Charm mixing from BaBar

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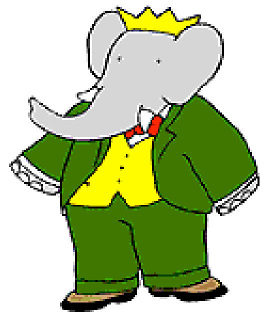
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Joint Workshop on Charm Physics
Beijing, 26-27 November 2007

Outline

- Charm mixing: a short introduction
- Experimental overview:
  - selection of the events
  - analysis methods
  - results
- Summary of the results

D^0 mixing formalism

Time evolution according to Schrödinger equation:

$$i\frac{\partial}{\partial t}\begin{pmatrix} D^0(t) \\ \overline{D^0}(t) \end{pmatrix} = \mathrm{H}_{\mathit{eff}} \begin{pmatrix} D^0(t) \\ \overline{D^0}(t) \end{pmatrix} \qquad \mathrm{H}_{\mathit{eff}} = \left(\mathbf{M} - \frac{i}{2}\mathbf{\Gamma}\right) \text{ effective hamiltonian}$$

M, Γ hermitian matrices

Mass eigenstates
≠
flavor eigenstates:

$$\left|D^0_{1,2}\right\rangle = p\left|D^0\right\rangle \pm q\left|\overline{D^0}\right\rangle$$

$$\left(\frac{q}{p}\right)^2 = \frac{M^*_{12} - \frac{i}{2}\Gamma^*_{12}}{M_{12} - \frac{i}{2}\Gamma_{12}}$$

Propagate with different mass $m_{1,2}$ and widths $\Gamma_{1,2}$:

$$\left|D_{1,2}(t)\right\rangle = e^{-i\left(m_{1,2} - i\Gamma_{1,2}/2\right)t}\left|D_{1,2}(t=0)\right\rangle$$

D^0 mesons oscillations

Time evolution for meson of ***known flavor at t=0***

$$x = \frac{m_2 - m_1}{\Gamma} \qquad \Gamma = \frac{\Gamma_2 + \Gamma_1}{2}$$
$$y = \frac{\Gamma_2 - \Gamma_1}{2\Gamma}$$

$$\left|D^0(t)\right\rangle = e^{-\bar{\gamma}t/2}\left(\cosh(\Delta\gamma t/2)\left|D^0\right\rangle - \frac{q}{p}\sinh(\Delta\gamma t/2)\left|\bar{D}^0\right\rangle\right)$$

Where $\Delta\gamma = (y + ix)\Gamma \qquad \bar{\gamma} = (\Gamma_1 + \Gamma_2)/2 - i(m_1 + m_2)$

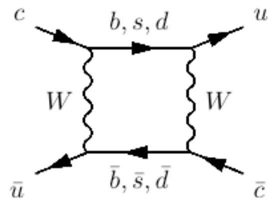
An opposite flavor component appears after a while

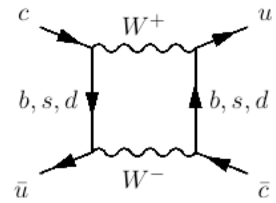
D^0 "oscillates" into $\overline{D}^0$!
(charm meson "mixing")

Standard Model predictions

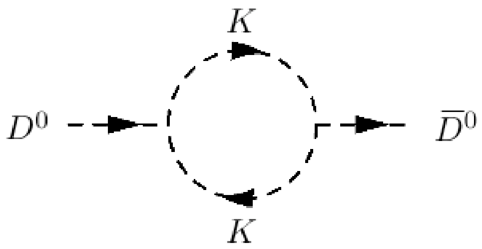
- Short-distance contributions from mixing box diagrams in the Standard Model are expected to be small :
  - *b* quark is CKM-suppressed
  - *s* and *d* quarks are GIM suppressed
  - mainly contributes to the mass difference

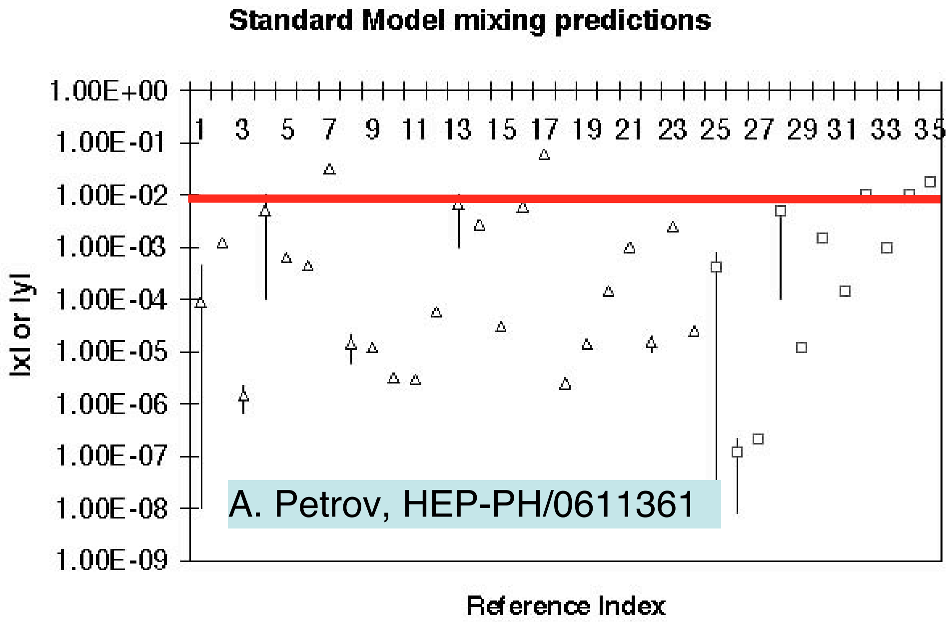
    $\boldsymbol{x} \approx O(10^{-5})$ or less





- Long-distance contributions dominate but hard to estimate precisely
  - expect $|y| \leq 0.01$
  - $|x| \sim 0.1 - 1|y|$





- No CP violation in mixing expected in SM with current experimental sensitivity

CP violation formalism

Let's define the amplitudes:

$$A_f = \langle f | H | D^0 \rangle \quad \bar{A}_f = \langle f | H | \bar{D}^0 \rangle$$

CP violation in decay is very small in SM $\quad \dfrac{\bar{A}_{\bar{f}}}{A_f} \neq 1$

Effect of CP violation due to mixing parameterized in terms of:

$$r_m = \left| \frac{q}{p} \right| \qquad \varphi_f = \arg\left(\frac{q}{p} \frac{\bar{A}_f}{A_f} \right)$$

$r_m \neq 1$ CP violation in mixing

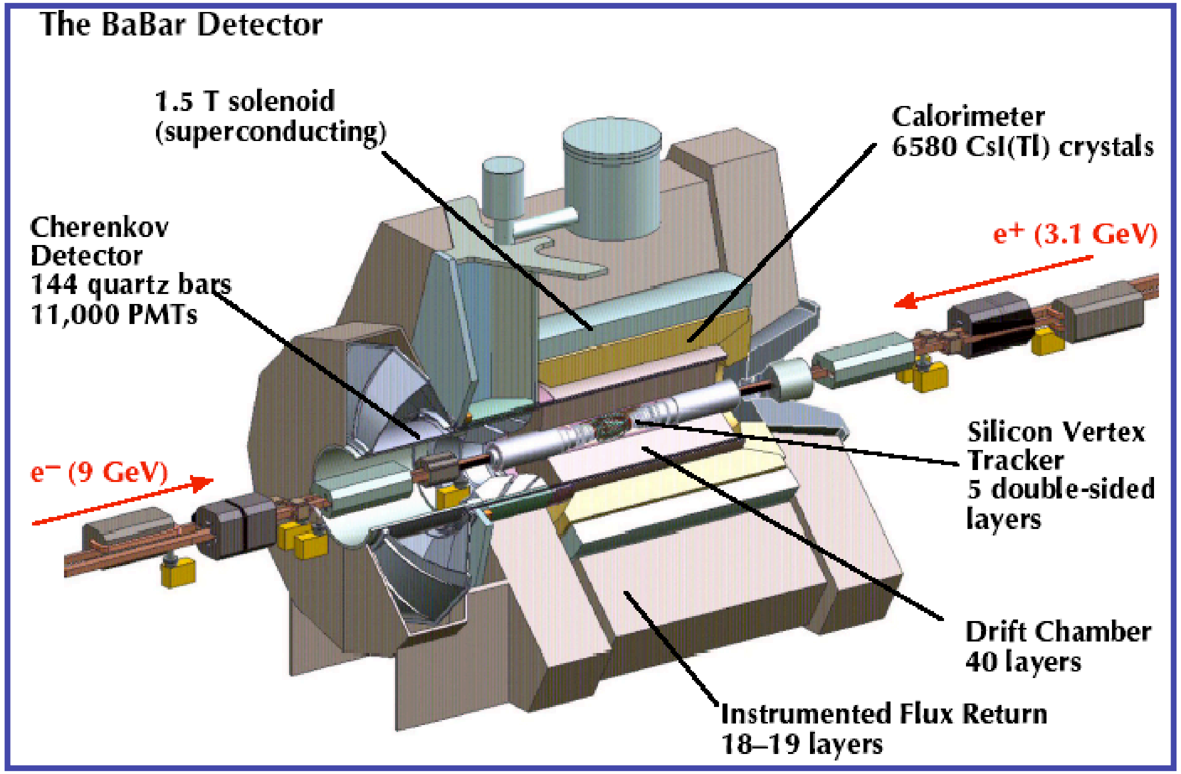
$\varphi_f \neq 0$ CP violation in interference of mixing and decay

An observation of CP violation in charm mixing with present experimental sensitivity would provide evidence of New Physics

Charm laboratory and analysis techniques

BaBar experiment

BaBar detector records data delivered by PEP-II asymmetric B-factory ($\beta\gamma=0.55$) running at the $\Upsilon(4S)$ mass peak (10.58 GeV) at SLAC.



