Charm Input for Determining γ/ϕ_3

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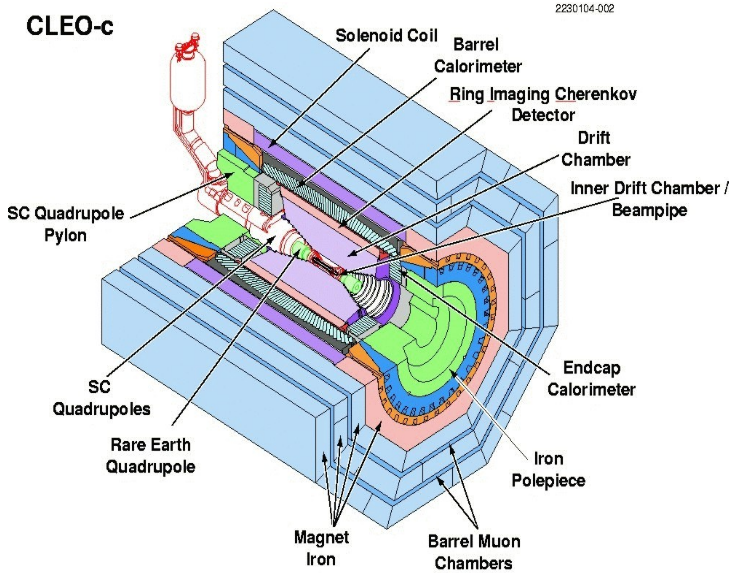
on behalf of the CLEO-c Collaboration



Introduction

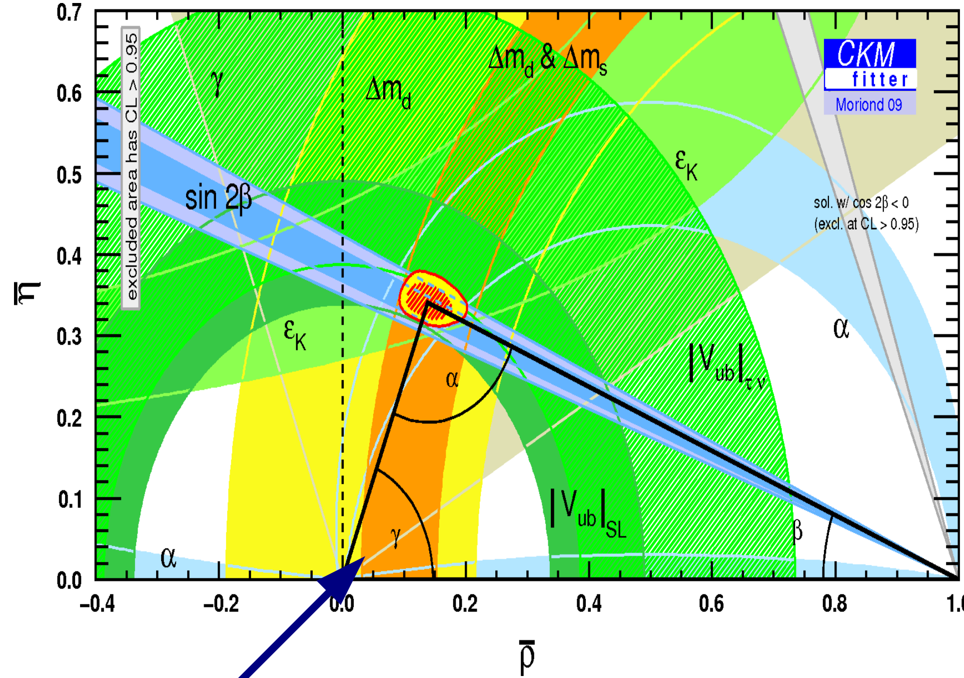
Measuring the angles of the CKM Unitarity Triangle (UT) is
an important way to study weak interactions in the Standard Model
and to search for Physics Beyond the Standard Model

$$\alpha/\phi_1 = (88.2^{+6.1}_{-4.8})^\circ$$

$$\beta/\phi_2 = (21.11^{+0.94}_{-0.92})^\circ$$

$$\gamma/\phi_3 = (70^{+27}_{-29})^\circ$$

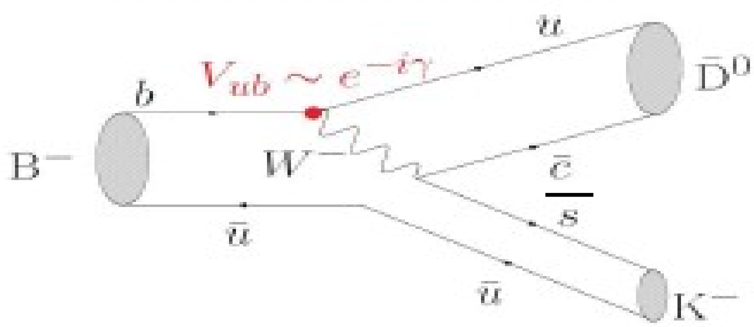
CKMfitter (direct measurements)

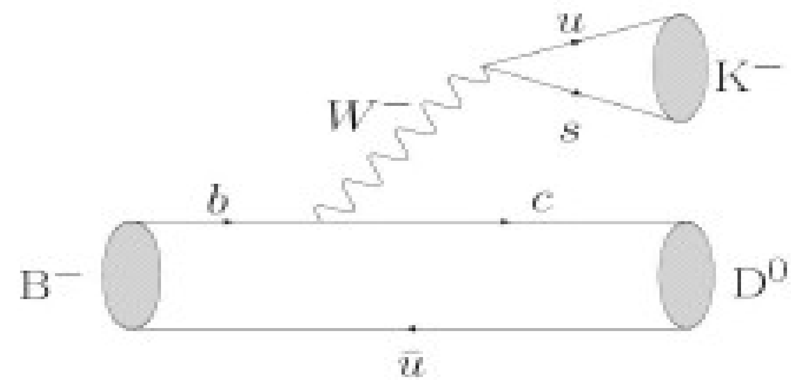


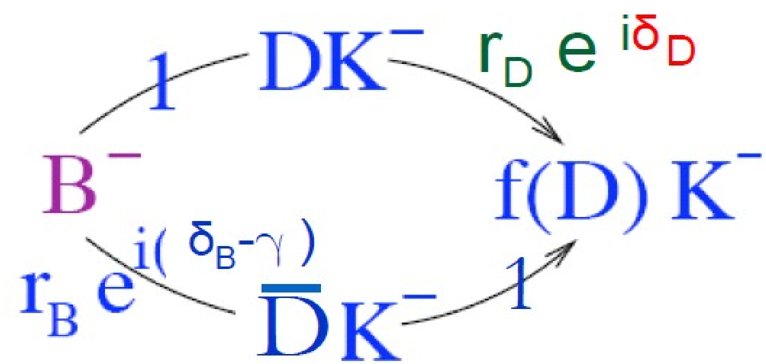
γ is the most poorly measured UT angle

This talk will focus on how high precision measurements
from CLEO-c provide information for measuring γ

