A study of CP asymmetry in $B^0 \to D^{(*)}\pi$ and $B^0 \to D\rho$ decays in BaBar

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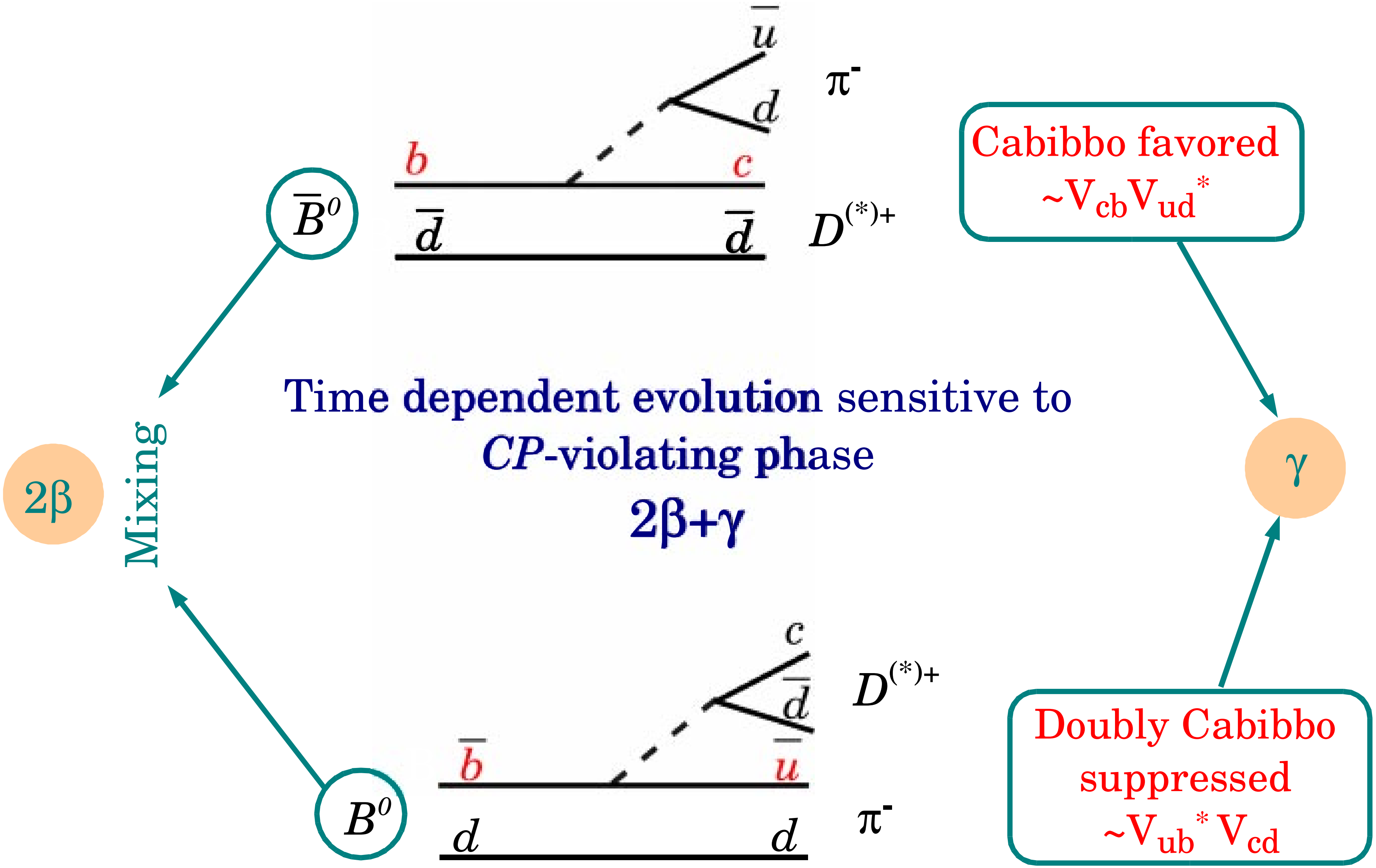
$2\beta+\gamma$ phase in $B \to D^{(*)}\pi$



Theoretical assumptions

✗ Final state not *CP* eigenstate ⇒ extract strong phase δ from $A_{D^-\pi^+}(t)$ and $A_{D^+\pi^-}(t)$