BaBar is a large acceptance general purpose detector providing excellent tracking, vertexing, particle ID and neutrals detection

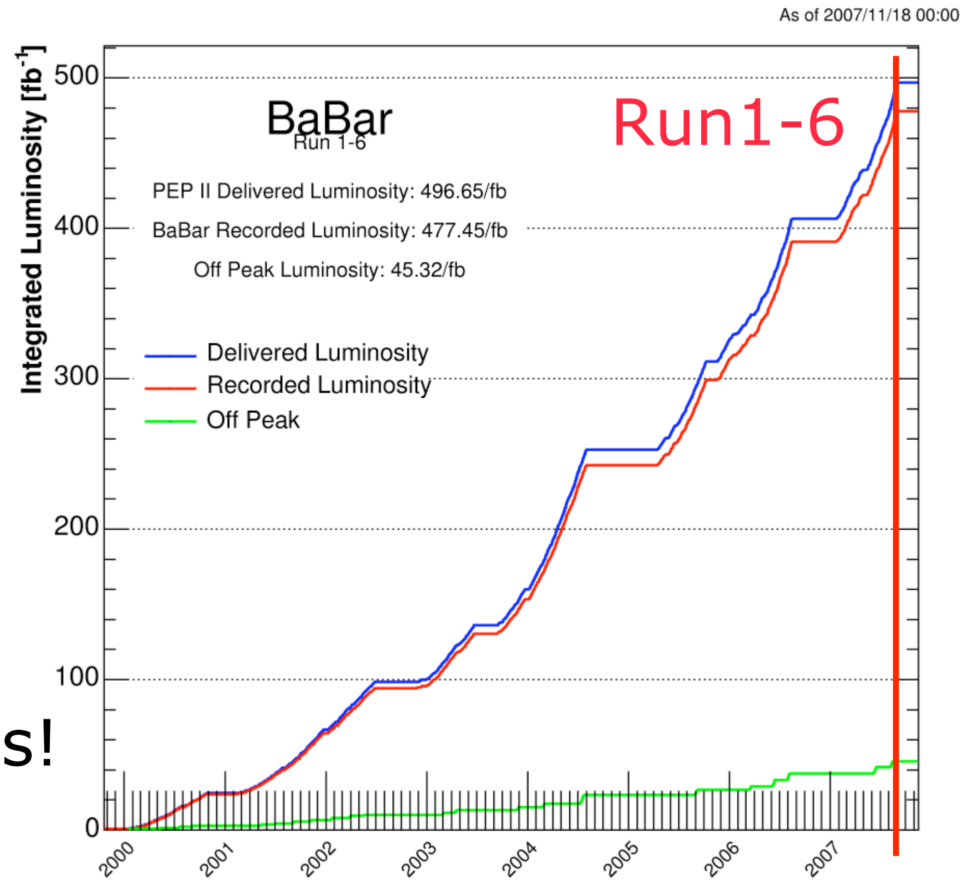
BaBar is also a charm factory

B-factories are wonderful laboratories for charm physics:

$$\sigma\left(B\bar{B}\right) \simeq 1.1\ nb$$

$$\sigma\left(c\bar{c}\right) \simeq 1.3\ nb$$

PEP-II delivered ~500fb^{-1}
more than 600M $c\bar{c}$ events!



Luminosity ~384 fb^{-1} for mixing results presented here ~500M $c\bar{c}$ events

Experimental techniques

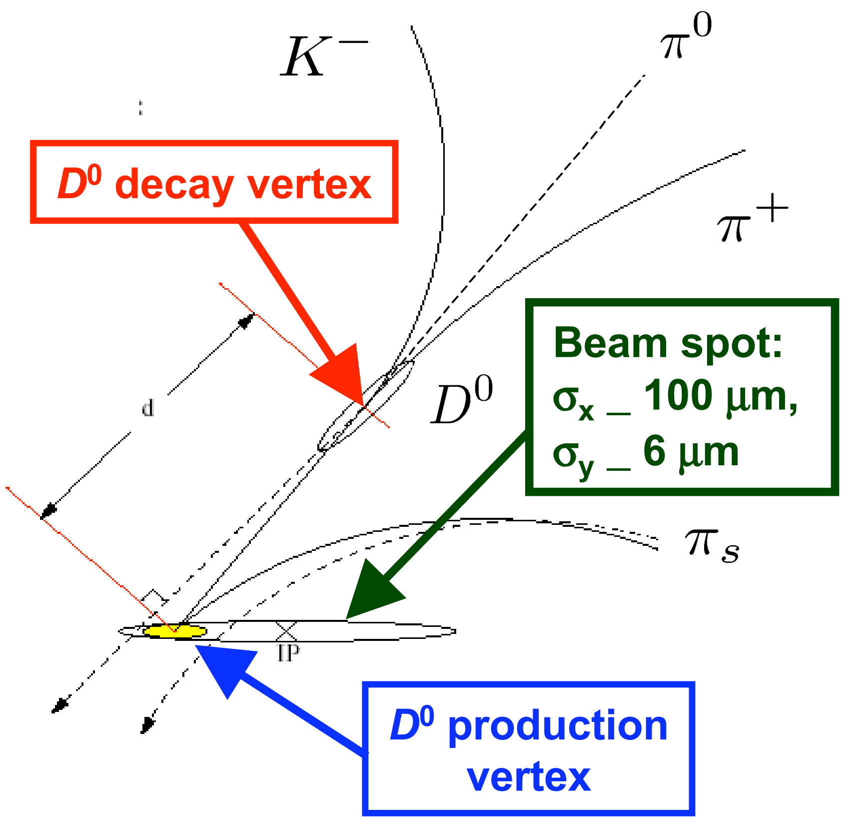
Identify the D^0 flavor at production using the decays $D^{*\pm} \rightarrow \pi_s^{\pm} D^0$

- select events around the expected $\Delta m = m(D^{*+}_{\mathrm{rec.}}) - m(D^0_{\mathrm{rec.}})$
- The charge of the soft pion determines the flavor of the D^0
- p*(D^0)>2.5 GeV/c (reject $B\bar{B}$ bkg)

Identify the D^0 flavor at decay using the charge of the Kaon

$D^0 \rightarrow K^-\pi^+\pi^0$ right-sign (RS)

$D^0 \rightarrow K^+\pi^-\pi^0$ wrong-sign (WS)

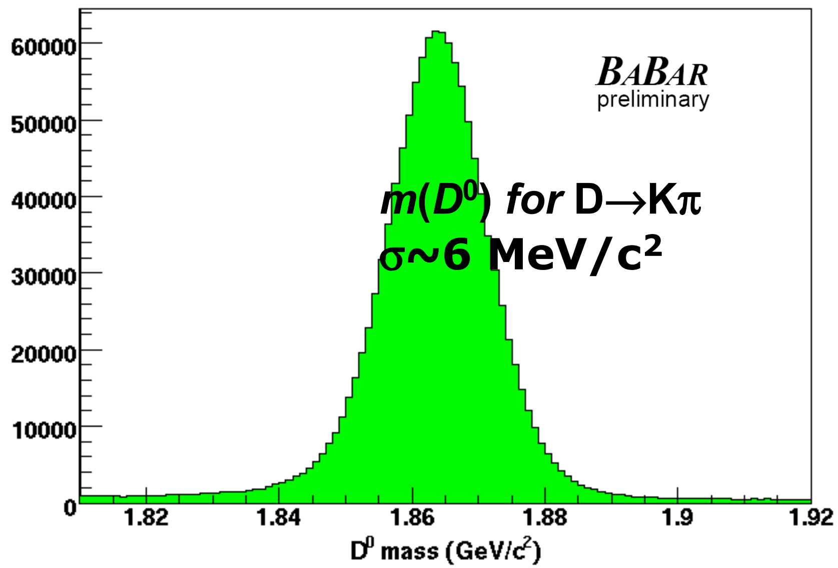


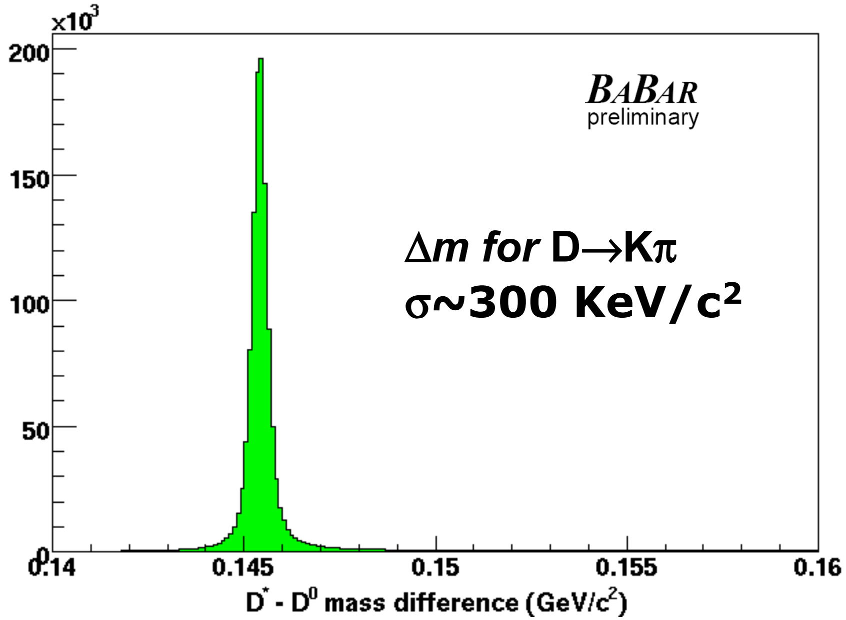
Vertexing with beam spot constraint determines decay time, t and decay time error, σ_t It also affects resolution on $m_{K\pi\pi^0}$, Δm

Charm event selection

- Excellent bkg rejection:
  - D^0 invariant mass and Δm well separate signal from bkg.

  Very good resolution on Δm: $Q = m(D^{*+}) - m(D^0) - m(\pi^+) \approx 6\,\mathrm{MeV}/c^2$
  - Typical signal purity at level of 99% *(for RS D decays)*

