DCPV in Charmed B Decays and γ/φ_3 Average From Belle

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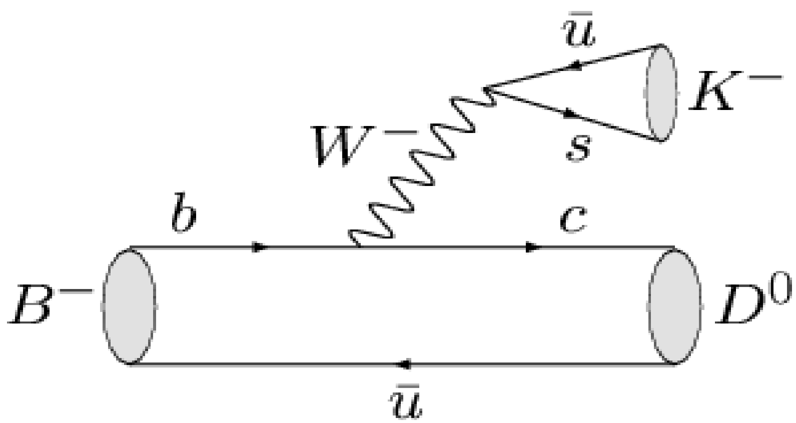
The 7th International Workshop on the CKM Unitarity Triangle
Sep 28 - Oct 2, 2012

γ measurements from $B^{\pm} \to DK^{\pm}$

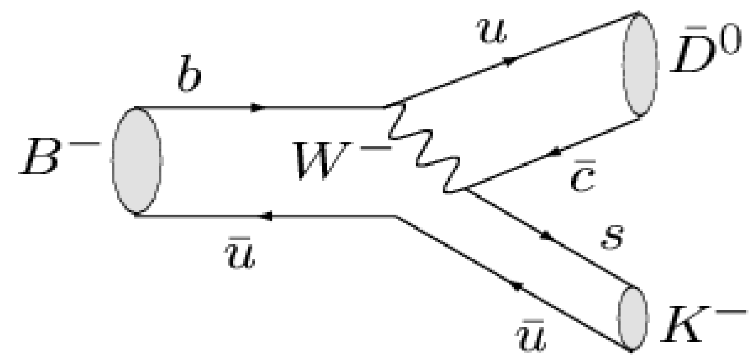
- Theoretically pristine $B \to DK$ approach
- Access γ via interference between $B^- \to D^0 K^-$ and $B^- \to \bar{D}^0 K^-$



color allowed

$B^- \to D^0 K^- \sim V_{cb} V_{us}^*$

$\sim \mathbf{A\lambda^3}$



color suppressed

$B^- \to \bar{D}^0 K^- \sim V_{ub} V_{cs}^*$

$\sim \mathbf{A\lambda^3(\rho + i\eta)}$

relative magnitude of suppressed amplitude is r_B

$$r_B = \frac{|A_{suppressed}|}{|A_{favoured}|} \sim \frac{|V_{ub} V_{cs}^*|}{|V_{cb} V_{us}^*|} \times [\text{color supp}] = 0.1\text{-}0.2$$

relative weak phase is γ, relative strong phase is δ_B

γ measurements from $B^{\pm} \to DK^{\pm}$

- Reconstruct D in final states accessible to both D^0 and $\overline{D}^0$
  - $D = D_{CP}$, CP eigenstates as K^+K^-, $\pi^+\pi^-$, $K_S\pi^0$

    GLW method (Gronau-London-Wyler)
  - $D = D_{sup}$, Doubly-Cabbibo suppressed decays as $K\pi$

    ADS method (Atwood-Dunietz-Soni)
  - Three-body decays as $D \to K_S\pi^+\pi^-$, $K_SK^+K^-$

    GGSZ (Dalitz) method (Giri-Grossman-Soffer-Zupan)

- Largest effects due to
  - charm mixing
  - charm CP violation

  } negligible

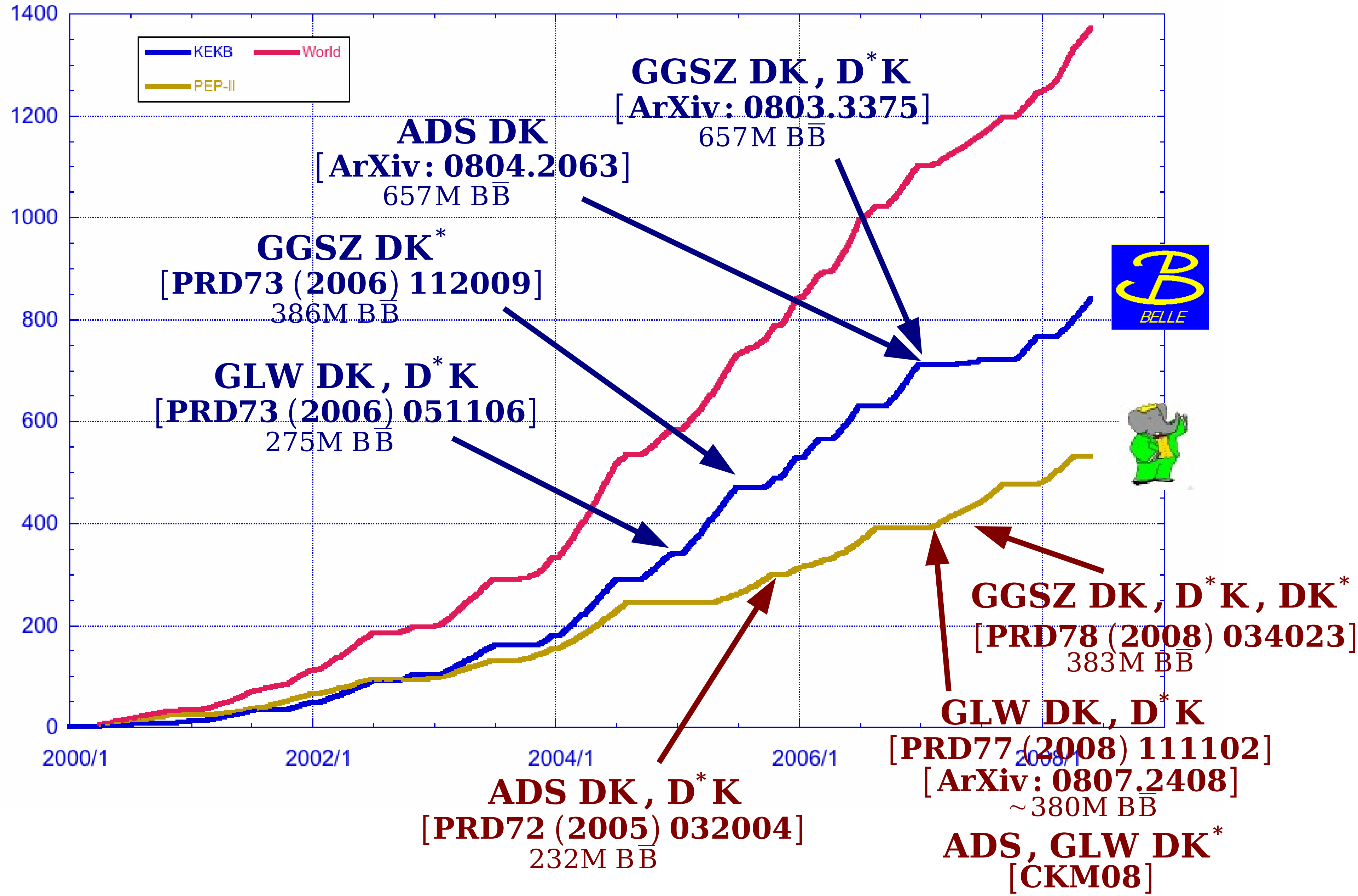
  Y.Grossman, A.Soffer, J.Zupan [PRD 72, 031501 (2005)]

- **Different B decays (DK, D^*K, ...)**
  - **different hadronic factors (r_B, δ_B) for each**

Measurements @ CKM 2008

B factories: BaBar and Belle

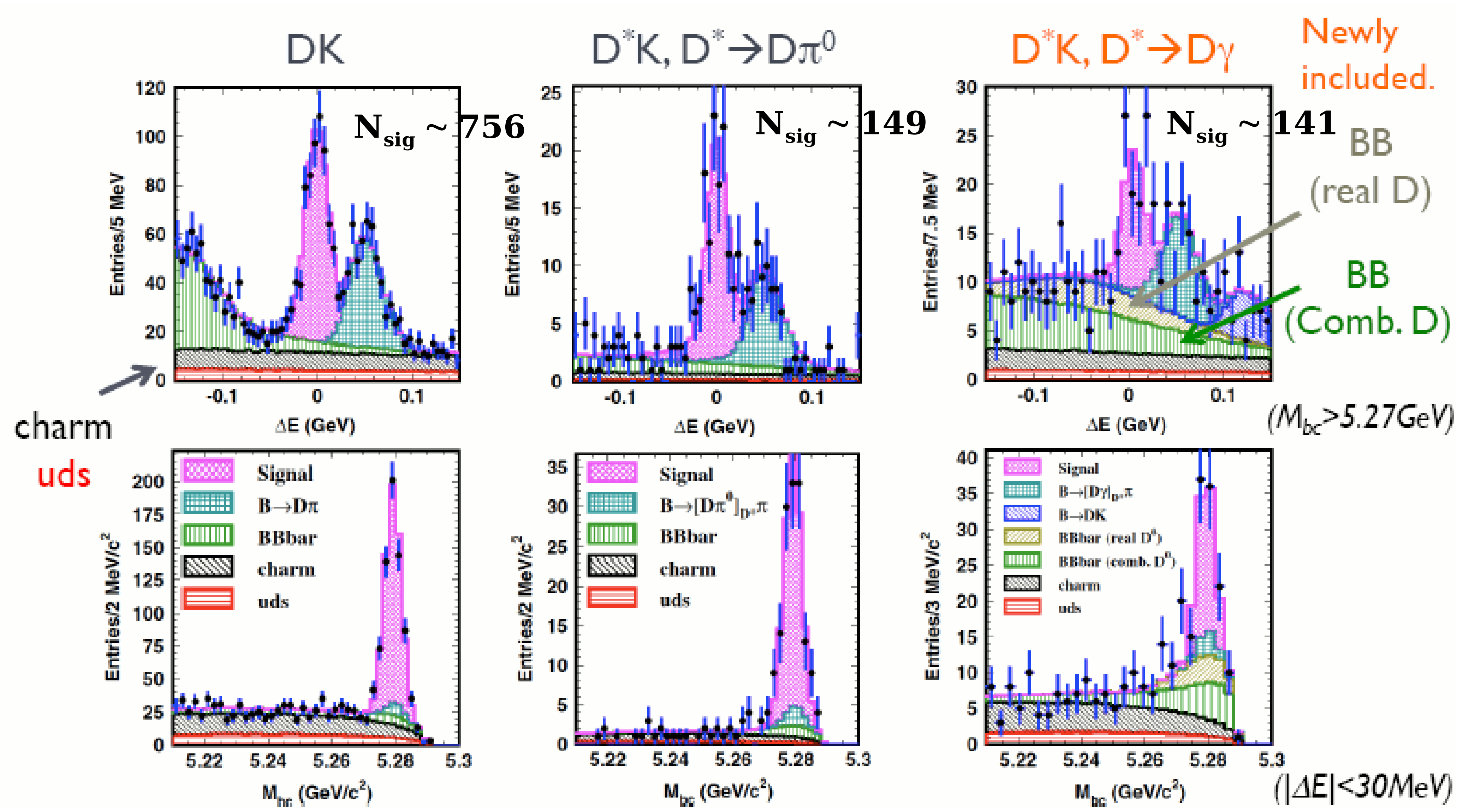
Luminosity (fb^{-1})



$B^- \to D^{(*)}(K_S\pi\pi)K^-$ Dalitz, ΔE and M_{bc} projections

$|\cos\theta_{thr}| < 0.8$ and $F > -0.7$

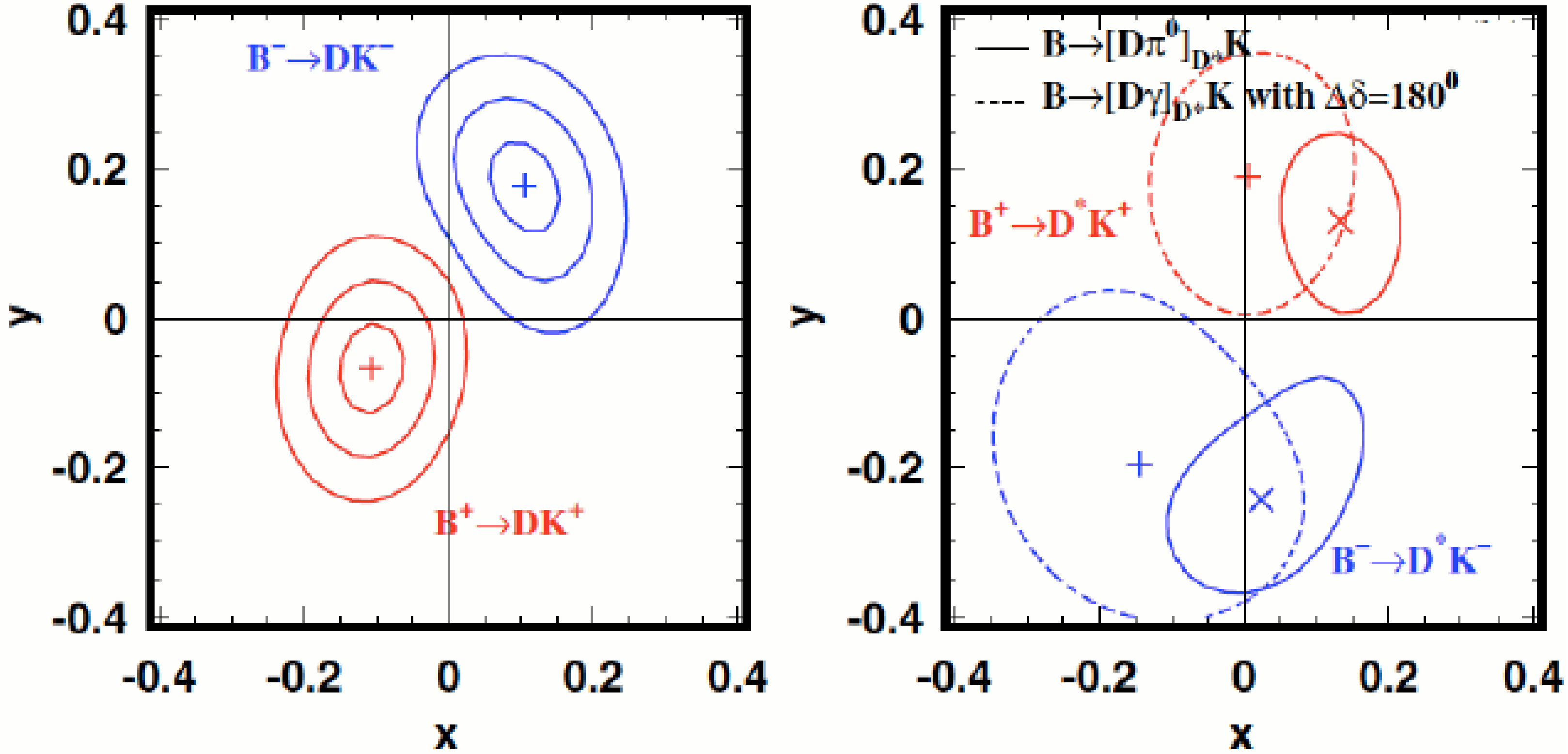
PRD 81, 112002 (2010)
657×10^6 $B\bar{B}$ pairs



γ measurement with $B \to D(K_S\pi\pi)K$

PRD 81, 112002 (2010)
657×10^6 $B\bar{B}$ pairs

$$x_\pm = r_B \cos(\delta_B \pm \gamma), \quad y_\pm = r_B \sin(\delta_B \pm \gamma)$$



$$\gamma = (80.8\,^{+13.1}_{-14.8} \pm 5.0 \pm 8.9)^\circ$$
$$r_B = 0.161\,^{+0.040}_{-0.038} \pm 0.011\,^{+0.050}_{-0.010}$$
$$\delta_B = (137.4\,^{+13.0}_{-15.7} \pm 4.0 \pm 22.9)^\circ$$

$$\gamma = (73.9\,^{+18.9}_{-20.2} \pm 4.2 \pm 8.9)^\circ$$
$$r_B = 0.196\,^{+0.073}_{-0.072} \pm 0.013\,^{+0.062}_{-0.012}$$
$$\delta_B = (341.7\,^{+18.6}_{-20.9} \pm 3.2 \pm 22.9)^\circ$$

combining both B modes (Dalitz): $\boldsymbol{\gamma = (78.4\,^{+10.8}_{-11.6} \pm 3.6 \pm 8.9)^\circ}$

CPV significance is 3.5 standard deviations

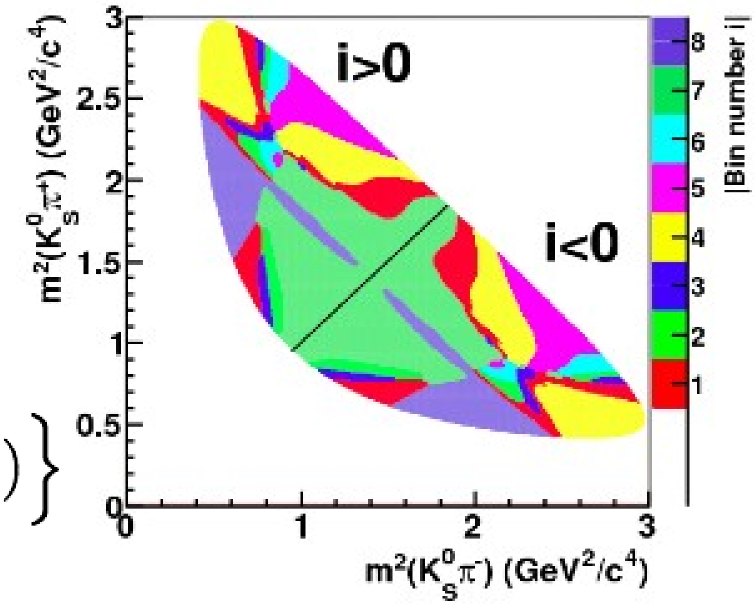
(model-dependent error will limit viability of this approach)

<u>Binned Dalitz method</u>: avoid the modeling error by "optimal" binning of the Dalitz plot

Bondar and Poluektov
EPJ C55, 51 (2008)

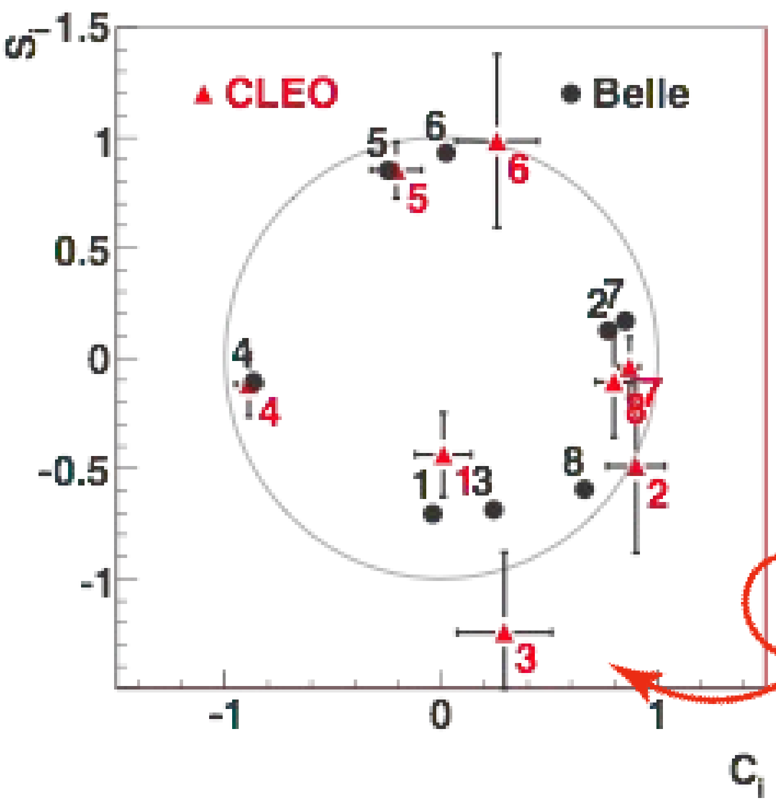
[choice of bins guided by model, but extraction of γ is not biased by this choice]

minimize χ^2 in fit to all bins for each mode



Expected number of $B^\pm \to DK^\pm$ events in bin *i* is:

$$N_i^\pm = h\left\{K_i + r_B^2 K_{-i} + 2\sqrt{K_i K_{-i}}(x_\pm c_i + y_\pm s_i)\right\}$$