✗ Need to evaluate : $\lambda = r\, e^{-i(2\beta+\gamma-\delta)} = \dfrac{A(B^0 \to D^{(*)+}\pi^-)}{A(\bar{B}^0 \to D^{(*)+}\pi^-)}\, e^{-i(2\beta)}$

Expected: $r \approx \left|\dfrac{V_{ub}^*\, V_{cd}}{V_{ud}^*\, V_{cb}}\right| \approx 0.02$ ⇒ small *CP* asymmetry

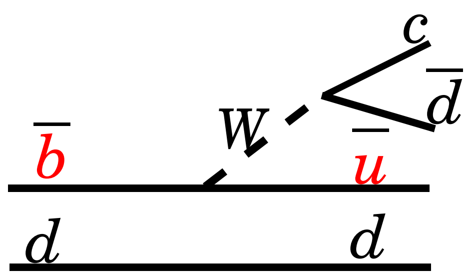
✗ Problem: *Doubly Cabibbo Suppressed* not directly measurable.
Solution: Use $B^0 \to D_s^{(*)+}\pi^-$ assuming :

- *SU(3)* symmetry
- *W*-exchange negligible ⇒ $B^+ \to D^{(*)+} K^0$

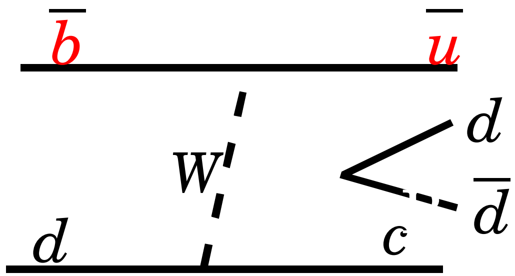
Use of $B^0 \to D_s^{(*)} \pi$

SU(3)

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

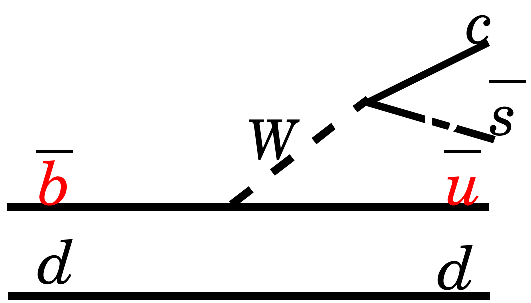


Tree diagram



W-exchange diagram

$B^0 \to D_s^{(*)+} \pi^-$



Only a tree diagram

$$r^{(*)} = tg\theta_c \sqrt{\frac{BR\,(B^0 \to D_s^{(*)+}\pi^-)}{BR\,(B^0 \to D^{(*)-}\pi^+)}}\;\frac{f_{D^{(*)}}}{f_{D_s^{(*)}}}$$

$$r = 0.019 \pm 0.004$$

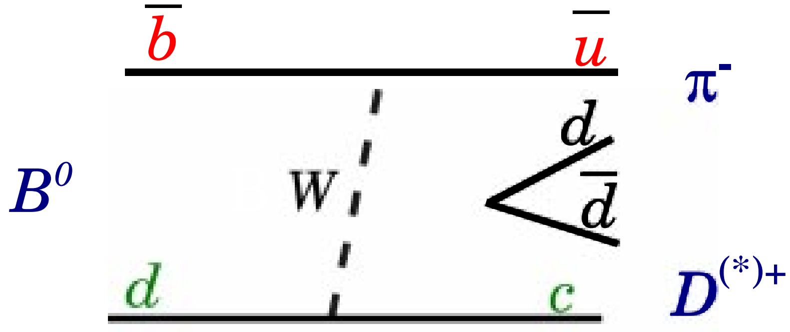
$$r^* = 0.017^{+0.005}_{-0.007}$$

We assume 30% theoretical error on *r*

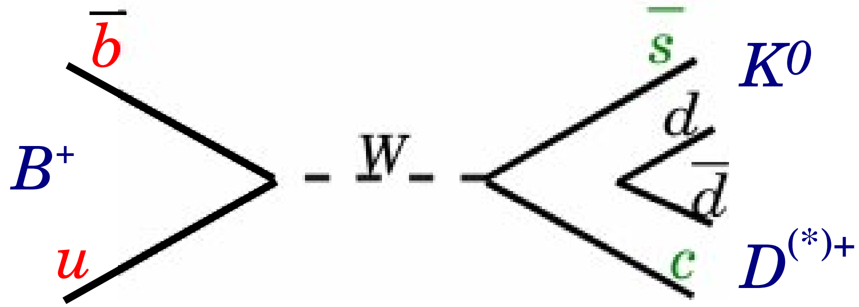
Annihilation & W-exchange

- $B^+ \to D^{(*)+} K^0$ is a pure annihilation process.
- Annihilation & W-exchange are the same kind of process in *OPE*.
- No precise theoretical evaluation (factorization is not possible)
- One expect also a suppression factor: $f_B / m_B \sim \lambda^2_{cab}$
- Theories considering rescattering predicts amplitude enhancement of λ^2_{cab}
- Usually neglected
- We find (@ 90% CL) :

