Status and Prospects for the measurement of angle γ

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On behalf of the BaBar Collaboration

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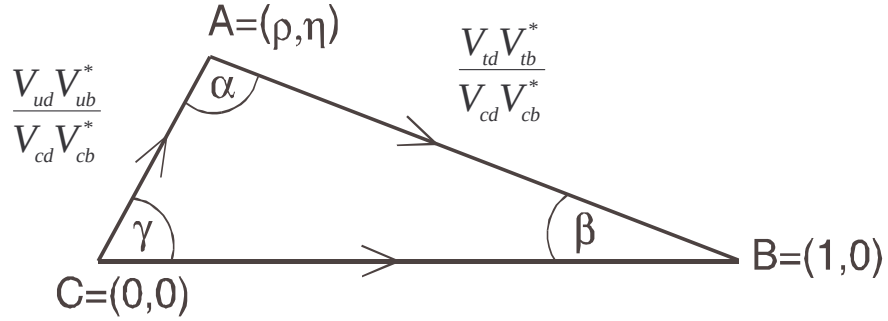
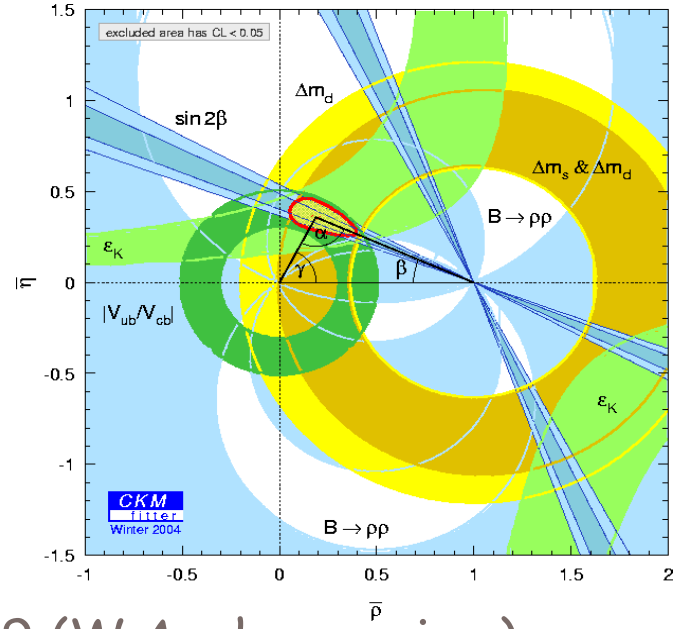
Status of CP violation in the B mesons system & angle γ

