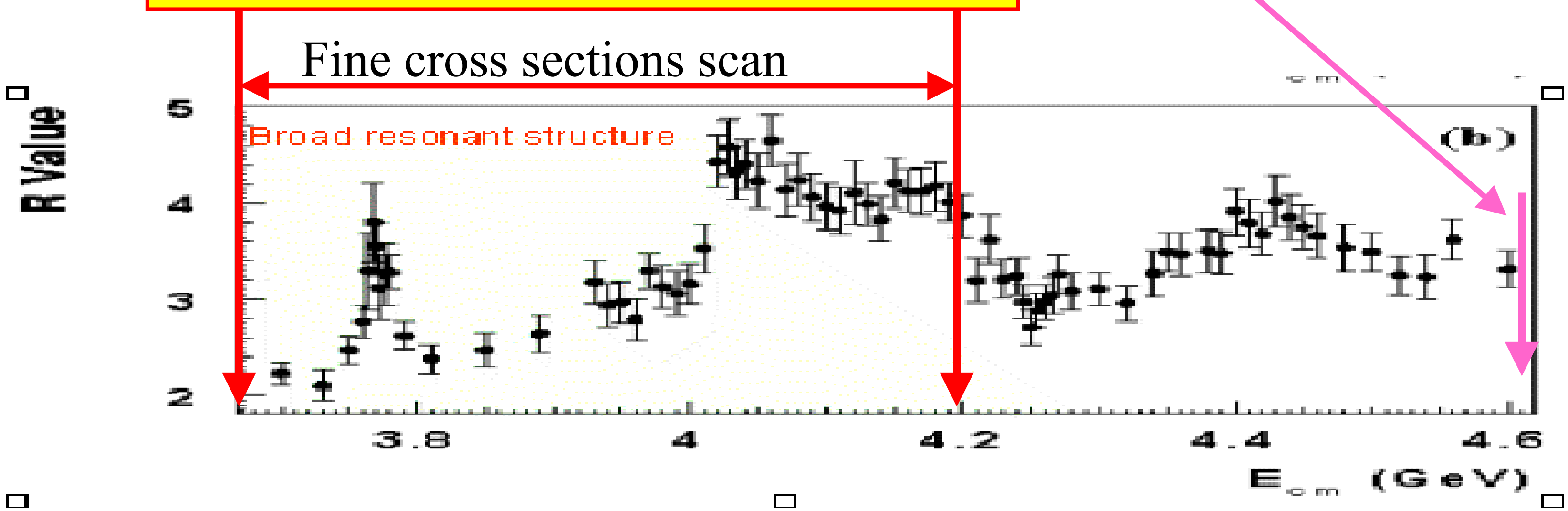
Search for hybrid charmonium, $D\bar{D}$ molecular or other exotic states

BES-III will collect data at 3.773 GeV, 4.03 GeV or 4.14 (or 4.17) GeV, and perform finer cross section scans covering the resonances.

"Finer resonance line-shape analysis" provides an opportunity to search for heavy hybrid, DD-bar molecular, and four-quark states.

Analysis of the fine cross section scan data may probe new structures associated with hybrid charmonium, DD-bar molecular or other exotic states in this energy region…

If BEPC-II maximum energy can extend more than 4.2 GeV, that will be nice.



Search for New 1^{--} states

Measurements of the line-shapes of the cross sections for the exclusive processes:

$$e^+e^- \to D^0\overline{D}^0, D^+D^-, D_S^+D_S^-$$
$$e^+e^- \to \omega\eta_c, \ldots.$$
$$e^+e^- \to J/\psi\pi^+\pi^-, J/\psi\eta, J/\psi\eta', J/\psi X, \ldots$$
$$e^+e^- \to \varphi K^+K^-, \varphi\pi^+\pi^- \ldots$$
$$e^+e^- \to \chi_{cJ\,(J=0,1,2)}\rho, \chi_{cJ\,(J=0,1,2)}\omega \ldots$$

We will try to measure all possible access components

and comparing these line-shapes with the one for the inclusive hadron production, one may find something new.

BES-II made finer cross section scan from 3.65 to 3.88 GeV, and studied the line-shapes of the inclusive hadron production, $D\overline{D}$ production and some exclusive charmless final states production. But data sample is too small. At BES-III, we are going to make the finer cross section scans covering the resonances with large samples to carefully study the structures.

