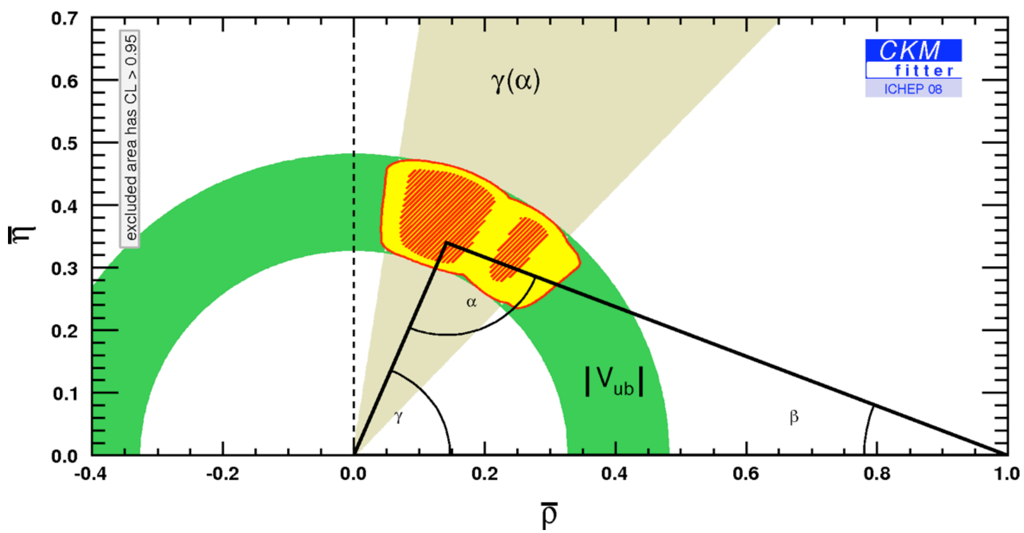
CLEO-c's impact on γ/φ_3 from $B^{\pm(0)} \rightarrow D(K_S\pi\pi)K^{\pm(0*)}$

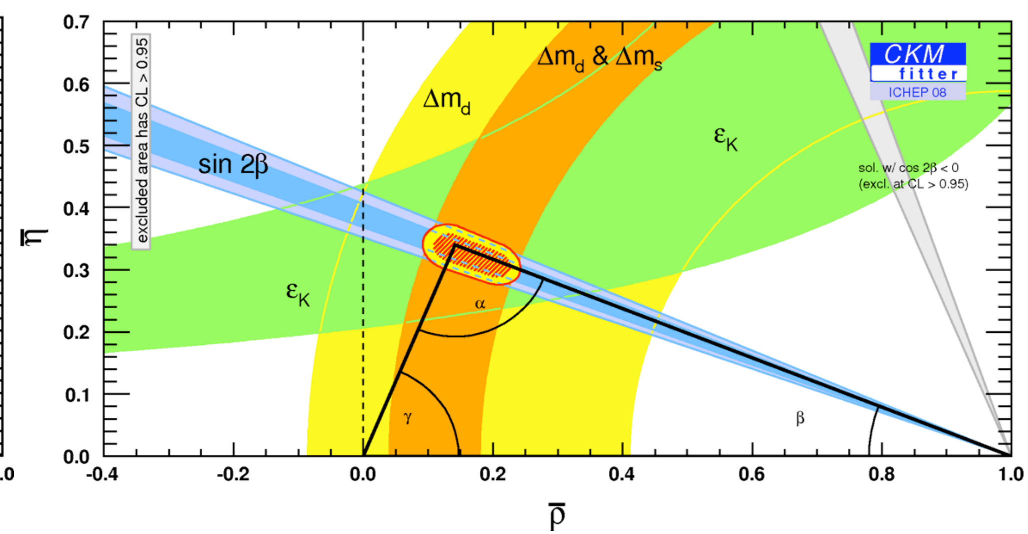
Jonas Rademacker on behalf of the CLEO-c collaboration

The importance of measuring tree-level γ

Constraints from Trees

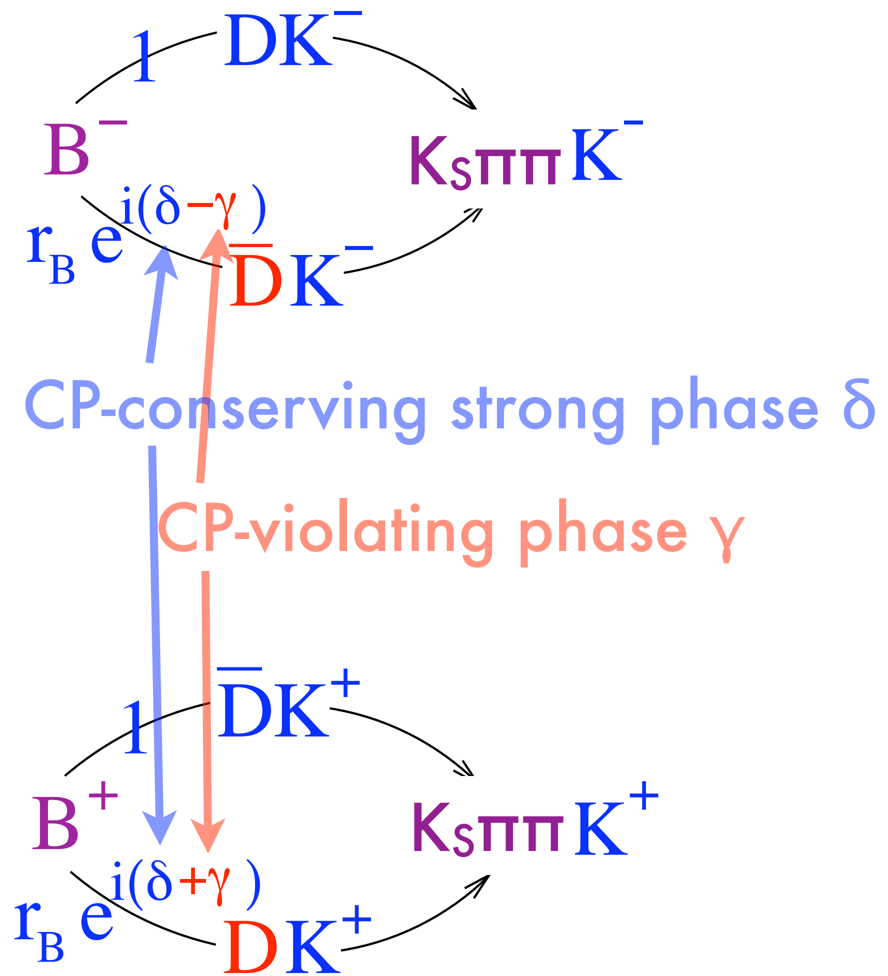


Constraints from Loops



$B^{\pm} \to D(K_S\pi\pi)K^{\pm}$

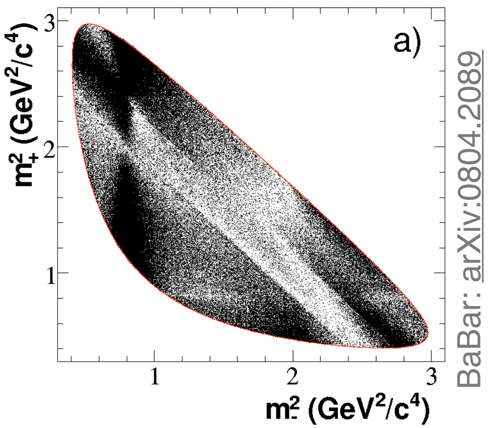
- Tree level only - no new physics
- Crucial for NP sensitivity by providing a theoretically clean reference.
- No time measurement, no tagging.



Gronau, Wyler Phys.Lett.B265:172-176,1991, (GLW)
Gronau, London Phys.Lett.B253:483-488,1991 (GLW)
Atwood, Dunietz and Soni Phys.Rev.Lett. 78 (1997) 3257-3260 (ADS)
Giri, Grossman, Soffer and Zupan Phys.Rev. D68 (2003) 054018
Belle Collaboration Phys.Rev. D70 (2004) 072003

Dalitz Plots for γ at Belle&BaBar

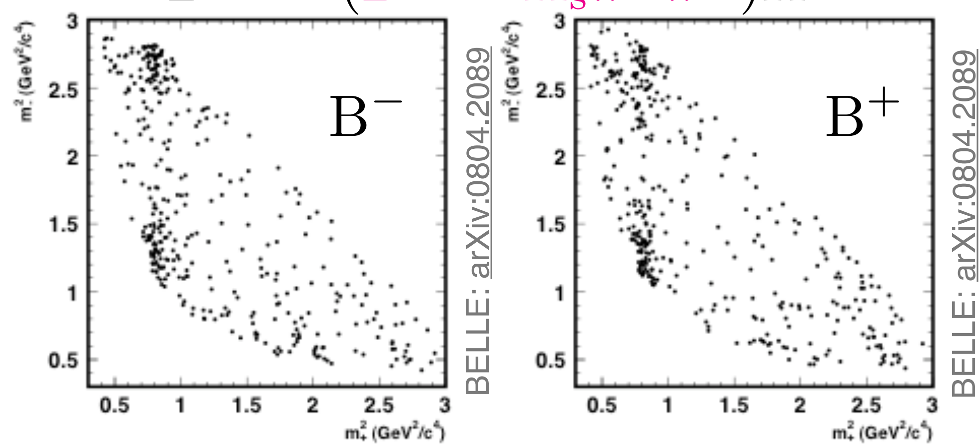
$D^0 \to K_S\pi^+\pi^-$



+ D

D flavour amplitude model **+**

$B^\pm \to (D^0 \to K_S\pi^+\pi^-)K^\pm$



BaBar* ($K_SKK + K_S\pi\pi$): $\gamma = 76^\circ{}^{+23^\circ}_{-24^\circ}(\text{stat}) \pm 5^\circ(\text{sys}) \pm 5^\circ(\text{model})$

$K_S\pi\pi$ only: $\gamma = 63^\circ{}^{+30^\circ}_{-28^\circ}(\text{stat}) \pm 8^\circ(\text{sys}) \pm 7^\circ(\text{model})$

BELLE** ($K_S\pi\pi$ only): $\gamma = 76^\circ{}^{+12^\circ}_{-13^\circ}(\text{stat}) \pm 4^\circ(\text{sys}) \pm 9^\circ(\text{model})$

Difference between overall stat precision predominantly due to different fit result for r_B

*383M BB events, arXiv:0804.2089; 04/08 **657M BB events. arXiv:0803.3375, 03/08

Model independent γ fit

Giri, Grossmann, Soffer, Zupan, Phys Rev D 68, 054018 (2003).

