Preliminary Results on Charm Decays at BESIII

L.L. Jiang
[For BESIII Collaboration]
Institute of High Energy Physics, Beijing, China

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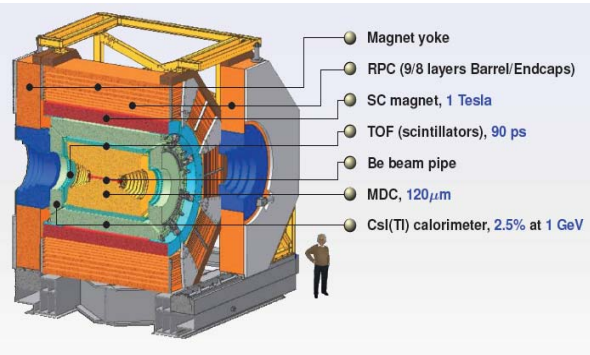
OUTLINE

- Introduction of BEPCII and BESIII
- The Major Physics Topics
- Ongoing analysis
- Summary

Satellite view of BEPCII /BESIII

BESIII- A brand-new detector



The BEPCII is a double-ring machine with designed peak luminosity of 1×10^{33} cm^{-2}s^{-1} at $\sqrt{s}$ = 3.78 GeV.

2004: start construction

2008: test run

2009-now: BEPCII/BESIII data taking

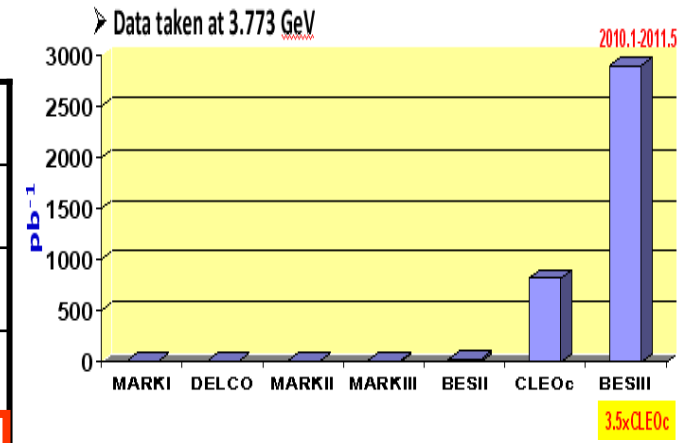
Achieved Luminosity: 0.65×10^{33} cm^{-2}s^{-1}

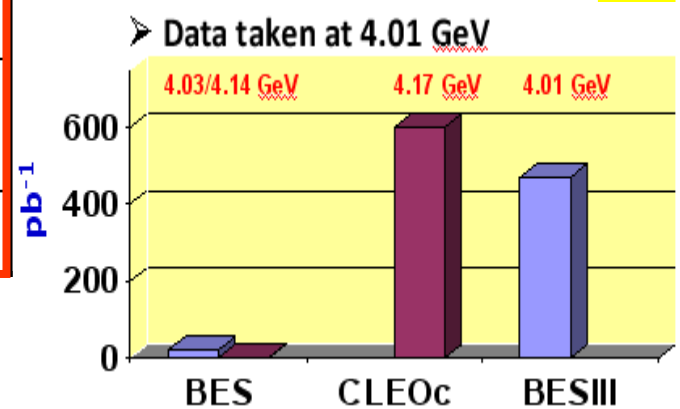
Detector parameters comparison

Sub-system	BESIII	BESII
MDC	σ_{xy} = 130 μ m	250 μ m
	Δ P/P=0.5% @ 1GeV SC magnet	2.4%@1GeV
	$\sigma_{dE/dx}$= (6-7) %	8.5%
EM Calorimeter	Δ E/E = 2.5% @ 1 GeV σ_z = 0.6cm @ 1 GeV	20%@1GeV 3cm @ 1 GeV
TOF detector	σ_T(ps)=100 ps barrel 110 ps endcap	180 ps barrel 350 ps endcap
μ counters	9 layers	3 layers
Magnet	1.0 tesla	0.4 tesla

Data samples at BESIII at present

Ecm [GeV]	Physics	Size
3.097	J/ψ decays	225M
3.686	ψ(3686) decays	106M
3.650	--	~44pb^{-1}
3.773	ψ(3770), D	2.9fb^{-1}
ψ(3770) scan data From 3.64 to 3.89 GeV	--	~76pb^{-1}
4.010	Ds and XYZ spectroscopy	~0.5fb^{-1}





More data above the DD thresthold will be collected at BESIII in the future!

Good opportunity for us!