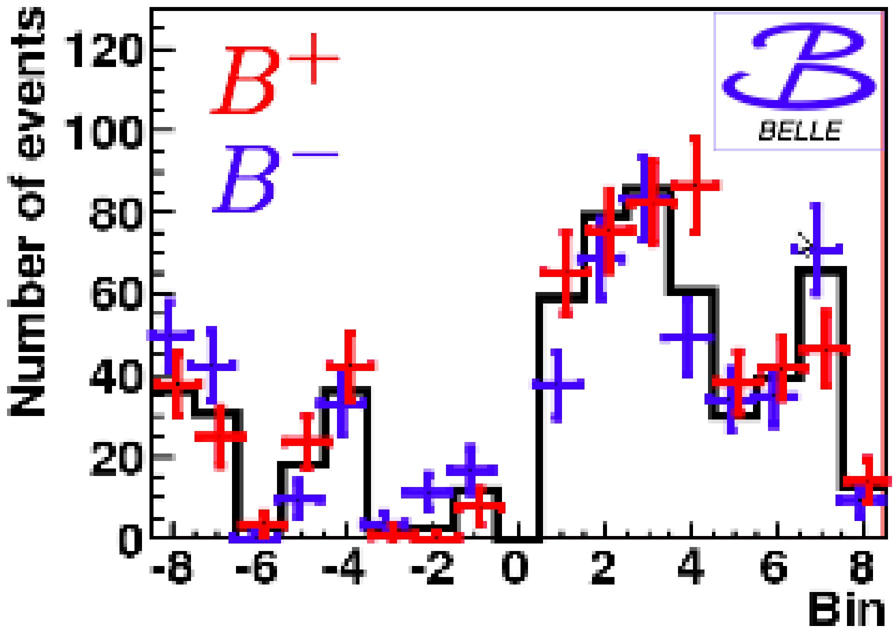
K_i is the # of events in bin *i* from a flavour-tagged sample ($D^{*\pm} \to D\pi^\pm$)

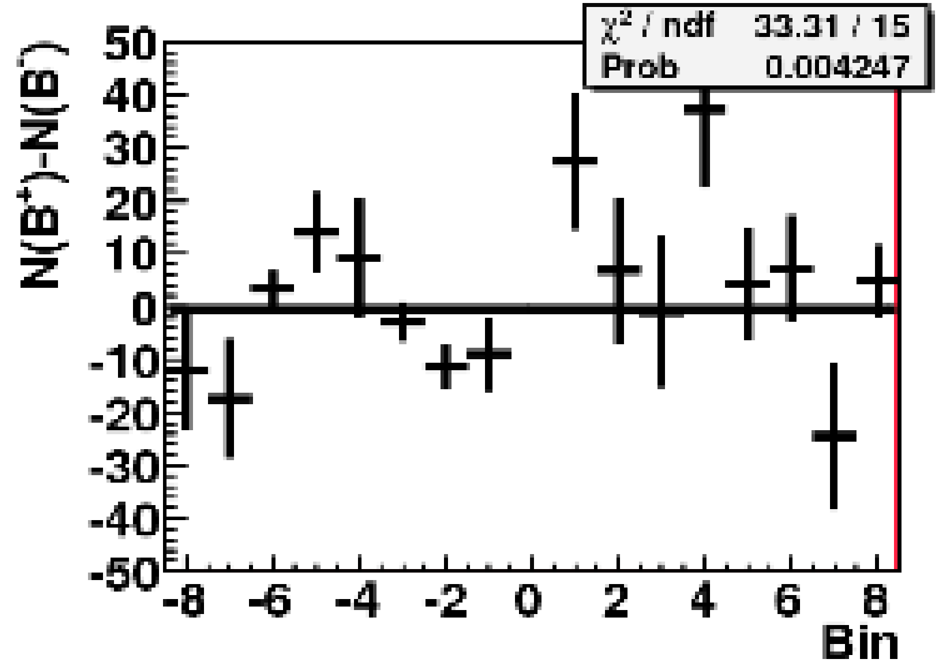
c_i and s_i contain information about the strong-phase difference in bin *i*

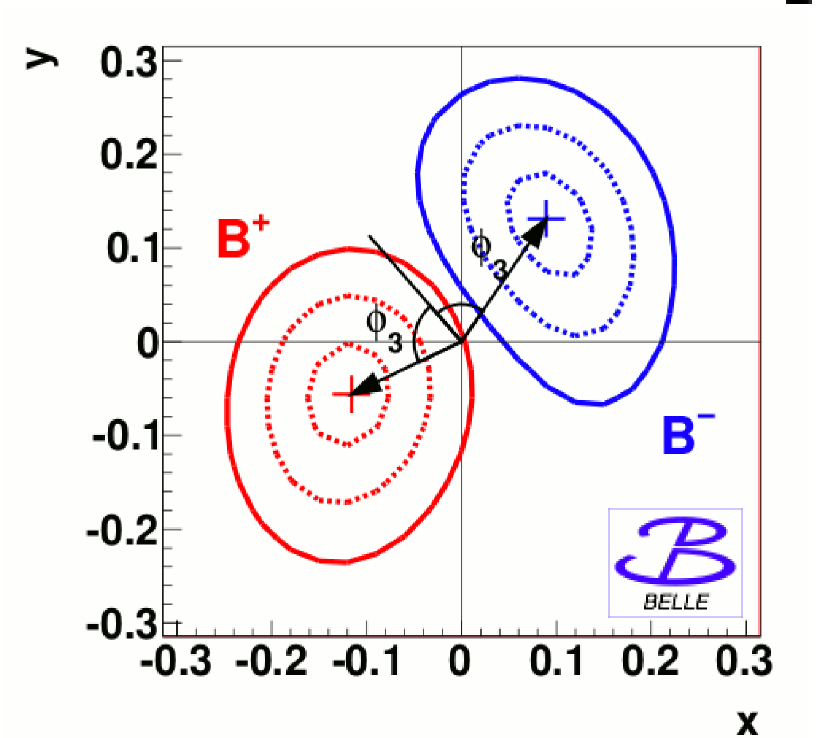
(use CLEO data for $\psi(3770) \to D^0 \overline{D}^0$ here; can be measured by BES-III too)

Binned Dalitz method result in B → DK

772M $B\bar{B}$
PRD 85, 112014 (2012)
[arXiv:1204.6561]







$$\gamma = \left(77.3\,^{+15.1}_{-14.9} \pm 4.1 \pm 4.3\right)^\circ$$

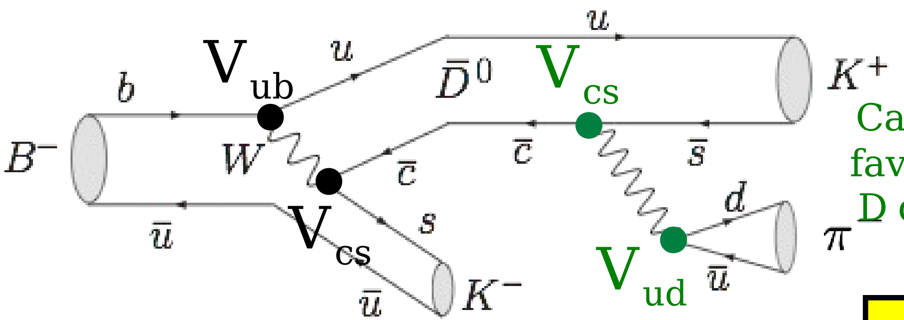
$$r_B = 0.145 \pm 0.030 \pm 0.010 \pm 0.011$$

$$\delta_B = \left(129.9 \pm 15.0 \pm 3.8 \pm 4.7\right)^\circ$$

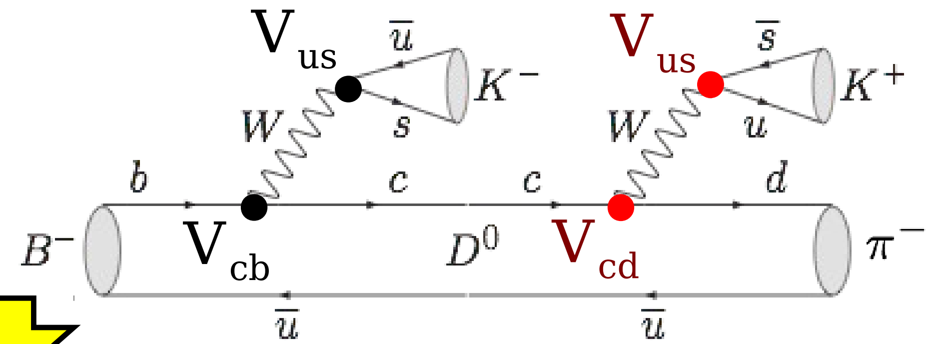
uncertainty in c_i, s_i
from CLEO data size
(can be reduced using
future BES-III data)

ADS method: γ via the interference in rare $B^- \to [K^+\pi^-]_D K^-$ decays

rate and asymmetry (relative to the common decay):

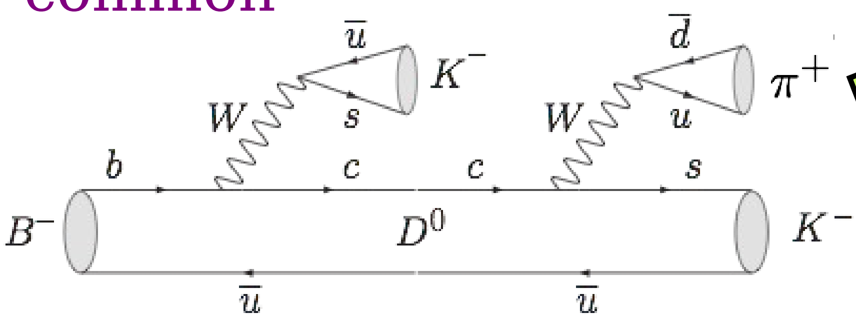


Cabibbo favoured D decay



doubly-Cabibbo suppressed D decay

common



$$\mathcal{R}_{DK} = \frac{\Gamma([K^+\pi^-]\,K^-) + \Gamma([K^-\pi^+]\,K^+)}{\Gamma([K^-\pi^+]\,K^-) + \Gamma([K^+\pi^-]\,K^+)}$$

$$= r_B^2 + r_D^2 + 2 r_B r_D \cos(\delta_B + \delta_D)\cos\gamma$$

$$\mathcal{A}_{DK} = \frac{\Gamma([K^+\pi^-]\,K^-) - \Gamma([K^-\pi^+]\,K^+)}{\Gamma([K^-\pi^+]\,K^-) + \Gamma([K^+\pi^-]\,K^+)}$$

$$= 2\, r_B r_D \sin(\delta_B + \delta_D)\sin\gamma \;\; / \mathcal{R}_{DK}$$

where $r_D = \left| \frac{\mathcal{A}(D^0 \to K^+\pi^-)}{\mathcal{A}(\bar{D}^0 \to K^+\pi^-)} \right| = 0.0613 \pm 0.0010$

$B^- \to DK^-$, $D \to K^+\pi^-$ ADS

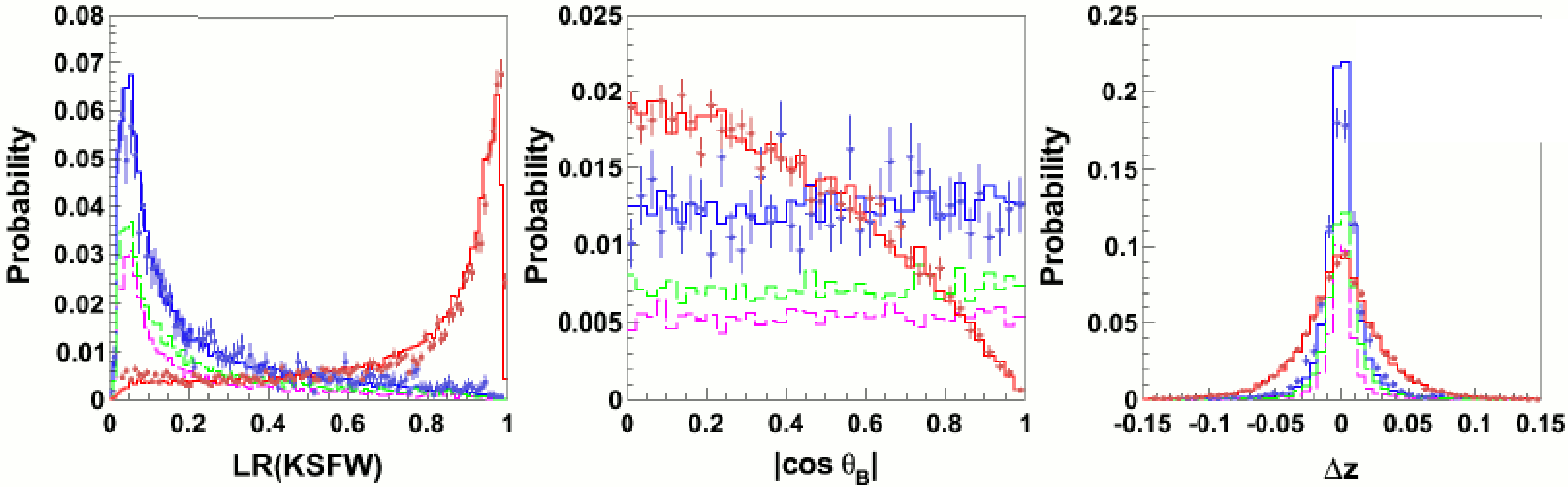
Main background is $e^+e^- \to q\bar{q}$ $(q = u, d, s, c)$ continuum

combine 10 variables with neural network:

- Variables which have different distributions for signal and $q\bar{q}$ background are used.

$B^- \to D\pi^-$
$\to K^-\pi^+$
M_{bc}-sideband

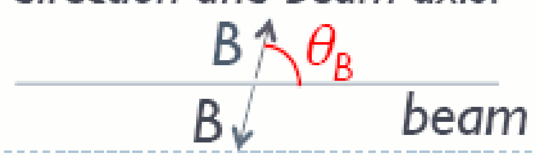
histogram: MC, dots: data
signal
qq = charm + uds

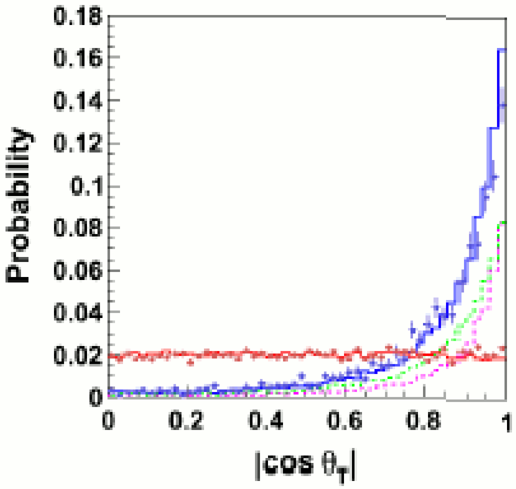


Likelihood ratio for KSFW.

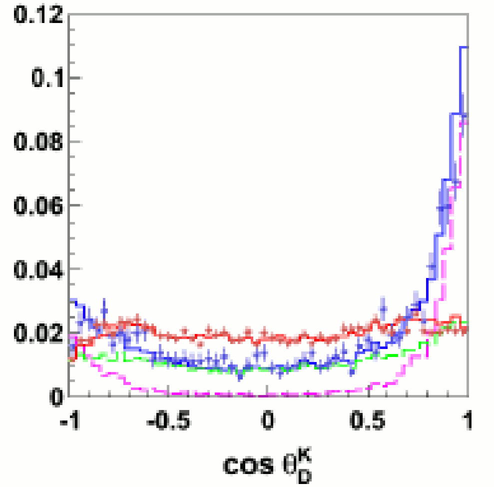
θ_B is angle between B-flight direction and beam axis.

Vertex separation between reconstructed B and the other B.

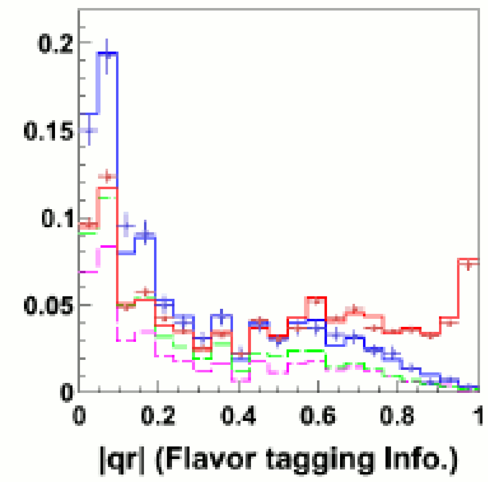




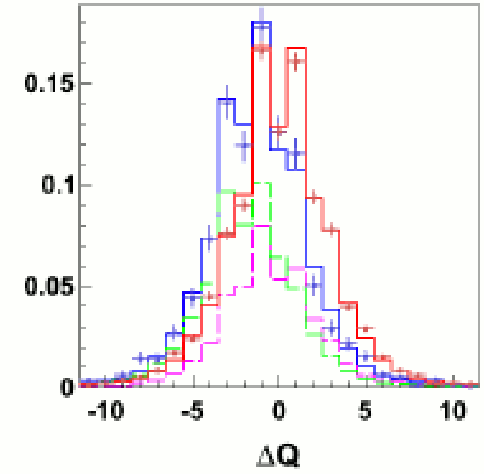
Angle between thrust axes of B decay and remainder.
No full correlation to LR(KSFW).



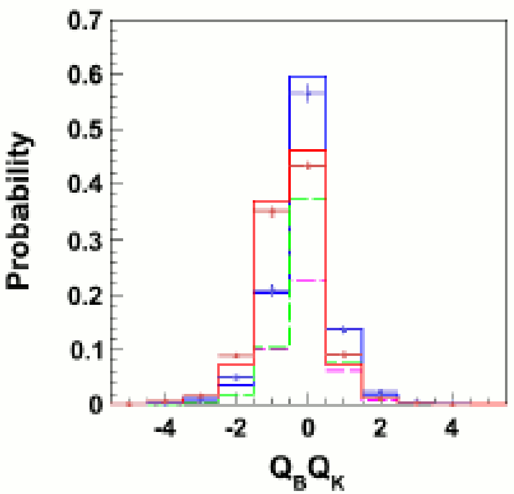
Decay angle of D → kπ.



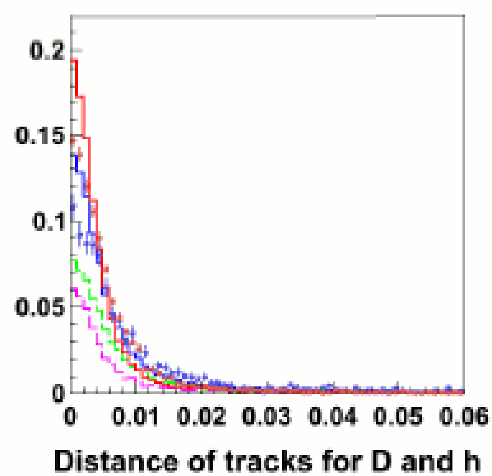
Flavor tagging Info. by MDLH. (NB possible.)



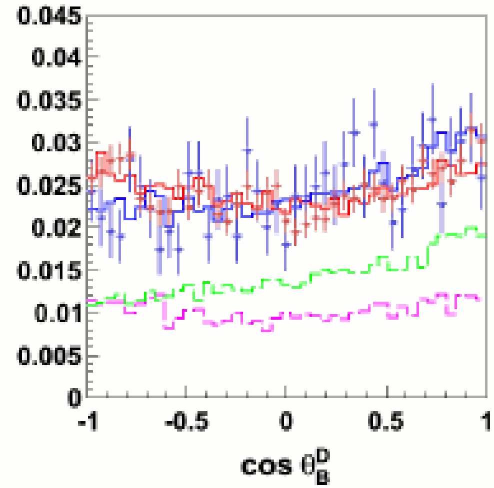
Difference of charges in D hemisphere and opposite hemisphere.



Product of charge of B and sum of charges for K not used in B reconstruction.



Distance of tracks for D and K.



Decay angle of B → DK.

