The Open Charm Physics Program at BES-III

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OUTLINE

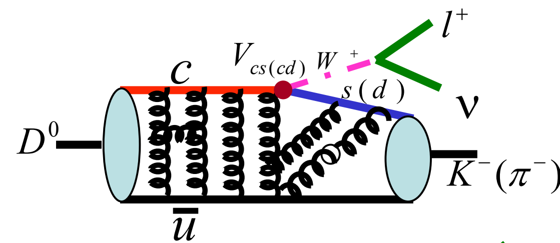
- The Major Physics Topics
- BES-III & Data Taking Plan
- Prospects
- Summary

The major charm physics topics (1)

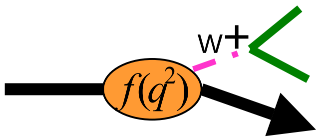
Purpose

To overcome the non perturbative QCD roadblock, to test pQCD calculations & to probe for New Physics beyond SM

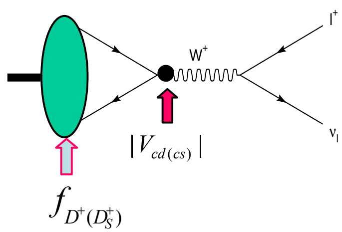
Precision measurements



- Semileptonic decays of D and Ds
  - ➡ $|V_{cs}|$, $|V_{cd}|$, and form factors



- Purely leptonic decays of D+ and Ds+
  - ➡ decay constants f_D & f_{Ds}



- Absolute hadronic branching fractions
  - ➡ To normalize B and Z physics

Test QCD techniques in charm sector, and apply to B sector

➡ Improve determinations of $|V_{ub}|$, $|V_{cb}|$, $|V_{td}|$ & $|V_{ts}|$

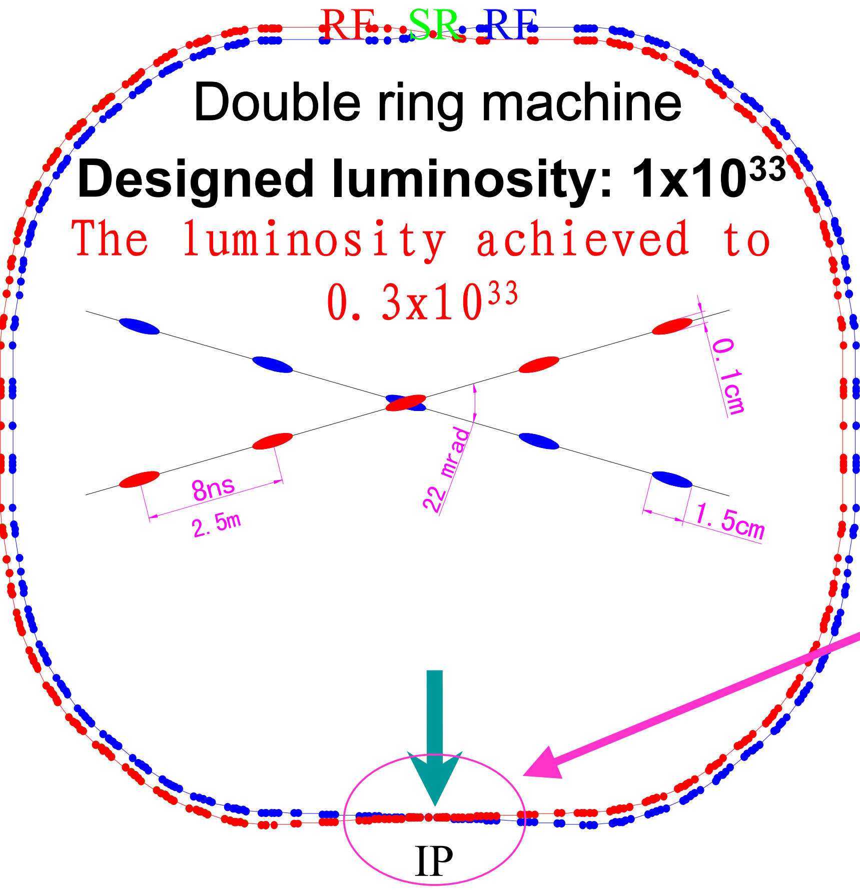
The major charm physics topics (2)

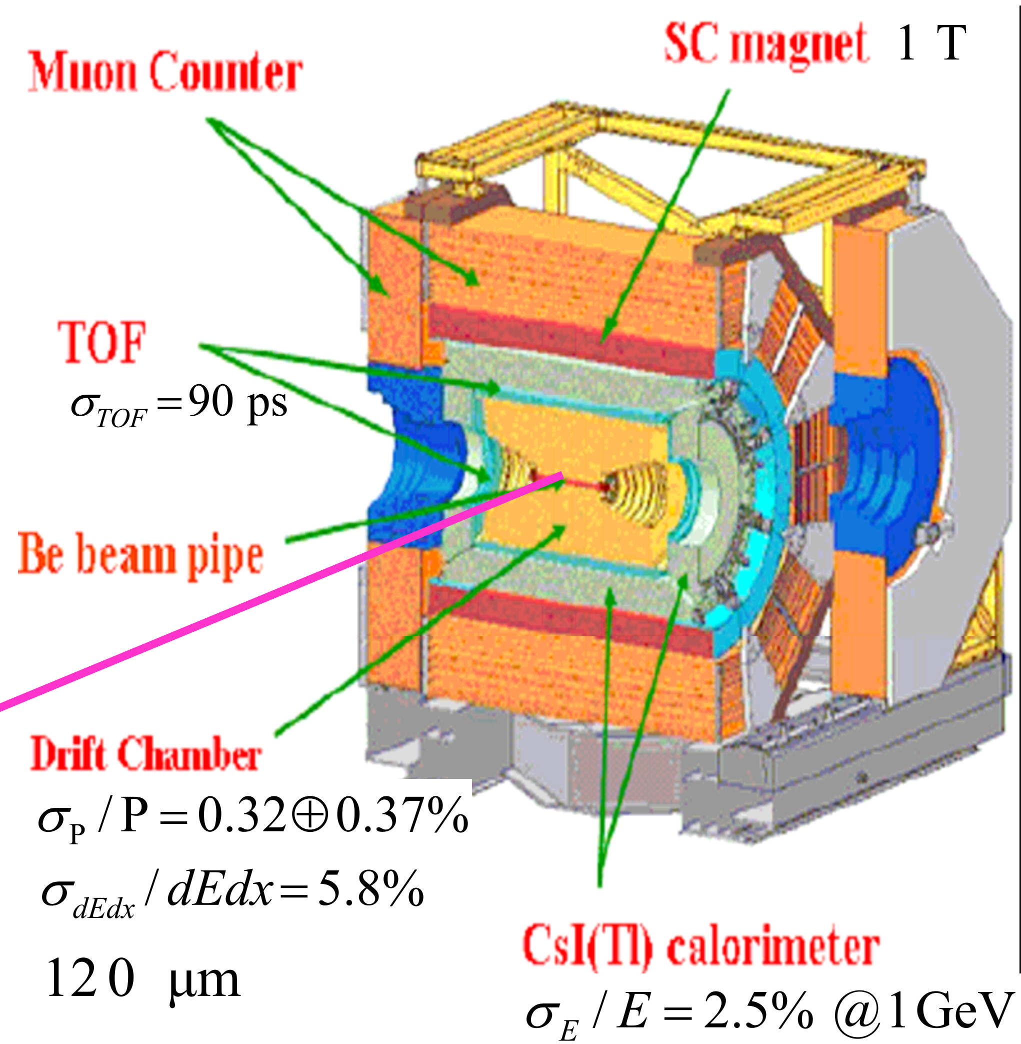
Probes for New Physics

- $D^0\overline{D}^0$ mixing
- Searching for CP Violation decays of D
- Searching for Rare Decays of D and Ds mesons

Precision measurements on charm decays can be served as precisely test the Standard Model.

The BEPC-II & the BES-III





BES-III data taking plan

~5 months for data taking until next summer.

Possible data taking plans:

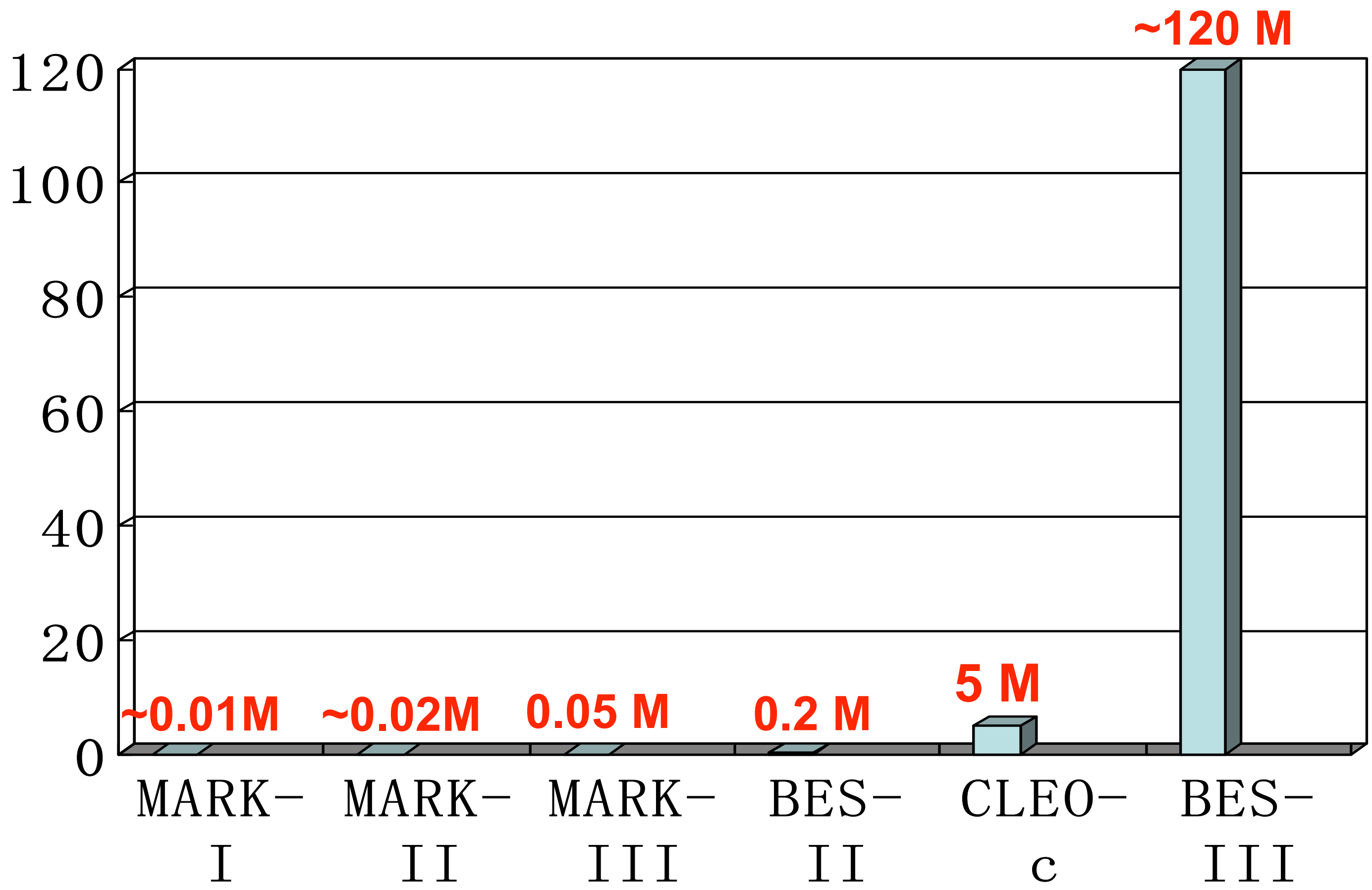
- **500–1000 M J/ψ events (2-4 months)**
- **100–300 M ψ(3868) events (2-4 months)**
- **Energy scan over ψ(3770) (~2 weeks)**
- **~1.3 fb^{-1} ψ(3770) (4 months)**

To be decided in this Nov.

