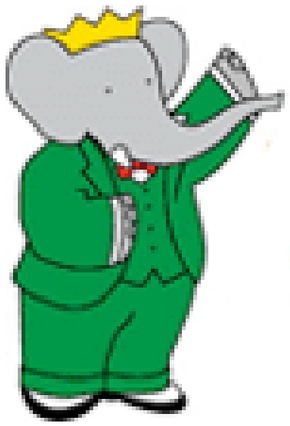
BABAR Hot Topics II:
New D^0-$\overline{D}^0$ Mixing Results

Michael Wilson
Santa Cruz Institute for Particle Physics
for
the *BABAR* Collaboration



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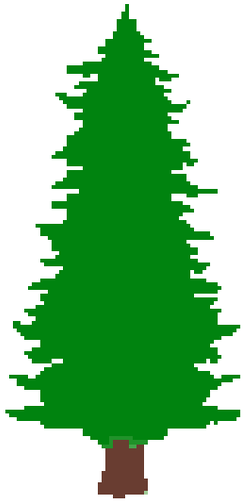
Flavor Physics & CP Violation Conference
9 April 2006



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

A new mode and a new analysis technique:

- Motivation for using this mode
- Mixing formalism in a multibody decay
- Lifetime fit and mixing results

Introduction

Obtain a pure sample by reconstructing

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

in $c\bar{c}$ events (230 fb^{-1} $\approx$ 300 million $c\bar{c}$ events)

- Obtain the flavor of the $D^0/\overline{D}^0$ from charge of $\pi_s^\pm$
- Right-sign Cabibbo-favored (CF) $D^0 \to K^- \pi^+ \pi^0$ used for normalization
- Wrong-sign $D^0 \to K^+ \pi^- \pi^0$ has contributions from doubly Cabibbo-suppressed (DCS) decays and CF mixed decays
- Separate signal from background by fitting to $m_{K\pi\pi^0}$ and $\Delta m \equiv m_{K\pi\pi^0\pi_s} - m_{K\pi\pi^0}$

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

In a nonleptonic search for D mixing, DCS decays obscure signs of mixing:

- Consider $R = \dfrac{\Gamma(D^0 \to K^+\pi^-\pi^0)}{\Gamma(D^0 \to K^-\pi^+\pi^0)}$

- Belle: $R = (0.229 \pm 0.015\,(\text{stat})\,^{+0.013}_{-0.009}\,(\text{syst}))\%$ (PRL, 2005)
- *BABAR*: $R = (0.214 \pm 0.008\,(\text{stat}) \pm 0.008\,(\text{syst}))\%$ (preliminary)

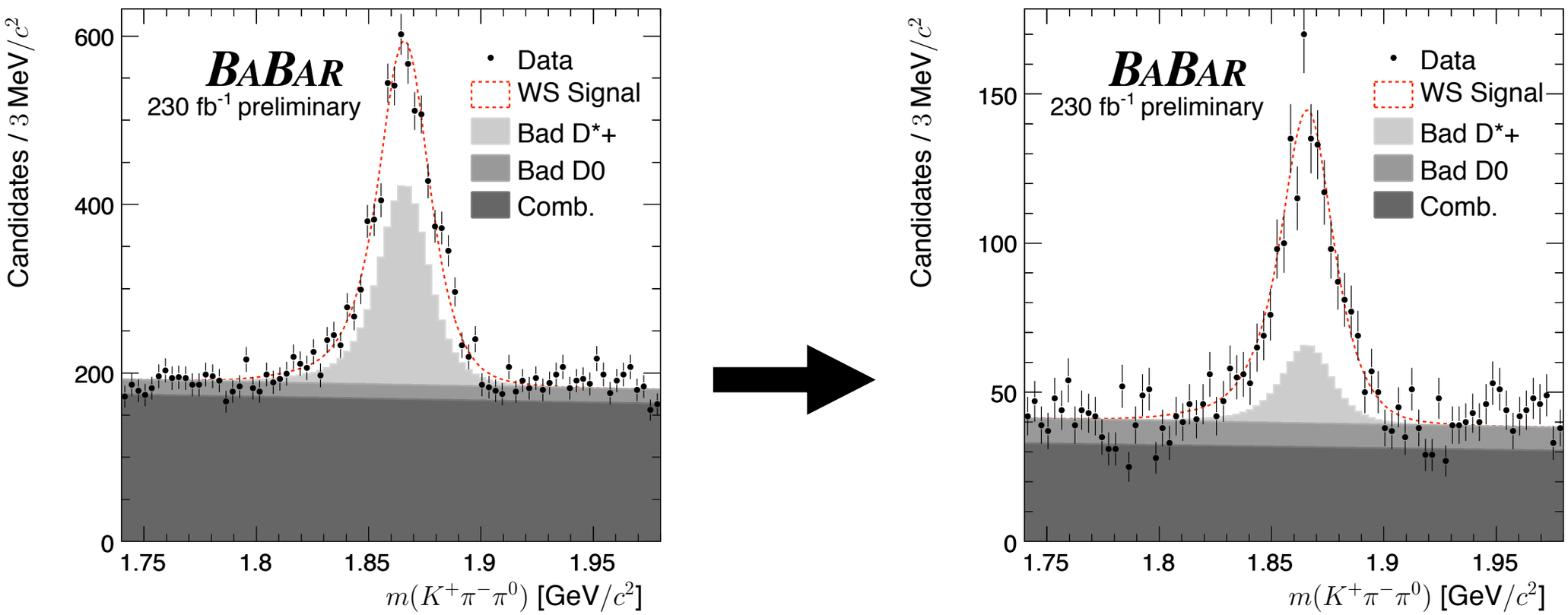
- Compare to the standard decay $D^0 \to K^+\pi^-$

