Evidence for D^0-$\bar{D}^0$ Mixing at Belle

KEK Physics Seminar

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Belle Collaboration

Outline

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2. Phenomenology
3. Measurements
   - semileptonic
   - $K^+\pi^-$
   - $K_S\pi^+\pi^-$
   - $K^+K^{-/}\pi^+\pi^-$
   - CPV
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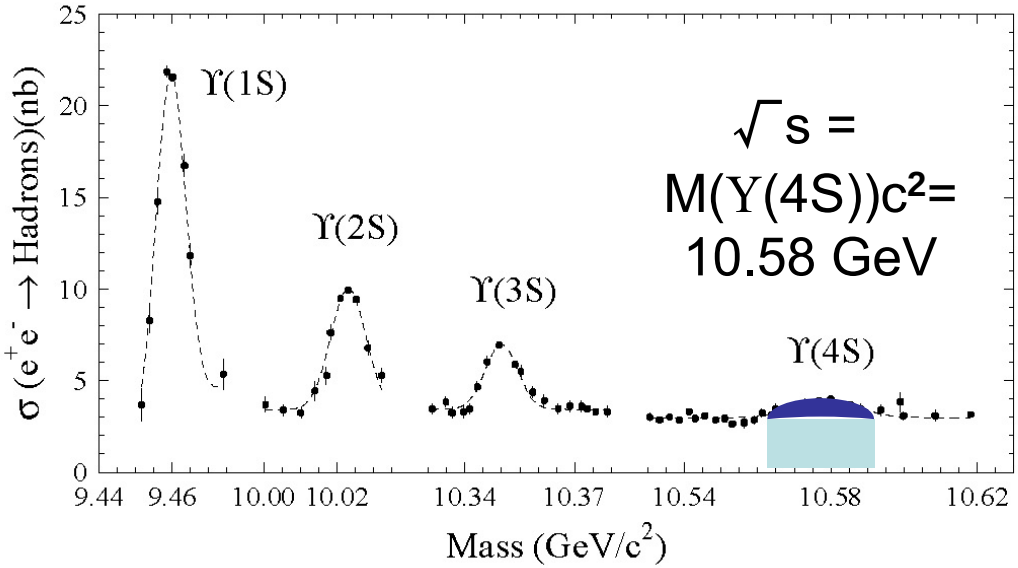
Introduction

Physics of c-hadrons

increased interest at
B-factories in recent years



B-factory, c-factory

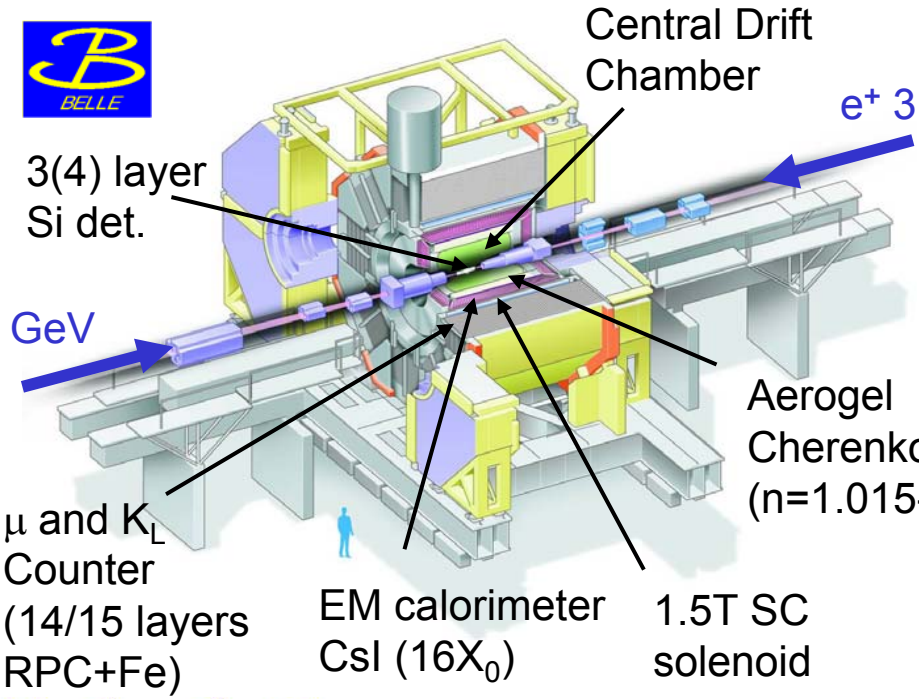
$\sigma(B\bar{B}) \approx 1.1$ nb (~750·10⁶ $B\bar{B}$ pairs)

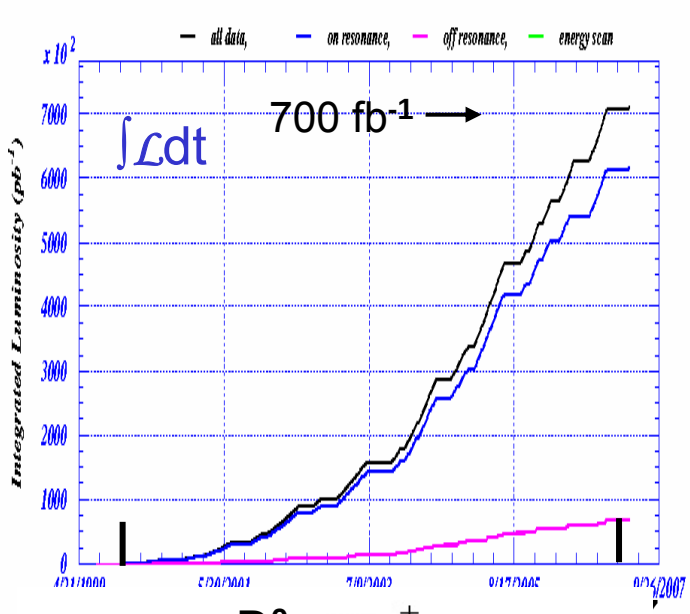
$\sigma(c\bar{c}) \approx 1.3$ nb (~850·10⁶ $X_c\bar{Y}_c$ pairs)

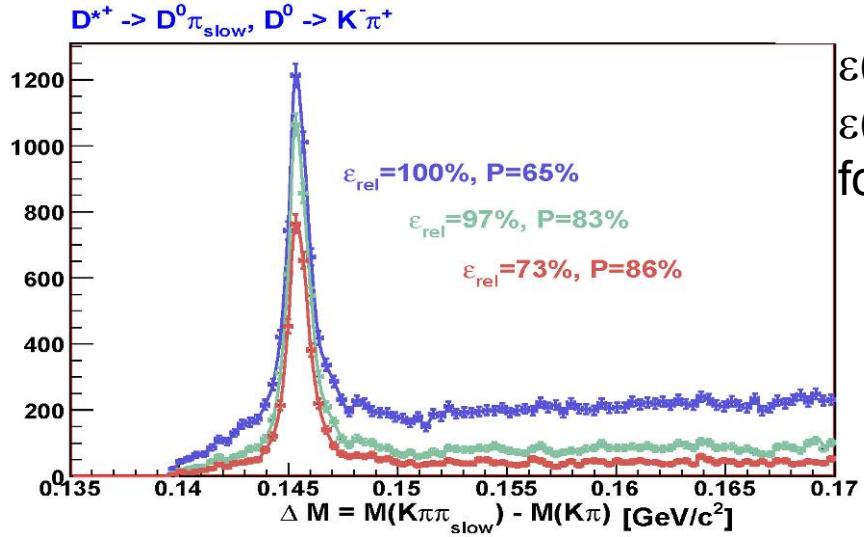
benchmark: $D^{*0} \rightarrow D^0 \pi^+_{slow}$; $D^0 \rightarrow K^-\pi^+$

Facility	N_{rec}	int. lumin. [fb^{-1}]	
Belle	2.5x10⁶	1000	P ≥ 99%
Super KEKB	13x10⁶	5000	
c-factory	0.4x10⁶	20	coherent
CDF/D0	0.5x10⁶	0.35	

Introduction

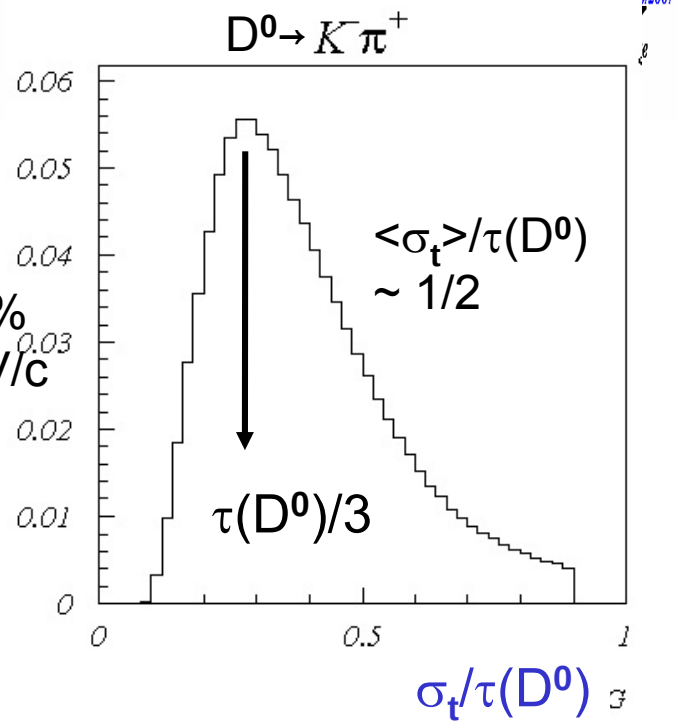






$\varepsilon(K^{\pm}) \sim 85\%$

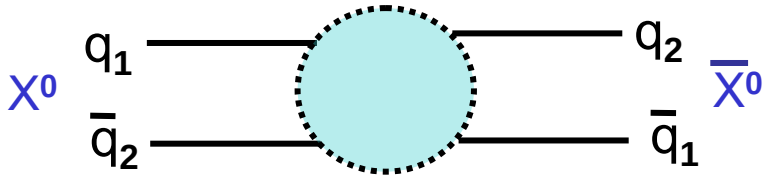
$\varepsilon(\pi^{\pm} \rightarrow K^{\pm}) \leq 10\%$ for $p < 3.5$ GeV/c



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

Mixing phenomena

in course of life neutral meson X^0 can transform into anti-meson $\overline{X}^0$



$X^0 = K^0, B_d^0, B_s^0$ and D^0

t-dependent Schrödinger eq.:

$$i\frac{\partial}{\partial t}\left[\begin{array}{c}|X^0(t)\rangle\\ |\overline{X}^0(t)\rangle\end{array}\right]=\left(\mathbf{M}-\frac{i}{2}\mathbf{\Gamma}\right)\left[\begin{array}{c}|X^0(t)\rangle\\ |\overline{X}^0(t)\rangle\end{array}\right]$$

mass eigenstates:

$$|X_{1,2}\rangle = p|X^0\rangle \pm q|\overline{X}^0\rangle$$

CP eigenstates if q/p=1;

decay time evolution:

$$x\equiv\frac{m_1-m_2}{\overline{\Gamma}};y\equiv\frac{\Gamma_1-\Gamma_2}{2\overline{\Gamma}};\overline{\Gamma}\equiv\frac{\Gamma_1+\Gamma_2}{2}$$

propagate in t according to distinct eigenvalues;

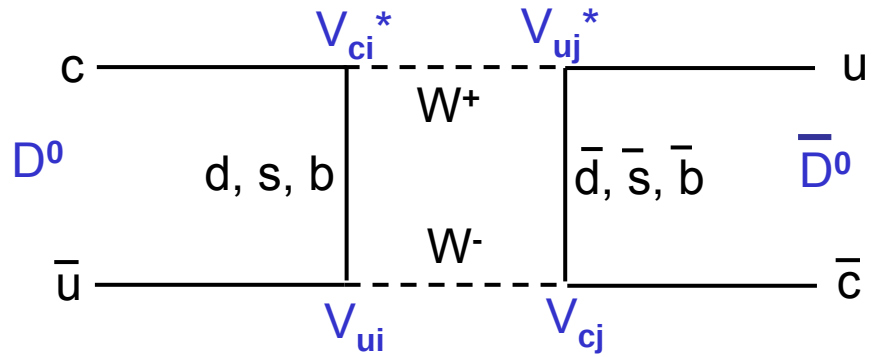
$$|X^0(t)\rangle=\left[|X^0\rangle\cosh\left(\frac{ix+y}{2}t\right)+\frac{q}{p}|\overline{X}^0\rangle\sinh\left(\frac{ix+y}{2}t\right)\right]e^{-(\frac{1}{2}+i\frac{m}{\overline{\Gamma}})t}$$

