FPCP 2008 @ NTU, May 5-9, 2008

D^0 mixing & CPV from Belle & BaBar

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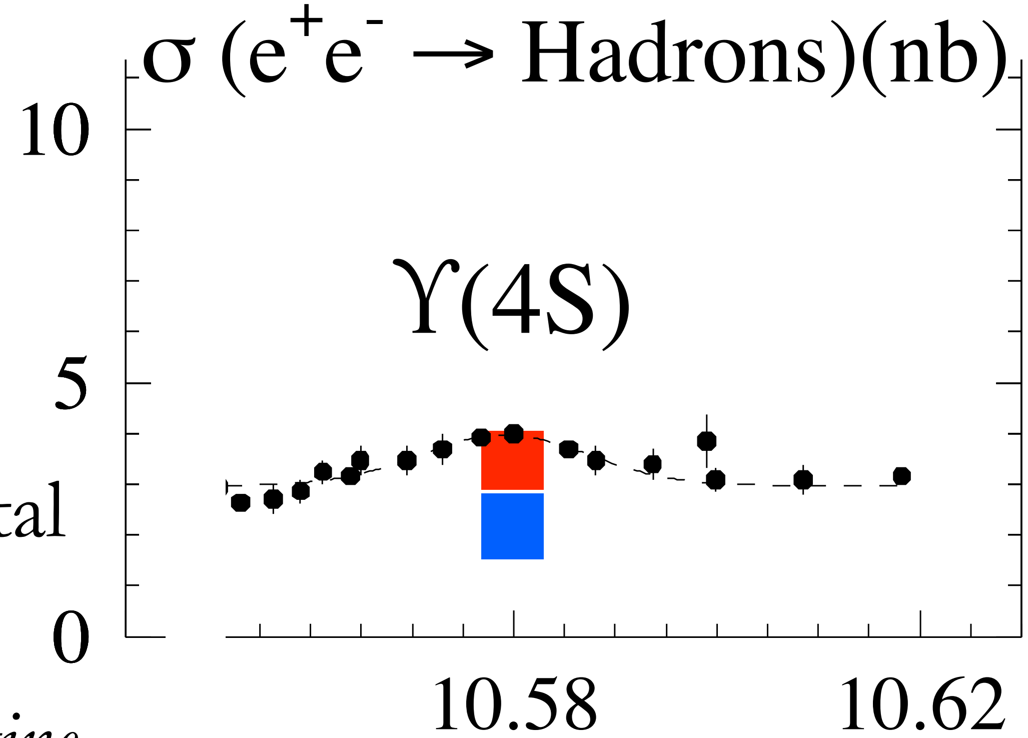
There is an unimpeachable reason to visit the Sistine Chapel, namely to see Michelangleo's frescoes. ... Most of you who have been [there] will have forgotten ... there are wonderful frescoes by other famous masters, namely Botticelli...

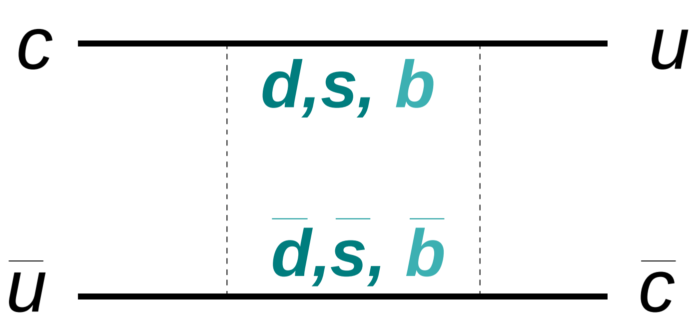
... I concede that the fascination of charm decays might not match that of beauty decays any more than Botticelli can match the power of Michelangelo. Of course, Botticelli is still Botticelli, i.e. a first-rate artist, but what about charm?

... I will argue that future charm studies can provide us with first rate lessons of fundamental dynamics...

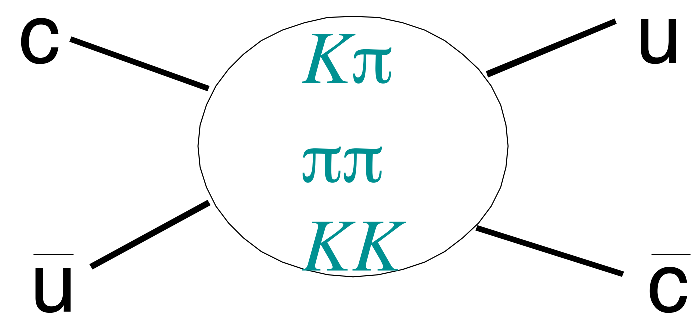
- I. Bigi, "*Charm Physics - Like Botticelli in the Sistine Chapel (2001)*"



Neutral Meson Mixing



"box" diagram: Δm



D0 mixing is dominated by long-distance contributions (both Δm and $\Delta\Gamma$)

Meson	flavors	$\Delta m/\Gamma$	$\Delta\Gamma/2\Gamma$	observed?
K^0	$\bar{s}d$	0.474	0.997	1958
B^0	$\bar{b}d$	0.77	< 1%	1987
B_s^0	$\bar{b}s$	27	0.15 ±0.07	2006
D^0	$c\bar{u}$	< 0.029	0.011±0.005	March 2007

D^0 mixing - the Formalism

$$i\frac{\partial}{\partial t}\begin{pmatrix} |D^0\rangle \\ |\bar{D}^0\rangle \end{pmatrix} = \left(M - \frac{i}{2}\Gamma\right)\begin{pmatrix} |D^0\rangle \\ |\bar{D}^0\rangle \end{pmatrix}$$

$$|D_1(t)\rangle = |D_1\rangle e^{-(\Gamma_1/2+im_1)}$$
$$|D_2(t)\rangle = |D_2\rangle e^{-(\Gamma_2/2+im_2)}$$

$$|D^0\rangle = \left(|D_1\rangle + |D_2\rangle\right)/2p$$
$$|\bar{D}^0\rangle = \left(|D_1\rangle - |D_2\rangle\right)/2q$$

$$\begin{aligned} |D^0(t)\rangle &= e^{-(\overline{\Gamma}/2+i\overline{m})t}\left\{\cosh\left[(...)t\right]|D^0\rangle + \frac{q}{p}\sinh\left[(...)t\right]|\bar{D}^0\rangle\right\} \\ |\bar{D}^0(t)\rangle &= e^{-(\overline{\Gamma}/2+i\overline{m})t}\left\{\frac{p}{q}\sinh\left[(...)t\right]|D^0\rangle + \cosh\left[(...)t\right]|\bar{D}^0\rangle\right\} \end{aligned}$$

$$\overline{m} \equiv (m_1+m_2)/2 \qquad \overline{\Gamma} \equiv (\Gamma_1+\Gamma_2)/2$$
$$\Delta m \equiv m_2 - m_1 \qquad \Delta\Gamma \equiv \Gamma_2 - \Gamma_1$$

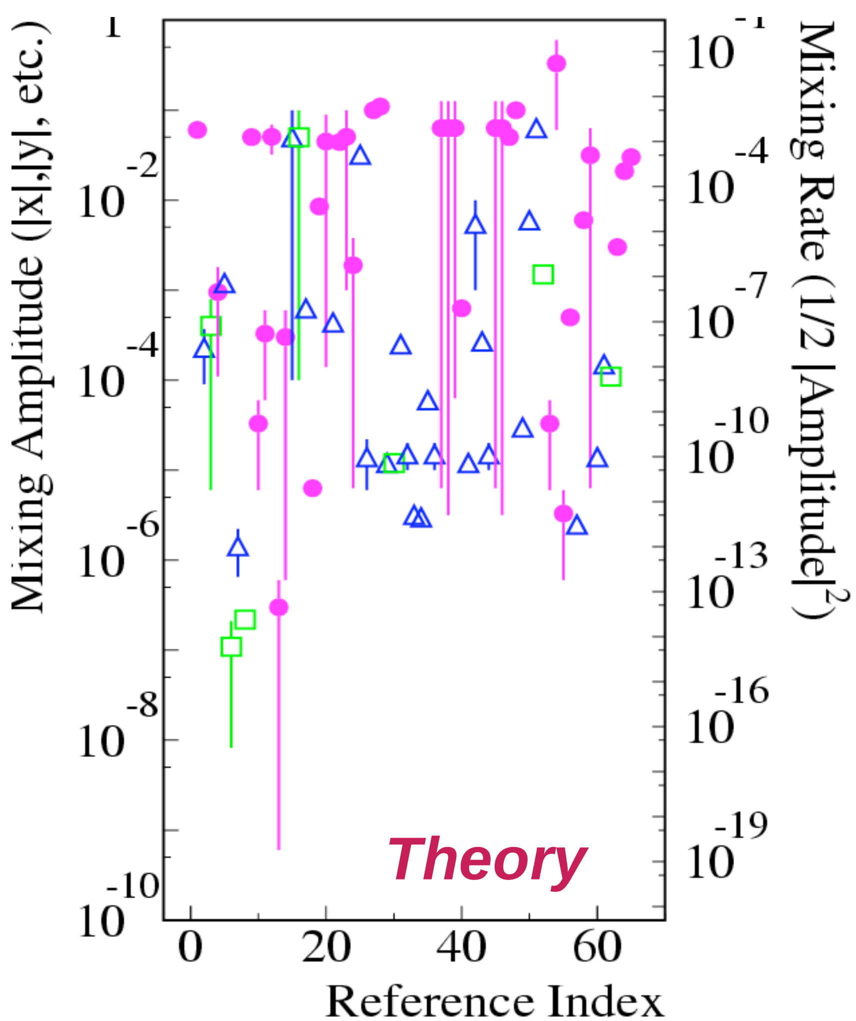
$$(...) = \frac{\Delta\Gamma}{4} + i\frac{\Delta m}{2}$$

D^0 mixing - the Formalism

For $\Delta m\, t \ll 1$ and $\Delta\Gamma\, t \ll 1$

$$|\langle f|H|D^0(t)\rangle|^2 \propto e^{-\overline{\Gamma}t}\left\{1+\left(y\mathcal{R}(\lambda)-x\mathcal{I}(\lambda)\right)\overline{\Gamma}t+|\lambda|^2\frac{x^2+y^2}{4}(\overline{\Gamma}t)^2\right\}$$

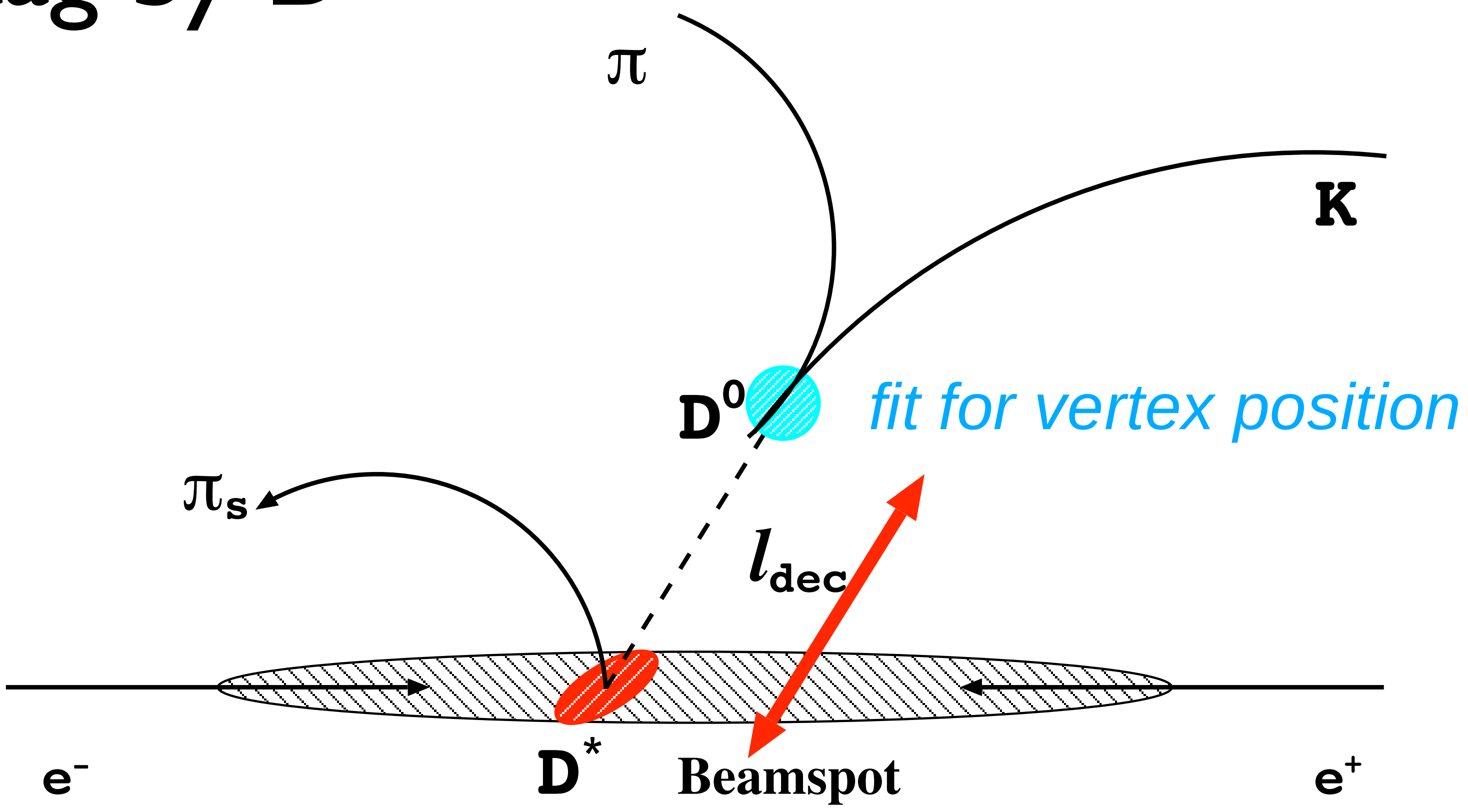
$$x \equiv \frac{\Delta m}{\overline{\Gamma}} \qquad y \equiv \frac{\Delta\Gamma}{2\overline{\Gamma}} \qquad \lambda \equiv \frac{q}{p}\frac{\mathcal{A}(\bar{D}^0 \to f)}{\mathcal{A}(D^0 \to f)}$$



$$\boldsymbol{x \lesssim y} \;\sim\; \begin{array}{ll} \mathbf{10^{-6}-10^{-3}} & \textbf{(short distance)} \\ \mathbf{10^{-3}-10^{-2}} & \textbf{(long distance)} \end{array}$$

D^0 mixing - key exp'tal features

- Flavor tag by D*



- p(D*) > ~2.5 GeV to eliminate D^0's from B decays

D^0 mixing - exp'tal results

∃ various measurements using

- Lifetime difference
  - PRL 98, 211803
  - 0712.2249
- Hadronic D^0 decays
  - PRL 99, 131803
  - PRL 98, 211802
- Semileptonic D^0 decays
  - 0802.2952
  - PRD 76, 014018

BELLE

D^0 mixing - by lifetime difference

- Study D^0 mixing by apparent lifetime difference for $D^0 \to K^+K^-$, $\pi^+\pi^-$ and $D^0 \to K^-\pi^+$
- Approximately, the effective lifetimes are:

$$\varphi_f \equiv \arg(\lambda)$$

$$\tau^+_{hh} = \tau_{K\pi} / \left[1 + \left|\frac{q}{p}\right| (y \cos\varphi_f - x \sin\varphi_f)\right]$$

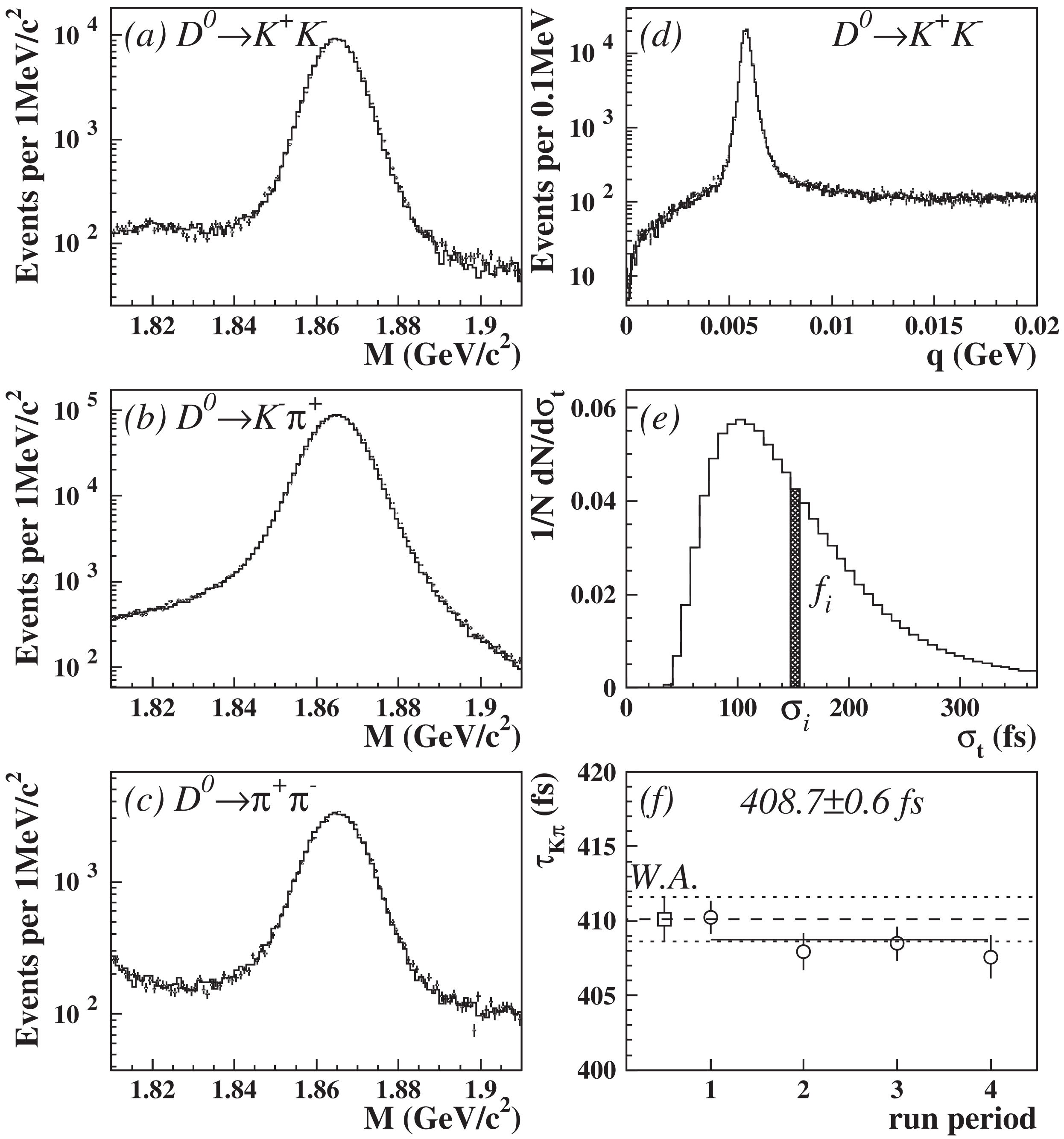
$$\tau^-_{hh} = \tau_{K\pi} / \left[1 + \left|\frac{p}{q}\right| (y \cos\varphi_f + x \sin\varphi_f)\right]$$