$$\frac{\Gamma(D^0 \to K^+\pi^-)}{\Gamma(D^0 \to K^-\pi^+)} = (0.362 \pm 0.029)\%$$

Event-Level Tagging

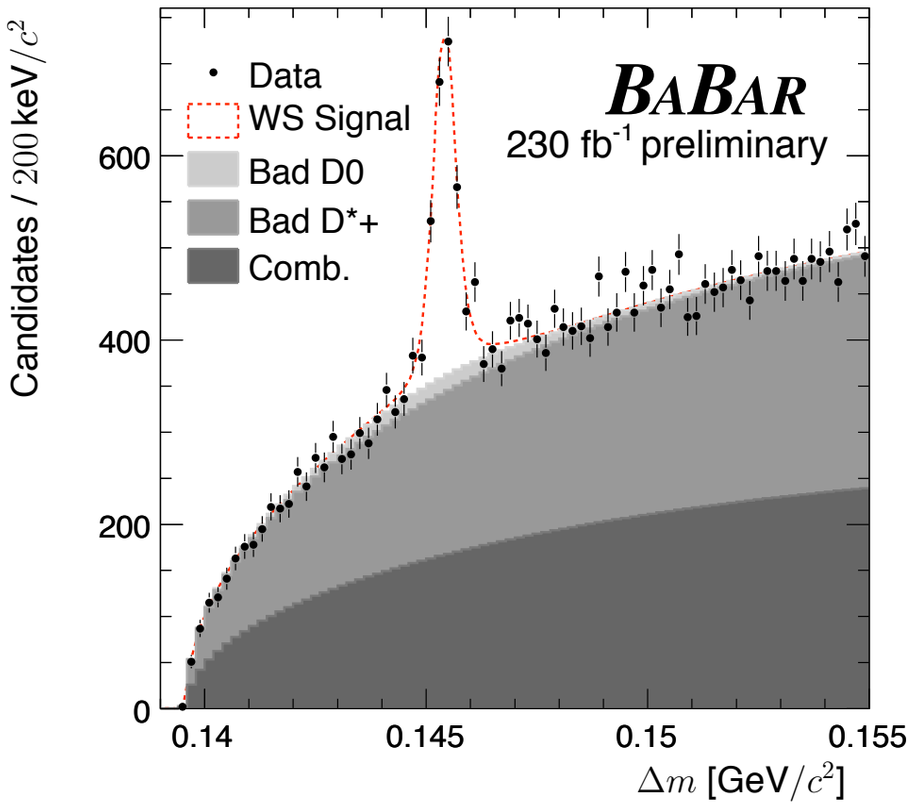
Using an event-level tag significantly reduces background

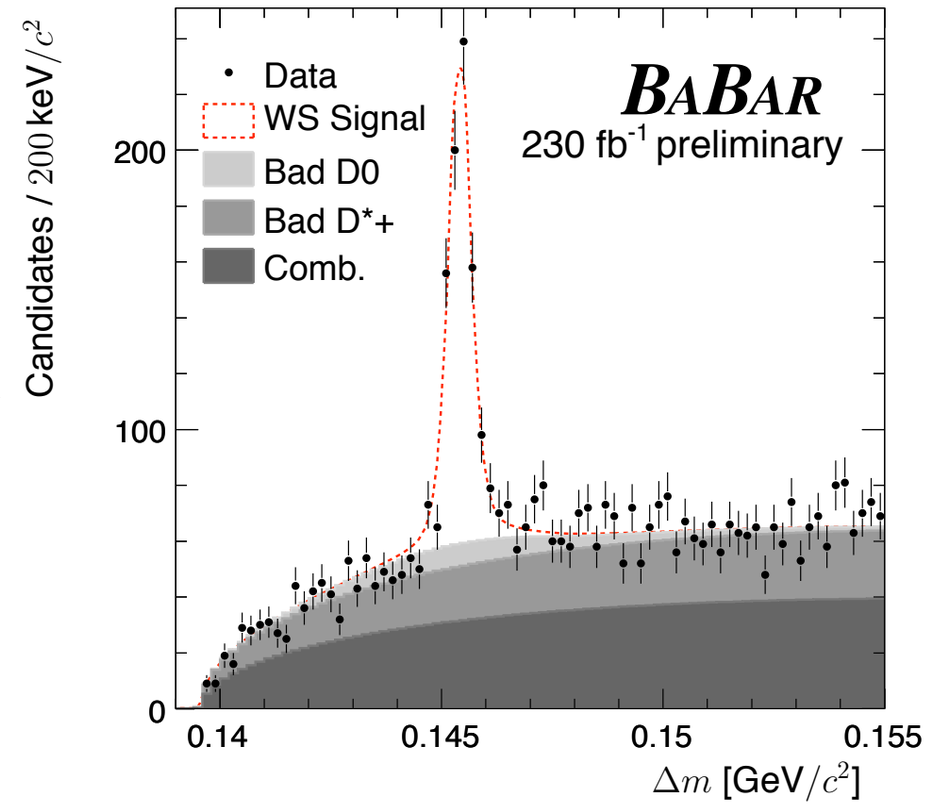
- Use $K^{\pm}$, $\pi_s^{\mp}$, $e^{\mp}$, and $\mu^{\mp}$ in the other side of the event



