Search for $D^{+,0} \to \omega\pi$ and $\mathcal{BF}$ measurement of $D^0 \to K_s^0 K^+ K^-$

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University of Mainz

Charm 2015

2015-05-20 Detroit

Charm activities @BESIII

- Rare decays
  - e.g. $D^0 \to \gamma\gamma$
- (Semi-) leptonic decays
  - e.g. $D^0 \to K\pi e\nu_e$
- D^0 mixing parameters
  - e.g. strong phases, y_{CP}
- Hadronic decays

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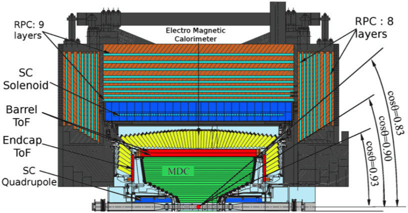
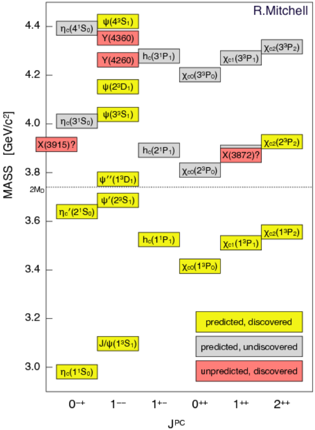
Experiment



- BEPCII symmetric e^+e^- collisions 2.0 GeV to 4.6 GeV
- BESIII 4π detector with 93% acceptance

Energy region



- Charm physics @3.773 GeV
  2.92 fb^{-1} ($\sim 3\times$ CLEO-c)

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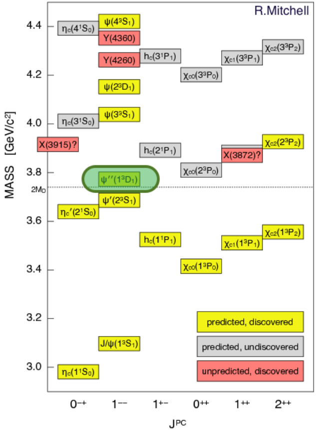

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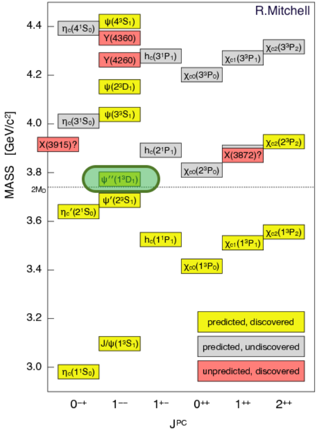

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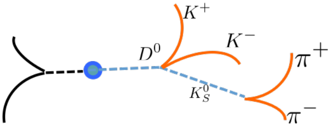
Charm physics



- Predominant decay $\Psi(3770) \to D\bar{D}$
- $(m_\Psi - 2m_D) \lesssim 43.5$ MeV
  $\hookrightarrow$ no phase-space for additional π
- $D^0\ \bar{D}^0$ quantum-correlation
  $\hookrightarrow$ $CP^\pm$ Eigenstate
  $\hookrightarrow$ Flavour
- Produce a tagged D beam

	$\sigma_{e^+e^-\to X}$	N_{pair}
$D^0\ \bar{D}^0$	3.66nb	10M
$D^+\ D^-$	2.91nb	8M

Observation of Singly Cabibbo-Suppressed decays
$D^+ \to \omega\pi^+$ and $D^0 \to \omega\pi^0$

Observation of SCS decays $D^{\pm,0} \to \omega\pi$

Motivation

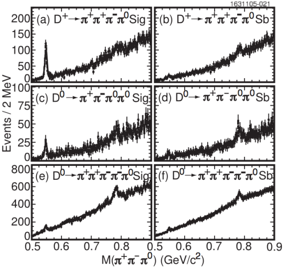
- Measurements of SCS charm decaus challenging
  $\hookrightarrow$ statistics, background
- $D^{\pm,0} \to \omega\pi$ not observed yet
- Theoretical prediction: 1×10^{-4}

PRD 81, 074021(2010)