$$BR (B^+ \to D^+ \ K^0) < 2.2 \bullet 10^{-5}$$
$$BR (B^+ \to D^{*+} K^0) < 1.3 \bullet 10^{-5}$$

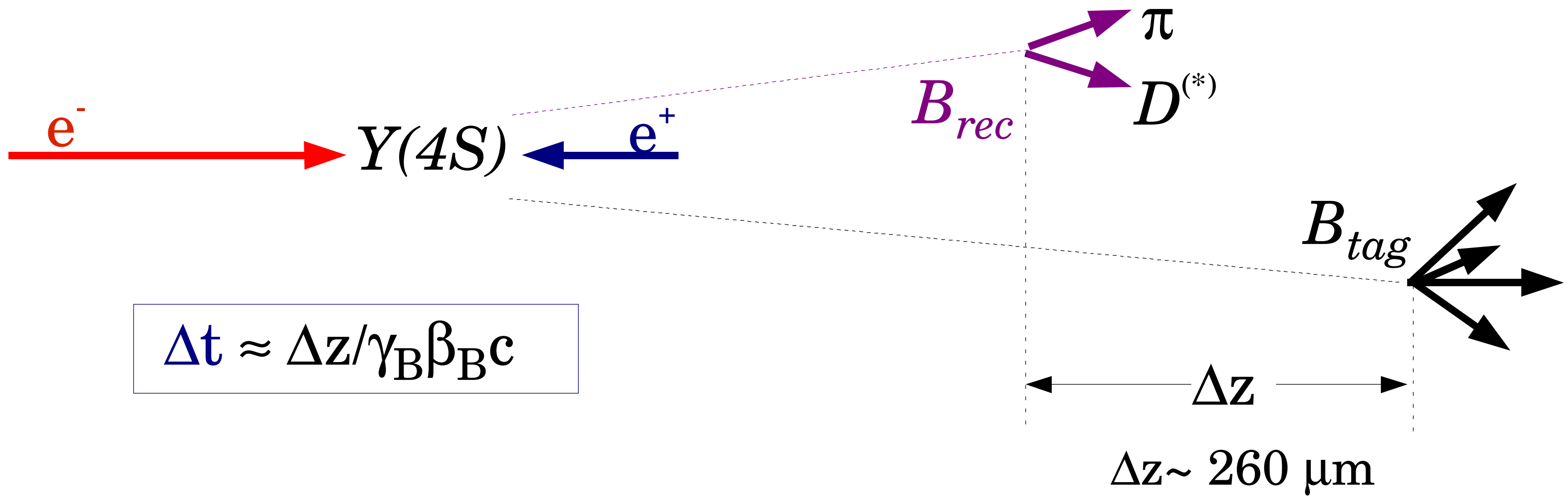


W-exchange diagram



Annihilation diagram

Time-dependent analysis



$$\Gamma(B \to D^{(*)}\pi) \propto 1 + \xi_m \cos(\Delta m \Delta t) - [\xi_l a + \xi_m c + \xi_l \xi_m b]\sin(\Delta m \Delta t)$$

ξ_m = 1(-1) for events tagged as unmixed (mixed)

ξ_l = 1(-1) for B_{tag} identified as B^0 ($\bar{B}^0$)

r',δ' are the ratio and difference between the $b \to u$ and $b \to c$ amplitudes in the B_{tag} decay. r'= 0 in lepton tags.