- Binned decay rate:

$\mathcal{T}_i$ known from flavour-specifc D decays (e.g. D*)

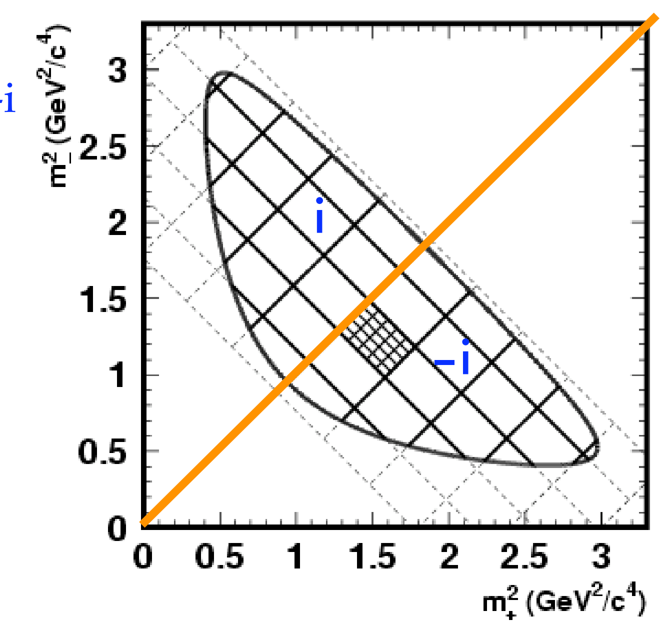
$$\Gamma\left(B^\pm \to D(K_s\pi^+\pi^-)K^\pm\right)_i =$$

$\delta_D \equiv$ phase of $A(D\to K_S\pi\pi)$

$$\mathcal{T}_i + r_B^2\mathcal{T}_{-i} + 2r_B\sqrt{\mathcal{T}_i\mathcal{T}_{-i}}\left\{c_i\cos\left(\delta\pm\gamma\right) + s_i\sin\left(\delta\pm\gamma\right)\right\}$$

(weighted) average of $\cos(\delta_D(s_{12},s_{23})-\delta_D(s_{23},s_{12}))$ and $\sin(\delta_D(s_{12},s_{23})-\delta_D(s_{23},s_{12}))$ over bin i

- Binning such that such that $c_i = c_{-i}$, $s_i = -s_{-i}$
- Distribution sensitive to c_i, s_i, r_B, δ and γ.
- To extract γ from realistic numbers of B events need external input from CLEO's quantum-correlated DDbar pairs.



Model independent γ fit

Giri, Grossmann, Soffer, Zupan, Phys Rev D 68, 054018 (2003).

- Binned decay rate:

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$\mathcal{T}_i$ known from flavour-specifc D decays (e.g. D*)

δ_D≡phase of $A(D\rightarrow K_S\pi\pi)$

(weighted) average of $\cos(\delta_D(s_{12},s_{23})-\delta_D(s_{23},s_{12}))$ and $\sin(\delta_D(s_{12},s_{23})-\delta_D(s_{23},s_{12}))$ over bin i

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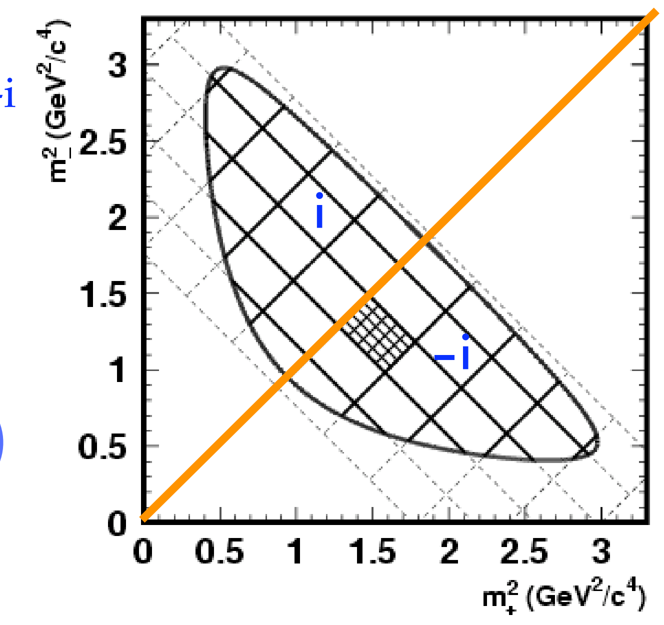


Optimal binning

Bondar, Poluektov hep-ph/0703267v1 (2007)

- Best γ sensitivity if phase difference

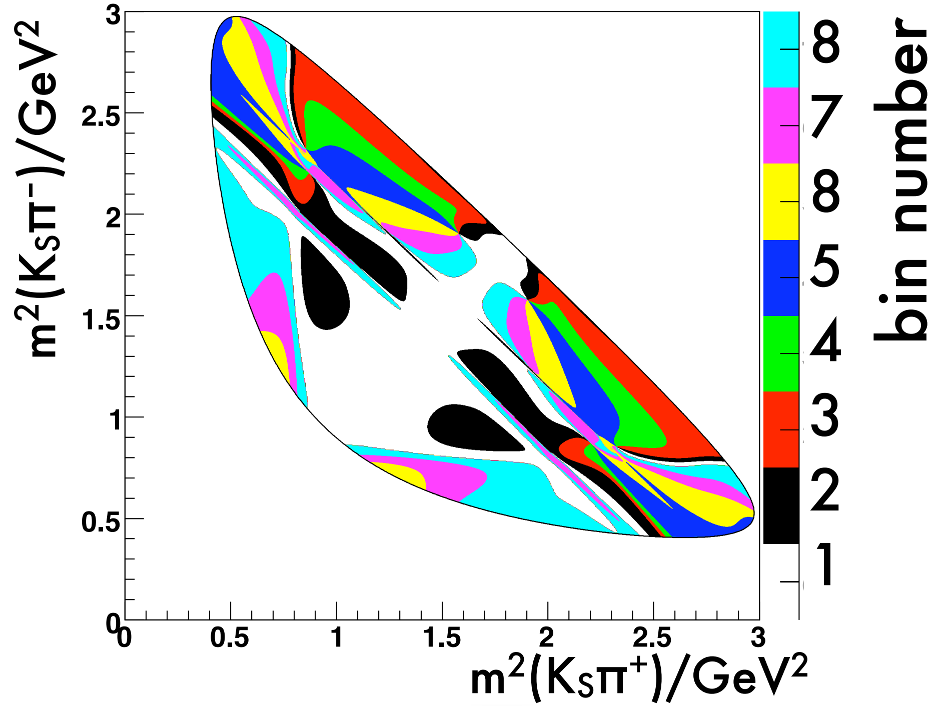
$$\Delta\delta \equiv \delta_D(s_{12}, s_{23}) - \delta_D(s_{23}, s_{12})$$

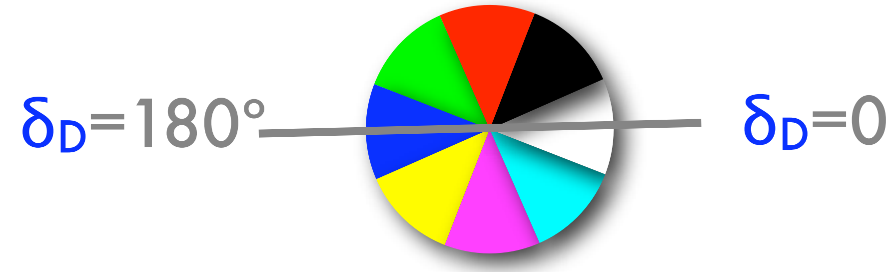
δ_D = phase of $A(D_{flavour} \to K_S\pi\pi)$

is as constant as possible over each bin.

- Plot shows CLEO-c's 8 bins, uniform in $\Delta\delta$, (based on BaBar model).

Optimal binning at CLEO-c



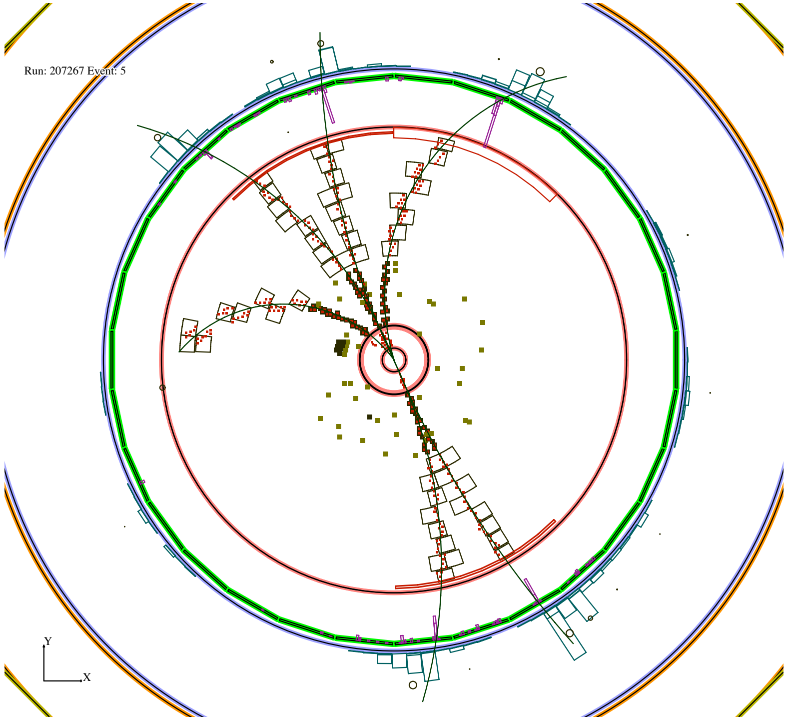


CLEO-c

$e^+e^- \rightarrow \psi(3770) \rightarrow D\bar{D}$

CLEAN-c

- Threshold production of correlated DD.
- Final state must be CP-odd,
- ...and flavour-neutral.
- That gives us access to both amplitude and phase across the Dalitz plot.

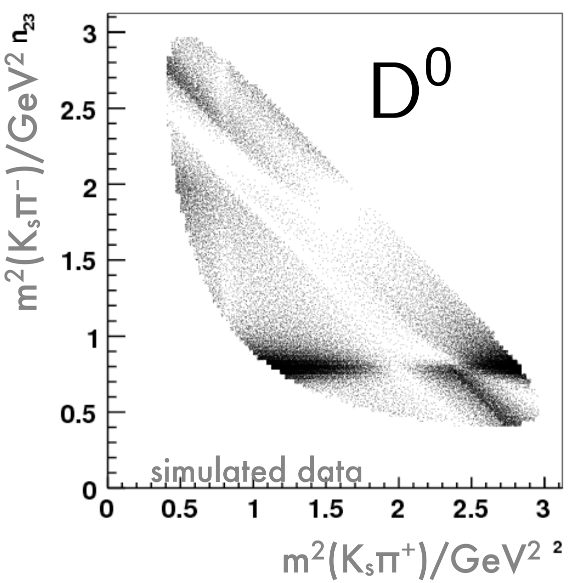


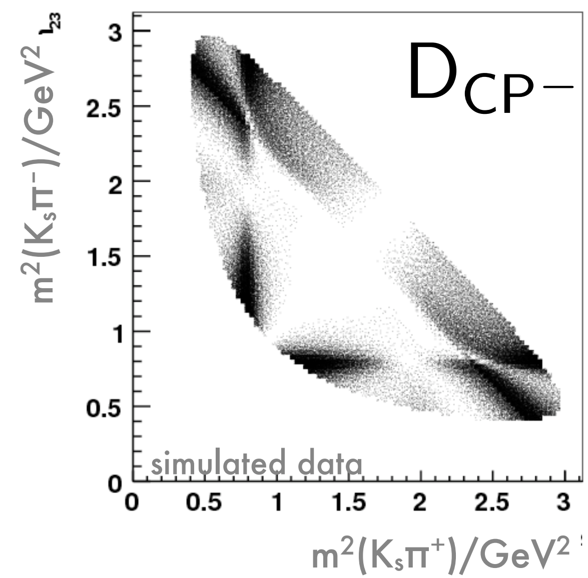
$$\psi(3770) \rightarrow D^0(K_S\pi^+\pi^-)\bar{D}^0(K^+\pi^-)$$

