CP Violation, Mixing and non-Leptonic Decays at BESIII

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(On behalf of the BESIII Collaboration)

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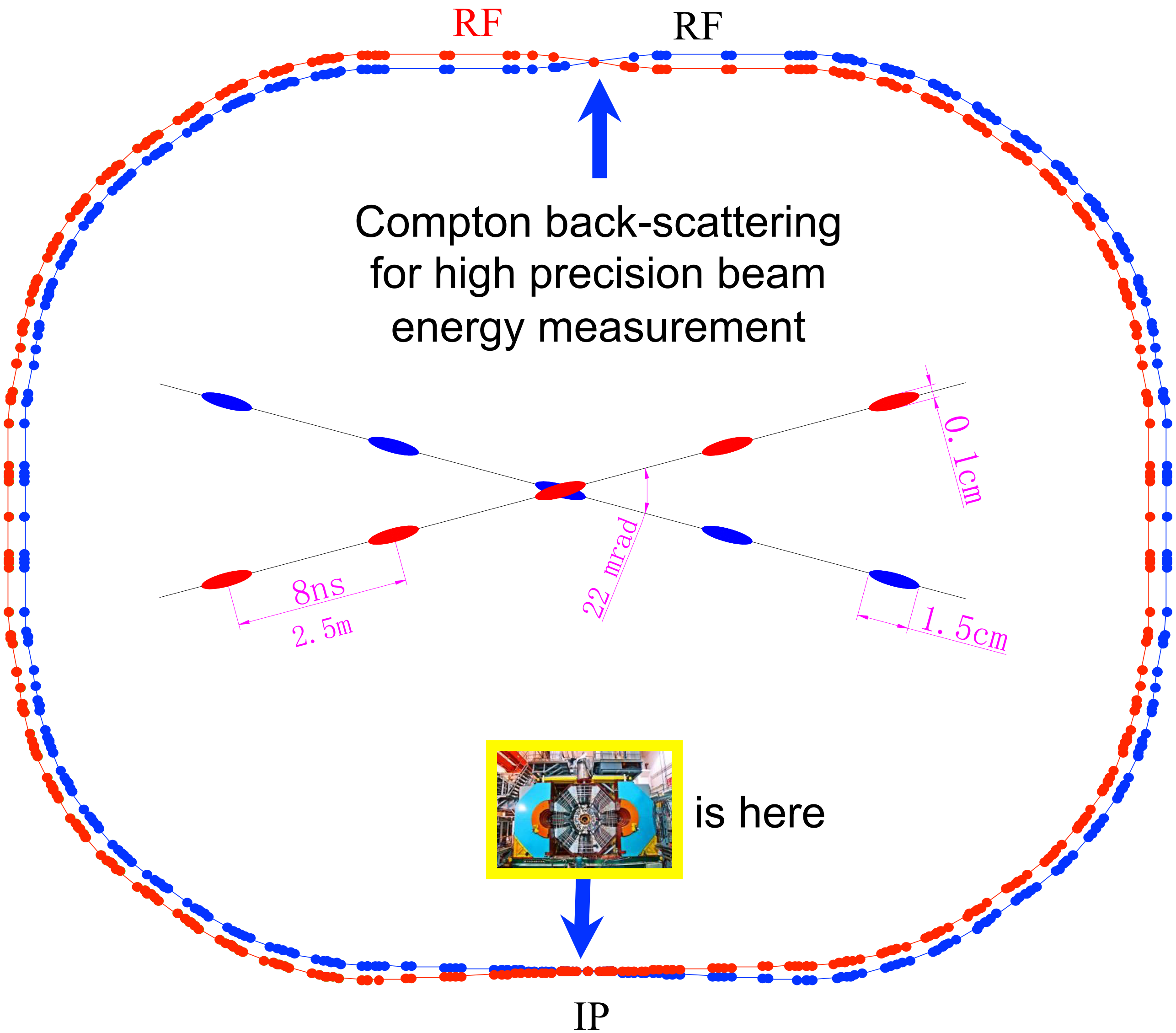
5 - 9 September 2016, Bologna, Italy

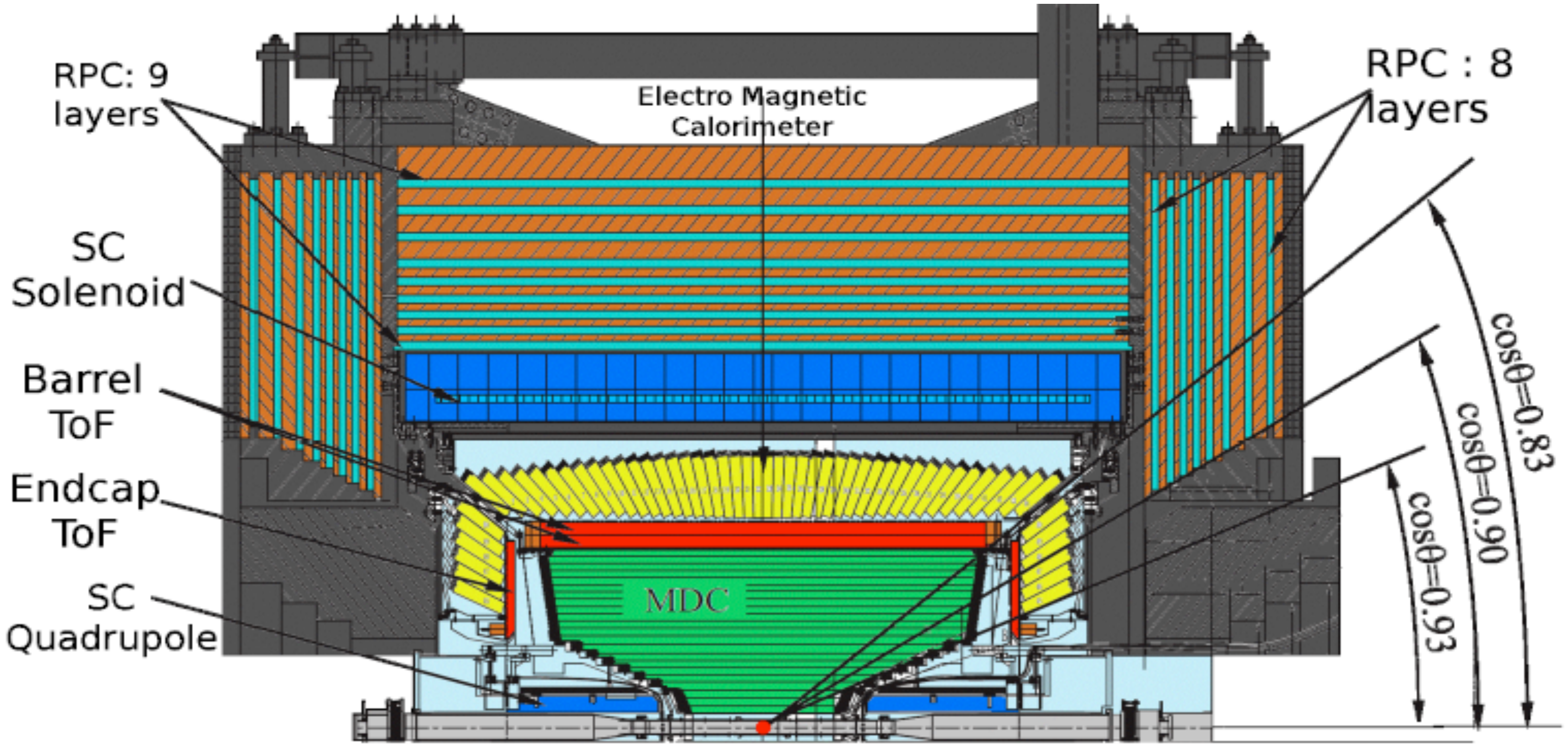
Beijing Electron Positron Collider II (BEPCII)

BEPCII: a double-ring machine



Beam energy:
1-2.3 GeV
Luminosity:
1×10^{33} $cm^{-2}s^{-1}$
Optimum energy:
1.89 GeV
Energy spread:
5.16×10^{-4}
No. of bunches:
93
Bunch length:
1.5 cm
Total current:
0.91 A
SR mode:
0.25A @ 2.5 GeV

BESIII Detector



Wire tracker (no Si); TOF + dE/dx for PID; CsI Ecal ; RPC muon

BESIII Collaboration

Political Map of the World, June 1999

US (5)

Univ. of Hawaii
Carnegie Mellon Univ.
Univ. of Minnesota
Univ. of Rochester
Univ. of Indiana

Europe (14)

Germany: Univ. of Bochum, Univ. of Giessen, GSI
Univ. of Johannes Gutenberg
Helmholtz Ins. In Mainz
Russia: JINR Dubna; BINP Novosibirsk
Italy: Univ. of Torino, Univ. of Ferrara, Frascati Lab
Netherland: KVI/Univ. of Groningen
Sweden: Uppsala Univ.
……

Korea (1)

Seoul Nat. Univ.