Decay time distribution of experimentally accessible states X^0, $\overline{X}^0$ sensitive to mixing parameters

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

Mixing description

observation of K^0:
1950 (Caletch)
mixing in K^0: 6 years
1956 (Columbia)
observation of B_d^0:
1983 (CESR)
mixing in B_d^0: 4 years
1987 (Desy)
observation of B_s^0:
1992 (LEP)
mixing in B_s^0: 14 years
2006 (Fermilab)
observation of D^0:
1976 (SLAC)
mixing in D^0: 31 years
2007 (KEK, SLAC)
(evidence of)



d-like quarks in loop

$$\left\langle \overline{D}^0 \left| H_{eff} \right| D^0 \right\rangle = \sum_{i,j=d,s,b} V_{ci}^* V_{ui} V_{cj} V_{uj}^* \mathcal{F}(m_i^2, m_j^2)$$

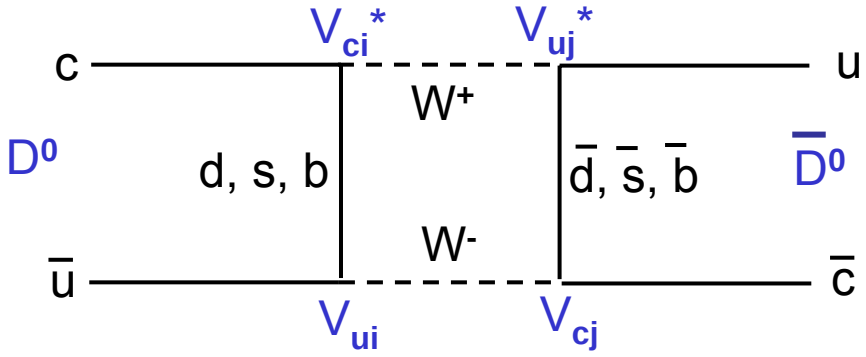
if $m_i = m_j \Rightarrow$ due to CKM unitarity: no D^0 $\overline{D}^0$ mixing

$|V_{cb}^* V_{ub}| << |V_{cs}^* V_{us}|, |V_{cd}^* V_{ud}|$

mainly d,s contrib.; $m_d \sim m_s \Rightarrow$ mixing small

(as opposed to B_d^0, where term with $m_t^2 |V_{tb}^* V_{td}|^2$ dominates)

D^0 - $\bar{D}^0$ Phenomenology



x and y in SM

2nd order perturb.:

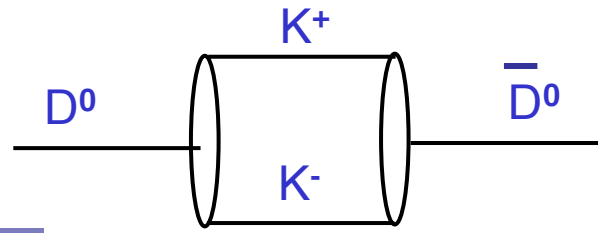
$$(M-i\frac{\Gamma}{2})_{12}=\frac{1}{2M_D}\left\langle \bar{D}^0\left|H_w^{\Delta C=-2}\right|D^0\right\rangle+\frac{1}{2M_D}\sum_n\frac{\left\langle \bar{D}^0\left|H_w^{\Delta C=-1}\right|n\right\rangle\left\langle n\left|H_w^{\Delta C=-1}\right|D^0\right\rangle}{M_D-E_n+i\varepsilon}$$

short distance: $\left\langle \bar{D}^0\left|H_w^{\Delta C=-2}\right|D^0\right\rangle=\frac{G_F^2}{4\pi^2}\underbrace{V_{cs}^*V_{cd}^*V_{ud}V_{us}}_{\text{DCS}}\underbrace{\frac{(m_s^2-m_d^2)^2}{m_c^2}}_{\text{SU(3) breaking}}\left\langle \bar{D}^0\left|\bar{u}\gamma^\mu(1-\gamma_5)c\bar{u}\gamma_\mu(1-\gamma_5)c\right|D^0\right\rangle$

G. Burdman, I. Shipsey,
Ann.Rev.Nucl.Sci. 53, 431 (2003)

$|x| \sim R(10^{-5})$

absorptive part (real interm. states) $\Rightarrow$ y
dispersive part (off-shell interm. states) $\Rightarrow$ x



long distance:

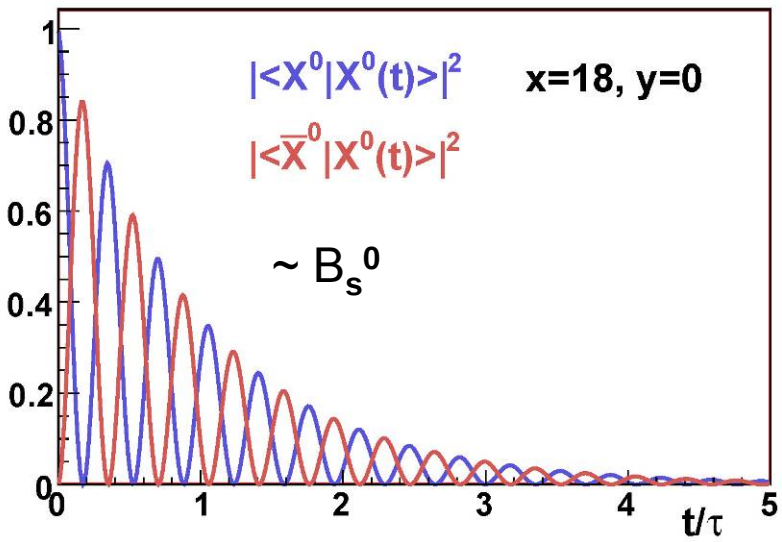
I.I. Bigi, N. Uraltsev,
Nucl. Phys. B592, 92 (2001);
A.F. Falk et al., PRD69, 114021 (2004)

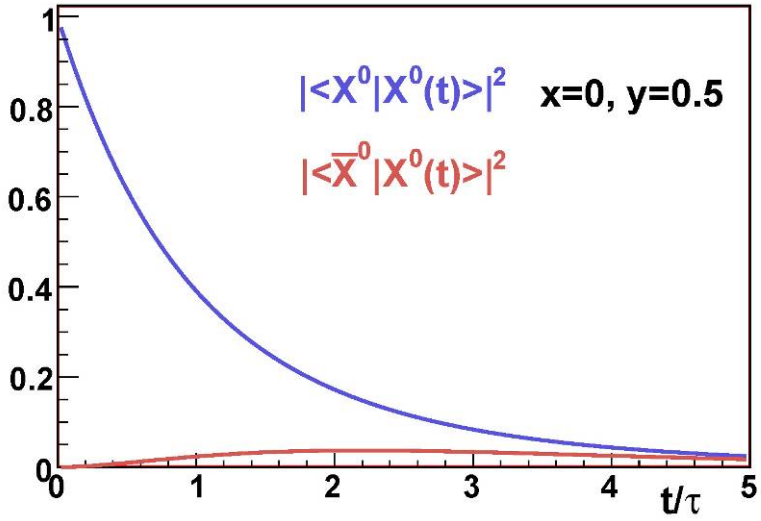
$|x|, |y| \sim R(10^{-2})$

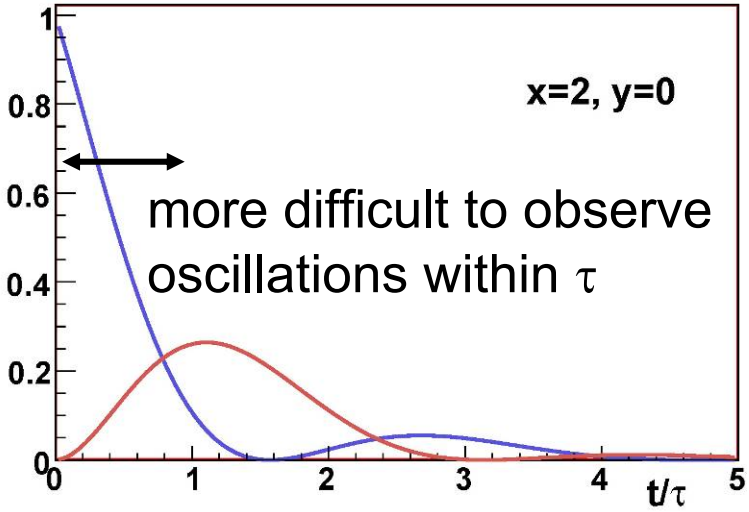
D^0 mixing: rare process in SM;
possible contrib. from NP

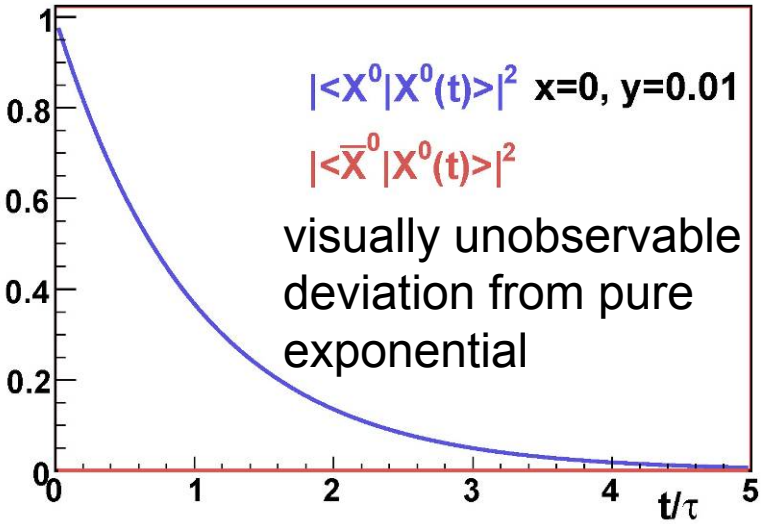
D^0 - $\overline{D}^0$ Phenomenology

Oscillations





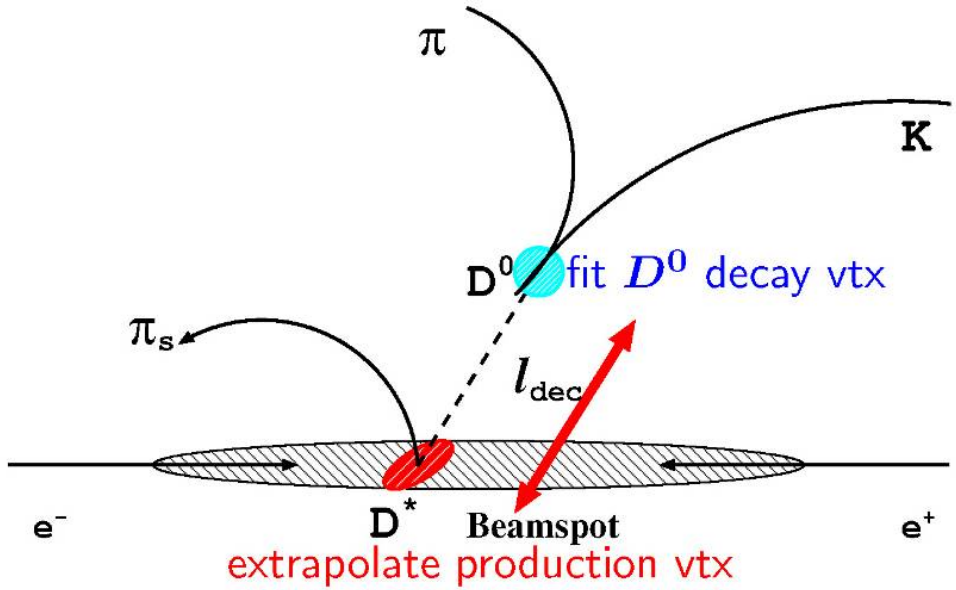




Measurements

Belle measurements

- semileptonic decays,
  $D^0 \to K^{(*)} \ell \nu$
  PRD72, 071101 (2005), 253 fb^{-1}
- hadronic decays to non-CP final
  $D^0 \to K^+\pi^-$
  PRL96, 151801 (2006), 400 fb^{-1}
- hadronic decays to multi-body final state, $D^0 \to K_S \pi^+\pi^-$
  arXiv: 0704.1000, 540 fb^{-1}
- decays to CP final state,
  $D^0 \to K^+K^-/\pi^+\pi^-$
  hep-ex/0703036v2, 540fb^{-1}, acc. to PRL



common:
$D^{*+} \to D^0\pi_s^+$
charge of π_s tags the flavor of initially produced D^0;