Unitarity test : $V_{ud}V_{ub}^{*}+V_{cd}V_{cb}^{*}+V_{td}V_{tb}^{*}=0$

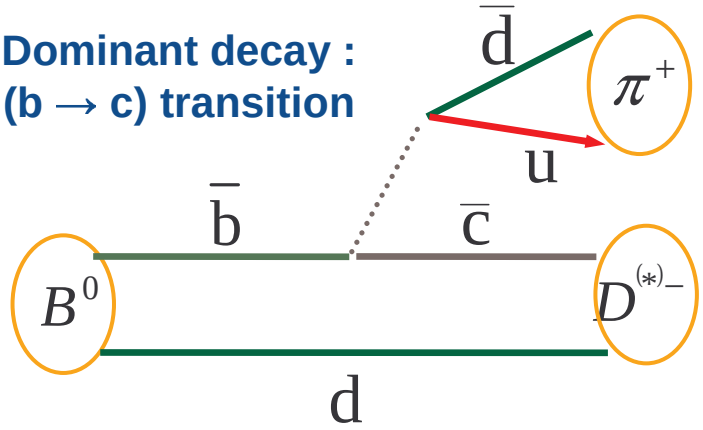




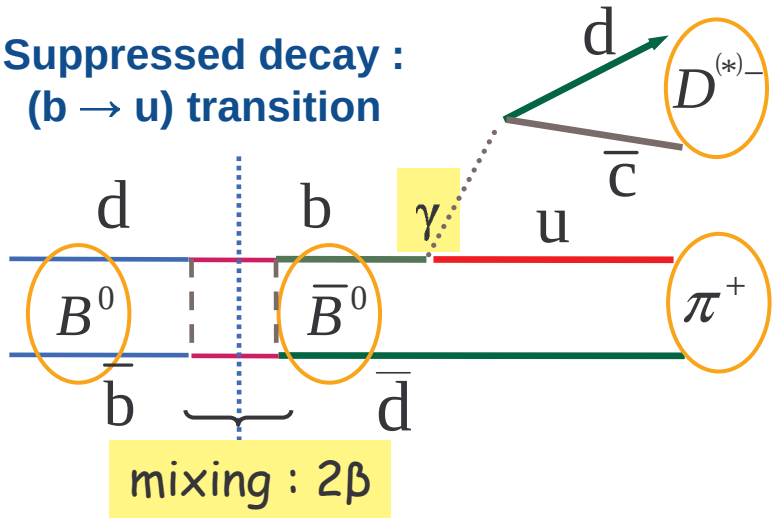
- CP violation well established in B mesons
  - measurement of sin(2β) = 0.736 ± 0.049 (W.A. charmonium)
- next step : need to overconstrain the triangle
- ways to measure γ :
  - sin(2β+γ) with $B^0 \rightarrow D^{(*)}\pi$:
    - full reconstruction
    - partial reconstruction
  - γ with the decays $B^{\pm} \rightarrow D^0K^{\pm}$ (GLW and ADS methods)

CP violation in $B^0 \to D^{(*)}\,\pi$

Dominant decay :
(b → c) transition



Suppressed decay :
(b → u) transition



- **interference between decays with and without mixing :**

  relative weak phase (2β+γ)

- **relative strong phase δ between both amplitudes**

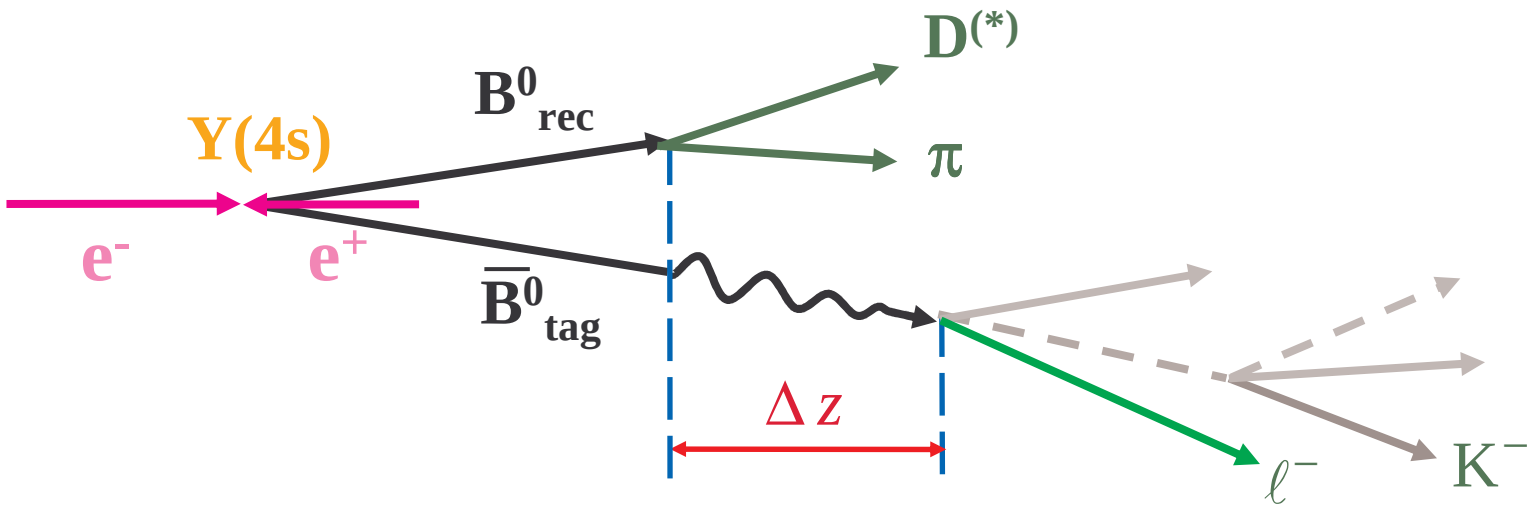
  - no penguin contributions
  - small CP asymmetries (~ $2r^{(*)}$)

$$r^{(*)} = \left| \frac{A(\bar{B}^0 \to D^{(*)-}\pi^+)}{A(B^0 \to D^{(*)-}\pi^+)} \right| \approx 0.02$$