Previous result

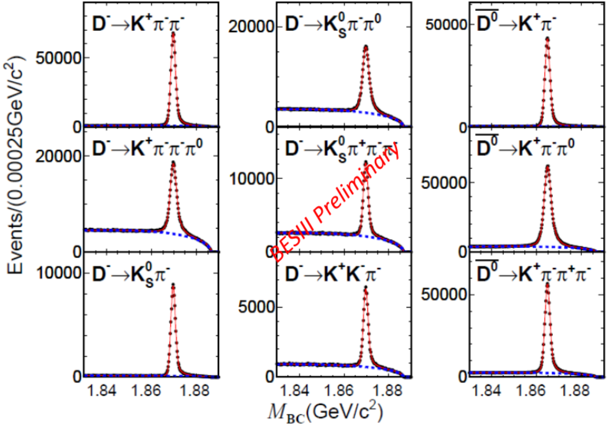
- Upper limits by CLEO-c

PRL 96, 081802(2006)



Decay	Upper limit @90%C.L.
$D^+ \to \omega\pi^+$	$< 3.0 \times 10^{-4}$
$D^0 \to \omega\pi^0$	$< 2.26 \times 10^{-4}$

Tag reconstruction



- $\bar{D}$ is reconstructed 3 neutral and 6 charged modes
- beam-constraint mass: $M_{bc}^2 = E_{beam}^2/c^4 - |p_D|^2/c^2$

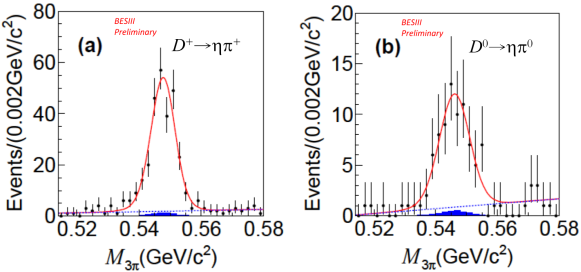
Category	Tag yield
D^-	1462041±1359
$\bar{D}^0$	2234741±2425

$D^+ \to \eta\pi^+$ and $D^0 \to \eta\pi^0$

- Reconstruct signal $D \to (\pi^+\pi^-\pi^0)_\eta \pi$ in all tagged events
- Cross-check
- Branching-fraction: $\mathcal{B} = \dfrac{N_{sig}/\epsilon_{tag,sig}}{N_{tag}/\epsilon_{tag}}$

Signal MC shape.

Bkg 1st order poly and sideband for peak.



N_η	262 ± 17	71 ± 9
N_η^{bkg}	6 ± 2	3 ± 2
N_{sig}^{obs}	256 ± 18	68 ± 10
$\mathcal{B}[10^{-3}]$	$3.13 \pm 0.22\,(\text{stat.}) \pm 0.19\,(\text{sys.})$	$0.67 \pm 0.10\,(\text{stat.}) \pm 0.05\,(\text{sys.})$
$\mathcal{B}_{PDG}[10^{-3}]$	$(3.53 \pm 0.21) \times 10^{-3}$	$(0.68 \pm 0.07) \times 10^{-3}$

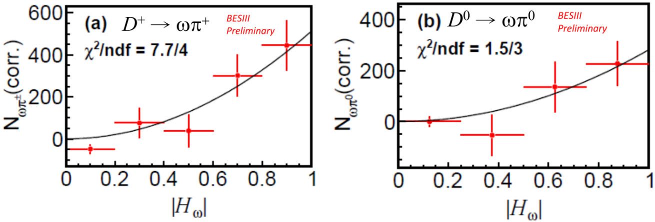
BESIII preliminary

Helicity distribution $D^{+,0} \to \omega\pi^{+,0}$

- Helicity of ω: Angle between normal of ω decay plane and D^0 momentum in ω rest frame

$$|H_\omega| =$$

- Expectation for P→VP: $|H_\omega| \sim \cos\theta^2$



Systematics

Source of Systematic	$\omega\pi^\pm$	$\omega\pi^0$	$\eta\pi^\pm$	$\eta\pi^0$
$\pi^\pm$ tracking	3.0	2.0	3.0	2.0
$\pi^\pm$ PID	1.5	1.0	1.5	1.0
π^0 reconstruction	1.0	2.0	1.0	2.0
2D M_{BC} window	0.1	0.2	0.1	0.2
ΔE requirement	0.5	1.6	0.5	1.6
$\lvert H_\omega \rvert$ requirement	3.4	3.4	–	–
K_S^0 veto	0.8	0.8	–	–
Sideband regions	0.5	6.7	0.0	0.5
Signal resolution(Signal shape)	0.9	0.9	4.3	5.4
Background shape	3.3	2.0	2.0	3.2
Fit range	0.6	1.9	0.8	1.1
$\mathcal{B}(\omega(\eta) \to \pi^+\pi^-\pi^0)$	0.8	0.8	1.2	1.2
Overall	6.1	8.8	6.1	7.3