10 variables combined to obtain a single NN output (NB)

for example, at 99% bckg rej. signal eff. = 42% now becomes 60%

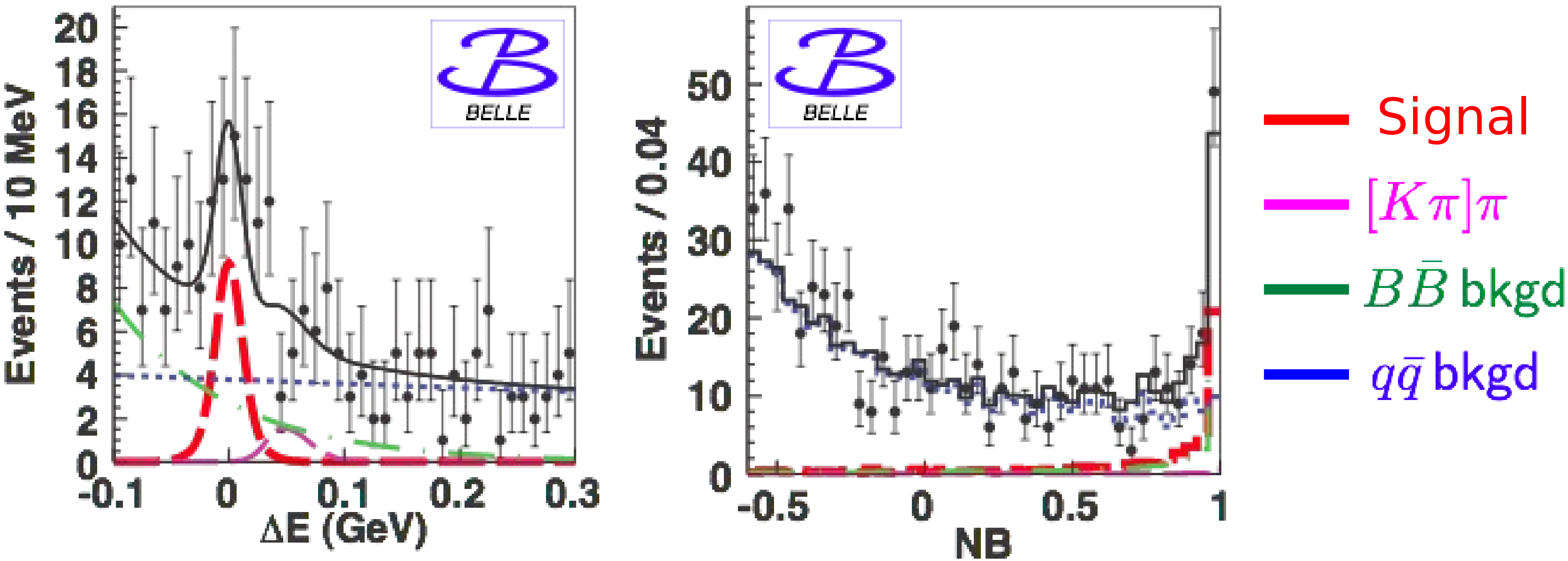
Yields for the ADS mode $B^- \to [K^+\pi^-]_D K^-$ from 772 million $B\overline{B}$ events

PRL 106, 231803 (2011)

Fit ΔE and NB distributions together to extract signal

for NB > 0.9

for $|\Delta E| < 0.03$ GeV



$56.0^{+15.1}_{-14.2}$ events

First evidence obtained with a significance of 4.1σ (including syst.)

$$\mathbf{R_{DK} = (1.63\,^{+0.44}_{-0.41}\,^{+0.07}_{-0.13}) \times 10^{-2}}$$

$$\mathbf{A_{DK} = -0.39\,^{+0.26}_{-0.28}\,^{+0.04}_{-0.03}}$$

First evidence for the ADS mode $B^- \to [K^+ \pi^-]_{D^*} K^-$

Preliminary
LP 2011

$B \to D\pi$
$B \to DK$
$B\bar{B}$
continuum

study both modes: $D^* \to D\pi^0$, $D\gamma$:
[see ''On φ_3 Measurements Using $B \to D^* K^-$ Decays'', arXiv:hep-ph/0409281]

Signal seen
with a significance of 3.5σ
for $D^* \to D\gamma$ mode

Ratio to favored mode:

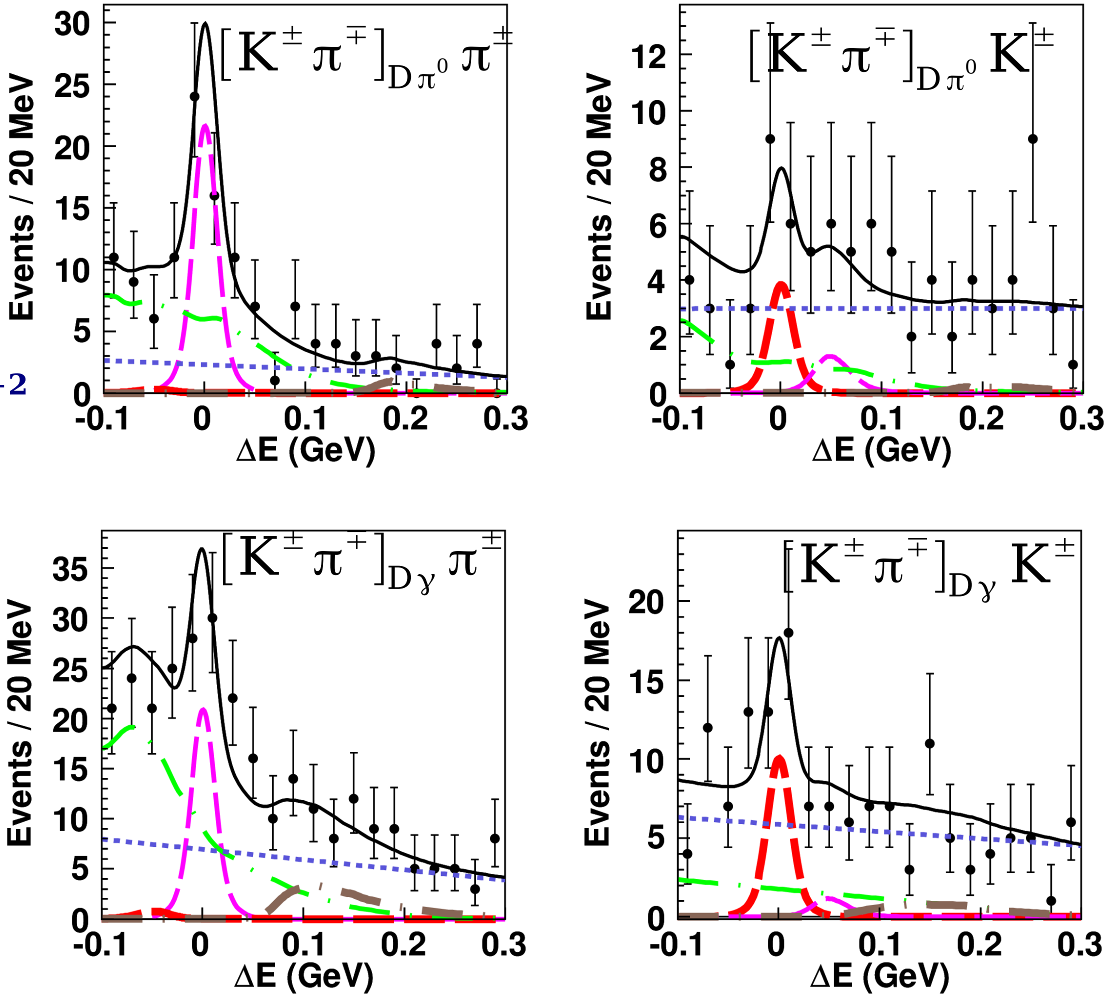
$$R_{D\pi^0} = (1.0\,^{+0.8}_{-0.7}(\text{stat})\,^{+0.1}_{-0.2}(\text{syst})) \times 10^{-2}$$

$$R_{D\gamma} = (3.6\,^{+1.4}_{-1.2}(\text{stat}) \pm 0.2(\text{syst})) \times 10^{-2}$$

asymmetry:

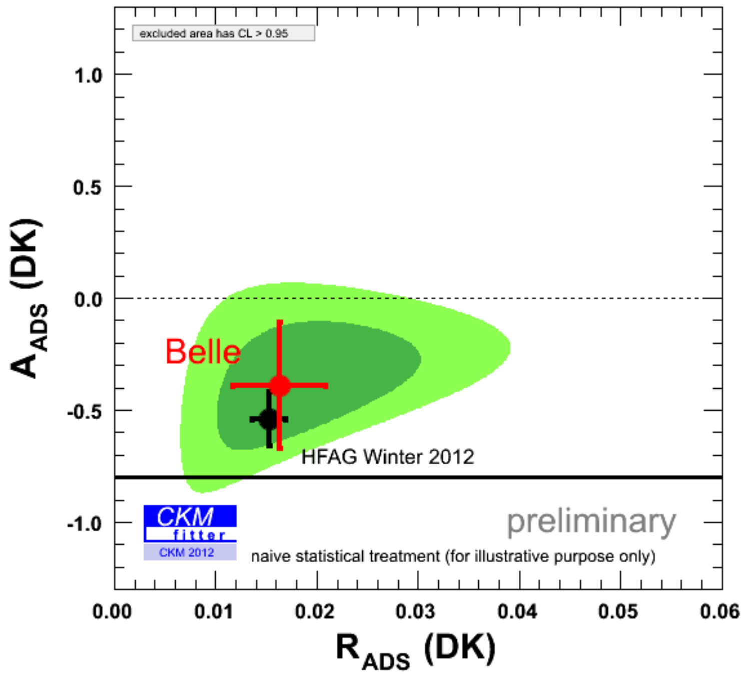
$$A_{D\pi^0} = 0.4\,^{+1.1}_{-0.7}(\text{stat})\,^{+0.2}_{-0.1}(\text{syst})$$

$$A_{D\gamma} = -0.51\,^{+0.33}_{-0.29}(\text{stat}) \pm 0.08(\text{syst})$$



Comparison of the results obtained for $D^{(*)}K$ with expectations

where "expectations" are derived from the GGSZ observables (W.A.), δ_D and γ_{UT}

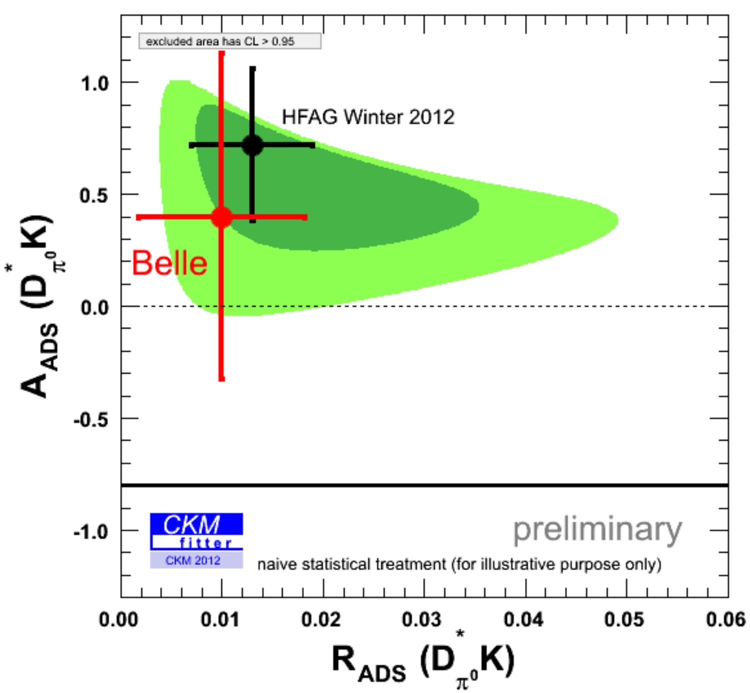


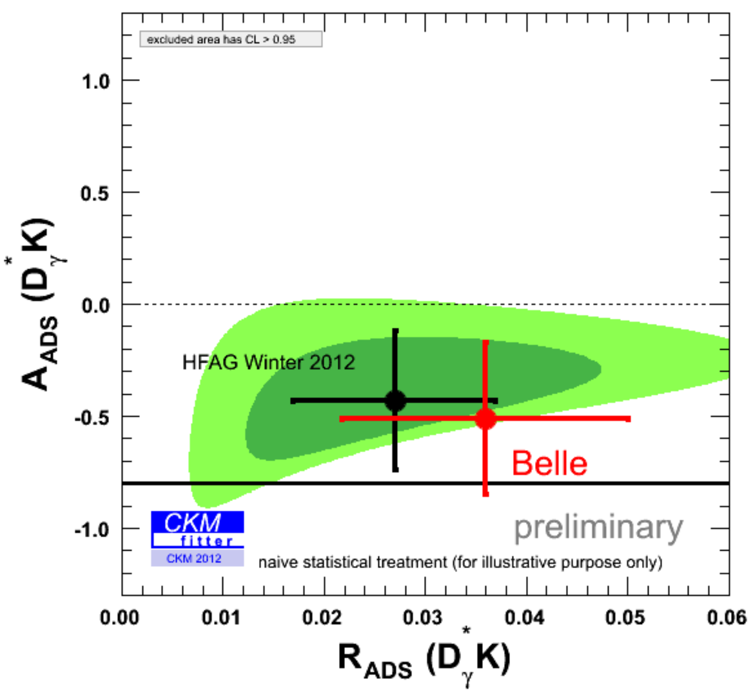
$$R_{ADS}(DK) = r_B^2 + r_D^2 + 2 r_B r_D \cos(\delta_B + \delta_D) \cos\gamma$$
$$A_{ADS}(DK) = 2 r_B r_D \sin(\delta_B + \delta_D) \sin\gamma / R_{ADS}(DK)$$

$$R_{ADS}(D^*_{\pi^0}K) = r_B^{*2} + r_D^2 + 2 r_B^* r_D \cos(\delta_B^* + \delta_D) \cos\gamma$$
$$A_{ADS}(D^*_{\pi^0}K) = 2 r_B^* r_D \sin(\delta_B^* + \delta_D) \sin\gamma / R_{ADS}(D^*_{\pi^0}K)$$

$$R_{ADS}(D^*_\gamma K) = r_B^{*2} + r_D^2 - 2 r_B^* r_D \cos(\delta_B^* + \delta_D) \cos\gamma$$
$$A_{ADS}(D^*_\gamma K) = -2 r_B^* r_D \sin(\delta_B^* + \delta_D) \sin\gamma / R_{ADS}(D^*_\gamma K)$$

(HFAG winter 2012 includes Belle results)

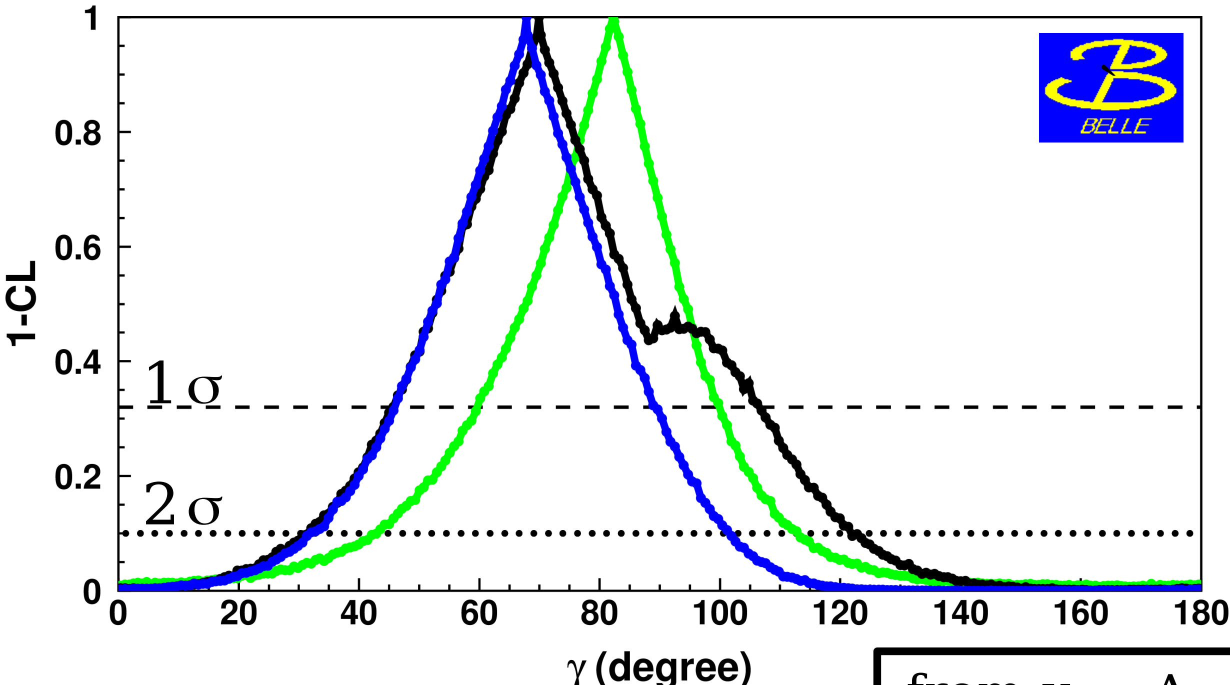




Determination of γ with GGSZ and ADS

[using $D^0 K^-$, $D^{*0} K^-$ Belle results]

frequentist construction of 1-dimensional confidence interval:

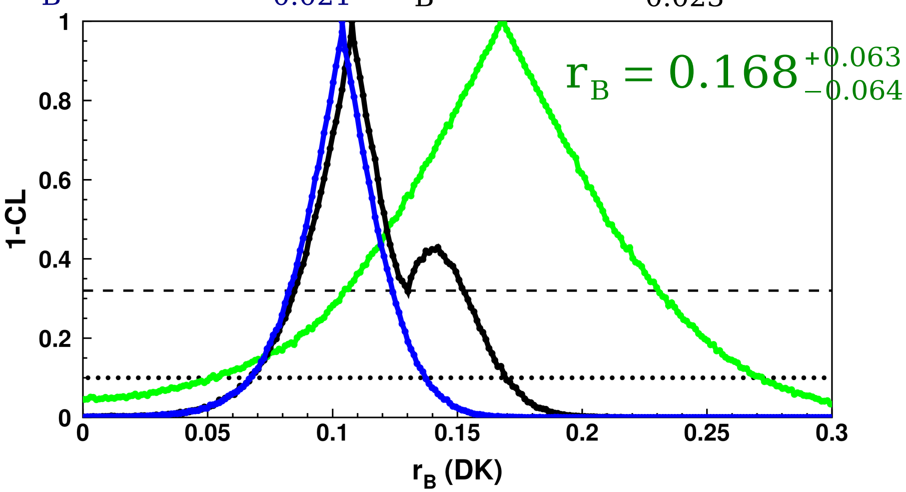


GGSZ
$\gamma = (\mathbf{82}\ ^{+18}_{-23})^\circ$

GGSZ+ADS
$\gamma = (\mathbf{70}\ ^{+37}_{-24})^\circ$

GGSZ+ADS+δ_D
$\gamma = (\mathbf{68} \pm \mathbf{22})^\circ$

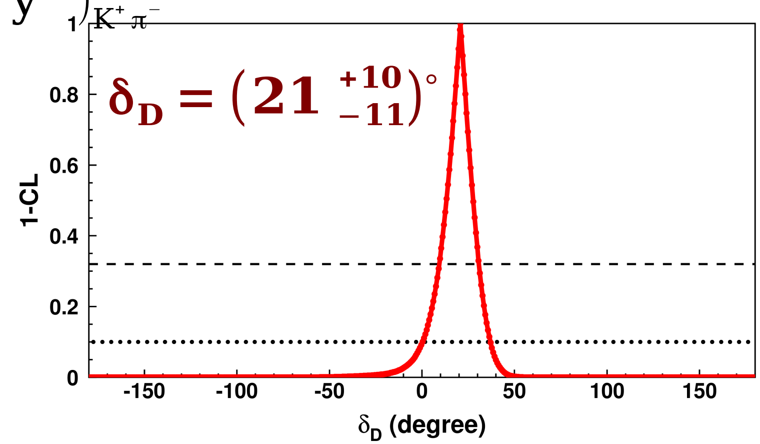
$r_B = 0.104^{+0.020}_{-0.021}$ $r_B = 0.108^{+0.045}_{-0.023}$



à la HFAG: δ_D

from y_{CP}, A_Γ, $(x, y, |q/p|, \varphi)_{K_S\pi^+\pi^-}$, $(R_M)_{semilep}$, $(x'', y'')_{K\pi\pi^0}$, $(x^2, y, R_D, \sqrt{R_D}\cos\delta)_{\psi(3770)}$, $(R_D, A_D, x'^{2\pm}, y'^{\pm})_{K^+\pi^-}$

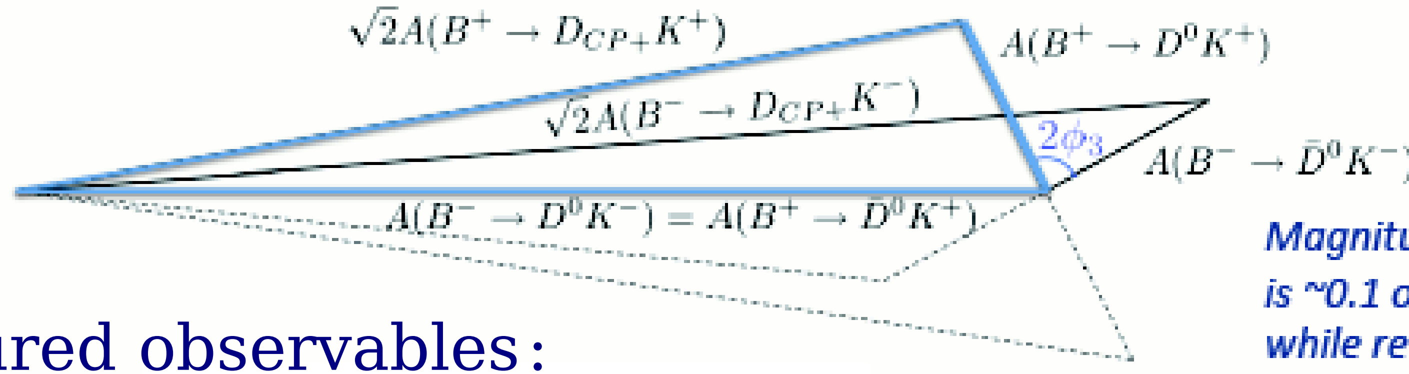
to obtain
x, y, δ_D,
$\delta_D^{K\pi\pi}$, R_D, A_D,
$|q/p|$, φ



GLW with $D^{(*)}_{CP}K$

D decays to CP eigenstates

- Amplitude triangle:



Magnitude of one side is ~0.1 of the others while relative magnitude of the others help ϕ_3 constraint.

measured observables:

$$R_{CP\pm} \equiv \frac{Br(B^- \to D_{CP\pm}K^-) + Br(B^+ \to D_{CP\pm}K^+)}{Br(B^- \to D^0 K^-) + Br(B^+ \to \bar{D}^0 K^+)}$$

$$A_{CP\pm} \equiv \frac{Br(B^- \to D_{CP\pm}K^-) - Br(B^+ \to D_{CP\pm}K^+)}{Br(B^- \to D_{CP\pm}K^-) + Br(B^+ \to D_{CP\pm}K^+)}$$