$r^{(*)}$ is estimated using :
$\mathcal{B}(B^0 \to D_s^{(*)+}\,\pi^-)$ + SU(3)

$$r = 0.021^{+0.004}_{-0.005} \qquad r^* = 0.017^{+0.005}_{-0.007}$$

Time-dependent CP asymmetries



$$\begin{cases} P(B^0 \to D^{(*)\mp}\pi^{\pm}, \Delta t) \propto \{1 \pm \cos(\Delta m_d \Delta t) + [\pm a \mp c \pm b]\sin(\Delta m_d \Delta t)\} \\ P(\overline{B}^0 \to D^{(*)\mp}\pi^{\pm}, \Delta t) \propto \{1 \mp \cos(\Delta m_d \Delta t) - [\mp a \pm c \mp b]\sin(\Delta m_d \Delta t)\} \end{cases}$$

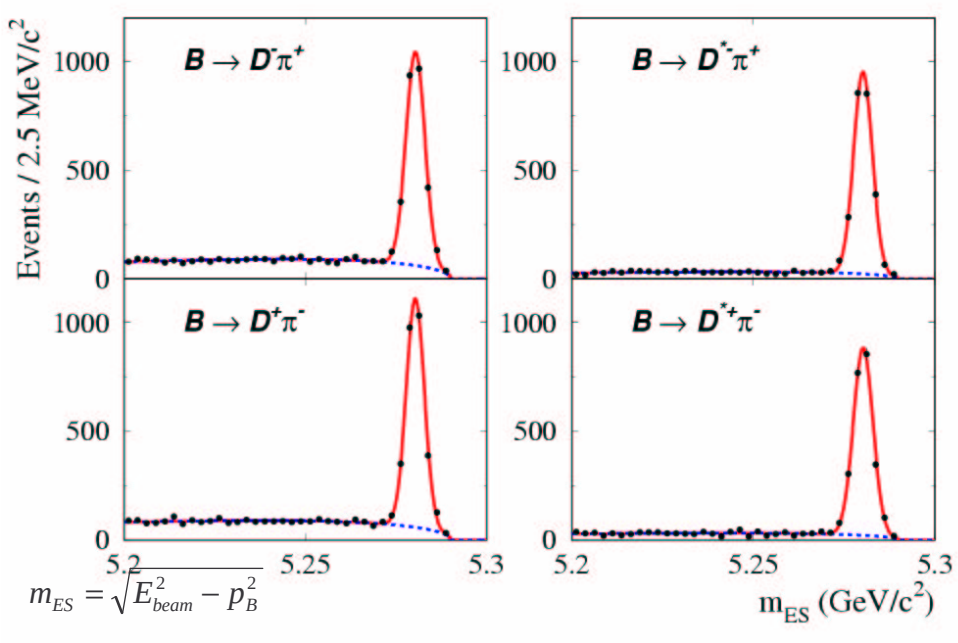
Measured CP parameters :

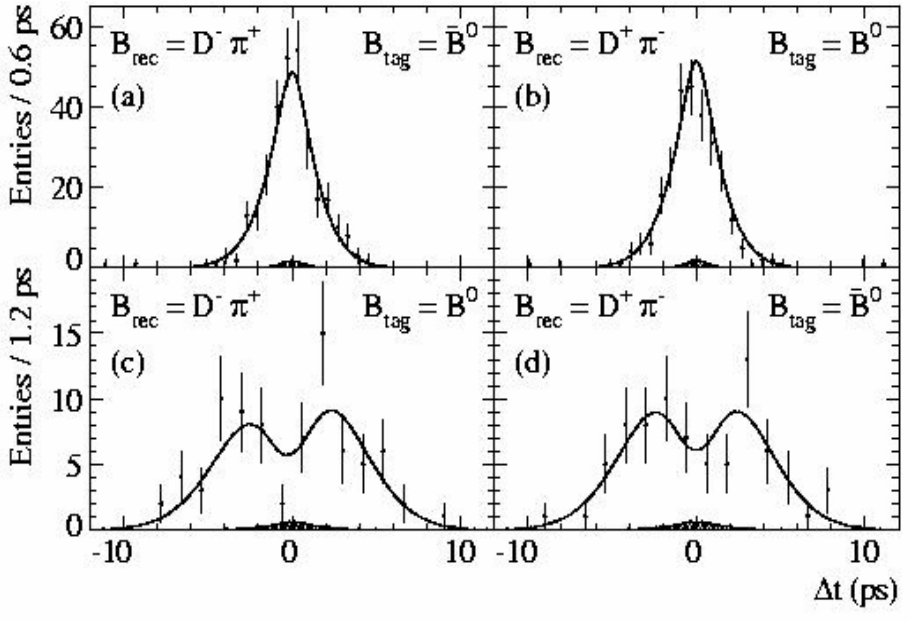
$$\begin{cases} a = 2r\sin(2\beta+\gamma)\cos(\delta) \\ b = 2r'\sin(2\beta+\gamma)\cos(\delta') \\ c = 2\cos(2\beta+\gamma)(r\sin(\delta) - r'\sin(\delta')) \end{cases}$$