Analyzing the finer cross section line-shapes would give us some useful information about whether new resonances exist in the energy region.

Summary for BESII

Measured f_D significantly for the first time

Measured CKM matrix elements and form factors

Measured $\frac{\Gamma(D^0 \to K^- e^+ \nu_e)}{\Gamma(D^+ \to \overline{K}^0 e^+ \nu_e)} = 1.00 \pm 0.05 \pm 0.04$, which supports that isospin conservation holds in the exclusive D semileptonic decays, solving the "Long-standing puzzle"

Observed the first non-DDbar decay mode of $\psi(3770) \to J/\psi \pi^+ \pi^-$ for the first time

Measured branching fraction for $\psi(3770) \to$ non-$D\bar{D}$ for the first time

Precisely measured R_{uds}, parameters of $\psi(3770)$ and $\psi(3686)$ etc……

Summary for BESIII

Precision test SM (with 4 fb^{-1} data)

- Pure leptonic decays — f_{D+} ~ 2.0%; f_{Ds+} ~ 1.3%
- Semileptonic decays — V_{cs} ~ 1.6%; V_{cd} ~1.8%
- Absolute Hadronic Branching fractions — $B(D^0 \to K^- \pi^+)$ ~ 0.5%; $B(D^+ \to K^- \pi^+ \pi^+)$ ~ 0.5%
- Something more……

Search for New Physics (with 4 fb^{-1} data)

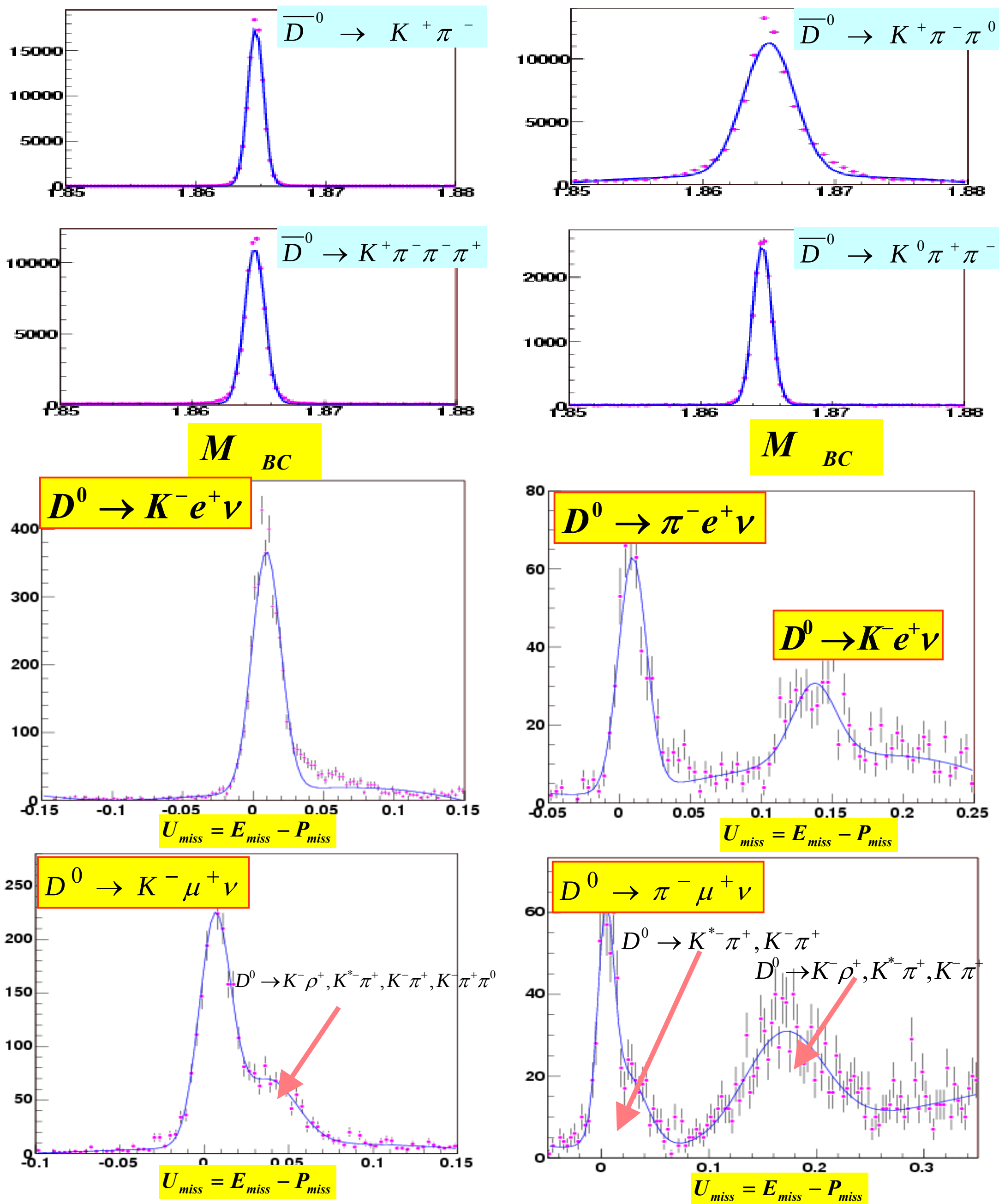
- $D^0\bar{D}^0$ Mixing — Sensitivity : 7.5×10^{-4}
- CP Violation — Sensitivity : $A_{CP} < 2.5 \times 10^{-2}$ @ 90% C.L.
- Rare Decays — Sensitivity : 10^{-7} for D mesons @ 90% C.L.; Sensitivity : $10^{-5} \sim 10^{-6}$ for D_s mesons @ 90% C.L.