γ from $B \to DK$ decays





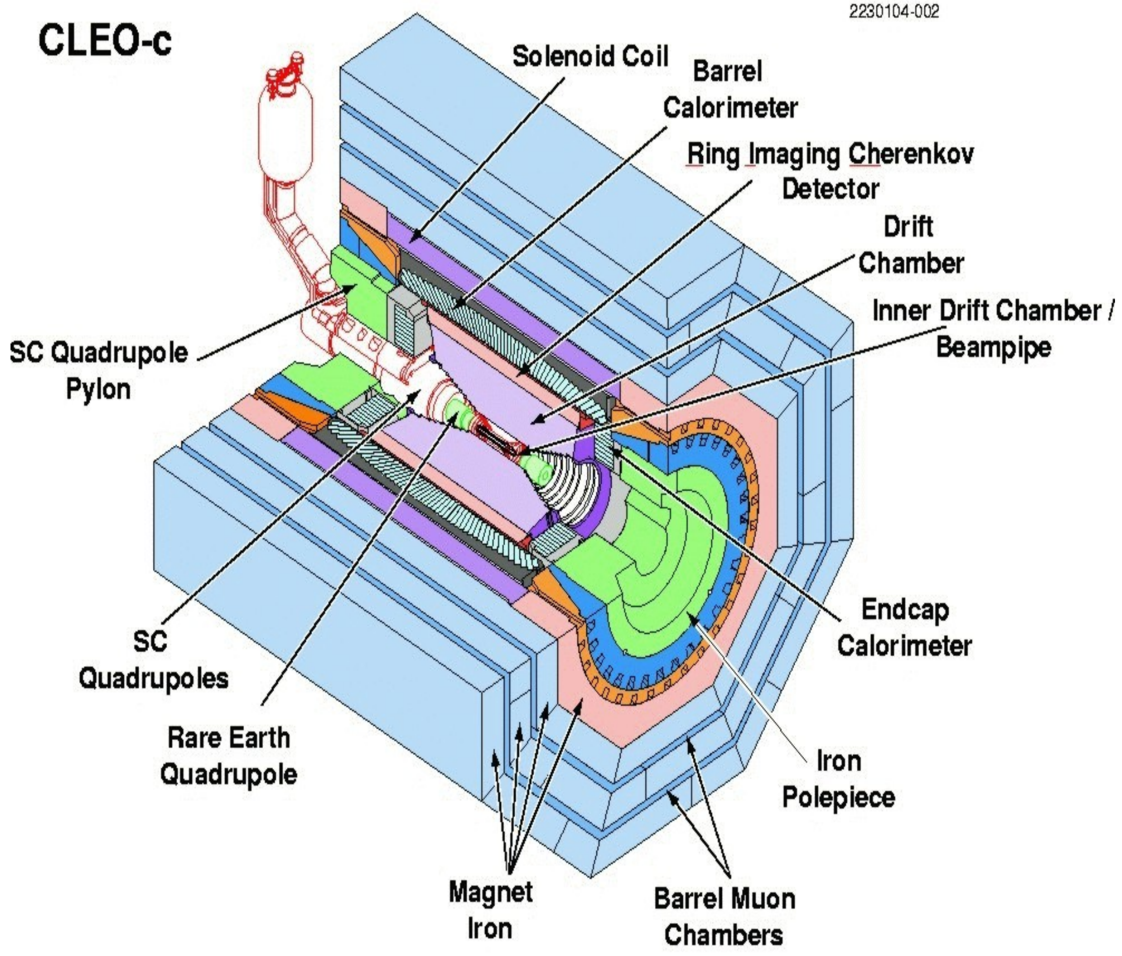


Determine γ by measuring
the interference of
$b \to u$ and $b \to c$ transitions
in $B \to D(D^0/\bar{D}^0)\, K$ decays,
with the $D^0/\bar{D}^0$ decaying to the same final state

* $B^\pm \to DK^\pm$, $D^*K^\pm$, $DK^{*\pm}$ and $B^0 \to DK^{*0}$ studies have been published

* Charm input provides information on D decays
  - ADS (Atwood-Dunietz-Soni) method: $D \to K\pi$, $K\pi\pi\pi$, $K\pi\pi^0$
  - Binned model-independent analysis of $D \to K_{S,L}\, \pi^+ \pi^-$

CESR-c/CLEO-c



Data produced at the Cornell Electron Storage Ring, a symmetric e^+e^- collider with both beams in the same ring

CLEO-c Detector

- Covered 93% of solid angle
- Tracking: $\sigma_p / \mathbf{p} = 0.6\%$ @ 1GeV
- Shower Calorimetry: $\sigma_E / E = 5\ (2.2)\%$ @ 0.1 (1) GeV
- Charged PID (dE/dx + RICH): Good K/π separation over whole momentum range (**p** < 2.5 GeV/c)

818 pb^{-1} collected @ $E_{CM} = M[\psi(3770)]$

Quantum Correlation with $e^+e^- \to \psi(3770)$

Best environment for Quantum Correlated D decays is $e^+e^- \to \psi(3770) \to D^0\overline{D}^0$

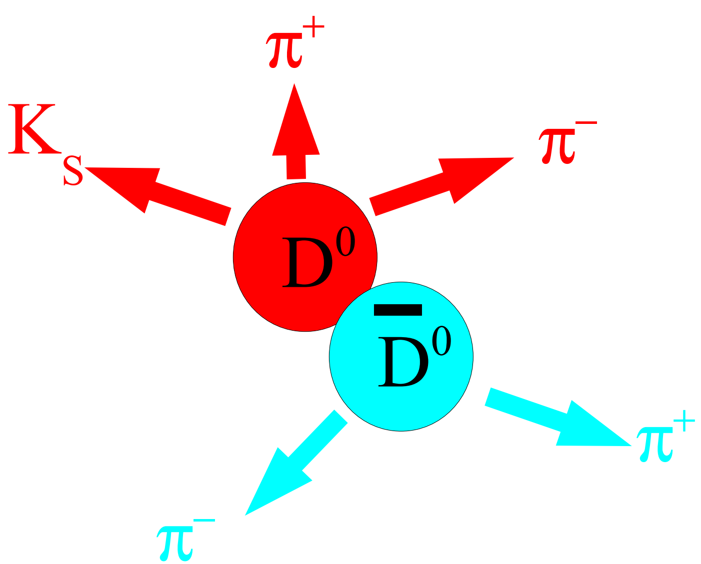
Since $\psi(3770)$ is $C = -1$, $CP(D^0\overline{D}^0) = -1$

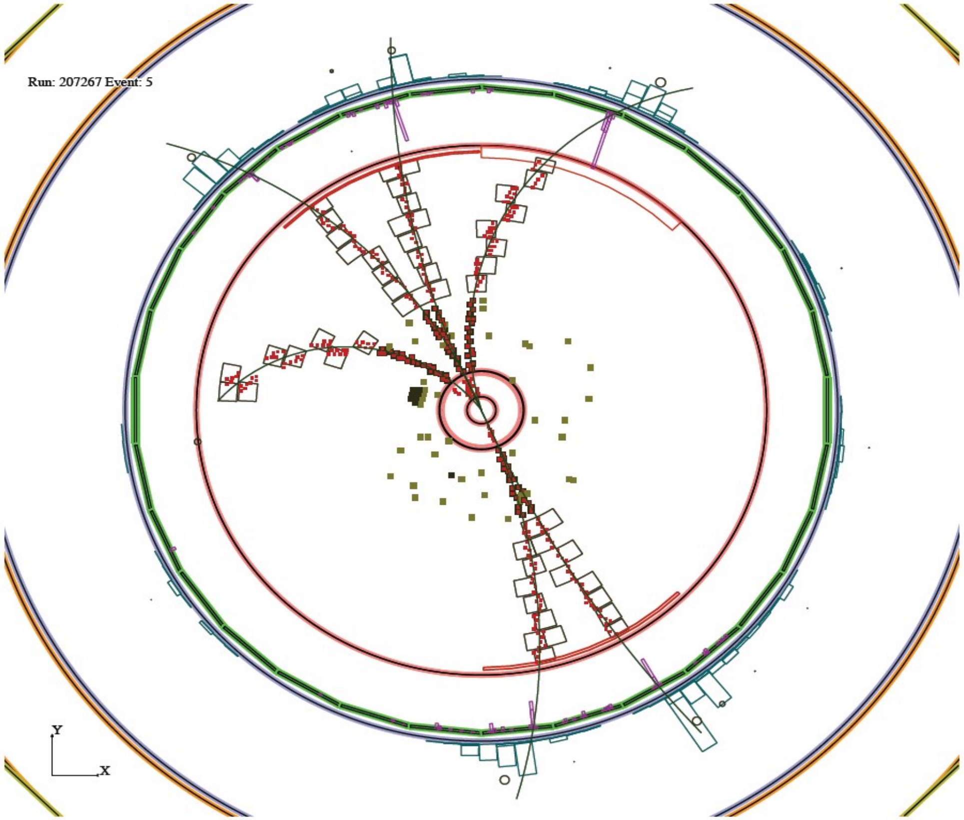
Reconstruct one decay of interest (e.g., $D^0 \to K_S\pi^+\pi^-$),

other is of known CP (e.g., $\overline{D}^0 \to \pi^+\pi^-$, CP+)

Very clean signals

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





$\delta_D^{K\pi}$ for $D \to K\pi$ decays

For $B \to D(K\pi)\,K$ decays, two of four final states can have large CP-asymmetry

$$\Gamma(B^- \to (K^+\pi^-)_D K^-) \propto r_B^2 + (r_D^{K\pi})^2 + 2\, r_B\, r_D^{K\pi} \cos(\delta_B + \delta_D^{K\pi} - \gamma)$$

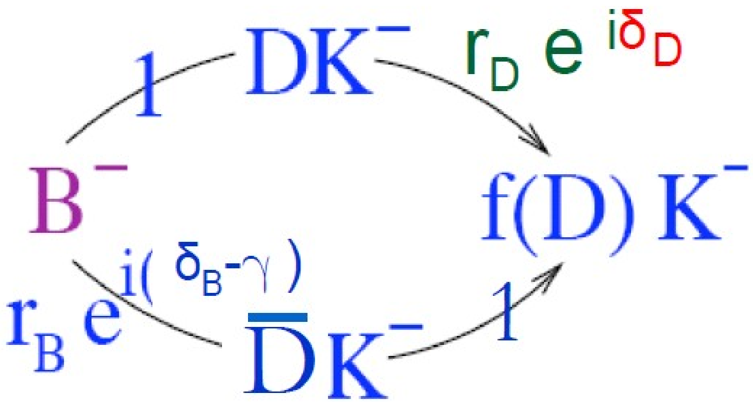
$$\Gamma(B^+ \to (K^-\pi^+)_D K^+) \propto r_B^2 + (r_D^{K\pi})^2 + 2\, r_B\, r_D^{K\pi} \cos(\delta_B + \delta_D^{K\pi} + \gamma)$$