r' and δ' take into account (b → u) interference effects in the tag side

Full reconstruction of $B^0 \to D^{(*)} \pi$

82 fb^{-1}





Large sample, very few background

N(Dπ) = 5207 ± 87 (purity=85%)

N(D*π) = 4746 ± 78 (purity=94%)

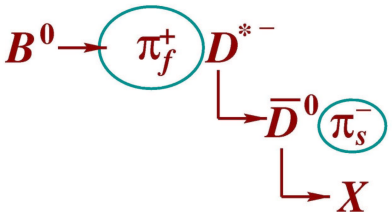
$$a = 2r\sin(2\beta+\gamma)\cos(\delta) = -0.022 \pm 0.038 \pm 0.020$$
$$a^* = 2r^*\sin(2\beta+\gamma)\cos(\delta^*) = -0.068 \pm 0.038 \pm 0.020$$

measurement limited by the statistics

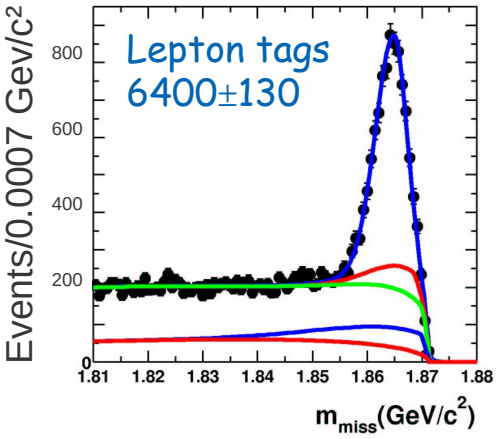
(Hep-ex/0308048, accepted by PRL)

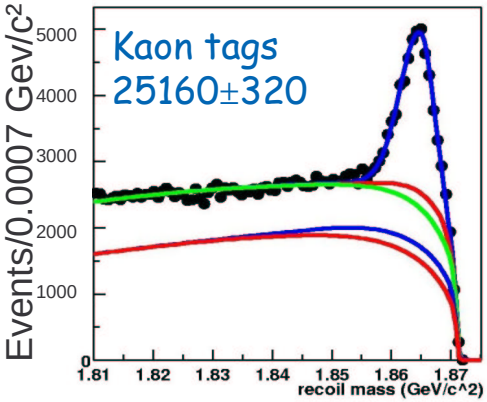
Partial reconstruction of $B^0 \to D^* \pi$

76 fb^{-1}

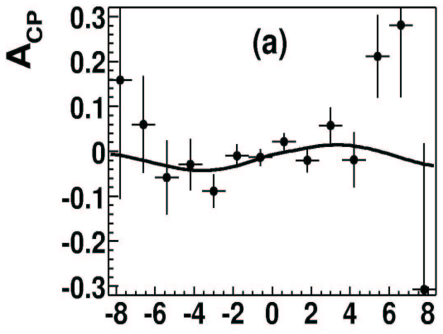


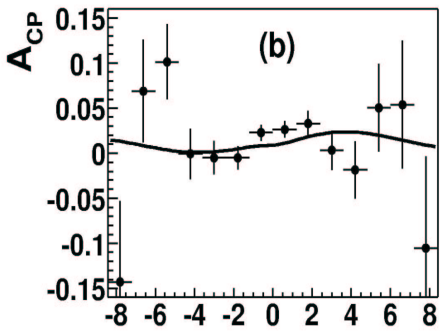
- no attempt to reconstruct D^0
- more events but more background