Other topics

- Uncover the puzzle of $\psi(3770)$ production & decays
- Search for new particles in the range from 3.7 to 4.8 GeV
- something more ……

Thank You！

Exclusive Semileptonic Decays-MC simulation BOSS6.1.0



BOSS6.1.0 ~500pb^{-1}

N_{tag}	203541±451	
Mode	$D^0 \to K^-e^+\nu$	$D^0 \to \pi^-e^+\nu$
ε	48%	49%
N_{sig}	3631±60	407±20
B(%)	3.17±0.06	0.35±0.02
Lum	ΔB/B[stat.]	ΔB/B[stat.]
0.5fb^{-1}	~1.9[2.5]%	~5.0[6.0]%
4 fb^{-1}	~0.7[0.9]%	~1.8[2.1]%
20 fb^{-1}	~0.3[0.4]%	~0.8[1.0]%

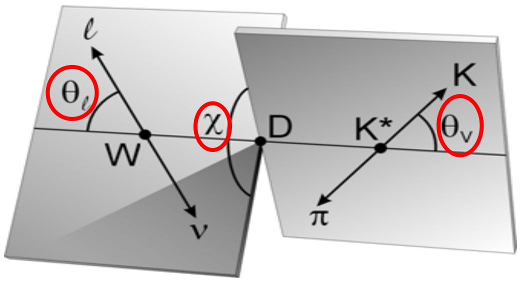
Mode	$D^0 \to K^-\mu^+\nu$	$D^0 \to \pi^-\mu^+\nu$
ε	21%	31%
N_{sig}	1588±40	272±16
B(%)	3.16±0.08	0.35±0.02

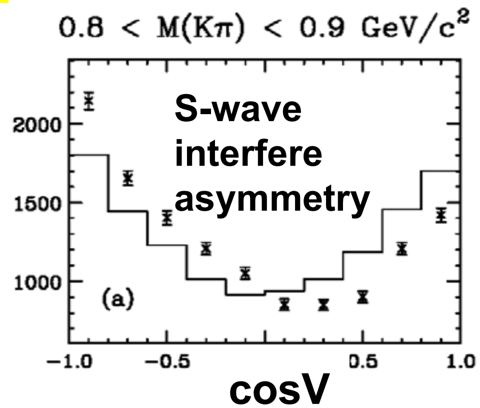
Precision Measuremets

Exclusive Semileptonic Decays-VPSL decay rates

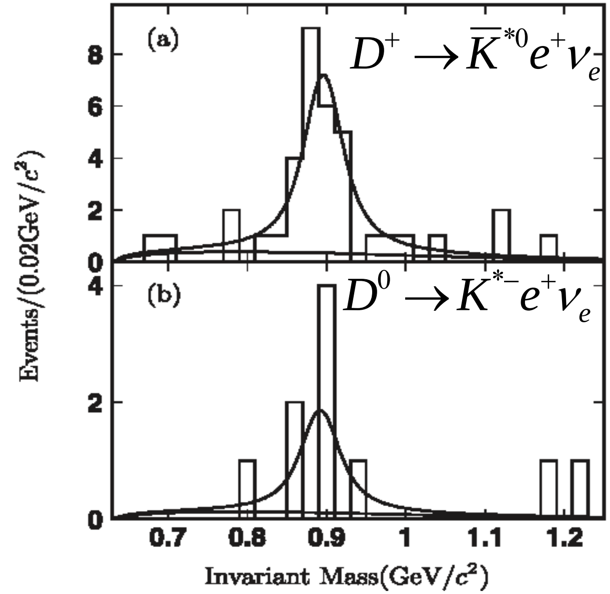
$$D^+ \to \overline{K}^{*0}(892)e^+\nu_e$$