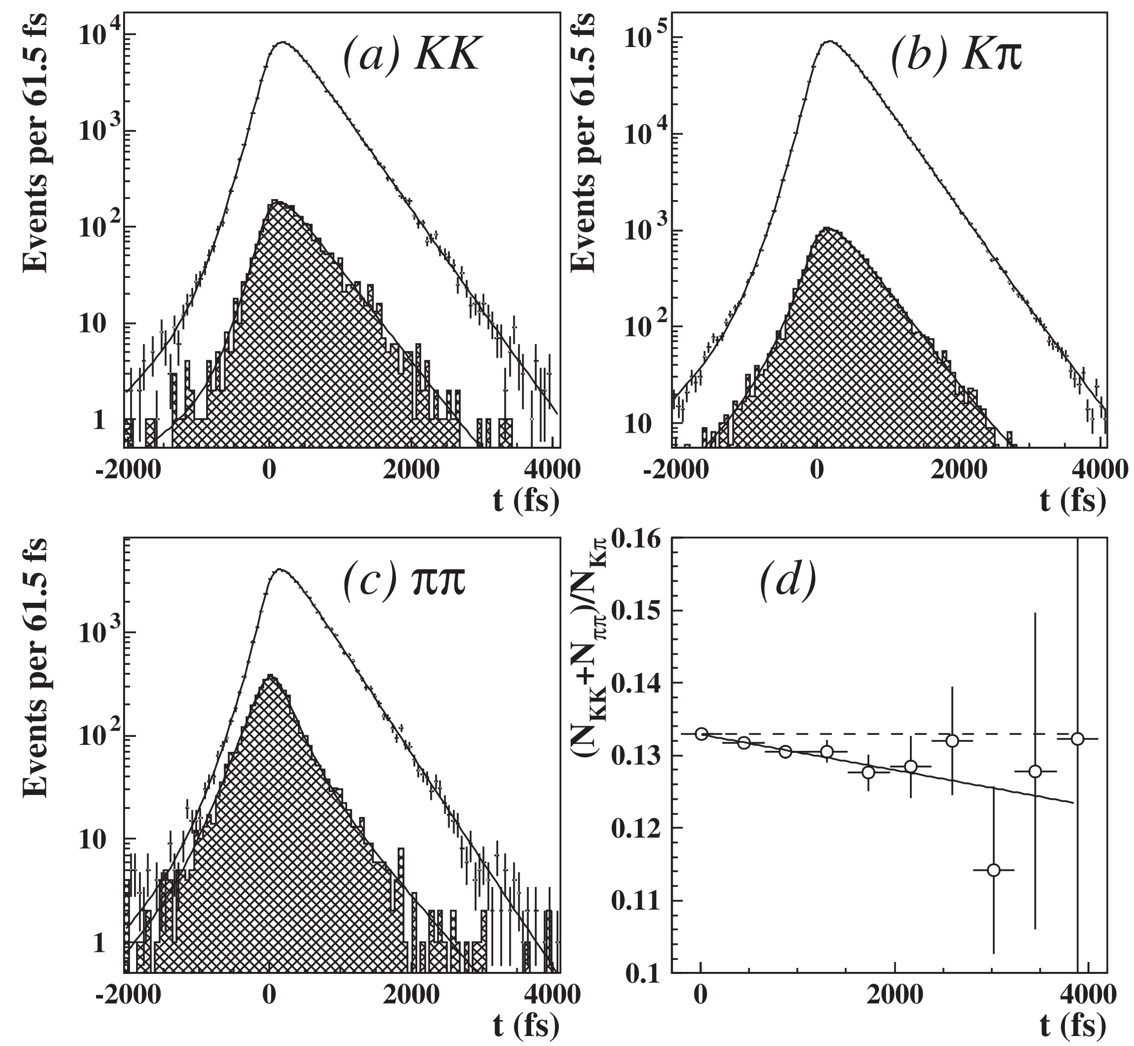
$$y_{CP} = \frac{\tau_{k^\pm\pi^\mp}}{\langle \tau_{h^+h^-} \rangle} - 1 \xrightarrow[\text{conserved}]{\text{CP}} y_{CP} = y = \Delta\Gamma / 2\overline{\Gamma}$$

$$A_\Gamma = \frac{\tau^+_{hh} - \tau^-_{hh}}{\tau^+_{hh} + \tau^-_{hh}} \qquad \Delta Y = \frac{\tau_{k^\pm\pi^\mp}}{\langle \tau_{h^+h^-} \rangle} A_\Gamma \xrightarrow[\text{conserved}]{\text{CP}} 0$$

PRL 98, 211803 (2007)

D^0 mixing - by lifetime difference



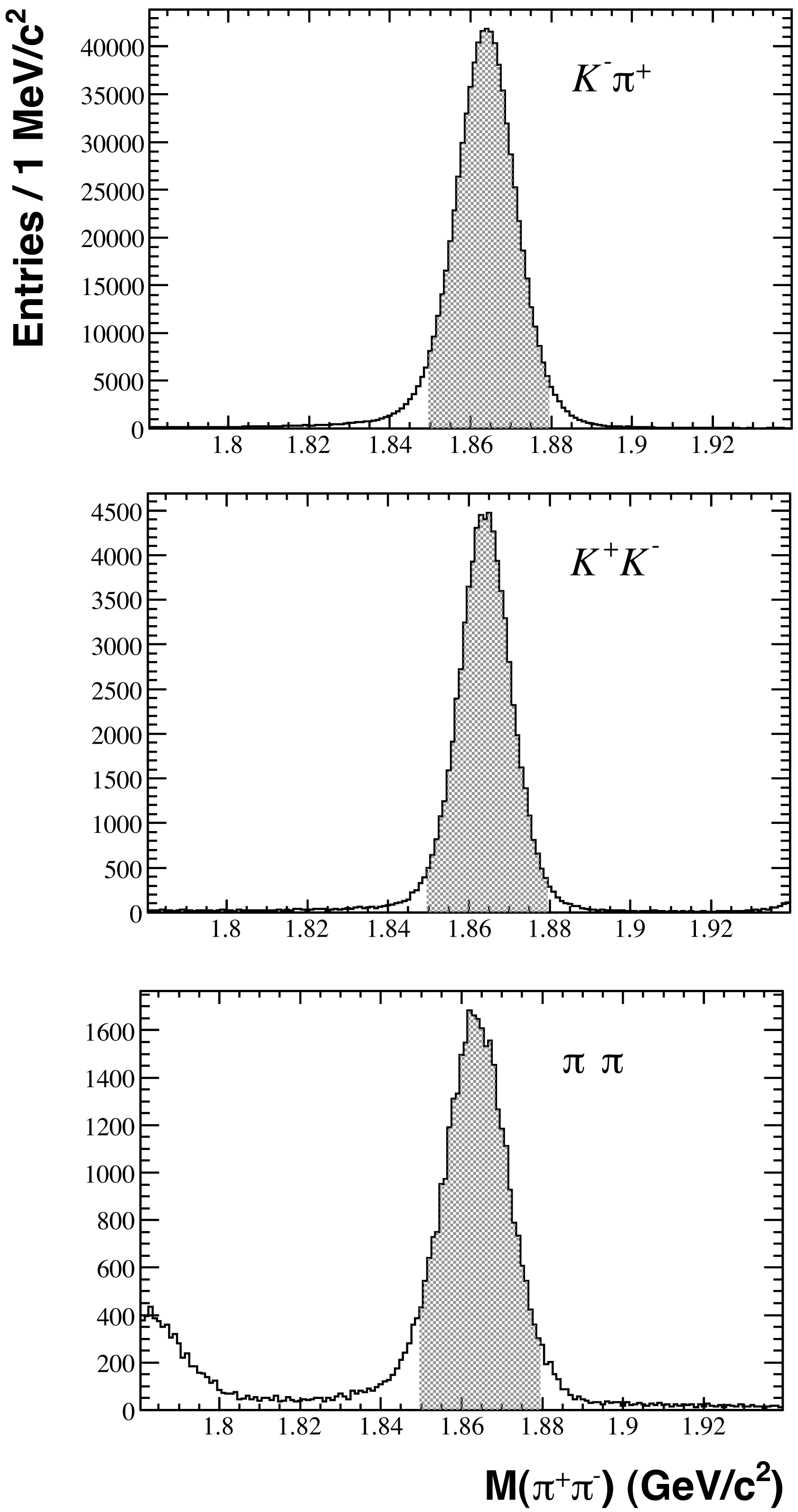


$$y_{CP} = (1.31 \pm 0.32 \pm 0.25)\%$$

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

0712.2249

D^0 mixing - by lifetime difference



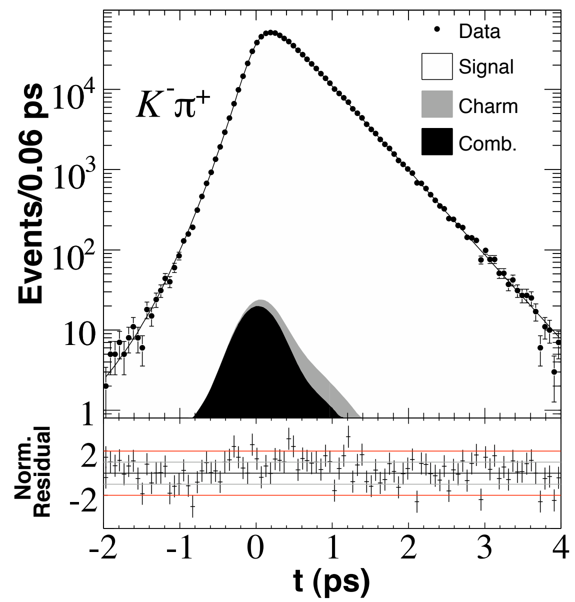
- Background events may contain effects differing in each mode
- Event selection is chosen for high purity
- e.g. require $|\delta m - q_0| < 0.8\ \mathrm{MeV/c^2}$

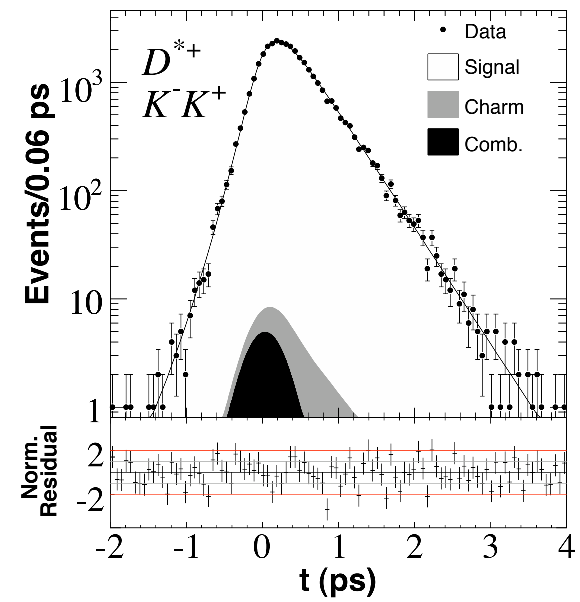
  $q_0 = 145.4\ \mathrm{MeV/c^2}$: nominal value for $D^{*+} - D^0$ mass difference (δm)

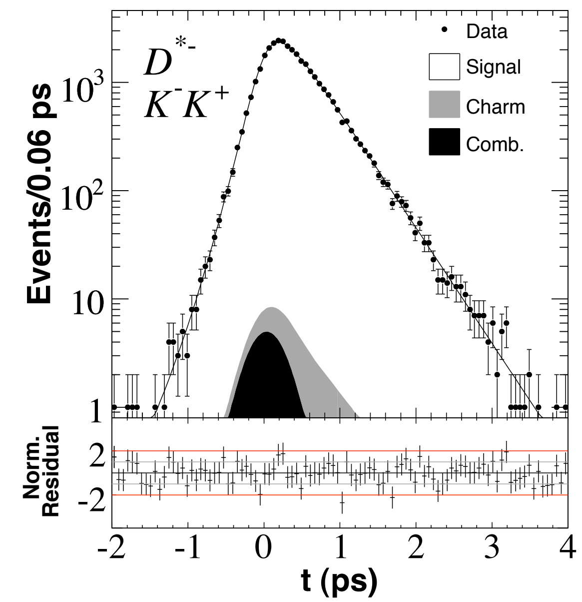
Sample	Size	Purity (%)
$K^-\pi^+$	730,880	99.9
K^-K^+	69,696	99.6
$\pi^-\pi^+$	30,679	98.0

