D and D_s hadronic branching fractions at B factories

Marco Pappagallo
University of Bari & INFN
On behalf of BaBar Collaboration

Charm07, Cornell University, Ithaca, New York, August 5-8, 2007

Outline

- $D^0 \to K^- \pi^+$ BR — arXiv:0704.2080 (Submitted to Phys.Rev.Lett.)
- $D_s^+ \to K^+ K^- \pi^+$ BR — hep-ex/0701053
- $D^0 \to K^+ K^- \pi^0$ and $D^0 \to \pi^+ \pi^- \pi^0$ BR's — Phys.Rev.D74:091102,2006 ; hep-ex/0610062
- Amplitude Analysis of D and D_s decay:
  - $D_s^+ \to K^+ K^- \pi^+$ — Preliminary
  - $D^0 \to K^+ K^- \pi^0$ — Phys.Rev.D76:011102,2007
  - $D^0 \to \bar{K}^0 \pi^+ \pi^-$ — hep-ex/0507101 & hep-ex/0607104 ; arXiv:0704.1000

BABAR™

210 fb^{-1}

Preliminary

Absolute Branching Fraction of $D^0 \rightarrow K^- \pi^+$

Motivation:

- **Need to normalize other $\mathcal{B}$(D): (semi)leptonic for V_{cb}, f_D measurements**

$\mathcal{B}(D^0 \to K^-\pi^+)$

Step 1

Partial reconstruction:

$\bar{B}^0 \to D^{*+} X \ell^- \bar{\nu}_\ell \quad (\ell = \mu, e)$

$\quad \hookrightarrow D^0 \pi_s^+$

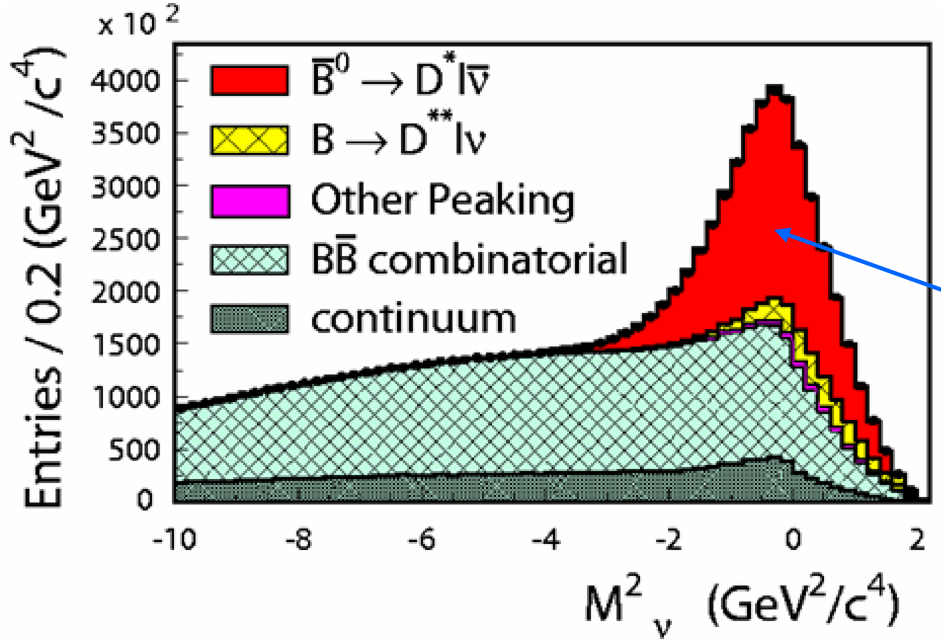
Request for selection

$M_\nu^2 = (E_{beam} - E_{D^*} - E_\ell)^2 - (p_{D^*} + p_\ell)^2$

When M_ν^2 peaks near to zero

$\bar{B}^0 \to D^{*+} \ell^- \bar{\nu} \quad (\ell = \mu, e)$

$\quad \hookrightarrow D^0 \pi_s^+$



2.2M Events

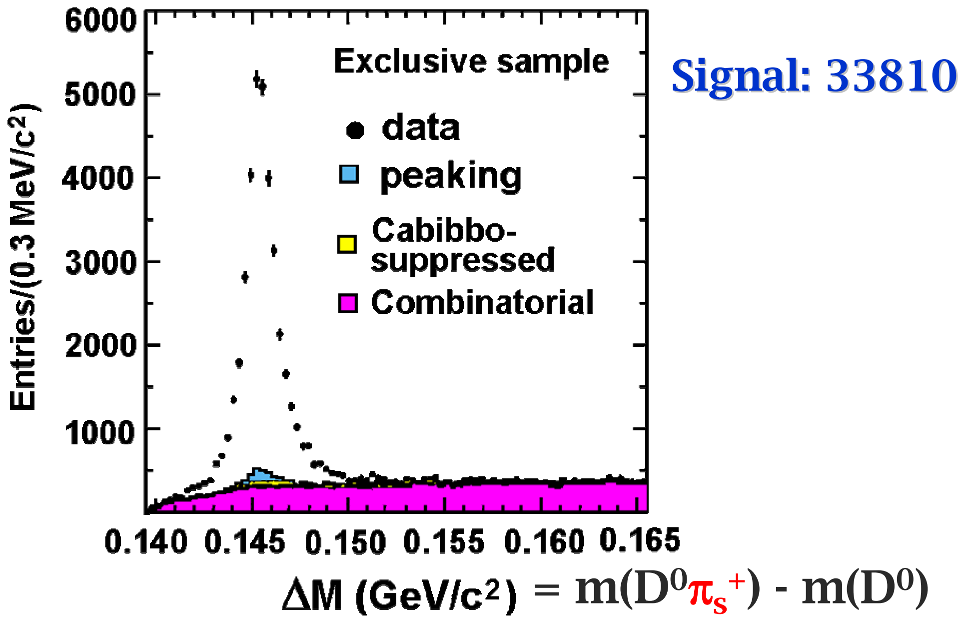
$\mathcal{B}(D^0 \to K^- \pi^+)$

Step 2

Exclusive: $D^{*+} \to D^0 \pi_s^+$, with $D^0 \to K^- \pi^+$

Same π_s^+ of Step 1

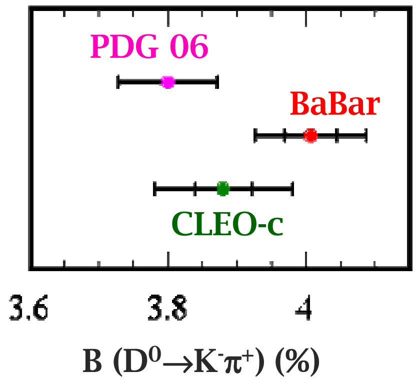
Request for selection



Signal: 33810 ± 290

BaBar Preliminary	PDG 06
$\mathcal{B}(D^0 \to K^- \pi^+) = \frac{N^{excl}}{N^{incl}} \frac{1}{\varepsilon_{(K^-\pi^+)}\zeta} = (4.007 \pm 0.037 \pm 0.070)\%$	$(3.80 \pm 0.07)\%$

- ζ → Selection bias
- $\varepsilon_{(K^-\pi^+)}$ → D^0 reconstruction efficiency = 37%



552.3 fb^{-1}

Preliminary

Absolute Branching Fraction of $D_s^+ \rightarrow K^+K^- \pi^+$

Motivation:

- Normalization of many decays involving a D_s^+ in the final state
- It is a systematic limitation for some precise measurements: CP violation in $B^0 \rightarrow D^{(*)\pm} \pi^{\mp}$ decays