Data taking plan in the future:

- **~10 B J/ψ events (1 year)**
- **~3 B ψ(3686) events (1 year)**
- **~20 fb^{-1} ψ(3770)+ ψ(4040)+ ψ(4160) (~5 years)**
- **R scan/resonance scan: 2.0–4.6 GeV (months)**
- **Tau physics (several months)**

$D\bar{D}$ events near threshold from different experiments

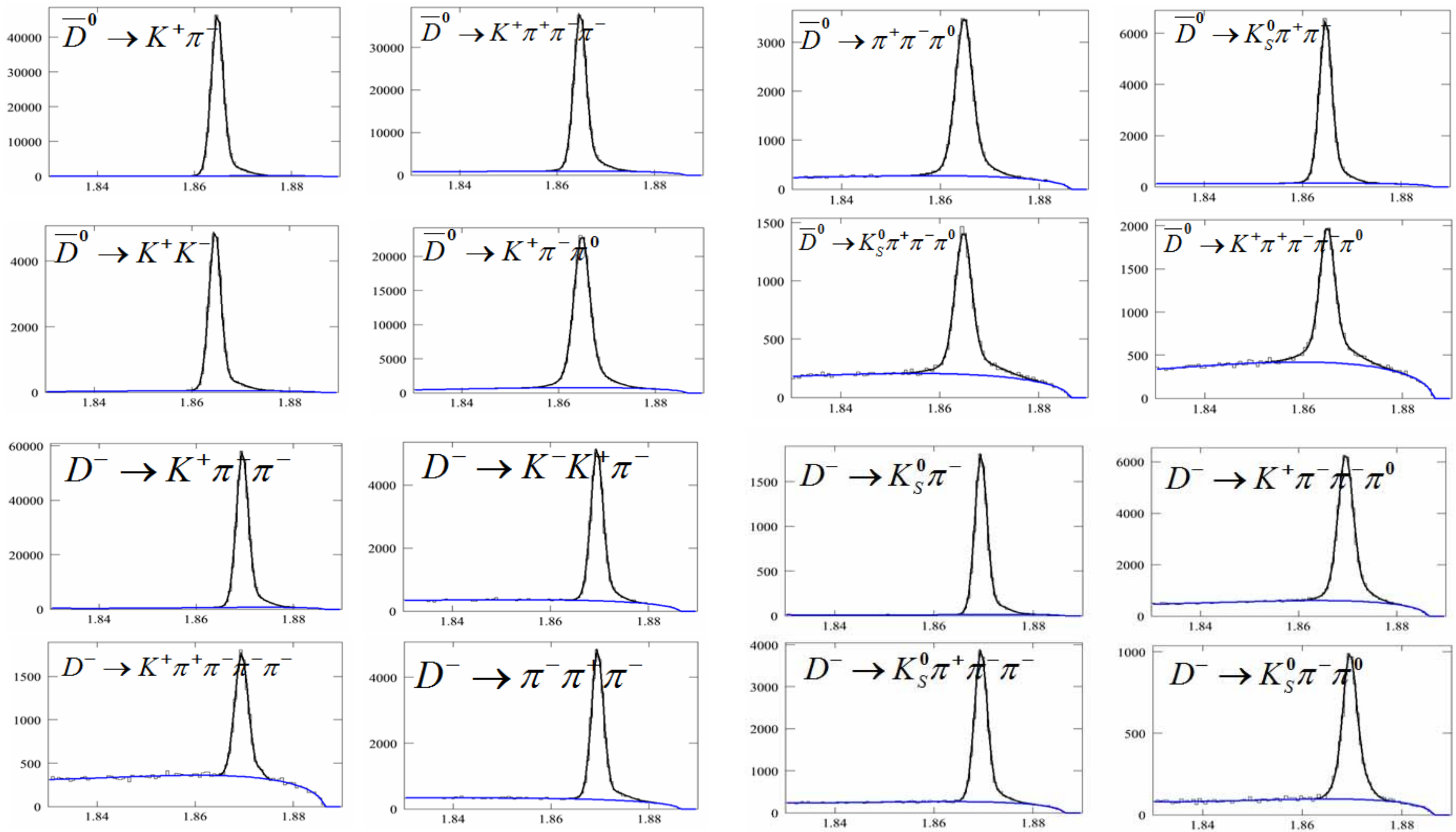


Assuming designed luminosity achieved, about 120 M $D\bar{D}$ events will be collected at BES-III for 4 years data taking at $\psi(3770)$ peak.

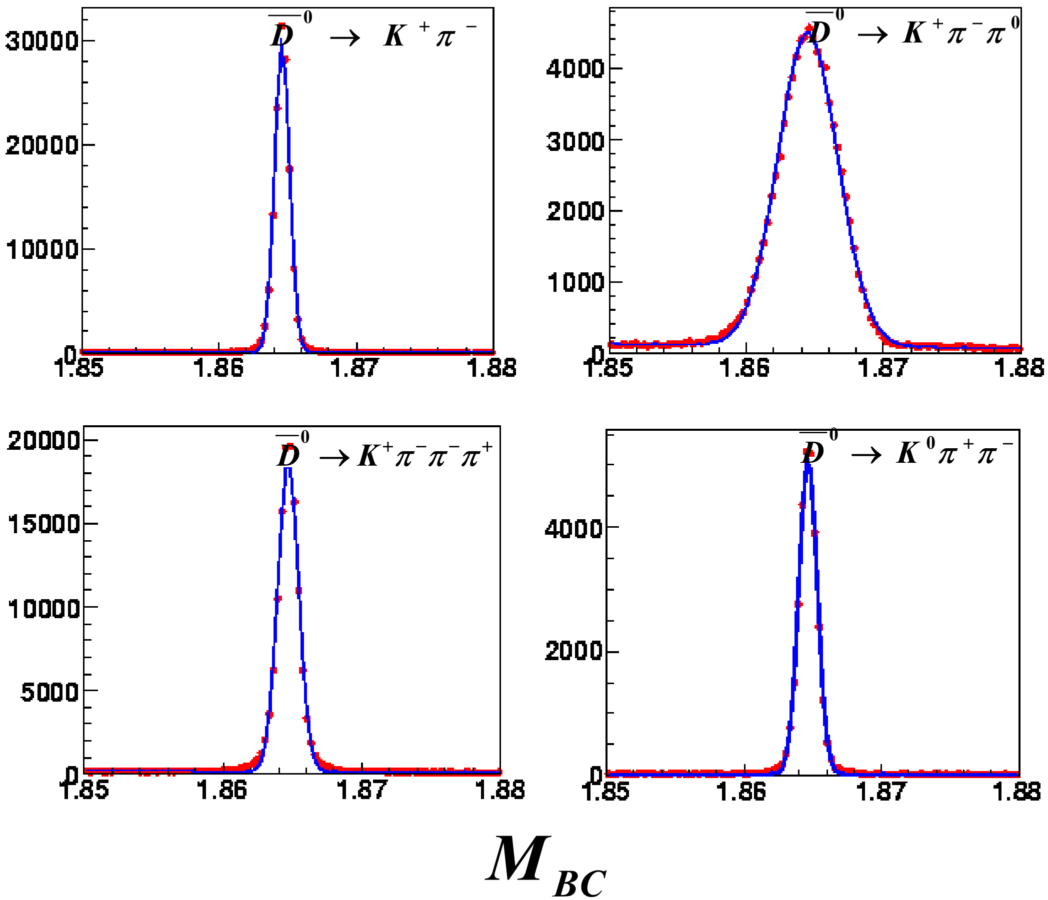
Singly tagged D events

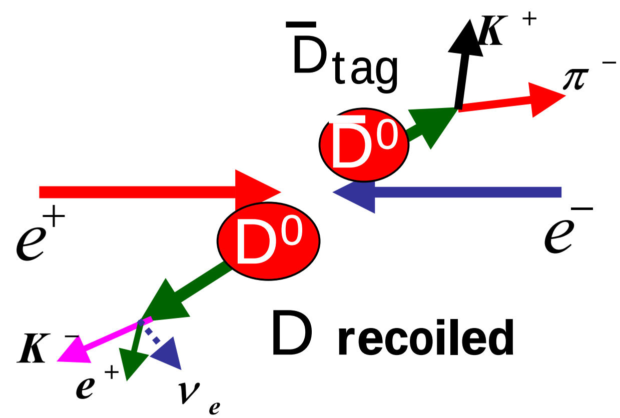
$e^+e^- \rightarrow \psi(3770) \rightarrow D\bar{D}$

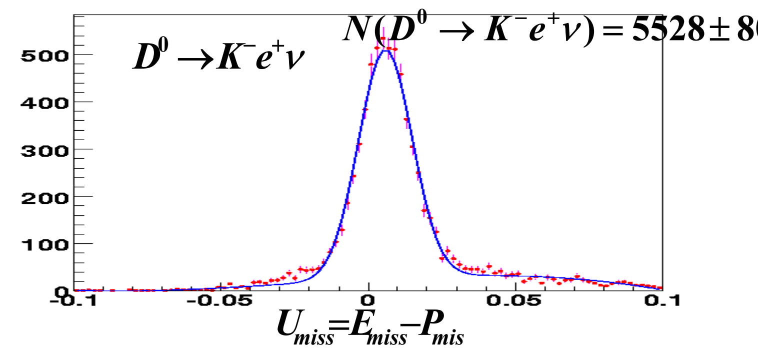
BES-III Monte Carlo

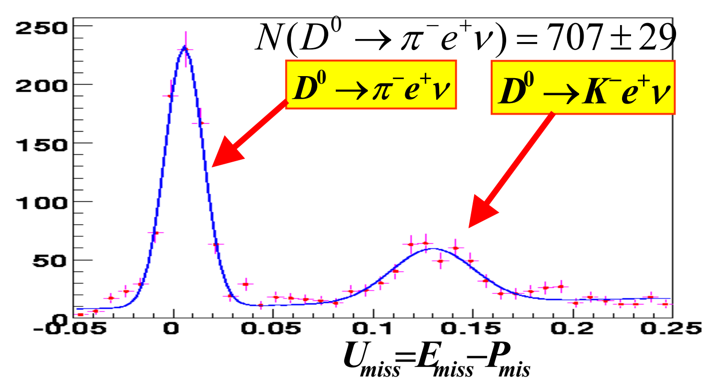


MC simulation for D^0 Semileptonic decays









$$N_{tag} = 359884 \pm 600$$

Singly tagged $\bar{D}^0$ samples 0.8 pb^{-1} MC

V_{cs}, V_{cd} and form factors

Decay rates relates to CKM Matrix elements and form factor

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

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

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

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

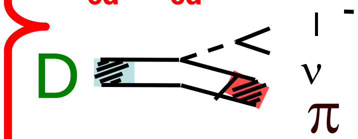
To extract V_{cs} & V_{cd} need form factor from theory.

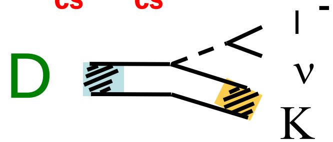
$$\frac{\Delta|V_{cq}|}{|V_{cq}|}=\sqrt{\left(\frac{\Delta B}{2B}\right)^2+\left(\frac{\Delta\tau_D}{2\tau_D}\right)^2+\left(\frac{\Delta f}{f}\right)^2}$$

BES-III: 4 fb^{-1} ψ(3770) MC

1. **PDG08:** $\frac{\Delta\tau_{D^0}}{\tau_{D^0}}=0.4\%$
2. **4 fb^{-1} ψ(3770) data:** $\left(\frac{\Delta B}{B}\right)_{\rm stat.}\sim0.7\%, 1.8\%$
3. **Form factor (LQCD): Assuming Δf/f ~1.5%.**

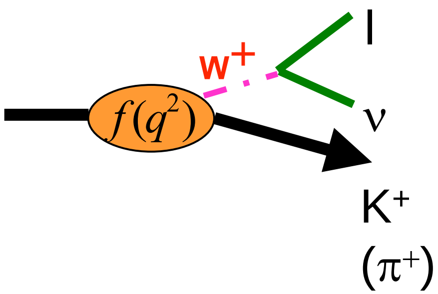
$\Delta V_{cd}/V_{cd}$ ~1.8% **$\Delta V_{cs}/V_{cs}$ ~1.6%**





Great contribution to CKM Unitarity

$$\frac{\Delta|f_+^{K(\pi)}(0)|}{|f_+^{K(\pi)}(0)|}=\sqrt{\left(\frac{\Delta B}{2B}\right)^2+\left(\frac{\Delta\tau_D}{2\tau_D}\right)^2+\left(\frac{\Delta V_{cs(cd)}}{V_{cs(cd)}}\right)^2}$$

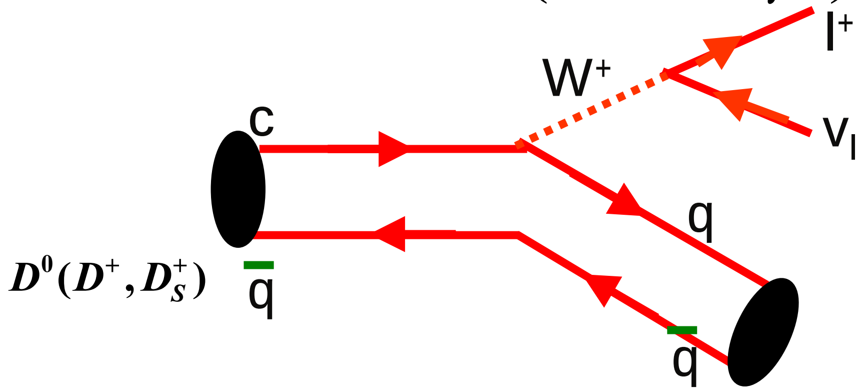


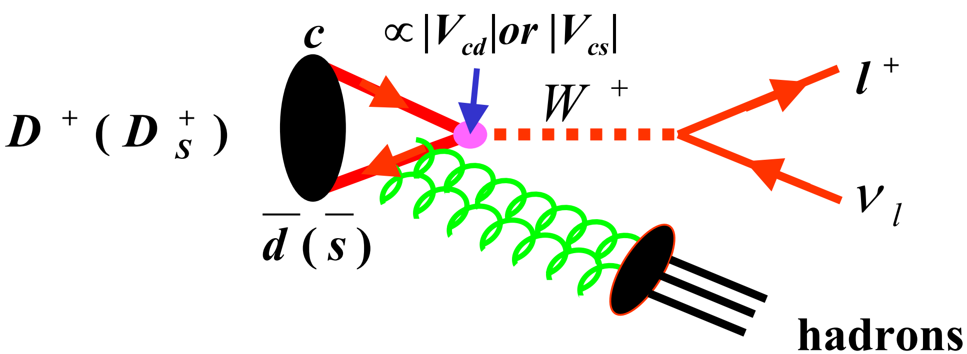
$$\frac{\Delta|f_+^K(0)|}{|f_+^K(0)|}=1.4\% \qquad \frac{\Delta|f_+^\pi(0)|}{|f_+^\pi(0)|}=5.4\%$$