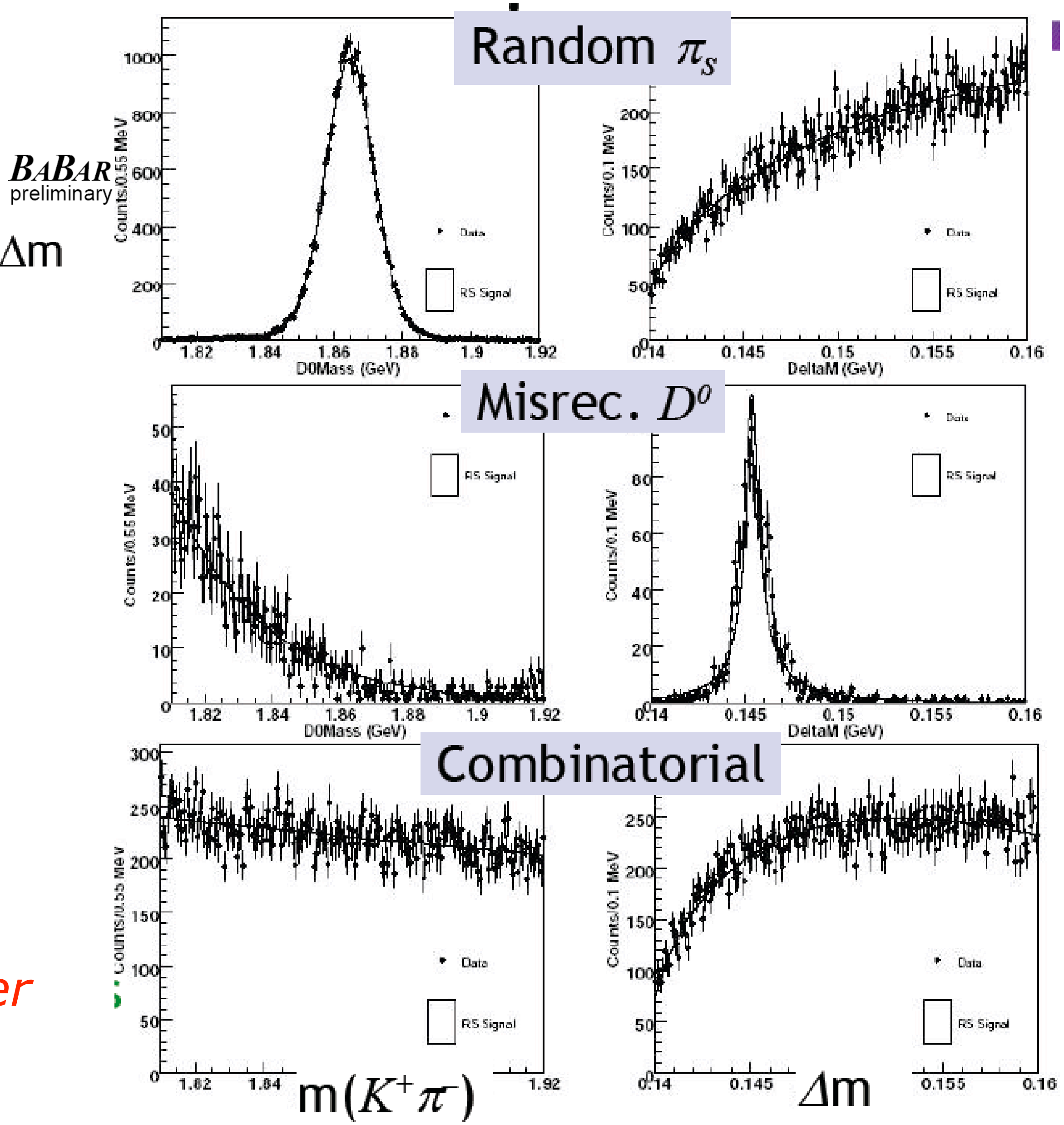




Bkg components *($D \to K\pi$ as example)*

Random π_s:

- Correct D^0, wrong π_s
- Peaks in m($K\pi$), not Δm



Misreconstructed D^0:

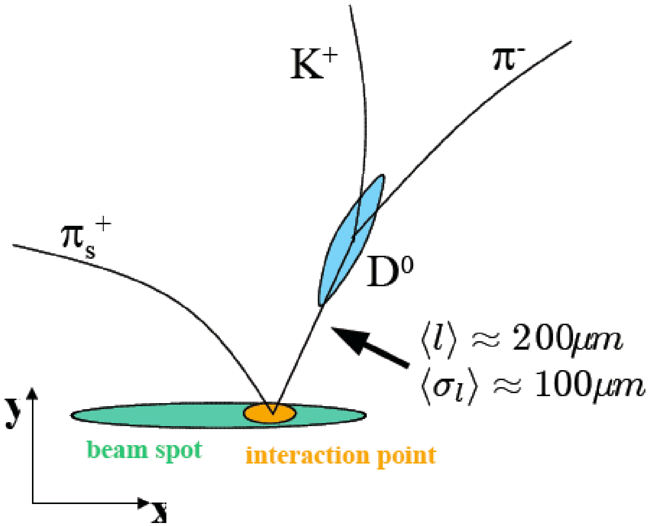
- Partially reco. D^0, $D^0 \to K^- \mu^+ \nu$
- Double misid $D^0 \to K^- \pi^+$ (WS events only)
- Peaks in Δm, not m($K\pi$)

Combinatoric:

- Random tracks

Discrimination power from m($K\pi$) and Δm

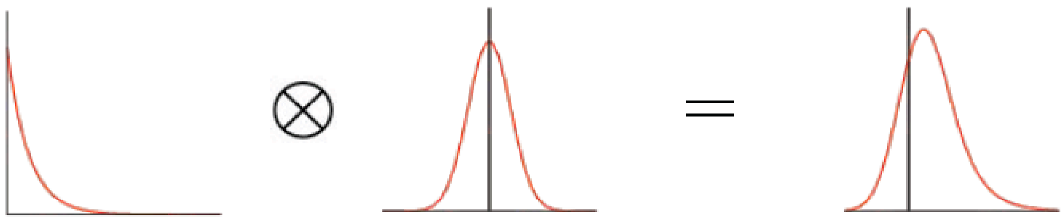
Proper time reconstruction



D* and π_{soft} constrained to the beam spot

Resolution on proper-time: $\tau_D/<\delta t>\sim 2$

- Signal resolution function:sum of 3 guassians:
  - Mean of gaussian allowed to be non-zero *(Vertex detector mis-alignment)*
- Combinatorial bkg:
  - gaussian + tail for small long-lived component



$$e^{-t/\tau} \otimes \frac{1}{\sqrt{2\pi}\sigma} e^{-t^2/2\sigma^2} = \frac{1}{\sqrt{2\pi}\sigma} \int_0^\infty e^{-t'/\tau} e^{-(t-t')^2/2\sigma^2}\, dt'$$

Experimental searches

- Mixing Time dependent analyses
  - $D^0 \to K^+\pi^-$
  - $D^0 \to K^+K^-$, $\pi^+\pi^-$
  - $D^0 \to K^+\pi^-\pi^0$
- Time integrated analysis:
  - $D^0 \to K^+K^-$, $\pi^+\pi^-$ search for CP violation

Evidence of mixing in $D^0 \to K^+\pi^-$

PRL 98:211802,2007

Data: 384 fb^{-1}

- **Reconstruct Wrong Sign (WS) decays:** $D^{*+} \to D^0 \pi_S^{+}, D^0 \to K^{+} \pi^-$
- **WS decays** come from two sources:
  - Double-Cabibbo-suppressed (DCS) D^0 decay:
    $$D^0 \to K^+\pi^-$$
  - D^0 has mixed into D^0, followed by CF decay:
    $$D^0 \to \overline{D}^0 \to K^+\pi^-$$

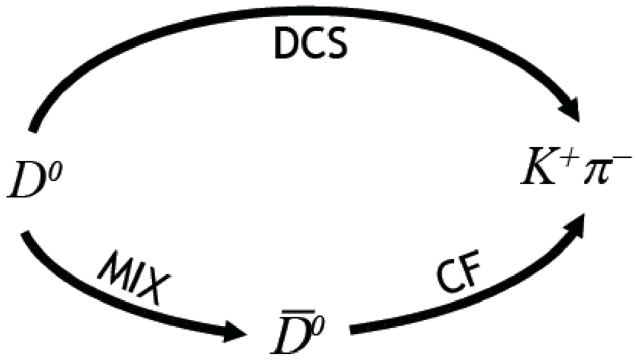
Expected relative rates

CF : DCS : Mixed

1000 : 5 : 0.1

Discriminate DCS and mixing by their different time evolution

Also have interference effect:



Distinguishing Mixing from DCS Decays

- Exploit different time dependence. Approx. x,y<<1:

$$\frac{d\Gamma}{dt}\left[\left|D^0(t)\right\rangle \to f\right] \propto e^{-\Gamma t}\left(\underbrace{R_D}_{\text{DCS}} + \underbrace{\sqrt{R_D}\,y'(\Gamma t)}_{\text{Interference}} + \underbrace{\frac{x'^2+y'^2}{4}(\Gamma t)^2}_{\text{Mixing}}\right)$$

$$x' = x\cos\delta_{K\pi} + y\sin\delta_{K\pi} \qquad y' = -x\sin\delta_{K\pi} + y\cos\delta_{K\pi}$$

$D^0 - \bar{D}^0$ relative phase

not directly measurable at B-factories

$$R_D = \frac{\Gamma\left(D^0 \to K^+\pi^-\right)}{\Gamma\left(D^0 \to K^-\pi^+\right)} \simeq 3 \cdot 10^{-3}$$

- Analysis of the proper time distribution of WS events permits extraction of D^0 mixing parameters y', x'^2

Event selection

Select the D^0 by requiring

$P_D > 2.5$ GeV/c in C.M.S.

K, π particle identification

$1.81 < m(K\pi) < 1.92$ GeV/c^2

Select the π_s by requiring

$p_\pi < 0.45$ GeV/c in C.M.S.

$p_\pi > 0.1$ GeV/c in lab frame

Perform a beam-constrained simultaneous fit to the chain

$$D^{*\pm} \to \pi_s^{\pm} D^0,\ D^0 \to K^{\mp}\pi^{\pm}$$

-2 < decay time t < 4 ps

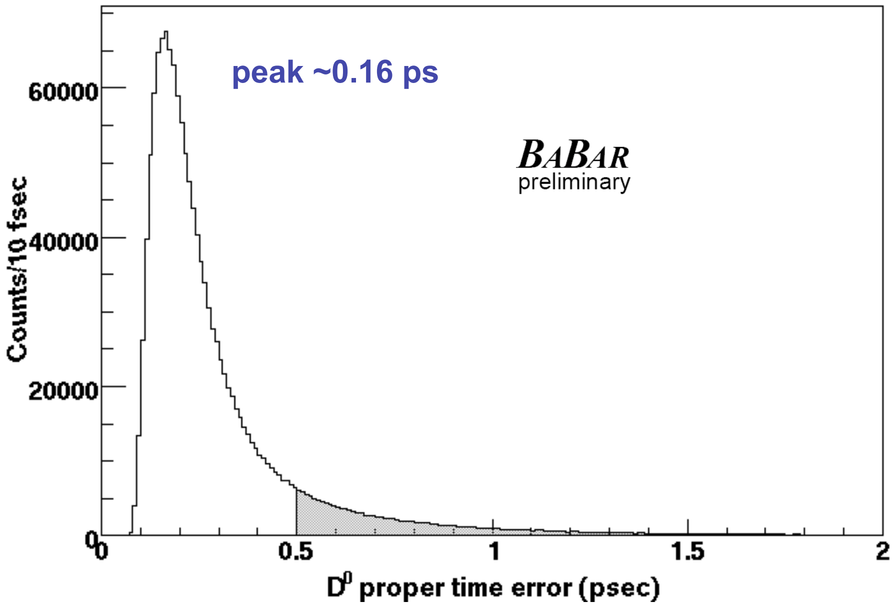
Decay time error δt < 0.5 ps

Insure well-measured decay time

Also require

$0.14 < \Delta m < 0.16$ GeV/c^2

Select candidate with greatest fit probability for multiple D^{*+} candidates sharing tracks



Fitting Strategy

Final goal is a fit of WS sample using $m(D^0)$, Δm and t → yields mixing parameters