$\mathcal{B}(D_s^+ \to K^+K^-\pi^+)$

D_{s1}^- Tag

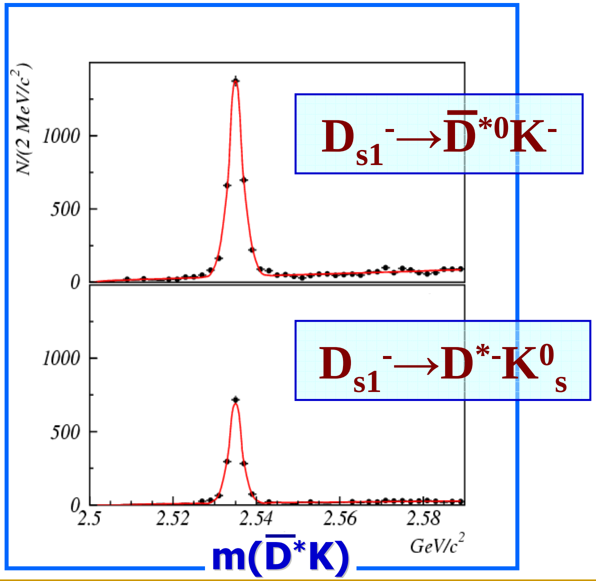
$e^+e^- \to D_{s1}^- D_s^{*+}$

$D_s^{*+} \to D_s^+ \gamma$

$D_{s1}^- \to \bar{D}^* K$

Request for selection

$N(D_{s1}^-)/\varepsilon(D_{s1}^-) \sim \mathcal{B}(D^*)$



D_s^{*+} Tag

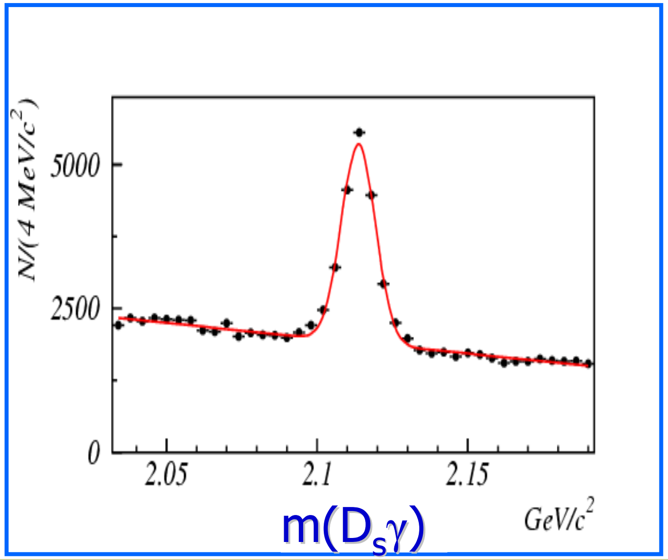
$e^+e^- \to D_{s1}^- D_s^{*+}$

$D_s^{*+} \to D_s^+ \gamma$, $D_s^+ \to K^+K^-\pi^+$

$D_{s1}^- \to D^* K$

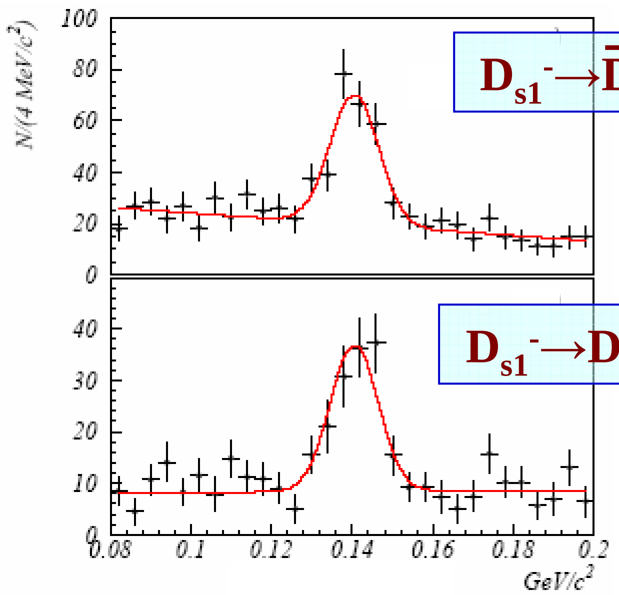
Request for selection

$N(D_s^{*+})/\varepsilon(D_s^{*+}) \sim \mathcal{B}(D_s^+ \to K^+K^-\pi^+)$



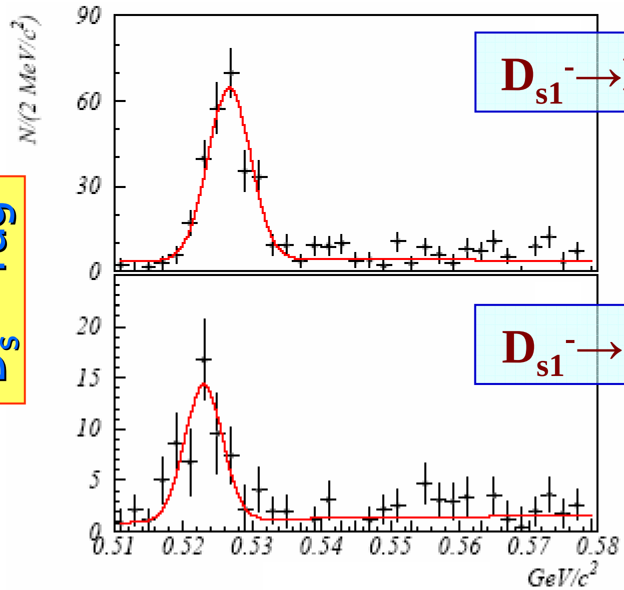
$\mathcal{B}(D_s^+ \to K^+K^-\pi^+)$

D_{s1}^- Tag



$\Delta M_{recoil}(D_{s1}^-\gamma)=M_{recoil}(D_{s1}^-)-M_{recoil}(D_{s1}^-\gamma)$

D_s^{*+} Tag



$\Delta M_{recoil}(D_s^{*+}K)=M_{recoil}(D_s^{*+})-M_{recoil}(D_s^{*+}K)$

$$M_{recoil}(X)=\sqrt{(\sqrt{s}-E_X)^2-P_X^2}$$

$\mathcal{B}(D_s^+ \to K^+K^-\pi^+) = (4.1\pm0.4\pm0.4)\%$

CLEO: $\mathcal{B}(D_s \to KK\pi) = (5.57\pm0.30\pm0.19)\%$

PDG 04: $\mathcal{B}(D_s \to KK\pi) = (4.4\pm1.2)\%$

Belle results are preliminary

232 fb^{-1}

357 fb^{-1}

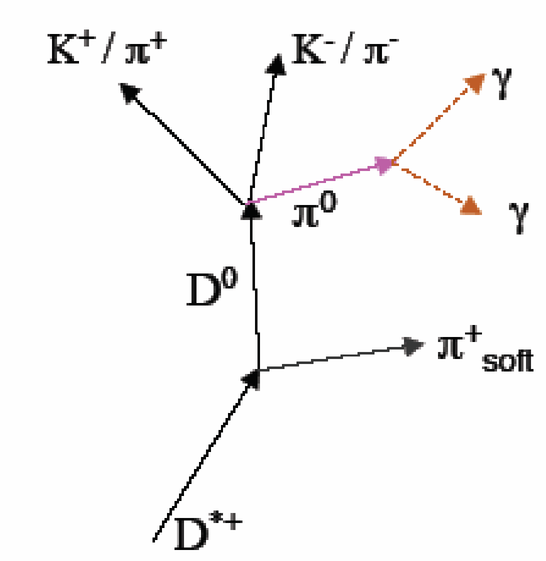
Preliminary

$D^0 \rightarrow K^+ K^- \pi^0$ and $D^0 \rightarrow \pi^+ \pi^- \pi^0$ Relative Branching Fraction

Motivation:

- **Precision measurement of the branching ratio of 3-body Cabibbo suppressed decays of D^0**
- **To investigate the anomaly in the branching ratio of 2- and 3-body CS decays of D^0**

$D^0 \to K^+K^-\pi^0$, $\pi^+\pi^-\pi^0$

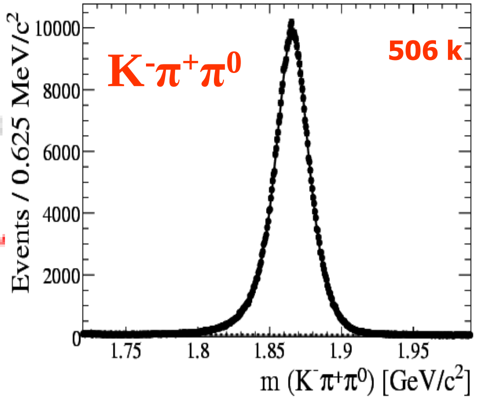


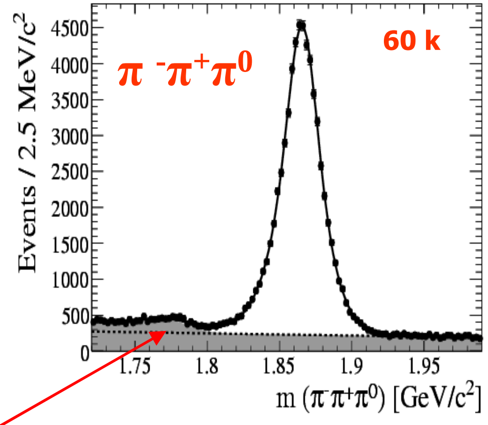
Use the Cabibbo favored decay $D^0 \to K^-\pi^+\pi^0$ as reference for normalization

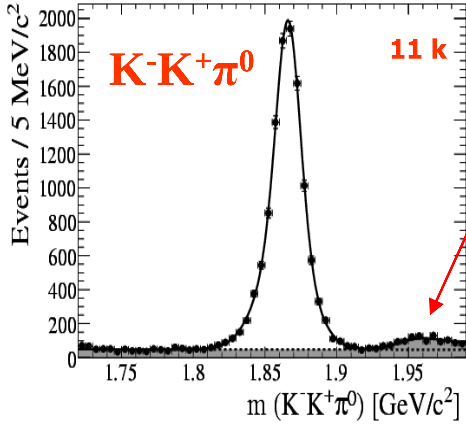
BaBar	Belle
$E_\gamma(\pi^0) > 100$ MeV	$E_\gamma(\pi^0) > 60$ MeV
$0.115 < M(\pi^0) < 0.160$ GeV/c^2	$0.124 < M(\pi^0) < 0.148$ GeV/c^2
$E_{Lab}(\pi^0) > 0.35$ GeV/c	$p_{Lab}(\pi^0) > 0.3$ GeV/c
$p^*(D^0) > 2.77$ GeV/c	$3.5 < p^*(D^0) < 4.3$ GeV/c
$0.1449 < \Delta m < 0.1461$ GeV/c^2	$0.1442 < \Delta m < 0.1468$ GeV/c^2

$\Delta m = m(D^0\pi_s^+) - m(D^0)$

$D^0 \to K^+K^-\pi^0$, $\pi^+\pi^-\pi^0$

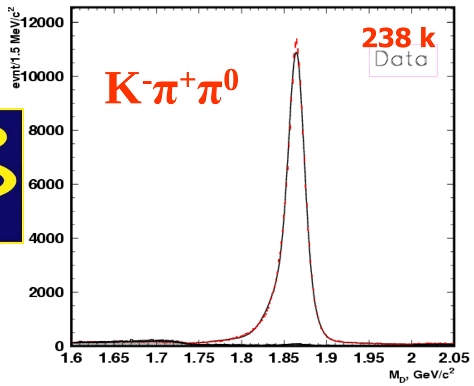


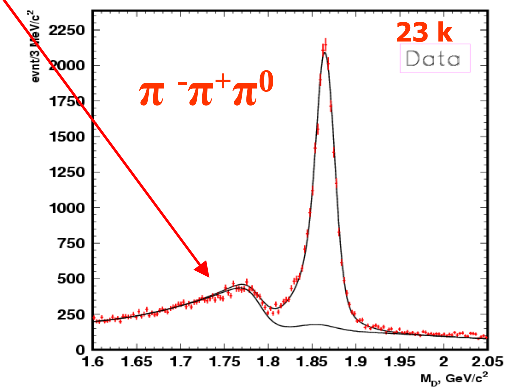




$K^-\pi^+\pi^0$ reflection

$K^-\pi^+\pi^0$ reflection





Belle results are preliminary

$\mathcal{B}(D^0 \to K^+K^-\pi^0)/\mathcal{B}(D^0 \to K^-\pi^+\pi^0)$

BaBar: (2.37 ± 0.03 ± 0.04)%

PDG 06: (0.95 ± 0.26)%

$\mathcal{B}(D^0 \to \pi^+\pi^-\pi^0)/\mathcal{B}(D^0 \to K^-\pi^+\pi^0)$

BaBar: (10.59 ± 0.06 ± 0.13)%

Belle: (9.71 ± 0.09 ± 0.3)%

PDG 06: (8.40 ± 3.11)%

$D^0 \to K^+K^-\pi^0, \pi^+\pi^-\pi^0$

The decay rate for each mode:

$$\Gamma = |M^2|\Phi$$

where:

M = Decay Matrix Element

Φ = Phase Space factor

Naive picture: CS/CF decays

Suppression is an effect of Cabibbo suppression at the quark level

Using 2-body B.R. values from PDG:

$|M^2|(\pi^-\pi^+)/|M^2|(K^-\pi^+) = 0.034 \pm 0.001$ ~0.05

$|M^2|(K^-K^+)/|M^2|(K^-\pi^+) = 0.111 \pm 0.002$ ~0.05

$|M^2|(K^-K^+)/|M^2|(\pi^-\pi^+) = 3.53 \pm 0.12$ ~1.