Relation between $(A_{CP+}, A_{CP-}, R_{CP+}, R_{CP-})$ and (γ, r_B, δ_B)

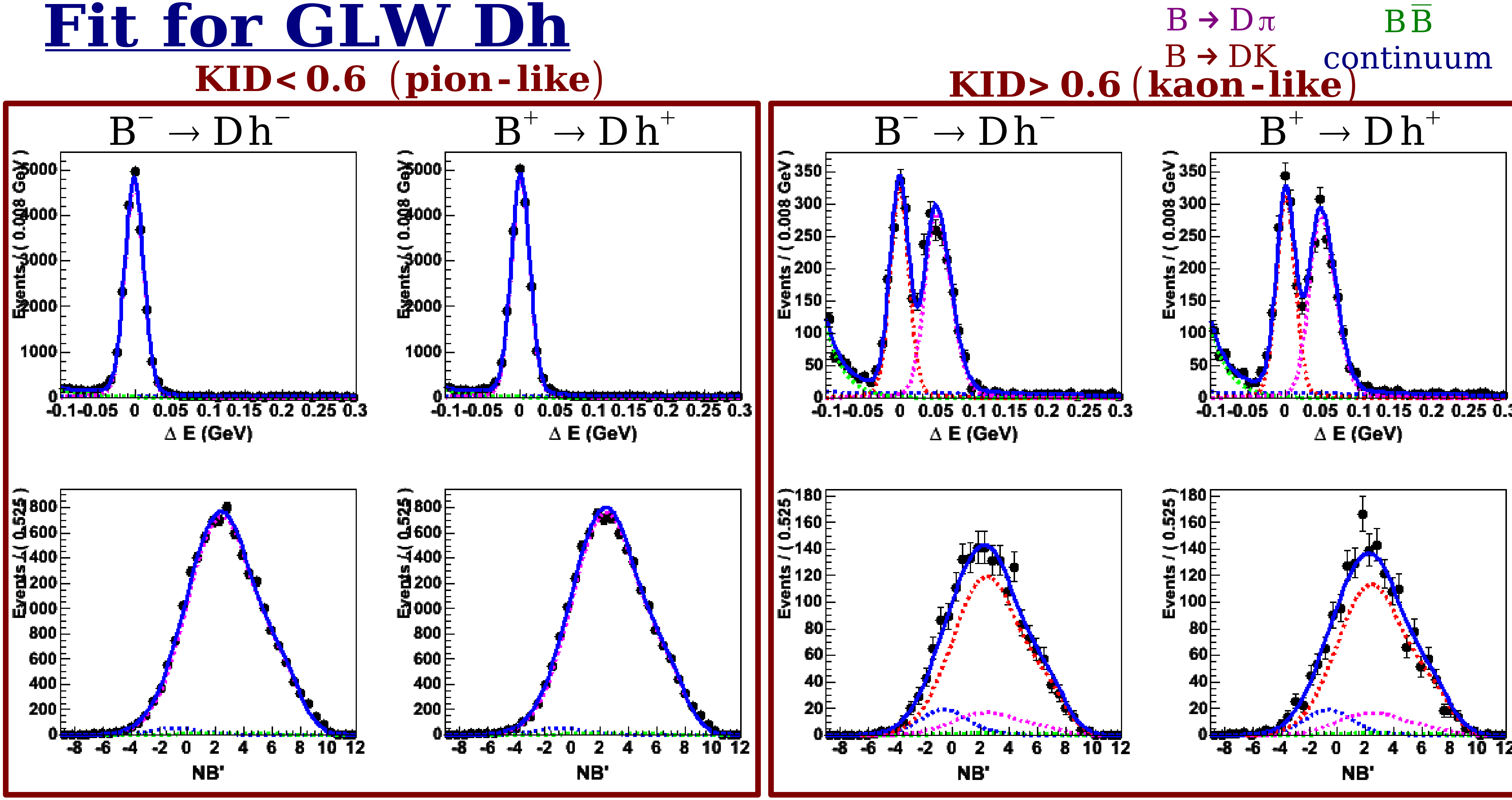
$$A_{CP+} = \frac{+2 r_B \sin\delta_B \sin\gamma}{1 + r_B^2 + 2 r_B \cos\delta_B \cos\gamma} \qquad A_{CP-} = \frac{-2 r_B \sin\delta_B \sin\gamma}{1 + r_B^2 - 2 r_B \cos\delta_B \cos\gamma}$$

$$R_{CP+} = 1 + r_B^2 + 2 r_B \cos\delta_B \cos\gamma \qquad R_{CP-} = 1 + r_B^2 - 2 r_B \cos\delta_B \cos\gamma$$

$\Rightarrow$ look for $R_{CP\pm} \neq 1$ and $A_{CP\pm} \neq 0$

$\Rightarrow$ $\neq$ CP, $\neq$ sign of asymmetry

Fit for GLW Dh



$$N^{DK}_{\eta,\,KID>0.6} = \frac{1}{2}\left(1-\eta A^{DK}\right) N^{D\pi}_{tot}\; R_{K/\pi}\; \epsilon$$

$$N^{DK}_{\eta,\,KID<0.6} = \frac{1}{2}\left(1-\eta A^{DK}\right) N^{D\pi}_{tot}\; R_{K/\pi}\; (1-\epsilon)$$

$$N^{D\pi}_{\eta,KID>0.6} = \frac{1}{2}\left(1-\eta A^{D\pi}\right) N^{D\pi}_{tot}\; \kappa$$

$$N^{D\pi}_{\eta,KID<0.6} = \frac{1}{2}\left(1-\eta A^{D\pi}\right) N^{D\pi}_{tot}\; (1-\kappa)$$

$B \to Dh$, $D \to K\pi$ $\to$ $R_{D_{fav}}$

$$N^{DK}_{\eta,\,KID>0.6} = \frac{1}{2}\left(1-\eta A^{DK}\right) N^{D\pi}_{tot}\, R_{K/\pi}\, \epsilon$$

$$N^{DK}_{\eta,\,KID<0.6} = \frac{1}{2}\left(1-\eta A^{DK}\right) N^{D\pi}_{tot}\, R_{K/\pi}\, (1-\epsilon)$$

$$N^{D\pi}_{\eta,KID>0.6} = \frac{1}{2}\left(1-\eta A^{D\pi}\right) N^{D\pi}_{tot}\, \kappa$$

$$N^{D\pi}_{\eta,KID<0.6} = \frac{1}{2}\left(1-\eta A^{D\pi}\right) N^{D\pi}_{tot}\, (1-\kappa)$$

	kaon fake (1-ϵ)	kaon eff ϵ	pion eff (1-κ)	pion fake κ
MC	14.70 ± 0.06	85.41 ± 0.06	95.42 ± 0.03	4.47 ± 0.03 ⇐
data	15.86 ± 0.40	84.32 ± 0.39	92.13 ± 0.46	7.94 ± 0.31

Efficiency and fake rate (in %) for kaon and pion, for data and MC. ϵ will be fixed in the fit but κ will be floated (see text for further explanations). These numbers are obtained after properly weighting the values provided by PID group for SVD1 and SVD2.

$B \to Dh\,,\ D \to K^+K^-\,,\ \pi^+\pi^- \ \to\ R_+$

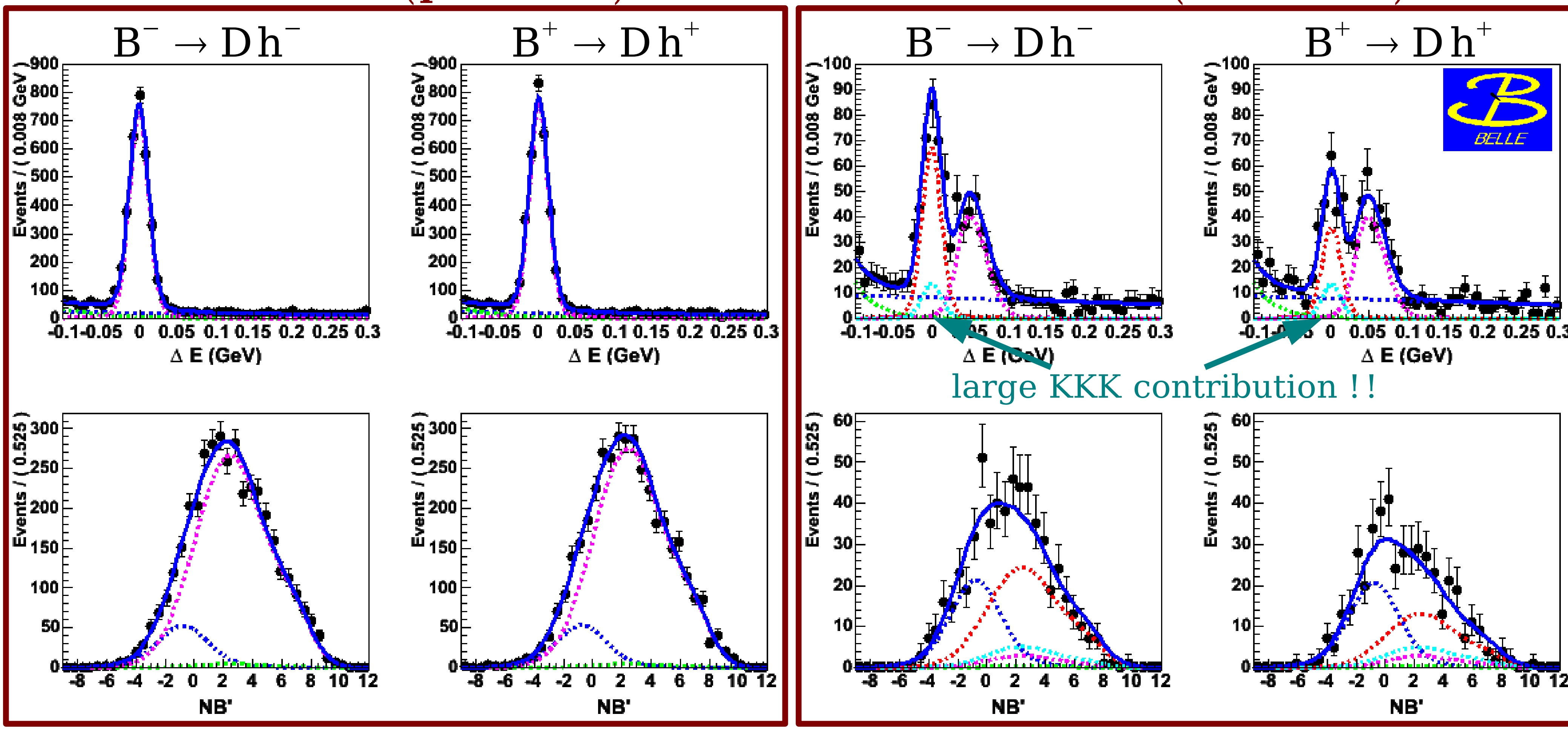
Preliminary
LP 2011

$(772\ \mathrm{M}\,B\bar{B})$
$B \to D\pi$
$B \to DK$
$B\bar{B}$
continuum

Yields	$B \to D\pi$	$B \to DK$
$D \to K\pi$	50432 ± 243	3692 ± 83
$D \to KK, \pi\pi$	7696 ± 106	582 ± 40

$\Rightarrow\ R_{D_{fav}} = (7.32 \pm 0.16)\%$
$A(DK) = (1.4 \pm 2.0)\%$

KID < 0.6 (pion-like) | **KID > 0.6 (kaon-like)**



$$\Rightarrow\ R_{D_{CP+}} = (7.56 \pm 0.51)\%,\quad A_{D_{CP+}} = (28.7 \pm 6.0)\%$$

large asymmetry !!

$B \to Dh,\ D \to K_S\pi^0,\ K_S\eta \to R_-$

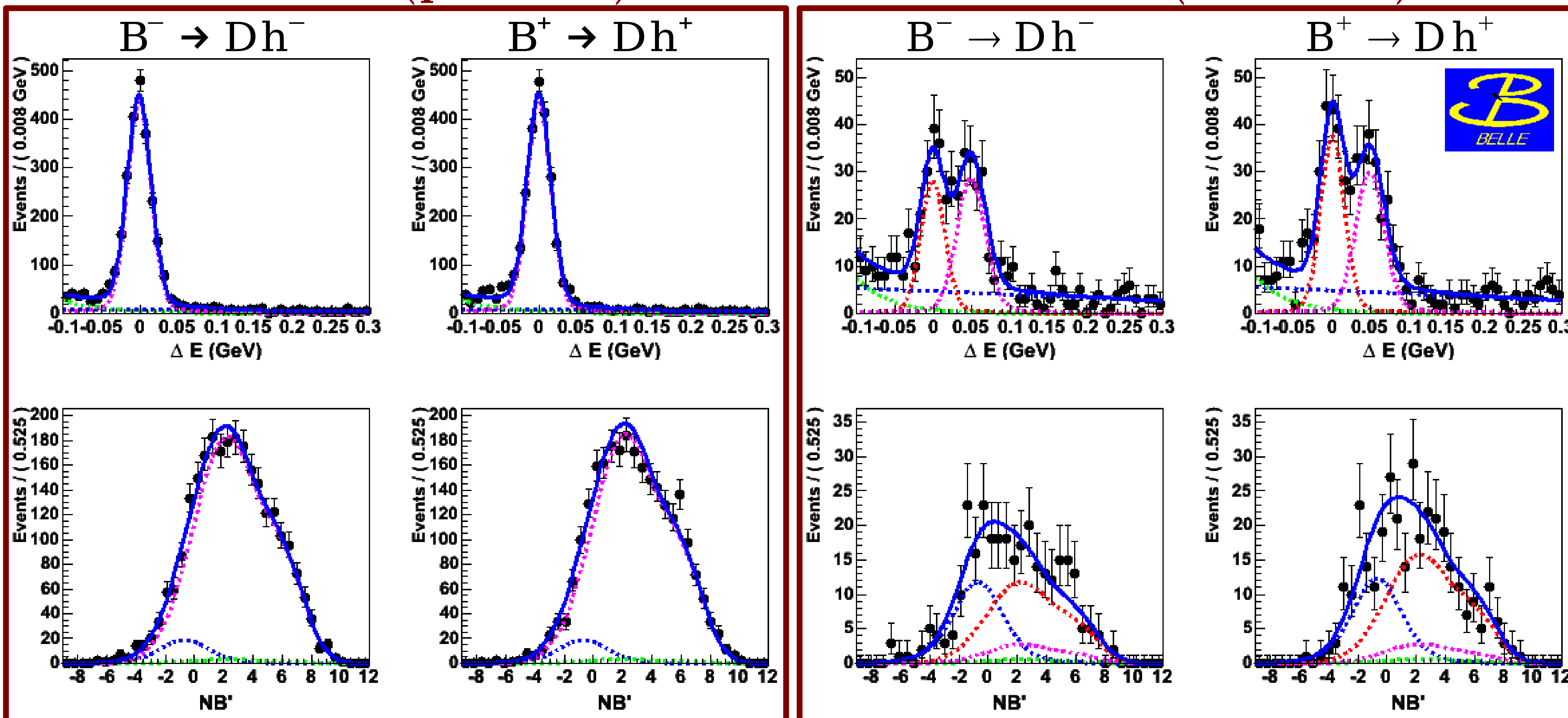
Preliminary
LP 2011

$(772\ \mathrm{M}\ B\bar{B})$

$B \to D\pi$
$B \to DK$
$B\bar{B}$
continuum

Yields	$B \to D\pi$	$B \to DK$
$D \to K_S\pi^0,\ K_S\eta$	5745 ± 91	476 ± 37

KID< 0.6 (pion-like) **KID> 0.6 (kaon-like)**



$\Rightarrow\ R_{D_{CP-}} = (8.29 \pm 0.63)\%,\ \ A_{D_{CP-}} = (-12.4 \pm 6.4)\%$

opposite asymmetry !!

GLW Results

Preliminary (LP 2011)

$$R_{CP+} = 1.03 \pm 0.07 \pm 0.03$$
$$R_{CP-} = 1.13 \pm 0.09 \pm 0.05$$

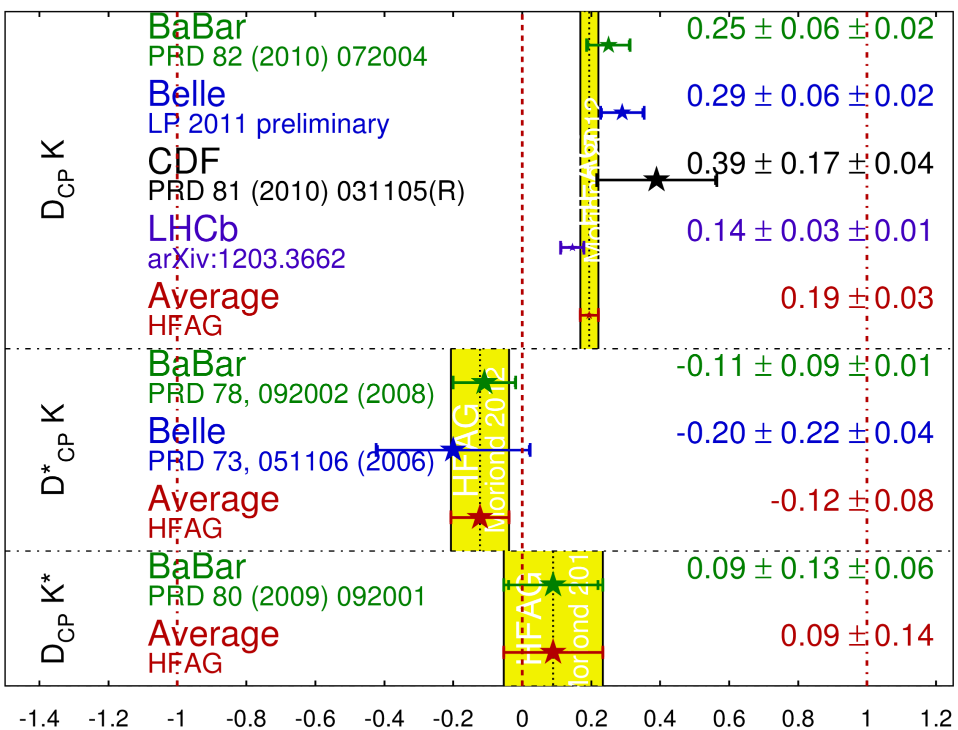
$$A_{CP+} = +0.29 \pm 0.06 \pm 0.02$$
$$A_{CP-} = -0.12 \pm 0.06 \pm 0.01$$

CP-odd observables
only available at B-factories

(systematics dominated by peaking background, double ratio approximation)

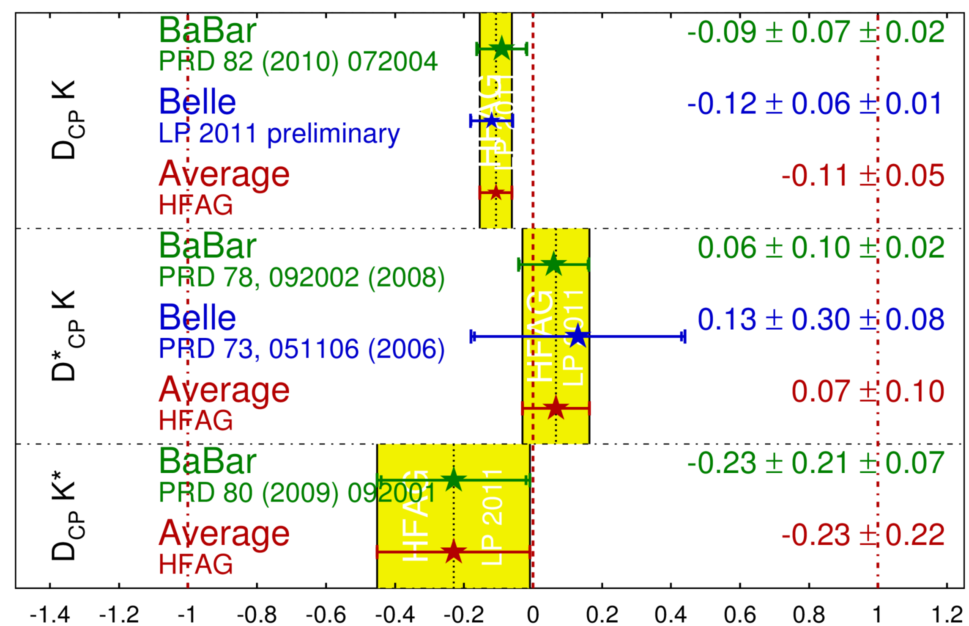
A_{CP+} Averages

HFAG Moriond 2012 PRELIMINARY

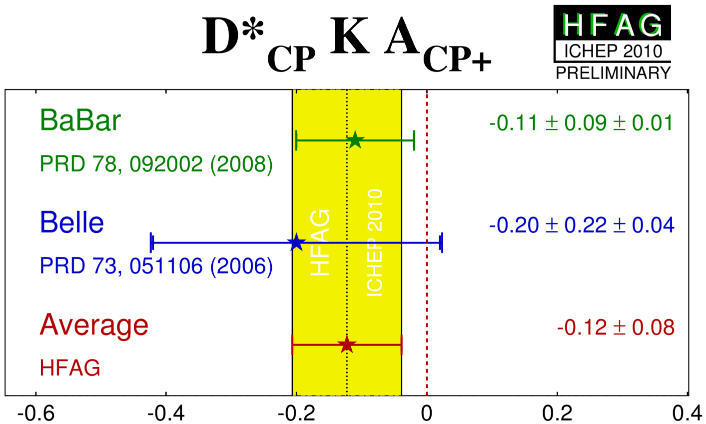


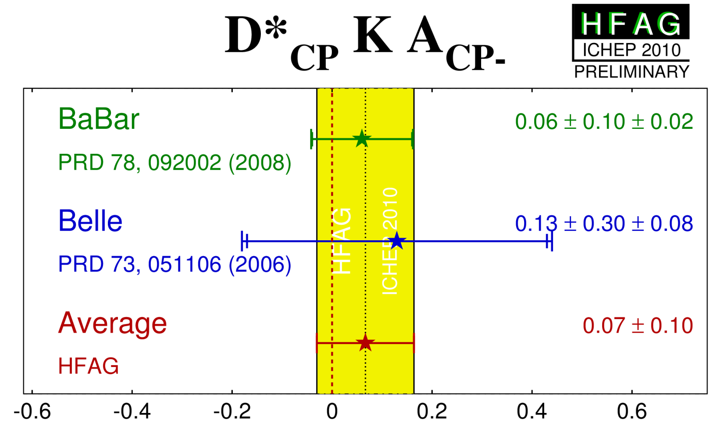
A_{CP-} Averages

HFAG LP 2011 PRELIMINARY



Status and motivation for GLW in $B \to D^{*0} K$





Mode	Experiment	A_{CP+}	A_{CP-}	R_{CP+}	R_{CP-}	Reference
$D^*_{CP}K^-$	BaBar N(BB)=383M	−0.11 ± 0.09 ± 0.01	0.06 ± 0.10 ± 0.02	1.31 ± 0.13 ± 0.03	1.09 ± 0.12 ± 0.04	PRD 78, 092002 (2008)
	Belle N(BB)=275M	−0.20 ± 0.22 ± 0.04	0.13 ± 0.30 ± 0.08	1.41 ± 0.25 ± 0.06	1.15 ± 0.31 ± 0.12	PRD 73, 051106 (2006)
	Average	−0.12 ± 0.08 χ^2 = 0.14 (CL=0.71 ⇒ 0.4σ)	0.07 ± 0.10 χ^2 = 0.05 (CL=0.83 ⇒ 0.2σ)	1.33 ± 0.12 χ^2 = 0.12 (CL=0.73 ⇒ 0.4σ)	1.10 ± 0.12 χ^2 = 0.03 (CL=0.87 ⇒ 0.2σ)	HFAG