$p^*(D^*) > 2.5$ GeV/c
eliminates D meson production from b → c

Measurements semileptonic

PRD72, 071101 (2005), 253 fb^{-1}

Semileptonic decays

Wrong charge combinations (WS):

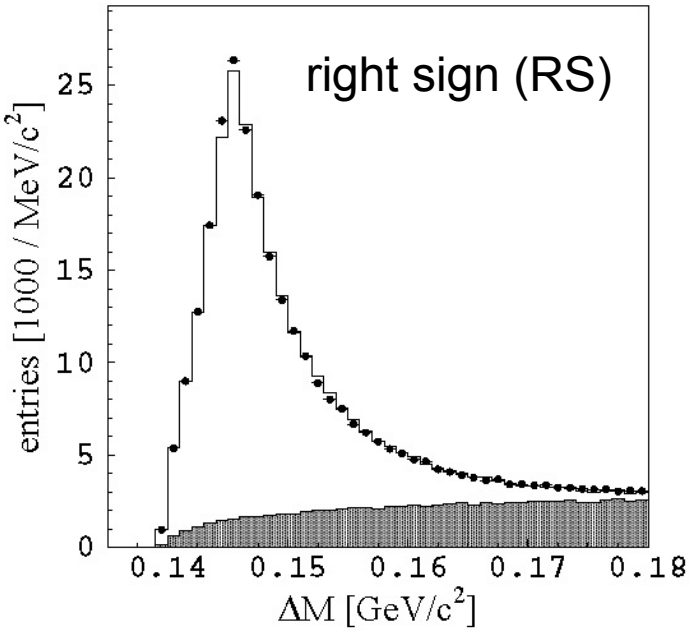
$D^{*+} \to D^0 \; \pi_{slow}^+ \qquad D^0 \to \overline{D}{}^0 \to K^{(*)+} e^- \nu$

no "DCS" decays $\Rightarrow N_{WS}/N_{RS} = R_M \approx (x^2+y^2)/2$

$$f = K^+\ell^-\nu; \quad A_f = \overline{A}_{\bar{f}} = 0 \qquad x,y << 1$$

$$\left|\left\langle K^+\ell^-\nu \middle| D^0(t)\right\rangle\right|^2 \propto \frac{x^2+y^2}{4} t^2 e^{-t}$$

$D^0 \to K^{(*)-} e^+ \nu$



Reconstruct ν:

missing momentum with kinematic constraints

$N_{RS} = (229.45 \pm 0.69) \cdot 10^3$

Signal:

$\Delta M = M(Ke\nu\pi_{slow}) - M(Ke\nu)$

Measurements semileptonic

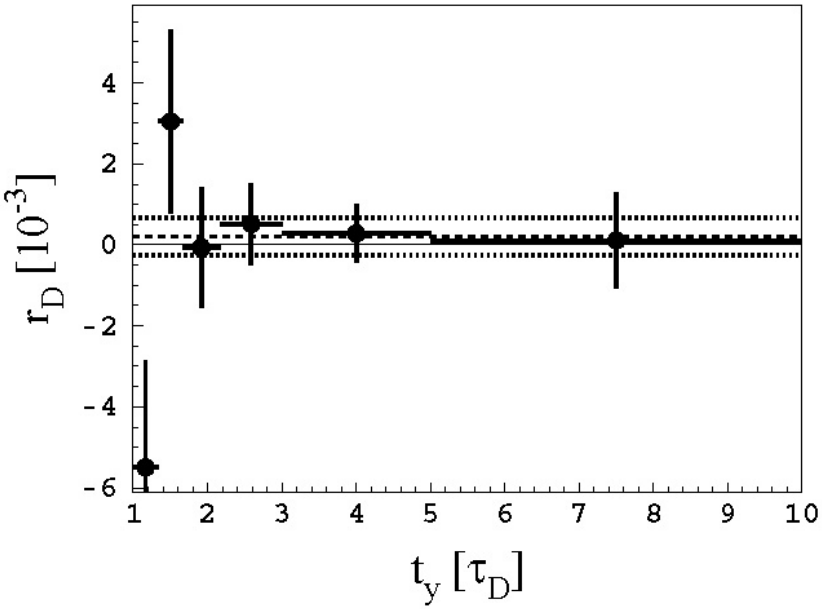
PRD72, 071101 (2005), 253 fb^{-1}

Decay time:

reduce bkg., increase sensitivity;
$\langle t \rangle$(bkg., RS) < $\langle t \rangle$(mix. signal)

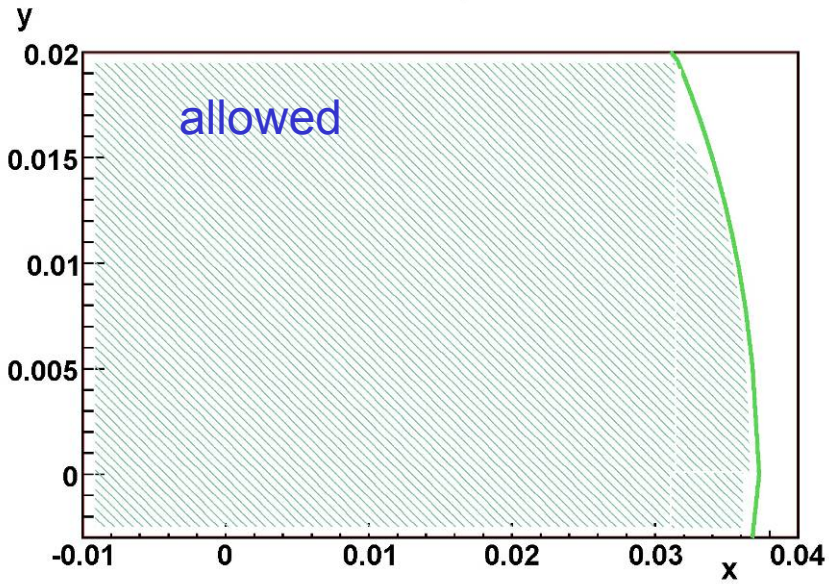
6 bins in 1 < t < 10

$$R_{M,i} = \frac{N_{WS,i}}{N_{RS,i}} \cdot \frac{\varepsilon_{RS,i}}{\varepsilon_{WS,i}}$$



Result:

$R_M = (0.20 \pm 0.47 \pm 0.14) \cdot 10^{-3}$
$R_M < 1.2 \cdot 10^{-3}$ 95% C.L.



dominating systematics from limited bkg. statistics (embedded π_{slow})

Measurements $K^+\pi^-$

Wrong charge combinations (WS):

$D^{*+} \to D^0\ \pi_{slow}^+ \qquad D^0 \to \overline{D}{}^0 \to K^+\pi^-$

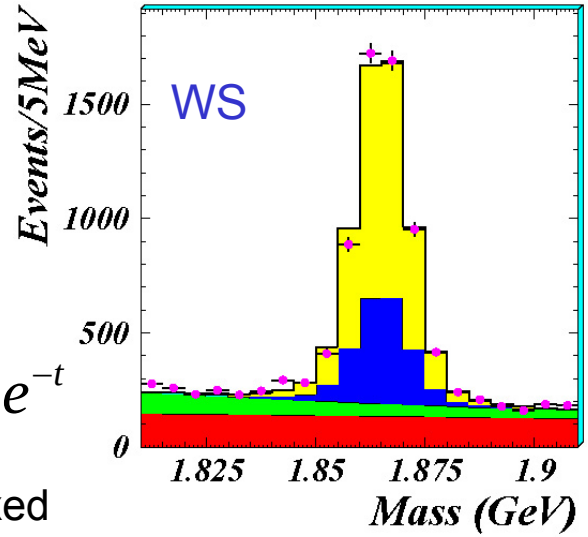
DCS decays $\Rightarrow$ interference

$$\left|\left\langle K^+\pi^- \middle| D^0(t)\right\rangle\right|^2 \propto \left[R_D + \sqrt{R_D}\,y't + \frac{x'^2+y'^2}{4}t^2\right]e^{-t}$$

t-dependence to separate DCS/mixed

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

3σ Q interval



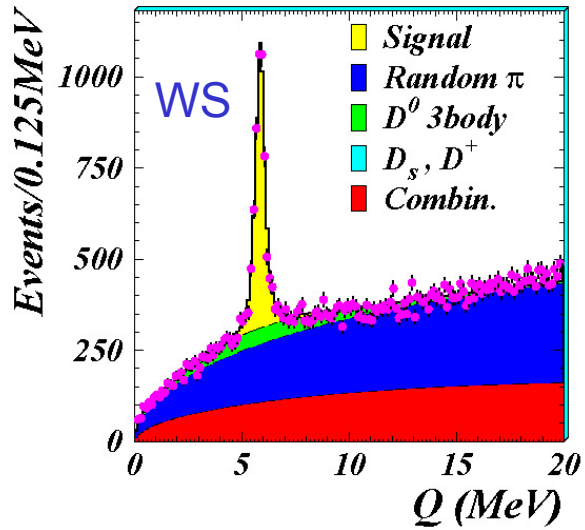
Signal:

$$R_D = \frac{DCS\ rate}{CF\ rate}$$

M= M(Kπ)

Q = M(K π π_{slow}) - M(Kπ) - M(π)

3σ M interval



2D M-Q fit:

$N_{WS} = 4024 \pm 88$

$N_{RS} \approx 10^6$

Measurements $K^+\pi^-$

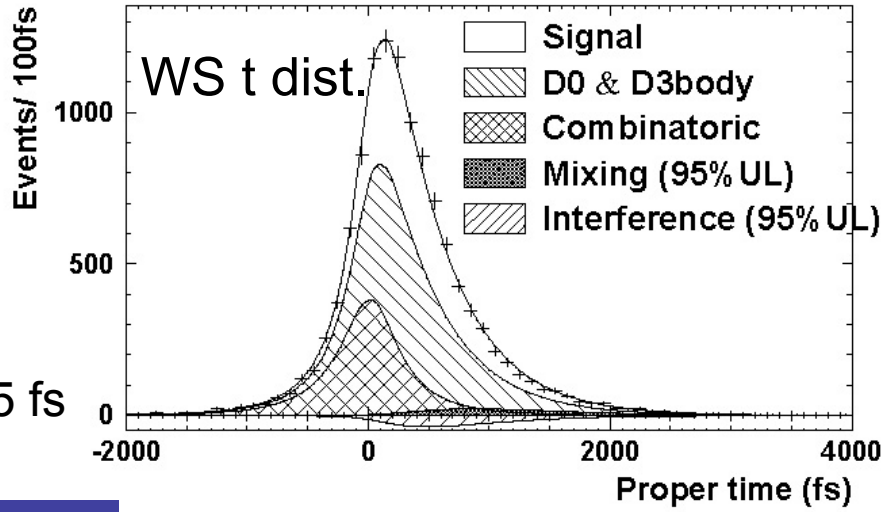
Decay time:

resol. function from RS

$\tau(D^0) = 409.9 \pm 0.7$ fs

τ_{PDG}=410.1±1.5 fs

x'^2, y', R_D free parameters

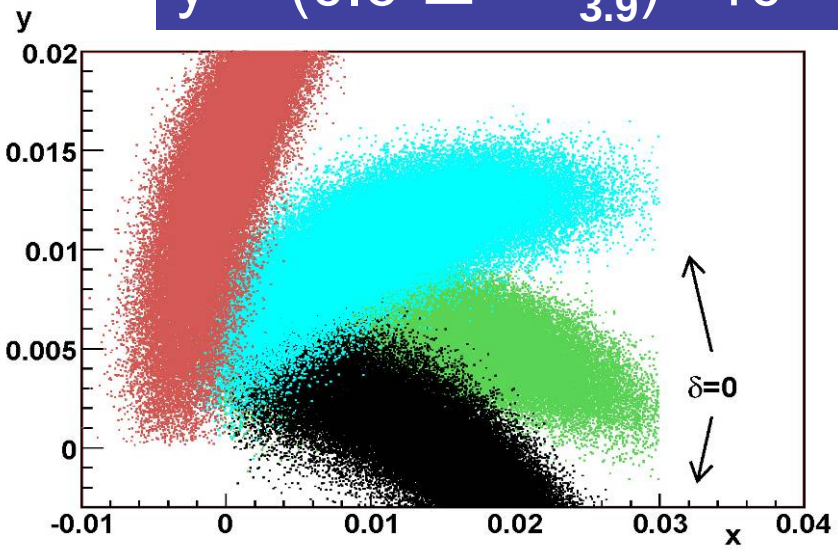


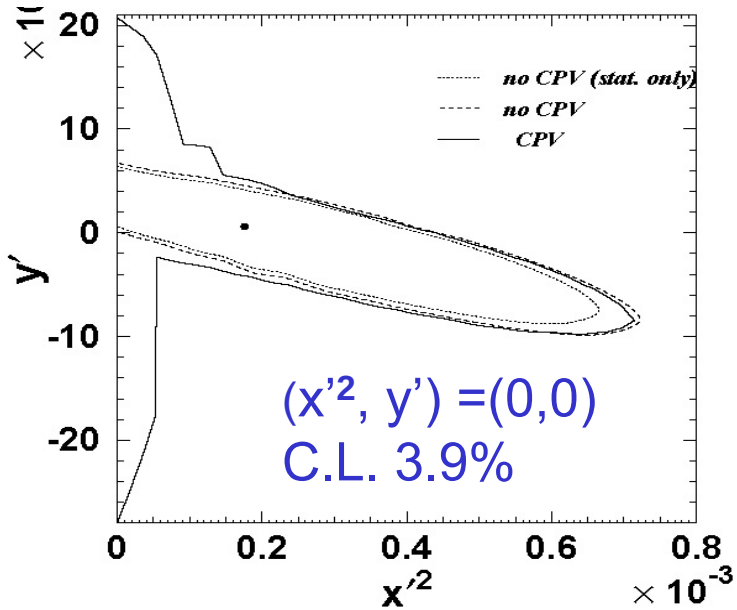
Results:

$R_D = (3.64 \pm 0.17) \cdot 10^{-3}$

$x'^2 = (0.18 \pm {}^{0.21}_{0.23}) \cdot 10^{-3}$

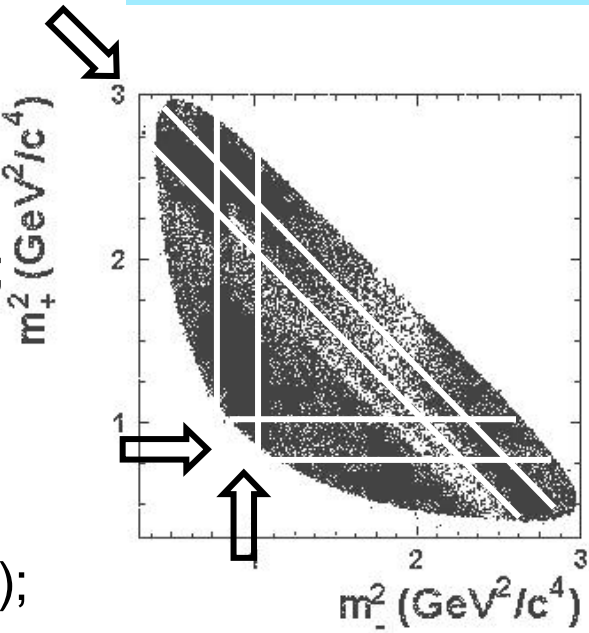
$y' = (0.6 \pm {}^{4.0}_{3.9}) \cdot 10^{-3}$





95% C.L. (x'^2, y') contour
frequentist, FC ordering

Measurements $K_S \pi^+\pi^-$



t-dependent Dalitz analysis

different decays identified through Dalitz analysis;

CF: $D^0 \to K^{*-}\pi^+$

DCS: $D^0 \to K^{*+}\pi^-$

CP: $D^0 \to \rho^0 K_S$

their relative phases determined (unlike $D^0 \to K^+\pi^-$);

t-dependence:

$$\mathcal{M}(m_-^2, m_+^2, t) \equiv \left\langle K_S\pi^+\pi^- \middle| D^0(t) \right\rangle =$$

$m_\pm^2$: Dalitz variables

$$= \frac{1}{2}\mathcal{A}(m_-^2, m_+^2)\left[e^{-i\lambda_1 t} + e^{-i\lambda_2 t}\right] + \frac{1}{2}\frac{q}{p}\bar{\mathcal{A}}(m_-^2, m_+^2)\left[e^{-i\lambda_1 t} - e^{-i\lambda_2 t}\right]$$

$< f \mid D^0 >$ $< f \mid \bar{D}^0 >$ $\lambda_{1,2} = f(x,y)$; n.b.: $K^+\pi^-$: x'^2, y'

analogous for $\bar{\mathcal{M}} = < f \mid \bar{D}^0(t) >$

sum of intermediate states

$$\mathcal{A}(m_-^2, m_+^2) = \sum a_r \, e^{i\Phi_r} B(m_-^2, m_+^2) + a_{NR} \, e^{i\Phi_{NR}}$$

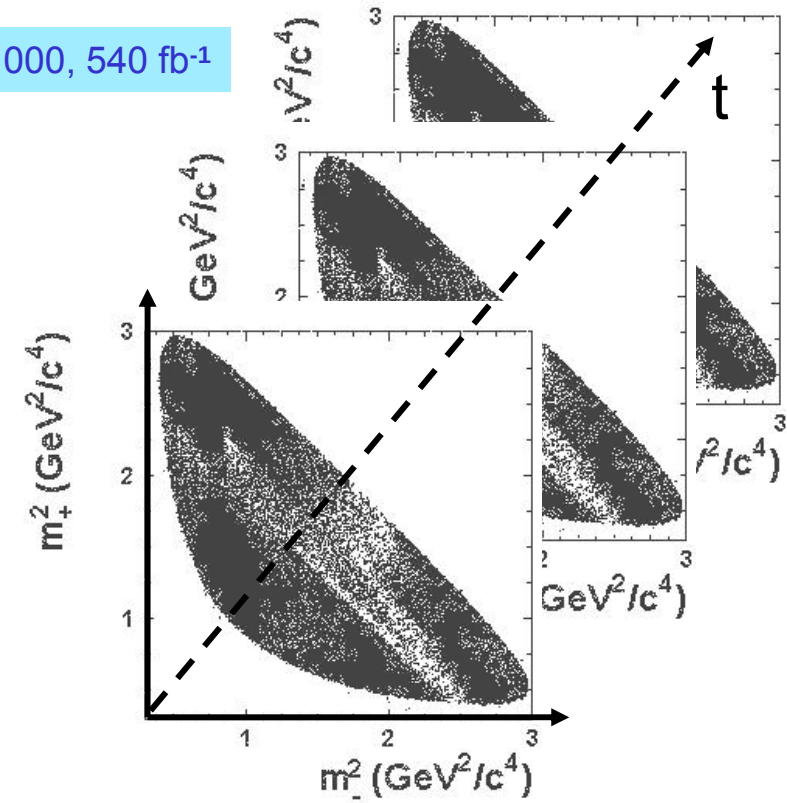
Measurements $K_S \pi^+\pi^-$

arXiv: 0704.1000, 540 fb^{-1}

Fit

no CPV: $\frac{q}{p} = 1, \mathcal{A} = \overline{\mathcal{A}} \Rightarrow \mathcal{M} = \overline{\mathcal{M}}$

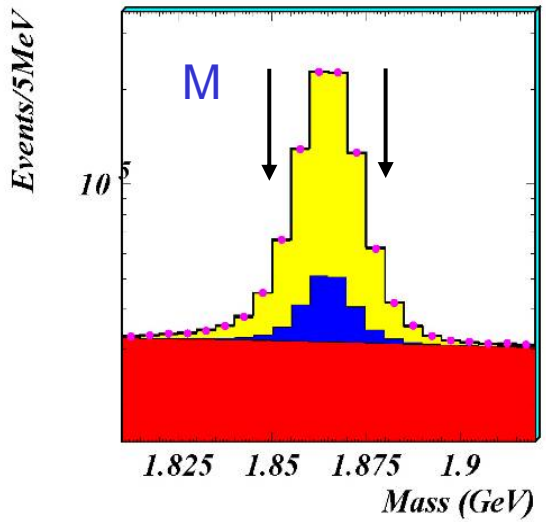
fit $\mathcal{M}(m_-^2, m_+^2, t)$ to data distribution $\Rightarrow$ x, y



Signal

M($K_S \pi^+\pi^-$) and
Q= M($K_S \pi^+\pi^-\pi_s$)- M($K_S \pi^+\pi^-$)- M(π);
3 σ signal region in M, Q

$N_{sig} = (534.4 \pm 0.8) \times 10^3$
$P \approx 95\%$



Dalitz model

$$\mathcal{A}(m_-^2, m_+^2) = \sum a_r \, e^{i\Phi_r} B(m_-^2, m_+^2)$$

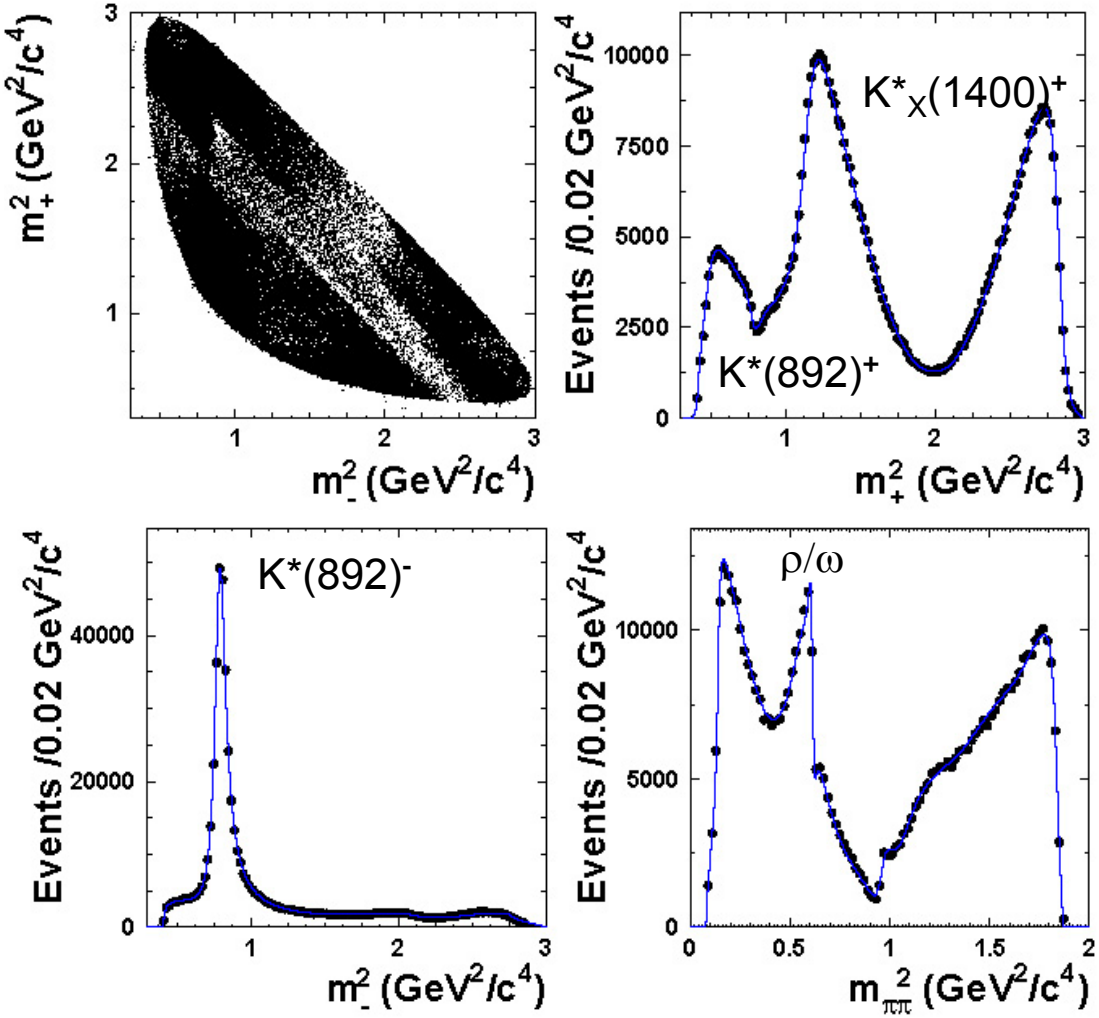
13 BW resonances, non-resonant contr.;