CP- tagged Decays

$$\psi'' \to \bar{D}_{flavour} \to K^+ e^- \nu_e$$
$$\psi'' \to D_{flavour} \to K_s \pi^+ \pi^-$$

$$\psi'' \to D_{CP+} \to KK$$
$$\psi'' \to D_{CP-} \to K_s \pi^+ \pi^-$$





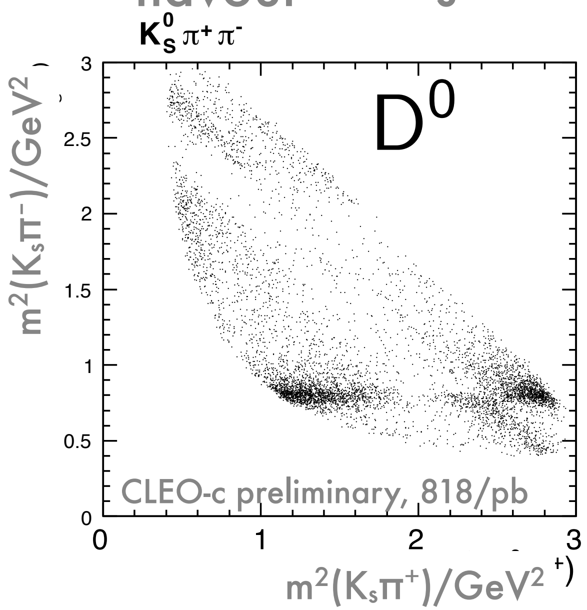
CP- tagged Decays

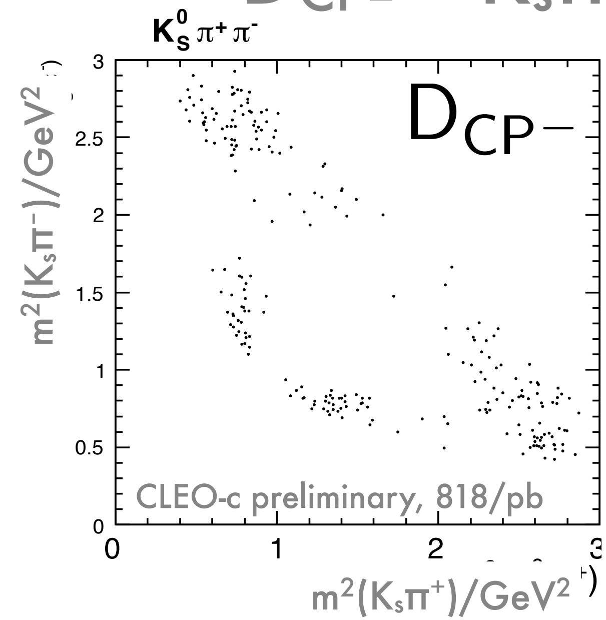
ψ'' → $\bar{D}_{flavour} \to K^+ e^- \nu_e$

ψ'' → $D_{flavour} \to K_s \pi^+ \pi^-$

ψ'' → $D_{CP+} \to KK$

ψ'' → $D_{CP-} \to K_s \pi^+ \pi^-$

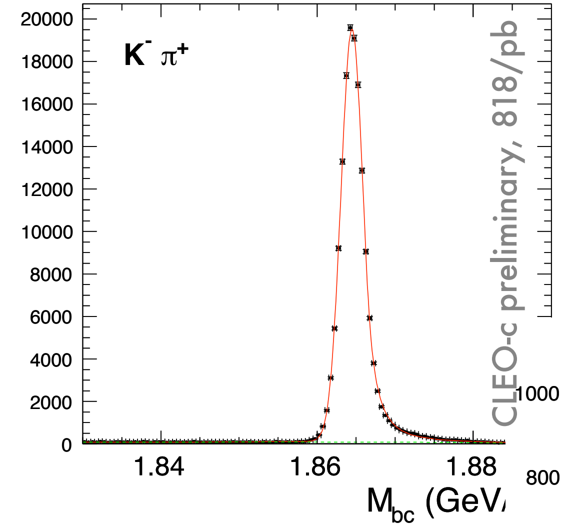


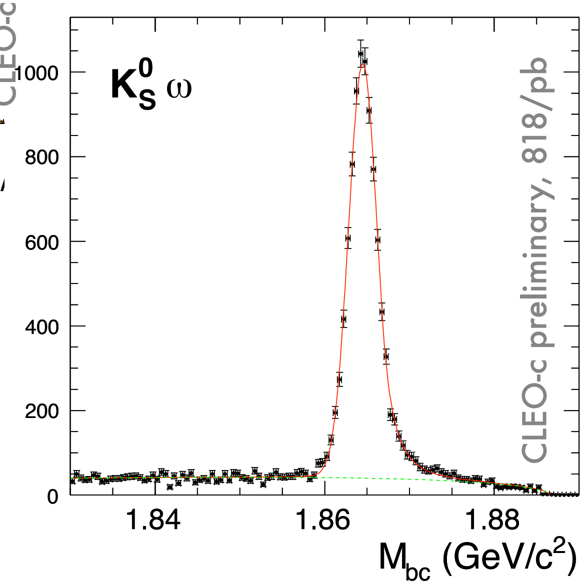


Tags

Reconstructed, beam-constrained D mass in CLEO-c tag-side data
(2 example plots, before requiring $K_S\pi\pi$ on other side)

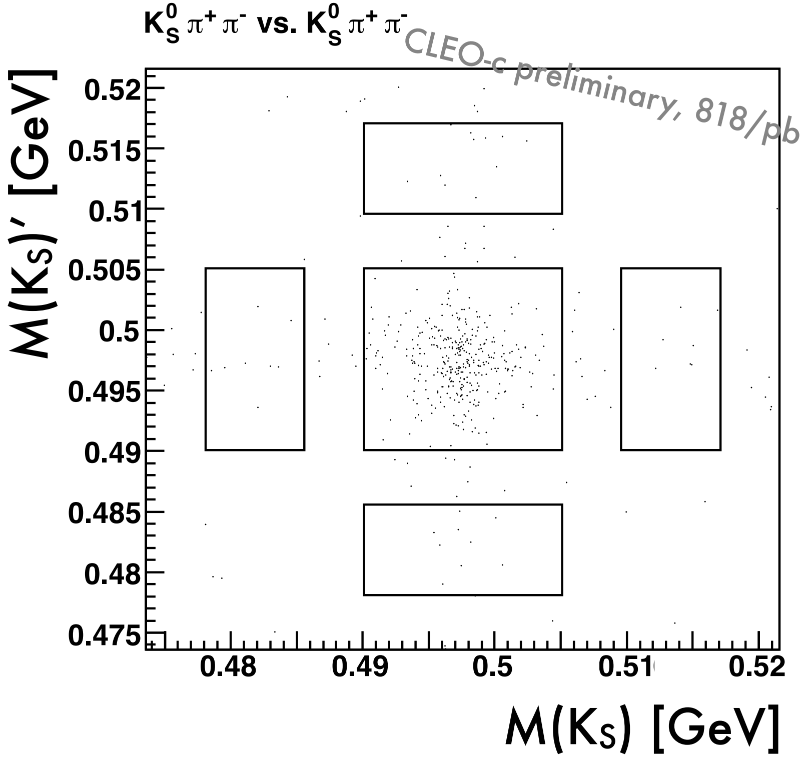
Flavour (semi-leptonic) (14k tagged $K_S\pi\pi$ evts, B/(S+B)=0.6%)	$K^-e^+\nu$
Flavour (hadronic) 4.4k tagged $K_S\pi\pi$ evts, B/(S+B)=3%	$K^-\pi^+$, $K^-\pi^+\pi^0$, $K^-\pi^+\pi^+\pi^-$
CP-even, 470 tagged $K_S\pi\pi$ evts, B/(S+B)=6%	$\pi^+\pi^-$, K^+K^-, $K^0_S\pi^0\pi^0$, $K^0_L\pi^0$
CP-odd, 310 tagged $K_S\pi\pi$ evts, B/(S+B)=4%	$K^0_S\pi^0$, $K^0_S\eta$, $K^0_S\omega$





s_i, c_i from $K_S\pi\pi$ vs $K_S\pi\pi$

- CP-tagged binned Dalitz Plots sensitive to c_i only.
- Simultaneous, binned analysis of quantum-correlated $D_a \to K_S\pi\pi$, $D_b \to K_S\pi\pi$ pairs gives access to both c_i and s_i:

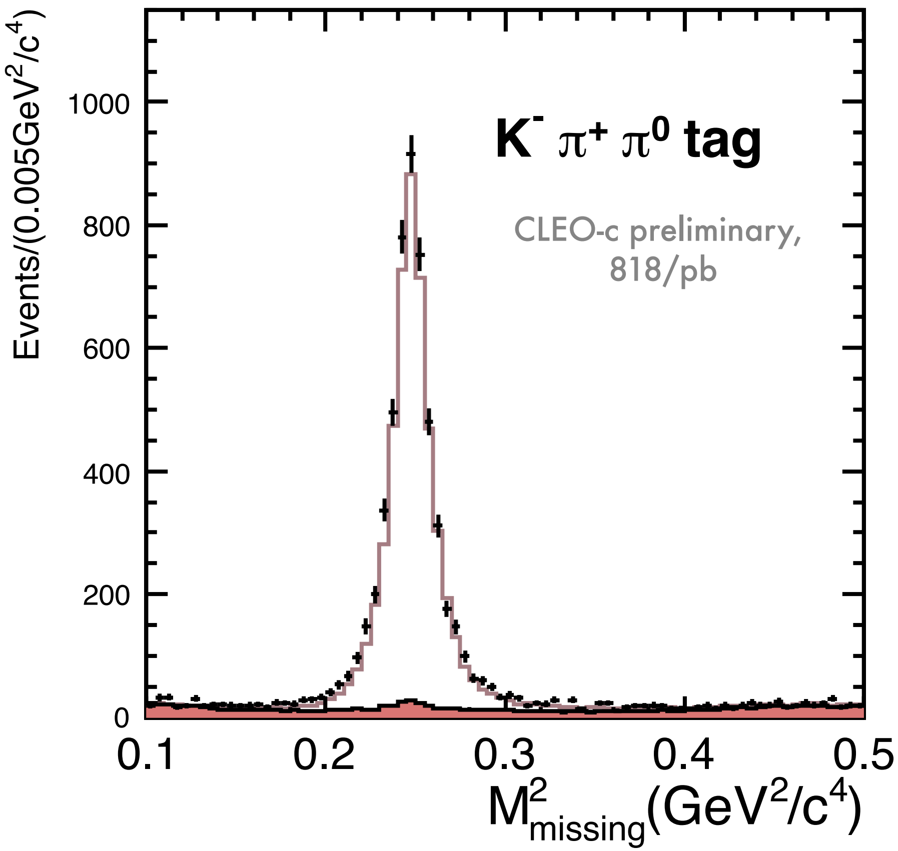


- 420 fully reconstructed events, S/(B+S) =90%
- 50 partially reconstructed events (ignore one π in reconstruction), S/(B+S)=85%

Adding $K_L\pi\pi$

- CLEO-c's clean environment allows the reconstruction of K_L from kinematic constraints.
- S/(S+B) >90% across all tag-modes.
- Doubles CP-tagged statistics (~800 each $K_S\pi^+\pi^-$, and $K_L\pi^+\pi^-$)
- Adds 1.2k $K_L\pi^+\pi^-$ vs $K_S\pi^+\pi^-$ to 0.48k $K_S\pi^+\pi^-$ vs $K_S\pi^+\pi^-$.