Never done before in this type of analysis

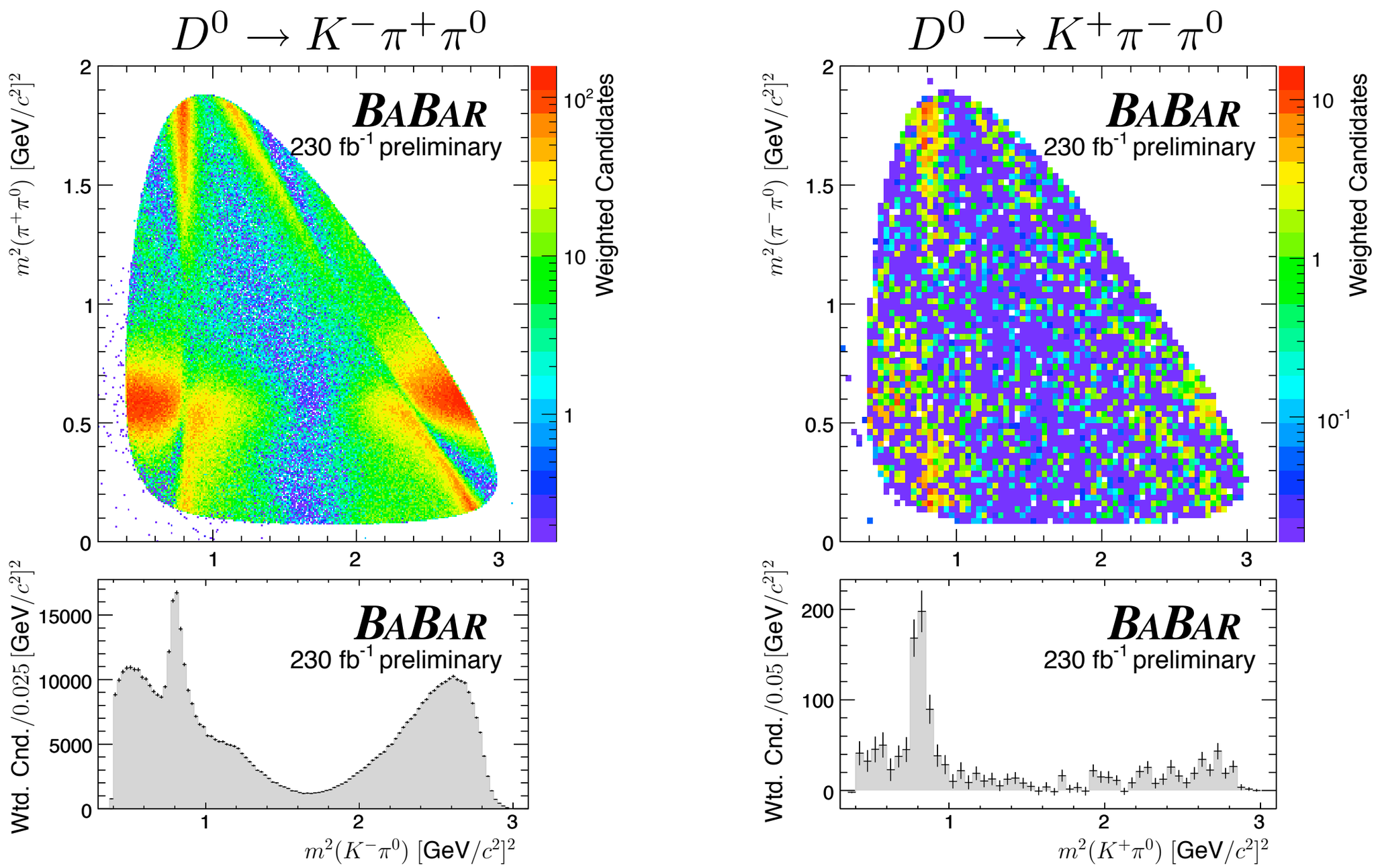
Event-Level Tagging





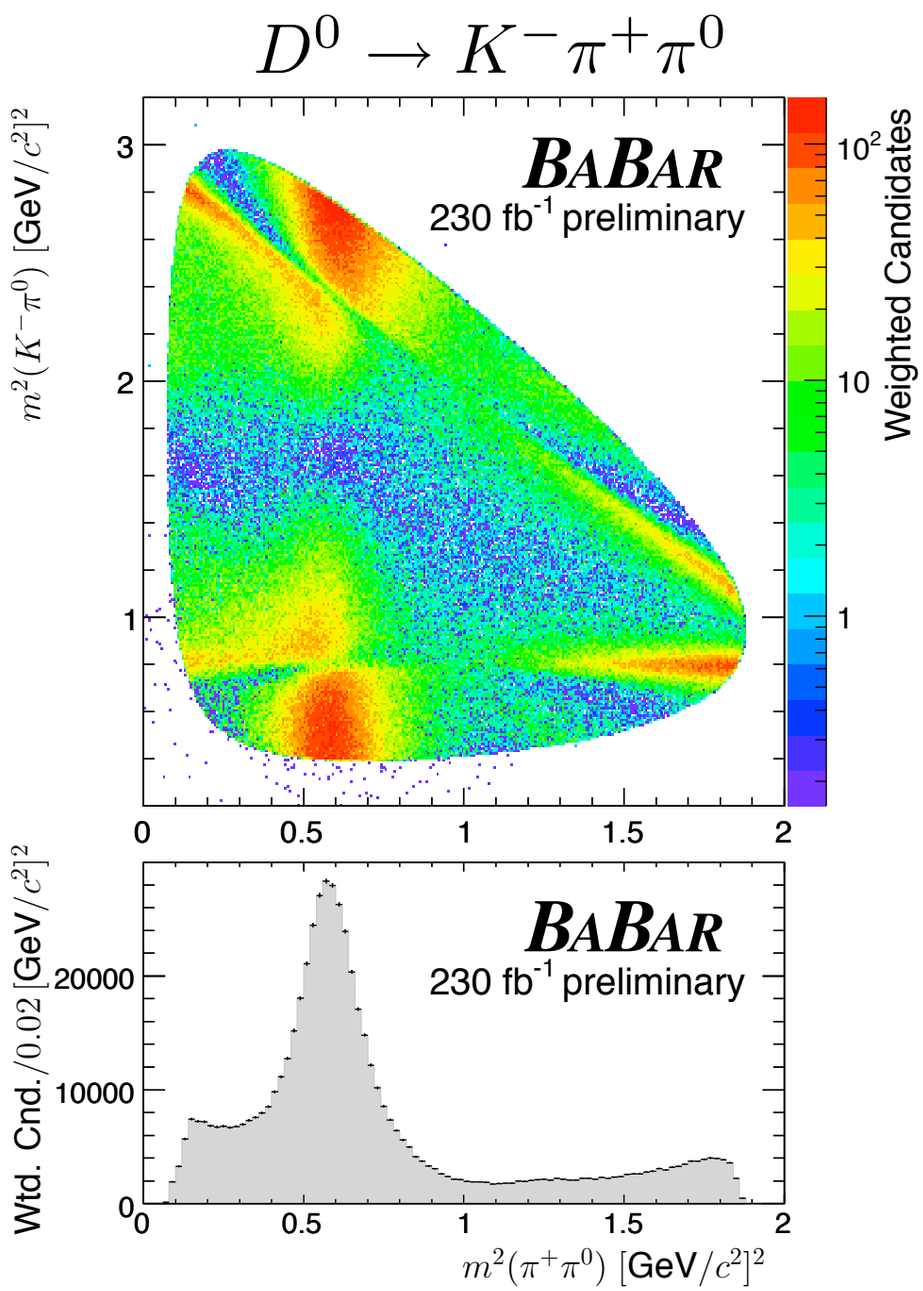
With this second tag, we can now look at the resonance contributions