Measurements $K_S \pi^+\pi^-$

arXiv: 0704.1000, 540 fb^{-1}

Dalitz projection of fit

Resonance	Amplitude	Phase (deg)	Fit fraction
$K^*(892)^-$	1.629 ± 0.006	134.3 ± 0.3	0.6227
$K_0^*(1430)^-$	2.12 ± 0.02	-0.9 ± 0.8	0.0724
$K_2^*(1430)^-$	0.87 ± 0.02	-47.3 ± 1.2	0.0133
$K^*(1410)^-$	0.65 ± 0.03	111 ± 4	0.0048
$K^*(1680)^-$	0.60 ± 0.25	147 ± 29	0.0002
$K^*(892)^+$	0.152 ± 0.003	-37.5 ± 1.3	0.0054
$K_0^*(1430)^+$	0.541 ± 0.019	91.8 ± 2.1	0.0047
$K_2^*(1430)^+$	0.276 ± 0.013	-106 ± 3	0.0013
$K^*(1410)^+$	0.33 ± 0.02	-102 ± 4	0.0013
$K^*(1680)^+$	0.73 ± 0.16	103 ± 11	0.0004
$\rho(770)$	1 (fixed)	0 (fixed)	0.2111
$\omega(782)$	0.0380 ± 0.0007	115.1 ± 1.1	0.0063
$f_0(980)$	0.380 ± 0.004	-147.1 ± 1.1	0.0452
$f_0(1370)$	1.46 ± 0.05	98.6 ± 1.8	0.0162
$f_2(1270)$	1.43 ± 0.02	-13.6 ± 1.2	0.0180
$\rho(1450)$	0.72 ± 0.04	41 ± 7	0.0024
σ_1	1.39 ± 0.02	-147 ± 1	0.0914
σ_2	0.267 ± 0.013	-157 ± 3	0.0088
NR	2.36 ± 0.07	155 ± 2	0.0615



test of S-wave $\pi\pi$ contr. (f_0, $\sigma_{1,2}$): K-matrix formalism

Results (fit fractions, phases) in agreement with (measurement of ϕ_3)

PRD73, 112009 (2006)

Measurements $K_S \pi^+\pi^-$

arXiv: 0704.1000, 540 fb^{-1}

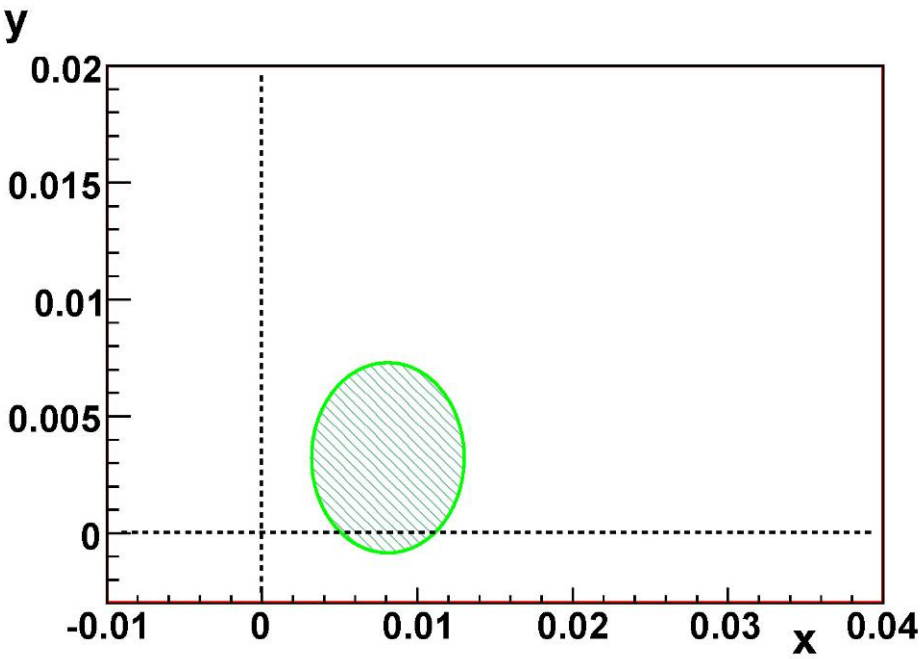
Decay-t projection of fit

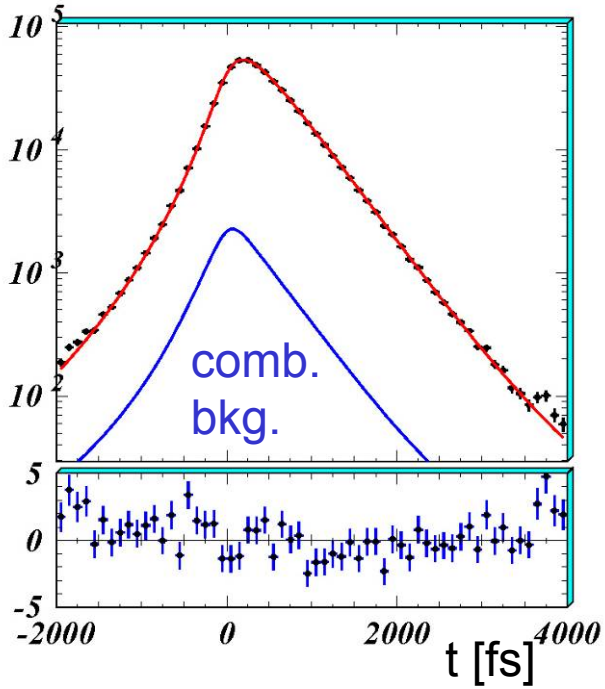
$$x = (0.80 \pm 0.29 \pm {}^{0.13}_{0.16})\%$$
$$y = (0.33 \pm 0.24 \pm {}^{0.10}_{0.14})\%$$

most sensitive meas. of x;

$x = 1.8 \pm 3.4 \pm 0.6\%$ Cleo, PRD72, 012001 (2005)

$y = -1.4 \pm 2.5 \pm 0.9\ \%$





$\tau = 409.9 \pm 0.9$ fs

$\tau_{PDG} = 410.1 \pm 1.5$ fs

Measurements K^+K^- / $\pi^+\pi^-$

hep-ex/0703036v2, 540fb^{-1}, acc. to PRL

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

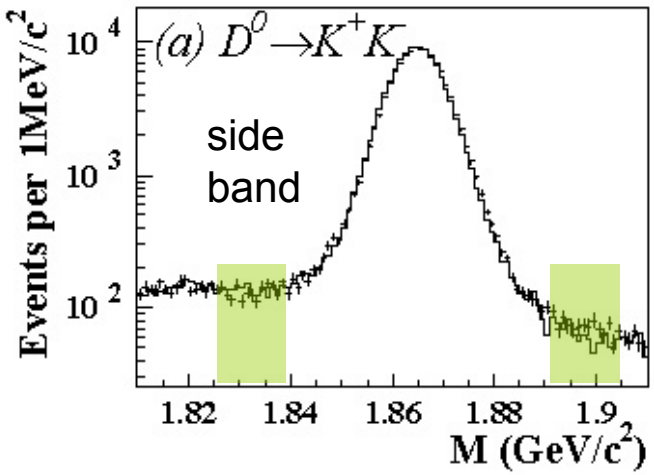
CP even final state;
in the limit of no CPV: $CP|D_2\rangle = |D_2\rangle$
$\Rightarrow$ measure $1/\Gamma_2$

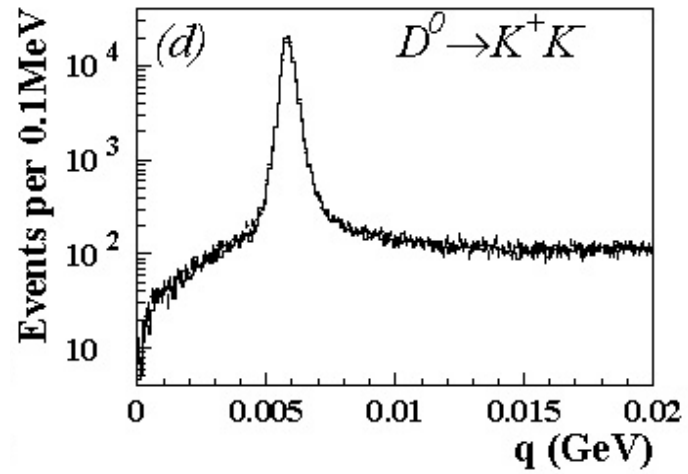
$$y_{CP} \equiv \frac{\tau(K^-\pi^+)}{\tau(K^-K^+)} - 1 = y\cos\varphi - \frac{1}{2}A_M\, x \sin\varphi = \underset{no\ CPV}{=} y$$

S. Bergman et al., PLB486, 418 (2000)

A_M, ϕ: CPV in mixing and interference

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





Signal

M, Q, σ_t selection optimized in MC

	K^+K^-	$K^-\pi^+$	$\pi^+\pi^-$
N_{sig}	111×10^3	1.22×10^6	49×10^3
P	98%	99%	92%

Measurements K^+K^- / $\pi^+\pi^-$

hep-ex/0703036v2, 540fb^{-1}, acc. to PRL

Fit

simultaneous binned likelihood fit to K^+K^- /$K^-\pi^+$/$\pi^+\pi^-$ decay-t, common free y_{CP}

$$\frac{dN}{dt} = \frac{N}{\tau}\int e^{-t'/\tau}\mathcal{R}(t-t')dt' + B(t)$$

(M sideband)

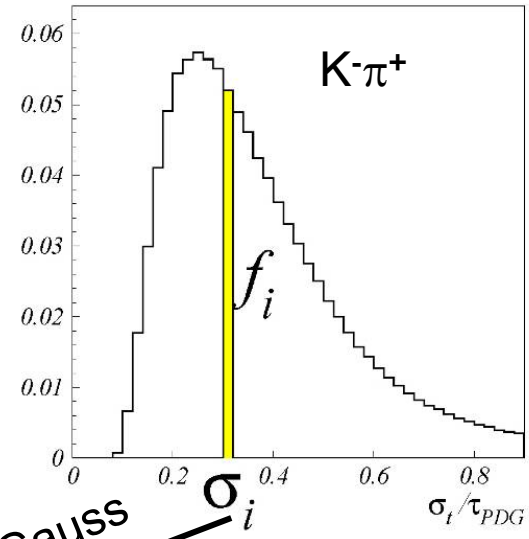
$\mathcal{R}$: ideally each σ_i Gaussian resol. term with fraction f_i;

t_{rec}-t_{gen}/σ_t : described by 3 Gaussians $\Rightarrow$ MC

$$\mathcal{R}(t-t') = \sum_{i=1}^{N} f_i \sum_{k=1}^{3} w_k G(t-t', s_k\sigma_i, t_0)$$

