CKM 2010, Warwick, UK - 6-10 September, 2010

CLEO-c inputs to the determination of the CKM angle γ

- Introduction: measuring the strong-phase difference δ_D between D^0 and $\overline{D}^0$ decays at CLEO-c
- Measurements of δ_D for $D \to K_S K^+ K^-$ and $D \to K_S \pi^+ \pi^-$
- Measurement of δ_D for $D \to K^+ \pi^-$
- Results from the coherence studies for $D \to K^+ \pi^- \pi^0$, $K^+ \pi^- \pi^+ \pi^-$

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PPd

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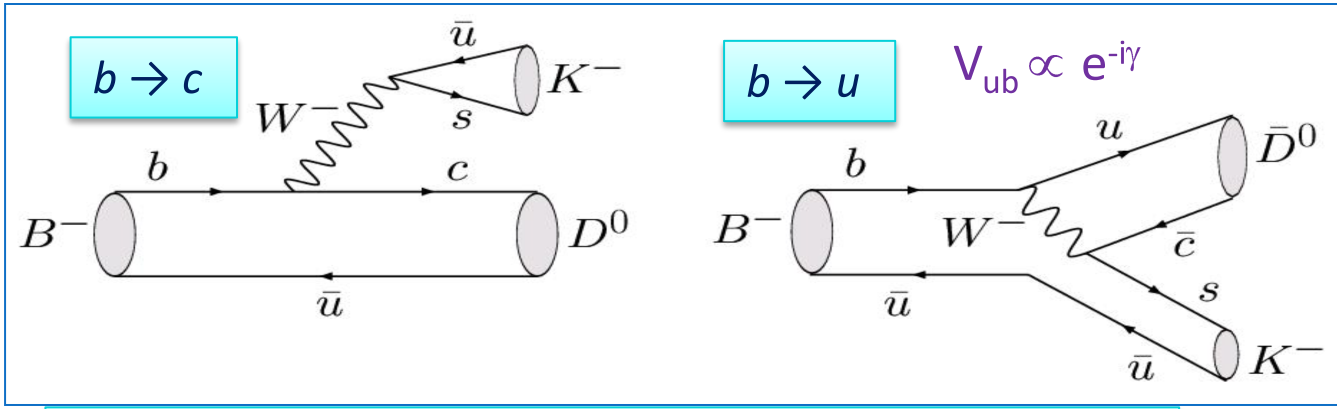
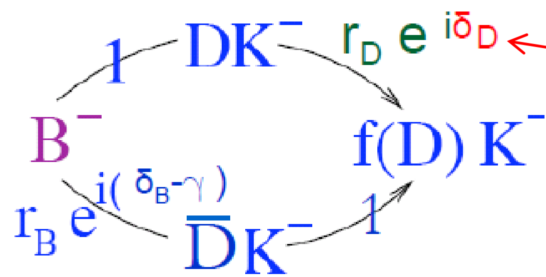
γ from $B^{\pm} \rightarrow DK^{\pm}$

Sensitivity to γ through interference of b → c and b → u transitions



Interference if D^0 and $\overline{D^0}$ decay to common final state ***f***

γ extracted from time-integrated measurements of B^+ and B^- decay rates [several well-established methods]



D decay parameters in particular δ_D not well-known

$$\frac{< D^0 \rightarrow f >}{< \overline{D}^0 \rightarrow f >} = r_D\, e^{i\delta_D}$$

Other B-decay parameters (to be extracted from data)

δ_B = *B*-decay strong phase difference

r_B = relative magnitude of suppressed B-decay amplitude

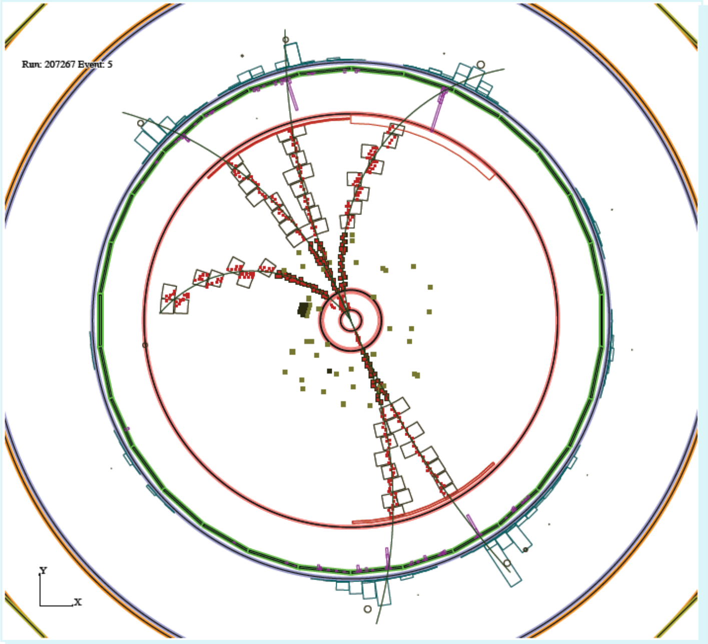
CLEO-c

- 818 pb^{-1} accumulated in
  $e^+e^- \rightarrow \psi(3770)$

- Just above open-charm threshold
  - very clean environment
  - no fragmentation particles
  - efficient reconstruction of both D decays
  - Efficient reconstruction of modes with missing particles (K_L,ν)

- Coherent decay of
  $\psi(3770) \rightarrow D^0\overline{D}^0$

$\Rightarrow$ Reconstructing one *D* decay in a CP eigenstate (CP-tag) allows one to infer CP of the other *D* (decay mode of interest) **CP(signal) = –1 x CP(tag)**



$\overline{D}^0 \longrightarrow K_S\pi\pi$ vs $D^0 \longrightarrow K^-\pi^+$

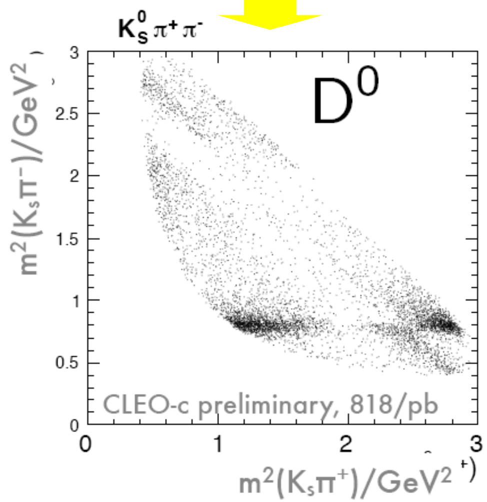
CP-tagged D sample, unique to ψ(3770) decays, gives access to phases

δ_D from quantum-correlations: the principle

E.g., decay mode of interest is $D^0 \to K_S\pi^+\pi^-$ (mixed CP)

- Flavour-tagged $D \to K_S\pi\pi$ decays (recoiling D decays to flavour-specific state)

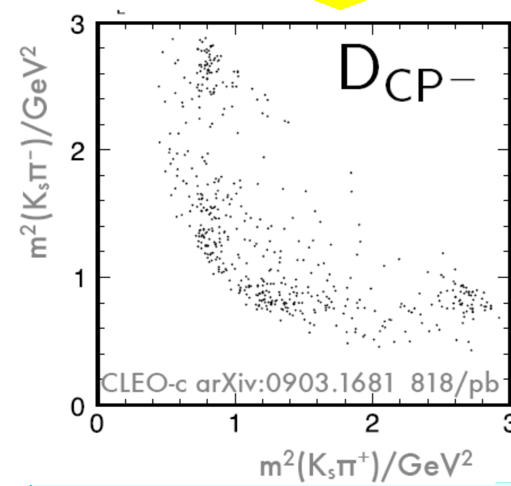
$\Psi(3770)$ → $\overline{D}^0 \to K^+ e^- \nu_e$ and $D^0 \to K_S \pi^+ \pi^-$