- Exploit large sample of RS events (>1.1M sig evt) to fix parameters of fit function
- Proceed in 3 well-defined steps:
  1. Fit in $m(D^0)$, Δm (i.e. time-independent) of RS and WS samples together → determines shapes for probability density functions (PDFs) for these variables
  2. Time-dependent fit to RS sample → determine D^0 lifetime and constrain the proper time resolution function (see below)
  3. Finally fit $m(D^0)$, Δm and t to WS sample to extract the mixing parameters
- Method allows determination of all fit function parameters from data → Monte Carlo events not needed

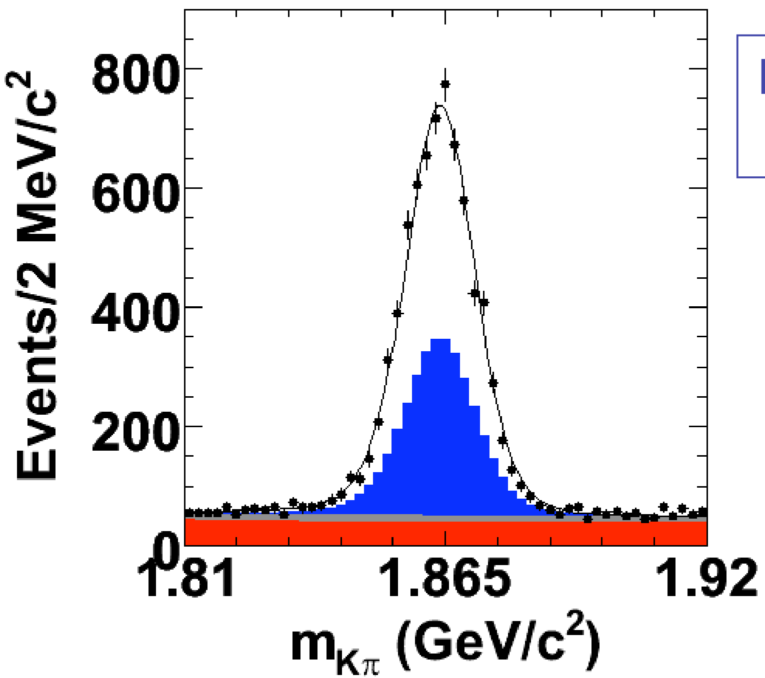
Wrong-sign $m(D^0)$, Δm fit

The fit determines the wrong-sign branching ratio R_{WS}.

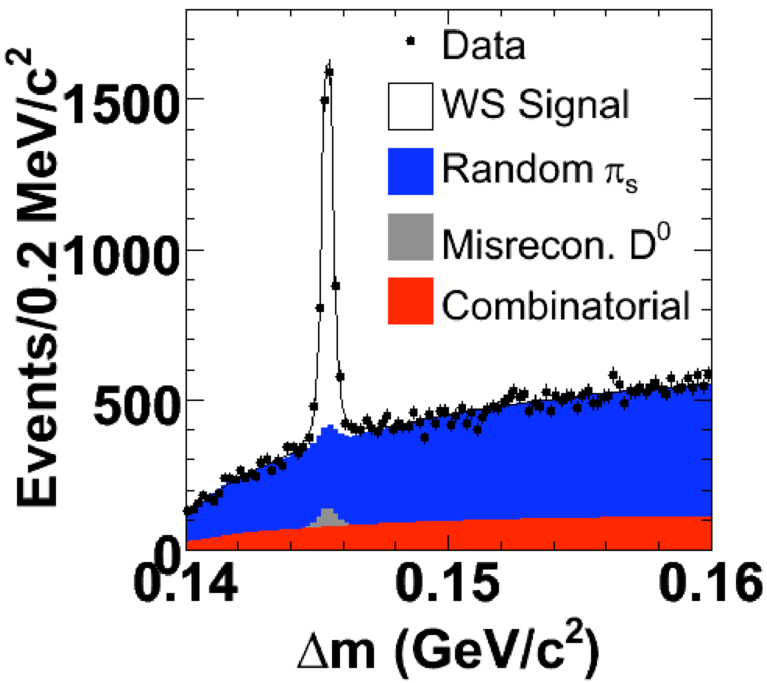
- A preliminary wrong-sign fit of D^0 mass and Δm distributions is shown, which yields $R_{WS} = (0.353 \pm 0.008 \pm 0.004)\%$.

This is a 3x improvement from the earlier 2003 BaBar measurement.

- It is comparable with the latest BELLE result of $(0.377 \pm 0.008 \pm 0.005)\%$ using 400 fb^{-1} *PRL 96, 151801 (2006).*

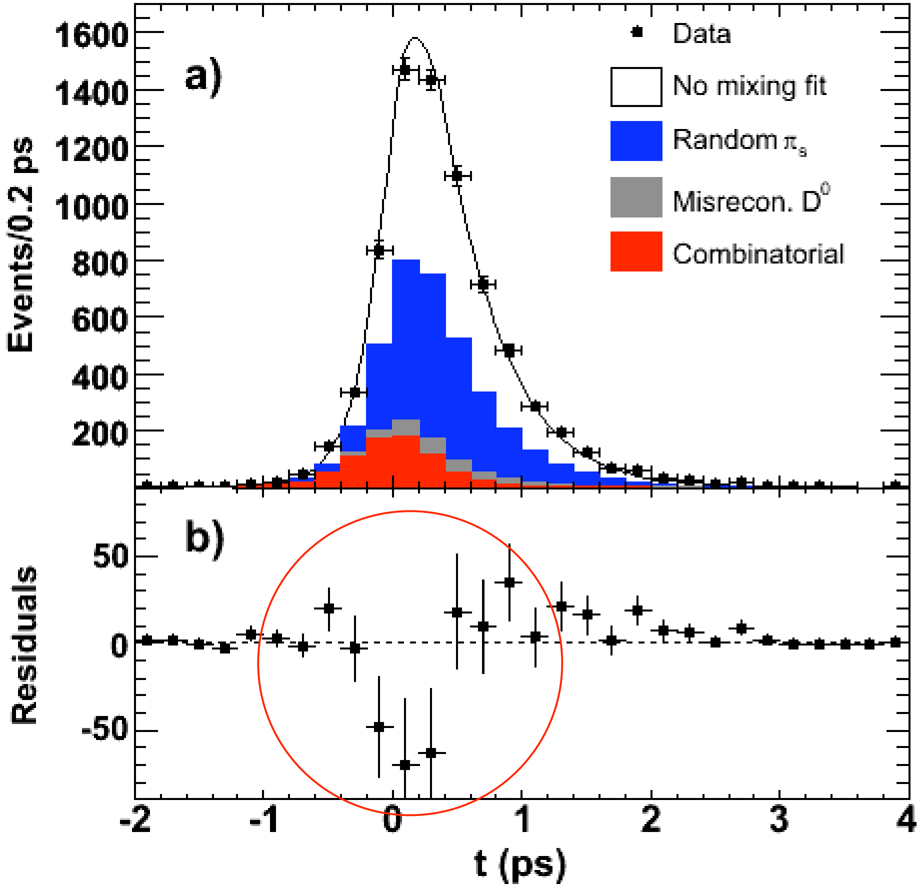


Fitted signal
4030 ± 88



WS decay time fit: Assuming No Mixing

- The parameters varied in the WS decay-time fit are the
  - WS category yields and the
  - WS combinatoric shape parameter
- As can be seen in the residual plot, there are large residuals.



WS *no-mixing* fit projection in signal region
1.843 GeV/c^2<m<1.883 GeV/c^2
0.1445 GeV/c^2<Δm< 0.1465 GeV/c^2

WS decay time fit: Mixing Allowed

The difference between the no-mixing hypothesis and the fit with mixing is shown in the residuals plot.

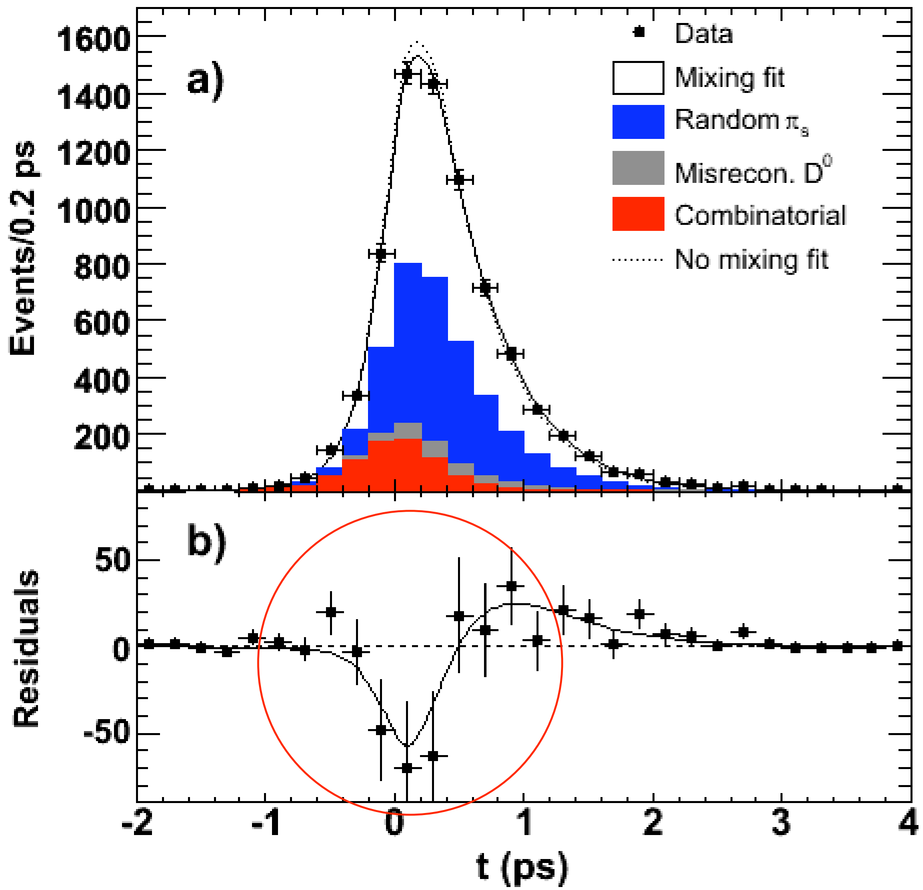
The dotted line is the no-mixing expectation.

The solid line is the mixing fit.