~0.1

Need to know parameters related to the D decay

$$\frac{\langle K^+\pi^-|D^0\rangle}{\langle K^+\pi^-|\overline{D}^0\rangle} = r_D^{K\pi} e^{i\delta_D^{K\pi}}$$

~0.06



Possible to constrain γ, but need to know $\delta_D^{K\pi}$

$\Rightarrow$ Use quantum-correlated D decays

Measurement of $\delta_D^{K\pi}$

Measuring correlated $\psi(3770) \rightarrow D^0\overline{D}^0$ decays allow access to D mixing parameters and relative strong phase $\delta_D^{K\pi}$

Mode	Correlated	Uncorr.	
$K^-\pi^+$	$1 + R_{WS}$	$1 + R_{WS}$	ST
$S_\pm$	2	2	
$K^-\pi^+, K^-\pi^+$	R_M	R_{WS}	DT
$K^-\pi^+, K^+\pi^-$	$(1 + R_{WS})^2 - 4r\cos\delta(r\cos\delta + y)$	$1 + R_{WS}^2$	
$K^-\pi^+, S_\pm$	$1 + R_{WS} \pm 2r\cos\delta \pm y$	$1 + R_{WS}$	
$K^-\pi^+, e^-$	$1 - ry\cos\delta - rx\sin\delta$	1	
$S_\pm, S_\pm$	0	1	
S_+, S_-	4	2	
$S_\pm, e^-$	$1 \pm y$	1	

$S_+ = CP+$, $S_- = CP-$

Type	Final states
Flavored	$K^-\pi^+, K^+\pi^-$
S_+	$K^+K^-, \pi^+\pi^-, K_S^0\pi^0\pi^0, K_L^0\pi^0$
S_-	$K_S^0\pi^0, K_S^0\eta, K_S^0\omega$
$e^\pm$	Inclusive $Xe^+\nu_e, Xe^-\bar{\nu}_e$

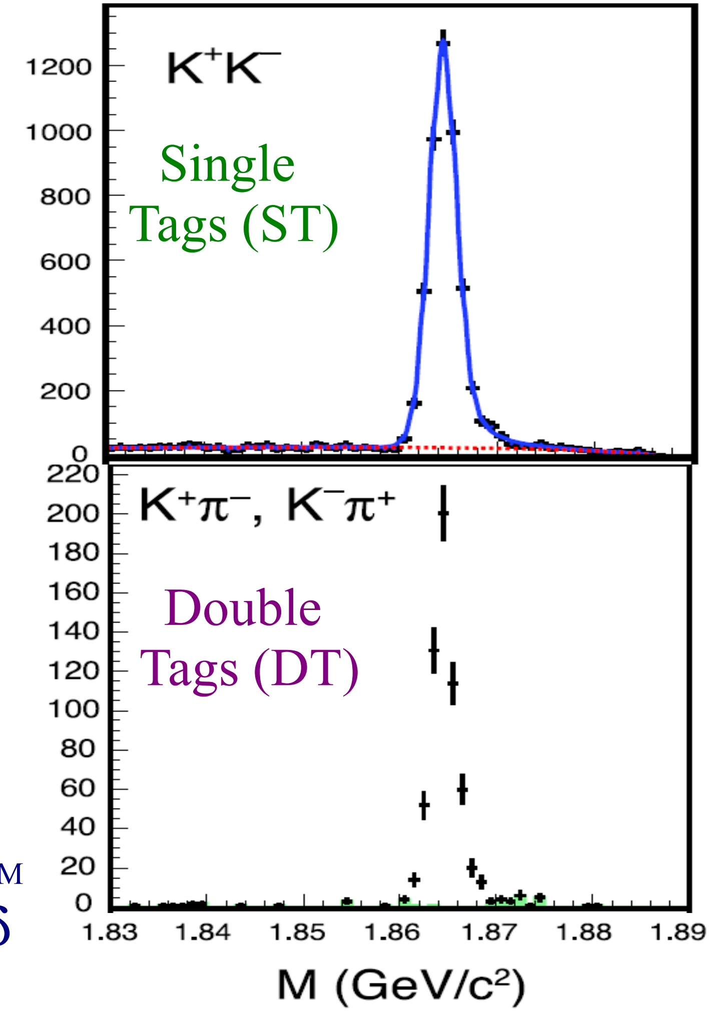
$x = (M_2 - M_1)/\Gamma$

$y = (\Gamma_2 - \Gamma_1)/2\Gamma$

$R_M = (x^2 + y^2)/2$

$R_{WS} = r^2 + ry' + R_M$

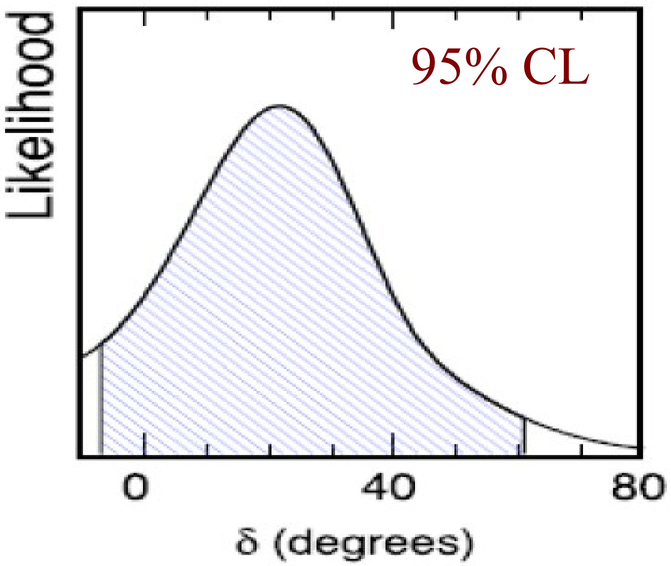
$y' = y\cos\delta - x\sin\delta$



$\delta_D^{K\pi}$ Results (281 pb^{-1})

Use CLEO-c measurements of signal and double tag yields and external r^2, x, y, x', y' measurements to determine r^2, x, y, r $\cos\delta_D^{K\pi}$ and rx $\sin\delta_D^{K\pi}$ from a least-squares fit [W. M. Sun, NIM, A556, 325 (2006)]

CLEO-c: PRL 100, 221801 (2008); PRD 78, 012001 (2008)



$$\delta_D^{K\pi} = (22^{+11+9}_{-12-11})^\circ$$

	Mode		Yield
ST	$K^-\pi^+$		$25\,374 \pm 168$
ST	$K^+\pi^-$		$25\,842 \pm 169$
ST	K^+K^-	CP(S)+	4740 ± 71
ST	$\pi^+\pi^-$	CP(S)+	2098 ± 60
ST	$K^0_S\pi^0\pi^0$	CP(S)+	2435 ± 74
ST	$K^0_S\pi^0$	CP(S)–	7523 ± 93
ST	$K^0_S\eta$	CP(S)–	1051 ± 43
ST	$K^0_S\omega$	CP(S)–	3239 ± 63
DT	$K^\mp\pi^\pm$, $K^\mp\pi^\pm$ (2)		4 ± 2
DT	$K^-\pi^+$, $K^+\pi^-$ (1)		600 ± 25
DT	$K^\mp\pi^\pm$, S_+ (8)		605 ± 25
DT	$K^\mp\pi^\pm$, S_- (6)		243 ± 16
DT	$K^\mp\pi^\pm$, $e^\mp$ (2)		2346 ± 65
DT	S_+, S_+ (9*)		10 ± 6
DT	S_-, S_- (6*)		2 ± 2
DT	S_+, S_- (12)		242 ± 16
DT	S_+, $e^\mp$ (6)		406 ± 44
DT	S_-, $e^\mp$ (6)		538 ± 40

First measurement of strong phase $\delta_D^{K\pi}$

Will be improved by including more tag modes in analysis of full 818 pb^{-1} $\psi(3770)$ sample

ADS method for multi-body D decays

ADS method can be extended to multi-body flavor-tagged D decays with larger BFs
[Atwood & Soni, PRD 68, 033003 (2003)]

Intermediate resonances of multi-body D decays have many contributing amplitudes, each point in phase space has its own relative strong phase

If particular intermediate resonances are not isolated,
then interference term is diluted by a coherence factor, e.g., $R_{K3\pi}$ for $D \to K\pi\pi\pi$

$$\Gamma(B^- \to (K^+\pi^-\pi^-\pi^+)_D K^-) \propto r_B^2 + (r_D^{K3\pi})^2 + 2\, r_B\, r_D^{K3\pi}\, R_{K3\pi} \cos(\delta_B + \delta_D^{K3\pi} - \gamma)$$