Very different from naive expectations

Using the previous 3-body B.R. values:

$|M^2|(\pi^-\pi^+\pi^0)/|M^2|(K^-\pi^+\pi^0) =$
- $0.0668 \pm 0.0004 \pm 0.0008$ (BaBar)
- $0.0613 \pm 0.0006 \pm 0.0019$ (Belle)

$|M^2|(K^-K^+\pi^0)/|M^2|(K^-\pi^+\pi^0) = 0.0453 \pm 0.0006 \pm 0.0008$(BaBar)

Rougly consistent with naive expectations, i.e. $\sin^2\Theta_c \sim 0.05$

$|M^2|(K^-K^+\pi^0)/|M^2|(\pi^-\pi^+\pi^0) = 0.678 \pm 0.014 \pm 0.021$(BaBar)

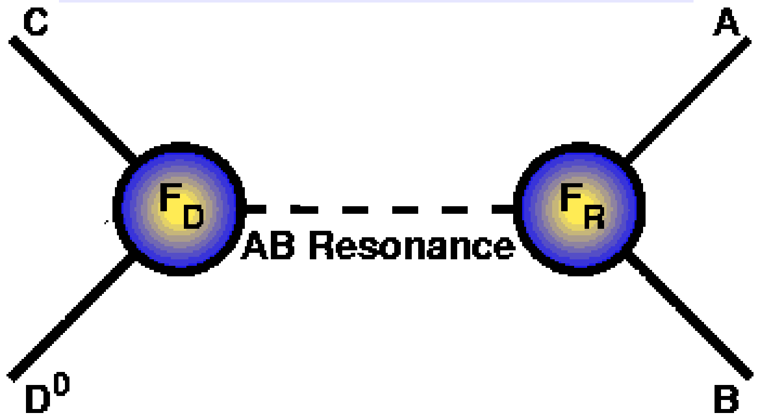
Naive expectation = 1

Amplitude Analysis of D and D_s decays

Isobar model formalism

D^0 three-body decay $D^0 \rightarrow ABC$ decaying through an r=[AB] resonance

S. Kopp *et al.*, Phys.Rev.**D63**:092001,2001



D^0 three-body amplitude

$$\mathcal{A}_D(s_{12}, s_{13}) = a_0 e^{i\delta_0} + \sum_r a_r e^{i\delta_r} \mathcal{A}_r(s_{12}, s_{13})$$

→ NR term (direct 3 body decay)

a_0, δ_0, a_r, δ_r : Free parameters of fit

$$\mathcal{A}_r(s_{12}, s_{13}) = F_D^J F_r^J \times M_r^J \times BW_r^J$$

Relativistic Breit-Wigner

$$BW_r^J(s) = \begin{cases} \dfrac{1}{M_r^2 - s - iM_r\Gamma_r(\sqrt{s})} \\ \dfrac{1}{M_r^2 - s - iM_r(\rho_1 g_1^2 + \rho_2 g_2^2)} \end{cases}$$

$a_0(980)/f_0(980)$

→ Angular distribution

→ *D* and *r* Blatt-Weisskopf form factors

240 fb^{-1}

Preliminary

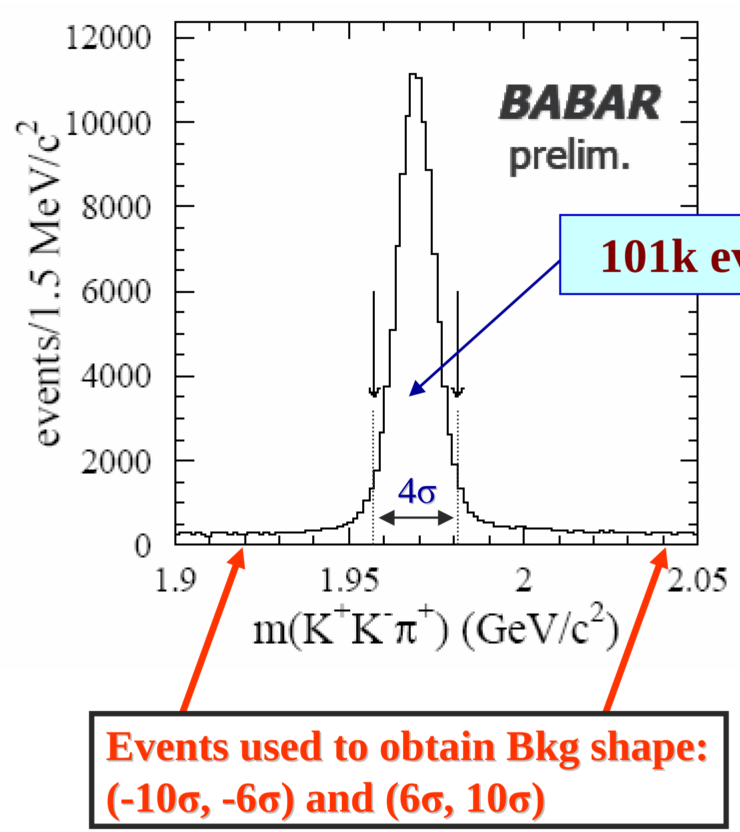
$D_s^+ \rightarrow K^+K^-\pi^+$ Dalitz Plot Analysis

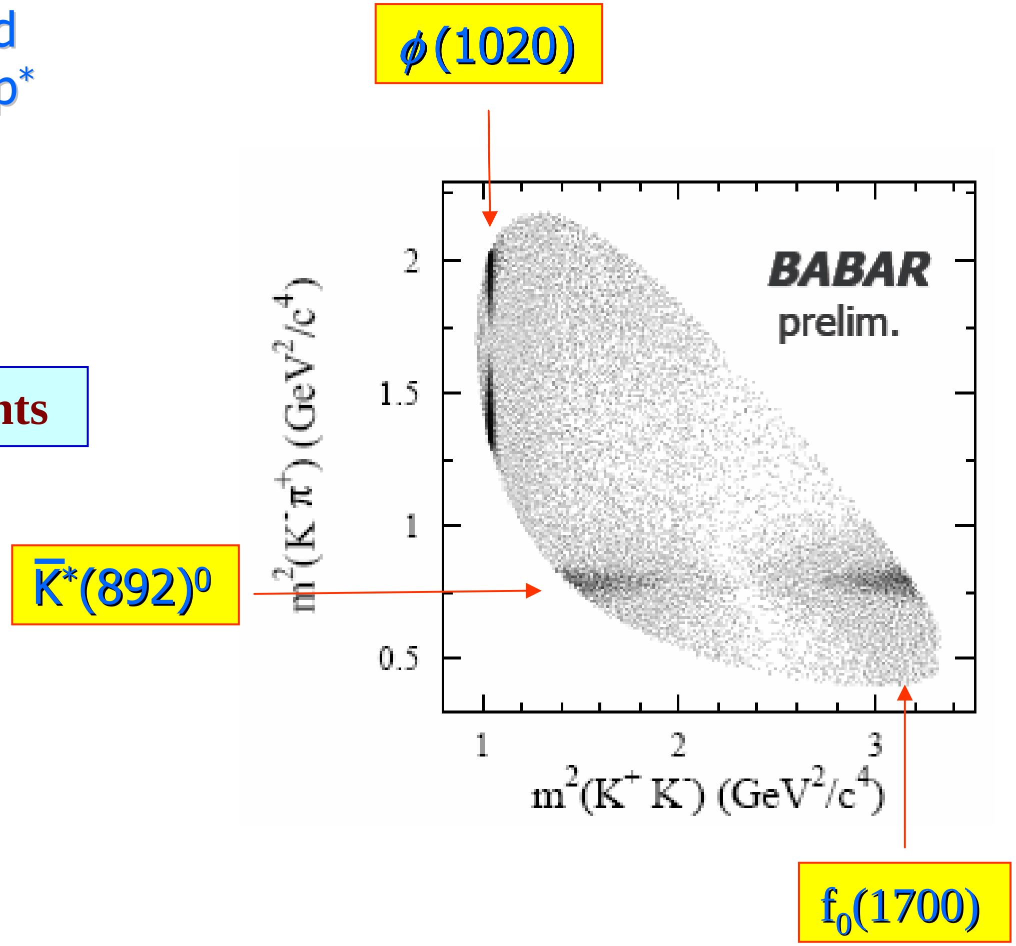
Motivation:

- **Using Dalitz plot results, we make a precise measurement of the branching ratios of the decays $D_s^+ \to \phi\pi^+$ and $D_s^+ \to \overline{K}(892)^0K^+$ integrated over the whole phase-space**
- **The $D_s^+ \to \phi\pi^+$ is frequently used as the D_s^+ reference decay mode for measurement of branching ratios.**
- **The previous analysis(E687) of this Dalitz plot was performed with ~700 events**

$D_s^+ \to K^+K^-\pi^+$

Clean signal obtained with a likelihood selection using vertex separation and p*



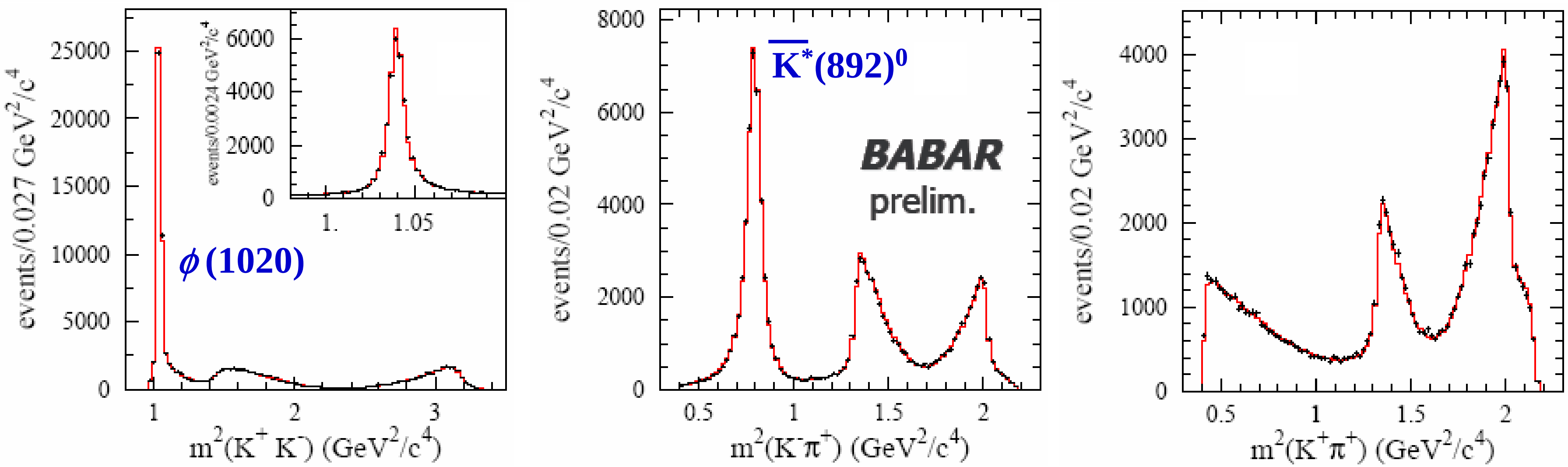


$D_s^+ \to K^+K^-\pi^+$

BaBar Preliminary

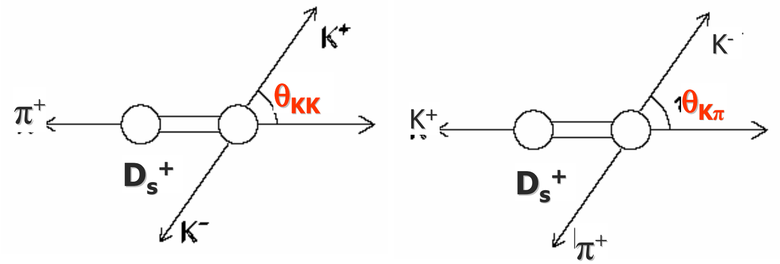
Decay Mode	Decay fraction(%)	Amplitude	Phase(radians)
$\bar{K}^*(892)^0K^+$	$48.7 \pm 0.2 \pm 1.6$	$1.(Fixed)$	$0.(Fixed)$
$\phi(1020)\pi^+$	$37.9 \pm 0.2 \pm 1.8$	$1.081 \pm 0.006 \pm 0.049$	$2.56 \pm 0.02 \pm 0.38$
$f_0(980)\pi^+$	$35 \pm 1 \pm 14$	$4.6 \pm 0.1 \pm 1.6$	$-1.04 \pm 0.04 \pm 0.48$
$\bar{K}_0^*(1430)^0K^+$	$2.0 \pm 0.2 \pm 3.3$	$1.07 \pm 0.06 \pm 0.73$	$-1.37 \pm 0.05 \pm 0.81$
$f_0(1710)\pi^+$	$2.0 \pm 0.1 \pm 1.0$	$0.83 \pm 0.02 \pm 0.18$	$-2.11 \pm 0.05 \pm 0.42$
$f_0(1370)\pi^+$	$6.3 \pm 0.6 \pm 4.8$	$1.74 \pm 0.09 \pm 1.05$	$-2.6 \pm 0.1 \pm 1.1$
$\bar{K}_2^*(1430)^0K^+$	$0.17 \pm 0.05 \pm 0.3$	$0.43 \pm 0.05 \pm 0.34$	$-2.5 \pm 0.1 \pm 0.3$
$f_2(1270)\pi^+$	$0.18 \pm 0.03 \pm 0.4$	$0.40 \pm 0.04 \pm 0.35$	$0.3 \pm 0.2 \pm 0.5$
Sum	$132 \pm 1.2 \pm 15.6$		
χ^2/NDF	1.5		