***Fit Results*:**

R_D: $(3.03 \pm 0.16 \pm 0.10) \times 10^{-3}$
x'^2: $(-0.22 \pm 0.30 \pm 0.21) \times 10^{-3}$
y': $(9.7 \pm 4.4 \pm 3.1) \times 10^{-3}$

χ^2/bin = 31/28



WS *mixing* fit projection in signal region

1.843 GeV/c^2<m<1.883 GeV/c^2

0.1445 GeV/c^2<Δm< 0.1465 GeV/c^2

Systematic Uncertainties

- Two types of systematics considered:
  - Variations in Fit Model
    - vary signal and background descriptions
      - Proper time resolution function, 3.6fs bias *(SVT mis-alignment)*
  - Variations in selection criteria
    - most important: cuts on decay time and its error t and δt

Systematic source	R_D	y'	x'^2
Fit Model:	0.59σ	0.45σ	0.40σ
Selection Criteria:	0.24σ	0.55σ	0.57σ
Quadrature total:	0.63σ	0.71σ	0.70σ

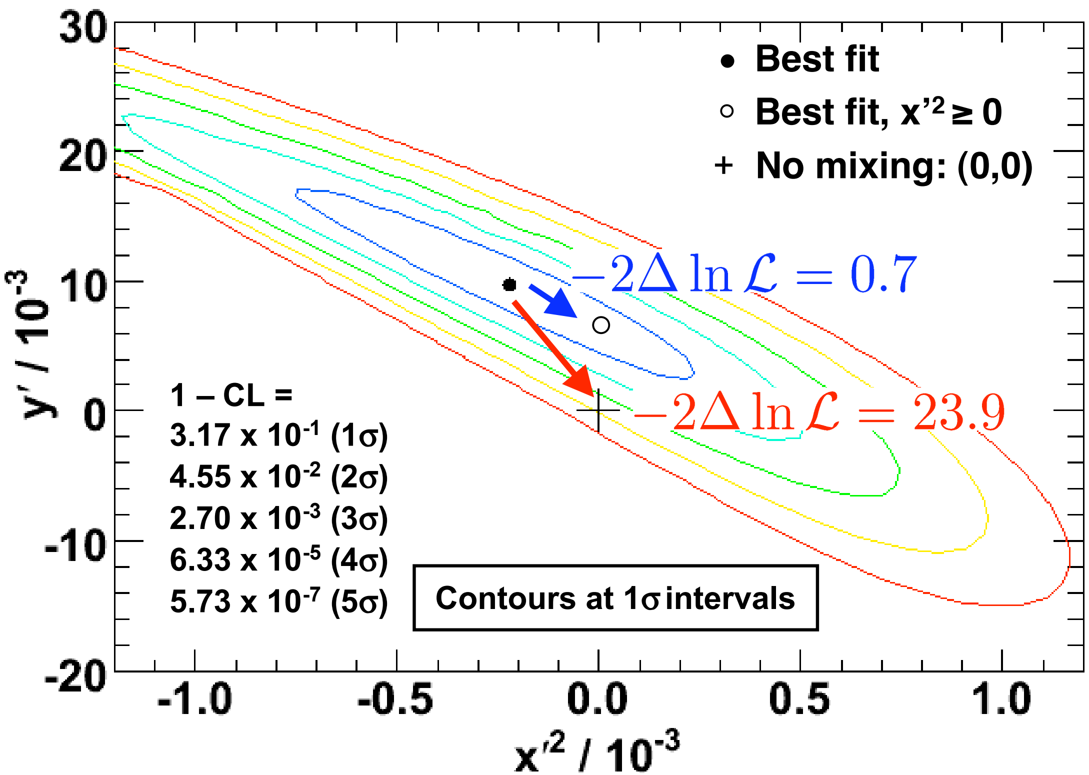
Results are expressed in units of the statistical error

Evidence of mixing at 3.9 σ

- *Contours in y', x'^2 computed from $2\Delta(\ln L)$*
- *Best-fit point is in the non-physical region $x'^2 < 0$*
- *1σ contour extends into physical region. Correlation: -0.94*
- Contours include systematic errors

The no-mixing point is at the 3.9σ contour

No evidence for CP violation fitting separately D^0 and $\overline{D^0}$



R_D: $(3.03 \pm 0.16 \pm 0.10) \times 10^{-3}$

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D^0-$\bar{D}^0$ Mixing in Lifetime Ratio of $D^0 \to K^+K^-$, $\pi^+\pi^-$ vs $D^0 \to K^-\pi^+$

- D^0 mixing and CP violation alter decay time distribution of CP eigenstates to exponential with effective lifetimes τ_{hh}:

$$\tau_{hh}^{\pm} = \tau_D \cdot f^{\pm}\left(r_m, x, y, \varphi_f\right)$$

$$\tau_{hh}^{+} = \tau\left(D^0 \to h^+h^-\right)$$

$$\tau_{hh}^{-} = \tau\left(\bar{D}^0 \to h^+h^-\right)$$

$$h = K, \pi$$

- Let's define

$$\langle \tau_{hh} \rangle = \frac{\tau_{hh}^{+} + \tau_{hh}^{-}}{2} \qquad A_\tau = \frac{\tau_{hh}^{+} - \tau_{hh}^{-}}{\tau_{hh}^{+} + \tau_{hh}^{-}}$$

$$y_{CP} = \frac{\tau_D}{\langle \tau_{hh} \rangle} - 1 \qquad \Delta Y = \frac{\tau_D}{\langle \tau_{hh} \rangle} A_\tau$$

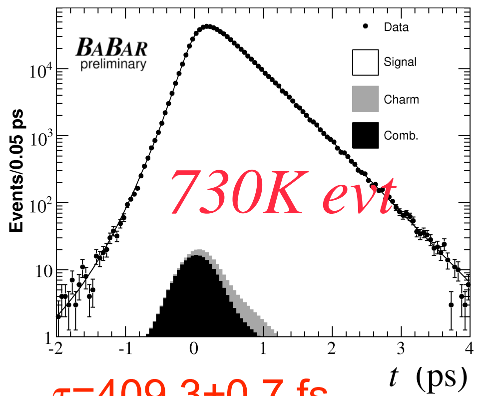
Measuring τ_D and $\langle\tau_{hh}\rangle$ we obtain

$$\boxed{\begin{aligned} y_{CP} &= y\cos\varphi_f \\ \Delta Y &= x\sin\varphi_f \end{aligned}}$$

$y_{CP}=y$ and $\Delta Y=0$ if CP conserved. $y_{CP}=0$ and $\Delta Y=0$ if no mixing

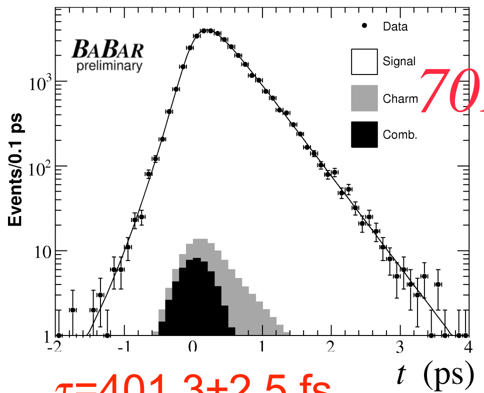
Decay time fits to determine (y_{CP}, ΔY)

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



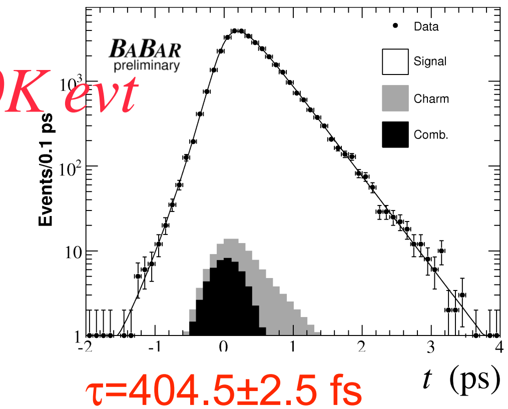
τ=409.3±0.7 fs

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

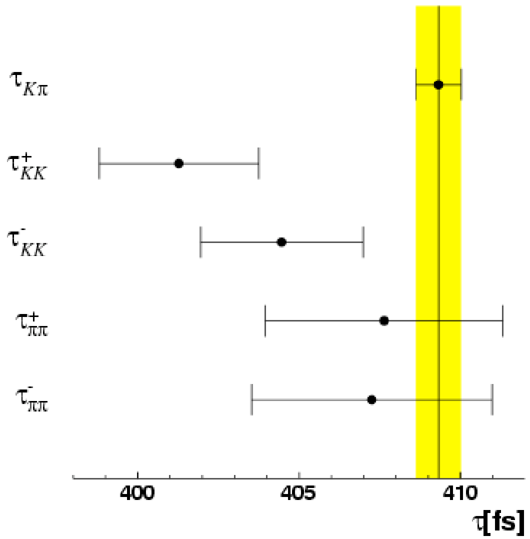


τ=401.3±2.5 fs

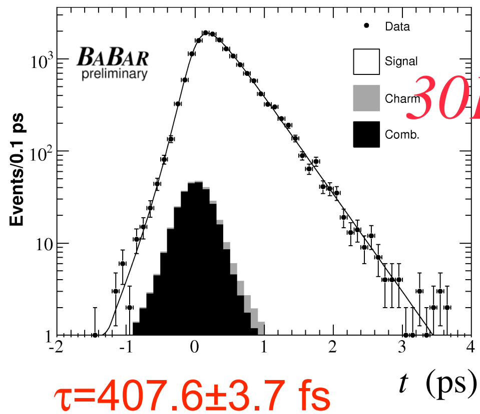
$\overline{D}^0 \to K^+K^-$



τ=404.5±2.5 fs

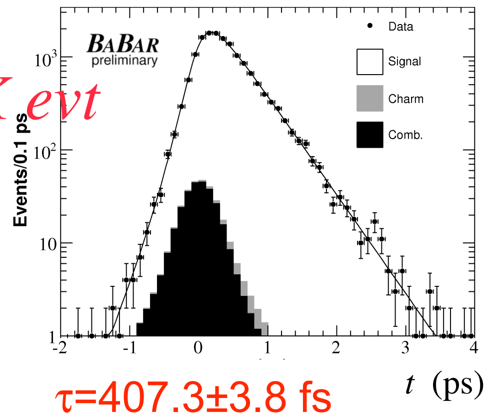


$D^0 \to \pi^+\pi^-$



τ=407.6±3.7 fs

$\overline{D}^0 \to \pi^+\pi^-$



τ=407.3±3.8 fs

***$K\pi$* and *KK* lifetimes differ!**

Results for y_{CP}, ΔY

Tagged results from 384 fb^{-1}:

	y_{CP}	ΔY
K^+K^-	$(1.60 \pm 0.46(\text{stat}) \pm 0.17(\text{syst}))\%$	$(-0.40 \pm 0.44(\text{stat}) \pm 0.12(\text{syst}))\%$
$\pi^+\pi^-$	$(0.46 \pm 0.65(\text{stat}) \pm 0.25(\text{syst}))\%$	$(0.05 \pm 0.64(\text{stat}) \pm 0.32(\text{syst}))\%$
Combined	$(1.24 \pm 0.39(\text{stat}) \pm 0.13(\text{syst}))\%$	$(-0.26 \pm 0.36(\text{stat}) \pm 0.08(\text{syst}))\%$

Evidence of charm mixing at 3σ level.