Flavour tagged rate
$\propto |D^0|^2$ or $|\overline{D}^0|^2$

- CP-tagged $D \to K_S\pi\pi$ (recoiling D decays to CP-eigenstate)

$\Psi(3770)$ → $D_{CP+} \to K^+ K^-$ and $D_{CP-} \to K_S \pi^+ \pi^-$



CP-tagged rate
$\propto |D^0|^2 + |\overline{D}^0|^2 \pm 2|D^0||\overline{D}^0| \cos(\delta_D)$

$\cos(\delta_D)$ from CP-tagged decays

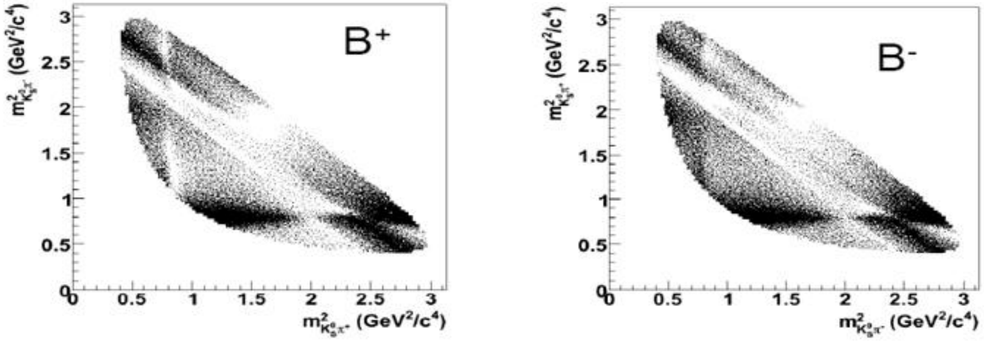
In addition, both $\cos(\delta_D)$ and $\sin(\delta_D)$ from mixed CP-tags

Measurements of δ_D for $D \to K_S K^+ K^-$ and $D \to K_S \pi^+ \pi^-$

- New preliminary results (to be submitted to PRD)
- Impact on γ from $B \to D(K_S hh)K$

γ from $B^+ \to D(K_S h^+ h^-)K^+$ [GGSZ,PRD 68, 054018 (2003)]

- Exploit interference pattern over *D-Dalitz* plots from B^+ and B^- decays



$m_\pm = m^2(K_S\pi^\pm)$

- Two ways to extract γ:

1. **Model-dependent method**
   - Unbinned amplitude fit
   - Relies on a model for D decay amplitude $f(m_+, m_-)$
   - Model-error
     - **BaBar** [arXiv1005.1096] **$K_S\pi\pi$+K_SKK :** ~3°
     - **Belle** [PRD 81 112002,2010] **$K_S\pi\pi$:** ~9°

$$A(B^\pm \to D(K_S\pi\pi)K^\pm) \propto f(m_\mp, m_\pm) + r_B e^{i(\delta_B \pm \gamma)} f(m_\mp, m_\pm)$$

Model error
- Hard to quantify
- Will limit future precision

2. **Model-independent method**
   - Binned fit
   - Small loss in statistical sensitivity compared to unbinned fit
   - No model error
   - Requires external inputs on δ_D

Model-independent extraction of γ

- Discrete measurements of δ_D in bins of the Dalitz plot are sufficient to extract γ in a **model-independent** way [GGSZ, PRD 68(2003)054018, Bondar&Poluektov, EPJ C 47(2006) 347]

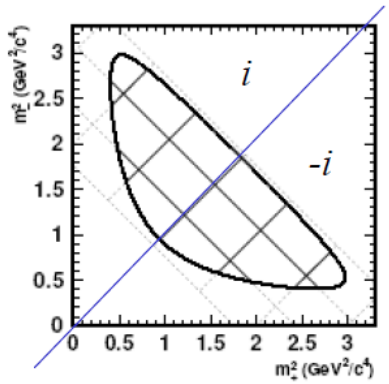
# of B decays in bin i

$T_i = \int_i |A_D(m_+,m_-)|^2 \, dm_+ dm_-$
# of flavour-tagged D decays in bin i

$$\Gamma(B^\pm \to D^0(K_s h^+ h^-)K^\pm)_i \propto$$

$$T_i + r_B^2 T_{-i} + 2 r_B \sqrt{T_i T_{-i}} \{c_i \cos(\delta_B \pm \gamma) + s_i \sin(\delta_B \pm \gamma)\}$$

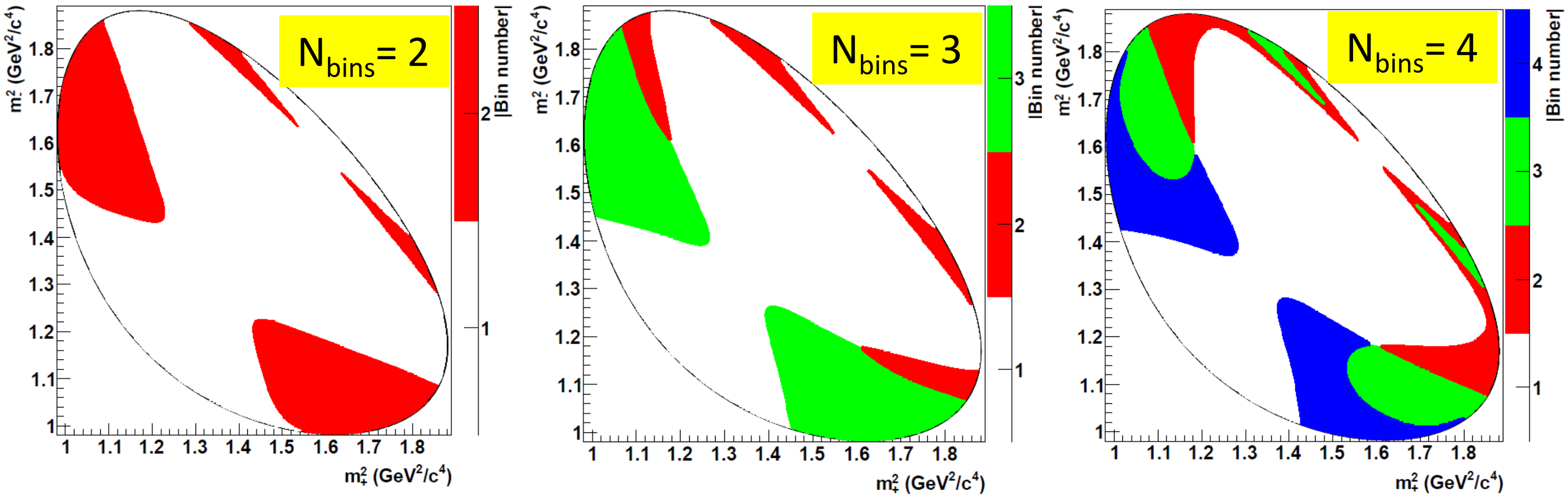
$$c_i = \langle \cos \delta_D \rangle_i \qquad s_i = \langle \sin \delta_D \rangle_i$$



- c_i and s_i are weighted averages of the cosine and sine of the phase-difference between D^0 and $\bar{D}^0$ in bin i
- Extracted from CP, mixed-CP, and flavour-tagged $D \to K_S hh$ decay yields in bin i (and –i)
  - CP-Tags → c_i
  - CP-mixed tags → c_i and s_i
  - Flavour-tags → T_i