- Decay dominated by P wave
- $f_0(980)$ contribution is large but big syst. uncertainces



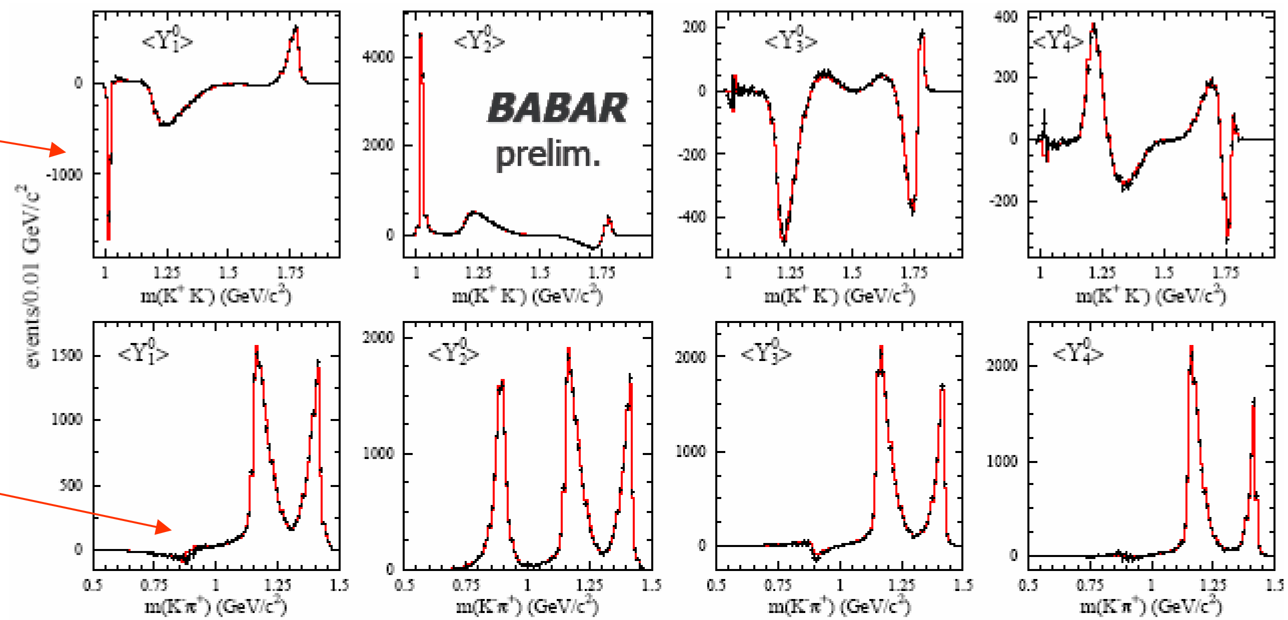
$D_s^+ \to K^+K^-\pi^+$

Each event was weighted by the spherical harmonic $Y^0_\ell(\cos\theta_{KK})$ and $Y^0_\ell(\cos\theta_{K\pi})$ (ℓ=1,2,3,4)



f0(980)/φ(1020) interference

Small S-P interference ⇒ No κ(800) ?



	BaBar Preliminary	PDG 06
$B(D_s^+\to\phi\pi^+)/B(D_s^+\to K^+K^-\pi^+)$	= 0.379 ± 0.002 ± 0.018	0.396 ± 0.033 ± 0.047
$B(D_s^+\to\overline{K}^*(892)^0\pi^+)/B(D_s^+\to K^+K^-\pi^+)$	= 0.487 ± 0.002 ± 0.016	0.478 ± 0.046 ± 0.040

BABAR™

385 fb^{-1}

$D^0 \rightarrow K^+K^- \pi^0$ DP analysis

Motivation:

- **Critical for CKM angle γ extraction in B decay: ADS method**
- **What is the nature of $K\pi$ S-wave below 1.4 GeV? Is there a charged $\kappa(800)$?**

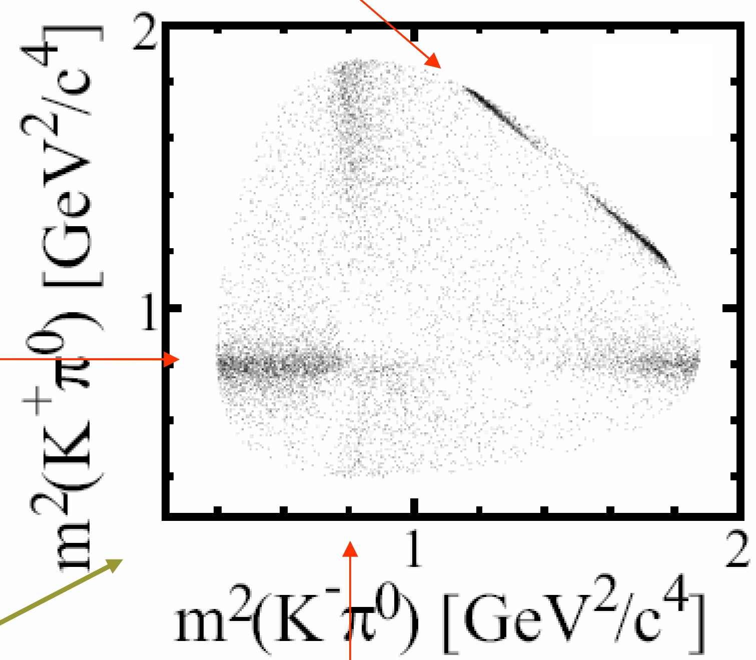
$D^0 \rightarrow K^+K^-\pi^0$

D⁰'s are required to result from a D* meson decay

$$e^+e^- \rightarrow D^{*+} + X$$
$$\hookrightarrow D^0\pi_s^+$$
$$\hookrightarrow K^+K^-\pi^0$$
$$\hookrightarrow \gamma\gamma$$

$\phi(1020)$

$K^*(892)^+$



$K^*(892)^-$

11k events @ Purity = 98%

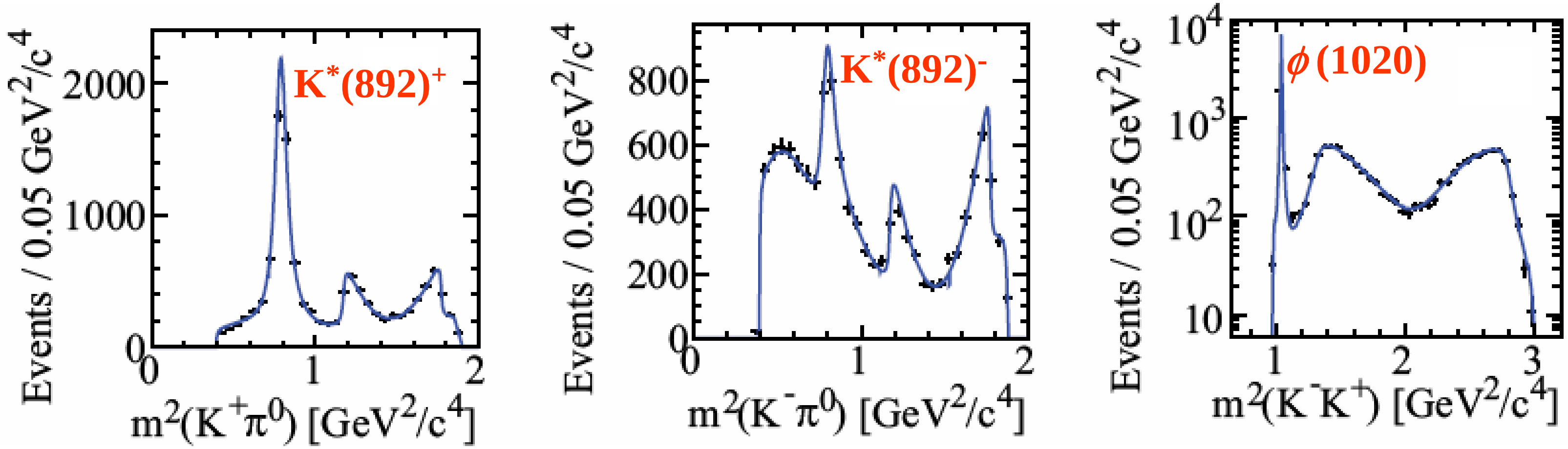
$D^0 \to K^+ K^- \pi^0$

State	Amplitude, a_r	Model I Phase, ϕ_r (°)	Fraction, f_r (%)
$K^*(892)^+$	1.0 (fixed)	0.0 (fixed)	$45.2 \pm 0.8 \pm 0.6$
$K^*(1410)^+$	$2.29 \pm 0.37 \pm 0.20$	$86.7 \pm 12.0 \pm 9.6$	$3.7 \pm 1.1 \pm 1.1$
$K^+\pi^0(S)$	$1.76 \pm 0.36 \pm 0.18$	$-179.8 \pm 21.3 \pm 12.3$	$16.3 \pm 3.4 \pm 2.1$
$\phi(1020)$	$0.69 \pm 0.01 \pm 0.02$	$-20.7 \pm 13.6 \pm 9.3$	$19.3 \pm 0.6 \pm 0.4$
$f_0(980)$	$0.51 \pm 0.07 \pm 0.04$	$-177.5 \pm 13.7 \pm 8.6$	$6.7 \pm 1.4 \pm 1.2$
$[a_0(980)^0]$	$[0.48 \pm 0.08 \pm 0.04]$	$[-154.0 \pm 14.1 \pm 8.6]$	$[6.0 \pm 1.8 \pm 1.2]$
$f_2'(1525)$	$1.11 \pm 0.38 \pm 0.28$	$-18.7 \pm 19.3 \pm 13.6$	$0.08 \pm 0.04 \pm 0.05$
$K^*(892)^-$	$0.601 \pm 0.011 \pm 0.011$	$-37.0 \pm 1.9 \pm 2.2$	$16.0 \pm 0.8 \pm 0.6$
$K^*(1410)^-$	$2.63 \pm 0.51 \pm 0.47$	$-172.0 \pm 6.6 \pm 6.2$	$4.8 \pm 1.8 \pm 1.2$
$K^-\pi^0(S)$	$0.70 \pm 0.27 \pm 0.24$	$133.2 \pm 22.5 \pm 25.2$	$2.7 \pm 1.4 \pm 0.8$