Focus FPCP 2006





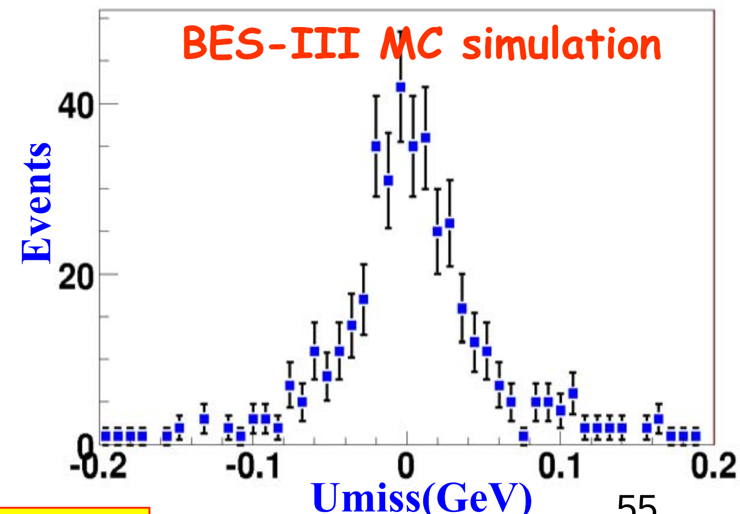
BES-II



$$\int |A|^2 d\chi = \frac{1}{8}q^2 \left\{ \begin{array}{l} \left((1+\cos\theta_l)\sin\theta_V\right)^2 |H_+(q^2)|^2 |BW|^2 \\ +\left((1-\cos\theta_l)\sin\theta_V\right)^2 |H_-(q^2)|^2 |BW|^2 \\ +\left(2\sin\theta_l\cos\theta_V\right)^2 |H_0(q^2)|^2 |BW|^2 \\ +8\left(\sin^2\theta_l\cos\theta_V\right)H_0(q^2)h_0(q^2)\mathrm{Re}\left\{Ae^{-i\delta}BW\right\} \\ +O(A^2) \end{array} \right\}$$

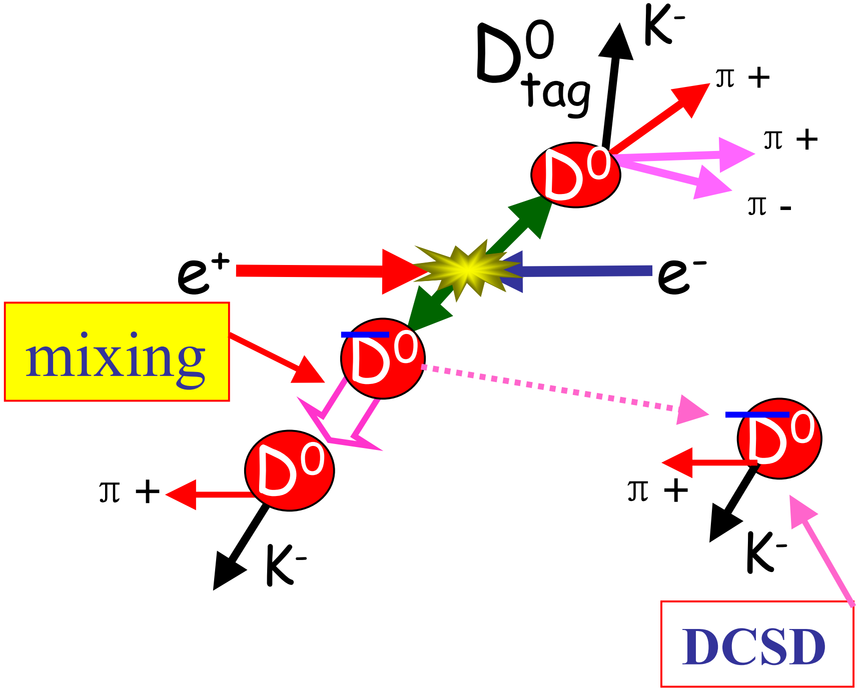
$H_0(q^2)$, $H_+(q^2)$, $H_-(q^2)$ are helicity-basis form factors which are computable by LQCD A new factor $h_0(q^2)$ is needed to describe s-wave interference piece.