No evidence of CP violation

Combining results with BaBar PRL 91, 162001(2002) with 91 fb^{-1} *(untagged D^0 sample, statistically independent)*

$$\boxed{y_{CP}=1.03\pm0.33 \pm0.19\ \%}$$

Search for CPV in $D^0 \rightarrow K^+K^-$, $\pi^+\pi^-$

arXiv:0709.2715

- CP violation in these modes is predicted to be $\mathcal{O}(10^{-5}\text{-}10^{-4})$ in SM

F. Bucella et al., Phys. Rev. **D51**, 3478 (1995)
S. Bianco et al., Riv. Nuovo Cim. 26N7, 1(2003)

- Evidence of CPV with current precision in these modes would be signal of New Physics
- Time integrated measurement:

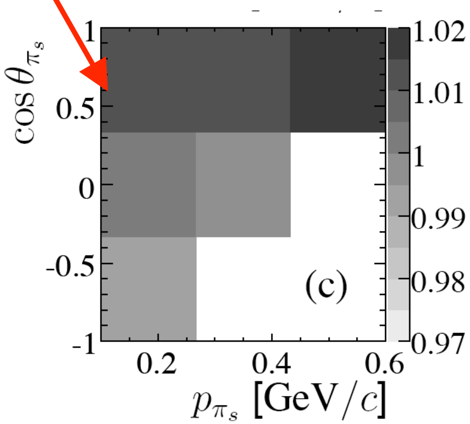
$$a_{CP}^{hh} = \frac{\Gamma\left(D^0 \rightarrow h^+h^-\right) - \Gamma\left(\bar{D}^0 \rightarrow h^+h^-\right)}{\Gamma\left(D^0 \rightarrow h^+h^-\right) + \Gamma\left(\bar{D}^0 \rightarrow h^+h^-\right)}; \qquad h = K, \pi$$

- Experimental difficulties:
  - precise determination of detector D^0 tagging asymmetry (π_{soft} reconstruction in $D^{*+} \rightarrow D^0\pi_{soft}$ decays)
  - forward-backward (FB) asymmetry in $c\bar{c}$ production.

Experimental procedure

- Determine relative $D^0/\bar{D}^0$ soft pion tagging efficiency using $D^0 \to K^- \pi^+$ data

  ⇒greatly reduces systematic uncertainties

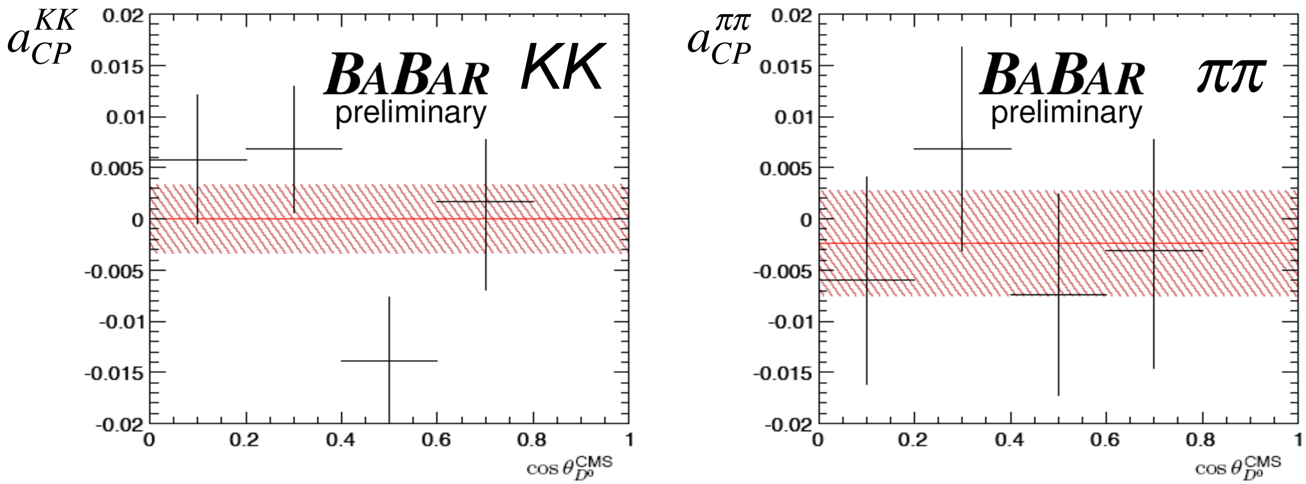


Category	Δa_{CP}^{KK}	$\Delta a_{CP}^{\pi\pi}$
2-Dim. PDF shapes	±0.04%	±0.05%
π_s correction	±0.08%	±0.08%
a_{CP} extraction	±0.09%	±0.20%
Quadrature sum	±0.13%	±0.22%

A_{FB}~*few %*

- Another thing to take into account:
  - correct for FB asymmetries A_{FB} in $e^+e^- \to c\bar{c}$ production: Z^0/γ mediated diagrams interference, high order QED diagrams interference.
  - effects are anti-symmetric in the $\cos\theta_{CM}$
- extract a_{CP} *(symmetric in $\cos\theta_{CM}$)*

Search for CPV in $D^0 \to K^+K^-$, $\pi^+\pi^-$



$$\boldsymbol{a_{CP}^{KK}} = (\ \mathbf{0.00} \pm \mathbf{0.34}\ (\mathrm{stat.}) \pm \mathbf{0.13}\ (\mathrm{syst.}))\%$$
$$\boldsymbol{a_{CP}^{\pi\pi}} = (\mathbf{-0.24} \pm \mathbf{0.52}\ (\mathrm{stat.}) \pm \mathbf{0.22}\ (\mathrm{syst.}))\%$$

No evidence for CPV in either mode

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

- Use WS events and exploit interference to distinguish mixing events from DCS, as in $D^0 \to K^+\pi^-$. *...but 3-body decay mode here.*
- Study the variation along time of the *Dalitz plot* distribution of the events due to mixing.

The WS signal amplitude contains both DCS and CF amplitudes.
The CF amplitudes are determined in the RS fit and fixed in the WS fit

$$\frac{d\Gamma(s_{12},s_{13},t)}{dt} \propto$$

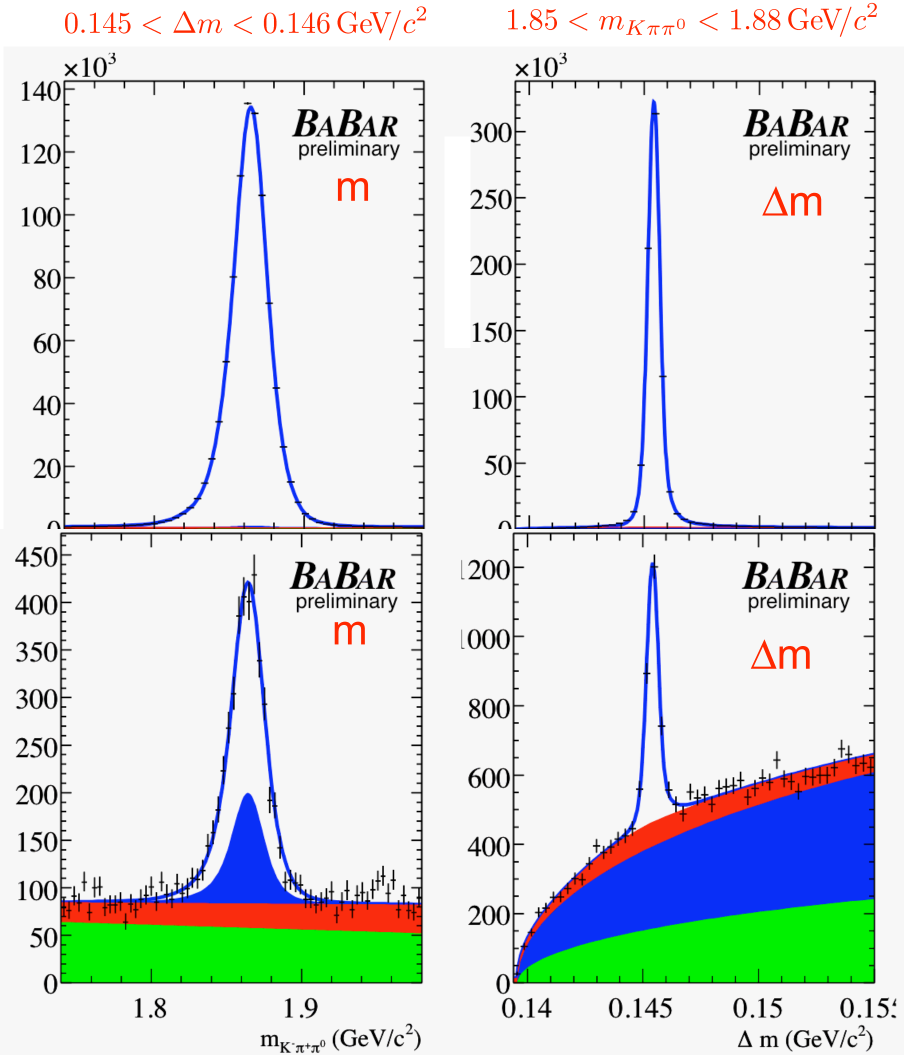
$$e^{-\Gamma t}\left(\underbrace{\left|A_{\bar f}\right|^2}_{\text{DCS}} + \left|A_{\bar f}\right|\left|\bar A_{\bar f}\right|\underbrace{\left[y''\cos\delta_{\bar f} - x''\sin\delta_{\bar f}\right](\Gamma t)}_{\text{Interference}} + \underbrace{\frac{x''^2+y''^2}{4}\left|\bar A_{\bar f}\right|^2(\Gamma t)^2}_{\text{Mixing}}\right)$$

$$x'' = x\cos\delta_{K\pi\pi^0} + y\sin\delta_{K\pi\pi^0} \qquad y'' = -x\sin\delta_{K\pi\pi^0} + y\cos\delta_{K\pi\pi^0}$$

$$\delta_f = \delta_f(s_{12},s_{13})$$

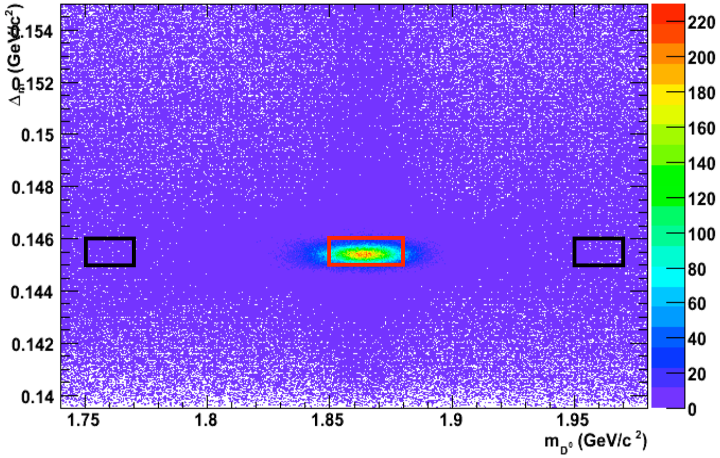
$D^0 - \bar D^0$ relative phase not directly measurable at B-factories