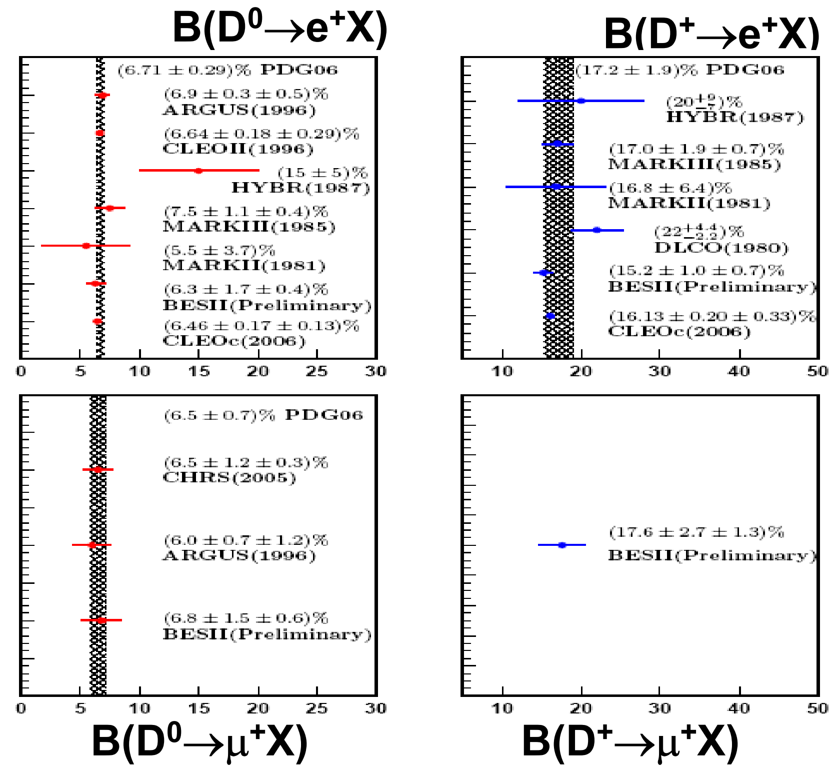
These uncertainties are dominated by the uncertainties of $|V_{cs(cd)}|$

Inclusive semi-leptonic decays

$$D \to \ell^+ X \quad (\ell = e, \mu)$$







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%

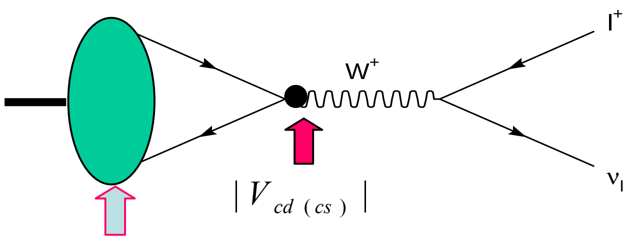
Accuracy limited by systematic error

BES-III will measure these branching fractions and check:

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

Purely leptonic decays

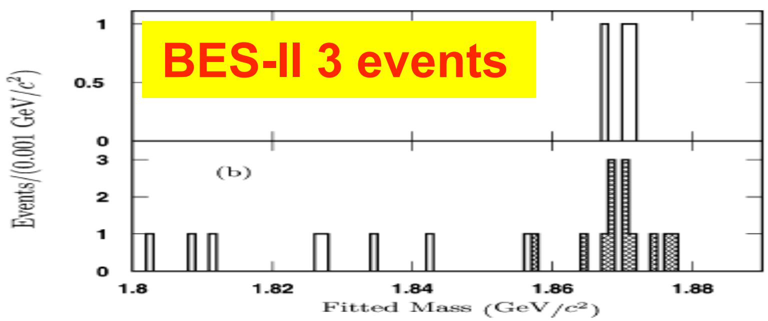
Measurements of f_D and f_{D_s}



BES-I 1 events

Three candidates for D^+ purely leptonic decay

Event	1	2	3
Tagging mode	$K^+\pi^-\pi^-$	$K^+\pi^-\pi^-\pi^0$	$K^+\pi^-\pi^-$
Fitted mass [MeV/c^2]	1870.8	1876.9	1871.4
Number of μ layer hits	2	2	2
μ^+ momentum [GeV/c]	0.974	0.981	0.919
U_{miss} [GeV]	−0.093	−0.023	0.117
Calculated momentum of neutrino [GeV/c]	1.000	1.007	0.843

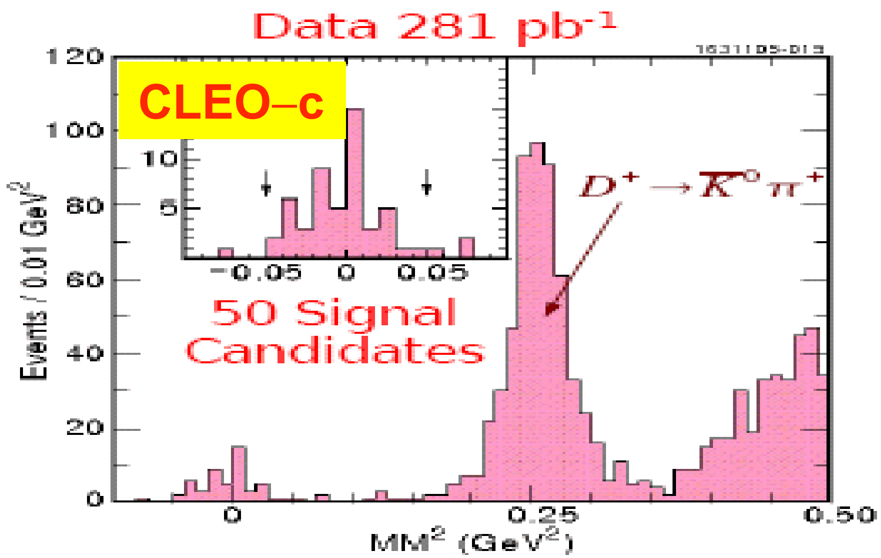


$$Br(D^+ \to l^+\nu) = \frac{G_F^2 |V_{cd}|^2}{8\pi} f_D^2 m_D m_l \tau_D \left(1 - \frac{m_l^2}{m_D^2}\right)^2$$

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

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

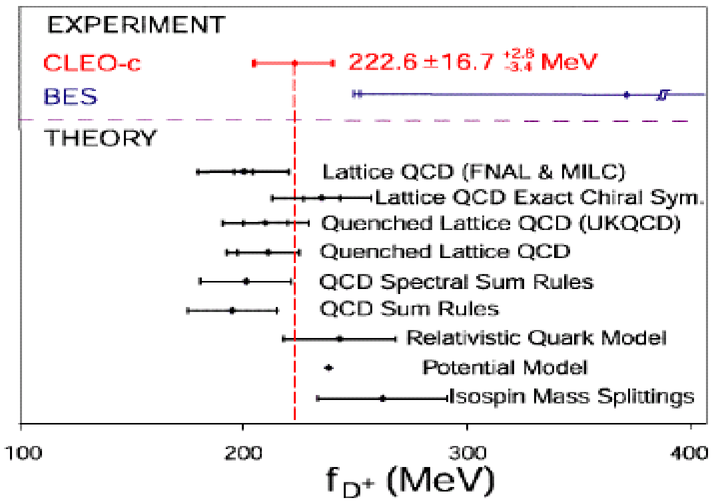
Lattice QCD predicts f_D, f_{Ds}, more precisely measured f_D and f_{Ds} can be used to calibrate the LQCD calculations.



$$f_{D^+} = (222.6 \pm 16.7\,^{+2.8}_{-3.4})\ \text{MeV}$$

Decay constants

Comparing with Theory



CELO-c expects to improve f $_{D+}$ measurement at an accuracy of 5% with ~800 pb^{-1} of ψ(3770) data

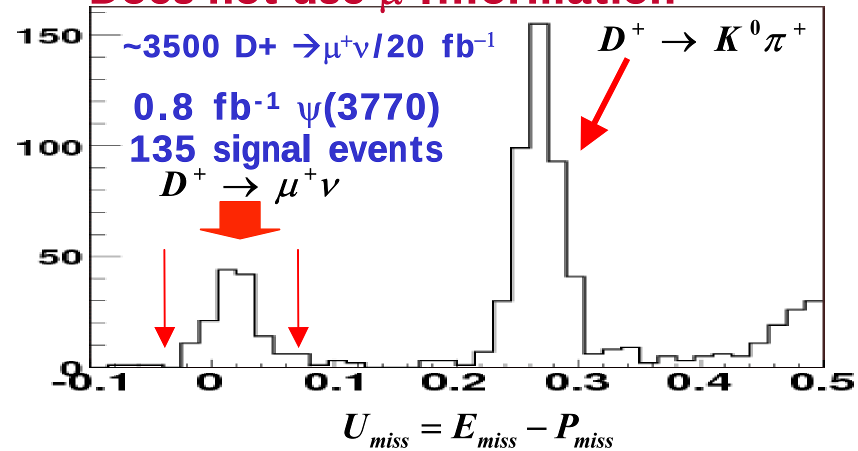
BES-III will improve f $_{D+}$ measurement at an accuracy of 2% (~1.5) with 4 fb^{-1} (20) of ψ(3770) data

$$\frac{\Delta f_{D^+}}{f_{D^+}} = \sqrt{\left(\frac{\Delta B}{2B}\right)^2 + \left(\frac{\Delta \tau_D}{2\tau_D}\right)^2 + \left(\frac{\Delta V_{cd}}{V_{cd}}\right)^2}$$

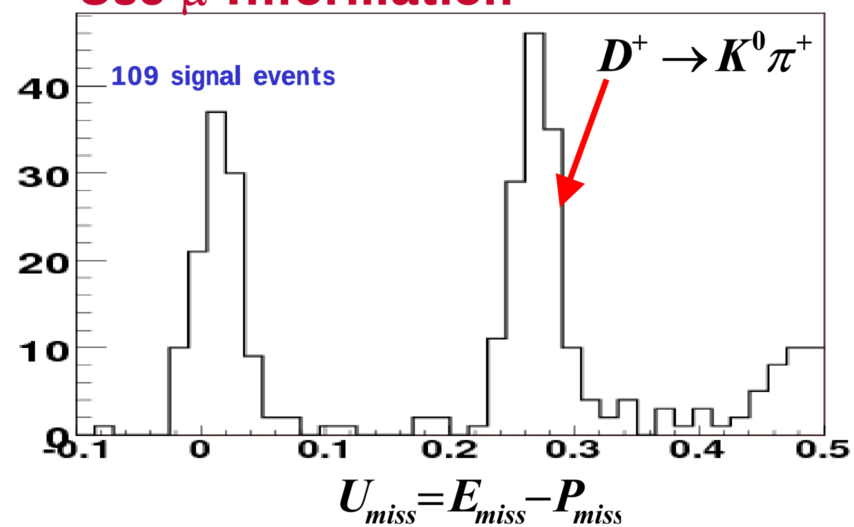
$$\left(\frac{\Delta B}{2B}\right) \approx 0.8\%$$