Japan (1)

Tokyo Univ.

Pakistan (2)

Univ. of Punjab
COMSAT CIIT

India (1)

Indian Institute of Technology Madras

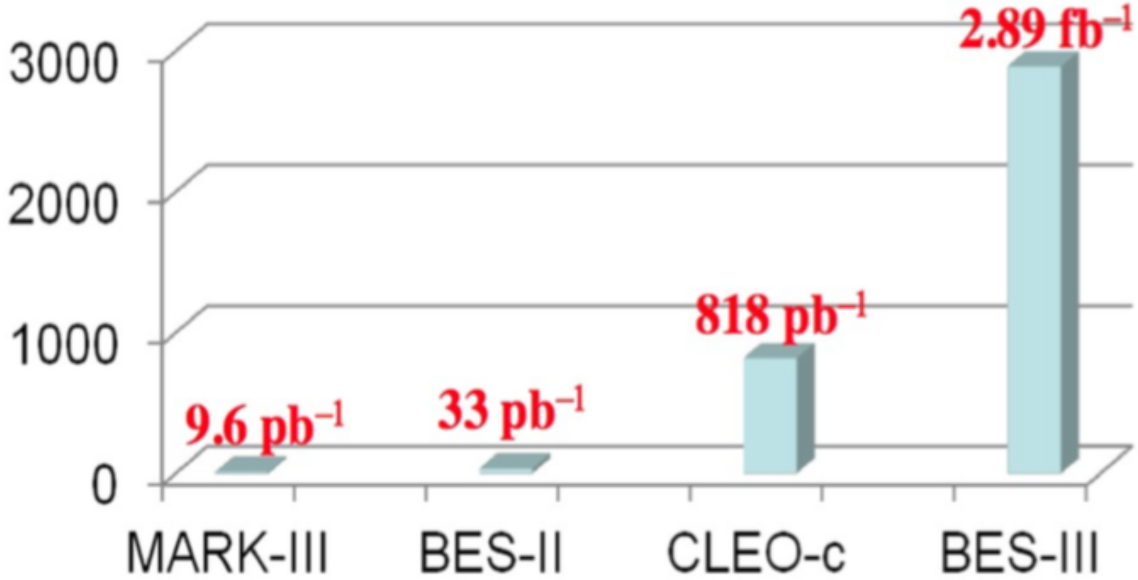
China(34)

IHEP, CCAST, GUCAS, Shandong Univ.,
Univ. of Sci. and Tech. of China
Zhejiang Univ., Huangshan Coll.
Huazhong Normal Univ., Wuhan Univ.
Zhengzhou Univ., Henan Normal Univ.
Peking Univ., Tsinghua Univ. ,
Zhongshan Univ.,Nankai Univ.
Shanxi Univ., Sichuan Univ., Univ. of South China
Hunan Univ., Liaoning Univ.
Nanjing Univ., Nanjing Normal Univ.
Guangxi Normal Univ., Guangxi Univ.
Suzhou Univ., Hangzhou Normal Univ.
Lanzhou Univ., Henan Sci. and Tech. Univ.
……

~450 members
59 institutions from 13 countries

Charm data sample

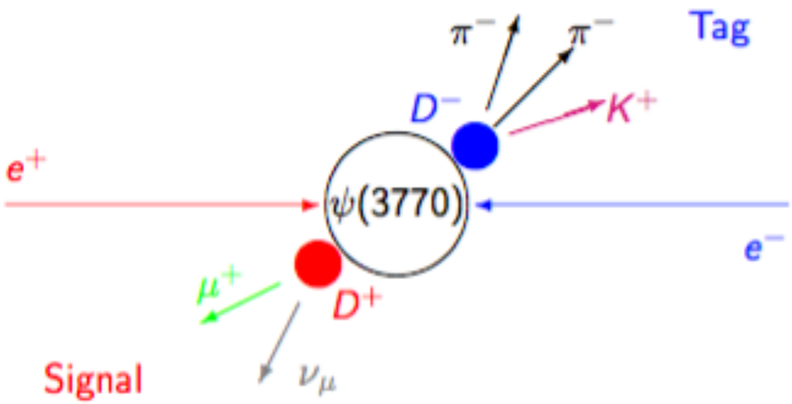
- ~2.9 fb^{-1} @ ψ(3770)



- ~0.5 fb^{-1} @ ψ(4040)
- ~3.0 fb^{-1} @ ψ(4170)

Analysis technique

$e^+e^- \to c\bar{c} \to \bar{D}_{\rm tag}\, D_{\rm sig}$: Double-tag technique, Absolute measurement



- Tag $\bar{D}_{\rm tag}$ in hadronic decay modes

$$\Delta E = E_{\bar{D}_{\rm tag}} - E_{\rm beam}$$

$$M_{\rm BC} = \sqrt{E^2_{\rm beam} - p^2_{\bar{D}_{\rm tag}}}$$

- Reconstruct $D_{\rm sig}$ using the remaining tracks not associated to $\bar{D}_{\rm tag}$
  - $E_{D_{\rm sig}} = E_{\rm beam}$, $\vec{p}_{D_{\rm sig}} = -\vec{p}_{\bar{D}_{\rm tag}}$
  - no additional tracks/showers
  - (semi-)leptonic decay: missing neutrino, $U_{\rm miss} \equiv E_{\rm miss} - |\vec{p}_{\rm miss}| \sim 0$
- High tagging efficiency
- Extremely clean
- Systematic uncertainties associated to tag side are mostly canceled out

Topics

- $D^+ \to K_S/K_L K^+(\pi^0)$ and CP asymmetry
- $D^0 \to K_S/K_L \pi^0(\pi^0)$ and mixing parameter y_{CP}
- Analysis of $D^0 \to K_S \pi^+ \pi^-$
- Branching fraction of $D^0 \to K_S K^+ K^-$
- Amplitude analysis of $D^0 \to K^- \pi^+ \pi^+ \pi^-$
- Measurement of $D^{0,+} \to PP$
- Cabibbo suppressed decay $D^{0,+} \to \omega \pi^{0,+}$
- $D_S^+ \to \eta' X$ and $D_S^+ \to \eta' \rho$

$D^+ \to K_S/K_L K^+(\pi^0)$ and CP asymmetry

- In the Standard Model (SM), the singly Cabibbo suppressed (SCS) D meason hadronic decays are predicted to exhibit CP asymmetries at the order of 10^{-3}.
- Direct CP violation in SCS decays could arise from the interference between tree-level and penguin decay processes.
- DCS and CF decays are expected to be CP invariant in the SM because they are dominated by a single weak amplitude.
- So, measurements of CP asymmetries in SCS processes greater than $O(10^{-3})$ would be evidence of physics beyond the SM.
- CP asymmetry can be tested by using SCS decays $D^+ \to K_S/K_L K^+(\pi^0)$ based on a charge-dependent measurement.

$$\mathcal{A}_{CP} = \frac{\mathcal{B}(D^+ \to K^0_{S,L} K^+(\pi^0)) - \mathcal{B}(D^- \to K^0_{S,L} K^-(\pi^0))}{\mathcal{B}(D^+ \to K^0_{S,L} K^+(\pi^0)) + \mathcal{B}(D^- \to K^0_{S,L} K^-(\pi^0))}$$