$a = 2r \sin(2\beta+\gamma) \cos\delta$

$b = 2r' \sin(2\beta+\gamma) \cos\delta'$

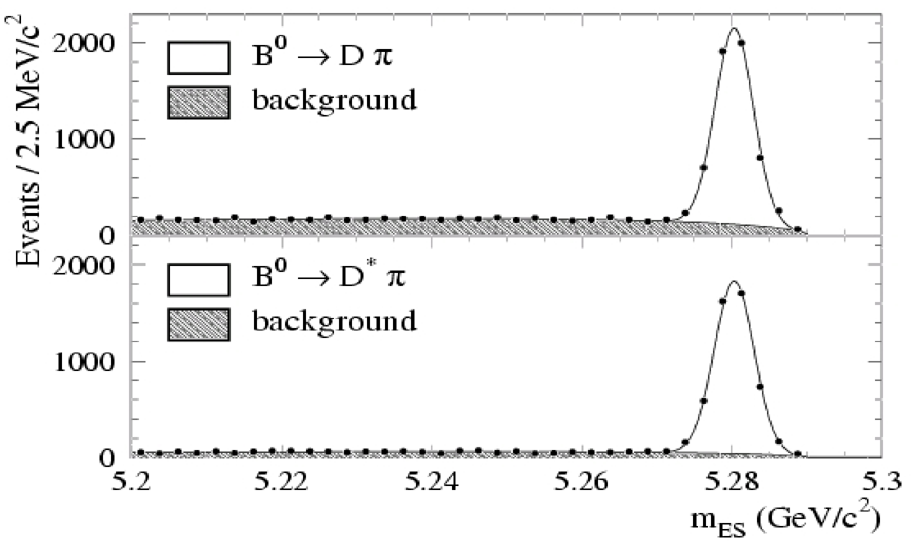
$c = 2 \cos(2\beta+\gamma) (r \sin\delta - r' \sin\delta')$

Full reconstruction

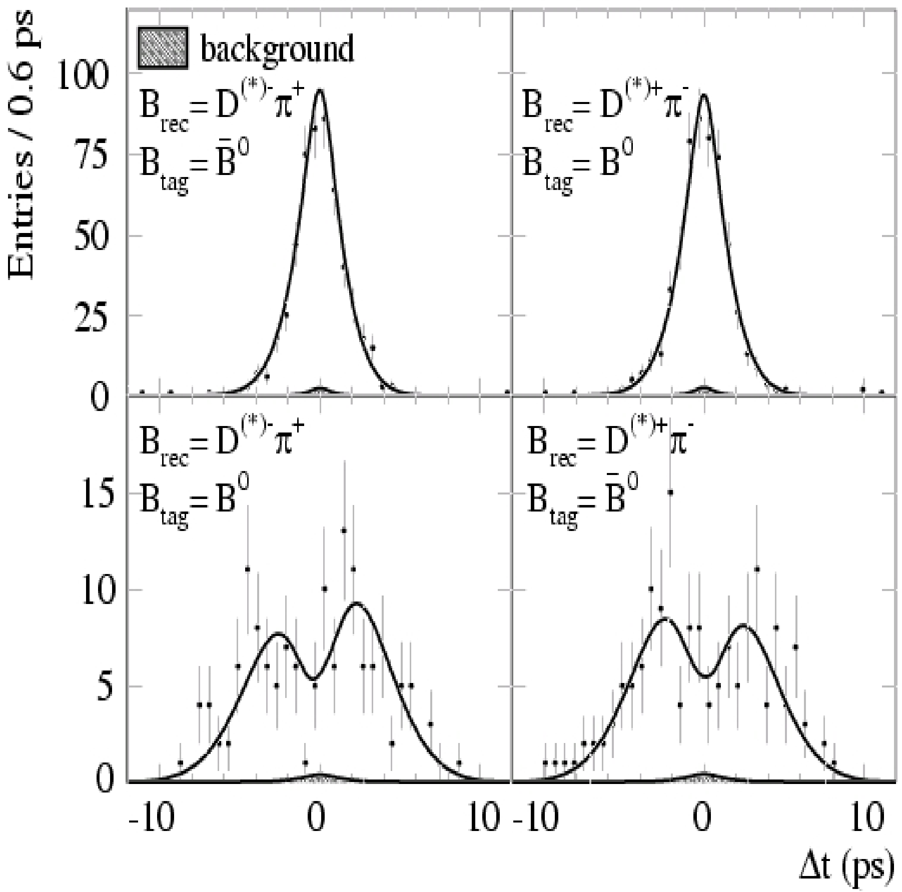
81 fb^{-1}
(hep-ex/0309017)

	signal events	purity
$B^0 \to D\pi$	5207 ± 87	84.9%
$B^0 \to D^*\pi$	4746 ± 78	94.4%