RS and WS ($m_{K\pi\pi^0}$, Δm) fits



signal
mis-tagged D^0
mis-reconstructed D^0
combinatoric

signal
sideband regions

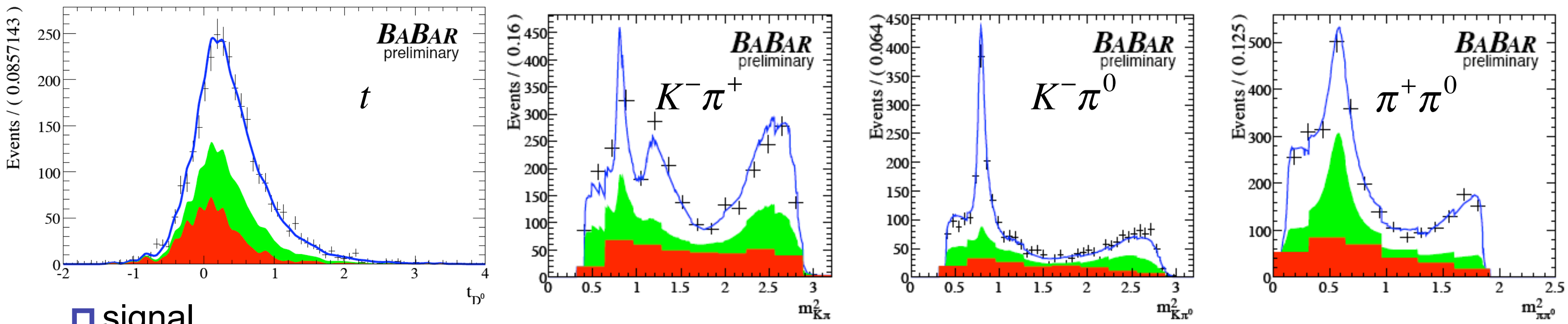


signal box yields:

Category	N events (RS)	N events (WS)
Signal	639802 ± 1538	1483 ± 56
Combinatoric	1537 ± 57	499 ± 57
Mistag	2384 ± 57	765 ± 29
Misreconstructed D^0	3117 ± 93	227 ± 75

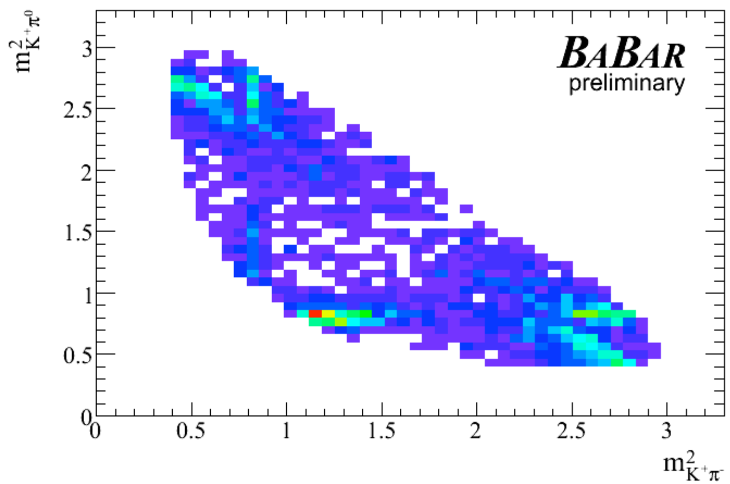
$D^0(t) \to K^+\pi^-\pi^0$ (WS) Dalitz-mixing fit

Through t-dependence, distinguish DCS amplitudes from the CF amplitudes arising from mixing.

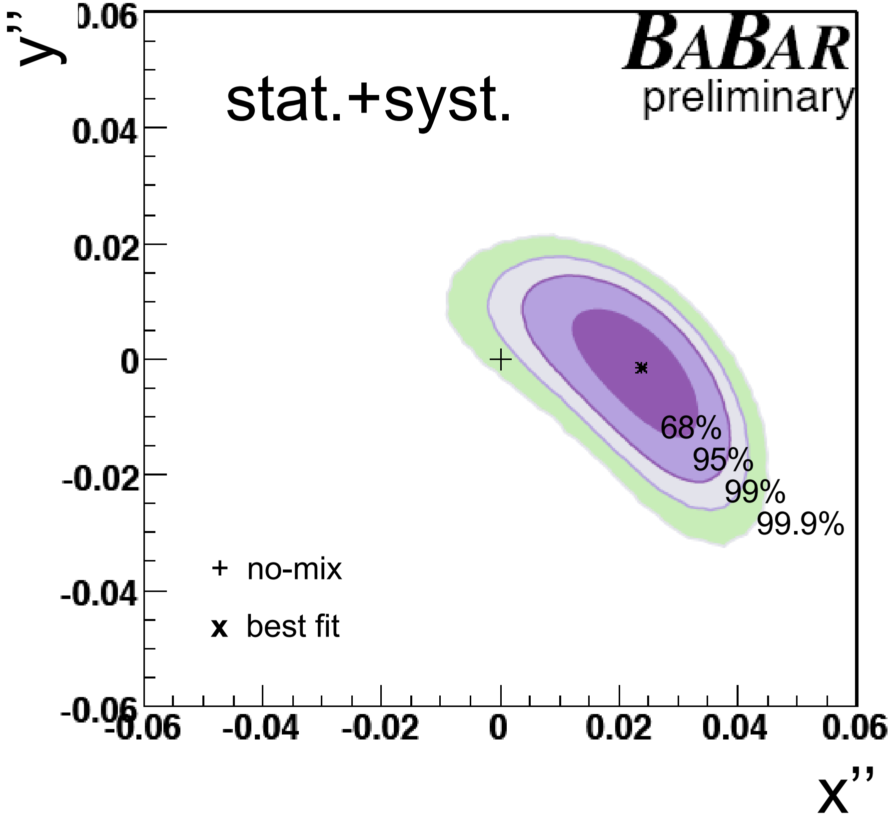


- signal
- mis-tagged D^0
- mis-reconstructed D^0 & combinatoric

Resonance	Amplitude	Phase (degrees)	Fit Fraction (%)
$\rho(770)$	1 (fixed)	0 (fixed)	39.8 ± 6.5
$K_2^{*0}(1430)$	0.088 ± 0.017	-17.2 ± 12.9	2.0 ± 0.7
$K_0^{*+}(1430)$	6.78 ± 1.00	69.1 ± 10.9	13.1 ± 3.3
$K^{*+}(892)$	0.899 ± 0.005	-171.0 ± 5.9	35.6 ± 5.5
$K_0^{*0}(1430)$	1.65 ± 0.59	-44.4 ± 18.5	2.8 ± 1.5
$K^{*0}(892)$	0.398 ± 0.038	24.1 ± 9.8	6.5 ± 1.4
$\rho(1700)$	5.4 ± 1.6	157.4 ± 20.3	2.0 ± 1.1
$\chi^2/ndof = 188/215 = 0.876$			
Total fit fraction = 102%			



Mixing parameter results



$$x'' = (\ \ 2.39 \pm 0.61\ (\text{stat.})\ \ \pm 0.32\ (\text{syst.}))\%$$
$$y'' = (-0.14 \pm 0.60\ (\text{stat.})\ \ \pm 0.40\ (\text{syst.}))\%$$

$$R_{\text{mix}} \equiv \frac{x''^2 + y''^2}{2} = (2.9 \pm 1.6) \times 10^{-4}$$
$$\text{world average} = (2.1 \pm 1.1) \times 10^{-4}$$

Results are consistent with no mixing at 0.8%, including systematics

BaBar D^0-$\bar{D}^0$ Mixing Summary

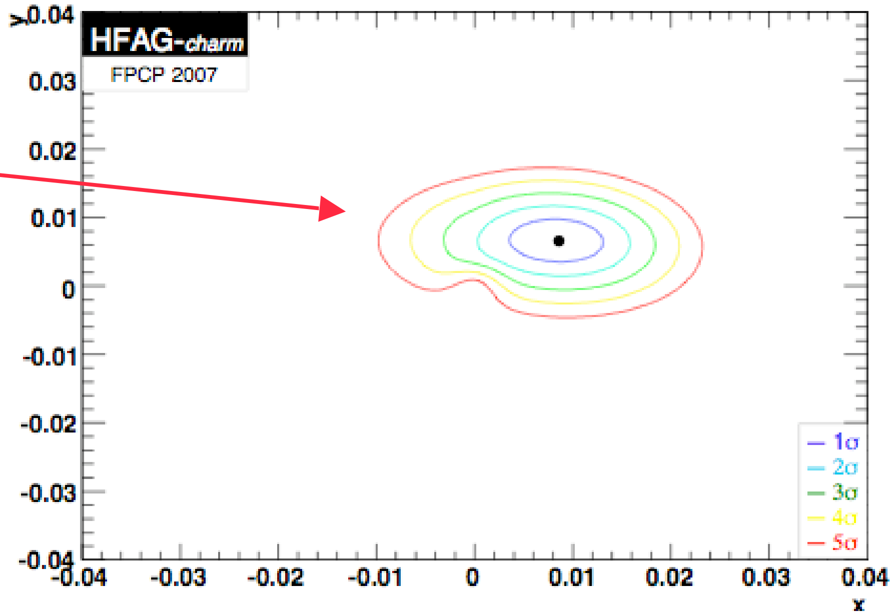
- *Evidence for $\bar{D}^0$-D^0 mixing from BaBar experiment*:
  - $D^0 \to K^+\pi^-$ WS time-depedent analysis
    $$x'^2 = (-0.022 \pm 0.030 \text{ (stat.)} \pm 0.010 \text{ (syst.)})\%$$
    $$y' = (\ 0.97 \pm 0.44 \text{ (stat.)} \pm 0.31 \text{ (syst.)})\%$$
    No mixing excluded at 3.9σ
  - $D^0 \to K^-\pi^+$ to $D^0 \to K^+K^-$, $\pi^+\pi^-$ lifetimes:
    $$y_{CP} = (\ 1.24 \pm 0.39 \text{ (stat.)} \pm 0.13 \text{ (syst.)})\%$$
    No mixing excluded at 3σ
  - $D^0 \to K^+\pi^-\pi^0$ time-dependent Dalitz analysis:
    $$x'' = (\ 2.39 \pm 0.61 \text{ (stat.)} \pm 0.32 \text{ (syst.)})\%$$
    $$y'' = (-0.14 \pm 0.60 \text{ (stat.)} \pm 0.40 \text{ (syst.)})\%$$