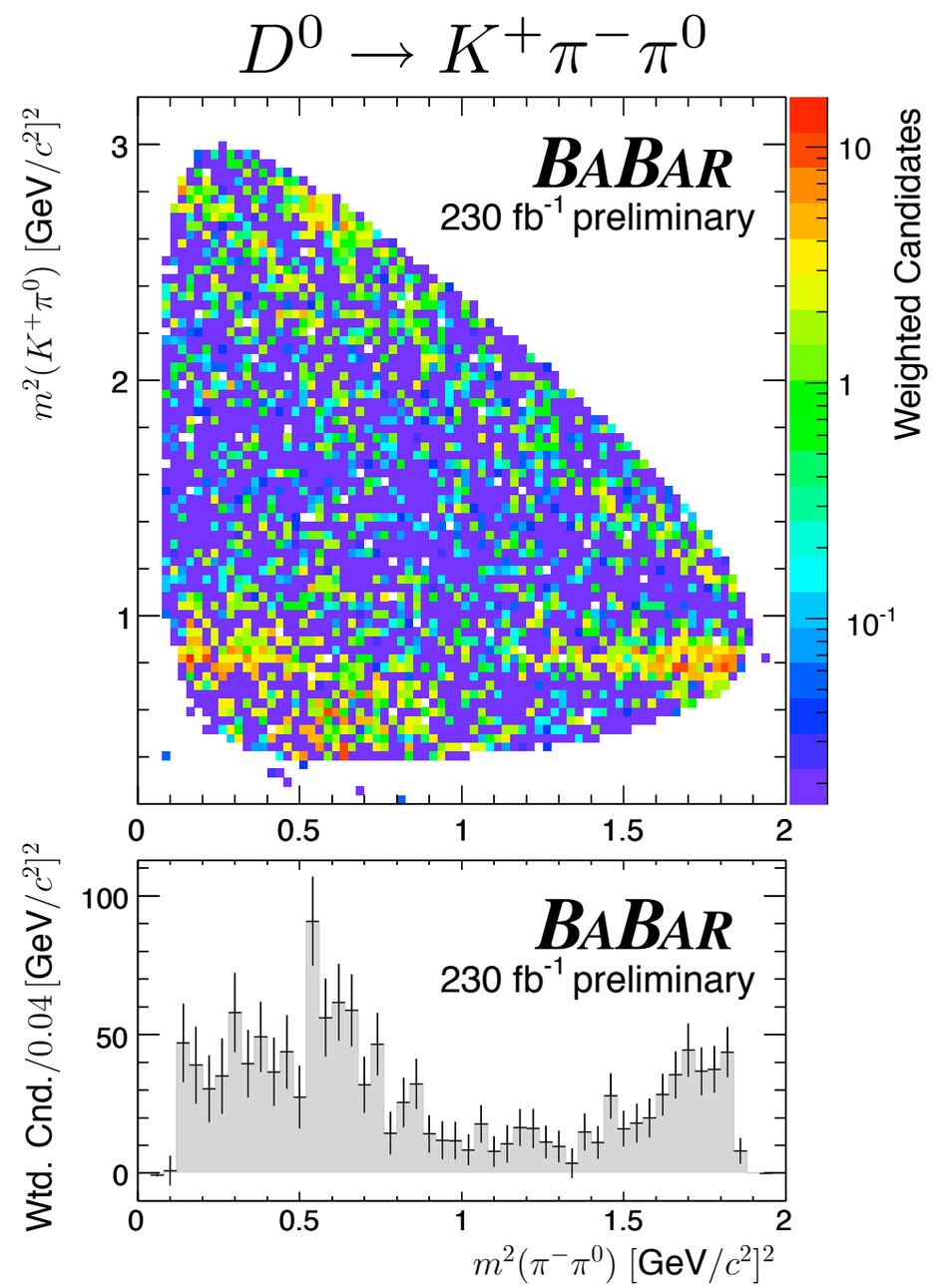
Resonance Contributions



Statistical background subtraction and efficiency correction applied

Resonance Contributions





Statistical background subtraction and efficiency correction applied

Mixing Formalism

The mass eigenstates $|D_1\rangle$ and $|D_2\rangle$ have different masses and lifetimes:

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

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

Signs of new physics:

- Observation of CP violation
- $x \gg y$

Time-integrated mixing rate: $R_M = \dfrac{x^2 + y^2}{2}$

Decay Time with Mixing

- At any particular point in phase space (Dalitz plot):

$$\frac{\Gamma_{\rm WS}(t)}{\Gamma_{\rm RS}(t)} = R_D + y'\sqrt{R_D}\,(\Gamma t) + \frac{x'^2 + y'^2}{4}(\Gamma t)^2$$

- Integrating over an arbitrary region of phase space:

$$\frac{\Gamma_{\rm WS}(t)}{\Gamma_{\rm RS}(t)} = \tilde{R}_D + \alpha\tilde{y}'\sqrt{\tilde{R}_D}\,(\Gamma t) + \frac{\tilde{x}'^2 + \tilde{y}'^2}{4}(\Gamma t)^2$$

$$0 \leq \alpha \leq 1$$

$$\tilde{x}'^2 + \tilde{y}'^2 = x^2 + y^2$$

$$\tilde{y}' = y\cos\tilde{\delta} - x\sin\tilde{\delta}$$
$$\tilde{x}' = x\cos\tilde{\delta} + y\sin\tilde{\delta}$$

Considering CP violation

We account for possible CP violation by fitting D^0 and $\overline{D}^0$ separately and making the substitutions:

$$\alpha\tilde{y}' \rightarrow \left|\frac{p}{q}\right|^{\pm 1} (\alpha\tilde{y}' \cos\tilde{\phi} \pm \beta\tilde{x}' \sin\tilde{\phi})$$

$$(x^2 + y^2) \rightarrow \left|\frac{p}{q}\right|^{\pm 2} (x^2 + y^2)$$

$$(+) \text{ for } \Gamma(\overline{D}^0 \rightarrow K^-\pi^+\pi^0)/\Gamma(D^0 \rightarrow K^-\pi^+\pi^0)$$

$$(-) \text{ for } \Gamma(D^0 \rightarrow K^+\pi^-\pi^0)/\Gamma(\overline{D}^0 \rightarrow K^+\pi^-\pi^0)$$