[Belle previous result: 1/3 of the full data sample, only $D^* \to D\pi^0$]

- compared to DK, the D^{*0} constraint suppresses the peaking multi-body charmless decays
- $D^{*0} \to D\pi^0$, $D\gamma$: effective strong phase shift of π between two cases (sign swap in asymmetries between $D\pi^0$ and $D\gamma$ cases)
- available only (in principle) at B-factories (independent observables)
- D^{*0} selection is same than ADS case, D selection same than GLW case

$B \to D^{*0} K,\ D^{*0} \to D\pi^0$

$D \to K^+K^-, \pi^+\pi^- \to CP+$

NEW (CKM 2012)

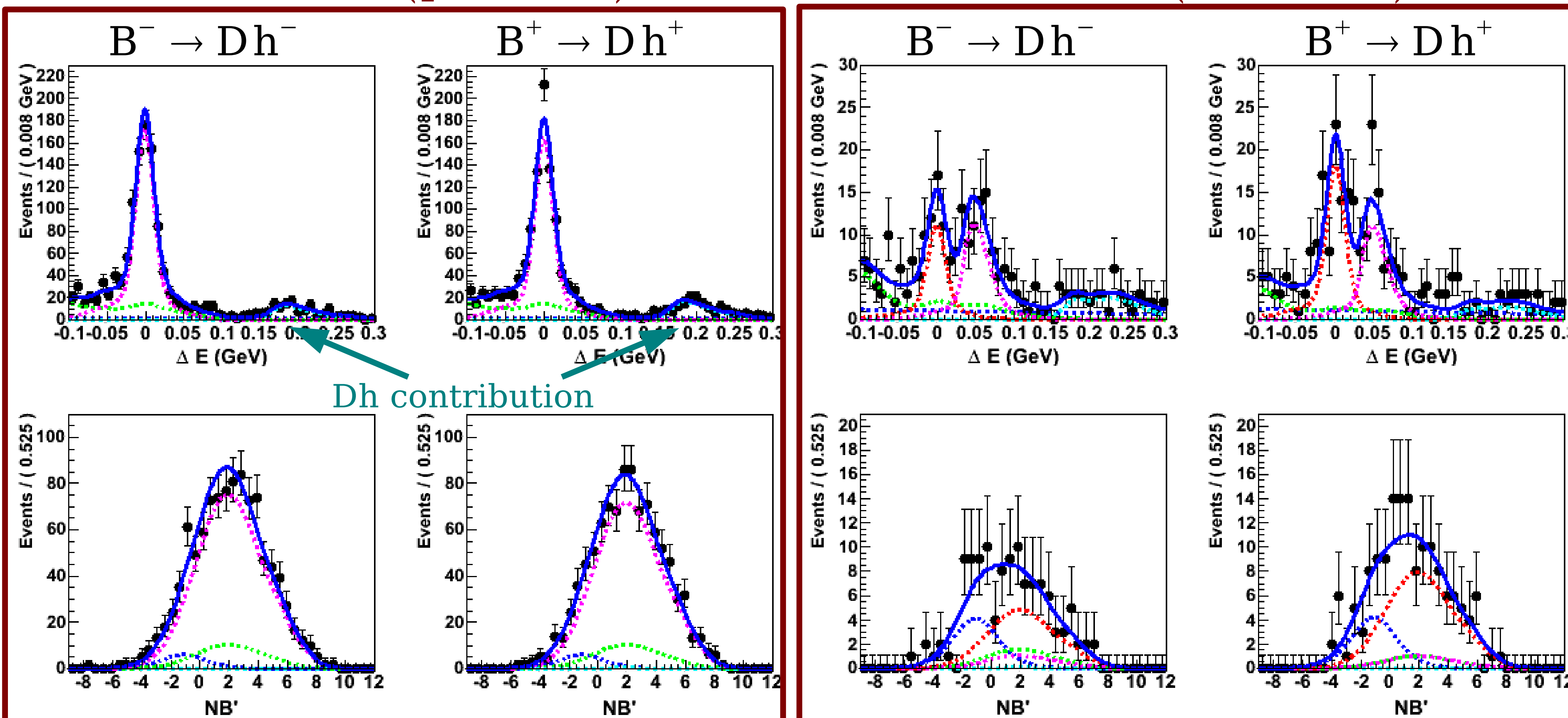
$(772\ MB\bar{B})$

Yields	$B \to D^*\pi$	$B \to D^*K$
$D \to K\pi$	$(14.4 \pm 0.2) \times 10^3$	1074 ± 52
$D \to KK, \pi\pi$	$(2.14 \pm 0.07) \times 10^3$	195 ± 20

$\Rightarrow\ R_{D_{fav}} = (7.46 \pm 0.36)\%$

$A(D^*_{fav} K) = (3.2 \pm 4.4)\%$

KID < 0.6 (pion-like) **KID > 0.6 (kaon-like)**



$$R_{CP+} = 1.25 \pm 0.16 \qquad A_{CP+} = -0.23 \pm 0.11$$

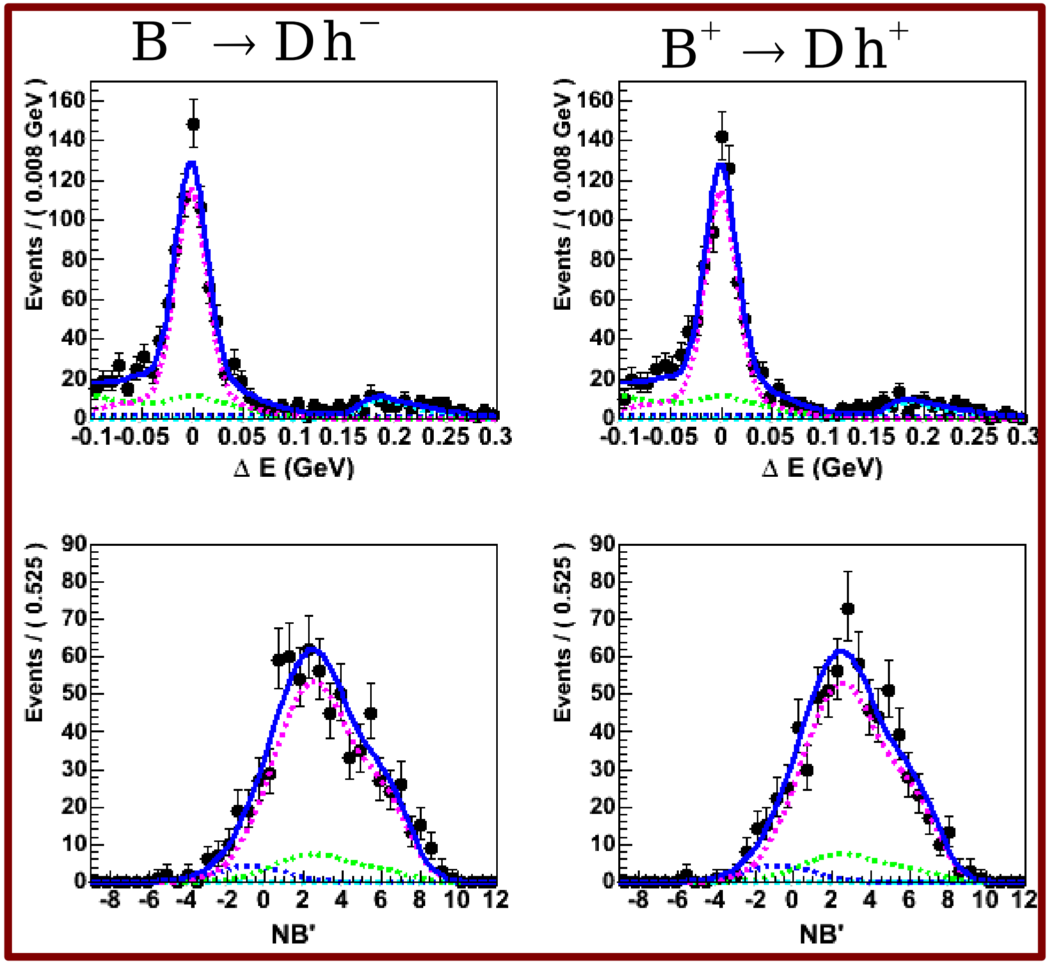
$B \rightarrow D^{*0} K$, $D^{*0} \rightarrow D\pi^0$

$D \rightarrow K_S\pi^0, K_S\eta \rightarrow CP-$

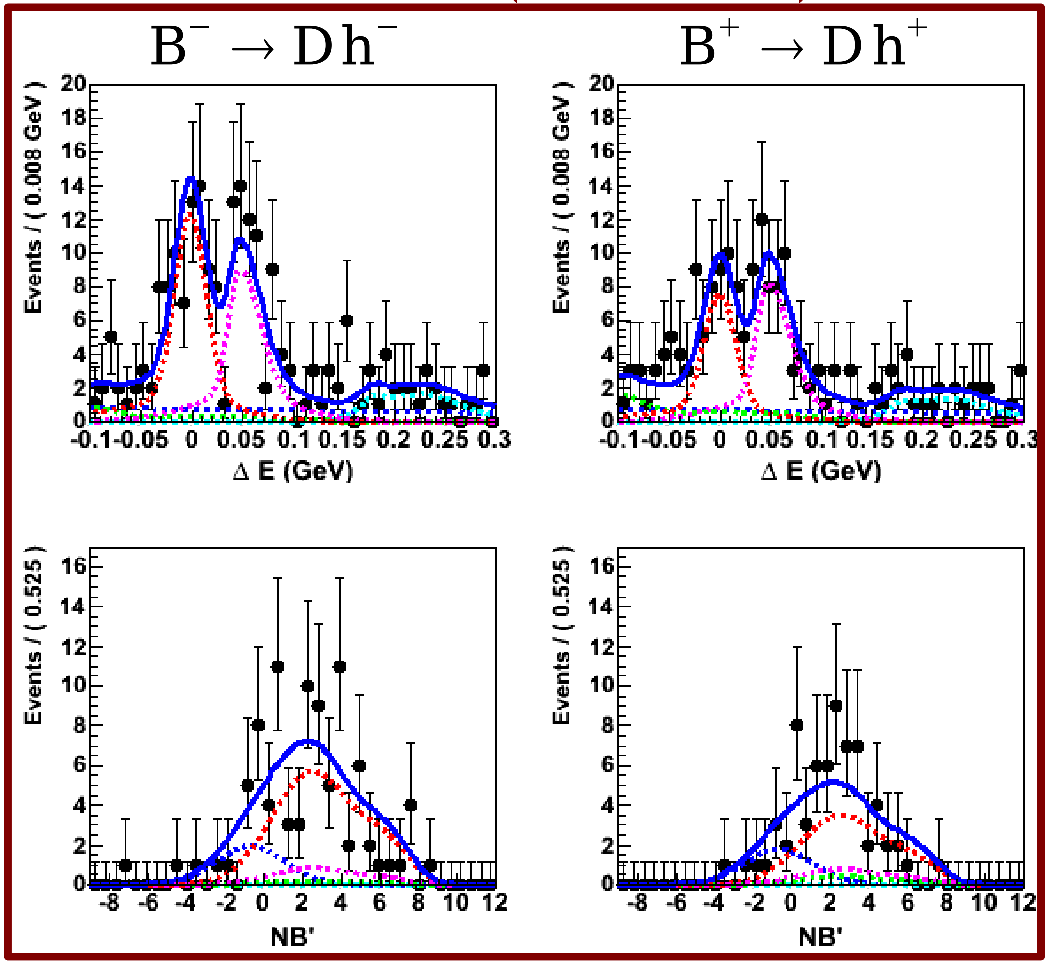
NEW (CKM 2012)
$(772\ \mathrm{M}B\bar{B})$

Yields	$B \rightarrow D^*\pi$	$B \rightarrow D^*K$
$D \rightarrow K_S\pi^0, K_S\eta$	$(1.67 \pm 0.07) \times 10^3$	156 ± 21

KID < 0.6 (pion-like)



KID > 0.6 (kaon-like)



$R_{CP-} = 1.26 \pm 0.18$ $A_{CP-} = +0.20 \pm 0.13$

$B \to D^{*0} K,\ D^{*0} \to D\gamma$

NEW (CKM 2012)

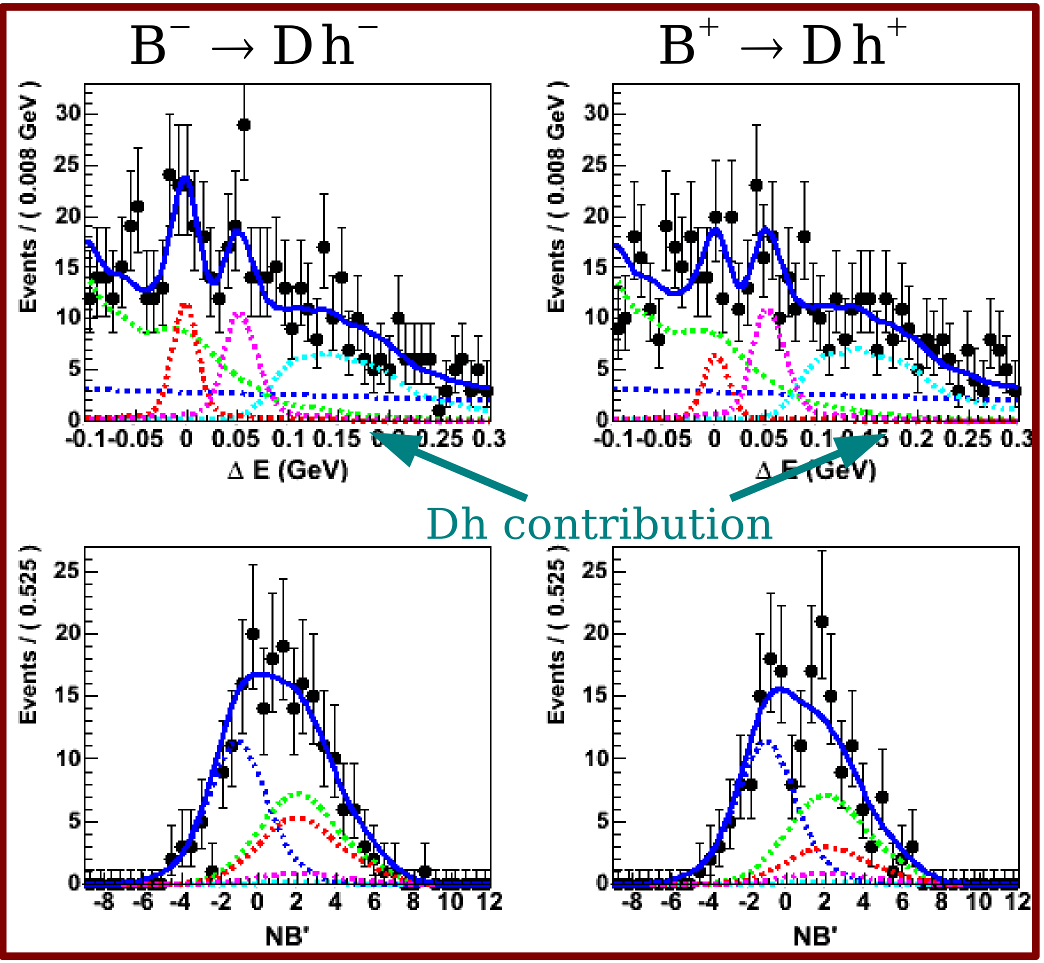
$(772\ \mathrm{M}\,B\bar{B})$

Yields	$B \to D^{*}\pi$	$B \to D^{*}K$
$D \to K\pi$	$(13.3 \pm 0.2) \times 10^{3}$	979 ± 59

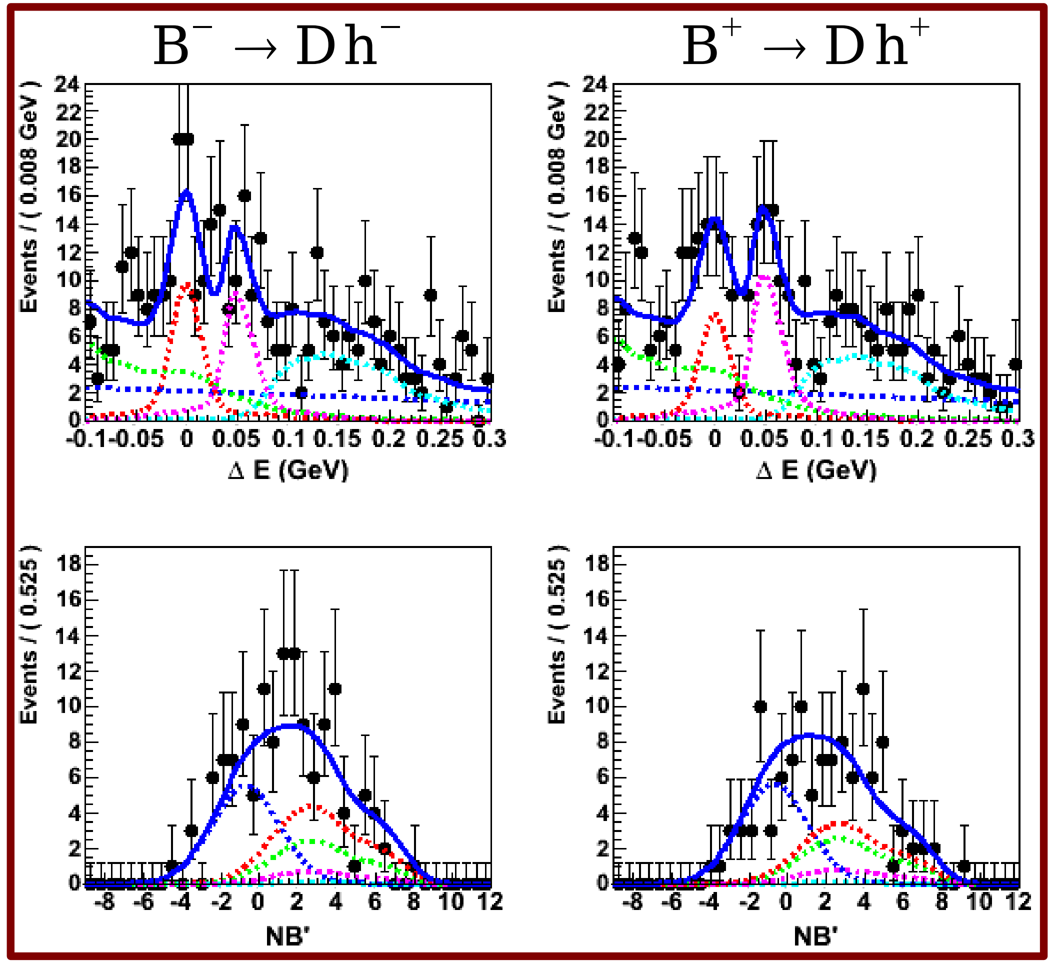
$\Rightarrow R_{D_{fav}} = (7.36 \pm 0.44)\%$