BESIII preliminary

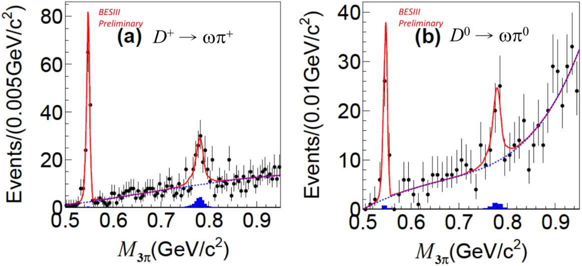
Major systematic uncertainties:

- Track reconstruction
- Selection
- Signal/background shape

$D^+ \to \omega\pi^+$ and $D^0 \to \omega\pi^0$

Signal MC shape.

Bkg 1st order poly and sideband for peak.



N_ω N_ω^{bkg}	98±15 22±4	40±11 4±8
N_{sig}^{obs} $\mathcal{B}[\times 10^{-4}]$ Significance	76±16 $2.74 \pm 0.58\,(\text{stat.}) \pm 0.17\,(\text{sys.})$ 5.4σ	36±14 $1.05 \pm 0.41\,(\text{stat.}) \pm 0.09\,(\text{sys.})$ 4.1σ

BESIII preliminary

Branching-fraction measurement of $D^0 \to K_s^0 K^+ K^-$

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Motivation

- PDG value: $(4.47 \pm 0.34) \times 10^{-3}$
- Not accurately known: 7.6%
- No absolute measurement
- Substructure: e.g. $a_0(980)$
  $\hookrightarrow$ Dalitz analysis ongoing

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Branching-fraction

$$\mathcal{B}_{D^0 \to K_S^0 K^+ K^-} = \frac{N^{sig}}{\epsilon_{BF} \cdot \mathcal{B}_{K_S^0 \to \pi\pi} \cdot \mathcal{L} \cdot 2\sigma_{D^0 \bar{D}^0}}$$

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Event selection

- Untagged reconstruction
- $K^{\pm}$ from IP
- PID from ToF and dE/dx
- $K_S^0 \to \pi^+\pi^-$, significant flight length
- Kin. fit with D^0 mass

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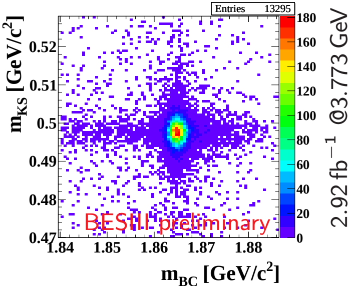
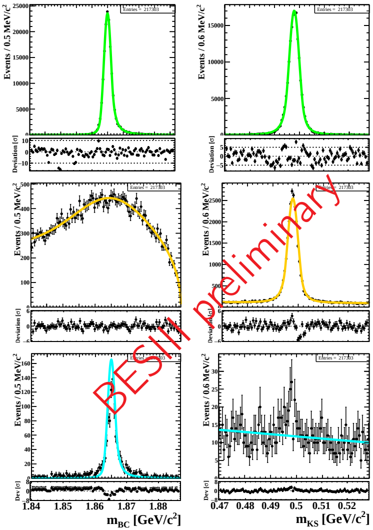


Signal and background PDF

- Signal/backgrounds can be disentangled in m_{BC} and m_{KS}
- PDF models for Signal and background
  - Signal: $S(\vec{x}) = CB2(m_{BC}) \times Gauss(m_{KS})$
  - qq/$D\bar{D}$: $B1(\vec{x}) = (Argus + Gauss)(m_{BC}) \times (Gauss + pol0)(m_{KS})$
  - non-KS: $B2(\vec{x}) = CB2(m_{BC}) \times pol1(m_{KS})$
- Simultaneous fit of common parameters