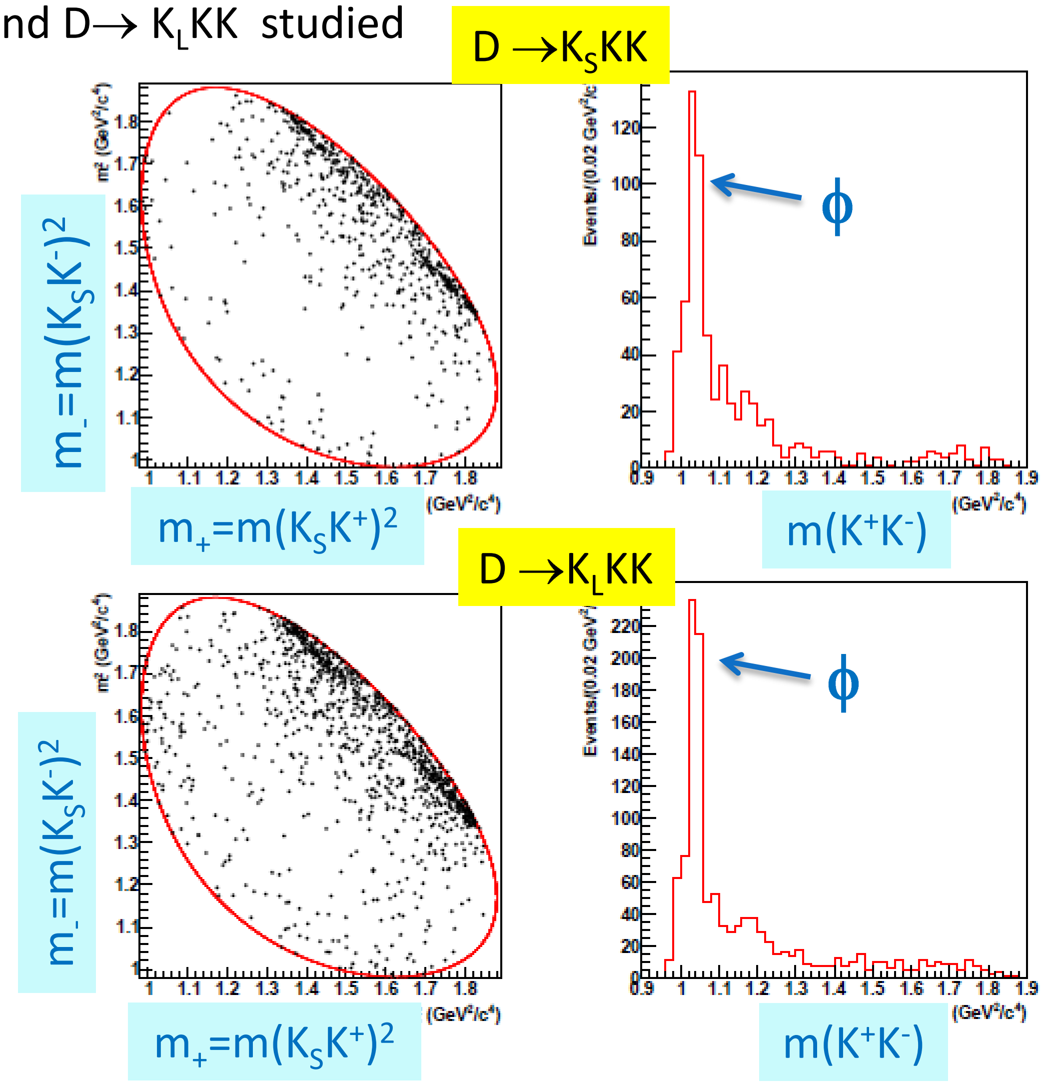
$D \rightarrow K_S KK$ Dalitz plot binning

- Bins of equal δ_D give a better statistical precision on c_i and s_i than rectangular binning [Bondar & Poluektov, EPJ C55 (2008) 51; EPJ C47 (2006)347]
  - D-decay model required to define δ_D binning
    - — No model-dependence: binning choice induces no bias on γ, but may affect statistical uncertainty
  - BaBar model used [arXiV:1005.1096] : isobar formalism with 8 intermediate resonances
- Three sets of equal δ_D bins studied (for N_{bins}=2,3 and 4)
  - Small number of bins to match size of D data-sample at CLEO-c
  - Different sets will allow B-experiments to perform cross-checks and to match binning to size of different B data-samples