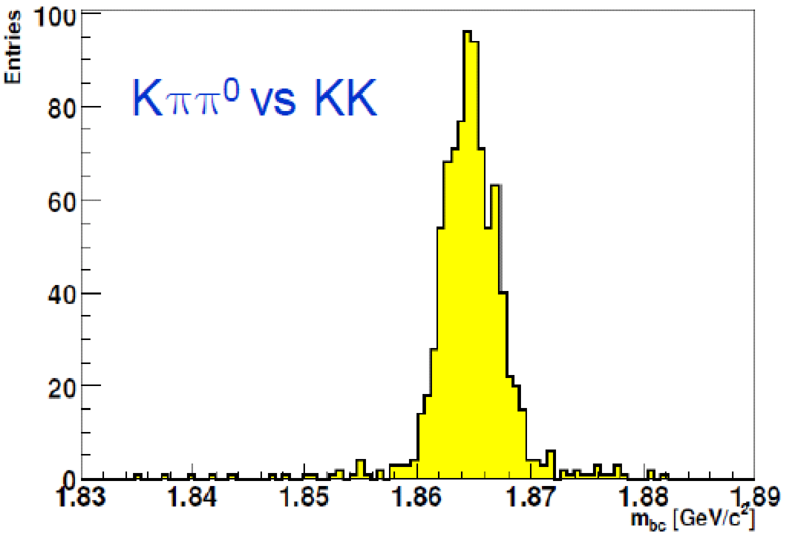
- $R_{K3\pi}$ = between 0 (several significant modes) and 1 (dominated by single mode)
- $\delta^{K3\pi}$ = average strong phase difference over entire phase space
- Large value of $R_{K3\pi}$ allows for higher sensitivity to γ

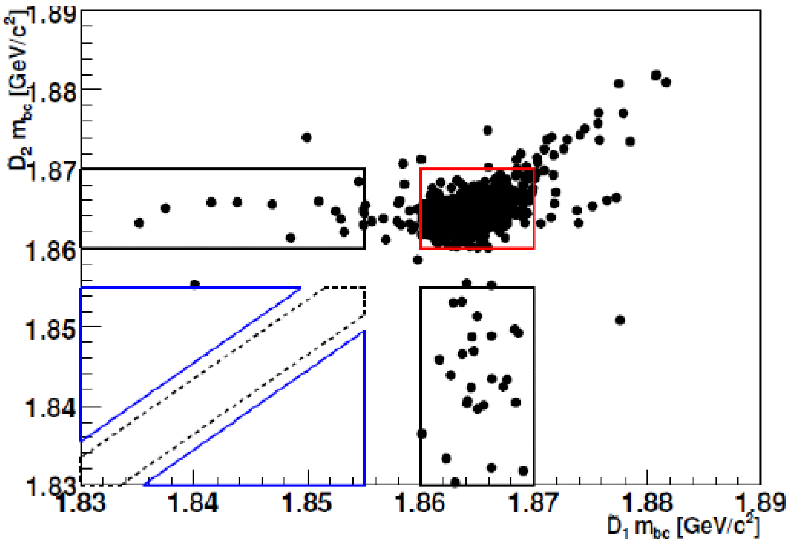
$R_{K3\pi}$ and $\delta^{K3\pi}$ can be measured with quantum-correlated $\psi(3770) \to D^0\overline{D}^0$ decays
Analogous parameters for other decays, e.g., $K\pi\pi^0$

Yields for $D \to K3\pi$, $K\pi\pi^0$ analysis

Uses full 818 pb^{-1} $\psi(3770)$ sample,
1 new CP+, 2 new CP– modes
(as compared to 281pb^{-1} $D \to K\pi$ analysis)

	Mode	$K^\pm\pi^\mp\pi^\mp\pi^\pm$	$K^\pm\pi^\mp\pi^0$
	$K^\mp\pi^\pm\pi^\pm\pi^\mp$	$4,044 \pm 64$	—
	$K^\pm\pi^\mp\pi^\mp\pi^\pm$	29.1 ± 5.9	—
	$K^\mp\pi^\pm\pi^0$	$9,594 \pm 99$	$7,342 \pm 87$
	$K^\pm\pi^\mp\pi^0$	63.6 ± 8.8	12.5 ± 4.1
	$K^\mp\pi^\pm$	$5,206 \pm 72$	$7,155 \pm 85$
	$K^\pm\pi^\mp$	35.6 ± 6.2	7.3 ± 3.3
CP+	K^+K^-	536 ± 23	764 ± 28
CP+	$\pi^+\pi^-$	246 ± 16	336 ± 18
CP+	$K^0_S\pi^0\pi^0$	283 ± 18	406 ± 21
CP+	$K^0_L\pi^0$	827 ± 30	$1,236 \pm 38$
CP+	$K^0_L\omega$	296 ± 18	449 ± 22
CP–	$K^0_S\pi^0$	705 ± 27	891 ± 30
CP–	$K^0_S\omega$	319 ± 19	389 ± 21
CP–	$K^0_S\phi$	53.0 ± 7.5	90.9 ± 9.9
CP–	$K^0_S\eta(\gamma\gamma)$	128 ± 12	116 ± 11
CP–	$K^0_S\eta(\pi^+\pi^-\pi^0)$	35.9 ± 6.5	36.3 ± 7.2
CP–	$K^0_S\eta'$	35.7 ± 6.0	60.6 ± 7.8





Observables for $D \to K3\pi, K\pi\pi^0$

$$\rho^F_{LS} = \frac{1-R_F^2}{1+\frac{(x^2+y^2)}{2(r_D^F)^2} - \frac{R_F}{r_D^F}(y\cos\delta_D^F - x\sin\delta_D^F)}$$

$$\rho^F_{CP\pm} = 1 \pm \Delta^F_{CP}, \text{ where } \Delta^F_{CP} = y - 2r_D^F R_F \cos\delta_D^F$$

$$\rho^F_{K\pi,LS} \propto \frac{\left[1-\left(\frac{r^F}{r^{K\pi}}\right)^2 - 2\left(\frac{r^F}{r^{K\pi}}\right)R_F\cos\delta_D^F\right]}{1+\frac{(x^2+y^2)}{2(r_D^{K\pi})^2} - \frac{1}{r_D^{K\pi}}(y\cos\delta_D^{K\pi} - x\sin\delta_D^{K\pi})}$$

F = $K3\pi, K\pi\pi^0$

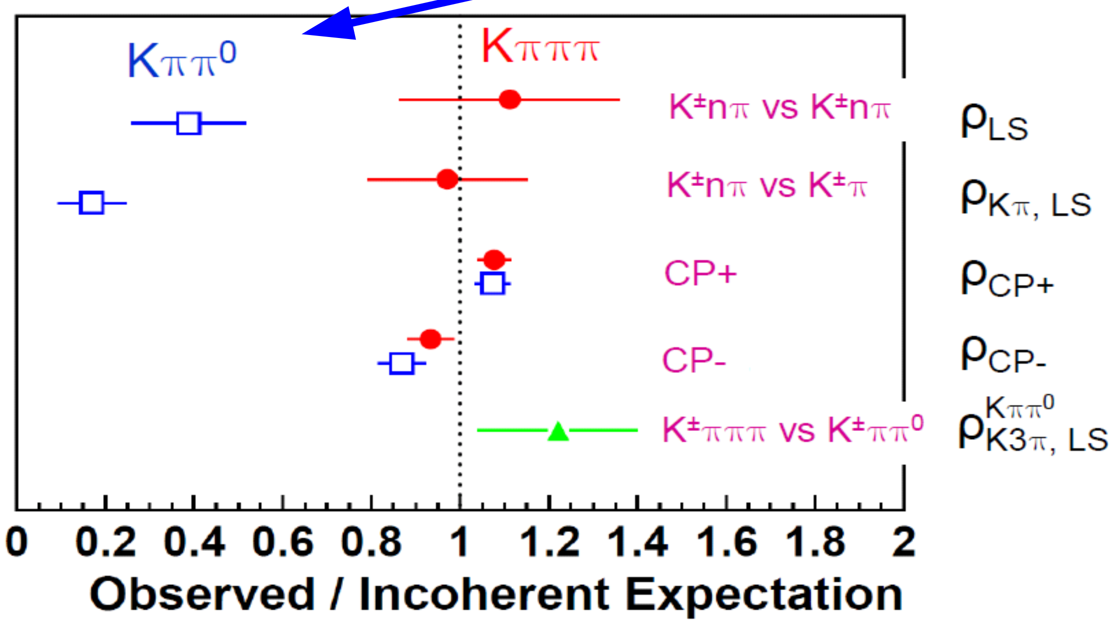
$$\rho^{K\pi\pi^0}_{K3\pi,LS} \propto \frac{\left[1-\left(\frac{r^{K\pi\pi^0}}{r^{K3\pi}}\right)^2 - 2\left(\frac{r^{K\pi\pi^0}}{r^{K3\pi}}\right)R_{K\pi\pi^0}R_{K3\pi}\cos\left(\delta_D^{K\pi\pi^0}-\delta_D^{K3\pi}\right)\right]}{1+\frac{(x^2+y^2)}{2(r_D^{K3\pi})^2} - \frac{R_{K3\pi}}{r_D^{K3\pi}}(y\cos\delta_D^{K3\pi} - x\sin\delta_D^{K3\pi})}$$