$$m_{ES} = \sqrt{E_{beam}^2 - p_B^2}$$



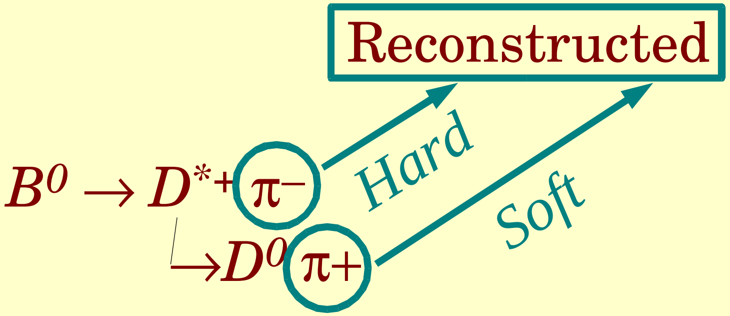
Time evolution for lepton category



Partial reconstruction

76 fb^{-1}

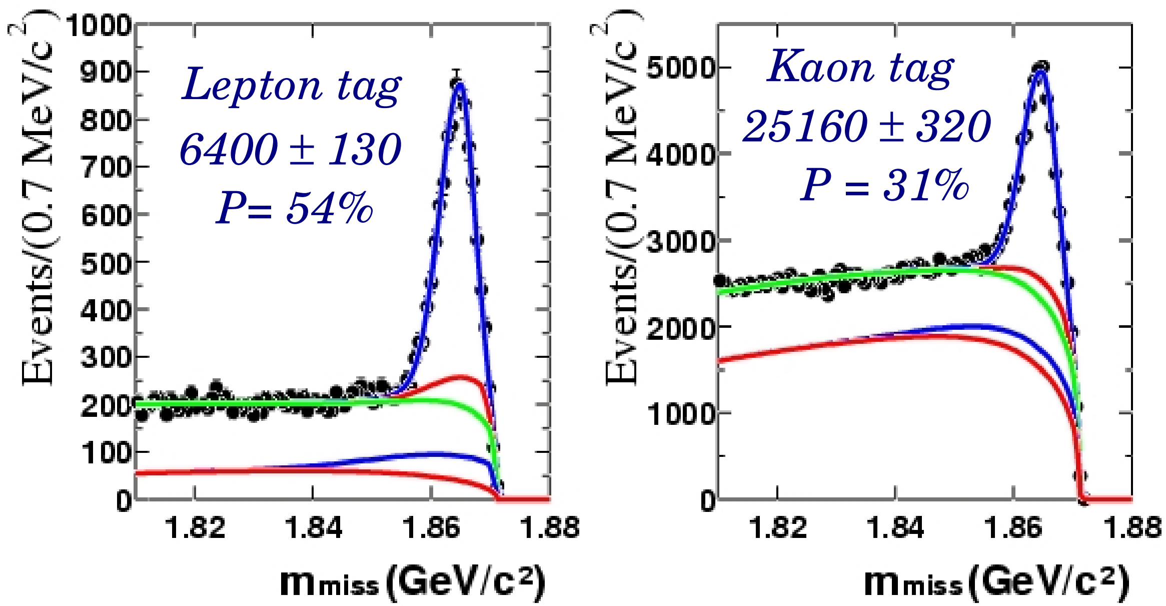
(hep-ex/0310037)



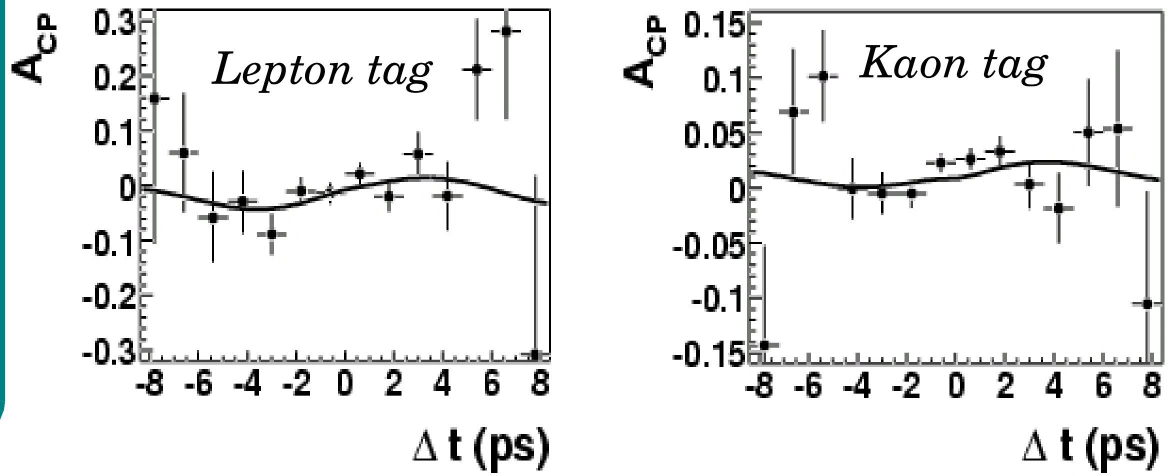
No efficiency loss for D^0 reconstruction