each $\sigma_i \rightarrow$ 3 Gauss

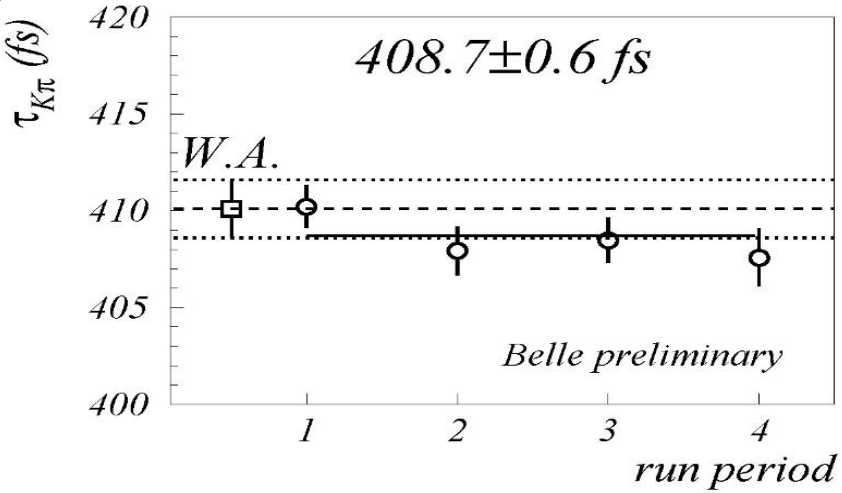
σ_t distribution



event-by-event σ_t

parameters of $\mathcal{R}$ depend slightly on data taking conditions

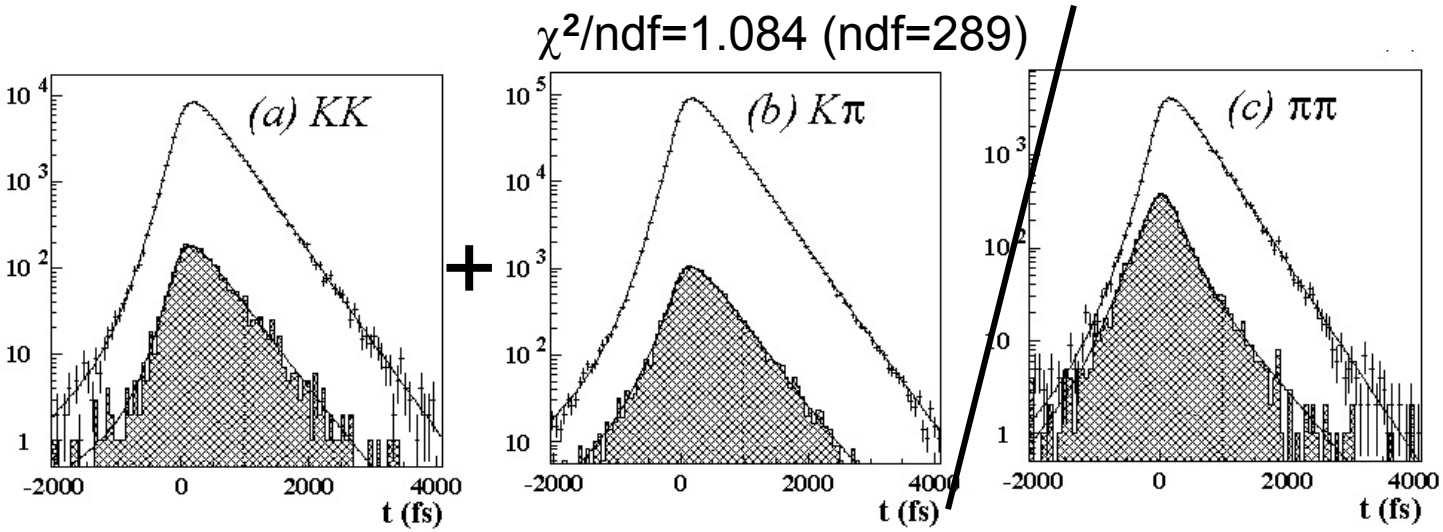
τ = 408.7±0.6 fs

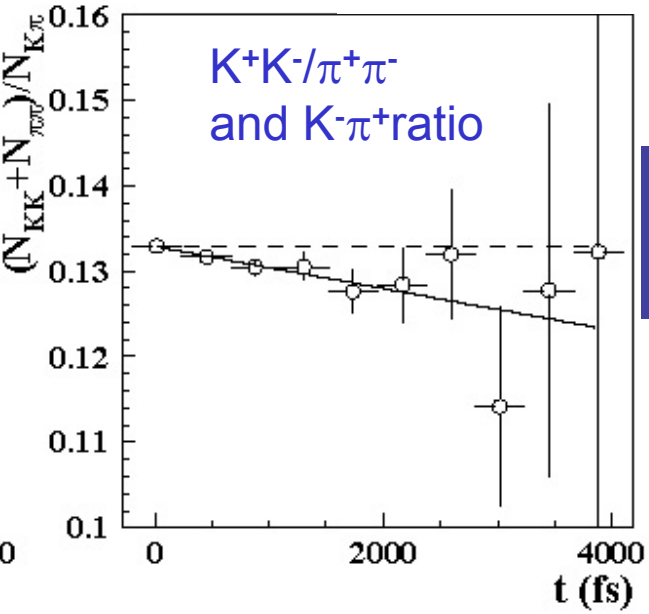


hep-ex/0703036v2, 540fb^{-1}, acc. to PRL

Measurements K^+K^- / $\pi^+\pi^-$

Result

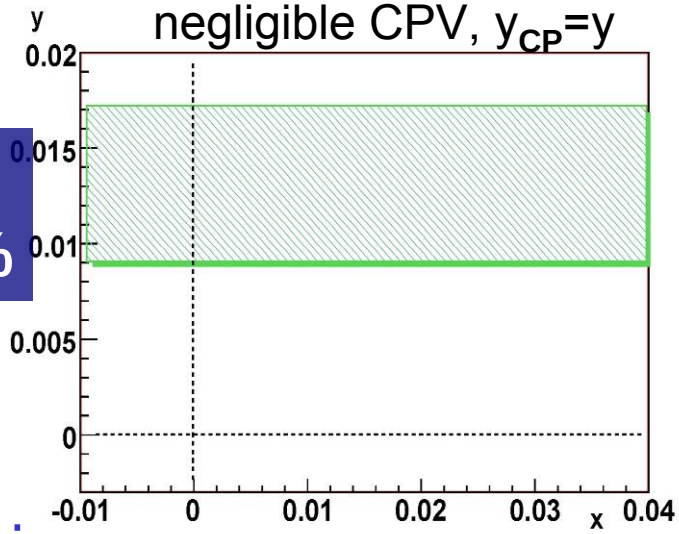




difference of lifetimes visually observable

y_{CP} = (1.31 ± 0.32 ± 0.25) %

3.2 σ from zero
(4.1 σ stat. only)



evidence for D^0 mixing
(regardless of possible CPV)

Measurements $K^+\pi^-$

BaBar, hep-ex/0703020, 384fb^{-1}, acc. to PRL

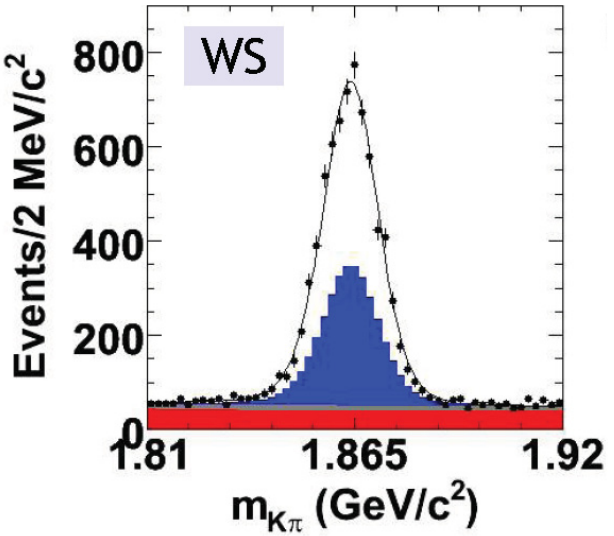
Reminder

$$\left|\left\langle K^+\pi^- \middle| D^0(t)\right\rangle\right|^2 \propto \left[R_D + \sqrt{R_D}\,y't + \frac{x'^2+y'^2}{4}t^2\right]e^{-t}$$

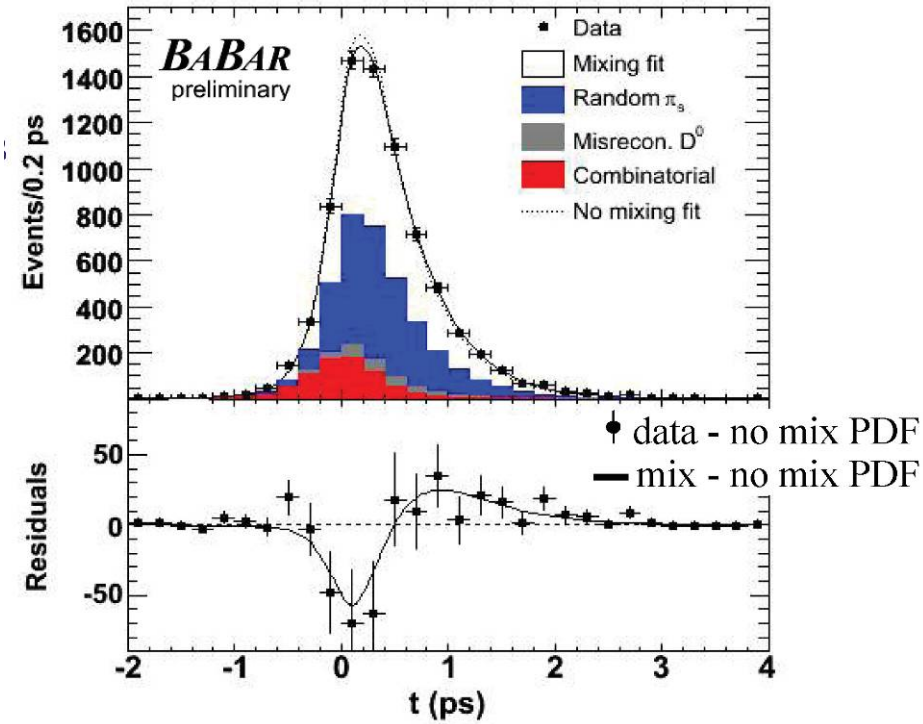
Signal:

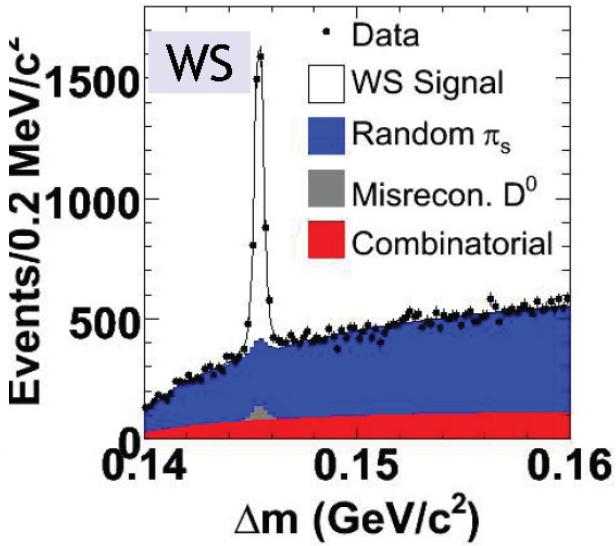
M= M(Kπ)

ΔM = M(K π π_{slow}) - M(Kπ)