$$\mathcal{A}_{CP}^{rec} = \frac{N(B^0_{tag}, B^0 \to D^{*\pm}\pi^{\mp})(t) - N(\bar{B}^0_{tag}, B^0 \to D^{*\pm}\pi^{\mp})(t)}{N(B^0_{tag}, B^0 \to D^{*\pm}\pi^{\mp})(t) + N(\bar{B}^0_{tag}, B^0 \to D^{*\pm}\pi^{\mp})(t)}$$





$$a^* = 2r\sin(2\beta+\gamma)\cos(\delta^*) = -0.063 \pm 0.024 \pm 0.014$$

Deviates from 0 at 2.3 σ

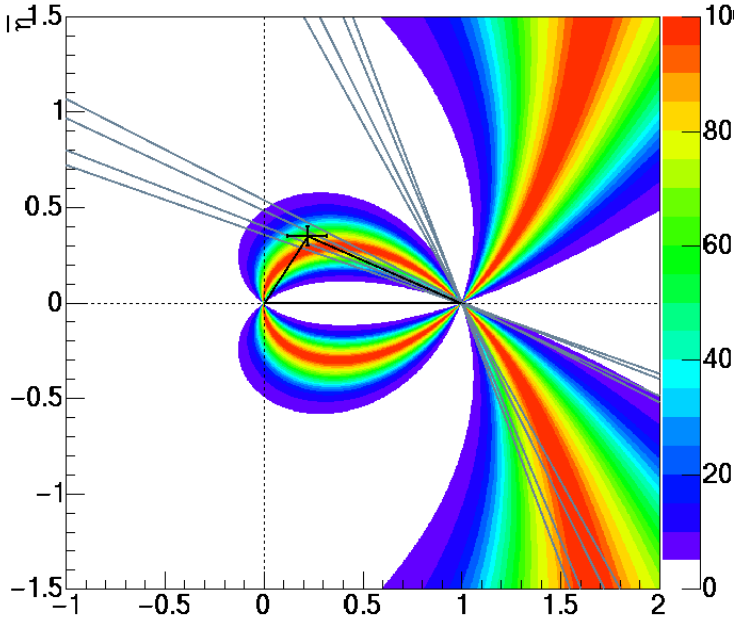
(Hep-ex/0310037, accepted by PRL)

Limits on $|\sin(2\beta+\gamma)|$

Method assuming SU(3) :

minimise a χ^2 : fit $|(\sin(2\beta+\gamma)|$, δ, δ^*, r & r*
assume a 30% flat theoretical error for r and r*

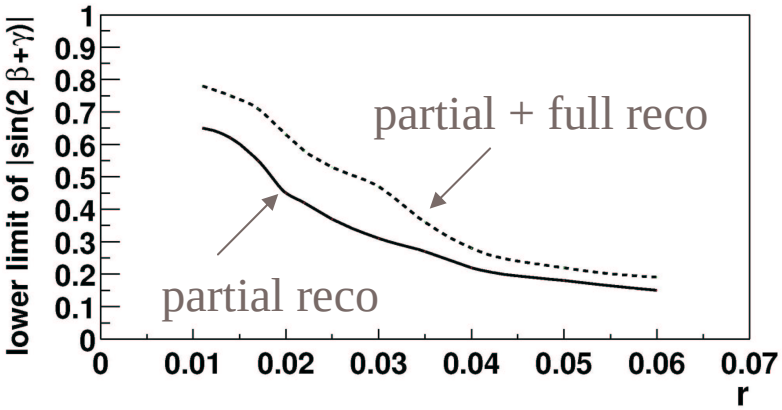
$|\sin(2\beta+\gamma)|$ > 0.74 at 90 % CL
$|\sin(2\beta+\gamma)|$ > 0.58 at 95 % CL



Constraints in the plane ρ,η (only BaBar)

Method « r* scan »
(only with $B^0 \to D^*\pi$)

To avoid any assumption on r* :
Fit only $|(\sin(2\beta+\gamma)|$ & δ^* in the χ^2