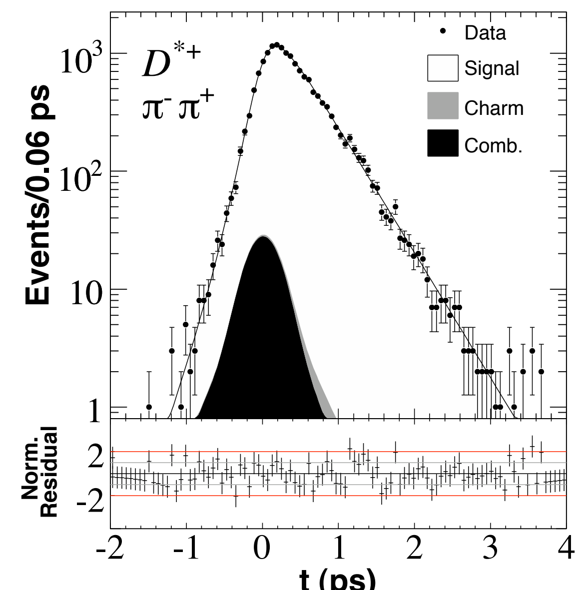
0712.2249

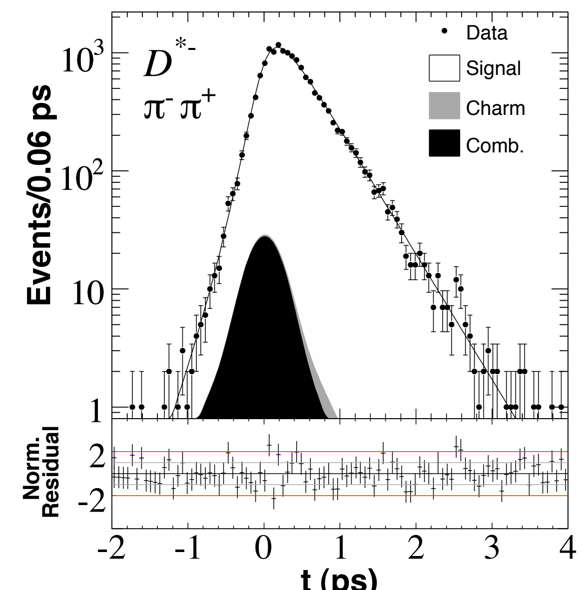
D^0 mixing - by lifetime difference

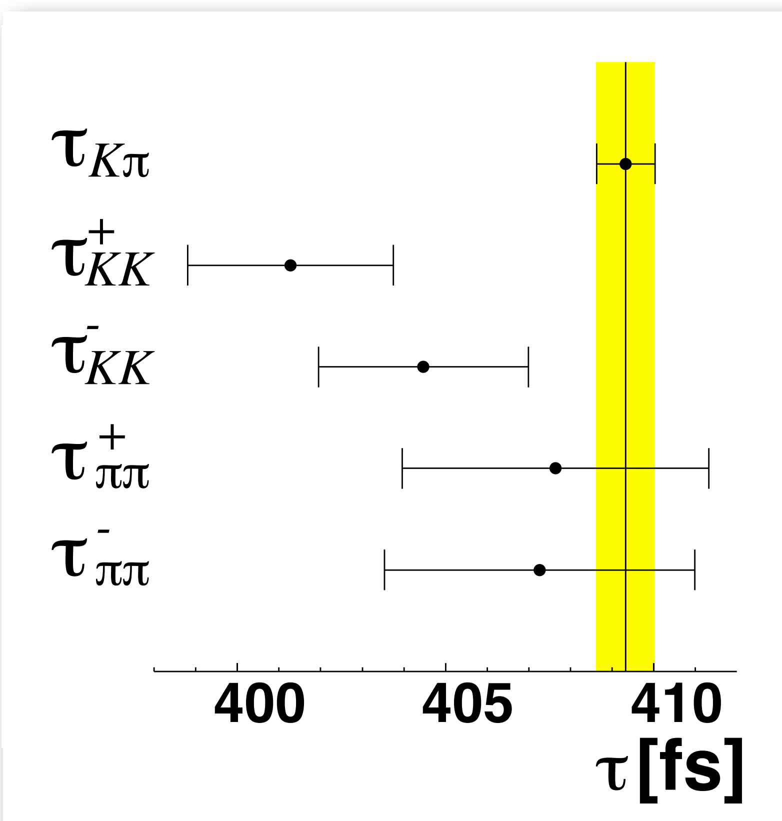












* BaBar's A_Γ def. is opposite to Belle's

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

0712.2249

D^0 mixing - by lifetime difference

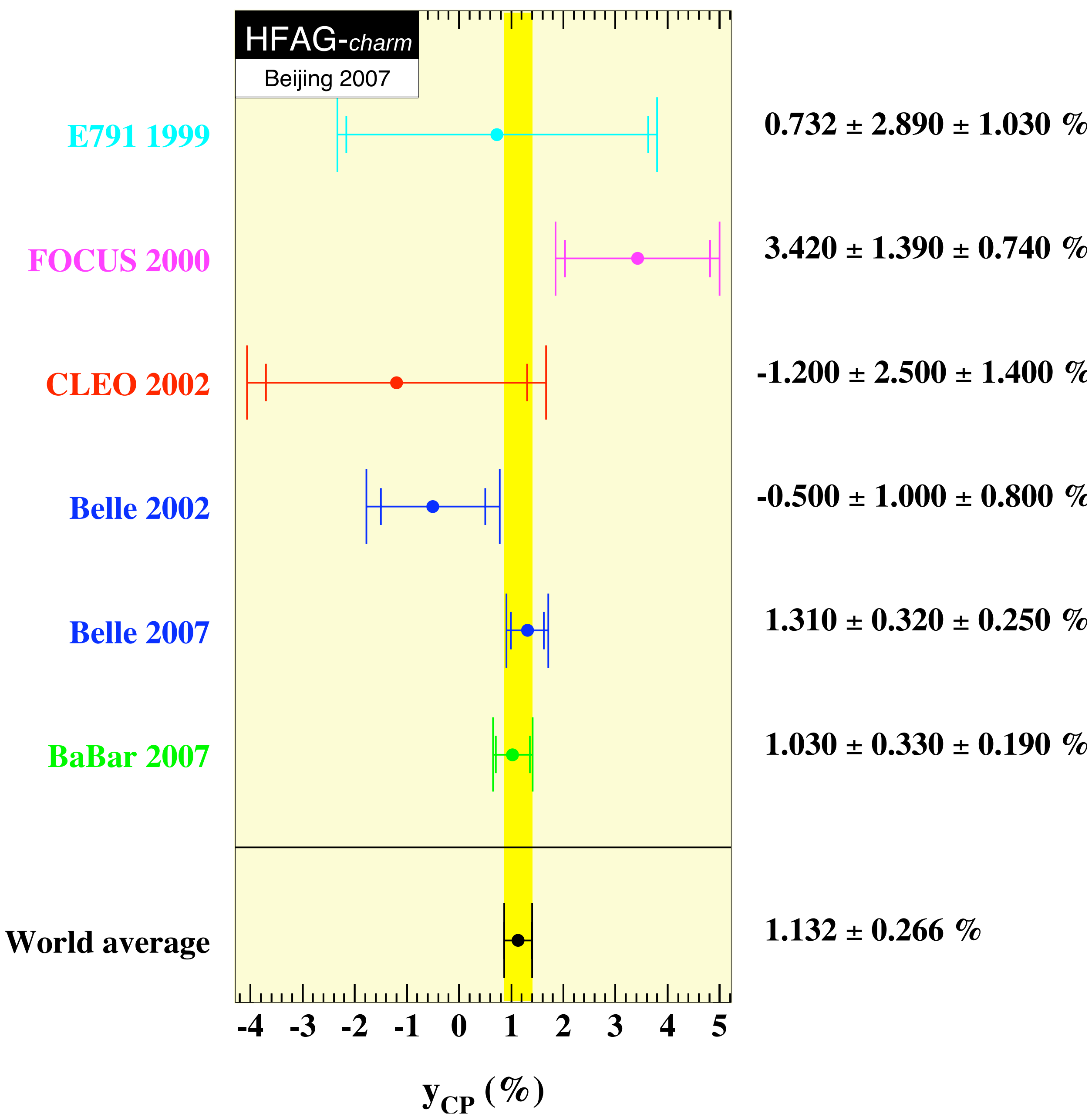
Systematic	$\sigma_{y_{CP}}$ (%) K^-K^+	$\pi^-\pi^+$	Av.	$\sigma_{\Delta Y}$ (%) K^-K^+	$\pi^-\pi^+$	Av.
Signal model	0.130	0.059	0.085	0.072	0.265	0.062
Charm bkg.	0.062	0.037	0.043	0.001	0.002	0.001
Combinatoric bkg.	0.019	0.142	0.045	0.001	0.005	0.002
Selection criteria	0.068	0.178	0.046	0.083	0.172	0.011
Detector model	0.064	0.080	0.064	0.054	0.040	0.054
Quadrature sum	0.172	0.251	0.132	0.122	0.318	0.083

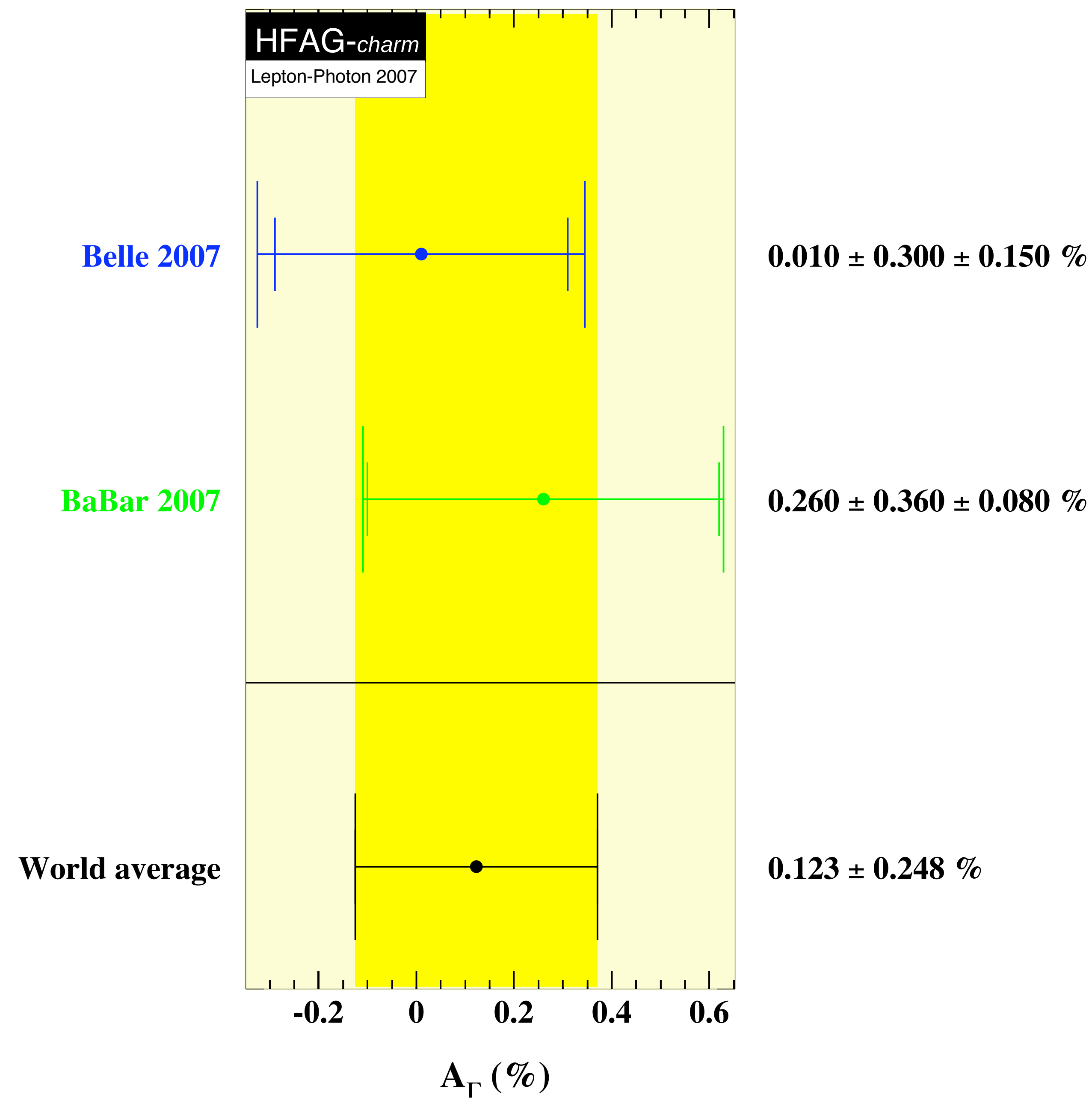
- Syst. error on the average can be smaller than the individual ones because of anti-correlations.
- Combined with the previous analysis (of untagged sample, $91\ \mathrm{fb}^{-1}$), improve stat. error for y_{CP}:

$$y_{CP} = (1.03 \pm 0.33 \pm 0.19)\%$$

cf. $y_{CP} = (1.24 \pm 0.39 \pm 0.13)\%$ (this analysis only)

D^0 mixing - by lifetime difference

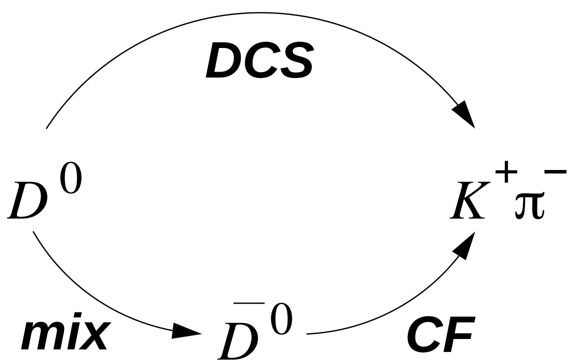




$\mathrm{D^0}$ mixing - by $D^0(t) \to K^+\pi^-$

Master formula

$$|\langle f|H|D^0(t)\rangle|^2 \propto e^{-\overline{\Gamma}t}\left\{1 + \left(y\mathcal{R}(\lambda) - x\mathcal{I}(\lambda)\right)\overline{\Gamma}t + |\lambda|^2\frac{x^2+y^2}{4}(\overline{\Gamma}t)^2\right\}$$



for $f = K^+\pi^-$ (wrong-sign), $\lambda = \dfrac{q}{p}\dfrac{\overline{\mathcal{A}}_f}{\mathcal{A}_f} = \left|\dfrac{q}{p}\right|\sqrt{R_D}e^{i(\phi+\delta)}$

δ : strong phase b/w DCS & CF

$$\propto \; e^{-\overline{\Gamma}t}\left\{R_D + \left|\frac{q}{p}\right|\sqrt{R_D}\,[\,y\;\cos(\phi+\delta) - x\;\sin(\phi+\delta)\,]\,(\overline{\Gamma}t) + \left|\frac{q}{p}\right|^2\frac{(x^2+y^2)}{4}(\overline{\Gamma}\,t)^2\right\}$$

$$= \; e^{-\overline{\Gamma}t}\left\{R_D + \sqrt{R_D}(y\cos\delta - x\sin\delta)(\overline{\Gamma}t) + \frac{(x^2+y^2)}{4}(\overline{\Gamma}\,t)^2\right\} \qquad \begin{pmatrix} |q/p| = 1 \\ \phi = 0 \end{pmatrix}$$

no CPV

$$= \boxed{e^{-\overline{\Gamma}t}\left\{R_D + \sqrt{R_D}\,y'\,(\overline{\Gamma}t) + \frac{(x'^2+y'^2)}{4}\,(\overline{\Gamma}\,t)^2\right\}}$$

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

PRL 98, 211802 (2007)

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

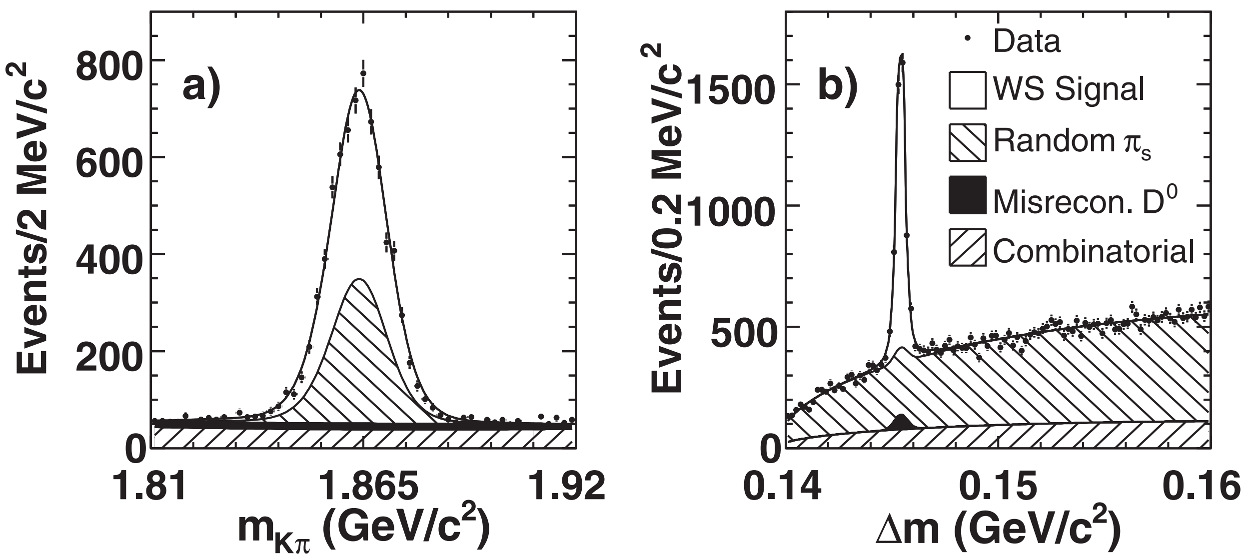
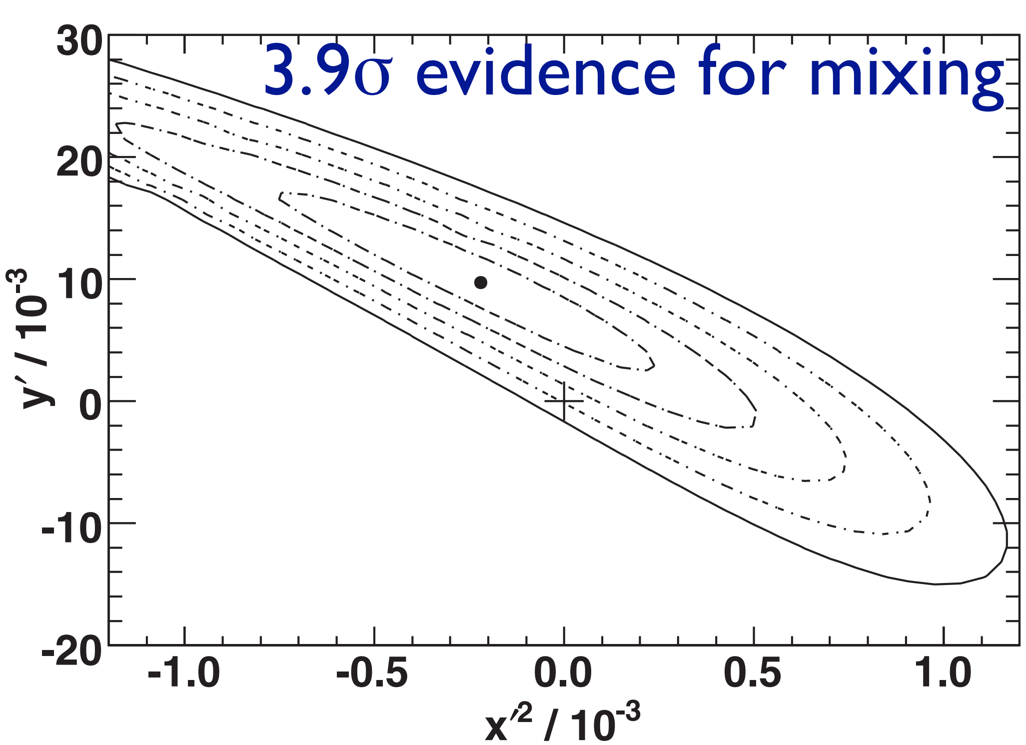
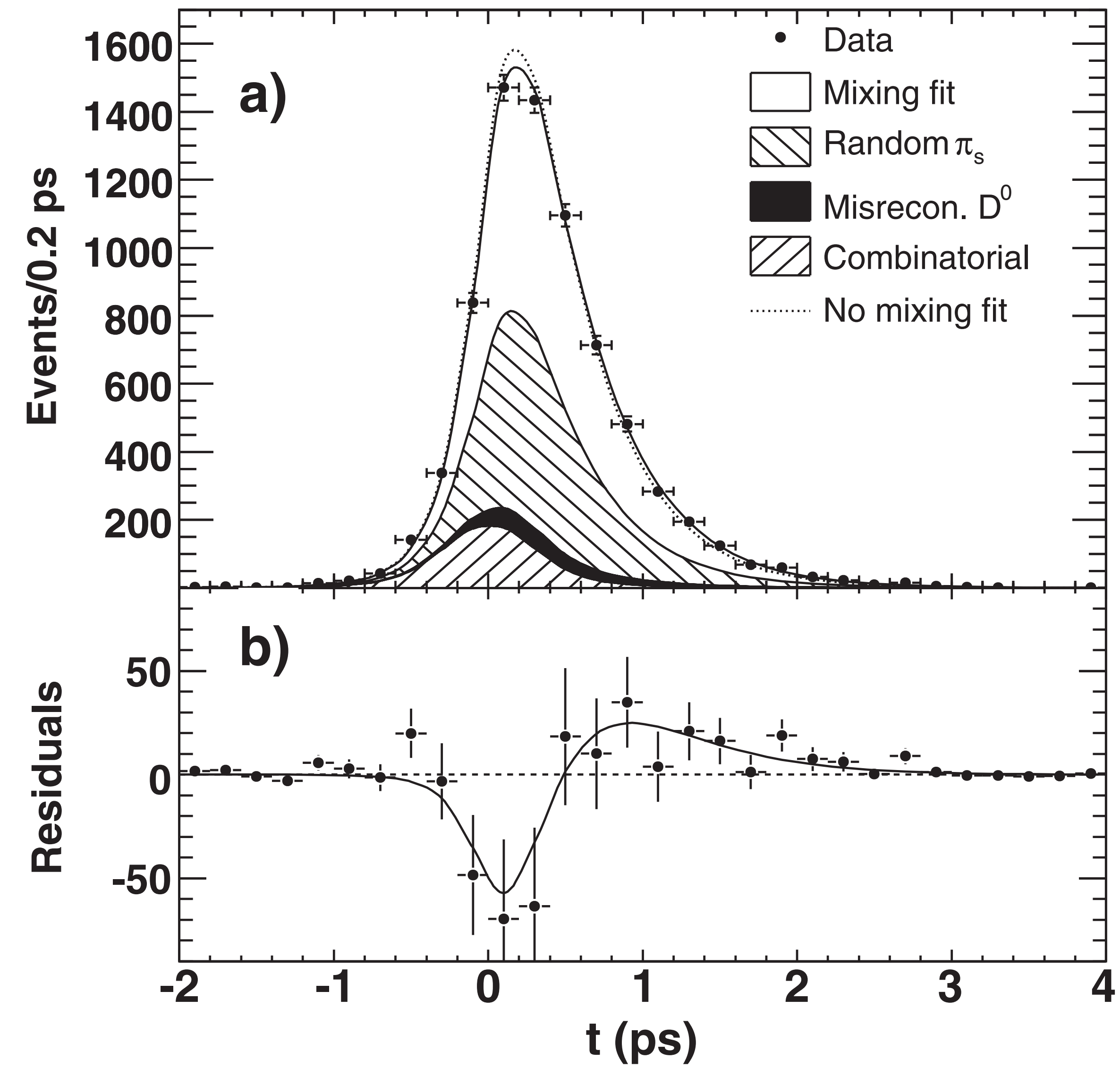