$K\pi\pi^0$ very coherent

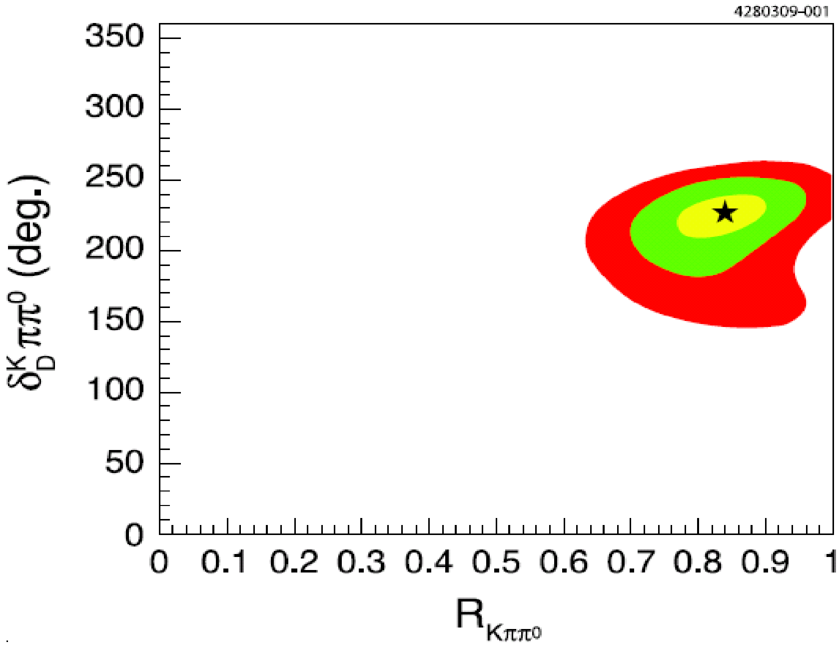
Measure the ρ observables from double-tag efficiency-corrected yields

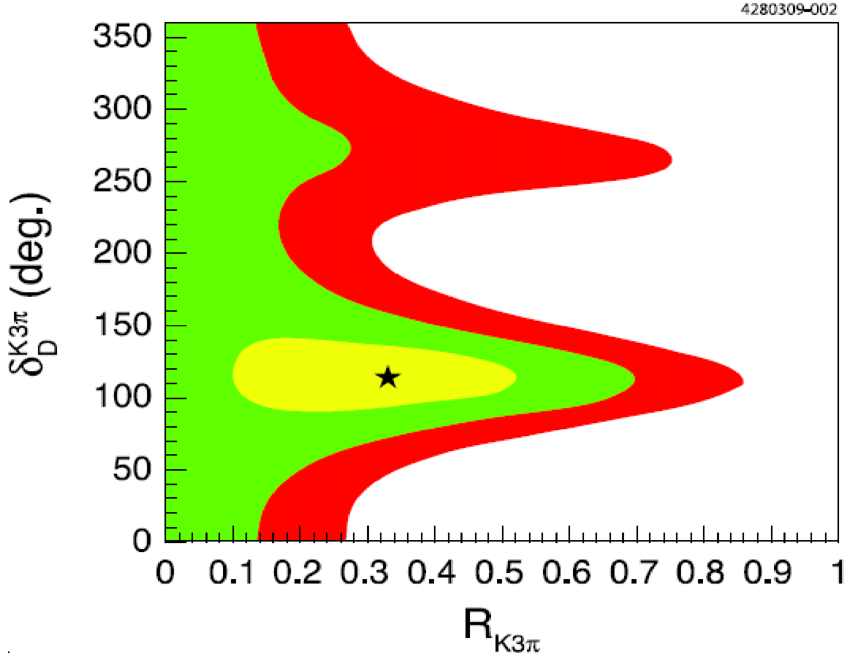
Use external measurements of r^F, x, y

⇒ Access to R_F, δ_D^F



Coherence Factors (818 pb^{-1})





CLEO-c: arXiv:0903.4852[hep-ex] (submitted)

$$R_{K\pi\pi^0} = 0.84 \pm 0.07 \qquad R_{K3\pi} = 0.33^{+0.20}_{-0.23}$$

$$\delta_D^{K\pi\pi^0} = (227^{+14}_{-17})^\circ \qquad \delta_D^{K3\pi} = (114^{+26}_{-23})^\circ$$

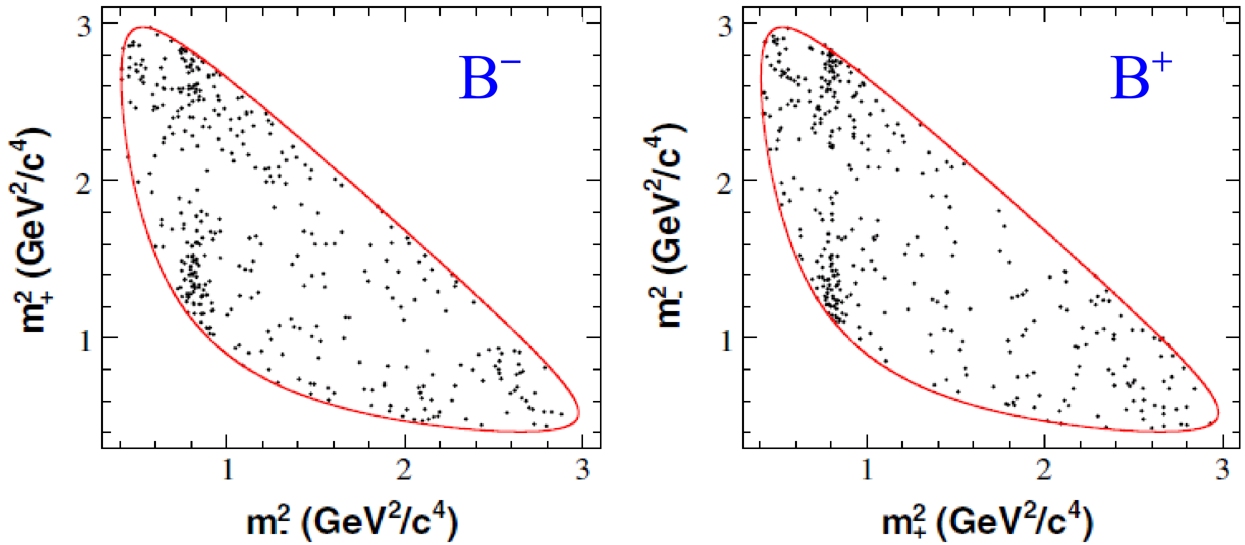
$B \to D(K\pi\pi^0)K$ decays sensitive to γ, $B \to D(K3\pi)K$ sensitive to r_B

$r_D \sim 0.06$

$$\Gamma(B^- \to (K^+\pi^-\pi^-\pi^+)_D K^-) \propto r_B^2 + (r_D^{K3\pi})^2 + 2\, r_B\, r_D^{K3\pi}\, R_{K3\pi} \cos(\delta_B + \delta_D^{K3\pi} - \gamma)$$

Measuring γ using $D \to K_S\pi^+\pi^-$ decays

The most precise measurements of γ are from $B^\pm \to D(K_S\pi^+\pi^-) K^\pm$ decays, since $D \to K_S\pi^+\pi^-$ decays are Cabbibo-favored



BaBar: PRD 78, 034023 (2008)

BaBar w/ 383M $B\overline{B}$ ($K_SK^+K^- + K_S\pi^+\pi^-$): $\gamma = [76\ ^{+23}_{-24}(stat) \pm 5(syst) \pm 5(model)]^\circ$

[PRD 78, 034023 (2008)] ($K_S\pi^+\pi^-$ only): $\gamma = [63\ ^{+30}_{-28}(stat) \pm 8(syst) \pm 7(model)]^\circ$

Belle w/ 657M $B\overline{B}$ ($K_S\pi^+\pi^-$ only): $\gamma = [76\ ^{+12}_{-13}(stat) \pm 4(syst) \pm 9(model)]^\circ$

[arXiv:0803.3375[hep-ex], preliminary]

Model uncertainty arises from isobar model analysis of flavor-tagged $D \to K_S\pi^+\pi^-$ decays from continuum-produced $D^{*\pm} \to D\,\pi^\pm$ events