The Major Physics Topics [1]

Purpose: Overcome the non-perturbative QCD roadblock, test pQCD calculations and probe for new Physics beyond SM

- **Semileptonic decays of D and D_s**

  $|V_{cs}|$, $|V_{cd}|$ and form factor

- **Purely leptonic decays of D^+ and D_s^+**

  decay constants f_D & f_{Ds}

- **Absolute hadronic branching fractions**

  To normalize B and Z physics

Which can be test QCD techniques in charm sector and apply to B sector. More to Improve determinations of $|V_{ub}|$, $|V_{cb}|$, $|V_{td}|$ and $|V_{ts}|$.

The Major Physics Topics [2]

Probe for New Physics

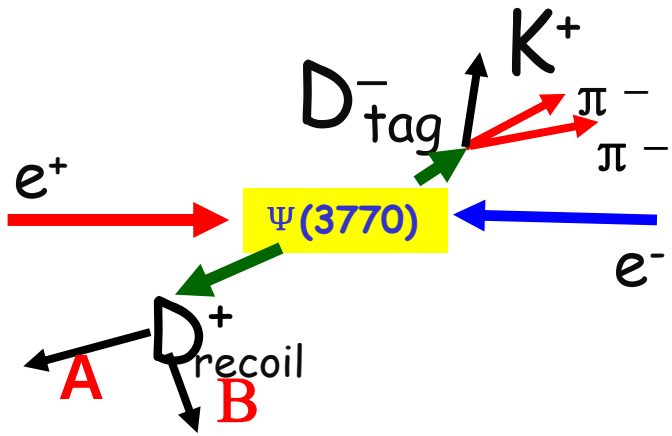
- *D^0D^0 mixing*
- *Searching for CP Violation decays of D*
- *Searching for Rare Decays of D and D_s mesons*

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

Advantage of Open Charm at Threshold

At the center-of-mass energies near the DD and $D_s^+D_s^-$ production thresholds, the D^0, D^+ and D_s^+ mesons are produced in pair.
We can take the advantage of the fully reconstructed one of the open-charm pair to study the other anti-open-charm decays

$D_{(s)} \rightarrow$ tag mode
Vs
$D_{(s)} \rightarrow A+B$



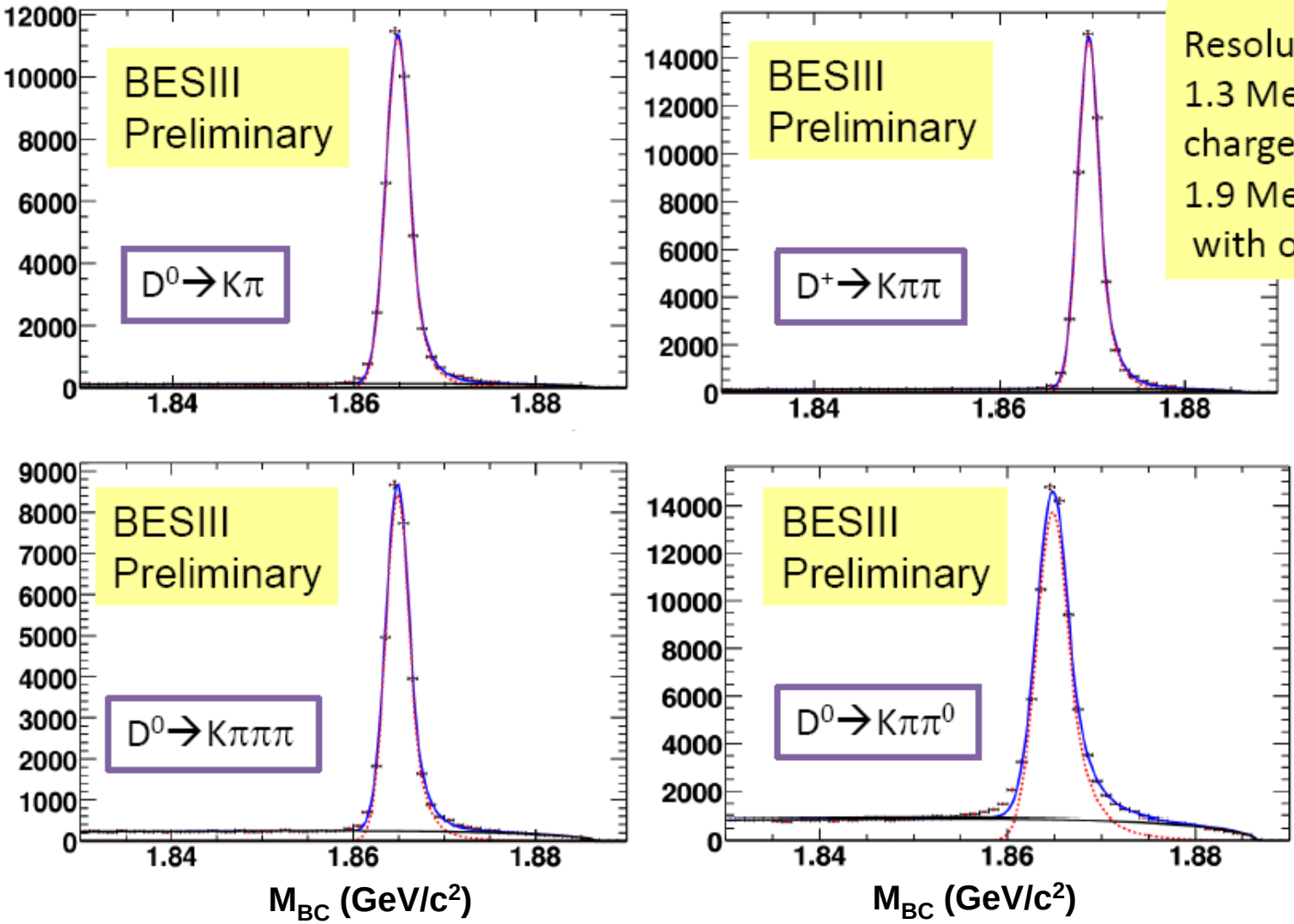
$$Br(D^+ \rightarrow A+B) = \frac{N^{obs} - N^b}{N_{tag} \times \varepsilon}$$