- Absolute branching fraction

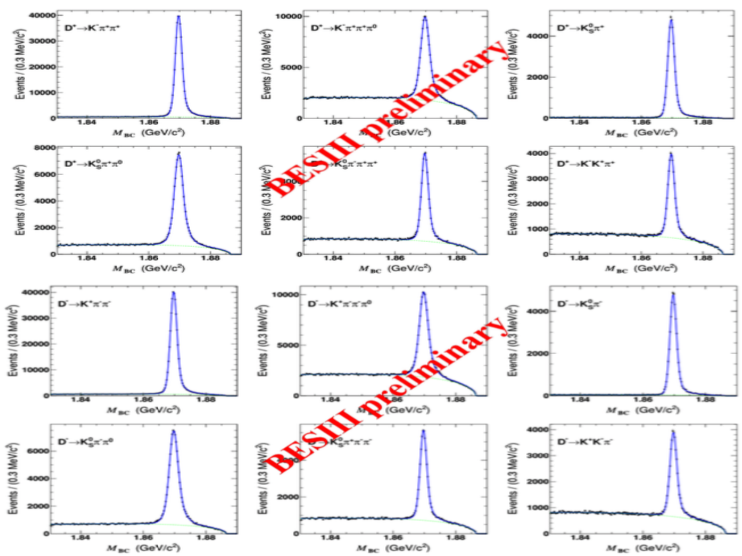
$$\mathcal{B}_{\rm sig} = \frac{N_{\rm DT}/\epsilon_{\rm DT}}{N_{\rm ST}/\epsilon_{\rm ST}} = \frac{N_{\rm DT}/\epsilon}{N_{\rm ST}}$$

where $\varepsilon = \varepsilon_{DT}/\varepsilon_{ST}$ is the efficiency of reconstructing the signal decay

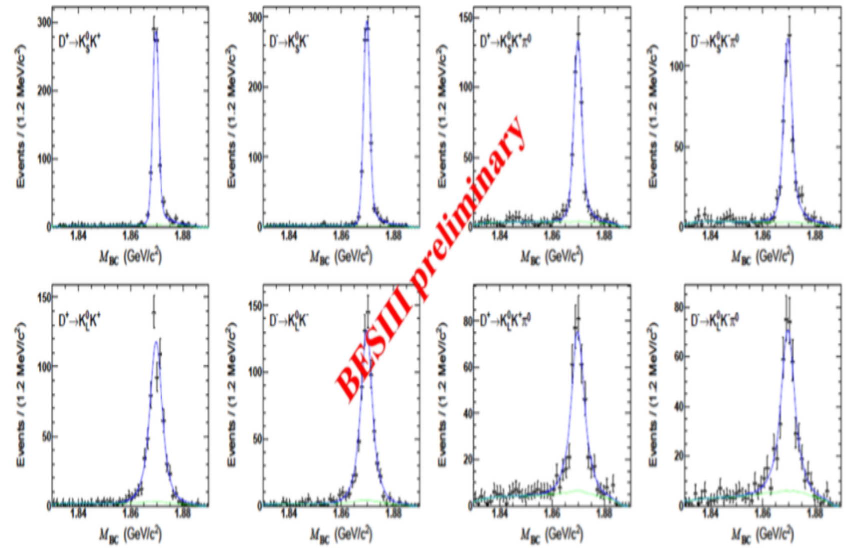
$D^+ \to K_S/K_L K^+(\pi^0)$ and CP asymmetry

[Details can be found in Wenjing Zheng's talk @ Sept.7]

$$N_{\mathrm{ST}} = 2N_{D^+D^-}\mathcal{B}_{\mathrm{tag}}\epsilon_{\mathrm{ST}}$$



$$N_{\mathrm{DT}} = 2N_{D^+D^-}\mathcal{B}_{\mathrm{tag}}\mathcal{B}_{\mathrm{sig}}\epsilon_{\mathrm{DT}}$$



The first and second uncertainties are statistical and systematic errors.

BESIII preliminary

Mode	$\mathcal{B}(D^+)$ $(\times 10^{-3})$	$\mathcal{B}(D^-)$ $(\times 10^{-3})$	$\overline{\mathcal{B}}$ $(\times 10^{-3})$	$\mathcal{A}_{CP}$ (%)
$K^0_S K^\pm$	$3.01 \pm 0.12 \pm 0.10$	$3.10 \pm 0.12 \pm 0.10$	$3.06 \pm 0.09 \pm 0.10$	$-1.5 \pm 2.8 \pm 1.6$
$K^0_S K^\pm \pi^0$	$5.23 \pm 0.28 \pm 0.24$	$5.09 \pm 0.29 \pm 0.22$	$5.16 \pm 0.21 \pm 0.23$	$1.4 \pm 4.0 \pm 2.4$
$K^0_L K^\pm$	$3.13 \pm 0.14 \pm 0.13$	$3.32 \pm 0.15 \pm 0.13$	$3.23 \pm 0.11 \pm 0.13$	$-3.0 \pm 3.2 \pm 1.2$
$K^0_L K^\pm \pi^0$	$5.17 \pm 0.30 \pm 0.21$	$5.26 \pm 0.30 \pm 0.20$	$5.22 \pm 0.22 \pm 0.21$	$-0.9 \pm 4.1 \pm 1.6$

$D^0 \to K_S/K_L\pi^0(\pi^0)$ and mixing parameter y_{CP}

- The decay rates of $D \to K_S\pi$'s and $D \to K_L\pi$'s are not the same because of the interference between Cabibbo Favored component $D \to K^0\pi$'s and doubly Cabibbo suppressed $D \to K^{0bar}\pi$'s component[PLB 349(1995)363]. The sign of this interference of K^0 with K^{0bar} is opposite for K^0_L and K^0_S, so, Br($D \to K_S\pi$'s) and Br($D0 \to K_L\pi$'s) should not in general be equal. The scale of the asymmetry is set by doubly Cabibbo suppression factor $\tan^2\theta_C \approx 0.05$, where θ_C is the Cabibbo angle.
- Previous CLEO-c result based on 281 pb^{-1}@$\psi(3770)$

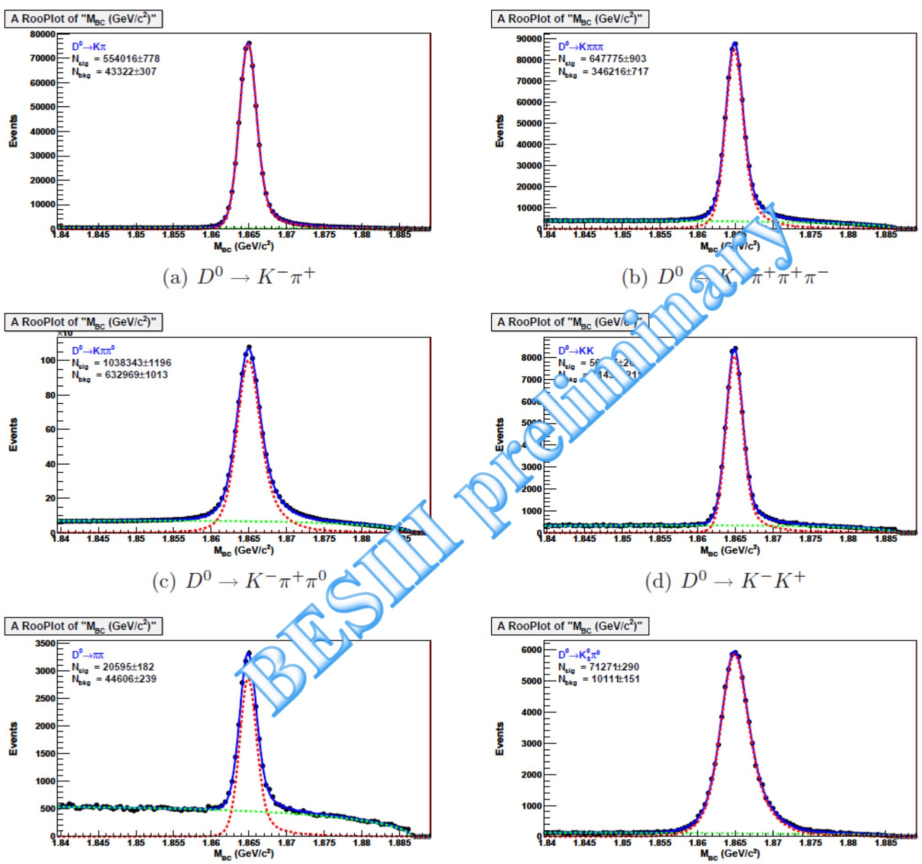
$$R(D^0 \to K_{S,L}\pi^0) = 0.108 \pm 0.025 \pm 0.024$$