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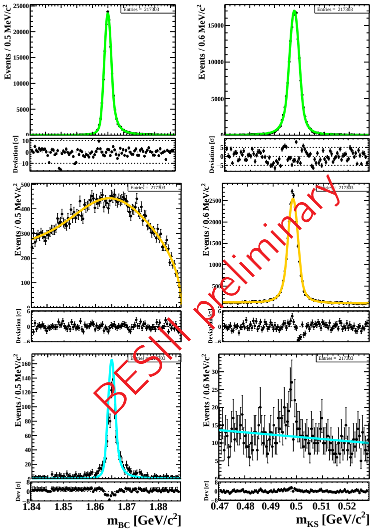
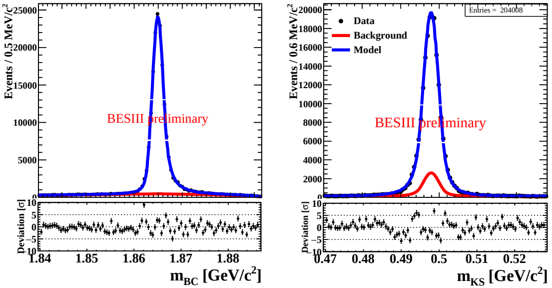
  - non-KS: $B2(\vec{x}) = CB2(m_{BC}) \times pol1(m_{KS})$
- Simultaneous fit of common parameters
- Fix shape parameters and determine yields:

$$PDF(m_{BC}, m_{KS}) = N_{sig} \times S(m_{BC}, m_{KS}) + N_{\mathrm{Bkg}_{\mathbf{KS}}} B_1(m_{BC}, m_{KS}) + N_{\mathrm{Bkg}_{\mathbf{nonKS}}} B_2(m_{BC}, m_{KS})$$



Efficiency

- Determine yields on inclusive MC
- Signal reconstruction efficiency: $\epsilon_{BF} = 0.1719 \pm 0.0004(\text{stat.})$



- Efficiency sensitive to amplitude model in MC
  - Data $\Leftrightarrow$ MC comparison: resonable agreement
  - No additional systematic uncertainty in efficiency

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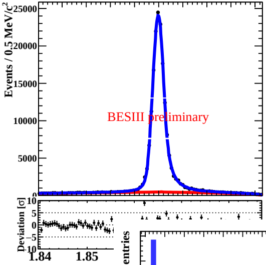
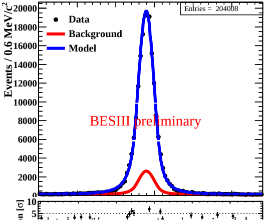
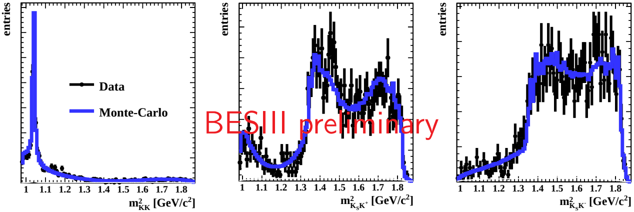






- Efficiency sensitive
  - Data ⇔ MC c
  - No additional

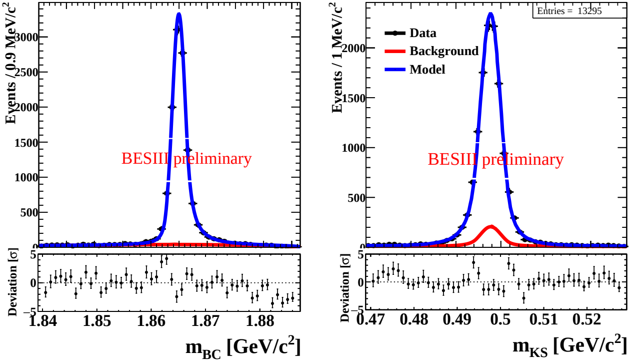
Systematics

BESIII preliminary

Systematic uncertainties [%]	
PDF shape	0.20
selection	0.80
Efficiency	
statistics	0.33
PID (K^+K^-)	2.00
tracking	2.00
K_S^0 reconstruction	1.50
External	
Luminosity measurement	1.00
cross-section $e^+e^- \to D^0\bar{D}^0$	1.83
K_S^0 BF	0.07
Total	3.92

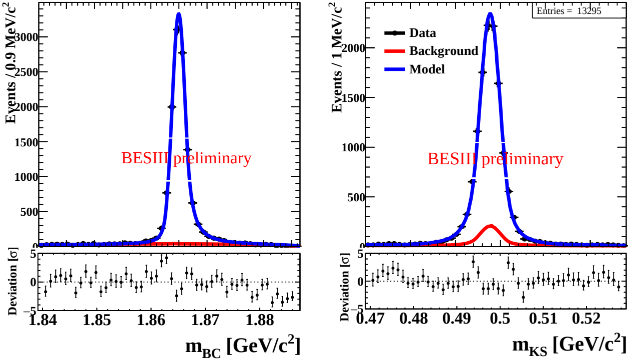
- PDF shape (0.20): Signal and background model parameters are varied within their errors
- selection (0.80): Selection cuts are varied within a reasonable range
- statistics (0.33): Statistical error of efficiency determination
- cross-section (1.83): Measured by CLEO-c