Singly tagged D events

From a portion of the data @ 3.773 GeV

$$M_{BC} = \sqrt{E_{beam}^2 - |p_D|^2}$$

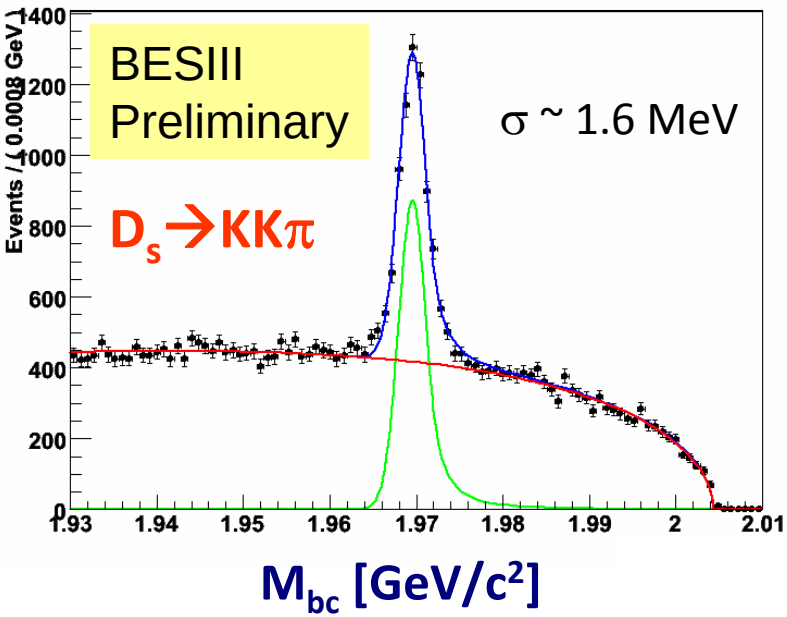
Resolution:
1.3 MeV for pure charged modes;
1.9 MeV for modes with one π^0.

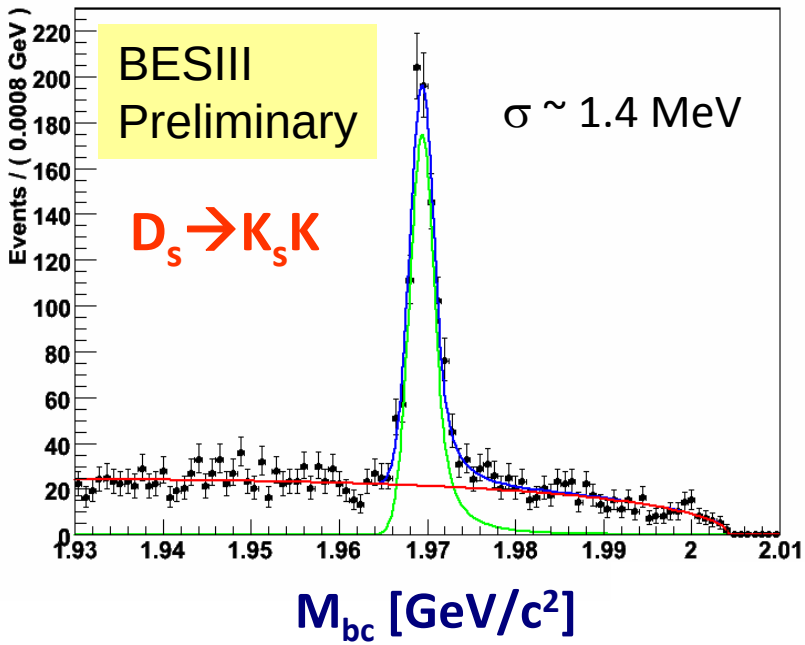


More singly tagged D^0/D^+ modes can be used in BESIII analysis frame at present.