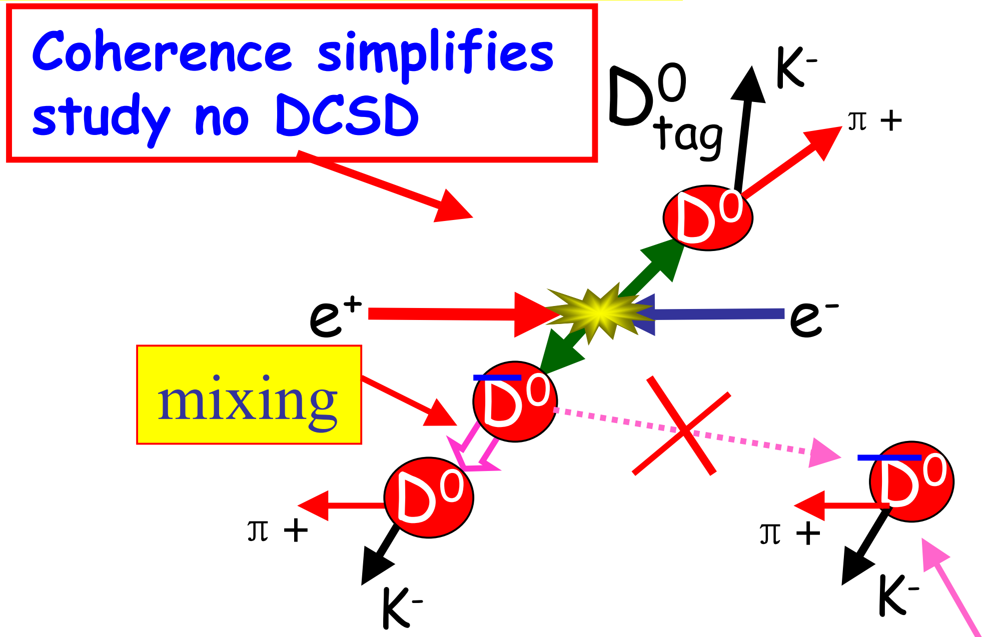
More MC simulations are needed



4 fb^{-1} ➔ about 8000 $D^+ \to \overline{K}^{*0}e^+\nu_e$ doubly tagged events

Search for D0D0-bar Mixing





$\psi(3770) \to D^0\overline{D}^0$ are coherent

Can not measure the time evolution of D^0 meson decays, DCS decay can not be separated from the final states. The level of the DCSD background is higher than the level of the mixing.

$$\psi(3770) \to D^0\overline{D}^0 \to K^-\pi^+K^-\pi^+$$

DCSD

requiring L to be even,

$\psi(3770)$ L = 1

So DCSD can not happen

$$R_{mix} \equiv \frac{x_D^2 + y_D^2}{2} \approx \frac{N(K^\pm\pi^\mp, K^\pm\pi^\mp)}{N(K^\pm\pi^\mp, K^\mp\pi^\pm)}$$

Other topics-Cabibbo-suppressed Decays

◆Cabibbo-suppressed decays are valuable for the understanding of the final state interactions, some D^+ hadronic decays provide a test of the interference in charm decays

◆Many experiments, such as MARKII, MARKIII, E691, E689, E791, FOCUS, CLEO, BESII, BABAR, BELLE, CLEOc have reported their measurements of branching fractions for the Cabibbo-suppressed D hadronic decays.

Relative Branching Fraction

$$\text{Ratio} = \frac{B^{\text{sup}}}{B^{\text{ref}}} = \frac{N^{\text{sup}} \times \varepsilon^{\text{ref}}}{N^{\text{ref}} \times \varepsilon^{\text{sup}}}$$

Refrence Modes: $D^0 \to K^-\pi^+$, $D^0 \to K^-\pi^+\pi^+\pi^-$, $D^+ \to K^-\pi^+\pi^+$, $D^+ \to K^0\pi^+$,etc.