Overlaying Data (black) and MC (red) for missing M^2 in K_L reconstruction in $K_L\pi^+\pi^-$ vs $K^-\pi^+\pi^0$



CP-even $K_L\pi\pi \approx$ CP-odd $K_S\pi\pi$

unfortunately only "≈", not quite "="

$$K_S^0 = (K^0 + \bar{K}^0)/\sqrt{2}$$
$$K_L^0 = (K^0 - \bar{K}^0)/\sqrt{2}.$$

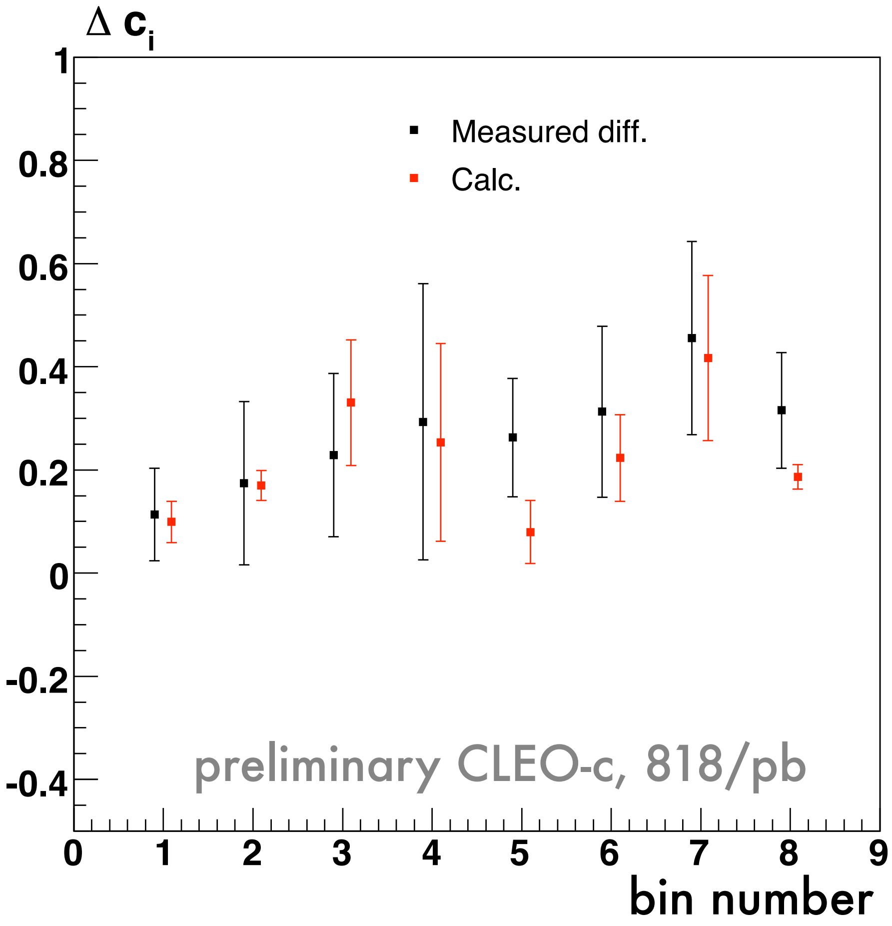
$$-A\left(D^0 \to K_L^0\pi^+\pi^-\right) = \underbrace{A\left(D^0 \to K_S^0\pi^+\pi^-\right)}_{\text{CF+DCS}} - \underbrace{\sqrt{2}A\left(D^0 \to K_{\text{flavour}}^0\pi^+\pi^-\right)}_{\text{DCS}}$$

- Using $K_L\pi\pi$ significantly enhances statistics.
- However, need a correction $\mathcal{O}(\tan^2\theta_C)$. Model dependence enters as an uncertainty on something that is in itself a small-ish correction.
- Notation: c_i, s_i from $K_S\pi\pi$. c_i', s_i' from $K_L\pi\pi$.

$\Delta c_i \equiv c_i - c_i'$, $\Delta s_i \equiv s_i - s_i'$

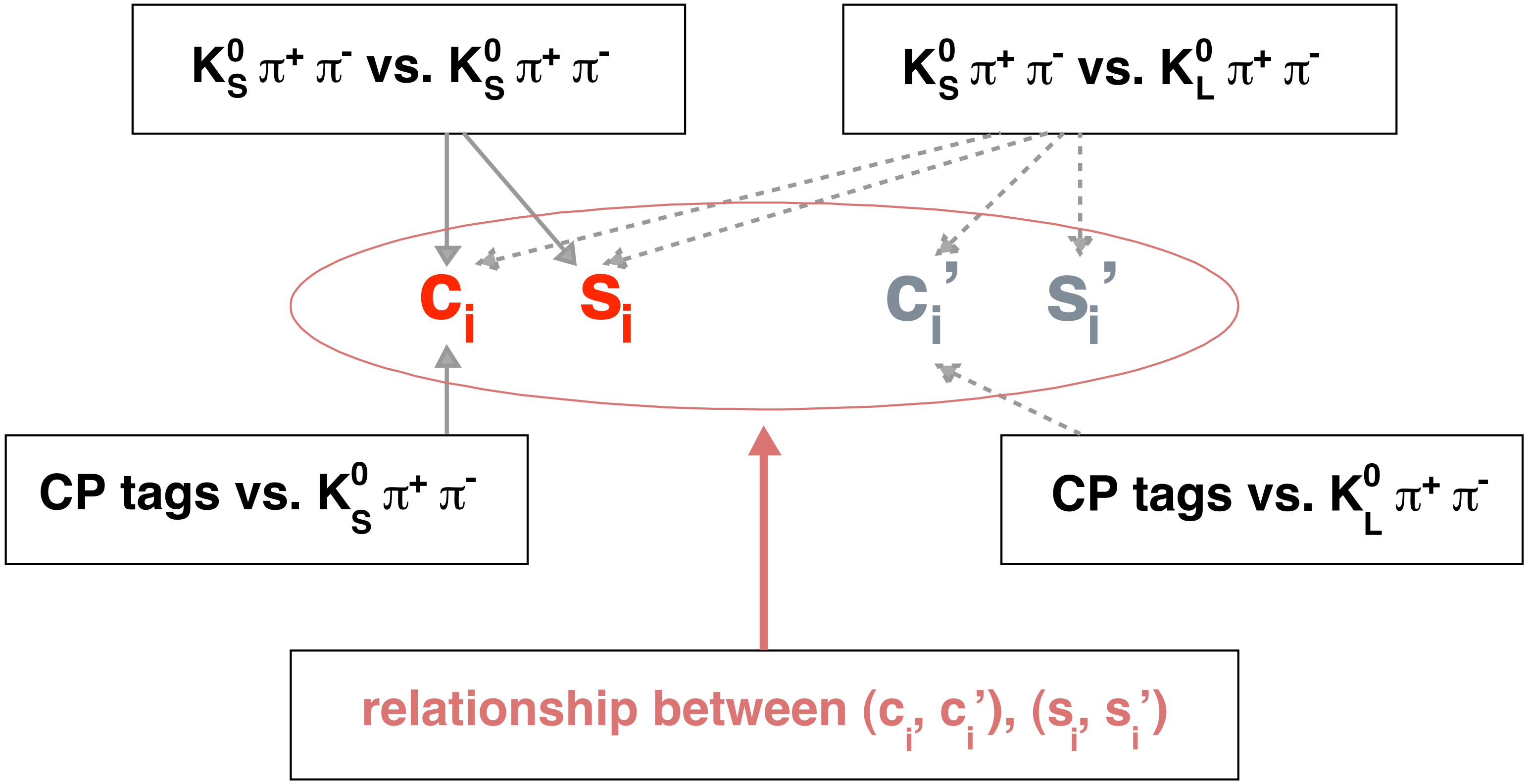
CP-even $K_L\pi\pi$ ≈ CP-odd $K_S\pi\pi$

- Δc_i from 0.1 – 0.4, $\sigma_{sys}(\Delta c_i)$ from 0.06 – 0.19
- $|\Delta s_i|$ from 0.02 – 0.13, $\sigma_{sys}(\Delta s_i)$ from 0.07 to 0.14
- Plot compares estimated Δc_i with separate measurements in CP-tagged $K_S\pi\pi$, and $K_L\pi\pi$ events.



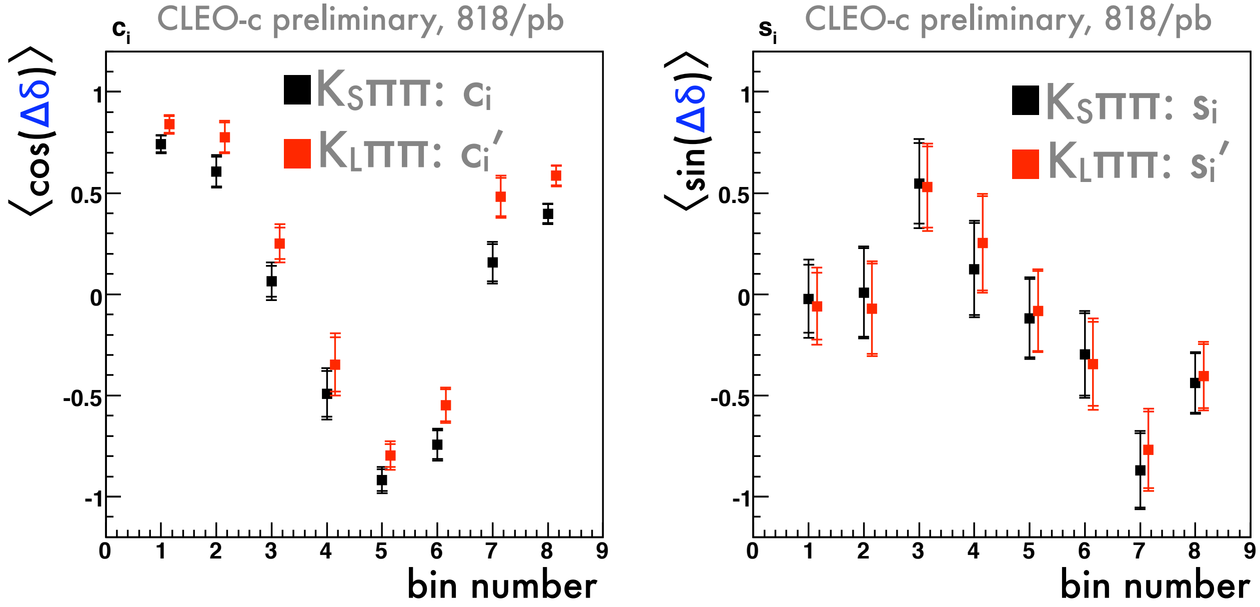
red: model predictions
black: CP-tagged data

Ingredients of combined fit



Notation: c_i, s_i from $K_S\pi\pi$. c_i', s_i' from $K_L\pi\pi$. $\Delta c_i \equiv c_i - c_i'$, $\Delta s_i \equiv s_i - s_i'$

The Result



- Results of combined fit in terms of c_i, s_i in $K_S\pi\pi$ and c_i', s_i' in $K_L\pi\pi$.
- Each series of results (black / red) contains full information from both $K_S\pi\pi$ and $K_L\pi\pi$ data, related by Δc_i, Δs_i.

- Fit errors (include $\sigma_{statistical} \oplus$ errors on Δc_i, Δs_i constraints):
  c_i: 0.04-0.11
  c_i': 0.04-0.14
  s_i: 0.15-0.23
  s_i': 0.16-0.23
- Systematic errors:
  c_i: 0.02-0.06
  c_i': 0.02-0.07
  s_i: 0.04-0.10
  s_i': 0.06-0.10

Impact on γ

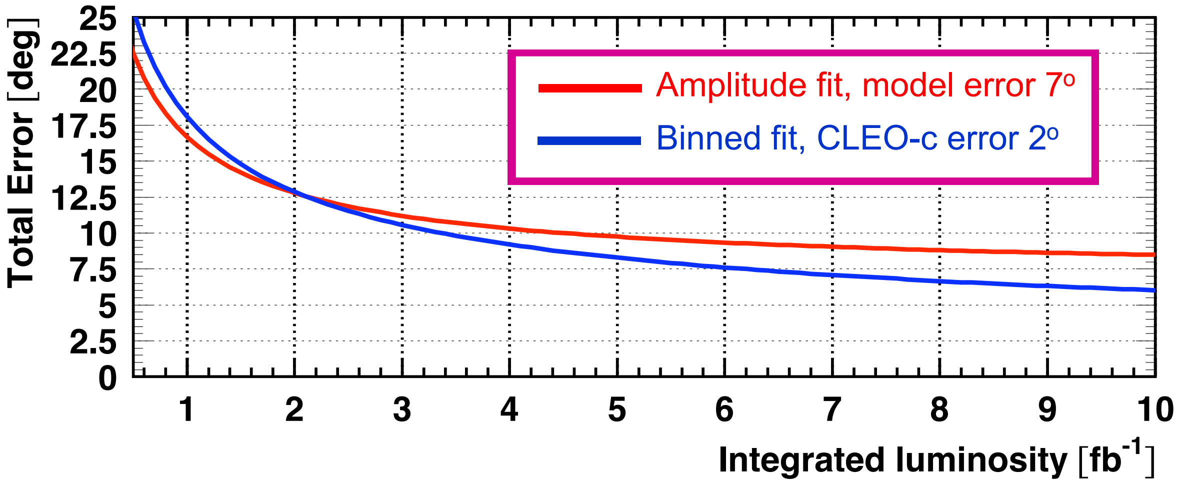
- Replace 7°–9° model error on γ from $B^{\pm}\to D(K_S\pi\pi)K^{\pm}$ with

  $\sigma_{\text{CLEO-input}}(\gamma) \sim 1^{\circ}$–$2^{\circ}$

  CLEO-c preliminary, 818/pb

- Significant reduction in BaBar/BELLE's systematic.
- Especially important for future flavour experiments, which will be systematics limited.