Fit

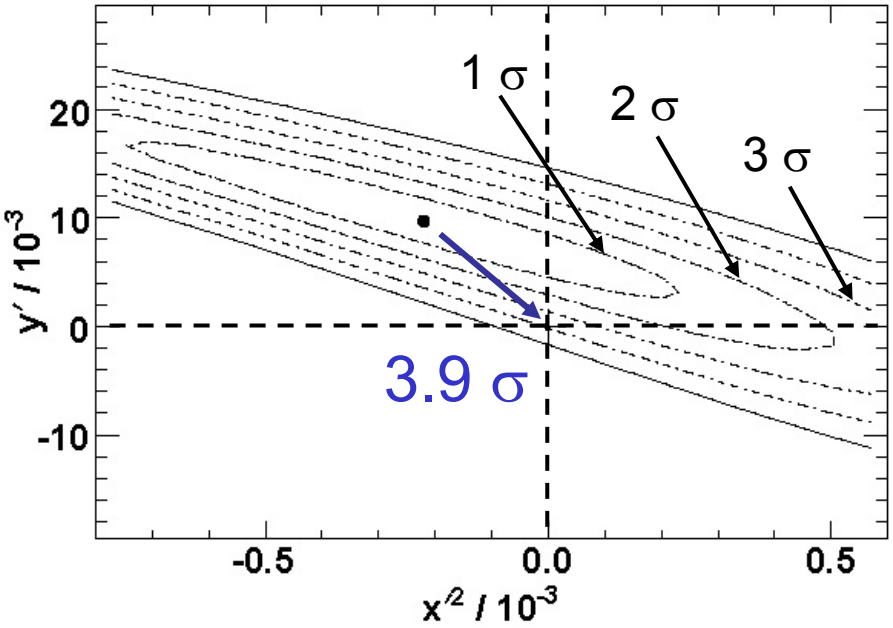




$N_{WS} = 4030 \pm 90$

Measurements $K^+\pi^-$

BaBar, hep-ex/0703020, 384fb^{-1}, acc. to PRL



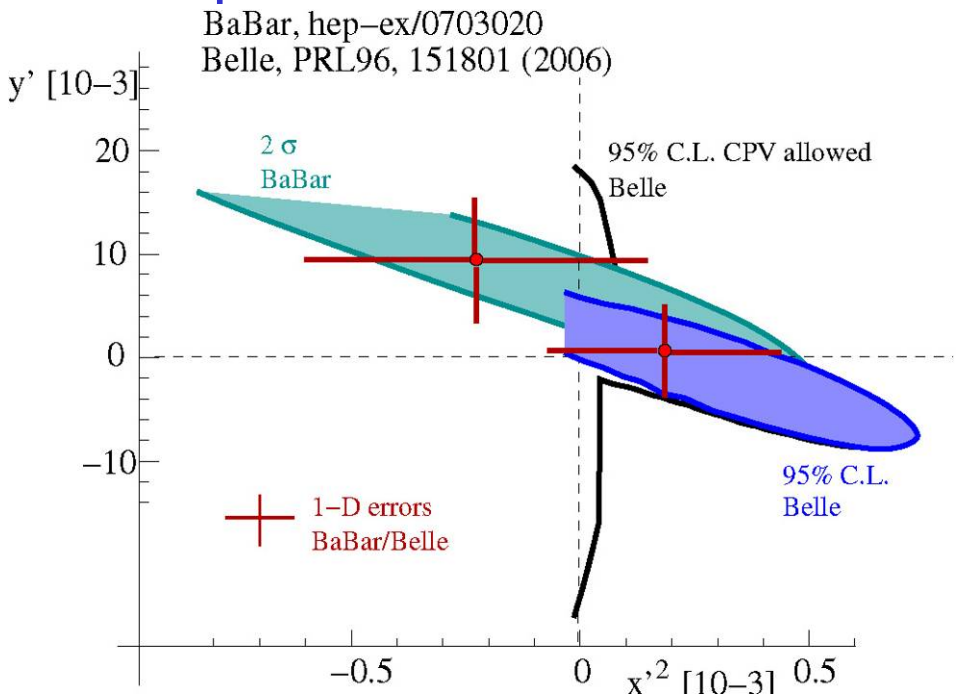
Result

$R_D = (3.03 \pm 0.19) \cdot 10^{-3}$
$x'^2 = (-0.22 \pm 0.37) \cdot 10^{-3}$
$y' = (9.7 \pm 5.4) \cdot 10^{-3}$

including sys. error

evidence for (x,y) ≠ (0,0)

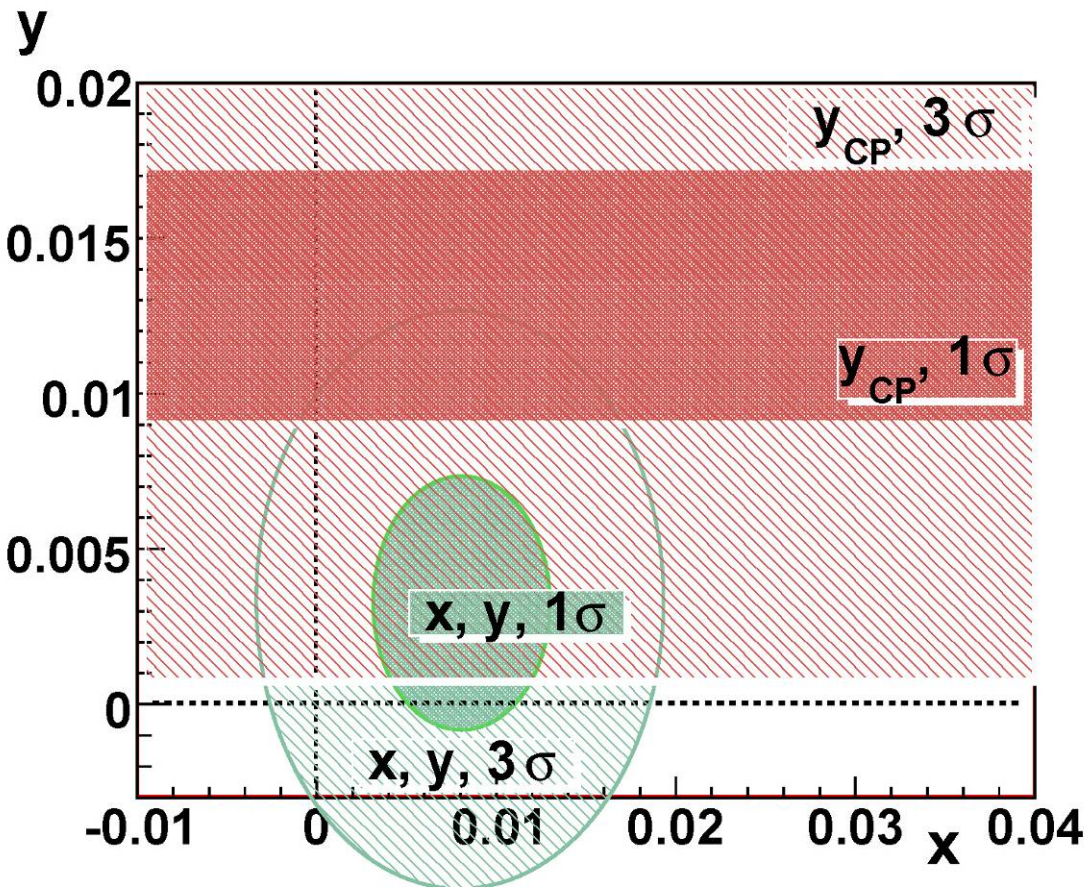
Comparison



consistent

Measurements

Results



$K_S \pi^+\pi^-$: (x,y)=(0,0) has C.L. 2.6%

K^+K^- / $\pi^+\pi^-$: y=0 has C.L. 6×10^{-4}

Measurements

Combination

1996 FNAL E791 $R_M = (0.11\ ^{+0.30}_{-0.27}\ ^{+0.00}_{-0.014})\%$
2005 CLEO II.V $R_M = (0.16 \pm 0.29 \pm 0.29)\%$
2004 BaBar $R_M = (0.23 \pm 0.12 \pm 0.04)\%$
2005 Belle $R_M = (0.020 \pm 0.047 \pm 0.014)$

R_M semil.

1999 FNAL E791 $\Delta\Gamma = (0.04 \pm 0.14 \pm 0.05)\ ps^{-1}$ ($y_{CP} = (0.8 \pm 3.1)\%$)
2000 FOCUS $y_{CP} = (3.42 \pm 1.39 \pm 0.74)\%$
2002 CLEO II.V $y_{CP} = (-1.2 \pm 2.5 \pm 1.4)\%$
2003 BaBar $y_{CP} = (0.8 \pm 0.4\ ^{+0.5}_{-0.4})\%$
2002 Belle $y_{CP} = (-0.5 \pm 1.0\ ^{+0.7}_{-0.8})\%$
2007 Belle $y_{CP} = (1.31 \pm 0.32 \pm 0.25)\%$

y_{CP}

2006 Belle $x'^2 = (0.018\ ^{+0.021}_{-0.023})\%$ $y' = (0.06\ ^{+0.40}_{-0.39})\%$
2007 BaBar $x'^2 = (-0.022 \pm 0.030 \pm 0.021)\%$ $y' = (0.97 \pm 0.44 \pm 0.31)\%$

x'^2, y'

2006 BaBar $K^+\pi^-\pi^0$ $R_M = (0.023\ ^{+0.018}_{-0.014} \pm 0.004)\%$
2006 BaBar $K^+\pi^-\pi^+\pi^-$ $R_M = (0.019\ ^{+0.016}_{-0.015} \pm 0.002)\%$

R_M Knπ

2005/2007 CLEO II.V $x = (1.9\ ^{+3.2}_{-3.3} \pm 0.4 \pm 0.4)\%$ $y = (-1.4 \pm 2.4 \pm 0.8 \pm 0.4)\%$
2007 Belle $x = (0.80 \pm 0.29 \pm 0.17)\%$ $y = (0.33 \pm 0.24 \pm 0.15)\%$

x, y

2006 CLEO-c $R_M = (0.17 \pm 0.15)\%$ $y = (-5.8 \pm 6.6)\%$ $\cos\delta_{K\pi} = 1.09 \pm 0.66$

Cleo-c

Measurements average

$x = (0.94 \pm 0.36)\%$
$y = (0.68 \pm 0.21)\%$
$\delta = 21^o \pm 19^o$

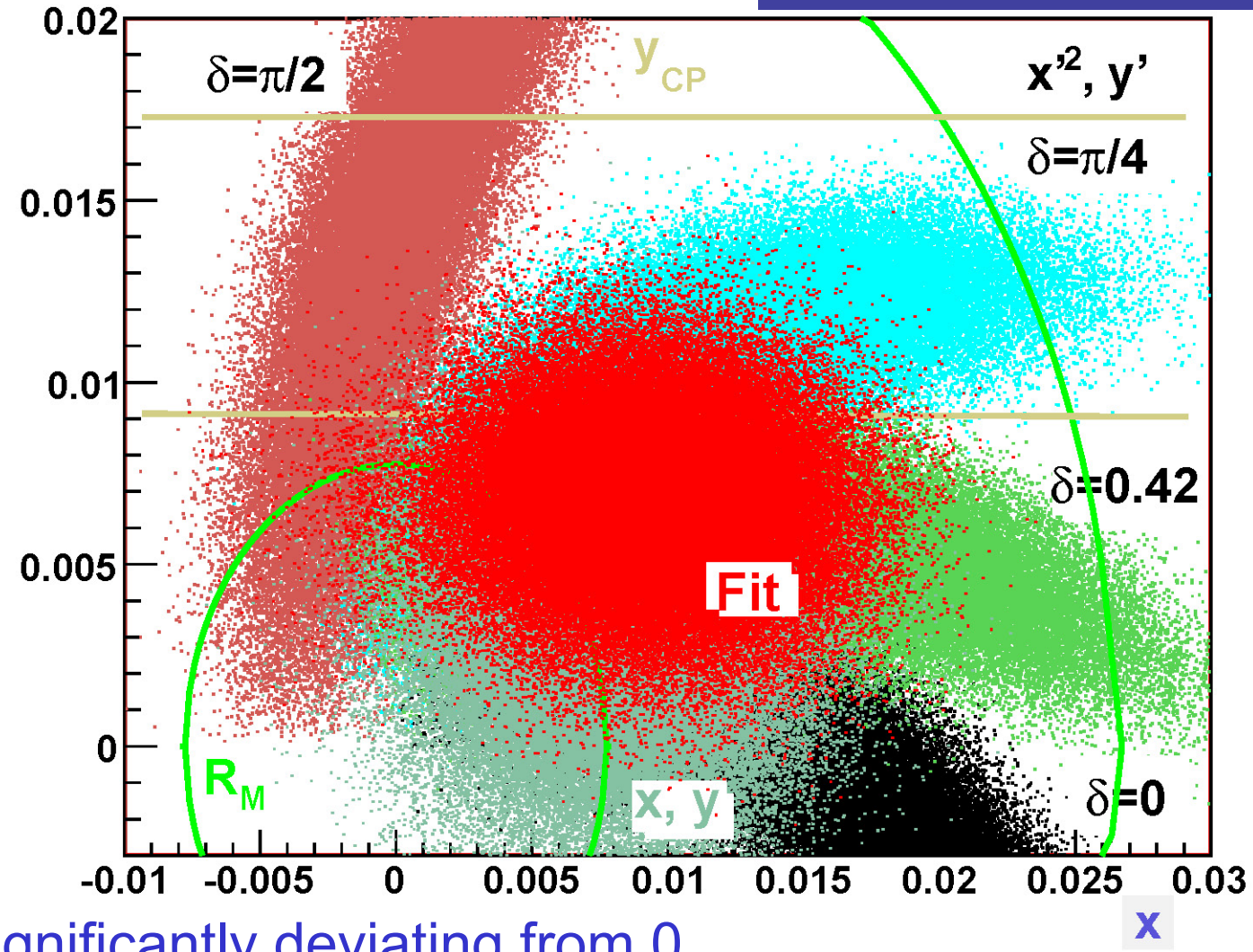
Average y

unofficial!