$$R(D^+ \to K_{S,L}\pi^+) = 0.022 \pm 0.016 \pm 0.018$$

- Oscillations between meson and antimeson can occur when the flavor eigenstates differ from the physical mass eigenstates. These effects provide a mechanism whereby interference in the transition amplitudes of mesons and antimesons may occur. The oscillations are conventionally characterized by two dimensionless parameters $x=\Delta m/\Gamma$ and $y = \Delta\Gamma/\Gamma$. In the absence of CP violation, one has $y_{CP} = y$.

$D^0 \to K_S/K_L\pi^0(\pi^0)$ and mixing parameter y_{CP}

- Branching fractions and asymmetries



(a) $D^0 \to K^-\pi^+$ (b) $D^0 \to K^-\pi^+\pi^+\pi^-$ (c) $D^0 \to K^-\pi^+\pi^0$ (d) $D^0 \to K^-K^+$ (e) $D^0 \to \pi^-\pi^+$ (f) $D^0 \to K_S^0\pi^0$

$$R(D \to K_{S,L} + \pi's) = \frac{Br(D \to K_S\pi's) - Br(D \to K_L\pi's)}{Br(D \to K_S\pi's) + Br(D \to K_L\pi's)}$$

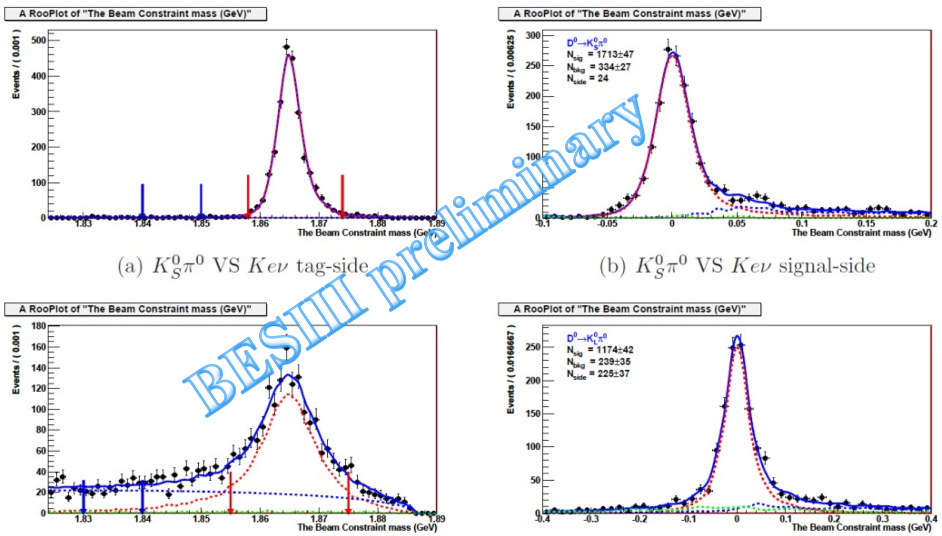
$D \to K^0_{S,L}\pi^0$			
	$Br_{K_S\pi^0}(\%)$	$Br_{K_L\pi^0}(\%)$	$R(D \to K_{S,L}\pi^0)$
$K\pi$	1.208±0.041	1.061±0.038	0.0646±0.0245
$K3\pi$	1.212±0.037	0.985±0.036	0.1035±0.0237
$K\pi\pi^0$	1.251±0.028	0.953±0.029	0.1351±0.0186
All	1.230±0.020	0.991±0.019	0.1077±0.0125

$D \to K^0_{S,L}\pi^0\pi^0$			
	$Br_{K_S2\pi^0}(\%)$	$Br_{K_L2\pi^0}(\%)$	$R(D \to K_{S,L}2\pi^0)$
$K\pi$	1.024±0.049	1.299±0.080	-0.1183±0.0385
$K3\pi$	0.887±0.043	1.097±0.073	-0.1060±0.0409
$K\pi\pi^0$	1.010±0.036	1.158±0.060	-0.0681±0.0313
All	0.975±0.024	1.175±0.040	-0.0929±0.0209

[Details can be found in Wenjing Zheng's talk @ Sept.7]

$D^0 \to K_S/K_L\pi^0(\pi^0)$ and mixing parameter y_{CP}

- y_{CP} measurement



(a) $K_S^0\pi^0$ VS $Ke\nu$ tag-side

(b) $K_S^0\pi^0$ VS $Ke\nu$ signal-side

(c) $K_L^0\pi^0$ VS $Ke\nu$ tag-side

(d) $K_L^0\pi^0$ VS $Ke\nu$ signal-side

y_{CP} is obtained based on CP± + SL analysis: $D^0 \to K_S\pi^0$ and $D^0 \to K_L\pi^0$ versus $D^0 \to Kev_e$

$$N_{\mathrm{ST(CP\pm)}} = (1 \mp y_{\mathrm{CP}}) \cdot 2N_{D^0\bar{D}^0}\mathcal{B}_{\mathrm{tag}}\epsilon_{\mathrm{ST}}$$

$$N_{\mathrm{DT(CP\pm,Ke\nu_e)}} = (1 + y_{\mathrm{CP}}^2) \cdot 2N_{D^0\bar{D}^0}\mathcal{B}_{\mathrm{tag}}\mathcal{B}_{\mathrm{sig}}\epsilon_{\mathrm{DT}}$$

$$\alpha = \frac{N_{\mathrm{DT(CP+,Ke\nu_e)}}/\epsilon}{N_{\mathrm{ST(CP+)}}} \qquad \beta = \frac{N_{\mathrm{DT(CP-,Ke\nu_e)}}/\epsilon}{N_{\mathrm{ST(CP-)}}} \qquad y_{\mathrm{CP}} = \frac{\alpha - \beta}{\alpha + \beta}$$

statistical error only

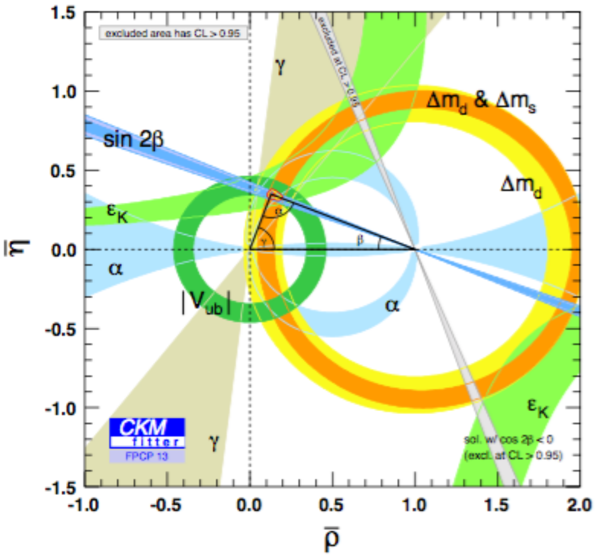
α $(K_L^0\pi^0,\ Ke\nu_e)$	β $(K_S^0\pi^0,\ Ke\nu_e)$	$y_{\mathrm{CP}} = \frac{\alpha-\beta}{\alpha+\beta}$
3.603 ± 0.142	3.533 ± 0.100	$(0.98 \pm 2.43)\%$

[Details can be found in Wenjing Zheng's talk @ Sept.7]

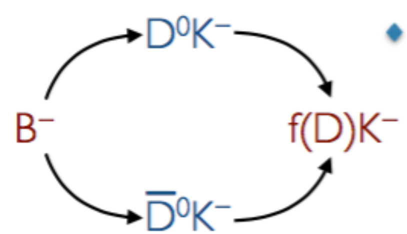
Analysis of $D^0 \to K_S \pi^+ \pi^-$

Motivated by the quest to increase the precision of the angle γ measurement in $B^- \to DK^-$ decay.

$$\gamma = \arg(-V_{ud}V^*_{ub}/V_{cd}V^*_{cb})$$



Determine γ through the interference between $b \to c$ and $b \to u$ transitions when D^0 and $\bar{D}^0$ both decay to the same final state f(D).