FIG. 1. (a) $m_{K\pi}$ for WS candidates with $0.1445 < \Delta m < 0.1465$ GeV$/c^2$ and (b) Δm for WS candidates with $1.843 < m_{K\pi} < 1.883$ GeV$/c^2$. The fitted PDFs are overlaid.





for combined WS candidates

$$y' = (0.97 \pm 0.44 \pm 0.31)\%$$
$$R_D = (0.303 \pm 0.016 \pm 0.010)\%$$

D^0 mixing - by $D^0(t) \to K^0_S\pi^+\pi^-$

Master formula

$$\begin{aligned}\langle K^0_S\pi^+\pi^-|H|D^0(t)\rangle &= \frac{1}{2p}\left(\langle K^0_S\pi^+\pi^-|H|D_1(t)\rangle + \langle K^0_S\pi^+\pi^-|H|D_1(t)\rangle\right)\\ &= A_1 e^{-(\Gamma_1/2+im_1)t} + A_2 e^{-(\Gamma_2/2+im_2)t}\end{aligned}$$

$$\begin{aligned}|\langle K^0_S\pi^+\pi^-|H|D^0(t)\rangle|^2 &= |A_1|^2 e^{-\overline{\Gamma}(1+y)t} + |A_2|^2 e^{-\overline{\Gamma}(1-y)t}\\ &\quad +2e^{-\overline{\Gamma}t}\left[\mathcal{R}(A_1A_2^*)\cos xt - \mathcal{I}(A_1A_2^*)\sin xt\right]\end{aligned}$$

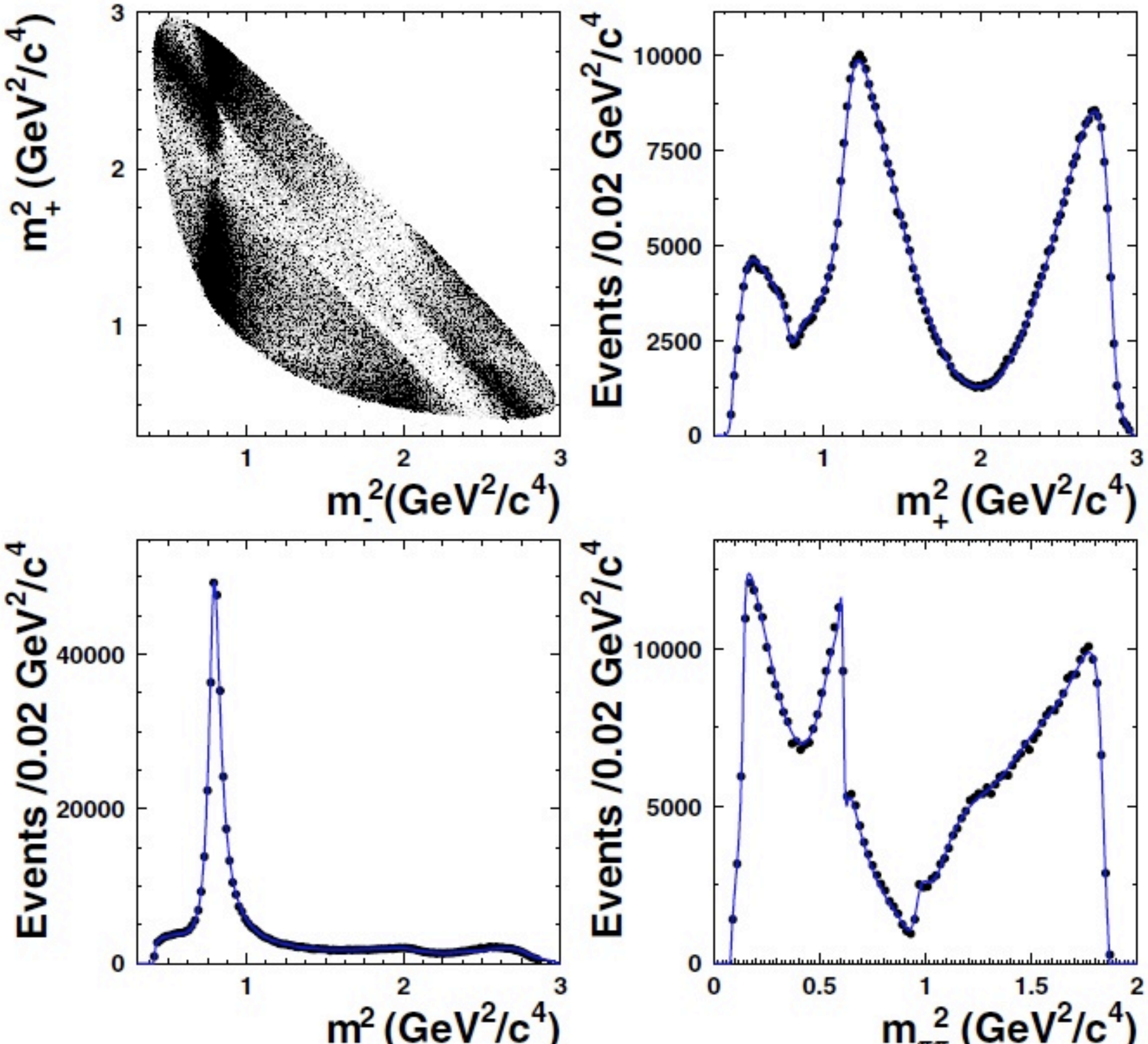
- The amplitudes A_j are functions of Dalitz plot (DP) variables $m^2_+ = m^2(K^0_S\pi^+)$ and $m^2_- = m^2(K^0_S\pi^-)$ and account for intermediate states.
- The amplitude as a ftn. of m^2_+ and m^2_- is expressed as a sum of quasi-2-body amplitudes and a const. non-res. term.
- The t-dependent decay amplitude is fitted over the DP and the mixing param's. are extracted.

PRL 99, 131803 (2007)

D⁰ mixing - by $D^0(t) \to K_S^0\pi^+\pi^-$

$$\mathcal{A}\left(m_-^2, m_+^2\right) = \sum_r a_r e^{i\phi_r}\mathcal{A}_r(m_-^2, m_+^2) + a_{\mathrm{NR}}e^{i\phi_{\mathrm{NR}}}$$

$$\bar{\mathcal{A}}(m_-^2, m_+^2) = \sum_r \bar{a}_r e^{i\bar{\phi}_r}\mathcal{A}_r(m_+^2, m_-^2) + \bar{a}_{\mathrm{NR}}e^{i\bar{\phi}_{\mathrm{NR}}}$$



PRL 99, 131803 (2007)

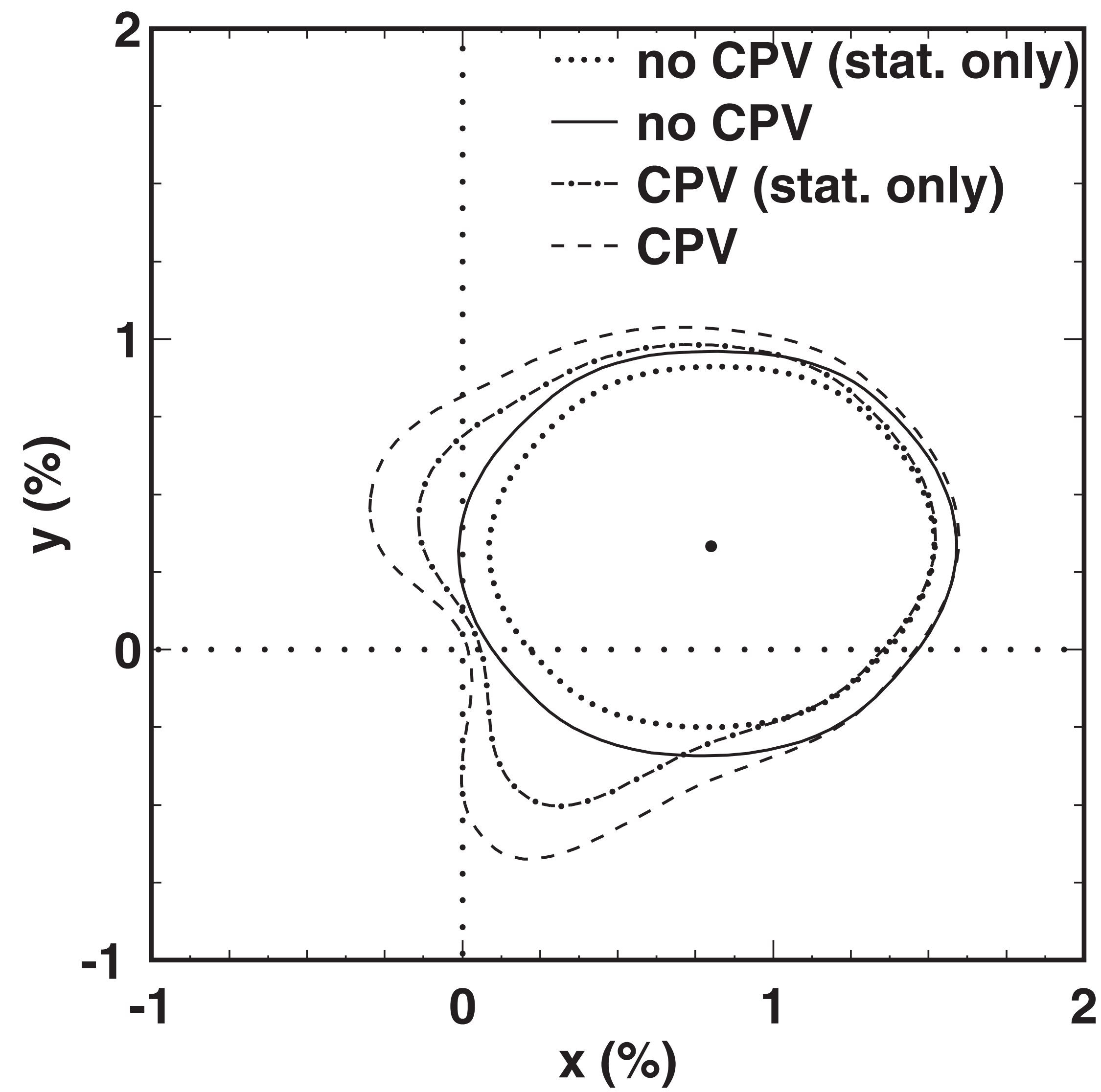
D^0 mixing - by $D^0(t) \to K_S^0\pi^+\pi^-$

$$\mathcal{L} = \prod_{i=1}^{N_{D^0}} \sum_j f_j(m_{K_S^0\pi\pi,i}, Q_i)\mathcal{P}_j(m^2_{-,i}, m^2_{+,i}, t_i)$$

Determine x, y, by maximizing $\ln\mathcal{L} + \ln\bar{\mathcal{L}}$

Fit case	Parameter	Fit result	95% C.L. interval
No	$x(\%)$	$0.80 \pm 0.29^{+0.09+0.10}_{-0.07-0.14}$	$(0.0, 1.6)$
CPV	$y(\%)$	$0.33 \pm 0.24^{+0.08+0.06}_{-0.12-0.08}$	$(-0.34, 0.96)$
CPV	$x(\%)$	$0.81 \pm 0.30^{+0.10+0.09}_{-0.07-0.16}$	$\|x\| < 1.6$
	$y(\%)$	$0.37 \pm 0.25^{+0.07+0.07}_{-0.13-0.08}$	$\|y\| < 1.04$
	$\|q/p\|$	$0.86^{+0.30+0.06}_{-0.29-0.03} \pm 0.08$	$\cdots$
	$\arg(q/p)(^\circ)$	$-14^{+16+5+2}_{-18-3-4}$	$\cdots$

CL. for no mixing = 2.6%



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PRD accepted

D^0 mixing - by $D^0 \to K^{(*)}\ell^+\nu$

- semileptonic decays, with no DCS contribution, gives direct access to mixing rate R_M

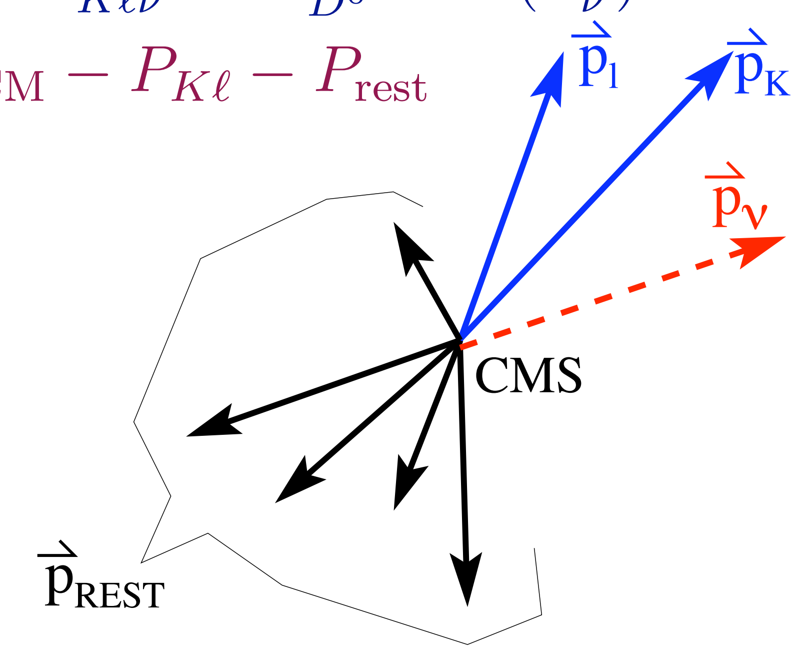
$$\mathcal{P}(D^0 \to \overline{D}^0 \to X^+\ell^-\overline{\nu}_\ell) \propto R_M\ t^2\ e^{-\Gamma t}$$

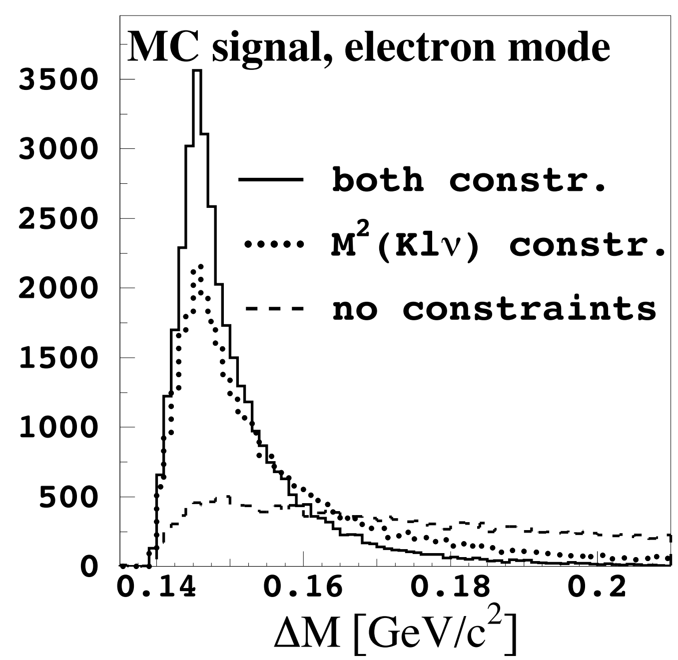
$$R_M = \frac{\int_0^\infty dt\ \mathcal{P}(D^0 \to \overline{D}^0 \to X^+\ell^-\overline{\nu}_\ell)}{\int_0^\infty dt\ \mathcal{P}(D^0 \to X^-\ell^+\nu_\ell)} \approx \frac{x^2+y^2}{2}$$

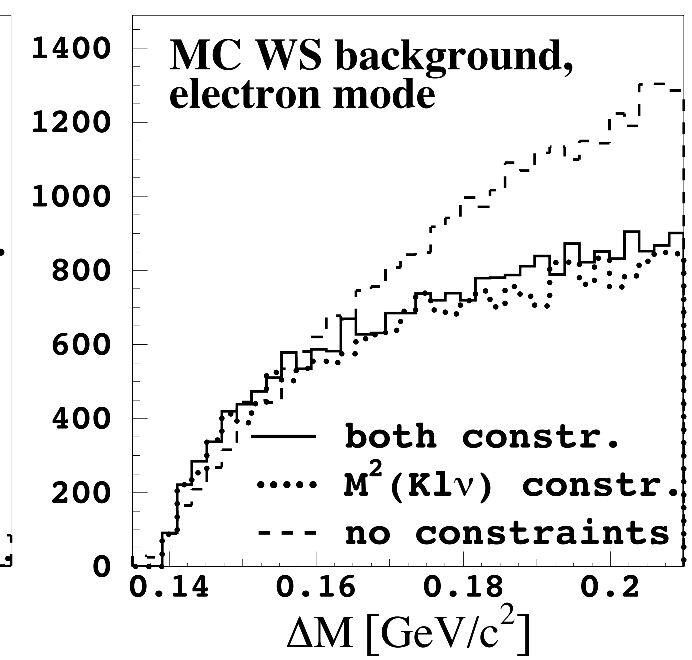
- select $D^0 \to K^-\ell^+\nu$ ($\ell = e, \mu$) from $D^{*+} \to D^0\pi^+$
- search for signals in $\Delta M \equiv M(\pi_s K\ell\nu) - M(K\ell\nu)$