Singly tagged D_s events

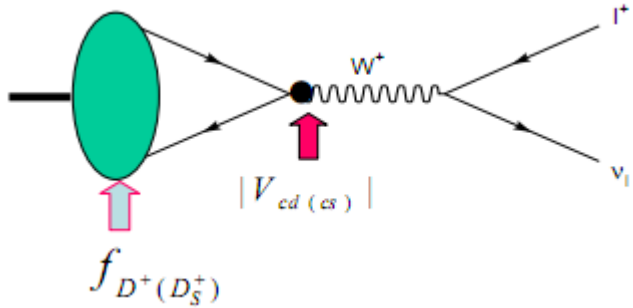
BESIII Data @ 4.01 GeV





Purely-leptonic decays

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



The decay diagram for $D^+ \rightarrow l^+\nu$

The decay constant f_{D+} is related to the decay rate by:

$$\Gamma(D^+ \rightarrow l^+ \upsilon_l) = \frac{G_F^2 f_{D^+}^2}{8\pi} |V_{cd}|^2 m_l^2 m_{D^+} (1 - \frac{m_l^2}{m_{D^+}^2})^2$$

- **Ongoing analysis of the purely leptonic decays:**

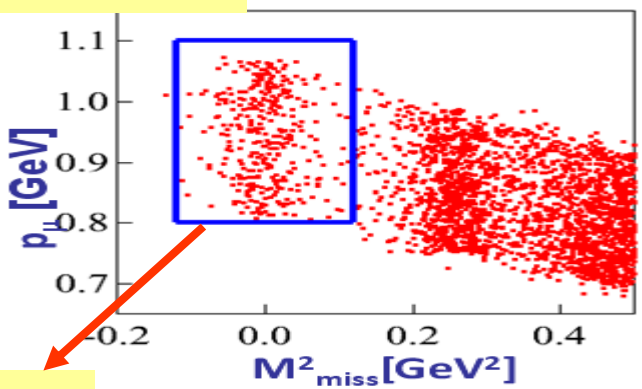
$D^+ \rightarrow \mu^+\nu_\mu, \tau^+\nu_\tau, e^+\nu_e$

$D_s^+ \rightarrow \mu^+\nu_\mu, \tau^+\nu_\tau$

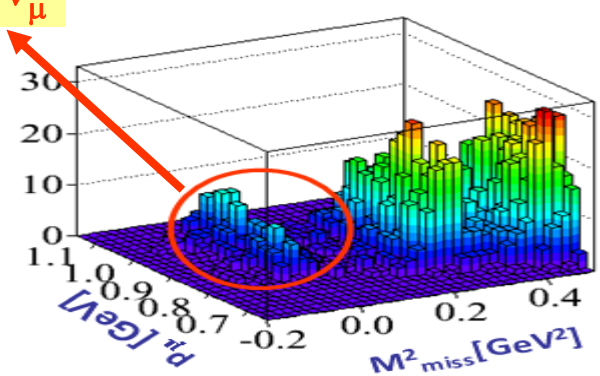
Purely-leptonic decays

Candidate events for $D^+ \rightarrow \mu^+ \nu_\mu$

BESIII Preliminary



$D^+ \rightarrow \mu^+ \nu_\mu$



$$M^2_{miss} = E^2_{miss} - P^2_{miss}$$

If with ~2.9fb^{-1} ψ(3770) data at BESIII:

$$\frac{\Delta Br}{Br} = 5.5\%$$

BESIII Physics book

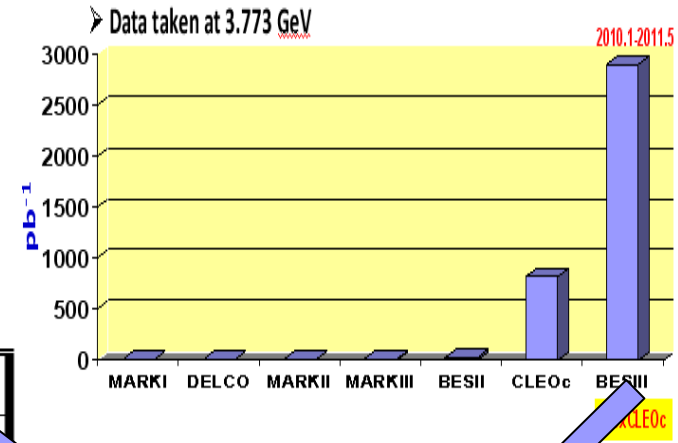
Insert the quantities:

$$\frac{\Delta \tau_D}{\tau_D} = 0.7\% \qquad \frac{\Delta |V_{cd}|}{|V_{cd}|} = 0.4\%$$ **[PDG10]**