- $\mathcal{A}(B^\pm \to K^\pm \tilde{D}^0, \tilde{D}^0 \to K^0_S\pi^+\pi^-(x,y))$
  $\propto f_D(x,y) + r_B e^{i\theta_\pm} f_{\bar{D}}(x,y)$.
- $\theta_\pm \equiv \delta_B \pm \gamma$
- $x \equiv m^2_{K^0_S\pi^+}, y \equiv m^2_{K^0_S\pi^-}$
- $\Delta\delta_D \equiv \delta_D(x,y) - \delta_D(y,x)$

BESIII can help reducing the systematics on this important measurement with providing more information on the

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

With the amount of data LHCb collecting, γ measurement soon will be systematically limited.

We will use the GGSZ* method to investigate the decay
Final states are three body, self-conjugate modes
eg: K_sKK, $K_s\pi\pi$

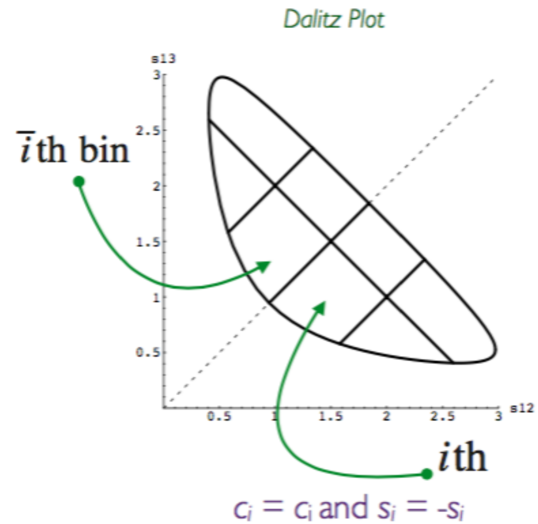
- Binning regions of Dalitz plot where δ_D is similar
- Model independent, there is no incorrect binning.
- Optimization for binning for increased sensitivity.

*Giri, Grossman, Soffer, Zupan (**GGSZ**)
Phys. Rev. D 68 (2003) 054018

Analysis of $D^0 \to K_S \pi^+ \pi^-$

- T_i : measured in flavor decays
- r_B : color suppression ~0.1
- δ_B : strong phase of B
- c_i, s_i : weighted average of $\cos(\Delta\delta_D)$ and $\sin(\Delta\delta_D)$, phase difference between Ds given by $\Delta\delta_D$.

  All but c_i, s_i variables will be measured in B factories.



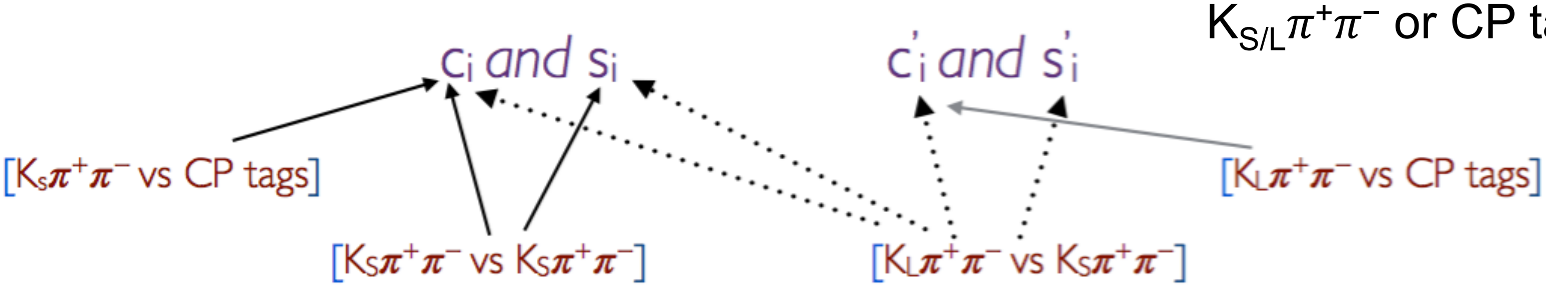
Belle model independent γ measurement: $77.3^{+15.1}_{-14.9}(stat) \pm 4.2(syst) \pm 4.3(c_i/s_i)$

c_i, s_i error dominates

Phys. Rev. D 85, 112014 (2012)

$$\Gamma_i^{\pm} \equiv \int_i d\Gamma(B^{\pm} \to (K_S^0 \pi^- \pi^+)_D K^{\pm})$$
$$= T_i + r_B^2 T_{\bar{i}} \pm 2 r_B \sqrt{T_i T_{\bar{i}}}[\cos(\delta_B + \gamma) c_i - \sin(\delta_B + \gamma) s_i]$$

c_i, s_i can be measured using DT:
$D^0 \to K_S \pi^+ \pi^-$ versus $K_{S/L} \pi^+ \pi^-$ or CP tags



Analysis of $D^0 \to K_S \pi^+ \pi^-$

Measured using the worlds largest ψ(3770) data sample taken at the threshold.

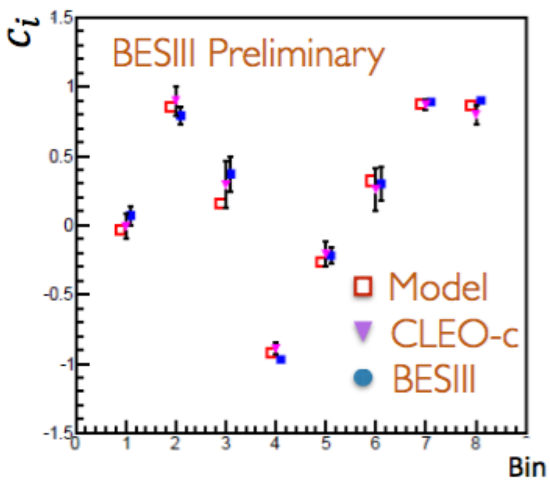
Results consistent with the CLEO-c with superior statistical uncertainties.

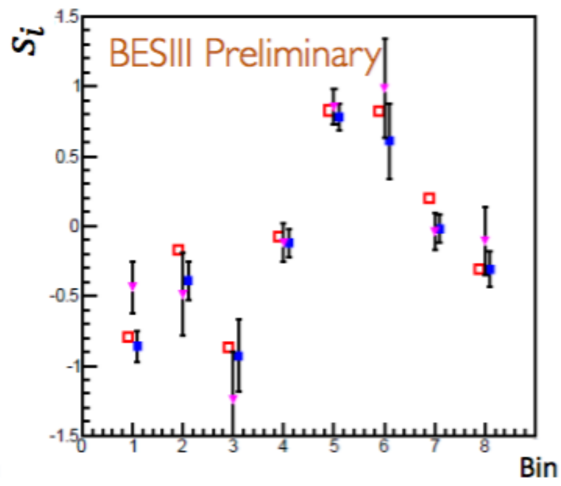
Contribution to the uncertainty in gamma of ±2.1° using optimal binning, compared to Belle's current measurement of ±4.3° from CLEO-c's results.