- LASS parametrization for Kpi S-wave
- Kpi S-wave from E791 as systematic
- Model with charged $\kappa(800)$ not favoured by data

$m = 870 \pm 30$ MeV/c^2

$\Gamma = 150 \pm 20$ MeV/c^2



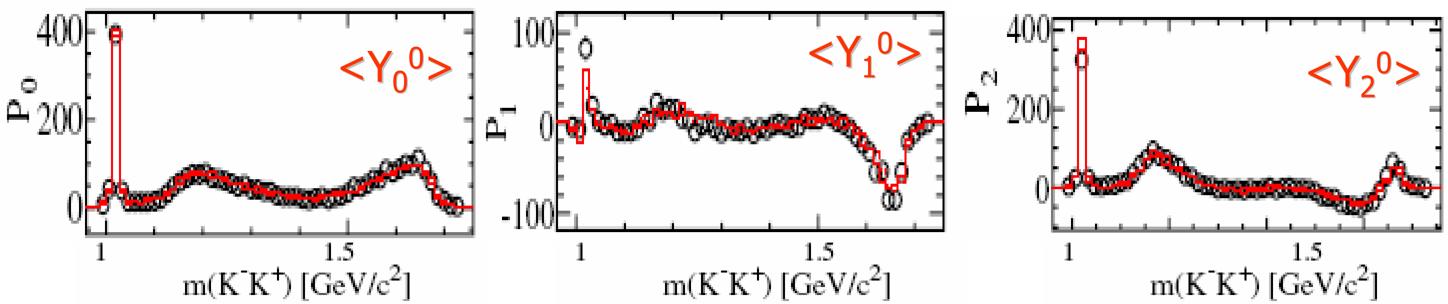
$D^0 \rightarrow K^+K^-\pi^0$

Strong Phase Measurement

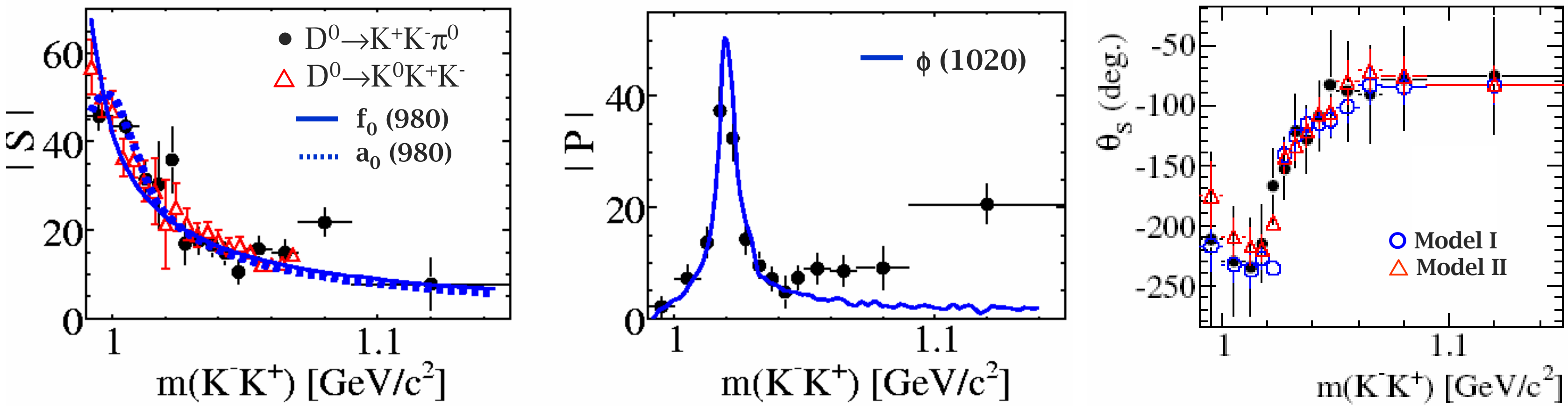
$$r_D e^{i\delta_D} = \frac{a_{D^0 \rightarrow K^{*-}K^+}}{a_{D^0 \rightarrow K^{*+}K^-}} e^{i(\delta_{K^{*-}K^+} - \delta_{K^{*+}K^-})}$$

BaBar	Cleo-c
$r_D = 0.599 \pm 0.013 \pm 0.011$ $\delta_D = -35.5° \pm 1.9° \pm 2.2°$	$r_D = 0.52 \pm 0.05 \pm 0.04$ $\delta_D = -28° \pm 8° \pm 11°$

Partial Wave Analysis in K^+K^-



$$\begin{cases} \sqrt{4\pi}\langle Y_0^0 \rangle = S^2 + P^2 \\ \sqrt{4\pi}\langle Y_1^0 \rangle = 2|S||P|\cos\phi_{SP} \\ \sqrt{4\pi}\langle Y_2^0 \rangle = \frac{2}{\sqrt{5}} P^2 \end{cases}$$



BaBar

Isobar Model	270 fb^{-1}	*Preliminary*
K-Matrix Model	91.5 fb^{-1}	*Preliminary*

BELLE

Isobar Model 540 fb^{-1}

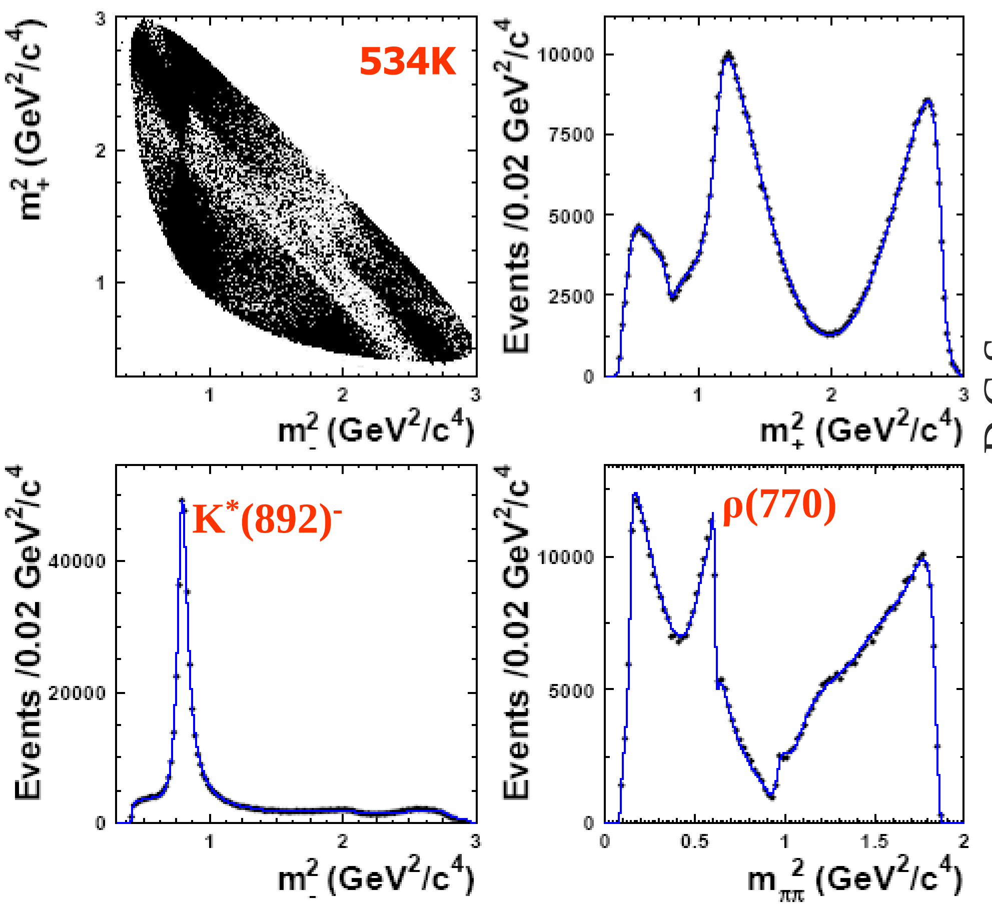
Preliminary

$D^0 \rightarrow K_S^0 \pi^+ \pi^-$ DP analysis

Motivation:

- **CKM angle γ extraction in B decay**
- **D^0-$\overline{D^0}$ Mixing**

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

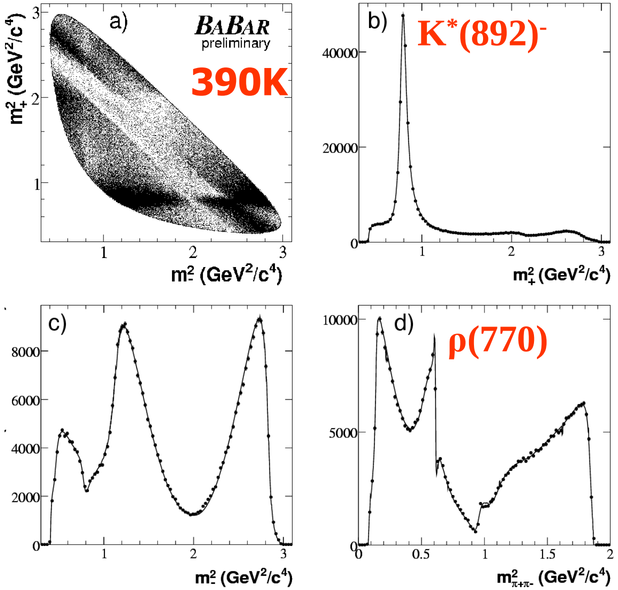


	Resonance	Amplitude	Phase (deg)	Fit fraction
CF	$K^*(892)^-$	1.629 ± 0.005	134.3 ± 0.3	0.6227
CF	$K_0^*(1430)^-$	2.12 ± 0.02	-0.9 ± 0.5	0.0724
CF	$K_2^*(1430)^-$	0.87 ± 0.01	-47.3 ± 0.7	0.0133
CF	$K^*(1410)^-$	0.65 ± 0.02	111 ± 2	0.0048
CF	$K^*(1680)^-$	0.60 ± 0.05	147 ± 5	0.0002
DCS	$K^*(892)^+$	0.152 ± 0.003	-37.5 ± 1.1	0.0054
DCS	$K_0^*(1430)^+$	0.541 ± 0.013	91.8 ± 1.5	0.0047
DCS	$K_2^*(1430)^+$	0.276 ± 0.010	-106 ± 3	0.0013
DCS	$K^*(1410)^+$	0.333 ± 0.016	-102 ± 2	0.0013
DCS	$K^*(1680)^+$	0.73 ± 0.10	103 ± 6	0.0004
	$\rho(770)$	1 (fixed)	0 (fixed)	0.2111
	$\omega(782)$	0.0380 ± 0.0006	115.1 ± 0.9	0.0063
	$f_0(980)$	0.380 ± 0.002	-147.1 ± 0.9	0.0452
	$f_0(1370)$	1.46 ± 0.04	98.6 ± 1.4	0.0162
	$f_2(1270)$	1.43 ± 0.02	-13.6 ± 1.1	0.0180
	$\rho(1450)$	0.72 ± 0.02	40.9 ± 1.9	0.0024
	σ_1	1.387 ± 0.018	-147 ± 1	0.0914
	σ_2	0.267 ± 0.009	-157 ± 3	0.0088
	NR	2.36 ± 0.05	155 ± 2	0.0615