fit to individual measurements with x, y, δ free

assuming Gaussian p.d.f.'s;

correlation for $K^+\pi^-$;



x, y ~ 1%, significantly deviating from 0

Measurements CPV

CPV in D^0 system

$$\langle f|H|D^0(t)\rangle \underbrace{\neq}_{CPV} \langle \bar{f}|H|\bar{D}^0(t)\rangle$$

first two generations involved;

$$\begin{pmatrix} 1-\frac{1}{2}\lambda^2-\frac{1}{8}\lambda^4 & \lambda & A\lambda^3(\rho-i\eta) \\ -\lambda+\frac{1}{2}A^2\lambda^5[1-2(\rho+i\eta)] & 1-\frac{1}{2}\lambda^2-\frac{1}{8}\lambda^4(1+4A^2) & A\lambda^2 \\ A\lambda^3[1-(1-\frac{1}{2}\lambda^2)(\rho+i\eta)] & -A\lambda^2+\frac{1}{2}A\lambda^4[1-2(\rho+i\eta)] & 1-\frac{1}{2}A^2\lambda^4 \end{pmatrix}$$

Wolfenstein param.,

$$\varphi \sim \frac{2\eta A^2\lambda^5}{\lambda} \sim O(10^{-3})$$

CPV in D^0 very small, $\leq 10^{-3}$; parameterization:

$$\frac{q}{p} \neq 1;\ \frac{q}{p} \equiv (1+\frac{A_M}{2})e^{i\varphi};\ A_M, \varphi \neq 0$$

$D^0 \rightarrow K^+\pi^-, K^+K^- / \pi^+\pi^-, K_S\pi^+\pi^-$

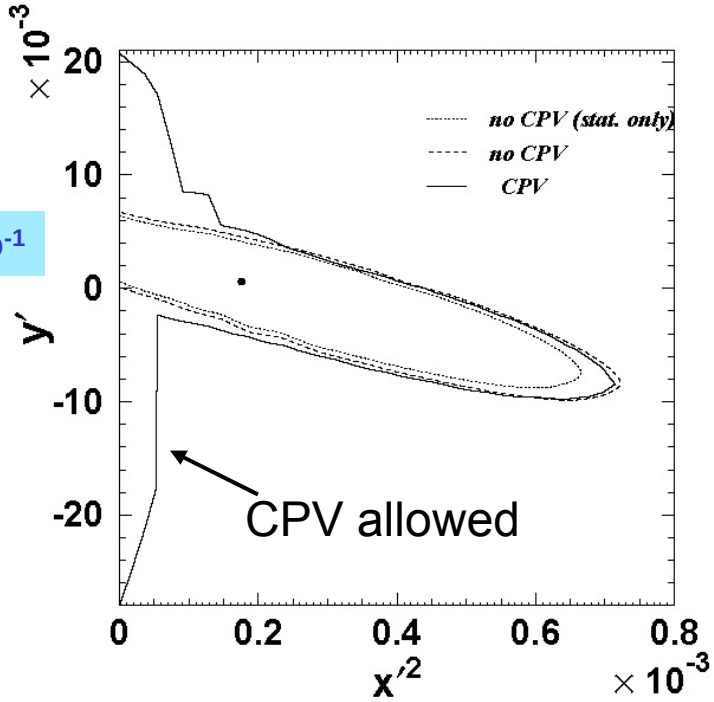
t distributions depend also on CPV parameters

x, y at upper limit of SM expectation → search for CPV;
at current level of sensitivity positive signal clear indication of NP;

Measurements CPV

CPV in $D^0 \to K^+\pi^-$ PRL96, 151801 (2006), 400 fb^{-1}

CPV allowed fit:
separate D^0 and $\overline{D}^0$ tags
$(x'^2, y', R_D) \to (x'^{\pm 2}, y'^{\pm}, R_D^{\pm})$



$$A_D = \frac{R_D^+ - R_D^-}{R_D^+ + R_D^-} \qquad A_M = \frac{R_M^+ - R_M^-}{R_M^+ + R_M^-}$$

$A_D = (23 \pm 47) \cdot 10^{-3}$ direct CPV
$A_M = (670 \pm 1200) \cdot 10^{-3}$ indirect CPV

hep-ex/0703036v2, 540fb^{-1}, acc. to PRL

CPV in $D^0 \to K^+K^-$ / $\pi^+\pi^-$

$A_\Gamma = (0.01 \pm 0.30 \pm 0.15)\ \%$ indirect CPV

$$y_{CP} \equiv \frac{\tau(K^-\pi^+)}{\tau(K^-K^+)} - 1 = y\cos\varphi - \frac{1}{2}A_M\, x \sin\varphi$$

$$A_\Gamma = \frac{\tau(\overline{D}^0 \to K^-K^+) - \tau(D^0 \to K^-K^+)}{\tau(\overline{D}^0 \to K^-K^+) + \tau(D^0 \to K^-K^+)} = \frac{1}{2}A_M\, y\cos\varphi - x\sin\varphi$$

Prospects

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

arXiv: 0704.1000, 540 fb^{-1}

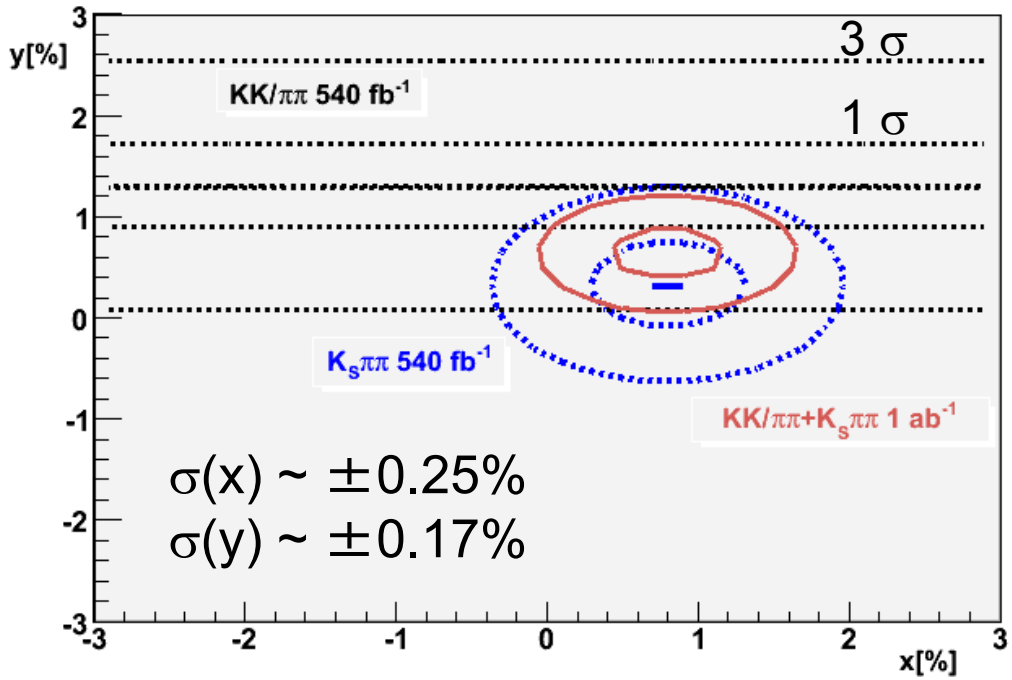
preliminary study:
$\sigma(|q/p| \approx 1 + A_M/2) \sim 0.30$,
$\sigma(\phi) \sim 0.3$ rad

individual meas. test CPV with sensitivity ~ R(0.3)

no evidence so far

Prospects

near future: 1 ab^{-1}



Prospects

Super-B

rough expectations, 5 ab^{-1}

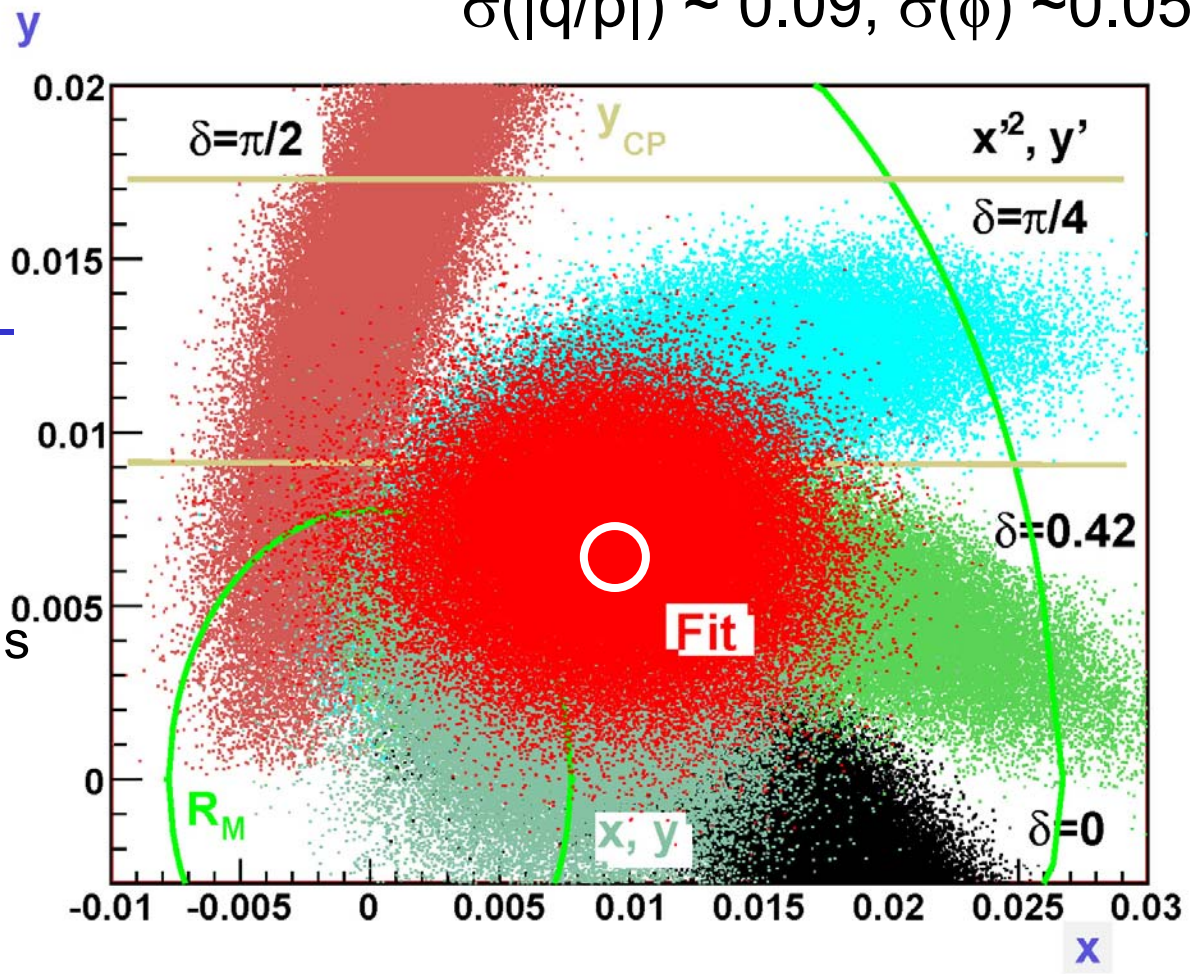
combination of results

$\sigma(x) \sim \sigma(y) \sim 0.10\%$ mixing

$\sigma(|q/p|) \sim 0.09$, $\sigma(\phi) \sim 0.05$ CPV

possible CPV
- New Physics -
tested with
~ R(5) better
sensitivity;
(several extensions
of SM predict
CPV ~ R(1%))

Y. Grossman et al.,
hep-ph/0609178



Summary

- Belle and BaBar presented evidence for D^0 mixing
  $x = (0.94 \pm 0.36)\%$
  $y = (0.68 \pm 0.21)\%$

- Values of mixing parameters at upper end of SM expectations;
  new measurements to further constrain x, y
  (and hope for more accurate predictions?)

- Search for CPV = NP search;
  Super-B factory would allow for sensitive searches in reasonable extensions of SM