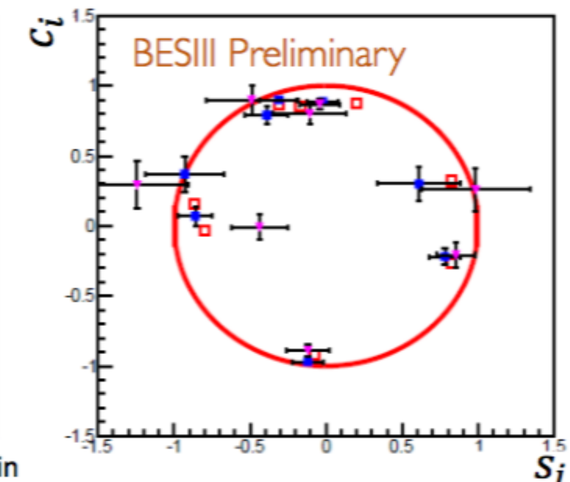
BESIII Preliminary

Bins	c_i BES-III	c_i CLEO-c	s_i BES-III	s_i CLEO-c
1	0.066 ± 0.066	-0.009 ± 0.088	-0.843 ± 0.119	-0.438 ± 0.184
2	0.796 ± 0.061	0.900 ± 0.106	-0.357 ± 0.148	-0.490 ± 0.295
3	0.361 ± 0.125	0.292 ± 0.168	-0.962 ± 0.258	-1.243 ± 0.341
4	-0.985 ± 0.017	-0.890 ± 0.041	-0.090 ± 0.093	-0.119 ± 0.141
5	-0.278 ± 0.056	-0.208 ± 0.085	0.778 ± 0.092	0.853 ± 0.123
6	0.267 ± 0.119	0.258 ± 0.155	0.635 ± 0.293	0.984 ± 0.357
7	0.902 ± 0.017	0.869 ± 0.034	-0.018 ± 0.103	-0.041 ± 0.132
8	0.888 ± 0.036	0.798 ± 0.070	-0.301 ± 0.140	-0.107 ± 0.240

CLEO-c result: Phys. Rev. D 82, 112006

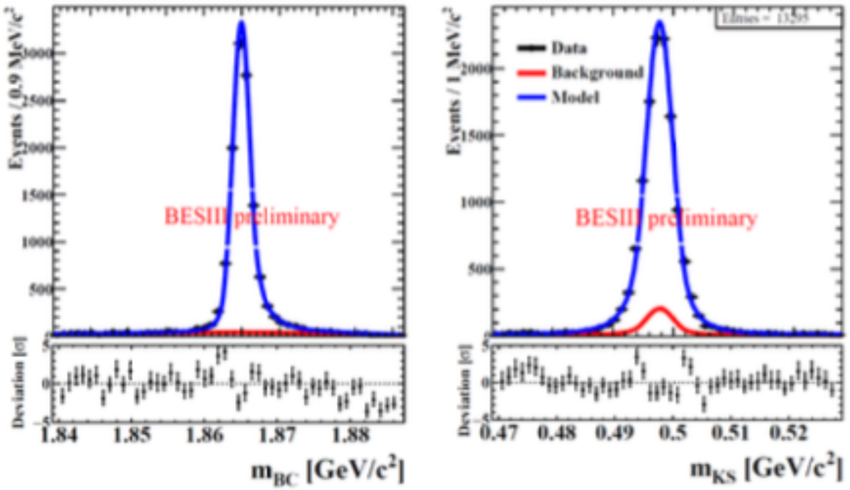




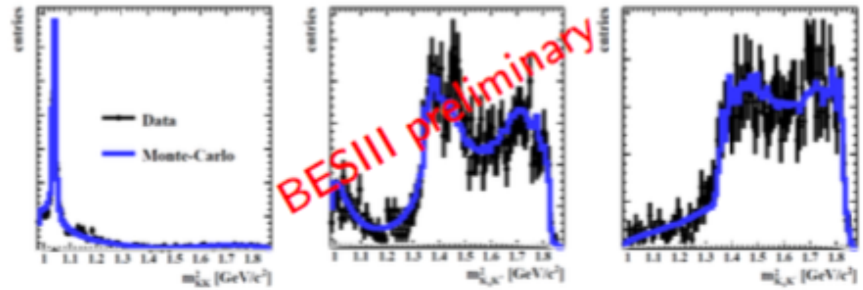


Branching fraction of $D^0 \to K_S K^+ K^-$

- Preliminary result on the branching fraction measurement via single tag



- Fit to "m_{BC} vs. $m_{K_S^0}$"
- Dalitz analysis is ongoing



$$\mathcal{B}(D^0 \to K_S^0 K^+ K^-) = (4.622 \pm 0.045 \pm 0.181) \times 10^{-3}$$

- Relative uncertainty: 4.0%
- Good agreement with PDG2015 value:

$$\mathcal{B}(D^0 \to K_S^0 K^+ K^-) = (4.51 \pm 0.34)\%$$

$\hookrightarrow$ 7.5% relative uncertainty

Amplitude analysis of $D^0 \to K^- \pi^+ \pi^+ \pi^-$

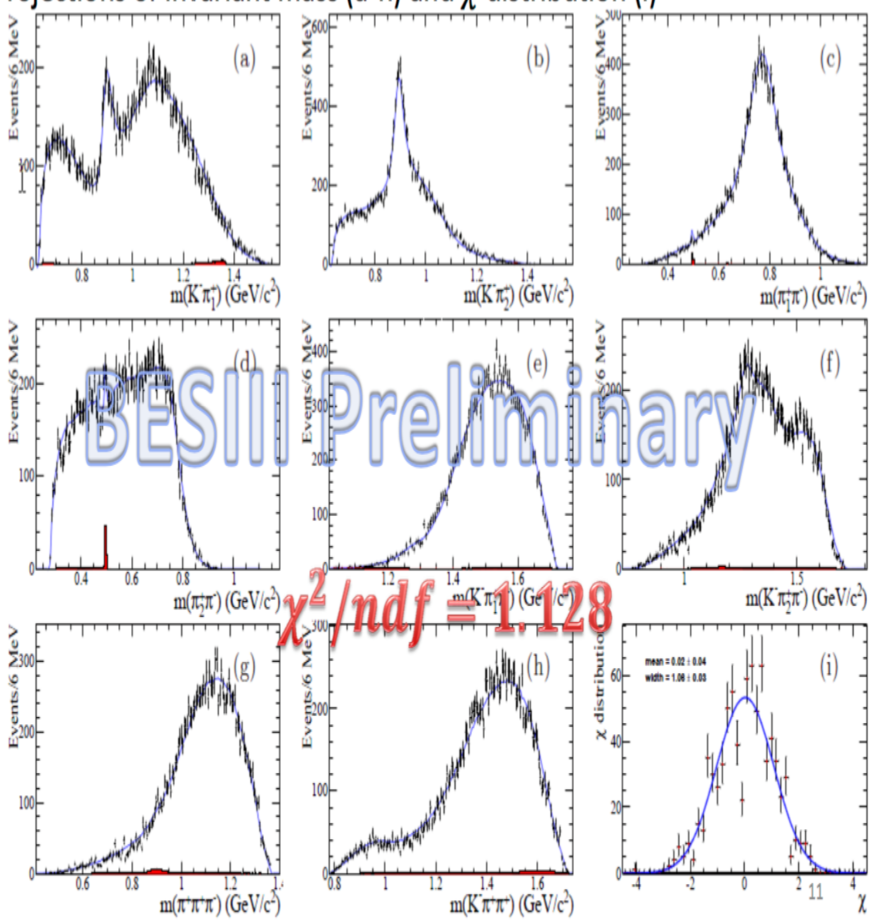
- $D^0 \to K^- \pi^+ \pi^+ \pi^-$ is one of the golden decay mode of D^0, its branching fraction is widely use to normalize other charm analysis, such as BF measurements, strong phase measurements, CKM unitary triangle measurement.
- Poor knowledge of intermediate processes will introduce large systematic uncertainty.
- Some intermediate process such as $D^0 \to K^{*0bar} \rho^0$ can be used to check the calculation of LQCD or effective theories.