Impact on LHCb's $B^{\pm}\to D(K_S\pi\pi)K^{\pm}$ γ result (from Guy Wilkinson's talk at this workshop):



Error at the end of baseline LHCb (10 fb^{-1}): 8.5°(amplitude model); 6°(binned, with CLEO-c input)

(numbers for r_B=0.1)

Summary: CLEO-c's impact on γ

- CLEO-c's quantum-correlated D-Dbar pairs give model-independent access to c_i, s_i.
- Including $K_L\pi\pi$ in addition to $K_S\pi\pi$ significantly increases statistics at small systematic cost.
- With CLEO-c 818/pb of data, replace 7^o–9^o model error on γ from $B^{\pm}\to D(K_S\pi\pi)K^{\pm}$ with a statistical error:

$$\sigma_{\text{CLEO-input}}(\gamma) \sim 1^o\text{–}2^o$$ CLEO-c preliminary, 818/pb

- Significant reduction in systematics at BaBar/BELLE
- Crucial for LHCb and LHCb-Upgrade, Super-B.

Backup

Results Table

CLEO-c preliminary, 818/pb

	c_i	c_i'	s_i	s_i'
1	0.742±0.041±0.022	0.839±0.041±0.024	-0.022±0.168±0.096	-0.059±0.165±0.095
2	0.607±0.073±0.038	0.776±0.073±0.039	0.009±0.220±0.054	-0.071±0.223±0.070
3	0.064±0.077±0.052	0.251±0.078±0.053	0.548±0.198±0.096	0.529±0.200±0.082
4	-0.492±0.113±0.056	-0.347±0.135±0.074	0.124±0.227±0.074	0.252±0.233±0.069
5	-0.918±0.053±0.039	-0.796±0.056±0.043	-0.118±0.194±0.057	-0.082±0.197±0.055
6	-0.743±0.071±0.033	-0.548±0.080±0.036	-0.296±0.203±0.070	-0.344±0.208±0.088
7	0.156±0.092±0.050	0.481±0.094±0.045	-0.870±0.183±0.062	-0.768±0.189±0.073
8	0.398±0.047±0.020	0.586±0.048±0.020	-0.438±0.146±0.041	-0.405±0.158±0.060

Event Yield Summary

- Yields in 818 pb^{-1}, all with B/S < 0.1:
  - flavour-tagged: 12k $K_L\pi^+\pi^-$, 4k $K_S\pi^+\pi^-$.
  - 517 CP-odd $K_L\pi^+\pi^-$ 311 CP-even $K_S\pi^+\pi^-$
    322 CP-even $K_L\pi^+\pi^-$ 471 CP-odd $K_S\pi^+\pi^-$
  - 1.2k $K_L\pi^+\pi^-$ vs $K_S\pi^+\pi^-$, 475 $K_S\pi^+\pi^-$ vs $K_S\pi^+\pi^-$
- (Note: larger reconstruction efficiency for $K_L\pi^+\pi^-$, but fewer suitable tag modes)
- Nomenclatura trap: Often, esp. within CLEO-c, we refer to "CP-even-tagged" $K_S\pi^+\pi^-$. This is $K_S\pi^+\pi^-$ with CP-even D on the OTHER side. So that's a CP-odd $K_S\pi^+\pi^-$. In this slide CP refers to the CP of the $K_S\pi^+\pi^-$ (not the tag).

CLEO-c preliminary, 818/pb

List of Tags

- Flavor Tags
  - $K^- e^+ \nu$ vs. $K^0_S \pi^+\pi^-$
  - $K^-\pi^+$ vs. $K^0_{S,L}\pi^+\pi^-$
  - $K^-\pi^+\pi^0$ vs. $K^0_{S,L}\pi^+\pi^-$
  - $K^-\pi^+\pi^+\pi^-$ vs. $K^0_{S,L}\pi^+\pi^-$
- CP even Tags
  - $\pi^+\pi^-$ vs. $K^0_{S,L}\pi^+\pi^-$
  - K^+K^- vs. $K^0_{S,L}\pi^+\pi^-$
  - $K^0_S\pi^0\pi^0$ vs. $K^0_S\pi^+\pi^-$
  - $K^0_L\pi^0$ vs. $K^0_S\pi^+\pi^-$
- CP odd Tags
  - $K^0_S\pi^0$ vs. $K^0_{S,L}\pi^+\pi^-$
  - $K^0_S\eta$ vs. $K^0_{S,L}\pi^+\pi^-$
  - $K^0_S\omega$ vs. $K^0_S\pi^+\pi^-$
- Double Dalitz
  - $K^0_S\pi^+\pi^-$ vs. $K^0_{S,L}\pi^+\pi^-$

Model dependence on difference between c_i, s_i from $K_L\pi\pi$, $K_S\pi\pi$

CLEO-c preliminary, 818/pb

	Δc_1	Δc_2	Δc_3	Δc_4	Δc_5	Δc_6	Δc_7	Δc_8
Babar	0.099	0.167	0.327	0.253	0.077	0.22	0.416	0.184
Belle	0.104	0.16	0.217	0.087	0.03	0.153	0.353	0.189
CLEO II.V	0.06	0.143	0.234	0.084	0.111	0.211	0.259	0.17
Sys.	0.039	0.024	0.11	0.169	0.047	0.067	0.157	0.014
	Δs_1	Δs_2	Δs_3	Δs_4	Δs_5	Δs_6	Δs_7	Δs_8
Babar	-0.034	-0.064	-0.013	0.133	0.041	-0.038	0.095	0.015
Belle	-0.056	-0.146	-0.031	0.006	0.004	-0.091	0.036	-0.01
CLEO II.V	0.032	-0.025	0.083	0.091	-0.02	-0.035	0.081	0.099
Sys.	0.066	0.082	0.096	0.127	0.061	0.053	0.059	0.084

Total systematic error on $\Delta c_i, \Delta s_i$

CLEO-c preliminary, 818/pb

Table 17: Systematic errors of $\Delta c_i = c_i - c'_i$ and $\Delta s_i = s_i - s'_i$

	Δc_1	Δc_2	Δc_3	Δc_4	Δc_5	Δc_6	Δc_7	Δc_8
Model Depen.	0.039	0.024	0.11	0.169	0.047	0.067	0.157	0.014
ρ, f_0	0.010	0.018	0.041	0.072	0.037	0.055	0.026	0.018
Sum	0.040	0.029	0.122	0.192	0.061	0.084	0.160	0.024
	Δs_1	Δs_2	Δs_3	Δs_4	Δs_5	Δs_6	Δs_7	Δs_8
Model Depen.	0.066	0.082	0.096	0.127	0.061	0.053	0.059	0.084
ρ, f_0	0.011	0.015	0.011	0.044	0.055	0.037	0.018	0.017
Sum	0.068	0.084	0.097	0.136	0.080	0.065	0.063	0.086

Systematics Table

Table 50: Systematic errors for c_i.