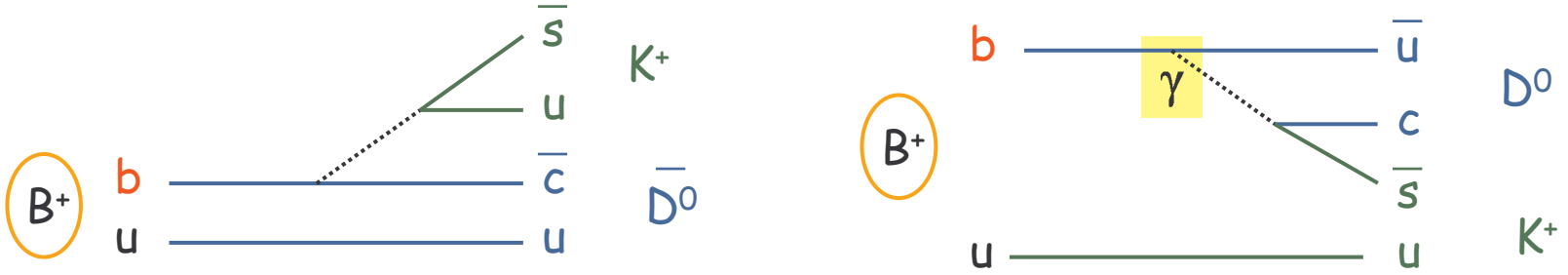


95% CL lower limit on $|\sin(2\beta+\gamma)|$ as a function of r*

(Hep-ex/0310037, accepted by PRL)

Measuring γ with B→DK decays

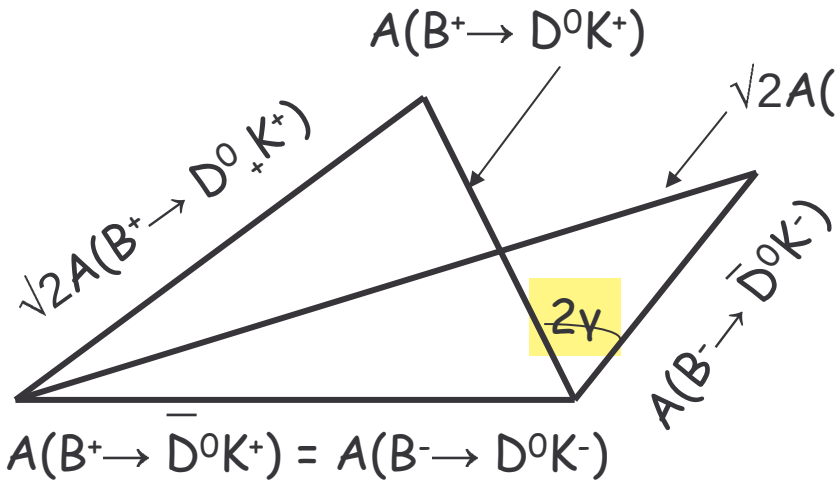
- γ from interferences between (b→u) and (b→c) decay amplitudes



- Interferences if D^0 and $\overline{D^0}$ decay in the same final state f
  - if f is a CP eigenstate : Gronau-London-Wyler method (GLW) :
    $D^0 \to \pi^+\pi^-$, K^+K^- (η_{CP}=+1), $K_S\pi^0$ (η_{CP}=-1)
  - if f is a non-CP eigenstate : Atwood-Dunietz-Soni (ADS) method :
    $D^0 \to K^+\pi^-$ ...

GLW : $B^+ \to D_{CP} K^+$: theoretical framework

$|D^0_{\pm}\rangle = (1/\sqrt{2})\,(\,|D^0\rangle \pm |\bar{D}^0\rangle\,) \Rightarrow$ relations between decay amplitudes can be represented in the complex plane by 2 triangles



$r_{DK} = |(A(b\to u)/A(b\to c)| \sim 0.1\text{-}0.2$

triangles very flat : difficult measurement

Observables :

$$R_{\pm} = \frac{Br(D^0_{\pm}K^+) + Br(D^0_{\pm}K^-)}{Br(D^0K^+) + Br(\bar{D}^0K^-)} = 1 + r^2_{DK} \pm 2r_{DK}\cos(\gamma)\cos(\delta)$$

$$A_{CP\pm} = \frac{Br(D^0_{CP\pm}K^-) - Br(D^0_{CP\pm}K^+)}{Br(D^0_{CP\pm}K^-) + Br(D^0_{CP\pm}K^+)} = \pm 2r_{DK}\sin(\gamma)\sin(\delta)/R_{\pm}$$