K_SKK and K_LKK flavour-tagged samples

- Both $D \rightarrow K_SKK$ and $D \rightarrow K_LKK$ studied

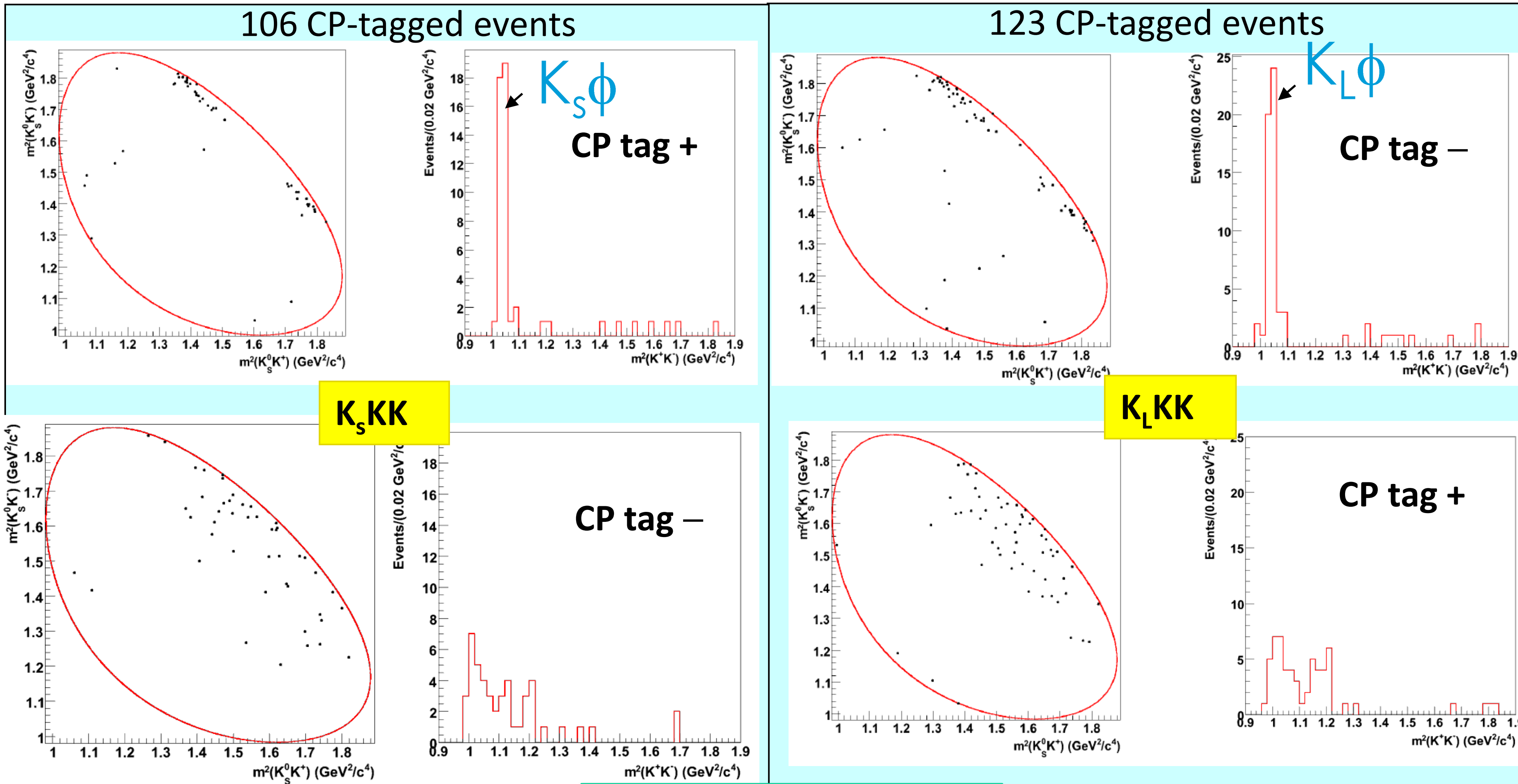


846 events

1174 events

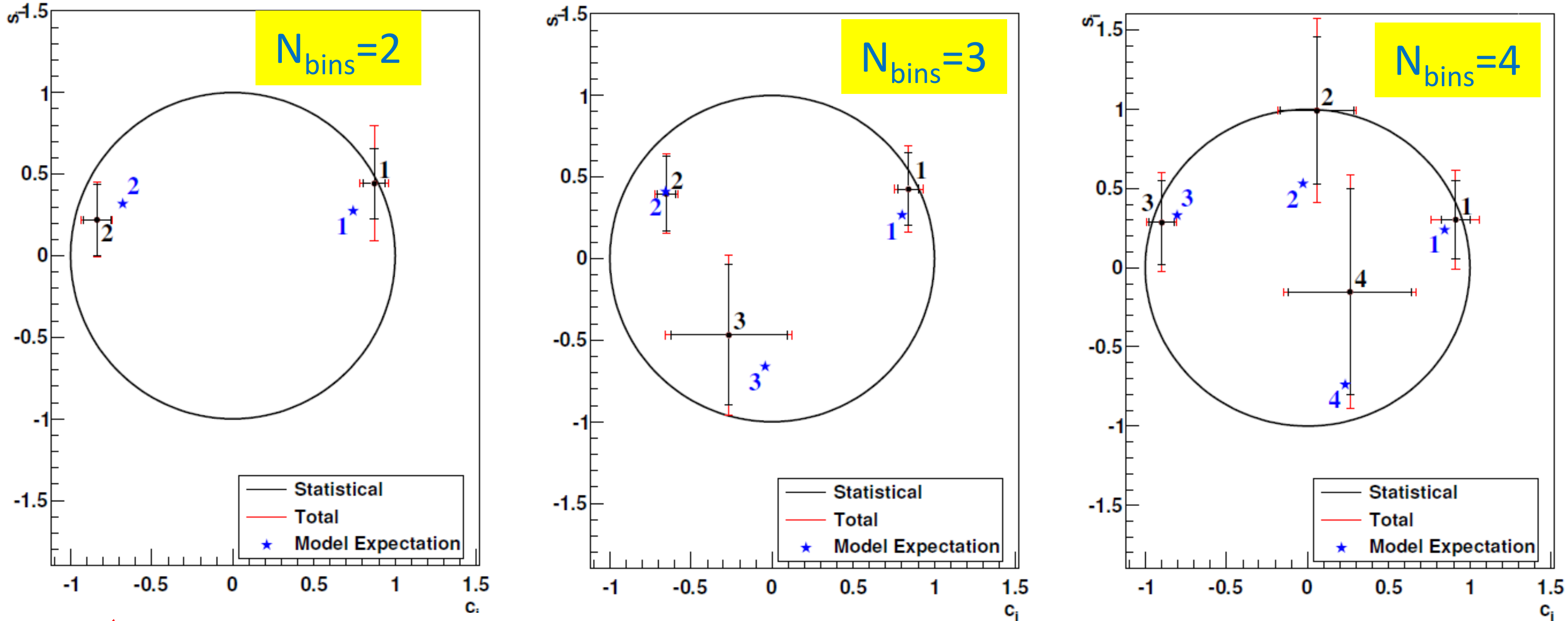
- $D \rightarrow K_LKK$ inclusion effectively doubles useful data-sample

$K_S KK$ and $K_L KK$ CP-tagged samples



$K_s hh$ vs CP $\mp \cong K_L hh$ vs CP$\pm$

c_i vs s_i for $D \rightarrow K_S KK$ (preliminary)



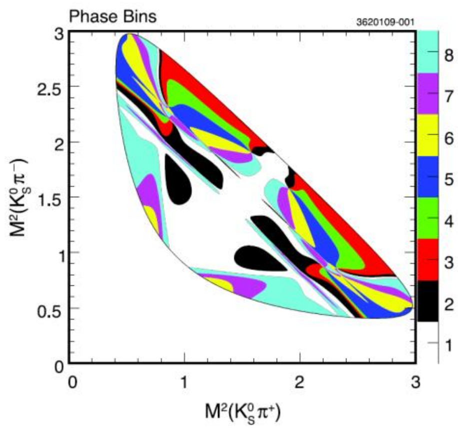
Preliminary

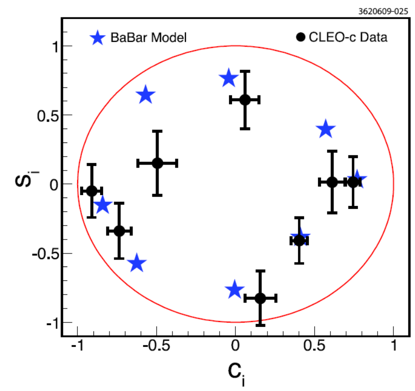
i	c_i	s_i
	$\mathcal{N} = 2$ equal $\Delta\delta_D$ bins	
1	$0.872 \pm 0.068 \pm 0.057$	$0.443 \pm 0.216 \pm 0.280$
2	$-0.838 \pm 0.085 \pm 0.042$	$0.220 \pm 0.217 \pm 0.074$
	$\mathcal{N} = 3$ equal $\Delta\delta_D$ bins	
1	$0.840 \pm 0.066 \pm 0.061$	$0.426 \pm 0.223 \pm 0.143$
2	$-0.652 \pm 0.059 \pm 0.040$	$0.397 \pm 0.231 \pm 0.077$
3	$-0.267 \pm 0.360 \pm 0.156$	$-0.468 \pm 0.431 \pm 0.233$
	$\mathcal{N} = 4$ equal $\Delta\delta_D$ bins	
1	$0.913 \pm 0.088 \pm 0.120$	$0.303 \pm 0.248 \pm 0.185$
2	$0.058 \pm 0.224 \pm 0.091$	$0.992 \pm 0.464 \pm 0.348$
3	$-0.899 \pm 0.081 \pm 0.047$	$0.285 \pm 0.262 \pm 0.171$
4	$0.261 \pm 0.378 \pm 0.152$	$-0.153 \pm 0.651 \pm 0.344$

- Good agreement of measured values with model predictions but no model-dependency
- Statistic uncertainty dominant
- Main systematic uncertainty due to background determination

Measurements of δ_D for $D \to K_S\pi\pi$

- First measurement published by CLEO last year [PRD 80, 032002, 2009] using total data sample
- Results produced for 8 bins of equal δ_D derived from BABAR 2005 model
  [BaBar, PRL 95,121802,2005]
- Projected uncertainty on γ: ~2°
- Statistical sensitivity on γ: 75% of unbinned method



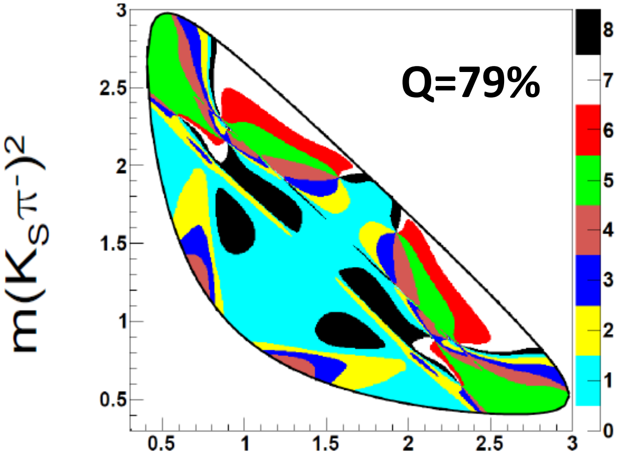


Motivation for updating the first measurement

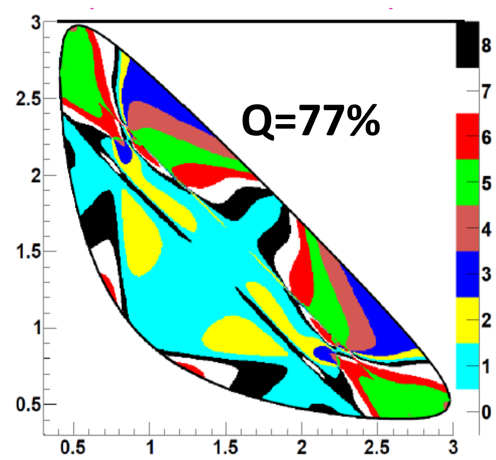
- use updated models of D decay amplitude from BABAR [1] and Belle[2]
- investigate different ways of binning, which may improve statistical sensitivity to γ