Binning of $D \to K_S\pi^+\pi^-$ Dalitz plot

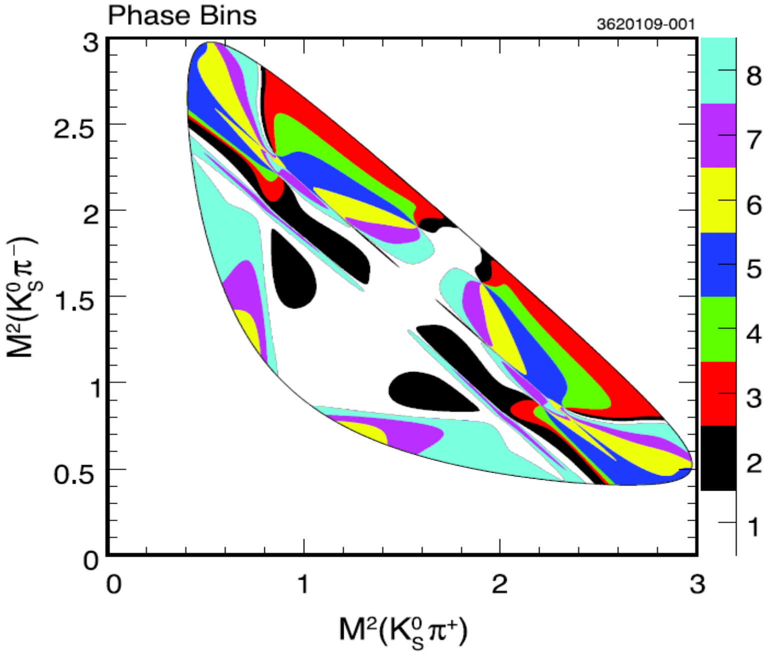
Model dependence can be removed by performing binned analysis of Dalitz plot

Giri *et al.* [PRD 68, 054018 (2003)]

* Divide Dalitz plot into 2N bins
* –N to N bins (omitting N = 0)
* Symmetric about $M^2(K_S\pi^+) = M^2(K_S\pi^-)$

Bondar & Poluekov [EPJC 47, 347 (2006); EPJC 55, 51 (2008)] proposed to bin plot to minimize the variation of $\Delta\delta_D = \delta_D(M^2(K_S\pi^+)) - \delta_D(M^2(K_S\pi^-))$ in each bin

Binning determined from BaBar model



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

$$\langle N_i^\pm \rangle = h_B \left[K_i + r_B^2 K_{-i} + 2r_B\sqrt{K_i K_{-i}}(c_i \cos(\delta_B \pm \gamma) + s_i \sin(\delta_B \pm \gamma)) \right]$$

$N_i^\pm$ = Number of $B^\pm$ events in bin i of Dalitz plot

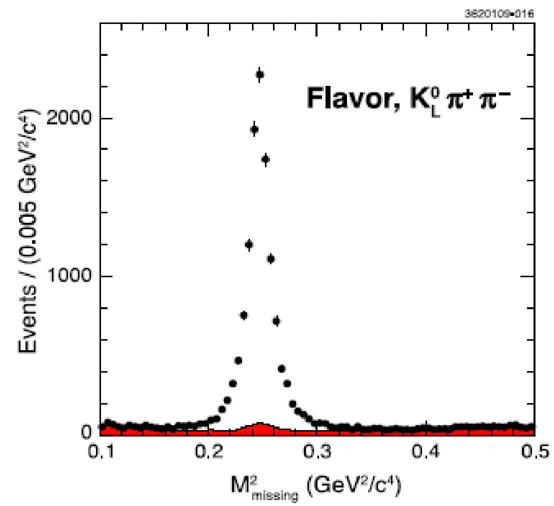
$K_{i(-i)}$ = Number of D events in bin i ($-i$) from flavor-tagged D sample

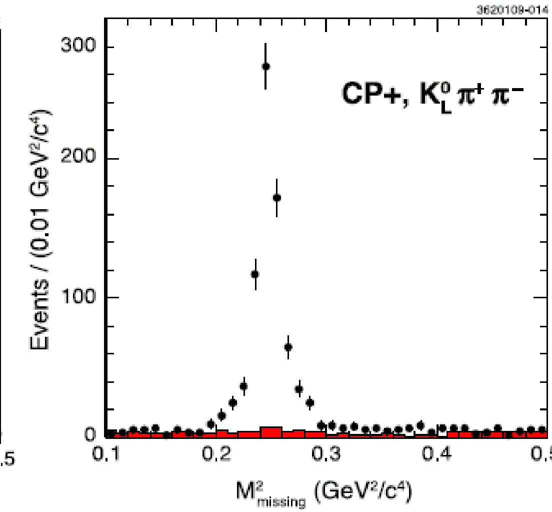
$c_i = \cos\Delta\delta_D$, $s_i = \sin\Delta\delta_D$ can be measured in quantum-correlated $\psi(3770)$ decays

CLEO-c binned $D \to K_{S,L}\pi^+\pi^-$ analysis

Uses full 818 pb^{-1} $\psi(3770)$ sample

Mode	ST Yield	$K_S^0\pi^+\pi^-$ yield	$K_L^0\pi^+\pi^-$ yield
Flavor Tags			
$K^-\pi^+$	144563 ± 403	1447	2858
$K^-\pi^+\pi^0$	258938 ± 581	2776	5130
$K^-\pi^+\pi^+\pi^-$	220831 ± 541	2250	4110
$K^-e^+\nu$	123412 ± 4591	1356	-
CP-Even Tags			
K^+K^-	12867 ± 126	124	345
$\pi^+\pi^-$	5950 ± 112	62	172
$K_S^0\pi^0\pi^0$	6562 ± 131	56	-
$K_L^0\pi^0$	27955 ± 2013	229	-
CP-Odd Tags			
$K_S^0\pi^0$	19059 ± 150	189	281
$K_S^0\eta$	2793 ± 69	39	41
$K_S^0\omega$	8512 ± 107	83	-
$K_S^0\pi^+\pi^-$	-	475	867





Use of $K_L\pi^+\pi^-$ increases statistics by more than factor 2, but introduces c_i', s_i' and

$$\mathcal{A}(K_L\pi^+\pi^-) = \sqrt{2}\mathcal{A}(K^0\pi^+\pi^-) - \mathcal{A}(K_S\pi^+\pi^-)$$

$K_S\pi^+\pi^-$ vs. CP tags: $M_i^{\pm} = h_{CP\pm}(K_i \pm 2c_i\sqrt{K_iK_{-i}} + K_{-i})$ — K_i: flavor-tagged $K_S\pi^+\pi^-$ in bin i

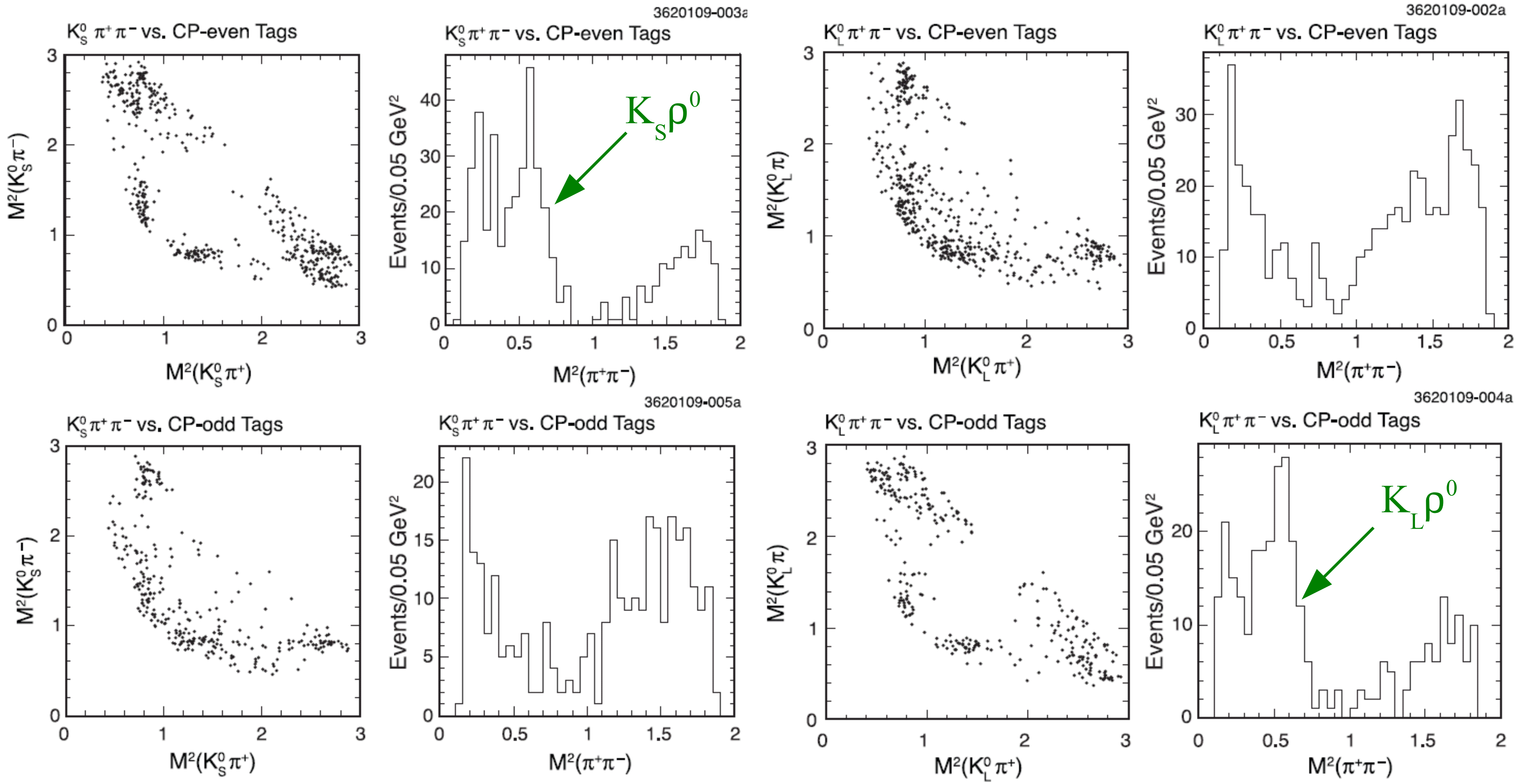
$K_S\pi^+\pi^-$ vs. $K_S\pi^+\pi^-$: $M_{ij} = h_{corr}(K_iK_{-j} + K_{-i}K_j - 2\sqrt{K_iK_{-j}K_{-i}K_j}(c_ic_j + s_is_j))$