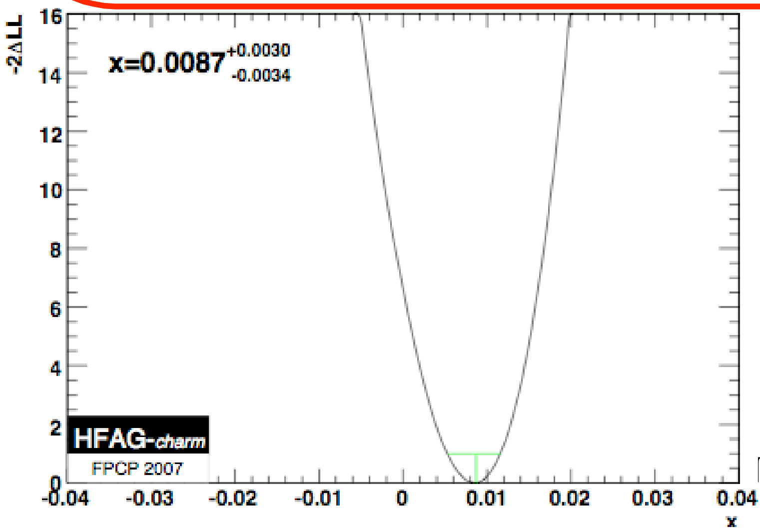
In $D^0 \to K^+K^-$, $\pi^+\pi^-$ decays,

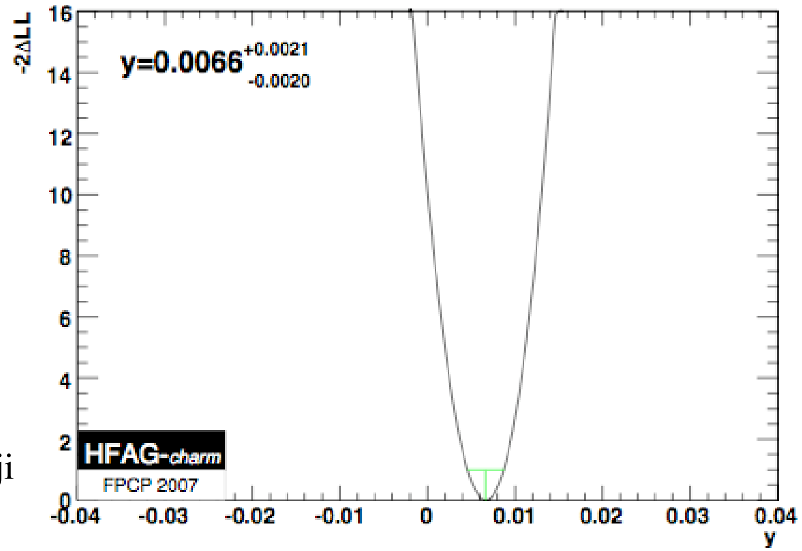
- no evidence for CP violation
  $$a_{CP}^{KK} = (\ 0.00 \pm 0.34 \text{ (stat.)} \pm 0.13 \text{ (syst.)})\%$$
  $$a_{CP}^{\pi\pi} = (-0.24 \pm 0.52 \text{ (stat.)} \pm 0.22 \text{ (syst.)})\%$$
- no evidence for CP violation in mixing:
  $$\Delta Y = (-0.26 \pm 0.36 \text{ (stat.)} \pm 0.08 \text{ (syst.)})\%$$

Mixing: status of art

- *The significance of oscillation effect exceeds 5σ.*
- *Not clear if the effect is caused by $x \neq 0$ or $y \neq 0$*
- *Charm oscillation not definitely established since no single measurement exceeds 5σ*







Towards a SuperB Factory

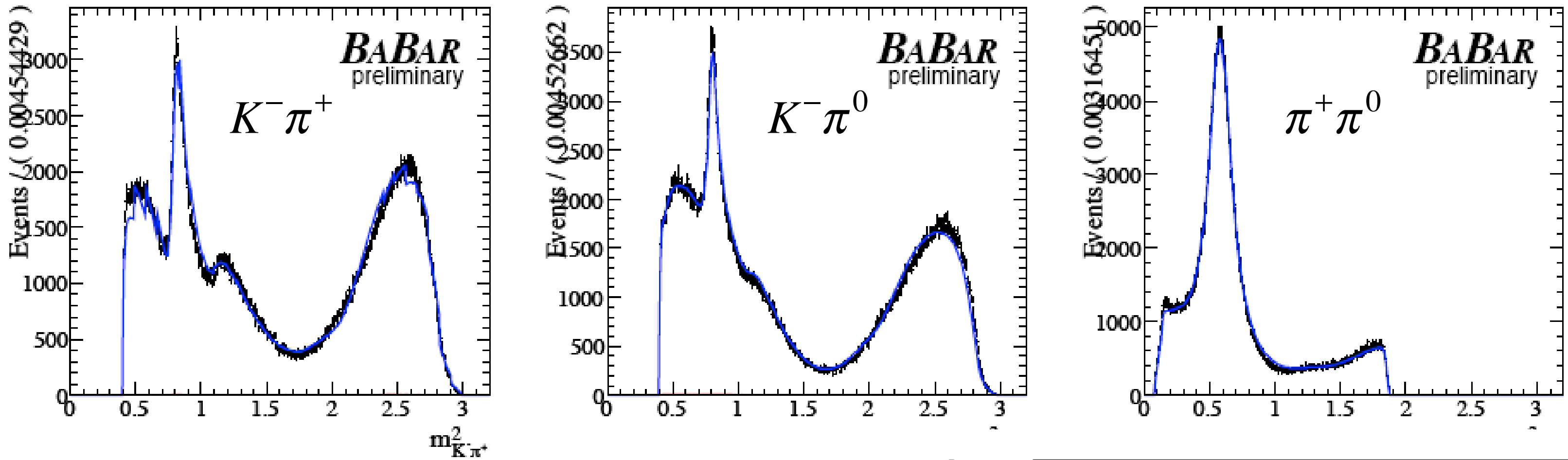
Table III Summary of the expected precision on charm mixing parameters. For comparison we put the reach of the B Factories at 2 ab^{-1}. The estimates for Super$B$ assume that systematic uncertainties can be kept under control.

Mode		B Factories (2 ab^{-1}	Super$B$ (75 ab^{-1}
$D^0 \to K^+K^-$	y_{CP}	2–3×10^{-3}	5×10^{-4}
$D^0 \to K^+\pi^-$	y'_D	2–3×10^{-3}	7×10^{-4}
	x'^2_D	1–2×10^{-4}	3×10^{-5}
$D^0 \to K^0_S\pi^+\pi^-$	y_D	2–3×10^{-3}	5×10^{-4}
	x_D	2–3×10^{-3}	5×10^{-4}
Average	y_D	1–2×10^{-3}	3×10^{-4}
	x_D	2–3×10^{-3}	5×10^{-4}

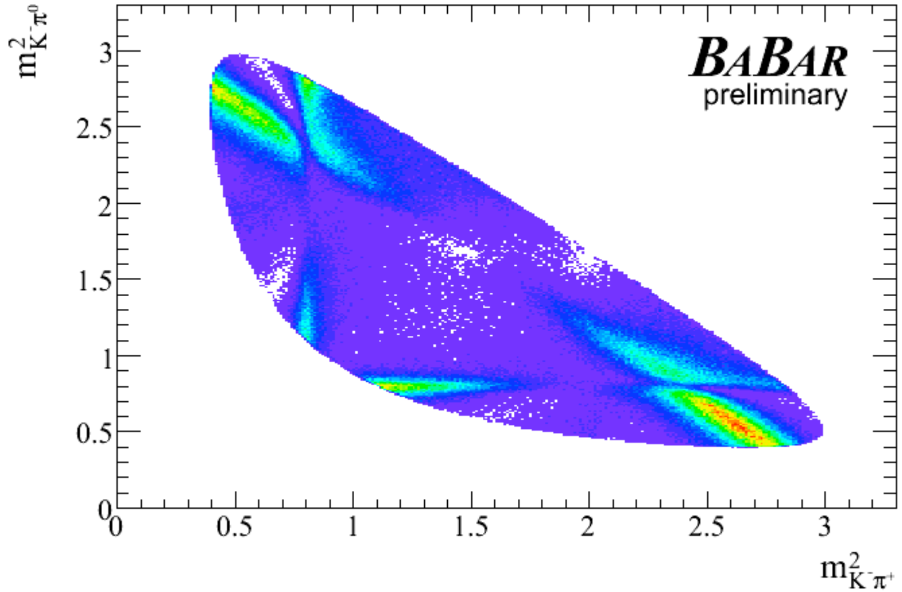
Backup slides

$D^0 \to K^-\pi^+\pi^0$ RS Dalitz fit

Time-integrated analysis to determine CF amplitudes, $\bar{A}_{\bar{f}}$



Resonance	Amplitude	Phase (degrees)	Fit Fraction (%)
$\rho(770)$	1 (fixed)	0 (fixed)	65.2 ± 4.5
$K^{*-}(1680)$	1.52 ± 0.06	144.3 ± 3.2	0.39 ± 0.04
$K_2^{*-}(1430)$	0.030 ± 0.001	-167.5 ± 2.5	0.31 ± 0.03
$K_2^{*0}(1430)$	0.0431 ± 0.0007	13.4 ± 0.9	0.73 ± 0.06
$K^{*-}(1410)$	0.24 ± 0.01	39.1 ± 4.1	0.17 ± 0.02
$K_0^{*-}(1430)$	2.95 ± 0.05	183.7 ± 0.9	3.6 ± 0.3
$K^{*-}(892)$	0.382 ± 0.001	163.3 ± 0.2	10.3 ± 0.7
$K^{*0}(1410)$	0.17 ± 0.01	-221.0 ± 3.5	0.009 ± 0.0001
$K_0^{*0}(1430)$	2.53 ± 0.01	91.6 ± 0.3	8.3 ± 0.6
$K^{*0}(1680)$	2.74 ± 0.07	-17.0 ± 1.5	1.4 ± 0.1
$K^{*0}(892)$	0.400 ± 0.001	3.4 ± 0.3	11.1 ± 0.7
$\rho(1700)$	6.06 ± 0.09	136.3 ± 0.7	4.1 ± 0.3
Total fit fraction = 106%			



$D^0(t) \to K^+\pi^-\pi^0$ Systematics

- Systematics: (describe main systematics here if there will be time). Expecially Dalitz model.

Syst.	x''/r_0	y''/r_0
Dalitz model	0.338	0.472
t resolution function	0.259	0.0621
Background model	0.55	0.464
Signal and Background yields	0.168	0.0132
Dalitz plot efficiency	0.0876	0.0794
Selection	0.391	0.287
Total	0.858	0.745