$A(D^{*}_{fav}K) = (-1.93 \pm 5.8)\%$

$D \to K^{+}K^{-},\ \pi^{+}\pi^{-} \ \to\ CP-$



$D \to K_S\pi^{0},\ K_S\eta \ \to\ CP+$



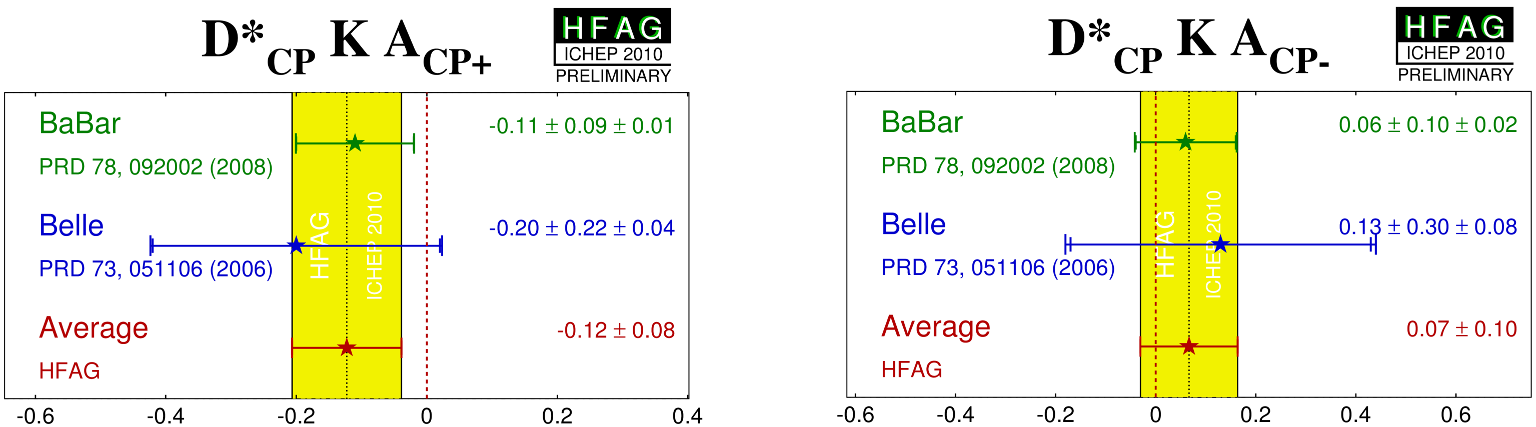
$R_{CP-} = 0.77 \pm 0.19$

$A_{CP-} = +0.28 \pm 0.23$

$R_{CP+} = 1.07 \pm 0.22$

$A_{CP+} = +0.13 \pm 0.19$

Status and motivation for GLW in $B \to D^{*0}K$



Mode	Experiment	A_{CP+}	A_{CP-}	R_{CP+}	R_{CP-}	Reference
$D^*_{CP}K^-$	BaBar N(BB)=383M	−0.11 ± 0.09 ± 0.01	0.06 ± 0.10 ± 0.02	1.31 ± 0.13 ± 0.03	1.09 ± 0.12 ± 0.04	PRD 78, 092002 (2008)
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	Average	−0.12 ± 0.08 χ^2 = 0.14 (CL=0.71 ⇒ 0.4σ)	0.07 ± 0.10 χ^2 = 0.05 (CL=0.83 ⇒ 0.2σ)	1.33 ± 0.12 χ^2 = 0.12 (CL=0.73 ⇒ 0.4σ)	1.10 ± 0.12 χ^2 = 0.03 (CL=0.87 ⇒ 0.2σ)	HFAG

[Belle previous result: 1/3 of the full data sample, only $D^* \to D\pi^0$]

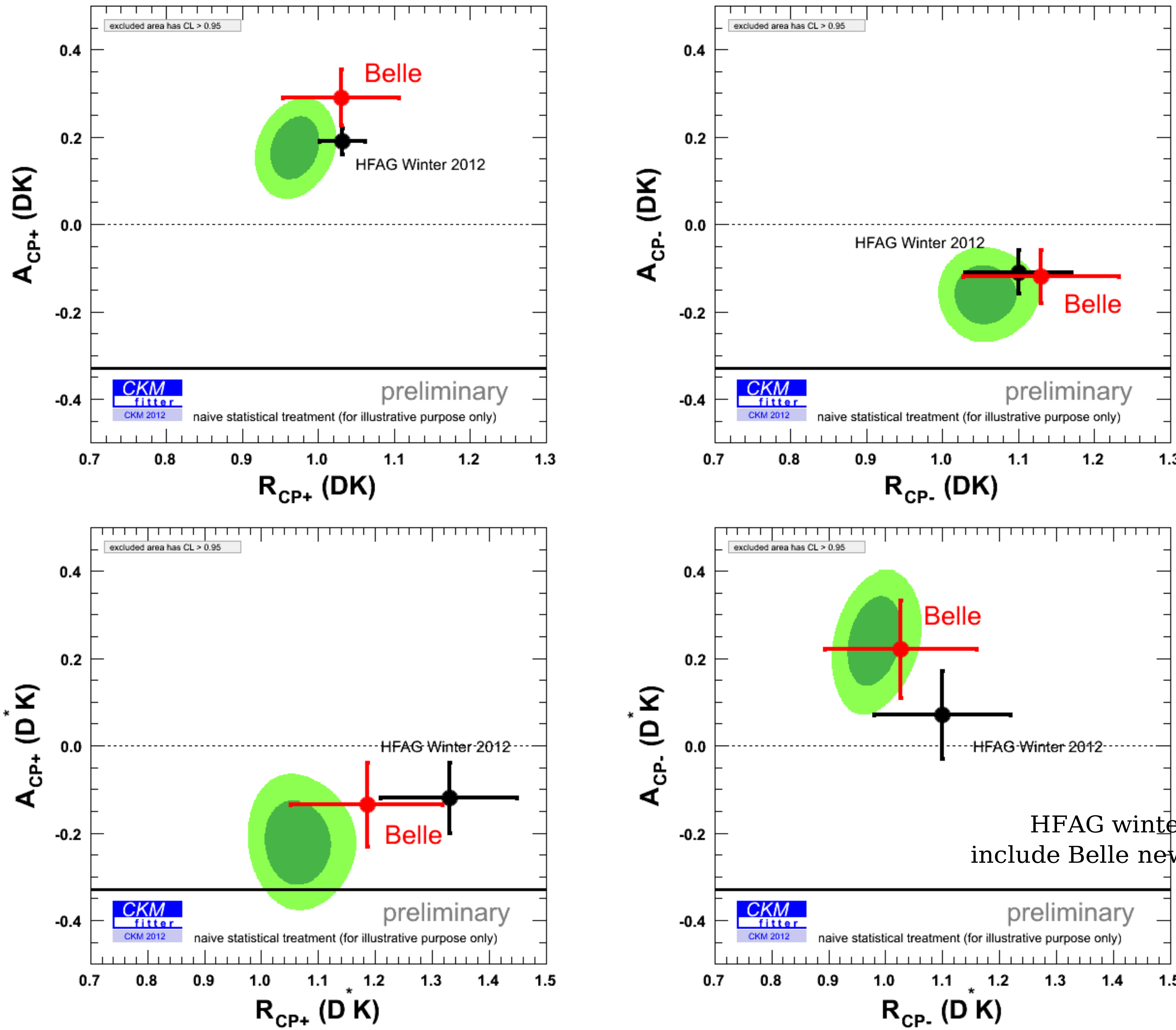
Combining the results of $D^* \to D\pi^0$, $D\gamma$:

$$R_{CP+} = 1.19 \pm 0.13 \pm 0.03$$
$$R_{CP-} = 1.03 \pm 0.13 \pm 0.03$$
$$A_{CP+} = -0.14 \pm 0.10 \pm 0.01$$
$$A_{CP-} = +0.22 \pm 0.11 \pm 0.01$$

significant improvement, consistent with expected pattern

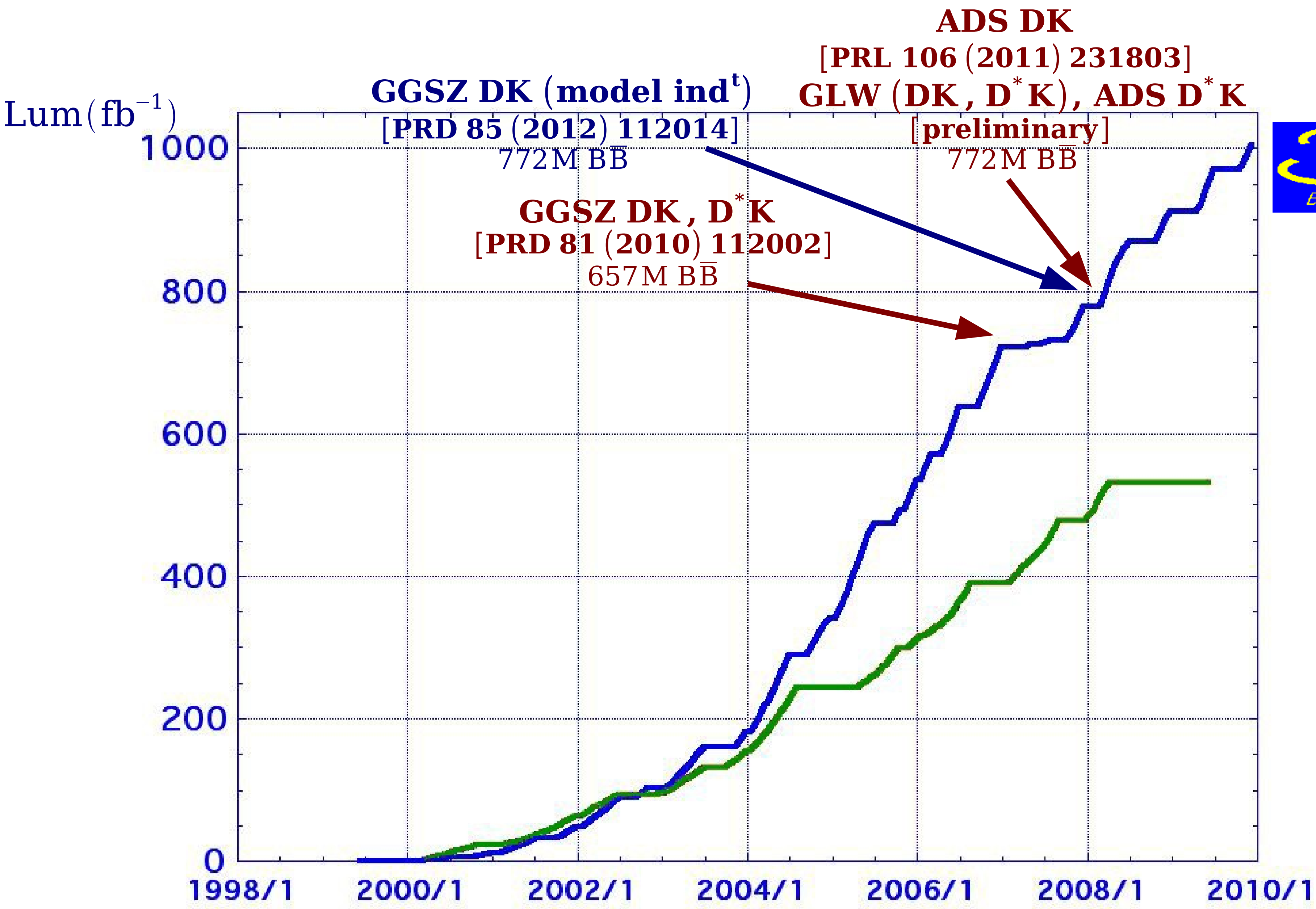
Comparison of the results obtained for $D^{(*)}K$ with expectations

where "expectations" are derived from the GGSZ observables (W.A.), δ_D and γ_{UT}



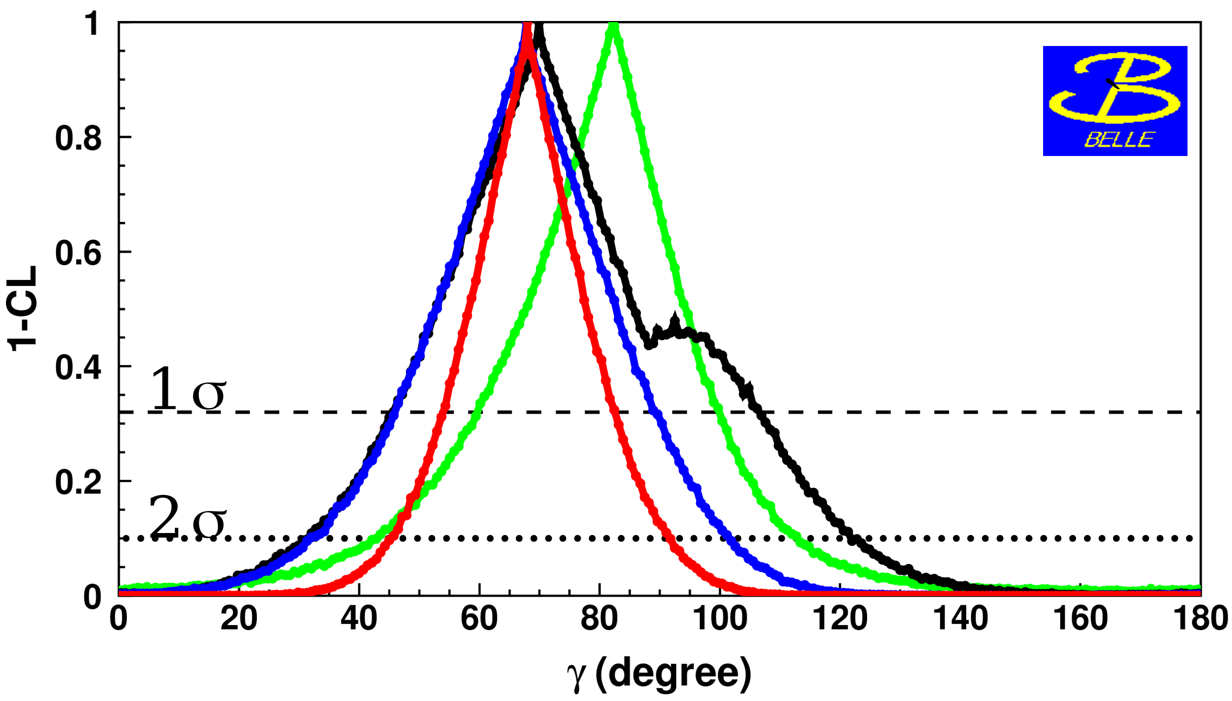
HFAG winter 2012 doesn't include Belle new (GLW D^*K) results

$D^{(*)0}K^{\pm}$ measurements related to γ determination



Determination of γ with Belle $D^0 K$, $D^{*0} K$ results

[GGSZ+ADS+GLW : 8+6+8=22 observables, 5 parameters]



GGSZ

$\gamma = [82\,^{+18}_{-23}]^\circ$

GGSZ+ADS

$\gamma = [70\,^{+37}_{-24}]^\circ$

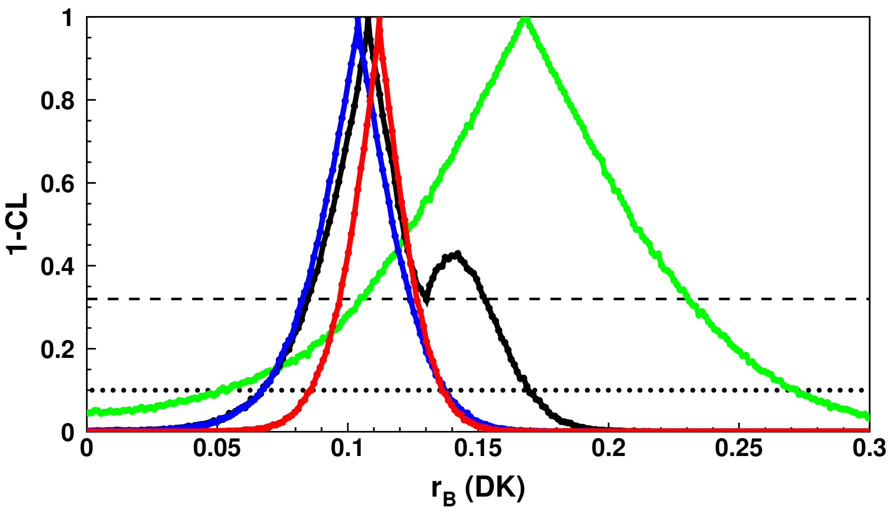
GGSZ+ADS+δ_D

$\gamma = [68 \pm 22]^\circ$

GGSZ+ADS+GLW+δ_D

$\gamma = [68\,^{+15}_{-14}]^\circ$

$(2\sigma = ^{+28\circ}_{-27})$



for B→DK :

$r_B = 0.168^{+0.063}_{-0.064}$

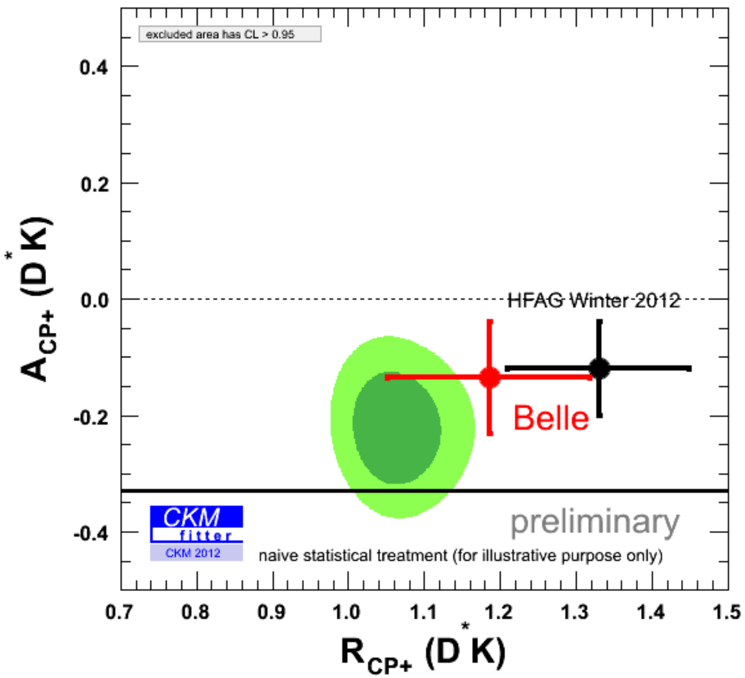
$r_B = 0.108^{+0.045}_{-0.023}$

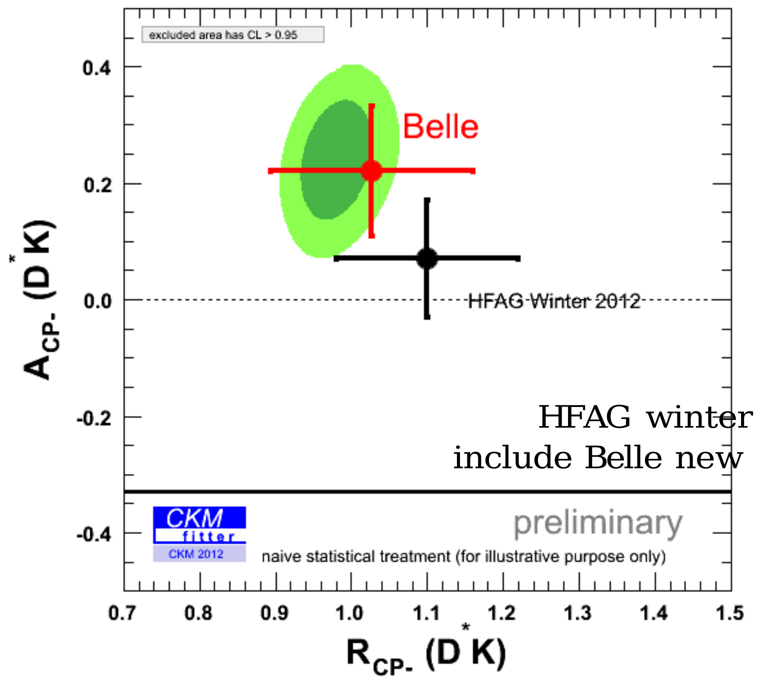
$r_B = 0.104^{+0.020}_{-0.021}$

$\mathbf{r_B = 0.112^{+0.014}_{-0.015}}$

Summary

- New D^*K GLW results from Belle presented at CKM2012





HFAG winter 2012 doesn't include Belle new (GLW D^*K) results

- ADS, GLW observables consistent with expectations (promising D^*K pattern)

- Combining DK, D^*K GGSZ+GLW+ADS:

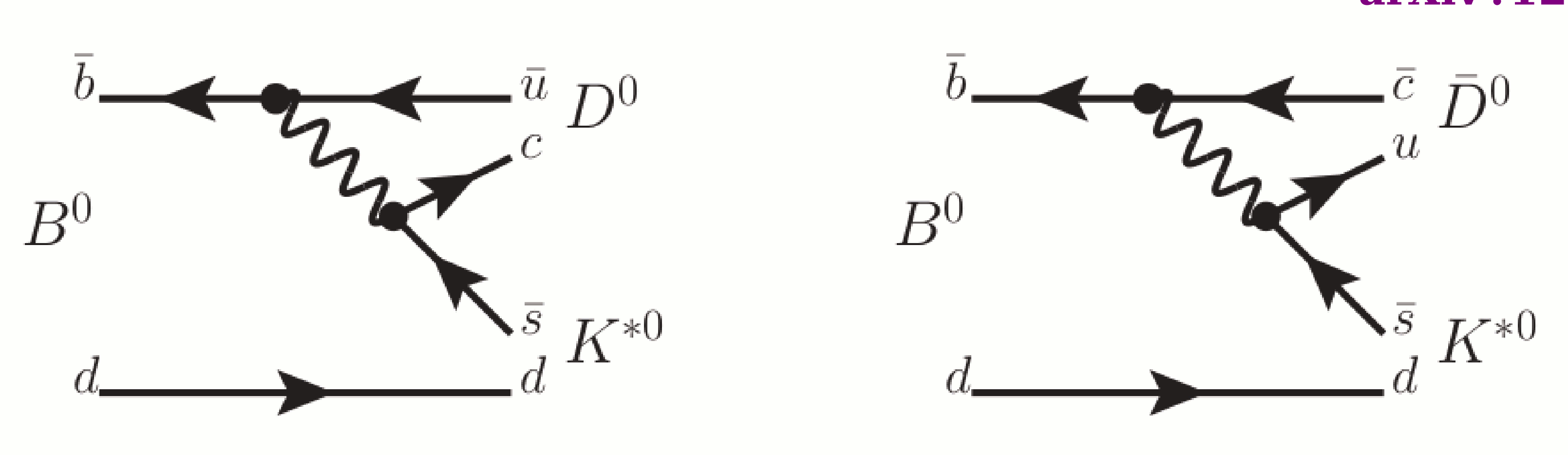
$$\boldsymbol{\gamma = (68\,^{+15}_{-14})^\circ} \qquad (\text{important } 2\sigma = {}^{+28^\circ}_{-27}\ !)$$

- Coming relevant updates: ADS $D(K\pi\pi^0)K$, GGSZ $D(K_S KK)K$ ...