[1]BABAR PRD 78,034023,2008
[2]Belle, PRD 81,112002,2010

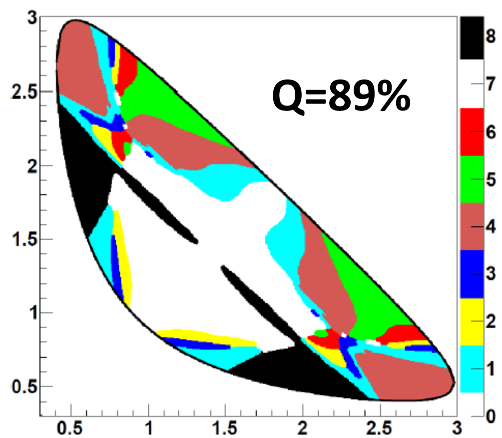
D→$K_S\pi\pi$ Dalitz plot binning



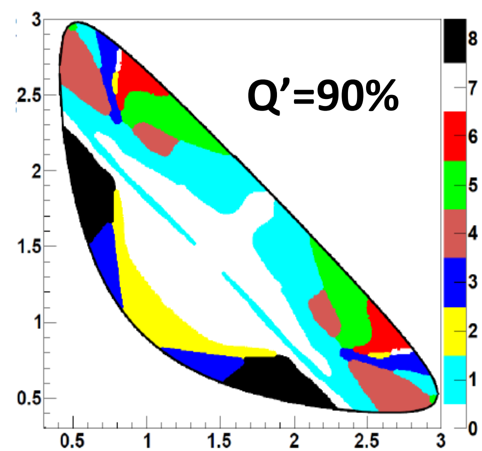
Equal δ_D
BABAR 2008
model



Equal δ_D
Belle 2010
model



Optimal
BABAR 2008
model



Modified optimal
BABAR 2008
model

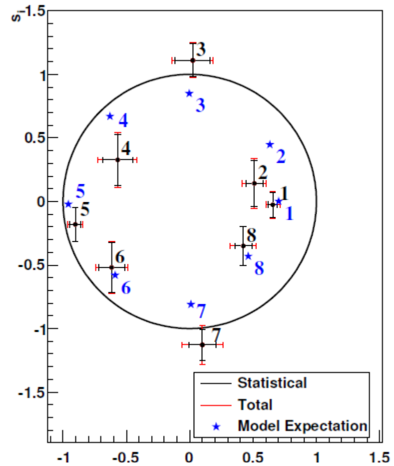
Q metric quantifies relative statistical sensitivity of binned and unbinned method (in absence of background)
Bondar and Poluektov [EPJC 55,51, 2008]

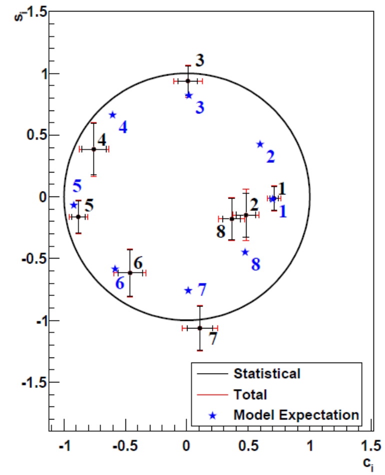
Q' modified metric quantifies relative statistical sensitivity in presence of background (B/S=1, typical value for LHCb)

s_i vs c_i for $D \rightarrow K_S\pi\pi$ (preliminary)

Equal δ_D
BABAR 2008

$\chi^2/DOF = 25.3/16$



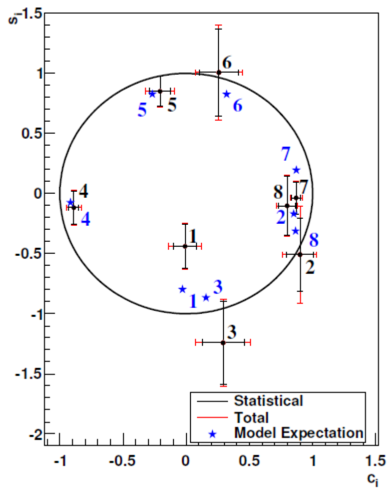


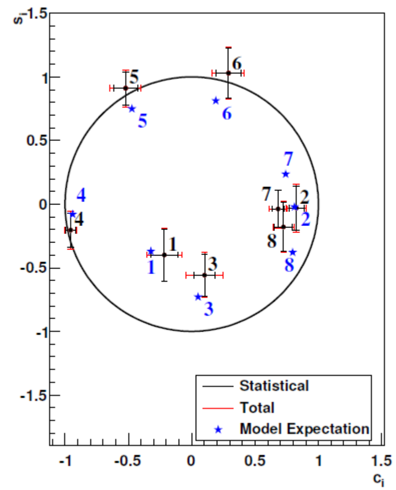
Equal δ_D
Belle 2008

$\chi^2/DOF = 26.8/16$

Optimal
BABAR 2008

$\chi^2/DOF = 15.5/16$





Modified
optimal
BABAR 2008

$\chi^2/DOF = 13.8/16$

Reasonable consistency among model predictions and measurements

Expected impact on γ

- Toy MC used to estimate two different consequences:
  1. Induced systematic uncertainty on γ due to uncertainties on ci and si (σ_{CLEO})
  2. loss in statistical precision relative to unbinned fit (1-Q)

K_SKK

$B^+ \to D(K_SKK)K^+$: $\sigma_{CLEO}(\gamma)$ ~3-4°
Small dependence on number of bins
Q ~90% (all binnings)

$\sigma_{CLEO}(\gamma)$
[instead of model error]
Error of experimental origin dominated by statistical uncertainty on c_i and s_i coefficients

$K_S\pi\pi$

$B^+ \to D(K_S\pi\pi)K^+$: $\sigma_{CLEO}(\gamma)$ ~ 2° for δ_D and modified optimal binning
$\sigma_{CLEO}(\gamma)$ ~ 4° for optimal binning
Q ~ 80% for δ_D binnings
Q ~ 90% for optimal binnings

- Update of the previous CLEO-c measurement (281 pb^{-1})

[PRL 100, 221801 (2008), PRD 78 , 012001 (2008)]

$$\frac{< D^0 \to K^+\pi^- >}{< \overline{D}^0 \to K^+\pi^- >} = r_{K\pi}\ e^{i\delta_D^{K\pi}}$$

Measurement of strong-phase difference $\delta_D^{K\pi}$ between D^0 and $\overline{D}^0 \to K^+\pi^-$

- New preliminary result using full data sample (818 pb^{-1}) and additional tags

Important input to measurements of γ from $B \to DK$ with $D \to K\pi$

Measuring $\delta_D^{K\pi}$ with quantum-correlation

- Another application of threshold production of Quantum-Correlated $D\bar{D}$

[Asner and Sun, PRD73, 034024, 2006]