Require $M^2_{K\ell\nu} = m^2_{D^0}$ and $(P^*_\nu)^2 = 0$

$P_\nu = P_{\rm CM} - P_{K\ell} - P_{\rm rest}$





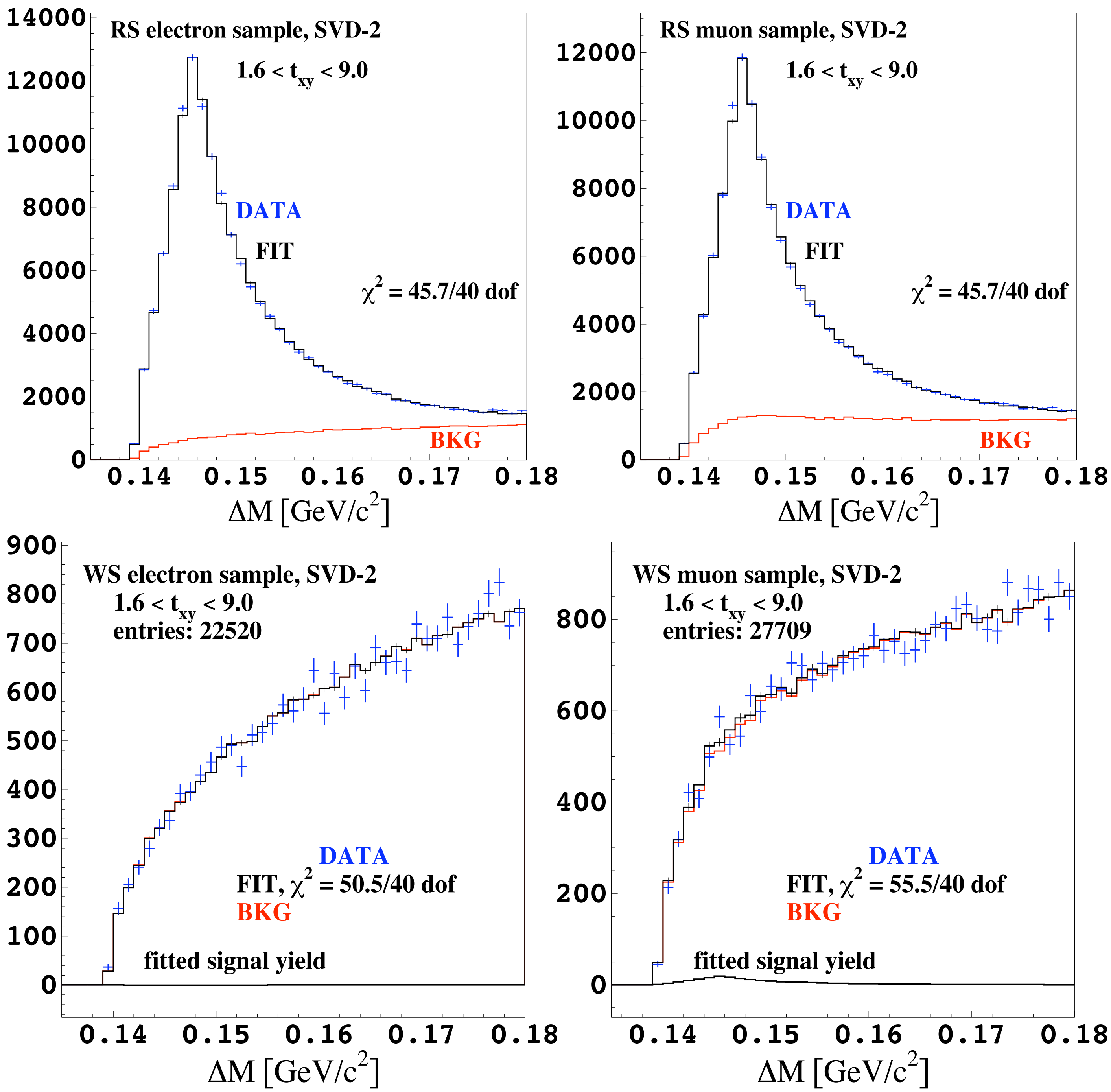


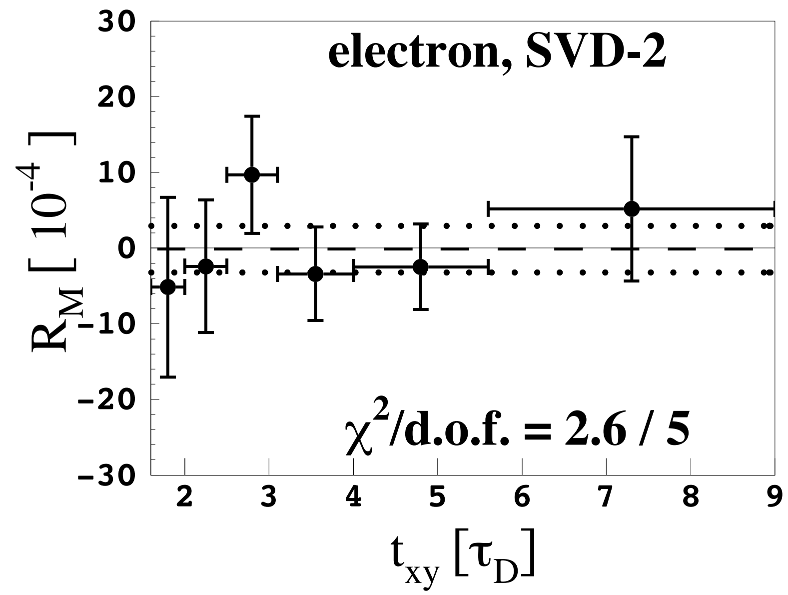
0802.2952
PRD accepted

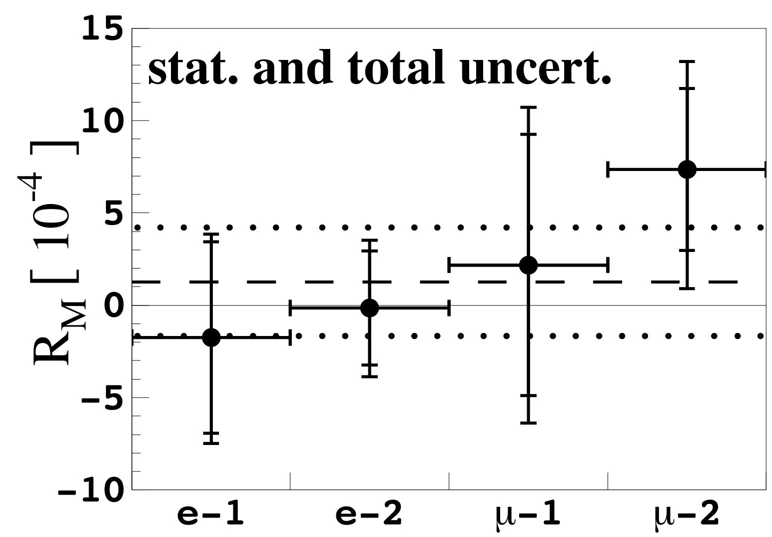
D⁰ mixing - by $D^0 \to K^{(*)}\ell^+\nu$

$$\Delta M \equiv M(\pi_s K\ell\nu) - M(K\ell\nu)$$

t_{xy} : proper decay time in xy plane normalized to τ_{D^0}





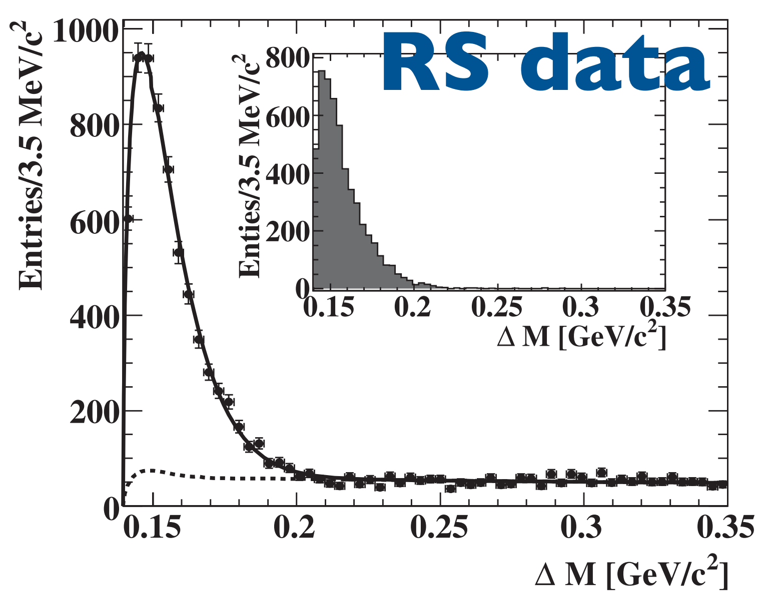


$$R_M = (1.3 \pm 2.2 \pm 2.0) \times 10^{-4}$$
$$< 6.1 \times 10^{-4} \quad @\, 90\%\ \mathrm{CL}$$

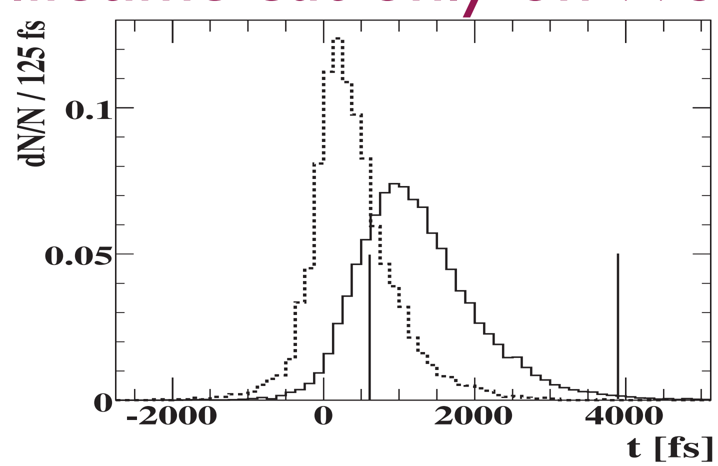
PRD 76, 014018 (2007)

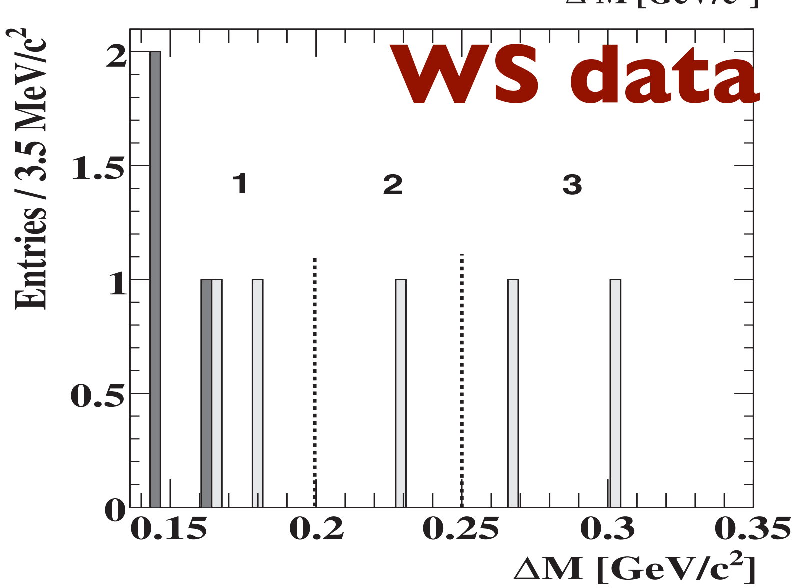
D⁰ mixing - by $D^0 \to K^{(*)}\ell^+\nu$

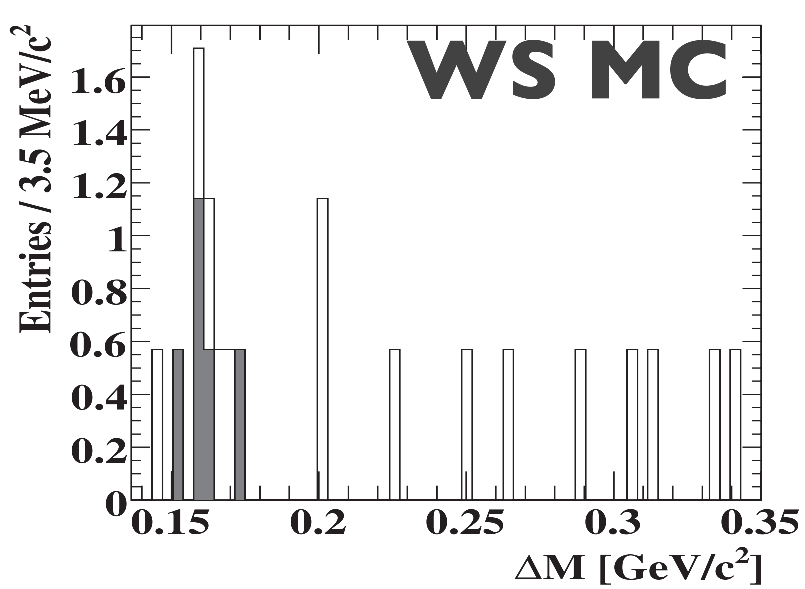
- full reconstruction of the opposite side (“double-tagging”)
- neural-network selection based on p_π, p_{Ke}, thrust axis, opening angle
- “signal yield” by counting ; backg’d estimate comes from MC



lifetime cut only on WS





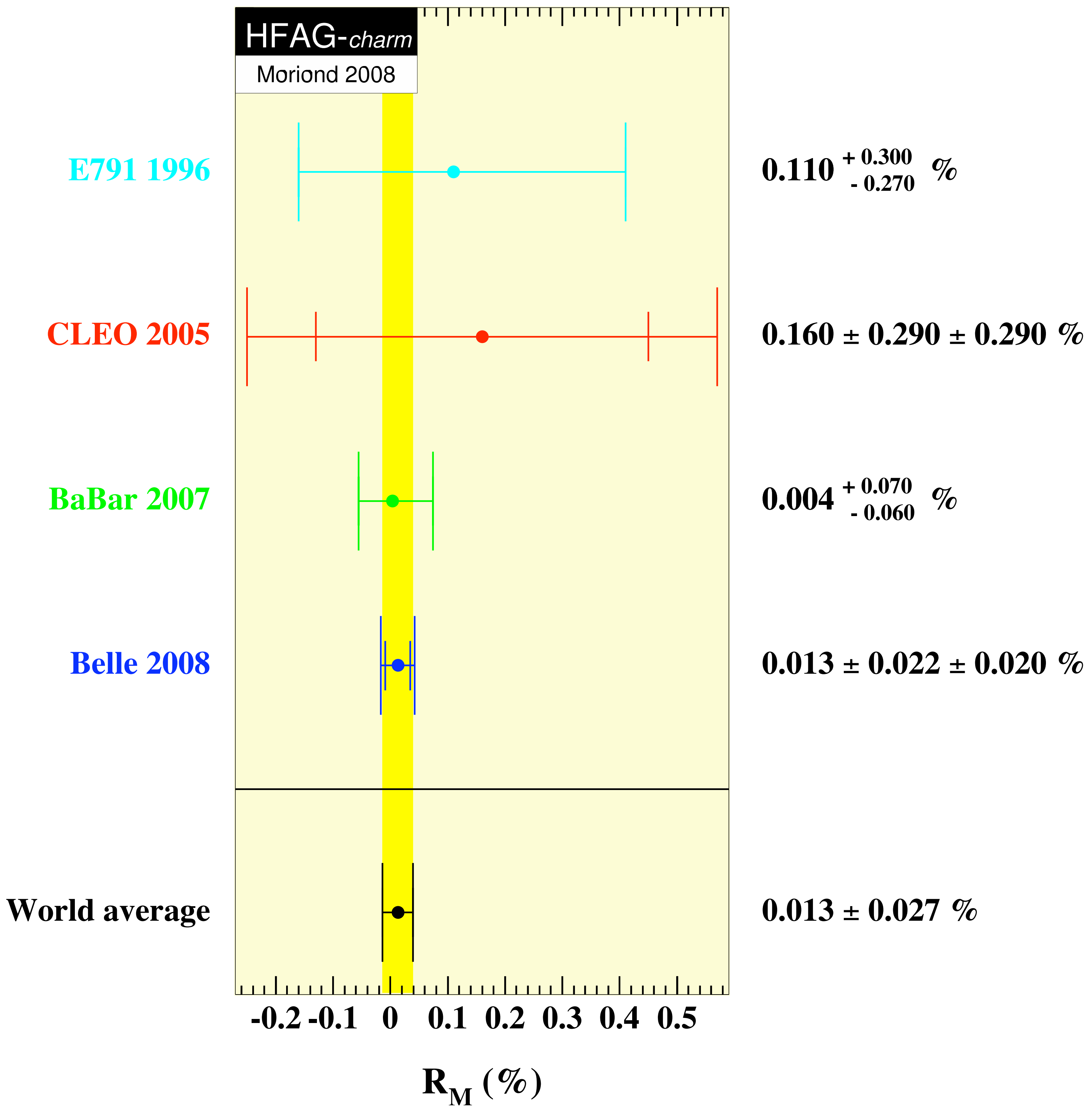


determine confidence interval by rise of Likelihood ftn.

$$R_M = (-13, 12) \times 10^{-4}$$

@ 90% CL

D^0 mixing - by $D^0 \to K^{(*)}\ell^+\nu$



CP violation in D^0

- time-integrated asymmetry: $A_{CP} = \dfrac{\Gamma(D^0 \to f) - \Gamma(\bar{D}^0 \to \bar{f})}{\Gamma(D^0 \to f) + \Gamma(\bar{D}^0 \to \bar{f})}$
  - in decays
  - in mixing
  - in interference b/w mixing & decays
- for $f = K^- K^+,\ \pi^- \pi^+$: $A_{CP} \sim \mathcal{O}(10^{-5} - 10^{-4})$
- for $f = \pi^- \pi^+ \pi^0$: $A_{CP} \sim \mathcal{O}(10^{-3})$

- Principle of measurements
  - $D^{*+} \to D^0 \pi_s^+$
  - $N_{D^0}^{\text{reco}} = N_{D^{*+}}^{\text{prod}} \cdot \mathcal{B}(D^{*+} \to D^0 \pi^+) \cdot \mathcal{B}(D^0 \to f) \cdot \epsilon_f \cdot \epsilon_{\pi_s}$
  - contributions to measured asymmetry:
    $A^{\text{meas}} = A_{FB} + A_{CP} + A_\epsilon^\pi$

D^0 CPV - exp'tal results

∃ *several searches for CPV using*

- In singly Cabibbo-suppressed modes
  - preliminary
  - PRL 100, 061803
- In 3-body modes
  - 0801.2439
  - 0802.4035