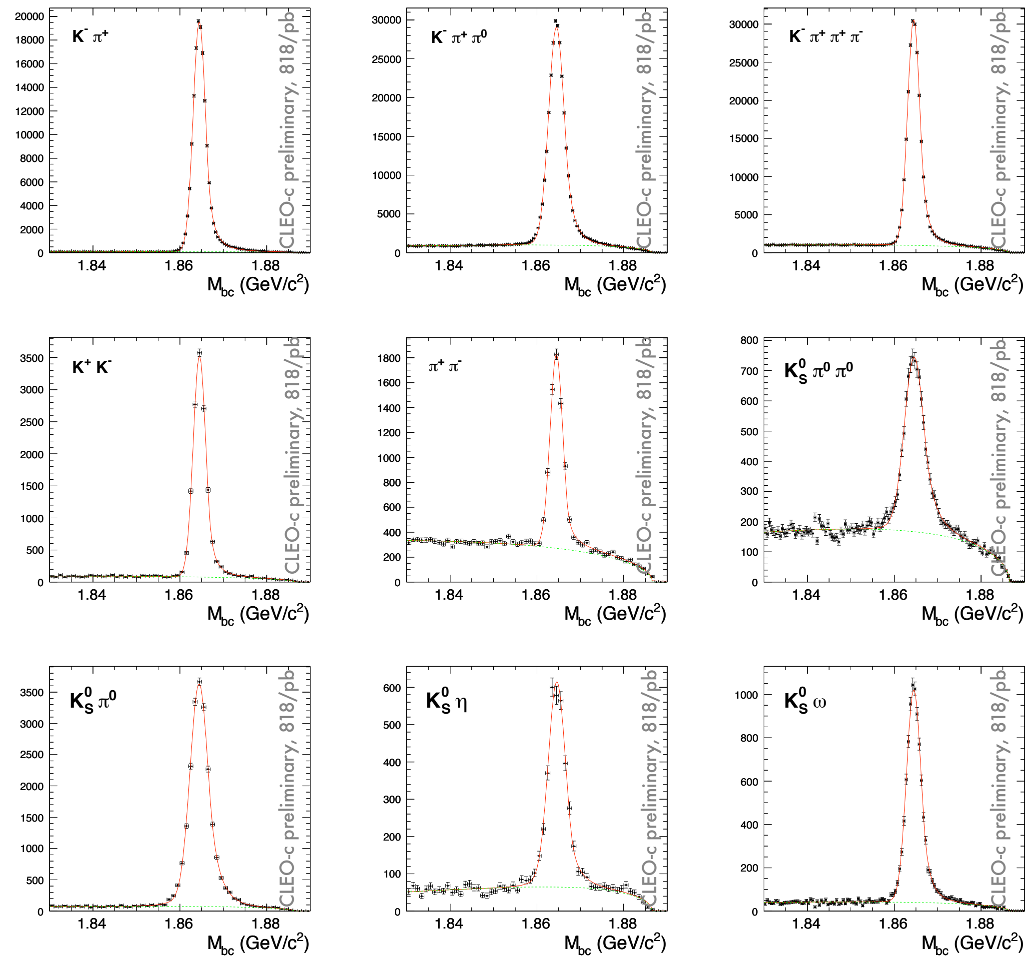
	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8
p resolution	0.008	0.014	0.010	0.017	0.010	0.011	0.015	0.008
Efficiency	0.004	0.007	0.011	0.008	0.005	0.008	0.010	0.006
$N_{K^+K^-}$	-0.000	0.000	0.001	-0.000	-0.000	0.000	0.001	-0.001
$N_{\pi^+\pi^-}$	-0.000	0.000	0.001	-0.000	-0.001	0.000	0.001	-0.001
$N_{K^0_S\pi^0\pi^0}$	0.000	0.001	0.001	0.000	-0.000	0.001	0.001	0.000
$N_{K^0_S\pi^0}$	-0.000	0.000	-0.000	-0.000	-0.000	0.001	-0.000	-0.000
$N_{K^0_S\eta}$	-0.000	0.000	0.000	-0.000	-0.000	0.001	-0.000	-0.000
$N_{K^0_S\omega}$	-0.001	-0.000	-0.000	-0.001	-0.001	-0.000	-0.001	-0.001
$\mathcal{B}_{K^-e^+\nu}$	0.001	0.003	0.004	0.003	0.001	0.002	0.004	0.002
N_{flavor}	-0.000	0.000	0.000	-0.001	-0.001	0.000	-0.000	-0.001
$N_{D^0/\bar{D}^0}$	0.001	0.002	0.003	0.002	0.000	0.002	0.003	0.001
$\mathcal{B}_{K^0_L\pi^0}$	0.005	0.007	0.013	0.010	0.004	0.008	0.015	0.006
$K^0_L\pi^0$ sys.	0.004	0.005	0.009	0.008	0.003	0.006	0.009	0.006
$K^0_L\pi^0$ BG.	0.004	0.006	0.011	0.009	0.004	0.006	0.010	0.007
$K^0_S\pi^0\pi^0$ vs. $K^0_S\pi^+\pi^-$	0.001	0.001	0.004	0.002	0.001	0.002	0.002	0.001
$K^0_S\pi^0$ vs. $K^0_S\pi^+\pi^-$	-0.001	-0.001	-0.001	-0.001	-0.001	-0.000	-0.002	-0.001
$K^0_S\eta$ vs. $K^0_S\pi^+\pi^-$	-0.000	0.000	-0.000	-0.001	-0.000	0.000	-0.000	-0.001
$K^0_S\omega$ vs. $K^0_S\pi^+\pi^-$	-0.001	-0.000	-0.001	-0.002	-0.000	-0.001	-0.001	-0.001
Signal side	-0.001	-0.001	-0.008	-0.026	-0.013	-0.005	0.003	-0.002
$K^0_S\pi^0$ vs. $K^0_L\pi^+\pi^-$	0.001	0.002	0.001	0.001	0.001	0.002	0.001	0.001
$K^0_S\eta$ vs. $K^0_L\pi^+\pi^-$	-0.000	0.000	0.001	0.000	-0.000	0.001	0.000	-0.000
Multi. Candidate (1)	0.000	-0.000	0.002	-0.005	-0.000	-0.000	-0.003	-0.000
K^0_S cut	-0.000	0.000	0.001	0.000	0.000	0.001	0.001	0.000
$K^0_S\pi^+\pi^-$ BG.	0.001	0.001	0.004	0.002	0.001	0.003	0.000	-0.002
Partical Reconst.	0.000	0.001	0.001	-0.004	-0.001	0.001	0.000	-0.001
Multi. Candidate (2)	0.001	0.003	0.000	-0.004	-0.005	-0.006	-0.001	0.001
$K^0_L\pi^+\pi^-$ BG.(1)	0.005	0.011	0.002	0.002	0.001	0.002	0.006	0.001
$K^0_L\pi^+\pi^-$ BG.(2)	-0.000	0.001	-0.000	0.010	-0.007	-0.003	-0.003	0.001
$K^0_L\pi^+\pi^-$ BG.(3)	0.002	0.015	0.003	-0.005	-0.000	0.001	-0.002	0.001
$K^0_L\pi^+\pi^-$ BG.(4)	0.004	-0.004	-0.000	-0.021	-0.015	-0.011	-0.016	0.005
Constrain	0.001	0.003	0.041	0.024	-0.023	0.011	0.028	-0.004
Non-$D/\bar{D}$ (1)	0.001	0.003	0.002	0.001	0.000	0.001	0.003	0.001
Non-$D/\bar{D}$ (2)	0.007	0.015	0.002	0.004	0.002	0.004	0.003	0.003
Non-$D/\bar{D}$ (3)	-0.000	0.000	-0.002	-0.004	-0.003	-0.003	-0.002	-0.001
Non-$D/\bar{D}$ (4)	0.006	0.007	0.003	0.003	0.001	0.002	0.004	0.002
DCSD (1)	0.009	0.012	0.005	-0.013	0.014	0.012	0.013	0.005
DCSD (2)	0.002	0.001	0.004	0.001	-0.000	0.001	0.003	-0.001
Flavor stat.	0.010	0.015	0.015	0.019	0.010	0.015	0.019	0.009
Sum	0.022	0.038	0.052	0.056	0.039	0.033	0.050	0.020

Table 51: Systematic errors for s_i.

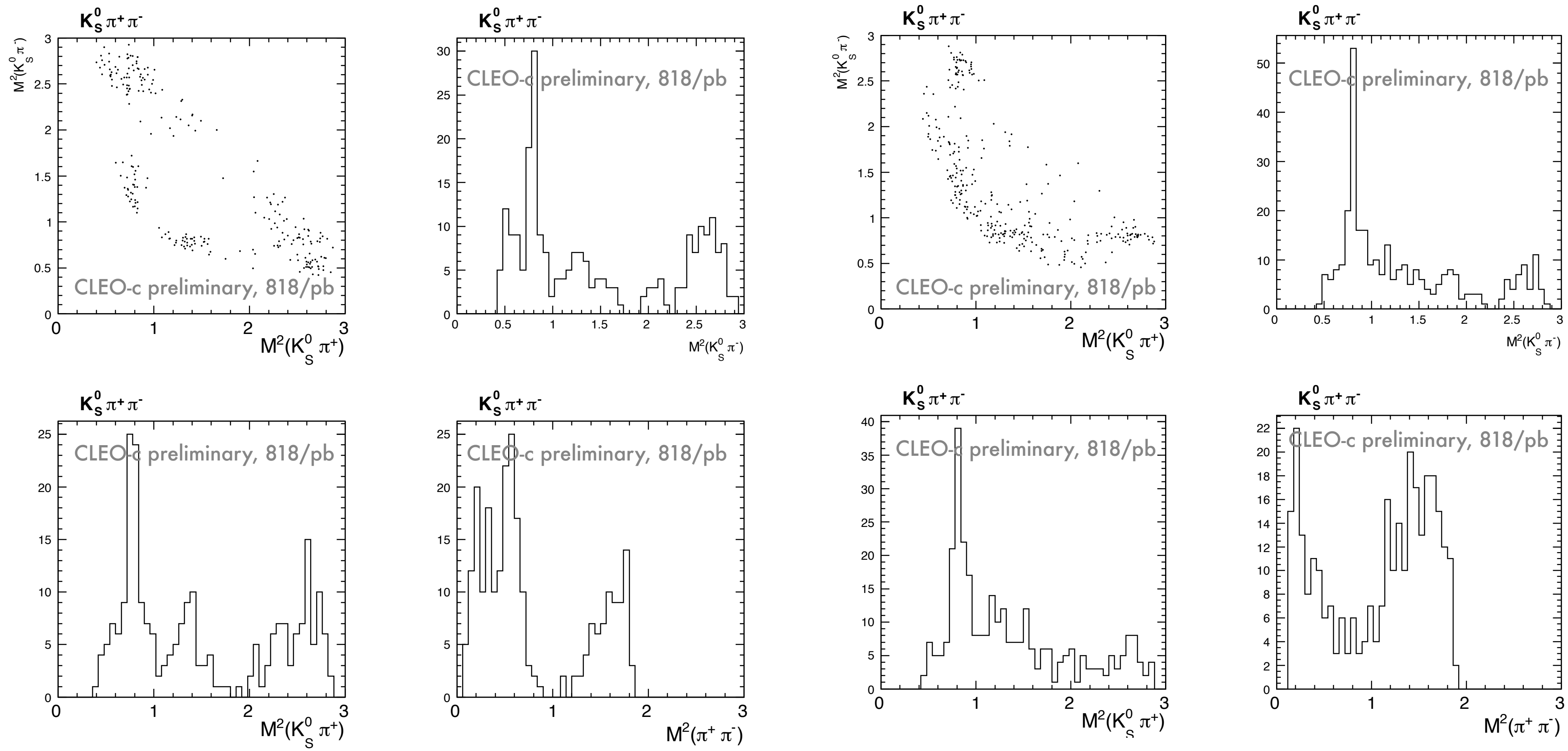
	s_1	s_2	s_3	s_4	s_5	s_6	s_7	s_8
p resolution	0.017	0.031	0.018	0.027	0.028	0.016	0.021	0.017
Efficiency	0.018	0.012	0.019	0.010	0.013	0.018	0.013	0.012
$N_{K^+K^-}$	0.001	0.000	0.000	0.000	-0.000	-0.000	0.000	0.000
$N_{\pi^+\pi^-}$	0.001	0.000	0.000	0.000	-0.000	-0.000	0.000	0.000
$N_{K^0_S\pi^0\pi^0}$	0.001	0.000	0.000	0.000	-0.000	-0.000	0.000	0.000
$N_{K^0_S\pi^0}$	0.000	0.000	-0.000	0.000	-0.001	0.000	0.000	0.000
$N_{K^0_S\eta}$	0.000	0.000	-0.000	0.000	-0.000	0.000	0.000	0.000
$N_{K^0_S\omega}$	0.000	0.000	-0.000	0.000	-0.000	0.000	0.000	0.000
$\mathcal{B}_{K^-e^+\nu}$	-0.004	0.000	-0.006	-0.004	-0.005	0.002	-0.005	-0.002
N_{flavor}	0.000	0.000	-0.000	0.000	-0.000	-0.000	0.000	0.000
$N_{D^0/\bar{D}^0}$	-0.000	0.000	-0.001	-0.001	-0.002	-0.000	-0.001	-0.000
$\mathcal{B}_{K^0_L\pi^0}$	0.004	-0.000	0.003	0.002	-0.000	-0.003	0.002	0.001
$K^0_L\pi^0$ sys.	0.003	-0.000	0.002	0.002	-0.000	-0.002	0.001	0.001
$K^0_L\pi^0$ BG.	0.003	-0.000	0.003	0.002	-0.000	-0.003	0.002	0.001
$K^0_S\pi^0\pi^0$ vs. $K^0_S\pi^+\pi^-$	0.001	0.000	0.000	0.001	-0.000	-0.000	0.000	0.000
$K^0_S\pi^0$ vs. $K^0_S\pi^+\pi^-$	0.000	0.000	-0.000	0.000	-0.000	0.000	0.000	0.000
$K^0_S\eta$ vs. $K^0_S\pi^+\pi^-$	0.000	0.000	-0.000	0.000	-0.000	-0.000	0.000	0.000
$K^0_S\omega$ vs. $K^0_S\pi^+\pi^-$	0.000	0.000	-0.000	0.000	-0.000	0.000	0.000	0.000
Signal side	0.001	0.000	-0.001	-0.002	-0.000	-0.000	0.000	0.001
$K^0_S\pi^0$ vs. $K^0_L\pi^+\pi^-$	0.001	0.000	-0.000	0.000	-0.001	-0.000	0.000	0.000
$K^0_S\eta$ vs. $K^0_L\pi^+\pi^-$	0.000	0.000	-0.000	0.000	-0.000	0.000	0.000	0.000
Multi. Candidate (1)	-0.003	-0.003	0.015	0.004	0.002	0.003	-0.010	0.006
K^0_S cut	-0.000	0.000	0.000	0.000	-0.001	0.001	0.000	0.001
$K^0_S\pi^+\pi^-$ BG.	-0.009	0.011	-0.038	-0.024	-0.011	0.001	-0.019	-0.013
Partical Reconst.	-0.000	0.004	-0.001	0.003	0.003	0.005	0.002	-0.004
Multi. Candidate (2)	0.035	0.017	0.029	0.011	0.024	-0.026	0.024	0.007
$K^0_L\pi^+\pi^-$ BG.(1)	-0.011	-0.008	-0.012	-0.009	-0.003	-0.002	-0.009	-0.005
$K^0_L\pi^+\pi^-$ BG.(2)	-0.000	-0.001	0.000	0.002	-0.000	0.000	0.000	0.000
$K^0_L\pi^+\pi^-$ BG.(3)	-0.000	-0.001	-0.001	0.001	0.002	0.000	0.000	0.000
$K^0_L\pi^+\pi^-$ BG.(4)	0.065	0.016	0.035	0.041	0.012	-0.043	0.008	-0.010
Constrain	0.037	0.008	0.040	0.025	0.007	-0.030	0.014	-0.004
Non-$D/\bar{D}$ (1)	-0.002	-0.001	-0.002	-0.001	-0.002	-0.000	-0.002	-0.001
Non-$D/\bar{D}$ (2)	0.002	-0.001	0.001	0.001	-0.001	-0.001	0.001	0.000
Non-$D/\bar{D}$ (3)	0.004	0.001	0.005	0.005	0.003	-0.003	0.002	0.001
Non-$D/\bar{D}$ (4)	0.002	-0.001	0.001	0.001	-0.000	-0.002	0.001	0.000
DCSD (1)	0.004	0.001	-0.003	0.002	-0.001	-0.003	0.002	0.001
DCSD (2)	0.021	-0.004	0.031	0.017	0.015	-0.005	0.024	0.016
Flavor stat.	0.034	0.032	0.045	0.033	0.034	0.029	0.036	0.024
Sum	0.096	0.054	0.096	0.074	0.057	0.070	0.062	0.041