More MC simulations are needed

Now, only few modes have <1.5% statistical error, and most have (3~16)% statistical error. We will be able to systematically study these Cabibbo-suppressed decays with greatly improved precisions (0.4-6)% at BESIII with 4 fb^{-1} data taken at 3.773 GeV

Other topics-Dalitz Plot Analysis

◆Access to study the interference between intermediate state resonances and the final state interactions

◆Opportunity to measure both the amplitudes and phases of the intermediate decay channels, which in turn to deduce their relative branching fraction

◆It also probes for New Physics Beyond Stand Model

Decays	Experiments
$D^0 \to K^0_s \pi^+ \pi^-$	MARKII, MARKIII, E691, E687, ARGUS, CLEO
$D^0 \to K^- \pi^+ \pi^0$	MARKIII, E687, E691, CLEO
$D^0 \to K^+ \pi^- \pi^0$	BABAR
$D^0 \to K^0 K^- \pi^+$	BABAR
$D^0 \to K^0 K^+ \pi^-$	BABAR
$D^0 \to \pi^- \pi^+ \pi^0$	CLEO
$D^0 \to K^0_s K^- K^+$	BABAR
$D^+ \to K^- \pi^+ \pi^+$	MARKIII, E687, E691, E791, BABAR
$D^+ \to K^0 \pi^+ \pi^0$	MARKIII
$D^+ \to \pi^- \pi^+ \pi^+$	E687, E791, FOCUS, CLEOc
$D^+ \to K^- K^+ \pi^+$	E687, FOCUS
$D^+ \to K^- K^+ \pi^0$	CLEO
$D^+ \to K^- \eta \pi^0$	CLEO
$D^+ \to K^+ \pi^+ \pi^-$	FOCUS

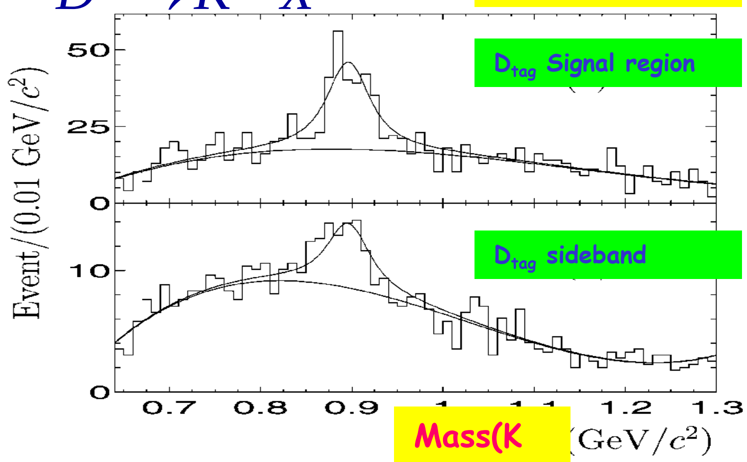
Other topics-Inclusive hadronic measurements

- ✓Serve to check the sum of the measured branching fractions on PDG for the exclusive D decays
- ✓Provide some information about the relative strength of the Cabibbo-suppressed and Cabibbo-favored inclusive decays, which will purse theoretical calculation to understand them
- ✓They are limited by the data sample in history, which can be systematically study at BESIII

Decays	Experiments
$D^{0,+} \to K^0 X$	MARKI, MARKII, MARKIII, BESII
$D^{0,+} \to K^- X$	MARKI, MARKII, MARKIII, HYBR, ACCM, BESII
$D^{0,+} \to K^+ X$	MARKI, MARKII, MARKIII, HYBR, BESII
$D^{0,+} \to K^{*0}\text{-}bX$	BESII
$D^{0,+} \to K^{*0} X$	BESII
$D^{0,+} \to K^{*-} X$	BESII
$D^{0,+} \to K^{*+} X$	BESII
$D^{0,+} \to \phi X$	BES, CLEOc
$D^{0,+} \to \eta X$	CLEOc
$D^{0,+} \to \eta' X$	CLEOc
$D^{0,+} \to \omega X$	-

$D^+ \to \overline{K}^{*0} X^+$

From BESII



$$BF = \frac{N_{rec}^{net}}{\epsilon \times N_{Tag}},$$

BESIII provide nice opportunity to more precisely measure the branching fractions of these inclusive decays. The statistical error in most measurements will reach <1% level