BELLE

PRD 100, 061803 (2008)

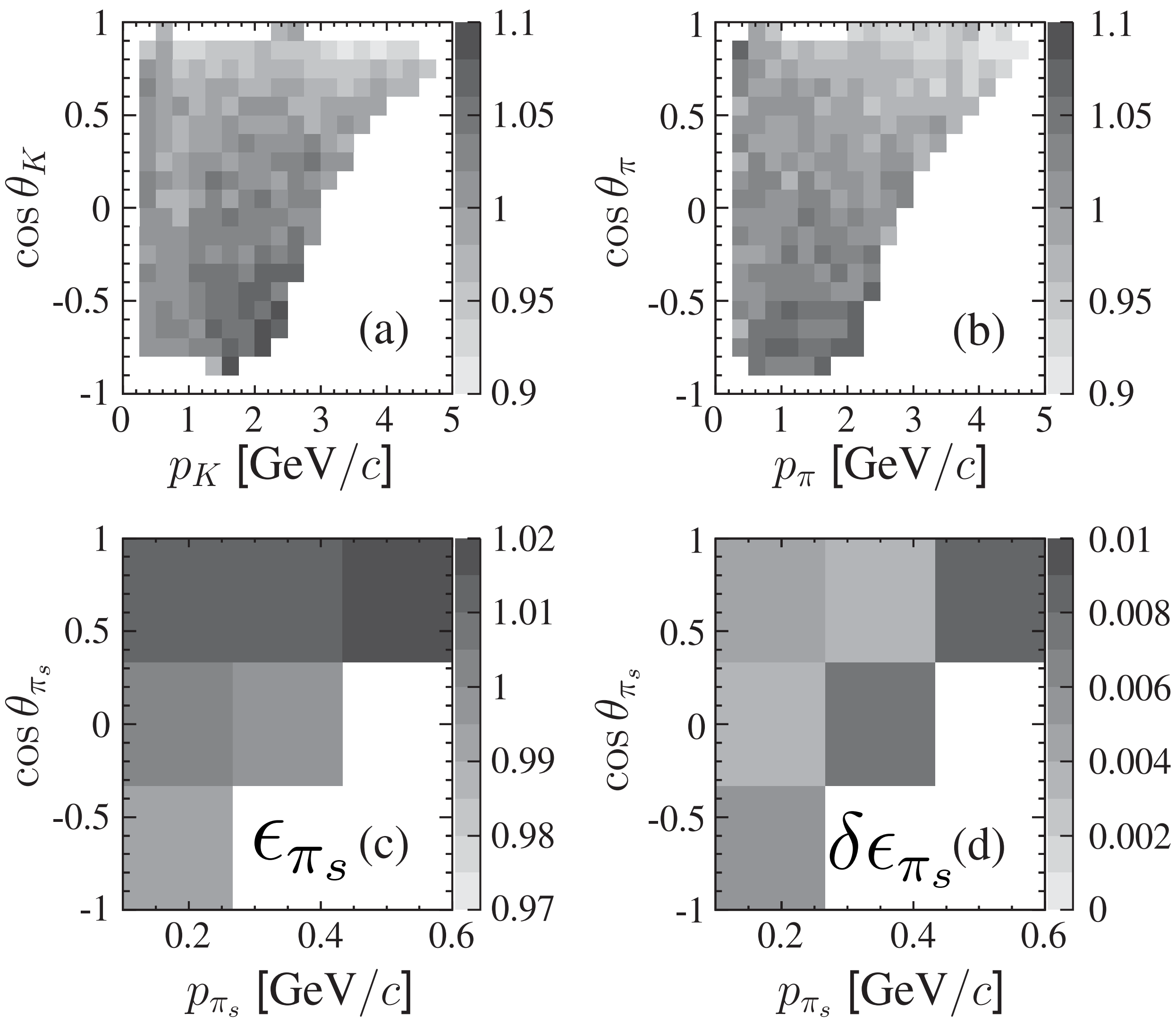
CPV in $D^0 \rightarrow K^+K^-, \pi^+\pi^-$

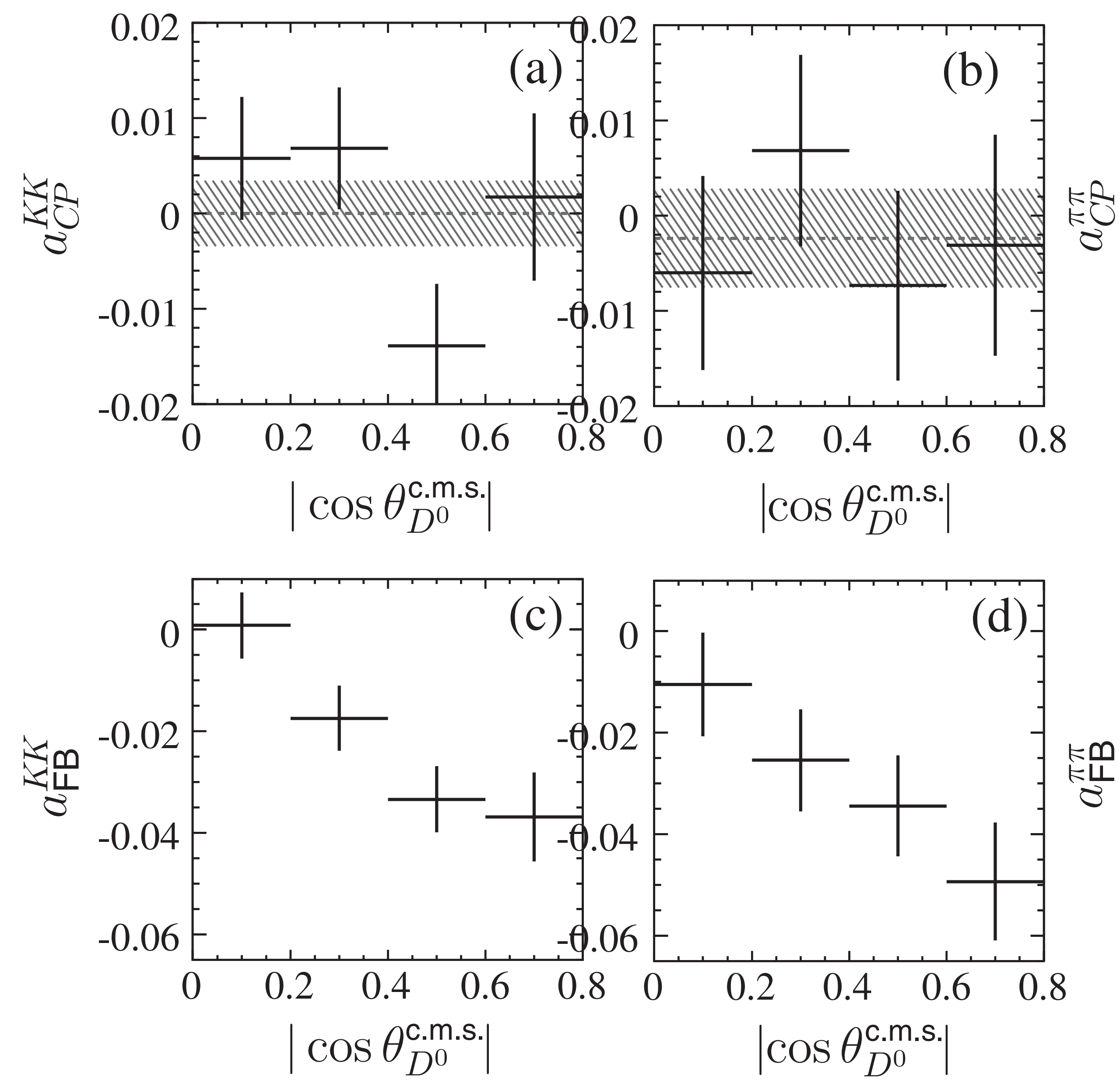
$$A^{\text{rec}}_{\text{corr}}(\cos\theta^*) = A^{D^*}_{FB} + A^{h^+h^-}_{CP}$$

$$A_{CP} = \frac{A^{\text{rec}}_{\text{corr}}(\cos\theta^*) + A^{\text{rec}}_{\text{corr}}(-\cos\theta^*)}{2}$$

$$A_{FB} = \frac{A^{\text{rec}}_{\text{corr}}(\cos\theta^*) - A^{\text{rec}}_{\text{corr}}(-\cos\theta^*)}{2}$$

efficiency map





preliminary

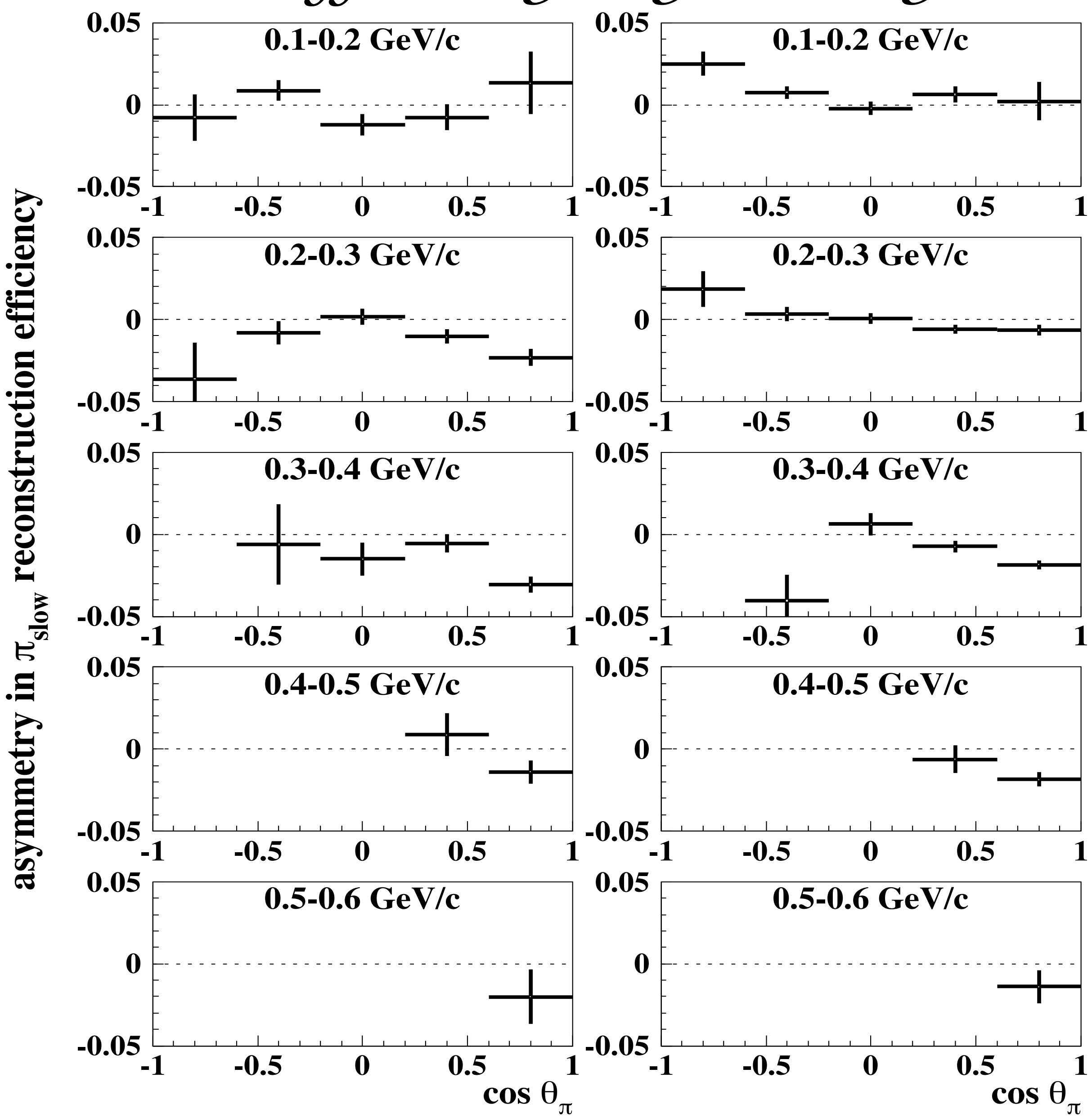
CPV in $D^0 \to K^+K^-, \pi^+\pi^-$

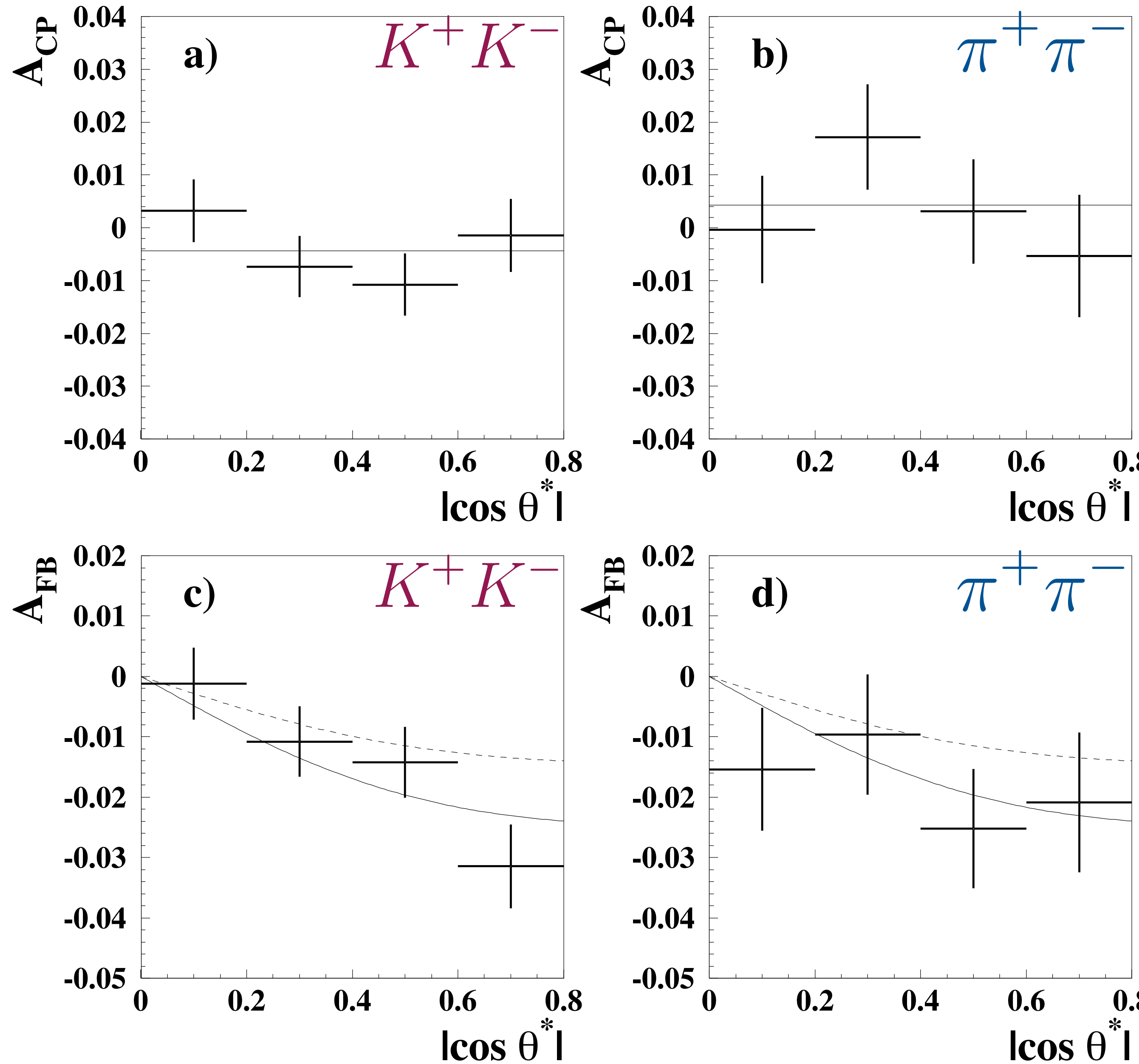
$$A^{rec}_{corr}(\cos\theta^*) = A^{D^*}_{FB} + A^{h^+h^-}_{CP}$$

$$A_{CP} = \frac{A^{rec}_{corr}(\cos\theta^*) + A^{rec}_{corr}(-\cos\theta^*)}{2}$$

$$A_{FB} = \frac{A^{rec}_{corr}(\cos\theta^*) - A^{rec}_{corr}(-\cos\theta^*)}{2}$$

π_s *efficiency asymmetry*





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

$$A_{CP}^{KK} = (-0.41 \pm 0.30 \pm 0.11)\,\%$$
$$A_{CP}^{\pi\pi} = (+0.41 \pm 0.52 \pm 0.12)\,\%$$

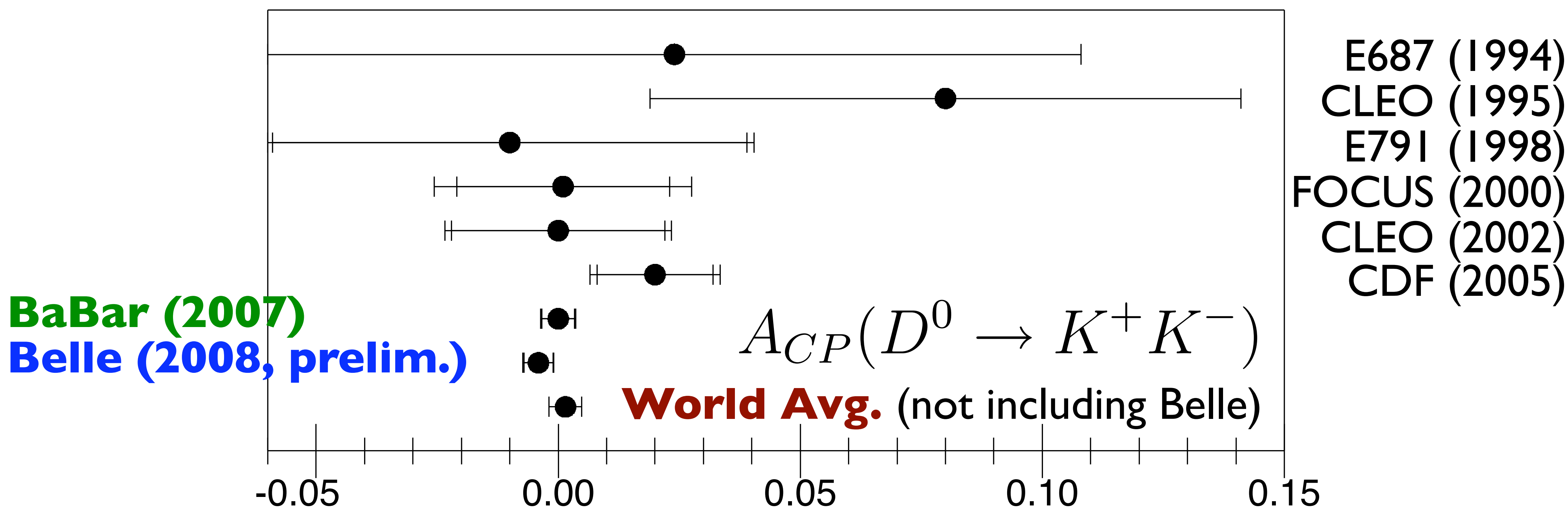
$$A_{CP}^{KK} = (0.00 \pm 0.34 \pm 0.13)\,\%$$
$$A_{CP}^{\pi\pi} = (-0.24 \pm 0.52 \pm 0.22)\,\%$$