Result



$$N_{sig} = 11743 \pm 113$$

Result



$$N_{sig} = 11743 \pm 113$$

$$BF_{data}(D^0 \to K_S^0 K^+ K^-) = (4.622 \pm 0.045\,(\text{stat.}) \pm 0.181\,(\text{sys.})) \times 10^{-3}$$

- Relative uncertainty: 4.0 %
- Agreement with PDG better $1\,\sigma$

- PDG(2014) value: $(4.47 \pm 0.34) \times 10^{-3}$
  $\hookrightarrow$ 7.6% uncertainty

Summary

With the large data sample of 2.92 fb^{-1} at @$\Psi(3770)$ BESIII provides excellent conditions to study (quantum correlated) charm decays in a clean environment. We present preliminary results from two analyses.

$D^{0,+} \to \omega\pi$

BESIII preliminary

- Double tag method

Decay mode	This work
$D^+ \to \omega\pi^+$	$(2.74 \pm 0.58 \pm 0.17) \times 10^{-4}$
$D^0 \to \omega\pi^0$	$(1.05 \pm 0.41 \pm 0.09) \times 10^{-4}$
$D^+ \to \eta\pi^+$	$(3.13 \pm 0.22 \pm 0.19) \times 10^{-3}$
$D^0 \to \eta\pi^0$	$(0.67 \pm 0.10 \pm 0.05) \times 10^{-3}$

- Observation for $D^+ \to \omega\pi^+$: 5.4σ
- Evidence of $D^0 \to \omega\pi^0$: 4.1σ
- $D^{+,0} \to \eta\pi^{+,0}$ consistent with PDG

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

- Single tag analysis
- Preliminary branching-fraction $D^0 \to K_S^0 K^+ K^-$:

$$\frac{\Gamma_{K_S^0 K^+ K^-}}{\Gamma_{tot}} = (4.622 \,{}^{\pm 0.045\,(\text{stat.})}_{\pm 0.181\,(\text{sys.})}) \times 10^{-3}$$

- Relative uncertainty: 4.0 %
- First absolute measurement
- Dalitz plot analysis ongoing

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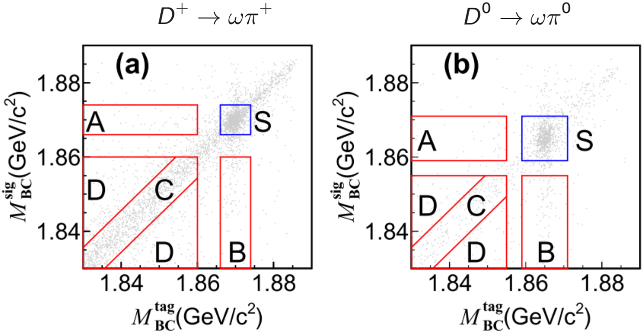
Thank you for your attention!

BACKUP

$D \to \omega\pi$ - sidebands



S signal

A,B mis-rec D or $\bar{D}$

C mis-rec D and $\bar{D}$, correlated

D mis-rec D and $\bar{D}$, uncorrelated

Normalization and quantum-correlation

- If subchannels of signal decays are CP eigenstates
  $\hookrightarrow$ QC has influence on double tag measurement
- Double tag branching-fraction:

$$\mathcal{B} = \frac{N^{double}}{N_{single} \times \epsilon} = \frac{2N_{D^0\bar{D}^0} \cdot \mathcal{B}_{tag} \cdot \mathcal{B}_{signal} \cdot \epsilon_{tag} \cdot \epsilon_{signal|tag}}{2N_{D^0\bar{D}^0} \cdot \mathcal{B}_{tag}\epsilon_{tag}}$$

- With quantum-correlation:

$$\mathcal{B}_{tag}\mathcal{B}_{signal} \rightarrow \mathcal{B}_{tag} \sum_i \mathcal{B}_i f_{\pm,i}$$

- Correction-factor $f_{\pm,i}$:

$$f_{\pm} = (1 + 2r\cos(\delta) \pm R_{WS} \pm y)$$

- r,δ, R_{WS} parameters of the tag channel