- Combined analysis in many modes measures $\delta_D^{K\pi}$ without ambiguities

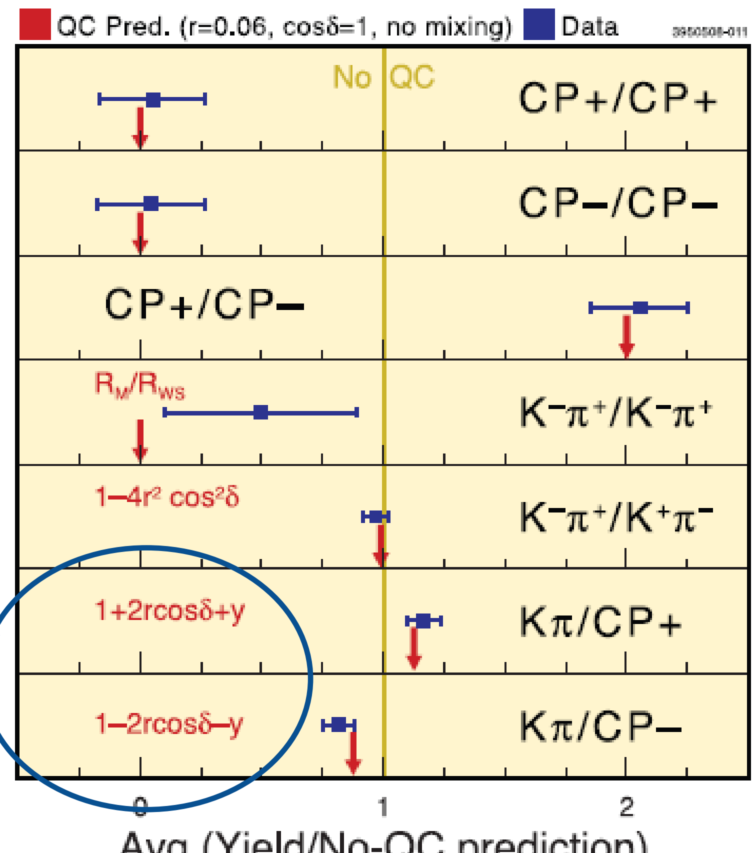
- First-order dependence on D-mixing parameters y

Sensitivity also to D-mixing parameter

CP tagged rates give $\cos\delta_D$

$$x = \frac{\Delta m}{\Gamma} \quad y = \frac{\Delta\Gamma}{2\Gamma}$$

$$y' = y\cos(\delta_D^{K\pi}) - x\sin(\delta_D^{K\pi})$$



[PRL 100, 221801 (2008), PRD 78 , 012001 (2008)]

Results for $\delta_D^{K\pi}$ (818 pb^{-1}, preliminary)

- Fit to extract
  - $K\pi$ decay and mixing parameters
  - Branching fractions, normalisation parameters
  - $K_S\pi\pi$ amplitude/phase coefficients

- Fit result w/o external measurements:
  - Statistical uncertainty on $r_{K\pi}\cos\delta^{K\pi}$ and y 3x smaller than previous analysis
  - first direct determination of $r_{K\pi}^2$ and $\sin\delta^{K\pi}$

Parameter	Previous: PDG, HFAG, or CLEO	Fit: no ext. meas.	Fit: with ext. y, x, y'
y (10^{-2})	0.79 ± 0.13	$3.0 \pm 2.0 \pm 1.2$	0.635 ± 0.118
x^2 (10^{-3})	0.037 ± 0.024	$1.5 \pm 2.0 \pm 0.9$	0.022 ± 0.017
r^2 (10^{-3})	3.32 ± 0.08	$4.12 \pm 0.92 \pm 0.23$	3.32 ± 0.08
$\cos\delta$	1.10 ± 0.36	$0.98\ ^{+0.27}_{-0.20} \pm 0.08$	$1.15 \pm 0.16 \pm 0.12$
$\sin\delta$	---	$-0.04 \pm 0.49 \pm 0.08$	$0.55\ ^{+0.36}_{-0.40} \pm 0.08$
δ (°) [derived]	$22\ ^{+11}_{-12}\ ^{+9}_{-11}$	$0 \pm 22 \pm 6$	$\delta_D^{K\pi} = (15\ ^{+11}_{-17} \pm 7)°$

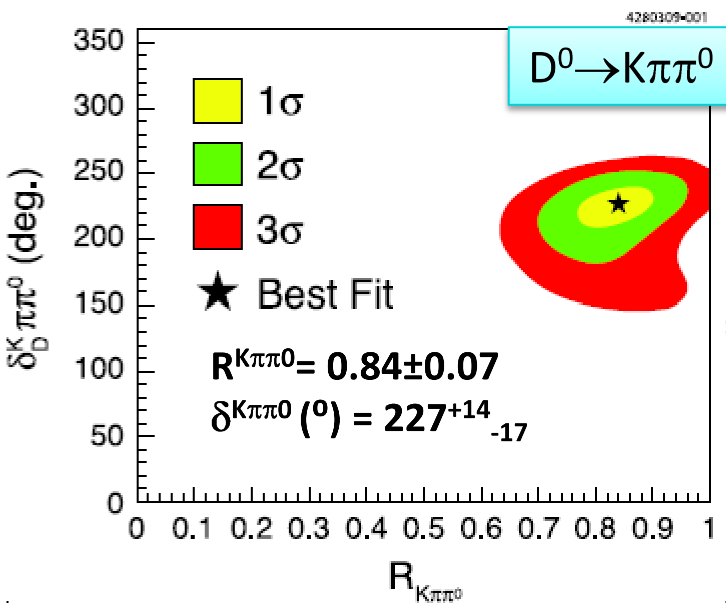
- Fit results with external y,x,y' gives $\delta_D^{K\pi}$
- Preliminary systematic uncertainty

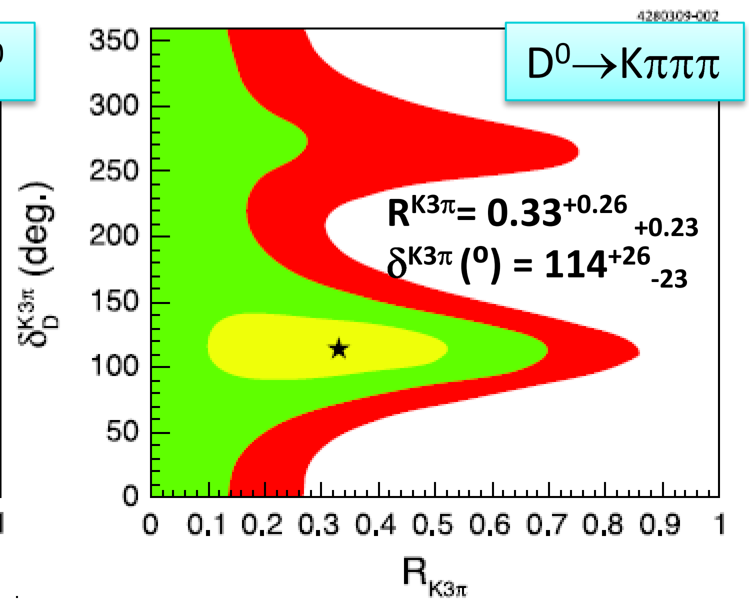
Coherence studies for $D^0 \to K\pi\pi^0$ and $D^0 \to K\pi\pi\pi$

- Published results use total CLEO-c data sample [PRD 80, 031105 (R) (2009)]
- Multi-body decay
  - $\Rightarrow$measure *average strong phase and Coherence factor (R)*
- Extract both *R* and δ_D from CP-tagged and flavour-tagged decays

$$R_f e^{-i\delta_D^f} = \frac{\int A_f(x) A_{\bar{f}}(x) dx}{A_f A_{\bar{f}}}$$

0 < R <1
R→1 in the limit of a single contributing resonance





$D^0 \to K\pi\pi^0$ very coherent
High-sensitivity to γ

$D^0 \to K\pi\pi\pi$ lower-coherence favoured
Less sensitive to γ
(but increases sensitivity to r_B)

Conclusions

- Quantum-correlation at $\psi(3770)$ gives access to strong-phase δ_D and provides crucial input to measurements of γ (and charm-mixing)
- Several results from CLEO-c:
  - **$D\to K_SKK$: first measurement of c_i and s_i in bins of δ_D** NEW
  - **$D\to K_S\pi\pi$: c_i and s_i for 4 different ways of binning** NEW
  - **$D\to K\pi$: updated result for δ_D on full statistics** NEW
  - **$D\to K\pi\pi^0$,$K\pi\pi\pi$ coherence factors and average strong-phase**
- Exploitation of precious CLEO-c data sample continues; soon also high-statistics data sample at BES-III expected to provide new measurements and improved results

  [prospects for the next decade in P. Spradlin's talk]