$\Rightarrow$ **$\Delta f_{D+}/f_{D+} \cong 2.8\%$ [stat]**

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

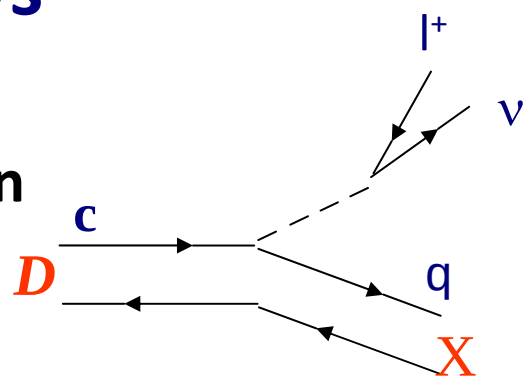
Purely-leptonic decays



EXP or Theory	f_{D+} (MeV)
BESIII expectation [2.9 fb^{-1}]	~2.8% (stat.)
CLEO-c (818 pb^{-1})	206 ± 9 [4.1% stat]
Lattice[1]	208 ± 4
Lattice[2]	217 ± 10
PQL	197 ± 9
QL(QCDSF)	206 ± 23
QS(Taiwan)	235 ± 16
QL(UKQCD)	210 ± 20
QL	211 ± 18
QCD Sum Rules[1]	177 ± 21
QCD Sum Rules[2]	203 ± 20
Field Correlators	210 ± 10
Light Front	206

With 2.9 fb^{-1} $\psi(3770)$ data collected at BESIII till now, the relative uncertainty of fD could reduced to ~2.8% by fully Monte Carlo simulation!

Semi-leptonic decays



- Extract out the form factor, which in turn be used to calibrate LQCD calculations

- Extract the $|V_{cs}|$ and $|V_{cd}|$. Any significant inconsistency between the measured values and the ones obtained from the CKM fit could provide a valuable indication of the NP beyond the SM in the first two quark generation

- Ongoing analysis of the semi-leptonic decays:

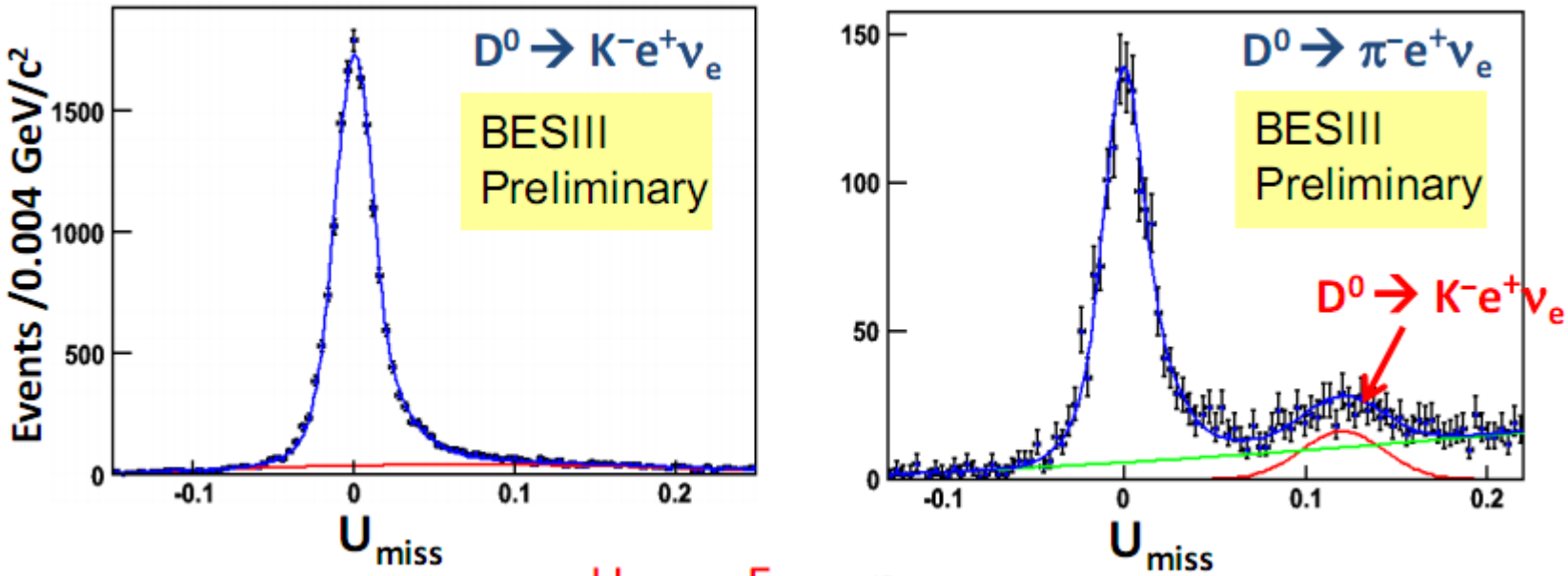
$D^0 \rightarrow K^- e^+ \nu_e$, $\pi^- e^+ \nu_e$