Selection of Phase-Space Regions

Based on inspection of the Dalitz plots, we exclude events in the regions:

$$850 < m(K\pi) < 950\,\mathrm{MeV}/c^2$$

$$850 < m(K\pi^0) < 950\,\mathrm{MeV}/c^2$$

suppress K^{*+} and K^{*0}

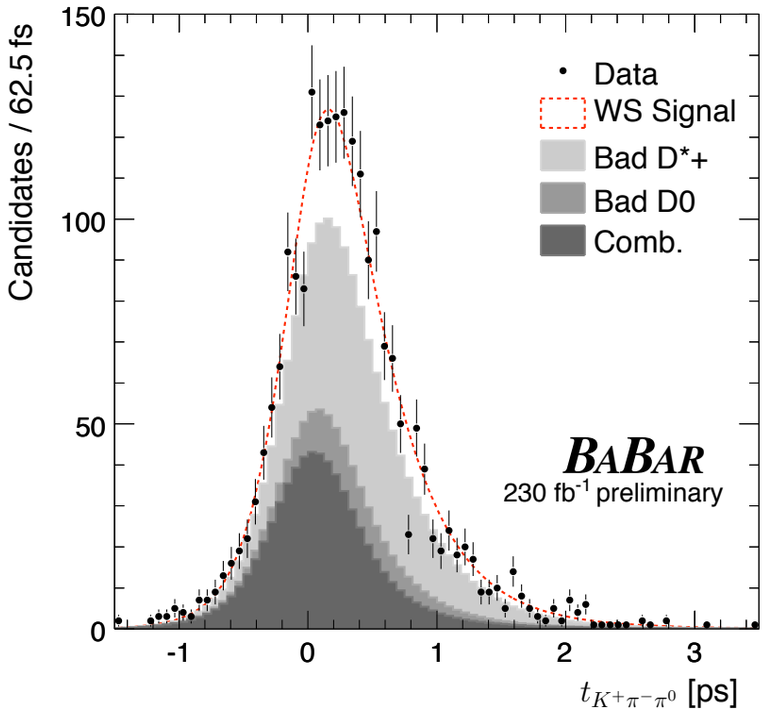
(a) selected phase-space region for mixing analysis