Dalitz model: 18 **resonances** + non-resonant

	Mass (MeV/c²)	Width (MeV/c²)
σ_1	519±6	454±12
σ_2	1050±8	101±7

$D^0 \rightarrow K_s^0 \pi^+ \pi^-$ (Isobar Model)



Fit requires two additional BW amplitudes but…

	Mass(MeV/c²)	Width(MeV/c²)
σ	490±6	406±11
σ'	1024±4	89±7

…in this analysis the Dalitz amplitude is only a means to extract the CP parameters

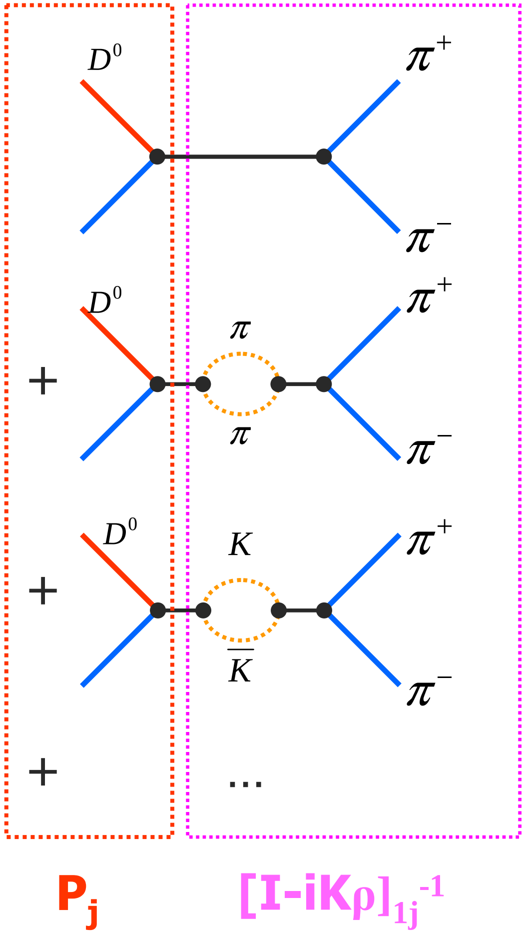
γ systematic errors include a fit without σ's

Isobar model resonances + Non resonant term

Component	$Re\{a_r e^{i\phi_r}\}$	$Im\{a_r e^{i\phi_r}\}$	Fit fraction (%)
$K^*(892)^-$	-1.223 ± 0.011	1.3461 ± 0.0096	58.1
$K_0^*(1430)^-$	-1.698 ± 0.022	-0.576 ± 0.024	6.7
$K_2^*(1430)^-$	-0.834 ± 0.021	0.931 ± 0.022	3.6
$K^*(1410)^-$	-0.248 ± 0.038	-0.108 ± 0.031	0.1
$K^*(1680)^-$	-1.285 ± 0.014	0.205 ± 0.013	0.6
$K^*(892)^+$ DCS	0.0997 ± 0.0036	-0.1271 ± 0.0034	0.5
$K_0^*(1430)^+$ DCS	-0.027 ± 0.016	-0.076 ± 0.017	0.0
$K_2^*(1430)^+$ DCS	0.019 ± 0.017	0.177 ± 0.018	0.1
$\rho(770)$	1	0	21.6
$\omega(782)$	-0.02194 ± 0.00099	0.03942 ± 0.00066	0.7
$f_2(1270)$	-0.699 ± 0.018	0.387 ± 0.018	2.1
$\rho(1450)$	0.253 ± 0.038	0.036 ± 0.055	0.1
Non-resonant	-0.99 ± 0.19	3.82 ± 0.13	8.5
$f_0(980)$	0.4465 ± 0.0057	0.2572 ± 0.0081	6.4
$f_0(1370)$	0.95 ± 0.11	-1.619 ± 0.011	2.0
σ	1.28 ± 0.02	0.273 ± 0.024	7.6
σ'	0.290 ± 0.010	-0.0655 ± 0.0098	0.9

Total fit fraction = 119.5%

K-Matrix Model in ππ S-wave



K-Matrix formalism overcomes the main limitation of the BW model to parameterize large and overlapping *S*-wave ππ resonances.

$D^0 \to \bar{K}^0\pi^+\pi^-$ amplitude

$$\mathcal{A}_D(s_{12}, s_{13}) = \underbrace{F_1}_{\pi\pi\ S-wave} + \underbrace{\sum_r a_r e^{i\delta_r} A_r(s_{12}, s_{13})}_{\pi\pi\ P,D-waves;\ K\pi\ S,P,D-waves}$$

$$F_1 = \sum_j [\mathbf{I} - i\mathbf{K\rho}]^{-1}_{1j} \mathbf{P}_j$$

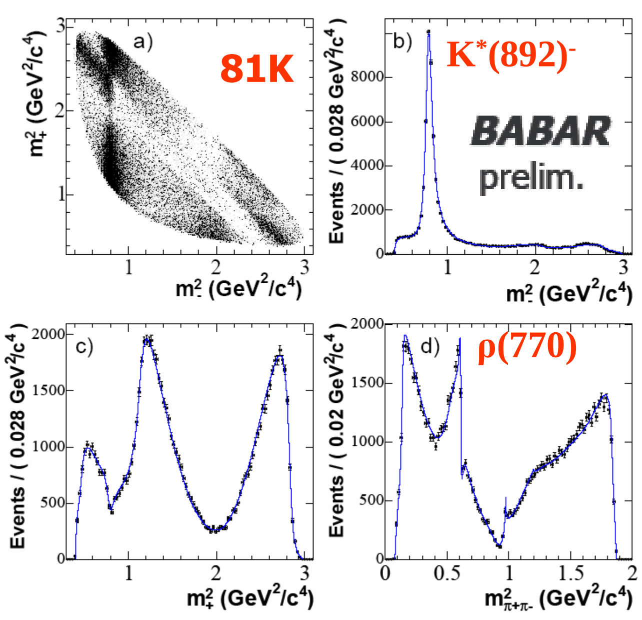
I.J.R. Aitchison, Nucl. Phys. **A189**, 417 (1972)

$\mathbf{P}_j$ → Initial production vector

$[\mathbf{I} - i\mathbf{K\rho}]^{-1}_{1j}$ → Provided by scattering experiment

5 channels: **1**=ππ **2**=KK **3**=multi-meson **4**= ηη **5**= ηη´
V.V. Anisovitch, A.V Sarantev Eur. Phys. Jour. **A16**, 229 (2003)

$D^0 \rightarrow K_s^0 \pi^+ \pi^-$ (K-Matrix Model)



K-Matrix model resonances + ππ S-wave term

Resonance	$\mathrm{Re}\{a_r e^{i\phi_r}\}$	$\mathrm{Im}\{a_r e^{i\phi_r}\}$	Fit fraction (%)
$K^*(892)^-$	-1.159 ± 0.022	1.361 ± 0.020	58.9
$K_0^*(1430)^-$	2.482 ± 0.075	-0.653 ± 0.073	9.1
$K_2^*(1430)^-$	0.852 ± 0.042	-0.729 ± 0.051	3.1
$K^*(1410)^-$	-0.402 ± 0.076	0.050 ± 0.072	0.2
$K^*(1680)^-$	-1.00 ± 0.29	1.69 ± 0.28	1.4
$K^*(892)^+$ **DCS**	0.133 ± 0.008	-0.132 ± 0.007	0.7
$K_0^*(1430)^+$ **DCS**	0.375 ± 0.060	-0.143 ± 0.066	0.2
$K_2^*(1430)^+$ **DCS**	0.088 ± 0.037	-0.057 ± 0.038	0.0
$\rho(770)$	1 (fixed)	0 (fixed)	22.3
$\omega(782)$	-0.0182 ± 0.0019	0.0367 ± 0.0014	0.6
$f_2(1270)$	0.787 ± 0.039	-0.397 ± 0.049	2.7
$\rho(1450)$	0.405 ± 0.079	-0.458 ± 0.116	0.3
β_1	-3.78 ± 0.13	1.23 ± 0.16	–
β_2	9.55 ± 0.20	3.43 ± 0.40	–
β_4	12.97 ± 0.67	1.27 ± 0.66	–
f_{11}^{prod}	-10.22 ± 0.32	-6.35 ± 0.39	–
sum of $\pi^+\pi^-$ S-wave			16.2

ππ S-wave term

Value of χ^2 compatible with nominal model since it is dominate by the P-wave components, which are identical between the two model

Total fit fraction = 1.16

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

	Belle	BaBar	
	Isobar Model 534k @ 540 fb^{-1}	Isobar Model 390k @ 270 fb^{-1}	K-Matrix 81k @ 91.5 fb^{-1}
State	Fit Fraction(%)		
$K^*(892)^-$	62.27	58.1	58.9
$K_0^*(1430)^-$	7.24	6.7	9.1
$K_2^*(1430)^-$	1.33	3.6	3.1
$K^*(1410)^-$	0.48	0.1	0.2
$K^*(1680)^-$	0.02	0.6	1.4
$K^*(892)^+$	0.54	0.5	0.7
$K_0^*(1430)^+$	0.47	0.0	0.2
$K_2^*(1430)^+$	0.13	0.1	0.0
$K^*(1410)^+$	0.13	---	---
$K^*(1680)^+$	0.04	---	---
$\rho(770)$	21.11	21.6	22.3
$\omega(782)$	0.63	0.7	0.6
$f_2(1270)$	1.8	2.1	2.7
$\rho(1450)$	0.24	0.1	0.3
$f_0(980)$	4.52	6.4	
$f_0(1370)$	1.62	2.0	
σ_1	9.14	7.6	S-wave 16.2
σ_2	0.88	0.9	
NR	6.15	8.5	

How does the Dalitz model affect the measurements?