$K_L\pi^+\pi^-$ vs. CP tags: $M_i^{\pm} = h_{CP\pm}(K_i' \mp 2c_i'\sqrt{K_i'K_{-i}'} + K_{-i}')$ — K_j': flavor-tagged $K_L\pi^+\pi^-$ in bin j

$K_L\pi^+\pi^-$ vs. $K_S\pi^+\pi^-$: $M_{ij} = h_{corr}[K_iK_{-j}' + K_{-i}K_j' + 2\sqrt{K_iK_{-j}'K_{-i}K_j'}(c_ic_j' + s_is_j')]$

$K_{S,L}\pi^+\pi^-$ Dalitz Plots

$K_S\pi^+\pi^-$ $K_L\pi^+\pi^-$

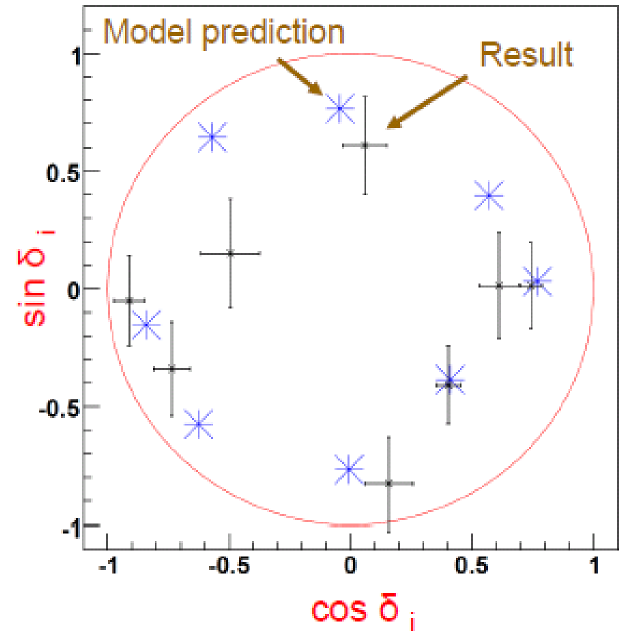


$K_{S,L}\pi^+\pi^-$ Results (818 pb^{-1})

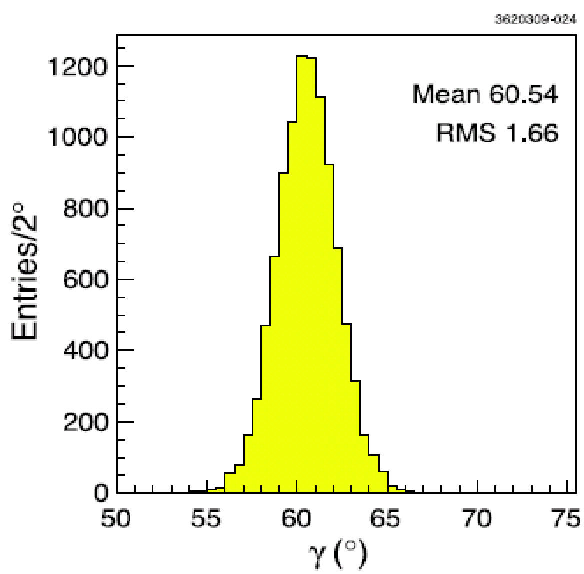
CLEO-c: arXiv:0903.1681[hep-ex] (submitted to PRD)

Result ± stat ± syst ± ($K_L\pi^+\pi^- \leftrightarrow K_S\pi^+\pi^-$)

i	c_i	s_i
0	$0.743 \pm 0.037 \pm 0.022 \pm 0.013$	$0.014 \pm 0.160 \pm 0.077 \pm 0.045$
1	$0.611 \pm 0.071 \pm 0.037 \pm 0.009$	$0.014 \pm 0.215 \pm 0.055 \pm 0.017$
2	$0.059 \pm 0.063 \pm 0.031 \pm 0.057$	$0.609 \pm 0.190 \pm 0.076 \pm 0.037$
3	$-0.495 \pm 0.101 \pm 0.052 \pm 0.045$	$0.151 \pm 0.217 \pm 0.069 \pm 0.048$
4	$-0.911 \pm 0.049 \pm 0.032 \pm 0.021$	$-0.050 \pm 0.183 \pm 0.045 \pm 0.036$
5	$-0.736 \pm 0.066 \pm 0.030 \pm 0.018$	$-0.340 \pm 0.187 \pm 0.052 \pm 0.047$
6	$0.157 \pm 0.074 \pm 0.042 \pm 0.051$	$-0.827 \pm 0.185 \pm 0.060 \pm 0.036$
7	$0.403 \pm 0.046 \pm 0.021 \pm 0.002$	$-0.409 \pm 0.158 \pm 0.050 \pm 0.002$



Model = BaBar: PRL 95, 121802 (2005)