BES-III Monte Carlo simulation

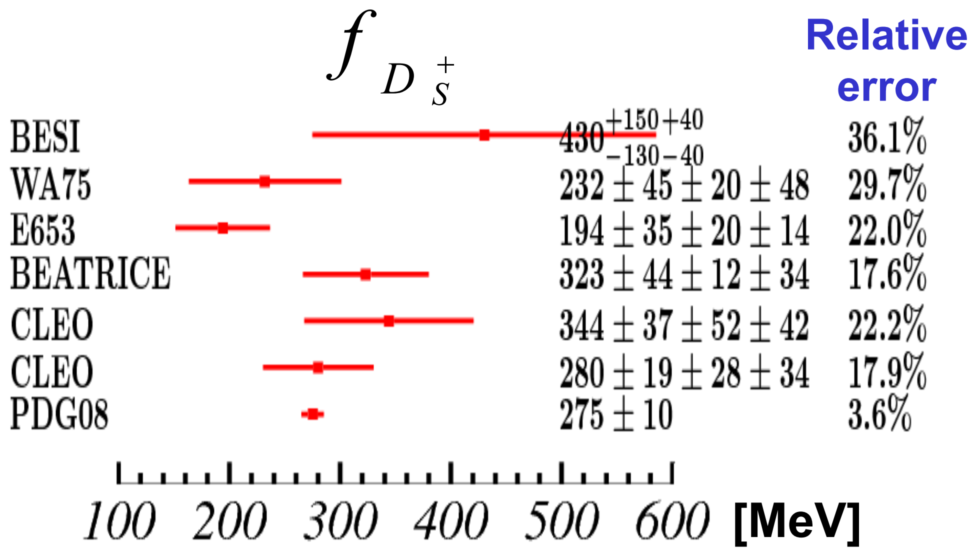
Does not use μ Information

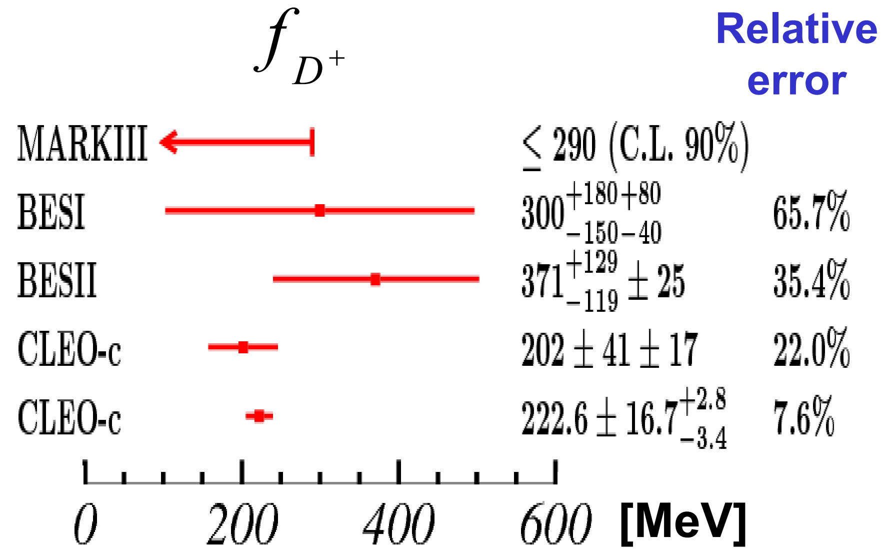


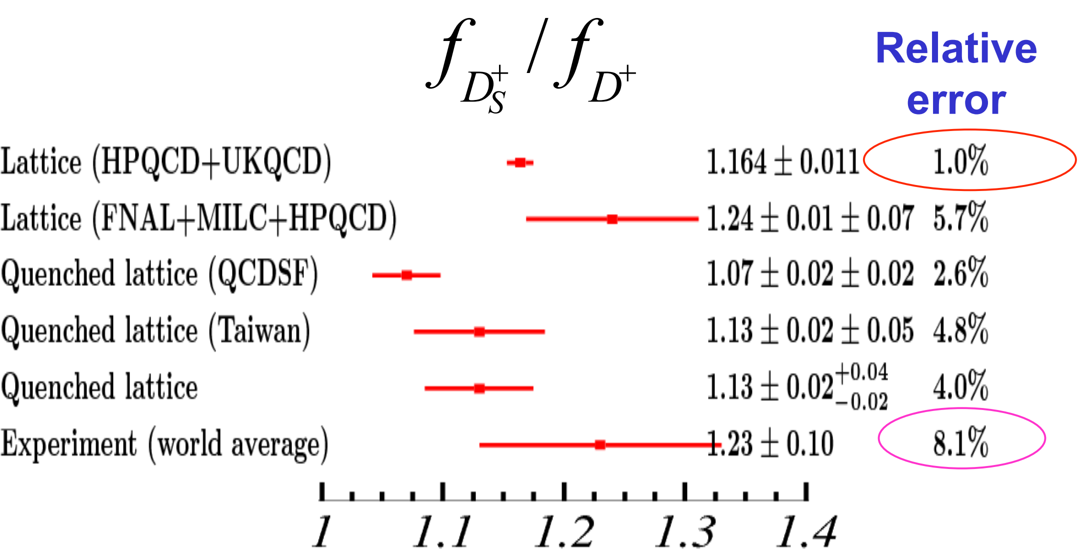
Use μ Information



Decay constants







at BES-III, we can reduce the errors

(4 pb^{-1} data)

$$\Delta f_{D^+} / f_{D^+} \approx 2\%$$

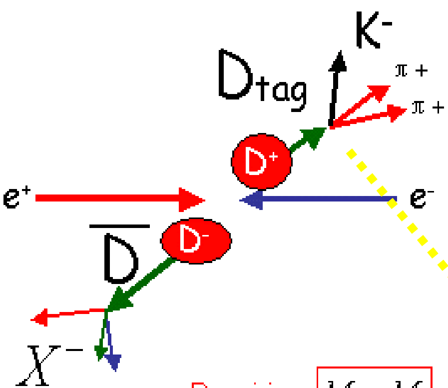
$$\Delta f_{D_S^+} / f_{D_S^+} \approx 1.3\%$$

$$\frac{\Delta [f_{D_S^+} / f_{D^+}]}{f_{D_S^+} / f_{D^+}} \approx 3\%$$

To test LQCD calculations

Single & Double Tag Analyses

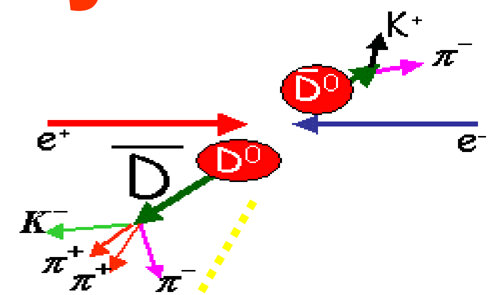
$D^0 \to K^- \pi^+$, $D^+ \to K^- \pi^+ \pi^+$ absolute Br's



Requiring $M_{fit} = M_X$

Single tag

Double tags



$$N_s(i) = 2N_{D\bar{D}} Br(i)\varepsilon(i) - \sum_{j=i}^{N} (2N_{D\bar{D}} \varepsilon(i)\varepsilon(i,j) Br(i) Br(j))$$

$$N_d(i,j) = N_{D\bar{D}} Br(i) Br(j) \varepsilon(i,j) \quad (i = j)$$

$$N_d(i,j) = 2N_{D\bar{D}} Br(i) Br(j) \varepsilon(i,j) \quad (i \neq j)$$

MARK-III method

$$\chi^2 = \sum_{i=1}^{N} \left(\frac{N_s(i) - N_s^{\exp}(i)}{\sigma_{N_s(i)}}\right)^2 + \sum_{i=1,j=i}^{N,N} \left(\frac{N_d(i,j) - N_d^{\exp}(i,j)}{\sigma_{N_d(i,j)}}\right)^2$$

yields

Branching fractions for the D hadronic decays

$$\sigma_{D^0\bar{D}^0} = \frac{N_{D^0\bar{D}^0}}{L} \text{ and } \sigma_{D^+D^-} = \frac{N_{D^+D^-}}{L}$$

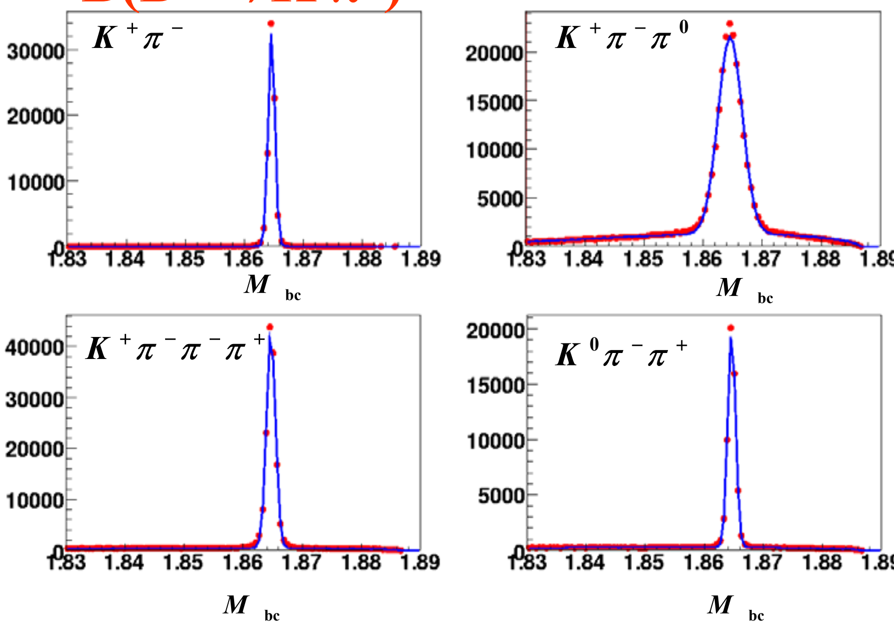
$$\sigma_{D\bar{D}} = \sigma_{D^0\bar{D}^0} + \sigma_{D^+D^-}$$

Normalized constants !

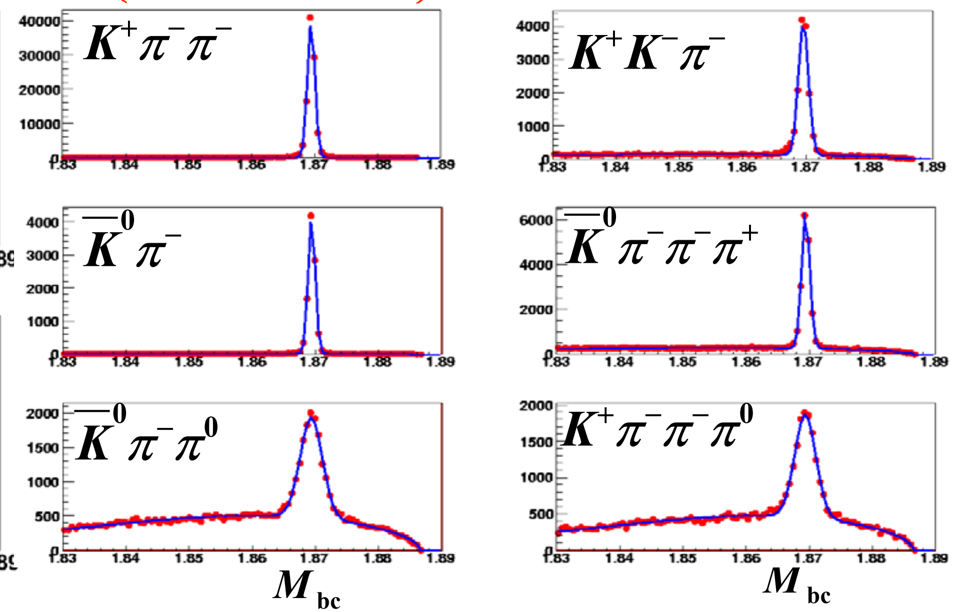
L is the integrated luminosity of the data set

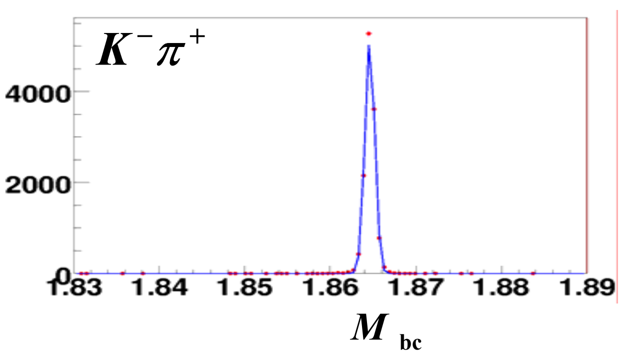
Accuracy on hadronic Br. fractions

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

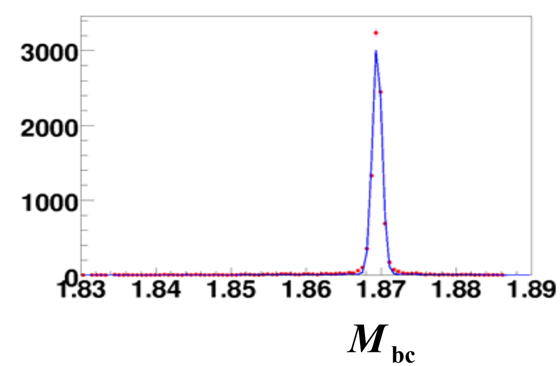


$B(D^+ \rightarrow K^-\pi^+\pi^+)$





BES-III MC simulation



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

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

Expected Results on Charm Decays

Statistical error only

Relative error (%) on the measurements

Mode	$\delta B/B$ (4 fb^{-1})	$\delta B/B$ (20 fb^{-1})	$\delta B/B$ (PDG 08)	CLEO-c
$D^0 \to K^-\pi^+$	0.5	0.2	1.3	2.0 [281 pb^{-1}]
$D^+ \to K^-\pi^+\pi^+$	0.5	0.2	2.3	2.2 [281 pb^{-1}]
$D^0 \to K^-e^+\nu$	0.7	0.3	1.7	1.4 [818 pb^{-1}]
$D^0 \to \pi^-e^+\nu$	1.8	0.8	6.0	3.0 [818 pb^{-1}]
$D^0 \to K^-\mu^+\nu$	0.9	0.4	3.9	----
$D^0 \to \pi^-\mu^+\nu$	2.1	1.0	10.1	----
$D^+ \to \mu^+\nu$	4.0	2.0	15.9	15.2 [281 pb^{-1}]
f_{D^+}	2.0	0.9		7.7 [281 pb^{-1}]