Previous measurements (fit fractions) have performed by Mark III and E691, respectively:

Decay mode	Mark III	E691
$D^0 \to K^- a_1^+(1260)$	$0.492 \pm 0.024 \pm 0.08$	$0.47 \pm 0.05 \pm 0.10$
$D^0 \to \bar{K}^{*0} \rho^0$	$0.142 \pm 0.016 \pm 0.05$	$0.13 \pm 0.02 \pm 0.02$
$D^0 \to K_1^-(1270) \pi^+$	$0.066 \pm 0.019 \pm 0.03$	
$D^0 \to \bar{K}^{*0} \pi^- \pi^+$	$0.140 \pm 0.018 \pm 0.04$	$0.11 \pm 0.02 \pm 0.03$
$D^0 \to K^- \pi^+ \rho^0$	$0.084 \pm 0.022 \pm 0.04$	$0.05 \pm 0.03 \pm 0.02$
$D^0 \to$ 4-body non-resonance	$0.242 \pm 0.025 \pm 0.06$	$0.23 \pm 0.02 \pm 0.03$

Amplitude analysis of $D^0 \to K^-\pi^+\pi^+\pi^-$

Projections of invariant mass (a-h) and χ distribution (i)



Fit fractions(FF) for different components

Component	Fit fraction (%)
$D^0 \to \bar{K}^{*0}\rho^0$	$12.3 \pm 0.4 \pm 0.5$
$D^0 \to K^- a_1^+(1260)(\rho^0\pi^+)$	$54.6 \pm 2.8 \pm 3.7$
$D^0 \to K_1^-(1270)(\bar{K}^{*0}\pi^-)\pi^+$	$0.8 \pm 0.2 \pm 0.2$
$D^0 \to K_1^-(1270)(K^-\rho^0)\pi^+$	$3.4 \pm 0.3 \pm 0.2$
$D^0 \to K^-\pi^+\rho^0$	$8.4 \pm 1.1 \pm 2.2$
$D^0 \to \bar{K}^{*0}\pi^+\pi^-$	$7.0 \pm 0.4 \pm 0.3$
$D^0 \to K^-\pi^+\pi^+\pi^-$	$21.9 \pm 0.6 \pm 0.6$

With the fit fractions and the BF of $D^0 \to K3\pi$, we get the BFs of the components

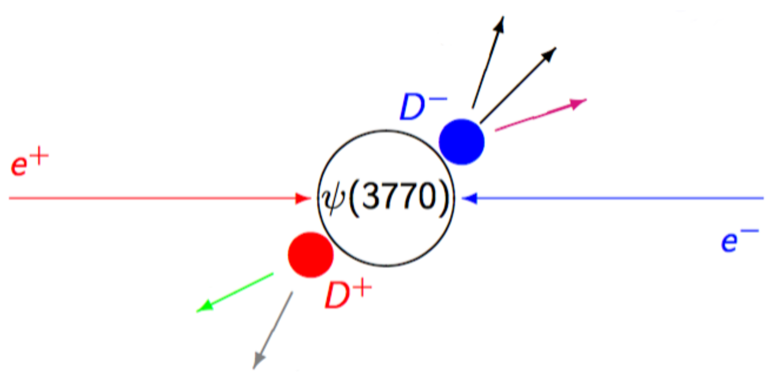
Component	Branching fraction (%)	PDG value (%)
$D^0 \to \bar{K}^{*0}\rho^0$	$0.99 \pm 0.04 \pm 0.04 \pm 0.03$	1.05 ± 0.23
$D^0 \to K^- a_1^+(1260)(\rho^0\pi^+)$	$4.41 \pm 0.22 \pm 0.30 \pm 0.13$	3.6 ± 0.6
$D^0 \to K_1^-(1270)(\bar{K}^{*0}\pi^-)\pi^+$	$0.07 \pm 0.01 \pm 0.02 \pm 0.00$	0.29 ± 0.03
$D^0 \to K_1^-(1270)(K^-\rho^0)\pi^+$	$0.27 \pm 0.02 \pm 0.02 \pm 0.01$	
$D^0 \to K^-\pi^+\rho^0$	$0.68 \pm 0.09 \pm 0.18 \pm 0.02$	0.51 ± 0.23
$D^0 \to \bar{K}^{*0}\pi^+\pi^-$	$0.57 \pm 0.03 \pm 0.03 \pm 0.02$	0.99 ± 0.23
$D^0 \to K^-\pi^+\pi^+\pi^-$	$1.77 \pm 0.05 \pm 0.04 \pm 0.05$	1.88 ± 0.26

BESIII Preliminary

[Details can be found in Yu Lu's talk @ Sept.7]

Branching fraction of $D^{0,+} \to PP$

- Analysis of D→PP modes can provide information for SU(3) breaking effect study[PLB 712 (2012) 8186] and CP violation searching.
- Absolute measurement of $D^0 \to K\pi$ is very important since it is commonly used as normalization mode in charm study.
- This measurement is completed with single tag technique



Only one D meson is built in the analysis

$$\Delta E = E_{\bar{D}_{\rm tag}} - E_{\rm beam}$$

$$M_{\rm BC} = \sqrt{E_{\rm beam}^2 - p_{\bar{D}_{\rm tag}}^2}$$

Branching fraction of $D^{0,+} \to PP$

- BESIII Preliminary

Mode	N^{net}_{signal}	ε (%)	$\mathcal{B}\pm$(stat)$\pm$(sys)	$\mathcal{B}_{PDG}$
$\pi^+\pi^-$	21105 ± 249	66.03 ± 0.25	$(1.505 \pm 0.018 \pm 0.031) \times 10^{-3}$	$(1.421 \pm 0.025) \times 10^{-3}$
K^+K^-	56438 ± 273	62.82 ± 0.32	$(4.229 \pm 0.020 \pm 0.087) \times 10^{-3}$	$(4.01 \pm 0.07) \times 10^{-3}$
$K^-\pi^+$	537745 ± 767	64.98 ± 0.09	$(3.896 \pm 0.006 \pm 0.073)$ %	(3.93 ± 0.04) %
$K^0_S\pi^0$	66539 ± 302	38.06 ± 0.17	$(1.236 \pm 0.006 \pm 0.032)$ %	(1.20 ± 0.04) %
$K^0_S\eta$	9532 ± 126	31.96 ± 0.14	$(5.149 \pm 0.068 \pm 0.134) \times 10^{-3}$	$(4.85 \pm 0.30) \times 10^{-3}$
$K^0_S\eta'$	3007 ± 61	12.66 ± 0.08	$(9.562 \pm 0.197 \pm 0.379) \times 10^{-3}$	$(9.5 \pm 0.5) \times 10^{-3}$
$\pi^0\pi^+$	10108 ± 267	48.98 ± 0.34	$(1.259 \pm 0.033 \pm 0.025) \times 10^{-3}$	$(1.24 \pm 0.06) \times 10^{-3}$
π^0K^+	1834 ± 168	51.52 ± 0.42	$(2.171 \pm 0.198 \pm 0.060) \times 10^{-4}$	$(1.89 \pm 0.25) \times 10^{-4}$
$\eta\pi^+$	11636 ± 215	46.96 ± 0.25	$(3.790 \pm 0.070 \pm 0.075) \times 10^{-3}$	$(3.66 \pm 0.22) \times 10^{-3}$
ηK^+	439 ± 72	48.21 ± 0.31	$(1.393 \pm 0.228 \pm 0.124) \times 10^{-4}$	$(1.12 \pm 0.18) \times 10^{-4}$
$\eta'\pi^+$	3088 ± 83	21.49 ± 0.18	$(5.122 \pm 0.140 \pm 0.210) \times 10^{-3}$	$(4.84 \pm 0.31) \times 10^{-3}$
$\eta' K^+$	87 ± 25	22.39 ± 0.22	$(1.377 \pm 0.428 \pm 0.202) \times 10^{-4}$	$(1.83 \pm 0.23) \times 10^{-4}$
$K^0_S\pi^+$	93884 ± 352	51.38 ± 0.18	$(1.591 \pm 0.006 \pm 0.033) \times 10^{-2}$	$(1.53 \pm 0.06) \times 10^{-2}$
$K^0_S K^+$	17704 ± 151	48.45 ± 0.14	$(3.183 \pm 0.028 \pm 0.065) \times 10^{-3}$	$(2.95 \pm 0.15) \times 10^{-3}$