m_{miss} = D invariant mass

$$A_{CP} = \frac{N_{B^0_{tag}} - N_{\overline{B}^0_{tag}}}{N_{B^0_{tag}} + N_{\overline{B}^0_{tag}}}$$



$D^*\rho$ Combinatorial *BB* Peaking *BB* Continuum



Results

From Time–Dependent Maximum Likelihood Fit

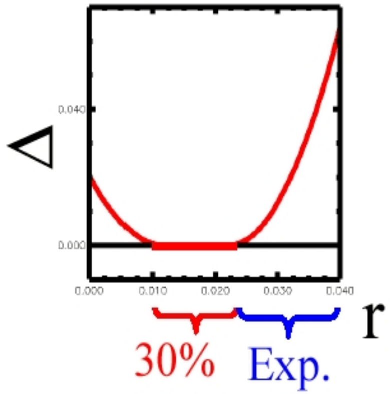
		a	c_{lep}
Full reco	$D\pi$	-0.022 ± 0.038 ± 0.020	0.025 ± 0.068 ± 0.033
	$D^*\pi$	-0.068 ± 0.038 ± 0.020	0.031 ± 0.070 ± 0.033
Partial reco	$D^*\pi$	-0.022 ± 0.038 ± 0.020	-0.022 ± 0.038 ± 0.020

Partial reco has 5% overlap with full reconstruction sample

Systematics

- ✗ Control sample statistics
- ✗ Monte Carlo statistics
- ✗ Detector alignment
- ✗ Tagging
- ✗ Background modeling
- ✗ Fit procedure