(b) entire allowed phase-space region

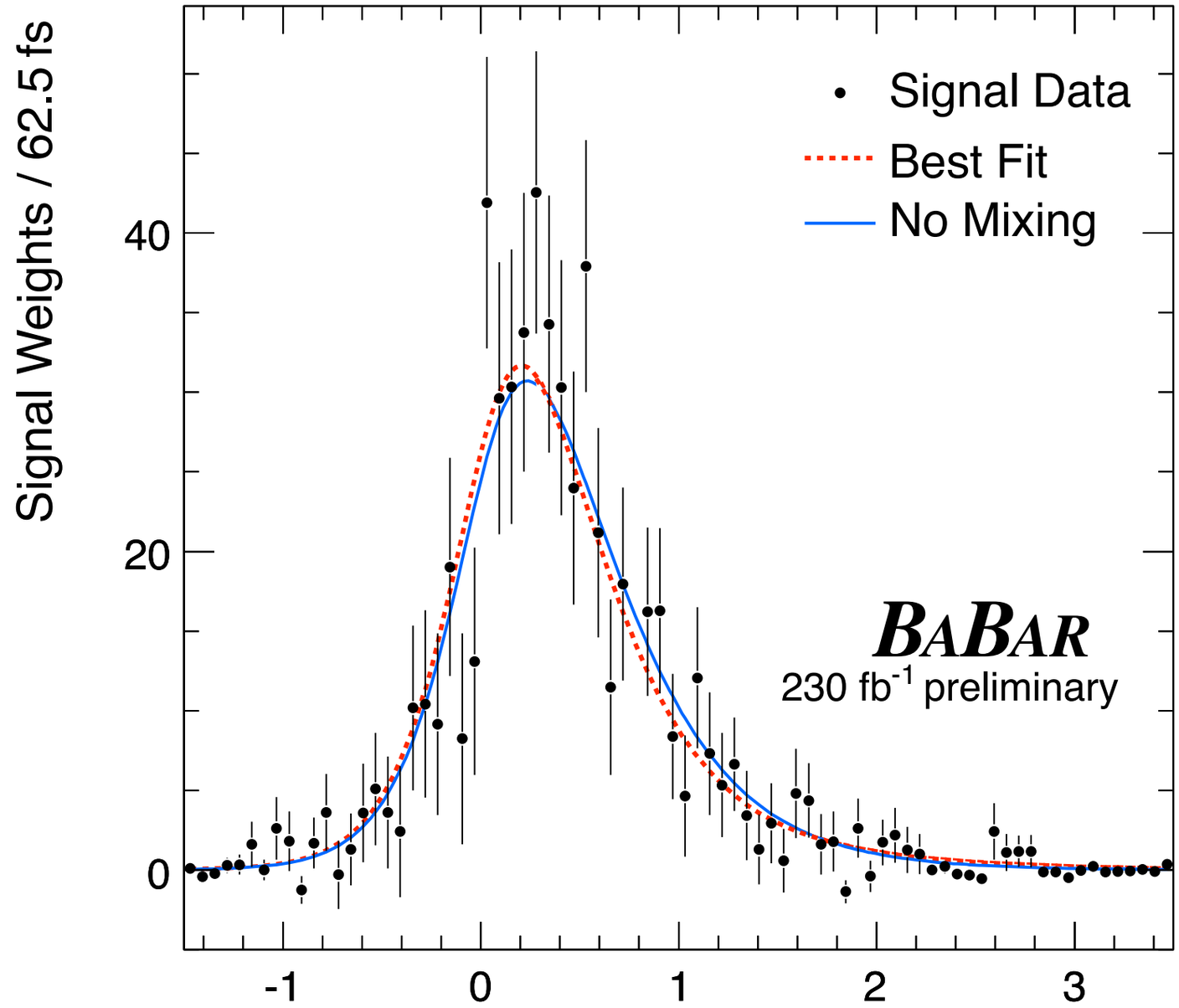
preliminary

		D^0 Cand.	$\overline{D}^0$ Cand.
(a)	WS	$(3.84 \pm 0.36) \times 10^2$	$(3.79 \pm 0.36) \times 10^2$
	RS	$(2.518 \pm 0.006) \times 10^5$	$(2.512 \pm 0.006) \times 10^5$
(b)	WS	$(7.5 \pm 0.5) \times 10^2$	$(8.1 \pm 0.5) \times 10^2$
	RS	$(3.648 \pm 0.007) \times 10^5$	$(3.646 \pm 0.007) \times 10^5$