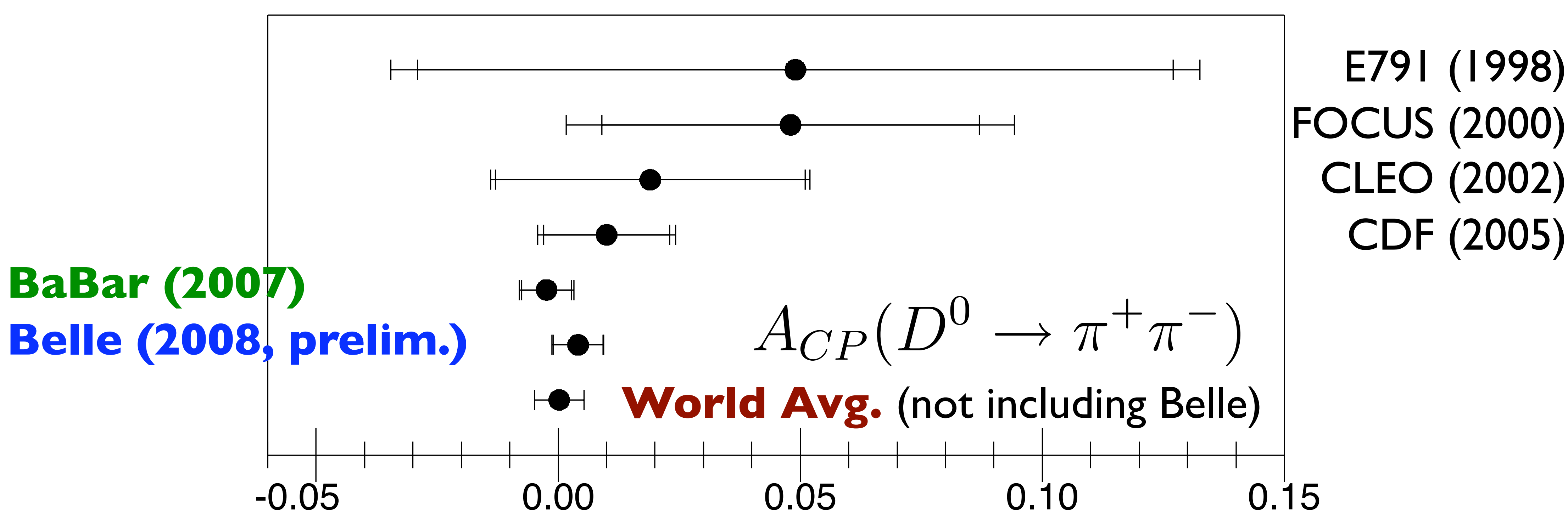
Summary of systematic uncertainties of A_{CP}.

Source	$D^0 \to K^+K^-$	$D^0 \to \pi^+\pi^-$
Signal counting	0.04%	0.06%
Slow pion corrections	0.10%	0.10%
A_{CP} extraction	0.03%	0.04%
Quadrature sum	0.11%	0.12%

Syst. err. will improve w/ more D* sample

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





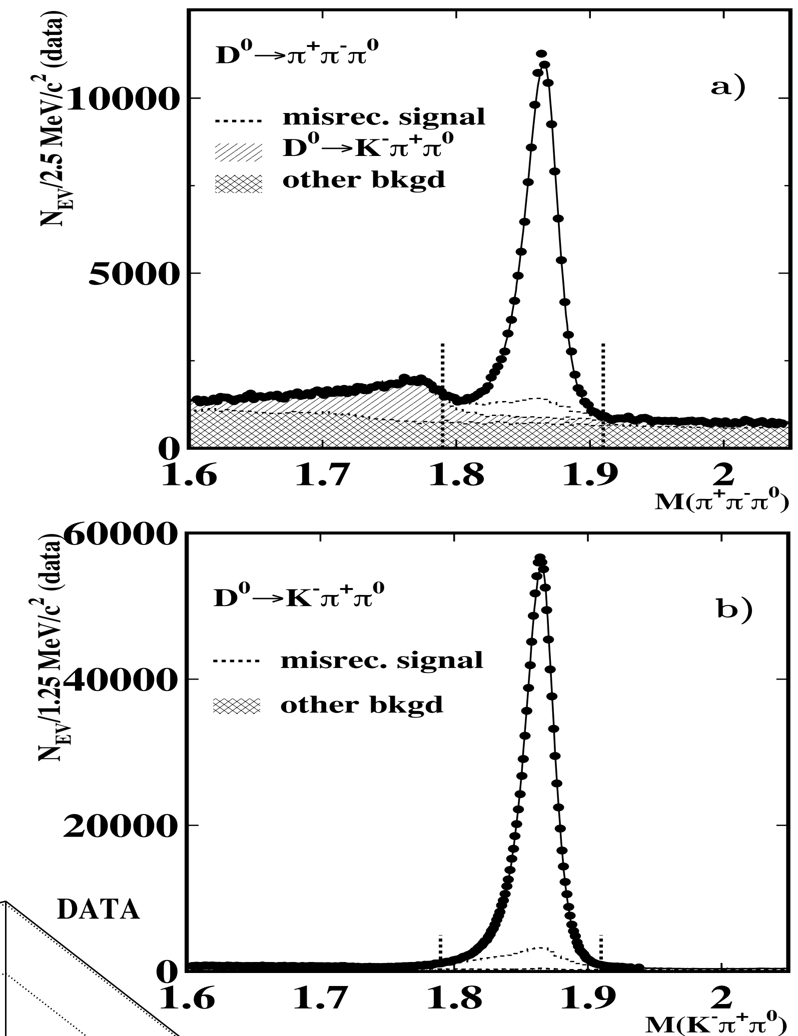
CPV in 3-body SCS D^0 decays

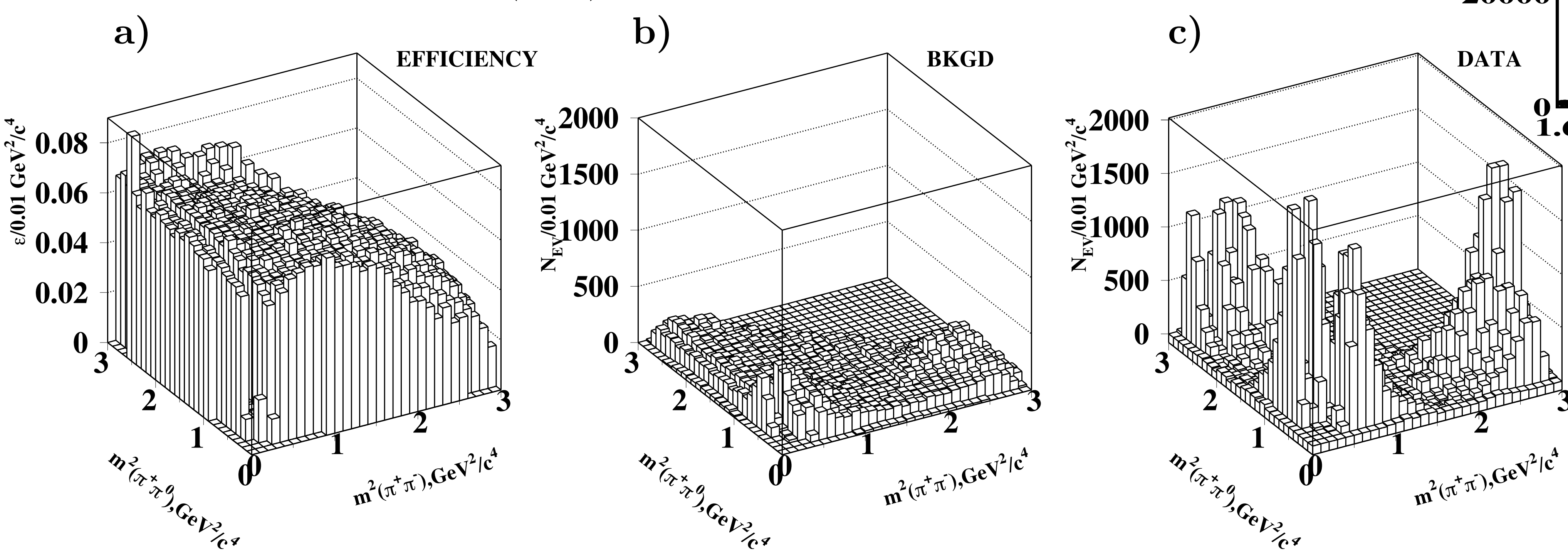
- In singly Cabibbo-suppressed 3-body D^0 modes
  - $D^0 \to \pi^+\pi^-\pi^0, \quad K^+K^-\pi^0$

- What to look for
  - differences in D^0 and $\overline{D}^0$ Dalitz plots in 2-d.
  - differences in angular moments
  - Intermediate states (model-dep.)
  - phase-space-integrated asymmety

CPV in 3-body SCS D^0 decays

- Fit $M(D^0)$ for signal & backg'd yield
- $D^{*+} \to D^0\pi^+$ for flavor-tagging and backg'd suppression
- Fill separate Dalitz histograms
  - events from $M(D^0)$ signal region for data
  - simulated backg'd w/ the normaliz'n fixed from the $M(D^0)$ fit

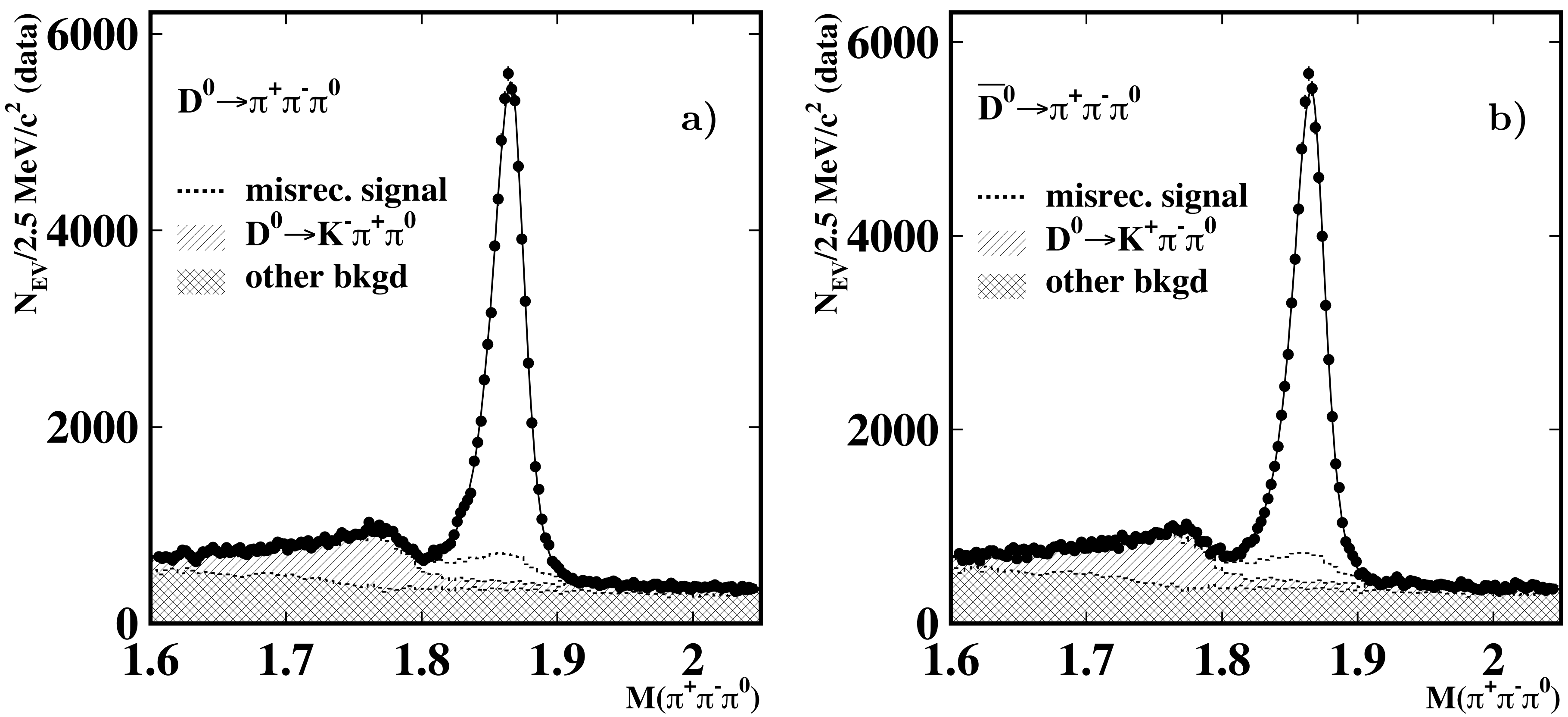




$$\mathcal{B}(D^0 \to \pi^+\pi^-\pi^0)/\mathcal{B}(D^0 \to K^-\pi^+\pi^0) \;=\; (10.12 \pm 0.04(\mathrm{stat}) \pm 0.18(\mathrm{syst})) \times 10^{-2}$$

CPV in 3-body SCS D^0 decays

- effi'cy-corrected signal yield separately for D^0 and $\bar{D}^0$
- detector-bias in tracking is the main source of syst. err.
- A_{FB} effect is also studied with $D^0 \to K^+K^-, \pi^+\pi^-$ events



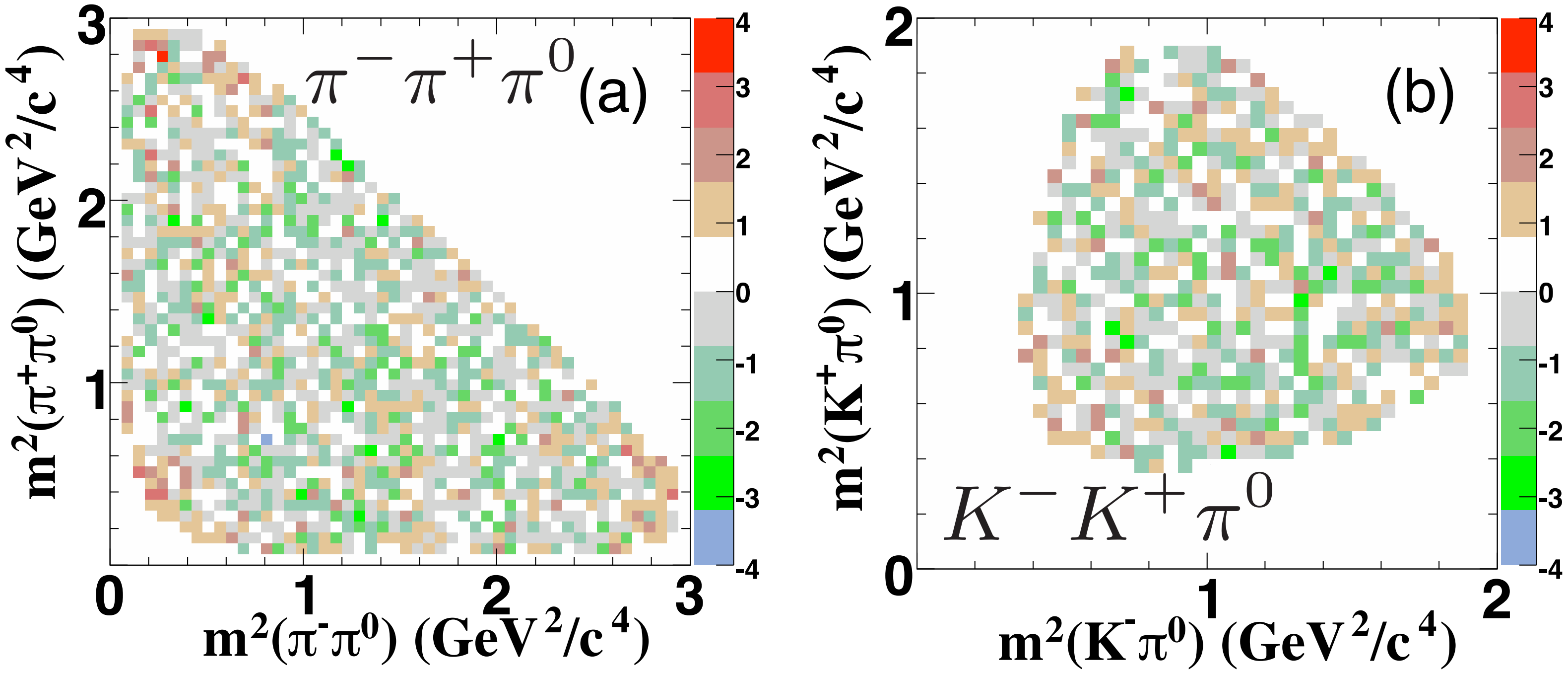
$$A_{CP} = (S_{D^0} - S_{\overline{D}^0})/(S_{D^0} + S_{\overline{D}^0}) =$$
$$= (0.43 \pm 0.41(\mathrm{stat}) \pm 1.01(\mathrm{track}) \pm 0.70(\mathrm{other\ syst}))\%$$