Limits on sin(2β+γ): strategy

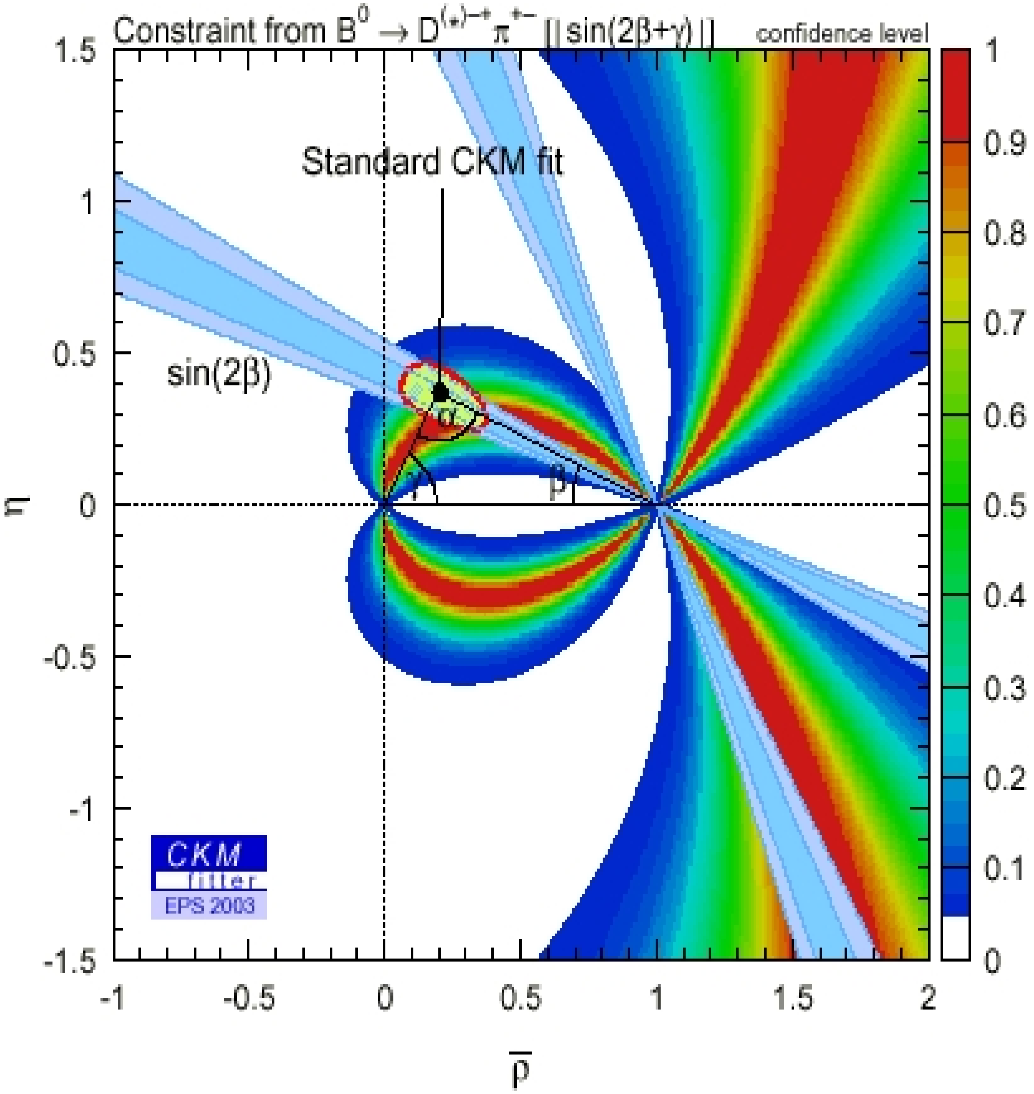


- The observables a and c_{lep} are functions of the physical parameters $sin(2\beta+\gamma)$, δ, r.
- Minimize:

$$\chi^2\,(sin(2\beta+\gamma),\,\delta,\,r) = \sum_i \left(\frac{x_i - x_i^{meas}}{\sigma_i^{meas}}\right)^2 + \Delta(r_{D\pi}) + \Delta(r_{D^*\pi})$$

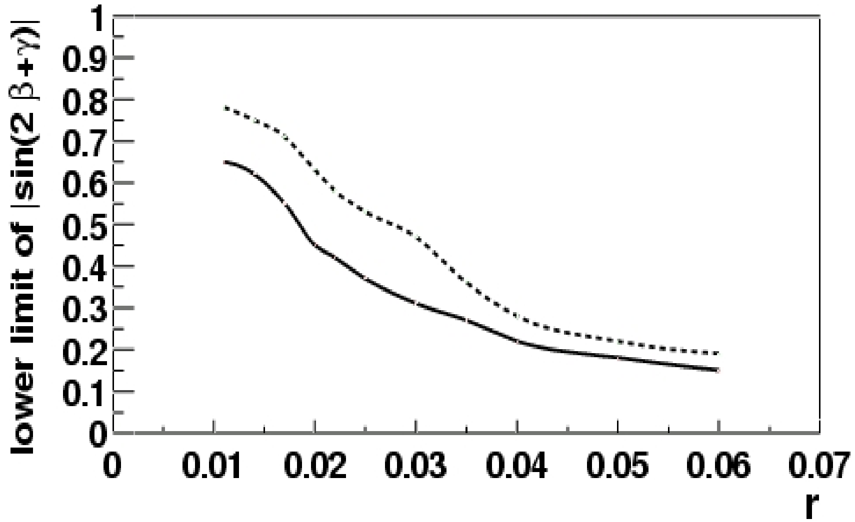
- Large errors and edge effects near $sin(2\beta+\gamma)=1$, so χ^2 highly non-quadratic
- Use a frequentist approach to obtain a limit on $|sin(2\beta+\gamma)|$:
  - Run many parameterized *MC* experiments for different values of $sin(2\beta+\gamma)$
  - The fraction of such experiments for which $\chi^2\,(sin(2\beta+\gamma) - \chi^2_{min}$ is smaller than in the data is the confidence level of the lower limit for that value of $sin(2\beta+\gamma)$

Limits on sin(2β+γ): results



$|sin(2\beta+\gamma)| > 0.87$ (@ 68% CL)
$|sin(2\beta+\gamma)| > 0.58$ (@ 95% CL)