Thank YOU

Additional material

$$c_i = \frac{1}{\sqrt{T_i T_{\bar{i}}}} \int_{D_i} |A_D(x,y)||A_D(y,x)| \cos(\delta_{x,y} - \delta_{y,x}) dx dy$$

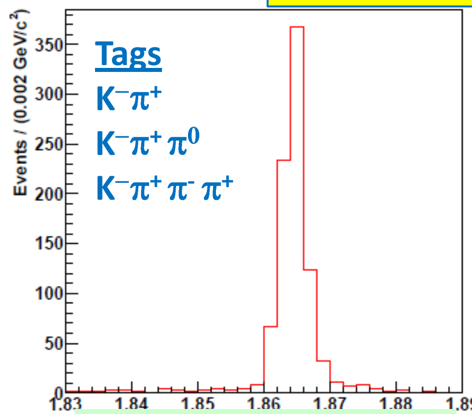
$$s_i = \frac{1}{\sqrt{T_i T_{\bar{i}}}} \int_{D_i} |A_D(x,y)||A_D(y,x)| \sin(\delta_{x,y} - \delta_{y,x}) dx dy$$

$$T_i \equiv \int_i |A_D(x,y)|^2 dx dy$$

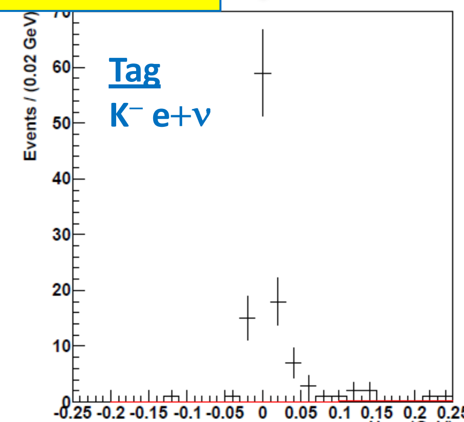
D→K_SKK Data samples

- Large number of D-tags considered to mitigate statistics limitations

Flavour tagged K_SKK → T_i



$$m_{BC} \equiv \sqrt{E_{beam}^2 - |p_D|^2}$$

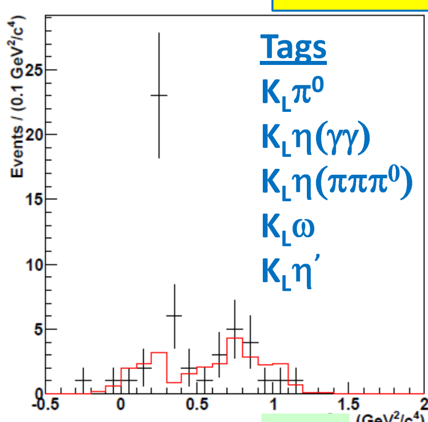


$$U_{miss} \equiv E_{miss} - |p_{miss}|$$

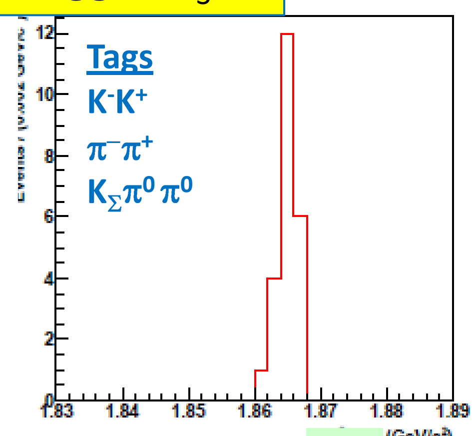
CP-mixed tags
K_SKK
K_S ππ
K_L ππ
→ c_i and s_i