$D^+ \rightarrow \omega e^+ \nu_e$, $\phi e^+ \nu_e$

$D^+ \rightarrow \pi^0 e^+ \nu_e$, $\eta e^+ \nu_e$

Semi-leptonic decays

Candidate events for $D^0 \rightarrow K^- e^+ \nu_e$, $\pi^- e^+ \nu_e$



$U_{miss} = E_{miss} - p_{miss}$.

The accuracy levels for measurements of $Br[D^0 \rightarrow K^- e^+ \nu_e]$ and $Br[D^0 \rightarrow \pi^- e^+ \nu_e]$ are , respectively, ~0.8% and ~1.9% with 2.9fb^{-1} $\psi(3770)$ data at BESIII.

Semi-leptonic decays

For the transition to pseudoscalar meson, the decay rates Γ ralates to the CKM matrix elements and the form factors by:

$$\Gamma(D^0 \to K^- e^+ \nu_e) = 1.53 \times |V_{cs}|^2 \times |f_+^K(0)|^2 \times 10^{11} s^{-1}$$

$$\Gamma(D^0 \to \pi^- e^+ \nu_e) = 3.01 \times |V_{cd}|^2 \times |f_+^\pi(0)|^2 \times 10^{11} s^{-1}$$

- **$f^K_+(0)$ and $f^\pi_+(0)$**

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

- **$|V_{cs}|$ and $|V_{cd}|$**

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

$\Delta Br/Br$ = 0.8%, 1.9%, with 2.9fb^{-1} $\psi(3770)$ data.

$\Delta\tau_D/\tau_D$ = 0.4%, [PDG10]

$\Delta f/f$ = 2.5% [HPQCD]

$\Delta|V_{cs}|/|V_{cs}|$ = 0.02%, $\Delta|V_{cd}|/|V_{cd}|$ = 0.3%, [PDG10 CKMfitter]

$$\frac{\Delta|f_+^K(0)|}{|f_+^K(0)|} = 0.4\%, \quad \frac{\Delta|f_+^\pi(0)|}{|f_+^\pi(0)|} = 1.0\%,$$

$$\frac{\Delta|V_{cs}|}{|V_{cs}|} = 2.5\%, \quad \frac{\Delta|V_{cd}|}{|V_{cd}|} = 2.7\%,$$

PDG10: $\Delta V_{cs}/V_{cs}$~ 3.5% $\Delta V_{cd}/V_{cd}$~ 4.8%

Absolute branching fraction measurements

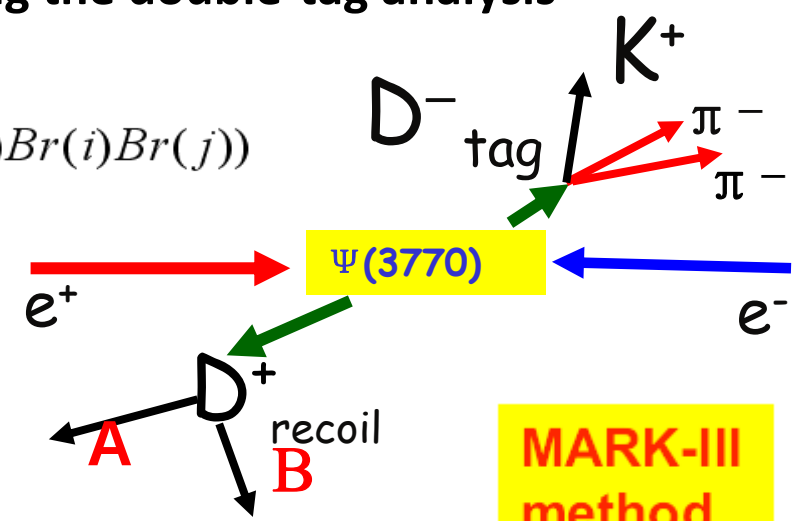
Single tag events:

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

double tag events:

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

Using the double-tag analysis



MARK-III method

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

- **Normalize the branching fractions for B and Z decays.**
- **Affect determinations of the CKM matrx elements related to B semi-leptonic decays**

Measurements of the cross sections for DD production

By analyzing open-charm data taken at BESIII, we can precisely measure the the cross sections for D meson pair production.