CKM angle γ

$$\gamma = 92^\circ \pm 41^\circ \pm 11^\circ \pm 12^\circ$$

$$\gamma = 53^\circ{}^{+15^\circ}_{-18^\circ} \pm 3^\circ \pm 9^\circ$$

D^0-$\overline{D}^0$ mixing

$$x = (0.80 \pm 0.29^{+0.09}_{-0.07}{}^{+0.10}_{-0.14})\%$$

$$y = (0.33 \pm 0.24^{+0.08}_{-0.12}{}^{+0.06}_{-0.08})\%$$

Summary

- $\mathcal{B}(D^0 \to K^- \pi^+) = (4.007 \pm 0.037 \pm 0.070)\%$
- $\mathcal{B}(D_s^+ \to K^+ K^- \pi^+) = (4.1 \pm 0.4 \pm 0.4)\%$
- $\mathcal{B}(D^0 \to K^+ K^- \pi^0)/\mathcal{B}(D^0 \to K^- \pi^+ \pi^0) = (2.37 \pm 0.03 \pm 0.04)\%$

  $\mathcal{B}(D^0 \to \pi^+ \pi^- \pi^0)/\mathcal{B}(D^0 \to K^- \pi^+ \pi^0) = \begin{cases} (10.59 \pm 0.06 \pm 0.13)\% \\ (9.71 \pm 0.09 \pm 0.3)\% \end{cases}$
- $\mathcal{B}(D_s^+ \to \phi \pi^+)/\mathcal{B}(D_s^+ \to K^+ K^- \pi^+) = 0.379 \pm 0.002 \pm 0.018$

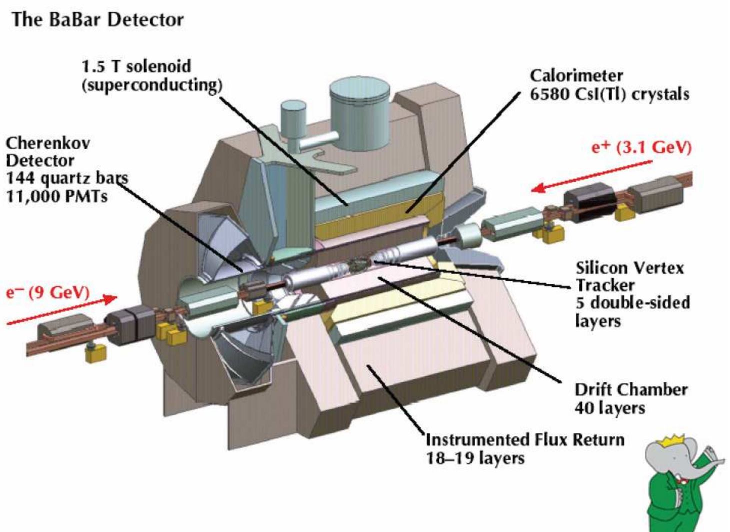
  $\mathcal{B}(D_s^+ \to \overline{K}^*(892)^0 \pi^+)/\mathcal{B}(D_s^+ \to K^+ K^- \pi^+) = 0.487 \pm 0.002 \pm 0.016$
- $r_D = 0.599 \pm 0.013 \pm 0.011$

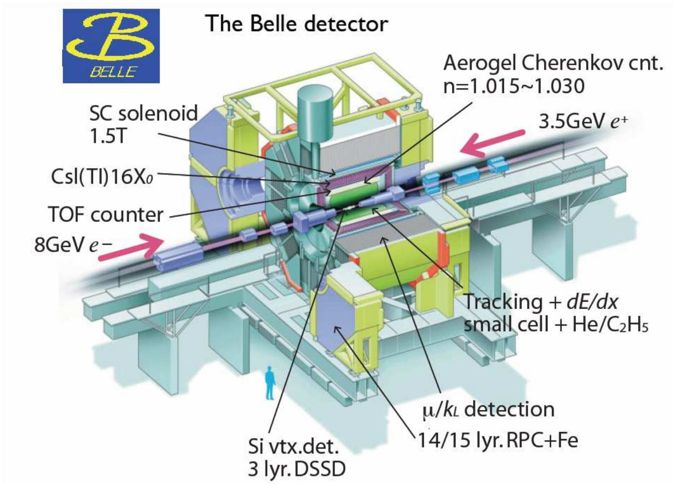
  $\delta_D = -35.5° \pm 1.9° \pm 2.2°$
- $D_s^+ \to K^+ K^- \pi^+$, $D^0 \to K^+ K^- \pi^0$, $D^0 \to K_s^0 \pi^+ \pi^-$ Dalitz plot analysis
- …
- …

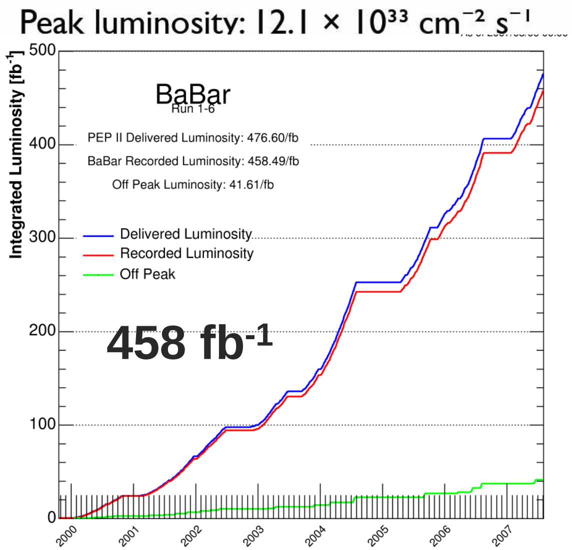
More results are on the way!

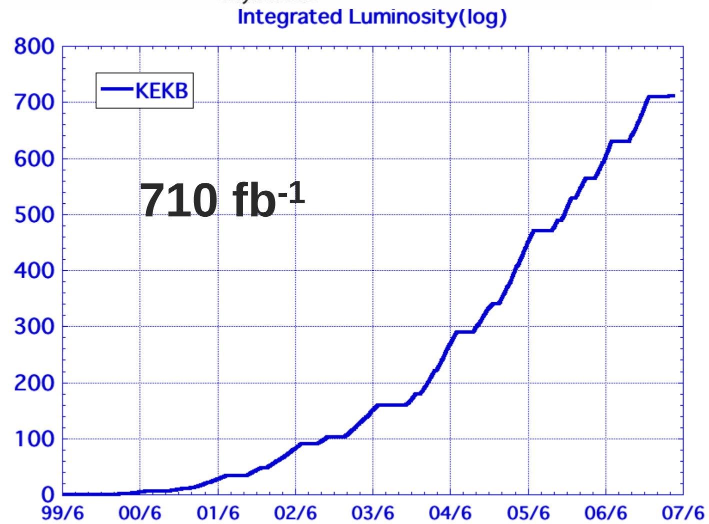
Back Slides

BaBar and Belle: B and c-Factories

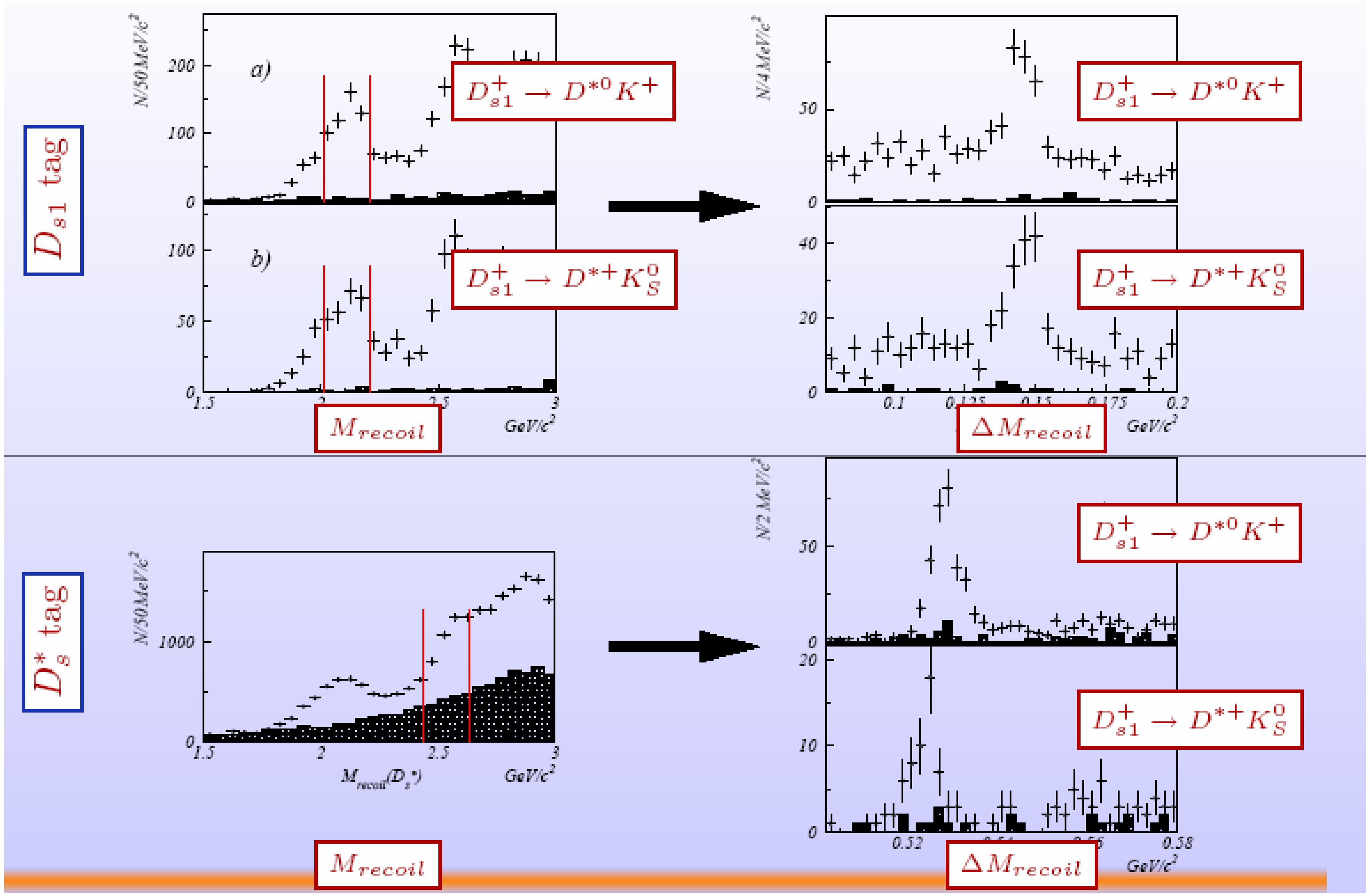








$\mathcal{B}(D_s^+ \to K^+K^-\pi^+)$



$\mathcal{B}(D^0 \to K^+K^-\pi^0)$

Phys.Rev.D54:4211,1996

150 Events @ 2.7 fb^{-1}

$\mathcal{B}(D^0 \to K^+K^-\pi^0)/\mathcal{B}(D^0 \to K^-\pi^+\pi^0)$

$(0.95 \pm 0.26)\%$

→

$\mathcal{B}(D^0 \to K^+K^-\pi^0)$

$(0.14 \pm 0.04)\%$

Phys.Rev.D74:091102,2006

11k Events @ 232 fb^{-1}

$\mathcal{B}(D^0 \to K^+K^-\pi^0)/\mathcal{B}(D^0 \to K^-\pi^+\pi^0)$

$(2.37 \pm 0.03 \pm 0.04)\%$

→

$\mathcal{B}(D^0 \to K^+K^-\pi^0)$

$(0.334 \pm 0.004 \pm 0.006 \pm 0.012)\%$

hep-ex/0606045

627 Events @ 9.0 fb^{-1}

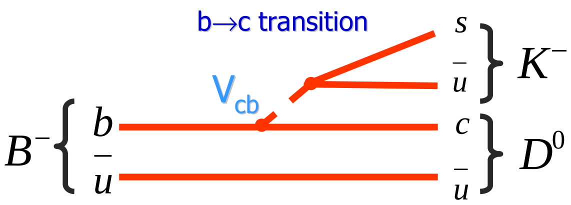
→

$\mathcal{B}(D^0 \to K^+K^-\pi^0)$

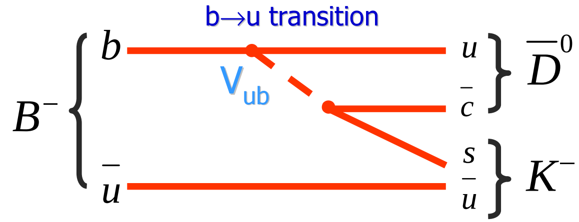
$(0.30 \pm 0.02)\%$

$D^0 \to \overline{K}^0 \pi^+ \pi^-$ decay & CKM angle γ

γ can be measured from the interference between decays with $b \to c\bar{u}s$ and $b \to u\bar{c}s$ transitions