CP-even tagged K_SKK → c_i ← CP-odd tagged K_SKK

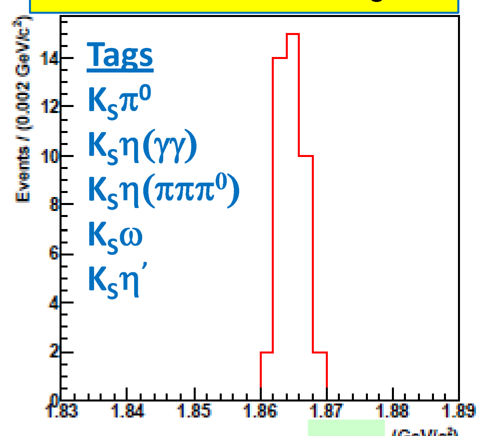
- B/S < 10% for all tags



m^2_{miss}

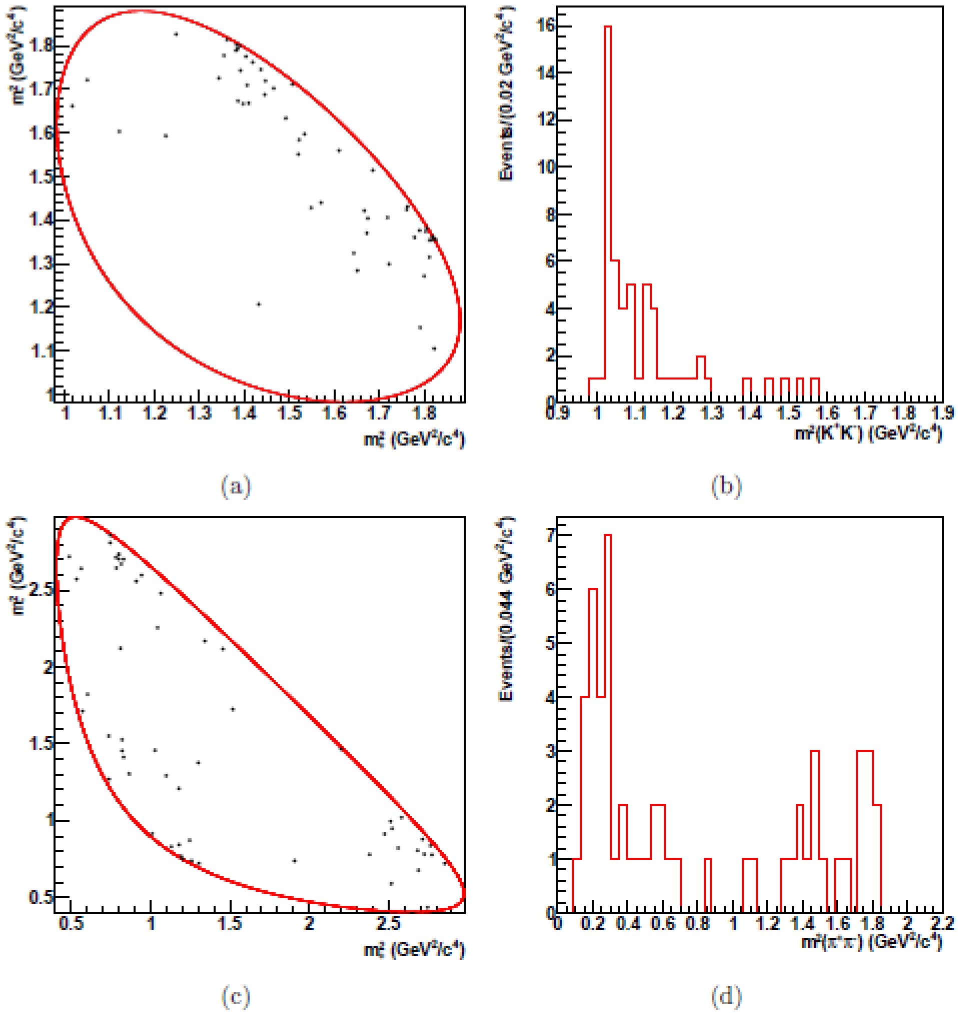


m_{BC}



m_{BC}

K_SKK vs $K_S\pi\pi$



$K_S KK$ and $K_S \pi\pi$ yields

Mode	ST yield	DT yields			
		$K^0_S\pi^+\pi^-$	$K^0_L\pi^+\pi^-$	$K^0_S K^+K^-$	$K^0_L K^+K^-$
Flavor tags					
$K^-\pi^+$	144563 ± 403	1444	2857	168	302
$K^-\pi^+\pi^0$	258938 ± 581	2759	5133	330	585
$K^-\pi^+\pi^+\pi^-$	220831 ± 541	2240	4100	248	287
$K^-e^+\nu$		1191		100	
CP-even tags					
K^+K^-	13349 ± 128	124	357	12	32
$\pi^+\pi^-$	6177 ± 114	61	184	4	13
$K^0_S\pi^0\pi^0$	6838 ± 134	56		7	14
$K^0_L\pi^0$		237		17	
$K^0_L\eta(\gamma\gamma)$				4	
$K^0_L\eta(\pi^+\pi^-\pi^0)$				1	
$K^0_L\omega$				4	
$K^0_L\eta'$				1	
CP-odd tags					
$K^0_S\pi^0$	19753 ± 153	189	288	18	43
$K^0_S\eta(\gamma\gamma)$	2886 ± 71	39	43	4	6
$K^0_S\eta(\pi^+\pi^-\pi^0)$				2	1
$K^0_S\omega$	8830 ± 110	83		14	10
$K^0_S\eta'$				3	4
$K^0_L\pi^0\pi^0$				5	
$K^0_S\pi^+\pi^-$		473	1201	56	126
$K^0_L\pi^+\pi^-$				140	
$K^0_S K^+K^-$				4	9

Systematic uncertainties

TABLE XVIII: Statistical and systematic uncertainties on c_i and s_i determined for the $\mathcal{N} =$ equal $\Delta\delta_D$ binning of $D^0 \to K^0_S K^+ K^-$ data.

Uncertainty	c_1	c_2	c_3	s_1	s_2	s_3
Pseudo-flavor statistics	0.006	0.007	0.056	0.015	0.014	0.040
Momentum resolution	0.002	0.004	0.013	0.018	0.023	0.030
Mode-to-mode normalisation	0.004	0.005	0.013	0.001	0.007	0.004
Multiple-candidate selection	0.015	0.004	0.006	0.003	0.000	0.003
DCS correction	0.001	0.001	0.003	0.002	0.004	0.002
$K^0_{S,L}\pi^+\pi^-$ $(c_i^{(\prime)}, s_i^{(\prime)})$	0.010	0.013	0.052	0.135	0.062	0.127
Fitter assumptions	0.013	0.009	0.030	0.010	0.007	0.038
Parameterisation of non-K^0_L final state background	0.002	0.002	0.012	0.000	0.005	0.003
Parameterisation of K^0_L final state background	0.054	0.024	0.087	0.038	0.016	0.184
Background Dalitz space distribution	0.010	0.023	0.092	0.006	0.030	0.021
Assumed background $\mathcal{B}$	0.010	0.011	0.032	0.001	0.009	0.000
Total systematic	0.061	0.040	0.156	0.143	0.077	0.233
Statistical plus $K^0_L K^+ K^-$model	0.066	0.059	0.360	0.223	0.231	0.431
$K^0_L K^+ K^-$model alone	0.000	0.000	0.120	0.008	0.000	0.035
Total	0.090	0.071	0.392	0.265	0.243	0.490

$K_L hh$ vs $K_S hh$ and Residual Model Uncertainty

$$A(D^0 \to K_S^0\pi^+\pi^-) = \frac{1}{\sqrt{2}}[A(D^0 \to \bar{K}^0\pi^+\pi^-) + A(D^0 \to K^0\pi^+\pi^-)]$$
$$A(D^0 \to K_L^0\pi^+\pi^-) = \frac{1}{\sqrt{2}}[A(D^0 \to \bar{K}^0\pi^+\pi^-) - A(D^0 \to K^0\pi^+\pi^-)]$$

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

DCS

- Correction to approximate equality between $K_S\pi\pi$ and K_SKK
  - Minus sign introduce a 180 degrees shift for all DCS resonances
  - CP eigenstate resonances acquire a factor $\propto -2re^{i\delta}$ [$r = \tan^2(\theta_c)$]
- Residual model dependence due to uncertainty on this small correction $\Rightarrow$small effect

Determining c_i and s_i

Observables

Normalisations

M_i = Number of K_Shh vs CPtag in bin i

$$M_i^{\pm} = h_{CP\pm}(K_i \pm 2c_i\sqrt{K_iK_{-i}} + K_{-i}),$$

$$h_{CP\pm} = S^{\pm}/2S_f$$

M_{ij} = K_Shh in bin i vs K_shh in bin j

$$M_{ij} = h_{corr}(K_iK_{-j} + K_{-i}K_j - 2\sqrt{K_iK_{-j}K_{-i}K_j}(c_ic_j + s_is_j))$$

$$h_{corr} = N_{D\bar{D}}/2S_f^2$$

M_i =K_Lhh vs CPtag in bin i

$$M_i^{\pm} = h_{CP\pm}(K'_i \mp 2c'_i\sqrt{K'_iK'_{-i}} + K'_{-i})$$

M_{ij} = K_Shh in bin i vs KLhh in bin j

$$M_{ij} = h_{corr}[K_iK'_{-j} + K_{-i}K'_j + 2\sqrt{K_iK'_{-j}K_{-i}K'_j}(c_ic'_j + s_is'_j)]$$

$K_i = A_DT_i$ number of flavour-tagged decays in bin $_i$

The Q and Q' metrics

$$Q^2 = \frac{\sum_i \left[\left(\frac{1}{\sqrt{\Gamma_i}} \frac{d\Gamma_i}{dx} \right)^2 + \left(\frac{1}{\sqrt{\Gamma_i}} \frac{d\Gamma_i}{dy} \right)^2 \right]}{\int \left[\left(\frac{1}{\sqrt{|f_{B^-}|^2}} \frac{d|f_{B^-}|^2}{dx} \right)^2 + \left(\frac{1}{\sqrt{|f_{B^-}|^2}} \frac{d|f_{B^-}|^2}{dy} \right)^2 \right] dm_+^2 dm_-^2}$$

$$\Gamma_i = \int_i |f_{B^-}|^2 dm_+^2 dm_-^2 \ .$$

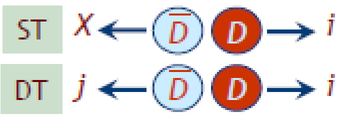
$$f_{B^-} = f_D(m_+^2, m_-^2) + (x + iy) f_D(m_-^2, m_+^2)$$

$$Q'^2|_{x=y=0} = \frac{\sum_i \frac{f_s^2 F_i F_{-i}}{f_s F_i + f_1 B_{1i} + f_2 B_{2i}} (c_i^2 + s_i^2)}{\int \frac{f_s^2 |f_D(m_+^2, m_-^2)|^2 |f_D(m_-^2, m_+^2)|^2}{f_s |f_D(m_+^2, m_-^2)|^2 + f_1 \mathcal{B}_1 + f_2 \mathcal{B}_2} dm_+^2 dm_-^2}$$

$$|f_{B^-}|^2 = f_s \cdot |f_D(m_+^2, m_-^2) + (x + iy) f_D(m_-^2, m_+^2)|^2 + f_1 \cdot \mathcal{B}_1(m_+^2, m_-^2) + f_2 \cdot \mathcal{B}_2(m_+^2, m_-^2)$$

Data samples and yields in 818 pb^{-1}

261 yield measurements in total, including most double-tag combinations and single-tags



New to this analysis:

- Additional K_L and semi-leptonic modes
  - semi-muonic modes double semileptonic data-sample
  - CP-tagged semileptonic sensitive to y
- Addition of binned measurements of $K_S\pi\pi$
  - sensitive to $\sin\delta_{K\pi}$ as well as $\cos\delta_{K\pi}$

  [yields from PRD80, 032002, 2009]
- Addition of semileptonic vs DCS $K\pi$
  - direct determination of $r_{K\pi}$
- All decay and mixing parameters , and branching fractions extracted from a fit w/o external constraints