$B \to D_{CP} K$: analysis method

82 fb^{-1}

Use $B \to DK$ decays, where $D \to f_{CP+}$ (CP-even) or $D \to f_{nonCP}$ and measure :

$$R^{K/\pi}_{CP+} = \frac{Br(D^0_{CP+}K^+) + Br(D^0_{CP+}K^-)}{Br(D^0_{CP+}\pi^+) + Br(D^0_{CP+}\pi^-)} \qquad R^{K/\pi}_{nonCP} = \frac{Br(\bar{D}^0_{nonCP}K^+) + Br(D^0_{nonCP}K^-)}{Br(\bar{D}^0_{nonCP}\pi^+) + Br(D^0_{nonCP}\pi^-)}$$

From this, extract : $R_+ = R^{K/\pi}_{CP+} / R^{K/\pi}_{nonCP}$

Results :

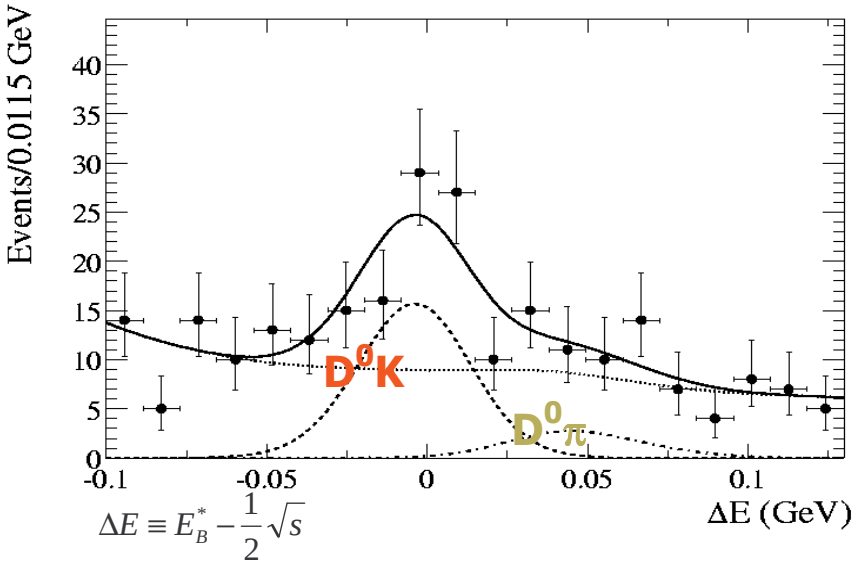
$R^{K/\pi}_{CP+} = (8.8 \pm 1.6 \pm 0.5)\%$

$R^{K/\pi}_{nonCP} = (8.31 \pm 0.35 \pm 0.20)\%$

$\Rightarrow R_+ = 1.06 \pm 0.19 \pm 0.06$

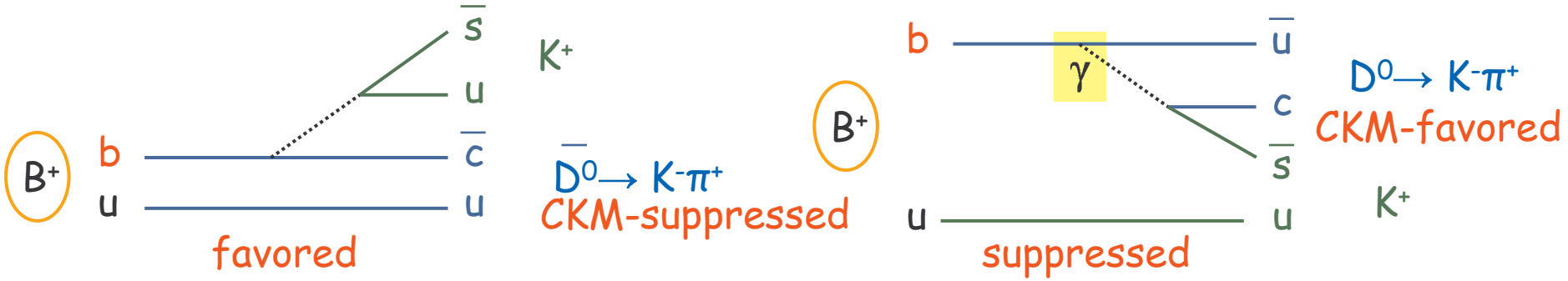
$A_{CP+} = 0.07 \pm 0.17 \pm 0.06$

Need more statistics



(Hep-ex/0311032, accepted by PRL)