Mode	$\delta B/B$ (4.03GeV)	$\delta B/B$ (4.16GeV)	$\delta B/B$ (PDG 08)	CLEO-c
$D_s^+ \to \phi\pi^+$	4.0		8.0	
$D_s^+ \to \phi e^+\nu$	5		11.0	16.9 [310 pb^{-1}]
$D_s^+ \to \mu^+\nu$	5.7		9.7	8.5 [600 pb^{-1}]
$D_s^+ \to \tau^+\nu$			9.1	12.9 [600 pb^{-1}]
$f_{D_s^+}$	~2.8	1.3	3.7	2.8 [600 pb^{-1}]

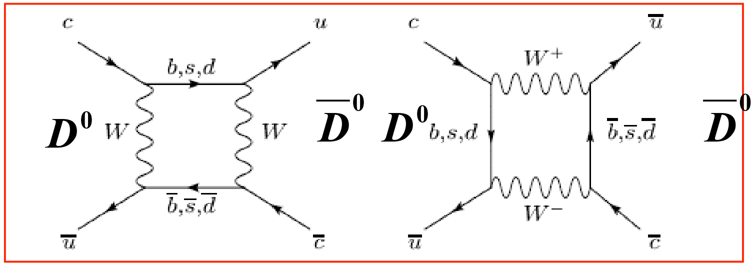
About one year data taking → 4fb^{-1} for designed luminosity

$D^0\bar{D}^0$ mixing

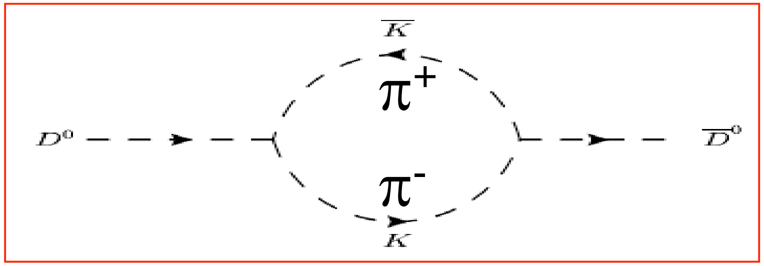
Definition of mixing

$'\text{produce}' - (c\bar{u})$ — mixing: $D^0 \Rightarrow \bar{D}^0$ → $'\text{decay}' - (u\bar{c})$

change of identity due to



Standard Model box diagrams of flavor-changing neutral current contribution to $D^0 - \bar{D}^0$ mixing at quark level



A hadron-level diagram of a long-distance physics contribution to $D^0 - \bar{D}^0$ mixing

The weak eigenstates are

$$|D_1\rangle = \frac{1}{\sqrt{|p|^2 + |q|^2}}(p|D^0\rangle + q|\bar{D}^0\rangle)$$

$$|D_2\rangle = \frac{1}{\sqrt{|p|^2 + |q|^2}}(p|D^0\rangle - q|\bar{D}^0\rangle)$$

The eigenvalues are

$$\lambda_{D_1} = m_1 - \frac{i}{2}\Gamma_1$$

$$\lambda_{D_2} = m_2 - \frac{i}{2}\Gamma_2$$

$D^0\bar{D}^0$ mixing

Definition of mixing

$$\Delta m = m_2 - m_1 \qquad \Delta\Gamma \equiv (\Gamma_2 - \Gamma_1)$$

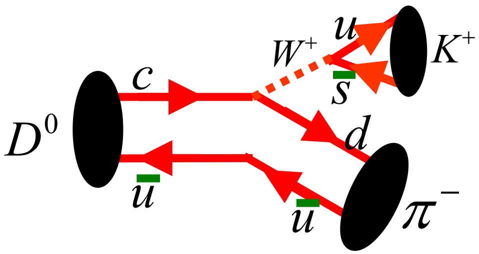
$$m = \frac{m_1 + m_2}{2} \qquad \Gamma = \frac{\Gamma_1 + \Gamma_2}{2}$$

m_1 and m_2 are the masses of D^0_1 and D^0_2, respectively.

Γ_1 and Γ_2 are the decay widths of D^0_1 and D^0_2, respectively.

$$x \equiv \frac{\Delta m}{\Gamma} \qquad y \equiv \frac{\Delta\Gamma}{2\Gamma}$$

$$R_{mix} \equiv \frac{x^2 + y^2}{2}$$



Time dependent rate

$$T_{WS}(t) = e^{-\Gamma t}\left(R_D + \sqrt{R_D}\, y'\Gamma t + \frac{x'^2 + y'^2}{4}\Gamma^2 t^2\right)$$

DCS — interference — mixing

In the limit of CP conservation

DCS decay goes to the same final states as the mixing does!

$$x' = x\cos\delta_{K\pi} + y\sin\delta_{K\pi}, \qquad y' = -x\sin\delta_{K\pi} + y\cos\delta_{K\pi}$$

The strong phase

$\delta_{K\pi}$ is the strong phase between DCS and CF amplitudes

$D^0\bar{D}^0$ mixing at BES-III

Quantum correlation at $\psi(3770)$

If we only examine the $K^-\pi^+$ mode, the DCS decays can not happen in the final states due to quantum correlation.

[The old C initial stat can not produce the symmetric final state required by Bose statistics if D^0 and $\bar{D}^0$ decay into the same $K^-\pi^+$) final state]

- Hadronic decay modes

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

$$R_{mix} \equiv \frac{x^2+y^2}{2} \approx \frac{N(K^-\pi^+)(K^-\pi^+)}{N(K^-\pi^+)(K^+\pi^-)}$$

- Semileptonic decay modes

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

$$R_{mix} \equiv \frac{x^2+y^2}{2} \approx \frac{N(K^-l^+\nu)(K^-l^+\nu)}{N(K^-l^+\nu)(K^+l^-\nu)}$$

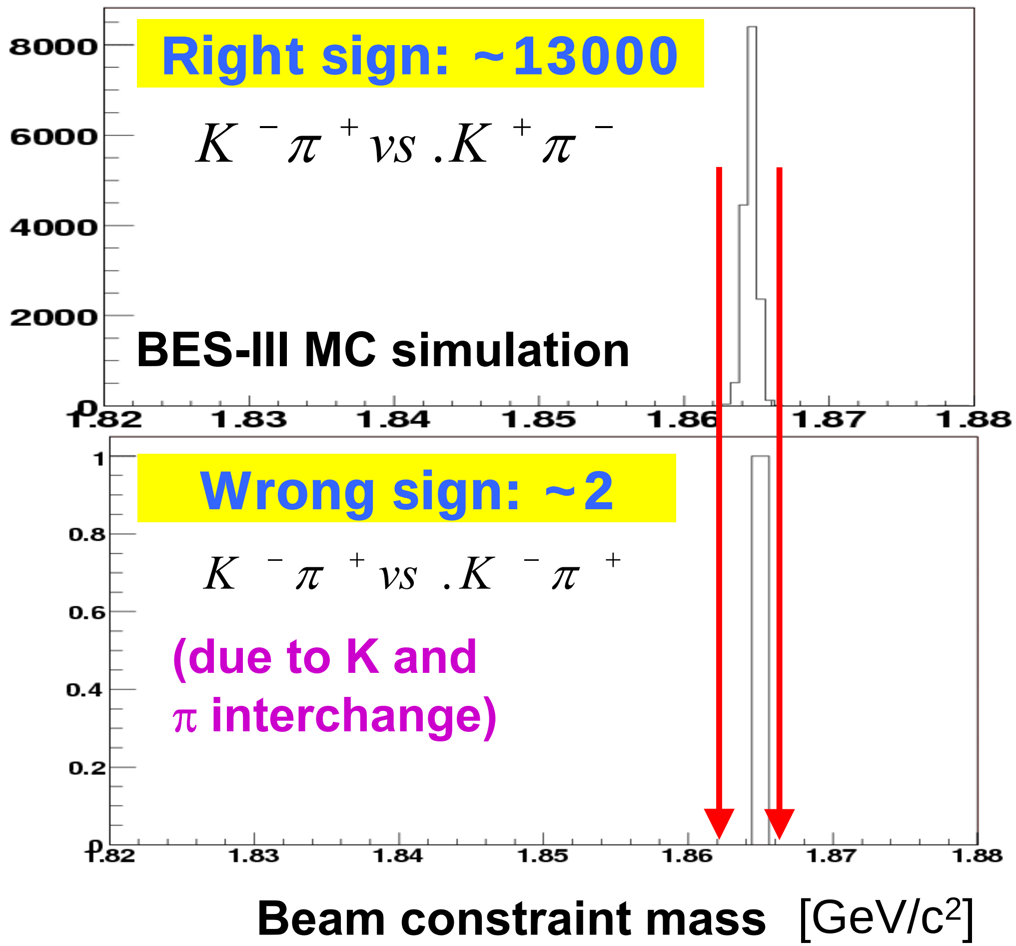
- Hadronic & Semileptonic decay modes

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

$$\frac{x^2+y^2}{2} + R_D \approx \frac{N(K^-\pi^+)(K^-l^+\nu)}{N(K^-\pi^+)(K^+l^-\nu)}$$

Mixing from $D^0\bar{D}^0 \to (K^-\pi^+)(K^-\pi^+)$ at $\psi(3770)$

Experimental sensitivity



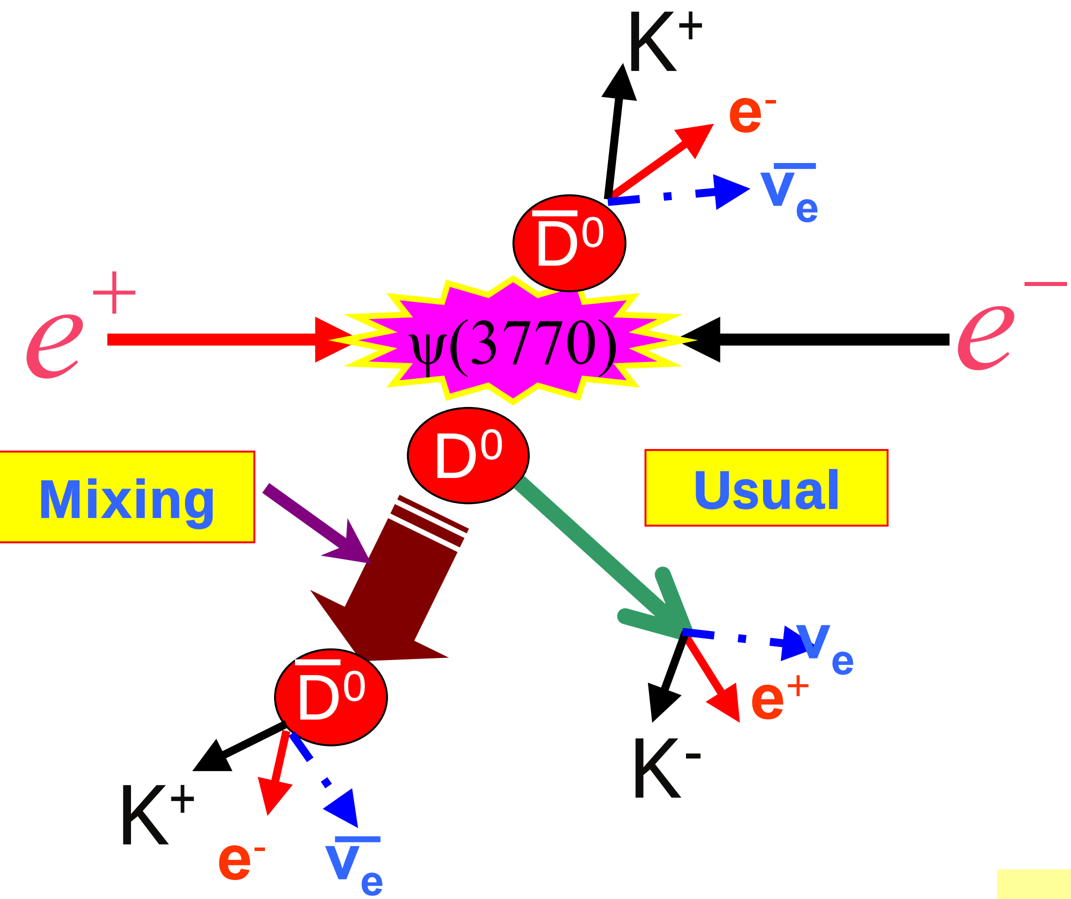
~71224000 $N_{D0\bar{D}0}$(20 fb^{-1})

Background estimate -- In the recoiling side:

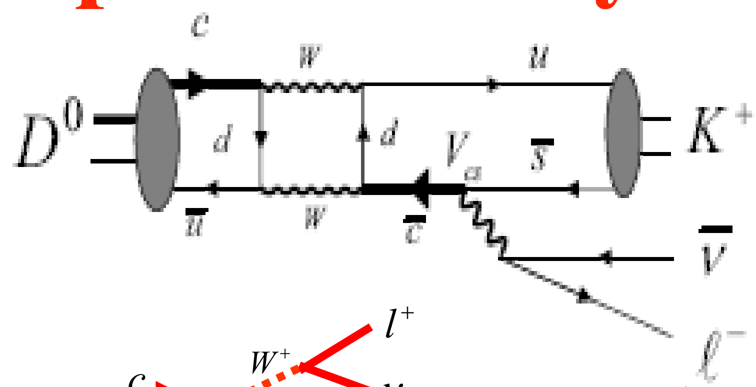
$K^+K^- vs. K^+K^-$	1078	0
$\pi^+\pi^- vs. \pi^+\pi^-$	136	0
$K^+\pi^- vs. K^+K^-$	21057	0
$K^+\pi^- vs. \pi^+\pi^-$	7470	0
$K^+K^- vs. \pi^+\pi^-$	765	0
$K^+\pi^- vs. K^-\pi^+$	150000	2

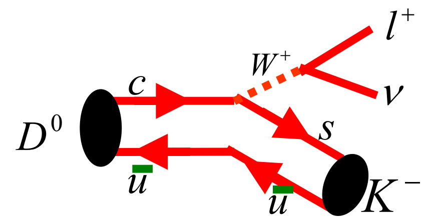
Sensitivity ~1.5x10^{-4}

Mixing from the semileptonic decays



Wrong Sign **Right Sign**





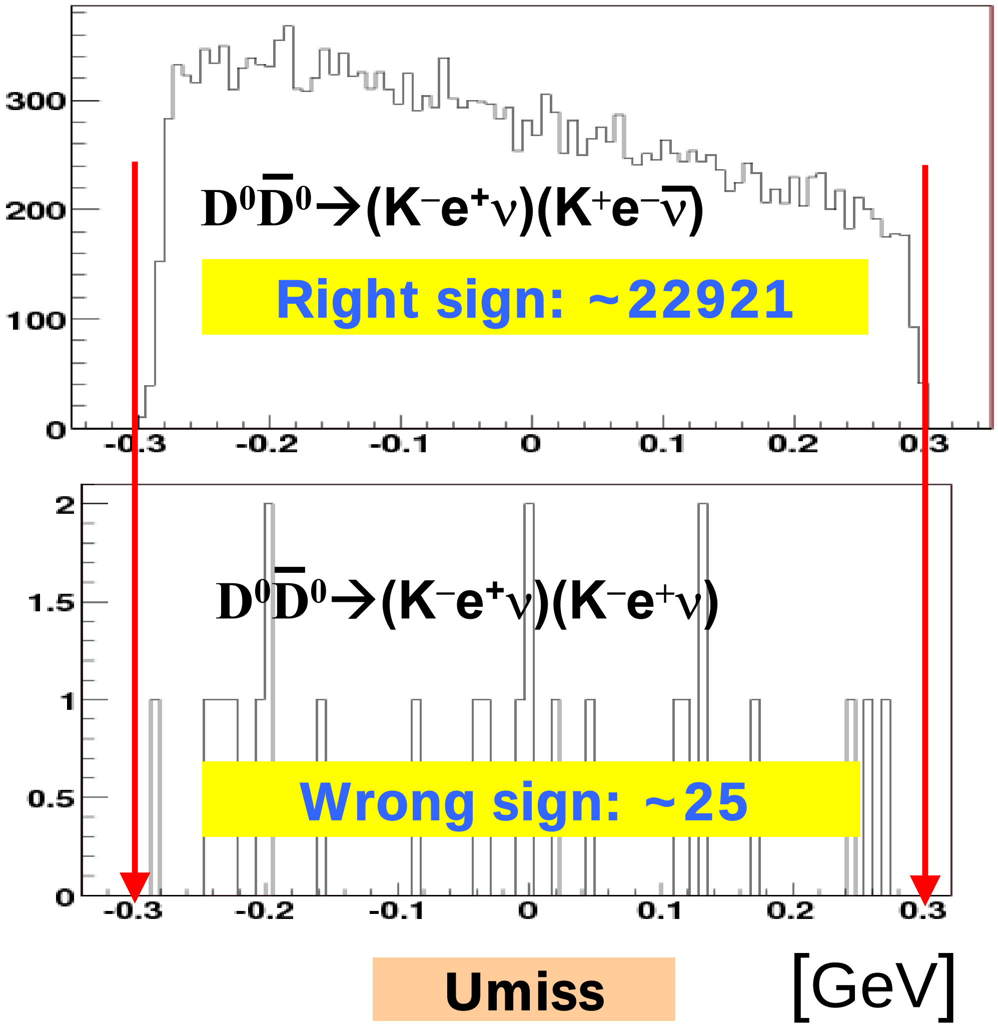
Right sign

Wrong Sign semileptonic decay final states can only occur through Mixing

In principle ideal for mixing, but suffer from backgrounds.

Mixing from semileptonic decays at ψ(3770)

Experimental sensitivity



~71224000 $N_{D0\bar{D}0}$(20 fb^{-1})

The background is high. The sensitivity is about 1×10^{-3}.

One can not claim a D^0 mixing based on the D^0 semileptonic decay along.

Bigi [SLAC 343(1989)169] pointed out that an observation of a signal for D0→l-X+ establish only that a certain selection rule is violated in the processes, where charm quantum number is changed. This violation can occur either through D0$\bar{D}$0 mixing, or through new physics beyond SM.

Summary for the sensitivity

$D^0\overline{D}^0$ mixing	
Reaction	**Sensitivity of R_M**
$\psi(37700) \rightarrow (K^-\pi^+)(K^-\pi^+)$	$\sim 2\times10^{-4}$
$\psi(37700) \rightarrow (K^-e^+v)(K^-e^+v)$ $\psi(37700) \rightarrow (K^-e^+v)(K^-\mu^+v)$ $\psi(37700) \rightarrow (K^-\mu^+v)(K^-\mu^+v)$	$\sim 4\times10^{-4}$
$D^{*+}D^- \rightarrow [\pi_s^+ (K^+e^-\overline{v})(K^+\pi^-\pi^-)]$ $D^{*+}D^- \rightarrow [\pi_s^+ (K^+\mu^-\overline{v})(K^+\pi^-\pi^-)]$ $D^{*+}D^- \rightarrow [\pi_s^+ (K^+e^-\overline{v})(\text{other } D^- \text{ tag})]$ $D^{*+}D^- \rightarrow [\pi_s^+ (K^+\mu^-\overline{v})(\text{other } D^- \text{ tag})]$	$\sim 5\times10^{-5}$

$\psi(4040)$ and/or $\psi(4170)$

Physics at BES-III, Int. J. of Modern Physics, V24, Suppl., May, 2009

CP Violation at BESIII

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 $\psi(3770) \to f_1^+ f_2^+, f_1^- f_2^-$

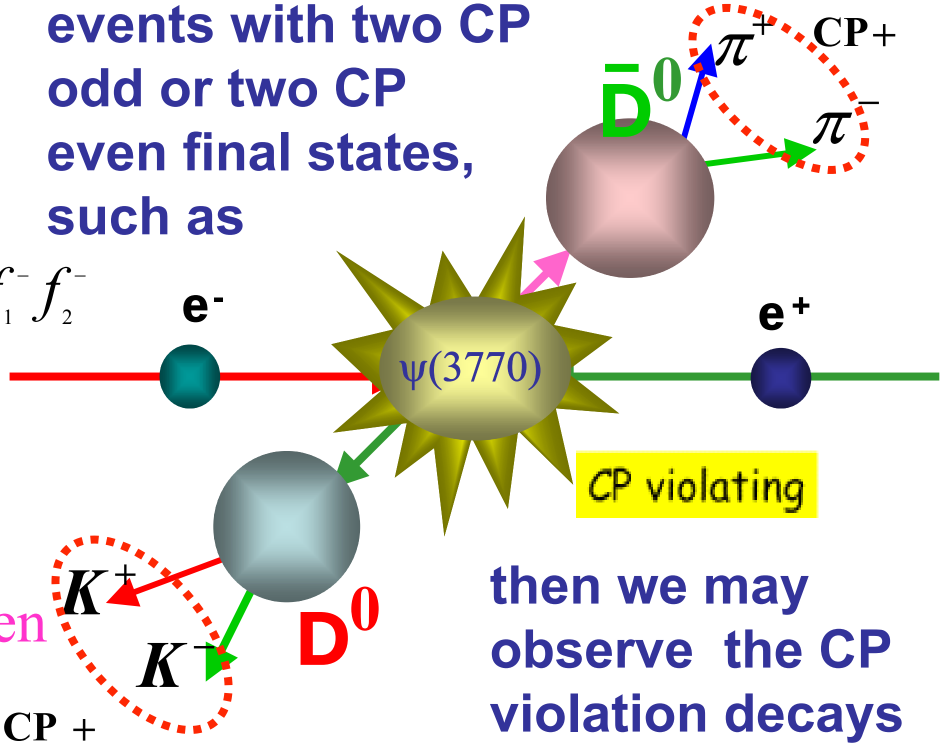
$$CP(f_1 f_2) = CP(f_1) \cdot CP(f_2) \cdot (-1)^L = -$$

$(D^0 \overline{D}^0$ are in a p wave, L = 1)

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

$\psi(3770) \to f_1^+ f_2^+$ or $f_1^- f_2^-$ are forbidden

If we observe the events with two CP odd or two CP even final states, such as



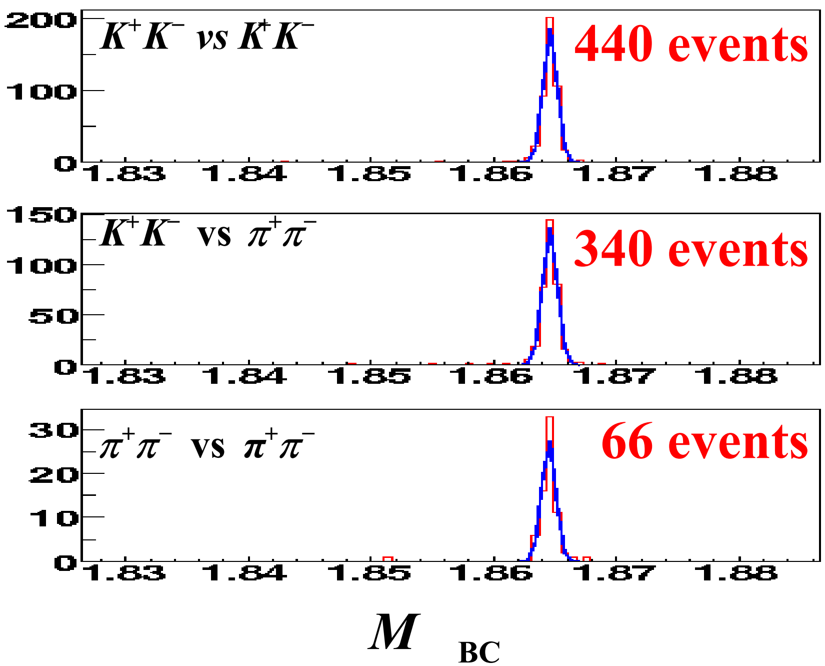
then we may observe the CP violation decays

20 fb^{-1} Ψ(3770) data ➔ ~5x10^5 CP+ and ~5x10^5 CP– tags.
With the large CP tagged samples we can search for the direct CP violation decays.

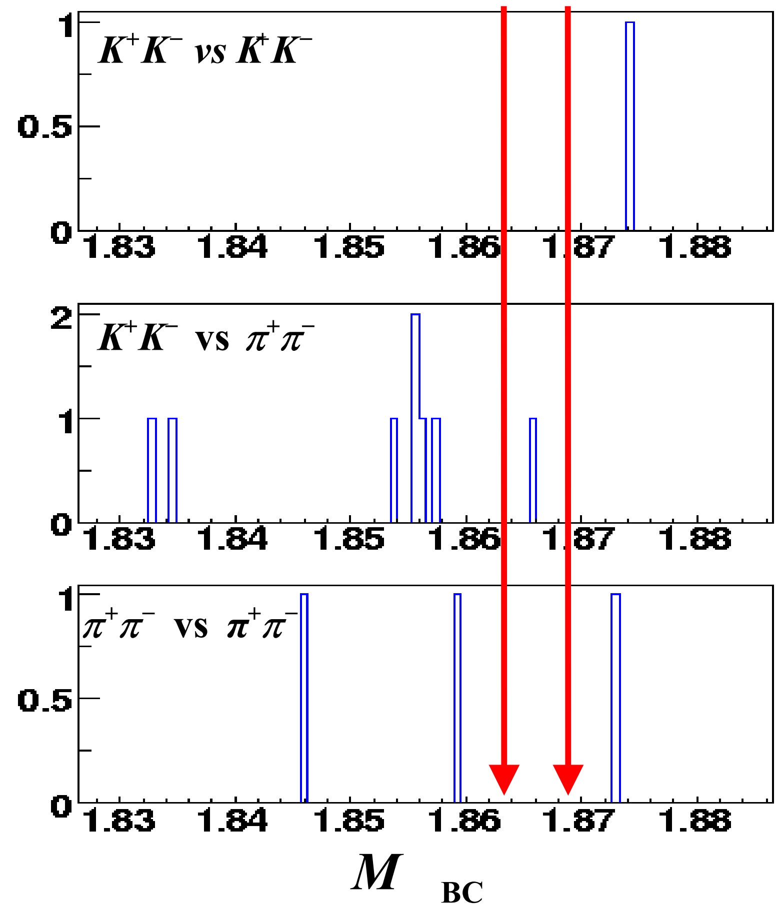
If we observed two CP odd or two CP even final states simultaneously ➔ we need to analyze many channels to elucidate the sources of CP violation !