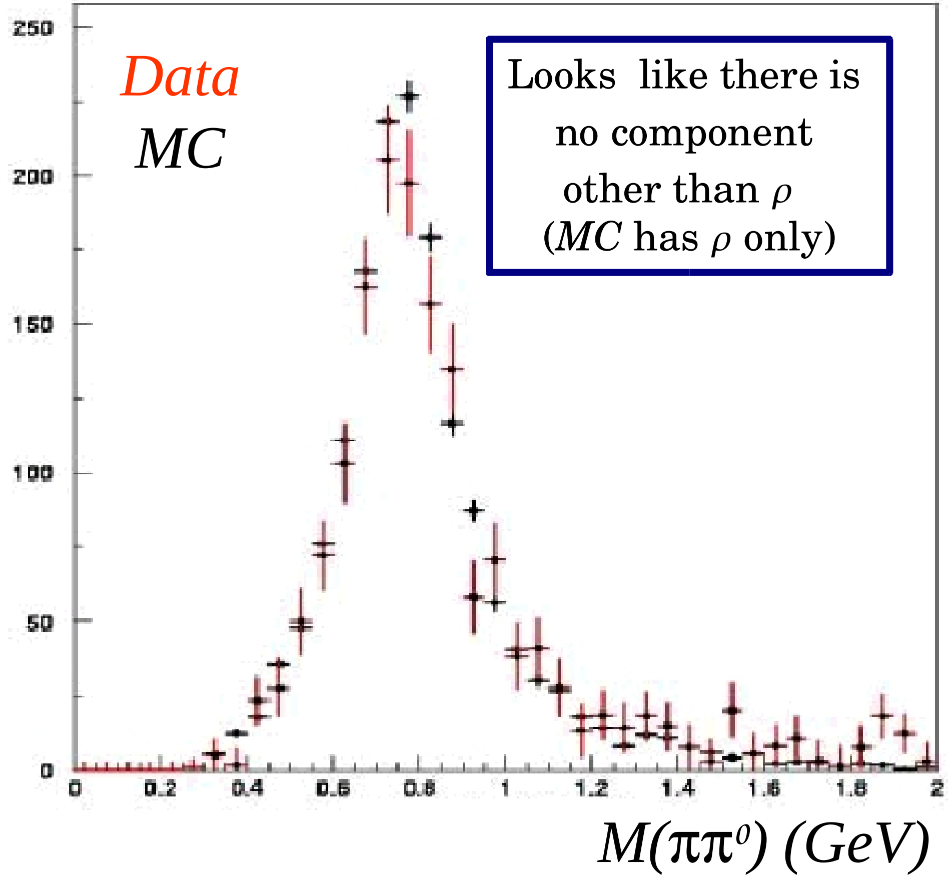
Limit from $D^*\pi$ without theoretical assumptions on r



$\sin(2\beta+\gamma)$ with $B \to D\rho$

If only a ρ component in the selected $\pi\pi^0$ invariant mass region:

- same time evolution of $D^{(*)}\pi$ final states (sensitive to $\sin(2\beta+\gamma)$)
- same analysis technique



Detailed background studies underway

We are working for a global fit of $B \to D^{(*)}\pi$ and $B \to D\rho$ to improve constraints on $\sin(2\beta+\gamma)$

Conclusions

- Time dependent evolution of $B \to D(*)\pi$ and $B \to D\rho$ decays is sensitive to *CP* violating phase $\sin(2\beta+\gamma)$.

- Full reconstruction of $B \to D(*)\pi$ decays performed on $81 fb^{-1}$:

  $a(D\pi) = -0.022 \pm 0.038 \pm 0.020$ $\quad$ $c(D\pi) = 0.025 \pm 0.068 \pm 0.033$

  $a(D^{*}\pi) = -0.068 \pm 0.038 \pm 0.020$ $\quad$ $c(D^{*}\pi) = 0.031 \pm 0.070 \pm 0.033$

- Partial reconstruction of $B \to D^{*}\pi$ decays performed on $76\ fb^{-1}$:

  $a(D^{*}\pi) = -0.063 \pm 0.024 \pm 0.014$ $\quad$ $c(D^{*}\pi) = 0.008 \pm 0.0037 \pm 0.020$

- $B \to D\rho$ analysis needs to verify the presence of contributions other than ρ *in* $\pi\pi^{0}$ invariant mass.

- The time-dependent maximum likelihood fit on $B \to D\rho$ is underway.