Reconstructed mass in tag modes

CLEO-c preliminary, 818/pb

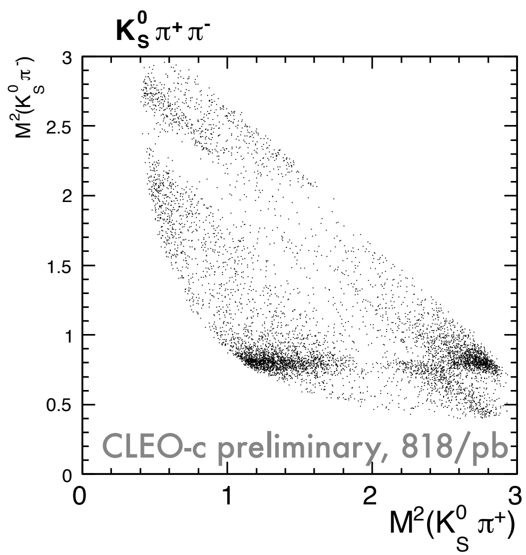


CP-even and odd $K_s\pi\pi$

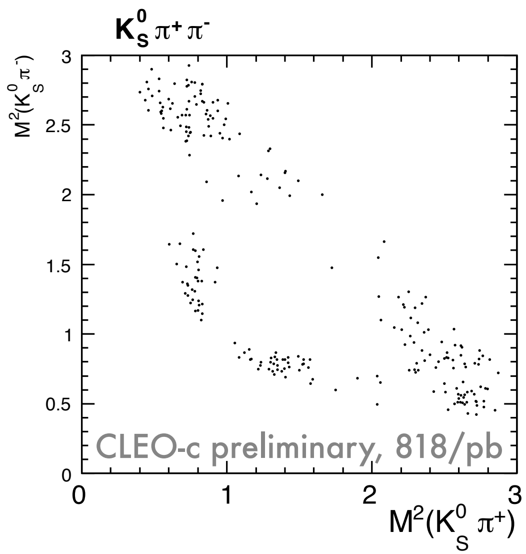


$K^0_S\pi^+\pi^-$ Dalitz plot vs. CP even taggs $(K^+K^-, \pi^+\pi^-, K^0_S\pi^0\pi^0)$ in Data. $K^0_S\pi^+\pi^-$ Dalitz plot vs. CP odd taggs $(K^0_S\pi^0, K^0_S\eta, K^0_S\omega)$ in Data.

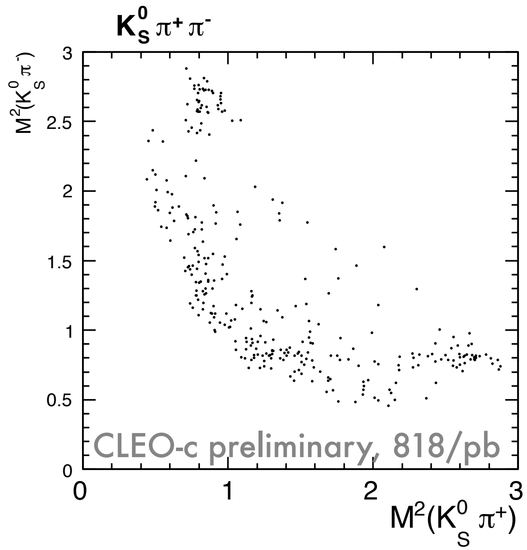
Flavour- and CP-tagged $K_s\pi\pi$



flavour-tagged

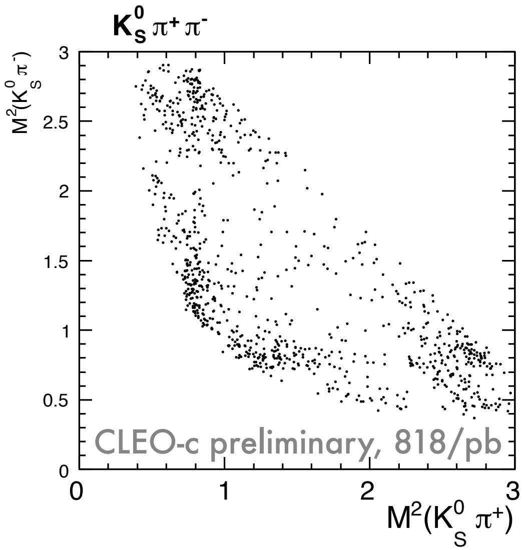


CP-even

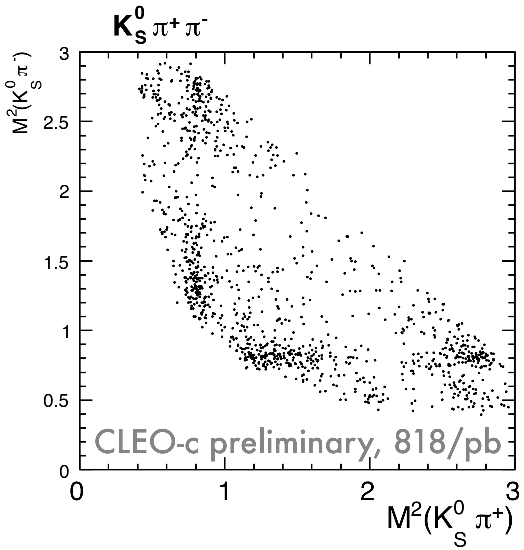


CP-odd

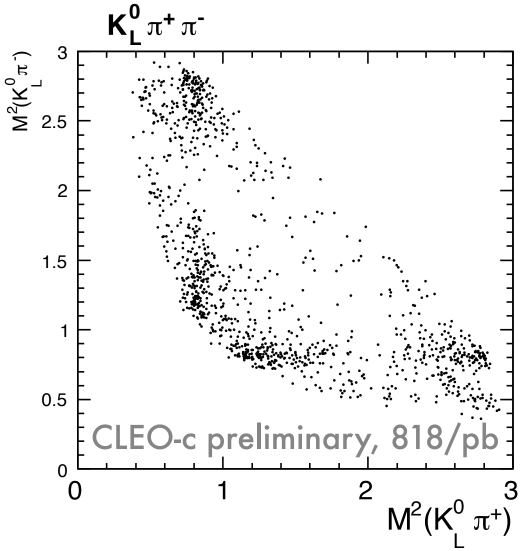
Double-Dalitz Dalitz Plots



$K_s\pi\pi + K_s\pi\pi$

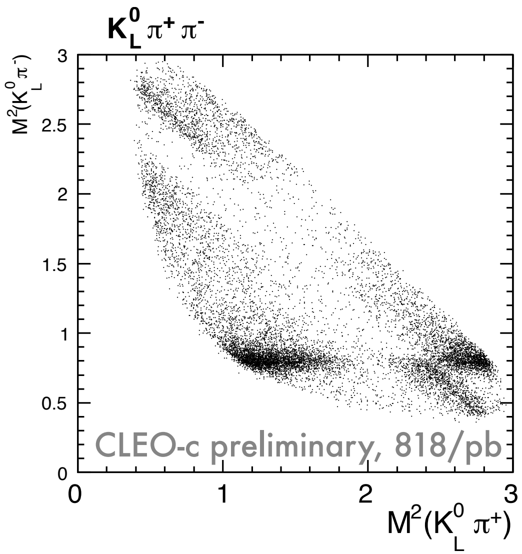


$K_S\pi\pi$ with $K_L\pi\pi$-tag

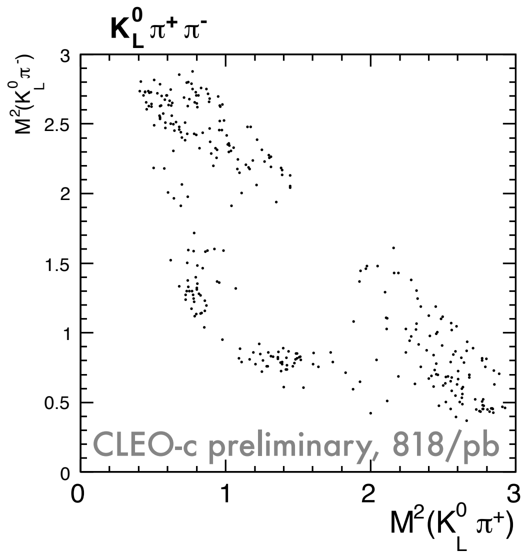


$K_L\pi\pi$ with $K_S\pi\pi$-tag

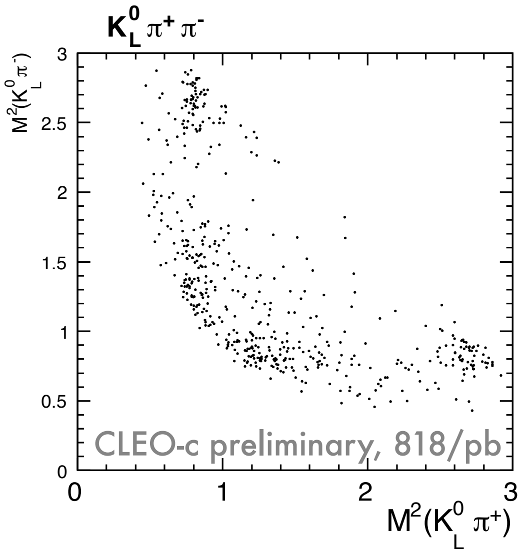
$K_L\pi\pi$



flavour-tagged



CP-odd tags (i.e. CP-even $K_L\pi\pi$)



CP-even tags (i.e. CP-odd $K_L\pi\pi$)

Double-Dalitz, $K_S\pi\pi$ vs $K_S\pi\pi$

- Simultaneous, binned analysis of quantum-correlated $D_a \to K_S\pi\pi$, $D_b \to K_S\pi\pi$ pairs gives access to both, c_i and s_i.