CP violation in D decays at BESIII

Experiment sensitivity



20 fb^{-1}

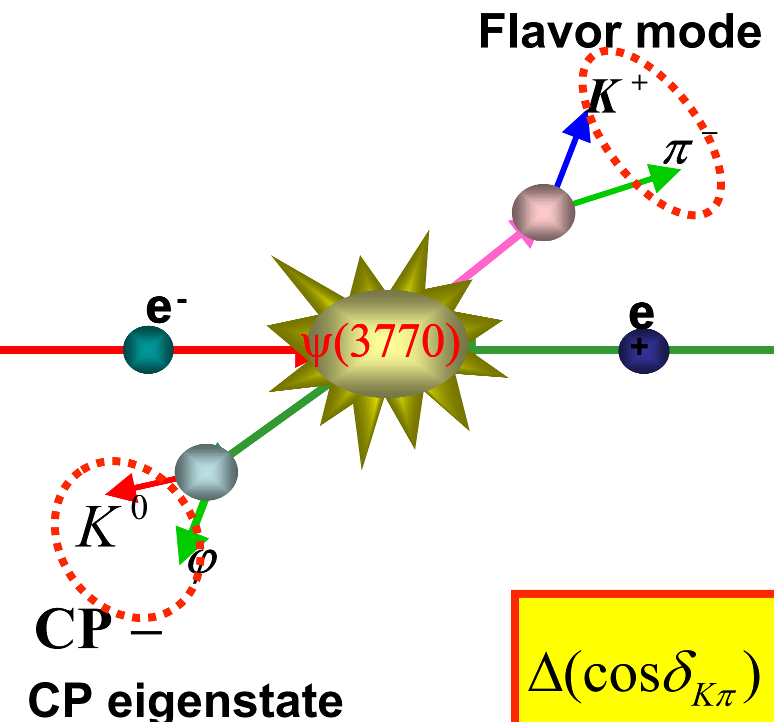


Remove the events of K^+K^- vs K^+K^-, K^+K^- vs $\pi^+\pi^-$ and $\pi^+\pi^-$ vs $\pi^+\pi^-$ away from the MC sample to study the ability of background rejection with the BES-III detector by looking for these modes from the MC samples

A_{CP} < 2.5×10^{-2} @ 90% C.L. for 4 fb^{-1}

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

The strong phase $\delta_{K\pi}$ at BES-III



We can measure the strong phase at $\psi(3770)$ with the CP tags vs $K\pi$

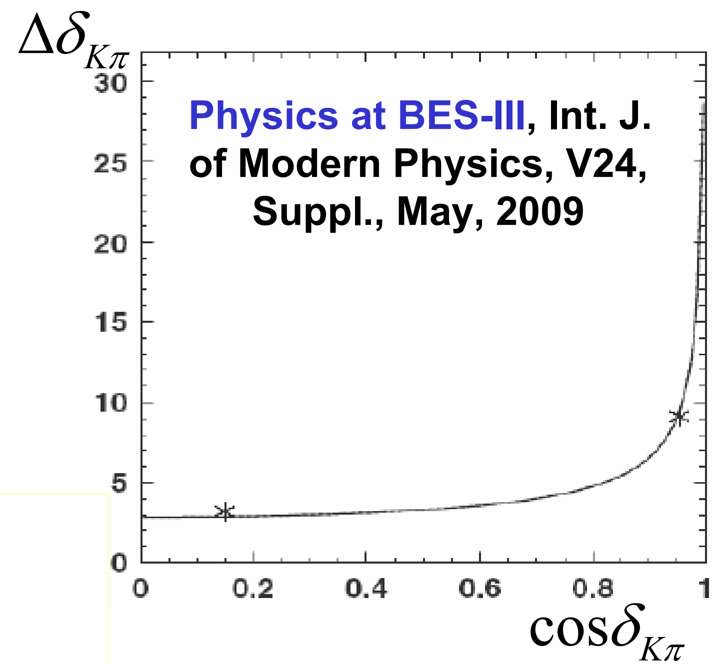
Decay rate

$$A = \frac{\Gamma_{K\pi \text{ VS } f_+} - \Gamma_{K\pi \text{ VS } f_-}}{\Gamma_{K\pi \text{ VS } f_+} + \Gamma_{K\pi \text{ VS } f_-}} = 2\sqrt{R_D}\cos\delta_{K\pi}$$

$$[R_D = (3.7 \pm 0.19) \times 10^{-3}]$$

$$\Delta(\cos\delta_{K\pi}) \approx \frac{1}{\sqrt{N_{K^-\pi^+}}}\frac{1}{2\sqrt{R_D}}$$

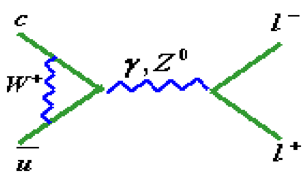
20 fb^{-1} $\psi(3770)$ data at BES-III, the expected error: $\Delta(\cos\delta_{K\pi}) \approx \pm 0.04$

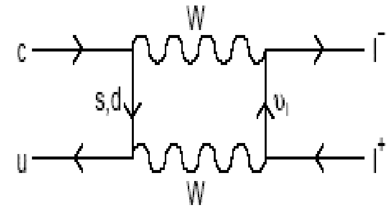


Rare D decays at BES-III

Charm FCNC decays are much highly GIM suppressed in SM.

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





New Physics may enhance these decay processes.

For example, R-parity violating SUSY gives

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

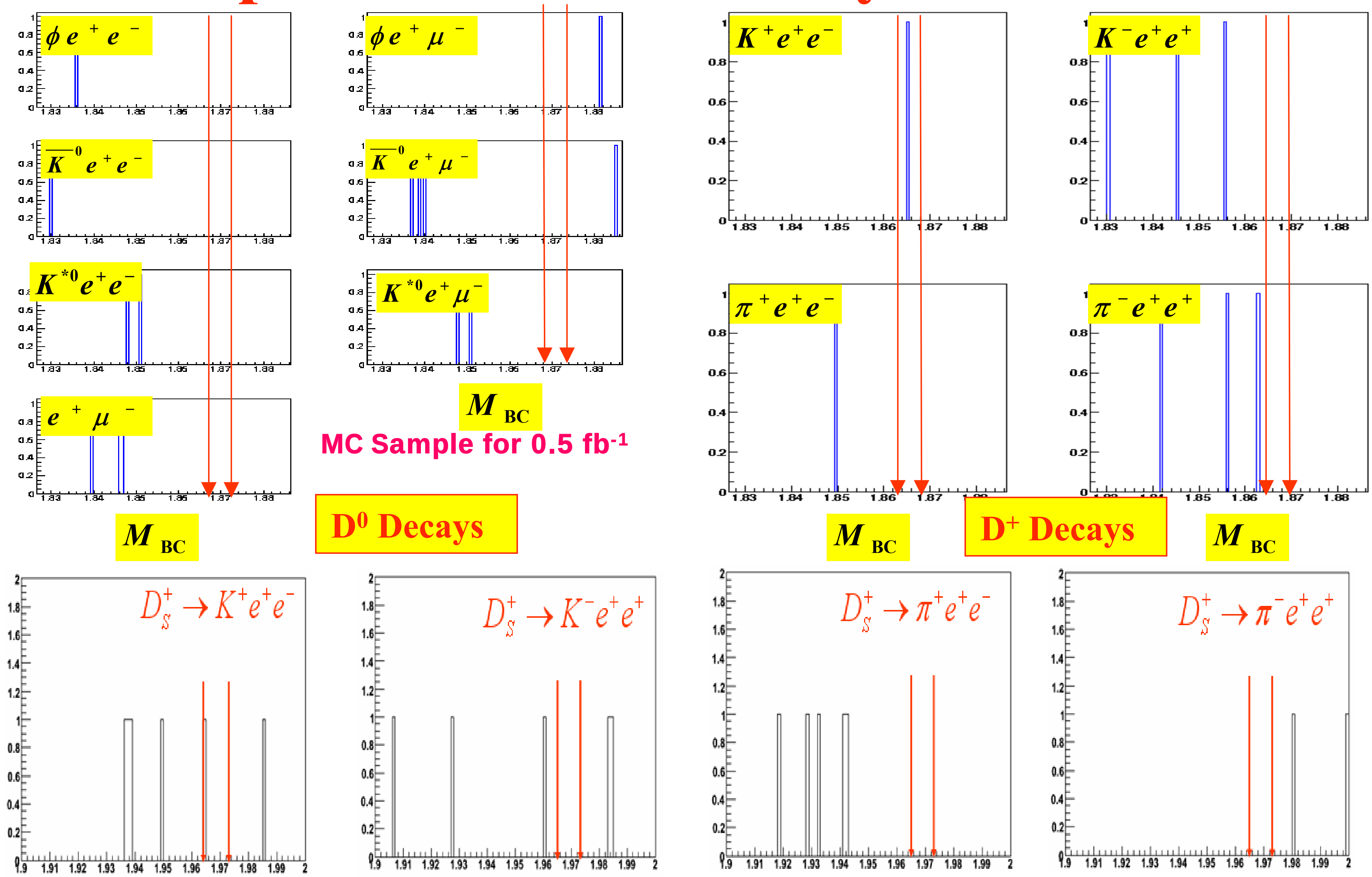
Currently, the best limits for these decays are from BABAR, **[Phys. Rev. D66, (2002)014009]**

Observation of charm FCNC and lepton number violating decays could indicate new physics.

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

Search for these kinds of rare decays can probe for NP

Experimental sensitivity at BES-III



D^+_S Decays

MC Sample for 4 fb^{-1}

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

Experimental sensitivity at BES-III

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 $\psi(4030)$ 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 $\psi(3770)$ data,.

Experimental sensitivity at BES-III

Mode	Exp.	Best U.L. (10^{-6})	BES-III ($\times 10^{-8}$)
$\pi^+e^+e^-$	CLEO-c	7.4	5.6
$\pi^+\mu^+\mu^-$	FOCUS	8.8	8.7
$\pi^+\mu^+e^-$	E791	34	5.9
$\pi^-e^+e^+$	CLEO-c	3.6	5.6
$\pi^-\mu^+\mu^+$	FOCUS	4.8	8.7
$\pi^-\mu^+e^+$	E791	50	5.9
$K^+e^+e^-$	CLEO-c	6.2	6.7
$K^+\mu^+\mu^-$	FOCUS	9.2	10.5
$K^+\mu^+e^-$	E791	68	8.3
$K^-e^+e^+$	CLEO-c	4.5	6.7
$K^-\mu^+\mu^+$	FOCUS	13	10.4
$K^-\mu^+e^+$	E687	130	8.3

Mode	Expt.	Best U.L. (10^{-6})	BES-III ($\times 10^{-8}$)
$\gamma\gamma$	CLEO	28	5.0
$\mu^+\mu^-$	D0	2.4	17.0
μ^+e^-	E791	8.1	4.3
e^+e^-	E791	6.2	2.4
$\pi^0\mu^+\mu^-$	E653	180	12.3
$\pi^0\mu^+e^-$	CLEO	86	9.7
$\pi^0e^+e^-$	CLEO	45	7.9
$K_S\mu^+\mu^-$	E653	260	10.6
$K_S\mu^+e^-$	CLEO	100	9.6
$K_Se^+e^-$	CLEO	110	7.5
$\eta\mu^+\mu^-$	CLEO	530	15.0
$\eta\mu^+e^-$	CLEO	100	12.0
ηe^+e^-	CLEO	110	10.0

The sensitivities at BES-III are obtained based on fully BES-III Monte Carlo simulation for 20 fb^{-1} $\psi(3770)$ data.

Other physics topics

A lost of other physics topics are not mentioned, which are D→Vlν, $K^-\mu^+\nu$, Ds semileptonic decays, other kinds of D and Ds hadronic decays, Dalitz plot analyses, interference between two different D hadronic decay amplitudes, measurements of the masses of charmed mesons, production cross sections, and so on …

Studies of the non-$D\bar{D}$ decays of the resonances also are interesting, which will be used to test PQCD calculations and search for some new physics phenomenon. These physics topics are also going to be studied with the open charm data at the BES-III.

Summary

Uncertainties

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 20+4 fb^{-1} data)

- $D^0\bar{D}^0$ Mixing — Sensitivity : 10^{-4}
- CP Violation — Sensitivity : $A_{CP} < 10^{-3}$ @ 90% C.L.
- Rare Decays — Sensitivity : 10^{-8} for D mesons @ 90% C.L.
  Sensitivity : 10^{-5}~10^{-6} for D_s meson @ 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 !