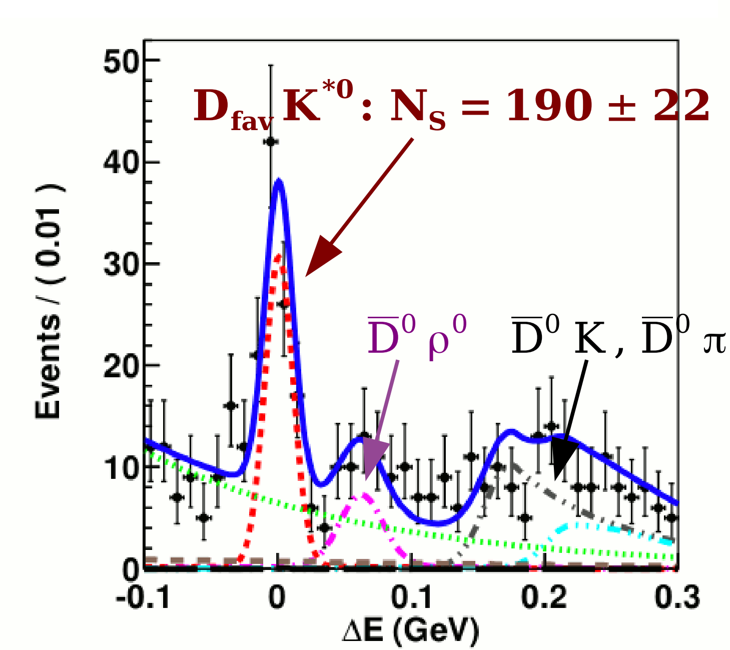
Backup slides

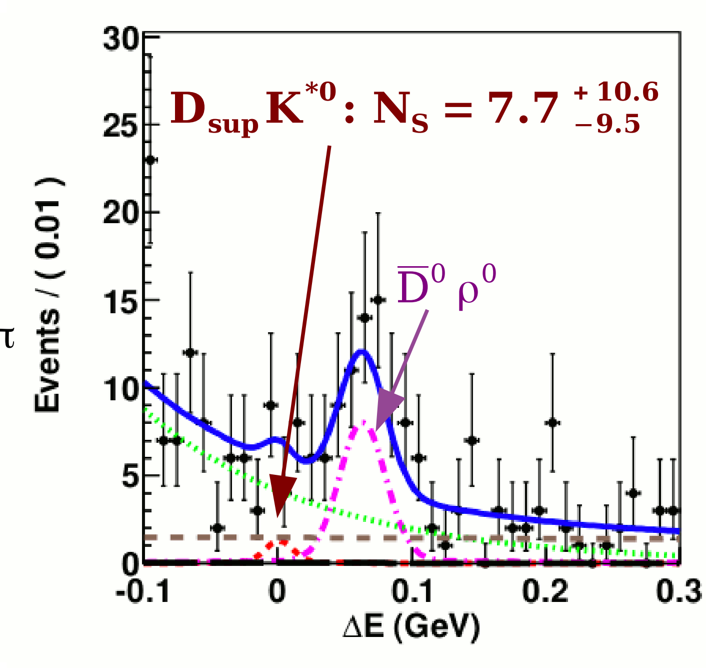
Search for $B^0 \to DK^{*0}$, $D \to K^- \pi^+$

772M $B\bar{B}$
arXiv:1205.0422



$$R_{DK^{*0}} = \frac{\Gamma(B^0 \to [K^- \pi^+]_D K^+ \pi^-)}{\Gamma(B^0 \to [K^+ \pi^-]_D K^+ \pi^-)} = r_S^2 + r_D^2 + 2 k r_S r_D \cos(\delta_S + \delta_D) \cos\gamma$$





$R_{DK^{*0}} < 0.16$ @ 95% C.L.

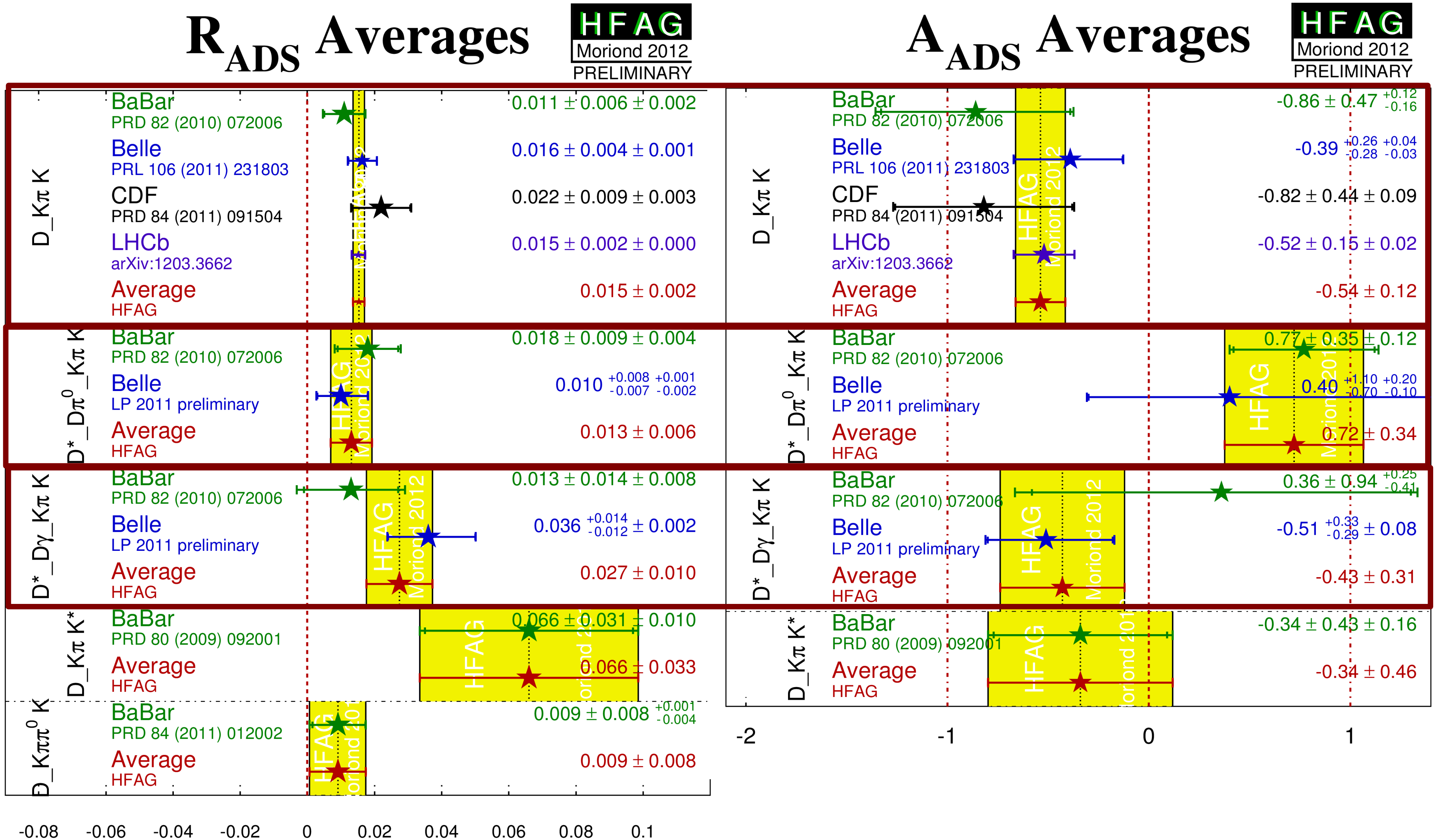
$r_S < 0.4$ @ 95% C.L.

465M $B\bar{B}$
[PRD 80 (2009) 031102]

$R_{DK^{*0}} < 0.24$ @ 95% C.L.

$r_S < 0.41$ @ 95% C.L.

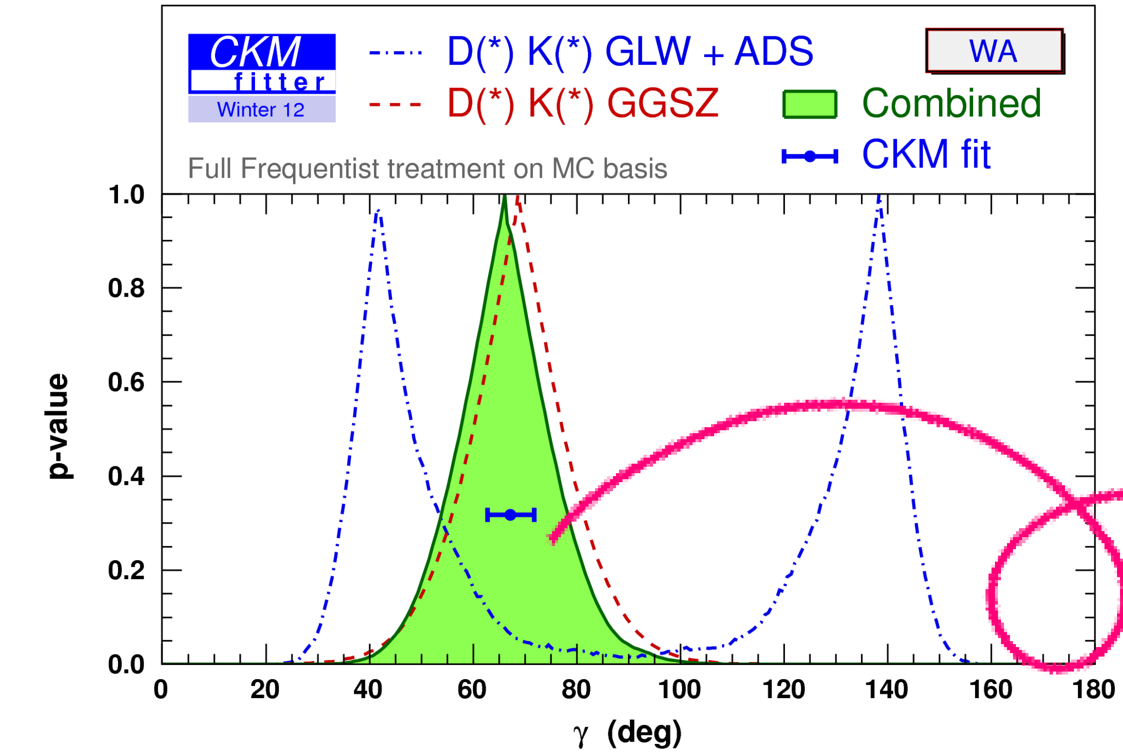
ADS results

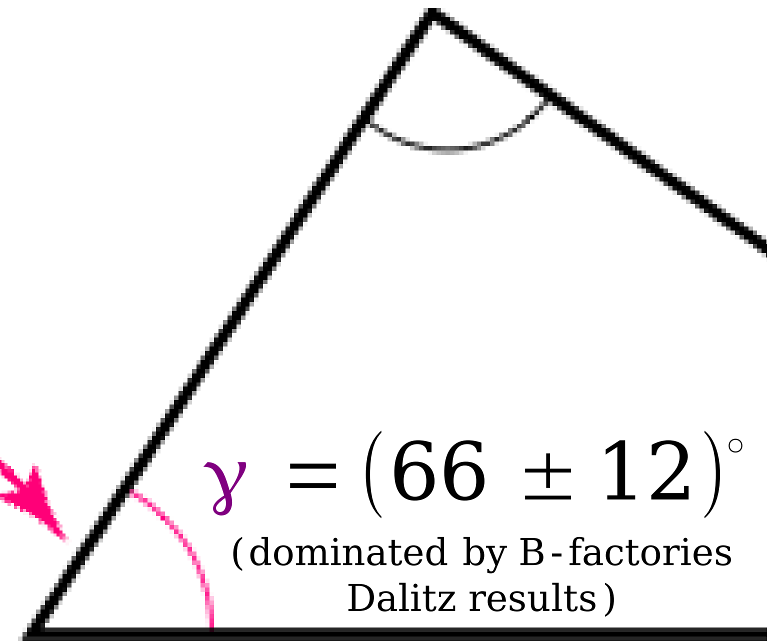


R_{ADS} Averages
HFAG
Moriond 2012
PRELIMINARY
D_Kπ K
BaBar PRD 82 (2010) 072006 0.011 ± 0.006 ± 0.002
Belle PRL 106 (2011) 231803 0.016 ± 0.004 ± 0.001
CDF PRD 84 (2011) 091504 0.022 ± 0.009 ± 0.003
LHCb arXiv:1203.3662 0.015 ± 0.002 ± 0.000
Average HFAG 0.015 ± 0.002
D*_Dπ0_Kπ K
BaBar PRD 82 (2010) 072006 0.018 ± 0.009 ± 0.004
Belle LP 2011 preliminary 0.010 +0.008 -0.007 +0.001 -0.002
Average HFAG 0.013 ± 0.006
D*_Dγ_Kπ K
BaBar PRD 82 (2010) 072006 0.013 ± 0.014 ± 0.008
Belle LP 2011 preliminary 0.036 +0.014 -0.012 ± 0.002
Average HFAG 0.027 ± 0.010
D_Kπ K*
BaBar PRD 80 (2009) 092001 0.066 ± 0.031 ± 0.010
Average HFAG 0.066 ± 0.033
D_Kππ0 K
BaBar PRD 84 (2011) 012002 0.009 ± 0.008 +0.001 -0.004
Average HFAG 0.009 ± 0.008
-0.08 -0.06 -0.04 -0.02 0 0.02 0.04 0.06 0.08 0.1
A_{ADS} Averages
HFAG
Moriond 2012
PRELIMINARY
D_Kπ K
BaBar PRD 82 (2010) 072006 -0.86 ± 0.47 +0.12 -0.16
Belle PRL 106 (2011) 231803 -0.39 +0.26 -0.28 +0.04 -0.03
CDF PRD 84 (2011) 091504 -0.82 ± 0.44 ± 0.09
LHCb arXiv:1203.3662 -0.52 ± 0.15 ± 0.02
Average HFAG -0.54 ± 0.12
D*_Dπ0_Kπ K
BaBar PRD 82 (2010) 072006 0.77 ± 0.35 ± 0.12
Belle LP 2011 preliminary 0.40 +1.10 -0.70 +0.20 -0.10
Average HFAG 0.72 ± 0.34
D*_Dγ_Kπ K
BaBar PRD 82 (2010) 072006 0.36 ± 0.94 +0.25 -0.41
Belle LP 2011 preliminary -0.51 +0.33 -0.29 ± 0.08
Average HFAG -0.43 ± 0.31
D_Kπ K*
BaBar PRD 80 (2009) 092001 -0.34 ± 0.43 ± 0.16
Average HFAG -0.34 ± 0.46
-2 -1 0 1

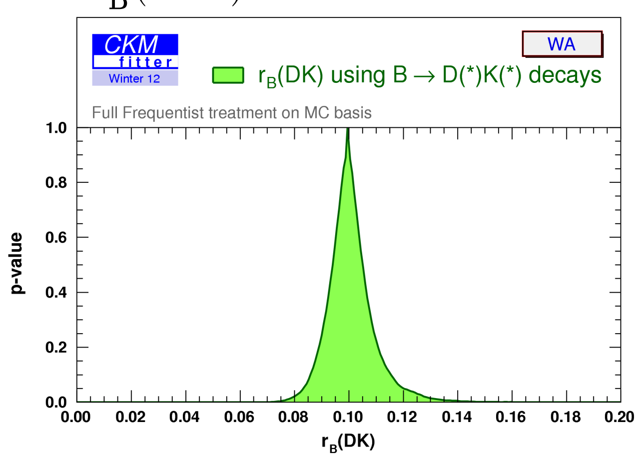
Combined measurements for γ from all methods

http://ckmfitter.in2p3.fr/

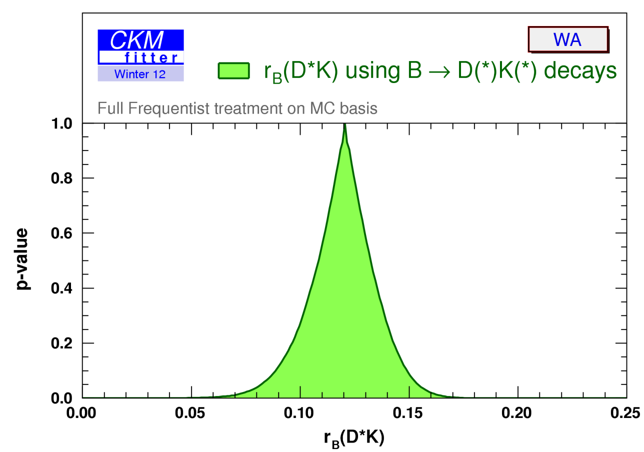




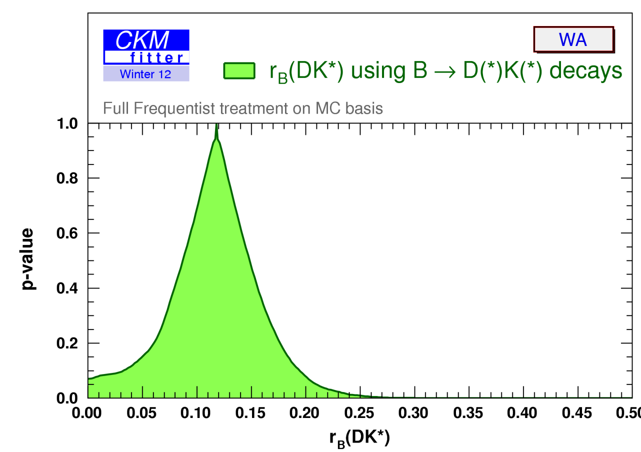
$r_B(DK) = 0.099 \pm 0.008$



$r_B(D^*K) = 0.121\ ^{+0.018}_{-0.019}$

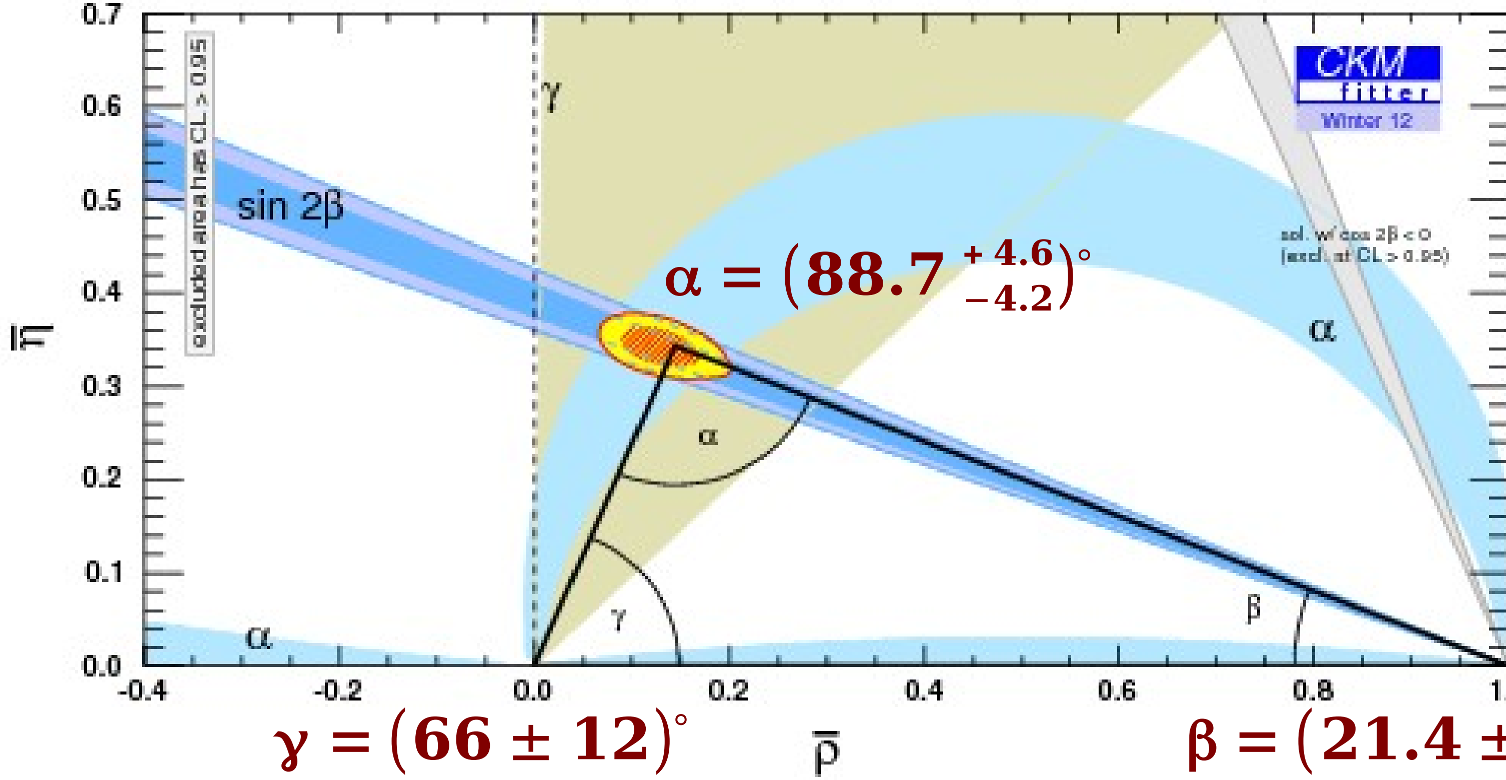


$r_B(DK^*) = 0.118 \pm 0.045$



Angles

- B-factories have provided (most of) the current picture:



$\alpha = (88.7^{+4.6}_{-4.2})^\circ$

$\gamma = (66 \pm 12)^\circ$

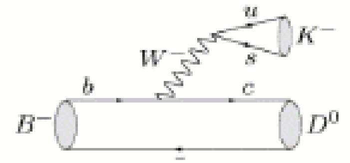
$\beta = (21.4 \pm 0.8)^\circ$

Improved Treatment of γ

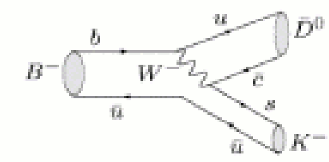
■ **γ from interferences** between $B^- \to D^0 K^-$ and $B^- \to \bar{D}^0 K^-$. 3 methods with different D final states: GLW (CP eigenstates), ADS (Kπ, 2 Cabibbo supp.) & GGSZ (3 body, Dalitz).