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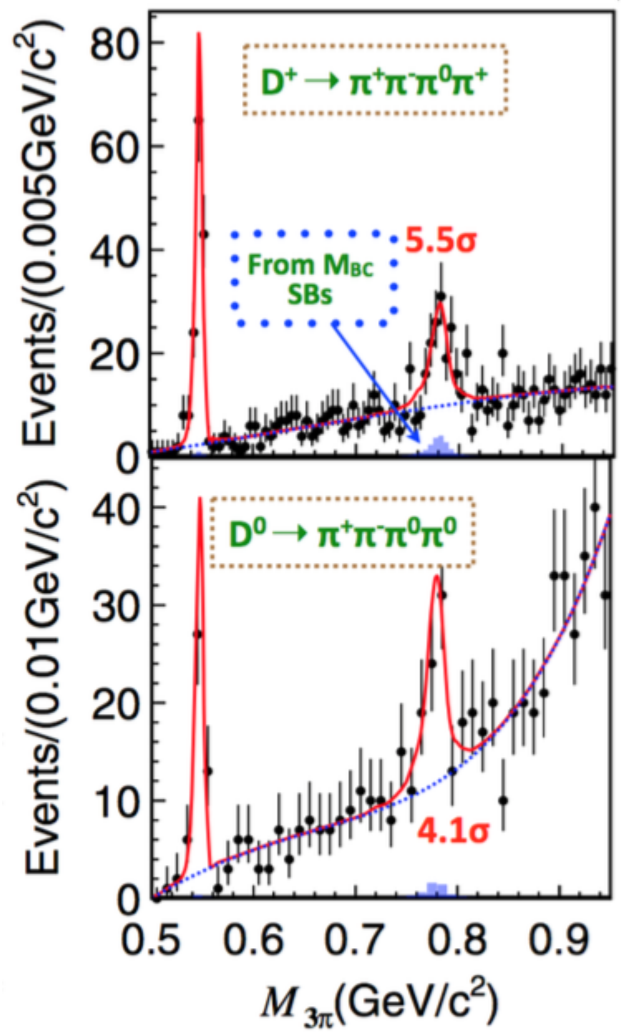
Cabibbo suppressed decay $D^{0,+} \to \omega\pi^{0,+}$

PRL116, 082001 (2016)



- The first observation of the singly Cabibbo-supressed decay
- Double tag method to suppress backgrounds
- Also measure $D^{0(+)} \to \eta\pi^{0(+)}$

Branching fraction	This work	Previous measurements
$\mathcal{B}(D^+ \to \omega\pi^+)$ (10^{-4})	$2.79 \pm 0.57 \pm 0.16$	< 3.4 at 90% C.L.
$\mathcal{B}(D^0 \to \omega\pi^0)$ (10^{-4})	$1.17 \pm 0.34 \pm 0.07$	< 2.6 at 90% C.L.
$\mathcal{B}(D^+ \to \eta\pi^+)$ (10^{-3})	$3.07 \pm 0.22 \pm 0.13$	3.53 ± 0.21
$\mathcal{B}(D^0 \to \eta\pi^0)$ (10^{-3})	$0.65 \pm 0.09 \pm 0.04$	0.68 ± 0.07

Improve understanding of U-spin and SU(3) flavor symmetry breaking effects in D decays and benefitting theoretical prediction of CP violation in D decays

$D_s^+ \to \eta' X$ and $D_s^+ \to \eta' \rho$

PLB750, 466 (2015)

- Old CLEO-c data gave $B(D_s^+ \to \eta'\rho^+) = (12.5 \pm 2.2)\%$
  - exceed the difference between $B(D_s^+ \to \eta' X)$ and known $B(D_s^+ \to \eta'\text{+exclusive})$
  - Theoretical calculation: $B(D_s^+ \to \eta'\rho^+) = (3.0 \pm 0.5)\%$
- BESIII results resolve the tension between inclusive and exclusive modes involving η'

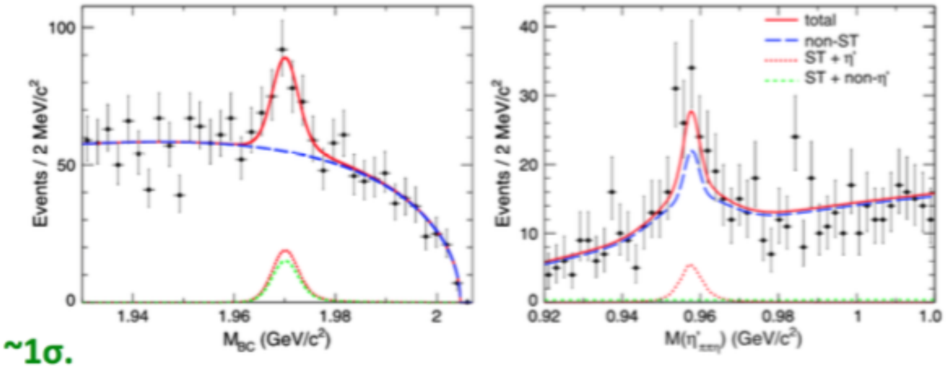
0.482 pb^{-1}@4.009GeV

DT method for $B(D_s^+ \to \eta' X)$

- 9 ST modes
- Fit to a 2D: $M(\pi\pi\eta)$ vs M_{BC}(ST)

$BF(D_s^+ \to \eta' X) = (8.8 \pm 1.8 \pm 0.5)\%$,

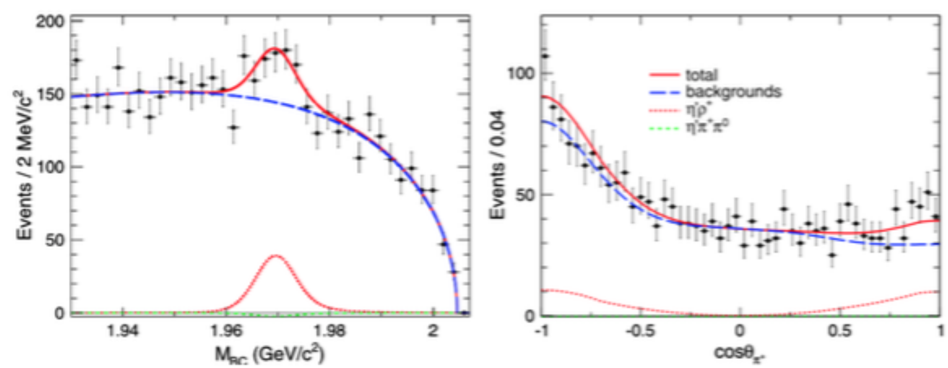
consistent with PDG = $(11.7 \pm 1.7 \pm 0.7)\%$ within ~1σ.



ST method for $B(D_s^+ \to \eta'\rho^+)$

- Relative to $B(K^-K^+\pi^+)$
- 2D fit : M_{BC}(ST) vs helicity angle (ρ^+ decays)

$BF(D_s^+ \to \eta'\rho^+) = (5.8 \pm 1.4 \pm 0.4)\%$



Summary

- A_{CP} measurement in $D^+ \to K_S/K_L K^+(\pi^0)$, the BFs are consistent with PDG.
- y_{CP} measurement in $D^0 \to K_S/K_L \pi^0(\pi^0)$, the BFs and its asymmetry are also obtained.
- Strong phase difference between D0 and $D^{0bar} \to K_S \pi^+ \pi^-$ are measured.
- Branching fractions for $D^0 \to K_S K^+ K^-$, $D \to PP$ (14 modes), $D \to \omega/\eta\pi$ and $D_S^+ \to \eta' X$ and $D_S^+ \to \eta' \rho$.
- Amplitude analysis of $D^0 \to K^- \pi^+ \pi^+ \pi^-$

Thank you !