- $M_{ij} \equiv$ number of events in ith bin in first Dalitz plot, and jth bin in 2nd Dalitz plot (symmetric in i,j)

$$M_{ij} = \mathcal{T}_i\mathcal{T}_{-j} + \mathcal{T}_{-i}\mathcal{T}_j - 2\sqrt{\mathcal{T}_i\mathcal{T}_{-j}\mathcal{T}_{-i}\mathcal{T}_j}(c_i c_j + s_i s_j)$$

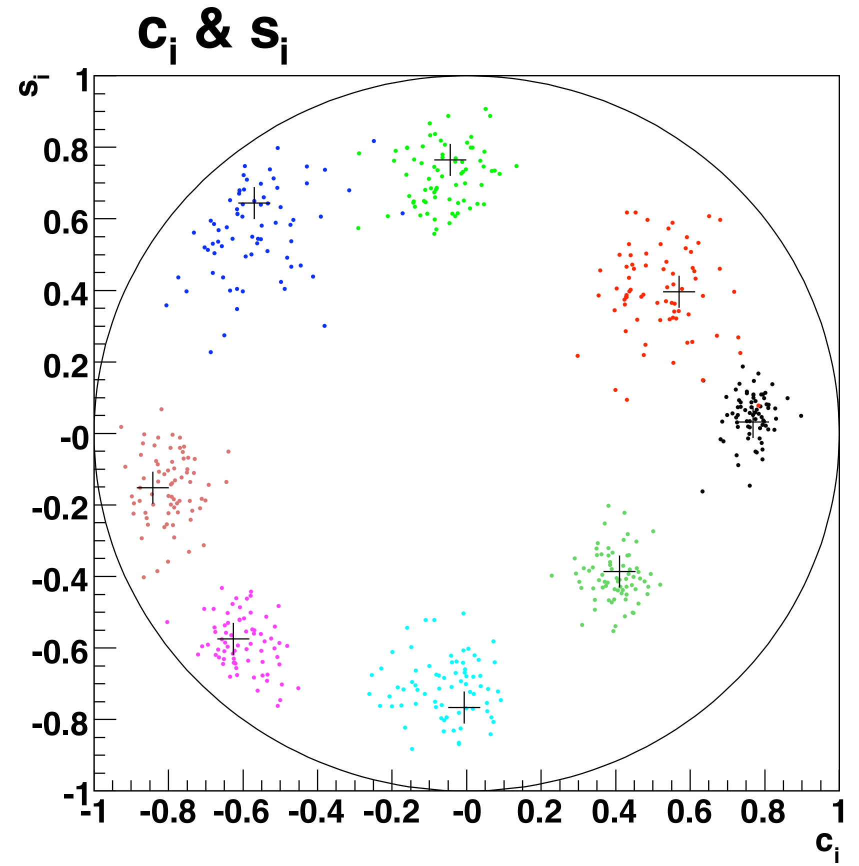
($\mathcal{T}_i$ known from flavour-specifc D decays)

(apart from detector efficiencies)

- Enough information to extract both c_i and s_i.

MC study: c_i and s_i from $K_s\pi\pi$ vs $K_s\pi\pi$

- Crosses = input (from BaBar Model)
- Dots: Fit results from Toy MC study, using $K_s\pi\pi$ vs $K_s\pi\pi$ only.
- Plot also illustrates how careful binning insures $c_i^2 + s_i^2 \approx 1$.



Ks pi pi Event Yields

Table 6: $K_S^0\pi^+\pi^-$ yields in QCMC and data.

Mode	entry	Tag BG	$2\pi^+2\pi^-$	other	B/(S+B)	Data	Tagside sideband
$K^-\pi^+$	6592	15	22	71	0.016	1447	9
$K^-\pi^+\pi^0$	12620	165	32	116	0.025	2776	46
$K^-\pi^+\pi^+\pi^-$	9998	323	27	91	0.044	2250	32
$\pi^+\pi^-$	334	1	0	0	0.003	62	2
K^+K^-	689	4	1	2	0.010	124	2
$K_S^0\pi^0\pi^0$	327	39	1	1	0.125	56	3
$K_S^0\pi^0$	750	9	3	9	0.028	189	3
$K_S^0\eta$	108	1	1	4	0.056	39	0
$K_S^0\omega$	377	27	0	0	0.072	83	6

data	sideband
4443	87
242	7
311	9

Table 8: $K_L^0\pi^+\pi^-$ Yields in QCMC and data.

Mode	entry	Tag BG	$K_S^0\pi^+\pi^-$	other BG	total	B/(S+B)	Data
$K^-\pi^+$	44281	111	682	1527	2320	0.0523927	2858
$K^-\pi^+\pi^0$	81427	1931	1257	2757	5273	0.0647574	5130
$K^-\pi^+\pi^+\pi^-$	58404	1678	1079	2014	4771	0.0816896	4110
$\pi^+\pi^-$	651	2	15	11	28	0.0430108	172
K^+K^-	1382	8	27	26	61	0.0441389	345
$K_S^0\pi^0\pi^0$	719	118	6	17	141	0.196106	225
$K_S^0\pi^0$	1684	12	32	60	104	0.0617577	281
$K_S^0\eta$	202	6	5	6	17	0.0841584	41
$K_S^0\omega$	768	61	9	30	100	0.130208	115

12098
742
437

(not all modes used in $K_L\pi\pi$)

Model independent γ fit

Giri, Grossmann, Soffer, Zupan, Phys Rev D 68, 054018 (2003).

- Binned decay rate:

$$\Gamma\left(B^\pm \to D(K_s\pi^+\pi^-)K^\pm\right)_i =$$

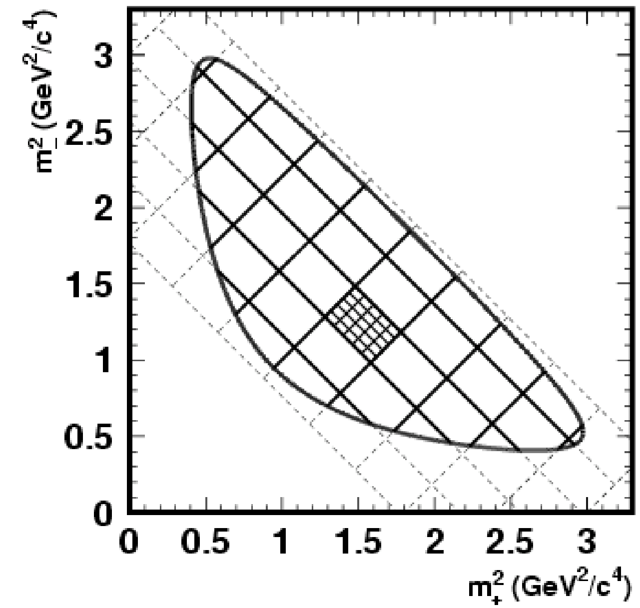
$$\mathcal{T}_i + r_B^2\mathcal{T}_{-i} + 2r_B\sqrt{\mathcal{T}_i\mathcal{T}_{-i}}\left\{c_i\cos\left(\delta-\gamma\right) + s_i\sin\left(\delta-\gamma\right)\right\}$$

$\mathcal{T}_i$ known from flavour-specifc D decays (e.g. D*)

- c_i and s_i: weighted average of cos and sine of the strong phase difference between A_D and $A_{\bar{D}}$, over one bin.

$$c_i \equiv \frac{1}{\sqrt{\mathcal{T}_i\mathcal{T}_{-i}}}\int \left|A_D(m_{12}^2, m_{21}^2)\right|\left|A_D(m_{21}^2, m_{12}^2)\right|\cos\left(\delta(m_{12}^2)-\delta(m_{21}^2)\right)\, dm_{12}^2\, dm_{21}^2$$

$$s_i \equiv \frac{1}{\sqrt{\mathcal{T}_i\mathcal{T}_{-i}}}\int \left|A_D(m_{12}^2, m_{21}^2)\right|\left|A_D(m_{21}^2, m_{12}^2)\right|\sin\left(\delta(m_{12}^2)-\delta(m_{21}^2)\right)\, dm_{12}^2\, dm_{21}^2$$



c_i from CP-tags

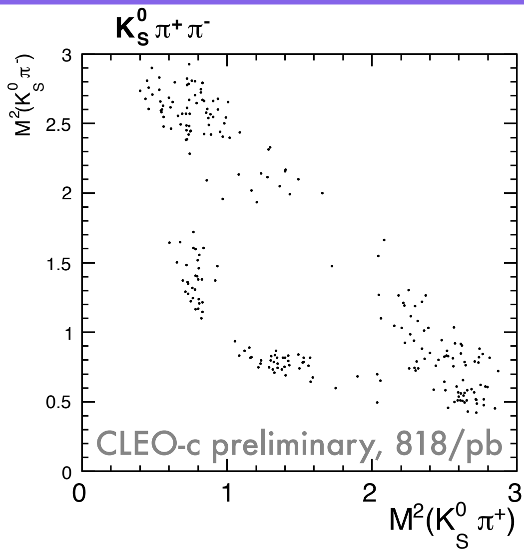
- CP-tagged binned Dalitz Plots sensitive to c_i.
- Number of events in ith bin:

$$M_i^{CP\pm} = \mathcal{T}_i + \mathcal{T}_{-i} \pm 2c_i\sqrt{\mathcal{T}_i\mathcal{T}_{-i}}$$

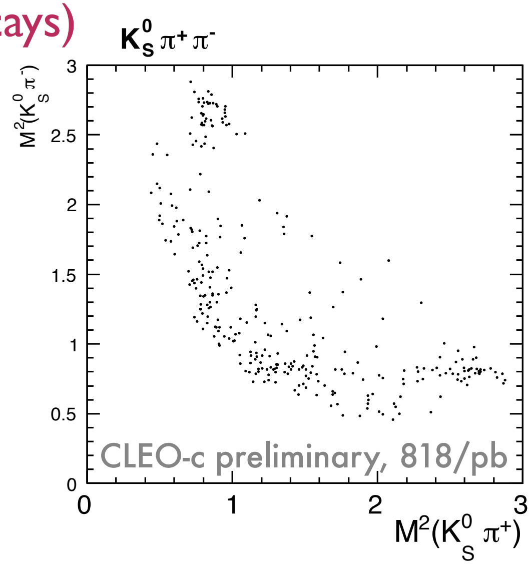
($\mathcal{T}_i$ known from flavour-specifc D decays)

(apart from efficiency corrections)

- For binning with $\delta_D(s_{12})-\delta(s_{34})$ ~ const over bin, $c_i^2 + s_i^2 \approx 1$. We'll use clever binning, but don't rely on this relationship



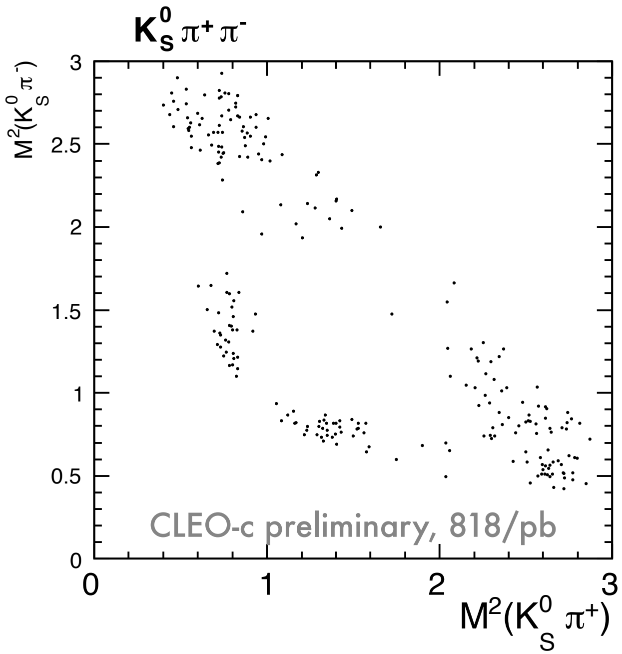
471 CP-odd $D\rightarrow K_S\pi\pi$ events, S/(S+B)=94%



300 CP-even $D\rightarrow K_S\pi\pi$ events with S/(S+B)=96%

c_i from CP-tags

471 CP-odd $D \rightarrow K_S\pi\pi$ events with $S/(S+B)=94\%$



300 CP-even $D \rightarrow K_S\pi\pi$ events with $S/(S+B)=96\%$