The CKM Matrix

The parameters of SM are: $\alpha, G_F, \sin^2\theta_w, M_H,$ **Fermion masses 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

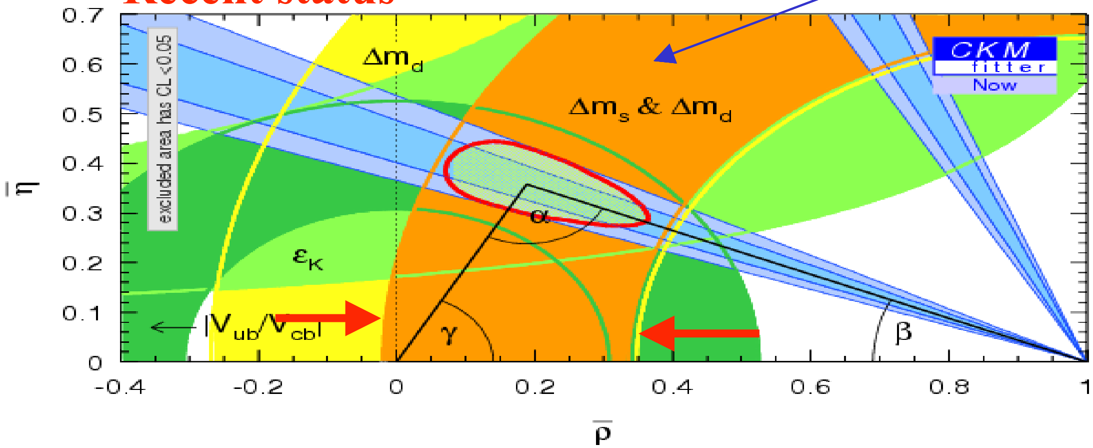
λ, A, ρ and η **are fundamental parameters in SM**

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 !

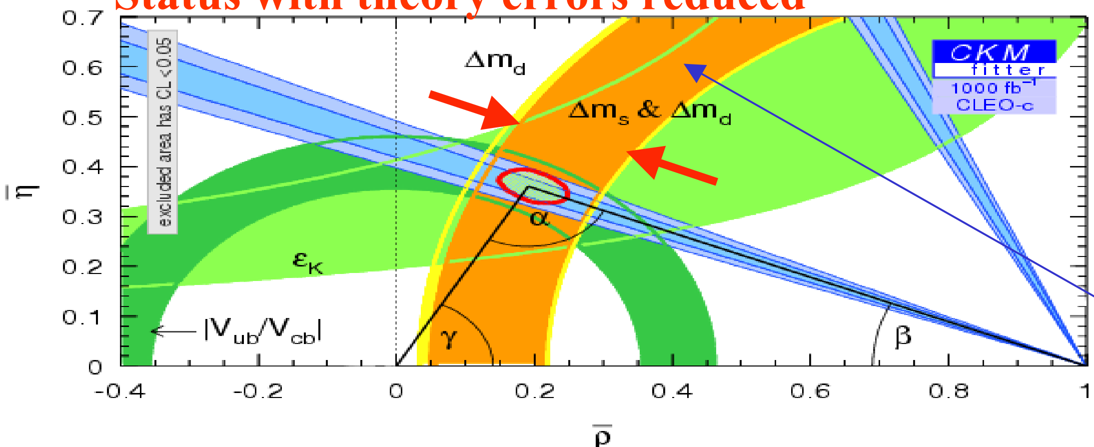
The CKM Matrix at BES-III

The constraints in (rho, eta) plane arising from some measurements …

Recent status



Status with theory errors reduced

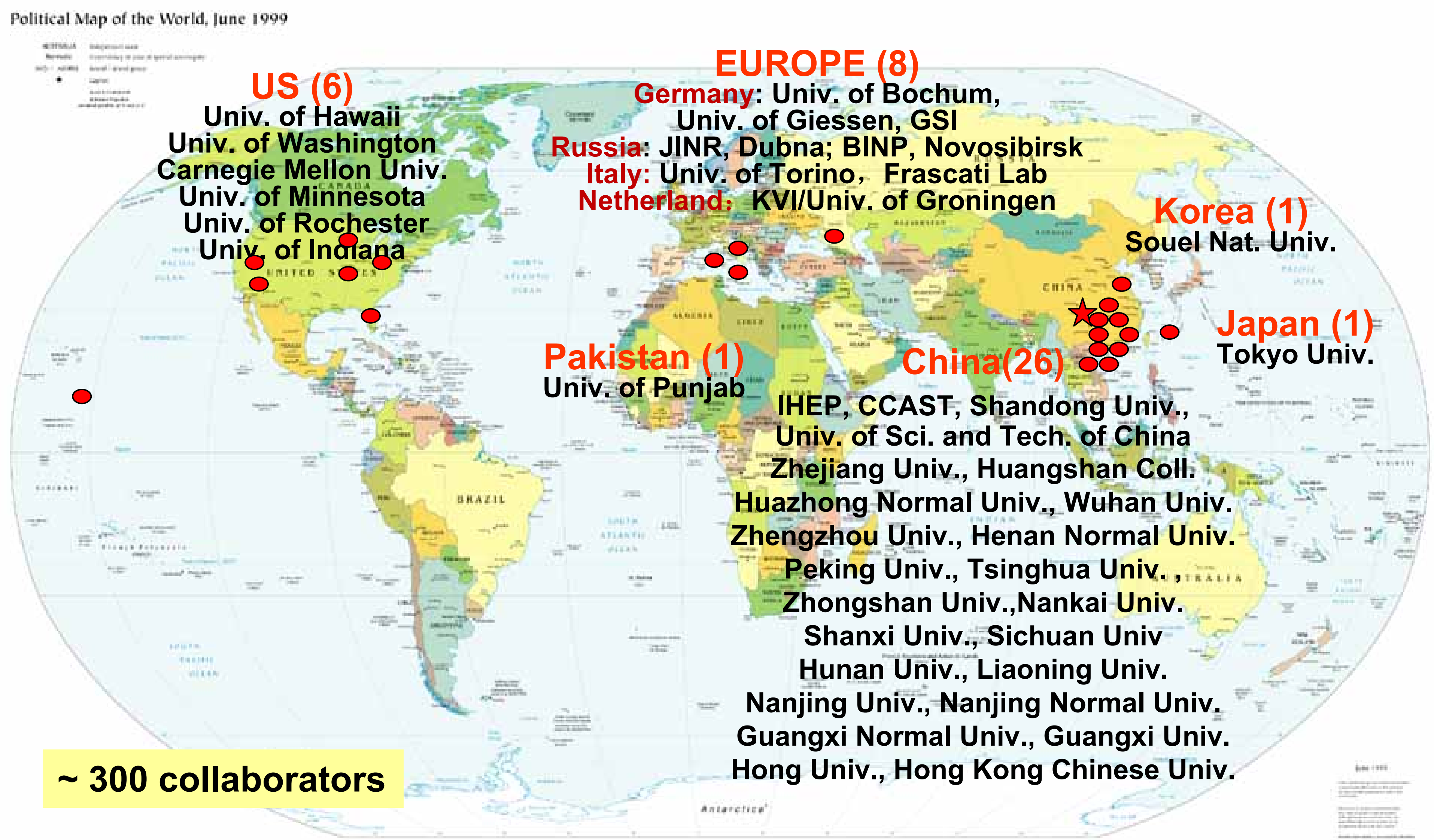


The width of the bands is mainly dominated by theoretical (LQCD) errors on f_B, f_{Bs} and B semileptonic form factors.

The decay constants and the form factors of charmed mesons to be measured at BES-III can be used to calibrate and improve the LQCD calculations on the quantities, in turn, to improve the constraints

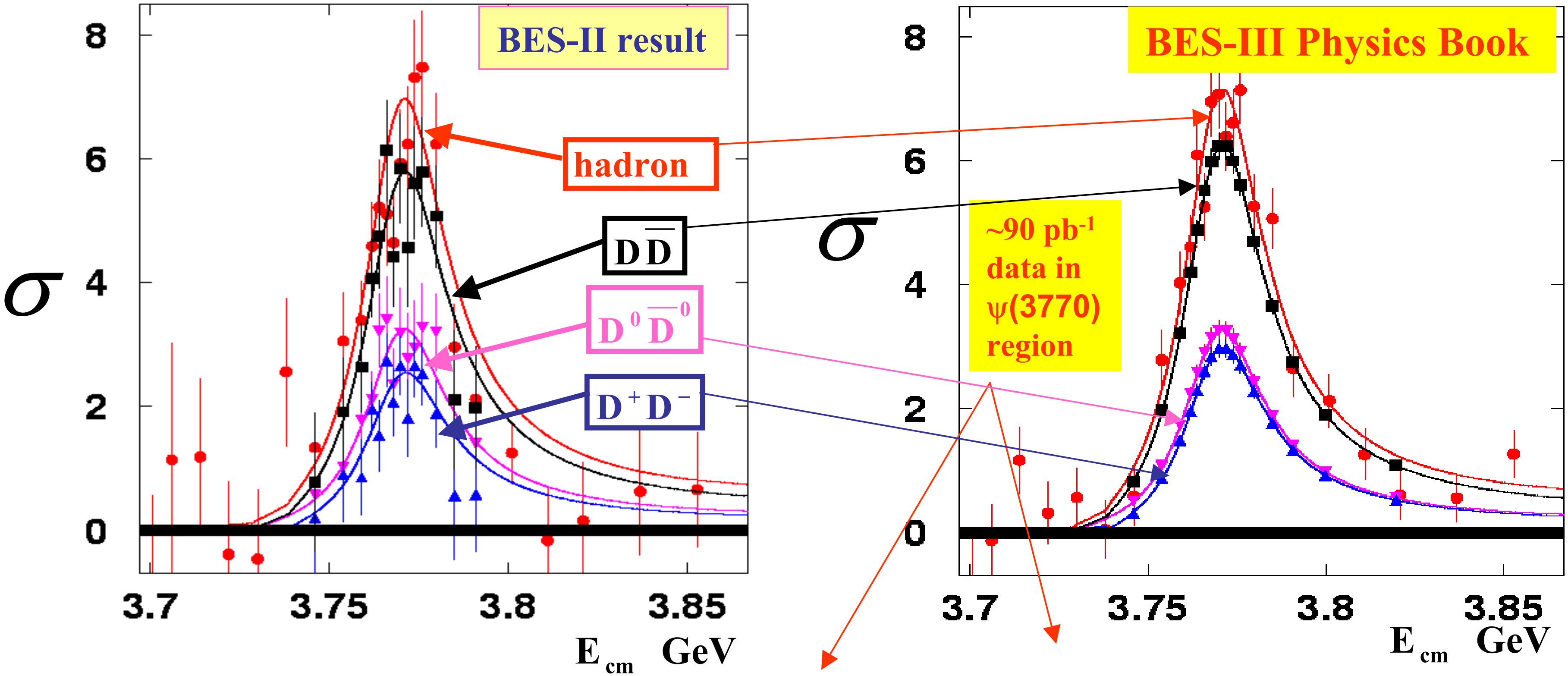
Then the uncertainties can be reduced

BESIII collaboration



Decay Mode	Experimental Limit	$Br_{S.D.}$	$Br_{L.D.}$
$D^+ \to X_u^+ e^+ e^-$		2×10^{-8}	
$D^+ \to \pi^+ e^+ e^-$	$<4.5\times10^{-5}$		2×10^{-6}
$D^+ \to \pi^+ \mu^+ \mu^-$	$<1.5\times10^{-5}$		1.9×10^{-6}
$D^+ \to \rho^+ e^+ e^-$	$<1.0\times10^{-4}$		4.5×10^{-6}
$D^0 \to X_u^0 e^+ e^-$		0.8×10^{-8}	
$D^0 \to \pi^0 e^+ e^-$	$<6.6\times10^{-5}$		0.8×10^{-6}
$D^0 \to \rho^0 e^+ e^-$	$<5.8\times10^{-4}$		1.8×10^{-6}
$D^0 \to \rho^0 \mu^+ \mu^-$	$<2.3\times10^{-4}$		1.8×10^{-6}
$D^+ \to X_u^+ \nu \bar{\nu}$		1.2×10^{-15}	
$D^+ \to \pi^+ \nu \bar{\nu}$			5×10^{-16}
$D^0 \to K^0 \nu \bar{\nu}$			2.4×10^{-16}
$D_s \to \pi^+ \nu \nu$			8×10^{-15}
$D^0 \to \gamma\gamma$		4×10^{-10}	few $\times10^{-8}$
$D^0 \to \mu^+ \mu^-$	$<3.3\times10^{-6}$	1.3×10^{-19}	few $\times10^{-13}$
$D^0 \to e^+ e^-$	$<1.3\times10^{-5}$	$(2.3\text{-}4.7)\times10^{-24}$	
$D^0 \to \mu^\pm e^\mp$	$<8.1\times10^{-6}$	0	0
$D^+ \to \pi^+ \mu^\pm e^\mp$	$<3.4\times10^{-5}$	0	0
$D^0 \to \rho^0 \mu^\pm e^\mp$	$<4.9\times10^{-5}$	0	0

non-D$\bar{D}$ Br. Fraction of ψ(3770)



	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

$B[\psi(3770) \to D\bar{D}]$

$(88.2 \pm 2.4 \pm \sim 2.0)$ %	Measured value
89 %	Input value

With ~90 pb^{-1} of data collected from 3.65 to 3.875 GeV with the BES-III at the BEPC-II, we can measured the non-DDbar branching fraction of ψ (3770) decays at an absolute precision of ~3% (from cross section scans).