PDF Fit to Decay Times

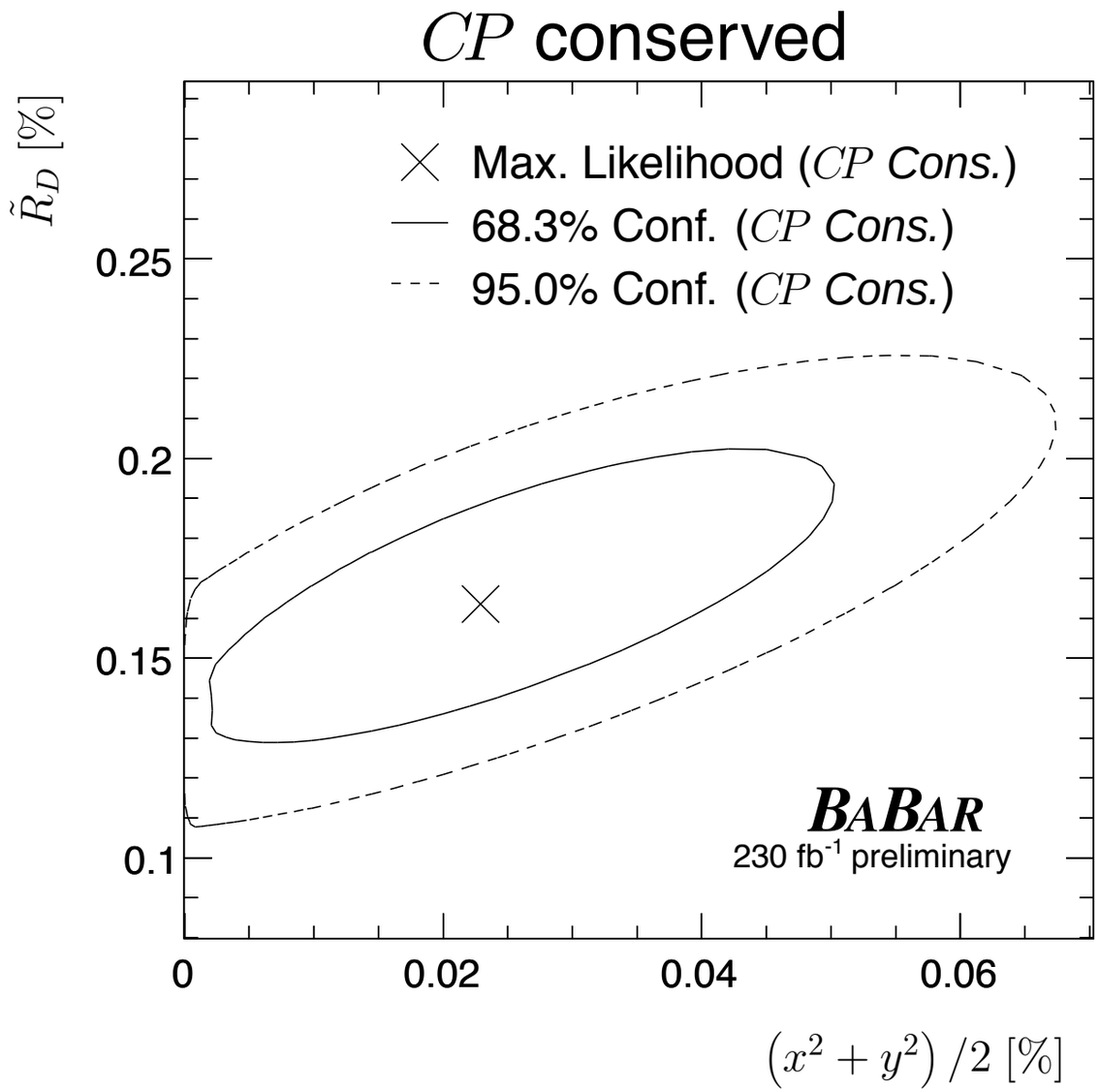


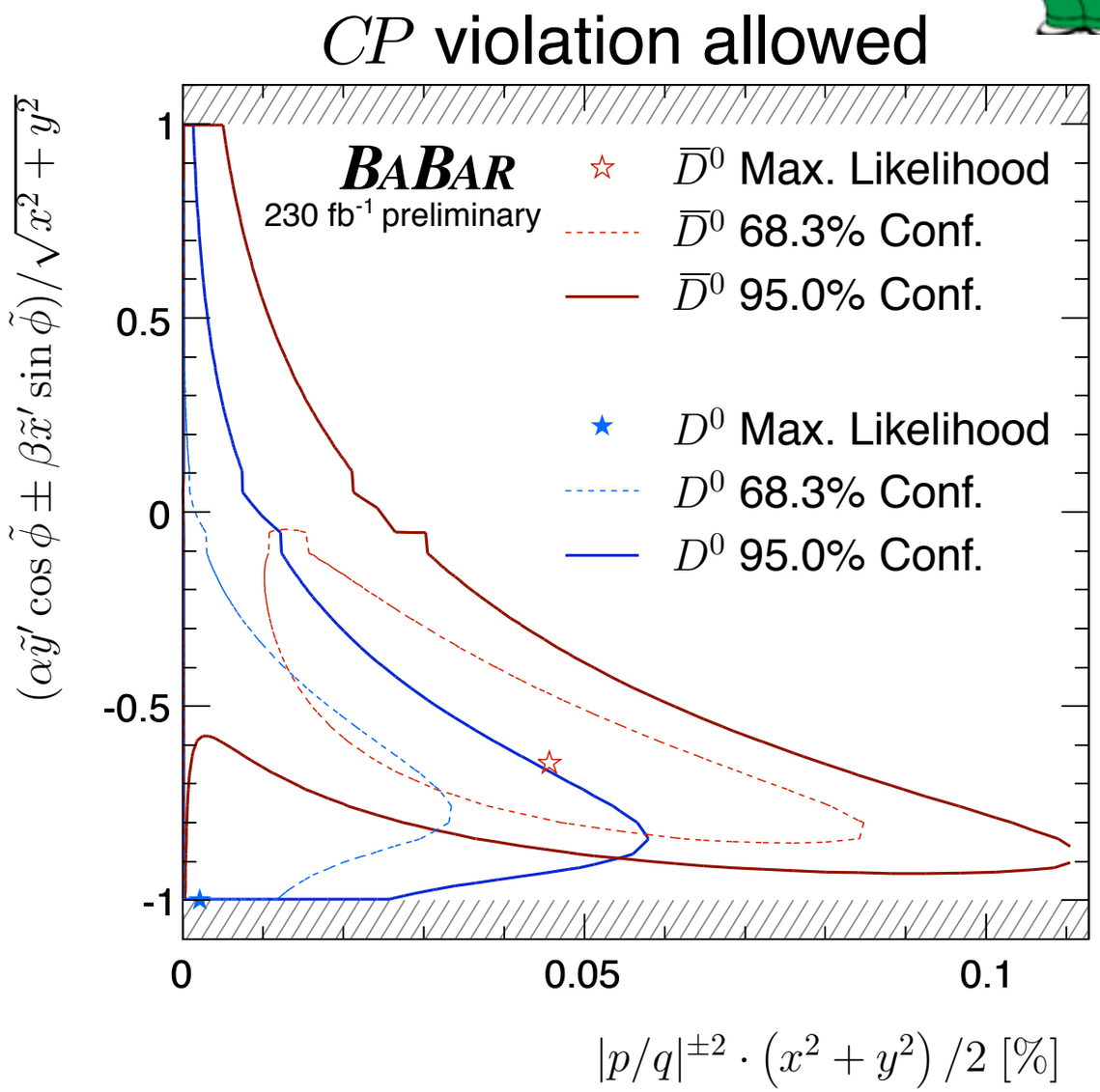
Decay times in a signal region



Data after a statistical background subtraction

Preliminary Mixing Results





Contours determined using $\Delta \log \mathcal{L}$ levels

Summary of Preliminary Results

	CP conserved		CP violation allowed
R_M	$(0.023\,^{+0.018}_{-0.014} \pm 0.004)\%$		$(0.010\,^{+0.022}_{-0.007})\%$
$\tilde{R}_D$	$(0.164\,^{+0.026}_{-0.022} \pm 0.012)\%$		
$\alpha\tilde{y}'$	$-0.012\,^{+0.006}_{-0.008} \pm 0.002$	$\alpha\tilde{y}' \cos\tilde{\phi}$	$-0.012\,^{+0.006}_{-0.007}$
		$\beta\tilde{x}' \sin\tilde{\phi}$	$0.003\,^{+0.002}_{-0.005}$
		$\lvert p/q \rvert$	$2.2\,^{+1.9}_{-1.0}$

$R_M < 0.054\%$ upper limit at 95% confidence level
(determined using $\Delta \log \mathcal{L}$)

Consistent with no mixing at 4.5% confidence level
(determined using a frequentist method)