$e^{i\delta_B} e^{-i\gamma}$



Interference occurs when some final state is accessible by both D^0 and $\overline{D}^0$

Giri-Grossman-Soffer-Zupan: PRD68, 054018 (2003): Final state = $K_S^0\pi^+\pi^-$ ⇒ Dalitz Plot Analysis

$$B^-: \quad \mathcal{A}_-(m_-^2, m_+^2) = |A(B^- \to D^0 K^-)| \left[f(m_-^2, m_+^2) + r_B e^{i\delta_B} e^{-i\gamma} f(m_+^2, m_-^2) \right]$$

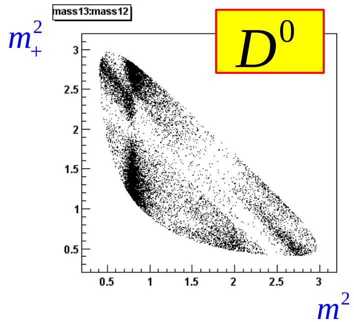
$$B^+: \quad \mathcal{A}_+(m_-^2, m_+^2) = |A(B^+ \to \overline{D}^0 K^+)| \left[f(m_+^2, m_-^2) + r_B e^{i\delta_B} e^{+i\gamma} f(m_-^2, m_+^2) \right]$$

$$r_B = \frac{|\mathcal{A}(B^- \to \overline{D}^0 K^-)|}{|\mathcal{A}(B^- \to D^0 K^-)|} \approx 0.1 - 0.3$$

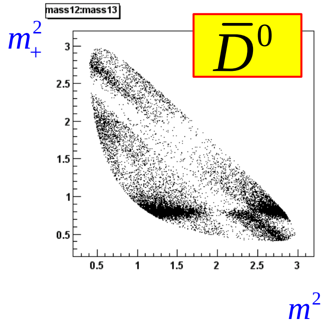
δ_B = strong phase

γ = weak phase

$|\mathcal{A}_-|^2 = \Bigg|$



$+ r_B e^{i(\delta_B - \gamma)}$



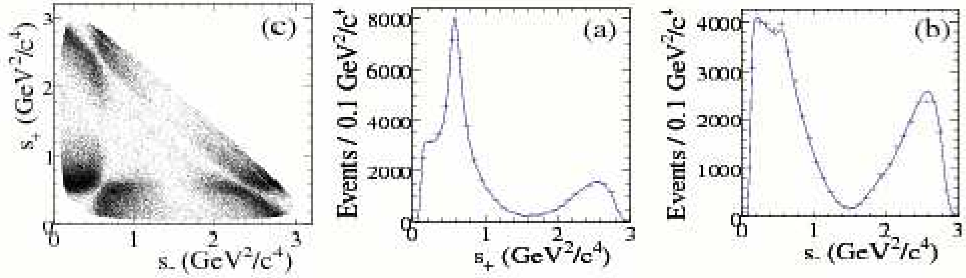
$\Bigg|^2$

Schematic view of the interference

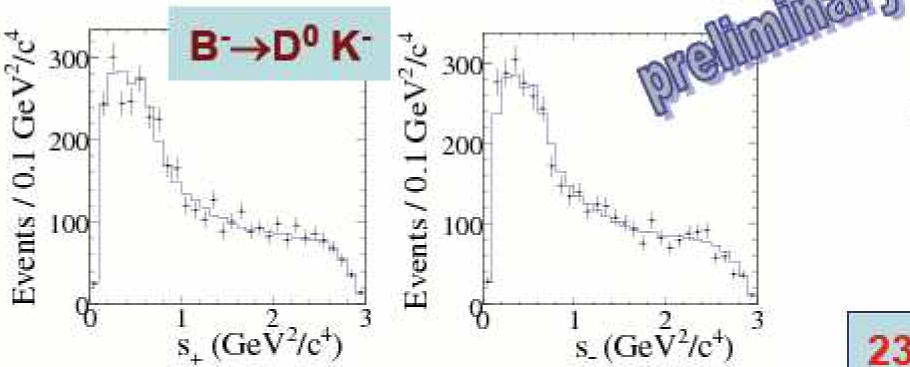
$m_-^2 = M(K_S^0\pi^-)^2$
$m_+^2 = M(K_S^0\pi^+)^2$

Simultaneous fit to the $|\mathcal{A}_-(m_-^2, m_+^2)|^2$ and $|\mathcal{A}_+(m_-^2, m_+^2)|^2$ distributions to determine the CP parameters r_B, δ_B and γ for each decay mode ($B^\pm \to D^{(*)0} K^{(*)\pm}$).

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



State	R_r (%)	$\Delta\phi_r$ (°)	f_r (%)
$\rho^+(770)$	100	0	67.8±0.0±0.6
$\rho^0(770)$	58.8±0.6±0.2	16.2±0.6±0.4	26.2±0.5±1.1
$\rho^-(770)$	71.4±0.8±0.3	−2.0±0.6±0.6	34.6±0.8±0.3
$\rho^+(1450)$	21±6±13	−146±18±24	0.11±0.07±0.12
$\rho^0(1450)$	33±6±4	10±8±13	0.30±0.11±0.07
$\rho^-(1450)$	82±5±4	16±3±3	1.79±0.22±0.12
$\rho^+(1700)$	225±18±14	−17±2±3	4.1±0.7±0.7
$\rho^0(1700)$	251±15±13	−17±2±2	5.0±0.6±1.0
$\rho^-(1700)$	200±11±7	−50±3±3	3.2±0.4±0.6
$f_0(980)$	1.50±0.12±0.17	−59±5±4	0.25±0.04±0.04
$f_0(1370)$	6.3±0.9±0.9	156±9±6	0.37±0.11±0.09
$f_0(1500)$	5.8±0.6±0.6	12±9±4	0.39±0.08±0.07
$f_0(1710)$	11.2±1.4±1.7	51±8±7	0.31±0.07±0.08
$f_2(1270)$	104±3±21	−171±3±4	1.32±0.08±0.10
$\sigma(400)$	6.9±0.6±1.2	8±4±8	0.82±0.10±0.10
Non-Res	57±7±8	−11±4±2	0.84±0.21±0.12



232 fb⁻¹ BABAR data for γ measurement

$BR(B^- \to D_{\pi\pi\pi^0}K^-) = (4.6 \pm 0.8 \pm 0.7) \times 10^{-6}$

$A(B^- \to D_{\pi\pi\pi^0}K^-) = -0.02 \pm 0.15 \pm 0.03$

$\rho^- = 0.72 \pm 0.11 \pm 0.06$; $\theta^- = (173 \pm 42 \pm 19)^\circ$

$\rho^+ = 0.75 \pm 0.11 \pm 0.06$; $\theta^- = (147 \pm 23 \pm 13)^\circ$

b→u vs. b→C

$r_B e^{i(\delta_B - \gamma)} \to (\rho, \theta)$

Observation of $D_{s1}(2536)^+ \to D^+\pi^-K^+$

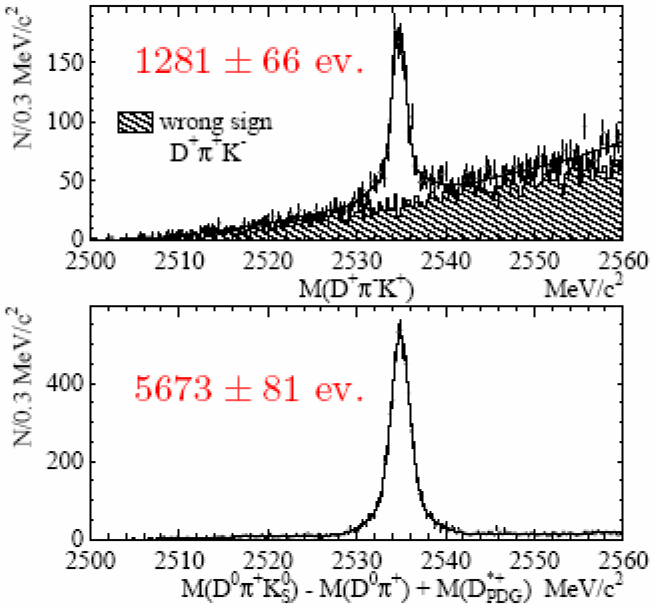
$D_{s1}(2536)^+$: $J^P = 1^+$, $j_l = 3/2$; known modes $D^{*+}K^0_S$, $D^{*0}K^+$, $D_s^+\pi^+\pi^-$.
$D^+\pi^-$ cannot come from D^{*0}: $M_{D^0}+M_{\pi^-} > M_{D^{*0}}$.

$x_P = p_{D_{s1}}/\sqrt{s/4 - M^2_{D_{s1}}} > 0.8$,

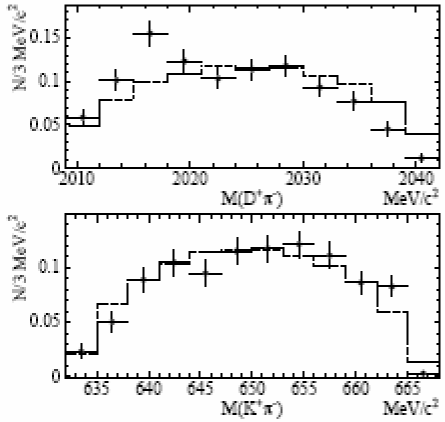
$D^0 \to K^-\pi^+ | K^0_S\pi^+\pi^- | K^-\pi^+\pi^+\pi^-$,
$D^+ \to K^0_S\pi^+ | K^-\pi^+\pi^+$,
$|\Delta M_D| < 20$ MeV/c^2 (99% eff.),

$D^{*+} \to D^0\pi^+$,
$|\Delta M_{D^{*+}}| < 1.5$ MeV/c^2 (98% eff.)

462 fb^{-1} of data



$M_{D^+\pi^-}$ and $M_{K^+\pi^-}$



data (•) vs. ph. space MC
→ No visible resonant substructure

$$\frac{B(D^+_{s1}\to D^+\pi^-K^+)}{B(D^+_{s1}\to D^{*+}K^0)} = 3.17 \pm 0.17 \pm 0.36\%$$