ADS method : $B \to D^0 K$, $D^0 \to K^+\pi^-$ / $K^-\pi^+$



suppressed decays

$$R = \frac{Br(D_{K^-\pi^+}\, K^+) + Br(D_{K^+\pi^-}\, K^-)}{Br(D_{K^+\pi^-}\, K^+) + Br(D_{K^-\pi^+}\, K^-)} = r^2_D + r^2_{DK} + 2 r_D\, r_{DK} \cos(\gamma)\cos(\delta)$$

favored decays

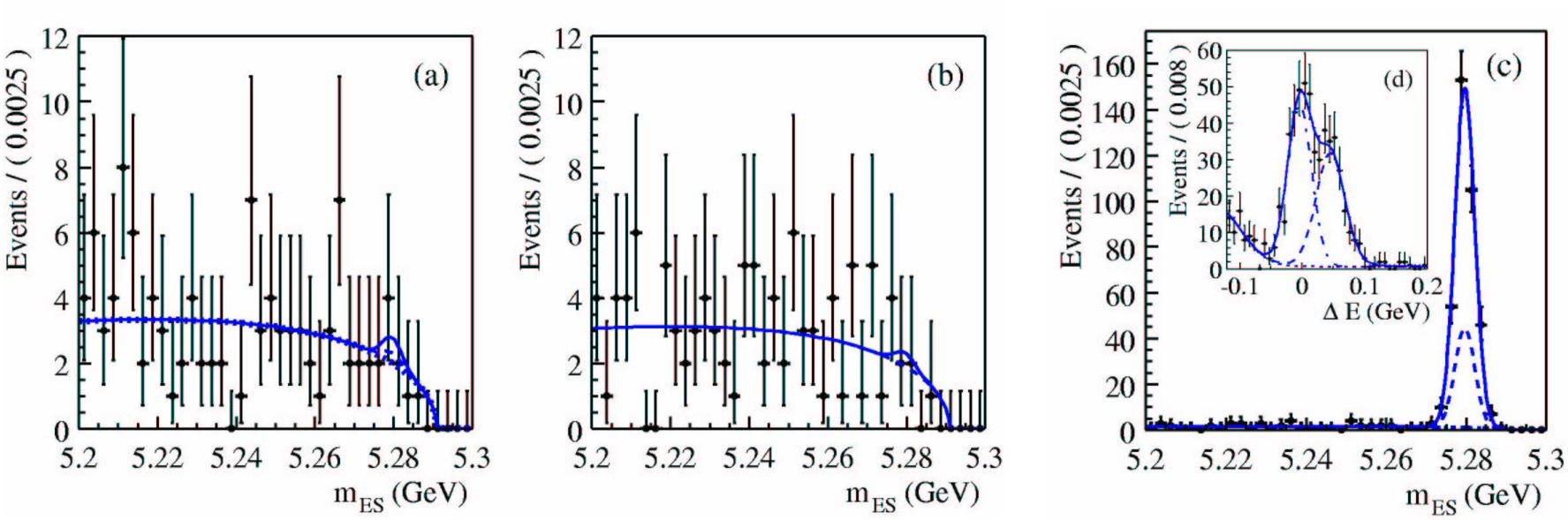
$r_{DK} = |(A(B^- \to \bar{D}^0 K^-)/\, A(B^- \to D^0 K^-)| \sim 0.1\text{-}0.2$

$r_D = |(A(D^0 \to K^+\pi^-)/\, A(D^0 \to K^+\pi^-)| = 0.060 \pm 0.003^*$

*mesured with $D^{*+} \to D^0 \pi^+$, $D^0 \to K\pi$

ADS : Results

109 fb^{-1}



Measure no events for the suppressed decay : $N_{suppressed} = 1.1 \pm 3.0$

$N_{favored} = 261 \pm 22$

$R = 0.004 \pm 0.012$

$R < 0.026$ at 90 % CL

Conclusion and prospects

- First steps to extract γ are promising :
  - $D^{(*)}\pi$ analysis well established :
    $|\sin(2\beta+\gamma)| > 0.58$ at 95 % CL
  - GLW and ADS : need more statistics
  - The presented analysis will be updated with more data
- Other channels to measure γ :
  - $D^{(*)}\rho$ for $\sin(2\beta+\gamma)$
  - GLW with D^0 decays into CP-odd
  - ADS with other final states
  - D^*K, D^*K^* decays…