- **Ongoing analysis :**
  - **Cross sections for D^0D^0, D^+D^- and DD @ 3.773 GeV**
  - **Cross sections for charm pairs @ 4.01 GeV**
  - **Cross sections for D^0D^0, D^+D^- and DD in 3.73-3.89 GeV region**

Measurements of the cross sections for DD production

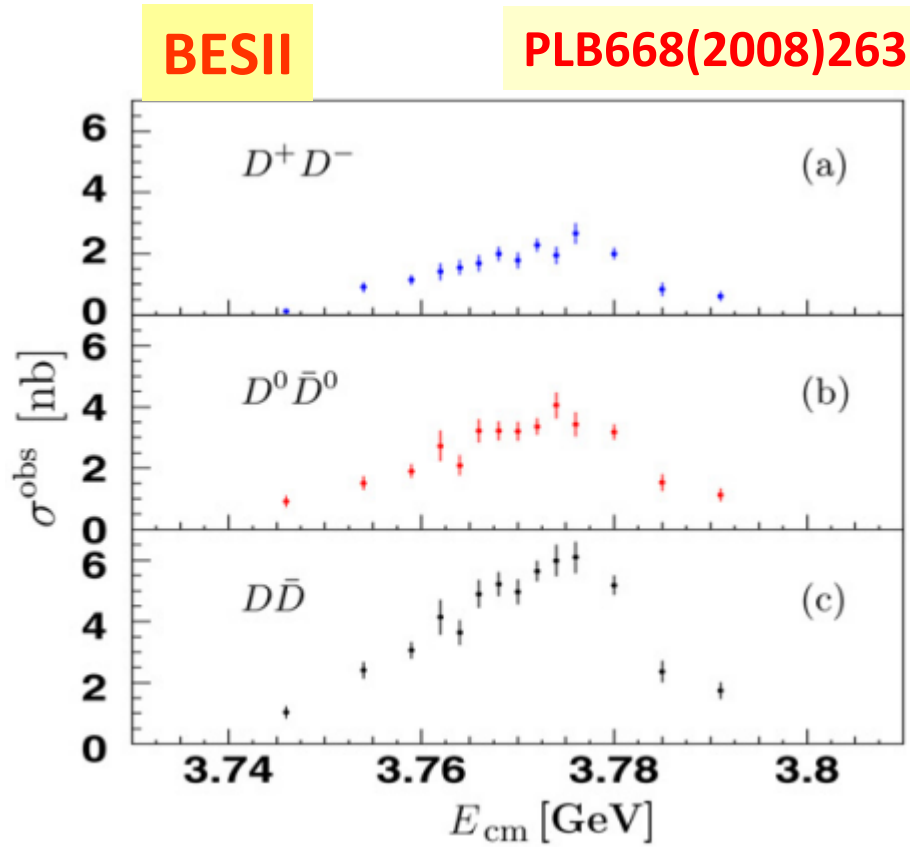
Why we are so interested in the cross sections—

- Sensitive to the strong interaction dynamics for the DD production and decays.
- Sensitive to some possible new structure(s) existing around the DD thresthold region.

The measured cross sections for D^+D^-, D^0D^0 and DD production in the $\psi(3770)$ resonance region may help us to understand the "non-DD" decay of the traditional $\psi(3770)$.