<u>Effect on precision of γ</u>

Generated toy MC samples of $B^\pm \to D(K_S\pi^+\pi^-) K^\pm$ decays

$\gamma = 60^o$, $\delta_B = 130^o$, $r_B = 0.1$

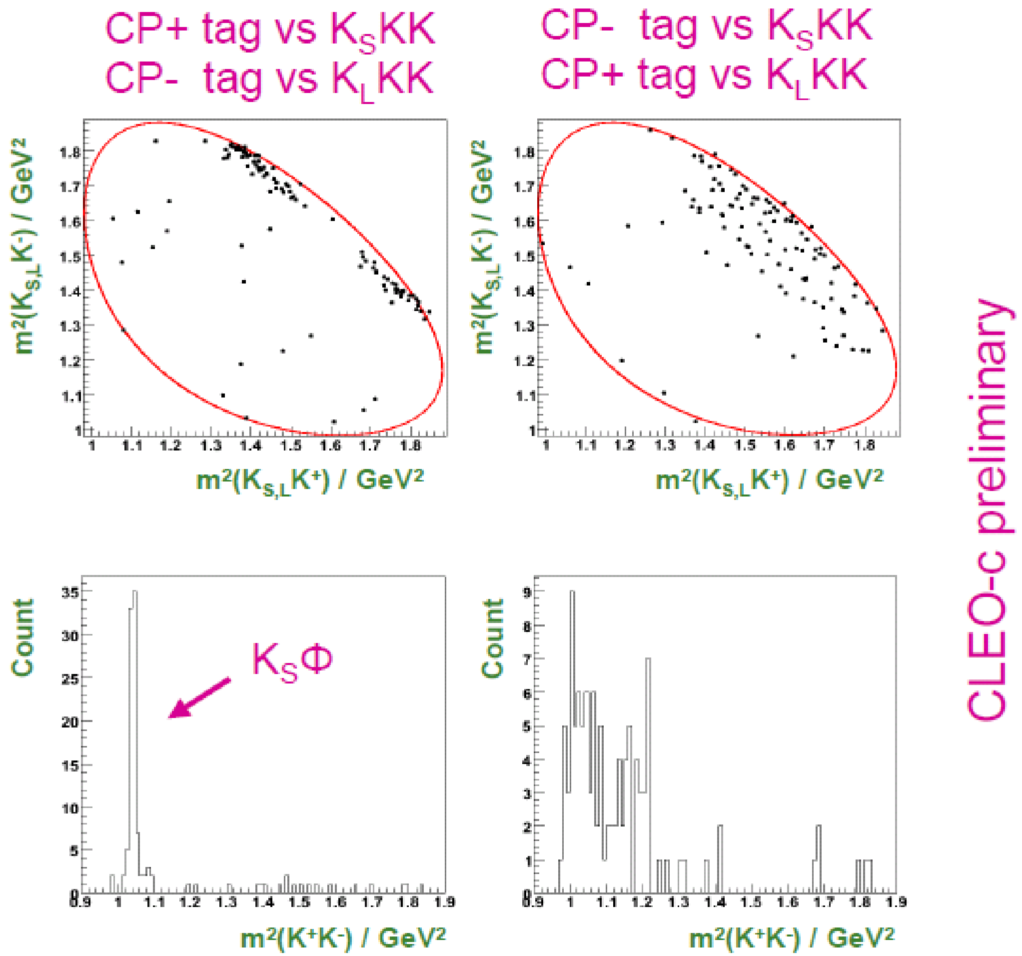
$\sigma_\gamma = 1.7^o$

Binned analysis of $D \rightarrow K_{S,L} K^+ K^-$

As suggested by Giri *et al.* [PRD 68, 054018 (2003)],
the binned Dalitz plot analysis method
can be extended to quantum-correlated $D \rightarrow K_{S,L} K^+ K^-$ decays

Measurement of $c_i^{(\prime)}$, $s_i^{(\prime)}$ currently underway at CLEO-c using full 818 pb^{-1} $\psi(3770)$ data sample

~550 quantum-correlated double tags



Summary

Using the quantum-correlated $\psi(3770) \rightarrow D^0\overline{D}^0$ decays @ CLEO-c

* Measured relative strong phase for $D \rightarrow K\pi$: $\delta_D^{K\pi} = (22^{+11+9}_{-12-11})^\circ$
  - From 281 pb^{-1} $\psi(3770)$ data sample
  - Analysis using full 818 pb^{-1} sample in progress, additional improvement by using more flavor and CP-tag modes
* Measured coherence factors using 818 pb^{-1} sample:

$$R_{K\pi\pi^0} = 0.84 \pm 0.07 \qquad R_{K3\pi} = 0.33^{+0.20}_{-0.23}$$

  - $B \rightarrow D(K\pi\pi^0)K$ decays sensitive to γ, $B \rightarrow D(K3\pi)K$ sensitive to r_B

* Measured $\cos\Delta\delta_D$, $\sin\Delta\delta_D$ for $D \rightarrow K_S\pi^+\pi^-$ using binned Dalitz plot method
  - $\sigma_\gamma < 2^o$ from modeling of $D \rightarrow K_S\pi^+\pi^-$ (818 pb^{-1} sample)
  - Binned analysis of $D \rightarrow K_{S,L}K^+K^-$ in progress

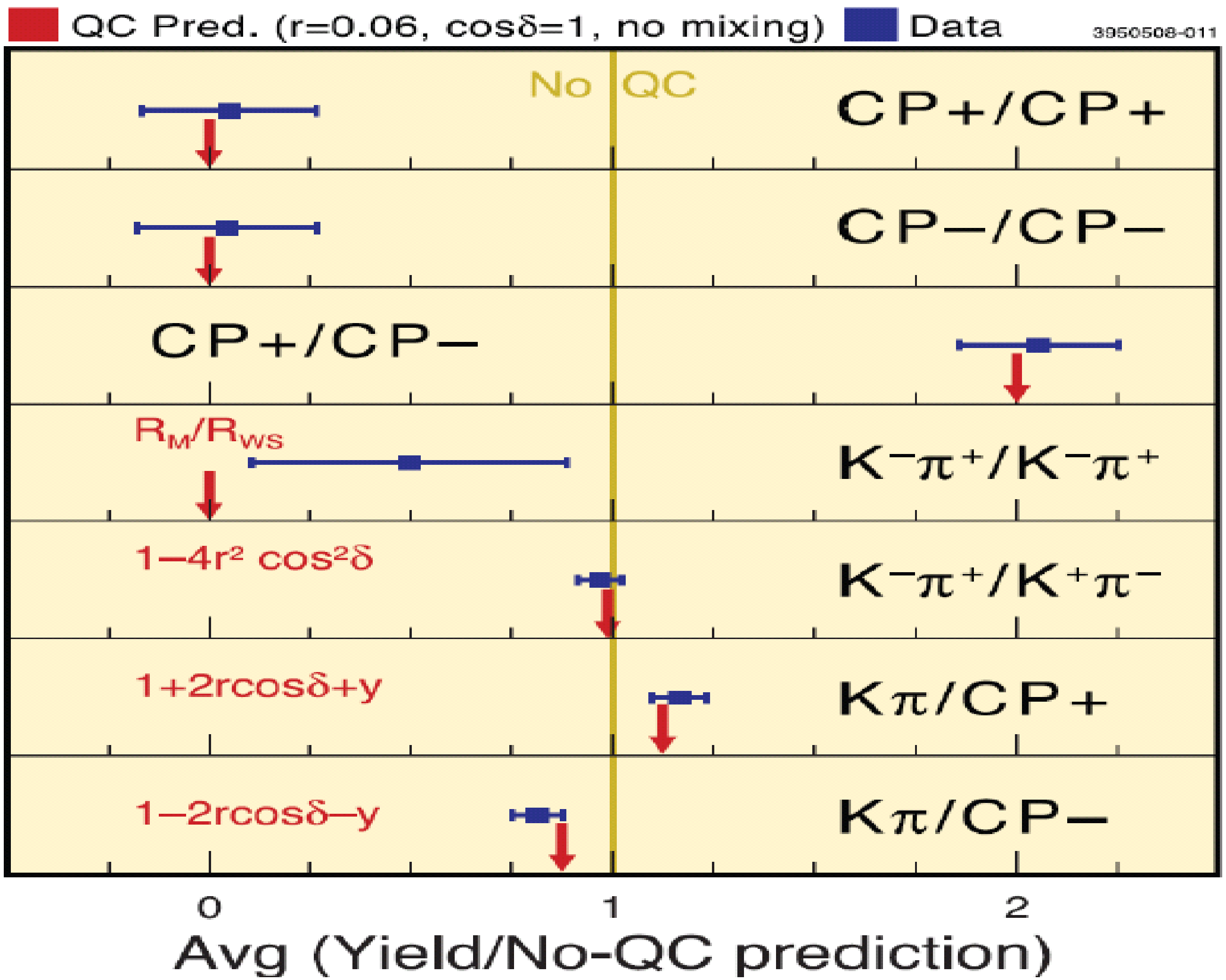
These measurements will help limit the external uncertainties on γ in future measurements from present B-factories and from LHCb and super-B experiments

BES-III will improve these measurements

Backup Slides

D Kp Results (281 pb^{-1})

CLEO-c: PRL 100, 221801 (2008); PRD 78, 012001 (2008)



ρ measurements for $D \to K3\pi$, $K\pi\pi^0$

Relations between efficiency-corrected yields, S, and ρ observables

$$\rho^F_{LS} = \frac{S(F|F) + S(\overline{F}|\overline{F})}{2N_{D^0\overline{D}^0}\mathcal{B}(D^0 \to F)\mathcal{B}(D^0 \to \overline{F})}$$

$$\rho^F_{K\pi,LS} = \frac{S(F|K^-\pi^+) + S(\overline{F}|K^+\pi^-)}{2N_{D^0\overline{D}^0}[\mathcal{B}(D^0 \to F)\mathcal{B}(D^0 \to K^+\pi^-) + \mathcal{B}(D^0 \to \overline{F})\mathcal{B}(D^0 \to K^-\pi^+)]}$$

$$\rho^F_{CP\pm} = \frac{S(F|CP) + S(\overline{F}|CP)}{2N_{D^0\overline{D}^0}\mathcal{B}(D^0 \to CP)[\mathcal{B}(D^0 \to F) + \mathcal{B}(D^0 \to \overline{F})]}$$

$$\rho^{K\pi\pi^0}_{K3\pi,LS} = \frac{S(K^-\pi^+\pi^0|K^-3\pi) + S(K^+\pi^-\pi^0|K^+3\pi)}{2N_{D^0\overline{D}^0}[\mathcal{B}(D^0 \to K^-\pi^+\pi^0)\mathcal{B}(D^0 \to K^+3\pi) + \mathcal{B}(D^0 \to K^+\pi^-\pi^0)\mathcal{B}(D^0 \to K^-3\pi)]}$$

$$N_{D^0\overline{D}^0} = \text{Number of produced } D^0\overline{D}^0 \text{ pairs}$$