■ **Fit simultaneously γ and hadronic quantities**: phases δ_B, suppression ratios, r_B. The accuracy on γ **depends critically on rB** $\subset$ [0.1;0.2]

⇒ nuisance treated within a full frequentist /conservative scheme.



colour allowed
$A\lambda^3$



colour suppressed
$A\lambda^3(\rho + i\eta)$

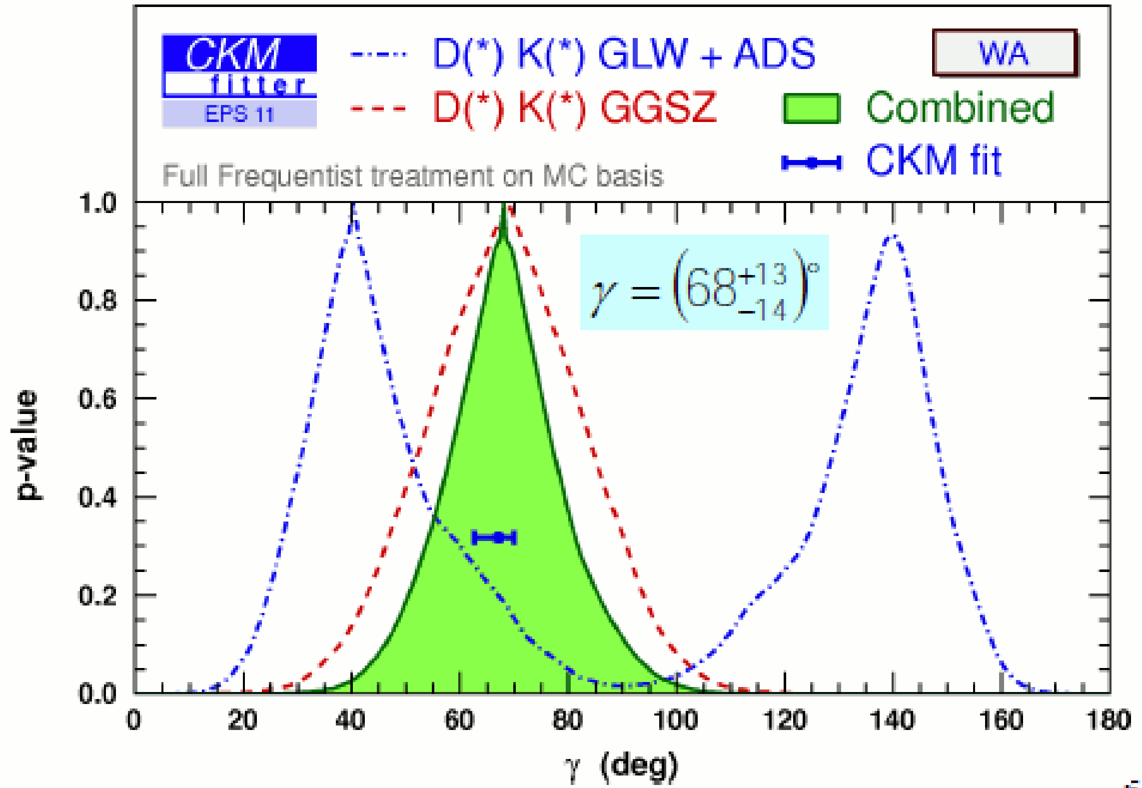
$$r_B = \frac{|A_{suppressed}|}{|A_{favoured}|} \approx \left|\frac{V_{ub}V_{cs}^*}{V_{cb}V_{us}^*}\right| \times [\text{colour supp}]$$

■ **Updated ADS (D(Kπ)K) inputs :**

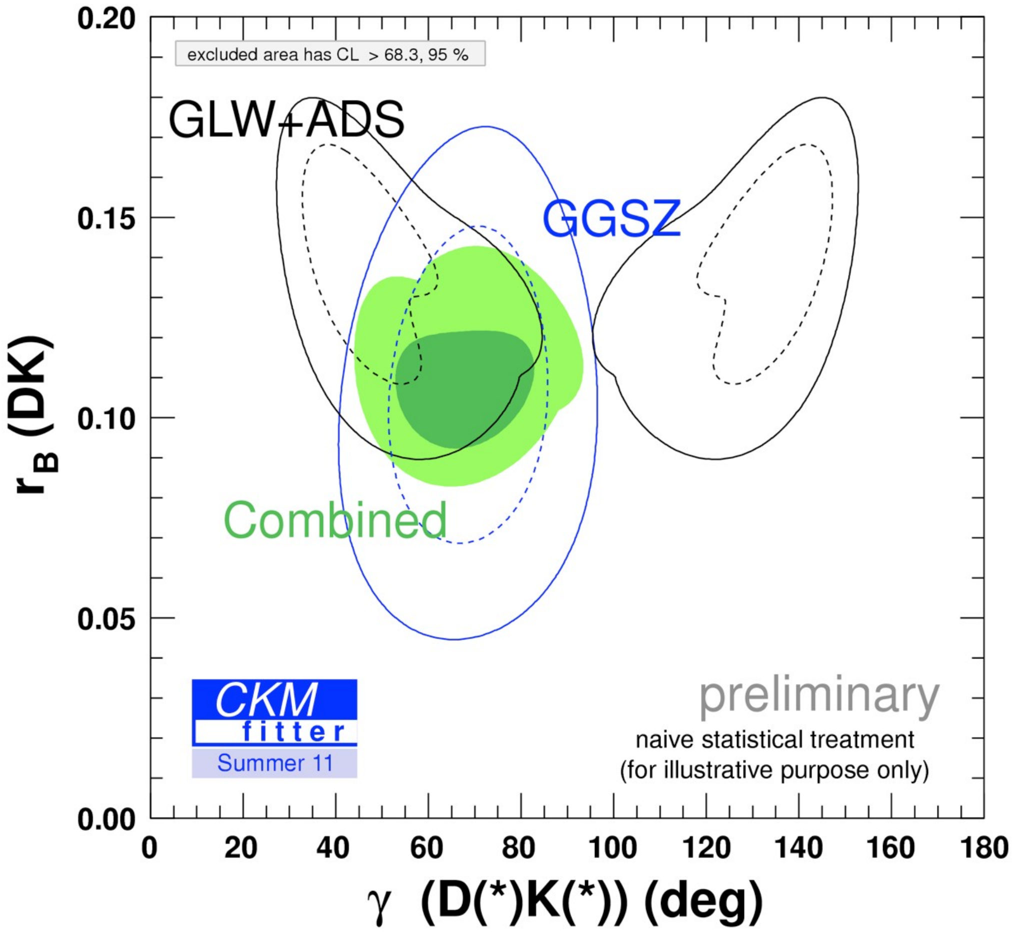
- **Belle**, PRL **106**, 231803 (2011)
- **CDF** , P@LHC2011

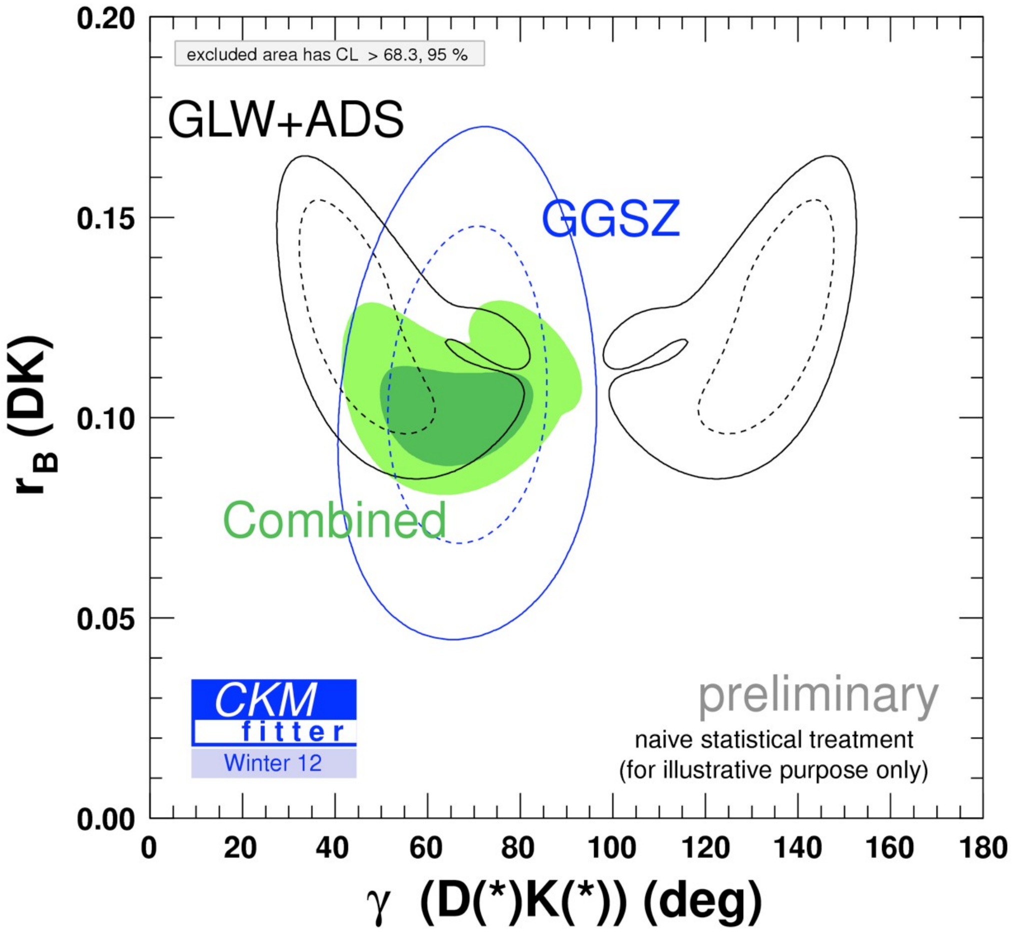
⇒ **better rejection of small r_B values**

■ **Changed** from the supremum, p_{sup}, p-Value **to the Berger-Boos, p_β, p-Value** [JASA 89, 427 (1994)] : **better control over nuisance parameters** from an auxiliary test; nuisances are constrained to a 3.3 σ confidence interval based on their Likelihood.



New inputs (Winter 2012) ⇐ LHCb





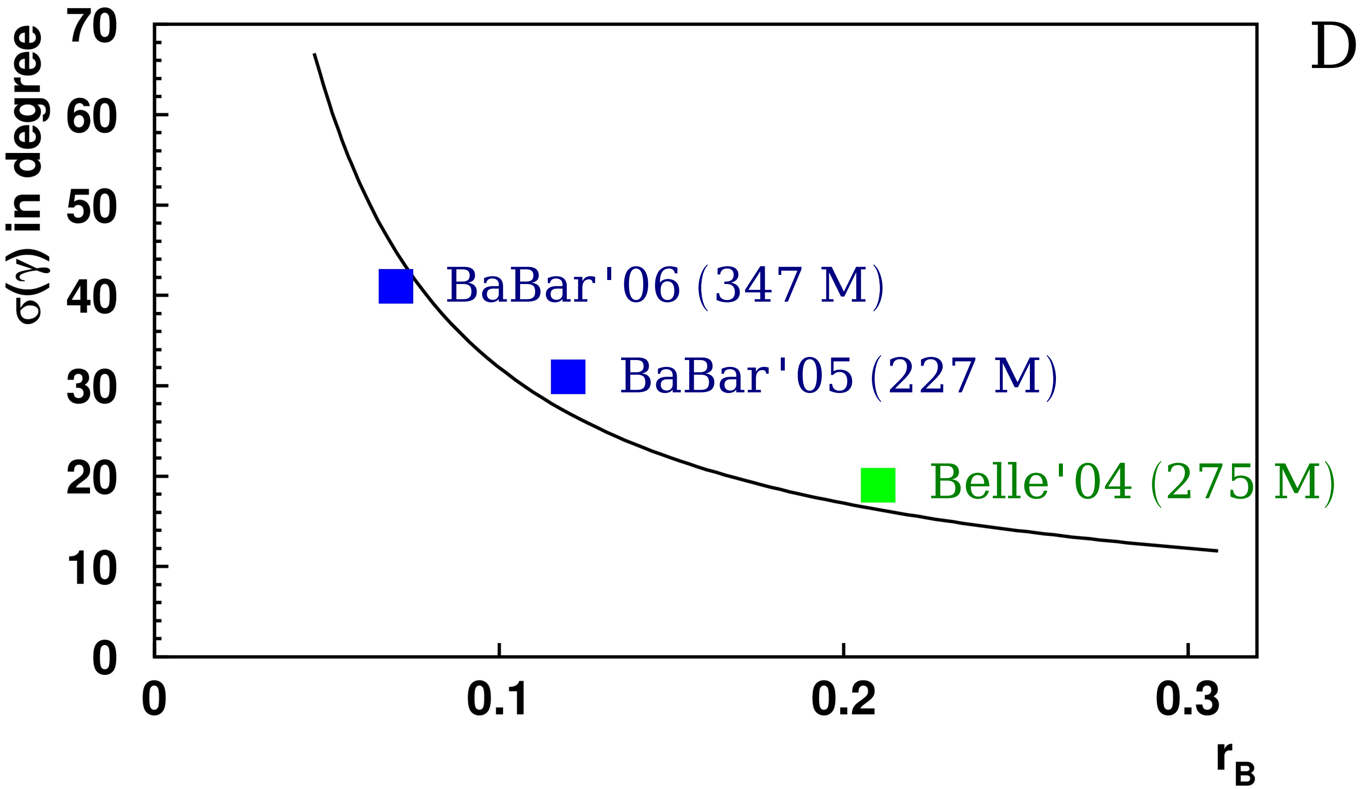
γ measurements from $B^{\pm} \to DK^{\pm}$ r_B dependence

Dalitz $B \to D(K_S \pi\pi)K$

experimental inputs:

$$x_{\pm} = r_B \cos(\delta_B \pm \gamma)$$
$$y_{\pm} = r_B \sin(\delta_B \pm \gamma)$$

uncertainty on γ scales as $1/r_B$!



DK (stat only)

$\sigma(x_{\pm}) \sim 0.07$

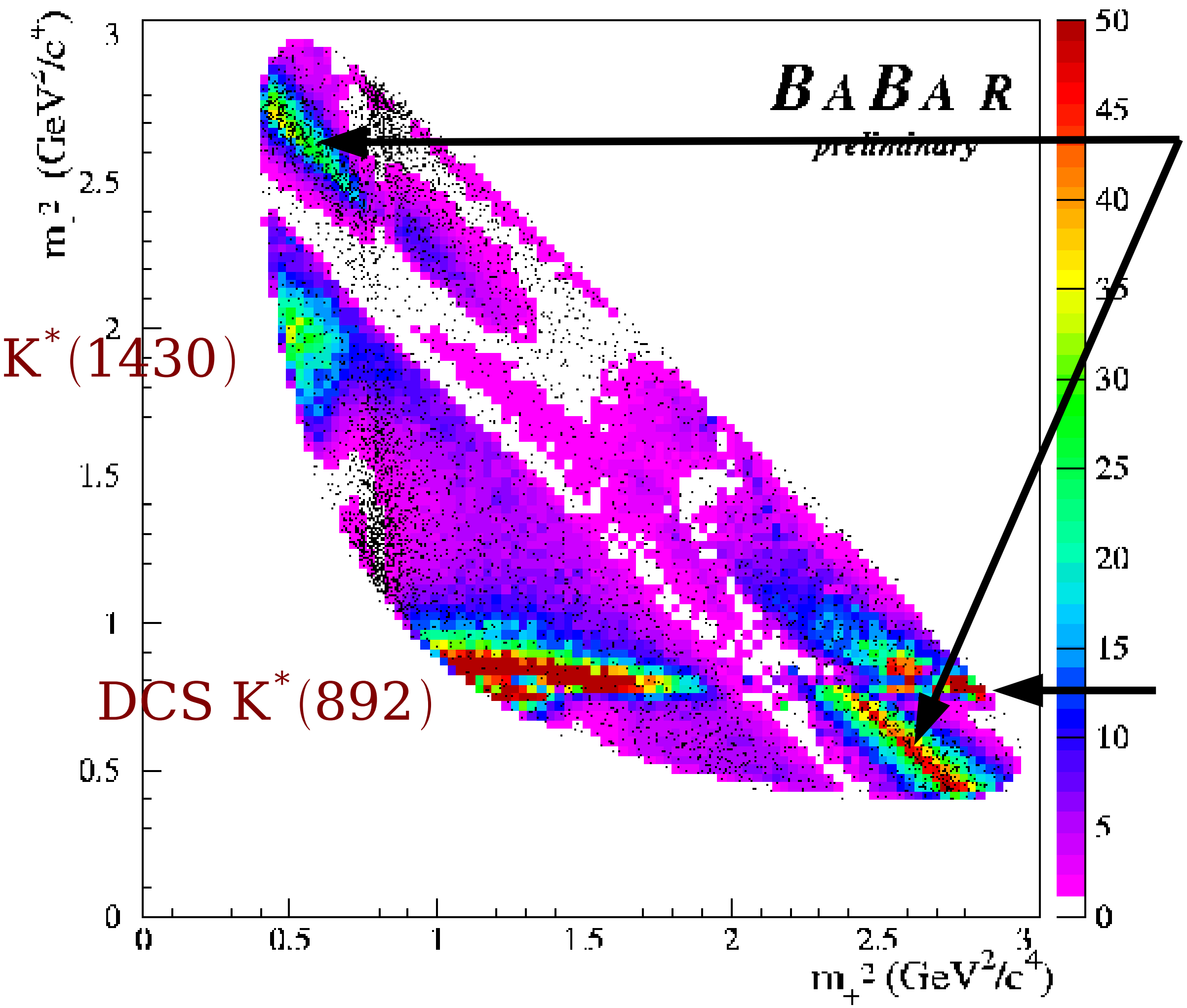
$\sigma(y_{\pm}) \sim 0.08$

Sensitivity to γ

sensitivity to γ/ϕ_3 varies across the Dalitz plot

$\gamma=75^\circ,\ \delta=180^\circ,\ r_B=0.125$

$w=1/(d^2L/d\gamma^2)$



DCS $K^*(1430)$

DCS $K^*(892)$

GLW like

Interference of

$B^- \to D^0 K^-,\ D^0 \to K^0_S \rho^0$

with

$B^- \to \overline{D}^0 K^-,\ \overline{D}^0 \to K^0_S \rho^0$

ADS like

Interference of

$B^- \to D^0 K^-,\ D^0 \to K^{*+} \pi^-$

with

$B^- \to \overline{D}^0 K^-,\ \overline{D}^0 \to K^{*+} \pi^-$