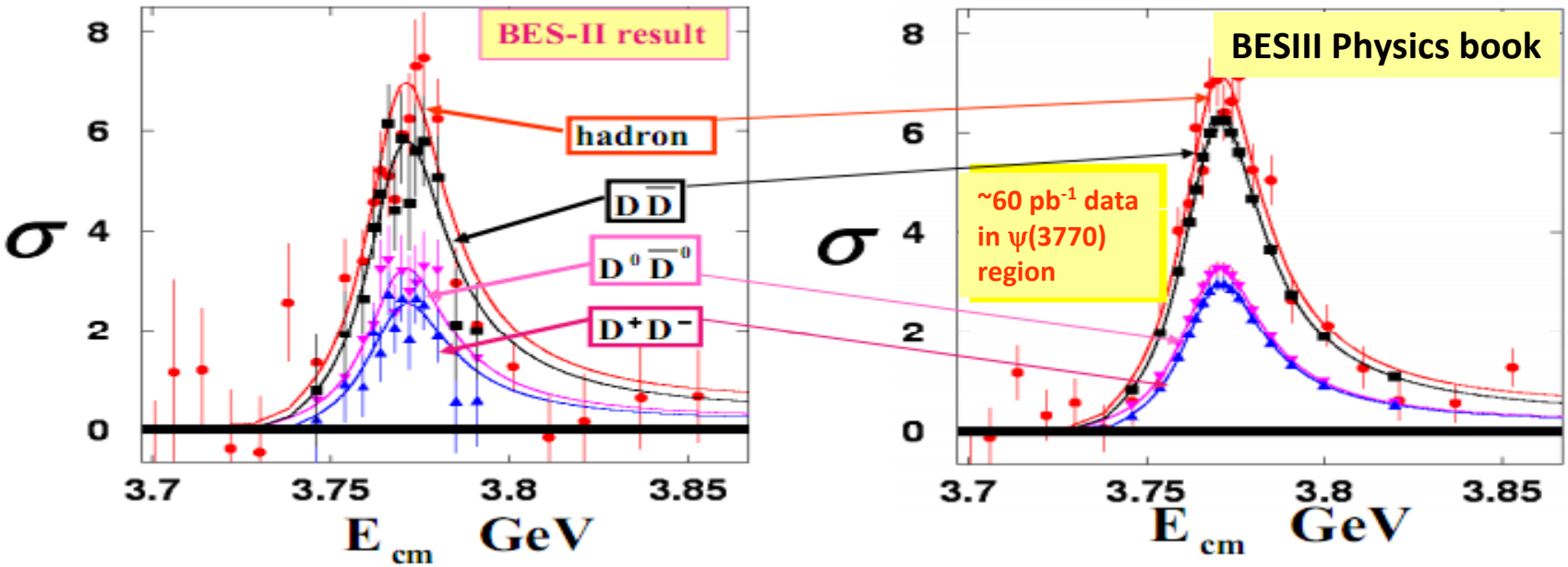
Measurements of the cross sections for DD production

Unfortunately, due to statistical limit, there measurements can not give definite conclusion about the production dynamics or whether there is a new structure around 3.770 GeV.



Now at BESIII, we have ~76pb^{-1} ψ(3770) scan data. By fully Monte Carlo simulation, the relative statistical uncertainty in the measured DD cross section can be reduced to be **~3%.** While the uncertainty in the measurements at the BESII is **~8%.**

Non-DD Branching Fraction of ψ(3770)



With ~60pb^{-1} data collected from 3.65 to 3.875 GeV with the BESIII at the BEPC-II, we can measure the non-DD branching fraction of ψ(3770) decays at an obsolute precison of ~3%(from cross section scans).

Non-DD Branching Fraction of $\psi(3770)$

The large open-charm data allows us to searching for the exlusive non-DD final states of the heavy charmonium states decay above the DD thresthold.

- A method to search for the new structure(s) in the open charm energy region
- To undersand the nature of the heavy cc states above the DD threshold well.

- **Ongoing analysis :**
  - **Measurement of the Br[$\psi(3770) \rightarrow$non-DD]**
  - **Searching for the non-DD final states of $\psi(3770)$ decays**
    - VP [$\rho\pi$, $\rho^0\pi^0$, $\rho^+\pi^-$, $\rho\eta$, $\phi\eta$,K*K……]
    - LH$|_{\text{multi_body}}$
    - BB
    - ……

Other Analysis at BESIII

- **Dalitz plot analysis ($D^0 \to K^-\pi^+\pi^0$, $D^+ \to K^0_s\pi^+\pi^0$, $D^0 \to K^-\pi^+\eta$, $D^+ \to K^+K^-\pi^+$)**
  - Study the $K\pi$ system, searching for the low mass scalar resonance κ
  - Develop the Dalitz plot analysis software for Charm physics at BESIII
- **Searching for CP violation through T-violation in modes: $D^+ \to K_s^0K^+\pi^+\pi^-$ and $D^+ \to K^+K^-\pi^+\pi^0$.**
- **Measurement of the line shape for $e^+e^- \to$ inclusive hadrons production in the energy region from 3.64 to 3.89 GeV.**
- **……**

Summary

- **High luminosity of BEPCII and the good performance of BESIII give us better chance to study the charm decays.**
- **Rich results are coming out soon**
  - Challenge SM with precisely measurements on decay constants f_{D+} & f_{Ds}
  - Check the LQCD with precisly measurements on form factors and CKM matrix.
  - Precise measurement on absolute branching fractions.
  - Precise measurement on the line shapes of the cross sections for $e^+e^- \rightarrow D^+D^-$, D^0D^0 and DD.
  - Measurement of Br[$\psi(3770) \rightarrow$non-DD] with lower statistical error.
  - More works about the study of the non-DD decays of $\psi(3770)$.
  - Dalitz plot analysis
  - Searching for CP or T Violation in D-meson decays

Thank you!