CPV in 3-body SCS D^0 decays

- a direct comparison of the effi'cy-corrected, backg'd-subtracted Dalitz plot for D^0 and $\bar{D}^0$

$$\Delta = \left(n_{\bar{D}^0} - R \cdot n_{D^0}\right) / \sqrt{\sigma^2_{n_{\bar{D}^0}} + R^2 \cdot \sigma^2_{n_{D^0}}} \qquad \chi^2/\nu = \frac{1}{\nu}\sum_{i=1}^{\nu} \Delta_i^2$$

$R = 0.983 \pm 0.006$ $\quad$ 1.020 ± 0.016

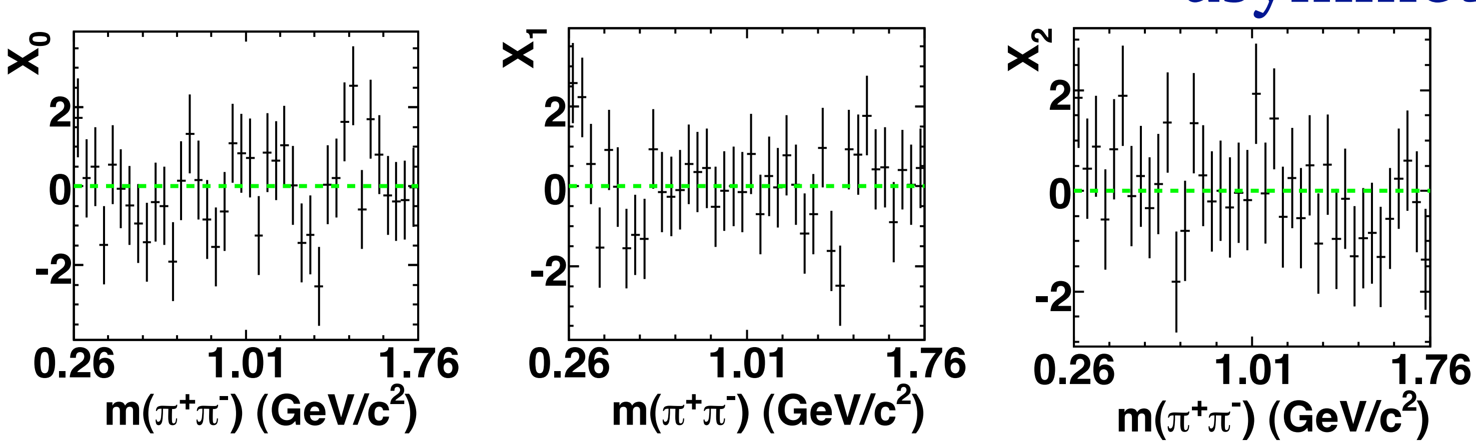


~ 1 in the simulated ensemble

(Data)
1.020 (πππ), 1.056 (KKπ)

CL. for **No CPV**
0.328 (πππ), 0.166 (KKπ)

- asymmetry in moments of helicity angle θ_H



$$X_l = \left(\overline{P_l} - R \cdot P_l\right) / \sqrt{\sigma^2_{\overline{P_l}} + R^2 \cdot \sigma^2_{P_l}}$$

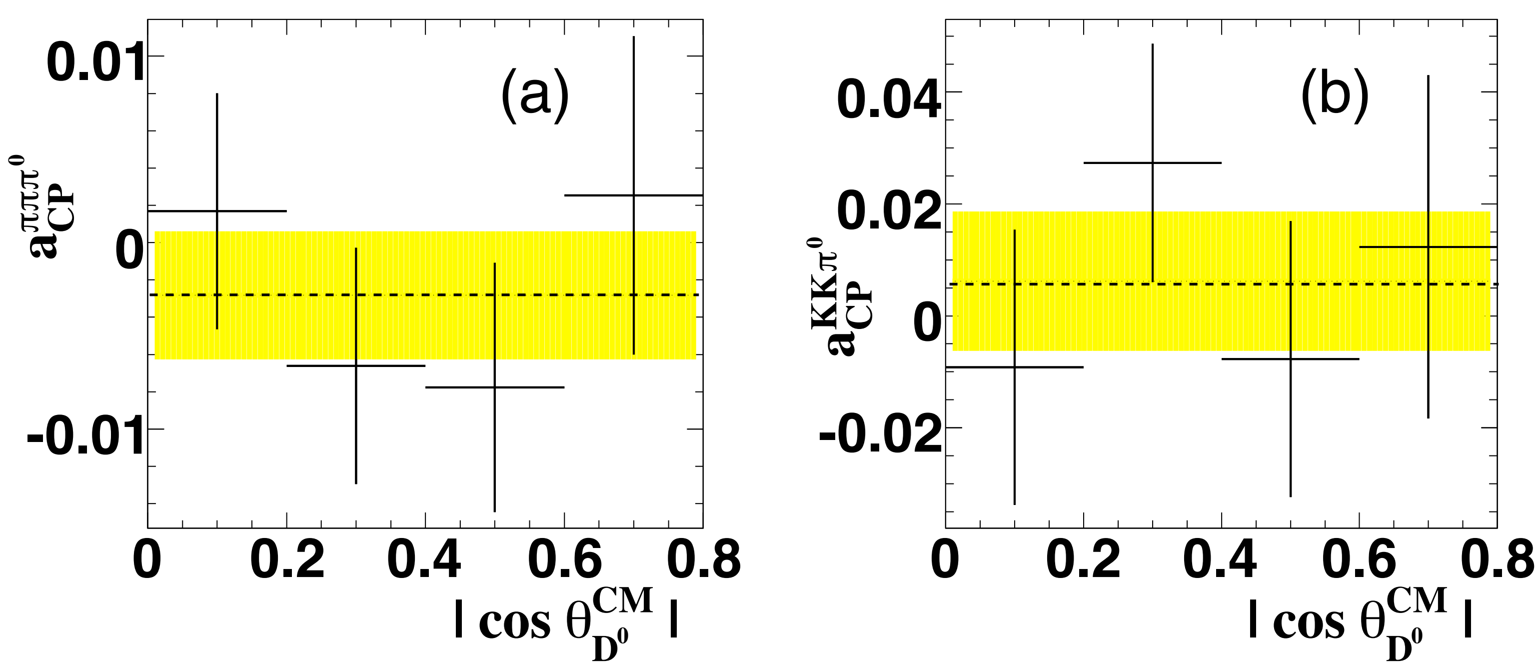
CL. for **No CPV**
~ O(30%)

0802.4035

CPV in 3-body SCS D^0 decays

- model-dependent asymmetry in Dalitz plot amplitudes : $\lesssim$ (a few)% and consistent with 0

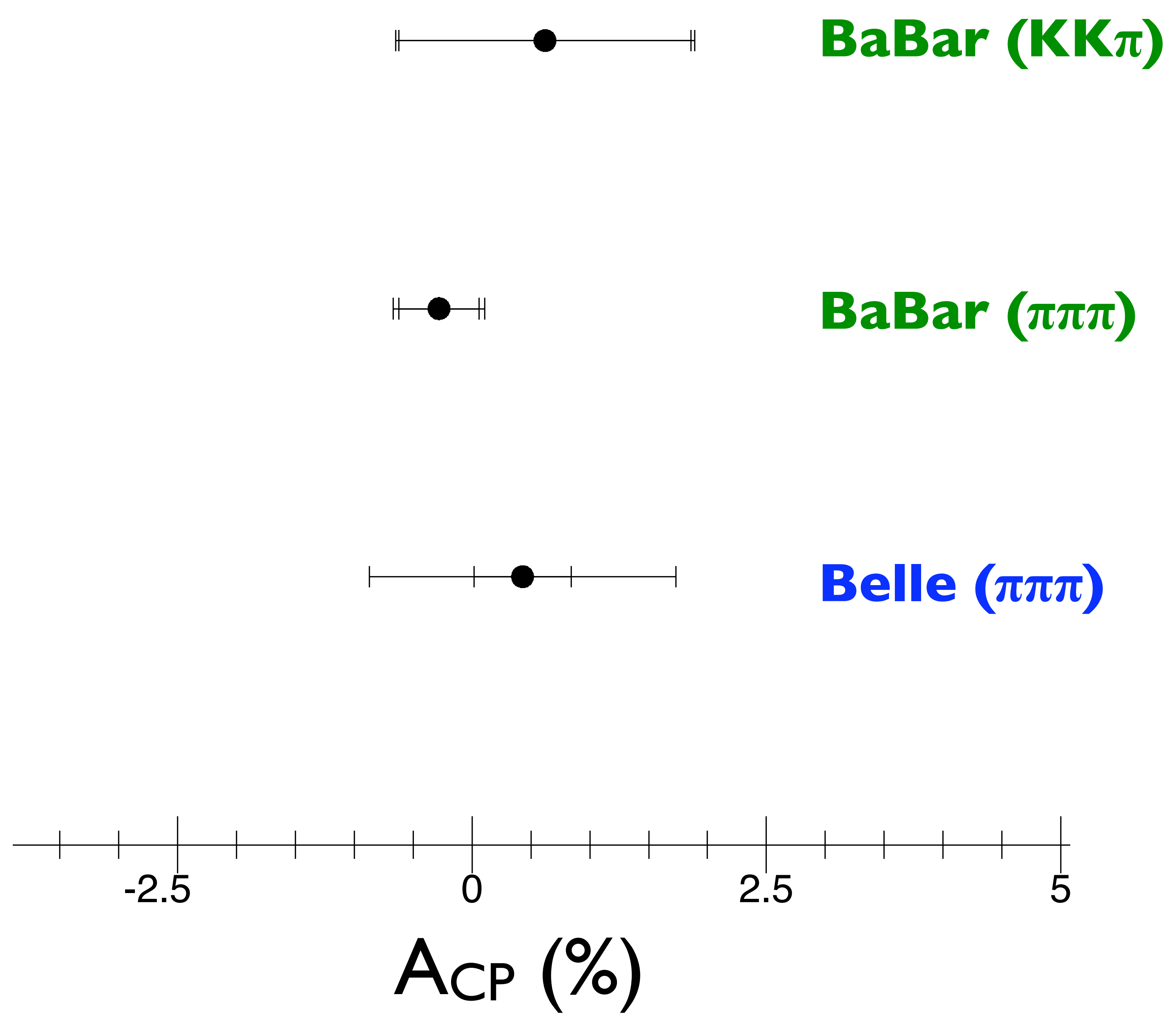
- phase-space-integrated asymmetry



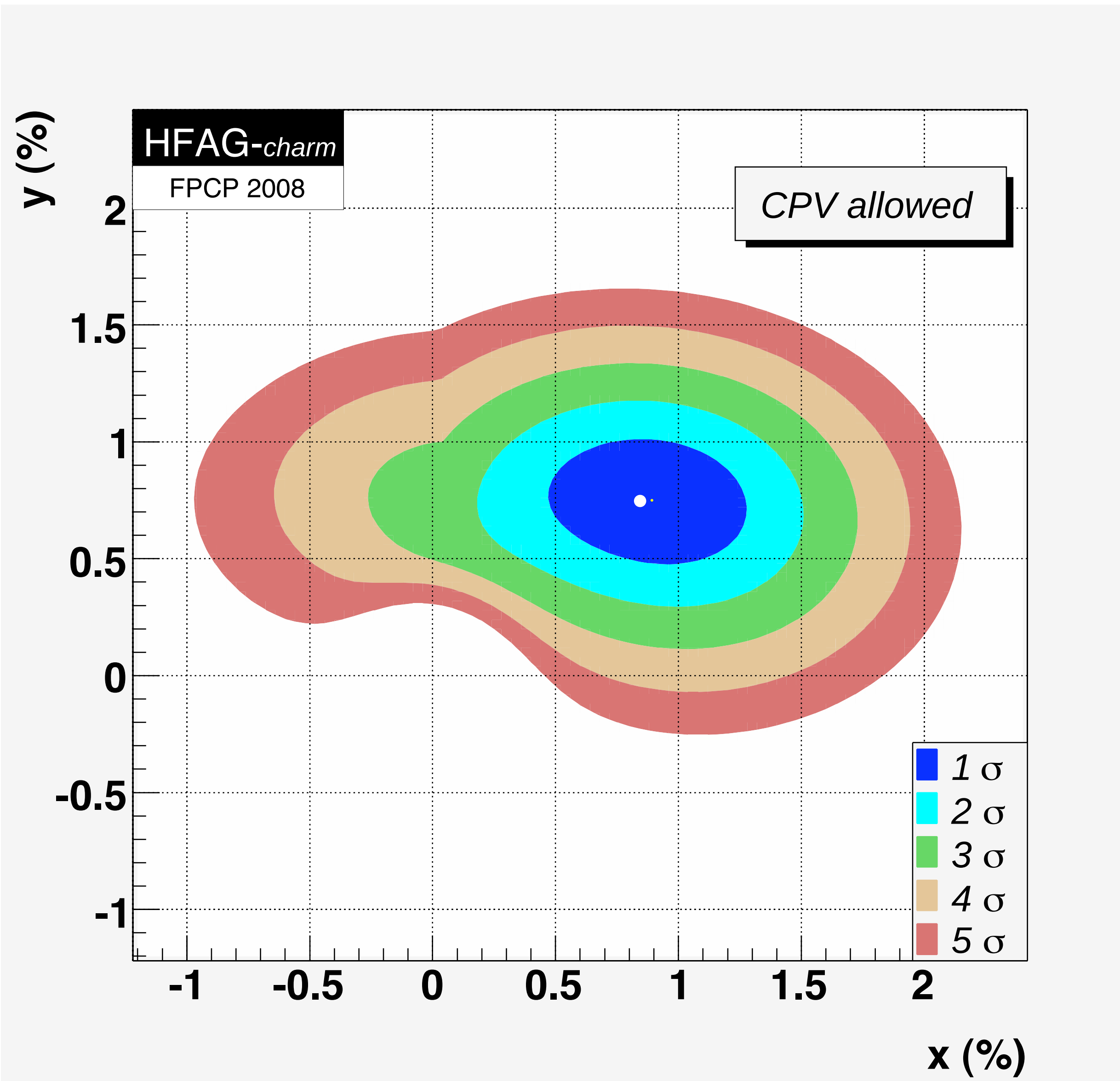
- any A_{FB} is cancelled in $|\cos\theta_{D^0}^{\rm CM}|$

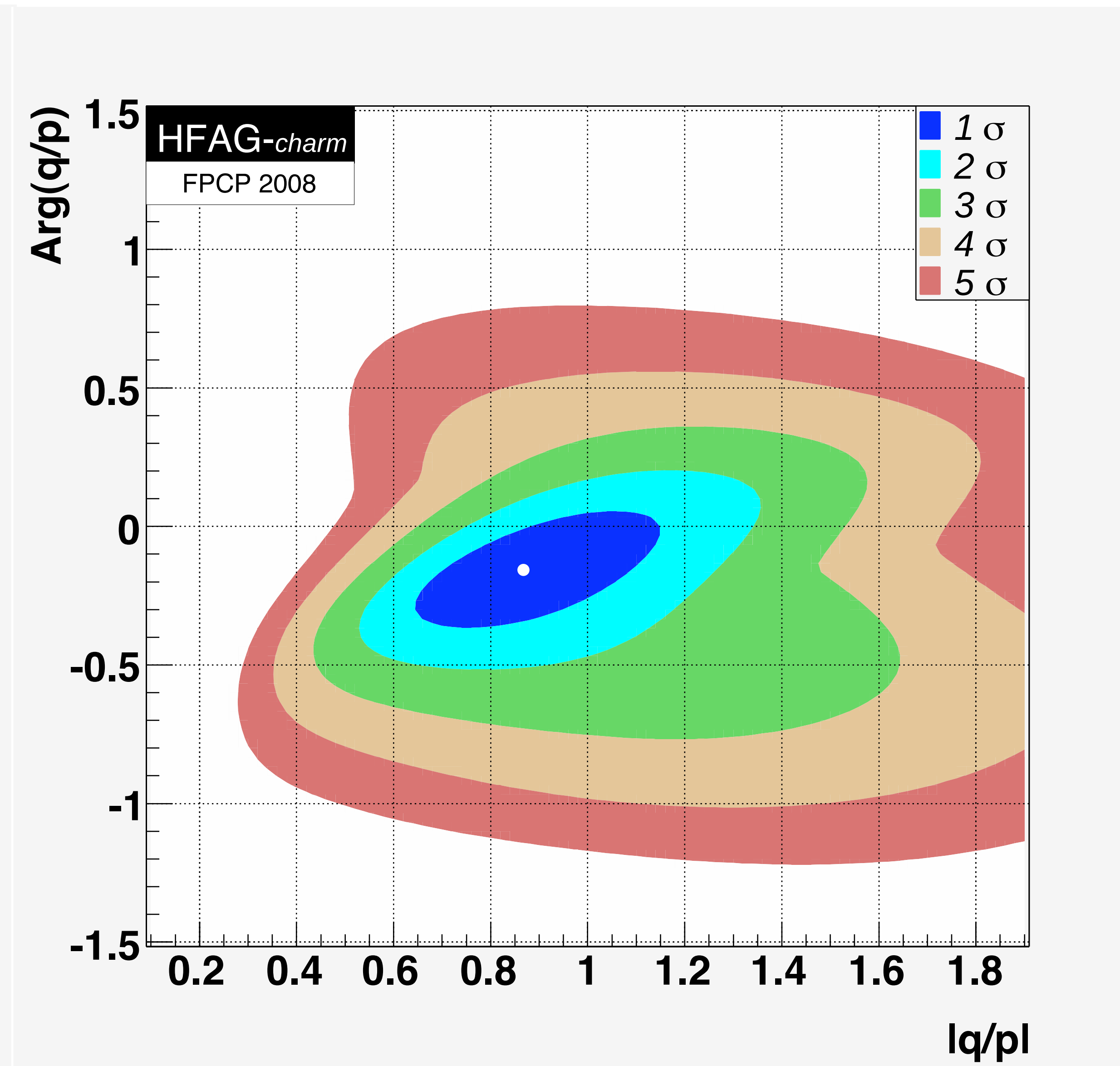
$$A_{\rm CP} = \begin{cases} (-0.28 \pm 0.34 \pm 0.19)\% & (\pi\pi\pi) \\ (0.62 \pm 1.24 \pm 0.28)\% & (KK\pi) \end{cases}$$

CPV in 3-body SCS D^0 decays



Updated mixing/CPV parameters





Summary

- Firm and consistent evidences for D^0 mixing
  - Systematic efforts are going on to measure D^0 mixing parameters in various ways
- No evidence for CPV in D^0
  - Perhaps, not much bigger than O(1%) level
  - Improving the syst. uncertainties shall be important